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José António Faria Araújo

Design of Cold-formed Steel Structures

Master Dissertation in Steel and Composite Construction, supervised by the Professor Rui António Duarte Simões and presented to the Department of Civil Engineering of the Faculty of Sciences and Technology of the University of Coimbra

September 2019

Faculty of Sciences and Technology of the University of Coimbra
Department of the Civil Engineering

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DESIGN OF COLD-FORMED STEEL STRUCTURES

DIMENSIONAMENTO DE ESTRUTURAS EM AÇO ENFORMADO A FRIO SEGUNDO AS NORMAS EUROPEIAS, AMERICANAS E AUSTRALIANAS

Master Dissertation in Steel and Composite Construction, supervised by the Professor Rui António Duarte Simões and presented to the Department of Civil Engineering of the Faculty of Sciences and Technology of the University of Coimbra

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RESUMO

O principal objectivo de qualquer engenheiro estrutural em todo o mundo é o desenho de estruturas mais leves e seguras. Através de estudos técnicos e melhoria da tecnologia, a aplicação de secções enformadas a frio permitiu aumentar a resistência das estruturas, garantindo também perfis mais leves.

No sector fotovoltaico, assim como em outros sectores, é extremamente importante saber quais normas, em termos de projecto, fornecem melhores estruturas relativamente à resistência e peso. Assim, com o objectivo de aumentar a optimização das estruturas, utilizando-se quatro estruturas diferentes e as normas Norte Americanas, Australianas/Nova Zelândia e Europeia, foi realizada uma comparação entre elas.

ASCE 7-10, AS/NZS 1170 e EN 1990/1991, sendo baseadas em normas idealizadas pela Organização Internacional de Normalização (ISO), possuem semelhanças entre elas. Todas fornecem um bom apoio para as quantificações de cargas de projecto, embora o ASCE 7-10, em comparação com os outros dois, forneça orientações para um leque mais alargado de cargas a serem utilizadas no projecto, falhando nas combinações de carga a serem usadas nos Estados Limite de Utilização.

A EN 1993-1-3 é uma norma mais teórica, fornecendo linhas de orientação para o estudo de vários tipos de seções abertas enformadas a frio, relativamente à AISI S100 e AS/NZS 4600, que são mais focadas no uso de secções padronizadas, sendo a validação efectuada pela realização de testes.

A aplicação das três normas, cada uma delas, envolve uma quantidade considerável de tempo, devido às inúmeras particularidades e parâmetros, mas, embora o AISI S100 pareça mais fácil de aplicar, o conhecimento da norma Europeia para estruturas enformadas a frio fornece um melhor conhecimento e facilita a transição da EN 1993-1-3 para a AISI S100 / AS/NZS 4600. Engenheiros que usam apenas as normas americanas podem considerar a norma europeia complexa mas o conhecimento ganho torna o trabalho lucrativo.

Palavras-chave: Aço enformado a frio, AISI S100, AS/NZS 4600, EN 1993-1-3, AISI

ABSTRACT

The main goal of any structural engineer worldwide is the design of lighter and safer structures. Through technical research and technology improvements, the application of cold-formed sections provided a way to increase the structures strength assuring, as well, lighter members.

In the Photovoltaic sector, as well in other sectors, knowing which design standard provides better structures in terms of strength and lightness is extremely important. So, with the purpose of increasing the structures optimization, using four different structures types and the North American, Australian/New Zealand and European Standards, a comparison between them was made.

ASCE 7-10, AS/NZS 1170 and EN 1990/1991, because are based in norms idealized by the International Organization for Standardization (ISO), possess similarities between them. All of them provides a good background for the design loads quantifications, although ASCE 7-10, compared to the other two, gives guidance for a more various loads essential in the design process but a negative aspect is the lack of guidance concerning the load combinations used in the Serviceability Limit States.

EN 1993-1-3 is a theoretical standard, giving guidance lines for the study of various types of cold-formed open sections while compared to AISI S100 and AS/NZS 4600, which is more focused in the use of standard sections, that are previously validated by a certain quantity of tests.

The application of the three standards, each one, involves a considerable amount of time, because of the numerous particularities and parameters, but, although the fact that AISI S100 looks easier to apply, the knowledge of the European cold-formed design code provides a better background and facilitates the transition from EN 1993-1-3 to AISI S100 / AS/NZS 4600. Engineers that only use the American Specifications may consider the European code complex, which in fact is, but the knowledge gain makes the work profitable.

Key words: Cold-Formed Steel, AISI S100, AS/NZS 4600, EN 1993-1-3, AISI

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1 INTRODUCTION

1.1 Cold-Formed Steel (CFS)

Cold-formed steel (CFS) was been used as construction material since the beginning of the 1800s. It was used principally in the construction sector, between 1920 to 1950 in the United States and United Kingdom but, nowadays, CFS members are used with diverse applications in different sectors, Automotive, Aircraft, Agricultural/Industrial Equipment, Mining, Nuclear and Space Industries.

The use of CFS as structural members is increasing due to the improvement of the manufacture technology that assures pieces have uniform cross-sections, good protection against corrosion as well tight dimensional tolerances. This leads to the fabrication of new products with high levels of acceptance and competitiveness compared to the traditional construction materials, concrete and timber.

Because of its reduced thickness members and light weight, CFS structures are easier to transport, construct and install, assuring at the same time size-to-thickness members ratio with high efficiency and flexibility, reduction members and connecting bolts. Pieces are separated into structural members (Figures 1.1, 1.2 and 1.3) or sheeting.

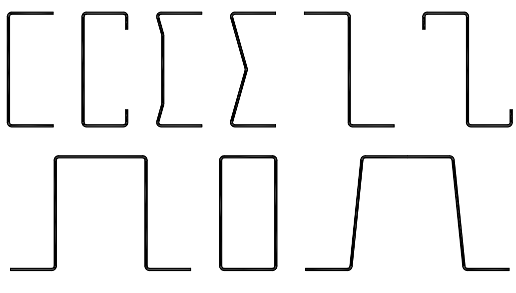


Figure 1.1 - Cold-Formed Structural Members: Single Opens Sections

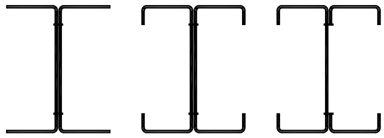


Figure 1.2 - Cold-Formed Structural Members: Open Built-up Sections

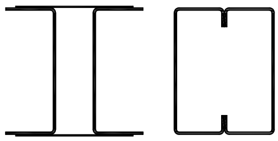


Figure 1.3 - Cold-Formed Structural Members: Closed Built-up Sections

CFS members, although provides members with light weight, high efficiency and flexibility, are sensitive to particular problems that must be tend in consideration in the design, as: (1) Buckling strength of cold-formed steel members because of four generic types of buckling, namely local, global, distortional and shear; (2) Torsional rigidity in cold-formed steel sections, because of its reduced thickness members and shear centre not coincident with the gravity centre (if it is a mono-symmetric section), generally have low torsional values. To prevent considerable deformations in a mono-symmetric thin-walled beam, the use of restraints, at intervals or continuously along the length, assures the resistance of the cold-formed section; (3) Web crippling is a critical problem at points of concentrated load supports because of the reduced thickness of high height of the webs; (4) Connections; (5) Fire resistance in CFS sections is reduced due to small ratio of the heated volume to the cross sectional area of the member; (6) Corrosion and (7) Ductility and plastic design in cold-formed steel sections, because, for example in EUROCODE, cold-formed sections are class 4 or 3, the use of plastic design is not allowable. Also, the use of cold-forming/work hardening, increases the resistance but reduces the ductility, not permitting the use of cold-formed steel sections to dissipate energy in seismic resistant structures.

1.2 Cold-Formed Steel (CFS): Applications

CFS members are used with different applications:

- Industrial, Commercial and Agricultural building's roof systems (Figure 1.4)
- Steel racks storage structures (Figure 1.5)
- Cold-formed steel trusses (Figure 1.6)
- Residential steel framing (Figure 1.7)

- Cold-formed steel floor joists (Figure 1.8)
- Wall partitions (Figure 1.9)
- Frame with bolted beam-to-column joists (Figure 1.10)
- Cold-formed tubular members

Figure 1.4 - Industrial building roof system (Metsec, 2018)

Figure 1.5 - Steel racks storage structures (The Fabricator, 2018)

Figure 1.6 - Cold-formed steel trusses (Vanderwal Homes, 2018)

Figure 1.7 - Residential steel framing (Argos Systems, Vertex BD BIM, 2018)

Figure 1.8 - Cold-formed steel floor joists (FDR Engineers, 2019)

Figure 1.9 - Wall partitions (Steel Formed Sections [SFS], 2018)

Figure 1.10 - Frame with bolted beam-to-column joists (Bone Structure, 2015)

1.3 Cold-Formed Steel (CFS): Design Standards History

CFS members have been used as structural elements since 1850s (USA and UK) but, since there was no specific design standard to cover cold-formed issues, it made implementation and acceptance very difficult. American Iron and Steel Institute (AISI), understanding that the incorporation of CFS members produces safer and lighter structures, sponsored a survey that was conducted in 1939 by Professor George Winter of the Cornel University. That work led to the creation of the first cold-formed steel design specification guide in 1946.

Due to the increase of research and technical developments made through the years, focused on CFS members, AISI Standard has constantly been updated and also lead to the creation of other international standards, Australian/New Zealand Standard AS/NZS 4600 (based on AISI specifications), Canadian Standard CAN/CSA S136 (replaced by North American Standard, AISI S100), British Standard BS 5950 Part 5 (replaced by EUROCODE EN 1993-1-3) and finally, European Design Code, EUROCODE EN 1993-1-3.

Through the analysis of different standards, it is possible to identify that AISI S100 is one of the more organized and versatile standards that was ever been developed. AISI S100 permits the use of three different unit systems (U.S. customary units, SI units and MKS units), when AS/NZS 4600 and EN 1993-1-3 only uses SI units. AS/NZS 4600 and EN 1993-1-3 only permits the analysis through Limit States Design (LSD) when AISI S100 provides an integrated treatment for Allowable Strength Design (ASD), Load and Resistance Factor Design (LRFD) and Limit States Design (LSD). In AISI S100 specification, LSD analysis is only applied in Canada and ASD/LRFD is applied to both United States and Mexico, with the application of the appropriate resistance factors (ϕ) in LRFD/LSD and safety factors (Ω) in ASD. LRFD and LSD are almost equal, only differing load factors, nomenclature and load combinations.

1.4 Master Thesis Main Goal

The main purpose of Structural Engineers around the world is the design of lighter and safer structures. The inexistence of a global design standard, in this case regarding the study of CFS structures, “presents a little problem”, because isn’t possible to know which standard offers better results, in terms of strength and lightness, without the knowledge and proper use of each one. In the Photovoltaic Market, the optimization of the CFS structures is of extreme importance.

Taking into account the previously mentioned, the present thesis will be focused in the application of three cold-formed design codes (AISI S100 in the United States of America, Mexico and Canada; AS/NZS 4600 in Australia and New Zealand; EUROCODE EN 1993-1-3 in the European Union as well as other countries without proper design codes) to four types of structures. The structures that were used in the analysis are showed in Figures 1.11 to 1.14, composed with standard cross-sections fabricated in the company where the author works. It will be made a comparison between the different codes, regarding is applicability, restrictions and proper rules.

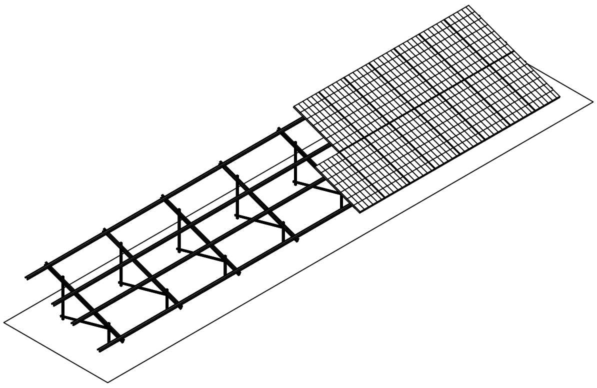


Figure 1.11 - 3D Photovoltaic Structure (Type 1)

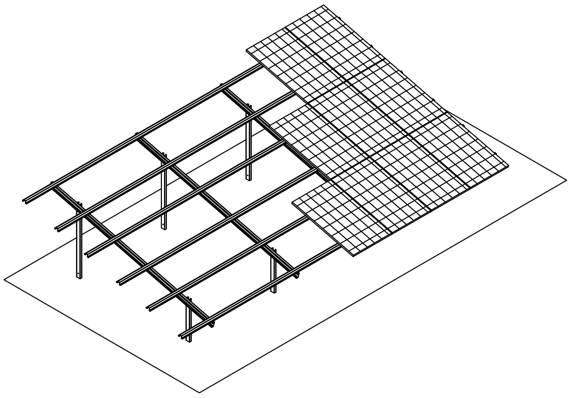


Figure 1.12 - 3D Photovoltaic Structure (Type 2)

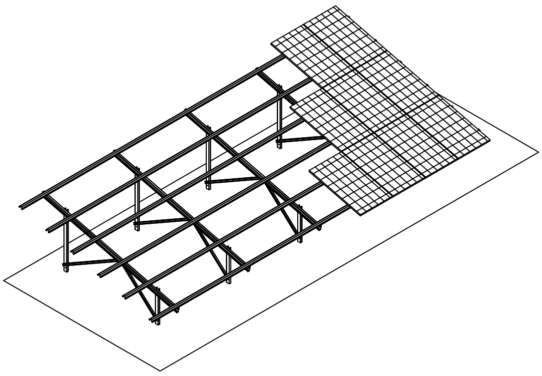


Figure 1.13 - 3D Photovoltaic Structure (Type 3)

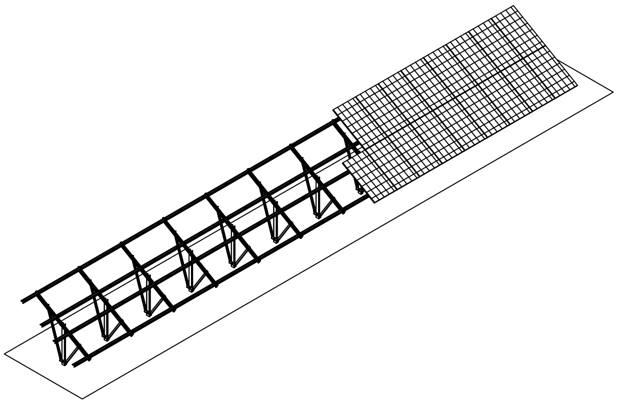


Figure 1.14 - 3D Photovoltaic Structure (Type 4)

1.5 Master Thesis Organization

This thesis is organized in six chapters. First chapter provides a brief historical review about CFS structures, its applications and decisions that were taken to elaborate the actual design codes. Second chapter presents the structures used in the design, location of study, material and cold-formed sections. Third chapter provides information about the design load codes (ASCE 7, AS/NZS 1170 and EUROCODE EN 1990 / EN 1991), for the specific loads considered in the design models, through the application of flow charts. Fourth chapter contains a brief presentation of some points of the design codes, AISI S100, AS/NZS 4600 and EN 1993-1-3, through the use of flow charts that were used for the verification of members' subjected to compression forces and bending moments. In the fifth chapter, a comparison between codes, based on the mentioned four types of structures, is presented and the sixth chapter presents the conclusions obtained in the study.

2 PROJECT INFORMATION

2.1 Structure Types

The use of cold-formed steel members permits the creation of structures with different configurations. Photovoltaic structures are created with the purpose of obtaining the maximize energy output and the optimization of the solar farm design, so, they are disposed in arrays containing the photovoltaic modules in landscape (module with the longest side parallel to the ground) or portrait (module with the shortest side parallel to the ground) layout, with a specific tilt degree facing south. In the present study, photovoltaic modules are disposed in the portrait layout.

The used structures, Figures 2.1 to 2.12, were idealized so that the frame supporting purlins, that cross the clamping fixation zone, defined in function of a photovoltaic model, were optimized to maximize the ratio in each structural section member.

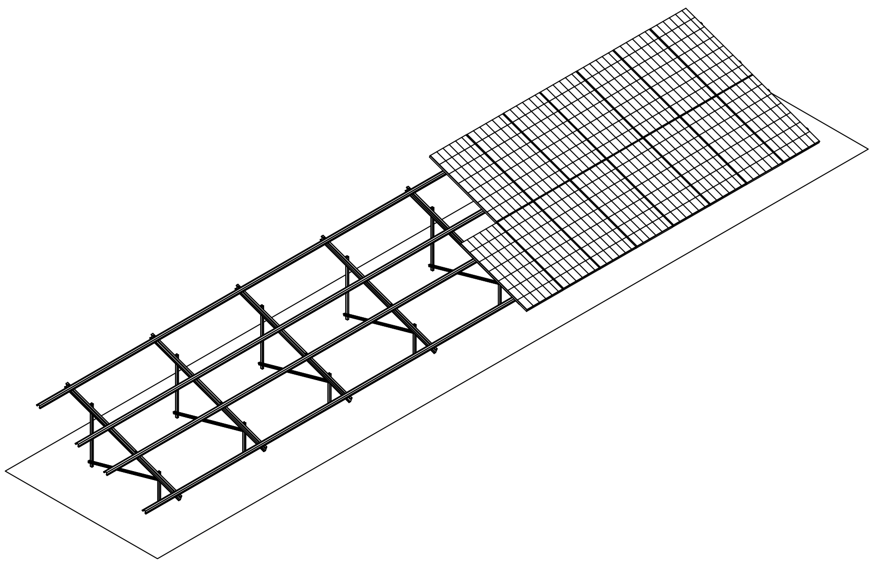


Figure 2.1 - 3D Photovoltaic Structure (Type 1)

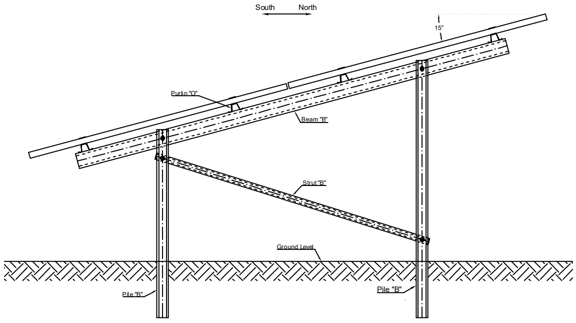


Figure 2.2 - Photovoltaic Structure (Type 1): Standard Frame

Figure 2.3 - Autodesk ROBOT Structural 3D Design Model (Type 1)

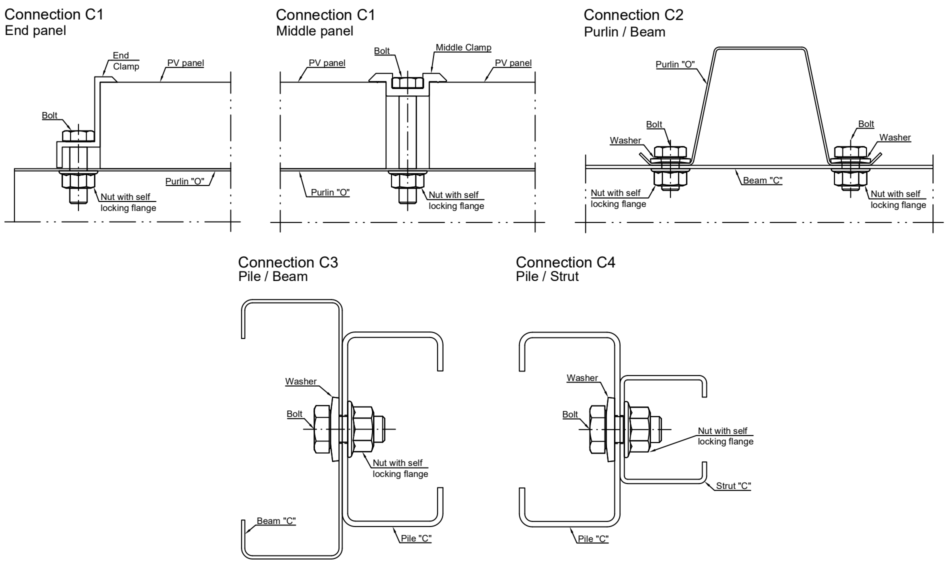


Figure 2.4 - 3D Photovoltaic Structure (Type 1): Connections

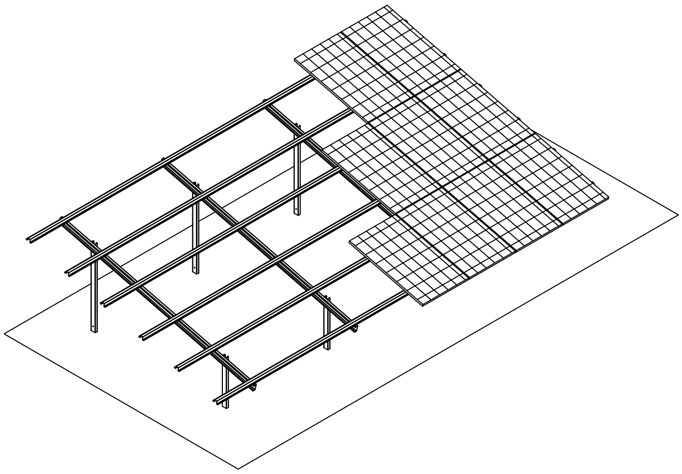


Figure 2.5 - 3D Photovoltaic Structure (Type 2)

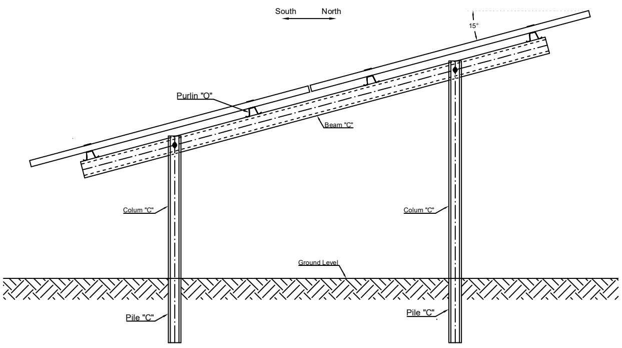


Figure 2.6 - Photovoltaic Structure (Type 2): Standard Frame

Figure 2.7 - Autodesk ROBOT Structural 3D Design Model (Type 2)

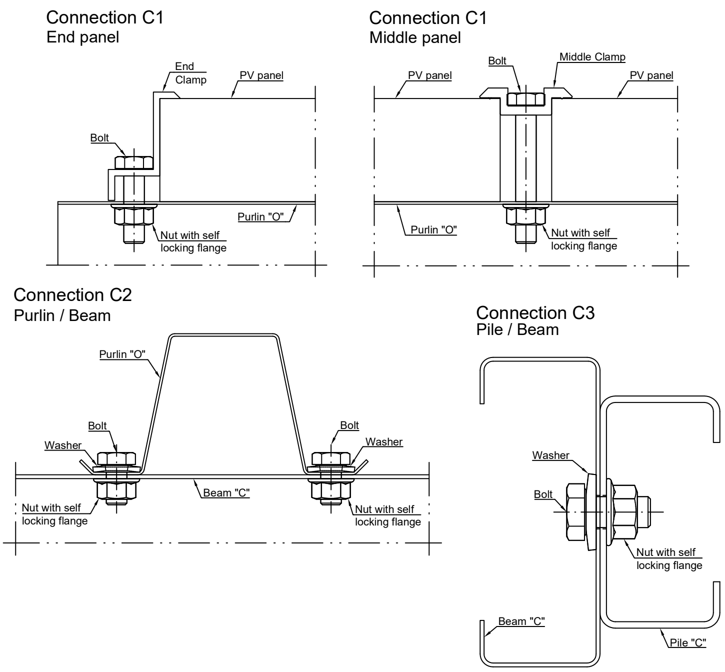


Figure 2.8 - 3D Photovoltaic Structure (Type 2); Connections

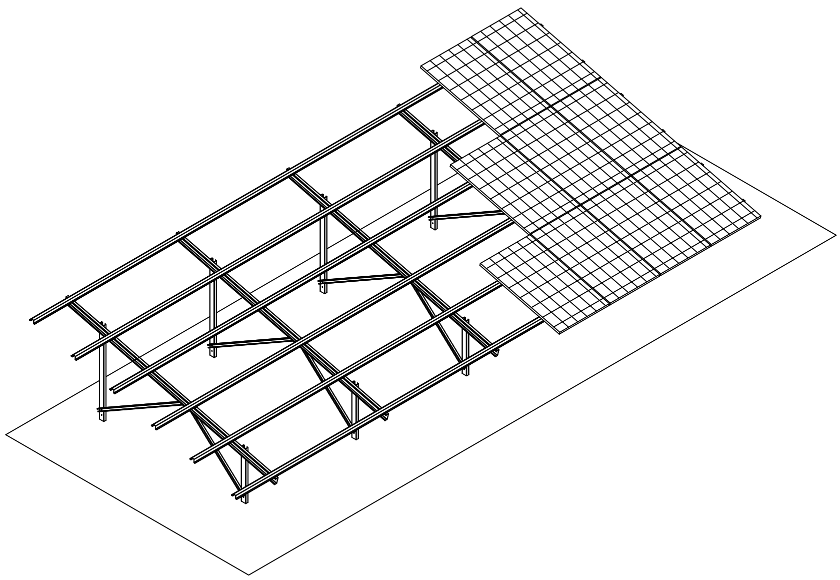


Figure 2.9 - 3D Photovoltaic Structure (Type 3)

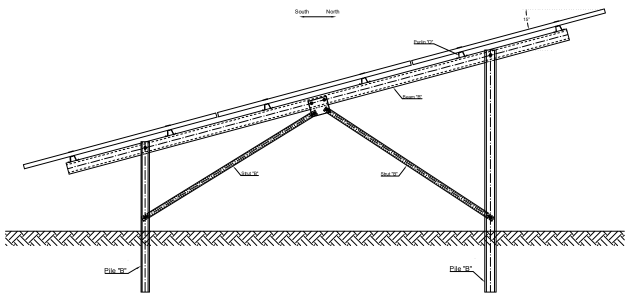


Figure 2.10 - Photovoltaic Structure (Type 3): Standard Frame

Figure 2.11 - Autodesk ROBOT Structural 3D Design Model (Type 3)

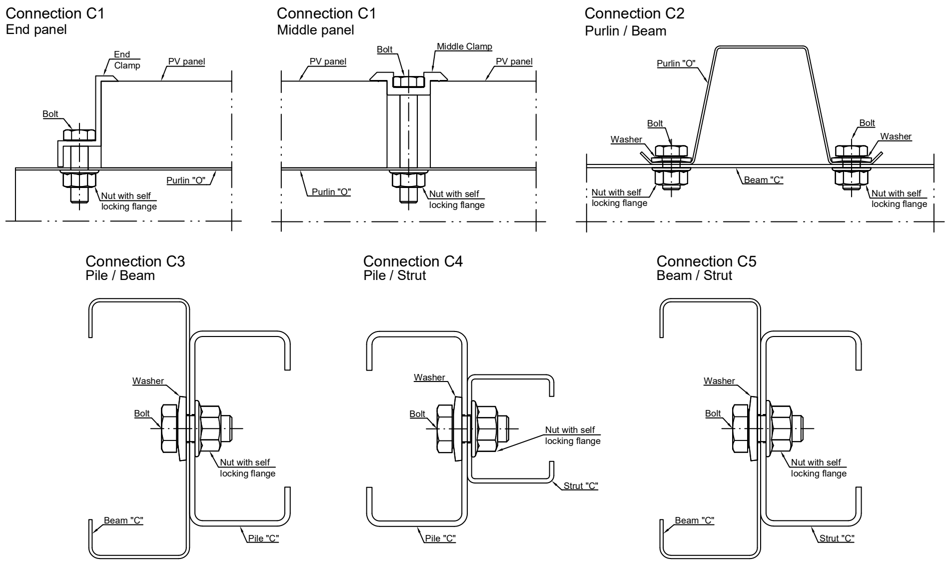


Figure 2.12 - 3D Photovoltaic Structure (Type 3): Connections

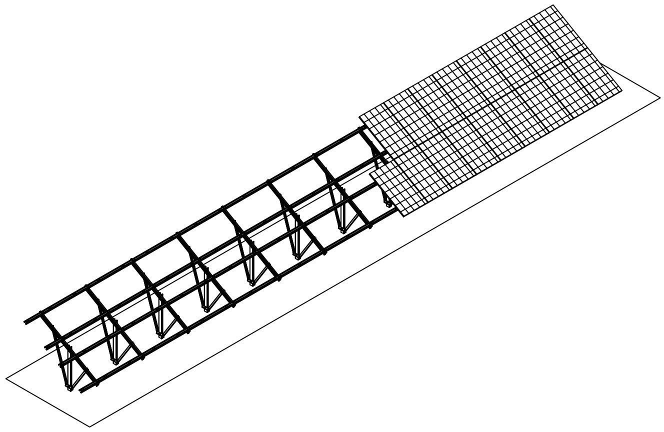


Figure 2.13 - 3D Photovoltaic Structure (Type 4)

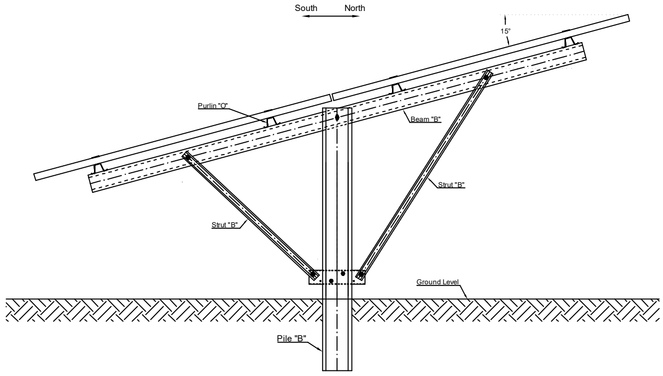


Figure 2.14 - Photovoltaic Structure (Type 4): Standard Frame

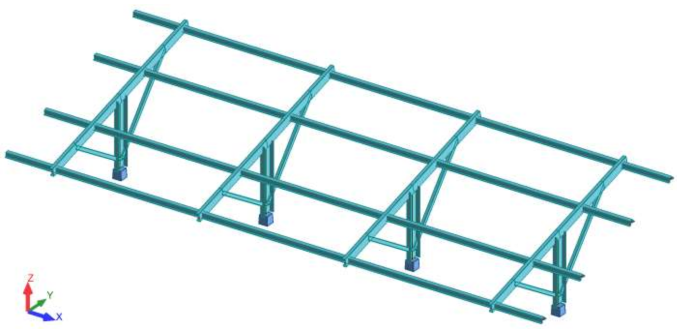


Figure 2.15 - Autodesk ROBOT Structural 3D Design Model (Type 4)

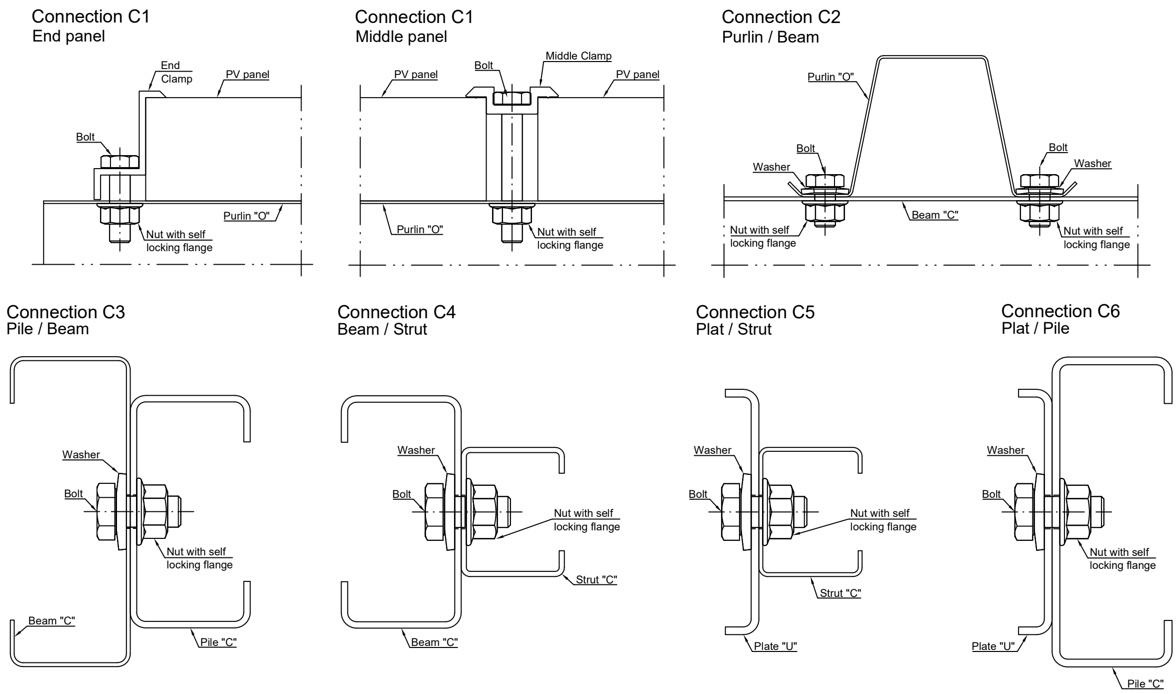


Figure 2.16 - 3D Photovoltaic Structure (Type 4); Connections

2.2 Cold-formed steel (CFS) sections and manufactured process

The CFS sections used in the design are the result of years of study and tests, allowing dimensions to be optimized to meet the purposes for which they were created. They are patented and so it will only be possibly to present its commercial designation, "B" for lipped channel sections and "Ω" for OMEGA sections. These sections, presented in Figure 2.17, are obtained with the roll forming process that corresponds to the deformation of a continuous steel strip, through the utilization of a series of rolls, in various stages, until the final section is obtained. According to Dubina et al (2012), the use of this manufactured process, besides press braking, has an impact on the basic strengths of cold-formed profiles, as showed in Table 2.1.

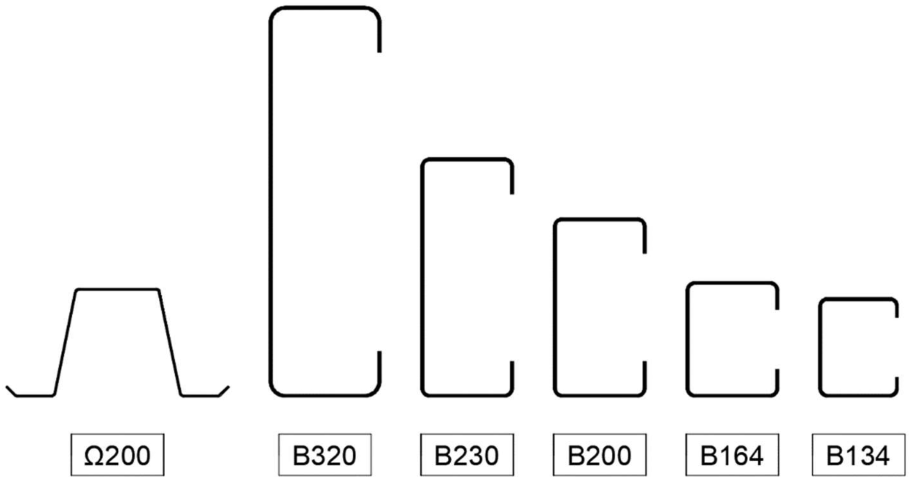


Figure 2.17 - Cold-formed sections (Commercial definitions)

Table 2.1 - Influence of manufacturing process on the basic strengths of cold-formed profiles (Dubina et al, 2012)

Forming method		Cold forming	
		Cold rolling	Press braking
Yield strength	Corner	High	High
	Flange	Moderate	---
Ultimate strength	Corner	High	High
	Flange	moderate	---

2.3 Material

The cold-formed steel material is S350 MAGNELIS® ZM310. The mechanical properties are, according to EN 10326:

- Basic Yield Strength, $f_{yb} = 350 \ N/mm^2$
- Ultimate Tensile Strength, $f_u = 420 \ N/mm^2$

According to EN 1993-1-1, Clause 3.2.6, material coefficients are:

- Modulus of Elasticity, $E = 210000 \ N/mm^2$
- Poisson’s ratio in elastic stage, $\nu = 0.300$
- Shear Modulus, $G = 80769 \ N/mm^2$

The materials used in the three continents (Australia, Europe and North America) are different in terms of resistance and ductility. It was adopted the values used in Europe to simplify the design process.

2.4 Project Location

The structures are located in Netherlands, on a flat terrain. Figures 2.18 and 2.19 presents the approximate location with a visualization of the terrain where they are installed.

Figure 2.18 - Master Thesis Project Location

Figure 2.19 - Master Thesis Project: Terrain (Google Earth)

3 STRUCTURAL DESIGN ACTION STANDARDS

3.1 ASCE/SEI 7-10, AS/NZS 1170 and EN 1990 / EN 1991

The standards that provide minimum load requirements for the design of structures, taking into account the norms that will be studied, are:

- **United States of America:** ASCE/SEI 7-10, Minimum Design Loads for Buildings and Other Structures
- **Australia/New Zealand:** AS/NZS 1170, Structural Design Actions
- **Europe:** EUROCODE EN 1990, Basis of Structural Design and EN 1991, Actions in Structures

In the design of photovoltaic structures, the applied loads are (1) Dead load; (2) Photovoltaic module load; (3) Snow load; (4) Wind load; (5) Temperature load and (6) Seismic load. In the study, temperature and seismic loads were disregarded. Temperature because the use of stress release mechanisms, like slotted or oversized holes with proper length permits the member length variation and seismic loads because, experience on photovoltaic structures has shown that the structure global low weight is not relevant when compared to wind and snow loads. So, considering the previously mentioned, only flow charts for wind and snow loads will be presented.

3.2 Design Loading and Load Combinations

3.2.1 Minimum Design Loads for Buildings and Other Structures (ASCE/SEI 7-10)

ASCE/SEI 7-10 lets the designer choose between two different types of strength limit state, providing information and guidance to the loads and appropriate load combinations that were to be used, depending if the limit state is according to the *"Allowable Stress Design"* (ASD) or *"Load and Resistance Factor Design"* (LFRD) / *"Strength Design"*.

According to ASCE/SEI 7-10 (ASCE, 2010), **Allowable Stress Design** is "*a method of proportioning structural members such that elastically computed stresses produced in the members by nominal loads do not exceed specified allowable stresses (also called "working stress design")*". **Strength Design** is "*a method of proportioning structural members such that the computed forces produced in the members by the factored loads do not exceed the member design strength (also called "Load and Resistance Factor Design")*".

ASCE/SEI 7-10 gives guidance for the following loads:

- Load or load effect arising from extra ordinary event A, A_k
- Dead load, D
- Weight of ice, D_i
- Earthquake load, E
- Load due to fluids with well-defined pressures and maximum heights, F
- Flood load, F_a
- Load due to lateral earth, ground water or pressure of bulk materials, H
- Live load, L
- Roof live load, L_r
- Rain load, R
- Snow load, S
- Self-straining load, T
- Wind load, W
- Wind-on-ice, W_i

In the "Load and Resistance Factor Design" (LFRD), the load combinations are:

		Permanent actions		Leading variable actions		Accompanying variable actions	Equation
E_d	$=$	$1.40 \times D$					(3.1)
E_d	$=$	$1.20 \times D$	$+$	$1.60 \times L$	$+$	$0.50 \times L_r$ $0.50 \times S$ $0.50 \times R$	(3.2)

		Permanent actions		Leading variable actions		Accompanying variable actions	Equation
E_d	=	$1.20 \times D$	+	$1.60 \times L_r$ $1.60 \times S$ $1.60 \times R$	+	L $0.50 \times W$	(3.3)
E_d	=	$1.20 \times D$	+	$1.00 \times (W + L)$	+	$0.50 \times L_r$ $0.50 \times S$ $0.50 \times R$	(3.4)
E_d	=	$1.20 \times D$	+	$1.00 \times (E + L)$	+	$0.20 \times S$	(3.5)
E_d	=	$0.90 \times D$	+	$1.00 \times W$			(3.6)
E_d	=	$0.90 \times D$	+	$1.00 \times E$			(3.7)

The load combinations used in the “Allowable Stress Design” (ASD) are:

		Permanent actions		Leading variable actions		Accompanying variable actions	Equation
E_d	=	$1.00 \times D$					(3.8)
E_d	=	$1.00 \times D$	+	$1.00 \times L$			(3.9)
E_d	=	$1.00 \times D$	+	$1.00 \times L_r$ $1.00 \times S$ $1.00 \times R$			(3.10)
E_d	=	$1.00 \times D$	+	$0.75 \times L$	+	$0.75 \times L_r$ $0.75 \times S$ $0.75 \times R$	(3.11)

		Permanent actions		Leading variable actions		Accompanying variable actions	Equation
E_d	=	$1.00 \times D$	+	$0.60 \times W$ $0.70 \times E$			(3.12)
E_d	=	$1.00 \times D$	+	$0.75 \times L$	+	$0.45 \times W + 0.75 \times L_r$ $0.45 \times W + 0.75 \times S$ $0.45 \times W + 0.75 \times R$	(3.13)
E_d	=	$1.00 \times D$	+	$0.75 \times L$	+	$0.53 \times E + 0.75 \times S$	(3.14)
E_d	=	$0.60 \times D$	+	$0.60 \times W$			(3.15)
E_d	=	$0.60 \times D$	+	$0.70 \times E$			(3.16)

ASCE/SEI 7-10 defines the combination values to been used in the strength limit states calculations but, for serviceability limit states, leaves that choice for the owners, designers or builders. This measure has been adopted because is a non-catastrophic event, producing only local minor damage and, also, the level of acceptance regarding the quality of the structure or member varies from person to person.

Figures 3.1, 3.2, 3.3 and 3.4 gives a description of the procedure used for determination of snow and wind loads, for the type of structures used in the study, monopitch open roof structures.

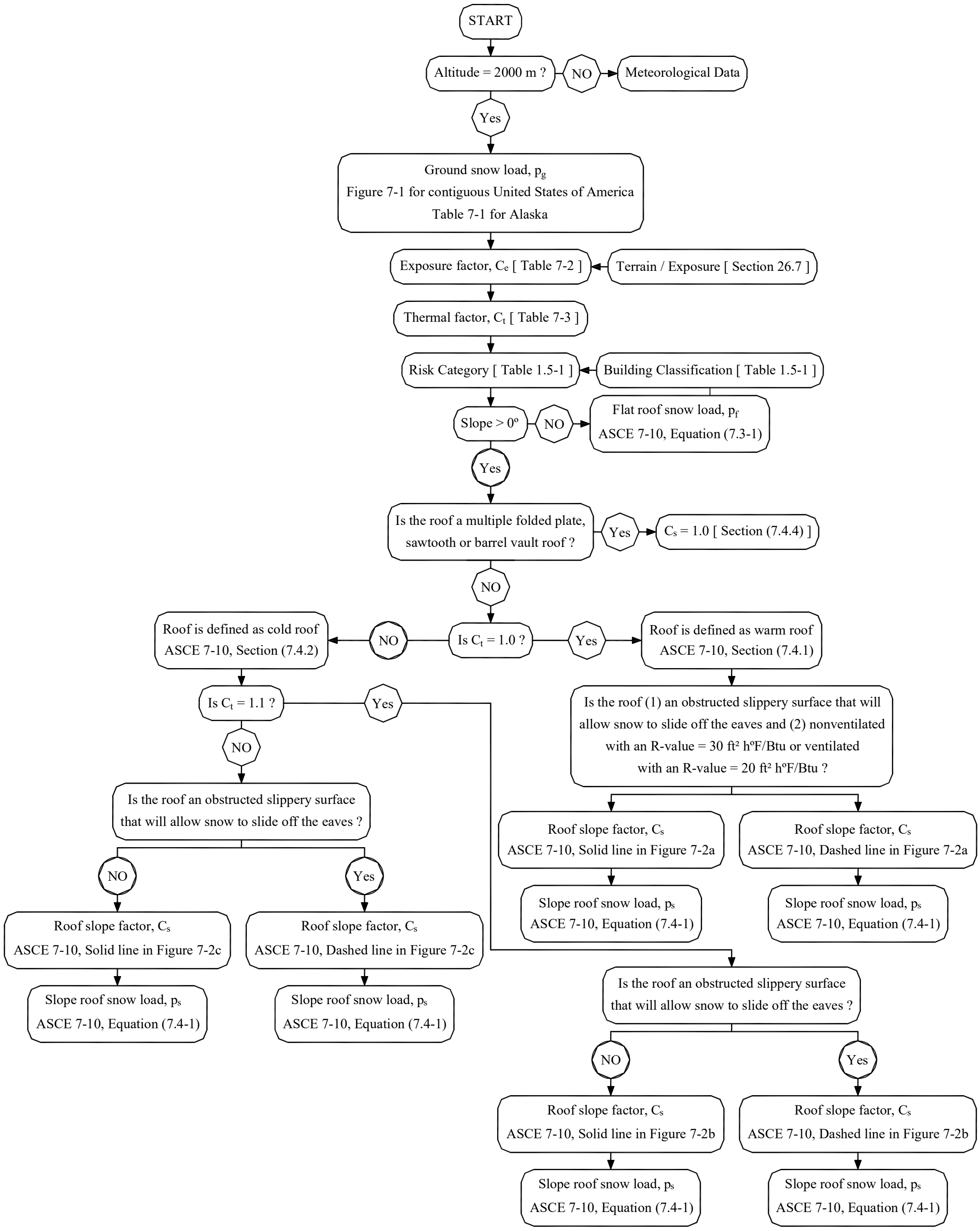


Figure 3.1 - Snow load for monopitch roof
(Adapted from "Structural load determination under 2009 IBC and ASCE/SEI 7-05")

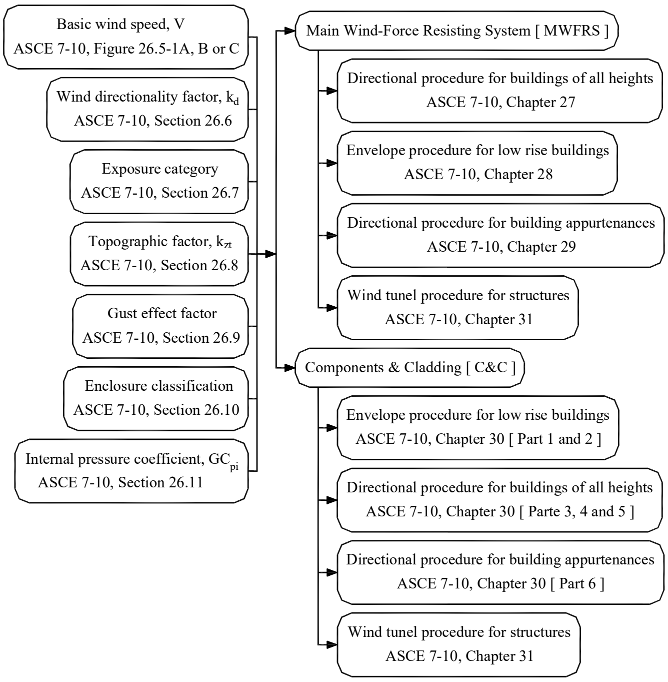


Figure 3.2 - Process for Determining Wind
(Adapted from ASCE/SEI 7-10, Figure 26.1-1)

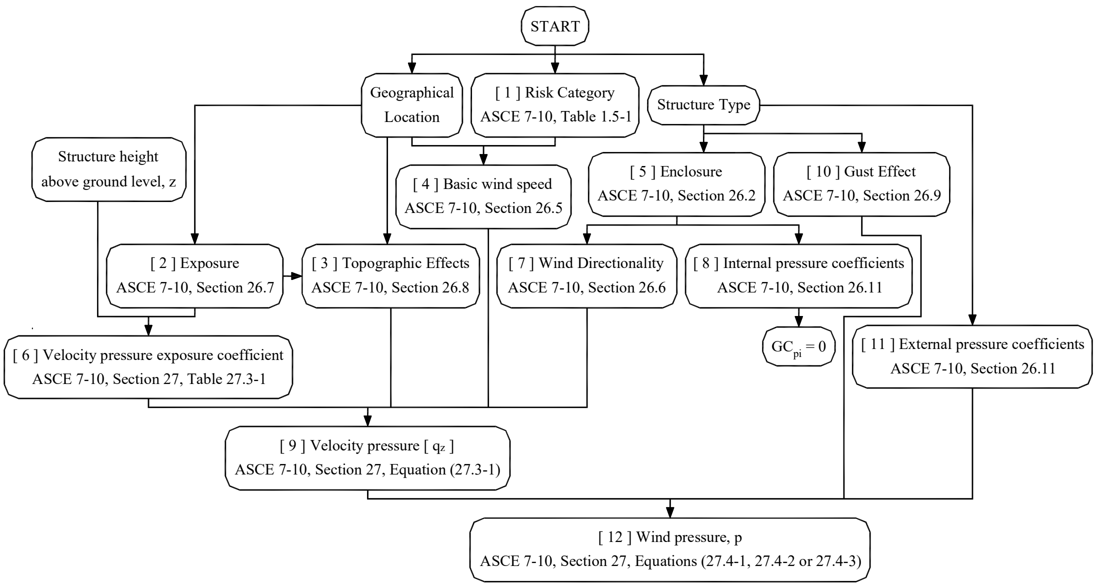


Figure 3.3 - Steps to determine MWFRS Wind Loads for Open Buildings of All Heights
(Adapted from ASCE/SEI 7-10, Table 27.2-1)

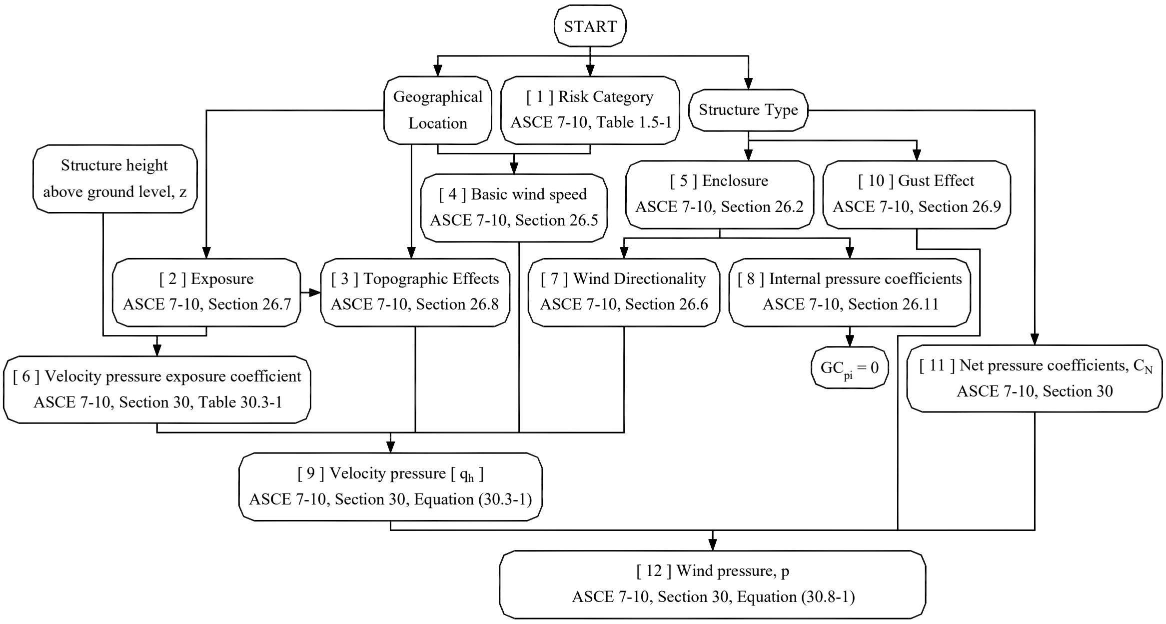


Figure 3.4 - Steps to determine C&C Wind Loads for Open Buildings
(Adapted from ASCE/SEI 7-10, Table 30.8-1)

3.2.2 Australian/New Zealand Standard™: Structural Design Actions (AS/NZS 1170)

Australian/New Zealand Standard™: Structural Design Actions is composed of six parts:

- AS/NZS 1170.0: General principles
- AS/NZS 1170.1: Permanent, imposed and other actions
- AS/NZS 1170.2: Wind actions
- AS/NZS 1170.3: Snow and ice actions
- AS 1170.4: Earthquake actions in Australia
- NZS 1170.5: Earthquake actions in New Zealand

AS/NZS 1170 provides information for loads like:

- Permanent action (dead load), G
- Imposed action (live load), Q
- Wind, W (W_u, Wind for ultimate limit states | W_s, Wind for serviceability limit states)
- Snow, F_{sn}
- Earthquake, E
- Static liquid pressure, F_{lp}

- Ground water, F_{gw}
- Rainwater ponding, F_{pnd}
- Earth pressure, F_e

In design, the purpose of Ultimate Limit States is to assure that all members and connections have design resistance to avoid the probability of collapse. Serviceability Limit States are used to see if the structure is capable of providing comfort, avoiding excessive deflections, sways, slopes or loss of material due to corrosion or abrasion. With this purpose, for three different cases, AS/NZS 1170.0 defines a series of load combinations:

- Ultimate Limit States: Stability
- Ultimate Limit States: Strength
- Serviceability Limit States

The basic combinations for the verification of stability in the ultimate limit states are:

- Equation (3.17), combinations with net stabilizing effects. Permanent actions only (not applied to prestressing forces)
- Equation (3.18), combinations with net destabilizing effects. Permanent actions only (not applied to prestressing forces)
- Equation (3.19), combinations with net destabilizing effects. Permanent and imposed actions
- Equation (3.20), combinations with net destabilizing effects. Permanent, wind and imposed actions
- Equation (3.21), combinations with net destabilizing effects. Permanent, earthquake and imposed actions
- Equation (3.22), combinations with net destabilizing effects. Permanent, snow and imposed actions

		Permanent actions	Leading variable actions	Accompanying variable actions	Equation
$E_{d,stb}$	=	$0.90 \times G$			(3.17)
$E_{d,dst}$	=	$1.35 \times G$			(3.18)

		Permanent actions		Leading variable actions		Accompanying variable actions	Equation
$E_{d,dst}$	=	$1.20 \times G$	+	$1.50 \times Q$			(3.19)
$E_{d,stb}$	=	$1.20 \times G$	+	W_u	+	$\psi_c \times Q$	(3.20)
$E_{d,stb}$	=	$1.20 \times G$	+	E_u	+	$\psi_E \times Q$	(3.21)
$E_{d,stb}$	=	$1.20 \times G$	+	S_u	+	$\psi_c \times Q$	(3.22)

The basic combinations for the verification of strength in the ultimate limit states are:

- Equation (2.23), permanent actions only (not applied to prestressing forces)
- Equation (3.24), permanent and imposed actions
- Equation (3.25), permanent and long-term imposed actions
- Equation (3.26), permanent, wind and imposed actions
- Equation (3.27), permanent and wind action reversal
- Equation (3.28), permanent, wind and imposed actions
- Equation (3.29), permanent, snow and imposed actions

		Permanent actions		Leading variable actions		Accompanying variable actions	Equation
E_d	=	$1.35 \times G$					(3.23)
E_d	=	$1.20 \times G$	+	$1.50 \times Q$			(3.24)
E_d	=	$1.20 \times G$	+	$1.50 \times \psi_l \times Q$			(3.25)
E_d	=	$1.20 \times G$	+	W_u	+	$\psi_c \times Q$	(3.26)

		Permanent actions		Leading variable actions		Accompanying variable actions	Equation
E_d	=	$0.90 \times G$	+	W_u			(3.27)
E_d	=	$1.00 \times G$	+	W_u	+	$\psi_E \times Q$	(3.28)
E_d	=	$1.20 \times G$	+	S_u	+	$\psi_c \times Q$	(3.29)

For serviceability limit states, the basic combinations are:

		Permanent actions	Leading variable actions	Accompanying variable actions	Equation
E_d	=	G			(3.30)
E_d	=		$\psi_s \times Q$		(3.31)
E_d	=		$\psi_l \times Q$		(3.32)
E_d	=		W_s		(3.33)
E_d	=		E_s		(3.34)

Figures 3.5 and 3.6 gives a description of the procedure used for determination of snow and wind loads, for the type of structures used in the study, monopitch open roof structures.

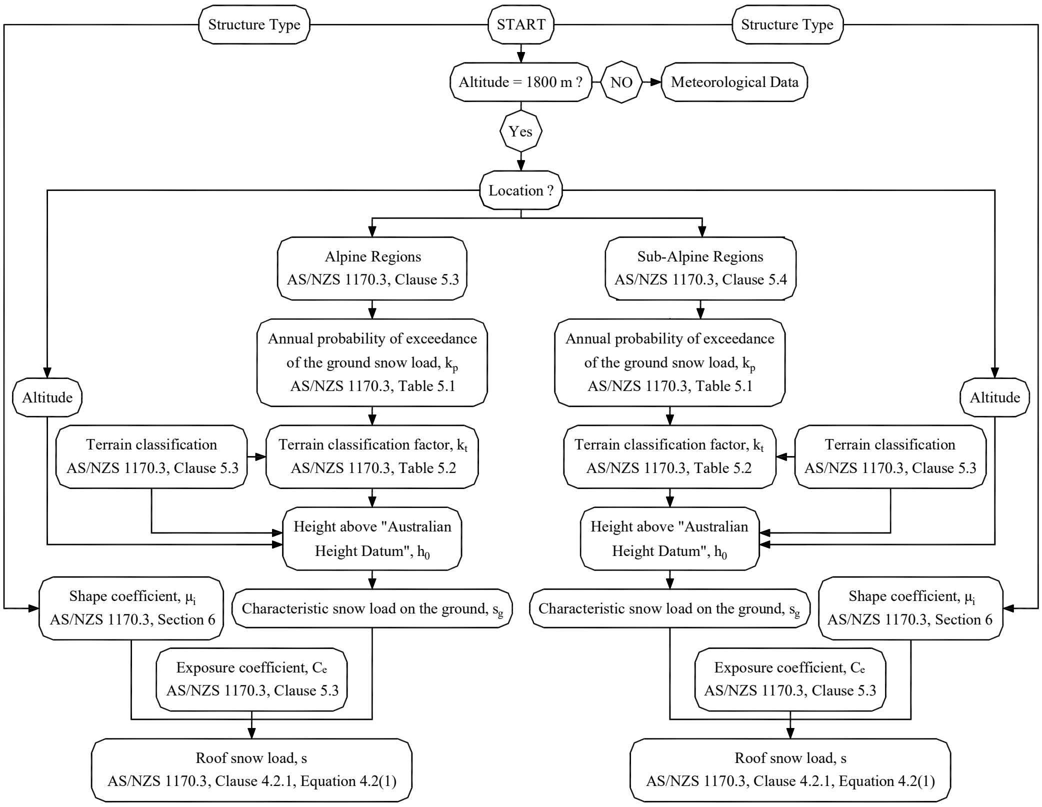


Figure 3.5 - Snow load for monopitch roof
(Based on AS/NZS 1170:3)

3.2.3 EUROCODE: Basis of Structural Design (EN 1990) and EUROCODE: Actions on Structures (EN 1991)

European Structural Design Standards is composed of eight parts:

- EUROCODE 0, Basis of structural design
- EUROCODE 1, Actions on structures (Part 1-1): Densities, self-weight, imposed loads for buildings
- EUROCODE 1, Actions on structures (Part 1-2): Actions on structures exposed to fire
- EUROCODE 1, Actions on structures (Part 1-3): Snow loads
- EUROCODE 1, Actions on structures (Part 1-4): Wind loads
- EUROCODE 1, Actions on structures (Part 1-5): Thermal actions
- EUROCODE 1, Actions on structures (Part 1-6): Actions during execution
- EUROCODE 1, Actions on structures (Part 1-7): Accidental actions

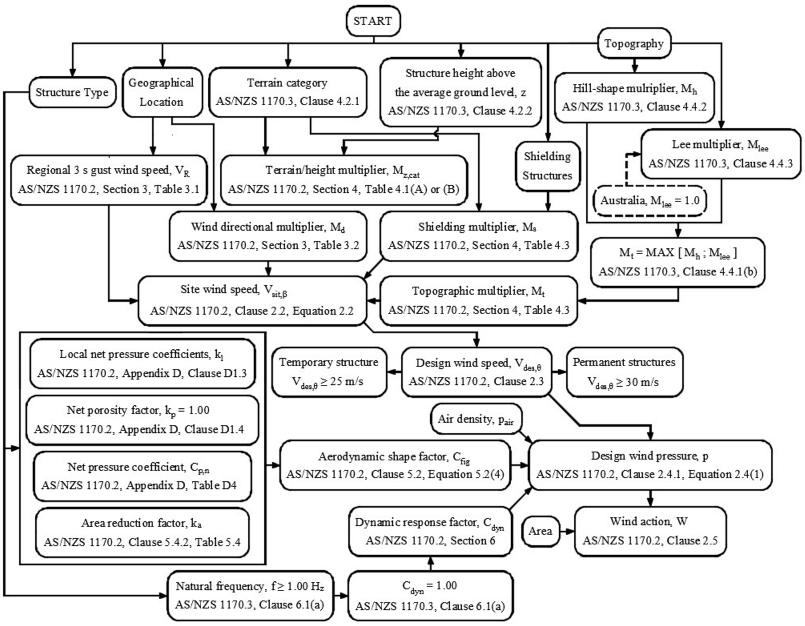


Figure 3.6 - Steps to determine Wind Loads for Open Buildings (Based on AS/NZS 1170:2)

One crucial aspect in the design of a structure is if the structure is capable of sustain the loads that will be applied over the years so, the definition of limit states is a crucial aspect. EUROCODE, to assures that the structure is capable of sustaining the loads that, if not controlled will increase the probability of structure collapse or deformation beyond repair, defines equations to been used for the verification of the Ultimate Limit States (ULS) and Serviceability Limit States (SLS).

In the ULS, is essential to be verified the EQU Limit States, involving the loss of static equilibrium of the structure, in a member or the whole structure. Destabilizing actions must be taken into account by adopting higher design values, while stabilizing effects (favors the structure equilibrium) have lower design values.

For the verification of the structure strength and serviceability, the following steps are followed:

1. Selection of appropriate design situations and limit states
2. Determination of load arrangements and critical load cases.
3. Calculation of design values for ultimate and serviceability limit states

Ultimate Limit States are designed for actions in persistent and transient design situations. **Transient design situation** (EN 1990, Clause 1.5.2.3) corresponds to a "*design situation which is relevant during a period much shorter that the design working life of the structure and which has a high probability of occurrence*". It equals to a state that occurs only during, for example, the construction or reparation. A **persistent design situation**, which refers to normal use conditions, is defined as a "*design situation which is relevant during a period of the same order as the design working life of the structure*" (EN 1990, Clause 1.5.2.4).

For the verification of transient or persistent design situations, EUROCODE defined three equations, (6.10), (6.10a) and (6.10b). Expression (6.10) is more conservative but it leads to a less number of combinations to be considered. Equation (3.35), (3.36) and (3.37) corresponds to the equation (6.10), (6.10a) and (6.11b) in EN 1990.

		Permanent actions		Leading variable actions		Accompanying variable actions	Equation
E_d	=	$\sum_{j\geq 1}\gamma_{G,j}G_{k,j}$	+	$\gamma_{Q,1}Q_{k,1}$	+	$\sum_{i>1}\gamma_{Q,i}\psi_{0,i}Q_{k,i}$	(3.35)
E_d	=	$\sum_{j\geq 1}\gamma_{G,j}G_{k,j}$	+	$\psi_{0,1}\gamma_{Q,1}Q_{k,1}$	+	$\sum_{i>1}\gamma_{Q,i}\psi_{0,i}Q_{k,i}$	(3.36)
E_d	=	$\xi\sum_{j\geq 1}\gamma_{G,j}G_{k,j}$	+	$\gamma_{Q,1}Q_{k,1}$	+	$\sum_{i>1}\gamma_{Q,i}\psi_{0,i}Q_{k,i}$	(3.37)

In serviceability limit states, the load combinations depend on the action effects. EN 1990 defines that actions can be irreversible, reversible or long-term effects, which one producing combinations that serve the verification of the structure functionality. The load combinations are written as:

- Equation (3.38), characteristic combination of actions, EN 1990 equation (6.14), for the irreversible limit states
- Equation (3.39), frequent combination, EN 1990 equation (6.15), for the reversible limit states
- Equation (3.40), quasi-permanent combination, EN 1990 equation (6.16), for long-term effects.

In serviceability limit states all partial factors are equal to unity.

		Permanent actions		Leading variable actions		Accompanying variable actions	Equation
E_d	=	$\sum_{j\geq 1} G_{k,j}$	+	$Q_{k,1}$	+	$\sum_{i>1} \psi_{0,i} Q_{k,i}$	(3.38)
E_d	=	$\sum_{j\geq 1} G_{k,j}$	+	$\psi_{1,1} Q_{k,1}$	+	$\sum_{i>1} \psi_{2,i} Q_{k,i}$	(3.39)
E_d	=	$\sum_{j\geq 1} G_{k,j}$	+	$\sum_{i>1} \psi_{2,i} Q_{k,i}$			(3.40)

Figures 3.7 and 3.8 gives a description of the procedure used for determination of snow and wind loads, for the type of structures used in the study, monopitch open roof structures.

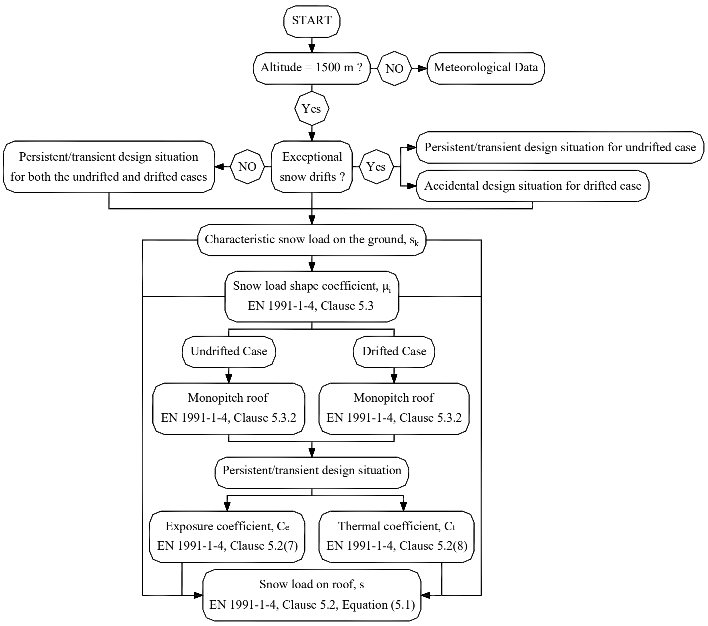


Figure 3.7 - Snow load for monopitch roof (Based on EN 1991-1-3)

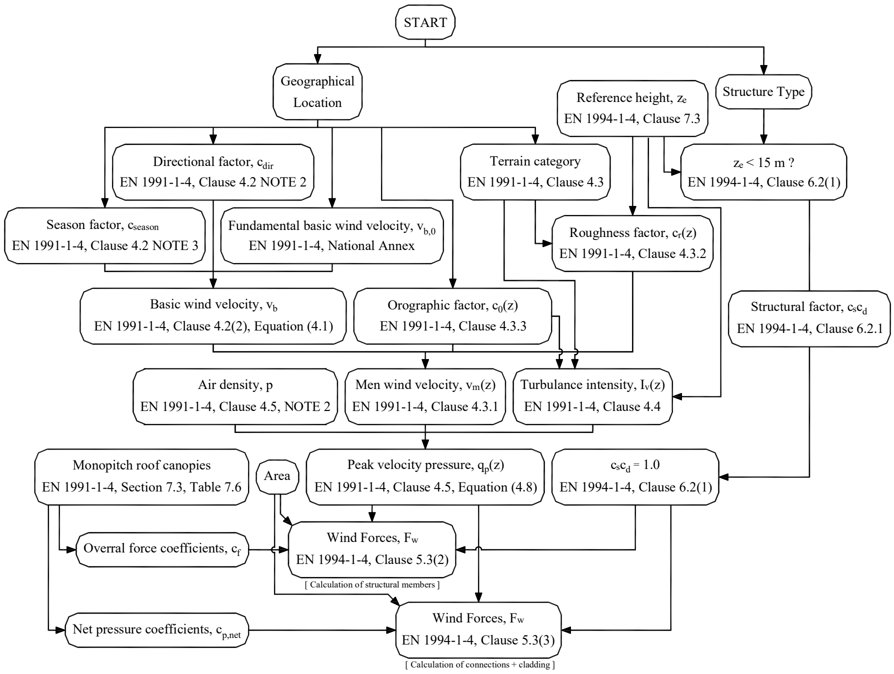


Figure 3.8 - Steps to determine Wind Loads for Open Buildings (Based on EN 1991-1-4)

3.2.4 Comparison among codes

Actually, there is no acceptable international standard that can be used in the determination of the snow and wind loads, verifying as well, considerable difference in terms of format and type of information displayed in the three different studied standards. However, for the studied codes, serving as base, all adopt some points of the codes defined by the International Organization of Standardization (ISO), more concretely, ISO 4354 for wind loads and ISO 4355 for snow loads.

Through the analysis of the snow load design codes, it was possible to identify that, although there is differences in terms of notations and equations, AS/NZS 1170.3 and EN 1991-1-3 don't cover, (a) impacts resulting for snow or ice sliding off or failing from a higher roof; (b) additional wind loads that could result from changes in shape or size of the building structures due to the presence of snow or a built-up ice; (c) lateral loading on structures due to snow on the ground (e.g. lateral loads exerted by drifts), while ASCE 7 provides design situations for the situations prescribed before like, for example, *"Sliding Snow"* (ASCE 7-10, clause 7.9) or *"Drifts on lower roofs"* (ASCE 7-10, clause 7.7). ASCE 7-10 considers as well the effect of rain-on-snow while both AS/NZS 1170.3 and EN 1991-1-3 don't. All the standards have limitations in altitudes, 1500 m to EN 1991-1-3, approximately 1800 m to AS/NZS 1170.3 and around 2000 m to ASCE 7-10, in the contiguous zones of the United States of America (Alaska is a different case).

In the determination of the design wind loads, all three standard codes have in common that the characteristic/basic wind speed is determined for a height of 10 m in open terrains with low vegetation and scattered obstructions, only differing the time measurement duration, which is 10-minutes for EN 1991-1-4 and 3-sec to both ASCE 7-10 and AS/NZS 1170:2. The velocity measured in EN 1991-1-4 is the characteristic mean wind velocity while in ASCE 7-10 and AS/NZS 1170:2 is the gust wind speed. The wind speed profile in atmospheric boundary layer can be modeled using or the power law or logarithmic law. The logarithmic law, used in codes like EN 1991-1-4 and AS/NZS 1170:2, is valid in unmodified form in strong wind conditions in the atmospheric boundary layer near the surface, which is influenced by the surface roughness, defined by the parameter of roughness length (z_0). ASCE 7-10 uses the power law, which is better to identify the overturning effects at the base of tall structures.

A roughness length depends on the terrains, leading to different wind speed profiles. In the wind standard codes, there isn't a global definition for the quantity and type for the terrain categories. According to Yang et al (2014), in 2009, Choi summarized information about terrain categories and its respective roughness length values. This table is presented in Table 3.1.

Table 3.1 - Summary of terrain category information for various wind codes
(Adapted from Local wind assessment in Australia, Table 2.4)

Standard / Codes	**Terrain categories**	**Roughness length z_0 range for all terrain categories [m]**
ASCE 7-10	5	0.003 - 1.000
AS/NZS 1170.2	3	0.0039 - 0.580
EN 1991-1-4	4	0.002 - 2.000

Ngo and Letchford compared ASCE 7-10, AS/NZS 1170.2 and EN 1991-1-4 to determine the topographic effects (orography in EUROCODE) and verified that only ASCE 7-10 considers the influence of terrain roughness on the speed effect of wind flows, treating hills and ridges differently, while both EN 1991-1-4 and AS/NZS 1170.2 treats them identically (Yang et al, 2014). They verified, as well, that there is a difference in the slope variation, with the following slope ranges defined in Table 3.2.

Table 3.2 - Different slope ranges for ASCE 7-10, AS/NZS 1170.2 and EN 1991-1-4 (Adapted from Local wind assessment in Australia, Table 2.6)

Standard / Codes	**Lower Limit[%]**	**Upper Limit [%]**
ASCE 7-10	10	25
AS/NZS 1170.2	5	45
EN 1991-1-4	5	30

3.3 Load Combination, Practical Example

1. Structure location: Netherlands

2. Loads:
   - Dead weight (D): $1.000\ kN/m^2$
   - Snow (S): $0.700\ kN/m^2$
   - Wind (W): $0.470\ kN/m^2$

3. ASCE 7-10 Load combinations, Load and Resistance Factor Design (LFRD)
   - $E_d = 1.40 \times D = 1.40\ kN/m^2$
   - $E_d = 1.20 \times D + 0.50 \times S = 1.55\ kN/m^2$
   - $\boldsymbol{E_d = 1.20 \times D + 1.60 \times S + 0.50 \times W = 2.55\ kN/m^2}$
   - $E_d = 1.20 \times D + 1.00 \times W + 0.50 \times S = 2.01\ kN/m^2$
   - $E_d = 1.20 \times D + 0.20 \times S = 1.34\ kN/m^2$
   - $E_d = 0.90 \times D + 1.00 \times W = 1.36\ kN/m^2$
   - $E_d = 0.90 \times D = 0.90\ kN/m^2$

4. ASCE 7-10 Load combinations, Allowable Stress Design (ASD)
   - $E_d = D = 1.00\ kN/m^2$
   - $E_d = D + S = 1.70\ kN/m^2$
   - $E_d = D + 0.75 \times S = 1.53\ kN/m^2$
   - $E_d = D + W = 1.46\ kN/m^2$
   - $\boldsymbol{E_d = D + 0.75 \times 0.60 \times W + 0.75 \times S = 1.73\ kN/m^2}$
   - $E_d = 0.60 \times D + 0.60 \times W = \ kN/m^2$
   - $E_d = 0.60 \times D = 0.60\ kN/m^2$

5. AS/NZS 1170.2 Load combinations, Ultimate Limit State (Stability)
   - $E_{d,stb} = 0.90 \times G = 0.90\ kN/m^2$
   - $E_{d,dst} = 1.35 \times G = 1.35\ kN/m^2$
   - $E_{d,dst} = 1.20 \times G = 1.20\ kN/m^2$
   - $E_{d,dst} = 1.20 \times G + W_u = 1.66\ kN/m^2$
   - $\boldsymbol{E_{d,dst} = 1.20 \times G + S_u = 1.96\ kN/m^2}$

6. AS/NZS 1170.2 Load combinations, Ultimate Limit State (Strength)
   - $E_d = 1.35 \times G = 1.35\ kN/m^2$
   - $E_d = 1.20 \times G = 1.20\ kN/m^2$
   - $\boldsymbol{E_d = 1.20 \times G + W_u = 1.66\ kN/m^2}$
   - $E_d = 0.90 \times G + W_u = 1.56\ kN/m^2$
   - $E_d = 1.00 \times G + W_u = 1.46\ kN/m^2$

7. EN 1990 Load combinations
   - $\boldsymbol{E_d = 1.35 \times D + 1.50 \times S + 0.00 \times W = 2.40\ kN/m^2}$
   - $E_d = 1.35 \times D + 1.50 \times W + 0.00 \times S = 2.04\ kN/m^2$

In the photovoltaic market, usually it's used design loads obtained, for example, using ASCE 7-10 loads and combinations and verifications been done with a different standard that the one that must have been used, like EUROCODE 1993-1-3 instead of AISI S100. Using the same loads and applying load combinations given in standards, it is possible to see that load combinations from ASCE 7-10 (LFRD) gives worst values, followed by EUROCODE EN 1990, AS/NZS 1170.0 (Stability), ASCE 7-10 (ASD) and finally AS/NZS 1170.0 (Strength). In the design process, if load values weren't used with the respective load combinations codes, the results obtained in the analysis will be different than the reality.

4 STRUCTURAL DESIGN STANDARDS FOR COLD-FORMED STEEL

The design of cold-formed steel structures, depending on the structure location or client request, is regulated by different standards. In this study, the codes utilized are accepted and used worldwide, AISI S100, AS/NZS 4600 and EUROCODE EN 1993-1-3.

Taking into account the level of detail present in each code, and the fact that one of the major points of interest is the comparison between codes, it will only be presented some parts of each standard showing, as well, calculation procedures that were used in the cold-formed steel analysis.

The text presented in points 4.1, 4.2, 4.3 and 4.4 is extracted directly from standards, as well from technical documents that are available to public, like the discontinued "Project Access Steel" for Europe and "AISI Design Tool: Design flowchart for using the 2007 Edition of the North American cold-formed steel specification and the 2008 Edition of the AISI Cold-formed steel design" (AISI D101-09, 2009) for North America.

4.1 North American Specification for the Design of Cold-Formed Steel Structural Members

4.1.1 Strength increase from cold work of forming

AISI S100, clause A7.2 (AISI, 2007) defines that the strength increase from cold work of forming shall be permitted by substituting F_{ya} for F_y, where F_{ya} is the average yield stress of the full section. The limits and methods for determining F_{ya} shall be in accordance with (a), (b) and (c):

a. For axially loaded compression members and flexural members whose proportions are such that the quantity ρ for strength determination is unity for each of the component elements of the section, the design yield stress, F_{ya}, of the steel shall be determined on the basis of one of the following methods:
   1. full section tensile tests

2. stub column tests
3. computed in accordance with Equation (4.1)

$$F_{ya} = C \times F_{yc} + (1 - C) \times F_{yf} \leq F_{uv} \quad (4.1)$$

F_{ya} average yield stress of full unreduced section of compression members or full flange sections of flexural members;

C for compression members, ratio of total corner cross-sectional area to total cross-sectional area of full section; for flexural members, ratio of total corner cross-sectional area of controlling flange to full cross-sectional area of controlling flange;

F_{yc} tensile yield stress of corners. Equation (4.2) applies only when $(F_{uv}/F_{yv}) \geq 1.20$, $(R/t) \leq 7.00$ and the included angle $\leq 120º$;

$$F_{yc} = (B_c \times F_{yv})/(R/t)^m \quad (4.2)$$

$$B_c = 3.69 \times (F_{uv}/F_{yv}) - 0.819 \times (F_{uv}/F_{yv})^2 - 1.79 \quad (4.3)$$

F_{yv} Tensile yield stress of virgin steel specified by Section A2 or established in accordance with Section F3.3;

R Inside bend radius;

t Thickness of section;

$$m = 0.192 \times (F_{uv}/F_{yv}) - 0.068 \quad (4.4)$$

F_{uv} Tensile strength of virgin steel specified by Section A2 or established in accordance with Section F3.3;

F_{yf} Weighted average tensile yield stress of flat portions established in accordance with AISI S100, Section F3.2 or virgin steel yield stress if tests are not made

b. For axially loaded tension members, the yield stress of the steel shall be determined by either method (1) or method (3) prescribed in paragraph (a) of this section.
c. The effect of any welding on mechanical properties of a member shall be determined on the basis of tests of full section specimens containing, within the gage length, such welding as the manufacturer intends to use. Any necessary allowance for such effect shall be made in the structural use of the member.

4.1.2 Elements: Dimensional limits and considerations

AISI S100, Section B, defines limits and considerations for:

a. Maximum Flat-Width-to-Thickness Ratios

Maximum allowable overall flat-width-to-thickness ratios, w/t, disregarding intermediate stiffeners and taking t as the actual thickness of the element, shall be determined as follows:

1. Stiffened compression element having one longitudinal edge connected to a web or flange element, the other stiffened by:
Simple lip .... $w/t \leq 60$
Any other kind of stiffener, $I_s < I_a$ .... $w/t \leq 60$
Any other kind of stiffener, $I_s \geq I_a$ .... $w/t \leq 90$

I_s actual moment of inertia of full stiffener about its own centroid axis parallel to element to be stiffened

I_a adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

2. Stiffened compression element with both longitudinal edges connected to other stiffened elements .... $w/t \leq 500$
3. Unstiffened compression element .... $w/t \leq 60$

It shall be noted that unstiffened compression elements that have w/t ratios exceeding approximately 30 and stiffened compression elements that have w/t ratios exceeding approximately 250 are likely to develop noticeable deformation at the full available strength (factored resistance), without affecting the ability of the member to develop the required strength [effect of factored loads].

Stiffened elements having w/t ratios greater than 500 provide adequate available strength (factored resistance) to sustain the required loads; however, substantial deformations of such elements usually will invalidate the design equations of this Specification.

b. Flange Curling

Where the flange of a flexural member is unusually wide and it is desired to limit the maximum amount of curling or movement of the flange toward the neutral axis, Equation (4.5) shall be permitted to be applied to compression and tension flanges, either stiffened or unstiffened as follows:

$$w_f = \sqrt{0.061 \times t \times d \times E/f_{av}} \times \sqrt[4]{(100 \times c_f)/d} \qquad (4.5)$$

- w_f width of flange projecting beyond web; or half of distance between webs for box- or U-type beams;
- t flange thickness;
- d depth of beam;
- f_{av} average stress in full unreduced flange width. (Where members are designed by the effective design width procedure, the average stress equals the maximum stress multiplied by the ratio of the effective design width to the actual width);
- c_f amount of curling displacement

c. Maximum Web Depth-to-Thickness Ratios

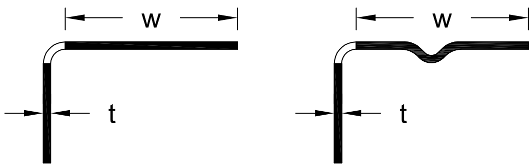
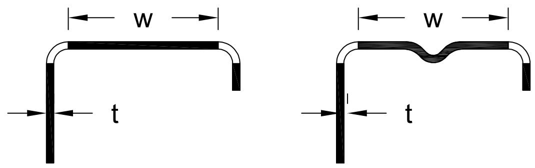
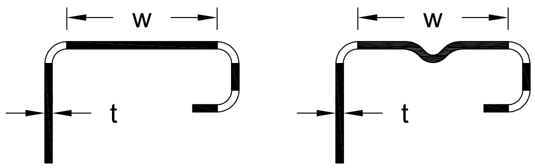
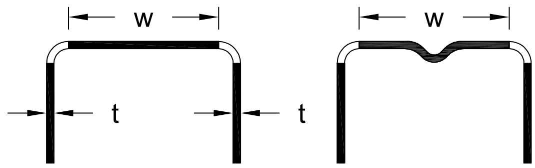
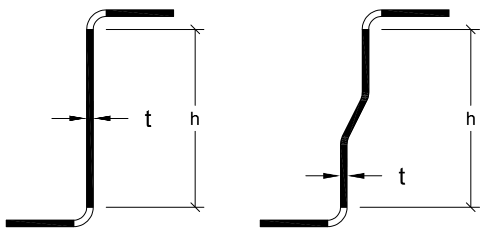
The ratio, h/t, of the webs of flexural members shall not exceed the following limits:

1. For unreinforced webs .... $(h/t)_{max} = 200$
2. For webs which are provided with bearing stiffeners satisfying the requirements of Section C3.7.1:
   Bearing stiffeners only .... $(h/t)_{max} = 260$
   Bearing stiffeners and intermediate stiffeners .... $(h/t)_{max} = 300$

- h depth of flat portion of web measured along plane of web;
- t web thickness. Where a web consists of two or more sheets, the h/t ratio is computed for the individual sheets

The provisions for design by calculation given in AISI S100 are not applied to cross-sections outside the range of width-to-thickness ratios w/t and h/t given in Table 4.1.

Table 4.1 - AISI S100: Maximum width-to-thickness ratios

Element of cross-section	**Maximum value**
	30 (60)
	60
	90
	250 (500)
	200

4.2 Australian/New Zealand Standard™: Cold-formed steel Structures

4.2.1 Strength increase resulting from cold forming

AS/NZS 4600, clause 1.5.1.2 (AS/NZS, 2005) defines that the strength increase resulting from cold forming shall be permitted by substituting the average design yield stress (f_{ya}) of the full section for f_y. The limitations and methods for determining f_{ya} shall be as follows:

a. For axially loaded compression members and flexural members whose proportions are such that the quantity (ρ) for load capacity is unity, as determined in accordance with Clause 2.2 for each of the component elements of the sections, the average design yield stress (f_{ya}) shall be determined on the basis of one of the following:
   1. Full section tensile tests
   2. Stub column tests
   3. The following calculation:

$$f_{ya} = C \times f_{yc} + (1 - C) \times f_{yf} \leq f_{uv} \quad (4.6)$$

f_{ya} average design yield stress of the steel in the full section of compression members or full flange sections of flexural members

C for compression members, ratio of the total bend cross-sectional area to the total cross-sectional area of the full section; and for flexural members, ratio of the total bend cross-sectional area of the controlling flange to the full cross-sectional area of the controlling flange

f_{yc} Tensile yield stress of corners. Equation (4.7) applies only when $(f_{uv}/f_{yv}) \geq 1.20$, $(r_i/t) \leq 7.00$ and the included angle $\leq 120º$

$$f_{yc} = (B_c \times f_{yv})/(r_i/t)^m \quad (4.7)$$

$$B_c = 3.69 \times (f_{uv}/f_{yv}) - 0.819 \times (f_{uv}/f_{yv})^2 - 1.79 \quad (4.8)$$

f_{yv} tensile yield stress of unformed steel;

r_i inside bend radius;

t thickness of section;

$$m = 0.192 \times (f_{uv}/f_{yv}) - 0.068 \tag{4.9}$$

f_{uv} tensile strength of unformed steel;

f_{yf} yield stress of the flat portions (see Clause 8.1.4); or yield stress of unformed steel if tests are not made

b. For axially loaded tension members, f_{ya} shall be determined by either Item (a)(1) or Item (a)(3).

4.2.2 Elements: Dimensional limits and considerations

AS/NZS 4600, Section 2.1, defines limits and considerations for:

a. Maximum flat-width-to-thickness ratios

The maximum overall flat-width-to-thickness ratios, b/t, disregarding intermediate stiffeners and taking t as the nominal thickness of the element, shall be as follows:

1. For a stiffened compression element having one longitudinal edge connected to a web or flange element and the other stiffened by
   Simple lip …………………………………………………..……...... $b/t \leq 60$
   Any other kind of stiffener, $I_s < I_a$ …………………………….………… $b/t \leq 60$
   Any other kind of stiffener, $I_s \geq I_a$ …………………………….………… $b/t \leq 90$
2. For a stiffened compression element with both longitudinal edges connected to other stiffened elements .... $b/t \leq 500$
3. For an unstiffened compression element .... $b/t \leq 60$

NOTE: Unstiffened compression elements with b/t ratios greater than 30 and stiffened compression elements with b/t ratios greater than 250 are likely to develop noticeable deformation at the full design load, without affecting the ability of the member to carry the design load. Stiffened elements with b/t ratios greater than 500 can be used with adequate design capacity to sustain the design loads. However, substantial deformations of such elements usually will invalidate the design equations of this Standard.

b. Flange curling

Where the flange of a flexural member is unusually wide and it is desired to limit the maximum amount of curling or movement of the flange toward the neutral axis, the maximum width (b_1) of the compression and tension flanges, either stiffened or unstiffened projecting beyond the web for I-beams and similar sections or the maximum half distance (b_1) between webs for box- or U-type beams, shall be determined from the following equation:

$$b_1 = \sqrt{0.061 \times t_f \times d \times E/f_{av}} \times \sqrt[4]{(100 \times c_f)/d} \quad (4.10)$$

t_f thickness of the flange;
d depth of the section;
f_{av} average design stress in the full, unreduced flange width (see Note 1);
c_f amount of curling (see Note 2)

NOTES: (1) Where members are designed by the effective design width procedure, the average stress equals the maximum stress multiplied by the ratio of the effective design width to the actual width; (2) The amount of curling that can be tolerated will vary with different kinds of sections and should be established by the designer. Amount of curling in the order of 5% of the depth of the section is usually not considered excessive.

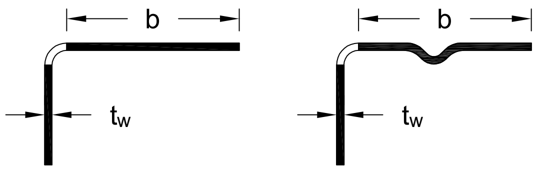
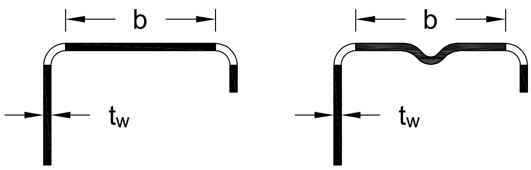
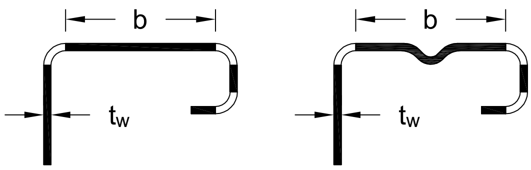
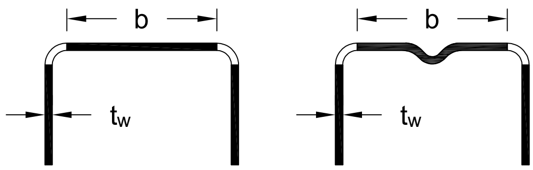
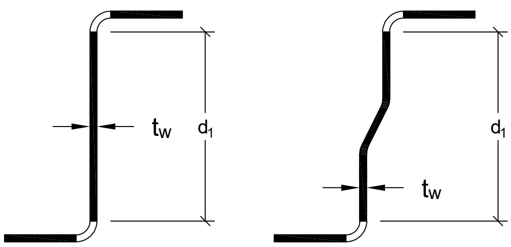
c. Maximum web depth-to-thickness ratio
The maximum web depth-to-thickness ratio, d_1/t_w, of flexural members shall not exceed the following:
1. For unreinforced webs .... $d_1/t_w = 200$
2. For webs with transverse stiffeners complying with Clause 3.3.8.1:
Bearing stiffeners only .... $d_1/t_w = 260$
Bearing stiffeners and intermediate stiffeners .... $d_1/t_w = 300$

d_1 depth of the flat portion of the web measured along the plane of the web
t_w thickness of web

Where a web consists of two or more sheets, the ratio d_1/t_w shall be calculated for each sheet.

The provisions for design by calculation given in AS/NZS 4600 are not applied to cross-sections outside the range of width-to-thickness ratios b/t and d_1/t_w given in Table 4.2.

Table 4.2 - AS/NZS 4600: Maximum width-to-thickness ratios

Element of cross-section	Maximum value
	30 (60)
	60
	90
	250 (500)
	200

4.3 EUROCODE 3, Design of steel structures (Part 1-3), Supplementary rules for cold-formed members and sheeting

4.3.1 Material properties of cold formed sections and sheeting

EN 1993-1-3, clause 3.2.2 defines that, where the yield strength is specified using the symbol f_y the average yield strength f_{ya} may be used with some limitations. In other cases, the basic yield strength f_{yb} should be used. Where the yield strength is specified using the symbol f_{yb} the basic yield strength f_{yb} should be used.

The average yield strength f_{ya} of a cross-section due to cold working may be determined from the results of full size tests. Alternatively, the increased average yield strength f_{ya} may be determined by calculation using:

$$f_{ya} = f_{yb} + (f_u - f_{yb}) \times \frac{k \times n \times t^2}{A_g} \tag{4.11}$$

$$f_{ya} \leq \frac{(f_u + f_{yb})}{2} \tag{4.12}$$

A_g is the gross cross-sectional area;

k is a numerical coefficient that depends on the type of forming, $k = 7$ for roll forming and $k = 5$ for other methods of forming

n is the number of 90º bends in the cross-section with an internal radius $r \leq 5t$ (fractions of 90º bends should be counted as fractions of n)

t is the design core thickness of the steel material before cold-forming, exclusive of metal and organic coatings

The increased yield strength due to cold forming may be taken into account as follows:

- in axially loaded members in which the effective cross-sectional area A_{eff} equals the gross area A_g
- in determining A_{eff} the yield strength f_y should be taken as f_{yb}

The average yield strength f_{ya} may be utilized in determining:

- the cross-section resistance of an axially loaded tension member
- the cross-section resistance and the buckling resistance of an axially loaded compression member with a fully effective cross-section
- the moment resistance of a cross-section with fully effective flanges

4.3.2 Elements: Dimensional limits and considerations

The provisions for design by calculation given in this Part 1-3 of EN 1993 should not be applied to cross-sections outside the range of width-to-thickness ratios b/t, h/t, c/t and d/t given in Table 4.3.

NOTE: These limits b/t, h/t, c/t and d/t given in table 4.3 may be assumed to represent the field for which sufficient experience and verification by testing is already available. Cross-sections with larger width-to-thickness ratios may also be used, provided that their resistance at ultimate limit states and their behaviour at serviceability limit states are verified by testing and/or by calculations, where the results are confirmed by an appropriate number of tests.

Table 4.3 - EN 1993-1-3: Maximum width-to-thickness ratios

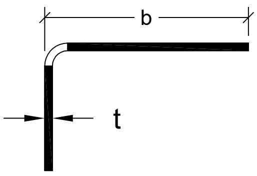
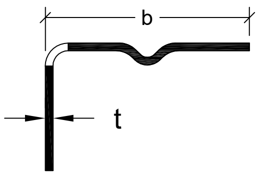
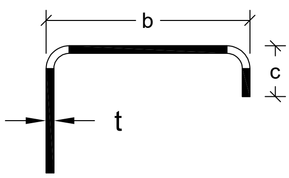
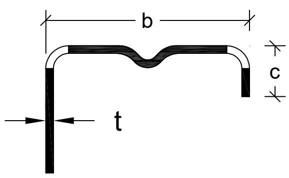
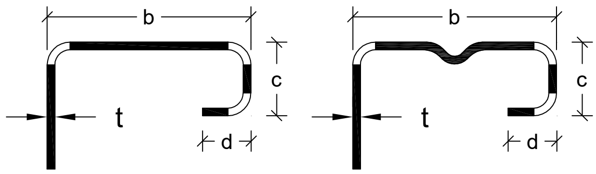
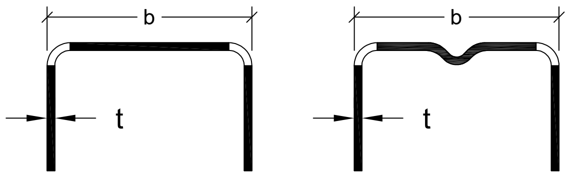
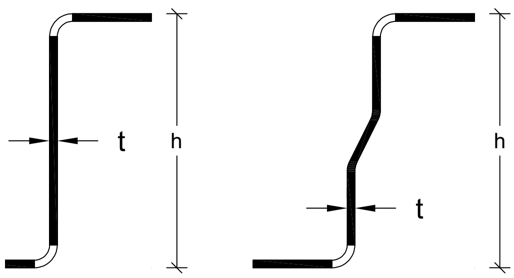
Element of cross-section	**Maximum value**
 	$b/t \leq 50$
 	$b/t \leq 60$ $c/t \leq 50$

Table 4.3 - EN 1993-1-3: Maximum width-to-thickness ratios (Continuation)

Element of cross-section	**Maximum value**
	$b/t \leq 90$ $c/t \leq 60$ $d/t \leq 50$
	$b/t \leq 500$
	$45^{\circ} \leq \phi \leq 90^{\circ}$ $h/t \leq 500\ sin\,\phi$

EN 1993-1-3 defines that, for the flange curling analysis, the effect on the load-bearing resistance of curling (i.e. inward curvature towards the neutral plane) of a very wide flange in a profile subjected to flexure, or of a flange in an arched profile subjected to flexure in which the concave side is in compression, should be taken into account unless such curling is less than 5% of the depth of the profile cross-section. If curling is larger, then the reduction in loadbearing resistance, for instance due to a decrease in the length of the lever arm for parts of the wide flanges, and to the possible effect of the bending of the webs should be taken into account.

The formulae used in the calculation of flange curling apply to both compression and tensile flanges, both with and without stiffeners, but without closely spaced transversal stiffeners at flanges. For a profile which is straight prior to application of loading (see figure 4.1):

$$u = 2 \times \frac{{\sigma_a}^2}{E^2} \frac{{b_s}^4}{t^2 \times z} \quad (4.13)$$

u is bending of the flange towards the neutral axis (curling);

b_s is one half the distance between webs in box and hat sections, or the width of the portion of flange projecting from the web;

t is flange thickness;

z is distance of flange under consideration from neutral axis;

σ_a is mean stress in the flanges calculated with gross area. If the stress has been calculated over the effective cross-section, the mean stress is obtained by multiplying the stress for the effective cross-section by the ratio of the effective flange area to the gross flange area

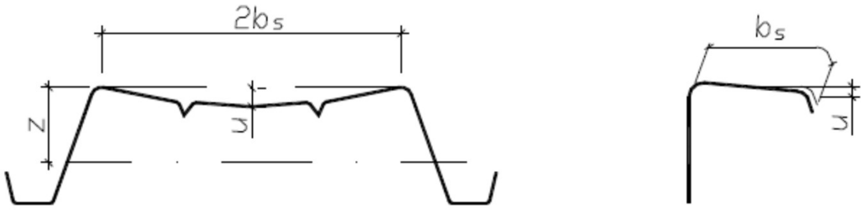


Figure 4.1 - Flange curling
(Figure 5.3, EN 1993-1-3)

4.4 AISI S100, AS/NZS 4600 and EN 1993-1-3: Calculation procedures

In this section, due to the quantity of calculations that were need to be done, it was chosen only to show some flow charts, containing steps to been used in the verification of cold-formed steel problems. The North American Specification is updated regularly, and also gives documents containing guidance to solve some specific problems.

The AISI document D101-09, "*AISI Design Tool: Design flowchart for using the 2007 edition of the North American cold-formed steel specification and the 2008 edition of the AISI Cold-formed steel design*", gives a series of considerations, as well flow charts, to been used. So, according to AISI D101-09, the following steps that should be considered in cold-formed steel member design are:

a. Calculate the loads and load combinations according to an applicable building code. Perform structural analysis to determine member forces
b. Layout the lateral bracing for preventing buckling of members. The bracing needs to be designed with consideration of the strength and the stiffness in accordance with AISI S100, Specification D3.3.
c. If the member is subjected to compression force, determine and check the compression strength based on flow charts I(a) (Figure 4.2) and I(b) (Figure 4.3)
d. If the member is subjected to bending:
   - ✓ Determine and check the flexural strength, if applicable, based on flow chats II(a) (Figure 4.3) and II(b) (Figure 4.4)
   - ✓ Determine the shear strength based on AISI S100, Specification C3.2 and check the strength based on AISI S100, Specification A4.1 or A5.1
   - ✓ Perform bending and shear interaction check based on AISI S100, Specification C3.3
   - ✓ Calculate web crippling strength for the sections at the supports and locations with concentrated loads based on AISI S100, Specification C3.4.1 (without web openings) and AISI S100, Specification C3.4.2 (with web openings)
   - ✓ Perform bending and web crippling check based on AISI 100, Specification C3.5
e. If the member is subjected to tension, Determine the tension strength based on AISI S100, Specification C2
f. If the member is subject to both bending and compression, perform bending and compression interaction check per AISI S100, Specification C5.2
g. If the member is subjected to tension and bending, perform bending and tension interaction check per AISI S100, Specification C5.1
h. If an unsheathed flexural member subjected to torsion (could be due to loading that not go through the shear center), AISI S100, Specification Section C3.6 should be considered
i. Check member connection strengths with consideration of bearing strength of connected members, shear or/and tension of connectors, and pull-over and pull-out as applicable for fasteners and edge distance requirements

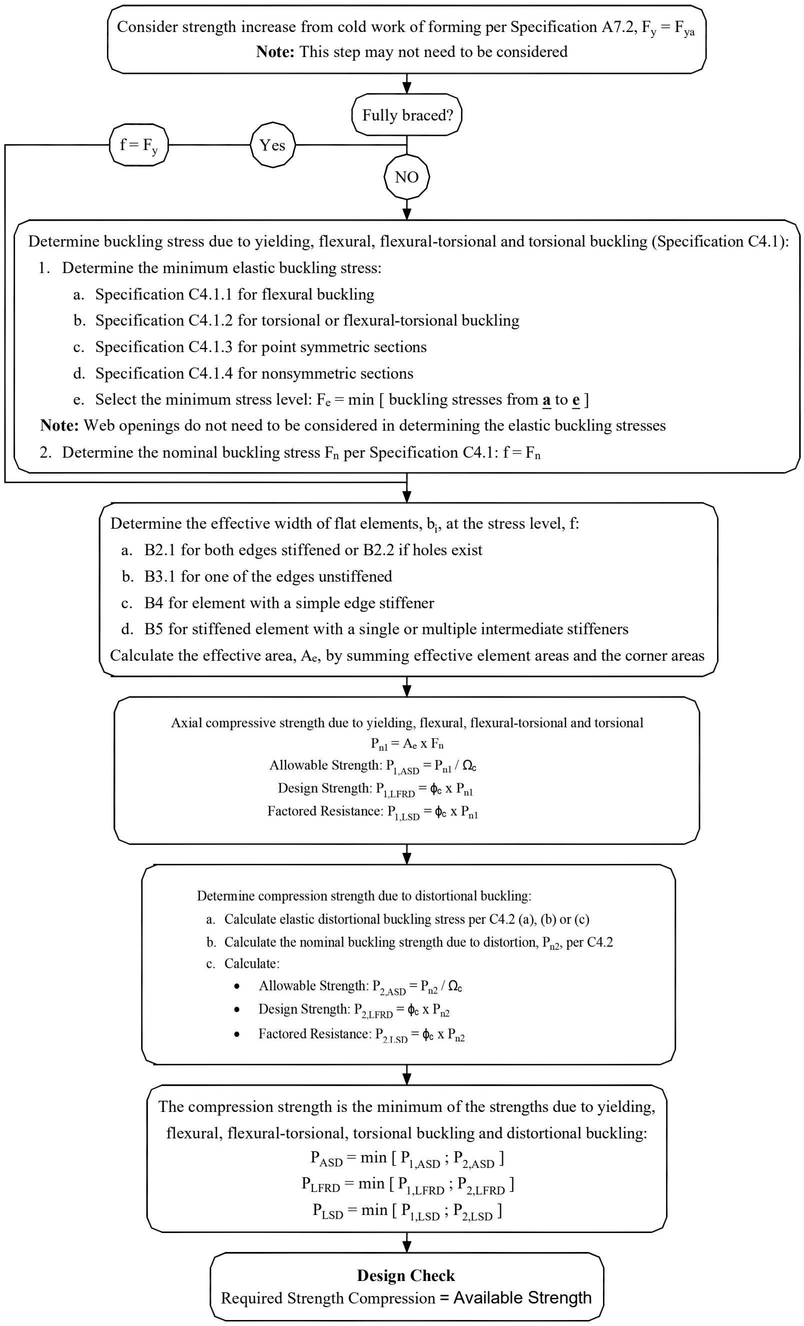


Figure 4.2 – Flow chart I(a): Compression Member Strength Determination (Adapted from AISI Design Tool D101-09, 2009)

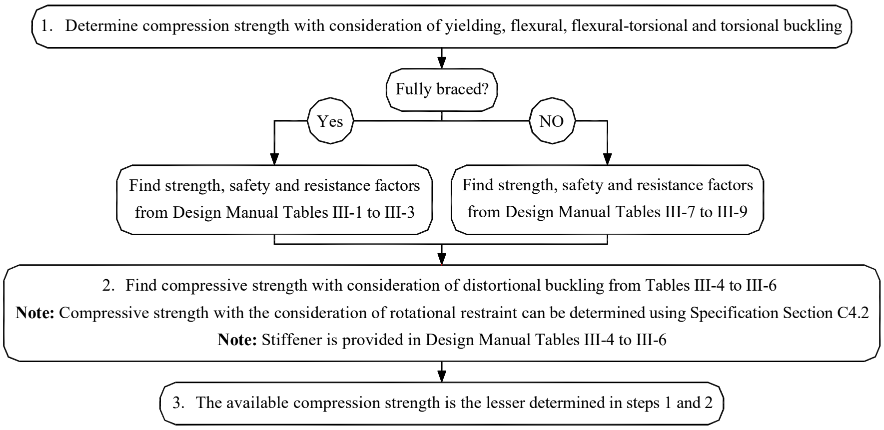


Figure 4.3 – Flow chart I(b): Compression Member Strength Using AISI Cold-Formed Steel Design Manual
(Adapted from AISI Design Tool D101-09, 2009)

Flow chart II(a) provides design guide for members under the following conditions:

- Z-section bending about the centroid axis that is perpendicular to the web
- C-sections bending about both principal axes
- Symmetric Angles bending about the symmetric axis
- Boxed sections
- Hat sections with lips in tension, which can be treated the same as C-section bending about the weak axis.

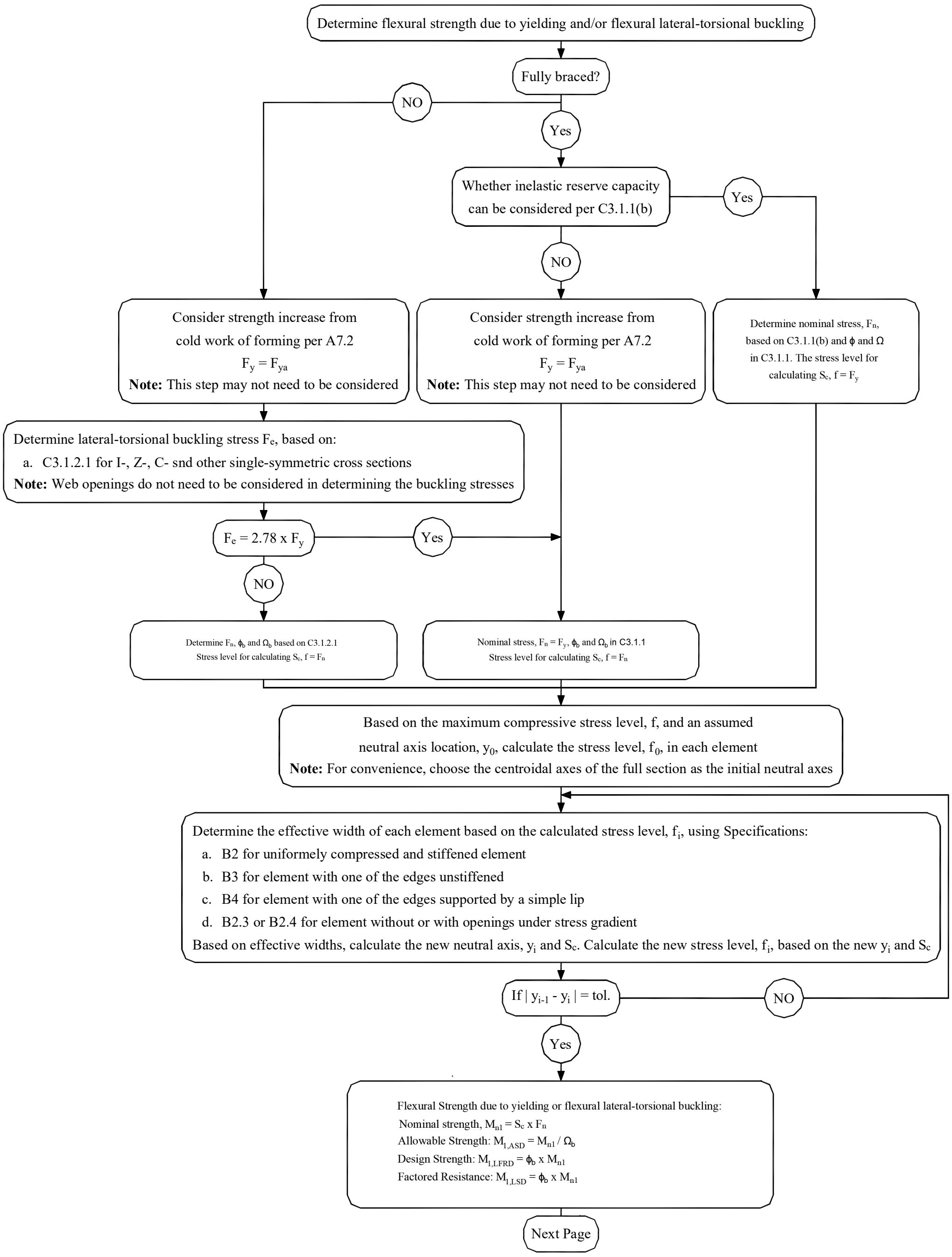


Figure 4.4 - Flow Chart II(a): Flexural Strength of Members with an I-, C-, or Z- Section, a Boxed Section or an Angle Bending about the Symmetric Axis (Adapted from AISI Design Tool D101-09, 2009)

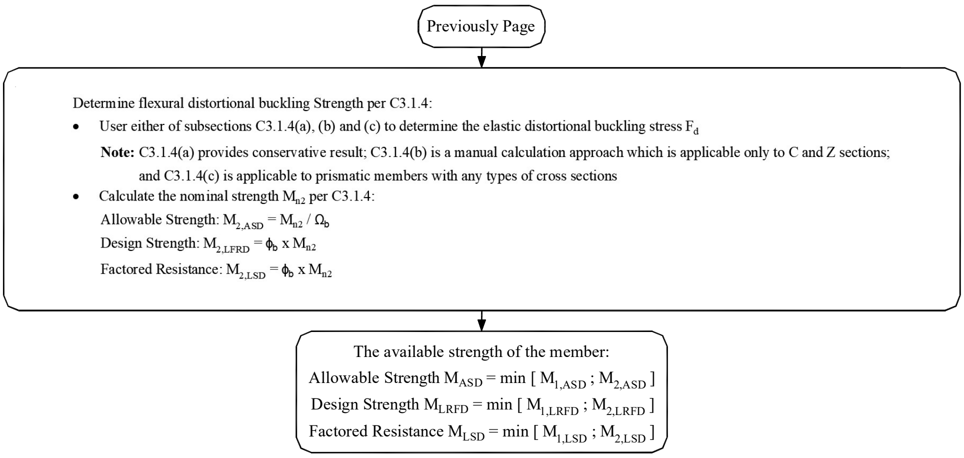


Figure 4.4 - Flow Chart II(a): Flexural Strength of Members with an I-, C-, or Z- Section, a Boxed Section or an Angle Bending about the Symmetric Axis (Adapted from AISI Design Tool D101-09, 2009) (Continuation)

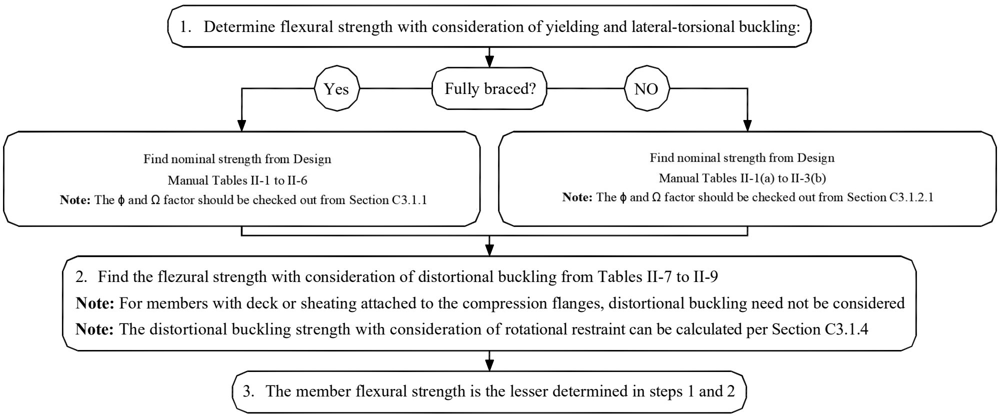


Figure 4.5 – Flow chart II(b): Flexural Member Strength for C- and Z-Sections using AISI Cold-Formed Steel Design Manual (Adapted from AISI Design Tool D101-09, 2009)

The Australian/New Zealand Standard is almost identical to the AISI Specification. According to Dubina et al (2012), Sections 1 to 5 in the AS/NZS 4600 corresponds to Section A to E in the AISI Specification, as the author was also capable to see. The equations are similar, differing only in the position and designation in the standards. The design procedure, for a typical compression member design, should be considered:

a. Consider strength increase from cold work of forming (1.5.1.2) (A7.2 in AISI S100-07)
b. Determine member strength with consideration of yielding, flexural, lateral-torsional, torsional buckling (3.4.1) (C4.1 in AISI S100-07):
   - ✓ Determine minimum elastic buckling stresses due to yielding, flexural, lateral-torsional, torsional buckling, f_{oc} (F_e in AISI S100-07)
   - ✓ Determine the nominal buckling stress, f_n (F_n in AISI S100-07)
   - ✓ Calculate the effective area, A_e, based on the stress level $f = f_n$
   - ✓ Calculate the nominal strength $N_c = f_n \times A_e$ (P_{n1} in AISI S100-07)
c. Determine the member strength, N_{cd} (P_{n2} in AISI S100-07), with consideration of distortional buckling per Section 7.2.1.4
d. The member strength is the lesser of member strengths determined per b and c

In the European Union, until 2006, "Project Access Steel" elaborated a series of 274 documents to been used in the analysis of steel structures. Regarding the specific study of cold-formed steel structures:

- "Flow chart: Calculation of effective section properties for cold-formed steel lipped channel sections under compression or bending" and "Flowchart: Effective section properties of the flange and lip in compression – General (iterative) procedure" (Document reference SF038a)
- "Flow chart: Design of a cold-formed steel member in compression" (Document reference SF039)
- "Flow chart: Design of a cold-formed steel lipped channel member in tension" (Document reference SF040)
- "Flow chart: Design and serviceability limit state check of a cold-formed steel member in bending" (Document reference SF041)
- "Flow chart: Design of a cold-formed steel wall stud in combined compression and uniaxial bending" (Document reference SF042)
- "Flow chart: Design resistance of screwed connections of cold-formed members" (Document reference SF043)
- "Example: Calculation of effective section properties for a cold-formed lipped channel section in bending" (Document reference SX022)
- "Example: Calculation of effective section properties for a cold-formed lipped channel section in compression" (Document SX023)
- "Example: Design of a cold-formed steel lipped channel wall stud in compression" (Document reference SX024)

- "Example: Design of a cold-formed steel lipped channel wall stud in tension" (Document SX025)
- "Example: Design and serviceability limit state check of a cold-formed steel member in bending" (Document reference SX026)
- "Example: Design of a cold-formed steel lipped channel wall stud in compression and bending" (Document reference SX027)
- "Example: Design resistance of a screwed connection of cold-formed members" (Document reference SX028)

Figure 4.6, 4.7 and 4.8 presents some examples regarding the use of the European cold-formed design code, EN 1993-1-3.

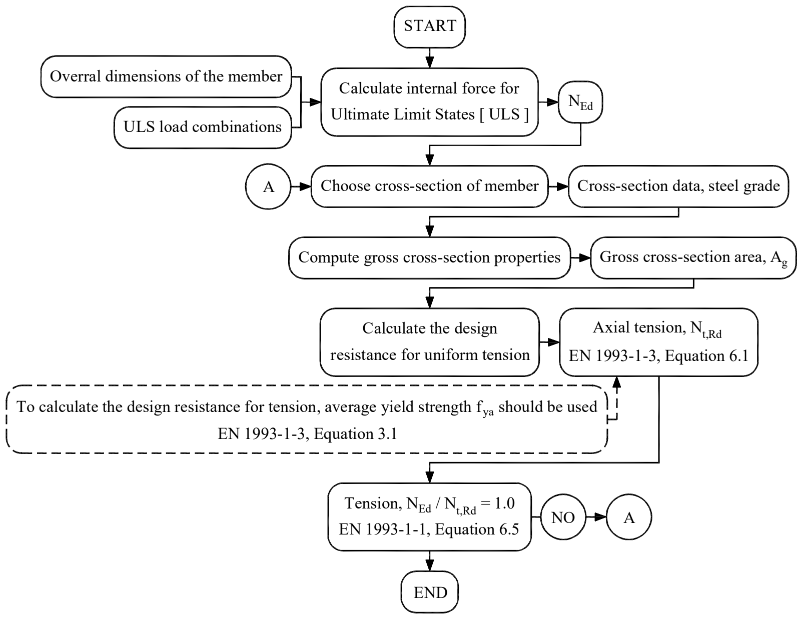


Figure 4.6 - Flow chart: Design of a cold-formed steel lipped channel member in tension (Adapted from SF040a-EN-EU, 2006)

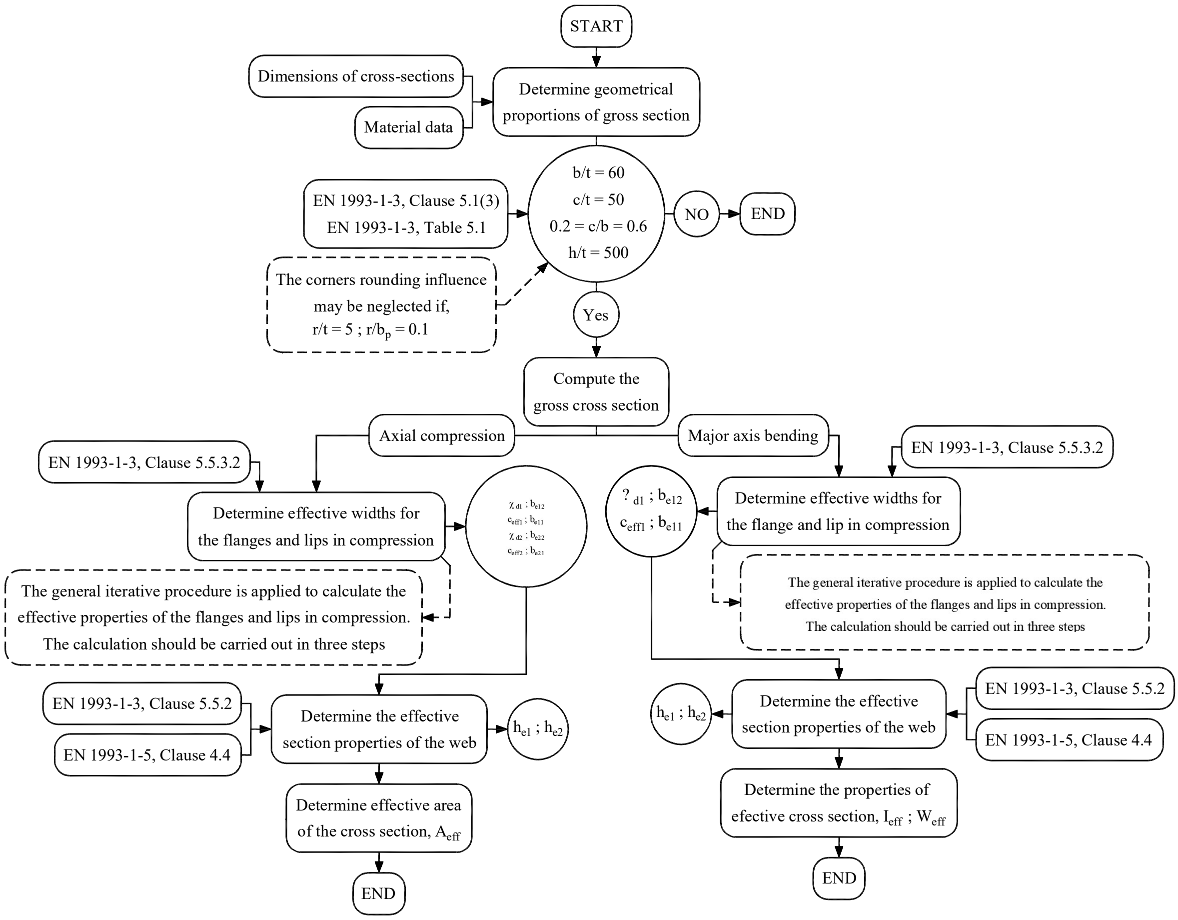


Figure 4.7 - Calculation of effective section properties for cold-formed steel lipped channel sections under compression or bending
(Adapted from SF0380a-EN-EU, 2006)

Figure 4.8 - Flow Chart: Calculation of effective section properties of the flange and lip in compression - General iterative procedure
(Adapted from SF038a-EN-EU, 2006)

5 COLD-FORMED DESIGN STANDARDS COMPARISON

5.1 Main differences between cold-formed design standards

In this chapter, it will be presented some points identified through the application of the cold-formed design codes in the practical cases. It was possible to see that all codes are very similar, giving provisions for the following topics:

1. Geographic target work
   - **EC3:** Multiple countries in Europe
   - **North American Specification [NAS]:** USA, Canada and Mexico
   - **Australian/New Zealand Standard:** Australia and New Zealand
2. National specialties
   - **EC3:** Can be considered by the application of National Annexes
   - **North American Specification [NAS]:** Can be considered by the application of National Annexes
   - **Australian/New Zealand Standard:** Incorporated in the standard
3. Design Basis
   - **EC3:** Limit State Design (LSD)
   - **North American Specification [NAS]:** Allowable Strength Design (ASD) and Load and Resistance Factor Design (LRFD) in USA, and Mexico; Limit State Design (LSD) in Canada
   - **Australian/New Zealand Standard:** Limit State Design (LSD)
4. Plate Thickness
   - **EC3:** $0.45\,mm \leq t_{cor} \leq 15\,mm$ for members; $0.45\,mm \leq t_{cor} \leq 4\,mm$ for connections
   - **North American Specification [NAS]:** $t_{cor} \leq 25.40\,mm$ for members; $t_{cor} \leq 4.76\,mm$ for bolted connections
   - **Australian/New Zealand Standard:** $t_{cor} \leq 25.40\,mm$ for members; $t_{cor} \leq 3.00\,mm$ for bolted connections

5. Material Coefficients
   - **EC3:**
     - ✓ Modulus of elasticity, $E = 210000\ MPa$
     - ✓ Poisson's ratio in elastic stage, $\upsilon = 0.300$
     - ✓ Shear modulus, $G = 80769\ MPa$
   - **North American Specification [NAS]:**
     - ✓ Modulus of elasticity, $E = 203000\ MPa$
     - ✓ Poisson's ratio in elastic stage, $\upsilon = 0.300$
     - ✓ Shear modulus, $G = 78077\ MPa$
   - **Australia/New Zealand Standard:**
     - ✓ Modulus of elasticity, $E = 200000\ MPa$
     - ✓ Poisson's ratio in elastic stage, $\upsilon = 0.300$
     - ✓ Shear modulus, $G = 76923\ MPa$
6. Sections with longitudinal intermediate stiffeners
   - **EC3:** Covered for intermediate stiffeners in flanges and webs of members
   - **North American Specification [NAS]:** Covered for intermediate stiffeners in flanges of members, but not webs. Direct Strength is used when the web has one intermediate stiffener
   - **Australian/New Zealand Standard:** Covered for intermediate stiffeners in flanges of members, but not webs. Direct Strength is used when the web has one intermediate stiffener
7. Standard materials
   - **EC3:** 63 standardized materials
   - **North American Specification [NAS]:** 16 ASTM materials
   - **Australian/New Zealand Standard:** 37 AS and AS/NZS materials
8. Yield strength
   - **EC3:** $f_y = 220\ to\ 700\ MPa$
   - **North American Specification [NAS]:** $f_y = 165\ to\ 550\ MPa$
   - **Australian/New Zealand Standard:** $f_y = 170\ to\ 550\ MPa$
9. Tensile strength
   - **EC3:** $f_u = 300\ to\ 750\ MPa$
   - **North American Specification [NAS]:** $f_u = 290\ to\ 690\ MPa$
   - **Australian/New Zealand Standard:** $f_u = 280\ to\ 570\ MPa$

10. Non-standard materials
    - **EC3:** Allowed if " $f_u/ f_y \geq 1.00$ ", " elongation at failure not less than 15% " and " $\varepsilon_u \geq 15 \times \varepsilon_y$ "
    - **North American Specification [NAS]:** Allowed if " $f_u/f_y \geq 1.08$ " and "elongation at failure not less than 10% for a 50 mm gauge length or 7% for a 200 mm "
    - **Australian/New Zealand Standard:** Allowed if " $f_u/f_y \geq 1.08$ " and " elongation at failure not less than 10% for a 50 mm gauge length or 7% for a 200 mm "
11. Effect of cold hardening
    - **EC3:** Taken into consideration, for fully effective sections. Formula used in EN 1993-1-3 is different from the used in both AISI S100 and AS/NZS 4600
    - **North American Specification [NAS]:** Taken into consideration, for fully effective sections. Values differing if it's a compression or flexural member.
    - **Australian/New Zealand Standard:** Taken into consideration, for fully effective sections. Values differing if it's a compression or flexural member.
12. Effect of rounded corners
    - **EC3:** Fictitious plane elements are introduced. The influence of rounded corners may be neglected if internal radius (r), $r \leq 5 \times t$, $r \leq 0.10 \times b_p$, so the cross-section can be assumed to consist of plane elements with sharp corners.
    - **North American Specification [NAS]:** Rounded corners are always fully effective. Treated separately from the flats
    - **Australian/New Zealand Standard:** Rounded corners are always fully effective. Treated separately from the flats
13. Upper limit for corner radius
    - **EC3:** $r \leq 0.04 \times t \times E/f_y$
    - **North American Specification [NAS]:** None
    - **Australian/New Zealand Standard:** None
14. Geometrical limits
    - **EC3:** Width-to-thickness ratios of plates | Width-to-thickness rations of lips | Inclination of webs | Web height-to-thickness ratios
    - **North American Specification [NAS]:** Flange flat-width-to-thickness ratios of plates | Maximum web depth-to-thickness ratios of plates | Maximum inside radius-to-thickness ratio (Equation A7.2-2)
    - **Australian/New Zealand Standard:** Maximum flat-width-to-thickness ratios of plates | Maximum web depth-to-thickness ratios of plates | Maximum inside radius-to-thickness ratio (difference between clause 1.3.5 and the one used in equation 1.5.1.2(2))

15. Handling local buckling
    - **EC3:** Effective width approach
    - **North American Specification [NAS]:** Effective width approach
    - **Australian/New Zealand Standard:** Effective width approach
16. Effective width calculation
    - **EC3:** Winter formula (depends if it is an outstand or internal element)
    - **North American Specification [NAS]:** Winter formula for compressed elements. Different formula is used in flexural elements
    - **Australian/New Zealand Standard:** Winter formula for compressed elements. Different formula is used for flexural elements
17. Distortional buckling
    - **EC3:** Must be considered, by thickness reduction of the effective part of stiffeners
    - **North American Specification [NAS]:** Provisions for distortional buckling from beams (Section C3.1.4) and columns (Section C4.2)
    - **Australian/New Zealand Standard:** Provisions for distortional buckling from beams (Clause 3.3.3.3) and columns (Clause 7.2.1.4)
18. Hand-formulae for distortional buckling
    - **EC3:** Included for C/Z sections, but the proposed procedure is computationally demanding, including iterations
    - **North American Specification [NAS]:** Included for C and Z-sections
    - **Australian/New Zealand Standard:** Included for C and Z-sections (Appendix D)
19. Column buckling resistance
    - **EC3:** European multiple buckling curves (3 curves)
    - **North American Specification [NAS]:** Single buckling curve
    - **Australian/New Zealand Standard:** Single buckling curve
20. Flexural, torsional and flexural-torsional buckling
    - **EC3:** All included. Used three different curves, depending of the type of cross-section, axis of buckling and yield strength.
    - **North American Specification [NAS]:** Included
    - **Australian/New Zealand Standard:** All Included
21. Flange Curling
    - **EC3:** Taken into account unless such curling is less than 5% of the depth of the profile cross-section
    - **North American Specification [NAS]:** Taken into account unless such curling is less than 5% (AISI S100 Commentary) of the depth of the profile cross-section. Formula is different from the one used in EUROCODE

- **Australian/New Zealand Standard:** Taken into account unless such curling is less than 5% of the depth of the profile cross-section. Formula is equal to the one used in AISI S100 and different from EUROCODE

22. Torsion
    - **EC3:** Both St. Venant and Warping stresses are considered. Axial forces and bending moments are based on the effective cross-sections. Shear stresses, due to transverse forces, uniform torsion and warping are based on the gross cross-section
    - **North American Specification [NAS]:** Without specific guidance
    - **Australian/New Zealand Standard:** Without specific guidance
23. Crippling
    - **EC3:** Designed by "Local transverse forces", involving crushing, crippling or buckling. Empirical formulae. Sections with longitudinal web stiffeners are handled
    - **North American Specification [NAS]:** Empirical formulae. Contains equation to include the effects of the presence of holes on webs or not, updated constantly
    - **Australian/New Zealand Standard:** Empirical formulae. Contains equation to include the effects of the presence of holes on webs or not, updated constantly
24. Shear
    - **EC3:** Sections with longitudinal web stiffeners and transverse stiffeners are handled
    - **North American Specification [NAS]:** Sections with transverse, shear and bearing stiffeners are handled
    - **Australian/New Zealand Standard:** Sections with transverse, shear and bearing stiffeners are handled
25. Design assisted by test
    - **EC3:** Allowed with detailed rules for testing of steel and fasteners
    - **North American Specification [NAS]:** Tests for special cases, like, tests for determining structural performance, tests form conforming structural performance and tests for determining mechanical properties
    - **Australian/New Zealand Standard:** Testing for determining material properties and testing for assessment or verification are permitted
26. Manufactured process
    - **EC3:** Taking into account on the determination of the average yield strength
    - **North American Specification [NAS]:** No reference is made
    - **Australian/New Zealand Standard:** No reference is made

5.2 Cold-formed design standards comparison

AISI S100, compared to AS/NZS 4600 and EUROCODE EN 1993-1-3, is the more versatile of them all because of its capacity to use different unit systems and permits the structure analysis through different design processes. As it's well known in Europe, EUROCODE EN 1993-1-3 only permits the structure analysis through the application of the Limit States Design (LSD), the same in the Australian/New Zealand Standard^{TM}, AS/NZS 4600, when the North American Specification, AISI S100, gives a treatment about the Allowable Strength Design (ASD), Load and Resistance Factor Design (LRFD) and, finally, the Limit States Design (LSD).

About the plate thickness, while the European Standard only permits members with thickness between $0.45\ mm \leq t_{cor} \leq 15\ mm$, both American and Australian/New Zealand Standards accept higher values, $t_{cor} \leq 25.40\ mm$. Regarding the plate thickness used for bolted connections, the values used in the North American and European Specifications are very similar, $t_{cor} \leq 4.76\ mm$ and $0.45\ mm \leq t_{cor} \leq 4\ mm$, when the Australian/New Zealand Standard only permits a maximum thickness of $t_{cor} \leq 3.00\ mm$.

Tables 4.1, 4.2 and 4.3, regarding the geometrical limits, presents a set of values to been used in the definition of the profiles that can be used for each specific standard. Through the analysis and comparison, it is possible to conclude that the values are similar between the three standards, although EN 1993-1-3 is more detailed than AISI S100 and AS/NZS 4600.

Another point that is different is the calculation of the effective widths. EN 1993-1-3, for the effective width calculation, considers two different approaches, rounded or sharp corners in the determination of the real widths when, both the AISI S100 and AS/NZS 4600 always considers the corners as fully effective, removing this part from the final width, considering only the flat part of the elements, as showed in Figures 5.1, 5.2 and 5.3.

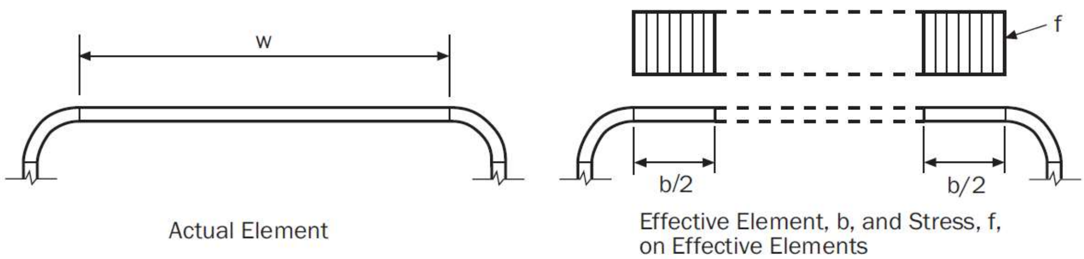


Figure 5.1 - Uniformly Compressed Stiffened Elements
(Adapted from Figure B2.1-1, AISI S100)

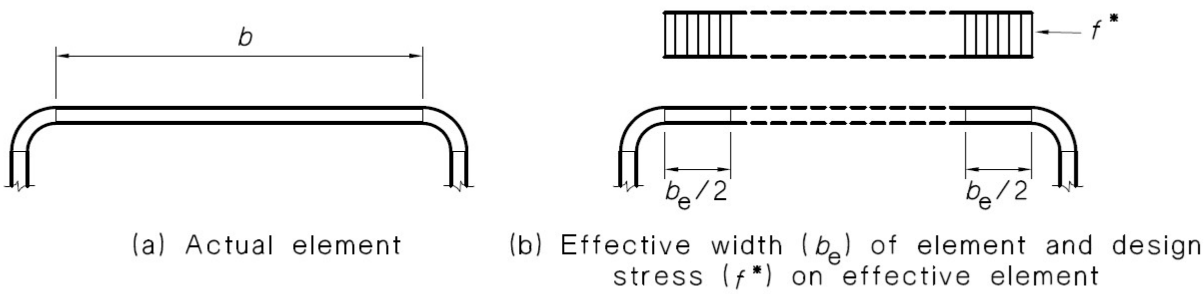


Figure 5.2 - Stiffened Elements with Uniform Compression
(Adapted from Figure 2.2.1, AS/NZS 4600)

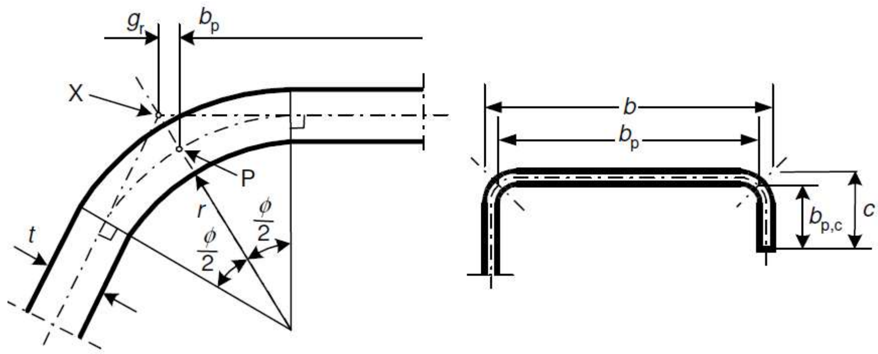


Figure 5.3 - Notional widths of plane cross section parts b_p allowing for corner radii
(Adapted from Figure 5.1, EN 1993-1-3)

The effect of cold hardening is taking into the North American, Australian/New Zealand and European Specifications. AISI S100 and AS/NZS 4600, if it's a compression of flexural member, considers different average yield strength (f_{ya}) values when EN 1993-1-3 considers only one value. Figure 5.4 presents one of the sections used in the design, to help in the illustration of the differences between the three standards.

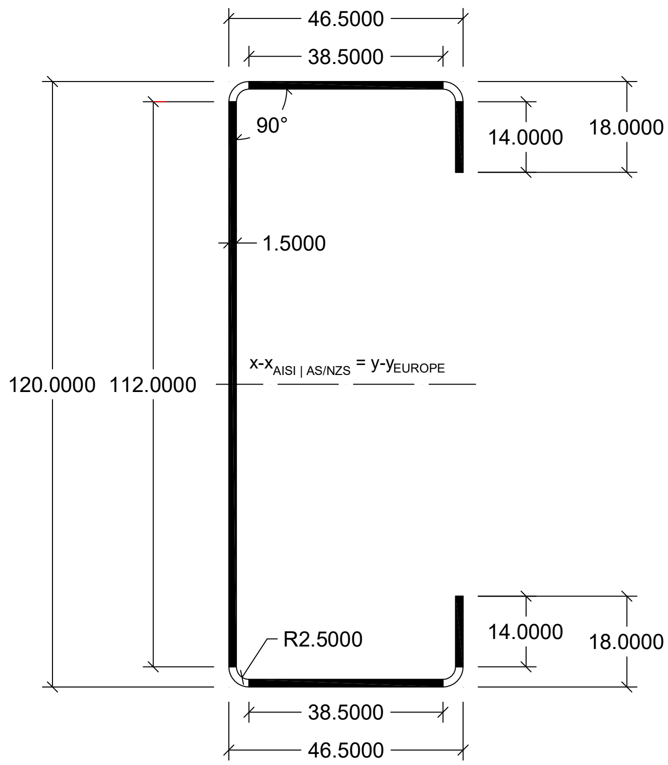


Figure 5.4 - Section $B\ 230 \times 1.50$

Cold-formed steel, S350 MAGNELIS® ZM310

Basic Yield, $f_{yb} = 350\ N/mm^2$ | Ultimate Tensile, $f_u = 420\ N/mm^2$

Practical Example: Utilization of cold form of working

Check North American (AISI S100) Requirements

The average yield strength F_{ya} may be utilised in determining:

- For axially loaded compression members, the quantity ρ is unity for each of the component elements of the section
- For flexural members, the quantity ρ is unity for each of the component elements of the section
- For axially loaded tension members

$$(F_{uv}/F_{yv}) \geq 1.20 \leftrightarrow (420/350) \geq 1.20 \leftrightarrow 1.20 \geq 1.20 \rightarrow OK$$

$$(R/t) \leq 7.00 \leftrightarrow (2.500/1.500) \leq 7.00 \leftrightarrow 1.667 \leq 7.00 \rightarrow OK$$

$$\emptyset \leq 120º \leftrightarrow 90º \leq 120º \rightarrow OK$$

$$B_c = 3.69 \times \left(F_{uv}/F_{yv}\right) - 0.819 \times \left(F_{uv}/F_{yv}\right)^2 - 1.79$$

$$B_c = 3.69 \times (420/350) - 0.819 \times (420/350)^2 - 1.79 = 1.459$$

$$m = 0.192 \times \left(F_{uv}/F_{yv}\right) - 0.068$$

$$m = 0.192 \times (420/350) - 0.068 = 0.162$$

$$F_{yc} = \left(B_c \times F_{yv}\right)/(R/t)^m$$

$$F_{yc} = (1.459 \times 350)/(2.500/1.500)^{0.162} = 470.093\ MPa$$

C For compression members, ratio of total corner cross-sectional area to total cross-sectional area of full section; for flexural members, ratio of total corner cross-sectional area of controlling flange to full cross-sectional area of controlling flange

Compression Members

$$C_{Compression} = \frac{Total\ cross - sectional\ area\ of\ all\ corners}{Full\ cross - sectional\ area}$$

$$C_{Compression} = \frac{7.647 + 7.649 + 7.647 + 7.649}{356.121} = 0.086$$

$$F_{ya} = C \times F_{yc} + (1 - C) \times F_{yf} \leq F_{uv}$$

$$F_{ya} = 0.086 \times 470.093 + (1 - 0.086) \times 350 \leq 420$$

$$F_{ya} = 360.328\ MPa \leq 420\ MPa \rightarrow OK$$

Flexural Members

$$C_{Flexural} = \frac{Total\ cross - sectional\ area\ of\ two\ corners}{Full\ cross - sectional\ area\ of\ flange}$$

$$C_{Flexural} = \frac{7.647 + 7.649}{7.647 + 57.759 + 7.649} = 0.209$$

$$F_{ya} = C \times F_{yc} + (1 - C) \times F_{yf} \leq F_{uv}$$

$$F_{ya} = 0.209 \times 470.093 + (1 - 0.209) \times 350 \leq 420$$

$$F_{ya} = 375.099\ MPa \leq 420\ MPa \rightarrow OK$$

Check Australian/New Zealand (AS/NZS 4600) Requirements

The average yield strength f_{ya} may be utilised in determining:

- For axially loaded compression members, the quantity ρ is unity for each of the component elements of the section
- For flexural members, the quantity ρ is unity for each of the component elements of the section
- For axially loaded tension members

$$(\mathrm{f_{uv}/f_{yv}}) \geq 1.20 \leftrightarrow (420/350) \geq 1.20 \leftrightarrow 1.20 \geq 1.20 \rightarrow \mathrm{OK}$$

$$(\mathrm{r_i/t}) \leq 7.00 \leftrightarrow (2.500/1.500) \leq 7.00 \leftrightarrow 1.667 \leq 7.00 \rightarrow \mathrm{OK}$$

$$\emptyset \leq 120º \leftrightarrow 90º \leq 120º \rightarrow \mathrm{OK}$$

$$\mathrm{B_c} = 3.69 \times (\mathrm{f_{uv}/f_{yv}}) - 0.819 \times (\mathrm{f_{uv}/f_{yv}})^2 - 1.79$$

$$\mathrm{B_c} = 3.69 \times (420/350) - 0.819 \times (420/350)^2 - 1.79 = 1.459$$

$$\mathrm{m} = 0.192 \times (\mathrm{f_{uv}/f_{yv}}) - 0.068$$

$$\mathrm{m} = 0.192 \times (420/350) - 0.068 = 0.162$$

$$\mathrm{f_{yc}} = (\mathrm{B_c} \times \mathrm{f_{yv}})/(\mathrm{r_i/t})^{\mathrm{m}}$$

$$\mathrm{F_{yc}} = (1.459 \times 350)/(2.500/1.500)^{0.162} = 470.093\ \mathrm{MPa}$$

C For compression members, ratio of total corner cross-sectional area to total cross-sectional area of full section; for flexural members, ratio of total corner cross-sectional area of controlling flange to full cross-sectional area of controlling flange

<u>Compression Members</u>

$$C_{Compression} = \frac{Total\ cross - sectional\ area\ of\ all\ corners}{Full\ cross - sectional\ area}$$

$$C_{Compression} = \frac{7.647 + 7.649 + 7.647 + 7.649}{356.121} = 0.086$$

$$f_{ya} = C \times f_{yc} + (1 - C) \times f_{yf} \leq f_{uv}$$

$$f_{ya} = 0.086 \times 470.093 + (1 - 0.086) \times 350 \leq 420$$

$$f_{ya} = 360.328\ MPa \leq 420\ MPa \rightarrow OK$$

<u>Flexural Members</u>

$$C_{Flexural} = \frac{Total\ cross - sectional\ area\ of\ two\ corners}{Full\ cross - sectional\ area\ of\ flange}$$

$$C_{Flexural} = \frac{7.647 + 7.649}{7.647 + 57.759 + 7.649} = 0.209$$

$$f_{ya} = C \times f_{yc} + (1 - C) \times f_{yf} \leq f_{uv}$$

$$f_{ya} = 0.209 \times 470.093 + (1 - 0.209) \times 350 \leq 420$$

$$f_{ya} = 375.099\ MPa \leq 420\ MPa \rightarrow OK$$

Check European (EN 1993-1-3) Requirements

The average yield strength f_{ya} may be utilised in determining:

- Cross-section resistance of an axially loaded tension number
- Cross-section resistance / Buckling resistance of axially loaded compression member with fully effective cross-section
- Moment resistance of a cross-section with fully effective flanges

k is a numerical coefficient that depends on the type of forming, k = 7 for roll forming and k = 5 for other methods of forming

$$r \leq 5 \times t \rightarrow 2.500 \leq 5 \times 1.500\ t \rightarrow 2.500 \leq 7.500 \rightarrow OK$$

$$n = \frac{\emptyset_{Corner\ 1}}{90º} + \frac{\emptyset_{Corner\ 1}}{90º} + \frac{\emptyset_{Corner\ 1}}{90º} + \frac{\emptyset_{Corner\ 1}}{90º}$$

$$n = \frac{90º}{90º} + \frac{90º}{90º} + \frac{90º}{90º} + \frac{90º}{90º} = 4.000$$

$$t = 1.500\ mm$$

Gross cross-sectional area $(A_g) \rightarrow A_g = 356.121\ mm^2$

$$f_{ya} = f_{yb} + (f_u - f_{yb}) \times \frac{k \times n \times t^2}{A_g} \leq \frac{(f_u + f_{yb})}{2}$$

Cold-Formed Manufacturing Process → Roll Forming → $k = 7.000$

$$f_{ya} = 350 + (420 - 350) \times \frac{7 \times 4 \times 1.500^2}{356.121} \leq \frac{(420 + 350)}{2}$$

$$f_{ya} = 362.383\ MPa \leq 385\ MPa \rightarrow OK$$

Cold-Formed Manufacturing Process → Other methods of Forming → $k = 5.000$

$$f_{ya} = 350 + (420 - 350) \times \frac{5 \times 4 \times 1.500^2}{356.121} \leq \frac{(420 + 350)}{2}$$

$$f_{ya} = 358.845\ MPa \leq 385\ MPa \rightarrow OK$$

Due to extension of the calculations, regarding the four different structures subjected to study, it was defined that only some calculations were being presented. Table 5.1 shows the sections used in the study, in a perspective of comparison between the different standards. Table 5.2 shows, according to the used sections, the mechanical resistances values obtained using AISI S100, AS/NZS 4600 and EN 1993-1-3.

Table 5.1 - Photovoltaic Structures: Cold-formed sections

Designation	Purlin	Beam	Column	Strut
Photovoltaic Structure (Type 1)	$\Omega\ 200\ \times 1.00$	$B\ 230\ \times 1.50$	$B\ 200\ \times 2.50$	$B\ 134\ \times 1.50$
Photovoltaic Structure (Type 2)	$\Omega\ 200\ \times 1.00$	$B\ 230\ \times 1.50$	$B\ 200\ \times 2.50$	----
Photovoltaic Structure (Type 3)	$\Omega\ 200\ \times 1.00$	$B\ 230\ \times 1.50$	$B\ 200\ \times 2.50$	$B\ 134\ \times 1.50$
Photovoltaic Structure (Type 4)	$\Omega\ 200\ \times 1.00$	$B\ 230\ \times 1.50$	$B\ 320\ \times 2.50$	$B\ 134\ \times 1.50$

Table 5.2 - Photovoltaic Structure (Type 1): Cold-formed sections Resistances

Designation	$AISI_{ASD}$	$AISI_{LRFD}$	AS/NZS	$EUROCODE$
Purlin: Axial Tension	$68.6\ kN$	$68.6\ kN$	$68.6\ kN$	$68.9\ kN$
Purlin: Bending $M_{y,Ed}{}^{+}$	$1.0\ kNm$	$1.0\ kNm$	$1.0\ kNm$	$1.0\ kNm$
Purlin: Bending $M_{y,Ed}{}^{-}$	$1.2\ kNm$	$1.2\ kNm$	$1.2\ kNm$	$1.2\ kNm$
Purlin: Bending $M_{z,Ed}{}^{+}$	$1.1\ kNm$	$1.1\ kNm$	$1.1\ kNm$	$1.0\ kNm$
Purlin: Bending $M_{z,Ed}{}^{-}$	$1.1\ kNm$	$1.1\ kNm$	$1.1\ kNm$	$1.0\ kNm$
Purlin: Shear	$20.6\ kN$	$20.6\ kN$	$22.0\ kN$	$21.2\ kN$
Purlin: Local Transverse Forces	$2.3\ kN$	$2.3\ kN$	$2.3\ kN$	$2.3\ kN$
Beam: Axial Tension	$124.2\ kN$	$124.2\ kN$	$124.2\ kN$	$124.9\ kN$

Table 5.2 - Photovoltaic Structure (Type 1): Cold-formed sections Resistances (Continuation)

Designation	$AISI_{ASD}$	$AISI_{LRFD}$	AS/NZS	$EUROCODE$
Beam: Bending $M_{y,Ed}{}^{+}$	$4.2\ kNm$	$4.2\ kNm$	$2.7\ kNm$	$4.4\ kNm$
Beam: Bending $M_{y,Ed}{}^{-}$	$4.2\ kNm$	$4.2\ kNm$	$2.7\ kNm$	$4.4\ kNm$
Beam: Bending $M_{z,Ed}{}^{+}$	$1.3\ kNm$	$1.3\ kNm$	$2.0\ kNm$	$1.5\ kNm$
Beam: Bending $M_{z,Ed}{}^{-}$	$1.3\ kNm$	$1.3\ kNm$	$1.3\ kNm$	$1.3\ kNm$
Beam: Shear	$25.1\ kN$	$25.1\ kN$	$26.7\ kN$	$25.1\ kN$
Beam: Local Transverse Forces	$4.6\ kN$	$4.6\ kN$	$4.6\ kN$	$4.3\ kN$
Column: Axial Tension	$183.1\ kN$	$183.1\ kN$	$183.1\ kN$	$185.8\ kN$
Column: Bending $M_{y,Ed}{}^{+}$	$4.6\ kNm$	$4.6\ kNm$	$4.3\ kNm$	$5.3\ kNm$
Column: Bending $M_{y,Ed}{}^{-}$	$4.6\ kNm$	$4.6\ kNm$	$4.3\ kNm$	$5.3\ kNm$
Column: Bending $M_{z,Ed}{}^{+}$	$2.1\ kNm$	$2.1\ kNm$	$3.3\ kNm$	$3.2\ kNm$
Column: Bending $M_{z,Ed}{}^{-}$	$2.1\ kNm$	$2.1\ kNm$	$1.9\ kNm$	$2.1\ kNm$
Column: Shear	$41.2\ kN$	$41.2\ kN$	$44.0\ kN$	$43.6\ kN$
Column: Local Transverse Forces	$17.1\ kN$	$17.1\ kN$	$17.1\ kN$	$15.5\ kN$
Strut: Axial Tension	$73.9\ kN$	$73.9\ kN$	$73.9\ kN$	$74.6\ kN$

Table 5.2 - Photovoltaic Structure (Type 1): Cold-formed sections Resistances (Continuation)

Designation	$AISI_{ASD}$	$AISI_{LRFD}$	AS/NZS	$EUROCODE$
Strut: Bending $M_{y,Ed}{}^{+}$	$0.7\ kNm$	$0.7\ kNm$	$0.9\ kNm$	$1.2\ kNm$
Strut: Bending $M_{y,Ed}{}^{-}$	$0.7\ kNm$	$0.7\ kNm$	$0.9\ kNm$	$1.2\ kNm$
Strut: Bending $M_{z,Ed}{}^{+}$	$1.1\ kNm$	$1.1\ kNm$	$1.1\ kNm$	$1.1\ kNm$
Strut: Bending $M_{z,Ed}{}^{-}$	$0.3\ kNm$	$0.3\ kNm$	$0.7\ kNm$	$0.7\ kNm$

Tables 5.3, 5.4 and 5.5 indicate the percentages obtained for each sections, using the same load values and combinations. It's important to say that, in virtue that only been used the load combinations defined by EUROCODE, the percentages presented for ASD, LRFD and AS/NZS don't correspond to the values that must be obtained, using the appropriate load standards (ASCE7 and AS/NZS 1170). This way it was possible to established values of comparison between the three different standards.

Table 5.3 - Photovoltaic Structure (Type 1): Purlin Verifications

Designation	$AISI_{ASD}$	$AISI_{LRFD}$	AS/NZS	$EUROCODE$
Shear + Axial + Bending	60.9 %	38.4 %	16.4 %	44.0 %
Bending + Local Load	153.0 %	102.0 %	103.0 %	81.6 %

Table 5.4 - Photovoltaic Structure (Type 2): Beam Verifications

Designation	$AISI_{ASD}$	$AISI_{LRFD}$	AS/NZS	$EUROCODE$
Tension + Bending	35.0 %	23.0 %	21.7 %	31.0 %
Compression+ Bending	37.0 %	21.9 %	21.7 %	36.8 %
Shear + Axial + Bending	35.6 %	22.6 %	11.5 %	19.9 %
Bending + Local Load	109.4 %	73.9 %	92.4 %	66.4 %

Table 5.5 - Photovoltaic Structure (Type 3): Column Verifications

Designation	$AISI_{ASD}$	$AISI_{LRFD}$	AS/NZS	$EUROCODE$
Tension + Bending	19.0 %	12.5 %	13.0 %	19.6 %
Compression+ Bending	34.4 %	22.7 %	16.4 %	52.7 %
Shear + Axial + Bending	25.6 %	16.3 %	2.0 %	29.7 %
Bending + Local Load	54.7 %	36.7 %	36.8 %	30.4 %

6 CONCLUSION

The career of Civil Engineering is a life of constant challenges and study because there isn't a global accepted standard regarding the structure design, as well the fact that the technical knowledge is always increasing. Through the study presented, it was possible to identify that, although the standards had things in common, there are some specific matters that are treated with more detail in some standards than in others.

Although ASCE/SEI 7, AS/NZS 1170 and EUROCODE EN 1991 possess similarities because are based in standards created by the International Organization of Standardization (ISO), they are different in numerous aspects. ASCE/SEI 7 provides information for 14 different load types, when AS/NZS only provides for 9 and EUROCODE EN 1991 only for 7, providing that way a better background for a structural engineer in the quantification of the loads to be applied on a design model.

One negative point in ASCE/SEI 7, in the authors view, is the absence of load combinations for the Serviceability Limit State. Although it's comprehensive that the acceptance of the deflections presented in a structure depends on the person in charge, a similar procedure equal to the one provided in EUROCODE is well accepted, were the load combinations were simply given as guidance, as well the deflection limit values.

One point of extreme importance is the knowledge that the use of, for example, load combinations provided by the European standards with the cold-formed design verifications provided by the North American Specification will give results that don't correspond to the reality. It's important to say that if the code used was AISI S100, the loads values and combinations used must be provided by ASCE/SEI 7, was well AS/NZS 1170 to AS/NZS 4600 and the EUROCODE as well because each one was specifically calibrated for one standard.

Regarding the cold-formed design standards, although all off then are full detailed, the fact that AISI S100 permits the use of three different system units (U.S. customary units, SI units and MKS units), as well the structure analysis for three different methods (Allowable Strength Design (ASD), Load and Resistance Factor Design (LRFD) and Limit States Design (LSD)), AS/NZS 4600 and EN 1993-1-3 only permits the use of SI units and Limit States Design (LSD). EUROCODE, North American and Australian/New Zealand Specifications shared many similarities but EN 1993-1-3 is more theoretical than AISI S100 and AS/NZS 4600.

EUROCODE provides better information in the treatment of more complex open cross-sections than AISI S100. AS/NZS 4600 is practically equal to AISI S100, differing on the determination of the distortional buckling.

The application of the three standards, each one, involves a considerable amount of time, because of the numerous particularities and parameters, but, although the fact that AISI S100 looks easier to apply, the knowledge of the European cold-formed design code provides a better background and facilitates the transition from EN 1993-1-3 to AISI S100 / AS/NZS 4600. Users that only use the American Specifications may consider the European code complex, which in fact is, but the gain makes the work profitable.

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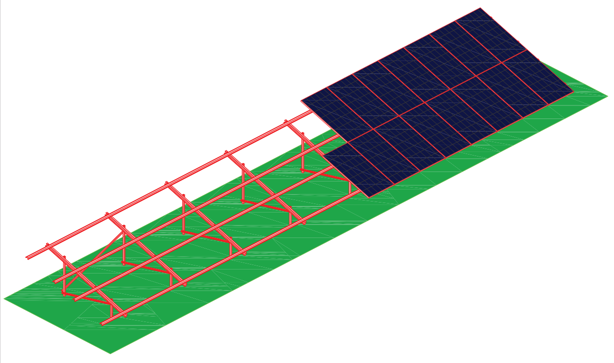
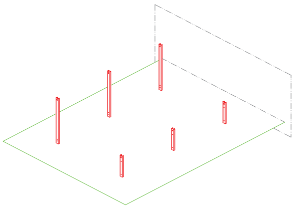
ANNEX A STRUCTURE TYPE I: EUROCODE VERIFICATION

[1] Presentation of the Photovoltaic Structure

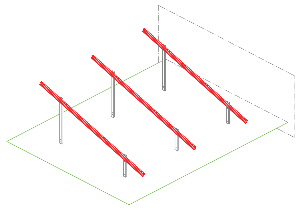


Photovoltaic Structure [Portrait Configuration] : 3D View [Example]

[2] Photovoltaic Structure : Assemby Guide



1.º Step of the Assembly Guide [Example]

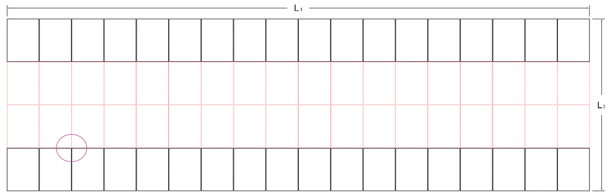


2.º Step of the Assembly Guide [Example]

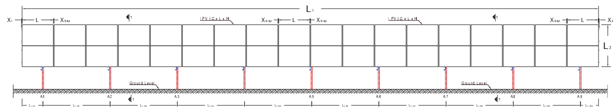
Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode References: EN 1990 | EN 1991 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

[4] Photovoltaic Structure : Structure Definition

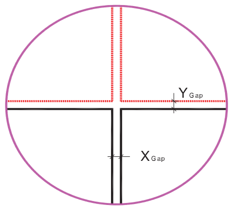
Photovoltaic Module Orientation	Portrait	N.º Rows	2	N.º Columns	18



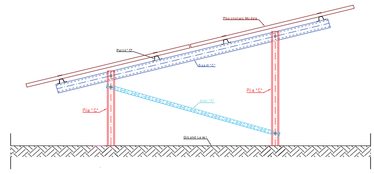
Photovoltaic Structure Definition : L_1 [mm] and L_2 [mm]



Photovoltaic Structure Definition : Tables Spacing [L_{1,X_n} ... $L_{1,X_{n+1}}$]



Gap between Photovoltaic Modules

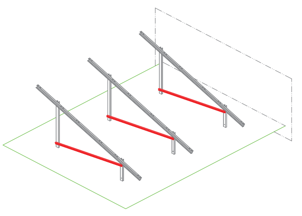


Ω-Section Purlin — C-Section Beam
C-Section Column — C-Section Strut

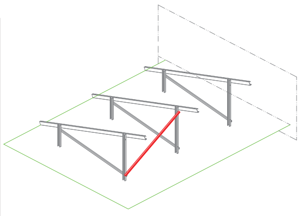
Photovoltaic Structure Definition: Cut View

$L_{PV,Module}$	992.000	[mm]	→	L_1	18236.000	[mm]
$C_{PV,Module}$	1956.000	[mm]	→	L_2	3932.000	[mm]

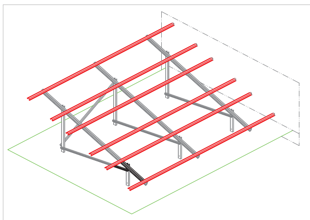
Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode References: EN 1990 | EN 1991 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY



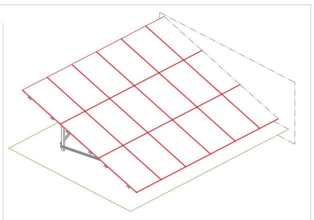
3.º Step of the Assembly Guide [Example]



4.º Step of the Assembly Guide [Example]

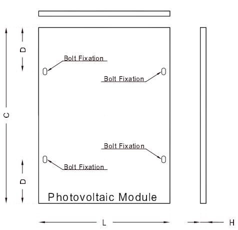


5.º Step of the Assembly Guide [Example]



6.º Step of the Assembly Guide [Example]

[3] Photovoltaic Structure : Photovoltaic Module



Photovoltaic Module

Photovoltaic Module			
Fabricant	----		
Designation	----		
N.º of Cells		72	[un]
Maximum Power [P_{Max}]		340	[Wp]
Dimensions	$C_{PV,Module}$	1956.000	[mm]
	$L_{PV,Module}$	992.000	[mm]
	$H_{PV,Module}$	40.000	[mm]
Installing Holes [$D_{PV,Module}$]		548	[mm]
Weight	$G_{PV,Module}$	26.500	[Kg]
	$G_{PV,Module}$	0.137	[kN/m^2]

Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode References: EN 1990 | EN 1991 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

N.º of Spacings	8	[un]
Distance between tables	2125.000	[mm]

$L_{1,Console}$	618.000	[mm]	→	Middle length beam is well defined
$L_{1,Middle}$	2125.000	[mm]	→	Middle length beam is well defined

[a] Ω-Section Purlin

Ω-Section Purlin Length	18236.000	[mm]
Maximum Ω-Section Purlin Length	13000.000	[mm]

Quantity of Ω-Section Purlin Length 2.000 [un] → Purlin with overlaps or sleeves

[b] C-Section Beam

$L_{Beam,Front Console}$	510.000	[mm]
$L_{Beam,Middle}$	1976.000	[mm]
$L_{Beam,Rear Console}$	510.000	[mm]

C-Section Beam Length 2996.000 [mm]

$L_{Beam,Front Console}$ → Beam console length is according to rules of construction
$L_{Beam,Rear Console}$ → Beam console length is according to rules of construction

Maximum C-Section Beam Length 6000.000 [mm]

Quantity of C-Section Beam Length 1.000 [un] → Beam without splices connections

[c] C-Section Column

$L_{Colum,Front Column}$	700.000	[mm]	Pthotovoltaic Structure Inclination [α]	15	[º]
Distance between Columns	1908.669	[mm]	$L_{Colum,Rear Column}$	1211.426	[mm]

Maximum C-Section Column Length 4000.000 [mm]

Quantity of C-Section Front Column Length	1.000	[un]	→	Front Column without splices connections
Quantity of C-Section Rear Column Length	1.000	[un]	→	Rear Column without splices connections

[d] C-Section Strut

Strut Fixation Point in the Front Column 550.000 [mm]
Strut Fixation Point in the Rear Column 150.000 [mm] → Distance from the Ground Level

L_{Strut} 1950.133 [mm] — Maximum C-Section Strut Length 6000.000 [mm]

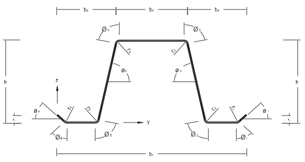
Quantity of C-Section Strut Length 1.000 [un] → Strut without splices connections

[5] Photovoltaic Structure : Material Properties — [BS EN 1993-1-3:2006]

Steel	S 350 GD + Z	→	f_{yb}	350.000	[MPa]	f_u	420.000	[MPa]

[6] Photovoltaic Structure : Section Definition

[a] Ω-Section Purlin



Ω-Section Purlin

Ω-Section	Ω 200 * 1.00	
h	54.693	[mm]
h_c	5.096	[mm]
b_1	112.008	[mm]
b_2	34.919	[mm]
b_3	42.170	[mm]
b_4	34.919	[mm]
t_{nom}	1.000	[mm]

r_1	1.500	[mm]	$Ø_3$	78.393	[°]
r_2	1.500	[mm]	$Ø_4$	78.393	[°]
r_3	1.500	[mm]	$Ø_5$	78.393	[°]
r_4	1.500	[mm]	$Ø_6$	45.000	[°]
r_5	1.500	[mm]	$Φ_1$	45.000	[°]
r_6	1.500	[mm]	$Φ_2$	78.393	[°]
$Ø_1$	45.000	[°]	$Φ_3$	78.393	[°]
$Ø_2$	78.393	[°]	$Φ_4$	45.000	[°]

Continuously hot-dip coated steel sheet and strip : Tolerances on dimensions and shape — [EN 10143:2006]

w	200.000	[mm]	Tolerance	Special
$t_{metallic\ coatings}^{[+]}$	0.050	[mm]	[EN 10143, Table 2]	
$t_{metallic\ coatings}^{[-]}$	-0.050	[mm]	[EN 10143, Table 2]	

Thickness and thickness tolerances — [EN 1993-1-3:2006, 3.2.4]

NOTE The ranges of core thickness t_{cor} for sheeting and members are:

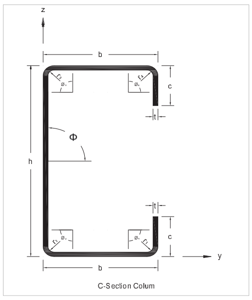
- Sheeting / Members: $0.450\ mm \le t_{cor} \le 15.000\ mm$
- Connections: $0.450\ mm \le t_{cor} \le 4.000\ mm$

[EN 1993-1-3:2006, Equation 3.3c]

$t_{cor,maximum}$	1.050	[mm]
$t_{cor,minimum}$	0.950	[mm]

Tolerance	≤ 5%	→	[EN 1993-1-3, Equation 3.3a]	t	0.952	[mm]
Coating	ZM310	→	Zinc-magnesium alloy coating [ZM]	→	0.048	[mm]

[c] C-Section Column



C-Section Colum

C-Section	B 200 * 2.50	
h	90.000	[mm]
b	46.500	[mm]
c	18.000	[mm]
r_1	2.500	[mm]
r_2	2.500	[mm]
r_3	2.500	[mm]
r_4	2.500	[mm]
t_{nom}	2.500	[mm]
$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
Φ	90.000	[°]

Continuously hot-dip coated steel sheet and strip : Tolerances on dimensions and shape — [EN 10143:2006]

w	200.000	mm	Tolerance	Special
$t_{metallic\ coatings}^{[+]}$	0.110	mm	[EN 10143, Table 2]	
$t_{metallic\ coatings}^{[-]}$	-0.110	mm	[EN 10143, Table 2]	

Thickness and thickness tolerances — [EN 1993-1-3:2006, 3.2.4]

NOTE The ranges of core thickness t_{cor} for sheeting and members are:

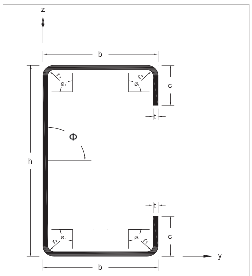
- Sheeting / Members: $0.450\ mm \le t_{cor} \le 15.000\ mm$
- Connections: $0.450\ mm \le t_{cor} \le 4.000\ mm$

[EN 1993-1-3:2006, Equation 3.3c]

$t_{cor,maximum}$	2.610	mm
$t_{cor,minimum}$	2.390	mm

Tolerance	≤ 5%	→	[EN 1993-1-3, Equation 3.3a]	t	2.452	mm
Coating	ZM310	→	Zinc-magnesium alloy coating [ZM]	→	0.048	[mm]

[b] C-Section Beam



C-Section Beam

C-Section	B 230 * 1.50	
h	120.000	[mm]
b	46.500	[mm]
c	18.000	[mm]
r_1	2.500	[mm]
r_2	2.500	[mm]
r_3	2.500	[mm]
r_4	2.500	[mm]
t_{nom}	1.500	[mm]
$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
Φ	90.000	[°]

Continuously hot-dip coated steel sheet and strip : Tolerances on dimensions and shape — [EN 10143:2006]

w	230.000	mm	Tolerance	Special
$t_{metallic\ coatings}^{[+]}$	0.070	mm	[EN 10143, Table 2]	
$t_{metallic\ coatings}^{[-]}$	-0.070	mm	[EN 10143, Table 2]	

Thickness and thickness tolerances — [EN 1993-1-3:2006, 3.2.4]

NOTE The ranges of core thickness t_{cor} for sheeting and members are:

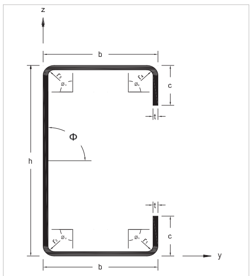
- Sheeting / Members: $0.450\ mm \le t_{cor} \le 15.000\ mm$
- Connections: $0.450\ mm \le t_{cor} \le 4.000\ mm$

[EN 1993-1-3:2006, Equation 3.3c]

$t_{cor,maximum}$	1.570	mm
$t_{cor,minimum}$	1.430	mm

Tolerance	≤ 5%	→	[EN 1993-1-3, Equation 3.3a]	t	1.452	mm
Coating	ZM310	→	Zinc-magnesium alloy coating [ZM]	→	0.048	[mm]

[d] C-Section Strut



C-Section Strut

C-Section	B 134 * 1.50	
h	50.000	[mm]
b	40.000	[mm]
c	10.000	[mm]
r_1	2.500	[mm]
r_2	2.500	[mm]
r_3	2.500	[mm]
r_4	2.500	[mm]
t_{nom}	1.500	[mm]
$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
Φ	90.000	[°]

Continuously hot-dip coated steel sheet and strip : Tolerances on dimensions and shape — [EN 10143:2006]

w	134.000	mm	Tolerance	Special
$t_{metallic\ coatings}^{[+]}$	0.070	mm	[EN 10143, Table 2]	
$t_{metallic\ coatings}^{[-]}$	-0.070	mm	[EN 10143, Table 2]	

Thickness and thickness tolerances — [EN 1993-1-3:2006, 3.2.4]

NOTE The ranges of core thickness t_{cor} for sheeting and members are:

- Sheeting / Members: $0.450\ mm \le t_{cor} \le 15.000\ mm$
- Connections: $0.450\ mm \le t_{cor} \le 4.000\ mm$

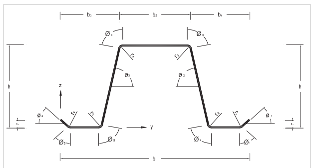
[EN 1993-1-3:2006, Equation 3.3c]

$t_{cor,maximum}$	1.570	mm
$t_{cor,minimum}$	1.430	mm

Tolerance	≤ 5%	→	[EN 1993-1-3, Equation 3.3a]	t	1.452	mm
Coating	ZM310	→	Zinc-magnesium alloy coating [ZM]	→	0.048	[mm]

[7] Photovoltaic Structure : Geometrical Proportions [BS EN 1993-1-3:2006, 5.2]

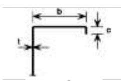
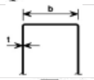
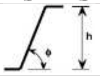
[a] Ω-Section Purlin



Ω-Section Purlin

Ω-Section	Ω 200 * 1.00	
h	54.693	[mm]
h_c	5.096	[mm]
b_1	112.008	[mm]
b_2	34.919	[mm]
b_3	42.170	[mm]
b_4	34.919	[mm]
t_{nom}	1.000	[mm]
t	0.952	[mm]

r_1	1.500	[mm]	$Ø_3$	78.393	[°]
r_2	1.500	[mm]	$Ø_4$	78.393	[°]
r_3	1.500	[mm]	$Ø_5$	78.393	[°]
r_4	1.500	[mm]	$Ø_6$	45.000	[°]
r_5	1.500	[mm]	$Φ_1$	45.000	[°]
r_6	1.500	[mm]	$Φ_2$	78.393	[°]
$Ø_1$	45.000	[°]	$Φ_3$	78.393	[°]
$Ø_2$	78.393	[°]	$Φ_4$	45.000	[°]

Maximum width-to-thickness ratios	
Element of cross-section	Maximum value [mm]
	b / t ≤ 60 c / t ≤ 50
	b / t ≤ 500
	45° ≤ Φ ≤ 90° h / t ≤ 500 * sin [Φ]

NOTE Influence of rounded corners on cross-section resistance may be neglected when internal radius r ≤ 5 * t and r ≤ 0.10 * b_p and the cross-section may be assumed to consist of plane elements with sharp corners [EN 1993-1-3:2006, 5.1]

NOTE Round corners considered in gross cross sections

NOTE Lip measure c is perpendicular to the flange if the lip is not perpendicular to the flange.

r ≤ 0.04 * t * E / f_y [EN 1993-1-3:2006, 5.1(6)]

0.200 ≤ c / b ≤ 0.600 [Equation 5.2(a)]

Geometrical Proportions Verifications

t	0.952	[mm]	≥ 0.450 mm	→	OK
			≤ 15.000 mm	→	OK

$b_{Flange,Top}$	42.170	[mm]	b / t ≤ 500	→	OK
Φ	78.393	[°]	≥ 45°	→	OK
			≤ 90°	→	OK
h_{Web}	54.693	[mm]	h / t ≤ 500 sin Φ	→	OK
$b_{Flange,Inferior}$	39.572	[mm]	b / t ≤ 60	→	OK
c	5.572	[mm]	c / t ≤ 50	→	OK

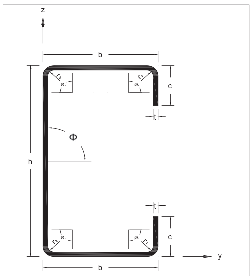
NOTE In order to provide sufficient stiffness and to avoid primary buckling of the stiffener itself, the sizes of the stiffeners should be within :

0.200 ≤ c / b ≤ 0.600 → If c / b < 0.200 the lip should be ignored [c = 0]

c / $b_{Flange,Inferior}$	≥ 0.200	→	KO! Stiffener is ignored in the mechanical properties calculation

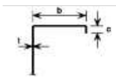
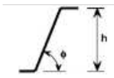
r_{max}	1.500	[mm]	r ≤ 0.04 * t * E / f_y	→	OK

[b] C-Section Beam



C-Section Beam

C-Section	B 230 * 1.50	
h	120.000	[mm]
b	46.500	[mm]
c	18.000	[mm]
r_1	2.500	[mm]
r_2	2.500	[mm]
r_3	2.500	[mm]
r_4	2.500	[mm]
t_{nom}	1.500	[mm]
$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
Φ	90.000	[°]
t	1.452	[mm]

Maximum width-to-thickness ratios	
Element of cross-section	Maximum value [mm]
	b / t ≤ 60 c / t ≤ 50
Element of cross-section	Maximum value [mm]
	45° ≤ Φ ≤ 90° h / t ≤ 500 * sin [Φ]

NOTE Influence of rounded corners on cross-section resistance may be neglected when internal radius r ≤ 5 * t and r ≤ 0.10 * b_p and the cross-section may be assumed to consist of plane elements with sharp corners [EN 1993-1-3:2006, 5.1]

NOTE Round corners considered in gross cross sections

NOTE Lip measure c is perpendicular to the flange if the lip is not perpendicular to the flange.

r ≤ 0.04 * t * E / f_y [EN 1993-1-3:2006, 5.1(6)]

0.200 ≤ c / b ≤ 0.600 [Equation 5.2(a)]

Geometrical Proportions Verifications

t	1.452	[mm]	≥ 0.450 mm	→	OK
			≤ 15.000 mm	→	OK
$b_{Flange,Top}$	46.500	[mm]	b / t ≤ 60	→	OK
Φ	90.000	[°]	≥ 45°	→	OK
			≤ 90°	→	OK
h_{Web}	120.000	[mm]	h / t ≤ 500 sin Φ	→	OK
$b_{Flange,Inferior}$	46.500	[mm]	b / t ≤ 60	→	OK
c	18.000	[mm]	c / t ≤ 50	→	OK

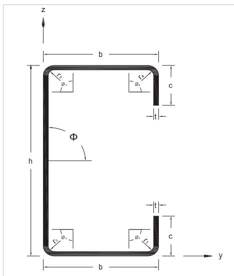
NOTE In order to provide sufficient stiffness and to avoid primary buckling of the stiffener itself, the sizes of the stiffeners should be within :

0.200 ≤ c / b ≤ 0.600 → If c / b < 0.200 the lip should be ignored [c = 0]

c / $b_{Flange,Inferior}$	≥ 0.200	→	Stiffener it sufficient stiffness to avoid primary buckling
c / $b_{Flange,Inferior}$	≤ 0.600	→	Stiffener it sufficient stiffness to avoid primary buckling

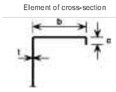
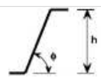
r_{max}	2.500	[mm]	r ≤ 0.04 * t * E / f_y	→	OK

[c] C-Section Column



C-Section Column

C-Section	B 200 * 2.50	
h	90.000	[mm]
b	46.500	[mm]
c	18.000	[mm]
r_1	2.500	[mm]
r_2	2.500	[mm]
r_3	2.500	[mm]
r_4	2.500	[mm]
t_{nom}	2.500	[mm]
$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
Φ	90.000	[°]
t	2.452	[mm]

Maximum width-to-thickness ratios	
Element of cross-section	Maximum value [mm]
	b / t ≤ 60 c / t ≤ 50
Element of cross-section	Maximum value [mm]
	45° ≤ Φ ≤ 90° h / t ≤ 500 * sin [Φ]

NOTE Influence of rounded corners on cross-section resistance may be neglected when internal radius r ≤ 5 * t and r ≤ 0.10 * b_p and the cross-section may be assumed to consist of plane elements with sharp corners [EN 1993-1-3:2006, 5.1]

NOTE Round corners considered in gross cross sections

NOTE Lip measure c is perpendicular to the flange if the lip is not perpendicular to the flange.

r ≤ 0.04 * t * E / f_y [EN 1993-1-3:2006, 5.1(6)]

0.200 ≤ c / b ≤ 0.600 [Equation 5.2(a)]

Geometrical Proportions Verifications

t	2.452	[mm]	≥ 0.450 mm	→	OK
			≤ 15.000 mm	→	OK
$b_{Flange,Top}$	46.500	[mm]	b / t ≤ 60	→	OK
Φ	90.000	[°]	≥ 45°	→	OK
			≤ 90°	→	OK
h_{Web}	90.000	[mm]	h / t ≤ 500 sin Φ	→	OK

$b_{Flange,Inferior}$	46.500	[mm]	b / t ≤ 60	→	OK
c	18.000	[mm]	c / t ≤ 50	→	OK

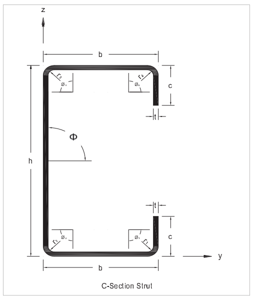
NOTE In order to provide sufficient stiffness and to avoid primary buckling of the stiffener itself, the sizes of the stiffeners should be within :

0.200 ≤ c / b ≤ 0.600 → If c / b < 0.200 the lip should be ignored [c = 0]

$c / b_{Flange,Inferior}$	≥ 0.200	→	Stiffener it sufficient stiffness to avoid primary buckling
$c / b_{Flange,Inferior}$	≤ 0.600	→	Stiffener it sufficient stiffness to avoid primary buckling

r_{max}	2.500	[mm]	$r \leq 0.04 * t * E / f_y$	→	OK

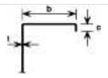
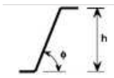
[d] C-Section Strut



C-Section Strut

C-Section	B 134 * 1.50	
h	50.000	[mm]
b	40.000	[mm]
c	10.000	[mm]
r_1	2.500	[mm]
r_2	2.500	[mm]
r_3	2.500	[mm]
r_4	2.500	[mm]
t_{nom}	1.500	[mm]
$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
Φ	90.000	[°]
t	1.452	[mm]

Maximum width-to-thickness ratios

Element of cross-section	Maximum value [mm]
	b / t ≤ 60 c / t ≤ 50
Element of cross-section	Maximum value [mm]
	45° ≤ Φ ≤ 90° h / t ≤ 500 * sin [Φ]

NOTE Influence of rounded corners on cross-section resistance may be neglected when internal radius r ≤ 5 * t and r ≤ 0.10 * b_p and the cross-section may be assumed to consist of plane elements with sharp corners [EN 1993-1-3:2006, 5.1]

NOTE Round corners considered in gross cross sections

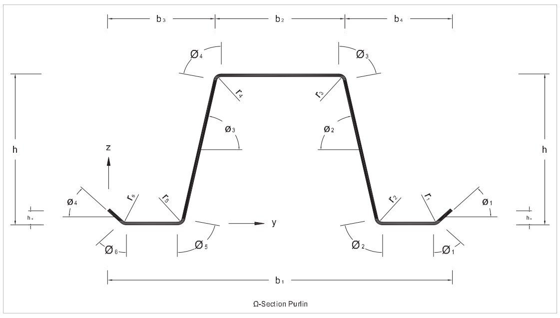
NOTE Lip measure c is perpendicular to the flange if the lip is not perpendicular to the flange.

$r \leq 0.04 * t * E / f_y$ [EN 1993-1-3:2006, 5.1(6)]

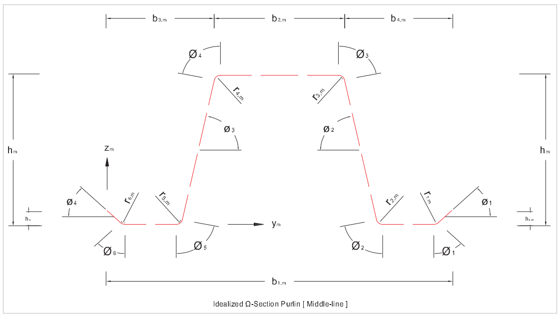
0.200 ≤ c / b ≤ 0.600 [Equation 5.2(a)]

[8] Photovoltaic Structure : Cold-Formed Section Properties [BS EN 1993-1-3:2006]

[a] Ω-Section Purlin



Ω-Section Purlin



Idealized Ω-Section Purlin [Middle-line]

Geometrical Proportions Verifications

t	1.452	[mm]	≥ 0.450 mm	→	OK
			≤ 15.000 mm	→	OK
$b_{Flange,Top}$	40.000	[mm]	b / t ≤ 60	→	OK
Φ	90.000	[°]	≥ 45°	→	OK
			≤ 90°	→	OK
h_{Web}	50.000	[mm]	h / t ≤ 500 sin Φ	→	OK
$b_{Flange,Inferior}$	40.000	[mm]	b / t ≤ 60	→	OK
c	10.000	[mm]	c / t ≤ 50	→	OK

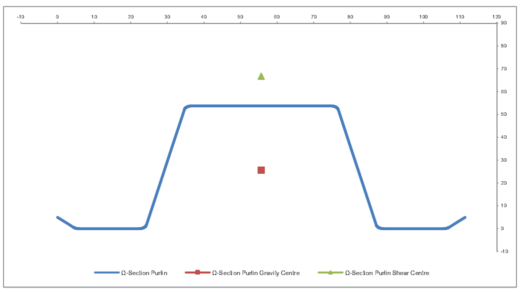
NOTE In order to provide sufficient stiffness and to avoid primary buckling of the stiffener itself, the sizes of the stiffeners should be within :

0.200 ≤ c / b ≤ 0.600 → If c / b < 0.200 the lip should be ignored [c = 0]

$c / b_{Flange,Inferior}$	≥ 0.200	→	Stiffener it sufficient stiffness to avoid primary buckling
$c / b_{Flange,Inferior}$	≤ 0.600	→	Stiffener it sufficient stiffness to avoid primary buckling

r_{max}	2.500	[mm]	$r \leq 0.04 * t * E / f_y$	→	OK

Ω-Section Purlin				Idealized Ω-Section Purlin [Middle-line]		
h	54.693	[mm]	→	h_m	53.741	[mm]
$h_{c,Right}$	5.096	[mm]	→	$h_{c,Right,m}$	4.957	[mm]
$h_{c,Left}$	5.096	[mm]	→	$h_{c,Left,m}$	4.957	[mm]
b_1	112.008	[mm]	→	$b_{1,m}$	111.335	[mm]
b_2	34.919	[mm]	→	$b_{2,m}$	35.513	[mm]
b_3	42.170	[mm]	→	$b_{3,m}$	40.617	[mm]
b_4	34.919	[mm]	→	$b_{4,m}$	35.513	[mm]
r_1	1.500	[mm]	→	$r_{1,m}$	1.976	[mm]
r_2	1.500	[mm]	→	$r_{2,m}$	1.976	[mm]
r_3	1.500	[mm]	→	$r_{3,m}$	1.976	[mm]
r_4	1.500	[mm]	→	$r_{4,m}$	1.976	[mm]
r_5	1.500	[mm]	→	$r_{5,m}$	1.976	[mm]
r_6	1.500	[mm]	→	$r_{6,m}$	1.976	[mm]
$Ø_1$	45.000	[°]	→	$Ø_1$	45.000	[°]
$Ø_2$	78.393	[°]	→	$Ø_2$	78.393	[°]
$Ø_3$	78.393	[°]	→	$Ø_3$	78.393	[°]
$Ø_4$	78.393	[°]	→	$Ø_4$	78.393	[°]
$Ø_5$	78.393	[°]	→	$Ø_5$	78.393	[°]
$Ø_6$	45.000	[°]	→	$Ø_6$	45.000	[°]
$Φ_1$	45.000	[°]	→	$Φ_1$	45.000	[°]
$Φ_2$	78.393	[°]	→	$Φ_2$	78.393	[°]
$Φ_3$	78.393	[°]	→	$Φ_3$	78.393	[°]
$Φ_4$	45.000	[°]	→	$Φ_4$	45.000	[°]
t	0.952	[mm]				

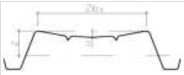


Ω-Section Purlin : Geometrical Presentation

Ω-Section Purlin Mechanical Properties

Area	A	191.199	[mm^2]
First Moment of Area	S_{Y0}	4904.647	[mm^3]
	S_{Z0}	10643.543	[mm^3]
Gravity Centre	y_{GC}	55.667	[mm]
	z_{GC}	25.652	[mm]
Second Moment of Area through Gravity Centre	I_Y	85759.975	[mm^4]
	I_Z	176909.935	[mm^4]
Product Moment of Area through Gravity Centre	I_{YZ}	0.000	[mm^6]
Principal Axis	α	0.000	[°]
	I_ξ	176909.935	[mm^4]
	I_η	85759.975	[mm^4]
Mean of Sectorial Coordinate	I_ω	710997.113	[mm^3]
	ω_{mean}	3718.621	[mm]
Sectorial Constants	$I_{y\omega 0}$	27763255.770	[mm^6]
	$I_{y\omega}$	-11816046.037	[mm^6]
	$I_{z\omega 0}$	23012551.876	[mm^6]
	$I_{z\omega}$	4774027.730	[mm^6]
	$I_{\omega\omega 0}$	3727328529.525	[mm^6]
	$I_{\omega\omega}$	1083399663.544	[mm^6]
Shear Centre	y_{SC}	55.667	[mm]
	z_{SC}	66.791	[mm]
Warping Constant	I_W	28433171.015	[mm^6]
Torsion Constants	I_t	57.762	[mm^4]
	W_t	60.674	[mm^3]
Distance between Shear Centre and Gravity Centre	y_S	0.000	[mm]
	z_S	41.139	[mm]
Polar Moment of Area with respect to Shear Centre	I_p	586262.901	[mm^4]
Non-symmetry Factors	y_j	0.000	[mm]
	z_j	54.491	[mm]

Ω-Section Purlin : Flange Curling [BS EN 1993-1-3:2006, 5.4]



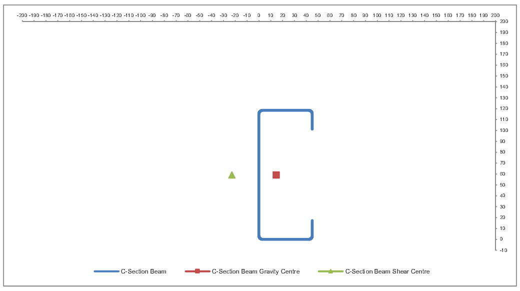
$$u = 2\frac{\sigma_a^2}{E^2}\frac{b_s^4}{t^2 z}$$

Ω-Section Purlin : Flange Curling [EN 1993-1-3, Equation (5.3a)]

σ_a	350.000	[MPa]
E	210.000	[GPa]
b_s	20.308	[mm]
t	0.952	[mm]
z	25.652	[mm]

u 9.856E-05 [mm] → Not considered because is less than 5% of the depth of the profile cross-section

Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode | References: EN 1990 | EN 1991 | EN 1993
Version: 1.000
Office: ---- | Author: JOSÉ ANTÓNIO
Date: 05/09/2019 | Project: MASTER THESIS
Client: COIMBRA UNIVERSITY



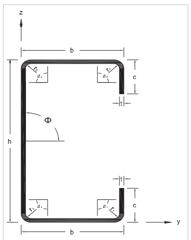
C-Section Beam : Geometrical Presentation

C-Section Beam Mechanical Properties

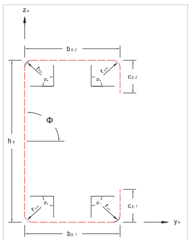
Area	A	345.063	[mm^2]
First Moment of Area	S_{Y0}	20453.287	[mm^3]
	S_{Z0}	5025.001	[mm^3]
Gravity Centre	y_{GC}	14.563	[mm]
	z_{GC}	59.274	[mm]
Second Moment of Area through Gravity Centre	I_Y	762290.565	[mm^4]
	I_Z	108754.009	[mm^4]
Product Moment of Area through Gravity Centre	I_{YZ}	0.000	[mm^6]
Principal Axis	α	0.000	[°]
	I_ξ	762290.565	[mm^4]
	I_η	108754.009	[mm^4]
Mean of Sectorial Coordinate	I_ω	-563270.965	[mm^3]
	ω_{mean}	-1632.370	[mm]
Sectorial Constants	$I_{y\omega 0}$	-14648942.986	[mm^6]
	$I_{y\omega}$	-6446285.130	[mm^6]
	$I_{z\omega 0}$	-50761926.637	[mm^6]
	$I_{z\omega}$	-17374603.429	[mm^6]
	$I_{\omega\omega 0}$	2051436893.361	[mm^6]
	$I_{\omega\omega}$	1131970533.845	[mm^6]
Shear Centre	y_{SC}	-22.793	[mm]
	z_{SC}	59.274	[mm]
Warping Constant	I_W	353860598.321	[mm^6]
Torsion Constants	I_t	242.500	[mm^4]
	W_t	167.011	[mm^3]

Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode | References: EN 1990 | EN 1991 | EN 1993
Version: 1.000
Office: ---- | Author: JOSÉ ANTÓNIO
Date: 05/09/2019 | Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

[b] C-Section Beam



C-Section Beam



Idealized C-Section Beam [Middle-line]

C-Section Beam				Idealized C-Section Beam [Middle-line]		
h	120.000	[mm]	→	h_p	118.548	[mm]
b_1	46.500	[mm]	→	$b_{p,1}$	45.048	[mm]
b_2	46.500	[mm]	→	$b_{p,2}$	45.048	[mm]
c_1	18.000	[mm]	→	$c_{p,1}$	17.274	[mm]
c_2	18.000	[mm]	→	$c_{p,2}$	17.274	[mm]
r_1	2.500	[mm]	→	$r_{1,m}$	3.226	[mm]
r_2	2.500	[mm]	→	$r_{2,m}$	3.226	[mm]
r_3	2.500	[mm]	→	$r_{3,m}$	3.226	[mm]
r_4	2.500	[mm]	→	$r_{4,m}$	3.226	[mm]
$Ø_1$	90.000	[°]	→	$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]	→	$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]	→	$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]	→	$Ø_4$	90.000	[°]
Φ	90.000	[°]	→	Φ	90.000	[°]
t	1.452	[mm]				

Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode | References: EN 1990 | EN 1991 | EN 1993
Version: 1.000
Office: ---- | Author: JOSÉ ANTÓNIO
Date: 05/09/2019 | Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

C-Section Beam Mechanical Properties [Continuation]

Distance between Shear Centre and Gravity Centre	y_S	-37.355	[mm]
	z_S	0.000	[mm]
Polar Moment of Area with respect to Shear Centre	I_p	1352549.014	[mm^4]
Non-symmetry Factors	y_j	-64.166	[mm]
	z_j	0.000	[mm]

C-Section Beam : Flange Curling [BS EN 1993-1-3:2006, 5.4]

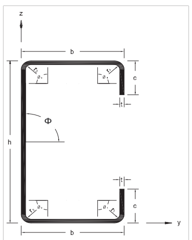
$$u = 2\frac{\sigma_a^2}{E^2}\frac{b_s^4}{t^2 z}$$

C-Section Beam : Flange Curling [EN 1993-1-3, Equation (5.3a)]

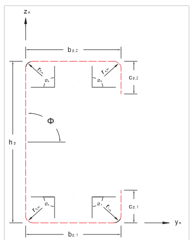
σ_a	350.000	[MPa]
E	210.000	[GPa]
b_s	62.322	[mm]
t	1.452	[mm]
z	59.274	[mm]

u 1.727E-04 [mm] → Not considered because is less than 5% of the depth of the profile cross-section

[c] C-Section Column

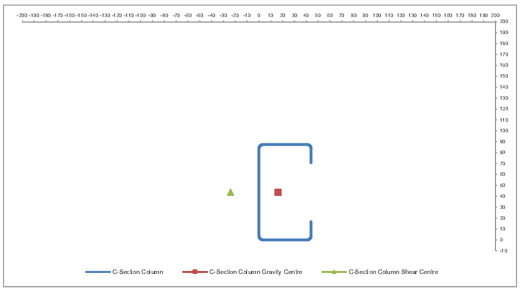


C-Section Column



Idealized C-Section Column [Middle-line]

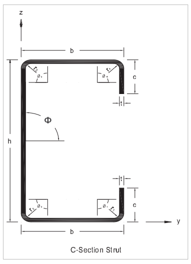
C-Section Column				Idealized C-Section Column [Middle-line]		
h	90.000	[mm]	→	h_p	87.548	[mm]
b_1	46.500	[mm]	→	$b_{p,1}$	44.048	[mm]
b_2	46.500	[mm]	→	$b_{p,2}$	44.048	[mm]
c_1	18.000	[mm]	→	$c_{p,1}$	16.774	[mm]
c_2	18.000	[mm]	→	$c_{p,2}$	16.774	[mm]
r_1	2.500	[mm]	→	$r_{1,m}$	3.726	[mm]
r_2	2.500	[mm]	→	$r_{2,m}$	3.726	[mm]
r_3	2.500	[mm]	→	$r_{3,m}$	3.726	[mm]
r_4	2.500	[mm]	→	$r_{4,m}$	3.726	[mm]
$Ø_1$	90.000	[°]	→	$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]	→	$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]	→	$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]	→	$Ø_4$	90.000	[°]
Φ	90.000	[°]	→	Φ	90.000	[°]
t	2.452	[mm]				



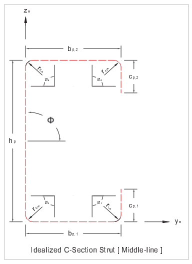
C-Section Column : Geometrical Presentation

C-Section Column Mechanical Properties			
Area	A	497.235	[mm^2]
First Moment of Area	S_{Y0}	21765.966	[mm^3]
	S_{Z0}	8034.951	[mm^3]
Gravity Centre	y_{GC}	16.159	[mm]
	z_{GC}	43.774	[mm]

[d] C-Section Strut



C-Section Strut



Idealized C-Section Strut [Middle-line]

C-Section Strut				Idealized C-Section Strut [Middle-line]		
h	50.000	[mm]	→	h_p	48.548	[mm]
b_1	40.000	[mm]	→	$b_{p,1}$	38.548	[mm]
b_2	40.000	[mm]	→	$b_{p,2}$	38.548	[mm]
c_1	10.000	[mm]	→	$c_{p,1}$	9.274	[mm]
c_2	10.000	[mm]	→	$c_{p,2}$	9.274	[mm]
r_1	2.500	[mm]	→	$r_{1,m}$	3.226	[mm]
r_2	2.500	[mm]	→	$r_{2,m}$	3.226	[mm]
r_3	2.500	[mm]	→	$r_{3,m}$	3.226	[mm]
r_4	2.500	[mm]	→	$r_{4,m}$	3.226	[mm]
$Ø_1$	90.000	[°]	→	$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]	→	$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]	→	$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]	→	$Ø_4$	90.000	[°]
Φ	90.000	[°]	→	Φ	90.000	[°]
t	1.452	[mm]				

C-Section Column Mechanical Properties [Continuation]			
Second Moment of Area through Gravity Centre	I_Y	625036.020	[mm^4]
	I_Z	153816.866	[mm^4]
Product Moment of Area through Gravity Centre	I_{YZ}	0.000	[mm^6]
Principal Axis	α	0.000	[°]
	I_ξ	625036.020	[mm^4]
	I_η	153816.866	[mm^4]
Mean of Sectorial Coordinate	I_ω	-713159.780	[mm^3]
	ω_{mean}	-1434.251	[mm]
Sectorial Constants	$I_{y\omega 0}$	-18257314.383	[mm^6]
	$I_{y\omega}$	-6733179.492	[mm^6]
	$I_{z\omega 0}$	-46186806.596	[mm^6]
	$I_{z\omega}$	-14968950.402	[mm^6]
	$I_{\omega\omega 0}$	1987326582.140	[mm^6]
	$I_{\omega\omega}$	964476551.941	[mm^6]
Shear Centre	y_{SC}	-23.949	[mm]
	z_{SC}	43.774	[mm]
Warping Constant	I_W	311247851.419	[mm^6]
Torsion Constants	I_t	996.509	[mm^4]
	W_t	406.407	[mm^3]
Distance between Shear Centre and Gravity Centre	y_S	-40.108	[mm]
	z_S	0.000	[mm]
Polar Moment of Area with respect to Shear Centre	I_p	1578738.881	[mm^4]
Non-symmetry Factors	y_j	-54.246	[mm]
	z_j	0.000	[mm]

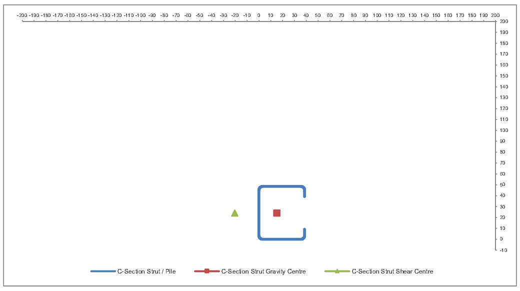
C-Section Column : Flange Curling **[BS EN 1993-1-3:2006, 5.4]**

$$u = 2\frac{\sigma_a^2}{E^2}\frac{b_s^4}{t^2 z}$$

C-Section Column : Flange Curling [EN 1993-1-3, Equation (5.3a)]

σ_a	350.000	[MPa]
E	210.000	[GPa]
b_s	60.822	[mm]
t	2.452	[mm]
z	43.774	[mm]

u 7.809E-05 [mm] → Not considered because is less than 5% of the depth of the profile cross-section



C-Section Strut : Geometrical Presentation

C-Section Strut Mechanical Properties			
Area	A	201.315	[mm^2]
First Moment of Area	S_{Y0}	4886.730	[mm^3]
	S_{Z0}	3040.577	[mm^3]
Gravity Centre	y_{GC}	15.104	[mm]
	z_{GC}	24.274	[mm]
Second Moment of Area through Gravity Centre	I_Y	85435.109	[mm^4]
	I_Z	43399.345	[mm^4]
Product Moment of Area through Gravity Centre	I_{YZ}	0.000	[mm^6]
Principal Axis	α	0.000	[°]
	I_ξ	85435.109	[mm^4]
	I_η	43399.345	[mm^4]
Mean of Sectorial Coordinate	I_ω	-143970.289	[mm^3]
	ω_{mean}	-715.148	[mm]
Sectorial Constants	$I_{y\omega 0}$	-3227938.382	[mm^6]
	$I_{y\omega}$	-1053475.689	[mm^6]
	$I_{z\omega 0}$	-5240440.083	[mm^6]
	$I_{z\omega}$	-1745705.295	[mm^6]
	$I_{\omega\omega 0}$	190513401.065	[mm^6]
	$I_{\omega\omega}$	87553344.926	[mm^6]
Shear Centre	y_{SC}	-20.433	[mm]
	z_{SC}	24.274	[mm]
Warping Constant	I_W	26311081.398	[mm^6]
Torsion Constants	I_t	141.478	[mm^4]
	W_t	97.437	[mm^3]

C-Section Strut Mechanical Properties [Continuarion]

Distance between Shear Centre and Gravity Centre	y_0	-35.537	[mm]
	z_0	0.000	[mm]
Polar Moment of Area with respect to Shear Centre	I_p	383066.518	[mm^4]
Non-symmetry Factors	y_j	-41.747	[mm]
	z_j	0.000	[mm]

C-Section Strut : Flange Curling [BS EN 1993-1-3:2006, 5.4]

$$u = 2\frac{\sigma_a^2}{E^2}\frac{b_s^4}{t^2 z}$$

C-Section Strut : Flange Curling [EN 1993-1-3, Equation (5.3a)]

σ_a	350.000	[MPa]
E	210.000	[GPa]
b_s	47.822	[mm]
t	1.452	[mm]
z	24.274	[mm]

u 2.483E-04 [mm] → Not considered because is less than 5% of the depth of the profile cross-section

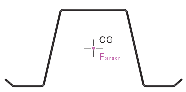
g_{r1}	0.062	[mm]	f_{r1}	0.756	[mm]
g_{r2}	0.363	[mm]	f_{r2}	1.249	[mm]
g_{r3}	0.363	[mm]	f_{r3}	1.249	[mm]
g_{r4}	0.363	[mm]	f_{r4}	1.249	[mm]
g_{r5}	0.363	[mm]	f_{r5}	1.249	[mm]
g_{r6}	0.062	[mm]	f_{r6}	0.756	[mm]

Ω-Section Nominal Widths

$c_{p,Nom,Right\ Lip}$	7.010	[mm]
$b_{p,Nom,Inf.\ Right\ Flange}$	18.975	[mm]
$h_{p,Nom,Right\ Web}$	54.863	[mm]
$b_{p,Nom,Sup.\ Web}$	41.393	[mm]
$h_{p,Nom,Left\ Web}$	54.863	[mm]
$b_{p,Nom,Inf.\ Left\ Flange}$	18.975	[mm]
$c_{p,Nom,Left\ Lip}$	7.010	[mm]

Ω-Section Purlin Classification [EN 1993-1-1:2005, 5.5.2, Table 5.2]

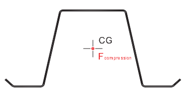
Ω-Section subjected to Tension Force



Right Edge Stiffner [$c_{p,Nom,Right\ Lip}$]	→	Tension
Inferior Right Flange [$b_{p,Nom,Inf.\ Right\ Flange}$]	→	Tension
Right Web [$h_{p,Nom,Right\ Web}$]	→	Tension
Superior Flange [$b_{p,Nom,Sup.\ Flange}$]	→	Tension
Left Web [$h_{p,Nom,Left\ Web}$]	→	Tension
Inferior Left Flange [$b_{p,Nom,Inf.\ Left\ Flange}$]	→	Tension
Left Edge Stiffener [$c_{p,Nom,Left\ Lip}$]	→	Tension

C-Section Classification: Not Classified

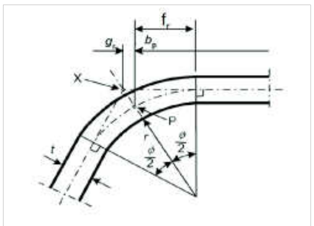
Ω-Section subjected to Compression Force



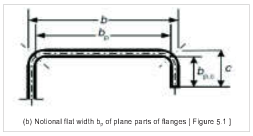
Right Edge Stiffner [$c_{p,Nom,Right\ Lip}$]	→	Class 1
Inferior Right Flange [$b_{p,Nom,Inf.\ Right\ Flange}$]	→	Class 1
Right Web [$h_{p,Nom,Right\ Web}$]	→	Class 4
Superior Flange [$b_{p,Nom,Sup.\ Flange}$]	→	Class 4
Left Web [$h_{p,Nom,Left\ Web}$]	→	Class 4
Inferior Left Flange [$b_{p,Nom,Inf.\ Left\ Flange}$]	→	Class 1
Left Edge Stiffener [$c_{p,Nom,Left\ Lip}$]	→	Class 1

C-Section Classification: Class 4

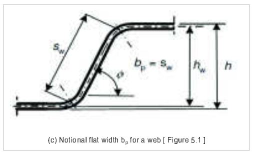
[9] Photovoltaic Structure : Cold-Formed Section, Section Classification [BS EN 1993-1-3:2006]



(a) Midpoint of corner or bend [Figure 5.1]

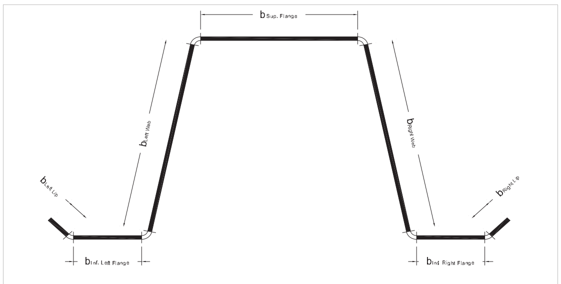


(b) Notional flat width b_p of plane parts of flanges [Figure 5.1]



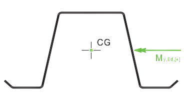
(c) Notional flat width b_p for a web [Figure 5.1]

[a] Ω-Section Purlin



$Ø_1$	45.000	[°]	$r_{1,m}$	1.976	[mm]
$Ø_2$	78.393	[°]	$r_{2,m}$	1.976	[mm]
$Ø_3$	78.393	[°]	$r_{3,m}$	1.976	[mm]
$Ø_4$	78.393	[°]	$r_{4,m}$	1.976	[mm]
$Ø_5$	78.393	[°]	$r_{5,m}$	1.976	[mm]
$Ø_6$	45.000	[°]	$r_{6,m}$	1.976	[mm]

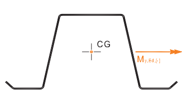
Ω-Section subjected to Positive Moment in y-y axis [$M_{y,Ed}^+$]



Right Edge Stiffner [$c_{p,Nom,Right\ Lip}$]	→	Tension
Inferior Right Flange [$b_{p,Nom,Inf.\ Right\ Flange}$]	→	Tension
Right Web [$h_{p,Nom,Right\ Web}$]	→	Class 1
Superior Flange [$b_{p,Nom,Sup.\ Flange}$]	→	Class 4
Left Web [$h_{p,Nom,Left\ Web}$]	→	Class 1
Inferior Left Flange [$b_{p,Nom,Inf.\ Left\ Flange}$]	→	Tension
Left Edge Stiffener [$c_{p,Nom,Left\ Lip}$]	→	Tension

C-Section Classification: Class 4

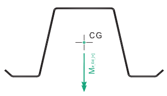
Ω-Section subjected to Negative Moment in y-y axis [$M_{y,Ed}^-$]



Right Edge Stiffner [$c_{p,Nom,Right\ Lip}$]	→	Class 1
Inferior Right Flange [$b_{p,Nom,Inf.\ Right\ Flange}$]	→	Class 1
Right Web [$h_{p,Nom,Right\ Web}$]	→	Class 1
Superior Flange [$b_{p,Nom,Sup.\ Flange}$]	→	Tension
Left Web [$h_{p,Nom,Left\ Web}$]	→	Class 1
Inferior Left Flange [$b_{p,Nom,Inf.\ Left\ Flange}$]	→	Class 1
Left Edge Stiffener [$c_{p,Nom,Left\ Lip}$]	→	Class 1

C-Section Classification: Class 1

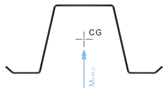
Ω-Section subjected to Positive Moment in z-z axis [$M_{z,Ed}^+$]



Right Edge Stiffner [$c_{p,Nom,Right\ Lip}$]	→	Tension
Inferior Right Flange [$b_{p,Nom,Inf.\ Right\ Flange}$]	→	Tension
Right Web [$h_{p,Nom,Right\ Web}$]	→	Tension
Superior Flange [$b_{p,Nom,Sup.\ Flange}$]	→	Class 1
Left Web [$h_{p,Nom,Left\ Web}$]	→	Class 4
Inferior Left Flange [$b_{p,Nom,Inf.\ Left\ Flange}$]	→	Class 1
Left Edge Stiffener [$c_{p,Nom,Left\ Lip}$]	→	Class 1

C-Section Classification: Class 4

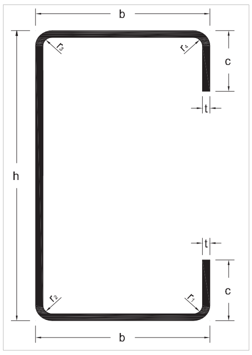
Ω-Section subjected to Negative Moment in z-z axis [$M_{z,Ed}^-$]



Right Edge Stiffner [$c_{p,Nom,Right\ Lip}$]	→	Class 1
Inferior Right Flange [$b_{p,Nom,Inf.\ Right\ Flange}$]	→	Class 1
Right Web [$h_{p,Nom,Right\ Web}$]	→	Class 4
Superior Flange [$b_{p,Nom,Sup.\ Flange}$]	→	Class 1
Left Web [$h_{p,Nom,Left\ Web}$]	→	Tension
Inferior Left Flange [$b_{p,Nom,Inf.\ Left\ Flange}$]	→	Tension
Left Edge Stiffener [$c_{p,Nom,Left\ Lip}$]	→	Tension

C-Section Classification	Class 4

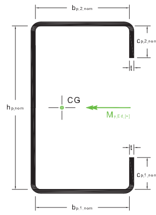
[b] C-Section Beam



$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
$r_{1,m}$	3.226	[mm]
$r_{2,m}$	3.226	[mm]
$r_{3,m}$	3.226	[mm]
$r_{4,m}$	3.226	[mm]
$g_{r,1}$	0.945	[mm]
$g_{r,2}$	0.945	[mm]
$g_{r,3}$	0.945	[mm]
$g_{r,4}$	0.945	[mm]
$f_{r,1}$	2.281	[mm]
$f_{r,2}$	2.281	[mm]
$f_{r,3}$	2.281	[mm]
$f_{r,4}$	2.281	[mm]

C-Section Nominal Widths		
$c_{p,1,nom}$	17.274	[mm]
$b_{p,1,nom}$	45.048	[mm]
$h_{p,nom}$	118.548	[mm]
$b_{p,2,nom}$	45.048	[mm]
$c_{p,2,nom}$	17.274	[mm]

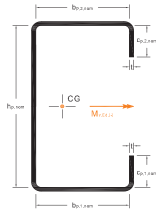
C-Section subjected to Positive Moment in y-y axis [$M_{y,Ed}^+$]



Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Tension
Inferior Flange [$b_{p,1,nom}$]	→	Tension
Web [$h_{p,nom}$]	→	Class 3
Superior Flange [$b_{p,2,nom}$]	→	Class 2
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Class 4

C-Section Classification	Class 4

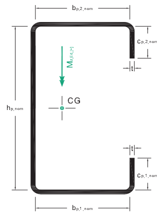
C-Section subjected to Negative Moment in y-y axis [$M_{y,Ed}^-$]



Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Class 4
Inferior Flange [$b_{p,1,nom}$]	→	Class 2
Web [$h_{p,nom}$]	→	Class 3
Superior Flange [$b_{p,2,nom}$]	→	Tension
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Tension

C-Section Classification	Class 4

C-Section subjected to Positive Moment in z-z axis [$M_{z,Ed}^+$]

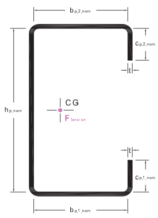


Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Tension
Inferior Flange [$b_{p,1,nom}$]	→	Class 1
Web [$h_{p,nom}$]	→	Class 4
Superior Flange [$b_{p,2,nom}$]	→	Class 1
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Tension

C-Section Classification	Class 4

C-Section Beam Classification [EN 1993-1-1:2005, 5.5.2, Table 5.2]

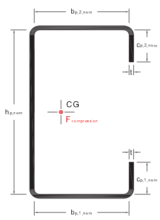
C-Section subjected to Tension Force



Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Tension
Inferior Flange [$b_{p,1,nom}$]	→	Tension
Web [$h_{p,nom}$]	→	Tension
Superior Flange [$b_{p,2,nom}$]	→	Tension
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Tension

C-Section Classification	Not Classified

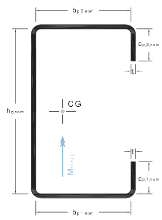
C-Section subjected to Compression Force



Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Class 4
Inferior Flange [$b_{p,1,nom}$]	→	Class 2
Web [$h_{p,nom}$]	→	Class 4
Superior Flange [$b_{p,2,nom}$]	→	Class 2
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Class 4

C-Section Classification	Class 4

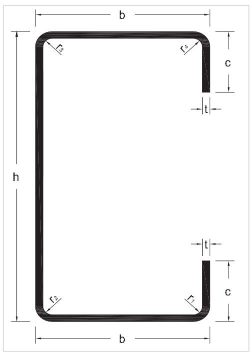
C-Section subjected to Negative Moment in z-z axis [$M_{z,Ed}^-$]



Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Class 4
Inferior Flange [$b_{p,1,nom}$]	→	Class 1
Web [$h_{p,nom}$]	→	Tension
Superior Flange [$b_{p,2,nom}$]	→	Class 1
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Class 4

C-Section Classification	Class 4

[c] C-Section Column

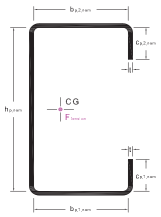


$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
$r_{1,m}$	3.726	[mm]
$r_{2,m}$	3.726	[mm]
$r_{3,m}$	3.726	[mm]
$r_{4,m}$	3.726	[mm]
$g_{r,1}$	1.091	[mm]
$g_{r,2}$	1.091	[mm]
$g_{r,3}$	1.091	[mm]
$g_{r,4}$	1.091	[mm]
$f_{r,1}$	2.635	[mm]
$f_{r,2}$	2.635	[mm]
$f_{r,3}$	2.635	[mm]
$f_{r,4}$	2.635	[mm]

C-Section Nominal Widths		
$c_{p,1,nom}$	16.774	[mm]
$b_{p,1,nom}$	44.048	[mm]
$h_{p,nom}$	87.548	[mm]
$b_{p,2,nom}$	44.048	[mm]
$c_{p,2,nom}$	16.774	[mm]

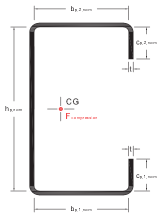
C-Section Column Classification [EN 1993-1-1:2005, 5.5.2, Table 5.2]

C-Section subjected to Tension Force



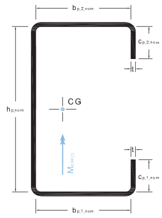
Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Tension
Inferior Flange [$b_{p,1,nom}$]	→	Tension
Web [$h_{p,nom}$]	→	Tension
Superior Flange [$b_{p,2,nom}$]	→	Tension
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Tension
C-Section Classification		**Not Classified**

C-Section subjected to Compression Force



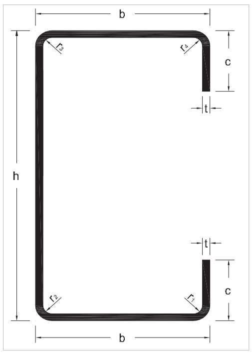
Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Class 1
Inferior Flange [$b_{p,1,nom}$]	→	Class 1
Web [$h_{p,nom}$]	→	Class 4
Superior Flange [$b_{p,2,nom}$]	→	Class 1
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Class 1
C-Section Classification		**Class 4**

C-Section subjected to Negative Moment in z-z axis [$M_{z,Ed}^-$]



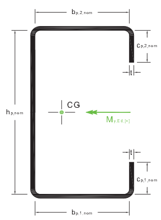
Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Class 1
Inferior Flange [$b_{p,1,nom}$]	→	Class 1
Web [$h_{p,nom}$]	→	Tension
Superior Flange [$b_{p,2,nom}$]	→	Class 1
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Class 1
C-Section Classification		**Class 1**

[d] C-Section Strut



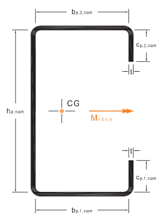
$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
$r_{1,m}$	3.226	[mm]
$r_{2,m}$	3.226	[mm]
$r_{3,m}$	3.226	[mm]
$r_{4,m}$	3.226	[mm]
$g_{r,1}$	0.945	[mm]
$g_{r,2}$	0.945	[mm]
$g_{r,3}$	0.945	[mm]
$g_{r,4}$	0.945	[mm]
$f_{r,1}$	2.281	[mm]
$f_{r,2}$	2.281	[mm]
$f_{r,3}$	2.281	[mm]
$f_{r,4}$	2.281	[mm]

C-Section subjected to Positive Moment in y-y axis [$M_{y,Ed}^+$]



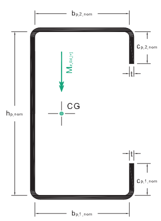
Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Tension
Inferior Flange [$b_{p,1,nom}$]	→	Tension
Web [$h_{p,nom}$]	→	Class 1
Superior Flange [$b_{p,2,nom}$]	→	Class 1
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Class 1
C-Section Classification		**Class 1**

C-Section subjected to Negative Moment in y-y axis [$M_{y,Ed}^-$]



Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Class 1
Inferior Flange [$b_{p,1,nom}$]	→	Class 1
Web [$h_{p,nom}$]	→	Class 1
Superior Flange [$b_{p,2,nom}$]	→	Tension
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Tension
C-Section Classification		**Class 1**

C-Section subjected to Positive Moment in z-z axis [$M_{z,Ed}^+$]

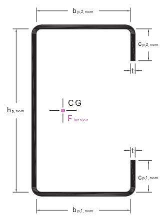


Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Tension
Inferior Flange [$b_{p,1,nom}$]	→	Class 1
Web [$h_{p,nom}$]	→	Class 4
Superior Flange [$b_{p,2,nom}$]	→	Class 1
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Tension
C-Section Classification		**Class 4**

C-Section Nominal Widths		
$c_{s,1,nom}$	9.274	[mm]
$b_{s,1,nom}$	38.548	[mm]
$h_{s,nom}$	48.548	[mm]
$b_{s,2,nom}$	38.548	[mm]
$c_{s,2,nom}$	9.274	[mm]

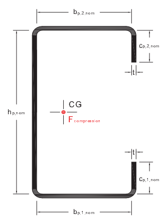
C-Section Strut Classification [EN 1993-1-1:2005, 5.5.2, Table 5.2]

C-Section subjected to Tension Force



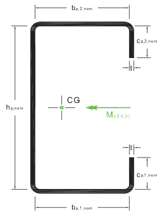
Inferior Edge Stiffener [$c_{s,1,nom}$]	→	Tension
Inferior Flange [$b_{s,1,nom}$]	→	Tension
Web [$h_{s,nom}$]	→	Tension
Superior Flange [$b_{s,2,nom}$]	→	Tension
Superior Edge Stiffener [$c_{s,2,nom}$]	→	Tension
C-Section Classification		**Not Classified**

C-Section subjected to Compression Force



Inferior Edge Stiffener [$c_{s,1,nom}$]	→	Class 1
Inferior Flange [$b_{s,1,nom}$]	→	Class 1
Web [$h_{s,nom}$]	→	Class 3
Superior Flange [$b_{s,2,nom}$]	→	Class 1
Superior Edge Stiffener [$c_{s,2,nom}$]	→	Class 1
C-Section Classification		**Class 3**

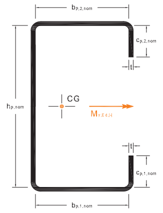
C-Section subjected to Positive Moment in y-y axis [$M_{y,Ed}^{+}$]



Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Tension
Inferior Flange [$b_{p,1,nom}$]	→	Tension
Web [$h_{p,nom}$]	→	Class 1
Superior Flange [$b_{p,2,nom}$]	→	Class 1
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Class 1

C-Section Classification	Class 1

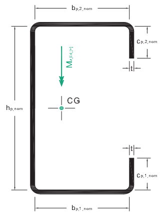
C-Section subjected to Negative Moment in y-y axis [$M_{y,Ed}^{-}$]



Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Class 1
Inferior Flange [$b_{p,1,nom}$]	→	Class 1
Web [$h_{p,nom}$]	→	Class 1
Superior Flange [$b_{p,2,nom}$]	→	Tension
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Tension

C-Section Classification	Class 1

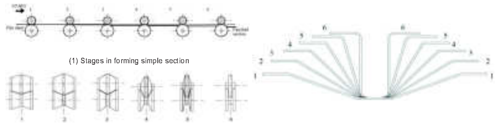
C-Section subjected to Positive Moment in z-z axis [$M_{z,Ed}^{+}$]



Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Tension
Inferior Flange [$b_{p,1,nom}$]	→	Class 1
Web [$h_{p,nom}$]	→	Class 3
Superior Flange [$b_{p,2,nom}$]	→	Class 1
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Tension

C-Section Classification	Class 3

[10] Photovoltaic Structure : Cold-Formed Manufacturing Process — [BS EN 1993-1-3:2006]

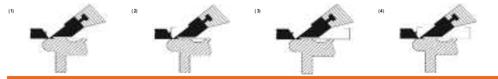


(1) Stages in forming simple section

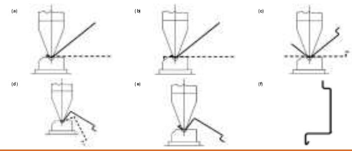
(2) Roller shapes at each stage

(3) Profile at each stage

Stages in roll forming a simple section [Rhodes, 1991]



Forming of folding



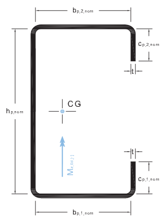
Forming steps in press braking process

Ω-Section Purlin, Manufacturing Process	Roll Forming →	k	7.00
C-Section Beam, Manufacturing Process	Roll Forming →	k	7.00
C-Section Column, Manufacturing Process	Roll Forming →	k	7.00
C-Section Strut, Manufacturing Process	Roll Forming →	k	7.00

Influence of manufacturing process on hot and cold-formed profiles

Forming method		Hot rolling	Cold forming	
			Cold rolling	Press Braking
Yield strength	Corner	----	High	High
	Flange	----	Moderate	----
Ultimate strength	Corner	---	High	High
	Flange	---	Moderate	---

C-Section subjected to Negative Moment in z-z axis [$M_{z,Ed}^{-}$]



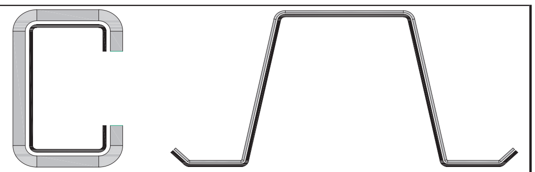
Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Class 1
Inferior Flange [$b_{p,1,nom}$]	→	Class 1
Web [$h_{p,nom}$]	→	Tension
Superior Flange [$b_{p,2,nom}$]	→	Class 1
Superior Edge Stiffener [$c_{p,2,nom}$]	→	Class 1

C-Section Classification	Class 1

NOTE Manufacturing process leads to a modification of the stress-strain curve of the steel virgin material.

The average yield strength f_{ya} may be utilised in determining:

- Cross-section resistance of an axially loaded tension number
- Cross-section resistance / Buckling resistance of axially loaded compression member with fully effective cross-section
- Moment resistance of a cross-section with fully effective flanges



Average Yield Strength [f_{ya}]

[a] Ω-Section Purlin

$$f_{ya} = f_{yb} + (f_u - f_{yb})\frac{knt^2}{A_g}$$

$$f_{ya} \le \frac{(f_u + f_{yb})}{2}$$

Parameters		
A_g	191.199	[mm^2]
k	7.000	
$r_{max} \le 5.t$	OK	
n	4.484	[un.]
t	0.952	[mm]

Cold-Formed Material Properties			
S 350 GD + Z	f_{yb}	350.000	[MPa]
	f_u	420.000	[MPa]

f_{ya}	360.415	[MPa]	OK

[b] C-Section Beam

$$f_{ya} = f_{yb} + (f_u - f_{yb})\frac{knt^2}{A_g}$$

$$f_{ya} \le \frac{(f_u + f_{yb})}{2}$$

Parameters		
A_g	345.063	[mm^2]
k	7.000	
$r_{max} \le 5.t$	OK	
n	4.000	[un.]
t	1.452	[mm]

Cold-Formed Material Properties			
S 350 GD + Z	f_{yb}	350.000	[MPa]
	f_u	420.000	[MPa]

f_{ya}	361.975	[MPa]	OK

[c] C-Section Column

$$f_{ya} = f_{yb} + (f_u - f_{yb})\frac{knt^2}{A_g}$$

$$f_{ya} \leq \frac{(f_u + f_{yb})}{2}$$

Parameters		
A_g	497.235	[mm^2]
k	7.000	
$r_{max} \leq 5.t$	OK	
n	4.000	[un.]
t	2.452	[mm]

Cold-Formed Material Properties			
S 350 GD + Z	f_{yb}	350.000	[MPa]
	f_u	420.000	[MPa]

f_{ya}	373.699	[MPa]	OK

[d] C-Section Strut

$$f_{ya} = f_{yb} + (f_u - f_{yb})\frac{knt^2}{A_g}$$

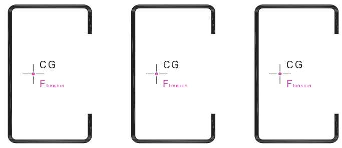
$$f_{ya} \leq \frac{(f_u + f_{yb})}{2}$$

Parameters		
A_g	201.315	[mm^2]
k	7.000	
$r_{max} \leq 5.t$	OK	
n	4.000	[un.]
t	1.452	[mm]

Cold-Formed Material Properties			
S 350 GD + Z	f_{yb}	350.000	[MPa]
	f_u	420.000	[MPa]

f_{ya}	370.526	[MPa]	OK

[c] C-Section Column

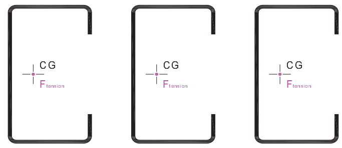


Gross C-Section | Effective C-Section [L] — Local Buckling — EN 1993-1-5 | Effective C-Section [L + D] — Local + Distortional Buckling — EN 1993-1-3

C-Section Column : Mechanical Properties — **C-Section** B 200 * 2.50

Area	$A_g = A_{eff}$	497.235	[mm^2]
Gravity Centre	$y_{GC} = y_{GC,eff}$	16.159	[mm]
	$z_{GC} = z_{GC,eff}$	43.774	[mm]
Second Moment of Area through Gravity Centre	$I_Y = I_{Y,eff}$	625036.020	[mm^4]
	$I_Z = I_{Z,eff}$	153816.866	[mm^4]

[d] C-Section Strut



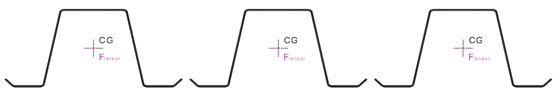
Gross C-Section | Effective C-Section [L] — Local Buckling — EN 1993-1-5 | Effective C-Section [L + D] — Local + Distortional Buckling — EN 1993-1-3

C-Section Strut : Mechanical Properties — **C-Section** B 134 * 1.50

Area	$A_g = A_{eff}$	201.315	[mm^2]
Gravity Centre	$y_{GC} = y_{GC,eff}$	15.104	[mm]
	$z_{GC} = z_{GC,eff}$	24.274	[mm]
Second Moment of Area through Gravity Centre	$I_Y = I_{Y,eff}$	85435.109	[mm^4]
	$I_Z = I_{Z,eff}$	43399.345	[mm^4]

[11.1] Cold-Formed Section subjected to Tension Force

[a] Ω-Section Purlin



Gross Ω-Section | Effective Ω-Section [L] — Local Buckling — EN 1993-1-5 | Effective Ω-Section [L + D] — Local + Distortional Buckling — EN 1993-1-3

Ω-Section Purlin : Mechanical Properties — **Ω-Section** Ω 200 * 1.00

Area	$A_g = A_{eff}$	191.199	[mm^2]
Gravity Centre	$y_{GC} = y_{GC,eff}$	55.667	[mm]
	$z_{GC} = z_{GC,eff}$	25.652	[mm]
Second Moment of Area through Gravity Centre	$I_Y = I_{Y,eff}$	85759.975	[mm^4]
	$I_Z = I_{Z,eff}$	176909.935	[mm^4]

[b] C-Section Beam

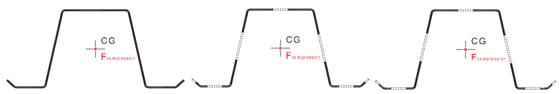
Gross C-Section | Effective C-Section [L] — Local Buckling — EN 1993-1-5 | Effective C-Section [L + D] — Local + Distortional Buckling — EN 1993-1-3

C-Section Beam : Mechanical Properties — **C-Section** B 230 * 1.50

Area	$A_g = A_{eff}$	345.063	[mm^2]
Gravity Centre	$y_{GC} = y_{GC,eff}$	14.563	[mm]
	$z_{GC} = z_{GC,eff}$	59.274	[mm]
Second Moment of Area through Gravity Centre	$I_Y = I_{Y,eff}$	762290.565	[mm^4]
	$I_Z = I_{Z,eff}$	108754.009	[mm^4]

[11.2] Cold-Formed Section subjected to Compression Force

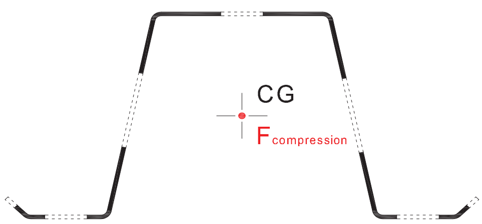
[a] Ω-Section Purlin



Gross Ω-Section | Effective Ω-Section [L] — Local Buckling — EN 1993-1-5 | Effective Ω-Section [L + D] — Local + Distortional Buckling — EN 1993-1-3

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

Ω-Section Classification | **Class 4** → Effective width must be calculated



Effective Ω-Section [Worst Case] [Class 4]

Right Edge Stiffner [$c_{p,Nom,Right\ Lip}$] → Class 1

OPTION [2] Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

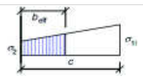
Ω-Section Purlin Nominal Dimension		
$c_{p,Nom,Right\ Lip}$	7.010	mm
$b_{p,Nom,Inf.\ Right\ Flange}$	18.975	mm

ε	0.819	
t	0.952	mm

For a single edge stiffener, Equation (5.13c)

$b_{p,c} / b_p$	0.369	→	k_σ	0.560

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ (2) $\bar{\lambda}_d$ 0.423 → $\rho_{OPTION\,(2)}$ 1.000

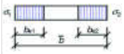
Stress distribution [Compressive positive]	Effective^p width b_{eff}	
	1.000 > ψ ≥ 0.000	$b_{eff} = \rho * c$

Ω-Section	Class 1	$c_{p,Right\,Lip,eff} = \rho * c$	7.010	[mm]

Inferior Right Flange [$b_{p,Nom,Inf.\,Right\,Flange}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension			ε	0.819	
$b_{p,Nom,Inf.\,Right\,Flange}$	18.975	mm	t	0.952	mm



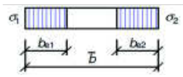
Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Internal Compression Elements [EN 1993-1-5, Table 4.1]

ψ = σ₂ / σ₁ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.428 → ρ 1.000

$\bar{\lambda}_p$	0.428	ρ	1.000	Effective width equal to gross width	
		[EN 1993-1-5, Equation (4.2)]	[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive]	Effective^p width b_{eff}		
	ψ = 1.000	$b_{eff} = \rho * b^{¨}$	$b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

ρ ≤ 1.000	OK	Ω-Section	Class 1	$b_{p,Inf.\,Right\,Flange,eff} = \rho * b^{¨}$	18.975	[mm]

$b_{p,Inf.\,Right\,Flange,eff,1}$	9.488	[mm]	$b_{p,Inf.\,Right\,Flange,eff,2}$	9.488	[mm]

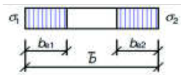
Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode References: EN 1990 | EN 1991 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

Internal Compression Elements [EN 1993-1-5, Table 4.1]

ψ = σ₂ / σ₁ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.934 → ρ 0.818

$\bar{\lambda}_p$	0.934	ρ	0.818	Gross width will be reduced	
		[EN 1993-1-5, Equation (4.2)]	[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive]	Effective^p width b_{eff}		
	ψ = 1.000	$b_{eff} = \rho * b^{¨}$	$b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

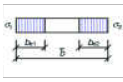
ρ ≤ 1.000	OK	Ω-Section	Class 4	$b_{p,Sup.\,Flange,eff} = \rho * b^{¨}$	33.874	[mm]

$b_{p,Sup.\,Flange,eff,1}$	16.937	[mm]	$b_{p,Sup.\,Flange,eff,2}$	16.937	[mm]

Left Web [$h_{p,Nom,Left\,Web}$] → Class 4

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension			ε	0.819	
$h_{p,Nom,Left\,Web}$	54.863	mm	t	0.952	mm



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Internal Compression Elements [EN 1993-1-5, Table 4.1]

ψ = σ₂ / σ₁ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 1.238 → ρ 0.664

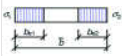
$\bar{\lambda}_p$	1.238	ρ	0.664	Gross width will be reduced	
		[EN 1993-1-5, Equation (4.2)]	[3 + ψ] ≥ 0	→	OK

Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode References: EN 1990 | EN 1991 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

Right Web [$h_{p,Nom,Right\,Web}$] → Class 4

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension			ε	0.819	
$h_{p,Nom,Right\,Web}$	54.863	mm	t	0.952	mm



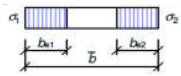
Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Internal Compression Elements [EN 1993-1-5, Table 4.1]

ψ = σ₂ / σ₁ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 1.238 → ρ 0.664

$\bar{\lambda}_p$	1.238	ρ	0.664	Gross width will be reduced	
		[EN 1993-1-5, Equation (4.2)]	[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive]	Effective^p width b_{eff}		
	ψ = 1.000	$b_{eff} = \rho * b^{¨}$	$b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

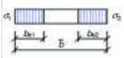
ρ ≤ 1.000	OK	Ω-Section	Class 4	$h_{p,Right\,Web,eff} = \rho * b^{¨}$	36.436	[mm]

$h_{p,Right\,Web,eff,1}$	18.218	[mm]	$h_{p,Right\,Web,eff,2}$	18.218	[mm]

Superior Flange [$b_{p,Nom,Sup.\,Flange}$] → Class 4

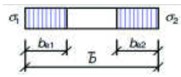
Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension			ε	0.819	
$b_{p,Nom,Sup.\,Flange}$	41.393	mm	t	0.952	mm



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode References: EN 1990 | EN 1991 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

Stress distribution [Compressive positive]	Effective^p width b_{eff}		
	ψ = 1.000	$b_{eff} = \rho * b^{¨}$	$b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

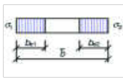
ρ ≤ 1.000	OK	Ω-Section	Class 4	$h_{p,Left\,Web,eff} = \rho * b^{¨}$	36.436	[mm]

$h_{p,Left\,Web,eff,1}$	18.218	[mm]	$h_{p,Left\,Web,eff,2}$	18.218	[mm]

Inferior Left Flange [$b_{p,Nom,Inf.\,Left\,Flange}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension			ε	0.819	
$b_{p,Nom,Inf.\,Left\,Flange}$	18.975	mm	t	0.952	mm



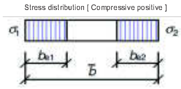
Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Internal Compression Elements [EN 1993-1-5, Table 4.1]

ψ = σ₂ / σ₁ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.428 → ρ 1.000

$\bar{\lambda}_p$	0.428	ρ	1.000	Effective width equal to gross width	
		[EN 1993-1-5, Equation (4.2)]	[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive]	Effective^p width b_{eff}		
	ψ = 1.000	$b_{eff} = \rho * b^{¨}$	$b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

ρ ≤ 1.000	OK	Ω-Section	Class 1	$b_{p,Inf.\,Left\,Flange,eff} = \rho * b^{¨}$	18.975	[mm]

$b_{p,Inf.\,Left\,Flange,eff,1}$	9.488	[mm]	$b_{p,Inf.\,Left\,Flange,eff,2}$	9.488	[mm]

Left Edge Stiffener [$c_{p,Nom,Left\ Lip}$] → Class 1

OPTION [2] Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

Ω-Section Purlin Nominal Dimension		
$c_{p,Nom,Left\ Lip}$	7.010	mm
$b_{p,Nom,Inf.\ Left\ Flange}$	18.975	mm

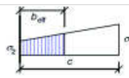
ε	0.819	
t	0.952	mm

For a single edge stiffener, Equation (5.13c)

$b_{p,c}$ / b_p	0.369	→	k_σ	0.560

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$ (2)

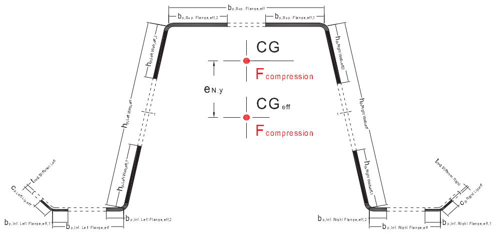
$\bar{\lambda}_d$ 0.423 → $\rho_{OPTION\ (2)}$ 1.000

Stress distribution [Compressive positive]	Effective[P] width b_{eff}	
	1.000 > ψ ≥ 0.000	$b_{eff} = \rho * c$

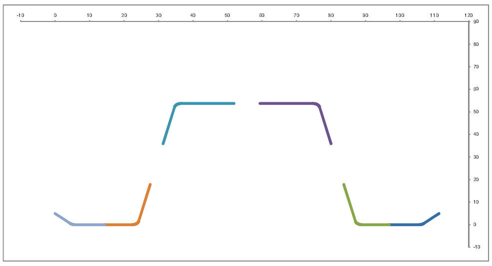
Ω-Section	Class 1	$c_{p,Left\ Lip,eff} = \rho * c$	7.010	[mm]

[ii] **Effective Ω-Section Purlin [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

Effective Ω-Section Purlin Widths			
Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	7.010	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff}$	18.975	[mm]
Right Web	$h_{p,Right\ Web,eff}$	36.436	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff}$	33.874	[mm]
Left Web	$h_{p,Left\ Web,eff}$	36.436	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff}$	18.975	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	7.010	[mm]

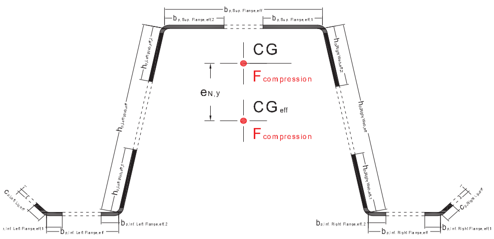


Effective Ω-Section Purlin with Reduced Thickness [L + D] [Compression Force]



Effective Ω-Section Purlin with Reduced Thickness [L + D] [Compression Force]

A_{eff}	148.955	[mm^2]
$e_{N,y} = z_{GC,eff} - z_{GC}$	-1.637	[mm]
$e_{N,z} = y_{GC,eff} - y_{GC}$	0.000	[mm]



Effective Ω-Section Purlin [Compression Force]

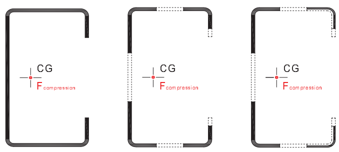
[iii] **Plane elements with edge stiffeners [Distortional Buckling]** **[EN 1993-1-3:2006, 5.5.1(5)]**

NOTE Distortional buckling effects were not considered for this type of structure

[iv] **Effective Cross Ω-Section Purlin with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

Effective Ω-Section Purlin Widths			
Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	7.010	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff,1}$	9.488	[mm]
	$b_{p,Inf.\ Right\ Flange,eff,2}$	9.488	[mm]
Right Web	$h_{p,Right\ Web,eff,1}$	18.218	[mm]
	$h_{p,Right\ Web,eff,2}$	18.218	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff,1}$	16.937	[mm]
	$b_{p,Sup.\ Flange,eff,2}$	16.937	[mm]
Left Web	$h_{p,Left\ Web,eff,1}$	18.218	[mm]
	$h_{p,Left\ Web,eff,2}$	18.218	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff,1}$	9.488	[mm]
	$b_{p,Inf.\ Left\ Flange,eff,2}$	9.488	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	7.010	[mm]

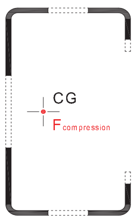
[b] C-Section Beam



Gross C-Section	Effective C-Section [L]	Effective C-Section [L + D]
	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

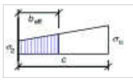
C-Section Classification | **Class 4** → Effective width must be calculated



Effective C-Section [Worst Case] [Class 4]

Inferior Edge Stiffener [$c_{p,1,nom}$] → Class 4

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

$\psi = \sigma_2 / \sigma_1$	→	ψ	1.000
σ_1 Free Point	→	k_σ	0.430

C-Section Beam Nominal Dimension		
$b_{p,1,nom}$	45.048	mm
$c_{p,1,nom}$	17.274	mm

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

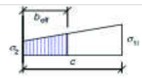
For a single edge stiffener, Equation (5.13c)

$b_{p,c}$ / b_p	0.383	→	k_σ	0.586

ε	0.819	t	1.452	mm

(1)	$\bar{\lambda}_p$	0.780	→	$\rho_{OPTION (1)}$	0.973
(2)	$\bar{\lambda}_d$	0.668	→	$\rho_{OPTION (2)}$	1.000

[EN 1993-1-5, Equation (4.3)] $\rho \le 1.000$ → OK

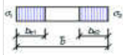
Stress distribution [Compressive positive]	Effective[ρ] width b_{eff}	
	$1.000 > \psi \ge 0.000$	$b_{eff} = \rho * c$

C-Section	Class 4	$c_{p,1,eff} = \rho * c$	17.274	[mm]

Inferior Flange [$b_{p,1,nom}$] → Class 2

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension			ε	0.819	
$b_{p,1,nom}$	45.048	mm	t	1.452	mm



Compression Stress

σ_1	350.000	MPa
σ_2	350.000	MPa

Tension Stress

Internal Compression Elements [EN 1993-1-5, Table 4.1]

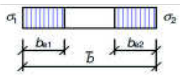
$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$

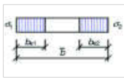
$\bar{\lambda}_p$ 0.667 → ρ 1.000

$\bar{\lambda}_p$ 0.667

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] $[3 + \psi] \ge 0$ → OK

Stress distribution [Compressive positive]	Effective[ρ] width b_{eff}		
	$\psi = 1.000$	$b_{eff} = \rho * b^{¨}$	$b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

$\rho \le 1.000$	OK	C-Section	Class 2	$b_{p,1,eff} = \rho * b^{¨}$	45.048	[mm]



Compression Stress

σ_1	350.000	MPa
σ_2	350.000	MPa

Tension Stress

Internal Compression Elements [EN 1993-1-5, Table 4.1]

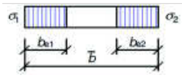
$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.667 → ρ 1.000

$\bar{\lambda}_p$ 0.667

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] $[3 + \psi] \ge 0$ → OK

Stress distribution [Compressive positive]	Effective[ρ] width b_{eff}		
	$\psi = 1.000$	$b_{eff} = \rho * b^{¨}$	$b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

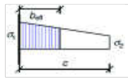
$\rho \le 1.000$	OK	C-Section	Class 2	$b_{p,2,eff} = \rho * b^{¨}$	45.048	[mm]

$b_{p,2,eff,1}$	22.524	[mm]	$b_{p,2,eff,2}$	22.524	[mm]

Superior Edge Stiffener [$c_{p,2,nom}$] → Class 4

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension			ε	0.819	
$b_{p,2,nom}$	45.048	mm	t	1.452	mm
$c_{p,2,nom}$	17.274	mm			



Compression Stress

σ_1	350.000	MPa
σ_2	350.000	MPa

Tension Stress

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

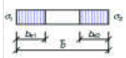
$\psi = \sigma_2 / \sigma_1$		→	ψ	1.000
σ_1	Free Point	→	k_σ	0.430

$b_{p,1,eff,1}$	22.524	[mm]	$b_{p,1,eff,2}$	22.524	[mm]

Web [$h_{p,nom}$] → Class 4

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension			ε	0.819	
$h_{p,nom}$	118.548	mm	t	1.452	mm



Compression Stress

σ_1	350.000	MPa
σ_2	350.000	MPa

Tension Stress

Internal Compression Elements [EN 1993-1-5, Table 4.1]

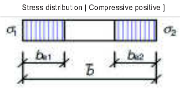
$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 1.754 → ρ 0.499

$\bar{\lambda}_p$ 1.754

ρ 0.499 Gross width will be reduced
[EN 1993-1-5, Equation (4.2)] $[3 + \psi] \ge 0$ → OK

Stress distribution [Compressive positive]	Effective[ρ] width b_{eff}		
	$\psi = 1.000$	$b_{eff} = \rho * b^{¨}$	$b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

$\rho \le 1.000$	OK	C-Section	Class 4	$h_{p,eff} = \rho * b^{¨}$	59.104	[mm]

$h_{p,eff,1}$	29.552	[mm]	$h_{p,eff,2}$	29.552	[mm]

Superior Flange [$b_{p,2,nom}$] → Class 2

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension			ε	0.819	
$b_{p,2,nom}$	45.048	mm	t	1.452	mm

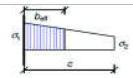
OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$

For a single edge stiffener, Equation (5.13c)

	$b_{p,c} / b_p$	0.383	→	k_σ	0.586
(1)	$\bar{\lambda}_p$	0.780	→	$\rho_{OPTION (1)}$	0.973
(2)	$\bar{\lambda}_d$	0.668	→	$\rho_{OPTION (2)}$	1.000

[EN 1993-1-5, Equation (4.3)] $\rho \le 1.000$ → OK

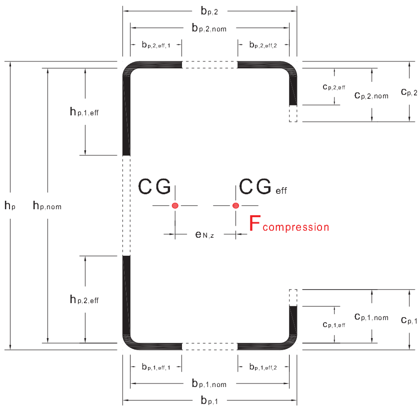
Stress distribution [Compressive positive]	Effective[ρ] width b_{eff}	
	$1.000 > \psi \ge 0.000$	$b_{eff} = \rho * c$

C-Section	Class 4	$c_{p,2,eff} = \rho * c$	17.274	[mm]

[ii] **Effective C-Section Beam [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

Effective C-Section Beam Widths

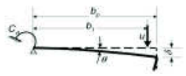
Inferior Edge Stiffener	$c_{p,1,eff}$	17.274	[mm]
Inferior Flange	$b_{p,1,eff}$	45.048	[mm]
Web	$h_{p,eff}$	59.104	[mm]
Superior Flange	$b_{p,2,eff}$	45.048	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	17.274	[mm]



Effective C-Section Beam [Compression Force]

[iii] **Plane elements with edge stiffeners [Distortional Buckling]** **[EN 1993-1-3:2006, 5.5.1(5)]**

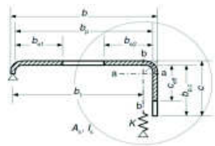
- **Plane elements with edge stiffeners** **[EN 1993-1-3:2006, 5.5.3.2]**



[a] Actual system

→

[b] Equivalent system



Single Edge Stiffener [EN 1993-1-3, Figure 5.7]

[EN 1993-1-3, 5.5.3.2(1)]	
b / t ≤ 60	OK
45º ≤ Ø	OK
Ø ≤ 135	OK

[EN 1993-1-3, 5.5.3.2(6)]

Round corners were considered in the effective cross-section area of the edge stiffener, A_s

- **Determination of Elastic Critical Buckling Stress [$\sigma_{cr,s}$]** **[EN 1993-1-3:2006, 5.5.3.2(7)]**

$$\sigma_{cr,s} = \frac{2\sqrt{K E I_s}}{A_s}$$

[EN 1993-1-3, Equation 5.15]

K	0.533	
E	210.000	[GPa]
$I_{s,Stiffener,1}$	1926.805	[mm^4]
$I_{s,Stiffener,2}$	1926.805	[mm^4]
$A_{s,1}$	58.518	[mm^2]
$A_{s,2}$	58.518	[mm^2]

Elastic Critical Buckling Stress, $\sigma_{cr,s}$, for edge stiffener 1	501.692	[MPa]
Elastic Critical Buckling Stress, $\sigma_{cr,s}$, for edge stiffener 2	501.692	[MPa]

- **Relative Distortional Slenderness [$\bar{\lambda}_d$]** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

$$\bar{\lambda}_d = \sqrt{f_{yb}/\sigma_{cr,s}}$$

[EN 1993-1-3, Equation 5.12d]

f_{yb}	350.000	[MPa]
Edge Stiffener 1	$\bar{\lambda}_d$	0.835
Edge Stiffener 2	$\bar{\lambda}_d$	0.835

- **Reduction X_d Distortional Buckling Resistance [Stiffener Flexural Buckling]** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

Edge Stiffener 1	$\bar{\lambda}_d$	0.835	$X_{d,Stiffener,1}$	0.866	[EN 1993-1-3, Equation 5.12b]
Edge Stiffener 2	$\bar{\lambda}_d$	0.835	$X_{d,Stiffener,2}$	0.866	[EN 1993-1-3, Equation 5.12b]

- **Edge Stiffener Reduced Thickness** **[EN 1993-1-3:2006, 5.5.3.2(12)]**

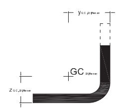
In effective section properties, reduced effective area is represented using a reduced thickness for all elements in A_s

Edge Stiffener 1			**Edge Stiffener 2**		
$t_{red,Stiffener,1}$	1.258	[mm]	$t_{red,Stiffener,2}$	1.258	[mm]

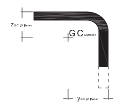
[iv] **Effective C-Section Beam with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

Effective C-Section Beam Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	17.274	[mm]
Inferior Flange	$b_{p,1,eff,1}$	22.524	[mm]
	$b_{p,1,eff,2}$	22.524	[mm]
Web	$h_{p,eff,1}$	29.552	[mm]
	$h_{p,eff,2}$	29.552	[mm]
Superior Flange	$b_{p,2,eff,1}$	22.524	[mm]
	$b_{p,2,eff,2}$	22.524	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	17.274	[mm]

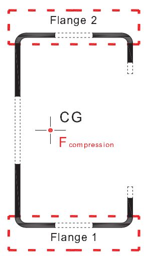
- **Determination of Spring Stiffness [K]** **[EN 1993-1-3:2006, 5.5.3.2(5)]**

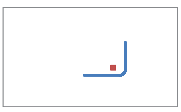


Inferior Edge Stiffener [Flange 1]



Superior Edge Stiffener [Flange 2]

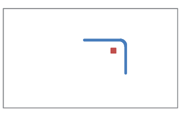




$A_{s,1}$	58.518	[mm^2]
b_1	38.922	[mm]
$y_{GC,Stiffener}$	7.578	[mm]
$z_{GC,Stiffener}$	4.862	[mm]

Inferior Edge Stiffener [Flange 1]

Compression



$A_{s,2}$	58.518	[mm^2]
b_2	38.922	[mm]
$y_{GC,Stiffener}$	7.578	[mm]
$z_{GC,Stiffener}$	4.862	[mm]

Superior Edge Stiffener [Flange 2]

Compression

$$K_1 = \frac{E t^3}{4(1-\nu^2)} \cdot \frac{1}{b_1^2 h_w + b_1^3 + 0.5 b_1 b_2 h_w k_f}$$

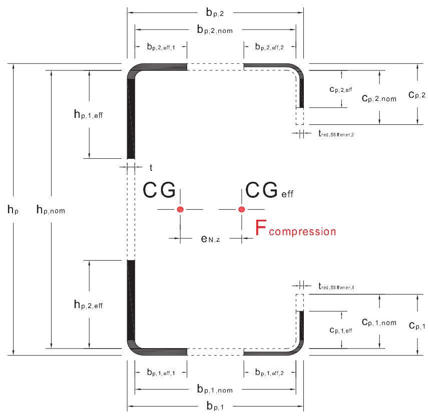
[EN 1993-1-3, Equation 5.10b]

$k_f = 0$	Flange 2 in Tension
$k_f = \frac{A_{s2}}{A_{s1}}$	Flange 2 in Compression

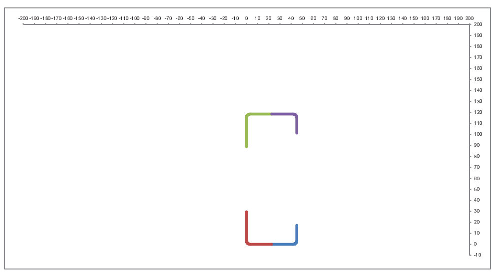
E	210.000	[GPa]
v	0.300	
$h_w = h$	120.000	[mm]
K_f	1.000	

t	1.452	[mm]
b_1	38.922	[mm]
b_2	38.922	[mm]

K	0.533	[EN 1993-1-3, Equation 5.10b]



Effective C-Section Beam with Reduced Thickness [L + D] [Compression Force]

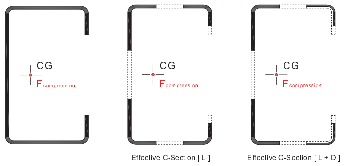


Effective C-Section Beam with Reduced Thickness [L + D] [Compression Force]

A_{eff}	243.816	[mm^2]

$e_{N,y} = z_{GC,eff} - z_{GC}$	0.000	[mm]
$e_{N,z} = y_{GC,eff} - y_{GC}$	3.694	[mm]

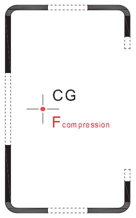
[c] C-Section Column



Gross C-Section	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

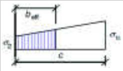
C-Section Classification | **Class 4** → Effective width must be calculated



Effective C-Section [Worst Case] [Class 4]

Inferior Edge Stiffener [$c_{p,1,nom}$] → Class 1

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

$\psi = \sigma_2 / \sigma_1$	→	ψ	1.000
σ_1 Free Point	→	k_σ	0.430

C-Section Column Nominal Dimension		
$b_{p,1,nom}$	44.048	mm
$c_{p,1,nom}$	16.774	mm

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

For a single edge stiffener, Equation (5.13c)

$b_{p,c} / b_p$	0.381	→	k_σ	0.582

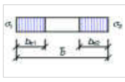
ε	0.819		t	2.452	mm

$b_{p,1,eff,1}$	22.024	[mm]	$b_{p,1,eff,2}$	22.024	[mm]

Web [$h_{p,nom}$] → Class 4

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Column Nominal Dimension					
$h_{p,nom}$	87.548	mm	ε	0.819	
			t	2.452	mm



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$	→	ψ	1.000	→	k_σ	4.000

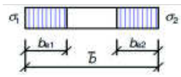
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$	0.767	→	ρ	0.930

$\bar{\lambda}_p$ 0.767

ρ	0.930	Gross width will be reduced		
[EN 1993-1-5, Equation (4.2)]		[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive] | Effective[p] width b_{eff}



ψ = 1.000 $b_{eff} = \rho * b^{¨}$

$b_{eff,1} = 0.500 * b_{eff}$

$b_{eff,2} = 0.500 * b_{eff}$

ρ ≤ 1.000	OK	C-Section	Class 4	$h_{p,eff} = \rho * b^{¨}$	81.394	[mm]

$h_{p,eff,1}$	40.697	[mm]	$h_{p,eff,2}$	40.697	[mm]

Superior Flange [$b_{p,2,nom}$] → Class 1

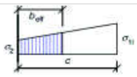
Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Column Nominal Dimension					
$b_{p,2,nom}$	44.048	mm	ε	0.819	
			t	2.452	mm

(1)	$\bar{\lambda}_p$	0.448	→	$\rho_{OPTION (1)}$	1.000
(2)	$\bar{\lambda}_d$	0.385	→	$\rho_{OPTION (2)}$	1.000

[EN 1993-1-5, Equation (4.3)]	ρ ≤ 1.000	→	OK

Stress distribution [Compressive positive] | Effective[p] width b_{eff}



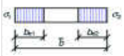
1.000 > ψ ≥ 0.000 $b_{eff} = \rho * c$

C-Section	Class 1	$c_{p,1,eff} = \rho * c$	16.774	[mm]

Inferior Flange [$b_{p,1,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Column Nominal Dimension					
$b_{p,1,nom}$	44.048	mm	ε	0.819	
			t	2.452	mm



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$	→	ψ	1.000	→	k_σ	4.000

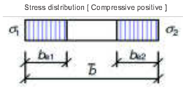
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$	0.386	→	ρ	1.000

$\bar{\lambda}_p$ 0.386

ρ	1.000	Effective width equal to gross width		
[EN 1993-1-5, Equation (4.2)]		[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive] | Effective[p] width b_{eff}

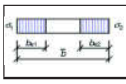


ψ = 1.000 $b_{eff} = \rho * b^{¨}$

$b_{eff,1} = 0.500 * b_{eff}$

$b_{eff,2} = 0.500 * b_{eff}$

ρ ≤ 1.000	OK	C-Section	Class 1	$b_{p,1,eff} = \rho * b^{¨}$	44.048	[mm]



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$	→	ψ	1.000	→	k_σ	4.000

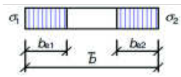
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$	0.386	→	ρ	1.000

$\bar{\lambda}_p$ 0.386

ρ	1.000	Effective width equal to gross width		
[EN 1993-1-5, Equation (4.2)]		[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive] | Effective[p] width b_{eff}



ψ = 1.000 $b_{eff} = \rho * b^{¨}$

$b_{eff,1} = 0.500 * b_{eff}$

$b_{eff,2} = 0.500 * b_{eff}$

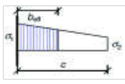
ρ ≤ 1.000	OK	C-Section	Class 1	$b_{p,2,eff} = \rho * b^{¨}$	44.048	[mm]

$b_{p,2,eff,1}$	22.024	[mm]	$b_{p,2,eff,2}$	22.024	[mm]

Superior Edge Stiffener [$c_{p,2,nom}$] → Class 1

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Column Nominal Dimension					
$b_{p,2,nom}$	44.048	mm	ε	0.819	
$c_{p,2,nom}$	16.774	mm	t	2.452	mm



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

$\psi = \sigma_2 / \sigma_1$	→	ψ	1.000
σ_1 Free Point	→	k_σ	0.430

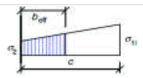
OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$

For a single edge stiffener, Equation (5.13c)

	$b_{p,c} / b_p$	0.381	→	k_σ	0.582
(1)	$\bar{\lambda}_p$	0.448	→	$\rho_{OPTION (1)}$	1.000
(2)	$\bar{\lambda}_p$	0.385	→	$\rho_{OPTION (2)}$	1.000

[EN 1993-1-5, Equation (4.3)]	$\rho \le 1.000$	→	OK

Stress distribution [Compressive positive]		Effective^p width b_{eff}
	$1.000 > \psi \ge 0.000$	$b_{eff} = \rho * c$

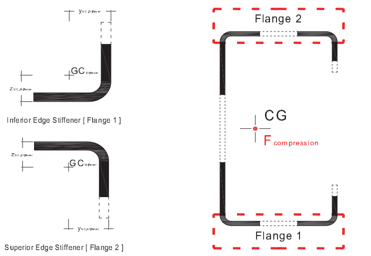
C-Section	Class 1	$c_{p,2,eff} = \rho * c$	16.774	[mm]

[ii] **Effective C-Section Column [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	16.774	[mm]
Inferior Flange	$b_{p,1,eff}$	44.048	[mm]
Web	$h_{p,eff}$	81.394	[mm]
Superior Flange	$b_{p,2,eff}$	44.048	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	16.774	[mm]

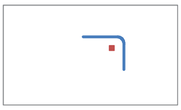
Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode | References: EN 1990 | EN 1991 | EN 1993
Version: 1.000
Office: ---- | Author: JOSÉ ANTÓNIO
Date: 05/09/2019 | Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

- **Determination of Spring Stiffness [K]** **[EN 1993-1-3:2006, 5.5.3.2(5)]**



$A_{s,1}$	96.559	[mm^2]
b_1	38.465	[mm]
$y_{GC,Stiffener}$	8.035	[mm]
$z_{GC,Stiffener}$	5.304	[mm]

Inferior Edge Stiffener [Flange 1] — Compression



$A_{s,2}$	96.559	[mm^2]
b_2	38.465	[mm]
$y_{GC,Stiffener}$	8.035	[mm]
$z_{GC,Stiffener}$	5.304	[mm]

Superior Edge Stiffener [Flange 2] — Compression

$$K_1 = \frac{E t^3}{4(1-\nu^2)} \cdot \frac{1}{b_1^2 h_w + b_1^3 + 0.5 b_1 b_2 h_w k_f}$$

[EN 1993-1-3, Equation 5.10b]

$k_f = 0$ — Flange 2 in Tension

$k_f = \frac{A_{s2}}{A_{s1}}$ — Flange 2 in Compression

E	210.000	[GPa]	t	2.452	[mm]
v	0.300		b_1	38.465	[mm]
$h_w = h$	90.000	[mm]	b_2	38.465	[mm]
K_f	1.000				

K	3.314	[EN 1993-1-3, Equation 5.10b]

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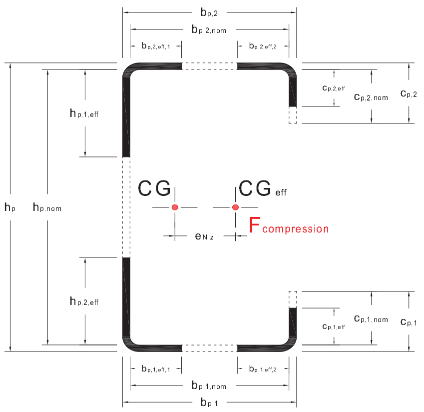
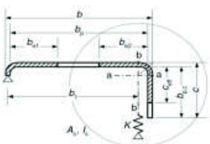


Effective C-Section Column [Compression Force]

[iii] **Plane elements with edge stiffeners [Distortional Buckling]** **[EN 1993-1-3:2006, 5.5.1(5)]**

- **Plane elements with edge stiffeners** **[EN 1993-1-3:2006, 5.5.3.2]**

[a] Actual system — [b] Equivalent system



Single Edge Stiffener [EN 1993-1-3, Figure 5.7]

[EN 1993-1-3, 5.5.3.2(1)]	
b / t ≤ 60	OK
45º ≤ Ø	OK
Ø ≤ 135	OK

[EN 1993-1-3, 5.5.3.2(6)]

Round corners were considered in the effective cross-section area of the edge stiffener, A_s

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- **Determination of Elastic Critical Buckling Stress [$\sigma_{cr,s}$]** **[EN 1993-1-3:2006, 5.5.3.2(7)]**

$$\sigma_{cr,s} = \frac{2\sqrt{K E I_s}}{A_s}$$

[EN 1993-1-3, Equation 5.15]

K	3.314	
E	210.000	[GPa]
$I_{s,Stiffener,1}$	3057.998	[mm^4]
$I_{s,Stiffener,2}$	3057.998	[mm^4]
$A_{s,1}$	96.559	[mm^2]
$A_{s,2}$	96.559	[mm^2]

Elastic Critical Buckling Stress, $\sigma_{cr,s}$, for edge stiffener 1	955.520	[MPa]
Elastic Critical Buckling Stress, $\sigma_{cr,s}$, for edge stiffener 2	955.520	[MPa]

- **Relative Distortional Slenderness [ ] $\bar{\lambda}_d$** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

$$\bar{\lambda}_d = \sqrt{f_{yb}/\sigma_{cr,s}}$$

[EN 1993-1-3, Equation 5.12d]

f_{yb}	350.000	[MPa]
Edge Stiffener 1	$\bar{\lambda}_d$	0.605
Edge Stiffener 2	$\bar{\lambda}_d$	0.605

- **Reduction X_d Distortional Buckling Resistance [Stiffener Flexural Buckling]** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

Edge Stiffener 1	$\bar{\lambda}_d$	0.605	$X_{d,Stiffener,1}$	1.000	[EN 1993-1-3, Equation 5.12a]
Edge Stiffener 2	$\bar{\lambda}_d$	0.605	$X_{d,Stiffener,2}$	1.000	[EN 1993-1-3, Equation 5.12a]

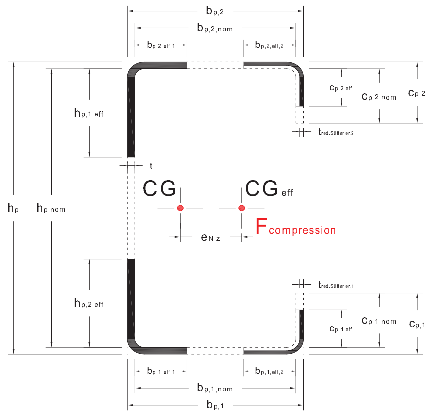
- **Edge Stiffener Reduced Thickness** **[EN 1993-1-3:2006, 5.5.3.2(12)]**

In effective section properties, reduced effective area is represented using a reduced thickness for all elements in A_s

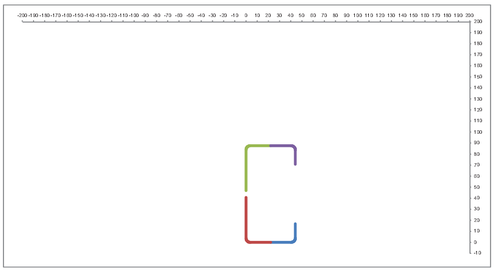
Edge Stiffener 1			Edge Stiffener 2		
$t_{red,Stiffener,1}$	2.452	[mm]	$t_{red,Stiffener,2}$	2.452	[mm]

[iv] **Effective C-Section Column with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	16.774	[mm]
Inferior Flange	$b_{p,1,eff,1}$	22.024	[mm]
	$b_{p,1,eff,2}$	22.024	[mm]
Web	$h_{p,eff,1}$	40.697	[mm]
	$h_{p,eff,2}$	40.697	[mm]
Superior Flange	$b_{p,2,eff,1}$	22.024	[mm]
	$b_{p,2,eff,2}$	22.024	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	16.774	[mm]



Effective C-Section Column with Reduced Thickness [L + D] [Compression Force]



Effective C-Section Column with Reduced Thickness [L + D] [Compression Force]

A_{eff}	482.146	[mm^2]	$e_{N,z} = z_{GC,eff} - z_{GC}$	0.000	[mm]
			$e_{N,y} = y_{GC,eff} - y_{GC}$	0.506	[mm]

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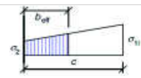
(1) $\bar{\lambda}_p$	0.419	→	$\rho_{OPTION (1)}$	1.000
(2) $\bar{\lambda}_d$	0.388	→	$\rho_{OPTION (2)}$	1.000

[EN 1993-1-5, Equation (4.3)] $\rho \le 1.000$ → OK

Stress distribution [Compressive positive] | Effective^p width b_{eff}



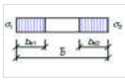
$1.000 > \psi \ge 0.000$ $b_{eff} = \rho \cdot c$

C-Section	Class 1	$c_{p,1,eff} = \rho \cdot c$	9.274	[mm]

Inferior Flange [$b_{p,1,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Strut Nominal Dimension			ε	0.819	
$b_{p,1,nom}$	38.548	mm	t	1.452	mm



Compression Stress
σ_1 350.000 MPa
σ_2 350.000 MPa
Tension Stress

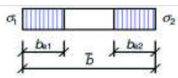
Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.570 → ρ 1.000

$\bar{\lambda}_p$ 0.570 | ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [$3 + \psi$] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective^p width b_{eff}



$\psi = 1.000$ $b_{eff} = \rho \cdot \bar{b}$ $b_{e1} = 0.500 \cdot b_{eff}$ $b_{e2} = 0.500 \cdot b_{eff}$

$\rho \le 1.000$	OK	C-Section	Class 1	$b_{p,1,eff} = \rho \cdot \bar{b}$	38.548	[mm]

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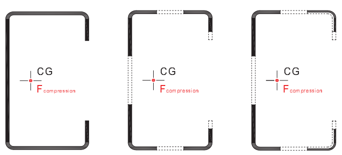
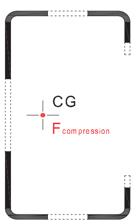
[d] C-Section Strut



Gross C-Section | Effective C-Section [L] | Effective C-Section [L + D]
Local Buckling | Local + Distortional Buckling
EN 1993-1-5 | EN 1993-1-3

[i] Determination of the Effective Width [Local Buckling] [EN 1993-1-3:2006, 5.5]

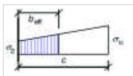
C-Section Classification | Class 3 → Effective width is equal to the actual width



Effective C-Section [Worst Case] [Class 4]

Inferior Edge Stiffener [$c_{p,1,nom}$] → Class 1

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]



Compression Stress
σ_1 350.000 MPa
σ_2 350.000 MPa
Tension Stress

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000
σ_1 Free Point → k_σ 0.430

C-Section Strut Nominal Dimension		
$b_{p,1,nom}$	38.548	mm
$c_{p,1,nom}$	9.274	mm

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

For a single edge stiffener, Equation (5.13b)

$b_{p,c} / b_p$ 0.241 → k_σ 0.500

ε 0.819 | t 1.452 mm

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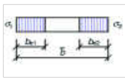
$b_{p,1,eff,1}$	19.274	[mm]	$b_{p,1,eff,2}$	19.274	[mm]

Web [$h_{p,nom}$] → Class 3

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Strut Nominal Dimension			ε	0.819	
$h_{p,nom}$	48.548	mm	t	1.452	mm



Compression Stress
σ_1 350.000 MPa
σ_2 350.000 MPa
Tension Stress

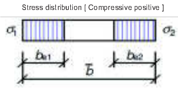
Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.718 → ρ 0.966

$\bar{\lambda}_p$ 0.718 | ρ 0.966 Gross width will be reduced
[EN 1993-1-5, Equation (4.2)] [$3 + \psi$] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective^p width b_{eff}



$\psi = 1.000$ $b_{eff} = \rho \cdot \bar{b}$ $b_{e1} = 0.500 \cdot b_{eff}$ $b_{e2} = 0.500 \cdot b_{eff}$

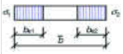
$\rho \le 1.000$	OK	C-Section	Class 3	$h_{p,eff} = \rho \cdot \bar{b}$	46.884	[mm]

$h_{p,eff,1}$	23.442	[mm]	$h_{p,eff,2}$	23.442	[mm]

Superior Flange [$b_{p,2,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Strut Nominal Dimension			ε	0.819	
$b_{p,2,nom}$	38.548	mm	t	1.452	mm



	Compression Stress		
σ_1	350.000	MPa	
σ_2	350.000	MPa	
	Tension Stress		

Internal Compression Elements [EN 1993-1-5, Table 4.1]

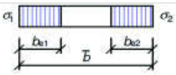
$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.570 → ρ 1.000

$\bar{\lambda}_p$ 0.570

ρ 1.000 — Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive]	Effective[p] width b_{eff}
	ψ = 1.000; $b_{eff} = \rho * b^{..}$; $b_{eff,1} = 0.500 * b_{eff}$; $b_{eff,2} = 0.500 * b_{eff}$

ρ ≤ 1.000	OK	C-Section	Class 1	$b_{p,2,eff} = \rho * b^{..}$	38.548	[mm]

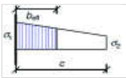
$b_{p,2,eff,1}$	19.274	[mm]	$b_{p,2,eff,2}$	19.274	[mm]

Superior Edge Stiffener [$c_{p,2,nom}$] → Class 1

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Strut Nominal Dimension		
$b_{p,2,nom}$	38.548	mm
$c_{p,2,nom}$	9.274	mm

ε	0.819	
t	1.452	mm



	Compression Stress	
σ_1	350.000	MPa
σ_2	350.000	MPa
	Tension Stress	

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000

σ_1 Free Point → k_σ 0.430

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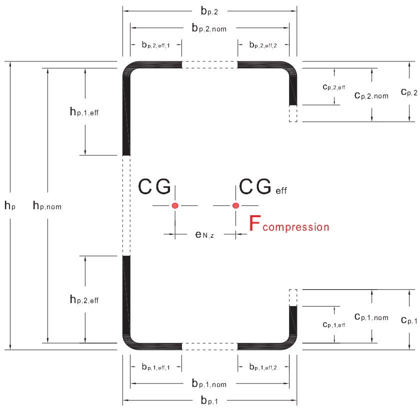
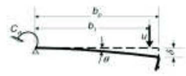


Effective C-Section Strut [Compression Force]

[iii] **Plane elements with edge stiffeners [Distortional Buckling]** **[EN 1993-1-3:2006, 5.5.1(5)]**

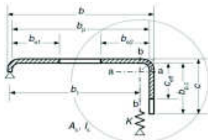
- **Plane elements with edge stiffeners** **[EN 1993-1-3:2006, 5.5.3.2]**



[a] Actual system

→

[b] Equivalent system



Single Edge Stiffener [EN 1993-1-3, Figure 5.7]

[EN 1993-1-3, 5.5.3.2(1)]	
b / t ≤ 60	OK
45° ≤ Ø	OK
Ø ≤ 135	OK

[EN 1993-1-3, 5.5.3.2(6)]

Round corners were considered in the effective cross-section area of the edge stiffener, A_s

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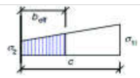
OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

For a single edge stiffener, Equation (5.13b)

$b_{p,c} / b_p$	0.241	→	k_σ	0.500
(1) $\bar{\lambda}_p$	0.419	→	$\rho_{OPTION (1)}$	1.000
(2) $\bar{\lambda}_{p}$	0.388	→	$\rho_{OPTION (2)}$	1.000

[EN 1993-1-5, Equation (4.3)] ρ ≤ 1.000 → OK

Stress distribution [Compressive positive]	Effective[p] width b_{eff}
	1.000 > ψ ≥ 0.000; $b_{eff} = \rho * c$

C-Section	Class 1	$c_{p,2,eff} = \rho * c$	9.274	[mm]

[ii] **Effective C-Section Strut [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

Effective C-Section Strut Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	9.274	[mm]
Inferior Flange	$b_{p,1,eff}$	38.548	[mm]
Web	$h_{p,eff}$	46.884	[mm]
Superior Flange	$b_{p,2,eff}$	38.548	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	9.274	[mm]

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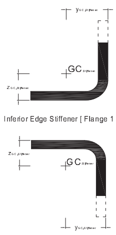
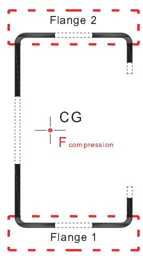
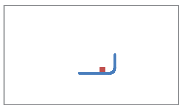
- **Determination of Spring Stiffness [K]** **[EN 1993-1-3:2006, 5.5.3.2(5)]**



Inferior Edge Stiffener [Flange 1]

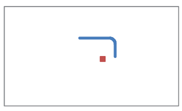
Superior Edge Stiffener [Flange 2]





$A_{s,1}$	42.183	[mm^2]
b_1	32.213	[mm]
$y_{GC,Stiffener}$	7.787	[mm]
$z_{GC,Stiffener}$	2.549	[mm]

Inferior Edge Stiffener [Flange 1] — Compression



$A_{s,2}$	42.183	[mm^2]
b_2	32.213	[mm]
$y_{GC,Stiffener}$	7.787	[mm]
$z_{GC,Stiffener}$	2.549	[mm]

Superior Edge Stiffener [Flange 2] — Compression

$$K_1 = \frac{E t^3}{4(1-\nu^2)} \cdot \frac{1}{b_1^2 h_w + b_1^3 + 0.5 b_1 b_2 h_w k_f}$$

[EN 1993-1-3, Equation 5.10b]

$k_f = 0$ — Flange 2 in Tension

$k_f = \frac{A_{s2}}{A_{s1}}$ — Flange 2 in Compression

E	210.000	[GPa]
v	0.300	
$h_w = h$	50.000	[mm]
K_f	1.000	

t	1.452	[mm]
b_1	32.213	[mm]
b_2	32.213	[mm]

K	1.588	[EN 1993-1-3, Equation 5.10b]

- **Determination of Elastic Critical Buckling Stress [$\sigma_{cr,s}$]** **[EN 1993-1-3:2006, 5.5.3.2(7)]**

$$\sigma_{cr,s} = \frac{2\sqrt{K E I_s}}{A_s}$$

[EN 1993-1-3, Equation 5.15]

K	1.588	
E	210.000	[GPa]
$I_{s,Stiffener,1}$	377.466	[mm^4]
$I_{s,Stiffener,2}$	377.466	[mm^4]
$A_{s,1}$	42.183	[mm^2]
$A_{s,2}$	42.183	[mm^2]

Elastic Critical Buckling Stress, $\sigma_{cr,s}$, for edge stiffener 1	531.868	[MPa]
Elastic Critical Buckling Stress, $\sigma_{cr,s}$, for edge stiffener 2	531.868	[MPa]

- **Relative Distortional Slenderness [$\bar{\lambda}_d$]** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

$$\bar{\lambda}_d = \sqrt{f_{yb}/\sigma_{cr,s}}$$

[EN 1993-1-3, Equation 5.12d]

f_{yb}	350.000	[MPa]
Edge Stiffener 1	$\bar{\lambda}_d$	0.811
Edge Stiffener 2	$\bar{\lambda}_d$	0.811

- **Reduction X_d Distortional Buckling Resistance [Stiffener Flexural Buckling]** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

Edge Stiffener 1	$\bar{\lambda}_d$	0.811	$X_{d,Stiffener,1}$	0.883	[EN 1993-1-3, Equation 5.12b]
Edge Stiffener 2	$\bar{\lambda}_d$	0.811	$X_{d,Stiffener,2}$	0.883	[EN 1993-1-3, Equation 5.12b]

- **Edge Stiffener Reduced Thickness** **[EN 1993-1-3:2006, 5.5.3.2(12)]**

In effective section properties, reduced effective area is represented using a reduced thickness for all elements in A_s

Edge Stiffener 1			Edge Stiffener 2		
$t_{red,Stiffener,1}$	1.283	[mm]	$t_{red,Stiffener,2}$	1.283	[mm]

[iv] **Effective C-Section Strut with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

Effective C-Section Strut Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	9.274	[mm]
Inferior Flange	$b_{p,1,eff,1}$	19.274	[mm]
	$b_{p,1,eff,2}$	19.274	[mm]
Web	$h_{p,eff,1}$	23.442	[mm]
	$h_{p,eff,2}$	23.442	[mm]
Superior Flange	$b_{p,2,eff,1}$	19.274	[mm]
	$b_{p,2,eff,2}$	19.274	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	9.274	[mm]

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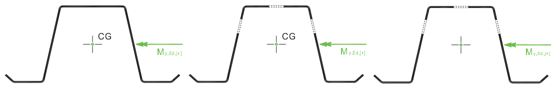
[11.3] Cold-Formed Section subjected to Positive Moment in y-y axis [$M_{y,Ed}^{+}$]

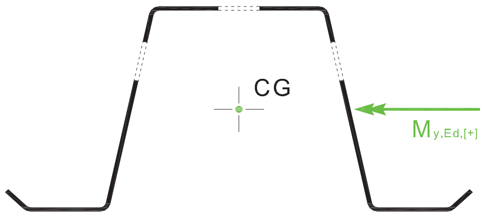
[a] Ω-Section Purlin



Gross Ω-Section	Effective Ω-Section [L]	Effective Ω-Section [L + D]
	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

Ω-Section Classification | **Class 4** → Effective width must be calculated



Effective Ω-Section [Worst Case] [Class 4]

Right Edge Stiffner [$c_{p,Nom,Right\ Lip}$] → Tension

NOTE Effective width is equal to the real width

Inferior Right Flange [$b_{p,Nom,Inf.\ Right\ Flange}$] → Tension

NOTE Effective width is equal to the real width

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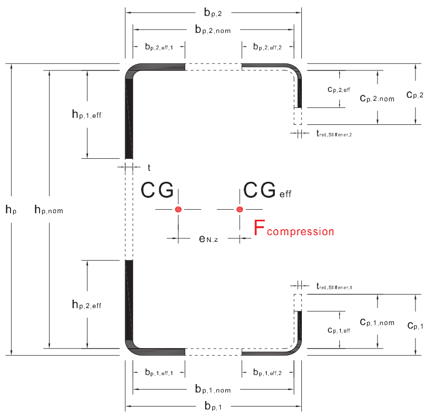
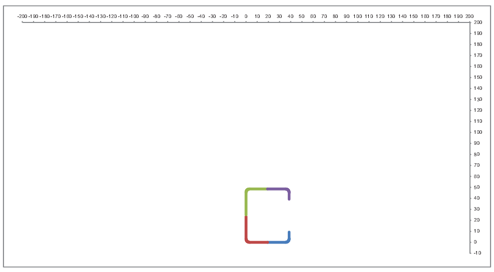


Effective C-Section Strut with Reduced Thickness [L + D] [Compression Force]



Effective C-Section Strut with Reduced Thickness [L + D] [Compression Force]

A_{eff}	189.709	[mm^2]	$e_{N,y} = z_{GC,eff} - z_{GC}$	0.000	[mm]
			$e_{N,z} = y_{GC,eff} - y_{GC}$	-0.611	[mm]

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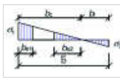
Right Web [$h_{p,Nom,Right\ Web}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension						
$h_{p,Nom,Right\ Web}$	54.863	mm		ε	0.819	
				t	0.952	mm



Compression Stress		
σ_1	350.000	MPa
Tension Stress		
σ_2	-350.000	MPa

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

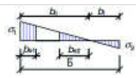
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.507 → ρ 1.000

$\bar{\lambda}_p$ 0.507

ρ 1.000 Effective width equal to gross width

[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive]	Effective$^{\rho}$ width b_{eff}		
	ψ < 0.000	$b_{eff} = \rho * b_c = \rho * [b'' / (1 - \psi)]$	$b_{e,1} = 0.400 * b_{eff}$
		$b_t = b'' - b_c = b'' - [b'' / (1 - \psi)]$	$b_{e,2} = 0.600 * b_{eff}$

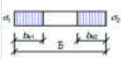
ρ ≤ 1.000	OK	$h_{p,Right\ Web,t} = b'' - b_c = b'' - [b'' / (1 - \psi)]$	27.432	[mm]
ρ ≤ 1.000	OK	$h_{p,Right\ Web,eff} = \rho * b_c = \rho * [b'' / (1 - \psi)]$	27.432	[mm]

$h_{p,Right\ Web,eff,1}$	10.973	[mm]	$h_{p,Right\ Web,eff,2}$	16.459	[mm]

Superior Flange [$b_{p,Nom,Sup.\ Flange}$] → Class 4

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension						
$b_{p,Nom,Sup.\ Flange}$	41.393	mm		ε	0.819	
				t	0.952	mm



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

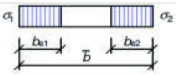
$\bar{\lambda}_p$ 0.934 → ρ 0.818

$\bar{\lambda}_p$ 0.934

ρ 0.818 Gross width will be reduced

[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective^p width b_{eff}



ψ = 1.000 $b_{eff} = \rho * b^{¨}$ $b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

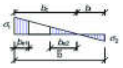
$\rho \le 1.000$	OK	Ω-Section	Class 4	$b_{p,Sup.\,Flange,eff} = \rho * b^{¨}$	33.874	[mm]

$b_{p,Sup.\,Flange,eff,1}$	16.937	[mm]	$b_{p,Sup.\,Flange,eff,2}$	16.937	[mm]

Left Web [$h_{p,Nom,Left\,Web}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension					
$h_{p,Nom,Left\,Web}$	54.863	mm	ε	0.819	
			t	0.952	mm



Compression Stress		
σ_1	350.000	MPa
Tension Stress		
σ_2	-350.000	MPa

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

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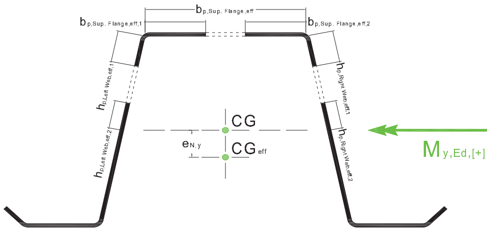

Effective Ω-Section Purlin [Positive Moment in y-y axis, $M_{y,Ed}^{+}$]

[iii] **Plane elements with edge stiffeners [Distortional Buckling]** **[EN 1993-1-3:2006, 5.5.1(5)]**

NOTE Distortional buckling effects were not considered for this type of structure

[iv] **Effective Cross Ω-Section Purlin with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

Effective Ω-Section Purlin Widths

Right Edge Stiffner	$c_{p,Right\,Lip,eff}$	----	[mm]
Inferior Right Flange	$b_{p,Inf.\,Right\,Flange,eff}$	----	[mm]
Right Web	$h_{p,Right\,Web,eff,1}$	10.973	[mm]
	$h_{p,Right\,Web,eff,2}$	16.459	[mm]
Superior Flange	$b_{p,Sup.\,Flange,eff,1}$	16.937	[mm]
	$b_{p,Sup.\,Flange,eff,2}$	16.937	[mm]
Left Web	$h_{p,Left\,Web,eff,1}$	10.973	[mm]
	$h_{p,Left\,Web,eff,2}$	16.459	[mm]
Inferior Left Flange	$b_{p,Inf.\,Left\,Flange,eff}$	----	[mm]
Left Edge Stiffener	$c_{p,Left\,Lip,eff}$	----	[mm]

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$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

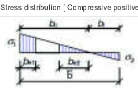
$\bar{\lambda}_p$ 0.507 → ρ 1.000

$\bar{\lambda}_p$ 0.507

ρ 1.000 Effective width equal to gross width

[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective^p width b_{eff}



ψ < 0.000

$b_{eff} = \rho * b_c = \rho * [b^{¨} / (1 - \psi)]$ $b_{e,1} = 0.400 * b_{eff}$

$b_t = b^{¨} - b_c = b^{¨} - [b^{¨} / (1 - \psi)]$ $b_{e,2} = 0.600 * b_{eff}$

$\rho \le 1.000$	OK	$h_{p,Left\,Web,t} = b^{¨} - b_c = b^{¨} - [b^{¨} / (1 - \psi)]$	27.432	[mm]
$\rho \le 1.000$	OK	$h_{p,Left\,Web,eff} = \rho * b_c = \rho * [b^{¨} / (1 - \psi)]$	27.432	[mm]

$h_{p,Left\,Web,eff,1}$	10.973	[mm]	$h_{p,Left\,Web,eff,2}$	16.459	[mm]

Inferior Left Flange [$b_{p,Nom,Inf.\,Left\,Flange}$] → Tension

NOTE Effective width is equal to the real width

Left Edge Stiffener [$c_{p,Nom,Left\,Lip}$] → Tension

NOTE Effective width is equal to the real width

[ii] **Effective Ω-Section Purlin [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

Effective Ω-Section Purlin Widths

Right Edge Stiffner	$c_{p,Right\,Lip,eff}$	----	[mm]
Inferior Right Flange	$b_{p,Inf.\,Right\,Flange,eff}$	----	[mm]
Right Web	$h_{p,Right\,Web,eff}$	27.432	[mm]
Superior Flange	$b_{p,Sup.\,Flange,eff}$	33.874	[mm]
Left Web	$h_{p,Left\,Web,eff}$	27.432	[mm]
Inferior Left Flange	$b_{p,Inf.\,Left\,Flange,eff}$	----	[mm]
Left Edge Stiffener	$c_{p,Left\,Lip,eff}$	----	[mm]

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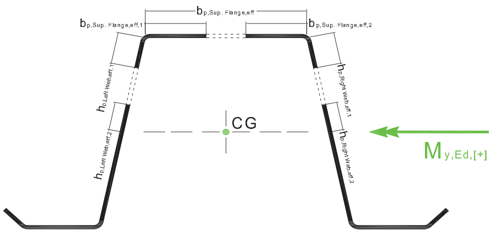
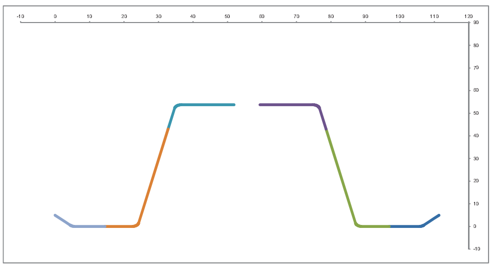


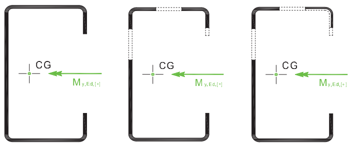
Effective Ω-Section Purlin with Reduced Thickness [L + D] [Positive Moment in y-y axis, $M_{y,Ed}^{+}$]



Effective Ω-Section Purlin with Reduced Thickness [L + D] [Compression Force]

$I_{Y,eff}^{[+]}$ 79892.362 [mm^4]

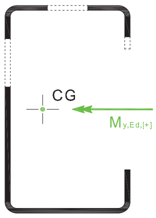
[b] C-Section Beam



Gross C-Section	Effective C-Section [L]	Effective C-Section [L + D]
	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

C-Section Classification | **Class 4** → Effective width must be calculated



Effective C-Section [Worst Case] [Class 4]

Inferior Edge Stiffener [$c_{p,1,nom}$] → Tension

NOTE: Effective width is equal to the real width

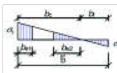
Inferior Flange [$b_{p,1,nom}$] → Tension

NOTE: Effective width is equal to the real width

Web [$h_{p,nom}$] → Class 3

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension			ε	0.819	
$h_{p,nom}$	118.548	mm	t	1.452	mm



Compression Stress		
σ_1	350.000	MPa
Tension Stress		
σ_2	-350.000	MPa

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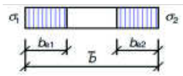
$\bar{\lambda}_p$	0.667	ρ	1.000	Effective width equal to gross width	
		[EN 1993-1-5, Equation (4.2)]	[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive] | Effective^{P} width b_{eff}



ψ = 1.000 — $b_{eff} = \rho * b^{¨}$ — $b_{eff,1} = 0.500 * b_{eff}$ — $b_{eff,2} = 0.500 * b_{eff}$

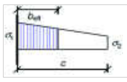
ρ ≤ 1.000	OK	C-Section	Class 2	$b_{p,2,eff} = \rho * b^{¨}$	45.048	[mm]

$b_{p,2,eff,1}$	22.524	[mm]	$b_{p,2,eff,2}$	22.524	[mm]

Superior Edge Stiffener [$c_{p,2,nom}$] → Class 4

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension			ε	0.819	
$b_{p,2,nom}$	45.048	mm	t	1.452	mm
$c_{p,2,nom}$	17.274	mm			

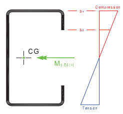


Compression Stress		
σ_1	350.000	MPa
σ_2	248.001	MPa
Tension Stress		

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

ψ = σ₂ / σ₁	→	ψ	0.709
σ_1 Free Point	→	k_σ	0.456

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]



Stress Distribution

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$0.50*h_{p,nom}$	59.274	mm	m	5.905

For a single edge stiffener, Equation (5.13c)

	$b_{p,c} / b_p$	0.383	→	k_σ	0.586
(1)	$\bar{\lambda}_p$	0.757	→	$\rho_{OPTION (1)}$	0.993
(2)	$\bar{\lambda}_d$	0.668	→	$\rho_{OPTION (2)}$	1.000

[EN 1993-1-5, Equation (4.3)] ρ ≤ 1.000 → OK

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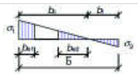
Internal Compression Elements [EN 1993-1-5, Table 4.1]

ψ = σ₂ / σ₁ → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.718 → ρ 1.180

$\bar{\lambda}_p$	0.718	ρ	1.180	Gross width will be reduced	
		[EN 1993-1-5, Equation (4.2)]	[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive] | Effective^{P} width b_{eff}



ψ < 0.000

$b_{eff} = \rho * b_c = \rho * [b^{¨} / (1 - \psi)]$ — $b_{e,1} = 0.400 * b_{eff}$

$b_t = b^{¨} - b_c = b^{¨} - [b^{¨} / (1 - \psi)]$ — $b_{e,2} = 0.600 * b_{eff}$

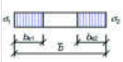
ρ ≤ 1.000	Consider ρ = 1.000	$h_{p,t} = b^{¨} - b_c = b^{¨} - [b^{¨} / (1 - \psi)]$	59.274	[mm]
ρ ≤ 1.000	Consider ρ = 1.000	$h_{p,eff} = \rho * b_c = \rho * [b^{¨} / (1 - \psi)]$	59.274	[mm]

$h_{p,eff,1}$	23.710	[mm]	$h_{p,eff,2}$	35.564	[mm]

Superior Flange [$b_{p,2,nom}$] → Class 2

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension			ε	0.819	
$b_{p,2,nom}$	45.048	mm	t	1.452	mm



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Internal Compression Elements [EN 1993-1-5, Table 4.1]

ψ = σ₂ / σ₁ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.667 → ρ 1.000

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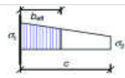
Stress distribution [Compressive positive] | Effective^{P} width b_{eff}

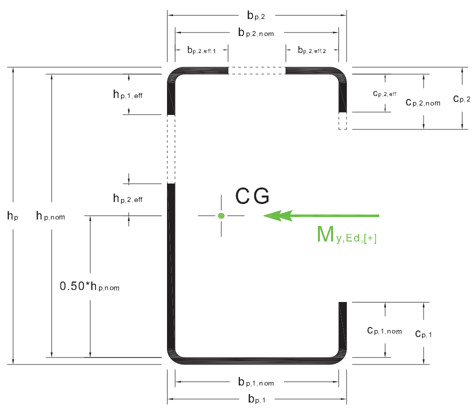


1.000 > ψ ≥ 0.000 — $b_{eff} = \rho * c$

C-Section	Class 4	$c_{p,2,eff} = \rho * c$	17.274	[mm]

[ii] **Effective C-Section Beam [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

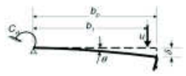
Effective C-Section Beam Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	----	[mm]
Web	$h_{p,eff}$	59.274	[mm]
Superior Flange	$b_{p,2,eff}$	45.048	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	17.274	[mm]



Effective Cross C-Section [Bending Moment $M_{y,Ed}^{+}$]

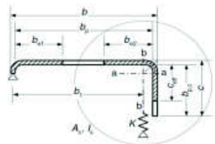
[iii] Plane elements with edge stiffeners [Distortional Buckling] **[EN 1993-1-3:2006, 5.5.1(5)]**

- **Plane elements with edge stiffeners** **[EN 1993-1-3:2006, 5.5.3.2]**



[a] Actual system

[b] Equivalent system



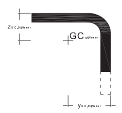
Single Edge Stiffener [EN 1993-1-3, Figure 5.7]

[EN 1993-1-3, 5.5.3.2(1)]	
b / t ≤ 60	OK
45° ≤ Ø	OK
Ø ≤ 135	OK

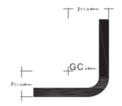
[EN 1993-1-3, 5.5.3.2(6)]

Round corners were considered in the effective cross-section area of the edge stiffener, A_s

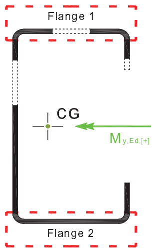
- **Determination of Spring Stiffness [K]** **[EN 1993-1-3:2006, 5.5.3.2(5)]**

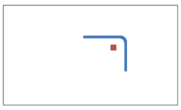


Inferior Edge Stiffener [Flange 1]



Superior Edge Stiffener [Flange 2]



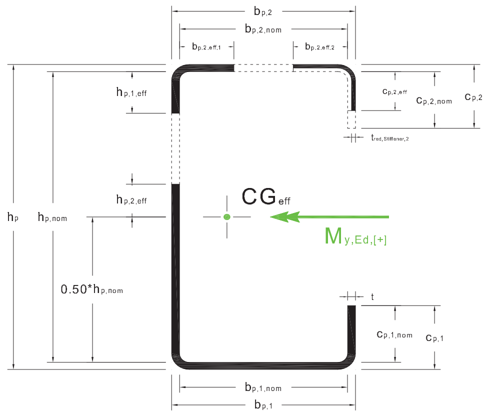


$A_{s,1}$	58.518	[mm²]
b_1	38.922	[mm]
$y_{GC,Stiffener}$	7.578	[mm]
$z_{GC,Stiffener}$	4.862	[mm]

Inferior Edge Stiffener [Flange 1] — Compression

[iv] Effective C-Section Beam with Reduced Thickness [Local + Distortional Buckling] **[EN 1993-1-5:2006, 5.5]**

Effective C-Section Beam Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	----	[mm]
Web	$h_{p,eff,1}$	23.710	[mm]
	$h_{p,eff,2}$	35.564	[mm]
Superior Flange	$b_{p,2,eff,1}$	22.524	[mm]
	$b_{p,2,eff,2}$	22.524	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	17.274	[mm]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{y,Ed}$ +]

$A_{s,2}$	0.000	[mm²]
b_2	0.000	[mm]
$y_{GC,Stiffener}$	0.000	[mm]
$z_{GC,Stiffener}$	0.000	[mm]

Superior Edge Stiffener [Flange 2] — Tension

$$K_1 = \frac{E t^3}{4(1-\nu^2)} \cdot \frac{1}{b_1^2 h_w + b_1^3 + 0.5 b_1 b_2 h_w k_f}$$

[EN 1993-1-3, Equation 5.10b]

$k_f = 0$	Flange 2 in Tension
$k_f = \frac{A_{s2}}{A_{s1}}$	Flange 2 in Compression

E	210.000	[GPa]	t	1.452	[mm]
v	0.300		b_1	38.922	[mm]
h_w = h	120.000	[mm]	b_2	0.000	[mm]
K_f	0.000				

K	0.734	[EN 1993-1-3, Equation 5.10b]

- **Determination of Elastic Critical Buckling Stress [$\sigma_{cr,s}$]** **[EN 1993-1-3:2006, 5.5.3.2(7)]**

$$\sigma_{cr,s} = \frac{2\sqrt{K E I_s}}{A_s}$$

[EN 1993-1-3, Equation 5.15]

K	0.734	
E	210.000	[GPa]
$I_{s,Stiffener,1}$	1926.805	[mm⁴]
$A_{s,1}$	58.518	[mm²]

Elastic Critical Buckling Stress, $\sigma_{cr,s}$, for edge stiffener 1 — 588.829 [MPa]

- **Relative Distortional Slenderness [$\bar{\lambda}_d$]** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

$$\bar{\lambda}_d = \sqrt{f_{yb} / \sigma_{cr,s}}$$

[EN 1993-1-3, Equation 5.12d]

f_{yb}	350.000	[MPa]
Edge Stiffener 1 $\bar{\lambda}_d$	0.771	

- **Reduction X_d Distortional Buckling Resistance [Stiffener Flexural Buckling]** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

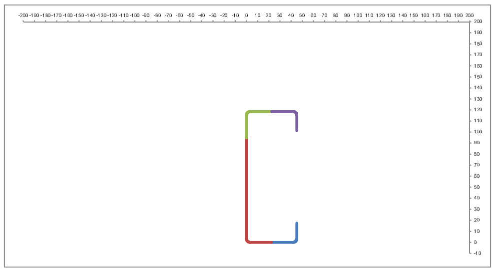
Edge Stiffener 1 — $\bar{\lambda}_d$ 0.771 — $X_{d,Stiffener,1}$ 0.913 — [EN 1993-1-3, Equation 5.12b]

- **Edge Stiffener Reduced Thickness** **[EN 1993-1-3:2006, 5.5.3.2(12)]**

In effective section properties, reduced effective area is represented using a reduced thickness for all elements in A_s

Edge Stiffener 1

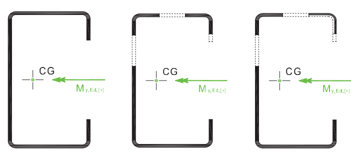
$t_{red,Stiffener,1}$ 1.325 [mm]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{y,Ed}$ +]

$I_{Y,eff}^{[+]}$ 746984.961 [mm⁴]

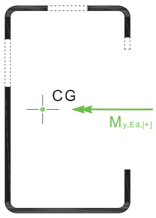
[c] C-Section Column



Gross C-Section	Effective C-Section [L]	Effective C-Section [L + D]
	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

[i] Determination of the Effective Width [Local Buckling] **[EN 1993-1-3:2006, 5.5]**

C-Section Classification | **Class 1** → Effective width is equal to the actual width



Effective C-Section [Worst Case] [Class 4]

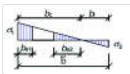
Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Tension
NOTE	Effective width is equal to the real width	
Inferior Flange [$b_{p,1,nom}$]	→	Tension
NOTE	Effective width is equal to the real width	

Web [$h_{p,nom}$]	→	Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Column Nominal Dimension		
$h_{p,nom}$	87.548	mm

ε	0.819	
t	2.452	mm



Compression Stress		
σ_1	350.000	MPa
Tension Stress		
σ_2	-350.000	MPa

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

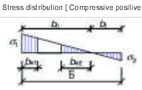
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.314 → ρ 1.000

$\bar{\lambda}_p$ 0.314

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

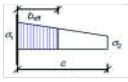
Stress distribution [Compressive positive]



Effective[ρ] width b_{eff}

ψ < 0.000
$b_{eff} = \rho \cdot b_c = \rho \cdot [\, b'' / (1 - \psi)\,]$ | $b_{e,1} = 0.400 \cdot b_{eff}$
$b_t = b'' - b_c = b'' - [\, b'' / (1 - \psi)\,]$ | $b_{e,2} = 0.600 \cdot b_{eff}$

ρ ≤ 1.000	OK	$h_{p,t} = b'' - b_c = b'' - [\, b'' / (1 - \psi)\,]$	43.774	[mm]

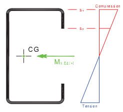


Compression Stress		
σ_1	350.000	MPa
σ_2	215.882	MPa
Tension Stress		

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

$\psi = \sigma_2 / \sigma_1$ → ψ 0.617
σ_1 Free Point → k_σ 0.467

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]



Stress Distribution

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

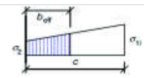
$0.50 \cdot h_{p,nom}$	43.774	mm	m	7.996

For a single edge stiffener, Equation (5.13c)

$b_{p,c} / b_p$	0.381	→	k_σ	0.582
(1) $\bar{\lambda}_p$	0.430	→	$\rho_{OPTION\,(1)}$	1.000
(2) $\bar{\lambda}_d$	0.385	→	$\rho_{OPTION\,(2)}$	1.000

[EN 1993-1-5, Equation (4.3)] ρ ≤ 1.000 → OK

Stress distribution [Compressive positive]



Effective[ρ] width b_{eff}

1.000 > ψ ≥ 0.000 $b_{eff} = \rho \cdot c$

C-Section	Class 1	$c_{p,2,eff} = \rho \cdot c$	16.774	[mm]

[ii] **Effective C-Section Column [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	----	[mm]
Web	$h_{p,eff}$	43.774	[mm]
Superior Flange	$b_{p,2,eff}$	44.048	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	16.774	[mm]

ρ ≤ 1.000	OK	$h_{p,eff} = \rho \cdot b_c = \rho \cdot [\, b'' / (1 - \psi)\,]$	43.774	[mm]

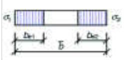
$h_{p,eff,1}$	17.510	[mm]	$h_{p,eff,2}$	26.264	[mm]

Superior Flange [$b_{p,2,nom}$]	→	Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Column Nominal Dimension		
$b_{p,2,nom}$	44.048	mm

ε	0.819	
t	2.452	mm



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

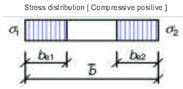
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.386 → ρ 1.000

$\bar{\lambda}_p$ 0.386

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive]



Effective[ρ] width b_{eff}

ψ = 1.000 $b_{eff} = \rho \cdot b''$
$b_{eff,1} = 0.500 \cdot b_{eff}$
$b_{eff,2} = 0.500 \cdot b_{eff}$

ρ ≤ 1.000	OK	C-Section	Class 1	$b_{p,2,eff} = \rho \cdot b''$	44.048	[mm]

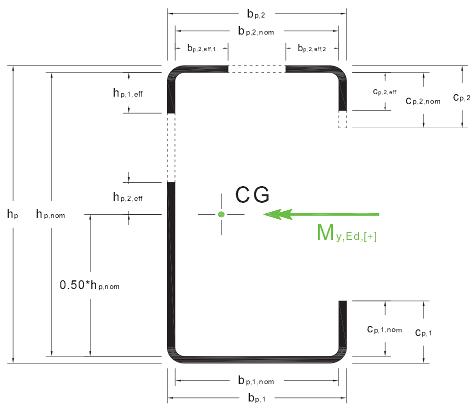
$b_{p,2,eff,1}$	22.024	[mm]	$b_{p,2,eff,2}$	22.024	[mm]

Superior Edge Stiffener [$c_{p,2,nom}$]	→	Class 1

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Column Nominal Dimension		
$b_{p,2,nom}$	44.048	mm
$c_{p,2,nom}$	16.774	mm

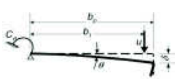
ε	0.819	
t	2.452	mm



Effective Cross C-Section [Bending Moment $M_{y,Ed}^{+}$]

[iii] **Plane elements with edge stiffeners [Distortional Buckling]** **[EN 1993-1-3:2006, 5.5.1(5)]**

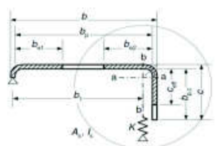
- **Plane elements with edge stiffeners** **[EN 1993-1-3:2006, 5.5.3.2]**



[a] Actual system

→

[b] Equivalent system



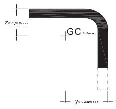
Single Edge Stiffener [EN 1993-1-3, Figure 5.7]

[EN 1993-1-3, 5.5.3.2(1)]	
b / t ≤ 60	OK
45° ≤ Ø	OK
Ø ≤ 135	OK

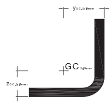
[EN 1993-1-3, 5.5.3.2(6)]

Round corners were considered in the effective cross-section area of the edge stiffener, A_s

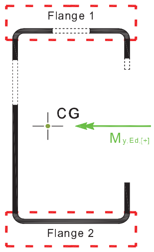
- **Determination of Spring Stiffness [K]** **[EN 1993-1-3:2006, 5.5.3.2(5)]**



Inferior Edge Stiffener [Flange 1]



Superior Edge Stiffener [Flange 2]



$A_{s,1}$	96.559	[mm^2]
b_1	38.465	[mm]
$y_{GC,Stiffener}$	8.035	[mm]
$z_{GC,Stiffener}$	5.304	[mm]

Inferior Edge Stiffener [Flange 1] Compression

$A_{s,2}$	0.000	[mm^2]
b_2	0.000	[mm]
$y_{GC,Stiffener}$	0.000	[mm]
$z_{GC,Stiffener}$	0.000	[mm]

Superior Edge Stiffener [Flange 2] Tension

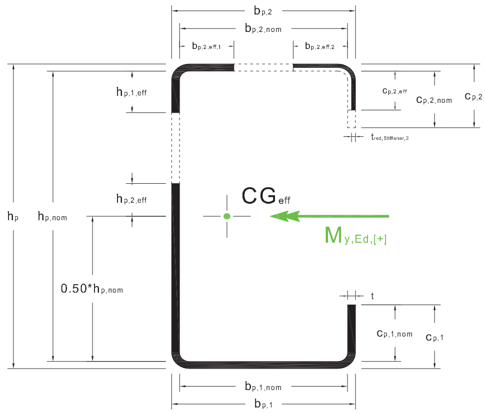
$$K_1 = \frac{E t^3}{4(1-\nu^2)} \cdot \frac{1}{b_1^2 h_w + b_1^3 + 0.5 b_1 b_2 h_w k_f}$$

[EN 1993-1-3, Equation 5.10b]

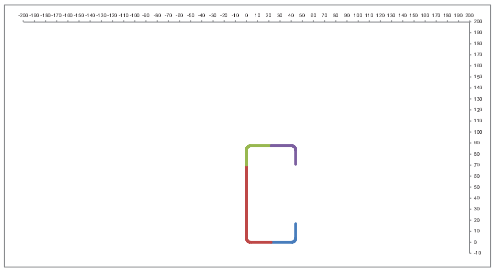
$k_f = 0$	Flange 2 in Tension
$k_f = \frac{A_{s2}}{A_{s1}}$	Flange 2 in Compression

E	210.000	[GPa]	t	2.452	[mm]
v	0.300		b_1	38.465	[mm]
h_w = h	90.000	[mm]	b_2	0.000	[mm]
K_f	0.000				

K	4.475	[EN 1993-1-3, Equation 5.10b]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{y,Ed}$ +]



Effective C-Section Column with Reduced Thickness [L + D] [Bending Moment $M_{y,Ed}$ +]

$I_{Y,eff}$ 625036.020 [mm^4]

- **Determination of Elastic Critical Buckling Stress [$\sigma_{cr,s}$]** **[EN 1993-1-3:2006, 5.5.3.2(7)]**

$$\sigma_{cr,s} = \frac{2\sqrt{K E I_s}}{A_s}$$

[EN 1993-1-3, Equation 5.15]

K	4.475	
E	210.000	[GPa]
$I_{s,Stiffener,1}$	3057.998	[mm^4]
$A_{s,1}$	96.559	[mm^2]

Elastic Critical Buckling Stress, $\sigma_{cr,s}$, for edge stiffener 1 1110.333 [MPa]

- **Relative Distortional Slenderness [ ] $\bar{\lambda}_d$** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

$$\bar{\lambda}_d = \sqrt{f_{yb} / \sigma_{cr,s}}$$

[EN 1993-1-3, Equation 5.12d]

f_{yb} 350.000 [MPa]

Edge Stiffener 1 $\bar{\lambda}_d$ 0.561

- **Reduction X_d Distortional Buckling Resistance [Stiffener Flexural Buckling]** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

Edge Stiffener 1 $\bar{\lambda}_d$ 0.561 $X_{d,Stiffener,1}$ 1.000 [EN 1993-1-3, Equation 5.12a]

- **Edge Stiffener Reduced Thickness** **[EN 1993-1-3:2006, 5.5.3.2(12)]**

In effective section properties, reduced effective area is represented using a reduced thickness for all elements in A_s

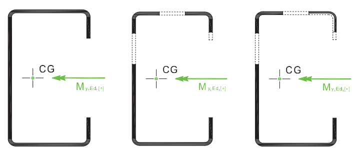
Edge Stiffener 1

$t_{red,Stiffener,1}$ 2.452 [mm]

[iv] **Effective C-Section Column with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	----	[mm]
Web	$h_{p,eff,1}$	17.510	[mm]
	$h_{p,eff,2}$	26.264	[mm]
Superior Flange	$b_{p,2,eff,1}$	22.024	[mm]
	$b_{p,2,eff,2}$	22.024	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	16.774	[mm]

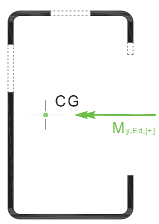
[d] C-Section Strut



Gross C-Section	Effective C-Section [L]	Effective C-Section [L + D]
	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

C-Section Classification **Class 1** → Effective width is equal to the actual width



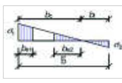
Effective C-Section [Worst Case] [Class 4]

Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Tension
NOTE	Effective width is equal to the real width	
Inferior Flange [$b_{p,1,nom}$]	→	Tension
NOTE	Effective width is equal to the real width	
Web [$h_{p,nom}$]	→	Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Strut Nominal Dimension		
$h_{p,nom}$	48.548	mm

ε	0.819	
t	1.452	mm



Compression Stress		
σ_1	350.000	MPa
Tension Stress		
σ_2	-350.000	MPa

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$	→	ψ	-1.000	→	k_σ	23.900

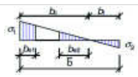
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.294 → ρ 1.000

$\bar{\lambda}_p$ 0.294

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive]



Effective[p] width b_{eff}

ψ < 0.000

$b_{eff} = \rho * b_c = \rho * [\, b^{¨} / (1 - \psi) \,]$ $b_{e,1} = 0.400 * b_{eff}$

$b_t = b^{¨} - b_c = b^{¨} - [\, b^{¨} / (1 - \psi) \,]$ $b_{e,2} = 0.600 * b_{eff}$

ρ ≤ 1.000	OK	$h_{p,t} = b^{¨} - b_c = b^{¨} - [\, b^{¨} / (1 - \psi) \,]$	48.548	[mm]
ρ ≤ 1.000	OK	$h_{p,eff} = \rho * b_c = \rho * [\, b^{¨} / (1 - \psi) \,]$	24.274	[mm]

$h_{p,eff,1}$	9.710	[mm]	$h_{p,eff,2}$	14.564	[mm]

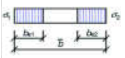
Superior Flange [$b_{p,2,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Strut Nominal Dimension

$b_{p,2,nom}$ 38.548 mm

ε 0.819
t 1.452 mm



Compression Stress
σ_1 350.000 MPa
σ_2 350.000 MPa
Tension Stress

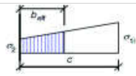
Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$	→	ψ	1.000	→	k_σ	4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.570 → ρ 1.000

Stress distribution [Compressive positive]



Effective[p] width b_{eff}

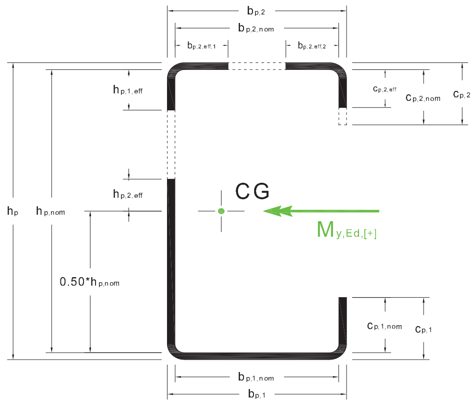
1.000 > ψ ≥ 0.000 $b_{eff} = \rho * c$

C-Section	Class 1	$c_{p,2,eff} = \rho * c$	9.274	[mm]

[ii] **Effective C-Section Strut [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

Effective C-Section Strut Widths

Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	----	[mm]
Web	$h_{p,eff}$	24.274	[mm]
Superior Flange	$b_{p,2,eff}$	38.548	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	9.274	[mm]

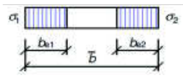


Effective Cross C-Section [Bending Moment $M_{y,Ed}^{+}$]

$\bar{\lambda}_p$ 0.570

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive]



Effective[p] width b_{eff}

ψ = 1.000 $b_{eff} = \rho * b^{¨}$

$b_{eff,1} = 0.500 * b_{eff}$

$b_{eff,2} = 0.500 * b_{eff}$

ρ ≤ 1.000	OK	C-Section	Class 1	$b_{p,2,eff} = \rho * b^{¨}$	38.548	[mm]

$b_{p,2,eff,1}$	19.274	[mm]	$b_{p,2,eff,2}$	19.274	[mm]

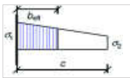
Superior Edge Stiffener [$c_{p,2,nom}$] → Class 1

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Strut Nominal Dimension

$b_{p,2,nom}$	38.548	mm
$c_{p,2,nom}$	9.274	mm

ε 0.819
t 1.452 mm

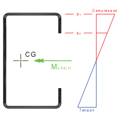


Compression Stress
σ_1 350.000 MPa
σ_2 216.281 MPa
Tension Stress

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

$\psi = \sigma_2 / \sigma_1$	→	ψ	0.618
σ_1 Free Point	→	k_σ	0.467

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]



Stress Distribution

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$0.50{*}h_{p,nom}$	24.274	mm	m	14.419

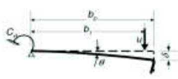
For a single edge stiffener, Equation (5.13b)

	$b_{p,c} / b_p$	0.241	→	k_σ	0.500
(1)	$\bar{\lambda}_p$	0.402	→	$\rho_{OPTION\,(1)}$	1.000
(2)	$\bar{\lambda}_d$	0.388	→	$\rho_{OPTION\,(2)}$	1.000

[EN 1993-1-5, Equation (4.3)] ρ ≤ 1.000 → OK

[iii] **Plane elements with edge stiffeners [Distortional Buckling]** **[EN 1993-1-3:2006, 5.5.1(5)]**

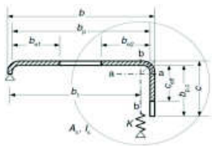
- **Plane elements with edge stiffeners** **[EN 1993-1-3:2006, 5.5.3.2]**



[a] Actual system

→

[b] Equivalent system



Single Edge Stiffener [EN 1993-1-3, Figure 5.7]

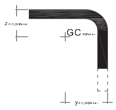
[EN 1993-1-3, 5.5.3.2(1)]

b / t ≤ 60	OK
45° ≤ Ø	OK
Ø ≤ 135	OK

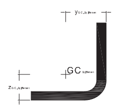
[EN 1993-1-3, 5.5.3.2(6)]

Round corners were considered in the effective cross-section area of the edge stiffener, A_s

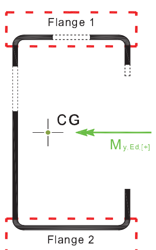
- **Determination of Spring Stiffness [K]** **[EN 1993-1-3:2006, 5.5.3.2(5)]**

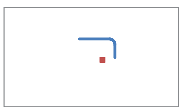


Inferior Edge Stiffener [Flange 1]



Superior Edge Stiffener [Flange 2]





Inferior Edge Stiffener [Flange 1]

$A_{s,1}$	42.183	[mm^2]
b_1	32.213	[mm]
$y_{GC,Stiffener}$	7.787	[mm]
$z_{GC,Stiffener}$	2.549	[mm]

Compression

$A_{s,2}$	0.000	[mm^2]
b_2	0.000	[mm]
$y_{GC,Stiffener}$	0.000	[mm]
$z_{GC,Stiffener}$	0.000	[mm]

Superior Edge Stiffener [Flange 2] — Tension

$$K_1 = \frac{E t^3}{4(1-\nu^2)} \cdot \frac{1}{b_1^2 h_w + b_1^3 + 0.5 b_1 b_2 h_w k_f}$$

[EN 1993-1-3, Equation 5.10b]

$k_f = 0$	Flange 2 in Tension
$k_f = \frac{A_{s2}}{A_{s1}}$	Flange 2 in Compression

E	210.000	[GPa]	t	1.452	[mm]
v	0.300		b_1	32.213	[mm]
h_w = h	50.000	[mm]	b_2	0.000	[mm]
K_f	0.000				

K	2.070	[EN 1993-1-3, Equation 5.10b]

- **Determination of Elastic Critical Buckling Stress [$\sigma_{cr,s}$]** **[EN 1993-1-3:2006, 5.5.3.2(7)]**

$$\sigma_{cr,s} = \frac{2\sqrt{K E I_s}}{A_s}$$

[EN 1993-1-3, Equation 5.15]

K	2.070	
E	210.000	[GPa]
$I_{s,Stiffener,1}$	377.466	[mm^4]
$A_{s,1}$	42.183	[mm^2]

Elastic Critical Buckling Stress, $\sigma_{cr,s}$, for edge stiffener 1 — 607.375 [MPa]

- **Relative Distortional Slenderness [ ] $\bar{\lambda}_d$** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

$$\bar{\lambda}_d = \sqrt{f_{yb}/\sigma_{cr,s}}$$

[EN 1993-1-3, Equation 5.12d]

f_{yb}	350.000	[MPa]
Edge Stiffener 1 — $\bar{\lambda}_d$	0.759	

- **Reduction X_d Distortional Buckling Resistance [Stiffener Flexural Buckling]** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

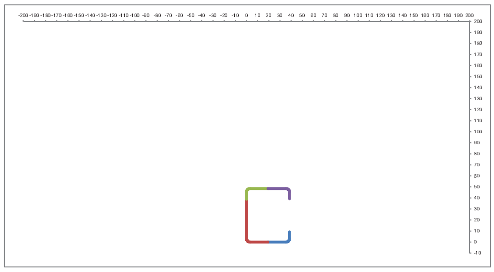
Edge Stiffener 1	$\bar{\lambda}_d$	0.759	$X_{d,Stiffener,1}$	0.921	[EN 1993-1-3, Equation 5.12b]

- **Edge Stiffener Reduced Thickness** **[EN 1993-1-3:2006, 5.5.3.2(12)]**

In effective section properties, reduced effective area is represented using a reduced thickness for all elements in A_s

Edge Stiffener 1

$t_{red,Stiffener,1}$	1.338	[mm]

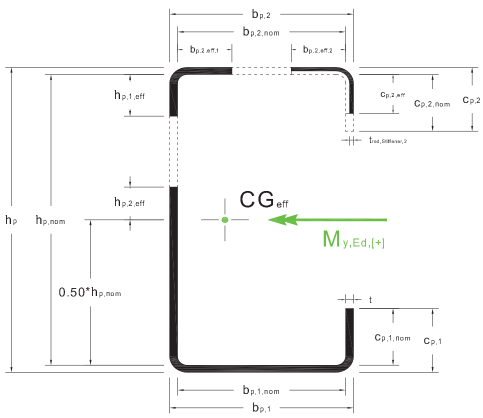


Effective C-Section Strut with Reduced Thickness [L + D] [Bending Moment $M_{y,Ed}$ ⁺]

$I_{y,eff}$ [+]	83790.577	[mm^4]

[iv] **Effective C-Section Strut with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

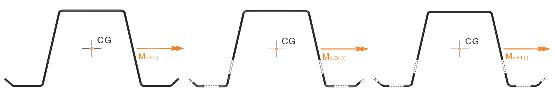
Effective C-Section Strut Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	----	[mm]
Web	$h_{p,eff,1}$	9.710	[mm]
	$h_{p,eff,2}$	14.564	[mm]
Superior Flange	$b_{p,2,eff,1}$	19.274	[mm]
	$b_{p,2,eff,2}$	19.274	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	9.274	[mm]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{y,Ed}$ ⁺]

[11.4] Cold-Formed Section subjected to Negative Moment in y-y axis [$M_{y,Ed}^-$]

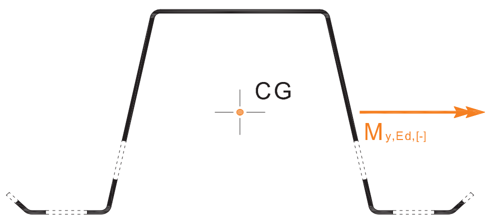
[a] Ω-Section Purlin



Gross Ω-Section	Effective Ω-Section [L]	Effective Ω-Section [L + D]
	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

Ω-Section Classification | **Class 1** → Effective width is equal to the actual width



Effective Ω-Section [Worst Case] [Class 4]

Right Edge Stiffner [$c_{p,Nom,Right Lip}$] → Class 1

OPTION [2] Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

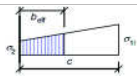
Ω-Section Purlin Nominal Dimension		
$c_{p,Nom,Right Lip}$	7.010	mm
$b_{p,Nom,Inf. Right Flange}$	18.975	mm

ε	0.819	
t	0.952	mm

For a single edge stiffener, Equation (5.13c)

$b_{p,c} / b_p$	0.369	→	k_σ	0.560

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$ (2) $\bar{\lambda}_d$ 0.423 → $\rho_{OPTION (2)}$ 1.000

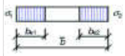
Stress distribution [Compressive positive]	Effective[p] width b_{eff}	
	1.000 > ψ ≥ 0.000	$b_{eff} = \rho * c$

Ω-Section	Class 1	$c_{p,Right\ Lip,eff} = \rho * c$	7.010	[mm]

Inferior Right Flange [$b_{p,Nom,Inf.\ Right\ Flange}$] → Class 1

Elements without longitudinal stiffeners — [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension			ε	0.819	
$b_{p,Nom,Inf.\ Right\ Flange}$	18.975	mm	t	0.952	mm



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

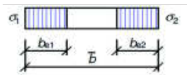
Internal Compression Elements — [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.428 → ρ 1.000

$\bar{\lambda}_p$ 0.428

ρ	1.000	Effective width equal to gross width	
[EN 1993-1-5, Equation (4.2)]	[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive]	Effective[p] width b_{eff}		
	ψ = 1.000	$b_{eff} = \rho * b^{¨}$	$b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

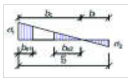
ρ ≤ 1.000	OK	Ω-Section	Class 1	$b_{p,Inf.\ Right\ Flange,eff} = \rho * b^{¨}$	18.975	[mm]

$b_{p,Inf.\ Right\ Flange,eff,1}$	9.488	[mm]	$b_{p,Inf.\ Right\ Flange,eff,2}$	9.488	[mm]

Left Web [$h_{p,Nom,Left\ Web}$] → Class 1

Elements without longitudinal stiffeners — [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension			ε	0.819	
$h_{p,Nom,Right\ Web}$	54.863	mm	t	0.952	mm



Compression Stress		
σ_1	350.000	MPa
Tension Stress		
σ_2	-350.000	MPa

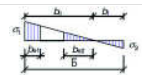
Internal Compression Elements — [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.507 → ρ 1.000

$\bar{\lambda}_p$ 0.507

ρ	1.000	Effective width equal to gross width	
[EN 1993-1-5, Equation (4.2)]	[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive]	Effective[p] width b_{eff}		
	ψ < 0.000	$b_{eff} = \rho * b_c = \rho * [b^{¨} / (1 - \psi)]$ $b_t = b^{¨} - b_c = b^{¨} - [b^{¨} / (1 - \psi)]$	$b_{e,1} = 0.400 * b_{eff}$ $b_{e,2} = 0.600 * b_{eff}$

ρ ≤ 1.000	OK	$h_{p,Right\ Web,t} = b^{¨} - b_c = b^{¨} - [b^{¨} / (1 - \psi)]$	27.432	[mm]

ρ ≤ 1.000	OK	$h_{p,Right\ Web,eff} = \rho * b_c = \rho * [b^{¨} / (1 - \psi)]$	27.432	[mm]

$h_{p,Right\ Web,eff,1}$	10.973	[mm]	$h_{p,Right\ Web,eff,2}$	16.459	[mm]

Inferior Left Flange [$b_{p,Nom,Inf.\ Left\ Flange}$] → Class 1

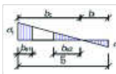
Elements without longitudinal stiffeners — [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension			ε	0.819	
$b_{p,Nom,Inf.\ Left\ Flange}$	18.975	mm	t	0.952	mm

Right Web [$h_{p,Nom,Right\ Web}$] → Class 1

Elements without longitudinal stiffeners — [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension			ε	0.819	
$h_{p,Nom,Right\ Web}$	54.863	mm	t	0.952	mm



Compression Stress		
σ_1	350.000	MPa
Tension Stress		
σ_2	-350.000	MPa

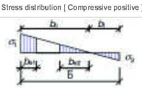
Internal Compression Elements — [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.507 → ρ 1.000

$\bar{\lambda}_p$ 0.507

ρ	1.000	Effective width equal to gross width	
[EN 1993-1-5, Equation (4.2)]	[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive]	Effective[p] width b_{eff}		
	ψ < 0.000	$b_{eff} = \rho * b_c = \rho * [b^{¨} / (1 - \psi)]$ $b_t = b^{¨} - b_c = b^{¨} - [b^{¨} / (1 - \psi)]$	$b_{e,1} = 0.400 * b_{eff}$ $b_{e,2} = 0.600 * b_{eff}$

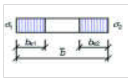
ρ ≤ 1.000	OK	$h_{p,Right\ Web,t} = b^{¨} - b_c = b^{¨} - [b^{¨} / (1 - \psi)]$	27.432	[mm]

ρ ≤ 1.000	OK	$h_{p,Right\ Web,eff} = \rho * b_c = \rho * [b^{¨} / (1 - \psi)]$	27.432	[mm]

$h_{p,Right\ Web,eff,1}$	10.973	[mm]	$h_{p,Right\ Web,eff,2}$	16.459	[mm]

Superior Flange [$b_{p,Nom,Sup.\ Flange}$] → Tension

NOTE	Effective width is equal to the real width



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

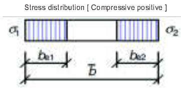
Internal Compression Elements — [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.428 → ρ 1.000

$\bar{\lambda}_p$ 0.428

ρ	1.000	Effective width equal to gross width	
[EN 1993-1-5, Equation (4.2)]	[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive]	Effective[p] width b_{eff}		
	ψ = 1.000	$b_{eff} = \rho * b^{¨}$	$b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

ρ ≤ 1.000	OK	Ω-Section	Class 1	$b_{p,Inf.\ Left\ Flange,eff} = \rho * b^{¨}$	18.975	[mm]

$b_{p,Inf.\ Left\ Flange,eff,1}$	9.488	[mm]	$b_{p,Inf.\ Left\ Flange,eff,2}$	9.488	[mm]

Left Edge Stiffener [$c_{p,Nom,Left\ Lip}$] → Class 1

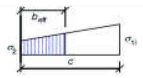
OPTION [2] Elements without longitudinal stiffeners — [EN 1993-1-3:2006, 5.5.3.2(5)]

Ω-Section Purlin Nominal Dimension			ε	0.819	
$c_{p,Nom,Left\ Lip}$	7.010	mm	t	0.952	mm
$b_{p,Nom,Inf.\ Left\ Flange}$	18.975	mm			

For a single edge stiffener, Equation (5.13c)

$b_{p,c} / b_p$ 0.369 → k_σ 0.560

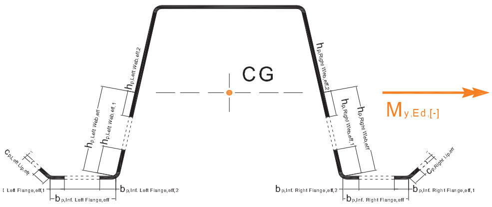
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$ (2) $\bar{\lambda}_d$ 0.423 → $\rho_{OPTION (2)}$ 1.000

Stress distribution [Compressive positive]	Effective[p] width b_{eff}
	1.000 > ψ ≥ 0.000 $b_{eff} = \rho * c$

Ω-Section	Class 1	$c_{p,Left\ Lip,eff} = \rho * c$	7.010	[mm]

[ii] **Effective Ω-Section Purlin [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

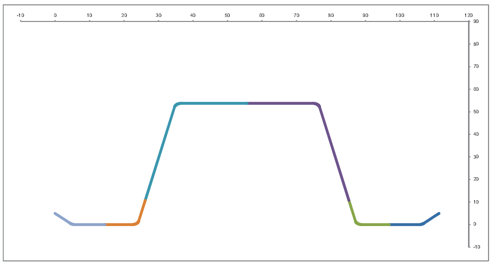
Effective Ω-Section Purlin Widths			
Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	7.010	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff}$	18.975	[mm]
Right Web	$h_{p,Right\ Web,eff}$	27.432	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff}$	----	[mm]
Left Web	$h_{p,Left\ Web,eff}$	27.432	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff}$	18.975	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	7.010	[mm]



Effective Ω-Section Purlin [Negative Moment in y-y axis, $M_{y,Ed}^{-}$]

[iii] **Plane elements with edge stiffeners [Distortional Buckling]** **[EN 1993-1-3:2006, 5.5.1(5)]**

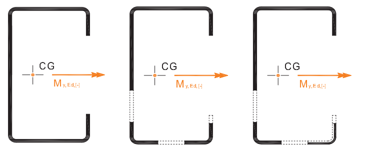
NOTE	Distortional buckling effects were not considered for this type of structural member



Effective Ω-Section Purlin with Reduced Thickness [L + D] [Negative Moment in y-y axis, $M_{y,Ed}^{-}$]

$I_{y,eff}^{[-]}$ 85759.975 [mm^4]

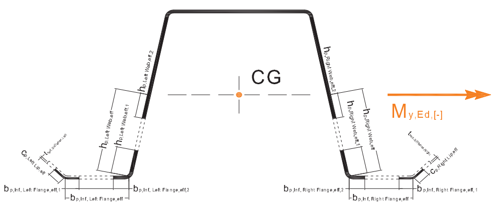
[b] C-Section Beam



Gross C-Section	Effective C-Section [L]	Effective C-Section [L + D]
	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

[iv] **Effective Cross Ω-Section Purlin with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

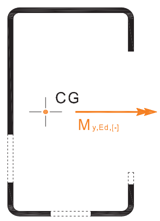
Effective Ω-Section Purlin Widths			
Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	7.010	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff,1}$	9.488	[mm]
	$b_{p,Inf.\ Right\ Flange,eff,2}$	9.488	[mm]
Right Web	$h_{p,Right\ Web,eff,1}$	10.973	[mm]
	$h_{p,Right\ Web,eff,2}$	16.459	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff}$	----	[mm]
Left Web	$h_{p,Left\ Web,eff,1}$	10.973	[mm]
	$h_{p,Left\ Web,eff,2}$	16.459	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff,1}$	9.488	[mm]
	$b_{p,Inf.\ Left\ Flange,eff,2}$	9.488	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	7.010	[mm]



Effective Ω-Section Purlin with Reduced Thickness [L + D] [Negative Moment in y-y axis, $M_{y,Ed}^{-}$]

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

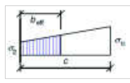
C-Section Classification	Class 4	→	Effective width must be calculated



Effective C-Section [Worst Case] [Class 4]

Inferior Edge Stiffener [$c_{p,1,nom}$]	→	Class 4

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]



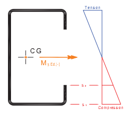
Compression Stress		
σ_1	350.000	MPa
σ_2	248.001	MPa
Tension Stress		

Outstand Compression Elements		[EN 1993-1-5, Table 4.2]	
$\psi = \sigma_2 / \sigma_1$	→	ψ	0.709
σ_1 Free Point	→	k_σ	0.456

C-Section Beam Nominal Dimension		
$b_{p,1,nom}$	45.048	mm
$c_{p,1,nom}$	17.274	mm

ε	0.819	
t	1.452	mm

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]



Stress Distribution

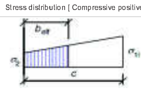
$0.50 * h_{p,nom}$	59.274	mm	m	5.905

For a single edge stiffener, Equation (5.13c)

	$b_{p,c} / b_p$	0.383	→ k_σ	0.586
(1)	$\bar{\lambda}_p$	0.757	→ $\rho_{OPTION\ (1)}$	0.993
(2)	$\bar{\lambda}_d$	0.668	→ $\rho_{OPTION\ (2)}$	1.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$

[EN 1993-1-5, Equation (4.3)]	$\rho \leq 1.000$	→	OK

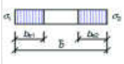
Stress distribution [Compressive positive]	Effective[p] width b_{eff}
	1.000 > ψ ≥ 0.000 $b_{eff} = \rho * c$

C-Section	Class 4	$c_{p,1,eff} = \rho * c$	17.274	[mm]

Inferior Flange [$b_{p,1,nom}$] → Class 2

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension						
$b_{p,1,nom}$	45.048	mm	ε	0.819		
			t	1.452	mm	



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

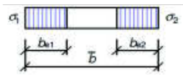
$\bar{\lambda}_p$ 0.667 → ρ 1.000

$\bar{\lambda}_p$ 0.667

ρ 1.000 — Effective width equal to gross width

[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective[p] width b_{eff}



ψ = 1.000 $b_{eff} = \rho * b^{¨}$ $b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

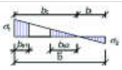
ρ ≤ 1.000	OK	C-Section	Class 2	$b_{p,1,eff} = \rho * b^{¨}$	45.048	[mm]

$b_{p,1,eff,1}$	22.524	[mm]	$b_{p,1,eff,2}$	22.524	[mm]

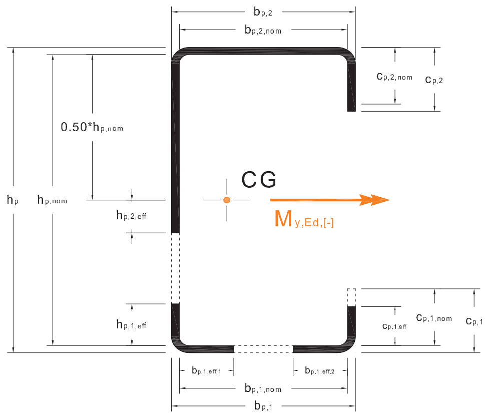
Web [$h_{p,nom}$] → Class 3

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension					
$h_{p,nom}$	118.548	mm	ε	0.819	
			t	1.452	mm



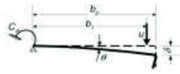
Compression Stress		
σ_1	350.000	MPa
Tension Stress		
σ_2	-350.000	MPa



Effective Cross C-Section [Bending Moment $M_{y,Ed}$ +]

[iii] **Plane elements with edge stiffeners [Distortional Buckling]** **[EN 1993-1-3:2006, 5.5.1(5)]**

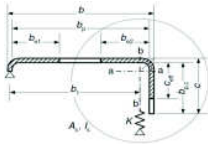
- **Plane elements with edge stiffeners** **[EN 1993-1-3:2006, 5.5.3.2]**



[a] Actual system

→

[b] Equivalent system



Single Edge Stiffener [EN 1993-1-3, Figure 5.7]

[EN 1993-1-3, 5.5.3.2(1)]	
b / t ≤ 60	OK
45° ≤ Ø	OK
Ø ≤ 135	OK

[EN 1993-1-3, 5.5.3.2(6)]

Round corners were considered in the effective cross-section area of the edge stiffener, A_s

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

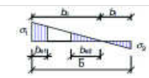
$\bar{\lambda}_p$ 0.718 → ρ 1.180

$\bar{\lambda}_p$ 0.718

ρ 1.180 — Gross width will be reduced

[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective[p] width b_{eff}



ψ < 0.000

$b_{eff} = \rho * b_c = \rho * [b^{¨} / (1 - \psi)]$ $b_{e,1} = 0.400 * b_{eff}$

$b_t = b^{¨} - b_c = b^{¨} - [b^{¨} / (1 - \psi)]$ $b_{e,2} = 0.600 * b_{eff}$

ρ ≤ 1.000	Consider ρ = 1.000	$h_{p,t} = b^{¨} - b_c = b^{¨} - [b^{¨} / (1 - \psi)]$	59.274	[mm]
ρ ≤ 1.000	Consider ρ = 1.000	$h_{p,eff} = \rho * b_c = \rho * [b^{¨} / (1 - \psi)]$	59.274	[mm]

$h_{p,eff,1}$	23.710	[mm]	$h_{p,eff,2}$	35.564	[mm]

Superior Flange [$b_{p,2,nom}$] → Tension

NOTE — Effective width is equal to the real width

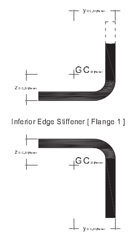
Superior Edge Stiffener [$c_{p,2,nom}$] → Tension

NOTE — Effective width is equal to the real width

[ii] **Effective C-Section Beam [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

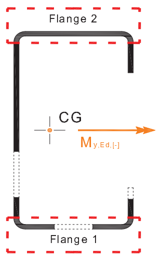
Effective C-Section Beam Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	17.274	[mm]
Inferior Flange	$b_{p,1,eff}$	45.048	[mm]
Web	$h_{p,eff}$	59.274	[mm]
Superior Flange	$b_{p,2,eff}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]

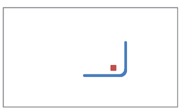
- **Determination of Spring Stiffness [K]** **[EN 1993-1-3:2006, 5.5.3.2(5)]**



Inferior Edge Stiffener [Flange 1]

Superior Edge Stiffener [Flange 2]





$A_{s,1}$	58.518	[mm^2]
b_1	38.922	[mm]
$y_{GC,Stiffener}$	7.578	[mm]
$z_{GC,Stiffener}$	4.862	[mm]

Inferior Edge Stiffener [Flange 1] — Compression

$A_{s,2}$	0.000	[mm^2]
b_2	0.000	[mm]
$y_{GC,Stiffener}$	0.000	[mm]
$z_{GC,Stiffener}$	0.000	[mm]

Superior Edge Stiffener [Flange 2] — Tension

$$K_1 = \frac{E t^3}{4(1-\nu^2)} \cdot \frac{1}{b_1^2 h_w + b_1^3 + 0.5 b_1 b_2 h_w k_f}$$

[EN 1993-1-3, Equation 5.10b]

$k_f = 0$ — Flange 2 in Tension

$k_f = \frac{A_{s2}}{A_{s1}}$ — Flange 2 in Compression

E	210.000	[GPa]	t	1.452	[mm]
ν	0.300		b_1	38.922	[mm]
$h_w = h$	120.000	[mm]	b_2	0.000	[mm]
K_f	0.000				

K	0.734	[EN 1993-1-3, Equation 5.10b]

- **Determination of Elastic Critical Buckling Stress [$\sigma_{cr,s}$]** **[EN 1993-1-3:2006, 5.5.3.2(7)]**

$$\sigma_{cr,s} = \frac{2\sqrt{K E I_s}}{A_s}$$

[EN 1993-1-3, Equation 5.15]

K	0.734	
E	210.000	[GPa]
$I_{s,Stiffener,1}$	1926.805	[mm^4]
$A_{s,1}$	58.518	[mm^2]

Elastic Critical Buckling Stress, $\sigma_{cr,s}$, for edge stiffener 1 — 588.829 [MPa]

- **Relative Distortional Slenderness [$\bar{\lambda}_d$]** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

$$\bar{\lambda}_d = \sqrt{f_{yb}/\sigma_{cr,s}}$$

[EN 1993-1-3, Equation 5.12d]

f_{yb} 350.000 [MPa]

Edge Stiffener 1 $\bar{\lambda}_d$ 0.771

- **Reduction X_d Distortional Buckling Resistance [Stiffener Flexural Buckling]** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

Edge Stiffener 1 $\bar{\lambda}_d$ 0.771 $X_{d,Stiffener,1}$ 0.913 [EN 1993-1-3, Equation 5.12b]

- **Edge Stiffener Reduced Thickness** **[EN 1993-1-3:2006, 5.5.3.2(12)]**

In effective section properties, reduced effective area is represented using a reduced thickness for all elements in A_s

Edge Stiffener 1		
$t_{red,Stiffener,1}$	1.325	[mm]

[iv] **Effective C-Section Beam with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

Effective C-Section Beam Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	17.274	[mm]
Inferior Flange	$b_{p,1,eff,1}$	22.524	[mm]
	$b_{p,1,eff,2}$	22.524	[mm]
Web	$h_{p,eff,1}$	23.710	[mm]
	$h_{p,eff,2}$	35.564	[mm]
Superior Flange	$b_{p,2,eff,1}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]

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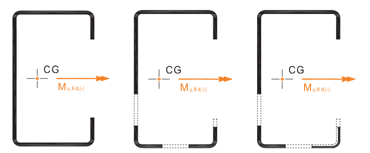
Date: 05/09/2019 | Project: MASTER THESIS
Code: Eurocode | References: EN 1990 | EN 1991 | EN 1993
Version: 1.000 | Client: COIMBRA UNIVERSITY

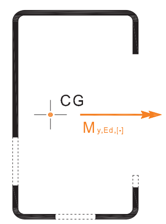
[c] C-Section Column



Gross C-Section | Effective C-Section [L] — Local Buckling — EN 1993-1-5 | Effective C-Section [L + D] — Local + Distortional Buckling — EN 1993-1-3

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

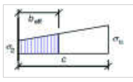
C-Section Classification | **Class 1** → Effective width is equal to the actual width



Effective C-Section [Worst Case] [Class 4]

Inferior Edge Stiffener [$c_{p,1,nom}$] → Class 1

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]



Compression Stress

σ_1	350.000	MPa
σ_2	215.882	MPa

Tension Stress

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

$\psi = \sigma_2 / \sigma_1$ → ψ 0.617

σ_1 Free Point → k_σ 0.467

C-Section Column Nominal Dimension		
$b_{p,1,nom}$	44.048	mm
$c_{p,1,nom}$	16.774	mm

ε	0.819	
t	2.452	mm

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Code: Eurocode | References: EN 1990 | EN 1991 | EN 1993
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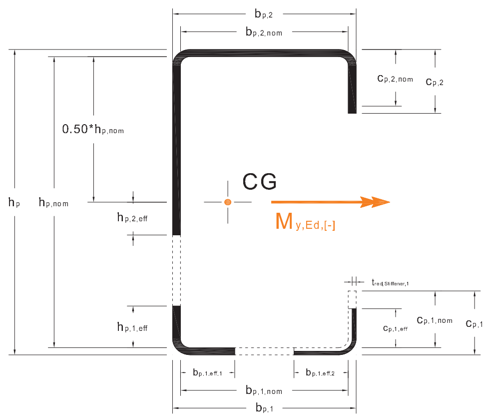
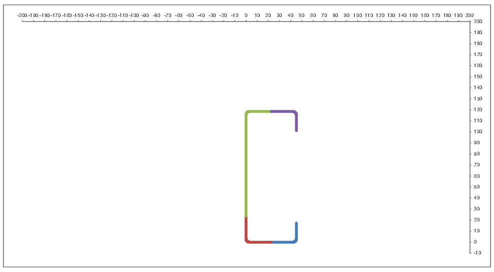


Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{y,Ed}^{-}$]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{y,Ed}^{-}$]

$I_{Y,eff}^{[-]}$ 746984.961 [mm^4]

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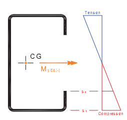
Code: Eurocode | References: EN 1990 | EN 1991 | EN 1993
Version: 1.000 | Client: COIMBRA UNIVERSITY

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]



Stress Distribution

$0.50*h_{p,nom}$ 43.774 mm | m 7.996

For a single edge stiffener, Equation (5.13c)

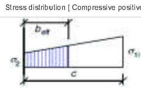
$b_{p,c} / b_p$ 0.381 → k_σ 0.582

(1) $\bar{\lambda}_p$ 0.430 → $\rho_{OPTION (1)}$ 1.000

(2) $\bar{\lambda}_d$ 0.385 → $\rho_{OPTION (2)}$ 1.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

[EN 1993-1-5, Equation (4.3)] $\rho \leq 1.000$ → OK

Stress distribution [Compressive positive]	Effective^p width b_{eff}	
	$1.000 > \psi \geq 0.000$	$b_{eff} = \rho * c$

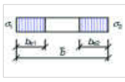
C-Section | Class 1 | $c_{p,1,eff} = \rho * c$ | 16.774 | [mm]

Inferior Flange [$b_{p,1,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Column Nominal Dimension		
$b_{p,1,nom}$	44.048	mm

ε	0.819	
t	2.452	mm



Compression Stress

σ_1	350.000	MPa
σ_2	350.000	MPa

Tension Stress

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

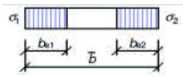
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.386 → ρ 1.000

$\bar{\lambda}_p$ 0.386

ρ 1.000 Effective width equal to gross width

[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive]	Effective^p width b_{eff}		
	ψ = 1.000	$b_{eff} = \rho * b^{¨}$	$b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

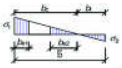
ρ ≤ 1.000	OK	C-Section	Class 1	$b_{p,1,eff} = \rho * b^{¨}$	44.048	[mm]

$b_{p,1,eff,1}$	22.024	[mm]	$b_{p,1,eff,2}$	22.024	[mm]

Web [$h_{p,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Column Nominal Dimension					
$h_{p,nom}$	87.548	mm	ε	0.819	
			t	2.452	mm



Compression Stress		
σ_1	350.000	MPa
Tension Stress		
σ_2	-350.000	MPa

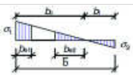
Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.314 → ρ 1.000

$\bar{\lambda}_p$	0.314	ρ	1.000	Effective width equal to gross width	
		[EN 1993-1-5, Equation (4.2)]	[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive]	Effective^p width b_{eff}		
	ψ < 0.000	$b_{eff} = \rho * b_c = \rho * [b^{¨} / (1 - \psi)]$	$b_{e,1} = 0.400 * b_{eff}$
		$b_t = b^{¨} - b_c = b^{¨} - [b^{¨} / (1 - \psi)]$	$b_{e,2} = 0.600 * b_{eff}$

ρ ≤ 1.000	OK	$h_{p,t} = b^{¨} - b_c = b^{¨} - [b^{¨} / (1 - \psi)]$	43.774	[mm]
ρ ≤ 1.000	OK	$h_{p,eff} = \rho * b_c = \rho * [b^{¨} / (1 - \psi)]$	43.774	[mm]

$h_{p,eff,1}$	17.510	[mm]	$h_{p,eff,2}$	26.264	[mm]

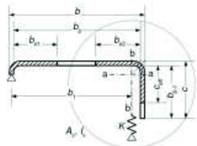
[iii] Plane elements with edge stiffeners [Distortional Buckling] **[EN 1993-1-3:2006, 5.5.1(5)]**

- **Plane elements with edge stiffeners** **[EN 1993-1-3:2006, 5.5.3.2]**

[a] Actual system

→

[b] Equivalent system



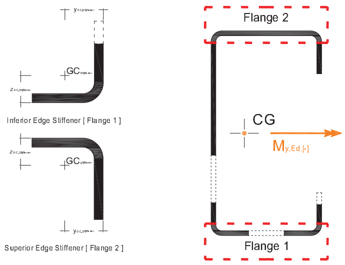
Single Edge Stiffener [EN 1993-1-3, Figure 5.7]

[EN 1993-1-3, 5.5.3.2(1)]	
b / t ≤ 60	OK
45° ≤ Ø	OK
Ø ≤ 135	OK

[EN 1993-1-3, 5.5.3.2(6)]

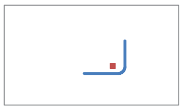
Round corners were considered in the effective cross-section area of the edge stiffener, A_s

- **Determination of Spring Stiffness [K]** **[EN 1993-1-3:2006, 5.5.3.2(5)]**



Inferior Edge Stiffener [Flange 1]

Superior Edge Stiffener [Flange 2]



$A_{s,1}$	96.559	[mm^2]
b_1	38.465	[mm]
$y_{GC,Stiffener}$	8.035	[mm]
$z_{GC,Stiffener}$	5.304	[mm]

Inferior Edge Stiffener [Flange 1] Compression

Superior Flange [$b_{p,2,nom}$] → Tension

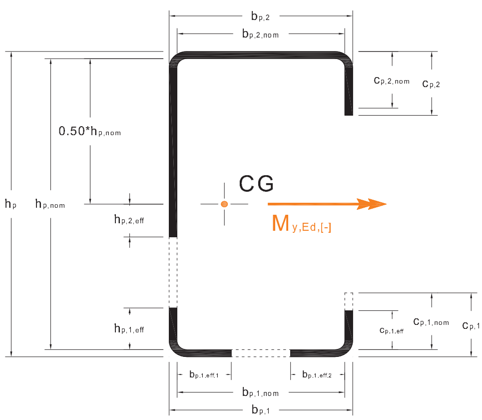
NOTE Effective width is equal to the real width

Superior Edge Stiffener [$c_{p,2,nom}$] → Tension

NOTE Effective width is equal to the real width

[ii] Effective C-Section Column [Local Buckling] **[EN 1993-1-5:2006, 4.3]**

Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	16.774	[mm]
Inferior Flange	$b_{p,1,eff}$	44.048	[mm]
Web	$h_{p,eff}$	43.774	[mm]
Superior Flange	$b_{p,2,eff}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]



Effective Cross C-Section [Bending Moment $M_{y,Ed}$$^-$]

$A_{s,2}$	0.000	[mm^2]
b_2	0.000	[mm]
$y_{GC,Stiffener}$	0.000	[mm]
$z_{GC,Stiffener}$	0.000	[mm]

Superior Edge Stiffener [Flange 2] Tension

$$K_1 = \frac{E t^3}{4(1-\nu^2)} \cdot \frac{1}{b_1^2 h_w + b_1^3 + 0.5 b_1 b_2 h_w k_f}$$

[EN 1993-1-3, Equation 5.10b]

$k_f = 0$	Flange 2 in Tension
$k_f = \frac{A_{s2}}{A_{s1}}$	Flange 2 in Compression

E	210.000	[GPa]	t	2.452	[mm]
ν	0.300		b_1	38.465	[mm]
h_w = h	90.000	[mm]	b_2	0.000	[mm]
K_f	0.000				

K	4.475	[EN 1993-1-3, Equation 5.10b]

- **Determination of Elastic Critical Buckling Stress [$\sigma_{cr,s}$]** **[EN 1993-1-3:2006, 5.5.3.2(7)]**

$$\sigma_{cr,s} = \frac{2\sqrt{K E I_s}}{A_s}$$

[EN 1993-1-3, Equation 5.15]

K	4.475	
E	210.000	[GPa]
$I_{s,Stiffener,1}$	3057.998	[mm^4]
$A_{s,1}$	96.559	[mm^2]

Elastic Critical Buckling Stress, $\sigma_{cr,s}$, for edge stiffener 1 1110.333 [MPa]

- **Relative Distortional Slenderness [$\bar{\lambda}_d$]** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

$$\bar{\lambda}_d = \sqrt{f_{yb}/\sigma_{cr,s}}$$

[EN 1993-1-3, Equation 5.12d]

f_{yb} 350.000 [MPa]

Edge Stiffener 1 $\bar{\lambda}_d$ 0.561

- **Reduction X_d Distortional Buckling Resistance [Stiffener Flexural Buckling]** **[EN 1993-1-3:2006, 5.5.3.1(7)]**

Edge Stiffener 1 $\bar{\lambda}_d$ 0.561 $X_{d,Stiffener,1}$ 1.000 [EN 1993-1-3, Equation 5.12a]

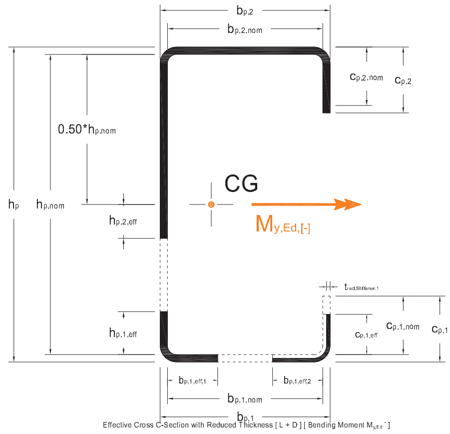
- **Edge Stiffener Reduced Thickness** **[EN 1993-1-3:2006, 5.5.3.2(12)]**

In effective section properties, reduced effective area is represented using a reduced thickness for all elements in A_s

Edge Stiffener 1		
$t_{red,Stiffener,1}$	2.452	[mm]

[iv] **Effective C-Section Column with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

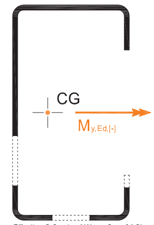
Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	16.774	[mm]
Inferior Flange	$b_{p,1,eff,1}$	22.024	[mm]
	$b_{p,1,eff,2}$	22.024	[mm]
Web	$h_{p,eff,1}$	17.510	[mm]
	$h_{p,eff,2}$	26.264	[mm]
Superior Flange	$b_{p,2,eff,1}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{y,Ed}^{-}$]

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

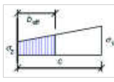
C-Section Classification | **Class 1** → Effective width is equal to the actual width



Effective C-Section [Worst Case] [Class 4]

Inferior Edge Stiffener [$c_{p,1,nom}$] → Class 1

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]



Compression Stress		
σ_1	350.000	MPa
σ_2	216.281	MPa
Tension Stress		

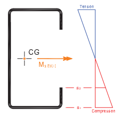
Outstand Compression Elements [EN 1993-1-5, Table 4.2]

$\psi = \sigma_2 / \sigma_1$	→	ψ	0.618
σ_1 Free Point	→	k_σ	0.467

C-Section Strut Nominal Dimension		
$b_{p,1,nom}$	38.548	mm
$c_{p,1,nom}$	9.274	mm

ε	0.819	
t	1.452	mm

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]



Stress Distribution

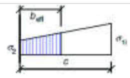
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$0.50^*h_{p,nom}$	24.274	mm	m	14.419

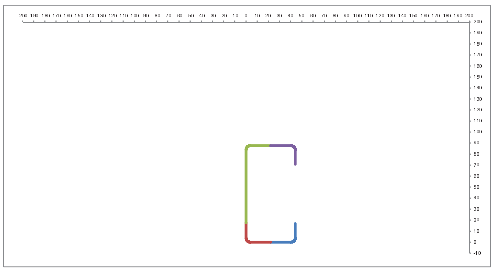
For a single edge stiffener, Equation (5.13b)

	$b_{p,c} / b_p$	0.241	→ k_σ	0.500
(1)	$\bar{\lambda}_p$	0.402	→ $\rho_{OPTION\,(1)}$	1.000
(2)	$\bar{\lambda}_d$	0.388	→ $\rho_{OPTION\,(2)}$	1.000

[EN 1993-1-5, Equation (4.3)] $\rho \le 1.000$ → OK

Stress distribution [Compressive positive]	Effective[P] width b_{eff}	
	$1.000 > \psi \ge 0.000$	$b_{eff} = \rho * c$

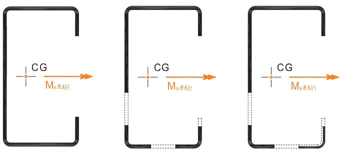
C-Section	Class 1	$c_{p,1,eff} = \rho * c$	9.274	[mm]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{y,Ed}^{-}$]

$I_{Y,eff}^{[-]}$ 625036.020 [mm⁴]

[d] C-Section Strut



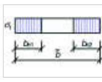
Gross C-Section	Effective C-Section [L]	Effective C-Section [L + D]
	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

Inferior Flange [$b_{p,1,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Strut Nominal Dimension		
$b_{p,1,nom}$	38.548	mm

ε	0.819	
t	1.452	mm



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Internal Compression Elements [EN 1993-1-5, Table 4.1]

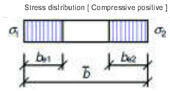
$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.570 → ρ 1.000

$\bar{\lambda}_p$ 0.570

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] $[3 + \psi] \ge 0$ → OK

Stress distribution [Compressive positive]	Effective[P] width b_{eff}		
	$\psi = 1.000$	$b_{eff} = \rho * \bar{b}$	$b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

$\rho \le 1.000$	OK	C-Section	Class 1	$b_{p,1,eff} = \rho * \bar{b}$	38.548	[mm]

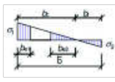
$b_{p,1,eff,1}$	19.274	[mm]	$b_{p,1,eff,2}$	19.274	[mm]

Web [$h_{p,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Strut Nominal Dimension		
$h_{p,nom}$	48.548	mm

ε	0.819	
t	1.452	mm



Compression Stress		
σ_1	350.000	MPa
Tension Stress		
σ_2	-350.000	MPa

Internal Compression Elements [EN 1993-1-5, Table 4.1]

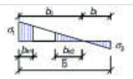
$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.294 → ρ 1.000

$\bar{\lambda}_p$ 0.294

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective^p width b_{eff}



ψ < 0.000
$b_{eff} = \rho * b_c = \rho * [\,b' / (1 - \psi)\,]$ $b_{e1} = 0.400 * b_{eff}$
$b_t = b' - b_c = b' - [\,b' / (1 - \psi)\,]$ $b_{e2} = 0.600 * b_{eff}$

ρ ≤ 1.000	OK	$h_{p,t} = b' - b_c = b' - [\,b' / (1 - \psi)\,]$	24.274	[mm]
ρ ≤ 1.000	OK	$h_{p,eff} = \rho * b_c = \rho * [\,b' / (1 - \psi)\,]$	24.274	[mm]

$h_{p,eff,1}$ 9.710 [mm] $h_{p,eff,2}$ 14.564 [mm]

Superior Flange [$b_{p,2,nom}$] → Tension

NOTE Effective width is equal to the real width

Superior Edge Stiffener [$c_{p,2,nom}$] → Tension

NOTE Effective width is equal to the real width

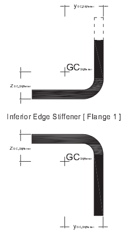
[ii] **Effective C-Section Strut [Local Buckling]** [EN 1993-1-5:2006, 4.3]

Effective C-Section Strut Widths

Inferior Edge Stiffener	$c_{p,1,eff}$	9.274	[mm]
Inferior Flange	$b_{p,1,eff}$	38.548	[mm]
Web	$h_{p,eff}$	24.274	[mm]
Superior Flange	$b_{p,2,eff}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]

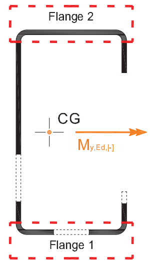
Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode | References: EN 1990 | EN 1991 | EN 1993
Version: 1.000
Office: ---- | Author: JOSÉ ANTÓNIO
Date: 05/09/2019 | Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

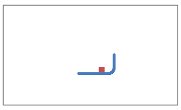
• **Determination of Spring Stiffness [K]** [EN 1993-1-3:2006, 5.5.3.2(5)]



Inferior Edge Stiffener [Flange 1]

Superior Edge Stiffener [Flange 2]





$A_{s,1}$	42.183	[mm²]
b_1	32.213	[mm]
$y_{GC,Stiffener}$	7.787	[mm]
$z_{GC,Stiffener}$	2.549	[mm]

Inferior Edge Stiffener [Flange 1] Compression

$A_{s,2}$	0.000	[mm²]
b_2	0.000	[mm]
$y_{GC,Stiffener}$	0.000	[mm]
$z_{GC,Stiffener}$	0.000	[mm]

Superior Edge Stiffener [Flange 2] Tension

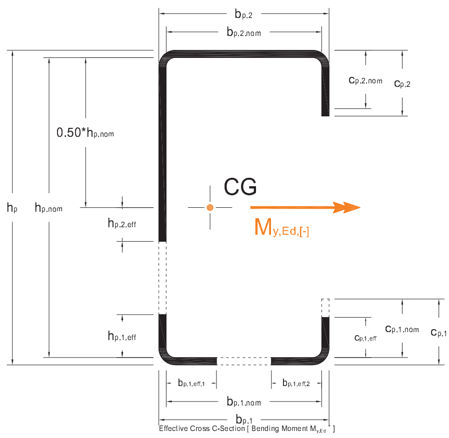
$$K_1 = \frac{E t^3}{4(1-\nu^2)} \cdot \frac{1}{b_1^2 h_w + b_1^3 + 0.5 b_1 b_2 h_w k_f}$$
[EN 1993-1-3, Equation 5.10b]

$k_f = 0$ Flange 2 in Tension
$k_f = \frac{A_{s2}}{A_{s1}}$ Flange 2 in Compression

E	210.000	[GPa]	t	1.452	[mm]
ν	0.300		b_1	32.213	[mm]
$h_w = h$	50.000	[mm]	b_2	0.000	[mm]
K_f	0.000				

K 2.070 [EN 1993-1-3, Equation 5.10b]

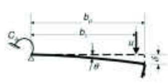
Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode | References: EN 1990 | EN 1991 | EN 1993
Version: 1.000
Office: ---- | Author: JOSÉ ANTÓNIO
Date: 05/09/2019 | Project: MASTER THESIS
Client: COIMBRA UNIVERSITY



Effective Cross C-Section [Bending Moment $M_{y,Ed}$]

[iii] **Plane elements with edge stiffeners [Distortional Buckling]** [EN 1993-1-3:2006, 5.5.1(5)]

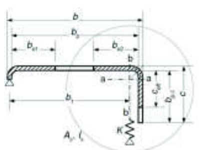
• **Plane elements with edge stiffeners** [EN 1993-1-3:2006, 5.5.3.2]



[a] Actual system

→

[b] Equivalent system



Single Edge Stiffener [EN 1993-1-3, Figure 5.7]

[EN 1993-1-3, 5.5.3.2(1)]

b / t ≤ 60	OK
45° ≤ Ø	OK
Ø ≤ 135	OK

[EN 1993-1-3, 5.5.3.2(6)]

Round corners were considered in the effective cross-section area of the edge stiffener, A_s

Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode | References: EN 1990 | EN 1991 | EN 1993
Version: 1.000
Office: ---- | Author: JOSÉ ANTÓNIO
Date: 05/09/2019 | Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

• **Determination of Elastic Critical Buckling Stress [$\sigma_{cr,s}$]** [EN 1993-1-3:2006, 5.5.3.2(7)]

$$\sigma_{cr,s} = \frac{2\sqrt{K E I_s}}{A_s}$$
[EN 1993-1-3, Equation 5.15]

K	2.070	
E	210.000	[GPa]
$I_{s,Stiffener,1}$	377.466	[mm⁴]
$A_{s,1}$	42.183	[mm²]

Elastic Critical Buckling Stress, $\sigma_{cr,s}$, for edge stiffener 1 607.375 [MPa]

• **Relative Distortional Slenderness [$\bar{\lambda}_d$]** [EN 1993-1-3:2006, 5.5.3.1(7)]

$$\bar{\lambda}_d = \sqrt{f_{yb} / \sigma_{cr,s}}$$
[EN 1993-1-3, Equation 5.12d]

f_{yb} 350.000 [MPa]
Edge Stiffener 1 $\bar{\lambda}_d$ 0.759

• **Reduction X_d Distortional Buckling Resistance [Stiffener Flexural Buckling]** [EN 1993-1-3:2006, 5.5.3.1(7)]

Edge Stiffener 1 $\bar{\lambda}_d$ 0.759 $X_{d,Stiffener,1}$ 0.921 [EN 1993-1-3, Equation 5.12b]

• **Edge Stiffener Reduced Thickness** [EN 1993-1-3:2006, 5.5.3.2(12)]

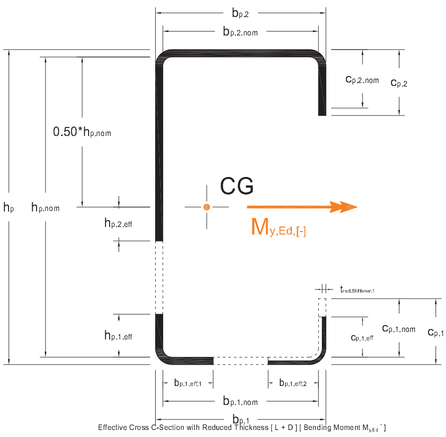
In effective section properties, reduced effective area is represented using a reduced thickness for all elements in A_s

Edge Stiffener 1
$t_{red,Stiffener,1}$ 1.338 [mm]

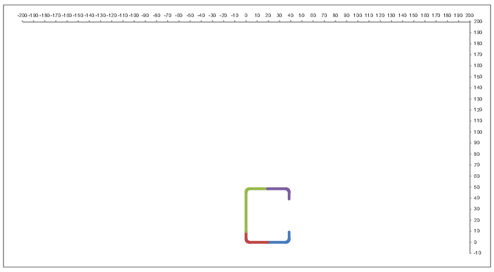
[iv] **Effective C-Section Strut with Reduced Thickness [Local + Distortional Buckling]** [EN 1993-1-5:2006, 5.5]

Effective C-Section Strut Widths

Inferior Edge Stiffener	$c_{p,1,eff}$	9.274	[mm]
Inferior Flange	$b_{p,1,eff,1}$	19.274	[mm]
	$b_{p,1,eff,2}$	19.274	[mm]
Web	$h_{p,eff,1}$	9.710	[mm]
	$h_{p,eff,2}$	14.564	[mm]
Superior Flange	$b_{p,2,eff,1}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{y,Ed}^{-}$]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{y,Ed}^{-}$]

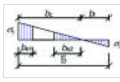
$I_{y,eff}^{[-]}$ 83790.577 [mm^4]

Superior Flange [$b_{p,Nom,Sup. Flange}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension

$b_{p,Nom,Sup. Flange}$ 41.393 mm | ε 0.819 | t 0.952 mm



Compression Stress
σ_1 350.000 MPa
Tension Stress
σ_2 -350.000 MPa

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

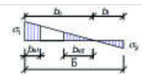
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.382 → ρ 1.000

$\bar{\lambda}_p$ 0.382

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective^p width b_{eff}



ψ < 0.000
$b_{eff} = \rho * b_c = \rho * [b^{¨} / (1 - \psi)]$ $b_{e,1} = 0.400 * b_{eff}$
$b_t = b^{¨} - b_c = b^{¨} - [b^{¨} / (1 - \psi)]$ $b_{e,2} = 0.600 * b_{eff}$

ρ ≤ 1.000 OK $b_{p,Sup. Flange,t} = b^{¨} - b_c = b^{¨} - [b^{¨} / (1 - \psi)]$ 20.697 [mm]

ρ ≤ 1.000 OK $b_{p,Sup. Flange,eff} = \rho * b_c = \rho * [b^{¨} / (1 - \psi)]$ 20.697 [mm]

$b_{p,Sup. Flange,1}$ 8.279 [mm] $b_{p,Sup. Flange,2}$ 12.418 [mm]

Left Web [$h_{p,Nom,Left Web}$] → Class 4

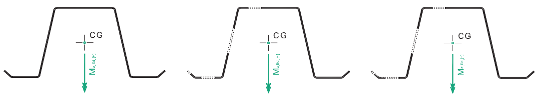
Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension

$h_{p,Nom,Left Web}$ 54.863 mm | ε 0.819 | t 0.952 mm

[11.5] Cold-Formed Section subjected to Positive Moment in z-z axis [$M_{z,Ed}^{+}$]

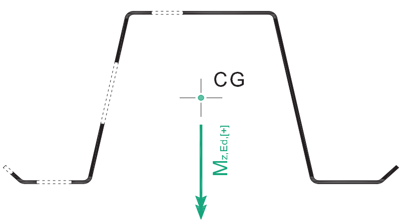
[a] Ω-Section Purlin



Gross Ω-Section	Effective Ω-Section [L]	Effective Ω-Section [L + D]
	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

[i] Determination of the Effective Width [Local Buckling] [EN 1993-1-3:2006, 5.5]

Ω-Section Classification | Class 4 → Effective width must be calculated



Effective Ω-Section [Worst Case] [Class 4]

Right Edge Stiffner [$c_{p,Nom,Right Ed.}$] → Tension

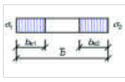
NOTE Effective width is equal to the real width

Inferior Right Flange [$b_{p,Nom,Inf. Right Flange}$] → Tension

NOTE Effective width is equal to the real width

Right Web [$h_{p,Nom,Right Web}$] → Tension

NOTE Effective width is equal to the real width



Compression Stress
σ_1 350.000 MPa
σ_2 350.000 MPa
Tension Stress

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

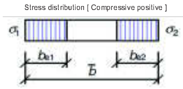
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 1.238 → ρ 0.664

$\bar{\lambda}_p$ 1.238

ρ 0.664 Gross width will be reduced
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective^p width b_{eff}



ψ = 1.000 $b_{eff} = \rho * b^{¨}$ $b_{e,1} = 0.500 * b_{eff}$ $b_{e,2} = 0.500 * b_{eff}$

ρ ≤ 1.000 OK Ω-Section Class 4 $h_{p,Left Web,eff} = \rho * b^{¨}$ 36.436 [mm]

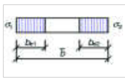
$h_{p,Left Web,eff,1}$ 18.218 [mm] $h_{p,Left Web,eff,2}$ 18.218 [mm]

Inferior Left Flange [$b_{p,Nom,Inf. Left Flange}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension

$b_{p,Nom,Inf. Left Flange}$ 18.975 mm | ε 0.819 | t 0.952 mm



Compression Stress
σ_1 350.000 MPa
σ_2 350.000 MPa
Tension Stress

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

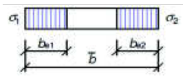
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$	0.428	→	ρ	1.000

$\bar{\lambda}_p$	0.428

ρ	1.000	Effective width equal to gross width	
[EN 1993-1-5, Equation (4.2)]	[3 + ψ] ≥ 0	→	OK

Stress distribution [Compressive positive] | Effective[p] width b_{eff}



ψ = 1.000 $b_{eff} = \rho * \bar{b}$

$b_{eff,1} = 0.500 * b_{eff}$

$b_{eff,2} = 0.500 * b_{eff}$

ρ ≤ 1.000	OK	Ω-Section	Class 1	$b_{p,Inf.\ Left\ Flange,eff} = \rho * \bar{b}$	18.975	[mm]

$b_{p,Inf.\ Left\ Flange,eff,1}$	9.488	[mm]	$b_{p,Inf.\ Left\ Flange,eff,2}$	9.488	[mm]

Left Edge Stiffener [$c_{p,Nom,Left\ Lip}$] → Class 1

OPTION [2] Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

Ω-Section Purlin Nominal Dimension		
$c_{p,Nom,Left\ Lip}$	7.010	mm
$b_{p,Nom,Inf.\ Left\ Flange}$	18.975	mm

ε	0.819	
t	0.952	mm

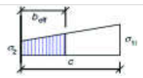
For a single edge stiffener, Equation (5.13c)

$b_{p,c} / b_p$	0.369	→	k_σ	0.560

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}} \quad (2)$$

$\bar{\lambda}_d$	0.423	→	$\rho_{OPTION\ (2)}$	1.000

Stress distribution [Compressive positive] | Effective[p] width b_{eff}

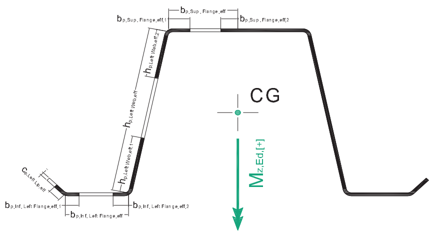


1.000 > ψ ≥ 0.000 $b_{eff} = \rho * c$

Ω-Section	Class 1	$c_{p,Left\ Lip,eff} = \rho * c$	7.010	[mm]

[ii] **Effective Ω-Section Purlin [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

Effective Ω-Section Purlin Widths			
Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	----	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff}$	----	[mm]
Right Web	$h_{p,Right\ Web,eff}$	----	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff}$	20.697	[mm]
Left Web	$h_{p,Left\ Web,eff}$	36.436	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff}$	18.975	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	7.010	[mm]



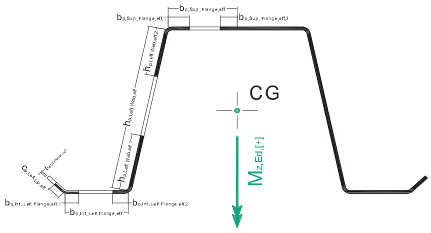
Effective Ω-Section Purlin [Positive Moment in z-z axis, $M_{z,Ed}^+$]

[iii] **Plane elements with edge stiffeners [Distortional Buckling]** **[EN 1993-1-3:2006, 5.5.1(5)]**

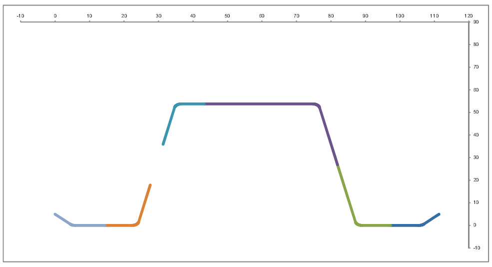
NOTE Distortional buckling effects were not considered for this type of structure

[iv] **Effective Cross Ω-Section Purlin with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

Effective Ω-Section Purlin Widths			
Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	----	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff}$	----	[mm]
Right Web	$h_{p,Right\ Web,eff,1}$	----	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff,1}$	8.279	[mm]
	$b_{p,Sup.\ Flange,eff,2}$	12.418	[mm]
Left Web	$h_{p,Left\ Web,eff,1}$	18.218	[mm]
	$h_{p,Left\ Web,eff,2}$	18.218	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff,1}$	9.488	[mm]
	$b_{p,Inf.\ Left\ Flange,eff,2}$	9.488	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	7.010	[mm]



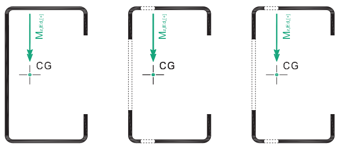
Effective Ω-Section Purlin with Reduced Thickness [L + D] [Positive Moment in z-z axis, $M_{z,Ed}^+$]



Effective Ω-Section Purlin with Reduced Thickness [L + D] [Positive Moment in z-z axis, $M_{z,Ed}^+$]

$I_{z,eff}^{[+]}$	163614.967	[mm^4]

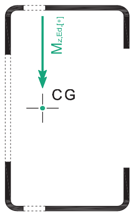
[b] C-Section Beam



Gross C-Section	Effective C-Section [L]	Effective C-Section [L + D]
	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

C-Section Classification | **Class 4** → Effective width must be calculated



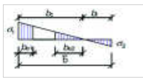
Effective C-Section [Worst Case] [Class 4]

Inferior Edge Stiffener [$c_{p,1,nom}$] → Tension

NOTE Effective width is equal to the real width

Inferior Flange [$b_{p,1,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]



Compression Stress
σ_1 350.000 MPa
Tension Stress
σ_2 -350.000 MPa

C-Section Beam Nominal Dimension				ε	0.819	
$b_{p,1,nom}$	45.048	mm		t	1.452	mm

Internal Compression Elements [EN 1993-1-5, Table 4.1]

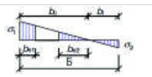
$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.273 → ρ 1.000

$\bar{\lambda}_p$ 0.273

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective^p width b_{eff}



ψ < 0.000
$b_{eff} = \rho * b_c = \rho * [b¨ / (1 - \psi)]$ $b_{e,1} = 0.400 * b_{eff}$
$b_t = b¨ - b_c = b¨ - [b¨ / (1 - \psi)]$ $b_{e,2} = 0.600 * b_{eff}$

ρ ≤ 1.000	OK	$b_{p,1,t} = b¨ - b_c = b¨ - [b¨ / (1 - \psi)]$	22.524	[mm]
ρ ≤ 1.000	OK	$b_{p,1,eff} = \rho * b_c = \rho * [b¨ / (1 - \psi)]$	22.524	[mm]

$b_{p,1,eff,1}$	9.010	[mm]	$b_{p,1,eff,2}$	13.514	[mm]

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Internal Compression Elements [EN 1993-1-5, Table 4.1]

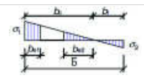
$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.273 → ρ 1.000

$\bar{\lambda}_p$ 0.273

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective^p width b_{eff}



ψ < 0.000
$b_{eff} = \rho * b_c = \rho * [b¨ / (1 - \psi)]$ $b_{e,1} = 0.400 * b_{eff}$
$b_t = b¨ - b_c = b¨ - [b¨ / (1 - \psi)]$ $b_{e,2} = 0.600 * b_{eff}$

ρ ≤ 1.000	OK	$b_{p,2,t} = b¨ - b_c = b¨ - [b¨ / (1 - \psi)]$	22.524	[mm]
ρ ≤ 1.000	OK	$b_{p,2,eff} = \rho * b_c = \rho * [b¨ / (1 - \psi)]$	22.524	[mm]

$b_{p,2,eff,1}$	9.010	[mm]	$b_{p,2,eff,2}$	13.514	[mm]

Superior Edge Stiffener [$c_{p,2,nom}$] → Tension

NOTE Effective width is equal to the real width

[ii] **Effective C-Section Beam [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

Effective C-Section Beam Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	22.524	[mm]
Web	$h_{p,eff}$	59.104	[mm]
Superior Flange	$b_{p,2,eff}$	22.524	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]

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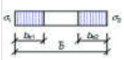
Web [$h_{p,nom}$] → Class 4

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension				ε	0.819	
$h_{p,nom}$	118.548	mm		t	1.452	mm



Compression Stress
σ_1 350.000 MPa
σ_2 350.000 MPa
Tension Stress

Internal Compression Elements [EN 1993-1-5, Table 4.1]

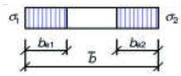
$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 1.754 → ρ 0.499

$\bar{\lambda}_p$ 1.754

ρ 0.499 Gross width will be reduced
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective^p width b_{eff}



ψ = 1.000 $b_{eff} = \rho * b¨$
$b_{eff,1} = 0.500 * b_{eff}$
$b_{eff,2} = 0.500 * b_{eff}$

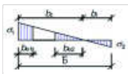
ρ ≤ 1.000	OK	C-Section	Class 4	$h_{p,eff} = \rho * b¨$	59.104	[mm]

$h_{p,eff,1}$	29.552	[mm]	$h_{p,eff,2}$	29.552	[mm]

Superior Flange [$b_{p,2,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension				ε	0.819	
$b_{p,2,nom}$	45.048	mm		t	1.452	mm



Compression Stress
σ_1 350.000 MPa
Tension Stress
σ_2 -350.000 MPa

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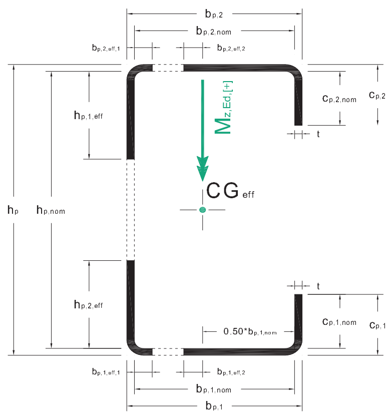


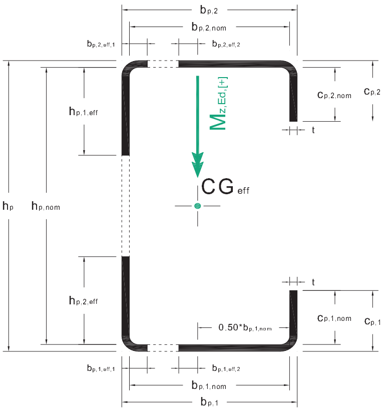
Effective Cross C-Section [Bending Moment $M_{z,Ed}^{+}$]

[iii] **Plane elements with edge stiffeners [Distortional Buckling]** **[EN 1993-1-3:2006, 5.5.1(5)]**

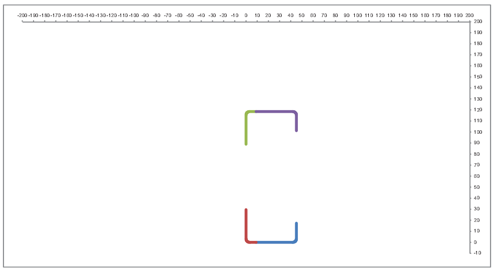
NOTE Inferior/Superior Flanges are both in tension/compression stress, so there isn't any reducing because of the distortional buckling in edge stiffeners.

[iv] **Effective C-Section Beam with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

Effective C-Section Beam Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff,1}$	9.010	[mm]
	$b_{p,1,eff,2}$	13.514	[mm]
Web	$h_{p,eff,1}$	29.552	[mm]
	$h_{p,eff,2}$	29.552	[mm]
Superior Flange	$b_{p,2,eff,1}$	9.010	[mm]
	$b_{p,2,eff,2}$	13.514	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{z,Ed}$ +]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{z,Ed}$ +]

$I_{z,eff}$ [+] 84344.150 [mm^4]

Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
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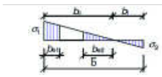
$\bar{\lambda}_p$	0.158	ρ 1.000	Effective width equal to gross width
		[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 →	OK

Stress distribution [Compressive positive] — Effective[p] width b_{eff}



ψ < 0.000 — $b_{eff} = \rho \cdot b_c = \rho \cdot \bar{b} / (1 - \psi)$ — $b_{e1} = 0.400 \cdot b_{eff}$

$b_t = \bar{b} - b_c = \bar{b} - [\bar{b} / (1 - \psi)]$ — $b_{e2} = 0.600 \cdot b_{eff}$

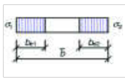
ρ ≤ 1.000	OK	$b_{h,t,f} = \bar{b} - b_c = \bar{b} - [\bar{b} / (1 - \psi)]$	22.024	[mm]
ρ ≤ 1.000	OK	$b_{h,1,eff} = \rho \cdot b_c = \rho \cdot [\bar{b} / (1 - \psi)]$	22.024	[mm]
$b_{h,1,eff,1}$ 8.810 [mm]		$b_{h,1,eff,2}$	13.214	[mm]

Web [$h_{p,nom}$] → Class 4

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Column Nominal Dimension

$h_{p,nom}$	87.548	mm	ε	0.819	
			t	2.452	mm



Compression Stress
σ_1 350.000 MPa
σ_2 350.000 MPa
Tension Stress

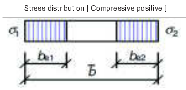
Internal Compression Elements [EN 1993-1-5, Table 4.1]

ψ = σ_2 / σ_1 → ψ 1.000 → k_σ 4.000

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.767 → ρ 0.930

$\bar{\lambda}_p$	0.767	ρ 0.930	Gross width will be reduced
		[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 →	OK

Stress distribution [Compressive positive] — Effective[p] width b_{eff}



ψ = 1.000 — $b_{eff} = \rho \cdot \bar{b}$ — $b_{e1} = 0.500 \cdot b_{eff}$ — $b_{e2} = 0.500 \cdot b_{eff}$

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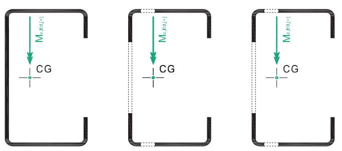
[c] C-Section Column

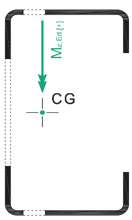


Gross C-Section — Effective C-Section [L] — Effective C-Section [L + D]

Local Buckling (EN 1993-1-5) — Local + Distortional Buckling (EN 1993-1-3)

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

C-Section Classification — **Class 4** → Effective width must be calculated



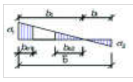
Effective C-Section [Worst Case] [Class 4]

Inferior Edge Stiffener [$c_{p,1,nom}$] → Tension

NOTE — Effective width is equal to the real width

Inferior Flange [$b_{p,1,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]



Compression Stress
σ_1 350.000 MPa
Tension Stress
σ_2 -350.000 MPa

C-Section Column Nominal Dimension

$b_{p,1,nom}$	44.048	mm	ε	0.819	
			t	2.452	mm

Internal Compression Elements [EN 1993-1-5, Table 4.1]

ψ = σ_2 / σ_1 → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.158 → ρ 1.000

Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
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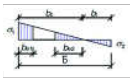
ρ ≤ 1.000	OK	C-Section	Class 4	$h_{p,eff} = \rho \cdot \bar{b}$	81.394	[mm]
$h_{p,eff,1}$	40.697	[mm]	$h_{p,eff,2}$	40.697	[mm]	

Superior Flange [$b_{p,2,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Column Nominal Dimension

$b_{p,2,nom}$	44.048	mm	ε	0.819	
			t	2.452	mm



Compression Stress
σ_1 350.000 MPa
Tension Stress
σ_2 -350.000 MPa

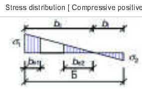
Internal Compression Elements [EN 1993-1-5, Table 4.1]

ψ = σ_2 / σ_1 → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.158 → ρ 1.000

$\bar{\lambda}_p$	0.158	ρ 1.000	Effective width equal to gross width
		[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 →	OK

Stress distribution [Compressive positive] — Effective[p] width b_{eff}



ψ < 0.000 — $b_{eff} = \rho \cdot b_c = \rho \cdot \bar{b} / (1 - \psi)$ — $b_{e1} = 0.400 \cdot b_{eff}$

$b_t = \bar{b} - b_c = \bar{b} - [\bar{b} / (1 - \psi)]$ — $b_{e2} = 0.600 \cdot b_{eff}$

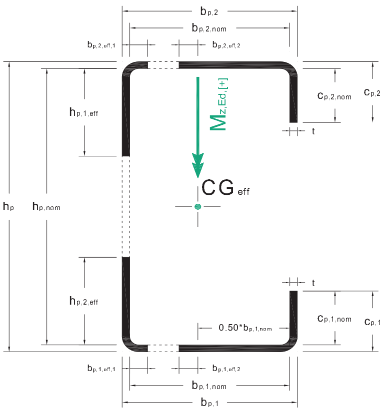
ρ ≤ 1.000	OK	$b_{p,2,t} = \bar{b} - b_c = \bar{b} - [\bar{b} / (1 - \psi)]$	22.024	[mm]
ρ ≤ 1.000	OK	$b_{p,2,eff} = \rho \cdot b_c = \rho \cdot [\bar{b} / (1 - \psi)]$	22.024	[mm]
$b_{p,2,eff,1}$ 8.810 [mm]		$b_{p,2,eff,2}$	13.214	[mm]

Superior Edge Stiffener [$c_{p,2,nom}$] → Tension

NOTE — Effective width is equal to the real width

[ii] Effective C-Section Column [Local Buckling] **[EN 1993-1-5:2006, 4.3]**

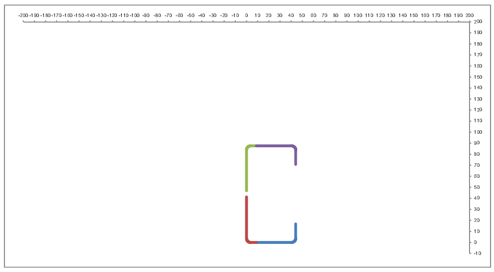
Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	22.024	[mm]
Web	$h_{p,eff}$	81.394	[mm]
Superior Flange	$b_{p,2,eff}$	22.024	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]



Effective Cross C-Section [Bending Moment $M_{z,Ed}^{+}$]

[iii] Plane elements with edge stiffeners [Distortional Buckling] **[EN 1993-1-3:2006, 5.5.1(5)]**

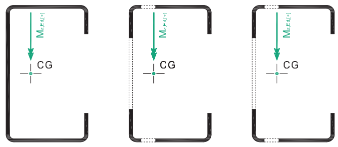
NOTE — Inferior/Superior Flanges are both in tension/compression stress, so there isn't any reducing because of the distortional buckling in edge stiffeners.



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{z,Ed}^{+}$]

$I_{z,eff}^{[+]}$ 150093.116 [mm^4]

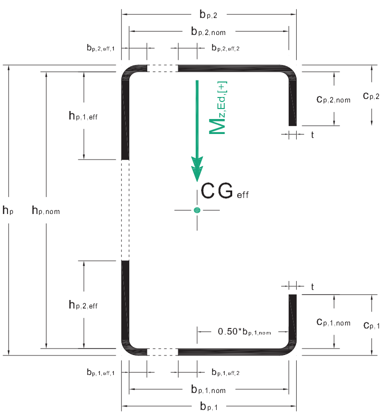
[d] C-Section Strut



Gross C-Section	Effective C-Section [L]	Effective C-Section [L + D]
	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

[iv] Effective C-Section Column / Pile with Reduced Thickness [Local + Distortional Buckling] **[EN 1993-1-5:2006, 5.5]**

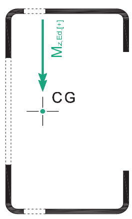
Effective C-Section Column / Pile Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff,1}$	8.810	[mm]
	$b_{p,1,eff,2}$	13.214	[mm]
Web	$h_{p,eff,1}$	40.697	[mm]
	$h_{p,eff,2}$	40.697	[mm]
Superior Flange	$b_{p,2,eff,1}$	8.810	[mm]
	$b_{p,2,eff,2}$	13.214	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{z,Ed}^{+}$]

[i] Determination of the Effective Width [Local Buckling] **[EN 1993-1-3:2006, 5.5]**

C-Section Classification | **Class 3** → Effective width is equal to the actual width



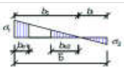
Effective C-Section [Worst Case] [Class 4]

Inferior Edge Stiffener [$c_{p,1,nom}$] → Tension

NOTE — Effective width is equal to the real width

Inferior Flange [$b_{p,1,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]



Compression Stress		
σ_1	350.000	MPa
Tension Stress		
σ_2	-350.000	MPa

C-Section Strut Nominal Dimension		
$b_{p,1,nom}$	38.548	mm

ε	0.819	
t	1.452	mm

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

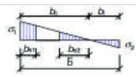
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.233 → ρ 1.000

$\bar{\lambda}_p$ 0.233

ρ 1.000 — Effective width equal to gross width

[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive]	Effective[p] width b_{eff}		
	ψ < 0.000	$b_{eff} = \rho * b_c = \rho * [b^{..} / (1 - \psi)]$	$b_{e,1} = 0.400 * b_{eff}$
		$b_t = b^{..} - b_c = b^{..} - [b^{..} / (1 - \psi)]$	$b_{e,2} = 0.600 * b_{eff}$

ρ ≤ 1.000	OK	$b_{p,1,t} = b^{..} - b_c = b^{..} - [b^{..} / (1 - \psi)]$	19.274	[mm]
ρ ≤ 1.000	OK	$b_{p,1,eff} = \rho * b_c = \rho * [b^{..} / (1 - \psi)]$	19.274	[mm]

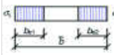
$b_{p,1,eff,1}$	7.710	[mm]	$b_{p,1,eff,2}$	11.564	[mm]

Web [$h_{p,nom}$]	→	Class 3

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Strut Nominal Dimension		
$h_{p,nom}$	48.548	mm

ε	0.819	
t	1.452	mm



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

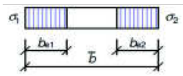
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.718 → ρ 0.966

$\bar{\lambda}_p$ 0.718

ρ 0.966 Gross width will be reduced
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective[p] width b_{eff}



ψ = 1.000 $b_{eff} = \rho * b¨$ $b_{eff,1} = 0.500 * b_{eff}$ $b_{eff,2} = 0.500 * b_{eff}$

ρ ≤ 1.000	OK	C-Section	Class 3	$h_{p,eff} = \rho * b¨$	48.548	[mm]

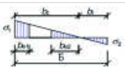
$h_{p,eff,1}$	24.274	[mm]	$h_{p,eff,2}$	24.274	[mm]

Superior Flange [$b_{p,2,nom}$]	→	Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Strut Nominal Dimension		
$b_{p,2,nom}$	38.548	mm

ε	0.819	
t	1.452	mm



Compression Stress		
σ_1	350.000	MPa
Tension Stress		
σ_2	-350.000	MPa

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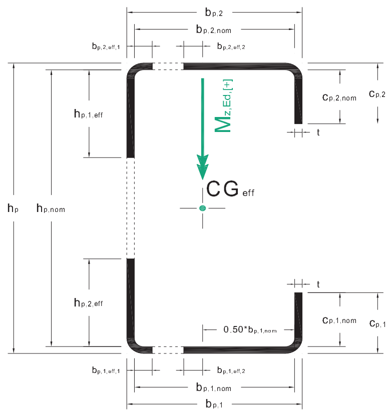

Effective Cross C-Section [Bending Moment $M_{z,Ed}{}^{+}$]

[iii] **Plane elements with edge stiffeners [Distortional Buckling]** **[EN 1993-1-3:2006, 5.5.1(5)]**

NOTE: Inferior/Superior Flanges are both in tension/compression stress, so there isn't any reducing because of the distortional buckling in edge stiffeners.

[iv] **Effective C-Section Strut with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

Effective C-Section Strut Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff,1}$	7.710	[mm]
	$b_{p,1,eff,2}$	11.564	[mm]
Web	$h_{p,eff,1}$	24.274	[mm]
	$h_{p,eff,2}$	24.274	[mm]
Superior Flange	$b_{p,2,eff,1}$	7.710	[mm]
	$b_{p,2,eff,2}$	11.564	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]

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Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

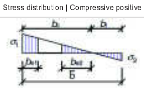
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.233 → ρ 1.000

$\bar{\lambda}_p$ 0.233

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective[p] width b_{eff}



ψ < 0.000
$b_{eff} = \rho * b_c = \rho * [b¨ / (1 - \psi)]$ $b_{e,1} = 0.400 * b_{eff}$
$b_t = b¨ - b_c = b¨ - [b¨ / (1 - \psi)]$ $b_{e,2} = 0.600 * b_{eff}$

ρ ≤ 1.000	OK	$b_{p,2,t} = b¨ - b_c = b¨ - [b¨ / (1 - \psi)]$	19.274	[mm]
ρ ≤ 1.000	OK	$b_{p,2,eff} = \rho * b_c = \rho * [b¨ / (1 - \psi)]$	19.274	[mm]

$b_{p,2,eff,1}$	7.710	[mm]	$b_{p,2,eff,2}$	11.564	[mm]

Superior Edge Stiffener [$c_{p,2,nom}$]	→	Tension

NOTE: Effective width is equal to the real width

[ii] **Effective C-Section Strut [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

Effective C-Section Strut Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	19.274	[mm]
Web	$h_{p,eff}$	48.548	[mm]
Superior Flange	$b_{p,2,eff}$	19.274	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]

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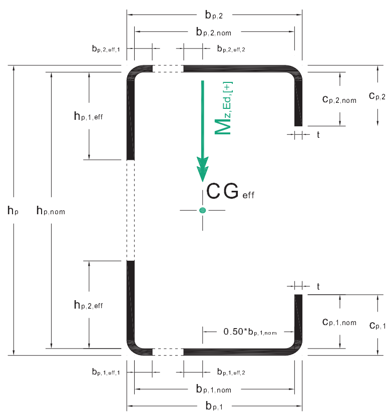
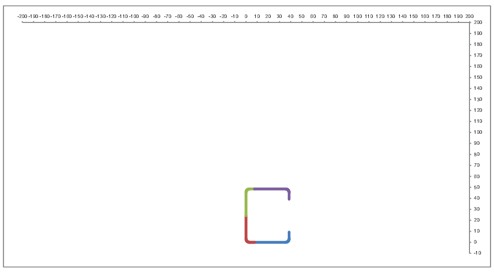


Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{z,Ed}{}^{+}$]

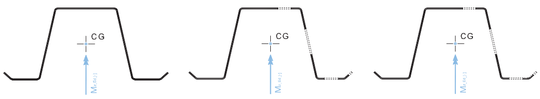


Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{z,Ed}{}^{+}$]

$I_{z,eff}{}^{[+]}$ 44100.416 [mm^4]

[11.6] Cold-Formed Section subjected to Negative Moment in z-z axis [$M_{z.Ed}^{-}$]

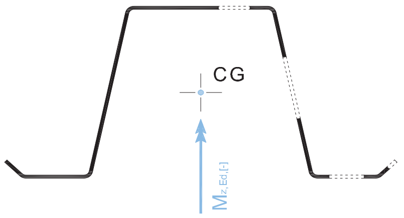
[a] Ω-Section Purlin



Gross Ω-Section | Effective Ω-Section [L] — Local Buckling — EN 1993-1-5 | Effective Ω-Section [L + D] — Local + Distortional Buckling — EN 1993-1-3

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

Ω-Section Classification | **Class 4** → Effective width must be calculated



Effective Ω-Section [Worst Case] [Class 4]

Right Edge Stiffner [$c_{p,Nom,Right\ Lip}$] → Class 1

OPTION [2] Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

Ω-Section Purlin Nominal Dimension		
$c_{p,Nom,Right\ Lip}$	7.010	mm
$b_{p,Nom,Inf.\ Right\ Flange}$	18.975	mm

ε	0.819	
t	0.952	mm

For a single edge stiffener, Equation (5.13c)

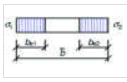
$b_{p,c} / b_p$ 0.369 → k_σ 0.560

Right Web [$h_{p,Nom,Right\ Web}$] → Class 4

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension		
$h_{p,Nom,Right\ Web}$	54.863	mm

ε	0.819	
t	0.952	mm



Compression Stress
σ_1 350.000 MPa
σ_2 350.000 MPa
Tension Stress

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

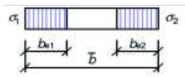
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 1.238 → ρ 0.664

$\bar{\lambda}_p$ 1.238

ρ 0.664 — Gross width will be reduced
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective^{p} width b_{eff}



ψ = 1.000 | $b_{eff} = \rho * \bar{b}$ | $b_{eff,1} = 0.500 * b_{eff}$ | $b_{eff,2} = 0.500 * b_{eff}$

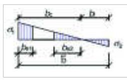
ρ ≤ 1.000	OK	Ω-Section	Class 4	$h_{p,Right\ Web,eff} = \rho * \bar{b}$	36.436	[mm]
$h_{p,Right\ Web,eff,1}$	18.218	[mm]		$h_{p,Right\ Web,eff,2}$	18.218	[mm]

Superior Flange [$b_{p,Nom,Sup.\ Flange}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension		
$b_{p,Nom,Sup.\ Flange}$	41.393	mm

ε	0.819	
t	0.952	mm

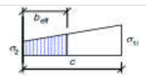


Compression Stress
σ_1 350.000 MPa
Tension Stress
σ_2 -350.000 MPa

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$ (2)

$\bar{\lambda}_d$ 0.423 → $\rho_{OPTION\ (2)}$ 1.000

Stress distribution [Compressive positive] | Effective^{p} width b_{eff}



1.000 > ψ ≥ 0.000 | $b_{eff} = \rho * c$

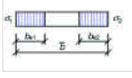
Ω-Section	Class 1	$c_{p,Right\ Lip,eff} = \rho * c$	7.010	[mm]

Inferior Right Flange [$b_{p,Nom,Inf.\ Right\ Flange}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Ω-Section Purlin Nominal Dimension		
$b_{p,Nom,Inf.\ Right\ Flange}$	18.975	mm

ε	0.819	
t	0.952	mm



Compression Stress
σ_1 350.000 MPa
σ_2 350.000 MPa
Tension Stress

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000 → k_σ 4.000

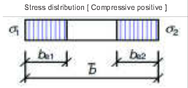
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.428 → ρ 1.000

$\bar{\lambda}_p$ 0.428

ρ 1.000 — Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective^{p} width b_{eff}



ψ = 1.000 | $b_{eff} = \rho * \bar{b}$ | $b_{eff,1} = 0.500 * b_{eff}$ | $b_{eff,2} = 0.500 * b_{eff}$

ρ ≤ 1.000	OK	Ω-Section	Class 1	$b_{p,Inf.\ Right\ Flange,eff} = \rho * \bar{b}$	18.975	[mm]
$b_{p,Inf.\ Right\ Flange,eff,1}$	9.488	[mm]		$b_{p,Inf.\ Right\ Flange,eff,2}$	9.488	[mm]

Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

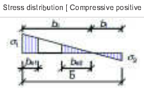
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.382 → ρ 1.000

$\bar{\lambda}_p$ 0.382

ρ 1.000 — Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive] | Effective^{p} width b_{eff}



ψ < 0.000
$b_{eff} = \rho * b_c = \rho * [\, \bar{b} / (1 - \psi) \,]$ | $b_{e,1} = 0.400 * b_{eff}$
$b_t = \bar{b} - b_c = \bar{b} - [\, \bar{b} / (1 - \psi) \,]$ | $b_{e,2} = 0.600 * b_{eff}$

ρ ≤ 1.000	OK	$b_{p,Sup.\ Flange,t} = \bar{b} - b_c = \bar{b} - [\, \bar{b} / (1 - \psi) \,]$	20.697	[mm]
ρ ≤ 1.000	OK	$b_{p,Sup.\ Flange,eff} = \rho * b_c = \rho * [\, \bar{b} / (1 - \psi) \,]$	20.697	[mm]

$b_{p,Sup.\ Flange,1}$	8.279	[mm]	$b_{p,Sup.\ Flange,2}$	12.418	[mm]

Left Web [$h_{p,Nom,Left\ Web}$] → Tension

NOTE — Effective width is equal to the real width

Inferior Left Flange [$b_{p,Nom,Inf.\ Left\ Flange}$] → Tension

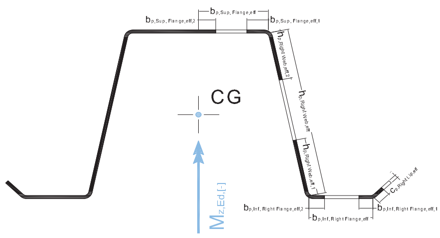
NOTE — Effective width is equal to the real width

Left Edge Stiffener [$c_{p,Nom,Left\ Lip}$] → Tension

NOTE — Effective width is equal to the real width

[ii] **Effective Ω-Section Purlin [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

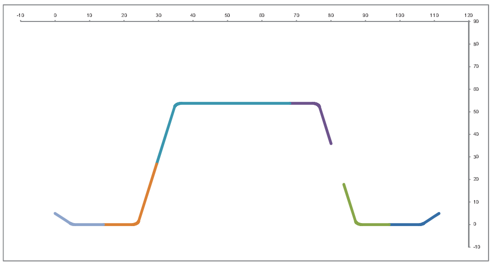
Effective Ω-Section Purlin Widths			
Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	7.010	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff}$	18.975	[mm]
Right Web	$h_{p,Right\ Web,eff}$	36.436	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff}$	20.697	[mm]
Left Web	$h_{p,Left\ Web,eff}$	----	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff}$	----	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	----	[mm]



Effective Ω-Section Purlin [Negative Moment in z-z axis, $M_{z,Ed}^-$]

[iii] **Plane elements with edge stiffeners [Distortional Buckling]** **[EN 1993-1-3:2006, 5.5.1(5)]**

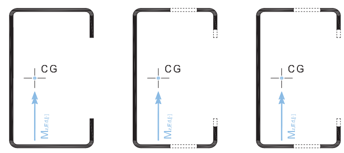
NOTE	Distortional buckling effects were not considered for this type of structure



Effective Ω-Section Purlin with Reduced Thickness [L + D] [Negative Moment in z-z axis, $M_{z,Ed}^-$]

$I_{z,eff}^{(-)}$ 163614.967 [mm^4]

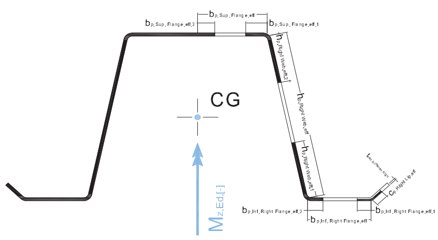
[b] C-Section Beam



Gross C-Section	Effective C-Section [L]	Effective C-Section [L + D]
	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

[iv] **Effective Cross Ω-Section Purlin with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

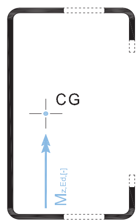
Effective Ω-Section Purlin Widths			
Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	7.010	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff,1}$	9.488	[mm]
	$b_{p,Inf.\ Right\ Flange,eff,2}$	9.488	[mm]
Right Web	$h_{p,Right\ Web,eff,1}$	18.218	[mm]
	$h_{p,Right\ Web,eff,2}$	18.218	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff,1}$	8.279	[mm]
	$b_{p,Sup.\ Flange,eff,2}$	12.418	[mm]
Left Web	$h_{p,Left\ Web,eff,1}$	----	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff,1}$	----	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	----	[mm]



Effective Ω-Section Purlin with Reduced Thickness [L + D] [Negative Moment in z-z axis, $M_{z,Ed}^-$]

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

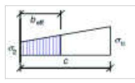
C-Section Classification | **Class 4** → Effective width must be calculated



Effective C-Section [Worst Case] [Class 4]

Inferior Edge Stiffener [$c_{p,1,nom}$] → Class 4

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]



	Compression Stress	
σ_1	350.000	MPa
σ_2	350.000	MPa
	Tension Stress	

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

$\psi = \sigma_2 / \sigma_1$		→	ψ	1.000
σ_1	Free Point	→	k_σ	0.430

C-Section Beam Nominal Dimension		
$b_{p,1,nom}$	45.048	mm
$c_{p,1,nom}$	17.274	mm

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

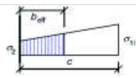
For a single edge stiffener, Equation (5.13c)

$b_{p,c} / b_p$	0.383	→	k_σ	0.586

ε	0.819	t	1.452	mm

(1)	$\bar{\lambda}_p$	0.780	→	$\rho_{OPTION\ (1)}$	0.973
(2)	$\bar{\lambda}_d$	0.668	→	$\rho_{OPTION\ (2)}$	1.000

[EN 1993-1-5, Equation (4.3)]	$\rho \leq 1.000$	→	OK

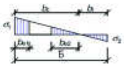
Stress distribution [Compressive positive]	Effective^p width b_{eff}	
	$1.000 > \psi \geq 0.000$	$b_{eff} = \rho * c$

C-Section	Class 4	$c_{p,1,eff} = \rho * c$	17.274	[mm]

Inferior Flange [$b_{p,1,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension						
$b_{p,1,nom}$	45.048	mm		ε	0.819	
				t	1.452	mm



Compression Stress
σ_1 350.000 MPa
Tension Stress
σ_2 -350.000 MPa

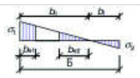
Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.273 → ρ 1.000

$\bar{\lambda}_p$ 0.273

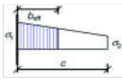
ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive]	Effective^p width b_{eff}		
	$\psi < 0.000$	$b_{eff} = \rho * b_c = \rho * [b¨ / (1 - \psi)]$	$b_{e,1} = 0.400 * b_{eff}$
		$b_t = b¨ - b_c = b¨ - [b¨ / (1 - \psi)]$	$b_{e,2} = 0.600 * b_{eff}$

$\rho \le 1.000$	OK	$b_{p,1,t} = b¨ - b_c = b¨ - [b¨ / (1 - \psi)]$	22.524	[mm]	
$\rho \le 1.000$	OK	$b_{p,1,eff} = \rho * b_c = \rho * [b¨ / (1 - \psi)]$	22.524	[mm]	
$b_{p,1,eff,1}$	9.010	[mm]	$b_{p,1,eff,2}$	13.514	[mm]

Web [$h_{p,nom}$] → Tension

NOTE Effective width is equal to the real width



Compression Stress
σ_1 350.000 MPa
σ_2 350.000 MPa
Tension Stress

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

$\psi = \sigma_2 / \sigma_1$ → ψ 1.000
σ_1 Free Point → k_σ 0.430

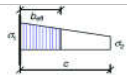
OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

For a single edge stiffener, Equation (5.13c)

$b_{p,c} / b_p$	1.000	→	k_σ	1.123
(1) $\bar{\lambda}_p$	0.780	→	$\rho_{OPTION\,(1)}$	0.973
(2) $\bar{\lambda}_p$	0.482	→	$\rho_{OPTION\,(2)}$	1.000

[EN 1993-1-5, Equation (4.3)] $\rho \le 1.000$ → OK

Stress distribution [Compressive positive]	Effective^p width b_{eff}	
	$1.000 > \psi \ge 0.000$	$b_{eff} = \rho * c$

C-Section | Class 4 | $c_{p,2,eff} = \rho * c$ | 17.274 | [mm]

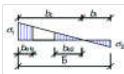
[ii] **Effective C-Section Beam [Local Buckling]** **[EN 1993-1-5:2006, 4.3]**

Effective C-Section Beam Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	17.274	[mm]
Inferior Flange	$b_{p,1,eff}$	22.524	[mm]
Web	$h_{p,eff}$	----	[mm]
Superior Flange	$b_{p,2,eff}$	22.524	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	17.274	[mm]

Superior Flange [$b_{p,2,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension						
$b_{p,2,nom}$	45.048	mm		ε	0.819	
				t	1.452	mm



Compression Stress
σ_1 350.000 MPa
Tension Stress
σ_2 -350.000 MPa

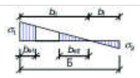
Internal Compression Elements [EN 1993-1-5, Table 4.1]

$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$ $\bar{\lambda}_p$ 0.273 → ρ 1.000

$\bar{\lambda}_p$ 0.273

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

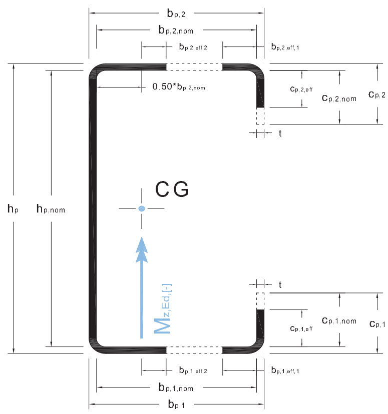
Stress distribution [Compressive positive]	Effective^p width b_{eff}		
	$\psi < 0.000$	$b_{eff} = \rho * b_c = \rho * [b¨ / (1 - \psi)]$	$b_{e,1} = 0.400 * b_{eff}$
		$b_t = b¨ - b_c = b¨ - [b¨ / (1 - \psi)]$	$b_{e,2} = 0.600 * b_{eff}$

$\rho \le 1.000$	OK	$b_{p,2,t} = b¨ - b_c = b¨ - [b¨ / (1 - \psi)]$	22.524	[mm]	
$\rho \le 1.000$	OK	$b_{p,2,eff} = \rho * b_c = \rho * [b¨ / (1 - \psi)]$	22.524	[mm]	
$b_{p,2,eff,1}$	9.010	[mm]	$b_{p,2,eff,2}$	13.514	[mm]

Superior Edge Stiffener [$c_{p,2,nom}$] → Class 4

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension						
$b_{p,2,nom}$	17.274	mm		ε	0.819	
$c_{p,2,nom}$	17.274	mm		t	1.452	mm



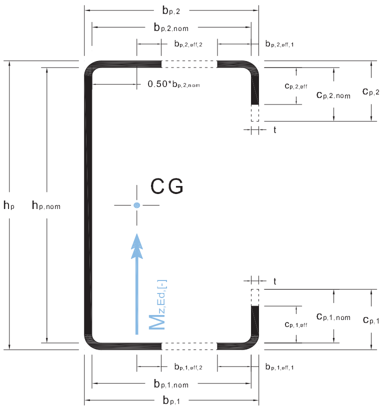
Effective Cross C-Section [Bending Moment $M_{z,Ed}$ ⁻]

[iii] **Plane elements with edge stiffeners [Distortional Buckling]** **[EN 1993-1-3:2006, 5.5.1(5)]**

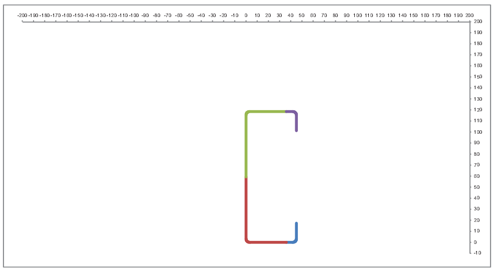
NOTE Inferior/Superior Flanges are both in tension/compression stress, so there isn't any reducing because of the distortional buckling in edge stiffeners.

[iv] **Effective C-Section Beam with Reduced Thickness [Local + Distortional Buckling]** **[EN 1993-1-5:2006, 5.5]**

Effective C-Section Beam Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	17.274	[mm]
Inferior Flange	$b_{p,1,eff,1}$	9.010	[mm]
	$b_{p,1,eff,2}$	13.514	[mm]
Web	$h_{p,eff}$	----	[mm]
Superior Flange	$b_{p,2,eff,1}$	9.010	[mm]
	$b_{p,2,eff,2}$	13.514	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	17.274	[mm]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{z,Ed}^-$]

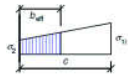


Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{z,Ed}^-$]

$I_{z,eff}^{(-)}$ 108754.009 [mm^4]

(1)	$\bar{\lambda}_p$	0.448	→	$\rho_{OPTION\,(1)}$	1.000
(2)	$\bar{\lambda}_d$	0.385	→	$\rho_{OPTION\,(2)}$	1.000

[EN 1993-1-5, Equation (4.3)] ρ ≤ 1.000 → OK

Stress distribution [Compressive positive]	Effective^p width b_{eff}	
	1.000 > ψ ≥ 0.000	$b_{eff} = \rho * c$

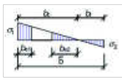
C-Section	Class 1	$c_{p,1,eff} = \rho * c$	16.774	[mm]

Inferior Flange [$b_{p,1,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Column Nominal Dimension		
$b_{p,1,nom}$	44.048	mm

ε	0.819	
t	2.452	mm



Compression Stress
σ_1 350.000 MPa
Tension Stress
σ_2 -350.000 MPa

Internal Compression Elements [EN 1993-1-5, Table 4.1]

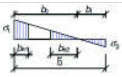
ψ = σ₂ / σ₁ → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.158 → ρ 1.000

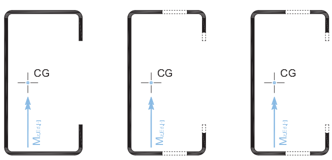
$\bar{\lambda}_p$ 0.158

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive]	Effective^p width b_{eff}		
	ψ < 0.000	$b_{eff} = \rho * b_c = \rho * [\, b'' / (1 - \psi) \,]$	$b_{e,1} = 0.400 * b_{eff}$
		$b_t = b'' - b_c = b'' - [\, b'' / (1 - \psi) \,]$	$b_{e,2} = 0.600 * b_{eff}$

ρ ≤ 1.000	OK	$b_{p,1,t} = b'' - b_c = b'' - [\, b'' / (1 - \psi) \,]$	22.024	[mm]

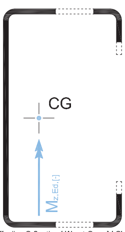
[c] C-Section Column



Gross C-Section	Effective C-Section [L]	Effective C-Section [L + D]
	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

[i] **Determination of the Effective Width [Local Buckling]** **[EN 1993-1-3:2006, 5.5]**

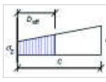
C-Section Classification | **Class 1** → Effective width is equal to the actual width



Effective C-Section [Worst Case] [Class 4]

Inferior Edge Stiffener [$c_{p,1,nom}$] → Class 1

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]



Compression Stress
σ_1 350.000 MPa
σ_2 350.000 MPa
Tension Stress

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

ψ = σ₂ / σ₁ → ψ 1.000
σ₁ Free Point → k_σ 0.430

C-Section Column Nominal Dimension		
$b_{p,1,nom}$	44.048	mm
$c_{p,1,nom}$	16.774	mm

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

For a single edge stiffener, Equation (5.13c)

$b_{p,c} / b_p$ 0.381 → k_σ 0.582

ε 0.819 t 2.452 mm

ρ ≤ 1.000	OK	$b_{p,1,eff} = \rho * b_c = \rho * [\, b'' / (1 - \psi) \,]$	22.024	[mm]

$b_{p,1,eff,1}$	8.810	[mm]	$b_{p,1,eff,2}$	13.214	[mm]

Web [$h_{p,nom}$] → Tension

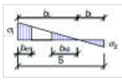
NOTE Effective width is equal to the real width

Superior Flange [$b_{p,2,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Column Nominal Dimension		
$b_{p,2,nom}$	44.048	mm

ε	0.819	
t	2.452	mm



Compression Stress
σ_1 350.000 MPa
Tension Stress
σ_2 -350.000 MPa

Internal Compression Elements [EN 1993-1-5, Table 4.1]

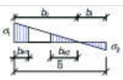
ψ = σ₂ / σ₁ → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\,\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.158 → ρ 1.000

$\bar{\lambda}_p$ 0.158

ρ 1.000 Effective width equal to gross width
[EN 1993-1-5, Equation (4.2)] [3 + ψ] ≥ 0 → OK

Stress distribution [Compressive positive]	Effective^p width b_{eff}		
	ψ < 0.000	$b_{eff} = \rho * b_c = \rho * [\, b'' / (1 - \psi) \,]$	$b_{e,1} = 0.400 * b_{eff}$
		$b_t = b'' - b_c = b'' - [\, b'' / (1 - \psi) \,]$	$b_{e,2} = 0.600 * b_{eff}$

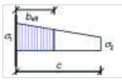
ρ ≤ 1.000	OK	$b_{p,2,t} = b'' - b_c = b'' - [\, b'' / (1 - \psi) \,]$	22.024	[mm]
ρ ≤ 1.000	OK	$b_{p,2,eff} = \rho * b_c = \rho * [\, b'' / (1 - \psi) \,]$	22.024	[mm]

$b_{p,2,eff,1}$	8.810	[mm]	$b_{p,2,eff,2}$	13.214	[mm]

Superior Edge Stiffener [$c_{p,2,nom}$] → Class 1

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Column Nominal Dimension					
$b_{p,2,nom}$	44.048	mm	ε	0.819	
$c_{p,2,nom}$	16.774	mm	t	2.452	mm



Compression Stress

σ_1	350.000	MPa
σ_2	350.000	MPa

Tension Stress

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

$\psi = \sigma_2 / \sigma_1$	→	ψ	1.000
σ_1 Free Point	→	k_σ	0.430

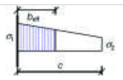
OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28{,}4\,\varepsilon\,\sqrt{k_\sigma}}$$

For a single edge stiffener, Equation (5.13c)

	$b_{p,c} / b_p$	0.381	→ k_σ	0.582
(1)	$\bar{\lambda}_p$	0.448	→ $\rho_{OPTION (1)}$	1.000
(2)	$\bar{\lambda}_d$	0.385	→ $\rho_{OPTION (2)}$	1.000

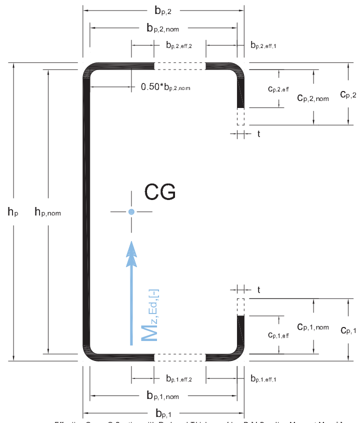
[EN 1993-1-5, Equation (4.3)] $\rho \le 1.000$ → OK

Stress distribution [Compressive positive]	Effective width b_{eff}	
	$1.000 > \psi \ge 0.000$	$b_{eff} = \rho * c$

C-Section	Class 1	$c_{p,2,eff} = \rho * c$	16.774	[mm]

[iv] Effective C-Section Column with Reduced Thickness [Local + Distortional Buckling] **[EN 1993-1-5:2006, 5.5]**

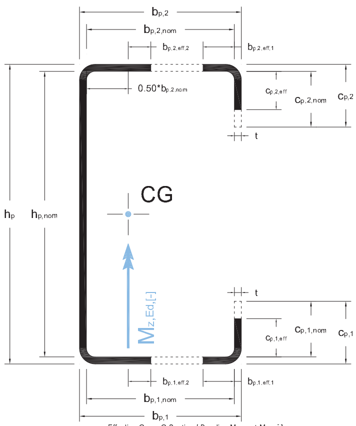
Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	16.774	[mm]
Inferior Flange	$b_{p,1,eff,1}$	8.810	[mm]
	$b_{p,1,eff,2}$	13.214	[mm]
Web	$h_{p,eff}$	----	[mm]
Superior Flange	$b_{p,2,eff,1}$	8.810	[mm]
	$b_{p,2,eff,2}$	13.214	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	16.774	[mm]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{z,Ed}^{-}$]

[ii] Effective C-Section Column [Local Buckling] **[EN 1993-1-5:2006, 4.3]**

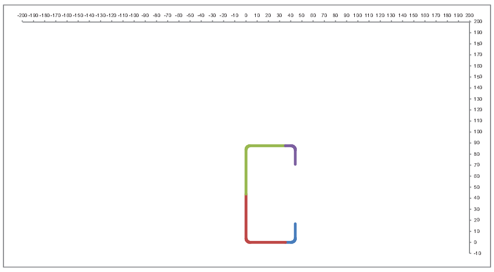
Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	16.774	[mm]
Inferior Flange	$b_{p,1,eff}$	22.024	[mm]
Web	$h_{p,eff}$	----	[mm]
Superior Flange	$b_{p,2,eff}$	22.024	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	16.774	[mm]



Effective Cross C-Section [Bending Moment $M_{z,Ed}^{-}$]

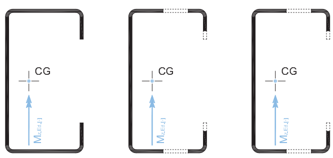
[iii] Plane elements with edge stiffeners [Distortional Buckling] **[EN 1993-1-3:2006, 5.5.1(5)]**

NOTE	Inferior/Superior Flanges are both in tension/compression stress, so there isn't any reducing because of the distortional buckling in edge stiffeners.


Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{z,Ed}^{-}$]

$I_{z,eff}^{[-]}$ 153816.866 [mm^4]

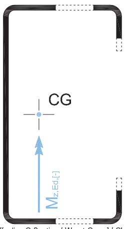
[d] C-Section Strut



Gross C-Section	Local Buckling	Local + Distortional Buckling
	EN 1993-1-5	EN 1993-1-3

[i] Determination of the Effective Width [Local Buckling] **[EN 1993-1-3:2006, 5.5]**

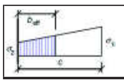
C-Section Classification	Class 1	→	Effective width is equal to the actual width



Effective C-Section [Worst Case] [Class 4]

Inferior Edge Stiffener [$c_{p,1,nom}$] → Class 1

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

$\psi = \sigma_2 / \sigma_1$	→	ψ	1.000
σ_1 Free Point	→	k_σ	0.430

C-Section Strut Nominal Dimension		
$b_{p,1,nom}$	38.548	mm
$c_{p,1,nom}$	9.274	mm

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

For a single edge stiffener, Equation (5.13b)

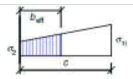
$b_{p,c} / b_p$	0.241	→	k_σ	0.500

ε	0.819	t	1.452	mm

(1) $\bar{\lambda}_p$	0.419	→	$\rho_{OPTION\,(1)}$	1.000
(2) $\bar{\lambda}_d$	0.388	→	$\rho_{OPTION\,(2)}$	1.000

[EN 1993-1-5, Equation (4.3)] $\rho \leq 1.000$ → OK

Stress distribution [Compressive positive] | Effective[P] width b_{eff}



$1.000 > \psi \geq 0.000$ $b_{eff} = \rho * c$

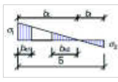
C-Section	Class 1	$c_{p,1,eff} = \rho * c$	9.274	[mm]

Superior Flange [$b_{p,2,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Strut Nominal Dimension		
$b_{p,2,nom}$	38.548	mm

ε	0.819	
t	1.452	mm



Compression Stress		
σ_1	350.000	MPa
Tension Stress		
σ_2	-350.000	MPa

Internal Compression Elements [EN 1993-1-5, Table 4.1]

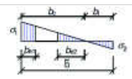
$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.233 → ρ 1.000

$\bar{\lambda}_p$ 0.233	ρ	1.000	Effective width equal to gross width	
	[EN 1993-1-5, Equation (4.2)]	$[3 + \psi] \geq 0$	→	OK

Stress distribution [Compressive positive] | Effective[P] width b_{eff}



$\psi < 0.000$

$b_{eff} = \rho * b_c = \rho * [\, b'' / (1 - \psi)\,]$ $b_{e,1} = 0.400 * b_{eff}$

$b_t = b'' - b_c = b'' - [\, b'' / (1 - \psi)\,]$ $b_{e,2} = 0.600 * b_{eff}$

$\rho \leq 1.000$	OK	$b_{p,2,t} = b'' - b_c = b'' - [\, b'' / (1 - \psi)\,]$	19.274	[mm]
$\rho \leq 1.000$	OK	$b_{p,2,eff} = \rho * b_c = \rho * [\, b'' / (1 - \psi)\,]$	19.274	[mm]

$b_{p,2,eff,1}$	7.710	[mm]	$b_{p,2,eff,2}$	11.564	[mm]

Superior Edge Stiffener [$c_{p,2,nom}$] → Class 1

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Strut Nominal Dimension		
$b_{p,2,nom}$	38.548	mm
$c_{p,2,nom}$	9.274	mm

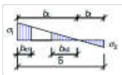
ε	0.819	
t	1.452	mm

Inferior Flange [$b_{p,1,nom}$] → Class 1

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Strut Nominal Dimension		
$b_{p,1,nom}$	38.548	mm

ε	0.819	
t	1.452	mm



Compression Stress		
σ_1	350.000	MPa
Tension Stress		
σ_2	-350.000	MPa

Internal Compression Elements [EN 1993-1-5, Table 4.1]

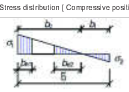
$\psi = \sigma_2 / \sigma_1$ → ψ -1.000 → k_σ 23.900

$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

$\bar{\lambda}_p$ 0.233 → ρ 1.000

$\bar{\lambda}_p$ 0.233	ρ	1.000	Effective width equal to gross width	
	[EN 1993-1-5, Equation (4.2)]	$[3 + \psi] \geq 0$	→	OK

Stress distribution [Compressive positive] | Effective[P] width b_{eff}



$\psi < 0.000$

$b_{eff} = \rho * b_c = \rho * [\, b'' / (1 - \psi)\,]$ $b_{e,1} = 0.400 * b_{eff}$

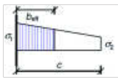
$b_t = b'' - b_c = b'' - [\, b'' / (1 - \psi)\,]$ $b_{e,2} = 0.600 * b_{eff}$

$\rho \leq 1.000$	OK	$b_{p,1,t} = b'' - b_c = b'' - [\, b'' / (1 - \psi)\,]$	19.274	[mm]
$\rho \leq 1.000$	OK	$b_{p,1,eff} = \rho * b_c = \rho * [\, b'' / (1 - \psi)\,]$	19.274	[mm]

$b_{p,1,eff,1}$	7.710	[mm]	$b_{p,1,eff,2}$	11.564	[mm]

Web [$h_{p,nom}$] → Tension

NOTE: Effective width is equal to the real width



Compression Stress		
σ_1	350.000	MPa
σ_2	350.000	MPa
Tension Stress		

Outstand Compression Elements [EN 1993-1-5, Table 4.2]

$\psi = \sigma_2 / \sigma_1$	→	ψ	1.000
σ_1 Free Point	→	k_σ	0.430

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(5)]

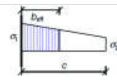
$$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/t}{28.4\,\varepsilon\sqrt{k_\sigma}}$$

For a single edge stiffener, Equation (5.13b)

$b_{p,c} / b_p$	0.241	→	k_σ	0.500
(1) $\bar{\lambda}_p$	0.419	→	$\rho_{OPTION\,(1)}$	1.000
(2) $\bar{\lambda}_d$	0.388	→	$\rho_{OPTION\,(2)}$	1.000

[EN 1993-1-5, Equation (4.3)] $\rho \leq 1.000$ → OK

Stress distribution [Compressive positive] | Effective[P] width b_{eff}



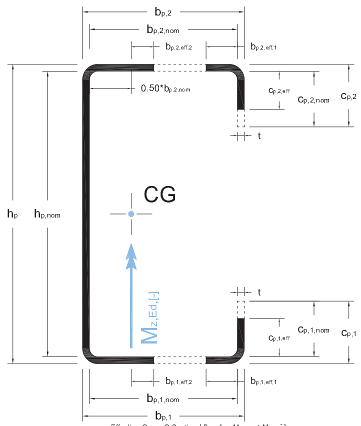
$1.000 > \psi \geq 0.000$ $b_{eff} = \rho * c$

C-Section	Class 1	$c_{p,2,eff} = \rho * c$	9.274	[mm]

[ii] Effective C-Section Strut [Local Buckling] **[EN 1993-1-5:2006, 4.3]**

Effective C-Section Strut Widths

Inferior Edge Stiffener	$c_{p,1,eff}$	9.274	[mm]
Inferior Flange	$b_{p,1,eff}$	19.274	[mm]
Web	$h_{p,eff}$	----	[mm]
Superior Flange	$b_{p,2,eff}$	19.274	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	9.274	[mm]



Effective Cross C-Section [Bending Moment $M_{z,Ed}^{-}$]

[iii] Plane elements with edge stiffeners [Distortional Buckling] **[EN 1993-1-3:2006, 5.5.1(5)]**

NOTE	Inferior/Superior Flanges are both in tension/compression stress, so there isn't any reducing because of the distortional buckling in edge stiffeners.

[iv] Effective C-Section Strut with Reduced Thickness [Local + Distortional Buckling] **[EN 1993-1-5:2006, 5.5]**

Effective C-Section Strut Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	9.274	[mm]
Inferior Flange	$b_{p,1,eff,1}$	7.710	[mm]
	$b_{p,1,eff,2}$	11.564	[mm]
Web	$h_{p,eff}$	----	[mm]
Superior Flange	$b_{p,2,eff,1}$	7.710	[mm]
	$b_{p,2,eff,2}$	11.564	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	9.274	[mm]

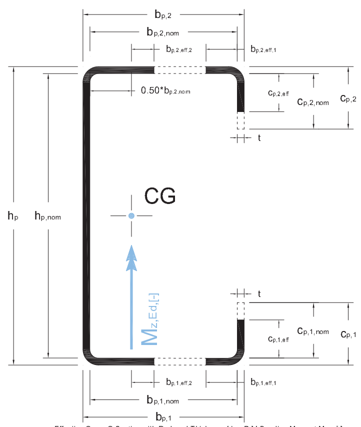
[12] Cold-Formed Efective Section

[a] Ω-Section Purlin

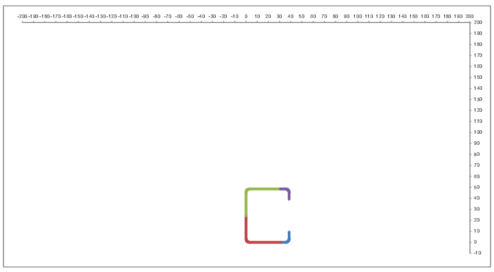
Ω-Section Purlin subjected to Tension Force	$A_{eff,Tension}$	191.199	[mm²]
Ω-Section Purlin subjected to Compression Force	$A_{eff,Compression}$	148.955	[mm²]
	$e_{N,z}$	0.000	[mm]
	$e_{N,y}$	-1.637	[mm]
Ω-Section Purlin subjected to Positive Moment in y-y axis [$M_{y,Ed}^{+}$]	$I_{y,eff,M[+]}$	79892.362	[mm⁴]
Ω-Section Purlin subjected to Negative Moment in y-y axis [$M_{y,Ed}^{-}$]	$I_{y,eff,M[-]}$	85759.975	[mm⁴]
Ω-Section Purlin subjected to Positive Moment in z-z axis [$M_{z,Ed}^{+}$]	$I_{z,eff,M[+]}$	163614.967	[mm⁴]
Ω-Section Purlin subjected to Negative Moment in z-z axis [$M_{z,Ed}^{-}$]	$I_{z,eff,M[-]}$	163614.967	[mm⁴]

[b] C-Section Beam

C-Section Beam subjected to Tension Force	$A_{eff,Tension}$	345.063	[mm²]
C-Section Beam subjected to Compression Force	$A_{eff,Compression}$	243.816	[mm²]
	$e_{N,z}$	3.694	[mm]
	$e_{N,y}$	0.000	[mm]
C-Section Beam subjected to Positive Moment in y-y axis [$M_{y,Ed}^{+}$]	$I_{y,eff,M[+]}$	746984.961	[mm⁴]
C-Section Beam subjected to Negative Moment in y-y axis [$M_{y,Ed}^{-}$]	$I_{y,eff,M[-]}$	746984.961	[mm⁴]
C-Section Beam subjected to Positive Moment in z-z axis [$M_{z,Ed}^{+}$]	$I_{z,eff,M[+]}$	84344.150	[mm⁴]
C-Section Beam subjected to Negative Moment in z-z axis [$M_{z,Ed}^{-}$]	$I_{z,eff,M[-]}$	108754.009	[mm⁴]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{z,Ed}^{-}$]



Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{z,Ed}^{-}$]

$I_{z,eff}^{[-]}$ 43399.345 [mm⁴]

[c] C-Section Column

C-Section Column subjected to Tension Force	$A_{eff,Tension}$	497.235	[mm²]
C-Section Column subjected to Compression Force	$A_{eff,Compression}$	482.146	[mm²]
	$e_{N,z}$	0.506	[mm]
	$e_{N,y}$	0.000	[mm]
C-Section Column subjected to Positive Moment in y-y axis [$M_{y,Ed}^{+}$]	$I_{y,eff,M[+]}$	625036.020	[mm⁴]
C-Section Column subjected to Negative Moment in y-y axis [$M_{y,Ed}^{-}$]	$I_{y,eff,M[-]}$	625036.020	[mm⁴]
C-Section Column subjected to Positive Moment in z-z axis [$M_{z,Ed}^{+}$]	$I_{z,eff,M[+]}$	150093.116	[mm⁴]
C-Section Column subjected to Negative Moment in z-z axis [$M_{z,Ed}^{-}$]	$I_{z,eff,M[-]}$	153816.866	[mm⁴]

[d] C-Section Strut

C-Section Strut subjected to Tension Force	$A_{eff,Tension}$	201.315	[mm²]
C-Section Strut subjected to Compression Force	$A_{eff,Compression}$	189.709	[mm²]
	$e_{N,z}$	-0.611	[mm]
	$e_{N,y}$	0.000	[mm]
C-Section Strut subjected to Positive Moment in y-y axis [$M_{y,Ed}^{+}$]	$I_{y,eff,M[+]}$	83790.577	[mm⁴]
C-Section Strut subjected to Negative Moment in y-y axis [$M_{y,Ed}^{-}$]	$I_{y,eff,M[-]}$	83790.577	[mm⁴]
C-Section Strut subjected to Positive Moment in z-z axis [$M_{z,Ed}^{+}$]	$I_{z,eff,M[+]}$	44100.416	[mm⁴]
C-Section Strut subjected to Negative Moment in z-z axis [$M_{z,Ed}^{-}$]	$I_{z,eff,M[-]}$	43399.345	[mm⁴]

[13] Basis of Design [BS EN 1993-1-3:2006, 2]

(3)P For verifications by calculations at ultimate limit states the partial factor γ_M are:

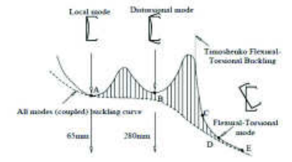
- Resistance of cross-sections to excessive yielding [Local and Distortional Buckling — γ_{M0} 1.000
- Resistance of members and sheeting where failure is caused by Global Buckling — γ_{M1} 1.000
- Resistance of net sections at fastener holes — γ_{M2} 1.250

(6) For the design of structures made of cold-formed members and sheeting a distinction should be made between "structural classes" associated with failure consequences according to EN 1990 [Annex B] defined as:

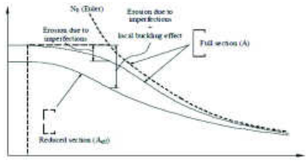
Structural Class I	Construction where cold-formed members and sheeting are designed to contribute to the overall strength and stability of a structure
Structural Class II	Construction where cold-formed members and sheeting are designed to contribute to the overall strength and stability of individual structural members
Structural Class III	Construction where cold-formed sheeting is used as an element that only transfers loads to the structure

Buckling strength of cold-formed steel members

Steel sections may be subject to one of four generic types of buckling, namely local, global, distortional and shear. Local buckling is particularly prevalent in cold-formed steel sections and is characterized by the relatively short wavelength buckling of individual plate element. The term "global buckling" embraces Euler (flexural) and flexural-torsional buckling of columns and lateral-torsional buckling of beams. Distortional buckling is buckling which takes place as a consequence of distortion of the cross section. In cold-formed sections, it is characterized by relative movement of the fold-lines. Local and distortional buckling can be considered as "sectional" modes, and they can interact with each other as well as with global buckling.



(a) Buckling modes for a lipped channel [C-Section] in compression



(b) Effect of local buckling on the member capacity

[15] Ultimate Limit States [BS EN 1993-1-3:2006, 6]

[15.1] Resistance of Cross-Sections [BS EN 1993-1-3:2006, 6.1]

[a] Ω-Section Purlin

[i] Ω-Section Purlin: Axial Tension [BS EN 1993-1-3:2006, 6.1.2]

$$N_{t,Rd} = \frac{f_{ya} A_g}{\gamma_{M0}}$$

[BS EN 1993-1-3, Equation (6.1)]

f_{ya}	360.415	[MPa]
A_g	191.199	[mm^2]
γ_{M0}	1.000	

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1{,}0$$

$N_{t,Rd}$ 68911.039 [N] → $N_{t,Rd}$ **68.911** **[kN]**

$N_{t,Ed}$	0.040	[kN]	Ratio	0.058 [%]
$N_{t,Rd}$	68.911	[kN]		

[ii] Ω-Section Purlin: Axial Compression [BS EN 1993-1-3:2006, 6.1.3]

[BS EN 1993-1-3, Equation (6.2)]

$A_{eff} < A_g$ → $N_{c,Rd} = A_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.3)]

$A_{eff} = A_g$ → $N_{c,Rd} = A_g * [f_{yb} + [f_{ya} - f_{yb}] * 4 * [1 - \lambda_e^{-} / \lambda_{e0}^{-}]] / \gamma_{M0} \leq A_g * f_{ya} / \gamma_{M0}$

A_g 191.199 [mm^2] — A_{eff} 148.955 [mm^2]

[BS EN 1993-1-3, Equation (6.2)]

$N_{c,Rd}$ 52134.268 [N] → $N_{c,Rd}$ **52.134** **[kN]**

NOTE: The internal axial force in a member is taken as acting at the centroid of its gross-cross section.

NOTE: The design compression resistance of a cross-section refers to the axial load acting at the centroid of its effective cross-section. If this does not coincide with the centroid of its gross cross-section, the shift e_N of the centroid axes is taken into account. If the shift of the neutral axis gives a favourable result in the stress check, the shift should be neglected only if the shift has been calculated at yield strength and not with the actual compressive stresses.

$N_{c,Rd} \leq A_g * f_{ya} / \gamma_{M0}$ — OK

$e_{N,z}$	0.000	[mm]	In stress check, shift is neglected because has been calculated at yield strength and not with actual compressive stresse
$e_{N,y}$	-1.637	[mm]	

$$\frac{N_{Ed}}{N_{c,Rd}} \leq 1{,}0$$

$N_{c,Ed}$	0.040	[kN]	Ratio	0.077 [%]
$N_{c,Rd}$	52.134	[kN]		

[14] Reactions Values

Ω-Section Console Purlin		
$N_{t,Ed}$	0.000	[kN]
$N_{c,Ed}$	0.000	[kN]
$V_{y,Ed}$	0.170	[kN]
$V_{z,Ed}$	0.630	[kN]
$M_{y,Ed [+]}$	0.220	[kN]
$M_{y,Ed [-]}$	0.220	[kN]
$M_{z,Ed [+]}$	0.060	[kN]
$M_{z,Ed [-]}$	0.060	[kN]

Ω-Section Middle Purlin		
$N_{t,Ed}$	0.040	[kN]
$N_{c,Ed}$	0.040	[kN]
$V_{y,Ed}$	0.260	[kN]
$V_{z,Ed}$	1.010	[kN]
$M_{y,Ed [+]}$	0.360	[kN]
$M_{y,Ed [-]}$	0.360	[kN]
$M_{z,Ed [+]}$	0.090	[kN]
$M_{z,Ed [-]}$	0.090	[kN]

C-Section Console Beam		
$N_{t,Ed}$	0.520	[kN]
$N_{c,Ed}$	0.520	[kN]
$V_{y,Ed}$	0.040	[kN]
$V_{z,Ed}$	1.970	[kN]
$M_{y,Ed [+]}$	0.840	[kN]
$M_{y,Ed [-]}$	0.840	[kN]
$M_{z,Ed [+]}$	0.020	[kN]
$M_{z,Ed [-]}$	0.020	[kN]

C-Section Middle Beam		
$N_{t,Ed}$	0.700	[kN]
$N_{c,Ed}$	1.030	[kN]
$V_{y,Ed}$	0.040	[kN]
$V_{z,Ed}$	2.000	[kN]
$M_{y,Ed [+]}$	0.840	[kN]
$M_{y,Ed [-]}$	0.840	[kN]
$M_{z,Ed [+]}$	0.010	[kN]
$M_{z,Ed [-]}$	0.010	[kN]

C-Section Front Column		
$N_{t,Ed}$	2.700	[kN]
$N_{c,Ed}$	4.140	[kN]
$V_{y,Ed}$	0.000	[kN]
$V_{z,Ed}$	1.790	[kN]
$M_{y,Ed [+]}$	0.270	[kN]
$M_{y,Ed [-]}$	0.270	[kN]
$M_{z,Ed [+]}$	0.000	[kN]
$M_{z,Ed [-]}$	0.000	[kN]

C-Section Rear Column		
$N_{t,Ed}$	3.340	[kN]
$N_{c,Ed}$	4.170	[kN]
$V_{y,Ed}$	0.000	[kN]
$V_{z,Ed}$	2.240	[kN]
$M_{y,Ed [+]}$	0.350	[kN]
$M_{y,Ed [-]}$	0.350	[kN]
$M_{z,Ed [+]}$	0.000	[kN]
$M_{z,Ed [-]}$	0.000	[kN]

C-Section Strut		
$N_{t,Ed}$	2.280	[kN]
$N_{c,Ed}$	1.470	[kN]
$V_{y,Ed}$	0.000	[kN]
$V_{z,Ed}$	0.020	[kN]
$M_{y,Ed [+]}$	0.010	[kN]
$M_{y,Ed [-]}$	0.010	[kN]
$M_{z,Ed [+]}$	0.000	[kN]
$M_{z,Ed [-]}$	0.000	[kN]

[iii] Ω-Section Purlin: Bending Moment [BS EN 1993-1-3:2006, 6.1.4]

Positive Moment in y-y axis [$M_{y,Ed}^{+}$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max}^{-} / \lambda_{e0}^{-}]] / \gamma_{M0} \leq W_{pl} * f_{yb} / \gamma_{M0}$

Equation [6.5] is applicable provided that the following conditions are satisfied:

[a] Bending moment is applied only about one principal axes of the cross-section

[b] Member not subject to torsion or to torsional, torsional flexural or lateral-torsional or distortional buckling

[c] Angle Φ between the web and the flange is larger than 60º

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{el} * f_{ya} / \gamma_{M0}$

$I_{y,el,M [+]}$	85759.975	[mm^4]	→	$W_{el,Comp}$	3053.134	[mm^3]
				$W_{el,Tens}$	3343.203	[mm^3]
$I_{y,eff,M [+]}$	79892.362	[mm^4]	→	$W_{eff,Comp}$	2737.755	[mm^3]
				$W_{eff,Tens}$	3253.013	[mm^3]

$W_{el,Comp}$ 3053.134 [mm^3] — $W_{eff,Comp}$ 2737.755 [mm^3]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cy,Rd,comp,M [+]}$ 958214.390 [Nmm] → $M_{cy,Rd,comp,M [+]}$ **0.958** **[kNm]**

$$\frac{M_{Ed}}{M_{c,Rd}} \leq 1{,}0$$

$M_{cy,Ed,M [+]}$	0.360	[kNm]	Ratio	37.570 [%]
$M_{cy,Rd,comp,M [+]}$	0.958	[kNm]		

$W_{el,Tens}$ 3343.203 [mm^3] — $W_{eff,Tens}$ 3253.013 [mm^3]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cy,Rd,Tens,M [+]}$ 1138554.471 [Nmm] → $M_{cy,Rd,Tens,M [+]}$ **1.139** **[kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^{-}$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max}'' / \lambda_{e0}'']] / \gamma_{M0} \leq W_{pl} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{el} * f_{ya} / \gamma_{M0}$

$I_{y,el,M[-]}$	85759.975	[mm^4]	→	$W_{el,Comp}$	3343.203	[mm^3]
				$W_{el,Tens}$	3053.134	[mm^3]
$I_{y,eff,M[-]}$	85759.975	[mm^4]	→	$W_{eff,Comp}$	3343.203	[mm^3]
				$W_{eff,Tens}$	3053.134	[mm^3]
$W_{el,Comp}$	3343.203	[mm^3]		$W_{eff,Comp}$	3343.203	[mm^3]

[BS EN 1993-1-3, Equation (6.6)]

$M_{cy,Rd,comp,M[-]}$	1204940.723	[Nmm]	→	$M_{cy,Rd,comp,M[-]}$	**1.205**	**[kNm]**
$M_{cy,Ed,M[-]}$	0.360	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \leq 1{,}0$	Ratio	29.877	[%]
$M_{cy,Rd,comp,M[-]}$	1.205	[kNm]				
$W_{el,Tens}$	3053.134	[mm^3]		$W_{eff,Tens}$	3053.134	[mm^3]

[BS EN 1993-1-3, Equation (6.6)]

$M_{cy,Rd,Tens,M[-]}$	1100395.326	[Nmm]	→	$M_{cy,Rd,Tens,M[-]}$	**1.100**	**[kNm]**

Positive Moment in z-z axis [$M_{z,Ed}^+$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max}'' / \lambda_{e0}'']] / \gamma_{M0} \leq W_{pl} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{el} * f_{ya} / \gamma_{M0}$

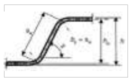
$I_{z,el,M[+]}$	176909.935	[mm^4]	→	$W_{el,Comp}$	3177.986	[mm^3]
				$W_{el,Tens}$	3177.986	[mm^3]
$I_{z,eff,M[+]}$	163614.967	[mm^4]	→	$W_{eff,Comp}$	2805.677	[mm^3]
				$W_{eff,Tens}$	3085.971	[mm^3]

$M_{cz,Rd,Tens,M[-]}$	1080089.902	[Nmm]	→	$M_{cz,Rd,Tens,M[-]}$	**1.080**	**[kNm]**

[iv] Ω-Section Purlin: Shear Force [BS EN 1993-1-3:2006, 6.1.5]

$$V_{b,Rd} = \frac{\frac{h_w}{\sin\phi} t f_{bv}}{\gamma_{M0}}$$

$h_w = h_m$	53.741	[mm]
Φ	78.393	[°]
γ_{M0}	1.000	



Webs without longitudinal stiffeners $\bar{\lambda}_w = 0{,}346 \frac{s_w}{t} \sqrt{\frac{f_{yb}}{E}}$ [EN 1993-1-3, Equation (6.10a)]

s_w	54.863	[mm]	f_{yb}	350.000	[MPa]
t	0.952	[mm]	E	210.000	[GPa]

Table 6.1: Shear buckling strength f_{bv} [BS EN 1993-1-3:2006]

Relative web slenderness	Web without stiffening at the support
$\bar{\lambda}_w \leq 0{,}83$	$0{,}58 f_{yb}$
$0{,}83 < \bar{\lambda}_w < 1{,}40$	$0{,}48 f_{yb} / \bar{\lambda}_w$
$\bar{\lambda}_w \geq 1{,}40$	$0{,}67 f_{yb} / \bar{\lambda}_w^2$

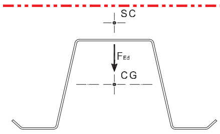
$\bar{\lambda}_w$	0.814	[EN 1993-1-3, Equation (6.10a)]	f_{bv}	203.000	[MPa]
$V_{b,Rd}$	10602.645	[N / Web] →	$V_{b,Rd}$	**10.603**	**[kN / Web]**

$V_{z,Ed}$	1.010	[kN]	$\frac{V_{Ed}}{V_{c,Rd}} \leq 1{,}0$	Ratio	4.763	[%]
$V_{b,Rd}$	21.205	[kN]				

[v] Ω-Section Purlin: Torsional Moment [EN 1993-1-3:2006, 6.1.6]

NOTE: Where loads are applied eccentric to the shear centre of the cross-section, the effects of torsion are taken into account

Gravity Centre			Shear Centre			Δ	
y_{GC}	55.667	[mm]	y_{SC}	55.667	[mm]	**0.000**	[mm]
z_{GC}	25.652	[mm]	z_{SC}	66.791	[mm]	**-41.139**	[mm]



The applied loads are not eccentric to the shear centre of the cross-section, so, the effects of torsion are not taken into account

$W_{el,Comp}$	3177.986	[mm^3]		$W_{eff,Comp}$	2805.677	[mm^3]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cz,Rd,comp,M[+]}$	981986.994	[Nmm]	→	$M_{cz,Rd,comp,M[+]}$	**0.982**	**[kNm]**
$M_{cz,Ed,M[+]}$	0.090	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \leq 1{,}0$	Ratio	9.165	[%]
$M_{cz,Rd,comp,M[+]}$	0.982	[kNm]				
$W_{el,Tens}$	3177.986	[mm^3]		$W_{eff,Tens}$	3085.971	[mm^3]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cz,Rd,Tens,M[+]}$	1080089.902	[Nmm]	→	$M_{cz,Rd,Tens,M[+]}$	**1.080**	**[kNm]**

Negative Moment in z-z axis [$M_{z,Ed}^-$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max}'' / \lambda_{e0}'']] / \gamma_{M0} \leq W_{pl} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{el} * f_{ya} / \gamma_{M0}$

$I_{z,el,M[-]}$	176909.935	[mm^4]	→	$W_{el,Comp}$	3177.986	[mm^3]
				$W_{el,Tens}$	3177.986	[mm^3]
$I_{z,eff,M[-]}$	163614.967	[mm^4]	→	$W_{eff,Comp}$	2805.677	[mm^3]
				$W_{eff,Tens}$	3085.971	[mm^3]
$W_{el,Comp}$	3177.986	[mm^3]		$W_{eff,Comp}$	2805.677	[mm^3]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cz,Rd,M[-]}$	981986.994	[Nmm]	→	$M_{cz,Rd,comp,M[-]}$	**0.982**	**[kNm]**
$M_{cz,Ed,comp,M[-]}$	0.090	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \leq 1{,}0$	Ratio	9.165	[%]
$M_{cz,Rd,comp,M[-]}$	0.982	[kNm]				
$W_{el,Tens}$	3177.986	[mm^3]		$W_{eff,Tens}$	3085.971	[mm^3]

[BS EN 1993-1-3, Equation (6.4)]

[vi] Ω-Section Purlin: Local Transverse Forces [EN 1993-1-3:2006, 6.1.7]

$F_{Ed} \leq R_{w,Rd}$ [BS EN 1993-1-3, Equation (6.13)]

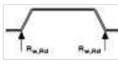
$R_{w,Rd}$ Local Transverse Resistance of the Web

NOTE: To avoid crushing, crippling or buckling in a web subject to a support reaction or other local transverse force applied through the flange

Cross-sections with two or more unstiffened web [BS EN 1993-1-3, 6.1.7.3]

The clear distance c from the bearing length for the support reaction or local load to a free end is at least 40 mm

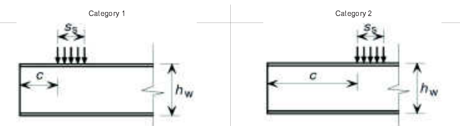
$r/t \leq 10$ [BS EN 1993-1-3, Equation (6.17a)]	r_m	1.976	[mm]	→	OK
	t	0.952	[mm]		
$h_w/t \leq 200 \sin\phi$ [BS EN 1993-1-3, Equation (6.17b)]	h_m	53.741	[mm]	→	OK
	Φ	78.393	[°]		
	t	0.952	[mm]		
$45° \leq \phi \leq 90°$ [BS EN 1993-1-3, Equation (6.17c)]		1			
	Φ	78.393	[°]	→	OK
		1			



$$R_{w,Rd} = \alpha t^2 \sqrt{f_{yb} E} \left(1 - 0{,}1\sqrt{r/t}\right)\left[0{,}5 + \sqrt{0{,}02 l_a / t}\right]\left(2{,}4 + (\phi/90)^2\right) / \gamma_{M1}$$

[BS EN 1993-1-3, Equation (6.18)]

Local loads and supports: Categories of cross-sections with two or more webs [BS EN 1993-1-3:2006, Figure 6.9]



Local load applied with c ≤ 1.500 * h_w clear from a free end | Local load applied with c > 1.500 * h_w clear from a free end

Hat Sections [Category 1]	α	0.057	**Hat Sections [Category 2]**	α	0.115

When the support is a cold-formed section with one web, for s_s should be taken a value of 10 mm

The maximum design value for l_a = 200 mm

Category	Category 1	→	α	0.057	
$R_{w,Rd}$	1147.522	[N]	→	$R_{w,Rd}$ **1.148**	**[kN / Web]**

$V_{z,Ed}$	1.010	[kN]	Ratio	44.008	[%]
$R_{w,Rd}$	2.295	[kN]			

[vii] Ω-Section Purlin: Combined Tension and Bending [EN 1993-1-3:2006, 6.1.8]

$$\frac{N_{Ed}}{N_{t,Rd}} + \frac{M_{y,Ed}}{M_{cy,Rd,ten}} + \frac{M_{z,Ed}}{M_{cz,Rd,ten}} \leq 1$$

[BS EN 1993-1-3, Equation (6.23)]

$M_{cy,Rd,Com} \leq M_{cy,Rd,Ten}$ or $M_{cz,Rd,Com} \leq M_{cz,Rd,Ten}$

$$\frac{M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed}}{M_{cz,Rd,com}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[BS EN 1993-1-3, Equation (6.24)]

Combined Tension and Bending Moment [$M_{y,Ed}^{+} + M_{z,Ed}^{+}$]

$N_{t,Ed}$	0.040	[kN]	$N_{t,Rd}$	68.911	[kN]
$M_{cy,Ed,M[+]}$	0.360	[kNm]	$M_{cy,Rd,Tension,[+]}$	1.139	[kNm]
$M_{cz,Ed,M[+]}$	0.090	[kNm]	$M_{cz,Rd,Tension,M[+]}$	1.080	[kNm]

[EN 1993-1-3, Equation (6.23)] Ratio 40.010 [%]

$M_{cy,Rd,Comp,M[+]}$	0.958	[kNm]	$M_{cz,Rd,Comp,M[+]}$	0.982	[kNm]
$M_{cy,Rd,Comp,M[+]} \leq M_{cy,Rd,Tens,M[+]}$	OK		$M_{cz,Rd,Comp,M[+]} \leq M_{cz,Rd,Tens,M[+]}$	OK	

$$\frac{M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed}}{M_{cz,Rd,com}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[EN 1993-1-3: Equation (6.24)] — [EN 1993-1-3, Equation (6.24) must be verified] Ratio 46.677 [%]

Combined Tension and Bending Moment [$M_{y,Ed}^{-} + M_{z,Ed}^{-}$]

$N_{t,Ed}$	0.040	[kN]	$N_{t,Rd}$	68.911	[kN]
$M_{cy,Ed,M[-]}$	0.360	[kNm]	$M_{cy,Rd,Tension,M[-]}$	1.100	[kNm]
$M_{cz,Ed,M[-]}$	0.090	[kNm]	$M_{cz,Rd,Tension,M[-]}$	1.080	[kNm]

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Version: 1.000	Client: COIMBRA UNIVERSITY		

Combined Compression and Bending Moment [$M_{y,Ed}^{-} + M_{z,Ed}^{-}$]

$N_{c,Ed}$	0.040	[kN]	$N_{c,Rd}$	52.134	[kN]
$M_{cy,Ed,Comp,M[-]}$	0.360	[kNm]	$M_{cy,Rd,Comp,M[-]}$	1.205	[kNm]
$M_{cz,Ed,Comp,M[-]}$	0.090	[kNm]	$M_{cz,Rd,Comp,M[-]}$	0.982	[kNm]

[EN 1993-1-3, Equation (6.25)] Ratio 39.113 [%]

$M_{cy,Rd,Tens,M[-]}$	1.100	[kNm]	$M_{cz,Rd,Tens,M[-]}$	1.080	[kNm]
$M_{cy,Rd,Tens,M[-]} \leq M_{cy,Rd,Comp,M[-]}$	OK		$M_{cz,Rd,Tens,M[-]} \leq M_{cz,Rd,Comp,M[-]}$	KO	

$$\frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{cy,Rd,ten}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{cz,Rd,ten}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[EN 1993-1-3: Equation (6.26)] — [EN 1993-1-3, Equation (6.26) don't need to be verified] Ratio 0.000 [%]

[ix] Ω-Section Purlin: Combined Shear Force, Axial Force and Bending Moment [EN 1993-1-3:2006, 6.1.10]

$V_{z,Ed}$	1.010	[kN]	$R_{w,Rd}$	2.295	[kN]

$V_{Ed} \leq 0.50\ V_{w,Rd}$	OK	No reduction due to shear force is need to be done

[x] Ω-Section Purlin: Combined Bending Moment and Local Load or Support Reaction [EN 1993-1-3:2006, 6.1.11]

Check	Reference	Values		Ratio	[%]
$M_{Ed} / M_{c,Rd} \leq 1$	[BS EN 1993-1-3, Equation (6.28a)]	$M_{cy,Ed,M[+]}$	$M_{cy,Rd,comp,M[+]}$	37.570	[%]
$M_{Ed} / M_{c,Rd} \leq 1$	[BS EN 1993-1-3, Equation (6.28a)]	$M_{cy,Ed,M[-]}$	$M_{cy,Rd,comp,M[-]}$	29.877	[%]
$M_{Ed} / M_{c,Rd} \leq 1$	[BS EN 1993-1-3, Equation (6.28a)]	$M_{cz,Ed,M[+]}$	$M_{cz,Rd,comp,M[+]}$	9.165	[%]
$M_{Ed} / M_{c,Rd} \leq 1$	[BS EN 1993-1-3, Equation (6.28a)]	$M_{cz,Ed,M[-]}$	$M_{cz,Rd,comp,M[-]}$	9.165	[%]
$F_{Ed} / R_{w,Rd} \leq 1$	[BS EN 1993-1-3, Equation (6.28b)]	$V_{z,ed}$	$R_{w,Rd}$	44.008	[%]
$\frac{M_{Ed}}{M_{c,Rd}} + \frac{F_{Ed}}{R_{w,Rd}} \leq 1.25$	[BS EN 1993-1-3, Equation (6.28c)]	$M_{cy,Ed,M[+]}$	$M_{cy,Rd,comp,M[+]}$; $F_{z,ed}$ | $V_{z,Ed}$	81.578	[%]

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[EN 1993-1-3, Equation (6.23)] Ratio 41.106 [%]

$M_{cy,Rd,Comp,M[-]}$	1.205	[kNm]	$M_{cz,Rd,Comp,M[-]}$	0.982	[kNm]
$M_{cy,Rd,Comp,M[-]} \leq M_{cy,Rd,Tens,M[-]}$	KO		$M_{cz,Rd,Comp,M[-]} \leq M_{cz,Rd,Tens,M[-]}$	OK	

$$\frac{M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed}}{M_{cz,Rd,com}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[EN 1993-1-3: Equation (6.24)] — [EN 1993-1-3, Equation (6.24) don't need to be verified] Ratio 0.000 [%]

[viii] Ω-Section Purlin: Combined Compression and Bending [EN 1993-1-3:2006, 6.1.9]

$$\frac{N_{Ed}}{N_{c,Rd}} + \frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{cz,Rd,com}} \leq 1$$

[BS EN 1993-1-3, Equation (6.25)]

$\Delta M_{y,Ed} = N_{ed,Compression} * e_{Ny}$			$\Delta M_{z,Ed} = N_{ed,Compression} * e_{Nz}$		
$N_{Ed,Compression}$	0.040	[kN]	$N_{Ed,Compression}$	0.040	[kN]
$e_{N,y,Compression}$	-0.002	[m]	$e_{N,z,Compression}$	0.000	[m]
$\Delta M_{y,Ed}$	0.000	[kNm]	$\Delta M_{z,Ed}$	0.000	[kNm]

Combined Compression and Bending Moment [$M_{y,Ed}^{+} + M_{z,Ed}^{+}$]

$N_{c,Ed}$	0.040	[kN]	$N_{c,Rd}$	52.134	[kN]
$M_{cy,Ed,M[+]}$	0.360	[kNm]	$M_{cy,Rd,Comp,M[+]}$	0.958	[kNm]
$M_{cz,Ed,M[+]}$	0.090	[kNm]	$M_{cz,Rd,Comp,M[+]}$	0.982	[kNm]

[EN 1993-1-3, Equation (6.25)] Ratio 46.805 [%]

$M_{cy,Rd,Tens,M[+]}$	1.139	[kNm]	$M_{cz,Rd,Tens,M[+]}$	1.080	[kNm]
$M_{cy,Rd,Tens[+]} \leq M_{cy,Rd,Comp[+]}$	KO		$M_{cz,Rd,Tens[+]} \leq M_{cz,Rd,Comp[+]}$	KO	

$$\frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{cy,Rd,ten}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{cz,Rd,ten}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[EN 1993-1-3: Equation (6.26)] — [EN 1993-1-3, Equation (6.26) don't need to be verified] Ratio 0.000 [%]

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Version: 1.000	Client: COIMBRA UNIVERSITY		

Check	Reference	Values		Ratio	[%]
$\frac{M_{Ed}}{M_{c,Rd}} + \frac{F_{Ed}}{R_{w,Rd}} \leq 1.25$	[BS EN 1993-1-3, Equation (6.28c)]	$M_{cy,Ed,M[-]}$	$M_{cy,Rd,comp,M[-]}$; $F_{z,Ed}$ | $V_{z,Ed}$	73.885	[%]
$\frac{M_{Ed}}{M_{c,Rd}} + \frac{F_{Ed}}{R_{w,Rd}} \leq 1.25$	[BS EN 1993-1-3, Equation (6.28c)]	$M_{cz,Ed,M[+]}$	$M_{cz,Rd,comp,M[+]}$; $F_{z,E}$ | $V_{z,Ed}$	53.173	[%]
$\frac{M_{Ed}}{M_{c,Rd}} + \frac{F_{Ed}}{R_{w,Rd}} \leq 1.25$	[BS EN 1993-1-3, Equation (6.28c)]	$M_{cz,Ed,M[-]}$	$M_{cz,Rd,comp,M[-]}$; $F_{z,Ed}$ | $V_{z,Ed}$	53.173	[%]

[b] C-Section Beam

[i] C-Section Beam: Axial Tension [BS EN 1993-1-3:2006, 6.1.2]

$$N_{t,Rd} = \frac{f_{ya} A_g}{\gamma_{M0}}$$

[BS EN 1993-1-3, Equation (6.1)]

f_{ya}	361.975	[MPa]
A_g	345.063	[mm^2]
γ_{M0}	1.000	

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1{,}0$$

$N_{t,Rd}$	124904.463	[N]	→	$N_{t,Rd}$	**124.904**	**[kN]**

$N_{t,Ed}$	0.700	[kN]	Ratio	0.560	[%]
$N_{t,Rd}$	124.904	[kN]			

[ii] C-Section Beam: Axial Compression [BS EN 1993-1-3:2006, 6.1.3]

[BS EN 1993-1-3, Equation (6.2)]

$A_{eff} < A_g$ → $N_{c,Rd} = A_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.3)]

$A_{eff} = A_g$ → $N_{c,Rd} = A_g * [f_{yb} + [f_{ya} - f_{yb}] * 4 * [1 - \lambda_e^{-} / \lambda_{e0}^{-}]] / \gamma_{M0} \leq A_g * f_{ya} / \gamma_{M0}$

A_g	345.063	[mm^2]	A_{eff}	243.816	[mm^2]

[BS EN 1993-1-3, Equation (6.2)]

$N_{c,Rd}$	85335.730	[N]	→	$N_{c,Rd}$	**85.336**	**[kN]**

NOTE	The internal axial force in a member is taken as acting at the centroid of its gross-cross section.
NOTE	The design compression resistance of a cross-section refers to the axial load acting at the centroid of its effective cross-section. If this does not coincide with the centroid of its gross cross-section, the shift e_N of the centroid axes is taken into account. If the shift of the neutral axis gives a favourable result in the stress check, the shift should be neglected only if the shift has been calculated at yield strength and not with the actual compressive stresses.

$N_{c,Rd} \leq A_g * f_{ya} / \gamma_{M0}$ OK

$e_{N,z,Compression}$	3.694	[mm]	In stress check, shift is used
$e_{N,y,Compression}$	0.000	[mm]	

$N_{c,Ed}$	1.030	[kN]	$\frac{N_{Ed}}{N_{c,Rd}} \leq 1,0$	Ratio	1.207	[%]
$N_{c,Rd}$	85.336	[kN]				

[iii] C-Section Beam: Bending Moment [BS EN 1993-1-3:2006, 6.1.4]

Positive Moment in y-y axis [$M_{y,Ed}^+$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max}'' / \lambda_{e0}'']] / \gamma_{M0} \leq W_{pl} * f_{yb} / \gamma_{M0}$

Equation [6.5] is applicable provided that the following conditions are satisfied:

[a] Bending moment is applied only about one principal axes of the cross-section

[b] Member not subject to torsion or to torsional, torsional flexural or lateral-torsional or distortional buckling

[c] Angle Φ between the web and the flange is larger than 60º

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{el} * f_{ya} / \gamma_{M0}$

$I_{y,el,M[+]}$	762290.565	[mm^4]	→	$W_{el,Comp}$	12860.454	[mm^3]
				$W_{el,Tens}$	12860.454	[mm^3]
$I_{y,eff,M[+]}$	746984.961	[mm^4]	→	$W_{eff,Comp}$	12435.750	[mm^3]
				$W_{eff,Tens}$	12773.241	[mm^3]
$W_{el,Comp}$	12860.454	[mm^3]		$W_{eff,Comp}$	12435.750	[mm^3]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cy,Rd,comp,M[+]}$ 4352512.618 [Nmm] → $M_{cy,Rd,comp,M[+]}$ **4.353** **[kNm]**

$M_{cy,Ed,M[+]}$	0.840	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \leq 1,0$	Ratio	19.299	[%]
$M_{cy,Rd,comp,M[+]}$	4.353	[kNm]				

Positive Moment in z-z axis [$M_{z,Ed}^+$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max}'' / \lambda_{e0}'']] / \gamma_{M0} \leq W_{pl} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{el} * f_{ya} / \gamma_{M0}$

$I_{z,el,M[+]}$	108754.009	[mm^4]	→	$W_{el,Comp}$	7468.064	[mm^3]
				$W_{el,Tens}$	3567.406	[mm^3]
$I_{z,eff,M[+]}$	84344.150	[mm^4]	→	$W_{eff,Comp}$	4343.109	[mm^3]
				$W_{eff,Tens}$	3291.123	[mm^3]
$W_{el,Comp}$	7468.064	[mm^3]		$W_{eff,Comp}$	4343.109	[mm^3]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cz,Rd,comp,M[+]}$ 1520088.003 [Nmm] → $M_{cz,Rd,comp,M[+]}$ **1.520** **[kNm]**

$M_{cz,Ed,M[+]}$	0.020	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \leq 1,0$	Ratio	1.316	[%]
$M_{cz,Rd,comp,M[+]}$	1.520	[kNm]				

$W_{el,Tens}$ 3567.406 [mm^3] $W_{eff,Tens}$ 3291.123 [mm^3]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cz,Rd,Tens,M[+]}$ 1151892.971 [Nmm] → $M_{cz,Rd,Tens,M[+]}$ **1.152** **[kNm]**

Negative Moment in z-z axis [$M_{z,Ed}^-$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max}'' / \lambda_{e0}'']] / \gamma_{M0} \leq W_{pl} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{el} * f_{ya} / \gamma_{M0}$

$W_{el,Tens}$ 12860.454 [mm^3] $W_{eff,Tens}$ 12773.241 [mm^3]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cy,Rd,Tens,M[+]}$ 4470634.244 [Nmm] → $M_{cy,Rd,Tens,M[+]}$ **4.471** **[kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^-$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max}'' / \lambda_{e0}'']] / \gamma_{M0} \leq W_{pl} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{el} * f_{ya} / \gamma_{M0}$

$I_{y,el,M[-]}$	762290.565	[mm^4]	→	$W_{el,Comp}$	12860.454	[mm^3]
				$W_{el,Tens}$	12860.454	[mm^3]
$I_{y,eff,M[-]}$	746984.961	[mm^4]	→	$W_{eff,Comp}$	12435.750	[mm^3]
				$W_{eff,Tens}$	12773.241	[mm^3]
$W_{el,Comp}$	12860.454	[mm^3]		$W_{eff,Comp}$	12435.750	[mm^3]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cy,Rd,comp,M[-]}$ 4352512.618 [Nmm] → $M_{cy,Rd,comp,M[-]}$ **4.353** **[kNm]**

$M_{cy,Ed,M[-]}$	0.840	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \leq 1,0$	Ratio	19.299	[%]
$M_{cy,Rd,comp,M[-]}$	4.353	[kNm]				

$W_{el,Tens}$ 12860.454 [mm^3] $W_{eff,Tens}$ 12773.241 [mm^3]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cy,Rd,Tens,M[-]}$ 4470634.244 [Nmm] → $M_{cy,Rd,Tens,M[-]}$ **4.471** **[kNm]**

$I_{z,el,M[-]}$	108754.009	[mm^4]	→	$W_{el,Comp}$	3567.406	[mm^3]
				$W_{el,Tens}$	7468.064	[mm^3]
$I_{z,eff,M[-]}$	108754.009	[mm^4]	→	$W_{eff,Comp}$	3567.406	[mm^3]
				$W_{eff,Tens}$	7468.064	[mm^3]
$W_{el,Comp}$	3567.406	[mm^3]		$W_{eff,Comp}$	3567.406	[mm^3]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cz,Rd,comp,M[-]}$ 1248592.193 [Nmm] → $M_{cz,Rd,comp,M[-]}$ **1.249** **[kNm]**

$M_{cz,Ed,M[-]}$	0.020	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \leq 1,0$	Ratio	1.602	[%]
$M_{cz,Rd,comp,M[-]}$	1.249	[kNm]				

$W_{el,Tens}$ 7468.064 [mm^3] $W_{eff,Tens}$ 7468.064 [mm^3]

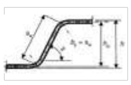
[BS EN 1993-1-3, Equation (6.4)]

$M_{cz,Rd,Tens,M[-]}$ 2613822.477 [Nmm] → $M_{cz,Rd,Tens,M[-]}$ **2.614** **[kNm]**

[iv] C-Section Beam: Shear Force [BS EN 1993-1-3:2006, 6.1.5]

$$V_{b,Rd} = \frac{\frac{h_w}{\sin \phi} t f_{bv}}{\gamma_{M0}}$$

$h_w = h_m$	118.548	[mm]
Φ	90.000	[º]
γ_{M0}	1.000	



Webs without longitudinal stiffeners $\bar{\lambda}_w = 0,346 \frac{s_w}{t} \sqrt{\frac{f_{yb}}{E}}$ [EN 1993-1-3, Equation (6.10a)]

s_w	118.548	[mm]	f_{yb}	350.000	[MPa]
t	1.452	[mm]	E	210.000	[GPa]

Table 6.1: Shear buckling strength f_{bv} [BS EN 1993-1-3:2006]

Relative web slenderness	Web without stiffening at the support
$\bar{\lambda}_w \leq 0,83$	$0,58 f_{yb}$
$0,83 < \bar{\lambda}_w < 1,40$	$0,48 f_{yb} / \bar{\lambda}_w$
$\bar{\lambda}_w \geq 1,40$	$0,67 f_{yb} / \bar{\lambda}_w^2$

$\bar{\lambda}_w$ 1.153 [EN 1993-1-3, Equation (6.10a)] f_{bv} 145.674 [MPa]

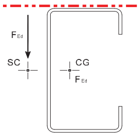
$V_{b,Rd}$ 25075.063 [N / Web] → $V_{b,Rd}$ **25.075** **[kN]**

$V_{z,Ed}$	2.000	[kN]	$\frac{V_{Ed}}{V_{c,Rd}} \leq 1{,}0$	Ratio	7.976	[%]
$V_{b,Rd}$	25.075	[kN]				

[v] C-Section Beam: Torsional Moment [EN 1993-1-3:2006, 6.1.6]

NOTE Where loads are applied eccentric to the shear centre of the cross-section, the effects of torsion are taken into account

Gravity Centre			Shear Centre			Δ	
y_{GC}	14.563	[mm]	y_{SC}	-22.793	[mm]	**37.355**	[mm]
z_{GC}	59.274	[mm]	z_{SC}	59.274	[mm]	**0.000**	[mm]



The applied loads are eccentric to the shear centre of the cross-section, so, the effects of torsion are taken into account

Significance of St Venant Torsion and Warping Torsion for Thin Cold-Formed Section

Section Type	Shape	St Venant	Warping
Thin Cold-Formed Sections	Z Σ	X	V
Key	X Negligible	V	Significant

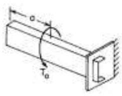
$$\sigma_{tot,Ed} = \sigma_{N,Ed} + \sigma_{My,Ed} + \sigma_{Mz,Ed} + \sigma_{w,Ed}$$

[BS EN 1993-1-3, Equation (6.12a)]

$$\tau_{tot,Ed} = \tau_{Vy,Ed} + \tau_{Vz,Ed} + \tau_{t,Ed} + \tau_{w,Ed}$$

[BS EN 1993-1-3, Equation (6.12b)]

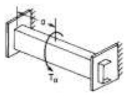
$\sigma_{N,Ed}$	2.900	[MPa]	$\tau_{Vy,Ed}$	1.154	[MPa]
$\sigma_{My,Ed}$	64.110	[MPa]	$\tau_{Vz,Ed}$	0.040	[MPa]
$\sigma_{Mz,Ed}$	5.300	[MPa]	$\tau_{t,Ed}$	0.000	[MPa]
$\sigma_{w,Ed}$	0.000	[MPa]	$\tau_{w,Ed}$	0.000	[MPa]
$\sigma_{tot,Ed}$	72.310	[MPa]	$\tau_{tot,Ed}$	1.194	[MPa]



Left end free to twist and warp

Right end free to warp but not twist

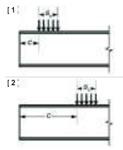
C-Section Console Beam



Both ends free to warp but not twist

C-Section Middle Beam

Local loads and supports: Cross-sections with a single web [BS EN 1993-1-3:2006, Figure 6.7a]



[1] Cross-Section with stiffened Flanges

$$R_{w,Rd} = \frac{k_1 k_2 k_3 \left[9{,}04 - \frac{h_w/t}{60}\right]\left[1 + 0{,}01\frac{s_s}{t}\right] t^2 f_{yb}}{\gamma_{M1}}$$

[BS EN 1993-1-3, Equation (6.15a)]

Local load applied with c ≤ 1.500 * h_w clear from a free end

[2]Cross-Section with stiffened Flanges

$$R_{w,Rd} = \frac{k_3 k_4 k_5 \left[14{,}7 - \frac{h_w/t}{49{,}5}\right]\left[1 + 0{,}007\frac{s_s}{t}\right] t^2 f_{yb}}{\gamma_{M1}}$$

[s_s / t ≤ 60] [BS EN 1993-1-3, Equation (6.15d)

$$R_{w,Rd} = \frac{k_3 k_4 k_5 \left[14{,}7 - \frac{h_w/t}{49{,}5}\right]\left[0{,}75 + 0{,}011\frac{s_s}{t}\right] t^2 f_{yb}}{\gamma_{M1}}$$

[s_s / t > 60] [BS EN 1993-1-3, Equation (6.15e)

Local load applied with c > 1.500 * h_w clear from a free end

c	80.000	[mm]	h_p	118.548	[mm]

BS EN 1993-1-3, Equation (6.15a)

s_s	16.545	[mm]	t	1.452	[mm]

BS EN 1993-1-3, Equation (6.15a)

$R_{w,Rd}$	4245.108	[N]	→	**$R_{w,Rd}$**	**4.245**	**[kN]**

$V_{z,Ed}$	2.000	[kN]	Ratio	47.113	[%]
$R_{w,Rd}$	4.245	[kN]			

[vii] C-Section Beam: Combined Tension and Bending [EN 1993-1-3:2006, 6.1.8]

$$\frac{N_{Ed}}{N_{t,Rd}} + \frac{M_{y,Ed}}{M_{cy,Rd,ten}} + \frac{M_{z,Ed}}{M_{cz,Rd,ten}} \leq 1$$

[BS EN 1993-1-3, Equation (6.23)]

$M_{cy,Rd,Com} \leq M_{cy,Rd,Ten}$ or $M_{cz,Rd,Com} \leq M_{cz,Rd,Ten}$

$$\frac{M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed}}{M_{cz,Rd,com}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[BS EN 1993-1-3, Equation (6.24)]

Combined Tension and Bending Moment [$M_{y,Ed}^{+}$ + $M_{z,Ed}^{+}$]

$N_{t,Ed}$	0.700	[kN]	$N_{t,Rd}$	124.904	[kN]
$M_{cy,Ed,M[+]}$	0.840	[kNm]	$M_{cy,Rd,Tension,M[+]}$	4.471	[kNm]
$M_{cz,Ed,M[+]}$	0.020	[kNm]	$M_{cz,Rd,Tension,M[+]}$	1.152	[kNm]

[EN 1993-1-3, Equation (6.23)]	Ratio	21.086	[%]

$\sigma_{tot,Ed} \leq f_{ya} / \gamma_{M0}$ [BS EN 1993-1-3, Equation (6.11a)]	$\sigma_{tot,Ed}$	72.310	[MPa]	OK
	f_{ya} / γ_{M0}	361.975	[MPa]	

$\tau_{tot,Ed} \leq \frac{f_{ya}/\sqrt{3}}{\gamma_{M0}}$	$\tau_{tot,Ed}$	1.194	[MPa]	OK
	[f_{ya} * √3] / γ_{M0}	626.960	[MPa]	

[BS EN 1993-1-3, Equation (6.11b)]

$\sqrt{\sigma_{tot,Ed}^2 + 3\tau_{tot,Ed}^2} \leq 1{,}1\frac{f_{ya}}{\gamma_{M0}}$	$\sqrt{\sigma_{tot,Ed}^2 + 3\tau_{tot,Ed}^2}$	72.320	[MPa]	OK
	1.10 * [f_{ya} / γ_{M0}]	398.173	[MPa]	

[BS EN 1993-1-3, Equation (6.11c)]

[vi] C-Section Beam: Local Transverse Forces [EN 1993-1-3:2006, 6.1.7]

$$F_{Ed} \leq R_{w,Rd}$$

[BS EN 1993-1-3, Equation (6.13)]

$R_{w,Rd}$ Local Transverse Resistance of the Web

ADVICE To avoid crushing, crippling or buckling in a web subject to a support reaction or other local transverse force applied through the flange

Cross-sections with a single unstiffened web [BS EN 1993-1-3, 6.1.7.2]

$h_w / t \leq 200$ [BS EN 1993-1-3, Equation (6.14a)]	h_w	118.548	[mm]	→	OK
	Φ	90.000	[°]		
	t	1.452	[mm]		
$r / t \leq 6$ [BS EN 1993-1-3, Equation (6.14b)]	r_m	3.226	[mm]	→	OK
	t	1.452	[mm]		
$45° \leq \phi \leq 90°$ [BS EN 1993-1-3, Equation (6.14c)]		1			
	Φ	90.000	[°]	→	OK
		1			

$k_1 = 1{,}33 - 0{,}33\,k$	k_1	0.823
$k_2 = 1{,}15 - 0{,}15\,r/t$	k_2	0.817
$k_2 \geq 0{,}50$ OK	$k_2 \leq 1{,}0$	OK
$k_3 = 0{,}7 + 0{,}3\,(\phi/90)^2$	k_3	1.000

$k = f_{yb}/228$	k	1.535	$k_4 = 1{,}22 - 0{,}22\,k$	k_4	0.882

$k_5 = 1{,}06 - 0{,}06\,r/t$	k_5	0.927	$k_5 \leq 1{,}0$	OK

$M_{cy,Rd,Comp,M[+]}$	4.353	[kNm]	$M_{cz,Rd,Comp,M[+]}$	1.520	[kNm]
$M_{cy,Rd,Comp,M[+]} \leq M_{cy,Rd,Tens,M[+]}$	OK		$M_{cz,Rd,Comp,M[+]} \leq M_{cz,Rd,Tens,M[+]}$	KO	

$$\frac{M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed}}{M_{cz,Rd,com}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[EN 1993-1-3: Equation (6.24)]

[EN 1993-1-3, Equation (6.24) don't need to be verified]

Ratio 0.000 [%]

Combined Tension and Bending Moment [$M_{y,Ed}^{-}$ + $M_{z,Ed}^{-}$]

$N_{t,Ed}$	0.700	[kN]	$N_{t,Rd}$	124.904	[kN]
$M_{cy,Ed,M[-]}$	0.840	[kNm]	$M_{cy,Rd,Tension,M[-]}$	4.471	[kNm]
$M_{cz,Ed,M[-]}$	0.020	[kNm]	$M_{cz,Rd,Tension,M[-]}$	2.614	[kNm]

[EN 1993-1-3, Equation (6.23)]	Ratio	20.115	[%]

$M_{cy,Rd,Comp,M[-]}$	4.353	[kNm]	$M_{cz,Rd,Comp,M[-]}$	1.249	[kNm]
$M_{cy,Rd,Comp,M[-]} \leq M_{cy,Rd,Tens,M[-]}$	OK		$M_{cz,Rd,Comp,M[-]} \leq M_{cz,Rd,Tens,M[-]}$	OK	

$$\frac{M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed}}{M_{cz,Rd,com}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[EN 1993-1-3: Equation (6.24)]

[EN 1993-1-3, Equation (6.24) must be verified]

Ratio 20.341 [%]

[viii] C-Section Beam: Combined Compression and Bending [EN 1993-1-3:2006, 6.1.9]

$$\frac{N_{Ed}}{N_{c,Rd}} + \frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{cz,Rd,com}} \leq 1$$

[BS EN 1993-1-3, Equation (6.25)]

$\Delta M_{y,Ed} = N_{ed,Compression} * e_{N,y,Compression}$			$\Delta M_{z,Ed} = N_{ed,Compression} * e_{N,z,Compression}$		
$N_{Ed,Compression}$	1.030	[kN]	$N_{Ed,Compression}$	1.030	[kN]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.004	[m]
$\Delta M_{y,Ed}$	0.000	[kNm]	$\Delta M_{z,Ed}$	0.004	[kNm]

Combined Compression and Bending Moment [$M_{y,Ed}^{+}$ + $M_{z,Ed}^{+}$]

$N_{c,Ed}$	1.030	[kN]	$N_{c,Rd}$	85.336	[kN]
$M_{cy,Ed,M[+]}$	0.840	[kNm]	$M_{cy,Rd,Comp,M[+]}$	4.353	[kNm]
$M_{cz,Ed,M[+]}$	0.020	[kNm]	$M_{cz,Rd,Comp,M[+]}$	1.520	[kNm]

[EN 1993-1-3, Equation (6.25)]	Ratio 22.072	[%]

$M_{cy,Rd,Tens,M[+]}$	4.471	[kNm]	$M_{cz,Rd,Tens,M[+]}$	1.152	[kNm]
$M_{cy,Rd,Tens,M[+]} \le M_{cy,Rd,Comp,M[+]}$	KO		$M_{cz,Rd,Tens,M[+]} \le M_{cz,Rd,Comp,M[+]}$	OK	

$$\frac{M_{y,Ed}+\Delta M_{y,Ed}}{M_{cy,Rd,ten}}+\frac{M_{z,Ed}+\Delta M_{z,Ed}}{M_{cz,Rd,ten}}-\frac{N_{Ed}}{N_{t,Rd}}\le 1$$

[EN 1993-1-3: Equation (6.26)]

[EN 1993-1-3, Equation (6.26) don't need to be verified] — Ratio 0.000 [%]

Combined Compression and Bending Moment [$M_{y,Ed}^{-} + M_{z,Ed}^{-}$]

$N_{c,Ed}$	1.030	[kN]	$N_{c,Rd}$	85.336	[kN]
$M_{cy,Ed,M[-]}$	0.840	[kNm]	$M_{cy,Rd,Comp,M[-]}$	4.353	[kNm]
$M_{cz,Ed,M[-]}$	0.020	[kNm]	$M_{cz,Rd,Comp,M[-]}$	1.249	[kNm]

[EN 1993-1-3, Equation (6.25)]	Ratio 22.413	[%]

$M_{cy,Rd,Tens,M[-]}$	4.471	[kNm]	$M_{cz,Rd,Tens,M[-]}$	2.614	[kNm]
$M_{cy,Rd,Tens,M[-]} \le M_{cy,Rd,Comp,M[-]}$	KO		$M_{cz,Rd,Tens,M[-]} \le M_{cz,Rd,Comp,M[-]}$	KO	

$$\frac{M_{y,Ed}+\Delta M_{y,Ed}}{M_{cy,Rd,ten}}+\frac{M_{z,Ed}+\Delta M_{z,Ed}}{M_{cz,Rd,ten}}-\frac{N_{Ed}}{N_{t,Rd}}\le 1$$

[EN 1993-1-3: Equation (6.26)]

[EN 1993-1-3, Equation (6.26) don't need to be verified] — Ratio 0.000 [%]

[ix] C-Section Beam: Combined Shear Force, Axial Force and Bending Moment [EN 1993-1-3:2006, 6.1.10]

$V_{z,Ed}$	2.000	[kN]	$R_{w,Rd}$	4.245	[kN]

$V_{z,Ed} \le 0.50\, V_{w,Rd}$	OK	No reduction due to shear force is need to be done

$$\frac{N_{Ed}}{N_{Rd}}+\frac{M_{y,Ed}}{M_{y,Rd}}+\left(1-\frac{M_{f,Rd}}{M_{pl,Rd}}\right)\left(\frac{2V_{Ed}}{V_{w,Rd}}-1\right)^2\le 1{,}0$$

[BS EN 1993-1-3, Equation (6.27)]

$M_{pl,y,Rd}$	5.389	[kNm]
$M_{f,Rd}$	2.325	[kNm]

$N_{t,Ed}$	0.700	[kN]	$N_{t,Rd}$	124.904	[kN]
$N_{c,Ed}$	1.030	[kN]	$N_{c,Rd}$	85.336	[kN]
$M_{y,Ed[+]}$	0.840	[kNm]	$M_{y,Rd[+]}$	4.501	[kNm]
$M_{y,Ed[-]}$	0.840	[kNm]	$M_{y,Rd[-]}$	4.501	[kNm]

$$\frac{M_{Ed}}{M_{c,Rd}}+\frac{F_{Ed}}{R_{w,Rd}}\le 1.25$$

[BS EN 1993-1-3, Equation (6.28c)]	$M_{cy,Ed,M[+]}$, $M_{cy,Rd,comp,M[+]}$, $F_{z,Ed} \mid V_{z,Ed}$	Ratio	66.412	[%]
[BS EN 1993-1-3, Equation (6.28c)]	$M_{cy,Ed,M[-]}$, $M_{cy,Rd,comp,M[-]}$, $F_{z,Ed} \mid V_{z,Ed}$	Ratio	66.412	[%]
[BS EN 1993-1-3, Equation (6.28c)]	$M_{cz,Ed,M[+]}$, $M_{cz,Rd,comp,M[+]}$, $F_{z,Ed} \mid V_{z,Ed}$	Ratio	48.429	[%]
[BS EN 1993-1-3, Equation (6.28c)]	$M_{cz,Ed,M[-]}$, $M_{cz,Rd,comp,M[-]}$, $F_{z,Ed} \mid V_{z,Ed}$	Ratio	48.715	[%]

[c] C-Section Column

[i] C-Section Column: Axial Tension [BS EN 1993-1-3:2006, 6.1.2]

$$N_{t,Rd}=\frac{f_{ya}A_g}{\gamma_{M0}}$$

[BS EN 1993-1-3, Equation (6.1)]

f_{ya}	373.699	[MPa]
A_g	497.235	[mm^2]
γ_{M0}	1.000	

$$\frac{N_{Ed}}{N_{t,Rd}}\le 1{,}0$$

$N_{t,Rd}$ 185816.378 [N] → **$N_{t,Rd}$ 185.816 [kN]**

$N_{t,Ed}$	3.340	[kN]	Ratio	1.797 [%]
$N_{t,Rd}$	185.816	[kN]		

[ii] C-Section Column: Axial Compression [BS EN 1993-1-3:2006, 6.1.3]

[BS EN 1993-1-3, Equation (6.2)]

$A_{eff} < A_g$ → $N_{c,Rd} = A_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.3)]

$A_{eff} = A_g$ → $N_{c,Rd} = A_g * [f_{yb} + [f_{ya} - f_{yb}] * 4 * [1 - \lambda_e^{-} / \lambda_{e0}^{-}]] / \gamma_{M0} \le A_g * f_{ya} / \gamma_{M0}$

A_g	497.235	[mm^2]	A_{eff}	482.146	[mm^2]

[BS EN 1993-1-3, Equation (6.2)]

$N_{c,Rd}$ 168751.112 [N] → **$N_{c,Rd}$ 168.751 [kN]**

$N_{t,Ed}$	0.700	[kN]	Ratio	19.412 [%]
$N_{t,Rd}$	124.904	[kN]		
$M_{y,Ed,M[+]}$	0.840	[kNm]		
$M_{y,Rd,M[+]}$	4.501	[kNm]		
$V_{z,Ed}$	2.000	[kN]		
$R_{w,Rd}$	4.245	[kN]		

$N_{t,Ed}$	0.700	[kN]	Ratio	19.412 [%]
$N_{t,Rd}$	124.904	[kN]		
$M_{y,Ed,M[-]}$	0.840	[kNm]		
$M_{y,Rd,M[-]}$	4.501	[kNm]		
$V_{z,Ed}$	2.000	[kN]		
$R_{w,Rd}$	4.245	[kN]		

$N_{c,Ed}$	1.030	[kN]	Ratio	20.058 [%]
$N_{c,Rd}$	85.336	[kN]		
$M_{y,Ed,M[+]}$	0.840	[kNm]		
$M_{y,Rd,M[+]}$	4.501	[kNm]		
$V_{z,Ed}$	2.000	[kN]		
$R_{w,Rd}$	4.245	[kN]		

$N_{c,Ed}$	1.030	[kN]	Ratio	20.058 [%]
$N_{c,Rd}$	85.336	[kN]		
$M_{y,Ed,M[-]}$	0.840	[kNm]		
$M_{y,Rd,M[-]}$	4.501	[kNm]		
$V_{z,Ed}$	2.000	[kN]		
$R_{w,Rd}$	4.245	[kN]		

[x] C-Section Beam: Combined Bending Moment and Local Load or Support Reaction [EN 1993-1-3:2006, 6.1.11]

$M_{Ed} / M_{c,Rd} \le 1$	[BS EN 1993-1-3, Equation (6.28a)]	$M_{cy,Ed,M[+]}$, $M_{cy,Rd,comp,M[+]}$	Ratio	19.299	[%]
$M_{Ed} / M_{c,Rd} \le 1$	[BS EN 1993-1-3, Equation (6.28a)]	$M_{cy,Ed,M[-]}$, $M_{cy,Rd,comp,M[-]}$	Ratio	19.299	[%]
$M_{Ed} / M_{c,Rd} \le 1$	[BS EN 1993-1-3, Equation (6.28a)]	$M_{cz,Ed,M[+]}$, $M_{cz,Rd,comp,M[+]}$	Ratio	1.316	[%]
$M_{Ed} / M_{c,Rd} \le 1$	[BS EN 1993-1-3, Equation (6.28a)]	$M_{cz,Ed,M[-]}$, $M_{cz,Rd,comp,M[-]}$	Ratio	1.602	[%]
$F_{Ed} / R_{w,Rd} \le 1$	[BS EN 1993-1-3, Equation (6.28b)]	$F_{z,Ed} \mid V_{z,Ed}$, $R_{w,Rd}$	Ratio	47.113	[%]

NOTE — The internal axial force in a member is taken as acting at the centroid of its gross-cross section.

NOTE — The design compression resistance of a cross-section refers to the axial load acting at the centroid of its effective cross-section. If this does not coincide with the centroid of its gross cross-section, the shift e_N of the centroid axes is taken into account. If the shift of the neutral axis gives a favourable result in the stress check, the shift should be neglected only if the shift has been calculated at yield strength and not with the actual compressive stresses.

$N_{c,Rd} \le A_g * f_{ya} / \gamma_{M0}$ — OK

$e_{N,z}$	0.506	[mm]	In stress check, shift is used
$e_{N,y}$	0.000	[mm]	

$$\frac{N_{Ed}}{N_{c,Rd}}\le 1{,}0$$

$N_{c,Ed}$	4.170	[kN]	Ratio	2.471 [%]
$N_{c,Rd}$	168.751	[kN]		

[iii] C-Section Column: Bending Moment [BS EN 1993-1-3:2006, 6.1.4]

Positive Moment in y-y axis [$M_{y,Ed}^{+}$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max}^{-} / \lambda_{e0}^{-}]] / \gamma_{M0} \le W_{pl} * f_{yb} / \gamma_{M0}$

Equation [6.5] is applicable provided that the following conditions are satisfied:

[a] Bending moment is applied only about one principal axes of the cross-section

[b] Member not subject to torsion or to torsional, torsional flexural or lateral-torsional or distortional buckling

[c] Angle Φ between the web and the flange is larger than 60º

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{el} * f_{ya} / \gamma_{M0}$

$I_{y,el,M[+]}$	625036.020	[mm^4]	→	$W_{el,Comp}$	14278.705	[mm^3]
				$W_{el,Tens}$	14278.705	[mm^3]
$I_{y,eff,M[+]}$	625036.020	[mm^4]	→	$W_{eff,Comp}$	14278.705	[mm^3]
				$W_{eff,Tens}$	14278.705	[mm^3]
$W_{el,Comp}$	14278.705	[mm^3]		$W_{eff,Comp}$	14278.705	[mm^3]

[BS EN 1993-1-3, Equation (6.6)]

$M_{cy,Rd,comp,M[+]}$ 5335941.768 [Nmm] → **$M_{cy,Rd,comp,M[+]}$ 5.336 [kNm]**

$M_{cy,Ed,M[+]}$	0.350	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \leq 1,0$	Ratio	6.559	[%]
$M_{cy,Rd,comp,M+}$	5.336	[kNm]				

$W_{el,Tens}$	14278.705	[mm^3]	$W_{eff,Tens}$	14278.705	[mm^3]

[BS EN 1993-1-3, Equation (6.6)]

$M_{cy,Rd,Tens,M[+]}$ 5335941.768 [Nmm] → **$M_{cy,Rd,Tens,M[+]}$ 5.336 [kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^-$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max} / \lambda_{e0}]] / \gamma_{M0} \leq W_{pl} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{ell} * f_{ya} / \gamma_{M0}$

$I_{y,el,M[-]}$	625036.020	[mm^4]	→	$W_{el,Comp}$	14278.705	[mm^3]
				$W_{el,Tens}$	14278.705	[mm^3]
$I_{y,eff,M[-]}$	625036.020	[mm^4]	→	$W_{eff,Comp}$	14278.705	[mm^3]
				$W_{eff,Tens}$	14278.705	[mm^3]
$W_{el,Comp}$	14278.705	[mm^3]		$W_{eff,Comp}$	14278.705	[mm^3]

[BS EN 1993-1-3, Equation (6.6)]

$M_{cy,Rd,comp,M[-]}$ 5335941.768 [Nmm] → **$M_{cy,Rd,comp,M[-]}$ 5.336 [kNm]**

$M_{cy,Ed,M[-]}$	0.350	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \leq 1,0$	Ratio	6.559	[%]
$M_{cy,Rd,comp,M[-]}$	5.336	[kNm]				

$W_{el,Tens}$	14278.705	[mm^3]	$W_{eff,Tens}$	14278.705	[mm^3]

[BS EN 1993-1-3, Equation (6.6)]

$M_{cy,Rd,Tens,M[-]}$ 5335941.768 [Nmm] → **$M_{cy,Rd,Tens,M[-]}$ 5.336 [kNm]**

$I_{z,el,M[-]}$	153816.866	[mm^4]	→	$W_{el,Comp}$	5515.375	[mm^3]
				$W_{el,Tens}$	9518.806	[mm^3]
$I_{z,eff,M[-]}$	153816.866	[mm^4]	→	$W_{eff,Comp}$	5515.375	[mm^3]
				$W_{eff,Tens}$	9518.806	[mm^3]
$W_{el,Comp}$	5515.375	[mm^3]		$W_{eff,Comp}$	5515.375	[mm^3]

[BS EN 1993-1-3, Equation (6.6)]

$M_{cz,Rd,comp,M[-]}$ 2061091.855 [Nmm] → **$M_{cz,Rd,comp,M[-]}$ 2.061 [kNm]**

$M_{cz,Ed,M[-]}$	0.000	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \leq 1,0$	Ratio	0.000	[%]
$M_{cz,Rd,comp,M[-]}$	2.061	[kNm]				

$W_{el,Tens}$	9518.806	[mm^3]	$W_{eff,Tens}$	9518.806	[mm^3]

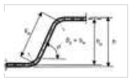
[BS EN 1993-1-3, Equation (6.6)]

$M_{cz,Rd,Tens,M[-]}$ 3557170.948 [Nmm] → **$M_{cz,Rd,Tens,M[-]}$ 3.557 [kNm]**

[iv] C-Section Column: Shear Force [BS EN 1993-1-3:2006, 6.1.5]

$$V_{b,Rd} = \frac{\frac{h_w}{\sin\phi} t f_{bv}}{\gamma_{M0}}$$

$h_w = h_m$	87.548	[mm]
Φ	90.000	[°]
γ_{M0}	1.000	



Webs without longitudinal stiffeners $\bar{\lambda}_w = 0{,}346 \frac{s_w}{t} \sqrt{\frac{f_{yb}}{E}}$ [EN 1993-1-3, Equation (6.10a)]

s_w	87.548	[mm]	f_{yb}	350.000	[MPa]
t	2.452	[mm]	E	210.000	[GPa]

Table 6.1: Shear buckling strength f_{bv} [BS EN 1993-1-3:2006]

Relative web slenderness	Web without stiffening at the support
$\bar{\lambda}_w \leq 0{,}83$	$0{,}58 f_{yb}$
$0{,}83 < \bar{\lambda}_w < 1{,}40$	$0{,}48 f_{yb} / \bar{\lambda}_w$
$\bar{\lambda}_w \geq 1{,}40$	$0{,}67 f_{yb} / \bar{\lambda}_w^2$

$\bar{\lambda}_w$ 0.504 [EN 1993-1-3, Equation (6.10a)] f_{bv} 203.000 [MPa]

$V_{b,Rd}$ 43577.542 [N] → **$V_{b,Rd}$ 43.578 [kN]**

Positive Moment in z-z axis [$M_{z,Ed}^+$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max} / \lambda_{e0}]] / \gamma_{M0} \leq W_{pl} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{ell} * f_{ya} / \gamma_{M0}$

$I_{z,el,M[+]}$	153816.866	[mm^4]	→	$W_{el,Comp}$	9518.806	[mm^3]
				$W_{el,Tens}$	5515.375	[mm^3]
$I_{z,eff,M[+]}$	150093.116	[mm^4]	→	$W_{eff,Comp}$	9029.404	[mm^3]
				$W_{eff,Tens}$	5472.799	[mm^3]
$W_{el,Comp}$	9518.806	[mm^3]		$W_{eff,Comp}$	9029.404	[mm^3]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cz,Rd,comp,M[+]}$ 3160291.380 [Nmm] → **$M_{cz,Rd,comp,M[+]}$ 3.160 [kNm]**

$M_{cz,Ed,M[+]}$	0.000	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \leq 1,0$	Ratio	0.000	[%]
$M_{cz,Rd,comp,M+}$	3.160	[kNm]				

$W_{el,Tens}$	5515.375	[mm^3]	$W_{eff,Tens}$	5472.799	[mm^3]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cz,Rd,Tens,M[+]}$ 1915479.502 [Nmm] → **$M_{cz,Rd,Tens,M[+]}$ 1.915 [kNm]**

Negative Moment in z-z axis [$M_{z,Ed}^-$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max} / \lambda_{e0}]] / \gamma_{M0} \leq W_{pl} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.6)]

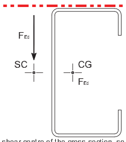
$M_{c,Rd} = W_{ell} * f_{ya} / \gamma_{M0}$

$V_{z,Ed}$	2.240	[kN]	$\frac{V_{Ed}}{V_{c,Rd}} \leq 1,0$	Ratio	5.140	[%]
$V_{b,Rd}$	43.578	[kN]				

[v] C-Section Column: Torsional Moment [EN 1993-1-3:2006, 6.1.6]

NOTE Where loads are applied eccentric to the shear centre of the cross-section, the effects of torsion are taken into account

Gravity Centre			Shear Centre			Δ	
y_{GC}	16.159	[mm]	y_{SC}	-23.949	[mm]	**40.108**	[mm]
z_{GC}	43.774	[mm]	z_{SC}	43.774	[mm]	**0.000**	[mm]



The applied loads are eccentric to the shear centre of the cross-section, so, the effects of torsion are taken into account

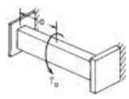
Significance of St Venant Torsion and Warping Torsion for Thin Cold-Formed Section

Section Type	Shape	St Venant	Warping
Thin Cold-Formed Sections	Z Σ	X	V
Key	X — Negligible	V — Significant	

$\sigma_{tot,Ed} = \sigma_{N,Ed} + \sigma_{My,Ed} + \sigma_{Mz,Ed} + \sigma_{w,Ed}$ [BS EN 1993-1-3, Equation (6.12a)]

$\tau_{tot,Ed} = \tau_{Vy,Ed} + \tau_{Vz,Ed} + \tau_{t,Ed} + \tau_{w,Ed}$ [BS EN 1993-1-3, Equation (6.12b)]

$\sigma_{N,Ed}$	8.210	[MPa]	$\tau_{Vy,Ed}$	0.000	[MPa]
$\sigma_{My,Ed}$	23.710	[MPa]	$\tau_{Vz,Ed}$	0.000	[MPa]
$\sigma_{Mz,Ed}$	0.260	[MPa]	$\tau_{t,Ed}$	221.065	[MPa]
$\sigma_{w,Ed}$	124.558	[MPa]	$\tau_{w,Ed}$	0.000	[MPa]
$\sigma_{tot,Ed}$	156.738	[MPa]	$\tau_{tot,Ed}$	221.065	[MPa]



Left end free to warp but not twist

Right end fixed [no twist or warp]

C-Section Column

$\sigma_{tot,Ed} \le f_{ya} / \gamma_{M0}$ [BS EN 1993-1-3, Equation (6.11a)]

$\sigma_{tot,Ed}$	156.738	[MPa]	OK
f_{ya} / γ_{M0}	373.699	[MPa]	

$$\tau_{tot,Ed} \le \frac{f_{ya}/\sqrt{3}}{\gamma_{M0}}$$

[BS EN 1993-1-3, Equation (6.11b)]

$\tau_{tot,Ed}$	221.065	[MPa]	OK
[f_{ya} * √3] / γ_{M0}	647.266	[MPa]	

$$\sqrt{\sigma_{tot,Ed}^2 + 3\tau_{tot,Ed}^2} \le 1{,}1\frac{f_{ya}}{\gamma_{M0}}$$

[BS EN 1993-1-3, Equation (6.11c)]

$\sqrt{\sigma_{tot,Ed}^2 + 3\tau_{tot,Ed}^2}$	270.992	[MPa]	OK
1.10 * [f_{ya} / γ_{M0}]	411.069	[MPa]	

[vi] C-Section Column: Local Transverse Forces [EN 1993-1-3:2006, 6.1.7]

$F_{Ed} \le R_{w,Rd}$ [BS EN 1993-1-3, Equation (6.13)]

$R_{w,Rd}$ Local Transverse Resistance of the Web

ADVICE: To avoid crushing, crippling or buckling in a web subject to a support reaction or other local transverse force applied through the flange

Cross-sections with a single unstiffened web [BS EN 1993-1-3, 6.1.7.2]

$h_w / t \le 200$ [BS EN 1993-1-3, Equation (6.14a)]

h_w	87.548	[mm]	→ OK
Φ	90.000	[°]	
t	2.452	[mm]	

$r / t \le 6$ [BS EN 1993-1-3, Equation (6.14b)]

r_m	3.726	[mm]	→ OK
t	2.452	[mm]	

$45° \le \phi \le 90°$ [BS EN 1993-1-3, Equation (6.14c)]

	1		
Φ	90.000	[°]	→ OK
	1		

$k_1 = 1{,}33 - 0{,}33\,k$	k_1	0.823
$k_2 = 1{,}15 - 0{,}15\,r/t$	k_2	0.922
$k_2 \ge 0{,}50$ OK	$k_2 \le 1{,}0$	OK
$k_3 = 0{,}7 + 0{,}3\,(\phi/90)^2$	k_3	1.000
$k = f_{yb}/228$	k	1.535
$k_4 = 1{,}22 - 0{,}22\,k$	k_4	0.882
$k_5 = 1{,}06 - 0{,}06\,r/t$	k_5	0.969
$k_5 \le 1{,}0$		OK

$M_{cy,Rd,Comp,M[+]}$	5.336	[kNm]	$M_{cz,Rd,Comp,M[+]}$	3.160	[kNm]
$M_{cy,Rd,Comp,M[+]} \le M_{cy,Rd,Tens,M[+]}$	OK		$M_{cz,Rd,Comp,M[+]} \le M_{cz,Rd,Tens,M[+]}$	KO	

$$\frac{M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed}}{M_{cz,Rd,com}} - \frac{N_{Ed}}{N_{t,Rd}} \le 1$$

[EN 1993-1-3: Equation (6.24)] — [EN 1993-1-3, Equation (6.24) don't need to be verified] Ratio 0.000 [%]

Combined Tension and Bending Moment [$M_{y,Ed}^-$ + $M_{z,Ed}^-$]

$N_{t,Ed}$	3.340	[kN]	$N_{t,Rd}$	185.816	[kN]
$M_{cy,Ed,M[-]}$	0.350	[kNm]	$M_{cy,Rd,Tension,M[*]}$	5.336	[kNm]
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{cz,Rd,Tension,M[-]}$	3.557	[kNm]

[EN 1993-1-3, Equation (6.23)] Ratio 8.357 [%]

$M_{cy,Rd,Comp,M[-]}$	5.336	[kNm]	$M_{cz,Rd,Comp,M[-]}$	2.061	[kNm]
$M_{cy,Rd,Comp,M[-]} \le M_{cy,Rd,Tens,M[-]}$	OK		$M_{cz,Rd,Comp,M[-]} \le M_{cz,Rd,Tens,M[-]}$	OK	

$$\frac{M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed}}{M_{cz,Rd,com}} - \frac{N_{Ed}}{N_{t,Rd}} \le 1$$

[EN 1993-1-3: Equation (6.24)] — [EN 1993-1-3, Equation (6.24) must be verified] Ratio 4.762 [%]

[viii] C-Section Column: Combined Compression and Bending [EN 1993-1-3:2006, 6.1.9]

$$\frac{N_{Ed}}{N_{c,Rd}} + \frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{cz,Rd,com}} \le 1$$

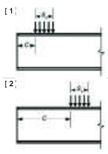
[BS EN 1993-1-3, Equation (6.25)]

$\Delta M_{y,Ed} = N_{ed,Compression} * e_{N,y,Compression}$			$\Delta M_{z,Ed} = N_{ed,Compression} * e_{N,z,Compression}$		
$N_{Ed,Compression}$	4.170	[kN]	$N_{Ed,Compression}$	4.170	[kN]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.001	[m]
$\Delta M_{y,Ed}$	0.000	[kNm]	$\Delta M_{z,Ed}$	0.002	[kNm]

Combined Compression and Bending Moment [$M_{y,Ed}^+$ + $M_{z,Ed}^+$]

$N_{c,Ed}$	4.170	[kN]	$N_{c,Rd}$	168.751	[kN]
$M_{cy,Ed,M[+]}$	0.350	[kNm]	$M_{cy,Rd,Comp,M[+]}$	5.336	[kNm]
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{cz,Rd,Comp,M[+]}$	3.160	[kNm]

Local loads and supports: Cross-sections with a single web [BS EN 1993-1-3:2006, Figure 6.7a]



[1] Cross-Section with stiffened Flanges	[2]Cross-Section with stiffened Flanges
$R_{w,Rd} = \frac{k_1 k_2 k_3 \left[9{,}04 - \frac{h_w/t}{60}\right]\left[1 + 0{,}01\frac{s_s}{t}\right] t^2 f_{yb}}{\gamma_{M1}}$	$R_{w,Rd} = \frac{k_3 k_4 k_5 \left[14{,}7 - \frac{h_w/t}{49{,}5}\right]\left[1 + 0{,}007\frac{s_s}{t}\right] t^2 f_{yb}}{\gamma_{M1}}$ [s_s / t ≤ 60] [BS EN 1993-1-3, Equation (6.15d)]
[BS EN 1993-1-3, Equation (6.15a)]	$R_{w,Rd} = \frac{k_3 k_4 k_5 \left[14{,}7 - \frac{h_w/t}{49{,}5}\right]\left[0{,}75 + 0{,}011\frac{s_s}{t}\right] t^2 f_{yb}}{\gamma_{M1}}$ [s_s / t > 60] [BS EN 1993-1-3, Equation (6.15e)]
Local load applied with c ≤ 1.500 * h_w clear from a free end	Local load applied with c > 1.500 * h_w clear from a free end

c	0.000	[mm]	h_p	87.548	[mm]

BS EN 1993-1-3, Equation (6.15a)

s_s	36.596	[mm]	t	2.452	[mm]

BS EN 1993-1-3, Equation (6.15a)

$R_{w,Rd}$ 15506.072 [N] → **$R_{w,Rd}$ 15.506 [kN]**

$V_{z,Ed}$	2.240	[kN]	Ratio	14.446	[%]
$R_{w,Rd}$	15.506	[kN]			

[vii] C-Section Column: Combined Tension and Bending [EN 1993-1-3:2006, 6.1.8]

$$\frac{N_{Ed}}{N_{t,Rd}} + \frac{M_{y,Ed}}{M_{cy,Rd,ten}} + \frac{M_{z,Ed}}{M_{cz,Rd,ten}} \le 1$$

[BS EN 1993-1-3, Equation (6.23)]

$M_{cy,Rd,Com} \le M_{cy,Rd,Ten}$ or $M_{cz,Rd,Com} \le M_{cz,Rd,Ten}$

$$\frac{M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed}}{M_{cz,Rd,com}} - \frac{N_{Ed}}{N_{t,Rd}} \le 1$$

[BS EN 1993-1-3, Equation (6.24)]

Combined Tension and Bending Moment [$M_{y,Ed}^+$ + $M_{z,Ed}^+$]

$N_{t,Ed}$	3.340	[kN]	$N_{t,Rd}$	185.816	[kN]
$M_{cy,Ed,M[+]}$	0.350	[kNm]	$M_{cy,Rd,Tension,M[+]}$	5.336	[kNm]
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{cz,Rd,Tension,M[+]}$	1.915	[kNm]

[EN 1993-1-3, Equation (6.23)] Ratio 8.357 [%]

[EN 1993-1-3, Equation (6.25)] Ratio 9.097 [%]

$M_{cy,Rd,Tens,M[+]}$	5.336	[kNm]	$M_{cz,Rd,Tens,M[+]}$	1.915	[kNm]
$M_{cy,Rd,Tens,M[+]} \le M_{cy,Rd,Comp,M[+]}$	OK		$M_{cz,Rd,Tens,M[+]} \le M_{cz,Rd,Comp,M[+]}$	OK	

$$\frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{cy,Rd,ten}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{cz,Rd,ten}} - \frac{N_{Ed}}{N_{c,Rd}} \le 1$$

[EN 1993-1-3: Equation (6.26)] — [EN 1993-1-3, Equation (6.26) must be verified] Ratio 0.000 [%]

Combined Compression and Bending Moment [$M_{y,Ed}^-$ + $M_{z,Ed}^-$]

$N_{c,Ed}$	4.170	[kN]	$N_{c,Rd}$	168.751	[kN]
$M_{cy,Ed,M[-]}$	0.350	[kNm]	$M_{cy,Rd,Comp,M[-]}$	5.336	[kNm]
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{cz,Rd,Comp,M[-]}$	2.061	[kNm]

[EN 1993-1-3, Equation (6.25)] Ratio 9.133 [%]

$M_{cy,Rd,Tens,M[-]}$	5.336	[kNm]	$M_{cz,Rd,Tens,M[-]}$	3.557	[kNm]
$M_{cy,Rd,Tens,M[-]} \le M_{cy,Rd,Comp,M[-]}$	OK		$M_{cz,Rd,Tens,M[-]} \le M_{cz,Rd,Comp,M[-]}$	KO	

$$\frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{cy,Rd,ten}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{cz,Rd,ten}} - \frac{N_{Ed}}{N_{c,Rd}} \le 1$$

[EN 1993-1-3: Equation (6.26)] — [EN 1993-1-3, Equation (6.26) don't need to be verified] Ratio 0.000 [%]

[ix] C-Section Column: Combined Shear Force, Axial Force and Bending Moment [EN 1993-1-3:2006, 6.1.10]

$V_{z,Ed}$	2.240	[kN]	$R_{w,Rd}$	15.506	[kN]

$V_{Ed} \le 0.50\ V_{w,Rd}$ — OK — No reduction due to shear force is need to be done

$$\frac{N_{Ed}}{N_{Rd}} + \frac{M_{y,Ed}}{M_{y,Rd}} + \left(1 - \frac{M_{f,Rd}}{M_{pl,Rd}}\right)\left(\frac{2V_{Ed}}{V_{w,Rd}} - 1\right)^2 \le 1{,}0$$

[BS EN 1993-1-3, Equation (6.27)]

$M_{pl,y,Rd}$	5.973	[kNm]
$M_{f,Rd}$	2.750	[kNm]

$N_{t,Ed}$	3.340	[kN]	$N_{t,Rd}$	185.816	[kN]
$N_{c,Ed}$	4.170	[kN]	$N_{c,Rd}$	168.751	[kN]
$M_{y,Ed[+]}$	0.350	[kNm]	$M_{y,Rd[+]}$	4.998	[kNm]
$M_{y,Ed[-]}$	0.350	[kNm]	$M_{y,Rd[-]}$	4.998	[kNm]

N_{Ed}	3.340	[kN]			
N_{Rd}	185.816	[kN]			
$M_{y,Ed,M[+]}$	0.350	[kNm]	Ratio	36.081	[%]
$M_{y,Rd,M[+]}$	4.998	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
$R_{w,Rd}$	15.506	[kN]			

N_{Ed}	3.340	[kN]			
N_{Rd}	185.816	[kN]			
$M_{y,Ed,M[-]}$	0.350	[kNm]	Ratio	36.081	[%]
$M_{y,Rd,M[-]}$	4.998	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
$R_{w,Rd}$	15.506	[kN]			

$N_{c,Ed}$	4.170	[kN]			
$N_{c,Rd}$	168.751	[kN]			
$M_{y,Ed,M[+]}$	0.350	[kNm]	Ratio	36.755	[%]
$M_{y,Rd,M[+]}$	4.998	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
$R_{w,Rd}$	15.506	[kN]			

$N_{c,Ed}$	4.170	[kN]			
$N_{c,Rd}$	168.751	[kN]			
$M_{y,Ed,M[-]}$	0.350	[kNm]	Ratio	36.755	[%]
$M_{y,Rd,M[-]}$	4.998	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
$R_{w,Rd}$	15.506	[kN]			

[x] C-Section Column: Combined Bending Moment and Local Load or Support Reaction [EN 1993-1-3:2006, 6.1.11]

$M_{Ed} / M_{c,Rd} \le 1$ [BS EN 1993-1-3, Equation (6.28a)]	$M_{cy,Ed,M[+]}$ / $M_{cy,Rd,comp,M[+]}$	Ratio	6.559	[%]
$M_{Ed} / M_{c,Rd} \le 1$ [BS EN 1993-1-3, Equation (6.28a)]	$M_{cy,Ed,M[-]}$ / $M_{cy,Rd,comp,M[-]}$	Ratio	6.559	[%]
$M_{Ed} / M_{c,Rd} \le 1$ [BS EN 1993-1-3, Equation (6.28a)]	$M_{cz,Ed,M[+]}$ / $M_{cz,Rd,comp,M[+]}$	Ratio	0.000	[%]
$M_{Ed} / M_{c,Rd} \le 1$ [BS EN 1993-1-3, Equation (6.28a)]	$M_{cz,Ed,M[-]}$ / $M_{cz,Rd,comp,M[-]}$	Ratio	0.000	[%]
$F_{Ed} / R_{w,Rd} \le 1$ [BS EN 1993-1-3, Equation (6.28b)]	$F_{z,Ed}$ | $V_{z,Ed}$ / $R_{w,Rd}$	Ratio	14.446	[%]

NOTE: The internal axial force in a member is taken as acting at the centroid of its gross-cross section.

NOTE: The design compression resistance of a cross-section refers to the axial load acting at the centroid of its effective cross-section. If this does not coincide with the centroid of its gross cross-section, the shift e_N of the centroid axes is taken into account. If the shift of the neutral axis gives a favourable result in the stress check, the shift should be neglected only if the shift has been calculated at yield strength and not with the actual compressive stresses.

$N_{c,Rd} \le A_g * f_{ya} / \gamma_{M0}$ — OK

$e_{N,y}$	-0.611	[mm]
$e_{N,z}$	0.000	[mm]

In stress check, shift is neglected because has been calculated at yield strength and not with actual compressive stresse

$N_{c,Ed}$	1.470	[kN]	$\frac{N_{Ed}}{N_{c,Rd}} \le 1{,}0$	Ratio	2.214	[%]
$N_{c,Rd}$	66.398	[kN]				

[iii] C-Section Strut: Bending Moment [BS EN 1993-1-3:2006, 6.1.4]

Positive Moment in y-y axis [$M_{y,Ed}^{+}$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max} / \lambda_{e0}]] / \gamma_{M0} \le W_{pl} * f_{yb} / \gamma_{M0}$

Equation [6.5] is applicable provided that the following conditions are satisfied:

[a] Bending moment is applied only about one principal axes of the cross-section

[b] Member not subject to torsion or to torsional, torsional flexural or lateral-torsional or distortional buckling

[c] Angle Φ between the web and the flange is larger than 60º

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{el} * f_{ya} / \gamma_{M0}$

$I_{y,el,M[+]}$	85435.109	[mm⁴]	→	$W_{el,Comp}$	3519.614	[mm³]
				$W_{el,Tens}$	3519.614	[mm³]
$I_{y,eff,M[+]}$	83790.577	[mm⁴]	→	$W_{eff,Comp}$	3402.038	[mm³]
				$W_{eff,Tens}$	3503.173	[mm³]
$W_{el,Comp}$	3519.614	[mm³]		$W_{eff,Comp}$	3402.038	[mm³]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cy,Rd,comp,M[+]}$ 1190713.405 [Nmm] → **$M_{cy,Rd,comp,M[+]}$ 1.191 [kNm]**

$\frac{M_{Ed}}{M_{c,Rd}} + \frac{F_{Ed}}{R_{w,Rd}} \le 1{,}25$ [BS EN 1993-1-3, Equation (6.28c)]	$M_{cy,Ed,M[+]}$ / $M_{cy,Rd,comp,M[+]}$ / $F_{z,Ed}$ | $V_{z,Ed}$	Ratio	21.005	[%]
$\frac{M_{Ed}}{M_{c,Rd}} + \frac{F_{Ed}}{R_{w,Rd}} \le 1{,}25$ [BS EN 1993-1-3, Equation (6.28c)]	$M_{cy,Ed,M[-]}$ / $M_{cy,Rd,comp,M[-]}$ / $F_{z,Ed}$ | $V_{z,Ed}$	Ratio	21.005	[%]
$\frac{M_{Ed}}{M_{c,Rd}} + \frac{F_{Ed}}{R_{w,Rd}} \le 1{,}25$ [BS EN 1993-1-3, Equation (6.28c)]	$M_{cz,Ed,M[+]}$ / $M_{cz,Rd,comp,M[+]}$ / $F_{z,Ed}$ | $V_{z,Ed}$	Ratio	14.446	[%]
$\frac{M_{Ed}}{M_{c,Rd}} + \frac{F_{Ed}}{R_{w,Rd}} \le 1{,}25$ [BS EN 1993-1-3, Equation (6.28c)]	$M_{cz,Ed,M[-]}$ / $M_{cz,Rd,comp,M[-]}$ / $F_{z,Ed}$ | $V_{z,Ed}$	Ratio	14.446	[%]

[d] C-Section Strut

[i] C-Section Strut: Axial Tension [BS EN 1993-1-3:2006, 6.1.2]

$$N_{t,Rd} = \frac{f_{ya} A_g}{\gamma_{M0}}$$

[BS EN 1993-1-3, Equation (6.1)]

f_{ya}	370.526	[MPa]
A_g	201.315	[mm²]
γ_{M0}	1.000	

$$\frac{N_{Ed}}{N_{t,Rd}} \le 1{,}0$$

$N_{t,Rd}$ 74592.663 [N] → **$N_{t,Rd}$ 74.593 [kN]**

$N_{t,Ed}$	2.280	[kN]	Ratio	3.057	[%]
$N_{t,Rd}$	74.593	[kN]			

[ii] C-Section Strut: Axial Compression [BS EN 1993-1-3:2006, 6.1.3]

[BS EN 1993-1-3, Equation (6.2)]

$A_{eff} < A_g$ → $N_{c,Rd} = A_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.3)]

$A_{eff} = A_g$ → $N_{c,Rd} = A_g * [f_{yb} + [f_{ya} - f_{yb}] * 4 * [1 - \lambda_e / \lambda_{e0}]] / \gamma_{M0} \le A_g * f_{ya} / \gamma_{M0}$

A_g	201.315	[mm²]	A_{eff}	189.709	[mm²]

[BS EN 1993-1-3, Equation (6.2)]

$N_{c,Rd}$ 66398.276 [N] → **$N_{c,Rd}$ 66.398 [kN]**

$M_{cy,Ed,M[+]}$	0.010	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \le 1{,}0$	Ratio	0.840	[%]
$M_{cy,Rd,comp,M+}$	1.191	[kNm]				

$W_{el,Tens}$	3519.614	[mm³]	$W_{eff,Tens}$	3503.173	[mm³]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cy,Rd,Tens,M[+]}$ 1226110.697 [Nmm] → **$M_{cy,Rd,Tens,M[+]}$ 1.226 [kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^{-}$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max} / \lambda_{e0}]] / \gamma_{M0} \le W_{pl} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{el} * f_{ya} / \gamma_{M0}$

$I_{y,el,M[-]}$	85435.109	[mm⁴]	→	$W_{el,Comp}$	3519.614	[mm³]
				$W_{el,Tens}$	3519.614	[mm³]
$I_{y,eff,M[-]}$	83790.577	[mm⁴]	→	$W_{eff,Comp}$	3402.038	[mm³]
				$W_{eff,Tens}$	3503.173	[mm³]
$W_{el,Comp}$	3519.614	[mm³]		$W_{eff,Comp}$	3402.038	[mm³]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cy,Rd,comp,M[-]}$ 1190713.405 [Nmm] → **$M_{cy,Rd,comp,M[-]}$ 1.191 [kNm]**

$M_{cy,Ed,M[-]}$	0.010	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \le 1{,}0$	Ratio	0.840	[%]
$M_{cy,Rd,comp,M-}$	1.191	[kNm]				

$W_{el,Tens}$	3519.614	[mm³]	$W_{eff,Tens}$	3503.173	[mm³]

[BS EN 1993-1-3, Equation (6.4)]

$M_{cy,Rd,Tens,M[-]}$ 1226110.697 [Nmm] → **$M_{cy,Rd,Tens,M[-]}$ 1.226 [kNm]**

Positive Moment in z-z axis [$M_{z,Ed}^{+}$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max} / \lambda_{e0}]] / \gamma_{M0} \leq W_{pl} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{eff} * f_{ya} / \gamma_{M0}$

$I_{z,el,M[+]}$	43399.345	[mm⁴]	→	$W_{el,Comp}$	2873.453	[mm^3]
				$W_{el,Tens}$	1851.157	[mm^3]
$I_{z,eff,M[+]}$	44100.416	[mm^4]	→	$W_{eff,Comp}$	2988.002	[mm^3]
				$W_{eff,Tens}$	1853.828	[mm^3]
$W_{el,Comp}$	2873.453	[mm^3]		$W_{eff,Comp}$	2988.002	[mm^3]

[BS EN 1993-1-3, Equation (6.6)]

$M_{cz,Rd,comp,M[+]}$	1064690.100	[Nmm]	→	$M_{cz,Rd,comp,M[+]}$	**1.065**	**[kNm]**
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \leq 1.0$	Ratio	0.000	[%]
$M_{cz,Rd,comp,M+}$	1.065	[kNm]				
$W_{el,Tens}$	1851.157	[mm^3]		$W_{eff,Tens}$	1853.828	[mm^3]

[BS EN 1993-1-3, Equation (6.6)]

$M_{cz,Rd,Tens,M[+]}$	685902.338	[Nmm]	→	$M_{cz,Rd,Tens,M[+]}$	**0.686**	**[kNm]**

Negative Moment in z-z axis [$M_{z,Ed}^{-}$]

[BS EN 1993-1-3, Equation (6.4)]

$W_{eff} < W_{el}$ → $M_{c,Rd} = W_{eff} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.5)]

$W_{eff} = W_{el}$ → $M_{c,Rd} = f_{yb} * [W_{el} + [W_{pl} - W_{el}] * 4 * [1 - \lambda_{e,max} / \lambda_{e0}]] / \gamma_{M0} \leq W_{pl} * f_{yb} / \gamma_{M0}$

[BS EN 1993-1-3, Equation (6.6)]

$M_{c,Rd} = W_{eff} * f_{ya} / \gamma_{M0}$

Combined Tension and Bending Moment [$M_{y,Ed}^{+} + M_{z,Ed}^{+}$]

$N_{t,Ed}$	2.280	[kN]	$N_{t,Rd}$	74.593	[kN]
$M_{cy,Ed,M[+]}$	0.010	[kNm]	$M_{cy,Rd,Tension,M[+]}$	1.226	[kNm]
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{cz,Rd,Tension,M[+]}$	0.686	[kNm]

[EN 1993-1-3, Equation (6.23)] Ratio 3.872 [%]

$M_{cy,Rd,Comp,M[+]}$	1.191	[kNm]	$M_{cz,Rd,Comp,M[+]}$	1.065	[kNm]
$M_{cy,Rd,Comp,M[+]} \leq M_{cy,Rd,Tens,M[+]}$	OK		$M_{cz,Rd,Comp,M[+]} \leq M_{cz,Rd,Tens,M[+]}$	KO	

$$\frac{M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed}}{M_{cz,Rd,com}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[EN 1993-1-3: Equation (6.24)]

[EN 1993-1-3, Equation (6.24) don't need to be verified] Ratio 0.000 [%]

Combined Tension and Bending Moment [$M_{y,Ed}^{-} + M_{z,Ed}^{-}$]

$N_{t,Ed}$	2.280	[kN]	$N_{t,Rd}$	74.593	[kN]
$M_{cy,Ed,M[-]}$	0.010	[kNm]	$M_{cy,Rd,Tension,M[-]}$	1.226	[kNm]
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{cz,Rd,Tension,M[-]}$	1.065	[kNm]

[EN 1993-1-3, Equation (6.23)] Ratio 3.872 [%]

$M_{cy,Rd,Comp,M[-]}$	1.191	[kNm]	$M_{cz,Rd,Comp,M[-]}$	0.686	[kNm]
$M_{cy,Rd,Comp,M[-]} \leq M_{cy,Rd,Tens,M[-]}$	OK		$M_{cz,Rd,Comp,M[-]} \leq M_{cz,Rd,Tens,M[-]}$	OK	

$$\frac{M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed}}{M_{cz,Rd,com}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[EN 1993-1-3: Equation (6.24)]

[EN 1993-1-3, Equation (6.24) must be verified] Ratio -2.217 [%]

[viii]	C-Section Strut: Combined Compression and Bending	[EN 1993-1-3:2006, 6.1.9]

$$\frac{N_{Ed}}{N_{c,Rd}} + \frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{cz,Rd,com}} \leq 1$$

[BS EN 1993-1-3, Equation (6.25)]

$I_{z,el,M[-]}$	43399.345	[mm^4]	→	$W_{el,Comp}$	1851.157	[mm^3]
				$W_{el,Tens}$	2873.453	[mm^3]
$I_{z,eff,M[-]}$	43399.345	[mm^4]	→	$W_{eff,Comp}$	1851.157	[mm^3]
				$W_{eff,Tens}$	2873.453	[mm^3]
$W_{el,Comp}$	1851.157	[mm^3]		$W_{eff,Comp}$	1851.157	[mm^3]

[BS EN 1993-1-3, Equation (6.6)]

$M_{cz,Rd,comp,M[-]}$	685902.338	[Nmm]	→	$M_{cz,Rd,comp,M[-]}$	**0.686**	**[kNm]**
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$\frac{M_{Ed}}{M_{c,Rd}} \leq 1.0$	Ratio	0.000	[%]
$M_{cz,Rd,comp,M[-]}$	0.686	[kNm]				
$W_{el,Tens}$	2873.453	[mm^3]		$W_{eff,Tens}$	2873.453	[mm^3]

[BS EN 1993-1-3, Equation (6.6)]

$M_{cz,Rd,Tens,M[-]}$	1064690.100	[Nmm]	→	$M_{cz,Rd,Tens,M[-]}$	**1.065**	**[kNm]**

[iv]	C-Section Strut: Shear Force	[BS EN 1993-1-3:2006, 6.1.5]

This verification isn't needed for this type of structural member

[v]	C-Section Strut: Torsional Moment	[EN 1993-1-3:2006, 6.1.6]

This verification isn't needed for this type of structural member

[vi]	C-Section Strut: Local Transverse Forces	[EN 1993-1-3:2006, 6.1.7]

This verification isn't needed for this type of structural member

[vii]	C-Section Strut: Combined Tension and Bending	[EN 1993-1-3:2006, 6.1.8]

$$\frac{N_{Ed}}{N_{t,Rd}} + \frac{M_{y,Ed}}{M_{cy,Rd,ten}} + \frac{M_{z,Ed}}{M_{cz,Rd,ten}} \leq 1$$

[BS EN 1993-1-3, Equation (6.23)]

$M_{cy,Rd,Com} \leq M_{cy,Rd,Ten}$ or $M_{cz,Rd,Com} \leq M_{cz,Rd,Ten}$

$$\frac{M_{y,Ed}}{M_{cy,Rd,com}} + \frac{M_{z,Ed}}{M_{cz,Rd,com}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[BS EN 1993-1-3, Equation (6.24)]

$\Delta M_{y,Ed} = N_{ed,Compression} * e_{N,y,Compression}$			$\Delta M_{z,Ed} = N_{ed,Compression} * e_{N,z,Compression}$		
$N_{Ed,Compression}$	1.470	[kN]	$N_{Ed,Compression}$	1.470	[kN]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	-0.001	[m]
$\Delta M_{y,Ed}$	0.000	[kNm]	$\Delta M_{z,Ed}$	-0.001	[kNm]

Combined Compression and Bending Moment [$M_{y,Ed}^{+} + M_{z,Ed}^{+}$]

$N_{c,Ed}$	1.470	[kN]	$N_{c,Rd}$	66.398	[kN]
$M_{cy,Ed,M[+]}$	0.010	[kNm]	$M_{cy,Rd,Comp,M[+]}$	1.191	[kNm]
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{cz,Rd,Comp,M[+]}$	1.065	[kNm]

[EN 1993-1-3, Equation (6.25)] Ratio 2.969 [%]

$M_{cy,Rd,Tens,M[+]}$	1.226	[kNm]	$M_{cz,Rd,Tens,M[+]}$	0.686	[kNm]
$M_{cy,Rd,Tens,M[+]} \leq M_{cy,Rd,Comp,M[+]}$	KO		$M_{cz,Rd,Tens,M[+]} \leq M_{cz,Rd,Comp,M[+]}$	OK	

$$\frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{cy,Rd,ten}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{cz,Rd,ten}} - \frac{N_{Ed}}{N_{c,Rd}} \leq 1$$

[EN 1993-1-3: Equation (6.26)]

[EN 1993-1-3, Equation (6.26) don't need to be verified] Ratio 0.000 [%]

Combined Compression and Bending Moment [$M_{y,Ed}^{-} + M_{z,Ed}^{-}$]

$N_{c,Ed}$	1.470	[kN]	$N_{c,Rd}$	66.398	[kN]
$M_{cy,Ed,M[-]}$	0.010	[kNm]	$M_{cy,Rd,Comp,M[-]}$	1.191	[kNm]
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{cz,Rd,Comp,M[-]}$	0.686	[kNm]

[EN 1993-1-3, Equation (6.25)] Ratio 2.923 [%]

$M_{cy,Rd,Tens,M[-]}$	1.226	[kNm]	$M_{cz,Rd,Tens,M[-]}$	1.065	[kNm]
$M_{cy,Rd,Tens,M[-]} \leq M_{cy,Rd,Comp,M[-]}$	KO		$M_{cz,Rd,Tens,M[-]} \leq M_{cz,Rd,Comp,M[-]}$	KO	

$$\frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{cy,Rd,ten}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{cz,Rd,ten}} - \frac{N_{Ed}}{N_{c,Rd}} \leq 1$$

[EN 1993-1-3: Equation (6.26)]

[EN 1993-1-3, Equation (6.26) don't need to be verified] Ratio 0.000 [%]

[ix]	C-Section Strut: Combined Shear Force, Axial Force and Bending Moment	[EN 1993-1-3:2006, 6.1.10]

This verification isn't needed for this type of structural member

[x] C-Section Strut: Combined Bending Moment and Local Load or Support Reaction [EN 1993-1-3:2006, 6.1.11]

This verification isn't needed for this type of structural member

[15.2] Buckling Resistance **[BS EN 1993-1-3:2006, 6.2]**

[a] Ω-Section Purlin

This verification isn't needed for this type of structural member

[b] C-Section Beam

[i] C-Section Beam: Flexural Buckling [$N_{b,Rd,FB}$] [EN 1993-1-3:2006, 6.2.2]

Appropriate buckling curve for C-Sections [BS EN 1993-1-3, Table 6.3]

Type of cross-section	Buckling about Axis	Buckling Curve
	Any	b

Imperfection factors for buckling curves [BS EN 1993-1-1, Table 6.1]

Buckling Curve: b → Imperfection factor [α]: 0.340

Console C-Section Beam

$$P_{Ey} = \frac{\pi^2 EI_y}{L_y^2}$$

E	210.000	[GPa]
I_Y	762290.565	[mm^4]
$L_{cr,y,Console\,Beam}$	1020.000	[mm]
$P_{cr,y,Console\,Beam}$	1518.585472	[kN]

$$P_{Ez} = \frac{\pi^2 EI_z}{L_z^2}$$

E	210.000	[GPa]
I_Z	108754.009	[mm^4]
$L_{cr,z,Console\,Beam}$	429.930	[mm]
$P_{cr,y,Console\,Beam}$	1219.463523	[kN]

Console C-Section Beam			Middle C-Section Beam		
$N_{cr,y}$	1518585.472	[N]	$N_{cr,y}$	1618548.416	[N]
$N_{cr,z}$	1219463.523	[N]	$N_{cr,z}$	1214723.540	[N]
$N_{cr,T}$	184841.265	[N]	$N_{cr,T}$	196679.762	[N]

Console C-Section Beam

$N_{cr,TF}$ 176570.8371 [N] — $N_{cr,TF}$ 176.571 [kN]

Middle C-Section Beam

$N_{cr,TF}$ 187894.756 [N] — $N_{cr,TF}$ 187.895 [kN]

Console C-Section Beam N_{cr} = MIN [$P_{cr,y}$; $P_{cr,z}$; $N_{cr,T}$; $N_{cr,TF}$] 176.571 [kN]

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}}$$ Class 1, Class 2, Class 3 [BS EN 1993-1-1, Equation (6.47)]

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}}$$ Class 4 [BS EN 1993-1-1, Equation (6.48)]

$$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}}$$ Class 1, Class 2, Class 3

$$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}}$$ Class 4

C-Section Beam Classification [Compression] Class 4

A 345.063 [mm^2] — A_{eff} 243.816 [mm^2]

Class 4 $\bar{\lambda}$ 0.695

$$\Phi = 0{,}5\left[1 + \alpha\left(\bar{\lambda} - 0{,}2\right) + \bar{\lambda}^2\right]$$ Φ 0.826

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}}$$ X 0.786 $\chi \le 1{,}0$ OK

Class 4 → $N_{b,Rd,Console\,Beam}$ **67.110** **[kN]**

Middle C-Section Beam N_{cr} = MIN [$P_{cr,y}$; $P_{cr,z}$; $N_{cr,T}$; $N_{cr,TF}$] 187.895 [kN]

C-Section Beam Classification [Compression] Class 4

A 345.063 [mm^2] — A_{eff} 243.816 [mm^2]

Class 4 $\bar{\lambda}$ 0.674

Middle C-Section Beam

$$P_{Ey} = \frac{\pi^2 EI_y}{L_y^2}$$

E	210.000	[GPa]
I_Y	762290.565	[mm^4]
$L_{cr,y,Middle\,Beam}$	988.000	[mm]
$P_{cr,y,Middle\,Beam}$	1618.548416	[kN]

$$P_{Ez} = \frac{\pi^2 EI_z}{L_z^2}$$

E	210.000	[GPa]
I_Y	108754.009	[mm^4]
$L_{cr,z,Middle\,Beam}$	430.768	[mm]
$P_{cr,y,Middle\,Beam}$	1214.72354	[kN]

[ii] C-Section Beam: Torsional Buckling [$N_{b,Rd,T}$] + Torsional-Flexural Buckling [$N_{b,Rd,TF}$] [EN 1993-1-3:2006, 6.2.3]

$$N_{cr,T} = \frac{1}{i_o^2}\left(G I_t + \frac{\pi^2 E I_w}{l_T^2}\right)$$ [BS EN 1993-1-3, Equation (6.33a)]

$$i_o^2 = i_y^2 + i_z^2 + y_o^2 + z_o^2$$ [BS EN 1993-1-3, Equation (6.33b)]

Elastic critical force $N_{cr,T}$ for torsional buckling

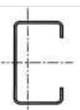
A	345.063	[mm^2]	y_0	-37.355	[mm]
I_Y	762290.565	[mm^4]			
I_Z	108754.009	[mm^4]	z_0	0.000	[mm]
I_W	353860598.321	[mm^6]			
I_T	242.500	[mm^4]	G	80.769	[GPa]
i_Y	47.001	[mm]	i_0	62.608	[mm]
i_Z	17.753	[mm]			

Console C-Section Beam

$N_{cr,T}$ 184841.2651 [N] → $N_{cr,T}$ 184.841 [kN]

Middle C-Section Beam

$N_{cr,T}$ 196679.7623 [N] → $N_{cr,T}$ 196.680 [kN]



$$N_{cr,TF} = \frac{N_{cr,y}}{2\beta}\left[1 + \frac{N_{cr,T}}{N_{cr,y}} - \sqrt{\left(1 - \frac{N_{cr,T}}{N_{cr,y}}\right)^2 + 4\left(\frac{y_o}{i_o}\right)^2 \frac{N_{cr,T}}{N_{cr,y}}}\right]$$

Elastic critical force $N_{cr,TF}$ for torsional-flexural buckling [BS EN 1993-1-3, Equation (6.35)]

Monosymmetric cross-sections susceptible to torsional-flexural buckling [BS EN 1993-1-3, Figure 6.12]

$$\beta = 1 - \left(\frac{y_o}{i_o}\right)^2$$ [BS EN 1993-1-3, Equation (6.36)]

β 0.644

$$\Phi = 0{,}5\left[1 + \alpha\left(\bar{\lambda} - 0{,}2\right) + \bar{\lambda}^2\right]$$ Φ 0.808

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}}$$ X 0.798 $\chi \le 1{,}0$ OK

Class 4 → $N_{b,Rd,Middle\,Beam}$ **68.118** **[kN]**

[iii] C-Section Beam: Lateral-Torsional Buckling of members subject to bending [EN 1993-1-3:2006, 6.2.4]

Imperfection factors for lateral torsional buckling curves [BS EN 1993-1-1, Table 6.2]

Buckling Curve: b → Imperfection factor [α]: 0.340

$$M_{b,Rd} = \chi_{LT} W_y \frac{f_y}{\gamma_{M1}}$$ [BS EN 1993-1-1, Equation (6.55)]

$$\bar{\lambda}_{LT} = \sqrt{\frac{W_y f_y}{M_{cr}}}$$

$$M_{cr} = \frac{\pi^2 EI_z}{L^2}\left[\frac{I_w}{I_z} + \frac{L^2 G I_t}{\pi^2 EI_z}\right]^{0.5}$$ ENV 1993-1-1, Equation (F.1)]

$W_y = W_{pl,y}$ Class 1 and 2; $W_y = W_{el,y}$ Class 3; $W_y = W_{eff,y}$ Class 4

E	210.000	[GPa]	I_w	353860598.321	[mm^6]
v	0.300		I_t	242.500	[mm^4]
G	80.769	[GPa]	$L_{cr,T,Console}$	1020.000	[mm]
I_Z	108754.009	[mm^4]	$L_{cr,T,Middle}$	988.000	[mm]

C-Section Console Beam [Elastic Critical Moment]			C-Section Middle Beam [Elastic Critical Moment]		
$M_{cr,Console\,Beam}$	12528772.255	[Nmm]	$M_{cr,Middle\,Beam}$	13342343.372	[Nmm]
$M_{cr,Console\,Beam}$	**12.529**	**[kNm]**	**$M_{cr,Middle\,Beam}$**	**13.342**	**[kNm]**

C-Section Beam Classification [Bending y-y] Class 4

C-Section Console Beam

$W_{el,y}$ 12860.454 [mm^3] — $W_{eff,y}$ 12435.750 [mm^3]

A 345.063 [mm^2] — A_{eff} 340.188 [mm^2]

$\bar{\lambda}_{LT}$ 0.589

$$\Phi_{LT} = 0{,}5\left[1 + \alpha_{LT}\left(\bar{\lambda}_{LT} - 0{,}2\right) + \bar{\lambda}_{LT}^2\right]$$ Φ_{LT} 0.740

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \bar{\lambda}_{LT}^2}}$$

χ_{LT} 0.842 — $\chi_{LT} \le 1{,}0$ OK

Class 4 → $M_{b,Rd,Console\ Beam}$ 3.666 [kNm]

C-Section Middle Beam

$W_{el,y}$	12860.454	[mm³]	$W_{eff,y}$	12435.750	[mm³]
A	345.063	[mm²]	A_{eff}	340.188	[mm²]

$\bar{\lambda}_{LT}$ 0.571

$$\Phi_{LT} = 0{,}5\left[1 + \alpha_{LT}\left(\bar{\lambda}_{LT} - 0{,}2\right) + \bar{\lambda}_{LT}^2\right]$$

Φ_{LT} 0.726

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \bar{\lambda}_{LT}^2}}$$

χ_{LT} 0.851 — $\chi_{LT} \le 1{,}0$ OK

Class 4 → $M_{b,Rd,Middle\ Beam}$ 3.705 [kNm]

C-Section Console Beam	$N_{b,Rd,Console\ Beam}$	67.110	[kN]	$M_{b,Rd,Console\ Beam}$	3.666	[kNm]
C-Section Middle Beam	$N_{b,Rd,Middle\ Beam}$	68.118	[kN]	$M_{b,Rd,Middle\ Beam}$	3.705	[kNm]

[iv] C-Section Beam: Bending and axial compression [EN 1993-1-3:2006, 6.2.5]

$$\left(\frac{N_{Ed}}{N_{b,Rd}}\right)^{0,8} + \left(\frac{M_{Ed}}{M_{b,Rd}}\right)^{0,8} \le 1{,}0$$

[BS EN 1993-1-3, Equation (6.36)]

C-Section Console Beam

$N_{c,Ed}$	0.520	[kN]	Ratio	34.994	[%]
$M_{cy,Ed,M[+]}$	0.840	[kNm]			
$M_{cz,Ed,M[+]}$	0.020	[kNm]	$M_{z,Rd,M[+]}$	2.614	[kNm]
$N_{b,Rd,Console\ Beam}$	67.110	[kN]	$M_{b,Rd,Console\ Beam}$	3.666	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.004	[m]

[v] C-Section Beam: Bending and axial tension [EN 1993-1-3:2006, 6.3]

$$\left(\frac{N_{Ed}}{N_{b,Rd}}\right)^{0,8} + \left(\frac{M_{Ed}}{M_{b,Rd}}\right)^{0,8} \le 1{,}0$$

[BS EN 1993-1-3, Equation (6.36)]

C-Section Console Beam

$N_{c,Ed}$	0.520	[kN]	Ratio	30.017	[%]
$M_{cy,Ed,M[+]}$	0.840	[kNm]			
$M_{cz,Ed,M[+]}$	0.020	[kNm]	$M_{z,Rd,M[+]}$	2.614	[kNm]
$N_{t,Rd}$	74.593	[kN]	$M_{y,Rd,M[+]}$	4.501	[kNm]

$N_{c,Ed}$	0.520	[kN]	Ratio	31.651	[%]
$M_{cy,Ed,M[-]}$	0.840	[kNm]			
$M_{cz,Ed,M[-]}$	0.020	[kNm]	$M_{z,Rd,M[-]}$	1.249	[kNm]
$N_{t,Rd}$	74.593	[kN]	$M_{y,Rd,M[-]}$	4.501	[kNm]

$N_{c,Ed}$	0.520	[kN]	Ratio	31.651	[%]
$M_{cy,Ed,M[+]}$	0.840	[kNm]			
$M_{cz,Ed,M[-]}$	0.020	[kNm]	$M_{z,Rd[-]}$	1.249	[kNm]
$N_{t,Rd}$	74.593	[kN]	$M_{y,Rd[+]}$	4.501	[kNm]

$N_{c,Ed}$	0.520	[kN]	Ratio	30.017	[%]
$M_{cy,Ed,M[-]}$	0.840	[kNm]			
$M_{cz,Ed,M[+]}$	0.020	[kNm]	$M_{z,Rd,M[+]}$	2.614	[kNm]
$N_{t,Rd}$	74.593	[kN]	$M_{y,Rd,M[-]}$	4.501	[kNm]

C-Section Middle Beam

$N_{c,Ed}$	0.700	[kN]	Ratio	29.659	[%]
$M_{cy,Ed,M[+]}$	0.840	[kNm]			
$M_{cz,Ed,M[+]}$	0.010	[kNm]	$M_{z,Rd,M[+]}$	2.614	[kNm]
$N_{t,Rd}$	74.593	[kN]	$M_{y,Rd,M[+]}$	4.501	[kNm]

$N_{c,Ed}$	0.700	[kN]	Ratio	30.598	[%]
$M_{cy,Ed,M[-]}$	0.840	[kNm]			
$M_{cz,Ed,M[-]}$	0.010	[kNm]	$M_{z,Rd,M[-]}$	1.249	[kNm]
$N_{t,Rd}$	74.593	[kN]	$M_{y,Rd,M[-]}$	4.501	[kNm]

$N_{c,Ed}$	0.520	[kN]	Ratio	36.753	[%]
$M_{cy,Ed,M[-]}$	0.840	[kNm]			
$M_{cz,Ed,M[-]}$	0.020	[kNm]	$M_{z,Rd,M[-]}$	1.249	[kNm]
$N_{b,Rd,Console\ Beam}$	67.110	[kN]	$M_{b,Rd,Console\ Beam}$	3.666	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.004	[m]

$N_{c,Ed}$	0.520	[kN]	Ratio	36.753	[%]
$M_{cy,Ed,M[+]}$	0.840	[kNm]			
$M_{cz,Ed,M[-]}$	0.020	[kNm]	$M_{z,Rd,M[-]}$	1.249	[kNm]
$N_{b,Rd,Console\ Beam}$	67.110	[kN]	$M_{b,Rd,Console\ Beam}$	3.666	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.004	[m]

$N_{c,Ed}$	0.520	[kN]	Ratio	34.994	[%]
$M_{cy,Ed,M[-]}$	0.840	[kNm]			
$M_{cz,Ed,M[+]}$	0.020	[kNm]	$M_{z,Rd,M[+]}$	2.614	[kNm]
$N_{b,Rd,Console\ Beam}$	67.110	[kN]	$M_{b,Rd,Console\ Beam}$	3.666	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.004	[m]

C-Section Middle Beam

$N_{c,Ed}$	1.030	[kN]	Ratio	35.509	[%]
$M_{cy,Ed,M[+]}$	0.840	[kNm]			
$M_{cz,Ed,M[+]}$	0.010	[kNm]	$M_{z,Rd,M[+]}$	2.614	[kNm]
$N_{b,Rd,Middle\ Beam}$	68.118	[kN]	$M_{b,Rd,Middle\ Beam}$	3.705	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.004	[m]

$N_{c,Ed}$	1.030	[kN]	Ratio	36.724	[%]
$M_{cy,Ed,M[-]}$	0.840	[kNm]			
$M_{cz,Ed,M[-]}$	0.010	[kNm]	$M_{z,Rd[-]}$	1.249	[kNm]
$N_{b,Rd,Middle\ Beam}$	68.118	[kN]	$M_{b,Rd,Middle\ Beam}$	3.705	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.004	[m]

$N_{c,Ed}$	1.030	[kN]	Ratio	36.724	[%]
$M_{cy,Ed,M[+]}$	0.840	[kNm]			
$M_{cz,Ed,M[-]}$	0.010	[kNm]	$M_{z,Rd,M[-]}$	1.249	[kNm]
$N_{b,Rd,Middle\ Beam}$	68.118	[kN]	$M_{b,Rd,Middle\ Beam}$	3.705	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.004	[m]

$N_{c,Ed}$	1.030	[kN]	Ratio	35.509	[%]
$M_{cy,Ed,M[-]}$	0.840	[kNm]			
$M_{cz,Ed,M[+]}$	0.010	[kNm]	$M_{z,Rd[+]}$	2.614	[kNm]
$N_{b,Rd,Middle\ Beam}$	68.118	[kN]	$M_{b,Rd,Middle\ Beam}$	3.705	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.004	[m]

$N_{c,Ed}$	0.700	[kN]	Ratio	30.598	[%]
$M_{cy,Ed,M[+]}$	0.840	[kNm]			
$M_{cz,Ed,M[-]}$	0.010	[kNm]	$M_{z,Rd[-]}$	1.249	[kNm]
$N_{t,Rd}$	74.593	[kN]	$M_{y,Rd[+]}$	4.501	[kNm]

$N_{c,Ed}$	0.700	[kN]	Ratio	29.659	[%]
$M_{cy,Ed,M[-]}$	0.840	[kNm]			
$M_{cz,Ed,M[+]}$	0.010	[kNm]	$M_{z,Rd,M[+]}$	2.614	[kNm]
$N_{t,Rd}$	74.593	[kN]	$M_{y,Rd,M[-]}$	4.501	[kNm]

[c] C-Section Column

[i] C-Section Column: Flexural Buckling [$N_{b,Rd,FB}$] [EN 1993-1-3:2006, 6.2.2]

Appropriate buckling curve for C-Sections [BS EN 1993-1-3, Table 6.3]

Type of cross-section	Buckling about Axis	Buckling Curve
	Any	b

Imperfection factors for buckling curves [BS EN 1993-1-1, Table 6.1]

Buckling Curve: b → Imperfection factor [α]: 0.340

Front C-Section Column

$$P_{Ey} = \frac{\pi^2 E I_y}{L_y^2}$$

E	210.000	[GPa]
I_Y	625036.020	[mm⁴]
$L_{cr,y,Front\ Column}$	1036.000	[mm]
$P_{cr,y,Front\ Column}$	1206.99251	[kN]

$$P_{Ez} = \frac{\pi^2 E I_z}{L_z^2}$$

E	210.000	[GPa]
I_Z	153816.866	[mm⁴]
$L_{cr,z,Front\ Column}$	1400.000	[mm]
$P_{cr,y,Front\ Column}$	162.6548162	[kN]

Rear C-Section Column

$$P_{Ey} = \frac{\pi^2 EI_y}{L_y^2}$$

E	210.000	[GPa]
I_Y	625036.020	[mm^4]
$L_{cr,y,Rear Column}$	1898.668	[mm]
$P_{cr,y,Rear Column}$	359.3567978	[kN]

$$P_{Ez} = \frac{\pi^2 EI_z}{L_z^2}$$

E	210.000	[GPa]
I_Y	153816.866	[mm^4]
$L_{cr,z,Rear Column}$	2422.853	[mm]
$P_{cr,y,Rear Column}$	54.30863857	[kN]

[ii] C-Section Column: Torsional Buckling [$N_{b,Rd,T}$] + Torsional-Flexural Buckling [$N_{b,Rd,TF}$] [EN 1993-1-3:2006, 6.2.3]

$$N_{cr,T} = \frac{1}{i_o^2}\left(G I_t + \frac{\pi^2 E I_w}{l_T^2}\right)$$

[BS EN 1993-1-3, Equation (6.33a)]

$$i_o^2 = i_y^2 + i_z^2 + y_o^2 + z_o^2$$

[BS EN 1993-1-3, Equation (6.33b)]

Elastic critical force $N_{cr,T}$ for torsional buckling

A	497.235	[mm^2]	y_0	-40.108	[mm]
I_Y	625036.020	[mm^4]			
I_Z	153816.866	[mm^4]	z_0	0.000	[mm]
I_W	311247851.419	[mm^6]			
I_T	996.509	[mm^4]	G	80.769	[GPa]
i_Y	35.455	[mm]	i_0	56.347	[mm]
i_Z	17.588	[mm]			

Front C-Section Column

$N_{cr,T}$	871572.7236	[N]	→	$N_{cr,T}$	871.573	[kN]

Rear C-Section Column

$N_{cr,T}$	307894.4102	[N]	→	$N_{cr,T}$	307.894	[kN]

$$N_{cr,TF} = \frac{N_{cr,y}}{2\beta}\left[1 + \frac{N_{cr,T}}{N_{cr,y}} - \sqrt{\left(1 - \frac{N_{cr,T}}{N_{cr,y}}\right)^2 + 4\left(\frac{y_o}{i_o}\right)^2 \frac{N_{cr,T}}{N_{cr,y}}}\right]$$

Elastic critical force $N_{cr,TF}$ for torsional-flexural buckling [BS EN 1993-1-3, Equation (6.35)]

Monosymmetric cross-sections susceptible to torsional-flexural buckling [BS EN 1993-1-3, Figure 6.12]

$$\beta = 1 - \left(\frac{y_o}{i_o}\right)^2$$

[BS EN 1993-1-3, Equation (6.36)]

β 0.493

$$\Phi = 0,5\left[1 + \alpha\left(\bar{\lambda} - 0,2\right) + \bar{\lambda}^2\right]$$

Φ 2.319

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}}$$

χ 0.261 $\chi \leq 1,0$ OK

Class 4	→	$N_{b,Rd,Rear Column}$	**44.100**	**[kN]**

[iii] C-Section Column: Lateral-Torsional Buckling of members subject to bending [EN 1993-1-3:2006, 6.2.4]

Imperfection factors for lateral torsional buckling curves [BS EN 1993-1-1, Table 6.2]

Buckling Curve b → Imperfection factor [α] 0.340

$$M_{b,Rd} = \chi_{LT} W_y \frac{f_y}{\gamma_{M1}}$$

[BS EN 1993-1-1, Equation (6.55)]

$$\bar{\lambda}_{LT} = \sqrt{\frac{W_y f_y}{M_{cr}}}$$

$$M_{cr} = \frac{\pi^2 EI_z}{L^2}\left[\frac{I_w}{I_z} + \frac{L^2 GI_t}{\pi^2 EI_z}\right]^{0,5}$$

ENV 1993-1-1, Equation (F.1)]

$W_y = W_{pl,y}$	Class 1 and 2
$W_y = W_{el,y}$	Class 3
$W_y = W_{eff,y}$	Class 4

E	210.000	[GPa]	I_w	311247851.419	[mm^6]
v	0.300		I_t	996.509	[mm^4]
G	80.769	[GPa]	$L_{cr,T,Front}$	490.000	[mm]
I_Z	153816.866	[mm^4]	$L_{cr,T,Rear}$	847.999	[mm]

Front C-Section Column [Elastic Critical Moment]			Rear C-Section Column [Elastic Critical Moment]		
$M_{cr,Front}$	60616593.410	[Nmm]	$M_{cr,Rear}$	20818124.777	[Nmm]
$M_{cr,Front}$	**60.617**	**[kNm]**	**$M_{cr,Rear}$**	**20.818**	**[kNm]**

C-Section Column Classification [Bending y-y] Class 1

Front C-Section Column

$W_{el,y}$	14278.705	[mm^3]	$W_{eff,y}$	14278.705	[mm^3]
A	497.235	[mm^2]	A_{eff}	497.235	[mm^2]

$\bar{\lambda}_{LT}$ 0.287

$$\Phi_{LT} = 0,5\left[1 + \alpha_{LT}\left(\bar{\lambda}_{LT} - 0,2\right) + \bar{\lambda}_{LT}^2\right]$$

Φ_{LT} 0.556

Front C-Section Column			Rear C-Section Column		
$N_{cr,y}$	1206992.510	[N]	$N_{cr,y}$	359356.798	[N]
$N_{cr,z}$	162654.816	[N]	$N_{cr,z}$	54308.639	[N]
$N_{cr,T}$	871572.724	[N]	$N_{cr,T}$	307894.410	[N]

Front C-Section Column

$N_{cr,TF}$	588236.4476	[N]	$N_{cr,TF}$	588.236	[kN]

Rear C-Section Column

$N_{cr,TF}$	193505.352	[N]	$N_{cr,TF}$	193.505	[kN]

Front C-Section Column	N_{cr} = MIN [$P_{cr,y}$; $P_{cr,z}$; $N_{cr,T}$; $N_{cr,TF}$]	162.655	[kN]

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}}$$

Class 1 / Class 2 / Class 3

[BS EN 1993-1-1, Equation (6.47)]

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}}$$

Class 4

[BS EN 1993-1-1, Equation (6.48)]

$$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}}$$

Class 1 / Class 2 / Class 3

$$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}}$$

Class 4

C-Section Column Classification [Compression] Class 4

A	497.235	[mm^2]	A_{eff}	482.146	[mm^2]

Class 4 $\bar{\lambda}$ 1.019

$$\Phi = 0,5\left[1 + \alpha\left(\bar{\lambda} - 0,2\right) + \bar{\lambda}^2\right]$$

Φ 1.158

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}}$$

χ 0.585 $\chi \leq 1,0$ OK

Class 4	→	$N_{b,Rd,Front Column}$	**98.767**	**[kN]**

Rear C-Section Column	N_{cr} = MIN [$P_{cr,y}$; $P_{cr,z}$; $N_{cr,T}$; $N_{cr,TF}$]	54.309	[kN]

C-Section Column Classification [Compression] Class 4

A	497.235	[mm^2]	A_{eff}	482.146	[mm^2]

Class 4 $\bar{\lambda}$ 1.763

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \bar{\lambda}_{LT}^2}}$$

χ_{LT} 0.969 $\chi_{LT} \leq 1,0$ OK

Class 1	→	$M_{b,Rd,Front Column}$	**4.842**	**[kNm]**

Rear C-Section Column

$W_{el,y}$	14278.705	[mm^3]	$W_{eff,y}$	14278.705	[mm^3]
A	497.235	[mm^2]	A_{eff}	497.235	[mm^2]

$\bar{\lambda}_{LT}$ 0.490

$$\Phi_{LT} = 0,5\left[1 + \alpha_{LT}\left(\bar{\lambda}_{LT} - 0,2\right) + \bar{\lambda}_{LT}^2\right]$$

Φ_{LT} 0.669

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \bar{\lambda}_{LT}^2}}$$

χ_{LT} 0.889 $\chi_{LT} \leq 1,0$ OK

Class 1	→	$M_{b,Rd,Rear Column}$	**4.441**	**[kNm]**

Front C-Section Column	$N_{b,Rd,Front Column}$	98.767	[kN]	$M_{b,Rd,Front Column}$	4.842	[kNm]
Rear C-Section Column	$N_{b,Rd,Rear Column}$	44.100	[kN]	$M_{b,Rd,Rear Column}$	4.441	[kNm]

[iv] C-Section Column: Bending and axial compression [EN 1993-1-3:2006, 6.2.5]

$$\left(\frac{N_{Ed}}{N_{b,Rd}}\right)^{0,8} + \left(\frac{M_{Ed}}{M_{b,Rd}}\right)^{0,8} \leq 1,0$$

[BS EN 1993-1-3, Equation (6.36)]

Front C-Section Column

$N_{c,Ed}$	4.140	[kN]	Ratio	18.113	[%]
$M_{cy,Ed,M[+]}$	0.270	[kNm]			
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{z,Rd,M[+]}$	3.332	[kNm]
$N_{b,Rd,Front Column}$	98.767	[kN]	$M_{b,Rd,Front Column}$	4.842	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.001	[m]

$N_{c,Ed}$	4.140	[kN]	Ratio	18.263	[%]
$M_{cy,Ed,M[-]}$	0.270	[kNm]			
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{z,Rd,M[-]}$	1.930	[kNm]
$N_{b,Rd,Front\ Column}$	98.767	[kN]	$M_{b,Rd,Front\ Column}$	4.842	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.001	[m]

$N_{c,Ed}$	4.140	[kN]	Ratio	18.263	[%]
$M_{cy,Ed,M[+]}$	0.270	[kNm]			
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{z,Rd,M[-]}$	1.930	[kNm]
$N_{b,Rd,Front\ Column}$	98.767	[kN]	$M_{b,Rd,Front\ Column}$	4.842	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.001	[m]

$N_{c,Ed}$	4.140	[kN]	Ratio	18.113	[%]
$M_{cy,Ed,M[-]}$	0.270	[kNm]			
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{z,Rd,M[+]}$	3.332	[kNm]
$N_{b,Rd,Front\ Column}$	98.767	[kN]	$M_{b,Rd,Front\ Column}$	4.842	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.001	[m]

Rear C-Section Column

$N_{c,Ed}$	4.170	[kN]	Ratio	28.531	[%]
$M_{cy,Ed,M[+]}$	0.350	[kNm]			
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{z,Rd,M[+]}$	3.332	[kNm]
$N_{b,Rd,Rear\ Column}$	44.100	[kN]	$M_{b,Rd,Rear\ Column}$	4.441	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.001	[m]

$N_{c,Ed}$	4.170	[kN]	Ratio	28.682	[%]
$M_{cy,Ed,M[-]}$	0.350	[kNm]			
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{z,Rd[-]}$	1.930	[kNm]
$N_{b,Rd,Rear\ Column}$	44.100	[kN]	$M_{b,Rd,Rear\ Column}$	4.441	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.001	[m]

$N_{c,Ed}$	4.170	[kN]	Ratio	28.682	[%]
$M_{cy,Ed,M[+]}$	0.350	[kNm]			
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{z,Rd,M[-]}$	1.930	[kNm]
$N_{b,Rd,Rear\ Column}$	44.100	[kN]	$M_{b,Rd,Rear\ Column}$	4.441	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.001	[m]

$N_{c,Ed}$	4.170	[kN]	Ratio	28.531	[%]
$M_{cy,Ed,M[-]}$	0.350	[kNm]			
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{z,Rd[+]}$	3.332	[kNm]
$N_{b,Rd,Rear\ Column}$	44.100	[kN]	$M_{b,Rd,Rear\ Column}$	4.441	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	0.001	[m]

Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode | References: EN 1990 | EN 1991 | EN 1993 | Version: 1.000
Office: ---- | Author: JOSÉ ANTÓNIO | Date: 05/09/2019 | Project: MASTER THESIS | Client: COIMBRA UNIVERSITY

$N_{c,Ed}$	3.340	[kN]	Ratio	15.935	[%]
$M_{cy,Ed,M[+]}$	0.350	[kNm]			
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{z,Rd[-]}$	1.930	[kNm]
$N_{t,Rd}$	185.816	[kN]	$M_{y,Rd[+]}$	4.998	[kNm]

$N_{c,Ed}$	3.340	[kN]	Ratio	15.935	[%]
$M_{cy,Ed,M[-]}$	0.350	[kNm]			
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{z,Rd,M[+]}$	3.332	[kNm]
$N_{t,Rd}$	185.816	[kN]	$M_{y,Rd,M[-]}$	4.998	[kNm]

[d] C-Section Strut

[i] C-Section Strut: Flexural Buckling [$N_{b,Rd,FB}$] [EN 1993-1-3:2006, 6.2.2]

Appropriate buckling curve for C-Sections [BS EN 1993-1-3, Table 6.3]		
Type of cross-section	Buckling about Axis	Buckling Curve
	Any	b

Imperfection factors for buckling curves [BS EN 1993-1-1, Table 6.1]

Buckling Curve: b → Imperfection factor [α]: 0.340

C-Section Strut

$$P_{Ey} = \frac{\pi^2 E I_y}{L_y^2}$$

E	210.000	[GPa]
I_Y	85435.109	[mm^4]
$L_{cr,y,Strut}$	1950.133	[mm]
$P_{cr,y,Strut}$	46.5614958	[kN]

$$P_{Ez} = \frac{\pi^2 E I_z}{L_z^2}$$

E	210.000	[GPa]
I_Z	43399.345	[mm^4]
$L_{cr,z,Strut}$	1950.133	[mm]
$P_{cr,y,Strut}$	23.65231829	[kN]

[ii] C-Section Strut: Torsional Buckling [$N_{b,Rd,T}$] + Torsional-Flexural Buckling [$N_{b,Rd,TF}$] [EN 1993-1-3:2006, 6.2.3]

$$N_{cr,T} = \frac{1}{i_o^2}\left(G I_t + \frac{\pi^2 E I_w}{l_T^2}\right)$$

[BS EN 1993-1-3, Equation (6.33a)]

$$i_o^2 = i_y^2 + i_z^2 + y_o^2 + z_o^2$$

[BS EN 1993-1-3, Equation (6.33b)]

Elastic critical force $N_{cr,T}$ for torsional buckling

Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode | References: EN 1990 | EN 1991 | EN 1993 | Version: 1.000
Office: ---- | Author: JOSÉ ANTÓNIO | Date: 05/09/2019 | Project: MASTER THESIS | Client: COIMBRA UNIVERSITY

[v] C-Section Column: Bending and axial tension [EN 1993-1-3:2006, 6.3]

$$\left(\frac{N_{Ed}}{N_{b,Rd}}\right)^{0.8} + \left(\frac{M_{Ed}}{M_{b,Rd}}\right)^{0.8} \leq 1.0$$

[BS EN 1993-1-3, Equation (6.36)]

Front C-Section Column

$N_{t,Ed}$	2.700	[kN]	Ratio	13.072	[%]
$M_{cy,Ed,M[+]}$	0.270	[kNm]			
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{z,Rd,M[+]}$	3.332	[kNm]
$N_{t,Rd}$	185.816	[kN]	$M_{y,Rd,M[+]}$	4.998	[kNm]

$N_{t,Ed}$	2.700	[kN]	Ratio	13.072	[%]
$M_{cy,Ed,M[-]}$	0.270	[kNm]			
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{z,Rd,M[-]}$	1.930	[kNm]
$N_{t,Rd}$	185.816	[kN]	$M_{y,Rd,M[-]}$	4.998	[kNm]

$N_{t,Ed}$	2.700	[kN]	Ratio	13.072	[%]
$M_{cy,Ed,M[+]}$	0.270	[kNm]			
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{z,Rd[-]}$	1.930	[kNm]
$N_{t,Rd}$	185.816	[kN]	$M_{y,Rd[+]}$	4.998	[kNm]

$N_{t,Ed}$	2.700	[kN]	Ratio	13.072	[%]
$M_{cy,Ed,M[-]}$	0.270	[kNm]			
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{z,Rd,M[+]}$	3.332	[kNm]
$N_{t,Rd}$	185.816	[kN]	$M_{y,Rd,M[-]}$	4.998	[kNm]

Rear C-Section Column

$N_{t,Ed}$	3.340	[kN]	Ratio	15.935	[%]
$M_{cy,Ed,M[+]}$	0.350	[kNm]			
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{z,Rd,M[+]}$	3.332	[kNm]
$N_{t,Rd}$	185.816	[kN]	$M_{y,Rd,M[+]}$	4.998	[kNm]

$N_{t,Ed}$	3.340	[kN]	Ratio	15.935	[%]
$M_{cy,Ed,M[-]}$	0.350	[kNm]			
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{z,Rd,M[-]}$	1.930	[kNm]
$N_{t,Rd}$	185.816	[kN]	$M_{y,Rd,M[-]}$	4.998	[kNm]

Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes
Code: Eurocode | References: EN 1990 | EN 1991 | EN 1993 | Version: 1.000
Office: ---- | Author: JOSÉ ANTÓNIO | Date: 05/09/2019 | Project: MASTER THESIS | Client: COIMBRA UNIVERSITY

A	201.315	[mm^2]
I_Y	85435.109	[mm^4]
I_Z	43399.345	[mm^4]
I_W	26311081.398	[mm^6]
I_T	141.478	[mm^4]
i_Y	20.601	[mm]
i_Z	14.683	[mm]

y_0	-35.537	[mm]
z_0	0.000	[mm]
G	80.769	[GPa]
i_0	43.621	[mm]

C-Section Strut

$N_{cr,T}$ 13541.1875 [N] → $N_{cr,T}$ 13.541 [kN]

$$N_{cr,TF} = \frac{N_{cr,y}}{2\beta}\left[1 + \frac{N_{cr,T}}{N_{cr,y}} - \sqrt{\left(1 - \frac{N_{cr,T}}{N_{cr,y}}\right)^2 + 4\left(\frac{y_o}{i_o}\right)^2 \frac{N_{cr,T}}{N_{cr,y}}}\right]$$

Elastic critical force $N_{cr,TF}$ for torsional-flexural buckling [BS EN 1993-1-3, Equation (6.35)]

Monosymmetric cross-sections susceptible to torsional-flexural buckling [BS EN 1993-1-3, Figure 6.12]

$$\beta = 1 - \left(\frac{y_o}{i_o}\right)^2$$

[BS EN 1993-1-3, Equation (6.36)]

β 0.336

C-Section Strut

$N_{cr,y}$	46561.496	[N]
$N_{cr,z}$	23652.318	[N]
$N_{cr,T}$	13541.187	[N]

C-Section Strut

$N_{cr,TF}$ 11191.18107 [N] | $N_{cr,TF}$ 11.191 [kN]

C-Section Strut N_{cr} = MIN [$P_{cr,y}$; $P_{cr,z}$; $N_{cr,T}$; $N_{cr,TF}$] 11.191 [kN]

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}}$$ Class 1, Class 2, Class 3

[BS EN 1993-1-1, Equation (6.47)]

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}}$$ Class 4

[BS EN 1993-1-1, Equation (6.48)]

$$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}}$$ Class 1, Class 2, Class 3

$$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}}$$ Class 4

C-Section Column Classification [Compression] Class 3

A	201.315	[mm^2]	A_{eff}	189.709	[mm^2]

Class 3 — $\bar{\lambda}$ = 2.509

$$\Phi = 0{,}5\left[1+\alpha\left(\bar{\lambda}-0{,}2\right)+\bar{\lambda}^2\right]$$

Φ = 4.041

$$\chi = \frac{1}{\Phi+\sqrt{\Phi^2-\bar{\lambda}^2}}$$

χ = 0.139 — $\chi \leq 1{,}0$ — OK

Class 3 → $N_{b,Rd,Strut}$ **9.776** **[kN]**

[iii] C-Section Strut: Lateral-Torsional Buckling of members subject to bending [EN 1993-1-3:2006, 6.2.4]

Imperfection factors for lateral torsional buckling curves [BS EN 1993-1-1, Table 6.2]

Buckling Curve: b → Imperfection factor [α]: 0.340

$$M_{b,Rd} = \chi_{LT} W_y \frac{f_y}{\gamma_{M1}}$$

[BS EN 1993-1-1, Equation (6.55)]

$$\bar{\lambda}_{LT} = \sqrt{\frac{W_y f_y}{M_{cr}}}$$

$$M_{cr} = \frac{\pi^2 E I_z}{L^2}\left[\frac{I_w}{I_z}+\frac{L^2 G I_t}{\pi^2 E I_z}\right]^{0,5}$$

ENV 1993-1-1, Equation (F.1)]

$W_y = W_{pl,y}$	Class 1 and 2
$W_y = W_{el,y}$	Class 3
$W_y = W_{eff,y}$	Class 4

E	210.000	[GPa]
v	0.300	
G	80.769	[GPa]
I_Z	43399.345	[mm^4]

I_w	26311081.398	[mm^6]
I_t	141.478	[mm^4]
$L_{cr,T}$	1950.133	[mm]

Front C-Section Strut [Elastic Critical Moment]					
$M_{cr,Front\ Strut}$	780663.438	[Nmm]	**$M_{cr,Front\ Strut}$**	**0.781**	**[kNm]**

C-Section Strut Classification [Bending y-y]	Class 1

C-Section Strut					
$W_{el,y}$	3519.614	[mm^3]	$W_{eff,y}$	3402.038	[mm^3]
A	201.315	[mm^2]	A_{eff}	198.206	[mm^2]

$\bar{\lambda}_{LT}$ = 1.256

$$\Phi_{LT} = 0{,}5\left[1+\alpha_{LT}\left(\bar{\lambda}_{LT}-0{,}2\right)+\bar{\lambda}_{LT}^2\right]$$

Φ_{LT} = 1.469

$$\chi_{LT} = \frac{1}{\Phi_{LT}+\sqrt{\Phi_{LT}^2-\bar{\lambda}_{LT}^2}}$$

X_{LT} = 0.449 — $\chi_{LT} \leq 1{,}0$ — OK

Class 1 → $M_{b,Rd,Strut}$ **0.553** **[kNm]**

C-Section Strut	$N_{b,Rd,Strut}$	9.776	[kN]	$M_{b,Rd,Strut}$	0.553	[kNm]

[iv] C-Section Strut: Bending and axial compression [EN 1993-1-3:2006, 6.2.5]

$$\left(\frac{N_{Ed}}{N_{b,Rd}}\right)^{0,8}+\left(\frac{M_{Ed}}{M_{b,Rd}}\right)^{0,8} \leq 1{,}0$$

[BS EN 1993-1-3, Equation (6.36)]

$N_{c,Ed}$	1.470	[kN]	Ratio	26.002	[%]
$M_{cy,Ed,M[+]}$	0.010	[kNm]			
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{z,Rd,M[+]}$	1.006	[kNm]
$N_{b,Rd,Front\ Strut}$	9.776	[kN]	$M_{b,Rd,Front\ Strut}$	0.553	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	-0.001	[m]

$N_{c,Ed}$	1.470	[kN]	Ratio	26.002	[%]
$M_{cy,Ed,M[-]}$	0.010	[kNm]			
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{z,Rd,M[-]}$	0.648	[kNm]
$N_{b,Rd,Front\ Strut}$	9.776	[kN]	$M_{b,Rd,Front\ Strut}$	0.553	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	-0.001	[m]

$N_{c,Ed}$	1.470	[kN]	Ratio	26.002	[%]
$M_{cy,Ed,M[+]}$	0.010	[kNm]			
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{z,Rd,M[-]}$	0.648	[kNm]
$N_{b,Rd,Front\ Strut}$	9.776	[kN]	$M_{b,Rd,Front\ Strut}$	0.553	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	-0.001	[m]

$N_{c,Ed}$	1.470	[kN]	Ratio	26.002	[%]
$M_{cy,Ed,M[-]}$	0.010	[kNm]			
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{z,Rd,M[+]}$	1.006	[kNm]
$N_{b,Rd,Front\ Strut}$	9.776	[kN]	$M_{b,Rd,Front\ Strut}$	0.553	[kNm]
$e_{N,y,Compression}$	0.000	[m]	$e_{N,z,Compression}$	-0.001	[m]

[v] C-Section Strut: Bending and axial tension [EN 1993-1-3:2006, 6.3]

$$\left(\frac{N_{Ed}}{N_{b,Rd}}\right)^{0,8}+\left(\frac{M_{Ed}}{M_{b,Rd}}\right)^{0,8} \leq 1{,}0$$

[BS EN 1993-1-3, Equation (6.36)]

Front C-Section Strut

$N_{t,Ed}$	2.280	[kN]	Ratio	8.266	[%]
$M_{cy,Ed,M[+]}$	0.010	[kNm]			
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{z,Rd,M[+]}$	1.006	[kNm]
$N_{t,Rd}$	74.593	[kN]	$M_{y,Rd,M[+]}$	1.232	[kNm]

$N_{c,Ed}$	2.280	[kN]	Ratio	8.266	[%]
$M_{cy,Ed,M[-]}$	0.010	[kNm]			
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{z,Rd,M[-]}$	0.648	[kNm]
$N_{t,Rd}$	74.593	[kN]	$M_{y,Rd,M[-]}$	1.232	[kNm]

$N_{c,Ed}$	2.280	[kN]	Ratio	8.266	[%]
$M_{cy,Ed,M[+]}$	0.010	[kNm]			
$M_{cz,Ed,M[-]}$	0.000	[kNm]	$M_{z,Rd[-]}$	0.648	[kNm]
$N_{t,Rd}$	74.593	[kN]	$M_{y,Rd[+]}$	1.232	[kNm]

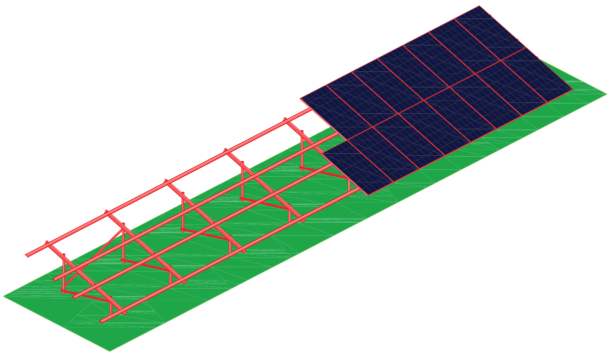
$N_{c,Ed}$	2.280	[kN]	Ratio	8.266	[%]
$M_{cy,Ed,M[-]}$	0.010	[kNm]			
$M_{cz,Ed,M[+]}$	0.000	[kNm]	$M_{z,Rd,M[+]}$	1.006	[kNm]
$N_{t,Rd}$	74.593	[kN]	$M_{y,Rd,M[-]}$	1.232	[kNm]

ANNEX B STRUCTURE TYPE I: AISI AND AS/NZS VERIFICATION

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

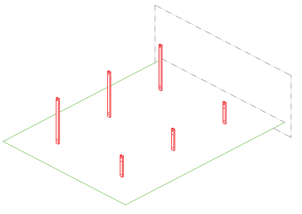
Code: AISI | AS/NZS	References: AISI S100 | AS/NZS 4600 | EN 1993	Office: ----	Author: JOSÉ ANTÓNIO
Version: 1.000		Date: 05/09/2019	Project: MASTER THESIS
		Client: COIMBRA UNIVERSITY	

[1] Presentation of the Photovoltaic Structure

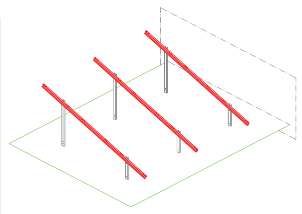


Photovoltaic Structure [Portrait Configuration] : 3D View [Example]

[2] Photovoltaic Structure: Assemby Guide

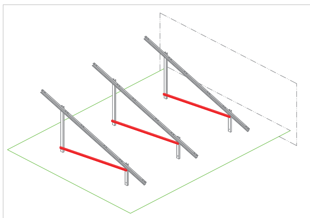


1.º Step of the Assembly Guide [Example]

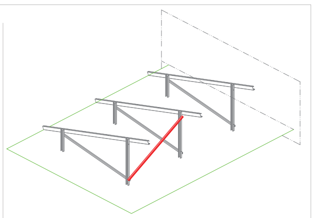


2.º Step of the Assembly Guide [Example]

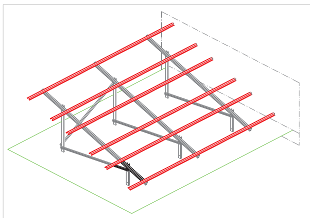
Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993 Office: ---- Author: JOSÉ ANTÓNIO
Version: 1.000 Date: 05/09/2019 Project: MASTER THESIS Client: COIMBRA UNIVERSITY



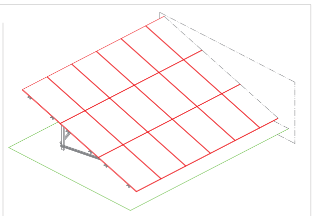
3.º Step of the Assembly Guide [Example]



4.º Step of the Assembly Guide [Example]

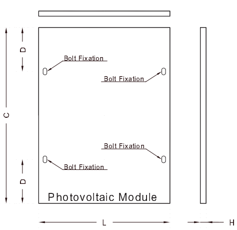


5.º Step of the Assembly Guide [Example]



6.º Step of the Assembly Guide [Example]

[3] Photovoltaic Structure: Photovoltaic Module



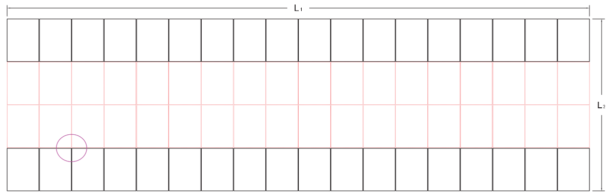
Photovoltaic Module

Photovoltaic Module			
Fabricant	----		
Designation	----		
N.º of Cells	72		[un]
Maximum Power [P_{Max}]	340		[Wp]
Dimensions	$C_{PV,Module}$	1956.000	[mm]
	$L_{PV,Module}$	992.000	[mm]
	$H_{PV,Module}$	40.000	[mm]
Installing Holes [$D_{PV,Module}$]	548		[mm]
Weight	$G_{PV,Module}$	26.500	[Kg]
	$G_{PV,Module}$	0.137	[kN/m^2]

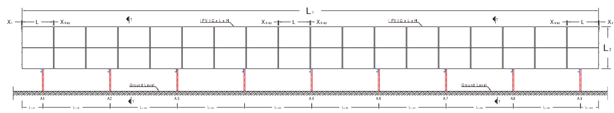
Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993 Office: ---- Author: JOSÉ ANTÓNIO
Version: 1.000 Date: 05/09/2019 Project: MASTER THESIS Client: COIMBRA UNIVERSITY

[4] Photovoltaic Structure: Structure Definition

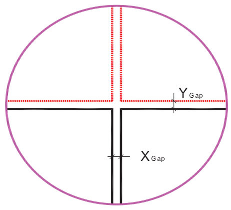
Photovoltaic Module Orientation	Portrait	N.º Rows	2	N.º Columns	18



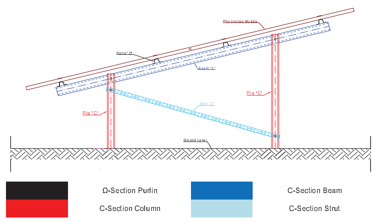
Photovoltaic Structure Definition : L_1 [mm] and L_2 [mm]



Photovoltaic Structure Definition : Tables Spacing [$L_{1,Xn}$, ..., $L_{1,Xn+1}$]



Gap between Photovoltaic Modules



Photovoltaic Structure Definition: Cut View

$L_{PV,Module}$	992.000	[mm]	→	L_1	18236.000	[mm]
$C_{PV,Module}$	1956.000	[mm]	→	L_2	3932.000	[mm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993 Office: ---- Author: JOSÉ ANTÓNIO
Version: 1.000 Date: 05/09/2019 Project: MASTER THESIS Client: COIMBRA UNIVERSITY

N.º of Spacings	8	[un]
Distance between tables	2125.000	[mm]

$L_{1,Console}$	618.000	[mm]	→	Middle length beam is well defined
$L_{1,Middle}$	2125.000	[mm]	→	Middle length beam is well defined

[a] Ω-Section Purlin

Ω-Section Purlin Length	18236.000	[mm]		
Maximum Ω-Section Purlin Length	13000.000	[mm]		
Quantity of Ω-Section Purlin Length	2.000	[un]	→	Purlin with overlaps or sleeves

[b] C-Section Beam

$L_{Beam,Front Console}$	510.000	[mm]			
$L_{Beam,Middle}$	1976.000	[mm]	C-Section Beam Length	2996.000	[mm]
$L_{Beam,Rear Console}$	510.000	[mm]			

$L_{Beam,Front Console}$	→	Beam console length is according to rules of construction
$L_{Beam,Rear Console}$	→	Beam console length is according to rules of construction

Maximum C-Section Beam Length	6000.000	[mm]		
Quantity of C-Section Beam Length	1.000	[un]	→	Beam without splices connections

[c] C-Section Column

$L_{Colum,Front Column}$	700.000	[mm]	Pthotovoltaic Structure Inclination [α]	15	[º]
Distance between Columns	1908.669	[mm]	$L_{Colum,Rear Column}$	1211.426	[mm]

Maximum C-Section Column Length	4000.000	[mm]		
Quantity of C-Section Front Column Length	1.000	[un]	→	Front Column without splices connections
Quantity of C-Section Rear Column Length	1.000	[un]	→	Rear Column without splices connections

[d] C-Section Strut

Strut Fixation Point in the Front Pile	550.000	[mm]		
Strut Fixation Point in the Rear Pile	150.000	[mm]	→	Distance from the Ground Level

L_{Strut}	1950.133	[mm]	Maximum C-Section Strut Length	6000.000	[mm]

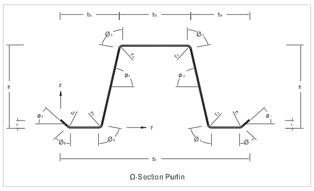
Quantity of C-Section Strut Length	1.000	[un]	→	Strut without splices connections

[5] Photovoltaic Structure : Material Properties [BS EN 1993-1-3:2006]

Steel	S 350 GD + Z	→	f_{yb}	350.000	[MPa]	f_u	420.000	[MPa]

[6] Photovoltaic Structure : Section Definition

[a] Ω-Section Purlin



Ω-Section Purlin

Ω-Section	Ω 200 * 1.00	
h	54.693	[mm]
h_c	5.096	[mm]
b_1	112.008	[mm]
b_2	34.919	[mm]
b_3	42.170	[mm]
b_4	34.919	[mm]
t_{nom}	1.000	[mm]

r_1	1.500	[mm]	$Ø_3$	78.393	[°]
r_2	1.500	[mm]	$Ø_4$	78.393	[°]
r_3	1.500	[mm]	$Ø_5$	78.393	[°]
r_4	1.500	[mm]	$Ø_6$	45.000	[°]
r_5	1.500	[mm]	$Φ_1$	45.000	[°]
r_6	1.500	[mm]	$Φ_2$	78.393	[°]
$Ø_1$	45.000	[°]	$Φ_3$	78.393	[°]
$Ø_2$	78.393	[°]	$Φ_4$	45.000	[°]

Continuously hot-dip coated steel sheet and strip: Tolerances on dimensions and shape [EN 10143:2006]

w	200.000	[mm]	Tolerance	Special
$t_{metallic\ coatings}^{[+]}$	0.050	[mm]	[EN 10143, Table 2]	
$t_{metallic\ coatings}^{[-]}$	-0.050	[mm]	[EN 10143, Table 2]	

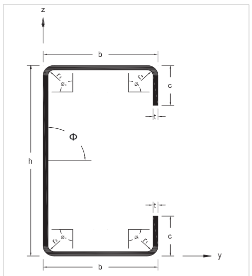
Thickness and thickness tolerances [EN 1993-1-3:2006, 3.2.4]

NOTE The ranges of core thickness t_{cor} for sheeting and members are:
- Members [AISI / AS-NZS] $t_{cor} \leq 25.400$ mm
- Connections [AISI / AS-NZS] $t_{cor} \leq 4.760$ mm and 3.000 mm

[EN 1993-1-3:2006, Equation 3.3c]		
$t_{cor,maximum}$	1.050	[mm]
$t_{cor,minimum}$	0.950	[mm]

Tolerance	≤ 5%	→	[EN 1993-1-3, Equation 3.3a]	t	0.952	[mm]
Coating	ZM310	→	Zinc-magnesium alloy coating [ZM]	→	0.048	[mm]

[b] C-Section Beam



C-Section Beam

C-Section	B 230 * 1.50	
h	120.000	[mm]
b	46.500	[mm]
c	18.000	[mm]
r_1	2.500	[mm]
r_2	2.500	[mm]
r_3	2.500	[mm]
r_4	2.500	[mm]
t_{nom}	1.500	[mm]
$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
Φ	90.000	[°]

Continuously hot-dip coated steel sheet and strip: Tolerances on dimensions and shape [EN 10143:2006]

w	230.000	mm	Tolerance	Special
$t_{metallic\ coatings}^{[+]}$	0.070	mm	[EN 10143, Table 2]	
$t_{metallic\ coatings}^{[-]}$	-0.070	mm	[EN 10143, Table 2]	

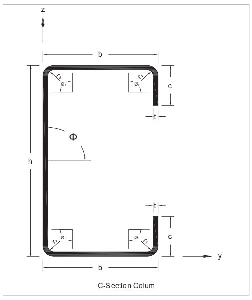
Thickness and thickness tolerances [EN 1993-1-3:2006, 3.2.4]

NOTE The ranges of core thickness t_{cor} for sheeting and members are:
- Members [AISI / AS-NZS] $t_{cor} \leq 25.400$ mm
- Connections [AISI / AS-NZS] $t_{cor} \leq 4.760$ mm and 3.000 mm

[EN 1993-1-3:2006, Equation 3.3c]		
$t_{cor,maximum}$	1.570	mm
$t_{cor,minimum}$	1.430	mm

Tolerance	≤ 5%	→	[EN 1993-1-3, Equation 3.3a]	t	1.452	mm
Coating	ZM310	→	Zinc-magnesium alloy coating [ZM]	→	0.048	[mm]

[c] C-Section Column



C-Section Colum

C-Section	B 200 * 2.50	
h	90.000	[mm]
b	46.500	[mm]
c	18.000	[mm]
r_1	2.500	[mm]
r_2	2.500	[mm]
r_3	2.500	[mm]
r_4	2.500	[mm]
t_{nom}	2.500	[mm]
$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
Φ	90.000	[°]

Continuously hot-dip coated steel sheet and strip: Tolerances on dimensions and shape [EN 10143:2006]

w	200.000	mm	Tolerance	Special
$t_{metallic\ coatings}^{[+]}$	0.110	mm	[EN 10143, Table 2]	
$t_{metallic\ coatings}^{[-]}$	-0.110	mm	[EN 10143, Table 2]	

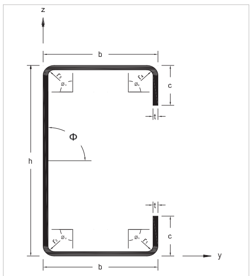
Thickness and thickness tolerances [EN 1993-1-3:2006, 3.2.4]

NOTE The ranges of core thickness t_{cor} for sheeting and members are:
- Members [AISI / AS-NZS] $t_{cor} \leq 25.400$ mm
- Connections [AISI / AS-NZS] $t_{cor} \leq 4.760$ mm and 3.000 mm

[EN 1993-1-3:2006, Equation 3.3c]		
$t_{cor,maximum}$	2.610	mm
$t_{cor,minimum}$	2.390	mm

Tolerance	≤ 5%	→	[EN 1993-1-3, Equation 3.3a]	t	2.452	mm
Coating	ZM310	→	Zinc-magnesium alloy coating [ZM]	→	0.048	[mm]

[d] C-Section Strut



C-Section Strut

C-Section	B 134 * 1.50	
h	50.000	[mm]
b	40.000	[mm]
c	10.000	[mm]
r_1	2.500	[mm]
r_2	2.500	[mm]
r_3	2.500	[mm]
r_4	2.500	[mm]
t_{nom}	1.500	[mm]
$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
Φ	90.000	[°]

Continuously hot-dip coated steel sheet and strip: Tolerances on dimensions and shape [EN 10143:2006]

w	134.000	mm	Tolerance	Special
$t_{metallic\ coatings}^{[+]}$	0.070	mm	[EN 10143, Table 2]	
$t_{metallic\ coatings}^{[-]}$	-0.070	mm	[EN 10143, Table 2]	

Thickness and thickness tolerances [EN 1993-1-3:2006, 3.2.4]

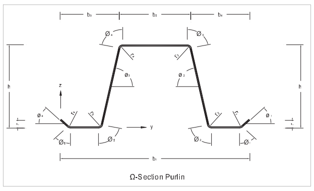
NOTE The ranges of core thickness t_{cor} for sheeting and members are:
- Members [AISI / AS-NZS] $t_{cor} \leq 25.400$ mm
- Connections [AISI / AS-NZS] $t_{cor} \leq 4.760$ mm and 3.000 mm

[EN 1993-1-3:2006, Equation 3.3c]		
$t_{cor,maximum}$	1.570	mm
$t_{cor,minimum}$	1.430	mm

Tolerance	≤ 5%	→	[EN 1993-1-3, Equation 3.3a]	t	1.452	mm
Coating	ZM310	→	Zinc-magnesium alloy coating [ZM]	→	0.048	[mm]

[7] Photovoltaic Structure : Geometrical Proportions [AISI S100 | AS-NZS 4600]

[a] Ω-Section Purlin

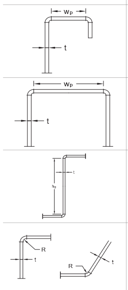


Ω-Section Purlin

Ω-Section	Ω 200 * 1.00	
h	54.693	[mm]
h_c	5.096	[mm]
b_1	112.008	[mm]
b_2	34.919	[mm]
b_3	42.170	[mm]
b_4	34.919	[mm]
t_{nom}	1.000	[mm]
t	0.952	[mm]

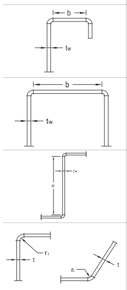
r_1	1.500	[mm]	$Ø_3$	78.393	[°]
r_2	1.500	[mm]	$Ø_4$	78.393	[°]
r_3	1.500	[mm]	$Ø_5$	78.393	[°]
r_4	1.500	[mm]	$Ø_6$	45.000	[°]
r_5	1.500	[mm]	$Φ_1$	45.000	[°]
r_6	1.500	[mm]	$Φ_2$	78.393	[°]
$Ø_1$	45.000	[°]	$Φ_3$	78.393	[°]
$Ø_2$	78.393	[°]	$Φ_4$	45.000	[°]

Maximum width-to-thickness ratios [AISI S100, B1]



Element of cross-section	Maximum value [mm]
	w / t ≤ 60
	w / t ≤ 500
	h / t ≤ 200
	R / t ≤ 7 [Condition to Equation A7.2-2]

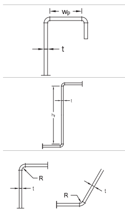
Maximum width-to-thickness ratios [AS/NZS 4600, 2.1.3]



Element of cross-section	Maximum value [mm]
	$b / t_w ≤ 60$
	$b / t_w ≤ 500$
	$d_1 / t_w ≤ 200$
	$r_i / t ≤ 8$ [AS/NZS 4600, Clause 1.3.18] $r_i / t ≤ 7$ [Condition to Equation 1.5.1.2(2)]

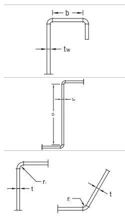
NOTE In AS/NZS 4600:2005, relatively to the bends, the limitation that was adopted in the design verifications was $r_i / t ≤ 7$

Maximum width-to-thickness ratios [AISI S100, B1]



Element of cross-section	Maximum value [mm]
	w / t ≤ 60
	h / t ≤ 200
	R / t ≤ 7 [Condition to Equation A7.2-2]

Maximum width-to-thickness ratios [AS/NZS 4600, 2.1.3]



Element of cross-section	Maximum value [mm]
	$b / t_w ≤ 60$
	$d_1 / t_w ≤ 200$
	$r_i / t ≤ 8$ [AS/NZS 4600, Clause 1.3.18] $r_i / t ≤ 7$ [Condition to Equation 1.5.1.2(2)]

NOTE In AS/NZS 4600:2005, relatively to the bends, the limitation that was adopted in the design verifications was $r_i / t ≤ 7$

Geometrical Proportions Verifications [AISI S100-07]

t	1.452	[mm]	≤ 25.400 mm	→	OK
$w_{Flange,Top}$	38.596	[mm]	b / t ≤ 60	→	OK
h_{Web}	112.096	[mm]	h / t ≤ 200	→	OK
R	2.500	[mm]	R / t ≤ 7	→	OK

Geometrical Proportions Verifications [AS/NZS 4600:2005]

t	1.452	[mm]	≤ 25.400 mm	→	OK
$b_{Flange,Top}$	38.596	[mm]	b / t ≤ 60	→	OK
d_1	112.096	[mm]	$d_1 / t_w ≤ 200$	→	OK
r_i	2.500	[mm]	$r_i / t ≤ 7$	→	OK
			$r_i / t ≤ 8$	→	OK

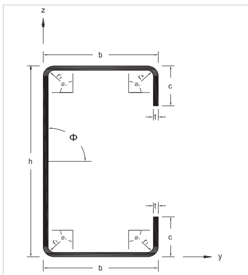
Geometrical Proportions Verifications [AISI S100-07]

t	0.952	[mm]	≤ 25.400 mm	→	OK
$w_{Flange,Top}$	38.171	[mm]	w / t ≤ 500	→	OK
h_{Web}	54.693	[mm]	h / t ≤ 200	→	OK
$w_{Flange,Inferior}$	16.545	[mm]	w / t ≤ 60	→	OK
R	1.500	[mm]	R / t ≤ 7	→	OK

Geometrical Proportions Verifications [AS/NZS 4600:2005]

t	0.952	[mm]	≤ 25.400 mm	→	OK
$b_{Flange,Top}$	38.171	[mm]	w / t ≤ 500	→	OK
d_1	54.693	[mm]	$d_1 / t_w ≤ 200$	→	OK
$b_{Flange,Inferior}$	16.545	[mm]	b / t ≤ 60	→	OK
r_i	1.500	[mm]	$r_i / t ≤ 7$	→	OK
			$r_i / t ≤ 8$	→	OK

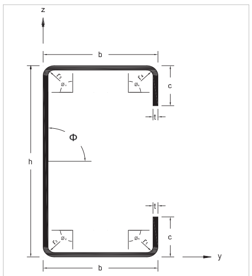
[b] C-Section Beam



C-Section Beam

C-Section	B 230 * 1.50	
h	120.000	[mm]
b	46.500	[mm]
c	18.000	[mm]
r_1	2.500	[mm]
r_2	2.500	[mm]
r_3	2.500	[mm]
r_4	2.500	[mm]
t_{nom}	1.500	[mm]
$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
Φ	90.000	[°]
t	1.452	[mm]

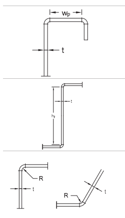
[c] C-Section Column



C-Section Column

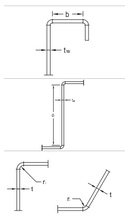
C-Section	B 200 * 2.50	
h	90.000	[mm]
b	46.500	[mm]
c	18.000	[mm]
r_1	2.500	[mm]
r_2	2.500	[mm]
r_3	2.500	[mm]
r_4	2.500	[mm]
t_{nom}	2.500	[mm]
$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
Φ	90.000	[°]
t	2.452	[mm]

Maximum width-to-thickness ratios [AISI S100, B1]



Element of cross-section	Maximum value [mm]
	w / t ≤ 60
	h / t ≤ 200
	R / t ≤ 7 [Condition to Equation A7.2-2]

Maximum width-to-thickness ratios [AS/NZS 4600, 2.1.3]



Element of cross-section	Maximum value [mm]
	$b / t_w ≤ 60$
	$d_1 / t_w ≤ 200$
	$r_i / t ≤ 8$ [AS/NZS 4600, Clause 1.3.18] $r_i / t ≤ 7$ [Condition to Equation 1.5.1.2(2)]

NOTE In AS/NZS 4600:2005, relatively to the bends, the limitation that was adopted in the design verifications was $r_i / t ≤ 7$

Geometrical Proportions Verifications [AISI S100-07]

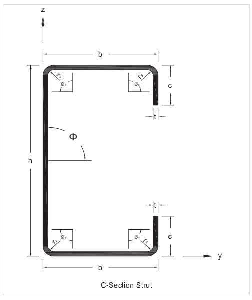
t	2.452	[mm]	≤ 25.400 mm	→	OK
$w_{Flange,Top}$	36.596	[mm]	b / t ≤ 60	→	OK
h_{Web}	80.096	[mm]	h / t ≤ 200	→	OK

R	2.500	[mm]	R / t ≤ 7	→	OK

Geometrical Proportions Verifications [AS/NZS 4600:2005]

t	2.452	[mm]	≤ 25.400 mm	→	OK
$b_{Flange,Top}$	36.596	[mm]	b / t ≤ 60	→	OK
d_1	80.096	[mm]	$d_1 / t_w \leq 200$	→	OK
r_i	2.500	[mm]	$r_i / t \leq 7$	→	OK
			$r_i / t \leq 8$	→	OK

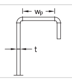
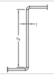
[d] C-Section Strut



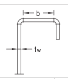
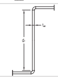
C-Section Strut

C-Section	B 134 * 1.50	
h	50.000	[mm]
b	40.000	[mm]
c	10.000	[mm]
r_1	2.500	[mm]
r_2	2.500	[mm]
r_3	2.500	[mm]
r_4	2.500	[mm]
t_{nom}	1.500	[mm]
$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]
$Ø_4$	90.000	[°]
Φ	90.000	[°]
t	1.452	[mm]

Maximum width-to-thickness ratios [AISI S100, B1]

Element of cross-section	Maximum value [mm]
	w / t ≤ 60
	h / t ≤ 200

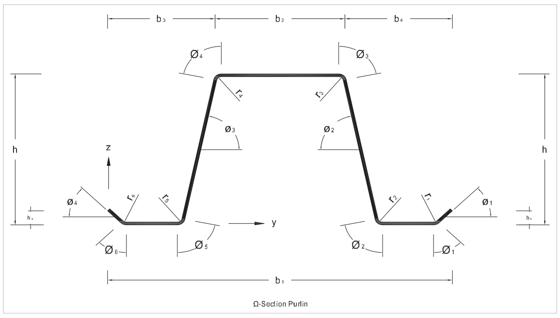
Maximum width-to-thickness ratios [AS/NZS 4600, 2.1.3]

Element of cross-section	Maximum value [mm]
	$b / t_w \leq 60$
	$d_1 / t_w \leq 200$

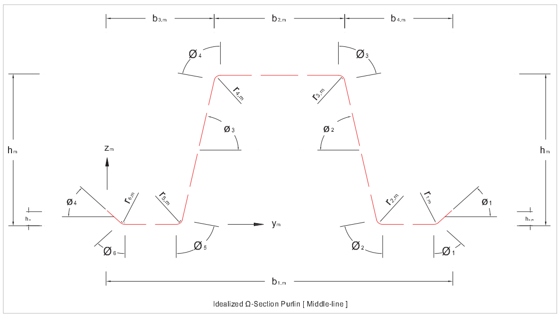
Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

[8] Photovoltaic Structure : Cold-Formed Section Properties [BS EN 1993-1-3 / AISI COLD-FORMED STEEL DESIGN MANUAL]

[a] Ω-Section Purlin

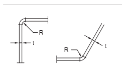
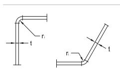


Ω-Section Purlin



Idealized Ω-Section Purlin [Middle-line]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

	R / t ≤ 7 [Condition to Equation A7.2-2]		$r_i / t \leq 8$ [AS/NZS 4600, Clause 1.3.18] $r_i / t \leq 7$ [Condition to Equation 1.5.1.2(2)]

NOTE In AS/NZS 4600:2005, relatively to the bends, the limitation that was adopted in the design verifications was $r_i / t \leq 7$

Geometrical Proportions Verifications [AISI S100-07]

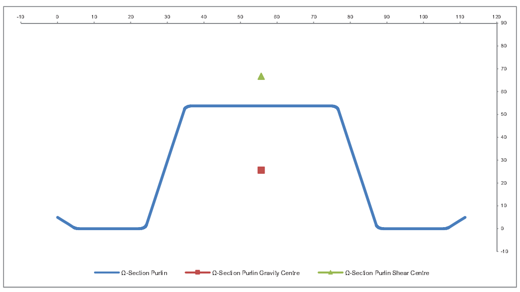
t	1.452	[mm]	≤ 25.400 mm	→	OK
$w_{Flange,Top}$	32.096	[mm]	b / t ≤ 60	→	OK
h_{Web}	42.096	[mm]	h / t ≤ 200	→	OK
R	2.500	[mm]	R / t ≤ 7	→	OK

Geometrical Proportions Verifications [AS/NZS 4600:2005]

t	1.452	[mm]	≤ 25.400 mm	→	OK
$b_{Flange,Top}$	32.096	[mm]	b / t ≤ 60	→	OK
d_1	42.096	[mm]	$d_1 / t_w \leq 200$	→	OK
r_i	2.500	[mm]	$r_i / t \leq 7$	→	OK
			$r_i / t \leq 8$	→	OK

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

Ω-Section Purlin				Idealized Ω-Section Purlin [Middle-line]		
h [d]	54.693	[mm]	→	h_m	53.741	[mm]
$h_{c,Right}$	5.096	[mm]	→	$h_{c,Right,m}$	4.957	[mm]
$h_{c,Left}$	5.096	[mm]	→	$h_{c,Left,m}$	4.957	[mm]
b_1	112.008	[mm]	→	$b_{1,m}$	111.335	[mm]
b_2	34.919	[mm]	→	$b_{2,m}$	35.513	[mm]
b_3	42.170	[mm]	→	$b_{3,m}$	40.617	[mm]
b_4	34.919	[mm]	→	$b_{4,m}$	35.513	[mm]
r_1	1.500	[mm]	→	$r_{1,m}$	1.976	[mm]
r_2	1.500	[mm]	→	$r_{2,m}$	1.976	[mm]
r_3	1.500	[mm]	→	$r_{3,m}$	1.976	[mm]
r_4	1.500	[mm]	→	$r_{4,m}$	1.976	[mm]
r_5	1.500	[mm]	→	$r_{5,m}$	1.976	[mm]
r_6	1.500	[mm]	→	$r_{6,m}$	1.976	[mm]
$Ø_1$	45.000	[°]	→	$Ø_1$	45.000	[°]
$Ø_2$	78.393	[°]	→	$Ø_2$	78.393	[°]
$Ø_3$	78.393	[°]	→	$Ø_3$	78.393	[°]
$Ø_4$	78.393	[°]	→	$Ø_4$	78.393	[°]
$Ø_5$	78.393	[°]	→	$Ø_5$	78.393	[°]
$Ø_6$	45.000	[°]	→	$Ø_6$	45.000	[°]
$Φ_1$	45.000	[°]	→	$Φ_1$	45.000	[°]
$Φ_2$	78.393	[°]	→	$Φ_2$	78.393	[°]
$Φ_3$	78.393	[°]	→	$Φ_3$	78.393	[°]
$Φ_4$	45.000	[°]	→	$Φ_4$	45.000	[°]
t	0.952	[mm]				

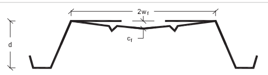


Ω-Section Purlin: Geometrical Presentation

Ω-Section Purlin Mechanical Properties

Area	A	191.199	[mm²]
First Moment of Area	S_{Y0}	4904.647	[mm³]
	S_{Z0}	10643.543	[mm³]
Gravity Centre	y_{GC}	55.667	[mm]
	z_{GC}	25.652	[mm]
Second Moment of Area through Gravity Centre	$I_{X,AISI}$	85759.975	[mm⁴]
[$I_{X,AISI} = I_{Y,EUROPE}$ | $I_{Y,AISI} = I_{Z,EUROPE}$]	$I_{Y,AISI}$	176909.935	[mm⁴]
Product Moment of Area through Gravity Centre	I_{YZ}	0.000	[mm⁴]
Principal Axis	α	0.000	[°]
	I_ξ	176909.935	[mm⁴]
	I_η	85759.975	[mm⁴]
Mean of Sectorial Coordinate	I_ω	710997.113	[mm³]
	ω_{mean}	3718.621	[mm]
Sectorial Constants	$I_{y\omega0}$	27763255.770	[mm⁵]
	$I_{y\omega}$	-11816046.037	[mm⁵]
	$I_{z\omega0}$	23012551.876	[mm⁵]
	$I_{z\omega}$	4774027.730	[mm⁵]
	$I_{\omega\omega0}$	3727328529.525	[mm⁶]
	$I_{\omega\omega}$	1083399663.544	[mm⁶]
Shear Centre	y_{SC}	55.667	[mm]
	z_{SC}	66.791	[mm]
Warping Constant [$I_{W,EUROPE}$]	$C_{W,AISI}$	28433171.015	[mm⁶]
Torsion Constants	J_{AISI}	57.762	[mm⁴]
[$J_{AISI} = I_{t,EUROPE}$]	W_t	60.674	[mm³]
Distance between Shear Centre and Gravity Centre	y_S	0.000	[mm]
	z_S	41.139	[mm]
Polar Moment of Area with respect to Shear Centre	I_p	586262.901	[mm⁴]
Non-symmetry Factors	y_j	0.000	[mm]
	z_j	54.491	[mm]

Ω-Section Purlin: Flange Curling — [AISI S100-07, B1.1(b)]



Ω-Section Purlin: Flange Curling

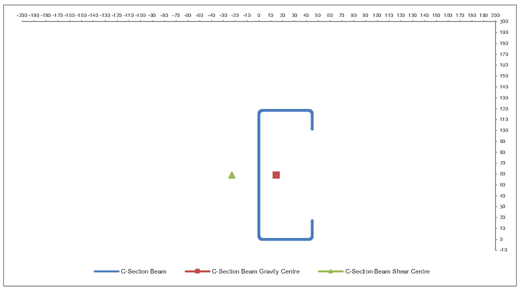
$$w_f = \sqrt{0.061 t d E / f_{av}} \sqrt[4]{(100 c_f / d)}$$

[AISI S100-07, Equation (B1.1-1)]

f_{av}	350.000	[MPa]
E	210.000	[GPa]
c_f [= 0.05 * h]	2.735	[mm]
t	0.952	[mm]
d [= h]	54.693	[mm]

$w_{f,Max}$ 65.278 [mm] → Flange Curling is not considered in the calculation

C-Section Beam				Idealized C-Section Beam [Middle-line]		
$Ø_4$	90.000	[°]	→	$Ø_4$	90.000	[°]
Φ	90.000	[°]	→	Φ	90.000	[°]
t	1.452	[mm]				

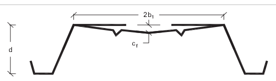


C-Section Beam: Geometrical Presentation

C-Section Beam Mechanical Properties

Area	EUROCODE	A	345.063	[mm²]
	AISI	A	345.073	[mm²]
First Moment of Area		S_{Y0}	20453.287	[mm³]
		S_{Z0}	5025.001	[mm³]
Gravity Centre	EUROCODE	y_{GC}	14.563	[mm]
		z_{GC}	59.274	[mm]
	AISI	x_c [y_{GC}]	14.563	[mm]
Second Moment of Area through Gravity Centre	EUROCODE	$I_{Y,EUROPE}$	762290.565	[mm⁴]
		$I_{Z,EUROPE}$	108754.009	[mm⁴]
	AISI	$I_{X,AISI}$	762467.029	[mm⁴]
		$I_{Y,AISI}$	108762.389	[mm⁴]
Product Moment of Area through Gravity Centre		I_{YZ}	0.000	[mm⁴]
Principal Axis		α	0.000	[°]
		I_ξ	762290.565	[mm⁴]
		I_η	108754.009	[mm⁴]
Mean of Sectorial Coordinate		I_ω	-563270.965	[mm³]
		ω_{mean}	-1632.370	[mm]

Ω-Section Purlin: Flange Curling — [AS/NZS 4600:2005, 2.1.3.2]



Ω-Section Purlin: Flange Curling

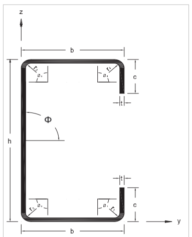
$$b_f = \sqrt{\frac{0.061 t_f d E}{f_{av}}} \sqrt[4]{\frac{100 c_f}{d}}$$

[AS/NZS 4600:2005, Equation (2.1.3.2)]

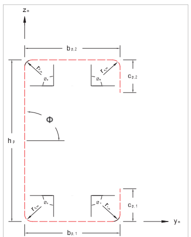
f_{av}	350.000	[MPa]
E	210.000	[GPa]
c_f [= 0.05 * h]	2.735	[mm]
t	0.952	[mm]
d [= h]	54.693	[mm]

$b_{f,Max}$ 65.278 [mm] → Flange Curling is not considered in the calculation

[b] C-Section Beam



C-Section Beam



Idealized C-Section Beam [Middle-line]

C-Section Beam				Idealized C-Section Beam [Middle-line]		
h	120.000	[mm]	→	h_p	118.548	[mm]
b_1	46.500	[mm]	→	$b_{p,1}$	45.048	[mm]
b_2	46.500	[mm]	→	$b_{p,2}$	45.048	[mm]
c_1	18.000	[mm]	→	$c_{p,1}$	17.274	[mm]
c_2	18.000	[mm]	→	$c_{p,2}$	17.274	[mm]
r_1	2.500	[mm]	→	$r_{1,m}$	3.226	[mm]
r_2	2.500	[mm]	→	$r_{2,m}$	3.226	[mm]
r_3	2.500	[mm]	→	$r_{3,m}$	3.226	[mm]
r_4	2.500	[mm]	→	$r_{4,m}$	3.226	[mm]
$Ø_1$	90.000	[°]	→	$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]	→	$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]	→	$Ø_3$	90.000	[°]

C-Section Beam Mechanical Properties [Continuation]

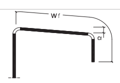
Sectorial Constants		$I_{y\omega0}$	-14648942.986	[mm⁵]
		$I_{y\omega}$	-6446285.130	[mm⁵]
		$I_{z\omega0}$	-50761926.637	[mm⁵]
		$I_{z\omega}$	-17374603.429	[mm⁵]
		$I_{\omega\omega0}$	2051436893.361	[mm⁶]
		$I_{\omega\omega}$	1131970533.845	[mm⁶]
Shear Centre	EUROCODE	y_{SC}	-22.793	[mm]
		z_{SC}	59.274	[mm]
	AISI	m [y_{SC}]	22.839	[mm]
Warping Constant	EUROCODE	I_W	353860598.321	[mm⁶]
	AISI	C_W	370290871.907	[mm⁶]
Torsion Constants	EUROCODE	I_t	242.500	[mm⁴]
		W_t	167.011	[mm³]
	AISI	J [I_t]	242.506	[mm⁴]
Distance between Shear Centre and Gravity Centre	EUROCODE	y_S	-37.355	[mm]
		z_S	0.000	[mm]
	AISI	x_0 [y_S]	-37.401	[mm]
Polar Moment of Area with respect to Shear Centre		I_p	1352549.014	[mm⁴]
Non-symmetry Factors		y_j	-64.166	[mm]
		z_j	0.000	[mm]
AISI Parameters used in determination of elastic critical moment		β_w	-3467310.381	[mm]
		β_f	4253544.635	[mm]
		β_l	5380400.235	[mm]
		j	65.750	[mm]

AISI MANUAL: Cold-Formed Steel Design [2008 Edition]

All expressions consider the sections to contain round corners with the exception of those for torsional properties [m, j and C_W]

All expressions are given for the full, unreduced sections.

C-Section Beam: Flange Curling — [AISI S100-07, B1.1(b)]



C-Section Beam: Flange Curling

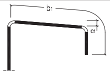
$$w_f = \sqrt{0.061 t d E / f_{av}} \sqrt[4]{(100 c_f / d)}$$

[AISI S100-07, Equation (B1.1-1)]

f_{av}	350.000	[MPa]
E	210.000	[GPa]
c_f [= 0.05 * h]	6.000	[mm]
t	1.452	[mm]
d [= h]	120.000	[mm]

$w_{f,Max}$ 119.414 [mm] → Flange Curling is not considered in the calculation

Ω-Section Beam: Flange Curling — [AS/NZS 4600:2005, 2.1.3.2]



Ω-Section Purlin: Flange Curling

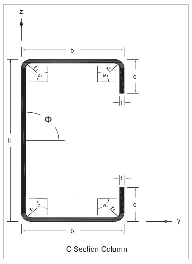
$$b_1 = \sqrt{\frac{0.061 t_f d E}{f_{av}}} \sqrt[4]{\frac{100 c_f}{d}}$$

[AS/NZS 4600:2005, Equation (2.1.3.2)]

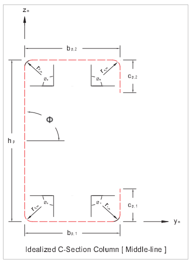
f_{av}	350.000	[MPa]
E	210.000	[GPa]
c_f [= 0.05 * h]	6.000	[mm]
t	1.452	[mm]
d [= h]	120.000	[mm]

$b_{1,Max}$ 119.414 [mm] → Flange Curling is not considered in the calculation

[c] C-Section Column



C-Section Column



Idealized C-Section Column [Middle-line]

C-Section Column				Idealized C-Section Column [Middle-line]		
h	90.000	[mm]	→	h_p	87.548	[mm]
b_1	46.500	[mm]	→	$b_{p,1}$	44.048	[mm]
b_2	46.500	[mm]	→	$b_{p,2}$	44.048	[mm]
c_1	18.000	[mm]	→	$c_{p,1}$	16.774	[mm]
c_2	18.000	[mm]	→	$c_{p,2}$	16.774	[mm]
r_1	2.500	[mm]	→	$r_{1,m}$	3.726	[mm]
r_2	2.500	[mm]	→	$r_{2,m}$	3.726	[mm]
r_3	2.500	[mm]	→	$r_{3,m}$	3.726	[mm]
r_4	2.500	[mm]	→	$r_{4,m}$	3.726	[mm]
$Ø_1$	90.000	[°]	→	$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]	→	$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]	→	$Ø_3$	90.000	[°]

C-Section Column Mechanical Properties [Continuation]

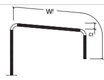
Sectorial Constants		$I_{y\omega 0}$	-18257314.383	[mm^6]
		$I_{y\omega}$	-6733179.492	[mm^6]
		$I_{z\omega 0}$	-46186806.596	[mm^6]
		$I_{z\omega}$	-14968950.402	[mm^6]
		$I_{\omega\omega 0}$	1987326582.140	[mm^6]
		$I_{\omega\omega}$	964476551.941	[mm^6]
Shear Centre	EUROCODE	y_{SC}	-23.949	[mm]
		z_{SC}	43.774	[mm]
	AISI	m [y_{SC}]	23.963	[mm]
Warping Constant	EUROCODE	I_W	311247851.419	[mm^6]
	AISI	C_W	328992829.963	[mm^6]
Torsion Constants	EUROCODE	I_t	996.509	[mm^4]
		W_t	406.407	[mm^3]
	AISI	J [I_t]	996.547	[mm^4]
Distance between Shear Centre and Gravity Centre	EUROCODE	y_S	-40.108	[mm]
		z_S	0.000	[mm]
	AISI	x_0 [y_S]	-40.123	[mm]
Polar Moment of Area with respect to Shear Centre		I_p	1578738.881	[mm^4]
Non-symmetry Factors		y_j	-54.246	[mm]
		z_j	0.000	[mm]
AISI Parameters used in determination of elastic critical moment		β_w	-3121505.848	[mm]
		β_f	3085440.670	[mm]
		β_l	4710836.843	[mm]
		j	55.317	[mm]

AISI MANUAL: Cold-Formed Steel Design [2008 Edition]

All expressions consider the sections to contain round corners with the exception of those for torsional properties [m, j and C_W]

All expressions are given for the full, unreduced sections.

C-Section Column: Flange Curling — [AISI S100-07, B1.1(b)]



C-Section Beam: Flange Curling

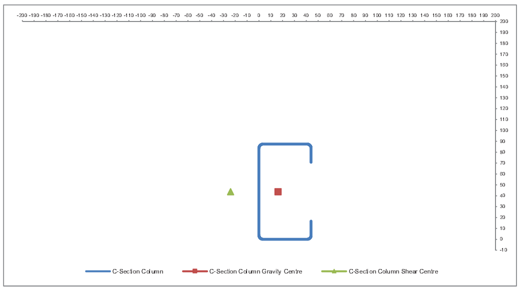
$$w_f = \sqrt{0.061 t d E / f_{av}} \sqrt[4]{(100 c_f / d)}$$

[AISI S100-07, Equation (B1.1-1)]

f_{av}	350.000	[MPa]
E	210.000	[GPa]
c_f [= 0.05 * h]	4.500	[mm]
t	2.452	[mm]
d [= h]	90.000	[mm]

$w_{f,Max}$ 134.389 [mm] → Flange Curling is not considered in the calculation

C-Section Column				Idealized C-Section Column [Middle-line]		
$Ø_4$	90.000	[°]	→	$Ø_4$	90.000	[°]
Φ	90.000	[°]	→	Φ	90.000	[°]
t	2.452	[mm]				

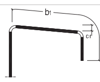


C-Section Column: Geometrical Presentation

C-Section Column Mechanical Properties

Area	EUROCODE	A	497.235	[mm^2]
	AISI	A	497.254	[mm^2]
First Moment of Area		S_{Y0}	21765.966	[mm^3]
		S_{Z0}	8034.951	[mm^3]
Gravity Centre	EUROCODE	y_{GC}	16.159	[mm]
		z_{GC}	43.774	[mm]
	AISI	x_c [y_{GC}]	16.159	[mm]
Second Moment of Area through Gravity Centre	EUROCODE	$I_{Y,EUROPE}$	625036.020	[mm^4]
		$I_{Z,EUROPE}$	153816.866	[mm^4]
	AISI	$I_{X,AISI}$	625166.562	[mm^4]
		$I_{Y,AISI}$	153832.964	[mm^4]
Product Moment of Area through Gravity Centre		I_{YZ}	0.000	[mm^6]
Principal Axis		α	0.000	[°]
		I_ξ	625036.020	[mm^4]
		I_η	153816.866	[mm^4]
Mean of Sectorial Coordinate		I_ω	-713159.780	[mm^3]
		ω_{mean}	-1434.251	[mm]

Ω-Section Column: Flange Curling — [AS/NZS 4600:2005, 2.1.3.2]



Ω-Section Purlin: Flange Curling

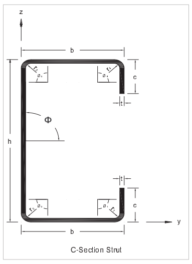
$$b_1 = \sqrt{\frac{0.061 t_f d E}{f_{av}}} \sqrt[4]{\frac{100 c_f}{d}}$$

[AS/NZS 4600:2005, Equation (2.1.3.2)]

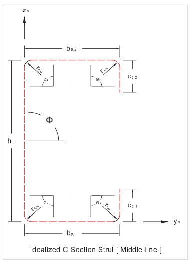
f_{av}	350.000	[MPa]
E	210.000	[GPa]
c_f [= 0.05 * h]	4.500	[mm]
t	2.452	[mm]
d [= h]	90.000	[mm]

$b_{1,Max}$ 134.389 [mm] → Flange Curling is not considered in the calculation

[d] C-Section Strut



C-Section Strut

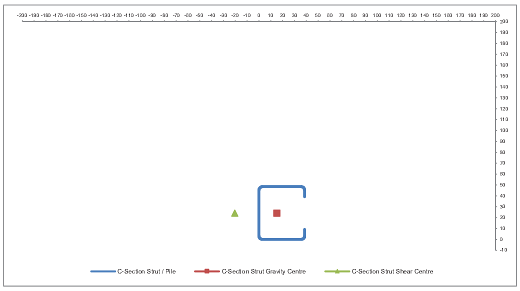


Idealized C-Section Strut [Middle-line]

C-Section Strut				Idealized C-Section Strut [Middle-line]		
h	50.000	[mm]	→	h_p	48.548	[mm]
b_1	40.000	[mm]	→	$b_{p,1}$	38.548	[mm]
b_2	40.000	[mm]	→	$b_{p,2}$	38.548	[mm]
c_1	10.000	[mm]	→	$c_{p,1}$	9.274	[mm]
c_2	10.000	[mm]	→	$c_{p,2}$	9.274	[mm]
r_1	2.500	[mm]	→	$r_{1,m}$	3.226	[mm]
r_2	2.500	[mm]	→	$r_{2,m}$	3.226	[mm]
r_3	2.500	[mm]	→	$r_{3,m}$	3.226	[mm]
r_4	2.500	[mm]	→	$r_{4,m}$	3.226	[mm]
$Ø_1$	90.000	[°]	→	$Ø_1$	90.000	[°]
$Ø_2$	90.000	[°]	→	$Ø_2$	90.000	[°]
$Ø_3$	90.000	[°]	→	$Ø_3$	90.000	[°]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS		Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS	References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000		Client: COIMBRA UNIVERSITY	

C-Section Strut				Idealized C-Section Strut [Middle-line]		
$Ø_s$	90.000	[º]	→	$Ø_s$	90.000	[º]
Φ	90.000	[º]	→	Φ	90.000	[º]
t	1.452	[mm]				



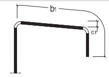
C-Section Strut: Geometrical Presentation

C-Section Strut Mechanical Properties

Area	**EUROCODE**	A	201.315	[mm^2]
	AISI	A	201.325	[mm^2]
First Moment of Area		S_{Y0}	4886.730	[mm^3]
		S_{Z0}	3040.577	[mm^3]
Gravity Centre	**EUROCODE**	y_{GC}	15.104	[mm]
		z_{GC}	24.274	[mm]
	AISI	x_c [y_{GC}]	15.104	[mm]
Second Moment of Area through Gravity Centre	**EUROCODE**	$I_{Y,EUROPE}$	85435.109	[mm^4]
		$I_{Z,EUROPE}$	43399.345	[mm^4]
	AISI	$I_{X,AISI}$	85450.650	[mm^4]
		$I_{Y,AISI}$	43405.554	[mm^4]
Product Moment of Area through Gravity Centre		I_{YZ}	0.000	[mm^6]
Principal Axis		α	0.000	[º]
		I_ξ	85435.109	[mm^4]
		I_η	43399.345	[mm^4]
Mean of Sectorial Coordinate		I_ω	-143970.289	[mm^3]
		ω_{mean}	-715.148	[mm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS		Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS	References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000		Client: COIMBRA UNIVERSITY	

Ω-Section Strut: Flange Curling [AS/NZS 4600:2005, 2.1.3.2]



Ω-Section Purlin: Flange Curling

$$b_f = \sqrt{\frac{0.061 t_f d E}{f_{av}}} \sqrt[4]{\frac{100 c_f}{d}}$$

[AS/NZS 4600:2005, Equation (2.1.3.2)]

f_{av}	350.000	[MPa]
E	210.000	[GPa]
c_f [= 0.05 * h]	2.500	[mm]
t	1.452	[mm]
d [= h]	50.000	[mm]

$b_{f,Max}$ 77.082 [mm] → Flange Curling is not considered in the calculation

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS		Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS	References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000		Client: COIMBRA UNIVERSITY	

C-Section Strut Mechanical Properties [Continuarion]

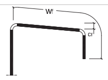
Sectorial Constants		$I_{y\omega0}$	-3227938.382	[mm^6]
		$I_{y\omega}$	-1053475.689	[mm^6]
		$I_{z\omega0}$	-5240440.083	[mm^6]
		$I_{z\omega}$	-1745705.295	[mm^6]
		$I_{\omega\omega0}$	190513401.065	[mm^6]
		$I_{\omega\omega}$	87553344.926	[mm^6]
Shear Centre	**EUROCODE**	y_{SC}	-20.433	[mm]
		z_{SC}	24.274	[mm]
	AISI	m [y_{SC}]	20.504	[mm]
Warping Constant	**EUROCODE**	I_W	26311081.398	[mm^6]
	AISI	C_W	28407510.884	[mm^6]
Torsion Constants	**EUROCODE**	I_t	141.478	[mm^4]
		W_t	97.437	[mm^3]
	AISI	J [I_t]	141.485	[mm^4]
Distance between Shear Centre and Gravity Centre	**EUROCODE**	y_S	-35.537	[mm]
		z_S	0.000	[mm]
	AISI	x_0 [y_S]	-35.608	[mm]
Polar Moment of Area with respect to Shear Centre		I_p	383066.518	[mm^4]
Non-symmetry Factors		y_j	-41.747	[mm]
		z_j	0.000	[mm]
AISI Parameters used in determination of elastic critical moment		β_w	-451994.835	[mm]
		β_f	456610.717	[mm]
		β_l	595032.660	[mm]
		j	42.516	[mm]

AISI MANUAL: Cold-Formed Steel Design [2008 Edition]

All expressions consider the sections to contain round corners with the exception of those for torsional properties [m, j and C_W]

All expressions are given for the full, unreduced sections.

C-Section Strut: Flange Curling [AISI S100-07, B1.1(b)]



C-Section Beam: Flange Curling

$$w_f = \sqrt{0.061 t d E / f_{av}} \sqrt[4]{(100 c_f / d)}$$

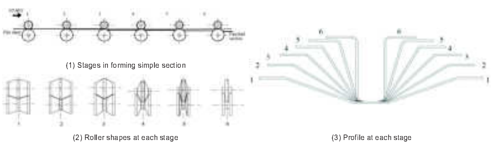
[AISI S100-07, Equation (B1.1-1)]

f_{av}	350.000	[MPa]
E	210.000	[GPa]
c_f [= 0.05 * h]	2.500	[mm]
t	1.452	[mm]
d [= h]	50.000	[mm]

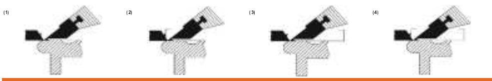
$w_{f,Max}$ 77.082 [mm] → Flange Curling is not considered in the calculation

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS		Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS	References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000		Client: COIMBRA UNIVERSITY	

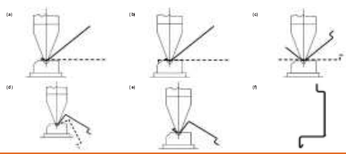
[10] Photovoltaic Structure : Strength increase resulting from cold forming [AISI S100-07, A7.2 / AS/NZS 4600, 1.5.1.2]



Stages in roll forming a simple section [Rhodes, 1991]



Forming of folding



Forming steps in press braking process

Ω-Section Purlin, Manufacturing Process	Roll Forming
C-Section Beam, Manufacturing Process	Roll Forming
C-Section Column, Manufacturing Process	Roll Forming
C-Section Strut, Manufacturing Process	Roll Forming

Influence of manufacturing process on hot and cold-formed profiles

Forming method		Hot rolling	Cold forming: Cold rolling	Cold forming: Press Braking
Yield strength	Corner	----	High	High
	Flange	----	Moderate	----
Ultimate strength	Corner	---	High	High
	Flange	---	Moderate	---

AISI S100-2007, Clause A7.2

NOTE Manufacturing process leads to a modification of the stress-strain curve of the steel virgin material

The average yield strength F_{ya} may be utilised in determining:

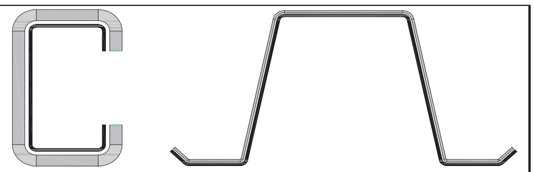
- For axially loaded compression members, the quantity ρ is unity for each of the component elements of the section
- For flexural members, the quantity ρ is unity for each of the component elements of the section
- For axially loaded tension members

AS/NZS 4600>2005, Clause 1.5.1.2

NOTE Manufacturing process leads to a modification of the stress-strain curve of the steel virgin material

The average yield strength f_{ya} may be utilised in determining:

- For axially loaded compression members, the quantity ρ is unity for each of the component elements of the section
- For flexural members, the quantity ρ is unity for each of the component elements of the section
- For axially loaded tension members



Average Yield Stress [F_{ya} | f_{ya}]

[a] Ω-Section Purlin

$$F_{ya} = CF_{yc} + (1 - C)F_{yf} \leq F_{uv}$$

[AISI S100-2007, Equation A7.2-1]

$$f_{ya} = Cf_{yc} + (1 - C)f_{yf} \leq f_{uv}$$

[AS/NZS 4600:2005, Equation 1.5.1.2(1)]

Cold-Formed Material Properties							
S 350 GD + Z	F_{yv} | f_{yv}	350.000	[MPa]	F_{uv} | f_{uv}	420.000	[MPa]	

Equations A7.2-2 and 1.5.1.2(2) are only applicable if:			
AISI	$F_{uv} / F_{yv} \geq 1.20$	$R / t \leq 7.00$	$Ø \leq 120°$
AS/NZS	$f_{uv} / f_{yv} \geq 1.20$	$r_i / t \leq 7.00$	$Ø \leq 120°$

Parameters					
r_{max}	1.500	[°]	t	0.952	[mm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993 — Version: 1.000

Office: ---- | Author: JOSÉ ANTÓNIO | Date: 05/09/2019 | Project: MASTER THESIS | Client: COIMBRA UNIVERSITY

AISI S100-2007					
Compression Members	F_{ya}	358.592	[MPa]	$\leq F_{uv}$	OK
Flexural Members	F_{ya}	365.389	[MPa]	$\leq F_{uv}$	OK

AS/NZS 4600:2005					
Compression Members	f_{ya}	358.592	[MPa]	$\leq f_{uv}$	OK
Flexural Members	f_{ya}	365.389	[MPa]	$\leq f_{uv}$	OK

[b] C-Section Beam

$$F_{ya} = CF_{yc} + (1 - C)F_{yf} \leq F_{uv}$$

[AISI S100-2007, Equation A7.2-1]

$$f_{ya} = Cf_{yc} + (1 - C)f_{yf} \leq f_{uv}$$

[AS/NZS 4600:2005, Equation 1.5.1.2(1)]

Cold-Formed Material Properties						
S 350 GD + Z	F_{yv} | f_{yv}	350.000	[MPa]	F_{uv} | f_{uv}	420.000	[MPa]

Equations A7.2-2 and 1.5.1.2(2) are only applicable if:			
AISI	$F_{uv} / F_{yv} \geq 1.20$	$R / t \leq 7.00$	$Ø \leq 120°$
AS/NZS	$f_{uv} / f_{yv} \geq 1.20$	$r_i / t \leq 7.00$	$Ø \leq 120°$

Parameters					
r_{max}	2.500	[°]	t	1.452	[mm]

AISI S100-2007		AS/NZS 4600:2005	
$F_{uv} / F_{yv} \geq 1.20$	OK	$f_{uv} / f_{yv} \geq 1.20$	OK
$R / t \leq 7.00$	OK	$r_i / t \leq 7.00$	OK
$Ø \leq 120°$	OK	$Ø \leq 120°$	OK

$$B_c = 3.69\,(F_{uv}/F_{yv}) - 0.819\,(F_{uv}/F_{yv})^2 - 1.79$$

[AISI S100-2007, Equation A7.2-3]

$$B_c = 3.69\left(\frac{f_{uv}}{f_{yv}}\right) - 0.819\left(\frac{f_{uv}}{f_{yv}}\right)^2 - 1.79$$

[AS/NZS 4600:2005, Equation 1.5.1.2(3)]

AISI S100-2007			AS/NZS 4600:2005		
B_c	1.459	[ ]	B_c	1.459	[ ]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993 — Version: 1.000

Office: ---- | Author: JOSÉ ANTÓNIO | Date: 05/09/2019 | Project: MASTER THESIS | Client: COIMBRA UNIVERSITY

AISI S100-2007		AS/NZS 4600:2005	
$F_{uv} / F_{yv} \geq 1.20$	OK	$f_{uv} / f_{yv} \geq 1.20$	OK
$R / t \leq 7.00$	OK	$r_i / t \leq 7.00$	OK
$Ø \leq 120°$	OK	$Ø \leq 120°$	OK

$$B_c = 3.69\,(F_{uv}/F_{yv}) - 0.819\,(F_{uv}/F_{yv})^2 - 1.79$$

[AISI S100-2007, Equation A7.2-3]

$$B_c = 3.69\left(\frac{f_{uv}}{f_{yv}}\right) - 0.819\left(\frac{f_{uv}}{f_{yv}}\right)^2 - 1.79$$

[AS/NZS 4600:2005, Equation 1.5.1.2(3)]

AISI S100-2007			AS/NZS 4600:2005		
B_c	1.459	[ ]	B_c	1.459	[ ]

$$m = 0.192\,(F_{uv}/F_{yv}) - 0.068$$

[AISI S100-2007, Equation A7.2-4]

$$m = 0.192\left(\frac{f_{uv}}{f_{yv}}\right) - 0.068$$

[AS/NZS 4600:2005, Equation 1.5.1.2(4)]

AISI S100-2007			AS/NZS 4600:2005		
m	0.162	[ ]	m	0.162	[ ]

$$F_{yc} = B_c F_{yv}/(R/t)^m$$

[AISI S100-2007, Equation A7.2-2]

$$f_{yc} = \frac{B_c f_{yv}}{(r_i/t)^m}$$

[AS/NZS 4600:2005, Equation 1.5.1.2(2)]

AISI S100-2007			AS/NZS 4600:2005		
F_{yc}	474.187	[MPa]	f_{yc}	474.187	[MPa]

AISI S100/2007 | AS/NZS 4600:2005

C

Compression members: ratio of the total bend cross-sectional area to the total cross-sectional area of the full section

Flexural members: ratio of the total bend cross-sectional area to the controlling flange to the full cross-sectional area of the controlling flange

AISI S100-2007			AS/NZS 4600:2005		
Compression Members			Compression Members		
$C_{Compression}$	0.069	[ ]	$C_{Compression}$	0.069	[ ]
Flexural Members			Flexural Members		
$C_{Flexural}$	0.124	[ ]	$C_{Flexural}$	0.124	[ ]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993 — Version: 1.000

Office: ---- | Author: JOSÉ ANTÓNIO | Date: 05/09/2019 | Project: MASTER THESIS | Client: COIMBRA UNIVERSITY

$$m = 0.192\,(F_{uv}/F_{yv}) - 0.068$$

[AISI S100-2007, Equation A7.2-4]

$$m = 0.192\left(\frac{f_{uv}}{f_{yv}}\right) - 0.068$$

[AS/NZS 4600:2005, Equation 1.5.1.2(4)]

AISI S100-2007			AS/NZS 4600:2005		
m	0.162	[ ]	m	0.162	[ ]

$$F_{yc} = B_c F_{yv}/(R/t)^m$$

[AISI S100-2007, Equation A7.2-2]

$$f_{yc} = \frac{B_c f_{yv}}{(r_i/t)^m}$$

[AS/NZS 4600:2005, Equation 1.5.1.2(2)]

AISI S100-2007			AS/NZS 4600:2005		
F_{yc}	467.406	[MPa]	f_{yc}	467.406	[MPa]

AISI S100/2007 | AS/NZS 4600:2005

C

Compression members: ratio of the total bend cross-sectional area to the total cross-sectional area of the full section

Flexural members: ratio of the total bend cross-sectional area to the controlling flange to the full cross-sectional area of the controlling flange

AISI S100-2007			AS/NZS 4600:2005		
Compression Members			Compression Members		
$C_{Compression}$	0.085	[ ]	$C_{Compression}$	0.085	[ ]
Flexural Members			Flexural Members		
$C_{Flexural}$	0.208	[ ]	$C_{Flexural}$	0.208	[ ]

AISI S100-2007					
Compression Members	F_{ya}	360.001	[MPa]	$\leq F_{uv}$	OK
Flexural Members	F_{ya}	374.390	[MPa]	$\leq F_{uv}$	OK

AS/NZS 4600:2005					
Compression Members	f_{ya}	360.001	[MPa]	$\leq f_{uv}$	OK
Flexural Members	f_{ya}	374.390	[MPa]	$\leq f_{uv}$	OK

[c] C-Section Column

$$F_{ya} = CF_{yc} + (1 - C)F_{yf} \leq F_{uv}$$

[AISI S100-2007, Equation A7.2-1]

$$f_{ya} = Cf_{yc} + (1 - C)f_{yf} \leq f_{uv}$$

[AS/NZS 4600:2005, Equation 1.5.1.2(1)]

Cold-Formed Material Properties						
S 350 GD + Z	F_{yv} | f_{yv}	350.000	[MPa]	F_{uv} | f_{uv}	420.000	[MPa]

Equations A7.2-2 and 1.5.1.2(2) are only applicable if:			
AISI	$F_{uv} / F_{yv} \geq 1.20$	$R / t \leq 7.00$	$Ø \leq 120°$
AS/NZS	$f_{uv} / f_{yv} \geq 1.20$	$r_i / t \leq 7.00$	$Ø \leq 120°$

Parameters					
r_{max}	2.500	[°]	t	2.452	[mm]

AISI S100-2007	
$F_{uv} / F_{yv} \geq 1.20$	OK
$R / t \leq 7.00$	OK
$Ø \leq 120°$	OK

AS/NZS 4600:2005	
$f_{uv} / f_{yv} \geq 1.20$	OK
$r_i / t \leq 7.00$	OK
$Ø \leq 120°$	OK

$$B_c = 3.69 (F_{uv}/F_{yv}) - 0.819 (F_{uv}/F_{yv})^2 - 1.79$$

[AISI S100-2007, Equation A7.2-3]

$$B_c = 3.69\left(\frac{f_{uv}}{f_{yv}}\right) - 0.819\left(\frac{f_{uv}}{f_{yv}}\right)^2 - 1.79$$

[AS/NZS 4600:2005, Equation 1.5.1.2(3)]

AISI S100-2007		
B_c	1.459	[ ]

AS/NZS 4600:2005		
B_c	1.459	[ ]

$$m = 0.192 (F_{uv}/F_{yv}) - 0.068$$

[AISI S100-2007, Equation A7.2-4]

$$m = 0.192\left(\frac{f_{uv}}{f_{yv}}\right) - 0.068$$

[AS/NZS 4600:2005, Equation 1.5.1.2(4)]

AISI S100-2007		
m	0.162	[ ]

AS/NZS 4600:2005		
m	0.162	[ ]

$$F_{yc} = B_c F_{yv}/(R/t)^m$$

[AISI S100-2007, Equation A7.2-2]

$$f_{yc} = \frac{B_c f_{yv}}{(r_i/t)^m}$$

[AS/NZS 4600:2005, Equation 1.5.1.2(2)]

AISI S100-2007		
F_{yc}	508.919	[MPa]

AS/NZS 4600:2005		
f_{yc}	508.919	[MPa]

AISI S100/2007 | AS/NZS 4600:2005

C

Compression members: ratio of the total bend cross-sectional area to the total cross-sectional area of the full section

Flexural members: ratio of the total bend cross-sectional area to the controlling flange to the full cross-sectional area of the controlling flange

AISI S100-2007		
B_c	1.459	[ ]

AS/NZS 4600:2005		
B_c	1.459	[ ]

$$m = 0.192 (F_{uv}/F_{yv}) - 0.068$$

[AISI S100-2007, Equation A7.2-4]

$$m = 0.192\left(\frac{f_{uv}}{f_{yv}}\right) - 0.068$$

[AS/NZS 4600:2005, Equation 1.5.1.2(4)]

AISI S100-2007		
m	0.162	[ ]

AS/NZS 4600:2005		
m	0.162	[ ]

$$F_{yc} = B_c F_{yv}/(R/t)^m$$

[AISI S100-2007, Equation A7.2-2]

$$f_{yc} = \frac{B_c f_{yv}}{(r_i/t)^m}$$

[AS/NZS 4600:2005, Equation 1.5.1.2(2)]

AISI S100-2007		
F_{yc}	467.406	[MPa]

AS/NZS 4600:2005		
f_{yc}	467.406	[MPa]

AISI S100/2007 | AS/NZS 4600:2005

C

Compression members: ratio of the total bend cross-sectional area to the total cross-sectional area of the full section

Flexural members: ratio of the total bend cross-sectional area to the controlling flange to the full cross-sectional area of the controlling flange

AISI S100-2007		
Compression Members		
$C_{Compression}$	0.146	[ ]
Flexural Members		
$C_{Flexural}$	0.240	[ ]

AS/NZS 4600:2005		
Compression Members		
$C_{Compression}$	0.146	[ ]
Flexural Members		
$C_{Flexural}$	0.240	[ ]

AISI S100-2007					
Compression Members	F_{ya}	367.142	[MPa]	$\leq F_{uv}$	OK
Flexural Members	F_{ya}	378.145	[MPa]	$\leq F_{uv}$	OK

AS/NZS 4600:2005					
Compression Members	f_{ya}	367.142	[MPa]	$\leq f_{uv}$	OK
Flexural Members	f_{ya}	378.145	[MPa]	$\leq f_{uv}$	OK

AISI S100-2007		
Compression Members		
$C_{Compression}$	0.115	[ ]
Flexural Members		
$C_{Flexural}$	0.242	[ ]

AS/NZS 4600:2005		
Compression Members		
$C_{Compression}$	0.115	[ ]
Flexural Members		
$C_{Flexural}$	0.242	[ ]

AISI S100-2007					
Compression Members	F_{ya}	368.323	[MPa]	$\leq F_{uv}$	OK
Flexural Members	F_{ya}	388.471	[MPa]	$\leq F_{uv}$	OK

AS/NZS 4600:2005					
Compression Members	f_{ya}	368.323	[MPa]	$\leq f_{uv}$	OK
Flexural Members	f_{ya}	388.471	[MPa]	$\leq f_{uv}$	OK

[d] C-Section Strut

$$F_{ya} = CF_{yc} + (1 - C) F_{yf} \leq F_{uv}$$

[AISI S100-2007, Equation A7.2-1]

$$f_{ya} = Cf_{yc} + (1 - C)f_{yf} \leq f_{uv}$$

[AS/NZS 4600:2005, Equation 1.5.1.2(1)]

Cold-Formed Material Properties						
S 350 GD + Z	F_{yv} | f_{yv}	350.000	[MPa]	F_{uv} | f_{uv}	420.000	[MPa]

Equations A7.2-2 and 1.5.1.2(2) are only applicable if:			
AISI	$F_{uv} / F_{yv} \geq 1.20$	$R / t \leq 7.00$	$Ø \leq 120°$
AS/NZS	$f_{uv} / f_{yv} \geq 1.20$	$r_i / t \leq 7.00$	$Ø \leq 120°$

Parameters					
r_{max}	2.500	[°]	t	1.452	[mm]

AISI S100-2007	
$F_{uv} / F_{yv} \geq 1.20$	OK
$R / t \leq 7.00$	OK
$Ø \leq 120°$	OK

AS/NZS 4600:2005	
$f_{uv} / f_{yv} \geq 1.20$	OK
$r_i / t \leq 7.00$	OK
$Ø \leq 120°$	OK

$$B_c = 3.69 (F_{uv}/F_{yv}) - 0.819 (F_{uv}/F_{yv})^2 - 1.79$$

[AISI S100-2007, Equation A7.2-3]

$$B_c = 3.69\left(\frac{f_{uv}}{f_{yv}}\right) - 0.819\left(\frac{f_{uv}}{f_{yv}}\right)^2 - 1.79$$

[AS/NZS 4600:2005, Equation 1.5.1.2(3)]

[11.1] Cold-Formed Section subjected to Tension Force

[a] Ω-Section Purlin

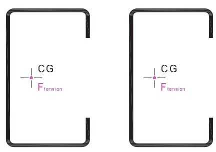
Gross Ω-Section

Effective Ω-Section [L]

Local Buckling

Ω-Section Purlin : Mechanical Properties		Ω-Section	Ω 200 * 1.00
Area	$A_g = A_{eff}$	191.199	[mm^2]
Gravity Centre	$y_{GC} = y_{GC,eff}$	55.667	[mm]
	$z_{GC} = z_{GC,eff}$	25.652	[mm]
Second Moment of Area through Gravity Centre	$I_Y = I_{Y,eff}$	85759.975	[mm^4]
	$I_Z = I_{Z,eff}$	176909.935	[mm^4]

[b] C-Section Beam



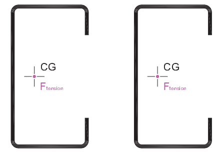
Gross C-Section

Effective C-Section [L]

Local Buckling

C-Section Beam : Mechanical Properties		C-Section	B 230 * 1.50
Area	$A_g = A_{eff}$	345.063	[mm^2]
Gravity Centre	$y_{GC} = y_{GC,eff}$	14.563	[mm]
	$z_{GC} = z_{GC,eff}$	59.274	[mm]
Second Moment of Area through Gravity Centre	$I_Y = I_{Y,eff}$	762290.565	[mm^4]
	$I_Z = I_{Z,eff}$	108754.009	[mm^4]

[c] C-Section Column



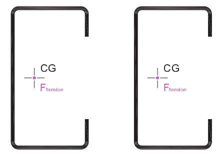
Gross C-Section

Effective C-Section [L]

Local Buckling

C-Section Column : Mechanical Properties		C-Section	B 200 * 2.50
Area	$A_g = A_{eff}$	497.235	[mm^2]
Gravity Centre	$y_{GC} = y_{GC,eff}$	16.159	[mm]
	$z_{GC} = z_{GC,eff}$	43.774	[mm]
Second Moment of Area through Gravity Centre	$I_Y = I_{Y,eff}$	625036.020	[mm^4]
	$I_Z = I_{Z,eff}$	153816.866	[mm^4]

[d] C-Section Strut



Gross C-Section

Effective C-Section [L]

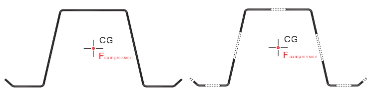
Local Buckling

C-Section Strut : Mechanical Properties		C-Section	B 134 * 1.50
Area	$A_g = A_{eff}$	201.315	[mm^2]
Gravity Centre	$y_{GC} = y_{GC,eff}$	15.104	[mm]
	$z_{GC} = z_{GC,eff}$	24.274	[mm]
Second Moment of Area through Gravity Centre	$I_Y = I_{Y,eff}$	85435.109	[mm^4]
	$I_Z = I_{Z,eff}$	43399.345	[mm^4]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

[11.2] Cold-Formed Section subjected to Compression Force

[a] Ω-Section Purlin

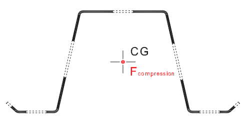


Gross Ω-Section

Effective Ω-Section [L]

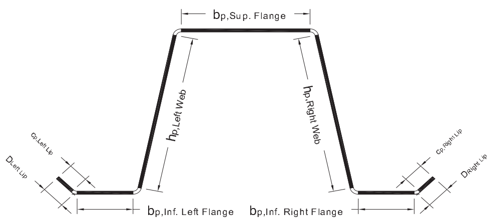
Local Buckling

[i] Effective Widths for Strength Determination [Local Buckling] **AISI S100, Sector B | AS/NZS 4600, Section 2**



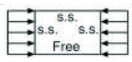
Effective Ω-Section [Worst Case]

Ω-Section Purlin Dimension		
$c_{p,Right\ Lip}$	6.191	[mm]
$b_{p,Inf.\ Right\ Flange}$	16.545	[mm]
$h_{p,Right\ Web}$	51.640	[mm]
$b_{p,Sup.\ Web}$	38.171	[mm]
$h_{p,Left\ Web}$	51.640	[mm]
$b_{p,Inf.\ Left\ Flange}$	16.545	[mm]
$c_{p,Left\ Lip}$	6.191	[mm]

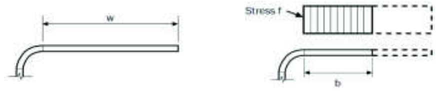


Ω-Section Plate Widths

Right Edge Stiffner [$c_{p,Right\ Lip}$] [AISI S100, Sector B3.1]

Boundary condition	Types of stress	k
	Compression	0.425

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY



Actual Element	Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

Ω-Section Purlin Dimension

$c_{p,Right\ Lip}$ 6.191 [mm]

NOTE $w = c_{p,Right\ Lip}$

E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 1907.096 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$

350.000 [MPa]

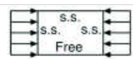
λ 0.428

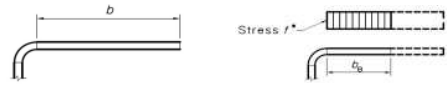
$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$c_{p,Right\ Lip,eff,AISI}$	6.191	[mm]

Right Edge Stiffner [$c_{p,Right\ Lip}$] [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k
	Compression	0.425



Actual Element	Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

Ω-Section Purlin Dimension

$c_{p,Right\ Lip}$ 6.191 [mm]

NOTE $b = c_{p,Right\ Lip}$

E	210.000	[GPa]	t	0.952	[mm]	v	0.300

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 1907.096 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$

350.000 [MPa]

λ 0.428

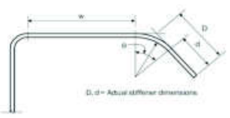
$$\rho = \frac{\left(1-\frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$c_{p,Right\ Lip,eff,AS/NZS}$	6.191	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,Right\ Lip,eff,AISI}$	6.191	=	$c_{p,Right\ Lip,eff,AS/NZS}$	6.191

Inferior Right Flange [$b_{p,Inf.\ Right\ Flange}$] [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

Ω-Section Purlin Dimension		
$c_{p,Right\ Lip}$	6.191	[mm]
$b_{p,Inf.\ Right\ Flange}$	16.545	[mm]
t	0.952	[mm]

$c_{p,Right\ Lip} = d$ | $b_{p,Inf.\ Right\ Flange} = w$

$D_{Right\ Lip}$ 7.207 [mm]

$$S = 1.28\sqrt{E/f}$$

[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	350.000	[MPa]
S	31.353	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	$b_1 = [\ b / 2\ ] * [\ R_I\ ]$
$b_1 = b_2 = w / 2$	$b_2 = b - b_1$
$d_s = d'_s$	$d_s = d'_s * [\ R_I\ ]$

w / t 17.379 Edge stiffener is needed 0.328 * S 10.284

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \le t^4\left[115\frac{w/t}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4-8]

I_a	3.799	[mm^4]	≤	56.466	→	OK

$$(R_I) = I_s/I_a \leq 1$$
[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$
[AISI S100, Eq. B4-10]

$Ø_1$	45.000	[°]	→	I_s	179.657	[mm^4]	
[R_I]	47.297	≤ 1.000	→	KO	→	[R_I]	1.000

$$n = \left(0.582 - \frac{w/t}{4S}\right) \geq \frac{1}{3}$$
[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK	140° ≥	$Ø_1$	45.000	[°]	≥ 40°	OK	
n	0.443	≥ 1 / 3 ?	OK	→	n	0.443	
[AISI S100, Table B4-1]		D / w	0.436	→	k	3.072	OK

Ω-Section Purlin Dimension

NOTE $w = b_{p,Inf.\ Right\ Flange}$

$b_{p,Inf.\ Right\ Flange}$	16.545	[mm]

E	210.000	[GPa]	t	0.952	[mm]	ν [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]

F_{cr} 1930.391 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

$f = f_y$

350.000 [MPa]

λ 0.426

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,Inf.\ Right\ Flange,eff,AISI}$	16.545	[mm]
$b_{p,Inf.\ Right\ Flange,eff,AISI,1}$	8.273	[mm]	$b_{p,Inf.\ Right\ Flange,eff,AISI,2}$	8.273	[mm]

n	0.443	≥ 1 / 3 ?	OK	→	n	0.443	
[AS/NZS 4600, Table 2.4.2]		d_l / b	0.436	→	k	3.072	OK

Ω-Section Purlin Dimension

NOTE $b = b_{p,Inf.\ Right\ Flange}$

$b_{p,Inf.\ Right\ Flange}$	16.545	[mm]

E	210.000	[GPa]	t	0.952	[mm]	ν	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$
[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 1930.391 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$
[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$

350.000 [MPa]

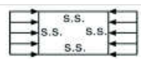
λ 0.426

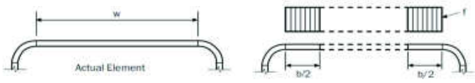
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,Inf.\ Right\ Flange,eff,AS/NZS}$	16.545	[mm]
$b_{p,Inf.\ Right\ Flange,eff,AS/NZS,1}$	8.273	[mm]	$b_{p,Inf.\ Right\ Flange,eff,AS/NZS,2}$	8.273	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,Inf.\ Right\ Flange,eff,AISI,1}$	8.273	=	$b_{p,Inf.\ Right\ Flange,eff,AS/NZS,1}$	8.273
$b_{p,Inf.\ Right\ Flange,eff,AISI,2}$	8.273	=	$b_{p,Inf.\ Right\ Flange,eff,AS/NZS,2}$	8.273

Right Web [$h_{p,Right\ Web}$] [AISI S100, Sector B2.1]

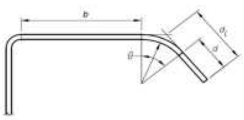
Boundary condition	Types of stress	k
	Compression	4.000



Actual Element | Effective Element, b, and Stress, f, on Effective Elements

Stiffened Elements [AISI S100, Figure B2.1-1]

Inferior Right Flange [$b_{p,Inf.\ Right\ Flange}$] [AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

Ω-Section Purlin Dimension		
$c_{p,Right\ Lip}$	6.191	[mm]
$b_{p,Inf.\ Right\ Flange}$	16.545	[mm]
t	0.952	[mm]

$c_{p,Right\ Lip}$ = d | $b_{p,Inf.\ Right\ Flange}$ = b

$d_{R,Right\ Lip}$ 7.207 [mm]

$$S = 1.28\sqrt{E/f^*}$$
[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	350.000	[MPa]
S	31.353	[ ]

b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b_e = b	b_1 = [b_e / 2] * [I_s / I_a]
b_1 = b_2 = b / 2	b_2 = b_e – b_1
d_s = d_{se}	d_s = d_{se} * [I_s / I_a]

b / t	17.379	Edge stiffener is needed	0.328 * S	10.284

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \leq t^4\left[115\frac{(b/t)}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(11)]

I_a	3.799	[mm^4]	≤	56.466	→	OK

$$I_s/I_a \leq 1$$
[AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$
[AS/NZS 4600, Eq. 2.4.2(110)]

$Ø_1$	45.000	[°]	→	I_s	179.657	[mm^4]	
[I_s / I_a]	47.297	≤ 1.000	→	KO	→	[I_s / I_a]	1.000

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \geq \frac{1}{3}$$
[AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

d_l / b ≤ 0.250	0.250 < d_l / b ≤ 0.800
3.570 * [I_s / I_a] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * d_l / b]] * [I_s / I_a] ^{n} + 0.430 ≤ 4.000

OK	140° ≥	$Ø_1$	45.000	[°]	≥ 40°	OK

Ω-Section Purlin Dimension

NOTE $w = h_{p,Right\ Web}$

$h_{p,Right\ Web}$	51.640	[mm]

E	210.000	[GPa]	t	0.952	[mm]	ν [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]

F_{cr} 258.018 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

$f = f_y$

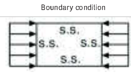
350.000 [MPa]

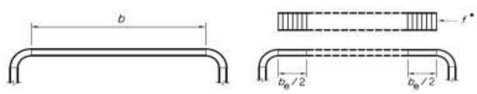
λ 1.165

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ	0.696	→	$h_{p,Right\ Web,eff,AISI}$	35.963	[mm]
$h_{p,Right\ Web,eff,AISI,1}$	17.982	[mm]	$h_{p,Right\ Web,eff,AISI,2}$	17.982	[mm]

Right Web [$h_{p,Right\ Web}$] [AS/NZS 4600, Clause 2.2.1]

Boundary condition	Types of stress	k
	Compression	4.000



Actual Element | Effective Width [be] of Element and Design on Effective Elements | Stress [f*]

Stiffened Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

Ω-Section Purlin Dimension

NOTE $b = h_{p,Right\ Web}$

$h_{p,Right\ Web}$	51.640	[mm]

E	210.000	[GPa]	t	0.952	[mm]	ν	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$
[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 258.018 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

f* = f_y: 350.000 [MPa]

λ: 1.165

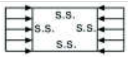
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	0.696	→	$h_{0,Right\ Web,eff,AS/NZS}$	35.963	[mm]
$h_{0,Right\ Web,eff,AS/NZS,1}$	17.982	[mm]	$h_{0,Right\ Web,eff,AS/NZS,2}$	17.982	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{0,Right\ Web,eff,AISI,1}$	17.982	=	$h_{0,Right\ Web,eff,AS/NZS,1}$	17.982
$h_{0,Right\ Web,eff,AISI,2}$	17.982	=	$h_{0,Right\ Web,eff,AS/NZS,2}$	17.982

Superior Flange [$b_{0,Sup.\ Flange}$] — [AISI S100, Sector B2.1]

Boundary condition	Types of stress	k
	Compression	4.000

Actual Element | Effective Element, b, and Stress, f, on Effective Elements

Stiffened Elements [AISI S100, Figure B2.1-1]

Ω-Section Purlin Dimension — NOTE: w = $b_{0,Sup.\ Web}$

$b_{0,Sup.\ Web}$	38.171	[mm]						
E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300	

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr}: 472.252 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

f = f_y: 350.000 [MPa]

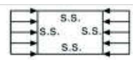
λ: 0.861

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office:	Author: JOSÉ ANTÓNIO	
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS	
Version: 1.000	Client: COIMBRA UNIVERSITY		

Left Web [$h_{0,Left\ Web}$] — [AISI S100, Sector B2.1]

Boundary condition	Types of stress	k
	Compression	4.000

Actual Element | Effective Element, b, and Stress, f, on Effective Elements

Stiffened Elements [AISI S100, Figure B2.1-1]

Ω-Section Purlin Dimension — NOTE: b = $h_{0,Left\ Web}$

$h_{0,Left\ Web}$	51.640	[mm]						
E	210.000	[GPa]	t	0.952	[mm]	v	0.300	

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr}: 258.018 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

f = f_y: 350.000 [MPa]

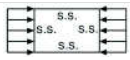
λ: 1.165

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	0.696	→	$h_{0,Left\ Web,eff,AISI}$	35.963	[mm]
$h_{0,Left\ Web,eff,AISI,1}$	17.982	[mm]	$h_{0,Left\ Web,eff,AISI,2}$	17.982	[mm]

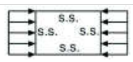
Left Web [$h_{0,Left\ Web}$] — [AS/NZS 4600, Clause 2.2.1]

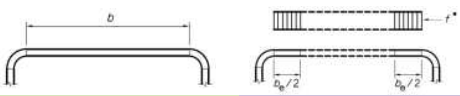
Boundary condition	Types of stress	k
	Compression	4.000

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office:	Author: JOSÉ ANTÓNIO	
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS	
Version: 1.000	Client: COIMBRA UNIVERSITY		

ρ	0.865	→	$b_{0,Sup.\ Web,eff,AISI}$	33.008	[mm]
$b_{0,Sup.\ Web,eff,AISI,1}$	16.504	[mm]	$b_{0,Sup.\ Web,eff,AISI,2}$	16.504	[mm]

Superior Flange [$b_{0,Sup.\ Flange}$] — [AS/NZS 4600, Clause 2.2.1]

Boundary condition	Types of stress	k
	Compression	4.000



Actual Element | Effective Width [be] of Element and Design on Effective Elements | Stress [f*]

Stiffened Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

Ω-Section Purlin Dimension — NOTE: b = $b_{0,Sup.\ Web}$

$b_{0,Sup.\ Web}$	38.171	[mm]						
E	210.000	[GPa]	t	0.952	[mm]	v	0.300	

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr}: 472.252 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

f* = f_y: 350.000 [MPa]

λ: 0.861

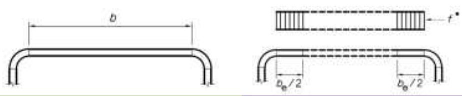
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	0.865	→	$b_{0,Sup.\ Web,eff,AS/NZS}$	33.008	[mm]
$b_{0,Sup.\ Web,eff,AS/NZS,1}$	16.504	[mm]	$b_{0,Sup.\ Web,eff,AS/NZS,2}$	16.504	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{0,Sup.\ Web,eff,AISI,1}$	16.504	=	$b_{0,Sup.\ Web,eff,AS/NZS,1}$	16.504
$b_{0,Sup.\ Web,eff,AISI,2}$	16.504	=	$b_{0,Sup.\ Web,eff,AS/NZS,2}$	16.504

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office:	Author: JOSÉ ANTÓNIO	
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS	
Version: 1.000	Client: COIMBRA UNIVERSITY		



Actual Element | Effective Width [be] of Element and Design on Effective Elements | Stress [f*]

Stiffened Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

Ω-Section Purlin Dimension — NOTE: b = $h_{0,Left\ Web}$

$h_{0,Left\ Web}$	51.640	[mm]						
E	210.000	[GPa]	t	0.952	[mm]	v	0.300	

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr}: 258.018 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

f* = f_y: 350.000 [MPa]

λ: 1.165

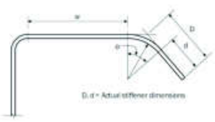
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	0.696	→	$h_{0,Left\ Web,eff,AS/NZS}$	35.963	[mm]
$h_{0,Left\ Web,eff,AS/NZS,1}$	17.982	[mm]	$h_{0,Left\ Web,eff,AS/NZS,2}$	17.982	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{0,Left\ Web,eff,AISI,1}$	17.982	=	$h_{0,Left\ Web,eff,AS/NZS,1}$	17.982
$h_{0,Left\ Web,eff,AISI,2}$	17.982	=	$h_{0,Left\ Web,eff,AS/NZS,2}$	17.982

Inferior Left Flange [$b_{0,Inf.\ Left\ Flange}$] — [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

Ω-Section Purlin Dimension

$c_{0,Left\ Lip}$	6.191	[mm]
$b_{0,Inf.\ Left\ Flange}$	16.545	[mm]
t	0.952	[mm]

$c_{0,Left\ Lip}$ = d \| $b_{0,Inf.\ Left\ Flange}$ = w

$D_{Left\ Lip}$	7.207	[mm]

$$S = 1.28\sqrt{E/f}$$

[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	350.000	[MPa]
S	31.353	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	b_1 = [b / 2] * [R_I]
$b_1 = b_2$ = w / 2	$b_2 = b - b_1$
$d_s = d_s'$	$d_s = d_s'$ * [R_I]

w / t: 17.379 — Edge stiffener is needed — 0.328 * S: 10.284

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \le t^4\left[115\frac{w/t}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4-8]

I_a	3.799	[mm^4]	≤	56.466	→	OK

$$(R_I) = I_s/I_a \le 1$$

[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AISI S100, Eq. B4-10]

$Ø_1$	45.000	[°]	→	I_s	179.657	[mm^4]	
[R_I]	47.297	≤ 1.000	→	KO	→	[R_I]	1.000

$$n = \left(0.582 - \frac{w/t}{4S}\right) \ge \frac{1}{3}$$

[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK	140° ≥	$Ø_1$	45.000	[°]	≥ 40°	OK	
n	0.443	≥ 1 / 3 ?	OK	→	n	0.443	
[AISI S100, Table B4-1]	D / w	0.436	→	k	3.072	OK	

Ω-Section Purlin Dimension — **NOTE** w = $b_{p,Inf. Left Flange}$

$b_{p,Inf. Left Flange}$	16.545	[mm]					
E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300

I_a	3.799	[mm^4]	≤	56.466	→	OK

$$I_s/I_a \le 1$$

[AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AS/NZS 4600, Eq. 2.4.2(110)]

$Ø_1$	45.000	[°]	→	I_s	179.657	[mm^4]	
[I_s / I_a]	47.297	≤ 1.000	→	KO	→	[I_s / I_a]	1.000

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \ge \frac{1}{3}$$

[AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

d_l / b ≤ 0.250	0.250 < d_l / b ≤ 0.800
3.570 * [I_s / I_a] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * d_l / b]] * [I_s / I_a] ^{n} + 0.430 ≤ 4.000

OK	140° ≥	$Ø_1$	45.000	[°]	≥ 40°	OK	
n	0.443	≥ 1 / 3 ?	OK	→	n	0.443	
[AS/NZS 4600, Table 2.4.2]	d_l / b	0.436	→	k	3.072	OK	

Ω-Section Purlin Dimension — **NOTE** b = $b_{p,Inf. Left Flange}$

$b_{p,Inf. Left Flange}$	16.545	[mm]					
E	210.000	[GPa]	t	0.952	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 1930.391 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 350.000 [MPa]; λ 0.426

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,Inf. Left Flange,eff,AS/NZS}$	16.545	[mm]
$b_{p,Inf. Left Flange,eff,AS/NZS,1}$	8.273	[mm]	$b_{p,Inf. Left Flange,eff,AS/NZS,2}$	8.273	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,Inf. Left Flange,eff,AISI,1}$	8.273	=	$b_{p,Inf. Left Flange,eff,AS/NZS,1}$	8.273
$b_{p,Inf. Left Flange,eff,AISI,2}$	8.273	=	$b_{p,Inf. Left Flange,eff,AS/NZS,2}$	8.273

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 1930.391 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

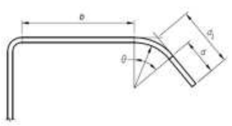
$f = f_y$: 350.000 [MPa]; λ 0.426

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,Inf. Left Flange,eff,AISI}$	16.545	[mm]
$b_{p,Inf. Left Flange,eff,AISI,1}$	8.273	[mm]	$b_{p,Inf. Left Flange,eff,AISI,2}$	8.273	[mm]

Inferior Left Flange [$b_{p,Inf. Left Flange}$] [AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

Ω-Section Purlin Dimension		
$c_{p,Left Lip}$	6.191	[mm]
$b_{p,Inf. Left Flange}$	16.545	[mm]
t	0.952	[mm]

$c_{p,Left Lip}$ = d | $b_{p,Inf. Left Flange}$ = b

$d_{R,Left Lip}$ 7.207 [mm]

$$S = 1.28\sqrt{E/f^*}$$

[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	350.000	[MPa]
S	31.353	[ ]

b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b_e = b	b_1 = [b_e / 2] * [I_s / I_a]
$b_1 = b_2$ = b / 2	$b_2 = b_e - b_1$
$d_s = d_{se}$	$d_s = d_{se}$ * [I_s / I_a]

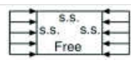
b / t: 17.379 — Edge stiffener is needed — 0.328 * S: 10.284

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \le t^4\left[115\frac{(b/t)}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(11)]

Left Edge Stiffener [$c_{p,Left Lip}$] [AISI S100, Sector B3.1]

Boundary condition	Types of stress	k
	Compression	0.425

Actual Element — Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

Ω-Section Purlin Dimension — **NOTE** w = $c_{p,Left Lip}$

$c_{p,Left Lip}$	6.191	[mm]					
E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 1907.096 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

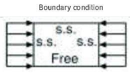
$f = f_y$: 350.000 [MPa]; λ 0.428

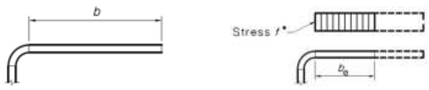
$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$c_{p,Left Lip,eff,AISI}$	6.191	[mm]

Left Edge Stiffener [$c_{p,Left Lip}$] [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k
	Compression	0.425



Actual Element	Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

Ω-Section Purlin Dimension			NOTE	$b = c_{p,Left\ Lip}$
$c_{p,Left\ Lip}$	6.191	[mm]		

E	210.000	[GPa]	t	0.952	[mm]	ν	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

f_{cr} 1907.096 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 350.000 [MPa]

λ: 0.428

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

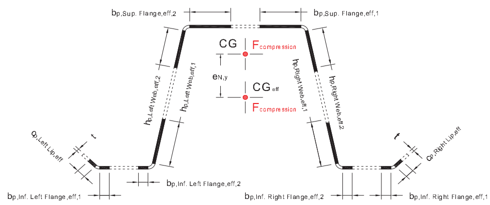
ρ	1.000	→	$c_{p,Left\ Lip,eff,AS/NZS}$	6.191	[mm]

AISI S100, Effective Width		Comparison [= or ≠]	AS/NZS 4600, Effective Width	
$c_{p,Left\ Lip,eff,AISI}$	6.191	=	$c_{p,Left\ Lip,eff,AS/NZS}$	6.191

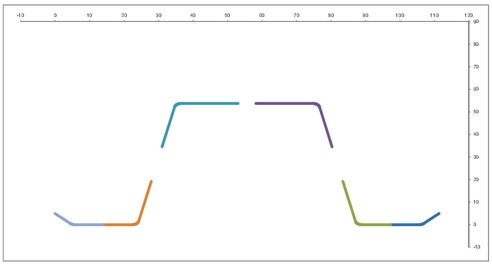
[ii] **Effective Ω-Section Purlin [Local Buckling]**

Effective Ω-Section Purlin Widths [AISI S100]

Right Edge Stiffner	$c_{p,Right\ Lip,eff,AISI}$	6.191	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff,AISI}$	16.545	[mm]
Right Web	$h_{p,Right\ Web,eff,AISI}$	35.963	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff,AISI}$	33.008	[mm]
Left Web	$h_{p,Left\ Web,eff,AISI}$	35.963	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff,AISI}$	16.545	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff,AISI}$	6.191	[mm]



Effective Ω-Section Purlin [Compression Force] [AISI S100 | AS/NZS 4600]



Effective Ω-Section Purlin [Local Buckling] [Compression Force]

A_{eff}	156.435	[mm^2]	$e_{N,y} = z_{GC,eff} - z_{GC}$	+1.115	[mm]
			$e_{N,z} = y_{GC,eff} - y_{GC}$	0.000	[mm]

Effective Ω-Section Purlin Widths [AS/NZS 4600]

Right Edge Stiffner	$c_{p,Right\ Lip,eff,AS/NZS}$	6.191	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff,AS/NZS}$	16.545	[mm]
Right Web	$h_{p,Right\ Web,eff,AS/NZS}$	35.963	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff,AS/NZS}$	33.008	[mm]
Left Web	$h_{p,Left\ Web,eff,AS/NZS}$	35.963	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff,AS/NZS}$	16.545	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff,AS/NZS}$	6.191	[mm]

Effective Ω-Section Purlin Widths [AISI S100 | AS/NZS 4600]

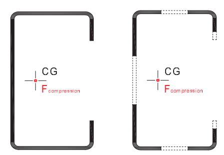
Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	6.191	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff}$	16.545	[mm]
Right Web	$h_{p,Right\ Web,eff}$	35.963	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff}$	33.008	[mm]
Left Web	$h_{p,Left\ Web,eff}$	35.963	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff}$	16.545	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	6.191	[mm]

[iii] **Effective Cross Ω-Section Purlin [Local Buckling]**

Effective Ω-Section Purlin Widths

Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	6.191	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff,1}$	8.273	[mm]
	$b_{p,Inf.\ Right\ Flange,eff,2}$	8.273	[mm]
Right Web	$h_{p,Right\ Web,eff,1}$	17.982	[mm]
	$h_{p,Right\ Web,eff,2}$	17.982	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff,1}$	16.504	[mm]
	$b_{p,Sup.\ Flange,eff,2}$	16.504	[mm]
Left Web	$h_{p,Left\ Web,eff,1}$	17.982	[mm]
	$h_{p,Left\ Web,eff,2}$	17.982	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff,1}$	8.273	[mm]
	$b_{p,Inf.\ Left\ Flange,eff,2}$	8.273	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	6.191	[mm]

[b] C-Section Beam



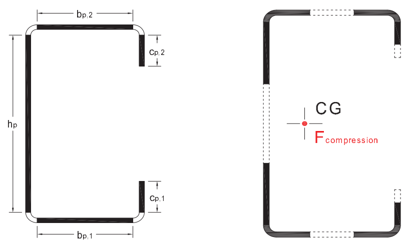
Gross C-Section

Effective C-Section [L]

Local Buckling

C-Section Beam Dimension		
$c_{p,1}$	14.048	[mm]
$b_{p,1}$	38.596	[mm]
h_p	112.096	[mm]
$b_{p,2}$	38.596	[mm]
$c_{p,2}$	14.048	[mm]
t	1.452	[mm]

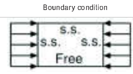
[i] **Effective Widths for Strength Determination [Local Buckling]** — **AISI S100, Sector B | AS/NZS 4600, Section 2**



C-Section Plate Widths

Effective C-Section [Worst Case]

Inferior Edge Stiffner [$c_{p,1}$]	[AISI S100, Sector B3.1]

Boundary condition	Types of stress	k
	Compression	0.425

Actual Element	Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

C-Section Beam Dimension — NOTE: $w = c_{p,1}$

$c_{p,1}$ 14.048 [mm]

E	210.000	[GPa]	t	1.452	[mm]	ν [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)] — F_{cr} 861.766 [MPa]

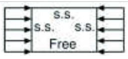
$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$ [AISI S100, Eq. B2.1-4]

f = f_y 350.000 [MPa]; λ 0.637

$$\rho = (1 - 0.22/\lambda)/\lambda$$ [AISI S100, Eq. B2.1-4]

ρ 1.000 → $c_{p,1,eff,AISI}$ 14.048 [mm]

Inferior Edge Stiffener [$c_{p,1}$] — [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k
	Compression	0.425

Actual Element — Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

C-Section Beam Dimension — NOTE: $b = c_{p,1}$

$c_{p,1}$ 14.048 [mm]

E	210.000	[GPa]	t	1.452	[mm]	ν	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)] — f_{cr} 861.766 [MPa]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

θ_1	90.000	[º]	→	I_s	6956.844	[mm^4]
[R_I]	27.931	≤ 1.000	→	KO	→	[R_I] 1.000

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

$$n = \left(0.582 - \frac{w/t}{4S}\right) \geq \frac{1}{3}$$ [AISI S100, Eq. B4-11]

Simple Lip Edge Stiffener [140º ≥ θ ≥ 40º]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK	140º ≥	θ_1	90.000	[º]	≥ 40º	OK
n	0.370	≥ 1 / 3 ?	OK	→	n	0.370
[AISI S100, Table B4-1]	D / w	0.466	→	k	2.918	OK

C-Section Beam Dimension — NOTE: $w = b_{p,1}$

$b_{p,1}$ 38.596 [mm]

E	210.000	[GPa]	t	1.452	[mm]	ν [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)] — F_{cr} 783.886 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$ [AISI S100, Eq. B2.1-4]

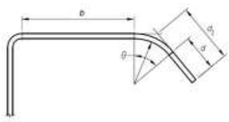
f = f_y 350.000 [MPa]; λ 0.668

$$\rho = (1 - 0.22/\lambda)/\lambda$$ [AISI S100, Eq. B2.1-4]

ρ 1.000 → $b_{p,1,eff,AISI}$ 38.596 [mm]

$b_{p,1,eff,AISI,1}$ 19.298 [mm] — $b_{p,1,eff,AISI,2}$ 19.298 [mm]

Inferior Flange [$b_{p,1}$] — [AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

C-Section Beam Dimension		
$c_{p,1}$	14.048	[mm]
$b_{p,1}$	38.596	[mm]
t	1.452	[mm]

$c_{p,1} = d$ \| $b_{p,1} = b$

$d_{Inf. Lip}$ 18.000 [mm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

$$\lambda = \left(\frac{1.052}{\sqrt{k}}\right)\left(\frac{b}{t}\right)\sqrt{\frac{f^*}{E}} = \sqrt{\frac{f^*}{f_{cr}}}$$ [AS/NZS 4600, Eq. 2.2.1.2(4)]

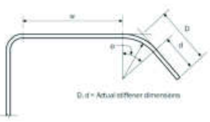
f* = f_y 350.000 [MPa]; λ 0.637

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$ [AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $c_{p,1,eff,AS/NZS}$ 14.048 [mm]

AISI S100, Effective Width [mm]	Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]
$c_{p,1,eff,AISI}$ 14.048	=	$c_{p,1,eff,AS/NZS}$ 14.048

Inferior Flange [$b_{p,1}$] — [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

C-Section Beam Dimension		
$c_{p,1}$	14.048	[mm]
$b_{p,1}$	38.596	[mm]
t	1.452	[mm]

$c_{p,1} = d$ \| $b_{p,1} = w$

$D_{Inf. Lip}$ 18.000 [mm]

$$S = 1.28\sqrt{E/f}$$ [AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	350.000	[MPa]
S	31.353	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	b_1 = [b / 2] * [R_I]
$b_1 = b_2$ = w / 2	b_2 = b − b_1
d_s = d'_s	d_s = d'_s * [R_I]

w / t 26.581 — Edge stiffener is needed — 0.328 * S 10.284

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \leq t^4\left[115\frac{w/t}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4-8]

I_a 249.076 [mm^4] ≤ 455.590 → OK

$$(R_I) = I_s/I_a \leq 1$$ [AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$ [AISI S100, Eq. B4-10]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

$$S = 1.28\sqrt{E/f^*}$$ [AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	350.000	[MPa]
S	31.353	[ ]

b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b_e = b	b_1 = [b_e / 2] * [I_s / I_a]
$b_1 = b_2$ = b / 2	b_2 = b_e − b_1
d_s = d_{es}	d_s = d_{es} * [I_s / I_a]

b / t 26.581 — Edge stiffener is needed — 0.328 * S 10.284

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \leq t^4\left[115\frac{(b/t)}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(11)]

I_a 249.076 [mm^4] ≤ 455.590 → OK

$$I_s/I_a \leq 1$$ [AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$ [AS/NZS 4600, Eq. 2.4.2(110)]

θ_1	90.000	[º]	→	I_s	6956.844	[mm^4]
[I_s / I_a]	27.931	≤ 1.000	→	KO	→	[I_s / I_a] 1.000

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \geq \frac{1}{3}$$ [AS/NZS 4600, Eq. 2.4.2(12)]

Simple Lip Edge Stiffener [140º ≥ θ ≥ 40º]

d / b ≤ 0.250	0.250 < d / b ≤ 0.800
3.570 * [I_s / I_a] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * d / b]] * [I_s / I_a] ^{n} + 0.430 ≤ 4.000

OK	140º ≥	θ_1	90.000	[º]	≥ 40º	OK
n	0.370	≥ 1 / 3 ?	OK	→	n	0.370
[AS/NZS 4600, Table 2.4.2]	d / b	0.466	→	k	2.918	OK

C-Section Beam Dimension — NOTE: $b = b_{p,1}$

$b_{p,1}$ 38.596 [mm]

E	210.000	[GPa]	t	1.452	[mm]	ν	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 783.886 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$ 350.000 [MPa]

λ 0.668

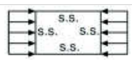
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,1,eff,AS/NZS}$	38.596	[mm]
$b_{p,1,eff,AS/NZS,1}$	19.298	[mm]	$b_{p,1,eff,AS/NZS,2}$	19.298	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,1,eff,AISI,1}$	19.298	=	$b_{p,1,eff,AS/NZS,1}$	19.298
$b_{p,1,eff,AISI,2}$	19.298	=	$b_{p,1,eff,AS/NZS,2}$	19.298

Web [h_p] [AISI S100, Sector B2.1]

Boundary condition	Types of stress	k
	Compression	4.000

Actual Element | Effective Element, b, and Stress, f, on Effective Elements

Stiffened Elements [AISI S100, Figure B2.1-1]

C-Section Beam Dimension

NOTE $w = h_p$

h_p	112.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

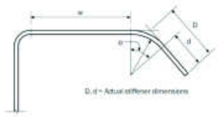
$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 127.382 [MPa]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,eff,AISI,1}$	29.325	=	$h_{p,eff,AS/NZS,1}$	29.325
$h_{p,eff,AISI,2}$	29.325	=	$h_{p,eff,AS/NZS,2}$	29.325

Superior Flange [$b_{p,2}$] [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

C-Section Beam Dimension		
$c_{p,2}$	14.048	[mm]
$b_{p,2}$	38.596	[mm]
t	1.452	[mm]

$c_{p,2} = d$ | $b_{p,2} = w$

$D_{Sup. Lip}$ 18.000 [mm]

$$S = 1.28\sqrt{E/f}$$

[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	350.000	[MPa]
S	31.353	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	b_1 = [b / 2] * [R_I]
$b_1 = b_2$ = w / 2	$b_2 = b - b_1$
$d_s = d'_s$	$d_s = d'_s$ * [R_I]

w / t 26.581 Edge stiffener is needed 0.328 * S 10.284

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \leq t^4\left[115\frac{w/t}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4-8]

I_a 249.076 [mm^4] ≤ 455.590 → OK

$$(R_I) = I_s/I_a \leq 1$$

[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AISI S100, Eq. B4-10]

$Ø_1$	90.000	[º]	→	I_s	6956.844	[mm^4]
[R_I]	27.931	≤ 1.000	→	KO	→	[R_I] 1.000

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$ 350.000 [MPa]

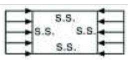
λ 1.658

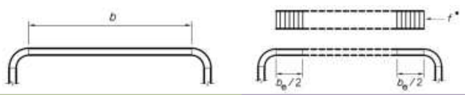
$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	0.523	→	$h_{p,eff,AISI}$	58.650	[mm]
$h_{p,eff,AISI,1}$	29.325	[mm]	$h_{p,eff,AISI,2}$	29.325	[mm]

Web [h_p] [AS/NZS 4600, Clause 2.2.1]

Boundary condition	Types of stress	k
	Compression	4.000



Actual Element | Effective Width [be] of Element and Design Stress [f*] on Effective Elements

Stiffened Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

C-Section Beam Dimension

NOTE $b = h_p$

h_p	112.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 127.382 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$ 350.000 [MPa]

λ 1.658

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	0.523	→	$h_{p,eff,AS/NZS}$	58.650	[mm]
$h_{p,eff,AS/NZS,1}$	29.325	[mm]	$h_{p,eff,AS/NZS,2}$	29.325	[mm]

$$n = \left(0.582 - \frac{w/t}{4S}\right) \geq \frac{1}{3}$$

[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140º ≥ θ ≥ 40º]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK	140º ≥	$Ø_1$	90.000	[º]	≥ 40º	OK	
n	0.370	≥ 1 / 3 ?	OK	→	n	0.370	
[AISI S100, Table B4-1]		D / w	0.466	→	k	2.918	OK

C-Section Beam Dimension

NOTE $w = b_{p,2}$

$b_{p,2}$	38.596	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 783.886 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$ 350.000 [MPa]

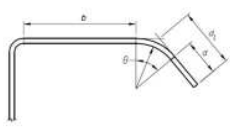
λ 0.668

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,2,eff,AISI}$	38.596	[mm]
$b_{p,2,eff,AISI,1}$	19.298	[mm]	$b_{p,2,eff,AISI,2}$	19.298	[mm]

Superior Flange [$b_{p,2}$] [AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

C-Section Beam Dimension		
$c_{p,2}$	14.048	[mm]
$b_{p,2}$	38.596	[mm]
t	1.452	[mm]

$c_{p,2} = d$ | $b_{p,2} = b$

$d_{R,Sup. Lip}$ 18.000 [mm]

$$S = 1.28\sqrt{E/f^*}$$

[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	350.000	[MPa]
S	31.353	[ ]

$b / t \leq 0.328 * S$	$b / t > 0.328 * S$
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
$b_e = b$	$b_1 = [b_e / 2] * [I_s / I_a]$
$b_1 = b_2 = b / 2$	$b_2 = b_e - b_1$
$d_s = d_{se}$	$d_s = d_{se} * [I_s / I_a]$

b / t 26.581 Edge stiffener is needed 0.328 * S 10.284

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \leq t^4\left[115\frac{(b/t)}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(11)]

I_a 249.076 [mm^4] ≤ 455.590 → OK

$$I_s / I_a \leq 1$$

[AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AS/NZS 4600, Eq. 2.4.2(110)]

$Ø_1$ 90.000 [º] → I_s 6956.844 [mm^4]

[I_s / I_a] 27.931 ≤ 1.000 → KO → [I_s / I_a] 1.000

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \geq \frac{1}{3}$$

[AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140º ≥ θ ≥ 40º]

$d_l / b \leq 0.250$	$0.250 < d_l / b \leq 0.800$
$3.570 * [I_s / I_a]^n + 0.430 \leq 4.000$	$[4.820 - [5 * d_l / b]] * [I_s / I_a]^n + 0.430 \leq 4.000$

OK 140º ≥ $Ø_1$ 90.000 [º] ≥ 40º OK

n 0.370 ≥ 1 / 3 ? OK → n 0.370

[AS/NZS 4600, Table 2.4.2] d_l / b 0.466 → k 2.918 OK

C-Section Beam Dimension — **NOTE** $b = b_{p,2}$

$b_{p,2}$ 38.596 [mm]

E 210.000 [GPa] | t 1.452 [mm] | v 0.300

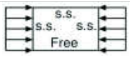
$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-v^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 783.886 [MPa]

ρ 1.000 → $c_{p,2,eff,AISI}$ 14.048 [mm]

Superior Edge Stiffener [$c_{p,2}$] — [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k
	Compression	0.425

Actual Element — Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

C-Section Beam Dimension — **NOTE** $b = c_{p,2}$

$c_{p,2}$ 14.048 [mm]

E 210.000 [GPa] | t 1.452 [mm] | v 0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-v^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 861.766 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 350.000 [MPa]

λ 0.637

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $c_{p,2,eff,AS/NZS}$ 14.048 [mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,2,eff,AISI}$	14.048	=	$c_{p,2,eff,AS/NZS}$	14.048

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 350.000 [MPa]

λ 0.668

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

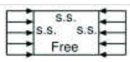
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $b_{p,2,eff,AS/NZS}$ 38.596 [mm]

$b_{p,2,eff,AS/NZS,1}$ 19.298 [mm] $b_{p,2,eff,AS/NZS,2}$ 19.298 [mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,2,eff,AISI,1}$	19.298	=	$b_{p,2,eff,AS/NZS,1}$	19.298
$b_{p,2,eff,AISI,2}$	19.298	=	$b_{p,2,eff,AS/NZS,2}$	19.298

Superior Edge Stiffener [$c_{p,2}$] — [AISI S100, Sector B3.1]

Boundary condition	Types of stress	k
	Compression	0.425

Actual Element — Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

C-Section Beam Dimension — **NOTE** $w = c_{p,2}$

$c_{p,2}$ 14.048 [mm]

E 210.000 [GPa] | t 1.452 [mm] | v [μ] 0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 861.766 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$: 350.000 [MPa]

λ 0.637

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

[ii] **Effective C-Section Beam [Local Buckling]**

Effective C-Section Beam Widths [AISI S100]

Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	14.048	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	38.596	[mm]
Web	$h_{p,eff,AISI}$	58.650	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	38.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	14.048	[mm]

Effective C-Section Beam Widths [AS/NZS 4600]

Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	14.048	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	38.596	[mm]
Web	$h_{p,eff,AS/NZS}$	58.650	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	38.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	14.048	[mm]

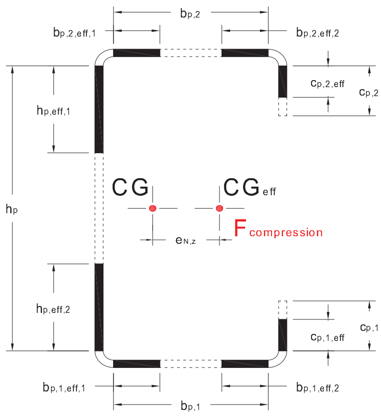
Effective C-Section Beam Widths [AISI S100 | AS/NZS 4600]

Inferior Edge Stiffener	$c_{p,1,eff}$	14.048	[mm]
Inferior Flange	$b_{p,1,eff}$	38.596	[mm]
Web	$h_{p,eff}$	58.650	[mm]
Superior Flange	$b_{p,2,eff}$	38.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	14.048	[mm]

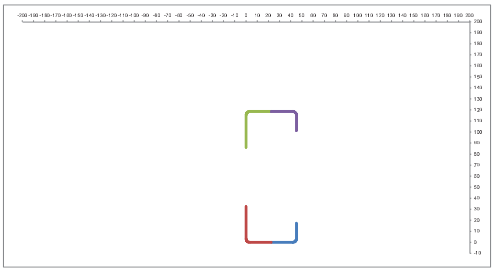
[iii] **Effective Cross C-Section Beam [Local Buckling]**

Effective C-Section Beam Widths

Inferior Edge Stiffener	$c_{p,1,eff}$	14.048	[mm]
Inferior Flange	$b_{p,1,eff,1}$	19.298	[mm]
	$b_{p,1,eff,2}$	19.298	[mm]
Web	$h_{p,eff,1}$	29.325	[mm]
	$h_{p,eff,2}$	29.325	[mm]
Superior Flange	$b_{p,2,eff,1}$	19.298	[mm]
	$b_{p,2,eff,2}$	19.298	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	14.048	[mm]



Effective C-Section Beam [Compression Force] [AISI S100 | AS/NZS 4600]



Effective C-Section Beam [Local Buckling] [Compression Force]

A_{eff}	267.460	[mm^2]	$e_{N,y} = z_{GC,eff} - z_{GC}$	0.000	[mm]
			$e_{N,z} = y_{GC,eff} - y_{GC}$	4.225	[mm]

C-Section Column Dimension

NOTE $w = c_{p,1}$

$c_{p,1}$	13.048	[mm]					
E	210.000	[GPa]	t	2.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 2848.645 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$ 350.000 [MPa]

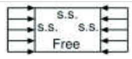
λ 0.351

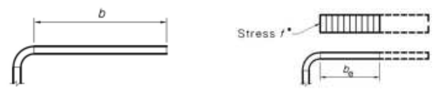
$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$c_{p,1,eff,AISI}$	13.048	[mm]

Inferior Edge Stiffner [$c_{p,1}$] [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k
	Compression	0.425



Actual Element | Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

C-Section Column Dimension

NOTE $b = c_{p,1}$

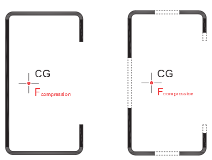
$c_{p,1}$	13.048	[mm]					
E	210.000	[GPa]	t	2.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 2848.645 [MPa]

[c] C-Section Column



Gross C-Section

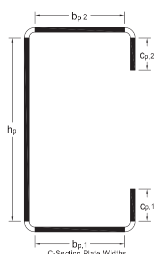
Effective C-Section [L]

Local Buckling

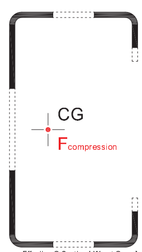
C-Section Column Dimension		
$c_{p,1}$	13.048	[mm]
$b_{p,1}$	36.596	[mm]
h_p	80.096	[mm]
$b_{p,2}$	36.596	[mm]
$c_{p,2}$	13.048	[mm]
t	2.452	[mm]

[i] **Effective Widths for Strength Determination [Local Buckling]**

AISI S100, Sector B | AS/NZS 4600, Section 2

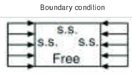


C-Section Plate Widths



Effective C-Section [Worst Case]

Inferior Edge Stiffner [$c_{p,1}$] [AISI S100, Sector B3.1]

Boundary condition	Types of stress	k
	Compression	0.425

Actual Element | Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$ 350.000 [MPa]

λ 0.351

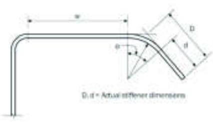
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$c_{p,1,eff,AS/NZS}$	13.048	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,1,eff,AISI}$	13.048	=	$c_{p,1,eff,AS/NZS}$	13.048

Inferior Flange [$b_{p,1}$] [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

C-Section Column Dimension		
$c_{p,1}$	13.048	[mm]
$b_{p,1}$	36.596	[mm]
t	2.452	[mm]

$c_{p,1} = d$ | $b_{p,1} = w$

$D_{Inf. Lip}$ 18.000 [mm]

$$S = 1.28\sqrt{E/f}$$

[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	350.000	[MPa]
S	31.353	[ ]

$w/t \leq 0.328 * S$	$w/t > 0.328 * S$
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	$b_1 = [b / 2] * [R_I]$
$b_1 = b_2 = w / 2$	$b_2 = b - b_1$
$d_s = d'_s$	$d_s = d'_s * [R_I]$

w / t 14.925 Edge stiffener is needed 0.328 * S 10.284

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \leq t^4\left[115\frac{w/t}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4-8]

I_a 46.778 [mm^4] ≤ 2159.563 → OK

$$(R_I) = I_s/I_a \leq 1$$

[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AISI S100, Eq. B4-10]

$Ø_1$	90.000	[°]	→	I_s	10014.749	[mm^4]
[R_I]	214.092	≤ 1.000	→	KO	→	[R_I] 1.000

$$n = \left(0.582 - \frac{w/t}{4S}\right) \geq \frac{1}{3}$$

[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK	140° ≥	$Ø_1$	90.000	[°]	≥ 40°	OK
n	0.463	≥ 1 / 3 ?	OK	→	n	0.463
[AISI S100, Table B4-1]	D / w	0.492	→	k	2.791	OK

C-Section Column Dimension — **NOTE** $w = b_{p,1}$

$b_{p,1}$ 36.596 [mm]

E	210.000	[GPa]	t	2.452	[mm]	ν [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 2377.856 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$: 350.000 [MPa]

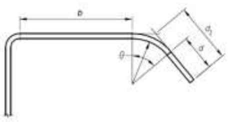
λ 0.384

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,1,eff,AISI}$	36.596	[mm]
$b_{p,1,eff,AISI,1}$	18.298	[mm]	$b_{p,1,eff,AISI,2}$	18.298	[mm]

Inferior Flange [$b_{p,1}$] — [AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

C-Section Column Dimension		
$c_{p,1}$	13.048	[mm]
$b_{p,1}$	36.596	[mm]
t	2.452	[mm]

$c_{p,1} = d$ | $b_{p,1} = b$

$d_{R,Int\ Lip}$ 18.000 [mm]

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 2377.856 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 350.000 [MPa]

λ 0.384

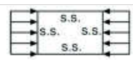
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,1,eff,AS/NZS}$	36.596	[mm]
$b_{p,1,eff,AS/NZS,1}$	18.298	[mm]	$b_{p,1,eff,AS/NZS,2}$	18.298	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,1,eff,AISI,1}$	18.298	=	$b_{p,1,eff,AS/NZS,1}$	18.298
$b_{p,1,eff,AISI,2}$	18.298	=	$b_{p,1,eff,AS/NZS,2}$	18.298

Web [h_p] — [AISI S100, Sector B2.1]

Boundary condition	Types of stress	k
	Compression	4.000

Actual Element | Effective Element, b, and Stress, f, on Effective Elements

Stiffened Elements [AISI S100, Figure B2.1-1]

C-Section Column Dimension — **NOTE** $w = h_p$

h_p 80.096 [mm]

E	210.000	[GPa]	t	2.452	[mm]	ν [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 711.501 [MPa]

$$S = 1.28\sqrt{E/f^*}$$

[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	350.000	[MPa]
S	31.353	[ ]

b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
$b_e = b$	b_1 = [b_e / 2] * [I_s / I_a]
$b_1 = b_2 = b / 2$	$b_2 = b_e - b_1$
$d_s = d_{se}$	$d_s = d_{se}$ * [I_s / I_a]

b / t	14.925	Edge stiffener is needed	0.328 * S	10.284

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \leq t^4\left[115\frac{(b/t)}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(11)]

I_a	46.778	[mm^4]	≤	2159.563	→	OK

$$I_s/I_a \leq 1$$

[AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AS/NZS 4600, Eq. 2.4.2(110)]

$Ø_1$	90.000	[°]	→	I_s	10014.749	[mm^4]
[I_s / I_a]	214.092	≤ 1.000	→	KO	→	[I_s / I_a] 1.000

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \geq \frac{1}{3}$$

[AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

d_l / b ≤ 0.250	0.250 < d_l / b ≤ 0.800
3.570 * [I_s / I_a] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * d_l / b]] * [I_s / I_a] ^{n} + 0.430 ≤ 4.000

OK	140° ≥	$Ø_1$	90.000	[°]	≥ 40°	OK
n	0.463	≥ 1 / 3 ?	OK	→	n	0.463
[AS/NZS 4600, Table 2.4.2]	d_l / b	0.492	→	k	2.791	OK

C-Section Column Dimension — **NOTE** $b = b_{p,1}$

$b_{p,1}$ 36.596 [mm]

E	210.000	[GPa]	t	2.452	[mm]	v	0.300

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$: 350.000 [MPa]

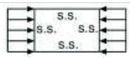
λ 0.701

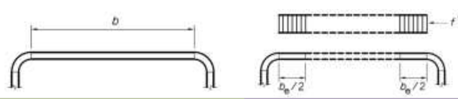
$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	0.979	→	$h_{p,eff,AISI}$	78.378	[mm]
$h_{p,eff,AISI,1}$	39.189	[mm]	$h_{p,eff,AISI,2}$	39.189	[mm]

Web [h_p] — [AS/NZS 4600, Clause 2.2.1]

Boundary condition	Types of stress	k
	Compression	4.000



Actual Element | Effective Width [be] of Element and Design on Effective Elements | Stress [f*]

Stiffened Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

C-Section Column Dimension — **NOTE** $b = h_p$

h_p 80.096 [mm]

E	210.000	[GPa]	t	2.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 711.501 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 350.000 [MPa]

λ 0.701

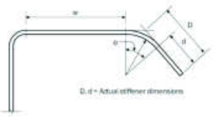
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	0.979	→	$h_{p,eff,AS/NZS}$	78.378	[mm]
$h_{p,eff,AS/NZS,1}$	39.189	[mm]	$h_{p,eff,AS/NZS,2}$	39.189	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,eff,AISI,1}$	39.189	=	$h_{p,eff,AS/NZS,1}$	39.189
$h_{p,eff,AISI,2}$	39.189	=	$h_{p,eff,AS/NZS,2}$	39.189

Superior Flange [$b_{p,2}$] [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

C-Section Column Dimension		
$c_{p,2}$	13.048	[mm]
$b_{p,2}$	36.596	[mm]
t	2.452	[mm]

$c_{p,2}$ = d | $b_{p,2}$ = w

$D_{Sup, Lip}$ 18.000 [mm]

$$S = 1.28\sqrt{E/f}$$
[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	350.000	[MPa]
S	31.353	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	b_1 = [b / 2] * [R_I]
$b_1 = b_2$ = w / 2	$b_2 = b - b_1$
$d_s = d'_s$	$d_s = d'_s$ * [R_I]

w / t 14.925 Edge stiffener is needed 0.328 * S 10.284

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \le t^4\left[115\frac{w/t}{S} + 5\right]$$
Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element
[AISI S100, Eq. B4-8]

I_a 46.778 [mm^4] ≤ 2159.563 → OK

$$(R_I) = I_s/I_a \le 1$$
[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$
[AISI S100, Eq. B4-10]

$Ø_1$ 90.000 [°] → I_s 10014.749 [mm^4]

[R_I] 214.092 ≤ 1.000 → KO → [R_I] 1.000

b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b_e = b	b_1 = [b_e / 2] * [I_s / I_a]
$b_1 = b_2$ = b / 2	$b_2 = b_e - b_1$
$d_s = d_{se}$	$d_s = d_{se}$ * [I_s / I_a]

b / t 14.925 Edge stiffener is needed 0.328 * S 10.284

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \le t^4\left[115\frac{(b/t)}{S} + 5\right]$$
Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element
[AS/NZS 4600, Eq. 2.4.2(11)]

I_a 46.778 [mm^4] ≤ 2159.563 → OK

$$I_s/I_a \le 1$$
[AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$
[AS/NZS 4600, Eq. 2.4.2(110)]

$Ø_1$ 90.000 [°] → I_s 10014.749 [mm^4]

[I_s / I_a] 214.092 ≤ 1.000 → KO → [I_s / I_a] 1.000

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \ge \frac{1}{3}$$
[AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140º ≥ θ ≥ 40º]

d_l / b ≤ 0.250	0.250 < d_l / b ≤ 0.800
3.570 * [I_s / I_a] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * d_l / b]] * [I_s / I_a] ^{n} + 0.430 ≤ 4.000

OK 140º ≥ $Ø_1$ 90.000 [º] ≥ 40º OK

n 0.463 ≥ 1 / 3 ? OK → n 0.463

[AS/NZS 4600, Table 2.4.2] d_l / b 0.492 → k 2.791 OK

C-Section Column Dimension		
$b_{p,2}$	36.596	[mm]

NOTE b = $b_{p,2}$

E 210.000 [GPa] | t 2.452 [mm] | v 0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$
[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 2377.856 [MPa]

$$n = \left(0.582 - \frac{w/t}{4S}\right) \ge \frac{1}{3}$$
[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140º ≥ θ ≥ 40º]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK 140º ≥ $Ø_1$ 90.000 [º] ≥ 40º OK

n 0.463 ≥ 1 / 3 ? OK → n 0.463

[AISI S100, Table B4-1] D / w 0.492 → k 2.791 OK

C-Section Column Dimension		
$b_{p,2}$	36.596	[mm]

NOTE w = $b_{p,2}$

E 210.000 [GPa] | t 2.452 [mm] | v [μ] 0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]

F_{cr} 2377.856 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

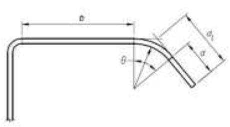
f = f_y: 350.000 [MPa]
λ 0.384

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ 1.000 → $b_{p,2,eff,AISI}$ 36.596 [mm]

$b_{p,2,eff,AISI,1}$ 18.298 [mm] $b_{p,2,eff,AISI,2}$ 18.298 [mm]

Superior Flange [$b_{p,2}$] [AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

C-Section Column Dimension		
$c_{p,2}$	13.048	[mm]
$b_{p,2}$	36.596	[mm]
t	2.452	[mm]

$c_{p,2}$ = d | $b_{p,2}$ = b

$d_{R,Sup, Lip}$ 18.000 [mm]

$$S = 1.28\sqrt{E/f^*}$$
[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	350.000	[MPa]
S	31.353	[ ]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$
[AS/NZS 4600, Eq. 2.2.1.2(4)]

f* = f_y: 350.000 [MPa]
λ 0.384

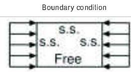
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$
[AS/NZS 4600, Eq. 2.2.1.2(3)]

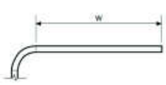
ρ 1.000 → $b_{p,2,eff,AS/NZS}$ 36.596 [mm]

$b_{p,2,eff,AS/NZS,1}$ 18.298 [mm] $b_{p,2,eff,AS/NZS,2}$ 18.298 [mm]

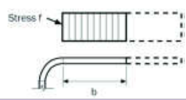
AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,2,eff,AISI,1}$	18.298	=	$b_{p,2,eff,AS/NZS,1}$	18.298
$b_{p,2,eff,AISI,2}$	18.298	=	$b_{p,2,eff,AS/NZS,2}$	18.298

Superior Edge Stiffener [$c_{p,2}$] [AISI S100, Sector B3.1]

Boundary condition	Types of stress	k
	Compression	0.425



Actual Element



Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

C-Section Column Dimension		
$c_{p,2}$	13.048	[mm]

NOTE w = $c_{p,2}$

E 210.000 [GPa] | t 2.452 [mm] | v [μ] 0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]

F_{cr} 2848.645 [MPa]

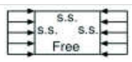
$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

f = f_y: 350.000 [MPa]
λ 0.351

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$c_{p,2,eff,AISI}$	13.048	[mm]

Superior Edge Stiffener [$c_{p,2}$] — [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k
	Compression	0.425

Actual Element | Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

C-Section Column Dimension

$c_{p,2}$ 13.048 [mm]

NOTE: $b = c_{p,2}$

E	210.000	[GPa]	t	2.452	[mm]	v	0.300	

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 2848.645 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$ 350.000 [MPa]

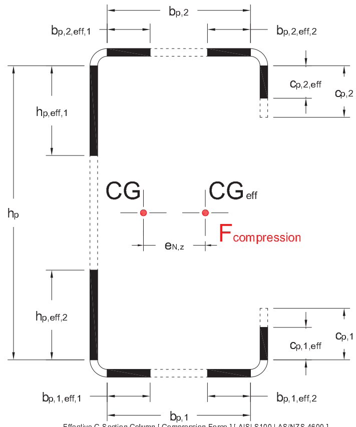
λ 0.351

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

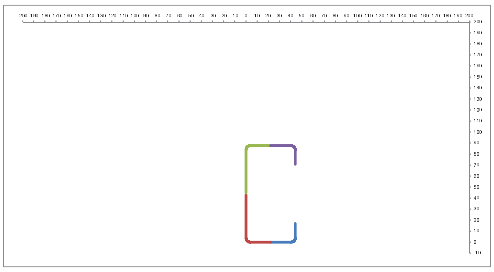
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$c_{p,2,eff,AS/NZS}$	13.048	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,2,eff,AISI}$	13.048	=	$c_{p,2,eff,AS/NZS}$	13.048



Effective C-Section Column [Compression Force] [AISI S100 | AS/NZS 4600]



Effective C-Section Column [Local Buckling] [Compression Force]

A_{eff}	493.023	[mm^2]	$e_{N,y} = z_{GC,eff} - z_{GC}$	0.000	[mm]
			$e_{N,z} = y_{GC,eff} - y_{GC}$	0.138	[mm]

[ii] **Effective C-Section Column [Local Buckling]**

Effective C-Section Column Widths [AISI S100]			
Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	13.048	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	36.596	[mm]
Web	$h_{p,eff,AISI}$	78.378	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	36.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	13.048	[mm]

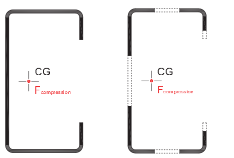
Effective C-Section Column Widths [AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	13.048	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	36.596	[mm]
Web	$h_{p,eff,AS/NZS}$	78.378	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	36.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	13.048	[mm]

Effective C-Section Column Widths [AISI S100 | AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff}$	13.048	[mm]
Inferior Flange	$b_{p,1,eff}$	36.596	[mm]
Web	$h_{p,eff}$	78.378	[mm]
Superior Flange	$b_{p,2,eff}$	36.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	13.048	[mm]

[iii] **Effective Cross C-Section Column [Local Buckling]**

Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	13.048	[mm]
Inferior Flange	$b_{p,1,eff,1}$	18.298	[mm]
	$b_{p,1,eff,2}$	18.298	[mm]
Web	$h_{p,eff,1}$	39.189	[mm]
	$h_{p,eff,2}$	39.189	[mm]
Superior Flange	$b_{p,2,eff,1}$	18.298	[mm]
	$b_{p,2,eff,2}$	18.298	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	13.048	[mm]

[d] C-Section Strut

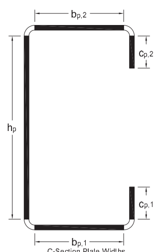


Gross C-Section | Effective C-Section [L]

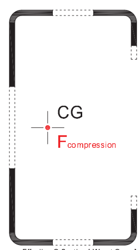
Local Buckling

C-Section Strut Dimension		
$c_{p,1}$	6.048	[mm]
$b_{p,1}$	32.096	[mm]
h_p	42.096	[mm]
$b_{p,2}$	32.096	[mm]
$c_{p,2}$	6.048	[mm]
t	1.452	[mm]

[i] **Effective Widths for Strength Determination [Local Buckling]** **AISI S100, Sector B | AS/NZS 4600, Section 2**

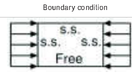


C-Section Plate Widths



Effective C-Section [Worst Case]

Inferior Edge Stiffener [$c_{p,1}$] — [AISI S100, Sector B3.1]

Boundary condition	Types of stress	k
	Compression	0.425

Actual Element | Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO	
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS	
Version: 1.000	Client: COIMBRA UNIVERSITY		

C-Section Strut Dimension — NOTE: $w = c_{p,1}$

$c_{p,1}$ 6.048 [mm]

E 210.000 [GPa] | t 1.452 [mm] | v [μ] 0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 4649.380 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

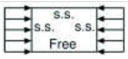
$f = f_y$: 350.000 [MPa]; λ 0.274

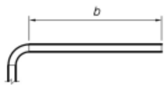
$$\rho = (1 - 0.22/\lambda)/\lambda$$

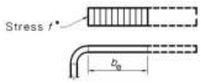
[AISI S100, Eq. B2.1-4]

ρ 1.000 → $c_{p,1,eff,AISI}$ 6.048 [mm]

Inferior Edge Stiffener [$c_{p,1}$] — [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k
	Compression	0.425





Actual Element | Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

C-Section Strut Dimension — NOTE: $b = c_{p,1}$

$c_{p,1}$ 6.048 [mm]

E 210.000 [GPa] | t 1.452 [mm] | v 0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 4649.380 [MPa]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Office: ---- Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993 Date: 05/09/2019 Project: MASTER THESIS
Version: 1.000 Client: COIMBRA UNIVERSITY

Ø1 90.000 [°] → I_s 4000.720 [mm^4]

[R_I] 42.094 ≤ 1.000 → KO → [R_I] 1.000

$$n = \left(0.582 - \frac{w/t}{4S}\right) \geq \frac{1}{3}$$

[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK 140° ≥ Ø1 90.000 [°] ≥ 40° OK

n 0.406 ≥ 1 / 3 ? OK → n 0.406

[AISI S100, Table B4-1] D / w 0.312 → k 3.692 OK

C-Section Strut Dimension — NOTE: $w = b_{p,1}$

$b_{p,1}$ 32.096 [mm]

E 210.000 [GPa] | t 1.452 [mm] | v [μ] 0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 1434.201 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$: 350.000 [MPa]; λ 0.494

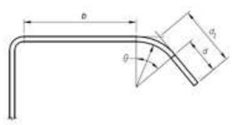
$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ 1.000 → $b_{p,1,eff,AISI}$ 32.096 [mm]

$b_{p,1,eff,AISI,1}$ 16.048 [mm] | $b_{p,1,eff,AISI,2}$ 16.048 [mm]

Inferior Flange [$b_{p,1}$] — [AS/NZS 4600, Clause 2.4]



C-Section Strut Dimension		
$c_{p,1}$	6.048	[mm]
$b_{p,1}$	32.096	[mm]
t	1.452	[mm]

$c_{p,1} = d \mid b_{p,1} = b$

[AS/NZS 4600, Figure 2.4.2]

$d_{Inf. Lip}$ 10.000 [mm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Office: ---- Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993 Date: 05/09/2019 Project: MASTER THESIS
Version: 1.000 Client: COIMBRA UNIVERSITY

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 350.000 [MPa]; λ 0.274

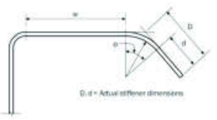
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $c_{p,1,eff,AS/NZS}$ 6.048 [mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,1,eff,AISI}$	6.048	=	$c_{p,1,eff,AS/NZS}$	6.048

Inferior Flange [$b_{p,1}$] — [AISI S100, Sector B4]



C-Section Strut Dimension		
$c_{p,1}$	6.048	[mm]
$b_{p,1}$	32.096	[mm]
t	1.452	[mm]

$c_{p,1} = d \mid b_{p,1} = w$

[AISI S100, Figure B4-1]

$D_{Inf. Lip}$ 10.000 [mm]

$$S = 1.28\sqrt{E/f}$$

[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	350.000	[MPa]
S	31.353	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	b_1 = [b / 2] * [R_I]
$b_1 = b_2$ = w / 2	$b_2 = b - b_1$
$d_s = d_s'$	$d_s = d_s'$ * [R_I]

w / t 22.105 Edge stiffener is needed 0.328 * S 10.284

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \leq t^4\left[115\frac{w/t}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4-8]

I_a 95.042 [mm^4] ≤ 382.607 → OK

$$(R_I) = I_s/I_a \leq 1$$

[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AISI S100, Eq. B4-10]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Office: ---- Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993 Date: 05/09/2019 Project: MASTER THESIS
Version: 1.000 Client: COIMBRA UNIVERSITY

$$S = 1.28\sqrt{E/f^*}$$

[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	350.000	[MPa]
S	31.353	[ ]

b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b_e = b	b_1 = [b_e / 2] * [I_s / I_a]
$b_1 = b_2$ = b / 2	$b_2 = b_e - b_1$
$d_s = d_{se}$	$d_s = d_{se}$ * [I_s / I_a]

b / t 22.105 Edge stiffener is needed 0.328 * S 10.284

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \leq t^4\left[115\frac{(b/t)}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(11)]

I_a 95.042 [mm^4] ≤ 382.607 → OK

$$I_s/I_a \leq 1$$

[AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AS/NZS 4600, Eq. 2.4.2(10)]

Ø1 90.000 [°] → I_s 4000.720 [mm^4]

[I_s / I_a] 42.094 ≤ 1.000 → KO → [I_s / I_a] 1.000

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \geq \frac{1}{3}$$

[AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

d / b ≤ 0.250	0.250 < d / b ≤ 0.800
3.570 * [I_s / I_a] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * d / b]] * [I_s / I_a] ^{n} + 0.430 ≤ 4.000

OK 140° ≥ Ø1 90.000 [°] ≥ 40° OK

n 0.406 ≥ 1 / 3 ? OK → n 0.406

[AS/NZS 4600, Table 2.4.2] d / b 0.312 → k 3.692 OK

C-Section Strut Dimension — NOTE: $b = b_{p,1}$

$b_{p,1}$ 32.096 [mm]

E 210.000 [GPa] | t 1.452 [mm] | v 0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$
[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 1434.201 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$
[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 350.000 [MPa]

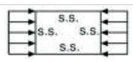
λ 0.494

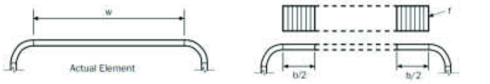
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,1,eff,AS/NZS}$	32.096	[mm]
$b_{p,1,eff,AS/NZS,1}$	16.048	[mm]	$b_{p,1,eff,AS/NZS,2}$	16.048	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,1,eff,AISI,1}$	16.048	=	$b_{p,1,eff,AS/NZS,1}$	16.048
$b_{p,1,eff,AISI,2}$	16.048	=	$b_{p,1,eff,AS/NZS,2}$	16.048

Web [h_p] [AISI S100, Sector B2.1]

Boundary condition	Types of stress	k
	Compression	4.000



Actual Element | Effective Element, b, and Stress, f, on Effective Elements

Stiffened Elements [AISI S100, Figure B2.1-1]

C-Section Strut Dimension | NOTE: $w = h_p$

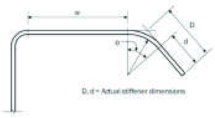
h_p	42.096	[mm]						
E	210.000	[GPa]	t	1.452	[mm]	ν [μ]	0.300	

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]

F_{cr} 903.250 [MPa]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,eff,AISI,1}$	21.048	=	$h_{p,eff,AS/NZS,1}$	21.048
$h_{p,eff,AISI,2}$	21.048	=	$h_{p,eff,AS/NZS,2}$	21.048

Superior Flange [$b_{p,2}$] [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

C-Section Strut Dimension		
$c_{p,2}$	6.048	[mm]
$b_{p,2}$	32.096	[mm]
t	1.452	[mm]

$c_{p,2} = d$ | $b_{p,2} = w$

$D_{Sup. Lip}$ 10.000 [mm]

$$S = 1.28\sqrt{E/f}$$
[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	350.000	[MPa]
S	31.353	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	b_1 = [b / 2] * [R_I]
$b_1 = b_2$ = w / 2	$b_2 = b - b_1$
$d_s = d'_s$	$d_s = d'_s$ * [R_I]

w / t: 22.105 | Edge stiffener is needed | 0.328 * S: 10.284

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \leq t^4\left[115\frac{w/t}{S} + 5\right]$$
Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4-8]

I_a 95.042 [mm^4] ≤ 382.607 → OK

$$(R_I) = I_s/I_a \leq 1$$
[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$
[AISI S100, Eq. B4-10]

$Ø_1$	90.000	[°]	→	I_s	4000.720	[mm^4]	
[R_I]	42.094	≤ 1.000	→	KO	→	[R_I]	1.000

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

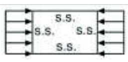
$f = f_y$: 350.000 [MPa]

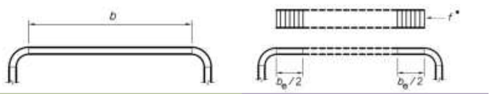
λ 0.622

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$h_{p,eff,AISI}$	42.096	[mm]
$h_{p,eff,AISI,1}$	21.048	[mm]	$h_{p,eff,AISI,2}$	21.048	[mm]

Web [h_p] [AS/NZS 4600, Clause 2.2.1]

Boundary condition	Types of stress	k
	Compression	4.000



Actual Element | Effective Width [be] of Element and Design on Effective Elements | Stress [f*]

Stiffened Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

C-Section Strut Dimension | NOTE: $b = h_p$

h_p	42.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$
[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 903.250 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$
[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 350.000 [MPa]

λ 0.622

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$h_{p,eff,AS/NZS}$	42.096	[mm]
$h_{p,eff,AS/NZS,1}$	21.048	[mm]	$h_{p,eff,AS/NZS,2}$	21.048	[mm]

$$n = \left(0.582 - \frac{w/t}{4S}\right) \geq \frac{1}{3}$$
[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK	140° ≥	$Ø_1$	90.000	[°]	≥ 40°	OK		
n	0.406	≥ 1 / 3 ?	OK	→	n	0.406		
[AISI S100, Table B4-1]		D / w	0.312	→	k	3.692	OK	

C-Section Strut Dimension | NOTE: $w = b_{p,2}$

$b_{p,2}$	32.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	ν [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]

F_{cr} 1434.201 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

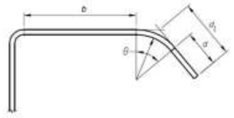
$f = f_y$: 350.000 [MPa]

λ 0.494

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,2,eff,AISI}$	32.096	[mm]
$b_{p,2,eff,AISI,1}$	16.048	[mm]	$b_{p,2,eff,AISI,2}$	16.048	[mm]

Superior Flange [$b_{p,2}$] [AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

C-Section Strut Dimension		
$c_{p,2}$	6.048	[mm]
$b_{p,2}$	32.096	[mm]
t	1.452	[mm]

$c_{p,2} = d$ | $b_{p,2} = b$

$d_{R,Sup. Lip}$ 10.000 [mm]

$$S = 1.28\sqrt{E/f^*}$$
[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	350.000	[MPa]
S	31.353	[ ]

b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
$b_e = b$	$b_1 = [b_e / 2] * [I_s / I_a]$
$b_1 = b_2 = b / 2$	$b_2 = b_e - b_1$
$d_s = d_{se}$	$d_s = d_{se} * [I_s / I_a]$

b / t: 22.105 — Edge stiffener is needed — 0.328 * S: 10.284

$$I_a = 399 t^4 \left[\frac{(b/t)}{S} - 0.328\right]^3 \le t^4 \left[115 \frac{(b/t)}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(11)]

I_a 95.042 [mm^4] ≤ 382.607 → OK

$$I_s / I_a \le 1$$

[AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AS/NZS 4600, Eq. 2.4.2(110)]

$Ø_1$ 90.000 [°] → I_s 4000.720 [mm^4]

[I_s / I_a] 42.094 ≤ 1.000 → KO → [I_s / I_a] 1.000

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \ge \frac{1}{3}$$

[AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

$d_l / b \le 0.250$	$0.250 < d_l / b \le 0.800$
$3.570 * [I_s / I_a]^n + 0.430 \le 4.000$	$[4.820 - [5 * d_l / b]] * [I_s / I_a]^n + 0.430 \le 4.000$

OK — 140° ≥ $Ø_1$ 90.000 [°] ≥ 40° — OK

n 0.406 ≥ 1 / 3 ? OK → n 0.406

[AS/NZS 4600, Table 2.4.2] — d_l / b 0.312 → k 3.692 OK

C-Section Strut Dimension — **NOTE** $b = b_{p,2}$

$b_{p,2}$ 32.096 [mm]

E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

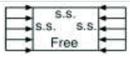
[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 1434.201 [MPa]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993 — Version: 1.000
Office: ---- | Author: JOSÉ ANTÓNIO | Date: 05/09/2019 | Project: MASTER THESIS | Client: COIMBRA UNIVERSITY

ρ 1.000 → $c_{p,2,eff,AISI}$ 6.048 [mm]

Superior Edge Stiffener [$c_{p,2}$] — [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k
	Compression	0.425

Actual Element — Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

C-Section Strut Dimension — **NOTE** $b = c_{p,2}$

$c_{p,2}$ 6.048 [mm]

E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 4649.380 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 350.000 [MPa]; λ 0.274

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $c_{p,2,eff,AS/NZS}$ 6.048 [mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,2,eff,AISI}$	6.048	=	$c_{p,2,eff,AS/NZS}$	6.048

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993 — Version: 1.000
Office: ---- | Author: JOSÉ ANTÓNIO | Date: 05/09/2019 | Project: MASTER THESIS | Client: COIMBRA UNIVERSITY

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 350.000 [MPa]; λ 0.494

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

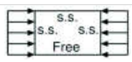
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $b_{p,2,eff,AS/NZS}$ 32.096 [mm]

$b_{p,2,eff,AS/NZS,1}$ 16.048 [mm] — $b_{p,2,eff,AS/NZS,2}$ 16.048 [mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,2,eff,AISI,1}$	16.048	=	$b_{p,2,eff,AS/NZS,1}$	16.048
$b_{p,2,eff,AISI,2}$	16.048	=	$b_{p,2,eff,AS/NZS,2}$	16.048

Superior Edge Stiffener [$c_{p,2}$] — [AISI S100, Sector B3.1]

Boundary condition	Types of stress	k
	Compression	0.425

Actual Element — Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

C-Section Strut Dimension — **NOTE** $w = c_{p,2}$

$c_{p,2}$ 6.048 [mm]

E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 4649.380 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$: 350.000 [MPa]; λ 0.274

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993 — Version: 1.000
Office: ---- | Author: JOSÉ ANTÓNIO | Date: 05/09/2019 | Project: MASTER THESIS | Client: COIMBRA UNIVERSITY

[ii] Effective C-Section Strut [Local Buckling]

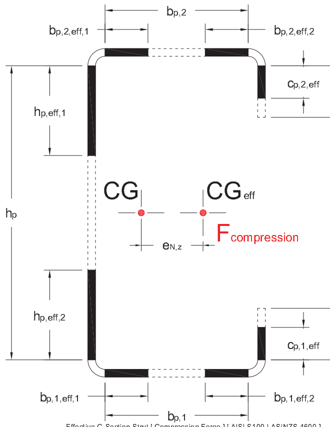
Effective C-Section Strut Widths [AISI S100]			
Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	6.048	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	32.096	[mm]
Web	$h_{p,eff,AISI}$	42.096	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	32.096	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	6.048	[mm]

Effective C-Section Strut Widths [AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	6.048	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	32.096	[mm]
Web	$h_{p,eff,AS/NZS}$	42.096	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	32.096	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	6.048	[mm]

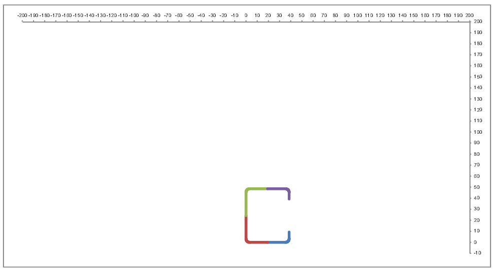
Effective C-Section Strut Widths [AISI S100 | AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff}$	6.048	[mm]
Inferior Flange	$b_{p,1,eff}$	32.096	[mm]
Web	$h_{p,eff}$	42.096	[mm]
Superior Flange	$b_{p,2,eff}$	32.096	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	6.048	[mm]

[iii] Effective Cross C-Section Strut [Local Buckling]

Effective C-Section Strut Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	6.048	[mm]
Inferior Flange	$b_{p,1,eff,1}$	16.048	[mm]
	$b_{p,1,eff,2}$	16.048	[mm]
Web	$h_{p,eff,1}$	21.048	[mm]
	$h_{p,eff,2}$	21.048	[mm]
Superior Flange	$b_{p,2,eff,1}$	16.048	[mm]
	$b_{p,2,eff,2}$	16.048	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	6.048	[mm]



Effective C-Section Strut [Compression Force] [AISI S100 | AS/NZS 4600]


Effective C-Section Strut [Local Buckling] [Compression Force]

A_{eff}	201.315	[mm^2]
$e_{N,y} = z_{GC,eff} - z_{GC}$	0.000	[mm]
$e_{N,z} = y_{GC,eff} - y_{GC}$	0.000	[mm]

Right Edge Stiffner [$c_{p,Right Lip}$] — [AS/NZS 4600, Clause 2.3.2]

NOTE — Zone in Tension. Effective width is equal to the real width

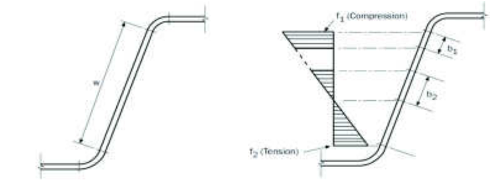
Inferior Right Flange [$b_{p,Inf. Right Flange}$] — [AISI S100, Sector B4]

NOTE — Zone in Tension. Effective width is equal to the real width

Inferior Right Flange [$b_{p,Inf. Right Flange}$] — [AS/NZS 4600, Clause 2.4]

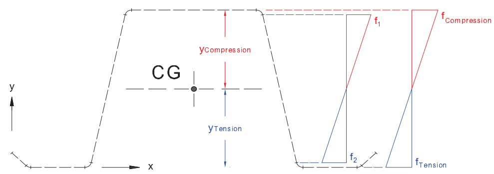
NOTE — Zone in Tension. Effective width is equal to the real width

Right Web [$h_{p,Right Web}$] — [AISI S100, Sector B2.3]



Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



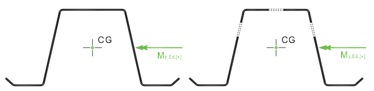
Ω-Section Purlin: Stress Gradient

$y_{Compression}$	28.089	[mm]	$y_{Tension}$	25.652	[mm]

Compression Stress is reached!

[11.3] Cold-Formed Section subjected to Positive Moment in x-x axis [$M_{x,Ed}^{+}$]

[a] Ω-Section Purlin

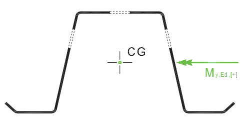


Gross Ω-Section

Effective Ω-Section [L]

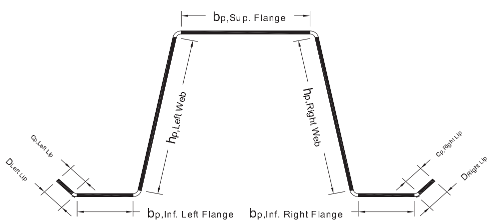
Local Buckling

[i] **Effective Widths for Strength Determination [Local Buckling]** — **AISI S100, Sector B | AS/NZS 4600, Section 2**



Effective Ω-Section [Worst Case]

Ω-Section Purlin Dimension		
$c_{p,Right Lip}$	6.191	[mm]
$b_{p,Inf. Right Flange}$	16.545	[mm]
$h_{p,Right Web}$	51.640	[mm]
$b_{p,Sup. Web}$	38.171	[mm]
$h_{p,Left Web}$	51.640	[mm]
$b_{p,Inf. Left Flange}$	16.545	[mm]
$c_{p,Left Lip}$	6.191	[mm]



Ω-Section Plate Widths

1º Iteration

Right Edge Stiffner [$c_{p,Right Lip}$] — [AISI S100, Sector B3.2]

NOTE — Zone in Tension. Effective width is equal to the real width

1º Iteration	$f_{Compression,Top fiber}$	350.000	[MPa]	y_{CG}	25.652	[mm]
$f_{Compression}$ 350.000 [MPa]		m	12.460	$f_{Tension}$	-319.633	[MPa]

h_0	55.835	[mm]
b_0	42.170	[mm]
h_0 / b_0	1.324	[ ]

Out-to-Out Dimensions of Webs and Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-2]

For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \le 4$	$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \le 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \le$ Compression portion of the web calculated on the basis of effective section

f_1	330.332	[MPa]	m	12.460	f_2	-299.965	[MPa]

$$\psi = |f_2/f_1|$$
[AISI S100, Eq. B2.3-1]

$|\psi|$ 0.908

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$
[AISI S100, Eq. B2.3-2]

k 21.710

Ω-Section Purlin Dimension

$h_{p,Right Web}$ 51.640 [mm]

NOTE — $w = h_{p,Right Web}$

E	210.000	[GPa]	t	0.952	[mm]	ν [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]

F_{cr} 1400.372 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

$f = f_1$

330.332 [MPa]

λ 0.486

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$h_{p,Right Web,eff,AISI}$	51.640	[mm]

$b_e = h_{p,Right\ Web,eff,AISI}$	51.640	[mm]

↓

h_0 / b_0	1.324

↓

| ψ |	0.908

↓

$b_1 = b_e / [3 + \psi]$	13.214	[mm]

↓

$h_o / b_o \leq 4$				$h_o / b_o > 4$		
$\psi > 0.236$	$b_2 = b_e / 2$	25.820	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
$\psi \leq 0.236$	$b_2 = b_e - b_1$	----	[mm]			

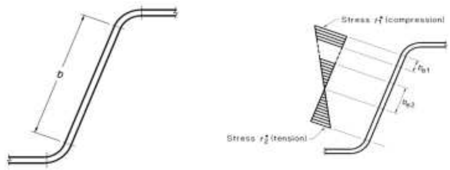
↓

$b_1 + b_2 \leq w_{Comp}$	KO	Web is fully effective	**No more iterations!**

↓

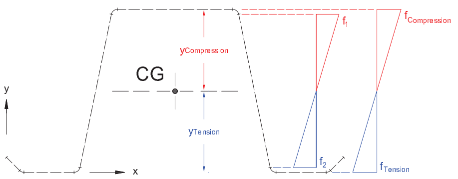
$h_{p,Right\ Web,eff,AISI,1}$	13.214	[mm]	$h_{p,Right\ Web,eff,AISI,2}$	13.850	[mm]

Right Web [$h_{p,Right\ Web}$] [AS/NZS 4600, Clause 2.2.3]



Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



Ω-Section Purlin: Stress Gradient

$b_e = h_{p,Right\ Web,eff,AS/NZS}$	51.640	[mm]

↓

ψ	-0.908

↓

$b_{e1} = b_e / [3 - \psi]$	13.214	[mm]

↓

$\psi \leq -0.236$	$b_2 = b_e / 2$	25.820	[mm]	$\psi > -0.236$	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2} \leq$ Compression portion of the web calculated on the basis of effective section

↓

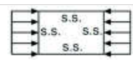
$b_{e1} + b_{e2} \leq b_{Comp}$	KO	Web is fully effective	**No more iterations!**

↓

$h_{p,Right\ Web,eff,AS/NZS,1}$	13.214	[mm]	$h_{p,Right\ Web,eff,AS/NZS,2}$	13.850	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,Right\ Web,eff,AISI,1}$	13.214	=	$h_{p,Right\ Web,eff,AS/NZS,1}$	13.214
$h_{p,Right\ Web,eff,AISI,2}$	13.850	=	$h_{p,Right\ Web,eff,AS/NZS,2}$	13.850

Superior Flange [$b_{p,Sup.\ Flange}$] [AISI S100, Sector B2.1]

Boundary condition	Types of stress	k
	Compression	4.000

Actual Element | Effective Element, b, and Stress, f, on Effective Elements

Stiffened Elements [AISI S100, Figure B2.1-1]

Ω-Section Purlin Dimension | **NOTE** $w = b_{p,Sup.\ Web}$

$b_{p,Sup.\ Web}$	38.171	[mm]

E	210.000	[GPa]	t	0.952	[mm]	ν [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 472.252 [MPa]

$y_{Compression}$	28.089	[mm]	$y_{Tension}$	25.652	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Top\ fiber}$	**350.000**	**[MPa]**	y_{CG}	**25.652**	**[mm]**

$f_{Compression}$	**350.000**	**[MPa]**	m	12.205	$f_{Tension}$	**-319.633**	**[MPa]**
f_1^*	**330.332**	**[MPa]**	m	12.205	f_2^*	**-299.965**	**[MPa]**

$$\psi = \frac{f_2^*}{f_1^*}$$

[AS/NZS 4600, Eq. 2.2.3.2(5)]

ψ -0.908

$$k = 4 + 2(1 - \psi)^3 + 2(1 - \psi)$$

[AS/NZS 4600, Eq. 2.2.3.2(4)]

k 21.710

Ω-Section Purlin Dimension | **NOTE** $b = h_{p,Right\ Web}$

$h_{p,Right\ Web}$	51.640	[mm]

E	210.000	[GPa]	t	0.952	[mm]	ν	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 1400.372 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 330.332 [MPa]

λ 0.486

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$h_{p,Right\ Web,eff,AS/NZS}$	51.640	[mm]

$$b_{e1} = \frac{b_e}{3 - \psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

$\psi \leq -0.236$

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

$\psi > -0.236$

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$: 350.000 [MPa]

λ 0.861

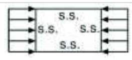
$$\rho = (1 - 0.22/\lambda)/\lambda$$

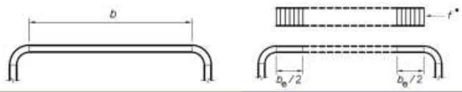
[AISI S100, Eq. B2.1-4]

ρ	0.865	→	$b_{p,Sup.\ Web,eff,AISI}$	33.008	[mm]

$b_{p,Sup.\ Web,eff,AISI,1}$	16.504	[mm]	$b_{p,Sup.\ Web,eff,AISI,2}$	16.504	[mm]

Superior Flange [$b_{p,Sup.\ Flange}$] [AS/NZS 4600, Clause 2.2.1]

Boundary condition	Types of stress	k
	Compression	4.000



Actual Element | Effective Width [be] of Element and Design Stress [f*] on Effective Elements

Stiffened Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

Ω-Section Purlin Dimension | **NOTE** $b = b_{p,Sup.\ Web}$

$b_{p,Sup.\ Web}$	38.171	[mm]

E	210.000	[GPa]	t	0.952	[mm]	ν	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 472.252 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 350.000 [MPa]

λ 0.861

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

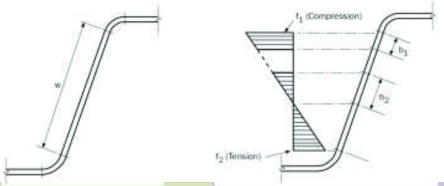
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	0.865	→	$b_{p,Sup.\ Web,eff,AS/NZS}$	33.008	[mm]

$b_{p,Sup.\ Web,eff,AS/NZS,1}$	16.504	[mm]	$b_{p,Sup.\ Web,eff,AS/NZS,2}$	16.504	[mm]

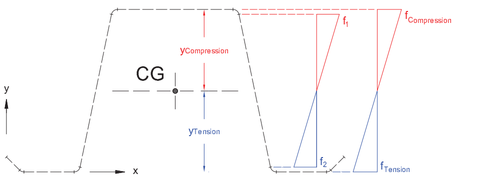
AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{0,Sup. Web,eff,AISI,1}$	16.504	=	$b_{0,Sup. Web,eff,AS/NZS,1}$	16.504
$b_{0,Sup. Web,eff,AISI,2}$	16.504	=	$b_{0,Sup. Web,eff,AS/NZS,2}$	16.504

Left Web [$h_{0,Left Web}$] [AISI S100, Sector B2.3]



Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



Ω-Section Purlin: Stress Gradient

$y_{Compression}$	28.089	[mm]	$y_{Tension}$	25.652	[mm]

Compression Stress is reached!

1ª Iteration	$f_{Compression,Top fiber}$	350.000	[MPa]	y_{CG}	25.652	[mm]
$f_{Compression}$	350.000 [MPa]	m	12.460	$f_{Tension}$	-319.633	[MPa]

$b_e = h_{0,Left Web,eff,AISI}$ 51.640 [mm]
↓
h_0 / b_0 1.324
↓
| ψ | 0.908
↓
$b_1 = b_e / [3 + ψ]$ 13.214 [mm]
↓

$h_o / b_o \le 4$				$h_o / b_o > 4$		
ψ > 0.236	$b_2 = b_e / 2$	25.820	[mm]	$b_2 = b_e / [1 + ψ] - b_1$	----	[mm]
ψ ≤ 0.236	$b_2 = b_e - b_1$	----	[mm]			

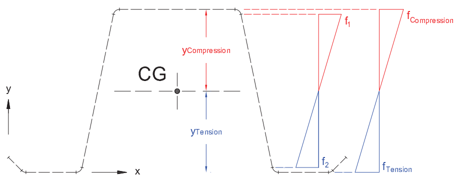
↓
$b_1 + b_2 \le w / 2$ KO Web is fully effective No more iterations!
↓

$h_{0,Left Web,eff,AISI,1}$	13.214	[mm]	$h_{0,Left Web,eff,AISI,2}$	13.850	[mm]

Left Web [$h_{0,Left Web}$] [AS/NZS 4600, Clause 2.2.3]

Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



Ω-Section Purlin: Stress Gradient

h_0	55.835	[mm]
b_0	42.170	[mm]
h_0 / b_0	1.324	[ ]

Out-to-Out Dimensions of Webs and Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-2]

For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \le 4$	$h_o / b_o > 4$
	$b_1 = b_e / [3 + ψ]$	$b_1 = b_e / [3 + ψ]$
ψ > 0.236	$b_2 = b_e / 2$	$b_2 = b_e / [1 + ψ] - b_1$
ψ ≤ 0.236	$b_2 = b_e - b_1$	

$b_1 + b_2 \le$ Compression portion of the web calculated on the basis of effective section

f_1	330.332	[MPa]	m 12.460	f_2	-299.965	[MPa]

$$\psi = |f_2/f_1|$$
[AISI S100, Eq. B2.3-1] | ψ | 0.908

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$
[AISI S100, Eq. B2.3-2] k 21.710

Ω-Section Purlin Dimension			NOTE	$w = h_{0,Left Web}$	
$h_{0,Left Web}$	51.640	[mm]			
E	210.000	[GPa]	t 0.952 [mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)] F_{cr} 1400.372 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

$f = f_1$: 330.332 [MPa]; λ 0.486

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$h_{0,Left Web,eff,AISI}$	51.640	[mm]

$y_{Compression}$	28.089	[mm]	$y_{Tension}$	25.652	[mm]

Compression Stress is reached!

1ª Iteration	$f_{Compression,Top fiber}$	350.000	[MPa]	y_{CG}	25.652	[mm]
$f_{Compression}$	350.000 [MPa]	m	12.205	$f_{Tension}$	-319.633	[MPa]
f_1^*	330.332 [MPa]	m	12.205	f_2^*	-299.965	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$
[AS/NZS 4600, Eq. 2.2.3.2(5)] ψ -0.908

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$
[AS/NZS 4600, Eq. 2.2.3.2(4)] k 21.710

Ω-Section Purlin Dimension			NOTE	$b = h_{0,Left Web}$	
$h_{0,Left Web}$	51.640	[mm]			
E	210.000	[GPa]	t 0.952 [mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$
[AS/NZS 4600, Eq. 2.2.1.2(5)] f_{cr} 1400.372 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$
[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 330.332 [MPa]; λ 0.486

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$h_{0,Left Web,eff,AS/NZS}$	51.640	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$
[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$
ψ ≤ −0.236
[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$
ψ > −0.236
[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = h_{p,Left\ Web,eff,AS/NZS}$	51.640	[mm]

↓

ψ	-0.908

↓

$b_{e1} = b_e / [3 - \psi]$	13.214	[mm]

↓

$\psi \leq -0.236$	$b_2 = b_e / 2$	25.820	[mm]	$\psi > -0.236$	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2} \leq$ Compression portion of the web calculated on the basis of effective section

↓

$b_{e1} + b_{e2} \leq b_{Comp}$	KO	Web is fully effective	No more iterations!

↓

$h_{p,Left\ Web,eff,AS/NZS,1}$	13.214	[mm]	$h_{p,Left\ Web,eff,AS/NZS,2}$	13.850	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,Left\ Web,eff,AISI,1}$	13.214	=	$h_{p,Left\ Web,eff,AS/NZS,1}$	13.214
$h_{p,Left\ Web,eff,AISI,2}$	13.850	=	$h_{p,Left\ Web,eff,AS/NZS,2}$	13.850

Inferior Left Flange [$b_{p,Inf.\ Left\ Flange}$] [AISI S100, Sector B4]

NOTE Zone in Tension. Effective width is equal to the real width

Inferior Left Flange [$b_{p,Inf.\ Left\ Flange}$] [AS/NZS 4600, Clause 2.4]

NOTE Zone in Tension. Effective width is equal to the real width

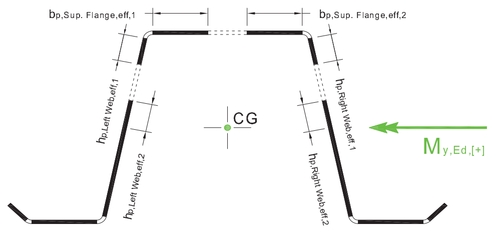
Left Edge Stiffener [$c_{p,Left\ Lip}$] [AISI S100, Sector B3.2]

NOTE Zone in Tension. Effective width is equal to the real width

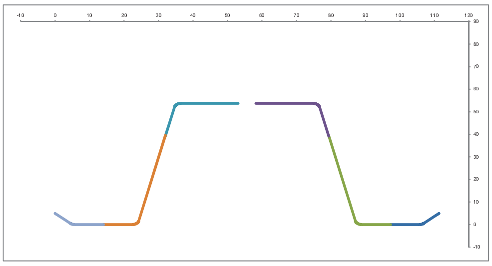
Left Edge Stiffener [$c_{p,Left\ Lip}$] [AS/NZS 4600, Clause 2.3.2]

NOTE Zone in Tension. Effective width is equal to the real width

Effective Ω-Section Purlin Widths			
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff}$	----	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	----	[mm]



Effective Ω-Section Purlin [Positive Moment in y-y axis, $M_{x,Ed}^{+}$] [AISI S100 | AS/NZS 4600]



Effective Ω-Section Purlin [Local Buckling] [Positive Moment in x-x axis, $M_{x,Ed}^{+}$]

$I_{x,eff}^{[+]}$	81891.327	[mm^4]

[ii] **Effective Ω-Section Purlin [Local Buckling]**

Effective Ω-Section Purlin Widths [AISI S100]			
Right Edge Stiffner	$c_{p,Right\ Lip,eff,AISI}$	----	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff,AISI}$	----	[mm]
Right Web	$h_{p,Right\ Web,eff,AISI}$	51.640	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff,AISI}$	33.008	[mm]
Left Web	$h_{p,Left\ Web,eff,AISI}$	51.640	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff,AISI}$	----	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff,AISI}$	----	[mm]

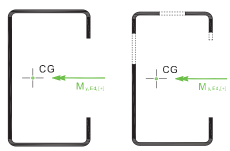
Effective Ω-Section Purlin Widths [AS/NZS 4600]			
Right Edge Stiffner	$c_{p,Right\ Lip,eff,AS/NZS}$	----	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff,AS/NZS}$	----	[mm]
Right Web	$h_{p,Right\ Web,eff,AS/NZS}$	51.640	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff,AS/NZS}$	33.008	[mm]
Left Web	$h_{p,Left\ Web,eff,AS/NZS}$	51.640	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff,AS/NZS}$	----	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff,AS/NZS}$	----	[mm]

Effective Ω-Section Purlin Widths [AISI S100 | AS/NZS 4600]			
Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	----	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff}$	----	[mm]
Right Web	$h_{p,Right\ Web,eff}$	51.640	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff}$	33.008	[mm]
Left Web	$h_{p,Left\ Web,eff}$	51.640	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff}$	----	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	----	[mm]

[iii] **Effective Cross Ω-Section Purlin [Local Buckling]**

Effective Ω-Section Purlin Widths			
Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	----	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff}$	----	[mm]
Right Web	$h_{p,Right\ Web,eff,1}$	13.214	[mm]
	$h_{p,Right\ Web,eff,2}$	13.850	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff,1}$	16.504	[mm]
	$b_{p,Sup.\ Flange,eff,2}$	16.504	[mm]
Left Web	$h_{p,Left\ Web,eff,1}$	13.214	[mm]
	$h_{p,Left\ Web,eff,2}$	13.850	[mm]

[b] C-Section Beam



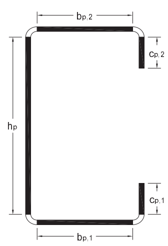
Gross C-Section

Effective C-Section [L]

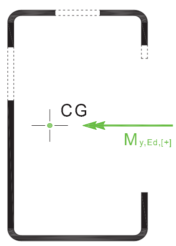
Local Buckling

C-Section Beam Dimension		
$c_{p,1}$	14.048	[mm]
$b_{p,1}$	38.596	[mm]
h_p	112.096	[mm]
$b_{p,2}$	38.596	[mm]
$c_{p,2}$	14.048	[mm]
t	1.452	[mm]

[i] **Effective Widths for Strength Determination [Local Buckling]** **AISI S100, Sector B | AS/NZS 4600, Section 2**



C-Section Plate Widths



Effective C-Section [Worst Case]

1º Iteration

Inferior Edge Stiffner [$c_{p,1}$] [AISI S100, Sector B3.2]

NOTE Zone in Tension. Effective width is equal to the real width

Inferior Edge Stiffener [$c_{p,1}$] [AS/NZS 4600, Clause 2.3.2]

NOTE Zone in Tension. Effective width is equal to the real width

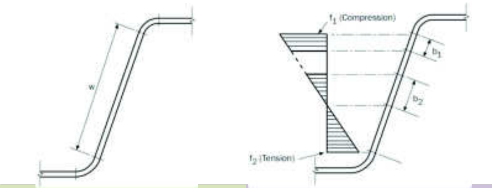
Inferior Flange [$b_{p,1}$] [AISI S100, Sector B4]

NOTE Zone in Tension. Effective width is equal to the real width

Inferior Flange [$b_{i,f}$] — [AS/NZS 4600, Clause 2.4]

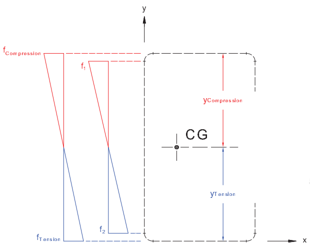
NOTE — Zone in Tension. Effective width is equal to the real width

Web [h_p] — [AISI S100, Sector B2.3]

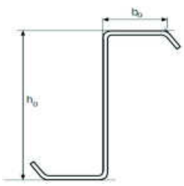


Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



C-Section Beam: Stress Gradient



[AISI S100, Figure B2.3-2]

h_0	120.000	[mm]
b_0	46.500	[mm]
h_0 / b_0	2.581	[ ]

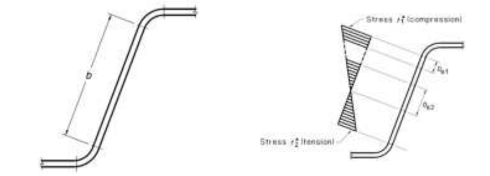
$y_{Compression}$	59.274	[mm]	$y_{Tension}$	59.274	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Top\ fiber}$	350.000	[MPa]	y_{CG}	59.274	[mm]
$f_{Compression}$	350.000	[MPa]	m 5.905	$f_{Tension}$	-350.000	[MPa]
f_1	330.951	[MPa]	m 5.905	f_2	-330.951	[MPa]

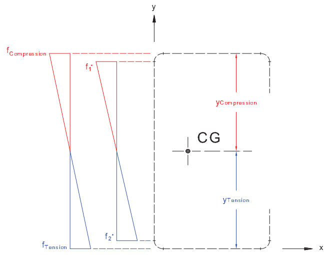
$h_{p,eff,AISI,1}$	28.024	[mm]	$h_{p,eff,AISI,2}$	28.024	[mm]

Web [h_p] — [AS/NZS 4600, Clause 2.2.3]



Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Beam: Stress Gradient

$y_{Compression}$	59.274	[mm]	$y_{Tension}$	59.274	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Top\ fiber}$	350.000	[MPa]	y_{CG}	59.274	[mm]
$f_{Compression}$	350.000	[MPa]	m 5.905	$f_{Tension}$	-350.000	[MPa]
f_1^*	330.951	[MPa]	m 5.905	f_2^*	-330.951	[MPa]

For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \leq 4$	$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \leq 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \leq$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B2.3-1] — $|\psi|$ 1.000

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$

[AISI S100, Eq. B2.3-2] — k 24.000

C-Section Beam Dimension | NOTE: $w = h_p$

h_p	112.096	[mm]						
E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300	

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)] — F_{cr} 764.294 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$: 330.951 [MPa]; λ 0.658

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$h_{p,eff,AISI}$	112.096	[mm]

$b_e = h_{p,eff,AISI}$ 112.096 [mm]

↓

h_0 / b_0 2.581

↓

$|\psi|$ 1.000

↓

$b_1 = b_e / [3 + \psi]$ 28.024 [mm]

↓

	$h_o / b_o \leq 4$			$h_o / b_o > 4$		
$\psi > 0.236$	$b_2 = b_e / 2$	56.048	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
$\psi \leq 0.236$	$b_2 = b_e - b_1$	----	[mm]			

↓

$b_1 + b_2 \leq w_{Comp}$	KO	Web is fully effective	No more iterations!

$$\psi = \frac{f_2^*}{f_1^*}$$

[AS/NZS 4600, Eq. 2.2.3.2(5)] — ψ -1.000

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

[AS/NZS 4600, Eq. 2.2.3.2(4)] — k 24.000

C-Section Beam | NOTE: $b = h_p$

h_p	112.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)] — f_{cr} 764.294 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 330.951 [MPa]; λ 0.658

$$\rho = \frac{\left(1-\frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$h_{p,eff,AS/NZS}$	112.096	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

$\psi \leq -0.236$ [AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

$\psi > -0.236$ [AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = h_{p,Right\ Web,eff\ AS/NZS}$ 112.096 [mm]

↓

ψ -1.000

↓

$b_{e1} = b_e / [3 - \psi]$ 28.024 [mm]

↓

$\psi \leq -0.236$	$b_2 = b_e / 2$	56.048	[mm]	$\psi > -0.236$	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2} \leq$ Compression portion of the web calculated on the basis of effective section

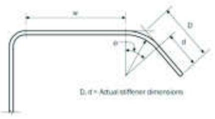
↓

$b_{e1} + b_{e2} \leq b_{Comp}$	KO	Web is fully effective	No more iterations!

$h_{p,eff,AS/NZS,1}$	28.024	[mm]	$h_{p,eff,AS/NZS,2}$	28.024	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,eff,AISI,1}$	28.024	=	$h_{p,eff,AS/NZS,1}$	28.024
$h_{p,eff,AISI,2}$	28.024	=	$h_{p,eff,AS/NZS,2}$	28.024

Superior Flange [$b_{p,2}$] — [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

C-Section Beam Dimension		
$c_{p,2}$	14.048	[mm]
$b_{p,2}$	38.596	[mm]
t	1.452	[mm]

$c_{p,2} = d$ | $b_{p,2} = w$

$D_{Sup. Lip}$ 18.000 [mm]

$$S = 1.28\sqrt{E/f}$$

[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	350.000	[MPa]
S	31.353	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	b_1 = [b / 2] * [R_I]
$b_1 = b_2$ = w / 2	$b_2 = b - b_1$
$d_s = d'_s$	$d_s = d'_s$ * [R_I]

w / t 26.581 Edge stiffener is needed 0.328 * S 10.284

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \le t^4\left[115\frac{w/t}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4-8]

I_a 249.076 [mm^4] ≤ 455.590 → OK

$$(R_I) = I_s/I_a \le 1$$

[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AISI S100, Eq. B4-10]

$Ø_1$	90.000	[°]	→	I_s	6956.844	[mm^4]
[R_I]	27.931	≤ 1.000	→	KO	→	[R_I] 1.000

b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b_e = b	b_1 = [b_e / 2] * [I_s / I_a]
$b_1 = b_2$ = b / 2	$b_2 = b_e - b_1$
$d_s = d_{se}$	$d_s = d_{se}$ * [I_s / I_a]

b / t 26.581 Edge stiffener is needed 0.328 * S 10.284

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \le t^4\left[115\frac{(b/t)}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(11)]

I_a 249.076 [mm^4] ≤ 455.590 → OK

$$I_s/I_a \le 1$$

[AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AS/NZS 4600, Eq. 2.4.2(110)]

$Ø_1$	90.000	[°]	→	I_s	6956.844	[mm^4]
[I_s / I_a]	27.931	≤ 1.000	→	KO	→	[I_s / I_a] 1.000

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \ge \frac{1}{3}$$

[AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

d_l / b ≤ 0.250	0.250 < d_l / b ≤ 0.800
3.570 * [I_s / I_a] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * d_l / b]] * [I_s / I_a] ^{n} + 0.430 ≤ 4.000

OK	140° ≥	$Ø_1$	90.000	[°]	≥ 40°	OK
n	0.370	≥ 1 / 3 ?	OK	→	n	0.370
[AS/NZS 4600, Table 2.4.2]	d_l / b	0.466	→	k	2.918	OK

C-Section Beam Dimension			NOTE	$b = b_{p,2}$
$b_{p,2}$	38.596	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 783.886 [MPa]

$$n = \left(0.582 - \frac{w/t}{4S}\right) \ge \frac{1}{3}$$

[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK	140° ≥	$Ø_1$	90.000	[°]	≥ 40°	OK
n	0.370	≥ 1 / 3 ?	OK	→	n	0.370
[AISI S100, Table B4-1]	D / w	0.466	→	k	2.918	OK

C-Section Beam Dimension			NOTE	$w = b_{p,2}$
$b_{p,2}$	38.596	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 783.886 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

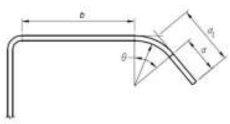
f = f_y	
350.000	[MPa]
λ	0.668

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→		$b_{p,2,eff,AISI}$	38.596	[mm]
$b_{p,2,eff,AISI,1}$	19.298	[mm]		$b_{p,2,eff,AISI,2}$	19.298	[mm]

Superior Flange [$b_{p,2}$] — [AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

C-Section Beam Dimension		
$c_{p,2}$	14.048	[mm]
$b_{p,2}$	38.596	[mm]
t	1.452	[mm]

$c_{p,2} = d$ | $b_{p,2} = b$

$d_{l,Sup. Lip}$ 18.000 [mm]

$$S = 1.28\sqrt{E/f^*}$$

[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	350.000	[MPa]
S	31.353	[ ]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

f* = f_y	
350.000	[MPa]
λ	0.668

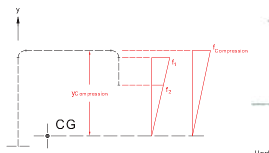
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

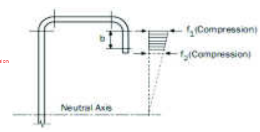
ρ	1.000	→		$b_{p,2,eff,AS/NZS}$	38.596	[mm]
$b_{p,2,eff,AS/NZS,1}$	19.298	[mm]		$b_{p,2,eff,AS/NZS,2}$	19.298	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,2,eff,AISI,1}$	19.298	=	$b_{p,2,eff,AS/NZS,1}$	19.298
$b_{p,2,eff,AISI,2}$	19.298	=	$b_{p,2,eff,AS/NZS,2}$	19.298

Superior Edge Stiffener [$c_{p,2}$] — [AISI S100, Sector B3.2]



C-Section Beam: Stress Gradient



[a] Inward Facing Lip

Unstiffened Elements under Stress Gradient, Both Longitudinal Edges in Compression [AISI S100, Figure B3.2-1]

$f_{Compression,Top fiber}$	350.000	[MPa]		y_{CG}	59.274	[mm]
$f_{Compression}$	350.000	[MPa]	m 5.905	$f_{Tension}$	-350.000	[MPa]
f_1	330.951	[MPa]	m 5.905	f_2	248.001	[MPa]

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B3.2-1]

| ψ | 0.749

f_1 Compression
f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$

[AISI S100, Eq. B3.2-2]

k 0.531

C-Section Beam Dimension			NOTE	$w = c_{p,2}$
$c_{p,2}$	14.048	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

w 14.048 [mm] → w / t ≤ 60 OK

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

F_{cr} 1075.865 [MPa]

[AISI S100, Eq. (B2.1-5)]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$

330.951 [MPa]

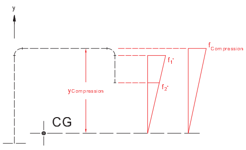
λ 0.555

$$\rho = (1 - 0.22/\lambda)/\lambda$$

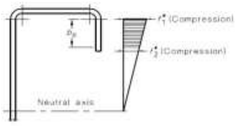
[AISI S100, Eq. B2.1-4]

ρ 1.000 → $c_{p,2,eff,AISI}$ 14.048 [mm]

Superior Edge Stiffener [$c_{p,2}$] [AS/NZS 4600, Clause 2.3.2]



C-Section Beam: Stress Gradient



[a] Inward Facing Lip

Unstiffened Elements with Stress Gradient: Both Edges in Compression [AS/NZS 4600, Figure B2.3.2(a)]

$f_{Compression,Top\ fiber}$	350.000	[MPa]		y_{CG}	59.274	[mm]
$f_{Compression}$	350.000	[MPa]	m 5.905	$f_{Tension}$	-350.000	[MPa]
f_1^*	330.951	[MPa]	m 5.905	f_2^*	248.001	[MPa]

$$\psi = f_2^* / f_1^*$$

ψ 0.749

[AS/NZS 4600, Eq. 2.3.2.2(1)]

f_1 Compression

f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$

k 0.531

[AS/NZS 4600, Eq. 2.3.2.2(2)]

C-Section Beam Dimension

$c_{p,2}$ 14.048 [mm]

NOTE $b = c_{p,2}$

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

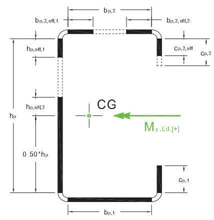
Office:	----	Author:	JOSÉ ANTÓNIO
Date:	05/09/2019	Project:	MASTER THESIS
Client:	COIMBRA UNIVERSITY		

Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000

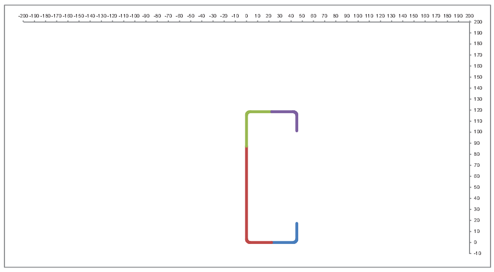
[iii] **Effective Cross C-Section Beam [Local Buckling]**

Effective C-Section Beam Widths

Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	----	[mm]
Web	$h_{p,eff,1}$	28.024	[mm]
	$h_{p,eff,2}$	28.024	[mm]
Superior Flange	$b_{p,2,eff,1}$	19.298	[mm]
	$b_{p,2,eff,2}$	19.298	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	14.048	[mm]



Effective C-Section Beam [Local Buckling] [Bending Moment $M_{y,Ed}$ ⁺] [AISI S100 | AS/NZS 4600]



Effective C-Section Beam [Local Buckling] [Bending Moment $M_{y,Ed}$ ⁺]

$I_{y,eff}^{[+]}$ 762290.565 [mm^4]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

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Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000

E 210.000 [GPa] | t 1.452 [mm] | ν 0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

f_{cr} 1075.865 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$

330.951 [MPa]

λ 0.555

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $c_{p,2,eff,AS/NZS}$ 14.048 [mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,2,eff,AISI}$	14.048	=	$c_{p,2,eff,AS/NZS}$	14.048

[ii] **Effective C-Section Beam [Local Buckling]**

Effective C-Section Beam Widths [AISI S100]

Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	----	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	----	[mm]
Web	$h_{p,eff,AISI}$	112.096	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	38.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	14.048	[mm]

Effective C-Section Beam Widths [AS/NZS 4600]

Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	----	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	----	[mm]
Web	$h_{p,eff,AS/NZS}$	112.096	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	38.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	14.048	[mm]

Effective C-Section Beam Widths [AISI S100 | AS/NZS 4600]

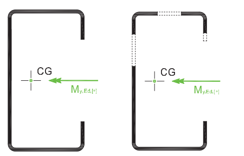
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	----	[mm]
Web	$h_{p,eff}$	112.096	[mm]
Superior Flange	$b_{p,2,eff}$	38.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	14.048	[mm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

Office:	----	Author:	JOSÉ ANTÓNIO
Date:	05/09/2019	Project:	MASTER THESIS
Client:	COIMBRA UNIVERSITY		

Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000

[c] C-Section Column



Gross C-Section

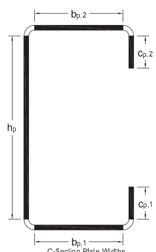
Effective C-Section [L]

Local Buckling

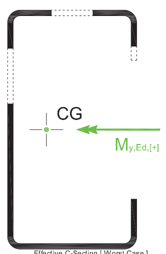
C-Section Column Dimension

$c_{p,1}$	13.048	[mm]
$b_{p,1}$	36.596	[mm]
h_p	80.096	[mm]
$b_{p,2}$	36.596	[mm]
$c_{p,2}$	13.048	[mm]
t	2.452	[mm]

[i] **Effective Widths for Strength Determination [Local Buckling]** **AISI S100, Sector B | AS/NZS 4600, Section 2**



C-Section Plate Widths



Effective C-Section | Worst Case]

1ª Iteration

Inferior Edge Stiffener [$c_{p,1}$] [AISI S100, Sector B3.2]

NOTE Zone in Tension. Effective width is equal to the real width

Inferior Edge Stiffener [$c_{p,1}$] [AS/NZS 4600, Clause 2.3.2]

NOTE Zone in Tension. Effective width is equal to the real width

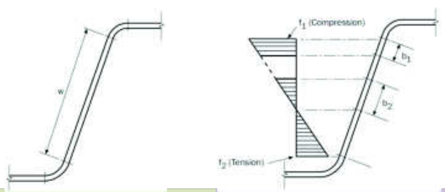
Inferior Flange [$b_{p,1}$] [AISI S100, Sector B4]

NOTE Zone in Tension. Effective width is equal to the real width

Inferior Flange [$b_{p,1}$] [AS/NZS 4600, Clause 2.4]

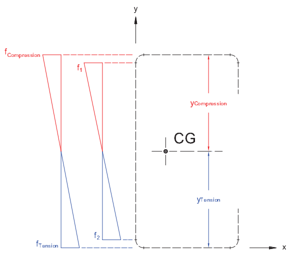
NOTE Zone in Tension. Effective width is equal to the real width

Web [h_p] [AISI S100, Sector B2.3]

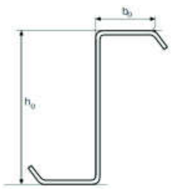


Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



C-Section Column: Stress Gradient



[AISI S100, Figure B2.3-2]

h_0	90.000	[mm]
b_0	46.500	[mm]
h_0 / b_0	1.935	[ ]

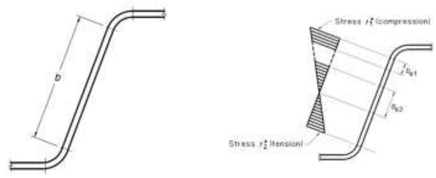
$y_{Compression}$	43.774	[mm]	$y_{Tension}$	43.774	[mm]

Tension Stress is reached!

1º Iteration	$f_{Compression,Top\ fiber}$	**350.000**	**[MPa]**	y_{CG}	**43.774**	**[mm]**
$f_{Compression}$	350.000	[MPa]	m 7.996	$f_{Tension}$	-350.000	[MPa]
f_1	320.208	[MPa]	m 7.996	f_2	-320.208	[MPa]

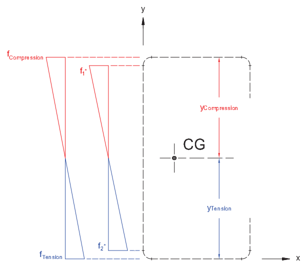
$h_{p,eff,AISI,1}$	20.024	[mm]	$h_{p,eff,AISI,2}$	20.024	[mm]

Web [h_p] [AS/NZS 4600, Clause 2.2.3]



Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Column: Stress Gradient

$y_{Compression}$	43.774	[mm]	$y_{Tension}$	43.774	[mm]

Tension Stress is reached!

1º Iteration	$f_{Compression,Top\ fiber}$	**350.000**	**[MPa]**	y_{CG}	**43.774**	**[mm]**
$f_{Compression}$	350.000	[MPa]	m 7.996	$f_{Tension}$	-350.000	[MPa]
f_1^*	320.208	[MPa]	m 7.996	f_2^*	-320.208	[MPa]

For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \leq 4$	$h_o / b_o > 4$
	$b_1 = b_e / [\,3 + \psi\,]$	$b_1 = b_e / [\,3 + \psi\,]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [\,1 + \psi\,] - b_1$
$\psi \leq 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \leq$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B2.3-1]

| ψ | 1.000

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$

[AISI S100, Eq. B2.3-2]

k 24.000

C-Section Column Dimension

NOTE **$w = h_p$**

h_p	80.096	[mm]						
E	210.000	[GPa]	t	2.452	[mm]	v [μ]	0.300	

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 4269.008 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$

320.208	[MPa]	
λ	0.274	

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$h_{p,eff,AISI}$	80.096	[mm]

$b_e = h_{p,eff,AISI}$	80.096	[mm]

↓

h_0 / b_0	1.935

↓

| ψ |	1.000

↓

$b_1 = b_e / [\,3 + \psi\,]$	20.024	[mm]

↓

	$h_o / b_o \leq 4$			**$h_o / b_o > 4$**		
$\psi > 0.236$	$b_2 = b_e / 2$	40.048	[mm]	$b_2 = b_e / [\,1 + \psi\,] - b_1$	----	[mm]
$\psi \leq 0.236$	$b_2 = b_e - b_1$	----	[mm]			

↓

$b_1 + b_2 \leq w_{Comp}$	KO	Web is fully effective	**No more iterations!**

$$\psi = \frac{f_2^*}{f_1^*}$$

[AS/NZS 4600, Eq. 2.2.3.2(5)]

ψ -1.000

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

[AS/NZS 4600, Eq. 2.2.3.2(4)]

k 24.000

C-Section Column

NOTE **$b = h_p$**

h_p	80.096	[mm]					
E	210.000	[GPa]	t	2.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 4269.008 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$

320.208	[MPa]	
λ	0.274	

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$h_{p,eff,AS/NZS}$	80.096	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

$\psi \leq -0.236$

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

$\psi > -0.236$

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = h_{p,Right\ Web,eff,AS/NZS}$	80.096	[mm]

↓

ψ	-1.000

↓

$b_{e1} = b_e / [\,3 - \psi\,]$	20.024	[mm]

↓

$\psi \leq -0.236$	$b_2 = b_e / 2$	40.048	[mm]	$\psi > -0.236$	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2} \leq$ Compression portion of the web calculated on the basis of effective section

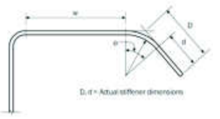
↓

$b_{e1} + b_{e2} \leq b_{Comp}$	KO	Web is fully effective	**No more iterations!**

$h_{p,eff,AS/NZS,1}$	20.024	[mm]	$h_{p,eff,AS/NZS,2}$	20.024	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,eff,AISI,1}$	20.024	=	$h_{p,eff,AS/NZS,1}$	20.024
$h_{p,eff,AISI,2}$	20.024	=	$h_{p,eff,AS/NZS,2}$	20.024

Superior Flange [$b_{p,2}$] [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

C-Section Column Dimension		
$c_{p,2}$	13.048	[mm]
$b_{p,2}$	36.596	[mm]
t	2.452	[mm]

$c_{p,2}$ = d | $b_{p,2}$ = w

$D_{Sup.\ Lip}$ 18.000 [mm]

$$S = 1.28\sqrt{E/f}$$

[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	350.000	[MPa]
S	31.353	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	b_1 = [b / 2] * [R_I]
b_1 = b_2 = w / 2	b_2 = b – b_1
d_s = d'_s	d_s = d'_s * [R_I]

w / t 14.925 Edge stiffener is needed 0.328 * S 10.284

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \le t^4\left[115\frac{w/t}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4-8]

I_a	46.778	[mm^4]	≤	2159.563	→	OK

$$(R_I) = I_s/I_a \le 1$$

[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AISI S100, Eq. B4-10]

$Ø_1$	90.000	[º]	→	I_s	10014.749	[mm^4]	
[R_I]	214.092	≤ 1.000	→	KO	→	[R_I]	1.000

b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b_e = b	b_1 = [b_e / 2] * [I_s / I_a]
b_1 = b_2 = b / 2	b_2 = b_e – b_1
d_s = d_{se}	d_s = d_{se} * [I_s / I_a]

b / t 14.925 Edge stiffener is needed 0.328 * S 10.284

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \le t^4\left[115\frac{(b/t)}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(11)]

I_a	46.778	[mm^4]	≤	2159.563	→	OK

$$I_s/I_a \le 1$$

[AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AS/NZS 4600, Eq. 2.4.2(110)]

$Ø_1$	90.000	[º]	→	I_s	10014.749	[mm^4]	
[I_s / I_a]	214.092	≤ 1.000	→	KO	→	[I_s / I_a]	1.000

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \ge \frac{1}{3}$$

[AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140º ≥ θ ≥ 40º]

d_l / b ≤ 0.250	0.250 < d_l / b ≤ 0.800
3.570 * [I_s / I_a] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * d_l / b]] * [I_s / I_a] ^{n} + 0.430 ≤ 4.000

OK	140º ≥	$Ø_1$	90.000	[º]	≥ 40º	OK	
n	0.463	≥ 1 / 3 ?	OK	→	n	0.463	
[AS/NZS 4600, Table 2.4.2]	d_l / b	0.492	→	k	2.791	OK	

C-Section Column Dimension		
$b_{p,2}$	36.596	[mm]

NOTE b = $b_{p,2}$

E	210.000	[GPa]	t	2.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-v^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 2377.856 [MPa]

$$n = \left(0.582 - \frac{w/t}{4S}\right) \ge \frac{1}{3}$$

[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140º ≥ θ ≥ 40º]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK	140º ≥	$Ø_1$	90.000	[º]	≥ 40º	OK	
n	0.463	≥ 1 / 3 ?	OK	→	n	0.463	
[AISI S100, Table B4-1]	D / w	0.492	→	k	2.791	OK	

C-Section Column Dimension		
$b_{p,2}$	36.596	[mm]

NOTE w = $b_{p,2}$

E	210.000	[GPa]	t	2.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 2377.856 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

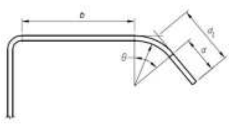
f = f_y	
350.000	[MPa]
λ	0.384

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,2,eff,AISI}$	36.596	[mm]
$b_{p,2,eff,AISI,1}$	18.298	[mm]	$b_{p,2,eff,AISI,2}$	18.298	[mm]

Superior Flange [$b_{p,2}$] [AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

C-Section Column Dimension		
$c_{p,2}$	13.048	[mm]
$b_{p,2}$	36.596	[mm]
t	2.452	[mm]

$c_{p,2}$ = d | $b_{p,2}$ = b

$d_{R,Sup.\ Lip}$ 18.000 [mm]

$$S = 1.28\sqrt{E/f^*}$$

[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	350.000	[MPa]
S	31.353	[ ]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

f* = f_y	
350.000	[MPa]
λ	0.384

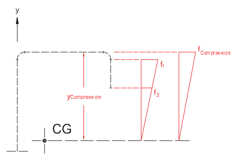
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

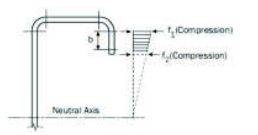
ρ	1.000	→	$b_{p,2,eff,AS/NZS}$	36.596	[mm]
$b_{p,2,eff,AS/NZS,1}$	18.298	[mm]	$b_{p,2,eff,AS/NZS,2}$	18.298	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,2,eff,AISI,1}$	18.298	=	$b_{p,2,eff,AS/NZS,1}$	18.298
$b_{p,2,eff,AISI,2}$	18.298	=	$b_{p,2,eff,AS/NZS,2}$	18.298

Superior Edge Stiffener [$c_{p,2}$] [AISI S100, Sector B3.2]



C-Section Beam: Stress Gradient



[a] Inward Facing Lip

Unstiffened Elements under Stress Gradient, Both Longitudinal Edges in Compression [AISI S100, Figure B3.2-1]

$f_{Compression,Top\ fiber}$	350.000	[MPa]		y_{CG}	43.774	[mm]
$f_{Compression}$	350.000	[MPa]	m 7.996	$f_{Tension}$	-350.000	[MPa]
f_1	320.208	[MPa]	m 7.996	f_2	215.882	[MPa]

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B3.2-1]

| ψ | 0.674

f_1 Compression

f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$

[AISI S100, Eq. B3.2-2]

k 0.570

C-Section Column Dimension		
$c_{p,2}$	13.048	[mm]

NOTE w = $c_{p,2}$

E	210.000	[GPa]	t	2.452	[mm]	v [μ]	0.300

w	13.048	[mm]	→	w / t ≤ 60	OK

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

F_{cr} 3819.949 [MPa]

[AISI S100, Eq. (B2.1-5)]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

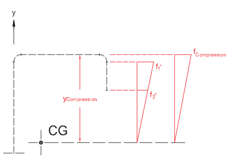
$f = f_1$	
320.208	[MPa]
λ	0.290

$$\rho = (1 - 0.22/\lambda)/\lambda$$

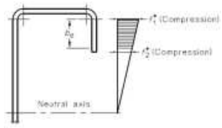
[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$c_{p,2,eff,AISI}$	13.048	[mm]

Superior Edge Stiffener [$c_{p,2}$] | [AS/NZS 4600, Clause 2.3.2]



C-Section Beam: Stress Gradient



[a] Inward Facing Lip

Unstiffened Elements with Stress Gradient: Both Edges in Compression [AS/NZS 4600, Figure B2.3.2(a)]

$f_{Compression,Top\ fiber}$	350.000	[MPa]		y_{CG}	43.774	[mm]
$f_{Compression}$	350.000	[MPa]	m 7.996	$f_{Tension}$	-350.000	[MPa]
f_1^*	320.208	[MPa]	m 7.996	f_2^*	215.882	[MPa]

$$\psi = f_2^* / f_1^*$$

ψ 0.674

[AS/NZS 4600, Eq. 2.3.2.2(1)]

f_1 Compression
f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$

k 0.570

[AS/NZS 4600, Eq. 2.3.2.2(2)]

C-Section Column Dimension

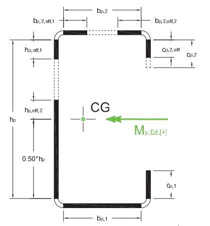
$c_{p,2}$ 13.048 [mm]

NOTE $b = c_{p,2}$

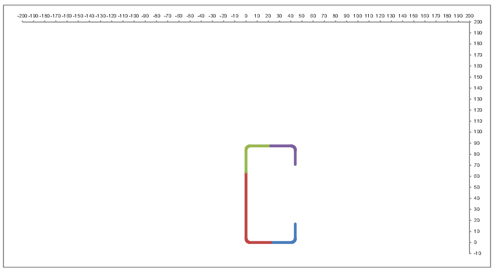
[iii] **Effective Cross C-Section Beam [Local Buckling]**

Effective C-Section Beam Widths

Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	----	[mm]
Web	$h_{p,eff,1}$	20.024	[mm]
	$h_{p,eff,2}$	20.024	[mm]
Superior Flange	$b_{p,2,eff,1}$	18.298	[mm]
	$b_{p,2,eff,2}$	18.298	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	13.048	[mm]



Effective C-Section Column [Local Buckling] [Bending Moment $M_{y,Ed}$ +] [AISI S100 | AS/NZS 4600]



Effective C-Section Column [Local Buckling] [Bending Moment $M_{y,Ed}$ +]

$I_{y,eff}$ 625036.020 [mm^4]

E	210.000	[GPa]	t	2.452	[mm]	ν	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

f_{cr} 3819.949 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$	
320.208	[MPa]
λ	0.290

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$c_{p,2,eff,AS/NZS}$	13.048	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,2,eff,AISI}$	13.048	=	$c_{p,2,eff,AS/NZS}$	13.048

[iii] **Effective C-Section Column [Local Buckling]**

Effective C-Section Column Widths [AISI S100]

Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	----	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	----	[mm]
Web	$h_{p,eff,AISI}$	80.096	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	36.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	13.048	[mm]

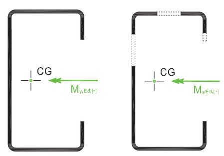
Effective C-Section Column Widths [AS/NZS 4600]

Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	----	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	----	[mm]
Web	$h_{p,eff,AS/NZS}$	80.096	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	36.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	13.048	[mm]

Effective C-Section Column Widths [AISI S100 | AS/NZS 4600]

Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	----	[mm]
Web	$h_{p,eff}$	80.096	[mm]
Superior Flange	$b_{p,2,eff}$	36.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	13.048	[mm]

[d] C-Section Strut

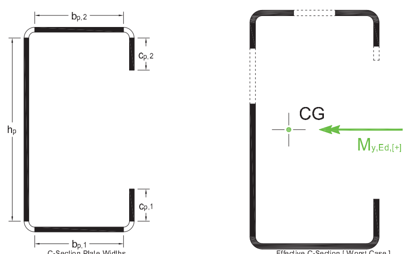


Gross C-Section | Effective C-Section [L] | Local Buckling

C-Section Strut Dimension

$c_{p,1}$	6.048	[mm]
$b_{p,1}$	32.096	[mm]
h_p	42.096	[mm]
$b_{p,2}$	32.096	[mm]
$c_{p,2}$	6.048	[mm]
t	1.452	[mm]

[i] **Effective Widths for Strength Determination [Local Buckling]** **AISI S100, Sector B | AS/NZS 4600, Section 2**



C-Section Plate Widths | Effective C-Section [Worst Case]

1st Iteration

Inferior Edge Stiffener [$c_{p,1}$] | [AISI S100, Sector B3.2]

NOTE Zone in Tension. Effective width is equal to the real width

Inferior Edge Stiffener [$c_{p,1}$] | [AS/NZS 4600, Clause 2.3.2]

NOTE Zone in Tension. Effective width is equal to the real width

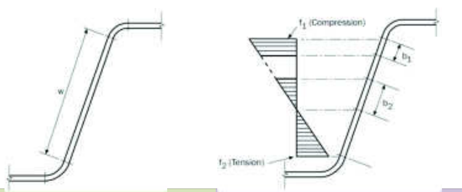
Inferior Flange [$b_{p,1}$] | [AISI S100, Sector B4]

NOTE Zone in Tension. Effective width is equal to the real width

Inferior Flange [$b_{p,1}$] [AS/NZS 4600, Clause 2.4]

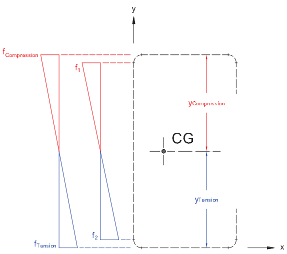
NOTE: Zone in Tension. Effective width is equal to the real width

Web [h_p] [AISI S100, Sector B2.3]

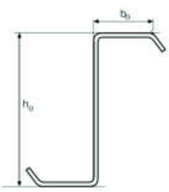


Actual Element	Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



C-Section Strut: Stress Gradient



[AISI S100, Figure B2.3-2]

h_0	50.000	[mm]
b_0	40.000	[mm]
h_0 / b_0	1.250	[ ]

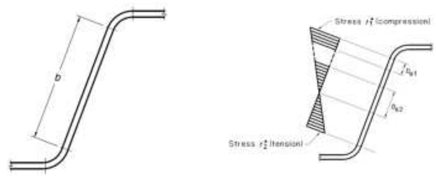
$y_{Compression}$ 24.274 [mm] $y_{Tension}$ 24.274 [mm]

Tension Stress is reached!

1º Iteration	$f_{Compression,Top fiber}$	350.000	[MPa]	y_{CG}	24.274	[mm]
$f_{Compression}$	350.000	[MPa]	m 14.419	$f_{Tension}$	-350.000	[MPa]
f_1	303.485	[MPa]	m 14.419	f_2	-303.485	[MPa]

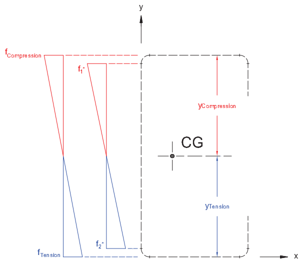
$h_{p,eff,AISI,1}$	10.524	[mm]	$h_{p,eff,AISI,2}$	10.524	[mm]

Web [h_p] [AS/NZS 4600, Clause 2.2.3]



Actual Element	Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Strut: Stress Gradient

$y_{Compression}$ 24.274 [mm] $y_{Tension}$ 24.274 [mm]

Tension Stress is reached!

1º Iteration	$f_{Compression,Top fiber}$	350.000	[MPa]	y_{CG}	24.274	[mm]
$f_{Compression}$	350.000	[MPa]	m 14.419	$f_{Tension}$	-350.000	[MPa]
f_1^*	303.485	[MPa]	m 14.419	f_2^*	-303.485	[MPa]

For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \le 4$	$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \le 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \le$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B2.3-1]

| ψ | 1.000

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$

[AISI S100, Eq. B2.3-2]

k 24.000

C-Section Strut Dimension

NOTE: $w = h_p$

h_p 42.096 [mm]

E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 5419.500 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

f = f_1: 303.485 [MPa]

λ 0.237

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ 1.000 → $h_{p,eff,AISI}$ 42.096 [mm]

$b_e = h_{p,eff,AISI}$ 42.096 [mm]

↓

h_0 / b_0 1.250

↓

| ψ | 1.000

↓

$b_1 = b_e / [3 + \psi]$ 10.524 [mm]

↓

	$h_o / b_o \le 4$			$h_o / b_o > 4$		
$\psi > 0.236$	$b_2 = b_e / 2$	21.048	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
$\psi \le 0.236$	$b_2 = b_e - b_1$	----	[mm]			

↓

$b_1 + b_2 \le w_{Comp}$ KO Web is fully effective **No more iterations!**

$$\psi = \frac{f_2^*}{f_1^*}$$

[AS/NZS 4600, Eq. 2.2.3.2(5)]

ψ -1.000

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

[AS/NZS 4600, Eq. 2.2.3.2(4)]

k 24.000

C-Section Strut

NOTE: $b = h_p$

h_p 42.096 [mm]

E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 5419.500 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 303.485 [MPa]

λ 0.237

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $h_{p,eff,AS/NZS}$ 42.096 [mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

ψ ≤ −0.236

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

ψ > −0.236

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = h_{p,Right Web,eff,AS/NZS}$ 42.096 [mm]

↓

ψ -1.000

↓

$b_{e1} = b_e / [3 - \psi]$ 10.524 [mm]

↓

ψ ≤ -0.236	$b_2 = b_e / 2$	21.048	[mm]	ψ > -0.236	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2} \le$ Compression portion of the web calculated on the basis of effective section

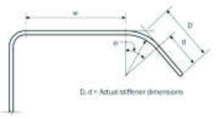
↓

$b_{e1} + b_{e2} \le b_{Comp}$ KO Web is fully effective **No more iterations!**

$h_{p,eff,AS/NZS,1}$	10.524	[mm]	$h_{p,eff,AS/NZS,2}$	10.524	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,eff,AISI,1}$	10.524	=	$h_{p,eff,AS/NZS,1}$	10.524
$h_{p,eff,AISI,2}$	10.524	=	$h_{p,eff,AS/NZS,2}$	10.524

Superior Flange [$b_{p,2}$] — [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

C-Section Strut Dimension		
$c_{p,2}$	6.048	[mm]
$b_{p,2}$	32.096	[mm]
t	1.452	[mm]

$c_{p,2} = d \mid b_{p,2} = w$

$D_{Sup, Lip}$ 10.000 [mm]

$$S = 1.28\sqrt{E/f}$$

[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	350.000	[MPa]
S	31.353	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	b_1 = [b / 2] * [R_I]
$b_1 = b_2$ = w / 2	$b_2 = b - b_1$
$d_s = d_s'$	$d_s = d_s'$ * [R_I]

w / t	22.105	Edge stiffener is needed	0.328 * S	10.284

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \le t^4\left[115\frac{w/t}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4-8]

I_a	95.042	[mm^4]	≤	382.607	→	OK

$$(R_I) = I_s/I_a \le 1$$

[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AISI S100, Eq. B4-10]

$Ø_1$	90.000	[°]	→	I_s	4000.720	[mm^4]	
[R_I]	42.094	≤ 1.000	→	KO	→	[R_I]	1.000

b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b_e = b	b_1 = [b_e / 2] * [I_s / I_a]
$b_1 = b_2$ = b / 2	$b_2 = b_e - b_1$
$d_s = d_{se}$	$d_s = d_{se}$ * [I_s / I_a]

b / t	22.105	Edge stiffener is needed	0.328 * S	10.284

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \le t^4\left[115\frac{(b/t)}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(11)]

I_a	95.042	[mm^4]	≤	382.607	→	OK

$$I_s/I_a \le 1$$

[AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AS/NZS 4600, Eq. 2.4.2(110)]

$Ø_1$	90.000	[°]	→	I_s	4000.720	[mm^4]	
[I_s / I_a]	42.094	≤ 1.000	→	KO	→	[I_s / I_a]	1.000

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \ge \frac{1}{3}$$

[AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140º ≥ θ ≥ 40º]

d_l / b ≤ 0.250	0.250 < d_l / b ≤ 0.800
3.570 * [I_s / I_a] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * d_l / b]] * [I_s / I_a] ^{n} + 0.430 ≤ 4.000

OK	140º ≥	$Ø_1$	90.000	[°]	≥ 40º	OK	
n	0.406	≥ 1 / 3 ?	OK	→	n	0.406	
[AS/NZS 4600, Table 2.4.2]	d_l / b	0.312	→	k	3.692	OK	

C-Section Strut Dimension			NOTE	b = $b_{p,2}$
$b_{p,2}$	32.096	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 1434.201 [MPa]

$$n = \left(0.582 - \frac{w/t}{4S}\right) \ge \frac{1}{3}$$

[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140º ≥ θ ≥ 40º]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK	140º ≥	$Ø_1$	90.000	[°]	≥ 40º	OK	
n	0.406	≥ 1 / 3 ?	OK	→	n	0.406	
[AISI S100, Table B4-1]	D / w	0.312	→	k	3.692	OK	

C-Section Strut Dimension			NOTE	w = $b_{p,2}$
$b_{p,2}$	32.096	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 1434.201 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

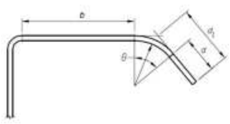
f = f_y	
350.000	[MPa]
λ	0.494

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,2,eff,AISI}$	32.096	[mm]
$b_{p,2,eff,AISI,1}$	16.048	[mm]	$b_{p,2,eff,AISI,2}$	16.048	[mm]

Superior Flange [$b_{p,2}$] — [AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

C-Section Strut Dimension		
$c_{p,2}$	6.048	[mm]
$b_{p,2}$	32.096	[mm]
t	1.452	[mm]

$c_{p,2} = d \mid b_{p,2} = b$

$d_{R,Sup, Lip}$ 10.000 [mm]

$$S = 1.28\sqrt{E/f^*}$$

[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	350.000	[MPa]
S	31.353	[ ]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

f* = f_y	
350.000	[MPa]
λ	0.494

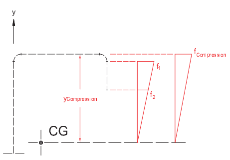
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

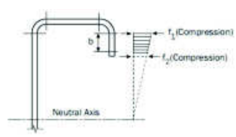
ρ	1.000	→	$b_{p,2,eff,AS/NZS}$	32.096	[mm]
$b_{p,2,eff,AS/NZS,1}$	16.048	[mm]	$b_{p,2,eff,AS/NZS,2}$	16.048	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,2,eff,AISI,1}$	16.048	=	$b_{p,2,eff,AS/NZS,1}$	16.048
$b_{p,2,eff,AISI,2}$	16.048	=	$b_{p,2,eff,AS/NZS,2}$	16.048

Superior Edge Stiffener [$c_{p,2}$] — [AISI S100, Sector B3.2]



C-Section Beam: Stress Gradient



[a] Inward Facing Lip

Unstiffened Elements under Stress Gradient, Both Longitudinal Edges in Compression [AISI S100, Figure B3.2-1]

$f_{Compression,Top\ fiber}$	350.000	[MPa]			y_{CG}	24.274	[mm]
$f_{Compression}$	350.000	[MPa]	m	14.419	$f_{Tension}$	-350.000	[MPa]
f_1	303.485	[MPa]	m	14.419	f_2	216.281	[MPa]

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B3.2-1]

| ψ | 0.713

f_1	Compression
f_2	Compression

$$k = \frac{0.578}{\psi + 0.34}$$

[AISI S100, Eq. B3.2-2]

k 0.549

C-Section Strut Dimension			NOTE	w = $c_{p,2}$
$c_{p,2}$	6.048	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

w	6.048	[mm]	→	w / t ≤ 60	OK

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 6006.855 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$

303.485 [MPa]

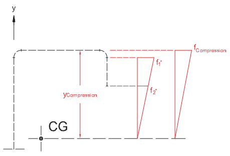
λ 0.225

$$\rho = (1 - 0.22/\lambda)/\lambda$$

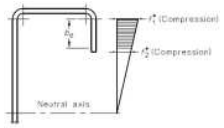
[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$c_{p,2,eff,AISI}$	6.048	[mm]

Superior Edge Stiffener [$c_{p,2}$] — [AS/NZS 4600, Clause 2.3.2]



C-Section Beam: Stress Gradient



[a] Inward Facing Lip

Unstiffened Elements with Stress Gradient: Both Edges in Compression [AS/NZS 4600, Figure B2.3.2(a)]

$f_{Compression,Top\ fiber}$	350.000	[MPa]	y_{CG}	24.274	[mm]

$f_{Compression}$	350.000	[MPa]	m	14.419	$f_{Tension}$	-350.000	[MPa]
f_1^*	303.485	[MPa]	m	14.419	f_2^*	216.281	[MPa]

$$\psi = f_2^* / f_1^*$$

ψ 0.713

[AS/NZS 4600, Eq. 2.3.2.2(1)]

f_1 Compression
f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$

k 0.549

[AS/NZS 4600, Eq. 2.3.2.2(2)]

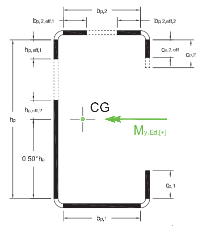
C-Section Strut Dimension

$c_{p,2}$ 6.048 [mm]

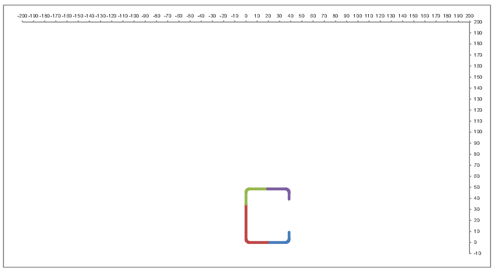
NOTE $b = c_{p,2}$

[iii] **Effective Cross C-Section Strut [Local Buckling]**

Effective C-Section Strut Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	----	[mm]
Web	$h_{p,eff,1}$	10.524	[mm]
	$h_{p,eff,2}$	10.524	[mm]
Superior Flange	$b_{p,2,eff,1}$	16.048	[mm]
	$b_{p,2,eff,2}$	16.048	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	6.048	[mm]



Effective C-Section Strut [Local Buckling] [Bending Moment $M_{x,Ed}^+$] [AISI S100 | AS/NZS 4600]



Effective C-Section Strut [Local Buckling] [Bending Moment $M_{x,Ed}^+$]

$I_{x,eff}^{[+]}$ 85435.109 [mm^4]

E	210.000	[GPa]	t	1.452	[mm]	v	0.300	

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 6006.855 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$

303.485 [MPa]

λ 0.225

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$c_{p,2,eff,AS/NZS}$	6.048	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,2,eff,AISI}$	6.048	=	$c_{p,2,eff,AS/NZS}$	6.048

[ii] **Effective C-Section Strut [Local Buckling]**

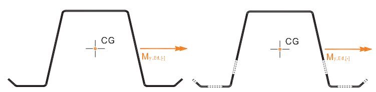
Effective C-Section Strut Widths [AISI S100]			
Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	----	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	----	[mm]
Web	$h_{p,eff,AISI}$	42.096	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	32.096	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	6.048	[mm]

Effective C-Section Strut Widths [AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	----	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	----	[mm]
Web	$h_{p,eff,AS/NZS}$	42.096	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	32.096	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	6.048	[mm]

Effective C-Section Strut Widths [AISI S100 | AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	----	[mm]
Web	$h_{p,eff}$	42.096	[mm]
Superior Flange	$b_{p,2,eff}$	32.096	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	6.048	[mm]

[11.4] Cold-Formed Section subjected to Negative Moment in x-x axis [$M_{x,Ed}^-$]

[a] Ω-Section Purlin

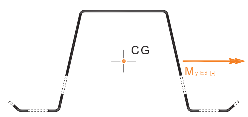


Gross Ω-Section

Effective Ω-Section [L]

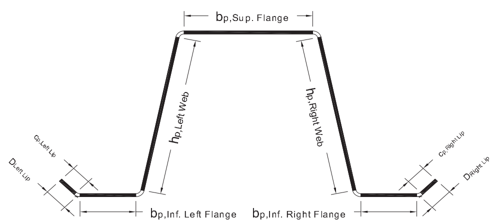
Local Buckling

[i] **Effective Widths for Strength Determination [Local Buckling]** — **AISI S100, Sector B | AS/NZS 4600, Section 2**



Effective Ω-Section [Worst Case]

Ω-Section Purlin Dimension		
$c_{p,Right\ Lip}$	6.191	[mm]
$b_{p,Inf.\ Right\ Flange}$	16.545	[mm]
$h_{p,Right\ Web}$	51.640	[mm]
$b_{p,Sup.\ Web}$	38.171	[mm]
$h_{p,Left\ Web}$	51.640	[mm]
$b_{p,Inf.\ Left\ Flange}$	16.545	[mm]
$c_{p,Left\ Lip}$	6.191	[mm]



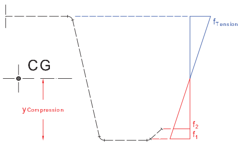
Ω-Section Plate Widths

$y_{Compression}$	25.652	[mm]	$y_{Tension}$	28.089	[mm]

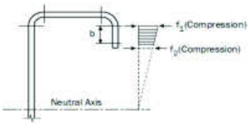
Tension Stress is reached!

1º Iteration

Right Edge Stiffner [$c_{p,Right\ Lip}$] [AISI S100, Sector B3.2]



Ω-Section Purlin: Stress Gradient



[a] Inward Facing Lip

Unstiffened Elements under Stress Gradient, Both Longitudinal Edges in Compression [AISI S100, Figure B3.2-1]

$f_{Tension,Top fiber}$	350.000	[MPa]			y_{CG}	25.652	[mm]
$f_{Compression}$	319.633	[MPa]	m	12.460	$f_{Tension}$	-350.000	[MPa]
f_1	312.421	[MPa]	m	12.460	f_2	257.870	[MPa]

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B3.2-1]

| ψ | | 0.825

f_1 Compression
f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$

[AISI S100, Eq. B3.2-2]

k 0.496

Ω-Section Purlin Dimension			NOTE	$w = c_{p,Right Lip}$
$c_{p,Right Lip}$	6.191	[mm]		

E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300
w	6.191	[mm]	→	w / t ≤ 60	OK		

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 2225.563 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$
312.421 [MPa]
λ 0.375

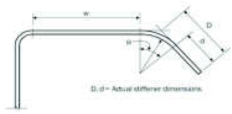
$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$c_{p,Right Lip,eff,AISI}$	6.191	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,Right Lip,eff,AISI}$	6.191	=	$c_{p,Right Lip,eff,AS/NZS}$	6.191

Inferior Right Flange [$b_{p,Inf. Right Flange}$] [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

Ω-Section Purlin Dimension		
$c_{p,Right Lip}$	6.191	[mm]
$b_{p,Inf. Right Flange}$	16.545	[mm]
t	0.952	[mm]

$c_{p,Right Lip} = d$ | $b_{p,Inf. Right Flange} = w$

$D_{Right Lip}$ 7.207 [mm]

$f_{Tension,Top fiber}$	350.000	[MPa]			y_{CG}	25.652	[mm]
$f_{Compression}$	319.633	[MPa]	m	12.460	$f_{Tension}$	-350.000	[MPa]

$$S = 1.28\sqrt{E/f}$$

[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	319.633	[MPa]
S	32.809	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	$b_1 = [b / 2] * [R_I]$
$b_1 = b_2 = w / 2$	$b_2 = b - b_1$
$d_s = d'_s$	$d_s = d'_s * [R_I]$

w / t 17.379 Edge stiffener is needed 0.328 * S 10.761

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \le t^4\left[115\frac{w/t}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4-8]

I_a 2.690 [mm^4] ≤ 54.143 → OK

$$(R_I) = I_s/I_a \le 1$$

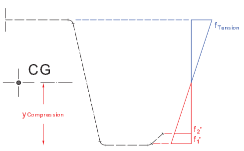
[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$

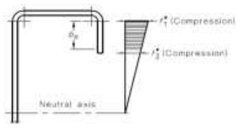
[AISI S100, Eq. B4-10]

$Ø_1$ 45.000 [°] → I_s 179.657 [mm^4]

Right Edge Stiffner [$c_{p,Right Lip}$] [AS/NZS 4600, Clause 2.3.2]



Ω-Section Purlin: Stress Gradient



[a] Inward Facing Lip

Unstiffened Elements with Stress Gradient: Both Edges in Compression [AS/NZS 4600, Figure B2.3.2(a)]

$f_{Tension,Top fiber}$	350.000	[MPa]			y_{CG}	25.652	[mm]
$f_{Compression}$	319.633	[MPa]	m	12.460	$f_{Tension}$	-350.000	[MPa]
f_1^*	312.421	[MPa]	m	12.460	f_2^*	257.870	[MPa]

$$\psi = f_2^* / f_1^*$$

ψ 0.825

[AS/NZS 4600, Eq. 2.3.2.2(1)]

f_1 Compression
f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$

[AS/NZS 4600, Eq. 2.3.2.2(2)]

k 0.496

Ω-Section Purlin Dimension			NOTE	$b = c_{p,Right Lip}$
$c_{p,Right Lip}$	6.191	[mm]		

E	210.000	[GPa]	t	0.952	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 2225.563 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$
312.421 [MPa]
λ 0.375

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$c_{p,Right Lip,eff,AS/NZS}$	6.191	[mm]

[R_I] 66.790 ≤ 1.000 → KO → [R_I] 1.000

$$n = \left(0.582 - \frac{w/t}{4S}\right) \ge \frac{1}{3}$$

[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140º ≥ θ ≥ 40º]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK	140º ≥	$Ø_1$	45.000	[º]	≥ 40º	OK	
n	0.450	≥ 1 / 3 ?	OK	→	n	0.450	
[AISI S100, Table B4-1]		D / w	0.436	→	k	3.072	OK

Ω-Section Purlin Dimension			NOTE	$w = b_{p,Inf. Right Flange}$
$b_{p,Inf. Right Flange}$	16.545	[mm]		

E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 1930.391 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

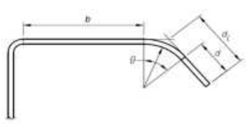
$f = f_y$
319.633 [MPa]
λ 0.407

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,Inf. Right Flange,eff,AISI}$	16.545	[mm]
$b_{p,Inf. Right Flange,eff,AISI,1}$	8.273	[mm]	$b_{p,Inf. Right Flange,eff,AISI,2}$	8.273	[mm]

Inferior Right Flange [$b_{p,Inf. Right Flange}$] [AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

Ω-Section Purlin Dimension		
$c_{p,Right Lip}$	6.191	[mm]
$b_{p,Inf. Right Flange}$	16.545	[mm]
t	0.952	[mm]

$c_{p,Right Lip} = d$ | $b_{p,Inf. Right Flange} = b$

$d_{R,Right Lip}$ 7.207 [mm]

$f_{Tension,Top fiber}$	350.000	[MPa]	y_{CG}	25.652	[mm]

$f_{Compression}$	319.633	[MPa]	m	12.460	$f_{Tension}$	-350.000 [MPa]

$$S = 1.28\sqrt{E/f^*}$$

[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	319.633	[MPa]
S	32.809	[ ]

b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
$b_e = b$	$b_1 = [b_e / 2] * [I_s / I_a]$
$b_1 = b_2 = b / 2$	$b_2 = b_e - b_1$
$d_s = d_{se}$	$d_s = d_{se} * [I_s / I_a]$

b / t	17.379	Edge stiffener is needed	0.328 * S	10.761

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \le t^4\left[115\frac{(b/t)}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(11)]

I_a	2.690	[mm^4]	≤	54.143	→	OK

$$I_s / I_a \le 1$$

[AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AS/NZS 4600, Eq. 2.4.2(110)]

$Ø_1$	45.000	[º]	→	I_s	179.657	[mm^4]
[I_s / I_a]	66.790	≤ 1.000	→	KO	→	[I_s / I_a] 1.000

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \ge \frac{1}{3}$$

[AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140º ≥ θ ≥ 40º]

d_l / b ≤ 0.250	0.250 < d_l / b ≤ 0.800
3.570 * [I_s / I_a] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * d_l / b]] * [I_s / I_a] ^{n} + 0.430 ≤ 4.000

OK	140º ≥	$Ø_1$	45.000	[º]	≥ 40º	OK
n	0.450	≥ 1 / 3 ?	OK	→	n	0.450
[AS/NZS 4600, Table 2.4.2]	d_l / b	0.436	→	k	3.072	OK

Ω-Section Purlin Dimension — **NOTE** $b = b_{p,Inf.\ Right\ Flange}$

$b_{p,Inf.\ Right\ Flange}$	16.545	[mm]

E	210.000	[GPa]	t	0.952	[mm]	v	0.300

$y_{Compression}$	25.652	[mm]	$y_{Tension}$	28.089	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Top\ fiber}$	**350.000**	**[MPa]**	y_{CG}	**25.652**	**[mm]**
$f_{Compression}$	319.633 [MPa]	m	12.460	$f_{Tension}$	-350.000	[MPa]

h_0	55.835	[mm]
b_0	42.170	[mm]
h_0 / b_0	1.324	[ ]

Out-to-Out Dimensions of Webs and Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-2]

For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \le 4$	$h_o / b_o > 4$
	$b_1 = b_e / [3 + ψ]$	$b_1 = b_e / [3 + ψ]$
ψ > 0.236	$b_2 = b_e / 2$	$b_2 = b_e / [1 + ψ] - b_1$
ψ ≤ 0.236	$b_2 = b_e - b_1$	

$b_1 + b_2$ ≤ Compression portion of the web calculated on the basis of effective section

f_1	299.965	[MPa]	m	12.460	f_2	-330.332 [MPa]

$$ψ = |f_2/f_1|$$

[AISI S100, Eq. B2.3-1]

| ψ | 1.101

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1 + ψ)^3 + 2(1 + ψ)$$

k 26.757

[AISI S100, Eq. B2.3-2]

Ω-Section Purlin Dimension — **NOTE** $w = h_{p,Right\ Web}$

$h_{p,Right\ Web}$	51.640	[mm]

E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 1725.960 [MPa]

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 1930.391 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

f* = f_y	
319.633	[MPa]
λ	0.407

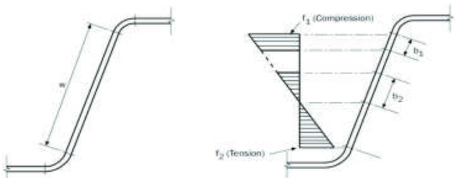
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,Inf.\ Right\ Flange,eff,AS/NZS}$	16.545	[mm]
$b_{p,Inf.\ Right\ Flange,eff,AS/NZS,1}$	8.273 [mm]		$b_{p,Inf.\ Right\ Flange,eff,AS/NZS,2}$	8.273	[mm]

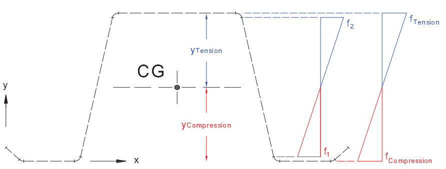
AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,Inf.\ Right\ Flange,eff,AISI,1}$	8.273	=	$b_{p,Inf.\ Right\ Flange,eff,AS/NZS,1}$	8.273
$b_{p,Inf.\ Right\ Flange,eff,AISI,2}$	8.273	=	$b_{p,Inf.\ Right\ Flange,eff,AS/NZS,2}$	8.273

Right Web [$h_{p,Right\ Web}$] — [AISI S100, Sector B2.3]



Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



Ω-Section Purlin: Stress Gradient

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

f = f_1	
299.965	[MPa]
λ	0.417

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$h_{p,Right\ Web,eff,AISI}$	51.640	[mm]

$b_e = h_{p,Right\ Web,eff,AISI}$ 51.640 [mm]

↓

h_0 / b_0 1.324

↓

| ψ | 1.101

↓

$b_1 = b_e / [3 + ψ]$ 12.591 [mm]

↓

	$h_o / b_o \le 4$			$h_o / b_o > 4$		
ψ > 0.236	$b_2 = b_e / 2$	25.820	[mm]	$b_2 = b_e / [1 + ψ] - b_1$	----	[mm]
ψ ≤ 0.236	$b_2 = b_e - b_1$	----	[mm]			

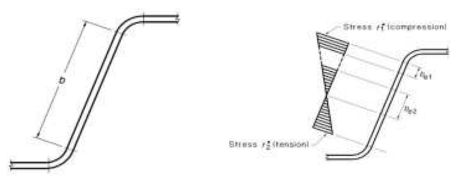
↓

$b_1 + b_2 \le w_{Comp}$	KO	Web is fully effective	No more iterations!

↓

$h_{p,Right\ Web,eff,AISI,1}$	12.591	[mm]	$h_{p,Right\ Web,eff,AISI,2}$	11.985	[mm]

Right Web [$h_{p,Right\ Web}$] — [AS/NZS 4600, Clause 2.2.3]



Actual Element | Effective element and stress on effective Element

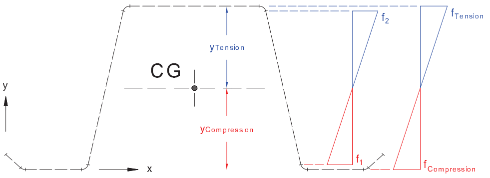
Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]

$y_{Compression}$	25.652	[mm]	$y_{Tension}$	28.089	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Top\ fiber}$	**350.000**	**[MPa]**	y_{CG}	**25.652**	**[mm]**

$f_{Compression}$	319.633	[MPa]	m	12.205	$f_{Tension}$	-350.000	[MPa]



Ω-Section Purlin: Stress Gradient

f_1^*	299.965	[MPa]	m	12.205	f_2^*	-330.332	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$ ψ -1.101

[AS/NZS 4600, Eq. 2.2.3.2(5)]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$ k 26.757

[AS/NZS 4600, Eq. 2.2.3.2(4)]

Ω-Section Purlin Dimension			NOTE	$b = h_{p,Right\ Web}$
$h_{p,Right\ Web}$	51.640	[mm]		

E	210.000	[GPa]	t	0.952	[mm]	v	0.300	

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$ f_{cr} 1725.960 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

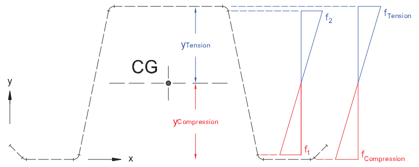
$f^* = f_1^*$: 299.965 [MPa]

λ 0.417

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$h_{p,Right\ Web,eff,AS/NZS}$	51.640	[mm]



Ω-Section Purlin: Stress Gradient

$y_{Compression}$	25.652	[mm]	$y_{Tension}$	28.089	[mm]

Tension Stress is reached!

1° Iteration	$f_{Tension,Top\ fiber}$	350.000	[MPa]	y_{CG}	25.652	[mm]

$f_{Compression}$	319.633	[MPa]	m	12.460	$f_{Tension}$	-350.000	[MPa]

h_0	55.835	[mm]
b_0	42.170	[mm]
h_0 / b_0	1.324	[ ]

Out-to-Out Dimensions of Webs and Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-2]

For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \leq 4$	$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \leq 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \leq$ Compression portion of the web calculated on the basis of effective section

f_1	299.965	[MPa]	m	12.460	f_2	-330.332	[MPa]

$$\psi = |f_2 / f_1|$$ | ψ | 1.101

[AISI S100, Eq. B2.3-1]

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$ k 26.757

[AISI S100, Eq. B2.3-2]

Ω-Section Purlin Dimension			NOTE	$w = h_{p,Left\ Web}$
$h_{p,Left\ Web}$	51.640	[mm]		

$$b_{e1} = \frac{b_e}{3 - \psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

$\psi \leq -0.236$

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

$\psi > -0.236$

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = h_{p,Right\ Web,eff,AS/NZS}$	51.640	[mm]

↓

ψ	-1.101

↓

$b_{e1} = b_e / [3 - \psi]$	12.591	[mm]

↓

ψ ≤ -0.236	$b_2 = b_e / 2$	25.820	[mm]	ψ > -0.236	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2} \leq$ Compression portion of the web calculated on the basis of effective section

↓

$b_{e1} + b_{e2} \leq b_{Comp}$	KO	Web is fully effective	No more iterations!

↓

$h_{p,Right\ Web,eff,AS/NZS,1}$	12.591	[mm]	$h_{p,Right\ Web,eff,AS/NZS,2}$	11.985	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,Right\ Web,eff,AISI,1}$	12.591	=	$h_{p,Right\ Web,eff,AS/NZS,1}$	12.591
$h_{p,Right\ Web,eff,AISI,2}$	11.985	=	$h_{p,Right\ Web,eff,AS/NZS,2}$	11.985

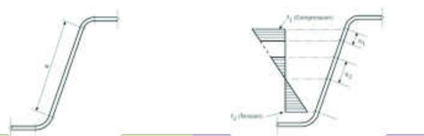
Superior Flange [$b_{p,Sup.\ Flange}$] [AISI S100, Sector B2.1]

NOTE Zone in Tension. Effective width is equal to the real width

Superior Flange [$b_{p,Sup.\ Flange}$] [AS/NZS 4600, Clause 2.2.1]

NOTE Zone in Tension. Effective width is equal to the real width

Left Web [$h_{p,Left\ Web}$] [AISI S100, Sector B2.3]



Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]

E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300	

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$ F_{cr} 1725.960 [MPa]

[AISI S100, Eq. (B2.1-5)]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$: 299.965 [MPa]

λ 0.417

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$h_{p,Left\ Web,eff,AISI}$	51.640	[mm]

$b_e = h_{p,Left\ Web,eff,AISI}$	51.640	[mm]

↓

h_0 / b_0	1.324

↓

| ψ |	1.101

↓

$b_1 = b_e / [3 + \psi]$	12.591	[mm]

↓

$h_o / b_o \leq 4$				$h_o / b_o > 4$		
ψ > 0.236	$b_2 = b_e / 2$	25.820	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
ψ ≤ 0.236	$b_2 = b_e - b_1$	----	[mm]			

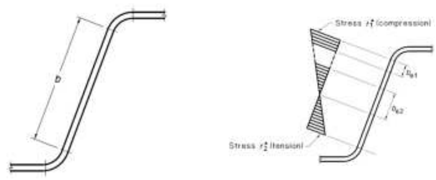
↓

$b_1 + b_2 \leq w_{Comp}$	KO	Web is fully effective	No more iterations!

↓

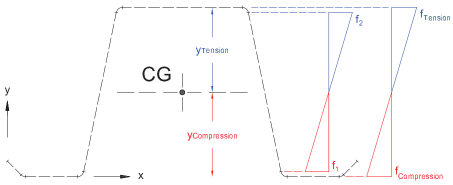
$h_{p,Left\ Web,eff,AISI,1}$	12.591	[mm]	$h_{p,Left\ Web,eff,AISI,2}$	11.985	[mm]

Left Web [$h_{p,Left\ Web}$] [AS/NZS 4600, Clause 2.2.3]



Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



Ω-Section Purlin: Stress Gradient

$y_{Compression}$	25.652	[mm]	$y_{Tension}$	28.089	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Top\ fiber}$	**350.000**	**[MPa]**	y_{CG}	**25.652**	**[mm]**
$f_{Compression}$	**319.633**	**[MPa]**	m 12.205	$f_{Tension}$	**-350.000**	**[MPa]**
f_1^*	**299.965**	**[MPa]**	m 12.205	f_2^*	**-330.332**	**[MPa]**

$$\psi = \frac{f_2^*}{f_1^*}$$ ψ -1.101

[AS/NZS 4600, Eq. 2.2.3.2(5)]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$ k 26.757

[AS/NZS 4600, Eq. 2.2.3.2(4)]

Ω-Section Purlin Dimension			NOTE	$b = h_{p,Left\ Web}$
$h_{p,Left\ Web}$	51.640	[mm]		

E	210.000	[GPa]	t	0.952	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$ f_{cr} 1725.960 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$f_{Compression}$	**319.633**	**[MPa]**	m 12.460	$f_{Tension}$	**-350.000**	**[MPa]**

$$S = 1.28\sqrt{E/f}$$

[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	319.633	[MPa]
S	32.809	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	b_1 = [b / 2] * [R_I]
$b_1 = b_2$ = w / 2	$b_2 = b - b_1$
$d_s = d_s'$	$d_s = d_s'$ * [R_I]

w / t	17.379	Edge stiffener is needed	0.328 * S	10.761

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \le t^4\left[115\frac{w/t}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4-8]

I_a	2.690	[mm^4]	≤	54.143	→	OK

$$(R_I) = I_s/I_a \le 1$$

[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AISI S100, Eq. B4-10]

$Ø_B$	45.000	[º]	→	I_s	179.657	[mm^4]
[R_I]	66.790	≤ 1.000	→	KO	→	[R_I] 1.000

$$n = \left(0.582 - \frac{w/t}{4S}\right) \ge \frac{1}{3}$$

[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140º ≥ θ ≥ 40º]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK	140º ≥	$Ø_B$	45.000	[º]	≥ 40º	OK	
n	0.450	≥ 1 / 3 ?	OK	→	n	0.450	
[AISI S100, Table B4-1]		D / w	0.436	→	k	3.072	OK

Ω-Section Purlin Dimension			NOTE	$w = b_{p,Inf.\ Left\ Flange}$
$b_{p,Inf.\ Left\ Flange}$	16.545	[mm]		

E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$

299.965 [MPa]

λ 0.417

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$h_{p,Left\ Web,eff,AS/NZS}$	51.640	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

ψ ≤ −0.236

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

ψ > −0.236

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = h_{p,Left\ Web,eff,AS/NZS}$ 51.640 [mm]

↓

ψ -1.101

↓

$b_{e1} = b_e$ / [3 - ψ] 12.591 [mm]

↓

ψ ≤ -0.236	$b_2 = b_e$ / 2	25.820	[mm]	ψ > -0.236	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2}$ ≤ Compression portion of the web calculated on the basis of effective section

↓

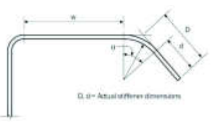
$b_{e1} + b_{e2} \le b_{Comp}$	KO	Web is fully effective	**No more iterations!**

↓

$h_{p,Left\ Web,eff,AS/NZS,1}$	12.591	[mm]	$h_{p,Left\ Web,eff,AS/NZS,2}$	11.985	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,Left\ Web,eff,AISI,1}$	12.591	=	$h_{p,Left\ Web,eff,AS/NZS,1}$	12.591
$h_{p,Left\ Web,eff,AISI,2}$	11.985	=	$h_{p,Left\ Web,eff,AS/NZS,2}$	11.985

Inferior Left Flange [$b_{p,Inf.\ Left\ Flange}$] [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

Ω-Section Purlin Dimension		
$c_{p,Left\ Lip}$	6.191	[mm]
$b_{p,Inf.\ Left\ Flange}$	16.545	[mm]
t	0.952	[mm]

$c_{p,Left\ Lip}$ = d | $b_{p,Inf.\ Left\ Flange}$ = w

$D_{Right\ Lip}$	7.207	[mm]

$f_{Tension,Top\ fiber}$	**350.000**	**[MPa]**	y_{CG}	**25.652**	**[mm]**

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$ F_{cr} 1930.391 [MPa]

[AISI S100, Eq. (B2.1-5)]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$

319.633 [MPa]

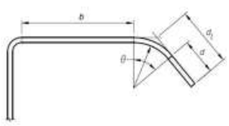
λ 0.407

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,Inf.\ Left\ Flange,eff,AISI}$	16.545	[mm]
$b_{p,Inf.\ Left\ Flange,eff,AISI,1}$	8.273	[mm]	$b_{p,Inf.\ Left\ Flange,eff,AISI,2}$	8.273	[mm]

Inferior Left Flange [$b_{p,Inf.\ Left\ Flange}$] [AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

Ω-Section Purlin Dimension		
$c_{p,Left\ Lip}$	6.191	[mm]
$b_{p,Inf.\ Left\ Flange}$	16.545	[mm]
t	0.952	[mm]

$c_{p,Left\ Lip}$ = d | $b_{p,Inf.\ Left\ Flange}$ = b

$d_{R,Right\ Lip}$	7.207	[mm]

$f_{Tension,Top\ fiber}$	**350.000**	**[MPa]**		y_{CG}	**25.652**	**[mm]**
$f_{Compression}$	**319.633**	**[MPa]**	m 12.460	$f_{Tension}$	**-350.000**	**[MPa]**

$$S = 1.28\sqrt{E/f^*}$$

[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	319.633	[MPa]
S	32.809	[ ]

b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b_e = b	b_1 = [b_e / 2] * [I_s / I_a]
$b_1 = b_2$ = b / 2	$b_2 = b_e - b_1$
$d_s = d_{se}$	$d_s = d_{se}$ * [I_s / I_a]

b / t	17.379	Edge stiffener is needed	0.328 * S	10.761

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \le t^4\left[115\frac{(b/t)}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(11)]

I_a	2.690	[mm^4]	≤	54.143	→	OK

$$I_s/I_a \le 1$$ [AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$ [AS/NZS 4600, Eq. 2.4.2(110)]

$Ø_8$	45.000	[°]	→	I_s	179.657	[mm^4]	
[I_s / I_a]	66.790	≤ 1.000	→	KO	→	[I_s / I_a]	1.000

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \ge \frac{1}{3}$$ [AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140º ≥ θ ≥ 40º]

d_l / b ≤ 0.250	0.250 < d_l / b ≤ 0.800
3.570 * [I_s / I_a] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * d_l / b]] * [I_s / I_a] ^{n} + 0.430 ≤ 4.000

OK	140º ≥	$Ø_8$	45.000	[°]	≥ 40º	OK	
n	0.450	≥ 1 / 3 ?	OK	→	n	0.450	
[AS/NZS 4600, Table 2.4.2]		d_l / b	0.436	→	k	3.072	OK

Ω-Section Purlin Dimension — **NOTE** b = $b_{p,Inf. Left Flange}$

$b_{p,Inf. Left Flange}$	16.545	[mm]					
E	210.000	[GPa]	t	0.952	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$ [AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 1930.391 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$ [AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1$: 319.633 [MPa]; λ 0.407

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$ [AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,Inf. Left Flange,eff,AS/NZS}$	16.545	[mm]
$b_{p,Inf. Left Flange,eff,AS/NZS,1}$	8.273	[mm]	$b_{p,Inf. Left Flange,eff,AS/NZS,2}$	8.273	[mm]

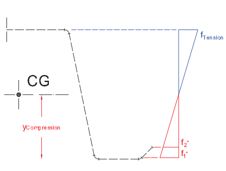
$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$ [AISI S100, Eq. B2.1-4]

$f = f_1$: 312.421 [MPa]; λ 0.375

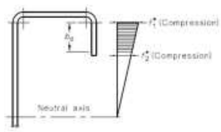
$$\rho = (1 - 0.22/\lambda)/\lambda$$ [AISI S100, Eq. B2.1-4]

ρ	1.000	→	$c_{p,Left Lip,eff,AISI}$	6.191	[mm]

Left Edge Stiffener [$c_{p,Left Lip}$] — [AS/NZS 4600, Clause 2.3.2]



Ω-Section Purlin: Stress Gradient



[a] Inward Facing Lip

Unstiffened Elements with Stress Gradient: Both Edges in Compression [AS/NZS 4600, Figure B2.3.2(a)]

$f_{Tension,Top fiber}$	350.000	[MPa]			y_{CG}	25.652	[mm]
$f_{Compression}$	319.633	[MPa]	m	12.460	$f_{Tension}$	-350.000	[MPa]
f_1^*	312.421	[MPa]	m	12.460	f_2^*	257.870	[MPa]

$$\psi = f_2^* / f_1^*$$ [AS/NZS 4600, Eq. 2.3.2.2(1)]

ψ 0.825

f_1 Compression; f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$ [AS/NZS 4600, Eq. 2.3.2.2(2)]

k 0.496

Ω-Section Purlin Dimension — **NOTE** b = $c_{p,Left Lip}$

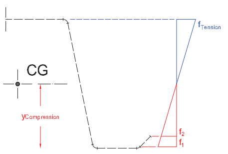
$c_{p,Left Lip}$	6.191	[mm]					
E	210.000	[GPa]	t	0.952	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$ [AS/NZS 4600, Eq. 2.2.1.2(5)]

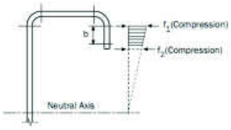
f_{cr} 2225.563 [MPa]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,Inf. Left Flange,eff,AISI,1}$	8.273	=	$b_{p,Inf. Left Flange,eff,AS/NZS,1}$	8.273
$b_{p,Inf. Left Flange,eff,AISI,2}$	8.273	=	$b_{p,Inf. Left Flange,eff,AS/NZS,2}$	8.273

Left Edge Stiffener [$c_{p,Left Lip}$] — [AISI S100, Sector B3.2]



Ω-Section Purlin: Stress Gradient



[a] Inward Facing Lip

Unstiffened Elements under Stress Gradient, Both Longitudinal Edges in Compression [AISI S100, Figure B3.2-1]

$f_{Tension,Top fiber}$	350.000	[MPa]			y_{CG}	25.652	[mm]
$f_{Compression}$	319.633	[MPa]	m	12.460	$f_{Tension}$	-350.000	[MPa]
f_1	312.421	[MPa]	m	12.460	f_2	257.870	[MPa]

$$\psi = |f_2/f_1|$$ [AISI S100, Eq. B3.2-1]

| ψ | 0.825

f_1 Compression; f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$ [AISI S100, Eq. B3.2-2]

k 0.496

Ω-Section Purlin Dimension — **NOTE** w = $c_{p,Left Lip}$

$c_{p,Left Lip}$	6.191	[mm]					
E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300
w	6.191	[mm]	→	w / t ≤ 60	OK		

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$ [AISI S100, Eq. (B2.1-5)]

F_{cr} 2225.563 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$ [AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 312.421 [MPa]; λ 0.375

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$ [AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$c_{p,Left Lip,eff,AS/NZS}$	6.191	[mm]

AISI S100, Effective Width		Comparison [= or ≠]	AS/NZS 4600, Effective Width	
$c_{p,Left Lip,eff,AISI}$	6.191	=	$c_{p,Left Lip,eff,AS/NZS}$	6.191

[ii] **Effective Ω-Section Purlin [Local Buckling]**

Effective Ω-Section Purlin Widths [AISI S100]

Right Edge Stiffener	$c_{p,Right Lip,eff,AISI}$	6.191	[mm]
Inferior Right Flange	$b_{p,Inf. Right Flange,eff,AISI}$	16.545	[mm]
Right Web	$h_{p,Right Web,eff,AISI}$	51.640	[mm]
Superior Flange	$b_{p,Sup. Flange,eff,AISI}$	----	[mm]
Left Web	$h_{p,Left Web,eff,AISI}$	51.640	[mm]
Inferior Left Flange	$b_{p,Inf. Left Flange,eff,AISI}$	16.545	[mm]
Left Edge Stiffener	$c_{p,Left Lip,eff,AISI}$	6.191	[mm]

Effective Ω-Section Purlin Widths [AS/NZS 4600]

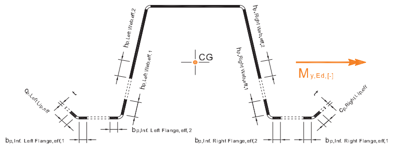
Right Edge Stiffener	$c_{p,Right Lip,eff,AS/NZS}$	6.191	[mm]
Inferior Right Flange	$b_{p,Inf. Right Flange,eff,AS/NZS}$	16.545	[mm]
Right Web	$h_{p,Right Web,eff,AS/NZS}$	51.640	[mm]
Superior Flange	$b_{p,Sup. Flange,eff,AS/NZS}$	----	[mm]
Left Web	$h_{p,Left Web,eff,AS/NZS}$	51.640	[mm]
Inferior Left Flange	$b_{p,Inf. Left Flange,eff,AS/NZS}$	16.545	[mm]
Left Edge Stiffener	$c_{p,Left Lip,eff,AS/NZS}$	6.191	[mm]

Effective Ω-Section Purlin Widths [AISI S100 | AS/NZS 4600]

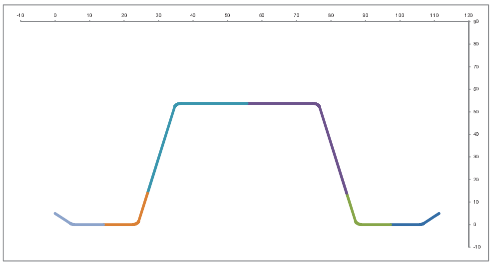
Right Edge Stiffener	$c_{p,Right Lip,eff}$	6.191	[mm]
Inferior Right Flange	$b_{p,Inf. Right Flange,eff}$	16.545	[mm]
Right Web	$h_{p,Right Web,eff}$	51.640	[mm]
Superior Flange	$b_{p,Sup. Flange,eff}$	----	[mm]
Left Web	$h_{p,Left Web,eff}$	51.640	[mm]
Inferior Left Flange	$b_{p,Inf. Left Flange,eff}$	16.545	[mm]
Left Edge Stiffener	$c_{p,Left Lip,eff}$	6.191	[mm]

[iii] **Effective Cross Ω-Section Purlin [Local Buckling]**

Effective Ω-Section Purlin Widths			
Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	6.191	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff,1}$	8.273	[mm]
	$b_{p,Inf.\ Right\ Flange,eff,2}$	8.273	[mm]
Right Web	$h_{p,Right\ Web,eff,1}$	12.591	[mm]
	$h_{p,Right\ Web,eff,2}$	11.985	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff}$	----	[mm]
Left Web	$h_{p,Left\ Web,eff,1}$	12.591	[mm]
	$h_{p,Left\ Web,eff,2}$	11.985	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff,1}$	8.273	[mm]
	$b_{p,Inf.\ Left\ Flange,eff,2}$	8.273	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	6.191	[mm]



Effective Ω-Section Purlin [Negative Moment in x-x axis, $M_{x,Ed}^-$] [AISI S100 | AS/NZS 4600]



Effective Ω-Section Purlin [Local Buckling] [Negative Moment in x-x axis, $M_{x,Ed}^-$]

$I_{y,eff}^{[-]}$ 85759.975 [mm^4]

$f_{Compression,Bottom\ fiber}$	350.000	[MPa]			y_{CG}	59.274	[mm]
$f_{Compression}$	350.000	[MPa]	m	5.905	$f_{Tension}$	-350.000	[MPa]
f_1	330.951	[MPa]	m	5.905	f_2	248.001	[MPa]

$$\psi = |f_2/f_1|$$
[AISI S100, Eq. B3.2-1]

| ψ | 0.749

f_1 Compression
f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$
[AISI S100, Eq. B3.2-2]

k 0.531

C-Section Beam Dimension		
$c_{p,1}$	14.048	[mm]

NOTE $w = c_{p,1}$

E	210.000	[GPa]	t	1.452	[mm]	ν [μ]	0.300
w	14.048	[mm]	→	w / t ≤ 60	OK		

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]

F_{cr} 1075.865 [MPa]

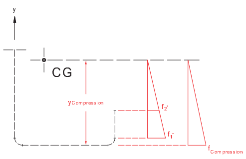
$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

$f = f_1$
330.951 [MPa]
λ 0.555

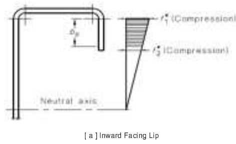
$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ 1.000 → $c_{p,1,eff,AISI}$ 14.048 [mm]

Inferior Edge Stiffner [$c_{p,1}$] [AS/NZS 4600, Clause 2.3.2]



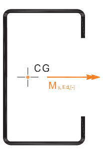
C-Section Beam: Stress Gradient



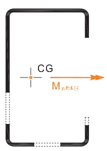
[a] Inward Facing Lip

Unstiffened Elements with Stress Gradient: Both Edges in Compression [AS/NZS 4600, Figure B2.3.2(a)]

[b] C-Section Beam



Gross C-Section

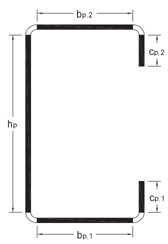


Effective C-Section [L]

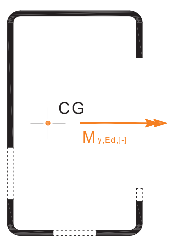
Local Buckling

C-Section Beam Dimension		
$c_{p,1}$	14.048	[mm]
$b_{p,1}$	38.596	[mm]
h_p	112.096	[mm]
$b_{p,2}$	38.596	[mm]
$c_{p,2}$	14.048	[mm]
t	1.452	[mm]

[i] **Effective Widths for Strength Determination [Local Buckling]** **AISI S100, Sector B | AS/NZS 4600, Section 2**



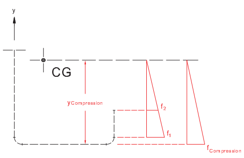
C-Section Plate Widths



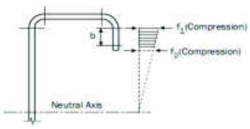
Effective C-Section [Worst Case]

1º Iteration

Inferior Edge Stiffner [$c_{p,1}$] [AISI S100, Sector B3.2]



C-Section Beam: Stress Gradient



[a] Inward Facing Lip

Unstiffened Elements under Stress Gradient, Both Longitudinal Edges in Compression [AISI S100, Figure B3.2-1]

$f_{Compression,Top\ fiber}$	350.000	[MPa]			y_{CG}	59.274	[mm]
$f_{Compression}$	350.000	[MPa]	m	5.905	$f_{Tension}$	-350.000	[MPa]
f_1^*	330.951	[MPa]	m	5.905	f_2^*	248.001	[MPa]

$$\psi = f_2^* / f_1^*$$
[AS/NZS 4600, Eq. 2.3.2.2(1)]

ψ 0.749

f_1 Compression
f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$
[AS/NZS 4600, Eq. 2.3.2.2(2)]

k 0.531

C-Section Beam Dimension		
$c_{p,1}$	14.048	[mm]

NOTE $b = c_{p,1}$

E	210.000	[GPa]	t	1.452	[mm]	ν	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$
[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 1075.865 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$
[AS/NZS 4600, Eq. 2.2.1.2(4)]

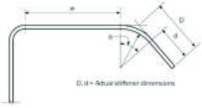
$f^* = f_1^*$
330.951 [MPa]
λ 0.555

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $c_{p,1,eff,AS/NZS}$ 14.048 [mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,1,eff,AISI}$	14.048	=	$c_{p,1,eff,AS/NZS}$	14.048

Inferior Flange [$b_{p,1}$] [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

C-Section Beam Dimension		
$c_{p,1}$	14.048	[mm]
$b_{p,1}$	38.596	[mm]
t	1.452	[mm]

$c_{p,1} = d$ | $b_{p,1} = w$

$D_{Inf.\ Lip}$ 18.000 [mm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

$$S = 1.28\sqrt{E/f}$$

[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	350.000	[MPa]
S	31.353	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	b_1 = [b / 2] * [R_I]
$b_1 = b_2$ = w / 2	$b_2 = b - b_1$
$d_s = d'_s$	$d_s = d'_s$ * [R_I]

w / t	26.581	Edge stiffener is needed	0.328 * S	10.284

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \le t^4\left[115\frac{w/t}{S} + 5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4-8]

I_a	249.076	[mm⁴]	≤	455.590	→	OK

$$(R_I) = I_s/I_a \le 1$$

[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AISI S100, Eq. B4-10]

θ_1	90.000	[°]	→	I_s	6956.844	[mm⁴]		
[R_I]	27.931	≤ 1.000	→	KO	→	[R_I]	1.000	

$$n = \left(0.582 - \frac{w/t}{4S}\right) \ge \frac{1}{3}$$

[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I]ⁿ + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I]ⁿ + 0.430 ≤ 4.000

OK	140° ≥	θ_1	90.000	[°]	≥ 40°	OK	
n	0.370	≥ 1 / 3 ?	OK	→	n	0.370	
[AISI S100, Table B4-1]	D / w	0.466	→	k	2.918	OK	

C-Section Beam Dimension			NOTE	w = $b_{o,1}$
$b_{o,1}$	38.596	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300	

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

$$I_s/I_a \le 1$$

[AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AS/NZS 4600, Eq. 2.4.2(11θ)]

θ_1	90.000	[°]	→	I_s	6956.844	[mm⁴]		
[I_s / I_a]	27.931	≤ 1.000	→	KO	→	[I_s / I_a]	1.000	

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \ge \frac{1}{3}$$

[AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

d_l / b ≤ 0.250	0.250 < d_l / b ≤ 0.800
3.570 * [I_s / I_a]ⁿ + 0.430 ≤ 4.000	[4.820 - [5 * d_l / b]] * [I_s / I_a]ⁿ + 0.430 ≤ 4.000

OK	140° ≥	θ_1	90.000	[°]	≥ 40°	OK	
n	0.370	≥ 1 / 3 ?	OK	→	n	0.370	
[AS/NZS 4600, Table 2.4.2]	d_l / b	0.466	→	k	2.918	OK	

C-Section Beam Dimension			NOTE	b = $b_{o,1}$
$b_{o,1}$	38.596	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr}	783.886	[MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

f* = f_y	
350.000	[MPa]
λ	0.668

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{o,1,eff,AS/NZS}$	38.596	[mm]
$b_{o,1,eff,AS/NZS,1}$	19.298	[mm]	$b_{o,1,eff,AS/NZS,2}$	19.298	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{o,1,eff,AISI,1}$	19.298	=	$b_{o,1,eff,AS/NZS,1}$	19.298
$b_{o,1,eff,AISI,2}$	19.298	=	$b_{o,1,eff,AS/NZS,2}$	19.298

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr}	783.886	[MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

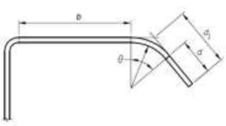
f = f_y	
350.000	[MPa]
λ	0.668

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{o,1,eff,AISI}$	38.596	[mm]
$b_{o,1,eff,AISI,1}$	19.298	[mm]	$b_{o,1,eff,AISI,2}$	19.298	[mm]

Inferior Flange [$b_{o,1}$]	[AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

C-Section Beam Dimension		
$c_{o,1}$	14.048	[mm]
$b_{o,1}$	38.596	[mm]
t	1.452	[mm]
$c_{o,1}$ = d | $b_{o,1}$ = b		
$d_{θ,lnf. Lip}$	18.000	[mm]

$$S = 1.28\sqrt{E/f^*}$$

[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	350.000	[MPa]
S	31.353	[ ]

b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b_e = b	b_1 = [b_e / 2] * [I_s / I_a]
$b_1 = b_2$ = b / 2	$b_2 = b_e - b_1$
$d_s = d_{se}$	$d_s = d_{se}$ * [I_s / I_a]

b / t	26.581	Edge stiffener is needed	0.328 * S	10.284

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \le t^4\left[115\frac{(b/t)}{S} + 5\right]$$

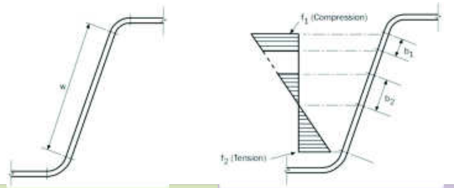
Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(11)]

I_a	249.076	[mm⁴]	≤	455.590	→	OK

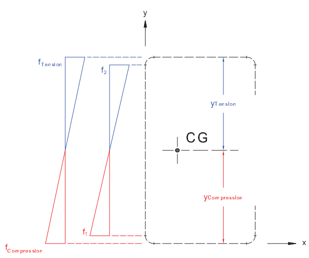
Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

Web [h_0]	[AISI S100, Section B2.3]

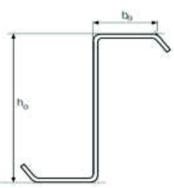


Actual Element	Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



C-Section Beam: Stress Gradient



[AISI S100, Figure B2.3-2]

h_0	120.000	[mm]
b_0	46.500	[mm]
h_0 / b_0	2.581	[ ]

$y_{Compression}$	59.274	[mm]	$y_{Tension}$	59.274	[mm]

Tension Stress is reached!

1ª Iteration	$f_{Compression,Top fiber}$	350.000	[MPa]	y_{CG}	59.274	[mm]
$f_{Compression}$	350.000	[MPa]	m	5.905	$f_{Tension}$	-350.000 [MPa]
f_1	330.951	[MPa]	m	5.905	f_2	-330.951 [MPa]

For webs under stress gradient [f_1 in compression and f_2 in tension]

$h_o / b_o \le 4$		$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \le 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \le$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$
[AISI S100, Eq. B2.3-1]

$|\psi|$ 1.000

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$
[AISI S100, Eq. B2.3-2]

k 24.000

C-Section Beam Dimension			NOTE	$w = h_p$
h_p	112.096	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]

F_{cr} 764.294 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

$f = f_1$: 330.951 [MPa]

λ 0.658

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$h_{p,eff,AISI}$	112.096	[mm]

$b_e = h_{p,eff,AISI}$	112.096	[mm]

↓

h_0 / b_0	2.581

↓

$\|\psi\|$	1.000

↓

$b_1 = b_e / [3 + \psi]$	28.024	[mm]

↓

$h_o / b_o \le 4$				$h_o / b_o > 4$		
$\psi > 0.236$	$b_2 = b_e / 2$	56.048	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
$\psi \le 0.236$	$b_2 = b_e - b_1$	----	[mm]			

↓

$b_1 + b_2 \le w_{Comp}$	KO	Web is fully effective	No more iterations!

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$
[AS/NZS 4600, Eq. 2.2.3.2(4)]

k 24.000

C-Section Beam			NOTE	$b = h_p$
h_p	112.096	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$
[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 764.294 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$
[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 330.951 [MPa]

λ 0.658

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$h_{p,eff,AS/NZS}$	112.096	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$
[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$
$\psi \le -0.236$
[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$
$\psi > -0.236$
[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = h_{p,Right Web,eff,AS/NZS}$	112.096	[mm]

↓

ψ	-1.000

↓

$b_{e1} = b_e / [3 - \psi]$	28.024	[mm]

↓

$\psi \le -0.236$	$b_2 = b_e / 2$	56.048	[mm]	$\psi > -0.236$	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2} \le$ Compression portion of the web calculated on the basis of effective section

↓

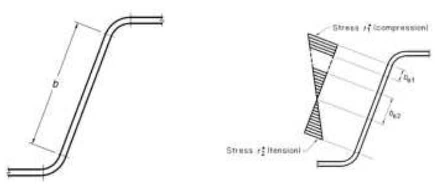
$b_{e1} + b_{e2} \le b_{Comp}$	KO	Web is fully effective	No more iterations!

$h_{p,eff,AS/NZS,1}$	28.024	[mm]	$h_{p,eff,AS/NZS,2}$	28.024	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,eff,AISI,1}$	28.024	=	$h_{p,eff,AS/NZS,1}$	28.024
$h_{p,eff,AISI,2}$	28.024	=	$h_{p,eff,AS/NZS,2}$	28.024

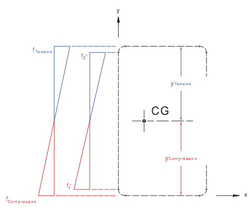
$h_{p,eff,AISI,1}$	28.024	[mm]	$h_{p,eff,AISI,2}$	28.024	[mm]

Web [h_p]	[AS/NZS 4600, Clause 2.2.3]



Actual Element	Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Beam: Stress Gradient

$y_{Compression}$	59.274	[mm]	$y_{Tension}$	59.274	[mm]

Tension Stress is reached!

1º Iteration	$f_{Compression,Top fiber}$	350.000	[MPa]	y_{CG}	59.274	[mm]
$f_{Compression}$	350.000	[MPa]	m 5.905	$f_{Tension}$	-350.000	[MPa]
f_1^*	330.951	[MPa]	m 5.905	f_2^*	-330.951	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$
[AS/NZS 4600, Eq. 2.2.3.2(5)]

ψ -1.000

Superior Flange [$b_{p,2}$]	[AISI S100, Sector B4]

NOTE — Zone in Tension. Effective width is equal to the real width

Superior Flange [$b_{p,2}$]	[AS/NZS 4600, Clause 2.4]

NOTE — Zone in Tension. Effective width is equal to the real width

Superior Edge Stiffener [$c_{p,2}$]	[AISI S100, Sector B3.2]

NOTE — Zone in Tension. Effective width is equal to the real width

Superior Edge Stiffener [$c_{p,2}$]	[AS/NZS 4600, Clause 2.3.2]

NOTE — Zone in Tension. Effective width is equal to the real width

[ii] **Effective C-Section Beam [Local Buckling]**

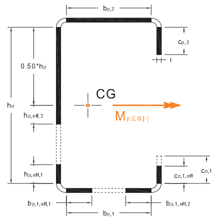
Effective C-Section Beam Widths [AISI S100]			
Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	14.048	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	38.596	[mm]
Web	$h_{p,eff,AISI}$	112.096	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	----	[mm]

Effective C-Section Beam Widths [AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	14.048	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	38.596	[mm]
Web	$h_{p,eff,AS/NZS}$	112.096	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	----	[mm]

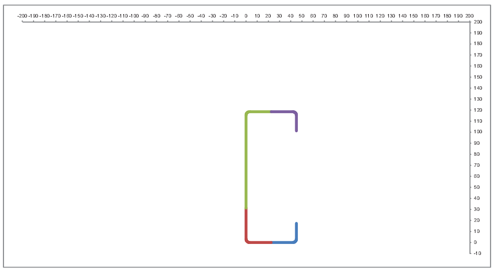
Effective C-Section Beam Widths [AISI S100 | AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff}$	14.048	[mm]
Inferior Flange	$b_{p,1,eff}$	38.596	[mm]
Web	$h_{p,eff}$	112.096	[mm]
Superior Flange	$b_{p,2,eff}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]

[iii] **Effective Cross C-Section Beam [Local Buckling]**

Effective C-Section Beam Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	14.048	[mm]
Inferior Flange	$b_{p,1,eff,1}$	19.298	[mm]
	$b_{p,1,eff,2}$	19.298	[mm]
Web	$h_{p,eff,1}$	28.024	[mm]
	$h_{p,eff,2}$	28.024	[mm]
Superior Flange	$b_{p,2,eff,1}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]



Effective C-Section Beam [Local Buckling] [Bending Moment $M_{x,Ed}^-$] [AISI S100 | AS/NZS 4600]



Effective C-Section Beam [Local Buckling] [Bending Moment $M_{x,Ed}^-$]

$I_{y,eff}$ [-] 762290.565 [mm^4]

$f_{Compression,Bottom\ fiber}$	350.000	[MPa]			y_{CG}	43.774	[mm]	
$f_{Compression}$	350.000	[MPa]	m	7.996	$f_{Tension}$	-350.000	[MPa]	
f_1	320.208	[MPa]	m	7.996	f_2	215.882	[MPa]	

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B3.2-1]

| ψ | 0.674

f_1 Compression
f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$

[AISI S100, Eq. B3.2-2]

k 0.570

C-Section Column Dimension		
$c_{p,1}$	13.048	[mm]

NOTE $w = c_{p,1}$

E	210.000	[GPa]	t	2.452	[mm]	v [μ]	0.300
w	13.048	[mm]	→	w / t ≤ 60	OK		

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 3819.949 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$: 320.208 [MPa]

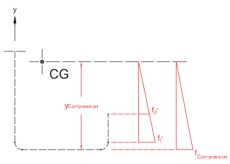
λ 0.290

$$\rho = (1 - 0.22/\lambda)/\lambda$$

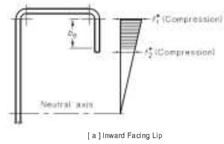
[AISI S100, Eq. B2.1-4]

ρ 1.000 → $c_{p,1,eff,AISI}$ 13.048 [mm]

Inferior Edge Stiffner [$c_{p,1}$] [AS/NZS 4600, Clause 2.3.2]



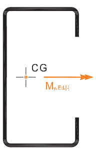
C-Section Beam: Stress Gradient



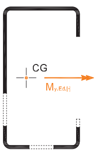
[a] Inward Facing Lip

Unstiffened Elements with Stress Gradient: Both Edges in Compression [AS/NZS 4600, Figure B2.3.2(a)]

[c] C-Section Column



Gross C-Section

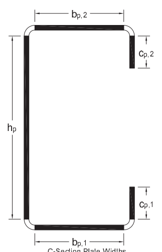


Effective C-Section [L]

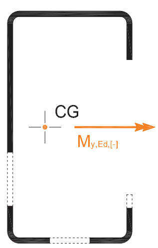
Local Buckling

C-Section Column Dimension		
$c_{p,1}$	13.048	[mm]
$b_{p,1}$	36.596	[mm]
h_p	80.096	[mm]
$b_{p,2}$	36.596	[mm]
$c_{p,2}$	13.048	[mm]
t	2.452	[mm]

[i] **Effective Widths for Strength Determination [Local Buckling]** **AISI S100, Sector B | AS/NZS 4600, Section 2**



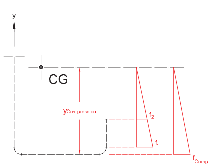
C-Section Plate Widths



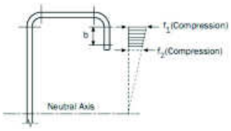
Effective C-Section [Worst Case]

1st Iteration

Inferior Edge Stiffner [$c_{p,1}$] [AISI S100, Sector B3.2]



C-Section Beam: Stress Gradient



[a] Inward Facing Lip

Unstiffened Elements under Stress Gradient, Both Longitudinal Edges in Compression [AISI S100, Figure B3.2-1]

$f_{Compression,Top\ fiber}$	350.000	[MPa]			y_{CG}	43.774	[mm]
$f_{Compression}$	350.000	[MPa]	m	7.996	$f_{Tension}$	-350.000	[MPa]
f_1^*	320.208	[MPa]	m	7.996	f_2^*	215.882	[MPa]

$$\psi = f_2^* / f_1^*$$

ψ 0.674

[AS/NZS 4600, Eq. 2.3.2.2(1)]

f_1 Compression
f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$

[AS/NZS 4600, Eq. 2.3.2.2(2)]

k 0.570

C-Section Column Dimension		
$c_{p,1}$	13.048	[mm]

NOTE $b = c_{p,1}$

E	210.000	[GPa]	t	2.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 3819.949 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 320.208 [MPa]

λ 0.290

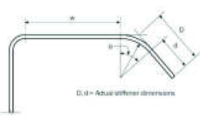
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $c_{p,1,eff,AS/NZS}$ 13.048 [mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,1,eff,AISI}$	13.048	=	$c_{p,1,eff,AS/NZS}$	13.048

Inferior Flange [$b_{p,1}$] [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

C-Section Column Dimension		
$c_{p,1}$	13.048	[mm]
$b_{p,1}$	36.596	[mm]
t	2.452	[mm]

$c_{p,1} = d$ | $b_{p,1} = w$

$D_{Ind.\ Lip}$ 18.000 [mm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office:	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

$$S = 1.28\sqrt{E/f}$$

[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	350.000	[MPa]
S	31.353	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	b_1 = [b / 2] * [R_I]
$b_1 = b_2$ = w / 2	$b_2 = b - b_1$
$d_s = d_s'$	$d_s = d_s'$ * [R_I]

w / t: 14.925 — Edge stiffener is needed — 0.328 * S: 10.284

$$I_a = 399t^4\left[\frac{w/t}{S}-0.328\right]^3 \le t^4\left[115\frac{w/t}{S}+5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4-8]

I_a: 46.778 [mm^4] ≤ 2159.563 → OK

$$(R_I) = I_s/I_a \le 1$$

[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AISI S100, Eq. B4-10]

$Ø_1$: 90.000 [°] → I_s: 10014.749 [mm^4]

[R_I]: 214.092 ≤ 1.000 → KO → [R_I]: 1.000

$$n = \left(0.582 - \frac{w/t}{4S}\right) \ge \frac{1}{3}$$

[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK — 140° ≥ — $Ø_1$: 90.000 [°] ≥ 40° — OK

n: 0.463 ≥ 1 / 3 ? OK → n: 0.463

[AISI S100, Table B4-1] — D / w: 0.492 → k: 2.791 OK

C-Section Strut Dimension — **NOTE**: w = $b_{p,1}$

$b_{p,1}$: 36.596 [mm]

E: 210.000 [GPa] — t: 2.452 [mm] — v [μ]: 0.300

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office:	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

$$I_s/I_a \le 1$$

[AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$

[AS/NZS 4600, Eq. 2.4.2(110)]

$Ø_1$: 90.000 [°] → I_s: 10014.749 [mm^4]

[I_s / I_a]: 214.092 ≤ 1.000 → KO → [I_s / I_a]: 1.000

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \ge \frac{1}{3}$$

[AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

d_l / b ≤ 0.250	0.250 < d_l / b ≤ 0.800
3.570 * [I_s / I_a] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * d_l / b]] * [I_s / I_a] ^{n} + 0.430 ≤ 4.000

OK — 140° ≥ — $Ø_1$: 90.000 [°] ≥ 40° — OK

n: 0.463 ≥ 1 / 3 ? OK → n: 0.463

[AS/NZS 4600, Table 2.4.2] — d_l / b: 0.492 → k: 2.791 OK

C-Section Column Dimension — **NOTE**: b = $b_{p,1}$

$b_{p,1}$: 36.596 [mm]

E: 210.000 [GPa] — t: 2.452 [mm] — v: 0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr}: 2377.856 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 350.000 [MPa]

λ: 0.384

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ: 1.000 → $b_{p,1,eff,AS/NZS}$: 36.596 [mm]

$b_{p,1,eff,AS/NZS,1}$: 18.298 [mm] — $b_{p,1,eff,AS/NZS,2}$: 18.298 [mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,1,eff,AISI,1}$	18.298	=	$b_{p,1,eff,AS/NZS,1}$	18.298
$b_{p,1,eff,AISI,2}$	18.298	=	$b_{p,1,eff,AS/NZS,2}$	18.298

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office:	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr}: 2377.856 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

f = f_y: 350.000 [MPa]

λ: 0.384

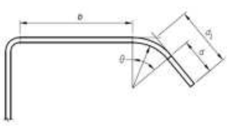
$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ: 1.000 → $b_{p,1,eff,AISI}$: 36.596 [mm]

$b_{p,1,eff,AISI,1}$: 18.298 [mm] — $b_{p,1,eff,AISI,2}$: 18.298 [mm]

Inferior Flange [$b_{p,1}$] — [AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

C-Section Column Dimension		
$c_{p,1}$	13.048	[mm]
$b_{p,1}$	36.596	[mm]
t	2.452	[mm]

$c_{p,1}$ = d \| $b_{p,1}$ = b

$d_{lip,Ind\ Lip}$: 18.000 [mm]

$$S = 1.28\sqrt{E/f^*}$$

[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	350.000	[MPa]
S	31.353	[ ]

b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b_e = b	b_1 = [b_e / 2] * [I_s / I_a]
$b_1 = b_2$ = b / 2	$b_2 = b_e - b_1$
$d_s = d_{se}$	$d_s = d_{se}$ * [I_s / I_a]

b / t: 14.925 — Edge stiffener is needed — 0.328 * S: 10.284

$$I_a = 399t^4\left[\frac{(b/t)}{S}-0.328\right]^3 \le t^4\left[115\frac{(b/t)}{S}+5\right]$$

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(11)]

I_a: 46.778 [mm^4] ≤ 2159.563 → OK

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office:	Author: JOSÉ ANTÓNIO
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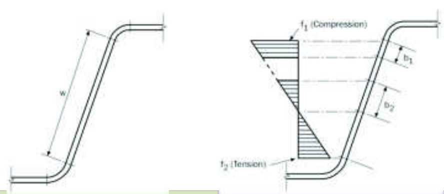
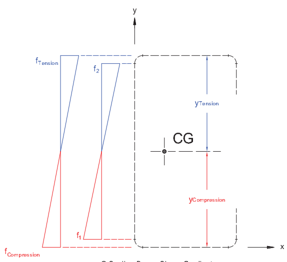
Web [h_0] — [AISI S100, Section B2.3]

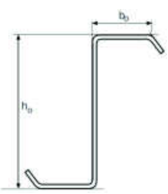


Actual Element — Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



C-Section Beam: Stress Gradient



[AISI S100, Figure B2.3-2]

h_0	90.000	[mm]
b_0	46.500	[mm]
h_0 / b_0	1.935	[ ]

$y_{Compression}$: 43.774 [mm] — $y_{Tension}$: 43.774 [mm]

Compression Stress is reached!

1ª Iteration	$f_{Compression,Top fiber}$	350.000	[MPa]	y_{CG}	43.774	[mm]
$f_{Compression}$	350.000	[MPa]	m: 7.996	$f_{Tension}$	-350.000	[MPa]
f_1	320.208	[MPa]	m: 7.996	f_2	-320.208	[MPa]

For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \leq 4$		$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$		$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$		$b_2 = b_e / [1 + \psi] - b_1$
$\psi \leq 0.236$	$b_2 = b_e - b_1$		

$b_1 + b_2 \leq$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B2.3-1]

$|\psi|$ 1.000

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$

[AISI S100, Eq. B2.3-2]

k 24.000

C-Section Column Dimension			NOTE	$w = h_p$
h_p	80.096	[mm]		

E	210.000	[GPa]	t	2.452	[mm]	v [μ]	0.300

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 4269.008 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$: 320.208 [MPa]

λ 0.274

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ 1.000 → $h_{p,eff,AISI}$ 80.096 [mm]

$b_e = h_{p,eff,AISI}$ 80.096 [mm]

↓

h_0 / b_0 1.935

↓

$|\psi|$ 1.000

↓

$b_1 = b_e / [3 + \psi]$ 20.024 [mm]

↓

$h_o / b_o \leq 4$				$h_o / b_o > 4$		
$\psi > 0.236$	$b_2 = b_e / 2$	40.048	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
$\psi \leq 0.236$	$b_2 = b_e - b_1$	----	[mm]			

↓

$b_1 + b_2 \leq w_{Comp}$ KO | Web is fully effective | No more iterations!

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

[AS/NZS 4600, Eq. 2.2.3.2(4)]

k 24.000

C-Section Column			NOTE	$b = h_p$
h_p	80.096	[mm]		

E	210.000	[GPa]	t	2.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 4269.008 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}} \right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 320.208 [MPa]

λ 0.274

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $h_{p,eff,AS/NZS}$ 80.096 [mm]

$$b_{e1} = \frac{b_e}{3 - \psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

$\psi \leq -0.236$

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

$\psi > -0.236$

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = h_{p,Right Web,eff,AS/NZS}$ 80.096 [mm]

↓

ψ -1.000

↓

$b_{e1} = b_e / [3 - \psi]$ 20.024 [mm]

↓

$\psi \leq -0.236$	$b_2 = b_e / 2$	40.048	[mm]	$\psi > -0.236$	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2} \leq$ Compression portion of the web calculated on the basis of effective section

↓

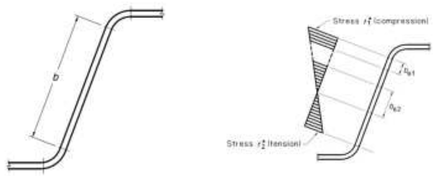
$b_{e1} + b_{e2} \leq b_{Comp}$ KO | Web is fully effective | No more iterations!

$h_{p,eff,AS/NZS,1}$ 20.024 [mm] | $h_{p,eff,AS/NZS,2}$ 20.024 [mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,eff,AISI,1}$	20.024	=	$h_{p,eff,AS/NZS,1}$	20.024
$h_{p,eff,AISI,2}$	20.024	=	$h_{p,eff,AS/NZS,2}$	20.024

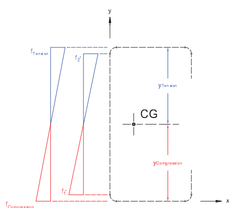
$h_{p,eff,AISI,1}$ 20.024 [mm] | $h_{p,eff,AISI,2}$ 20.024 [mm]

Web [h_p] — [AS/NZS 4600, Clause 2.2.3]



Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Beam: Stress Gradient

$y_{Compression}$ 43.774 [mm] | $y_{Tension}$ 43.774 [mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Top fiber}$	350.000	[MPa]		y_{CG}	43.774	[mm]
$f_{Compression}$	350.000	[MPa]	m	7.996	$f_{Tension}$	-350.000	[MPa]
f_1^*	320.208	[MPa]	m	7.996	f_2^*	-320.208	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$

[AS/NZS 4600, Eq. 2.2.3.2(5)]

ψ -1.000

Superior Flange [$b_{p,2}$] — [AISI S100, Sector B4]

NOTE: Zone in Tension. Effective width is equal to the real width

Superior Flange [$b_{p,2}$] — [AS/NZS 4600, Clause 2.4]

NOTE: Zone in Tension. Effective width is equal to the real width

Superior Edge Stiffener [$c_{p,2}$] — [AISI S100, Sector B3.2]

NOTE: Zone in Tension. Effective width is equal to the real width

Superior Edge Stiffener [$c_{p,2}$] — [AS/NZS 4600, Clause 2.3.2]

NOTE: Zone in Tension. Effective width is equal to the real width

[ii] **Effective C-Section Column [Local Buckling]**

Effective C-Section Column Widths [AISI S100]

Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	13.048	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	36.596	[mm]
Web	$h_{p,eff,AISI}$	80.096	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	----	[mm]

Effective C-Section Column Widths [AS/NZS 4600]

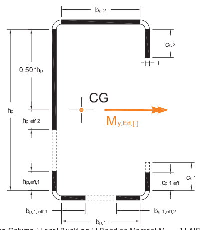
Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	13.048	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	36.596	[mm]
Web	$h_{p,eff,AS/NZS}$	80.096	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	----	[mm]

Effective C-Section Column Widths [AISI S100 | AS/NZS 4600]

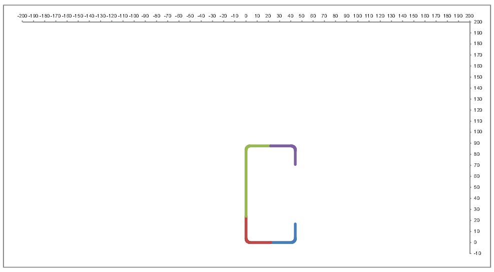
Inferior Edge Stiffener	$c_{p,1,eff}$	13.048	[mm]
Inferior Flange	$b_{p,1,eff}$	36.596	[mm]
Web	$h_{p,eff}$	80.096	[mm]
Superior Flange	$b_{p,2,eff}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]

[iii] **Effective Cross C-Section Column [Local Buckling]**

Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	13.048	[mm]
Inferior Flange	$b_{p,1,eff,1}$	18.298	[mm]
	$b_{p,1,eff,2}$	18.298	[mm]
Web	$h_{p,eff,1}$	20.024	[mm]
	$h_{p,eff,2}$	20.024	[mm]
Superior Flange	$b_{p,2,eff,1}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]



Effective C-Section Column [Local Buckling] [Bending Moment $M_{x,Ed}^{-}$] [AISI S100 | AS/NZS 4600]



Effective C-Section Column [Local Buckling] [Bending Moment $M_{x,Ed}^{-}$]

$I_{x,eff}^{(-)}$ 625036.020 [mm^4]

$f_{Compression,Bottom\ fiber}$	350.000	[MPa]			y_{CG}	24.274	[mm]
$f_{Compression}$	350.000	[MPa]	m	14.419	$f_{Tension}$	-350.000	[MPa]
f_1	303.485	[MPa]	m	14.419	f_2	216.281	[MPa]

$$\psi = |f_2/f_1|$$
[AISI S100, Eq. B3.2-1]

$|\psi|$ 0.713

f_1 Compression
f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$
[AISI S100, Eq. B3.2-2]

k 0.549

C-Section Strut Dimension — NOTE: $w = c_{p,1}$

$c_{p,1}$ 6.048 [mm]

E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300
w	6.048	[mm]	→	w / t ≤ 60	OK		

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]

F_{cr} 6006.855 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

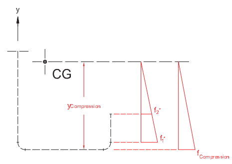
$f = f_1$: 303.485 [MPa]

λ 0.225

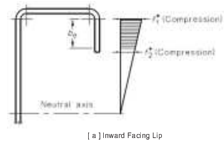
$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ 1.000 → $c_{p,1,eff,AISI}$ 6.048 [mm]

Inferior Edge Stiffner [$c_{p,1}$] — [AS/NZS 4600, Clause 2.3.2]



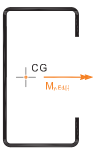
C-Section Beam: Stress Gradient



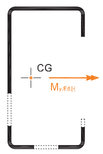
[a] Inward Facing Lip

Unstiffened Elements with Stress Gradient: Both Edges in Compression [AS/NZS 4600, Figure B2.3.2(a)]

[d] C-Section Strut



Gross C-Section

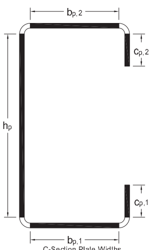


Effective C-Section [L]

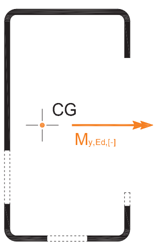
Local Buckling

C-Section Strut Dimension		
$c_{p,1}$	6.048	[mm]
$b_{p,1}$	32.096	[mm]
h_p	42.096	[mm]
$b_{p,2}$	32.096	[mm]
$c_{p,2}$	6.048	[mm]
t	1.452	[mm]

[i] **Effective Widths for Strength Determination [Local Buckling]** **AISI S100, Sector B | AS/NZS 4600, Section 2**



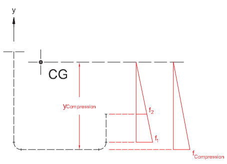
C-Section Plate Widths



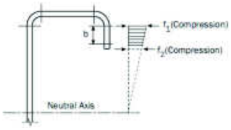
Effective C-Section [Worst Case]

1º Iteration

Inferior Edge Stiffner [$c_{p,1}$] — [AISI S100, Sector B3.2]



C-Section Beam: Stress Gradient



[a] Inward Facing Lip

Unstiffened Elements under Stress Gradient, Both Longitudinal Edges in Compression [AISI S100, Figure B3.2-1]

$f_{Compression,Top\ fiber}$	350.000	[MPa]			y_{CG}	24.274	[mm]
$f_{Compression}$	350.000	[MPa]	m	14.419	$f_{Tension}$	-350.000	[MPa]
f_1^*	303.485	[MPa]	m	14.419	f_2^*	216.281	[MPa]

$$\psi = f_2^* / f_1^*$$
[AS/NZS 4600, Eq. 2.3.2.2(1)]

ψ 0.713

f_1 Compression
f_2 Compression

$$k = \frac{0.578}{\psi + 0.34}$$
[AS/NZS 4600, Eq. 2.3.2.2(2)]

k 0.549

C-Section Strut Dimension — NOTE: $b = c_{p,1}$

$c_{p,1}$ 6.048 [mm]

E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$
[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 6006.855 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$
[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 303.485 [MPa]

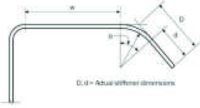
λ 0.225

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $c_{p,1,eff,AS/NZS}$ 6.048 [mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,1,eff,AISI}$	6.048	=	$c_{p,1,eff,AS/NZS}$	6.048

Inferior Flange [$b_{p,1}$] — [AISI S100, Sector B4]



[AISI S100, Figure B4-1]

C-Section Strut Dimension		
$c_{p,1}$	6.048	[mm]
$b_{p,1}$	32.096	[mm]
t	1.452	[mm]

$c_{p,1} = d$ | $b_{p,1} = w$

$D_{Inf.\ Lip}$ 10.000 [mm]

$$S = 1.28\sqrt{E/f}$$
[AISI S100, Eq. B4-7]

E	210.000	[GPa]
f	350.000	[MPa]
S	31.353	[ ]

w / t ≤ 0.328 * S	w / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b = w	b_1 = [b / 2] * [R_I]
$b_1 = b_2$ = w / 2	$b_2 = b - b_1$
$d_s = d_s'$	$d_s = d_s'$ * [R_I]

w / t — 22.105 — Edge stiffener is needed — 0.328 * S — 10.284

$$I_a = 399t^4\left[\frac{w/t}{S} - 0.328\right]^3 \le t^4\left[115\frac{w/t}{S} + 5\right]$$
Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element
[AISI S100, Eq. B4-8]

I_a — 95.042 — [mm^4] — ≤ — 382.607 — → — OK

$$(R_I) = I_s / I_a \le 1$$
[AISI S100, Eq. B4-9]

$$I_s = (d^3 t \sin^2\theta)/12$$
[AISI S100, Eq. B4-10]

$Ø_1$ — 90.000 — [°] — → — I_s — 4000.720 — [mm^4]

[R_I] — 42.094 — ≤ 1.000 — → — KO — → — [R_I] 1.000

$$n = \left(0.582 - \frac{w/t}{4S}\right) \ge \frac{1}{3}$$
[AISI S100, Eq. B4-11]

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

D / w ≤ 0.250	0.250 < D / w ≤ 0.800
3.570 * [R_I] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * D / w]] * [R_I] ^{n} + 0.430 ≤ 4.000

OK — 140° ≥ — $Ø_1$ — 90.000 — [°] — ≥ 40° — OK

n — 0.406 — ≥ 1 / 3 ? — OK — → — n — 0.406

[AISI S100, Table B4-1] — D / w — 0.312 — → — k — 3.692 — OK

C-Section Strut Dimension — **NOTE** — w = $b_{p,1}$

$b_{p,1}$ — 32.096 — [mm]

E — 210.000 — [GPa] — t — 1.452 — [mm] — v [μ] — 0.300

$$I_s / I_a \le 1$$
[AS/NZS 4600]

$$I_s = (d^3 t \sin^2\theta)/12$$
[AS/NZS 4600, Eq. 2.4.2(11O)]

$Ø_1$ — 90.000 — [°] — → — I_s — 4000.720 — [mm^4]

[I_s / I_a] — 42.094 — ≤ 1.000 — → — KO — → — [I_s / I_a] — 1.000

$$n = \left[0.582 - \frac{(b/t)}{4S}\right] \ge \frac{1}{3}$$
[AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140° ≥ θ ≥ 40°]

d_l / b ≤ 0.250	0.250 < d_l / b ≤ 0.800
3.570 * [I_s / I_a] ^{n} + 0.430 ≤ 4.000	[4.820 - [5 * d_l / b]] * [I_s / I_a] ^{n} + 0.430 ≤ 4.000

OK — 140° ≥ — $Ø_1$ — 90.000 — [°] — ≥ 40° — OK

n — 0.406 — ≥ 1 / 3 ? — OK — → — n — 0.406

[AS/NZS 4600, Table 2.4.2] — d_l / b — 0.312 — → — k — 3.692 — OK

C-Section Strut Dimension — **NOTE** — b = $b_{p,1}$

$b_{p,1}$ — 32.096 — [mm]

E — 210.000 — [GPa] — t — 1.452 — [mm] — v — 0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$
[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} — 1434.201 — [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$
[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$ — 350.000 — [MPa] — λ — 0.494

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ — 1.000 — → — $b_{p,1,ef,AS/NZS}$ — 32.096 — [mm]

$b_{p,1,ef,AS/NZS,1}$ — 16.048 — [mm] — $b_{p,1,ef,AS/NZS,2}$ — 16.048 — [mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,1,ef,AISI,1}$	16.048	=	$b_{p,1,ef,AS/NZS,1}$	16.048
$b_{p,1,ef,AISI,2}$	16.048	=	$b_{p,1,ef,AS/NZS,2}$	16.048

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]

F_{cr} — 1434.201 — [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

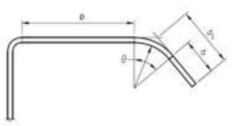
$f = f_y$ — 350.000 — [MPa] — λ — 0.494

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ — 1.000 — → — $b_{p,1,ef,AISI}$ — 32.096 — [mm]

$b_{p,1,ef,AISI,1}$ — 16.048 — [mm] — $b_{p,1,ef,AISI,2}$ — 16.048 — [mm]

Inferior Flange [$b_{p,1}$] — [AS/NZS 4600, Clause 2.4]



[AS/NZS 4600, Figure 2.4.2]

C-Section Strut Dimension		
$c_{p,1}$	6.048	[mm]
$b_{p,1}$	32.096	[mm]
t	1.452	[mm]

$c_{p,1}$ = d \| $b_{p,1}$ = b

$d_{lip,Ind. Exp.}$ — 10.000 — [mm]

$$S = 1.28\sqrt{E/f^*}$$
[AS/NZS, Eq. 2.4.2(13)]

E	210.000	[GPa]
f*	350.000	[MPa]
S	31.353	[ ]

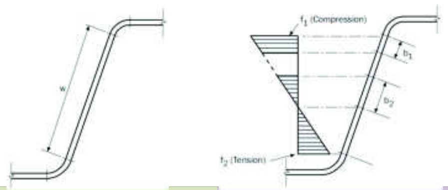
b / t ≤ 0.328 * S	b / t > 0.328 * S
I_a = 0.000 [no edge stiffener needed]	I_a = ... [edge stiffener is needed]
b_e = b	b_1 = [b_e / 2] * [I_s / I_a]
$b_1 = b_2$ = b / 2	$b_2 = b_e - b_1$
$d_s = d_{es}$	$d_s = d_{es}$ * [I_s / I_a]

b / t — 22.105 — Edge stiffener is needed — 0.328 * S — 10.284

$$I_a = 399t^4\left[\frac{(b/t)}{S} - 0.328\right]^3 \le t^4\left[115\frac{(b/t)}{S} + 5\right]$$
Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element
[AS/NZS 4600, Eq. 2.4.2(11)]

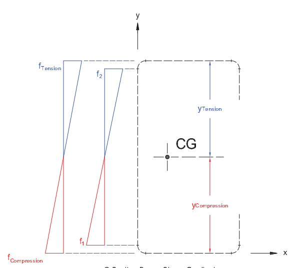
I_a — 95.042 — [mm^4] — ≤ — 382.607 — → — OK

Web [h_0] — [AISI S100, Sector B2.3]

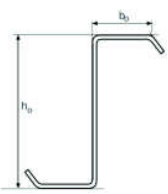


Actual Element — Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



C-Section Beam: Stress Gradient



[AISI S100, Figure B2.3-2]

h_0	50.000	[mm]
b_0	40.000	[mm]
h_0 / b_0	1.250	[ ]

$y_{Compression}$ — 24.274 — [mm] — $y_{Tension}$ — 24.274 — [mm]

Compression Stress is reached!

1° Iteration — $f_{Compression,Top fiber}$ — **350.000** — **[MPa]** — y_{CG} — **24.274** — **[mm]**

$f_{Compression}$	350.000	[MPa]	m	14.419	$f_{Tension}$	-350.000	[MPa]
f_1	303.485	[MPa]	m	14.419	f_2	-303.485	[MPa]

For webs under stress gradient [f_1 in compression and f_2 in tension]

$h_o / b_o \leq 4$		$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \leq 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \leq$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$
[AISI S100, Eq. B2.3-1]

$|\psi|$ 1.000

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$
[AISI S100, Eq. B2.3-2]

k 24.000

C-Section Strut Dimension

NOTE $w = h_p$

h_p	42.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]

F_{cr} 5419.500 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

$f = f_1$: 303.485 [MPa]

λ 0.237

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ 1.000 → $h_{p,eff,AISI}$ 42.096 [mm]

$b_e = h_{p,eff,AISI}$ 42.096 [mm]

↓

h_0 / b_0 1.250

↓

$|\psi|$ 1.000

↓

$b_1 = b_e / [3 + \psi]$ 10.524 [mm]

↓

$h_o / b_o \leq 4$				$h_o / b_o > 4$		
$\psi > 0.236$	$b_2 = b_e / 2$	21.048	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
$\psi \leq 0.236$	$b_2 = b_e - b_1$	----	[mm]			

↓

$b_1 + b_2 \leq w_{Comp}$ KO Web is fully effective **No more iterations!**

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$
[AS/NZS 4600, Eq. 2.2.3.2(4)]

k 24.000

C-Section Strut

NOTE $b = h_p$

h_p	42.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$
[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 5419.500 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$
[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 303.485 [MPa]

λ 0.237

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $h_{p,eff,AS/NZS}$ 42.096 [mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$
[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$
$\psi \leq -0.236$
[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$
$\psi > -0.236$
[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = h_{p,Right Web,eff,AS/NZS}$ 42.096 [mm]

↓

ψ -1.000

↓

$b_{e1} = b_e / [3 - \psi]$ 10.524 [mm]

↓

$\psi \leq -0.236$	$b_2 = b_e / 2$	21.048	[mm]	$\psi > -0.236$	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2} \leq$ Compression portion of the web calculated on the basis of effective section

↓

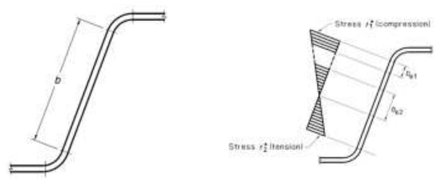
$b_{e1} + b_{e2} \leq b_{Comp}$ KO Web is fully effective **No more iterations!**

$h_{p,eff,AS/NZS,1}$	10.524	[mm]	$h_{p,eff,AS/NZS,2}$	10.524	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,eff,AISI,1}$	10.524	=	$h_{p,eff,AS/NZS,1}$	10.524
$h_{p,eff,AISI,2}$	10.524	=	$h_{p,eff,AS/NZS,2}$	10.524

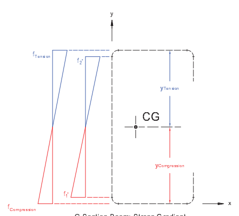
$h_{p,eff,AISI,1}$	10.524	[mm]	$h_{p,eff,AISI,2}$	10.524	[mm]

Web [h_p] [AS/NZS 4600, Clause 2.2.3]



Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Beam: Stress Gradient

$y_{Compression}$	24.274	[mm]	$y_{Tension}$	24.274	[mm]

Compression Stress is reached!

1° Iteration	$f_{Compression,Top fiber}$	**350.000**	**[MPa]**	y_{CG}	**24.274**	**[mm]**	
$f_{Compression}$	350.000	[MPa]	m	14.419	$f_{Tension}$	-350.000	[MPa]
f_1^*	303.485	[MPa]	m	14.419	f_2^*	-303.485	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$
[AS/NZS 4600, Eq. 2.2.3.2(5)]

ψ -1.000

Superior Flange [$b_{p,2}$] [AISI S100, Sector B4]

NOTE Zone in Tension. Effective width is equal to the real width

Superior Flange [$b_{p,2}$] [AS/NZS 4600, Clause 2.4]

NOTE Zone in Tension. Effective width is equal to the real width

Superior Edge Stiffener [$c_{p,2}$] [AISI S100, Sector B3.2]

NOTE Zone in Tension. Effective width is equal to the real width

Superior Edge Stiffener [$c_{p,2}$] [AS/NZS 4600, Clause 2.3.2]

NOTE Zone in Tension. Effective width is equal to the real width

[ii] **Effective C-Section Strut [Local Buckling]**

Effective C-Section Strut Widths [AISI S100]

Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	6.048	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	32.096	[mm]
Web	$h_{p,eff,AISI}$	42.096	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	----	[mm]

Effective C-Section Strut Widths [AS/NZS 4600]

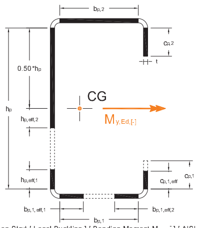
Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	6.048	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	32.096	[mm]
Web	$h_{p,eff,AS/NZS}$	42.096	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	----	[mm]

Effective C-Section Strut Widths [AISI S100 | AS/NZS 4600]

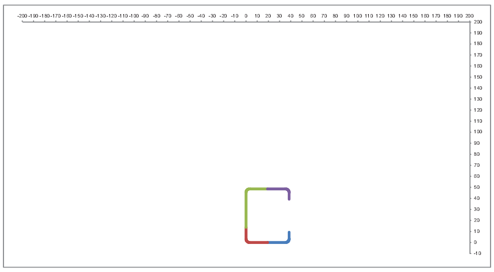
Inferior Edge Stiffener	$c_{p,1,eff}$	6.048	[mm]
Inferior Flange	$b_{p,1,eff}$	32.096	[mm]
Web	$h_{p,eff}$	42.096	[mm]
Superior Flange	$b_{p,2,eff}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]

[iii] **Effective Cross C-Section Strut [Local Buckling]**

Effective C-Section Strut Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	6.048	[mm]
Inferior Flange	$b_{p,1,eff,1}$	16.048	[mm]
	$b_{p,1,eff,2}$	16.048	[mm]
Web	$h_{p,eff,1}$	10.524	[mm]
	$h_{p,eff,2}$	10.524	[mm]
Superior Flange	$b_{p,2,eff,1}$	----	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]



Effective C-Section Strut [Local Buckling] [Bending Moment $M_{x,Ed}^-$] [AISI S100 | AS/NZS 4600]



Effective C-Section Strut [Local Buckling] [Bending Moment $M_{x,Ed}^-$]

$I_{x,eff}^{[-]}$ 85435.109 [mm^4]

Right Edge Stiffner [$c_{p,Right Lip}$] — [AS/NZS 4600, Clause 2.3.2]

NOTE — Zone in Tension. Effective width is equal to the real width

Inferior Right Flange [$b_{p,Inf. Right Flange}$] — [AISI S100, Sector B2.3]

NOTE — Zone in Tension. Effective width is equal to the real width

Inferior Right Flange [$b_{p,Inf. Right Flange}$] — [AS/NZS 4600, Clause 2.2.3]

NOTE — Zone in Tension. Effective width is equal to the real width

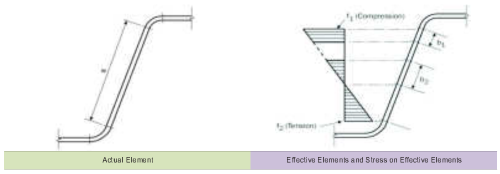
Right Web [$h_{p,Right Web}$] — [AISI S100, Sector B2.3]

NOTE — Zone in Tension. Effective width is equal to the real width

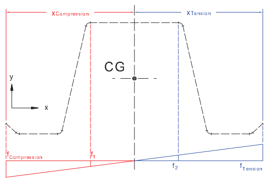
Right Web [$h_{p,Right Web}$] — [AS/NZS 4600, Clause 2.2.3]

NOTE — Zone in Tension. Effective width is equal to the real width

Superior Flange [$b_{p,Sup. Flange}$] — [AISI S100, Sector B2.3]



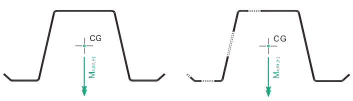
Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



Ω-Section Purlin: Stress Gradient

[11.5] Cold-Formed Section subjected to Positive Moment in y-y axis [$M_{y,Ed}^+$]

[a] Ω-Section Purlin

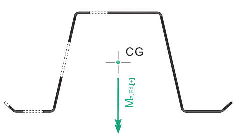


Gross Ω-Section

Effective Ω-Section [L]

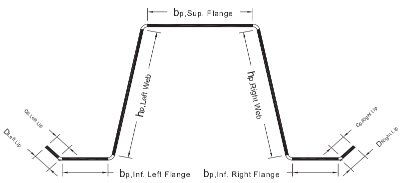
Local Buckling

[i] **Effective Widths for Strength Determination [Local Buckling]** — **AISI S100, Sector B | AS/NZS 4600, Section 2**



Effective Ω-Section [Worst Case]

Ω-Section Purlin Dimension		
$c_{p,Right Lip}$	6.191	[mm]
$b_{p,Inf. Right Flange}$	16.545	[mm]
$h_{p,Right Web}$	51.640	[mm]
$b_{p,Sup. Web}$	38.171	[mm]
$h_{p,Left Web}$	51.640	[mm]
$b_{p,Inf. Left Flange}$	16.545	[mm]
$c_{p,Left Lip}$	6.191	[mm]



Ω-Section Plate Widths

$x_{Compression}$ 55.667 [mm] $x_{Tension}$ 55.667 [mm]

Compression Stress is reached!

1º Iteration

Right Edge Stiffner [$c_{p,Right Lip}$] — [AISI S100, Sector B3.2]

NOTE — Zone in Tension. Effective width is equal to the real width

$x_{Compression}$ 55.667 [mm] $x_{Tension}$ 55.667 [mm]

Compression Stress is reached!

1º Iteration — $f_{Compression,Left Stiffener}$ **350.000** **[MPa]** — x_{CG} **55.667** **[mm]**

$f_{Compression}$ 350.000 [MPa] — m 6.287 — $f_{Tension}$ -350.000 [MPa]

h_0	53.741	[mm]
b_0	42.170	[mm]
h_0 / b_0	1.274	[ ]

Out-to-Out Dimensions of Webs and Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-2]

For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \le 4$	$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \le 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \le$ Compression portion of the web calculated on the basis of effective section

f_1 119.996 [MPa] — m 6.287 — f_2 -119.996 [MPa]

$$\psi = |f_2/f_1|$$
[AISI S100, Eq. B2.3-1]

$| \psi |$ 1.000

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$
[AISI S100, Eq. B2.3-2]

k 24.000

Ω-Section Purlin Dimension — NOTE — $w = b_{p,Sup. Web}$

$b_{p,Sup. Web}$ 38.171 [mm]

E 210.000 [GPa] — t 0.952 [mm] — ν [μ] 0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]

F_{cr} 2833.513 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

$f = f_1$: 119.996 [MPa]

λ 0.206

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,Sup.\,Web,eff,AISI}$	38.171	[mm]

$b_e = b_{p,Sup.\,Web,eff,AISI}$ 38.171 [mm]

↓

h_0 / b_0 1.274

↓

| ψ | 1.000

↓

$b_1 = b_e / [3 + \psi]$ 9.543 [mm]

↓

$h_o / b_o \leq 4$				$h_o / b_o > 4$		
ψ > 0.236	$b_2 = b_e / 2$	19.085	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
ψ ≤ 0.236	$b_2 = b_e - b_1$	----	[mm]			

↓

$b_1 + b_2 \leq w_{Comp}$ KO Web is fully effective **No more iterations!**

↓

$b_{p,Sup.\,Web,eff,AISI,1}$	9.543	[mm]	$b_{p,Sup.\,Web,eff,AISI,2}$	9.543	[mm]

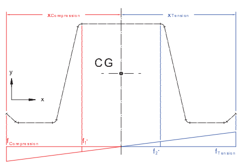
Superior Flange [$b_{p,Sup.\,Flange}$] [AS/NZS 4600, Clause 2.2.3]

Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]

$x_{Compression}$	55.667	[mm]	$x_{Tension}$	55.667	[mm]

Compression Stress is reached!



Ω-Section Purlin: Stress Gradient

Previous Page

↓

$b_{e1} = b_e / [3 - \psi]$ 9.543 [mm]

↓

ψ ≤ -0.236	$b_2 = b_e / 2$	19.085	[mm]	ψ > -0.236	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2} \leq$ Compression portion of the web calculated on the basis of effective section

↓

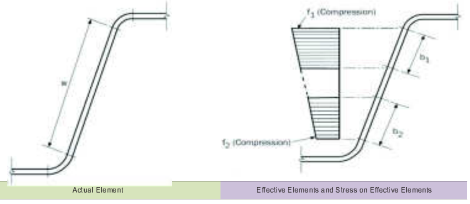
$b_{e1} + b_{e2} \leq b_{Comp}$ KO Web is fully effective **No more iterations!**

↓

$b_{p,Sup.\,Web,eff,AS/NZS,1}$	9.543	[mm]	$b_{p,Sup.\,Web,eff,AS/NZS,2}$	9.543	[mm]

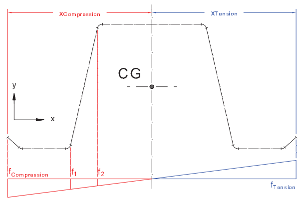
AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,Sup.\,Web,eff,AISI,1}$	9.543	=	$b_{p,Sup.\,Web,eff,AS/NZS,1}$	9.543
$b_{p,Sup.\,Web,eff,AISI,2}$	9.543	=	$b_{p,Sup.\,Web,eff,AS/NZS,2}$	9.543

Left Web [$h_{p,Left\,Web}$] [AISI S100, Sector B2.3]



Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



Ω-Section Purlin: Stress Gradient

1º Iteration	$f_{Compression,Left\,Stiffener}$	**350.000**	**[MPa]**	x_{CG}	**55.667**	**[mm]**
$f_{Compression}$	350.000	[MPa]	m 6.287	$f_{Tension}$	-350.000	[MPa]
f_1^*	119.996	[MPa]	m 6.287	f_2^*	-119.996	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$ ψ -1.000

[AS/NZS 4600, Eq. 2.2.3.2(5)]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$ k 24.000

[AS/NZS 4600, Eq. 2.2.3.2(4)]

Ω-Section Purlin Dimension | NOTE: $b = b_{p,Sup.\,Web}$

$b_{p,Sup.\,Web}$	38.171	[mm]					
E	210.000	[GPa]	t	0.952	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$ f_{cr} 2833.513 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$ [AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 119.996 [MPa]; λ 0.206

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$ [AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,Sup.\,Web,eff,AS/NZS}$	38.171	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$ [AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$ ψ ≤ −0.236 [AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$ ψ > −0.236 [AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = b_{p,Sup.\,Web,eff,AS/NZS}$ 38.171 [mm]

↓

ψ -1.000

↓

Next Page

$x_{Compression}$	55.667	[mm]	$x_{Tension}$	55.667	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Left\,Stiffener}$	**350.000**	**[MPa]**	x_{CG}	**55.667**	**[mm]**
$f_{Compression}$	350.000	[MPa]	m 6.287	$f_{Tension}$	-350.000	[MPa]
f_1	197.493	[MPa]	m 6.287	f_2	132.165	[MPa]

$$\psi = |f_2/f_1|$$ [AISI S100, Eq. B2.3-1] | ψ | 0.669

For webs under stress gradient [f_1 and f_2 in compression]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$ k 4.734

[AISI S100, Eq. B2.3-8]

Ω-Section Purlin Dimension | NOTE: $w = h_{p,Left\,Web}$

$h_{p,Left\,Web}$	51.640	[mm]					
E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$ F_{cr} 305.362 [MPa]

[AISI S100, Eq. (B2.1-5)]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$ [AISI S100, Eq. B2.1-4]

$f = f_1$: 197.493 [MPa]; λ 0.804

$$\rho = (1 - 0.22/\lambda)/\lambda$$ [AISI S100, Eq. B2.1-4]

ρ	0.903	→	$h_{p,Left\,Web,eff,AISI}$	46.647	[mm]

$b_e = h_{p,Right\,Web,eff,AISI}$ 46.647 [mm]

↓

$$b_1 = b_e/(3-\psi)$$ [AISI S100, Eq. B2.3-9] b_1 20.013 [mm]

↓

$$b_2 = b_e - b_1$$ [AISI S100, Eq. B2.3-10] b_2 26.633 [mm]

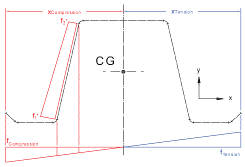
↓

$h_{p,Left\,Web,eff,AISI,1}$	20.013	[mm]	$h_{p,Left\,Web,eff,AISI,2}$	26.633	[mm]

Left Web [$h_{p,Left Web}$] [AS/NZS 4600, Clause 2.2.3]

Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



Ω-Section Purlin: Stress Gradient

$x_{Compression}$	0.000	[mm]	$x_{Tension}$	0.000	[mm]

Tension Stress is reached!

1º Iteration	$f_{Compression,Left Stiffener}$	350.000	[MPa]		x_{CG}	55.667	[mm]
$f_{Compression}$	350.000	[MPa]	m	6.287	$f_{Tension}$	-350.000	[MPa]
f_1^*	197.493	[MPa]	m	6.287	f_2^*	132.165	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$

ψ 0.669

[AS/NZS 4600, Eq. 2.2.3.2(5)]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

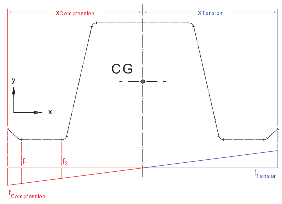
k 4.734

[AS/NZS 4600, Eq. 2.2.3.2(4)]

Ω-Section Purlin Dimension

$h_{p,Left Web}$ 51.640 [mm]

NOTE: $b = h_{p,Left Web}$



Ω-Section Purlin: Stress Gradient

$x_{Compression}$	55.667	[mm]	$x_{Tension}$	55.667	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Left Stiffener}$	350.000	[MPa]		x_{CG}	55.667	[mm]
$f_{Compression}$	350.000	[MPa]	m	6.287	$f_{Tension}$	-350.000	[MPa]
f_1	313.689	[MPa]	m	6.287	f_2	209.663	[MPa]

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B2.3-1]

| ψ | 0.668

For webs under stress gradient [f_1 and f_2 in compression]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

k 4.736

[AISI S100, Eq. B2.3-8]

Ω-Section Purlin Dimension

$b_{p,Inf. Left Flange}$ 16.545 [mm]

NOTE: $w = b_{p,Inf. Left Flange}$

E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

F_{cr} 2976.136 [MPa]

[AISI S100, Eq. (B2.1-5)]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$: 313.689 [MPa]

λ 0.325

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

E	210.000	[GPa]	t	0.952	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

f_{cr} 305.362 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 197.493 [MPa]

λ 0.804

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	0.903	→	$h_{p,Left Web,eff,AS/NZS}$	46.647 [mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

ψ ≤ −0.236

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

ψ > −0.236

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = h_{p,Left Web,eff,AS/NZS}$ 46.647 [mm]

↓

ψ 0.669

↓

$b_{e1} = b_e / [3 - \psi]$ 20.013 [mm]

↓

ψ ≤ -0.236	$b_2 = b_e / 2$	----	[mm]	ψ > -0.236	$b_{e2} = b_e - b_{e1}$	26.633	[mm]

↓

$h_{p,Left Web,eff,AS/NZS,1}$	20.013	[mm]	$h_{p,Left Web,eff,AS/NZS,2}$	26.633	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,Left Web,eff,AISI,1}$	20.013	=	$h_{p,Left Web,eff,AS/NZS,1}$	20.013
$h_{p,Left Web,eff,AISI,2}$	26.633	=	$h_{p,Left Web,eff,AS/NZS,2}$	26.633

Inferior Left Flange [$b_{p,Inf. Left Flange}$] [AISI S100, Sector B2.3]

Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]

ρ	1.000	→	$b_{p,Inf. Left Flange,eff,AISI}$	16.545 [mm]

$b_e = h_{p,Inf. Left Flange,eff,AISI}$ 16.545 [mm]

↓

$$b_1 = b_e/(3-\psi)$$

[AISI S100, Eq. B2.3-9]

b_1 7.096 [mm]

↓

$$b_2 = b_e - b_1$$

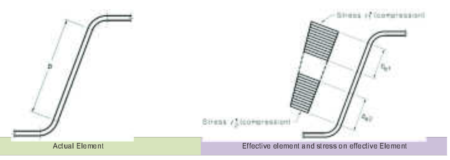
[AISI S100, Eq. B2.3-10]

b_2 9.449 [mm]

↓

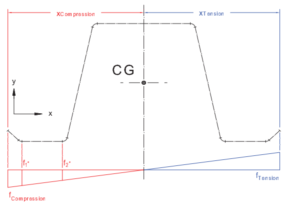
$b_{p,Inf. Left Flange,eff,AISI,1}$	7.096	[mm]	$b_{p,Inf. Left Flange,eff,AISI,2}$	9.449	[mm]

Inferior Left Flange [$b_{p,Inf. Left Flange}$] [AS/NZS 4600, Clause 2.2.3]



Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



Ω-Section Purlin: Stress Gradient

$x_{Compression}$	55.667	[mm]	$x_{Tension}$	55.667	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Left Stiffener}$	350.000	[MPa]		x_{CG}	55.667	[mm]
$f_{Compression}$	350.000	[MPa]	m	6.287	$f_{Tension}$	-350.000	[MPa]

f_1^*	313.689	[MPa]	m	6.287	f_2^*	209.663	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$ ψ 0.668

[AS/NZS 4600, Eq. 2.2.3.2(5)]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$ k 4.736

[AS/NZS 4600, Eq. 2.2.3.2(4)]

Ω-Section Purlin Dimension			NOTE	$w = b_{0,Inf.\ Left\ Flange}$
$b_{0,Inf.\ Left\ Flange}$	16.545	[mm]		

E	210.000	[GPa]	t	0.952	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$ f_{cr} 2976.136 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$ [AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 313.689 [MPa]; λ 0.325

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$ [AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $b_{0,Inf.\ Left\ Flange,eff,AS/NZS}$ 16.545 [mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$ [AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$ ψ ≤ -0.236 [AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$ ψ > -0.236 [AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = b_{0,Inf.\ Left\ Flange,AS/NZS}$ 16.545 [mm]
↓
ψ 0.668
↓
$b_{e1} = b_e / [3 - \psi]$ 7.096 [mm]
↓

ψ ≤ -0.236	$b_2 = b_e / 2$	----	[mm]	ψ > -0.236	$b_{e2} = b_e - b_{e1}$	9.449	[mm]

↓

$b_{0,Inf.\ Left\ Flange,eff,AS/NZS,1}$	7.096	[mm]	$b_{0,Inf.\ Left\ Flange,eff,AS/NZS,2}$	9.449	[mm]

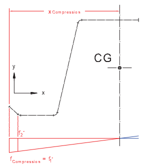
$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$ [AISI S100, Eq. B2.1-4]

$f = f_1$: 350.000 [MPa]; λ 0.423

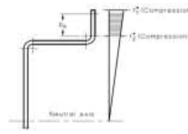
$$\rho = (1 - 0.22/\lambda)/\lambda$$ [AISI S100, Eq. B2.1-4]

ρ 1.000 → $c_{0,Left\ Lip,eff,AISI}$ 6.191 [mm]

Left Edge Stiffener [$c_{0,Left\ Lip}$] — [AS/NZS 4600, Clause 2.3.2]



Ω-Section Purlin: Stress Gradient



[b] Outward Facing Lip

Unstiffened Elements with Stress Gradient: Both Edges in Compression [AS/NZS 4600, Figure B2.3.2(a)]

1st Iteration	$f_{Compression,Left\ Stiffener}$	350.000	[MPa]	x_{CG}	55.667	[mm]

$f_{Compression}$	350.000	[MPa]	m	6.287	$f_{Tension}$	-350.000	[MPa]
f_1^*	350.000	[MPa]	m	6.287	f_2^*	322.474	[MPa]

$$\psi = f_2^* / f_1^*$$ ψ 0.921

[AS/NZS 4600, Eq. 2.3.2.2(1)]

f_1 Compression; f_2 Compression

$$k = 0.57 - 0.21\psi + 0.07\psi^2$$ k 0.436

[AS/NZS 4600, Eq. 2.3.2.2(3)]

Ω-Section Purlin Dimension			NOTE	$b = c_{0,Left\ Lip}$
$c_{0,Left\ Lip}$	6.191	[mm]		

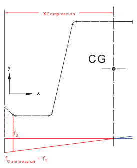
E	210.000	[GPa]	t	0.952	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$ f_{cr} 1956.179 [MPa]

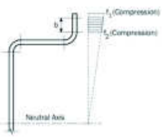
[AS/NZS 4600, Eq. 2.2.1.2(5)]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{0,Inf.\ Left\ Flange,eff,AISI,1}$	7.096	=	$b_{0,Inf.\ Left\ Flange,eff,AS/NZS,1}$	7.096
$b_{0,Inf.\ Left\ Flange,eff,AISI,2}$	9.449	=	$b_{0,Inf.\ Left\ Flange,eff,AS/NZS,2}$	9.449

Left Edge Stiffener [$c_{0,Left\ Lip}$] — [AISI S100, Section B3.2]



Ω-Section Purlin: Stress Gradient



[b] Outward Facing Lip

Unstiffened Elements under Stress Gradient, Both Longitudinal Edges in Compression [AISI S100, Figure B3.2-1]

1st Iteration	$f_{Compression,Left\ Stiffener}$	350.000	[MPa]	x_{CG}	55.667	[mm]

$f_{Compression}$	350.000	[MPa]	m	6.287	$f_{Tension}$	-350.000	[MPa]
f_1	350.000	[MPa]	m	6.287	f_2	322.474	[MPa]

$$\psi = |f_2/f_1|$$ |ψ| 0.921

[AISI S100, Eq. B3.2-1]

f_1 Compression; f_2 Compression

$$k = 0.57 - 0.21\psi + 0.07\psi^2$$ k 0.436

[AISI S100, Eq. B3.2-3]

Ω-Section Purlin Dimension			NOTE	$w = c_{0,Left\ Lip}$
$c_{0,Left\ Lip}$	6.191	[mm]		

E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300
w	6.191	[mm]	→	w / t ≤ 60	OK		

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$ F_{cr} 1956.179 [MPa]

[AISI S100, Eq. (B2.1-5)]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$ [AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 350.000 [MPa]; λ 0.423

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$ [AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $c_{0,Left\ Lip,eff,AS/NZS}$ 6.191 [mm]

AISI S100, Effective Width		Comparison [= or ≠]	AS/NZS 4600, Effective Width	
$c_{0,Left\ Lip,eff,AISI}$	6.191	=	$c_{0,Left\ Lip,eff,AS/NZS}$	6.191

[ii] **Effective Ω-Section Purlin [Local Buckling]**

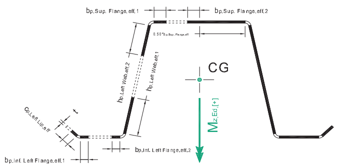
Effective Ω-Section Purlin Widths [AISI S100]			
Right Edge Stiffener	$c_{0,Right\ Lip,eff,AISI}$	----	[mm]
Inferior Right Flange	$b_{0,Inf.\ Right\ Flange,eff,AISI}$	----	[mm]
Right Web	$h_{0,Right\ Web,eff,AISI}$	----	[mm]
Superior Flange	$b_{0,Sup.\ Flange,eff,AISI}$	38.171	[mm]
Left Web	$h_{0,Left\ Web,eff,AISI}$	46.647	[mm]
Inferior Left Flange	$b_{0,Inf.\ Left\ Flange,eff,AISI}$	16.545	[mm]
Left Edge Stiffener	$c_{0,Left\ Lip,eff,AISI}$	6.191	[mm]

Effective Ω-Section Purlin Widths [AS/NZS 4600]			
Right Edge Stiffener	$c_{0,Right\ Lip,eff,AS/NZS}$	----	[mm]
Inferior Right Flange	$b_{0,Inf.\ Right\ Flange,eff,AS/NZS}$	----	[mm]
Right Web	$h_{0,Right\ Web,eff,AS/NZS}$	----	[mm]
Superior Flange	$b_{0,Sup.\ Flange,eff,AS/NZS}$	38.171	[mm]
Left Web	$h_{0,Left\ Web,eff,AS/NZS}$	46.647	[mm]
Inferior Left Flange	$b_{0,Inf.\ Left\ Flange,eff,AS/NZS}$	16.545	[mm]
Left Edge Stiffener	$c_{0,Left\ Lip,eff,AS/NZS}$	6.191	[mm]

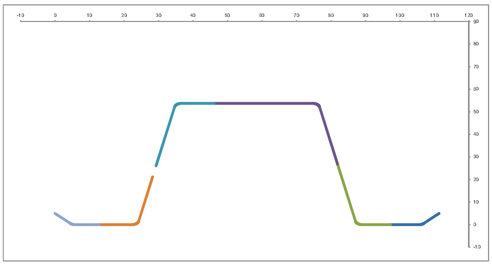
Effective Ω-Section Purlin Widths [AISI S100 | AS/NZS 4600]			
Right Edge Stiffener	$c_{0,Right\ Lip,eff}$	----	[mm]
Inferior Right Flange	$b_{0,Inf.\ Right\ Flange,eff}$	----	[mm]
Right Web	$h_{0,Right\ Web,eff}$	----	[mm]
Superior Flange	$b_{0,Sup.\ Flange,eff}$	38.171	[mm]
Left Web	$h_{0,Left\ Web,eff}$	46.647	[mm]
Inferior Left Flange	$b_{0,Inf.\ Left\ Flange,eff}$	16.545	[mm]
Left Edge Stiffener	$c_{0,Left\ Lip,eff}$	6.191	[mm]

[iii] **Effective Cross Ω-Section Purlin [Local Buckling]**

Effective Ω-Section Purlin Widths			
Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	----	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff}$	----	[mm]
Right Web	$h_{p,Right\ Web,eff,1}$	----	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff,1}$	9.543	[mm]
	$b_{p,Sup.\ Flange,eff,2}$	9.543	[mm]
Left Web	$h_{p,Left\ Web,eff,1}$	20.013	[mm]
	$h_{p,Left\ Web,eff,2}$	26.633	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff,1}$	7.096	[mm]
	$b_{p,Inf.\ Left\ Flange,eff,2}$	9.449	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	6.191	[mm]



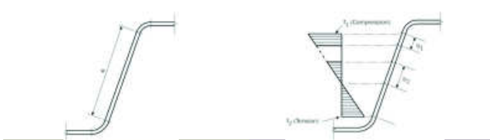
Effective Ω-Section Purlin [Positive Moment in y-y axis, $M_{y,Ed}^{*}$] [AISI S100 | AS/NZS 4600]



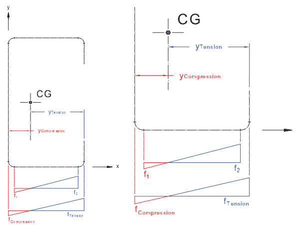
Effective Ω-Section Purlin [Local Buckling] [Positive Moment in y-y axis, $M_{y,Ed}^{*}$]

$I_{y,eff}^{(+)}$ 173380.870 [mm^4]

Inferior Flange [$b_{p,1}$] [AISI S100, Sector B2.3]


Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



C-Section Beam: Stress Gradient

[AISI S100, Figure B2.3-2]

h_0	120.000	[mm]
b_0	46.500	[mm]
h_0 / b_0	2.581	[ ]

$x_{Compression}$ 14.563 [mm] $x_{Tension}$ 30.485 [mm]

Tension Stress is reached!

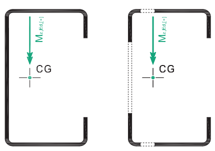
1º Iteration	$f_{Tension,Inf.\ fiber}$	350.000	[MPa]		x_{CG}	14.563	[mm]
$f_{Compression}$	167.191	[MPa]	m	11.481	$f_{Tension}$	-350.000	[MPa]
f_1	130.154	[MPa]	m	11.481	f_2	-312.963	[MPa]

For webs under stress gradient [f_1 in compression and f_2 in tension]

$h_o / b_o \leq 4$		$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \leq 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \leq$ Compression portion of the web calculated on the basis of effective section

[b] C-Section Beam

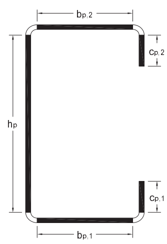


Gross C-Section | Effective C-Section [L]

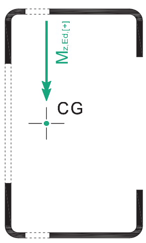
Local Buckling

C-Section Beam Dimension		
$c_{p,1}$	14.048	[mm]
$b_{p,1}$	38.596	[mm]
h_p	112.096	[mm]
$b_{p,2}$	38.596	[mm]
$c_{p,2}$	14.048	[mm]
t	1.452	[mm]

[i] **Effective Widths for Strength Determination [Local Buckling]** **AISI S100, Sector B | AS/NZS 4600, Section 2**



C-Section Plate Widths



Effective C-Section [Worst Case]

1º Iteration

Inferior Edge Stiffner [$c_{p,1}$] [AISI S100, Sector B3.1]

NOTE Zone in Tension. Effective width is equal to the real width

Inferior Edge Stiffener [$c_{p,1}$] [AS/NZS 4600, Clause 2.3.1]

NOTE Zone in Tension. Effective width is equal to the real width

$$\psi = |f_2/f_1|$$
[AISI S100, Eq. B2.3-1] | ψ | 2.405

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$
[AISI S100, Eq. B2.3-2] k 89.734

C-Section Beam Dimension			NOTE	$w = b_{p,1}$
$b_{p,1}$	38.596	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	ν [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)] F_{cr} 24104.770 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

$f = f_1$: 130.154 [MPa]

λ 0.073

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ 1.000 → $b_{p,1,eff,AISI}$ 38.596 [mm]

$b_e = b_{p,1,eff,AISI}$ 38.596 [mm]

↓

h_0 / b_0 2.581

↓

| ψ | 2.405

↓

$b_1 = b_e / [3 + \psi]$ 7.141 [mm]

↓

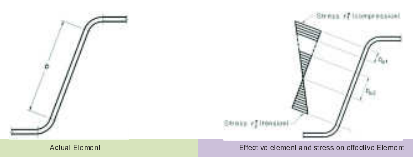
$h_o / b_o \leq 4$				$h_o / b_o > 4$		
$\psi > 0.236$	$b_2 = b_e / 2$	19.298	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
$\psi \leq 0.236$	$b_2 = b_e - b_1$	----	[mm]			

↓

$b_1 + b_2 \leq w_{Comp}$ KO Web is fully effective **No more iterations!**

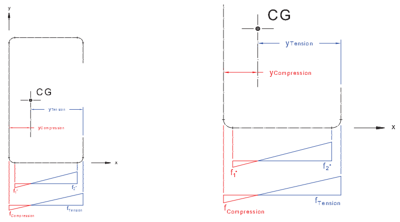
$b_{p,1,eff,AISI,1}$ 7.141 [mm] $b_{p,1,eff,AISI,2}$ 4.195 [mm]

Inferior Flange [$b_{p,1}$]	[AS/NZS 4600, Clause 2.2.3]



Actual Element	Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Beam: Stress Gradient

$x_{Compression}$	14.563	[mm]	$x_{Tension}$	30.485	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf. fiber}$	350.000	[MPa]	x_{CG}	14.563	[mm]
$f_{Compression}$	167.191	[MPa]	m 11.481	$f_{Tension}$	-350.000	[MPa]
f_1^*	130.154	[MPa]	m 11.481	f_2^*	-312.963	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$

ψ -2.405

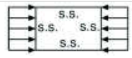
[AS/NZS 4600, Eq. 2.2.3.2(5)]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

k 89.734

[AS/NZS 4600, Eq. 2.2.3.2(4)]

Web [h_p]	[AISI S100, Sector B2.1]

Boundary condition	Types of stress	k
	Compression	4.000

Actual Element	Effective Element, b, and Stress, f, on Effective Elements

Stiffened Elements [AISI S100, Figure B2.1-1]

$x_{Compression}$	14.563	[mm]	$x_{Tension}$	30.485	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf. fiber}$	350.000	[MPa]	x_{CG}	14.563	[mm]
$f_{Compression}$	167.191	[MPa]	m 11.481	$f_{Tension}$	-350.000	[MPa]

C-Section Beam Dimension			NOTE	$w = h_p$
h_p	112.096	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300	

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 127.382 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$: 167.191 [MPa]

λ 1.146

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	0.705	→	$h_{p,eff,AISI}$	79.056	[mm]
$h_{p,eff,AISI,1}$	39.528	[mm]	$h_{p,eff,AISI,2}$	39.528	[mm]

C-Section Beam Dimension			NOTE	$b = b_{p,1}$
$b_{p,1}$	38.596	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 24104.770 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 130.154 [MPa]

λ 0.073

$$\rho = \frac{\left(1-\frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,1,eff,AS/NZS}$	38.596	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

ψ ≤ −0.236

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

ψ > −0.236

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = b_{p,1,eff,AS/NZS}$ 38.596 [mm]

↓

ψ -2.405

↓

$b_{e1} = b_e / [3 - \psi]$ 7.141 [mm]

↓

ψ ≤ -0.236	$b_2 = b_e / 2$	19.298	[mm]	ψ > -0.236	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2}$ ≤ Compression portion of the web calculated on the basis of effective section

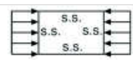
↓

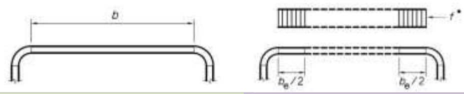
$b_{e1} + b_{e2} \le b_{Comp}$	KO	Web is fully effective	No more iterations!

$b_{p,1,eff,AS/NZS,1}$	7.141	[mm]	$b_{p,1,eff,AS/NZS,2}$	4.195	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,1,eff,AISI,1}$	7.141	=	$b_{p,1,eff,AS/NZS,1}$	7.141
$b_{p,1,eff,AISI,2}$	4.195	=	$b_{p,1,eff,AS/NZS,2}$	4.195

Web [h_p]	[AS/NZS 4600, Clause 2.2.1]

Boundary condition	Types of stress	k
	Compression	4.000



Actual Element	Effective Width [be] of Element and Design Stress [f*] on Effective Elements

Stiffened Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

$x_{Compression}$	14.563	[mm]	$x_{Tension}$	30.485	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf. fiber}$	350.000	[MPa]	x_{CG}	14.563	[mm]
$f_{Compression}$	167.191	[MPa]	m 11.481	$f_{Tension}$	-350.000	[MPa]

C-Section Beam Dimension			NOTE	$b = h_p$
h_p	112.096	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 127.382 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 167.191 [MPa]

λ 1.146

$$\rho = \frac{\left(1-\frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

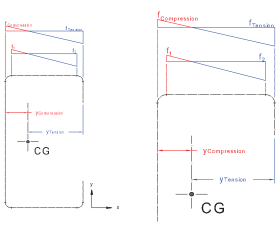
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	0.705	→	$h_{p,eff,AS/NZS}$	79.056	[mm]
$h_{p,eff,AS/NZS,1}$	39.528	[mm]	$h_{p,eff,AS/NZS,2}$	39.528	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,eff,AISI,1}$	39.528	=	$h_{p,eff,AS/NZS,1}$	39.528
$h_{p,eff,AISI,2}$	39.528	=	$h_{p,eff,AS/NZS,2}$	39.528

Superior Flange [$b_{p,2}$] [AISI S100, Sector B2.3]

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



[AISI S100, Figure B2.3-2]

C-Section Beam: Stress Gradient

h_0	120.000	[mm]
b_0	46.500	[mm]
h_0 / b_0	2.581	[ ]

$x_{Compression}$ 14.563 [mm] $x_{Tension}$ 30.485 [mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf. fiber}$	350.000	[MPa]	x_{CG}	14.563	[mm]
$f_{Compression}$	167.191	[MPa]	m 11.481	$f_{Tension}$	-350.000	[MPa]
f_1	130.154	[MPa]	m 11.481	f_2	-312.963	[MPa]

Previous Page

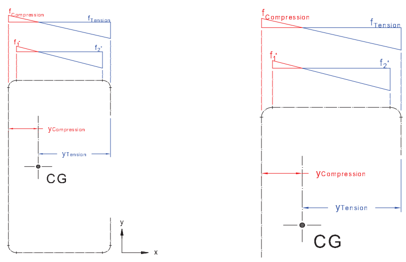
↓

$b_1 + b_2 \le w_{Comp}$ KO Web is fully effective **No more iterations!**

$b_{p,2,eff,AISI,1}$ 7.141 [mm] $b_{p,2,eff,AISI,2}$ 4.195 [mm]

Superior Flange [$b_{p,2}$] [AS/NZS 4600, Clause 2.2.3]

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Beam: Stress Gradient

$x_{Compression}$ 14.563 [mm] $x_{Tension}$ 30.485 [mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf. fiber}$	350.000	[MPa]	x_{CG}	14.563	[mm]
$f_{Compression}$	167.191	[MPa]	m 11.481	$f_{Tension}$	-350.000	[MPa]
f_1^*	130.154	[MPa]	m 11.481	f_2^*	-312.963	[MPa]

For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \le 4$	$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \le 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \le$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B2.3-1] | ψ | 2.405

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$

[AISI S100, Eq. B2.3-2] k 89.734

C-Section Beam Dimension

NOTE **$w = b_{p,2}$**

$b_{p,2}$ 38.596 [mm]

E	210.000	[GPa]	t	1.452	[mm]	ν [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)] F_{cr} 24104.770 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$: 130.154 [MPa]

λ 0.073

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ 1.000 → $b_{p,2,eff,AISI}$ 38.596 [mm]

$b_e = h_{p,eff,AISI}$ 38.596 [mm]

↓

h_0 / b_0 2.581

↓

| ψ | 2.405

↓

$b_1 = b_e / [3 + \psi]$ 7.141 [mm]

↓

$h_o / b_o \le 4$				$h_o / b_o > 4$		
$\psi > 0.236$	$b_2 = b_e / 2$	19.298	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
$\psi \le 0.236$	$b_2 = b_e - b_1$	----	[mm]			

↓

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$$\psi = \frac{f_2^*}{f_1^*}$$

[AS/NZS 4600, Eq. 2.2.3.2(5)] ψ -2.405

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

[AS/NZS 4600, Eq. 2.2.3.2(4)] k 89.734

C-Section Beam

NOTE **$b = b_{p,2}$**

$b_{p,2}$ 38.596 [mm]

E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)] f_{cr} 24104.770 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 130.154 [MPa]

λ 0.073

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $b_{p,2,eff,AS/NZS}$ 38.596 [mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

ψ ≤ −0.236

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

ψ > −0.236

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = h_{p,Right Web,eff,AS/NZS}$ 38.596 [mm]

↓

ψ -2.405

↓

$b_{e1} = b_e / [3 - \psi]$ 7.141 [mm]

↓

$\psi \le -0.236$	$b_2 = b_e / 2$	19.298	[mm]	$\psi > -0.236$	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2} \le$ Compression portion of the web calculated on the basis of effective section

↓

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↓

$b_{e1} + b_{e2} \leq b_{Comp}$	KO	Web is fully effective	No more iterations!

$b_{p,2,eff,AS/NZS,1}$	7.141	[mm]	$b_{p,2,eff,AS/NZS,2}$	4.195	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,2,eff,AISI,1}$	7.141	=	$b_{p,2,eff,AS/NZS,1}$	7.141
$b_{p,2,eff,AISI,2}$	4.195	=	$b_{p,2,eff,AS/NZS,2}$	4.195

Superior Edge Stiffener [$c_{p,2}$] [AISI S100, Sector B3.1]

NOTE Zone in Tension. Effective width is equal to the real width

Superior Edge Stiffener [$c_{p,2}$] [AS/NZS 4600, Clause 2.3.1]

NOTE Zone in Tension. Effective width is equal to the real width

[ii] **Effective C-Section Beam [Local Buckling]**

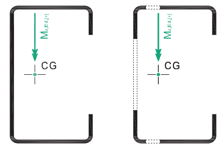
Effective C-Section Beam Widths [AISI S100]			
Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	----	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	38.596	[mm]
Web	$h_{p,eff,AISI}$	79.056	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	38.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	----	[mm]

Effective C-Section Beam Widths [AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	----	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	38.596	[mm]
Web	$h_{p,eff,AS/NZS}$	79.056	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	38.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	----	[mm]

Effective C-Section Beam Widths [AISI S100 | AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	38.596	[mm]
Web	$h_{p,eff}$	79.056	[mm]
Superior Flange	$b_{p,2,eff}$	38.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

[c] C-Section Column



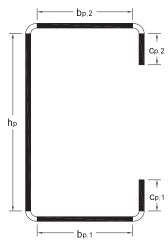
Gross C-Section

Effective C-Section [L]

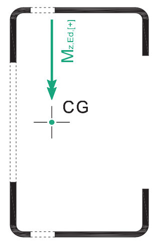
Local Buckling

C-Section Column Dimension		
$c_{p,1}$	13.048	[mm]
$b_{p,1}$	36.596	[mm]
h_p	80.096	[mm]
$b_{p,2}$	36.596	[mm]
$c_{p,2}$	13.048	[mm]
t	2.452	[mm]

[i] **Effective Widths for Strength Determination [Local Buckling]** **AISI S100, Sector B | AS/NZS 4600, Section 2**



C-Section Plate Widths



Effective C-Section [Worst Case]

1º Iteration

Inferior Edge Stiffner [$c_{p,1}$] [AISI S100, Sector B3.1]

NOTE Zone in Tension. Effective width is equal to the real width

Inferior Edge Stiffener [$c_{p,1}$] [AS/NZS 4600, Clause 2.3.1]

NOTE Zone in Tension. Effective width is equal to the real width

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
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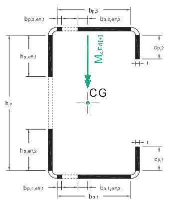
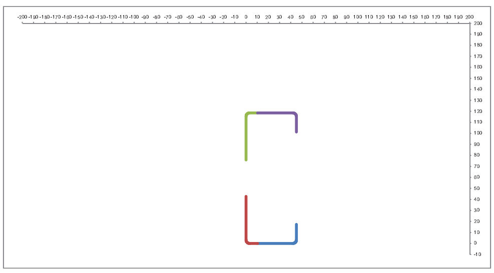
[iii] **Effective Cross C-Section Beam [Local Buckling]**

Effective C-Section Beam Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff,1}$	7.141	[mm]
	$b_{p,1,eff,2}$	4.195	[mm]
Web	$h_{p,eff,1}$	39.528	[mm]
	$h_{p,eff,2}$	39.528	[mm]
Superior Flange	$b_{p,2,eff,1}$	7.141	[mm]
	$b_{p,2,eff,2}$	4.195	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]



Effective C-Section Beam [Local Buckling] [Bending Moment $M_{y,Ed}{}^{+}$] [AISI S100 | AS/NZS 4600]



Effective C-Section Beam [Local Buckling] [Bending Moment $M_{y,Ed}{}^{+}$]

$I_{y,eff}{}^{[+]}$ 96937.280 [mm^4]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
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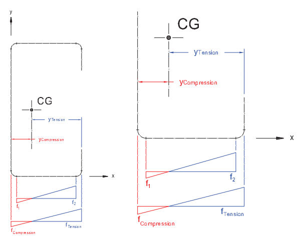
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

Inferior Flange [$b_{p,1}$] [AISI S100, Sector B2.3]

Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



C-Section Column: Stress Gradient

[AISI S100, Figure B2.3-2]

h_o	90.000	[mm]
b_o	46.500	[mm]
h_o / b_o	1.935	[ ]

$x_{Compression}$	16.159	[mm]	$x_{Tension}$	27.889	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf. fiber}$	350.000	[MPa]	x_{CG}	16.159	[mm]
$f_{Compression}$	202.797	[MPa]	m 12.550	$f_{Tension}$	-350.000	[MPa]
f_1	156.036	[MPa]	m 12.550	f_2	-303.239	[MPa]

For webs under stress gradient [f_1 in compression and f_2 in tension]

$h_o / b_o \leq 4$		$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \leq 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \leq$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B2.3-1]

| ψ | | 1.943

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$

[AISI S100, Eq. B2.3-2]

k 60.887

C-Section Column Dimension			**NOTE**	$w = b_{p,1}$
$b_{p,1}$	36.596	[mm]		

E	210.000	[GPa]	t	2.452	[mm]	v [μ]	0.300	

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 51879.743 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$: 156.036 [MPa]

λ 0.055

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,1,eff,AISI}$	36.596	[mm]

$b_e = b_{p,1,eff,AISI}$	36.596	[mm]

↓

h_0 / b_0	1.935

↓

| ψ |	1.943

↓

$b_1 = b_e / [3 + \psi]$	7.403	[mm]

↓

$h_o / b_o \le 4$				$h_o / b_o > 4$		
ψ > 0.236	$b_2 = b_e / 2$	18.298	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
ψ ≤ 0.236	$b_2 = b_e - b_1$	----	[mm]			

↓

$b_1 + b_2 \le w_{Comp}$	KO	Web is fully effective	**No more iterations!**

$b_{p,1,eff,AISI,1}$	7.403	[mm]	$b_{p,1,eff,AISI,2}$	5.030	[mm]

C-Section Column			**NOTE**	$b = b_{p,1}$
$b_{p,1}$	36.596	[mm]		

E	210.000	[GPa]	t	2.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 51879.743 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 156.036 [MPa]

λ 0.055

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,1,eff,AS/NZS}$	36.596	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

ψ ≤ −0.236

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

ψ > −0.236

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = b_{p,1,eff,AS/NZS}$	36.596	[mm]

↓

ψ	-1.943

↓

$b_{e1} = b_e / [3 - \psi]$	7.403	[mm]

↓

ψ ≤ -0.236	$b_2 = b_e / 2$	18.298	[mm]	ψ > -0.236	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2} \le$ Compression portion of the web calculated on the basis of effective section

↓

$b_{e1} + b_{e2} \le b_{Comp}$	KO	Web is fully effective	**No more iterations!**

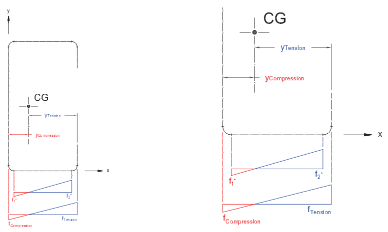
$b_{p,1,eff,AS/NZS,1}$	7.403	[mm]	$b_{p,1,eff,AS/NZS,2}$	5.030	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,1,eff,AISI,1}$	7.403	=	$b_{p,1,eff,AS/NZS,1}$	7.403
$b_{p,1,eff,AISI,2}$	5.030	=	$b_{p,1,eff,AS/NZS,2}$	5.030

Inferior Flange [$b_{p,1}$] | [AS/NZS 4600, Clause 2.2.3]

Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Column: Stress Gradient

$x_{Compression}$	16.159	[mm]	$x_{Tension}$	27.889	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf. fiber}$	**350.000**	**[MPa]**	x_{CG}	**16.159**	**[mm]**
$f_{Compression}$	**202.797**	**[MPa]**	m 12.550	$f_{Tension}$	**-350.000**	**[MPa]**
f_1^*	**156.036**	**[MPa]**	m 12.550	f_2^*	**-303.239**	**[MPa]**

$$\psi = \frac{f_2^*}{f_1^*}$$

[AS/NZS 4600, Eq. 2.2.3.2(5)]

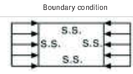
ψ -1.943

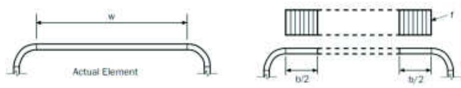
$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

[AS/NZS 4600, Eq. 2.2.3.2(4)]

k 60.887

Web [h_p] | [AISI S100, Sector B2.1]

Boundary condition	Types of stress	k
	Compression	4.000



Actual Element | Effective Element, b, and Stress, f, on Effective Elements

Stiffened Elements [AISI S100, Figure B2.1-1]

$x_{Compression}$	16.159	[mm]	$x_{Tension}$	27.889	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf. fiber}$	**350.000**	**[MPa]**	x_{CG}	**16.159**	**[mm]**
$f_{Compression}$	**202.797**	**[MPa]**	m 12.550	$f_{Tension}$	**-350.000**	**[MPa]**

C-Section Column Dimension			**NOTE**	$w = h_p$
h_p	80.096	[mm]		

E	210.000	[GPa]	t	2.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 711.501 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$: 202.797 [MPa]

λ 0.534

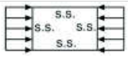
$$\rho = (1 - 0.22/\lambda)/\lambda$$

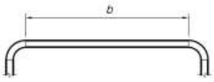
[AISI S100, Eq. B2.1-4]

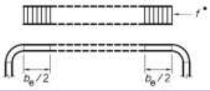
ρ	1.000	→	$h_{p,eff,AISI}$	80.096	[mm]

$h_{p,eff,AISI,1}$	40.048	[mm]	$h_{p,eff,AISI,2}$	40.048	[mm]

Web [h_p] [AS/NZS 4600, Clause 2.2.1]

Boundary condition	Types of stress	k
	Compression	4.000





Actual Element | Effective Width [be] of Element and Design Stress [f*] on Effective Elements

Stiffened Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

$x_{Compression}$	16.159	[mm]	$x_{Tension}$	27.889	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf. fiber}$	**350.000**	**[MPa]**		x_{CG}	**16.159**	**[mm]**
$f_{Compression}$	202.797	[MPa]	m	12.550	$f_{Tension}$	-350.000	[MPa]

C-Section Column Dimension | **NOTE** $b = h_p$

h_p	80.096	[mm]					
E	210.000	[GPa]	t	2.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)] f_{cr} 711.501 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 202.797 [MPa]

λ 0.534

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$h_{p,eff,AS/NZS}$	80.096	[mm]
$h_{p,eff,AS/NZS,1}$	40.048	[mm]	$h_{p,eff,AS/NZS,2}$	40.048	[mm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

Office:	----	Author:	JOSÉ ANTÓNIO
Date:	05/09/2019	Project:	MASTER THESIS
Client:	COIMBRA UNIVERSITY		

Code: AISI \| AS/NZS References: AISI S 100 \| AS/NZS 4600 \| EN 1993
Version: 1.000

For webs under stress gradient [f_1 in compression and f_2 in tension]

$h_o / b_o \leq 4$	$h_o / b_o > 4$
$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$: $b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \leq 0.236$: $b_2 = b_e - b_1$	

$b_1 + b_2 \leq$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B2.3-1] $|\psi|$ 1.943

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$

[AISI S100, Eq. B2.3-2] k 60.887

C-Section Column Dimension | **NOTE** $w = b_{p,2}$

$b_{p,2}$	36.596	[mm]					
E	210.000	[GPa]	t	2.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)] F_{cr} 51879.743 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$: 156.036 [MPa]

λ 0.055

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,2,eff,AISI}$	36.596	[mm]

$b_e = h_{p,eff,AISI}$ 36.596 [mm]

↓

h_0 / b_0 1.935

↓

$|\psi|$ 1.943

↓

$b_1 = b_e / [3 + \psi]$ 7.403 [mm]

↓

$h_o / b_o \leq 4$				**$h_o / b_o > 4$**		
$\psi > 0.236$	$b_2 = b_e / 2$	18.298	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
$\psi \leq 0.236$	$b_2 = b_e - b_1$	----	[mm]			

↓

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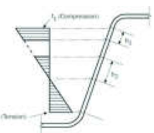
Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

Office:	----	Author:	JOSÉ ANTÓNIO
Date:	05/09/2019	Project:	MASTER THESIS
Client:	COIMBRA UNIVERSITY		

Code: AISI \| AS/NZS References: AISI S 100 \| AS/NZS 4600 \| EN 1993
Version: 1.000

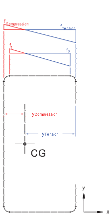
AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,eff,AISI,1}$	40.048	=	$h_{p,eff,AS/NZS,1}$	40.048
$h_{p,eff,AISI,2}$	40.048	=	$h_{p,eff,AS/NZS,2}$	40.048

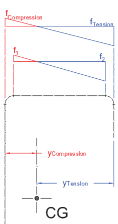
Superior Flange [$b_{p,2}$] [AISI S100, Sector B2.3]



Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]





C-Section Column: Stress Gradient

[AISI S100, Figure B2.3-2]

h_0	90.000	[mm]
b_0	46.500	[mm]
h_0 / b_0	1.935	[ ]

$x_{Compression}$	16.159	[mm]	$x_{Tension}$	27.889	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf. fiber}$	**350.000**	**[MPa]**		x_{CG}	**16.159**	**[mm]**
$f_{Compression}$	202.797	[MPa]	m	12.550	$f_{Tension}$	-350.000	[MPa]
f_1	156.036	[MPa]	m	12.550	f_2	-303.239	[MPa]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

Office:	----	Author:	JOSÉ ANTÓNIO
Date:	05/09/2019	Project:	MASTER THESIS
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Code: AISI \| AS/NZS References: AISI S 100 \| AS/NZS 4600 \| EN 1993
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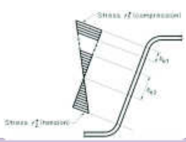
↓

$b_1 + b_2 \leq w_{Comp}$	KO	Web is fully effective	**No more iterations!**

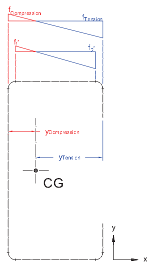
$b_{p,2,eff,AISI,1}$	7.403	[mm]	$b_{p,2,eff,AISI,2}$	5.030	[mm]

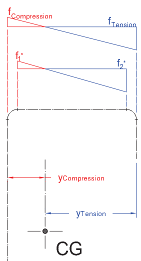
Superior Flange [$b_{p,2}$] [AS/NZS 4600, Clause 2.2.3]



Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]





C-Section Column: Stress Gradient

$x_{Compression}$	16.159	[mm]	$x_{Tension}$	27.889	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf. fiber}$	**350.000**	**[MPa]**		x_{CG}	**16.159**	**[mm]**
$f_{Compression}$	202.797	[MPa]	m	12.550	$f_{Tension}$	-350.000	[MPa]
f_1^*	156.036	[MPa]	m	12.550	f_2^*	-303.239	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$ ψ -1.943

[AS/NZS 4600, Eq. 2.2.3.2(5)]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$ k 60.887

[AS/NZS 4600, Eq. 2.2.3.2(4)]

C-Section Column Dimension		
$b_{p,2}$	36.596	[mm]

NOTE $b = b_{p,2}$

E 210.000 [GPa] | t 2.452 [mm] | v 0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$ f_{cr} 51879.743 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 156.036 [MPa]

λ 0.055

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $b_{p,2,eff,AS/NZS}$ 36.596 [mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

ψ ≤ −0.236

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

ψ > −0.236

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = h_{p,Right Web,eff,AS/NZS}$ 36.596 [mm]

↓

ψ -1.943

↓

$b_{e1} = b_e / [3 - \psi]$ 7.403 [mm]

↓

ψ ≤ -0.236 | $b_2 = b_e / 2$ | 18.298 | [mm] | ψ > -0.236 | $b_{e2} = b_e - b_{e1}$ | ---- | [mm]

↓

$b_{e1} + b_{e2} \leq$ Compression portion of the web calculated on the basis of effective section

↓

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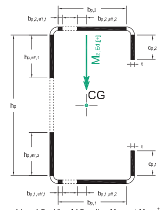
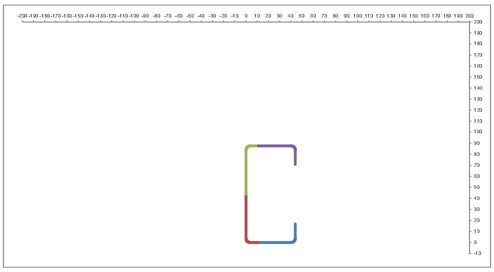
[iii] **Effective Cross C-Section Column [Local Buckling]**

Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff,1}$	7.403	[mm]
	$b_{p,1,eff,2}$	5.030	[mm]
Web	$h_{p,eff,1}$	40.048	[mm]
	$h_{p,eff,2}$	40.048	[mm]
Superior Flange	$b_{p,2,eff,1}$	7.403	[mm]
	$b_{p,2,eff,2}$	5.030	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]



Effective C-Section Column [Local Buckling] [Bending Moment $M_{z,Ed}^{+}$] [AISI S100 | AS/NZS 4600]



Effective C-Section Column [Local Buckling] [Bending Moment $M_{z,Ed}^{+}$]

$I_{z,eff}^{(+)}$ 153816.866 [mm^4]

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↓

$b_{e1} + b_{e2} \leq b_{Comp}$ KO Web is fully effective **No more iterations!**

$b_{p,2,eff,AS/NZS,1}$ 7.403 [mm] $b_{p,2,eff,AS/NZS,2}$ 5.030 [mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,2,eff,AISI,1}$	7.403	=	$b_{p,2,eff,AS/NZS,1}$	7.403
$b_{p,2,eff,AISI,2}$	5.030	=	$b_{p,2,eff,AS/NZS,2}$	5.030

Superior Edge Stiffener [$c_{p,2}$] [AISI S100, Sector B3.1]

NOTE Zone in Tension. Effective width is equal to the real width

Superior Edge Stiffener [$c_{p,2}$] [AS/NZS 4600, Clause 2.3.1]

NOTE Zone in Tension. Effective width is equal to the real width

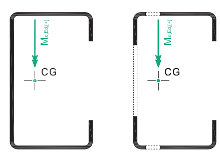
[ii] **Effective C-Section Column [Local Buckling]**

Effective C-Section Column Widths [AISI S100]			
Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	----	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	36.596	[mm]
Web	$h_{p,eff,AISI}$	80.096	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	36.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	----	[mm]

Effective C-Section Column Widths [AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	----	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	36.596	[mm]
Web	$h_{p,eff,AS/NZS}$	80.096	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	36.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	----	[mm]

Effective C-Section Column Widths [AISI S100 | AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	36.596	[mm]
Web	$h_{p,eff}$	80.096	[mm]
Superior Flange	$b_{p,2,eff}$	36.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]

[d] C-Section Strut



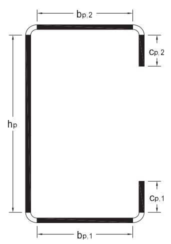
Gross C-Section

Effective C-Section [L]

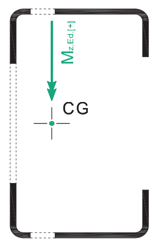
Local Buckling

C-Section Strut Dimension		
$c_{p,1}$	6.048	[mm]
$b_{p,1}$	32.096	[mm]
h_p	42.096	[mm]
$b_{p,2}$	32.096	[mm]
$c_{p,2}$	6.048	[mm]
t	1.452	[mm]

[i] **Effective Widths for Strength Determination [Local Buckling]** **AISI S100, Sector B | AS/NZS 4600, Section 2**



C-Section Plate Widths



Effective C-Section [Worst Case]

1st Iteration

Inferior Edge Stiffener [$c_{p,1}$] [AISI S100, Sector B3.1]

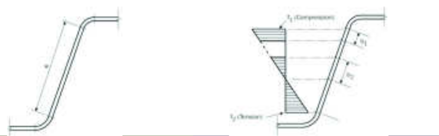
NOTE Zone in Tension. Effective width is equal to the real width

Inferior Edge Stiffener [$c_{p,1}$] [AS/NZS 4600, Clause 2.3.1]

NOTE Zone in Tension. Effective width is equal to the real width

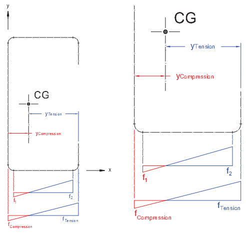
Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

Inferior Flange [$b_{0,1}$] — [AISI S100, Sector B2.3]



Actual Element — Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



C-Section Strut: Stress Gradient

[AISI S100, Figure B2.3-2]

h_0	50.000	[mm]
b_0	40.000	[mm]
h_0 / b_0	1.250	[ ]

$x_{Compression}$	15.104	[mm]	$x_{Tension}$	23.444	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,inf. fiber}$	350.000	[MPa]	x_{CG}	15.104	[mm]
$f_{Compression}$	225.480	[MPa]	m	14.929	$f_{Tension}$	-350.000	[MPa]
f_1	177.319	[MPa]	m	14.929	f_2	-301.839	[MPa]

For webs under stress gradient [f_1 in compression and f_2 in tension]

	h_o / b_o ≤ 4	h_o / b_o > 4
	$b_1 = b_e$ / [3 + ψ]	$b_1 = b_e$ / [3 + ψ]
ψ > 0.236	$b_2 = b_e$ / 2	$b_2 = b_e$ / [1 + ψ] − b_1
ψ ≤ 0.236	$b_2 = b_e − b_1$	

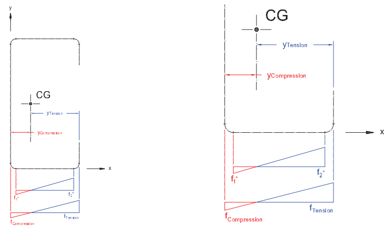
$b_1 + b_2$ ≤ Compression portion of the web calculated on the basis of effective section

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

Inferior Flange [$b_{0,1}$] — [AS/NZS 4600, Clause 2.2.3]

Actual Element — Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Strut: Stress Gradient

$x_{Compression}$	15.104	[mm]	$x_{Tension}$	23.444	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,inf. fiber}$	350.000	[MPa]	x_{CG}	15.104	[mm]
$f_{Compression}$	225.480	[MPa]	m	14.929	$f_{Tension}$	-350.000	[MPa]
f_1^*	177.319	[MPa]	m	14.929	f_2^*	-301.839	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$ ψ -1.702

[AS/NZS 4600, Eq. 2.2.3.2(5)]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$ k 48.869

[AS/NZS 4600, Eq. 2.2.3.2(4)]

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Version: 1.000	Client: COIMBRA UNIVERSITY	

$$\psi = |f_2/f_1|$$ | ψ | 1.702

[AISI S100, Eq. B2.3-1]

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$ k 48.869

[AISI S100, Eq. B2.3-2]

C-Section Strut Dimension — NOTE: w = $b_{0,1}$

$b_{0,1}$	32.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	ν [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$ F_{cr} 18982.671 [MPa]

[AISI S100, Eq. (B2.1-5)]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$ [AISI S100, Eq. B2.1-4]

f = f_1: 177.319 [MPa]; λ 0.097

$$\rho = (1 - 0.22/\lambda)/\lambda$$ [AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{0,1,eff,AISI}$	32.096	[mm]

$b_e = b_{0,1,eff,AISI}$ 32.096 [mm]

↓

h_0 / b_0 1.250

↓

| ψ | 1.702

↓

$b_1 = b_e$ / [3 + ψ] 6.826 [mm]

↓

h_o / b_o ≤ 4				h_o / b_o > 4		
ψ > 0.236	$b_2 = b_e$ / 2	16.048	[mm]	$b_2 = b_e$ / [1 + ψ] − b_1	----	[mm]
ψ ≤ 0.236	$b_2 = b_e − b_1$	----	[mm]			

↓

$b_1 + b_2 \le w_{Comp}$	KO	Web is fully effective	No more iterations!

$b_{0,1,eff,AISI,1}$	6.826	[mm]	$b_{0,1,eff,AISI,2}$	5.052	[mm]

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Version: 1.000	Client: COIMBRA UNIVERSITY	

C-Section Strut — NOTE: b = $b_{0,1}$

$b_{0,1}$	32.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	ν	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$ f_{cr} 18982.671 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$ [AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 177.319 [MPa]; λ 0.097

$$\rho = \frac{\left(1-\frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$ [AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{0,1,eff,AS/NZS}$	32.096	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$ [AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$ ψ ≤ −0.236 [AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$ ψ > −0.236 [AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = b_{0,1,eff,AS/NZS}$ 32.096 [mm]

↓

ψ -1.702

↓

$b_{e1} = b_e$ / [3 - ψ] 6.826 [mm]

↓

ψ ≤ -0.236	$b_2 = b_e$ / 2	16.048	[mm]	ψ > -0.236	$b_{e2} = b_e − b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2}$ ≤ Compression portion of the web calculated on the basis of effective section

↓

$b_{e1} + b_{e2} \le b_{Comp}$	KO	Web is fully effective	No more iterations!

$b_{0,1,eff,AS/NZS,1}$	6.826	[mm]	$b_{0,1,eff,AS/NZS,2}$	5.052	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{0,1,eff,AISI,1}$	6.826	=	$b_{0,1,eff,AS/NZS,1}$	6.826
$b_{0,1,eff,AISI,2}$	5.052	=	$b_{0,1,eff,AS/NZS,2}$	5.052

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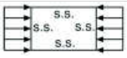
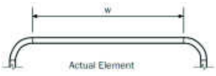
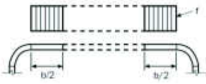
Web [h_p] — [AISI S100, Sector B2.1]

Boundary condition	Types of stress	k
	Compression	4.000





Actual Element | Effective Element, b, and Stress, f, on Effective Elements

Stiffened Elements [AISI S100, Figure B2.1-1]

$x_{Compression}$	15.104	[mm]	$x_{Tension}$	23.444	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf.\ fiber}$	350.000	[MPa]	x_{CG}	15.104	[mm]	
$f_{Compression}$	225.480	[MPa]	m	14.929	$f_{Tension}$	-350.000	[MPa]

C-Section Strut Dimension | NOTE: $w = h_p$

h_p	42.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)] F_{cr} 903.250 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$: 225.480 [MPa]; λ 0.500

$$\rho = (1 - 0.22/\lambda)/\lambda$$

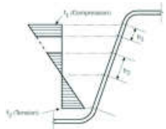
[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$h_{p,eff,AISI}$	42.096	[mm]
$h_{p,eff,AISI,1}$	21.048	[mm]	$h_{p,eff,AISI,2}$	21.048	[mm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

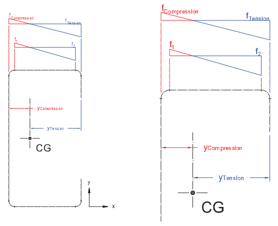
AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,eff,AISI,1}$	21.048	=	$h_{p,eff,AS/NZS,1}$	21.048
$h_{p,eff,AISI,2}$	21.048	=	$h_{p,eff,AS/NZS,2}$	21.048

Superior Flange [$b_{p,2}$] — [AISI S100, Sector B2.3]

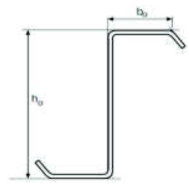


Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



C-Section Strut: Stress Gradient



[AISI S100, Figure B2.3-2]

h_0	50.000	[mm]
b_0	40.000	[mm]
h_0 / b_0	1.250	[ ]

$x_{Compression}$	15.104	[mm]	$x_{Tension}$	23.444	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf.\ fiber}$	350.000	[MPa]	x_{CG}	15.104	[mm]	
$f_{Compression}$	225.480	[MPa]	m	14.929	$f_{Tension}$	-350.000	[MPa]
f_1	177.319	[MPa]	m	14.929	f_2	-301.839	[MPa]

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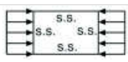
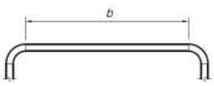
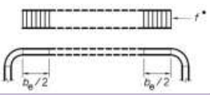
Web [h_p] — [AS/NZS 4600, Clause 2.2.1]

Boundary condition	Types of stress	k
	Compression	4.000





Actual Element | Effective Width [be] of Element and Design Stress [f*] on Effective Elements

Stiffened Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

$x_{Compression}$	15.104	[mm]	$x_{Tension}$	23.444	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf.\ fiber}$	350.000	[MPa]	x_{CG}	15.104	[mm]	
$f_{Compression}$	225.480	[MPa]	m	14.929	$f_{Tension}$	-350.000	[MPa]

C-Section Strut Dimension | NOTE: $b = h_p$

h_p	42.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-v^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)] f_{cr} 903.250 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 225.480 [MPa]; λ 0.500

$$\rho = \frac{\left(1-\frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$h_{p,eff,AS/NZS}$	42.096	[mm]
$h_{p,eff,AS/NZS,1}$	21.048	[mm]	$h_{p,eff,AS/NZS,2}$	21.048	[mm]

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For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \leq 4$	$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \leq 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \leq$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B2.3-1] | ψ | 1.702

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$

[AISI S100, Eq. B2.3-2] k 48.869

C-Section Strut Dimension | NOTE: $w = b_{p,2}$

$b_{p,2}$	32.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)] F_{cr} 18982.671 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$: 177.319 [MPa]; λ 0.097

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,2,eff,AISI}$	32.096	[mm]

$b_e = h_{p,eff,AISI}$	32.096	[mm]

↓

h_0 / b_0	1.250

↓

| ψ |	1.702

↓

$b_1 = b_e / [3 + \psi]$	6.826	[mm]

↓

$h_o / b_o \leq 4$				$h_o / b_o > 4$		
$\psi > 0.236$	$b_2 = b_e / 2$	16.048	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
$\psi \leq 0.236$	$b_2 = b_e - b_1$	----	[mm]			

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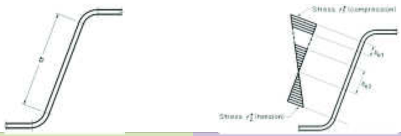
$b_1 + b_2 \leq w_{Comp}$	KO	Web is fully effective	**No more iterations!**

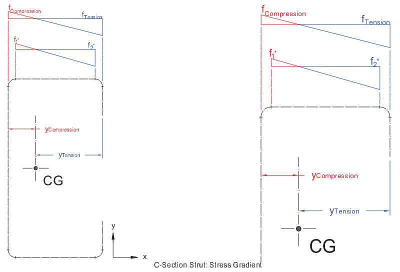
$b_{p,2,eff,AISI,1}$	6.826	[mm]	$b_{p,2,eff,AISI,2}$	5.052	[mm]

Superior Flange [$b_{p,2}$] — [AS/NZS 4600, Clause 2.2.3]



Actual Element — Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Strut: Stress Gradient

$x_{Compression}$	15.104	[mm]	$x_{Tension}$	23.444	[mm]

Tension Stress is reached!

1º Iteration	$f_{Tension,Inf. fiber}$	**350.000**	**[MPa]**	x_{CG}	**15.104**	**[mm]**
$f_{Compression}$	**225.480**	**[MPa]**	m 14.929	$f_{Tension}$	**-350.000**	**[MPa]**
f_1^*	**177.319**	**[MPa]**	m 14.929	f_2^*	**-301.839**	**[MPa]**

$$\psi = \frac{f_2^*}{f_1^*}$$

ψ -1.702

[AS/NZS 4600, Eq. 2.2.3.2(5)]

$$k = 4 + 2(1 - \psi)^3 + 2(1 - \psi)$$

k 48.869

[AS/NZS 4600, Eq. 2.2.3.2(4)]

C-Section Strut Dimension

$b_{p,2}$	32.096	[mm]						
E	210.000	[GPa]	t	1.452	[mm]	v	0.300	

NOTE $b = b_{p,2}$

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

f_{cr} 18982.671 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$

177.319 [MPa]

λ 0.097

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,2,eff,AS/NZS}$	32.096	[mm]

$$b_{e1} = \frac{b_e}{3 - \psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

ψ ≤ −0.236

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

ψ > −0.236

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = h_{p,Right Web,eff,AS/NZS}$	32.096	[mm]

↓

ψ	-1.702

↓

$b_{e1} = b_e / [3 - \psi]$	6.826	[mm]

↓

ψ ≤ -0.236	$b_2 = b_e / 2$	16.048	[mm]	ψ > -0.236	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2} \leq$ Compression portion of the web calculated on the basis of effective section

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$b_{e1} + b_{e2} \leq b_{Comp}$	KO	Web is fully effective	**No more iterations!**

$b_{p,2,eff,AS/NZS,1}$	6.826	[mm]	$b_{p,2,eff,AS/NZS,2}$	5.052	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,2,eff,AISI,1}$	6.826	=	$b_{p,2,eff,AS/NZS,1}$	6.826
$b_{p,2,eff,AISI,2}$	5.052	=	$b_{p,2,eff,AS/NZS,2}$	5.052

Superior Edge Stiffener [$c_{p,2}$] — [AISI S100, Sector B3.1]

NOTE Zone in Tension. Effective width is equal to the real width

Superior Edge Stiffener [$c_{p,2}$] — [AS/NZS 4600, Clause 2.3.1]

NOTE Zone in Tension. Effective width is equal to the real width

[ii] **Effective C-Section Strut [Local Buckling]**

Effective C-Section Strut Widths [AISI S100]

Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	----	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	32.096	[mm]
Web	$h_{p,eff,AISI}$	42.096	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	32.096	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	----	[mm]

Effective C-Section Strut Widths [AS/NZS 4600]

Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	----	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	32.096	[mm]
Web	$h_{p,eff,AS/NZS}$	42.096	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	32.096	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	----	[mm]

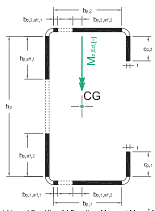
Effective C-Section Strut Widths [AISI S100 | AS/NZS 4600]

Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff}$	32.096	[mm]
Web	$h_{p,eff}$	42.096	[mm]
Superior Flange	$b_{p,2,eff}$	32.096	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]

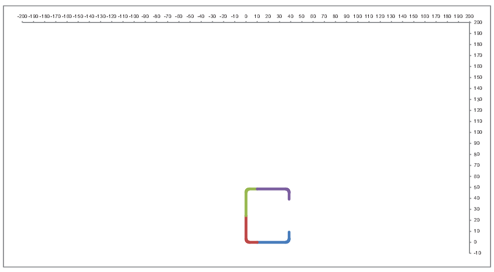
[iii] **Effective Cross C-Section Strut [Local Buckling]**

Effective C-Section Strut Widths

Inferior Edge Stiffener	$c_{p,1,eff}$	----	[mm]
Inferior Flange	$b_{p,1,eff,1}$	6.826	[mm]
	$b_{p,1,eff,2}$	5.052	[mm]
Web	$h_{p,eff,1}$	21.048	[mm]
	$h_{p,eff,2}$	21.048	[mm]
Superior Flange	$b_{p,2,eff,1}$	6.826	[mm]
	$b_{p,2,eff,2}$	5.052	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	----	[mm]



Effective C-Section Strut [Local Buckling] [Bending Moment $M_{y,Ed}^+$] [AISI S100 | AS/NZS 4600]



Effective C-Section Strut [Local Buckling] [Bending Moment $M_{y,Ed}^+$]

$I_{y,eff}^{[+]}$	43399.345	[mm^4]

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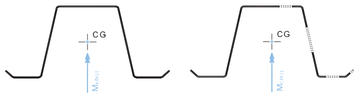
[11.6] Cold-Formed Section subjected to Negative Moment in y-y axis [$M_{y,Ed}^{-}$]

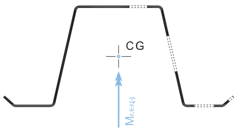
[a] Ω-Section Purlin



Gross Ω-Section — Effective Ω-Section [L]

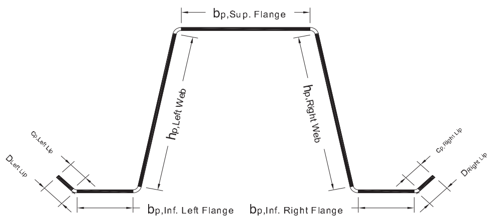
Local Buckling

[i] Effective Widths for Strength Determination [Local Buckling] — AISI S100, Sector B | AS/NZS 4600, Section 2



Effective Ω-Section [Worst Case]

Ω-Section Purlin Dimension		
$c_{p,Right\ Lip}$	6.191	[mm]
$b_{p,Inf.\ Right\ Flange}$	16.545	[mm]
$h_{p,Right\ Web}$	51.640	[mm]
$b_{p,Sup.\ Web}$	38.171	[mm]
$h_{p,Left\ Web}$	51.640	[mm]
$b_{p,Inf.\ Left\ Flange}$	16.545	[mm]
$c_{p,Left\ Lip}$	6.191	[mm]



Ω-Section Plate Widths

$x_{Compression}$	55.667	[mm]	$x_{Tension}$	55.667	[mm]

Compression Stress is reached!

1st Iteration

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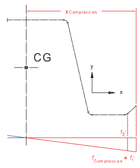
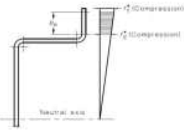
Right Edge Stiffner [$c_{p,Right\ Lip}$] — [AS/NZS 4600, Clause 2.3.2]



Ω-Section Purlin: Stress Gradient



[b] Outward Facing Lip

Unstiffened Elements with Stress Gradient: Both Edges in Compression [AS/NZS 4600, Figure B2.3.2(a)]

1st Iteration	$f_{Compression,Right\ Stiffener}$	350.000	[MPa]	x_{CG}	55.667	[mm]
$f_{Compression}$	350.000	[MPa]	m	6.287	$f_{Tension}$	-350.000 [MPa]
f_1^*	350.000	[MPa]	m	6.287	f_2^*	322.474 [MPa]

$$\psi = f_2^* / f_1^*$$ ψ 0.921

[AS/NZS 4600, Eq. 2.3.2.2(1)]

f_1 Compression, f_2 Compression

$$k = 0.57 - 0.21\psi + 0.07\psi^2$$ k 0.436

[AS/NZS 4600, Eq. 2.3.2.2(3)]

Ω-Section Purlin Dimension			NOTE	$b = c_{p,Right\ Lip}$
$c_{p,Right\ Lip}$	6.191	[mm]		

E	210.000	[GPa]	t	0.952	[mm]	ν	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$ f_{cr} 1956.179 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$\lambda = \sqrt{\frac{f^*}{f_{cr}}}$$ [AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 350.000 [MPa]

λ 0.423

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$ [AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$c_{p,Right\ Lip,eff,AS/NZS}$	6.191	[mm]

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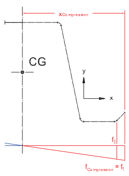
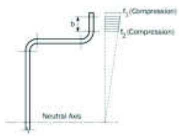
Right Edge Stiffner [$c_{p,Right\ Lip}$] — [AISI S100, Sector B3.2]



Ω-Section Purlin: Stress Gradient



[b] Outward Facing Lip

Unstiffened Elements under Stress Gradient, Both Longitudinal Edges in Compression [AISI S100, Figure B3.2-1]

1st Iteration	$f_{Compression,Right\ Stiffener}$	350.000	[MPa]	x_{CG}	55.667	[mm]
$f_{Compression}$	350.000	[MPa]	m	6.287	$f_{Tension}$	-350.000 [MPa]
f_1	350.000	[MPa]	m	6.287	f_2	322.474 [MPa]

$$\psi = |f_2/f_1|$$ | ψ | 0.921

[AISI S100, Eq. B3.2-1]

f_1 Compression, f_2 Compression

$$k = 0.57 - 0.21\psi + 0.07\psi^2$$ k 0.436

[AISI S100, Eq. B3.2-3]

Ω-Section Purlin Dimension			NOTE	$w = c_{p,Right\ Lip}$
$c_{p,Right\ Lip}$	6.191	[mm]		

E	210.000	[GPa]	t	0.952	[mm]	ν [μ]	0.300
w	6.191	[mm]	→	w / t ≤ 60	OK		

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$ F_{cr} 1956.179 [MPa]

[AISI S100, Eq. (B2.1-5)]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$ [AISI S100, Eq. B2.1-4]

$f = f_1$: 350.000 [MPa]

λ 0.423

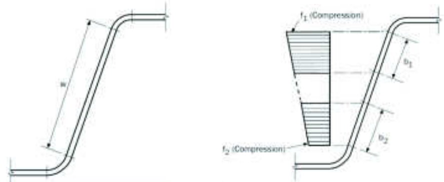
$$\rho = (1 - 0.22/\lambda)/\lambda$$ [AISI S100, Eq. B2.1-4]

ρ	1.000	→	$c_{p,Right\ Lip,eff,AISI}$	6.191	[mm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office:	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS — References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

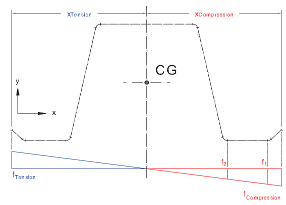
AISI S100, Effective Width		Comparison [= or ≠]	AS/NZS 4600, Effective Width	
$c_{p,Left\ Lip,eff,AISI}$	6.191	=	$c_{p,Right\ Lip,eff,AS/NZS}$	6.191

Inferior Right Flange [$b_{p,Inf.\ Right\ Flange}$] — [AISI S100, Sector B2.3]



Actual Element — Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



Ω-Section Purlin: Stress Gradient

$x_{Compression}$	55.667	[mm]	$x_{Tension}$	55.667	[mm]

Compression Stress is reached!

1st Iteration	$f_{Compression,Right\ Stiffener}$	350.000	[MPa]	x_{CG}	55.667	[mm]
$f_{Compression}$	350.000	[MPa]	m	6.287	$f_{Tension}$	-350.000 [MPa]
f_1	313.689	[MPa]	m	6.287	f_2	209.663 [MPa]

$$\psi = |f_2/f_1|$$ | ψ | 0.668

[AISI S100, Eq. B2.3-1]

For webs under stress gradient [f_1 and f_2 in compression]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

k 4.736

[AISI S100, Eq. B2.3-8]

Ω-Section Purlin Dimension				**NOTE**	$w = b_{p,Inf. Right Flange}$
$b_{p,Inf. Right Flange}$	16.545	[mm]			

E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 2976.136 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$: 313.689 [MPa]

λ 0.325

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,Inf. Right Flange,eff,AISI}$	16.545	[mm]

$b_e = h_{p,Inf. Right Flange,eff,AISI}$ 16.545 [mm]

↓

$$b_1 = b_e/(3-\psi)$$

[AISI S100, Eq. B2.3-9]

b_1 7.096 [mm]

↓

$$b_2 = b_e - b_1$$

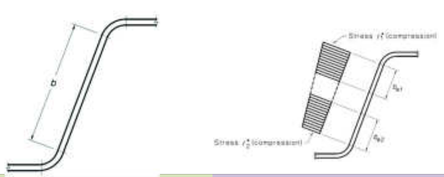
[AISI S100, Eq. B2.3-10]

b_2 9.449 [mm]

↓

$b_{p,Inf. Right Flange,eff,AISI,1}$	7.096	[mm]	$b_{p,Inf. Right Flange,eff,AISI,2}$	9.449	[mm]

Inferior Right Flange [$b_{p,Inf. Right Flange}$] [AS/NZS 4600, Clause 2.2.3]



Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 313.689 [MPa]

λ 0.325

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,Inf. Right Flange,eff,AS/NZS}$	16.545	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

ψ ≤ −0.236

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

ψ > −0.236

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = b_{p,Inf. Right Flange,eff,AS/NZS}$ 16.545 [mm]

↓

ψ 0.668

↓

$b_{e1} = b_e / [3 - \psi]$ 7.096 [mm]

↓

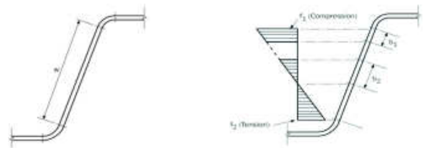
ψ ≤ -0.236	$b_2 = b_e / 2$	----	[mm]	ψ > -0.236	$b_{e2} = b_e - b_{e1}$	9.449	[mm]

↓

$b_{p,Inf. Right Flange,eff,AS/NZS,1}$	7.096	[mm]	$b_{p,Inf. Right Flange,eff,AS/NZS,2}$	9.449	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,Inf. Right Flange,eff,AISI,1}$	7.096	=	$b_{p,Inf. Right Flange,eff,AS/NZS,1}$	7.096
$b_{p,Inf. Right Flange,eff,AISI,2}$	9.449	=	$b_{p,Inf. Right Flange,eff,AS/NZS,2}$	9.449

Right Web [$h_{p,Right Web}$] [AISI S100, Sector B2.3]

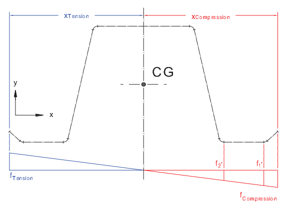


Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]

$x_{Compression}$	55.667	[mm]	$x_{Tension}$	55.667	[mm]

Compression Stress is reached!



Ω-Section Purlin: Stress Gradient

$x_{Compression}$	55.667	[mm]	$x_{Tension}$	55.667	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Right Stiffener}$	350.000	[MPa]	x_{CG}	55.667	[mm]
$f_{Compression}$	350.000	[MPa]	m 6.287	$f_{Tension}$	-350.000	[MPa]
f_1^*	313.689	[MPa]	m 6.287	f_2^*	209.663	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$

[AS/NZS 4600, Eq. 2.2.3.2(5)]

ψ 0.668

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

[AS/NZS 4600, Eq. 2.2.3.2(4)]

k 4.736

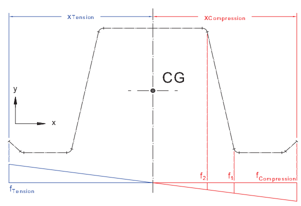
Ω-Section Purlin Dimension				**NOTE**	$b = b_{p,Inf. Right Flange}$
$b_{p,Inf. Right Flange}$	16.545	[mm]			

E	210.000	[GPa]	t	0.952	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 2976.136 [MPa]



Ω-Section Purlin: Stress Gradient

$x_{Compression}$	55.667	[mm]	$x_{Tension}$	55.667	[mm]

Tension Stress is reached!

1º Iteration	$f_{Compression,Right Stiffener}$	350.000	[MPa]	x_{CG}	55.667	[mm]
$f_{Compression}$	350.000	[MPa]	m 6.287	$f_{Tension}$	-350.000	[MPa]
f_1	197.493	[MPa]	m 6.287	f_2	132.165	[MPa]

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B2.3-1]

| ψ | 0.669

For webs under stress gradient [f_1 and f_2 in compression]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

[AISI S100, Eq. B2.3-8]

k 4.734

Ω-Section Purlin Dimension				**NOTE**	$w = h_{p,Right Web}$
$h_{p,Right Web}$	51.640	[mm]			

E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 305.362 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$: 197.493 [MPa]

λ 0.804

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	0.903	→	$h_{p,Right\ Web,eff,AISI}$	46.647	[mm]

$b_e = h_{p,Right\ Web,eff,AISI}$ 46.647 [mm]

↓

$$b_1 = b_e/(3-\psi)$$

[AISI S100, Eq. B2.3-9] b_1 20.013 [mm]

↓

$$b_2 = b_e - b_1$$

[AISI S100, Eq. B2.3-10] b_2 26.633 [mm]

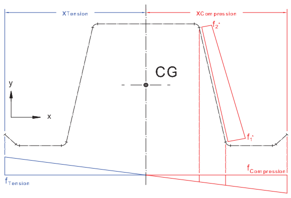
↓

$h_{p,Right\ Web,eff,AISI,1}$	20.013	[mm]	$h_{p,Right\ Web,eff,AISI,2}$	26.633	[mm]

Right Web [$h_{p,Right\ Web}$] [AS/NZS 4600, Clause 2.2.3]

Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



Ω-Section Purlin: Stress Gradient

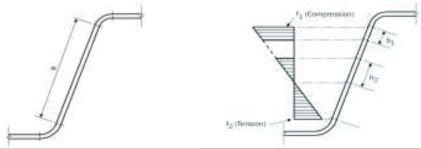
$x_{Compression}$	55.667	[mm]	$x_{Tension}$	55.667	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Right\ Stiffener}$	**350.000**	**[MPa]**	x_{CG}	**55.667**	**[mm]**	
$f_{Compression}$	**350.000**	**[MPa]**	m	6.287	$f_{Tension}$	**-350.000**	**[MPa]**

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$h_{p,Right\ Web,eff,AISI,1}$	20.013	=	$h_{p,Right\ Web,eff,AS/NZS,1}$	20.013
$h_{p,Right\ Web,eff,AISI,2}$	26.633	=	$h_{p,Right\ Web,eff,AS/NZS,2}$	26.633

Superior Flange [$b_{p,Sup.\ Flange}$] [AISI S100, Sector B2.3]

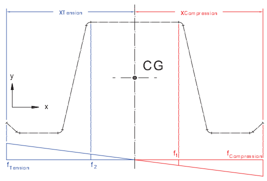


Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]

$x_{Compression}$	55.667	[mm]	$x_{Tension}$	55.667	[mm]

Compression Stress is reached!



Ω-Section Purlin: Stress Gradient

1º Iteration	$f_{Compression,Right\ Stiffener}$	**350.000**	**[MPa]**	x_{CG}	**55.667**	**[mm]**	
$f_{Compression}$	**350.000**	**[MPa]**	m	6.287	$f_{Tension}$	**-350.000**	**[MPa]**

h_0	53.741	[mm]
b_0	42.170	[mm]
h_0 / b_0	1.274	[ ]

Out-to-Out Dimensions of Webs and Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-2]

f_1^*	**197.493**	**[MPa]**	m	6.287	f_2^*	**132.165**	**[MPa]**

$$\psi = \frac{f_2^*}{f_1^*}$$

[AS/NZS 4600, Eq. 2.2.3.2(5)] ψ 0.669

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

[AS/NZS 4600, Eq. 2.2.3.2(4)] k 4.734

Ω-Section Purlin Dimension | **NOTE** $b = h_{p,Right\ Web}$

$h_{p,Right\ Web}$	51.640	[mm]					
E	210.000	[GPa]	t	0.952	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)] f_{cr} 305.362 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 197.493 [MPa]; λ 0.804

$$\rho = \frac{\left(1-\frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	0.903	→	$h_{p,Right\ Web,eff,AS/NZS}$	46.647	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

ψ ≤ −0.236 [AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

ψ > −0.236 [AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = h_{p,Right\ Web,eff,AS/NZS}$ 46.647 [mm]

↓

ψ 0.669

↓

$b_{e1} = b_e$ / [3 - ψ] 20.013 [mm]

↓

ψ ≤ -0.236	$b_2 = b_e / 2$	----	[mm]	ψ > -0.236	$b_{e2} = b_e - b_{e1}$	26.633	[mm]

↓

$h_{p,Right\ Web,eff,AS/NZS,1}$	20.013	[mm]	$h_{p,Right\ Web,eff,AS/NZS,2}$	26.633	[mm]

For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \le 4$	$h_o / b_o > 4$
	$b_1 = b_e$ / [3 + ψ]	$b_1 = b_e$ / [3 + ψ]
ψ > 0.236	$b_2 = b_e / 2$	$b_2 = b_e$ / [1 + ψ] – b_1
ψ ≤ 0.236	$b_2 = b_e - b_1$	

$b_1 + b_2 \le$ Compression portion of the web calculated on the basis of effective section

f_1	**119.996**	**[MPa]**	m	6.287	f_2	**-119.996**	**[MPa]**

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B2.3-1] | ψ | 1.000

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$

[AISI S100, Eq. B2.3-2] k 24.000

Ω-Section Purlin Dimension | **NOTE** $w = b_{p,Sup.\ Web}$

$b_{p,Sup.\ Web}$	38.171	[mm]					
E	210.000	[GPa]	t	0.952	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)] F_{cr} 2833.513 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$: 119.996 [MPa]; λ 0.206

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,Sup.\ Web,eff,AISI}$	38.171	[mm]

$b_e = b_{p,Sup.\ Web,eff,AISI}$ 38.171 [mm]

↓

h_0 / b_0 1.274

↓

| ψ | 1.000

↓

$b_1 = b_e$ / [3 + ψ] 9.543 [mm]

↓

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$h_o / b_o \leq 4$				$h_o / b_o > 4$		
$\psi > 0.236$	$b_2 = b_e / 2$	19.085	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
$\psi \leq 0.236$	$b_2 = b_e - b_1$	----	[mm]			

↓

$b_1 + b_2 \leq w_{Comp}$	KO	Web is fully effective	No more iterations!

↓

$b_{p,Sup.\ Web,eff,AISI,1}$	9.543	[mm]	$b_{p,Sup.\ Web,eff,AISI,2}$	9.543	[mm]

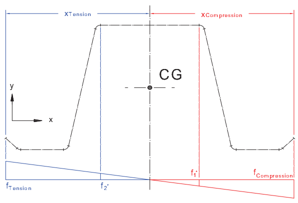
Superior Flange [$b_{p,Sup.\ Flange}$] | [AS/NZS 4600, Clause 2.2.3]

Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]

$x_{Compression}$	55.667	[mm]	$x_{Tension}$	55.667	[mm]

Compression Stress is reached!



Ω-Section Purlin: Stress Gradient

1st Iteration	$f_{Compression,Right\ Stiffener}$	350.000	[MPa]	x_{CG}	55.667	[mm]
$f_{Compression}$ 350.000 [MPa]	m	6.287		$f_{Tension}$	-350.000	[MPa]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

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$b_{e1} + b_{e2} \leq$ Compression portion of the web calculated on the basis of effective section

↓

$b_{e1} + b_{e2} \leq b_{Comp}$	KO	Web is fully effective	No more iterations!

↓

$b_{p,Sup.\ Web,eff,AS/NZS,1}$	9.543	[mm]	$b_{p,Sup.\ Web,eff,AS/NZS,2}$	9.543	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,Sup.\ Web,eff,AISI,1}$	9.543	=	$b_{p,Sup.\ Web,eff,AS/NZS,1}$	9.543
$b_{p,Sup.\ Web,eff,AISI,2}$	9.543	=	$b_{p,Sup.\ Web,eff,AS/NZS,2}$	9.543

Left Web [$h_{p,Left\ Web}$] | [AISI S100, Sector B2.3]

NOTE: Zone in Tension. Effective width is equal to the real width

Left Web [$h_{p,Left\ Web}$] | [AS/NZS 4600, Clause 2.2.3]

NOTE: Zone in Tension. Effective width is equal to the real width

Inferior Left Flange [$b_{p,Inf.\ Left\ Flange}$] | [AISI S100, Sector B2.3]

NOTE: Zone in Tension. Effective width is equal to the real width

Inferior Left Flange [$b_{p,Inf.\ Left\ Flange}$] | [AS/NZS 4600, Clause 2.2.3]

NOTE: Zone in Tension. Effective width is equal to the real width

Left Edge Stiffener [$c_{p,Left\ Lip}$] | [AISI S100, Sector B3.2]

NOTE: Zone in Tension. Effective width is equal to the real width

Left Edge Stiffener [$c_{p,Left\ Lip}$] | [AS/NZS 4600, Clause 2.3.2]

NOTE: Zone in Tension. Effective width is equal to the real width

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1.000	Client: COIMBRA UNIVERSITY	

f_1^*	119.996	[MPa]	m	6.287	f_2^*	-119.996	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$

ψ -1.000

[AS/NZS 4600, Eq. 2.2.3.2(5)]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

k 24.000

[AS/NZS 4600, Eq. 2.2.3.2(4)]

Ω-Section Purlin Dimension			NOTE	$b = b_{p,Sup.\ Web}$
$b_{p,Sup.\ Web}$	38.171	[mm]		

E	210.000	[GPa]	t	0.952	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

f_{cr} 2833.513 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 119.996 [MPa]

λ 0.206

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,Sup.\ Web,eff,AS/NZS}$	38.171	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

$\psi \leq -0.236$

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

$\psi > -0.236$

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = b_{p,Sup.\ Web,eff,AS/NZS}$ 38.171 [mm]

↓

ψ -1.000

↓

$b_{e1} = b_e / [3 - \psi]$ 9.543 [mm]

↓

$\psi \leq -0.236$	$b_2 = b_e / 2$	19.085	[mm]	$\psi > -0.236$	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

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Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS	Office: ----	Author: JOSÉ ANTÓNIO
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Version: 1.000	Client: COIMBRA UNIVERSITY	

[ii] Effective Ω-Section Purlin [Local Buckling]

Effective Ω-Section Purlin Widths [AISI S100]

Right Edge Stiffner	$c_{p,Right\ Lip,eff,AISI}$	6.191	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff,AISI}$	16.545	[mm]
Right Web	$h_{p,Right\ Web,eff,AISI}$	46.647	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff,AISI}$	38.171	[mm]
Left Web	$h_{p,Left\ Web,eff,AISI}$	----	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff,AISI}$	----	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff,AISI}$	----	[mm]

Effective Ω-Section Purlin Widths [AS/NZS 4600]

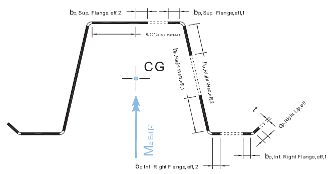
Right Edge Stiffner	$c_{p,Right\ Lip,eff,AS/NZS}$	6.191	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff,AS/NZS}$	16.545	[mm]
Right Web	$h_{p,Right\ Web,eff,AS/NZS}$	46.647	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff,AS/NZS}$	38.171	[mm]
Left Web	$h_{p,Left\ Web,eff,AS/NZS}$	----	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff,AS/NZS}$	----	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff,AS/NZS}$	----	[mm]

Effective Ω-Section Purlin Widths [AISI S100 | AS/NZS 4600]

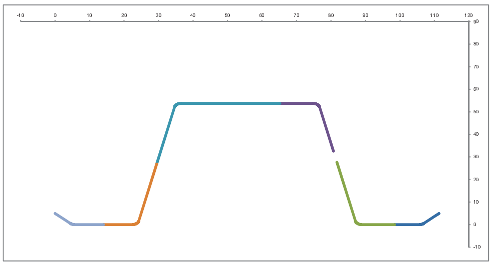
Right Edge Stiffner	$c_{p,Right\ Lip,eff}$	6.191	[mm]
Inferior Right Flange	$b_{p,Inf.\ Right\ Flange,eff}$	16.545	[mm]
Right Web	$h_{p,Right\ Web,eff}$	46.647	[mm]
Superior Flange	$b_{p,Sup.\ Flange,eff}$	38.171	[mm]
Left Web	$h_{p,Left\ Web,eff}$	----	[mm]
Inferior Left Flange	$b_{p,Inf.\ Left\ Flange,eff}$	----	[mm]
Left Edge Stiffener	$c_{p,Left\ Lip,eff}$	----	[mm]

[iii] **Effective Cross Ω-Section Purlin [Local Buckling]**

Effective Ω-Section Purlin Widths			
Right Edge Stiffner	$c_{p, Right Lip, eff}$	6.191	[mm]
Inferior Right Flange	$b_{p, Inf. Right Flange, eff,1}$	7.096	[mm]
	$b_{p, Inf. Right Flange, eff,2}$	9.449	[mm]
Right Web	$h_{p, Right Web, eff,1}$	20.013	[mm]
	$h_{p, Right Web, eff,2}$	26.633	[mm]
Superior Flange	$b_{p, Sup. Flange, eff,1}$	9.543	[mm]
	$b_{p, Sup. Flange, eff,2}$	9.543	[mm]
Left Web	$h_{p, Left Web, eff,1}$	----	[mm]
Inferior Left Flange	$b_{p, Inf. Left Flange, eff,1}$	----	[mm]
Left Edge Stiffener	$c_{p, Left Lip, eff}$	----	[mm]

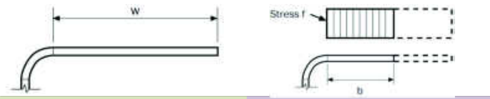


Effective Ω-Section Purlin [Negative Moment in y-y axis, $M_{y,Ed}^-$] [AISI S100 | AS/NZS 4600]



Effective Ω-Section Purlin [Local Buckling] [Negative Moment in y-y axis, $M_{y,Ed}^-$]

$I_{y,eff}^{(-)}$ 173726.891 [mm^4]



Actual Element	Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

1º Iteration	$f_{Compression, Inf. fiber}$	350.000	[MPa]	x_{CG}	14.563	[mm]
$f_{Compression}$ 350.000 [MPa]		m	11.481	$f_{Tension}$	-167.191	[MPa]

C-Section Beam Dimension			NOTE	$w = c_{p,1}$
$c_{p,1}$	14.048	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 861.766 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$ 350.000 [MPa]

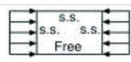
λ 0.637

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$c_{p,1,eff,AISI}$	14.048	[mm]

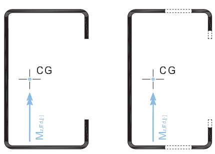
Inferior Edge Stiffner [$c_{p,1}$] [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k
	Compression	0.425

Actual Element	Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

[b] C-Section Beam



Gross C-Section

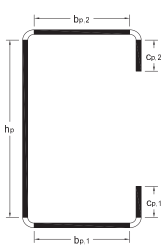
Effective C-Section [L]

Local Buckling

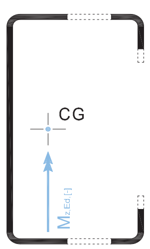
C-Section Beam Dimension		
$c_{p,1}$	14.048	[mm]
$b_{p,1}$	38.596	[mm]
h_p	112.096	[mm]
$b_{p,2}$	38.596	[mm]
$c_{p,2}$	14.048	[mm]
t	1.452	[mm]

[i] **Effective Widths for Strength Determination [Local Buckling]**

AISI S100, Sector B | AS/NZS 4600, Section 2



C-Section Plate Widths



Effective C-Section [Worst Case]

1º Iteration

Inferior Edge Stiffner [$c_{p,1}$] [AISI S100, Sector B3.1]

Boundary condition	Types of stress	k
	Compression	0.425

$x_{Compression}$	30.485	[mm]	$x_{Tension}$	14.563	[mm]

Compression Stress is reached!

$x_{Compression}$	30.485	[mm]	$x_{Tension}$	14.563	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression, Inf. fiber}$	350.000	[MPa]	x_{CG}	14.563	[mm]
$f_{Compression}$ 350.000 [MPa]		m	11.481	$f_{Tension}$	-167.191	[MPa]

C-Section Beam Dimension			NOTE	$b = c_{p,1}$
$c_{p,1}$	14.048	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 861.766 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$ 350.000 [MPa]

λ 0.637

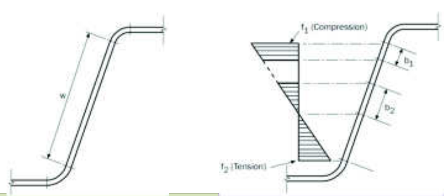
$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$c_{p,1,eff,AS/NZS}$	14.048	[mm]

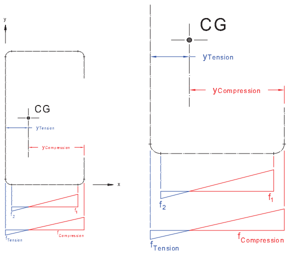
AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,1,eff,AISI}$	14.048	=	$c_{p,1,eff,AS/NZS}$	14.048

Inferior Flange [$b_{p,1}$] [AISI S100, Sector B2.3]



Actual Element	Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



C-Section Beam: Stress Gradient

[AISI S100, Figure B2.3-2]

h_0	120.000	[mm]
b_0	46.500	[mm]
h_0 / b_0	2.581	[ ]

$x_{Compression}$	30.485	[mm]	$x_{Tension}$	14.563	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Top\ fiber}$ 350.000	[MPa]	x_{CG}	14.563	[mm]
$f_{Compression}$ 350.000	[MPa]	m 11.481	$f_{Tension}$	-167.191	[MPa]
f_1 312.963	[MPa]	m 11.481	f_2	-130.154	[MPa]

For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \le 4$	$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \le 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \le$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$

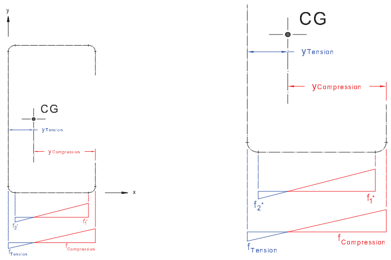
[AISI S100, Eq. B2.3-1] | ψ | 0.416

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$

[AISI S100, Eq. B2.3-2] k 12.509

C-Section Beam Dimension			NOTE	$w = b_{o,1}$
$b_{o,1}$	38.596	[mm]		
E 210.000 [GPa]	t 1.452	[mm]	v [μ]	0.300



C-Section Beam: Stress Gradient

$x_{Compression}$	30.485	[mm]	$x_{Tension}$	14.563	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Top\ fiber}$ 350.000	[MPa]	x_{CG}	14.563	[mm]
$f_{Compression}$ 350.000	[MPa]	m 11.481	$f_{Tension}$	-167.191	[MPa]
f_1^* 312.963	[MPa]	m 11.481	f_2^*	-130.154	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$

[AS/NZS 4600, Eq. 2.2.3.2(5)] ψ -0.416

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

[AS/NZS 4600, Eq. 2.2.3.2(4)] k 12.509

C-Section Beam Dimension			NOTE	$b = b_{o,1}$
$b_{o,1}$	38.596	[mm]		
E 210.000 [GPa]	t 1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)] f_{cr} 3360.105 [MPa]

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)] F_{cr} 3360.105 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$: 312.963 [MPa]; λ 0.305

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{0,1,eff,AISI}$	38.596	[mm]

$b_e = b_{o,1,eff,AISI}$	38.596	[mm]
↓		
h_0 / b_0	2.581	
↓		
| ψ |	0.416	
↓		
$b_1 = b_e / [3 + \psi]$	11.299	[mm]
↓		

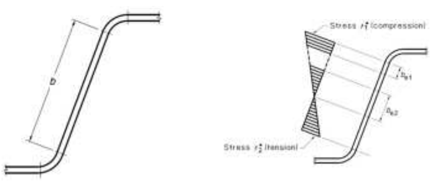
$h_o / b_o \le 4$				$h_o / b_o > 4$		
$\psi > 0.236$	$b_2 = b_e / 2$	19.298	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
$\psi \le 0.236$	$b_2 = b_e - b_1$	----	[mm]			

↓

$b_1 + b_2 \le w_{Comp}$	KO	Web is fully effective	No more iterations!

$b_{0,1,eff,AISI,1}$	11.299	[mm]	$b_{0,1,eff,AISI,2}$	15.960	[mm]

Inferior Flange [$b_{o,1}$] [AS/NZS 4600, Clause 2.2.3]



Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]

$$\lambda = \left(\frac{1.052}{\sqrt{k}}\right)\left(\frac{b}{t}\right)\sqrt{\frac{f^*}{E}}$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 312.963 [MPa]; λ 0.305

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{o,1,eff,AS/NZS}$	38.596	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

$\psi \le -0.236$ [AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

$\psi > -0.236$ [AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = b_{o,1,eff,AS/NZS}$	38.596	[mm]
↓		
ψ	-0.416	
↓		
$b_{e1} = b_e / [3 - \psi]$	11.299	[mm]
↓		

$\psi \le -0.236$	$b_2 = b_e / 2$	19.298	[mm]	$\psi > -0.236$	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2} \le$ Compression portion of the web calculated on the basis of effective section

↓

$b_{e1} + b_{e2} \le b_{Comp}$	KO	Web is fully effective	No more iterations!

$b_{0,1,eff,AS/NZS,1}$	11.299	[mm]	$b_{0,1,eff,AS/NZS,2}$	15.960	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{0,1,eff,AISI,1}$	11.299	=	$b_{0,1,eff,AS/NZS,1}$	11.299
$b_{0,1,eff,AISI,2}$	15.960	=	$b_{0,1,eff,AS/NZS,2}$	15.960

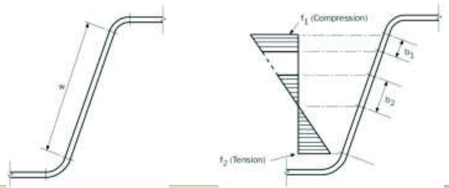
Web [h_o] [AISI S100, Section B2.1]

NOTE Zone in Tension. Effective width is equal to the real width

Web [h_o] [AS/NZS 4600, Clause 2.2.1]

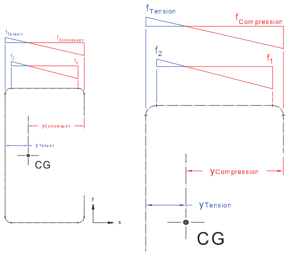
NOTE Zone in Tension. Effective width is equal to the real width

Superior Flange [$b_{p,2}$]	[AISI S100, Sector B2.3]

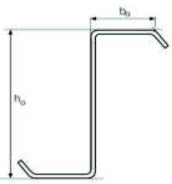


Actual Element	Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



C-Section Beam: Stress Gradient



[AISI S100, Figure B2.3-2]

h_0	120.000	[mm]
b_0	46.500	[mm]
h_0 / b_0	2.581	[ ]

$x_{Compression}$	30.485	[mm]	$x_{Tension}$	14.563	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Top\ fiber}$	**350.000**	**[MPa]**		x_{CG}	**14.563**	**[mm]**
$f_{Compression}$	**350.000**	**[MPa]**	m	11.481	$f_{Tension}$	**-167.191**	**[MPa]**
f_1	**312.963**	**[MPa]**	m	11.481	f_2	**-130.154**	**[MPa]**

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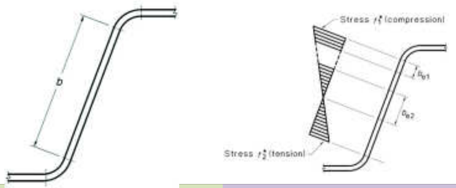
$b_1 + b_2 \leq w_{Comp}$	KO	Web is fully effective	**No more iterations!**

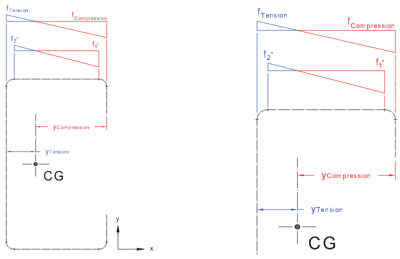
$b_{p,2,eff,AISI,1}$	11.299	[mm]	$b_{p,2,eff,AISI,2}$	15.960	[mm]

Superior Flange [$b_{p,2}$]	[AS/NZS 4600, Clause 2.2.3]



Actual Element	Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Beam: Stress Gradient

$x_{Compression}$	30.485	[mm]	$x_{Tension}$	14.563	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Top\ fiber}$	**350.000**	**[MPa]**		x_{CG}	**14.563**	**[mm]**
$f_{Compression}$	**350.000**	**[MPa]**	m	11.481	$f_{Tension}$	**-167.191**	**[MPa]**

For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \leq 4$	$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \leq 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \leq$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B2.3-1]

| ψ | = 0.416

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1 + \psi)^3 + 2(1 + \psi)$$

[AISI S100, Eq. B2.3-2]

k = 12.509

C-Section Beam Dimension			**NOTE**	$w = b_{p,2}$
$b_{p,2}$	38.596	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 3360.105 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$	
312.963	[MPa]
λ	0.305

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,2,eff,AISI}$	38.596	[mm]

$b_e = b_{p,2,eff,AISI}$	38.596	[mm]

↓

h_0 / b_0	2.581

↓

| ψ |	0.416

↓

$b_1 = b_e / [3 + \psi]$	11.299	[mm]

↓

$h_o / b_o \leq 4$				**$h_o / b_o > 4$**		
$\psi > 0.236$	$b_2 = b_e / 2$	19.298	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
$\psi \leq 0.236$	$b_2 = b_e - b_1$	----	[mm]			

↓

Next Page

f_1^*	**312.963**	**[MPa]**	m	11.481	f_2^*	**-130.154**	**[MPa]**

$$\psi = \frac{f_2^*}{f_1^*}$$

[AS/NZS 4600, Eq. 2.2.3.2(5)]

ψ -0.416

$$k = 4 + 2(1 - \psi)^3 + 2(1 - \psi)$$

[AS/NZS 4600, Eq. 2.2.3.2(4)]

k 12.509

C-Section Beam Dimension			**NOTE**	$b = b_{p,2}$
$b_{p,2}$	38.596	[mm]		

E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 3360.105 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$	
312.963	[MPa]
λ	0.305

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,2,eff,AS/NZS}$	38.596	[mm]

$$b_{e1} = \frac{b_e}{3 - \psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

$\psi \leq -0.236$

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

$\psi > -0.236$

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = b_{p,2,eff,AS/NZS}$	38.596	[mm]

↓

ψ	-0.416

↓

$b_{e1} = b_e / [3 - \psi]$	11.299	[mm]

↓

$\psi \leq -0.236$	$b_2 = b_e / 2$	19.298	[mm]	$\psi > -0.236$	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

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$b_{e1} + b_{e2} \leq$ Compression portion of the web calculated on the basis of effective section

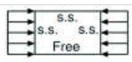
↓

$b_{e1} + b_{e2} \leq b_{Comp}$	KO	Web is fully effective	No more iterations!

$b_{p,2,eff,AS/NZS,1}$	11.299	[mm]	$b_{p,2,eff,AS/NZS,2}$	15.960	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,2,eff,AISI,1}$	11.299	=	$b_{p,2,eff,AS/NZS,1}$	11.299
$b_{p,2,eff,AISI,2}$	15.960	=	$b_{p,2,eff,AS/NZS,2}$	15.960

Superior Edge Stiffener [$c_{p,2}$] [AISI S100, Sector B3.1]

Boundary condition	Types of stress	k
	Compression	0.425

$x_{Compression}$ 30.485 [mm] $x_{Tension}$ 14.563 [mm]

Compression Stress is reached!

Actual Element | Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

1st iteration	$f_{Compression,Inf.fiber}$	350.000	[MPa]	x_{CG}	14.563	[mm]
$f_{Compression}$	350.000	[MPa]	m 11.481	$f_{Tension}$	-167.191	[MPa]

C-Section Beam Dimension | NOTE $w = c_{p,2}$

$c_{p,2}$ 14.048 [mm]

E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$ 350.000 [MPa]

λ 0.637

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$c_{p,2,eff,AS/NZS}$	14.048	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,2,eff,AISI}$	14.048	=	$c_{p,2,eff,AS/NZS}$	14.048

[ii] **Effective C-Section Beam [Local Buckling]**

Effective C-Section Beam Widths [AISI S100]			
Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	14.048	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	38.596	[mm]
Web	$h_{p,eff,AISI}$	----	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	38.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	14.048	[mm]

Effective C-Section Beam Widths [AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	14.048	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	38.596	[mm]
Web	$h_{p,eff,AS/NZS}$	----	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	38.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	14.048	[mm]

Effective C-Section Beam Widths [AISI S100 | AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff}$	14.048	[mm]
Inferior Flange	$b_{p,1,eff}$	38.596	[mm]
Web	$h_{p,eff}$	----	[mm]
Superior Flange	$b_{p,2,eff}$	38.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	14.048	[mm]

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

F_{cr} 861.766 [MPa]

[AISI S100, Eq. (B2.1-5)]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$ 350.000 [MPa]

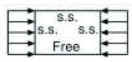
λ 0.637

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

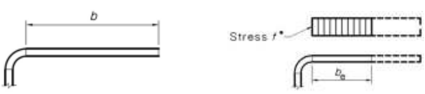
ρ	1.000	→	$c_{p,2,eff,AISI}$	14.048	[mm]

Superior Edge Stiffener [$c_{p,2}$] [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k
	Compression	0.425

$x_{Compression}$ 30.485 [mm] $x_{Tension}$ 14.563 [mm]

Compression Stress is reached!



Actual Element | Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

1st iteration	$f_{Compression,Inf.fiber}$	350.000	[MPa]	x_{CG}	14.563	[mm]
$f_{Compression}$	350.000	[MPa]	m 11.481	$f_{Tension}$	-167.191	[MPa]

C-Section Beam Dimension | NOTE $b = c_{p,2}$

$c_{p,2}$ 14.048 [mm]

E	210.000	[GPa]	t	1.452	[mm]	v	0.300

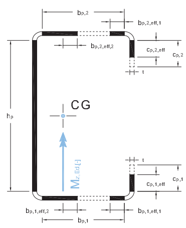
$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

f_{cr} 861.766 [MPa]

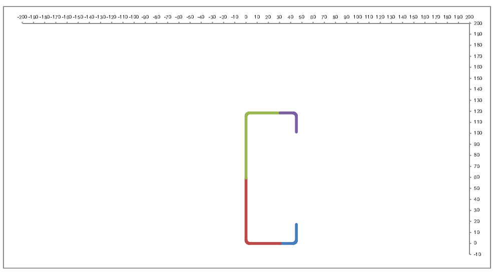
[AS/NZS 4600, Eq. 2.2.1.2(5)]

[iii] **Effective Cross C-Section Beam [Local Buckling]**

Effective C-Section Beam Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	14.048	[mm]
Inferior Flange	$b_{p,1,eff,1}$	11.299	[mm]
	$b_{p,1,eff,2}$	15.960	[mm]
Web	$h_{p,eff}$	----	[mm]
Superior Flange	$b_{p,2,eff,1}$	11.299	[mm]
	$b_{p,2,eff,2}$	15.960	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	14.048	[mm]



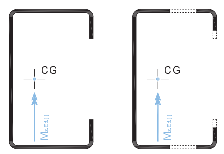
Effective C-Section Beam [Local Buckling] [Bending Moment $M_{y,Ed}^-$] [AISI S100 | AS/NZS 4600]



Effective C-Section Beam [Local Buckling] [Bending Moment $M_{y,Ed}^-$]

$I_{y,eff}^{(-)}$ 108754.009 [mm^4]

[c] C-Section Column

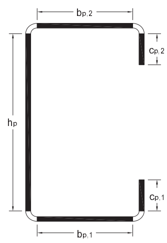


Gross C-Section Effective C-Section [L]

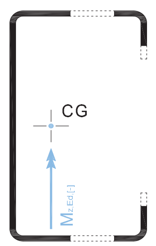
Local Buckling

C-Section Column Dimension		
$c_{p,1}$	13.048	[mm]
$b_{p,1}$	36.596	[mm]
h_p	80.096	[mm]
$b_{p,2}$	36.596	[mm]
$c_{p,2}$	13.048	[mm]
t	2.452	[mm]

[i] Effective Widths for Strength Determination [Local Buckling] AISI S100, Sector B | AS/NZS 4600, Section 2



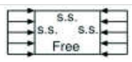
C-Section Plate Widths



Effective C-Section [Worst Case]

1º Iteration

Inferior Edge Stiffner [$c_{p,1}$] [AISI S100, Sector B3.1]

Boundary condition	Types of stress	k
	Compression	0.425

$x_{Compression}$ 27.889 [mm] $x_{Tension}$ 27.889 [mm]

Compression Stress is reached!

$x_{Compression}$ 27.889 [mm] $x_{Tension}$ 27.889 [mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Inf. fiber}$	350.000	[MPa]	x_{CG}	16.159	[mm]

$f_{Compression}$ 350.000 [MPa] m 12.550 $f_{Tension}$ -202.797 [MPa]

C-Section Column Dimension NOTE $b = c_{p,1}$

$c_{p,1}$ 13.048 [mm]

E 210.000 [GPa] t 2.452 [mm] v 0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)] f_{cr} 2848.645 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$ 350.000 [MPa]

λ 0.351

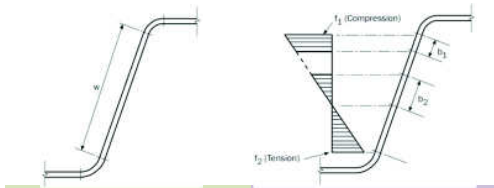
$$\rho = \frac{\left(1-\frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $c_{p,1,eff,AS/NZS}$ 13.048 [mm]

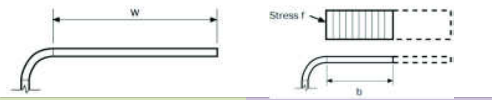
AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,1,eff,AISI}$	13.048	=	$c_{p,1,eff,AS/NZS}$	13.048

Inferior Flange [$b_{p,1}$] [AISI S100, Sector B2.3]



Actual Element Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



Actual Element Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

1º Iteration	$f_{Compression,Inf. fiber}$	350.000	[MPa]	x_{CG}	16.159	[mm]

$f_{Compression}$ 350.000 [MPa] m 12.550 $f_{Tension}$ -202.797 [MPa]

C-Section Column Dimension NOTE $w = c_{p,1}$

$c_{p,1}$ 13.048 [mm]

E 210.000 [GPa] t 2.452 [mm] v [μ] 0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)] F_{cr} 2848.645 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$ 350.000 [MPa]

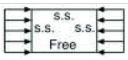
λ 0.351

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

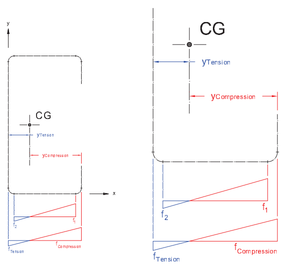
ρ 1.000 → $c_{p,1,eff,AISI}$ 13.048 [mm]

Inferior Edge Stiffner [$c_{p,1}$] [AS/NZS 4600, Clause 2.3.1]

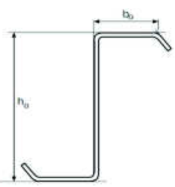
Boundary condition	Types of stress	k
	Compression	0.425

Actual Element Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]



C-Section Column: Stress Gradient



[AISI S100, Figure B2.3-2]

h_0	90.000	[mm]
b_0	46.500	[mm]
h_0 / b_0	1.935	[ ]

$x_{Compression}$ 27.889 [mm] $x_{Tension}$ 27.889 [mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Top fiber}$	350.000	[MPa]	x_{CG}	16.159	[mm]

$f_{Compression}$ 350.000 [MPa] m 12.550 $f_{Tension}$ -202.797 [MPa]

f_1 303.239 [MPa] m 12.550 f_2 -156.036 [MPa]

For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \leq 4$		$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$		$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$		$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \leq 0.236$		$b_2 = b_e - b_1$	

$b_1 + b_2 \leq$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$

[AISI S100, Eq. B2.3-1] | ψ | 0.515

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$

[AISI S100, Eq. B2.3-2] k 13.978

C-Section Column Dimension NOTE $w = b_{p,1}$

$b_{p,1}$ 36.596 [mm]

E 210.000 [GPa] t 2.452 [mm] v [μ] 0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 11909.792 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_1$

303.239 [MPa]

λ 0.160

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1.000	→	$b_{p,1,eff,AISI}$	36.596	[mm]

$b_e = b_{p,1,eff,AISI}$	36.596	[mm]

↓

h_0 / b_0	1.935

↓

| ψ |	0.515

↓

$b_1 = b_e / [3 + \psi]$	10.413	[mm]

↓

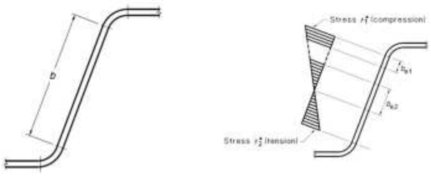
$h_o / b_o \leq 4$				$h_o / b_o > 4$		
ψ > 0.236	$b_2 = b_e / 2$	18.298	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
ψ ≤ 0.236	$b_2 = b_e - b_1$	----	[mm]			

↓

$b_1 + b_2 \leq w_{Comp}$	KO	Web is fully effective	**No more iterations!**

$b_{p,1,eff,AISI,1}$	10.413	[mm]	$b_{p,1,eff,AISI,2}$	13.750	[mm]

Inferior Flange [$b_{p,1}$] [AS/NZS 4600, Clause 2.2.3]



Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$

303.239 [MPa]

λ 0.160

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,1,eff,AS/NZS}$	36.596	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

ψ ≤ −0.236

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

ψ > −0.236

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = b_{p,1,eff,AS/NZS}$	36.596	[mm]

↓

ψ	-0.515

↓

$b_{e1} = b_e / [3 - \psi]$	10.413	[mm]

↓

ψ ≤ -0.236	$b_2 = b_e / 2$	18.298	[mm]	ψ > -0.236	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

$b_{e1} + b_{e2}$ ≤ Compression portion of the web calculated on the basis of effective section

↓

$b_{e1} + b_{e2} \leq b_{Comp}$	KO	Web is fully effective	**No more iterations!**

$b_{p,1,eff,AS/NZS,1}$	10.413	[mm]	$b_{p,1,eff,AS/NZS,2}$	13.750	[mm]

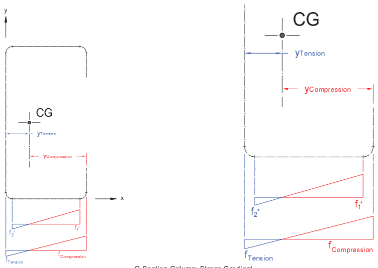
AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,1,eff,AISI,1}$	10.413	=	$b_{p,1,eff,AS/NZS,1}$	10.413
$b_{p,1,eff,AISI,2}$	13.750	=	$b_{p,1,eff,AS/NZS,2}$	13.750

Web [h_p] [AISI S100, Sector B2.1]

NOTE	Zone in Tension. Effective width is equal to the real width

Web [h_p] [AS/NZS 4600, Clause 2.2.1]

NOTE	Zone in Tension. Effective width is equal to the real width



C-Section Column: Stress Gradient

$x_{Compression}$	27.889	[mm]	$x_{Tension}$	27.889	[mm]

Tension Stress is reached!

1º Iteration	$f_{Compression,Top fiber}$	**350.000**	**[MPa]**	x_{CG}	**16.159**	**[mm]**
$f_{Compression}$	**350.000**	**[MPa]**	m 12.550	$f_{Tension}$	**-202.797**	**[MPa]**
f_1^*	**303.239**	**[MPa]**	m 12.550	f_2^*	**-156.036**	**[MPa]**

$$\psi = \frac{f_2^*}{f_1^*}$$

ψ -0.515

[AS/NZS 4600, Eq. 2.2.3.2(5)]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

k 13.978

[AS/NZS 4600, Eq. 2.2.3.2(4)]

C-Section Column Dimension			NOTE	$b = b_{p,1}$
$b_{p,1}$	36.596	[mm]		

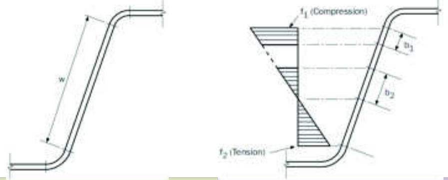
E	210.000	[GPa]	t	2.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

f_{cr} 11909.792 [MPa]

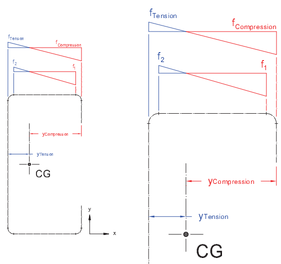
[AS/NZS 4600, Eq. 2.2.1.2(5)]

Superior Flange [$b_{p,2}$] [AISI S100, Sector B2.3]



Actual Element | Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



C-Section Column: Stress Gradient

[AISI S100, Figure B2.3-2]

h_0	90.000	[mm]
b_0	46.500	[mm]
h_0 / b_0	1.935	[ ]

$x_{Compression}$	27.889	[mm]	$x_{Tension}$	27.889	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Top fiber}$	**350.000**	**[MPa]**	x_{CG}	**16.159**	**[mm]**
$f_{Compression}$	**350.000**	**[MPa]**	m 12.550	$f_{Tension}$	**-202.797**	**[MPa]**
f_1	**303.239**	**[MPa]**	m 12.550	f_2	**-156.036**	**[MPa]**

For webs under stress gradient [f_1 in compression and f_2 in tension]

$h_o / b_o \le 4$		$h_o / b_o > 4$
	$b_1 = b_e / [3 + \psi]$	$b_1 = b_e / [3 + \psi]$
$\psi > 0.236$	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
$\psi \le 0.236$	$b_2 = b_e - b_1$	

$b_1 + b_2 \le$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$
[AISI S100, Eq. B2.3-1]

$|\psi|$ 0.515

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$
[AISI S100, Eq. B2.3-2]

k 13.978

C-Section Column Dimension

$b_{p,2}$ 36.596 [mm]

NOTE $w = b_{p,2}$

E	210.000	[GPa]	t	2.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]

F_{cr} 11909.792 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

$f = f_1$
303.239 [MPa]
λ 0.160

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ 1.000 → $b_{p,2,eff,AISI}$ 36.596 [mm]

$b_e = b_{p,2,eff,AISI}$ 36.596 [mm]
↓
h_0 / b_0 1.935
↓
$|\psi|$ 0.515
↓
$b_1 = b_e / [3 + \psi]$ 10.413 [mm]
↓

$h_o / b_o \le 4$				$h_o / b_o > 4$		
$\psi > 0.236$	$b_2 = b_e / 2$	18.298	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
$\psi \le 0.236$	$b_2 = b_e - b_1$	----	[mm]			

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Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
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f_1^*	303.239	[MPa]	m	12.550	f_2^*	-156.036	[MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$
[AS/NZS 4600, Eq. 2.2.3.2(5)]

ψ -0.515

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$
[AS/NZS 4600, Eq. 2.2.3.2(4)]

k 13.978

C-Section Column Dimension

$b_{p,2}$ 36.596 [mm]

NOTE $b = b_{p,2}$

E	210.000	[GPa]	t	2.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$
[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 11909.792 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$
[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$
303.239 [MPa]
λ 0.160

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $b_{p,2,eff,AS/NZS}$ 36.596 [mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$
[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$
$\psi \le -0.236$
[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$
$\psi > -0.236$
[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = b_{p,2,eff,AS/NZS}$ 36.596 [mm]
↓
ψ -0.515
↓
$b_{e1} = b_e / [3 - \psi]$ 10.413 [mm]
↓

$\psi \le -0.236$	$b_2 = b_e / 2$	18.298	[mm]	$\psi > -0.236$	$b_{e2} = b_e - b_{e1}$	----	[mm]

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Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
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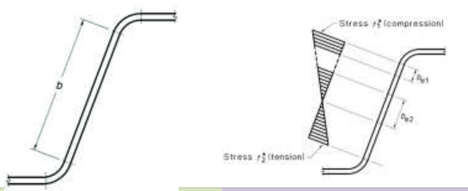
$b_1 + b_2 \le w_{Comp}$	KO	Web is fully effective	No more iterations!

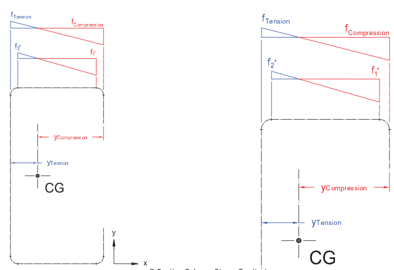
$b_{p,2,eff,AISI,1}$	10.413	[mm]	$b_{p,2,eff,AISI,2}$	13.750	[mm]

Superior Flange [$b_{p,2}$] [AS/NZS 4600, Clause 2.2.3]



Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Column: Stress Gradient

$x_{Compression}$	27.889	[mm]	$x_{Tension}$	27.889	[mm]

Tension Stress is reached!

1º Iteration	$f_{Compression,Top\ fiber}$	350.000	[MPa]	x_{CG}	16.159	[mm]

$f_{Compression}$	350.000	[MPa]	m	12.550	$f_{Tension}$	-202.797	[MPa]

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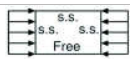
↓
$b_{e1} + b_{e2} \le$ Compression portion of the web calculated on the basis of effective section
↓

$b_{e1} + b_{e2} \le b_{Comp}$	KO	Web is fully effective	No more iterations!

$b_{p,2,eff,AS/NZS,1}$	10.413	[mm]	$b_{p,2,eff,AS/NZS,2}$	13.750	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,2,eff,AISI,1}$	10.413	=	$b_{p,2,eff,AS/NZS,1}$	10.413
$b_{p,2,eff,AISI,2}$	13.750	=	$b_{p,2,eff,AS/NZS,2}$	13.750

Superior Edge Stiffener [$c_{p,2}$] [AISI S100, Sector B3.1]

Boundary condition	Types of stress	k
	Compression	0.425

$x_{Compression}$	27.889	[mm]	$x_{Tension}$	27.889	[mm]

Compression Stress is reached!

Actual Element | Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

1º Iteration	$f_{Compression,Inf.\ fiber}$	350.000	[MPa]	x_{CG}	16.159	[mm]

$f_{Compression}$	350.000	[MPa]	m	12.550	$f_{Tension}$	-202.797	[MPa]

C-Section Column Dimension

$c_{p,2}$ 13.048 [mm]

NOTE $w = c_{p,2}$

E	210.000	[GPa]	t	2.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.1-5)]

F_{cr} 2848.645 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$: 350.000 [MPa]

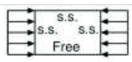
λ 0.351

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

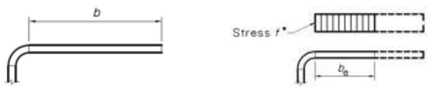
ρ	1.000	→	$c_{p,2,eff,AISI}$	13.048	[mm]

Superior Edge Stiffener [$c_{p,2}$] [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k
	Compression	0.425

$x_{Compression}$ 27.889 [mm] $x_{Tension}$ 27.889 [mm]

Compression Stress is reached!



Actual Element | Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

1º Iteration	$f_{Compression,Inf.\ fiber}$	**350.000**	**[MPa]**	x_{CG}	**16.159**	**[mm]**
$f_{Compression}$	**350.000**	**[MPa]**	m 12.550	$f_{Tension}$	**-202.797**	**[MPa]**

C-Section Column Dimension

$c_{p,2}$ 13.048 [mm]

NOTE $b = c_{p,2}$

E	210.000	[GPa]	t	2.452	[mm]	v	0.300	

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} 2848.645 [MPa]

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Date: 05/09/2019 Project: MASTER THESIS
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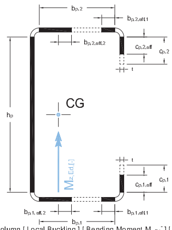
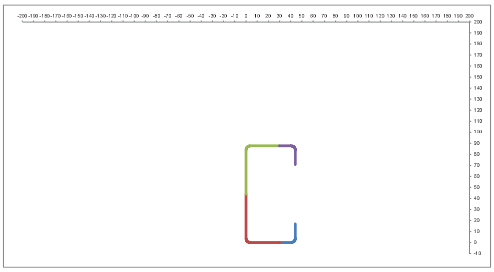
[iii] **Effective Cross C-Section Column [Local Buckling]**

Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	13.048	[mm]
Inferior Flange	$b_{p,1,eff,1}$	10.413	[mm]
	$b_{p,1,eff,2}$	13.750	[mm]
Web	$h_{p,eff}$	----	[mm]
Superior Flange	$b_{p,2,eff,1}$	10.413	[mm]
	$b_{p,2,eff,2}$	13.750	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	13.048	[mm]



Effective C-Section Column [Local Buckling] [Bending Moment $M_{y,Ed}^-$] [AISI S100 | AS/NZS 4600]



Effective C-Section Column [Local Buckling] [Bending Moment $M_{y,Ed}^-$]

$I_{z,eff}^{[-]}$ 153816.866 [mm^4]

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$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$: 350.000 [MPa]

λ 0.351

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$c_{p,2,eff,AS/NZS}$	13.048	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,2,eff,AISI}$	13.048	=	$c_{p,2,eff,AS/NZS}$	13.048

[ii] **Effective C-Section Column [Local Buckling]**

Effective C-Section Column Widths [AISI S100]			
Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	13.048	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	36.596	[mm]
Web	$h_{p,eff,AISI}$	----	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	36.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	13.048	[mm]

Effective C-Section Column Widths [AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	13.048	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	36.596	[mm]
Web	$h_{p,eff,AS/NZS}$	----	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	36.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	13.048	[mm]

Effective C-Section Column Widths [AISI S100 | AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff}$	13.048	[mm]
Inferior Flange	$b_{p,1,eff}$	36.596	[mm]
Web	$h_{p,eff}$	----	[mm]
Superior Flange	$b_{p,2,eff}$	36.596	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	13.048	[mm]

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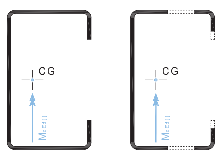
[d] C-Section Strut

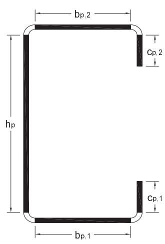


Gross C-Section | Effective C-Section [L]

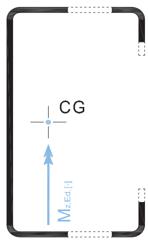
Local Buckling

C-Section Strut Dimension		
$c_{p,1}$	6.048	[mm]
$b_{p,1}$	32.096	[mm]
h_p	42.096	[mm]
$b_{p,2}$	32.096	[mm]
$c_{p,2}$	6.048	[mm]
t	1.452	[mm]

[i] **Effective Widths for Strength Determination [Local Buckling]** **AISI S100, Sector B | AS/NZS 4600, Section 2**



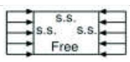
C-Section Plate Widths



Effective C-Section [Worst Case]

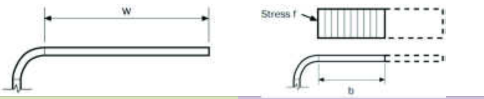
1º Iteration

Inferior Edge Stiffner [$c_{p,1}$] [AISI S100, Sector B3.1]

Boundary condition	Types of stress	k
	Compression	0.425

$x_{Compression}$ 23.444 [mm] $x_{Tension}$ 15.104 [mm]

Compression Stress is reached!



Actual Element	Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

1º Iteration	$f_{Compression,Inf. fiber}$	350.000	[MPa]	x_{CG}	15.104	[mm]
$f_{Compression}$ 350.000 [MPa]	m	14.929		$f_{Tension}$	-225.480	[MPa]

C-Section Strut Dimension — NOTE: $w = c_{p,1}$

$c_{p,1}$	6.048	[mm]						
E	210.000	[GPa]	t	1.452	[mm]	ν [μ]	0.300	

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]
F_{cr} 4649.380 [MPa]

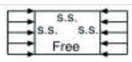
$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

$f = f_y$: 350.000 [MPa]
λ 0.274

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

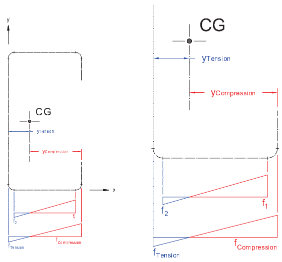
ρ 1.000 → $c_{p,1,eff,AISI}$ 6.048 [mm]

Inferior Edge Stiffner [$c_{p,1}$] — [AS/NZS 4600, Clause 2.3.1]

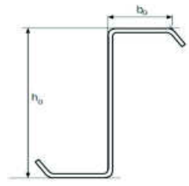
Boundary condition	Types of stress	k
	Compression	0.425

Actual Element	Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]



C-Section Strut: Stress Gradient



[AISI S100, Figure B2.3-2]

h_0	50.000	[mm]
b_0	40.000	[mm]
h_0 / b_0	1.250	[ ]

$x_{Compression}$ 23.444 [mm] $x_{Tension}$ 15.104 [mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Top fiber}$	350.000	[MPa]	x_{CG}	15.104	[mm]
$f_{Compression}$ 350.000 [MPa]	m	14.929		$f_{Tension}$	-225.480	[MPa]
f_1 301.839 [MPa]	m	14.929		f_2	-177.319	[MPa]

For webs under stress gradient [f_1 in compression and f_2 in tension]

$h_o / b_o \leq 4$		$h_o / b_o > 4$
$b_1 = b_e / [3 + \psi]$		$b_1 = b_e / [3 + \psi]$
ψ > 0.236	$b_2 = b_e / 2$	$b_2 = b_e / [1 + \psi] - b_1$
ψ ≤ 0.236	$b_2 = b_e - b_1$	

$b_1 + b_2 \leq$ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$
[AISI S100, Eq. B2.3-1]
| ψ | 0.587

For webs under stress gradient [f_1 in compression and f_2 in tension]
$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$
[AISI S100, Eq. B2.3-2]
k 15.176

C-Section Strut Dimension — NOTE: $w = b_{p,1}$

$b_{p,1}$	32.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	ν [μ]	0.300

$x_{Compression}$ 23.444 [mm] $x_{Tension}$ 15.104 [mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Inf. fiber}$	350.000	[MPa]	x_{CG}	15.104	[mm]
$f_{Compression}$ 350.000 [MPa]	m	14.929		$f_{Tension}$	-225.480	[MPa]

C-Section Strut Dimension — NOTE: $b = c_{p,1}$

$c_{p,1}$	6.048	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	ν	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$
[AS/NZS 4600, Eq. 2.2.1.2(5)]
f_{cr} 4649.380 [MPa]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$
[AS/NZS 4600, Eq. 2.2.1.2(4)]

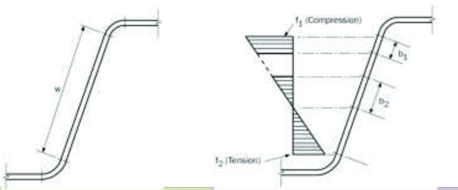
$f^* = f_y$: 350.000 [MPa]
λ 0.274

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$
[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $c_{p,1,eff,AS/NZS}$ 6.048 [mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,1,eff,AISI}$	6.048	=	$c_{p,1,eff,AS/NZS}$	6.048

Inferior Flange [$b_{p,1}$] — [AISI S100, Sector B2.3]



Actual Element	Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$
[AISI S100, Eq. (B2.1-5)]
F_{cr} 5894.952 [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
[AISI S100, Eq. B2.1-4]

$f = f_1$: 301.839 [MPa]
λ 0.226

$$\rho = (1 - 0.22/\lambda)/\lambda$$
[AISI S100, Eq. B2.1-4]

ρ 1.000 → $b_{p,1,eff,AISI}$ 32.096 [mm]

$b_e = b_{p,1,eff,AISI}$ 32.096 [mm]
↓
h_0 / b_0 1.250
↓
| ψ | 0.587
↓
$b_1 = b_e / [3 + \psi]$ 8.947 [mm]
↓

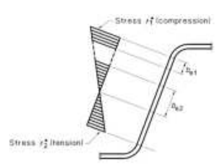
$h_o / b_o \leq 4$				$h_o / b_o > 4$		
ψ > 0.236	$b_2 = b_e / 2$	16.048	[mm]	$b_2 = b_e / [1 + \psi] - b_1$	----	[mm]
ψ ≤ 0.236	$b_2 = b_e - b_1$	----	[mm]			

↓

$b_1 + b_2 \leq w_{Comp}$ KO Web is fully effective **No more iterations!**

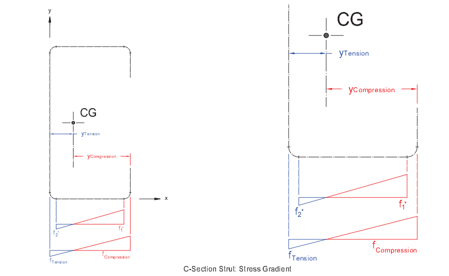
$b_{p,1,eff,AISI,1}$	8.947	[mm]	$b_{p,1,eff,AISI,2}$	11.272	[mm]

Inferior Flange [$b_{p,1}$] — [AS/NZS 4600, Clause 2.2.3]



Actual Element	Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Strut: Stress Gradient

$x_{Compression}$	23.444	[mm]	$x_{Tension}$	15.104	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Top\ fiber}$	350.000	[MPa]	x_{CG}	15.104 [mm]
$f_{Compression}$	350.000 [MPa]	m	14.929	$f_{Tension}$	-225.480 [MPa]
f_1^*	301.839 [MPa]	m	14.929	f_2^*	-177.319 [MPa]

$$\psi = \frac{f_2^*}{f_1^*}$$ ψ -0.587

[AS/NZS 4600, Eq. 2.2.3.2(5)]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$ k 15.176

[AS/NZS 4600, Eq. 2.2.3.2(4)]

C-Section Strut Dimension — NOTE: $b = b_{p,1}$

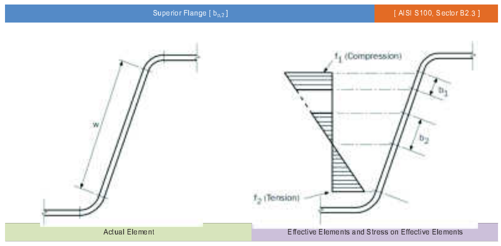
$b_{p,1}$	32.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	v	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$ f_{cr} 5894.952 [MPa]

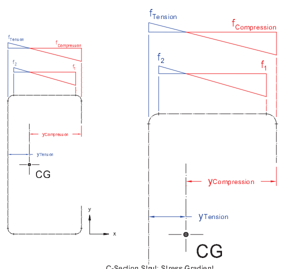
[AS/NZS 4600, Eq. 2.2.1.2(5)]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

Superior Flange [$b_{p,2}$] — [AISI S100, Sector B2.3]



Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]



C-Section Strut: Stress Gradient

[AISI S100, Figure B2.3-2]

h_0	50.000	[mm]
b_0	40.000	[mm]
h_0 / b_0	1.250	[ ]

$x_{Compression}$	23.444	[mm]	$x_{Tension}$	15.104	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Top\ fiber}$	350.000	[MPa]	x_{CG}	15.104 [mm]
$f_{Compression}$	350.000 [MPa]	m	14.929	$f_{Tension}$	-225.480 [MPa]
f_1	301.839 [MPa]	m	14.929	f_2	-177.319 [MPa]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
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$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$ [AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 301.839 [MPa]; λ 0.226

$$\rho = \frac{\left(1-\frac{0.22}{\lambda}\right)}{\lambda} \le 1.0$$ [AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ 1.000 → $b_{p,1,eff,AS/NZS}$ 32.096 [mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$ [AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$ ψ ≤ −0.236 [AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$ ψ > −0.236 [AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = b_{p,1,eff,AS/NZS}$ 32.096 [mm]
↓
ψ -0.587
↓
$b_{e1} = b_e / [3 - ψ]$ 8.947 [mm]
↓

ψ ≤ -0.236	$b_2 = b_e / 2$	16.048	[mm]	ψ > -0.236	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓
$b_{e1} + b_{e2}$ ≤ Compression portion of the web calculated on the basis of effective section
↓

$b_{e1} + b_{e2} \le b_{Comp}$	KO	Web is fully effective	No more iterations!

$b_{p,1,eff,AS/NZS,1}$	8.947	[mm]	$b_{p,1,eff,AS/NZS,2}$	11.272	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,1,eff,AISI,1}$	8.947	=	$b_{p,1,eff,AS/NZS,1}$	8.947
$b_{p,1,eff,AISI,2}$	11.272	=	$b_{p,1,eff,AS/NZS,2}$	11.272

Web [h_p] — [AISI S100, Sector B2.1]

NOTE: Zone in Tension. Effective width is equal to the real width

Web [h_p] — [AS/NZS 4600, Clause 2.2.1]

NOTE: Zone in Tension. Effective width is equal to the real width

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
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For webs under stress gradient [f_1 in compression and f_2 in tension]

	$h_o / b_o \le 4$	$h_o / b_o > 4$
	$b_1 = b_e / [3 + ψ]$	$b_1 = b_e / [3 + ψ]$
ψ > 0.236	$b_2 = b_e / 2$	$b_2 = b_e / [1 + ψ] - b_1$
ψ ≤ 0.236	$b_2 = b_e - b_1$	

$b_1 + b_2$ ≤ Compression portion of the web calculated on the basis of effective section

$$\psi = |f_2/f_1|$$ [AISI S100, Eq. B2.3-1] |ψ| 0.587

For webs under stress gradient [f_1 in compression and f_2 in tension]

$$k = 4 + 2(1+\psi)^3 + 2(1+\psi)$$ k 15.176

[AISI S100, Eq. B2.3-2]

C-Section Strut Dimension — NOTE: $w = b_{p,2}$

$b_{p,2}$	32.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	v [μ]	0.300

$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$ F_{cr} 5894.952 [MPa]

[AISI S100, Eq. (B2.1-5)]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$ [AISI S100, Eq. B2.1-4]

$f = f_1$: 301.839 [MPa]; λ 0.226

$$\rho = (1 - 0.22/\lambda)/\lambda$$ [AISI S100, Eq. B2.1-4]

ρ 1.000 → $b_{p,2,eff,AISI}$ 32.096 [mm]

$b_e = b_{p,2,eff,AISI}$ 32.096 [mm]
↓
h_0 / b_0 1.250
↓
|ψ| 0.587
↓
$b_1 = b_e / [3 + ψ]$ 8.947 [mm]
↓

$h_o / b_o \le 4$				$h_o / b_o > 4$		
ψ > 0.236	$b_2 = b_e / 2$	16.048	[mm]	$b_2 = b_e / [1 + ψ] - b_1$	----	[mm]
ψ ≤ 0.236	$b_2 = b_e - b_1$	----	[mm]			

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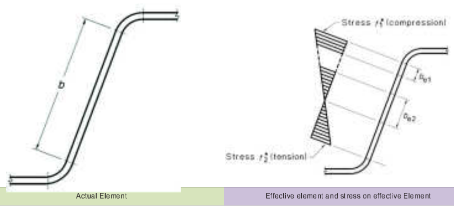
$b_1 + b_2 \leq w_{Comp}$	KO	Web is fully effective	No more iterations!

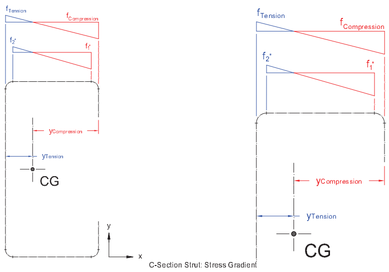
$b_{p,2,eff,AISI,1}$	8.947	[mm]	$b_{p,2,eff,AISI,2}$	11.272	[mm]

Superior Flange [$b_{p,2}$] — [AS/NZS 4600, Clause 2.2.3]



Actual Element | Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]



C-Section Strut: Stress Gradient

$x_{Compression}$	23.444	[mm]	$x_{Tension}$	15.104	[mm]

Compression Stress is reached!

1º Iteration	$f_{Compression,Top\ fiber}$	**350.000**	**[MPa]**		x_{CG}	**15.104**	**[mm]**
$f_{Compression}$	**350.000**	**[MPa]**	m	14.929	$f_{Tension}$	**-225.480**	**[MPa]**

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$b_{e1} + b_{e2} \leq$ Compression portion of the web calculated on the basis of effective section

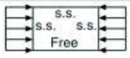
↓

$b_{e1} + b_{e2} \leq b_{Comp}$	KO	Web is fully effective	No more iterations!

$b_{p,2,eff,AS/NZS,1}$	8.947	[mm]	$b_{p,2,eff,AS/NZS,2}$	11.272	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$b_{p,2,eff,AISI,1}$	8.947	=	$b_{p,2,eff,AS/NZS,1}$	8.947
$b_{p,2,eff,AISI,2}$	11.272	=	$b_{p,2,eff,AS/NZS,2}$	11.272

Superior Edge Stiffener [$c_{p,2}$] — [AISI S100, Sector B3.1]

Boundary condition	Types of stress	k
	Compression	0.425

$x_{Compression}$	23.444	[mm]	$x_{Tension}$	15.104	[mm]

Compression Stress is reached!

Actual Element | Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

1º Iteration	$f_{Compression,Inf.\ fiber}$	**350.000**	**[MPa]**		x_{CG}	**15.104**	**[mm]**
$f_{Compression}$	**350.000**	**[MPa]**	m	14.929	$f_{Tension}$	**-225.480**	**[MPa]**

C-Section Strut Dimension — **NOTE**: $w = c_{p,2}$

$c_{p,2}$	6.048	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	ν [μ]	0.300

f_1^*	**301.839**	**[MPa]**	m	14.929	f_2^*	**-177.319**	**[MPa]**

$$\psi = \frac{f_2^*}{f_1^*}$$

ψ = -0.587

[AS/NZS 4600, Eq. 2.2.3.2(5)]

$$k = 4 + 2(1-\psi)^3 + 2(1-\psi)$$

k = 15.176

[AS/NZS 4600, Eq. 2.2.3.2(4)]

C-Section Strut Dimension — **NOTE**: $b = b_{p,2}$

$b_{p,2}$	32.096	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	ν	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

f_{cr} = 5894.952 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_1^*$: 301.839 [MPa]

λ = 0.226

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$b_{p,2,eff,AS/NZS}$	32.096	[mm]

$$b_{e1} = \frac{b_e}{3-\psi}$$

[AS/NZS 4600, Eq. 2.2.3.2(1)]

$$b_{e2} = \frac{b_e}{2}$$

ψ ≤ −0.236

[AS/NZS 4600, Eq. 2.2.3.2(2)]

$$b_{e2} = b_e - b_{e1}$$

ψ > −0.236

[AS/NZS 4600, Eq. 2.2.3.2(3)]

$b_e = b_{p,2,eff,AS/NZS}$	32.096	[mm]

↓

ψ	-0.587

↓

$b_{e1} = b_e / [\ 3 - \psi\ ]$	8.947	[mm]

↓

ψ ≤ -0.236	$b_2 = b_e / 2$	16.048	[mm]	ψ > -0.236	$b_{e2} = b_e - b_{e1}$	----	[mm]

↓

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$$F_{cr} = k\frac{\pi^2 E}{12(1-\mu^2)}\left(\frac{t}{w}\right)^2$$

F_{cr} = 4649.380 [MPa]

[AISI S100, Eq. (B2.1-5)]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$f = f_y$: 350.000 [MPa]

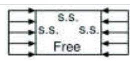
λ = 0.274

$$\rho = (1 - 0.22/\lambda)/\lambda$$

[AISI S100, Eq. B2.1-4]

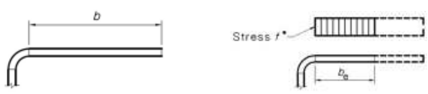
ρ	1.000	→	$c_{p,2,eff,AISI}$	6.048	[mm]

Superior Edge Stiffener [$c_{p,2}$] — [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k
	Compression	0.425

$x_{Compression}$	23.444	[mm]	$x_{Tension}$	15.104	[mm]

Compression Stress is reached!



Actual Element | Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

1º Iteration	$f_{Compression,Inf.\ fiber}$	**350.000**	**[MPa]**		x_{CG}	**15.104**	**[mm]**
$f_{Compression}$	**350.000**	**[MPa]**	m	14.929	$f_{Tension}$	**-225.480**	**[MPa]**

C-Section Strut Dimension — **NOTE**: $b = c_{p,2}$

$c_{p,2}$	6.048	[mm]					
E	210.000	[GPa]	t	1.452	[mm]	ν	0.300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right)\left(\frac{t}{b}\right)^2$$

f_{cr} = 4649.380 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$\lambda = \left(\sqrt{\frac{f^*}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$f^* = f_y$	
350.000	[MPa]
λ	0.274

$$\rho = \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(3)]

ρ	1.000	→	$c_{p,2,eff,AS/NZS}$	6.048	[mm]

AISI S100, Effective Width [mm]		Comparison [= or ≠]	AS/NZS 4600, Effective Width [mm]	
$c_{p,2,eff,AISI}$	6.048	=	$c_{p,2,eff,AS/NZS}$	6.048

[ii] **Effective C-Section Strut [Local Buckling]**

Effective C-Section Strut Widths [AISI S100]			
Inferior Edge Stiffener	$c_{p,1,eff,AISI}$	6.048	[mm]
Inferior Flange	$b_{p,1,eff,AISI}$	32.096	[mm]
Web	$h_{p,eff,AISI}$	----	[mm]
Superior Flange	$b_{p,2,eff,AISI}$	32.096	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AISI}$	6.048	[mm]

Effective C-Section Strut Widths [AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff,AS/NZS}$	6.048	[mm]
Inferior Flange	$b_{p,1,eff,AS/NZS}$	32.096	[mm]
Web	$h_{p,eff,AS/NZS}$	----	[mm]
Superior Flange	$b_{p,2,eff,AS/NZS}$	0.000	[mm]
Superior Edge Stiffener	$c_{p,2,eff,AS/NZS}$	6.048	[mm]

Effective C-Section Strut Widths [AISI S100 | AS/NZS 4600]			
Inferior Edge Stiffener	$c_{p,1,eff}$	6.048	[mm]
Inferior Flange	$b_{p,1,eff}$	32.096	[mm]
Web	$h_{p,eff}$	----	[mm]
Superior Flange	$b_{p,2,eff}$	32.096	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	6.048	[mm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993

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Date: 05/09/2019 Project: MASTER THESIS

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[12] Cold-Formed Efective Section

[a] Ω-Section Purlin

Ω-Section Purlin subjected to Tension Force	$A_{eff,Tension}$	191.199	[mm^2]
Ω-Section Purlin subjected to Compression Force	$A_{eff,Compression}$	156.435	[mm^2]
	$e_{N,y}$	0.000	[mm]
	$e_{N,x}$	-1.115	[mm]
Ω-Section Purlin subjected to Positive Moment in y-y axis [$M_{y,Ed}^+$]	$I_{x,eff,M+}$	81891.327	[mm^4]
Ω-Section Purlin subjected to Negative Moment in y-y axis [$M_{y,Ed}^-$]	$I_{x,eff,M-}$	85759.975	[mm^4]
Ω-Section Purlin subjected to Positive Moment in z-z axis [$M_{z,Ed}^+$]	$I_{y,eff,M+}$	173380.870	[mm^4]
Ω-Section Purlin subjected to Negative Moment in z-z axis [$M_{z,Ed}^-$]	$I_{y,eff,M-}$	173726.891	[mm^4]

[b] C-Section Beam

C-Section Beam subjected to Tension Force	$A_{eff,Tension}$	345.063	[mm^2]
C-Section Beam subjected to Compression Force	$A_{eff,Compression}$	267.460	[mm^2]
	$e_{N,y}$	4.225	[mm]
	$e_{N,x}$	0.000	[mm]
C-Section Beam subjected to Positive Moment in y-y axis [$M_{y,Ed}^+$]	$I_{x,eff,M+}$	762290.565	[mm^4]
C-Section Beam subjected to Negative Moment in y-y axis [$M_{y,Ed}^-$]	$I_{x,eff,M-}$	762290.565	[mm^4]
C-Section Beam subjected to Positive Moment in z-z axis [$M_{z,Ed}^+$]	$I_{y,eff,M+}$	96937.280	[mm^4]
C-Section Beam subjected to Negative Moment in z-z axis [$M_{z,Ed}^-$]	$I_{y,eff,M-}$	108754.009	[mm^4]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

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Date: 05/09/2019 Project: MASTER THESIS

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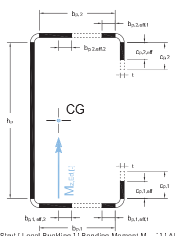
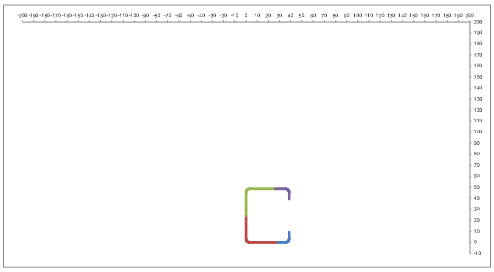
[iii] **Effective Cross C-Section Strut [Local Buckling]**

Effective C-Section Strut Widths			
Inferior Edge Stiffener	$c_{p,1,eff}$	6.048	[mm]
Inferior Flange	$b_{p,1,eff,1}$	8.947	[mm]
	$b_{p,1,eff,2}$	11.272	[mm]
Web	$h_{p,eff}$	----	[mm]
Superior Flange	$b_{p,2,eff,1}$	8.947	[mm]
	$b_{p,2,eff,2}$	11.272	[mm]
Superior Edge Stiffener	$c_{p,2,eff}$	6.048	[mm]



Effective C-Section Strut [Local Buckling] [Bending Moment $M_{y,Ed}^-$] [AISI S100 | AS/NZS 4600]



Effective C-Section Strut [Local Buckling] [Bending Moment $M_{y,Ed}^-$]

$I_{y,eff}$ [-] 43399.345 [mm^4]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993

Version: 1.000

Office: ---- Author: JOSÉ ANTÓNIO

Date: 05/09/2019 Project: MASTER THESIS

Client: COIMBRA UNIVERSITY

[c] C-Section Column

C-Section Column subjected to Tension Force	$A_{eff,Tension}$	497.235	[mm^2]
C-Section Column subjected to Compression Force	$A_{eff,Compression}$	493.023	[mm^2]
	$e_{N,y}$	0.138	[mm]
	$e_{N,x}$	0.000	[mm]
C-Section Column subjected to Positive Moment in y-y axis [$M_{y,Ed}^+$]	$I_{x,eff,M+}$	625036.020	[mm^4]
C-Section Column subjected to Negative Moment in y-y axis [$M_{y,Ed}^-$]	$I_{x,eff,M-}$	625036.020	[mm^4]
C-Section Column subjected to Positive Moment in z-z axis [$M_{z,Ed}^+$]	$I_{y,eff,M+}$	153816.866	[mm^4]
C-Section Column subjected to Negative Moment in z-z axis [$M_{z,Ed}^-$]	$I_{y,eff,M-}$	153816.866	[mm^4]

[d] C-Section Strut

C-Section Strut subjected to Tension Force	$A_{eff,Tension}$	201.315	[mm^2]
C-Section Strut subjected to Compression Force	$A_{eff,Compression}$	201.315	[mm^2]
	$e_{N,y}$	0.000	[mm]
	$e_{N,x}$	0.000	[mm]
C-Section Strut subjected to Positive Moment in y-y axis [$M_{y,Ed}^+$]	$I_{x,eff,M+}$	85435.109	[mm^4]
C-Section Strut subjected to Negative Moment in y-y axis [$M_{y,Ed}^-$]	$I_{x,eff,M-}$	85435.109	[mm^4]
C-Section Strut subjected to Positive Moment in z-z axis [$M_{z,Ed}^+$]	$I_{y,eff,M+}$	43399.345	[mm^4]
C-Section Strut subjected to Negative Moment in z-z axis [$M_{z,Ed}^-$]	$I_{y,eff,M-}$	43399.345	[mm^4]

[14] Reactions Values

Ω-Section Console Purlin		
$N_{t,Ed}$	0.000	[kN]
$N_{c,Ed}$	0.000	[kN]
$V_{y,Ed}$	0.170	[kN]
$V_{z,Ed}$	0.630	[kN]
$M_{y,Ed\,[+]}$	0.220	[kN]
$M_{y,Ed\,[-]}$	0.220	[kN]
$M_{z,Ed\,[+]}$	0.060	[kN]
$M_{z,Ed\,[-]}$	0.060	[kN]

Ω-Section Middle Purlin		
$N_{t,Ed}$	0.040	[kN]
$N_{c,Ed}$	0.040	[kN]
$V_{y,Ed}$	0.260	[kN]
$V_{z,Ed}$	1.010	[kN]
$M_{y,Ed\,[+]}$	0.360	[kN]
$M_{y,Ed\,[-]}$	0.360	[kN]
$M_{z,Ed\,[+]}$	0.090	[kN]
$M_{z,Ed\,[-]}$	0.090	[kN]

C-Section Console Beam		
$N_{t,Ed}$	0.520	[kN]
$N_{c,Ed}$	0.520	[kN]
$V_{y,Ed}$	0.040	[kN]
$V_{z,Ed}$	1.970	[kN]
$M_{y,Ed\,[+]}$	0.840	[kN]
$M_{y,Ed\,[-]}$	0.840	[kN]
$M_{z,Ed\,[+]}$	0.020	[kN]
$M_{z,Ed\,[-]}$	0.020	[kN]

C-Section Middle Beam		
$N_{t,Ed}$	0.700	[kN]
$N_{c,Ed}$	1.030	[kN]
$V_{y,Ed}$	0.040	[kN]
$V_{z,Ed}$	2.000	[kN]
$M_{y,Ed\,[+]}$	0.840	[kN]
$M_{y,Ed\,[-]}$	0.840	[kN]
$M_{z,Ed\,[+]}$	0.010	[kN]
$M_{z,Ed\,[-]}$	0.010	[kN]

C-Section Front Column		
$N_{t,Ed}$	2.700	[kN]
$N_{c,Ed}$	4.140	[kN]
$V_{y,Ed}$	0.000	[kN]
$V_{z,Ed}$	1.790	[kN]
$M_{y,Ed\,[+]}$	0.270	[kN]
$M_{y,Ed\,[-]}$	0.270	[kN]
$M_{z,Ed\,[+]}$	0.000	[kN]
$M_{z,Ed\,[-]}$	0.000	[kN]

C-Section Rear Column		
$N_{t,Ed}$	3.340	[kN]
$N_{c,Ed}$	4.170	[kN]
$V_{y,Ed}$	0.000	[kN]
$V_{z,Ed}$	2.240	[kN]
$M_{y,Ed\,[+]}$	0.350	[kN]
$M_{y,Ed\,[-]}$	0.350	[kN]
$M_{z,Ed\,[+]}$	0.000	[kN]
$M_{z,Ed\,[-]}$	0.000	[kN]

C-Section Strut		
$N_{t,Ed}$	2.280	[kN]
$N_{c,Ed}$	1.470	[kN]
$V_{y,Ed}$	0.000	[kN]
$V_{z,Ed}$	0.020	[kN]
$M_{y,Ed\,[+]}$	0.010	[kN]
$M_{y,Ed\,[-]}$	0.010	[kN]
$M_{z,Ed\,[+]}$	0.000	[kN]
$M_{z,Ed\,[-]}$	0.000	[kN]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
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[b] C-Section Beam

[i] C-Section Beam : Axial Tension [AISI S100, ASD]

$T_n = A_g * F_y$	f_{ya}	360.001	[MPa]	$T \le T_n / \Omega_t$
Yielding in gross section	A_g	345.063	[mm^2]	
[AISI S100, Eq. C2-1]	Ω_t	1.670	[ASD]	[AISI S100, Eq. A4.1.1-1]

T_n 124223.202 [N] → T_n **124.223** [kN]

R	0.700	[kN]	Ratio	0.941 [%]
$R_n = T_n$	124.223	[kN]		

[ii] C-Section Beam : Axial Tension [AISI S100, LRFD]

$T_n = A_g * F_y$	f_{ya}	360.001	[MPa]	$T \le \Phi_t * T_n$
Yielding in gross section	A_g	345.063	[mm^2]	
[AISI S100, Eq. C2-1]	Φ_t	0.900	[ASD]	[AISI S100, Eq. A5.1.1-1]

T_n 124223.202 [N] → T_n **124.223** [kN]

R_u	0.700	[kN]	Ratio	0.626 [%]
$R_n = T_n$	124.223	[kN]		

[iii] C-Section Beam : Axial Tension [AS/NZS 4600, LSD]

$N_t = A_g * f_y$	f_{ya}	360.001	[MPa]	$N^* \le \Phi_t * N_t$
	A_g	345.063	[mm^2]	
[AS/NZS 4600, Eq. 3.2.2(1)]	Φ_t	0.900	[ASD]	[AS/NZS 4600, Eq. 3.2.1]

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_t]
Members subject to axial tension	3.2.1	0.900

N_t 124223.202 [N] → N_t **124.223** [kN]

N^*	0.700	[kN]	Ratio	0.626 [%]
N_t	124.223	[kN]		

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
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[15] Members [AISI S100, C | AS/NZS 4600, 3]

[15.1] Members subjected to Axial Tension [AISI S100, C2 | AS/NZS 4600, 3.2]

[a] Ω-Section Purlin

[i] Ω-Section Purlin : Axial Tension [AISI S100, ASD]

$T_n = A_g * F_y$	f_{ya}	358.592	[MPa]	$T \le T_n / \Omega_t$
Yielding in gross section	A_g	191.199	[mm^2]	
[AISI S100, Eq. C2-1]	Ω_t	1.670	[ASD]	[AISI S100, Eq. A4.1.1-1]

T_n 68562.518 [N] → T_n **68.563** [kN]

T	0.040	[kN]	Ratio	0.097 [%]
T_n	68.563	[kN]		

[ii] Ω-Section Purlin : Axial Tension [AISI S100, LRFD]

$T_n = A_g * F_y$	f_{ya}	358.592	[MPa]	$T \le \Phi_t * T_n$
Yielding in gross section	A_g	191.199	[mm^2]	
[AISI S100, Eq. C2-1]	Φ_t	0.900	[ASD]	[AISI S100, Eq. A5.1.1-1]

T_n 68562.518 [N] → T_n **68.563** [kN]

T	0.040	[kN]	Ratio	0.065 [%]
T_n	68.563	[kN]		

[iii] Ω-Section Purlin : Axial Tension [AS/NZS 4600, LSD]

$N_t = A_g * f_y$	f_{ya}	358.592	[MPa]	$N^* \le \Phi_t * N_t$
	A_g	191.199	[mm^2]	
[AS/NZS 4600, Eq. 3.2.2(1)]	Φ_t	0.900	[ASD]	[AS/NZS 4600, Eq. 3.2.1]

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_t]
Members subject to axial tension	3.2.1	0.900

N_t 68562.518 [N] → N_t **68.563** [kN]

N^*	0.040	[kN]	Ratio	0.065 [%]
N_t	68.563	[kN]		

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
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[c] C-Section Column

[i] C-Section Column : Axial Tension [AISI S100, ASD]

$T_n = A_g * F_y$	f_{ya}	368.323	[MPa]	$T \le T_n / \Omega_t$
Yielding in gross section	A_g	497.235	[mm^2]	
[AISI S100, Eq. C2-1]	Ω_t	1.670	[ASD]	[AISI S100, Eq. A4.1.1-1]

T_n 183143.262 [N] → T_n **183.143** [kN]

R	3.340	[kN]	Ratio	3.046 [%]
$R_n = T_n$	183.143	[kN]		

[ii] C-Section Column : Axial Tension [AISI S100, LRFD]

$T_n = A_g * F_y$	f_{ya}	368.323	[MPa]	$T \le \Phi_t * T_n$
Yielding in gross section	A_g	497.235	[mm^2]	
[AISI S100, Eq. C2-1]	Φ_t	0.900	[ASD]	[AISI S100, Eq. A5.1.1-1]

T_n 183143.262 [N] → T_n **183.143** [kN]

R_u	3.340	[kN]	Ratio	2.026 [%]
$R_n = T_n$	183.143	[kN]		

[iii] C-Section Column : Axial Tension [AS/NZS 4600, LSD]

$N_t = A_g * f_y$	f_{ya}	368.323	[MPa]	$N^* \le \Phi_t * N_t$
	A_g	497.235	[mm^2]	
[AS/NZS 4600, Eq. 3.2.2(1)]	Φ_t	0.900	[ASD]	[AS/NZS 4600, Eq. 3.2.1]

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_t]
Members subject to axial tension	3.2.1	0.900

N_t 183143.262 [N] → N_t **183.143** [kN]

N^*	3.340	[kN]	Ratio	2.026 [%]
N_t	183.143	[kN]		

[d] C-Section Strut

[i] C-Section Strut : Axial Tension [AISI S100, ASD]

$T_n = A_g * F_y$	f_{ya}	367.142	[MPa]	$T \leq T_n / \Omega_t$
Yielding in gross section	A_g	201.315	[mm^2]	
[AISI S100, Eq. C2-1]	Ω_t	1.670	[ASD]	[AISI S100, Eq. A4.1.1-1]

T_n 73911.402 [N] → **T_n 73.911 [kN]**

R	2.280	[kN]	Ratio	5.152	[%]
$R_n = T_n$	73.911	[kN]			

[ii] C-Section Strut : Axial Tension [AISI S100, LRFD]

$T_n = A_g * F_y$	f_{ya}	367.142	[MPa]	$T \leq \Phi_t * T_n$
Yielding in gross section	A_g	201.315	[mm^2]	
[AISI S100, Eq. C2-1]	Φ_t	0.900	[ASD]	[AISI S100, Eq. A5.1.1-1]

T_n 73911.402 [N] → **T_n 73.911 [kN]**

R_u	2.280	[kN]	Ratio	3.428	[%]
$R_n = T_n$	73.911	[kN]			

[iii] C-Section Strut : Axial Tension [AS/NZS 4600, LSD]

$N_t = A_g * f_y$	f_{ya}	367.142	[MPa]	$N^* \leq \Phi_t * N_t$
	A_g	201.315	[mm^2]	
[AS/NZS 4600, Eq. 3.2.2(1)]	Φ_t	0.900	[ASD]	[AS/NZS 4600, Eq. 3.2.1]

Table 1.6: Capacity Reduction Factor | AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_t]
Members subject to axial tension	3.2.1	0.900

N_t 73911.402 [N] → **N_t 73.911 [kN]**

N^*	2.280	[kN]	Ratio	3.428	[%]
N_t	73.911	[kN]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

$I_{x,el,M[-]}$ 85759.975 [mm^4]

$S_{el,Comp}$	3343.203	[mm^3]	$S_{el,Tens}$	3053.134	[mm^3]

$I_{x,eff,M[-]}$ 85759.975 [mm^4]

$S_{eff,Comp}$	3343.203	[mm^3]	$S_{eff,Tens}$	3053.134	[mm^3]

$S_{el,Comp}$ **Section is fully effective** $S_{eff,Comp}$

F_y ---- [MPa]
F_{ya} 365.389 [MPa]

↓

$M_{n,x,Comp,M[-]}$	1221568.857	[Nmm]	$M_{n,x,Tens,M[-]}$	1115580.737	[Nmm]
$M_{n,x,Comp,M[-]}$	**1.222**	**[kNm]**	**$M_{n,x,Tens,M[-]}$**	**1.116**	**[kNm]**

Positive Moment in y-y axis [$M_{y,Ed}^+$]

$I_{y,el,M[+]}$ 176909.935 [mm^4]

$S_{el,Comp}$	3177.986	[mm^3]	$S_{el,Tens}$	3177.986	[mm^3]

$I_{y,eff,M[+]}$ 173380.870 [mm^4]

$S_{eff,Comp}$	3076.745	[mm^3]	$S_{eff,Tens}$	3153.378	[mm^3]

$S_{el,Comp}$ **Section is not fully effective** $S_{eff,Comp}$

F_y 350.000 [MPa]
F_{ya} ---- [MPa]

↓

$M_{n,y,Comp,M[+]}$	1076860.61	[Nmm]	$M_{n,y,Tens,M[+]}$	1103682.315	[Nmm]
$M_{n,y,Comp,M[+]}$	**1.077**	**[kNm]**	**$M_{n,y,Tens,M[+]}$**	**1.104**	**[kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^-$]

$I_{y,el,M[-]}$ 176909.935 [mm^4]

$S_{el,Comp}$	3177.986	[mm^3]	$S_{el,Tens}$	3177.986	[mm^3]

[15.2] Members subjected to Bending [AISI S100, C3 | AS/NZS 4600, 3.3]

[a] Ω-Section Purlin

[i] Ω-Section Purlin : Bending Moment [AISI S100, ASD]

[1] Ω-Section Purlin : Nominal Section Strength [Resistance] [AISI S100, C3.1.1]

Procedure	Description
I	Based on Initiation of Yielding
II	Based on Inelastic Reserve Capacity

Procedure II : Based on Inelastic Reserve Capacity

The inelastic flexural reserve capacity shall be permitted to be used when:

[1] Member is not subject to twisting, lateral, torsional, or flexural-torsional buckling
[2] Effect of cold work of forming is not included in determining the yield stress F_y
[3] Ratio of the depth of the compressed portion of the web to its thickness not exceed λ_1
[4] Shear force does not exceed:
$0.35*F_y$ [ASD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]
$0.60*F_y$ [LRFD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]
[5] The angle between any web and the vertical does not exceed 30

Sections with stiffened or partially stiffened compression flanges Ω_b 1.670

Procedure I $M_n = S_eF_y$ [AISI S100, Eq. C3.1.1-1]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

$I_{x,el,M[+]}$ 85759.975 [mm^4]

$S_{el,Comp}$	3053.134	[mm^3]	$S_{el,Tens}$	3343.203	[mm^3]

$I_{x,eff,M[+]}$ 81891.327 [mm^4]

$S_{eff,Comp}$	2844.717	[mm^3]	$S_{eff,Tens}$	3281.686	[mm^3]

$S_{el,Comp}$ **Section is not fully effective** $S_{eff,Comp}$

F_y 350.000 [MPa]
F_{ya} ---- [MPa]

↓

$M_{n,x,Comp,M[+]}$	995651.0514	[Nmm]	$M_{n,x,Tens,M[+]}$	1148590.066	[Nmm]
$M_{n,x,Comp,M[+]}$	**0.996**	**[kNm]**	**$M_{n,x,Tens,M[+]}$**	**1.149**	**[kNm]**

$I_{y,eff,M[-]}$ 173726.891 [mm^4]

$S_{eff,Comp}$	3084.704	[mm^3]	$S_{eff,Tens}$	3157.762	[mm^3]

$S_{el,Comp}$ **Section is not fully effective** $S_{eff,Comp}$

F_y 350.000 [MPa]
F_{ya} ---- [MPa]

↓

$M_{n,y,Comp,M[-]}$	1079646.574	[Nmm]	$M_{n,y,Tens,M[-]}$	1105216.801	[Nmm]
$M_{n,y,Comp,M[-]}$	**1.080**	**[kNm]**	**$M_{n,y,Tens,M[-]}$**	**1.105**	**[kNm]**

[2] Ω-Section Purlin : Lateral-Torsional Buckling Strength [Resistance] [AISI S100, C3.1.2.1]

Provisions of this section are not applied to multiple-web deck, U, closed box-type members, curved or arch members

[3] Ω-Section Purlin : Distortional Buckling Strength [Resistance] [AISI S100, C3.1.4]

Provisions of this section are not applied to multiple-web deck, U, closed box-type members, curved or arch members

[4] Ω-Section Purlin : Bending Moment Verification [AISI S100, ASD]

$M \leq M_n / \Omega_b$ [AISI S100, Eq. A4.1.1-1] M_n = MIN [$M_{n,C3.1.1}$; $M_{n,C3.1.2.1}$; $M_{n,C3.1.4}$]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	60.383	[%]
$M_{n,x,Comp,M[+]}$	0.996	[kNm]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	49.215	[%]
$M_{n,x,Comp,M[-]}$	1.222	[kNm]			

Positive Moment in y-y axis [$M_{y,Ed}^+$]

$M_{y,Ed,M[+]}$	0.090	[kNm]	Ratio	13.957	[%]
$M_{n,y,Comp,M[+]}$	1.077	[kNm]			

Negative Moment in y-y axis [$M_{y,Ed}^-$]

$M_{y,Ed,M[-]}$	0.090	[kNm]	Ratio	13.921	[%]
$M_{n,y,Comp,M[-]}$	1.080	[kNm]			

[ii] Ω-Section Purlin : Bending Moment [AISI S100, LRFD]

[1] Ω-Section Purlin : Nominal Section Strength [Resistance] [AISI S100, C3.1.1]

Procedure	Description
I	Based on Initiation of Yielding
II	Based on Inelastic Reserve Capacity

Procedure II : Based on Inelastic Reserve Capacity

The inelastic flexural reserve capacity shall be permitted to be used when:

[1] Member is not subject to twisting, lateral, torsional, or flexural-torsional buckling

[2] Effect of cold work of forming is not included in determining the yield stress F_y

[3] Ratio of the depth of the compressed portion of the web to its thickness not exceed λ_1

[4] Shear force does not exceed:

0.35*F_y [ASD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]

0.60*F_y [LRFD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]

[5] The angle between any web and the vertical does not exceed 30

Sections with stiffened or partially stiffened compression flanges | Φ_b 0.950

Procedure | I | $M_n = S_eF_y$ [AISI S100, Eq. C3.1.1-1]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

	$I_{x,el,M[+]}$	85759.975	[mm^4]		
$S_{el,Comp}$	3053.134	[mm^3]	$S_{el,Tens}$	3343.203	[mm^3]
	$I_{x,eff,M[+]}$	81891.327	[mm^4]		
$S_{eff,Comp}$	2844.717	[mm^3]	$S_{eff,Tens}$	3281.686	[mm^3]

$S_{el,Comp}$ | **Section is not fully effective** | $S_{eff,Comp}$

F_y	350.000	[MPa]
F_{ya}	----	[MPa]

↓

$M_{n,x,Comp,M[+]}$	995651.0514	[Nmm]	$M_{n,x,Tens,M[+]}$	1148590.066	[Nmm]
$M_{n,x,Comp,M[+]}$	**0.996**	**[kNm]**	**$M_{n,x,Tens,M[+]}$**	**1.149**	**[kNm]**

	$I_{y,eff,M[-]}$	173726.891	[mm^4]		
$S_{eff,Comp}$	3084.704	[mm^3]	$S_{eff,Tens}$	3157.762	[mm^3]

$S_{el,Comp}$ | **Section is not fully effective** | $S_{eff,Comp}$

F_y	350.000	[MPa]
F_{ya}	----	[MPa]

↓

$M_{n,y,Comp,M[-]}$	1079646.574	[Nmm]	$M_{n,y,Tens,M[-]}$	1105216.801	[Nmm]
$M_{n,y,Comp,M[-]}$	**1.080**	**[kNm]**	**$M_{n,y,Tens,M[-]}$**	**1.105**	**[kNm]**

[2] Ω-Section Purlin : Lateral-Torsional Buckling Strength [Resistance] [AISI S100, C3.1.2.1]

Provisions of this section are not applied to multiple-web deck, U, closed box-type members, curved or arch members

[3] Ω-Section Purlin : Distortional Buckling Strength [Resistance] [AISI S100, C3.1.4]

Provisions of this section are not applied to multiple-web deck, U, closed box-type members, curved or arch members

[4] Ω-Section Purlin : Bending Moment Verification [AISI S100, LRFD]

$M \le \Phi_b * M_n$ [AISI S100, Eq. A4.1.1-1] | M_n = MIN [$M_{n,C3.1.1}$; $M_{n,C3.1.2.1}$; $M_{n,C3.1.4}$]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	38.060	[%]
$M_{n,x,Comp,M[+]}$	0.996	[kNm]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	31.021	[%]
$M_{n,x,Comp,M[-]}$	1.222	[kNm]			

Positive Moment in y-y axis [$M_{y,Ed}^+$]

$M_{y,Ed,M[+]}$	0.090	[kNm]	Ratio	8.798	[%]
$M_{n,y,Comp,M[+]}$	1.077	[kNm]			

Negative Moment in y-y axis [$M_{y,Ed}^-$]

$M_{y,Ed,M[-]}$	0.090	[kNm]	Ratio	8.775	[%]
$M_{n,y,Comp,M[-]}$	1.080	[kNm]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

	$I_{x,el,M[-]}$	85759.975	[mm^4]		
$S_{el,Comp}$	3343.203	[mm^3]	$S_{el,Tens}$	3053.134	[mm^3]
	$I_{x,eff,M[-]}$	85759.975	[mm^4]		
$S_{eff,Comp}$	3343.203	[mm^3]	$S_{eff,Tens}$	3053.134	[mm^3]

$S_{el,Comp}$ | **Section is fully effective** | $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	365.389	[MPa]

↓

$M_{n,x,Comp,M[-]}$	1221568.857	[Nmm]	$M_{n,x,Tens,M[-]}$	1115580.737	[Nmm]
$M_{n,x,Comp,M[-]}$	**1.222**	**[kNm]**	**$M_{n,x,Tens,M[-]}$**	**1.116**	**[kNm]**

Positive Moment in y-y axis [$M_{y,Ed}^+$]

	$I_{y,el,M[+]}$	176909.935	[mm^4]		
$S_{el,Comp}$	3177.986	[mm^3]	$S_{el,Tens}$	3177.986	[mm^3]
	$I_{y,eff,M[+]}$	173380.870	[mm^4]		
$S_{eff,Comp}$	3076.745	[mm^3]	$S_{eff,Tens}$	3153.378	[mm^3]

$S_{el,Comp}$ | **Section is not fully effective** | $S_{eff,Comp}$

F_y	350.000	[MPa]
F_{ya}	----	[MPa]

↓

$M_{n,y,Comp,M[+]}$	1076860.61	[Nmm]	$M_{n,y,Tens,M[+]}$	1103682.315	[Nmm]
$M_{n,y,Comp,M[+]}$	**1.077**	**[kNm]**	**$M_{n,y,Tens,M[+]}$**	**1.104**	**[kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^-$]

	$I_{y,el,M[-]}$	176909.935	[mm^4]		
$S_{el,Comp}$	3177.986	[mm^3]	$S_{el,Tens}$	3177.986	[mm^3]

[iii] Ω-Section Purlin : Bending Moment [AS/NZS 4600, LSD]

[1] Ω-Section Purlin : Nominal Section Moment Capacity [AS/NZS 4600, 3.3.2.2]

Procedure	Description
I	Based on Initiation of Yielding
II	Based on Inelastic Reserve Capacity

Procedure II : Based on Inelastic Reserve Capacity

The inelastic flexural reserve capacity shall be permitted to be used when:

[1] Member is not subject to twisting, lateral, torsional, or flexural-torsional buckling

[2] Effect of cold work of forming is not included in determining the yield stress f_y

[3] Ratio of the depth of the compressed portion of the web to its thickness not exceed λ_1

[4] Shear force does not exceed **0.35*fy** times web area

[5] The angle between any web and the vertical does not exceed 30

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_t]
Sections with stiffened or partially stiffened compression flanges	3.3.2	0.900

Procedure | I | $M_s = Z_ef_y$ [AS/NZS 4600, Eq. 3.3.2.2]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

	$I_{x,el,M[+]}$	85759.975	[mm^4]		
$Z_{el,Comp}$	3053.134	[mm^3]	$Z_{el,Tens}$	3343.203	[mm^3]
	$I_{x,eff,M[+]}$	81891.327	[mm^4]		
$Z_{eff,Comp}$	2844.717	[mm^3]	$Z_{eff,Tens}$	3281.686	[mm^3]

$Z_{el,Comp}$ | **Section is not fully effective** | $Z_{eff,Comp}$

f_y	350.000	[MPa]
f_{ya}	----	[MPa]

↓

$M_{s,x,Comp,M[+]}$	995651.0514	[Nmm]	$M_{s,x,Tens,M[+]}$	1148590.066	[Nmm]
$M_{s,x,Comp,M[+]}$	**0.996**	**[kNm]**	**$M_{s,x,Tens,M[+]}$**	**1.149**	**[kNm]**

Negative Moment in x-x axis [$M_{x,Ed}^-$]

	$I_{x,el,M[-]}$	85759.975	[mm⁴]		
$Z_{el,Comp}$	3343.203	[mm³]	$Z_{el,Tens}$	3053.134	[mm³]
	$I_{x,eff,M[-]}$	85759.975	[mm⁴]		
$Z_{eff,Comp}$	3343.203	[mm³]	$Z_{eff,Tens}$	3053.134	[mm³]

$Z_{el,Comp}$ — **Section is fully effective** — $Z_{eff,Comp}$

f_y	----	[MPa]
f_{ya}	365.389	[MPa]

↓

$M_{s,x,Comp,M[-]}$	1221568.857	[Nmm]	$M_{s,x,Tens,M[-]}$	1115580.737	[Nmm]
$M_{s,x,Comp,M[-]}$	**1.222**	**[kNm]**	**$M_{s,x,Tens,M[-]}$**	**1.116**	**[kNm]**

Positive Moment in y-y axis [$M_{y,Ed}^+$]

	$I_{y,el,M[+]}$	176909.935	[mm⁴]		
$Z_{el,Comp}$	3177.986	[mm³]	$Z_{el,Tens}$	3177.986	[mm³]
	$I_{y,eff,M[+]}$	173380.870	[mm⁴]		
$Z_{eff,Comp}$	3076.745	[mm³]	$Z_{eff,Tens}$	3153.378	[mm³]

$Z_{el,Comp}$ — **Section is not fully effective** — $Z_{eff,Comp}$

f_y	350.000	[MPa]
f_{ya}	----	[MPa]

↓

$M_{s,y,Comp,M[+]}$	1076860.61	[Nmm]	$M_{s,y,Tens,M[+]}$	1103682.315	[Nmm]
$M_{s,y,Comp,M[+]}$	**1.077**	**[kNm]**	**$M_{s,y,Tens,M[+]}$**	**1.104**	**[kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^-$]

	$I_{y,el,M[-]}$	176909.935	[mm⁴]		
$Z_{el,Comp}$	3177.986	[mm³]	$Z_{el,Tens}$	3177.986	[mm³]

[b] C-Section Beam

[i] C-Section Beam : Bending Moment [AISI S100, ASD]

[1] C-Section Beam : Nominal Section Strength [Resistance] [AISI S100, C3.1.1]

Procedure	Description
I	Based on Initiation of Yielding
II	Based on Inelastic Reserve Capacity

Procedure II : Based on Inelastic Reserve Capacity

The inelastic flexural reserve capacity shall be permitted to be used when:

[1] Member is not subject to twisting, lateral, torsional, or flexural-torsional buckling

[2] Effect of cold work of forming is not included in determining the yield stress F_y

[3] Ratio of the depth of the compressed portion of the web to its thickness not exceed λ_1

[4] Shear force does not exceed:

0.35*F_y [ASD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]

0.60*F_y [LRFD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]

[5] The angle between any web and the vertical does not exceed 30

Sections with stiffened or partially stiffened compression flanges: Ω_b 1.670

Procedure: I — $M_n = S_e F_y$ [AISI S100, Eq. C3.1.1-1]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

	$I_{x,el,M[+]}$	762290.565	[mm⁴]		
$S_{el,Comp}$	12860.454	[mm³]	$S_{el,Tens}$	12860.454	[mm³]
	$I_{x,eff,M[+]}$	762290.565	[mm⁴]		
$S_{eff,Comp}$	12860.454	[mm³]	$S_{eff,Tens}$	12860.454	[mm³]

$S_{el,Comp}$ — **Section is fully effective** — $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	374.390	[MPa]

↓

$M_{n,x,Comp,M[+]}$	4814825.421	[Nmm]	$M_{n,x,Tens,M[+]}$	4814825.421	[Nmm]
$M_{n,x,Comp,M[+]}$	**4.815**	**[kNm]**	**$M_{n,x,Tens,M[+]}$**	**4.815**	**[kNm]**

	$I_{y,eff,M[-]}$	173726.891	[mm⁴]		
$Z_{eff,Comp}$	3084.704	[mm³]	$Z_{eff,Tens}$	3157.762	[mm³]

$Z_{el,Comp}$ — **Section is not fully effective** — $Z_{eff,Comp}$

f_y	350.000	[MPa]
f_{ya}	----	[MPa]

↓

$M_{s,y,Comp,M[-]}$	1079646.574	[Nmm]	$M_{s,y,Tens,M[-]}$	1105216.801	[Nmm]
$M_{s,y,Comp,M[-]}$	**1.080**	**[kNm]**	**$M_{s,y,Tens,M[-]}$**	**1.105**	**[kNm]**

[2] Ω-Section Purlin : Members subject to Lateral Buckling [AS/NZS 4600, 3.3.3.2.1]

Provisions of this clause are not applied to multiple-web deck, U-box and curved or arch members M_b = 0 kNm

[3] Ω-Section Purlin : Members subject to Distortional Buckling [AS/NZS 4600, 3.3.3.3]

Provisions of this clause are not applied to multiple-web deck, U-box and curved or arch members M_b = 0 kNm

[4] Ω-Section Purlin : Bending Moment Verification [AS/NZS 4600, LSD]

$M^* \leq \Phi_b * M_s$ [AS/NZS 4600, Eq. 3.3.1(1)] | $M^* \leq \Phi_b * M_b$ [AS/NZS 4600, Eq. 3.3.1(2)]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	40.175	[%]
$M_{s,x,Comp,M[+]}$	0.996	[kNm]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	32.745	[%]
$M_{s,x,Comp,M[-]}$	1.222	[kNm]			

Positive Moment in y-y axis [$M_{y,Ed}^+$]

$M_{y,Ed,M[+]}$	0.090	[kNm]	Ratio	9.286	[%]
$M_{s,y,Comp,M[+]}$	1.077	[kNm]			

Negative Moment in y-y axis [$M_{y,Ed}^-$]

$M_{y,Ed,M[-]}$	0.090	[kNm]	Ratio	9.262	[%]
$M_{s,y,Comp,M[-]}$	1.080	[kNm]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

	$I_{x,el,M[-]}$	762290.565	[mm⁴]		
$S_{el,Comp}$	12860.454	[mm³]	$S_{el,Tens}$	12860.454	[mm³]
	$I_{x,eff,M[-]}$	762290.565	[mm⁴]		
$S_{eff,Comp}$	12860.454	[mm³]	$S_{eff,Tens}$	12860.454	[mm³]

$S_{el,Comp}$ — **Section is fully effective** — $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	374.390	[MPa]

↓

$M_{n,x,Comp,M[-]}$	4814825.421	[Nmm]	$M_{n,x,Tens,M[-]}$	4814825.421	[Nmm]
$M_{n,x,Comp,M[-]}$	**4.815**	**[kNm]**	**$M_{n,x,Tens,M[-]}$**	**4.815**	**[kNm]**

Positive Moment in y-y axis [$M_{y,Ed}^+$]

	$I_{y,el,M[+]}$	108754.009	[mm⁴]		
$S_{el,Comp}$	7468.064	[mm³]	$S_{el,Tens}$	3567.406	[mm³]
	$I_{y,eff,M[+]}$	96937.280	[mm⁴]		
$S_{eff,Comp}$	5731.142	[mm³]	$S_{eff,Tens}$	3445.572	[mm³]

$S_{el,Comp}$ — **Section is not fully effective** — $S_{eff,Comp}$

F_y	350.000	[MPa]
F_{ya}	----	[MPa]

↓

$M_{n,y,Comp,M[+]}$	2005899.557	[Nmm]	$M_{n,y,Tens,M[+]}$	1205950.304	[Nmm]
$M_{n,y,Comp,M[+]}$	**2.006**	**[kNm]**	**$M_{n,y,Tens,M[+]}$**	**1.206**	**[kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^-$]

	$I_{y,el,M[-]}$	108754.009	[mm⁴]		
$S_{el,Comp}$	3567.406	[mm³]	$S_{el,Tens}$	7468.064	[mm³]

	$I_{y,eff,M\,[-]}$	108754.009	[mm^4]		
$S_{eff,Comp}$	3567.406	[mm^3]	$S_{eff,Tens}$	7468.064	[mm^3]

$S_{el,Comp}$ — **Section is fully effective** — $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	374.390	[MPa]

↓

$M_{n,y,Comp,M\,[-]}$	1335601.22	[Nmm]	$M_{n,y,Tens,M\,[-]}$	2795968.54	[Nmm]

↓

$M_{n,y,Comp,M\,[-]}$	**1.336**	**[kNm]**	**$M_{n,y,Tens,M\,[-]}$**	**2.796**	**[kNm]**

[2] C-Section Beam : Lateral-Torsional Buckling Strength [Resistance] [AISI S100, C3.1.2.1]

Ω_b 1.670 — $M_n = S_C F_C$ [AISI S100, Eq. C3.1.2.1-1]

Singly-symmetric sections bending about the symmetry axis [x-x]

C_b

C_b shall be permitted to be conservatively taken as unity for all cases.

For cantilevers or overhangs where the free end is unbraced, C_b shall be taken as unity

C_b	1.000	r_x	47.001	[mm^2]
		r_y	17.753	[mm^2]
		x_0	-37.355	[mm]
		r_0	62.608	[mm^2]

$$r_0 = \sqrt{r_x^2 + r_y^2 + x_0^2}$$

[AISI S100, Eq. C3.1.2.1-7]

S_f	12860.454	[mm^3]	E	210.000	[GPa]

$$\sigma_{ey} = \frac{\pi^2 E}{(K_y L_y / r_y)^2}$$

$\sigma_{ey,Console\,Beam}$ 3534.028 [N/mm^2]
$\sigma_{ey,Middle\,Beam}$ 3520.291 [N/mm^2]

[AISI S100, Eq. C3.1.2.1-8]

$$\sigma_t = \frac{1}{A r_o^2}\left[GJ + \frac{\pi^2 E C_w}{(K_t L_t)^2}\right]$$

$\sigma_{t,Console\,Beam}$ 535.673 [N/mm^2]
$\sigma_{t,Middle\,Beam}$ 569.982 [N/mm^2]

[AISI S100, Eq. C3.1.2.1-9]

$$F_e = \frac{C_b r_o A}{S_f}\sqrt{\sigma_{ey}\sigma_t}$$

$F_{e,Console\,Beam}$ 2311.291 [MPa]
$F_{e,Middle\,Beam}$ 2379.520 [MPa]

[AISI S100, Eq. C3.1.2.1-4]

F_y	----	[MPa]	F_{ya}	374.390	[MPa]

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$$C_{TF} = 0.6 - 0.4\,(M_1/M_2)$$

C_{TF} 1.000

[AISI S100, Eq. C3.1.2.1-11]

$$F_e = \frac{C_s A \sigma_{ex}}{C_{TF} S_f}\left[j + C_s\sqrt{j^2 + r_o^2(\sigma_t/\sigma_{ex})}\right]$$

[AISI S100, Eq. C3.1.2.1-10]

$M_{y,Ed}^+$	→	C_s	1.000
$M_{y,Ed}^-$	→	C_s	-1.000

A_g	345.063	[mm^2]	r_0	62.608	[mm^2]
$S_{f,y}^+$	7468.064	[mm^3]	$S_{f,y}^-$	3567.406	[mm^3]
$\sigma_{t,Console\,Beam}$	535.673	[N/mm^2]	$\sigma_{t,Middle\,Beam}$	569.982	[N/mm^2]

Console Beam

$F_{e,Console\,B,M\,[+]}$	27458.386	[MPa]	$F_{e,Console\,B,M\,[-]}$	1504.031	[MPa]

Middle Beam

$F_{e,Middle\,B,M\,[+]}$	29264.626	[MPa]	$F_{e,Middle\,B,M\,[-]}$	1600.427	[MPa]

$M_{n,Comp}^+$

F_y	350.000	[MPa]	F_{ya}	----	[MPa]

$M_{n,Comp}^-$

F_y	----	[MPa]	F_{ya}	374.390	[MPa]

$F_e \geq 2.780 * F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_y

Available flexural strength [moment resistance] shall be determined with Section C3.1.1(a)

$2.780 * F_y > F_e > 0.560 * F_y$

$$F_c = \frac{10}{9}F_y\left(1 - \frac{10F_y}{36F_e}\right)$$

[AISI S100, Eq. C3.1.2.1-2]

$0.560 * F_y \geq F_e$

$F_c = F_e$

[AISI S100, Eq. C3.1.2.1-3]

$S_{c,y}^+$	7468.064	[mm^3]	$S_{c,y}^-$	3567.406	[mm^3]

Console Beam [$F_{c,M\,[+]}$]

$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

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Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

$F_e \geq 2.780 * F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_y

Available flexural strength [moment resistance] shall be determined with Section C3.1.1(a)

$2.780 * F_y > F_e > 0.560 * F_y$

$$F_c = \frac{10}{9}F_y\left(1 - \frac{10F_y}{36F_e}\right)$$

[AISI S100, Eq. C3.1.2.1-2]

$0.560 * F_y \geq F_e$

$F_c = F_e$

[AISI S100, Eq. C3.1.2.1-3]

S_c 12860.454 [mm^3]

Console Beam [F_c]

$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Middle Beam [F_c]

$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Console Beam [$M_{n,Comp}^{+/-}$]

$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
4.815	[kNm]	----	[kNm]	----	[kNm]

Middle Beam [$M_{n,Comp}^{+/-}$]

$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
4.815	[kNm]	----	[kNm]	----	[kNm]

$M_{n,Comp,\,Console\,B}$	4.815	[kNm]	$M_{n,Comp,Middle\,B}$	4.815	[kNm]

Singly-symmetric sections bending about the axis perpendicular to the axis of simmetry [y-y]

C_S

C_S = [+] 1.000 → Moment causing compression on shear center side of centroid

C_S = [-] 1.000 → Moment causing tension on shear center side of centroid

$$\sigma_{ex} = \frac{\pi^2 E}{(K_x L_x / r_x)^2}$$

$\sigma_{ex,Console\,Beam}$ 4400.888 [N/mm^2]
$\sigma_{ex,Middle\,Beam}$ 4690.583 [N/mm^2]

[AISI S100, Eq. C3.1.2.1-11]

$$j = \frac{1}{2I_y}\left[\int_A x^3 dA + \int_A xy^2 dA\right] - x_o$$

j 65.750 [mm]

[AISI S100, Eq. C3.1.2.1-11]

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Console Beam [$F_{c,M\,[-]}$]

$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Middle Beam [$F_{c,M\,[+]}$]

$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Middle Beam [$F_{c,M\,[+]}$]

$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Console Beam [$M_{n,Comp}^+$]

$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
2.006	[kNm]	----	[kNm]	----	[kNm]

Console Beam [$M_{n,Comp}^-$]

$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
1.336	[kNm]	----	[kNm]	----	[kNm]

Middle Beam [$M_{n,Comp}^+$]

$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
2.006	[kNm]	----	[kNm]	----	[kNm]

Middle Beam [$M_{n,Comp}^-$]

$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
1.336	[kNm]	----	[kNm]	----	[kNm]

Console Beam [$M_{n,Comp}$]

$M_{n,Comp}^+$	2.006	[kNm]	$M_{n,Comp}^-$	1.336	[kNm]

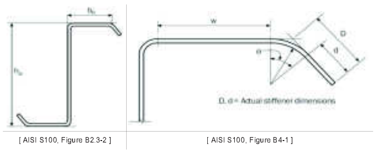
Middle Beam [$M_{n,Comp}$]

$M_{n,Comp}^+$	2.006	[kNm]	$M_{n,Comp}^-$	1.336	[kNm]

[3] C-Section Beam : Distortional Buckling Strength [Resistance] [AISI S100, C3.1.4]

Ω_b 1.670

For C- and Z-Sections or any Open Section with a Stiffened Compression Flange Extending to One Side of the Web where the Stiffener is either a Simple Lip or a Complex Edge Stiffener



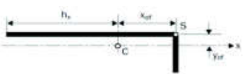
[AISI S100, Figure B2.3-2] [AISI S100, Figure B4-1]

Dimensional Limits		
[1]	$50 \le h_o / t$	OK
	$h_o / t \le 200$	OK
[2]	$25 \le b_o / t$	OK
	$b_o / t \le 100$	OK
[3]	$6.25 < D / t$	OK
	$D / t \le 50$	OK
[4]	$45° \le \theta$	OK
	$\theta \le 90°$	OK
[5]	$2 \le h_o / b_o$	OK
	$h_o / b_o \le 8$	OK
[6]	$0.04 \le D \cdot \sin[\theta] / b_o$	OK
	$D \cdot \sin[\theta] / b_o \le 0.50$	OK

$$L_{cr} = \left(\frac{4\pi^4 h_o (1-\mu^2)}{t^3} \left(I_{xf}(x_o - h_x)^2 + C_{wf} - \frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2 \right) + \frac{\pi^4 h_o^4}{720} \right)^{1/4}$$

[AISI S100, Eq. C3.1.4-12]

NOTE Flanges with 90 Degree Lips



A_f	76.439	[mm^2]
I_{xf}	1083.105	[mm^4]
I_{yf}	12526.125	[mm^4]
I_{xyf}	2027.082	[mm^5]
h_x	-24.448	[mm]
x_{0f}	14.148	[mm]
J_f	53.719	[mm^4]
y_{0f}	-1.874	[mm]
C_{wf}	0.000	[mm^6]
h_0	120.000	[mm]
v [μ]	0.300	[ ]
β	1.000	
$L = L_{cr}$	353.759	[mm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

$\lambda_d \le 0.673$	$\lambda_d > 0.673$
$M_n = M_y$	$M_n = \left(1 - 0.22\left(\frac{M_{crd}}{M_y}\right)^{0.5}\right)\left(\frac{M_{crd}}{M_y}\right)^{0.5} M_y$
[AISI S100, Eq. C3.1.4-1]	[AISI S100, Eq. C3.1.4-2]

M_n 4224619.134 [Nmm] **M_n** **4.225** **[kNm]**

[4] C-Section Beam : Bending Moment Verification [AISI S100, ASD]

$M \le M_n / \Omega_b$ [AISI S100, Eq. A4.1.1-1] $M_n = MIN[M_{n,C3.1.1} ; M_{n,C3.1.2.1} ; M_{n,C3.1.4}]$

Positive Moment in x-x axis [$M_{x,Ed}^+$]

C-Section Console Beam

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	33.205	[%]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]			

C-Section Middle Beam

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	33.205	[%]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

C-Section Console Beam

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	33.205	[%]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]			

C-Section Middle Beam

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	33.205	[%]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]			

Positive Moment in y-y axis [$M_{y,Ed}^+$]

C-Section Console Beam

$M_{y,Ed,M[+]}$	0.020	[kNm]	Ratio	1.665	[%]
$M_{n,y,Comp,M[+]}$	2.006	[kNm]			

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

E 210.000 [GPa] **G** 80.769 [GPa]

$$k_{\phi fe} = \left(\frac{\pi}{L}\right)^4 \left(EI_{xf}(x_o - h_x)^2 + EC_{wf} - E\frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2 \right) + \left(\frac{\pi}{L}\right)^2 GJ_f$$

[AISI S100, Eq. C3.1.4-13]

$$k_{\phi we} = \frac{Et^3}{12(1-\mu^2)}\left(\frac{3}{h_o} + \left(\frac{\pi}{L}\right)^2 \frac{19 h_o}{60} + \left(\frac{\pi}{L}\right)^4 \frac{h_o^3}{240} \right)$$

[AISI S100, Eq. C3.1.4-14]

$k_{\phi fe}$ 1811.305 [N] $k_{\phi we}$ 1650.822 [N]

$$\tilde{k}_{\phi fg} = \left(\frac{\pi}{L}\right)^2 \left[A_f \left((x_o - h_x)^2 \left(\frac{I_{xyf}}{I_{yf}}\right)^2 - 2y_o(x_o - h_x)\left(\frac{I_{xyf}}{I_{yf}}\right) + h_x^2 + y_o^2 \right) + I_{xf} + I_{yf} \right]$$

[AISI S100, Eq. C3.1.4-15]

$$\tilde{k}_{\phi wg} = \frac{h_o t \pi^2}{13440} \left(\frac{[45360(1-\xi_{web}) + 62160]\left(\frac{L}{h_o}\right)^2 + 448\pi^2 + \left(\frac{h_o}{L}\right)^2 [53 + 3(1-\xi_{web})]\pi^4}{\pi^4 + 28\pi^2\left(\frac{L}{h_o}\right)^2 + 420\left(\frac{L}{h_o}\right)^4} \right)$$

[AISI S100, Eq. C3.1.4-16]

k_ϕ	0.000	[N]	ξ_{web}	2.000	[ ]
$\tilde{k}_{\phi fg}$	5.074	[mm^2]	$\tilde{k}_{\phi wg}$	0.565	[mm^2]

$$F_d = \beta \frac{k_{\phi fe} + k_{\phi we} + k_\phi}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}}$$

F_d 614.024 [MPa]

[AISI S100, Eq. C3.1.4-16]

$M_y = S_{fy} \cdot F_y$ [AISI S100, Eq. C3.1.4-4]

$M_{cr} = S_f \cdot F_d$ [AISI S100, Eq. C3.1.4-5]

S_f	12860.454	[mm^3]	→	M_{cr}	7896629.491	[Nmm]
S_{fy}	12860.454	[mm^3]	→	M_y	4501158.984	[Nmm]

$$\lambda_d = \sqrt{M_y / M_{crd}}$$

λd 0.755

[AISI S100, Eq. C3.1.4-3]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

C-Section Middle Beam

$M_{y,Ed,M[+]}$	0.010	[kNm]	Ratio	1.250	[%]
$M_{n,y,Comp,M[+]}$	1.336	[kNm]			

Negative Moment in y-y axis [$M_{y,Ed}^-$]

C-Section Console Beam

$M_{y,Ed,M[-]}$	0.020	[kNm]	Ratio	2.501	[%]
$M_{n,y,Comp,M[-]}$	1.336	[kNm]			

C-Section Middle Beam

$M_{y,Ed,M[-]}$	0.010	[kNm]	Ratio	1.250	[%]
$M_{n,y,Comp,M[-]}$	1.336	[kNm]			

[ii] C-Section Beam : Bending Moment [AISI S100, LRFD]

[1] C-Section Beam : Nominal Section Strength [Resistance] [AISI S100, C3.1.1]

Procedure	Description
I	Based on Initiation of Yielding
II	Based on Inelastic Reserve Capacity

Procedure II : Based on Inelastic Reserve Capacity

The inelastic flexural reserve capacity shall be permitted to be used when:

[1] Member is not subject to twisting, lateral, torsional, or flexural-torsional buckling

[2] Effect of cold work of forming is not included in determining the yield stress F_y

[3] Ratio of the depth of the compressed portion of the web to its thickness not exceed λ_1

[4] Shear force does not exceed:

$0.35 \cdot F_y$ [ASD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]

$0.60 \cdot F_y$ [LRFD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]

[5] The angle between any web and the vertical does not exceed 30

Sections with stiffened or partially stiffened compression flanges Φ_b 0.950

Procedure I $M_n = S_e F_y$ [AISI S100, Eq. C3.1.1-1]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

$I_{x,el,M[+]}$ 762290.565 [mm^4]

$S_{el,Comp}$	12860.454	[mm^3]	$S_{el,Tens}$	12860.454	[mm^3]

	$I_{x,eff,M[+]}$	762290.565	[mm^4]		
$S_{eff,Comp}$	12860.454	[mm^3]	$S_{eff,Tens}$	12860.454	[mm^3]

$S_{el,Comp}$ | **Section is fully effective** | $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	374.390	[MPa]

↓

$M_{n,x,Comp,M[+]}$	4814825.421	[Nmm]	$M_{n,x,Tens,M[+]}$	4814825.421	[Nmm]
$M_{n,x,Comp,M[+]}$	**4.815**	**[kNm]**	**$M_{n,x,Tens,M[+]}$**	**4.815**	**[kNm]**

Negative Moment in x-x axis [$M_{x,Ed}^-$]

	$I_{x,el,M[-]}$	762290.565	[mm^4]		
$S_{el,Comp}$	12860.454	[mm^3]	$S_{el,Tens}$	12860.454	[mm^3]
	$I_{x,eff,M[-]}$	762290.565	[mm^4]		
$S_{eff,Comp}$	12860.454	[mm^3]	$S_{eff,Tens}$	12860.454	[mm^3]

$S_{el,Comp}$ | **Section is fully effective** | $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	374.390	[MPa]

↓

$M_{n,x,Comp,M[-]}$	4814825.421	[Nmm]	$M_{n,x,Tens,M[-]}$	4814825.421	[Nmm]
$M_{n,x,Comp,M[-]}$	**4.815**	**[kNm]**	**$M_{n,x,Tens,M[-]}$**	**4.815**	**[kNm]**

Positive Moment in y-y axis [$M_{y,Ed}^+$]

	$I_{y,el,M[+]}$	108754.009	[mm^4]		
$S_{el,Comp}$	7468.064	[mm^3]	$S_{el,Tens}$	3567.406	[mm^3]
	$I_{y,eff,M[+]}$	96937.280	[mm^4]		
$S_{eff,Comp}$	5731.142	[mm^3]	$S_{eff,Tens}$	3445.572	[mm^3]

S_f	12860.454	[mm^3]	E	210.000	[GPa]

$$\sigma_{ey} = \frac{\pi^2 E}{(K_y L_y / r_y)^2}$$

$\sigma_{ey,Console\ Beam}$	3534.028	[N/mm^2]
$\sigma_{ey,Middle\ Beam}$	3520.291	[N/mm^2]

[AISI S100, Eq. C3.1.2.1-8]

$$\sigma_t = \frac{1}{A r_o^2}\left[GJ + \frac{\pi^2 E C_w}{(K_t L_t)^2}\right]$$

$\sigma_{t,Console\ Beam}$	535.673	[N/mm^2]
$\sigma_{t,Middle\ Beam}$	569.982	[N/mm^2]

[AISI S100, Eq. C3.1.2.1-9]

$$F_e = \frac{C_b r_o A}{S_f}\sqrt{\sigma_{ey}\sigma_t}$$

$F_{e,Console\ Beam}$	2311.291	[MPa]
$F_{e,Middle\ Beam}$	2379.520	[MPa]

[AISI S100, Eq. C3.1.2.1-4]

F_y	----	[MPa]	F_{ya}	374.390	[MPa]

$F_e \geq 2.780 * F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_y

Available flexural strength [moment resistance] shall be determined with Section C3.1.1(a)

$2.780 * F_y > F_e > 0.560 * F_y$

$$F_c = \frac{10}{9}F_y\left(1 - \frac{10F_y}{36F_e}\right)$$

[AISI S100, Eq. C3.1.2.1-2]

$0.560 * F_y \geq F_e$

$F_c = F_e$

[AISI S100, Eq. C3.1.2.1-3]

S_c 12860.454 [mm^3]

Console Beam [F_c]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Middle Beam [F_c]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Console Beam [$M_{n,Comp}^{+/-}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
4.815	[kNm]	----	[kNm]	----	[kNm]

Middle Beam [$M_{n,Comp}^{+/-}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
4.815	[kNm]	----	[kNm]	----	[kNm]

$S_{el,Comp}$ | **Section is not fully effective** | $S_{eff,Comp}$

F_y	350.000	[MPa]
F_{ya}	----	[MPa]

↓

$M_{n,y,Comp,M[+]}$	2005899.557	[Nmm]	$M_{n,y,Tens,M[+]}$	1205950.304	[Nmm]
$M_{n,y,Comp,M[+]}$	**2.006**	**[kNm]**	**$M_{n,y,Tens,M[+]}$**	**1.206**	**[kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^-$]

	$I_{y,el,M[-]}$	108754.009	[mm^4]		
$S_{el,Comp}$	3567.406	[mm^3]	$S_{el,Tens}$	7468.064	[mm^3]
	$I_{y,eff,M[-]}$	108754.009	[mm^4]		
$S_{eff,Comp}$	3567.406	[mm^3]	$S_{eff,Tens}$	7468.064	[mm^3]

$S_{el,Comp}$ | **Section is fully effective** | $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	374.390	[MPa]

↓

$M_{n,y,Comp,M[-]}$	1335601.22	[Nmm]	$M_{n,y,Tens,M[-]}$	2795968.54	[Nmm]
$M_{n,y,Comp,M[-]}$	**1.336**	**[kNm]**	**$M_{n,y,Tens,M[-]}$**	**2.796**	**[kNm]**

[2] C-Section Beam : Lateral-Torsional Buckling Strength [Resistance] [AISI S100, C3.1.2.1]

Φ_b	0.900	$M_n = S_C F_C$	[AISI S100, Eq. C3.1.2.1-1]

Singly-symmetric sections bending about the symmetry axis [x-x]

C_b

C_b shall be permitted to be conservatively taken as unity for all cases.

For cantilevers or overhangs where the free end is unbraced, C_b shall be taken as unity

C_b 1.000

$$r_o = \sqrt{r_x^2 + r_y^2 + x_o^2}$$

[AISI S100, Eq. C3.1.2.1-7]

r_x	47.001	[mm^2]
r_y	17.753	[mm^2]
x_0	-37.355	[mm]
r_0	62.608	[mm^2]

$M_{n,Comp,\ Console\ B}$	4.815	[kNm]	$M_{n,Comp,Middle\ B}$	4.815	[kNm]

Singly-symmetric sections bending about the axis perpendicular to the axis of simmetry [y-y]

C_S

C_S = [+] 1.000 → Moment causing compression on shear center side of centroid

C_S = [-] 1.000 → Moment causing tension on shear center side of centroid

$$\sigma_{ex} = \frac{\pi^2 E}{(K_x L_x / r_x)^2}$$

$\sigma_{ex,Console\ Beam}$	4400.888	[N/mm^2]
$\sigma_{ex,Middle\ Beam}$	4690.583	[N/mm^2]

[AISI S100, Eq. C3.1.2.1-11]

$$j = \frac{1}{2I_y}\left[\int_A x^3 dA + \int_A xy^2 dA\right] - x_o$$

j 65.750 [mm]

[AISI S100, Eq. C3.1.2.1-11]

$$C_{TF} = 0.6 - 0.4\,(M_1/M_2)$$

C_{TF} 1.000

[AISI S100, Eq. C3.1.2.1-11]

$$F_e = \frac{C_s A \sigma_{ex}}{C_{TF} S_f}\left[j + C_s\sqrt{j^2 + r_o^2(\sigma_t/\sigma_{ex})}\right]$$

[AISI S100, Eq. C3.1.2.1-10]

$M_{y,Ed}^+$	→	C_s	1.000
$M_{y,Ed}^-$	→	C_s	-1.000

A_g	345.063	[mm^2]	r_0	62.608	[mm^2]
$S_{f,y}^+$	7468.064	[mm^3]	$S_{f,y}^-$	3567.406	[mm^3]
$\sigma_{t,Console\ Beam}$	535.673	[N/mm^2]	$\sigma_{t,Middle\ Beam}$	569.982	[N/mm^2]

Console Beam					
$F_{e,Console\ B,M[+]}$	27458.386	[MPa]	$F_{e,Console\ B,M[-]}$	1504.031	[MPa]

Middle Beam					
$F_{e,Middle\ B,M[+]}$	29264.626	[MPa]	$F_{e,Middle\ B,M[-]}$	1600.427	[MPa]

$M_{n,Comp}^+$

F_y	350.000	[MPa]	F_{ya}	----	[MPa]

$M_{n,Comp}^-$

F_y	----	[MPa]	F_{ya}	374.390	[MPa]

$F_e \geq 2.780 * F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_y

Available flexural strength [moment resistance] shall be determined with Section C3.1.1(a)

$2.780 * F_y > F_e > 0.560 * F_y$	**$0.560 * F_y \geq F_e$**
$$F_c = \frac{10}{9}F_y\left(1-\frac{10F_y}{36F_e}\right)$$	$F_c = F_e$
[AISI S100, Eq. C3.1.2.1-2]	[AISI S100, Eq. C3.1.2.1-3]

$S_{c,y}^+$	7468.064	[mm³]	$S_{c,y}^-$	3567.406	[mm³]

Console Beam [$F_{c,M[+]}$]

$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Console Beam [$F_{c,M[-]}$]

$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Middle Beam [$F_{c,M[+]}$]

$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Middle Beam [$F_{c,M[+]}$]

$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Console Beam [$M_{n,Comp}^+$]

$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
2.006	[kNm]	----	[kNm]	----	[kNm]

Console Beam [$M_{n,Comp}^-$]

$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
1.336	[kNm]	----	[kNm]	----	[kNm]

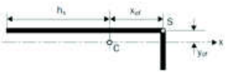
Middle Beam [$M_{n,Comp}^+$]

$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
2.006	[kNm]	----	[kNm]	----	[kNm]

$$L_{cr} = \left(\frac{4\pi^4 h_o(1-\mu^2)}{t^3}\left(I_{xf}(x_o-h_x)^2 + C_{wf} - \frac{I_{xyf}^2}{I_{yf}}(x_o-h_x)^2\right) + \frac{\pi^4 h_o^4}{720}\right)^{1/4}$$

[AISI S100, Eq. C3.1.4-12]

NOTE — Flanges with 90 Degree Lips



			A_f	76.439	[mm²]
			I_{xf}	1083.105	[mm⁴]
			I_{yf}	12526.125	[mm⁴]
			I_{xyf}	2027.082	[mm⁵]
			h_x	-24.448	[mm]
x_{0f}	14.148	[mm]	J_f	53.719	[mm⁴]
y_{0f}	-1.874	[mm]	C_{wf}	0.000	[mm⁶]
h_0	120.000	[mm]	v [μ]	0.300	[ ]
β	1.000		L = L_{cr}	353.759	[mm]
E	210.000	[GPa]	**G**	80.769	[GPa]

$$k_{\phi fe} = \left(\frac{\pi}{L}\right)^4\left(EI_{xf}(x_o-h_x)^2 + EC_{wf} - E\frac{I_{xyf}^2}{I_{yf}}(x_o-h_x)^2\right) + \left(\frac{\pi}{L}\right)^2 GJ_f$$

[AISI S100, Eq. C3.1.4-13]

$$k_{\phi we} = \frac{Et^3}{12(1-\mu^2)}\left(\frac{3}{h_o} + \left(\frac{\pi}{L}\right)^2\frac{19h_o}{60} + \left(\frac{\pi}{L}\right)^4\frac{h_o^3}{240}\right)$$

[AISI S100, Eq. C3.1.4-14]

$k_{\varphi fe}$	1811.305	[N]	$k_{\varphi we}$	1650.822	[N]

$$\tilde{k}_{\phi fg} = \left(\frac{\pi}{L}\right)^2\left[A_f\left((x_o-h_x)^2\left(\frac{I_{xyf}}{I_{yf}}\right)^2 - 2y_o(x_o-h_x)\left(\frac{I_{xyf}}{I_{yf}}\right) + h_x^2 + y_o^2\right) + I_{xf} + I_{yf}\right]$$

[AISI S100, Eq. C3.1.4-15]

$$\tilde{k}_{\phi wg} = \frac{h_o t\pi^2}{13440}\left(\frac{[45360(1-\xi_{web}) + 62160]\left(\frac{L}{h_o}\right)^2 + 448\pi^2 + \left(\frac{h_o}{L}\right)^2[53+3(1-\xi_{web})]\pi^4}{\pi^4 + 28\pi^2\left(\frac{L}{h_o}\right)^2 + 420\left(\frac{L}{h_o}\right)^4}\right)$$

[AISI S100, Eq. C3.1.4-16]

Middle Beam [$M_{n,Comp}^-$]

$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
1.336	[kNm]	----	[kNm]	----	[kNm]

Console Beam [$M_{n,Comp}$]

$M_{n,Comp}^+$	2.006	[kNm]	$M_{n,Comp}^-$	1.336	[kNm]

Middle Beam [$M_{n,Comp}$]

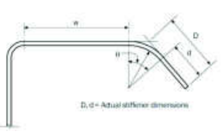
$M_{n,Comp}^+$	2.006	[kNm]	$M_{n,Comp}^-$	1.336	[kNm]

[3] C-Section Beam : Distortional Buckling Strength [Resistance] [AISI S100, C3.1.4]

Φ_b 0.900

For C- and Z-Sections or any Open Section with a Stiffened Compression Flange Extending to One Side of the Web where the Stiffener is either a Simple Lip or a Complex Edge Stiffener

[AISI S100, Figure B2.3-2]



[AISI S100, Figure B4-1]

Dimensional Limits

[1]	$50 \leq h_o / t$	OK
	$h_o / t \leq 200$	OK
[2]	$25 \leq b_o / t$	OK
	$b_o / t \leq 100$	OK
[3]	$6.25 < D / t$	OK
	$D / t \leq 50$	OK
[4]	$45° \leq θ$	OK
	$θ \leq 90°$	OK
[5]	$2 \leq h_o / b_o$	OK
	$h_o / b_o \leq 8$	OK
[6]	$0.04 \leq D * \sin[θ] / b_o$	OK
	$D * \sin[θ] / b_o \leq 0.50$	OK

k_φ	0.000	[N]	ξ_{web}	2.000	[ ]
$\tilde{k}_{\phi fg}$	5.074	[mm²]	$\tilde{k}_{\phi wg}$	0.565	[mm²]

$$F_d = \beta\frac{k_{\phi fe} + k_{\phi we} + k_\phi}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}}$$

F_d 614.024 [MPa]

[AISI S100, Eq. C3.1.4-16]

$M_y = S_{fy} * F_y$ [AISI S100, Eq. C3.1.4-4]

$M_{cr} = S_f * F_d$ [AISI S100, Eq. C3.1.4-5]

S_f	12860.454	[mm³]	→	M_{cr}	7896629.491	[Nmm]
S_{fy}	12860.454	[mm³]	→	M_y	4501158.984	[Nmm]

$$\lambda_d = \sqrt{M_y / M_{crd}}$$

λd 0.755

[AISI S100, Eq. C3.1.4-3]

$\lambda_d \leq 0.673$	**$\lambda_d > 0.673$**
$M_n = M_y$	$$M_n = \left(1-0.22\left(\frac{M_{crd}}{M_y}\right)^{0.5}\right)\left(\frac{M_{crd}}{M_y}\right)^{0.5} M_y$$
[AISI S100, Eq. C3.1.4-1]	[AISI S100, Eq. C3.1.4-2]

M_n	4224619.134	[Nmm]	**M_n**	**4.225**	**[kNm]**

[4] C-Section Beam : Bending Moment Verification [AISI S100, LRFD]

$M \leq \Phi_b * M_n$ [AISI S100, Eq. A5.1.1-1] — $M_n = MIN [M_{n,C3.1.1} ; M_{n,C3.1.2.1} ; M_{n,C3.1.4}]$

Positive Moment in x-x axis [$M_{x,Ed}^+$]

C-Section Console Beam

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	22.093	[%]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]			

C-Section Middle Beam

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	22.093	[%]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

C-Section Console Beam

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	22.093	[%]
$M_{a,x,Comp,M[-]}$	4.225	[kNm]			

C-Section Middle Beam

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	22.093	[%]
$M_{a,x,Comp,M[-]}$	4.225	[kNm]			

Positive Moment in y-y axis [$M_{y,Ed}^+$]

C-Section Console Beam

$M_{y,Ed,M[+]}$	0.020	[kNm]	Ratio	1.108	[%]
$M_{a,y,Comp,M[+]}$	2.006	[kNm]			

C-Section Middle Beam

$M_{y,Ed,M[+]}$	0.010	[kNm]	Ratio	0.832	[%]
$M_{a,y,Comp,M[-]}$	1.336	[kNm]			

Negative Moment in y-y axis [$M_{y,Ed}^-$]

C-Section Console Beam

$M_{y,Ed,M[-]}$	0.020	[kNm]	Ratio	1.664	[%]
$M_{a,y,Comp,M[+]}$	1.336	[kNm]			

C-Section Middle Beam

$M_{y,Ed,M[-]}$	0.010	[kNm]	Ratio	0.832	[%]
$M_{a,y,Comp,M[+]}$	1.336	[kNm]			

[iii] C-Section Beam : Bending Moment [AS/NZS 4600, LSD]

[1] C-Section Beam : Nominal Section Moment Capacity [AS/NZS 4600, 3.3.2.2]

Procedure	Description
I	Based on Initiation of Yielding
II	Based on Inelastic Reserve Capacity

$Z_{el,Comp}$ — Section is fully effective — $Z_{eff,Comp}$

f_y	----	[MPa]
f_{ya}	374.390	[MPa]

↓

$M_{s,x,Comp,M[-]}$	4814825.421	[Nmm]	$M_{s,x,Tens,M[-]}$	4814825.421	[Nmm]
$M_{s,x,Comp,M[-]}$	**4.815**	**[kNm]**	**$M_{s,x,Tens,M[-]}$**	**4.815**	**[kNm]**

Positive Moment in y-y axis [$M_{y,Ed}^+$]

	$I_{y,el,M[+]}$	108754.009	[mm^4]		
$Z_{el,Comp}$	7468.064	[mm^3]	$Z_{el,Tens}$	3567.406	[mm^3]
	$I_{y,eff,M[+]}$	96937.280	[mm^4]		
$Z_{eff,Comp}$	5731.142	[mm^3]	$Z_{eff,Tens}$	3445.572	[mm^3]

$Z_{el,Comp}$ — Section is not fully effective — $Z_{eff,Comp}$

f_y	350.000	[MPa]
f_{ya}	----	[MPa]

↓

$M_{s,y,Comp,M[+]}$	2005899.557	[Nmm]	$M_{s,y,Tens,M[+]}$	1205950.304	[Nmm]
$M_{s,y,Comp,M[+]}$	**2.006**	**[kNm]**	**$M_{s,y,Tens,M[+]}$**	**1.206**	**[kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^-$]

	$I_{y,el,M[-]}$	108754.009	[mm^4]		
$Z_{el,Comp}$	3567.406	[mm^3]	$Z_{el,Tens}$	7468.064	[mm^3]
	$I_{y,eff,M[-]}$	108754.009	[mm^4]		
$Z_{eff,Comp}$	3567.406	[mm^3]	$Z_{eff,Tens}$	7468.064	[mm^3]

$Z_{el,Comp}$ — Section is fully effective — $Z_{eff,Comp}$

f_y	----	[MPa]
f_{ya}	374.390	[MPa]

↓

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Procedure II : Based on Inelastic Reserve Capacity

The inelastic flexural reserve capacity shall be permitted to be used when:

[1] Member is not subject to twisting, lateral, torsional, or flexural-torsional buckling
[2] Effect of cold work of forming is not included in determining the yield stress f_y
[3] Ratio of the depth of the compressed portion of the web to its thickness not exceed λ_1
[4] Shear force does not exceed **0.35*fy** times web area
[5] The angle between any web and the vertical does not exceed 30

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_b]
Sections with stiffened or partially stiffened compression flanges	3.3.2	0.950

Procedure: I — $M_s = Z_e f_y$ [AS/NZS 4600, Eq. 3.3.2.2]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

	$I_{x,el,M[+]}$	762290.565	[mm^4]		
$Z_{el,Comp}$	12860.454	[mm^3]	$Z_{el,Tens}$	12860.454	[mm^3]
	$I_{x,eff,M[+]}$	762290.565	[mm^4]		
$Z_{eff,Comp}$	12860.454	[mm^3]	$Z_{eff,Tens}$	12860.454	[mm^3]

$Z_{el,Comp}$ — Section is fully effective — $Z_{eff,Comp}$

f_y	----	[MPa]
f_{ya}	374.390	[MPa]

↓

$M_{s,x,Comp,M[+]}$	4814825.421	[Nmm]	$M_{s,x,Tens,M[+]}$	4814825.421	[Nmm]
$M_{s,x,Comp,M[+]}$	**4.815**	**[kNm]**	**$M_{s,x,Tens,M[+]}$**	**4.815**	**[kNm]**

Negative Moment in x-x axis [$M_{x,Ed}^-$]

	$I_{x,el,M[-]}$	762290.565	[mm^4]		
$Z_{el,Comp}$	12860.454	[mm^3]	$Z_{el,Tens}$	12860.454	[mm^3]
	$I_{x,eff,M[-]}$	762290.565	[mm^4]		
$Z_{eff,Comp}$	12860.454	[mm^3]	$Z_{eff,Tens}$	12860.454	[mm^3]

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$M_{s,y,Comp,M[-]}$	1335601.22	[Nmm]	$M_{s,y,Tens,M[-]}$	2795968.54	[Nmm]
$M_{s,y,Comp,M[-]}$	**1.336**	**[kNm]**	**$M_{s,y,Tens,M[-]}$**	**2.796**	**[kNm]**

[2] C-Section Beam : Members subject to Lateral Buckling [AS/NZS 4600, 3.3.3.2.1]

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_b]
Member moment capacity: Members subject to lateral buckling	3.3.2	0.900

$M_b = Z_c f_c$ [AS/NZS 4600, Eq. 3.3.3.2(1)]

Singly, doubly and point-symmetric sections bending about the symmetry axis [x-x]

C_b

C_b shall be permitted to be conservatively taken as unity for all cases

For cantilevers or overhangs where the free end is unbraced, C_b shall be taken as unity

C_b	1.000	r_x	47.001	[mm^2]
		r_y	17.753	[mm^2]
		x_0	-37.355	[mm]
		y_0	0.000	[mm]
		r_{01}	62.608	[mm^2]

$$r_{01} = \sqrt{r_x^2 + r_y^2 + x_0^2 + y_0^2}$$

[AS/NZS, Eq. 3.3.3.2(10)]

Z_f	12860.454	[mm^3]	E	210.000	[GPa]

$$f_{oy} = \frac{\pi^2 E}{(l_{ey}/r_y)^2}$$

$f_{oy,Console Beam}$	3534.028	[N/mm^2]
$f_{oy,Middle Beam}$	3520.291	[N/mm^2]

[AS/NZS 4600, Eq. 3.3.3.2(11)]

$$f_{oz} = \frac{GJ}{Ar_{01}^2}\left(1 + \frac{\pi^2 EI_w}{GJl_{ez}^2}\right)$$

$f_{oz,Console Beam}$	535.673	[N/mm^2]
$f_{oz,Middle Beam}$	569.982	[N/mm^2]

[AS/NZS 4600, Eq. 3.3.3.2(12)]

$$M_o = C_b A r_{01} \sqrt{f_{oy} f_{oz}}$$

$M_{o,Console Beam}$	29724252.088	[MPa]
$M_{o,Middle Beam}$	30601704.981	[MPa]

[AS/NZS 4600, Eq. 3.3.3.2(8)]

$M_y = Z_f * f_y$ [AS/NZS 4600, Eq. 3.3.3.2(7)] — M_y 4501158.984 [Nmm]

$$\lambda_b = \sqrt{\frac{M_y}{M_o}}$$

[AS/NZS 4600, Eq. 3.3.3.2(7)]

$\lambda_{b,Console\ Beam}$	0.389	[ ]
$\lambda_{b,Middle\ Beam}$	0.384	[ ]

$\lambda_b \leq 0.600$ $M_c = M_y$ [AS/NZS 4600, Eq. 3.3.3.2(3)]

$0.600 < \lambda_b < 1.336$
$$M_c = 1.11 M_y \left[1 - \left(\frac{10\lambda_b^2}{36}\right)\right]$$
[AS/NZS 4600, Eq. 3.3.3.2(4)]

$\lambda_b \geq 1.336$
$$M_c = M_y \left(\frac{1}{\lambda_b^2}\right)$$
[AS/NZS 4600, Eq. 3.3.3.2(5)]

Console Beam [M_c]					
$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_c		M_c		M_c	
4501158.984	[Nmm]	----	[Nmm]	----	[Nmm]

Middle Beam [M_c]					
$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_c		M_c		M_c	
4501158.984	[Nmm]	----	[Nmm]	----	[Nmm]

$f_c = M_c / Z_f$ [AS/NZS 4600, Eq. 3.3.3.2(2)]

$f_{c,Console\ Beam}$	350.000	[MPa]
$f_{c,Middle\ Beam}$	350.000	[MPa]

$Z_c^{+/-}$ 12860.454 [mm^3] $M_b = Z_c * f_c$ [AS/NZS 4600, Eq. 3.3.3.2(1)]

Console Beam [$M_{b,Comp}^{+/-}$]					
$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_b		M_b		M_b	
4501158.984	[Nmm]	----	[Nmm]	----	[Nmm]

Middle Beam [$M_{b,Comp}^{+/-}$]					
$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_b		M_b		M_b	
4501158.984	[Nmm]	----	[Nmm]	----	[Nmm]

$M_{n,Comp,\ Console\ B}$	4.501	[kNm]	$M_{n,Comp,Middle\ B}$	4.501	[kNm]

$\lambda_b \leq 0.600$ $M_c = M_y$ [AS/NZS 4600, Eq. 3.3.3.2(3)]

$0.600 < \lambda_b < 1.336$
$$M_c = 1.11 M_y \left[1 - \left(\frac{10\lambda_b^2}{36}\right)\right]$$
[AS/NZS 4600, Eq. 3.3.3.2(4)]

$\lambda_b \geq 1.336$
$$M_c = M_y \left(\frac{1}{\lambda_b^2}\right)$$
[AS/NZS 4600, Eq. 3.3.3.2(5)]

Console Beam [M_c^+]					
$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_c^+		M_c^+		M_c^+	
2613822.477	[Nmm]	----	[Nmm]	----	[Nmm]

Console Beam [M_c^-]					
$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_c^-		M_c^-		M_c^-	
1248592.193	[Nmm]	----	[Nmm]	----	[Nmm]

Middle Beam [M_c^+]					
$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_c^+		M_c^+		M_c^+	
2613822.477	[Nmm]	----	[Nmm]	----	[Nmm]

Middle Beam [M_c^-]					
$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_c^-		M_c^-		M_c^-	
1248592.193	[Nmm]	----	[Nmm]	----	[Nmm]

$f_c = M_c / Z_f$ [AS/NZS 4600, Eq. 3.3.3.2(2)]

$f_{c,Console\ Beam}^+$	350.000	[MPa]
$f_{c,Console\ Beam}^-$	350.000	[MPa]
$f_{c,Middle\ Beam}^+$	350.000	[MPa]
$f_{c,Middle\ Beam}^-$	350.000	[MPa]

$M_b = Z_c * f_c$ [AS/NZS 4600, Eq. 3.3.3.2(1)]

Z_c^+	5731.142	[mm^3]	Z_c^-	3567.406	[mm^3]

Singly-symmetric sections bending about the axis perpendicular to the axis of simmetry [y-y]

C_S

C_S = [+] 1.000 → Moment causing compression on shear center side of centroid

C_S = [-] 1.000 → Moment causing tension on shear center side of centroid

$$f_{ox} = \frac{\pi^2 E}{(l_{ex} / r_x)^2}$$

[AS/NZS 4600, Eq. 3.3.3.2(14)]

$f_{ox,Console\ Beam}$	4400.888	[N/mm^2]
$f_{ox,Middle\ Beam}$	4690.583	[N/mm^2]

$$\beta_y = \frac{1}{I_y}\left(\int_A xy^2\,dA + \int_A x^3\,dA\right) - 2x_o$$

β_y 65.750 [mm]

[AS/NZS 4600, Eq. 3.3.3.2(16)]

$C_{TF} = 0.6 - 0.4\,(M_1/M_2)$ C_{TF} 1.000

[AS/NZS 4600, Eq. 3.3.3.2(15)]

$$M_o = \frac{C_s A f_{ox}\left[(\beta_y/2) + C_s\sqrt{(\beta_y/2)^2 + r_{01}^2 (f_{oz}/f_{ox})}\right]}{C_{TF}}$$

[AS/NZS 4600, Eq. 3.3.3.2(13)]

$M_{y,Ed}^+$	→	C_s	1.000
$M_{y,Ed}^-$	→	C_s	-1.000

A	345.063	[mm^2]	r_{01}	62.608	[mm^2]
$Z_{f,y}^+$	7468.064	[mm^3]	$Z_{f,y}^-$	3567.406	[mm^3]
$f_{oz,Console\ Beam}$	535.673	[N/mm^2]	$f_{oz,Middle\ Beam}$	569.982	[N/mm^2]

Console Beam					
$M_{o,ConsoleB,M[+]}$	109862558.904	[Nmm]	$M_{o,Console\ B,M[-]}$	10014807.092	[Nmm]

Middle Beam					
$M_{o,Middle\ B,M[+]}$	117078075.727	[Nmm]	$M_{o,Middle\ B,M[-]}$	10657710.510	[Nmm]

M_y^+	2613822.477	[Nmm]	M_y^-	1248592.193	[Nmm]
f_y	350.000	[MPa]	f_y	350.000	[MPa]

$$\lambda_b = \sqrt{\frac{M_y}{M_o}}$$

[AS/NZS 4600, Eq. 3.3.3.2(7)]

$\lambda_{b,Console\ Beam}^+$	0.154	[ ]
$\lambda_{b,Console\ Beam}^-$	0.353	[ ]
$\lambda_{b,Middle\ Beam}^+$	0.149	[ ]
$\lambda_{b,Middle\ Beam}^-$	0.342	[ ]

Console Beam [$M_{b,Comp}^+$]					
$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_b		M_b		M_b	
2005899.557	[Nmm]	----	[Nmm]	----	[Nmm]

Console Beam [$M_{b,Comp}^-$]					
$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_b		M_b		M_b	
1248592.193	[Nmm]	----	[Nmm]	----	[Nmm]

Middle Beam [$M_{b,Comp}^+$]					
$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_b		M_b		M_b	
2005899.557	[Nmm]	----	[Nmm]	----	[Nmm]

Middle Beam [$M_{b,Comp}^-$]					
$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_b		M_b		M_b	
1248592.193	[Nmm]	----	[Nmm]	----	[Nmm]

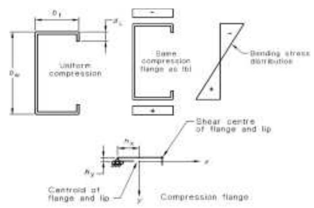
$M_{b,Comp,\ Console}^+$	2.006	[kNm]	$M_{b,Comp,\ Console}^-$	1.249	[kNm]
$M_{b,Comp,Middle}^+$	2.006	[kNm]	$M_{b,Comp,Middle}^-$	1.249	[kNm]

[3] C-Section Beam : Members subject to Distortional Buckling [AS/NZS 4600, 3.3.3.3]

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_b]
Member moment capacity: Members subject to distortional buckling	3.3.3.3	0.900

$M_b = Z_C f_C$ [AS/NZS 4600, Eq. 3.3.3.3(1)]



Simple Lipped Channel Models for Distortional Buckling [AS/NZS 4600, Figure D1]

NOTE	Flanges with 90 Degree Lips	[AS/NZS 4600, D2]

b_w	120.000	[mm]	d_l	18.000	[mm]
b_f	46.500	[mm]	t	1.452	[mm]
A_f	93.654	[mm^2]	J_f	65.817	[mm^4]
$\bar{x}$	29.738	[mm]	I_{xf}	2243.755	[mm^4]
$\bar{y}$	2.512	[mm]	I_{yf}	22355.896	[mm^4]
E	210.000	[GPa]	I_{xyf}	3942.737	[mm^4]

$$\lambda = 4.80\left(\frac{I_x b_f^2 b_w}{t^3}\right)^{0.25}$$
λ 563.679 [mm]
[AS/NZS 4600, Eq. D2(6)]

$$\eta = \left(\frac{\pi}{\lambda}\right)^2$$
η 3.106E-05 [ ]
[AS/NZS 4600, Eq. D2(7)]

$$\beta_1 = \bar{x}^2 + \left(\frac{I_x + I_y}{A}\right)$$
β_1 1147.036 [mm^2]
[AS/NZS 4600, Eq. D2(5)]

$$\alpha_2 = \eta\left(I_y + \frac{2}{\beta_1}\bar{y} b_f I_{xy}\right)$$
α_2 0.719 [ ]
[AS/NZS 4600, Eq. D2(3)]

$$\alpha_1 = \frac{\eta}{\beta_1}\left(I_x b_f^2 + 0.039 J \lambda^2\right)$$
α_1' 0.153 [ ]
[AS/NZS 4600, Eq. D2(9)]

$$\alpha_3 = \eta\left(\alpha_1 I_y - \frac{\eta}{\beta_1} I_{xy}^2 b_f^2\right)$$
α_3' 0.078 [ ]
[AS/NZS 4600, Eq. D2(4)]

$$f_{od} = \frac{E}{2A}\left[(\alpha_1 + \alpha_2) - \sqrt{(\alpha_1 + \alpha_2)^2 - 4\alpha_3}\right]$$
f_{od}' 227.621 [MPa]
[AS/NZS 4600, Eq. D2(1)]

$$K_\Phi = \frac{Et^3}{5.46(b_w + 0.06\lambda)}\left[1 - \frac{1.11 f_{od}'}{Et^2}\left(\frac{b_w^2 \lambda}{b_w^2 + \lambda^2}\right)^2\right]$$
K_Φ 504.551 [mm]
[AS/NZS 4600, Eq. D2(8)]

$$\alpha_1 = \frac{\eta}{\beta_1}\left(I_x b_f^2 + 0.039 J \lambda^2\right) + \frac{K_\Phi}{\beta_1 \eta E}$$
α_1 0.221 [ ]
[AS/NZS 4600, Eq. D2(2)]

$$\alpha_3 = \eta\left(\alpha_1 I_y - \frac{\eta}{\beta_1} I_{xy}^2 b_f^2\right)$$
α_3 0.125 [ ]
[AS/NZS 4600, Eq. D2(4)]

$$f_{od} = \frac{E}{2A}\left[(\alpha_1 + \alpha_2) - \sqrt{(\alpha_1 + \alpha_2)^2 - 4\alpha_3}\right]$$
f_{od} 359.792 [MPa]
[AS/NZS 4600, Eq. D2(1)]

Distortional buckling involves rotation of a flange and lip about the flange/web junction of a channel

K_Φ	504.551	[mm]	Z_c	Full section modulus	
$Z_{c,Full\ Section}$	12860.454	[mm^3]	$Z_{c,Effective\ Section}$	----	[mm^3]

$M_{od} = Z_f f_{od}$
[AS/NZS 4600, Eq. 3.3.3.3(9)]

Z_f 12860.454 [mm^3]
M_{od} 4627091.321 [Nmm]

$$\lambda_d = \sqrt{\frac{M_y}{M_{od}}}$$
[AS/NZS 4600, Eq. 3.3.3.3(8)]

M_y 4501158.984 [Nmm]
λ_d 0.986 [ ]

$\lambda_d \le 0.674$	$\lambda_d > 0.674$
$M_c = M_y$	$M_c = \frac{M_y}{\lambda_d}\left(1 - \frac{0.22}{\lambda_d}\right)$
[AS/NZS 4600, Eq. 3.3.3.3(3)]	[AS/NZS 4600, Eq. 3.3.3.3(4)]

$\lambda_d \le 0.674$		$\lambda_d > 0.674$	
M_c		M_c	
----	[Nmm]	3545730.704	[Nmm]

$f_c = M_c / Z_f$ — f_c 275.708 [MPa]
[AS/NZS 4600, Eq. 3.3.3.3(2)]

↓

$M_b = Z_c f_c$ [AS/NZS 4600, Eq. 3.3.3.3(1)]

↓

M_b 3545730.704 [Nmm]

↓

M_b 3.546 [kNm]

Distortional buckling involves transverse bending of a vertical web with lateral displacement of the compression flange

$M_{od} = Z_f f_{od}$
[AS/NZS 4600, Eq. 3.3.3.3(9)]

Z_f 12860.454 [mm^3]
M_{od} 4627091.321 [Nmm]

$$\lambda_d = \sqrt{\frac{M_y}{M_{od}}}$$
[AS/NZS 4600, Eq. 3.3.3.3(8)]

M_y 4501158.984 [Nmm]
λ_d 0.986 [ ]

$\lambda_d \le 0.590$	$0.590 < \lambda_d \le 1.700$	$\lambda_d > 1.700$
$M_c = M_y$	$M_c = M_y\left(\frac{0.59}{\lambda_d}\right)$	$M_c = M_y\left(\frac{1}{\lambda_d^2}\right)$
[AS/NZS 4600, Eq. 3.3.3.3(5)]	[AS/NZS 4600, Eq. 3.3.3.3(6)]	[AS/NZS 4600, Eq. 3.3.3.3(7)]

$\lambda_d \le 0.590$		$0.590 < \lambda_d \le 1.700$		$\lambda_d > 1.700$	
M_c		M_c		M_c	
----	[Nmm]	2692577.569	[Nmm]	----	[Nmm]

$f_c = M_c / Z_f$ — f_c 209.369 [MPa]
[AS/NZS 4600, Eq. 3.3.3.3(2)]

↓

$Z_{c,Effective\ Section}$ 12860.454 [mm^3]

↓

$M_b = Z_c f_c$ [AS/NZS 4600, Eq. 3.3.3.3(1)]

↓

M_b 2692577.569 [Nmm]

↓

M_b 2.693 [kNm]

M_b	2692577.569	[Nmm]	**M_b**	**2.693**	**[kNm]**

[4] C-Section Beam : Bending Moment Verification [AS/NZS 4600, LSD]

$M^* \le \Phi_b * M_s$	[AS/NZS 4600, Eq. 3.3.1(1)]	$M^* \le \Phi_b * M_b$	[AS/NZS 4600, Eq. 3.3.1(2)]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

C-Section Console Beam

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	34.663	[%]
$M_{s,x,Comp,M[+]}$	2.693	[kNm]			

C-Section Middle Beam

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	34.663	[%]
$M_{s,x,Comp,M[+]}$	2.693	[kNm]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

C-Section Console Beam

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	34.663	[%]
$M_{s,x,Comp,M[-]}$	2.693	[kNm]			

C-Section Middle Beam

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	34.663	[%]
$M_{s,x,Comp,M[-]}$	2.693	[kNm]			

Positive Moment in y-y axis [$M_{y,Ed}^+$]

C-Section Console Beam

$M_{y,Ed,M[+]}$	0.020	[kNm]	Ratio	1.108	[%]
$M_{s,y,Comp,M[+]}$	2.006	[kNm]			

C-Section Middle Beam

$M_{y,Ed,M[+]}$	0.010	[kNm]	Ratio	0.554	[%]
$M_{s,y,Comp,M[+]}$	2.006	[kNm]			

Negative Moment in y-y axis [$M_{y,Ed}^-$]

C-Section Console Beam

$M_{y,Ed,M[-]}$	0.020	[kNm]	Ratio	1.780	[%]
$M_{s,y,Comp,M[-]}$	1.249	[kNm]			

C-Section Middle Beam

$M_{y,Ed,M[-]}$	0.010	[kNm]	Ratio	0.890	[%]
$M_{s,y,Comp,M[-]}$	1.249	[kNm]			

[c] C-Section Column

[i] C-Section Column : Bending Moment [AISI S100, ASD]

[1] C-Section Column: Nominal Section Strength [Resistance] [AISI S100, C3.1.1]

Procedure	Description
I	Based on Initiation of Yielding
II	Based on Inelastic Reserve Capacity

Procedure II : Based on Inelastic Reserve Capacity

The inelastic flexural reserve capacity shall be permitted to be used when:

[1] Member is not subject to twisting, lateral, torsional, or flexural-torsional buckling

[2] Effect of cold work of forming is not included in determining the yield stress F_y

[3] Ratio of the depth of the compressed portion of the web to its thickness not exceed λ_1

[4] Shear force does not exceed:

0.35^*F_y [ASD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]

0.60^*F_y [LRFD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]

[5] The angle between any web and the vertical does not exceed 30

Sections with stiffened or partially stiffened compression flanges: Ω_b 1.670

Procedure: I — $M_n = S_eF_y$ [AISI S100, Eq. C3.1.1-1]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

$I_{x\,el,M[+]}$ 625036.020 [mm^4]

$S_{el,Comp}$	13521.309	[mm^3]	$S_{el,Tens}$	14278.705	[mm^3]

$I_{x\,eff,M[+]}$ 625036.020 [mm^4]

$S_{eff,Comp}$	13521.309	[mm^3]	$S_{eff,Tens}$	14278.705	[mm^3]

$S_{el,Comp}$ — **Section is fully effective** — $S_{eff,Comp}$

F_y ---- [MPa]

F_{ya} 388.471 [MPa]

↓

$M_{n,x,Comp,M[+]}$	5252632.013	[Nmm]	$M_{n,x,Tens,M[+]}$	5546858.122	[Nmm]
$M_{n,x,Comp,M[+]}$	**5.253**	**[kNm]**	**$M_{n,x,Tens,M[+]}$**	**5.547**	**[kNm]**

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

$I_{y,eff,M[-]}$ 153816.866 [mm^4]

$S_{eff,Comp}$	5515.375	[mm^3]	$S_{eff,Tens}$	9518.806	[mm^3]

$S_{el,Comp}$ — **Section is fully effective** — $S_{eff,Comp}$

F_y ---- [MPa]

F_{ya} 388.471 [MPa]

↓

$M_{n,y,Comp,M[-]}$	2142561.631	[Nmm]	$M_{n,y,Tens,M[-]}$	3697776.967	[Nmm]
$M_{n,y,Comp,M[-]}$	**2.143**	**[kNm]**	**$M_{n,y,Tens,M[-]}$**	**3.698**	**[kNm]**

[2] C-Section Column : Lateral-Torsional Buckling Strength [Resistance] [AISI S100, C3.1.2.1]

Ω_b 1.670 — $M_n = S_CF_C$ [AISI S100, Eq. C3.1.2.1-1]

Singly-symmetric sections bending about the symmetry axis [x-x]

C_b

C_b shall be permitted to be conservatively taken as unity for all cases.

For cantilevers or overhangs where the free end is unbraced, C_b shall be taken as unity

C_b 1.000

r_x	35.455	[mm^2]
r_y	17.588	[mm^2]
x_0	-40.108	[mm]
r_0	56.347	[mm^2]

$$r_o = \sqrt{r_x^2 + r_y^2 + x_o^2}$$

[AISI S100, Eq. C3.1.2.1-7]

S_f 14278.705 [mm^3] | E 210.000 [GPa]

$$\sigma_{ey} = \frac{\pi^2 E}{(K_y L_y / r_y)^2}$$

[AISI S100, Eq. C3.1.2.1-8]

$\sigma_{ey,Front\,Column}$ 327.119 [N/mm^2]

$\sigma_{ey,Rear\,Column}$ 109.221 [N/mm^2]

$$\sigma_t = \frac{1}{Ar_o^2}\left[GJ + \frac{\pi^2 EC_w}{(K_t L_t)^2}\right]$$

[AISI S100, Eq. C3.1.2.1-9]

$\sigma_{t,Front\,Column}$ 1752.839 [N/mm^2]

$\sigma_{t,Rear\,Column}$ 619.213 [N/mm^2]

$$F_e = \frac{C_b r_o A}{S_f}\sqrt{\sigma_{ey}\sigma_t}$$

[AISI S100, Eq. C3.1.2.1-4]

$F_{e,Front\,Column}$ 1485.836 [MPa]

$F_{e,Rear\,Column}$ 510.294 [MPa]

F_y ---- [MPa] | F_{ya} 388.471 [MPa]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

Negative Moment in x-x axis [$M_{x,Ed}^-$]

$I_{x\,el,M[-]}$ 625036.020 [mm^4]

$S_{el,Comp}$	14278.705	[mm^3]	$S_{el,Tens}$	13521.309	[mm^3]

$I_{x,eff,M[-]}$ 625036.020 [mm^4]

$S_{eff,Comp}$	14278.705	[mm^3]	$S_{eff,Tens}$	13521.309	[mm^3]

$S_{el,Comp}$ — **Section is fully effective** — $S_{eff,Comp}$

F_y ---- [MPa]

F_{ya} 388.471 [MPa]

↓

$M_{n,x,Comp,M[-]}$	5546858.122	[Nmm]	$M_{n,x,Tens,M[-]}$	5252632.013	[Nmm]
$M_{n,x,Comp,M[-]}$	**5.547**	**[kNm]**	**$M_{n,x,Tens,M[-]}$**	**5.253**	**[kNm]**

Positive Moment in y-y axis [$M_{y,Ed}^+$]

$I_{y,el,M[+]}$ 153816.866 [mm^4]

$S_{el,Comp}$	9518.806	[mm^3]	$S_{el,Tens}$	5515.375	[mm^3]

$I_{y,eff,M[+]}$ 153816.866 [mm^4]

$S_{eff,Comp}$	9518.806	[mm^3]	$S_{eff,Tens}$	5515.375	[mm^3]

$S_{el,Comp}$ — **Section is fully effective** — $S_{eff,Comp}$

F_y ---- [MPa]

F_{ya} 388.471 [MPa]

↓

$M_{n,y,Comp,M[+]}$	3697776.967	[Nmm]	$M_{n,y,Tens,M[+]}$	2142561.631	[Nmm]
$M_{n,y,Comp,M[+]}$	**3.698**	**[kNm]**	**$M_{n,y,Tens,M[+]}$**	**2.143**	**[kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^-$]

$I_{y,el,M[-]}$ 153816.866 [mm^4]

$S_{el,Comp}$	5515.375	[mm^3]	$S_{el,Tens}$	9518.806	[mm^3]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
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Client: COIMBRA UNIVERSITY

$F_e \geq 2.780 * F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_y

Available flexural strength [moment resistance] shall be determined with Section C3.1.1(a)

$2.780 * F_y > F_e > 0.560 * F_y$

$$F_c = \frac{10}{9}F_y\left(1 - \frac{10F_y}{36F_e}\right)$$

[AISI S100, Eq. C3.1.2.1-2]

$0.560 * F_y \geq F_e$

$F_c = F_e$

[AISI S100, Eq. C3.1.2.1-3]

S_c 13521.309 [mm^3]

Front Column [F_c]

$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Rear Column [F_c]

$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
No		Yes		No	
----	[MPa]	340.359	[MPa]	----	[MPa]

Front Column [$M_{n,Comp}^{+/-}$]

$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
5.253	[kNm]	----	[kNm]	----	[kNm]

Rear Column [$M_{n,Comp}^{+/-}$]

$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
----	[kNm]	4.602	[kNm]	----	[kNm]

$M_{n,Comp,Front\,C}$	5.253	[kNm]	$M_{n,Comp,Rear\,C}$	4.602	[kNm]

Singly-symmetric sections bending about the axis perpendicular to the axis of simmetry [y-y]

C_S

C_S = [+] 1.000 → Moment causing compression on shear center side of centroid

C_S = [-] 1.000 → Moment causing tension on shear center side of centroid

$$\sigma_{ex} = \frac{\pi^2 E}{(K_x L_x / r_x)^2}$$

[AISI S100, Eq. C3.1.2.1-11]

$\sigma_{ex,Front\,Column}$ 2427.408 [N/mm^2]

$\sigma_{ex,Rear\,Column}$ 722.710 [N/mm^2]

$$j = \frac{1}{2I_y}\left[\int_A x^3 dA + \int_A xy^2 dA\right] - x_o$$

j 55.317 [mm]

[AISI S100, Eq. C3.1.2.1-11]

$$C_{TF} = 0.6 - 0.4\,(M_1/M_2)$$ C_{TF} 1.000

[AISI S100, Eq. C3.1.2.1-11]

$$F_e = \frac{C_s A \sigma_{ex}}{C_{TF} S_f}\left[j + C_s\sqrt{j^2 + r_o^2(\sigma_t/\sigma_{ex})}\right]$$

[AISI S100, Eq. C3.1.2.1-10]

$M_{y,Ed}^{+}$	→	C_s	1.000
$M_{y,Ed}^{-}$	→	C_s	-1.000

A_g	497.235	[mm²]	r_0	56.347	[mm²]
$S_{f,y}^{+}$	9518.806	[mm³]	$S_{f,y}^{-}$	5515.375	[mm³]
$\sigma_{t,Front\,Column}$	1752.839	[N/mm²]	$\sigma_{t,Rear\,Column}$	619.213	[N/mm²]

Front Column					
$F_{e,Front\,C,M[+]}$	16291.299	[MPa]	$F_{e,Front\,C,M[-]}$	3905.202	[MPa]

Rear Column					
$F_{e,Rear\,C,M[+]}$	4958.609	[MPa]	$F_{e,Rear\,C,M[-]}$	1349.456	[MPa]

$M_{n,Comp}^{+}$

F_y	----	[MPa]	F_{ya}	388.471	[MPa]

$M_{n,Comp}^{-}$

F_y	----	[MPa]	F_{ya}	388.471	[MPa]

$F_e \geq 2.780 * F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_y

Available flexural strength [moment resistance] shall be determined with Section C3.1.1(a)

$2.780 * F_y > F_e > 0.560 * F_y$

$$F_c = \frac{10}{9}F_y\left(1 - \frac{10F_y}{36F_e}\right)$$

[AISI S100, Eq. C3.1.2.1-2]

$0.560 * F_y \geq F_e$

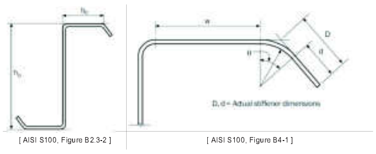
$F_c = F_e$

[AISI S100, Eq. C3.1.2.1-3]

$S_{c,y}^{+}$	9518.806	[mm³]	$S_{c,y}^{-}$	5515.375	[mm³]

Front Column [$F_{c,M[+]}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

For C- and Z-Sections or any Open Section with a Stiffened Compression Flange Extending to One Side of the Web where the Stiffener is either a Simple Lip or a Complex Edge Stiffener



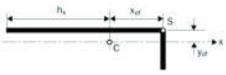
[AISI S100, Figure B2.3-2] [AISI S100, Figure B4-1]

Dimensional Limits		
[1]	$50 \leq h_o / t$	KO
	$h_o / t \leq 200$	OK
[2]	$25 \leq b_o / t$	KO
	$b_o / t \leq 100$	OK
[3]	$6.25 < D / t$	OK
	$D / t \leq 50$	OK
[4]	$45° \leq \theta$	OK
	$\theta \leq 90°$	OK
[5]	$2 \leq h_o / b_o$	KO
	$h_o / b_o \leq 8$	OK
[6]	$0.04 \leq D * \sin[\theta] / b_o$	OK
	$D * \sin[\theta] / b_o \leq 0.50$	OK

$$L_{cr} = \left(\frac{4\pi^4 h_o(1-\mu^2)}{t^3}\left(I_{xf}(x_o-h_x)^2 + C_{wf} - \frac{I_{xyf}^2}{I_{yf}}(x_o-h_x)^2\right) + \frac{\pi^4 h_o^4}{720}\right)^{1/4}$$

[AISI S100, Eq. C3.1.4-12]

NOTE	Flanges with 90 Degree Lips



			A_f	121.727	[mm²]
			I_{xf}	1502.698	[mm⁴]
			I_{yf}	17911.320	[mm⁴]
			I_{xyf}	2815.457	[mm⁵]
			h_x	-23.107	[mm]
x_{0f}	13.489	[mm]	J_f	243.953	[mm⁴]
y_{0f}	-1.715	[mm]	C_{wf}	0.000	[mm⁶]
h_0	90.000	[mm]	v [μ]	0.300	[ ]

β	1.000	$L = L_{cr}$	235.622	[mm]

Front Column [$F_{c,M[-]}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Rear Column [$F_{c,M[+]}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Rear Column [$F_{c,M[+]}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Front Column [$M_{n,Comp}^{+}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
3.698	[kNm]	----	[kNm]	----	[kNm]

Front Column [$M_{n,Comp}^{-}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
2.143	[kNm]	----	[kNm]	----	[kNm]

Rear Column [$M_{n,Comp}^{+}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
3.698	[kNm]	----	[kNm]	----	[kNm]

Rear Column [$M_{n,Comp}^{-}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
2.143	[kNm]	----	[kNm]	----	[kNm]

Front Column [$M_{n,Comp}$]					
$M_{n,Comp}^{+}$	3.698	[kNm]	$M_{n,Comp}^{-}$	2.143	[kNm]

Rear Column [$M_{n,Comp}$]					
$M_{n,Comp}^{+}$	3.698	[kNm]	$M_{n,Comp}^{-}$	2.143	[kNm]

[3] C-Section Beam : Distortional Buckling Strength [Resistance] [AISI S100, C3.1.4]

Ω_b	1.670

E	210.000	[GPa]	**G**	80.769	[GPa]

$$k_{\phi fe} = \left(\frac{\pi}{L}\right)^4\left(EI_{xf}(x_o-h_x)^2 + EC_{wf} - E\frac{I_{xyf}^2}{I_{yf}}(x_o-h_x)^2\right) + \left(\frac{\pi}{L}\right)^2 GJ_f$$

[AISI S100, Eq. C3.1.4-13]

$$k_{\phi we} = \frac{Et^3}{12(1-\mu^2)}\left(\frac{3}{h_o} + \left(\frac{\pi}{L}\right)^2\frac{19h_o}{60} + \left(\frac{\pi}{L}\right)^4\frac{h_o^3}{240}\right)$$

[AISI S100, Eq. C3.1.4-14]

$k_{\phi fe}$	12925.732	[N]	$k_{\phi we}$	10913.706	[N]

$$\tilde{k}_{\phi fg} = \left(\frac{\pi}{L}\right)^2\left[A_f\left((x_o-h_x)^2\left(\frac{I_{xyf}}{I_{yf}}\right)^2 - 2y_o(x_o-h_x)\left(\frac{I_{xyf}}{I_{yf}}\right) + h_x^2 + y_o^2\right) + I_{xf} + I_{yf}\right]$$

[AISI S100, Eq. C3.1.4-15]

$$\tilde{k}_{\phi wg} = \frac{h_o t\pi^2}{13440}\left(\frac{[45360(1-\xi_{web}) + 62160]\left(\frac{L}{h_o}\right)^2 + 448\pi^2 + \left(\frac{h_o}{L}\right)^2[53 + 3(1-\xi_{web})]\pi^4}{\pi^4 + 28\pi^2\left(\frac{L}{h_o}\right)^2 + 420\left(\frac{L}{h_o}\right)^4}\right)$$

[AISI S100, Eq. C3.1.4-16]

k_{ϕ}	0.000	[N]	ξ_{web}	2.000	[ ]
$\tilde{k}_{\phi fg}$	16.212	[mm²]	$\tilde{k}_{\phi wg}$	0.897	[mm²]

$$F_d = \beta\frac{k_{\phi fe} + k_{\phi we} + k_{\phi}}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}}$$ F_d 1393.322 [MPa]

[AISI S100, Eq. C3.1.4-16]

$M_y = S_{fy} * F_y$

[AISI S100, Eq. C3.1.4-4]

$M_{cr} = S_f * F_d$

[AISI S100, Eq. C3.1.4-5]

S_f	13521.309	[mm³]	→	M_{cr}	18839541.235	[Nmm]
S_{fy}	13521.309	[mm³]	→	M_y	4732458.074	[Nmm]

$$\lambda_d = \sqrt{M_y / M_{crd}}$$ λd 0.501

[AISI S100, Eq. C3.1.4-3]

$\lambda_d \leq 0.673$	$\lambda_d > 0.673$
$M_n = M_y$	$M_n = \left(1-0.22\left(\frac{M_{crd}}{M_y}\right)^{0.5}\right)\left(\frac{M_{crd}}{M_y}\right)^{0.5} M_y$
[AISI S100, Eq. C3.1.4-1]	[AISI S100, Eq. C3.1.4-2]

M_n	4732458.074	[Nmm]	**M_n**	**4.732**	**[kNm]**

[4] C-Section Column : Bending Moment Verification [AISI S100, ASD]

$M \leq M_n / \Omega_b$	[AISI S100, Eq. A4.1.1-1]	M_n = MIN [$M_{n,C3.1.1}$; $M_{n,C3.1.2.1}$; $M_{n,C3.1.4}$]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

C-Section Front Column

$M_{x,Ed,M[+]}$	0.270	[kNm]	Ratio	9.528	[%]
$M_{n,x,Comp,M[+]}$	4.732	[kNm]			

C-Section Rear Column

$M_{x,Ed,M[+]}$	0.350	[kNm]	Ratio	12.701	[%]
$M_{n,x,Comp,M[+]}$	4.602	[kNm]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

C-Section Front Column

$M_{x,Ed,M[-]}$	0.270	[kNm]	Ratio	9.528	[%]
$M_{n,x,Comp,M[-]}$	4.732	[kNm]			

C-Section Rear Column

$M_{x,Ed,M[-]}$	0.350	[kNm]	Ratio	12.701	[%]
$M_{n,x,Comp,M[-]}$	4.602	[kNm]			

Positive Moment in y-y axis [$M_{y,Ed}^+$]

C-Section Front Column

$M_{y,Ed,M[+]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{n,y,Comp,M[+]}$	3.698	[kNm]			

		$I_{x,eff,M[+]}$	625036.020	[mm⁴]	
$S_{eff,Comp}$	13521.309	[mm³]	$S_{eff,Tens}$	14278.705	[mm³]

$S_{el,Comp}$ — **Section is fully effective** — $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	388.471	[MPa]

↓

$M_{n,x,Comp,M[+]}$	5252632.013	[Nmm]	$M_{n,x,Tens,M[+]}$	5546858.122	[Nmm]
$M_{n,x,Comp,M[+]}$	**5.253**	**[kNm]**	**$M_{n,x,Tens,M[+]}$**	**5.547**	**[kNm]**

Negative Moment in x-x axis [$M_{x,Ed}^-$]

		$I_{x,el,M[-]}$	625036.020	[mm⁴]	
$S_{el,Comp}$	14278.705	[mm³]	$S_{el,Tens}$	13521.309	[mm³]
		$I_{x,eff,M[-]}$	625036.020	[mm⁴]	
$S_{eff,Comp}$	14278.705	[mm³]	$S_{eff,Tens}$	13521.309	[mm³]

$S_{el,Comp}$ — **Section is fully effective** — $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	388.471	[MPa]

↓

$M_{n,x,Comp,M[-]}$	5546858.122	[Nmm]	$M_{n,x,Tens,M[-]}$	5252632.013	[Nmm]
$M_{n,x,Comp,M[-]}$	**5.547**	**[kNm]**	**$M_{n,x,Tens,M[-]}$**	**5.253**	**[kNm]**

Positive Moment in y-y axis [$M_{y,Ed}^+$]

		$I_{y,el,M[+]}$	153816.866	[mm⁴]	
$S_{el,Comp}$	9518.806	[mm³]	$S_{el,Tens}$	5515.375	[mm³]
		$I_{y,eff,M[+]}$	153816.866	[mm⁴]	
$S_{eff,Comp}$	9518.806	[mm³]	$S_{eff,Tens}$	5515.375	[mm³]

C-Section Rear Column

$M_{y,Ed,M[+]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{n,y,Comp,M[+]}$	2.143	[kNm]			

Negative Moment in y-y axis [$M_{y,Ed}^-$]

C-Section Front Column

$M_{y,Ed,M[-]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{n,y,Comp,M[-]}$	2.143	[kNm]			

C-Section Rear Column

$M_{y,Ed,M[-]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{n,y,Comp,M[-]}$	2.143	[kNm]			

[ii] C-Section Column : Bending Moment [AISI S100, LRFD]

[1] C-Section Column : Nominal Section Strength [Resistance] [AISI S100, C3.1.1]

Procedure	Description
I	Based on Initiation of Yielding
II	Based on Inelastic Reserve Capacity

Procedure II : Based on Inelastic Reserve Capacity

The inelastic flexural reserve capacity shall be permitted to be used when:

[1] Member is not subject to twisting, lateral, torsional, or flexural-torsional buckling

[2] Effect of cold work of forming is not included in determining the yield stress F_y

[3] Ratio of the depth of the compressed portion of the web to its thickness not exceed λ_1

[4] Shear force does not exceed:

$0.35 * F_y$ [ASD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]

$0.60 * F_y$ [LRFD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]

[5] The angle between any web and the vertical does not exceed 30

Sections with stiffened or partially stiffened compression flanges — Φ_b 0.950

Procedure: I — $M_n = S_e F_y$ [AISI S100, Eq. C3.1.1-1]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

		$I_{x,el,M[+]}$	625036.020	[mm⁴]	
$S_{el,Comp}$	13521.309	[mm³]	$S_{el,Tens}$	14278.705	[mm³]

$S_{el,Comp}$ — **Section is fully effective** — $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	388.471	[MPa]

↓

$M_{n,y,Comp,M[+]}$	3697776.967	[Nmm]	$M_{n,y,Tens,M[+]}$	2142561.631	[Nmm]
$M_{n,y,Comp,M[+]}$	**3.698**	**[kNm]**	**$M_{n,y,Tens,M[+]}$**	**2.143**	**[kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^-$]

		$I_{y,el,M[-]}$	153816.866	[mm⁴]	
$S_{el,Comp}$	5515.375	[mm³]	$S_{el,Tens}$	9518.806	[mm³]
		$I_{y,eff,M[-]}$	153816.866	[mm⁴]	
$S_{eff,Comp}$	5515.375	[mm³]	$S_{eff,Tens}$	9518.806	[mm³]

$S_{el,Comp}$ — **Section is fully effective** — $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	388.471	[MPa]

↓

$M_{n,y,Comp,M[-]}$	2142561.631	[Nmm]	$M_{n,y,Tens,M[-]}$	3697776.967	[Nmm]
$M_{n,y,Comp,M[-]}$	**2.143**	**[kNm]**	**$M_{n,y,Tens,M[-]}$**	**3.698**	**[kNm]**

[2] C-Section Column : Lateral-Torsional Buckling Strength [Resistance] [AISI S100, C3.1.2.1]

Φ_b 0.900 — $M_n = S_C F_C$ [AISI S100, Eq. C3.1.2.1-1]

Singly-symmetric sections bending about the symmetry axis [x-x]

C_b

C_b shall be permitted to be conservatively taken as unity for all cases.

For cantilevers or overhangs where the free end is unbraced, C_b shall be taken as unity

C_b 1.000

$$r_0 = \sqrt{r_x^2 + r_y^2 + x_0^2}$$

[AISI S100, Eq. C3.1.2.1-7]

r_x	35.455	[mm²]
r_y	17.588	[mm²]
x_0	-40.108	[mm]
r_0	56.347	[mm²]

S_f	14278.705	[mm^3]	E	210.000	[GPa]

$$\sigma_{ey} = \frac{\pi^2 E}{(K_y L_y / r_y)^2}$$

$\sigma_{ey,Front\ Column}$	327.119	[N/mm^2]
$\sigma_{ey,Rear\ Column}$	109.221	[N/mm^2]

[AISI S100, Eq. C3.1.2.1-8]

$$\sigma_t = \frac{1}{A r_o^2}\left[GJ + \frac{\pi^2 E C_w}{(K_t L_t)^2}\right]$$

$\sigma_{t,Front\ Column}$	1752.839	[N/mm^2]
$\sigma_{t,Rear\ Column}$	619.213	[N/mm^2]

[AISI S100, Eq. C3.1.2.1-9]

$$F_e = \frac{C_b r_o A}{S_f}\sqrt{\sigma_{ey}\sigma_t}$$

$F_{e,Front\ Column}$	1485.836	[MPa]
$F_{e,Rear\ Column}$	510.294	[MPa]

[AISI S100, Eq. C3.1.2.1-4]

F_y	----	[MPa]	F_{ya}	388.471	[MPa]

$F_e \geq 2.780 * F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_y

Available flexural strength [moment resistance] shall be determined with Section C3.1.1(a)

$2.780 * F_y > F_e > 0.560 * F_y$

$$F_c = \frac{10}{9}F_y\left(1 - \frac{10F_y}{36F_e}\right)$$

[AISI S100, Eq. C3.1.2.1-2]

$0.560 * F_y \geq F_e$

$F_c = F_e$

[AISI S100, Eq. C3.1.2.1-3]

S_c	13521.309	[mm^3]

Front Column Beam [F_c]					
$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Rear Column [F_c]					
$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
No		Yes		No	
----	[MPa]	340.359	[MPa]	----	[MPa]

Front Column [$M_{n,Comp}^{+/-}$]					
$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
5.253	[kNm]	----	[kNm]	----	[kNm]

Rear Column [$M_{n,Comp}^{+/-}$]					
$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
----	[kNm]	4.602	[kNm]	----	[kNm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
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Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

$F_e \geq 2.780 * F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_y

Available flexural strength [moment resistance] shall be determined with Section C3.1.1(a)

$2.780 * F_y > F_e > 0.560 * F_y$

$$F_c = \frac{10}{9}F_y\left(1 - \frac{10F_y}{36F_e}\right)$$

[AISI S100, Eq. C3.1.2.1-2]

$0.560 * F_y \geq F_e$

$F_c = F_e$

[AISI S100, Eq. C3.1.2.1-3]

$S_{c,y}^+$	9518.806	[mm^3]	$S_{c,y}^-$	5515.375	[mm^3]

Front Column [$F_{c,M[+]}$]					
$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Front Column [$F_{c,M[-]}$]					
$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Rear Column [$F_{c,M[+]}$]					
$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Rear Column [$F_{c,M[+]}$]					
$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Front Column [$M_{n,Comp}^+$]					
$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
3.698	[kNm]	----	[kNm]	----	[kNm]

Front Column [$M_{n,Comp}^-$]					
$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
2.143	[kNm]	----	[kNm]	----	[kNm]

Rear Column [$M_{n,Comp}^+$]					
$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
3.698	[kNm]	----	[kNm]	----	[kNm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
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$M_{n,Comp,Front\ C}$	5.253	[kNm]	$M_{n,Comp,Rear\ C}$	4.602	[kNm]

Singly-symmetric sections bending about the axis perpendicular to the axis of simmetry [y-y]

C_S

C_S = [+] 1.000 → Moment causing compression on shear center side of centroid

C_S = [-] 1.000 → Moment causing tension on shear center side of centroid

$$\sigma_{ex} = \frac{\pi^2 E}{(K_x L_x / r_x)^2}$$

$\sigma_{ex,Front\ Column}$	2427.408	[N/mm^2]
$\sigma_{ex,Rear\ Column}$	722.710	[N/mm^2]

[AISI S100, Eq. C3.1.2.1-11]

$$j = \frac{1}{2I_y}\left[\int_A x^3 dA + \int_A xy^2 dA\right] - x_o$$

j	55.317	[mm]

[AISI S100, Eq. C3.1.2.1-11]

$$C_{TF} = 0.6 - 0.4\,(M_1/M_2)$$

C_{TF}	1.000

[AISI S100, Eq. C3.1.2.1-11]

$$F_e = \frac{C_s A \sigma_{ex}}{C_{TF} S_f}\left[j + C_s\sqrt{j^2 + r_o^2(\sigma_t/\sigma_{ex})}\right]$$

[AISI S100, Eq. C3.1.2.1-10]

$M_{y,Ed}^+$	→	C_s	1.000
$M_{y,Ed}^-$	→	C_s	-1.000

A_g	497.235	[mm^2]	r_0	56.347	[mm^2]
$S_{f,y}^+$	9518.806	[mm^3]	$S_{f,y}^-$	5515.375	[mm^3]
$\sigma_{t,Console\ Beam}$	1752.839	[N/mm^2]	$\sigma_{t,Middle\ Beam}$	619.213	[N/mm^2]

Front Column					
$F_{e,Front\ C,M[+]}$	16291.299	[MPa]	$F_{e,Front\ C,M[-]}$	3905.202	[MPa]

Rear Column					
$F_{e,Rear\ C,M[+]}$	4958.609	[MPa]	$F_{e,Rear\ C,M[-]}$	1349.456	[MPa]

$M_{n,Comp}^+$

F_y	----	[MPa]	F_{ya}	388.471	[MPa]

$M_{n,Comp}^-$

F_y	----	[MPa]	F_{ya}	388.471	[MPa]

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Rear Column [$M_{n,Comp}^-$]					
$F_e \geq 2.780 * F_y$		$2.780 * F_y > F_e > 0.560 * F_y$		$0.560 * F_y \geq F_e$	
2.143	[kNm]	----	[kNm]	----	[kNm]

Front Column [$M_{n,Comp}$]					
$M_{n,Comp}^+$	3.698	[kNm]	$M_{n,Comp}^-$	2.143	[kNm]

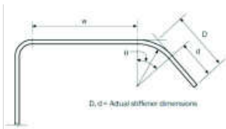
Rear Column Beam [$M_{n,Comp}$]					
$M_{n,Comp}^+$	3.698	[kNm]	$M_{n,Comp}^-$	2.143	[kNm]

[3] C-Section Column : Distortional Buckling Strength [Resistance] [AISI S100, C3.1.4]

Φ_b	0.900

For C- and Z-Sections or any Open Section with a Stiffened Compression Flange Extending to One Side of the Web where the Stiffener is either a Simple Lip or a Complex Edge Stiffener

[AISI S100, Figure B2.3-2]



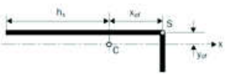
[AISI S100, Figure B4-1]

Dimensional Limits		
[1]	$50 \leq h_o / t$	KO
	$h_o / t \leq 200$	OK
[2]	$25 \leq b_o / t$	KO
	$b_o / t \leq 100$	OK
[3]	$6.25 < D / t$	OK
	$D / t \leq 50$	OK
[4]	$45° \leq \theta$	OK
	$\theta \leq 90°$	OK
[5]	$2 \leq h_o / b_o$	KO
	$h_o / b_o \leq 8$	OK
[6]	$0.04 \leq D * \sin[\theta] / b_o$	OK
	$D * \sin[\theta] / b_o \leq 0.50$	OK

$$L_{cr} = \left\{ \frac{4\pi^4 h_o (1-\mu^2)}{t^3} \left(I_{xf}(x_o - h_x)^2 + C_{wf} - \frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2 \right) + \frac{\pi^4 h_o^4}{720} \right\}^{1/4}$$

[AISI S100, Eq. C3.1.4-12]

NOTE — Flanges with 90 Degree Lips



			A_f	121.727	[mm²]
			I_{xf}	1502.698	[mm⁴]
			I_{yf}	17911.320	[mm⁴]
			I_{xyf}	2815.457	[mm⁴]
			h_x	-23.107	[mm]
x_{of}	13.489	[mm]	J_f	243.953	[mm⁴]
y_{of}	-1.715	[mm]	C_{wf}	0.000	[mm⁶]
h_0	90.000	[mm]	v [μ]	0.300	[ ]
β	1.000		L = L_{cr}	235.622	[mm]
E	210.000	[GPa]	G	80.769	[GPa]

$$k_{\phi fe} = \left(\frac{\pi}{L}\right)^4 \left(EI_{xf}(x_o - h_x)^2 + EC_{wf} - E\frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2 \right) + \left(\frac{\pi}{L}\right)^2 GJ_f$$

[AISI S100, Eq. C3.1.4-13]

$$k_{\phi we} = \frac{Et^3}{12(1-\mu^2)} \left(\frac{3}{h_o} + \left(\frac{\pi}{L}\right)^2 \frac{19 h_o}{60} + \left(\frac{\pi}{L}\right)^4 \frac{h_o^3}{240} \right)$$

[AISI S100, Eq. C3.1.4-14]

$k_{\phi fe}$	12925.732	[N]	$k_{\phi we}$	10913.706	[N]

$$\tilde{k}_{\phi fg} = \left(\frac{\pi}{L}\right)^2 \left[A_f \left((x_o - h_x)^2 \left(\frac{I_{xyf}}{I_{yf}}\right)^2 - 2y_o(x_o - h_x)\left(\frac{I_{xyf}}{I_{yf}}\right) + h_x^2 + y_o^2 \right) + I_{xf} + I_{yf} \right]$$

[AISI S100, Eq. C3.1.4-15]

$$\tilde{k}_{\phi wg} = \frac{h_o t \pi^2}{13440} \left[\frac{\left(45360(1-\xi_{web}) + 62160\right)\left(\frac{L}{h_o}\right)^2 + 448\pi^2 + \left(\frac{h_o}{L}\right)^2 \left[53 + 3(1-\xi_{web})\right]\pi^4}{\pi^4 + 28\pi^2\left(\frac{L}{h_o}\right)^2 + 420\left(\frac{L}{h_o}\right)^4} \right]$$

[AISI S100, Eq. C3.1.4-16]

Negative Moment in x-x axis [$M_{x,Ed}^-$]

C-Section Front Column

$M_{xEd,M[-]}$	0.270	[kNm]	Ratio	6.339	[%]
$M_{n,x,Comp,M[-]}$	4.732	[kNm]			

C-Section Rear Column

$M_{xEd,M[-]}$	0.350	[kNm]	Ratio	8.450	[%]
$M_{n,x,Comp,M[-]}$	4.602	[kNm]			

Positive Moment in y-y axis [$M_{y,Ed}^+$]

C-Section Front Column

$M_{yEd,M[+]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{n,y,Comp,M[+]}$	3.698	[kNm]			

C-Section Rear Column

$M_{yEd,M[+]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{n,y,Comp,M[+]}$	2.143	[kNm]			

Negative Moment in y-y axis [$M_{y,Ed}^-$]

C-Section Front Column

$M_{yEd,M[-]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{n,y,Comp,M[-]}$	2.143	[kNm]			

C-Section Rear Column

$M_{yEd,M[-]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{n,y,Comp,M[-]}$	2.143	[kNm]			

[iii] C-Section Column : Bending Moment [AS/NZS 4600, LSD]

[1] C-Section Column : Nominal Section Moment Capacity [AS/NZS 4600, 3.3.2.2]

Procedure	Description
I	Based on Initiation of Yielding
II	Based on Inelastic Reserve Capacity

k_φ	0.000	[N]	ξ_{web}	2.000	[ ]
$\tilde{k}_{\phi fg}$	16.212	[mm²]	$\tilde{k}_{\phi wg}$	0.897	[mm²]

$$F_d = \beta \frac{k_{\phi fe} + k_{\phi we} + k_\phi}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}}$$

F_d 1393.322 [MPa]

[AISI S100, Eq. C3.1.4-16]

$M_y = S_{fy} * F_y$ [AISI S100, Eq. C3.1.4-4]

$M_{cr} = S_f * F_d$ [AISI S100, Eq. C3.1.4-5]

S_f	13521.309	[mm³]	→	M_{cr}	18839541.235	[Nmm]
S_{fy}	13521.309	[mm³]	→	M_y	4732458.074	[Nmm]

$$\lambda_d = \sqrt{M_y / M_{crd}}$$

λd 0.501

[AISI S100, Eq. C3.1.4-3]

$\lambda_d \le 0.673$	$\lambda_d > 0.673$
$M_n = M_y$	$M_n = \left(1 - 0.22\left(\frac{M_{crd}}{M_y}\right)^{0.5}\right)\left(\frac{M_{crd}}{M_y}\right)^{0.5} M_y$
[AISI S100, Eq. C3.1.4-1]	[AISI S100, Eq. C3.1.4-2]

M_n	4732458.074	[Nmm]	**M_n**	**4.732**	**[kNm]**

[4] C-Section Column : Bending Moment Verification [AISI S100, LRFD]

$M \le \Phi_b * M_n$ [AISI S100, Eq. A5.1.1-1] | M_n = MIN [$M_{n,C3.1.1}$; $M_{n,C3.1.2.1}$; $M_{n,C3.1.4}$]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

C-Section Front Column

$M_{xEd,M[+]}$	0.270	0.270	Ratio	6.339	[%]
$M_{n,x,Comp,M[+]}$	4.732	[kNm]			

C-Section Rear Column

$M_{xEd,M[+]}$	0.350	[kNm]	Ratio	8.450	[%]
$M_{n,x,Comp,M[+]}$	4.602	[kNm]			

Procedure II : Based on Inelastic Reserve Capacity

The inelastic flexural reserve capacity shall be permitted to be used when:

[1] Member is not subject to twisting, lateral, torsional, or flexural-torsional buckling

[2] Effect of cold work of forming is not included in determining the yield stress f_y

[3] Ratio of the depth of the compressed portion of the web to its thickness not exceed λ_1

[4] Shear force does not exceed **0.35*fy** times web area

[5] The angle between any web and the vertical does not exceed 30

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_t]
Sections with stiffened or partially stiffened compression flanges	3.3.2	0.950

Procedure: I | $M_s = Z_e f_y$ [AS/NZS 4600, Eq. 3.3.2.2]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

	$I_{x,el,M[+]}$	625036.020	[mm⁴]		
$Z_{el,Comp}$	13521.309	[mm³]	$Z_{el,Tens}$	14278.705	[mm³]
	$I_{x,eff,M[+]}$	625036.020	[mm⁴]		
$Z_{eff,Comp}$	13521.309	[mm³]	$Z_{eff,Tens}$	14278.705	[mm³]

$Z_{el,Comp}$ | **Section is fully effective** | $Z_{eff,Comp}$

f_y	----	[MPa]
f_{ya}	388.471	[MPa]

↓

$M_{s,x,Comp,M[+]}$	5252632.013	[Nmm]	$M_{s,x,Tens,M[+]}$	5546858.122	[Nmm]
$M_{s,x,Comp,M[+]}$	**5.253**	**[kNm]**	**$M_{s,x,Tens,M[+]}$**	**5.547**	**[kNm]**

Negative Moment in x-x axis [$M_{x,Ed}^-$]

	$I_{x,el,M[-]}$	625036.020	[mm⁴]		
$Z_{el,Comp}$	14278.705	[mm³]	$Z_{el,Tens}$	13521.309	[mm³]
	$I_{x,eff,M[-]}$	625036.020	[mm⁴]		
$Z_{eff,Comp}$	14278.705	[mm³]	$Z_{eff,Tens}$	13521.309	[mm³]

$Z_{el,Comp}$	Section is fully effective	$Z_{eff,Comp}$

f_y	----	[MPa]
f_{ya}	388.471	[MPa]

↓

$M_{s,x,Comp,M[-]}$	5546858.122	[Nmm]	$M_{s,x,Tens,M[-]}$	5252632.013	[Nmm]
$M_{s,x,Comp,M[-]}$	**5.547**	**[kNm]**	**$M_{s,x,Tens,M[-]}$**	**5.253**	**[kNm]**

Positive Moment in y-y axis [$M_{y,Ed}^+$]

	$I_{y,el,M[+]}$	153816.866	[mm^4]		
$Z_{el,Comp}$	9518.806	[mm^3]	$Z_{el,Tens}$	5515.375	[mm^3]
	$I_{y,eff,M[+]}$	153816.866	[mm^4]		
$Z_{eff,Comp}$	9518.806	[mm^3]	$Z_{eff,Tens}$	5515.375	[mm^3]

$Z_{el,Comp}$	Section is fully effective	$Z_{eff,Comp}$

f_y	----	[MPa]
f_{ya}	388.471	[MPa]

↓

$M_{s,y,Comp,M[+]}$	3697776.967	[Nmm]	$M_{s,y,Tens,M[+]}$	2142561.631	[Nmm]
$M_{s,y,Comp,M[+]}$	**3.698**	**[kNm]**	**$M_{s,y,Tens,M[+]}$**	**2.143**	**[kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^-$]

	$I_{y,el,M[-]}$	153816.866	[mm^4]		
$Z_{el,Comp}$	5515.375	[mm^3]	$Z_{el,Tens}$	9518.806	[mm^3]
	$I_{y,eff,M[-]}$	153816.866	[mm^4]		
$Z_{eff,Comp}$	5515.375	[mm^3]	$Z_{eff,Tens}$	9518.806	[mm^3]

$Z_{el,Comp}$	Section is fully effective	$Z_{eff,Comp}$

f_y	----	[MPa]
f_{ya}	388.471	[MPa]

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Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993 Office: ---- Author: JOSÉ ANTÓNIO
Version: 1.000 Date: 05/09/2019 Project: MASTER THESIS Client: COIMBRA UNIVERSITY

$$\lambda_b = \sqrt{\frac{M_y}{M_o}}$$

[AS/NZS 4600, Eq. 3.3.3.2(7)]

$\lambda_{b,Front\ Column}$	0.485	[ ]
$\lambda_{b,Rear\ Column}$	0.828	[ ]

$\lambda_b \leq 0.600$ $M_c = M_y$ [AS/NZS 4600, Eq. 3.3.3.2(3)]

$0.600 < \lambda_b < 1.336$

$$M_c = 1.11 M_y \left[1 - \left(\frac{10\lambda_b^2}{36}\right)\right]$$

[AS/NZS 4600, Eq. 3.3.3.2(4)]

$\lambda_b \geq 1.336$

$$M_c = M_y \left(\frac{1}{\lambda_b^2}\right)$$

[AS/NZS 4600, Eq. 3.3.3.2(5)]

Front Column [M_c]

$\lambda_b \leq 0.600$		**$0.600 < \lambda_b < 1.336$**		**$\lambda_b \geq 1.336$**	
M_c		M_c		M_c	
4997546.647	[Nmm]	----	[Nmm]	----	[Nmm]

Rear Column [M_c]

$\lambda_b \leq 0.600$		**$0.600 < \lambda_b < 1.336$**		**$\lambda_b \geq 1.336$**	
M_c		M_c		M_c	
----	[Nmm]	5441589.056	[Nmm]	----	[Nmm]

$f_c = M_c / Z_f$

[AS/NZS 4600, Eq. 3.3.3.2(2)]

$f_{c,Console\ Beam}$	350.000	[MPa]
$f_{c,Middle\ Beam}$	381.098	[MPa]

$Z_c^{+/-}$ 13521.309 [mm^3] $M_b = Z_c * f_c$ [AS/NZS 4600, Eq. 3.3.3.2(1)]

Front Column [$M_{b,Comp}^{+/-}$]

$\lambda_b \leq 0.600$		**$0.600 < \lambda_b < 1.336$**		**$\lambda_b \geq 1.336$**	
M_b		M_b		M_b	
4732458.074	[Nmm]	----	[Nmm]	----	[Nmm]

Rear Column [$M_{b,Comp}^{+/-}$]

$\lambda_b \leq 0.600$		**$0.600 < \lambda_b < 1.336$**		**$\lambda_b \geq 1.336$**	
M_b		M_b		M_b	
----	[Nmm]	5152946.812	[Nmm]	----	[Nmm]

$M_{n,Comp,Front\ C}$	4.732	[kNm]	$M_{n,Comp,Rear\ C}$	5.153	[kNm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993 Office: ---- Author: JOSÉ ANTÓNIO
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$M_{s,y,Comp,M[-]}$	2142561.631	[Nmm]	$M_{s,y,Tens,M[-]}$	3697776.967	[Nmm]
$M_{s,y,Comp,M[-]}$	**2.143**	**[kNm]**	**$M_{s,y,Tens,M[-]}$**	**3.698**	**[kNm]**

[2] C-Section Column : Members subject to Lateral Buckling [AS/NZS 4600, 3.3.3.2.1]

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_b]
Member moment capacity: Members subject to lateral buckling	3.3.3.2	0.900

$M_b = Z_C f_C$ [AS/NZS 4600, Eq. 3.3.3.2(1)]

Singly, doubly and point-symmetric sections bending about the symmetry axis [x-x]

C_b

C_b shall be permitted to be conservatively taken as unity for all cases.

For cantilevers or overhangs where the free end is unbraced, C_b shall be taken as unily

C_b 1.000

$$r_{01} = \sqrt{r_x^2 + r_y^2 + x_o^2 + y_o^2}$$

[AS/NZS, Eq. 3.3.3.2(10)]

r_x	35.455	[mm^2]
r_y	17.588	[mm^2]
x_0	-40.108	[mm]
y_0	0.000	[mm]
r_{01}	56.347	[mm^2]

Z_f	14278.705	[mm^3]	E	210.000	[GPa]

$$f_{oy} = \frac{\pi^2 E}{(l_{ey}/r_y)^2}$$

[AS/NZS 4600, Eq. 3.3.3.2(11)]

$f_{oy,Front\ Column}$	327.119	[N/mm^2]
$f_{oy,Rear\ Column}$	109.221	[N/mm^2]

$$f_{oz} = \frac{GJ}{Ar_{01}^2}\left(1 + \frac{\pi^2 EI_w}{GJl_{ez}^2}\right)$$

[AS/NZS 4600, Eq. 3.3.2.2(12)]

$f_{oz,Front\ Column}$	1752.839	[N/mm^2]
$f_{oz,Rear\ Column}$	619.213	[N/mm^2]

$$M_o = C_b A r_{01} \sqrt{f_{oy} f_{oz}}$$

[AS/NZS 4600, Eq. 3.3.3.2(8)]

$M_{o,Front\ Column}$	21215807.694	[MPa]
$M_{o,Rear\ Column}$	7286343.672	[MPa]

$M_y = Z_f * f_y$ [AS/NZS 4600, Eq. 3.3.3.2(7)] M_y 4997546.647 [Nmm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS

Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993 Office: ---- Author: JOSÉ ANTÓNIO
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Singly-symmetric sections bending about the axis perpendicular to the axis of simmetry [y-y]

C_S

C_S = [+] 1.000 → Moment causing compression on shear center side of centroid

C_S = [-] 1.000 → Moment causing tension on shear center side of centroid

$$f_{ox} = \frac{\pi^2 E}{(l_{ex}/r_x)^2}$$

[AS/NZS 4600, Eq. 3.3.3.2(14)]

$f_{ox,Front\ Column}$	2427.408	[N/mm^2]
$f_{ox,Rear\ Column}$	722.710	[N/mm^2]

$$\beta_y = \frac{1}{I_y}\left(\int_A xy^2\,dA + \int_A x^3\,dA\right) - 2x_o$$

β_y 55.317 [mm]

[AS/NZS 4600, Eq. 3.3.3.2(16)]

$C_{TF} = 0.6 - 0.4\,(M_1/M_2)$ C_{TF} 1.000

[AS/NZS 4600, Eq. 3.3.3.2(15)]

$$M_o = \frac{C_s A f_{ox}\left[(\beta_y/2) + C_s\sqrt{(\beta_y/2)^2 + r_{01}^2 (f_{oz}/f_{ox})}\right]}{C_{TF}}$$

[AS/NZS 4600, Eq. 3.3.3.2(13)]

$M_{y,Ed}^+$	→	C_s	1.000
$M_{y,Ed}^-$	→	C_s	-1.000

A	497.235	[mm^2]	r_{01}	56.347	[mm^2]
$Z_{f,y}^+$	9518.806	[mm^3]	$Z_{f,y}^-$	5515.375	[mm^3]
$f_{oz,Front\ Column}$	1752.839	[N/mm^2]	$f_{oz,Rear\ Column}$	619.213	[N/mm^2]

Front Column

$M_{o,Front\ C,M[+]}$	100126219.000	[Nmm]	$M_{o,Front\ C,M[-]}$	33358688.785	[Nmm]

Rear Column

$M_{o,Rear\ C,M[+]}$	31154608.132	[Nmm]	$M_{o,Rear\ C,M[-]}$	11275971.224	[Nmm]
M_y^+	3331582.037	[Nmm]	M_y^-	1930381.39	[Nmm]
f_y	350.000	[MPa]	f_y	350.000	[MPa]

$$\lambda_b = \sqrt{\frac{M_y}{M_o}}$$

[AS/NZS 4600, Eq. 3.3.3.2(7)]

$\lambda_{b,Console\ Beam}^+$	0.182	[ ]
$\lambda_{b,Console\ Beam}^-$	0.241	[ ]
$\lambda_{b,Middle\ Beam}^+$	0.327	[ ]
$\lambda_{b,Middle\ Beam}^-$	0.414	[ ]

$\lambda_b \le 0.600$	$M_c = M_y$ [AS/NZS 4600, Eq. 3.3.3.2(3)]
$0.600 < \lambda_b < 1.336$	$$M_c = 1.11 M_y \left[1 - \left(\frac{10\lambda_b^2}{36}\right)\right]$$ [AS/NZS 4600, Eq. 3.3.3.2(4)]
$\lambda_b \ge 1.336$	$$M_c = M_y\left(\frac{1}{\lambda_b^2}\right)$$ [AS/NZS 4600, Eq. 3.3.3.2(5)]

Front Column [M_c^+]

$\lambda_b \le 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \ge 1.336$	
M_c^+		M_c^+		M_c^+	
3331582.037	[Nmm]	----	[Nmm]	----	[Nmm]

Front Column [M_c^-]

$\lambda_b \le 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \ge 1.336$	
M_c^-		M_c^-		M_c^-	
1930381.390	[Nmm]	----	[Nmm]	----	[Nmm]

Rear Column [M_c^+]

$\lambda_b \le 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \ge 1.336$	
M_c^+		M_c^+		M_c^+	
3331582.037	[Nmm]	----	[Nmm]	----	[Nmm]

Rear Column [M_c^-]

$\lambda_b \le 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \ge 1.336$	
M_c^-		M_c^-		M_c^-	
1930381.390	[Nmm]	----	[Nmm]	----	[Nmm]

$f_c = M_c / Z_f$ [AS/NZS 4600, Eq. 3.3.3.2(2)]

$f_{c,Front\ Column}^+$	350.000	[MPa]
$f_{c,Front\ Column}^-$	350.000	[MPa]
$f_{c,Rear\ Column}^+$	350.000	[MPa]
$f_{c,Rear\ Column}^-$	350.000	[MPa]

$M_b = Z_c * f_c$ [AS/NZS 4600, Eq. 3.3.3.2(1)]

Z_c^+	9518.806	[mm^3]	Z_c^-	5515.375	[mm^3]

NOTE Flanges with 90 Degree Lips [AS/NZS 4600, D2]

b_w	90.000	[mm]	d_l	18.000	[mm]
b_f	46.500	[mm]	t	2.452	[mm]
A_f	158.154	[mm^2]	J_f	316.957	[mm^4]
$\bar{x}$	29.738	[mm]	I_{xf}	3826.135	[mm^4]
$\bar{y}$	2.512	[mm]	I_{yf}	37766.877	[mm^4]
E	210.000	[GPa]	I_{xyf}	6658.121	[mm^4]

$\lambda = 4.80\left(\frac{I_x b_f^2 b_w}{t^3}\right)^{0.25}$ [AS/NZS 4600, Eq. D2(6)]	λ	404.649	[mm]
$\eta = \left(\frac{\pi}{\lambda}\right)^2$ [AS/NZS 4600, Eq. D2(7)]	η	6.028E-05	[ ]
$\beta_1 = \bar{x}^2 + \left(\frac{I_x + I_y}{A}\right)$ [AS/NZS 4600, Eq. D2(5)]	β_1	1147.361	[mm^2]
$\alpha_2 = \eta\left(I_y + \frac{2}{\beta_1}\bar{y} b_f I_{xy}\right)$ [AS/NZS 4600, Eq. D2(3)]	α_2	2.358	[ ]
$\alpha_1' = \frac{\eta}{\beta_1}\left(I_x b_f^2 + 0.039 J \lambda^2\right)$ [AS/NZS 4600, Eq. D2(9)]	α_1'	0.541	[ ]
$\alpha_3 = \eta\left(\alpha_1 I_y - \frac{\eta}{\beta_1} I_{xy}^2 b_f^2\right)$ [AS/NZS 4600, Eq. D2(4)]	α_3'	0.928	[ ]
$f_{od} = \frac{E}{2A}\left[(\alpha_1+\alpha_2) - \sqrt{(\alpha_1+\alpha_2)^2 - 4\alpha_3}\right]$ [AS/NZS 4600, Eq. D2(1)]	f_{od}'	486.475	[MPa]
$k_\phi = \frac{Et^3}{5.46(b_w + 0.06\lambda)}\left[1 - \frac{1.11 f_{od}'}{Et^2}\left(\frac{b_w^2\lambda}{b_w^2+\lambda^2}\right)^2\right]$ [AS/NZS 4600, Eq. D2(8)]	K_Φ	4189.597	[mm]

Front Column [$M_{b,Comp}^+$]

$\lambda_b \le 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \ge 1.336$	
M_b		M_b		M_b	
3331582.037	[Nmm]	----	[Nmm]	----	[Nmm]

Front Column [$M_{b,Comp}^-$]

$\lambda_b \le 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \ge 1.336$	
M_b		M_b		M_b	
1930381.390	[Nmm]	----	[Nmm]	----	[Nmm]

Rear Column [$M_{b,Comp}^+$]

$\lambda_b \le 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \ge 1.336$	
M_b		M_b		M_b	
3331582.037	[Nmm]	----	[Nmm]	----	[Nmm]

Rear Column [$M_{b,Comp}^-$]

$\lambda_b \le 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \ge 1.336$	
M_b		M_b		M_b	
1930381.390	[Nmm]	----	[Nmm]	----	[Nmm]

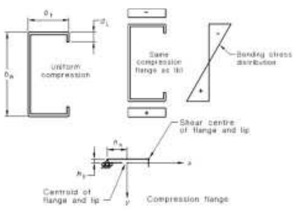
$M_{b,Comp,Front\ C}^+$	3.332	[kNm]	$M_{b,Comp,Front\ C}^-$	1.930	[kNm]
$M_{b,Comp,Rear\ C}^+$	3.332	[kNm]	$M_{b,Comp,Rear\ C}^-$	1.930	[kNm]

[3] C-Section Column : Members subject to Distortional Buckling [AS/NZS 4600, 3.3.3.3]

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_b]
Member moment capacity: Members subject to distortional buckling	3.3.3.3	0.900

$M_b = Z_C f_C$ [AS/NZS 4600, Eq. 3.3.3.3(1)]



Simple Lipped Channel Models for Distortional Buckling [AS/NZS 4600, Figure D1]

$\alpha_1 = \frac{\eta}{\beta_1}\left(I_x b_f^2 + 0.039 J \lambda^2\right) + \frac{k_\phi}{\beta_1 \eta E}$ [AS/NZS 4600, Eq. D2(2)]	α_1	0.829	[ ]
$\alpha_3 = \eta\left(\alpha_1 I_y - \frac{\eta}{\beta_1} I_{xy}^2 b_f^2\right)$ [AS/NZS 4600, Eq. D2(4)]	α_3	1.585	[ ]
$f_{od} = \frac{E}{2A}\left[(\alpha_1+\alpha_2) - \sqrt{(\alpha_1+\alpha_2)^2 - 4\alpha_3}\right]$ [AS/NZS 4600, Eq. D2(1)]	f_{od}	818.295	[MPa]

Distortional buckling involves rotation of a flange and lip about the flange/web junction of a channel

K_Φ	4189.597	[mm]	Z_c	Full section modulus	
$Z_{c,Full\ Section}$	13521.309	[mm^3]	$Z_{c,Effective\ Section}$	----	[mm^3]

$M_{od} = Z_f f_{od}$ [AS/NZS 4600, Eq. 3.3.3.3(9)]

$$\lambda_d = \sqrt{\frac{M_y}{M_{od}}}$$ [AS/NZS 4600, Eq. 3.3.3.3(8)]

Z_f	13521.309	[mm^3]
M_{od}	11064417.897	[Nmm]
M_y	4732458.074	[Nmm]
λ_d	0.654	[ ]

$\lambda_d \le 0.674$	**$\lambda_d > 0.674$**
$M_c = M_y$ [AS/NZS 4600, Eq. 3.3.3.3(3)]	$$M_c = \frac{M_y}{\lambda_d}\left(1 - \frac{0.22}{\lambda_d}\right)$$ [AS/NZS 4600, Eq. 3.3.3.3(4)]

$\lambda_d \le 0.674$		$\lambda_d > 0.674$	
M_c		M_c	
4732458.074	[Nmm]	----	[Nmm]

$f_c = M_c / Z_f$ [AS/NZS 4600, Eq. 3.3.3.3(2)] — f_c 350.000 [MPa]

↓

$M_b = Z_c f_c$ [AS/NZS 4600, Eq. 3.3.3.3(1)]

↓

M_b 4732458.074 [Nmm]

↓

M_b 4.732 [kNm]

Distortional buckling involves transverse bending of a vertical web with lateral displacement of the compression flange

$M_{od} = Z_f f_{od}$ [AS/NZS 4600, Eq. 3.3.3.3(9)]

Z_f	13521.309	[mm^3]
M_{od}	11064417.897	[Nmm]

$$\lambda_d = \sqrt{\frac{M_y}{M_{od}}}$$

[AS/NZS 4600, Eq. 3.3.3.3(8)]

M_y	4732458.074	[Nmm]
λ_d	0.654	[ ]

$\lambda_d \leq 0.590$	**$0.590 < \lambda_d \leq 1.700$**	**$\lambda_d > 1.700$**
$M_c = M_y$	$M_c = M_y\left(\frac{0.59}{\lambda_d}\right)$	$M_c = M_y\left(\frac{1}{\lambda_d^2}\right)$
[AS/NZS 4600, Eq. 3.3.3.3(5)]	[AS/NZS 4600, Eq. 3.3.3.3(6)]	[AS/NZS 4600, Eq. 3.3.3.3(7)]

$\lambda_d \leq 0.590$		**$0.590 < \lambda_d \leq 1.700$**		**$\lambda_d > 1.700$**	
M_c		M_c		M_c	
----	[Nmm]	4269329.600	[Nmm]	----	[Nmm]

$f_c = M_c / Z_f$ f_c 315.748 [MPa]
[AS/NZS 4600, Eq. 3.3.3.3(2)]

↓

$Z_{c,Effective\ Section}$ 13521.309 [mm^3]

↓

$M_b = Z_c f_c$ [AS/NZS 4600, Eq. 3.3.3.3(1)]

↓

M_b 4269329.600 [Nmm]

↓

M_b 4.269 [kNm]

M_b 4269329.600 [Nmm] **M_b 4.269 [kNm]**

[4] C-Section Column : Bending Moment Verification [AS/NZS 4600, LSD]

$M^* \leq \Phi_b * M_s$ [AS/NZS 4600, Eq. 3.3.1(1)] $M^* \leq \Phi_b * M_b$ [AS/NZS 4600, Eq. 3.3.1(2)]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

C-Section Front Column

$M_{x,Ed,M[+]}$	0.270	[kNm]	Ratio	7.027	[%]
$M_{s,x,Comp,M[+]}$	4.269	[kNm]			

[d] C-Section Strut

[i] C-Section Strut : Bending Moment [AISI S100, ASD]

[1] C-Section Strut: Nominal Section Strength [Resistance] [AISI S100, C3.1.1]

Procedure	Description
I	Based on Initiation of Yielding
II	Based on Inelastic Reserve Capacity

Procedure II : Based on Inelastic Reserve Capacity

The inelastic flexural reserve capacity shall be permitted to be used when:

[1] Member is not subject to twisting, lateral, torsional, or flexural-torsional buckling

[2] Effect of cold work of forming is not included in determining the yield stress F_y

[3] Ratio of the depth of the compressed portion of the web to its thickness not exceed λ_1

[4] Shear force does not exceed:

$0.35*F_y$ [ASD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]

$0.60*F_y$ [LRFD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]

[5] The angle between any web and the vertical does not exceed 30

Sections with stiffened or partially stiffened compression flanges Ω_b 1.670

Procedure I $M_n = S_e F_y$ [AISI S100, Eq. C3.1.1-1]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

$I_{x,el,M[+]}$ 85435.109 [mm^4]

$S_{el,Comp}$	3320.964	[mm^3]	$S_{el,Tens}$	3519.614	[mm^3]

$I_{x,eff,M[+]}$ 85435.109 [mm^4]

$S_{eff,Comp}$	3320.964	[mm^3]	$S_{eff,Tens}$	3519.614	[mm^3]

$S_{el,Comp}$ **Section is fully effective** $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	378.145	[MPa]

↓

$M_{n,x,Comp,M[+]}$	1255804.644	[Nmm]	$M_{n,x,Tens,M[+]}$	1330923.221	[Nmm]
$M_{n,x,Comp,M[+]}$	**1.256**	**[kNm]**	**$M_{n,x,Tens,M[+]}$**	**1.331**	**[kNm]**

C-Section Rear Column

$M_{x,Ed,M[+]}$	0.350	[kNm]	Ratio	9.109	[%]
$M_{s,x,Comp,M[+]}$	4.269	[kNm]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

C-Section Front Column

$M_{x,Ed,M[-]}$	0.270	[kNm]	Ratio	7.027	[%]
$M_{s,x,Comp,M[-]}$	4.269	[kNm]			

C-Section Rear Column

$M_{x,Ed,M[-]}$	0.350	[kNm]	Ratio	9.109	[%]
$M_{s,x,Comp,M[-]}$	4.269	[kNm]			

Positive Moment in y-y axis [$M_{y,Ed}^+$]

C-Section Front Column

$M_{y,Ed,M[+]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{s,y,Comp,M[+]}$	3.332	[kNm]			

C-Section Rear Column

$M_{y,Ed,M[+]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{s,y,Comp,M[+]}$	3.332	[kNm]			

Negative Moment in y-y axis [$M_{y,Ed}^-$]

C-Section Front Column

$M_{y,Ed,M[-]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{s,y,Comp,M[-]}$	1.930	[kNm]			

C-Section Rear Column

$M_{y,Ed,M[-]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{s,y,Comp,M[-]}$	1.930	[kNm]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

$I_{x,el,M[-]}$ 85435.109 [mm^4]

$S_{el,Comp}$	3519.614	[mm^3]	$S_{el,Tens}$	3320.964	[mm^3]

$I_{x,eff,M[-]}$ 85435.109 [mm^4]

$S_{eff,Comp}$	3519.614	[mm^3]	$S_{eff,Tens}$	3320.964	[mm^3]

$S_{el,Comp}$ **Section is fully effective** $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	378.145	[MPa]

↓

$M_{n,x,Comp,M[-]}$	1330923.221	[Nmm]	$M_{n,x,Tens,M[-]}$	1255804.644	[Nmm]
$M_{n,x,Comp,M[-]}$	**1.331**	**[kNm]**	**$M_{n,x,Tens,M[-]}$**	**1.256**	**[kNm]**

Positive Moment in y-y axis [$M_{y,Ed}^+$]

$I_{y,el,M[+]}$ 43399.345 [mm^4]

$S_{el,Comp}$	2873.453	[mm^3]	$S_{el,Tens}$	1851.157	[mm^3]

$I_{y,eff,M[+]}$ 43399.345 [mm^4]

$S_{eff,Comp}$	2873.453	[mm^3]	$S_{eff,Tens}$	1851.157	[mm^3]

$S_{el,Comp}$ **Section is fully effective** $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	378.145	[MPa]

↓

$M_{n,y,Comp,M[+]}$	1086580.872	[Nmm]	$M_{n,y,Tens,M[+]}$	700004.9691	[Nmm]
$M_{n,y,Comp,M[+]}$	**1.087**	**[kNm]**	**$M_{n,y,Tens,M[+]}$**	**0.700**	**[kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^-$]

$I_{y,el,M[-]}$ 43399.345 [mm^4]

$S_{el,Comp}$	1851.157	[mm^3]	$S_{el,Tens}$	2873.453	[mm^3]

$I_{y,eff,M[-]}$	43399.345	[mm^4]

$S_{eff,Comp}$	1851.157	[mm^3]	$S_{eff,Tens}$	2873.453	[mm^3]

$S_{el,Comp}$ **Section is fully effective** $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	378.145	[MPa]

↓

$M_{n,y,Comp,M[-]}$	700004.9691	[Nmm]	$M_{n,y,Tens,M[-]}$	1086580.872	[Nmm]

↓

$M_{n,y,Comp,M[-]}$	**0.700**	**[kNm]**	**$M_{n,y,Tens,M[-]}$**	**1.087**	**[kNm]**

[2] C-Section Strut : Lateral-Torsional Buckling Strength [Resistance] [AISI S100, C3.1.2.1]

Ω_b 1.670 | $M_n = S_C F_C$ [AISI S100, Eq. C3.1.2.1-1]

Singly-symmetric sections bending about the symmetry axis [x-x]

C_b

C_b shall be permitted to be conservatively taken as unity for all cases.

For cantilevers or overhangs where the free end is unbraced, C_b shall be taken as unity

C_b	1.000		r_x	20.601	[mm^2]
			r_y	14.683	[mm^2]
			x_0	-35.537	[mm]
			r_0	43.621	[mm^2]

$$r_0 = \sqrt{r_x^2 + r_y^2 + x_0^2}$$

[AISI S100, Eq. C3.1.2.1-7]

S_f	3519.614	[mm^3]	E	210.000	[GPa]

$$\sigma_{ey} = \frac{\pi^2 E}{(K_y L_y / r_y)^2}$$

$\sigma_{ey,Strut}$ 117.489 [N/mm^2]

[AISI S100, Eq. C3.1.2.1-8]

$$\sigma_t = \frac{1}{A r_o^2}\left[GJ + \frac{\pi^2 E C_w}{(K_t L_t)^2}\right]$$

$\sigma_{t,Strut}$ 67.264 [N/mm^2]

[AISI S100, Eq. C3.1.2.1-9]

$$F_e = \frac{C_b r_o A}{S_f}\sqrt{\sigma_{ey}\sigma_t}$$

$F_{e,Strut}$ 221.804 [MPa]

[AISI S100, Eq. C3.1.2.1-4]

F_y	----	[MPa]	F_{ya}	378.145	[MPa]

A_g	201.315	[mm^2]	r_0	43.621	[mm^2]
$S_{f,y}^+$	2873.453	[mm^3]	$S_{f,y}^-$	1851.157	[mm^3]
$\sigma_{t,Strut}$	67.264	[N/mm^2]			

Front Strut					
$F_{e,Front\ Strut,M[+]}$	1476.276	[MPa]	$F_{e,Front\ Strut,M[-]}$	152.780	[MPa]

$M_{n,Comp}^+$

F_y	----	[MPa]	F_{ya}	378.145	[MPa]

$M_{n,Comp}^-$

F_y	----	[MPa]	F_{ya}	378.145	[MPa]

$F_e \geq 2.780 * F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_y

Available flexural strength [moment resistance] shall be determined with Section C3.1.1(a)

$2.780 * F_y > F_e > 0.560 * F_y$

$$F_c = \frac{10}{9}F_y\left(1 - \frac{10F_y}{36F_e}\right)$$

[AISI S100, Eq. C3.1.2.1-2]

$0.560 * F_y \geq F_e$

$F_c = F_e$

[AISI S100, Eq. C3.1.2.1-3]

$S_{c,y}^+$	2873.453	[mm^3]	$S_{c,y}^-$	1851.157	[mm^3]

Strut [$F_{c,M[+]}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Strut [$F_{c,M[-]}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
No		No		Yes	
----	[MPa]	----	[MPa]	152.780	[MPa]

Strut [$M_{n,Comp}^+$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
1.087	[kNm]	----	[kNm]	----	[kNm]

Strut [$M_{n,Comp}^-$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
----	[kNm]	----	[kNm]	0.283	[kNm]

$F_e \geq 2.780 * F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_y

Available flexural strength [moment resistance] shall be determined with Section C3.1.1(a)

$2.780 * F_y > F_e > 0.560 * F_y$

$$F_c = \frac{10}{9}F_y\left(1 - \frac{10F_y}{36F_e}\right)$$

[AISI S100, Eq. C3.1.2.1-2]

$0.560 * F_y \geq F_e$

$F_c = F_e$

[AISI S100, Eq. C3.1.2.1-3]

S_c 3320.964 [mm^3]

Strut [F_c]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
No		Yes		No	
----	[MPa]	221.184	[MPa]	----	[MPa]

Strut [$M_{n,Comp}^{+/-}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
----	[kNm]	0.735	[kNm]	----	[kNm]

$M_{n,Comp,Strut}$ 0.735 [kNm]

Singly-symmetric sections bending about the axis perpendicular to the axis of simmetry [y-y]

C_S

C_S = [+] 1.000 → Moment causing compression on shear center side of centroid

C_S = [-] 1.000 → Moment causing tension on shear center side of centroid

$$\sigma_{ex} = \frac{\pi^2 E}{(K_x L_x / r_x)^2}$$

$\sigma_{ex,Strut}$ 231.286 [N/mm^2]

[AISI S100, Eq. C3.1.2.1-11]

$$j = \frac{1}{2I_y}\left[\int_A x^3 dA + \int_A xy^2 dA\right] - x_0$$

j 42.516 [mm]

[AISI S100, Eq. C3.1.2.1-11]

$$C_{TF} = 0.6 - 0.4\,(M_1/M_2)$$

C_{TF} 1.000

[AISI S100, Eq. C3.1.2.1-11]

$$F_e = \frac{C_s A \sigma_{ex}}{C_{TF} S_f}\left[j + C_s\sqrt{j^2 + r_0^2(\sigma_t/\sigma_{ex})}\right]$$

[AISI S100, Eq. C3.1.2.1-10]

$M_{y,Ed}^+$	→	C_s	1.000
$M_{y,Ed}^-$	→	C_s	-1.000

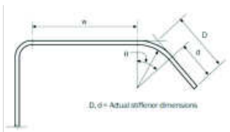
Strut [$M_{n,Comp}$]					
$M_{n,Comp}^+$	1.087	[kNm]	$M_{n,Comp}^-$	0.283	[kNm]

[3] C-Section Strut : Distortional Buckling Strength [Resistance] [AISI S100, C3.1.4]

Ω_b 1.670

For C- and Z-Sections or any Open Section with a Stiffened Compression Flange Extending to One Side of the Web where the Stiffener is either a Simple Lip or a Complex Edge Stiffener

[AISI S100, Figure B2.3-2]



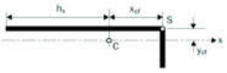
[AISI S100, Figure B4-1]

Dimensional Limits		
[1]	$50 \leq h_o / t$	KO
	$h_o / t \leq 200$	OK
[2]	$25 \leq b_o / t$	OK
	$b_o / t \leq 100$	OK
[3]	$6.25 < D / t$	OK
	$D / t \leq 50$	OK
[4]	$45° \leq \theta$	OK
	$\theta \leq 90°$	OK
[5]	$2 \leq h_o / b_o$	KO
	$h_o / b_o \leq 8$	OK
[6]	$0.04 \leq D * \sin[\theta] / b_o$	OK
	$D * \sin[\theta] / b_o \leq 0.50$	OK

$$L_{cr} = \left(\frac{4\pi^4 h_o(1-\mu^2)}{t^3}\left(I_{xf}(x_o - h_x)^2 + C_{wf} - \frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2\right) + \frac{\pi^4 h_o^4}{720}\right)^{1/4}$$

[AISI S100, Eq. C3.1.4-12]

NOTE — Flanges with 90 Degree Lips



			A_f	55.385	[mm^2]
			I_{xf}	102.528	[mm^4]
			I_{yf}	5903.746	[mm^4]
			I_{xyf}	358.596	[mm^5]
			h_x	-18.593	[mm]
x_{0f}	13.503	[mm]	J_f	38.923	[mm^4]
y_{0f}	-0.479	[mm]	C_{wf}	0.000	[mm^6]
h_0	50.000	[mm]	v [μ]	0.300	[ ]
β	1.000		$L = L_{cr}$	148.214	[mm]
E	210.000	[GPa]	G	80.769	[GPa]

$$k_{\phi fe} = \left(\frac{\pi}{L}\right)^4 \left(EI_{xf}(x_o - h_x)^2 + EC_{wf} - E\frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2 \right) + \left(\frac{\pi}{L}\right)^2 GJ_f$$

[AISI S100, Eq. C3.1.4-13]

$$k_{\phi we} = \frac{Et^3}{12(1-\mu^2)}\left(\frac{3}{h_o} + \left(\frac{\pi}{L}\right)^2 \frac{19 h_o}{60} + \left(\frac{\pi}{L}\right)^4 \frac{h_o^3}{240}\right)$$

[AISI S100, Eq. C3.1.4-14]

$k_{\phi fe}$	4938.473	[N]	$k_{\phi we}$	3957.192	[N]

$$\tilde{k}_{\phi fg} = \left(\frac{\pi}{L}\right)^2 \left[A_f\left((x_o - h_x)^2 \left(\frac{I_{xyf}}{I_{yf}}\right)^2 - 2y_o(x_o - h_x)\left(\frac{I_{xyf}}{I_{yf}}\right) + h_x^2 + y_o^2 \right) + I_{xf} + I_{yf} \right]$$

[AISI S100, Eq. C3.1.4-15]

$$\tilde{k}_{\phi wg} = \frac{h_o t \pi^2}{13440}\left(\frac{\left[45360(1-\xi_{web}) + 62160\right]\left(\frac{L}{h_o}\right)^2 + 448\pi^2 + \left(\frac{h_o}{L}\right)^2\left[53 + 3(1-\xi_{web})\right]\pi^4}{\pi^4 + 28\pi^2\left(\frac{L}{h_o}\right)^2 + 420\left(\frac{L}{h_o}\right)^4} \right)$$

[AISI S100, Eq. C3.1.4-16]

k_ϕ	0.000	[N]	ξ_{web}	2.000	[ ]
$\tilde{k}_{\phi fg}$	11.447	[mm^2]	$\tilde{k}_{\phi wg}$	0.233	[mm^2]

$$F_d = \beta \frac{k_{\phi fe} + k_{\phi we} + k_\phi}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}}$$

F_d 761.623 [MPa]

[AISI S100, Eq. C3.1.4-16]

$M_y = S_{fy} * F_y$ [AISI S100, Eq. C3.1.4-4]

$M_{cr} = S_f * F_d$ [AISI S100, Eq. C3.1.4-5]

S_f	3320.964	[mm^3]	→	M_{cr}	2529322.957	[Nmm]
S_{fy}	3320.964	[mm^3]	→	M_y	1162337.256	[Nmm]

$\lambda_d = \sqrt{M_y / M_{crd}}$ λd 0.678

[AISI S100, Eq. C3.1.4-3]

$\lambda_d \le 0.673$	$\lambda_d > 0.673$
$M_n = M_y$	$M_n = \left(1 - 0.22\left(\frac{M_{crd}}{M_y}\right)^{0.5}\right)\left(\frac{M_{crd}}{M_y}\right)^{0.5} M_y$
[AISI S100, Eq. C3.1.4-1]	[AISI S100, Eq. C3.1.4-2]

M_n	1158170.279	[Nmm]	**M_n**	**1.158**	**[kNm]**

[4] C-Section Strut: Bending Moment Verification [AISI S100, ASD]

$M \le M_n / \Omega_b$ [AISI S100, Eq. A4.1.1-1] | $M_n = MIN [M_{n,C3.1.1} ; M_{n,C3.1.2.1} ; M_{n,C3.1.4}]$

Positive Moment in x-x axis [$M_{x,Ed}^+$]

C-Section Strut

$M_{x,Ed,M[+]}$	0.010	[kNm]	Ratio	2.274	[%]
$M_{n,x,Comp,M[+]}$	0.735	[kNm]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

C-Section Strut

$M_{x,Ed,M[-]}$	0.010	[kNm]	Ratio	2.274	[%]
$M_{n,x,Comp,M[-]}$	0.735	[kNm]			

Positive Moment in y-y axis [$M_{y,Ed}^+$]

C-Section Strut

$M_{y,Ed,M[+]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{n,y,Comp,M[+]}$	1.087	[kNm]			

Negative Moment in y-y axis [$M_{y,Ed}^-$]

C-Section Strut

$M_{y,Ed,M[-]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{n,y,Comp,M[-]}$	0.283	[kNm]			

[ii] C-Section Strut : Bending Moment [AISI S100, LRFD]

[1] C-Section Strut: Nominal Section Strength [Resistance] [AISI S100, C3.1.1]

Procedure	Description
I	Based on Initiation of Yielding
II	Based on Inelastic Reserve Capacity

Procedure II : Based on Inelastic Reserve Capacity

The inelastic flexural reserve capacity shall be permitted to be used when:

[1] Member is not subject to twisting, lateral, torsional, or flexural-torsional buckling

[2] Effect of cold work of forming is not included in determining the yield stress F_y

[3] Ratio of the depth of the compressed portion of the web to its thickness not exceed λ_1

[4] Shear force does not exceed:

$0.35*F_y$ [ASD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]

$0.60*F_y$ [LRFD] times web area [h_t - Stiffened elements | w_t - Unstiffened elements]

[5] The angle between any web and the vertical does not exceed 30

Sections with stiffened or partially stiffened compression flanges — Φ_b 0.950

Procedure: I — $M_n = S_e F_y$ [AISI S100, Eq. C3.1.1-1]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

	$I_{x,el,M[+]}$	85435.109	[mm^4]		
$S_{el,Comp}$	3320.964	[mm^3]	$S_{el,Tens}$	3519.614	[mm^3]

	$I_{x,eff,M[+]}$	85435.109	[mm^4]		
$S_{eff,Comp}$	3320.964	[mm^3]	$S_{eff,Tens}$	3519.614	[mm^3]

$S_{el,Comp}$ — **Section is fully effective** — $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	378.145	[MPa]

↓

$M_{n,x,Comp,M[+]}$	1255804.644	[Nmm]	$M_{n,x,Tens,M[+]}$	1330923.221	[Nmm]
$M_{n,x,Comp,M[+]}$	**1.256**	**[kNm]**	**$M_{n,x,Tens,M[+]}$**	**1.331**	**[kNm]**

Negative Moment in x-x axis [$M_{x,Ed}^-$]

	$I_{x,el,M[-]}$	85435.109	[mm^4]		
$S_{el,Comp}$	3519.614	[mm^3]	$S_{el,Tens}$	3320.964	[mm^3]
	$I_{x,eff,M[-]}$	85435.109	[mm^4]		
$S_{eff,Comp}$	3519.614	[mm^3]	$S_{eff,Tens}$	3320.964	[mm^3]

$S_{el,Comp}$ — **Section is fully effective** — $S_{eff,Comp}$

F_y	----	[MPa]
F_{ya}	378.145	[MPa]

↓

$M_{n,x,Comp,M[-]}$	1330923.221	[Nmm]	$M_{n,x,Tens,M[-]}$	1255804.644	[Nmm]
$M_{n,x,Comp,M[-]}$	**1.331**	**[kNm]**	**$M_{n,x,Tens,M[-]}$**	**1.256**	**[kNm]**

Positive Moment in y-y axis [$M_{y,Ed}^+$]

	$I_{y,el,M[+]}$	43399.345	[mm^4]		
$S_{el,Comp}$	2873.453	[mm^3]	$S_{el,Tens}$	1851.157	[mm^3]
	$I_{y,eff,M[+]}$	43399.345	[mm^4]		
$S_{eff,Comp}$	2873.453	[mm^3]	$S_{eff,Tens}$	1851.157	[mm^3]

$S_{el,Comp}$	Section is fully effective	$S_{eff,Comp}$
F_y	----	[MPa]
F_{ya}	378.145	[MPa]

↓

$M_{n,y,Comp,M[+]}$	1086580.872	[Nmm]	$M_{n,y,Tens,M[+]}$	700004.9691	[Nmm]

↓

$M_{n,y,Comp,M[+]}$	**1.087**	**[kNm]**	**$M_{n,y,Tens,M[+]}$**	**0.700**	**[kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^-$]

	$I_{y,el,M[-]}$	43399.345	[mm^4]		
$S_{el,Comp}$	1851.157	[mm^3]	$S_{el,Tens}$	2873.453	[mm^3]
	$I_{y,eff,M[-]}$	43399.345	[mm^4]		
$S_{eff,Comp}$	1851.157	[mm^3]	$S_{eff,Tens}$	2873.453	[mm^3]

$S_{el,Comp}$	Section is fully effective	$S_{eff,Comp}$
F_y	----	[MPa]
F_{ya}	378.145	[MPa]

↓

$M_{n,y,Comp,M[-]}$	700004.9691	[Nmm]	$M_{n,y,Tens,M[-]}$	1086580.872	[Nmm]

↓

$M_{n,y,Comp,M[-]}$	**0.700**	**[kNm]**	**$M_{n,y,Tens,M[-]}$**	**1.087**	**[kNm]**

[2] C-Section Strut : Lateral-Torsional Buckling Strength [Resistance] [AISI S100, C3.1.2.1]

Φ_b 0.900

$M_n = S_C F_C$ [AISI S100, Eq. C3.1.2.1-1]

Singly-symmetric sections bending about the symmetry axis [x-x]

C_b

C_b shall be permitted to be conservatively taken as unily for all cases.

For cantilevers or overhangs where the free end is unbraced, C_b shall be taken as unity

C_b 1.000

$$r_o = \sqrt{r_x^2 + r_y^2 + x_o^2}$$

[AISI S100, Eq. C3.1.2.1-7]

r_x	20.601	[mm^2]
r_y	14.683	[mm^2]
x_0	-35.537	[mm]
r_0	43.621	[mm^2]

$$\sigma_{ex} = \frac{\pi^2 E}{(K_x L_x / r_x)^2}$$

$\sigma_{ex,Strut}$ 231.286 [N/mm^2]

[AISI S100, Eq. C3.1.2.1-11]

$$j = \frac{1}{2I_y}\left[\int_A x^3 dA + \int_A xy^2 dA\right] - x_o$$

j 42.516 [mm]

[AISI S100, Eq. C3.1.2.1-11]

$$C_{TF} = 0.6 - 0.4\,(M_1/M_2)$$

C_{TF} 1.000

[AISI S100, Eq. C3.1.2.1-11]

$$F_e = \frac{C_s A \sigma_{ex}}{C_{TF} S_f}\left[j + C_s\sqrt{j^2 + r_o^2(\sigma_t/\sigma_{ex})}\right]$$

[AISI S100, Eq. C3.1.2.1-10]

$M_{y,Ed}^+$	→	C_s	1.000
$M_{y,Ed}^-$	→	C_s	-1.000

A_g	201.315	[mm^2]	r_0	43.621	[mm^2]
$S_{f,y}^+$	2873.453	[mm^3]	$S_{f,y}^-$	1851.157	[mm^3]
$\sigma_{t,Strut}$	67.264	[N/mm^2]			

Strut					
$F_{e,Strut,M[+]}$	1476.276	[MPa]	$F_{e,Strut,M[-]}$	152.780	[MPa]
			$M_{n,Comp}^+$		
F_y	----	[MPa]	F_{ya}	378.145	[MPa]
			$M_{n,Comp}^-$		
F_y	----	[MPa]	F_{ya}	378.145	[MPa]

$F_e \geq 2.780 * F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_y

Available flexural strength [moment resistance] shall be determined with Section C3.1.1(a)

$2.780 * F_y > F_e > 0.560 * F_y$

$$F_c = \frac{10}{9}F_y\left(1 - \frac{10F_y}{36F_e}\right)$$

[AISI S100, Eq. C3.1.2.1-2]

$0.560 * F_y \geq F_e$

$F_c = F_e$

[AISI S100, Eq. C3.1.2.1-3]

$S_{c,y}^+$	2873.453	[mm^3]	$S_{c,y}^-$	1851.157	[mm^3]

S_f	3519.614	[mm^3]	E	210.000	[GPa]

$$\sigma_{ey} = \frac{\pi^2 E}{(K_y L_y / r_y)^2}$$

$\sigma_{ey,Strut}$ 117.489 [N/mm^2]

[AISI S100, Eq. C3.1.2.1-8]

$$\sigma_t = \frac{1}{A r_o^2}\left[GJ + \frac{\pi^2 E C_w}{(K_t L_t)^2}\right]$$

$\sigma_{t,Strut}$ 67.264 [N/mm^2]

[AISI S100, Eq. C3.1.2.1-9]

$$F_e = \frac{C_b r_o A}{S_f}\sqrt{\sigma_{ey}\sigma_t}$$

$F_{e,Strut}$ 221.804 [MPa]

[AISI S100, Eq. C3.1.2.1-4]

F_y	----	[MPa]	F_{ya}	378.145	[MPa]

$F_e \geq 2.780 * F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_y

Available flexural strength [moment resistance] shall be determined with Section C3.1.1(a)

$2.780 * F_y > F_e > 0.560 * F_y$

$$F_c = \frac{10}{9}F_y\left(1 - \frac{10F_y}{36F_e}\right)$$

[AISI S100, Eq. C3.1.2.1-2]

$0.560 * F_y \geq F_e$

$F_c = F_e$

[AISI S100, Eq. C3.1.2.1-3]

S_c 3320.964 [mm^3]

Strut [F_c]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
No		Yes		No	
----	[MPa]	221.184	[MPa]	----	[MPa]

Strut [$M_{n,Comp}^{+/-}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
----	[kNm]	0.735	[kNm]	----	[kNm]

$M_{n,CompStrut}$ 0.735 [kNm]

Singly-symmetric sections bending about the axis perpendicular to the axis of simmetry [y-y]

C_S

C_S = [+] 1.000 → Moment causing compression on shear center side of centroid

C_S = [-] 1.000 → Moment causing tension on shear center side of centroid

Strut [$F_{c,M[+]}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
Yes		No		No	
C3.1.1(a)	[MPa]	----	[MPa]	----	[MPa]

Strut [$F_{c,M[-]}$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
No		Yes		Yes	
----	[MPa]	131.289	[MPa]	152.780	[MPa]

Strut [$M_{n,Comp}^+$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
1.087	[kNm]	----	[kNm]	----	[kNm]

Strut [$M_{n,Comp}^-$]					
$F_e \geq 2.780 * F_y$		**$2.780 * F_y > F_e > 0.560 * F_y$**		**$0.560 * F_y \geq F_e$**	
----	[kNm]	0.243	[kNm]	0.283	[kNm]

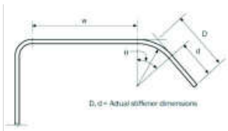
Strut [$M_{n,Comp}$]					
$M_{n,Comp}^+$	1.087	[kNm]	$M_{n,Comp}^-$	0.283	[kNm]

[3] C-Section Strut : Distortional Buckling Strength [Resistance] [AISI S100, C3.1.4]

Φ_b 0.900

For C- and Z-Sections or any Open Section with a Stiffened Compression Flange Extending to One Side of the Web where the Stiffener is either a Simple Lip or a Complex Edge Stiffener

[AISI S100, Figure B2.3-2]



[AISI S100, Figure B4-1]

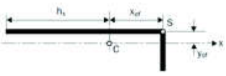
Dimensional Limits		
[1]	$50 \leq h_o / t$	KO
	$h_o / t \leq 200$	OK
[2]	$25 \leq b_o / t$	OK
	$b_o / t \leq 100$	OK
[3]	$6.25 < D / t$	OK
	$D / t \leq 50$	OK

Dimensional Limits		
[4]	45° ≤ θ	OK
	θ ≤ 90°	OK
[5]	2 ≤ h_o / b_o	KO
	h_o / b_o ≤ 8	OK
[6]	0.04 ≤ D * sin [θ] / b_o	OK
	D * sin [θ] / b_o ≤ 0.50	OK

$$L_{cr} = \left\{ \frac{4\pi^4 h_o (1-\mu^2)}{t^3} \left[I_{xf}(x_o - h_x)^2 + C_{wf} - \frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2 \right] + \frac{\pi^4 h_o^4}{720} \right\}^{1/4}$$

[AISI S100, Eq. C3.1.4-12]

NOTE Flanges with 90 Degree Lips



			A_f	55.385	[mm^2]
			I_{xf}	102.528	[mm^4]
			I_{yf}	5903.746	[mm^4]
			I_{xyf}	358.596	[mm^5]
			h_x	-18.593	[mm]
x_{0f}	13.503	[mm]	J_f	38.923	[mm^4]
y_{0f}	-0.479	[mm]	C_{wf}	0.000	[mm^6]
h_0	50.000	[mm]	v [μ]	0.300	[ ]
β	1.000		L = L_{cr}	148.214	[mm]
E	210.000	[GPa]	G	80.769	[GPa]

$$k_{\phi fe} = \left(\frac{\pi}{L}\right)^4 \left(EI_{xf}(x_o - h_x)^2 + EC_{wf} - E\frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2 \right) + \left(\frac{\pi}{L}\right)^2 GJ_f$$

[AISI S100, Eq. C3.1.4-13]

$$k_{\phi we} = \frac{Et^3}{12(1-\mu^2)} \left(\frac{3}{h_o} + \left(\frac{\pi}{L}\right)^2 \frac{19 h_o}{60} + \left(\frac{\pi}{L}\right)^4 \frac{h_o^3}{240} \right)$$

[AISI S100, Eq. C3.1.4-14]

$k_{\phi fe}$	4938.473	[N]	$k_{\phi we}$	3957.192	[N]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

C-Section Strut

$M_{x,Ed,M[+]}$	0.010	[kNm]	Ratio	1.513	[%]
$M_{n,x,Comp,M[+]}$	0.735	[kNm]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

C-Section Strut

$M_{x,Ed,M[-]}$	0.010	[kNm]	Ratio	1.513	[%]
$M_{n,x,Comp,M[-]}$	0.735	[kNm]			

Positive Moment in y-y axis [$M_{y,Ed}^+$]

C-Section Strut

$M_{y,Ed,M[+]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{n,y,Comp,M[+]}$	1.087	[kNm]			

Negative Moment in y-y axis [$M_{y,Ed}^-$]

C-Section Strut

$M_{y,Ed,M[-]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{n,y,Comp,M[-]}$	0.283	[kNm]			

[iii] C-Section Strut : Bending Moment [AS/NZS 4600, LSD]

[1] C-Section Strut : Nominal Section Moment Capacity [AS/NZS 4600, 3.3.2.2]

Procedure	Description
I	Based on Initiation of Yielding
II	Based on Inelastic Reserve Capacity

Procedure II : Based on Inelastic Reserve Capacity

The inelastic flexural reserve capacity shall be permitted to be used when:

[1] Member is not subject to twisting, lateral, torsional, or flexural-torsional buckling

[2] Effect of cold work of forming is not included in determining the yield stress f_y

[3] Ratio of the depth of the compressed portion of the web to its thickness not exceed λ_1

[4] Shear force does not exceed **0.35*fy** times web area

[5] The angle between any web and the vertical does not exceed 30

$$\tilde{k}_{\phi fg} = \left(\frac{\pi}{L}\right)^2 \left[A_f \left((x_o - h_x)^2 \left(\frac{I_{xyf}}{I_{yf}}\right)^2 - 2y_o(x_o - h_x)\left(\frac{I_{xyf}}{I_{yf}}\right) + h_x^2 + y_o^2 \right) + I_{xf} + I_{yf} \right]$$

[AISI S100, Eq. C3.1.4-15]

$$\tilde{k}_{\phi wg} = \frac{h_o t \pi^2}{13440} \left(\frac{\left[45360(1-\xi_{web}) + 62160\left(\frac{L}{h_o}\right)^2 + 448\pi^2 + \left(\frac{h_o}{L}\right)^2 [53 + 3(1-\xi_{web})]\pi^4\right]}{\pi^4 + 28\pi^2\left(\frac{L}{h_o}\right)^2 + 420\left(\frac{L}{h_o}\right)^4} \right)$$

[AISI S100, Eq. C3.1.4-16]

k_ϕ	0.000	[N]	ξ_{web}	2.000	[ ]
$\tilde{k}_{\phi fg}$	11.447	[mm^2]	$\tilde{k}_{\phi wg}$	0.233	[mm^2]

$$F_d = \beta \frac{k_{\phi fe} + k_{\phi we} + k_\phi}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}}$$

F_d 761.623 [MPa]

[AISI S100, Eq. C3.1.4-16]

$M_y = S_{fy} * F_y$ [AISI S100, Eq. C3.1.4-4]

$M_{cr} = S_f * F_d$ [AISI S100, Eq. C3.1.4-5]

S_f	3320.964	[mm^3]	→	M_{cr}	2529322.957	[Nmm]
S_{fy}	3320.964	[mm^3]	→	M_y	1162337.256	[Nmm]

$$\lambda_d = \sqrt{M_y / M_{crd}}$$

λd 0.678

[AISI S100, Eq. C3.1.4-3]

λ_d ≤ 0.673	**λ_d > 0.673**
$M_n = M_y$	$M_n = \left(1 - 0.22\left(\frac{M_{crd}}{M_y}\right)^{0.5}\right)\left(\frac{M_{crd}}{M_y}\right)^{0.5} M_y$
[AISI S100, Eq. C3.1.4-1]	[AISI S100, Eq. C3.1.4-2]

M_n	1158170.279	[Nmm]	**M_n**	**1.158**	**[kNm]**

[4] C-Section Strut : Bending Moment Verification [AISI S100, LRFD]

$M \le \Phi_b * M_n$ [AISI S100, Eq. A5.1.1-1] M_n = MIN [$M_{n,C3.1.1}$; $M_{n,C3.1.2.1}$; $M_{n,C3.1.4}$]

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_t]
Sections with stiffened or partially stiffened compression flanges	3.3.2	0.950

Procedure I $M_s = Z_e f_y$ [AS/NZS 4600, Eq. 3.3.2.2]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

$I_{x,el,M[+]}$	85435.109	[mm^4]			
$Z_{el,Comp}$	3320.964	[mm^3]	$Z_{el,Tens}$	3519.614	[mm^3]
$I_{x,eff,M[+]}$	85435.109	[mm^4]			
$Z_{eff,Comp}$	3320.964	[mm^3]	$Z_{eff,Tens}$	3519.614	[mm^3]
$Z_{el,Comp}$	Section is fully effective		$Z_{eff,Comp}$		
f_y	----	[MPa]			
f_{ya}	378.145	[MPa]			
$M_{s,x,Comp,M[+]}$	1255804.644	[Nmm]	$M_{s,x,Tens,M[+]}$	1330923.221	[Nmm]
$M_{s,x,Comp,M[+]}$	**1.256**	**[kNm]**	**$M_{s,x,Tens,M[+]}$**	**1.331**	**[kNm]**

Negative Moment in x-x axis [$M_{x,Ed}^-$]

$I_{x,el,M[-]}$	85435.109	[mm^4]			
$Z_{el,Comp}$	3519.614	[mm^3]	$Z_{el,Tens}$	3320.964	[mm^3]
$I_{x,eff,M[-]}$	85435.109	[mm^4]			
$Z_{eff,Comp}$	3519.614	[mm^3]	$Z_{eff,Tens}$	3320.964	[mm^3]
$Z_{el,Comp}$	Section is fully effective		$Z_{eff,Comp}$		
f_y	----	[MPa]			
f_{ya}	378.145	[MPa]			
$M_{s,x,Comp,M[-]}$	1330923.221	[Nmm]	$M_{s,x,Tens,M[-]}$	1255804.644	[Nmm]
$M_{s,x,Comp,M[-]}$	**1.331**	**[kNm]**	**$M_{s,x,Tens,M[-]}$**	**1.256**	**[kNm]**

Positive Moment in y-y axis [$M_{y,Ed}^{+}$]

	$I_{y,el,M[+]}$	43399.345	[mm^4]		
$Z_{el,Comp}$	2873.453	[mm^3]	$Z_{el,Tens}$	1851.157	[mm^3]
	$I_{y,eff,M[+]}$	43399.345	[mm^4]		
$Z_{eff,Comp}$	2873.453	[mm^3]	$Z_{eff,Tens}$	1851.157	[mm^3]

$Z_{el,Comp}$ | **Section is fully effective** | $Z_{eff,Comp}$

f_y	----	[MPa]
f_{ya}	378.145	[MPa]

↓

$M_{s,y,Comp,M[+]}$	1086580.872	[Nmm]	$M_{s,y,Tens,M[+]}$	700004.9691	[Nmm]
$M_{s,y,Comp,M[+]}$	**1.087**	**[kNm]**	**$M_{s,y,Tens,M[+]}$**	**0.700**	**[kNm]**

Negative Moment in y-y axis [$M_{y,Ed}^{-}$]

	$I_{y,el,M[-]}$	43399.345	[mm^4]		
$Z_{el,Comp}$	1851.157	[mm^3]	$Z_{el,Tens}$	2873.453	[mm^3]
	$I_{y,eff,M[-]}$	43399.345	[mm^4]		
$Z_{eff,Comp}$	1851.157	[mm^3]	$Z_{eff,Tens}$	2873.453	[mm^3]

$Z_{el,Comp}$ | **Section is fully effective** | $Z_{eff,Comp}$

f_y	----	[MPa]
f_{ya}	378.145	[MPa]

↓

$M_{s,y,Comp,M[-]}$	700004.9691	[Nmm]	$M_{s,y,Tens,M[-]}$	1086580.872	[Nmm]
$M_{s,y,Comp,M[-]}$	**0.700**	**[kNm]**	**$M_{s,y,Tens,M[-]}$**	**1.087**	**[kNm]**

[2] C-Section Strut : Members subject to Lateral Buckling [AS/NZS 4600, 3.3.3.2.1]

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_b]
Member moment capacity: Members subject to lateral buckling	3.3.3.2	0.900

$\lambda_b \geq 1.336$

$$M_c = M_y\left(\frac{1}{\lambda_b^2}\right)$$

[AS/NZS 4600, Eq. 3.3.3.2(5)]

Strut [M_c]

$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_c		M_c		M_c	
----	[Nmm]	1307434.709	[Nmm]	----	[Nmm]

$f_c = M_c / Z_f$ [AS/NZS 4600, Eq. 3.3.3.2(2)] — $f_{c,Strut}$ 371.471 [MPa]

$Z_c^{+/-}$ 3320.964 [mm^3] — $M_b = Z_c * f_c$ [AS/NZS 4600, Eq. 3.3.3.2(1)]

Strut [$M_{b,Comp}^{+/-}$]

$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_b		M_b		M_b	
----	[Nmm]	1233641.846	[Nmm]	----	[Nmm]

$M_{n,Comp,Front\ Strut}$ 1.234 [kNm]

Singly-symmetric sections bending about the axis perpendicular to the axis of simmetry [y-y]

C_S

C_S = [+] 1.000 → Moment causing compression on shear center side of centroid

C_S = [-] 1.000 → Moment causing tension on shear center side of centroid

$$f_{ox} = \frac{\pi^2 E}{(l_{ex}/r_x)^2}$$

$f_{ox,Strut}$ 231.286 [N/mm^2]

[AS/NZS 4600, Eq. 3.3.3.2(14)]

$$\beta_y = \frac{1}{I_y}\left(\int_A xy^2 dA + \int_A x^3 dA\right) - 2x_o$$

β_y 42.516 [mm]

[AS/NZS 4600, Eq. 3.3.3.2(16)]

$C_{TF} = 0.6 - 0.4\,(M_1/M_2)$ — C_{TF} 1.000

[AS/NZS 4600, Eq. 3.3.3.2(15)]

$$M_o = \frac{C_s A f_{ox}\left[(\beta_y/2) + C_s\sqrt{(\beta_y/2)^2 + r_{o1}^2 (f_{oz}/f_{ox})}\right]}{C_{TF}}$$

[AS/NZS 4600, Eq. 3.3.3.2(13)]

$M_b = Z_C f_C$ [AS/NZS 4600, Eq. 3.3.3.2(1)]

Singly, doubly and point-symmetric sections bending about the symmetry axis [x-x]

C_b

C_b shall be permitted to be conservatively taken as unity for all cases.

For cantilevers or overhangs where the free end is unbraced, C_b shall be taken as unity

C_b 1.000

$$r_{o1} = \sqrt{r_x^2 + r_y^2 + x_o^2 + y_o^2}$$

[AS/NZS, Eq. 3.3.3.2(10)]

r_x	20.601	[mm^2]
r_y	14.683	[mm^2]
x_0	-35.537	[mm]
y_0	0.000	[mm]
r_{01}	43.621	[mm^2]

Z_f	3519.614	[mm^3]	E	210.000	[GPa]

$$f_{oy} = \frac{\pi^2 E}{(l_{ey}/r_y)^2}$$

$f_{oy,Strut}$ 117.489 [N/mm^2]

[AS/NZS 4600, Eq. 3.3.3.2(11)]

$$f_{oz} = \frac{GJ}{Ar_{01}^2}\left(1 + \frac{\pi^2 E I_w}{GJ l_{ez}^2}\right)$$

$f_{oz,Strut}$ 67.264 [N/mm^2]

[AS/NZS 4600, Eq. 3.3.2.2(12)]

$$M_o = C_b A r_{o1}\sqrt{f_{oy} f_{oz}}$$

$M_{o,Strut}$ 780663.438 [MPa]

[AS/NZS 4600, Eq. 3.3.3.2(8)]

$M_y = Z_f * f_y$ [AS/NZS 4600, Eq. 3.3.3.2(7)] — M_y 1231864.886 [Nmm]

$$\lambda_b = \sqrt{\frac{M_y}{M_o}}$$

[AS/NZS 4600, Eq. 3.3.3.2(7)]

$\lambda_{b,Strut}$ 1.256 [ ]

$\lambda_b \leq 0.600$

$M_c = M_y$

[AS/NZS 4600, Eq. 3.3.3.2(3)]

$0.600 < \lambda_b < 1.336$

$$M_c = 1.11 M_y\left[1 - \left(\frac{10\lambda_b^2}{36}\right)\right]$$

[AS/NZS 4600, Eq. 3.3.3.2(4)]

$M_{y,Ed}^{+}$	→	C_s	1.000
$M_{y,Ed}^{-}$	→	C_s	-1.000

A	201.315	[mm^2]	r_{01}	43.621	[mm^2]
$Z_{f,y}^{+}$	2873.453	[mm^3]	$Z_{f,y}^{-}$	1851.157	[mm^3]
$f_{oz,Strut}$	67.264	[N/mm^2]			

Strut

$M_{o,Strut,M[+]}$	2466084.644	[Nmm]	$M_{o,Strut,M[-]}$	486488.872	[Nmm]
M_y^{+}	1005708.519	[Nmm]	M_y^{-}	647904.7987	[Nmm]
f_y	350.000	[MPa]	f_y	350.000	[MPa]

$$\lambda_b = \sqrt{\frac{M_y}{M_o}}$$

[AS/NZS 4600, Eq. 3.3.3.2(7)]

$\lambda_{b,Strut}^{+}$	0.639	[ ]
$\lambda_{b,Strut}^{-}$	1.154	[ ]

$\lambda_b \leq 0.600$

$M_c = M_y$

[AS/NZS 4600, Eq. 3.3.3.2(3)]

$0.600 < \lambda_b < 1.336$

$$M_c = 1.11 M_y\left[1 - \left(\frac{10\lambda_b^2}{36}\right)\right]$$

[AS/NZS 4600, Eq. 3.3.3.2(4)]

$\lambda_b \geq 1.336$

$$M_c = M_y\left(\frac{1}{\lambda_b^2}\right)$$

[AS/NZS 4600, Eq. 3.3.3.2(5)]

Strut [M_c^{+}]

$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_c^{+}		M_c^{+}		M_c^{+}	
----	[Nmm]	1103690.352	[Nmm]	----	[Nmm]

Strut [M_c^{-}]

$\lambda_b \leq 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \geq 1.336$	
M_c^{-}		M_c^{-}		M_c^{-}	
----	[Nmm]	692568.916	[Nmm]	----	[Nmm]

$f_c = M_c / Z_f$ [AS/NZS 4600, Eq. 3.3.3.2(2)]

$f_{c,Strut}^{+}$	384.099	[MPa]
$f_{c,Strut}^{-}$	374.128	[MPa]

$M_b = Z_c * f_c$ [AS/NZS 4600, Eq. 3.3.3.2(1)]

Z_c^+	2873.453	[mm^3]	Z_c^-	1851.157	[mm^3]

Strut [$M_{b,Comp}^+$]					
$\lambda_b \le 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \ge 1.336$	
M_b		M_b		M_b	
----	[Nmm]	1103690.352	[Nmm]	----	[Nmm]

Strut [$M_{b,Comp}^-$]					
$\lambda_b \le 0.600$		$0.600 < \lambda_b < 1.336$		$\lambda_b \ge 1.336$	
M_b		M_b		M_b	
----	[Nmm]	692568.916	[Nmm]	----	[Nmm]

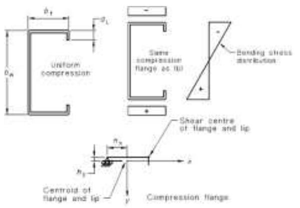
$M_{b,Comp,Strut}^+$	1.104	[kNm]	$M_{b,Comp,Strut}^-$	0.693	[kNm]

[3] C-Section Strut : Members subject to Distortional Buckling [AS/NZS 4600, 3.3.3.3]

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_b]
Member moment capacity: Members subject to distortional buckling	3.3.3.3	0.900

$M_b = Z_c f_c$ [AS/NZS 4600, Eq. 3.3.3.3(1)]



Simple Lipped Channel Models for Distortional Buckling [AS/NZS 4600, Figure D1]

$$\alpha_1 = \frac{\eta}{\beta_1}\left(I_x b_f^2 + 0.039 J \lambda^2\right) + \frac{k_\phi}{\beta_1 \eta E}$$ α_1 0.223 [ ]

[AS/NZS 4600, Eq. D2(2)]

$$\alpha_3 = \eta\left(\alpha_1 I_y - \frac{\eta}{\beta_1} I_{xy}^2 b_f^2\right)$$ α_3 0.309 [ ]

[AS/NZS 4600, Eq. D2(4)]

$$f_{od} = \frac{E}{2A}\left[(\alpha_1+\alpha_2) - \sqrt{(\alpha_1+\alpha_2)^2 - 4\alpha_3}\right]$$ f_{od} 541.768 [MPa]

[AS/NZS 4600, Eq. D2(1)]

Distortional buckling involves rotation of a flange and lip about the flange/web junction of a channel

K_Φ	1661.393	[mm]	Z_c	Full section modulus	
$Z_{c,Full\ Section}$	3320.964	[mm^3]	$Z_{c,Effective\ Section}$	----	[mm^3]

$M_{od} = Z_f f_{od}$ [AS/NZS 4600, Eq. 3.3.3.3(9)]

Z_f 3320.964 [mm^3]
M_{od} 1799193.159 [Nmm]

$$\lambda_d = \sqrt{\frac{M_y}{M_{od}}}$$ [AS/NZS 4600, Eq. 3.3.3.3(8)]

M_y 1162337.256 [Nmm]
λ_d 0.804 [ ]

$\lambda_d \le 0.674$	$\lambda_d > 0.674$
$M_c = M_y$	$M_c = \frac{M_y}{\lambda_d}\left(1 - \frac{0.22}{\lambda_d}\right)$
[AS/NZS 4600, Eq. 3.3.3.3(3)]	[AS/NZS 4600, Eq. 3.3.3.3(4)]

$\lambda_d \le 0.674$		$\lambda_d > 0.674$	
M_c		M_c	
----	[Nmm]	1050299.643	[Nmm]

$f_c = M_c / Z_f$ f_c 316.264 [MPa]

[AS/NZS 4600, Eq. 3.3.3.3(2)]

↓

$M_b = Z_c f_c$ [AS/NZS 4600, Eq. 3.3.3.3(1)]

↓

M_b 1050299.643 [Nmm]

↓

M_b 1.050 [kNm]

NOTE Flanges with 90 Degree Lips [AS/NZS 4600, D2]

b_w	50.000	[mm]	d_l	10.000	[mm]
b_f	40.000	[mm]	t	1.452	[mm]
A_f	72.600	[mm^2]	J_f	51.021	[mm^4]
$\bar{x}$	24.000	[mm]	I_{xf}	421.604	[mm^4]
$\bar{y}$	1.000	[mm]	I_{yf}	12392.951	[mm^4]
E	210.000	[GPa]	I_{xyf}	1161.600	[mm^4]

$$\lambda = 4.80\left(\frac{I_x b_f^2 b_w}{t^3}\right)^{0.25}$$ λ 276.544 [mm]

[AS/NZS 4600, Eq. D2(6)]

$$\eta = \left(\frac{\pi}{\lambda}\right)^2$$ η 1.291E-04 [ ]

[AS/NZS 4600, Eq. D2(7)]

$$\beta_1 = \bar{x}^2 + \left(\frac{I_x + I_y}{A}\right)$$ β_1 752.509 [mm^2]

[AS/NZS 4600, Eq. D2(5)]

$$\alpha_2 = \eta\left(I_y + \frac{2}{\beta_1}\bar{y} b_f I_{xy}\right)$$ α_2 1.615 [ ]

[AS/NZS 4600, Eq. D2(3)]

$$\alpha_1 = \frac{\eta}{\beta_1}\left(I_x b_f^2 + 0.039 J \lambda^2\right)$$ α_1' 0.142 [ ]

[AS/NZS 4600, Eq. D2(9)]

$$\alpha_3 = \eta\left(\alpha_1 I_y - \frac{\eta}{\beta_1} I_{xy}^2 b_f^2\right)$$ α_3' 0.179 [ ]

[AS/NZS 4600, Eq. D2(4)]

$$f_{od} = \frac{E}{2A}\left[(\alpha_1+\alpha_2) - \sqrt{(\alpha_1+\alpha_2)^2 - 4\alpha_3}\right]$$ f_{od}' 314.052 [MPa]

[AS/NZS 4600, Eq. D2(1)]

$$k_\phi = \frac{Et^3}{5.46(b_w + 0.06\lambda)}\left[1 - \frac{1.11 f_{od}'}{Et^2}\left(\frac{b_w^2 \lambda}{b_w^2 + \lambda^2}\right)^2\right]$$ K_Φ 1661.393 [mm]

[AS/NZS 4600, Eq. D2(8)]

Distortional buckling involves transverse bending of a vertical web with lateral displacement of the compression flange

$M_{od} = Z_f f_{od}$ [AS/NZS 4600, Eq. 3.3.3.3(9)]

Z_f 3320.964 [mm^3]
M_{od} 1799193.159 [Nmm]

$$\lambda_d = \sqrt{\frac{M_y}{M_{od}}}$$ [AS/NZS 4600, Eq. 3.3.3.3(8)]

M_y 1162337.256 [Nmm]
λ_d 0.804 [ ]

$\lambda_d \le 0.590$	$0.590 < \lambda_d \le 1.700$	$\lambda_d > 1.700$
$M_c = M_y$	$M_c = M_y\left(\frac{0.59}{\lambda_d}\right)$	$M_c = M_y\left(\frac{1}{\lambda_d^2}\right)$
[AS/NZS 4600, Eq. 3.3.3.3(5)]	[AS/NZS 4600, Eq. 3.3.3.3(6)]	[AS/NZS 4600, Eq. 3.3.3.3(7)]

$\lambda_d \le 0.590$		$0.590 < \lambda_d \le 1.700$		$\lambda_d > 1.700$	
M_c		M_c		M_c	
----	[Nmm]	853212.061	[Nmm]	----	[Nmm]

$f_c = M_c / Z_f$ f_c 256.917 [MPa]

[AS/NZS 4600, Eq. 3.3.3.3(2)]

↓

$Z_{c,Effective\ Section}$ 3320.964 [mm^3]

↓

$M_b = Z_c f_c$ [AS/NZS 4600, Eq. 3.3.3.3(1)]

↓

M_b 853212.061 [Nmm]

↓

M_b 0.853 [kNm]

M_b	853212.061	[Nmm]	**M_b**	**0.853**	**[kNm]**

[4] C-Section Beam : Bending Moment Verification [AS/NZS 4600, LSD]

$M^* \le \Phi_b * M_s$	[AS/NZS 4600, Eq. 3.3.1(1)]	$M^* \le \Phi_b * M_b$	[AS/NZS 4600, Eq. 3.3.1(2)]

Positive Moment in x-x axis [$M_{x,Ed}^+$]

C-Section Strut

$M_{x,Ed,M[+]}$	0.010	[kNm]	Ratio	1.302	[%]
$M_{s,x,Comp,M[+]}$	0.853	[kNm]			

Negative Moment in x-x axis [$M_{x,Ed}^-$]

C-Section Strut

$M_{x,Ed,M[-]}$	0.010	[kNm]	Ratio	1.302	[%]
$M_{s,x,Comp,M[-]}$	0.853	[kNm]			

Positive Moment in y-y axis [$M_{y,Ed}^+$]

C-Section Strut

$M_{y,Ed,M[+]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{s,y,Comp,M[+]}$	1.087	[kNm]			

Negative Moment in y-y axis [$M_{y,Ed}^-$]

C-Section Strut

$M_{y,Ed,M[-]}$	0.000	[kNm]	Ratio	0.000	[%]
$M_{s,y,Comp,M[-]}$	0.693	[kNm]			

[15.3] Shear **[AISI S100, C3.2 | AS/NZS 4600, 3.3.4]**

[a] Ω-Section Purlin

[i] Ω-Section Purlin : Shear [AISI S100, ASD]

[1] Ω-Section Purlin : Shear Strength [Resistance] of Webs without Holes [AISI S100, C3.2.1]

Ω_v	1.600		h_{plate}	51.640	[mm]
v [μ]	0.300		t	0.952	[mm]
$A_w = h * t$	A_w	49.162 [mm²]	Unreinforced Webs		
[AISI S100, Eq. C3.2.1-5]			k_v	5.340	
E	210.000	[GPa]	F_y	350.000	[MPa]

$h/t \le \sqrt{Ek_v/F_y}$	$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$	$h/t > 1.51\sqrt{Ek_v/F_y}$
$F_v = 0.60 * F_y$	$F_v = \frac{0.60\sqrt{Ek_vF_y}}{(h/t)}$	$F_v = \frac{\pi^2 Ek_v}{12(1-\mu^2)(h/t)^2}$
[AISI S100, Eq. C3.2.1-2]	[AISI S100, Eq. C3.2.1-3]	[AISI S100, Eq. C3.2.1-4]

[iii] Ω-Section Purlin : Shear [AS/NZS 4600, LSD]

[1] Ω-Section Purlin : Shear Strength [Resistance] of Webs without Holes [AS/NZS 4600, 3.3.4.1]

Table 1.6 : Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_v]
Web design : Shear	3.3.4	0.900

d_1	51.640	[mm]	t_w	0.952	[mm]
Unstiffened Webs	k_v	5.340	v	0.300	
E	210.000	[GPa]	f_y	350.000	[MPa]

$d_1/t_w \le \sqrt{Ek_v/f_y}$	$d_1/t_w > 1.415\sqrt{Ek_v/f_y}$
$V_v = 0.64 * f_y * d_1 * t_w$	$V_v = \frac{0.905 E k_v t_w^3}{d_1}$
[AS/NZS 4600, Eq. 3.3.4(1)]	[AS/NZS 4600, Eq. 3.3.4(3)]

$$\sqrt{Ek_v/f_y} < d_1/t_w \le 1.415\sqrt{Ek_v/f_y}$$

$$V_v = 0.64 t_w^2 \sqrt{Ek_v f_y}$$

[AS/NZS 4600, Eq. 3.3.4(2)]

[AS/NZS 4600, Eq. 3.3.4(1)]		[AS/NZS 4600, Eq. 3.3.4(2)]		[AS/NZS 4600, Eq. 3.3.4(3)]	
V_v		V_v		V_v	
11012.227	[N]	----	[N]	----	[N]

$V^* = \Phi_{vV}V_v$	[AS/NZS 4600]	V^*	**9.911**	**[kN / Web]**

$V_{z,Ed}$	1.010	[kN]	Ratio	5.095	[%]
V^*	19.822	[kN]			

[b] C-Section Beam

[i] C-Section Beam : Shear [AISI S100, ASD]

[1] C-Section Beam : Shear Strength [Resistance] of Webs without Holes [AISI S100, C3.2.1]

Ω_v	1.600	h_{plate}	112.096	[mm]

$h/t \le \sqrt{Ek_v/F_y}$		$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$		$h/t > 1.51\sqrt{Ek_v/F_y}$	
F_v		Fv		Fv	
210.000	[MPa]	----	[MPa]	----	[MPa]

$V_n = A_wF_v$	[AISI S100, Eq. C3.2.1-1]	V_n	**10.324**	**[kN / Web]**

$V_{z,Ed}$	1.010	[kN]	Ratio	7.826	[%]
V_n	20.648	[kN]			

[ii] Ω-Section Purlin : Shear [AISI S100, LRFD]

[1] Ω-Section Purlin : Shear Strength [Resistance] of Webs without Holes [AISI S100, C3.2.1]

Φ_v	0.950		h_{plate}	51.640	[mm]
v [μ]	0.300		t	0.952	[mm]
$A_w = h * t$	A_w	49.162 [mm²]	Unreinforced Webs		
[AISI S100, Eq. C3.2.1-5]			k_v	5.340	
E	210.000	[GPa]	F_y	350.000	[MPa]

$h/t \le \sqrt{Ek_v/F_y}$	$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$	$h/t > 1.51\sqrt{Ek_v/F_y}$
$F_v = 0.60 * F_y$	$F_v = \frac{0.60\sqrt{Ek_vF_y}}{(h/t)}$	$F_v = \frac{\pi^2 Ek_v}{12(1-\mu^2)(h/t)^2}$
[AISI S100, Eq. C3.2.1-2]	[AISI S100, Eq. C3.2.1-3]	[AISI S100, Eq. C3.2.1-4]

$h/t \le \sqrt{Ek_v/F_y}$		$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$		$h/t > 1.51\sqrt{Ek_v/F_y}$	
F_v		Fv		Fv	
210.000	[MPa]	----	[MPa]	----	[MPa]

$V_n = A_wF_v$	[AISI S100, Eq. C3.2.1-1]	V_n	**10.324**	**[kN / Web]**

$V_{z,Ed}$	1.010	[kN]	Ratio	5.149	[%]
V_n	20.648	[kN]			

v [μ]	0.300		t	1.452	[mm]
$A_w = h * t$	A_w	162.763 [mm²]	Unreinforced Webs		
[AISI S100, Eq. C3.2.1-5]			k_v	5.340	
E	210.000	[GPa]	F_y	350.000	[MPa]

$h/t \le \sqrt{Ek_v/F_y}$	$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$	$h/t > 1.51\sqrt{Ek_v/F_y}$
$F_v = 0.60 * F_y$	$F_v = \frac{0.60\sqrt{Ek_vF_y}}{(h/t)}$	$F_v = \frac{\pi^2 Ek_v}{12(1-\mu^2)(h/t)^2}$
[AISI S100, Eq. C3.2.1-2]	[AISI S100, Eq. C3.2.1-3]	[AISI S100, Eq. C3.2.1-4]

$h/t \le \sqrt{Ek_v/F_y}$		$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$		$h/t > 1.51\sqrt{Ek_v/F_y}$	
F_v		Fv		Fv	
----	[MPa]	153.9721057	[MPa]	----	[MPa]

$V_n = A_wF_v$	[AISI S100, Eq. C3.2.1-1]	V_n	**25.061**	**[kN]**

$V_{z,Ed}$	2.000	[kN]	Ratio	12.769	[%]
V_n	25.061	[kN]			

[ii] C-Section Beam : Shear [AISI S100, LRFD]

[1] C-Section Beam : Shear Strength [Resistance] of Webs without Holes [AISI S100, C3.2.1]

Φ_v	0.950		h_{plate}	112.096	[mm]
v [μ]	0.300		t	1.452	[mm]
$A_w = h * t$	A_w	162.763 [mm²]	Unreinforced Webs		
[AISI S100, Eq. C3.2.1-5]			k_v	5.340	
E	210.000	[GPa]	F_y	350.000	[MPa]

$h/t \le \sqrt{Ek_v/F_y}$	$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$	$h/t > 1.51\sqrt{Ek_v/F_y}$
$F_v = 0.60 * F_y$	$F_v = \frac{0.60\sqrt{Ek_vF_y}}{(h/t)}$	$F_v = \frac{\pi^2 Ek_v}{12(1-\mu^2)(h/t)^2}$
[AISI S100, Eq. C3.2.1-2]	[AISI S100, Eq. C3.2.1-3]	[AISI S100, Eq. C3.2.1-4]

$h/t \le \sqrt{Ek_v/F_y}$		$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$		$h/t > 1.51\sqrt{Ek_v/F_y}$	
F_v		Fv		Fv	
----	[MPa]	153.9721057	[MPa]	----	[MPa]

$V_n = A_wF_v$	[AISI S100, Eq. C3.2.1-1]	V_n	**25.061**	**[kN]**

$V_{z,Ed}$	2.000	[kN]	Ratio	8.401	[%]
V_n	25.061	[kN]			

[iii] C-Section Beam : Shear [AS/NZS 4600, LSD]

[1] C-Section Beam : Shear Strength [Resistance] of Webs without Holes [AS/NZS 4600, 3.3.4.1]

Table 1.6 : Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_v]
Web design : Shear	3.3.4	0.900

d_1	112.096	[mm]	t_w	1.452	[mm]
Unstiffened Webs	k_v	5.340	v	0.300	
E	210.000	[GPa]	f_y	350.000	[MPa]

$$d_1/t_w \le \sqrt{Ek_v/f_y} \qquad d_1/t_w > 1.415\sqrt{Ek_v/f_y}$$

$V_v = 0.64 * f_y * d_1 * t_w$ [AS/NZS 4600, Eq. 3.3.4(1)]

$$V_v = \frac{0.905Ek_vt_w^3}{d_1}$$

[AS/NZS 4600, Eq. 3.3.4(3)]

$$\sqrt{Ek_v/f_y} < d_1/t_w \le 1.415\sqrt{Ek_v/f_y}$$

$$V_v = 0.64t_w^2\sqrt{Ek_vf_y}$$

[AS/NZS 4600, Eq. 3.3.4(2)]

[AS/NZS 4600, Eq. 3.3.4(1)]		[AS/NZS 4600, Eq. 3.3.4(2)]		[AS/NZS 4600, Eq. 3.3.4(3)]	
V_v		V_v		V_v	
----	[N]	26731.75701	[N]	----	[N]

$V^* = \Phi_{vV}V_v$	[AS/NZS 4600]	V^*	**24.059**	**[kN]**

E	210.000	[GPa]	F_y	350.000	[MPa]

$h/t \le \sqrt{Ek_v/F_y}$	$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$	$h/t > 1.51\sqrt{Ek_v/F_y}$
$F_v = 0.60 * F_y$	$F_v = \frac{0.60\sqrt{Ek_vF_y}}{(h/t)}$	$F_v = \frac{\pi^2Ek_v}{12(1-\mu^2)(h/t)^2}$
[AISI S100, Eq. C3.2.1-2]	[AISI S100, Eq. C3.2.1-3]	[AISI S100, Eq. C3.2.1-4]

$h/t \le \sqrt{Ek_v/F_y}$		$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$		$h/t > 1.51\sqrt{Ek_v/F_y}$	
F_v		Fv		Fv	
210.000	[MPa]	----	[MPa]	----	[MPa]

$V_n = A_wF_v$	[AISI S100, Eq. C3.2.1-1]	V_n	**41.243**	**[kN]**

$V_{z,Ed}$	2.240	[kN]	Ratio	5.717	[%]
V_n	41.243	[kN]			

[iii] C-Section Column : Shear [AS/NZS 4600, LSD]

[1] C-Section Column : Shear Strength [Resistance] of Webs without Holes [AS/NZS 4600, 3.3.4.1]

Table 1.6 : Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_v]
Web design : Shear	3.3.4	0.900

d_1	80.096	[mm]	t_w	2.452	[mm]
Unstiffened Webs	k_v	5.340	v	0.300	
E	210.000	[GPa]	f_y	350.000	[MPa]

$$d_1/t_w \le \sqrt{Ek_v/f_y} \qquad d_1/t_w > 1.415\sqrt{Ek_v/f_y}$$

$V_v = 0.64 * f_y * d_1 * t_w$ [AS/NZS 4600, Eq. 3.3.4(1)]

$$V_v = \frac{0.905Ek_vt_w^3}{d_1}$$

[AS/NZS 4600, Eq. 3.3.4(3)]

$$\sqrt{Ek_v/f_y} < d_1/t_w \le 1.415\sqrt{Ek_v/f_y}$$

$$V_v = 0.64t_w^2\sqrt{Ek_vf_y}$$

[AS/NZS 4600, Eq. 3.3.4(2)]

$V_{z,Ed}$	2.000	[kN]	Ratio	8.313	[%]
V^*	24.059	[kN]			

[c] C-Section Column

[i] C-Section Column : Shear [AISI S100, ASD]

[1] C-Section Column : Shear Strength [Resistance] of Webs without Holes [AISI S100, C3.2.1]

Ω_v	1.600	h_{plate}	80.096	[mm]
v [μ]	0.300	t	2.452	[mm]

$A_w = h * t$ A_w 196.395 [mm^2] [AISI S100, Eq. C3.2.1-5]

Unreinforced Webs k_v 5.340

E	210.000	[GPa]	F_y	350.000	[MPa]

$h/t \le \sqrt{Ek_v/F_y}$	$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$	$h/t > 1.51\sqrt{Ek_v/F_y}$
$F_v = 0.60 * F_y$	$F_v = \frac{0.60\sqrt{Ek_vF_y}}{(h/t)}$	$F_v = \frac{\pi^2Ek_v}{12(1-\mu^2)(h/t)^2}$
[AISI S100, Eq. C3.2.1-2]	[AISI S100, Eq. C3.2.1-3]	[AISI S100, Eq. C3.2.1-4]

$h/t \le \sqrt{Ek_v/F_y}$		$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$		$h/t > 1.51\sqrt{Ek_v/F_y}$	
F_v		Fv		Fv	
210.000	[MPa]	----	[MPa]	----	[MPa]

$V_n = A_wF_v$	[AISI S100, Eq. C3.2.1-1]	V_n	**41.243**	**[kN]**

$V_{z,Ed}$	2.240	[kN]	Ratio	8.690	[%]
V_n	41.243	[kN]			

[ii] C-Section Column : Shear [AISI S100, LRFD]

[1] C-Section Column : Shear Strength [Resistance] of Webs without Holes [AISI S100, C3.2.1]

Φ_v	0.950	h_{plate}	80.096	[mm]
v [μ]	0.300	t	2.452	[mm]

$A_w = h * t$ A_w 196.395 [mm^2] [AISI S100, Eq. C3.2.1-5]

Unreinforced Webs k_v 5.340

[AS/NZS 4600, Eq. 3.3.4(1)]		[AS/NZS 4600, Eq. 3.3.4(2)]		[AS/NZS 4600, Eq. 3.3.4(3)]	
V_v		V_v		V_v	
43992.568	[N]	----	[N]	----	[N]

$V^* = \Phi_{vV}V_v$	[AS/NZS 4600]	V^*	**39.593**	**[kN]**

$V_{z,Ed}$	2.240	[kN]	Ratio	5.658	[%]
V^*	39.593	[kN]			

[d] C-Section Strut

[i] C-Section Strut : Shear [AISI S100, ASD]

[1] C-Section Strut : Shear Strength [Resistance] of Webs without Holes [AISI S100, C3.2.1]

Ω_v	1.600	h_{plate}	42.096	[mm]
v [μ]	0.300	t	1.452	[mm]

$A_w = h * t$ A_w 61.123 [mm^2] [AISI S100, Eq. C3.2.1-5]

Unreinforced Webs k_v 5.340

E	210.000	[GPa]	F_y	350.000	[MPa]

$h/t \le \sqrt{Ek_v/F_y}$	$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$	$h/t > 1.51\sqrt{Ek_v/F_y}$
$F_v = 0.60 * F_y$	$F_v = \frac{0.60\sqrt{Ek_vF_y}}{(h/t)}$	$F_v = \frac{\pi^2Ek_v}{12(1-\mu^2)(h/t)^2}$
[AISI S100, Eq. C3.2.1-2]	[AISI S100, Eq. C3.2.1-3]	[AISI S100, Eq. C3.2.1-4]

$h/t \le \sqrt{Ek_v/F_y}$		$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$		$h/t > 1.51\sqrt{Ek_v/F_y}$	
F_v		Fv		Fv	
210.000	[MPa]	----	[MPa]	----	[MPa]

$V_n = A_wF_v$	[AISI S100, Eq. C3.2.1-1]	V_n	**12.836**	**[kN]**

$V_{z,Ed}$	0.020	[kN]	Ratio	0.249	[%]
V_n	12.836	[kN]			

[ii] C-Section Strut : Shear [AISI S100, LRFD]

[1] C-Section Strut : Shear Strength [Resistance] of Webs without Holes [AISI S100, C3.2.1]

Φ_v	0.950	h_{plate}	42.096	[mm]
v [μ]	0.300	t	1.452	[mm]

$A_w = h * t$ A_w 61.123 [mm^2]
[AISI S100, Eq. C3.2.1-5]

Unreinforced Webs
k_v 5.340

E 210.000 [GPa] F_y 350.000 [MPa]

$h/t \le \sqrt{Ek_v/F_y}$	$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$	$h/t > 1.51\sqrt{Ek_v/F_y}$
$F_v = 0.60 * F_y$	$F_v = \frac{0.60\sqrt{Ek_vF_y}}{(h/t)}$	$F_v = \frac{\pi^2 Ek_v}{12(1-\mu^2)(h/t)^2}$
[AISI S100, Eq. C3.2.1-2]	[AISI S100, Eq. C3.2.1-3]	[AISI S100, Eq. C3.2.1-4]

$h/t \le \sqrt{Ek_v/F_y}$		$\sqrt{Ek_v/F_y} < h/t \le 1.51\sqrt{Ek_v/F_y}$		$h/t > 1.51\sqrt{Ek_v/F_y}$	
F_v		Fv		Fv	
210.000	[MPa]	----	[MPa]	----	[MPa]

$V_n = A_wF_v$ [AISI S100, Eq. C3.2.1-1] **V_n 12.836 [kN]**

$V_{z,Ed}$	0.020	[kN]	Ratio	0.164	[%]
V_n	12.836	[kN]			

[iii] C-Section Strut : Shear [AS/NZS 4600, LSD]

[1] C-Section Strut : Shear Strength [Resistance] of Webs without Holes [AS/NZS 4600, 3.3.4.1]

Table 1.6 : Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_v]
Web design : Shear	3.3.4	0.900

d_1	42.096	[mm]	t_w	1.452	[mm]
Unstiffened Webs	k_v	5.340	v	0.300	
E	210.000	[GPa]	f_y	350.000	[MPa]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	60.888	[%]
$M_{n,x,Comp,M[+]}$	0.996	[kNm]			
$V_{z,Ed}$	1.010	[kN]			
V_n	20.648	[kN]			

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	49.834	[%]
$M_{n,x,Comp,M[-]}$	1.222	[kNm]			
$V_{z,Ed}$	1.010	[kN]			
V_n	20.648	[kN]			

[ii] Ω-Section Purlin : Combined Bending and Shear [AISI S100, LRFD]

[1] Ω-Section Purlin : Combined Bending and Shear [LRFD Method] [AISI S100, C3.3.2]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	38.060	[%]
$M_{n,x,Comp,M[+]}$	0.996	[kNm]			

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	31.021	[%]
$M_{n,x,Comp,M[-]}$	1.222	[kNm]			

$V_{z,Ed}$	1.010	[kN]	Ratio	5.149	[%]
V_n	20.648	[kN]			

$$\sqrt{\left(\frac{\bar{M}}{\phi_b M_{nxo}}\right)^2 + \left(\frac{\bar{V}}{\phi_v V_n}\right)^2} \le 1.0$$

Unreinforced Webs
[AISI S100, Eq. C3.3.2-1]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	38.407	[%]
$M_{n,x,Comp,M[+]}$	0.996	[kNm]			
$V_{z,Ed}$	1.010	[kN]			
V_n	20.648	[kN]			

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	31.446	[%]
$M_{n,x,Comp,M[-]}$	1.222	[kNm]			
$V_{z,Ed}$	1.010	[kN]			
V_n	20.648	[kN]			

$d_1/t_w \le \sqrt{Ek_v/f_y}$	$d_1/t_w > 1.415\sqrt{Ek_v/f_y}$
$V_v = 0.64 * f_y * d_1 * t_w$	$V_v = \frac{0.905Ek_vt_w^3}{d_1}$
[AS/NZS 4600, Eq. 3.3.4(1)]	[AS/NZS 4600, Eq. 3.3.4(3)]

$$\sqrt{Ek_v/f_y} < d_1/t_w \le 1.415\sqrt{Ek_v/f_y}$$

$$V_v = 0.64t_w^2\sqrt{Ek_vf_y}$$

[AS/NZS 4600, Eq. 3.3.4(2)]

[AS/NZS 4600, Eq. 3.3.4(1)]		[AS/NZS 4600, Eq. 3.3.4(2)]		[AS/NZS 4600, Eq. 3.3.4(3)]	
V_v		V_v		V_v	
13691.640	[N]	----	[N]	----	[N]

$V^* = \Phi_{vV}V_v$ [AS/NZS 4600] **V^* 12.322 [kN]**

$V_{z,Ed}$	0.020	[kN]	Ratio	0.162	[%]
V^*	12.322	[kN]			

[15.4] Combined Bending and Shear [AISI S100, C3.3 | AS/NZS 4600, 3.3.5]

[a] Ω-Section Purlin

[i] Ω-Section Purlin : Combined Bending and Shear [AISI S100, ASD]

[1] Ω-Section Purlin : Combined Bending and Shear [ASD Method] [AISI S100, C3.3.1]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	60.383	[%]
$M_{n,x,Comp,M[+]}$	0.996	[kNm]			

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	49.215	[%]
$M_{n,x,Comp,M[-]}$	1.222	[kNm]			

$V_{z,Ed}$	1.010	[kN]	Ratio	7.826	[%]
V_n	20.648	[kN]			

$$\sqrt{\left(\frac{\Omega_b M}{M_{nxo}}\right)^2 + \left(\frac{\Omega_v V}{V_n}\right)^2} \le 1.0$$

Unreinforced Webs
[AISI S100, Eq. C3.3.1-1]

[iii] Ω-Section Purlin : Combined Bending and Shear [AS/NZS 4600, LSD]

[1] Ω-Section Purlin : Combined Bending and Shear [AS/NZS 4600, 3.3.5]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	40.175	[%]
$M_{s,x,Comp,M[+]}$	0.996	[kNm]			

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	32.745	[%]
$M_{s,x,Comp,M[-]}$	1.222	[kNm]			

$V_{z,Ed}$	1.010	[kN]	Ratio	5.095	[%]
V^*	19.822	[kN]			

$$\left(\frac{M^*}{\phi_b M_s}\right)^2 + \left(\frac{V^*}{\phi_v V_v}\right)^2 \le 1.0$$

Unstiffened Webs
[AS/NZS 4600, Eq. 3.3.5(1)]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	16.400	[%]
$M_{s,x,Comp,M[+]}$	0.996	[kNm]			
$V_{z,Ed}$	1.010	[kN]			
V_V	22.024	[kN]			

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	10.982	[%]
$M_{s,x,Comp,M[-]}$	1.222	[kNm]			
$V_{z,Ed}$	1.010	[kN]			
V_V	22.024	[kN]			

[b] C-Section Beam

[i] C-Section Beam : Combined Bending and Shear [AISI S100, ASD]

[1] C-Section Beam : Combined Bending and Shear [ASD Method] [AISI S100, C3.3.1]

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	33.205	[%]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]			

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	33.205	[%]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]			

$V_{z,Ed}$	2.000	[kN]	Ratio	12.769	[%]
V_n	25.061	[kN]			

$$\sqrt{\left(\frac{\Omega_b M}{M_{nxo}}\right)^2+\left(\frac{\Omega_v V}{V_n}\right)^2}\le 1.0$$

Unreinforced Webs

[AISI S100, Eq. C3.3.1-1]

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	35.576	[%]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]			
$V_{z,Ed}$	2.000	[kN]			
V_n	25.061	[kN]			

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	35.576	[%]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]			
$V_{z,Ed}$	2.000	[kN]			
V_n	25.061	[kN]			

[ii] C-Section Beam : Combined Bending and Shear [AISI S100, LRFD]

[1] C-Section Beam : Combined Bending and Shear [LRFD Method] [AISI S100, C3.3.2]

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	22.093	[%]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]			

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	22.093	[%]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]			

$V_{z,Ed}$	2.000	[kN]	Ratio	8.401	[%]
V_n	25.061	[kN]			

$$\sqrt{\left(\frac{\overline{M}}{\phi_b M_{nxo}}\right)^2+\left(\frac{\overline{V}}{\phi_v V_n}\right)^2}\le 1.0$$

Unreinforced Webs

[AISI S100, Eq. C3.3.2-1]

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	22.553	[%]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]			
$V_{z,Ed}$	2.000	[kN]			
V_n	25.061	[kN]			

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	22.553	[%]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]			
$V_{z,Ed}$	2.000	[kN]			
V_n	25.061	[kN]			

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

$$\sqrt{\left(\frac{\Omega_b M}{M_{nxo}}\right)^2+\left(\frac{\Omega_v V}{V_n}\right)^2}\le 1.0$$

Unreinforced Webs

[AISI S100, Eq. C3.3.1-1]

$M_{x,Ed,M[+]}$	0.350	[kNm]	Ratio	15.389	[%]
$M_{n,x,Comp,M[+]}$	4.602	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
V_n	41.243	[kN]			

$M_{x,Ed,M[-]}$	0.350	[kNm]	Ratio	15.389	[%]
$M_{n,x,Comp,M[-]}$	4.602	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
V_n	41.243	[kN]			

[ii] C-Section Column : Combined Bending and Shear [AISI S100, LRFD]

[1] C-Section Column : Combined Bending and Shear [LRFD Method] [AISI S100, C3.3.2]

$M_{x,Ed,M[+]}$	0.350	[kNm]	Ratio	8.450	[%]
$M_{n,x,Comp,M[+]}$	4.602	[kNm]			

$M_{x,Ed,M[-]}$	0.350	[kNm]	Ratio	8.450	[%]
$M_{n,x,Comp,M[-]}$	4.602	[kNm]			

$V_{z,Ed}$	2.240	[kN]	Ratio	5.717	[%]
V_n	41.243	[kN]			

$$\sqrt{\left(\frac{\overline{M}}{\phi_b M_{nxo}}\right)^2+\left(\frac{\overline{V}}{\phi_v V_n}\right)^2}\le 1.0$$

Unreinforced Webs

[AISI S100, Eq. C3.3.2-1]

$M_{x,Ed,M[+]}$	0.350	[kNm]	Ratio	9.837	[%]
$M_{n,x,Comp,M[+]}$	4.602	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
V_n	41.243	[kN]			

$M_{x,Ed,M[-]}$	0.350	[kNm]	Ratio	9.837	[%]
$M_{n,x,Comp,M[-]}$	4.602	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
V_n	41.243	[kN]			

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

[iii] C-Section Beam : Combined Bending and Shear [AS/NZS 4600, LSD]

[1] C-Section Beam : Combined Bending and Shear [AS/NZS 4600, 3.3.5]

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	34.663	[%]
$M_{n,x,Comp,M[+]}$	2.693	[kNm]			

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	34.663	[%]
$M_{n,x,Comp,M[-]}$	2.693	[kNm]			

$V_{z,Ed}$	2.000	[kN]	Ratio	8.313	[%]
V^*	24.059	[kN]			

$$\left(\frac{M^*}{\phi_b M_s}\right)^2+\left(\frac{V^*}{\phi_v V_v}\right)^2\le 1.0$$

Unstiffened Webs

[AS/NZS 4600, Eq. 3.3.5(1)]

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	11.475	[%]
$M_{n,x,Comp,M[+]}$	2.693	[kNm]			
$V_{z,Ed}$	2.000	[kN]			
V_v	26.732	[kN]			

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	11.475	[%]
$M_{n,x,Comp,M[-]}$	2.693	[kNm]			
$V_{z,Ed}$	2.000	[kN]			
V_v	26.732	[kN]			

[c] C-Section Column

[i] C-Section Column : Combined Bending and Shear [AISI S100, ASD]

[1] C-Section Column : Combined Bending and Shear [ASD Method] [AISI S100, C3.3.1]

$M_{x,Ed,M[+]}$	0.350	[kNm]	Ratio	12.701	[%]
$M_{n,x,Comp,M[+]}$	4.602	[kNm]			

$M_{x,Ed,M[-]}$	0.350	[kNm]	Ratio	12.701	[%]
$M_{n,x,Comp,M[-]}$	4.602	[kNm]			

$V_{z,Ed}$	2.240	[kN]	Ratio	8.690	[%]
V_n	41.243	[kN]			

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

[iii] C-Section Column : Combined Bending and Shear [AS/NZS 4600, LSD]

[1] C-Section Column : Combined Bending and Shear [AS/NZS 4600, 3.3.5]

$M_{x,Ed,M[+]}$	0.350	[kNm]	Ratio	9.109	[%]
$M_{n,x,Comp,M[+]}$	4.269	[kNm]			

$M_{x,Ed,M[-]}$	0.350	[kNm]	Ratio	9.109	[%]
$M_{n,x,Comp,M[-]}$	4.269	[kNm]			

$V_{z,Ed}$	2.240	[kN]	Ratio	5.658	[%]
V^*	39.593	[kN]			

$$\left(\frac{M^*}{\phi_b M_s}\right)^2+\left(\frac{V^*}{\phi_v V_v}\right)^2\le 1.0$$

Unstiffened Webs

[AS/NZS 4600, Eq. 3.3.5(1)]

$M_{x,Ed,M[+]}$	0.350	[kNm]	Ratio	1.065	[%]
$M_{n,x,Comp,M[+]}$	4.269	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
V_v	43.993	[kN]			

$M_{x,Ed,M[-]}$	0.350	[kNm]	Ratio	1.065	[%]
$M_{n,x,Comp,M[-]}$	4.269	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
V_v	43.993	[kN]			

[d] C-Section Strut

[i] C-Section Strut : Combined Bending and Shear [AISI S100, ASD]

[1] C-Section Strut: Combined Bending and Shear [ASD Method] [AISI S100, C3.3.1]

$M_{x,Ed,M[+]}$	0.010	[kNm]	Ratio	2.274	[%]
$M_{n,x,Comp,M[+]}$	0.735	[kNm]			

$M_{x,Ed,M[-]}$	0.010	[kNm]	Ratio	2.274	[%]
$M_{n,x,Comp,M[-]}$	0.735	[kNm]			

$V_{z,Ed}$	0.020	[kN]	Ratio	0.249	[%]
V_n	12.836	[kN]			

$$\sqrt{\left(\frac{\Omega_b M}{M_{nxo}}\right)^2+\left(\frac{\Omega_v V}{V_n}\right)^2}\leq 1.0$$

Unreinforced Webs

[AISI S100, Eq. C3.3.1-1]

$M_{x,Ed,M[+]}$	0.010	[kNm]	Ratio	2.287	[%]
$M_{n,x,Comp,M[+]}$	0.735	[kNm]			
$V_{z,Ed}$	0.020	[kN]			
V_n	12.836	[kN]			

$M_{x,Ed,M[-]}$	0.020	[kNm]	Ratio	0.360	[%]
$M_{n,x,Comp,M[-]}$	12.836	[kNm]			
$V_{z,Ed}$	0.020	[kN]			
V_n	12.836	[kN]			

[ii] C-Section Strut: Combined Bending and Shear [AISI S100, LRFD]

[1] C-Section Strut: Combined Bending and Shear [LRFD Method] [AISI S100, C3.3.2]

$M_{x,Ed,M[+]}$	0.010	[kNm]	Ratio	1.513	[%]
$M_{n,x,Comp,M[+]}$	0.735	[kNm]			

$M_{x,Ed,M[-]}$	0.010	[kNm]	Ratio	1.513	[%]
$M_{n,x,Comp,M[-]}$	0.735	[kNm]			

$V_{z,Ed}$	0.020	[kN]	Ratio	0.164	[%]
V_n	12.836	[kN]			

$$\sqrt{\left(\frac{\overline{M}}{\phi_b M_{nxo}}\right)^2+\left(\frac{\overline{V}}{\phi_v V_n}\right)^2}\leq 1.0$$

Unreinforced Webs

[AISI S100, Eq. C3.3.2-1]

$M_{x,Ed,M[+]}$	0.010	[kNm]	Ratio	1.442	[%]
$M_{n,x,Comp,M[+]}$	0.735	[kNm]			
$V_{z,Ed}$	0.020	[kN]			
V_n	12.836	[kN]			

$M_{x,Ed,M[-]}$	0.010	[kNm]	Ratio	1.442	[%]
$M_{n,x,Comp,M[-]}$	0.735	[kNm]			
$V_{z,Ed}$	0.020	[kN]			
V_n	12.836	[kN]			

t	0.952	[mm]	Φ	78.393	[º]
$F_{y,Mx[+]}$	350.000	[MPa]	$F_{ya,Mx[+]}$	----	[MPa]
$F_{y,Mx[-]}$	----	[MPa]	$F_{ya,Mx[-]}$	365.389	[MPa]
R	1.500	[mm]	h	54.693	[mm]

Support Conditions Fastened to Support

↓

Load Cases One-Flange Loading or Reaction

↓

End Loading or Reaction → Ω_w 2.000

↓

C	C_R	C_N	C_h
4.000	0.250	0.680	0.040

↓

P_n	2278.954	[N]	P_n	**2.279**	**[kN]**

$V_{z,Ed}$	1.010	[kN]	Ratio	88.637	[%]
P_n	2.279	[kN]			

[ii] Ω-Section Purlin : Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, LRFD]

[1] Ω-Section Purlin : Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, C3.4.1]

$$P_n = Ct^2F_y \sin\theta\left(1-C_R\sqrt{\frac{R}{t}}\right)\left(1+C_N\sqrt{\frac{N}{t}}\right)\left(1-C_h\sqrt{\frac{h}{t}}\right)$$

[AISI S100, Eq. C3.4.1-1]

t	0.952	[mm]	Φ	78.393	[º]
$F_{y,Mx[+]}$	350.000	[MPa]	$F_{ya,Mx[+]}$	----	[MPa]
$F_{y,Mx[-]}$	----	[MPa]	$F_{ya,Mx[-]}$	365.389	[MPa]
R	1.500	[mm]	h	54.693	[mm]

Support Conditions Fastened to Support

↓

Load Cases One-Flange Loading or Reaction

↓

End Loading or Reaction → Φ_w 0.750

↓

C	C_R	C_N	C_h
4.000	0.250	0.680	0.040

↓

P_n	2278.954	[N]	P_n	**2.279**	**[kN]**

[iii] C-Section Strut : Combined Bending and Shear [AS/NZS 4600, LSD]

[1] C-Section Strut : Combined Bending and Shear [AS/NZS 4600, 3.3.5]

$M_{x,Ed,M[+]}$	0.010	[kNm]	Ratio	1.302	[%]
$M_{s,x,Comp,M[+]}$	0.853	[kNm]			

$M_{x,Ed,M[-]}$	0.010	[kNm]	Ratio	1.302	[%]
$M_{s,x,Comp,M[-]}$	0.853	[kNm]			

$V_{z,Ed}$	0.020	[kN]	Ratio	0.162	[%]
V^*	12.322	[kN]			

$$\left(\frac{M^*}{\phi_b M_s}\right)^2+\left(\frac{V^*}{\phi_v V_v}\right)^2\leq 1.0$$

Unstiffened Webs

[AS/NZS 4600, Eq. 3.3.5(1)]

$M_{x,Ed,M[+]}$	0.010	[kNm]	Ratio	0.015	[%]
$M_{s,x,Comp,M[+]}$	0.853	[kNm]			
$V_{z,Ed}$	0.020	[kN]			
V_V	13.692	[kN]			

$M_{x,Ed,M[-]}$	0.010	[kNm]	Ratio	0.015	[%]
$M_{s,x,Comp,M[-]}$	0.853	[kNm]			
$V_{z,Ed}$	0.020	[kN]			
V_V	13.692	[kN]			

[15.5] Web Crippling **[AISI S100, C3.4 | AS/NZS 4600, 3.3.6]**

[a] Ω-Section Purlin

[i] Ω-Section Purlin : Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, ASD]

[1] Ω-Section Purlin : Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, C3.4.1]

$$P_n = Ct^2F_y \sin\theta\left(1-C_R\sqrt{\frac{R}{t}}\right)\left(1+C_N\sqrt{\frac{N}{t}}\right)\left(1-C_h\sqrt{\frac{h}{t}}\right)$$

[AISI S100, Eq. C3.4.1-1]

$V_{z,Ed}$	1.010	[kN]	Ratio	59.091	[%]
P_n	2.279	[kN]			

[iii] Ω-Section Purlin : Bearing | Web Crippling Strength of Webs without Holes [AS/NZS 4600, LSD]

Ω-Section Purlin : Bearing | Web Crippling Strength of Webs without Holes [AS/NZS 4600, 3.3.6]

$R_b^* \leq \Phi_w * R_b$ [AS/NZS 4600, Eq. 3.3.4(1)]

Table 1.6 : Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_w]
Bearing : Single Hat Sections	Table 3.3.6.2(D)	0.750 - 0.900

$$R_b = Ct_w^2 f_y \sin\theta\left(1-C_r\sqrt{\frac{r_i}{t_w}}\right)\left(1+C_l\sqrt{\frac{l_b}{t_w}}\right)\left(1-C_w\sqrt{\frac{d_1}{t_w}}\right)$$

[AS/NZS 4600, Eq. 3.3.6.2]

t_w	0.952	[mm]	Φ	78.393	[º]
$f_{y,Mx[+]}$	350.000	[MPa]	$f_{ya,Mx[+]}$	----	[MPa]
$f_{y,Mx[-]}$	----	[MPa]	$f_{ya,Mx[-]}$	365.389	[MPa]
r_i	1.500	[mm]	d_l	54.693	[mm]

Support Conditions Fastened to Support

↓

Load Cases One-Flange Loading or Reaction

↓

End Loading or Reaction → Φ_w 0.750

↓

C	C_r	C_l	C_w
4.000	0.250	0.680	0.040

↓

R_b	2278.954	[N]	R_b	**2.279**	**[kN]**

$V_{z,Ed}$	1.010	[kN]	Ratio	59.091	[%]
R_b	2.279	[kN]			

[b] C-Section Beam

[i] C-Section Beam : Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, ASD]

[1] C-Section Beam : Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, C3.4.1]

$$P_n = Ct^2 F_y \sin\theta\left(1 - C_R\sqrt{\frac{R}{t}}\right)\left(1 + C_N\sqrt{\frac{N}{t}}\right)\left(1 - C_h\sqrt{\frac{h}{t}}\right)$$

[AISI S100, Eq. C3.4.1-1]

t	1.452	[mm]	Φ	90.000	[º]
$F_{y,Mx(+)}$	----	[MPa]	$F_{ya,Mx(+)}$	374.390	[MPa]
$F_{y,Mx(-)}$	----	[MPa]	$F_{ya,Mx(-)}$	374.390	[MPa]
R	2.500	[mm]	h	112.096	[mm]

Support	Unfastened
Flange	Stiffened or Partially Stiffened Flanges
Load Cases	One-Flange Loading or Reaction

End Loading or Reaction → Ω_w 1.850

C	C_R	C_N	C_h
4.000	0.140	0.350	0.020

P_n	4634.307	[N]	P_n	**4.634**	**[kN]**

$V_{z,Ed}$	2.000	[kN]	Ratio	79.839	[%]
P_n	4.634	[kN]			

[ii] C-Section Beam : Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, LRFD]

[1] C-Section Beam : Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, C3.4.1]

$$P_n = Ct^2 F_y \sin\theta\left(1 - C_R\sqrt{\frac{R}{t}}\right)\left(1 + C_N\sqrt{\frac{N}{t}}\right)\left(1 - C_h\sqrt{\frac{h}{t}}\right)$$

[AISI S100, Eq. C3.4.1-1]

t	1.452	[mm]	Φ	90.000	[º]
$F_{y,Mx(+)}$	----	[MPa]	$F_{ya,Mx(+)}$	374.390	[MPa]
$F_{y,Mx(-)}$	----	[MPa]	$F_{ya,Mx(-)}$	374.390	[MPa]
R	2.500	[mm]	h	112.096	[mm]

[Previous Page]

End Loading or Reaction → Φ_w 0.800

C	C_r	C_l	C_w
4.000	0.140	0.350	0.020

R_b	4634.307	[N]	R_b	**4.634**	**[kN]**

$V_{z,Ed}$	2.000	[kN]	Ratio	53.945	[%]
R_b	4.634	[kN]			

[c] C-Section Column

[i] C-Section Column : Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, ASD]

[1] C-Section Column : Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, C3.4.1]

$$P_n = Ct^2 F_y \sin\theta\left(1 - C_R\sqrt{\frac{R}{t}}\right)\left(1 + C_N\sqrt{\frac{N}{t}}\right)\left(1 - C_h\sqrt{\frac{h}{t}}\right)$$

[AISI S100, Eq. C3.4.1-1]

t	2.452	[mm]	Φ	90.000	[º]
$F_{y,Mx(+)}$	----	[MPa]	$F_{ya,Mx(+)}$	388.471	[MPa]
$F_{y,Mx(-)}$	----	[MPa]	$F_{ya,Mx(-)}$	388.471	[MPa]
R	2.500	[mm]	h	80.096	[mm]

Support	Fastened to Support
Flange	Stiffened or Partially Stiffened Flanges
Load Cases	Two-Flange Loading or Reaction

End Loading or Reaction → Ω_w 1.750

C	C_R	C_N	C_h
7.500	0.080	0.120	0.048

P_n	17101.535	[N]	P_n	**17.102**	**[kN]**

$V_{z,Ed}$	2.240	[kN]	Ratio	22.922	[%]
P_n	17.102	[kN]			

Support	Unfastened
Flange	Stiffened or Partially Stiffened Flanges
Load Cases	One-Flange Loading or Reaction

End Loading or Reaction → Φ_w 0.800

C	C_R	C_N	C_h
4.000	0.140	0.350	0.020

P_n	4634.307	[N]	P_n	**4.634**	**[kN]**

$V_{z,Ed}$	2.000	[kN]	Ratio	53.945	[%]
P_n	4.634	[kN]			

[iii] C-Section Beam : Bearing | Web Crippling Strength of Webs without Holes [AS/NZS 4600, LSD]

C-Section Beam : Bearing | Web Crippling Strength of Webs without Holes [AS/NZS 4600, 3.3.6]

$R_b^* \leq \Phi_w * R_b$ [AS/NZS 4600, Eq. 3.3.4(1)]

Table 1.6 : Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_w]
Bearing : Single web channel	Table 3.3.6.2(B)	0.750 - 0.900

$$R_b = Ct_w^2 f_y \sin\theta\left(1 - C_r\sqrt{\frac{r_i}{t_w}}\right)\left(1 + C_l\sqrt{\frac{l_b}{t_w}}\right)\left(1 - C_w\sqrt{\frac{d_1}{t_w}}\right)$$

[AS/NZS 4600, Eq. 3.3.6.2]

t_w	1.452	[mm]	Φ	90.000	[º]
$f_{y,Mx(+)}$	----	[MPa]	$f_{ya,Mx(+)}$	374.390	[MPa]
$f_{y,Mx(-)}$	----	[MPa]	$f_{ya,Mx(-)}$	374.390	[MPa]
r_i	2.500	[mm]	d_1	112.096	[mm]

Support	Unfastened
Flange	Stiffened or Partially Stiffened Flanges
Load Cases	One-Flange Loading or Reaction

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[ii] C-Section Column : Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, LRFD]

[1] C-Section Column : Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, C3.4.1]

$$P_n = Ct^2 F_y \sin\theta\left(1 - C_R\sqrt{\frac{R}{t}}\right)\left(1 + C_N\sqrt{\frac{N}{t}}\right)\left(1 - C_h\sqrt{\frac{h}{t}}\right)$$

[AISI S100, Eq. C3.4.1-1]

t	2.452	[mm]	Φ	90.000	[º]
$F_{y,Mx(+)}$	----	[MPa]	$F_{ya,Mx(+)}$	388.471	[MPa]
$F_{y,Mx(-)}$	----	[MPa]	$F_{ya,Mx(-)}$	388.471	[MPa]
R	2.500	[mm]	h	80.096	[mm]

Support	Fastened to Support
Flange	Stiffened or Partially Stiffened Flanges
Load Cases	Two-Flange Loading or Reaction

End Loading or Reaction → Φ_w 0.850

C	C_R	C_N	C_h
7.500	0.080	0.120	0.048

P_n	17101.535	[N]	P_n	**17.102**	**[kN]**

$V_{z,Ed}$	2.240	[kN]	Ratio	15.410	[%]
P_n	17.102	[kN]			

[iii] C-Section Column : Bearing [AS/NZS 4600, LSD]

C-Section Column : Bearing | Web Crippling Strength of Webs without Holes [AS/NZS 4600, 3.3.6]

$R_b^* \leq \Phi_w * R_b$ [AS/NZS 4600, Eq. 3.3.4(1)]

Table 1.6 : Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_w]
Bearing : Single web channel	Table 3.3.6.2(D)	0.750 - 0.900

$$R_b = C t_w^2 f_y \sin\theta \left(1 - C_r \sqrt{\frac{r_i}{t_w}}\right)\left(1 + C_l \sqrt{\frac{l_b}{t_w}}\right)\left(1 - C_w \sqrt{\frac{d_1}{t_w}}\right)$$

[AS/NZS 4600, Eq. 3.3.6.2]

t_w	2.452	[mm]	Φ	90.000	[°]
$f_{y,Mx[+]}$	----	[MPa]	$f_{ya,Mx[+]}$	388.471	[MPa]
$f_{y,Mx[-]}$	----	[MPa]	$f_{ya,Mx[-]}$	388.471	[MPa]
r_i	2.500	[mm]	d_l	80.096	[mm]

Support Fastened to Support
↓
Flange Stiffened or Partially Stiffened Flanges
↓
Load Cases Two-Flange Loading or Reaction
↓
End Loading or Reaction → Φ_w 0.850
↓

C	C_r	C_l	C_w
7.500	0.080	0.120	0.048

↓

R_b	17101.535	[N]	**R_b**	**17.102**	**[kN]**

$V_{z,Ed}$	2.240	[kN]	Ratio	15.410	[%]
R_b	17.102	[kN]			

[d] C-Section Strut

[i] C-Section Strut : Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, ASD]

This verification isn't needed for this type of structural member

[ii] C-Section Strut : Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, LRFSD]

This verification isn't needed for this type of structural member

[iii] C-Section Strut : Bearing | Web Crippling Strength [Resistance] of Webs without Holes [AS/NZS 4600, LSD]

This verification isn't needed for this type of structural member

[15.6] **Combined Bending and Web Crippling** **[AISI S100, C3.5 | AS/NZS 4600, 3.3.7]**

[a] Ω-Section Purlin

[i] Ω-Section Purlin : Combined Bending and Web Crippling [AISI S100, ASD]

[1] Ω-Section Purlin : Combined Bending and Web Crippling [ASD Method] [AISI S100, C3.5.1]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	60.383	[%]
$M_{n,x,Comp,M[+]}$	0.996	[kNm]			

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	49.215	[%]
$M_{n,x,Comp,M[-]}$	1.222	[kNm]			

$V_{z,Ed}$	1.010	[kN]	Ratio	88.637	[%]
P_n	2.279	[kN]			

$$0.91\left(\frac{P}{P_n}\right) + \left(\frac{M}{M_{nxo}}\right) \leq \frac{1.33}{\Omega}$$

Unreinforced Webs

[AISI S100, Eq. C3.5.1-1]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	152.974	[%]
$M_{n,x,Comp,M[+]}$	0.996	[kNm]			
$V_{z,Ed}$	1.010	[kN]			
P_n	2.279	[kN]			

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	139.600	[%]
$M_{n,x,Comp,M[-]}$	1.222	[kNm]			
$V_{z,Ed}$	1.010	[kN]			
P_n	2.279	[kN]			

[ii] Ω-Section Purlin : Combined Bending and Web Crippling [AISI S100, LRFD]

[1] Ω-Section Purlin : Combined Bending and Web Crippling [LRFD Method] [AISI S100, C3.5.2]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	38.060	[%]
$M_{n,x,Comp,M[+]}$	0.996	[kNm]			

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	31.021	[%]
$M_{n,x,Comp,M[-]}$	1.222	[kNm]			

$V_{z,Ed}$	1.010	[kN]	Ratio	59.091	[%]
P_n	2.279	[kN]			

$$0.91\left(\frac{P}{P_n}\right) + \left(\frac{M}{M_{nxo}}\right) \leq 1.33\phi$$

Unreinforced Webs

[AISI S100, Eq. C3.5.2-1]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	101.983	[%]
$M_{n,x,Comp,M[+]}$	0.996	[kNm]			
$V_{z,Ed}$	1.010	[kN]			
P_n	2.279	[kN]			

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	93.067	[%]
$M_{n,x,Comp,M[-]}$	1.222	[kNm]			
$V_{z,Ed}$	1.010	[kN]			
P_n	2.279	[kN]			

[iii] Ω-Section Purlin : Combined Bending and Bearing [AS/NZS 4600, LSD]

[1] Ω-Section Purlin : Combined Bending and Bearing/Web Crippling [LSD Method] [AS/NZS 4600, 3.3.7]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	40.175	[%]
$M_{s,x,Comp,M[+]}$	0.996	[kNm]			

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	32.745	[%]
$M_{s,x,Comp,M[-]}$	1.222	[kNm]			

$V_{z,Ed}$	1.010	[kN]	Ratio	59.091	[%]
R_b	2.279	[kN]			

$$1.07\left(\frac{R^*}{\phi_w R_b}\right) + \left(\frac{M^*}{\phi_b M_s}\right) \leq 1.42$$

Unstiffened Webs

[AS/NZS 4600, Eq. 3.3.7(1)]

$M_{x,Ed,M[+]}$	0.360	[kNm]	Ratio	103.403	[%]
$M_{s,x,Comp,M[+]}$	0.996	[kNm]			
$V_{z,Ed}$	1.010	[kN]			
R_b	2.279	[kN]			

$M_{x,Ed,M[-]}$	0.360	[kNm]	Ratio	95.973	[%]
$M_{s,x,Comp,M[-]}$	1.222	[kNm]			
$V_{z,Ed}$	1.010	[kN]			
R_b	2.279	[kN]			

[b] C-Section Beam

[i] C-Section Beam : Combined Bending and Web Crippling [AISI S100, ASD]

[1] C-Section Beam : Combined Bending and Web Crippling [ASD Method] [AISI S100, C3.5.1]

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	33.205	[%]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]			

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	33.205	[%]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]			

$V_{z,Ed}$	2.000	[kN]	Ratio	79.839	[%]
P_n	4.634	[kN]			

$$0.91\left(\frac{P}{P_n}\right) + \left(\frac{M}{M_{nxo}}\right) \leq \frac{1.33}{\Omega}$$

Unreinforced Webs

[AISI S100, Eq. C3.5.1-1]

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	109.438	[%]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]			
$V_{z,Ed}$	2.000	[kN]			
P_n	4.634	[kN]			

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	109.438	[%]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]			
$V_{z,Ed}$	2.000	[kN]			
P_n	4.634	[kN]			

[ii] C-Section Beam : Combined Bending and Web Crippling [AISI S100, LRFD]

[1] C-Section Beam : Combined Bending and Web Crippling [LRFD Method] [AISI S100, C3.5.2]

$M_{x,Ed,M[+]}$	0.840	[kNm]	Ratio	22.093	[%]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]			

$M_{x,Ed,M[-]}$	0.840	[kNm]	Ratio	22.093	[%]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]			

$V_{z,Ed}$	2.000	[kN]	Ratio	53.945	[%]
P_n	4.634	[kN]			

$$0.91\left(\frac{P}{P_n}\right)+\left(\frac{M}{M_{nxo}}\right)\leq 1.33\phi$$

Unreinforced Webs

[AISI S100, Eq. C3.5.2-1]

$M_{x,Ed,M\,[+]}$	0.840	[kNm]	Ratio	73.945	[%]
$M_{n,x,Comp,M\,[+]}$	4.225	[kNm]			
$V_{z,Ed}$	2.000	[kN]			
P_n	4.634	[kN]			

$M_{x,Ed,M\,[-]}$	0.840	[kNm]	Ratio	73.945	[%]
$M_{n,x,Comp,M\,[-]}$	4.225	[kNm]			
$V_{z,Ed}$	2.000	[kN]			
P_n	4.634	[kN]			

[iii] C-Section Beam : Combined Bending and Bearing [AS/NZS 4600, LSD]

[1] C-Section Beam : Combined Bending and Bearing/Web Crippling [LSD Method] [AS/NZS 4600, 3.3.7]

$M_{x,Ed,M\,[+]}$	0.840	[kNm]	Ratio	34.663	[%]
$M_{s,x,Comp,M\,[+]}$	2.693	[kNm]			

$M_{x,Ed,M\,[-]}$	0.840	[kNm]	Ratio	34.663	[%]
$M_{s,x,Comp,M\,[-]}$	2.693	[kNm]			

$V_{z,Ed}$	2.000	[kN]	Ratio	53.945	[%]
R_b	4.634	[kN]			

$$1.07\left(\frac{R^*}{\phi_w R_b}\right)+\left(\frac{M^*}{\phi_b M_s}\right)\leq 1.42$$

Unstiffened Webs

[AS/NZS 4600, Eq. 3.3.7(1)]

$M_{x,Ed,M\,[+]}$	0.840	[kNm]	Ratio	92.385	[%]
$M_{s,x,Comp,M\,[+]}$	2.693	[kNm]			
$V_{z,Ed}$	2.000	[kN]			
R_b	4.634	[kN]			

$M_{x,Ed,M\,[-]}$	0.840	[kNm]	Ratio	92.385	[%]
$M_{s,x,Comp,M\,[-]}$	2.693	[kNm]			
$V_{z,Ed}$	2.000	[kN]			
R_b	4.634	[kN]			

$$0.91\left(\frac{P}{P_n}\right)+\left(\frac{M}{M_{nxo}}\right)\leq 1.33\phi$$

Unreinforced Webs

[AISI S100, Eq. C3.5.2-1]

$M_{x,Ed,M\,[+]}$	0.350	[kNm]	Ratio	22.970	[%]
$M_{n,x,Comp,M\,[+]}$	4.602	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
P_n	17.102	[kN]			

$M_{x,Ed,M\,[-]}$	0.350	[kNm]	Ratio	22.970	[%]
$M_{n,x,Comp,M\,[-]}$	4.602	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
P_n	17.102	[kN]			

[iii] C-Section Column : Combined Bending and Bearing [AS/NZS 4600, LSD]

[1] C-Section Column : Combined Bending and Bearing/Web Crippling [LSD Method] [AS/NZS 4600, 3.3.7]

$M_{x,Ed,M\,[+]}$	0.350	[kNm]	Ratio	9.109	[%]
$M_{s,x,Comp,M\,[+]}$	4.269	[kNm]			

$M_{x,Ed,M\,[-]}$	0.350	[kNm]	Ratio	9.109	[%]
$M_{s,x,Comp,M\,[-]}$	4.269	[kNm]			

$V_{z,Ed}$	2.240	[kN]	Ratio	15.410	[%]
R_b	17.102	[kN]			

$$1.07\left(\frac{R^*}{\phi_w R_b}\right)+\left(\frac{M^*}{\phi_b M_s}\right)\leq 1.42$$

Unstiffened Webs

[AS/NZS 4600, Eq. 3.3.7(1)]

$M_{x,Ed,M\,[+]}$	0.350	[kNm]	Ratio	25.597	[%]
$M_{s,x,Comp,M\,[+]}$	4.269	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
R_b	17.102	[kN]			

$M_{x,Ed,M\,[-]}$	0.350	[kNm]	Ratio	25.597	[%]
$M_{s,x,Comp,M\,[-]}$	4.269	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
R_b	17.102	[kN]			

[c] C-Section Column

[i] C-Section Column : Combined Bending and Web Crippling [AISI S100, ASD]

[1] C-Section Column : Combined Bending and Web Crippling [ASD Method] [AISI S100, C3.5.1]

$M_{x,Ed,M\,[+]}$	0.350	[kNm]	Ratio	12.701	[%]
$M_{n,x,Comp,M\,[+]}$	4.602	[kNm]			

$M_{x,Ed,M\,[-]}$	0.350	[kNm]	Ratio	12.701	[%]
$M_{n,x,Comp,M\,[-]}$	4.602	[kNm]			

$V_{z,Ed}$	2.240	[kN]	Ratio	22.922	[%]
P_n	17.102	[kN]			

$$0.91\left(\frac{P}{P_n}\right)+\left(\frac{M}{M_{nxo}}\right)\leq \frac{1.33}{\Omega}$$

Unreinforced Webs

[AISI S100, Eq. C3.5.1-1]

$M_{x,Ed,M\,[+]}$	0.350	[kNm]	Ratio	34.168	[%]
$M_{n,x,Comp,M\,[+]}$	4.602	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
P_n	17.102	[kN]			

$M_{x,Ed,M\,[-]}$	0.350	[kNm]	Ratio	34.168	[%]
$M_{n,x,Comp,M\,[-]}$	4.602	[kNm]			
$V_{z,Ed}$	2.240	[kN]			
P_n	17.102	[kN]			

[ii] C-Section Column : Combined Bending and Web Crippling [AISI S100, LRFD]

[1] C-Section Column : Combined Bending and Web Crippling [LRFD Method] [AISI S100, C3.5.2]

$M_{x,Ed,M\,[+]}$	0.350	[kNm]	Ratio	8.450	[%]
$M_{n,x,Comp,M\,[+]}$	4.602	[kNm]			

$M_{x,Ed,M\,[-]}$	0.350	[kNm]	Ratio	8.450	[%]
$M_{n,x,Comp,M\,[-]}$	4.602	[kNm]			

$V_{z,Ed}$	2.240	[kN]	Ratio	15.410	[%]
P_n	17.102	[kN]			

[d] C-Section Strut

[i] C-Section Strut : Combined Bending and Web Crippling [AISI S100, ASD]

This verification isn't needed for this type of structural member

[ii] C-Section Strut : Combined Bending and Web Crippling [AISI S100, LRFD]

This verification isn't needed for this type of structural member

[iii] C-Section Strut : Combined Bending and Bearing [AS/NZS 4600, LSD]

This verification isn't needed for this type of structural member

[15.7] Stiffeners **[AISI S100, C3.7 | AS/NZS 4600, 3.3.8]**

[a] Ω-Section Purlin

[i] Ω-Section Purlin : Stiffeners [AISI S100, ASD]

[1] Ω-Section Purlin : Bearing Stiffeners [AISI S100, C3.7.1]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[2] Ω-Section Purlin : Bearing Stiffeners in C-Section Flexural Members [AISI S100, C3.7.2]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[3] Ω-Section Purlin : Shear Stiffeners [AISI S100, C3.7.3]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[ii] Ω-Section Purlin : Stiffeners [AISI S100, LRFD]

[1] Ω-Section Purlin : Bearing Stiffeners [AISI S100, C3.7.1]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[2] Ω-Section Purlin : Bearing Stiffeners in C-Section Flexural Members [AISI S100, C3.7.2]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[3] Ω-Section Purlin : Shear Stiffeners [AISI S100, C3.7.3]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[iii] Ω-Section Purlin : Stiffeners [AS/NZS 4600, LSD]

[1] Ω-Section Purlin : Transverse Stiffeners [AS/NZS 4600, 3.3.8.1]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[2] Ω-Section Purlin : Bearing stiffeners in channel-section flexural members [AS/NZS 4600, 3.3.8.2]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[3] Ω-Section Purlin : Shear Stiffeners [AS/NZS 4600, 3.3.8.3]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[b] C-Section Beam

[i] C-Section Beam : Stiffeners [AISI S100, ASD]

[1] C-Section Beam : Bearing Stiffeners [AISI S100, C3.7.1]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[2] C-Section Beam : Bearing Stiffeners in C-Section Flexural Members [AISI S100, C3.7.2]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[3] C-Section Beam : Shear Stiffeners [AISI S100, C3.7.3]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[ii] C-Section Beam : Stiffeners [AISI S100, LRFD]

[1] C-Section Beam : Bearing Stiffeners [AISI S100, C3.7.1]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[2] C-Section Beam : Bearing Stiffeners in C-Section Flexural Members [AISI S100, C3.7.2]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

[3] C-Section Column : Shear Stiffeners [AISI S100, C3.7.3]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[iii] C-Section Column : Stiffeners [AS/NZS 4600, LSD]

[1] C-Section Column : Transverse Stiffeners [AS/NZS 4600, 3.3.8.1]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[2] C-Section Column : Bearing stiffeners in channel-section flexural members [AS/NZS 4600, 3.3.8.2]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[3] C-Section Column : Shear Stiffeners [AS/NZS 4600, 3.3.8.3]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[d] C-Section Strut

[i] C-Section Strut : Stiffeners [AISI S100, ASD]

[1] C-Section Strut : Bearing Stiffeners [AISI S100, C3.7.1]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[2] C-Section Strut : Bearing Stiffeners in C-Section Flexural Members [AISI S100, C3.7.2]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[3] C-Section Strut : Shear Stiffeners [AISI S100, C3.7.3]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[ii] C-Section Strut : Stiffeners [AISI S100, LRFD]

[1] C-Section Strut : Bearing Stiffeners [AISI S100, C3.7.1]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[2] C-Section Strut : Bearing Stiffeners in C-Section Flexural Members [AISI S100, C3.7.2]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

[3] C-Section Beam : Shear Stiffeners [AISI S100, C3.7.3]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[iii] C-Section Beam : Stiffeners [AS/NZS 4600, LSD]

[1] C-Section Beam : Transverse Stiffeners [AS/NZS 4600, 3.3.8.1]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[2] C-Section Beam : Bearing stiffeners in channel-section flexural members [AS/NZS 4600, 3.3.8.2]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[3] C-Section Beam : Shear Stiffeners [AS/NZS 4600, 3.3.8.3]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[c] C-Section Column

[i] C-Section Column : Stiffeners [AISI S100, ASD]

[1] C-Section Column : Bearing Stiffeners [AISI S100, C3.7.1]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[2] C-Section Column : Bearing Stiffeners in C-Section Flexural Members [AISI S100, C3.7.2]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[3] C-Section Column : Shear Stiffeners [AISI S100, C3.7.3]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[ii] C-Section Column : Stiffeners [AISI S100, LRFD]

[1] C-Section Column : Bearing Stiffeners [AISI S100, C3.7.1]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[2] C-Section Column : Bearing Stiffeners in C-Section Flexural Members [AISI S100, C3.7.2]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
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Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

[3] C-Section Strut : Shear Stiffeners [AISI S100, C3.7.3]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[iii] C-Section Strut : Stiffeners [AS/NZS 4600, LSD]

[1] C-Section Strut : Transverse Stiffeners [AS/NZS 4600, 3.3.8.1]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[2] C-Section Strut : Bearing stiffeners in channel-section flexural members [AS/NZS 4600, 3.3.8.2]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[3] C-Section Strut : Shear Stiffeners [AS/NZS 4600, 3.3.8.3]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[15.8] Concentrically Loaded Compression Members [AISI S100, C4 | AS/NZS 4600, 3.4]

[a] Ω-Section Purlin

This verification isn't needed for this type of structural member

[b] C-Section Beam

[i] C-Section Beam : Concentrically Loaded Compression Members [AISI S100, ASD]

[1] Nominal Strength for Yielding, Flexural, Flexural-Torsional and Torsional Buckling [AISI S100, C4.1]

Singly-Symmetric Sections subject to Torsional or Flexural-Torsional Buckling

$$F_e = \frac{1}{2\beta}\left[(\sigma_{ex} + \sigma_t) - \sqrt{(\sigma_{ex} + \sigma_t)^2 - 4\beta\sigma_{ex}\sigma_t}\right]$$

[AISI S100, Eq. C4.1.2-1]

$$F_e = \frac{\sigma_t \sigma_{ex}}{\sigma_t + \sigma_{ex}}$$

[AISI S100, Eq. C4.1.2-2]

NOTE

Eq. C4.1.2-2 gives a conservative estimate of F_e

x_0 -37.355 [mm] r_0 62.608 [mm]

$\beta = 1 - (x_0/r_0)^2$ [AISI S100, Eq. C4.1.2-3] → β 0.644

$\sigma_{ex,Console\ Beam}$	4400.888	[N/mm²]	$\sigma_{ex,Middle\ Beam}$	4690.583	[N/mm²]
$\sigma_{t,Console\ Beam}$	535.673	[N/mm²]	$\sigma_{t,Middle\ Beam}$	569.982	[N/mm²]

$F_{e,Console\ Beam}$

[AISI S100, Eq. C4.1.2-1]			[AISI S100, Eq. C4.1.2-2]		
$F_{e,Console\ Beam}$	511.706	[N/mm²]	$F_{e,Console\ Beam}$	477.547	[N/mm²]

$F_{e,Middle\ Beam}$

[AISI S100, Eq. C4.1.2-1]			[AISI S100, Eq. C4.1.2-2]		
$F_{e,Middle\ Beam}$	544.522	[N/mm²]	$F_{e,Middle\ Beam}$	508.224	[N/mm²]

$$\lambda_c = \sqrt{\frac{F_y}{F_e}}$$
[AISI S100, Eq. C4.1-4]

F_y	350.000	[MPa]
$\lambda_{c,Console\ Beam}$	0.827	[ ]
$\lambda_{c,Middle\ Beam}$	0.802	[ ]

$$F_n = \left(0.658^{\lambda_c^2}\right)F_y$$
$\lambda_c \le 1.50$
[AISI S100, Eq. C4.1-2]

$$F_n = \left[\frac{0.877}{\lambda_c^2}\right]F_y$$
$\lambda_c > 1.50$
[AISI S100, Eq. C4.1-3]

$F_{n,Console\ Beam}$	262.867	[N/mm²]	→	[AISI S100, Eq. C4.1-2]
$F_{n,Middle\ Beam}$	267.442	[N/mm²]	→	[AISI S100, Eq. C4.1-2]

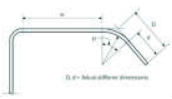
$P_n = A_eF_y$ [AISI S100, Eq. C4.1-1] Ω_c 1.800

$P_{n,Console\ Beam}$	70306.541	[N]	→	**$P_{n,Console\ Beam}$**	**70.307**	**[kN]**
$P_{n,Middle\ Beam}$	71530.102	[N]	→	**$P_{n,Middle\ Beam}$**	**71.530**	**[kN]**

[2] Distortional Buckling Strength [Resistance] [AISI S100, C4.2]

For C- and Z-Sections or any Open Section with a Stiffened Compression Flange Extending to One Side of the Web where the Stiffener is either a Simple Lip or a Complex Edge Stiffener


[AISI S100, Figure B2.3-2]


[AISI S100, Figure B4-1]

$$\tilde{k}_{\phi fg} = \left(\frac{\pi}{L}\right)^2\left[A_f\left((x_o-h_x)^2\left(\frac{I_{xyf}}{I_{yf}}\right)^2 - 2y_o(x_o-h_x)\left(\frac{I_{xyf}}{I_{yf}}\right) + h_x^2 + y_o^2\right) + I_{xf} + I_{yf}\right]$$
[AISI S100, Eq. C3.1.4-15]

$$\tilde{k}_{\phi wg} = \left(\frac{\pi}{L}\right)^2 \frac{t h_o^3}{60}$$
[AISI S100, Eq. C4.2-12]

$\tilde{k}_{\phi fg}$	4.147	[mm²]
$\tilde{k}_{\phi wg}$	2.695	[mm²]

$$F_d = \frac{k_{\phi fe} + k_{\phi we} + k_\phi}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}}$$
F_d 327.694 [MPa]
[AISI S100, Eq. C4.2-20]

F_y	350.000	[MPa]	A_g	345.063	[mm²]

$P_y = A_gF_y$	[AISI S100, Eq. C4.2-4]	→	P_y	120772.187	[N]
$P_{crd} = A_gF_d$	[AISI S100, Eq. C4.2-5]	→	P_{crd}	113075.314	[N]

$\lambda_d = \sqrt{P_y/P_{crd}}$ [AISI S100, Eq. C4.2-3]

↓

λ_d 1.033 Ω_b 1.800

↓

$P_n = P_y$
$\lambda_d \le 0.561$
[AISI S100, Eq. C4.2-1]

← →

$$P_n = \left(1-0.25\left(\frac{P_{crd}}{P_y}\right)^{0.6}\right)\left(\frac{P_{crd}}{P_y}\right)^{0.6}P_y$$
$\lambda_d > 0.561$
[AISI S100, Eq. C4.2-2]

$P_{n,Beam}$	88194.422	[N]	→	[AISI S100, Eq. C4.2-2]

$P_{n,Console\ Beam}$	70.307	[kN]	$P_{n,Middle\ Beam}$	71.530	[kN]

[ii] C-Section Beam : Concentrically Loaded Compression Members [AISI S100, LFRD]

[1] Nominal Strength for Yielding, Flexural, Flexural-Torsional and Torsional Buckling [AISI S100, C4.1]

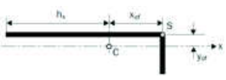
Singly-Symmetric Sections subject to Torsional or Flexural-Torsional Buckling

$$F_e = \frac{1}{2\beta}\left[(\sigma_{ex}+\sigma_t) - \sqrt{(\sigma_{ex}+\sigma_t)^2 - 4\beta\sigma_{ex}\sigma_t}\right]$$
[AISI S100, Eq. C4.1.2-1]

Dimensional Limits		
[1]	$50 \le h_o / t$	OK
	$h_o / t \le 200$	OK
[2]	$25 \le b_o / t$	OK
	$b_o / t \le 100$	OK
[3]	$6.25 < D / t$	OK
	$D / t \le 50$	OK
[4]	$45° \le \theta$	OK
	$\theta \le 90°$	OK
[5]	$2 \le h_o / b_o$	OK
	$h_o / b_o \le 8$	OK
[6]	$0.04 \le D * \sin[\theta] / b_o$	OK
	$D * \sin[\theta] / b_o \le 0.50$	OK

$$L_{cr} = \left(\frac{6\pi^4 h_o(1-\mu^2)}{t^3}\left(I_{xf}(x_o-h_x)^2 + C_{wf} - \frac{I_{xyf}^2}{I_{yf}}(x_o-h_x)^2\right)\right)^{1/4}$$
[AISI S100, Eq. C4.2-13]

NOTE Flanges with 90 Degree Lips



			A_f	76.439	[mm²]
			I_{xf}	1083.105	[mm⁴]
			I_{yf}	12526.125	[mm⁴]
			I_{xyf}	2027.082	[mm⁵]
x_{0f}	14.148	[mm]	h_x	-24.448	[mm]
y_{0f}	-1.874	[mm]	J_f	53.719	[mm⁴]
h_0	120.000	[mm]	C_{wf}	0.000	[mm⁶]
$L = L_{cr}$	391.323	[mm]	v [μ]	0.300	[ ]

E	210.000	[GPa]	**G**	80.769	[GPa]

$$k_{\phi fe} = \left(\frac{\pi}{L}\right)^4\left(EI_{xf}(x_o-h_x)^2 + EC_{wf} - E\frac{I_{xyf}^2}{I_{yf}}(x_o-h_x)^2\right) + \left(\frac{\pi}{L}\right)^2 GJ_f$$
[AISI S100, Eq. C3.1.4-13]

$$k_{\phi we} = \frac{Et^3}{6h_o(1-\mu^2)}$$
[AISI S100, Eq. C4.2-11]

$k_{\phi fe}$	1260.814	[N]
$k_{\phi we}$	981.172	[N]
k_ϕ	0.000	[N]

$$F_e = \frac{\sigma_t\sigma_{ex}}{\sigma_t + \sigma_{ex}}$$
[AISI S100, Eq. C4.1.2-2]

NOTE
Eq. C4.1.2-2 gives a conservative estimate of F_e

x_0	-37.355	[mm]	r_0	62.608	[mm]

$\beta = 1 - (x_o/r_o)^2$ [AISI S100, Eq. C4.1.2-3] → β 0.644

$\sigma_{ex,Console\ Beam}$	4400.888	[N/mm²]	$\sigma_{ex,Middle\ Beam}$	4690.583	[N/mm²]
$\sigma_{t,Console\ Beam}$	535.673	[N/mm²]	$\sigma_{t,Middle\ Beam}$	569.982	[N/mm²]

$F_{e,Console\ Beam}$

[AISI S100, Eq. C4.1.2-1]			[AISI S100, Eq. C4.1.2-2]		
$F_{e,Console\ Beam}$	511.706	[N/mm²]	$F_{e,Console\ Beam}$	477.547	[N/mm²]

$F_{e,Middle\ Beam}$

[AISI S100, Eq. C4.1.2-1]			[AISI S100, Eq. C4.1.2-2]		
$F_{e,Middle\ Beam}$	544.522	[N/mm²]	$F_{e,Middle\ Beam}$	508.224	[N/mm²]

$$\lambda_c = \sqrt{\frac{F_y}{F_e}}$$
[AISI S100, Eq. C4.1-4]

F_y	350.000	[MPa]
$\lambda_{c,Console\ Beam}$	0.827	[ ]
$\lambda_{c,Middle\ Beam}$	0.802	[ ]

$$F_n = \left(0.658^{\lambda_c^2}\right)F_y$$
$\lambda_c \le 1.50$
[AISI S100, Eq. C4.1-2]

$$F_n = \left[\frac{0.877}{\lambda_c^2}\right]F_y$$
$\lambda_c > 1.50$
[AISI S100, Eq. C4.1-3]

$F_{n,Console\ Beam}$	262.867	[N/mm²]	→	[AISI S100, Eq. C4.1-2]
$F_{n,Middle\ Beam}$	267.442	[N/mm²]	→	[AISI S100, Eq. C4.1-2]

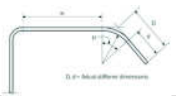
$P_n = A_eF_y$ [AISI S100, Eq. C4.1-1] Φ_c 0.850

$P_{n,Console\ Beam}$	70306.541	[N]	→	**$P_{n,Console\ Beam}$**	**70.307**	**[kN]**
$P_{n,Middle\ Beam}$	71530.102	[N]	→	**$P_{n,Middle\ Beam}$**	**71.530**	**[kN]**

[2] Distortional Buckling Strength [Resistance] [AISI S100, C4.2]

For C- and Z-Sections or any Open Section with a Stiffened Compression Flange Extending to One Side of the Web where the Stiffener is either a Simple Lip or a Complex Edge Stiffener

[AISI S100, Figure B2.3-2]



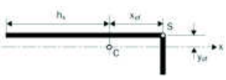
[AISI S100, Figure B4-1]

Dimensional Limits		
[1]	$50 \le h_o / t$	OK
	$h_o / t \le 200$	OK
[2]	$25 \le b_o / t$	OK
	$b_o / t \le 100$	OK
[3]	$6.25 < D / t$	OK
	$D / t \le 50$	OK
[4]	$45° \le \theta$	OK
	$\theta \le 90°$	OK
[5]	$2 \le h_o / b_o$	OK
	$h_o / b_o \le 8$	OK
[6]	$0.04 \le D \cdot \sin[\theta] / b_o$	OK
	$D \cdot \sin[\theta] / b_o \le 0.50$	OK

$$L_{cr} = \left(\frac{6\pi^4 h_o (1-\mu^2)}{t^3} \left(I_{xf}(x_o - h_x)^2 + C_{wf} - \frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2 \right) \right)^{1/4}$$

[AISI S100, Eq. C4.2-13]

NOTE — Flanges with 90 Degree Lips



			A_f	76.439	[mm^2]
			I_{xf}	1083.105	[mm^4]
			I_{yf}	12526.125	[mm^4]
			I_{xyf}	2027.082	[mm^5]
x_{0f}	14.148	[mm]	h_x	-24.448	[mm]
y_{0f}	-1.874	[mm]	J_f	53.719	[mm^4]
h_0	120.000	[mm]	C_{wf}	0.000	[mm^6]
$L = L_{cr}$	391.323	[mm]	v [μ]	0.300	[ ]
E	210.000	[GPa]	**G**	80.769	[GPa]

[iii] C-Section Beam : Concentrically Loaded Compression Members [AS/NZS 4600, LSD]

Table 1.6 : Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_b]
Concentrically loaded compression members	3.4	0.850

[1] Singly-Symmetric Sections subject to Torsional or Flexural-Torsional Buckling [AS/NZS 4600, 3.4.3]

$$f_{oxz} = \frac{1}{2\beta}\left[(f_{ox} + f_{oz}) - \sqrt{(f_{ox} + f_{oz})^2 - 4\beta f_{ox} f_{oz}} \right]$$

[AS/NZS 4600, Eq. 3.4.3(1)]

$$f_{oxz} = f_{oz} f_{ox} / (f_{oz} + f_{ox})$$

NOTE Eq. 3.4.3(2) gives a conservative estimate of f_{oxz}

[AS/NZS 4600, Eq. 3.4.3(2)]

x_0	-37.355	[mm]	r_{01}	62.608	[mm]

$$\beta = 1 - (x_0 / r_{01})^2$$

[AISI S100, Eq. C4.1.2-3] β 0.644

$f_{ox,Console\ Beam}$	4400.888	[N/mm^2]	$f_{ox,Middle\ Beam}$	4690.583	[N/mm^2]
$f_{oz,Console\ Beam}$	535.673	[N/mm^2]	$f_{oz,Middle\ Beam}$	569.982	[N/mm^2]

$f_{oxz,Console\ Beam}$

[AS/NZS 4600, Eq. 3.4.3(1)]			[AS/NZS 4600, Eq. 3.4.3(2)]		
$f_{oxz,Console\ Beam}$	511.706	[N/mm^2]	$f_{oxz,Console\ Beam}$	477.547	[N/mm^2]

$f_{oxz,Middle\ Beam}$

[AS/NZS 4600, Eq. 3.4.3(1)]			[AS/NZS 4600, Eq. 3.4.3(2)]		
$f_{oxz,Middle\ Beam}$	544.522	[N/mm^2]	$f_{oxz,Middle\ Beam}$	508.224	[N/mm^2]

$$f_{oc} = \frac{\pi^2 E}{(l_e / r)^2}$$

[AS/NZS 4600, Eq. 3.4.2(1)]

$r = r_y$	17.753	[mm]
E	210.000	[GPa]
$l_{e,Console\ Beam}$	1020.000	[mm]
$l_{e,Middle\ Beam}$	988.000	[mm]

$f_{oc,Console\ Beam}$	627.863	[N/mm^2]	$f_{oc,Middle\ Beam}$	669.193	[N/mm^2]

$$\lambda_c = \sqrt{\frac{f_y}{f_{oc}}}$$

[AS/NZS 4600, Eq. 3.4.1(5)]

f_y	350.000	[MPa]
$\lambda_{c,Console\ Beam}$	0.747	[ ]
$\lambda_{c,Middle\ Beam}$	0.723	[ ]

$$k_{\phi fe} = \left(\frac{\pi}{L}\right)^4 \left(EI_{xf}(x_o - h_x)^2 + EC_{wf} - E\frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2 \right) + \left(\frac{\pi}{L}\right)^2 GJ_f$$

[AISI S100, Eq. C3.1.4-13]

$$k_{\phi we} = \frac{Et^3}{6h_o(1-\mu^2)}$$

[AISI S100, Eq. C4.2-11]

$k_{\phi fe}$	1260.814	[N]
$k_{\phi we}$	981.172	[N]
k_{ϕ}	0.000	[N]

$$\tilde{k}_{\phi fg} = \left(\frac{\pi}{L}\right)^2 \left[A_f \left((x_o - h_x)^2 \left(\frac{I_{xyf}}{I_{yf}}\right)^2 - 2y_o(x_o - h_x)\left(\frac{I_{xyf}}{I_{yf}}\right) + h_x^2 + y_o^2 \right) + I_{xf} + I_{yf} \right]$$

[AISI S100, Eq. C3.1.4-15]

$$\tilde{k}_{\phi wg} = \left(\frac{\pi}{L}\right)^2 \frac{t h_o^3}{60}$$

[AISI S100, Eq. C4.2-12]

$\tilde{k}_{\phi fg}$	4.147	[mm^2]
$\tilde{k}_{\phi wg}$	2.695	[mm^2]

$$F_d = \frac{k_{\phi fe} + k_{\phi we} + k_\phi}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}}$$

[AISI S100, Eq. C4.2-20] F_d 327.694 [MPa]

F_y	350.000	[MPa]	A_g	345.063	[mm^2]

$P_y = A_g F_y$	[AISI S100, Eq. C4.2-4]	→	P_y	120772.187	[N]
$P_{crd} = A_g F_d$	[AISI S100, Eq. C4.2-5]	→	P_{crd}	113075.314	[N]

$$\lambda_d = \sqrt{P_y / P_{crd}}$$

[AISI S100, Eq. C4.2-3]

↓

λ_d 1.033 | Φ_b 0.850

↓ ↓

←	→
$P_n = P_y$ $\lambda_d \le 0.561$ [AISI S100, Eq. C4.2-1]	$P_n = \left(1 - 0.25\left(\frac{P_{crd}}{P_y}\right)^{0.6}\right)\left(\frac{P_{crd}}{P_y}\right)^{0.6} P_y$ $\lambda_d > 0.561$ [AISI S100, Eq. C4.2-2]

$P_{n,Beam}$	88194.422	[N]	→	[AISI S100, Eq. C4.2-2]

$P_{n,Console\ Beam}$	70.307	[kN]	$P_{n,Middle\ Beam}$	71.530	[kN]

$$f_n = \left(0.658^{\lambda_c^2}\right) f_y$$

$\lambda_c \le 1.50$

[AS/NZS 4600, Eq. 3.4.1(3)]

$$f_n = \left(0.877 / \lambda_c^2\right) f_y$$

$\lambda_c > 1.50$

[AS/NZS 4600, Eq. 3.4.1(4)]

$f_{n,Console\ Beam}$	550.636	[N/mm^2]	→	[AS/NZS 4600, Eq. 3.4.1(3)]
$f_{n,Middle\ Beam}$	586.882	[N/mm^2]	→	[AS/NZS 4600, Eq. 3.4.1(3)]

[2] Singly-Symmetric Sections subject to Distortional Buckling [AS/NZS 4600, 3.4.6]

$$f_{od} = \frac{E}{2A}\left\{ (\alpha_1 + \alpha_2) - \sqrt{(\alpha_1 + \alpha_2)^2 - 4\alpha_3} \right\}$$

[AS/NZS 4600, Eq. D2(1)] f_{od} 359.792 [MPa]

The value of N_c in Equation 3.4.1(2) shall be the lesser of:

	$f_{od} > f_y / 2$	$f_y / 13 \le f_{od} \le f_y / 2$
[$A_e f_n$] calculated in accordance with Equations 3.4.1(3) and 3.4.1(4)	$A f_n = A f_y \left(1 - \frac{f_y}{4 f_{od}}\right)$	$A f_n = A f_y \left[0.055 \left(\sqrt{\frac{f_y}{f_{od}}} - 3.6 \right)^2 + 0.237 \right]$
	[AS/NZS 4600, Eq. 3.4.6(1)]	[AS/NZS 4600, Eq. 3.4.6(2)]

f_{od}	359.792	[MPa]		$f_{od} > f_y / 2$	OK
			→	$f_{od} \le f_y / 2$	KO
f_y	350.000	[MPa]		$f_y / 13 \le f_{od}$	OK

$A_g f_n$	91400.884	[N]	→	[AS/NZS 4600, Eq. 3.4.6(1)]

[3] Concentrically Loaded Compression Members [AS/NZS 4600, 3.4.1]

$$N_s = A_e f_y$$

[AS/NZS 4600, Eq. 3.4.1(1)]

$$N_c = A_e f_n$$

[AS/NZS 4600, Eq. 3.4.1(2)]

$N_{s,Console\ Beam}$	93611.001	[N]	→	**$N_{s,Console\ Beam}$**	**93.611**	**[kN]**
$N_{c,Console\ Beam}$	91400.884	[N]	→	**$N_{c,Console\ Beam}$**	**91.401**	**[kN]**
$N_{s,Middle\ Beam}$	93611.001	[N]	→	**$N_{s,Middle\ Beam}$**	**93.611**	**[kN]**
$N_{c,Middle\ Beam}$	91400.884	[N]	→	**$N_{c,Middle\ Beam}$**	**91.401**	**[kN]**

[c] C-Section Column

[i] C-Section Column : Concentrically Loaded Compression Members [AISI S100, ASD]

[1] Nominal Strength for Yielding, Flexural, Flexural-Torsional and Torsional Buckling [AISI S100, C4.1]

Singly-Symmetric Sections subject to Torsional or Flexural-Torsional Buckling

$$F_e = \frac{1}{2\beta}\left[(\sigma_{ex}+\sigma_t) - \sqrt{(\sigma_{ex}+\sigma_t)^2 - 4\beta\sigma_{ex}\sigma_t}\right]$$

[AISI S100, Eq. C4.1.2-1]

$$F_e = \frac{\sigma_t\sigma_{ex}}{\sigma_t+\sigma_{ex}}$$

[AISI S100, Eq. C4.1.2-2]

NOTE
Eq. C4.1.2-2 gives a conservative estimate of F_e

x_0	-40.108	[mm]	r_0	56.347	[mm]

$\beta = 1 - (x_o/r_o)^2$ [AISI S100, Eq. C4.1.2-3] → β 0.493

$\sigma_{ex,Front\ Column}$	2427.408	[N/mm²]	$\sigma_{ex,Rear\ Column}$	722.710	[N/mm²]
$\sigma_{t,Front\ Column}$	1752.839	[N/mm²]	$\sigma_{t,Rear\ Column}$	619.213	[N/mm²]

$F_{e,Front\ Column}$

[AISI S100, Eq. C4.1.2-1]			[AISI S100, Eq. C4.1.2-2]		
$F_{e,Front\ Column}$	1183.015	[N/mm²]	$F_{e,Front\ Column}$	1017.848	[N/mm²]

$F_{e,Rear\ Column}$

[AISI S100, Eq. C4.1.2-1]			[AISI S100, Eq. C4.1.2-2]		
$F_{e,Rear\ Column}$	389.163	[N/mm²]	$F_{e,Rear\ Column}$	333.485	[N/mm²]

$$\lambda_c = \sqrt{\frac{F_y}{F_e}}$$

[AISI S100, Eq. C4.1-4]

F_y	350.000	[MPa]
$\lambda_{c,Front\ Column}$	0.544	[ ]
$\lambda_{c,Rear\ Column}$	0.948	[ ]

$$F_n = \left(0.658^{\lambda_c^2}\right)F_y$$

$\lambda_c \le 1.50$

[AISI S100, Eq. C4.1-2]

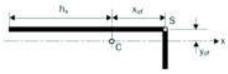
$$F_n = \left[\frac{0.877}{\lambda_c^2}\right]F_y$$

$\lambda_c > 1.50$

[AISI S100, Eq. C4.1-3]

$F_{n,Front\ Column}$	309.236	[N/mm²]	→	[AISI S100, Eq. C4.1-2]
$F_{n,Rear\ Column}$	240.207	[N/mm²]	→	[AISI S100, Eq. C4.1-2]

NOTE Flanges with 90 Degree Lips



			A_f	121.727	[mm²]
			I_{xf}	1502.698	[mm⁴]
			I_{yf}	17911.320	[mm⁴]
			I_{xyf}	2815.457	[mm⁵]
x_{0f}	13.489	[mm]	h_x	-23.107	[mm]
y_{0f}	-1.715	[mm]	J_f	243.953	[mm⁴]
h_0	90.000	[mm]	C_{wf}	0.000	[mm⁶]
$L = L_{cr}$	260.571	[mm]	v [μ]	0.300	[ ]
E	210.000	[GPa]	**G**	80.769	[GPa]

$$k_{\phi fe} = \left(\frac{\pi}{L}\right)^4\left(EI_{xf}(x_o-h_x)^2 + EC_{wf} - E\frac{I_{xyf}^2}{I_{yf}}(x_o-h_x)^2\right) + \left(\frac{\pi}{L}\right)^2 GJ_f$$

[AISI S100, Eq. C3.1.4-13]

$$k_{\phi we} = \frac{Et^3}{6h_o(1-\mu^2)}$$

[AISI S100, Eq. C4.2-11]

$k_{\phi fe}$	9164.255	[N]
$k_{\phi we}$	6300.072	[N]
k_ϕ	0.000	[N]

$$\tilde{k}_{\phi fg} = \left(\frac{\pi}{L}\right)^2\left[A_f\left((x_o-h_x)^2\left(\frac{I_{xyf}}{I_{yf}}\right)^2 - 2y_o(x_o-h_x)\left(\frac{I_{xyf}}{I_{yf}}\right) + h_x^2 + y_o^2\right) + I_{xf} + I_{yf}\right]$$

[AISI S100, Eq. C3.1.4-15]

$$\tilde{k}_{\phi wg} = \left(\frac{\pi}{L}\right)^2 \frac{th_o^3}{60}$$

[AISI S100, Eq. C4.2-12]

$\tilde{k}_{\phi fg}$	13.257	[mm²]
$\tilde{k}_{\phi wg}$	4.331	[mm²]

$$F_d = \frac{k_{\phi fe} + k_{\phi we} + k_\phi}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}}$$

F_d 879.301 [MPa]

[AISI S100, Eq. C4.2-20]

F_y	350.000	[MPa]	A_g	497.235	[mm²]

$P_y = A_gF_y$ [AISI S100, Eq. C4.2-4] → P_y 174032.262 [N]

$P_{crd} = A_gF_d$ [AISI S100, Eq. C4.2-5] → P_{crd} 437219.037 [N]

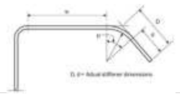
$P_n = A_eF_y$ [AISI S100, Eq. C4.1-1] Ω_c 1.800

$P_{n,Front\ Column}$	152460.330	[N]	→	**$P_{n,Front\ Column}$**	**152.460**	**[kN]**
$P_{n,Rear\ Column}$	118427.873	[N]	→	**$P_{n,Rear\ Column}$**	**118.428**	**[kN]**

[2] Distortional Buckling Strength [Resistance] [AISI S100, C4.2]

For C- and Z-Sections or any Open Section with a Stiffened Compression Flange Extending to One Side of the Web where the Stiffener is either a Simple Lip or a Complex Edge Stiffener

[AISI S100, Figure B2.3-2]



[AISI S100, Figure B4-1]

Dimensional Limits		
[1]	50 ≤ h_o / t	KO
	h_o / t ≤ 200	OK
[2]	25 ≤ b_o / t	KO
	b_o / t ≤ 100	OK
[3]	6.25 < D / t	OK
	D / t ≤ 50	OK
[4]	45° ≤ θ	OK
	θ ≤ 90°	OK
[5]	2 ≤ h_o / b_o	KO
	h_o / b_o ≤ 8	OK
[6]	0.04 ≤ D * sin [θ] / b_o	OK
	D * sin [θ] / b_o ≤ 0.50	OK

$$L_{cr} = \left(\frac{6\pi^4 h_o(1-\mu^2)}{t^3}\left(I_{xf}(x_o-h_x)^2 + C_{wf} - \frac{I_{xyf}^2}{I_{yf}}(x_o-h_x)^2\right)\right)^{1/4}$$

[AISI S100, Eq. C4.2-13]

$\lambda_d = \sqrt{P_y/P_{crd}}$ [AISI S100, Eq. C4.2-3]

↓

λ_d 0.631 Ω_b 1.800

$P_n = P_y$

$\lambda_d \le 0.561$

[AISI S100, Eq. C4.2-1]

$$P_n = \left(1 - 0.25\left(\frac{P_{crd}}{P_y}\right)^{0.6}\right)\left(\frac{P_{crd}}{P_y}\right)^{0.6} P_y$$

$\lambda_d > 0.561$

[AISI S100, Eq. C4.2-2]

$P_{n,Column}$	171044.947	[N]	→	[AISI S100, Eq. C4.2-2]	
$P_{n,Front\ Column}$	152.460	[kN]	$P_{n,Rear\ Column}$	118.428	[kN]

[ii] C-Section Column : Concentrically Loaded Compression Members [AISI S100, LFRD]

[1] Nominal Strength for Yielding, Flexural, Flexural-Torsional and Torsional Buckling [AISI S100, C4.1]

Singly-Symmetric Sections subject to Torsional or Flexural-Torsional Buckling

$$F_e = \frac{1}{2\beta}\left[(\sigma_{ex}+\sigma_t) - \sqrt{(\sigma_{ex}+\sigma_t)^2 - 4\beta\sigma_{ex}\sigma_t}\right]$$

[AISI S100, Eq. C4.1.2-1]

$$F_e = \frac{\sigma_t\sigma_{ex}}{\sigma_t+\sigma_{ex}}$$

[AISI S100, Eq. C4.1.2-2]

NOTE
Eq. C4.1.2-2 gives a conservative estimate of F_e

x_0	-40.108	[mm]	r_0	56.347	[mm]

$\beta = 1 - (x_o/r_o)^2$ [AISI S100, Eq. C4.1.2-3] → β 0.493

$\sigma_{ex,Front\ Column}$	2427.408	[N/mm²]	$\sigma_{ex,Rear\ Column}$	722.710	[N/mm²]
$\sigma_{t,Front\ Column}$	1752.839	[N/mm²]	$\sigma_{t,Rear\ Column}$	619.213	[N/mm²]

$F_{e,Front\ Column}$

[AISI S100, Eq. C4.1.2-1]			[AISI S100, Eq. C4.1.2-2]		
$F_{e,Front\ Column}$	1183.015	[N/mm²]	$F_{e,Front\ Column}$	1017.848	[N/mm²]

$F_{e,Rear\ Column}$

[AISI S100, Eq. C4.1.2-1]			[AISI S100, Eq. C4.1.2-2]		
$F_{e,Rear\ Column}$	389.163	[N/mm²]	$F_{e,Rear\ Column}$	333.485	[N/mm²]

$$\lambda_c = \sqrt{\frac{F_y}{F_e}}$$

[AISI S100, Eq. C4.1-4]

F_y	350.000	[MPa]
$\lambda_{c,Front\ Column}$	0.544	[ ]
$\lambda_{c,Rear\ Column}$	0.948	[ ]

$$F_n = \left(0.658^{\lambda_c^2}\right) F_y$$

$\lambda_c \le 1.50$

[AISI S100, Eq. C4.1-2]

$$F_n = \left[\frac{0.877}{\lambda_c^2}\right] F_y$$

$\lambda_c > 1.50$

[AISI S100, Eq. C4.1-3]

$F_{n,Front\ Column}$	309.236	[N/mm^2]	→	[AISI S100, Eq. C4.1-2]
$F_{n,Rear\ Column}$	240.207	[N/mm^2]	→	[AISI S100, Eq. C4.1-2]

$P_n = A_e F_y$ [AISI S100, Eq. C4.1-1]

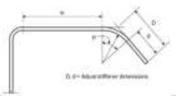
Φ_c 0.850

$P_{n,Front\ Column}$	152460.330	[N]	→	**$P_{n,Front\ Column}$**	**152.460**	**[kN]**
$P_{n,Rear\ Column}$	118427.873	[N]	→	**$P_{n,Rear\ Column}$**	**118.428**	**[kN]**

[2] Distortional Buckling Strength [Resistance] [AISI S100, C4.2]

For C- and Z-Sections or any Open Section with a Stiffened Compression Flange Extending to One Side of the Web where the Stiffener is either a Simple Lip or a Complex Edge Stiffener

[AISI S100, Figure B2.3-2]



[AISI S100, Figure B4-1]

Dimensional Limits		
[1]	$50 \le h_o / t$	KO
	$h_o / t \le 200$	OK
[2]	$25 \le b_o / t$	KO
	$b_o / t \le 100$	OK
[3]	$6.25 < D / t$	OK
	$D / t \le 50$	OK
[4]	$45° \le \theta$	OK
	$\theta \le 90°$	OK
[5]	$2 \le h_o / b_o$	KO
	$h_o / b_o \le 8$	OK
[6]	$0.04 \le D * \sin[\theta] / b_o$	OK
	$D * \sin[\theta] / b_o \le 0.50$	OK

$P_y = A_g F_y$	[AISI S100, Eq. C4.2-4]	→	P_y	174032.262	[N]
$P_{crd} = A_g F_d$	[AISI S100, Eq. C4.2-5]	→	P_{crd}	437219.037	[N]

$$\lambda_d = \sqrt{P_y / P_{crd}}$$

[AISI S100, Eq. C4.2-3]

λ_d 0.631 Φ_b 0.850

$P_n = P_y$

$\lambda_d \le 0.561$

[AISI S100, Eq. C4.2-1]

$$P_n = \left(1 - 0.25\left(\frac{P_{crd}}{P_y}\right)^{0.6}\right)\left(\frac{P_{crd}}{P_y}\right)^{0.6} P_y$$

$\lambda_d > 0.561$

[AISI S100, Eq. C4.2-2]

$P_{n,Column}$	171044.947	[N]	→	[AISI S100, Eq. C4.2-2]	
$P_{n,Front\ Column}$	152.460	[kN]	$P_{n,Rear\ Column}$	118.428	[kN]

[iii] C-Section Column : Concentrically Loaded Compression Members [AS/NZS 4600, LSD]

Table 1.6 : Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_b]
Concentrically loaded compression members	3.4	0.850

[1] Singly-Symmetric Sections subject to Torsional or Flexural-Torsional Buckling [AS/NZS 4600, 3.4.3]

$$f_{oxz} = \frac{1}{2\beta}\left[(f_{ox} + f_{oz}) - \sqrt{(f_{ox} + f_{oz})^2 - 4\beta f_{ox} f_{oz}}\right]$$

[AS/NZS 4600, Eq. 3.4.3(1)]

$$f_{oxz} = f_{oz} f_{ox} / (f_{oz} + f_{ox})$$

NOTE

Eq. 3.4.3(2) gives a conservative estimate of f_{oxz}

[AS/NZS 4600, Eq. 3.4.3(2)]

x_0	-40.108	[mm]	r_{01}	56.347	[mm]

$$\beta = 1 - (x_o / r_{01})^2$$

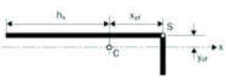
[AISI S100, Eq. C4.1.2-3] β 0.493

$f_{ox,Front\ Column}$	2427.408	[N/mm^2]	$f_{ox,Rear\ Column}$	722.710	[N/mm^2]
$f_{oz,Front\ Column}$	1752.839	[N/mm^2]	$f_{oz,Rear\ Column}$	619.213	[N/mm^2]

$$L_{cr} = \left(\frac{6\pi^4 h_o (1-\mu^2)}{t^3}\left(I_{xf}(x_o - h_x)^2 + C_{wf} - \frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2\right)\right)^{1/4}$$

[AISI S100, Eq. C4.2-13]

NOTE Flanges with 90 Degree Lips



			A_f	121.727	[mm^2]
			I_{xf}	1502.698	[mm^4]
			I_{yf}	17911.320	[mm^4]
			I_{xyf}	2815.457	[mm^5]
x_{0f}	13.489	[mm]	h_x	-23.107	[mm]
y_{0f}	-1.715	[mm]	J_f	243.953	[mm^4]
h_0	90.000	[mm]	C_{wf}	0.000	[mm^6]
$L = L_{cr}$	260.571	[mm]	v [μ]	0.300	[ ]
E	210.000	[GPa]	**G**	80.769	[GPa]

$$k_{\phi fe} = \left(\frac{\pi}{L}\right)^4\left(EI_{xf}(x_o - h_x)^2 + EC_{wf} - E\frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2\right) + \left(\frac{\pi}{L}\right)^2 GJ_f$$

[AISI S100, Eq. C3.1.4-13]

$$k_{\phi we} = \frac{Et^3}{6h_o(1-\mu^2)}$$

[AISI S100, Eq. C4.2-11]

$k_{\varphi fe}$	9164.255	[N]
$k_{\varphi we}$	6300.072	[N]
k_φ	0.000	[N]

$$\tilde{k}_{\phi fg} = \left(\frac{\pi}{L}\right)^2\left[A_f\left((x_o - h_x)^2\left(\frac{I_{xyf}}{I_{yf}}\right)^2 - 2y_o(x_o - h_x)\left(\frac{I_{xyf}}{I_{yf}}\right) + h_x^2 + y_o^2\right) + I_{xf} + I_{yf}\right]$$

[AISI S100, Eq. C3.1.4-15]

$$\tilde{k}_{\phi wg} = \left(\frac{\pi}{L}\right)^2 \frac{th_o^3}{60}$$

[AISI S100, Eq. C4.2-12]

$\tilde{k}_{\phi fg}$	13.257	[mm^2]
$\tilde{k}_{\phi wg}$	4.331	[mm^2]

$$F_d = \frac{k_{\phi fe} + k_{\phi we} + k_\phi}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}}$$

F_d 879.301 [MPa]

[AISI S100, Eq. C4.2-20]

F_y	350.000	[MPa]	A_g	497.235	[mm^2]

$f_{oxz,Front\ Column}$

[AS/NZS 4600, Eq. 3.4.3(1)]			[AS/NZS 4600, Eq. 3.4.3(2)]		
$f_{oxz,Front\ Column}$	1183.015	[N/mm^2]	$f_{oxz,Front\ Column}$	1017.848	[N/mm^2]

$f_{oxz,Rear\ Column}$

[AS/NZS 4600, Eq. 3.4.3(1)]			[AS/NZS 4600, Eq. 3.4.3(2)]		
$f_{oxz,Rear\ Column}$	389.163	[N/mm^2]	$f_{oxz,Rear\ Column}$	333.485	[N/mm^2]

$$f_{oc} = \frac{\pi^2 E}{(l_e / r)^2}$$

[AS/NZS 4600, Eq. 3.4.2(1)]

$r = r_y$	17.588	[mm]
E	210.000	[GPa]
$l_{e,Front\ Column}$	490.000	[mm]
$l_{e,Rear\ Column}$	847.999	[mm]

$f_{oc,Front\ Column}$	2670.356	[N/mm^2]	$f_{oc,Rear\ Column}$	891.602	[N/mm^2]

$$\lambda_c = \sqrt{\frac{f_y}{f_{oc}}}$$

[AS/NZS 4600, Eq. 3.4.1(5)]

f_y	350.000	[MPa]
$\lambda_{c,Front\ Column}$	0.362	[ ]
$\lambda_{c,Rear\ Column}$	0.627	[ ]

$$f_n = \left(0.658^{\lambda_c^2}\right) f_y$$

$\lambda_c \le 1.50$

[AS/NZS 4600, Eq. 3.4.1(3)]

$$f_n = \left(0.877 / \lambda_c^2\right) f_y$$

$\lambda_c > 1.50$

[AS/NZS 4600, Eq. 3.4.1(4)]

$f_{n,Front\ Column}$	2341.902	[N/mm^2]	→	[AS/NZS 4600, Eq. 3.4.1(3)]
$f_{n,Rear\ Column}$	781.935	[N/mm^2]	→	[AS/NZS 4600, Eq. 3.4.1(3)]

[2] Singly-Symmetric Sections subject to Distortional Buckling [AS/NZS 4600, 3.4.6]

$$f_{od} = \frac{E}{2A}\left[(\alpha_1 + \alpha_2) - \sqrt{(\alpha_1 + \alpha_2)^2 - 4\alpha_3}\right]$$

f_{od} 818.295 [MPa]

[AS/NZS 4600, Eq. D2(1)]

The value of N_c in Equation 3.4.1(2) shall be the lesser of:

[$A_e f_n$] calculated in accordance with Equations 3.4.1(3) and 3.4.1(4)

$f_{od} > f_y / 2$

$$Af_n = Af_y\left(1 - \frac{f_y}{4 f_{od}}\right)$$

[AS/NZS 4600, Eq. 3.4.6(1)]

$f_y / 13 \le f_{od} \le f_y / 2$

$$Af_n = Af_y\left[0.055\left(\sqrt{\frac{f_y}{f_{od}}} - 3.6\right)^2 + 0.237\right]$$

[AS/NZS 4600, Eq. 3.4.6(2)]

f_{od}	818.295	[MPa]		$f_{od} > f_y / 2$	OK
			→	$f_{od} \leq f_y / 2$	KO
f_y	350.000	[MPa]		$f_y / 13 \leq f_{od}$	OK

$A_g f_n$ 155423.051 [N] → [AS/NZS 4600, Eq. 3.4.6(1)]

[3] Concentrically Loaded Compression Members [AS/NZS 4600, 3.4.1]

$$N_s = A_e f_y$$
[AS/NZS 4600, Eq. 3.4.1(1)]

$$N_c = A_e f_n$$
[AS/NZS 4600, Eq. 3.4.1(2)]

$N_{s,Front\ Column}$	172558.160	[N]	→	**$N_{s,Front\ Column}$**	**172.558**	**[kN]**
$N_{c,Front\ Column}$	155423.051	[N]	→	**$N_{c,Front\ Column}$**	**155.423**	**[kN]**
$N_{s,Rear\ Column}$	172558.160	[N]	→	**$N_{s,Rear\ Column}$**	**172.558**	**[kN]**
$N_{c,Rear\ Column}$	155423.051	[N]	→	**$N_{c,Rear\ Column}$**	**155.423**	**[kN]**

[d] C-Section Strut

[i] C-Section Strut : Concentrically Loaded Compression Members [AISI S100, ASD]

[1] Nominal Strength for Yielding, Flexural, Flexural-Torsional and Torsional Buckling [AISI S100, C4.1]

Singly-Symmetric Sections subject to Torsional or Flexural-Torsional Buckling

$$F_e = \frac{1}{2\beta}\left[(\sigma_{ex} + \sigma_t) - \sqrt{(\sigma_{ex} + \sigma_t)^2 - 4\beta\sigma_{ex}\sigma_t}\right]$$
[AISI S100, Eq. C4.1.2-1]

$$F_e = \frac{\sigma_t \sigma_{ex}}{\sigma_t + \sigma_{ex}}$$
[AISI S100, Eq. C4.1.2-2]

NOTE
Eq. C4.1.2-2 gives a conservative estimate of F_e

x_0	-35.537	[mm]	r_0	43.621	[mm]

$\beta = 1 - (x_0/r_0)^2$ [AISI S100, Eq. C4.1.2-3] → β 0.336

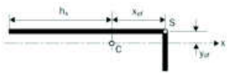
$\sigma_{ex,Strut}$	231.286	[N/mm^2]	$\sigma_{t,Strut}$	67.264	[N/mm^2]

$F_{e,Strut}$

[AISI S100, Eq. C4.1.2-1]			[AISI S100, Eq. C4.1.2-2]		
$F_{e,Strut}$	55.590	[N/mm^2]	$F_{e,Strut}$	52.109	[N/mm^2]

$$L_{cr} = \left(\frac{6\pi^4 h_o (1-\mu^2)}{t^3}\left(I_{xf}(x_o - h_x)^2 + C_{wf} - \frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2\right)\right)^{1/4}$$
[AISI S100, Eq. C4.2-13]

NOTE Flanges with 90 Degree Lips



			A_f	55.385	[mm^2]
			I_{xf}	102.528	[mm^4]
			I_{yf}	5903.746	[mm^4]
			I_{xyf}	358.596	[mm^5]
x_{0f}	13.503	[mm]	h_x	-18.593	[mm]
y_{0f}	-0.479	[mm]	J_f	38.923	[mm^4]
h_0	50.000	[mm]	C_{wf}	0.000	[mm^6]
$L = L_{cr}$	163.954	[mm]	v [μ]	0.300	[ ]

E	210.000	[GPa]	**G**	80.769	[GPa]

$$k_{\phi fe} = \left(\frac{\pi}{L}\right)^4\left(EI_{xf}(x_o - h_x)^2 + EC_{wf} - E\frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2\right) + \left(\frac{\pi}{L}\right)^2 GJ_f$$
[AISI S100, Eq. C3.1.4-13]

$$k_{\phi we} = \frac{Et^3}{6h_o(1-\mu^2)}$$
[AISI S100, Eq. C4.2-11]

$k_{\phi fe}$	3509.079	[N]
$k_{\phi we}$	2354.813	[N]
k_ϕ	0.000	[N]

$$\tilde{k}_{\phi fg} = \left(\frac{\pi}{L}\right)^2\left[A_f\left((x_o - h_x)^2\left(\frac{I_{xyf}}{I_{yf}}\right)^2 - 2y_o(x_o - h_x)\left(\frac{I_{xyf}}{I_{yf}}\right) + h_x^2 + y_o^2\right) + I_{xf} + I_{yf}\right]$$
[AISI S100, Eq. C3.1.4-15]

$$\tilde{k}_{\phi wg} = \left(\frac{\pi}{L}\right)^2 \frac{th_o^3}{60}$$
[AISI S100, Eq. C4.2-12]

$\tilde{k}_{\phi fg}$	9.355	[mm^2]
$\tilde{k}_{\phi wg}$	1.111	[mm^2]

$$F_d = \frac{k_{\phi fe} + k_{\phi we} + k_\phi}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}}$$
[AISI S100, Eq. C4.2-20]

F_d 560.312 [MPa]

F_y	350.000	[MPa]	A_g	201.315	[mm^2]

$$\lambda_c = \sqrt{\frac{F_y}{F_e}}$$
[AISI S100, Eq. C4.1-4]

F_y	350.000	[MPa]
$\lambda_{c,Strut}$	2.509	[ ]

$$F_n = \left(0.658^{\lambda_c^2}\right)F_y$$
$\lambda_c \leq 1.50$
[AISI S100, Eq. C4.1-2]

$$F_n = \left[\frac{0.877}{\lambda_c^2}\right]F_y$$
$\lambda_c > 1.50$
[AISI S100, Eq. C4.1-3]

$F_{n,Strut}$ 48.753 [N/mm^2] → [AISI S100, Eq. C4.1-3]

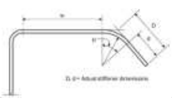
$P_n = A_e F_y$ [AISI S100, Eq. C4.1-1] Ω_c 1.800

$P_{n,Strut}$ 9814.666 [N] → **$P_{n,Strut}$ 9.815 [kN]**

[2] Distortional Buckling Strength [Resistance] [AISI S100, C4.2]

For C- and Z-Sections or any Open Section with a Stiffened Compression Flange Extending to One Side of the Web where the Stiffener is either a Simple Lip or a Complex Edge Stiffener

[AISI S100, Figure B2.3-2]



[AISI S100, Figure B4-1]

Dimensional Limits		
[1]	$50 \leq h_o / t$	KO
	$h_o / t \leq 200$	OK
[2]	$25 \leq b_o / t$	OK
	$b_o / t \leq 100$	OK
[3]	$6.25 < D / t$	OK
	$D / t \leq 50$	OK
[4]	$45° \leq \theta$	OK
	$\theta \leq 90°$	OK
[5]	$2 \leq h_o / b_o$	KO
	$h_o / b_o \leq 8$	OK
[6]	$0.04 \leq D * \sin[\theta] / b_o$	OK
	$D * \sin[\theta] / b_o \leq 0.50$	OK

$P_y = A_g F_y$ [AISI S100, Eq. C4.2-4] → P_y 70460.387 [N]

$P_{crd} = A_g F_d$ [AISI S100, Eq. C4.2-5] → P_{crd} 112799.494 [N]

$\lambda_d = \sqrt{P_y / P_{crd}}$ [AISI S100, Eq. C4.2-3]

λ_d 0.790 Ω_b 1.800

$P_n = P_y$
$\lambda_d \leq 0.561$
[AISI S100, Eq. C4.2-1]

$$P_n = \left(1 - 0.25\left(\frac{P_{crd}}{P_y}\right)^{0.6}\right)\left(\frac{P_{crd}}{P_y}\right)^{0.6} P_y$$
$\lambda_d > 0.561$
[AISI S100, Eq. C4.2-2]

$P_{n,Strut}$ 62463.618 [N] → [AISI S100, Eq. C4.2-2]

$P_{n,Strut}$ 9.815 [kN]

[ii] C-Section Strut: Concentrically Loaded Compression Members [AISI S100, LFRD]

[1] Nominal Strength for Yielding, Flexural, Flexural-Torsional and Torsional Buckling [AISI S100, C4.1]

Singly-Symmetric Sections subject to Torsional or Flexural-Torsional Buckling

$$F_e = \frac{1}{2\beta}\left[(\sigma_{ex} + \sigma_t) - \sqrt{(\sigma_{ex} + \sigma_t)^2 - 4\beta\sigma_{ex}\sigma_t}\right]$$
[AISI S100, Eq. C4.1.2-1]

$$F_e = \frac{\sigma_t \sigma_{ex}}{\sigma_t + \sigma_{ex}}$$
[AISI S100, Eq. C4.1.2-2]

NOTE
Eq. C4.1.2-2 gives a conservative estimate of F_e

x_0	-35.537	[mm]	r_0	43.621	[mm]

$\beta = 1 - (x_0/r_0)^2$ [AISI S100, Eq. C4.1.2-3] → β 0.336

$\sigma_{ex,Strut}$	231.286	[N/mm^2]	$\sigma_{t,Strut}$	67.264	[N/mm^2]

$F_{e,Strut}$

[AISI S100, Eq. C4.1.2-1]			[AISI S100, Eq. C4.1.2-2]		
$F_{e,Strut}$	55.590	[N/mm^2]	$F_{e,Strut}$	52.109	[N/mm^2]

$$\lambda_c = \sqrt{\frac{F_y}{F_e}}$$
[AISI S100, Eq. C4.1-4]

F_y	350.000	[MPa]
$\lambda_{c,Strut}$	2.509	[ ]

$$F_n = \left(0.658^{\lambda_c^2}\right)F_y$$
$\lambda_c \le 1.50$
[AISI S100, Eq. C4.1-2]

$$F_n = \left[\frac{0.877}{\lambda_c^2}\right]F_y$$
$\lambda_c > 1.50$
[AISI S100, Eq. C4.1-3]

$F_{n,Strut}$ 48.753 [N/mm^2] → [AISI S100, Eq. C4.1-3]

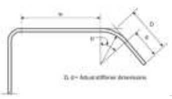
$P_n = A_e F_y$ [AISI S100, Eq. C4.1-1] Φ_c 0.850

$P_{n,Strut}$ 9814.666 [N] → **$P_{n,Strut}$ 9.815 [kN]**

[2] Distortional Buckling Strength [Resistance] [AISI S100, C4.2]

For C- and Z-Sections or any Open Section with a Stiffened Compression Flange Extending to One Side of the Web where the Stiffener is either a Simple Lip or a Complex Edge Stiffener


[AISI S100, Figure B2.3-2]


[AISI S100, Figure B4-1]

Dimensional Limits		
[1]	$50 \le h_o / t$	KO
	$h_o / t \le 200$	OK
[2]	$25 \le b_o / t$	OK
	$b_o / t \le 100$	OK
[3]	$6.25 < D / t$	OK
	$D / t \le 50$	OK
[4]	$45° \le \theta$	OK
	$\theta \le 90°$	OK
[5]	$2 \le h_o / b_o$	KO
	$h_o / b_o \le 8$	OK
[6]	$0.04 \le D * \sin[\theta] / b_o$	OK
	$D * \sin[\theta] / b_o \le 0.50$	OK

$P_y = A_g F_y$ [AISI S100, Eq. C4.2-4] → P_y 70460.387 [N]

$P_{crd} = A_g F_d$ [AISI S100, Eq. C4.2-5] → P_{crd} 112799.494 [N]

$$\lambda_d = \sqrt{P_y / P_{crd}}$$
[AISI S100, Eq. C4.2-3]

λ_d 0.790 Φ_b 0.850

$P_n = P_y$
$\lambda_d \le 0.561$
[AISI S100, Eq. C4.2-1]

$$P_n = \left(1 - 0.25\left(\frac{P_{crd}}{P_y}\right)^{0.6}\right)\left(\frac{P_{crd}}{P_y}\right)^{0.6} P_y$$
$\lambda_d > 0.561$
[AISI S100, Eq. C4.2-2]

$P_{n,Strut}$ 62463.618 [N] → [AISI S100, Eq. C4.2-2]

$P_{n,Strut}$ 9.815 [kN]

[iii] C-Section Strut : Concentrically Loaded Compression Members [AS/NZS 4600, LSD]

Table 1.6 : Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction Factor [Φ_b]
Concentrically loaded compression members	3.4	0.850

[1] Singly-Symmetric Sections subject to Torsional or Flexural-Torsional Buckling [AS/NZS 4600, 3.4.3]

$$f_{oxz} = \frac{1}{2\beta}\left[(f_{ox} + f_{oz}) - \sqrt{(f_{ox} + f_{oz})^2 - 4\beta f_{ox} f_{oz}}\right]$$
[AS/NZS 4600, Eq. 3.4.3(1)]

$$f_{oxz} = f_{oz} f_{ox} / (f_{oz} + f_{ox})$$
[AS/NZS 4600, Eq. 3.4.3(2)]

NOTE
Eq. 3.4.3(2) gives a conservative estimate of f_{oxz}

x_0	-35.537	[mm]	r_{01}	43.621	[mm]

$$\beta = 1 - (x_o / r_{o1})^2$$
[AISI S100, Eq. C4.1.2-3] β 0.336

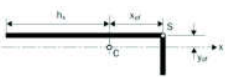
$f_{ox,Strut}$	231.286	[N/mm^2]	$f_{oz,Strut}$	67.264	[N/mm^2]

$f_{oxz,Strut}$

[AS/NZS 4600, Eq. 3.4.3(1)]			[AS/NZS 4600, Eq. 3.4.3(2)]		
$f_{oxz,Strut}$	55.590	[N/mm^2]	$f_{oxz,Strut}$	52.109	[N/mm^2]

$$L_{cr} = \left(\frac{6\pi^4 h_o (1-\mu^2)}{t^3}\left(I_{xf}(x_o - h_x)^2 + C_{wf} - \frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2\right)\right)^{1/4}$$
[AISI S100, Eq. C4.2-13]

NOTE Flanges with 90 Degree Lips



			A_f	55.385	[mm^2]
			I_{xf}	102.528	[mm^4]
			I_{yf}	5903.746	[mm^4]
			I_{xyf}	358.596	[mm^5]
x_{0f}	13.503	[mm]	h_x	-18.593	[mm]
y_{0f}	-0.479	[mm]	J_f	38.923	[mm^4]
h_0	50.000	[mm]	C_{wf}	0.000	[mm^6]
$L = L_{cr}$	163.954	[mm]	ν [μ]	0.300	[ ]
E	210.000	[GPa]	**G**	80.769	[GPa]

$$k_{\phi fe} = \left(\frac{\pi}{L}\right)^4\left(EI_{xf}(x_o - h_x)^2 + EC_{wf} - E\frac{I_{xyf}^2}{I_{yf}}(x_o - h_x)^2\right) + \left(\frac{\pi}{L}\right)^2 GJ_f$$
[AISI S100, Eq. C3.1.4-13]

$$k_{\phi we} = \frac{Et^3}{6h_o(1-\mu^2)}$$
[AISI S100, Eq. C4.2-11]

$k_{\phi fe}$	3509.079	[N]
$k_{\phi we}$	2354.813	[N]
k_ϕ	0.000	[N]

$$\tilde{k}_{\phi fg} = \left(\frac{\pi}{L}\right)^2\left[A_f\left((x_o - h_x)^2\left(\frac{I_{xyf}}{I_{yf}}\right)^2 - 2y_o(x_o - h_x)\left(\frac{I_{xyf}}{I_{yf}}\right) + h_x^2 + y_o^2\right) + I_{xf} + I_{yf}\right]$$
[AISI S100, Eq. C3.1.4-15]

$$\tilde{k}_{\phi wg} = \left(\frac{\pi}{L}\right)^2 \frac{t h_o^3}{60}$$
[AISI S100, Eq. C4.2-12]

$\tilde{k}_{\phi fg}$	9.355	[mm^2]
$\tilde{k}_{\phi wg}$	1.111	[mm^2]

$$F_d = \frac{k_{\phi fe} + k_{\phi we} + k_\phi}{\tilde{k}_{\phi fg} + \tilde{k}_{\phi wg}}$$
[AISI S100, Eq. C4.2-20] F_d 560.312 [MPa]

F_y	350.000	[MPa]	A_g	201.315	[mm^2]

$$f_{oc} = \frac{\pi^2 E}{(l_e / r)^2}$$
[AS/NZS 4600, Eq. 3.4.2(1)]

$r = r_y$	14.683	[mm]
E	210.000	[GPa]
$l_{e,Strut}$	1950.133	[mm]
$f_{oc,Strut}$	117.489	[N/mm^2]

$$\lambda_c = \sqrt{\frac{f_y}{f_{oc}}}$$
[AS/NZS 4600, Eq. 3.4.1(5)]

f_y	350.000	[MPa]
$\lambda_{c,Strut}$	1.726	[ ]

$$f_n = \left(0.658^{\lambda_c^2}\right)f_y$$
$\lambda_c \le 1.50$
[AS/NZS 4600, Eq. 3.4.1(3)]

$$f_n = \left(0.877 / \lambda_c^2\right)f_y$$
$\lambda_c > 1.50$
[AS/NZS 4600, Eq. 3.4.1(4)]

$f_{n,Strut}$ 103.038 [N/mm^2] → [AS/NZS 4600, Eq. 3.4.1(4)]

[2] Singly-Symmetric Sections subject to Distortional Buckling [AS/NZS 4600, 3.4.6]

$$f_{od} = \frac{E}{2A}\left\{(\alpha_1 + \alpha_2) - \sqrt{(\alpha_1 + \alpha_2)^2 - 4\alpha_3}\right\}$$
[AS/NZS 4600, Eq. D2(1)] f_{od} 541.768 [MPa]

The value of N_c in Equation 3.4.1(2) shall be the lesser of:

	$f_{od} > f_y / 2$	$f_y / 13 \le f_{od} \le f_y / 2$
[$A_e f_n$] calculated in accordance with Equations 3.4.1(3) and 3.4.1(4)	$Af_n = Af_y\left(1 - \frac{f_y}{4 f_{od}}\right)$	$Af_n = Af_y\left[0.055\left(\sqrt{\frac{f_y}{f_{od}}} - 3.6\right)^2 + 0.237\right]$
	[AS/NZS 4600, Eq. 3.4.6(1)]	[AS/NZS 4600, Eq. 3.4.6(2)]

f_{od}	541.768	[MPa]		$f_{od} > f_y / 2$	OK
			→	$f_{od} \le f_y / 2$	KO
f_y	350.000	[MPa]		$f_y / 13 \le f_{od}$	OK

$A_g f_n$ 59080.462 [N] → [AS/NZS 4600, Eq. 3.4.6(1)]

[3] Concentrically Loaded Compression Members [AS/NZS 4600, 3.4.1]

$$N_s = A_e f_y$$
[AS/NZS 4600, Eq. 3.4.1(1)]

$$N_c = A_e f_n$$
[AS/NZS 4600, Eq. 3.4.1(2)]

$N_{t,Strut}$	70460.387	[N]	→	$N_{t,Strut}$	**70.460** [kN]
$N_{c,Strut}$	20743.083	[N]	→	$N_{c,Strut}$	**20.743** [kN]

[15.9] Combined Axial Load and Bending **[AISI S100, C5 | AS/NZS 4600, 3.5]**

[a] Ω-Section Purlin

This verification isn't needed for this type of structural member

[b] C-Section Beam

[i] C-Section Beam : Combined Axial Load and Bending [AISI S100, ASD]

[1] Combined Tensile Axial Load and Bending [AISI S100, C5.1.1]

$$\frac{\Omega_b M_x}{M_{nxt}} + \frac{\Omega_b M_y}{M_{nyt}} + \frac{\Omega_t T}{T_n} \leq 1.0$$

[AISI S100, Eq. C5.1.1-1]

$$\frac{\Omega_b M_x}{M_{nx}} + \frac{\Omega_b M_y}{M_{ny}} - \frac{\Omega_t T}{T_n} \leq 1.0$$

[AISI S100, Eq. C5.1.1-2]

Ω_b	1.670	Ω_t	1.670

Console Beam

[AISI S100, Eq. C5.1.1-1]

R = T	0.520	[kN]	Ratio	34.539	[%]
$R_n = T_n$	124.223	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{n,y,Comp,M[+]}$	2.006	[kNm]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]	$M_{n,x,Tension,M[+]}$	4.501	[kNm]
$M_{y,Ed,M[+]}$	0.020	[kNm]	$M_{n,y,Tension,M[+]}$	1.249	[kNm]

[AISI S100, Eq. C5.1.1-2]

R = T	0.520	[kN]	Ratio	35.007	[%]
$R_n = T_n$	124.223	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{n,y,Comp,M[-]}$	1.336	[kNm]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]	$M_{n,x,Tension,M[-]}$	4.501	[kNm]
$M_{y,Ed,M[-]}$	0.020	[kNm]	$M_{n,y,Tension,M[-]}$	2.614	[kNm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
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Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

Members whose ends are unrestrained

C_{mx}	1.000	C_{my}	1.000

Console Beam

C_{mx}	1.000		C_{my}	0.850	
P_{Ex}	1518.585	[kN]	P_{Ey}	1219.464	[kN]
α_x	0.999	[ ]	α_y	0.999	[ ]

[AISI S100, Eq. C5.2.1-1]

P	0.520	[kN]	Ratio	35.974	[%]
P_n	70.307	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	α_x	0.999	[ ]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]	α_y	0.999	[ ]
$M_{y,Ed,M[+]}$	0.020	[kNm]	C_{mx}	1.000	[ ]
$M_{n,y,Comp,M[+]}$	2.006	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.1-2]

P	0.520	[kN]	Ratio	36.202	[%]
P_{n0}	70.307	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{y,Ed,M[+]}$	0.020	[kNm]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]	$M_{n,y,Comp,M[+]}$	2.006	[kNm]

[AISI S100, Eq. C5.2.1-3]

P	0.520	[kN]	Ratio	36.202	[%]
P_n	70.307	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{y,Ed,M[+]}$	0.020	[kNm]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]	$M_{n,y,Comp,M[+]}$	2.006	[kNm]

[AISI S100, Eq. C5.2.1-1]

P	0.520	[kN]	Ratio	36.684	[%]
P_n	70.307	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	α_x	0.999	[ ]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]	α_y	0.999	[ ]
$M_{y,Ed,M[-]}$	0.020	[kNm]	C_{mx}	1.000	[ ]
$M_{n,y,Comp,M[-]}$	1.336	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.1-2]

P	0.520	[kN]	Ratio	37.037	[%]
P_{n0}	70.307	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{y,Ed,M[-]}$	0.020	[kNm]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]	$M_{n,y,Comp,M[-]}$	1.336	[kNm]

[AISI S100, Eq. C5.2.1-3]

P	0.520	[kN]	Ratio	37.037	[%]
P_n	70.307	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{y,Ed,M[-]}$	0.020	[kNm]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]	$M_{n,y,Comp,M[-]}$	1.336	[kNm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
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Client: COIMBRA UNIVERSITY

Middle Beam

[AISI S100, Eq. C5.1.1-1]

R = T	0.700	[kN]	Ratio	33.444	[%]
$R_n = T_n$	124.223	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{n,y,Comp,M[+]}$	1.336	[kNm]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]	$M_{n,x,Tension,M[+]}$	4.501	[kNm]
$M_{y,Ed,M[+]}$	0.010	[kNm]	$M_{n,y,Tension,M[+]}$	1.249	[kNm]

[AISI S100, Eq. C5.1.1-2]

R = T	0.700	[kN]	Ratio	33.515	[%]
$R_n = T_n$	124.223	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{n,y,Comp,M[-]}$	1.336	[kNm]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]	$M_{n,x,Tension,M[-]}$	4.501	[kNm]
$M_{y,Ed,M[-]}$	0.010	[kNm]	$M_{n,y,Tension,M[-]}$	2.614	[kNm]

[2] Combined Compressive Axial Load and Bending [AISI S100, C5.2.1]

$$\frac{\Omega_c P}{P_n} + \frac{\Omega_b C_{mx} M_x}{M_{nx}\alpha_x} + \frac{\Omega_b C_{my} M_y}{M_{ny}\alpha_y} \leq 1.0$$

[AISI S100, Eq. C5.2.1-1]

$$\frac{\Omega_c P}{P_{no}} + \frac{\Omega_b M_x}{M_{nx}} + \frac{\Omega_b M_y}{M_{ny}} \leq 1.0$$

[AISI S100, Eq. C5.2.1-2]

$\Omega_c * P / P_n \leq 0.15$

$$\frac{\Omega_c P}{P_n} + \frac{\Omega_b M_x}{M_{nx}} + \frac{\Omega_b M_y}{M_{ny}} \leq 1.0$$

[AISI S100, Eq. C5.2.1-3]

Ω_c	1.800	Ω_b	1.670

$$\alpha_x = 1 - \frac{\Omega_c P}{P_{Ex}} > 0$$

[AISI S100, Eq. C5.2.1-4]

Console Beam: P [kN] 0.520

$$\alpha_y = 1 - \frac{\Omega_c P}{P_{Ey}} > 0$$

[AISI S100, Eq. C5.2.1-5]

$$P_{Ex} = \frac{\pi^2 E I_x}{(K_x L_x)^2}$$

[AISI S100, Eq. C5.2.1-6]

Middle Beam: P [kN] 1.030

$$P_{Ey} = \frac{\pi^2 E I_y}{(K_y L_y)^2}$$

[AISI S100, Eq. C5.2.1-7]

Members whose ends are restrained

C_{mx}	0.850	C_{my}	0.850

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Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

Middle Beam

C_{mx}	0.850		C_{my}	0.850	
P_{Ex}	1618.548	[kN]	P_{Ey}	1214.724	[kN]
α_x	0.999	[ ]	α_y	0.998	[ ]

[AISI S100, Eq. C5.2.1-1]

P	1.030	[kN]	Ratio	31.558	[%]
P_n	71.530	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	α_x	0.999	[ ]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]	α_y	0.998	[ ]
$M_{y,Ed,M[+]}$	0.010	[kNm]	C_{mx}	0.850	[ ]
$M_{n,y,Comp,M[+]}$	2.006	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.1-2]

P	1.030	[kN]	Ratio	36.630	[%]
P_{n0}	71.530	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{y,Ed,M[+]}$	0.010	[kNm]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]	$M_{n,y,Comp,M[+]}$	2.006	[kNm]

[AISI S100, Eq. C5.2.1-3]

P	1.030	[kN]	Ratio	36.630	[%]
P_n	71.530	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{y,Ed,M[+]}$	0.010	[kNm]
$M_{n,x,Comp,M[+]}$	4.225	[kNm]	$M_{n,y,Comp,M[+]}$	2.006	[kNm]

[AISI S100, Eq. C5.2.1-1]

P	1.030	[kN]	Ratio	31.913	[%]
P_n	71.530	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	α_x	0.999	[ ]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]	α_y	0.998	[ ]
$M_{y,Ed,M[-]}$	0.010	[kNm]	C_{mx}	0.850	[ ]
$M_{n,y,Comp,M[-]}$	1.336	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.1-2]

P	1.030	[kN]	Ratio	37.048	[%]
P_{n0}	71.530	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{y,Ed,M[-]}$	0.010	[kNm]
$M_{n,x,Comp,M[-]}$	4.225	[kNm]	$M_{n,y,Comp,M[-]}$	1.336	[kNm]

[AISI S100, Eq. C5.2.1-3]

P	1.030	[kN]	Ratio	37.048	[%]
P_n	71.530	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{y,Ed,M[-]}$	0.010	[kNm]
$M_{n,x,Comp,M[--]}$	4.225	[kNm]	$M_{n,y,Comp,M[-]}$	1.336	[kNm]

[ii]	C-Section Beam : Combined Axial Load and Bending	[AISI S100, LRFD]

[1] Combined Tensile Axial Load and Bending [AISI S100, C5.1.2]

$$\frac{\overline{M}_x}{\phi_b M_{nxt}} + \frac{\overline{M}_y}{\phi_b M_{nyt}} + \frac{\overline{T}}{\phi_t T_n} \leq 1.0$$

[AISI S100, Eq. C5.1.2-1]

Φ_b	0.900	Φ_t	0.950

$$\frac{\overline{M}_x}{\phi_b M_{nx}} + \frac{\overline{M}_y}{\phi_b M_{ny}} - \frac{\overline{T}}{\phi_t T_n} \leq 1.0$$

[AISI S100, Eq. C5.1.2-2]

Console Beam

[AISI S100, Eq. C5.1.2-1]

R = T	0.520	[kN]	Ratio	22.956	[%]
$R_n = T_n$	124.223	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{n,y,Comp,M[+]}$	2.006	[kNm]
$M_{n,x,Comp,M[+]}$	4.815	[kNm]	$M_{n,x,Tension,M[+]}$	4.501	[kNm]
$M_{y,Ed,M[+]}$	0.020	[kNm]	$M_{n,y,Tension,M[+]}$	1.249	[kNm]

[AISI S100, Eq. C5.1.2-2]

R = T	0.520	[kN]	Ratio	20.608	[%]
$R_n = T_n$	124.223	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{n,y,Comp,M[-]}$	1.336	[kNm]
$M_{n,x,Comp,M[-]}$	4.815	[kNm]	$M_{n,x,Tension,M[-]}$	4.501	[kNm]
$M_{y,Ed,M[-]}$	0.020	[kNm]	$M_{n,y,Tension,M[-]}$	2.614	[kNm]

Middle Beam

[AISI S100, Eq. C5.1.121]

R = T	0.700	[kN]	Ratio	22.218	[%]
$R_n = T_n$	124.223	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{n,y,Comp,M[+]}$	2.006	[kNm]
$M_{n,x,Comp,M[+]}$	4.815	[kNm]	$M_{n,x,Tension,M[+]}$	4.501	[kNm]
$M_{y,Ed,M[+]}$	0.010	[kNm]	$M_{n,y,Tension,M[+]}$	1.249	[kNm]

[AISI S100, Eq. C5.1.2-2]

R = T	0.700	[kN]	Ratio	19.623	[%]
$R_n = T_n$	124.223	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{n,y,Comp,M[-]}$	1.336	[kNm]
$M_{n,x,Comp,M[-]}$	4.815	[kNm]	$M_{n,x,Tension,M[-]}$	4.501	[kNm]
$M_{y,Ed,M[-]}$	0.010	[kNm]	$M_{n,y,Tension,M[-]}$	2.614	[kNm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

[AISI S100, Eq. C5.2.2-1]

P	0.520	[kN]	Ratio	21.202	[%]
P_n	70.307	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	α_x	1.000	[ ]
$M_{n,x,Comp,M[+]}$	4.815	[kNm]	α_y	1.000	[ ]
$M_{y,Ed,M[+]}$	0.020	[kNm]	C_{mx}	1.000	[ ]
$M_{n,y,Comp,M[+]}$	2.006	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.2-2]

P	0.520	[kN]	Ratio	21.363	[%]
P_{n0}	70.307	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{y,Ed,M[+]}$	0.020	[kNm]
$M_{n,x,Comp,M[+]}$	4.815	[kNm]	$M_{n,y,Comp,M[+]}$	2.006	[kNm]

[AISI S100, Eq. C5.2.2-3]

P	0.520	[kN]	Ratio	21.363	[%]
P_n	70.307	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{y,Ed,M[+]}$	0.020	[kNm]
$M_{n,x,Comp,M[+]}$	4.815	[kNm]	$M_{n,y,Comp,M[+]}$	2.006	[kNm]

[AISI S100, Eq. C5.2.2-1]

P	0.520	[kN]	Ratio	21.675	[%]
P_n	70.307	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	α_x	1.000	[ ]
$M_{n,x,Comp,M[-]}$	4.815	[kNm]	α_y	1.000	[ ]
$M_{y,Ed,M[-]}$	0.020	[kNm]	C_{mx}	1.000	[ ]
$M_{n,y,Comp,M[-]}$	1.336	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.2-2]

P	0.520	[kN]	Ratio	21.919	[%]
P_{n0}	70.307	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{y,Ed,M[-]}$	0.020	[kNm]
$M_{n,x,Comp,M[-]}$	4.815	[kNm]	$M_{n,y,Comp,M[-]}$	1.336	[kNm]

[AISI S100, Eq. C5.2.2-3]

P	0.520	[kN]	Ratio	21.919	[%]
P_n	70.307	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{y,Ed,M[-]}$	0.020	[kNm]
$M_{n,x,Comp,M[--]}$	4.815	[kNm]	$M_{n,y,Comp,M[-]}$	1.336	[kNm]

Middle Beam

	C_{mx}	0.850	C_{my}	0.850	
P_{Ex}	1618.548	[kN]	P_{Ey}	1214.724	[kN]
α_x	0.999	[ ]	α_y	0.999	[ ]

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[2] Combined Compressive Axial Load and Bending [AISI S100, C5.2.2]

$$\frac{\overline{P}}{\phi_c P_n} + \frac{C_{mx}\overline{M}_x}{\phi_b M_{nx}\alpha_x} + \frac{C_{my}\overline{M}_y}{\phi_b M_{ny}\alpha_y} \leq 1.0$$

[AISI S100, Eq. C5.2.2-1]

$$\frac{\overline{P}}{\phi_c P_{no}} + \frac{\overline{M}_x}{\phi_b M_{nx}} + \frac{\overline{M}_y}{\phi_b M_{ny}} \leq 1.0$$

[AISI S100, Eq. C5.2.2-2]

P / [Φ_c * P_n] ≤ 0.15

$$\frac{\overline{P}}{\phi_c P_n} + \frac{\overline{M}_x}{\phi_b M_{nx}} + \frac{\overline{M}_y}{\phi_b M_{ny}} \leq 1.0$$

[AISI S100, Eq. C5.2.2-3]

Φ_c	0.850	Φ_b	0.900

$$\alpha_x = 1 - \frac{\overline{P}}{P_{Ex}} > 0$$

[AISI S100, Eq. C5.2.2-4]

Console Beam

P [kN] 0.520

$$\alpha_y = 1 - \frac{\overline{P}}{P_{Ey}} > 0$$

[AISI S100, Eq. C5.2.2-5]

$$P_{Ex} = \frac{\pi^2 EI_x}{(K_x L_x)^2}$$

[AISI S100, Eq. C5.2.2-6]

Middle Beam

P [kN] 1.030

$$P_{Ey} = \frac{\pi^2 EI_y}{(K_y L_y)^2}$$

[AISI S100, Eq. C5.2.2-7]

Members whose ends are restrained

C_{mx}	0.850	C_{my}	0.850

Members whose ends are unrestrained

C_{mx}	1.000	C_{my}	1.000

Console Beam

	C_{mx}	1.000	C_{my}	0.850	
P_{Ex}	1518.585	[kN]	P_{Ey}	1219.464	[kN]
α_x	1.000	[ ]	α_y	1.000	[ ]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
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[AISI S100, Eq. C5.2.2-1]

P	1.030	[kN]	Ratio	18.651	[%]
P_n	71.530	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	α_x	0.999	[ ]
$M_{n,x,Comp,M[+]}$	4.815	[kNm]	α_y	0.999	[ ]
$M_{y,Ed,M[+]}$	0.010	[kNm]	C_{mx}	0.850	[ ]
$M_{n,y,Comp,M[+]}$	2.006	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.2-2]

P	1.030	[kN]	Ratio	21.633	[%]
P_{n0}	71.530	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{y,Ed,M[+]}$	0.010	[kNm]
$M_{n,x,Comp,M[+]}$	4.815	[kNm]	$M_{n,y,Comp,M[+]}$	2.006	[kNm]

[AISI S100, Eq. C5.2.2-3]

P	1.030	[kN]	Ratio	21.633	[%]
P_n	71.530	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{y,Ed,M[+]}$	0.010	[kNm]
$M_{n,x,Comp,M[+]}$	4.815	[kNm]	$M_{n,y,Comp,M[+]}$	2.006	[kNm]

[AISI S100, Eq. C5.2.2-1]

P	1.030	[kN]	Ratio	18.888	[%]
P_n	71.530	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	α_x	0.999	[ ]
$M_{n,x,Comp,M[-]}$	4.815	[kNm]	α_y	0.999	[ ]
$M_{y,Ed,M[-]}$	0.010	[kNm]	C_{mx}	0.850	[ ]
$M_{n,y,Comp,M[-]}$	1.336	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.2-2]

P	1.030	[kN]	Ratio	21.911	[%]
P_{n0}	71.530	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{y,Ed,M[-]}$	0.010	[kNm]
$M_{n,x,Comp,M[-]}$	4.815	[kNm]	$M_{n,y,Comp,M[-]}$	1.336	[kNm]

[AISI S100, Eq. C5.2.2-3]

P	1.030	[kN]	Ratio	21.911	[%]
P_n	71.530	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{y,Ed,M[-]}$	0.010	[kNm]
$M_{n,x,Comp,M[--]}$	4.815	[kNm]	$M_{n,y,Comp,M[-]}$	1.336	[kNm]

[iii]	C-Section Beam : Combined Axial Load and Bending	[AS/NZS 4600, LSD]

[1] Combined axial tension and bending [AS/NZS 4600, 3.5.2]

$$\frac{M_x^*}{\phi_b M_{bx}} + \frac{M_y^*}{\phi_b M_{by}} - \frac{N^*}{\phi_t N_t} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.2(1)]

$$\frac{N^*}{\phi_t N_t} + \frac{M_x^*}{\phi_b M_{sxf}} + \frac{M_y^*}{\phi_b M_{syf}} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.2(2)]

Φ_b	0.900	Φ_t	0.950

Console Beam

[AS/NZS 4600, Eq. 3.5.2(1)]

N*	0.520	[kN]	Ratio	20.052	[%]
N_t	124.223	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{s,y,Comp,M[+]}$	2.006	[kNm]
$M_{s,x,Comp,M[+]}$	4.815	[kNm]	$M_{sxf,M[+]}$	4.501	[kNm]
$M_{y,Ed,M[+]}$	0.020	[kNm]	$M_{syf,M[+]}$	1.249	[kNm]

[AS/NZS 4600, Eq. 3.5.2(2)]

N*	0.520	[kN]	Ratio	22.026	[%]
N_t	124.223	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{s,y,Comp,M[-]}$	1.336	[kNm]
$M_{s,x,Comp,M[-]}$	4.815	[kNm]	$M_{sxf,M[-]}$	4.501	[kNm]
$M_{y,Ed,M[-]}$	0.020	[kNm]	$M_{syf,M[-]}$	2.614	[kNm]

Middle Beam

[AS/NZS 4600, Eq. 3.5.2(1)]

N*	0.700	[kN]	Ratio	19.345	[%]
N_t	124.223	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{s,y,Comp,M[+]}$	2.006	[kNm]
$M_{s,x,Comp,M[+]}$	4.815	[kNm]	$M_{sxf,M[+]}$	4.501	[kNm]
$M_{y,Ed,M[+]}$	0.010	[kNm]	$M_{syf,M[+]}$	1.249	[kNm]

[AS/NZS 4600, Eq. 3.5.2(2)]

N*	0.700	[kN]	Ratio	21.754	[%]
N_t	124.223	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{s,y,Comp,M[-]}$	1.336	[kNm]
$M_{s,x,Comp,M[-]}$	4.815	[kNm]	$M_{sxf,M[-]}$	4.501	[kNm]
$M_{y,Ed,M[-]}$	0.010	[kNm]	$M_{syf,M[-]}$	2.614	[kNm]

[2] Combined Compressive Axial Load and Bending [AS/NZS 4600, 3.5.1]

$$\frac{N^*}{\phi_c N_c} + \frac{C_{mx} M_x^*}{\phi_b M_{bx} \alpha_{nx}} + \frac{C_{my} M_y^*}{\phi_b M_{by} \alpha_{ny}} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.1(1)]

$$\frac{N^*}{\phi_c N_s} + \frac{M_x^*}{\phi_b M_{bx}} + \frac{M_y^*}{\phi_b M_{by}} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.1(2)]

[AS/NZS 4600, Eq. 3.5.1(1)]

N*	0.520	[kN]	Ratio	21.476	[%]
N_c	91.401	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	α_{nx}	1.000	[ ]
$M_{s,x,Comp,M[-]}$	4.815	[kNm]	α_{ny}	0.999	[ ]
$M_{y,Ed,M[-]}$	0.020	[kNm]	C_{mx}	1.000	[ ]
$M_{s,y,Comp,M[-]}$	1.336	[kNm]	C_{my}	0.850	[ ]

[AS/NZS 4600, Eq. 3.5.1(2)]

N*	0.520	[kN]	Ratio	21.702	[%]
N_s	93.611	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{y,Ed,M[-]}$	0.020	[kNm]
$M_{s,x,Comp,M[-]}$	4.815	[kNm]	$M_{s,y,Comp,M[-]}$	1.336	[kNm]

[AS/NZS 4600, Eq. 3.5.1(3)]

N*	0.520	[kN]	Ratio	21.718	[%]
N_c	91.401	[kN]			
$M_{x,Ed,M[-]}$	0.840	[kNm]	$M_{y,Ed,M[-]}$	0.020	[kNm]
$M_{s,x,Comp,M[-]}$	4.815	[kNm]	$M_{s,y,Comp,M[-]}$	1.336	[kNm]

Middle Beam

C_{mx}	0.850		C_{my}	0.850	
N_{Ex}	1618.548	[kN]	N_{Ey}	1214.724	[kN]
α_{nx}	0.999	[ ]	α_{ny}	0.999	[ ]

[AS/NZS 4600, Eq. 3.5.1(1)]

N*	0.700	[kN]	Ratio	17.860	[%]
N_c	91.401	[kN]			
$M_{bx,Ed,M[+]}$	0.840	[kNm]	α_{nx}	0.999	[ ]
$M_{s,x,Comp,M[+]}$	4.815	[kNm]	α_{ny}	0.999	[ ]
$M_{by,Ed,M[+]}$	0.010	[kNm]	C_{mx}	0.850	[ ]
$M_{s,y,Comp,M[+]}$	2.006	[kNm]	C_{my}	0.850	[ ]

[AS/NZS 4600, Eq. 3.5.1(2)]

N*	0.700	[kN]	Ratio	20.818	[%]
N_s	93.611	[kN]			
$M_{bx,Ed,M[+]}$	0.840	[kNm]	$M_{by,Ed,M[+]}$	0.010	[kNm]
$M_{s,x,Comp,M[+]}$	4.815	[kNm]	$M_{s,y,Comp,M[+]}$	2.006	[kNm]

[AS/NZS 4600, Eq. 3.5.1(3)]

N*	0.700	[kN]	Ratio	20.840	[%]
N_c	91.401	[kN]			
$M_{bx,Ed,M[+]}$	0.840	[kNm]	$M_{by,Ed,M[+]}$	0.010	[kNm]
$M_{s,x,Comp,M[+]}$	4.815	[kNm]	$M_{s,y,Comp,M[+]}$	2.006	[kNm]

N* / [Φ_c * N_c] ≤ 0.15

$$\frac{N^*}{\phi_c N_c} + \frac{M_x^*}{\phi_b M_{bx}} + \frac{M_y^*}{\phi_b M_{by}} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.1(3)]

Φ_c	0.850	Φ_b	0.900

$$\alpha_{nx}, \alpha_{ny} = 1 - \left(\frac{N^*}{N_e}\right)$$

[AS/NZS 4600, Eq. 3.5.1(5)]

Console Beam	
N* [kN]	0.520
Middle Beam	
N* [kN]	1.030

$$N_e = \frac{\pi^2 EI_b}{(l_{eb})^2}$$

[AS/NZS 4600, Eq. 3.5.1(6)]

Members whose ends are restrained

C_{mx}	0.850	C_{my}	0.850

Members whose ends are unrestrained

C_{mx}	1.000	C_{my}	1.000

Console Beam

C_{mx}	1.000		C_{my}	0.850	
N_{Ex}	1518.585	[kN]	N_{Ey}	1219.464	[kN]
α_{nx}	1.000	[ ]	α_{ny}	0.999	[ ]

[AS/NZS 4600, Eq. 3.5.1(1)]

N*	0.520	[kN]	Ratio	21.003	[%]
N_c	91.401	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	α_{nx}	1.000	[ ]
$M_{s,x,Comp,M[+]}$	4.815	[kNm]	α_{ny}	0.999	[ ]
$M_{y,Ed,M[+]}$	0.020	[kNm]	C_{mx}	1.000	[ ]
$M_{s,y,Comp,M[+]}$	2.006	[kNm]	C_{my}	0.850	[ ]

[AS/NZS 4600, Eq. 3.5.1(2)]

N*	0.520	[kN]	Ratio	21.146	[%]
N_s	93.611	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{y,Ed,M[+]}$	0.020	[kNm]
$M_{s,x,Comp,M[+]}$	4.815	[kNm]	$M_{s,y,Comp,M[+]}$	2.006	[kNm]

[AS/NZS 4600, Eq. 3.5.1(3)]

N*	0.520	[kN]	Ratio	21.162	[%]
N_c	91.401	[kN]			
$M_{x,Ed,M[+]}$	0.840	[kNm]	$M_{y,Ed,M[+]}$	0.020	[kNm]
$M_{s,x,Comp,M[+]}$	4.815	[kNm]	$M_{s,y,Comp,M[+]}$	2.006	[kNm]

[AS/NZS 4600, Eq. 3.5.1(1)]

N*	0.700	[kN]	Ratio	18.096	[%]
N_c	91.401	[kN]			
$M_{bx,Ed,M[-]}$	0.840	[kNm]	α_{nx}	0.999	[ ]
$M_{s,x,Comp,M[-]}$	4.815	[kNm]	α_{ny}	0.999	[ ]
$M_{by,Ed,M[-]}$	0.010	[kNm]	C_{mx}	0.850	[ ]
$M_{s,y,Comp,M[-]}$	1.336	[kNm]	C_{my}	0.850	[ ]

[AS/NZS 4600, Eq. 3.5.1(2)]

N*	0.700	[kN]	Ratio	21.096	[%]
N_s	93.611	[kN]			
$M_{bx,Ed,M[-]}$	0.840	[kNm]	$M_{by,Ed,M[-]}$	0.010	[kNm]
$M_{s,x,Comp,M[-]}$	4.815	[kNm]	$M_{s,y,Comp,M[-]}$	1.336	[kNm]

[AS/NZS 4600, Eq. 3.5.1(3)]

N*	0.700	[kN]	Ratio	21.117	[%]
N_c	91.401	[kN]			
$M_{bx,Ed,M[-]}$	0.840	[kNm]	$M_{by,Ed,M[-]}$	0.010	[kNm]
$M_{s,x,Comp,M[-]}$	4.815	[kNm]	$M_{s,y,Comp,M[-]}$	1.336	[kNm]

[c] C-Section Column

[i] C-Section Column : Combined Axial Load and Bending [AISI S100, ASD]

[1] Combined Tensile Axial Load and Bending [AISI S100, C5.1.1]

$$\frac{\Omega_b M_x}{M_{nxt}} + \frac{\Omega_b M_y}{M_{nyt}} + \frac{\Omega_t T}{T_n} \leq 1.0$$

[AISI S100, Eq. C5.1.1-1]

$$\frac{\Omega_b M_x}{M_{nx}} + \frac{\Omega_b M_y}{M_{ny}} - \frac{\Omega_t T}{T_n} \leq 1.0$$

[AISI S100, Eq. C5.1.1-2]

Ω_b	1.670	Ω_t	1.670

Front Column

[AISI S100, Eq. C5.1.1-1]

R = T	2.700	[kN]	Ratio	11.484	[%]
R_n = T_n	183.143	[kN]			
$M_{x,Ed,M[+]}$	0.270	[kNm]	$M_{n,y,Comp,M[+]}$	3.698	[kNm]
$M_{n,x,Comp,M[+]}$	4.732	[kNm]	$M_{n,x,Tension,M[+]}$	4.998	[kNm]
$M_{y,Ed,M[+]}$	0.000	[kNm]	$M_{n,y,Tension,M[+]}$	1.930	[kNm]

[AISI S100, Eq. C5.1.1-2]

R = T	2.700	[kN]	Ratio	7.066	[%]
$R_n = T_n$	183.143	[kN]			
$M_{x,Ed,M[-]}$	0.270	[kNm]	$M_{n,y,Comp,M[-]}$	2.143	[kNm]
$M_{n,x,Comp,M[-]}$	4.732	[kNm]	$M_{n,x,Tension,M[-]}$	4.732	[kNm]
$M_{y,Ed,M[-]}$	0.000	[kNm]	$M_{n,y,Tension,M[-]}$	3.332	[kNm]

Rear Column

[AISI S100, Eq. C5.1.1-1]

R = T	3.340	[kN]	Ratio	14.741	[%]
$R_n = T_n$	183.143	[kN]			
$M_{x,Ed,M[+]}$	0.350	[kNm]	$M_{n,y,Comp,M[+]}$	3.698	[kNm]
$M_{n,x,Comp,M[+]}$	4.602	[kNm]	$M_{n,x,Tension,M[+]}$	4.998	[kNm]
$M_{y,Ed,M[+]}$	0.000	[kNm]	$M_{n,y,Tension,M[+]}$	1.930	[kNm]

[AISI S100, Eq. C5.1.1-2]

R = T	3.340	[kN]	Ratio	9.655	[%]
$R_n = T_n$	183.143	[kN]			
$M_{x,Ed,M[-]}$	0.350	[kNm]	$M_{n,y,Comp,M[-]}$	2.143	[kNm]
$M_{n,x,Comp,M[-]}$	4.602	[kNm]	$M_{n,x,Tension,M[-]}$	4.732	[kNm]
$M_{y,Ed,M[-]}$	0.000	[kNm]	$M_{n,y,Tension,M[-]}$	3.332	[kNm]

[2] Combined Compressive Axial Load and Bending [AISI S100, C5.2.1]

$$\frac{\Omega_c P}{P_n} + \frac{\Omega_b C_{mx} M_x}{M_{nx}\alpha_x} + \frac{\Omega_b C_{my} M_y}{M_{ny}\alpha_y} \leq 1.0$$

[AISI S100, Eq. C5.2.1-1]

$$\frac{\Omega_c P}{P_{no}} + \frac{\Omega_b M_x}{M_{nx}} + \frac{\Omega_b M_y}{M_{ny}} \leq 1.0$$

[AISI S100, Eq. C5.2.1-2]

Ω_c * P / $P_n \leq 0.15$

$$\frac{\Omega_c P}{P_n} + \frac{\Omega_b M_x}{M_{nx}} + \frac{\Omega_b M_y}{M_{ny}} \leq 1.0$$

[AISI S100, Eq. C5.2.1-3]

Ω_c 1.800 Ω_b 1.670

$$\alpha_x = 1 - \frac{\Omega_c P}{P_{Ex}} > 0$$

[AISI S100, Eq. C5.2.1-4]

Front Column

P [kN] 4.140

$$\alpha_y = 1 - \frac{\Omega_c P}{P_{Ey}} > 0$$

[AISI S100, Eq. C5.2.1-5]

[AISI S100, Eq. C5.2.1-2]

P	4.140	[kN]	Ratio	14.416	[%]
P_{n0}	152.460	[kN]			
$M_{x,Ed,M[-]}$	0.270	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{n,x,Comp,M[-]}$	4.732	[kNm]	$M_{n,y,Comp,M[-]}$	2.143	[kNm]

[AISI S100, Eq. C5.2.1-3]

P	4.140	[kN]	Ratio	14.416	[%]
P_n	152.460	[kN]			
$M_{x,Ed,M[-]}$	0.270	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{n,x,Comp,M[-]}$	4.732	[kNm]	$M_{n,y,Comp,M[-]}$	2.143	[kNm]

Rear Column

C_{mx}	0.850		C_{my}	0.850	
P_{Ex}	359.357	[kN]	P_{Ey}	54.309	[kN]
α_x	0.979	[ ]	α_y	0.862	[ ]

[AISI S100, Eq. C5.2.1-1]

P	4.170	[kN]	Ratio	17.364	[%]
P_n	118.428	[kN]			
$M_{x,Ed,M[+]}$	0.350	[kNm]	α_x	0.979	[ ]
$M_{n,x,Comp,M[+]}$	4.602	[kNm]	α_y	0.862	[ ]
$M_{y,Ed,M[+]}$	0.000	[kNm]	C_{mx}	0.850	[ ]
$M_{n,y,Comp,M[+]}$	3.698	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.1-2]

P	4.170	[kN]	Ratio	19.039	[%]
P_{n0}	118.428	[kN]			
$M_{x,Ed,M[+]}$	0.350	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{n,x,Comp,M[+]}$	4.602	[kNm]	$M_{n,y,Comp,M[+]}$	3.698	[kNm]

[AISI S100, Eq. C5.2.1-3]

P	4.170	[kN]	Ratio	19.039	[%]
P_n	118.428	[kN]			
$M_{x,Ed,M[+]}$	0.350	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{n,x,Comp,M[+]}$	4.602	[kNm]	$M_{n,y,Comp,M[+]}$	3.698	[kNm]

[AISI S100, Eq. C5.2.1-1]

P	4.170	[kN]	Ratio	17.364	[%]
P_n	118.428	[kN]			
$M_{x,Ed,M[-]}$	0.350	[kNm]	α_x	0.979	[ ]
$M_{n,x,Comp,M[-]}$	4.602	[kNm]	α_y	0.862	[ ]
$M_{y,Ed,M[-]}$	0.000	[kNm]	C_{mx}	0.850	[ ]
$M_{n,y,Comp,M[-]}$	2.143	[kNm]	C_{my}	0.850	[ ]

$$P_{Ex} = \frac{\pi^2 E I_x}{(K_x L_x)^2}$$

[AISI S100, Eq. C5.2.1-6]

Rear Column

P [kN] 4.170

$$P_{Ey} = \frac{\pi^2 E I_y}{(K_y L_y)^2}$$

[AISI S100, Eq. C5.2.1-7]

Members whose ends are restrained

C_{mx}	0.850	C_{my}	0.850

Members whose ends are unrestrained

C_{mx}	1.000	C_{my}	1.000

Front Column

C_{mx}	0.850		C_{my}	0.850	
P_{Ex}	1206.993	[kN]	P_{Ey}	162.655	[kN]
α_x	0.994	[ ]	α_y	0.954	[ ]

[AISI S100, Eq. C5.2.1-1]

P	4.140	[kN]	Ratio	13.037	[%]
P_n	152.460	[kN]			
$M_{x,Ed,M[+]}$	0.270	[kNm]	α_x	0.994	[ ]
$M_{n,x,Comp,M[+]}$	4.732	[kNm]	α_y	0.954	[ ]
$M_{y,Ed,M[+]}$	0.000	[kNm]	C_{mx}	0.850	[ ]
$M_{n,y,Comp,M[+]}$	3.698	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.1-2]

P	4.140	[kN]	Ratio	14.416	[%]
P_{n0}	152.460	[kN]			
$M_{x,Ed,M[+]}$	0.270	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{n,x,Comp,M[+]}$	4.732	[kNm]	$M_{n,y,Comp,M[+]}$	3.698	[kNm]

[AISI S100, Eq. C5.2.1-3]

P	4.140	[kN]	Ratio	14.416	[%]
P_n	152.460	[kN]			
$M_{x,Ed,M[+]}$	0.270	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{n,x,Comp,M[+]}$	4.732	[kNm]	$M_{n,y,Comp,M[+]}$	3.698	[kNm]

[AISI S100, Eq. C5.2.1-1]

P	4.140	[kN]	Ratio	13.037	[%]
P_n	152.460	[kN]			
$M_{x,Ed,M[-]}$	0.270	[kNm]	α_x	0.994	[ ]
$M_{n,x,Comp,M[-]}$	4.732	[kNm]	α_y	0.954	[ ]
$M_{y,Ed,M[-]}$	0.000	[kNm]	C_{mx}	0.850	[ ]
$M_{n,y,Comp,M[-]}$	2.143	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.1-2]

P	4.170	[kN]	Ratio	19.039	[%]
P_{n0}	118.428	[kN]			
$M_{x,Ed,M[-]}$	0.350	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{n,x,Comp,M[-]}$	4.602	[kNm]	$M_{n,y,Comp,M[-]}$	2.143	[kNm]

[AISI S100, Eq. C5.2.1-3]

P	4.170	[kN]	Ratio	19.039	[%]
P_n	118.428	[kN]			
$M_{x,Ed,M[-]}$	0.350	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{n,x,Comp,M[--]}$	4.602	[kNm]	$M_{n,y,Comp,M[-]}$	2.143	[kNm]

[ii] C-Section Column : Combined Axial Load and Bending [AISI S100, LRFD]

[1] Combined Tensile Axial Load and Bending [AISI S100, C5.1.2]

$$\frac{\bar{M}_x}{\phi_b M_{nxt}} + \frac{\bar{M}_y}{\phi_b M_{nyt}} + \frac{\bar{T}}{\phi_t T_n} \leq 1.0$$

[AISI S100, Eq. C5.1.2-1]

Φ_b 0.900 Φ_t 0.950

$$\frac{\bar{M}_x}{\phi_b M_{nx}} + \frac{\bar{M}_y}{\phi_b M_{ny}} - \frac{\bar{T}}{\phi_t T_n} \leq 1.0$$

[AISI S100, Eq. C5.1.2-2]

Front Column

[AISI S100, Eq. C5.1.2-1]

R = T	2.700	[kN]	Ratio	7.555	[%]
$R_n = T_n$	183.143	[kN]			
$M_{x,Ed,M[+]}$	0.270	[kNm]	$M_{n,y,Comp,M[+]}$	3.698	[kNm]
$M_{n,x,Comp,M[+]}$	4.732	[kNm]	$M_{n,x,Tension,M[+]}$	4.998	[kNm]
$M_{y,Ed,M[+]}$	0.000	[kNm]	$M_{n,y,Tension,M[+]}$	1.930	[kNm]

[AISI S100, Eq. C5.1.2-2]

R = T	2.700	[kN]	Ratio	4.967	[%]
$R_n = T_n$	183.143	[kN]			
$M_{x,Ed,M[-]}$	0.270	[kNm]	$M_{n,y,Comp,M[-]}$	2.143	[kNm]
$M_{n,x,Comp,M[-]}$	4.602	[kNm]	$M_{n,x,Tension,M[-]}$	4.732	[kNm]
$M_{y,Ed,M[-]}$	0.000	[kNm]	$M_{n,y,Tension,M[-]}$	3.332	[kNm]

Rear Column

[AISI S100, Eq. C5.1.1-2-1]

R = T	3.340	[kN]	Ratio	9.701	[%]
$R_n = T_n$	183.143	[kN]			
$M_{x,Ed,M[+]}$	0.350	[kNm]	$M_{n,y,Comp,M[+]}$	2.143	[kNm]
$M_{n,x,Comp,M[+]}$	4.732	[kNm]	$M_{n,x,Tension,M[+]}$	4.998	[kNm]
$M_{y,Ed,M[+]}$	0.000	[kNm]	$M_{n,y,Tension,M[+]}$	1.930	[kNm]

[AISI S100, Eq. C5.1.2-2]

R = T	3.340	[kN]	Ratio	6.531	[%]
$R_n = T_n$	183.143	[kN]			
$M_{x,Ed,M[-]}$	0.350	[kNm]	$M_{n,y,Comp,M[-]}$	2.143	[kNm]
$M_{n,x,Comp,M[-]}$	4.602	[kNm]	$M_{n,x,Tension,M[-]}$	4.732	[kNm]
$M_{y,Ed,M[-]}$	0.000	[kNm]	$M_{n,y,Tension,M[-]}$	3.332	[kNm]

[2] Combined Compressive Axial Load and Bending [AISI S100, C5.2.2]

$$\frac{\bar{P}}{\phi_c P_n} + \frac{C_{mx}\bar{M}_x}{\phi_b M_{nx}\alpha_x} + \frac{C_{my}\bar{M}_y}{\phi_b M_{ny}\alpha_y} \le 1.0$$

[AISI S100, Eq. C5.2.2-1]

$$\frac{\bar{P}}{\phi_c P_{no}} + \frac{\bar{M}_x}{\phi_b M_{nx}} + \frac{\bar{M}_y}{\phi_b M_{ny}} \le 1.0$$

[AISI S100, Eq. C5.2.2-2]

P / [Φ_c * P_n] ≤ 0.15

$$\frac{\bar{P}}{\phi_c P_n} + \frac{\bar{M}_x}{\phi_b M_{nx}} + \frac{\bar{M}_y}{\phi_b M_{ny}} \le 1.0$$

[AISI S100, Eq. C5.2.2-3]

Φ_c	0.850	Φ_b	0.900

$$\alpha_x = 1 - \frac{\bar{P}}{P_{Ex}} > 0$$

[AISI S100, Eq. C5.2.2-4]

Front Column

P [kN] 4.140

$$\alpha_y = 1 - \frac{\bar{P}}{P_{Ey}} > 0$$

[AISI S100, Eq. C5.2.2-5]

$$P_{Ex} = \frac{\pi^2 EI_x}{(K_x L_x)^2}$$

[AISI S100, Eq. C5.2.2-6]

Rear Column

P [kN] 4.170

$$P_{Ey} = \frac{\pi^2 EI_y}{(K_y L_y)^2}$$

[AISI S100, Eq. C5.2.2-7]

Members whose ends are restrained

C_{mx}	0.850	C_{my}	0.850

Rear Column

C_{mx}	0.850		C_{my}	0.850	
P_{Ex}	359.357	[kN]	P_{Ey}	54.309	[kN]
α_x	0.990	[ ]	α_y	0.935	[ ]

[AISI S100, Eq. C5.2.2-1]

P	4.170	[kN]	Ratio	11.397	[%]
P_n	118.428	[kN]			
$M_{x,Ed,M[+]}$	0.350	[kNm]	α_x	0.990	[ ]
$M_{n,x,Comp,M[+]}$	4.602	[kNm]	α_y	0.935	[ ]
$M_{y,Ed,M[+]}$	0.000	[kNm]	C_{mx}	0.850	[ ]
$M_{n,y,Comp,M[+]}$	2.143	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.2-2]

P	4.170	[kN]	Ratio	12.593	[%]
P_{n0}	118.428	[kN]			
$M_{x,Ed,M[+]}$	0.350	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{n,x,Comp,M[+]}$	4.602	[kNm]	$M_{n,y,Comp,M[+]}$	2.143	[kNm]

[AISI S100, Eq. C5.2.2-3]

P	4.170	[kN]	Ratio	12.593	[%]
P_n	118.428	[kN]			
$M_{x,Ed,M[+]}$	0.350	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{n,x,Comp,M[+]}$	4.602	[kNm]	$M_{n,y,Comp,M[+]}$	2.143	[kNm]

[AISI S100, Eq. C5.2.2-1]

P	4.170	[kN]	Ratio	11.397	[%]
P_n	118.428	[kN]			
$M_{x,Ed,M[-]}$	0.350	[kNm]	α_x	0.990	[ ]
$M_{n,x,Comp,M[-]}$	4.602	[kNm]	α_y	0.935	[ ]
$M_{y,Ed,M[-]}$	0.000	[kNm]	C_{mx}	0.850	[ ]
$M_{n,y,Comp,M[-]}$	2.143	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.2-2]

P	4.170	[kN]	Ratio	12.593	[%]
P_{n0}	118.428	[kN]			
$M_{x,Ed,M[-]}$	0.350	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{n,x,Comp,M[-]}$	4.602	[kNm]	$M_{n,y,Comp,M[-]}$	2.143	[kNm]

[AISI S100, Eq. C5.2.2-3]

P	4.170	[kN]	Ratio	12.593	[%]
P_n	118.428	[kN]			
$M_{x,Ed,M[-]}$	0.350	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{n,x,Comp,M[-]}$	4.602	[kNm]	$M_{n,y,Comp,M[-]}$	2.143	[kNm]

Members whose ends are unrestrained

C_{mx}	1.000	C_{my}	1.000

Front Column

C_{mx}	1.000		C_{my}	0.850	
P_{Ex}	1206.993	[kN]	P_{Ey}	162.655	[kN]
α_x	0.997	[ ]	α_y	0.978	[ ]

[AISI S100, Eq. C5.2.2-1]

P	4.140	[kN]	Ratio	9.552	[%]
P_n	152.460	[kN]			
$M_{x,Ed,M[+]}$	0.270	[kNm]	α_x	0.997	[ ]
$M_{n,x,Comp,M[+]}$	4.732	[kNm]	α_y	0.978	[ ]
$M_{y,Ed,M[+]}$	0.000	[kNm]	C_{mx}	1.000	[ ]
$M_{n,y,Comp,M[+]}$	3.698	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.2-2]

P	4.140	[kN]	Ratio	9.534	[%]
P_{n0}	152.460	[kN]			
$M_{x,Ed,M[+]}$	0.270	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{n,x,Comp,M[+]}$	4.732	[kNm]	$M_{n,y,Comp,M[+]}$	3.698	[kNm]

[AISI S100, Eq. C5.2.2-3]

P	4.140	[kN]	Ratio	9.534	[%]
P_n	152.460	[kN]			
$M_{x,Ed,M[+]}$	0.270	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{n,x,Comp,M[+]}$	4.732	[kNm]	$M_{n,y,Comp,M[+]}$	3.698	[kNm]

[AISI S100, Eq. C5.2.2-1]

P	4.140	[kN]	Ratio	9.552	[%]
P_n	152.460	[kN]			
$M_{x,Ed,M[-]}$	0.270	[kNm]	α_x	0.997	[ ]
$M_{n,x,Comp,M[-]}$	4.732	[kNm]	α_y	0.978	[ ]
$M_{y,Ed,M[-]}$	0.000	[kNm]	C_{mx}	1.000	[ ]
$M_{n,y,Comp,M[-]}$	2.143	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.2-2]

P	4.140	[kN]	Ratio	9.534	[%]
P_{n0}	152.460	[kN]			
$M_{x,Ed,M[-]}$	0.270	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{n,x,Comp,M[-]}$	4.732	[kNm]	$M_{n,y,Comp,M[-]}$	2.143	[kNm]

[AISI S100, Eq. C5.2.2-3]

P	4.140	[kN]	Ratio	9.534	[%]
P_n	152.460	[kN]			
$M_{x,Ed,M[-]}$	0.270	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{n,x,Comp,M[-]}$	4.732	[kNm]	$M_{n,y,Comp,M[-]}$	2.143	[kNm]

[iii] C-Section Column : Combined Axial Load and Bending [AS/NZS 4600, LSD]

[1] Combined axial tension and bending [AS/NZS 4600, 3.5.2]

$$\frac{M_x^*}{\phi_b M_{bx}} + \frac{M_y^*}{\phi_b M_{by}} - \frac{N^*}{\phi_t N_t} \le 1.0$$

[AS/NZS 4600, Eq. 3.5.2(1)]

$$\frac{N^*}{\phi_t N_t} + \frac{M_x^*}{\phi_b M_{sxf}} + \frac{M_y^*}{\phi_b M_{syf}} \le 1.0$$

[AS/NZS 4600, Eq. 3.5.2(2)]

Φ_b	0.900	Φ_t	0.950

Front Column

[AS/NZS 4600, Eq. 3.5.2(1)]

N*	2.700	[kN]	Ratio	5.475	[%]
N_t	183.143	[kN]			
$M_{x,Ed,M[+]}$	0.270	[kNm]	$M_{s,y,Comp,M[+]}$	3.332	[kNm]
$M_{s,x,Comp,M[+]}$	4.269	[kNm]	$M_{sxf,M[+]}$	4.998	[kNm]
$M_{y,Ed,M[+]}$	0.000	[kNm]	$M_{syf,M[+]}$	1.930	[kNm]

[AS/NZS 4600, Eq. 3.5.2(2)]

N*	2.700	[kN]	Ratio	7.891	[%]
N_t	183.143	[kN]			
$M_{x,Ed,M[-]}$	0.270	[kNm]	$M_{s,y,Comp,M[-]}$	1.930	[kNm]
$M_{s,x,Comp,M[-]}$	4.269	[kNm]	$M_{sxf,M[-]}$	4.732	[kNm]
$M_{y,Ed,M[-]}$	0.000	[kNm]	$M_{syf,M[-]}$	3.332	[kNm]

Rear Column

[AS/NZS 4600, Eq. 3.5.2(1)]

N*	3.340	[kN]	Ratio	7.189	[%]
N_t	183.143	[kN]			
$M_{x,Ed,M[+]}$	0.350	[kNm]	$M_{s,y,Comp,M[+]}$	3.332	[kNm]
$M_{s,x,Comp,M[+]}$	4.269	[kNm]	$M_{sxf,M[+]}$	4.998	[kNm]
$M_{y,Ed,M[+]}$	0.000	[kNm]	$M_{syf,M[+]}$	1.930	[kNm]

[AS/NZS 4600, Eq. 3.5.2(2)]

N*	3.340	[kN]	Ratio	10.137	[%]
N_t	183.143	[kN]			
$M_{x,Ed,M[-]}$	0.350	[kNm]	$M_{s,y,Comp,M[-]}$	1.930	[kNm]
$M_{s,x,Comp,M[-]}$	4.269	[kNm]	$M_{sxf,M[-]}$	4.732	[kNm]
$M_{y,Ed,M[-]}$	0.000	[kNm]	$M_{syf,M[-]}$	3.332	[kNm]

[2] Combined Compressive Axial Load and Bending [AS/NZS 4600, 3.5.1]

$$\frac{N^*}{\phi_c N_c} + \frac{C_{mx} M_x^*}{\phi_b M_{bx} \alpha_{nx}} + \frac{C_{my} M_y^*}{\phi_b M_{by} \alpha_{ny}} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.1(1)]

$$\frac{N^*}{\phi_c N_s} + \frac{M_x^*}{\phi_b M_{bx}} + \frac{M_y^*}{\phi_b M_{by}} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.1(2)]

N* / [Φ_c * N_c] ≤ 0.15

$$\frac{N^*}{\phi_c N_c} + \frac{M_x^*}{\phi_b M_{bx}} + \frac{M_y^*}{\phi_b M_{by}} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.1(3)]

Φ_c	0.850	Φ_b	0.900

$$\alpha_{nx}, \alpha_{ny} = 1 - \left(\frac{N^*}{N_e}\right)$$

[AS/NZS 4600, Eq. 3.5.1(5)]

Front Column	
N* [kN]	4.140
Rear Column	
N* [kN]	4.170

$$N_e = \frac{\pi^2 E I_b}{(l_{eb})^2}$$

[AS/NZS 4600, Eq. 3.5.1(6)]

Members whose ends are restrained

C_{mx}	0.850	C_{my}	0.850

Members whose ends are unrestrained

C_{mx}	1.000	C_{my}	1.000

Front Column

C_{mx}	1.000		C_{my}	0.850	
N_{Ex}	1206.993	[kN]	N_{Ey}	162.655	[kN]
α_{nx}	0.997	[ ]	α_{ny}	0.974	[ ]

[AS/NZS 4600, Eq. 3.5.1(1)]

N*	4.140	[kN]	Ratio	10.185	[%]
N_c	155.423	[kN]			
$M_{x,Ed,M[+]}$	0.270	[kNm]	α_{nx}	0.997	[ ]
$M_{s,x,Comp,M[+]}$	4.269	[kNm]	α_{ny}	0.974	[ ]
$M_{y,Ed,M[+]}$	0.000	[kNm]	C_{mx}	1.000	[ ]
$M_{s,y,Comp,M[+]}$	3.332	[kNm]	C_{my}	0.850	[ ]

[AS/NZS 4600, Eq. 3.5.1(2)]

N*	4.140	[kN]	Ratio	9.849	[%]
N_s	172.558	[kN]			
$M_{x,Ed,M[+]}$	0.270	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{s,x,Comp,M[+]}$	4.269	[kNm]	$M_{s,y,Comp,M[+]}$	3.332	[kNm]

[AS/NZS 4600, Eq. 3.5.1(3)]

N*	4.140	[kN]	Ratio	10.161	[%]
N_c	155.423	[kN]			
$M_{x,Ed,M[+]}$	0.270	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{s,x,Comp,M[+]}$	4.269	[kNm]	$M_{s,y,Comp,M[+]}$	3.332	[kNm]

[AS/NZS 4600, Eq. 3.5.1(1)]

N*	4.140	[kN]	Ratio	10.185	[%]
N_c	155.423	[kN]			
$M_{x,Ed,M[-]}$	0.270	[kNm]	α_{nx}	0.997	[ ]
$M_{s,x,Comp,M[-]}$	4.269	[kNm]	α_{ny}	0.974	[ ]
$M_{y,Ed,M[-]}$	0.000	[kNm]	C_{mx}	1.000	[ ]
$M_{s,y,Comp,M[-]}$	1.930	[kNm]	C_{my}	0.850	[ ]

[AS/NZS 4600, Eq. 3.5.1(2)]

N*	4.140	[kN]	Ratio	9.849	[%]
N_s	172.558	[kN]			
$M_{bx,Ed,M[-]}$	0.270	[kNm]	$M_{by,Ed,M[-]}$	0.000	[kNm]
$M_{s,x,Comp,M[-]}$	4.269	[kNm]	$M_{s,y,Comp,M[-]}$	1.930	[kNm]

[AS/NZS 4600, Eq. 3.5.1(3)]

N*	4.140	[kN]	Ratio	10.161	[%]
N_c	155.423	[kN]			
$M_{x,Ed,M[-]}$	0.270	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{s,x,Comp,M[-]}$	4.269	[kNm]	$M_{s,y,Comp,M[-]}$	1.930	[kNm]

Rear Column

C_{mx}	0.850		C_{my}	0.850	
N_{Ex}	359.357	[kN]	N_{Ey}	54.309	[kN]
α_{nx}	0.988	[ ]	α_{ny}	0.923	[ ]

[AS/NZS 4600, Eq. 3.5.1(1)]

N*	4.170	[kN]	Ratio	10.990	[%]
N_c	155.423	[kN]			
$M_{x,Ed,M[+]}$	0.350	[kNm]	α_{nx}	0.988	[ ]
$M_{s,x,Comp,M[+]}$	4.269	[kNm]	α_{ny}	0.923	[ ]
$M_{y,Ed,M[+]}$	0.000	[kNm]	C_{mx}	0.850	[ ]
$M_{s,y,Comp,M[+]}$	3.332	[kNm]	C_{my}	0.850	[ ]

[AS/NZS 4600, Eq. 3.5.1(2)]

N*	4.170	[kN]	Ratio	11.952	[%]
N_s	172.558	[kN]			
$M_{bx,Ed,M[+]}$	0.350	[kNm]	$M_{by,Ed,M[+]}$	0.000	[kNm]
$M_{s,x,Comp,M[+]}$	4.269	[kNm]	$M_{s,y,Comp,M[+]}$	3.332	[kNm]

[AS/NZS 4600, Eq. 3.5.1(3)]

N*	4.170	[kN]	Ratio	12.265	[%]
N_c	155.423	[kN]			
$M_{bx,Ed,M[+]}$	0.350	[kNm]	$M_{by,Ed,M[+]}$	0.000	[kNm]
$M_{s,x,Comp,M[+]}$	4.269	[kNm]	$M_{s,y,Comp,M[+]}$	3.332	[kNm]

[AS/NZS 4600, Eq. 3.5.1(1)]

N*	4.170	[kN]	Ratio	10.990	[%]
N_c	155.423	[kN]			
$M_{bx,Ed,M[-]}$	0.350	[kNm]	α_{nx}	0.988	[ ]
$M_{s,x,Comp,M[-]}$	4.269	[kNm]	α_{ny}	0.923	[ ]
$M_{by,Ed,M[-]}$	0.000	[kNm]	C_{mx}	0.850	[ ]
$M_{s,y,Comp,M[-]}$	1.930	[kNm]	C_{my}	0.850	[ ]

[AS/NZS 4600, Eq. 3.5.1(2)]

N*	4.170	[kN]	Ratio	11.952	[%]
N_s	172.558	[kN]			
$M_{bx,Ed,M[-]}$	0.350	[kNm]	$M_{by,Ed,M[-]}$	0.000	[kNm]
$M_{s,x,Comp,M[-]}$	4.269	[kNm]	$M_{s,y,Comp,M[-]}$	1.930	[kNm]

[AS/NZS 4600, Eq. 3.5.1(3)]

N*	4.170	[kN]	Ratio	12.265	[%]
N_c	155.423	[kN]			
$M_{bx,Ed,M[-]}$	0.350	[kNm]	$M_{by,Ed,M[-]}$	0.000	[kNm]
$M_{s,x,Comp,M[-]}$	4.269	[kNm]	$M_{s,y,Comp,M[-]}$	1.930	[kNm]

[d] C-Section Strut

[i] C-Section Strut : Combined Axial Load and Bending [AISI S100, ASD]

[1] Combined Tensile Axial Load and Bending [AISI S100, C5.1.1]

$$\frac{\Omega_b M_x}{M_{nxt}} + \frac{\Omega_b M_y}{M_{nyt}} + \frac{\Omega_t T}{T_n} \leq 1.0$$

[AISI S100, Eq. C5.1.1-1]

$$\frac{\Omega_b M_x}{M_{nx}} + \frac{\Omega_b M_y}{M_{ny}} - \frac{\Omega_t T}{T_n} \leq 1.0$$

[AISI S100, Eq. C5.1.1-2]

Ω_b	1.670	Ω_t	1.670

[AISI S100, Eq. C5.1.1-1]

R = T	2.280	[kN]	Ratio	6.507	[%]
$R_n = T_n$	73.911	[kN]			
$M_{x,Ed,M[+]}$	0.010	[kNm]	$M_{n,y,Comp,M[+]}$	1.087	[kNm]
$M_{n,x,Comp,M[+]}$	0.735	[kNm]	$M_{n,x,Tension,M[+]}$	1.232	[kNm]
$M_{y,Ed,M[+]}$	0.000	[kNm]	$M_{n,y,Tension,M[+]}$	0.648	[kNm]

[AISI S100, Eq. C5.1.1-2]

R = T	2.280	[kN]	Ratio	-2.878	[%]
$R_n = T_n$	73.911	[kN]			
$M_{x,Ed,M[-]}$	0.010	[kNm]	$M_{n,y,Comp,M[-]}$	0.283	[kNm]
$M_{n,x,Comp,M[-]}$	0.735	[kNm]	$M_{n,x,Tension,M[-]}$	1.162	[kNm]
$M_{y,Ed,M[-]}$	0.000	[kNm]	$M_{n,y,Tension,M[-]}$	1.006	[kNm]

[2] Combined Compressive Axial Load and Bending [AISI S100, C5.2.1]

$$\frac{\Omega_c P}{P_n} + \frac{\Omega_b C_{mx} M_x}{M_{nx} \alpha_x} + \frac{\Omega_b C_{my} M_y}{M_{ny} \alpha_y} \leq 1.0$$

[AISI S100, Eq. C5.2.1-1]

$$\frac{\Omega_c P}{P_{no}} + \frac{\Omega_b M_x}{M_{nx}} + \frac{\Omega_b M_y}{M_{ny}} \leq 1.0$$

[AISI S100, Eq. C5.2.1-2]

Ω_c * P / P_n ≤ 0.15

$$\frac{\Omega_c P}{P_n} + \frac{\Omega_b M_x}{M_{nx}} + \frac{\Omega_b M_y}{M_{ny}} \leq 1.0$$

[AISI S100, Eq. C5.2.1-3]

Ω_c	1.800	Ω_b	1.670

$$\alpha_x = 1 - \frac{\Omega_c P}{P_{Ex}} > 0$$

[AISI S100, Eq. C5.2.1-4]

Strut	
P [kN]	1.470

$$\alpha_y = 1 - \frac{\Omega_c P}{P_{Ey}} > 0$$

[AISI S100, Eq. C5.2.1-5]

$$P_{Ex} = \frac{\pi^2 E I_x}{(K_x L_x)^2}$$

[AISI S100, Eq. C5.2.1-6]

$$P_{Ey} = \frac{\pi^2 E I_y}{(K_y L_y)^2}$$

[AISI S100, Eq. C5.2.1-7]

Members whose ends are restrained

C_{mx}	0.850	C_{my}	0.850

Members whose ends are unrestrained

C_{mx}	1.000	C_{my}	1.000

Strut

	C_{mx}	1.000	C_{my}	0.850	
P_{Ex}	46.561	[kN]	P_{Ey}	23.652	[kN]
α_x	0.943	[ ]	α_y	0.888	[ ]

[AISI S100, Eq. C5.2.1-1]

P	1.470	[kN]	Ratio	29.370	[%]
P_n	9.815	[kN]			
$M_{x,Ed,M[+]}$	0.010	[kNm]	α_x	0.943	[ ]
$M_{n,x,Comp,M[+]}$	0.735	[kNm]	α_y	0.888	[ ]
$M_{y,Ed,M[+]}$	0.000	[kNm]	C_{mx}	1.000	[ ]
$M_{n,y,Comp,M[+]}$	1.087	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.1-2]

P	1.470	[kN]	Ratio	29.233	[%]
P_{n0}	9.815	[kN]			
$M_{x,Ed,M[+]}$	0.010	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{n,x,Comp,M[+]}$	0.735	[kNm]	$M_{n,y,Comp,M[+]}$	1.087	[kNm]

[AISI S100, Eq. C5.2.1-3]

P	1.470	[kN]	Ratio	29.233	[%]
P_n	9.815	[kN]			
$M_{x,Ed,M[+]}$	0.010	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{n,x,Comp,M[+]}$	0.735	[kNm]	$M_{n,y,Comp,M[+]}$	1.087	[kNm]

[AISI S100, Eq. C5.2.1-1]

P	1.470	[kN]	Ratio	29.370	[%]
P_n	9.815	[kN]			
$M_{x,Ed,M[-]}$	0.010	[kNm]	α_x	0.943	[ ]
$M_{n,x,Comp,M[-]}$	0.735	[kNm]	α_y	0.888	[ ]
$M_{y,Ed,M[-]}$	0.000	[kNm]	C_{mx}	1.000	[ ]
$M_{n,y,Comp,M[-]}$	0.283	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.1-2]

P	1.470	[kN]	Ratio	29.233	[%]
P_{n0}	9.815	[kN]			
$M_{x,Ed,M[-]}$	0.010	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{n,x,Comp,M[-]}$	0.735	[kNm]	$M_{n,y,Comp,M[-]}$	0.283	[kNm]

[AISI S100, Eq. C5.2.1-3]

P	1.470	[kN]	Ratio	29.233	[%]
P_n	9.815	[kN]			
$M_{x,Ed,M[-]}$	0.010	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{n,x,Comp,M[-]}$	0.735	[kNm]	$M_{n,y,Comp,M[-]}$	0.283	[kNm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

$$\alpha_x = 1 - \frac{\overline{P}}{P_{Ex}} > 0$$

[AISI S100, Eq. C5.2.2-4]

Strut

P [kN] 1.470

$$\alpha_y = 1 - \frac{\overline{P}}{P_{Ey}} > 0$$

[AISI S100, Eq. C5.2.2-5]

$$P_{Ex} = \frac{\pi^2 EI_x}{(K_x L_x)^2}$$

[AISI S100, Eq. C5.2.2-6]

$$P_{Ey} = \frac{\pi^2 EI_y}{(K_y L_y)^2}$$

[AISI S100, Eq. C5.2.2-7]

Members whose ends are restrained

C_{mx}	0.850	C_{my}	0.850

Members whose ends are unrestrained

C_{mx}	1.000	C_{my}	1.000

Strut

	C_{mx}	0.850	C_{my}	0.850	
P_{Ex}	46.561	[kN]	P_{Ey}	23.652	[kN]
α_x	0.973	[ ]	α_y	0.947	[ ]

[AISI S100, Eq. C5.2.2-1]

P	1.470	[kN]	Ratio	18.942	[%]
P_n	9.815	[kN]			
$M_{x,Ed,M[+]}$	0.010	[kNm]	α_x	0.973	[ ]
$M_{n,x,Comp,M[+]}$	0.735	[kNm]	α_y	0.947	[ ]
$M_{y,Ed,M[+]}$	0.000	[kNm]	C_{mx}	0.850	[ ]
$M_{n,y,Comp,M[+]}$	1.087	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.2-2]

P	1.470	[kN]	Ratio	19.133	[%]
P_{n0}	9.815	[kN]			
$M_{x,Ed,M[+]}$	0.010	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{n,x,Comp,M[+]}$	0.735	[kNm]	$M_{n,y,Comp,M[+]}$	1.087	[kNm]

[AISI S100, Eq. C5.2.2-3]

P	1.470	[kN]	Ratio	19.133	[%]
P_n	9.815	[kN]			
$M_{x,Ed,M[+]}$	0.010	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{n,x,Comp,M[+]}$	0.735	[kNm]	$M_{n,y,Comp,M[+]}$	1.087	[kNm]

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

[ii] C-Section Strut : Combined Axial Load and Bending [AISI S100, LRFD]

[1] Combined Tensile Axial Load and Bending [AISI S100, C5.1.2]

$$\frac{\overline{M}_x}{\phi_b M_{nxt}} + \frac{\overline{M}_y}{\phi_b M_{nyt}} + \frac{\overline{T}}{\phi_t T_n} \le 1.0$$

[AISI S100, Eq. C5.1.2-1]

Φ_b	0.900	Φ_t	0.950

$$\frac{\overline{M}_x}{\phi_b M_{nx}} + \frac{\overline{M}_y}{\phi_b M_{ny}} - \frac{\overline{T}}{\phi_t T_n} \le 1.0$$

[AISI S100, Eq. C5.1.2-2]

Strut

[AISI S100, Eq. C5.1.2-1]

R = T	2.280	[kN]	Ratio	4.149	[%]
$R_n = T_n$	73.911	[kN]			
$M_{x,Ed,M[+]}$	0.010	[kNm]	$M_{n,y,Comp,M[+]}$	1.087	[kNm]
$M_{n,x,Comp,M[+]}$	0.735	[kNm]	$M_{n,x,Tension,M[+]}$	1.232	[kNm]
$M_{y,Ed,M[+]}$	0.000	[kNm]	$M_{n,y,Tension,M[+]}$	0.648	[kNm]

[AISI S100, Eq. C5.1.2-2]

R = T	2.280	[kN]	Ratio	-1.734	[%]
$R_n = T_n$	73.911	[kN]			
$M_{x,Ed,M[-]}$	0.010	[kNm]	$M_{n,y,Comp,M[-]}$	0.283	[kNm]
$M_{n,x,Comp,M[-]}$	0.735	[kNm]	$M_{n,x,Tension,M[-]}$	1.162	[kNm]
$M_{y,Ed,M[-]}$	0.000	[kNm]	$M_{n,y,Tension,M[-]}$	1.006	[kNm]

[2] Combined Compressive Axial Load and Bending [AISI S100, C5.2.2]

$$\frac{\overline{P}}{\phi_c P_n} + \frac{C_{mx}\overline{M}_x}{\phi_b M_{nx}\alpha_x} + \frac{C_{my}\overline{M}_y}{\phi_b M_{ny}\alpha_y} \le 1.0$$

[AISI S100, Eq. C5.2.2-1]

$$\frac{\overline{P}}{\phi_c P_{no}} + \frac{\overline{M}_x}{\phi_b M_{nx}} + \frac{\overline{M}_y}{\phi_b M_{ny}} \le 1.0$$

[AISI S100, Eq. C5.2.2-2]

P / [Φ_c * P_n] ≤ 0.15

$$\frac{\overline{P}}{\phi_c P_n} + \frac{\overline{M}_x}{\phi_b M_{nx}} + \frac{\overline{M}_y}{\phi_b M_{ny}} \le 1.0$$

[AISI S100, Eq. C5.2.2-3]

Φ_c	0.850	Φ_b	0.900

Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS
Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993
Version: 1.000
Office: ---- Author: JOSÉ ANTÓNIO
Date: 05/09/2019 Project: MASTER THESIS
Client: COIMBRA UNIVERSITY

[AISI S100, Eq. C5.2.2-1]

P	1.470	[kN]	Ratio	18.942	[%]
P_n	9.815	[kN]			
$M_{x,Ed,M[-]}$	0.010	[kNm]	α_x	0.973	[ ]
$M_{n,x,Comp,M[-]}$	0.735	[kNm]	α_y	0.947	[ ]
$M_{y,Ed,M[-]}$	0.000	[kNm]	C_{mx}	0.850	[ ]
$M_{n,y,Comp,M[-]}$	0.283	[kNm]	C_{my}	0.850	[ ]

[AISI S100, Eq. C5.2.2-2]

P	1.470	[kN]	Ratio	19.133	[%]
P_{n0}	9.815	[kN]			
$M_{x,Ed,M[-]}$	0.010	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{n,x,Comp,M[-]}$	0.735	[kNm]	$M_{n,y,Comp,M[-]}$	0.283	[kNm]

[AISI S100, Eq. C5.2.2-3]

P	1.470	[kN]	Ratio	17.621	[%]
P_n	9.815	[kN]			
$M_{x,Ed,M[-]}$	0.000	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{n,x,Comp,M[-]}$	0.735	[kNm]	$M_{n,y,Comp,M[-]}$	0.283	[kNm]

[iii] C-Section Strut : Combined Axial Load and Bending [AS/NZS 4600, LSD]

[1] Combined axial tension and bending [AS/NZS 4600, 3.5.2]

$$\frac{M_x^*}{\phi_b M_{fx}} + \frac{M_y^*}{\phi_b M_{fy}} - \frac{N^*}{\phi_t N_t} \le 1.0$$

[AS/NZS 4600, Eq. 3.5.2(1)]

$$\frac{N^*}{\phi_t N_t} + \frac{M_x^*}{\phi_b M_{sxf}} + \frac{M_y^*}{\phi_b M_{syf}} \le 1.0$$

[AS/NZS 4600, Eq. 3.5.2(2)]

Φ_b	0.900	Φ_t	0.950

Strut

[AS/NZS 4600, Eq. 3.5.2(1)]

N*	2.280	[kN]	Ratio	-1.945	[%]
N_t	73.911	[kN]			
$M_{x,Ed,M[+]}$	0.010	[kNm]	$M_{s,y,Comp,M[+]}$	1.087	[kNm]
$M_{s,x,Comp,M[+]}$	0.853	[kNm]	$M_{sxf,M[+]}$	1.232	[kNm]
$M_{y,Ed,M[+]}$	0.000	[kNm]	$M_{syf,M[+]}$	0.648	[kNm]

[AS/NZS 4600, Eq. 3.5.2(2)]

N*	2.280	[kN]	Ratio	4.203	[%]
N_t	73.911	[kN]			
$M_{x,Ed,M[-]}$	0.010	[kNm]	$M_{s,y,Comp,M[-]}$	0.693	[kNm]
$M_{s,x,Comp,M[-]}$	0.853	[kNm]	$M_{sxf,M[-]}$	1.162	[kNm]
$M_{y,Ed,M[-]}$	0.000	[kNm]	$M_{syf,M[-]}$	1.006	[kNm]

[2] Combined Compressive Axial Load and Bending [AISI S100, C5.2.2]

$$\frac{N^*}{\phi_c N_c} + \frac{C_{mx} M_x^*}{\phi_b M_{bx} \alpha_{nx}} + \frac{C_{my} M_y^*}{\phi_b M_{by} \alpha_{ny}} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.1(1)]

$$\frac{N^*}{\phi_c N_s} + \frac{M_x^*}{\phi_b M_{bx}} + \frac{M_y^*}{\phi_b M_{by}} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.1(2)]

N* / [Φ_c * N_c] ≤ 0.15

$$\frac{N^*}{\phi_c N_c} + \frac{M_x^*}{\phi_b M_{bx}} + \frac{M_y^*}{\phi_b M_{by}} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.1(3)]

Φ_c 0.850

Φ_b 0.900

$$\alpha_{nx}, \alpha_{ny} = 1 - \left(\frac{N^*}{N_e}\right)$$

[AS/NZS 4600, Eq. 3.5.1(5)]

Strut

N* [kN] 1.470

$$N_e = \frac{\pi^2 E I_b}{(l_{eb})^2}$$

[AS/NZS 4600, Eq. 3.5.1(6)]

Members whose ends are restrained

C_{mx}	0.850	C_{my}	0.850

Members whose ends are unrestrained

C_{mx}	1.000	C_{my}	1.000

Strut

	C_{mx}	0.850	C_{my}	0.850	
N_{Ex}	46.561	[kN]	N_{Ey}	23.652	[kN]
α_{nx}	0.968	[ ]	α_{ny}	1.000	[ ]

[AS/NZS 4600, Eq. 3.5.1(1)]

N*	1.470	[kN]	Ratio	9.480	[%]
N_c	20.743	[kN]			
$M_{x,Ed,M[+]}$	0.010	[kNm]	α_{nx}	0.968	[ ]
$M_{s,x,Comp,M[+]}$	0.853	[kNm]	α_{ny}	1.000	[ ]
$M_{y,Ed,M[+]}$	0.000	[kNm]	C_{mx}	0.850	[ ]
$M_{s,y,Comp,M[+]}$	1.087	[kNm]	C_{my}	0.850	[ ]

[AS/NZS 4600, Eq. 3.5.1(2)]

N*	1.470	[kN]	Ratio	3.757	[%]
N_s	70.460	[kN]			
$M_{x,Ed,M[+]}$	0.010	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{s,x,Comp,M[+]}$	0.853	[kNm]	$M_{s,y,Comp,M[+]}$	1.087	[kNm]

[AS/NZS 4600, Eq. 3.5.1(3)]

N*	1.470	[kN]	Ratio	9.640	[%]
N_c	20.743	[kN]			
$M_{x,Ed,M[+]}$	0.010	[kNm]	$M_{y,Ed,M[+]}$	0.000	[kNm]
$M_{s,x,Comp,M[+]}$	0.853	[kNm]	$M_{s,y,Comp,M[+]}$	1.087	[kNm]

[AS/NZS 4600, Eq. 3.5.1(1)]

N*	1.470	[kN]	Ratio	9.480	[%]
N_c	20.743	[kN]			
$M_{x,Ed,M[-]}$	0.010	[kNm]	α_{nx}	0.968	[ ]
$M_{s,x,Comp,M[-]}$	0.853	[kNm]	α_{ny}	1.000	[ ]
$M_{y,Ed,M[-]}$	0.000	[kNm]	C_{mx}	0.850	[ ]
$M_{s,y,Comp,M[-]}$	0.693	[kNm]	C_{my}	0.850	[ ]

[AS/NZS 4600, Eq. 3.5.1(2)]

N*	1.470	[kN]	Ratio	3.757	[%]
N_s	70.460	[kN]			
$M_{x,Ed,M[-]}$	0.010	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{s,x,Comp,M[-]}$	0.853	[kNm]	$M_{s,y,Comp,M[-]}$	0.693	[kNm]

[AS/NZS 4600, Eq. 3.5.1(3)]

N*	1.470	[kN]	Ratio	9.640	[%]
N_c	20.743	[kN]			
$M_{x,Ed,M[-]}$	0.010	[kNm]	$M_{y,Ed,M[-]}$	0.000	[kNm]
$M_{s,x,Comp,M[-]}$	0.853	[kNm]	$M_{s,y,Comp,M[-]}$	0.693	[kNm]