



UNIVERSIDADE DE
COIMBRA

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

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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 secções 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.

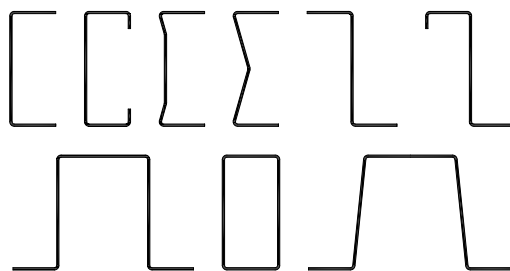


Figure 1.1 - Cold-Formed Structural Members: Single Opens Sections

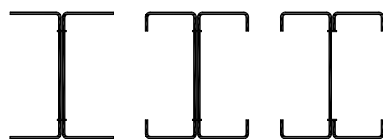


Figure 1.2 - Cold-Formed Structural Members: Open Built-up Sections

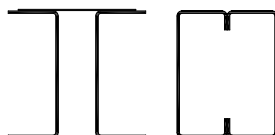


Figure 1.3 - Cold-Formed Structural Members: Closed Built-up Sections

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 Cornell 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.

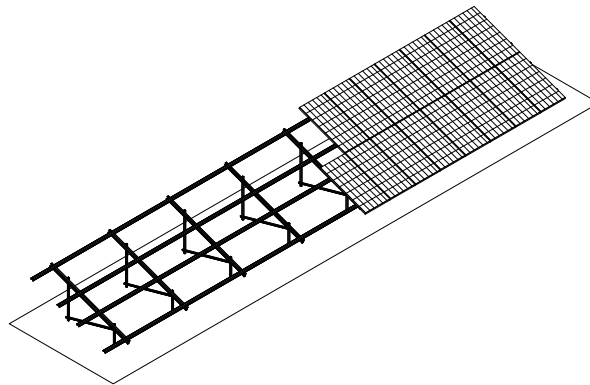


Figure 1.11 - 3D Photovoltaic Structure (Type 1)

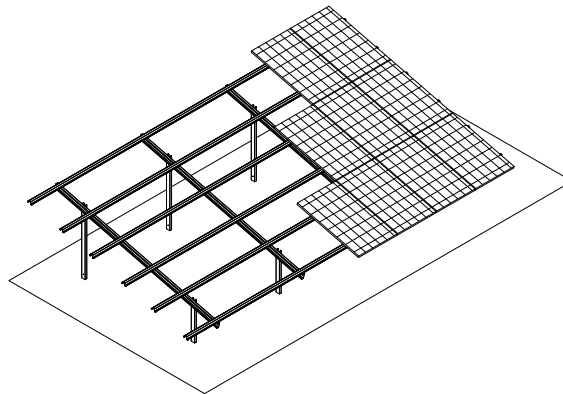


Figure 1.12 - 3D Photovoltaic Structure (Type 2)

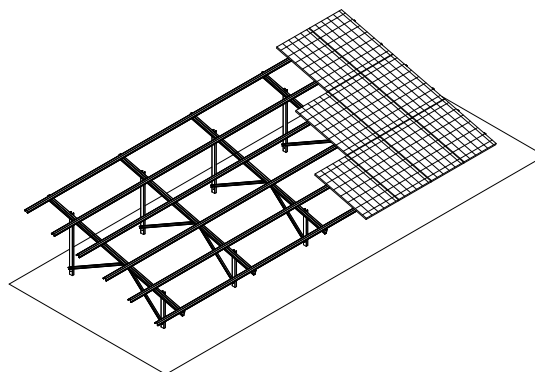


Figure 1.13 - 3D Photovoltaic Structure (Type 3)

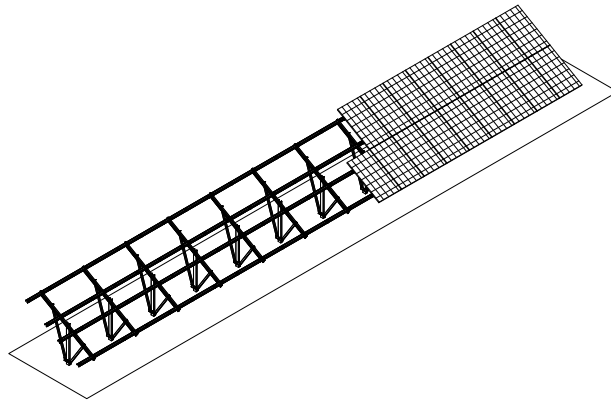


Figure 1.14 - 3D Photovoltaic Structure (Type 4)

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.

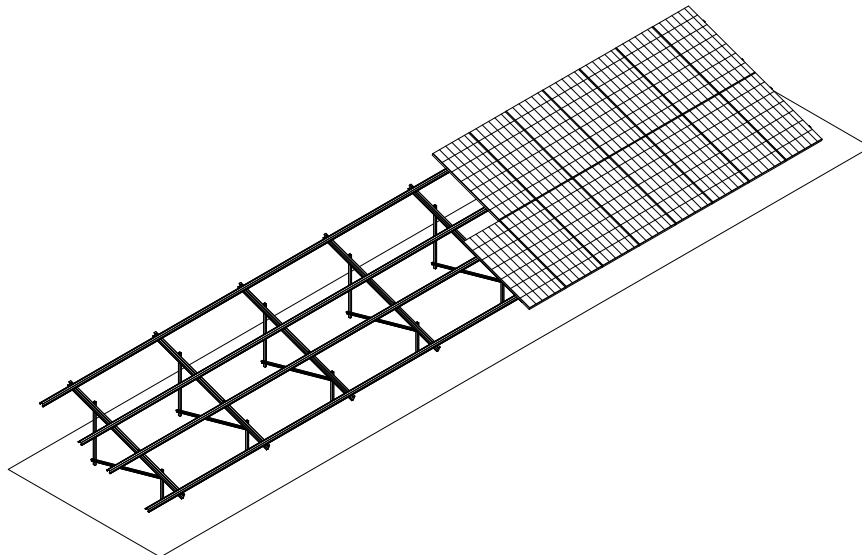


Figure 2.1 - 3D Photovoltaic Structure (Type 1)

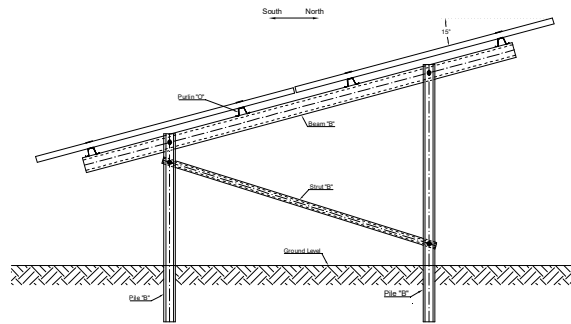


Figure 2.2 - Photovoltaic Structure (Type 1): Standard Frame

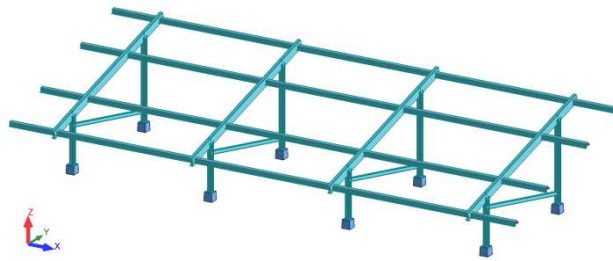


Figure 2.3 - Autodesk ROBOT Structural 3D Design Model (Type 1)

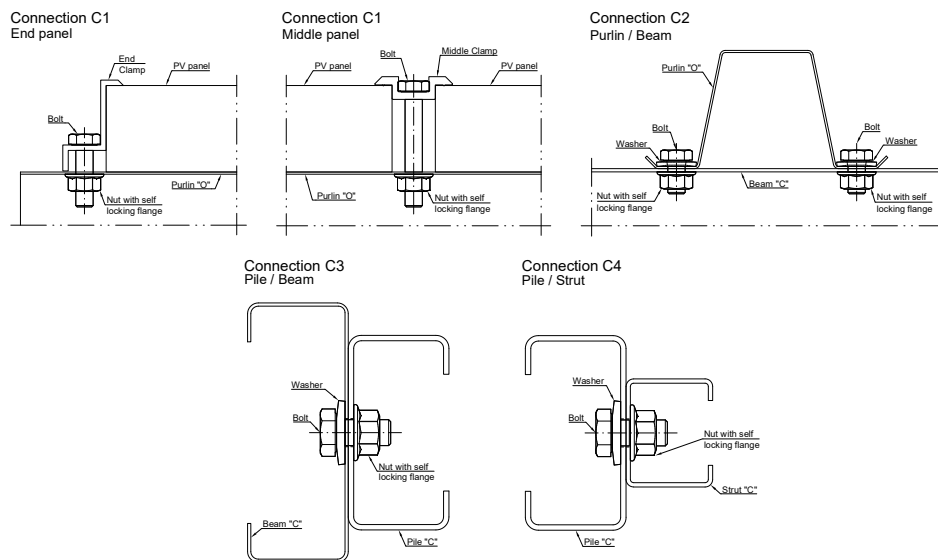


Figure 2.4 - 3D Photovoltaic Structure (Type 1): Connections

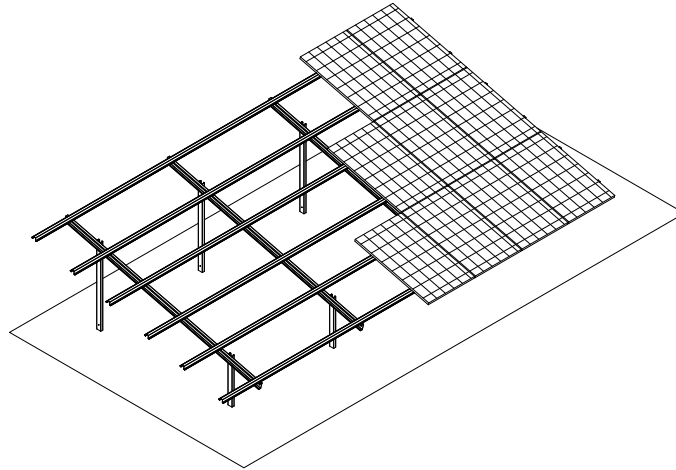


Figure 2.5 - 3D Photovoltaic Structure (Type 2)

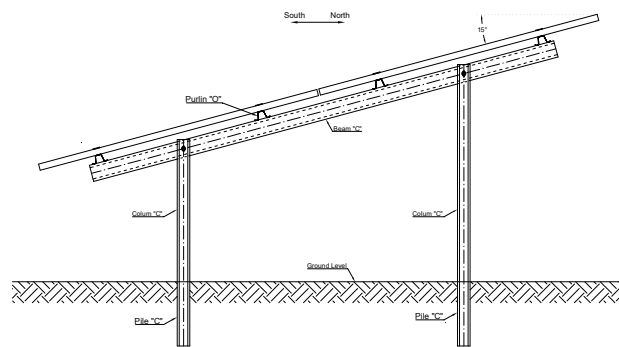


Figure 2.6 - Photovoltaic Structure (Type 2): Standard Frame

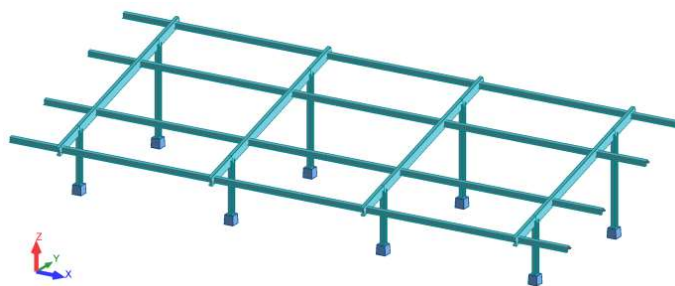


Figure 2.7 - Autodesk ROBOT Structural 3D Design Model (Type 2)

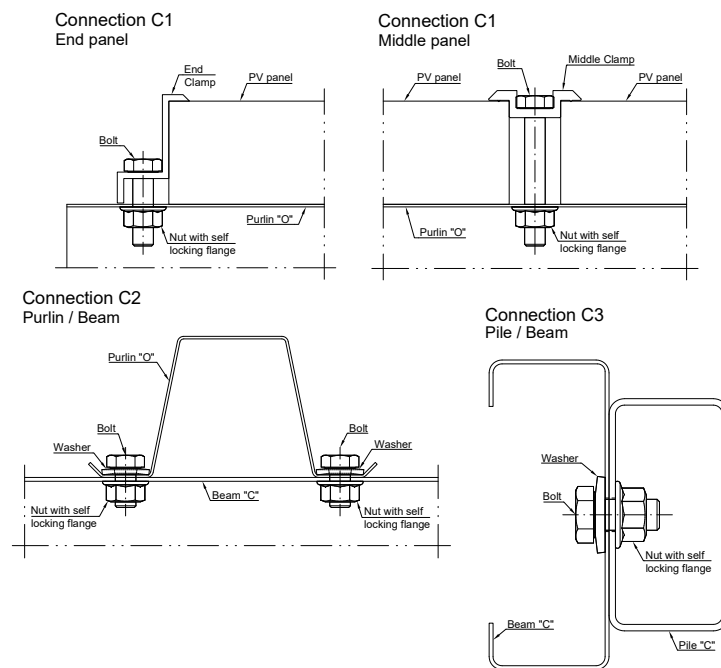


Figure 2.8 - 3D Photovoltaic Structure (Type 2); Connections

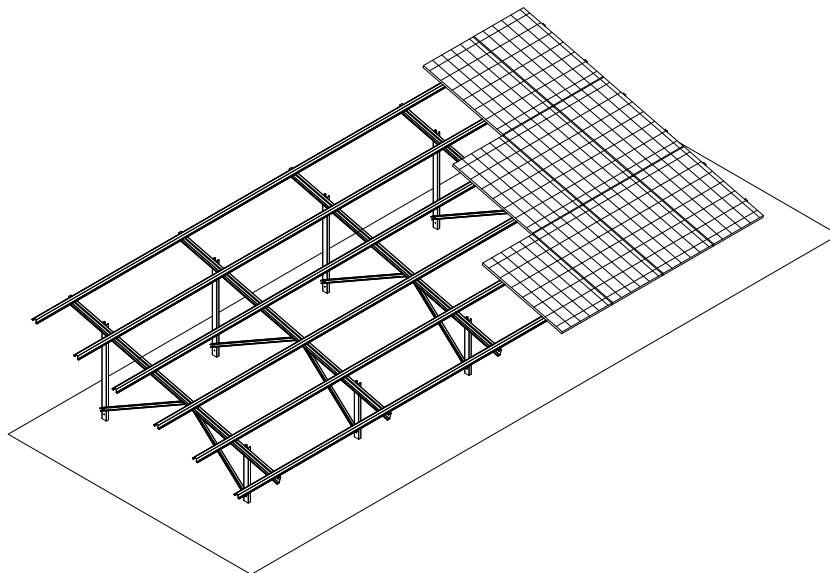


Figure 2.9 - 3D Photovoltaic Structure (Type 3)

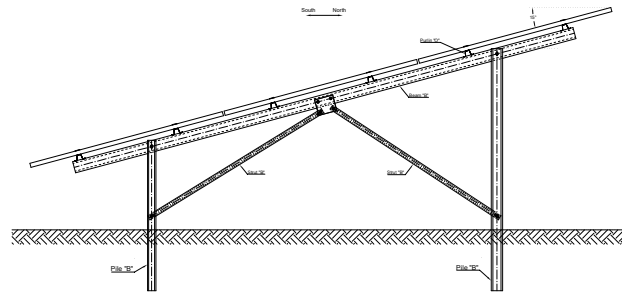


Figure 2.10 - Photovoltaic Structure (Type 3): Standard Frame



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

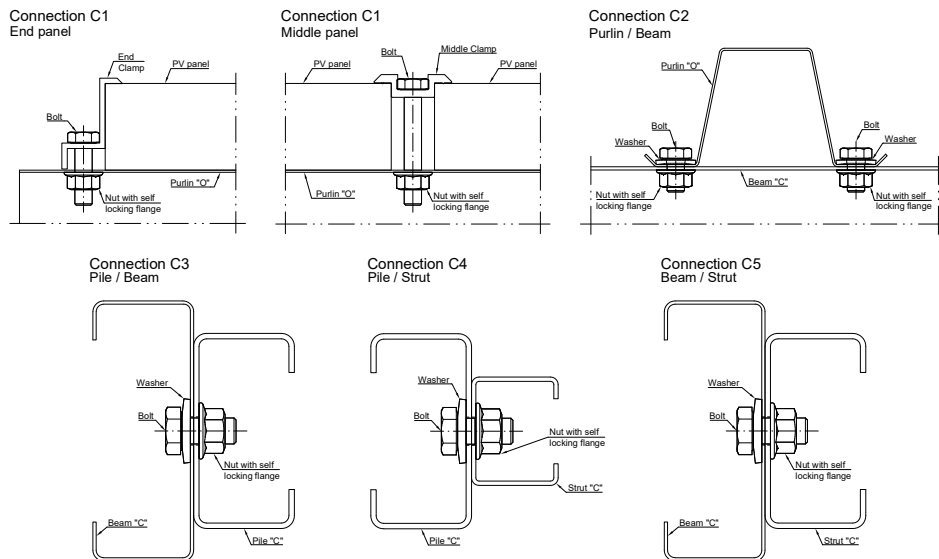


Figure 2.12 - 3D Photovoltaic Structure (Type 3): Connections

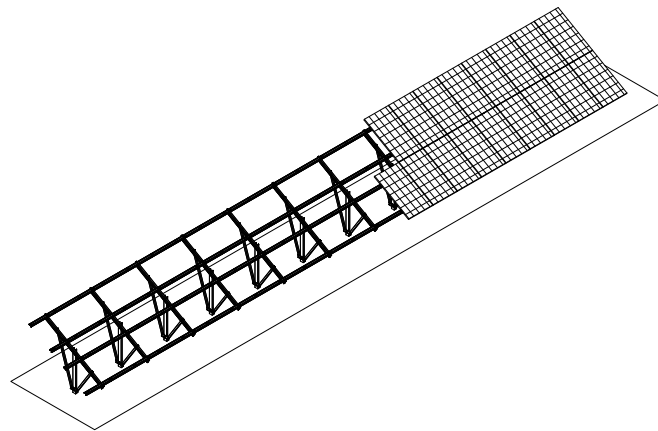


Figure 2.13 - 3D Photovoltaic Structure (Type 4)

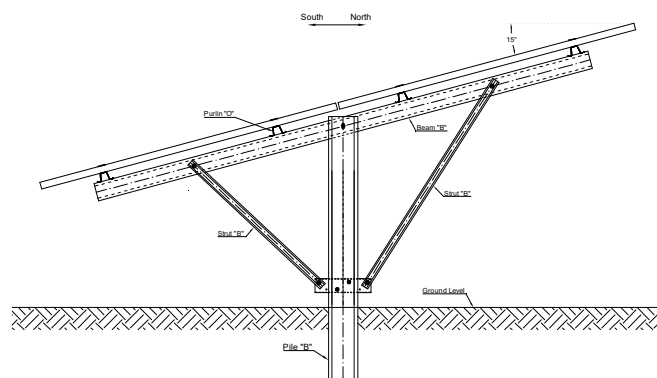


Figure 2.14 - Photovoltaic Structure (Type 4): Standard Frame

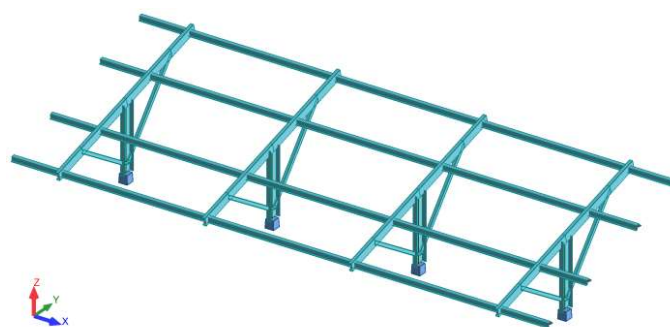


Figure 2.15 - Autodesk ROBOT Structural 3D Design Model (Type 4)

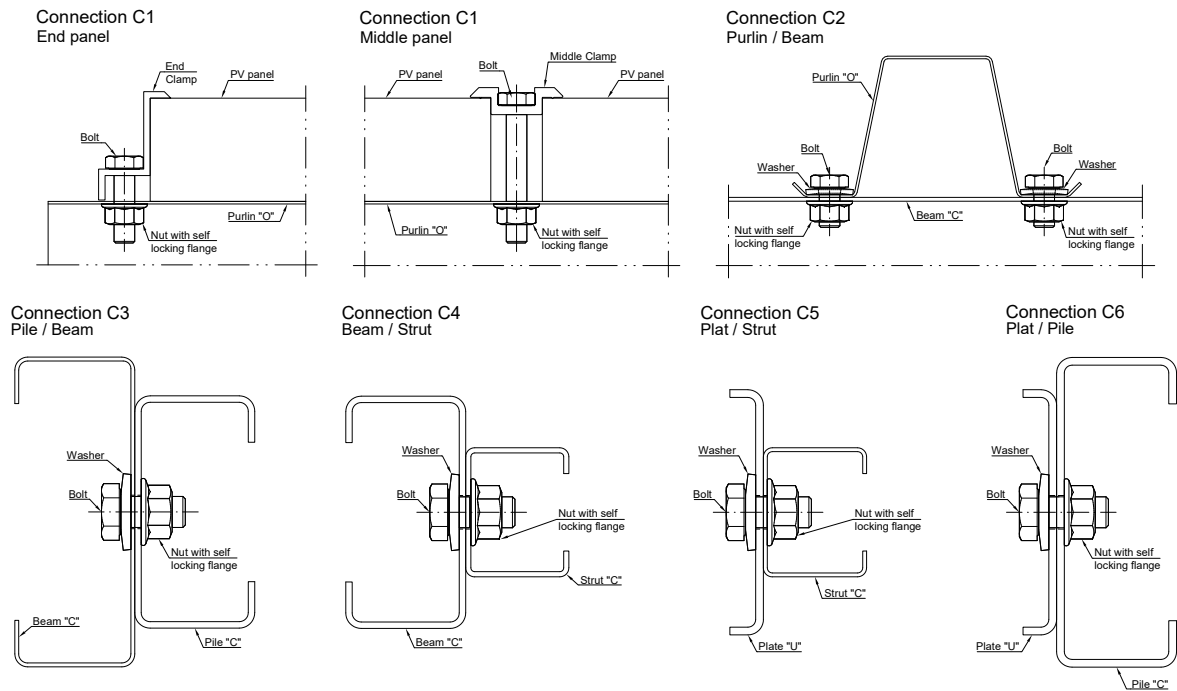


Figure 2.16 - 3D Photovoltaic Structure (Type 4); Connections

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 possible 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.

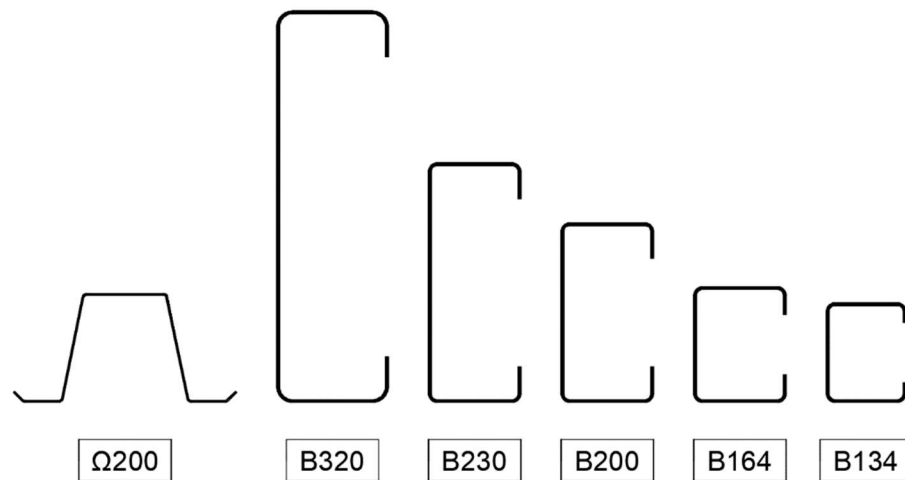


Figure 2.17 - Cold-formed sections (Commercial definitions)

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

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

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

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 be 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.

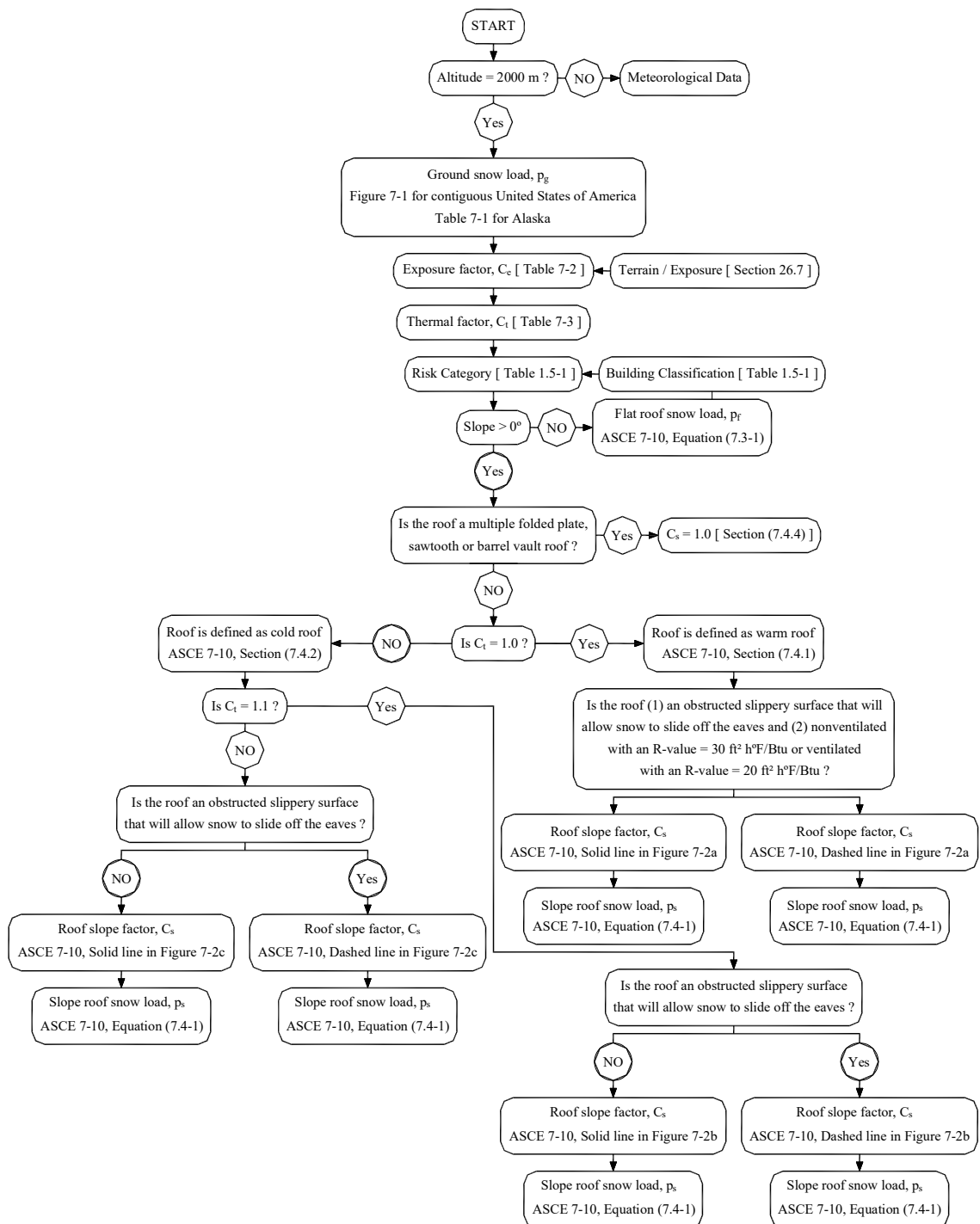


Figure 3.1 - Snow load for monopitch roof
(Adapted from “Structural load determination under 2009 IBC and ASCE/SEI 7-05”)

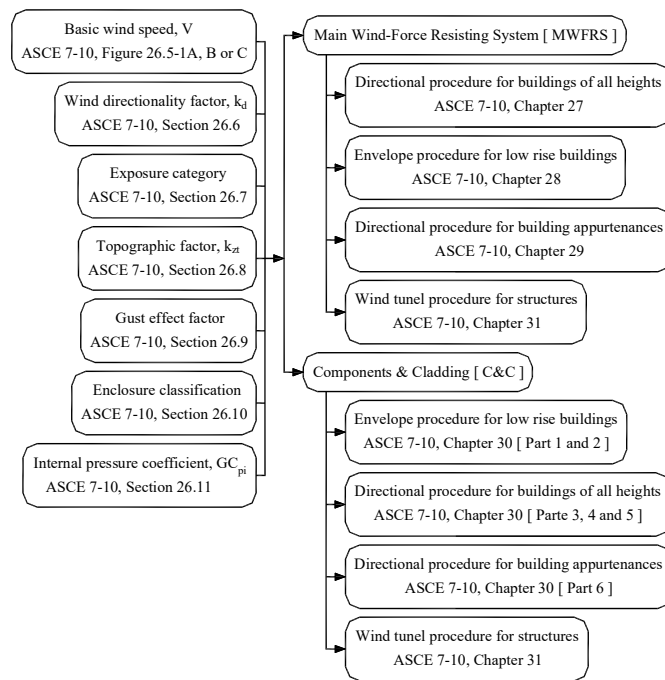


Figure 3.2 - Process for Determining Wind
(Adapted from ASCE/SEI 7-10, Figure 26.1-1)

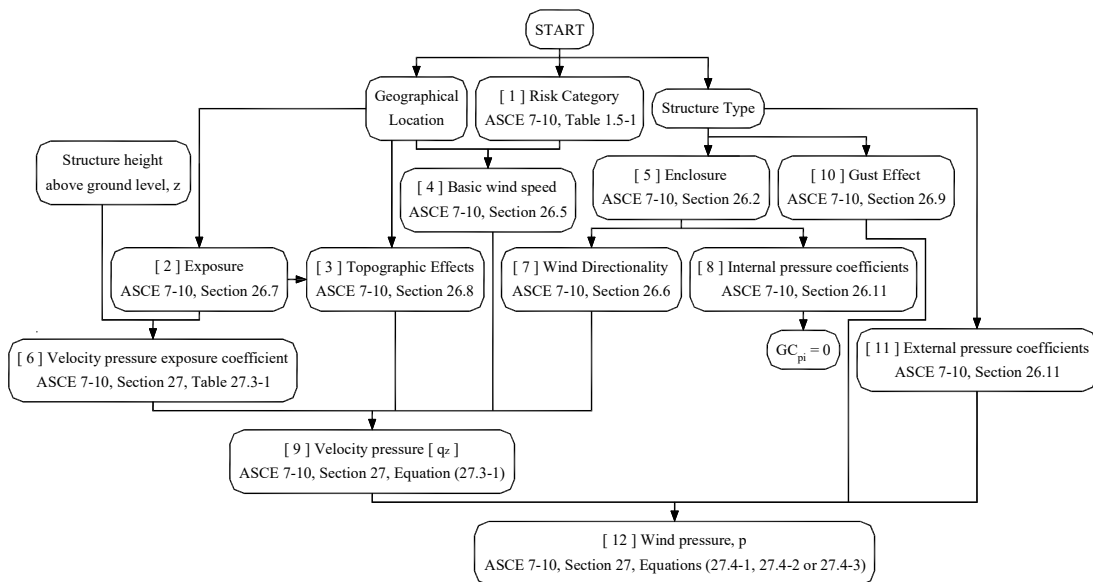


Figure 3.3 - Steps to determine MWFRS Wind Loads for Open Buildings of All Heights
(Adapted from ASCE/SEI 7-10, Table 27.2-1)

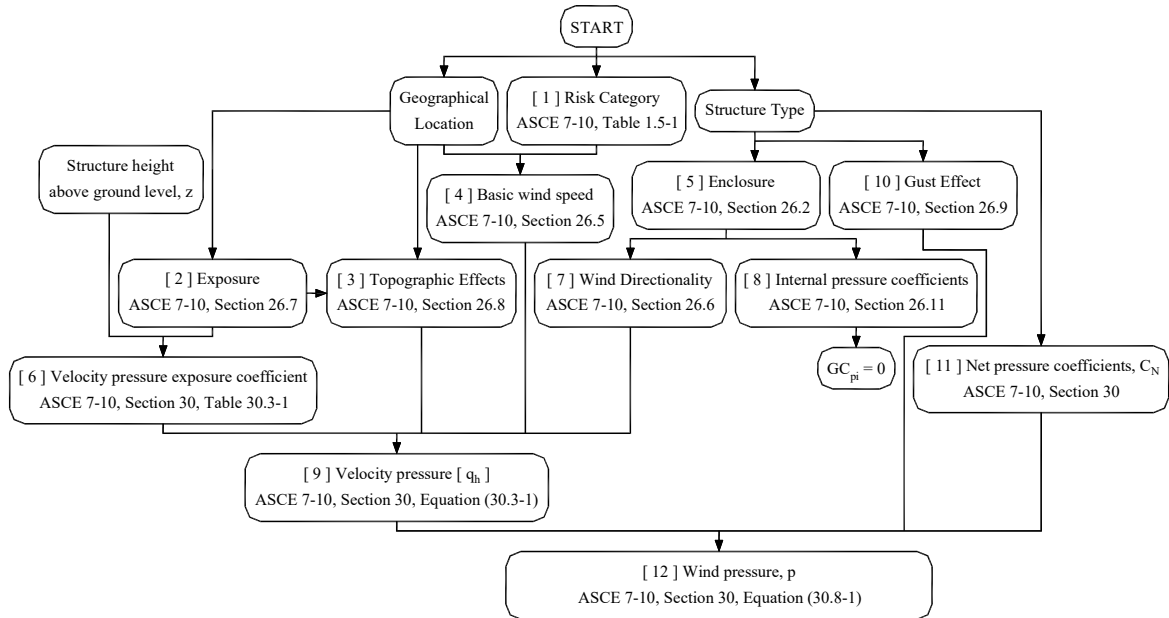


Figure 3.4 - Steps to determine C&C Wind Loads for Open Buildings
(Adapted from ASCE/SEI 7-10, Table 30.8-1)

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
$E_{d,stab}$	=	$0.90 \times G$			(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.

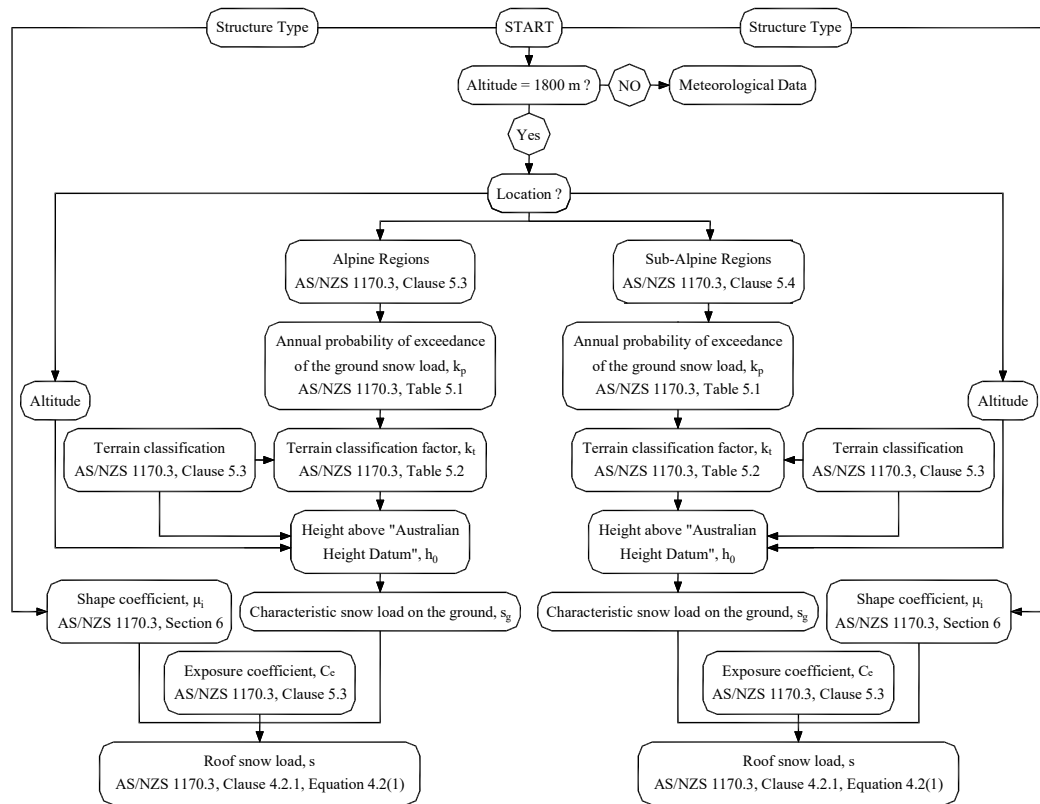


Figure 3.5 - Snow load for monopitch roof
(Based on AS/NZS 1170:3)

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

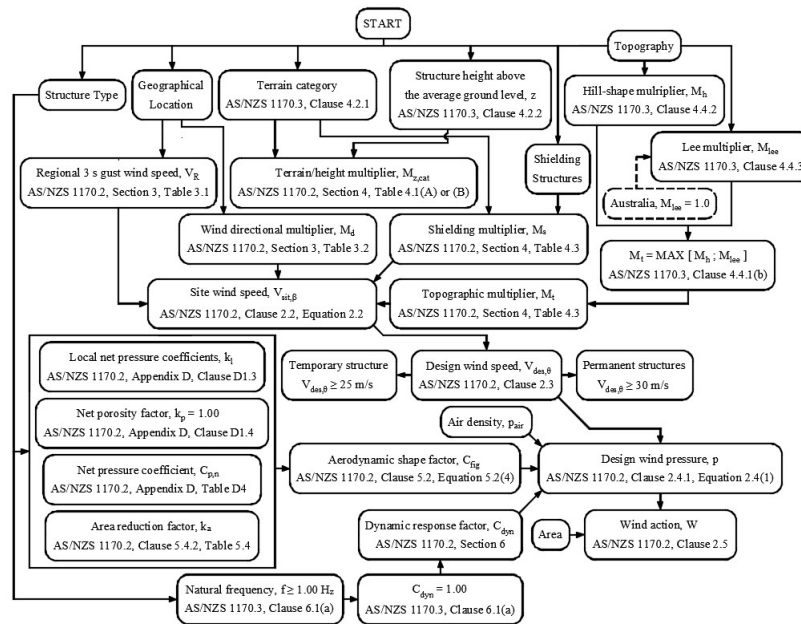


Figure 3.6 - Steps to determine Wind Loads for Open Buildings (Based on AS/NZS 1170:2)

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 be 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 than 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.

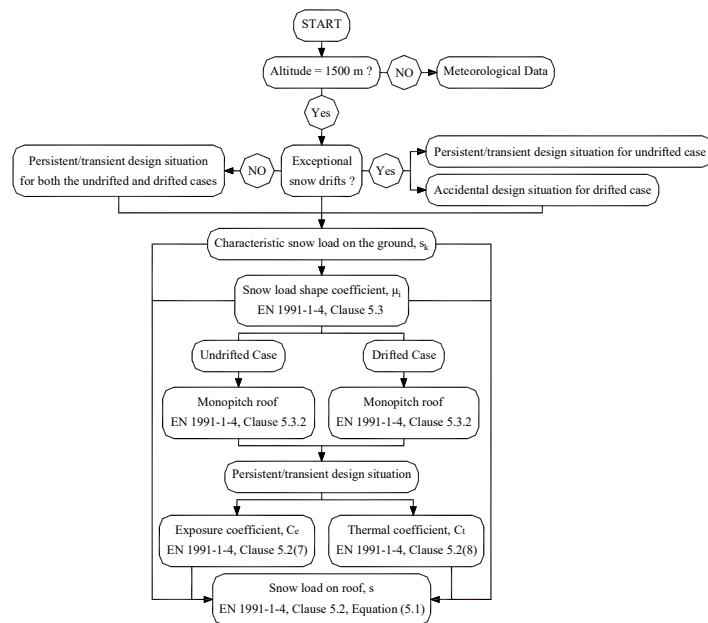


Figure 3.7 - Snow load for monopitch roof (Based on EN 1991-1-3)

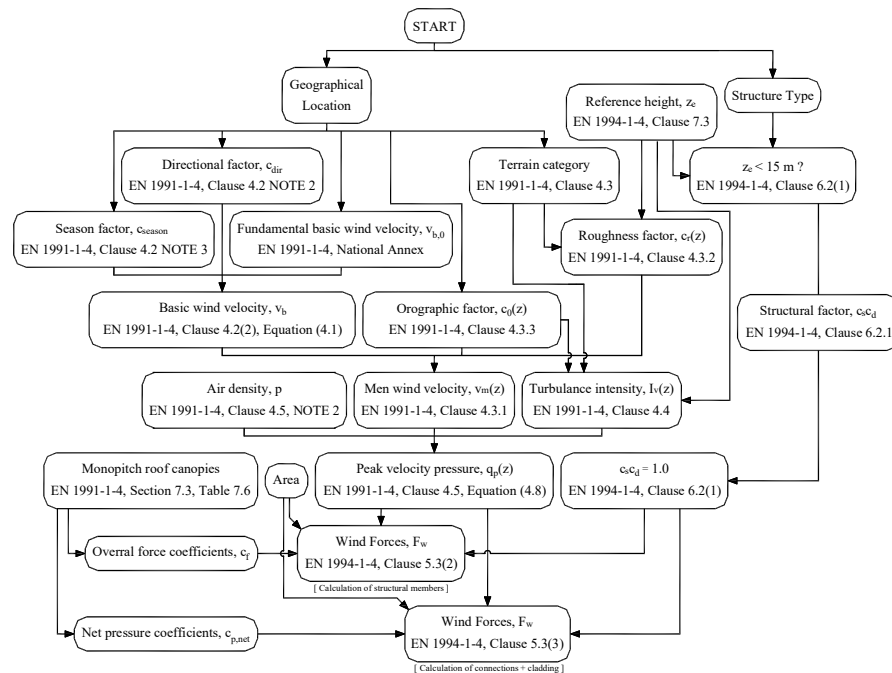


Figure 3.8 - Steps to determine Wind Loads for Open Buildings (Based on EN 1991-1-4)

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)

- $E_d = 1.40 \times D = 1.40 \text{ kN/m}^2$
- $E_d = 1.20 \times D + 0.50 \times S = 1.55 \text{ kN/m}^2$
- **$E_d = 1.20 \times D + 1.60 \times S + 0.50 \times W = 2.55 \text{ kN/m}^2$**
- $E_d = 1.20 \times D + 1.00 \times W + 0.50 \times S = 2.01 \text{ kN/m}^2$
- $E_d = 1.20 \times D + 0.20 \times S = 1.34 \text{ kN/m}^2$
- $E_d = 0.90 \times D + 1.00 \times W = 1.36 \text{ kN/m}^2$
- $E_d = 0.90 \times D = 0.90 \text{ kN/m}^2$

4. ASCE 7-10 Load combinations, Allowable Stress Design (ASD)

- $E_d = D = 1.00 \text{ kN/m}^2$
- $E_d = D + S = 1.70 \text{ kN/m}^2$
- $E_d = D + 0.75 \times S = 1.53 \text{ kN/m}^2$
- $E_d = D + W = 1.46 \text{ kN/m}^2$
- $E_d = D + 0.75 \times 0.60 \times W + 0.75 \times S = 1.73 \text{ kN/m}^2$
- $E_d = 0.60 \times D + 0.60 \times W = \text{ kN/m}^2$
- $E_d = 0.60 \times D = 0.60 \text{ kN/m}^2$

5. AS/NZS 1170.2 Load combinations, Ultimate Limit State (Stability)

- $E_{d,stab} = 0.90 \times G = 0.90 \text{ kN/m}^2$
- $E_{d,dst} = 1.35 \times G = 1.35 \text{ kN/m}^2$
- $E_{d,dst} = 1.20 \times G = 1.20 \text{ kN/m}^2$
- $E_{d,dst} = 1.20 \times G + W_u = 1.66 \text{ kN/m}^2$
- $E_{d,dst} = 1.20 \times G + S_u = 1.96 \text{ kN/m}^2$

6. AS/NZS 1170.2 Load combinations, Ultimate Limit State (Strength)

- $E_d = 1.35 \times G = 1.35 \text{ kN/m}^2$
- $E_d = 1.20 \times G = 1.20 \text{ kN/m}^2$
- $E_d = 1.20 \times G + W_u = 1.66 \text{ kN/m}^2$
- $E_d = 0.90 \times G + W_u = 1.56 \text{ kN/m}^2$
- $E_d = 1.00 \times G + W_u = 1.46 \text{ kN/m}^2$

7. EN 1990 Load combinations

- $E_d = 1.35 \times D + 1.50 \times S + 0.00 \times W = 2.40 \text{ kN/m}^2$
- $E_d = 1.35 \times D + 1.50 \times W + 0.00 \times S = 2.04 \text{ kN/m}^2$

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 $\leq 120^\circ$;

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

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

- 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:

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

- 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

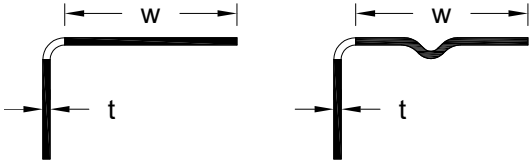
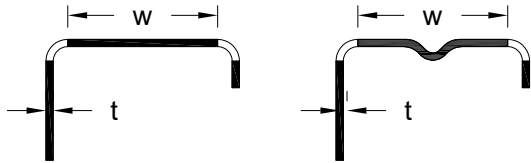
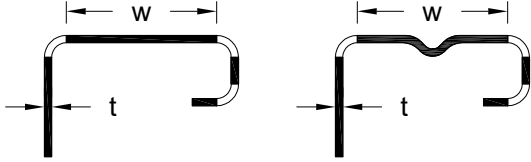
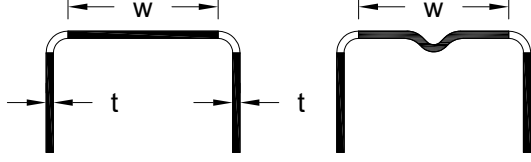
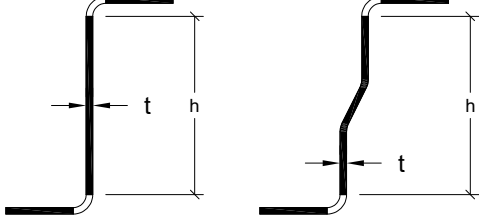
The ratio, h/t , of the webs of flexural members shall not exceed the following limits:

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 $\leq 120^\circ$

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

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

- f_{yv} tensile yield stress of unformed steel;
- r_i inside bend radius;

t thickness of section;

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

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:

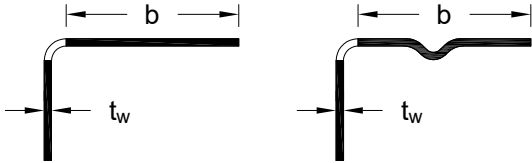
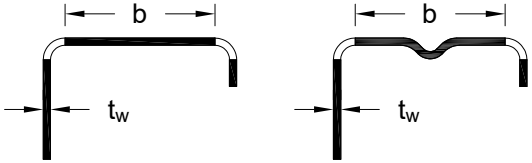
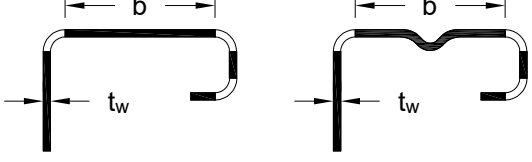
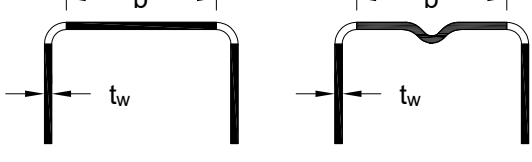
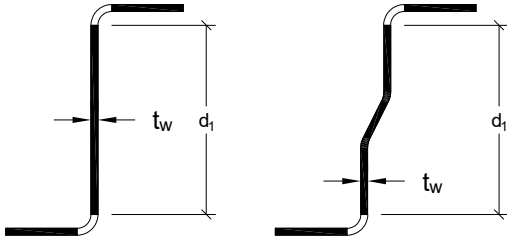
1. For unreinforced webs $d_1/t_w = 200$
2. For webs with transverse stiffeners complying with Clause 3.3.8.1:
 - Bearing stiffeners only $d_1/t_w = 260$
 - Bearing stiffeners and intermediate stiffeners $d_1/t_w = 300$

- 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:

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

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

- 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 90° bends in the cross-section with an internal radius $r \leq 5t$ (fractions of 90° 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

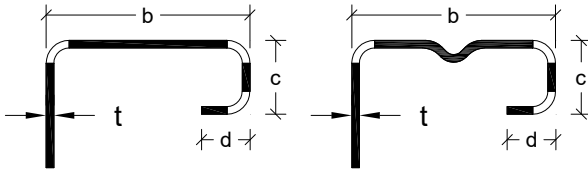
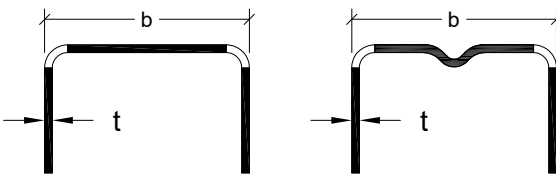
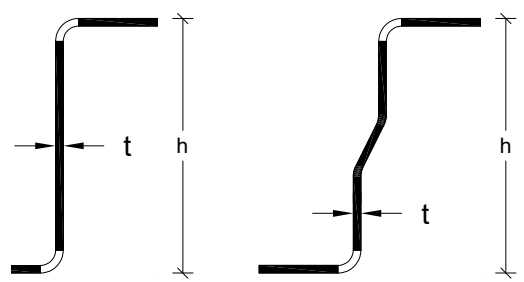
The provisions for design by calculation given in this Part 1-3 of EN 1993 should not be applied to cross-sections outside the range of width-to-thickness ratios b/t , h/t , c/t and d/t given in Table 4.3.

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):

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

- 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

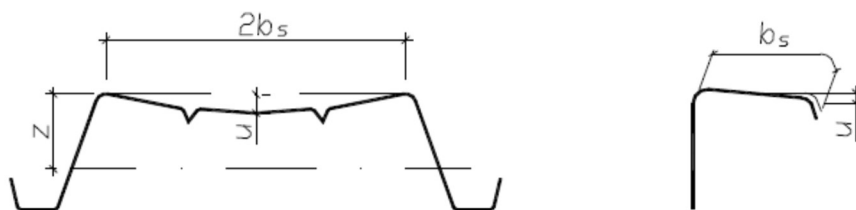


Figure 4.1 - Flange curling
(Figure 5.3, EN 1993-1-3)

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 charts 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

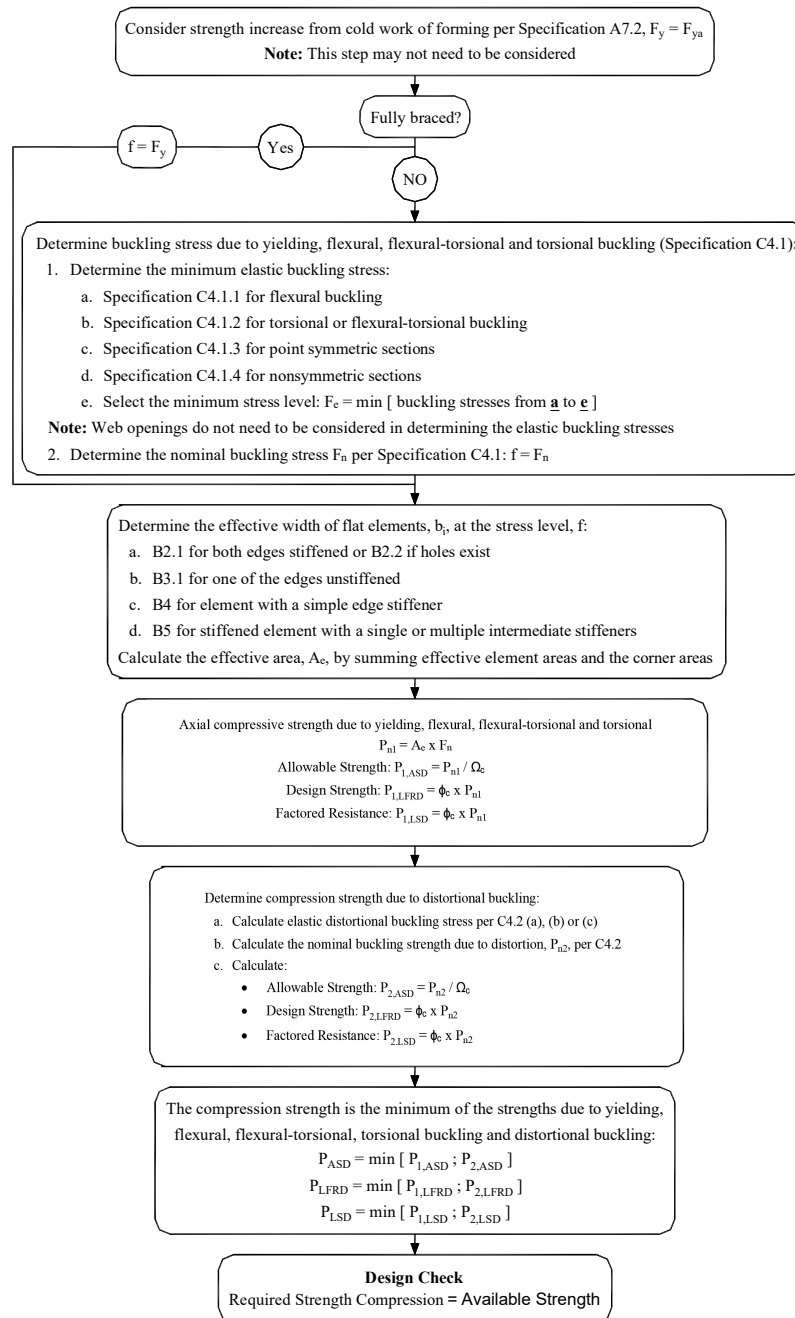


Figure 4.2 – Flow chart I(a): Compression Member Strength Determination (Adapted from AISI Design Tool D101-09, 2009)

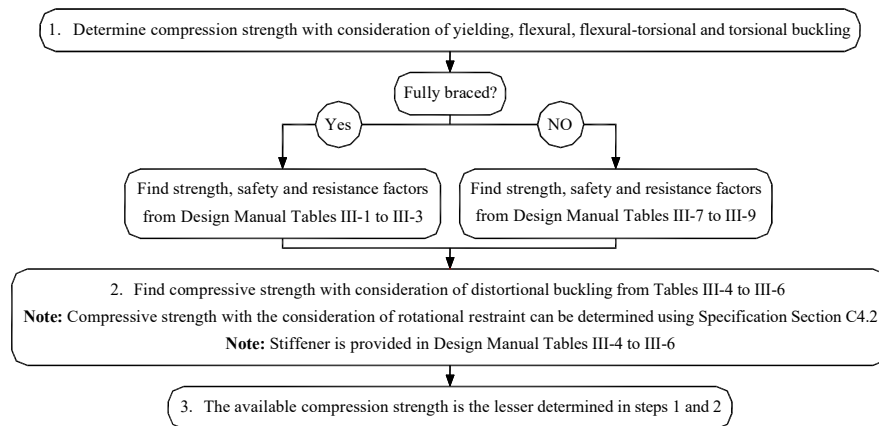


Figure 4.3 – Flow chart I(b): Compression Member Strength Using AISI Cold-Formed Steel Design Manual
(Adapted from AISI Design Tool D101-09, 2009)

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.

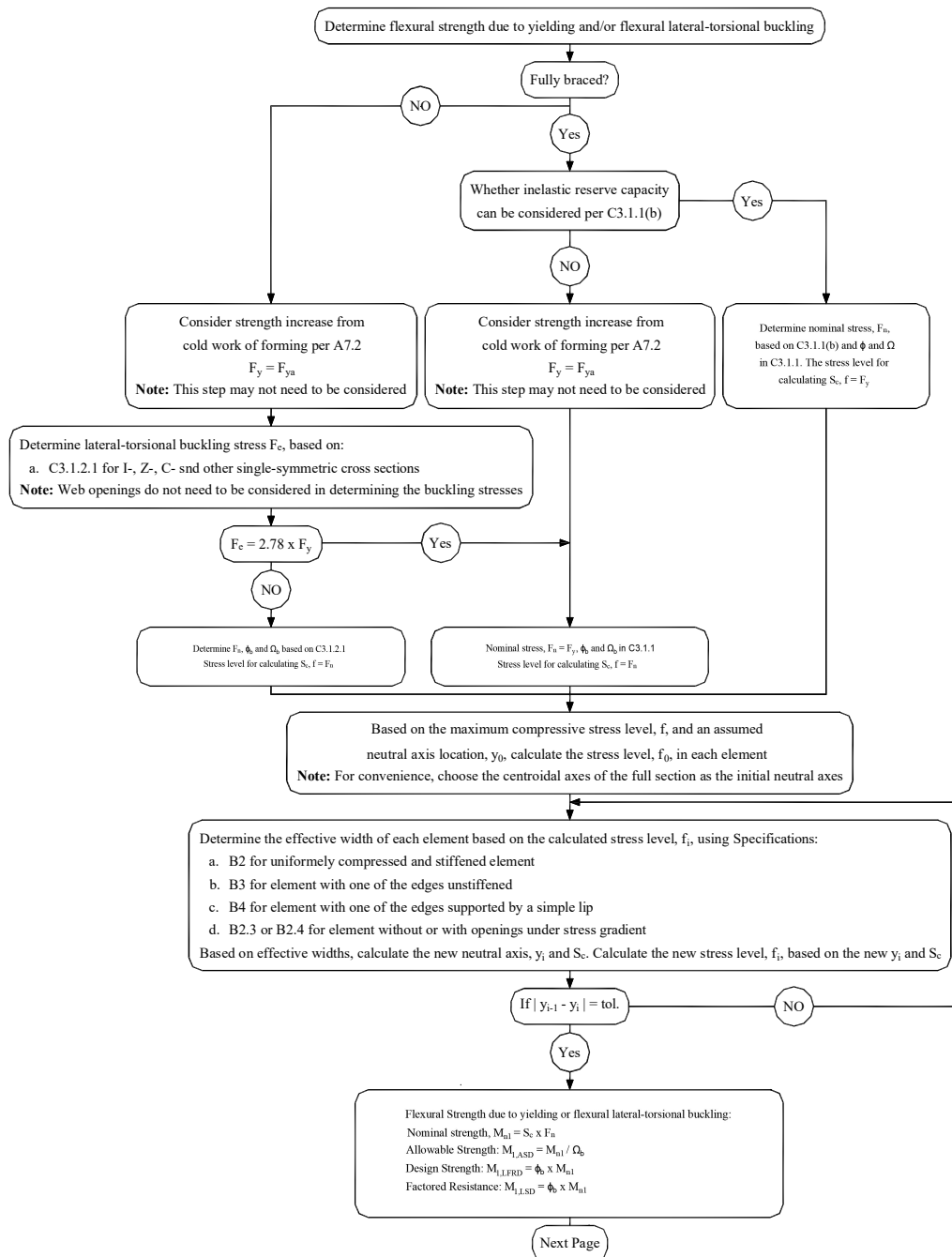


Figure 4.4 - Flow Chart II(a): Flexural Strength of Members with an I-, C-, or Z- Section, a Boxed Section or an Angle Bending about the Symmetric Axis (Adapted from AISI Design Tool D101-09, 2009)

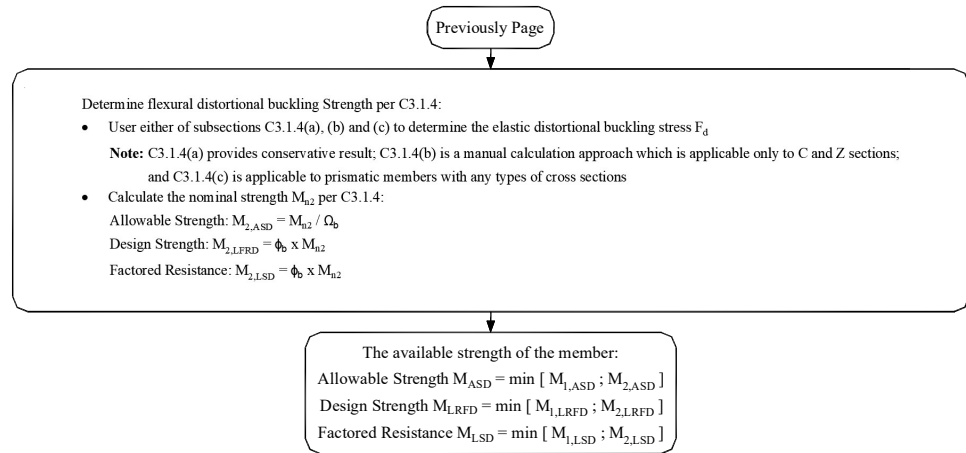


Figure 4.4 - Flow Chart II(a): Flexural Strength of Members with an I-, C-, or Z- Section, a Boxed Section or an Angle Bending about the Symmetric Axis (Adapted from AISI Design Tool D101-09, 2009) (Continuation)

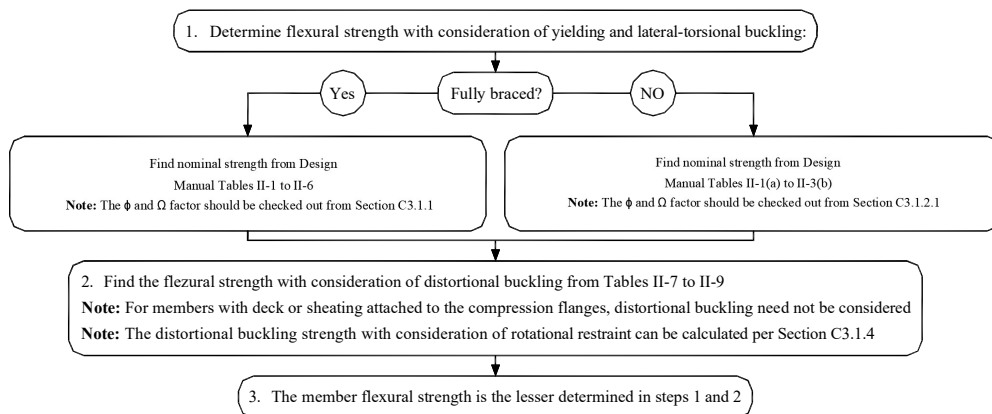


Figure 4.5 – Flow chart II(b): Flexural Member Strength for C- and Z-Sections using AISI Cold-Formed Steel Design Manual (Adapted from AISI Design Tool D101-09, 2009)

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 be 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.

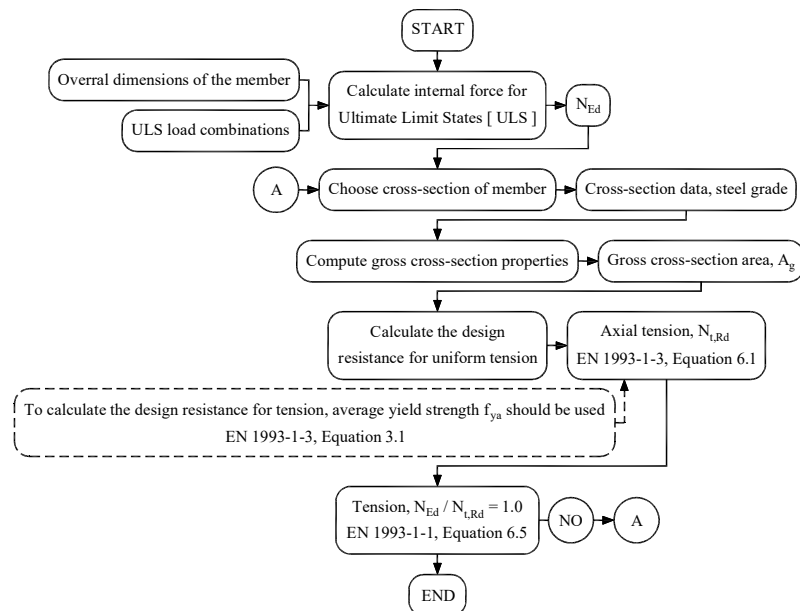


Figure 4.6 - Flow chart: Design of a cold-formed steel lipped channel member in tension
(Adapted from SF040a-EN-EU, 2006)

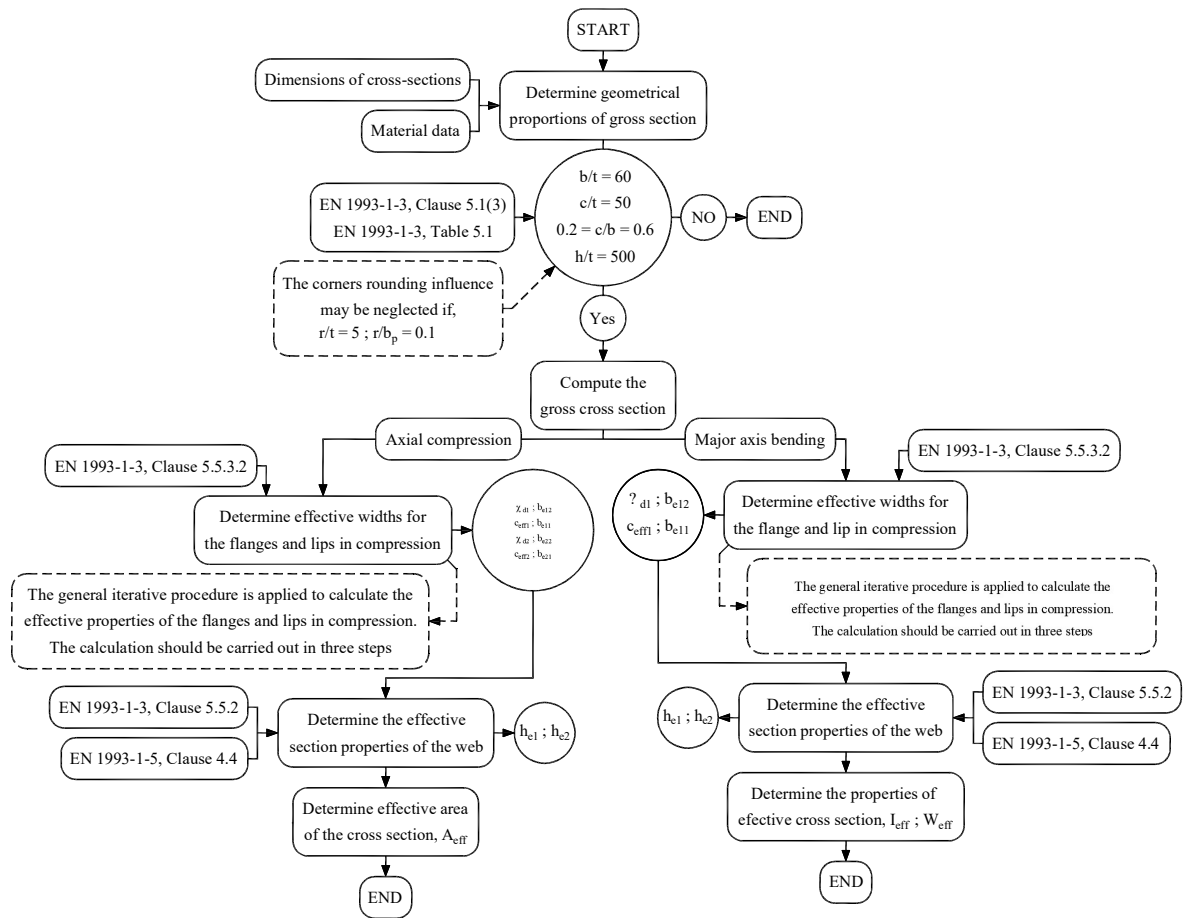


Figure 4.7 - Calculation of effective section properties for cold-formed steel lipped channel sections under compression or bending (Adapted from SF0380a-EN-EU, 2006)



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:** $0.45 \text{ mm} \leq t_{cor} \leq 15 \text{ mm}$ for members; $0.45 \text{ mm} \leq t_{cor} \leq 4 \text{ mm}$ for connections
 - **North American Specification [NAS]:** $t_{cor} \leq 25.40 \text{ mm}$ for members; $t_{cor} \leq 4.76 \text{ mm}$ for bolted connections
 - **Australian/New Zealand Standard:** $t_{cor} \leq 25.40 \text{ mm}$ for members; $t_{cor} \leq 3.00 \text{ mm}$ for bolted connections

5. Material Coefficients

▪ **EC3:**

- ✓ Modulus of elasticity, $E = 210000 \text{ MPa}$
- ✓ Poisson's ratio in elastic stage, $\nu = 0.300$
- ✓ Shear modulus, $G = 80769 \text{ MPa}$

▪ **North American Specification [NAS]:**

- ✓ Modulus of elasticity, $E = 203000 \text{ MPa}$
- ✓ Poisson's ratio in elastic stage, $\nu = 0.300$
- ✓ Shear modulus, $G = 78077 \text{ MPa}$

▪ **Australia/New Zealand Standard:**

- ✓ Modulus of elasticity, $E = 200000 \text{ MPa}$
- ✓ Poisson's ratio in elastic stage, $\nu = 0.300$
- ✓ Shear modulus, $G = 76923 \text{ MPa}$

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:** $f_y = 220 \text{ to } 700 \text{ MPa}$
- **North American Specification [NAS]:** $f_y = 165 \text{ to } 550 \text{ MPa}$
- **Australian/New Zealand Standard:** $f_y = 170 \text{ to } 550 \text{ MPa}$

9. Tensile strength

- **EC3:** $f_u = 300 \text{ to } 750 \text{ MPa}$
- **North American Specification [NAS]:** $f_u = 290 \text{ to } 690 \text{ MPa}$
- **Australian/New Zealand Standard:** $f_u = 280 \text{ to } 570 \text{ MPa}$

10. Non-standard materials

- **EC3:** Allowed if " $f_u/f_y \geq 1.00$ ", "elongation at failure not less than 15%" and " $\epsilon_u \geq 15 \times \epsilon_y$ "
- **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 ratios 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 for 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 StandardTM, 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 $0.45 \text{ mm} \leq t_{cor} \leq 15 \text{ mm}$, both American and Australian/New Zealand Standards accept higher values, $t_{cor} \leq 25.40 \text{ mm}$. Regarding the plate thickness used for bolted connections, the values used in the North American and European Specifications are very similar, $t_{cor} \leq 4.76 \text{ mm}$ and $0.45 \text{ mm} \leq t_{cor} \leq 4 \text{ mm}$, when the Australian/New Zealand Standard only permits a maximum thickness of $t_{cor} \leq 3.00 \text{ mm}$.

Tables 4.1, 4.2 and 4.3, regarding the geometrical limits, presents a set of values to be 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.

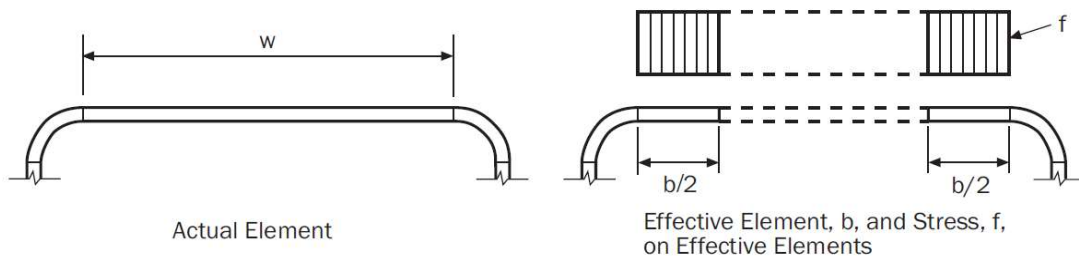


Figure 5.1 - Uniformly Compressed Stiffened Elements
(Adapted from Figure B2.1-1, AISI S100)

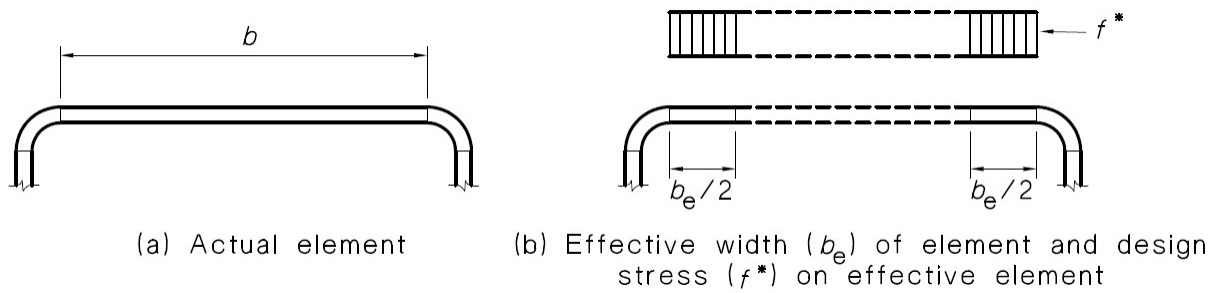


Figure 5.2 - Stiffened Elements with Uniform Compression
(Adapted from Figure 2.2.1, AS/NZS 4600)

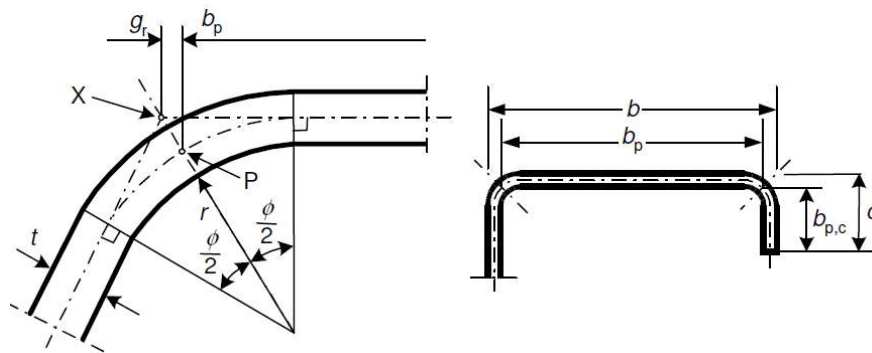


Figure 5.3 - Notional widths of plane cross section parts b_p allowing for corner radii
(Adapted from Figure 5.1, EN 1993-1-3)

The effect of cold hardening is taken 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.

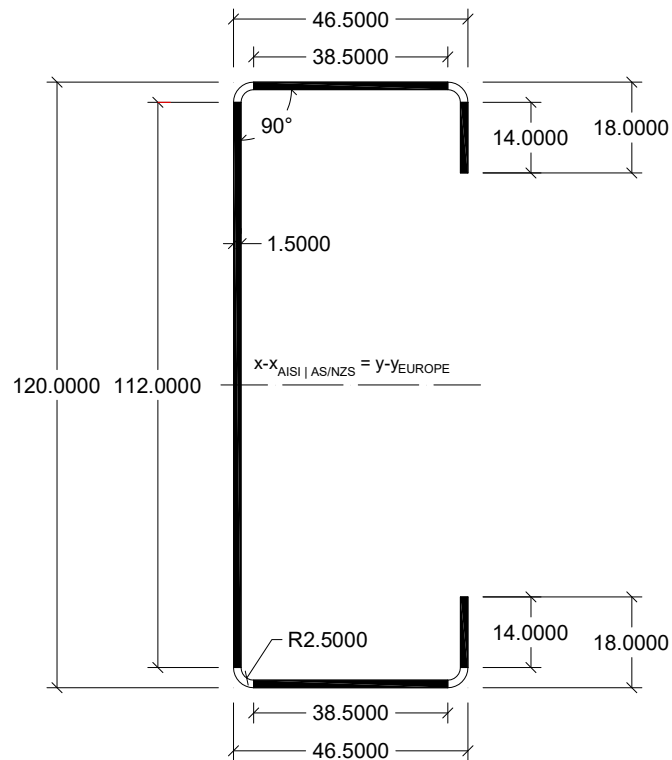


Figure 5.4 - Section B 230 × 1.50

Cold-formed steel, S350 MAGNELIS® ZM310Basic Yield, $f_{yb} = 350 \text{ N/mm}^2$ | Ultimate Tensile, $f_u = 420 \text{ N/mm}^2$ **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

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

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

$$\emptyset \leq 120^\circ \leftrightarrow 90^\circ \leq 120^\circ \rightarrow OK$$

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

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

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

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

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

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

- 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

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

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

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

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

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

Flexural Members

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

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

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

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

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

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

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

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

$$\emptyset \leq 120^\circ \leftrightarrow 90^\circ \leq 120^\circ \rightarrow \text{OK}$$

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

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

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

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

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

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

- 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

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

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

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

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

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

Flexural Members

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

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

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

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

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

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 member
- 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

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

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

$$n = \frac{90^\circ}{90^\circ} + \frac{90^\circ}{90^\circ} + \frac{90^\circ}{90^\circ} + \frac{90^\circ}{90^\circ} = 4.000$$

$$t = 1.500 \text{ mm}$$

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

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

Cold-Formed Manufacturing Process \rightarrow Roll Forming $\rightarrow k = 7.000$

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

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

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

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

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

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	<i>AISI</i> _{ASD}	<i>AISI</i> _{LRFD}	<i>AS/NZS</i>	<i>EUROCODE</i>
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	<i>AISI</i> _{ASD}	<i>AISI</i> _{LRFD}	<i>AS/NZS</i>	<i>EUROCODE</i>
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	<i>AISI</i> _{ASD}	<i>AISI</i> _{LRFD}	<i>AS/NZS</i>	<i>EUROCODE</i>
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	<i>AISI</i> _{ASD}	<i>AISI</i> _{LRFD}	<i>AS/NZS</i>	<i>EUROCODE</i>
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	<i>AISI</i>_{ASD}	<i>AISI</i>_{LRFD}	<i>AS/NZS</i>	<i>EUROCODE</i>
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	<i>AISI</i>_{ASD}	<i>AISI</i>_{LRFD}	<i>AS/NZS</i>	<i>EUROCODE</i>
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, as 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 of them 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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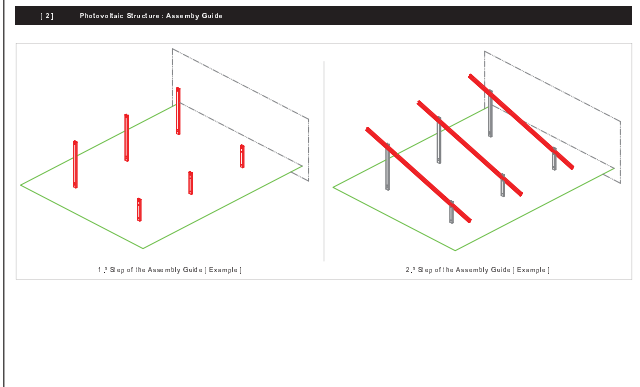
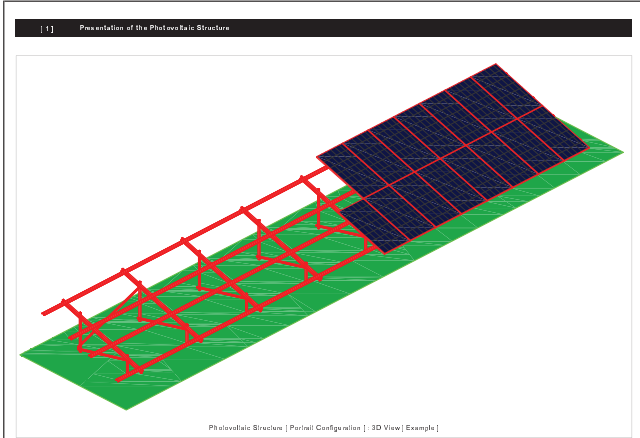
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ANNEX A STRUCTURE TYPE I: EUROCODE VERIFICATION

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Parallel configuration, according to Eurocodes			
Code:	Eurocode	Reference:	EN 1990 | EN 1991 | EN 1993
Version:	1,000		



Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Parallel configuration, according to Eurocodes			
Code:	Eurocode	Reference:	EN 1990 | EN 1991 | EN 1993
Version:	1,000		

Photovoltaic Module Orientation: Parallel, N: 2 Rows: 2, N: 2 Columns: 18

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

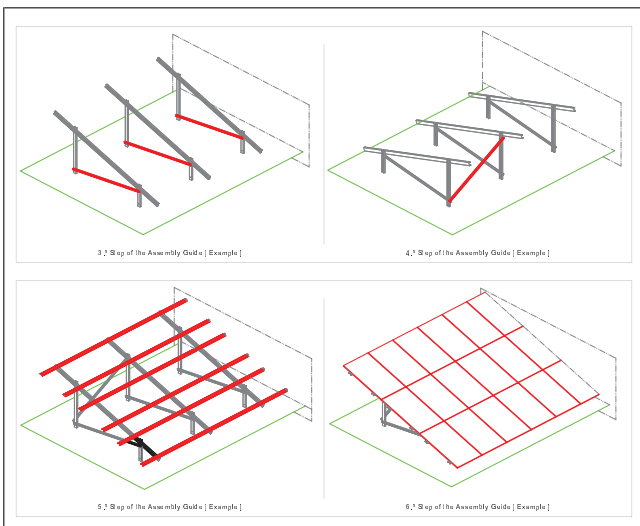
Photovoltaic Structure Definition: Tables Spacing [$L_{1,xx}$, $L_{1,yy}$] [mm]

Gap between Photovoltaic Modules

$L_{1,xx}$	992,000	[mm]	→	L_1	18236,000	[mm]
$L_{1,yy}$	1958,000	[mm]	→	L_2	3512,000	[mm]

Legend: O-Section Purlin, C-Section Column, C-Section Beam, C-Section Steel

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Parallel configuration, according to Eurocodes			
Code:	Eurocode	Reference:	EN 1990 | EN 1991 | EN 1993
Version:	1,000		



Photovoltaic Module

Fabricant	...	
Designation	...	
N° of Cells	72 [un]	
Maximum Power [P_{GM}]	340 [Wp]	
Dimensions	$C_{1,xx}$	1958,000 [mm]
	$L_{1,xx}$	992,000 [mm]
	$H_{1,xx}$	40,000 [mm]
Installing Hole [$D_{1,xx}$]	548 [mm]	
Weight	$G_{1,xx}$	26,000 [Kg]
	$G_{2,xx}$	0,337 [kN/m²]

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Parallel configuration, according to Eurocodes			
Code:	Eurocode	Reference:	EN 1990 | EN 1991 | EN 1993
Version:	1,000		

N° of Spacings	8	[un]
Distance between tables	2125,000	[mm]

$L_{1,xx}$ 618,000 [mm] → Middle length beam is well defined

$L_{1,yy}$ 2125,000 [mm] → Middle length beam is well defined

[a] O-Section Purlin

O-Section Purlin Length	18236,000	[mm]
Maximum O-Section Purlin Length	13000,000	[mm]
Quantity of O-Section Purlin Length	2,000	[un]

Purlin with a wedge or sleeve

[b] C-Section Beam

$L_{1,xx}$	510,000	[mm]
$L_{1,yy}$	1976,000	[mm]
$L_{2,xx}$	510,000	[mm]

C-Section Beam Length 2996,000 [mm]

Beam console length is according to reflex of construction

Maximum C-Section Beam Length 6000,000 [mm]

Quantity of C-Section Beam Length 1,000 [un]

Beam without splices on sections

[c] C-Section Column

$L_{1,xx}$	700,000	[mm]
Distance between Columns	1908,668	[mm]
Photovoltaic Structure Inclination α	15	[°]
$L_{1,xx}$	1211,426	[mm]

Maximum C-Section Column Length 4000,000 [mm]

Quantity of C-Section Front Column Length 1,000 [un]

Quantity of C-Section Rear Column Length 1,000 [un]

Front Columns without splices connections

Rear Columns without splices connections

[d] C-Section Steel

Steel Fixation Point in the Front Column	550,000	[mm]
Steel Fixation Point in the Rear Column	150,000	[mm]

Distance from the Ground Level

$L_{1,xx}$ 1950,333 [mm]

Maximum C-Section Steel Length 6000,000 [mm]

Quantity of C-Section Steel Length 1,000 [un]

Steel without splices connections

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes			
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993		
Version: 1,000			

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

Steel S 355 GD + Z → f_{yk} 355,000 [MPa] | f_{tk} 420,000 [MPa]

[6] Photovoltaic Structure - Section Definition

[a] D-Section Profile

D-Section		D200 * 1,00	
h	54,993	[mm]	
h ₁	5,096	[mm]	
b ₁	112,058	[mm]	
b ₂	34,919	[mm]	
b ₃	42,270	[mm]	
b ₄	34,919	[mm]	
l _{top}	1,000	[mm]	
φ ₁	78,393	[°]	
φ ₂	78,393	[°]	
φ ₃	78,393	[°]	
φ ₄	45,000	[°]	
φ ₅	45,000	[°]	
φ ₆	78,393	[°]	
φ ₇	78,393	[°]	
φ ₈	45,000	[°]	
φ ₉	45,000	[°]	

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

w 200,000 [mm] Tolerance Special

$f_{max, corrug}^{(+)}$ 0,350 [mm] [EN 10143, Table 2]

$f_{max, corrug}^{(-)}$ -0,350 [mm] [EN 10143, Table 2]

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

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

- Sheeting / Members 0,850 mm ≤ t_{min} ≤ 15,000 mm
- Connections 0,450 mm ≤ t_{min} ≤ 4,000 mm

$t_{tolerance}$ 1,050 [mm]

$t_{tolerance}$ 0,350 [mm]

Tolerance ≤ 5% → [EN 1993-1-3, Equation 3.3a] **t 0,352 [mm]**

Coating ZM310 → Zinc-magnesium alloy coating [ZM] → 0,048 [mm]

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes			
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993		
Version: 1,000			

[c] 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]	
r ₅	2,500	[mm]	
l _{top}	2,500	[mm]	
φ ₁	90,000	[°]	
φ ₂	90,000	[°]	
φ ₃	90,000	[°]	
φ ₄	90,000	[°]	
φ ₅	90,000	[°]	
φ ₆	90,000	[°]	

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

w 200,000 [mm] Tolerance Special

$f_{max, corrug}^{(+)}$ 0,310 [mm] [EN 10143, Table 2]

$f_{max, corrug}^{(-)}$ -0,310 [mm] [EN 10143, Table 2]

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

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

- Sheeting / Members 0,850 mm ≤ t_{min} ≤ 15,000 mm
- Connections 0,450 mm ≤ t_{min} ≤ 4,000 mm

$t_{tolerance}$ 2,510 [mm]

$t_{tolerance}$ 2,390 [mm]

Tolerance ≤ 5% → [EN 1993-1-3, Equation 3.3a] **t 2,652 [mm]**

Coating ZM310 → Zinc-magnesium alloy coating [ZM] → 0,048 [mm]

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes			
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993		
Version: 1,000			

[b] 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]	
r ₅	2,500	[mm]	
l _{top}	1,500	[mm]	
φ ₁	90,000	[°]	
φ ₂	90,000	[°]	
φ ₃	90,000	[°]	
φ ₄	90,000	[°]	
φ ₅	90,000	[°]	
φ ₆	90,000	[°]	

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

w 230,000 [mm] Tolerance Special

$f_{max, corrug}^{(+)}$ 0,370 [mm] [EN 10143, Table 2]

$f_{max, corrug}^{(-)}$ -0,370 [mm] [EN 10143, Table 2]

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

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

- Sheeting / Members 0,850 mm ≤ t_{min} ≤ 15,000 mm
- Connections 0,450 mm ≤ t_{min} ≤ 4,000 mm

$t_{tolerance}$ 1,570 [mm]

$t_{tolerance}$ 1,300 [mm]

Tolerance ≤ 5% → [EN 1993-1-3, Equation 3.3a] **t 1,652 [mm]**

Coating ZM310 → Zinc-magnesium alloy coating [ZM] → 0,048 [mm]

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Portrait configuration, according to Eurocodes			
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993		
Version: 1,000			

[d] C-Section Strut

C-Section		B 134 * 1,50	
h	50,000	[mm]	
b	40,000	[mm]	
c	16,000	[mm]	
r ₁	2,500	[mm]	
r ₂	2,500	[mm]	
r ₃	2,500	[mm]	
r ₄	2,500	[mm]	
r ₅	2,500	[mm]	
l _{top}	1,500	[mm]	
φ ₁	90,000	[°]	
φ ₂	90,000	[°]	
φ ₃	90,000	[°]	
φ ₄	90,000	[°]	
φ ₅	90,000	[°]	
φ ₆	90,000	[°]	

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

w 134,000 [mm] Tolerance Special

$f_{max, corrug}^{(+)}$ 0,370 [mm] [EN 10143, Table 2]

$f_{max, corrug}^{(-)}$ -0,370 [mm] [EN 10143, Table 2]

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

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

- Sheeting / Members 0,850 mm ≤ t_{min} ≤ 15,000 mm
- Connections 0,450 mm ≤ t_{min} ≤ 4,000 mm

$t_{tolerance}$ 1,570 [mm]

$t_{tolerance}$ 1,300 [mm]

Tolerance ≤ 5% → [EN 1993-1-3, Equation 3.3a] **t 1,652 [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] D-Section Profile

D-Section		D 200 * 1,00	
b	54,693	[mm]	
h	5,000	[mm]	
b ₁	112,008	[mm]	
b ₂	34,919	[mm]	
b ₃	42,370	[mm]	
b ₄	34,919	[mm]	
t _{lip}	1,000	[mm]	
i	0,952	[mm]	

r ₁	1,500	[mm]	
r ₂	1,500	[mm]	
r ₃	1,500	[mm]	
r ₄	1,500	[mm]	
r ₅	1,500	[mm]	
r ₆	1,500	[mm]	
Q ₁	45,000	[°]	
Q ₂	78,393	[°]	
Q ₃	78,393	[°]	
Q ₄	78,393	[°]	
Q ₅	45,000	[°]	
Q ₆	45,000	[°]	

Maximum width-thickness ratios

Element of cross-section	Maximum value [mm]
	b / t ≤ 60
	c / t ≤ 50
	b / t ≤ 50
	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 * b₁ and the cross-section may be assumed to consist of plane elements with sharp corners [EN 1993-1-3:2006, 5.2]

NOTE Rounded 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 / t ≤ 0,600 [Equation 5.2(a)]

Geometrical Proportions Verifications

t	0,952	[mm]	≥ 0,450 mm	→	OK
			≤ 15,000 mm	→	OK

Maximum width-thickness ratios

Element of cross-section	Maximum value [mm]
	b / t ≤ 60
	c / t ≤ 50
	b / t ≤ 50
	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 * b₁ and the cross-section may be assumed to consist of plane elements with sharp corners [EN 1993-1-3:2006, 5.2]

NOTE Rounded 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 / t ≤ 0,600 [Equation 5.2(a)]

Geometrical Proportions Verifications

t	1,000	[mm]	≥ 0,450 mm	→	OK
			≤ 15,000 mm	→	OK
r _{1,2,3,4,5,6}	46,500	[mm]	b / t ≤ 60	→	OK
φ	90,000	[°]	≥ 45°	→	OK
			≤ 90°	→	OK
r _{lip}	120,000	[mm]	h / t ≤ 500 sin φ	→	OK
r _{1,2,3,4,5,6}	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 / t ≤ 0,600	→	If c / t < 0,200 the lip should be ignored [c = 0]
c / t _{upper flange}	≥ 0,200	→	Stiffener is sufficient stiffness to avoid primary buckling		
c / t _{lower flange}	≤ 0,600	→	Stiffener is sufficient stiffness to avoid primary buckling		
r _{lip}	2,000	[mm]	r ≤ 0,04 * t * E / f _y	→	OK

[b] C-Section Beam

C-Section		C 230 * 1,50	
b	120,000	[mm]	
h	48,000	[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 _{lip}	1,000	[mm]	
Q ₁	90,000	[°]	
Q ₂	90,000	[°]	
Q ₃	90,000	[°]	
Q ₄	90,000	[°]	
φ	90,000	[°]	
i	1,452	[mm]	

Maximum width-thickness ratios

Element of cross-section	Maximum value [mm]
	b / t ≤ 60
	c / t ≤ 50
	b / t ≤ 50
	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 * b₁ and the cross-section may be assumed to consist of plane elements with sharp corners [EN 1993-1-3:2006, 5.2]

NOTE Rounded 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 / t ≤ 0,600 [Equation 5.2(a)]

Geometrical Proportions Verifications

t	2,000	[mm]	≥ 0,450 mm	→	OK
			≤ 15,000 mm	→	OK
r _{1,2,3,4}	46,500	[mm]	b / t ≤ 60	→	OK
φ	90,000	[°]	≥ 45°	→	OK
			≤ 90°	→	OK
r _{lip}	90,000	[mm]	h / t ≤ 500 sin φ	→	OK

[c] C-Section Column

C-Section		C 200 * 2,50	
b	90,000	[mm]	
h	48,000	[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 _{lip}	2,500	[mm]	
Q ₁	90,000	[°]	
Q ₂	90,000	[°]	
Q ₃	90,000	[°]	
Q ₄	90,000	[°]	
φ	90,000	[°]	
i	2,452	[mm]	

Maximum width-thickness ratios

Element of cross-section	Maximum value [mm]
	b / t ≤ 60
	c / t ≤ 50
	b / t ≤ 50
	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 * b₁ and the cross-section may be assumed to consist of plane elements with sharp corners [EN 1993-1-3:2006, 5.2]

NOTE Rounded 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 / t ≤ 0,600 [Equation 5.2(a)]

Geometrical Proportions Verifications

t	2,452	[mm]	≥ 0,450 mm	→	OK
			≤ 15,000 mm	→	OK
r _{1,2,3,4}	46,500	[mm]	b / t ≤ 60	→	OK
φ	90,000	[°]	≥ 45°	→	OK
			≤ 90°	→	OK
r _{lip}	90,000	[mm]	h / t ≤ 500 sin φ	→	OK

Design of a Photovoltaic Structure, Padral configuration, according to Eurocodes		Office: ...	Author: JOSE ANTONIO
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$b_{req,max}$	46,200 [mm]	$b \leq 60$	→	OK
c	18,200 [mm]	$c \leq 50$	→	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: $0,200 \leq c \leq 0,600$ → If $c > 0,200$ the lip should be ignored [$c = 0$].				
$c \leq b_{req,max}$	$\geq 0,200$	→	Stiffener is sufficient stiffness to avoid primary buckling	
$c \leq b_{req,max}$	$\leq 0,600$	→	Stiffener is sufficient stiffness to avoid primary buckling	
r_{req}	2,500 [mm]	$r \leq 0,04 \cdot l \cdot E \cdot I_y$	→	OK

14 | C-Section Size

C-Section		B 134 * 1,50
h	50,000	[mm]
b	40,000	[mm]
c	18,000	[mm]
r1	2,500	[mm]
r2	2,500	[mm]
r3	2,500	[mm]
r4	2,500	[mm]
r5	2,500	[mm]
r6	2,500	[mm]
r7	2,500	[mm]
r8	2,500	[mm]
r9	2,500	[mm]
r10	2,500	[mm]
r11	2,500	[mm]
r12	2,500	[mm]
r13	2,500	[mm]
r14	2,500	[mm]
r15	2,500	[mm]
r16	2,500	[mm]
r17	2,500	[mm]
r18	2,500	[mm]
r19	2,500	[mm]
r20	2,500	[mm]
r21	2,500	[mm]
r22	2,500	[mm]
r23	2,500	[mm]
r24	2,500	[mm]
r25	2,500	[mm]
r26	2,500	[mm]
r27	2,500	[mm]
r28	2,500	[mm]
r29	2,500	[mm]
r30	2,500	[mm]
r31	2,500	[mm]
r32	2,500	[mm]
r33	2,500	[mm]
r34	2,500	[mm]
r35	2,500	[mm]
r36	2,500	[mm]
r37	2,500	[mm]
r38	2,500	[mm]
r39	2,500	[mm]
r40	2,500	[mm]
r41	2,500	[mm]
r42	2,500	[mm]
r43	2,500	[mm]
r44	2,500	[mm]
r45	2,500	[mm]
r46	2,500	[mm]
r47	2,500	[mm]
r48	2,500	[mm]
r49	2,500	[mm]
r50	2,500	[mm]
r51	2,500	[mm]
r52	2,500	[mm]
r53	2,500	[mm]
r54	2,500	[mm]
r55	2,500	[mm]
r56	2,500	[mm]
r57	2,500	[mm]
r58	2,500	[mm]
r59	2,500	[mm]
r60	2,500	[mm]
r61	2,500	[mm]
r62	2,500	[mm]
r63	2,500	[mm]
r64	2,500	[mm]
r65	2,500	[mm]
r66	2,500	[mm]
r67	2,500	[mm]
r68	2,500	[mm]
r69	2,500	[mm]
r70	2,500	[mm]
r71	2,500	[mm]
r72	2,500	[mm]
r73	2,500	[mm]
r74	2,500	[mm]
r75	2,500	[mm]
r76	2,500	[mm]
r77	2,500	[mm]
r78	2,500	[mm]
r79	2,500	[mm]
r80	2,500	[mm]
r81	2,500	[mm]
r82	2,500	[mm]
r83	2,500	[mm]
r84	2,500	[mm]
r85	2,500	[mm]
r86	2,500	[mm]
r87	2,500	[mm]
r88	2,500	[mm]
r89	2,500	[mm]
r90	2,500	[mm]
r91	2,500	[mm]
r92	2,500	[mm]
r93	2,500	[mm]
r94	2,500	[mm]
r95	2,500	[mm]
r96	2,500	[mm]
r97	2,500	[mm]
r98	2,500	[mm]
r99	2,500	[mm]
r100	2,500	[mm]

Influence of rounded corners on cross-section resistance may be neglected when internal radius $r \geq 5 \cdot t$ and $r \leq 0,10 \cdot b_0$ and the cross-section may be assumed to consist of plane elements with sharp corners [EN 1993-1-3:2006, 5.2].

NOTE Rounded corners considered in gross area sections.

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

$r \leq 0,04 \cdot l \cdot E \cdot I_y$ [EN 1993-1-3:2006, 5.1(6)]

$0,200 \leq c \leq 0,600$ [Equation 5.2(1)]

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15 | D-Section Profile

D-Section Profile

16 | Idealized D-Section Profile [Middle Line]

Idealized D-Section Profile [Middle Line]

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Geometrical Properties Verification

t	1,452 [mm]	$\geq 0,450 \text{ mm}$	→	OK
		$\leq 15,000 \text{ mm}$	→	OK
$b_{req,max}$	40,000 [mm]	$b \leq 60$	→	OK
Φ	90,000 [°]	$> 45^\circ$	→	OK
		$\leq 90^\circ$	→	OK
r_{req}	50,000 [mm]	$r \leq 0,04 \cdot l \cdot E \cdot I_y$	→	OK
$b_{req,max}$	40,000 [mm]	$b \leq 60$	→	OK
c	18,000 [mm]	$c \leq 50$	→	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: $0,200 \leq c \leq 0,600$ → If $c > 0,200$ the lip should be ignored [$c = 0$].				
$c \leq b_{req,max}$	$\geq 0,200$	→	Stiffener is sufficient stiffness to avoid primary buckling	
$c \leq b_{req,max}$	$\leq 0,600$	→	Stiffener is sufficient stiffness to avoid primary buckling	
r_{req}	2,000 [mm]	$r \leq 0,04 \cdot l \cdot E \cdot I_y$	→	OK


Design of a Photovoltaic Structure, Padral configuration, according to Eurocodes		Office: ...	Author: JOSE ANTONIO
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D-Section Profile		Idealized D-Section Profile [Middle Line]	
h	54,693 [mm]	→	h_p 53,241 [mm]
$r_{L,max}$	9,096 [mm]	→	$r_{L,max}$ 4,957 [mm]
$r_{L,min}$	9,096 [mm]	→	$r_{L,min}$ 4,957 [mm]
b_1	112,008 [mm]	→	$b_{1,p}$ 111,335 [mm]
b_2	34,919 [mm]	→	$b_{2,p}$ 35,513 [mm]
b_3	42,370 [mm]	→	$b_{3,p}$ 40,817 [mm]
b_4	34,919 [mm]	→	$b_{4,p}$ 35,513 [mm]
r_1	1,500 [mm]	→	$r_{1,p}$ 1,976 [mm]
r_2	1,500 [mm]	→	$r_{2,p}$ 1,976 [mm]
r_3	1,500 [mm]	→	$r_{3,p}$ 1,976 [mm]
r_4	1,500 [mm]	→	$r_{4,p}$ 1,976 [mm]
r_5	1,500 [mm]	→	$r_{5,p}$ 1,976 [mm]
r_6	1,500 [mm]	→	$r_{6,p}$ 1,976 [mm]
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	78,393 [°]	→	Φ_4 78,393 [°]
Φ_5	78,393 [°]	→	Φ_5 78,393 [°]
Φ_6	45,000 [°]	→	Φ_6 45,000 [°]
Φ_7	45,000 [°]	→	Φ_7 45,000 [°]
Φ_8	78,393 [°]	→	Φ_8 78,393 [°]
Φ_9	78,393 [°]	→	Φ_9 78,393 [°]
Φ_{10}	45,000 [°]	→	Φ_{10} 45,000 [°]
t	0,952 [mm]		

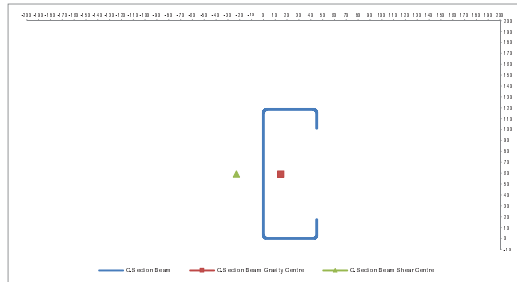
D-Section Profile - Geometrical Presentation

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Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes			
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993		
Version: 1,000			

D-Section Profile Mechanical Properties			
Area	A	191,199	[mm ²]
First Moment of Area	S _{yc}	4904,847	[mm ³]
	S _{yc}	10643,243	[mm ³]
Gravity Centre	y _{cc}	55,667	[mm]
	z _{cc}	25,552	[mm]
Second Moment of Area through Gravity Centre	I _{yc}	8579,975	[mm ⁴]
	I _{zc}	17699,936	[mm ⁴]
Product Moment of Area through Gravity Centre	I _{ycz}	0,000	[mm ⁴]
Principal Axis	α	0,000	[°]
	I _{1c}	17699,936	[mm ⁴]
Mean of Sectorial Coordinate	I _{yc}	8579,976	[mm ⁴]
	I _{zc}	71699,113	[mm ⁴]
Sectorial Constants	W _{pl,y}	3718,821	[mm ³]
	W _{pl,z}	2776,225,770	[mm ³]
Shear Centre	I _{yc}	-119,16048,037	[mm ⁴]
	I _{zc}	2301,2551,876	[mm ⁴]
Warping Constant	I _{yc}	47740,27,730	[mm ⁴]
	I _{zc}	37273,2823,325	[mm ⁴]
Torsion Constants	I _{yc}	10833,9963,544	[mm ⁴]
	I _{zc}	55,667	[mm]
Distance between Shear Centre and Gravity Centre	e _{yc}	68,791	[mm]
	e _{zc}	28433171,815	[mm]
Polar Moment of Area with respect to Shear Centre	I _p	57,762	[mm ⁴]
	W _p	60,874	[mm ³]
Non-symmetry Factors	γ	0,000	[mm]
	ε	54,491	[mm]

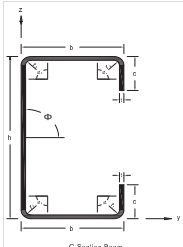
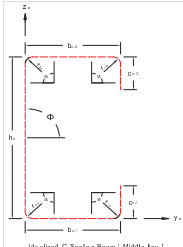
D-Section Profile Flange Curling		[S5 EN 1993-1-3:2006, 5.4]															
	$u = 2 \frac{\sigma_a^2 b_s^4}{E^2 t^2 z}$	<table border="1"> <tr><td>σ_a</td><td>350,000</td><td>[MPa]</td></tr> <tr><td>E</td><td>210,000</td><td>[GPa]</td></tr> <tr><td>b_s</td><td>20,208</td><td>[mm]</td></tr> <tr><td>t</td><td>0,952</td><td>[mm]</td></tr> <tr><td>z</td><td>25,552</td><td>[mm]</td></tr> </table>	σ _a	350,000	[MPa]	E	210,000	[GPa]	b _s	20,208	[mm]	t	0,952	[mm]	z	25,552	[mm]
σ _a	350,000	[MPa]															
E	210,000	[GPa]															
b _s	20,208	[mm]															
t	0,952	[mm]															
z	25,552	[mm]															
v = 9,858E-05 [mm]	→	Not considered because is less than 5% of the depth of the profile cross-section															

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
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Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes			
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993		
Version: 1,000			

C-Section Beam Geometrical Presentation			
			


C-Section Beam Mechanical Properties			
Area	A	345,043	[mm ²]
First Moment of Area	S _{yc}	24453,287	[mm ³]
	S _{zc}	5025,001	[mm ³]
Gravity Centre	y _{cc}	14,553	[mm]
	z _{cc}	59,274	[mm]
Second Moment of Area through Gravity Centre	I _{yc}	762290,865	[mm ⁴]
	I _{zc}	108754,009	[mm ⁴]
Product Moment of Area through Gravity Centre	I _{ycz}	0,000	[mm ⁴]
Principal Axis	α	0,000	[°]
	I _{1c}	762290,865	[mm ⁴]
Mean of Sectorial Coordinate	I _{yc}	108754,009	[mm ⁴]
	I _{zc}	-693270,365	[mm ⁴]
Sectorial Constants	W _{pl,y}	-1632,370	[mm ³]
	W _{pl,z}	-14648942,986	[mm ³]
Shear Centre	I _{yc}	-644285,130	[mm ⁴]
	I _{zc}	-47619,26,837	[mm ⁴]
Warping Constant	I _{yc}	-17374603,429	[mm ⁴]
	I _{zc}	20514369,93,361	[mm ⁴]
Torsion Constants	I _{yc}	113197059,93,845	[mm ⁴]
	I _{zc}	-22,793	[mm]
Distance between Shear Centre and Gravity Centre	e _{yc}	59,274	[mm]
	e _{zc}	35336598,321	[mm]
Polar Moment of Area with respect to Shear Centre	I _p	242,500	[mm ⁴]
	W _p	167,011	[mm ³]

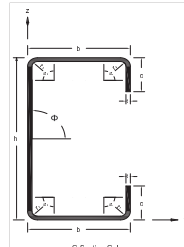
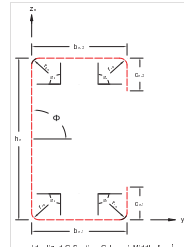
Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes			
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993		
Version: 1,000			

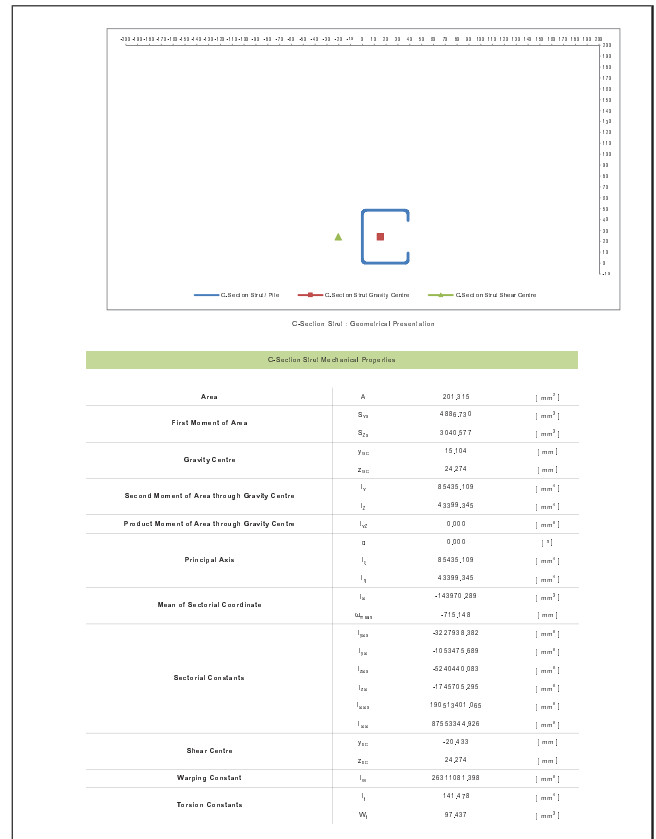
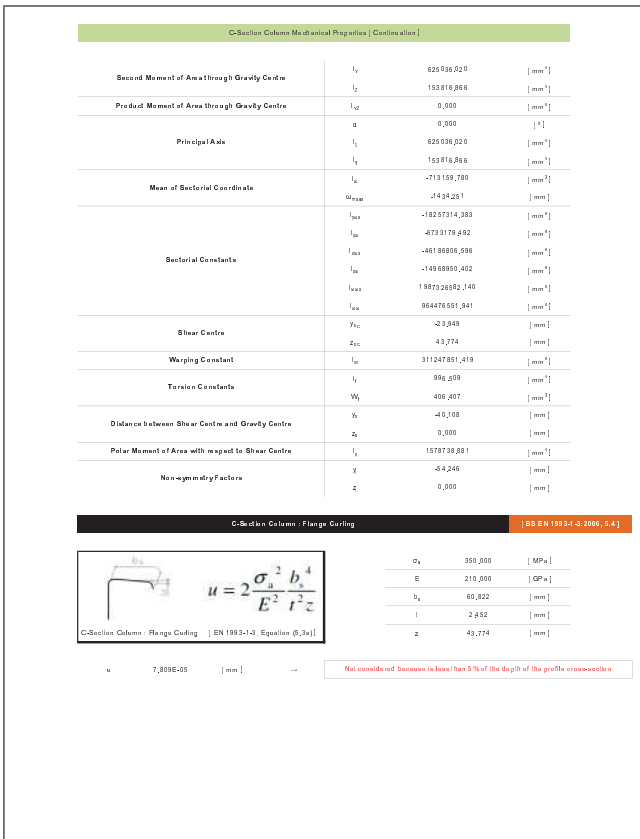
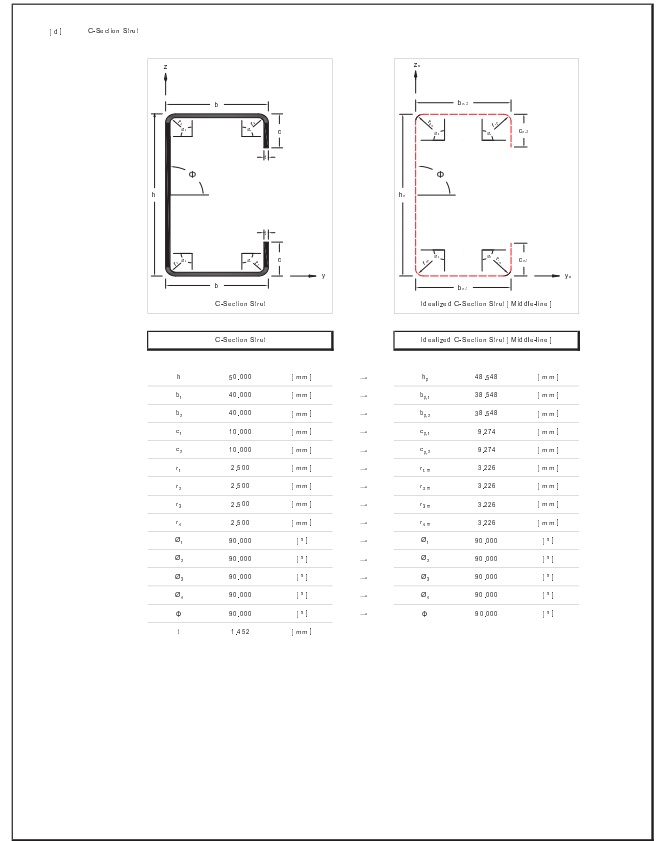
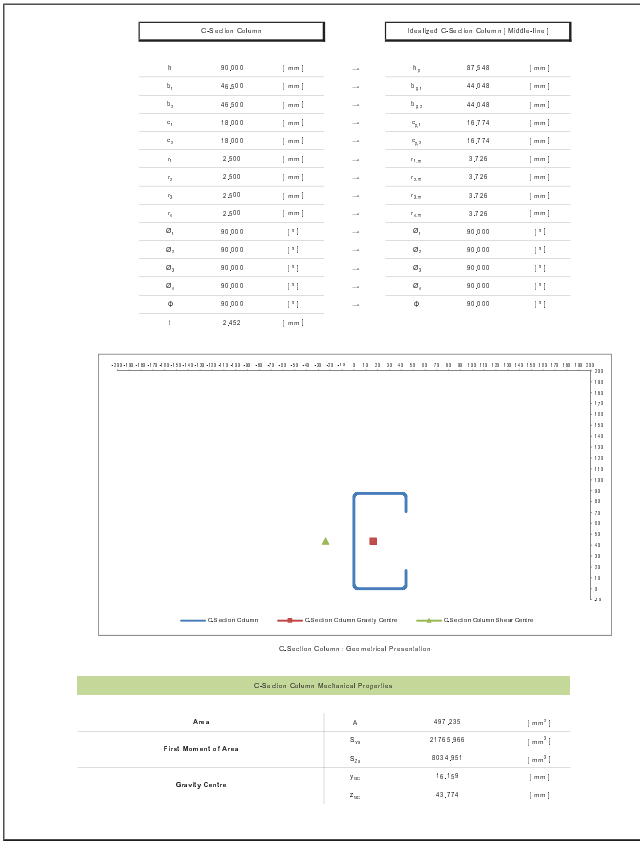
C-Section Beam		Idealized C-Section Beam | Middle-Line				
						
C-Section Beam	Idealized C-Section Beam | Middle-Line					
b	120,000	[mm]	→	b ₁	118,548	[mm]
b ₁	46,200	[mm]	→	b ₂₁	45,048	[mm]
b ₂	46,200	[mm]	→	b ₂₂	45,048	[mm]
c ₁	18,000	[mm]	→	c ₁₁	17,274	[mm]
c ₂	18,000	[mm]	→	c ₂₁	17,274	[mm]
c ₃	2,500	[mm]	→	c _{3a}	3,226	[mm]
c ₄	2,500	[mm]	→	c _{4a}	3,226	[mm]
c ₅	2,500	[mm]	→	c _{5a}	3,226	[mm]
c ₆	2,500	[mm]	→	c _{6a}	3,226	[mm]
α ₁	90,000	[°]	→	α ₁	90,000	[°]
α ₂	90,000	[°]	→	α ₂	90,000	[°]
α ₃	90,000	[°]	→	α ₃	90,000	[°]
α ₄	90,000	[°]	→	α ₄	90,000	[°]
α ₅	90,000	[°]	→	α ₅	90,000	[°]
α ₆	90,000	[°]	→	α ₆	90,000	[°]
φ	90,000	[°]	→	φ	90,000	[°]
t	1,452	[mm]				

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
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Code: Eurocode	Reference: EN 1990 EN 1991 EN 1993		
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C-Section Beam Mechanical Properties Continuation			
Distance between Shear Centre and Gravity Centre	y _c	-37,335	[mm]
Polar Moment of Area with respect to Shear Centre	I _p	1322649,014	[mm ⁴]
Non-symmetry Factors	γ	-64,166	[mm]
	z	0,000	[mm]

C-Section Beam Flange Curling		[S5 EN 1993-1-3:2006, 5.4]															
	$u = 2 \frac{\sigma_a^2 b_s^4}{E^2 t^2 z}$	<table border="1"> <tr><td>σ_a</td><td>350,000</td><td>[MPa]</td></tr> <tr><td>E</td><td>210,000</td><td>[GPa]</td></tr> <tr><td>b_s</td><td>62,322</td><td>[mm]</td></tr> <tr><td>t</td><td>1,452</td><td>[mm]</td></tr> <tr><td>z</td><td>59,274</td><td>[mm]</td></tr> </table>	σ _a	350,000	[MPa]	E	210,000	[GPa]	b _s	62,322	[mm]	t	1,452	[mm]	z	59,274	[mm]
σ _a	350,000	[MPa]															
E	210,000	[GPa]															
b _s	62,322	[mm]															
t	1,452	[mm]															
z	59,274	[mm]															
v = 1,227E-04 [mm]	→	Not considered because is less than 5% of the depth of the profile cross-section															

C-Section Column		Idealized C-Section Column | Middle-Line	
			
C-Section Column	Idealized C-Section Column | Middle-Line		

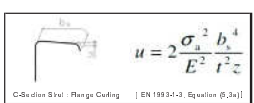


Design of a Photovoltaic Structure, Parafix configuration, according to Eurocodes		Office: ...	Author: JOSE ANTONIO
Code: Eurocode	References: EN 1990 EN 1991 EN 1993	Date: 05/09/2019	Project: MASTER THESIS
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C-Section Size Mechanical Properties | Classification

Distance between Shear Centre and Gravity Centre	y_c	-35,937	[mm]
	z_c	0,000	[mm]
Polar Moment of Area with respect to Shear Centre	I_p	393066,618	[mm ⁴]
Non-symmetry Factors	γ	-1,747	[mm]
	z	0,000	[mm]

C-Section Stud: Flange Curling [SB EN 1993-1-3:2006, 5.4]



σ_y	350,000	[MPa]
E	210,000	[GPa]
b_s	47,822	[mm]
t	1,652	[mm]
z	24,274	[mm]

$u = 2,483E-04$ [mm] → Not considered because its less than 5% of the depth of the profile cross-section

Design of a Photovoltaic Structure, Parafix configuration, according to Eurocodes		Office: ...	Author: JOSE ANTONIO
Code: Eurocode	References: EN 1990 | EN 1991 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1,000		Client: COIMBRA UNIVERSITY	

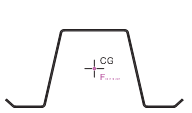
g_{11}	0,002	[mm]	f_{11}	0,758	[mm]
g_{12}	0,003	[mm]	f_{12}	1,249	[mm]
g_{13}	0,003	[mm]	f_{13}	1,249	[mm]
g_{14}	0,003	[mm]	f_{14}	1,249	[mm]
g_{15}	0,003	[mm]	f_{15}	1,249	[mm]
g_{16}	0,002	[mm]	f_{16}	0,758	[mm]

D-Section Nominal Widths

$s_{flange\ max}$	7,010	[mm]
$b_{flange\ max}$	18,975	[mm]
$h_{flange\ max}$	54,863	[mm]
$s_{web\ max}$	41,393	[mm]
$b_{web\ max}$	54,863	[mm]
$s_{flange\ min}$	18,975	[mm]
$s_{web\ min}$	7,010	[mm]

D-Section Part Classification [EN 1993-1-1:2005, 5.5.2, Table 5.2]

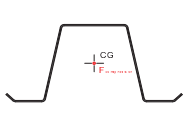
D-Section subjected to Tension Force



Right Edge Stiffener | $s_{flange\ min}$	→	Tension
Inferior Right Flange | $b_{flange\ max}$	→	Tension
Right Web | $h_{flange\ max}$	→	Tension
Superior Flange | $b_{flange\ max}$	→	Tension
Left Web | $h_{flange\ max}$	→	Tension
Inferior Left Flange | $b_{flange\ max}$	→	Tension
Left Edge Stiffener | $s_{flange\ min}$	→	Tension

D-Section Class Fraction **Not Classified**

D-Section subjected to Compression Force

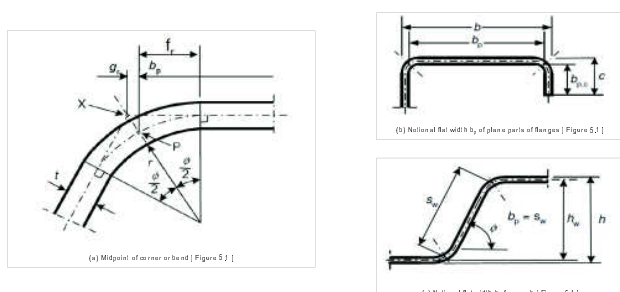


Right Edge Stiffener | $s_{flange\ min}$	→	Class 1
Inferior Right Flange | $b_{flange\ max}$	→	Class 1
Right Web | $h_{flange\ max}$	→	Class 4
Superior Flange | $b_{flange\ max}$	→	Class 4
Left Web | $h_{flange\ max}$	→	Class 4
Inferior Left Flange | $b_{flange\ max}$	→	Class 1
Left Edge Stiffener | $s_{flange\ min}$	→	Class 1

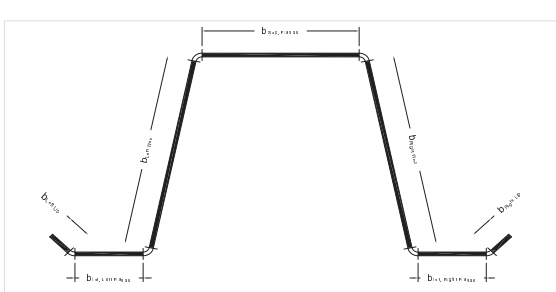
D-Section Class Fraction **Class 4**

Design of a Photovoltaic Structure, Cold Formed Section, Section Classification		Office: ...	Author: JOSE ANTONIO
Code: Eurocode	References: EN 1990 | EN 1991 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1,000		Client: COIMBRA UNIVERSITY	

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



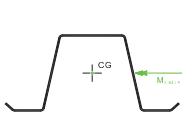
D-Section Part Classification



g_1	45,000	[°]	s_{fl}	1,976	[mm]
g_2	78,293	[°]	s_{fw}	1,976	[mm]
g_3	78,293	[°]	s_{fw}	1,976	[mm]
g_4	78,293	[°]	s_{fw}	1,976	[mm]
g_5	78,293	[°]	s_{fw}	1,976	[mm]
g_6	45,000	[°]	s_{fl}	1,976	[mm]

Design of a Photovoltaic Structure, Parafix configuration, according to Eurocodes		Office: ...	Author: JOSE ANTONIO
Code: Eurocode	References: EN 1990 | EN 1991 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1,000		Client: COIMBRA UNIVERSITY	

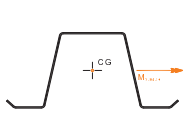
D-Section subjected to Positive Moment in y-y axis | M_{yy}



Right Edge Stiffener | $s_{flange\ min}$	→	Tension
Inferior Right Flange | $b_{flange\ max}$	→	Tension
Right Web | $h_{flange\ max}$	→	Class 1
Superior Flange | $b_{flange\ max}$	→	Class 4
Left Web | $h_{flange\ max}$	→	Class 4
Inferior Left Flange | $b_{flange\ max}$	→	Tension
Left Edge Stiffener | $s_{flange\ min}$	→	Tension

D-Section Class Fraction **Class 4**

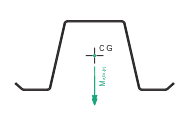
D-Section subjected to Negative Moment in y-y axis | M_{yy}



Right Edge Stiffener | $s_{flange\ min}$	→	Class 1
Inferior Right Flange | $b_{flange\ max}$	→	Class 1
Right Web | $h_{flange\ max}$	→	Class 1
Superior Flange | $b_{flange\ max}$	→	Tension
Left Web | $h_{flange\ max}$	→	Class 1
Inferior Left Flange | $b_{flange\ max}$	→	Class 1
Left Edge Stiffener | $s_{flange\ min}$	→	Class 1

D-Section Class Fraction **Class 1**

D-Section subjected to Positive Moment in z-z axis | M_{zz}



Right Edge Stiffener | $s_{flange\ min}$	→	Tension
Inferior Right Flange | $b_{flange\ max}$	→	Tension
Right Web | $h_{flange\ max}$	→	Tension
Superior Flange | $b_{flange\ max}$	→	Class 1
Left Web | $h_{flange\ max}$	→	Class 4
Inferior Left Flange | $b_{flange\ max}$	→	Class 1
Left Edge Stiffener | $s_{flange\ min}$	→	Class 1

D-Section Class Fraction **Class 4**

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Padrat configuration, according to Eurocodes			
Code:	Eurocode	Reference:	EN 1990 | EN 1991 | EN 1993
Version:	1,000		

C-Section subjected to Negative Moment in x-x axis [M_{xx}']

Right Edge Stiffener [s _{1,2} mm] →	Class 1
Inferior Right Flange [s _{2,1} mm] →	Class 1
Right Web [s _{3,2} mm] →	Class 4
Superior Flange [s _{2,2} mm] →	Class 1
Left Web [s _{3,1} mm] →	Tension
Inferior Left Flange [s _{2,1} mm] →	Tension
Left Edge Stiffener [s _{1,2} mm] →	Tension

C-Section Classification: Class 4

19 | C-Section Beam

ϕ ₁	90,000	[°]
ϕ ₂	90,000	[°]
ϕ ₃	90,000	[°]
ϕ ₄	90,000	[°]
r _{1w}	3,226	[mm]
r _{2w}	3,226	[mm]
r _{1fl}	3,226	[mm]
r _{2fl}	3,226	[mm]
g _{1x}	0,945	[mm]
g _{2x}	0,945	[mm]
g _{3x}	0,945	[mm]
g _{4x}	0,945	[mm]
r _{1y}	2,281	[mm]
r _{2y}	2,281	[mm]
r _{3y}	2,281	[mm]
r _{4y}	2,281	[mm]

C-Section Nominal Widths		
s _{1,2} mm	17,274	[mm]
s _{2,1} mm	45,048	[mm]
s _{2,2} mm	118,548	[mm]
s _{3,1} mm	45,048	[mm]
s _{3,2} mm	17,274	[mm]

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Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Padrat configuration, according to Eurocodes			
Code:	Eurocode	Reference:	EN 1990 | EN 1991 | EN 1993
Version:	1,000		

C-Section subjected to Positive Moment in y-y axis [M_{yy}']

Inferior Edge Stiffener [s _{1,1} mm] →	Tension
Inferior Flange [s _{2,1} mm] →	Tension
Web [s _{3,2} mm] →	Class 3
Superior Flange [s _{2,2} mm] →	Class 2
Superior Edge Stiffener [s _{1,2} mm] →	Class 4

C-Section Classification: Class 4

C-Section subjected to Negative Moment in y-y axis [M_{yy}']

Inferior Edge Stiffener [s _{1,1} mm] →	Class 4
Inferior Flange [s _{2,1} mm] →	Class 2
Web [s _{3,2} mm] →	Class 3
Superior Flange [s _{2,2} mm] →	Tension
Superior Edge Stiffener [s _{1,2} mm] →	Tension

C-Section Classification: Class 4

C-Section subjected to Positive Moment in x-x axis [M_{xx}']

Inferior Edge Stiffener [s _{1,1} mm] →	Tension
Inferior Flange [s _{2,1} mm] →	Class 1
Web [s _{3,2} mm] →	Class 4
Superior Flange [s _{2,2} mm] →	Class 1
Superior Edge Stiffener [s _{1,2} mm] →	Tension

C-Section Classification: Class 4

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Padrat configuration, according to Eurocodes			
Code:	Eurocode	Reference:	EN 1990 | EN 1991 | EN 1993
Version:	1,000		

C-Section Beam Classification [EN 1993-1-1:2005, 5.2.3, Table 5.2]

C-Section subjected to Tension Force

Inferior Edge Stiffener [s _{1,2} mm] →	Tension
Inferior Flange [s _{2,1} mm] →	Tension
Web [s _{3,2} mm] →	Tension
Superior Flange [s _{2,2} mm] →	Tension
Superior Edge Stiffener [s _{1,2} mm] →	Tension

C-Section Classification: Not Classified

C-Section subjected to Compression Force

Inferior Edge Stiffener [s _{1,2} mm] →	Class 4
Inferior Flange [s _{2,1} mm] →	Class 2
Web [s _{3,2} mm] →	Class 4
Superior Flange [s _{2,2} mm] →	Class 2
Superior Edge Stiffener [s _{1,2} mm] →	Class 4

C-Section Classification: Class 4

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Padrat configuration, according to Eurocodes			
Code:	Eurocode	Reference:	EN 1990 | EN 1991 | EN 1993
Version:	1,000		

C-Section subjected to Negative Moment in x-x axis [M_{xx}']

Inferior Edge Stiffener [s _{1,1} mm] →	Class 4
Inferior Flange [s _{2,1} mm] →	Class 1
Web [s _{3,2} mm] →	Tension
Superior Flange [s _{2,2} mm] →	Class 1
Superior Edge Stiffener [s _{1,2} mm] →	Class 4

C-Section Classification: Class 4

1c | C-Section Column

ϕ ₁	90,000	[°]
ϕ ₂	90,000	[°]
ϕ ₃	90,000	[°]
ϕ ₄	90,000	[°]
r _{1w}	3,226	[mm]
r _{2w}	3,226	[mm]
r _{1fl}	3,226	[mm]
r _{2fl}	3,226	[mm]
g _{1x}	1,981	[mm]
g _{2x}	1,981	[mm]
g _{3x}	1,981	[mm]
g _{4x}	1,981	[mm]
r _{1y}	2,835	[mm]
r _{2y}	2,835	[mm]
r _{3y}	2,835	[mm]
r _{4y}	2,835	[mm]

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Padrair configuration, according to Eurocodes			
Code:	Eurocode	Reference:	EN 1991 | EN 1991 | EN 1993
Version:	1,000		

C-Section Nominal Widths	
$s_{1,120}$	16,274 [mm]
$s_{2,120}$	44,048 [mm]
$s_{3,120}$	87,548 [mm]
$s_{4,120}$	44,048 [mm]
$s_{5,120}$	16,274 [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 [$s_{1,120}$]	→	Tension
Inferior Flange [$s_{2,120}$]	→	Tension
Web [$s_{3,120}$]	→	Tension
Superior Flange [$s_{4,120}$]	→	Tension
Superior Edge Stiffener [$s_{5,120}$]	→	Tension

C-Section Classification **Not Classified**

C-Section subjected to Compression Force

Inferior Edge Stiffener [$s_{1,120}$]	→	Class 1
Inferior Flange [$s_{2,120}$]	→	Class 1
Web [$s_{3,120}$]	→	Class 4
Superior Flange [$s_{4,120}$]	→	Class 1
Superior Edge Stiffener [$s_{5,120}$]	→	Class 1

C-Section Classification **Class 4**

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Padrair configuration, according to Eurocodes			
Code:	Eurocode	Reference:	EN 1991 | EN 1991 | EN 1993
Version:	1,000		

C-Section subjected to Negative Moment in x-x axis [M_{xx}]

Inferior Edge Stiffener [$s_{1,120}$]	→	Class 1
Inferior Flange [$s_{2,120}$]	→	Class 1
Web [$s_{3,120}$]	→	Tension
Superior Flange [$s_{4,120}$]	→	Class 1
Superior Edge Stiffener [$s_{5,120}$]	→	Class 1

C-Section Classification **Class 1**

[4] **C-Section Size**

ϕ_1	90,000 [°]
ϕ_2	90,000 [°]
ϕ_3	90,000 [°]
ϕ_4	90,000 [°]
r_{1a}	3,226 [mm]
r_{1b}	3,226 [mm]
r_{2a}	3,226 [mm]
r_{2b}	3,226 [mm]
g_{1a}	0,945 [mm]
g_{1b}	0,945 [mm]
g_{2a}	0,945 [mm]
g_{2b}	0,945 [mm]
f_{1a}	2,281 [mm]
f_{1b}	2,281 [mm]
f_{2a}	2,281 [mm]
f_{2b}	2,281 [mm]

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Padrair configuration, according to Eurocodes			
Code:	Eurocode	Reference:	EN 1991 | EN 1991 | EN 1993
Version:	1,000		

C-Section subjected to Positive Moment in y-y axis [M_{yy}]

Inferior Edge Stiffener [$s_{1,120}$]	→	Tension
Inferior Flange [$s_{2,120}$]	→	Tension
Web [$s_{3,120}$]	→	Class 1
Superior Flange [$s_{4,120}$]	→	Class 1
Superior Edge Stiffener [$s_{5,120}$]	→	Class 1

C-Section Classification **Class 1**

C-Section subjected to Negative Moment in y-y axis [M_{yy}]

Inferior Edge Stiffener [$s_{1,120}$]	→	Class 1
Inferior Flange [$s_{2,120}$]	→	Class 1
Web [$s_{3,120}$]	→	Class 1
Superior Flange [$s_{4,120}$]	→	Tension
Superior Edge Stiffener [$s_{5,120}$]	→	Tension

C-Section Classification **Class 1**

C-Section subjected to Positive Moment in x-x axis [M_{xx}]

Inferior Edge Stiffener [$s_{1,120}$]	→	Tension
Inferior Flange [$s_{2,120}$]	→	Class 1
Web [$s_{3,120}$]	→	Class 4
Superior Flange [$s_{4,120}$]	→	Class 1
Superior Edge Stiffener [$s_{5,120}$]	→	Tension

C-Section Classification **Class 4**

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Padrair configuration, according to Eurocodes			
Code:	Eurocode	Reference:	EN 1991 | EN 1991 | EN 1993
Version:	1,000		

C-Section Nominal Widths	
$s_{1,120}$	9,274 [mm]
$s_{2,120}$	39,548 [mm]
$s_{3,120}$	48,548 [mm]
$s_{4,120}$	39,548 [mm]
$s_{5,120}$	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 [$s_{1,120}$]	→	Tension
Inferior Flange [$s_{2,120}$]	→	Tension
Web [$s_{3,120}$]	→	Tension
Superior Flange [$s_{4,120}$]	→	Tension
Superior Edge Stiffener [$s_{5,120}$]	→	Tension

C-Section Classification **Not Classified**

C-Section subjected to Compression Force

Inferior Edge Stiffener [$s_{1,120}$]	→	Class 1
Inferior Flange [$s_{2,120}$]	→	Class 1
Web [$s_{3,120}$]	→	Class 3
Superior Flange [$s_{4,120}$]	→	Class 1
Superior Edge Stiffener [$s_{5,120}$]	→	Class 1

C-Section Classification **Class 3**

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Code: Eurocode	Reference: EN 1990 EN 1991 EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1,000		Client: COIMBRA UNIVERSITY	

C-Section subjected to Positive Moment in yy axis [M_{yy}]

Inferior Edge Stiffness [S_{1,100}] → Tension
 Inferior Flange [S_{2,100}] → Tension
 Web [S_{1,200}] → Class 1
 Superior Flange [S_{2,200}] → Class 1
 Superior Edge Stiffness [S_{1,200}] → Class 1

C-Section Classification: Class 1

C-Section subjected to Negative Moment in yy axis [M_{yy}]

Inferior Edge Stiffness [S_{1,100}] → Class 1
 Inferior Flange [S_{2,100}] → Class 1
 Web [S_{1,200}] → Class 1
 Superior Flange [S_{2,200}] → Tension
 Superior Edge Stiffness [S_{1,200}] → Tension

C-Section Classification: Class 1

C-Section subjected to Positive Moment in zz axis [M_{zz}]

Inferior Edge Stiffness [S_{1,100}] → Tension
 Inferior Flange [S_{2,100}] → Class 1
 Web [S_{1,200}] → Class 3
 Superior Flange [S_{2,200}] → Class 1
 Superior Edge Stiffness [S_{1,200}] → Tension

C-Section Classification: Class 3

Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes		Office: ---	Author: JOSE ANTONIO
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1,000		Client: COIMBRA UNIVERSITY	

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

D-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 Stud 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
	Flange	---	---
Ultimate strength	Corner	---	High
	Flange	---	---

Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes		Office: ---	Author: JOSE ANTONIO
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1,000		Client: COIMBRA UNIVERSITY	

C-Section subjected to Negative Moment in zz axis [M_{zz}]

Inferior Edge Stiffness [S_{1,100}] → Class 1
 Inferior Flange [S_{2,100}] → Class 1
 Web [S_{1,200}] → Tension
 Superior Flange [S_{2,200}] → Class 1
 Superior Edge Stiffness [S_{1,200}] → Class 1

C-Section Classification: Class 1

Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes		Office: ---	Author: JOSE ANTONIO
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1,000		Client: COIMBRA UNIVERSITY	

NOTE Manufacturing process leads to a modification of the stress-strain curve of the steel origin material. The average yield strength f_{yk} may be utilized in determining:

- Cross-section resistance of an axially loaded tension member
- 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

[*] D-Section Purlin

$$f_{yk} = f_{yk} + (f_{yk} - f_{yk}) \frac{k t^2}{A_y}$$

$$f_{yk} \leq \frac{(f_{yk} + f_{yk})}{2}$$

Parameters		Cold-Formed Material Properties	
A _y	191,199 [mm ²]	S 350 GD + Z	f _y 350,000 [MPa]
k	7,000		f _t 420,000 [MPa]
r _{mp} ≤ 5)	OK		
n	4,684 [mm]		f _y 360,415 [MPa] OK
t	0,952 [mm]		

[*] C-Section Beam

$$f_{yk} = f_{yk} + (f_{yk} - f_{yk}) \frac{k t^2}{A_y}$$

$$f_{yk} \leq \frac{(f_{yk} + f_{yk})}{2}$$

Parameters		Cold-Formed Material Properties	
A _y	345,093 [mm ²]	S 350 GD + Z	f _y 350,000 [MPa]
k	7,000		f _t 420,000 [MPa]
r _{mp} ≤ 5)	OK		
n	2,000 [mm]		f _y 361,975 [MPa] OK
t	1,552 [mm]		

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Code: Eurocode	Reference: EN 1990 EN 1991 EN 1993	Date: 05/09/2019	Project: MASTER THESIS	
Version: 1,000		Client: COIMBRA UNIVERSITY		

[c] C-Section Column

$$f_{yk} = f_{yk} + (f_{tk} - f_{yk}) \frac{kN^2}{A_g}$$

$$f_{yk} \leq \frac{(f_{tk} + f_{tk})}{2}$$

Parameters		Cold-Formed Material Properties	
A_g	497,235 [mm ²]	f_u	350,000 [MPa]
k	7,000	f_t	420,000 [MPa]
$t_{max} \leq 5,2$	OK		
n	4,000 [mm]	f_u	373,559 [MPa] OK
l	2,452 [mm]		

[d] C-Section Slab

$$f_{yk} = f_{yk} + (f_{tk} - f_{yk}) \frac{kN^2}{A_g}$$

$$f_{yk} \leq \frac{(f_{tk} + f_{tk})}{2}$$

Parameters		Cold-Formed Material Properties	
A_g	201,315 [mm ²]	f_u	350,000 [MPa]
k	7,000	f_t	420,000 [MPa]
$t_{max} \leq 5,2$	OK		
n	4,000 [mm]	f_u	370,326 [MPa] OK
l	1,452 [mm]		

Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes			Office: ...	Author: JOSE ANTONIO
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS	
Version: 1,000		Client: COIMBRA UNIVERSITY		

[c] C-Section Column

Effective C-Section [L] Effective C-Section [L + D]

Local Buckling Local + Distortional Buckling

EN 1993-1-5 EN 1993-1-5

C-Section Column: Mechanical Properties

Area		$A_g = A_{net}$	497,235 [mm ²]
Gravity Centre		$y_{cg} = y_{cg,net}$	16,359 [mm]
		$z_{cg} = z_{cg,net}$	43,274 [mm]
Second Moment of Area	through Gravity Centre	$I_y = I_{y,net}$	625 036,020 [mm ⁴]
		$I_z = I_{z,net}$	193 816,966 [mm ⁴]

[d] C-Section Slab

Effective C-Section [L] Effective C-Section [L + D]

Local Buckling Local + Distortional Buckling

EN 1993-1-5 EN 1993-1-5

C-Section Slab: Mechanical Properties

Area		$A_g = A_{net}$	201,315 [mm ²]
Gravity Centre		$y_{cg} = y_{cg,net}$	15,304 [mm]
		$z_{cg} = z_{cg,net}$	24,274 [mm]
Second Moment of Area	through Gravity Centre	$I_y = I_{y,net}$	85 435,209 [mm ⁴]
		$I_z = I_{z,net}$	43 399,245 [mm ⁴]

Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes			Office: ...	Author: JOSE ANTONIO
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS	
Version: 1,000		Client: COIMBRA UNIVERSITY		

[11.1] Cold-Formed Section subjected to Tension Force

[a] D-Section Purlin

Effective D-Section [L] Effective D-Section [L + D]

Local Buckling Local + Distortional Buckling

EN 1993-1-5 EN 1993-1-5

D-Section Purlin: Mechanical Properties

Area		$A_g = A_{net}$	191,199 [mm ²]
Gravity Centre		$y_{cg} = y_{cg,net}$	59,667 [mm]
		$z_{cg} = z_{cg,net}$	25,652 [mm]
Second Moment of Area	through Gravity Centre	$I_y = I_{y,net}$	85 759,975 [mm ⁴]
		$I_z = I_{z,net}$	1 789 939,335 [mm ⁴]

[b] C-Section Beam

Effective C-Section [L] Effective C-Section [L + D]

Local Buckling Local + Distortional Buckling

EN 1993-1-5 EN 1993-1-5

C-Section Beam: Mechanical Properties

Area		$A_g = A_{net}$	345,063 [mm ²]
Gravity Centre		$y_{cg} = y_{cg,net}$	14,643 [mm]
		$z_{cg} = z_{cg,net}$	59,274 [mm]
Second Moment of Area	through Gravity Centre	$I_y = I_{y,net}$	742 289,565 [mm ⁴]
		$I_z = I_{z,net}$	1 087 54,009 [mm ⁴]

Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes			Office: ...	Author: JOSE ANTONIO
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS	
Version: 1,000		Client: COIMBRA UNIVERSITY		

[11.2] Cold-Formed Section subjected to Compressive Force

[a] D-Section Purlin

Effective D-Section [L] Effective D-Section [L + D]

Local Buckling Local + Distortional Buckling

EN 1993-1-5 EN 1993-1-5

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

D-Section Classification: Class 4 → Effective width must be calculated

Effective D-Section [Weld Class] Class 4

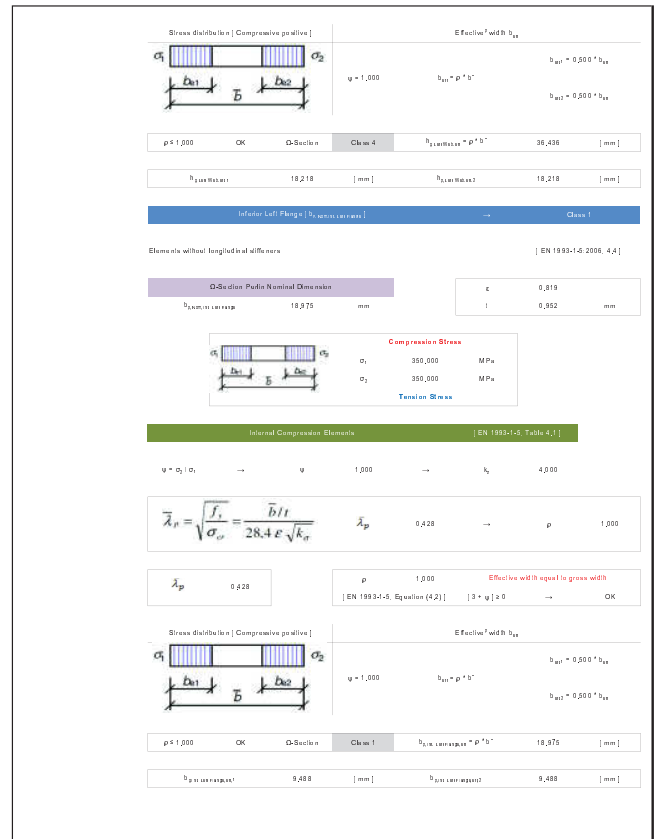
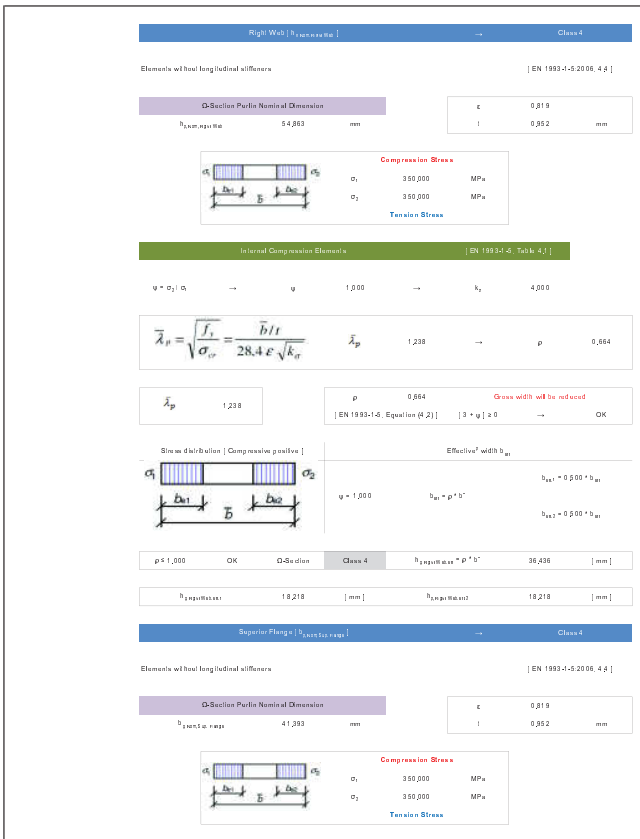
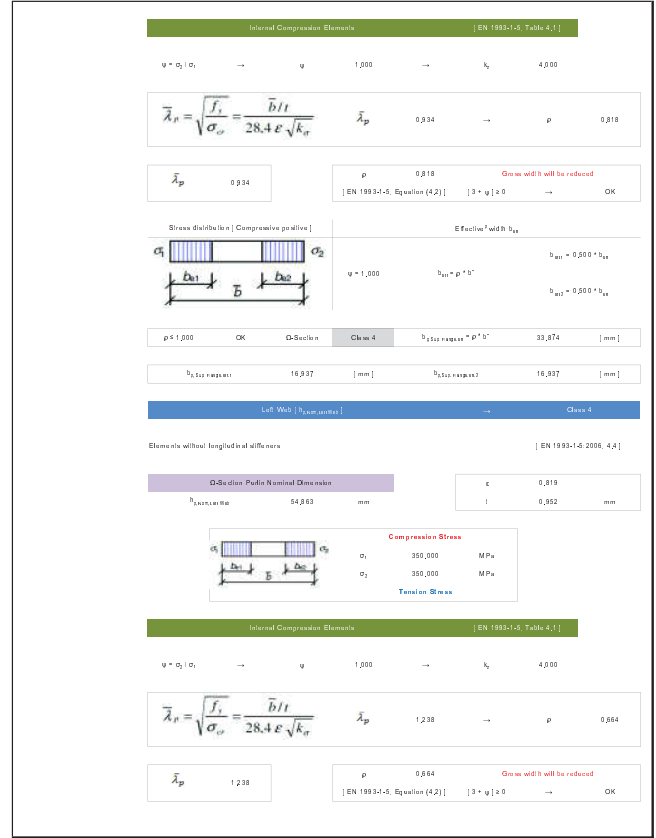
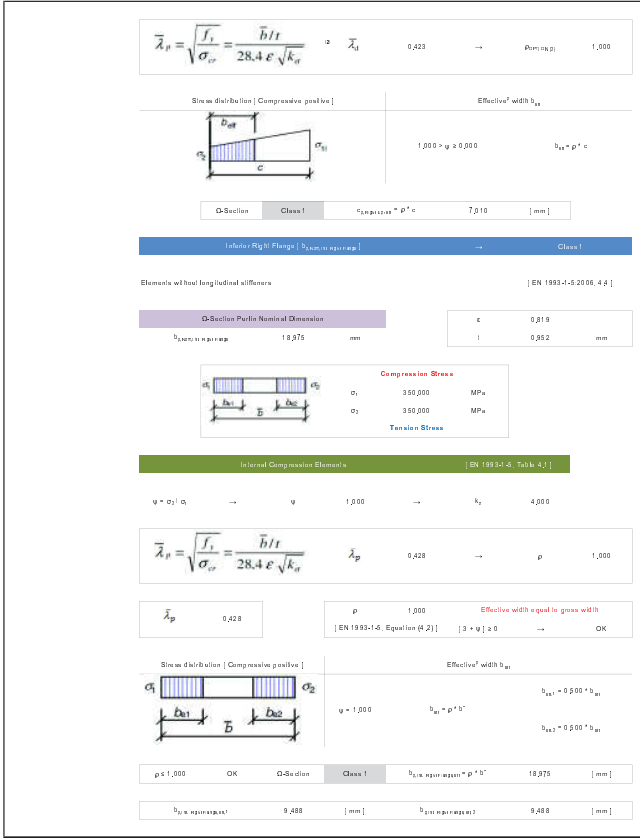
(R)gt. Edge Stiffness [EN 1993-1-3] → Class 1

OPTION [2] Elements without longitudinal stiffeners [EN 1993-1-3, 2006, 5.5.3, 206]

D-Section Purlin: Nominal Dimension		t	0,919 [mm]
$c_{max,permitted}$			7,010 [mm]
$b_{max,permitted}$			18,375 [mm]

For a single edge stiffener, Equation (B.33c)

$$b_{1,1} \cdot b_2 \cdot 0,369 \rightarrow k_2 \cdot 0,560$$



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Left Edge Stiffener [$\sigma_{y, \text{max}} = 100 \text{ MPa}$] → **Class 1**

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

D-Section Purlin Nominal Dimension

ϵ	0,919
t	0,952 mm

For a single edge stiffener, Equation (5.13c)

$b_{1,1} / b_2 \rightarrow k_2 \rightarrow 0,560$

$$\bar{\lambda}_{cr} = \sqrt{\frac{f_{cr}}{\sigma_{cr}}} = \frac{\bar{b}/t}{28,4 \epsilon \sqrt{k_2}} \Rightarrow \bar{\lambda}_{cr} \rightarrow 0,423 \rightarrow \text{Percentage: } 1,000$$

Stress distribution [Compressive positive]

Effective width b_{eff}

$1,000 > \alpha > 0,000 \rightarrow b_{eff} = \alpha \cdot c$

D-Section	Class 1	$\sigma_{y, \text{max}} \cdot \alpha \cdot c$	7,010 [mm]
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Effective D-Section Purlin [Local Buckling] [EN 1993-1-3:2006, 4.3]

Effective D-Section Purlin Widths

Right Edge Stiffener	$\sigma_{y, \text{max}} \cdot \alpha \cdot c$	7,010 [mm]
Inferior Right Flange	$b_{1, \text{max}} \cdot \alpha \cdot c$	18,975 [mm]
Right Web	$b_{1, \text{max}} \cdot \alpha \cdot c$	36,436 [mm]
Superior Flange	$b_{1, \text{max}} \cdot \alpha \cdot c$	37,874 [mm]
Left Web	$b_{1, \text{max}} \cdot \alpha \cdot c$	36,436 [mm]
Inferior Left Flange	$b_{1, \text{max}} \cdot \alpha \cdot c$	18,975 [mm]
Left Edge Stiffener	$\sigma_{y, \text{max}} \cdot \alpha \cdot c$	7,010 [mm]

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

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

A_{eff}	148,855 [mm ²]	$\sigma_{y, \text{max}} \cdot A_{eff} = F_{cr}$	1,637 [mm]
		$\sigma_{y, \text{max}} \cdot F_{cr} = F_{cr}$	0,000 [mm]

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Effective D-Section Purlin [Compression Force]

Plan elements with edge stiffeners [Distortional Buckling] [EN 1993-1-3:2006, 5.5.1(8)]

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

Effective Cross D-Section Purlin with Reduced Thickness [Local + Distortional Buckling] [EN 1993-1-3:2006, 5.5]

Effective D-Section Purlin Widths

Right Edge Stiffener	$\sigma_{y, \text{max}} \cdot \alpha \cdot c$	7,010 [mm]
Inferior Right Flange	$b_{1, \text{max}} \cdot \alpha \cdot c$	9,488 [mm]
Right Web	$b_{1, \text{max}} \cdot \alpha \cdot c$	18,218 [mm]
Superior Flange	$b_{1, \text{max}} \cdot \alpha \cdot c$	16,937 [mm]
Left Web	$b_{1, \text{max}} \cdot \alpha \cdot c$	18,218 [mm]
Inferior Left Flange	$b_{1, \text{max}} \cdot \alpha \cdot c$	9,488 [mm]
Left Edge Stiffener	$\sigma_{y, \text{max}} \cdot \alpha \cdot c$	7,010 [mm]

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C-Section Beam

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

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

Inferior Edge Stiffener [$\sigma_{y, \text{max}} = 100 \text{ MPa}$] → **Class 4**

OPTION [1] Elements without longitudinal stiffeners [EN 1993-1-3:2006, 4(1)]

Compression Stress $\sigma_{cr} = 350,000 \text{ MPa}$

Tension Stress $\sigma_{cr} = 350,000 \text{ MPa}$

Outlined Compression Elements [EN 1993-1-3, Table 4.2]

$\alpha = 0,000 \rightarrow \alpha > 0,000$

$\alpha = 0,430 \rightarrow \alpha > 0,430$

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

C-Section Beam Nominal Dimension

$b_{1, \text{max}}$	45,048 mm
$\sigma_{y, \text{max}}$	17,274 mm

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

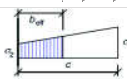
For a single edge stiffener, Equation (5.13c)

$b_{1,1} / b_2 \rightarrow k_2 \rightarrow 0,560$

ϵ	0,919	t	1,452 mm
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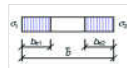
λ_{p1} 0,780 → ρ_{min} 0,973
 λ_{p2} 0,668 → $\rho_{min,max}$ 1,000
 [EN 1993-1-5, Equation (4.3)] $\rho \leq 1,000$ → OK

Stress distribution | Compressive positive | Effective width b_{eff}

 $1,000 > \psi \geq 0,500$ $b_{eff} = \rho \cdot c$
 C-Section Class 4 $c_{1,eff} = \rho \cdot c$ 17,274 [mm]

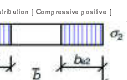
Inferior Flange | $b_{1,eff}$ | → Class 2

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

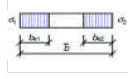
C-Section Beam Nominal Dimension
 $b_{1,net}$ 45,048 mm ϵ 0,919
 l 1,452 mm


Compression Stress
 σ_1 350,000 MPa
Tension Stress
 σ_2 350,000 MPa

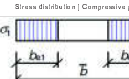
Internal Compression Elements [EN 1993-1-5, Table 4.1]
 $\psi = \sigma_1 / \sigma_2$ → ψ 1,000 → k_s 4,000
 $\lambda_{p1} = \sqrt{\frac{f_{t,c}}{\sigma_{cr}}} = \frac{\bar{b}/l}{28,4 \epsilon \sqrt{k_{cr}}}$ λ_{p2} 0,667 → ρ 1,000
 λ_{p1} 0,667 ρ 1,000 **Effective width equal to gross width**
 [EN 1993-1-5, Equation (4.2)] $|\psi + \psi| \geq 0$ → OK

Stress distribution | Compressive positive | Effective width b_{eff}

 $\psi = 1,000$ $b_{eff} = \rho \cdot b$
 $b_{1,net} = 0,500 \cdot b_{gross}$
 $b_{2,net} = 0,500 \cdot b_{gross}$
 $\rho \leq 1,000$ OK C-Section Class 2 $b_{1,net} = \rho \cdot b$ 45,048 [mm]

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Compression Stress
 σ_1 350,000 MPa
Tension Stress
 σ_2 350,000 MPa

Internal Compression Elements [EN 1993-1-5, Table 4.1]
 $\psi = \sigma_1 / \sigma_2$ → ψ 1,000 → k_s 4,000
 $\lambda_{p1} = \sqrt{\frac{f_{t,c}}{\sigma_{cr}}} = \frac{\bar{b}/l}{28,4 \epsilon \sqrt{k_{cr}}}$ λ_{p2} 0,667 → ρ 1,000
 λ_{p1} 0,667 ρ 1,000 **Effective width equal to gross width**
 [EN 1993-1-5, Equation (4.2)] $|\psi + \psi| \geq 0$ → OK

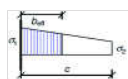
Stress distribution | Compressive positive | Effective width b_{eff}

 $\psi = 1,000$ $b_{eff} = \rho \cdot b$
 $b_{1,net} = 0,500 \cdot b_{gross}$
 $b_{2,net} = 0,500 \cdot b_{gross}$
 $\rho \leq 1,000$ OK C-Section Class 2 $b_{1,net} = \rho \cdot b$ 45,048 [mm]

$b_{1,net}$ 22,524 [mm] $b_{2,net}$ 22,524 [mm]

Superior Edge Stiffener | $b_{1,net}$ | → Class 4

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

C-Section Beam Nominal Dimension
 $b_{1,net}$ 45,048 mm ϵ 0,919
 $b_{2,net}$ 17,274 mm l 1,452 mm


Compression Stress
 σ_1 350,000 MPa
Tension Stress
 σ_2 350,000 MPa

Outstand Compression Elements [EN 1993-1-5, Table 4.2]
 $\psi = \sigma_1 / \sigma_2$ → ψ 1,000
 σ_1 Free Point → k_s 0,430


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$b_{1,net}$ 22,524 [mm] $b_{2,net}$ 22,524 [mm]

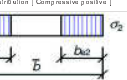
Web | $b_{1,net}$ | → Class 6

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

C-Section Beam Nominal Dimension
 $b_{1,net}$ 110,548 mm ϵ 0,919
 l 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]
 $\psi = \sigma_1 / \sigma_2$ → ψ 1,000 → k_s 4,000
 $\lambda_{p1} = \sqrt{\frac{f_{t,c}}{\sigma_{cr}}} = \frac{\bar{b}/l}{28,4 \epsilon \sqrt{k_{cr}}}$ λ_{p2} 1,754 → ρ 0,499
 λ_{p1} 1,754 ρ 0,499 **Gross width will be reduced**
 [EN 1993-1-5, Equation (4.2)] $|\psi + \psi| \geq 0$ → OK

Stress distribution | Compressive positive | Effective width b_{eff}

 $\psi = 1,000$ $b_{eff} = \rho \cdot b$
 $b_{1,net} = 0,500 \cdot b_{gross}$
 $b_{2,net} = 0,500 \cdot b_{gross}$
 $\rho \leq 1,000$ OK C-Section Class 4 $b_{1,net} = \rho \cdot b$ 59,664 [mm]

$b_{1,net}$ 29,832 [mm] $b_{2,net}$ 29,832 [mm]

Superior Flange | $b_{1,net}$ | → Class 2

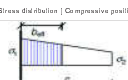
Elements with longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

C-Section Beam Nominal Dimension
 $b_{1,net}$ 45,048 mm ϵ 0,919
 l 1,452 mm

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OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 5.3.2(1)]

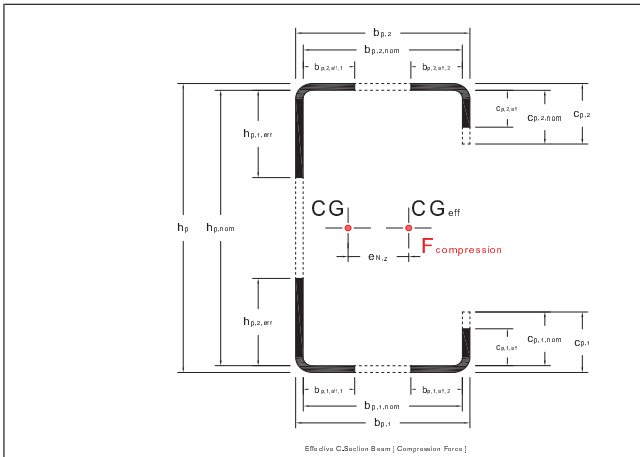
$\lambda_{p1} = \sqrt{\frac{f_{t,c}}{\sigma_{cr}}} = \frac{\bar{b}/l}{28,4 \epsilon \sqrt{k_{cr}}}$ For a single edge stiffener, Equation (5.23):
 $b_{1,1} / b_1$ 0,383 → k_s 0,586
 λ_{p1} 0,780 → $\rho_{min,max}$ 0,973
 λ_{p2} 0,668 → $\rho_{min,max}$ 1,000
 [EN 1993-1-5, Equation (6.2)] $\rho \leq 1,000$ → OK

Stress distribution | Compressive positive | Effective width b_{eff}

 $1,000 > \psi \geq 0,500$ $b_{eff} = \rho \cdot c$
 C-Section Class 4 $c_{1,eff} = \rho \cdot c$ 17,274 [mm]

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

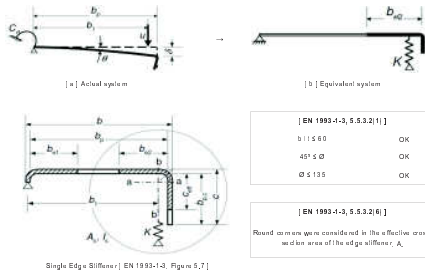
Effective C-Section Beam Widths

Inferior Edge Stiffener	$b_{1,net}$	17,274 [mm]
Inferior Flange	$b_{1,net}$	45,048 [mm]
Web	$b_{1,net}$	59,664 [mm]
Superior Flange	$b_{2,net}$	45,048 [mm]
Superior Edge Stiffener	$b_{2,net}$	17,274 [mm]



[III] Plane elements with edge stiffeners | Distortional Buckling | [EN 1993-1-3:2006, 5.5.3(5)]

Plane elements with edge stiffeners | [EN 1993-1-3:2006, 5.5.3(2)]



Determination of Elastic Critical Buckling Stress [F_cr] | [EN 1993-1-3:2006, 5.5.3(7)]

$$\sigma_{cr,el} = \frac{2 \sqrt{K E I_x}}{\lambda_{eff}} \quad [EN 1993-1-3, Equation 5.7(5)]$$

K	0,333
E	210,000 [GPa]
I_x,steel	1926,895 [mm ⁴]
I_x,concr	1926,895 [mm ⁴]
A_e1	58,518 [mm ²]
A_e2	58,518 [mm ²]

Elastic Critical Buckling Stress, sigma_cr,el for edge stiffener 1 | 501,892 [MPa]
 Elastic Critical Buckling Stress, sigma_cr,el for edge stiffener 2 | 501,892 [MPa]

Relative Distortional Slenderness | lambda_d | [EN 1993-1-3:2006, 5.5.3(7)]

$$\lambda_d = \sqrt{f_y b / \sigma_{cr,el}} \quad [EN 1993-1-3, Equation 5.7(2)]$$

f_y	350,000 [MPa]
Edge Stiffener 1 | lambda_d	0,835
Edge Stiffener 2 | lambda_d	0,835

Reduction X_d Distortional Buckling Resistance | Stiffener Flexural Buckling | [EN 1993-1-3:2006, 5.5.3(7)]

Edge Stiffener 1 | lambda_d | 0,835 | X_d,steel | 0,866 | [EN 1993-1-3, Equation 5.7(2)]
 Edge Stiffener 2 | lambda_d | 0,835 | X_d,concr | 0,866 | [EN 1993-1-3, Equation 5.7(2)]

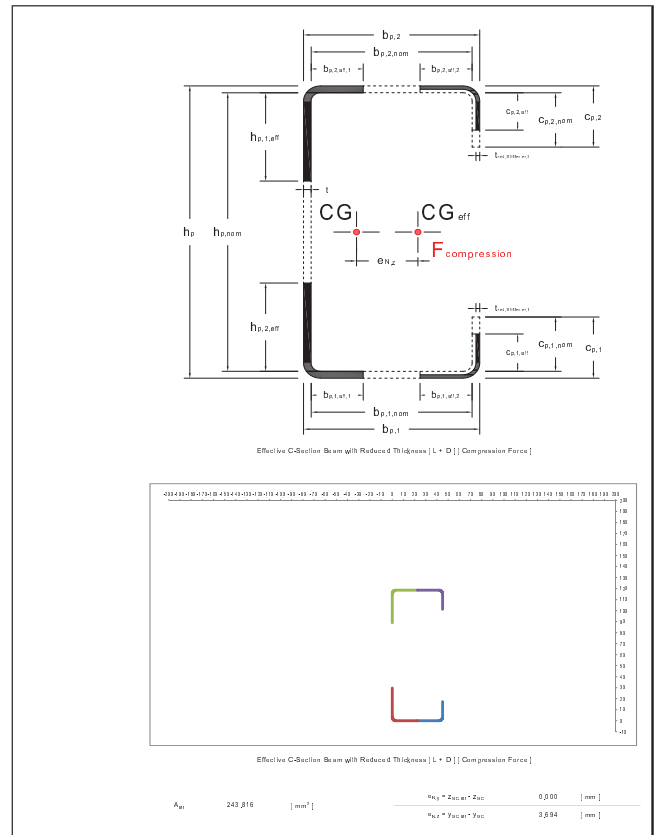
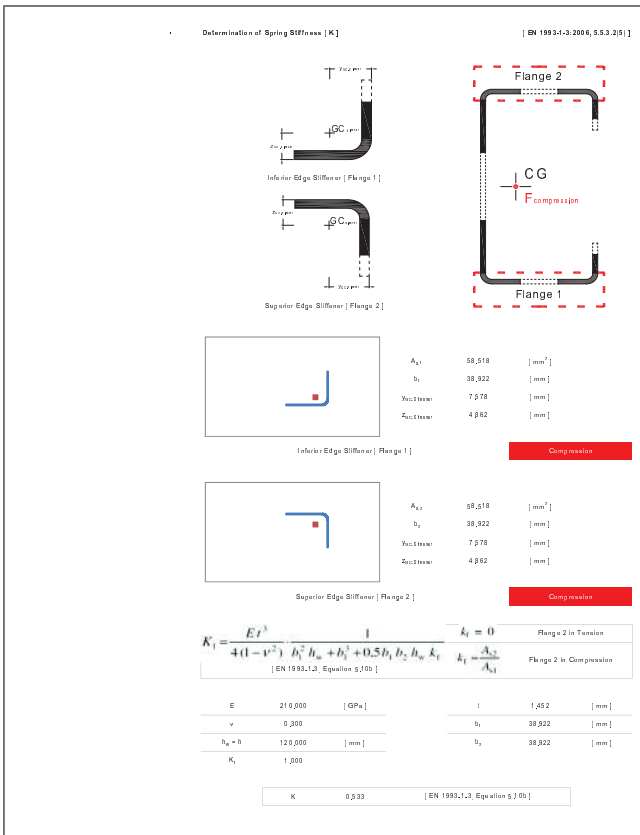
Edge Stiffener Reduced Thickness | [EN 1993-1-3:2006, 5.5.3(12)]

In effective cross-sections, reduced effective area is represented using a reduced thickness for all elements in A_e

Edge Stiffener 1	Edge Stiffener 2
t_eff,steel	t_eff,concr
1,258 [mm]	1,258 [mm]

[IV] Effective C-Section Beam with Reduced Thickness | Local + Distortional Buckling | [EN 1993-1-3:2006, 5.5]

Effective C-Section Beam Widths	
Inferior Edge Stiffener	t_eff,steel | 17,274 [mm]
Inferior Flange	t_eff,steel | 22,524 [mm]
Web	t_eff,steel | 29,552 [mm]
	t_eff,concr | 29,552 [mm]
Superior Flange	t_eff,steel 22,524 [mm]
	t_eff,concr 22,524 [mm]
Superior Edge Stiffener	t_eff,steel 17,274 [mm]



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[c] C-Section Columns

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

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

Inflator Edge Stiffener [s_{1,inst}] → **Class 1**

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

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

$\psi = \sigma_1 / \sigma_2$ → $\psi = 1,000$
Free Point → $k = 0,490$

C-Section Column Nominal Dimension

$b_{1,inst} = 44,048$ mm
 $b_{2,inst} = 16,274$ mm

OPTION [2] Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.2.2(5)]

For a single edge stiffener, Equation (5.13c)

$b_{1,1} / b_2 = 0,381$ → $k = 0,582$

$\epsilon = 0,919$ $l = 2,452$ mm

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$b_{1,inst} = 22,024$ [mm] $b_{2,inst} = 22,024$ [mm]

Web [s_{1,inst}] → **Class 4**

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

C-Section Column Nominal Dimension

$b_{1,inst} = 87,648$ mm $\epsilon = 0,919$
 $l = 2,452$ mm

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

$\psi = \sigma_1 / \sigma_2$ → $\psi = 1,000$ → $k = 4,000$

$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/l}{28,4 \epsilon \sqrt{k_{cr}}}$ $\bar{\lambda}_p = 0,767$ → $\rho = 0,930$

$\bar{\lambda}_p = 0,767$ $\rho = 0,930$ → **Effective width will be reduced**
[EN 1993-1-5, Equation (4.2)] | $3 < \psi < 6$ → OK

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

$b_{eff} = 0,900 \cdot b_{1,inst}$
 $b_{eff} = 0,500 \cdot b_{2,inst}$

$\psi = 1,000$ $b_{eff} = \rho \cdot b$

$\rho \leq 1,000$ OK C-Section **Class 4** $b_{1,inst} = \rho \cdot b$ $81,384$ [mm]

$b_{1,inst} = 40,697$ [mm] $b_{2,inst} = 40,697$ [mm]

Superior Flange [s_{1,inst}] → **Class 1**

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

C-Section Column Nominal Dimension

$b_{1,inst} = 44,048$ mm $\epsilon = 0,919$
 $l = 2,452$ mm

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$\bar{\lambda}_p = 0,448$ → $\rho = 1,000$
 $\bar{\lambda}_p = 0,385$ → $\rho = 1,000$

[EN 1993-1-5, Equation (4.3)] | $\rho \leq 1,000$ → OK

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

$1,000 > \psi > 0,500$ $b_{eff} = \rho \cdot c$

C-Section **Class 1** $b_{1,inst} = \rho \cdot c$ $16,274$ [mm]

Inflator Flange [s_{1,inst}] → **Class 1**

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

C-Section Column Nominal Dimension

$b_{1,inst} = 44,048$ mm $\epsilon = 0,919$
 $l = 2,452$ mm

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

$\psi = \sigma_1 / \sigma_2$ → $\psi = 1,000$ → $k = 4,000$

$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/l}{28,4 \epsilon \sqrt{k_{cr}}}$ $\bar{\lambda}_p = 0,386$ → $\rho = 1,000$

$\bar{\lambda}_p = 0,386$ $\rho = 1,000$ → **Effective width equal to gross width**
[EN 1993-1-5, Equation (4.2)] | $3 < \psi < 6$ → OK

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

$b_{eff} = 0,900 \cdot b_{1,inst}$
 $b_{eff} = 0,500 \cdot b_{2,inst}$

$\psi = 1,000$ $b_{eff} = \rho \cdot b$

$\rho \leq 1,000$ OK C-Section **Class 1** $b_{1,inst} = \rho \cdot b$ $44,048$ [mm]

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

$\psi = \sigma_1 / \sigma_2$ → $\psi = 1,000$ → $k = 4,000$

$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{b}/l}{28,4 \epsilon \sqrt{k_{cr}}}$ $\bar{\lambda}_p = 0,386$ → $\rho = 1,000$

$\bar{\lambda}_p = 0,386$ $\rho = 1,000$ → **Effective width equal to gross width**
[EN 1993-1-5, Equation (4.2)] | $3 < \psi < 6$ → OK

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

$b_{eff} = 0,900 \cdot b_{1,inst}$
 $b_{eff} = 0,500 \cdot b_{2,inst}$

$\psi = 1,000$ $b_{eff} = \rho \cdot b$

$\rho \leq 1,000$ OK C-Section **Class 1** $b_{1,inst} = \rho \cdot b$ $44,048$ [mm]

$b_{1,inst} = 22,024$ [mm] $b_{2,inst} = 22,024$ [mm]

Superior Edge Stiffener [s_{1,inst}] → **Class 1**

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

C-Section Column Nominal Dimension

$b_{1,inst} = 44,048$ mm $\epsilon = 0,919$
 $b_{2,inst} = 16,274$ mm

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

$\psi = \sigma_1 / \sigma_2$ → $\psi = 1,000$
Free Point → $k = 0,490$

OPTION 2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.2(5)]

$$\lambda_{pl} = \sqrt{\frac{f_{yk}}{\sigma_{yk}}} = \frac{b/t}{2\sqrt{4\epsilon f_{yk}}}$$

For a single edge stiffener, Equation (5.33c)

$b_{1,1} / b_1$	0,381	k_1	0,682
$b_{1,2} / b_2$	0,448	k_2	1,000
$b_{1,3} / b_3$	0,385	k_3	1,000

[EN 1993-1-3: Equation (5.31)] $\rho \leq 1,000$ → OK

Stress distribution [Compressive positive]

Effective width b_{eff}

$1,000 > \rho \geq 0,900$ $b_{eff} = \rho \cdot c$

C-Section Class 1 $c_{y,1st} \leq \rho \cdot c$ 16,774 [mm]

Effective C-Section Column [Local Buckling] [EN 1993-1-3:2006, 4.3]

Effective C-Section Column Widths		
Inferior Edge Stiffener	$b_{1,1st}$	16,774 [mm]
Inferior Flange	$b_{1,1st}$	44,048 [mm]
Web	$b_{1,1st}$	81,394 [mm]
Superior Flange	$b_{1,1st}$	44,048 [mm]
Superior Edge Stiffener	$b_{1,1st}$	16,774 [mm]

Determination of Spring Stiffness [K] [EN 1993-1-3:2006, 5.5.3.2(9)]

Inferior Edge Stiffener [Flange 1]

Superior Edge Stiffener [Flange 2]

Flange 2

CG

F compression

Flange 1

A_{y1}	96,559	[mm ²]
b_1	38,465	[mm]
$y_{cg,1st}$	8,035	[mm]
$y_{cg,1st}$	5,204	[mm]

Inferior Edge Stiffener [Flange 1] **Compression**

A_{y2}	96,559	[mm ²]
b_2	38,465	[mm]
$y_{cg,2nd}$	8,035	[mm]
$y_{cg,2nd}$	5,204	[mm]

Superior Edge Stiffener [Flange 2] **Compression**

$$K_1 = \frac{E I^3}{4(1-\nu^2) b_1^2 h_w + b_2^2 + 0,5 b_1 b_2 h_w k_f} \quad k_f = \frac{A_{y2}}{A_{y1}}$$

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

E	210,000	[GPa]	I	2,452	[mm ⁴]
ν	0,300		b_1	38,465	[mm]
$h_w = h$	98,000	[mm]	b_2	38,465	[mm]
K_1	1,000				

K 3,314 [EN 1993-1-3, Equation 5.10b]

Effective C-Section Column [Compression Force]

Plates elements with edge stiffeners [Distortional Buckling] [EN 1993-1-3:2006, 5.5.1(8)]

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

Actual system **Equivalent system**

[EN 1993-1-3, 5.5.2(1)]

- $b_1 \leq 60$ OK
- $45 \leq \phi$ OK
- $\phi \leq 135$ OK

[EN 1993-1-3, 5.5.2(6)]

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

Determination of Elastic Critical Buckling Stress [F_{cr,1}] [EN 1993-1-3:2006, 5.5.3.2(7)]

$$\sigma_{cr,1} = 2 \sqrt{K E I_x}$$

[EN 1993-1-3, Equation 5.15]

K	3,314
E	210,000 [GPa]
$I_{x,1st}$	3057,398 [mm ⁴]
$I_{x,2nd}$	3057,398 [mm ⁴]
A_{y1}	96,559 [mm ²]
A_{y2}	96,559 [mm ²]

Elastic Critical Buckling Stress $\sigma_{cr,1}$ for edge stiffener 1 955,520 [MPa]

Elastic Critical Buckling Stress $\sigma_{cr,2}$ for edge stiffener 2 955,520 [MPa]

Relative Distortional Slenderness [λ_d] [EN 1993-1-3:2006, 5.5.3.1(7)]

$$\lambda_{d1} = \sqrt{f_{yk} / \sigma_{cr,1}}$$

[EN 1993-1-3, Equation 5.20a]

f_{yk}	350,000 [MPa]
Edge Stiffener 1	λ_{d1} 0,605
Edge Stiffener 2	λ_{d2} 0,605

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

Edge Stiffener 1	λ_{d1} 0,605	$X_{d,1st}$	1,000	[EN 1993-1-3, Equation 5.22a]
Edge Stiffener 2	λ_{d2} 0,605	$X_{d,2nd}$	1,000	[EN 1993-1-3, Equation 5.22a]

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

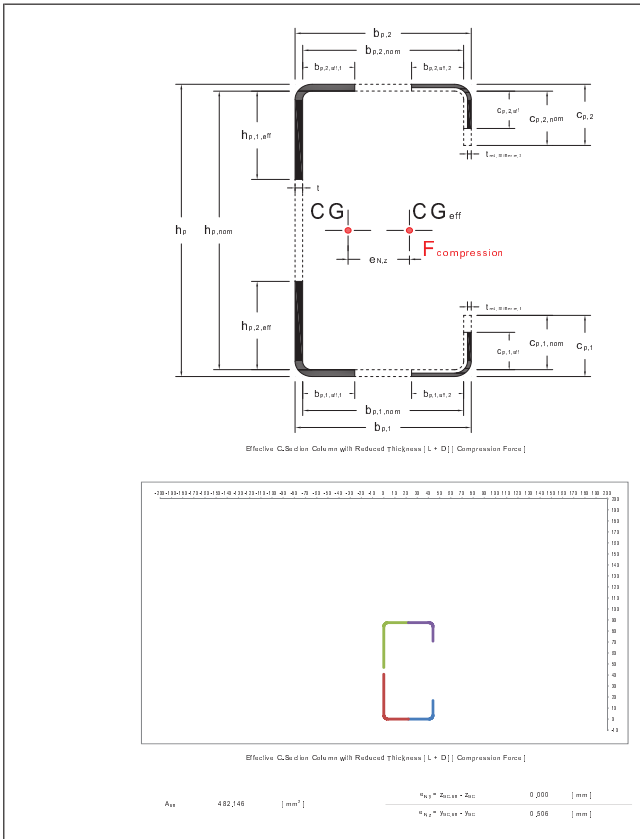
In effective section properties, reduced effective area is represented using a reduced thickness for all elements in A_y

Edge Stiffener 1	Edge Stiffener 2
$t_{red,1st}$ 2,452 [mm]	$t_{red,2nd}$ 2,452 [mm]

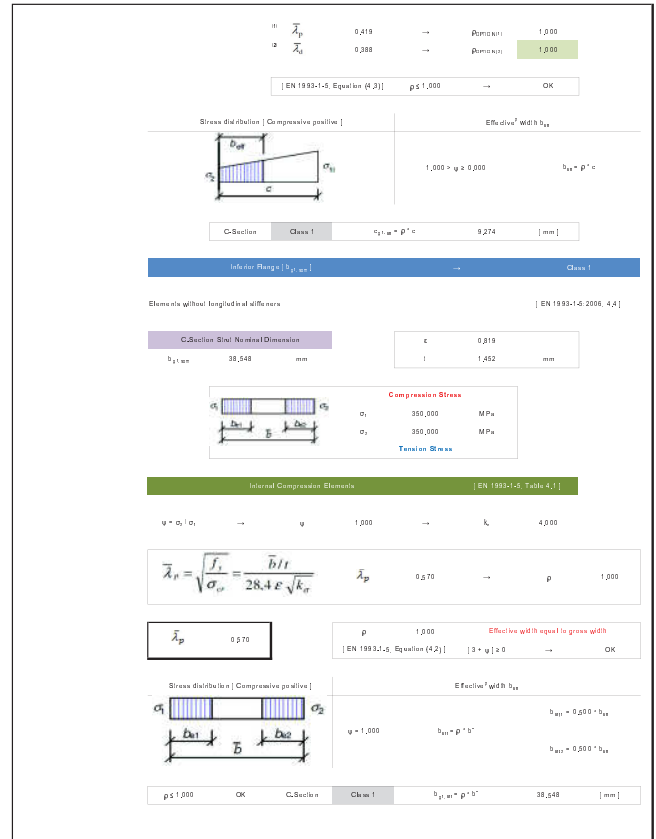
Effective C-Section Column with Reduced Thickness [Local + Distortional Buckling] [EN 1993-1-3:2006, 5.6]

Effective C-Section Column Widths		
Inferior Edge Stiffener	$b_{1,1st}$	16,774 [mm]
Inferior Flange	$b_{1,1st}$	22,024 [mm]
Web	$b_{1,1st}$	22,024 [mm]
Superior Flange	$b_{1,1st}$	22,024 [mm]
Superior Edge Stiffener	$b_{1,1st}$	16,774 [mm]

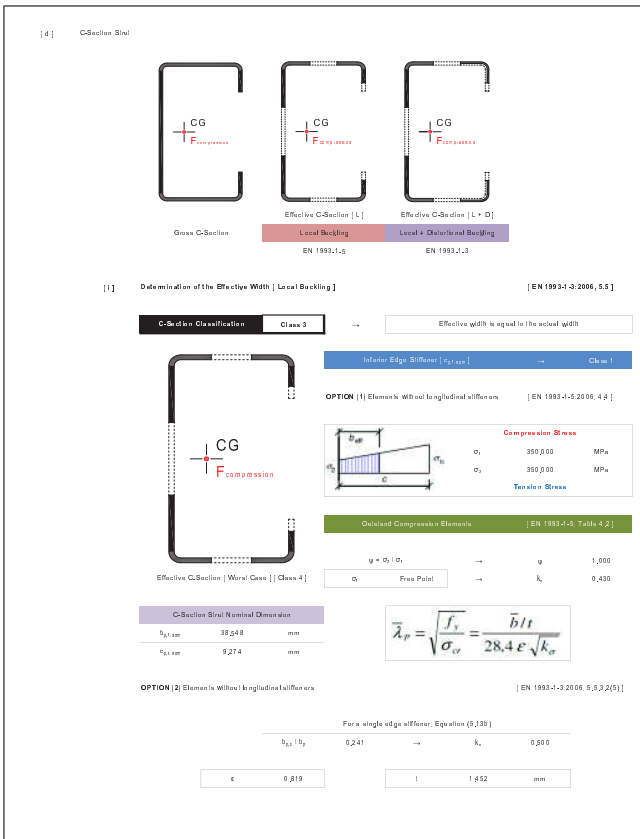
Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes		Office: ---	Author: JOSE ANTÓNIO
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1,000		Client: COIMBRA UNIVERSITY	



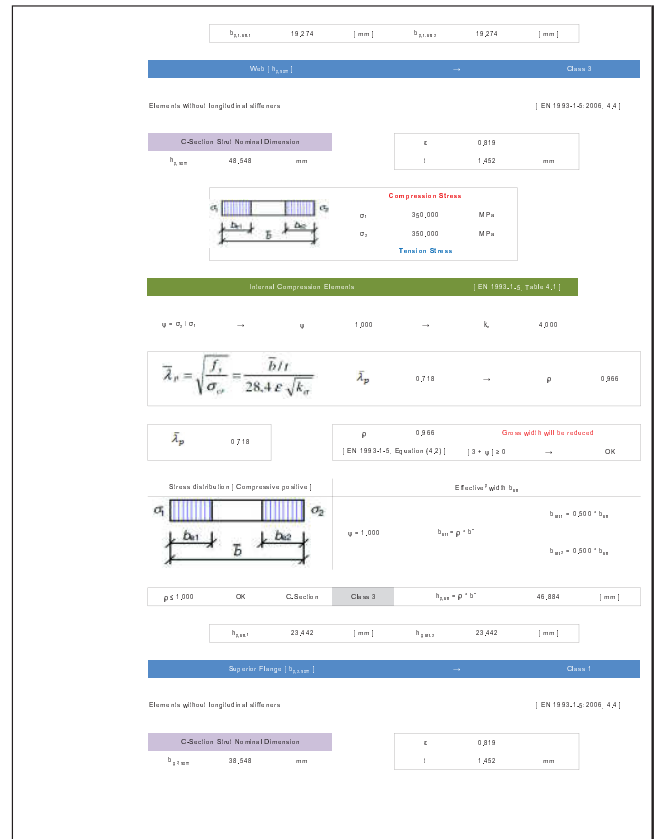
Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes		Office: ---	Author: JOSE ANTÓNIO
Code: Eurocode	Reference: EN 1990 EN 1991 EN 1993	Date: 05/09/2019	Project: MASTER THESIS
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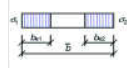
Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes		Office: ---	Author: JOSE ANTÓNIO
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1,000		Client: COIMBRA UNIVERSITY	



Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes		Office: ---	Author: JOSE ANTÓNIO
Code: Eurocode	Reference: EN 1990 EN 1991 EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1,000		Client: COIMBRA UNIVERSITY	



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Code: Eurocode	References: EN 1990 EN 1991 EN 1993	Date: 05/09/2019	Project: MASTER THESIS
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Compression Stress
 $\sigma_1 = 350,000 \text{ MPa}$
 $\sigma_2 = 350,000 \text{ MPa}$

Tension Stress

Internal Compression Elements [EN 1993-1-5, Table 4.3]

$\psi = \sigma_1 / \sigma_2 \rightarrow \psi = 1,000 \rightarrow k_1 = 4,000$

$$\bar{\lambda}_{pl} = \sqrt{\frac{f_{yk}}{\sigma_{cr}}} = \frac{h/t}{28,4 \varepsilon \sqrt{k_{pl}}}$$

$\bar{\lambda}_{pl} = 0,570 \rightarrow \rho = 1,000$

Effective width equal to gross width
 [EN 1993-1-5, Equation (6.2)] | $3 + \psi \geq 0 \rightarrow$ OK

Stress distribution | Compressive positive | Effective width b_{eff}

$\psi = 1,000 \rightarrow b_{eff} = \rho \cdot b^*$

$\rho \leq 1,000$ OK C-Section Class 1 $b_{eff} = \rho \cdot b^* = 38,248 \text{ [mm]}$

$b_{1,net} = 19,274 \text{ [mm]}$ $b_{1,gr} = 19,274 \text{ [mm]}$

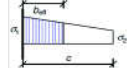
Superior Edge Stiffener | $\psi_{1,net} \rightarrow$ Class 1

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

C-Section Nominal Dimension

$b_{1,net} = 38,248 \text{ mm}$ $t = 1,452 \text{ mm}$

$c_{1,net} = 9,274 \text{ mm}$



Compression Stress
 $\sigma_1 = 350,000 \text{ MPa}$
 $\sigma_2 = 350,000 \text{ MPa}$

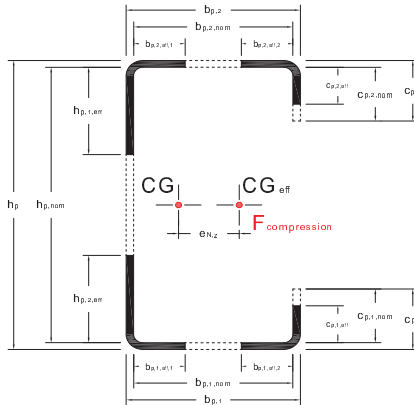
Tension Stress

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

$\psi = \sigma_1 / \sigma_2 \rightarrow \psi = 1,000$

$\alpha =$ Free Point $\rightarrow k_1 = 0,430$

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Effective C-Section Steel | Compression Force

CG CG_{eff}

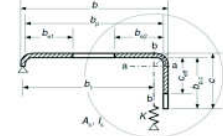
$\theta_{N,z}$ $F_{compression}$

Plane elements with edge stiffeners | Diagonal Buckling [EN 1993-1-3:2006, 5.5.3(5)]

Plane elements with edge stiffeners [EN 1993-1-3:2006, 5.5.3(2)]



[a] Active system [b] Equivalent system



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

[EN 1993-1-3, 5.5.3(1)]
 $b \leq 1,5 \lambda_0$ OK
 $45^\circ \leq \theta$ OK
 $\theta \leq 1,35$ OK

[EN 1993-1-3, 5.5.3(6)]
 Round corners were considered in the effective cross-section area of the edge stiffener, A_{st} .

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OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.2(5)]

$$\bar{\lambda}_{pl} = \sqrt{\frac{f_{yk}}{\sigma_{cr}}} = \frac{h/t}{28,4 \varepsilon \sqrt{k_{pl}}}$$

For a single edge stiffener, Equation (5.19)

$\eta_{1,1} \cdot \eta_2 = 0,241 \rightarrow k_1 = 0,500$

$\eta_2 = 0,419 \rightarrow \rho_{compression} = 1,000$

$\eta_1 = 0,388 \rightarrow \rho_{compression} = 1,000$

[EN 1993-1-3, Equation (4.3)] | $\rho \leq 1,000 \rightarrow$ OK

Stress distribution | Compressive positive | Effective width b_{eff}

$1,000 > \psi \geq 0,500 \rightarrow b_{eff} = \rho \cdot c$

C-Section Class 1 $c_{1,net} = \rho \cdot c = 9,274 \text{ [mm]}$

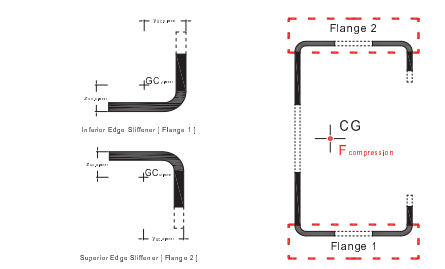
Effective C-Section Steel | Local Buckling [EN 1993-1-5:2006, 4.3]

Effective C-Section Steel Widths

Inferior Edge Stiffener	$c_{1,net}$	9,274	[mm]
Inferior Flange	$b_{1,net}$	38,248	[mm]
Web	$b_{2,net}$	48,884	[mm]
Superior Flange	$b_{3,net}$	38,248	[mm]
Superior Edge Stiffener	$c_{1,net}$	9,274	[mm]

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Determination of Spring Stiffness [K] [EN 1993-1-3:2006, 5.5.3(5)]



Inferior Edge Stiffener | Flange 1

Superior Edge Stiffener | Flange 2

Flange 2

CG

$F_{compression}$

Flange 1

A_{st1}	42,183	[mm ²]
b_1	32,213	[mm]
$\gamma_{red,flange}$	7,787	[mm]
$\gamma_{red,stiffener}$	2,548	[mm]

Inferior Edge Stiffener | Flange 1

Compressor

A_{st2}	42,183	[mm ²]
b_2	32,213	[mm]
$\gamma_{red,flange}$	7,787	[mm]
$\gamma_{red,stiffener}$	2,548	[mm]

Superior Edge Stiffener | Flange 2

Compressor

$$K_{fl} = \frac{E t^3}{4(1-\nu^2)} \left(\frac{b_1^3 h_{fl} + b_2^3 h_{fl}}{b_1^3 h_{fl} + b_2^3 h_{fl}} + 0,5 b_1 b_2 h_{fl} k_{fl} \right) \quad k_{fl} = 0 \quad \text{Flange 2 in Tension}$$

$$k_{fl} = \frac{A_{st2}}{A_{st1}} \quad \text{Flange 2 in Compression}$$

E	210,000	[GPa]	t	1,452	[mm]
ν	0,300		b_1	32,213	[mm]
$b_2 = h$	50,000	[mm]	b_2	32,213	[mm]
K_1	1,000				

K = 1,588 [EN 1993-1-3, Equation 5.10]

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

$$\sigma_{cr,Ed} = \frac{2 \sqrt{K E I_x}}{A_s}$$

[EN 1993-1-3, Equation 5.16]

K	1,988
E	210,000 [GPa]
$I_{x,stream}$	377,466 [mm ⁴]
$I_{x,trans}$	377,466 [mm ⁴]
A_{s1}	42,193 [mm ²]
A_{s2}	42,193 [mm ²]

Elastic Critical Buckling Stress, $\sigma_{cr,Ed}$, for edge stiffener 1: 531,888 [MPa]
Elastic Critical Buckling Stress, $\sigma_{cr,Ed}$, for edge stiffener 2: 531,888 [MPa]

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

$$\bar{\lambda}_d = \sqrt{f_y b / \sigma_{cr,Ed}}$$

[EN 1993-1-3, Equation 5.22]

f_y	360,000 [MPa]
Edge Stiffener 1	$\bar{\lambda}_d$: 0,811
Edge Stiffener 2	$\bar{\lambda}_d$: 0,811

Reduction χ_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	$\chi_{d,stream}$: 0,883	[EN 1993-1-3, Equation 5.12b]
Edge Stiffener 2	$\bar{\lambda}_d$: 0,811	$\chi_{d,trans}$: 0,883	[EN 1993-1-3, Equation 5.12b]

Edge Stiffener Reduced Thickness [EN 1993-1-3:2006, 5.5.3.2(2)]

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
$t_{red,stream}$: 1,283 [mm]	$t_{red,trans}$: 1,283 [mm]

[iv] Effective C-Section Stud with Reduced Thickness [Local + Distortional Buckling] [EN 1993-1-6:2006, 5.5]

Effective C-Section Stud Widths	
Inferior Edge Stiffener	$s_{1,red}$: 9,274 [mm]
Inferior Flange	$s_{2,red}$: 19,274 [mm]
Web	$s_{3,red}$: 23,442 [mm]
Superior Flange	$s_{4,red}$: 19,274 [mm]
Superior Edge Stiffener	$s_{5,red}$: 9,274 [mm]

[11.3] Cold-Formed Section subjected to Positive Moment in y-z axis [$M_{y,Ed}$]

[*] D-Section Profile

Effective D-Section [L] Local Buckling EN 1993-1-6
Effective D-Section [L + D] Local + Distortional Buckling EN 1993-1-3

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

D-Section Classification: **Class 4** → Effective width must be calculated

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

Right Edge Stiffener [$s_{1,red,eff}$] → Tension

NOTE Effective width is equal to the real width

Inferior Right Flange [$s_{2,red,eff}$] → Tension

NOTE Effective width is equal to the real width

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

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

A_{s1}	189,208 [mm ²]	$s_{y1}^* A_{s1,red}^* A_{s1}$	0,000 [mm]
		$s_{y2}^* A_{s2,red}^* A_{s2}$	-5,811 [mm]

Right Web [$s_{3,red,eff}$] → **Class 1**

Elements without longitudinal stiffeners [EN 1993-1-6:2006, 4.4]

D-Section Profile Nominal Dimension

$s_{3,nom,web}$	54,863 [mm]
-----------------	---------------

ϵ : 0,819
 t : 0,952 [mm]

Compression Stress

σ_1	380,000 [MPa]
σ_2	-350,000 [MPa]

Internal Compression Elements [EN 1993-1-6, Table 4.1]

$\psi = \sigma_1 / \sigma_2$ → ψ : -1,000 → s_y : 23,500

$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{b \cdot t}{28,4 \cdot E \cdot \sqrt{k_{cr}}}$ $\bar{\lambda}_p$: 0,507 → ρ : 1,000

$\bar{\lambda}_p$: 0,507
 ρ : 1,000 → Effective width equal to gross width [EN 1993-1-6, Equation (4.2)] [$3 \cdot \psi \geq 0$] → OK

Stress Distribution [Compression positive]

Effective width $s_{y,eff}$

$s_{y,eff}^* \rho^* s_{y,nom}^* \rho^{1,5} \cdot [1 - \psi]$	$s_{y,eff}$: 0,600 * $s_{y,nom}$
$s_{y,eff}^* \rho^* s_{y,nom}^* \rho^{1,5} \cdot [1 - \psi]$	$s_{y,eff}$: 0,600 * $s_{y,nom}$

$\rho \leq 1,000$ OK $s_{y,red,web}^* \rho^* s_{y,nom}^* \rho^{1,5} \cdot [1 - \psi]$ 27,492 [mm]

$\rho \leq 1,000$ OK $s_{y,red,web}^* \rho^* s_{y,nom}^* \rho^{1,5} \cdot [1 - \psi]$ 27,492 [mm]

$s_{3,red,web}$: 19,973 [mm] $s_{3,red,web,eff}$: 16,459 [mm]

Superior Flange [$s_{4,red,eff}$] → **Class 4**

Elements without longitudinal stiffeners [EN 1993-1-6:2006, 4.4]

D-Section Profile Nominal Dimension

$s_{4,nom,flange}$	41,993 [mm]
--------------------	---------------

ϵ : 0,819
 t : 0,952 [mm]

Compression Stress
 $\sigma_1 = 350,000$ MPa
Tension Stress
 $\sigma_2 = 350,000$ MPa

Internal Compression Elements [EN 1993-1-5, Table 4.3.1]
 $\psi = \sigma_1 / \sigma_c \rightarrow \psi = 1,000 \rightarrow k_y = 4,000$

$$\bar{\lambda}_p = \sqrt{\frac{f_{y,Ed}}{\sigma_{cr}}} = \frac{\bar{h}/t}{28,4 \cdot \epsilon \cdot \sqrt{k_{y,Ed}}}$$

$\bar{\lambda}_p = 0,934$ → $\rho = 0,818$

Effective width will be reduced [EN 1993-1-5, Equation (8.2)] | $3 \cdot \psi \geq 0 \rightarrow$ OK

Stress distribution | Compression positive | Effective width b_{eff}
 $\psi < 0,500$ $b_{eff} = \rho \cdot b^*$ $b_{y1} = 0,500 \cdot b_{y1}$
 $b_{y2} = 0,500 \cdot b_{y2}$

$\rho \leq 1,000$ OK	Q-Section	Class 4	$b_{y1,eff} = \rho \cdot b^*$	33,874	[mm]
			$b_{y2,eff} = \rho \cdot b^*$	16,937	[mm]

Left Web | $b_{y,web,eff}$ | --- | Class 1

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

Q-Section Purlin Nominal Dimension
 $b_{nominal,max}$ 54,863 mm
 $\epsilon = 0,819$
 $t = 0,952$ mm

Compression Stress
 $\sigma_1 = 350,000$ MPa
Tension Stress
 $\sigma_2 = -350,000$ MPa

Internal Compression Elements [EN 1993-1-5, Table 4.3.1]
 $\psi = \sigma_1 / \sigma_c \rightarrow \psi = -0,500 \rightarrow k_y = 23,900$

Effective Q-Section Purlin | Positive Moment in y-y axis, $M_{y,Ed}$ |

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

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

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

Effective Q-Section Purlin Widths			
Right Edge Stiffener	$b_{y,edge,eff}$	---	[mm]
Inferior Right Flange	$b_{y,inf,flange,eff}$	---	[mm]
Right Web	$b_{y,web,eff}$	10,973	[mm]
Superior Flange	$b_{y,sup,flange,eff}$	16,937	[mm]
Left Web	$b_{y,web,eff}$	10,973	[mm]
Inferior Left Flange	$b_{y,inf,flange,eff}$	---	[mm]
Left Edge Stiffener	$b_{y,edge,eff}$	---	[mm]

$$\bar{\lambda}_p = \sqrt{\frac{f_{y,Ed}}{\sigma_{cr}}} = \frac{\bar{h}/t}{28,4 \cdot \epsilon \cdot \sqrt{k_{y,Ed}}}$$

$\bar{\lambda}_p = 0,907$ → $\rho = 1,000$

Effective width equal to gross width [EN 1993-1-5, Equation (8.2)] | $3 \cdot \psi \geq 0 \rightarrow$ OK

Stress distribution | Compression positive | Effective width b_{eff}
 $\psi < 0,500$ $b_{eff} = \rho \cdot b^* \cdot \rho^{1-\psi} \cdot [1 - \psi]$ $b_{y1} = 0,500 \cdot b_{y1}$
 $b_{y2} = 0,500 \cdot b_{y2}$

$\rho \leq 1,000$ OK		$b_{y1,eff} = \rho \cdot b^* \cdot \rho^{1-\psi} \cdot [1 - \psi]$	27,432	[mm]
$\rho \leq 1,000$ OK		$b_{y2,eff} = \rho \cdot b^* \cdot \rho^{1-\psi} \cdot [1 - \psi]$	27,432	[mm]
		$b_{y,web,eff}$	10,973	[mm]
		$b_{y,sup,flange,eff}$	16,959	[mm]

Inferior Left Flange | $b_{y,inf,flange,eff}$ | --- | Tension

NOTE: Effective width is equal to the real width.

Left Edge Stiffener | $b_{y,edge,eff}$ | --- | Tension

NOTE: Effective width is equal to the real width.

Effective Q-Section Purlin | Local Buckling [EN 1993-1-5:2006, 4.3]

Effective Q-Section Purlin Widths			
Right Edge Stiffener	$b_{y,edge,eff}$	---	[mm]
Inferior Right Flange	$b_{y,inf,flange,eff}$	---	[mm]
Right Web	$b_{y,web,eff}$	27,432	[mm]
Superior Flange	$b_{y,sup,flange,eff}$	33,874	[mm]
Left Web	$b_{y,web,eff}$	27,432	[mm]
Inferior Left Flange	$b_{y,inf,flange,eff}$	---	[mm]
Left Edge Stiffener	$b_{y,edge,eff}$	---	[mm]

Effective Q-Section Purlin with Reduced Thickness | $L < D$ | Positive Moment in y-y axis, $M_{y,Ed}$ |

Effective Q-Section Purlin with Reduced Thickness | $L < D$ | Compression Force |

$I_{y,eff}^{(1)}$ 79892,362 [mm⁴]

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[0] 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

[1] 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

Web | $b_{w,eff}$ | **Class 3**

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.6]

C-Section Beam Nominal Dimension

ϵ	0,919
t	1,952 mm

$b_{w,net}$ 110,548 mm

Compression Stress σ_c 350,000 MPa
Tension Stress σ_t -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)] | $3 < \rho \leq 0$ \rightarrow OK

Stress distribution | Compressive positive | Effective width $b_{w,eff}$

$\rho = 1,000$ $b_{w,eff} = \rho \cdot b$ $b_{w,eff} = 0,667 \cdot b_{w,net}$
 $b_{w,eff} = 0,667 \cdot b_{w,net}$

$\rho \leq 1,000$ OK C-Section **Class 2** $b_{w,net} = \rho \cdot b$ 45,048 [mm]

$b_{w,net}$ 22,524 [mm] $b_{w,net}$ 22,524 [mm]

Superior Edge Stiffener | $c_{y,super}$ | **Class 4**

OPTRON (1) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3, 2(1)]

C-Section Beam Nominal Dimension

ϵ	0,919
t	1,952 mm

$b_{y,net}$ 45,048 mm $b_{z,net}$ 17,274 mm

Compression Stress σ_c 350,000 MPa
Tension Stress σ_t 248,001 MPa

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

$\psi = \sigma_c / \sigma_t$ \rightarrow ψ 0,709

σ_c Free Point \rightarrow λ_y 0,659

OPTRON (2) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3, 2(1)]

Stress Distribution

$0,50 \cdot b_{y,net}$	59,274 mm	m	5,905
For a single edge stiffener, Equation (5.13-d)			
b_{y1} / b_y	0,883	\rightarrow	λ_y 0,686
$\bar{\lambda}_p$	0,757	\rightarrow	OPTRON 0,993
λ_y	0,668	\rightarrow	PERMISSIBLE 1,000

[EN 1993-1-5, Equation (4.3)] | $\rho \leq 1,000$ \rightarrow OK

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Internal Compression Elements [EN 1993-1-5, Table 4.3]

$\psi = \sigma_c / \sigma_t$ \rightarrow ψ -0,600 \rightarrow λ_y 23,900

$\bar{\lambda}_{p1} = \sqrt{\frac{f_{cr}}{\sigma_{cr}}} = \frac{\bar{b}/t}{28,4 \cdot \epsilon \cdot \sqrt{k_{\sigma}}}$ $\bar{\lambda}_p$ 0,718 \rightarrow ρ 1,180

$\bar{\lambda}_p$ 0,718 ρ 1,180 Gross width will be reduced
[EN 1993-1-5, Equation (4.2)] | $3 < \rho \leq 0$ \rightarrow OK

Stress distribution | Compressive positive | Effective width $b_{w,eff}$

$\rho < 0,200$ $b_{w,eff} = \rho \cdot b_{w,net} \cdot \rho^{0,5} \cdot [1 - \psi]$ $b_{w,eff} = 0,400 \cdot b_{w,net}$
 $b_{w,eff} = \rho \cdot b_{w,net} \cdot \rho^{0,5} \cdot [1 - \psi]$ $b_{w,eff} = 0,500 \cdot b_{w,net}$

$\rho \leq 1,000$ Consider $\rho = 1,000$ $b_{w,eff} = b' \cdot b_{w,net} \cdot \rho^{0,5} \cdot [1 - \psi]$ 59,274 [mm]

$\rho \leq 1,000$ Consider $\rho = 1,000$ $b_{w,eff} = \rho \cdot b_{w,net} \cdot \rho^{0,5} \cdot [1 - \psi]$ 59,274 [mm]

$b_{w,net}$ 23,710 [mm] $b_{w,net}$ 35,564 [mm]

Superior Flange | $b_{y,super}$ | **Class 2**

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.6]

C-Section Beam Nominal Dimension

ϵ	0,919
t	1,952 mm

$b_{y,net}$ 45,048 mm

Compression Stress σ_c 350,000 MPa
Tension Stress σ_t 350,000 MPa

Internal Compression Elements [EN 1993-1-5, Table 4.3]

$\psi = \sigma_c / \sigma_t$ \rightarrow ψ 1,000 \rightarrow λ_y 4,000

$\bar{\lambda}_{p1} = \sqrt{\frac{f_{cr}}{\sigma_{cr}}} = \frac{\bar{b}/t}{28,4 \cdot \epsilon \cdot \sqrt{k_{\sigma}}}$ $\bar{\lambda}_p$ 0,667 \rightarrow ρ 1,000

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Stress distribution | Compressive positive | Effective width $b_{w,eff}$

$1,000 < \rho \leq 0,500$ $b_{w,eff} = \rho \cdot c$

C-Section **Class 4** $b_{w,net} = \rho \cdot c$ 17,274 [mm]

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

Effective C-Section Beam Widths

Inferior Edge Stiffener	$c_{y,inf}$	---	[mm]
Inferior Flange	$b_{y,inf}$	---	[mm]
Web	$b_{w,net}$	59,274	[mm]
Superior Flange	$b_{y,super}$	45,048	[mm]
Superior Edge Stiffener	$c_{y,super}$	17,274	[mm]

Effective Gross C-Section | Bending Moment $M_{y,Ed}(+)$

iii] Plane elements with edge stiffeners | Distortional Buckling [EN 1993-1-3:2006, 5.5.1(9)]

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)]
 $b_{11} \leq 60$ OK
 $45^\circ \leq \phi$ OK
 $\phi < 135$ 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.

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

Effective Cross-C-Section with Reduced Thickness | L * D | Bending Moment M_{Ed}

A_{eff} 58.518 [mm²]
 b_1 38.922 [mm]
 $x_{1,centroid}$ 7.578 [mm]
 $z_{1,centroid}$ 4.862 [mm]

Compression

iv] Effective C-Section Beam with Reduced Thickness | Local + Distortional Buckling [EN 1993-1-3:2006, 5.5]

Effective C-Section Beam Widths

Element	Width [mm]	Value [mm]
Inferior Edge Stiffener	$b_{1,ef}$	...
Inferior Flange	$b_{1,ef}$	...
Web	$b_{w,ef}$	23.710
	$b_{w,ef}$	35.564
Superior Flange	$b_{2,ef}$	22.524
	$b_{2,ef}$	22.524
Superior Edge Stiffener	$b_{2,ef}$	17.274

Effective Cross-C-Section with Reduced Thickness | L * D | Bending Moment M_{Ed}

Superior Edge Stiffener | Flange 2

A_{eff} 0.000 [mm²]
 b_2 0.000 [mm]
 $x_{1,centroid}$ 0.000 [mm]
 $z_{1,centroid}$ 0.000 [mm]

Tension

$K_1 = \frac{Et^3}{4(1-\nu^2)(b_1^2 h_w + b_2^2 h_w + 0.5 b_1 b_2 h_w)} k_1 = 0$ Flange 2 in Tension
 [EN 1993-1-3, Equation 5.10a] $k_1 = \frac{A_{2,eff}}{A_{1,eff}}$ Flange 2 in Compression

E	210.000 [GPa]	t	1.452 [mm]
ν	0.300	b_1	38.922 [mm]
$b_w = h$	120.000 [mm]	b_2	0.000 [mm]
K_1	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)]

$\sigma_{cr,s} = \frac{2\sqrt{KEI_s}}{A_{eff}}$ [EN 1993-1-3, Equation 5.15]

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 5.12a]

Edge Stiffener 1 $\bar{\lambda}_d$ 0.771

Reduction χ_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 $\chi_{d,stroke}$ 0.813 [EN 1993-1-3, Equation 5.10c]

Edge Stiffener Reduced Thickness [EN 1993-1-3:2006, 5.5.3.2(2)]

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

Edge Stiffener 1
 t_{stroke} 1.325 [mm]

Effective Cross-C-Section with Reduced Thickness | L * D | Bending Moment M_{Ed}

$I_{eff}^{y,y}$ 746884.861 [mm⁴]

v] C-Section Columns

Class 1

Effective width is equal to the actual width

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

Effective C-Section | Moral Case | Class 4 |

Web | t_w | Class 1

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

C-Section Column Nominal Dimension

h_{max}	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, Tab. 4.1 |

$\psi = \sigma_2 / \sigma_1$	-1.000		χ_y	23.900
------------------------------	--------	--	----------	--------

$$\bar{\lambda}_{y,cr} = \sqrt{\frac{f_{cr}}{\sigma_{cr}}} = \frac{\bar{b} / l}{28.4 \epsilon \sqrt{k_{cr}}}$$

$\bar{\lambda}_{y,cr}$ 0.314

ρ 1.000 Effective width equal to gross width | EN 1993-1-5, Equation (4.2) | $[3 \cdot \psi] > 0 \rightarrow$ OK

Stress distribution | Compressive positive |

Effective width b_{eff}

$\psi < 0.000$	$b_{y1} = \rho \cdot b_1 = \rho \cdot [b' \cdot (1 - \psi)]$	$b_{y2} = 0.400 \cdot b_w$
	$b_1 = b' \cdot b_1 = b' \cdot [b' \cdot (1 - \psi)]$	$b_{y2} = 0.800 \cdot b_w$
$\rho \leq 1.000$ OK	$b_{y1} = b' \cdot b_1 = b' \cdot [b' \cdot (1 - \psi)]$	43.774 [mm]

Outward Compression Elements | EN 1993-1-5, Tab. 4.2 |

$\psi = \sigma_2 / \sigma_1$	-	χ_y	0.817
Free Point	-	χ_z	0.467

OPTION (2) Elements without longitudinal stiffeners | EN 1993-1-5:2006, 5.3.2(5) |

Stress distribution

$0.50 \cdot h_{max}$	43.774	mm	$=$	7.996
b_{y1} / b_1	0.381		\rightarrow	χ_y
				0.582
$\bar{\lambda}_{y,cr}$	0.430		\rightarrow	Permitted
$\bar{\lambda}_{y,cr}$	0.385		\rightarrow	Permitted
				1.000

EN 1993-1-5, Equation (4.3) | $\rho \leq 1.000 \rightarrow$ OK

Stress distribution | Compressive positive |

Effective width b_{eff}

$1.000 > \psi > 0.000$	$b_{y1} = \rho \cdot b_1$	16.774 [mm]
------------------------	---------------------------	-------------

C-Section | Class 1 | $b_{y2} = \rho \cdot b_2$ 16.774 [mm]

Effective C-Section Column | Local Buckling | EN 1993-1-5:2006, 4.3 |

Effective C-Section Column Widths

Inferior Edge Stiffener	$b_{y1,ef}$	---	[mm]
Inferior Flange	$b_{y1,fl}$	---	[mm]
Web	$b_{y1,w}$	43.774	[mm]
Superior Flange	$b_{y1,fl}$	44.048	[mm]
Superior Edge Stiffener	$b_{y1,ef}$	16.774	[mm]

$\rho \leq 1.000$ OK

$b_{y1} = \rho \cdot b_1 = \rho \cdot [b' \cdot (1 - \psi)]$ 43.774 [mm]

$b_{y2,1}$ 17.510 [mm] $b_{y2,2}$ 26.284 [mm]

Superior Flange | $b_{y2,fl}$ | Class 1

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

C-Section Column Nominal Dimension

h_{max}	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, Tab. 4.1 |

$\psi = \sigma_2 / \sigma_1$	1.000		χ_y	4.000
------------------------------	-------	--	----------	-------

$$\bar{\lambda}_{y,cr} = \sqrt{\frac{f_{cr}}{\sigma_{cr}}} = \frac{\bar{b} / l}{28.4 \epsilon \sqrt{k_{cr}}}$$

$\bar{\lambda}_{y,cr}$ 0.386

ρ 1.000 Effective width equal to gross width | EN 1993-1-5, Equation (4.2) | $[3 \cdot \psi] > 0 \rightarrow$ OK

Stress distribution | Compressive positive |

Effective width b_{eff}

$\psi = 1.000$	$b_{y1} = 0.500 \cdot b_{gr}$	$b_{y2} = 0.500 \cdot b_{gr}$
	$b_{y1} = \rho \cdot b'$	$b_{y2} = 0.500 \cdot b_{gr}$
$\rho \leq 1.000$ OK	C-Section | Class 1 | $b_{y1,1} = \rho \cdot b'$	44.048 [mm]

$b_{y1,1}$ 22.024 [mm] $b_{y1,2}$ 22.024 [mm]

Superior Edge Stiffener | $b_{y2,ef}$ | Class 1

OPTION (3) Elements without longitudinal stiffeners | EN 1993-1-5:2006, 4.4 |

C-Section Column Nominal Dimension

h_{max}	44.048	mm
ϵ	0.819	
t	2.452	mm
$c_{y,max}$	16.774	mm

Effective Gross C-Section | Bending Moment $M_{y,Ed}$ |

Plane elements with edge stiffeners | Diagonal Buckling | EN 1993-1-3:2006, 5.5.1(8) |

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 |

b	$b \leq 60$	OK
$45^\circ < \theta$	OK	
$\phi \leq 1.35$	OK	

EN 1993-1-3, 5.5.3.2(1) |

EN 1993-1-3, 5.5.3.2(6) |

Round corners were considered in the effective compression area of the edge stiffener, A_{e1}

Determination of Spring Stiffness [K] [EN 1993-1-3:2006, 5.5.3.2(8)]

Inferior Edge Stiffener [Flange 1]

Superior Edge Stiffener [Flange 2]

A_{s1}	96.559	[mm ²]
b_1	38.465	[mm]
$h_{s1,eff}$	8.035	[mm]
$h_{s1,red}$	5.304	[mm]

Inferior Edge Stiffener [Flange 1] **Compression**

A_{s2}	0.000	[mm ²]
b_2	0.000	[mm]
$h_{s2,eff}$	0.000	[mm]
$h_{s2,red}$	0.000	[mm]

Superior Edge Stiffener [Flange 2] **Tension**

$$K_{fl} = \frac{E t^3}{4(1-\nu^2) b_1^2 h_{s1} + b_2^2 + 0.5 b_1 b_2 h_{s1} k_t} \quad k_t = 0 \quad \text{Flange 2 in Tension}$$

$$k_t = \frac{A_{s2}}{A_{s1}} \quad \text{Flange 2 in Compression}$$

E	210.000	[GPa]	t	2.452	[mm]
ν	0.300		b_1	38.465	[mm]
$h_s = h$	80.000	[mm]	b_2	0.000	[mm]
K_s	0.000				

$$K = 4.475 \quad \text{[EN 1993-1-3, Equation 5.10]}$$

Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment $M_{y,Ed,+1}$]

Effective C-Section Column with Reduced Thickness [L + D] [Bending Moment $M_{y,Ed,+1}$]

$t_{red} = 625096.020 \quad \text{[mm]}$

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

$$\sigma_{cr,Ed} = \frac{2 \sqrt{K E I_x}}{A_s}$$

Elastic Critical Buckling Stress, $\sigma_{cr,Ed}$, for edge stiffener 1: 1110.333 [MPa]

Relative Distortional Slenderness [$\bar{\lambda}_{d1}$] [EN 1993-1-3:2006, 5.5.3.1(7)]

$$\bar{\lambda}_{d1} = \sqrt{f_{yb} / \sigma_{cr,Ed}}$$

Edge Stiffener 1 $\bar{\lambda}_{d1}$: 0.561

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

Edge Stiffener 1 $\bar{\lambda}_{d1}$: 0.561 $\chi_{d,EN1993-1-3}$: 1.000 [EN 1993-1-3, Equation 5.12a]

Edge Stiffener Reduced Thickness [EN 1993-1-3:2006, 5.5.3.2(2)]

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

Edge Stiffener 1 $t_{red,EN1993-1-3}$: 2.452 [mm]

Effective C-Section Column with Reduced Thickness [Local + Distortional Buckling] [EN 1993-1-3:2006, 5.5]

Effective C-Section Column Widths		
Inferior Edge Stiffener	$t_{s1,red}$	--- [mm]
Inferior Flange	$b_{1,red}$	--- [mm]
Web	$b_{w,red}$	17.510 [mm]
	$b_{w,red}$	26.264 [mm]
Superior Flange	$b_{2,red}$	22.024 [mm]
	$b_{2,red}$	22.024 [mm]
Superior Edge Stiffener	$t_{s2,red}$	16.774 [mm]

C-Section Size

Effective C-Section [L] **Local Buckling** [EN 1993-1-3]

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

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.

Inferior Edge Stiffener [$t_{s1,red}$] → **Tension**

NOTE Effective width is equal to the real width

Inferior Flange [$b_{1,red}$] → **Tension**

NOTE Effective width is equal to the real width

Effective C-Section [Web Core] [Class 4]

WD [$t_{w,red}$] → **Class 4**

Edge stiffeners without longitudinal stiffeners [EN 1993-1-3:2006, 4.4]

C-Section Size: **Natural Dimension**

$t_{w,red}$	48.548	mm	ϵ	0.819
			l	1.452

Compression Stress σ_1 : 350.000 MPa

Tension Stress σ_2 : -350.000 MPa

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

$\psi = \sigma_1 / \sigma_2 \rightarrow \psi = 2.000 \rightarrow \lambda_1 = 28.900$

$$\bar{\lambda}_{pl} = \sqrt{\frac{f_{yk}}{\sigma_{cr}}} = \frac{\bar{h}/t}{28,4 \cdot \epsilon \cdot \sqrt{k_{\sigma}}}$$

$\bar{\lambda}_{pl} = 0.294 \rightarrow \rho = 1.000$

Effective width equal to gross width
[EN 1993-1-5, Equation (6.2)] | $3 + \psi \geq 0 \rightarrow$ OK

Stress distribution [Compressive positive]

Effective width b_{eff}

$\psi < 0.000$

$b_{e1} = \rho \cdot b_1 = \rho \cdot b' \cdot (1 - \psi)$ | $b_{e1} = 0.400 \cdot b_{e1}$

$b_{e2} = \rho \cdot b_2 = \rho \cdot b' \cdot (1 + \psi)$ | $b_{e2} = 0.600 \cdot b_{e2}$

$\rho \leq 1.000$ OK | $b_{e1} = b' \cdot b_1 = b' \cdot (1 - \psi)$ | 48.548 [mm]

$\rho \leq 1.000$ OK | $b_{e2} = \rho \cdot b_2 = \rho \cdot (1 + \psi)$ | 24.274 [mm]

$b_{e11} = 9.710$ [mm] | $b_{e12} = 14.564$ [mm]

Superior Flange [1,2,3,4] → Class 1

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

C-Section Size Nominal Dimension

$b_{2,net} = 38.548$ mm | $\epsilon = 0.819$

$t = 1.452$ mm

Compression Stress

$\sigma_1 = 350.000$ MPa

$\sigma_2 = 350.000$ MPa

Tension Stress

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

$\psi = \sigma_1 / \sigma_2 \rightarrow \psi = 1.000 \rightarrow \lambda_1 = 4.000$

$$\bar{\lambda}_{pl} = \sqrt{\frac{f_{yk}}{\sigma_{cr}}} = \frac{\bar{h}/t}{28,4 \cdot \epsilon \cdot \sqrt{k_{\sigma}}}$$

$\bar{\lambda}_{pl} = 0.570 \rightarrow \rho = 1.000$

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Stress distribution [Compressive positive]

Effective width b_{eff}

$1.000 \cdot \psi \geq 0.000$ | $b_{e1} = \rho \cdot b$

C-Section Class 1 | $\rho_{1,2} = \rho \cdot b' = 9.274$ [mm]

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

Effective C-Section Size Widths

Inferior Edge Stiffener	$b_{1,1}$	---	[mm]
Inferior Flange	$b_{1,2}$	---	[mm]
Web	$b_{1,3}$	24.274	[mm]
Superior Flange	$b_{1,4}$	38.548	[mm]
Superior Edge Stiffener	$b_{1,5}$	9.274	[mm]

CG

$M_{y,Ed} [+]$

Effective Cross-Section [Bending Moment $M_{y,Ed} [+]$]

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$\bar{\lambda}_{pl} = 0.570$ | $\rho = 1.000$ Effective width equal to gross width
[EN 1993-1-5, Equation (6.2)] | $3 + \psi \geq 0 \rightarrow$ OK

Stress distribution [Compressive positive]

Effective width b_{eff}

$\psi = 1.000$

$b_{e1} = \rho \cdot b$ | $b_{e1} = 0.500 \cdot b_{e1}$

$b_{e2} = \rho \cdot b$ | $b_{e2} = 0.500 \cdot b_{e2}$

$\rho \leq 1.000$ OK | C-Section Class 1 | $b_{1,1,net} = \rho \cdot b' = 38.548$ [mm]

$b_{1,2,net} = 19.274$ [mm] | $b_{1,3,net} = 19.274$ [mm]

Superior Edge Stiffener [1,2,3,4] → Class 1

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

C-Section Size Nominal Dimension

$b_{2,net} = 38.548$ mm | $\epsilon = 0.819$

$t = 1.452$ mm

$b_{1,net} = 9.274$ mm

Compression Stress

$\sigma_1 = 350.000$ MPa

$\sigma_2 = 216.281$ MPa

Tension Stress

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

$\psi = \sigma_1 / \sigma_2 \rightarrow \psi = 0.618$

σ_1 Free Point | $\sigma_2 = 0.467$

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 5.3.2(5)]

Stress Distribution

$0.50 \cdot b_{1,net} = 24.274$ mm | $m = 14.419$

For a single edge stiffener, Equation (5.193)

$b_{21} / b_2 = 0.241 \rightarrow \lambda_1 = 0.500$

$\bar{\lambda}_{pl} = 0.402 \rightarrow \rho_{1,1,1} = 1.000$

$\bar{\lambda}_{pl} = 0.388 \rightarrow \rho_{1,1,2} = 1.000$

[EN 1993-1-5, Equation (6.3)] | $\rho \leq 1.000 \rightarrow$ OK

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Plane elements with edge stiffeners [Directional Buckling] [EN 1993-1-3:2006, 5.3.1(5)]

Plane elements with edge stiffeners [EN 1993-1-3:2006, 5.3.2(1)]

[a] Actual system | [b] Spring system

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

Determination of Spring Stiffness K [EN 1993-1-3:2006, 5.3.2(5)]

Inferior Edge Stiffener [Flange 1]

Superior Edge Stiffener [Flange 2]

Flange 1

CG

$M_{y,Ed} [+]$

Flange 2

Inferior Edge Stiffener [Flange 1]

$A_{1,1} = 42.189$ [mm²]

$b_1 = 32.219$ [mm]

$Y_{1,1,base} = 7.787$ [mm]

$Z_{1,1,base} = 2.549$ [mm]

Compression

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A_{s1}	0,900	[mm ²]
b_1	0,900	[mm]
h_{s1max}	0,900	[mm]
h_{s1min}	0,900	[mm]

Superior Edge Stiffener [Range 2]

Tension

$$K_{t1} = \frac{E t^3}{4(1-\nu^2) (b_1^3 h_{s1} + b_2^3 + 0.5 b_1 b_2 h_{s1} k_t)}$$

[EN 1993-1-3, Equation 5.109]

E	219,000	[GPa]
ν	0,300	
$h_u = h$	50,000	[mm]
K_t	0,900	

t	1,452	[mm]
b_1	32,219	[mm]
b_2	0,900	[mm]

K 2,970 [EN 1993-1-3, Equation 5.12b]

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

$$\sigma_{cr,Ed} = \frac{2 \sqrt{K E I_x}}{A_s}$$

[EN 1993-1-3, Equation 5.16]

K	2,970	
E	219,000	[GPa]
$I_{x,inst,Ed}$	377,466	[mm ⁴]
A_{s1}	42,183	[mm ²]

Elastic Critical Buckling Stress $\sigma_{cr,Ed}$ for edge stiffener t 667,375 [MPa]

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

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

[EN 1993-1-3, Equation 5.20]

f_{yb}	350,000	[MPa]
Edge Stiffener t	$\bar{\lambda}_d$	0,759

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

Edge Stiffener t	$\bar{\lambda}_d$	0,759	$\chi_{d,inst,Ed}$	0,921
------------------	-------------------	-------	--------------------	-------

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

Edge Stiffener Reduced Thickness [EN 1993-1-3:2006, 5.5.3.2(2)]

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

Edge Stiffener t		
$t_{red,inst,Ed}$	1,338	[mm]

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Effective C-Section Steel with Reduced Thickness [L + D] Bending Moment $M_{y,Ed}$

$t_{red,Ed}$ 0,879,077 [mm]

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[14] Effective C-Section Steel with Reduced Thickness [Local + Distortional Buckling]

[EN 1993-1-3:2006, 5.5]

Effective C-Section Steel Widths		
Inferior Edge Stiffener	$b_{s1,inf}$	-- [mm]
Inferior Flange	$b_{1,inf}$	-- [mm]
Web	$h_{w,inf}$	9,710 [mm]
	$h_{w,s1}$	14,664 [mm]
Superior Flange	$b_{1,sup}$	19,274 [mm]
	$b_{2,sup}$	19,274 [mm]
Superior Edge Stiffener	$b_{s2,sup}$	9,274 [mm]

Effective Class C-Section with Reduced Thickness [L + D] Bending Moment $M_{y,Ed}$

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[14] Cold-Formed Section subjected to Negative Moment in xy axis [$M_{y,Ed}$]

[*] D-Section Profile

Effective D-Section [L] Local Buckling [EN 1993-1-3]

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

[1] Determination of the Effective Width [Local Buckling]

[EN 1993-1-3:2006, 5.5]

D-Section Classification Class 1 → Effective width is equal to the actual width

Effective D-Section [Weld Class] Class 4

[Rd] Edge Stiffener [$t_{red,inst,Ed}$] → Class 1

OPTION [2] Elements without longitudinal stiffeners [EN 1993-1-3:2006, 5.5.3.2(6)]

D-Section Profile Nominal Dimensions	
$C_{p,inst,Ed}$	7,010 mm
$C_{p,inst,Ed,average}$	10,870 mm

For a single edge stiffener, Equation (5.13c)

b_{11} / b_1	0,369	→	k_1	0,560
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$\bar{\lambda}_p = \sqrt{\frac{f_c}{\sigma_{cr}}} = \frac{\bar{h} l l}{28,4 E \sqrt{k_{cr}}}$ $\bar{\lambda}_p$ 0,428 → ρ 1,000

Stress distribution | Compressive positive

Effective width b_{eff}

$1,000 > \rho \geq 0,990$ $b_{eff} = \rho \cdot c$

D-Section Class I $c_{y, \text{effective}} = \rho \cdot c$ 7,910 [mm]

Inflector Right Flange | $b_{y, \text{effective}}$ → Class I

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

D-Section Part Nominal Dimension

$b_{y, \text{effective}}$ 18,975 mm ϵ 0,819 l 0,952 mm

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

$\psi = \sigma_1 / \sigma_2$ → ψ 1,000 → k_y 4,900

$\bar{\lambda}_p = \sqrt{\frac{f_c}{\sigma_{cr}}} = \frac{\bar{h} l l}{28,4 E \sqrt{k_{cr}}}$ $\bar{\lambda}_p$ 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)] $|\beta + \psi| \geq 0$ → OK

Stress distribution | Compressive positive

Effective width b_{eff}

$\psi = 1,000$ $b_{eff} = \rho \cdot b'$

$\rho \leq 1,000$ OK D-Section Class I $b_{y, \text{effective}} = \rho \cdot b'$ 18,975 [mm]

$b_{y, \text{effective}}$ 9,488 [mm] $b_{y, \text{effective}}$ 9,488 [mm]

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Left Web | $b_{y, \text{effective}}$ → Class I

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

D-Section Part Nominal Dimension

$b_{y, \text{effective}}$ 54,963 mm ϵ 0,819 l 0,952 mm

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

$\psi = \sigma_1 / \sigma_2$ → ψ -1,000 → k_y 23,900

$\bar{\lambda}_p = \sqrt{\frac{f_c}{\sigma_{cr}}} = \frac{\bar{h} l l}{28,4 E \sqrt{k_{cr}}}$ $\bar{\lambda}_p$ 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)] $|\beta + \psi| \geq 0$ → OK

Stress distribution | Compressive positive

Effective width b_{eff}

$\psi < 0,990$ $b_{eff} = \rho \cdot b' \cdot \psi^{1,5} \cdot [1 - \psi]$ $b_{eff} = 0,409 \cdot b_{gross}$

$\rho \leq 1,000$ OK $b_{y, \text{effective}} = \rho \cdot b' \cdot \psi^{1,5} \cdot [1 - \psi]$ 27,492 [mm]

$\rho \leq 1,000$ OK $b_{y, \text{effective}} = \rho \cdot b' \cdot \psi^{1,5} \cdot [1 - \psi]$ 27,492 [mm]

$b_{y, \text{effective}}$ 16,973 [mm] $b_{y, \text{effective}}$ 16,459 [mm]

Inflector Left Flange | $b_{y, \text{effective}}$ → Class I

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

D-Section Part Nominal Dimension

$b_{y, \text{effective}}$ 18,975 mm ϵ 0,819 l 0,952 mm

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Right Web | $b_{y, \text{effective}}$ → Class I

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

D-Section Part Nominal Dimension

$b_{y, \text{effective}}$ 54,963 mm ϵ 0,819 l 0,952 mm

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

$\psi = \sigma_1 / \sigma_2$ → ψ -1,000 → k_y 23,900

$\bar{\lambda}_p = \sqrt{\frac{f_c}{\sigma_{cr}}} = \frac{\bar{h} l l}{28,4 E \sqrt{k_{cr}}}$ $\bar{\lambda}_p$ 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)] $|\beta + \psi| \geq 0$ → OK

Stress distribution | Compressive positive

Effective width b_{eff}

$\psi < 0,990$ $b_{eff} = \rho \cdot b' \cdot \psi^{1,5} \cdot [1 - \psi]$ $b_{eff} = 0,409 \cdot b_{gross}$

$\rho \leq 1,000$ OK $b_{y, \text{effective}} = \rho \cdot b' \cdot \psi^{1,5} \cdot [1 - \psi]$ 27,492 [mm]

$\rho \leq 1,000$ OK $b_{y, \text{effective}} = \rho \cdot b' \cdot \psi^{1,5} \cdot [1 - \psi]$ 27,492 [mm]

$b_{y, \text{effective}}$ 16,973 [mm] $b_{y, \text{effective}}$ 16,459 [mm]

Superior Flange | $b_{y, \text{effective}}$ → Tension

NOTE Effective width is equal to the real width

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Left Edge Stiffener | $b_{y, \text{effective}}$ → Class I

OPTION 1 Elements without longitudinal stiffeners [EN 1993-1-5:2006, 5.3.2(5)]

D-Section Part Nominal Dimension

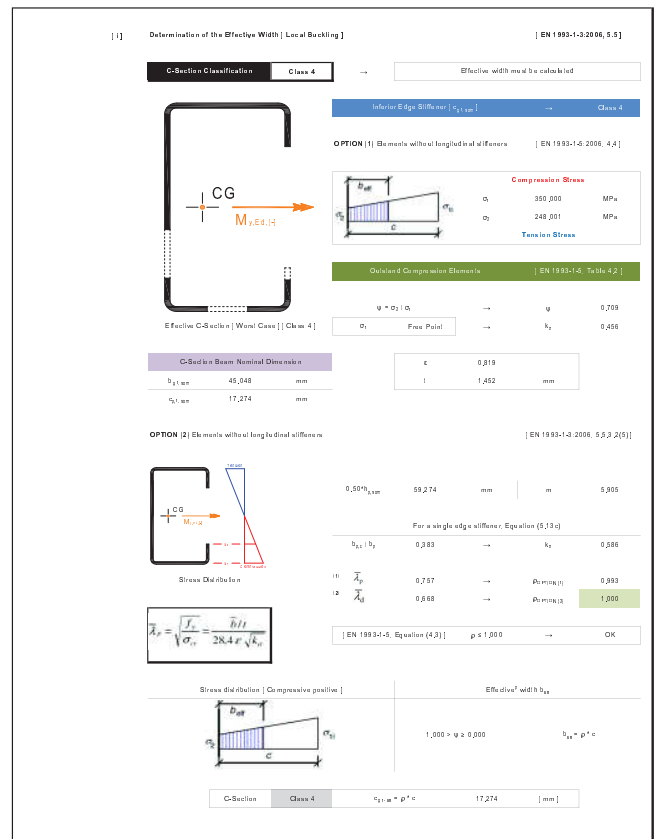
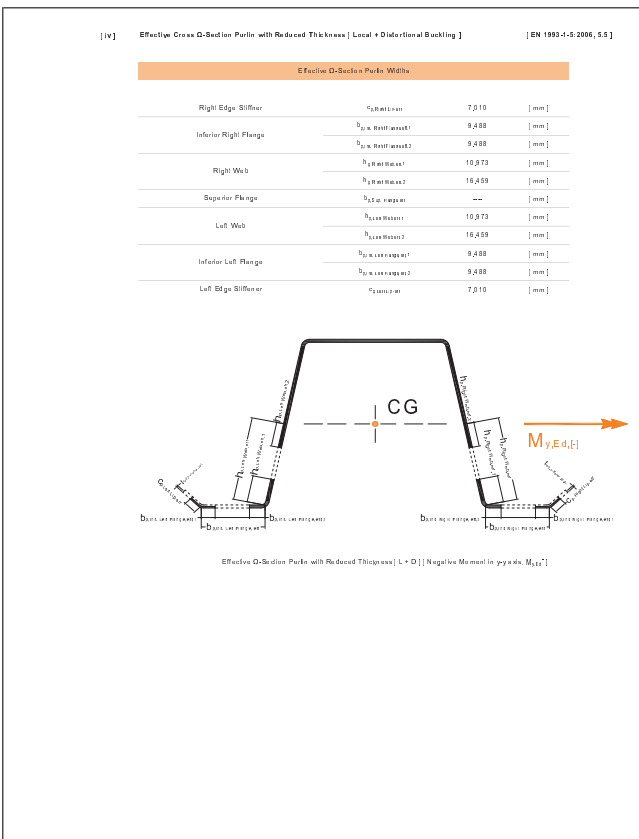
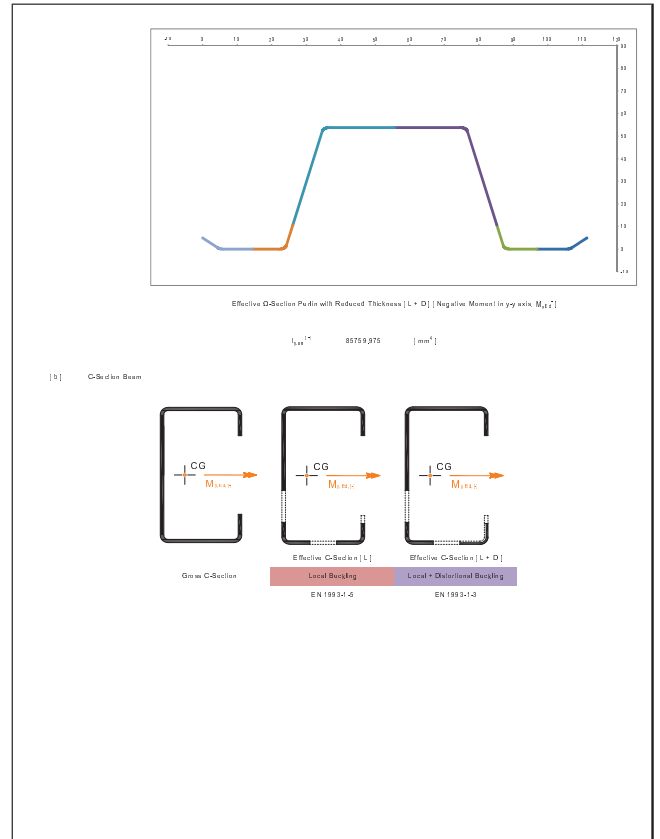
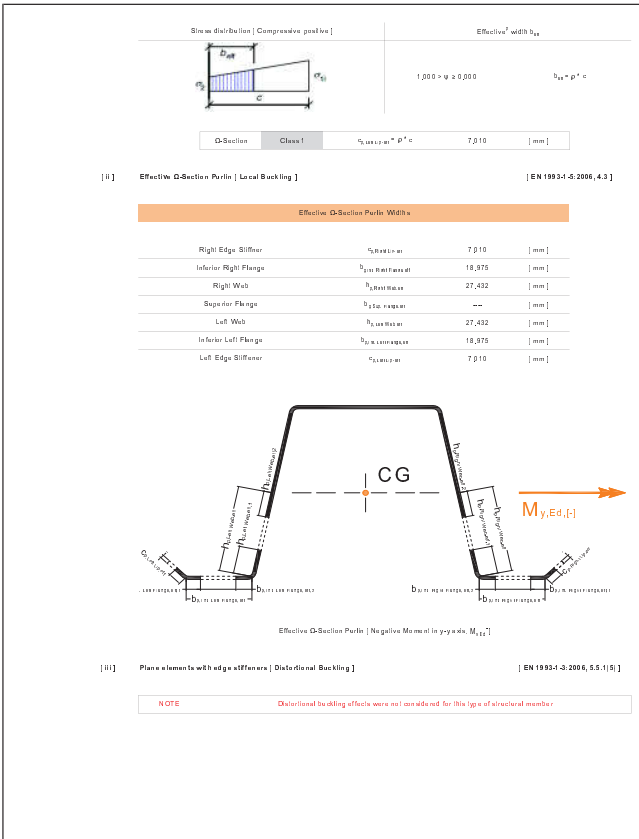
$c_{y, \text{effective}}$ 7,910 mm ϵ 0,819

$b_{y, \text{effective}}$ 18,975 mm l 0,952 mm

For a single edge stiffener, Equation (5.3c)

$b_{y, \text{effective}}$ 0,369 → k_y 0,560

$\bar{\lambda}_p = \sqrt{\frac{f_c}{\sigma_{cr}}} = \frac{\bar{h} l l}{28,4 E \sqrt{k_{cr}}}$ $\bar{\lambda}_p$ 0,428 → ρ 1,000



Inferior Flange | $b_{1,net}$ | → **Class 2**

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.8]

C-Section Beam Nominal Dimension

$b_{1,net}$	45,048	mm
ϵ	0,919	
t	1,652	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]

$\psi = \sigma_1 / \sigma_2$ → ψ 1,000 → λ_p 4,000

$$\bar{\lambda}_p = \sqrt{\frac{f_{y,t}}{\sigma_{cr}}} = \frac{\bar{b}/t}{28,4 \cdot \epsilon \cdot \sqrt{k_{cr}}}$$

$\bar{\lambda}_p$ 0,667 → ρ 1,000

Effective width equal to gross width
[EN 1993-1-5, Equation (6.2)] | $\lambda \cdot \psi \geq 0$ → OK

Stress distribution | Compressive positive |

Effective width b_{eff}

$\psi = 1,000$ $b_{eff} = \rho \cdot b^*$

$b_{1,net} = 0,500 \cdot b_{gross}$
 $b_{1,net} = 0,500 \cdot b_{gross}$

$\rho \leq 1,000$ OK C-Section **Class 2** $b_{1,net} = \rho \cdot b^*$ 45,048 [mm]

$b_{1,net}$ 22,524 [mm] $b_{1,net}$ 22,524 [mm]

Web | $b_{2,net}$ | → **Class 3**

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

C-Section Beam Nominal Dimension

$b_{2,net}$	119,548	mm
ϵ	0,919	
t	1,652	mm

Compression Stress

σ_1	350,000	MPa
σ_2	-350,000	MPa

Tension Stress

Effective Cross-C-Section | Bending Moment $M_{y,Ed}$ |

Plane elements with edge stiffeners | Diagonal Buckling [EN 1993-1-3:2006, 5.5.3(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)]

- $b \leq 40$ OK
- $45^\circ \leq \theta$ OK
- $\theta < 135$ 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_{st}

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

$\psi = \sigma_1 / \sigma_2$ → ψ -0,500 → λ_p 29,900

$$\bar{\lambda}_p = \sqrt{\frac{f_{y,t}}{\sigma_{cr}}} = \frac{\bar{b}/t}{28,4 \cdot \epsilon \cdot \sqrt{k_{cr}}}$$

$\bar{\lambda}_p$ 0,718 → ρ 1,180

Gross width will be reduced
[EN 1993-1-5, Equation (6.2)] | $\lambda \cdot \psi \geq 0$ → OK

Stress distribution | Compressive positive |

Effective width b_{eff}

$\psi < 0,200$

$b_{eff} = \rho \cdot b^* \cdot \psi^2 \cdot [1 - \psi]$ $b_{1,net} = 0,200 \cdot b_{gross}$
 $b_{eff} = \rho \cdot b^* \cdot \psi^2 \cdot [1 - \psi]$ $b_{2,net} = 0,500 \cdot b_{gross}$

$\rho \leq 1,000$ $\text{Class } \rho = 1,000$ $b_{1,net} = \rho \cdot b^* \cdot \psi^2 \cdot [1 - \psi]$ 59,274 [mm]

$\rho \leq 1,000$ $\text{Class } \rho = 1,000$ $b_{2,net} = \rho \cdot b^* \cdot \psi^2 \cdot [1 - \psi]$ 59,274 [mm]

$b_{1,net}$ 29,710 [mm] $b_{2,net}$ 35,564 [mm]

Superior Flange | $b_{2,net}$ | → **Tension**

NOTE Effective width is equal to the real width

Superior Edge Stiffener | $b_{2,net}$ | → **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	$b_{1,net}$	17,274	[mm]
Inferior Flange	$b_{1,net}$	45,048	[mm]
Web	$b_{2,net}$	59,274	[mm]
Superior Flange	$b_{2,net}$	--	[mm]
Superior Edge Stiffener	$b_{2,net}$	--	[mm]

Determination of Spring Stiffness | K | [EN 1993-1-3:2006, 5.5.3.2(9)]

Inferior Edge Stiffener | Flange 1 |

Superior Edge Stiffener | Flange 2 |

Flange 2

Flange 1

CG

$M_{y,Ed}$

Inferior Edge Stiffener | Flange 1 |

A_{st}	59,518	[mm ²]
b_t	39,922	[mm]
$r_{y,active}$	7,578	[mm]
$r_{z,active}$	4,982	[mm]

Compressor

Superior Edge Stiffener | Flange 2 |

A_{st}	0,000	[mm ²]
b_t	0,000	[mm]
$r_{y,active}$	0,000	[mm]
$r_{z,active}$	0,000	[mm]

Tension

$K_1 = \frac{EI^3}{4(1-\nu^2)} \cdot \frac{1}{b_{st}^3 h_{st} + b_{st}^2 + 0,5 b_{st} b_{st} h_{st} k_{st}}$ $k_{st} = \frac{A_{st}}{A_{fl}}$ **Flange 2 in Tension**
[EN 1993-1-3, Equation 5.109] **$k_{st} = 0$ Flange 2 in Compression**

E	210,000	[GPa]	t	1,652	[mm]
ν	0,300		b_t	39,922	[mm]
$b_{st} = h$	120,000	[mm]	b_t	0,000	[mm]
K_1	0,000				

K 0,734 [EN 1993-1-3, Equation 5.10] |

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

$$\sigma_{cr,1} = \frac{2 \sqrt{K E I_x}}{A_s}$$

K: 0.734
E: 210,000 [GPa]
 $I_{x,steel}$: 1926,805 [mm⁴]
 A_{s1} : 58,518 [mm²]

Elastic Critical Buckling Stress, $\sigma_{cr,1}$, for edge stiffener 1: 588,829 [MPa]

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

$$\bar{\lambda}_d = \sqrt{f_{yb} / \sigma_{cr,1}}$$

f_{yb} : 350,000 [MPa]
Edge Stiffener 1: $\bar{\lambda}_d$: 0.771

Reduction χ_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, $\chi_{d,steel}$: 0.913 [EN 1993-1-3, Equation 5.2(2)]

Edge Stiffener Reduced Thickness [EN 1993-1-3:2006, 5.5.3.2(2)]

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

Edge Stiffener 1

$t_{d,steel}$	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	$e_{s,1,red}$	17,274	[mm]
Inferior Flange	$e_{f,1,red}$	22,524	[mm]
	$e_{f,1,red}^2$	22,524	[mm]
Web	$e_{w,red}$	23,710	[mm]
	$e_{w,red}^2$	35,564	[mm]
Superior Flange	$e_{f,2,red}$	---	[mm]
Superior Edge Stiffener	$e_{s,2,red}$	---	[mm]

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[c] C-Section Column

[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

Inferior Edge Stiffener [$e_{s,1,red}$]: **Class 1**

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-3:2006, 4.4]

Compression Stress
 σ_c : 350,000 [MPa]
 σ_t : 215,882 [MPa]

Tension Stress

Outstand Compression Elements [EN 1993-1-3:2006, 4.2]

$\psi = \sigma_1 / \sigma_2$ → ψ : 0,817
 σ_1 : Free Paint → σ_2 : 0,887

C-Section Column Nominal Dimension

$b_{p,1,net}$	44,048	[mm]
$e_{s,1,net}$	16,274	[mm]

ϵ : 0,819
 t : 2,852 [mm]

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Effective Class C-Section with Reduced Thickness [L + D] Bending Moment $M_{y,Ed,1}$

Effective Class C-Section with Reduced Thickness [L + D] Bending Moment $M_{y,Ed,1}$

$I_{y,red}$: 746982,361 [mm⁴]

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

$0,50 \cdot h_{s,1,net}$: 43,774 [mm] → ψ : 7,996

For a single edge stiffener, Equation (5.19.4):
 $\psi_{c,1} / h_p$: 0,381 → ψ_c : 0,582

Stress Distribution

$\bar{\lambda}_{fp}$: 0,386 → ρ (compression): 1,000
 $\bar{\lambda}_{ft}$: 0,385 → ρ (tension): 1,000

[EN 1993-1-5, Equation (4.21)]: $\rho \leq 1,000$ → OK

Stress distribution [Compressive positive]

Effective width b_{eff}

$1,000 \cdot \psi \geq 0,950$ → $b_{eff} = \rho \cdot c$

C-Section: **Class 1** → $\psi_{c,1,red} = \rho \cdot c$: 16,274 [mm]

Inferior Flange [$e_{f,1,red}$]: **Class 1**

Elements without longitudinal stiffeners [EN 1993-1-3:2006, 4.4]

C-Section Column Nominal Dimension

ϵ	0,819
t	2,852 [mm]

Compression Stress
 σ_c : 350,000 [MPa]
 σ_t : 350,000 [MPa]

Tension Stress

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

$\psi = \sigma_1 / \sigma_2$ → ψ : 1,000 → ψ_c : 4,000

$\bar{\lambda}_{fp} = \sqrt{\frac{f_{yb}}{\sigma_{cr}}} = \frac{\bar{b} / t}{28,4 \cdot \epsilon \cdot \sqrt{k_{fp}}}$ → $\bar{\lambda}_{fp}$: 0,386 → ρ : 1,000

[EN 1993-1-5, Equation (4.21)]: $\rho \leq 1,000$ → Effective width equal to gross width → OK

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Stress distribution | Compressive positive

Effective width b_{eff}

$\psi = 1,000$ $\eta_{pl} = \rho \cdot b^*$ $\rho_{pl} = 0,200 \cdot \rho_{yk}$

$\rho \leq 1,000$ OK C-Section Class 1 $\eta_{pl,1,00} = \rho \cdot b^*$ 44,048 [mm]

$\eta_{pl,1,00}$ 22,024 [mm] $\eta_{pl,1,00}$ 22,024 [mm]

Web | $\eta_{pl,web}$ | --- Class 1

Elements with longitudinal stiffeners [EN 1993-1-3:2006, 4.4]

C-Section Column Nominal Dimension

$\eta_{pl,web}$ 87,548 mm

ϵ 0,919

t 2,452 mm

Compression Stress

σ_1 350,000 MPa

Tension Stress

σ_2 -350,000 MPa

Internal Compression Elements [EN 1993-1-3:2006, 4.2]

$\psi = \sigma_1 / \sigma_2$ --- ψ -1,000 --- η_{pl} 29,900

$\bar{\lambda}_{pl} = \sqrt{\frac{f_{yk}}{\sigma_{cr}}} = \frac{b/t}{28,4 \cdot \epsilon \cdot \sqrt{k_{pl}}}$ $\bar{\lambda}_{pl}$ 0,314 --- ρ 1,000

$\bar{\lambda}_{pl}$ 0,314 ρ 1,000 Effective width equal to gross width [EN 1993-1-3, Equation (6.2)] [3 + $\psi \geq 0$ --- OK

Stress distribution | Compressive positive

Effective width b_{eff}

$\psi < 0,200$ $b_{eff} = \rho^* \cdot b_{eff} = \rho^* \cdot b^* \cdot (1 - \psi)$ $b_{eff} = 0,800 \cdot b_{eff}$

$\rho \leq 1,000$ OK $b_{eff} = \rho^* \cdot b_{eff} = \rho^* \cdot b^* \cdot (1 - \psi)$ 43,274 [mm]

$\rho \leq 1,000$ OK $b_{eff} = \rho^* \cdot b_{eff} = \rho^* \cdot b^* \cdot (1 - \psi)$ 43,274 [mm]

$\eta_{pl,web}$ 17,510 [mm] $\eta_{pl,web}$ 26,264 [mm]

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Plane elements with edge stiffeners | Distortional Buckling [EN 1993-1-3:2006, 5.3.1(5)]

Plane elements with edge stiffeners [EN 1993-1-3:2006, 5.3.2(3)]

(a) Actual system (b) Equivalent system

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

Determination of Spring Stiffness [K] [EN 1993-1-3:2006, 5.3.2(5)]

Inferior Edge Stiffener | Flange 1

Superior Edge Stiffener | Flange 2

Inferior Edge Stiffener | Flange 1

Superior Edge Stiffener | Flange 2

Flange 2

CG

$M_{y,Ed}$

Flange 1

Inferior Edge Stiffener | Flange 1

Compression

A_{eff} 96,559 [mm²]

b_{eff} 38,465 [mm]

$y_{eff,flange}$ 0,035 [mm]

$z_{eff,flange}$ 5,304 [mm]

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Superior Flange | $\eta_{pl,flange}$ | --- Tension

NOTE Effective width is equal to the real width

Superior Edge Stiffener | $\eta_{pl,web}$ | --- Tension

NOTE Effective width is equal to the real width

Effective C-Section Column | Local Buckling [EN 1993-1-3:2006, 4.3]

Effective C-Section Column Widths

Inferior Edge Stiffener	$\eta_{pl,web}$	16,774 [mm]
Inferior Flange	$\eta_{pl,flange}$	44,048 [mm]
Web	$\eta_{pl,web}$	43,274 [mm]
Superior Flange	$\eta_{pl,flange}$	--- [mm]
Superior Edge Stiffener	$\eta_{pl,web}$	--- [mm]

Effective Cross C-Section | Bending Moment $M_{y,Ed}$

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Superior Edge Stiffener | Flange 2

A_{eff} 0,000 [mm²]

b_{eff} 0,000 [mm]

$y_{eff,flange}$ 0,000 [mm]

$z_{eff,flange}$ 0,000 [mm]

Tension

$K_1 = \frac{E t^3}{4(1-\nu^2) b_1^2 h_w + b_1^3 + 0,5 b_1 b_2 h_w k_1}$ $k_1 = 0$ Flange 2 in Tension

$k_2 = \frac{A_2}{A_1}$ Flange 2 in Compression

E 210,000 [GPa]

ν 0,300

$b_1 \cdot h$ 90,000 [mm]

K_1 0,000

K 4,475 [EN 1993-1-3, Equation 5.10]

Determination of Elastic Critical Buckling Stress | σ_{cr} [EN 1993-1-3:2006, 5.3.2(7)]

$\sigma_{cr,el} = \frac{2 \sqrt{K E I_x}}{A_{eff}}$

K 4,475

E 210,000 [GPa]

$I_{x,inst}$ 3057,398 [mm⁴]

A_{eff} 96,559 [mm²]

Elastic Critical Buckling Stress, σ_{cr} for edge stiffener 1 1110,393 [MPa]

Relative Distortional Slenderness | $\bar{\lambda}_d$ [EN 1993-1-3:2006, 5.3.1(7)]

$\bar{\lambda}_d = \sqrt{f_{yk} / \sigma_{cr,el}}$

f_{yk} 350,000 [MPa]

Edge Stiffener 1 $\bar{\lambda}_d$ 0,561

Reduction χ_d Distortional Buckling Resistance | Stiffener Flexural Buckling [EN 1993-1-3:2006, 5.3.1(7)]

Edge Stiffener 1 $\bar{\lambda}_d$ 0,561 $\chi_{d,inst}$ 1,000 [EN 1993-1-3, Equation 5.2(2)]

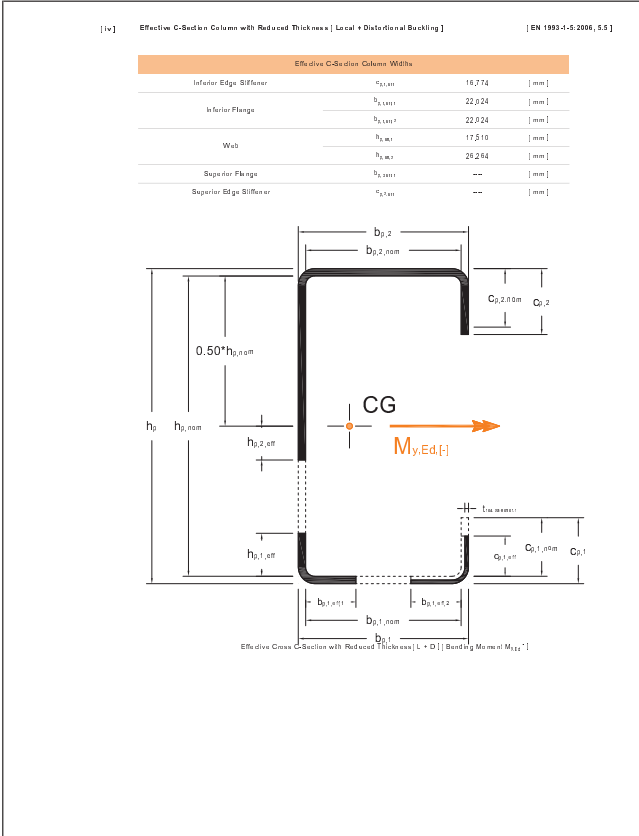
Edge Stiffener Reduced Thickness [EN 1993-1-3:2006, 5.3.2(12)]

In effective section properties, reduced effective area is represented using a reduced thickness for all elements in A_{eff}

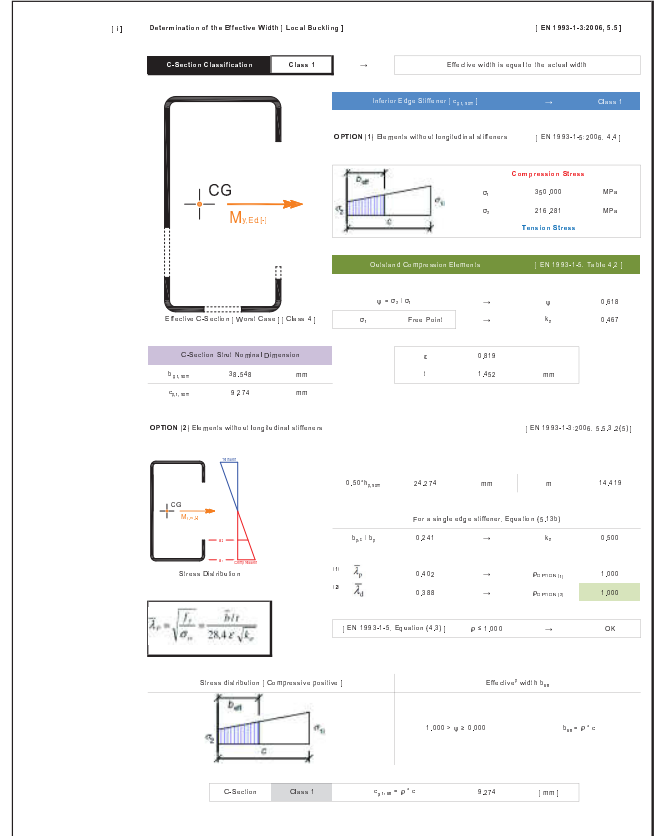
Edge Stiffener 1

$t_{eff,inst}$ 2,452 [mm]

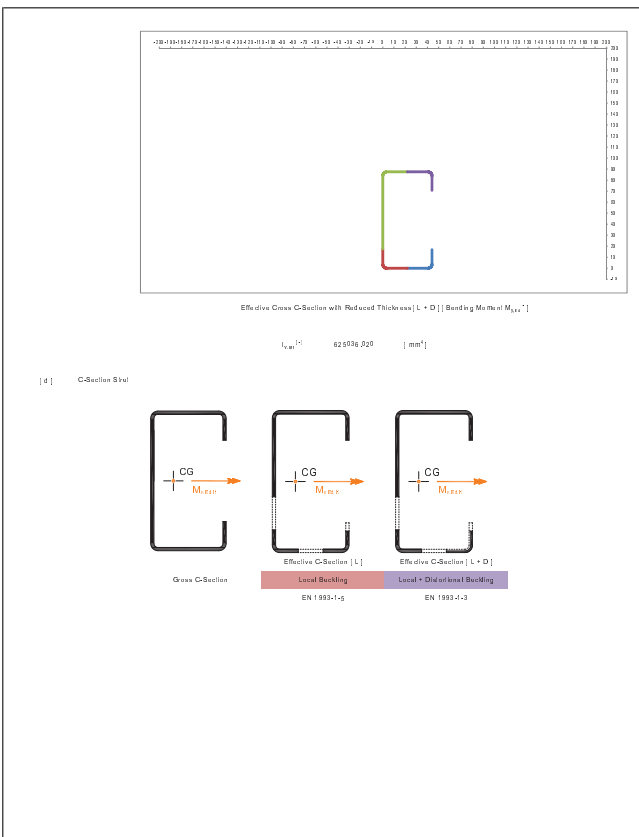
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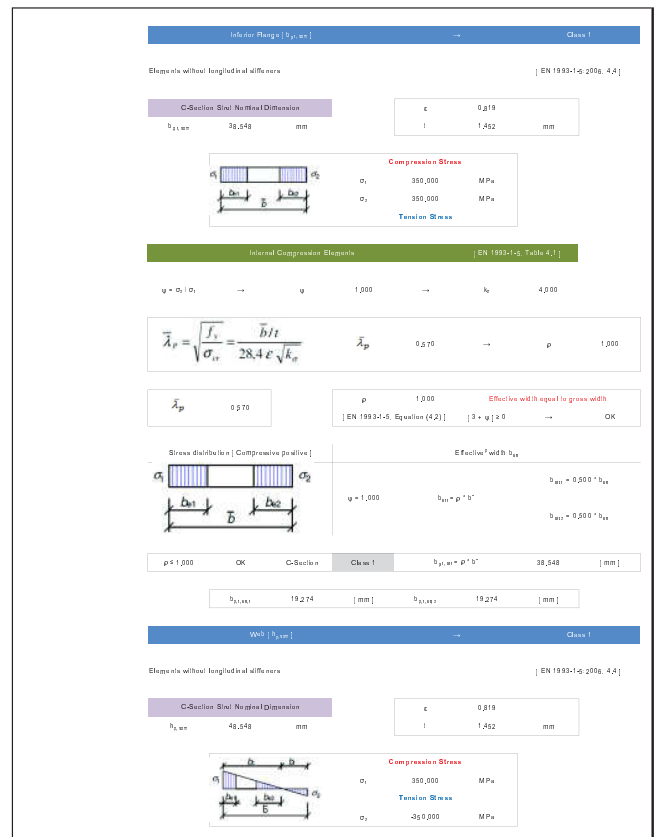
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Internal Compression Elements [EN 1993-1-3, Table 4.3] | [EN 1993-1-3, Table 4.3]

$\psi = \sigma_1 / \sigma_2 \rightarrow \psi = -0,800 \rightarrow k_1 = 23,900$

$$\bar{\lambda}_{pl} = \sqrt{\frac{f_{yk}}{\sigma_{cr}}} = \frac{b \cdot t}{28,4 \cdot \epsilon \cdot \sqrt{k_{\phi}}}$$

$\bar{\lambda}_{pl} = 0,284$ | $\rho = 1,000$ Effective width equal to gross width [EN 1993-1-3, Equation (6.2)] | $3 + \psi \geq 0 \rightarrow$ OK

Stress distribution [Compressive positive]

Effective width b_{eff}

$\psi < 0,020$

$b_{1,eff} = \rho \cdot b_1 = \rho \cdot [b' \cdot (1 - \psi)]$ | $b_{1,eff} = 0,600 \cdot b_{1,g}$

$b_{2,eff} = \rho \cdot b_2 = \rho \cdot [b' \cdot (1 - \psi)]$ | $b_{2,eff} = 0,600 \cdot b_{2,g}$

$\rho \leq 1,000$ OK	$b_{1,eff} = b' \cdot b_1 = b' \cdot [b' \cdot (1 - \psi)]$	24,274	[mm]
$\rho \leq 1,000$ OK	$b_{2,eff} = \rho \cdot b_2 = \rho \cdot [b' \cdot (1 - \psi)]$	24,274	[mm]
	$b_{1,ext} = 9,210$	14,564	[mm]

Superior Flange [Flange 1] | Tension

NOTE: Effective width is equal to the real width

Superior Edge Stiffener [Flange 1] | Tension

NOTE: Effective width is equal to the real width

Effective C-Section Strut [Local Buckling] [EN 1993-1-3, Table 4.3]

Effective C-Section Strut Widths			
Inferior Edge Stiffener	$s_{1,ext}$	9,274	[mm]
Inferior Flange	$b_{1,ext}$	38,548	[mm]
Web	$b_{w,ext}$	24,274	[mm]
Superior Flange	$b_{2,ext}$	---	[mm]
Superior Edge Stiffener	$s_{2,ext}$	---	[mm]

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Determination of Spring Stiffness [K] [EN 1993-1-3, Table 5.3.2(5)]

Inferior Edge Stiffener [Flange 1]

Superior Edge Stiffener [Flange 2]

$A_{1,1}$	42,183	[mm ²]
$b_{1,1}$	32,213	[mm]
$t_{1,1,ext}$	2,787	[mm]
$t_{1,1,ext}$	2,549	[mm]

Inferior Edge Stiffener [Flange 1] | Compression

$A_{2,2}$	0,000	[mm ²]
$b_{2,2}$	0,000	[mm]
$t_{2,2,ext}$	0,000	[mm]
$t_{2,2,ext}$	0,000	[mm]

Superior Edge Stiffener [Flange 2] | Tension

$$K_1 = \frac{E t^3}{4(1-\nu^2) h_1^2 h_w + h_1^3 + 0,5 h_2 b_2 h_w h_1}$$

[EN 1993-1-3, Equation 5.10]

E	210,000	[GPa]
ν	0,300	
$h_w = h$	58,000	[mm]
K_1	0,800	

$k_1 = 0$	Flange 2 in Tension
$k_2 = \frac{A_{1,1}}{A_{2,2}}$	Flange 2 in Compression

l	1,402	[mm]
b_1	32,213	[mm]
b_2	0,000	[mm]

K = 2,070 [EN 1993-1-3, Equation 5.10]

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Plane elements with edge stiffeners [Distortional Buckling] [EN 1993-1-3, Table 5.5.1(5)]

Effective Cross-Section [Bending Moment $M_{y,Ed,F}$]

Plane elements with edge stiffeners [EN 1993-1-3, Table 5.5.2] | [EN 1993-1-3, Table 5.5.2]

[a] Actual system | [b] Equivalent system

[EN 1993-1-3, 5.5.2(1)]

- $b_1 \leq 60$ OK
- $4\psi \leq \phi$ OK
- $\phi \leq 135$ OK

[EN 1993-1-3, 5.5.2(6)]

Round corners were considered in the effective cross-section area of the edge stiffener: A_e

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

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Determination of Elastic Critical Buckling Stress [$\sigma_{cr,el}$] [EN 1993-1-3, Table 5.5.2(7)]

$$\sigma_{cr,el} = \frac{2 \sqrt{K E I_x}}{A_e}$$

[EN 1993-1-3, Equation 5.15]

K	2,070
E	210,000 [GPa]
$I_{x,ext}$	377,566 [mm ⁴]
$A_{e,1}$	42,183 [mm ²]

Elastic Critical Buckling Stress $\sigma_{cr,el}$ for edge stiffener-1: 687,315 [MPa]

Relative Distortional Slenderness [$\bar{\lambda}_d$] [EN 1993-1-3, Table 5.5.1(7)]

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

[EN 1993-1-3, Equation 5.124]

f_{yb}	350,000 [MPa]
Edge Stiffener-1 $\bar{\lambda}_d$	0,759

Reduction χ_d Distortional Buckling Resistance [Stiffener Flexural Buckling] [EN 1993-1-3, Table 5.5.1(7)]

Edge Stiffener-1 $\bar{\lambda}_d$	0,759	$\chi_{d,ext}$	0,821
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[EN 1993-1-3, Equation 5.120]

Edge Stiffener Reduced Thickness [EN 1993-1-3, Table 5.5.2(12)]

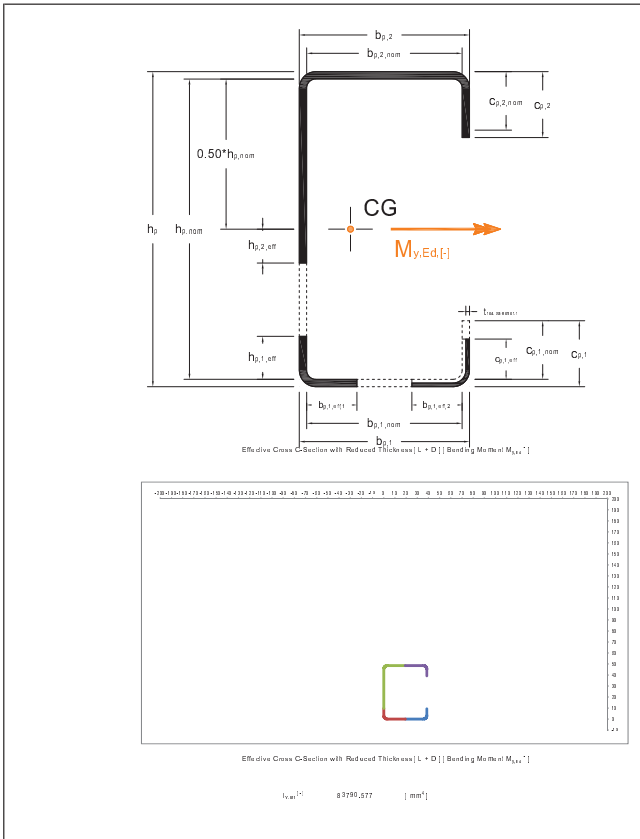
In effective section properties, reduced effective area is represented using a reduced thickness for all elements in A_e

Edge Stiffener-1 $t_{1,ext,red}$	1,338 [mm]
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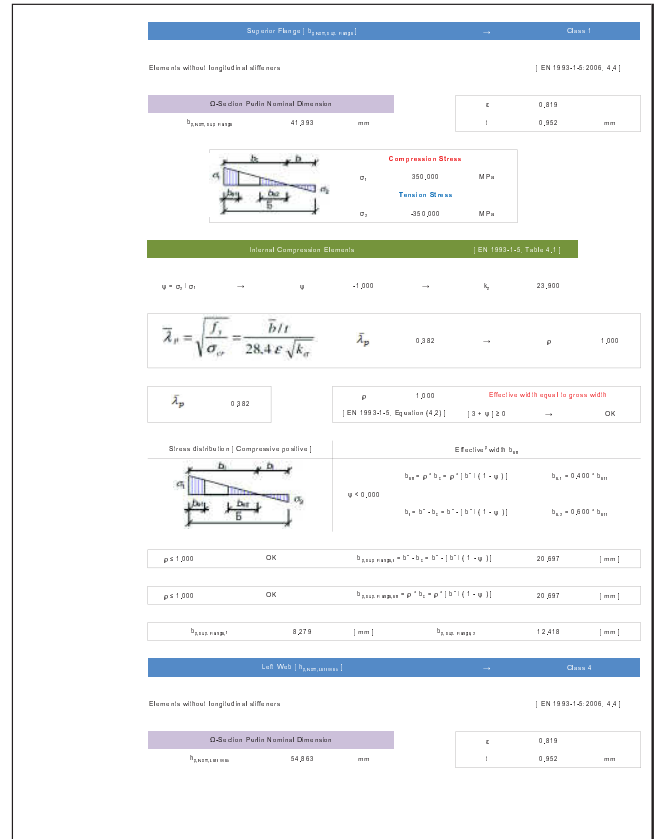
Effective C-Section Strut with Reduced Thickness [Local + Distortional Buckling] [EN 1993-1-3, Table 5.5.2(12)]

Effective C-Section Strut Widths			
Inferior Edge Stiffener	$s_{1,ext}$	9,274	[mm]
Inferior Flange	$b_{1,ext}$	19,274	[mm]
	$b_{1,ext}$	19,274	[mm]
Web	$b_{w,ext}$	9,210	[mm]
	$b_{w,ext}$	14,564	[mm]
Superior Flange	$b_{2,ext}$	---	[mm]
Superior Edge Stiffener	$s_{2,ext}$	---	[mm]

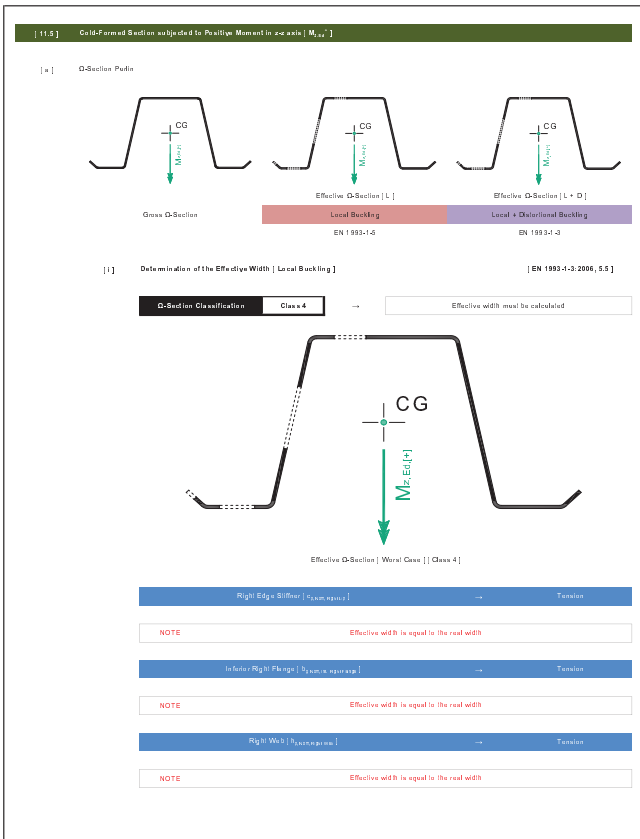
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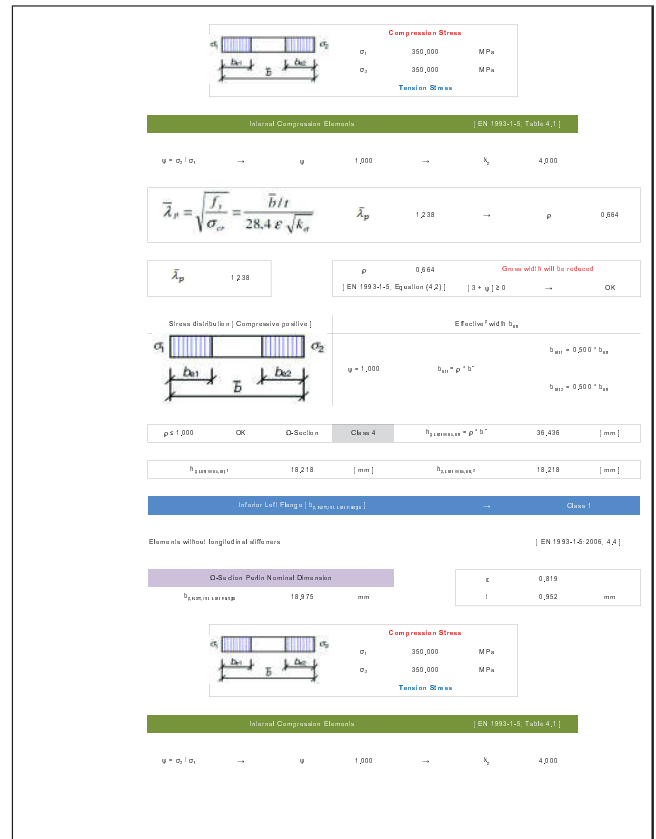
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$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{h}/t}{28,4 \cdot \epsilon \cdot \sqrt{k_{\sigma}}}$ $\bar{\lambda}_p$ 0,428 ρ 1,000

$\bar{\lambda}_p$ 0,428 ρ 1,000 Effective width equal to gross width
[EN 1993-1-6, Equation (6.2)] $3 \cdot \psi \geq 0$ OK

Show distribution | Compressive positive | Effective width b_{eff}

$\psi = 1,000$ $b_{eff} = \rho \cdot b$ $b_{eff} = 0,950 \cdot b_{gross}$
 $b_{eff} = 0,950 \cdot b_{gross}$

$\rho < 1,000$ OK Q-Section Class 1 $b_{eff,1} = 0,950 \cdot b_{gross} = \rho \cdot b$ 18,975 [mm]

$b_{eff,2} = 0,950 \cdot b_{gross}$ 9,488 [mm] $b_{eff,3} = 0,950 \cdot b_{gross}$ 9,488 [mm]

Left Edge Stiffener | $b_{eff,4} = 0,950 \cdot b_{gross}$ | Class 1

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

Q-Section Partial Dimension

ϵ	0,919
t	0,952 [mm]

$b_{eff,1} = 0,950 \cdot b_{gross}$ 18,975 [mm]

For a single edge stiffener, Equation (6.3c)

b_{11} / b_1 0,369 k_{σ} 0,560

$\bar{\lambda}_p = \sqrt{\frac{f_y}{\sigma_{cr}}} = \frac{\bar{h}/t}{28,4 \cdot \epsilon \cdot \sqrt{k_{\sigma}}}$ $\bar{\lambda}_p$ 0,423 ρ (approx) 1,000

Show distribution | Compressive positive | Effective width b_{eff}

$1,000 > \psi \geq 0,500$ $b_{eff} = \rho \cdot c$

Q-Section Class 1 $b_{eff,1} = 0,950 \cdot b_{gross} = \rho \cdot c$ 7,810 [mm]

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[iv] Effective Cross-Q-Section Profile with Reduced Thickness | Local + Distortional Buckling | [EN 1993-1-3:2006, 5.5]

Effective Q-Section Profile Widths

Right Edge Stiffener	$b_{eff,1} = 0,950 \cdot b_{gross}$	---	[mm]
Inferior Right Flange	$b_{eff,2} = 0,950 \cdot b_{gross}$	---	[mm]
Right Web	$b_{eff,3} = 0,950 \cdot b_{gross}$	---	[mm]
Superior Flange	$b_{eff,4} = 0,950 \cdot b_{gross}$	9,279	[mm]
Left Web	$b_{eff,5} = 0,950 \cdot b_{gross}$	12,418	[mm]
	$b_{eff,6} = 0,950 \cdot b_{gross}$	18,218	[mm]
Inferior Left Flange	$b_{eff,7} = 0,950 \cdot b_{gross}$	9,488	[mm]
Left Edge Stiffener	$b_{eff,8} = 0,950 \cdot b_{gross}$	7,810	[mm]

Effective Q-Section Profile with Reduced Thickness | L + D | Positive Moment in z-z axis $M_{z,Ed}$

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[i] Effective Q-Section Profile | Local Buckling | [EN 1993-1-3:2006, 4.3]

Effective Q-Section Profile Widths

Right Edge Stiffener	$b_{eff,1} = 0,950 \cdot b_{gross}$	---	[mm]
Inferior Right Flange	$b_{eff,2} = 0,950 \cdot b_{gross}$	---	[mm]
Right Web	$b_{eff,3} = 0,950 \cdot b_{gross}$	---	[mm]
Superior Flange	$b_{eff,4} = 0,950 \cdot b_{gross}$	20,597	[mm]
Left Web	$b_{eff,5} = 0,950 \cdot b_{gross}$	36,436	[mm]
Inferior Left Flange	$b_{eff,6} = 0,950 \cdot b_{gross}$	18,975	[mm]
Left Edge Stiffener	$b_{eff,7} = 0,950 \cdot b_{gross}$	7,810	[mm]

Effective Q-Section Profile | Positive Moment in z-z axis $M_{z,Ed}$

[ii] 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 slenderness

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[ii] C-Section Beam

Effective Q-Section Profile with Reduced Thickness | L + D | Positive Moment in z-z axis $M_{z,Ed}$

$I_{y,eff}^{(1)}$ 193614967 [mm⁴]

[iii] C-Section Beam

Gross C-Section Effective C-Section | L | Effective C-Section | L + D |

Local Buckling Local + Distortional Buckling

EN 1993-1-3 EN 1993-1-3

[I] Determination of the Effective Width | Local Buckling [EN 1993-1-5:2006, 5.5]

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

Inferior Edge Stiffener $c_{1,ext}$ → Tension

NOTE Effective width is equal to the real width

Inferior Flange $b_{1,ext}$ → Class 1

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

Compression Stress
 $\sigma_1 = 350,000$ MPa
Tension Stress
 $\sigma_2 = -350,000$ MPa

Effective C-Section | Worn Case | Class 4

C-Section Beam Nominal Dimension

ϵ	0,919
t	1,452 mm

Internal Compression Elements [EN 1993-1-5, Table 4.3]

$\psi = \sigma_1 / \sigma_2 \rightarrow \psi = -1,000 \rightarrow k_y = 23,900$

$$\bar{\lambda}_{p,fl} = \sqrt{\frac{f_{y,fl}}{\sigma_{cr,fl}}} = \frac{\bar{b}/t}{28,4 \epsilon \sqrt{k_{y,fl}}}$$

$\bar{\lambda}_{p,fl} = 0,273 \rightarrow \rho = 1,000$

Stress distribution | Compressive positive

Effective width b_{eff}

$\psi < 0,200$

$b_{eff} = \rho \cdot b_1 = \rho \cdot [b' \cdot (1 - \psi)]$	$b_{y1} = 0,600 \cdot b_{fl}$
$b_1 = b' \cdot \psi_1 = b' \cdot [1 - (\psi - \psi_1)]$	$b_{y2} = 0,600 \cdot b_{fl}$

$\rho \leq 1,000$ OK	$b_{y1,ext} = b' \cdot \psi_1 = b' \cdot [1 - (\psi - \psi_1)]$	22,524 [mm]	
$\rho \leq 1,000$ OK	$b_{y2,ext} = \rho \cdot b_2 = \rho \cdot [b' \cdot (1 - \psi)]$	22,524 [mm]	
$b_{y1,ext}$	9,010 [mm]	$b_{y2,ext}$	13,514 [mm]

Internal Compression Elements [EN 1993-1-5, Table 4.3]

$\psi = \sigma_1 / \sigma_2 \rightarrow \psi = -1,000 \rightarrow k_y = 23,900$

$$\bar{\lambda}_{p,fl} = \sqrt{\frac{f_{y,fl}}{\sigma_{cr,fl}}} = \frac{\bar{b}/t}{28,4 \epsilon \sqrt{k_{y,fl}}}$$

$\bar{\lambda}_{p,fl} = 0,273 \rightarrow \rho = 1,000$ Effective width equal to gross width [EN 1993-1-5, Equation (4.2)] | $3 \cdot \psi \geq 0 \rightarrow$ OK

Stress distribution | Compressive positive

Effective width b_{eff}

$\psi < 0,200$

$b_{y1,ext} = b' \cdot \psi_1 = b' \cdot [b' \cdot (1 - \psi)]$	22,524 [mm]
$b_{y2,ext} = \rho \cdot b_2 = \rho \cdot [b' \cdot (1 - \psi)]$	22,524 [mm]
$b_{y1,ext}$	9,010 [mm]
$b_{y2,ext}$	13,514 [mm]

Superior Edge Stiffener $c_{1,ext}$ → 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	$c_{1,ext}$	---	[mm]
Inferior Flange	$b_{1,ext}$	22,524	[mm]
Web	b_{web}	59,704	[mm]
Superior Flange	$b_{2,ext}$	22,524	[mm]
Superior Edge Stiffener	$c_{2,ext}$	---	[mm]

Web $b_{1,ext}$ → **Class 4**

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

C-Section Beam Nominal Dimension

ϵ	0,919
t	1,452 mm

$b_{web} = 118,648$ mm

Compression Stress
 $\sigma_1 = 350,000$ MPa
Tension Stress
 $\sigma_2 = 350,000$ MPa

Internal Compression Elements [EN 1993-1-5, Table 4.3]

$\psi = \sigma_1 / \sigma_2 \rightarrow \psi = 1,000 \rightarrow k_y = 4,000$

$$\bar{\lambda}_{p,fl} = \sqrt{\frac{f_{y,fl}}{\sigma_{cr,fl}}} = \frac{\bar{b}/t}{28,4 \epsilon \sqrt{k_{y,fl}}}$$

$\bar{\lambda}_{p,fl} = 1,754 \rightarrow \rho = 0,499$ Gross width will be reduced [EN 1993-1-5, Equation (4.2)] | $3 \cdot \psi \geq 0 \rightarrow$ OK

Stress distribution | Compressive positive

Effective width b_{eff}

$\psi = 1,000$

$b_{y1,ext} = \rho \cdot b' = 59,704$	$b_{y2,ext} = 0,500 \cdot b_{fl}$
$b_1 = b' \cdot \psi_1 = b' \cdot [1 - (\psi - \psi_1)]$	$b_{y2,ext} = 0,500 \cdot b_{fl}$

$\rho \leq 1,000$ OK	C-Section	Class 4	$b_{y1,ext} = \rho \cdot b'$	59,704 [mm]
$b_{y1,ext}$	29,852 [mm]	$b_{y2,ext}$	29,852 [mm]	

Superior Flange $b_{2,ext}$ → **Class 1**

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

C-Section Beam Nominal Dimension

ϵ	0,919
t	1,452 mm

$b_{web} = 45,048$ mm

Compression Stress
 $\sigma_1 = 350,000$ MPa
Tension Stress
 $\sigma_2 = -350,000$ MPa

Effective Cross C-Section | Bending Moment $M_{z,eff}$

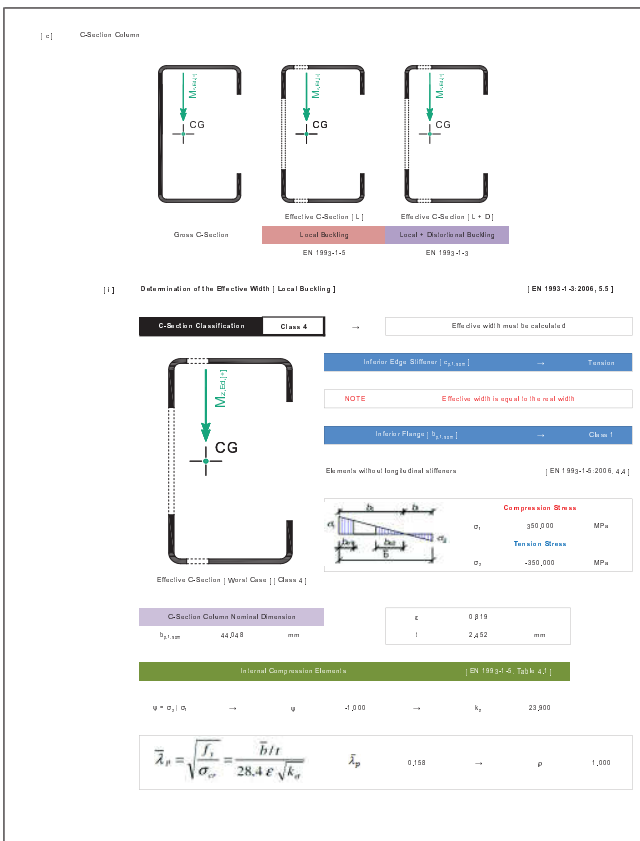
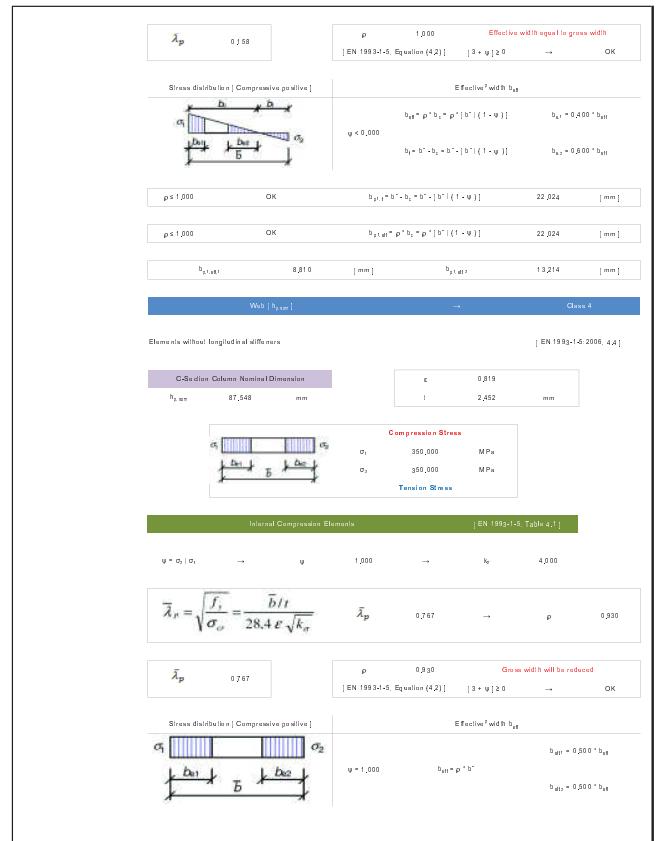
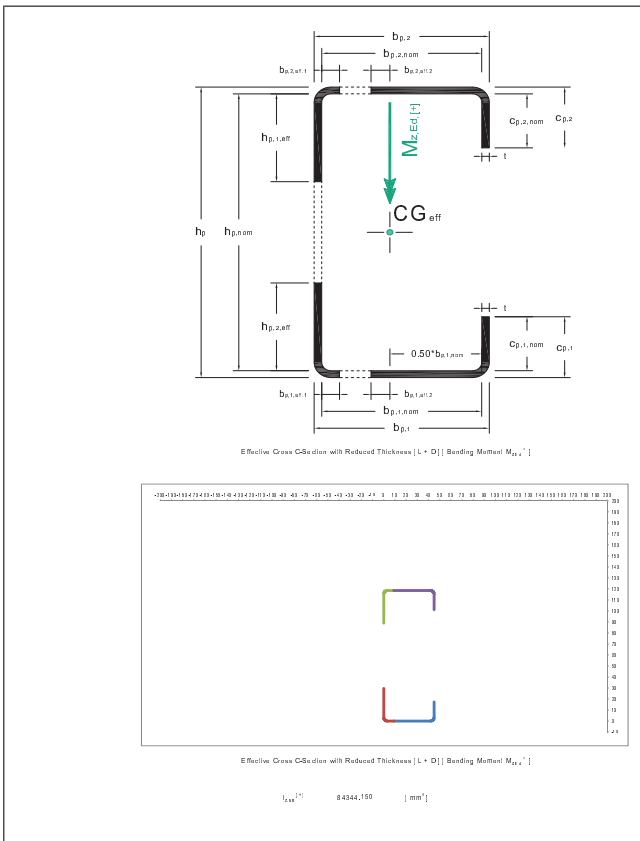
[III] Plane elements with edge stiffeners | Distortional Buckling [EN 1993-1-3:2006, 5.5.1(5)]

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	$c_{1,ext}$	---	[mm]
Inferior Flange	$b_{1,ext}$	9,010	[mm]
	$b_{2,ext}$	13,514	[mm]
	b_{web}	29,852	[mm]
Web	b_{web}	29,852	[mm]
	$b_{1,ext}$	9,010	[mm]
Superior Flange	$b_{2,ext}$	13,514	[mm]
Superior Edge Stiffener	$c_{2,ext}$	---	[mm]



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[1] Effective C-Section Column | Local Buckling | [EN 1993-1-5:2006, 4.3]

Effective C-Section Column Widths			
Inferior Edge Stiffener	$s_{1,eff}$	--	[mm]
Inferior Flange	$b_{1,eff}$	22,024	[mm]
Web	$b_{w,eff}$	81,384	[mm]
Superior Flange	$b_{3,eff}$	22,024	[mm]
Superior Edge Stiffener	$s_{3,eff}$	--	[mm]

[2] Plane elements with edge stiffeners | Distortional Buckling | [EN 1993-1-3:2006, 5.1.5]

NOTE: Inferior/Superior Flanges are both in tension/compression stress, so there isn't any reducing decrease of the distortional buckling in edge stiffeners.

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[3] C-Section Size

Effective C-Section [L] | Effective C-Section [L + D]

EN 1993-1-5 | EN 1993-1-3

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[1v] 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	$s_{1,eff}$	--	[mm]
Inferior Flange	$b_{1,eff}$	8,810	[mm]
	$b_{1,eff}$	13,214	[mm]
Web	$b_{w,eff}$	40,697	[mm]
	$b_{w,eff}$	40,697	[mm]
Superior Flange	$b_{3,eff}$	8,810	[mm]
	$b_{3,eff}$	13,214	[mm]
Superior Edge Stiffener	$s_{3,eff}$	--	[mm]

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[1] Determination of the Effective Width | Local Buckling | [EN 1993-1-5:2006, 5.5]

C-Section Classification: Class 3

Effective width is equal to the actual width

Inferior Edge Stiffener [$s_{1,eff}$] -- $T_{w,inf}$

NOTE: Effective width is equal to the real width

Inferior Flange [$b_{1,eff}$] -- Class 1

Elements with longitudinal stiffeners [EN 1993-1-5:2006, 4.4]

Compression Stress: 350,000 MPa
Tension Stress: -50,000 MPa

Effective C-Section | Worst Case | Class 4

C-Section Size | Nominal Dimension

$b_{1,net}$ 38,548 mm

ϵ 0,819
 t 1,452 mm

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

$\psi = \sigma_1 / \sigma_2$ -- ψ -1,000 -- ψ 29,800

$\bar{\lambda}_p = \sqrt{\frac{f_{t,c}}{\sigma_{cr}}} = \frac{\bar{b}/t}{28,4 \epsilon \sqrt{k_{\sigma}}}$ $\bar{\lambda}_p$ 0,233 -- ρ 1,000

$\bar{\lambda}_p$ 0,233

[EN 1993-1-5, Equation (4.2)] [$\rho > \psi/2.0$] -- OK

Stress Distribution | Compressive positive

Effective width b_{e1}

$\psi < 0,000$

$b_{e1} = \rho^2 \cdot b_1 = \rho^2 \cdot b' \cdot (1 - \psi)$ $b_{e1} = 0,600 \cdot b_{1,net}$

$b_{e2} = b' \cdot \psi_2 = b' \cdot \psi \cdot (1 - \psi)$ $b_{e2} = 0,600 \cdot b_{1,net}$

$\rho \leq 1,000$ OK $b_{e1} = b' \cdot b_1 = b' \cdot b' \cdot (1 - \psi)$ 19,274 [mm]

$\rho \leq 1,000$ OK $b_{e1,net} = \rho^2 \cdot b_1 = \rho^2 \cdot b' \cdot (1 - \psi)$ 19,274 [mm]

$b_{1,net}$ 7,210 [mm] $b_{1,eff}$ 11,564 [mm]

Web [h_{w,eff}] → **Class 3**

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.6]

C-Section Steel Nominal Dimension

ε	0,919
t	1,452 mm

h_{w,eff} 48,548 mm

Internal Compression Elements [EN 1993-1-6, Table 4.1]

ψ = σ₁ / σ₂ → ψ 1,000 → h_y 4,000

$$\bar{\lambda}_{p1} = \sqrt{\frac{f_{y1}}{\sigma_{cr}}} = \frac{b/t}{28,4 \cdot \sqrt{k_{cr}}}$$

$\bar{\lambda}_{p1}$ 0,718 → ρ 0,966

ρ 0,966 **Gross width will be reduced**
[EN 1993-1-6, Equation (6.2)] | 3 + ψ ≥ 0 → OK

Stress distribution [Compressive positive]

Effective width b_{eff}

ψ = 1,000 b_{eff} = ρ · b

h_{2,eff} = 0,500 · b_{eff}
h_{1,eff} = 0,500 · b_{eff}

ρ ≤ 1,000	OK	Class 3	h _{2,eff} = ρ · b	48,548	[mm]
-----------	----	---------	----------------------------	--------	------

h_{2,eff} 24,274 [mm] h_{1,eff} 24,274 [mm]

Superior Flange [h_{1,eff}] → **Class 1**

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

C-Section Steel Nominal Dimension

ε	0,919
t	1,452 mm

h_{1,eff} 38,248 mm

Effective Cross C-Section [Bending Moment M_{z,Ed}]

[III] **Plane elements with edge stiffeners [Diagonal 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 diagonal buckling in edge stiffeners.

[IV] **Effective C-Section Steel with Reduced Thickness [Local + Diagonal Buckling]** [EN 1993-1-5:2006, 5.5]

Effective C-Section Steel Widths

Element	h _{1,eff} [mm]	h _{2,eff} [mm]
Inferior Edge Stiffener	h _{1,eff}	---
Inferior Flange	h _{1,eff}	7,210
Web	h _{w,eff}	24,274
Superior Flange	h _{1,eff}	7,210
Superior Edge Stiffener	h _{1,eff}	---

Internal Compression Elements [EN 1993-1-6, Table 4.1]

ψ = σ₁ / σ₂ → ψ -0,500 → h_y 23,000

$$\bar{\lambda}_{p1} = \sqrt{\frac{f_{y1}}{\sigma_{cr}}} = \frac{b/t}{28,4 \cdot \sqrt{k_{cr}}}$$

$\bar{\lambda}_{p1}$ 0,233 → ρ 1,000

ρ 1,000 **Effective width equal to gross width**
[EN 1993-1-6, Equation (6.2)] | 3 + ψ ≥ 0 → OK

Stress distribution [Compressive positive]

Effective width b_{eff}

ψ < 0,200

b_{eff} = ρ · b₁ = ρ · b₂ · (1 - ψ) | b₁ = 0,600 · b₂
b₁ = b₂ · b₁ · b₂ · (1 - ψ) | b₂ = 0,500 · b₂

ρ ≤ 1,000	OK	b _{1,eff} = b ₁ = b ₂ · (1 - ψ)	19,274	[mm]
ρ ≤ 1,000	OK	b _{2,eff} = ρ · b ₂ = ρ · b ₁ · (1 - ψ)	19,274	[mm]

h_{1,eff} 7,210 [mm] h_{2,eff} 11,564 [mm]

Superior Edge Stiffener [h_{1,eff}] → **Tension**

NOTE Effective width is equal to the real width

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

Effective C-Section Steel Widths

Element	h _{1,eff} [mm]	h _{2,eff} [mm]
Inferior Edge Stiffener	h _{1,eff}	---
Inferior Flange	h _{1,eff}	19,274
Web	h _{w,eff}	48,548
Superior Flange	h _{1,eff}	19,274
Superior Edge Stiffener	h _{1,eff}	---

Effective Cross C-Section with Reduced Thickness [L + D] [Bending Moment M_{z,Ed}]

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

Effective C-Section Steel Widths

Element	h _{1,eff} [mm]	h _{2,eff} [mm]
Inferior Edge Stiffener	h _{1,eff}	---
Inferior Flange	h _{1,eff}	19,274
Web	h _{w,eff}	48,548
Superior Flange	h _{1,eff}	19,274
Superior Edge Stiffener	h _{1,eff}	---

I_{pl}¹ 4410,416 [mm⁴]

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[11.6] Cold-Formed Section subjected to Negative Moment in case min | $M_{Ed} \leq 0$ |

[*] D-Section Profile

[!] Determination of the Effective Width | Local Buckling | [EN 1993-1-5, 5.3.2(5)]

D-Section Classification: **Class 4** → Effective width must be calculated

Effective D-Section | Worst Case | [Class 4]

Right Edge Stiffener | [$b_{1,local} \leq b_{1,eff}$] → **Class 1**

OPTION [2] Elements without longitudinal stiffeners [EN 1993-1-5:2006, 5.3.2(5)]

D-Section Profile Nominal Dimension

t	0,819
$b_{1,max,unst}$	7,910
$b_{1,max,st}$	18,975

For a single edge stiffener, Equation (5.13c)

b_1 / b_2	0,389	k_1	0,560
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Right Web | [$b_{1,local} \leq b_{1,eff}$] → **Class 4**

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

D-Section Profile Nominal Dimension

t	0,819
$b_{1,max,unst}$	54,963

Compression Stress

σ_1	350,000	MPa
σ_2	350,000	MPa

Tension Stress

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

$\psi = \sigma_1 / \sigma_2$ → ψ 1,000 → k_1 4,000

$$\bar{\lambda}_{p1} = \sqrt{\frac{f_{y1}}{\sigma_{cr}}} = \frac{\bar{b}/l}{28,4 \cdot e \cdot \sqrt{k_{r1}}}$$

$\bar{\lambda}_{p1}$ 1,238 → ρ 0,864

$\bar{\lambda}_{p1}$ 1,238 [EN 1993-1-5, Equation (4.2)] | $3 \cdot \psi \geq 2,0$ → OK

Stress distribution | Compressive positive | Effective width b_{ef}

$\psi = 1,000$ $b_{ef} = \rho \cdot b^*$ $b_{ef} = 0,900 \cdot b_{un}$ $b_{ef} = 0,900 \cdot b_{un}$

$\rho \leq 1,000$ OK D-Section **Class 4** $b_{1,local,unst} = \rho \cdot b^*$ 38,406 [mm]

$b_{1,local,st}$ 18,218 [mm] $b_{1,local,st,2}$ 18,218 [mm]

Superior Flange | [$b_{1,local} \leq b_{1,eff}$] → **Class 1**

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

D-Section Profile Nominal Dimension

t	0,819
$b_{1,max,unst}$	41,393

Compression Stress

σ_1	350,000	MPa
σ_2	-350,000	MPa

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Stress distribution | Compressive positive | Effective width b_{ef}

$1,000 > \psi \geq 0,900$ $b_{ef} = \rho \cdot c$

D-Section **Class 1** $b_{1,local,unst} = \rho \cdot c$ 7,910 [mm]

Internal Right Flange | [$b_{1,local} \leq b_{1,eff}$] → **Class 1**

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

D-Section Profile Nominal Dimension

t	0,819
$b_{1,max,unst}$	18,975

Compression Stress

σ_1	350,000	MPa
σ_2	350,000	MPa

Tension Stress

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

$\psi = \sigma_1 / \sigma_2$ → ψ 1,000 → k_1 4,000

$$\bar{\lambda}_{p1} = \sqrt{\frac{f_{y1}}{\sigma_{cr}}} = \frac{\bar{b}/l}{28,4 \cdot e \cdot \sqrt{k_{r1}}}$$

$\bar{\lambda}_{p1}$ 0,428 → ρ 1,000

$\bar{\lambda}_{p1}$ 0,428 [EN 1993-1-5, Equation (4.2)] | $3 \cdot \psi \geq 2,0$ → OK

Effective width equal to gross width

Stress distribution | Compressive positive | Effective width b_{ef}

$\psi = 1,000$ $b_{ef} = \rho \cdot b^*$ $b_{ef} = 0,900 \cdot b_{un}$ $b_{ef} = 0,900 \cdot b_{un}$

$\rho \leq 1,000$ OK D-Section **Class 1** $b_{1,local,unst} = \rho \cdot b^*$ 18,975 [mm]

$b_{1,local,unst}$ 9,488 [mm] $b_{1,local,unst,2}$ 9,488 [mm]

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

$\psi = \sigma_1 / \sigma_2$ → ψ -1,000 → k_1 23,900

$$\bar{\lambda}_{p1} = \sqrt{\frac{f_{y1}}{\sigma_{cr}}} = \frac{\bar{b}/l}{28,4 \cdot e \cdot \sqrt{k_{r1}}}$$

$\bar{\lambda}_{p1}$ 0,982 → ρ 1,000

$\bar{\lambda}_{p1}$ 0,982 [EN 1993-1-5, Equation (4.2)] | $3 \cdot \psi \geq 2,0$ → OK

Effective width equal to gross width

Stress distribution | Compressive positive | Effective width b_{ef}

$\psi < 0,900$ $b_{ef} = \rho \cdot b^* \cdot \psi \cdot (1 - \psi)$ $b_{ef} = 0,400 \cdot b_{un}$ $b_{ef} = 0,800 \cdot b_{un}$

$\rho \leq 1,000$ OK $b_{1,local,unst} = \rho \cdot b^* \cdot \psi \cdot (1 - \psi)$ 20,697 [mm]

$\rho \leq 1,000$ OK $b_{1,local,unst} = \rho \cdot b^* \cdot \psi \cdot (1 - \psi)$ 20,697 [mm]

$b_{1,local,unst}$ 9,279 [mm] $b_{1,local,unst,2}$ 12,418 [mm]

Left Web | [$b_{1,local} \leq b_{1,eff}$] → **Tension**

NOTE Effective width is equal to the real width

Internal Left Flange | [$b_{1,local} \leq b_{1,eff}$] → **Tension**

NOTE Effective width is equal to the real width

Left Edge Stiffener | [$b_{1,local} \leq b_{1,eff}$] → **Tension**

NOTE Effective width is equal to the real width

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

Effective D-Section Purlin Widths			
Right Edge Stiffener	$s_{e, \text{Right Edge}}$	7,910	[mm]
Inferior Right Flange	$b_{e, \text{Inferior Right}}$	18,975	[mm]
Right Web	$b_{e, \text{Right Web}}$	35,436	[mm]
Superior Flange	$b_{e, \text{Superior}}$	20,897	[mm]
Left Web	$b_{e, \text{Left Web}}$	---	[mm]
Inferior Left Flange	$b_{e, \text{Inferior Left}}$	---	[mm]
Left Edge Stiffener	$s_{e, \text{Left Edge}}$	---	[mm]

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

NOTE Distortional buckling effects are not considered for this type of structure.

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Effective D-Section Purlin with Reduced Thickness [L + D] | Negative Moment in x-z axis, M_{x11}

I_{x11}^* 163 614,967 [mm⁴]

[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

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

Effective D-Section Purlin Widths			
Right Edge Stiffener	$s_{e, \text{Right Edge}}$	7,910	[mm]
Inferior Right Flange	$b_{e, \text{Inferior Right}}$	9,488	[mm]
Right Web	$b_{e, \text{Right Web}}$	18,218	[mm]
Superior Flange	$b_{e, \text{Superior}}$	8,279	[mm]
Left Web	$b_{e, \text{Left Web}}$	---	[mm]
Inferior Left Flange	$b_{e, \text{Inferior Left}}$	---	[mm]
Left Edge Stiffener	$s_{e, \text{Left Edge}}$	---	[mm]

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[i] Determination of the Effective Width | Local Buckling [EN 1993-1-5:2006, 5.5]

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

Inferior Edge Stiffener [EN 1993-1-5:2006, 5.5.1] → **Class 4**

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

Compression Stress: $\sigma_c = 350,000$ MPa
Tension Stress: $\sigma_t = 350,000$ MPa

Distortional Compression Elements [EN 1993-1-5:2006, Table 6.2]

$\psi = \sigma_t / \sigma_c \rightarrow \psi = 1,000$
Free Paint → $k_s = 0,400$

C-Section Beam Nominal Dimension

$b_{1, \text{top}}$	45,048	mm
$c_{1, \text{top}}$	17,274	mm

$$\bar{\lambda}_{p1} = \sqrt{\frac{f_{y1}}{\sigma_{cr}}} = \frac{\bar{b}}{28,4 \epsilon \sqrt{k_{\sigma}}}$$

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 5.5.3 (2)(5)]

For a single edge stiffener, Equation (6.13c)

b_{e1} / b_1	0,383	→	k_s	0,586
α	0,819	→	l	1,452
λ_{p1}	0,780	→	$\rho_{\text{compression}}$	0,973
λ_{p2}	0,668	→	ρ_{tension}	1,000

[EN 1993-1-5, Equation (6.31)] $\rho \leq 1,000$ → **OK**

Stress distribution | Compressive positive

Effective width b_{e1}

$1,000 + \psi \geq 0,900$ → $b_{e1} = \rho^* c$

C-Section	Class 4	$\rho_{1, \text{top}} = \rho^* c$	17,274	[mm]
-----------	---------	-----------------------------------	--------	------

Inferior Flange | $b_{1,inf}$ | → **Class 1**

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.6.1]

C-Section Beam Nominal Dimension

ϵ	0,919
t	1,452 mm

$b_{1,inf}$ 45,048 mm

Compression Stress
 σ_1 350,000 MPa

Tension Stress
 σ_2 -350,000 MPa

Internal Compression Elements [EN 1993-1-5, Table 4.3]

$\psi = \sigma_1 / \sigma_2$ → ψ -1,000 → k_s 23,900

$\bar{\lambda}_{pl} = \sqrt{\frac{f_{yk}}{\sigma_{cr}}} = \frac{\bar{b}/l}{28,4 \cdot \epsilon \cdot \sqrt{k_s}}$ $\bar{\lambda}_{pl}$ 0,273 → ρ 1,000

$\bar{\lambda}_{pl}$ 0,273 ρ 1,000 **Effective width equal to gross width**
[EN 1993-1-5, Equation (6.2)] | $3 \cdot \psi \geq 0$ → OK

Stress distribution | Compressive positive | **Effective width b_{eff}**

$\psi < 0,000$

$b_{ed,1} = \rho \cdot b_1 \cdot \psi^{-1} \cdot [1 - \psi]$ $b_{ed,1} = 0,900 \cdot b_1$

$b_{ed,2} = \rho \cdot b_2 \cdot \psi^{-1} \cdot [1 - \psi]$ $b_{ed,2} = 0,900 \cdot b_2$

$\rho \leq 1,000$ OK $b_{1,ed1} = b_1 \cdot \psi^{-1} \cdot [1 - \psi]$ 22,524 [mm]

$\rho \leq 1,000$ OK $b_{1,ed2} = \rho \cdot b_2 \cdot \psi^{-1} \cdot [1 - \psi]$ 22,524 [mm]

$b_{1,ed1}$ 9,010 [mm] $b_{1,ed2}$ 13,514 [mm]

Web | h_{web} | → **Class 4**

NOTE **Effective width is equal to the real width**

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

$\psi = \sigma_1 / \sigma_2$ → ψ 1,000

σ_1 Free Point → k_s 0,499

OPTION (2) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 5.3.2(5)]

$\bar{\lambda}_{pl} = \sqrt{\frac{f_{yk}}{\sigma_{cr}}} = \frac{\bar{b}/l}{28,4 \cdot \epsilon \cdot \sqrt{k_s}}$

For a single edge stiffener, Equation (5.3.2)

$b_{1,1} / b_1$	1,000	→	k_s	1,123
$\bar{\lambda}_{pl}$	0,280	→	$\rho_{max(1)}$	0,973
$\bar{\lambda}_{pl}$	0,492	→	$\rho_{max(2)}$	1,000

[EN 1993-1-5, Equation (6.2)] $\rho \leq 1,000$ → OK

Stress distribution | Compressive positive | **Effective width b_{eff}**

$1,000 - \psi \geq 0,000$ $b_{ed} = \rho \cdot c$

C-Section **Class 4** $c_{1,ed}$ $\rho \cdot c$ 17,274 [mm]

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

Effective C-Section Beam Widths

Inferior Edge Stiffener	$c_{1,ed}$	17,274 [mm]
Inferior Flange	$b_{1,ed1}$	22,524 [mm]
Web	h_{ed}	---
Superior Flange	$b_{1,ed2}$	22,524 [mm]
Superior Edge Stiffener	$c_{2,ed}$	17,274 [mm]

Superior Flange | $b_{1,sup}$ | → **Class 1**

Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.6.1]

C-Section Beam Nominal Dimension

ϵ	0,919
t	1,452 mm

$b_{1,sup}$ 45,048 mm

Compression Stress
 σ_1 350,000 MPa

Tension Stress
 σ_2 -350,000 MPa

Internal Compression Elements [EN 1993-1-5, Table 4.3]

$\psi = \sigma_1 / \sigma_2$ → ψ -1,000 → k_s 23,900

$\bar{\lambda}_{pl} = \sqrt{\frac{f_{yk}}{\sigma_{cr}}} = \frac{\bar{b}/l}{28,4 \cdot \epsilon \cdot \sqrt{k_s}}$ $\bar{\lambda}_{pl}$ 0,273 → ρ 1,000

$\bar{\lambda}_{pl}$ 0,273 ρ 1,000 **Effective width equal to gross width**
[EN 1993-1-5, Equation (6.2)] | $3 \cdot \psi \geq 0$ → OK

Stress distribution | Compressive positive | **Effective width b_{eff}**

$\psi < 0,000$

$b_{ed,1} = \rho \cdot b_1 \cdot \psi^{-1} \cdot [1 - \psi]$ $b_{ed,1} = 0,900 \cdot b_1$

$b_{ed,2} = \rho \cdot b_2 \cdot \psi^{-1} \cdot [1 - \psi]$ $b_{ed,2} = 0,900 \cdot b_2$

$\rho \leq 1,000$ OK $b_{1,ed1} = b_1 \cdot \psi^{-1} \cdot [1 - \psi]$ 22,524 [mm]

$\rho \leq 1,000$ OK $b_{1,ed2} = \rho \cdot b_2 \cdot \psi^{-1} \cdot [1 - \psi]$ 22,524 [mm]

$b_{1,ed1}$ 9,010 [mm] $b_{1,ed2}$ 13,514 [mm]

Superior Edge Stiffener | $c_{1,sup}$ | → **Class 4**

OPTION (1) Elements without longitudinal stiffeners [EN 1993-1-5:2006, 4.6.1]

C-Section Beam Nominal Dimension

ϵ	0,919
t	1,452 mm

$b_{1,sup}$ 17,274 mm

$c_{1,sup}$ 17,274 mm

Effective Cross-Section | Bending Moment M_{Ed1} |

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

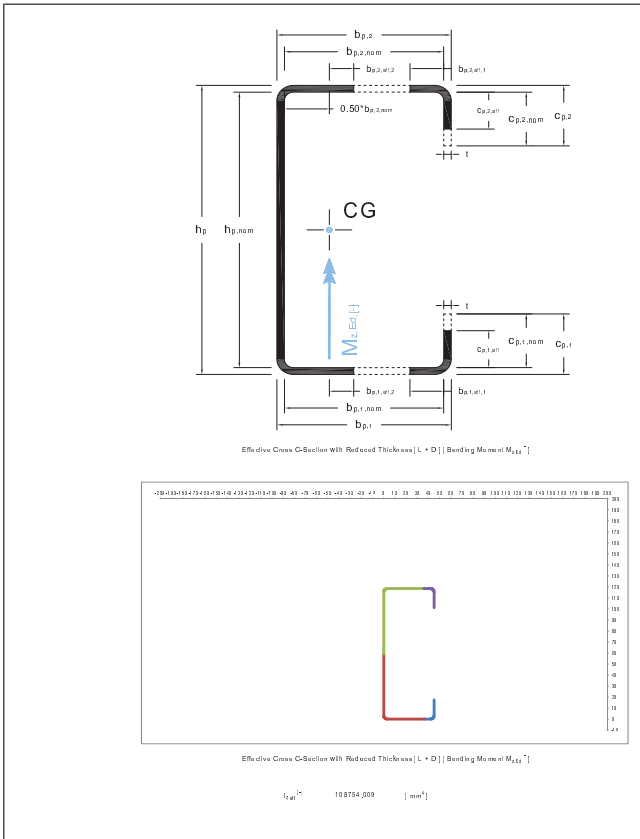
NOTE Inferior/Superior Flanges are both in tension/compression stress, so there isn't any reduction because of the diagonal buckling in edge stiffeners.

Effective C-Section Beam with Reduced Thickness | Local & Diagonal Buckling [EN 1993-1-5:2006, 5.5]

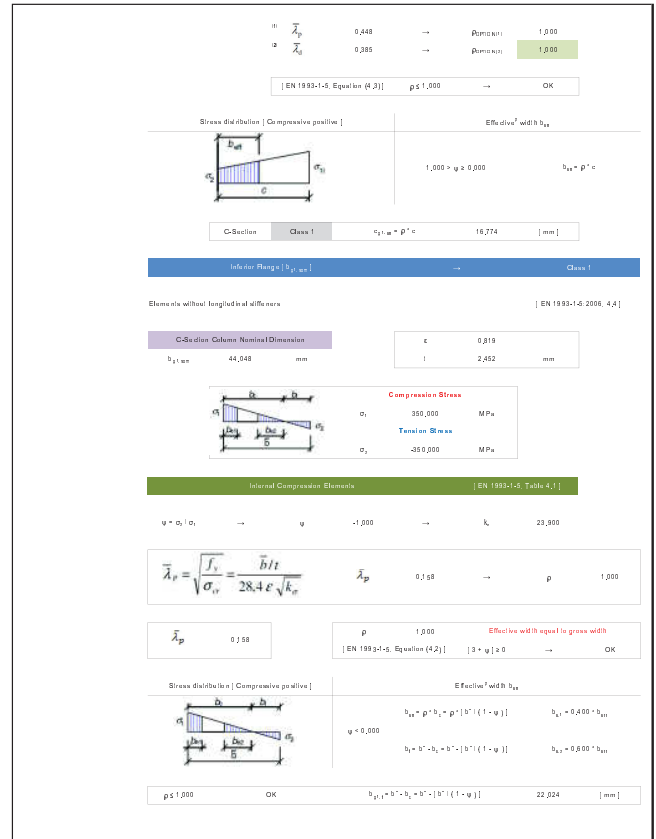
Effective C-Section Beam Widths

Inferior Edge Stiffener	$c_{1,ed}$	17,274 [mm]
Inferior Flange	$b_{1,ed1}$	9,010 [mm]
Web	h_{ed}	---
Superior Flange	$b_{1,ed2}$	13,514 [mm]
Superior Edge Stiffener	$c_{2,ed}$	17,274 [mm]

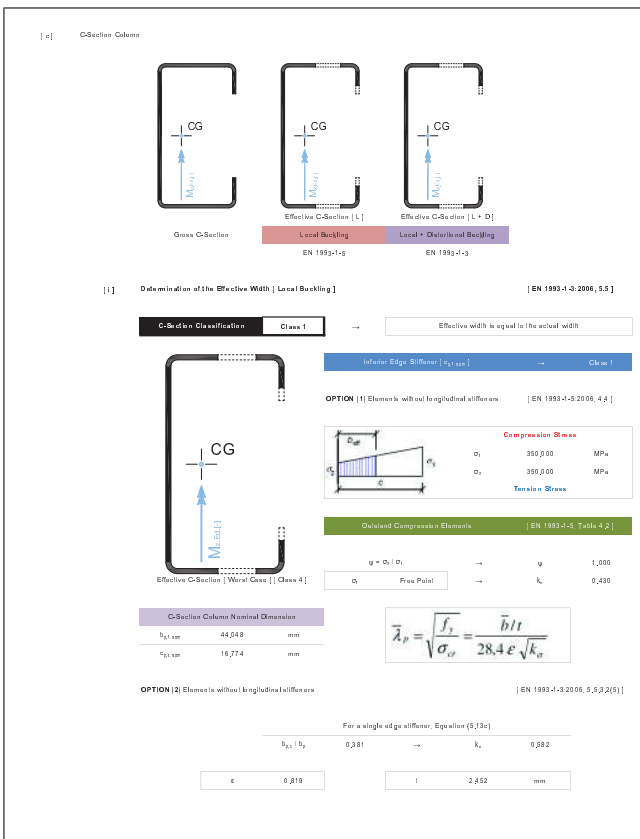
Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes		Office: ---	Author: JOSE ANTONIO
Code: Eurocode	Reference: EN 1990 | EN 1991 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1,000		Client: COIMBRA UNIVERSITY	



Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes		Office: ---	Author: JOSE ANTONIO
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Design of a Photovoltaic Structure, Padrat configuration, according to Eurocodes		Office: ...	Author: JOSE ANTONIO
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Superior Edge Stiffener | $c_{1,100}$ | Class 1

OPTION (1) Elements without longitudinal stiffeners | EN 1993-1-5:2006, 4.3 |

C-Section Column Nominal Dimension		ϵ	0.919
$b_{1,100}$	44.948 mm	t	2.452 mm
$c_{1,100}$	16.274 mm		

Original Compression Elements | EN 1993-1-5:2006, Table 4.2 |

$\psi = \sigma_c / \sigma_{yk}$ → $\psi = 1.000$
 α (Free Point) → $k_c = 0.930$

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

For a single edge stiffener, Equation (5.23c):
 $\lambda_{cr} = \sqrt{\frac{I_x}{\sigma_{yk}}} = \frac{b_{1,100}}{28.4 \epsilon \sqrt{k_c}}$
 $\lambda_{cr} = 0.381$ → $k_c = 0.582$
 $\lambda_{cr} = 0.448$ → $\rho_{lim,comp} = 1.000$
 $\lambda_{cr} = 0.385$ → $\rho_{lim,tens} = 1.000$

| EN 1993-1-5, Equation (4.31) | $\rho \leq 1.000$ → OK

Stress distribution | Compressive positive | Effective width b_{eff}
 $1.000 > \psi \geq 0.500$ → $b_{eff} = \rho \cdot c$

C-Section	Class 1	$c_{1,100} + \rho \cdot c$	16,274 [mm]
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[iv] Effective C-Section Column with Reduced Thickness | Local + Distortional Buckling | EN 1993-1-5:2006, 5.3 |

Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{1,100}$	16,274 [mm]	
Inferior Flange	$b_{1,100}$	8,810 [mm]	
Web	$b_{2,100}$	13,214 [mm]	
Superior Flange	$b_{3,100}$	8,810 [mm]	
Superior Edge Stiffener	$c_{2,100}$	13,214 [mm]	

Effective Cross-C-Section with Reduced Thickness | L + D | Bending Moment $M_{y,eff}$ |

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Code: Eurocode	References: EN 1990 EN 1991 EN 1993	Date: 05/09/2019	Project: MASTER THESIS
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[iii] Effective C-Section Column | Local Buckling | EN 1993-1-5:2006, 4.3 |

Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{1,100}$	16,274 [mm]	
Inferior Flange	$b_{1,100}$	22,024 [mm]	
Web	$b_{2,100}$	--- [mm]	
Superior Flange	$b_{3,100}$	22,024 [mm]	
Superior Edge Stiffener	$c_{2,100}$	16,274 [mm]	

Effective Cross-C-Section | Bending Moment $M_{y,eff}$ |

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

NOTE: Inferior/Superior Flanges are both in tension/compression stress, so there isn't any reducing increase of the distortional buckling in edge stiffeners.

Design of a Photovoltaic Structure, Padrat configuration, according to Eurocodes		Office: ...	Author: JOSE ANTONIO
Code: Eurocode	References: EN 1990 EN 1991 EN 1993	Date: 05/09/2019	Project: MASTER THESIS
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[iv] C-Section Size

Effective Cross-C-Section with Reduced Thickness | L + D | Bending Moment $M_{y,eff}$ |

$I_{y,eff}^{(C)} = 153.816.866 [mm^4]$

[iv] C-Section Size

Gross C-Section | Effective C-Section | L | | Effective C-Section | L + D |

Local Buckling | Local + Distortional Buckling

EN 1993-1-5 | EN 1993-1-5

[1] 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

Inferior Edge Stiffener | $c_{1,inst}$ | Class 1

OPTION (1) Elements without longitudinal stiffeners | [EN 1993-1-3:2006, 4.3]

Compression Stress: $\sigma_1 = 350,000$ MPa
Tension Stress: $\sigma_2 = -350,000$ MPa

Outstand Compression Elements | [EN 1993-1-3, Table 4.2]

$\psi = c_1 / c_2 \rightarrow \psi = -1,000 \rightarrow k_x = 23,900$

α_1 Free Paint → $k_x = 0,430$

C-Section Slab Nominal Dimension

$b_{1,inst}$	38,548	mm
$c_{1,inst}$	9,274	mm

$$\bar{\lambda}_{p1} = \sqrt{\frac{f_{y1}}{\sigma_{cr}}} = \frac{\bar{b} \sqrt{t}}{28,4 \epsilon \sqrt{k_x}}$$

OPTION (2) Elements without longitudinal stiffeners | [EN 1993-1-3:2006, 5.5.2.2(3)]

For a single edge stiffener, Equation (5.13b)

b_{11} / b_1	0,241	→	k_x	0,050
----------------	-------	---	-------	-------

ϵ	0,819			
$\bar{\lambda}_{p1}$	0,419	→	$\rho_{min,inst}$	1,000
$\bar{\lambda}_{p2}$	0,388	→	$\rho_{min,inst}$	1,000

[EN 1993-1-3, Equation (4.3)] $\rho \leq 1,000 \rightarrow$ OK

Stress distribution | Compressive positive | Effective width b_{eff}

$1,000 > \psi \geq 0,050 \rightarrow b_{eff} = \rho^* c$

C-Section	Class 1	$c_{1,inst} = \rho^* c$	9,274	[mm]
-----------	---------	-------------------------	-------	------

Superior Flange | $c_{1,inst}$ | Class 1

Elements without longitudinal stiffeners | [EN 1993-1-3:2006, 4.3]

C-Section Slab Nominal Dimension

$b_{1,inst}$	38,548	mm
$c_{1,inst}$	1,952	mm

Compression Stress: $\sigma_1 = 350,000$ MPa
Tension Stress: $\sigma_2 = -350,000$ MPa

Outstand Compression Elements | [EN 1993-1-3, Table 4.2]

$\psi = c_1 / c_2 \rightarrow \psi = -1,000 \rightarrow k_x = 23,900$

α_1 Free Paint → $k_x = 0,430$

C-Section Slab Nominal Dimension

$b_{1,inst}$	38,548	mm
$c_{1,inst}$	9,274	mm

$$\bar{\lambda}_{p1} = \sqrt{\frac{f_{y1}}{\sigma_{cr}}} = \frac{\bar{b} \sqrt{t}}{28,4 \epsilon \sqrt{k_x}}$$

$\bar{\lambda}_{p1} = 0,233$

$\rho = 1,000$ Effective width equal to gross width
[EN 1993-1-3, Equation (4.2)] $3 \cdot \psi \geq 0 \rightarrow$ OK

Stress distribution | Compressive positive | Effective width b_{eff}

$\psi < 0,050$

$\rho \leq 1,000$	OK	$b_{1,inst} = \rho^* b_1 = b_1 \cdot [0^*] \cdot [1 - \psi]$	19,274	[mm]	
$\rho \leq 1,000$	OK	$b_{1,inst} = \rho^* b_1 = b_1 \cdot [0^*] \cdot [1 - \psi]$	19,274	[mm]	
$b_{1,inst}$	7,710	[mm]	$b_{1,inst}$	11,264	[mm]

Superior Edge Stiffener | $c_{1,inst}$ | Class 1

OPTION (1) Elements without longitudinal stiffeners | [EN 1993-1-3:2006, 4.3]

C-Section Slab Nominal Dimension

$b_{1,inst}$	38,548	mm
$c_{1,inst}$	9,274	mm

Inferior Flange | $b_{1,inst}$ | Class 1

Elements without longitudinal stiffeners | [EN 1993-1-3:2006, 4.3]

C-Section Slab Nominal Dimension

$b_{1,inst}$	38,548	mm
$c_{1,inst}$	1,952	mm

Compression Stress: $\sigma_1 = 350,000$ MPa
Tension Stress: $\sigma_2 = -350,000$ MPa

Outstand Compression Elements | [EN 1993-1-3, Table 4.2]

$\psi = c_1 / c_2 \rightarrow \psi = -1,000 \rightarrow k_x = 23,900$

α_1 Free Paint → $k_x = 0,430$

OPTION (2) Elements without longitudinal stiffeners | [EN 1993-1-3:2006, 5.5.2.2(3)]

$$\bar{\lambda}_{p1} = \sqrt{\frac{f_{y1}}{\sigma_{cr}}} = \frac{\bar{b} \sqrt{t}}{28,4 \epsilon \sqrt{k_x}}$$

$\bar{\lambda}_{p1} = 0,233$

$\rho = 1,000$ Effective width equal to gross width
[EN 1993-1-3, Equation (4.2)] $3 \cdot \psi \geq 0 \rightarrow$ OK

Stress distribution | Compressive positive | Effective width b_{eff}

$1,000 > \psi \geq 0,050 \rightarrow b_{eff} = \rho^* c$

C-Section	Class 1	$c_{1,inst} = \rho^* c$	9,274	[mm]
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[2] Effective C-Section Slab | Local Buckling | [EN 1993-1-3:2006, 4.3]

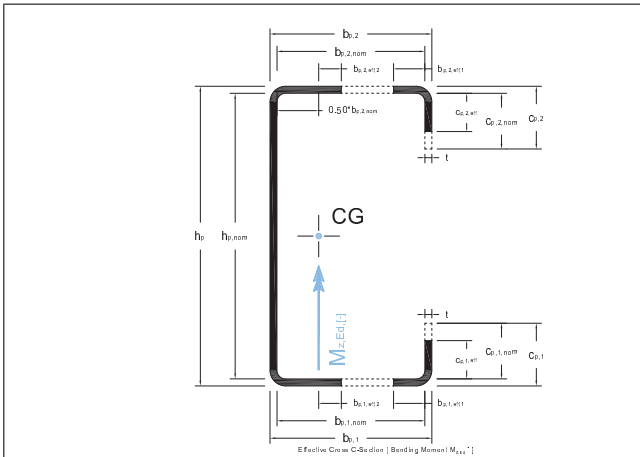
Effective C-Section Slab Widths

Inferior Edge Stiffener	$c_{1,inst}$	9,274	[mm]
Inferior Flange	$b_{1,inst}$	19,274	[mm]
Web	$b_{1,inst}$	---	[mm]
Superior Flange	$b_{1,inst}$	19,274	[mm]
Superior Edge Stiffener	$c_{1,inst}$	9,274	[mm]

NOTE Effective width is equal to the real width

Web | $b_{1,inst}$ | Tension

NOTE Effective width is equal to the real width



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

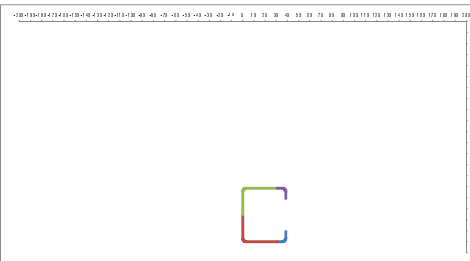
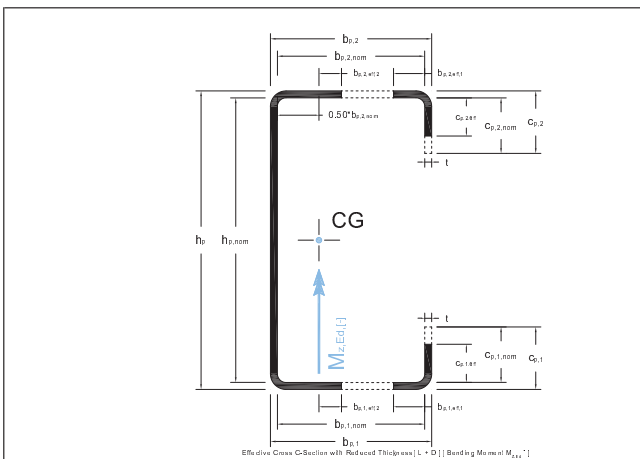
NOTE Inferior/Superior Flanges are built in tension/compression stress so there isn't any reducing because of the distortional buckling in edge stiffeners.

[IV] Effective C-Section Strut with Reduced Thickness [Local + Distortional Buckling] [EN 1993-1-3:2006, 5.5]

Effective C-Section Strut Widths			
Inferior Edge Stiffener	$b_{1,red}$	9,274	[mm]
Inferior Flange	$b_{2,red}$	7,210	[mm]
Web	$b_{3,red}$	11,564	[mm]
Superior Flange	$b_{4,red}$	7,210	[mm]
Superior Edge Stiffener	$b_{5,red}$	9,274	[mm]

[12] Cold-Formed Effective Section

[a] D-Section Profile			
D-Section Profile subjected to Tension Force	$A_{stension}$	191,199	[mm ²]
D-Section Profile subjected to Compression Force	$A_{stcompression}$	148,955	[mm ²]
	$\eta_{x,z}$	0,000	[mm]
	$\eta_{y,z}$	-1,697	[mm]
D-Section Profile subjected to Positive Moment in yy axis [$M_{yy,Ed}$]	$I_{yy,red}$	78892,362	[mm ⁴]
D-Section Profile subjected to Negative Moment in yy axis [$M_{yy,Ed}$]	$I_{yy,red}$	85759,975	[mm ⁴]
D-Section Profile subjected to Positive Moment in zz axis [$M_{zz,Ed}$]	$I_{zz,red}$	163614,967	[mm ⁴]
D-Section Profile subjected to Negative Moment in zz axis [$M_{zz,Ed}$]	$I_{zz,red}$	163614,967	[mm ⁴]
[b] C-Section Beam			
C-Section Beam subjected to Tension Force	$A_{stension}$	245,063	[mm ²]
C-Section Beam subjected to Compression Force	$A_{stcompression}$	243,816	[mm ²]
	$\eta_{x,z}$	3,694	[mm]
	$\eta_{y,z}$	0,000	[mm]
C-Section Beam subjected to Positive Moment in yy axis [$M_{yy,Ed}$]	$I_{yy,red}$	746984,961	[mm ⁴]
C-Section Beam subjected to Negative Moment in yy axis [$M_{yy,Ed}$]	$I_{yy,red}$	746984,961	[mm ⁴]
C-Section Beam subjected to Positive Moment in zz axis [$M_{zz,Ed}$]	$I_{zz,red}$	84344,150	[mm ⁴]
C-Section Beam subjected to Negative Moment in zz axis [$M_{zz,Ed}$]	$I_{zz,red}$	108754,009	[mm ⁴]



$I_{yy,red}$ 43399,345 [mm⁴]

[14] C-Section Column

C-Section Column subjected to Tension Force	$A_{stension}$	497,235	[mm ²]
C-Section Column subjected to Compression Force	$A_{stcompression}$	482,146	[mm ²]
	$\eta_{x,z}$	0,566	[mm]
	$\eta_{y,z}$	0,000	[mm]
C-Section Column subjected to Positive Moment in yy axis [$M_{yy,Ed}$]	$I_{yy,red}$	625030,620	[mm ⁴]
C-Section Column subjected to Negative Moment in yy axis [$M_{yy,Ed}$]	$I_{yy,red}$	625030,620	[mm ⁴]
C-Section Column subjected to Positive Moment in zz axis [$M_{zz,Ed}$]	$I_{zz,red}$	150089,216	[mm ⁴]
C-Section Column subjected to Negative Moment in zz axis [$M_{zz,Ed}$]	$I_{zz,red}$	153816,866	[mm ⁴]
[16] C-Section Strut			
C-Section Strut subjected to Tension Force	$A_{stension}$	201,315	[mm ²]
C-Section Strut subjected to Compression Force	$A_{stcompression}$	189,259	[mm ²]
	$\eta_{x,z}$	-0,611	[mm]
	$\eta_{y,z}$	0,000	[mm]
C-Section Strut subjected to Positive Moment in yy axis [$M_{yy,Ed}$]	$I_{yy,red}$	83780,577	[mm ⁴]
C-Section Strut subjected to Negative Moment in yy axis [$M_{yy,Ed}$]	$I_{yy,red}$	83780,577	[mm ⁴]
C-Section Strut subjected to Positive Moment in zz axis [$M_{zz,Ed}$]	$I_{zz,red}$	44109,416	[mm ⁴]
C-Section Strut subjected to Negative Moment in zz axis [$M_{zz,Ed}$]	$I_{zz,red}$	43989,345	[mm ⁴]

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[13] Basis of Design [BS EN 1993-1-2:2005, 2]

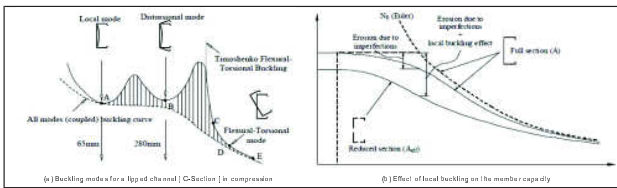
- (P) For verifications by calculations at ultimate limit states the partial factor γ_{M2} are:
- Resistance of cross-sections to excessive yielding (Local and Distortional Buckling) Yes 1,000
 - Resistance of members and shearing when failure is caused by Global Buckling Yes 1,000
 - Resistance of net sections of fastener holes Yes 1,250

(E) For the design of structures made of cold-formed members and shearing a distinction should be made between "structural classes" associated with failure consequences according to EN 1993 Annex B, defined as:

- Structural Class I** Connection where cold-formed members and shearing are designed to contribute to the overall strength and stability of a structure
- Structural Class II** Connection where cold-formed members and shearing are designed to contribute to the overall strength and stability of individual structural members
- Structural Class III** Connection where cold-formed shearing 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 elements. The term "Global Buckling" embraces Euler (Bending) and Flexural-torsional buckling of columns and is characterized by long wavelength buckling which takes place as a consequence of distortion of the cross-section. In cold-formed sections, the phenomena of local and global buckling can be considered as "structural" modes, and they can interact with each other as well as with distortional buckling.



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[15] Ultimate Limit States [BS EN 1993-1-2:2005, 6.1]

[*] D-Section Pullin

[1] D-Section Pullin: Axial Tension [BS EN 1993-1-2:2005, 6.1.2]

$$N_{Ed} = \frac{F_{Ed} A_2}{\gamma_{M2}}$$

[BS EN 1993-1-2, Equation (6.1)]

F_{Ed}	380,215	[MPa]
A_2	191,199	[mm ²]
γ_{M2}	1,000	

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1,0$$

N_{Ed}	68911,039	[N]
$N_{t,Rd}$	68911	[kN]

N_{Ed}	0,940	[kN]
$N_{t,Rd}$	68911	[kN]

Ratio: 0,938 [%]

[2] D-Section Pullin: Axial Compression [BS EN 1993-1-2:2005, 6.1.3]

$$A_{eff} < A_2 \rightarrow N_{Ed} < A_{eff} f_{yk} / \gamma_{M2}$$

[BS EN 1993-1-2, Equation (6.2)]

$$A_{eff} < A_2 \rightarrow N_{Ed} < A_2 f_{yk} [1 + \eta_1 (A_{eff} / A_2)] / \gamma_{M2} < A_2 f_{yk} / \gamma_{M2}$$

[BS EN 1993-1-2, Equation (6.3)]

A_1	191,199	[mm ²]
A_{eff}	148,955	[mm ²]

[BS EN 1993-1-2, Equation (6.2)]

N_{Ed}	52134,208	[N]
$N_{c,Rd}$	52134	[kN]

NOTE: The internal axial force in a member is taken as acting at the centroid of its gross cross-section.

NOTE: The design compressive 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 η_1 of the centroid axis is taken into account. (If the shift of the centroid axis gives a favorable result in the stress check, the shift should be neglected only if the shift has been included at yield strength and not with the actual compressive stresses.)

N_{Ed}	52134	[kN]
$N_{c,Rd}$	52134	[kN]

Ratio: 0,977 [%]

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[14] Reaction Values

D-Section Canale Pullin			D-Section Middle Pullin		
N_{Ed}	0,900	[kN]	N_{Ed}	0,940	[kN]
N_{Ed}	0,900	[kN]	N_{Ed}	0,940	[kN]
V_{Ed}	0,170	[kN]	V_{Ed}	0,260	[kN]
V_{Ed}	0,630	[kN]	V_{Ed}	1,010	[kN]
$M_{Ed(1)}$	0,220	[kN]	$M_{Ed(1)}$	0,260	[kN]
$M_{Ed(2)}$	0,220	[kN]	$M_{Ed(2)}$	0,660	[kN]
$M_{Ed(3)}$	0,260	[kN]	$M_{Ed(3)}$	0,890	[kN]
$M_{Ed(4)}$	0,260	[kN]	$M_{Ed(4)}$	0,890	[kN]

C-Section Canale Beam			C-Section Middle Beam		
N_{Ed}	0,520	[kN]	N_{Ed}	0,700	[kN]
N_{Ed}	0,520	[kN]	N_{Ed}	1,330	[kN]
V_{Ed}	0,840	[kN]	V_{Ed}	0,840	[kN]
V_{Ed}	1,970	[kN]	V_{Ed}	2,050	[kN]
$M_{Ed(1)}$	0,840	[kN]	$M_{Ed(1)}$	0,840	[kN]
$M_{Ed(2)}$	0,840	[kN]	$M_{Ed(2)}$	0,840	[kN]
$M_{Ed(3)}$	0,820	[kN]	$M_{Ed(3)}$	0,810	[kN]
$M_{Ed(4)}$	0,820	[kN]	$M_{Ed(4)}$	0,910	[kN]

C-Section Front Column			C-Section Rear Column		
N_{Ed}	2,700	[kN]	N_{Ed}	3,340	[kN]
N_{Ed}	4,140	[kN]	N_{Ed}	4,170	[kN]
V_{Ed}	0,900	[kN]	V_{Ed}	0,900	[kN]
V_{Ed}	1,780	[kN]	V_{Ed}	2,240	[kN]
$M_{Ed(1)}$	0,270	[kN]	$M_{Ed(1)}$	0,350	[kN]
$M_{Ed(2)}$	0,270	[kN]	$M_{Ed(2)}$	0,350	[kN]
$M_{Ed(3)}$	0,900	[kN]	$M_{Ed(3)}$	0,900	[kN]
$M_{Ed(4)}$	0,900	[kN]	$M_{Ed(4)}$	0,900	[kN]

C-Section Strut		
N_{Ed}	2,280	[kN]
N_{Ed}	1,570	[kN]
V_{Ed}	0,900	[kN]
V_{Ed}	0,220	[kN]
$M_{Ed(1)}$	0,910	[kN]
$M_{Ed(2)}$	0,910	[kN]
$M_{Ed(3)}$	0,900	[kN]
$M_{Ed(4)}$	0,900	[kN]

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[16] D-Section Pullin: Bending Moment [BS EN 1993-1-2:2005, 6.1.4]

Positive Moment in y-y axis [M_{Ed}^y]

$$W_{pl,y} < W_{pl,y} \rightarrow M_{Ed} < W_{pl,y} f_{yk} / \gamma_{M2}$$

[BS EN 1993-1-2, Equation (6.4)]

$$W_{pl,y} < W_{pl,y} \rightarrow M_{Ed} < W_{pl,y} f_{yk} [1 + \eta_2 (W_{pl,y} / W_{pl,y})] / \gamma_{M2} < W_{pl,y} f_{yk} / \gamma_{M2}$$

[BS EN 1993-1-2, Equation (6.5)]

Equation [6.5] is applicable provided that the following conditions are satisfied:

- [a] Bending moment is applied only about one principal axis of the cross-section
- [b] Member not welded to tension or to torsion, lateral flexural or torsion-distortional or distortional buckling
- [c] Angle θ between the web and the flange is larger than 60°

$$M_{Ed} < W_{pl,y} f_{yk} / \gamma_{M2}$$

$W_{pl,y(1)}$	85759,970	[mm ³]
$W_{pl,y(2)}$	3343,293	[mm ³]

$W_{pl,y(1)}$	7892,362	[mm ³]
$W_{pl,y(2)}$	3343,293	[mm ³]

$W_{pl,y(1)}$	3053,134	[mm ³]
$W_{pl,y(2)}$	3343,293	[mm ³]

$W_{pl,y(1)}$	3053,134	[mm ³]
$W_{pl,y(2)}$	2737,255	[mm ³]

[BS EN 1993-1-2, Equation (6.4)]

$M_{Ed(1)}$	958214,390	[Nmm]
$M_{Ed(2)}$	958	[kNm]

$M_{Ed(1)}$	0,960	[kNm]
$M_{Ed(2)}$	0,958	[kNm]

Ratio: 0,970 [%]

$W_{pl,y(1)}$	3343,293	[mm ³]
$W_{pl,y(2)}$	3343,293	[mm ³]

[BS EN 1993-1-2, Equation (6.4)]

$M_{Ed(1)}$	112854,977	[Nmm]
$M_{Ed(2)}$	1128	[kNm]

Negative Moment in y-y axis [M_{Ed}^y]

$$W_{pl,y} < W_{pl,y} \rightarrow M_{Ed} < W_{pl,y} f_{yk} / \gamma_{M2}$$

[BS EN 1993-1-2, Equation (6.4)]

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Category: Category 1 → s: 0,057

R_{Ed} : 1147,222 [N] → R_{Ed} : 1,148 [kN / Web]

V_{Ed} : 1,010 [kN] Ratio: 44,908 [%]

R_{Ed} : 2,295 [kN]

[v] D.Section Point: Combined Tension and Bending [EN 1993-3:2006, 6.1.3]

$$\frac{N_{Ed}}{N_{t,Rd}} + \frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} \leq 1$$

[BS EN 1993-3, Equation (6.23)]

$M_{y,Ed} < M_{y,Rd}$ or $M_{z,Ed} < M_{z,Rd}$

$$\frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[BS EN 1993-3, Equation (6.24)]

Combined Tension and Bending Moment [$M_{y,Ed} + M_{z,Ed}$]

N_{Ed} : 0,940 [kN]	N_{Ed} : 68,911 [kN]
$M_{y,Ed} < M_{y,Rd}$: 0,360 [kNm]	$M_{y,Ed} < M_{y,Rd}$: 1,739 [kNm]
$M_{z,Ed} < M_{z,Rd}$: 0,980 [kNm]	$M_{z,Ed} < M_{z,Rd}$: 1,989 [kNm]

[EN 1993-3, Equation (6.23)] Ratio: 40,910 [%]

$M_{y,Ed} < M_{y,Rd}$: 0,360 [kNm] $M_{z,Ed} < M_{z,Rd}$: 0,982 [kNm]

$M_{y,Ed} < M_{y,Rd}$: OK $M_{z,Ed} < M_{z,Rd}$: OK

$$\frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[EN 1993-3, Equation (6.24)] Ratio: 46,677 [%]

Combined Tension and Bending Moment [$M_{y,Ed} + M_{z,Ed}$]

N_{Ed} : 0,940 [kN]	N_{Ed} : 68,911 [kN]
$M_{y,Ed} < M_{y,Rd}$: 0,360 [kNm]	$M_{y,Ed} < M_{y,Rd}$: 1,739 [kNm]
$M_{z,Ed} < M_{z,Rd}$: 0,980 [kNm]	$M_{z,Ed} < M_{z,Rd}$: 1,989 [kNm]

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Combined Compression and Bending Moment [$M_{y,Ed} + M_{z,Ed}$]

N_{Ed} : 0,940 [kN]	N_{Ed} : 52,134 [kN]
$M_{y,Ed} < M_{y,Rd}$: 0,360 [kNm]	$M_{y,Ed} < M_{y,Rd}$: 1,265 [kNm]
$M_{z,Ed} < M_{z,Rd}$: 0,980 [kNm]	$M_{z,Ed} < M_{z,Rd}$: 0,982 [kNm]

[EN 1993-3, Equation (6.25)] Ratio: 39,113 [%]

$M_{y,Ed} < M_{y,Rd}$: 1,265 [kNm] $M_{z,Ed} < M_{z,Rd}$: 1,989 [kNm]

$M_{y,Ed} < M_{y,Rd}$: OK $M_{z,Ed} < M_{z,Rd}$: KO

$$\frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{z,Rd}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[EN 1993-3, Equation (6.26)] don't need to be verified

[EN 1993-3, Equation (6.26)] Ratio: 0,000 [%]

[ix] D.Section Point: Combined Shear Force, Axial Force and Bending Moment [EN 1993-3:2006, 6.1.10]

V_{Ed} : 1,010 [kN] R_{Ed} : 2,295 [kN]

$V_{Ed} < 0,59 V_{Ed}$: OK No reduction due to shear force is need to be done

[x] D.Section Point: Combined Bending Moment and Local Load or Support Reaction [EN 1993-3:2006, 6.1.11]

$M_{y,Ed} < M_{y,Rd} < 1$ $M_{z,Ed} < M_{z,Rd}$ Ratio: 37,974 [%]

[BS EN 1993-3, Equation (6.28a)] $M_{y,Ed} < M_{y,Rd} < 1$ $M_{z,Ed} < M_{z,Rd}$ Ratio: 29,277 [%]

[BS EN 1993-3, Equation (6.28a)] $M_{y,Ed} < M_{y,Rd} < 1$ $M_{z,Ed} < M_{z,Rd}$ Ratio: 9,165 [%]

[BS EN 1993-3, Equation (6.28a)] $M_{y,Ed} < M_{y,Rd} < 1$ $M_{z,Ed} < M_{z,Rd}$ Ratio: 9,165 [%]

[BS EN 1993-3, Equation (6.28b)] $F_{t,Ed} < R_{t,Rd} < 1$ $R_{t,Ed}$ Ratio: 44,908 [%]

[BS EN 1993-3, Equation (6.28b)] $F_{t,Ed} < R_{t,Rd} < 1,25$ $M_{y,Ed} < M_{y,Rd}$ $M_{z,Ed} < M_{z,Rd}$ $F_{t,Ed} < R_{t,Rd}$ Ratio: 81,978 [%]

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[EN 1993-3, Equation (6.23)] Ratio: 41,106 [%]

$M_{y,Ed} < M_{y,Rd}$: 1,265 [kNm] $M_{z,Ed} < M_{z,Rd}$: 0,982 [kNm]

$M_{y,Ed} < M_{y,Rd}$: KO $M_{z,Ed} < M_{z,Rd}$: OK

$$\frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[EN 1993-3, Equation (6.24)] Ratio: 0,000 [%]

[vi] D.Section Point: Combined Compression and Bending [EN 1993-3:2006, 6.1.9]

$$\frac{N_{Ed}}{N_{t,Rd}} + \frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{z,Rd}} \leq 1$$

[BS EN 1993-3, Equation (6.25)]

$\Delta M_{y,Ed} = N_{t,compression} \cdot y_{Ed}$	$\Delta M_{z,Ed} = N_{t,compression} \cdot z_{Ed}$
$N_{t,compression}$: 0,940 [kN]	$N_{t,compression}$: 0,940 [kN]
y_{Ed} : -0,002 [m]	z_{Ed} : 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_{Ed} : 0,940 [kN]	N_{Ed} : 52,134 [kN]
$M_{y,Ed} < M_{y,Rd}$: 0,360 [kNm]	$M_{y,Ed} < M_{y,Rd}$: 0,958 [kNm]
$M_{z,Ed} < M_{z,Rd}$: 0,980 [kNm]	$M_{z,Ed} < M_{z,Rd}$: 0,982 [kNm]

[EN 1993-3, Equation (6.25)] Ratio: 49,895 [%]

$M_{y,Ed} < M_{y,Rd}$: 1,339 [kNm] $M_{z,Ed} < M_{z,Rd}$: 1,989 [kNm]

$M_{y,Ed} < M_{y,Rd}$: KO $M_{z,Ed} < M_{z,Rd}$: KO

$$\frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{z,Rd}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[EN 1993-3, Equation (6.26)] don't need to be verified

[EN 1993-3, Equation (6.26)] Ratio: 0,000 [%]

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$\frac{M_{y,Ed} + F_{t,Ed}}{M_{y,Rd} + R_{t,Rd}} \leq 1,25$ $M_{y,Ed} < M_{y,Rd}$ $F_{t,Ed} < R_{t,Rd}$ Ratio: 73,889 [%]

[BS EN 1993-3, Equation (6.28a)] $M_{y,Ed} < M_{y,Rd} < 1,25$ $M_{z,Ed} < M_{z,Rd}$ $F_{t,Ed} < R_{t,Rd}$ Ratio: 93,773 [%]

[BS EN 1993-3, Equation (6.28a)] $M_{y,Ed} < M_{y,Rd} < 1,25$ $M_{z,Ed} < M_{z,Rd}$ $F_{t,Ed} < R_{t,Rd}$ Ratio: 93,773 [%]

[BS EN 1993-3, Equation (6.28a)] $M_{y,Ed} < M_{y,Rd} < 1,25$ $M_{z,Ed} < M_{z,Rd}$ $F_{t,Ed} < R_{t,Rd}$ Ratio: 93,773 [%]

[vii] C.Section Beam [BS EN 1993-3:2006, 6.1.2]

[i] C.Section Beam: Axial Tension [BS EN 1993-3:2006, 6.1.2]

$$N_{t,Rd} = \frac{F_{t,Ed}}{\gamma_{M0}}$$

[BS EN 1993-3, Equation (6.1)]

f_{td} : 381,975 [MPa]	$\frac{N_{t,Ed}}{N_{t,Rd}} \leq 1,0$
A_g : 345,063 [mm ²]	
γ_{M0} : 1,000	

$N_{t,Ed}$: 124904,463 [N] → $N_{t,Rd}$: 124,904 [kN]

$N_{t,Ed}$: 0,200 [kN] $N_{t,Rd}$: 124,904 [kN] Ratio: 0,160 [%]

[ii] C.Section Beam: Axial Compression [BS EN 1993-3:2006, 6.1.2]

[BS EN 1993-3, Equation (6.2)] $A_{t1} < A_{t2}$ → $N_{t,Ed} = A_{t1} \cdot f_{td} < N_{t,Rd}$

[BS EN 1993-3, Equation (6.2)] $A_{t1} < A_{t2}$ → $N_{t,Ed} = A_{t1} \cdot f_{td} + [f_{td} - f_{td} \cdot \gamma_{M0}] \cdot A_{t2} < N_{t,Rd}$

A_{t1} : 345,063 [mm²] A_{t2} : 243,816 [mm²]

[BS EN 1993-3, Equation (6.2)]

$N_{t,Ed}$: 85335,720 [N] → $N_{t,Rd}$: 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 compressive resistance of a gross 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_0 of the centroid axis is taken into account. If the shift of the centroid axis gives a favourable result in the stress check, the shift should be neglected only if the shift has been included at yield strength and not with the actual compressive stresses.

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$N_{Ed} = A_y \cdot f_{yk} / \gamma_{yk}$ OK

$N_{Ed,compression} = 3,894$ [mm] In stress check, still to code
 $N_{Ed,tension} = 0,000$ [mm]

$N_{Ed} = 1,207$ [kN] $\frac{N_{Ed}}{N_{Rd}} \leq 1,0$ Ratio: 1,207 [%]
 $N_{Rd} = 85,336$ [kN]

[9] C-Section Beam: Bending Moment [BS EN 1993-1-3:2005, 6.1.4]

Positive Moment in y-z axis [$M_{y,z}$]

[BS EN 1993-1-3, Equation (6.4)]
 $W_{pl,y} = W_{pl,z} \rightarrow M_{y,z,Ed} = W_{pl,y} \cdot f_{yk} / \gamma_{yk}$

[BS EN 1993-1-3, Equation (6.5)]
 $W_{pl,y} = W_{pl,z} \rightarrow M_{y,z,Ed} = f_{yk} \cdot [W_{pl,y} + W_{pl,z} \cdot 1,4 \cdot (1 - \lambda_{y,z,Ed}) \cdot |A_{y,z}|] / \gamma_{yk} \leq W_{pl,y} \cdot f_{yk} / \gamma_{yk}$

Equation (6.5) is applicable provided that the following conditions are satisfied:
 [*] Bending moment is applied only about one principal axis of the cross-section
 [†] Member not subject to tension or to torsion; torsion of flexural or lateral-torsional or distortional bending
 [‡] Angle ϕ between the web and the flange is larger than 60°

[BS EN 1993-1-3, Equation (6.4)]
 $M_{y,z,Ed} = W_{pl,y} \cdot f_{yk} / \gamma_{yk}$

$I_{y,Ed} = 782,290,265$ [mm⁴] \rightarrow $W_{pl,y,Ed} = 1,286,454$ [mm³]
 $W_{pl,z,Ed} = 1,286,454$ [mm³]
 $I_{z,Ed} = 748,984,961$ [mm⁴] \rightarrow $W_{pl,z,Ed} = 1,2435,750$ [mm³]
 $W_{pl,y,Ed} = 1,2773,241$ [mm³]
 $W_{pl,z,Ed} = 1,286,454$ [mm³] \rightarrow $W_{pl,z,Ed} = 1,2435,750$ [mm³]

[BS EN 1993-1-3, Equation (6.4)]
 $M_{y,z,Ed} = 4352,512,818$ [Nmm] \rightarrow $M_{y,z,Rd} = 4,352$ [kNm]

$M_{y,z,Ed} = 0,340$ [kNm] $\frac{M_{y,z,Ed}}{M_{y,z,Rd}} \leq 1,0$ Ratio: 19,293 [%]
 $M_{y,z,Rd} = 4,353$ [kNm]

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Positive Moment in x-z axis [$M_{x,z}$]

[BS EN 1993-1-3, Equation (6.4)]
 $W_{pl,x} = W_{pl,z} \rightarrow M_{x,z,Ed} = W_{pl,x} \cdot f_{yk} / \gamma_{yk}$

[BS EN 1993-1-3, Equation (6.5)]
 $W_{pl,x} = W_{pl,z} \rightarrow M_{x,z,Ed} = f_{yk} \cdot [W_{pl,x} + W_{pl,z} \cdot 1,4 \cdot (1 - \lambda_{x,z,Ed}) \cdot |A_{x,z}|] / \gamma_{yk} \leq W_{pl,x} \cdot f_{yk} / \gamma_{yk}$

[BS EN 1993-1-3, Equation (6.6)]
 $M_{x,z,Ed} = W_{pl,x} \cdot f_{yk} / \gamma_{yk}$

$I_{x,Ed} = 1,08754,009$ [mm⁴] \rightarrow $W_{pl,x,Ed} = 7488,064$ [mm³]
 $W_{pl,z,Ed} = 3567,406$ [mm³]
 $I_{z,Ed} = 84344,150$ [mm⁴] \rightarrow $W_{pl,z,Ed} = 4343,109$ [mm³]
 $W_{pl,x,Ed} = 3291,323$ [mm³]
 $W_{pl,z,Ed} = 7488,064$ [mm³] \rightarrow $W_{pl,z,Ed} = 4343,109$ [mm³]

[BS EN 1993-1-3, Equation (6.4)]
 $M_{x,z,Ed} = 1,52008,003$ [Nmm] \rightarrow $M_{x,z,Rd} = 1,520$ [kNm]

$M_{x,z,Ed} = 0,820$ [kNm] $\frac{M_{x,z,Ed}}{M_{x,z,Rd}} \leq 1,0$ Ratio: 1,316 [%]
 $M_{x,z,Rd} = 1,520$ [kNm]

$W_{pl,x,Ed} = 3567,406$ [mm³] \rightarrow $W_{pl,z,Ed} = 3291,323$ [mm³]

[BS EN 1993-1-3, Equation (6.4)]
 $M_{x,z,Ed} = 1,151892,071$ [Nmm] \rightarrow $M_{x,z,Rd} = 1,152$ [kNm]

Negative Moment in x-z axis [$M_{x,z}$]

[BS EN 1993-1-3, Equation (6.4)]
 $W_{pl,x} = W_{pl,z} \rightarrow M_{x,z,Ed} = W_{pl,x} \cdot f_{yk} / \gamma_{yk}$

[BS EN 1993-1-3, Equation (6.5)]
 $W_{pl,x} = W_{pl,z} \rightarrow M_{x,z,Ed} = f_{yk} \cdot [W_{pl,x} + W_{pl,z} \cdot 1,4 \cdot (1 - \lambda_{x,z,Ed}) \cdot |A_{x,z}|] / \gamma_{yk} \leq W_{pl,x} \cdot f_{yk} / \gamma_{yk}$

[BS EN 1993-1-3, Equation (6.6)]
 $M_{x,z,Ed} = W_{pl,x} \cdot f_{yk} / \gamma_{yk}$

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$W_{pl,y,Ed} = 1,286,454$ [mm³] \rightarrow $W_{pl,z,Ed} = 1,2773,241$ [mm³]

[BS EN 1993-1-3, Equation (6.4)]
 $M_{y,z,Ed} = 4470,634,244$ [Nmm] \rightarrow $M_{y,z,Rd} = 4,471$ [kNm]

Negative Moment in y-z axis [$M_{y,z}$]

[BS EN 1993-1-3, Equation (6.4)]
 $W_{pl,y} = W_{pl,z} \rightarrow M_{y,z,Ed} = W_{pl,y} \cdot f_{yk} / \gamma_{yk}$

[BS EN 1993-1-3, Equation (6.5)]
 $W_{pl,y} = W_{pl,z} \rightarrow M_{y,z,Ed} = f_{yk} \cdot [W_{pl,y} + W_{pl,z} \cdot 1,4 \cdot (1 - \lambda_{y,z,Ed}) \cdot |A_{y,z}|] / \gamma_{yk} \leq W_{pl,y} \cdot f_{yk} / \gamma_{yk}$

[BS EN 1993-1-3, Equation (6.6)]
 $M_{y,z,Ed} = W_{pl,y} \cdot f_{yk} / \gamma_{yk}$

$I_{y,Ed} = 782,290,265$ [mm⁴] \rightarrow $W_{pl,y,Ed} = 1,286,454$ [mm³]
 $W_{pl,z,Ed} = 1,286,454$ [mm³]
 $I_{z,Ed} = 748,984,961$ [mm⁴] \rightarrow $W_{pl,z,Ed} = 1,2435,750$ [mm³]
 $W_{pl,y,Ed} = 1,2773,241$ [mm³]
 $W_{pl,z,Ed} = 1,286,454$ [mm³] \rightarrow $W_{pl,z,Ed} = 1,2435,750$ [mm³]

[BS EN 1993-1-3, Equation (6.4)]
 $M_{y,z,Ed} = 4352,512,818$ [Nmm] \rightarrow $M_{y,z,Rd} = 4,353$ [kNm]

$M_{y,z,Ed} = 0,340$ [kNm] $\frac{M_{y,z,Ed}}{M_{y,z,Rd}} \leq 1,0$ Ratio: 19,293 [%]
 $M_{y,z,Rd} = 4,353$ [kNm]

$W_{pl,y,Ed} = 1,286,454$ [mm³] \rightarrow $W_{pl,z,Ed} = 1,2773,241$ [mm³]

[BS EN 1993-1-3, Equation (6.4)]
 $M_{y,z,Ed} = 4470,634,244$ [Nmm] \rightarrow $M_{y,z,Rd} = 4,471$ [kNm]

Office: ---		Author: JOSE ANTONIO	
Date: 05/03/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Padral configuration, according to Eurocodes			
Code:	Eurocode	References:	EN 1990 | EN 1991 | EN 1993
Version:	1,000		

$I_{x,Ed} = 1,08754,009$ [mm⁴] \rightarrow $W_{pl,x,Ed} = 3567,406$ [mm³]
 $W_{pl,z,Ed} = 7488,064$ [mm³]
 $I_{z,Ed} = 1,08754,009$ [mm⁴] \rightarrow $W_{pl,z,Ed} = 3567,406$ [mm³]
 $W_{pl,x,Ed} = 7488,064$ [mm³]
 $W_{pl,z,Ed} = 3567,406$ [mm³]

[BS EN 1993-1-3, Equation (6.4)]
 $M_{x,z,Ed} = 1,248992,193$ [Nmm] \rightarrow $M_{x,z,Rd} = 1,249$ [kNm]

$M_{x,z,Ed} = 0,820$ [kNm] $\frac{M_{x,z,Ed}}{M_{x,z,Rd}} \leq 1,0$ Ratio: 1,002 [%]
 $M_{x,z,Rd} = 1,249$ [kNm]

$W_{pl,x,Ed} = 7488,064$ [mm³] \rightarrow $W_{pl,z,Ed} = 7488,064$ [mm³]

[BS EN 1993-1-3, Equation (6.4)]
 $M_{x,z,Ed} = 2,613822,077$ [Nmm] \rightarrow $M_{x,z,Rd} = 2,614$ [kNm]

[14] C-Section Beam: Shear Force [BS EN 1993-1-3:2005, 6.1.5]

$V_{k,Rd} = \frac{h_w \cdot t_f \cdot \sin \phi}{\gamma_{M0}}$ $f_{yk} = f_{yk} = 118,048$ [mm]
 $\phi = 90,000$ [°]
 $\gamma_{M0} = 1,000$

Web without longitudinal stiffeners $\bar{\lambda}_{w} = 0,346 \cdot \frac{h_w}{t_f} \cdot \sqrt{\frac{f_{yk}}{E}}$ [EN 1993-1-3, Equation (6.10a)]

$h_w = 118,048$ [mm] $f_{yk} = 350,000$ [MPa]
 $t_f = 1,452$ [mm] $E = 210,000$ [GPa]

Table 6.1: Shear buckling strength f_{yk} BS EN 1993-1-3:2005

Ratio web slenderness	Web without longitudinal stiffeners
$\bar{\lambda}_w \leq 0,83$	$0,58 f_{yk}$
$0,83 < \bar{\lambda}_w < 1,40$	$0,48 f_{yk} / \bar{\lambda}_w$
$\bar{\lambda}_w \geq 1,40$	$0,60 f_{yk} / \bar{\lambda}_w^2$

$\bar{\lambda}_w = 1,193$ [EN 1993-1-3, Equation (6.10a)] $f_{yk} = 145,674$ [MPa]

$V_{k,Rd} = 25975,063$ [N] Web [\rightarrow $V_{k,Rd} = 25,975$ [kN]

V_{Ed}	2,900	[kN]	$\frac{V_{Ed}}{R_{w,Rd}} \leq 1,0$	Ratio	7,976	[%]
V_{Ed}	25,975	[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}	14,263	[mm]	y_{Sc}	22,793	[mm]	37,955	[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	ZΣ	X	V

Key	X	Negligible	V	Significant
$\sigma_{w,Ed}$				
$\tau_{w,Ed}$				

$\sigma_{w,Ed} = \sigma_{N,Ed} + \sigma_{M_y,Ed} + \sigma_{M_z,Ed} + \sigma_{w,Ed}$ [BS EN 1993-1-3, Equation (6.124)]
 $\tau_{w,Ed} = \tau_{V_y,Ed} + \tau_{V_z,Ed} + \tau_{t,Ed} + \tau_{w,Ed}$ [BS EN 1993-1-3, Equation (6.125)]

$\sigma_{N,Ed}$	2,900	[MPa]	$\tau_{N,Ed}$	1,154	[MPa]
$\sigma_{M_y,Ed}$	64,110	[MPa]	$\tau_{M_y,Ed}$	0,949	[MPa]
$\sigma_{M_z,Ed}$	6,300	[MPa]	$\tau_{M_z,Ed}$	0,900	[MPa]
$\sigma_{w,Ed}$	0,000	[MPa]	$\tau_{w,Ed}$	0,900	[MPa]
$\sigma_{N,Ed}$	72,310	[MPa]	$\tau_{N,Ed}$	1,154	[MPa]

Left end free to twist and warp

Both ends free to warp but not twist

C-Section Cantilever Beam C-Section Middle Beam

Local loads and supports: Cross-sections with a single web [BS EN 1993-1-3:2006, Figure 6.7.4]

1] Cross-Section with stiffened Flanges

$$R_{w,Rd} = \frac{k_1 A_{eff} \sigma_{yk} + k_2 A_{eff} \sigma_{yk}}{F_{t,Rd}}$$

2] Cross-Section with stiffened Flanges

$$R_{w,Rd} = \frac{k_1 A_{eff} \sigma_{yk} + k_2 A_{eff} \sigma_{yk}}{F_{t,Rd}}$$

[BS EN 1993-1-3, Equation (6.154)]

Local load applied with $\leq 100\%$ N_{yk} clear from a free end

Local load applied with $> 100\%$ N_{yk} clear from a free end

c	80,000	[mm]	h_f	118,548	[mm]
n_k	16,545	[mm]	l	1,452	[mm]

BS EN 1993-1-3, Equation (6.154)

BS EN 1993-1-3, Equation (6.154)

$R_{w,Rd}$	4,245,108	[kN]		$R_{w,Rd}$	4,245	[kN]
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V_{Ed}	2,900	[kN]		Ratio	47,113	[%]
$R_{w,Rd}$	4,245	[kN]				

[vi] C-Section Beam: Combined Tension and Bending [EN 1993-1-3:2006, 6.1.2.]

$$\frac{N_{Ed}}{N_{t,Rd}} + \frac{M_{y,Ed}}{M_{y,Rd,lim}} + \frac{M_{z,Ed}}{M_{z,Rd,lim}} \leq 1$$

[BS EN 1993-1-3, Equation (6.23)]

$M_{y,Rd,lim} \leq M_{y,Rd}$ or $M_{z,Rd,lim} \leq M_{z,Rd}$

$$\frac{M_{y,Ed}}{M_{y,Rd,lim}} + \frac{M_{z,Ed}}{M_{z,Rd,lim}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[BS EN 1993-1-3, Equation (6.24)]

Combined Tension and Bending Moment [$M_{y,Ed} + M_{z,Ed}$]					
N_{Ed}	0,700	[kN]	$N_{t,Rd}$	124,954	[kN]
$M_{y,Rd,lim}$	0,840	[kNm]	$M_{y,Rd,lim}$	4,271	[kNm]
$M_{z,Rd,lim}$	0,920	[kNm]	$M_{z,Rd,lim}$	1,152	[kNm]

			Ratio	21,088	[%]
--	--	--	-------	--------	-----

[EN 1993-1-3, Equation (6.23)]

$\sigma_{w,Ed} \leq f_{yk} / \gamma_{M2}$	$\sigma_{w,Ed}$	72,310	[MPa]	OK
[BS EN 1993-1-3, Equation (6.114)]	f_{yk} / γ_{M2}	361,975	[MPa]	
$\tau_{w,Ed} \leq \frac{f_{yk} \sqrt{3}}{\gamma_{M2}}$	$\tau_{w,Ed}$	1,154	[MPa]	OK
[BS EN 1993-1-3, Equation (6.116)]	$f_{yk} \sqrt{3} / \gamma_{M2}$	628,890	[MPa]	
$\sqrt{\sigma_{w,Ed}^2 + 3\tau_{w,Ed}^2} \leq 1,1 \frac{f_{yk}}{\gamma_{M2}}$		72,330	[MPa]	OK
[BS EN 1993-1-3, Equation (6.116)]	$1,1 \frac{f_{yk}}{\gamma_{M2}}$	398,173	[MPa]	

[vii] C-Section Beam: Local Transverse Forces [EN 1993-1-3:2006, 6.1.7.]

$F_{t,Ed} \leq R_{w,Rd}$

ADVICE: To avoid crushing, crippling or buckling in a web subjected to a support reaction or other local transverse force, applied through the flange

Cross-sections with a single unstiffened web [BS EN 1993-1-3:2006, 6.1.7.2.]

$h_w / t \leq 200$	h_w	118,548	[mm]	OK
[BS EN 1993-1-3, Equation (6.14a)]	t	1,452	[mm]	

$r / t \leq 6$	r	3,226	[mm]	OK
[BS EN 1993-1-3, Equation (6.14b)]	t	1,452	[mm]	

$45^\circ \leq \theta \leq 90^\circ$	θ	90,000	[°]	OK
[BS EN 1993-1-3, Equation (6.14c)]	t			

$k_1 = 1,33 - 0,33 k$	k_1	0,823		
$k_2 = 1,15 + 0,15 r/t$	k_2	0,817		
$k_3 \geq 0,50$	OK	$k_3 \leq 1,0$	OK	
$k_4 = (1,7 + 0,3(\theta/90^\circ))$	k_4	1,900		

$k = f_{yk} / 228$	k	1,325		
$k_5 = 1,06 - 0,06 r/t$	k_5	0,927	$k_5 \leq 1,0$	OK

$M_{y,Ed,comp}$	4,953	[kNm]	$M_{y,Rd,comp}$	1,520	[kNm]
$M_{z,Ed,comp}$	0,840	[kNm]	$M_{z,Rd,comp}$	2,614	[kNm]
$M_{y,Ed,comp} + M_{z,Ed,comp}$	OK		$M_{y,Rd,comp} + M_{z,Rd,comp}$	OK	

$$\frac{M_{y,Ed}}{M_{y,Rd,lim}} + \frac{M_{z,Ed}}{M_{z,Rd,lim}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[EN 1993-1-3, Equation (6.24) don't need to be verified]

[EN 1993-1-3, Equation (6.24)]

Ratio

0,000

[%]

Combined Tension and Bending Moment [$M_{y,Ed} + M_{z,Ed}$]

N_{Ed}	0,700	[kN]	$N_{t,Rd}$	124,954	[kN]
$M_{y,Ed,comp}$	0,840	[kNm]	$M_{y,Rd,comp}$	4,271	[kNm]
$M_{z,Ed,comp}$	0,920	[kNm]	$M_{z,Rd,comp}$	2,614	[kNm]

			Ratio	20,115	[%]
--	--	--	-------	--------	-----

[EN 1993-1-3, Equation (6.23)]

$M_{y,Ed,comp}$	4,953	[kNm]	$M_{y,Rd,comp}$	1,249	[kNm]
$M_{z,Ed,comp}$	0,840	[kNm]	$M_{z,Rd,comp}$	2,614	[kNm]
$M_{y,Ed,comp} + M_{z,Ed,comp}$	OK		$M_{y,Rd,comp} + M_{z,Rd,comp}$	OK	

$$\frac{M_{y,Ed}}{M_{y,Rd,lim}} + \frac{M_{z,Ed}}{M_{z,Rd,lim}} - \frac{N_{Ed}}{N_{t,Rd}} \leq 1$$

[EN 1993-1-3, Equation (6.24) need to be verified]

[EN 1993-1-3, Equation (6.24)]

Ratio

20,341

[%]

[viii] C-Section Beam: Combined Compression and Bending [EN 1993-1-3:2006, 6.1.9.]

$$\frac{N_{Ed}}{N_{t,Rd}} + \frac{M_{y,Ed} + \Delta M_{y,Ed}}{M_{y,Rd,lim}} + \frac{M_{z,Ed} + \Delta M_{z,Ed}}{M_{z,Rd,lim}} \leq 1$$

[BS EN 1993-1-3, Equation (6.25)]

$\Delta M_{y,Ed} = N_{y,comp} \cdot e_{y,comp}$		$\Delta M_{z,Ed} = N_{z,comp} \cdot e_{z,comp}$			
$N_{y,comp}$	1,930	[kN]	$N_{z,comp}$	1,930	[kN]
$e_{y,comp}$	0,000	[m]	$e_{z,comp}$	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_{Ed}	1,930	[kN]	$N_{t,Rd}$	85,358	[kN]
$M_{y,Ed,comp}$	0,840	[kNm]	$M_{y,Rd,comp}$	4,353	[kNm]
$M_{z,Ed,comp}$	0,920	[kNm]	$M_{z,Rd,comp}$	1,520	[kNm]

Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes				Office: ---	Author: JOSE ANTONIO
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[] EN 1993-1-3, Equation (6.25) | Ratio: 22,072 | [%]

$M_{y,Ed}^{max}$	4,471	[kNm]	$M_{y,Ed}^{min}$	1,352	[kNm]
$M_{z,Ed}^{max}$	KO		$M_{z,Ed}^{min} < M_{z,Ed}^{design}$	OK	

$\frac{M_{y,Ed} + M_{z,Ed}}{M_{y,Rd} + M_{z,Rd}} + \frac{M_{y,Ed} + M_{z,Ed}}{M_{y,Rd} + M_{z,Rd}} \leq 1$ [EN 1993-1-3, Equation (6.26)] | Ratio: 0,000 | [%]

[] EN 1993-1-3, Equation (6.26) | Ratio: 0,000 | [%]

Combined Compression and Bending Moment $[M_{y,Ed} + M_{z,Ed}]$

N_{Ed}	1,030	[kN]	N_{Ed}	85,336	[kN]
$M_{y,Ed}^{max}$	0,840	[kNm]	$M_{y,Ed}^{min}$	4,501	[kNm]
$M_{z,Ed}^{max}$	0,020	[kNm]	$M_{z,Ed}^{min}$	1,249	[kNm]

[] EN 1993-1-3, Equation (6.25) | Ratio: 22,413 | [%]

$M_{y,Ed}^{max}$	4,471	[kNm]	$M_{y,Ed}^{min}$	2,814	[kNm]
$M_{z,Ed}^{max}$	KO		$M_{z,Ed}^{min} < M_{z,Ed}^{design}$	KO	

$\frac{M_{y,Ed} + M_{z,Ed}}{M_{y,Rd} + M_{z,Rd}} + \frac{M_{y,Ed} + M_{z,Ed}}{M_{y,Rd} + M_{z,Rd}} \leq 1$ [EN 1993-1-3, Equation (6.26)] | Ratio: 0,000 | [%]

[] C-Section Beam: Combined Shear Force, Axial Force and Bending Moment [EN 1993-1-3:2006, 6.1.10]

V_{Ed}	2,000	[kN]	R_{Ed}	4,245	[kN]
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$V_{Ed} < 0,50 V_{Rd,s}$ OK | No reduction due to shear force is need to be done

$\frac{N_{Ed}}{N_{Rd}} + \frac{M_{y,Ed}}{M_{y,Rd}} + (1 - \frac{M_{y,Ed}}{M_{y,Rd}}) \frac{2V_{Ed}}{V_{Rd,s}} \leq 1,0$ [BS EN 1993-1-3, Equation (6.27)]

N_{Ed}	0,200	[kN]	N_{Rd}	124,954	[kN]
N_{Ed}	1,030	[kN]	N_{Rd}	85,336	[kN]
$M_{y,Ed}^{max}$	0,840	[kNm]	$M_{y,Rd}$	4,501	[kNm]
$M_{y,Ed}^{min}$	0,840	[kNm]	$M_{y,Rd}$	4,501	[kNm]

Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes				Office: ---	Author: JOSE ANTONIO
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$\frac{M_{y,Ed} + F_{t,Ed}}{M_{y,Rd} + R_{t,Rd}} \leq 1,25$ [BS EN 1993-1-3, Equation (6.28)] | Ratio: 66,412 | [%]

$\frac{M_{y,Ed} + F_{t,Ed}}{M_{y,Rd} + R_{t,Rd}} \leq 1,25$ [BS EN 1993-1-3, Equation (6.28)] | Ratio: 66,413 | [%]

$\frac{M_{y,Ed} + F_{t,Ed}}{M_{y,Rd} + R_{t,Rd}} \leq 1,25$ [BS EN 1993-1-3, Equation (6.28)] | Ratio: 48,429 | [%]

$\frac{M_{y,Ed} + F_{t,Ed}}{M_{y,Rd} + R_{t,Rd}} \leq 1,25$ [BS EN 1993-1-3, Equation (6.28)] | Ratio: 48,716 | [%]

[] C-Section Column

[] C-Section Column: Axial Tension [BS EN 1993-1-3:2006, 6.1.2]

N_{Ed}	18,816,378	[N]	N_{Rd}	185,816	[kN]
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$N_{Ed} < N_{Rd}$ OK

[] C-Section Column: Axial Compression [BS EN 1993-1-3:2006, 6.1.2]

N_{Ed}	3,340	[kN]	N_{Rd}	1,797	[kN]
N_{Ed}	185,816	[kN]	N_{Rd}	185,816	[kN]

$N_{Ed} > N_{Rd}$ OK

[] C-Section Column: Axial Compression [BS EN 1993-1-3:2006, 6.1.2]

$A_{y1} < A_{y2} \rightarrow N_{Ed} = A_{y1} \cdot f_{y1}$ Yes

[BS EN 1993-1-3, Equation (6.2)]

$A_{y1} = A_{y2} \rightarrow N_{Ed} = A_{y1} \cdot f_{y1} + [f_{y1} - f_{y2}] \cdot A_{y2}$ Yes

A_{y1}	497,235	[mm ²]	A_{y2}	497,246	[mm ²]
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[BS EN 1993-1-3, Equation (6.2)]

N_{Ed}	188,751,712	[N]	N_{Rd}	168,751	[kN]
----------	-------------	-----	----------	---------	------

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N_{Ed}

N_{Ed}	0,700	[kN]	N_{Rd}	124,954	[kN]
N_{Ed}	124,904	[kN]	N_{Rd}	85,336	[kN]
$M_{y,Ed}^{max}$	0,840	[kNm]	$M_{y,Rd}$	4,501	[kNm]
$M_{y,Ed}^{min}$	4,501	[kNm]	$M_{y,Rd}$	4,501	[kNm]
V_{Ed}	2,000	[kN]	R_{Ed}	4,245	[kN]

Ratio: 19,412 | [%]

N_{Ed}

N_{Ed}	0,700	[kN]	N_{Rd}	124,954	[kN]
N_{Ed}	124,904	[kN]	N_{Rd}	85,336	[kN]
$M_{y,Ed}^{max}$	0,840	[kNm]	$M_{y,Rd}$	4,501	[kNm]
$M_{y,Ed}^{min}$	4,501	[kNm]	$M_{y,Rd}$	4,501	[kNm]
V_{Ed}	2,000	[kN]	R_{Ed}	4,245	[kN]

Ratio: 19,412 | [%]

N_{Ed}

N_{Ed}	1,030	[kN]	N_{Rd}	85,336	[kN]
N_{Ed}	85,336	[kN]	N_{Rd}	124,954	[kN]
$M_{y,Ed}^{max}$	0,840	[kNm]	$M_{y,Rd}$	4,501	[kNm]
$M_{y,Ed}^{min}$	4,501	[kNm]	$M_{y,Rd}$	4,501	[kNm]
V_{Ed}	2,000	[kN]	R_{Ed}	4,245	[kN]

Ratio: 20,058 | [%]

N_{Ed}

N_{Ed}	1,030	[kN]	N_{Rd}	85,336	[kN]
N_{Ed}	85,336	[kN]	N_{Rd}	124,954	[kN]
$M_{y,Ed}^{max}$	0,840	[kNm]	$M_{y,Rd}$	4,501	[kNm]
$M_{y,Ed}^{min}$	4,501	[kNm]	$M_{y,Rd}$	4,501	[kNm]
V_{Ed}	2,000	[kN]	R_{Ed}	4,245	[kN]

Ratio: 20,058 | [%]

[] C-Section Beam: Combined Bending Moment and Local Load or Support Reaction [EN 1993-1-3:2006, 6.1.11]

$M_{y,Ed}^{max} < M_{y,Rd}$	$M_{y,Ed}^{min}$	Ratio	19,299	[%]
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[BS EN 1993-1-3, Equation (6.2b)]

$M_{z,Ed}^{max} < M_{z,Rd}$	$M_{z,Ed}^{min}$	Ratio	19,299	[%]
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[BS EN 1993-1-3, Equation (6.2b)]

[] C-Section Beam: Bending Moment [BS EN 1993-1-3:2006, 6.1.2]

$M_{y,Ed}^{max} < M_{y,Rd}$	$M_{y,Ed}^{min}$	Ratio	1,316	[%]
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[BS EN 1993-1-3, Equation (6.2b)]

$M_{z,Ed}^{max} < M_{z,Rd}$	$M_{z,Ed}^{min}$	Ratio	1,002	[%]
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[BS EN 1993-1-3, Equation (6.2b)]

$F_{t,Ed} < F_{t,Rd}$	$F_{t,Ed}$	Ratio	47,113	[%]
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[BS EN 1993-1-3, Equation (6.2b)]

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NOTE: The internal axial force in a member is taken as acting at the centroid of its gross cross-section.

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 of the centroid with respect to the centroid of the gross section gives a favorable result in the above check, the shift should be neglected only if the shift has been calculated at yield strength and not with the actual compression stresses.

$N_{Ed} < A_{y1} \cdot f_{y1}$ OK

e_{y2}	0,006	[mm]	e_{y3}	0,000	[mm]
----------	-------	------	----------	-------	------

In stress check, shift is used

[] C-Section Column: Bending Moment [BS EN 1993-1-3:2006, 6.1.2]

N_{Ed}	4,370	[kN]	N_{Rd}	168,751	[kN]
----------	-------	------	----------	---------	------

Ratio: 2,471 | [%]

[] C-Section Column: Bending Moment [BS EN 1993-1-3:2006, 6.1.2]

Positive Moment in y -axis $[M_{y,Ed}]$

[BS EN 1993-1-3, Equation (6.4)]

$W_{pl,y} < W_{pl,y} \rightarrow M_{y,Ed} = W_{pl,y} \cdot f_{y1}$ Yes

[BS EN 1993-1-3, Equation (6.5)]

$W_{pl,y} = W_{pl,y} \rightarrow M_{y,Ed} = f_{y1} \cdot [W_{pl,y} + [W_{pl,y} - W_{pl,y}] \cdot \frac{e_{y2}}{e_{y1}}]$ Yes

Equation (6.5) is applicable provided that the following conditions are satisfied:

- [] Bending moment is applied only about one principal axis of the cross-section
- [] Member not welded to torsion or to torsional, torsional flexural or flexural-torsional or distorsional buckling
- [] Angle ϕ between the web and the flange is larger than 60°

[BS EN 1993-1-3, Equation (6.4)]

$M_{y,Ed}^{max} < M_{y,Rd}$	$M_{y,Ed}^{min}$	Ratio	5,336	[%]
-----------------------------	------------------	-------	-------	-----

$M_{y1,Ed}^{(1)}$	0,390	[kNm]	$\frac{M_{y1,Ed}^{(1)}}{M_{y1,Rd}^{(1)}} \leq 1,0$	Ratio	0,553	[%]
$M_{y2,Ed}^{(1)}$	5,336	[kNm]	$\frac{M_{y2,Ed}^{(1)}}{M_{y2,Rd}^{(1)}}$			
$W_{pl,y1}$	14278,705	[mm ³]	$W_{pl,y1}$	14278,705	[mm ³]	
[BS EN 1993-1-3, Equation (6.4)]						
$M_{z1,Ed}^{(1)}$	5335941,768	[Nmm]	$M_{z1,Ed}^{(1)}$	5336	[kNm]	
Negative Moment in y-axis [$M_{y,Ed}^{(1)}$]						
[BS EN 1993-1-3, Equation (6.4)]						
$W_{pl,y2}$	$W_{pl,y2}$		$M_{y,Ed}^{(1)}$	$W_{pl,y2} \cdot f_{yk} / \gamma_{M2}$		
[BS EN 1993-1-3, Equation (6.5)]						
$W_{pl,y2}$	$W_{pl,y2}$		$M_{y,Ed}^{(1)}$	$W_{pl,y2} \cdot f_{yk} / \gamma_{M2}$		
[BS EN 1993-1-3, Equation (6.6)]						
$M_{y1,Ed}^{(1)}$	0,390	[kNm]	$\frac{M_{y1,Ed}^{(1)}}{M_{y1,Rd}^{(1)}} \leq 1,0$	Ratio	0,553	[%]
$M_{y2,Ed}^{(1)}$	5,336	[kNm]	$\frac{M_{y2,Ed}^{(1)}}{M_{y2,Rd}^{(1)}}$			
$W_{pl,y1}$	14278,705	[mm ³]	$W_{pl,y1}$	14278,705	[mm ³]	
[BS EN 1993-1-3, Equation (6.4)]						
$M_{z1,Ed}^{(1)}$	5335941,768	[Nmm]	$M_{z1,Ed}^{(1)}$	5336	[kNm]	

$I_{x,Ed}^{(1)}$	153816,866	[mm ⁴]	$I_{x,Ed}^{(1)}$	153816,866	[mm ⁴]	
$I_{y,Ed}^{(1)}$	153816,866	[mm ⁴]	$I_{y,Ed}^{(1)}$	153816,866	[mm ⁴]	
$W_{pl,y1}$	14278,705	[mm ³]	$W_{pl,y1}$	14278,705	[mm ³]	
[BS EN 1993-1-3, Equation (6.4)]						
$M_{z1,Ed}^{(1)}$	2081091,866	[Nmm]	$M_{z1,Ed}^{(1)}$	2081	[kNm]	
$M_{z2,Ed}^{(1)}$	0,000	[kNm]	$\frac{M_{z2,Ed}^{(1)}}{M_{z2,Rd}^{(1)}}$	0,000	[%]	
$W_{pl,y2}$	9518,866	[mm ³]	$W_{pl,y2}$	9518,866	[mm ³]	
[BS EN 1993-1-3, Equation (6.4)]						
$M_{z1,Ed}^{(1)}$	3507170,948	[Nmm]	$M_{z1,Ed}^{(1)}$	3507	[kNm]	
[γ_{M2}] C-Section Column Shear Force [BS EN 1993-1-3:2006, 8.1.5]						
$V_{k,Rd} = \frac{h_w \cdot t_{w1}}{\sin \phi} \cdot \frac{f_{yk}}{\gamma_{M0}}$						
h_w	87,548	[mm]	t_{w1}	3,000	[mm]	
ϕ	90,000	[°]	f_{yk}	350,000	[MPa]	
γ_{M0}	1,000		E	210,000	[GPa]	
Webs without longitudinal stiffeners $\bar{\lambda}_w = 0,346 \cdot \frac{v_w}{t_w} \sqrt{\frac{f_{yk}}{E}}$ [EN 1993-1-3, Equation (8.10a)]						
v_w	87,548	[mm]	f_{yk}	350,000	[MPa]	
t_w	2,452	[mm]	E	210,000	[GPa]	
Table 8.1 Shear buckling strength f_{yk} [BS EN 1993-1-3:2006]						
Ratio $\bar{\lambda}_w$ with slenderness $\bar{\lambda}_w$ with slenderness						
$\bar{\lambda}_w \leq 0,83$	$0,58 f_{yk}$		$\bar{\lambda}_w < 1,40$	$0,48 f_{yk} / \bar{\lambda}_w$		
$\bar{\lambda}_w \geq 1,40$	$0,48 f_{yk} / \bar{\lambda}_w$		$\bar{\lambda}_w \geq 1,40$	$0,48 f_{yk} / \bar{\lambda}_w$		
$\bar{\lambda}_w$	0,804	[EN 1993-1-3, Equation (8.10a)]	f_{yk}	203,000	[MPa]	
$V_{k,Ed}$	43977,542	[N]	$V_{k,Rd}$	43,978	[kN]	

Positive Moment in z-axis [$M_{z,Ed}^{(1)}$]						
[BS EN 1993-1-3, Equation (6.4)]						
$W_{pl,z}$	$W_{pl,z}$		$M_{z,Ed}^{(1)}$	$W_{pl,z} \cdot f_{yk} / \gamma_{M2}$		
[BS EN 1993-1-3, Equation (6.5)]						
$W_{pl,z}$	$W_{pl,z}$		$M_{z,Ed}^{(1)}$	$W_{pl,z} \cdot f_{yk} / \gamma_{M2}$		
[BS EN 1993-1-3, Equation (6.6)]						
$I_{x,Ed}^{(1)}$	153816,866	[mm ⁴]	$I_{x,Ed}^{(1)}$	153816,866	[mm ⁴]	
$I_{y,Ed}^{(1)}$	150933,116	[mm ⁴]	$I_{y,Ed}^{(1)}$	150933,116	[mm ⁴]	
$W_{pl,y1}$	9518,866	[mm ³]	$W_{pl,y1}$	9518,866	[mm ³]	
[BS EN 1993-1-3, Equation (6.4)]						
$M_{z1,Ed}^{(1)}$	318291,330	[Nmm]	$M_{z1,Ed}^{(1)}$	318	[kNm]	
$M_{z2,Ed}^{(1)}$	0,000	[kNm]	$\frac{M_{z2,Ed}^{(1)}}{M_{z2,Rd}^{(1)}}$	0,000	[%]	
$M_{z3,Ed}^{(1)}$	3,160	[kNm]	$\frac{M_{z3,Ed}^{(1)}}{M_{z3,Rd}^{(1)}}$			
$W_{pl,y2}$	5515,275	[mm ³]	$W_{pl,y2}$	5422,299	[mm ³]	
[BS EN 1993-1-3, Equation (6.4)]						
$M_{z1,Ed}^{(1)}$	1915478,602	[Nmm]	$M_{z1,Ed}^{(1)}$	1915	[kNm]	
Negative Moment in z-axis [$M_{z,Ed}^{(1)}$]						
[BS EN 1993-1-3, Equation (6.4)]						
$W_{pl,z}$	$W_{pl,z}$		$M_{z,Ed}^{(1)}$	$W_{pl,z} \cdot f_{yk} / \gamma_{M2}$		
[BS EN 1993-1-3, Equation (6.5)]						
$W_{pl,z}$	$W_{pl,z}$		$M_{z,Ed}^{(1)}$	$W_{pl,z} \cdot f_{yk} / \gamma_{M2}$		
[BS EN 1993-1-3, Equation (6.6)]						

$V_{k,Ed}^{(1)}$	43,978	[kN]	$\frac{V_{k,Ed}^{(1)}}{V_{k,Rd}^{(1)}}$	0,740	[%]	
$V_{k,Rd}^{(1)}$	59,428	[kN]	$\frac{V_{k,Ed}^{(1)}}{V_{k,Rd}^{(1)}}$			
[γ_{M2}] C-Section Column Torsional Moment [EN 1993-1-3:2006, 8.1.8]						
NOTE Where loads are applied eccentric to the shear centre of the cross-section, the effects of torsion are taken into account						
Gravity Centre						
y_{Gc}	16,159	[mm]	y_{Sc}	43,949	[mm]	Δ
z_{Gc}	43,774	[mm]	z_{Sc}	43,774	[mm]	0,000
The applied loads are eccentric to the shear centre of the cross-section, the effects of torsion are taken into account						
Significance of St Venant Torsion and Warping Torsion for This Cold-Formed Section						
Section Type	Shape	St Venant	Warping			
This Cold-Formed Section	Z	X	V			
Key	X	Negligible	V	Significant		
$\sigma_{k,Ed} = \sigma_{N,Ed} + \sigma_{M_y,Ed} + \sigma_{M_z,Ed} + \sigma_{w,Ed} + \sigma_{t,Ed} = \sigma_{N,Ed} + \sigma_{M_y,Ed} + \sigma_{M_z,Ed} + \sigma_{w,Ed} + \sigma_{t,Ed}$ [BS EN 1993-1-3, Equation (8.12a)] [BS EN 1993-1-3, Equation (8.12b)]						
$\sigma_{N,Ed}$	8,210	[MPa]	$\sigma_{N,Ed}$	0,000	[MPa]	
$\sigma_{M_y,Ed}$	23,710	[MPa]	$\sigma_{M_y,Ed}$	0,000	[MPa]	
$\sigma_{M_z,Ed}$	0,260	[MPa]	$\sigma_{w,Ed}$	221,865	[MPa]	
$\sigma_{w,Ed}$	124,598	[MPa]	$\sigma_{t,Ed}$	0,000	[MPa]	
$\sigma_{t,Ed}$	168,738	[MPa]	$\sigma_{t,Ed}$	221,865	[MPa]	
Left end free to warp but not twist Right end fixed (no twist or warp) C-Section Column						

$\sigma_{Ed,Ed} \leq f_{yk} / \gamma_{M1}$ [BS EN 1993-1-3, Equation (8.14a)]	$\sigma_{Ed,Ed}$	156,738 [MPa]	OK
f_{yk} / γ_{M1}	f_{yk} / γ_{M1}	373,699 [MPa]	
$f_{Ed,Ed} \leq \frac{f_{yk} \sqrt{3}}{\gamma_{M1}}$ [BS EN 1993-1-3, Equation (8.14b)]	$f_{Ed,Ed}$	221,885 [MPa]	OK
$\frac{f_{yk} \sqrt{3}}{\gamma_{M1}}$	$\frac{f_{yk} \sqrt{3}}{\gamma_{M1}}$	647,268 [MPa]	
$\sqrt{\sigma_{Ed,Ed}^2 + 3\tau_{Ed,Ed}^2} \leq 1,1 \frac{f_{yk}}{\gamma_{M1}} \sqrt{\sigma_{Ed,Ed}^2 + 3\tau_{Ed,Ed}^2}$ [BS EN 1993-1-3, Equation (8.14c)]	$\sqrt{\sigma_{Ed,Ed}^2 + 3\tau_{Ed,Ed}^2}$	270,492 [MPa]	OK
$1,1 \frac{f_{yk}}{\gamma_{M1}} \sqrt{\sigma_{Ed,Ed}^2 + 3\tau_{Ed,Ed}^2}$	$1,1 \frac{f_{yk}}{\gamma_{M1}} \sqrt{\sigma_{Ed,Ed}^2 + 3\tau_{Ed,Ed}^2}$	411,989 [MPa]	

[1] C-Section Column: Local Tension Forces [EN 1993-1-3:2006, 6.3.7]

$F_{Ed} \leq R_{w,Rd}$
[BS EN 1993-1-3, Equation (8.13)]

ADVICE: To avoid crushing, crippling or buckling in a web subjected to a support reaction or other local tension forces, force applied through the flange

Local Tension Resistance of the Web

Considerations with a single unslotted web [BS EN 1993-1-3, 6.3.7.2]

$h_w / t \leq 200$ [BS EN 1993-1-3, Equation (8.14a)]	h_w	87,548 [mm]	OK
ϕ	ϕ	90,000 [%]	
t	t	2,452 [mm]	
$r / t \leq 6$ [BS EN 1993-1-3, Equation (8.14b)]	r	3,726 [mm]	OK
t	t	2,452 [mm]	
$45^\circ \leq \theta \leq 90^\circ$ [BS EN 1993-1-3, Equation (8.14c)]	θ	90,000 [%]	OK
t	t		

$k_1 = 1,33 - 0,33k$ k_1 0,923

$k_2 = 1,15 - 0,15r/t$ k_2 0,922

$k_3 \geq 0,50$ OK $k_3 \leq 1,0$ OK

$k_3 = 0,7 + 0,3(\phi/90)$ k_3 1,000

$k = f_{yk} / 228$ k 1,235 $k_4 = 1,22 - 0,22k$ k_4 0,882

$k_5 = 1,06 - 0,06r/t$ k_5 0,989 $k_5 \leq 1,0$ OK

$M_{y,Ed,Ed}(\dots)$	5,338 [kNm]	$M_{y,Ed,Ed}(\dots)$	3,765 [kNm]
$M_{z,Ed,Ed}(\dots)$	0,000 [kNm]	$M_{z,Ed,Ed}(\dots)$	0,000 [kNm]
$M_{y,Ed,Ed}(\dots) \leq M_{y,Rd,Ed,Ed}(\dots)$	OK	$M_{y,Ed,Ed}(\dots) \leq M_{y,Rd,Ed,Ed}(\dots)$	KO

$\frac{M_{y,Ed,Ed}}{M_{y,Rd,Ed,Ed}} + \frac{M_{z,Ed,Ed}}{M_{z,Rd,Ed,Ed}} - \frac{N_{Ed,Ed}}{N_{Rd,Ed,Ed}} \leq 1$ [EN 1993-1-3, Equation (8.24) don't need to be verified]

[EN 1993-1-3, Equation (8.24)] Ratio 0,000 [%]

Combined Tension and Bending Moment [$M_{y,Ed}^2 + M_{z,Ed}^2$]

N_{Ed}	3,340 [kN]	N_{Ed}	185,816 [kN]
$M_{y,Ed,Ed}$	0,350 [kNm]	$M_{y,Ed,Ed}$	5,338 [kNm]
$M_{z,Ed,Ed}$	0,000 [kNm]	$M_{z,Ed,Ed}$	3,597 [kNm]

[EN 1993-1-3, Equation (8.23)] Ratio 0,357 [%]

$M_{y,Ed,Ed}(\dots)$	5,338 [kNm]	$M_{y,Ed,Ed}(\dots)$	2,961 [kNm]
$M_{z,Ed,Ed}(\dots)$	0,000 [kNm]	$M_{z,Ed,Ed}(\dots)$	0,000 [kNm]

$M_{y,Ed,Ed}(\dots) \leq M_{y,Rd,Ed,Ed}(\dots)$ OK $M_{z,Ed,Ed}(\dots) \leq M_{z,Rd,Ed,Ed}(\dots)$ OK

$\frac{M_{y,Ed,Ed}}{M_{y,Rd,Ed,Ed}} + \frac{M_{z,Ed,Ed}}{M_{z,Rd,Ed,Ed}} - \frac{N_{Ed,Ed}}{N_{Rd,Ed,Ed}} \leq 1$ [EN 1993-1-3, Equation (8.24) don't need to be verified]

[EN 1993-1-3, Equation (8.24)] Ratio 4,762 [%]

[1a] C-Section Column: Combined Compression and Bending [EN 1993-1-3:2006, 6.3.9]

$\frac{N_{Ed}}{N_{Rd}} + \frac{M_{y,Ed} + \Delta M_{y,Ed} + M_{z,Ed} + \Delta M_{z,Ed}}{M_{y,Rd} + M_{z,Rd}} \leq 1$
[BS EN 1993-1-3, Equation (8.25)]

$\Delta M_{y,Ed} = N_{Ed,Ed} \cdot \eta_{Ed,Ed}$	$\Delta M_{z,Ed} = N_{Ed,Ed} \cdot \eta_{Ed,Ed}$		
$N_{Ed,Ed}$	4,770 [kN]	$N_{Ed,Ed}$	4,770 [kN]
$\eta_{Ed,Ed}$	0,000 [m]	$\eta_{Ed,Ed}$	0,001 [m]
$\Delta M_{y,Ed}$	0,000 [kNm]	$\Delta M_{z,Ed}$	0,002 [kNm]

Combined Compression and Bending Moment [$M_{y,Ed}^2 + M_{z,Ed}^2$]

N_{Ed}	4,770 [kN]	N_{Ed}	188,251 [kN]
$M_{y,Ed,Ed}$	0,350 [kNm]	$M_{y,Ed,Ed}$	5,338 [kNm]
$M_{z,Ed,Ed}$	0,000 [kNm]	$M_{z,Ed,Ed}$	3,765 [kNm]

Local loads and supports: Considerations with a single web [BS EN 1993-1-3:2006, Figure 6.7a]

[1] Cross-Section with slotted Flanges [2] Cross-Section with slotted Flanges

$R_{w,Rd} = \frac{A_w \cdot \sigma_{yk} \cdot \sqrt{3}}{\gamma_{M1}} \left(1 + 0,001 \frac{h_w}{t} \right) / f_{yk}$
[BS EN 1993-1-3, Equation (8.15a)]

$\eta_w \leq 0,5$ [BS EN 1993-1-3, Equation (8.15a)]

$R_{w,Rd} = \frac{A_w \cdot \sigma_{yk} \cdot \sqrt{3}}{\gamma_{M1}} \left(1 + 0,001 \frac{h_w}{t} \right) / f_{yk}$
[BS EN 1993-1-3, Equation (8.15a)]

$\eta_w \leq 0,5$ [BS EN 1993-1-3, Equation (8.15a)]

Local load application $\leq 200 \cdot h_w$ clear from a free end Local load application $\leq 200 \cdot h_w$ clear from a free end

c	0,000 [mm]	h_w	87,548 [mm]
η_w	36,896 [mm]	t	2,452 [mm]

BS EN 1993-1-3, Equation (8.15a)

BS EN 1993-1-3, Equation (8.15a)

$R_{w,Rd}$ 15506,072 [N] $R_{w,Rd}$ 15,506 [kN]

V_{Ed} 2,240 [kN] Ratio 14,448 [%]

$R_{w,Rd}$ 15,506 [kN]

[1a] C-Section Column: Combined Tension and Bending [EN 1993-1-3:2006, 6.3.1]

$\frac{N_{Ed}}{N_{Rd}} + \frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} \leq 1$
[BS EN 1993-1-3, Equation (8.23)]

$M_{y,Ed,Ed} \leq M_{y,Rd,Ed,Ed}$ or $M_{z,Ed,Ed} \leq M_{z,Rd,Ed,Ed}$

$\frac{M_{y,Ed,Ed}}{M_{y,Rd,Ed,Ed}} + \frac{M_{z,Ed,Ed}}{M_{z,Rd,Ed,Ed}} - \frac{N_{Ed,Ed}}{N_{Rd,Ed,Ed}} \leq 1$
[BS EN 1993-1-3, Equation (8.24)]

Combined Tension and Bending Moment [$M_{y,Ed}^2 + M_{z,Ed}^2$]

N_{Ed}	3,340 [kN]	N_{Ed}	185,816 [kN]
$M_{y,Ed,Ed}$	0,350 [kNm]	$M_{y,Ed,Ed}$	5,338 [kNm]
$M_{z,Ed,Ed}$	0,000 [kNm]	$M_{z,Ed,Ed}$	1,815 [kNm]

[EN 1993-1-3, Equation (8.23)] Ratio 0,357 [%]

[EN 1993-1-3, Equation (8.25)] Ratio 9,337 [%]

$M_{y,Ed,Ed}(\dots)$	5,338 [kNm]	$M_{y,Ed,Ed}(\dots)$	1,815 [kNm]
$M_{z,Ed,Ed}(\dots)$	0,000 [kNm]	$M_{z,Ed,Ed}(\dots)$	0,000 [kNm]
$M_{y,Ed,Ed}(\dots) \leq M_{y,Rd,Ed,Ed}(\dots)$	OK	$M_{y,Ed,Ed}(\dots) \leq M_{y,Rd,Ed,Ed}(\dots)$	OK

$\frac{M_{y,Ed,Ed} + \Delta M_{y,Ed}}{M_{y,Rd,Ed,Ed}} + \frac{M_{z,Ed,Ed} + \Delta M_{z,Ed}}{M_{z,Rd,Ed,Ed}} - \frac{N_{Ed,Ed}}{N_{Rd,Ed,Ed}} \leq 1$ [EN 1993-1-3, Equation (8.26) don't need to be verified]

[EN 1993-1-3, Equation (8.26)] Ratio 0,000 [%]

Combined Compression and Bending Moment [$M_{y,Ed}^2 + M_{z,Ed}^2$]

N_{Ed}	4,770 [kN]	N_{Ed}	188,251 [kN]
$M_{y,Ed,Ed}$	0,350 [kNm]	$M_{y,Ed,Ed}$	5,338 [kNm]
$M_{z,Ed,Ed}$	0,000 [kNm]	$M_{z,Ed,Ed}$	2,961 [kNm]

[EN 1993-1-3, Equation (8.25)] Ratio 9,333 [%]

$M_{y,Ed,Ed}(\dots)$	5,338 [kNm]	$M_{y,Ed,Ed}(\dots)$	3,597 [kNm]
$M_{z,Ed,Ed}(\dots)$	0,000 [kNm]	$M_{z,Ed,Ed}(\dots)$	0,000 [kNm]

$M_{y,Ed,Ed}(\dots) \leq M_{y,Rd,Ed,Ed}(\dots)$ OK $M_{z,Ed,Ed}(\dots) \leq M_{z,Rd,Ed,Ed}(\dots)$ KO

[1a] C-Section Column: Combined Shear Force, Axial Force and Bending Moment [EN 1993-1-3:2006, 6.3.10]

V_{Ed} 2,240 [kN] $R_{w,Rd}$ 15,506 [kN]

$V_{Ed} \leq 0,25 V_{w,Rd}$ OK No reduction due to shear force is need to be done

$\frac{N_{Ed}}{N_{Rd}} + \frac{M_{y,Ed}}{M_{y,Rd}} + \left(1 - \frac{M_{z,Ed}}{M_{z,Rd}} \right) \left(\frac{2 V_{Ed}}{V_{w,Rd}} - 1 \right)^2 \leq 1,0$
[BS EN 1993-1-3, Equation (8.27)]

N_{Ed}	3,340 [kN]	N_{Ed}	185,816 [kN]
N_{Ed}	4,770 [kN]	N_{Ed}	188,251 [kN]
$M_{y,Ed,Ed}$	0,350 [kNm]	$M_{y,Ed,Ed}$	4,988 [kNm]
$M_{z,Ed,Ed}$	0,350 [kNm]	$M_{z,Ed,Ed}$	4,988 [kNm]

Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes			
Code:	Eurocode	Reference:	EN 1990 | EN 1991 | EN 1993
Version:	1,000	Client:	COIMBRA UNIVERSITY
Office:	---	Author:	JOSE ANTONIO
Date:	05/09/2019	Project:	MASTER THESIS

N_{Ed}	3,340	[kN]			
N_{Ed}	185,216	[kN]			
$M_{Ed,1-2}$	0,350	[kNm]	Ratio	36,081	[%]
$M_{Ed,2-3}$	4,998	[kNm]			
V_{Ed}	2,240	[kN]			
R_{Ed}	15,506	[kN]			

N_{Ed}	3,340	[kN]			
N_{Ed}	185,216	[kN]			
$M_{Ed,1-2}$	0,350	[kNm]	Ratio	36,081	[%]
$M_{Ed,2-3}$	4,998	[kNm]			
V_{Ed}	2,240	[kN]			
R_{Ed}	15,506	[kN]			

N_{Ed}	4,770	[kN]			
N_{Ed}	188,251	[kN]			
$M_{Ed,1-2}$	0,350	[kNm]	Ratio	36,755	[%]
$M_{Ed,2-3}$	4,998	[kNm]			
V_{Ed}	2,240	[kN]			
R_{Ed}	15,506	[kN]			

N_{Ed}	4,770	[kN]			
N_{Ed}	188,251	[kN]			
$M_{Ed,1-2}$	0,350	[kNm]	Ratio	36,755	[%]
$M_{Ed,2-3}$	4,998	[kNm]			
V_{Ed}	2,240	[kN]			
R_{Ed}	15,506	[kN]			

[x] C-Section (Column Combined Bending Moment and Local Load or Support Reaction) [BS EN 1993-1-1:2006, 6.1.1]

M_{Ed}	$M_{Ed,1-2}$	$M_{Ed,2-3}$	Ratio	6,559	[%]
[BS EN 1993-1-1, Equation (6.2b)]					
M_{Ed}	$M_{Ed,1-2}$	$M_{Ed,2-3}$	Ratio	6,559	[%]
[BS EN 1993-1-1, Equation (6.2b)]					
M_{Ed}	$M_{Ed,1-2}$	$M_{Ed,2-3}$	Ratio	0,000	[%]
[BS EN 1993-1-1, Equation (6.2b)]					
M_{Ed}	$M_{Ed,1-2}$	$M_{Ed,2-3}$	Ratio	0,000	[%]
[BS EN 1993-1-1, Equation (6.2b)]					
F_{Ed}	$F_{Ed,1-2}$	$F_{Ed,2-3}$	Ratio	14,948	[%]
[BS EN 1993-1-1, Equation (6.2b)]					

Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes			
Code:	Eurocode	Reference:	EN 1990 | EN 1991 | EN 1993
Version:	1,000	Client:	COIMBRA UNIVERSITY
Office:	---	Author:	JOSE ANTONIO
Date:	05/09/2019	Project:	MASTER THESIS

NOTE: The lateral axial force in a member is taken as acting at the centroid of its gross cross section.

The design compression resistance of a cross-section refers to the axial force 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_{eff} of the centroid axis is taken into account. If the shift of the centroid axis gives a favourable result in the stress check, the shift should be neglected only if the shift has been calculated at yield strength f_y and not with the actual compressive stresses.

$$N_{Ed} < A_g \cdot f_y / \gamma_{M2}$$

OK

e_{eff} 2,611 [mm]

e_{pl} 0,000 [mm]

In stress check, shift is neglected because it has been calculated at yield strength f_y and not with actual compressive stresses

N_{Ed}	1,570	[kN]	$\frac{N_{Ed}}{N_{Ed,pl}} \leq 1,0$	Ratio	2,214	[%]
N_{Ed}	68,398	[kN]				

[y] C-Section (Beam Bending Moment) [BS EN 1993-1-1:2006, 6.1.2]

Positive Moment in y-axis [$M_{Ed,y}$]

[BS EN 1993-1-1, Equation (6.4)]

$$W_{pl,y} < W_{pl,y} \rightarrow M_{Ed,y} < W_{pl,y} \cdot f_y / \gamma_{M2}$$

[BS EN 1993-1-1, Equation (6.5)]

$$W_{pl,y} < W_{pl,y} \rightarrow M_{Ed,y} < f_y \cdot [W_{pl,y} + W_{pl,y} \cdot (1 + \alpha) \cdot (1 + \alpha) \cdot (1 + \alpha) \cdot (1 + \alpha)] \cdot f_y / \gamma_{M2}$$

Equation (6.5) is applicable provided that the following conditions are satisfied:

- [a] Bending moment is applied only about one principal axis of the cross-section
- [b] Member not welded to tension or to torsion, torsion flexural or flexion-torsion and/or distortion buckling
- [c] Angle ϕ between the web and the flange is larger than 60°

[BS EN 1993-1-1, Equation (6.6)]

$$M_{Ed,y} < W_{pl,y} \cdot f_y / \gamma_{M2}$$

$I_{pl,y}$	85435,109	[mm ⁴]	$W_{pl,y}$	3519,614	[mm ³]
$I_{pl,y}$	83780,577	[mm ⁴]	$W_{pl,y}$	3519,614	[mm ³]
$W_{pl,y}$	3519,614	[mm ³]	$W_{pl,y}$	3492,958	[mm ³]
			$W_{pl,y}$	3593,773	[mm ³]
			$W_{pl,y}$	3492,958	[mm ³]

[BS EN 1993-1-1, Equation (6.4)]

$M_{Ed,y}$	1,90713,495	[kNm]	$M_{Ed,y}$	1,191	[kNm]
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Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes			
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[a] $\frac{M_{Ed} + F_{Ed}}{M_{Ed} + R_{Ed}} \leq 1,25$

M_{Ed}	$M_{Ed,1-2}$	$M_{Ed,2-3}$	Ratio	21,005	[%]
[BS EN 1993-1-1, Equation (6.2b)]					
F_{Ed}	$F_{Ed,1-2}$	$F_{Ed,2-3}$	Ratio	21,005	[%]
[BS EN 1993-1-1, Equation (6.2b)]					
M_{Ed}	$M_{Ed,1-2}$	$M_{Ed,2-3}$	Ratio	14,448	[%]
[BS EN 1993-1-1, Equation (6.2b)]					
F_{Ed}	$F_{Ed,1-2}$	$F_{Ed,2-3}$	Ratio	14,448	[%]
[BS EN 1993-1-1, Equation (6.2b)]					

[c] C-Section (Beam)

[i] C-Section (Beam Axial Tension) [BS EN 1993-1-1:2006, 6.1.2]

$$N_{Ed} = \frac{f_y \cdot A_g}{\gamma_{M2}}$$

[BS EN 1993-1-1, Equation (6.2)]

N_{Ed}	74592,683	[kN]	N_{Ed}	74,593	[kN]
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f_y 370,228 [MPa]

A_g 201,315 [mm²]

γ_{M2} 1,000

$\frac{N_{Ed}}{N_{Ed,pl}} \leq 1,0$

N_{Ed}	2,280	[kN]	Ratio	3,057	[%]
N_{Ed}	74,593	[kN]			

[ii] C-Section (Beam Axial Compression) [BS EN 1993-1-1:2006, 6.1.3]

[BS EN 1993-1-1, Equation (6.2)]

$$A_{pl} < A_g \rightarrow N_{Ed} < A_{pl} \cdot f_y / \gamma_{M2}$$

[BS EN 1993-1-1, Equation (6.3)]

$$A_{pl} < A_g \rightarrow N_{Ed} < A_{pl} \cdot f_y \cdot [1 + \alpha] \cdot [1 + \alpha] \cdot [1 + \alpha] \cdot [1 + \alpha] \cdot f_y / \gamma_{M2}$$

A_g	201,315	[mm ²]	A_{pl}	189,709	[mm ²]
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[BS EN 1993-1-1, Equation (6.2)]

N_{Ed}	68398,276	[kN]	N_{Ed}	64,398	[kN]
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$M_{Ed,y}$	0,910	[kNm]	$\frac{M_{Ed,y}}{M_{Ed,y,pl}} \leq 1,0$	Ratio	0,840	[%]
$M_{Ed,y}$	1,391	[kNm]				

$W_{pl,y}$ 3519,614 [mm³]

$W_{pl,y}$ 3593,773 [mm³]

[BS EN 1993-1-1, Equation (6.4)]

$M_{Ed,y}$	1,226110,897	[kNm]	$M_{Ed,y}$	1,226	[kNm]
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Negative Moment in y-axis [$M_{Ed,y}$]

[BS EN 1993-1-1, Equation (6.4)]

$$W_{pl,y} < W_{pl,y} \rightarrow M_{Ed,y} < W_{pl,y} \cdot f_y / \gamma_{M2}$$

[BS EN 1993-1-1, Equation (6.5)]

$$W_{pl,y} < W_{pl,y} \rightarrow M_{Ed,y} < f_y \cdot [W_{pl,y} + W_{pl,y} \cdot (1 + \alpha) \cdot (1 + \alpha) \cdot (1 + \alpha) \cdot (1 + \alpha)] \cdot f_y / \gamma_{M2}$$

[BS EN 1993-1-1, Equation (6.6)]

$$M_{Ed,y} < W_{pl,y} \cdot f_y / \gamma_{M2}$$

$I_{pl,y}$	85435,109	[mm ⁴]	$W_{pl,y}$	3519,614	[mm ³]
$I_{pl,y}$	83780,577	[mm ⁴]	$W_{pl,y}$	3519,614	[mm ³]
$W_{pl,y}$	3519,614	[mm ³]	$W_{pl,y}$	3492,958	[mm ³]
			$W_{pl,y}$	3593,773	[mm ³]
			$W_{pl,y}$	3492,958	[mm ³]

[BS EN 1993-1-1, Equation (6.4)]

$M_{Ed,y}$	1,90713,495	[kNm]	$M_{Ed,y}$	1,191	[kNm]
------------	-------------	-------	------------	-------	-------

$M_{Ed,y}$	0,910	[kNm]	$\frac{M_{Ed,y}}{M_{Ed,y,pl}} \leq 1,0$	Ratio	0,840	[%]
$M_{Ed,y}$	1,391	[kNm]				

$W_{pl,y}$ 3519,614 [mm³]

$W_{pl,y}$ 3593,773 [mm³]

[BS EN 1993-1-1, Equation (6.4)]

$M_{Ed,y}$	1,226110,897	[kNm]	$M_{Ed,y}$	1,226	[kNm]
------------	--------------	-------	------------	-------	-------

Design of a Photovoltaic Structure, Partial configuration, according to Eurocodes				Office: ---	Author: JOSE ANTONIO
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Pos. Biv. Moment (in z-axis) $M_{y,z}^+$

[BS EN 1993-1-3, Equation (6.4)]
 $W_{pl,y} = W_{pl,z} \rightarrow M_{y,z}^+ = W_{pl,y} \cdot f_{yk} \cdot Y_{M1}$

[BS EN 1993-1-3, Equation (6.5)]
 $W_{pl,y} = W_{pl,z} \rightarrow M_{y,z}^+ = f_{yk} \cdot [W_{pl,y} \cdot Y_{M1} + W_{pl,z} \cdot Y_{M2} + W_{pl,z} \cdot Y_{M3} + W_{pl,y} \cdot Y_{M4}] \cdot Y_{M5}$

[BS EN 1993-1-3, Equation (6.6)]
 $M_{y,z}^+ = W_{pl,y} \cdot f_{yk} \cdot Y_{M1}$

$W_{pl,y}(z)$	43399,345	[mm ³]	$W_{pl,z}(z)$	2873,453	[mm ³]
$W_{pl,y}(z)$	1851,197	[mm ³]	$W_{pl,z}(z)$	1853,828	[mm ³]
$W_{pl,y}(z)$	441,092,618	[mm ³]	$W_{pl,z}(z)$	2988,092	[mm ³]
$W_{pl,y}(z)$	2873,453	[mm ³]	$W_{pl,z}(z)$	2988,092	[mm ³]

[BS EN 1993-1-3, Equation (6.6)]
 $M_{z,2000mm(z)} = 1084690,100$ [Nm] $\rightarrow M_{z,2000mm(z)} = 1,065$ [kNm]

[BS EN 1993-1-3, Equation (6.6)]
 $M_{y,2000mm(z)} = 0,900$ [kNm] $\frac{M_{y,z}^+}{M_{y,Rd}} \leq 1,0$ Ratio = 0,000 [%]

[BS EN 1993-1-3, Equation (6.6)]
 $M_{y,1000mm(z)} = 1,065$ [kNm] $\frac{M_{y,z}^+}{M_{y,Rd}} \leq 1,0$ Ratio = 0,000 [%]

[BS EN 1993-1-3, Equation (6.4)]
 $W_{pl,y}(z)$ 1851,197 [mm³] $W_{pl,z}(z)$ 1853,828 [mm³]

[BS EN 1993-1-3, Equation (6.6)]
 $M_{z,1000mm(z)} = 685992,338$ [Nm] $\rightarrow M_{z,1000mm(z)} = 0,666$ [kNm]

Negative Moment (in z-axis) $M_{y,z}^-$

[BS EN 1993-1-3, Equation (6.4)]
 $W_{pl,y} = W_{pl,z} \rightarrow M_{y,z}^- = W_{pl,y} \cdot f_{yk} \cdot Y_{M1}$

[BS EN 1993-1-3, Equation (6.5)]
 $W_{pl,y} = W_{pl,z} \rightarrow M_{y,z}^- = f_{yk} \cdot [W_{pl,y} \cdot Y_{M1} + W_{pl,z} \cdot Y_{M2} + W_{pl,z} \cdot Y_{M3} + W_{pl,y} \cdot Y_{M4}] \cdot Y_{M5}$

[BS EN 1993-1-3, Equation (6.6)]
 $M_{y,z}^- = W_{pl,y} \cdot f_{yk} \cdot Y_{M1}$

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Combined Tension and Bending Moment $|M_{y,z}^+ + M_{y,z}^-|$

N_{Ed}	2,280	[kN]	N_{Ed}	74,593	[kN]
$M_{y,Ed}(z)$	0,910	[kNm]	$M_{z,Ed}(z)$	1,226	[kNm]
$M_{z,Ed}(z)$	0,900	[kNm]	$M_{y,Ed}(z)$	0,666	[kNm]

[EN 1993-1-3, Equation (6.23)] Ratio = 3,872 [%]

$M_{y,Ed}(z)$ 1,191 [kNm] $M_{z,Ed}(z)$ 1,666 [kNm]

$M_{y,Ed}(z) \leq M_{y,Rd}(z)$ OK $M_{z,Ed}(z) \leq M_{z,Rd}(z)$ KO

[BS EN 1993-1-3, Equation (6.24)]
 $\frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} - \frac{N_{Ed}}{N_{Rd}} \leq 1$ [EN 1993-1-3, Equation (6.24) don't need to be verified]
 Ratio = 0,000 [%]

[EN 1993-1-3, Equation (6.24)]
 $\frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} - \frac{N_{Ed}}{N_{Rd}} \leq 1$ [EN 1993-1-3, Equation (6.24)]
 Ratio = 0,000 [%]

Combined Tension and Bending Moment $|M_{y,z}^+ + M_{y,z}^-|$

N_{Ed}	2,280	[kN]	N_{Ed}	74,593	[kN]
$M_{y,Ed}(z)$	0,910	[kNm]	$M_{z,Ed}(z)$	1,226	[kNm]
$M_{z,Ed}(z)$	0,900	[kNm]	$M_{y,Ed}(z)$	1,666	[kNm]

[EN 1993-1-3, Equation (6.23)] Ratio = 3,872 [%]

$M_{y,Ed}(z)$ 1,191 [kNm] $M_{z,Ed}(z)$ 0,666 [kNm]

$M_{y,Ed}(z) \leq M_{y,Rd}(z)$ OK $M_{z,Ed}(z) \leq M_{z,Rd}(z)$ OK

[BS EN 1993-1-3, Equation (6.24)]
 $\frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} - \frac{N_{Ed}}{N_{Rd}} \leq 1$ [EN 1993-1-3, Equation (6.24) don't need to be verified]
 Ratio = -2,17 [%]

[BS EN 1993-1-3, Equation (6.25)]
 $\frac{N_{Ed}}{N_{Rd}} + \frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} \leq 1$

[BS EN 1993-1-3, Equation (6.25)]
 $\frac{N_{Ed}}{N_{Rd}} + \frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} \leq 1$

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$W_{pl,y}(z)$	43399,345	[mm ³]	$W_{pl,z}(z)$	1851,197	[mm ³]
$W_{pl,y}(z)$	1851,197	[mm ³]	$W_{pl,z}(z)$	2873,453	[mm ³]
$W_{pl,y}(z)$	43399,345	[mm ³]	$W_{pl,z}(z)$	1851,197	[mm ³]
$W_{pl,y}(z)$	1851,197	[mm ³]	$W_{pl,z}(z)$	2873,453	[mm ³]
$W_{pl,y}(z)$	1851,197	[mm ³]	$W_{pl,z}(z)$	1851,197	[mm ³]

[BS EN 1993-1-3, Equation (6.6)]
 $M_{z,2000mm(z)} = 685992,338$ [Nm] $\rightarrow M_{z,2000mm(z)} = 0,666$ [kNm]

[BS EN 1993-1-3, Equation (6.6)]
 $M_{y,2000mm(z)} = 0,900$ [kNm] $\frac{M_{y,z}^+}{M_{y,Rd}} \leq 1,0$ Ratio = 0,000 [%]

[BS EN 1993-1-3, Equation (6.6)]
 $M_{y,1000mm(z)} = 0,666$ [kNm] $\frac{M_{y,z}^+}{M_{y,Rd}} \leq 1,0$ Ratio = 0,000 [%]

[BS EN 1993-1-3, Equation (6.4)]
 $W_{pl,y}(z)$ 2873,453 [mm³] $W_{pl,z}(z)$ 2873,453 [mm³]

[BS EN 1993-1-3, Equation (6.6)]
 $M_{z,1000mm(z)} = 1084690,100$ [Nm] $\rightarrow M_{z,1000mm(z)} = 1,065$ [kNm]

[iv] C-Section Steel: Shear Force [BS EN 1993-1-3:2006, 6.1.6]
 This verification isn't needed for this type of structural member

[v] C-Section Steel: Torsional Moment [EN 1993-1-3:2006, 6.1.8]
 This verification isn't needed for this type of structural member

[vi] C-Section Steel: 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 Steel: Combined Tension and Bending [EN 1993-1-3:2006, 6.1.9]

[BS EN 1993-1-3, Equation (6.23)]
 $\frac{N_{Ed}}{N_{Rd}} + \frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} \leq 1$

[BS EN 1993-1-3, Equation (6.24)]
 $\frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} - \frac{N_{Ed}}{N_{Rd}} \leq 1$

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$\Delta M_{y,z} = N_{Ed,compression} \cdot \eta_{y,z,compression}$		$\Delta M_{y,z} = N_{Ed,compression} \cdot \eta_{y,z,compression}$			
$N_{Ed,compression}$	1,670	[kN]	$N_{Ed,compression}$	1,670	[kN]
$\eta_{y,z,compression}$	0,900	[m]	$\eta_{y,z,compression}$	-0,901	[m]
$\Delta M_{y,z}$	0,900	[kNm]	$\Delta M_{y,z}$	-0,901	[kNm]

Combined Compression and Bending Moment $|M_{y,z}^+ + M_{y,z}^-|$

N_{Ed}	1,670	[kN]	N_{Ed}	66,398	[kN]
$M_{y,Ed}(z)$	0,910	[kNm]	$M_{z,Ed}(z)$	1,191	[kNm]
$M_{z,Ed}(z)$	0,900	[kNm]	$M_{y,Ed}(z)$	1,666	[kNm]

[EN 1993-1-3, Equation (6.25)] Ratio = 2,969 [%]

$M_{z,Ed}(z)$ 1,226 [kNm] $M_{y,Ed}(z)$ 0,666 [kNm]

$M_{y,Ed}(z) \leq M_{y,Rd}(z)$ KO $M_{z,Ed}(z) \leq M_{z,Rd}(z)$ OK

[BS EN 1993-1-3, Equation (6.26)]
 $\frac{M_{y,Ed} + \Delta M_{y,z}}{M_{y,Rd}} + \frac{M_{z,Ed} + \Delta M_{z,z}}{M_{z,Rd}} - \frac{N_{Ed}}{N_{Rd}} \leq 1$ [EN 1993-1-3, Equation (6.26) don't need to be verified]
 Ratio = 0,000 [%]

[EN 1993-1-3, Equation (6.26)]
 $\frac{M_{y,Ed} + \Delta M_{y,z}}{M_{y,Rd}} + \frac{M_{z,Ed} + \Delta M_{z,z}}{M_{z,Rd}} - \frac{N_{Ed}}{N_{Rd}} \leq 1$ [EN 1993-1-3, Equation (6.26)]
 Ratio = 0,000 [%]

[iv] C-Section Steel: 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 Beam: Combined Bending Moment and Local Load or Support Reaction [EN 1993-1-3:2006, 6.1.1]

This verification isn't needed for this type of structural member

[152] Buckling Resistance [BS EN 1993-1-3:2006, 6.2]


[a] C-Section Profile

This verification isn't needed for this type of structural member

[b] C-Section Beam

[1] C-Section Beam: Flexural Buckling [N_{cr,xx}] [EN 1993-1-3:2006, 6.2.2]

Appropriate buckling curve for C-Sections [BS EN 1993-1-3, Table 6.2]

Type of cross-section	Buckling about Axis	Buckling Curve
	Any	b

Imperfection factors for buckling curves [BS EN 1993-1-3, Table 6.1]

Buckling Curve: b → Imperfection factor [α] 0,340

Console C-Section Beam

E	210.000	[GPa]
I _y	782290,965	[mm ⁴]
I _{yy,cons}	1020.000	[mm ⁴]
P _{Ey,cons}	1518,65472	[kN]

$P_{Ey} = \frac{\pi^2 EI_y}{L_y^2}$

E	210.000	[GPa]
I _z	108754,009	[mm ⁴]
I _{zz,cons}	429.930	[mm ⁴]
P _{Ez,cons}	1219,65323	[kN]

$P_{Ez} = \frac{\pi^2 EI_z}{L_z^2}$

Console C-Section Beam		Middle C-Section Beam			
N _{cr,x}	151895,472	[N]	N _{cr,x}	1618549,416	[N]
N _{cr,z}	1219463,523	[N]	N _{cr,z}	1214723,540	[N]
N _{cr,y}	184841,265	[N]	N _{cr,y}	196879,262	[N]

Console C-Section Beam

N _{cr,x}	176970,8371	[N]	N _{cr,y}	176,571	[kN]
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Middle C-Section Beam

N _{cr,x}	187894,356	[N]	N _{cr,y}	187,895	[kN]
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Console C-Section Beam N_{cr} = MIN [P_{Ey}, P_{Ez}, N_{cr,x}, N_{cr,y}] 176,571 [kN]

Middle C-Section Beam N_{cr} = MIN [P_{Ey}, P_{Ez}, N_{cr,x}, N_{cr,y}] 187,895 [kN]

C-Section Beam Classification [Compression] Class 4

A	345,083	[mm ²]	A _{cr}	243,816	[mm ²]
---	---------	--------------------	-----------------	---------	--------------------

Class 4 $\bar{\lambda}$ 0,895

$\Phi = 0,5 \left[1 + \alpha(\bar{\lambda} - 0,2) + \bar{\lambda}^2 \right]$ Φ 0,298

$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}}$ χ 0,788 $\chi \leq 1,0$ OK

Class 4 → N_{Ed,cr,cons} 67,110 [kN]

Middle C-Section Beam N_{cr} = MIN [P_{Ey}, P_{Ez}, N_{cr,x}, N_{cr,y}] 187,895 [kN]

C-Section Beam Classification [Compression] Class 4

A	345,083	[mm ²]	A _{cr}	243,816	[mm ²]
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Class 4 $\bar{\lambda}$ 0,874

[18] C-Section Beam: Torsional Buckling [N_{cr,t}] + Torsional Flexural Buckling [N_{cr,t,f}] [EN 1993-1-3:2006, 6.2.3]

Middle C-Section Beam

E	210.000	[GPa]
I _y	782290,965	[mm ⁴]
I _{yy,cons}	988.000	[mm ⁴]
P _{Ey,cons}	1618,54916	[kN]

$P_{Ey} = \frac{\pi^2 EI_y}{L_y^2}$

E	210.000	[GPa]
I _z	108754,009	[mm ⁴]
I _{zz,cons}	439,768	[mm ⁴]
P _{Ez,cons}	1214,72354	[kN]

$P_{Ez} = \frac{\pi^2 EI_z}{L_z^2}$

$N_{cr,t} = \frac{1}{\beta^2} \left(G I_t + \frac{\pi^2 E I_{\omega}}{L^2} \right)$ $i_{\omega}^2 = i_y^2 + i_z^2 + y_0^2 + z_0^2$

[BS EN 1993-1-3, Equation (6.33a)] [BS EN 1993-1-3, Equation (6.33b)]

Elastic critical force N_{cr,t} for torsional buckling

A	345,083	[mm ²]	y ₀	47,355	[mm]
I _y	782290,965	[mm ⁴]	z ₀	0,000	[mm]
I _z	108754,009	[mm ⁴]	G	81,769	[GPa]
I _ω	35388959,821	[mm ⁴]	I _ω	62,658	[mm]
I _{yy}	242,500	[mm ⁴]	I _{zz}	62,658	[mm]
I _{yy}	47,001	[mm]			
I _{zz}	17,359	[mm]			

Console C-Section Beam

N _{cr,t}	184841,2651	[N]	N _{cr,t,f}	184,841	[kN]
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Middle C-Section Beam

N _{cr,t}	196879,2623	[N]	N _{cr,t,f}	196,880	[kN]
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C-Section Beam Classification [Elastic Critical Moment] Class 4

M _{cr,cons}	125,28772,255	[Nm]	M _{cr,mid}	133,242	[kNm]
M _{cr,cons}	12,529	[kNm]	M _{cr,mid}	13,324	[kNm]

C-Section Beam Classification [Bending y-y] Class 4

C-Section Console Beam

W _{pl,y}	12869,454	[mm ³]	W _{pl,z}	12435,350	[mm ³]
A	345,083	[mm ²]	A _{cr}	340,388	[mm ²]

$\bar{\lambda}_{LT}$ 0,889

$\Phi_{LT} = 0,5 \left[1 + \alpha_{LT}(\bar{\lambda}_{LT} - 0,2) + \bar{\lambda}_{LT}^2 \right]$ Φ_{LT} 0,740

Monosymmetric cross-section susceptible to torsional-flexural buckling [BS EN 1993-1-3, Figure 6.22]

$\beta = 1 - \left(\frac{y_0}{i_y} \right)^2$ β 0,844 [BS EN 1993-1-3, Equation (6.36)]

[19] 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 1993-1-3, Table 6.2]

Buckling Curve: b → Imperfection factor [α] 0,340

$M_{cr,LT} = \chi_{LT} W_{pl,y} \frac{f_y}{\gamma_{M1}}$ [BS EN 1993-1-3, Equation (6.55)]

$\bar{\lambda}_{LT} = \sqrt{\frac{W_{pl,y} f_y}{M_{cr,LT}}}$

$M_{cr} = \frac{\pi^2 E I_{yy}}{L^2} \left[\frac{I_{yy}}{I_{yy}} + \frac{L^2 G I_t}{\pi^2 E I_{yy}} \right]^{0,5}$ [EN 1993-1-3, Equation (F.1)]

E	210.000	[GPa]	I _{yy}	35388959,821	[mm ⁴]
v	0,350		I _z	242,500	[mm ⁴]
G	81,769	[GPa]	I _{yy,cons}	1020,000	[mm ⁴]
I _z	108754,009	[mm ⁴]	I _{zz,cons}	988,000	[mm ⁴]

C-Section Console Beam [Elastic Critical Moment] Class 4

M _{cr,cons}	125,28772,255	[Nm]	M _{cr,mid}	133,242	[kNm]
M _{cr,cons}	12,529	[kNm]	M _{cr,mid}	13,324	[kNm]

C-Section Beam Classification [Bending y-y] Class 4

C-Section Console Beam

W _{pl,y}	12869,454	[mm ³]	W _{pl,z}	12435,350	[mm ³]
A	345,083	[mm ²]	A _{cr}	340,388	[mm ²]

$\bar{\lambda}_{LT}$ 0,889

$\Phi_{LT} = 0,5 \left[1 + \alpha_{LT}(\bar{\lambda}_{LT} - 0,2) + \bar{\lambda}_{LT}^2 \right]$ Φ_{LT} 0,740

$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \lambda_{LT}^2}}$ $\chi_{LT} = 0,842$ $\chi_{LT} \leq 1,0$ OK

Class 4 $M_{Ed,Consolidated} = 3,666$ [kNm]

C-Section Middle Beam

$W_{pl,y} = 12860,654$ [mm³] $W_{pl,z} = 12435,250$ [mm³]

$A = 345,083$ [mm²] $A_{eff} = 340,188$ [mm²]

$\lambda_{LT} = 0,271$

$\Phi_{LT} = 0,5 [1 + \alpha_{LT} (\lambda_{LT} - 0,2) + \lambda_{LT}^2]$ $\Phi_{LT} = 0,216$

$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \lambda_{LT}^2}}$ $\chi_{LT} = 0,851$ $\chi_{LT} \leq 1,0$ OK

Class 4 $M_{Ed,Consolidated} = 3,705$ [kNm]

C-Section Console Beam $N_{Ed,Consolidated} = 67,110$ [kN] $M_{Ed,Consolidated} = 3,666$ [kNm]

C-Section Middle Beam $N_{Ed,Consolidated} = 68,118$ [kN] $M_{Ed,Consolidated} = 3,705$ [kNm]

[iv] C-Section Beam: Bending and axial compression [EN 1993-1-1:2006, 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 1993-1-1, Equation (6.26)]

C-Section Console Beam

N_{Ed}	0,520	[kN]	Ratio	30,017	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	2,814	[kNm]
N_{Ed}	74,593	[kN]	$M_{b,Rd,1-1}$	4,501	[kNm]

C-Section Middle Beam

N_{Ed}	0,520	[kN]	Ratio	31,561	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	1,249	[kNm]
N_{Ed}	74,593	[kN]	$M_{b,Rd,1-1}$	4,501	[kNm]

[iv] C-Section Beam: Bending and axial compression [EN 1993-1-1:2006, 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 1993-1-1, Equation (6.26)]

C-Section Console Beam

N_{Ed}	0,520	[kN]	Ratio	34,984	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	2,814	[kNm]
$N_{Ed,Consolidated}$	67,110	[kN]	$M_{b,Rd,1-1}$	3,666	[kNm]
$N_{Ed,Consolidated}$	0,000	[kN]	$N_{b,Rd,1-1}$	0,004	[kN]

[v] C-Section Beam: Bending and axial tension [EN 1993-1-1:2006, 6.2.1]

$\left(\frac{N_{Ed}}{N_{t,Rd}} \right)^{0,8} + \left(\frac{M_{Ed}}{M_{b,Rd}} \right)^{0,8} \leq 1,0$ [BS EN 1993-1-1, Equation (6.26)]

C-Section Console Beam

N_{Ed}	0,520	[kN]	Ratio	30,017	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	2,814	[kNm]
N_{Ed}	74,593	[kN]	$M_{b,Rd,1-1}$	4,501	[kNm]

C-Section Middle Beam

N_{Ed}	0,520	[kN]	Ratio	31,561	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	1,249	[kNm]
N_{Ed}	74,593	[kN]	$M_{b,Rd,1-1}$	4,501	[kNm]

[v] C-Section Beam: Bending and axial tension [EN 1993-1-1:2006, 6.2.1]

$\left(\frac{N_{Ed}}{N_{t,Rd}} \right)^{0,8} + \left(\frac{M_{Ed}}{M_{b,Rd}} \right)^{0,8} \leq 1,0$ [BS EN 1993-1-1, Equation (6.26)]

C-Section Console Beam

N_{Ed}	0,520	[kN]	Ratio	30,017	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	2,814	[kNm]
N_{Ed}	74,593	[kN]	$M_{b,Rd,1-1}$	4,501	[kNm]

C-Section Middle Beam

N_{Ed}	0,520	[kN]	Ratio	31,561	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	1,249	[kNm]
N_{Ed}	74,593	[kN]	$M_{b,Rd,1-1}$	4,501	[kNm]

[v] C-Section Beam: Bending and axial tension [EN 1993-1-1:2006, 6.2.1]

$\left(\frac{N_{Ed}}{N_{t,Rd}} \right)^{0,8} + \left(\frac{M_{Ed}}{M_{b,Rd}} \right)^{0,8} \leq 1,0$ [BS EN 1993-1-1, Equation (6.26)]

C-Section Console Beam

N_{Ed}	0,520	[kN]	Ratio	30,017	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	2,814	[kNm]
N_{Ed}	74,593	[kN]	$M_{b,Rd,1-1}$	4,501	[kNm]

C-Section Middle Beam

N_{Ed}	0,520	[kN]	Ratio	31,561	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	1,249	[kNm]
N_{Ed}	74,593	[kN]	$M_{b,Rd,1-1}$	4,501	[kNm]

[vi] C-Section Column: Flexural Buckling [EN 1993-1-1:2006, 6.2.2]

C-Section Console Beam

N_{Ed}	0,520	[kN]	Ratio	36,793	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	1,249	[kNm]
$N_{Ed,Consolidated}$	67,110	[kN]	$M_{b,Rd,1-1}$	3,666	[kNm]
$N_{Ed,Consolidated}$	0,000	[kN]	$N_{b,Rd,1-1}$	0,004	[kN]

C-Section Middle Beam

N_{Ed}	0,520	[kN]	Ratio	36,793	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	1,249	[kNm]
$N_{Ed,Consolidated}$	67,110	[kN]	$M_{b,Rd,1-1}$	3,666	[kNm]
$N_{Ed,Consolidated}$	0,000	[kN]	$N_{b,Rd,1-1}$	0,004	[kN]

C-Section Console Beam

N_{Ed}	0,520	[kN]	Ratio	34,984	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	2,814	[kNm]
$N_{Ed,Consolidated}$	67,110	[kN]	$M_{b,Rd,1-1}$	3,666	[kNm]
$N_{Ed,Consolidated}$	0,000	[kN]	$N_{b,Rd,1-1}$	0,004	[kN]

C-Section Middle Beam

N_{Ed}	0,520	[kN]	Ratio	36,793	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	1,249	[kNm]
$N_{Ed,Consolidated}$	67,110	[kN]	$M_{b,Rd,1-1}$	3,666	[kNm]
$N_{Ed,Consolidated}$	0,000	[kN]	$N_{b,Rd,1-1}$	0,004	[kN]

[vi] C-Section Column: Flexural Buckling [EN 1993-1-1:2006, 6.2.2]

C-Section Console Beam

N_{Ed}	0,520	[kN]	Ratio	36,793	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	1,249	[kNm]
$N_{Ed,Consolidated}$	67,110	[kN]	$M_{b,Rd,1-1}$	3,666	[kNm]
$N_{Ed,Consolidated}$	0,000	[kN]	$N_{b,Rd,1-1}$	0,004	[kN]

C-Section Middle Beam

N_{Ed}	0,520	[kN]	Ratio	36,793	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	1,249	[kNm]
$N_{Ed,Consolidated}$	67,110	[kN]	$M_{b,Rd,1-1}$	3,666	[kNm]
$N_{Ed,Consolidated}$	0,000	[kN]	$N_{b,Rd,1-1}$	0,004	[kN]

C-Section Console Beam

N_{Ed}	0,520	[kN]	Ratio	34,984	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	2,814	[kNm]
$N_{Ed,Consolidated}$	67,110	[kN]	$M_{b,Rd,1-1}$	3,666	[kNm]
$N_{Ed,Consolidated}$	0,000	[kN]	$N_{b,Rd,1-1}$	0,004	[kN]

C-Section Middle Beam

N_{Ed}	0,520	[kN]	Ratio	36,793	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	1,249	[kNm]
$N_{Ed,Consolidated}$	67,110	[kN]	$M_{b,Rd,1-1}$	3,666	[kNm]
$N_{Ed,Consolidated}$	0,000	[kN]	$N_{b,Rd,1-1}$	0,004	[kN]

[vi] C-Section Column: Flexural Buckling [EN 1993-1-1:2006, 6.2.2]

C-Section Console Beam

N_{Ed}	0,520	[kN]	Ratio	36,793	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	1,249	[kNm]
$N_{Ed,Consolidated}$	67,110	[kN]	$M_{b,Rd,1-1}$	3,666	[kNm]
$N_{Ed,Consolidated}$	0,000	[kN]	$N_{b,Rd,1-1}$	0,004	[kN]

C-Section Middle Beam

N_{Ed}	0,520	[kN]	Ratio	36,793	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	1,249	[kNm]
$N_{Ed,Consolidated}$	67,110	[kN]	$M_{b,Rd,1-1}$	3,666	[kNm]
$N_{Ed,Consolidated}$	0,000	[kN]	$N_{b,Rd,1-1}$	0,004	[kN]

C-Section Console Beam


N_{Ed}	0,520	[kN]	Ratio	34,984	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	2,814	[kNm]
$N_{Ed,Consolidated}$	67,110	[kN]	$M_{b,Rd,1-1}$	3,666	[kNm]
$N_{Ed,Consolidated}$	0,000	[kN]	$N_{b,Rd,1-1}$	0,004	[kN]

C-Section Middle Beam

N_{Ed}	0,520	[kN]	Ratio	36,793	[%]
$M_{Ed,Consolidated}$	0,840	[kNm]			
$M_{Ed,Consolidated}$	0,020	[kNm]	$M_{b,Rd,1-1}$	1,249	[kNm]
$N_{Ed,Consolidated}$	67,110	[kN]	$M_{b,Rd,1-1}$	3,666	[kNm]
$N_{Ed,Consolidated}$	0,000	[kN]	$N_{b,Rd,1-1}$	0,004	[kN]

[vii] C-Section Column: Flexural Buckling [EN 1993-1-1:2006, 6.2.2]

Appropriate buckling curve for C-Sections [BS EN 1993-1-1, Table 6.2]

Type of cross-section	Buckling about Axis	Buckling Curve
	Any	b

Imperfection factor for buckling curves [BS EN 1993-1-1, Table 6.1]

Buckling Curve: b \rightarrow Imperfection factor [a]: 0,340

First C-Section Column

$P_{Ey} = \frac{\pi^2 E I_y}{L_{eff,y}^2}$	E	210,000	[GPa]
	I_y	826536,000	[mm ⁴]
	$L_{eff,y}$	1035,000	[mm]
	$P_{Ey,Consolidated}$	1296,86251	[kN]

Second C-Section Column

$P_{Ez} = \frac{\pi^2 E I_z}{L_{eff,z}^2}$	E	210,000	[GPa]
	I_z	153816,866	[mm ⁴]
	$L_{eff,z}$	1400,000	[mm]
	$P_{Ez,Consolidated}$	162,6348162	[kN]

Rear C-Section Column

$$P_{Ey} = \frac{\pi^2 E I_y}{L_y^2}$$

$$P_{Ex} = \frac{\pi^2 E I_x}{L_x^2}$$

E	210.000	[GPa]
I _y	625938,020	[mm ⁴]
I _x	153816,868	[mm ⁴]
P _{Ey,cr,elastic}	359,3567978	[kN]

E	210.000	[GPa]
I _y	193016,868	[mm ⁴]
I _x	2422,293	[mm ⁴]
P _{Ex,cr,elastic}	54,3983897	[kN]

[8] C-Section Column | Torsional Buckling | $N_{cr,t}$ | Torsional-Flexural Buckling | $N_{cr,t,f}$ | [EN 1993-1-3:2006, 6.2.3]

$$N_{cr,t} = \frac{1}{L_y^2} \left(G I_t + \frac{\pi^2 E I_x I_y}{L_x^2} \right) \quad i_{cr}^2 = i_y^2 + i_x^2 + i_z^2 + i_w^2$$

[8] EN 1993-1-3, Equation (6.23a) | [8] EN 1993-1-3, Equation (6.23b)

Elastic critical force $N_{cr,t}$ for torsional buckling

A	497,235	[mm ²]
I _y	625938,020	[mm ⁴]
I _x	153816,868	[mm ⁴]
I _w	311247851,219	[mm ⁶]
I _t	998,509	[mm ⁴]
y _c	49,108	[mm]
z _c	0,900	[mm]
G	80,769	[GPa]
i _y	35,455	[mm]
i _x	56,347	[mm]
i _z	17,288	[mm]

Front C-Section Column

N _{cr,t}	871,572,708	[kN]
N _{cr,t,f}	871,573	[kN]

Rear C-Section Column

N _{cr,t}	307,894,4102	[kN]
N _{cr,t,f}	307,894	[kN]

$$N_{cr,t,f} = \frac{N_{cr,t}}{2\beta} \left[1 + \frac{N_{cr,t}}{N_{cr,t,f}} \sqrt{1 - \frac{N_{cr,t}}{N_{cr,t,f}} + 4 \left(\frac{N_{cr,t}}{N_{cr,t,f}} \right)^2} \right]$$

Elastic critical force $N_{cr,t,f}$ for torsional-flexural buckling | [8] EN 1993-1-3, Equation (6.25)

Monosymmetric open sections susceptible to torsional-flexural buckling | [8] EN 1993-1-3, Figure 6.22

$$\beta = 1 - \left(\frac{y_c}{i_x} \right)^2$$

[8] EN 1993-1-3, Equation (6.26)

β = 0,493

Rear C-Section Column

$$\Phi = 0,5 \left[1 + \alpha \left(\bar{\lambda}_{LT} - 0,2 \right) + \bar{\lambda}_{LT}^2 \right]$$

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}_{LT}^2}}$$

Class 4 → N_{Ed,cr,elastic} = 441,00 [kN]

[8] C-Section Column | Lateral-Torsional Buckling of members subject to bending | [EN 1993-1-3:2006, 6.2.4]

Imperfection factor for lateral-torsional buckling curves | [8] EN 1993-1-3, Table 6.2

Buckling Curve: b → Imperfection factor | α | 0,340

$$M_{b,Rd} = \chi_{LT} W_{pl,y} \frac{f_y}{\gamma_{M1}}$$

[8] EN 1993-1-3, Equation (6.55)

$$\bar{\lambda}_{LT} = \sqrt{\frac{W_{pl,y} f_y}{M_{cr}}}$$

$$M_{cr} = \frac{\pi^2 E I_y}{L_{cr,LT}^2} \left[I_y + \frac{I_{cr}^2}{I_x} \right]^{0,5}$$

EN 1993-1-3, Equation (F.3)

E	210.000	[GPa]
v	0,300	
G	80,769	[GPa]
I _y	153816,868	[mm ⁴]
I _x	311247851,219	[mm ⁶]
I _w	998,509	[mm ⁴]
I _t	490,000	[mm ⁴]
I _{cr}	847,959	[mm ⁴]

Front C-Section Column | Elastic Critical Moment

M _{cr,front}	59816593,410	[Nmm]
M _{cr,rear}	69,417	[kNm]

Rear C-Section Column | Elastic Critical Moment

M _{cr,front}	209124,277	[Nmm]
M _{cr,rear}	20,818	[kNm]

C-Section Column Classification | Bending yy

Class 1

Front C-Section Column

W _{pl,y}	14278,705	[mm ³]
W _{pl,x}	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} = 0,558

Front C-Section Column

N _{cr,t}	1206,992,510	[kN]
N _{cr,t,f}	162,854,816	[kN]
N _{cr,t}	871,572,224	[kN]

Rear C-Section Column

N _{cr,t}	359,356,798	[kN]
N _{cr,t,f}	543,98,839	[kN]
N _{cr,t}	307,894,410	[kN]

Front C-Section Column

N _{cr,t}	588,238,4478	[kN]
N _{cr,t,f}	588,238	[kN]

Rear C-Section Column

N _{cr,t}	1,9805,352	[kN]
N _{cr,t,f}	193,265	[kN]

Front C-Section Column N_{Ed} = MIN { P_{Ed,y}; P_{Ed,x}; N_{cr,t}; N_{cr,t,f} } = 162,855 [kN]

Rear C-Section Column N_{Ed} = MIN { P_{Ed,y}; P_{Ed,x}; N_{cr,t}; N_{cr,t,f} } = 54,399 [kN]

C-Section Column Classification | Compression

Class 4

A	497,235	[mm ²]
A _{eff}	482,146	[mm ²]
$\bar{\lambda}$	1,019	

$$\Phi = 0,5 \left[1 + \alpha \left(\bar{\lambda} - 0,2 \right) + \bar{\lambda}^2 \right]$$

φ = 1,158

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}}$$

Class 4 → N_{Ed,cr,elastic} = 98,767 [kN]

Rear C-Section Column N_{Ed} = MIN { P_{Ed,y}; P_{Ed,x}; N_{cr,t}; N_{cr,t,f} } = 54,399 [kN]

C-Section Column Classification | Compression

Class 4

A	497,235	[mm ²]
A _{eff}	482,146	[mm ²]
$\bar{\lambda}$	1,783	

Front C-Section Column

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}}$$

Class 1, 2, 3 | [8] EN 1993-1-3, Equation (6.47)

Rear C-Section Column

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}}$$

Class 4 | [8] EN 1993-1-3, Equation (6.48)

$$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}}$$

Class 1, 2, 3 | Class 4

C-Section Column Classification | Compression

Class 4

Class 4 → N_{Ed,cr,elastic} = 4,842 [kNm]

Front C-Section Column N_{Ed,cr,elastic} = 98,767 [kN] | M_{Ed,cr,elastic} = 43,42 [kNm]

Rear C-Section Column N_{Ed,cr,elastic} = 43,500 [kN] | M_{Ed,cr,elastic} = 4,241 [kNm]

[14] C-Section Column | Bending and axial compression | [EN 1993-1-3:2006, 6.2.5]

$$\left(\frac{N_{Ed}}{N_{b,Rd}} \right)^{0,5} + \left(\frac{M_{Ed}}{M_{b,Rd}} \right)^{0,5} \leq 1,0$$

[8] EN 1993-1-3, Equation (6.36)

Front C-Section Column

N _{Ed}	4,540	[kN]
M _{Ed,cr,elastic}	0,270	[kNm]
M _{Ed,max}	0,000	[kNm]
N _{Ed,cr,elastic}	98,767	[kN]
M _{b,Rd}	0,000	[kNm]

Ratio = 18,313 [%]

M _{Ed,cr,elastic}	0,270	[kNm]
M _{Ed,max}	3,235	[kNm]
M _{b,Rd}	4,842	[kNm]
M _{Ed,cr,elastic}	0,000	[kNm]
M _{b,Rd}	0,000	[kNm]

Front C-Section Column

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \bar{\lambda}_{LT}^2}}$$

Class 1 → M_{Ed,cr,elastic} = 4,842 [kNm]

Rear C-Section Column

W _{pl,y}	14278,705	[mm ³]
W _{pl,x}	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} = 0,689

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \bar{\lambda}_{LT}^2}}$$

Class 1 → M_{Ed,cr,elastic} = 4,441 [kNm]

[14] C-Section Column | Bending and axial compression | [EN 1993-1-3:2006, 6.2.5]

Front C-Section Column

N _{Ed}	4,540	[kN]
M _{Ed,cr,elastic}	0,270	[kNm]
M _{Ed,max}	0,000	[kNm]
N _{Ed,cr,elastic}	98,767	[kN]
M _{b,Rd}	0,000	[kNm]

Ratio = 18,313 [%]

M _{Ed,cr,elastic}	0,270	[kNm]
M _{Ed,max}	3,235	[kNm]
M _{b,Rd}	4,842	[kNm]
M _{Ed,cr,elastic}	0,000	[kNm]
M _{b,Rd}	0,000	[kNm]

N_{Ed}	43,40	[kN]	Ratio	18,263	[%]
$M_{Ed,1-1}$	0,270	[kNm]	$M_{Ed,2-2}$	1,935	[kNm]
$M_{Ed,3-3}$	0,000	[kNm]	$M_{Ed,4-4}$	4,842	[kNm]
$N_{Ed,1-1}$	98,767	[kN]	$N_{Ed,2-2}$	0,000	[kN]
$N_{Ed,3-3}$	0,000	[kN]	$N_{Ed,4-4}$	0,001	[kN]

Rear C-Section Column

N_{Ed}	43,70	[kN]	Ratio	28,531	[%]
$M_{Ed,1-1}$	0,350	[kNm]	$M_{Ed,2-2}$	3,332	[kNm]
$M_{Ed,3-3}$	0,000	[kNm]	$M_{Ed,4-4}$	4,441	[kNm]
$N_{Ed,1-1}$	44,100	[kN]	$N_{Ed,2-2}$	0,000	[kN]
$N_{Ed,3-3}$	0,000	[kN]	$N_{Ed,4-4}$	0,001	[kN]

N_{Ed}	43,70	[kN]	Ratio	28,582	[%]
$M_{Ed,1-1}$	0,350	[kNm]	$M_{Ed,2-2}$	1,935	[kNm]
$M_{Ed,3-3}$	0,000	[kNm]	$M_{Ed,4-4}$	4,441	[kNm]
$N_{Ed,1-1}$	44,100	[kN]	$N_{Ed,2-2}$	0,000	[kN]
$N_{Ed,3-3}$	0,000	[kN]	$N_{Ed,4-4}$	0,001	[kN]

N_{Ed}	43,70	[kN]	Ratio	28,582	[%]
$M_{Ed,1-1}$	0,350	[kNm]	$M_{Ed,2-2}$	1,935	[kNm]
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$N_{Ed,1-1}$	44,100	[kN]	$N_{Ed,2-2}$	0,000	[kN]
$N_{Ed,3-3}$	0,000	[kN]	$N_{Ed,4-4}$	0,001	[kN]


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$N_{Ed,3-3}$	0,000	[kN]	$N_{Ed,4-4}$	0,001	[kN]

N_{Ed}	3,340	[kN]	Ratio	19,935	[%]
$M_{Ed,1-1}$	0,350	[kNm]	$M_{Ed,2-2}$	1,935	[kNm]
$M_{Ed,3-3}$	0,000	[kNm]	$M_{Ed,4-4}$	4,998	[kNm]
N_{Ed}	185,216	[kN]	N_{Ed}	0,000	[kN]

[4] C-Section Strut

[1] C-Section Strut: Flexural Buckling [$N_{Ed,1-1}$] [EN 1993-1-3, Table 6.2]

Appropriate buckling curve for C-Sections | BS EN 1993-1-3, Table 6.2

Type of cross-section	Buckling about Axis	Buckling Curve
	Any	b

Imperfection factors for buckling curves | BS EN 1993-1-3, Table 6.1

Buckling Curve: Imperfection factor:

C-Section Strut

$$P_{Ed} = \frac{\pi^2 EI_y}{L_{Ed}^2}$$

E	210,000	[GPa]
I_y	85435,109	[mm ⁴]
$L_{Ed,y}$	1950,333	[mm]
$P_{Ed,y}$	48,2614938	[kN]

$$P_{Ed} = \frac{\pi^2 EI_z}{L_{Ed}^2}$$

E	210,000	[GPa]
I_z	43399,345	[mm ⁴]
$L_{Ed,z}$	1950,333	[mm]
$P_{Ed,z}$	23,8221829	[kN]

[10] C-Section Strut: Torsional Buckling [$N_{Ed,1-1}$] + Torsional Flexural Buckling [$N_{Ed,1-1}$] [EN 1993-1-3, Table 6.2]

$$N_{Ed,1-1} = \frac{1}{L_{Ed}^2} \left(GI_T + \frac{\pi^2 EI_z}{L_{Ed}^2} \right) \quad i_0^2 = i_y^2 + i_z^2 + y_{cp}^2 + z_{cp}^2$$

[BS EN 1993-1-3, Equation (6.33a)] [BS EN 1993-1-3, Equation (6.33b)]

Elastic coefficient $N_{Ed,1-1}$ for torsional buckling

[6] C-Section Column: Bending and axial tension [EN 1993-1-3, Table 6.2]

$$\left(\frac{N_{Ed}}{N_{B,Rd}} \right)^{0,8} + \left(\frac{M_{Ed}}{M_{b,Rd}} \right)^{0,8} \leq 1,0$$

[BS EN 1993-1-3, Equation (6.26)]

Rear C-Section Column

N_{Ed}	2,700	[kN]	Ratio	13,072	[%]
$M_{Ed,1-1}$	0,270	[kNm]	$M_{Ed,2-2}$	1,935	[kNm]
$M_{Ed,3-3}$	0,000	[kNm]	$M_{Ed,4-4}$	4,998	[kNm]
N_{Ed}	185,216	[kN]	N_{Ed}	0,000	[kN]

N_{Ed}	2,700	[kN]	Ratio	13,072	[%]
$M_{Ed,1-1}$	0,270	[kNm]	$M_{Ed,2-2}$	1,935	[kNm]
$M_{Ed,3-3}$	0,000	[kNm]	$M_{Ed,4-4}$	4,998	[kNm]
N_{Ed}	185,216	[kN]	N_{Ed}	0,000	[kN]

N_{Ed}	2,700	[kN]	Ratio	13,072	[%]
$M_{Ed,1-1}$	0,270	[kNm]	$M_{Ed,2-2}$	1,935	[kNm]
$M_{Ed,3-3}$	0,000	[kNm]	$M_{Ed,4-4}$	4,998	[kNm]
N_{Ed}	185,216	[kN]	N_{Ed}	0,000	[kN]

N_{Ed}	2,700	[kN]	Ratio	13,072	[%]
$M_{Ed,1-1}$	0,270	[kNm]	$M_{Ed,2-2}$	3,332	[kNm]
$M_{Ed,3-3}$	0,000	[kNm]	$M_{Ed,4-4}$	4,998	[kNm]
N_{Ed}	185,216	[kN]	N_{Ed}	0,000	[kN]

Rear C-Section Column

N_{Ed}	3,340	[kN]	Ratio	19,935	[%]
$M_{Ed,1-1}$	0,350	[kNm]	$M_{Ed,2-2}$	3,332	[kNm]
$M_{Ed,3-3}$	0,000	[kNm]	$M_{Ed,4-4}$	4,998	[kNm]
N_{Ed}	185,216	[kN]	N_{Ed}	0,000	[kN]

N_{Ed}	3,340	[kN]	Ratio	19,935	[%]
$M_{Ed,1-1}$	0,350	[kNm]	$M_{Ed,2-2}$	1,935	[kNm]
$M_{Ed,3-3}$	0,000	[kNm]	$M_{Ed,4-4}$	4,998	[kNm]
N_{Ed}	185,216	[kN]	N_{Ed}	0,000	[kN]

A	281,315	[mm ²]	y_y	-35,537	[mm]
I_y	85435,109	[mm ⁴]	z_z	0,000	[mm]
I_z	43399,345	[mm ⁴]	G	80,769	[GPa]
I_{xy}	26311081,398	[mm ⁴]	I_x	141,478	[mm ⁴]
I_y	20,801	[mm ⁴]	I_y	43,824	[mm ⁴]
I_z	14,883	[mm ⁴]			

C-Section Strut

$$N_{Ed} = 13841,878 \quad [N] \quad N_{Ed} = 13,841 \quad [kN]$$

C-Section Strut

$$N_{Ed,1-1} = \frac{N_{Ed,y}}{2\beta} \left[1 + \frac{N_{Ed,y}}{N_{Ed,y}} \sqrt{1 - \frac{N_{Ed,y}}{N_{Ed,y}} + 4 \left(\frac{y_{cp}}{I_y} \right)^2 \frac{N_{Ed,y}}{N_{Ed,y}}} \right]$$

Elastic critical force $N_{Ed,1-1}$ 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, Fig. 6.22

$$\beta = 1 - \left(\frac{y_{cp}}{I_y} \right)^2$$

[BS EN 1993-1-3, Equation (6.26)]

$N_{Ed,1-1}$	4851,498	[N]
N_{Ed}	23852,318	[N]
N_{Ed}	13841,887	[N]

$\beta = 0,336$

C-Section Strut

N_{Ed}	11191,8107	[N]	N_{Ed}	11,191	[kN]
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C-Section Strut $N_{Ed} = \min [P_{Ed,y}, P_{Ed,z}, N_{Ed,1-1}]$ 11,191 [kN]

$$N_{B,Rd} = \frac{\chi A F_y}{\gamma_{M1}} \quad \text{Class 1}$$

$$N_{B,Rd} = \frac{\chi A_{eff} F_y}{\gamma_{M1}} \quad \text{Class 2}$$

$$N_{B,Rd} = \frac{\chi A_{eff} F_y}{\gamma_{M1}} \quad \text{Class 3}$$

$$N_{B,Rd} = \frac{\chi A_{eff} F_y}{\gamma_{M1}} \quad \text{Class 4}$$

[BS EN 1993-1-3, Equation (6.47)] [BS EN 1993-1-3, Equation (6.48)]

$$\chi = \frac{A F_y}{\sqrt{N_{Ed}}} \quad \text{Class 1}$$

$$\chi = \frac{A_{eff} F_y}{\sqrt{N_{Ed}}} \quad \text{Class 2}$$

$$\chi = \frac{A_{eff} F_y}{\sqrt{N_{Ed}}} \quad \text{Class 3}$$

$$\chi = \frac{A_{eff} F_y}{\sqrt{N_{Ed}}} \quad \text{Class 4}$$

C-Section Column Classification [Compression] Class 3

<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; border: 1px solid black;">A</td> <td style="width: 50%; border: 1px solid black;">201,316 [mm²]</td> </tr> <tr> <td style="width: 50%; border: 1px solid black;">A_{st}</td> <td style="width: 50%; border: 1px solid black;">189,299 [mm²]</td> </tr> <tr> <td colspan="2" style="text-align: center;">Class 3 $\bar{\lambda}$ 2,599</td> </tr> <tr> <td colspan="2" style="text-align: center;">$\Phi = 0,5 \left[1 + \alpha (\bar{\lambda} - 0,2) + \bar{\lambda}^2 \right]$ Φ 0,941</td> </tr> <tr> <td colspan="2" style="text-align: center;">$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}}$ χ 0,139 $\chi \leq 1,0$ OK</td> </tr> <tr> <td colspan="2" style="text-align: center;">Class 3 $N_{b,Ed,0.9}$ 9,776 [kN]</td> </tr> </table>	A	201,316 [mm ²]	A _{st}	189,299 [mm ²]	Class 3 $\bar{\lambda}$ 2,599		$\Phi = 0,5 \left[1 + \alpha (\bar{\lambda} - 0,2) + \bar{\lambda}^2 \right]$ Φ 0,941		$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}}$ χ 0,139 $\chi \leq 1,0$ OK		Class 3 $N_{b,Ed,0.9}$ 9,776 [kN]		<p>[#] C-Section Steel: Lateral-Torsional Buckling of members subject to bending [EN 1993-1-3:2006, 6.2.4]</p> <p style="background-color: #d4edda; padding: 2px;">Imperfection factor for lateral-torsional buckling curves [BS EN 1993-1-3, Table 6.2]</p> <p>Buckling Curve b α 0,340</p> <div style="border: 1px solid black; padding: 2px; margin-bottom: 5px;"> $M_{b,Ed} = \chi_{LT} W_{y,pl} \frac{f_y}{\gamma_{M1}}$ [BS EN 1993-1-3, Equation (6.54)] </div> <div style="border: 1px solid black; padding: 2px; margin-bottom: 5px;"> $\bar{\lambda}_{LT} = \sqrt{\frac{W_{y,pl} f_y}{M_{b,Ed}}}$ </div> <div style="border: 1px solid black; padding: 2px; margin-bottom: 5px;"> $M_{b,Ed} = \frac{\pi^2 E I_y}{L_{cr}^2} \left[\frac{I_y + L_{cr}^2 G I_T}{I_y + L_{cr}^2 G I_T} \right]^{0.5}$ [EN 1993-1-3, Equation (F.1)] </div> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; border: 1px solid black;">E</td> <td style="width: 50%; border: 1px solid black;">219,000 [GPa]</td> </tr> <tr> <td style="width: 50%; border: 1px solid black;">v</td> <td style="width: 50%; border: 1px solid black;">0,300</td> </tr> <tr> <td style="width: 50%; border: 1px solid black;">G</td> <td style="width: 50%; border: 1px solid black;">80,269 [GPa]</td> </tr> <tr> <td style="width: 50%; border: 1px solid black;">I_y</td> <td style="width: 50%; border: 1px solid black;">40399,245 [mm⁴]</td> </tr> <tr> <td style="width: 50%; border: 1px solid black;">I_y</td> <td style="width: 50%; border: 1px solid black;">2831081,368 [mm⁴]</td> </tr> <tr> <td style="width: 50%; border: 1px solid black;">I_y</td> <td style="width: 50%; border: 1px solid black;">141,478 [mm⁴]</td> </tr> <tr> <td style="width: 50%; border: 1px solid black;">I_{cr}</td> <td style="width: 50%; border: 1px solid black;">1950,193 [mm⁴]</td> </tr> </table> <div style="background-color: #343a40; color: white; padding: 2px; text-align: center; font-weight: bold;">Print: C-Section Steel Elastic Critical Moment</div> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; border: 1px solid black;">M_{b,Ed,0.9}</td> <td style="width: 50%; border: 1px solid black;">780,682,458 [Nm]</td> </tr> <tr> <td style="width: 50%; border: 1px solid black;">M_{b,Ed,0.9}</td> <td style="width: 50%; border: 1px solid black;">0,781 [kNm]</td> </tr> </table> <p style="text-align: center;">C-Section Steel Classification [Bending yy] Class 1</p> <div style="background-color: #6c757d; color: white; padding: 2px; text-align: center; font-weight: bold;">C-Section Steel</div> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; border: 1px solid black;">W_{pl,y}</td> <td style="width: 50%; border: 1px solid black;">3519,614 [mm³]</td> </tr> <tr> <td style="width: 50%; border: 1px solid black;">W_{pl,y}</td> <td style="width: 50%; border: 1px solid black;">3402,338 [mm³]</td> </tr> </table> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; border: 1px solid black;">A</td> <td style="width: 50%; border: 1px solid black;">201,316 [mm²]</td> </tr> <tr> <td style="width: 50%; border: 1px solid black;">A_{st}</td> <td style="width: 50%; border: 1px solid black;">189,299 [mm²]</td> </tr> <tr> <td colspan="2" style="text-align: center;">$\bar{\lambda}_{LT}$ 1,258</td> </tr> </table>	E	219,000 [GPa]	v	0,300	G	80,269 [GPa]	I _y	40399,245 [mm ⁴]	I _y	2831081,368 [mm ⁴]	I _y	141,478 [mm ⁴]	I _{cr}	1950,193 [mm ⁴]	M _{b,Ed,0.9}	780,682,458 [Nm]	M _{b,Ed,0.9}	0,781 [kNm]	W _{pl,y}	3519,614 [mm ³]	W _{pl,y}	3402,338 [mm ³]	A	201,316 [mm ²]	A _{st}	189,299 [mm ²]	$\bar{\lambda}_{LT}$ 1,258	
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[v] C-Section Steel: 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 (6.26)]

Print: C-Section Steel

N _{Ed}	2,280 [kN]	Ratio	8,266 [%]
M _{b,Ed,0.9}	0,010 [kNm]	Ratio	0,008 [%]
M _{b,Ed,0.9}	0,000 [kNm]	Ratio	0,000 [%]
N _{Ed}	74,993 [kN]	Ratio	1,232 [%]

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border: 1px solid black; padding: 5px; margin-bottom: 10px;"> $\left(\frac{N_{Ed}}{N_{b,Rd}} \right)^{0.8} + \left(\frac{M_{Ed}}{M_{b,Rd}} \right)^{0.8} \leq 1,0$ <p>[BS EN 1993-1-3, Equation (6.26)]</p> </div> <table style="width: 100%; border-collapse: collapse; border: 1px dashed red;"> <tr> <td style="width: 20%; border: 1px solid black;">N_{Ed}</td> <td style="width: 20%; border: 1px solid black;">1,470 [kN]</td> <td style="width: 20%; border: 1px solid black;">Ratio</td> <td style="width: 20%; border: 1px solid black;">26,092 [%]</td> </tr> <tr> <td style="width: 20%; border: 1px solid black;">M_{b,Ed,0.9}</td> <td style="width: 20%; border: 1px solid black;">0,010 [kNm]</td> <td style="width: 20%; border: 1px solid black;">Ratio</td> <td style="width: 20%; border: 1px solid black;">1,006 [%]</td> </tr> <tr> <td style="width: 20%; border: 1px solid black;">M_{b,Ed,0.9}</td> <td style="width: 20%; border: 1px solid black;">0,000 [kNm]</td> <td style="width: 20%; border: 1px solid black;">Ratio</td> <td style="width: 20%; 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ANNEX B STRUCTURE TYPE I: AISI AND AS/NZS VERIFICATION

Design of a Photovoltaic Structure, Parallel configuration, according to AISI or AS/NZS Code: AISI AS/NZS Reference: AISI S100 AS/NZS 4600 EN 1993 Version: 1,000	Office: ...	Author: JOSE ANTONIO
	Date: 05/09/2019	Project: MASTER THESIS
	Client: COIMBRA UNIVERSITY	

[1] Presentation of the Photovoltaic Structure

Photovoltaic Structure | Parallel Configuration | 3D View | Example |

[2] Photovoltaic Structure Assembly Guide

1.' Step of the Assembly Guide | Example |

2.' Step of the Assembly Guide | Example |

Design of a Photovoltaic Structure, Parallel configuration, according to AISI or AS/NZS Code: AISI | AS/NZS | Reference: AISI S100 | AS/NZS 4600 | EN 1993 Version: 1,000	Office: ...	Author: JOSE ANTONIO
	Date: 05/09/2019	Project: MASTER THESIS
	Client: COIMBRA UNIVERSITY	

[4] Photovoltaic Structure - Structure Definition

Photovoltaic Module Orientation: Parallel | N° Rows: 2 | N° Columns: 18

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

Photovoltaic Structure Definition: Tables Spacing [$L_{1,xx}$, ..., $L_{1,yy}$] [mm]

Gap between Photovoltaic Modules

$L_{1,xxxx}$	992,000	[mm]	→	L_1	18236,000	[mm]
C_{xxxx}	1958,000	[mm]	→	L_2	3912,000	[mm]

Legend:
 D-Section Purlin (Red)
 C-Section Column (Grey)
 C-Section Beam (Blue)
 C-Section Steel (Black)

Photovoltaic Structure Definition: Cut View

Design of a Photovoltaic Structure, Parallel configuration, according to AISI or AS/NZS Code: AISI | AS/NZS | Reference: AISI S100 | AS/NZS 4600 | EN 1993 Version: 1,000	Office: ...	Author: JOSE ANTONIO
	Date: 05/09/2019	Project: MASTER THESIS
	Client: COIMBRA UNIVERSITY	

[3] Photovoltaic Structure - Photovoltaic Module

3.' Step of the Assembly Guide | Example |

4.' Step of the Assembly Guide | Example |

5.' Step of the Assembly Guide | Example |

6.' Step of the Assembly Guide | Example |

Photovoltaic Module

Fabricant	...	
Designation	...	
N° of Cells	72 [un]	
Maximum Power [P_{PM}]	340 [Wp]	
Dimensions	C_{xxxx}	1958,000 [mm]
	$L_{1,xxxx}$	992,000 [mm]
	H_{xxxx}	40,000 [mm]
Installing Hole [$D_{1,xxxx}$]	548 [mm]	
Weight	C_{xxxx}	26,000 [Kg]
	C_{xxxx}	0,137 [kN/m²]

Photovoltaic Module

Design of a Photovoltaic Structure, Parallel configuration, according to AISI or AS/NZS Code: AISI | AS/NZS | Reference: AISI S100 | AS/NZS 4600 | EN 1993 Version: 1,000	Office: ...	Author: JOSE ANTONIO
	Date: 05/09/2019	Project: MASTER THESIS
	Client: COIMBRA UNIVERSITY	

[4] Photovoltaic Structure - Structure Definition

N° of Spacings: 8 [un]

Distance between tables: 2125,000 [mm]

$L_{1,xxxx}$	618,000	[mm]	→	Middle length beam is well defined
$L_{1,xxxx}$	2125,000	[mm]	→	Middle length beam is well defined

[a] D-Section Purlin

D-Section Purlin Length	18236,000	[mm]		
Maximum D-Section Purlin Length	13000,000	[mm]		
Quantity of D-Section Purlin Length	2,000	[un]	→	Purlin with a wedge or sleeve

[b] C-Section Beam

L_{xxxx}	510,000	[mm]		
L_{xxxx}	1976,000	[mm]		
L_{xxxx}	510,000	[mm]		
L_{xxxx}	→	Beam console length is according to reflex of construction		
L_{xxxx}	→	Beam console length is according to reflex of construction		
Maximum C-Section Beam Length	6000,000	[mm]		
Quantity of C-Section Beam Length	1,000	[un]	→	Beam without splices or connections

[c] C-Section Column

L_{xxxx}	700,000	[mm]	Photovoltaic Structure Inclination α	15	[°]
Distance between Columns	1908,668	[mm]	L_{xxxx}	1211,426	[mm]
Maximum C-Section Column Length	4000,000	[mm]			
Quantity of C-Section Front Column Length	1,000	[un]	→	Front Columns without splices connections	
Quantity of C-Section Rear Column Length	1,000	[un]	→	Rear Columns without splices connections	

[d] C-Section Steel

Steel Fixation Point in the Front Pile	550,000	[mm]			
Steel Fixation Point in the Rear Pile	150,000	[mm]	→	Distance from the Ground Level	
L_{xxxx}	1950,133	[mm]	Maximum C-Section Steel Length	6000,000	[mm]
Quantity of C-Section Steel Length	1,000	[un]	→	Steel without splices connections	

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS			
Code:	AISI | AS/NZS	Reference:	AISI S100 | AS/NZS 4600 | EN 1993
Version:	1,000		

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

Sheet S 350 GD + Z → f_u 350,000 [MPa] | f_t 420,000 [MPa]

[6] Photovoltaic Structure - Section Definition

[a] D-Section Profile

D-Section		D200 * 1,00	
h	54,993	[mm]	
h ₁	5,096	[mm]	
b ₁	112,058	[mm]	
b ₂	34,919	[mm]	
b ₃	42,270	[mm]	
b ₄	34,919	[mm]	
t _{leg}	1,000	[mm]	
r ₁	1,500	[mm]	
r ₂	1,500	[mm]	
r ₃	1,500	[mm]	
r ₄	1,500	[mm]	
r ₅	1,500	[mm]	
r ₆	1,500	[mm]	
φ ₁	45,000	[°]	
φ ₂	78,393	[°]	
φ ₃	78,393	[°]	
φ ₄	45,000	[°]	
φ ₅	78,393	[°]	
φ ₆	45,000	[°]	

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

w 200,000 [mm] Tolerance Special

$f_{max, corrug}^{(+)}$ 0,350 [mm] [EN 10143, Table 2]

$f_{max, corrug}^{(-)}$ -0,350 [mm] [EN 10143, Table 2]

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

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

- Members | AISI | AS/NZS | $t_{leg} \leq 25,400$ mm | $t_{tol, range}$ 1,050 [mm]
- Connections | AISI | AS/NZS | $t_{leg} \leq 4,760$ mm and 3,000 mm | $t_{tol, range}$ 0,350 [mm]

Tolerance $\leq 5\%$ → [EN 1993-1-3, Equation 3.3a] | t 0,952 [mm]

Coating ZM310 → Zinc-magnesium alloy coating | ZM | → 0,048 [mm]

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS			
Code:	AISI | AS/NZS	Reference:	AISI S100 | AS/NZS 4600 | EN 1993
Version:	1,000		

[c] 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]	
r ₅	2,500	[mm]	
t _{leg}	2,500	[mm]	
φ ₁	90,000	[°]	
φ ₂	90,000	[°]	
φ ₃	90,000	[°]	
φ ₄	90,000	[°]	
φ ₅	90,000	[°]	

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

w 200,000 [mm] Tolerance Special

$f_{max, corrug}^{(+)}$ 0,310 [mm] [EN 10143, Table 2]

$f_{max, corrug}^{(-)}$ -0,310 [mm] [EN 10143, Table 2]

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

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

- Members | AISI | AS/NZS | $t_{leg} \leq 25,400$ mm | $t_{tol, range}$ 2,510 [mm]
- Connections | AISI | AS/NZS | $t_{leg} \leq 4,760$ mm and 3,000 mm | $t_{tol, range}$ 2,390 [mm]

Tolerance $\leq 5\%$ → [EN 1993-1-3, Equation 3.3a] | t 2,652 [mm]

Coating ZM310 → Zinc-magnesium alloy coating | ZM | → 0,048 [mm]

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS			
Code:	AISI | AS/NZS	Reference:	AISI S100 | AS/NZS 4600 | EN 1993
Version:	1,000		

[b] 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]	
r ₅	2,500	[mm]	
t _{leg}	1,500	[mm]	
φ ₁	90,000	[°]	
φ ₂	90,000	[°]	
φ ₃	90,000	[°]	
φ ₄	90,000	[°]	
φ ₅	90,000	[°]	

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

w 230,000 [mm] Tolerance Special

$f_{max, corrug}^{(+)}$ 0,370 [mm] [EN 10143, Table 2]

$f_{max, corrug}^{(-)}$ -0,370 [mm] [EN 10143, Table 2]

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

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

- Members | AISI | AS/NZS | $t_{leg} \leq 25,400$ mm | $t_{tol, range}$ 1,570 [mm]
- Connections | AISI | AS/NZS | $t_{leg} \leq 4,760$ mm and 3,000 mm | $t_{tol, range}$ 1,300 [mm]

Tolerance $\leq 5\%$ → [EN 1993-1-3, Equation 3.3a] | t 1,652 [mm]

Coating ZM310 → Zinc-magnesium alloy coating | ZM | → 0,048 [mm]

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS			
Code:	AISI | AS/NZS	Reference:	AISI S100 | AS/NZS 4600 | EN 1993
Version:	1,000		

[d] C-Section Strut

C-Section		B 134 * 1,50	
h	50,000	[mm]	
b	40,000	[mm]	
c	16,000	[mm]	
r ₁	2,500	[mm]	
r ₂	2,500	[mm]	
r ₃	2,500	[mm]	
r ₄	2,500	[mm]	
r ₅	2,500	[mm]	
t _{leg}	1,500	[mm]	
φ ₁	90,000	[°]	
φ ₂	90,000	[°]	
φ ₃	90,000	[°]	
φ ₄	90,000	[°]	
φ ₅	90,000	[°]	

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

w 134,000 [mm] Tolerance Special

$f_{max, corrug}^{(+)}$ 0,370 [mm] [EN 10143, Table 2]

$f_{max, corrug}^{(-)}$ -0,370 [mm] [EN 10143, Table 2]

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

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

- Members | AISI | AS/NZS | $t_{leg} \leq 25,400$ mm | $t_{tol, range}$ 1,570 [mm]
- Connections | AISI | AS/NZS | $t_{leg} \leq 4,760$ mm and 3,000 mm | $t_{tol, range}$ 1,300 [mm]

Tolerance $\leq 5\%$ → [EN 1993-1-3, Equation 3.3a] | t 1,652 [mm]

Coating ZM310 → Zinc-magnesium alloy coating | ZM | → 0,048 [mm]

Design of a Photovoltaic Structure, Parafix configuration, according to AISI or AS/NZS Code: AISI | AS/NZS Reference: AISI S100 | AS/NZS 4600 | EN 1993 Version: 1,000	Office: ---	Author: JOSE ANTONIO
	Date: 05/09/2019	Project: MASTER THESIS
	Client: COIMBRA UNIVERSITY	

[7] Photovoltaic Structure - Geometrical Proportions | AISI S100 | AS/NZS 4600

[a] D-Section Profile

D-Section		D200 * 1,00	
h	54,993	[mm]	
h ₁	5,099	[mm]	
b ₁	112,096	[mm]	
b ₂	34,919	[mm]	
b ₃	42,370	[mm]	
b ₄	34,919	[mm]	
t _{web}	1,000	[mm]	
t	0,952	[mm]	
Φ ₁	78,393	[°]	
Φ ₂	78,393	[°]	
Φ ₃	78,393	[°]	
Φ ₄	45,000	[°]	
Φ ₅	45,000	[°]	
Φ ₆	78,393	[°]	
Φ ₇	45,000	[°]	

Maximum Width-to-thickness ratios | AISI S100, B1 |		Maximum Width-to-thickness ratios | AS/NZS 4600, 2.3.3 |	
Element of cross-section	Maximum value [mm]	Element of cross-section	Maximum value [mm]
	w | ≤ 60		b | ≤ 60
	w | ≤ 500		b | ≤ 500
	h | ≤ 200		d ₁ | ≤ 200
	R | ≤ 7		r | ≤ 8
	[Condition in Equation A7.2.2]		[AS/NZS 4600, Clause 1.3.18]
			r | ≤ 7
			[Condition in 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 | ≤ 7

Geometrical Proportions Verifications | AISI S100-07 |			
t	0,952	[mm]	≤ 25,400 mm → OK
W _{max,tip}	38,371	[mm]	w | ≤ 500 → OK
h _{max}	54,993	[mm]	h | ≤ 200 → OK
W _{max,edge}	16,245	[mm]	w | ≤ 60 → OK
R	1,500	[mm]	R | ≤ 7 → OK

Geometrical Proportions Verifications | AS/NZS 4600:2005 |			
t	0,952	[mm]	≤ 25,400 mm → OK
W _{max,tip}	38,371	[mm]	w | ≤ 500 → OK
d ₁	54,993	[mm]	d ₁ | ≤ 200 → OK
W _{max,edge}	16,245	[mm]	b | ≤ 60 → OK
r	1,500	[mm]	r | ≤ 7 → OK
			r | ≤ 8 → OK

[b] C-Section Beam

C-Section		B 230 * 1,50	
h	120,000	[mm]	
b	46,000	[mm]	
c	18,000	[mm]	
r ₁	2,800	[mm]	
r ₂	2,800	[mm]	
r ₃	2,800	[mm]	
r ₄	2,800	[mm]	
t _{web}	1,000	[mm]	
Φ ₁	90,000	[°]	
Φ ₂	90,000	[°]	
Φ ₃	90,000	[°]	
Φ ₄	90,000	[°]	
Φ	90,000	[°]	
t	1,452	[mm]	

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	Date: 05/09/2019	Project: MASTER THESIS
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[c] C-Section Column

C-Section		B 200 * 2,50	
h	90,000	[mm]	
b	46,000	[mm]	
c	18,000	[mm]	
r ₁	2,800	[mm]	
r ₂	2,800	[mm]	
r ₃	2,800	[mm]	
r ₄	2,800	[mm]	
t _{web}	2,500	[mm]	
Φ ₁	90,000	[°]	
Φ ₂	90,000	[°]	
Φ ₃	90,000	[°]	
Φ ₄	90,000	[°]	
Φ	90,000	[°]	
t	2,452	[mm]	

Maximum Width-to-thickness ratios | AISI S100, B1 |		Maximum Width-to-thickness ratios | AS/NZS 4600, 2.3.3 |	
Element of cross-section	Maximum value [mm]	Element of cross-section	Maximum value [mm]
	w | ≤ 60		b | ≤ 60
	h | ≤ 200		d ₁ | ≤ 200
	R | ≤ 7		r | ≤ 8
	[Condition in Equation A7.2.2]		[AS/NZS 4600, Clause 1.3.18]
			r | ≤ 7
			[Condition in 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 | ≤ 7

Geometrical Proportions Verifications | AISI S100-07 |			
t	2,452	[mm]	≤ 25,400 mm → OK
W _{max,tip}	38,396	[mm]	b | ≤ 60 → OK
h _{max}	80,996	[mm]	h | ≤ 200 → OK

Geometrical Proportions Verifications | AS/NZS 4600:2005 |			
t	2,452	[mm]	≤ 25,400 mm → OK
W _{max,tip}	38,396	[mm]	b ≤ 60 → OK
d ₁	112,096	[mm]	d ₁ ≤ 200 → OK
r	2,500	[mm]	r ≤ 7 → OK
			r ≤ 8 → OK

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	Date: 05/09/2019	Project: MASTER THESIS
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[b] C-Section Beam

C-Section		B 230 * 1,50	
h	120,000	[mm]	
b	46,000	[mm]	
c	18,000	[mm]	
r ₁	2,800	[mm]	
r ₂	2,800	[mm]	
r ₃	2,800	[mm]	
r ₄	2,800	[mm]	
t _{web}	1,000	[mm]	
Φ ₁	90,000	[°]	
Φ ₂	90,000	[°]	
Φ ₃	90,000	[°]	
Φ ₄	90,000	[°]	
Φ	90,000	[°]	
t	1,452	[mm]	

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	Date: 05/09/2019	Project: MASTER THESIS
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[c] C-Section Column

C-Section		B 200 * 2,50	
h	90,000	[mm]	
b	46,000	[mm]	
c	18,000	[mm]	
r ₁	2,800	[mm]	
r ₂	2,800	[mm]	
r ₃	2,800	[mm]	
r ₄	2,800	[mm]	
t _{web}	2,500	[mm]	
Φ ₁	90,000	[°]	
Φ ₂	90,000	[°]	
Φ ₃	90,000	[°]	
Φ ₄	90,000	[°]	
Φ	90,000	[°]	
t	2,452	[mm]	

Maximum Width-to-thickness ratios | AISI S100, B1 |		Maximum Width-to-thickness ratios | AS/NZS 4600, 2.3.3 |	
Element of cross-section	Maximum value [mm]	Element of cross-section	Maximum value [mm]
	w | ≤ 60		b | ≤ 60
	h | ≤ 200		d ₁ | ≤ 200
	R | ≤ 7		r | ≤ 8
	[Condition in Equation A7.2.2]		[AS/NZS 4600, Clause 1.3.18]
			r | ≤ 7
			[Condition in 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 | ≤ 7

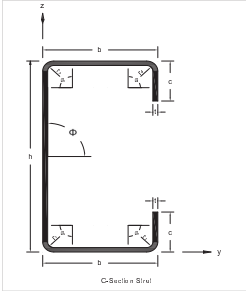
Geometrical Proportions Verifications | AISI S100-07 |			
t	2,452	[mm]	≤ 25,400 mm → OK
W _{max,tip}	38,396	[mm]	b | ≤ 60 → OK
h _{max}	80,996	[mm]	h | ≤ 200 → OK

Geometrical Proportions Verifications AS/NZS 4600:2005			
t	2,452	[mm]	≤ 25,400 mm → OK
W _{max,tip}	38,396	[mm]	b ≤ 60 → OK
h _{max}	80,996	[mm]	h ≤ 200 → OK

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Design of a Photovoltaic Structure, Padrat configuration, according to AISI or AS/NZS			
Code:	AISI AS/NZS	Reference:	AISI S100 AS/NZS 4600 EN 1993
Version:	1,000		

R	2,500	[mm]	R < 1,57	→	OK
Geometrical Proportions Verifications | AS/NZS 4600:2005 |					
l	2,452	[mm]	≤ 25,400 mm	→	OK
h_{max}	35,096	[mm]	b < 1,560	→	OK
d_1	80,096	[mm]	$d_1 < 1,4 \times 200$	→	OK
r	2,500	[mm]	r < 1,57	→	OK
			r < 1,58	→	OK

[4] C-Section Steel



C-Section		B 134 * 1,56	
h	50,000	[mm]	
b	40,000	[mm]	
c	10,000	[mm]	
r1	2,500	[mm]	
r2	2,500	[mm]	
r3	2,500	[mm]	
r4	2,500	[mm]	
r5	2,500	[mm]	
r6	2,500	[mm]	
r7	2,500	[mm]	
r8	2,500	[mm]	
r9	2,500	[mm]	
r10	2,500	[mm]	
r11	2,500	[mm]	
r12	2,500	[mm]	
r13	2,500	[mm]	
r14	2,500	[mm]	
r15	2,500	[mm]	
r16	2,500	[mm]	
r17	2,500	[mm]	
r18	2,500	[mm]	
r19	2,500	[mm]	
r20	2,500	[mm]	
r21	2,500	[mm]	
r22	2,500	[mm]	
r23	2,500	[mm]	
r24	2,500	[mm]	
r25	2,500	[mm]	
r26	2,500	[mm]	
r27	2,500	[mm]	
r28	2,500	[mm]	
r29	2,500	[mm]	
r30	2,500	[mm]	
r31	2,500	[mm]	
r32	2,500	[mm]	
r33	2,500	[mm]	
r34	2,500	[mm]	
r35	2,500	[mm]	
r36	2,500	[mm]	
r37	2,500	[mm]	
r38	2,500	[mm]	
r39	2,500	[mm]	
r40	2,500	[mm]	
r41	2,500	[mm]	
r42	2,500	[mm]	
r43	2,500	[mm]	
r44	2,500	[mm]	
r45	2,500	[mm]	
r46	2,500	[mm]	
r47	2,500	[mm]	
r48	2,500	[mm]	
r49	2,500	[mm]	
r50	2,500	[mm]	
r51	2,500	[mm]	
r52	2,500	[mm]	
r53	2,500	[mm]	
r54	2,500	[mm]	
r55	2,500	[mm]	
r56	2,500	[mm]	
r57	2,500	[mm]	
r58	2,500	[mm]	
r59	2,500	[mm]	
r60	2,500	[mm]	
r61	2,500	[mm]	
r62	2,500	[mm]	
r63	2,500	[mm]	
r64	2,500	[mm]	
r65	2,500	[mm]	
r66	2,500	[mm]	
r67	2,500	[mm]	
r68	2,500	[mm]	
r69	2,500	[mm]	
r70	2,500	[mm]	
r71	2,500	[mm]	
r72	2,500	[mm]	
r73	2,500	[mm]	
r74	2,500	[mm]	
r75	2,500	[mm]	
r76	2,500	[mm]	
r77	2,500	[mm]	
r78	2,500	[mm]	
r79	2,500	[mm]	
r80	2,500	[mm]	
r81	2,500	[mm]	
r82	2,500	[mm]	
r83	2,500	[mm]	
r84	2,500	[mm]	
r85	2,500	[mm]	
r86	2,500	[mm]	
r87	2,500	[mm]	
r88	2,500	[mm]	
r89	2,500	[mm]	
r90	2,500	[mm]	
r91	2,500	[mm]	
r92	2,500	[mm]	
r93	2,500	[mm]	
r94	2,500	[mm]	
r95	2,500	[mm]	
r96	2,500	[mm]	
r97	2,500	[mm]	
r98	2,500	[mm]	
r99	2,500	[mm]	
r100	2,500	[mm]	

Maximum Width-to-Thickness ratios | AISI S100, B1 |	
Element of cross-section	Maximum value [mm]
	w < 60
	b < 1,200

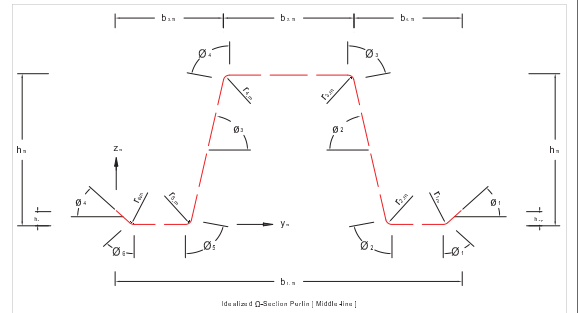
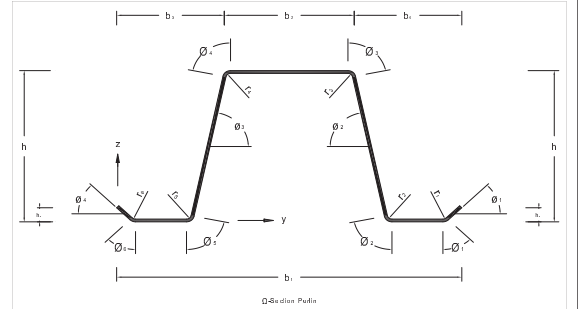
Maximum Width-to-Thickness ratios AS/NZS 4600, 2.1.3	
Element of cross-section	Maximum value [mm]
	b < 1,560
	$d_1 < 1,4 \times 200$

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Code:	AISI AS/NZS	Reference:	AISI S100 AS/NZS 4600 EN 1993
Version:	1,000		

[8] Photovoltaic Structure - Cold-Formed Section Properties

[BS EN 1993-1-3 / AISI COLD-FORMED STEEL DESIGN MANUAL]

[1*] D-Section Profile



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Version:	1,000		



NOTE: In AS/NZS 4600:2005, relatively to the bends, the limitation that was adopted in the design verifications was r < 1,57					
Geometrical Proportions Verifications | AISI S100-07 |					
l	1,452	[mm]	≤ 25,400 mm	→	OK
h_{max}	32,096	[mm]	b < 1,560	→	OK
h_{min}	42,096	[mm]	b < 1,200	→	OK
R	2,500	[mm]	R < 1,57	→	OK

Geometrical Proportions Verifications | AS/NZS 4600:2005 |					
l	1,452	[mm]	≤ 25,400 mm	→	OK
h_{max}	32,096	[mm]	b < 1,560	→	OK
d_1	42,096	[mm]	$d_1 < 1,4 \times 200$	→	OK
r	2,500	[mm]	r < 1,57	→	OK
			r < 1,58	→	OK

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Version:	1,000		

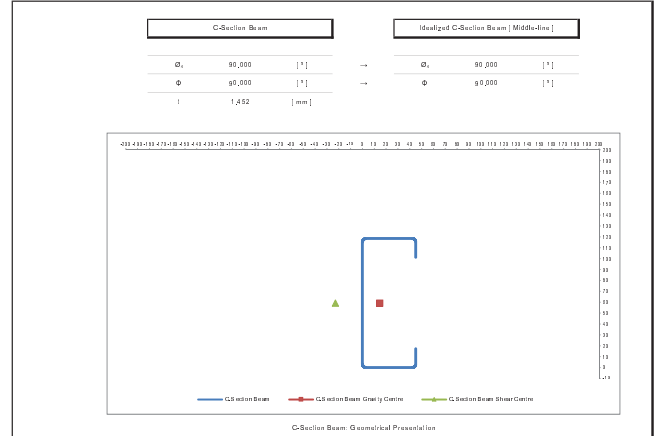
D-Section Profile			Idealized D-Section Profile Middle-line		
$h [\phi]$	54,693	[mm] →	h_p	53,241	[mm]
h_{max}	5,096	[mm] →	h_{max}	4,957	[mm]
h_{min}	5,096	[mm] →	h_{min}	4,957	[mm]
b_1	112,008	[mm] →	$b_{1,av}$	111,335	[mm]
b_2	34,919	[mm] →	$b_{2,av}$	35,513	[mm]
b_3	42,170	[mm] →	$b_{3,av}$	40,817	[mm]
b_4	34,919	[mm] →	$b_{4,av}$	35,513	[mm]
r_1	1,500	[mm] →	$r_{1,av}$	1,976	[mm]
r_2	1,500	[mm] →	$r_{2,av}$	1,976	[mm]
r_3	1,500	[mm] →	$r_{3,av}$	1,976	[mm]
r_4	1,500	[mm] →	$r_{4,av}$	1,976	[mm]
r_5	1,500	[mm] →	$r_{5,av}$	1,976	[mm]
r_6	1,500	[mm] →	$r_{6,av}$	1,976	[mm]
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	78,393	[°] →	ϕ_4	78,393	[°]
ϕ_5	78,393	[°] →	ϕ_5	78,393	[°]
ϕ_6	78,393	[°] →	ϕ_6	78,393	[°]
ϕ_7	45,000	[°] →	ϕ_7	45,000	[°]
ϕ_8	45,000	[°] →	ϕ_8	45,000	[°]
ϕ_9	45,000	[°] →	ϕ_9	45,000	[°]
ϕ_{10}	45,000	[°] →	ϕ_{10}	45,000	[°]
ϕ_{11}	45,000	[°] →	ϕ_{11}	45,000	[°]
ϕ_{12}	45,000	[°] →	ϕ_{12}	45,000	[°]
ϕ_{13}	45,000	[°] →	ϕ_{13}	45,000	[°]
ϕ_{14}	45,000	[°] →	ϕ_{14}	45,000	[°]
ϕ_{15}	45,000	[°] →	ϕ_{15}	45,000	[°]
ϕ_{16}	45,000	[°] →	ϕ_{16}	45,000	[°]
ϕ_{17}	45,000	[°] →	ϕ_{17}	45,000	[°]
ϕ_{18}	45,000	[°] →	ϕ_{18}	45,000	[°]
ϕ_{19}	45,000	[°] →	ϕ_{19}	45,000	[°]
ϕ_{20}	45,000	[°] →	ϕ_{20}	45,000	[°]
ϕ_{21}	45,000	[°] →	ϕ_{21}	45,000	[°]
ϕ_{22}	45,000	[°] →	ϕ_{22}	45,000	[°]
ϕ_{23}	45,000	[°] →	ϕ_{23}	45,000	[°]
ϕ_{24}	45,000	[°] →	ϕ_{24}	45,000	[°]
ϕ_{25}	45,000	[°] →	ϕ_{25}	45,000	[°]
ϕ_{26}	45,000	[°] →	ϕ_{26}	45,000	[°]
ϕ_{27}	45,000	[°] →	ϕ_{27}	45,000	[°]
ϕ_{28}	45,000	[°] →	ϕ_{28}	45,000	[°]
ϕ_{29}	45,000	[°] →	ϕ_{29}	45,000	[°]
ϕ_{30}	45,000	[°] →	ϕ_{30}	45,000	[°]
ϕ_{31}	45,000	[°] →	ϕ_{31}	45,000	[°]
ϕ_{32}	45,000	[°] →	ϕ_{32}	45,000	[°]
ϕ_{33}	45,000	[°] →	ϕ_{33}	45,000	[°]
ϕ_{34}	45,000	[°] →	ϕ_{34}	45,000	[°]
ϕ_{35}	45,000	[°			

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Version: 1,000			

C-Section Profile Mechanical Properties			
Area	A	191,399	[mm ²]
First Moment of Area	S _{xx}	4904,847	[mm ³]
	S _{yy}	10643,243	[mm ³]
Gravity Centre	Y _{cg}	55,667	[mm]
	Z _{cg}	25,552	[mm]
Second Moment of Area through Gravity Centre	I _{xxG}	8579,975	[mm ⁴]
	I _{yyG}	17699,935	[mm ⁴]
[I _{xxG} = I _{xxc} + I _{yyG} + I _{yyc} + I _{xyG} + I _{xyc}]			
Product Moment of Area through Gravity Centre	I _{xyG}	0,000	[mm ⁴]
Principal Axis	α	0,000	[°]
	I ₁	17699,935	[mm ⁴]
	I ₂	8579,975	[mm ⁴]
Mean of Sectorial Coordinate	I _ω	71697,113	[mm ⁶]
	ω _{1/2}	3718,821	[mm]
Sectorial Constants	I _{ωx}	2776325,770	[mm ⁶]
	I _{ωy}	-41816048,037	[mm ⁶]
	I _{ωz}	23012551,876	[mm ⁶]
	I _{ωx}	4774027,730	[mm ⁶]
	I _{ωy}	372732829,325	[mm ⁶]
	I _{ωz}	108339863,544	[mm ⁶]
Shear Centre	Y _{sc}	55,667	[mm]
	Z _{sc}	68,791	[mm]
Warping Constant [I _ω mm ⁶]	C _{ω,AS}	28433171,815	[mm ⁶]
Torsion Constants [J _{AS} = I _ω mm ⁶]	J _{AS}	57,762	[mm ⁴]
	W _t	60,874	[mm ³]
Distance between Shear Centre and Gravity Centre	Y _{cg}	0,000	[mm]
	Z _{cg}	41,139	[mm]
Polar Moment of Area with respect to Shear Centre	I _p	586262,901	[mm ⁴]
Non-symmetry Factors	ξ	0,000	[mm]
	ε	54,991	[mm]

C-Section Profile Flange Curling		[AISI S100-07, B1.1(b)]
<p> $W_t = \sqrt{0.06 I_{\omega} E / I_{\omega} \sqrt{100 r_f / d}}$ [AISI S100-07, Equation (B1.1-1)] </p>	f _u	350,000 [MPa]
	E	210,000 [GPa]
	c ₁ = 0,05 * h	2,735 [mm]
	t	0,952 [mm]
	d = h	54,993 [mm]
W _{flange}	65,278 [mm]	Flange Curling is not considered in the calculation

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C-Section Beam Mechanical Properties			
Area	EUROCODE	A	345,063 [mm ²]
	AISI	A	345,073 [mm ²]
First Moment of Area	S _{xx}	20493,287	[mm ³]
	S _{yy}	5625,501	[mm ³]
Gravity Centre	EUROCODE	Y _{cg}	14,569 [mm]
	AISI	X ₁ | Y _{cg}	14,569 [mm]
Second Moment of Area through Gravity Centre	EUROCODE	I _{xxG}	762295,065 [mm ⁴]
	I _{yyG}	108754,009 [mm ⁴]	
	AISI	I _{xxG}	762487,029 [mm ⁴]
	I _{yyG}	108763,389 [mm ⁴]	
Product Moment of Area through Gravity Centre	I _{xyG}	0,000	[mm ⁴]
Principal Axis	α	0,000	[°]
	I ₁	762295,065 [mm ⁴]	
	I ₂	108754,009 [mm ⁴]	
Mean of Sectorial Coordinate	I _ω	-593270,865 [mm ⁶]	
	ω _{1/2}	-1632,370 [mm]	

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C-Section Profile Flange Curling		[AS/NZS 4600:2005, 2.1.3.2]
<p> $W_t = \sqrt{0.06 I_{\omega} E / I_{\omega} \sqrt{100 r_f / d}}$ [AS/NZS 4600:2005, Equation (2.1.3.2)] </p>	f _u	350,000 [MPa]
	E	210,000 [GPa]
	c ₁ = 0,05 * h	2,735 [mm]
	t	0,952 [mm]
	d = h	54,993 [mm]
W _{flange}	65,278 [mm]	Flange Curling is not considered in the calculation

C-Section Beam		[AISI S100-07, B1.1(b)]
<p> $W_t = \sqrt{0.06 I_{\omega} E / I_{\omega} \sqrt{100 r_f / d}}$ [AISI S100-07, Equation (B1.1-1)] </p>	f _u	350,000 [MPa]
	E	210,000 [GPa]
	c ₁ = 0,05 * h	2,735 [mm]
	t	0,952 [mm]
	d = h	54,993 [mm]
W _{flange}	65,278 [mm]	Flange Curling is not considered in the calculation

C-Section Beam		[AISI S100-07, B1.1(b)]		
h	120,000 [mm]	→	h ₁	118,548 [mm]
b ₁	46,200 [mm]	→	b ₁₁	45,048 [mm]
b ₂	46,200 [mm]	→	b ₂₁	45,048 [mm]
c ₁	18,200 [mm]	→	c ₁₁	17,274 [mm]
c ₂	18,200 [mm]	→	c ₂₁	17,274 [mm]
c ₃	2,500 [mm]	→	c ₃₁	3,226 [mm]
c ₄	2,500 [mm]	→	c ₄₁	3,226 [mm]
c ₅	2,500 [mm]	→	c ₅₁	3,226 [mm]
c ₆	2,500 [mm]	→	c ₆₁	3,226 [mm]
φ ₁	90,000 [°]	→	φ ₁₁	90,000 [°]
φ ₂	90,000 [°]	→	φ ₂₁	90,000 [°]
φ ₃	90,000 [°]	→	φ ₃₁	90,000 [°]

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Version: 1,000			

C-Section Beam Mechanical Properties (Continuation)			
Sectorial Constants	I _{ωx}	J	4648942,856 [mm ⁶]
	I _{ωy}		-6446285,330 [mm ⁶]
	I _{ωz}		-60781926,937 [mm ⁶]
	I _{ωx}		-47374603,429 [mm ⁶]
	I _{ωy}		265143889,361 [mm ⁶]
	I _{ωz}		1131970553,245 [mm ⁶]
Shear Centre	EUROCODE	Y _{sc}	-22,743 [mm]
	AISI	m | Y _{sc}	59,274 [mm]
Warping Constant	EUROCODE	I _ω	353869598,321 [mm ⁶]
	AISI	C _ω	37026971,607 [mm ⁶]
Torsion Constants	EUROCODE	I _t	242,500 [mm ⁴]
	AISI	W _t	167,911 [mm ³]
Distance between Shear Centre and Gravity Centre	EUROCODE	Y _{cg}	242,506 [mm]
	AISI	X ₁ | Y _{cg}	-37,401 [mm]
Polar Moment of Area with respect to Shear Centre	EUROCODE	Y _{sc}	-37,355 [mm]
	AISI	Z _{sc}	0,000 [mm]
Non-symmetry Factors	ξ		-37,401 [mm]
	ε		0,000 [mm]
AISI Parameters used in elastic critical moment determination	β _u		-346731,6381 [mm]
	β ₁		4253544,635 [mm]
	β		5386409,235 [mm]
	j		65,750 [mm]

C-Section Beam Flange Curling		[AISI S100-07, B1.1(b)]
<p> $W_t = \sqrt{0.06 I_{\omega} E / I_{\omega} \sqrt{100 r_f / d}}$ [AISI S100-07, Equation (B1.1-1)] </p>	f _u	350,000 [MPa]
	E	210,000 [GPa]
	c ₁ = 0,05 * h	2,735 [mm]
	t	0,952 [mm]
	d = h	120,000 [mm]
W _{flange}	119,214 [mm]	Flange Curling is not considered in the calculation

C-Section Beam Flange Curling [AS/NZS 4600:2005, 2.1.3.2]

$$\lambda_y = \sqrt{\frac{0,061 t_y \sqrt{E}}{f_y} + \frac{100 t_y}{d}}$$

$\lambda_{y,req} = 119,414$ [mm] → Flange Curling is not considered in the calculation

[4] C-Section Column

Property	Value	Unit
h	90,000	[mm]
b ₁	46,500	[mm]
b ₂	46,500	[mm]
r _y	18,200	[mm]
r _z	18,200	[mm]
r ₁	2,500	[mm]
r ₂	2,500	[mm]
r ₃	2,500	[mm]
r ₄	2,500	[mm]
phi ₁	90,000	[°]
phi ₂	90,000	[°]
phi ₃	90,000	[°]
phi ₄	90,000	[°]

C-Section Column Mechanical Properties [Continuation]

Property	Value	Unit	
Sectroial Constants	I_{yy}	-1 825 731 4,383 [mm ⁴]	
	I_{zz}	-8 733 179,492 [mm ⁴]	
	I_{yyz}	-4 618 806,596 [mm ⁴]	
	I_{zzz}	-1 468 895,402 [mm ⁴]	
	I_{yzz}	198 732 652,240 [mm ⁴]	
	I_{zzy}	984 476 551,841 [mm ⁴]	
Shear Centre	EUROCODE	y_{sc}	-23,949 [mm]
		z_{sc}	43,774 [mm]
Warping Constant	AISI	m [mm]	23,963 [mm]
	EUROCODE	I_{ω}	311 247 851,419 [mm ⁶]
Tension Constants	AISI	C_{w}	328 928 23,963 [mm ⁶]
	EUROCODE	I_{t}	956,559 [mm ⁴]
Distance between Shear and Gravity Centre	EUROCODE	W_y	408,407 [mm ³]
		W_z	40,108 [mm ³]
Polar Moment of Area with respect to Shear Centre	EUROCODE	I_{p}	15 787 33,881 [mm ⁴]
		I_{p}	15 787 33,881 [mm ⁴]
Non-symmetry Factors	EUROCODE	α_y	-0,108 [mm]
		α_z	0,000 [mm]
AISI Parameters used in elastic critical moment determination		β_x	-3121 905,848 [mm]
		β_y	3085 440,870 [mm]
		β_z	471 033 6,843 [mm]
		β_w	55,317 [mm]

AISI MANUAL Cold-Formed Steel Design [2008 Edition]
 All expressions consider the sections to contain rounded corners with the exception of I-beams for lateral properties [m] and C_{w} .
 All expressions are given for the full unbraced sections.

C-Section Column Flange Curling [AISI S100-07, B1-10.1]

$$\lambda_y = \sqrt{\frac{0,061 t_y \sqrt{E}}{f_y} + \frac{100 t_y}{d}}$$

$\lambda_{y,req} = 134,389$ [mm] → Flange Curling is not considered in the calculation

C-Section Column [Idealized C-Section Column] Middle-line

Property	Value	Unit
phi ₁	90,000	[°]
phi ₂	90,000	[°]
phi ₃	90,000	[°]
phi ₄	90,000	[°]
r	2,452	[mm]

C-Section Column Mechanical Properties

Property	Value	Unit
Area	487,235	[mm ²]
First Moment of Area	2176 5,866	[mm ³]
Gravity Centre	16,159	[mm]
Second Moment of Area through Gravity Centre	6250 36,020	[mm ⁴]
Product Moment of Area through Gravity Centre	0,000	[mm ⁴]
Principal Axis	6250 36,020	[mm ⁴]
Mean of Sectorial Coordinates	-1434 251	[mm]

C-Section Column Flange Curling [AS/NZS 4600:2005, 2.1.3.2]

$$\lambda_y = \sqrt{\frac{0,061 t_y \sqrt{E}}{f_y} + \frac{100 t_y}{d}}$$

$\lambda_{y,req} = 134,389$ [mm] → Flange Curling is not considered in the calculation

[4] C-Section Strut

Property	Value	Unit
h	50,000	[mm]
b ₁	40,000	[mm]
b ₂	40,000	[mm]
r _y	10,000	[mm]
r _z	10,000	[mm]
r ₁	2,500	[mm]
r ₂	2,500	[mm]
r ₃	2,500	[mm]
r ₄	2,500	[mm]
phi ₁	90,000	[°]
phi ₂	90,000	[°]
phi ₃	90,000	[°]
phi ₄	90,000	[°]

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C-Section Steel

ϕ_x	90,000	[°]
ϕ	90,000	[°]
t	1,652	[mm]

Isolated C-Section Steel | Middleline

ϕ_x	90,000	[°]
ϕ	90,000	[°]

C-Section Steel: Geometrical Presentation

C-Section Steel Mechanical Properties				
Area	EUROCODE	A	281,315	[mm ²]
	AISI	A	281,325	[mm ²]
First Moment of Area		S_{xx}	4886,730	[mm ³]
		S_{yy}	3840,577	[mm ³]
Gravity Centre	EUROCODE	y_{ce}	15,104	[mm]
	AISI	x_c [y _{ce}]	15,104	[mm]
Second Moment of Area Gravity Centre	EUROCODE	I_{xx}	85435,709	[mm ⁴]
		I_{yy}	43399,245	[mm ⁴]
	AISI	I_{xx}	85435,850	[mm ⁴]
		I_{yy}	43405,554	[mm ⁴]
Product Moment of Area through Gravity Centre		I_{xy}	0,000	[mm ⁴]
Principal Axis		α	0,000	[°]
		I_1	85435,709	[mm ⁴]
		I_2	43399,245	[mm ⁴]
Mean of Sectorial Coordinate		I_w	-143970,284	[mm ⁶]
		$W_{pl,y}$	-715,148	[mm ³]

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C-Section Steel: Flange Curling

$\delta_{flange} = \sqrt{0.06 I_y \sigma / (I_w \frac{1}{4} (100k_y / d))}$
[AS/NZS 4600:2005, Equation (2.3.2)]

f_u	350,000	[MPa]
E	210,000	[GPa]
$\alpha_1 = 0.95 \cdot h$	2,500	[mm]
t	1,652	[mm]
$d = h$	90,000	[mm]

δ_{flange} 77,882 [mm] → Flange Curling is not considered in the calculation

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C-Section Steel Mechanical Properties Continuation				
Sectorial Constants		I_{pc}	3227639,382	[mm ⁶]
		I_{ps}	-1053475,989	[mm ⁶]
		I_{pc}	-4240440,983	[mm ⁶]
		I_{ps}	-1745709,295	[mm ⁶]
		I_{pc}	19051401,065	[mm ⁶]
		I_{ps}	87553344,236	[mm ⁶]
Shear Centre	EUROCODE	y_{sc}	-2,493	[mm]
	AISI	x_c [y _{sc}]	20,504	[mm]
Warping Constant	EUROCODE	I_w	28311081,398	[mm ⁶]
	AISI	C_w	28407510,884	[mm ⁶]
Torsion Constants	EUROCODE	I_t	141,478	[mm ⁴]
	AISI	W_t	87,497	[mm ³]
Distance between Shear and Gravity Centre	EUROCODE	y_s	-2,493	[mm]
	AISI	x_s [y _s]	-35,808	[mm]
Polar Moment of Area with respect to Shear Centre		J_p	383066,018	[mm ⁴]
Non-symmetry Factors		χ	-1,747	[mm]
		z	0,000	[mm]
AISI Parameters used in of elastic critical moment	determination	β_x	-451994,835	[mm]
		β_y	456010,717	[mm]
		β_z	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 I_w and C_w .
All expressions are given for the full, unrolled sections.

C-Section Steel: Flange Curling

$W_t = \sqrt{0.06 I_y \sigma / (I_w \frac{1}{4} (100k_y / d))}$
[AISI S100-07, Equation (B.1-1)]

f_u	350,000	[MPa]
E	210,000	[GPa]
$\alpha_1 = 0.95 \cdot h$	2,500	[mm]
t	1,652	[mm]
$d = h$	90,000	[mm]

W_t 77,882 [mm] → Flange Curling is not considered in the calculation

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Version:	1,000		

[10] Photovoltaic Structure - Strength increase resulting from cold forming

[AISI S100-07, Art.2 | AS/NZS 4600, 1.5.1.2]

(1) Stages in roll forming a simple section
(2) Roller shapes at each stage
(3) Profiles at each stage

Stages in roll forming a simple section | Rhodes, 1991

Forming of folding

Forming steps in press-braking process

C-Section Profile, 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	Press Braking
Yield strength	Corner	High	High
	Flange	Moderate	---
Ultimate strength	Corner	High	High
	Flange	Moderate	---

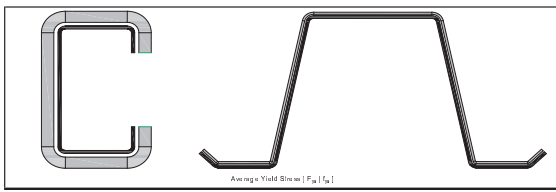
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NOTE Manufacturing processes lead to a modification of the stress-strain curve of the steel light material. The average yield strength F_y may be utilized in determining:

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

NOTE Manufacturing processes lead to a modification of the stress-strain curve of the steel light material. The average yield strength f_y may be utilized in determining:

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



Average Yield Stress (F_y) (f_y)

[*] C-Section Profile

$$F_{yA} = C F_{yc} + (1 - C) F_{yt} \leq F_{UV}$$

[AISI S100-2007, Equation A7.2-1]

$$f_{yA} = C f_{yc} + (1 - C) f_{ft} \leq f_{m}$$

[AS/NZS 4600-2005, Equation 1.5.1.2(1)]

Cold-Formed Material Properties			
S 350 GD + Z	F_y (f_y)	350,000	[MPa]
	F_{U1} (f_{U1})	420,000	[MPa]

Equations A7.2-2 and 1.5.1.2(2) are only applicable if:			
AISI	F_y (f_y) $\geq 1,20$	R (r) $\leq 7,00$	$\phi \leq 120^\circ$
AS/NZS	f_y (f_y) $\geq 1,20$	r (r) $\leq 7,00$	$\phi \leq 120^\circ$

Parameters			
r_{max}	2,000	[*]	1
			1,052
			[mm]

AISI S100-2007		AS/NZS 4600-2005	
F_y (f_y) $\geq 1,20$	OK	f_{U1} (f_{U1}) $\geq 1,20$	OK
R (r) $\leq 7,00$	OK	r (r) $\leq 7,00$	OK
$\phi \leq 120^\circ$	OK	$\phi \leq 120^\circ$	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

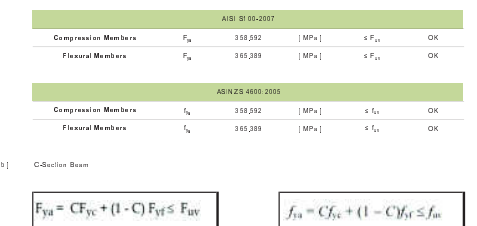
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Version: 1,000			

NOTE Manufacturing processes lead to a modification of the stress-strain curve of the steel light material. The average yield strength F_y may be utilized in determining:

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

NOTE Manufacturing processes lead to a modification of the stress-strain curve of the steel light material. The average yield strength f_y may be utilized in determining:

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



Average Yield Stress (F_y) (f_y)

[*] C-Section Beam

$$F_{yA} = C F_{yc} + (1 - C) F_{yt} \leq F_{UV}$$

[AISI S100-2007, Equation A7.2-1]

$$f_{yA} = C f_{yc} + (1 - C) f_{ft} \leq f_{m}$$

[AS/NZS 4600-2005, Equation 1.5.1.2(1)]

Cold-Formed Material Properties			
S 350 GD + Z	F_y (f_y)	350,000	[MPa]
	F_{U1} (f_{U1})	420,000	[MPa]

Equations A7.2-2 and 1.5.1.2(2) are only applicable if:			
AISI	F_y (f_y) $\geq 1,20$	R (r) $\leq 7,00$	$\phi \leq 120^\circ$
AS/NZS	f_y (f_y) $\geq 1,20$	r (r) $\leq 7,00$	$\phi \leq 120^\circ$

Parameters			
r_{max}	2,000	[*]	1
			1,052
			[mm]

AISI S100-2007		AS/NZS 4600-2005	
F_y (f_y) $\geq 1,20$	OK	f_{U1} (f_{U1}) $\geq 1,20$	OK
R (r) $\leq 7,00$	OK	r (r) $\leq 7,00$	OK
$\phi \leq 120^\circ$	OK	$\phi \leq 120^\circ$	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

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AISI S100-2007		AS/NZS 4600-2005	
F_y (f_y) $\geq 1,20$	OK	f_{U1} (f_{U1}) $\geq 1,20$	OK
R (r) $\leq 7,00$	OK	r (r) $\leq 7,00$	OK
$\phi \leq 120^\circ$	OK	$\phi \leq 120^\circ$	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]

$$f_{yc} = \frac{B_c f_{yV}}{(r/t)^m}$$

[AS/NZS 4600-2005, Equation 1.5.1.2(2)]

AISI S100-2007		AS/NZS 4600-2005	
F_{yc}	474,87	[MPa]	f_{yc}
			474,87
			[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	$C_{compression}$	0,269	||
Flexural Members	$C_{flexure}$	0,224	||

AS/NZS 4600-2005		AS/NZS 4600-2005	
Compression Members	$C_{compression}$	0,269	
Flexural Members	$C_{flexure}$	0,224	

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AISI S100-2007		AS/NZS 4600-2005	
F_y (f_y) $\geq 1,20$	OK	f_{U1} (f_{U1}) $\geq 1,20$	OK
R (r) $\leq 7,00$	OK	r (r) $\leq 7,00$	OK
$\phi \leq 120^\circ$	OK	$\phi \leq 120^\circ$	OK

$$m = 0.192 (F_{UV}/F_{yV}) - 0.068$$

[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]

$$f_{yc} = \frac{B_c f_{yV}}{(r/t)^m}$$

[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	$C_{compression}$	0,269	||
Flexural Members	$C_{flexure}$	0,208	||

AS/NZS 4600-2005		AS/NZS 4600-2005	
Compression Members	$C_{compression}$	0,269	||
Flexural Members	$C_{flexure}$	0,208	||

AISI S100-2007		AS/NZS 4600-2005	
Compression Members	F_y	360,001	[MPa]
Flexural Members	F_y	374,390	[MPa]
		$\leq F_{U1}$	OK

AS/NZS 4600-2005		AS/NZS 4600-2005	
Compression Members	f_y	360,001	[MPa]
Flexural Members	f_y	374,390	[MPa]
		$\leq f_{U1}$	OK

[*] C-Section Column

$$F_{yA} = C F_{yc} + (1 - C) F_{yt} \leq F_{UV}$$

[AISI S100-2007, Equation A7.2-1]

$$f_{yA} = C f_{yc} + (1 - C) f_{ft} \leq f_{m}$$

[AS/NZS 4600-2005, Equation 1.5.1.2(1)]

Cold-Formed Material Properties			
S 350 GD + Z	F_y (f_y)	350,000	[MPa]
	F_{U1} (f_{U1})	420,000	[MPa]

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Version: 1,000			

Equations A7.2-2 and 1.5.1.2(2) are only applicable if:

AISI	$F_u / F_y \geq 1.20$	$R / t \leq 7.00$	$\phi \leq 120^\circ$
AS/NZS	$f_u / f_y \geq 1.20$	$r / t \leq 7.00$	$\phi \leq 120^\circ$

Parameters

f_{yw}	2500	[N]		1	2452	[mm]
----------	------	-----	--	---	------	------

AISI S100-2007	$F_u / F_y \geq 1.20$ OK	$R / t \leq 7.00$ OK	$\phi \leq 120^\circ$ OK
AS/NZS 4600-2005	$f_u / f_y \geq 1.20$ OK	$r / t \leq 7.00$ OK	$\phi \leq 120^\circ$ 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]

$$f_{yc} = \frac{B_c f_{yv}}{(r/t)^m}$$

[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

Compression members: ratio of the total bend cross-sectional area to the total cross-sectional area of the full section

C Flexural members: ratio of the total bend cross-sectional area to the controlling flange to the full cross-sectional area of the controlling flange

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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]

$$f_{yc} = \frac{B_c f_{yv}}{(r/t)^m}$$

[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

Compression members: ratio of the total bend cross-sectional area to the total cross-sectional area of the full section

C 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		$C_{lcr,comp}$	0.146	[]
AS/NZS 4600-2005	Compression Members		$C_{lcr,comp}$	0.146	[]
AISI S100-2007	Flexural Members		$C_{lcr,flex}$	0.240	[]
AS/NZS 4600-2005	Flexural Members		$C_{lcr,flex}$	0.240	[]

AISI S100-2007	Compression Members	F_{bc}	367.142	[MPa]	$\leq F_{yt}$	OK
AISI S100-2007	Flexural Members	F_{bc}	378.145	[MPa]	$\leq F_{yt}$	OK
AS/NZS 4600-2005	Compression Members	f_{bc}	367.142	[MPa]	$\leq f_{yt}$	OK
AS/NZS 4600-2005	Flexural Members	f_{bc}	378.145	[MPa]	$\leq f_{yt}$	OK

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AISI S100-2007	Compression Members		$C_{lcr,comp}$	0.115	[]
AISI S100-2007	Flexural Members		$C_{lcr,flex}$	0.242	[]
AS/NZS 4600-2005	Compression Members		$C_{lcr,comp}$	0.115	[]
AS/NZS 4600-2005	Flexural Members		$C_{lcr,flex}$	0.242	[]

AISI S100-2007	Compression Members	F_{bc}	388.223	[MPa]	$\leq F_{yt}$	OK
AISI S100-2007	Flexural Members	F_{bc}	388.471	[MPa]	$\leq F_{yt}$	OK
AS/NZS 4600-2005	Compression Members	f_{bc}	388.223	[MPa]	$\leq f_{yt}$	OK
AS/NZS 4600-2005	Flexural Members	f_{bc}	388.471	[MPa]	$\leq f_{yt}$	OK

[4] C-Section Steel

$$F_{yc} = C F_{yc} + (1 - C) F_{yt} \leq F_{uv}$$

[AISI S100-2007, Equation A7.2-1]

$$f_{yc} = C f_{yc} + (1 - C) f_{yt} \leq f_{uv}$$

[AS/NZS 4600-2005, Equation 1.5.1.2(1)]

Cold-Formed Material Properties

S 355 GD + Z	F_u / f_u	39.000	[MPa]	F_u / f_u	420.000	[MPa]
--------------	-------------	--------	-------	-------------	---------	-------

Equations A7.2-2 and 1.5.1.2(2) are only applicable if:

AISI	$F_u / F_y \geq 1.20$	$R / t \leq 7.00$	$\phi \leq 120^\circ$
AS/NZS	$f_u / f_y \geq 1.20$	$r / t \leq 7.00$	$\phi \leq 120^\circ$

Parameters

f_{yw}	2500	[N]		1	2452	[mm]
----------	------	-----	--	---	------	------

AISI S100-2007	$F_u / F_y \geq 1.20$ OK	$R / t \leq 7.00$ OK	$\phi \leq 120^\circ$ OK
AS/NZS 4600-2005	$f_u / f_y \geq 1.20$ OK	$r / t \leq 7.00$ OK	$\phi \leq 120^\circ$ 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)]

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[1] Cold-Formed Section subjected to Tension Force

[*] D-Section Profile

Gross D-Section

Effective D-Section [L]

Local Buckling

D-Section Profile Mechanical Properties

Area	$A_g = A_{net}$	191.389	[mm ²]
Gravity Centm	$Y_{cg} = Y_{cg,net}$	55.867	[mm]
Second Moment of Area	$Z_{cg} = Z_{cg,net}$	25.852	[mm ³]
Gravity Centre	through	$I_y = I_{y,net}$	85759.975 [mm ⁴]
		$I_z = I_{z,net}$	176959.935 [mm ⁴]

[b] C-Section Beam

Gross C-Section

Effective C-Section [L]

Local Buckling

C-Section Beam Mechanical Properties

Area	$A_g = A_{net}$	345.883	[mm ²]
Gravity Centm	$Y_{cg} = Y_{cg,net}$	14.563	[mm]
Second Moment of Area	$Z_{cg} = Z_{cg,net}$	59.274	[mm ³]
Gravity Centre	through	$I_y = I_{y,net}$	762290.965 [mm ⁴]
		$I_z = I_{z,net}$	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	$A_g = A_{net}$	497,235	[mm ²]
Gravity Centre	$Y_{cg} = Y_{cg,net}$	16,559	[mm]
	$Z_{cg} = Z_{cg,net}$	43,274	[mm]
Second Moment of Area Gravity Centre	through $I_y = I_{y,net}$	62503,020	[mm ⁴]
	$I_z = I_{z,net}$	15381,6366	[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	$A_g = A_{net}$	201,315	[mm ²]
Gravity Centre	$Y_{cg} = Y_{cg,net}$	10,04	[mm]
	$Z_{cg} = Z_{cg,net}$	24,274	[mm]
Second Moment of Area Gravity Centre	through $I_y = I_{y,net}$	85435,209	[mm ⁴]
	$I_z = I_{z,net}$	43399,345	[mm ⁴]

Actual Element | Effective Element and Stress on Effective Elements

Uniformed Element with Uniform Compression [AISI S100, Figure D3.1-1]

C-Section Profile Dimension		NOTE	$W = C_{y,comp}$
$r_{y,eff}$	6,791	[mm]	
E	210,000	[GPa]	0,952 [mm] | v | u | 0,300

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. (B2.3-5)] | $F_c = 1907,586$ [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. (B2.3-4)] | $\lambda = 0,428$ | $\rho = (1 - 0,22/\lambda) \lambda$ [AISI S100, Eq. (B2.3-1)]

$\rho = 1,000$ | Compression | $r_{y,eff}$ | 6,791 [mm]

Right Edge Stiffener [AISI S100] | [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k
S.S. | S.S. | S.S. | Free	Compression	0,425

Actual Element | Effective Element and Stress on Effective Elements

Uniformed Element with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

C-Section Profile Dimension		NOTE	$b = C_{y,comp}$
$r_{y,eff}$	6,791	[mm]	
E	210,000	[GPa]	0,952 [mm] | v | 0,300

[11.2] Cold-Formed Section subjected to Compression Force

[x] D-Section Profile

Gross D-Section | Effective D-Section [L] | Local Buckling

[y] Effective Width for Strength Determination | Local Buckling | AISI S100, Section 8 | AS/NZS 4600, Section 2

D-Section Profile Dimension	
$r_{y,eff}$	6,791 [mm]
$r_{y,net}$	16,545 [mm]
$r_{z,net}$	51,640 [mm]
$r_{z,net}$	38,271 [mm]
$r_{y,net}$	51,640 [mm]
$r_{y,net}$	16,545 [mm]
$r_{y,net}$	6,791 [mm]

Effective D-Section | Weld Case

$b_{p,Sup. Flange}$, $b_{p,Inf. Left Flange}$, $b_{p,Inf. Right Flange}$, $r_{p,Left Web}$, $r_{p,Right Web}$, $r_{p,Left Lip}$, $r_{p,Right Lip}$, $r_{p,Left Lip}$, $r_{p,Right Lip}$

D-Section Plate Widths

Right Edge Stiffener [AISI S100] | [AISI S100, Section B3]

Boundary condition	Types of stress	k
S.S. | S.S. | S.S. | Free	Compression	0,425

Actual Element | Effective Element and Stress on Effective Elements

Uniformed Element with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)}\right) \left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(6)] | $f_c = 1907,586$ [MPa]

$$\lambda = \left(\sqrt{\frac{f}{f_{cr}}}\right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)] | $\lambda = 0,428$ | $\rho = \frac{(1 - 0,22/\lambda)}{\lambda} \leq 1,0$ [AS/NZS 4600, Eq. 2.2.1.2(5)]

$\rho = 1,000$ | Compression | $r_{y,eff}$ | 6,791 [mm]

AISI S100, Effective Width [mm] | Compression | $\rho \geq 1$ | AS/NZS 4600, Effective Width [mm]

$r_{y,eff}$ | 6,791 | $r_{y,net}$ | 16,545

Inflator Right Flange [AISI S100] | [AISI S100, Section B4]

D-Section Profile Dimension	
$r_{y,eff}$	6,791 [mm]
$r_{y,net}$	16,545 [mm]
t	0,952 [mm]

$$S = 1,28\sqrt{E/t}$$

[AISI S100, Eq. B4.2] | $S = 31,353$ [mm]

E	f	S
210,000 [GPa]	350,000 [MPa]	
		31,353 [mm]

$w \leq 0,328 \sqrt{S}$ | $w \leq 0,328 \sqrt{S}$

$I_w = 0,000$ no edge stiffener needed | $I_w = \dots$ edge stiffener is needed

$b = w$ | $b_1 = [b + 2t] \sqrt{R}$

$b_2 = b - b_1$ | $b_2 = b - b_1$

$d_1 = d_1$ | $d_1 = 4 \sqrt{tR}$

$w \leq 17,375$ Edge stiffener is needed | $0,328 \sqrt{S}$ | 10,284

$$I_w = 399h^4 \left[\frac{w/l}{S} - 0,328\right]^3 \leq t^4 [115 \frac{w/l}{S} + 5]$$

[AISI S100, Eq. B4.4] | Adequate moment of inertia of stiffener so that each component element will behave as a stiffened element

$I_s/I_y \leq 1$ [AISI S100, Eq. B4.4] $I_s = (d^3 t \sin^2 \theta) / 12$ [AISI S100, Eq. B4.10]

$\phi_x = 45,000$ [°] → $I_y = 179,857$ [mm⁴]

$[R_x] = 47,297 \leq 1,000$ → KO → $[R_x] = 1,000$

$n = \left(\frac{0.582 - w/t}{4S} \right) \geq \frac{1}{3}$ [AISI S100, Eq. B4.11] **Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]**
 Simple Lip Edge Stiffener [140°12.8 < 40°]
 $d/w \leq 0.250$ $0.250 < d/w \leq 0.400$ $[4.820 - (5^* d/w)] \leq [R_x] \leq [4.820 + (5^* d/w)]$ $[R_x] \leq 0.430 \leq 4.000$

OK 140°2 $\phi_y = 49,000$ [°] $\geq 40^\circ$ OK

$n = 0,443 \geq 1/3.7$ OK → $n = 0,443$

[AISI S100, Table B4-1] $d/w = 0,436$ → $k = 3,072$ OK

D-Section Profile Dimension **NOTE** **W ≠ b_{flange} spacing**

b_{flange} 16,545 [mm]

E 210,000 [GPa] $t = 0,952$ [mm] $v [\mu]$ 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$ $F_u = 1930,381$ [MPa] [AISI S100, Eq. B2.1-5]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $f = f_c = 350,000$ [MPa] $\rho = \left(1 - \frac{0,22}{\lambda} \right) \lambda \leq 1,0$ [AISI S100, Eq. B2.1-4]

$\lambda = 0,426$

$\rho = 1,000$ → $b_{flange, max}$ 16,545 [mm]

$b_{flange, min}$ 8,273 [mm] $b_{flange, max}$ 8,273 [mm]

AISI S100, Effective Width [mm] Comparison $w \leq w_f$ **AS/NZS 4600, Effective Width [mm]**

$b_{flange, min}$ 8,273 $b_{flange, min}$ 8,273

$b_{flange, max}$ 8,273 $b_{flange, max}$ 8,273

Right Web [b_{web}] [AISI S100, Section B2.1]

Boundary condition Types of stress k

 Compression 4,000

 Actual Element Effective Element, b, and Stiffness, f, on Effective Elements

Sifted Elements [AISI S100, Figure B2.1-1]

$n = 0,443 \geq 1/3.7$ OK → $n = 0,443$

[AS/NZS 4600, Table 2.4.2] $d/w = 0,436$ → $k = 3,072$ OK

D-Section Profile Dimension **NOTE** **W ≠ b_{flange} spacing**

b_{flange} 16,545 [mm]

E 210,000 [GPa] $t = 0,952$ [mm] $v [\mu]$ 0,300

$F_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$ $F_u = 1930,381$ [MPa] [AS/NZS 4600, Eq. 2.2.1.2(b)]

$\lambda = \left(\sqrt{\frac{f}{F_{cr}}} \right)$ $f = f_c = 350,000$ [MPa] $\rho = \left(\frac{1 - 0,22}{\lambda} \right) \lambda \leq 1,0$ [AS/NZS 4600, Eq. 2.2.1.2(c)]

$\lambda = 0,426$

$\rho = 1,000$ → $b_{flange, max}$ 16,545 [mm]

$b_{flange, min}$ 8,273 [mm] $b_{flange, max}$ 8,273 [mm]

AISI S100, Effective Width [mm] Comparison $w \leq w_f$ **AS/NZS 4600, Effective Width [mm]**

$b_{flange, min}$ 8,273 $b_{flange, min}$ 8,273

$b_{flange, max}$ 8,273 $b_{flange, max}$ 8,273

Right Web [b_{web}] [AISI S100, Section B2.1]

Boundary condition Types of stress k

 Compression 4,000

 Actual Element Effective Element, b, and Stiffness, f, on Effective Elements

Sifted Elements [AISI S100, Figure B2.1-1]

Inflator Right Flange [b_{flange} spacing] [AS/NZS 4600, Clause 2.2.1]

D-Section Profile Dimension

c_{flange} 6,391 [mm]

b_{flange} 16,545 [mm]

$t = 0,952$ [mm]

$c_{flange} \geq 4 t$ $b_{flange} \geq 4 t$

d_{flange} 7,207 [mm]

$S = 1,28 \sqrt{E / f^*}$ E 210,000 [GPa] $f^* = 350,000$ [MPa] S 31,393 [°]

$b \leq 0,328^* S$ $b > 0,328^* S$

$I_y = 0,000$ [no edge stiffener needed] $I_y = \dots$ [edge stiffener needed]

$b_1 = b$ $b_2 = [b_1 + 2 t] / 4$

$b_1 = b_2 = b/2$ $b_2 = b_1 = b_1$

$d_1 = d_{fl}$ $d_1 = d_{fl} [t_1 / t_1]$

$b_1 = 17,379$ Edge stiffener needed $0,328^* S = 10,284$

$I_s = 3097 t^3 \left[\frac{(b/t)}{S} - 0,328 \right] \leq t^3 \left[115 \frac{(b/t)}{S} + 5 \right]$ Adequate moment of inertia of stiffener so that each component element will behave as a stiff element [AS/NZS 4600, Eq. 2.4.2(1)]

$I_s/I_y \leq 1$ [AS/NZS 4600] $I_s = (d^3 t \sin^2 \theta) / 12$ [AS/NZS 4600, Eq. 2.4.2(1)(b)]

$\phi_x = 45,000$ [°] → $I_y = 179,857$ [mm⁴]

$[R_x] = 47,297 \leq 1,000$ → KO → $[R_x] = 1,000$

$n = \left[\frac{0,582 \left(\frac{b/t}{S} \right)}{4S} \right] \geq \frac{1}{3}$ [AS/NZS 4600, Eq. 2.4.2(2)] **Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]**
 Simple Lip Edge Stiffener [140°12.8 < 40°]
 $d/w \leq 0.250$ $0.250 < d/w \leq 0.400$ $[4.820 - (5^* d/w)] \leq [R_x] \leq [4.820 + (5^* d/w)]$ $[R_x] \leq 0.430 \leq 4.000$

OK 140°2 $\phi_y = 49,000$ [°] $\geq 40^\circ$ OK

D-Section Profile Dimension **NOTE** **W ≠ b_{flange} spacing**

b_{flange} 16,540 [mm]

E 210,000 [GPa] $t = 0,952$ [mm] $v [\mu]$ 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$ $F_u = 258,018$ [MPa] [AISI S100, Eq. B2.1-5]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $f = f_c = 350,000$ [MPa] $\rho = \left(1 - \frac{0,22}{\lambda} \right) \lambda$ [AISI S100, Eq. B2.1-4]

$\lambda = 1,165$

$\rho = 0,696$ → $b_{flange, max}$ 35,963 [mm]

$b_{flange, min}$ 17,982 [mm] $b_{flange, max}$ 17,982 [mm]

Right Web [b_{web}] [AS/NZS 4600, Clause 2.2.1]

Boundary condition Types of stress k

 Compression 4,000

 Actual Element Effective Width [b_{fl}] of Element and Design on Effective Elements Stiffness [f]

Sifted Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

D-Section Profile Dimension **NOTE** **W ≠ b_{flange} spacing**

b_{flange} 16,540 [mm]

E 210,000 [GPa] $t = 0,952$ [mm] $v [\mu]$ 0,300

$F_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$ $F_u = 258,018$ [MPa] [AS/NZS 4600, Eq. 2.2.1.2(b)]

Design of a Photovoltaic Structure, Partial configuration, according to AISI or AS/NZS		Office: ---	Author: JOSE ANTONIO
Code: AISI | AS/NZS	Reference: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1,000		Client: COIMBRA UNIVERSITY	

$$\lambda = \sqrt{\frac{f}{f_{cr}}}$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$P = f_c$
350,000 [MPa]

$$\rho = \left(1 - \frac{0.22}{\lambda}\right) \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

ρ	0.896	→	$\rho_{2,PERMANENT}$	35,963	[mm]
$\rho_{2,PERMANENT,1}$	17,982	[mm]	$\rho_{2,PERMANENT,2}$	17,982	[mm]

AISI S100, Effective Width [mm]	Comparison | = or ≠ |	AS/NZS 4600, Effective Width [mm]		
$\rho_{2,PERMANENT,1}$	17,982	-	$\rho_{2,PERMANENT,2}$	17,982
$\rho_{2,PERMANENT,2}$	17,982	-	$\rho_{2,PERMANENT,3}$	17,982

Superior Flange | $\rho_{2,PERMANENT}$
[AISI S100, Section B2.1]

Boundary condition	Types of stress	k
	Compression	4,000

w

t

Actual Element

Effective Element | b, and Stress f, on Effective Elements

Sifted Elements [AISI S100, Figure B2.1-1]

D-Section Profile Dimension	NOTE	$b = \rho_{2,PERMANENT} w$
$\rho_{2,PERMANENT}$	38,711	[mm]
E	210,000	[GPa]
t	0,952	[mm]
v	0,300	[μ]

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w}\right)^2$$

[AISI S100, Eq. B2.1-4]

F_{cr} : 472,252 [MPa]

$$\lambda = \sqrt{\frac{f}{f_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$P = f_c$
350,000 [MPa]

$$\rho = \left(1 - \frac{0.22}{\lambda}\right) \leq 1.0$$

[AISI S100, Eq. B2.1-4]

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Left Web | $\rho_{2,PERMANENT}$
[AISI S100, Section B2.1]

Boundary condition	Types of stress	k
	Compression	4,000

w

t

Actual Element

Effective Element | b, and Stress f, on Effective Elements

Sifted Elements [AISI S100, Figure B2.1-1]

D-Section Profile Dimension	NOTE	$b = \rho_{2,PERMANENT} w$
$\rho_{2,PERMANENT}$	51,640	[mm]
E	210,000	[GPa]
t	0,952	[mm]
v	0,300	[μ]

$$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)}\right) \left(\frac{t}{b}\right)^2$$

[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]

$P = f_c$
350,000 [MPa]

$$\rho = \left(1 - \frac{0.22}{\lambda}\right) \leq 1.0$$

[AISI S100, Eq. B2.1-4]

Left Web | $\rho_{2,PERMANENT}$
[AS/NZS 4600, Clause 2.2.1]

Boundary condition	Types of stress	k
	Compression	4,000

w

t

Actual Element

Effective Element | b, and Stress f, on Effective Elements

Sifted Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

D-Section Profile Dimension	NOTE	$b = \rho_{2,PERMANENT} w$
$\rho_{2,PERMANENT}$	51,640	[mm]
E	210,000	[GPa]
t	0,952	[mm]
v	0,300	[μ]

$$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)}\right) \left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} : 258,018 [MPa]

$$\lambda = \sqrt{\frac{f}{f_{cr}}}$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$P = f_c$
350,000 [MPa]

$$\rho = \left(1 - \frac{0.22}{\lambda}\right) \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

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Version: 1,000		Client: COIMBRA UNIVERSITY	

ρ	0.865	→	$\rho_{2,PERMANENT}$	33,058	[mm]
$\rho_{2,PERMANENT,1}$	16,204	[mm]	$\rho_{2,PERMANENT,2}$	16,204	[mm]

Superior Flange | $\rho_{2,PERMANENT}$
[AS/NZS 4600, Clause 2.2.1]

Boundary condition	Types of stress	k
	Compression	4,000

b

t

Actual Element

Effective Width | b, of Element and Design on Effective Elements

Sifted Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

D-Section Profile Dimension	NOTE	$b = \rho_{2,PERMANENT} w$
$\rho_{2,PERMANENT}$	38,711	[mm]
E	210,000	[GPa]
t	0,952	[mm]
v	0,300	[μ]

$$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)}\right) \left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} : 472,252 [MPa]

$$\lambda = \sqrt{\frac{f}{f_{cr}}}$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$P = f_c$
350,000 [MPa]

$$\rho = \left(1 - \frac{0.22}{\lambda}\right) \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

ρ	0.865	→	$\rho_{2,PERMANENT}$	33,058	[mm]
$\rho_{2,PERMANENT,1}$	16,204	[mm]	$\rho_{2,PERMANENT,2}$	16,204	[mm]

AISI S100, Effective Width [mm]	Comparison | = or ≠ |	AS/NZS 4600, Effective Width [mm]		
$\rho_{2,PERMANENT,1}$	16,204	-	$\rho_{2,PERMANENT,2}$	16,204
$\rho_{2,PERMANENT,2}$	16,204	-	$\rho_{2,PERMANENT,3}$	16,204

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Version: 1,000		Client: COIMBRA UNIVERSITY	

Boundary condition	Types of stress	k
	Compression	4,000

w

t

Actual Element

Effective Width | b, of Element and Design on Effective Elements

Sifted Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

D-Section Profile Dimension	NOTE	$b = \rho_{2,PERMANENT} w$
$\rho_{2,PERMANENT}$	51,640	[mm]
E	210,000	[GPa]
t	0,952	[mm]
v	0,300	[μ]

$$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)}\right) \left(\frac{t}{b}\right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

f_{cr} : 258,018 [MPa]

$$\lambda = \sqrt{\frac{f}{f_{cr}}}$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$P = f_c$
350,000 [MPa]

$$\rho = \left(1 - \frac{0.22}{\lambda}\right) \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

Inferior Left Flange | $\rho_{2,PERMANENT}$
[AISI S100, Section B4]

Boundary condition	Types of stress	k
	Compression	4,000

w

t

Actual Element

Effective Width | b, of Element and Design on Effective Elements

Sifted Elements with Uniform Compression [AISI S100, Figure B4-1]

D-Section Profile Dimension	NOTE	$\rho_{2,PERMANENT} \geq \rho_{2,PERMANENT} \geq W$
$\rho_{2,PERMANENT}$	6,791	[mm]
$\rho_{2,PERMANENT,1}$	16,245	[mm]
t	0,952	[mm]

$\rho_{2,PERMANENT}$	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 | 15 0,328 * S | w | 15 0,328 * S

$I_x = 0,000$ [no edge stiffener needed] | $I_x = \dots$ [edge stiffener needed]

b = w | $b_x = [b/2] * R$

$b_1 = b_2 = b/2$ | $b_1 = b_2 = b_0$

$d_x = d_y$ | $d_x = d_y * [R]$

w | 17,379 | Edge stiffener needed | 0,328 * S | 10,284

$I_x = 399t^4 \left[\frac{w/t - 0,328}{S} \leq t^4 \left[115 \frac{w/t + 5}{S} \right] \right]$ [AISI S100, Eq. B4-8] Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element.

I_x 3,799 [mm⁴] | s 56,466 → OK

$(R_1) = I_s/I_a \leq 1$ [AISI S100, Eq. B4-4] | $I_s = (d^3 t \sin^2 \theta) / 12$ [AISI S100, Eq. B4-10]

ϕ 45,000 [°] → | I_s 179,657 [mm⁴]

| R | 47,297 ≤ 1,000 → KO → | R | 1,000

$n = \left(\frac{0,582 - \frac{w/t}{4S} \right) \geq \frac{1}{3}$ [AISI S100, Eq. B4-11] | Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1] | $F_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$ [AS/NZS 4600, Eq. 2.2.1(2b)]

Simple Lip Edge Stiffener [140° ≤ θ ≤ 40°]

D | w ≤ 0,250 | 0,250 < D | w ≤ 0,300 | 3,570 * [R] * t + 0,430 ≤ 4,000 | 4,820 - [5 * D] * w | [R] * t + 0,430 ≤ 4,000

OK 140° ≥ | ϕ 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

D-Section Part Dimension | NOTE | $b = b_{lim, average}$

$b_{lim, average}$ 16,545 [mm]

E 210,000 [GPa] | f 0,952 [mm] | v | 0,300

$\lambda = \sqrt{\frac{f'}{f_a}}$ [AS/NZS 4600, Eq. 2.2.1(2c)] | $f' = f_s$ 350,000 [MPa] | $\rho = \left(\frac{1 - 0,22/\lambda}{\lambda} \right) \leq 1,0$ [AS/NZS 4600, Eq. 2.2.1(2d)]

λ 0,426

ρ 1,000 → | $b_{lim, average, max}$ 16,545 [mm]

$b_{lim, average, max}$ 8,273 [mm] | $b_{lim, average, max}$ 8,273 [mm]

AISI S100, Effective Width [mm] | Compression | or ± | AS/NZS 4600, Effective Width [mm]

$b_{lim, average, max}$ 8,273 | $b_{lim, average, max}$ 8,273

$b_{lim, average, max}$ 8,273 | $b_{lim, average, max}$ 8,273

$I_s/I_a \leq 1$ [AS/NZS 4600]

$I_s = (d^3 t \sin^2 \theta) / 12$ [AS/NZS 4600, Eq. 2.2(1f)]

ϕ 45,000 [°] → | I_s 179,657 [mm⁴]

| I_s/I_a | 47,297 ≤ 1,000 → KO → | I_s/I_a | 1,000

$n = \left(\frac{0,582 - \frac{b/t}{4S} \right) \geq \frac{1}{3}$ [AS/NZS 4600, Eq. 2.2(1g)] | 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 ≤ 0,300 | 3,570 * [I] * t | [I] * t + 0,430 ≤ 4,000 | 4,820 - [5 * D] * b | [I] * t + 0,430 ≤ 4,000

OK 140° ≥ | ϕ 45,000 [°] | ≥ 40° OK

n 0,443 ≥ 1/3 ? OK → n 0,443

[AS/NZS 4600, Table 2.4.2] | D | b 0,436 → | k 3,072 OK

D-Section Part Dimension | NOTE | $b = b_{lim, average}$

$b_{lim, average}$ 16,545 [mm]

E 210,000 [GPa] | f 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(2b)] | f_s 1930,391 [MPa]

$\lambda = \sqrt{\frac{f'}{f_a}}$ [AS/NZS 4600, Eq. 2.2.1(2c)] | $f' = f_s$ 350,000 [MPa] | $\rho = \left(\frac{1 - 0,22/\lambda}{\lambda} \right) \leq 1,0$ [AS/NZS 4600, Eq. 2.2.1(2d)]

λ 0,426

ρ 1,000 → | $b_{lim, average, max}$ 16,545 [mm]

$b_{lim, average, max}$ 8,273 [mm] | $b_{lim, average, max}$ 8,273 [mm]

AISI S100, Effective Width [mm] | Compression | or ± | AS/NZS 4600, Effective Width [mm]

$b_{lim, average, max}$ 8,273 | $b_{lim, average, max}$ 8,273

$b_{lim, average, max}$ 8,273 | $b_{lim, average, max}$ 8,273

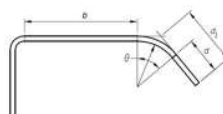
$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$ [AISI S100, Eq. B2.1-4] | F_s 1930,391 [MPa]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ [AISI S100, Eq. B2.1-4] | $f = f_s$ 350,000 [MPa] | $\rho = (1 - 0,22/\lambda) \lambda$ [AISI S100, Eq. B2.1-4]

ρ 1,000 → | $b_{lim, average, max}$ 16,545 [mm]

$b_{lim, average, max}$ 8,273 [mm] | $b_{lim, average, max}$ 8,273 [mm]

Infinite Lip Flange [No average] | [AS/NZS 4600, Clause 2.2]

 [AS/NZS 4600, Figure 2.4.2]

D-Section Part Dimension

$c_{lim, max}$ 6,291 [mm]

$b_{lim, average}$ 16,545 [mm]

t 0,952 [mm]

$c_{lim, max} \leq 4$ | $b_{lim, average} = b$

$c_{lim, max}$ 7,297 [mm]

$S = 1.28\sqrt{E/f'}$ [AS/NZS 4600, Eq. 2.2(19)]

E	210,000	[GPa]
f'	350,000	[MPa]
S	31,353	[]

b | 15 0,328 * S | b | 15 0,328 * S

$I_x = 0,000$ [no edge stiffener needed] | $I_x = \dots$ [edge stiffener needed]

$b_1 = b$ | $b_1 = [b/2] * [I_s/I_a]$

$b_2 = b_1 = b/2$ | $b_2 = b_1 = b_0$

$d_x = d_y$ | $d_x = d_y * [I_s/I_a]$

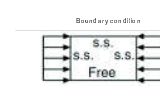
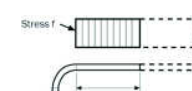
b | 17,379 | Edge stiffener needed | 0,328 * S | 10,284

$I_x = 399t^4 \left[\frac{b/t - 0,328}{S} \leq t^4 \left[115 \frac{b/t}{S} + 5 \right] \right]$ [AS/NZS 4600, Eq. 2.2(1j)] Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element.

Left Edge Stiffener [No average] | [AISI S100, Section B.2.1]

Boundary condition | Types of stress | k

S.S. S.S. Free | Compression | 0,425

 | 

Actual Element | Effective Element and Stress on Effective Element

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

D-Section Part Dimension | NOTE | $b = b_{lim, max}$

$c_{lim, max}$ 6,291 [mm]

E 210,000 [GPa] | f 0,952 [mm] | v | 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$ [AISI S100, Eq. (B2.1-4)] | F_s 1930,396 [MPa]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ [AISI S100, Eq. B2.1-4] | $f = f_s$ 350,000 [MPa] | $\rho = (1 - 0,22/\lambda) \lambda$ [AISI S100, Eq. B2.1-4]

λ 0,426


ρ 1,000 → | $c_{lim, max}$ 6,291 [mm]

Left Edge Stiffener [No average] | [AS/NZS 4600, Clause 2.2.1]

Boundary condition | Types of stress | k

S.S. S.S. Free | Compression | 0,425

Design of a Photovoltaic Structure, Partial configuration, according to AISI or AS/NZS				Office: ---	Author: JOSE ANTONIO
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Version: 1,000					



Actual Element | Effective Element and Stress on Effective Elements

Unflattened Element with Uniform Compression [AS/NZS 4600, Figure 2.2.1.1]

D-Section Profile Dimension		NOTE	$b = c_0 \cdot \lambda_{\text{local}}$
c_{max}	6,191 [mm]		
E	210,000 [GPa]	λ	0,552 [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(6)] f_{cr} : 1907,096 [MPa]

$$\lambda = \sqrt{\frac{f'}{f_{cr}}}$$

[AS/NZS 4600, Eq. 2.2.1.2(4)] λ : 0,428

$$\lambda_p = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

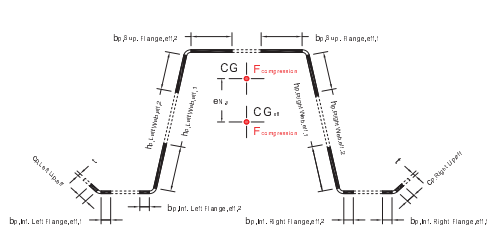
ρ	1,000	c_{max}	6,191 [mm]
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AISI S100, Effective Width	Comparison $\rho = 1$	AS/NZS 4600, Effective Width	
c_{max}	6,191	c_{max}	6,191

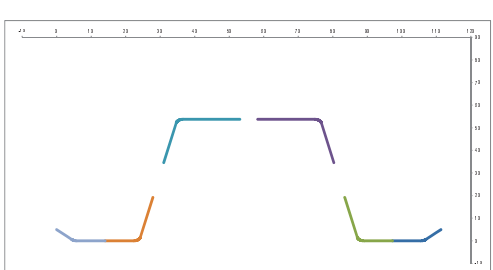
[II] Effective D-Section Profile | Local Buckling

Effective D-Section Profile Widths [AISI S100]		
Right Edge Stiffener	c_{max}	6,191 [mm]
Inferior Right Flange	b_{eff}	16,545 [mm]
Right Web	b_{eff}	35,963 [mm]
Superior Flange	b_{eff}	33,058 [mm]
Left Web	b_{eff}	35,963 [mm]
Inferior Left Flange	b_{eff}	16,545 [mm]
Left Edge Stiffener	c_{max}	6,191 [mm]

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Version: 1,000					



Effective D-Section Profile | Compression Force [AISI S100 | AS/NZS 4600]



Effective D-Section Profile | Local Buckling | Compression Force

A_{eff}	156,435 [mm ²]	$\rho_{\text{y}} = \frac{F_{\text{cr,y}}}{F_{\text{cr}}}$	1,115 [mm]
		$\rho_{\text{z}} = \frac{F_{\text{cr,z}}}{F_{\text{cr}}}$	0,000 [mm]

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Version: 1,000					

Effective D-Section Profile Widths [AS/NZS 4600]		
Right Edge Stiffener	c_{max}	6,191 [mm]
Inferior Right Flange	b_{eff}	16,545 [mm]
Right Web	b_{eff}	35,963 [mm]
Superior Flange	b_{eff}	33,058 [mm]
Left Web	b_{eff}	35,963 [mm]
Inferior Left Flange	b_{eff}	16,545 [mm]
Left Edge Stiffener	c_{max}	6,191 [mm]

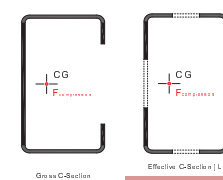
Effective D-Section Profile Widths [AISI S100 | AS/NZS 4600]		
Right Edge Stiffener	c_{max}	6,191 [mm]
Inferior Right Flange	b_{eff}	16,545 [mm]
Right Web	b_{eff}	35,963 [mm]
Superior Flange	b_{eff}	33,058 [mm]
Left Web	b_{eff}	35,963 [mm]
Inferior Left Flange	b_{eff}	16,545 [mm]
Left Edge Stiffener	c_{max}	6,191 [mm]

[III] Effective Cross D-Section Profile | Local Buckling

Effective D-Section Profile Widths		
Right Edge Stiffener	c_{max}	6,191 [mm]
Inferior Right Flange	b_{eff}	8,273 [mm]
Right Web	b_{eff}	17,982 [mm]
Superior Flange	b_{eff}	16,504 [mm]
Left Web	b_{eff}	17,982 [mm]
Inferior Left Flange	b_{eff}	8,273 [mm]
Left Edge Stiffener	c_{max}	6,191 [mm]

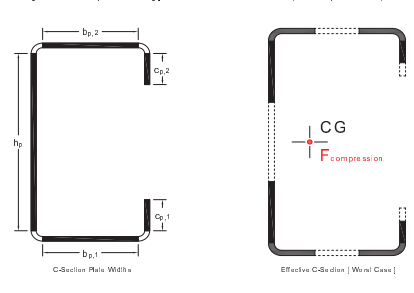
Design of a Photovoltaic Structure, Partial configuration, according to AISI or AS/NZS				Office: ---	Author: JOSE ANTONIO
Code: AISI | AS/NZS	Reference: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS	Client: COIMBRA UNIVERSITY	
Version: 1,000					

[II] C-Section Beam




C-Section Beam Dimension	
c_{11}	14,048 [mm]
c_{12}	38,596 [mm]
c_{21}	112,096 [mm]
c_{22}	38,596 [mm]
c_{23}	14,048 [mm]
λ	1,452 [mm]

[I] Effective Widths for Strength Determination | Local Buckling



Boundary condition	Type of stress	k
S.S. | S.S. | Free	Compression	0,425



Actual Element | Effective Element and Stress on Effective Elements

Unflattened Element with Uniform Compression [AISI S100, Figure B3.1.1]

C-Section Beam Dimension NOTE $w = c_{y1}$

c_{y1} 14,048 [mm]

E 210,000 [GPa] | t 1,452 [mm] | v μ 0,300

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$$

F_u 861,266 [MPa]

[AISI S100, Eq. (B2.1-9)]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $\rho = (1 - 0.22/\lambda) \lambda$

f 350,000 [MPa]

λ 0,637 [AISI S100, Eq. B2.1-4]

ρ 1,000 c_{y1max} 14,048 [mm]

Inflator: Edge Stiffener [c_{y1}] [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

Unflattened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

C-Section Beam Dimension NOTE $b = c_{y1}$

c_{y1} 14,048 [mm]

E 210,000 [GPa] | t 1,452 [mm] | v μ 0,300

$$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$$

f_u 861,266 [MPa]

[AS/NZS 4600, Eq. 2.1.2(5)]

ϕ_x 90,000 [°] \rightarrow I_x 6958,844 [mm⁴]

[R] 27,931 $<$ 1,000 \rightarrow KO \rightarrow [R] 1,000

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4.1]

Single Lip Edge Stiffener: $140^\circ \leq \theta \leq 40^\circ$

$D1 \leq 0,250$ $0,250 < D1 \leq 0,500$

$0,570 \cdot [R]^2 + 0,430 < 4,000$ $[4,000 - 1,5 \cdot [R]^2 + 0,430 < 4,000$

OK 140° ϕ_x 90,000 [°] $\geq 40^\circ$ OK

n 0,370 $\geq 1/3 ?$ OK \rightarrow n 0,370

[AISI S100, Table B4.1] $D1 \leq w$ 0,466 \rightarrow k 2,918 OK

C-Section Beam Dimension NOTE $w = b_{y1}$

b_{y1} 38,596 [mm]

E 210,000 [GPa] | t 1,452 [mm] | v μ 0,300

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$$

F_u 783,886 [MPa]

[AISI S100, Eq. (B2.1-9)]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $\rho = (1 - 0.22/\lambda) \lambda$

f 350,000 [MPa]

λ 0,668 [AISI S100, Eq. B2.1-4]

ρ 1,000 b_{y1max1} 38,596 [mm]

b_{y1max2} 19,298 [mm] b_{y1max3} 19,298 [mm]

Inflator: Flange [b_{y1}] [AS/NZS 4600, Clause 2.4.1]

[AS/NZS 4600, Figure 2.4.1]

C-Section Beam Dimension

c_{y1} 14,048 [mm]

b_{y1} 38,596 [mm]

t 1,452 [mm]

$c_{y1} = d | b_{y1} = b$

d_{max1} 19,200 [mm]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $\rho = \frac{1 - 0.22}{\lambda} \leq 1.0$

f 350,000 [MPa]

λ 0,637 [AS/NZS 4600, Eq. 2.1.2(4)]

[AS/NZS 4600, Eq. 2.1.2(4)]

ρ 1,000 c_{y1max1} 14,048 [mm]

AISI S100, Effective Width [mm] AS/NZS 4600, Effective Width [mm]

c_{y1max2} 14,048 c_{y1max3} 14,048

Inflator: Flange [b_{y1}] [AISI S100, Sect. B4.1]

C-Section Beam Dimension

b_{y1} 14,048 [mm]

b_{y1} 38,596 [mm]

t 1,452 [mm]

$c_{y1} = d | b_{y1} = w$

d_{max1} 19,200 [mm]

$S = 1.28 \sqrt{E/f}$

E 210,000 [GPa]

f 350,000 [MPa]

S 31,353 []

$w \leq 0,328 \cdot S$ $w \leq 0,328 \cdot S$

$I_x = 0,000$ [no edge stiffener needed] $I_x = \dots$ [edge stiffener is needed]

$b = w$ $b_1 = [b/2] \cdot [1]$

$b_1 = b_2 = b/2$ $b_2 = b_1 - b$

$d_1 = d_2$ $d_1 = d_2 \cdot [R]$

w1 28,581 Edge stiffener needed 0,328 · S 10,284

$I_x = 399t^4 \left[\frac{(b/t) - 0.328}{S} \right]^2 \leq t^4 \left[115 \frac{(b/t)}{S} + 5 \right]$ Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AISI S100, Eq. B4.3]

I_x 249,076 [mm⁴] s 455,500 \rightarrow OK

(Rp) = $I_x/I_d \leq 1$ [AISI S100, Eq. B4.4]

$I_d = (d^3 \sin^2 \theta) / 12$ [AISI S100, Eq. B4-10]

$S = 1.28 \sqrt{E/f}$

E 210,000 [GPa]

f 350,000 [MPa]

S 31,353 []

$w \leq 0,328 \cdot S$ $w \leq 0,328 \cdot S$

$I_x = 0,000$ [no edge stiffener needed] $I_x = \dots$ [edge stiffener is needed]

$b_1 = b$ $b_1 = [b_1/2] \cdot [1]$

$b_1 = b_2 = b/2$ $b_2 = b_1 - b$

$d_1 = d_2$ $d_1 = d_2 \cdot [1]$

b1 28,581 Edge stiffener is needed 0,328 · S 10,284

$I_x = 399t^4 \left[\frac{(b/t) - 0.328}{S} \right]^2 \leq t^4 \left[115 \frac{(b/t)}{S} + 5 \right]$ Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.2(1)]

I_x 249,076 [mm⁴] s 455,500 \rightarrow OK

$I_x/I_d \leq 1$ [AS/NZS 4600] $I_d = (d^3 \sin^2 \theta) / 12$ [AS/NZS 4600, Eq. 2.4.2(10)]

ϕ_x 90,000 [°] \rightarrow I_x 6958,844 [mm⁴]

[R] 27,931 $<$ 1,000 \rightarrow KO \rightarrow [R] 1,000

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Single Lip Edge Stiffener: $140^\circ \leq \theta \leq 40^\circ$

$d1 \leq 0,250$ $0,250 < d1 \leq 0,500$

$0,570 \cdot [I_x/I_d]^2 + 0,430 < 4,000$ $[4,000 - 1,5 \cdot [I_x/I_d]^2 + 0,430 < 4,000$

OK 140° ϕ_x 90,000 [°] $\geq 40^\circ$ OK

n 0,370 $\geq 1/3 ?$ OK \rightarrow n 0,370

[AS/NZS 4600, Table 2.4.2] $d1 \leq w$ 0,466 \rightarrow k 2,918 OK

C-Section Beam Dimension NOTE $b = b_{y1}$

b_{y1} 38,596 [mm]

E 210,000 [GPa] | t 1,452 [mm] | v μ 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(6)]

$f_c = 783,386$ [MPa]

$$\lambda = \sqrt{\frac{r}{f_{cr}}}$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$\lambda = 0,668$

$$r = \sqrt{\frac{I}{A}}$$

$r = 350,000$ [MPa]

$$\rho = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$$

[AS/NZS 4600, Eq. 2.2.1.2(9)]

$\rho = 0,988$

ρ	1,000	→	$\rho_{MINIMUM}$	0,988	[mm]
$\rho_{MINIMUM}$	19,298	[mm]	$\rho_{MAXIMUM}$	19,298	[mm]

AISI S100, Effective Width [mm]

$b_{EFF,MAX1}$ 19,298

$b_{EFF,MAX2}$ 19,298

AS/NZS 4600, Effective Width [mm]

$b_{EFF,MAX1}$ 19,298

$b_{EFF,MAX2}$ 19,298

Web [b₁]

[AISI S100, Section B2.1]

[AS/NZS 4600, Clause 2.2.2]

Boundary condition

Types of stress

Compression

k

4,000

Actual Element

Effective Element, b₁ and Stress, f₁ on Effective Elements

Sifted Elements [AISI S100, Figure B2.1-1]

C-Section Beam Dimension

b_1 112,096 [mm]

E 210,000 [GPa]

ν 0,300

NOTE $w = b_1$

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$$

[A9 S100, Eq. B2.1-4]

$F_c = 127,382$ [MPa]

$$\lambda = \sqrt{\frac{r}{F_{cr}}}$$

[A9 S100, Eq. B2.1-4]

$\lambda = 1,658$

AISI S100, Effective Width [mm]

$b_{EFF,MAX1}$ 29,325

$b_{EFF,MAX2}$ 29,325

AS/NZS 4600, Effective Width [mm]

$b_{EFF,MAX1}$ 29,325

$b_{EFF,MAX2}$ 29,325

Boundary Flange [b₂]

[AISI S100, Figure B4.1]

[AS/NZS 4600, Clause 2.2.2]

D, d = Actual flange dimensions

C-Section Beam Dimension

c_{22} 14,048 [mm]

b_{22} 38,596 [mm]

t 1,452 [mm]

$c_{22} \geq 0,1 b_{22} = w$

$D_{MIN,22}$ 18,000 [mm]

$$S = 1,28 \sqrt{E/t}$$

[AISI S100, Eq. B4.2]

E 210,000 [GPa]

t 350,000 [MPa]

S 31,353 []

$w \leq 0,328 \cdot S$

$l_e = 0,000$ [no edge stiffener needed]

$b = w$

$b_1 = b_2 = w/2$

$d_1 = d_2$

w 1 26,981

$w \leq 0,328 \cdot S$

$l_e = \dots$ [edge stiffener is needed]

$b_1 = 1,0 \cdot [2] \cdot R$

$b_2 = b = b_1$

$d_1 = d_2 = 1 \cdot R$

w 1 26,981

Edge stiffener is needed

0,328 * S 10,284

$$l_e = 399h \sqrt{\frac{w/t}{S} - 0,328} \leq t \sqrt{115 \frac{w/t}{S} + 5}$$

[AISI S100, Eq. B1-8]

l_e 249,076 [mm]

s 455,590 → OK

Adequate moment of inertia of stiffener so that each component element will behave as a stiffened element

$$(R_1) = I_s / I_e \leq 1$$

[AISI S100, Eq. B4-9]

ϕ 90,000 [°]

[R] 27,931 < 1,500 → KO

$$I_s = (d \cdot t \cdot \sin^2 \phi) / 12$$

[AISI S100, Eq. B4-10]

I_s 6956,844 [mm⁴]

[R] 1,000

$$\lambda = \sqrt{\frac{r}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$\lambda = 1,658$

$$\rho = (1 - 0,22/\lambda) \cdot \lambda$$

[AISI S100, Eq. B2.1-4]

$\rho = 0,523$

ρ	0,523	→	$\rho_{MINIMUM}$	0,523	[mm]
$\rho_{MINIMUM}$	29,325	[mm]	$\rho_{MAXIMUM}$	29,325	[mm]

Web [b₁]

[AS/NZS 4600, Clause 2.2.2]

[AS/NZS 4600, Clause 2.2.2]

Boundary condition

Types of stress

Compression

k

4,000

Actual Element

Effective Width [b₁] of Element and Design on Effective Elements

Sifted Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

C-Section Beam Dimension

b_1 112,096 [mm]

E 210,000 [GPa]

ν 0,300

NOTE $b = b_1$

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(6)]

$f_c = 127,382$ [MPa]

$$\lambda = \sqrt{\frac{r}{f_{cr}}}$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$\lambda = 1,658$

$$k = \left(0,328 \sqrt{\frac{w/t}{S}} - \frac{1}{3} \right)$$

[AISI S100, Eq. B4-1]

OK 14012

ϕ 90,000 [°]

α 0,370 > 1/3 ? OK

[AISI S100, Table B4.1]

D > w 0,466 → k 2,918 OK

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4.1]

Simply Lip Edge Stiffener | 140° < θ < 40°

0,250 < D < w < 0,800

3,070 < [R] < 4,030 < 4,000

4,820 < S < D < w < [R] < 4,030 < 4,000

C-Section Beam Dimension

b_{22} 38,596 [mm]

E 210,000 [GPa]

ν 0,300

NOTE $w = b_{22}$

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$$

[AISI S100, Eq. (B2.1-5)]

$F_c = 783,386$ [MPa]

$$\lambda = \sqrt{\frac{r}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$\lambda = 0,668$

ρ	1,000	→	$\rho_{MINIMUM}$	0,988	[mm]
$\rho_{MINIMUM}$	19,298	[mm]	$\rho_{MAXIMUM}$	19,298	[mm]

Boundary Flange [b₂]

[AS/NZS 4600, Figure 2.2.2]

[AS/NZS 4600, Clause 2.2.1]

[AS/NZS 4600, Figure 2.2.2]

C-Section Beam Dimension

c_{22} 14,048 [mm]

b_{22} 38,596 [mm]

t 1,452 [mm]

$c_{22} \geq 0,1 b_{22} = b$

$D_{MIN,22}$ 18,000 [mm]

$$S = 1,28 \sqrt{E/f}$$

[AS/NZS, Eq. 2.2.2(3)]

E 210,000 [GPa]

f 350,000 [MPa]

S 31,353 []

Design of a Photovoltaic Structure, Partial configuration, according to AISI or AS/NZS		Office: ---	Author: JOSE ANTONIO
Code: AISI | AS/NZS	Reference: AISI S100 | AS/NZS 4600 | EN 1993	Date: 05/09/2019	Project: MASTER THESIS
Version: 1,000		Client: COMBRA UNIVERSITY	

Edge Stiffener

$b \leq 0,328 \cdot S$ $b > 0,328 \cdot S$

$I_w = 0,000$ [no edge stiffener needed] $I_w = \dots$ [edge stiffeners needed]

$b_1 = b$ $b_1 = [b_1 \cdot 2] \cdot [I_w]$

$b_2 = b_2 + b \cdot 2$ $b_2 = b_2 - b_1$

$d_1 = d_1$ $d_1 = d_1 \cdot [I_w]$

$b \leq 1$ 26,581 Edge stiffeners needed 0,328 * S 10,284

$I_w = 3900 \cdot \left[\frac{(b/r)^2}{S} - 0,328 \right] \leq I_w^2 \left[115 \cdot \frac{(b/r)}{S} + 5 \right]$ Adequate moment of inertia of stiffener, so that each component element will behave as a fixed element

[AS/NZS 4600, Eq. 2.4.2(1)]

I_w 249,076 [mm⁴] < 455,500 -- OK

$I_s/I_w \leq 1$ [AS/NZS 4600]

$I_s = (d^3 t \sin^2 \theta) / 12$ [AS/NZS 4600, Eq. 2.4.2(119)]

ϕ_s 90,000 [°] -- I_w 6958,344 [mm⁴]

$[I_w/I_s]$ 27,931 < 1,000 -- KO -- $[I_w/I_s]$ 1,000

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Single Lip Edge Stiffener [140° ≤ θ ≤ 40°]

$d/b \leq 0,250$ $0,250 < d/b \leq 0,400$

$0,370 \cdot [I_w/I_s]^{1/4} + 0,430 \leq 4,000$ $[4,820 - 1,5 \cdot [I_w/I_s]^{1/4}] \cdot [I_w/I_s]^{1/4} + 0,430 \leq 4,000$

OK 1,402 > ϕ_s 90,000 [°] > 40° OK

n 0,370 > 1 | 3,7 OK -- n 0,370

[AS/NZS 4600, Table 2.4.2] d/b 0,466 -- k 2,918 OK

C-Section Beam Dimension

b_{12} 38,596 [mm]

E 210,000 [GPa] t 1,452 [mm] v 0,300

$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$ f_{cr} 783,386 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(9)]

Design of a Photovoltaic Structure, Partial configuration, according to AISI or AS/NZS		Office: ---	Author: JOSE ANTONIO
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ρ 1,000 -- ϕ_{12max} 14,048 [mm]

Superior Edge Stiffener [φ₁₂] [AS/NZS 4600, Clause 2.3.1]

Boundary condition Types of stress k

S.S. S.S. Compression 0,425

Free

b b_e

Actual Element **Effective Element and Stress on Effective Elements**

Unaffixed Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

C-Section Beam Dimension

ϕ_{12} 14,048 [mm]

NOTE $b \neq \phi_{12}$

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(9)]

$\lambda = \sqrt{\frac{f}{f_{cr}}}$ $f = 350,000$ [MPa] $\rho = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$

[AS/NZS 4600, Eq. 2.2.1.2(4)] λ 0,637 [AS/NZS 4600, Eq. 2.2.1.2(9)]

ρ 1,000 -- ϕ_{12max} 14,048 [mm]

AISI S100, Effective Width [mm] Compression | ρ or λ AS/NZS 4600, Effective Width [mm]

ϕ_{12max} 14,048 * ϕ_{12max} 14,048

Design of a Photovoltaic Structure, Partial configuration, according to AISI or AS/NZS		Office: ---	Author: JOSE ANTONIO
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Version: 1,000		Client: COMBRA UNIVERSITY	

$\lambda = \sqrt{\frac{f}{f_{cr}}}$ $f = 350,000$ [MPa] $\rho = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$

[AS/NZS 4600, Eq. 2.2.1.2(4)] λ 0,688 [AS/NZS 4600, Eq. 2.2.1.2(9)]

ρ 1,000 -- b_{12max} 38,596 [mm]

b_{12max} 19,298 [mm] b_{12max} 19,298 [mm]

AISI S100, Effective Width [mm] Compression | ρ or λ AS/NZS 4600, Effective Width [mm]

b_{12max} 19,298 * b_{12max} 19,298

b_{12max} 19,298 * b_{12max} 19,298

Superior Edge Stiffener [φ₁₂] [AISI S100, Section B3.1]

Boundary condition Types of stress k

S.S. S.S. Compression 0,425

Free

w b

Actual Element **Effective Element and Stress on Effective Elements**

Unaffixed Element with Uniform Compression [AISI S100, Figure B3.1.1]

C-Section Beam Dimension

ϕ_{12} 14,048 [mm]

NOTE $w \neq \phi_{12}$

E 210,000 [GPa] t 1,452 [mm] v 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{w} \right)^2$ F_{cr} 861,766 [MPa]

[AISI S100, Eq. B2.1.4-1]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $f = 350,000$ [MPa] $\rho = (1 - 0,22/\lambda) \lambda$

[AISI S100, Eq. B2.1.4-1] λ 0,637 [AISI S100, Eq. B2.1.4-1]

Design of a Photovoltaic Structure, Partial configuration, according to AISI or AS/NZS		Office: ---	Author: JOSE ANTONIO
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Version: 1,000		Client: COMBRA UNIVERSITY	

[II] Effective C-Section Beam | Local Buckling

Effective C-Section Beam Widths | AISI S100

Inferior Edge Stiffener	ϕ_{12max}	14,048	[mm]
Inferior Flange	b_{12max}	38,596	[mm]
Web	b_{12max}	59,550	[mm]
Superior Flange	b_{12max}	38,596	[mm]
Superior Edge Stiffener	ϕ_{12max}	14,048	[mm]

Effective C-Section Beam Widths | AS/NZS 4600

Inferior Edge Stiffener	ϕ_{12max}	14,048	[mm]
Inferior Flange	b_{12max}	38,596	[mm]
Web	b_{12max}	59,550	[mm]
Superior Flange	b_{12max}	38,596	[mm]
Superior Edge Stiffener	ϕ_{12max}	14,048	[mm]

Effective C-Section Beam Widths | AISI | AS/NZS 4600

Inferior Edge Stiffener	ϕ_{12}	14,048	[mm]
Inferior Flange	b_{12}	38,596	[mm]
Web	b_{12}	59,550	[mm]
Superior Flange	b_{12}	38,596	[mm]
Superior Edge Stiffener	ϕ_{12}	14,048	[mm]

[III] Effective Cross C-Section Beam | Local Buckling

Effective C-Section Beam Widths

Inferior Edge Stiffener	ϕ_{12}	14,048	[mm]
Inferior Flange	b_{12}	19,298	[mm]
Web	b_{12}	29,325	[mm]
Web	b_{12}	29,325	[mm]
Superior Flange	b_{12}	19,298	[mm]
Superior Edge Stiffener	ϕ_{12}	14,048	[mm]

Office: ---		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Partial configuration, according to AISI or AS/NZS			
Code: AISI | AS/NZS	Reference: AISI S100 | AS/NZS 4600 | EN 1993		
Version: 1,000			

$\phi_c = 90,000 \text{ [N]}$ → $f_c = 100,14,249 \text{ [mm]}$

$[R] = 214,092 < 1,000$ → KO → $[R] = 1,000$

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]
 Single Lip Edge Stiffener [14012.9 + 401]
 $D/w < 0,250$ $0,250 < D/w < 0,500$
 $3,570 \cdot [R]^2 + 0,490 < 4,000$ $[4,820 - (5 \cdot [D/w])^2] \cdot [R]^2 + 0,430 < 4,000$

$n = \left(\frac{0,502 \cdot W/t}{4S} \right) \geq \frac{1}{3}$
 [AISI S100, Eq. B4-11] → OK $n = 1,401$

$\lambda = \sqrt{\frac{f}{F_{cr}}} = 0,384$ [AISI S100, Eq. B2.1-4]

$\rho = (1 - 0,22/\lambda) \cdot \lambda = 0,979$ [AISI S100, Eq. B2.1-4]

$\rho = 1,000$ → $b_{\text{effective}} = 36,596 \text{ [mm]}$

$b_{\text{element,1}} = 18,298 \text{ [mm]}$ $b_{\text{element,2}} = 18,298 \text{ [mm]}$

C-Section Column Dimension **NOTE** $W \neq b_{\text{eff}}$

$b_f = 36,596 \text{ [mm]}$ $E = 210,000 \text{ [GPa]}$ $t = 2,452 \text{ [mm]}$ $v = \mu = 0,300$

$F_{cr} = k \cdot \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$ $F_c = 2377,356 \text{ [MPa]}$ [AISI S100, Eq. (B2.1-5)]

$\lambda = \sqrt{\frac{f}{F_{cr}}} = 0,384$ [AISI S100, Eq. B2.1-4]

$\rho = (1 - 0,22/\lambda) \cdot \lambda = 0,979$ [AISI S100, Eq. B2.1-4]

$\rho = 1,000$ → $b_{\text{effective}} = 36,596 \text{ [mm]}$

$b_{\text{element,1}} = 18,298 \text{ [mm]}$ $b_{\text{element,2}} = 18,298 \text{ [mm]}$

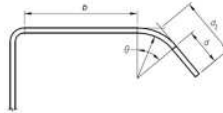
Info: Flange b_f [AS/NZS 4600, Clause 2.2.1]

C-Section Column Dimension **NOTE** $W \neq b_{\text{eff}}$

$b_f = 36,596 \text{ [mm]}$ $E = 210,000 \text{ [GPa]}$ $t = 2,452 \text{ [mm]}$ $v = \mu = 0,300$

$F_{cr} = k \cdot \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$ $F_c = 711,501 \text{ [MPa]}$ [AISI S100, Eq. (B2.1-5)]

$d_{\text{min,1}} = 18,000 \text{ [mm]}$



[AS/NZS 4600, Figure 2.2.2]

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$f_c = 2377,356 \text{ [MPa]}$ [AS/NZS 4600, Eq. 2.2.1,2(6)]

$\lambda = \sqrt{\frac{f}{F_{cr}}} = 0,384$ [AS/NZS 4600, Eq. 2.2.1,2(4)]

$\rho = (1 - 0,22/\lambda) \cdot \lambda = 0,979$ [AS/NZS 4600, Eq. 2.2.1,2(3)]

$\rho = 1,000$ → $b_{\text{effective}} = 36,596 \text{ [mm]}$

$b_{\text{element,1}} = 18,298 \text{ [mm]}$ $b_{\text{element,2}} = 18,298 \text{ [mm]}$

AISI S100, Effective Width [mm] **Comparison $\rho > \rho_c$** **AS/NZS 4600, Effective Width [mm]**

$b_{\text{element,1}} = 18,298$ $b_{\text{element,2}} = 18,298$

$b_{\text{element,1}} = 18,298$ $b_{\text{element,2}} = 18,298$

Web b_w [AISI S100, Section B2.1]

Boundary condition **Types of stress** **k**

S.S., S.S., S.S., S.S. → Compression → 4,000

Actual Element **Effective Element, b_w and Stress, f_c on Effective Elements**

Sifted Elements [AISI S100, Figure B2.1-1]

C-Section Column Dimension **NOTE** $W \neq b_{\text{eff}}$

$b_w = 80,596 \text{ [mm]}$ $E = 210,000 \text{ [GPa]}$ $t = 2,452 \text{ [mm]}$ $v = \mu = 0,300$

$F_{cr} = k \cdot \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$ $F_c = 711,501 \text{ [MPa]}$ [AISI S100, Eq. (B2.1-5)]

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$S = 1,28 \sqrt{E/f^*}$ [AS/NZS 4600, Eq. 2.2(19)]

$E = 210,000 \text{ [GPa]}$ $f^* = 350,000 \text{ [MPa]}$ $S = 31,353 \text{ [mm]}$

$b_{11} \leq 0,328 \cdot S$ $b_{12} \leq 0,328 \cdot S$

$t_w = 0,000$ [no edge stiffener needed] $t_w = \dots$ [edge stiffener needed]

$b_1 = b$ $b_2 = [b/2] \cdot [t_1/t_2]$

$b_1 = b_2 = b/2$ $b_2 = b_1 = b$

$d_w = d_w$ $d_w = d_w \cdot [t_1/t_2]$

$b_{11} = 14,925$ Edge stiffener needed $0,328 \cdot S = 10,284$

$I_w = 399t^4 \left[\left(\frac{b/t}{S} - 0,328 \right)^2 \right] \leq t^4 \left[11 \left(\frac{b/t}{S} + 5 \right) \right]$ [AS/NZS 4600, Eq. 2.2(21)]

$I_w = 46,278 \text{ [mm}^4]$ $S = 2159,263$ → OK

$I_s/I_w \leq 1$ [AS/NZS 4600] $I_s = (d^3 \sin^2 \theta) / 12$ [AS/NZS 4600, Eq. 2.2(110)]

$\phi_c = 90,000 \text{ [N]}$ → $f_c = 100,14,249 \text{ [mm]}$

$[R] = 214,092 < 1,000$ → KO → $[R] = 1,000$

$n = \left(\frac{0,582 \cdot (b/t)}{4S} \right) \geq \frac{1}{3}$ [AS/NZS 4600, Eq. 2.2(22)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 24.2]
 Single Lip Edge Stiffener [14012.9 + 401]
 $d/w < 0,250$ $0,250 < d/w < 0,500$
 $3,570 \cdot [R]^2 + 0,430 < 4,000$ $[4,820 - (5 \cdot [d/w])^2] \cdot [R]^2 + 0,430 < 4,000$

OK $n = 1,401$

$\lambda = \sqrt{\frac{f}{F_{cr}}} = 0,384$ [AISI S100, Eq. B2.1-4]

$\rho = (1 - 0,22/\lambda) \cdot \lambda = 0,979$ [AISI S100, Eq. B2.1-4]

$\rho = 0,979$ → $b_{\text{effective}} = 78,378 \text{ [mm]}$

$b_{\text{element,1}} = 39,189 \text{ [mm]}$ $b_{\text{element,2}} = 39,189 \text{ [mm]}$

Web b_w [AS/NZS 4600, Clause 2.2.1]

Boundary condition **Types of stress** **k**

S.S., S.S., S.S., S.S. → Compression → 4,000

Actual Element **Effective Width b_w of Element and Design on Effective Elements** **Stress f_c**

Sifted Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

C-Section Column Dimension **NOTE** $b \neq b_{\text{eff}}$

$b_w = 80,596 \text{ [mm]}$ $E = 210,000 \text{ [GPa]}$ $t = 2,452 \text{ [mm]}$ $v = \mu = 0,300$

$F_{cr} = k \cdot \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{b} \right)^2$ $F_c = 711,501 \text{ [MPa]}$ [AS/NZS 4600, Eq. 2.2.1,2(6)]

$\lambda = \sqrt{\frac{f}{F_{cr}}} = 0,384$ [AS/NZS 4600, Eq. 2.2.1,2(4)]

$\rho = (1 - 0,22/\lambda) \cdot \lambda = 0,979$ [AS/NZS 4600, Eq. 2.2.1,2(3)]

$\rho = 0,979$ → $b_{\text{effective}} = 78,378 \text{ [mm]}$

$b_{\text{element,1}} = 39,189 \text{ [mm]}$ $b_{\text{element,2}} = 39,189 \text{ [mm]}$

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$\lambda = \sqrt{\frac{f}{F_{cr}}} = 0,384$ [AISI S100, Eq. B2.1-4]

$\rho = (1 - 0,22/\lambda) \cdot \lambda = 0,979$ [AISI S100, Eq. B2.1-4]

$\rho = 0,979$ → $b_{\text{effective}} = 78,378 \text{ [mm]}$

$b_{\text{element,1}} = 39,189 \text{ [mm]}$ $b_{\text{element,2}} = 39,189 \text{ [mm]}$

Web b_w [AS/NZS 4600, Clause 2.2.1]

Boundary condition **Types of stress** **k**

S.S., S.S., S.S., S.S. → Compression → 4,000

Actual Element **Effective Width b_w of Element and Design on Effective Elements** **Stress f_c**

Sifted Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

C-Section Column Dimension **NOTE** $b \neq b_{\text{eff}}$

$b_w = 80,596 \text{ [mm]}$ $E = 210,000 \text{ [GPa]}$ $t = 2,452 \text{ [mm]}$ $v = \mu = 0,300$

$F_{cr} = k \cdot \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{b} \right)^2$ $F_c = 711,501 \text{ [MPa]}$ [AS/NZS 4600, Eq. 2.2.1,2(6)]

$\lambda = \sqrt{\frac{f}{F_{cr}}} = 0,384$ [AS/NZS 4600, Eq. 2.2.1,2(4)]

$\rho = (1 - 0,22/\lambda) \cdot \lambda = 0,979$ [AS/NZS 4600, Eq. 2.2.1,2(3)]

$\rho = 0,979$ → $b_{\text{effective}} = 78,378 \text{ [mm]}$

$b_{\text{element,1}} = 39,189 \text{ [mm]}$ $b_{\text{element,2}} = 39,189 \text{ [mm]}$

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AISI S100, Effective Width [mm]		Comparison $w \leq w_{eff}$		AS/NZS 4600, Effective Width [mm]	
$b_{2,avail,1}$	39,189	=		$b_{2,avail,1}$	39,189
$b_{2,avail,2}$	39,189	=		$b_{2,avail,2}$	39,189

Superior Flange $b_{2,fl}$ [AISI S100, Section B4]

C-Section Column Dimension

r_{y2}	13,048	[mm]
$b_{2,c}$	36,596	[mm]
t	2,452	[mm]

$C_{90} = d \leq b_{2,c} = w$

$d_{avail,12}$ 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	[]

$w \leq 0.328 \cdot S$		$w > 0.328 \cdot S$	
$I_x = 0.000$	[no edge stiffener needed]	$I_x = \dots$	[edge stiffener is needed]
$d = w$		$b_1 = [3/2] \cdot [R]$	
$b_1 = b_2 = w/2$		$b_2 = b - b_1$	
$d_1 = d_2$		$d_2 = d_1 \cdot [R]$	

w_{eff} 14,925 Edge stiffener is needed 0,328 · S 10,284

$I_x = 390t^4 \left[\frac{w/t}{S} - 0.328 \right]^2 \leq t^4 \left[115 \frac{w/t}{S} + 5 \right]$ Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element [AISI S100, Eq. B4-8]

I_x 46,778 [mm⁴] \leq 2159,563 \rightarrow OK

$(R_f) = I_x/I_d \leq 1$ [AISI S100, Eq. B4-10] $I_d = (d^3 \sin^2 \theta)/12$ [AISI S100, Eq. B4-10]

ϕ_x 90,000 [°] \rightarrow I_x 10014,249 [mm⁴]

$[R]$ 214,692 \leq 1,000 \rightarrow KO \rightarrow $[R]$ 1,000

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$b \leq 0.328 \cdot S$		$b > 0.328 \cdot S$	
$I_x = 0.000$	[no edge stiffener needed]	$I_x = \dots$	[edge stiffener is needed]
$d = b$		$b_1 = [3/2] \cdot [R]$	
$b_1 = b_2 = b/2$		$b_2 = b - b_1$	
$d_1 = d_2$		$d_2 = d_1 \cdot [R]$	

b_{eff} 14,925 Edge stiffener is needed 0,328 · S 10,284

$I_x = 390t^4 \left[\frac{b/t}{S} - 0.328 \right]^2 \leq t^4 \left[115 \frac{b/t}{S} + 5 \right]$ Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element [AS/NZS 4600, Eq. 2.4.20 (1)]

I_x 46,778 [mm⁴] \leq 2159,563 \rightarrow OK

$I_x/I_d \leq 1$ [AS/NZS 4600] $I_d = (d^3 \sin^2 \theta)/12$ [AS/NZS 4600, Eq. 2.4.20 (1)]

ϕ_x 90,000 [°] \rightarrow I_x 10014,249 [mm⁴]

$[I_x/I_d]$ 214,692 \leq 1,000 \rightarrow KO \rightarrow $[I_x/I_d]$ 1,000

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

$N = \frac{0.582 - (b/t)}{4S} \geq \frac{1}{3}$ Simple Lip Edge Stiffener [140° ≤ θ ≤ 40°]

$d/b \leq 0.250$ $0.250 < d/b \leq 0.800$

$3.570 \cdot [R]^{1/4} + 0.430 \leq 4.000$ $[4.820 - (5 \cdot d/b)]^{1/4} + 0.430 \leq 4.000$ $[4.820 - (5 \cdot d/b)]^{1/4} + 0.430 \leq 4.000$

OK 140° \geq ϕ_x 90,000 [°] \geq 40° OK

$n = 0.463 \geq 1/3.7$ OK \rightarrow $n = 0.463$

[AS/NZS 4600, Table 2.4.2] $d/b = 0.492 \rightarrow k = 2.791$ OK

C-Section Column Dimension

$b_{2,c}$ 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} 2377,356 [MPa]

NOTE $w \leq b_{2,c}$

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Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140° ≤ θ ≤ 40°]

$d/b \leq 0.250$ $0.250 < d/b \leq 0.800$

$3.570 \cdot [R]^{1/4} + 0.430 \leq 4.000$ $[4.820 - (5 \cdot d/b)]^{1/4} + 0.430 \leq 4.000$

OK 140° \geq ϕ_x 90,000 [°] \geq 40° OK

$n = 0.463 \geq 1/3.7$ OK \rightarrow $n = 0.463$

[AISI S100, Table B4-1] $d/b = 0.492 \rightarrow k = 2.791$ OK

C-Section Column Dimension

NOTE $w \leq b_{2,c}$

E 210,000 [GPa] t 2,452 [mm] v 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{w} \right)^2$ F_{cr} 2377,356 [MPa]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $f = f_c$ 350,000 [MPa] $\rho = (1 - 0.22/\lambda) \cdot \lambda$ [AISI S100, Eq. B2.1-4]

$\rho = 1,000 \rightarrow b_{2,avail}$ 36,596 [mm]

$b_{2,avail,1}$ 18,298 [mm] $b_{2,avail,2}$ 18,298 [mm]

Superior Flange $b_{2,fl}$ [AS/NZS 4600, Clause 2.4]

C-Section Column Dimension

r_{y2}	13,048	[mm]
$b_{2,c}$	36,596	[mm]
t	2,452	[mm]

$C_{90} = d \leq b_{2,c} = w$

$d_{avail,12}$ 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	[]

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$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $f = f_c$ 350,000 [MPa] $\rho = \left(\frac{1 - 0.22}{\lambda} \right) \cdot \lambda \leq 1.0$ [AS/NZS 4600, Eq. 2.4.2(13)]

$\rho = 1,000 \rightarrow b_{2,avail}$ 36,596 [mm]

$b_{2,avail,1}$ 18,298 [mm] $b_{2,avail,2}$ 18,298 [mm]

AISI S100, Effective Width [mm] Comparison $w \leq w_{eff}$ AS/NZS 4600, Effective Width [mm]

$b_{2,avail,1}$ 18,298 $b_{2,avail,2}$ 18,298

Superior Edge Stiffener $b_{2,fl}$ [AISI S100, Section B3.1]

Boundary condition: S.S., S.S., Free

Type of stress: Compression

$k = 0.425$

Stress f

Actual Element Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1-1]

C-Section Column Dimension

NOTE $w \leq b_{2,c}$

r_{y2} 13,048 [mm]

E 210,000 [GPa] t 2,452 [mm] v 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{w} \right)^2$ F_{cr} 2848,845 [MPa]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $f = f_c$ 350,000 [MPa] $\rho = (1 - 0.22/\lambda) \cdot \lambda$ [AISI S100, Eq. B2.1-4]

$\lambda = 0.351$

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$p = 1,200$ [mm] $r_{12,14,16,18} = 13,048$ [mm]

Superior Edge Stiffener [c₂₁] | AS/NZS 4600, Clause 2.2.1

Boundary condition	Types of stress	k
	Compression	0,425

Unstiffened Element with Uniform Compression | AS/NZS 4600, Figure 2.2.1

C-Section Column Dimension

NOTE $b = e_{22}$

$E = 210,000$ [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(6)] $f_{cr} = 2848,646$ [MPa]

$\lambda = \sqrt{\frac{f_{cr}}{f_y}}$ $f_y = 350,000$ [MPa] $\rho = \frac{(0,22)}{\lambda} \leq 1,0$

[AS/NZS 4600, Eq. 2.2.1.2(4)] $\lambda = 0,591$ [AS/NZS 4600, Eq. 2.2.1.2(5)]

$p = 1,200$ [mm] $r_{12,14,16,18} = 13,048$ [mm]

AISI S100, Effective Width [mm]	Compression $\lambda < \rho$	AS/NZS 4600, Effective Width [mm]	
$e_{21,14,16,18}$	13,048	$e_{21,14,16,18}$	13,048

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Effective C-Section Column | Compression Force | AISI S100 | AS/NZS 4600

$A_{eff} = 493,023$ [mm²] $r_{y,y} = \sqrt{I_{yy} / A_{eff}} = 0,500$ [mm] $r_{z,z} = \sqrt{I_{zz} / A_{eff}} = 0,138$ [mm]

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[10] Effective C-Section Column | Local Buckling

Effective C-Section Column Widths | AISI S100

Inflector Edge Stiffener	$e_{21,14,16,18}$	13,048	[mm]
Inflector Flange	$b_{21,14,16,18}$	36,596	[mm]
Web	$b_{2,14,16,18}$	78,378	[mm]
Superior Flange	$b_{12,14,16,18}$	36,596	[mm]
Superior Edge Stiffener	$e_{12,14,16,18}$	13,048	[mm]

Effective C-Section Column Widths | AS/NZS 4600

Inflector Edge Stiffener	$e_{21,14,16,18}$	13,048	[mm]
Inflector Flange	$b_{21,14,16,18}$	36,596	[mm]
Web	$b_{2,14,16,18}$	78,378	[mm]
Superior Flange	$b_{12,14,16,18}$	36,596	[mm]
Superior Edge Stiffener	$e_{12,14,16,18}$	13,048	[mm]

Effective C-Section Column Widths | AISI S100 | AS/NZS 4600

Inflector Edge Stiffener	$e_{21,14}$	13,048	[mm]
Inflector Flange	$b_{21,14}$	36,596	[mm]
Web	$b_{2,14}$	78,378	[mm]
Superior Flange	$b_{12,14}$	36,596	[mm]
Superior Edge Stiffener	$e_{12,14}$	13,048	[mm]

[11] Effective Cross C-Section Column | Local Buckling

Effective C-Section Column Widths

Inflector Edge Stiffener	$e_{21,14}$	13,048	[mm]
Inflector Flange	$b_{21,14,16,18}$	18,298	[mm]
Web	$b_{2,14,16,18}$	39,189	[mm]
Superior Flange	$b_{12,14,16,18}$	18,298	[mm]
Superior Edge Stiffener	$e_{12,14}$	13,048	[mm]

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[14] C-Section Stud

C-Section Stud Dimension	
e_{21}	6,848 [mm]
b_{21}	32,996 [mm]
b_w	42,996 [mm]
b_{12}	32,996 [mm]
e_{12}	6,848 [mm]
t	1,452 [mm]

[11] Effective Widths for Strength Determination | Local Buckling

Effective C-Section | Width Case

Boundary condition		Types of stress	k
		Compression	0,425

Unstiffened Element with Uniform Compression | AISI S100, Figure B3.1.1

C-Section Size Dimension NOTE $w = c_{y1}$

$c_{y1} = 6,048$ [mm]

$E = 210,000$ [GPa] | $t = 1,452$ [mm] | $v = \mu$ | $0,300$

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w}\right)^2$$

$F_{cr} = 4649,380$ [MPa] | [AISI S100, Eq. (B2.1-4)]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ | $f = f_y = 350,000$ [MPa] | $\rho = (1 - 0,22/\lambda) \lambda$ | [AISI S100, Eq. B2.1-4]

$\lambda = 0,274$

$\rho = 1,000$ | $c_{y1,eff} = 6,048$ [mm]

Inflator Edge Stiffener $[c_{y1}]$ | [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k
S.S. | S.S. | Free	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 Size Dimension NOTE $b = c_{y1}$

$c_{y1} = 6,048$ [mm]

$E = 210,000$ [GPa] | $t = 1,452$ [mm] | $v = \mu$ | $0,300$

$$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)}\right) \left(\frac{t}{b}\right)^2$$

$f_{cr} = 4649,380$ [MPa] | [AS/NZS 4600, Eq. 2.2.1(5)]

$\phi_x = 90,000$ [°] | \rightarrow | $I_x = 4000,720$ [mm⁴]

[R] | $42,994 < 1,000$ | \rightarrow | KO | \rightarrow | [R] | $1,000$

Determination of Plate Buckling Coefficient, k | [AISI S100, Table B4.1]

Single Lip Edge Stiffener | $140^\circ \leq \theta \leq 40^\circ$

$D1 = w \leq 0,250$ | $0,250 < D1 \leq w \leq 0,900$

$0,970 \leq [R]^* \leq 0,400 \leq 4,000$ | $[4,000 - 1,5 \cdot [R]^*] \leq [R]^* \leq 0,400 \leq 4,000$

OK | 140° | $\phi_x = 90,000$ [°] | $\geq 40^\circ$ | OK

$n = 0,906$ | $\geq 1,13 ?$ | OK | \rightarrow | $n = 0,406$

[AISI S100, Table B4.1] | $D1 = w = 0,312$ | \rightarrow | $k = 3,692$ | OK

C-Section Size Dimension NOTE $w = b_{y1}$

$b_{y1} = 32,096$ [mm]

$E = 210,000$ [GPa] | $t = 1,452$ [mm] | $v = \mu$ | $0,300$

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w}\right)^2$$

$F_{cr} = 1434,201$ [MPa] | [AISI S100, Eq. (B2.1-4)]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ | $f = f_y = 350,000$ [MPa] | $\rho = (1 - 0,22/\lambda) \lambda$ | [AISI S100, Eq. B2.1-4]

$\lambda = 0,494$

$\rho = 1,000$ | $b_{y1,eff} = 32,096$ [mm]

$b_{y1,actual} = 16,048$ [mm] | $b_{y1,eff,2} = 16,048$ [mm]

Inflator Flange $[b_{y1}]$ | [AS/NZS 4600, Clause 2.4]

C-Section Size Dimension

$c_{y1} = 6,048$ [mm]

$b_{y1} = 32,096$ [mm]

$t = 1,452$ [mm]

$c_{y1} = d | b_{y1} = b$

$d_{min,fl} = 10,000$ [mm]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ | $f = f_y = 350,000$ [MPa] | $\rho = \left(\frac{1 - 0,22}{\lambda}\right) \lambda \leq 1,0$ | [AS/NZS 4600, Eq. 2.2.1(4)]

$\lambda = 0,274$

$\rho = 1,000$ | $c_{y1,eff} = 6,048$ [mm]

AISI S100, Effective Width [mm] | **Compression $[w = c_{y1}]$** | **AS/NZS 4600, Effective Width [mm]**

$c_{y1,actual} = 6,048$ | $c_{y1,eff} = 6,048$

Inflator Flange $[b_{y1}]$ | [AISI S100, Sect. B4]

C-Section Size Dimension

$b_{y1} = 6,048$ [mm]

$b_{y1} = 32,096$ [mm]

$t = 1,452$ [mm]

$c_{y1} = d | b_{y1} = w$

$d_{min,fl} = 10,000$ [mm]

$S = 1,28 \sqrt{E/f}$ | [AISI S100, Eq. B4.7]

$E = 210,000$ [GPa] | $f = 350,000$ [MPa] | $S = 31,353$ []

$w \leq 0,328 \cdot S$ | $w \leq 0,328 \cdot S$

$I_x = 0,000$ [no edge stiffener needed] | $I_x = \dots$ [edge stiffener is needed]

$b_1 = b$ | $b_1 = [b/2] \cdot [1/1]$

$b_2 = b_1 - b/2$ | $b_2 = b_1 - b/2$

$d_1 = d_w$ | $d_1 = d_w \cdot [1/1]$

$w \leq 22,105$ | Edge stiffener needed | $0,328 \cdot S = 10,284$

$I_x = 399t^4 \left[\frac{(b/t) - 0,328}{S}\right]^2 \leq t^4 \left[115 \frac{(b/t)}{S} + 5\right]$ | Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element | [AISI S100, Eq. B4-3]

$I_x = 95,042$ [mm⁴] | $s = 382,607$ | \rightarrow | OK

$(R)_f = I_x/I_d \leq 1$ | [AISI S100, Eq. B4.9]

$I_s = (d^3 t \sin^2 \theta)/12$ | [AISI S100, Eq. B4-10]

$S = 1,28 \sqrt{E/f}$ | [AS/NZS 4600, Eq. 2.4(3)]

$E = 210,000$ [GPa] | $f = 350,000$ [MPa] | $S = 31,353$ []

$w \leq 0,328 \cdot S$ | $w \leq 0,328 \cdot S$

$I_x = 0,000$ [no edge stiffener needed] | $I_x = \dots$ [edge stiffener is needed]

$b_1 = b$ | $b_1 = [b/2] \cdot [1/1]$

$b_2 = b_1 - b/2$ | $b_2 = b_1 - b/2$

$d_1 = d_w$ | $d_1 = d_w \cdot [1/1]$

$w \leq 22,105$ | Edge stiffener needed | $0,328 \cdot S = 10,284$

$I_x = 399t^4 \left[\frac{(b/t) - 0,328}{S}\right]^2 \leq t^4 \left[115 \frac{(b/t)}{S} + 5\right]$ | Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element | [AS/NZS 4600, Eq. 2.4(2)(1)]

$I_x = 95,042$ [mm⁴] | $s = 382,607$ | \rightarrow | OK

$I_x/I_d \leq 1$ | [AS/NZS 4600]

$I_s = (d^3 t \sin^2 \theta)/12$ | [AS/NZS 4600, Eq. 2.4(10)]

$\phi_x = 90,000$ [°] | \rightarrow | $I_x = 4000,720$ [mm⁴]

[1/1] | $42,994 < 1,000$ | \rightarrow | KO | \rightarrow | [1/1] | $1,000$

Determination of Plate Buckling Coefficient, k | [AS/NZS 4600, Table 2.4.2]

Single Lip Edge Stiffener | $140^\circ \leq \theta \leq 40^\circ$

$d1 = b \leq 0,250$ | $0,250 < d1 \leq b \leq 0,900$

$3,510 \leq [1/1] \leq 0,400 \leq 4,000$ | $[4,000 - 1,5 \cdot [1/1]] \leq [1/1] \leq 0,400 \leq 4,000$

OK | 140° | $\phi_x = 90,000$ [°] | $\geq 40^\circ$ | OK

$n = 0,906$ | $\geq 1,13 ?$ | OK | \rightarrow | $n = 0,406$

[AS/NZS 4600, Table 2.4.2] | $d1 = b = 0,312$ | \rightarrow | $k = 3,692$ | OK

C-Section Size Dimension NOTE $b = b_{y1}$

$b_{y1} = 32,096$ [mm]

$E = 210,000$ [GPa] | $t = 1,452$ [mm] | $v = \mu$ | $0,300$

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(6)]

$f_c = 1434,201 \text{ [MPa]}$

$\lambda = \sqrt{\frac{f'}{f_{cr}}}$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

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Design of a Photovoltaic Structure, Partial configuration, according to AISI or AS/NZS			
Code: A/S AISI/AS/NZS	Reference: AISI S100 AS/NZS 4600 EN 1993		
Version: 1,000			

$b \leq 0,328 \cdot S$ $b \leq 0,328 \cdot S$

$I_w = 0,000$ [no edge stiffener needed] $I_w = \dots$ [edge stiffener needed]

$b_1 = b$ $b_1 = [b_1 \cdot 2] \cdot [I_w]$

$b_2 = b_2 + b \cdot 2$ $b_2 = b_2 - b_1$

$d_1 = d_1$ $d_1 = d_1 \cdot [I_w]$

$b \leq 1$ 22,065 Edge stiffeners needed 0,328 * S 10,284

$I_w = 3900 \cdot \left[\frac{(b/r)^2}{S} - 0,328 \right]^2 \leq I_w^2 \left[115 \cdot \frac{(b/r)^2}{S} + 5 \right]$ Adequate moment of inertia of stiffener, so that each component element will behave as a stiff element

[AS/NZS 4600, Eq. 2.4.2(1)]

I_w 95,042 [mm⁴] < 382,007 -- OK

$I_s/I_w \leq 1$ $I_b = (d^3 \sin^2 \theta) / 12$

[AS/NZS 4600] [AS/NZS 4600, Eq. 2.4.2(119)]

ϕ_1 90,000 [°] -- I_w 4009,220 [mm⁴]

$[I_w/I_w]$ 42,094 < 1,000 -- KO -- $[I_w/I_w]$ 1,000

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Single Lip Edge Stiffener [140° ≤ θ ≤ 40°]

$d/b \leq 0,250$ $0,250 < d/b \leq 0,800$

$3,970 \cdot [I_w/I_w]^{1/4} + 0,430 \leq 4,000$ $[4,820 - 1,5 \cdot d/b] \cdot [I_w/I_w]^{1/4} + 0,430 \leq 4,000$

OK 1,40° > ϕ_1 90,000 [°] > 40° OK

n 0,406 > 1/3,7 OK -- n 0,406

[AS/NZS 4600, Table 2.4.2] d/b 0,312 -- k 3,992 OK

C-Section Slit Dimension **NOTE** $b = b_{eff}$

b_{sl} 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} 1434,201 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(9)]

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Version: 1,000			

ρ 1,000 -- $\rho_{1,MAX}$ 6,048 [mm]

Superior Edge Stiffener [ρ_{sl}] [AS/NZS 4600, Clause 2.3.1]

Boundary condition Types of stress k

S.S. S.S. S.S. Free Compression 0,425

b Stress f

Actual Element Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

C-Section Slit Dimension **NOTE** $b = b_{eff}$

ρ_{sl} 6,048 [mm]

E 210,000 [GPa] t 1,452 [mm] v 0,300

$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$ f_{cr} 4649,380 [MPa]

[AS/NZS 4600, Eq. 2.2.1.2(9)]

$\lambda = \left(\sqrt{\frac{f}{f_{cr}}} \right)$ $\rho = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$

[AS/NZS 4600, Eq. 2.2.1.2(4)] λ 0,274 [AS/NZS 4600, Eq. 2.2.1.2(9)]

ρ 1,000 -- $\rho_{1,MAX}$ 6,048 [mm]

AISI S100, Effective Width [mm] Compression [ρ or λ] AS/NZS 4600, Effective Width [mm]

$\rho_{1,MAX}$ 6,048 - $\rho_{1,MAX}$ 6,048

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Version: 1,000			

$\lambda = \left(\sqrt{\frac{f}{f_{cr}}} \right)$ $\rho = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$

[AS/NZS 4600, Eq. 2.2.1.2(4)] λ 0,274 [AS/NZS 4600, Eq. 2.2.1.2(9)]

ρ 1,000 -- $\rho_{1,MAX}$ 32,096 [mm]

$\rho_{1,MAX}$ 16,048 [mm] $\rho_{1,MAX}$ 16,048 [mm]

AISI S100, Effective Width [mm] Compression [ρ or λ] AS/NZS 4600, Effective Width [mm]

$\rho_{1,MAX}$ 16,048 - $\rho_{1,MAX}$ 16,048

$\rho_{1,MAX}$ 16,048 - $\rho_{1,MAX}$ 16,048

Superior Edge Stiffener [ρ_{sl}] [AISI S100, Section B3.1]

Boundary condition Types of stress k

S.S. S.S. S.S. Free Compression 0,425

W Stress f

Actual Element Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1.4]

C-Section Slit Dimension **NOTE** $W = b_{eff}$

ρ_{sl} 6,048 [mm]

E 210,000 [GPa] t 1,452 [mm] v 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{W} \right)^2$ F_{cr} 4649,380 [MPa]

[AISI S100, Eq. B2.1.4-1]

$\lambda = \left(\sqrt{\frac{f}{F_{cr}}} \right)$ $\rho = (1 - 0,22/\lambda) \lambda$

[AISI S100, Eq. B2.1.4-1] λ 0,274 [AISI S100, Eq. B2.1.4-1]

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Version: 1,000			

[#] Effective C-Section Slit Local Buckling

Effective C-Section Slit Widths [AISI S100]

Inferior Edge Stiffener	$\rho_{1,MAX}$	6,048	[mm]
Inferior Flange	$\rho_{1,MAX}$	32,096	[mm]
Web	$\rho_{1,MAX}$	42,096	[mm]
Superior Flange	$\rho_{1,MAX}$	32,096	[mm]
Superior Edge Stiffener	$\rho_{1,MAX}$	6,048	[mm]

Effective C-Section Slit Widths [AS/NZS 4600]

Inferior Edge Stiffener	$\rho_{1,MAX}$	6,048	[mm]
Inferior Flange	$\rho_{1,MAX}$	32,096	[mm]
Web	$\rho_{1,MAX}$	42,096	[mm]
Superior Flange	$\rho_{1,MAX}$	32,096	[mm]
Superior Edge Stiffener	$\rho_{1,MAX}$	6,048	[mm]

Effective C-Section Slit Widths [AISI S100 | AS/NZS 4600]

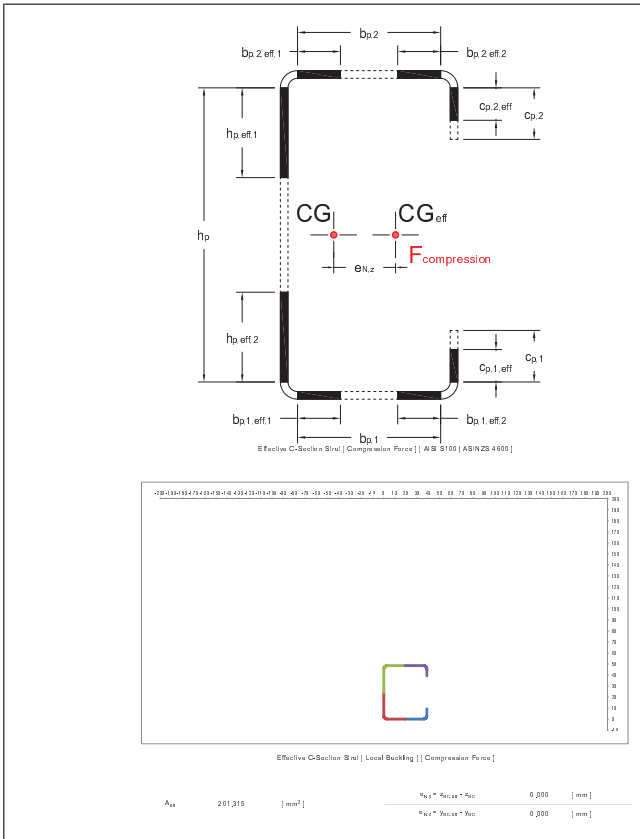
Inferior Edge Stiffener	$\rho_{1,MAX}$	6,048	[mm]
Inferior Flange	$\rho_{1,MAX}$	16,048	[mm]
Web	$\rho_{1,MAX}$	21,048	[mm]
Superior Flange	$\rho_{1,MAX}$	16,048	[mm]
Superior Edge Stiffener	$\rho_{1,MAX}$	6,048	[mm]

[#] Effective Cross C-Section Slit Local Buckling

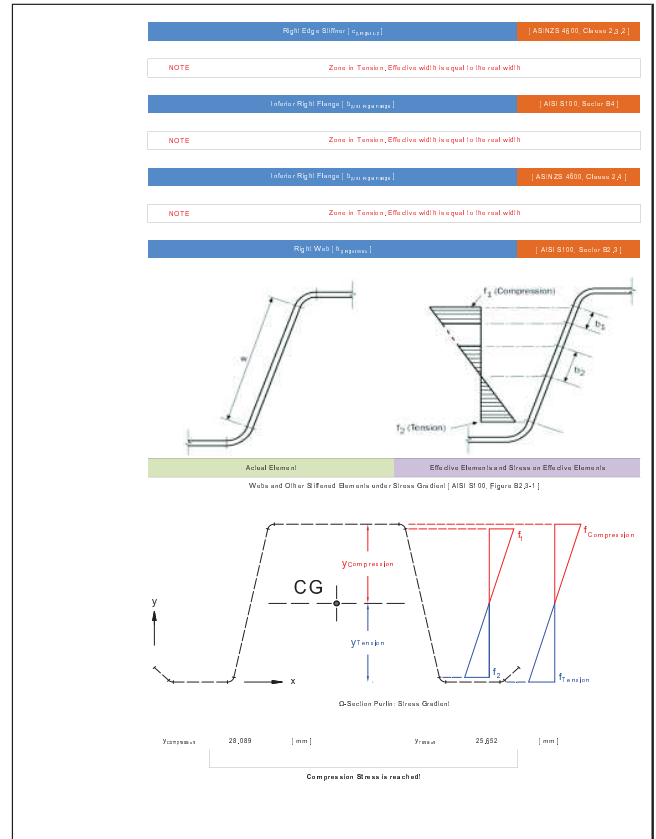
Effective C-Section Slit Widths

Inferior Edge Stiffener	$\rho_{1,MAX}$	6,048	[mm]
Inferior Flange	$\rho_{1,MAX}$	16,048	[mm]
Web	$\rho_{1,MAX}$	21,048	[mm]
Superior Flange	$\rho_{1,MAX}$	16,048	[mm]
Superior Edge Stiffener	$\rho_{1,MAX}$	6,048	[mm]

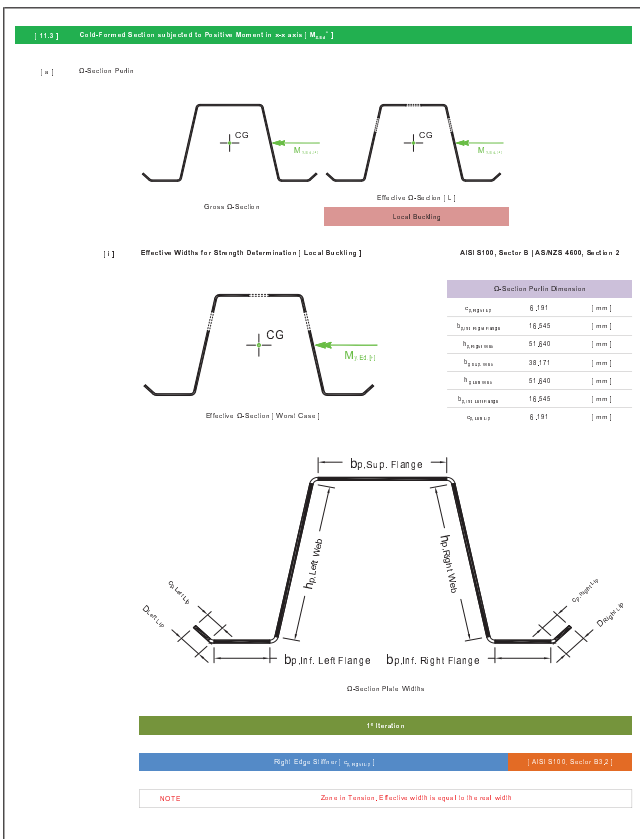
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Version:	1,000		



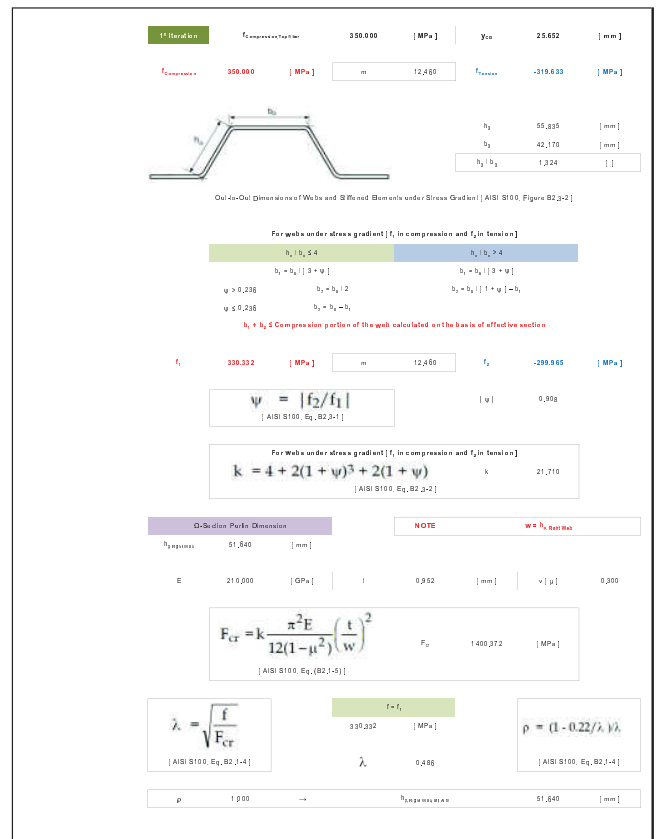
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Design of a Photovoltaic Structure, Partial configuration, according to AISI or AS/NZS			
Code:	AISI AS/NZS	Reference:	AISI S100 AS/NZS 4600 EN 1993
Version:	1,000		

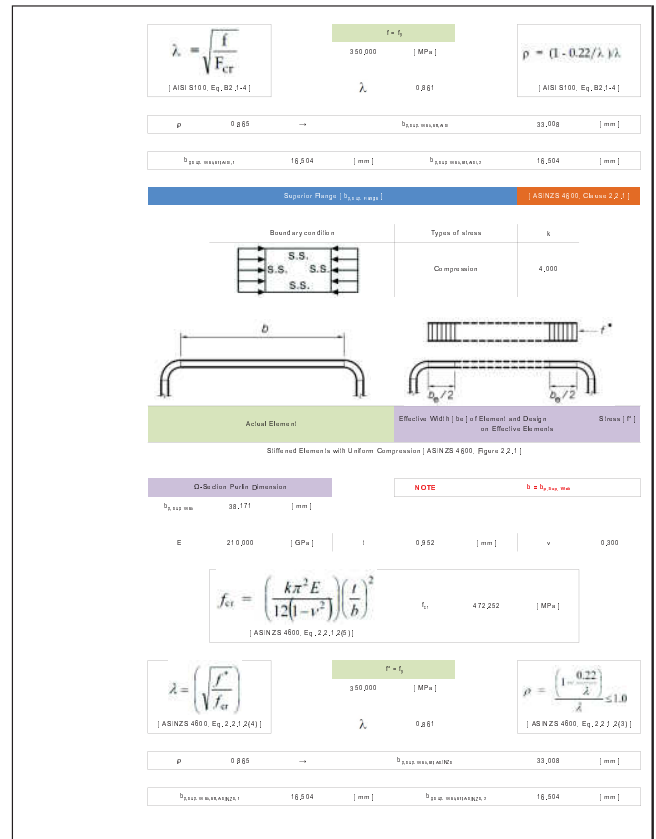
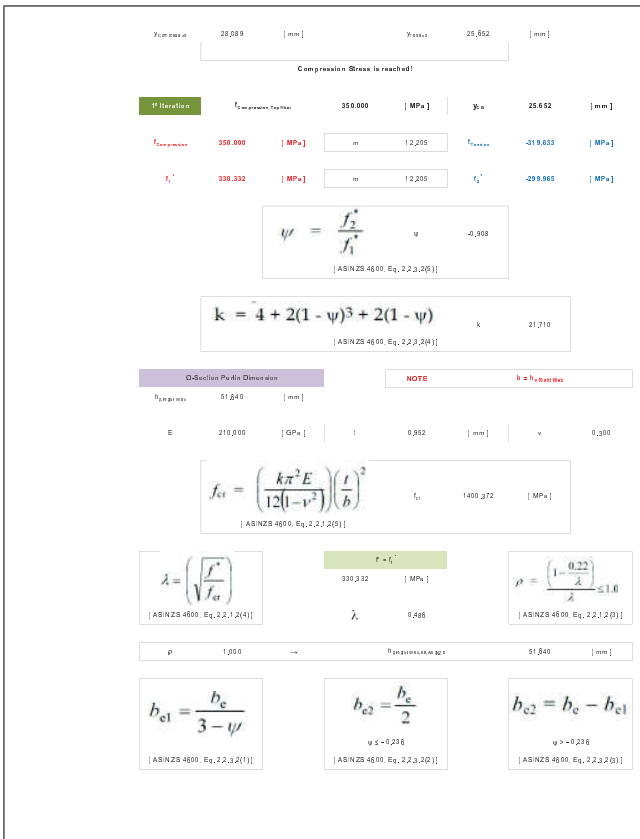
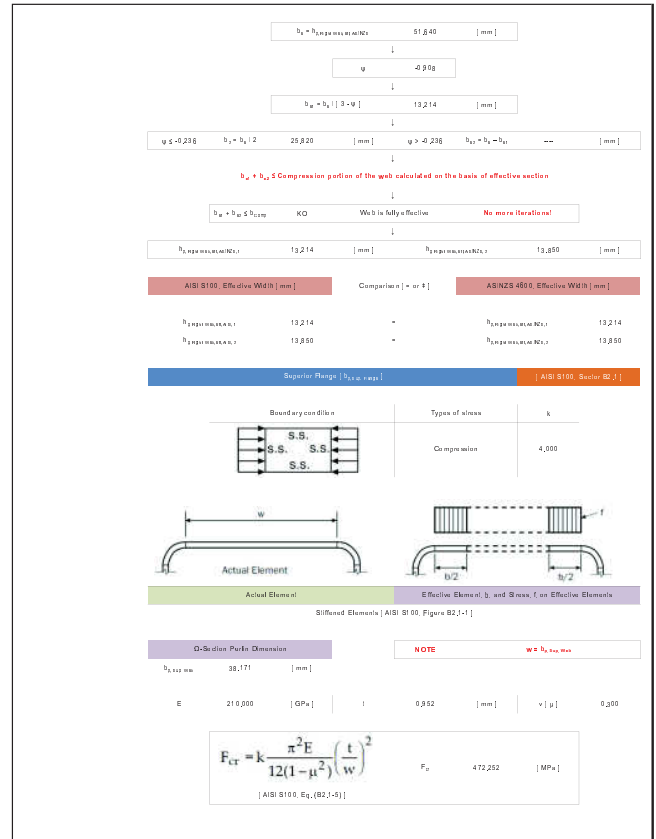
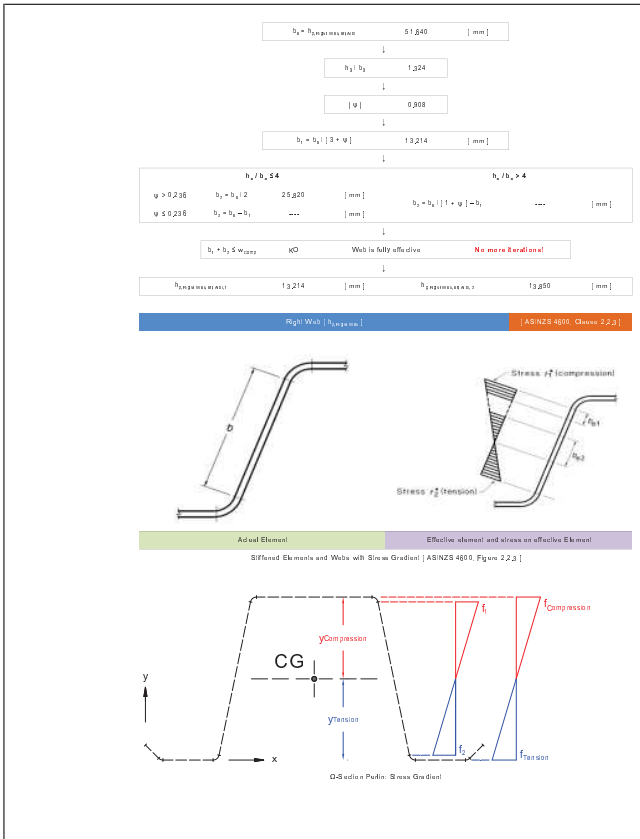


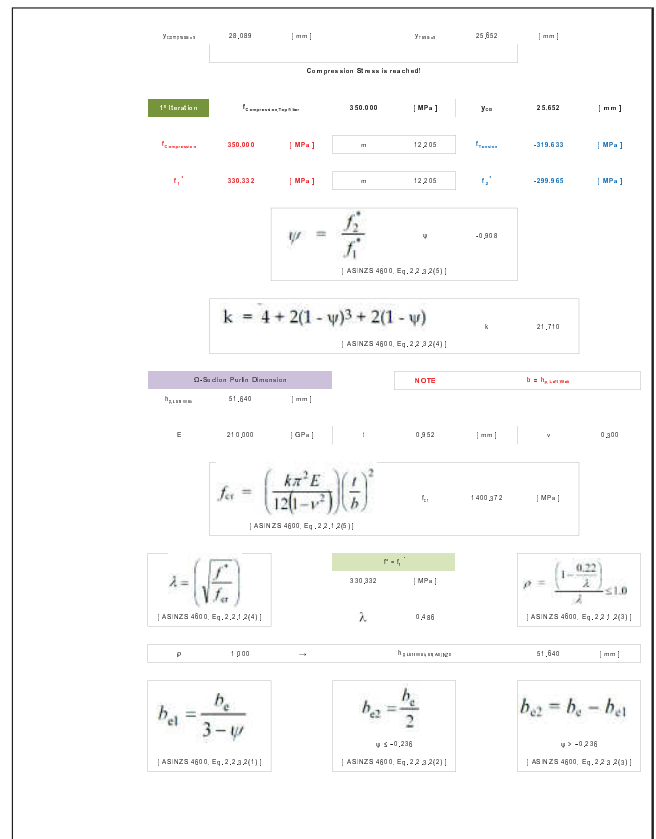
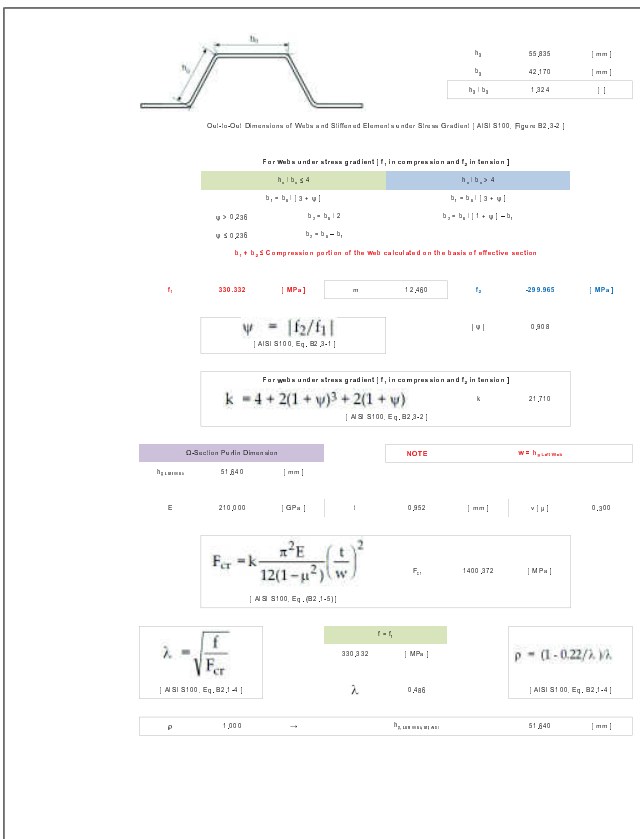
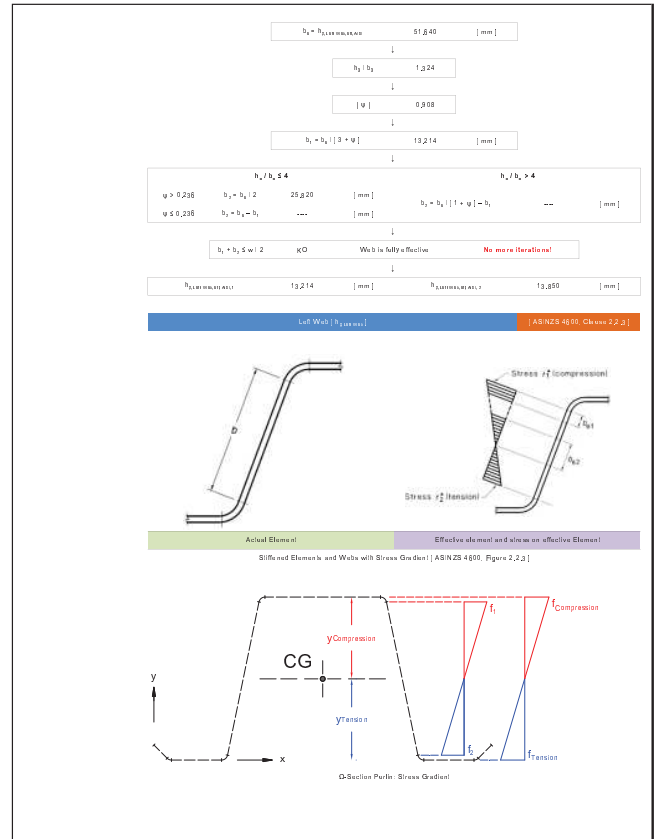
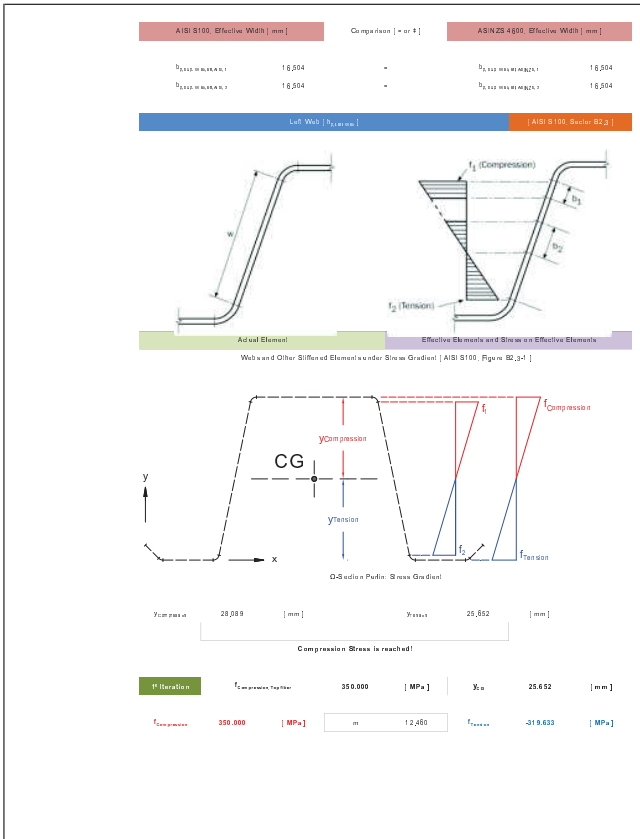
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$b_f = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$ 51,640 [mm]

$\psi = -0,238$

$b_{ef} = b_f \cdot [1 - \psi]$ 13,214 [mm]

$\psi < -0,238 \quad b_f = b_f / 2$ 25,820 [mm] $\psi > -0,238 \quad b_{ef} = b_f - b_w$ [mm]

b_{ef} & b_{we} Compression portion of the web calculated on the basis of effective section

$b_{we} = b_{we} \cdot \beta_{we}$ KO Web is fully effective **Notion Retentional**

$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$ 13,214 [mm] $b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$ 13,850 [mm]

AISI S100, Effective Width [mm]	Comparison = or <!	AS/NZS 4600, Effective Width [mm]
$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	*	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$
$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	*	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$

Inferior Left Flange | $b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$ | AISI S100, Section B4 |

NOTE: Zone in Tension, Effective width is equal to the real width

Inferior Left Flange | $b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$ | AS/NZS 4600, Clause 2, 2 |

NOTE: Zone in Tension, Effective width is equal to the real width

Left Edge Stiffener | $b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$ | AISI S100, Section B3, 2 |

NOTE: Zone in Tension, Effective width is equal to the real width

Left Edge Stiffener | $b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$ | AS/NZS 4600, Clause 2, 3, 2 |

NOTE: Zone in Tension, Effective width is equal to the real width

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Effective D-Section Purlin Widths

Inferior Left Flange | $b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$ [mm]

Left Edge Stiffener | $b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$ [mm]

$b_{p, Sup. Flange, eff. 1}$ $b_{p, Sup. Flange, eff. 2}$

$b_{p, Long. Web, eff. 1}$ $b_{p, Long. Web, eff. 2}$

CG

$M_{y, Ed. (+)}$

Effective D-Section Purlin | Positive Moment in x-y axis, $M_{y, Ed. (+)}$ | AISI S100 | AS/NZS 4600 |

Effective D-Section Purlin | Local Buckling | Positive Moment in x-y axis, $M_{y, Ed. (+)}$

$I_{p, eff. (+)}$ 8198.127 [mm²]

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II] Effective D-Section Purlin | Local Buckling

Effective D-Section Purlin Widths | AISI S100

Right Edge Stiffener	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	--	[mm]
Inferior Right Flange	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	--	[mm]
Right Web	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	51,640	[mm]
Superior Flange	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	33,058	[mm]
Left Web	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	51,640	[mm]
Inferior Left Flange	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	--	[mm]
Left Edge Stiffener	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	--	[mm]

Effective D-Section Purlin Widths | AS/NZS 4600

Right Edge Stiffener	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	--	[mm]
Inferior Right Flange	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	--	[mm]
Right Web	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	51,640	[mm]
Superior Flange	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	33,058	[mm]
Left Web	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	51,640	[mm]
Inferior Left Flange	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	--	[mm]
Left Edge Stiffener	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	--	[mm]

Effective D-Section Purlin Widths | AISI S100 | AS/NZS 4600

Right Edge Stiffener	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	--	[mm]
Inferior Right Flange	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	--	[mm]
Right Web	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	51,640	[mm]
Superior Flange	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	33,058	[mm]
Left Web	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	51,640	[mm]
Inferior Left Flange	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	--	[mm]
Left Edge Stiffener	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	--	[mm]

III] Effective Cross D-Section Purlin | Local Buckling

Effective D-Section Purlin Widths

Right Edge Stiffener	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	--	[mm]
Inferior Right Flange	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	--	[mm]
Right Web	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	13,214	[mm]
	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	13,850	[mm]
Superior Flange	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	16,054	[mm]
	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	16,054	[mm]
Left Web	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	13,214	[mm]
	$b_{110} = h_{110} \cdot \alpha_{110} \cdot \beta_{110} \cdot \gamma_{110}$	13,850	[mm]

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II] C-Section Beam

CG

$M_{x, Ed. (+)}$

CG

$M_{y, Ed. (+)}$

Original C-Section Effective C-Section [L] Local Buckling

C-Section Beam Dimension	
c_{11}	14,048 [mm]
c_{21}	38,598 [mm]
h_x	112,096 [mm]
h_y	38,598 [mm]
c_{22}	14,048 [mm]
l	1,652 [mm]

III] Effective Widths for Strength Determination | Local Buckling

$b_{p, 2}$ $c_{p, 2}$

$b_{p, 1}$ $c_{p, 1}$

$b_{p, 1}$ $b_{p, 2}$

C-Section Flange Widths

CG

$M_{y, Ed. (+)}$

Effective C-Section | Worst Case |

1] Iteration

Inferior Edge Stiffener | b_{11} | AISI S100, Section B3, 2 |

NOTE: Zone in Tension, Effective width is equal to the real width

Inferior Edge Stiffener | b_{11} | AS/NZS 4600, Clause 2, 3, 2 |

NOTE: Zone in Tension, Effective width is equal to the real width

Inferior Flange | b_{11} | AISI S100, Section B4 |

NOTE: Zone in Tension, Effective width is equal to the real width

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Inferior Flange (f_{t1}) [AS/NZS 4600, Clause 2.2.1]

NOTE Zone in Tension, Effective width is equal to the real width

Web (h_w) [AISI S100, Section B2.3]

Web 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_w	120,000	[mm]
b_f	48,000	[mm]
h_f / b_f	2,581	[]

$y_{Compress}$ 59,274 [mm] y_{Tensio} 59,274 [mm]

Compression Stress is reached!

$f_{Compress}$	350,000	[MPa]	y_{CG}	59,274	[mm]
f_{Tensio}	-350,000	[MPa]	f_{y1}	330,951	[MPa]
f_{y2}	-330,951	[MPa]			

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$h_{flange1}$ 28,024 [mm] $h_{flange2}$ 28,024 [mm]

Web (h_w) [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

$y_{Compress}$ 59,274 [mm] y_{Tensio} 59,274 [mm]

Compression Stress is reached!

$f_{Compress}$	350,000	[MPa]	y_{CG}	59,274	[mm]
f_{Tensio}	-350,000	[MPa]	f_{y1}	330,951	[MPa]
f_{y2}	-330,951	[MPa]			

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For webs under stress gradient [f_1 in compression and f_2 in tension]

$h_w / b_f \leq 4$ $h_w / b_f > 4$

$b_1 = b_f [1 + \psi]$ $b_2 = b_f [1 + \psi]$

$\psi > 0,236$ $b_1 = b_f / 2$ $b_2 = b_f [1 + \psi] - b_f$

$\psi \leq 0,236$ $b_1 = b_f = b_2$

$b_1, b_2 \leq$ Compression portion of the web calculated on the basis of effective section

$\psi = |f_2 / f_1|$ ψ 1,000

For webs under stress gradient [f_1 in compression and f_2 in tension]

$k = 4 + 2(1 + \psi)^3 + 2(1 - \psi)$ k 24,000

C-Section Beam Dimension **NOTE** $w = h_w$

h_w 112,086 [mm]

E 210,000 [GPa] t 1,452 [mm] v 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1 - \nu^2)} \left(\frac{t}{w}\right)^2$ F_{cr} 764,294 [MPa]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $f = 330,951$ [MPa] $\rho = (1 - 0,22/\lambda) \lambda$

λ 0,658

ρ 1,000 $h_{flange1}$ 112,086 [mm]

$b_1 = h_{flange1}$ 112,086 [mm]

h_1 / b_f 2,581

ψ 1,000

$b_1 = b_f [1 + \psi]$ 28,024 [mm]

$h_w / b_f \leq 4$ $h_w / b_f > 4$

$\psi > 0,236$ $b_1 = b_f / 2$ 56,048 [mm] $b_2 = b_f [1 + \psi] - b_f$ --- [mm]

$\psi \leq 0,236$ $b_1 = b_f = b_2$ --- [mm]

$b_1 + b_2 \leq h_{flange1}$ KO Web is fully effective **No more Iterations!**

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$\psi = \frac{f_2}{f_1}$ ψ 1,000

[AS/NZS 4600, Eq. 2.2.2(5)]

$k = 4 + 2(1 - \psi)^3 + 2(1 + \psi)$ k 24,000

[AS/NZS 4600, Eq. 2.2.2(4)]

C-Section Beam **NOTE** $b = h_w$

h_w 112,086 [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} 764,294 [MPa]

[AS/NZS 4600, Eq. 2.2.1(26)]

$\lambda = \sqrt{\frac{f}{f_{cr}}}$ $f = 330,951$ [MPa] $\rho = \left(\frac{1 - 0,22}{\lambda}\right) \lambda \leq 1,0$

[AS/NZS 4600, Eq. 2.2.2(4)] λ 0,658 [AS/NZS 4600, Eq. 2.2.2(5)]

ρ 1,000 $h_{flange1}$ 112,086 [mm]

$h_{e1} = \frac{b_e}{3 - \psi}$ $h_{e2} = \frac{b_e}{2}$ $h_{e3} = b_e - h_{e1}$

[AS/NZS 4600, Eq. 2.2.2(1)] $\psi \leq 0,236$ [AS/NZS 4600, Eq. 2.2.2(3)] $\psi > 0,236$ [AS/NZS 4600, Eq. 2.2.2(3)]

$b_1 = h_{flange1}$ 112,086 [mm]

ψ 1,000

$b_2 = b_f [1 + \psi]$ 28,024 [mm]

$\psi > 0,236$ $b_1 = b_f / 2$ 56,048 [mm] $b_2 = b_f [1 + \psi] - b_f$ --- [mm]

$b_1 + b_2 \leq h_{flange1}$ KO Web is fully effective **No more Iterations!**

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$b_{1,MINIMUM}$	28,024	[mm]	$b_{1,MAXIMUM}$	28,024	[mm]
-----------------	--------	------	-----------------	--------	------

AISI S100, Effective Width [mm]		Comparison = or ≠	AS/NZS 4600, Effective Width [mm]	
$b_{1,MINIMUM}$	28,024	-	$b_{1,MINIMUM}$	28,024
$b_{1,MAXIMUM}$	28,024	-	$b_{1,MAXIMUM}$	28,024

Superior Flange ($b_{1,2}$)

C-Section Beam Dimension

$b_{1,2}$	14,048	[mm]
$b_{2,1}$	38,596	[mm]
t	1,452	[mm]

$\epsilon_{1,2} \leq 0.1 b_{1,2} \leq b$

$\epsilon_{MAX,1,2}$ 18,000 [mm]

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$b_{1,1} \leq 0.328 \cdot S$	$b_{1,1} > 0.328 \cdot S$
------------------------------	---------------------------

$I_x = 0.000$ [no edge stiffener is needed] | $I_x = \dots$ [edge stiffener is needed]

$b_1 = b$ | $b_1 = [b_1 \cdot 2]^{1/2} \cdot I_x$

$b_2 = b_1 \cdot 1.2$ | $b_2 = b_1 - b_1$

$d_1 = d_{1,MIN}$ | $d_1 = d_{1,MAX} \cdot I_x$

$b_{1,1}$ 26,581 | Edge stiffener is needed | $0.328 \cdot S$ 10,284

$I_x = 390t^4 \left[\frac{(b/t) - 0.328}{S} \right] \leq t^4 \left[115 \frac{(b/t)}{S} + 5 \right]$ | Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element

[AS/NZS 4600, Eq. 2.4.20 (1)]

I_x 249,076 [mm⁴] ≤ 455,500 → OK

$I_y/I_x \leq 1$ | $I_y = (d^3 t \sin^2 \theta) / 12$

[AS/NZS 4600] | [AS/NZS 4600, Eq. 2.4.21 (1)]

ϕ_c 89,000 [%] → I_y 6956,844 [mm⁴]

$[I_y/I_x]$ 27,931 ≤ 1,000 → KO → $[I_y/I_x]$ 1,000

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

$N = \left[\frac{0.582 - (b/t)}{4S} \right] \geq \frac{1}{3}$ | Single Lip Edge Stiffener | $140^\circ \leq \theta \leq 40^\circ$

$d_1/b \leq 0.250$ | $0.250 < d_1/b \leq 0.800$

$3,670 \cdot [I_x/I_y]^{1/4} + 0.430 \leq 4,000$ | $[4,820 - 5 \cdot d_1/b] \cdot [I_x/I_y]^{1/4} + 0.430 \leq 4,000$

[AS/NZS 4600, Eq. 2.4.21 (2)]

OK 140° ≥ ϕ_c 89,000 [%] ≥ 40° OK

$n = 0.370$ ≥ 1.13? OK → $n = 0.370$

[AS/NZS 4600, Table 2.4.2] | d_1/b 0,466 → $k = 2,918$ OK

C-Section Beam Dimension

$b_{1,2}$ 38,596 [mm]

NOTE $b = b_{1,2}$

$E = 210,000$ [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} 783,886 [MPa]

[AS/NZS 4600, Eq. 2.4.21 (2)]

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Determination of Plate Buckling Coefficient, k [AISI S100, Table B4.1]

Single Lip Edge Stiffener | $140^\circ \leq \theta \leq 40^\circ$

$D/w \leq 0.250$ | $0.250 < D/w \leq 0.800$

$3,670 \cdot [I_x/I_y]^{1/4} + 0.430 \leq 4,000$ | $[4,820 - 5 \cdot D/w] \cdot [I_x/I_y]^{1/4} + 0.430 \leq 4,000$

OK 140° ≥ ϕ_c 89,000 [%] ≥ 40° OK

$n = 0.370$ ≥ 1.13? OK → $n = 0.370$

[AISI S100, Table B4.1] | D/w 0,466 → $k = 2,918$ OK

C-Section Beam Dimension

NOTE $b = b_{1,2}$

$E = 210,000$ [GPa] | $t = 1,452$ [mm] | v 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{w} \right)^2$ | F_{cr} 783,886 [MPa]

[AISI S100, Eq. B2.1-4]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ | $\Gamma = f_c$ 350,000 [MPa] | $\rho = (1 - 0.22/\lambda) \lambda$

[AISI S100, Eq. B2.1-4] | λ 0,668 | [AISI S100, Eq. B2.1-4]

ρ 1,000 → $b_{1,MINIMUM}$ 38,596 [mm]

$b_{1,MINIMUM}$ 19,298 [mm] | $b_{1,MAXIMUM}$ 19,298 [mm]

Superior Edge Stiffener ($b_{1,2}$)

[AS/NZS 4600, Clause 2.4]

C-Section Beam Dimension

$b_{1,2}$	14,048	[mm]
$b_{2,1}$	38,596	[mm]
t	1,452	[mm]

$\epsilon_{1,2} \leq 0.1 b_{1,2} \leq b$

$\epsilon_{MAX,1,2}$ 18,000 [mm]

$S = 1.28 \sqrt{E/f^*}$ | $E = 210,000$ [GPa] | $f^* = 350,000$ [MPa] | $S = 31,353$ [mm]

[AS/NZS, Eq. 2.4.21 (3)]

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Date: 05/09/2019		Project: MASTER THESIS	
Code: AISI AS/NZS		Reference: AISI S100 AS/NZS 4600 EN 1993	
Version: 1,000		Client: COIMBRA UNIVERSITY	

$\lambda = \left(\sqrt{\frac{f}{F_{cr}}} \right)$ | $\Gamma = f_c$ 350,000 [MPa] | $\rho = \left(\frac{1 - 0.22}{\lambda} \right) \lambda \leq 1.0$

[AS/NZS 4600, Eq. 2.4.21 (4)] | λ 0,668 | [AS/NZS 4600, Eq. 2.2.21 (3)]

ρ 1,000 → $b_{1,MINIMUM}$ 38,596 [mm]

$b_{1,MINIMUM}$ 19,298 [mm] | $b_{1,MAXIMUM}$ 19,298 [mm]

AISI S100, Effective Width [mm] | Comparison = or ≠ | AS/NZS 4600, Effective Width [mm]

$b_{1,MINIMUM}$ 19,298 - $b_{1,MINIMUM}$ 19,298

$b_{1,MAXIMUM}$ 19,298 - $b_{1,MAXIMUM}$ 19,298

Superior Edge Stiffener ($b_{1,2}$)

[AISI S100, Section B1.2]

C-Section Beam Stress Gradient

Uniformed Elements under Stress Gradient, Both Longitudinal Edges in Compression [AISI S100, Figure B1.2.4]

$f_{1,COMPRESSIVE}$ 350,000 [MPa] | $f_{2,COMPRESSIVE}$ 350,000 [MPa] | $f_{1,MINIMUM}$ 59,274 [MPa] | $f_{2,MINIMUM}$ -59,880 [MPa]

$f_{1,MINIMUM}$ 330,951 [MPa] | $f_{2,MINIMUM}$ 5,905 [MPa] | $f_{1,MAXIMUM}$ 248,091 [MPa]

$\psi = |f_2/f_1|$ | $|\psi|$ 0,749

f_1 Compression | $k = \frac{0.578}{\psi - 0.34}$ | k 0,531

f_2 Compression | [AISI S100, Eq. B1.2-4]

C-Section Beam Dimension

NOTE $b = b_{1,2}$

$E = 210,000$ [GPa] | $t = 1,452$ [mm] | v 0,300

$w = 14,048 \text{ [mm]}$ → $w \leq 60$ OK

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$$

$F_{cr} = 1075,365 \text{ [MPa]}$
 [AISI S100, Eq. B2.1-4]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

$f = 0$
 $\lambda = 0,555$
 $\rho = (1 - 0,22/\lambda) \lambda$
 $\rho = 1,000$ → $c_{1,beam} = 14,048 \text{ [mm]}$

Superior Edge Stiffener ($c_{1,1}$) [AS/NZS 4600, Clause 2.3.2]

Unaffined Elements With Stress Gradient: Both Edges Compression [AS/NZS 4600, Figure B2.2(a)]

C-Section Beam Dimension

$c_{1,1}$	14,048 [mm]
-----------	-------------

NOTE: $b = c_{1,2}$

[III] Effective Cross-C-Section Beam | Local Buckling

Effective C-Section Beam Widths

Inferior Edge Stiffener	$c_{1,1,1}$	---	[mm]
Inferior Flange	$b_{1,1,1}$	---	[mm]
Web	$b_{1,1,2}$	20,024	[mm]
	$b_{1,1,3}$	20,024	[mm]
Superior Flange	$b_{1,1,4}$	19,298	[mm]
	$b_{1,1,5}$	19,298	[mm]
Superior Edge Stiffener	$c_{1,1,6}$	14,048	[mm]

Effective C-Section Beam | Local Buckling | Bending Moment M_x [AISI S100 | AS/NZS 4600]

Effective C-Section Beam | Local Buckling | Bending Moment M_x [mm²]

$M_x = 762,290,565 \text{ [mm}^2\text{]}$

$E = 210,000 \text{ [GPa]}$ | $t = 1,652 \text{ [mm]}$ | $v = 0,300$

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$$

$f_{cr} = 1075,365 \text{ [MPa]}$
 [AS/NZS 4600, Eq. 2.3.2(5)]

$$\lambda = \sqrt{\frac{f}{f_{cr}}}$$

$f = 0$
 $\lambda = 0,555$
 $\rho = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$
 [AS/NZS 4600, Eq. 2.3.2(9)]

$\rho = 1,000$ → $c_{1,columns} = 14,048 \text{ [mm]}$

AISI S100, Effective Width [mm] | Comparison: $\rho \geq 0,4$ | AS/NZS 4600, Effective Width [mm]

$c_{1,columns}$	14,048	$c_{1,columns}$	14,048
-----------------	--------	-----------------	--------

[II] Effective C-Section Beam | Local Buckling

Effective C-Section Beam Widths [AISI S100]

Inferior Edge Stiffener	$c_{1,1,1,1}$	---	[mm]
Inferior Flange	$b_{1,1,1,1}$	---	[mm]
Web	$b_{1,1,1,2}$	112,996	[mm]
	$b_{1,1,1,3}$	38,596	[mm]
Superior Flange	$b_{1,1,1,4}$	38,596	[mm]
	$b_{1,1,1,5}$	14,048	[mm]

Effective C-Section Beam Widths [AS/NZS 4600]

Inferior Edge Stiffener	$c_{1,1,1,1,2}$	---	[mm]
Inferior Flange	$b_{1,1,1,1,2}$	---	[mm]
Web	$b_{1,1,1,1,3}$	112,996	[mm]
	$b_{1,1,1,1,4}$	38,596	[mm]
Superior Flange	$b_{1,1,1,1,5}$	38,596	[mm]
	$b_{1,1,1,1,6}$	14,048	[mm]

Effective C-Section Beam Widths [AISI S100 | AS/NZS 4600]

Inferior Edge Stiffener	$c_{1,1,1}$	---	[mm]
Inferior Flange	$b_{1,1,1}$	---	[mm]
Web	$b_{1,1,2}$	112,996	[mm]
	$b_{1,1,3}$	38,596	[mm]
Superior Flange	$b_{1,1,4}$	38,596	[mm]
	$b_{1,1,5}$	14,048	[mm]

[IV] C-Section Columns

Original C-Section | Effective C-Section [mm]

Local Buckling

C-Section Columns Dimension	
$c_{1,1}$	14,048 [mm]
$b_{1,1}$	38,596 [mm]
b_w	80,096 [mm]
$b_{1,2}$	38,596 [mm]
$c_{1,2}$	14,048 [mm]
t	2,652 [mm]

[I] Effective Widths for Strength Determination | Local Buckling

Effective C-Section | Width Case

1st Iteration

Inferior Edge Stiffener ($c_{1,1}$)	[AISI S100, Sect. B2.1]
---------------------------------------	---------------------------

NOTE: Zone in Tension, Effective width is equal to the real width

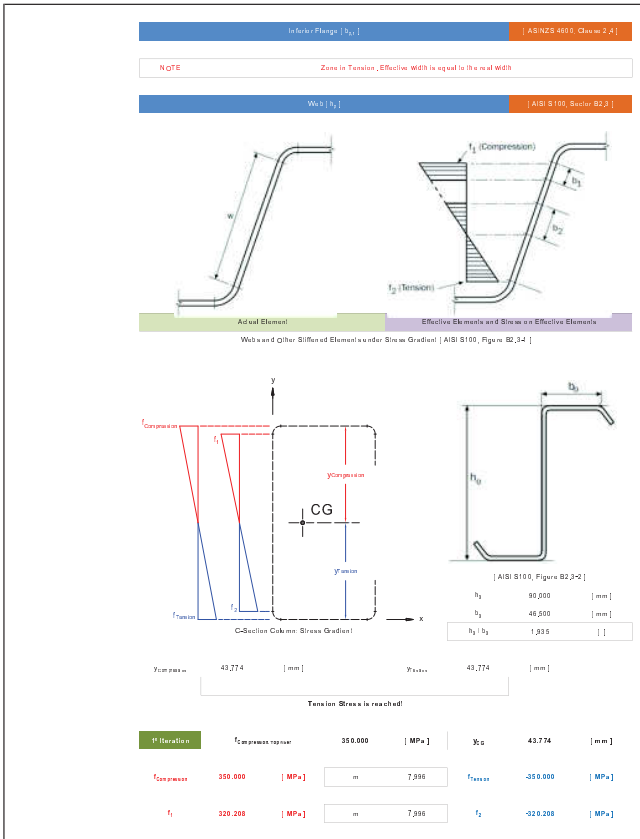
Inferior Edge Stiffener ($c_{1,1}$)	[AS/NZS 4600, Clause 2.3.2]
---------------------------------------	-------------------------------

NOTE: Zone in Tension, Effective width is equal to the real width

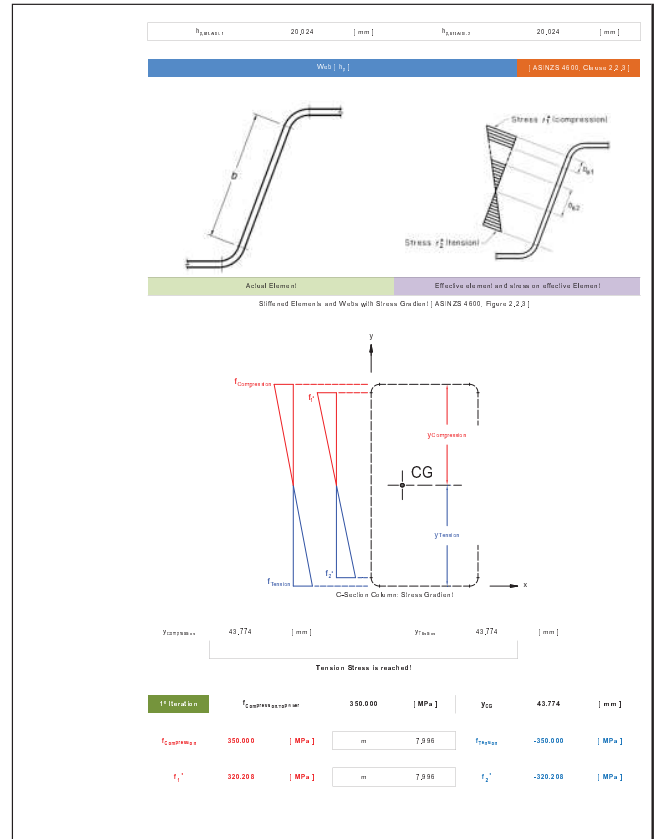
Inferior Flange ($b_{1,1}$)	[AISI S100, Sect. B4]
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NOTE: Zone in Tension, Effective width is equal to the real width

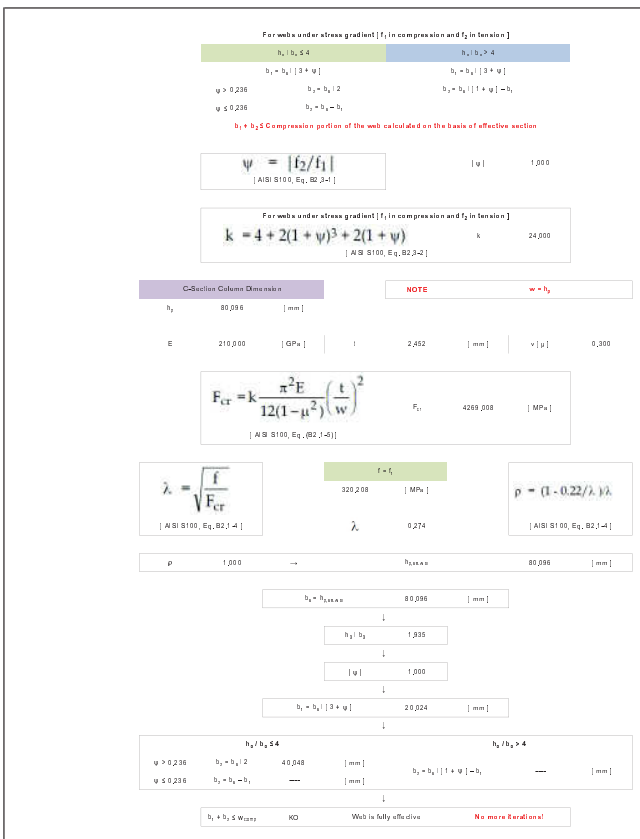
Office: ---		Author: JOSE ANTONIO	
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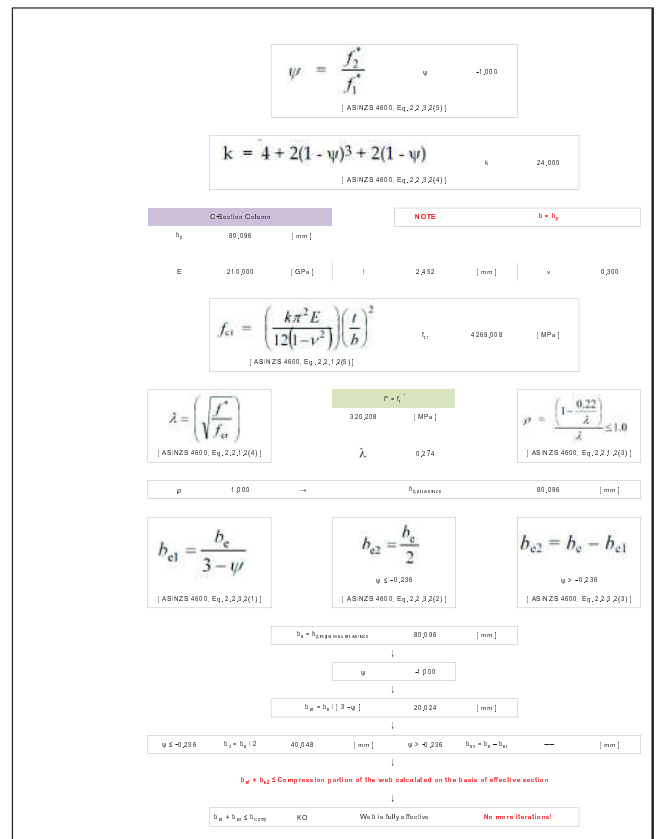
Office: ---		Author: JOSE ANTONIO	
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Version: 1,000		Client: COIMBRA UNIVERSITY	

$b_{1,MINIMUM}$	20,024	[mm]	$b_{1,MAXIMUM}$	20,024	[mm]
-----------------	--------	------	-----------------	--------	------

AISI S100, Effective Width [mm]	Comparison [= or <]	AS/NZS 4600, Effective Width [mm]
$b_{1,MINIMUM}$	-	$b_{1,MINIMUM}$
$b_{1,MAXIMUM}$	-	$b_{1,MAXIMUM}$

Superior Flange ($b_{1,2}$) [AISI S100, Section B4]

C-Section Column Dimension	
$b_{1,2}$	13,048 [mm]
$b_{2,1}$	36,596 [mm]
t	2,452 [mm]

$c_{1,2} = 0.1 b_{1,2} = 0$

$d_{MINIMUM}$ 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 []

$w \leq 0.328 \cdot S$	$w > 0.328 \cdot S$
$I_x = 0.000$ [no edge stiffener needed]	$I_x = \dots$ [edge stiffener is needed]
$b = w$	$b_1 = [5/2] \cdot [R]$
$b_2 = b_1 + 2$	$b_2 = b_1 - b_1$
$d_1 = d_2$	$d_1 = d_2 \cdot [R]$

$w = 14,925$ Edge stiffener is needed. $0.328 \cdot S = 10,284$

$I_x = 390t^4 \left[\frac{w/t}{S} - 0.328 \right] \leq t^4 \left[115 \frac{w/t}{S} + 5 \right]$ [AISI S100, Eq. B4-8]

Adapted moment of inertia of stiffener, so that each component element will behave as a stiffened element!

$I_x = 46,278$ [mm⁴] $\leq 2159,563$ → OK

$(R)_1 = I_x/I_d \leq 1$ [AISI S100, Eq. B4-4]

$I_d = (d \cdot t \sin^2 \theta) / 12$ [AISI S100, Eq. B4-10]

$\phi_1 = 90,000$ [°] → $I_d = 10014,249$ [mm⁴]

$[R]_1 = 214,692 \leq 1,000$ → KO → $[R]_1 = 1,000$

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$b \leq 0.328 \cdot S$	$b > 0.328 \cdot S$
$I_x = 0.000$ [no edge stiffener needed]	$I_x = \dots$ [edge stiffener is needed]
$b_1 = b$	$b_1 = [5/2] \cdot [R]$
$b_2 = b_1 + 2$	$b_2 = b_1 - b_1$
$d_1 = d_2$	$d_1 = d_2 \cdot [R]$

$b = 14,925$ Edge stiffener is needed. $0.328 \cdot S = 10,284$

$I_x = 390t^4 \left[\frac{b/t}{S} - 0.328 \right] \leq t^4 \left[115 \frac{b/t}{S} + 5 \right]$ [AS/NZS 4600, Eq. 2.4.20 (1)]

Adapted moment of inertia of stiffener, so that each component element will behave as a stiffened element!

$I_x = 46,278$ [mm⁴] $\leq 2159,563$ → OK

$I_x/I_d \leq 1$ [AS/NZS 4600]

$I_d = (d \cdot t \sin^2 \theta) / 12$ [AS/NZS 4600, Eq. 2.4.20 (1)]

$\phi_1 = 90,000$ [°] → $I_d = 10014,249$ [mm⁴]

$[I_x/I_d] = 214,692 \leq 1,000$ → KO → $[I_x/I_d] = 1,000$

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

$N = \left[\frac{0.582 - (b/t)}{4S} \right] \geq \frac{1}{3}$

Single Lip Edge Stiffener [140° ≤ θ ≤ 40°]

$d_1/b \leq 0.250$ $0.250 < d_1/b \leq 0.800$

$3,670 \cdot [I_x/I_d]^{1/4} + 0,490 \leq 4,000$ $[4,820 - 5 \cdot d_1/b] \cdot [I_x/I_d]^{1/4} + 0,490 \leq 4,000$

OK 140° $\phi_1 = 90,000$ [°] $\geq 40^\circ$ OK

$n = 0,463 \geq 1,137$ OK → $n = 0,463$

[AS/NZS 4600, Table 2.4.2] $d_1/b = 0,492$ → $k = 2,781$ OK

C-Section Column Dimension	
$b_{1,2}$	36,596 [mm]

NOTE $b = b_{1,2}$

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(6)]

$f_{cr} = 2377,356$ [MPa]

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Version: 1,000		Client: COIMBRA UNIVERSITY	

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Single Lip Edge Stiffener [140° ≤ θ ≤ 40°]

$D/w \leq 0.250$ $0.250 < D/w \leq 0.800$

$3,670 \cdot [R]^{1/4} + 0,490 \leq 4,000$ $[4,820 - 5 \cdot D/w] \cdot [R]^{1/4} + 0,490 \leq 4,000$

OK 140° $\phi_1 = 90,000$ [°] $\geq 40^\circ$ OK

$n = 0,463 \geq 1,137$ OK → $n = 0,463$

[AISI S100, Table B4-1] $D/w = 0,492$ → $k = 2,781$ OK

C-Section Column Dimension	
$b_{1,2}$	36,596 [mm]

NOTE $b = b_{1,2}$

E	210,000 [GPa]	t	2,452 [mm]	v	0,300
---	---------------	-----	------------	-----	-------

$F_{cr} = k \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{w} \right)^2$ [AISI S100, Eq. B2.1-4]

$F_{cr} = 2377,356$ [MPa]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ [AISI S100, Eq. B2.1-4]

$\lambda = 0,384$

$\rho = (1 - 0.22/\lambda) \cdot \lambda$ [AISI S100, Eq. B2.1-4]

$\rho = 1,000$ → $b_{1,MINIMUM} = 36,596$ [mm]

$b_{1,MAXIMUM} = 18,298$ [mm] $b_{2,MINIMUM} = 18,298$ [mm] $b_{2,MAXIMUM} = 18,298$ [mm]

Superior Edge Stiffener ($b_{1,2}$) [AS/NZS 4600, Clause 2.4]

C-Section Column Dimension	
$b_{1,2}$	13,048 [mm]
$b_{2,1}$	36,596 [mm]
t	2,452 [mm]

$c_{1,2} = 0.1 b_{1,2} = 0$

$d_{MINIMUM}$ 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 []

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$\lambda = \left(\sqrt{\frac{f}{F_{cr}}} \right)$ [AS/NZS 4600, Eq. 2.2.1.2(4)]

$\lambda = 0,384$

$\rho = \left(\frac{1 - 0.22}{\lambda} \right) \cdot \lambda$ [AS/NZS 4600, Eq. 2.2.1.2(3)]

$\rho = 1,000$ → $b_{1,MINIMUM} = 36,596$ [mm]

$b_{1,MAXIMUM} = 18,298$ [mm] $b_{2,MINIMUM} = 18,298$ [mm] $b_{2,MAXIMUM} = 18,298$ [mm]

AISI S100, Effective Width [mm]		Comparison [= or <]		AS/NZS 4600, Effective Width [mm]	
$b_{1,MINIMUM}$	18,298	-		$b_{1,MINIMUM}$	18,298
$b_{1,MAXIMUM}$	18,298	-		$b_{1,MAXIMUM}$	18,298

Superior Edge Stiffener ($b_{1,2}$) [AISI S100, Section B2.1]

C-Section Beam Stress Gradient

Uniformed Elements under Stress Gradient. Both Longitudinal Edges in Compression [AISI S100, Figure B2.1-4]

$f_{1,COMPRESSIVE} = 350,000$ [MPa] $y_{CG} = 43,774$ [mm]

$f_{2,COMPRESSIVE} = 350,000$ [MPa] $m = 7,936$ $f_{2,MINIMUM} = -350,000$ [MPa]

$f_1 = 320,208$ [MPa] $m = 7,936$ $f_2 = 215,882$ [MPa]

$\psi = |f_2/f_1|$ [AISI S100, Eq. B3.2-1]

$\psi = 0,674$

$k = \frac{0.578}{\psi - 0.34}$ [AISI S100, Eq. B3.2-4]

$k = 0,570$

C-Section Column Dimension	
$b_{1,2}$	13,048 [mm]

NOTE $b = b_{1,2}$

E	210,000 [GPa]	t	2,452 [mm]	v	0,300
---	---------------	-----	------------	-----	-------

$w = 13,048 \text{ [mm]}$ → $w \leq 60$ OK

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$$

[AISI S100, Eq. B2.1.4(1)] $F_{cr} = 9819,349 \text{ [MPa]}$

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1.4] $f = 320,268 \text{ [MPa]}$ $\lambda = 0,290$ $\rho = (1 - 0,22/\lambda) \lambda$ [AISI S100, Eq. B2.1.4]

$\rho = 1,000$ → $c_{1,MIN} = 13,048 \text{ [mm]}$

Superior Edge Stiffener ($c_{1,1}$) [AS/NZS 4600, Clause 2.3.2]

C-Section Beam Stress Gradient

Unstiffened Elements With Stress Gradient: Both Edges Compression [AS/NZS 4600, Figure B2.3.2(a)]

$f_{1,COMPRESSIVE} = 350,000 \text{ [MPa]}$ $t_{c1} = 43,774 \text{ [mm]}$

$f_{2,TENSIVE} = 350,000 \text{ [MPa]}$ $m = 7,936$ $f_{1,TENSIVE} = -350,000 \text{ [MPa]}$

$f_1^* = 320,268 \text{ [MPa]}$ $m = 7,936$ $f_2^* = 215,882 \text{ [MPa]}$

$$\psi = \frac{f_2^* / f_1^*}{\psi = 0,974}$$

[AS/NZS 4600, Eq. 2.3.2.2(1)]

f_1 Compression $k = \frac{0,578}{\psi + 0,34}$ $k = 0,570$

[AS/NZS 4600, Eq. 2.3.2.2(1)]

C-Section Column Dimension

$c_{1,1} = 13,048 \text{ [mm]}$ **NOTE** $b = c_{1,2}$

[III] Effective Cross-C-Section Beam [Local Buckling]

Effective C-Section Beam Widths

Inferior Edge Stiffener	$c_{1,1,1}$	---	[mm]
Inferior Flange	$b_{1,1,1,1}$	---	[mm]
Web	$b_{1,1,1,2}$	20,024	[mm]
Superior Flange	$b_{1,1,1,3}$	18,298	[mm]
Superior Edge Stiffener	$c_{1,1,1}$	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 $M_{y,Ed}$]

$I_{y,eff} = 625,936,020 \text{ [mm}^4\text{]}$

$E = 210,000 \text{ [GPa]}$ $t = 2,452 \text{ [mm]}$ $v = 0,300$

$$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$$

[AS/NZS 4600, Eq. 2.3.2.2(5)] $f_{cr} = 3819,349 \text{ [MPa]}$

$$\lambda = \left(\sqrt{\frac{f}{f_{cr}}} \right)$$

[AS/NZS 4600, Eq. 2.3.2.2(4)] $f = 320,268 \text{ [MPa]}$ $\lambda = 0,290$ $\rho = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$ [AS/NZS 4600, Eq. 2.3.2.2(3)]

$\rho = 1,000$ → $c_{1,MIN} = 13,048 \text{ [mm]}$

AISI S100, Effective Width [mm] Comparison $\rho = 1$ AS/NZS 4600, Effective Width [mm]

$c_{1,MIN} = 13,048$ $c_{1,MIN} = 13,048$

[II] Effective C-Section Column [Local Buckling]

Effective C-Section Column Widths [AISI S100]

Inferior Edge Stiffener	$c_{1,1,MIN}$	---	[mm]
Inferior Flange	$b_{1,1,1,MIN}$	---	[mm]
Web	$b_{1,1,1,2}$	80,596	[mm]
Superior Flange	$b_{1,1,1,3}$	36,596	[mm]
Superior Edge Stiffener	$c_{1,1,MIN}$	13,048	[mm]

Effective C-Section Column Widths [AS/NZS 4600]

Inferior Edge Stiffener	$c_{1,1,MIN}$	---	[mm]
Inferior Flange	$b_{1,1,1,MIN}$	---	[mm]
Web	$b_{1,1,1,2}$	80,596	[mm]
Superior Flange	$b_{1,1,1,3}$	36,596	[mm]
Superior Edge Stiffener	$c_{1,1,MIN}$	13,048	[mm]

Effective C-Section Column Widths [AISI S100 | AS/NZS 4600]

Inferior Edge Stiffener	$c_{1,1,1}$	---	[mm]
Inferior Flange	$b_{1,1,1,1}$	---	[mm]
Web	$b_{1,1,1,2}$	80,596	[mm]
Superior Flange	$b_{1,1,1,3}$	36,596	[mm]
Superior Edge Stiffener	$c_{1,1,1}$	13,048	[mm]

1st Iteration

Inferior Edge Stiffener ($c_{1,1}$) [AISI S100, Sect. B2.1]

NOTE Zone in Tension, Effective width is equal to the real width

Inferior Edge Stiffener ($c_{1,1}$) [AS/NZS 4600, Clause 2.3.2.1]

NOTE Zone in Tension, Effective width is equal to the real width

Inferior Flange ($b_{1,1}$) [AISI S100, Sector B4]

NOTE Zone in Tension, Effective width is equal to the real width

[IV] C-Section Size

Gross C-Section Effective C-Section [Local Buckling]

C-Section Size Dimension	
$c_{1,1}$	6,848 [mm]
$b_{1,1}$	32,596 [mm]
$b_{1,2}$	42,096 [mm]
$b_{1,3}$	32,596 [mm]
$c_{1,2}$	6,848 [mm]
t	1,452 [mm]

[I] Effective Widths for Strength Determination [Local Buckling]

Effective C-Section [Width Case]

1st Iteration

Inferior Edge Stiffener ($c_{1,1}$) [AISI S100, Sect. B2.1]

NOTE Zone in Tension, Effective width is equal to the real width

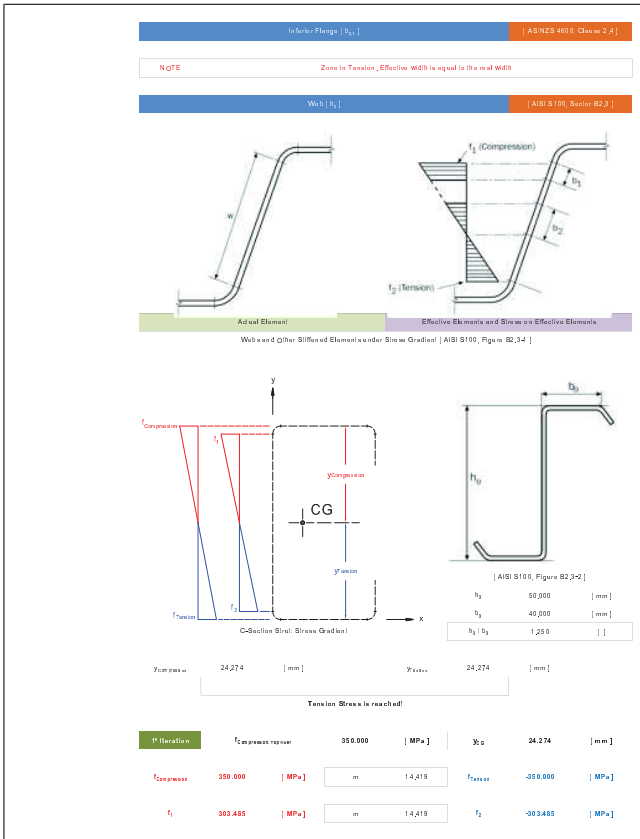
Inferior Edge Stiffener ($c_{1,1}$) [AS/NZS 4600, Clause 2.3.2.1]

NOTE Zone in Tension, Effective width is equal to the real width

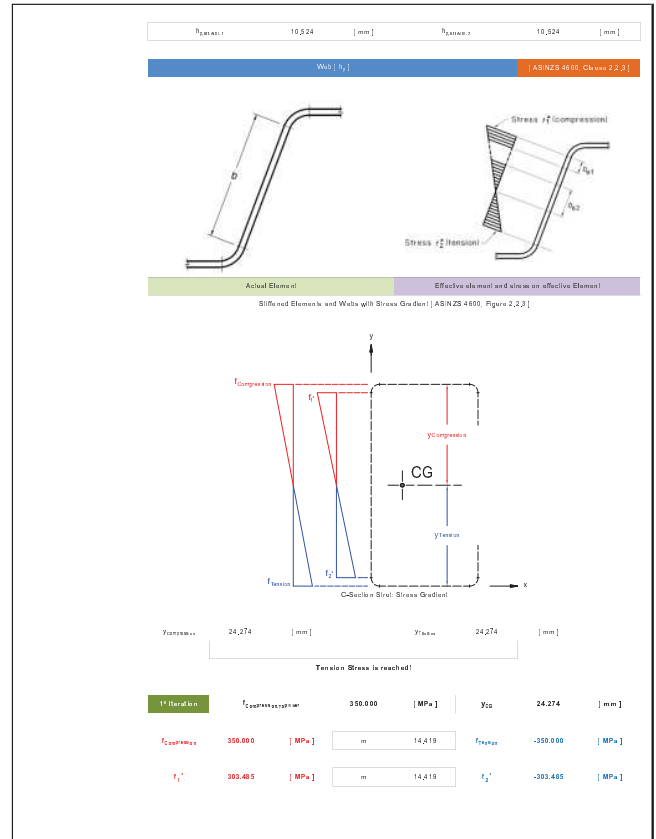
Inferior Flange ($b_{1,1}$) [AISI S100, Sector B4]

NOTE Zone in Tension, Effective width is equal to the real width

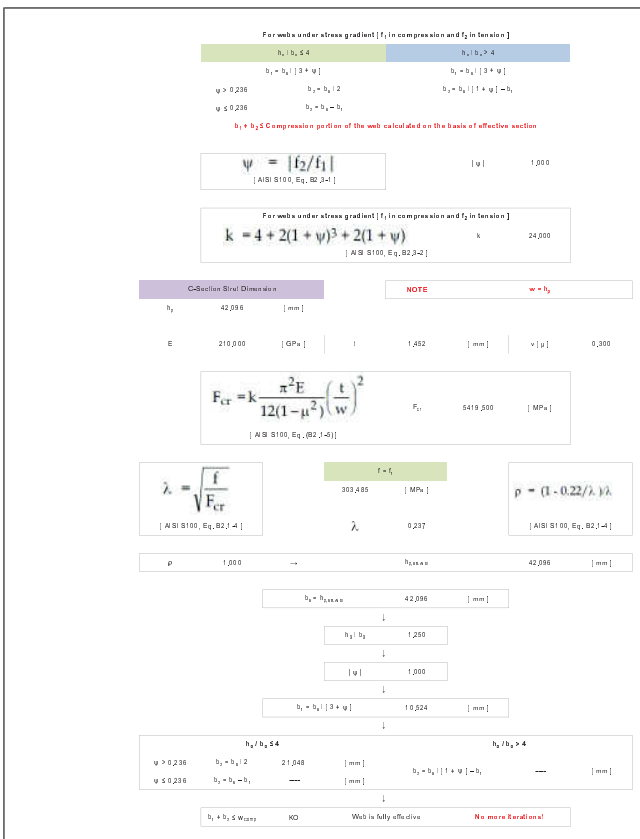
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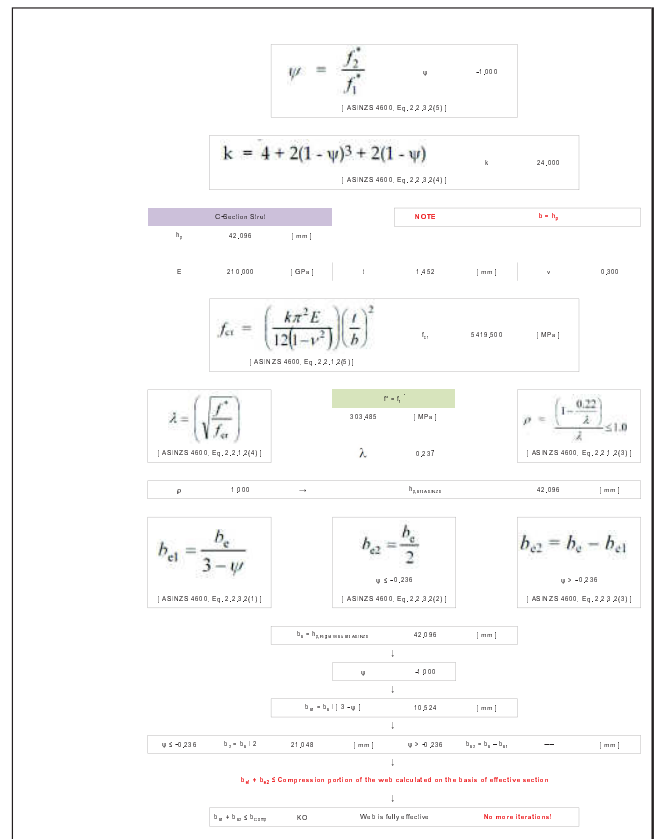
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$b_{1,MINIMUM}$	10,924	[mm]	$b_{1,MAXIMUM}$	10,924	[mm]
-----------------	--------	------	-----------------	--------	------

AISI S100, Effective Width [mm]		Comparison \leq or \neq	AS/NZS 4600, Effective Width [mm]	
$b_{1,MINIMUM}$	10,924	-	$b_{1,MINIMUM}$	10,924
$b_{1,MAXIMUM}$	10,924	-	$b_{1,MAXIMUM}$	10,924

Superior Flange ($b_{1,2}$) | AISI S100, Section B4.1

Actual flange dimensions

C-Section Size Dimension	
$b_{1,2}$	6,048 [mm]
$b_{2,2}$	32,996 [mm]
t	1,452 [mm]

$r_{1,2} \leq 0.1 b_{1,2} \leq r_{2,2}$

$d_{MINIMUM}$ 10,000 [mm]

$S = 1.28 \sqrt{E/t}$ | AISI S100, Eq. B4.7

E	210,000 [GPa]
f	350,000 [MPa]
S	31,353 []

$w \leq 0.328 \cdot S$		$w > 0.328 \cdot S$	
$I_x = 0.000$	[no edge stiffener needed]	$I_x = \dots$	[edge stiffener is needed]
$b = w$		$b_1 = [5/2] \cdot [R]$	
$b_1 = b_2 = w/2$		$b_2 = b_1$	
$d_1 = d_2$		$d_1 = d_2 \cdot [R]$	
w []	22,305	Edge stiffener needed	0,328 · S
			10,284

$I_x = 390t^4 \left[\frac{w/t}{S} - 0.328 \right] \leq t^4 \left[115 \frac{w/t}{S} + 5 \right]$ | AISI S100, Eq. B4.8

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

I_x	95,042 [mm ⁴]	\leq	382,607	OK
-------	---------------------------	--------	---------	----

$(R) = I_x/I_y \leq 1$ | AISI S100, Eq. B4.4

$I_y = (d^3 t \sin^2 \theta) / 12$ | AISI S100, Eq. B4.10

ϕ_x	90,000 [°]	\rightarrow	I_y	4000,220 [mm ⁴]
[R]	42,094	\leq 1,000	\rightarrow	KO

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$b \leq 0.328 \cdot S$		$b > 0.328 \cdot S$	
$I_x = 0.000$	[no edge stiffener needed]	$I_x = \dots$	[edge stiffener is needed]
$b_1 = b$		$b_1 = [5/2] \cdot [I_x]$	
$b_1 = b_2 = b/2$		$b_2 = b_1$	
$d_1 = d_2$		$d_1 = d_2 \cdot [I_x]$	
b []	22,305	Edge stiffener is needed	0,328 · S
			10,284

$I_x = 390t^4 \left[\frac{b/t}{S} - 0.328 \right] \leq t^4 \left[115 \frac{b/t}{S} + 5 \right]$ | AISI S100, Eq. B4.8

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

I_x	95,042 [mm ⁴]	\leq	382,607	OK
-------	---------------------------	--------	---------	----

$I_y/I_x \leq 1$ | AISI S100, Eq. B4.4

$I_y = (d^3 t \sin^2 \theta) / 12$ | AISI S100, Eq. B4.10

ϕ_x	90,000 [°]	\rightarrow	I_y	4000,220 [mm ⁴]
[I _y /I _x]	42,094	\leq 1,000	\rightarrow	KO

Determination of Plate Buckling Coefficient, k | AS/NZS 4600, Table 2.4.2

Single Lip Edge Stiffener | $140^\circ \leq \theta \leq 40^\circ$

$d_1/b \leq 0.250$ | $0.250 < d_1/b \leq 0.800$

$3,670 \cdot [I_x/I_y]^{1/4} + 0,490 \leq 4,000$ | $[4,820 - 5 \cdot d_1/b] \cdot [I_x/I_y]^{1/4} + 0,490 \leq 4,000$

OK	140°	ϕ_x	90,000 [°]	\rightarrow	$\geq 40^\circ$	OK
n	0,406	$\geq 1/3.7$	OK	\rightarrow	n	0,406
[AS/NZS 4600, Table 2.4.2]	d _{1/b}	0,10	0,312	\rightarrow	k	3,692
						OK

C-Section Size Dimension		NOTE	$w = b_{1,2}$
$b_{1,2}$	32,996 [mm]		
E	210,000 [GPa]	t	1,452 [mm]
		v [v]	0,300

$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$ | AISI S100, Eq. 2.2.1(2)

f_{cr}	1434,201 [MPa]
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Determination of Plate Buckling Coefficient, k | AISI S100, Table B4.1

Single Lip Edge Stiffener | $140^\circ \leq \theta \leq 40^\circ$

$0.250 < d_1/b \leq 0.800$

$3,670 \cdot [I_x/I_y]^{1/4} + 0,490 \leq 4,000$ | $[4,820 - 5 \cdot d_1/b] \cdot [I_x/I_y]^{1/4} + 0,490 \leq 4,000$

OK	140°	ϕ_x	90,000 [°]	\rightarrow	$\geq 40^\circ$	OK
n	0,406	$\geq 1/3.7$	OK	\rightarrow	n	0,406
[AISI S100, Table B4.1]	d _{1/b}	0,312	\rightarrow	k	3,692	OK

C-Section Size Dimension		NOTE	$w = b_{1,2}$
$b_{1,2}$	32,996 [mm]		
E	210,000 [GPa]	t	1,452 [mm]
		v [v]	0,300

$F_{cr} = k \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{w} \right)^2$ | AISI S100, Eq. B2.1(4)

F_{cr}	1434,201 [MPa]
----------	----------------

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ | AISI S100, Eq. B2.1(4)

ρ	1,000	\rightarrow	$b_{1,MINIMUM}$	32,996 [mm]
$b_{1,MINIMUM}$	16,048 [mm]	$b_{1,MAXIMUM}$	16,048 [mm]	

Superior Edge Stiffener ($b_{1,2}$) | AS/NZS 4600, Clause 2.4.1

Actual flange dimensions

C-Section Size Dimension	
$b_{1,2}$	6,048 [mm]
$b_{2,2}$	32,996 [mm]
t	1,452 [mm]

$r_{1,2} \leq 0.1 b_{1,2} \leq r_{2,2}$

$d_{MINIMUM}$ 10,000 [mm]

$S = 1.28 \sqrt{E/f}$ | AS/NZS, Eq. 2.2(13)

E	210,000 [GPa]
f	350,000 [MPa]
S	31,353 []

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$\lambda = \sqrt{\frac{f}{F_{cr}}}$ | AISI S100, Eq. B2.1(4)

ρ	1,000	\rightarrow	$b_{1,MINIMUM}$	32,996 [mm]
$b_{1,MINIMUM}$	16,048 [mm]	$b_{1,MAXIMUM}$	16,048 [mm]	

AISI S100, Effective Width [mm]		Comparison \leq or \neq	AS/NZS 4600, Effective Width [mm]	
$b_{1,MINIMUM}$	16,048	-	$b_{1,MINIMUM}$	16,048
$b_{1,MAXIMUM}$	16,048	-	$b_{1,MAXIMUM}$	16,048

Superior Edge Stiffener ($b_{1,2}$) | AISI S100, Section B2.1

Actual flange dimensions

C-Section Size Dimension	
$b_{1,2}$	6,048 [mm]
$b_{2,2}$	32,996 [mm]
t	1,452 [mm]

$r_{1,2} \leq 0.1 b_{1,2} \leq r_{2,2}$

$d_{MINIMUM}$ 10,000 [mm]

C-Section Beam Stress Gradient

Uniformed Elements under Stress Gradient, Both Longitudinal Edges in Compression | AISI S100, Figure B2.1(4)

$f_{1,COMPRESSION}$	350,000 [MPa]	y_{CG}	24,274 [mm]
$f_{2,COMPRESSION}$	350,000 [MPa]	m	14,419 [mm]
f_1	303,465 [MPa]	m	14,419 [mm]
f_2	216,281 [MPa]		

$\psi = |f_2/f_1|$ | AISI S100, Eq. B2.1(4)

ψ	0,713
--------	-------

$k = \frac{0.578}{\psi - 0.34}$ | AISI S100, Eq. B2.1(4)

k	0,549
---	-------

C-Section Size Dimension		NOTE	$w = b_{1,2}$
$b_{1,2}$	6,048 [mm]		
E	210,000 [GPa]	t	1,452 [mm]
		v [v]	0,300

w = 6,048 [mm] → w ≤ 60 [mm] OK

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$$

[AISI S100, Eq. B2.1-4] $F_{cr} = 6006,355$ [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4] $\lambda = 0,225$ $\rho = (1 - 0,22/\lambda) \lambda$ [AISI S100, Eq. B2.1-4]

$\rho = 1,000$ → $\rho_{LIM,MAX} = 6,048$ [mm]

Superior Edge Stiffener ($\rho_{1,1}$) [AS/NZS 4600, Clause 2.3.2]

C-Section Beam Stress Gradient Unflattened Elements With Stress Gradient: Both Edges Compression [AS/NZS 4600, Figure B2.3.2(a)]

$f_{COMPRESSIVE} = 350,000$ [MPa] $t_{CG} = 34,274$ [mm]

$f_{TENSIVE} = 350,000$ [MPa] $t_{TENS} = -350,000$ [MPa]

$f_1^* = 303,485$ [MPa] $t_1^* = 14,419$ [mm] $f_2^* = 216,201$ [MPa]

$$\psi = \frac{f_2^* / f_1^*}{\psi} = 0,719$$

[AS/NZS 4600, Eq. 2.3.2.2(1)]

$k = \frac{0,578}{\psi + 0,34} = 0,549$ $k = 0,549$

[AS/NZS 4600, Eq. 2.3.2.2(2)]

C-Section Steel Dimension **NOTE** $b = \rho_{1,2}$

$\rho_{1,2} = 6,048$ [mm]

[III] Effective Cross-C-Section Slit [Local Buckling]

Effective C-Section Steel Widths

Inferior Edge Stiffener	$\rho_{1,1,1}$	---	[mm]
Inferior Flange	$\rho_{1,1,2}$	---	[mm]
Web	$\rho_{1,1,3}$	10,254	[mm]
	$\rho_{1,1,4}$	10,254	[mm]
Superior Flange	$\rho_{1,2,1}$	16,048	[mm]
	$\rho_{1,2,2}$	16,048	[mm]
Superior Edge Stiffener	$\rho_{1,2,3}$	6,048	[mm]

Effective C-Section Slit [Local Buckling] [Bending Moment M_{max}] [AISI S100 | AS/NZS 4600]

Effective C-Section Slit [Local Buckling] [Bending Moment M_{max}]

$I_{eff}^{1st} = 85435,109$ [mm⁴]

E = 210,000 [GPa] t = 1,652 [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. 2.3.2.2(5)] $f_{cr} = 6006,355$ [MPa]

$$\lambda = \sqrt{\frac{f}{f_{cr}}}$$

[AS/NZS 4600, Eq. 2.3.2.2(4)] $\lambda = 0,225$ $\rho = \frac{(1 - 0,22/\lambda)}{\lambda} \leq 1,0$ [AS/NZS 4600, Eq. 2.3.2.2(3)]

$\rho = 1,000$ → $\rho_{LIM,MAX} = 6,048$ [mm]

AISI S100, Effective Width [mm] Comparison [$\rho = 1$] AS/NZS 4600, Effective Width [mm]

$\rho_{LIM,MAX} = 6,048$ $\rho_{LIM,MAX} = 6,048$

[II] Effective C-Section Slit [Local Buckling]

Effective C-Section Slit Widths [AISI S100]

Inferior Edge Stiffener	$\rho_{1,1,1,1}$	---	[mm]
Inferior Flange	$\rho_{1,1,1,2}$	---	[mm]
Web	$\rho_{1,1,1,3}$	42,096	[mm]
Superior Flange	$\rho_{1,1,1,4}$	32,096	[mm]
Superior Edge Stiffener	$\rho_{1,1,1,5}$	6,048	[mm]

Effective C-Section Slit Widths [AS/NZS 4600]

Inferior Edge Stiffener	$\rho_{1,1,1,1,2}$	---	[mm]
Inferior Flange	$\rho_{1,1,1,1,3}$	---	[mm]
Web	$\rho_{1,1,1,1,4}$	42,096	[mm]
Superior Flange	$\rho_{1,1,1,1,5}$	32,096	[mm]
Superior Edge Stiffener	$\rho_{1,1,1,1,6}$	6,048	[mm]

Effective C-Section Slit Widths [AISI S100 | AS/NZS 4600]

Inferior Edge Stiffener	$\rho_{1,1,1,1}$	---	[mm]
Inferior Flange	$\rho_{1,1,1,2}$	---	[mm]
Web	$\rho_{1,1,1,3}$	42,096	[mm]
Superior Flange	$\rho_{1,1,1,4}$	32,096	[mm]
Superior Edge Stiffener	$\rho_{1,1,1,5}$	6,048	[mm]

[IV.4] Cold-Formed Section subjected to Negative Moment in x-axis [M_{max}]

[I*] D-Section Profile

Gross D-Section Effective D-Section [L]

Local Buckling

[II] Effective Widths for Strength Determination [Local Buckling] AISI S100, Section 9 | AS/NZS 4600, Section 2

Effective D-Section [Weld Check]

D-Section Profile Dimension

$\rho_{1,1,1,1,1}$	6,791	[mm]
$\rho_{1,1,1,1,2}$	16,048	[mm]
$\rho_{1,1,1,1,3}$	51,640	[mm]
$\rho_{1,1,1,1,4}$	38,171	[mm]
$\rho_{1,1,1,1,5}$	51,640	[mm]
$\rho_{1,1,1,1,6}$	16,048	[mm]
$\rho_{1,1,1,1,7}$	6,791	[mm]

D-Section Profile Dimension

$\rho_{1,1,1,1,1} = 25,852$ [mm] $\rho_{1,1,1,1,2} = 28,269$ [mm]

Tension Stress is reached!

1st Iteration

D-Section Profile Stress Gradient

Unflattened Elements under Stress Gradient, Both Longitudinal Edges in Compression [AISI S100, Figure B9.2-1]

f_{tension}	350.000	[MPa]	y_{cg}	25.652	[mm]
$f_{\text{compression}}$	319.633	[MPa]	m	12.450	f_{tension} -350.000 [MPa]
f_1	312.421	[MPa]	m	12.450	f_2 257.870 [MPa]

$\psi = |f_2/f_1|$ [AISI S100, Eq. B1.2-1] $\psi = 0.825$

f_1 Compression $k = \frac{0.578}{\psi - 0.34}$ $k = 0.986$

f_2 Compression [AISI S100, Eq. B1.2-2]

D-Section Profile Dimension		NOTE	$W \neq \psi_{\text{max}} \text{max}$
$r_{\text{compression}}$	6,191	[mm]	
E	210,000	[GPa]	i 0,952 [mm] | v μ 0,300
w	8,191	[mm]	$w \leq 80$ OK

$F_{\text{cr}} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w}\right)^2$ F_{cr} 2225,563 [MPa]

[AISI S100, Eq. (B2.1-5)]

$\lambda = \sqrt{\frac{f}{F_{\text{cr}}}}$ [AISI S100, Eq. B2.1-4]

$\lambda = 0,375$

$r = c$

$r = 312,421$ [MPa]

$\rho = (1 - 0,22/\lambda) \lambda$ [AISI S100, Eq. B2.1-4]

$\rho = 1,000$

AISI S100, Effective Width [mm]	Compliance | $w \leq 1$	AS/NZS 4600, Effective Width [mm]	
$\psi_{\text{compression}}$	6,191	$\psi_{\text{compression}}$	6,191

Reference Right Flange [AS/NZS 4600, Figure 2.2.1]

D-Section Profile Dimension

$r_{\text{compression}}$	6,191	[mm]
r_{tension}	16,545	[mm]
i	0,952	[mm]

$\psi_{\text{max}} = 0.1 \psi_{\text{tension}} \text{max} + W$

[AISI S100, Figure B4.1] ψ_{max} 7,207 [mm]

f_{tension}	350.000	[MPa]	y_{cg}	25.652	[mm]
$f_{\text{compression}}$	319.633	[MPa]	m	12.450	f_{tension} -350.000 [MPa]

$S = 1.28 \sqrt{E/f}$ [AISI S100, Eq. B4.2]

$w \leq 0.228 \sqrt{S}$ $w \leq 0.228 \sqrt{S}$

$I_x = 0,000$ [no edge stiffener needed] $I_x = \dots$ [edge stiffener is needed]

$b = w$ $b_1 = |b_1 - 2| \sqrt{R}$

$b_2 = b - b_1$ $d_1 = d_1 \sqrt{R}$

$w \leq 1$ 17,379 Edge stiffener is needed 0,328 \sqrt{S} 10,761

$I_x = 399 \sqrt{\left[\frac{w}{S} - 0.328\right]^3} \leq t^4 \left[115 \frac{w}{S} + 5\right]$ Adequate moment of inertia of stiffener so that each component element will behave as a stiffened element

[AISI S100, Eq. B4.4]

I_x	2,680	[mm ⁴]	s	64,743	OK
-------	-------	--------------------	-----	--------	----

$(R_1) = I_x / I_y \leq 1$ [AISI S100, Eq. B4.9]

$(R_1) = 45,000$ [!]

$I_y = (d^3 t \sin^2 \theta) / 12$ [AISI S100, Eq. B4.10]

$I_y = 179,657$ [mm⁴]

D-Section Profile Stress Gradient

Unflattened Elements with Stress Gradient, Both Edges in Compression [AS/NZS 4600, Figure B2.2(a)]

f_{tension}	350.000	[MPa]	y_{cg}	25.652	[mm]
$f_{\text{compression}}$	319.633	[MPa]	m	12.450	f_{tension} -350.000 [MPa]
f_1	312.421	[MPa]	m	12.450	f_2 257.870 [MPa]

$\psi = f_2' / f_1'$ $\psi = 0.825$ [AS/NZS 4600, Eq. 2.2.2(1)]

f_1 Compression $k = \frac{0.578}{\psi - 0.34}$ $k = 0.986$

f_2 Compression [AS/NZS 4600, Eq. 2.2.2(2)]

D-Section Profile Dimension		NOTE	$b \neq \psi_{\text{max}} \text{max}$
$r_{\text{compression}}$	6,191	[mm]	
E	210,000	[GPa]	i 0,952 [mm] | v μ 0,300

$F_{\text{cr}} = \left(\frac{k \pi^2 E}{12(1-\nu^2)}\right) \left(\frac{t}{b}\right)^2$ F_{cr} 1930,981 [MPa]

[AS/NZS 4600, Eq. 2.2.2(5)]

$\lambda = \sqrt{\frac{f}{F_{\text{cr}}}}$ [AS/NZS 4600, Eq. 2.2.1-2(4)]

$\lambda = 0,375$

$r = c$

$r = 312,421$ [MPa]

$\rho = \left(\frac{1 - 0,22}{\lambda}\right) \lambda \leq 1,0$ [AS/NZS 4600, Eq. 2.2.1-2(3)]

$\rho = 1,000$

$ R $	66,790	$\leq 1,000$	OK	$ R $	1,000
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Determination of Plate Buckling Coefficient, k [AISI S100, Table B4.1]

Single Lip Edge Stiffener | $140^\circ \leq \theta \leq 40^\circ$

$D \leq 0.250$ $0.250 < D \leq 0.800$

$3,270 \sqrt{|R|} \sqrt{1 + 0,430 \sqrt{4,000}}$ | $4,820 \sqrt{1,5 \sqrt{|R|} \sqrt{1 + 0,430 \sqrt{4,000}}}$

OK 140 $\sqrt{2}$ θ_1 45,000 [!]

$n = 0,650$ $\geq 1/13,7$ OK $n = 0,650$

$|R|$	66,790	$\leq 1,000$	OK
-------	--------	--------------	----

D-Section Profile Dimension		NOTE	$W \neq \psi_{\text{max}} \text{max}$
$r_{\text{compression}}$	16,545	[mm]	
E	210,000	[GPa]	i 0,952 [mm] | v μ 0,300

$F_{\text{cr}} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w}\right)^2$ F_{cr} 1930,981 [MPa]

[AISI S100, Eq. (B2.1-5)]

$\lambda = \sqrt{\frac{f}{F_{\text{cr}}}}$ [AISI S100, Eq. B2.1-4]

$\lambda = 0,407$

$r = c$

$r = 319,633$ [MPa]

$\rho = (1 - 0,22/\lambda) \lambda$ [AISI S100, Eq. B2.1-4]

$\rho = 1,000$

$r_{\text{compression}}$	6,191	[mm]
r_{tension}	16,545	[mm]
i	0,952	[mm]

$\psi_{\text{max}} = 0.1 \psi_{\text{tension}} \text{max} + b$

[AS/NZS 4600, Figure 2.2.1] ψ_{max} 7,207 [mm]

f_{tension}	350.000	[MPa]	y_{cg}	25.652	[mm]
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Office: ---		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Portrait configuration, according to AISI or AS/NZS			
Code: A/S [AS/NZS]	Reference: AISI S100 [AS/NZS 4600] EN 1993		
Version: 1,000			

$f_{c,compress} = 319.633$ [MPa] | $m = 12,460$ | $f_{t,tension} = -350.000$ [MPa]

$E = 210,000$ [GPa] | $r = 319,633$ [MPa] | $s = 32,309$ []

$S = 1.28 \sqrt{E/f^*}$ [AS/NZS, Eq. 2.4.2(13)]

$b_1 \leq 0.229 \cdot S$ | $b_2 \leq 0.229 \cdot S$

$l_e = 0,000$ [no edge stiffener needed] | $l_e = \dots$ [edge stiffener needed]

$b_1 = b$ | $b_2 = [b_1/2] \cdot l_e/l_1$

$b_1 = b_2 = b/2$ | $b_1 = b_2 = b_1$

$d_e = d_{st}$ | $d_e = d_{st} \cdot [l_e/l_1]$

$b_1 = 17,279$ Edge stiffener needed | $0,229 \cdot S = 10,761$

$I_x = 3997 \cdot \left(\frac{b \cdot t}{S} - 0.328 \right)^2 \leq r^2 \left[115 \frac{b \cdot t}{S} + 5 \right]$ Adequate moment of inertia of stiffener, so that each component element will behave as a stiff element [AS/NZS 4600, Eq. 2.4.2(11)]

$l_e = 2,890$ [mm] | $\leq 54,743$ → OK

$I_s/I_0 \leq 1$ [AS/NZS 4600] | $I_s = (d^3 t \sin^2 \theta) / 12$ [AS/NZS 4600, Eq. 2.4.2(119)]

$\phi_s = 45,000$ [°] → $l_s = 179,857$ [mm]

$[l_e/l_1] = 66,790 \leq 1,000$ → KO → $[l_e/l_1] = 1,000$

$n = \left[0.582 \frac{b \cdot t}{4S} \right] \leq \frac{1}{3}$ [AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2.3]

Simple Lip Edge Stiffener [140° ≤ θ ≤ 40°]

$d/b \leq 0,250$ | $0,250 < d/b \leq 0,400$

$3,570 \cdot [l_e/l_1]^2 + 0,430 \leq 4,000$ | $[4,805 \cdot 10^{-5} \cdot d/b]^2 \cdot [l_e/l_1]^2 + 0,430 \leq 4,000$

OK | $140^\circ \leq \theta_s = 45,000$ [°] | $\leq 40^\circ$ → OK

$n = 0,450 \geq 1/3$ → OK → $n = 0,250$

[AS/NZS 4600, Table 2.4.2] | $d/b = 0,436$ → $k = 3,072$ → OK

D-Section Purlin Dimension

$b_{top,average} = 16,245$ [mm] | **NOTE** | $b = b_{top,average}$

$E = 210,000$ [GPa] | $t = 0,952$ [mm] | $v = 0,300$

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Code: AISI [AS/NZS]	Reference: AISI S100 [AS/NZS 4600] EN 1993		
Version: 1,000			

$f_{c,compress} = 319.633$ [MPa] | $m = 12,460$ | $f_{t,tension} = -350.000$ [MPa]

$E = 210,000$ [GPa] | $t = 0,952$ [mm] | $v = 0,300$

$b_{top,average} = 16,245$ [mm]

Tension Stress is reached!

1st Iteration | $f_{max,tension} = 350.000$ [MPa] | $y_{max} = 25,652$ [mm]

$f_{c,compress} = 319.633$ [MPa] | $m = 12,460$ | $f_{t,tension} = -350.000$ [MPa]

$b_1 = 55,835$ [mm] | $b_2 = 42,170$ [mm] | $b_1/b_2 = 1,324$ []

Out-Of-Plane Dimensions of Webs and Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-2]

For webs under stress gradient [f_c in compression and f_t in tension]

$b_1/b_2 \leq 4$ | $b_1/b_2 > 4$

$b_1 = b_2 [1.3 + \psi]$ | $b_1 = b_2 [1.3 + \psi]$

$\psi > 0,236$ | $b_1 = b_2 \cdot 1,2$ | $b_1 = b_2 [1 + \psi] - b_2$

$\psi \leq 0,236$ | $b_1 = b_2 = b_1$

$b_1 + b_2 \leq$ Compression portion of the web calculated on the basis of effective section

$f_c = 299,965$ [MPa] | $m = 12,460$ | $f_t = -350,332$ [MPa]

$\psi = |f_2/f_1|$ [AISI S100, Eq. B2.3-1] | $\psi = 1,101$

For webs under stress gradient [f_c in compression and f_t in tension]

$k = 4 + 2(1 + \psi)^2 + 2(1 + \psi)$ [AISI S100, Eq. B2.3-2] | $k = 26,757$

D-Section Purlin Dimension

NOTE | $W = b_{top,average}$

$b_{top,average} = 16,245$ [mm]

$E = 210,000$ [GPa] | $t = 0,952$ [mm] | $v = 0,300$

$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{W} \right)^2$ [AISI S100, Eq. (B2.3-5)] | $F_{cr} = 1,725,960$ [MPa]

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Version: 1,000			

$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$ [AISI S100, Eq. 2.2.1.2(5)] | $f_{cr} = 1,930,381$ [MPa]

$\lambda = \left(\frac{r}{f_{cr}} \right)$ [AS/NZS 4600, Eq. 2.2.1.2(4)] | $r = 319,633$ [MPa] | $\lambda = 0,407$ | $\rho = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$ [AS/NZS 4600, Eq. 2.2.1.2(6)]

$\rho = 1,000$ → $b_{top,average} = 16,245$ [mm]

$b_{top,average} = 8,273$ [mm] | $b_{top,average} = 8,273$ [mm]

AISI S100 [Effective Width] [mm] | Comparison \leq or \geq | AS/NZS 4600 [Effective Width] [mm]

$b_{top,average} = 8,273$ | $b_{top,average} = 8,273$

$b_{top,average} = 8,273$ | $b_{top,average} = 8,273$

Right Web [$b_{top,average}$] | [AISI S100, Section B2.3]

Actual Element | Effective Elements and Stiffeners under an Effective Element

Web and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-4]

D-Section Purlin Stress Gradient

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Version: 1,000			

$\lambda = \sqrt{\frac{r}{F_{cr}}}$ [AISI S100, Eq. B2.3-4] | $r = 319,633$ [MPa] | $\lambda = 0,417$ | $\rho = (1 - 0,22/\lambda) / \lambda$ [AISI S100, Eq. B2.3-6]

$\rho = 1,000$ → $b_{top,average} = 16,245$ [mm]

$b_1 = b_{top,average} = 16,245$ [mm]

$b_1/b_2 = 1,324$

$\psi = 1,101$

$b_1 = b_2 [1.3 + \psi] = 12,591$ [mm]

$b_1/b_2 \leq 4$ | $b_1/b_2 > 4$

$\psi > 0,236$ | $b_1 = b_2 \cdot 1,2 = 20,820$ [mm] | $b_1 = b_2 [1 + \psi] - b_2 = \dots$ [mm]

$\psi \leq 0,236$ | $b_1 = b_2 = b_1$

$b_1 + b_2 \leq W_{web}$ KO | Web is fully effective | **No more iteration!**

$b_{top,average} = 12,591$ [mm] | $b_{top,average} = 11,968$ [mm]

Right Web [$b_{top,average}$] | [AS/NZS 4600, Clause 2.2.3]

Actual Element | Effective element and stiffeners under an effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]

$y_{max} = 25,652$ [mm] | $y_{max} = 20,969$ [mm]

Tension Stress is reached!

1st Iteration | $f_{max,tension} = 350.000$ [MPa] | $y_{top} = 25.652$ [mm]

D-Section Profile: Stress Gradient

$f_{tension} = 25.852$ [MPa] $f_{compression} = 28.089$ [MPa]

Tension Stress is reached!

1st Iteration

$f_{tension} = 350.000$ [MPa] $\lambda_{CG} = 25.652$ [mm]

$f_{compression} = 319.603$ [MPa] $f_{tension} = -350.000$ [MPa]

$f_{tension} = 299.965$ [MPa] $f_{tension} = -330.332$ [MPa]

$\psi = \frac{f_2}{f_1} = -1,101$ [AS/NZS 4600, Eq. 2.2.3.2(9)]

$k = 4 + 2(1 - \psi)^3 + 2(1 - \psi) = 26,757$ [AS/NZS 4600, Eq. 2.2.3.2(8)]

D-Section Profile Dimension **NOTE** $b \leq b_{p,limit}$

$b_{p,limit} = 51.840$ [mm]

$E = 210.000$ [GPa] $t = 0,952$ [mm] $v = 0,300$

$f_{cr} = \left(\frac{k \pi^2 E}{12(1 - \nu^2)} \right) \left(\frac{t}{b} \right)^2 = 1725,969$ [MPa] [AS/NZS 4600, Eq. 2.2.1.2(9)]

$f_{compression} = 319.603$ [MPa] $m = 12,460$ $f_{tension} = -350.000$ [MPa]

$S = 1.28 \sqrt{E/t}$ [AISI S100, Eq. B4.7]

$w \leq 0,328 \cdot S$ $w \leq 0,328 \cdot S$

$l_e = 0,000$ no edge stiffener needed $l_e = \dots$ edge stiffener is needed

$b = w$ $b_e = [3 + 2] \cdot R$

$b_1 = b_2 = b/2$ $b_1 = b_2 = b_e$

$d_1 = d_2$ $d_1 = d_2 = [1/4] \cdot R$

$w \leq 17,279$ Edge stiffener is needed $0,328 \cdot S = 10,761$

$I_y = 3999 \cdot t^3 \left[\frac{w/l_e - 0,328}{S} \right]^3 \leq t^3 \left[113 \frac{w/l_e - 5}{S} \right]$ Adequate moment of inertia of stiffener for 1st and 2nd component element will behave as a stiffened element [AISI S100, Eq. B4.6]

$l_e = 2.890$ [mm] $s = 54,143$ → OK

$(R)_y = I_y/I_G \leq 1$ **$I_y = (d^3 t \sin^2 \theta) / 12$** [AISI S100, Eq. B4.9] [AISI S100, Eq. B4.10]

$\phi_y = 45,000$ [°] $l_y = 179,657$ [mm]

$|R| = 66,790 < 1,000$ → KO → $|R| = 1,000$

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4.1]

Simple Lip Edge Stiffener | $140^\circ \leq \theta \leq 40^\circ$

$D1 \leq 0,250$ $0,250 < D1 \leq 0,800$

$3,070 \cdot |R| \cdot t^3 + 0,430 \leq 4,000$ $4,420 \cdot |R| \cdot t^3 + 0,430 \leq 4,000$

OK 14012 $\phi_y = 45,000$ [°] $\lambda \geq 40^\circ$ OK

$n = 0,650$ $\lambda \geq 1,3 \cdot ?$ OK → $n = 0,650$

[AISI S100, Table B4.1] $D1 \leq w$ $k = 3,072$ OK

D-Section Profile Dimension **NOTE** $w \leq b_{p,limit}$

$b_{p,limit} = 16,545$ [mm]

$E = 210.000$ [GPa] $t = 0,952$ [mm] $v = 0,300$

$\lambda = \sqrt{\frac{f}{f_{cr}}} = 299,965$ [MPa] $r = c$ $\rho = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$ [AS/NZS 4600, Eq. 2.2.1.2(4)] [AS/NZS 4600, Eq. 2.2.1.2(9)]

$\lambda = 0,617$

$\rho = 1,000$ → $b_{p,limit} = 51,840$ [mm]

$b_{c1} = \frac{b_c}{3 - \psi}$ $b_{c2} = \frac{b_c}{2}$ $b_{c2} = b_c - b_{c1}$

[AS/NZS 4600, Eq. 2.2.3.2(1)] [AS/NZS 4600, Eq. 2.2.3.2(1)] [AS/NZS 4600, Eq. 2.2.3.2(9)]

$b_c = b_{p,limit} = 51,840$ [mm]

$\psi = -1,101$

$b_{c1} = b_c [1 - \psi] = 12,591$ [mm]

$\psi \leq -0,238$ $b_1 = b_1/2 = 25,820$ [mm] $\psi > -0,238$ $b_{c1} = b_{c1} - b_{c2}$ [mm]

$b_{c1} + b_{c2} \leq$ Compression portion of the web calculated on the basis of effective section

$b_{c1} + b_{c2} \leq b_{p,limit}$ KO Web is fully effective **No more Retention!**

$b_{p,limit} = 12,591$ [mm] $b_{p,limit} = 11,985$ [mm]

AISI S100, Effective Width [mm] Comparison $\lambda \leq \lambda_1$ **AS/NZS 4600, Effective Width [mm]**

$b_{p,limit} = 12,591$ $b_{p,limit} = 12,591$

$b_{p,limit} = 11,985$ $b_{p,limit} = 11,985$

Inferior Lip Flange [b_{p,limit}] [AISI S100, Section B4.1]

D-Section Profile Dimension

$\phi_{y,limit} = 6,791$ [mm]

$b_{p,limit} = 16,545$ [mm]

$t = 0,952$ [mm]

$\phi_{y,limit} \leq 4 [b_{p,limit} \leq b]$

$\phi_{y,limit} = 7,207$ [mm]

$f_{tension} = 350.000$ [MPa] $\lambda_{CG} = 25.652$ [mm]

$f_{compression} = 319.603$ [MPa] $m = 12,460$ $f_{tension} = -350.000$ [MPa]

$S = 1.28 \sqrt{E/t}$ [AS/NZS, Eq. 2.4.2(9)]

$b \leq 0,328 \cdot S$ $b \leq 0,328 \cdot S$

$l_e = 0,000$ no edge stiffener needed $l_e = \dots$ edge stiffener is needed

$b_e = b$ $b_e = [3 + 2] \cdot [1/4] \cdot R$

$b_1 = b_2 = b/2$ $b_1 = b_2 = b_e$

$d_1 = d_2$ $d_1 = d_2 = [1/4] \cdot R$

$b \leq 17,279$ Edge stiffener is needed $0,328 \cdot S = 10,761$

D-Section Profile Dimension

$\phi_{y,limit} = 6,791$ [mm]

$b_{p,limit} = 16,545$ [mm]

$t = 0,952$ [mm]

$\phi_{y,limit} \leq 4 [b_{p,limit} \leq b]$

$\phi_{y,limit} = 7,207$ [mm]

$f_{tension} = 350.000$ [MPa] $\lambda_{CG} = 25.652$ [mm]

$F_{cr} = k \frac{\pi^2 E}{12(1 - \mu^2)} \left(\frac{t}{w} \right)^2$ $F_{cr} = 1930,381$ [MPa] [AISI S100, Eq. (B2.1-6)]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $r = c$ $\rho = (1 - 0,22/\lambda) \cdot \lambda$

[AISI S100, Eq. B2.1-4] $\lambda = 0,607$ [AISI S100, Eq. B2.1-4]

$\rho = 1,000$ → $b_{p,limit} = 16,545$ [mm]

$b_{p,limit} = 8,273$ [mm] $b_{p,limit} = 8,273$ [mm]

Inferior Lip Flange [b_{p,limit}] [AS/NZS 4600, Clause 2.4.1]

[AS/NZS 4600, Figure 2.4.1]

D-Section Profile Dimension

$\phi_{y,limit} = 6,791$ [mm]

$b_{p,limit} = 16,545$ [mm]

$t = 0,952$ [mm]

$\phi_{y,limit} \leq 4 [b_{p,limit} \leq b]$

$\phi_{y,limit} = 7,207$ [mm]

$f_{tension} = 350.000$ [MPa] $\lambda_{CG} = 25.652$ [mm]

$f_{compression} = 319.603$ [MPa] $m = 12,460$ $f_{tension} = -350.000$ [MPa]

$S = 1.28 \sqrt{E/t}$ [AS/NZS, Eq. 2.4.2(9)]

$b \leq 0,328 \cdot S$ $b \leq 0,328 \cdot S$

$l_e = 0,000$ no edge stiffener needed $l_e = \dots$ edge stiffener is needed

$b_e = b$ $b_e = [3 + 2] \cdot [1/4] \cdot R$

$b_1 = b_2 = b/2$ $b_1 = b_2 = b_e$

$d_1 = d_2$ $d_1 = d_2 = [1/4] \cdot R$

$b \leq 17,279$ Edge stiffener is needed $0,328 \cdot S = 10,761$

D-Section Profile Dimension

$\phi_{y,limit} = 6,791$ [mm]

$b_{p,limit} = 16,545$ [mm]

$t = 0,952$ [mm]

$\phi_{y,limit} \leq 4 [b_{p,limit} \leq b]$

$\phi_{y,limit} = 7,207$ [mm]

$f_{tension} = 350.000$ [MPa] $\lambda_{CG} = 25.652$ [mm]

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$I_x = 3909 I^4 \left[\frac{(h/r)^2}{S} - 0.328 \right] \leq I^4 \left[115 \frac{(h/r)^2}{S} + 5 \right]$ [AS/NZS 4600, Eq. 2.4.2(1)]

Adequate moment of inertia of stiffener, so that each component element will behave as a flexed element

$I_y/I_x \leq 1$ [AS/NZS 4600]

$I_y = (d^3 t \sin^2 \theta) / 12$ [AS/NZS 4600, Eq. 2.4.2(119)]

$\phi_x = 45.200$ [°] → $\phi_y = 179.857$ [mm²]

$[I_y/I_x] = 66.790 < 1.000$ → OK → $[I_y/I_x] = 1.000$

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Single Lip Edge Stiffener [140°2.8 x 40°]

$d/b \leq 0.250$ | $0.250 < d/b \leq 0.300$ | $0.300 < d/b \leq 0.400$ | $0.400 < d/b \leq 0.500$ | $0.500 < d/b \leq 0.600$ | $0.600 < d/b \leq 0.700$ | $0.700 < d/b \leq 0.800$ | $0.800 < d/b \leq 0.900$ | $0.900 < d/b \leq 1.000$

OK | 1.401 ≤ $\phi_x = 45.200$ [°] | 2.40° OK

$n = 0.650$ | $n \leq 1.13.9$ OK → $n = 0.650$

[AS/NZS 4600, Table 2.4.2] | $d/b = 0.436$ → $k = 3.072$ OK

D-Section Partin Dimension

$b_{flange} = 16.545$ [mm]

$E = 210.000$ [GPa] | $\nu = 0.352$ [mm] | $\nu = 0.300$

$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$ | $f_{cr} = 1930.281$ [MPa]

$\lambda = \sqrt{\frac{f}{f_{cr}}}$ [AS/NZS 4600, Eq. 2.2.1.2(4)] | $\Gamma = \Gamma_y = 319.833$ [MPa] | $\rho = \frac{(1-0.22/\lambda)}{\lambda} \leq 1.0$ [AS/NZS 4600, Eq. 2.2.1.2(5)]

$\rho = 1.000$ → $b_{flange} = 16.545$ [mm]

$b_{flange} = 8.273$ [mm] | $b_{flange} = 8.273$ [mm]

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$\lambda = \sqrt{\frac{f}{f_{cr}}}$ [AISI S100, Eq. B2.1-4] | $\Gamma = \Gamma_y = 312.421$ [MPa] | $\rho = (1-0.22/\lambda)/\lambda$ [AISI S100, Eq. B2.1-4]

$\lambda = 0.375$

$\rho = 1.000$ → $b_{flange} = 8.191$ [mm]

Left Edge Stiffener [AS/NZS 4600, Clause 2.3.2]

D-Section Partin Stress Gradient

Unstiffened Elements with Stress Gradient: Both Edges in Compression [AS/NZS 4600, Figure B2.2.2(a)]

$f_{tension} = 350.000$ [MPa] | Yes | 25.652 [mm]

$f_{compression} = 319.633$ [MPa] | $m = 12.460$ | $f_{tension} = -350.000$ [MPa]

$f_1 = 312.421$ [MPa] | $m = 12.460$ | $f_2 = 257.670$ [MPa]

$\psi = f_2 / f_1$ | $\psi = 0.825$ [AS/NZS 4600, Eq. 2.3.2.2(1)]

f_1 Compression | $k = \frac{0.578}{\psi + 0.34}$ | $k = 0.498$ [AS/NZS 4600, Eq. 2.3.2.2(2)]

D-Section Partin Dimension

$b_{flange} = 8.191$ [mm]

$E = 210.000$ [GPa] | $\nu = 0.352$ [mm] | $\nu = 0.300$

$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$ | $f_{cr} = 2225.583$ [MPa]

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Version: 1.000		Client: COIMBRA UNIVERSITY	

AISI S100, Effective Width [mm] | Compression $\rho = \text{or } 1$ | AS/NZS 4600, Effective Width [mm]

$b_{flange} = 8.273$ | $b_{flange} = 8.273$

Left Edge Stiffener [AS/NZS 4600, Clause 2.3.2]

D-Section Partin Stress Gradient

Unstiffened Elements with Stress Gradient: Both Longitudinal Edges in Compression [AISI S100, Figure B3.2-1]

$f_{tension} = 350.000$ [MPa] | $\lambda = 25.652$ [mm]

$f_{compression} = 319.633$ [MPa] | $m = 12.460$ | $f_{tension} = -350.000$ [MPa]

$f_1 = 312.421$ [MPa] | $m = 12.460$ | $f_2 = 257.670$ [MPa]

$\psi = [f_2 / f_1]$ [AISI S100, Eq. B3.2-1] | $\psi = 0.825$

f_1 Compression | $k = \frac{0.578}{\psi + 0.34}$ | $k = 0.498$ [AISI S100, Eq. B3.2-2]

D-Section Partin Dimension

$b_{flange} = 8.191$ [mm]

$E = 210.000$ [GPa] | $\nu = 0.352$ [mm] | $\nu = 0.300$

$w = 8.191$ [mm] → $w \leq 60$ OK

$F_{cr} = k \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{w} \right)^2$ | $F_{cr} = 2225.583$ [MPa]

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$\lambda = \sqrt{\frac{f}{f_{cr}}}$ [AS/NZS 4600, Eq. 2.2.1.2(4)] | $\Gamma = \Gamma_y = 312.421$ [MPa] | $\rho = \frac{(1-0.22/\lambda)}{\lambda} \leq 1.0$ [AS/NZS 4600, Eq. 2.2.1.2(5)]

$\lambda = 0.375$

$\rho = 1.000$ → $b_{flange} = 8.191$ [mm]

AISI S100, Effective Width | Compression $\rho = \text{or } 1$ | AS/NZS 4600, Effective Width

$b_{flange} = 8.191$ | $b_{flange} = 8.191$

Effective D-Section Partin [Local Buckling]

Effective D-Section Partin Width [AISI S100]

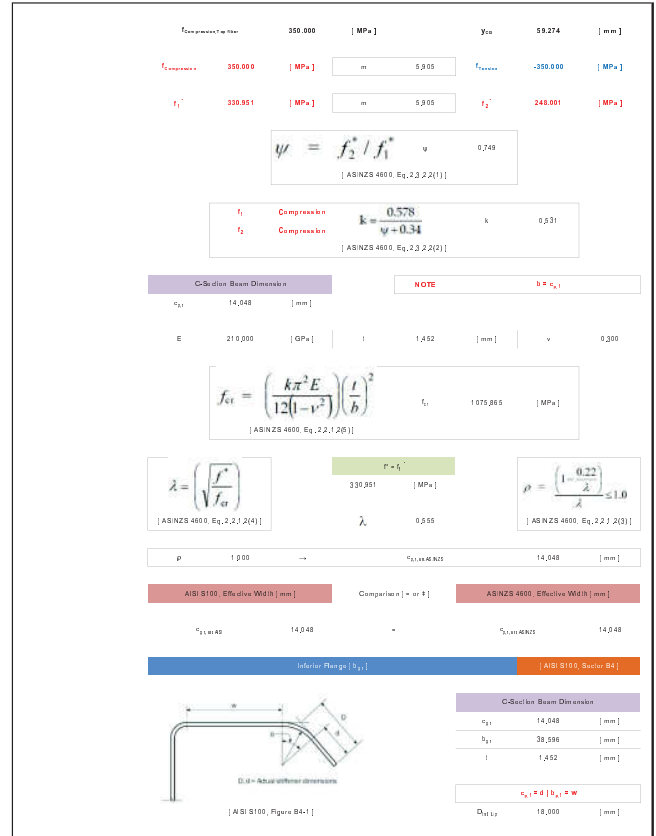
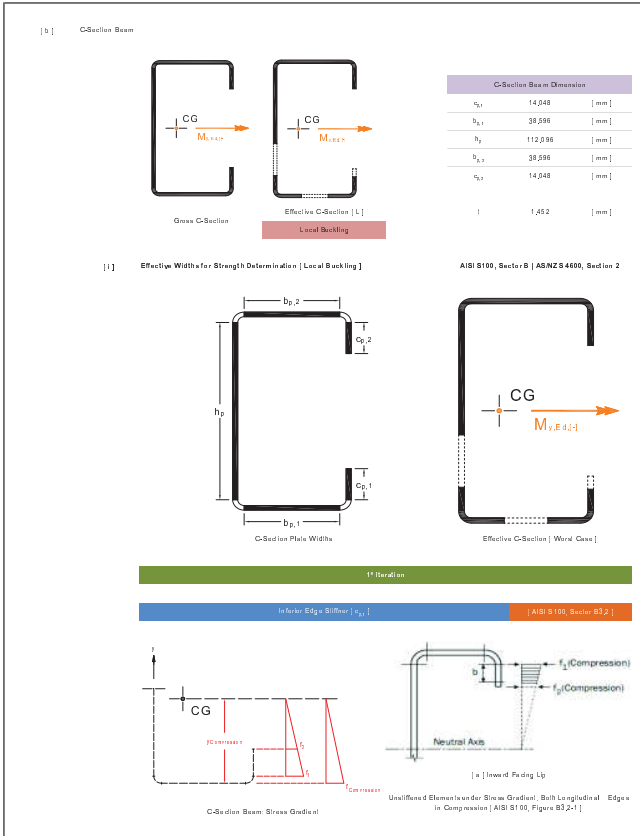
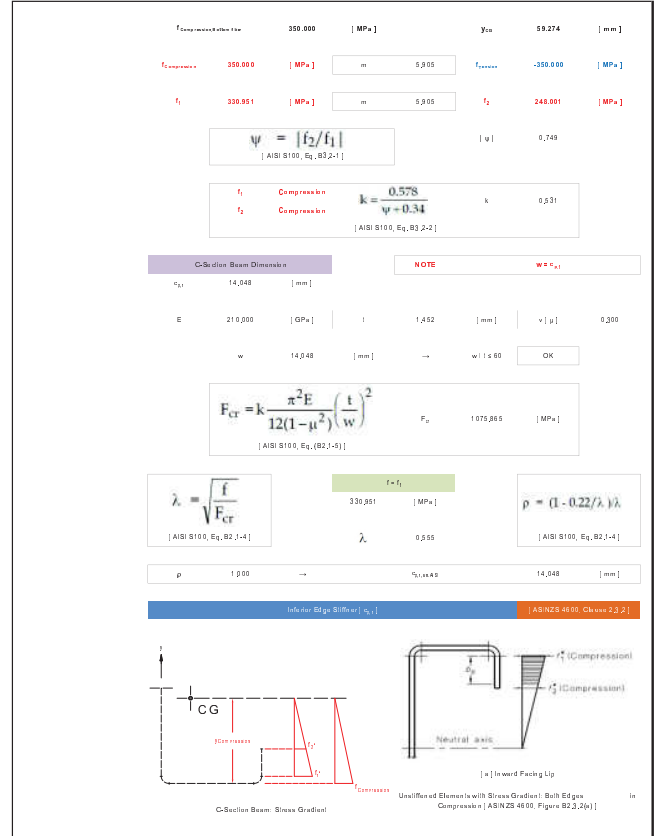
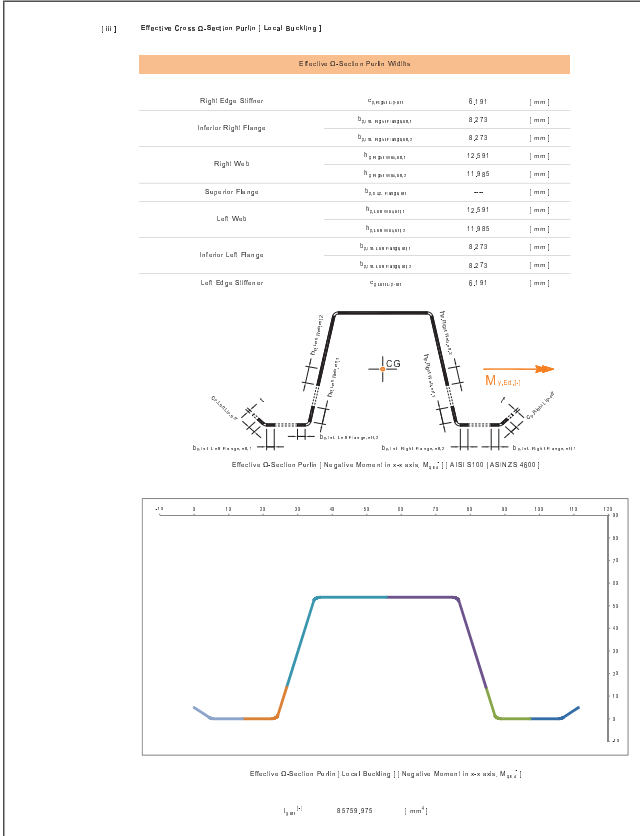
Right Edge Stiffener	$b_{flange} = 8.191$ [mm]
Inferior Right Flange	$b_{flange} = 16.545$ [mm]
Right Web	$b_{flange} = 51.640$ [mm]
Superior Flange	$b_{flange} = \dots$ [mm]
Left Web	$b_{flange} = 51.640$ [mm]
Inferior Left Flange	$b_{flange} = 16.545$ [mm]
Left Edge Stiffener	$b_{flange} = 8.191$ [mm]

Effective D-Section Partin Width [AS/NZS 4600]

Right Edge Stiffener	$b_{flange} = 8.191$ [mm]
Inferior Right Flange	$b_{flange} = 16.545$ [mm]
Right Web	$b_{flange} = 51.640$ [mm]
Superior Flange	$b_{flange} = \dots$ [mm]
Left Web	$b_{flange} = 51.640$ [mm]
Inferior Left Flange	$b_{flange} = 16.545$ [mm]
Left Edge Stiffener	$b_{flange} = 8.191$ [mm]

Effective D-Section Partin Width [AISI S100 | AS/NZS 4600]

Right Edge Stiffener	$b_{flange} = 8.191$ [mm]
Inferior Right Flange	$b_{flange} = 16.545$ [mm]
Right Web	$b_{flange} = 51.640$ [mm]
Superior Flange	$b_{flange} = \dots$ [mm]
Left Web	$b_{flange} = 51.640$ [mm]
Inferior Left Flange	$b_{flange} = 16.545$ [mm]
Left Edge Stiffener	$b_{flange} = 8.191$ [mm]



$S = 1.28\sqrt{E/t}$ [AISI S100, Eq. B4-7]

$E = 210,000$ [GPa]
 $t = 3,500$ [MPa]
 $S = 31,353$ []

$w \leq 0,328 \cdot S$ | $w \leq 0,328 \cdot S$
 $l_e = 0,000$ [no edge stiffener needed] | $l_e = \dots$ [edge stiffener needed]
 $b = w$ | $b_1 = [b/2] \cdot [R]$
 $b_2 = b - b_1$ | $b_2 = b - b_1$
 $d_e = d_e$ | $d_e = d_e \cdot [R]$

$w \leq$ | 26,881 | Edge stiffener needed | 0,328 · S | 10,284

$I_x = 399t^4 \left[\frac{w/t - 0,328}{S} \right]^3 \leq t^4 \left[115 \frac{w/t + 5}{S} \right]$ [AISI S100, Eq. B4-8]
 Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element.

$I_x = 249,076$ [mm⁴] | \leq | 455,590 | → | OK

$(R_1) = I_s/I_0 \leq 1$ [AISI S100, Eq. B4-8] | **$I_s = (d^3 t \sin^2 \theta)/12$** [AISI S100, Eq. B4-10]

$[R_1] = 27,931$ | \leq | 1,000 | → | KO | → | $[R_1] = 1,000$

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]
 Single Lip Edge Stiffener | $140^\circ \leq \theta \leq 40^\circ$
 $D \cdot l_w \leq 0,250$ | $0,250 < D \cdot l_w \leq 0,900$
 $3,370 \cdot [R_1] \cdot t \cdot 0,430 \leq 4,000$ | $[4,820 - (5 \cdot D \cdot l_w)] \cdot [R_1] \cdot t \cdot 0,430 \leq 4,000$

OK | $140^\circ \geq$ | $\theta_1 = 99,000$ [°] | $\geq 40^\circ$ | OK
 $n = 0,370$ | $\geq 1/3$? | OK | → | $n = 0,370$

[AISI S100, Table B4-1] | $D \cdot l_w = 0,466$ | → | $k = 2,918$ | OK

C-Section Beam Dimension | **NOTE** | **$w \neq b_{fl}$**

$b_{fl} = 38,596$ [mm]
 $E = 210,000$ [GPa] | $t = 1,452$ [mm] | $v [u] = 0,300$

$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$ [AS/NZS 4600, Eq. 2.2.1.2(6)]
 $f_{cr} = 793,386$ [MPa]

$\lambda = \sqrt{\frac{f}{f_{cr}}}$ [AS/NZS 4600, Eq. 2.2.1.2(4)] | $f = 350,000$ [MPa] | $\lambda = 0,668$ | **$\rho = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$** [AS/NZS 4600, Eq. 2.2.1.2(3)]

$\rho = 1,000$ | → | $b_{fl,AS/NZS} = 38,596$ [mm]

$b_{fl,AISI S100} = 19,298$ [mm] | $b_{fl,AS/NZS} = 19,298$ [mm]

AISI S100, Effective Width [mm] | Comparison | $w \neq b_{fl}$ | **AS/NZS 4600, Effective Width [mm]**

$b_{fl,AISI S100} = 19,298$ | $b_{fl,AS/NZS} = 19,298$
 $b_{fl,AISI S100} = 19,298$ | $b_{fl,AS/NZS} = 19,298$

$I_s/I_0 \leq 1$ [AS/NZS 4600] | **$I_s = (d^3 t \sin^2 \theta)/12$** [AS/NZS 4600, Eq. 2.2.2(10)]

$\theta_1 = 99,000$ [°] | → | $l_e = 6956,844$ [mm⁴]
 $[l_e/l_e] = 27,931$ | $< 1,000$ | → | KO | → | $[l_e/l_e] = 1,000$

$W = \left[\frac{0,582 - (h/t)}{4S} \right] \geq \frac{1}{3}$ [AS/NZS 4600, Eq. 2.2.2(12)] | **Determination of Plate Buckling Coefficient, k** [AS/NZS 4600, Table 2.4.2]
 Single Lip Edge Stiffener | $140^\circ \geq \theta \geq 40^\circ$
 $d \cdot l_b \leq 0,250$ | $0,250 < d \cdot l_b \leq 0,900$
 $3,370 \cdot [l_e/l_e] \cdot t \cdot 0,430 \leq 4,000$ | $[4,820 - (5 \cdot d \cdot l_b)] \cdot [l_e/l_e] \cdot t \cdot 0,430 \leq 4,000$

OK | $140^\circ \geq$ | $\theta_1 = 99,000$ [°] | $\geq 40^\circ$ | OK
 $n = 0,370$ | $\geq 1/3$? | OK | → | $n = 0,370$

[AS/NZS 4600, Table 2.4.2] | $d \cdot l_b = 0,466$ | → | $k = 2,918$ | OK

C-Section Beam Dimension | **NOTE** | **$w \neq b_{fl}$**

$b_{fl} = 38,596$ [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(6)]
 $f_{cr} = 793,386$ [MPa]

$\lambda = \sqrt{\frac{f}{f_{cr}}}$ [AS/NZS 4600, Eq. 2.2.1.2(4)] | $f = 350,000$ [MPa] | $\lambda = 0,668$ | **$\rho = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$** [AS/NZS 4600, Eq. 2.2.1.2(3)]

$\rho = 1,000$ | → | $b_{fl,AS/NZS} = 38,596$ [mm]

$b_{fl,AISI S100} = 19,298$ [mm] | $b_{fl,AS/NZS} = 19,298$ [mm]

AISI S100, Effective Width [mm] | Comparison | $w \neq b_{fl}$ | **AS/NZS 4600, Effective Width [mm]**

$b_{fl,AISI S100} = 19,298$ | $b_{fl,AS/NZS} = 19,298$
 $b_{fl,AISI S100} = 19,298$ | $b_{fl,AS/NZS} = 19,298$

$F_{cr} = k \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{w} \right)^2$ [AISI S100, Eq. B2.1-4] | $f_{cr} = 793,386$ [MPa]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ [AISI S100, Eq. B2.1-4] | $f = 350,000$ [MPa] | **$\rho = (1 - 0,22/\lambda)$** [AISI S100, Eq. B2.1-4]

$\rho = 1,000$ | → | $b_{fl,AS/NZS} = 38,596$ [mm]
 $b_{fl,AISI S100} = 19,298$ [mm] | $b_{fl,AS/NZS} = 19,298$ [mm]

Inferior Flange (b_{fl}) | **AS/NZS 4600, Class 2-2**

C-Section Beam Dimension
 $d_{fl} = 14,048$ [mm]
 $b_{fl} = 38,596$ [mm]
 $t = 1,452$ [mm]
 $r_{fl} = 0,4 [b_{fl}] \neq b$
 $d_{fl,AS/NZS} = 19,000$ [mm]

$S = 1.28\sqrt{E/f}$ [AS/NZS, Eq. 2.2.2(13)]
 $E = 210,000$ [GPa]
 $f = 350,000$ [MPa]
 $S = 31,353$ []

$b \leq 0,328 \cdot S$ | $b \leq 0,328 \cdot S$
 $l_e = 0,000$ [no edge stiffener needed] | $l_e = \dots$ [edge stiffener needed]
 $b_1 = b$ | $b_1 = [b/2] \cdot [l_e/l_e]$
 $b_2 = b - b_1$ | $b_2 = b - b_1$
 $d_e = d_e$ | $d_e = d_e \cdot [l_e/l_e]$

$b \leq$ | 26,881 | Edge stiffener needed | 0,328 · S | 10,284

$I_s = 399t^4 \left[\frac{(h/t) - 0,328}{S} \right]^3 \leq t^4 \left[115 \frac{(h/t)}{S} + 5 \right]$ [AS/NZS 4600, Eq. 2.2.2(11)]
 Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element.

$I_s = 249,076$ [mm⁴] | \leq | 455,590 | → | OK

Web (b_w) | **AISI S100, Section 2.3.1**

Actual Element | **Effective Element and Stress on Effective Elements**

Web and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.1-1]

C-Section Beam Stress Gradient

$f_{Tmax} = 350,000$ [MPa] | $f_{Tmin} = -350,000$ [MPa]
 $f_{Cmax} = 350,000$ [MPa] | $f_{Cmin} = -350,000$ [MPa]
 $f_1 = 350,000$ [MPa] | $f_2 = -350,000$ [MPa]

$y_{Tmax} = 59,274$ [mm] | $y_{Tmin} = 59,274$ [mm]
 $y_{Cmax} = 59,274$ [mm] | $y_{Cmin} = 59,274$ [mm]

Tension Stress is reached!

1st Iteration
 $f_{Cmax} = 350,000$ [MPa] | $y_{Cmax} = 59,274$ [mm]
 $f_{Tmax} = 350,000$ [MPa] | $y_{Tmax} = 59,274$ [mm]
 $f_1 = 350,000$ [MPa] | $f_2 = -350,000$ [MPa]

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Version: 1,000			

For Wbs under stress gradient [f₁ in compression and f₂ in tension]

$h_1, b_1 \leq 4$	$h_1, b_1 > 4$
$b_1 = b_1 | 3 + \psi$	$b_1 = b_1 | 3 + \psi$
$\psi > 0,236$ $b_2 = b_1 | 2$	$b_2 = b_1 | 1 + \psi - b_1$
$\psi \leq 0,236$ $b_2 = b_1 = b_1$	

$b_1 + b_2 \leq$ Compression portion of the Web calculated on the basis of effective section

$$\psi = \left| \frac{f_2 / f_1}{1} \right| \quad | \psi | \quad 1,000$$

For Wbs under stress gradient [f₁ in compression and f₂ in tension]

$$k = 4 + 2(1 + \psi)^3 + 2(1 - \psi) \quad k \quad 24,000$$

C-Section Beam Dimension **NOTE** $w \leq b_e$

h_1	112,096	[mm]
E	210,000	[GPa]
t	1,452	[mm]
v	0,300	

$$F_{cr} = k \frac{\pi^2 E}{12(1 - \mu^2)} \left(\frac{t}{w} \right)^2 \quad F_{cr} \quad 764,294 \quad [MPa]$$

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $f = f_1$ $\rho = (1 - 0,22/\lambda) \lambda$

λ	0,658
ρ	1,000
$\rho_{maxASIS}$	112,096
$\rho_{maxASNS}$	112,096

$b_1 = \rho_{maxASIS} = 112,096$ [mm]

$\psi = 0,300$

$b_2 = b_1 | 3 + \psi = 28,024$ [mm]

$\psi > 0,236$ $b_2 = b_1 | 2 = 56,048$ [mm] $\psi < 0,236$ $b_2 = b_1 = b_1 = 112,096$ [mm]

$b_1 + b_2 \leq w_{max}$ **NO** Web is fully effective **No more Iterations!**

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Version: 1,000			

$$k = 4 + 2(1 - \psi)^3 + 2(1 + \psi) \quad k \quad 24,000$$

C-Section Beam **NOTE** $b \leq b_e$

h_1	112,096	[mm]
E	210,000	[GPa]
t	1,452	[mm]
v	0,300	

$$f_{cr} = \left(\frac{k \pi^2 E}{12(1 - \nu^2)} \right) \left(\frac{t}{b} \right)^2 \quad f_{cr} \quad 764,294 \quad [MPa]$$

$\lambda = \sqrt{\frac{f}{f_{cr}}}$ $f = f_1$ $\rho = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$

λ	0,658
ρ	1,000
$\rho_{maxASIS}$	112,096
$\rho_{maxASNS}$	112,096

$b_1 = \rho_{maxASIS} = 112,096$ [mm]

$\psi = 0,300$

$b_2 = b_1 | 3 + \psi = 28,024$ [mm]

$\psi > 0,236$ $b_2 = b_1 | 2 = 56,048$ [mm] $\psi < 0,236$ $b_2 = b_1 = b_1 = 112,096$ [mm]

$b_1 + b_2 \leq w_{max}$ **NO** Web is fully effective **No more Iterations!**

$\rho_{maxASIS}$	28,024	[mm]	$\rho_{maxASNS}$	28,024	[mm]	
AISI S100, Effective Width [mm]	$\rho_{maxASIS}$	28,024	Comparison: $\rho \leq 1$	AS/NZS 4600, Effective Width [mm]	$\rho_{maxASNS}$	28,024
$\rho_{maxASIS}$	28,024			$\rho_{maxASNS}$	28,024	
$\rho_{maxASIS}$	28,024			$\rho_{maxASNS}$	28,024	

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$\rho_{maxASIS}$	28,024	[mm]	$\rho_{maxASNS}$	28,024	[mm]
Web [b ₁]		AS/NZS 4600, Clause 2.2.2			

Actual Element **Effective element and stress on effective Element**

Sifted Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]

C-Section Beam: Stress Gradient

$f_{t,max}$	59,274	[MPa]	$f_{c,max}$	59,274	[MPa]
-------------	--------	-------	-------------	--------	-------

Tension Stress is reached!

$f_{t,max}$	350,000	[MPa]	λ_{cr}	59,274	[mm]
$f_{c,max}$	350,000	[MPa]	$f_{t,max}$	350,000	[MPa]
f_1^*	330,951	[MPa]	f_2^*	330,951	[MPa]

$$\psi = \frac{f_2^*}{f_1^*} \quad \psi \quad 1,000$$

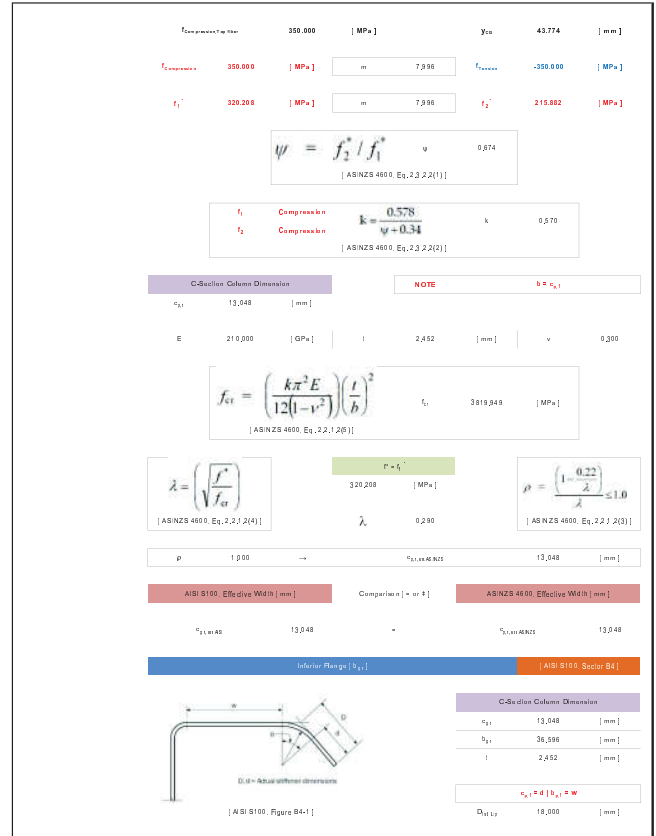
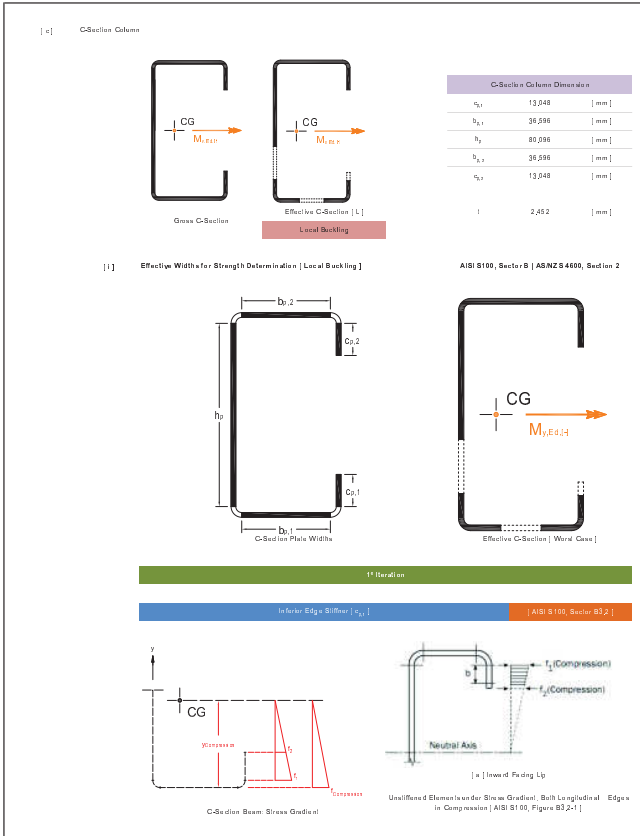
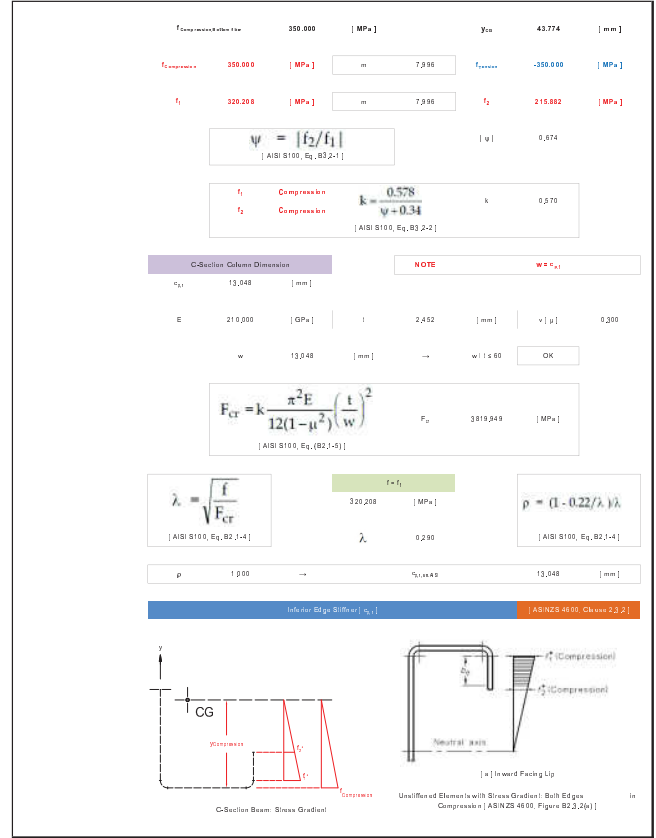
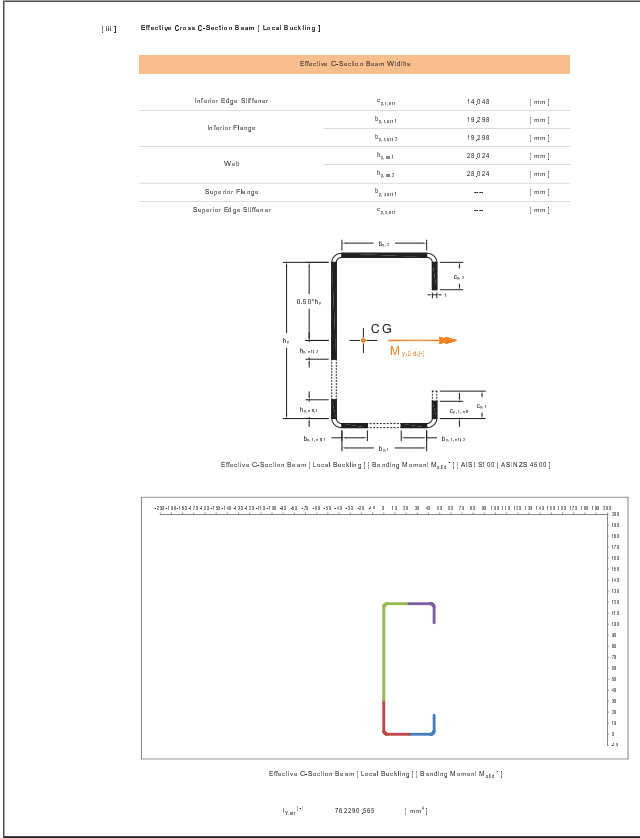
[AS/NZS 4600, Eq. 2.2.2(9)]

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Version: 1,000			

Superior Flange [b _{1f}]	ASIS S100, Section B4
NOTE	Zone in Tension, Effective width is equal to the real width
Superior Flange [b _{2f}]	AS/NZS 4600, Clause 2.4
NOTE	Zone in Tension, Effective width is equal to the real width
Superior Edge Stiffener [c _{1s}]	AISI S100, Section B3.2
NOTE	Zone in Tension, Effective width is equal to the real width
Superior Edge Stiffener [c _{2s}]	AS/NZS 4600, Clause 2.2.2
NOTE	Zone in Tension, Effective width is equal to the real width

[1] Effective C-Section Beam | Local Buckling

Effective C-Section Beam Widths | AISI S100			
Inferior Edge Stiffener	$\rho_{1,ASIS}$	14,048	[mm]
Inferior Flange	$\rho_{1,ASNS}$	38,556	[mm]
Web	$\rho_{1,ASIS}$	112,096	[mm]
Superior Flange	$\rho_{1,ASNS}$	---	[mm]
Superior Edge Stiffener	$\rho_{1,ASIS}$	---	[mm]
Effective C-Section Beam Widths | AS/NZS 4600			
Inferior Edge Stiffener	$\rho_{1,ASNS}$	14,048	[mm]
Inferior Flange	$\rho_{1,ASNS}$	38,556	[mm]
Web	$\rho_{1,ASNS}$	112,096	[mm]
Superior Flange	$\rho_{1,ASNS}$	---	[mm]
Superior Edge Stiffener	$\rho_{1,ASNS}$	---	[mm]
Effective C-Section Beam Widths | AISI S100 | AS/NZS 4600			
Inferior Edge Stiffener	$\rho_{1,ASIS}$	14,048	[mm]
Inferior Flange	$\rho_{1,ASNS}$	38,556	[mm]
Web	$\rho_{1,ASNS}$	112,096	[mm]
Superior Flange	$\rho_{1,ASNS}$	---	[mm]
Superior Edge Stiffener	$\rho_{1,ASNS}$	---	[mm]



$S_x = 1.28 \sqrt{E/t}$ [AISI S100, Eq. B4-7]

E	210,000	[GPa]
t	3,500	[MPa]
S	31,353	[]

$w \leq 0.328 \cdot S$ **$w \leq 0.328 \cdot S$**

$l_w = 0.000$ [no edge stiffener needed] $l_w = \dots$ [edge stiffener needed]

$b = w$ $b_1 = [b/2] \cdot [R]$

$b_1 = b_2 = b/2$ $b_2 = b - b_1$

$d_w = d_w$ $d_w = d_w \cdot [R]$

w/1: 14,925 Edge stiffener needed 0.328 · S 10,284

$I_x = 399t^4 \left[\frac{w/t - 0.328}{S} \right]^3 \leq t^4 \left[115 \frac{w/t + 5}{S} \right]$ [AISI S100, Eq. B4-8] Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element.

I_x 46,278 [mm⁴] ≤ 2159,263 → OK

$(R_1) = I_s/I_0 \leq 1$ [AISI S100, Eq. B4-8] **$I_s = (d^3 t \sin^2 \theta)/12$** [AISI S100, Eq. B4-10]

θ_1 99,000 [°] → I_s 10014,249 [mm⁴]

$[R_1]$ 214,992 ≤ 1,000 → KO → $[R_1]$ 1,000

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Simple Lip Edge Stiffener [140° ≤ θ ≤ 40°]

$D/w \leq 0.250$ 0.250 < D/w ≤ 0.900

$3.570 \cdot [R_1]^{1/4} \leq 0.430 \leq 4.000$ $[4.820 \cdot (5 \cdot D/w)^{1/4}] \cdot [R_1]^{1/4} \leq 0.430 \leq 4.000$

OK 140° > θ_1 99,000 [°] > 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 Flange Dimension NOTE w > b_{fl}

b _{fl}	36,596	[mm]
E	210,000	[GPa]
t	2,452	[mm]
v [μ]	0,300	

$I_s/I_0 \leq 1$ [AS/NZS 4600] **$I_s = (d^3 t \sin^2 \theta)/12$** [AS/NZS 4600, Eq. 2.2.2(10)]

θ_1 99,000 [°] → I_s 10014,249 [mm⁴]

$[I_s/I_0]$ 214,992 ≤ 1,000 → KO → $[I_s/I_0]$ 1,000

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Simple Lip Edge Stiffener [140° ≤ θ ≤ 40°]

$D/w \leq 0.250$ 0.250 < D/w ≤ 0.900

$3.570 \cdot [R_1]^{1/4} \leq 0.430 \leq 4.000$ $[4.820 \cdot (5 \cdot D/w)^{1/4}] \cdot [R_1]^{1/4} \leq 0.430 \leq 4.000$

OK 140° > θ_1 99,000 [°] > 40° OK

n = 0,463 ≥ 1/3 ? OK → n = 0,463

[AS/NZS 4600, Table 2.4.2] D/w 0,492 → k = 2,791 OK

C-Section Column Dimension NOTE b > b_{fl}

b _{fl}	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(26)] f_{cr} 2377,956 [MPa]

$\lambda = \sqrt{\frac{f'}{f_{cr}}}$ f' = 350,000 [MPa] λ = 0,384 **$\rho = \left(1 - \frac{0.22}{\lambda} \right) \leq 1.0$** [AS/NZS 4600, Eq. 2.2.1(28)]

ρ 1,000 → b_{eff,AS/NZS} 36,596 [mm]

b _{fl,AS/NZS1}	18,298	[mm]	b _{fl,AS/NZS2}	18,298	[mm]
b _{fl,AS/NZS1}	18,298		b _{fl,AS/NZS1}	18,298	
b _{fl,AS/NZS1}	18,298		b _{fl,AS/NZS1}	18,298	

AISI S100, Effective Width [mm] Comparison | = w/1 **AS/NZS 4600, Effective Width [mm]**

$F_{cr} = k \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{w} \right)^2$ [AISI S100, Eq. B2.1-4] F_{cr} 2377,956 [MPa]

$\lambda = \sqrt{\frac{f'}{F_{cr}}}$ [AISI S100, Eq. B2.1-4] f' = 350,000 [MPa] λ = 0,384 **$\rho = (1 - 0.22/\lambda)$** [AISI S100, Eq. B2.1-4]

ρ 1,000 → b_{eff,AS/NZS} 36,596 [mm]

b_{fl,AS/NZS1} 18,298 [mm] b_{fl,AS/NZS2} 18,298 [mm]

Inferior Flange [b_{fl}] [AS/NZS 4600, Class 2-2]

C-Section Column Dimension

b _{fl}	12,048	[mm]
b _{fl}	36,596	[mm]
t	2,452	[mm]

$\rho_{fl} \leq 0.1 \rho_{fl} \leq b$

$\rho_{fl,AS/NZS}$ 19,000 [mm]

$S_x = 1.28 \sqrt{E/f'}$ [AS/NZS, Eq. 2.2.2(13)]

E	210,000	[GPa]
f'	350,000	[MPa]
S	31,353	[]

$b \leq 0.328 \cdot S$ **$b \leq 0.328 \cdot S$**

$l_w = 0.000$ [no edge stiffener needed] $l_w = \dots$ [edge stiffener needed]

$b_1 = b$ $b_1 = [b/2] \cdot [R]$

$b_1 = b_2 = b/2$ $b_2 = b - b_1$

$d_w = d_w$ $d_w = d_w \cdot [R]$

b/1: 14,925 Edge stiffener needed 0.328 · S 10,284

$I_x = 399t^4 \left[\frac{b/t - 0.328}{S} \right]^3 \leq t^4 \left[115 \frac{b/t + 5}{S} \right]$ [AS/NZS 4600, Eq. 2.2.2(11)] Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element.

I_x 46,278 [mm⁴] ≤ 2159,263 → OK

Web [b_w] [AISI S100, Section B2.3]

Actual Element **Effective Element and Stress under Effective Elements**

Web and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]

C-Section Beam Stress Gradient

y_{top} 43,774 [mm] y_{bot} 43,774 [mm]

Compression Stress is reached!

Stress	f_{c,compression}	350,000	[MPa]	y_{top}	43,774	[mm]
f_{c,compression}	350,000	[MPa]	m	7,936	f_{c,compression}	-350,000 [MPa]
f_t	320,208	[MPa]	m	7,936	f_t	-320,208 [MPa]

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For Wbs under stress gradient [f₁ in compression and f₂ in tension]

$h_1, b_1 \leq 4$ $h_1, b_1 > 4$

$h_1 = b_1 | 3 + \psi$ $h_1 = b_1 | 3 + \psi$

$\psi > 0,236$ $b_2 = b_1 | 2$ $b_2 = b_1 | 1 + \psi - b_1$

$\psi \leq 0,236$ $b_2 = b_1 = b_1$

$h_1 + b_2 \leq$ Compression portion of the Web calculated on the basis of effective section

$\psi = \left| \frac{f_2 / f_1}{1} \right|$ ψ 1,000

[AISI S100, Eq. B2.3-1]

For Wbs under stress gradient [f₁ in compression and f₂ in tension]

$k = 4 + 2(1 + \psi)^3 + 2(1 - \psi)$ k 24,000

[AISI S100, Eq. B2.3-2]

C-Section Column Dimensions **NOTE** $w \leq h_x$

h_x 80,996 [mm]

E 210,000 [GPa] t 2,452 [mm] v 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1 - \mu^2)} \left(\frac{t}{w} \right)^2$ F_{cr} 4269,908 [MPa]

[AISI S100, Eq. B2.1-4]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $r = \lambda$ $\rho = (1 - 0,22/\lambda) \lambda$

[AISI S100, Eq. B2.1-4] 320,208 [MPa] 0,274 [AISI S100, Eq. B2.1-4]

ρ 1,000 $h_{x,eff}$ 80,996 [mm]

$b_1 = h_{x,eff}$ 80,996 [mm]

h_1, b_1 1,936

ψ 1,000

$h_1 = b_1 | 3 + \psi$ 20,024 [mm]

$h_1, b_1 \leq 4$ $h_1, b_1 > 4$

$\psi > 0,236$ $b_2 = b_1 | 2$ 40,048 [mm] $b_2 = b_1 | 1 + \psi - b_1$ --- [mm]

$\psi \leq 0,236$ $b_2 = b_1 = b_1$ --- [mm]

$h_1 + b_2 \leq w_{max}$ KO Web is fully effective **No more Iterations!**

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$k = 4 + 2(1 - \psi)^3 + 2(1 + \psi)$ k 24,000

[AS/NZS 4600, Eq. 2.2.2(4)]

C-Section Column **NOTE** $b \leq h_x$

h_x 80,996 [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} 4269,908 [MPa]

[AS/NZS 4600, Eq. 2.2.1(2)]

$\lambda = \left(\sqrt{\frac{f}{f_{cr}}} \right)$ $r = \lambda$ $\rho = \left(\frac{1 - 0,22}{\lambda} \right) \lambda \leq 1,0$

[AS/NZS 4600, Eq. 2.2.2(4)] 320,208 [MPa] 0,274 [AS/NZS 4600, Eq. 2.2.2(3)]

ρ 1,000 $h_{x,eff}$ 80,996 [mm]

$b_1 = h_{x,eff}$ 80,996 [mm]

ψ 1,000

$b_1 = b_1 | 3 + \psi$ 20,024 [mm]

$\psi > 0,236$ $b_2 = b_1 | 2$ 40,048 [mm] $b_2 = b_1 - b_{c1}$ --- [mm]

$\psi \leq 0,236$ $b_2 = b_1 = b_1$ --- [mm]

$h_1 + b_2 \leq$ Compression portion of the Web calculated on the basis of effective section

$b_1 + b_2 \leq w_{max}$ KO Web is fully effective **No more Iterations!**

$h_{x,eff}$ 20,024 [mm] $h_{x,eff}$ 20,024 [mm]

AISI S100, Effective Width [mm] Comparison $\leq w | t$ AS/NZS 4600, Effective Width [mm]

$h_{x,eff}$ 20,024 - $h_{x,eff}$ 20,024

$h_{x,eff}$ 20,024 - $h_{x,eff}$ 20,024

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$h_{x,eff}$ 20,024 [mm] $h_{x,eff}$ 20,024 [mm]

Web [h₁] [AS/NZS 4600, Clause 2.2.2]

Actual Element Effective element and stress on effective Element

Stiffened Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]

Stress f₁ (Tension) Stress f₂ (Compression)

C-Section Beam: Stress Gradient

$f_{comp,max}$ 43,774 [MPa] $f_{tens,max}$ 43,774 [MPa]

Compression Stress is reached!

1st Iteration $f_{comp,max}$ 350,000 [MPa] λ_{comp} 43,774 [mm]

$f_{tens,max}$ 350,000 [MPa] λ_{tens} 7,996 $f_{cr,max}$ 350,000 [MPa]

f_{cr} 320,208 [MPa] λ 7,996 f_{cr} 320,208 [MPa]

$\psi = \frac{f_{tens}}{f_{cr}}$ ψ 1,000

[AS/NZS 4600, Eq. 2.2.2(9)]

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Superior Flange [h_{1f}] [AISI S100, Section B4]

NOTE Zone in Tension, Effective width is equal to the real width

Superior Flange [h_{2f}] [AS/NZS 4600, Clause 2.2]

NOTE Zone in Tension, Effective width is equal to the real width

Superior Edge Stiffener [c_{1s}] [AISI S100, Section B3.2]

NOTE Zone in Tension, Effective width is equal to the real width

Superior Edge Stiffener [c_{2s}] [AS/NZS 4600, Clause 2.2.2]

NOTE Zone in Tension, Effective width is equal to the real width

[10] Effective C-Section Column Local Buckling

Effective C-Section Column Widths [AISI S100]

Inferior Edge Stiffener	$c_{1,eff}$	13,048	[mm]
Inferior Flange	$b_{1,eff}$	36,596	[mm]
Web	$h_{w,eff}$	80,996	[mm]
Superior Flange	$b_{2,eff}$	---	[mm]
Superior Edge Stiffener	$c_{2,eff}$	---	[mm]

Effective C-Section Column Widths [AS/NZS 4600]

Inferior Edge Stiffener	$c_{1,eff}$	13,048	[mm]
Inferior Flange	$b_{1,eff}$	36,596	[mm]
Web	$h_{w,eff}$	80,996	[mm]
Superior Flange	$b_{2,eff}$	---	[mm]
Superior Edge Stiffener	$c_{2,eff}$	---	[mm]

Effective C-Section Column Widths [AISI S100 | AS/NZS 4600]

Inferior Edge Stiffener	$c_{1,eff}$	13,048	[mm]
Inferior Flange	$b_{1,eff}$	36,596	[mm]
Web	$h_{w,eff}$	80,996	[mm]
Superior Flange	$b_{2,eff}$	---	[mm]
Superior Edge Stiffener	$c_{2,eff}$	---	[mm]

13] Effective C-Section Column | Local Buckling

Effective C-Section Column Widths			
Inferior Edge Stiffener	$c_{1,eff}$	13,048	[mm]
Inferior Flange	$b_{1,eff}$	18,238	[mm]
	$b_{2,eff}$	18,238	[mm]
Web	$b_{w,eff}$	20,024	[mm]
	$b_{w,eff}$	20,024	[mm]
Superior Flange	$b_{3,eff}$	---	[mm]
Superior Edge Stiffener	$c_{3,eff}$	---	[mm]

Effective C-Section Column | Local Buckling | Bending Moment M_{y,EI_y} | AISI S100 | AS/NZS 4600

Effective C-Section Column | Local Buckling | Bending Moment M_{y,EI_y}

$I_{y,eff}^2 = 62563,000$ [mm²]

$f_{compressive\ limit} = 350,000$ [MPa] $y_{1c} = 24,274$ [mm]

$f_{compressive} = 350,000$ [MPa] $m = 14,419$ $f_{tension} = -350,000$ [MPa]

$f_1 = 303,485$ [MPa] $m = 14,419$ $f_2 = 216,281$ [MPa]

$\psi = |f_2/f_1|$ $\psi = 0,713$

f_1 Compression $k = \frac{0,578}{\psi + 0,34}$ $k = 0,549$

f_2 Compression

C-Section Steel Dimension **NOTE** $w = c_{1,eff}$

$c_{1,eff} = 6,048$ [mm]

$E = 210,000$ [GPa] $i = 1,452$ [mm] $v = \mu$ $0,300$

$w = 6,048$ [mm] $w \leq 1,5i$ **OK**

$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w}\right)^2$ $F_c = 606,855$ [MPa]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $f = f_1 = 303,485$ [MPa] $\lambda = 0,225$ $\rho = (1 - 0,22/\lambda)\lambda$

$\rho = 1,000$ $\rho_{1,eff,max} = 6,048$ [mm]

Inferior Edge Stiffener $c_{1,eff}$ | AS/NZS 4600, Clause 2.3.2

C-Section Beam Stress Gradient

Uniaxial Elements with Stress Gradient | Both Edges Compression | AS/NZS 4600, Figure B2.2(b)

14] C-Section Steel

C-Section Steel Dimension	
$c_{1,eff}$	6,048 [mm]
$b_{1,eff}$	32,098 [mm]
b_2	42,056 [mm]
$b_{2,eff}$	32,098 [mm]
$c_{3,eff}$	6,048 [mm]
i	1,452 [mm]

Effective C-Section [L] | Local Buckling

11] Effective Widths for Strength Determination | Local Buckling | AISI S100, Section 6 | AS/NZS 4600, Section 2

Effective C-Section | Wall Case

1st Iteration

Inferior Edge Stiffener $c_{1,eff}$ | AISI S100, Section B3.2

C-Section Beam Stress Gradient

Uniaxial Elements under Stress Gradient | Both Longitudinal Edges in Compression | AISI S100, Figure B3.2-1

$f_{compressive\ limit} = 350,000$ [MPa] $y_{1c} = 24,274$ [mm]

$f_{compressive} = 350,000$ [MPa] $m = 14,419$ $f_{tension} = -350,000$ [MPa]

$f_1 = 303,485$ [MPa] $m = 14,419$ $f_2 = 216,281$ [MPa]

$\psi = f_2^* / f_1^*$ $\psi = 0,713$

f_1 Compression $k = \frac{0,578}{\psi + 0,34}$ $k = 0,549$

f_2 Compression

C-Section Steel Dimension **NOTE** $b = c_{1,eff}$

$c_{1,eff} = 6,048$ [mm]

$E = 210,000$ [GPa] $i = 1,452$ [mm] $v = \mu$ $0,300$

$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)}\right) \left(\frac{t}{b}\right)^2$ $f_c = 606,855$ [MPa]

$\lambda = \left(\sqrt{\frac{f}{f_{cr}}}\right)$ $f = f_1 = 303,485$ [MPa] $\lambda = 0,225$ $\rho = \left(\frac{1 - 0,22}{\lambda}\right) \leq 1,0$

$\rho = 1,000$ $\rho_{1,eff,max} = 6,048$ [mm]

AISI S100, Effective Width [mm] $\rho \geq 0,7$ | AS/NZS 4600, Effective Width [mm]

$c_{1,eff,max} = 6,048$ $c_{1,eff,max} = 6,048$

Inferior Flange $b_{1,eff}$ | AISI S100, Section B4

C-Section Steel Dimension

$c_{1,eff} = 6,048$ [mm]

$b_{1,eff} = 32,098$ [mm]

$i = 1,452$ [mm]

$c_{1,eff} = b_{1,eff} + w$

$D_{1,eff} = 10,000$ [mm]

AISI S100, Figure B4-1

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$S = 1.28\sqrt{E/t}$ [AISI S100, Eq. B4-7]

$E = 210,000$ [GPa]
 $t = 3,500$ [MPa]
 $S = 31,353$ []

$w = 0.328 \cdot S$ | $w = 10.328 \cdot S$

$l_e = 0.000$ [no edge stiffener needed] | $l_e = \dots$ [edge stiffener needed]

$b = w$ | $b_1 = [b/2] \cdot [R]$

$b_2 = b - b_1$ | $b_2 = b - b_1$

$d_e = d_e$ | $d_e = d_e \cdot [R]$

$w = 11$ | 22,065 | Edge stiffener needed | 0,328 * S | 10,284

$I_x = 399t^4 \left[\frac{w/t - 0.328}{S} \leq t^4 \left[115 \frac{w/t + 5}{S} \right] \right]$ [AISI S100, Eq. B4-8]

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element.

$I_x = 95,942$ [mm⁴] | \leq | 392,807 | OK

$(R_1) = I_s/I_a \leq 1$ [AISI S100, Eq. B4-8] | **$I_s = (d^3 t \sin^2 \theta)/12$** [AISI S100, Eq. B4-10]

$\phi_1 = 99,000$ [°] | \rightarrow | $I_s = 4900,720$ [mm⁴]

$[R_1] = 42,094$ | \leq | 1,000 | \rightarrow | KO | $[R_1] = 1,000$

Determination of Plate Buckling Coefficient, k [AISI S100, Table B4-1]

Single Lip Edge Stiffener [140° > θ > 40°]

$d/w \leq 0.250$ | $0.250 < d/w \leq 0.900$

$3,570 \cdot [R_1]^{1.4} + 0,430 \leq 4,000$ | $[4,820 - (5 \cdot [D] \cdot [R_1]^{1.4} + 0,430) \leq 4,000$

OK | 140° > $\phi_1 = 99,000$ [°] | > 40° | OK

$n = 0,496$ | \geq | 1 | 3 ? | OK | \rightarrow | $n = 0,496$

[AISI S100, Table B4-1] | $d/w = 0,312$ | \rightarrow | $k = 3,892$ | OK

C-Section Size Dimension | **NOTE** | **$w > b_{11}$**

$b_{11} = 32,096$ [mm]

$E = 210,000$ [GPa] | $t = 1,452$ [mm] | $v [\mu] = 0,300$

$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$ [AS/NZS 4600, Eq. 2.2.1.2(6)]

$f_{cr} = 1434,201$ [MPa]

$\lambda = \sqrt{\frac{f}{f_{cr}}}$ [AS/NZS 4600, Eq. 2.2.1.2(4)]

$\lambda = 0,494$

$\rho = \left(\frac{1 - 0,22/\lambda}{\lambda} \right) \leq 1,0$ [AS/NZS 4600, Eq. 2.2.1.2(3)]

$\rho = 1,000$ | $b_{11,MIN,REQD} = 16,048$ [mm] | $b_{11,MAX,REQD} = 16,048$ [mm]

AISI S100 Effective Width [mm] | Comparison $w > w_1$ | **AS/NZS 4600 Effective Width [mm]**

$b_{11,MIN,REQD} = 16,048$ | $b_{11,MAX,REQD} = 16,048$

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$I_s/I_a \leq 1$ [AS/NZS 4600] | **$I_s = (d^3 t \sin^2 \theta)/12$** [AS/NZS 4600, Eq. 2.2.2(11)]

$\phi_1 = 99,000$ [°] | \rightarrow | $I_s = 4900,720$ [mm⁴]

$[I_s/I_a] = 42,094$ | $<$ | 1,000 | \rightarrow | KO | $[I_s/I_a] = 1,000$

$w = \left[\frac{0.582 - (h/t)}{4S} \right] \geq \frac{1}{3}$ [AS/NZS 4600, Eq. 2.4.2(12)]

Determination of Plate Buckling Coefficient, k [AS/NZS 4600, Table 2.4.2]

Single Lip Edge Stiffener [140° > θ > 40°]

$d/b \leq 0.250$ | $0.250 < d/b \leq 0.900$

$3,570 \cdot [I_s/I_a]^{1.4} + 0,430 \leq 4,000$ | $[4,820 - (5 \cdot [I_s/I_a]^{1.4} + 0,430) \leq 4,000$

OK | 140° > $\phi_1 = 99,000$ [°] | > 40° | OK

$n = 0,496$ | \geq | 1 | 3 ? | OK | \rightarrow | $n = 0,496$

[AS/NZS 4600, Table 2.4.2] | $d/b = 0,312$ | \rightarrow | $k = 3,892$ | OK

C-Section Size Dimension | **NOTE** | **$w > b_{11}$**

$b_{11} = 32,096$ [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(6)]

$f_{cr} = 1434,201$ [MPa]

$\lambda = \sqrt{\frac{f}{f_{cr}}}$ [AS/NZS 4600, Eq. 2.2.1.2(4)]

$\lambda = 0,494$

$\rho = \left(\frac{1 - 0,22/\lambda}{\lambda} \right) \leq 1,0$ [AS/NZS 4600, Eq. 2.2.1.2(3)]

$\rho = 1,000$ | $b_{11,MIN,REQD} = 16,048$ [mm] | $b_{11,MAX,REQD} = 16,048$ [mm]

AISI S100 Effective Width [mm] | Comparison $w > w_1$ | **AS/NZS 4600 Effective Width [mm]**

$b_{11,MIN,REQD} = 16,048$ | $b_{11,MAX,REQD} = 16,048$

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$F_{cr} = k \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{w} \right)^2$ [AISI S100, Eq. B2.1-4]

$F_{cr} = 1434,201$ [MPa]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ [AISI S100, Eq. B2.1-4]

$\lambda = 0,494$

$\rho = (1 - 0,22/\lambda)$ [AISI S100, Eq. B2.1-4]

$\rho = 1,000$ | $b_{11,MIN,REQD} = 16,048$ [mm] | $b_{11,MAX,REQD} = 16,048$ [mm]

Inferior Flange (b_{11}) [AS/NZS 4600, Class 2.4.2]

C-Section Size Dimension

$d_{11} = 6,048$ [mm]

$b_{11} = 32,096$ [mm]

$t = 1,452$ [mm]

$c_{11} = 4 [b_{11}] \leq b$

$d_{11,MIN,REQD} = 10,000$ [mm]

$S = 1.28\sqrt{E/f^*}$ [AS/NZS, Eq. 2.4.2(13)]

$E = 210,000$ [GPa]
 $f^* = 350,000$ [MPa]
 $S = 31,353$ []

$b = 0.328 \cdot S$ | $b = 10.328 \cdot S$

$l_e = 0.000$ [no edge stiffener needed] | $l_e = \dots$ [edge stiffener needed]

$b_1 = b$ | $b_1 = [b/2] \cdot [I_s/I_a]$

$b_2 = b - b_1$ | $b_2 = b - b_1$

$d_e = d_e$ | $d_e = d_e \cdot [I_s/I_a]$

$b = 11$ | 22,065 | Edge stiffener needed | 0,328 * S | 10,284

$I_s = 399t^4 \left[\frac{(h/t) - 0.328}{S} \leq t^4 \left[115 \frac{(h/t)}{S} + 5 \right] \right]$ [AS/NZS 4600, Eq. 2.4.2(11)]

Adequate moment of inertia of stiffener, so that each component element will behave as a stiffened element.

$I_s = 95,942$ [mm⁴] | \leq | 392,807 | OK

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Web (b_{12}) [AISI S100, Section B2.3.1]

Actual Element | **Effective Element and Stress on Effective Elements**

Web and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]

C-Section Beam Stress Gradient

$F_{cr,MIN} = 350,000$ [MPa] | $F_{cr,MAX} = 350,000$ [MPa]

$f_1 = 350,000$ [MPa] | $f_2 = -350,000$ [MPa]

$f_1 = 303,485$ [MPa] | $f_2 = -303,485$ [MPa]

$y_{1,MIN} = 24,274$ [mm] | $y_{1,MAX} = 24,274$ [mm]

Compression Stress is reached!

1st Iteration

$f_{c,MIN,REQD} = 350,000$ [MPa] | $y_{1,MIN} = 24,274$ [mm]

$f_{c,MIN,REQD} = 350,000$ [MPa] | $m = 14,419$ | $f_{c,MIN,REQD} = -350,000$ [MPa]

$f_1 = 303,485$ [MPa] | $m = 14,419$ | $f_2 = -303,485$ [MPa]

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For webs under stress gradient [f₁ in compression and f₂ in tension]

$h_1, b_1 \leq 4$ $h_1, b_1 > 4$

$b_1 = b_w | 3 + \psi$ $b_1 = b_w | 3 + \psi$

$\psi > 0,236$ $b_2 = b_w | 2$ $b_2 = b_w | 1 + \psi - b_1$

$\psi \leq 0,236$ $b_2 = b_w - b_1$

$b_1, b_2 \leq$ Compression portion of the Web calculated on the basis of effective section

$\psi = \left| \frac{f_2/f_1}{1} \right|$ [AISI S100, Eq. B2.3-1] ψ 1,000

For webs under stress gradient [f₁ in compression and f₂ in tension]

$k = 4 + 2(1 + \psi)^3 + 2(1 - \psi)$ k 24,000

[AISI S100, Eq. B2.3-2]

C-Section Slit Dimension **NOTE** **w = h_w**

h_w 42,096 [mm]

E 210,000 [GPa] f_y 1,452 [mm] v 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1 - \nu^2)} \left(\frac{t}{w} \right)^2$ F_{cr} 5419,500 [MPa]

[AISI S100, Eq. B2.1-4]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $f = f_y$ 303,485 [MPa] $\rho = (1 - 0,22/\lambda) \lambda$

[AISI S100, Eq. B2.1-4] λ 0,237

ρ 1,000 $\rho_{MINIMUM}$ 42,096 [mm]

$b_1 = \rho_{MINIMUM}$ 42,096 [mm]

$b_1 | b_w$ 1,250

$|\psi|$ 1,000

$b_1 = b_w | 3 + \psi$ 10,524 [mm]

$h_1, b_1 \leq 4$ $h_1, b_1 > 4$

$\psi > 0,236$ $b_2 = b_w | 2$ 21,048 [mm] $b_2 = b_w | 1 + \psi - b_1$ --- [mm]

$\psi \leq 0,236$ $b_2 = b_w - b_1$ --- [mm]

$b_1 + b_2 \leq w_{web}$ KO Web is fully effective **No more iterations!**

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$k = 4 + 2(1 - \psi)^3 + 2(1 + \psi)$ k 24,000

[AS/NZS 4600, Eq. 2.2.2(4)]

C-Section Slit **NOTE** **b = h_w**

h_w 42,096 [mm]

E 210,000 [GPa] f_y 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} 5419,500 [MPa]

[AS/NZS 4600, Eq. 2.2.1(2)]

$\lambda = \left(\sqrt{\frac{f}{f_{cr}}} \right)$ $f = f_y$ 303,485 [MPa] $\rho = \left(\frac{1 - 0,22}{\lambda} \right) \lambda \leq 1,0$

[AS/NZS 4600, Eq. 2.2.2(4)] λ 0,237 [AS/NZS 4600, Eq. 2.2.2(3)]

ρ 1,000 $\rho_{MINIMUM}$ 42,096 [mm]

$b_1 = \rho_{MINIMUM}$ 42,096 [mm]

ψ 1,000

$b_w = b_w | 3 + \psi$ 10,524 [mm]

$\psi > 0,236$ $b_2 = b_w | 2$ 21,048 [mm] $b_2 = b_w - b_1$ --- [mm]

$\psi \leq 0,236$ $b_2 = b_w - b_1$ --- [mm]

$b_1, b_2 \leq$ Compression portion of the Web calculated on the basis of effective section

$b_w + b_1 \leq b_{w,eff}$ KO Web is fully effective **No more iterations!**

$\rho_{MINIMUM}$ 10,524 [mm] $\rho_{MINIMUM}$ 10,524 [mm]

AISI S100, Effective Width [mm] Comparison $\psi > 1$ AS/NZS 4600, Effective Width [mm]

$\rho_{MINIMUM}$ 10,524 - $\rho_{MINIMUM}$ 10,524

$\rho_{MINIMUM}$ 10,524 - $\rho_{MINIMUM}$ 10,524

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$\rho_{MINIMUM}$ 10,524 [mm] $\rho_{MINIMUM}$ 10,524 [mm]

Web [h_w] [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

$f_{COMPRESS}$ 24,274 [mm] $f_{TENSION}$ 24,274 [mm]

Compression Stress is reached!

1st Iteration $f_{COMPRESS,ITERATION}$ 350,000 [MPa] λ_w 34,274 [mm]

$f_{TENSION,ITERATION}$ 350,000 [MPa] m 14,419 $f_{TENSION}$ -350,000 [MPa]

f_1^* 303,485 [MPa] f_2^* -303,485 [MPa]

$\psi = \frac{f_2^*}{f_1^*}$ ψ -1,000

[AS/NZS 4600, Eq. 2.2.2(9)]

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Superior Flange [h_{1f}] [AISI S100, Section B4]

NOTE Zone in Tension, Effective width is equal to the real width

Superior Flange [h_{2f}] [AS/NZS 4600, Clause 2.4]

NOTE Zone in Tension, Effective width is equal to the real width

Superior Edge Stiffener [c_{1s}] [AISI S100, Section B3.2]

NOTE Zone in Tension, Effective width is equal to the real width

Superior Edge Stiffener [c_{2s}] [AS/NZS 4600, Clause 2.2.2]

NOTE Zone in Tension, Effective width is equal to the real width

[10] **Effective C-Section Slit | Local Buckling**

Effective C-Section Slit Widths [AISI S100]

Inferior Edge Stiffener	$\rho_{LL,MIN}$	6,048	[mm]
Inferior Flange	$\rho_{LL,MIN}$	32,096	[mm]
Web	$\rho_{LL,MIN}$	42,096	[mm]
Superior Flange	$\rho_{LL,MIN}$	---	[mm]
Superior Edge Stiffener	$\rho_{LL,MIN}$	---	[mm]

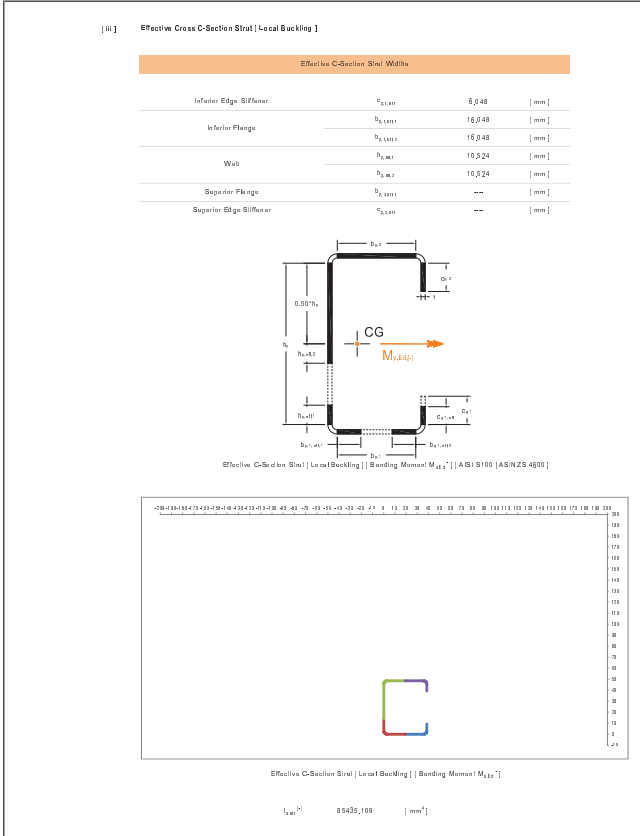
Effective C-Section Slit Widths [AS/NZS 4600]

Inferior Edge Stiffener	$\rho_{LL,MIN}$	6,048	[mm]
Inferior Flange	$\rho_{LL,MIN}$	32,096	[mm]
Web	$\rho_{LL,MIN}$	42,096	[mm]
Superior Flange	$\rho_{LL,MIN}$	---	[mm]
Superior Edge Stiffener	$\rho_{LL,MIN}$	---	[mm]

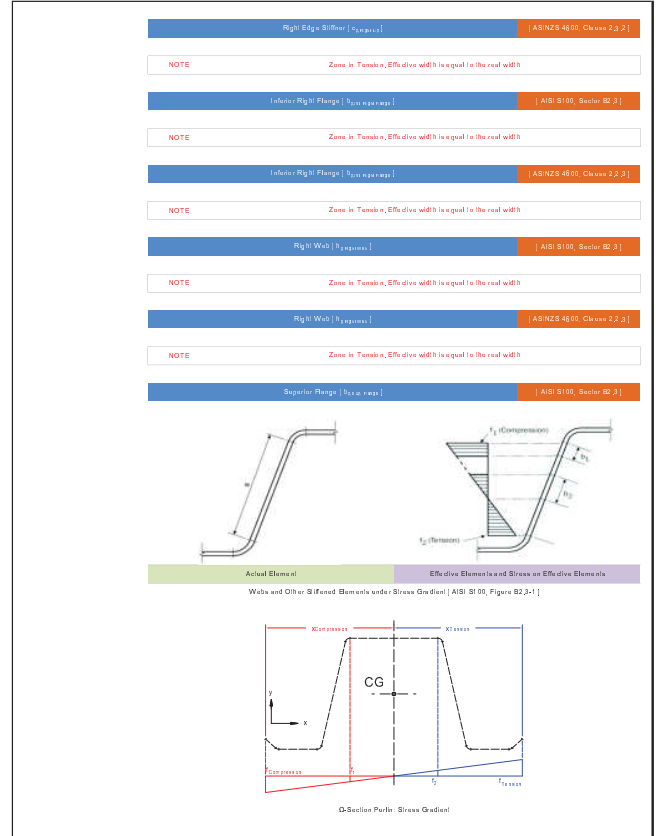
Effective C-Section Slit Widths [AISI S100 | AS/NZS 4600]

Inferior Edge Stiffener	$\rho_{LL,MIN}$	6,048	[mm]
Inferior Flange	$\rho_{LL,MIN}$	32,096	[mm]
Web	$\rho_{LL,MIN}$	42,096	[mm]
Superior Flange	$\rho_{LL,MIN}$	---	[mm]
Superior Edge Stiffener	$\rho_{LL,MIN}$	---	[mm]

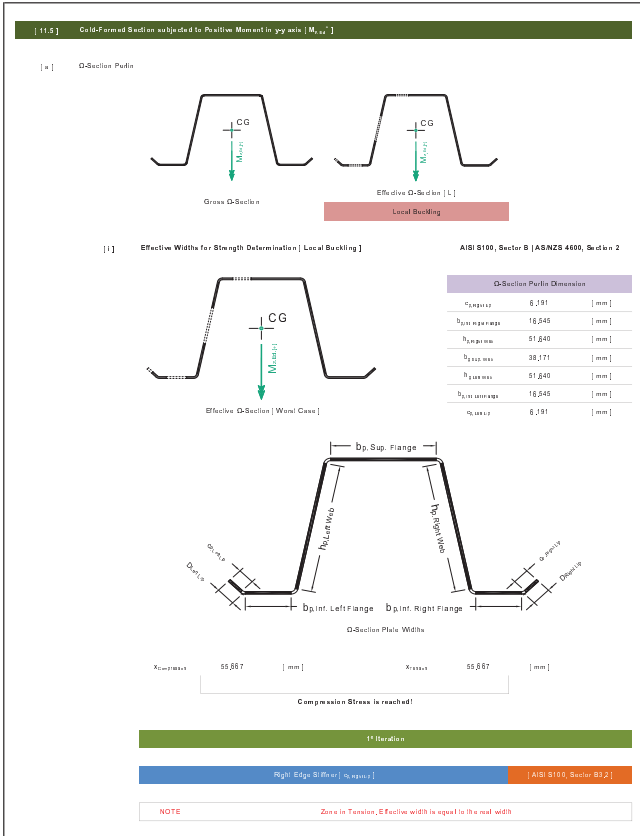
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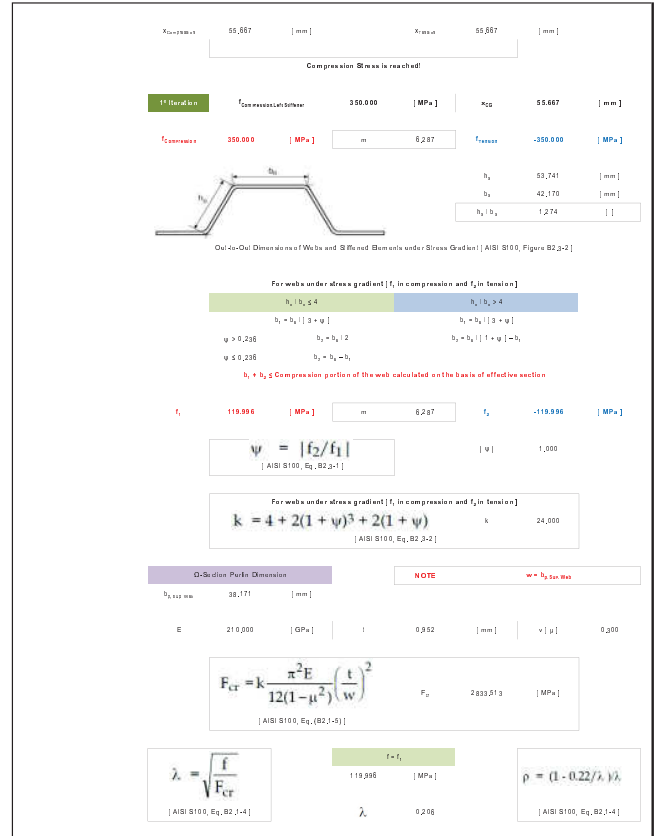
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$p = 1,000$ [mm] → $b_{1,122 \text{ max. min.}} = 38,771$ [mm]

$b_w = b_{1,122 \text{ max. min.}} = 38,771$ [mm]

$b_1 / b_w = 1,274$

$|\psi| = 1,000$

$b_2 = b_w / (3 + \psi) = 9,543$ [mm]

$b_1 / b_2 \leq 4$ $b_1 / b_2 > 4$

$\psi > -0,236$ $b_1 = b_w / 2 = 19,385$ [mm] $b_2 = b_w / (1 + \psi) = b_1$ [mm]

$\psi \leq -0,236$ $b_2 = b_w = b_1$ [mm]

$b_1 + b_2 \leq W_{web}$ KO Web is fully effective **No more Iterations!**

$b_{1,122 \text{ max. min.}} = 9,543$ [mm] $b_{2,122 \text{ max. min.}} = 9,543$ [mm]

Superior Flange | $b_{1,122 \text{ max. min.}}$ [AS/NZS 4600, Clause 2.2.2]

Actual Element **Effective Element and stress on effective Element**
 Stiffened Elements and Webs with Stress Gradient | AS/NZS 4600, Figure 2.2.3 |

$x_{1,122 \text{ max. min.}} = 55,667$ [mm] $x_{2,122 \text{ max. min.}} = 55,667$ [mm]

Compression Stress is reached!

D-Section Profile: Stress Gradient

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$b_w = b_w / (3 + \psi) = 9,543$ [mm]

$\psi \leq -0,236$ $b_1 = b_w / 2 = 19,385$ [mm] $\psi > -0,236$ $b_{1,122} = b_w = b_{2,122}$ [mm]

$b_w = b_w \leq b_{1,122}$ KO Web is fully effective **No more Iterations!**

$b_{1,122 \text{ max. min.}} = 9,543$ [mm] $b_{2,122 \text{ max. min.}} = 9,543$ [mm]

AISI S100, Effective Width [mm]	Comparison | \leq or \neq	AS/NZS 4600, Effective Width [mm]
$b_{1,122 \text{ max. min.}} = 9,543$	=	$b_{1,122 \text{ max. min.}} = 9,543$
$b_{2,122 \text{ max. min.}} = 9,543$	=	$b_{2,122 \text{ max. min.}} = 9,543$

Left Web | $b_{2,122 \text{ max. min.}}$ [AISI S100, Section B2.3]

Actual Element **Effective Element and stress on effective Element**
 Webs and Other Stiffened Elements under Stress Gradient | AISI S100, Figure B2.3 |

D-Section Profile: Stress Gradient

1st Iteration $f_{\text{compression}} = 350,000$ [MPa] $f_{cp} = 55,667$ [mm]

$f_{\text{compression}} = 350,000$ [MPa] $m = 6,287$ $f_{\text{tension}} = -350,000$ [MPa]

$f_1 = 119,996$ [MPa] $m = 6,287$ $f_2 = -119,996$ [MPa]

$\psi = \frac{f_2}{f_1} = -1,000$ [AS/NZS 4600, Eq. 2.2.3.2(6)]

$k = 4 + 2(1 - \psi)^3 + 2(1 + \psi)$ $k = 24,000$ [AS/NZS 4600, Eq. 2.2.3.2(4)]

D-Section Profile Dimension **NOTE** $w = b_{1,122 \text{ max. min.}}$

$b_{1,122 \text{ max. min.}} = 38,771$ [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. 2.2.3.2(5)]

$\lambda = \sqrt{\frac{f'}{f_{cr}}}$ $f' = 119,996$ [MPa] $\lambda = 0,206$ [AS/NZS 4600, Eq. 2.2.3.2(4)]

$\rho = \frac{1 - 0,22}{\lambda} \leq 1,0$ [AS/NZS 4600, Eq. 2.2.3.2(3)]

$p = 1,000$ → $b_{1,122 \text{ max. min.}} = 38,771$ [mm]

$b_{e1} = \frac{b_e}{3 - \psi}$ $b_{e2} = \frac{b_e}{2}$ $b_{e2} = b_e - b_{e1}$

$b_w = b_{1,122 \text{ max. min.}} = 38,771$ [mm]

$\psi = -1,000$

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$x_{1,122 \text{ max. min.}} = 55,667$ [mm] $x_{2,122 \text{ max. min.}} = 55,667$ [mm]

Compression Stress is reached!

1st Iteration $f_{\text{compression}} = 350,000$ [MPa] $f_{cp} = 55,667$ [mm]

$f_{\text{compression}} = 350,000$ [MPa] $m = 6,287$ $f_{\text{tension}} = -350,000$ [MPa]

$f_1 = 197,493$ [MPa] $m = 6,287$ $f_2 = 132,165$ [MPa]

$\psi = |f_2 / f_1|$ $|\psi| = 0,669$

For webs under stress gradient | f_1 and f_2 in compression

$k = 4 + 2(1 - \psi)^3 + 2(1 + \psi)$ $k = 47,24$ [AISI S100, Eq. B2.3-4]

D-Section Profile Dimension **NOTE** $w = b_{1,122 \text{ max. min.}}$

$b_{1,122 \text{ max. min.}} = 51,540$ [mm]

$E = 210,000$ [GPa] $t = 0,952$ [mm] $v = 0,300$

$F_{cr} = k \frac{\pi^2 E}{12(1 - \nu^2)} \left(\frac{t}{w} \right)^2$ $F_{cr} = 395,382$ [MPa] [AISI S100, Eq. B2.3-5]

$\lambda = \sqrt{\frac{f'}{F_{cr}}}$ $f' = 197,493$ [MPa] $\lambda = 0,604$ $\rho = (1 - 0,22 / \lambda) \lambda$ [AISI S100, Eq. B2.3-4]

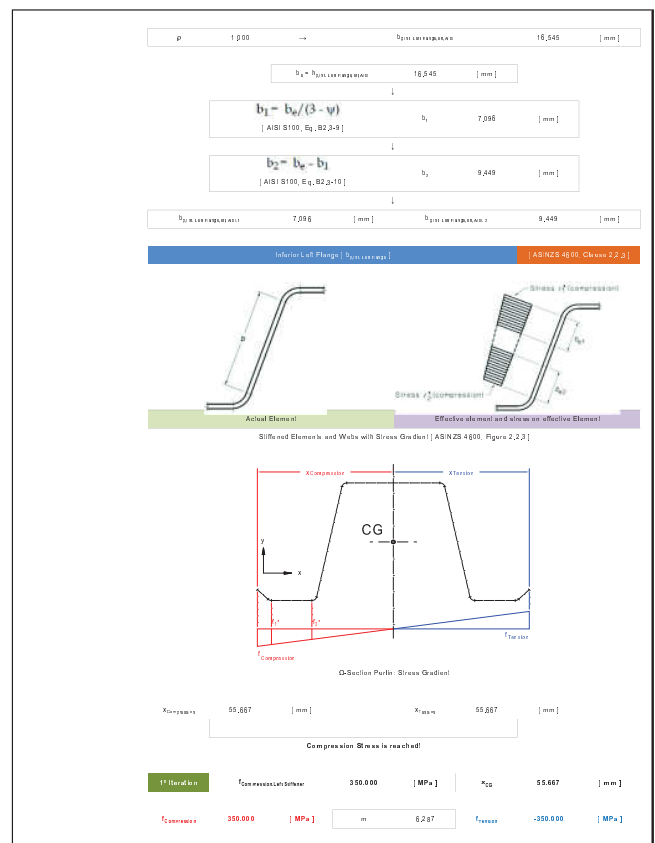
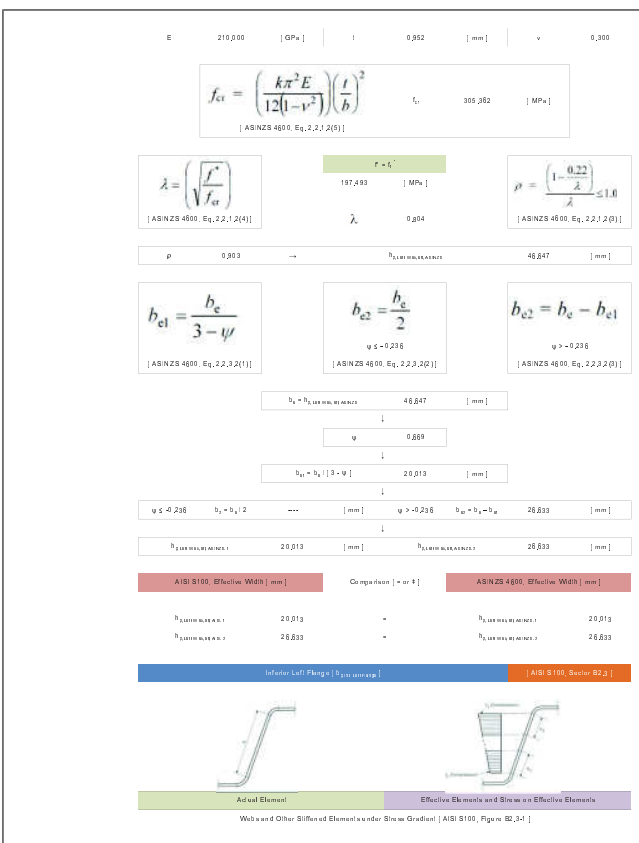
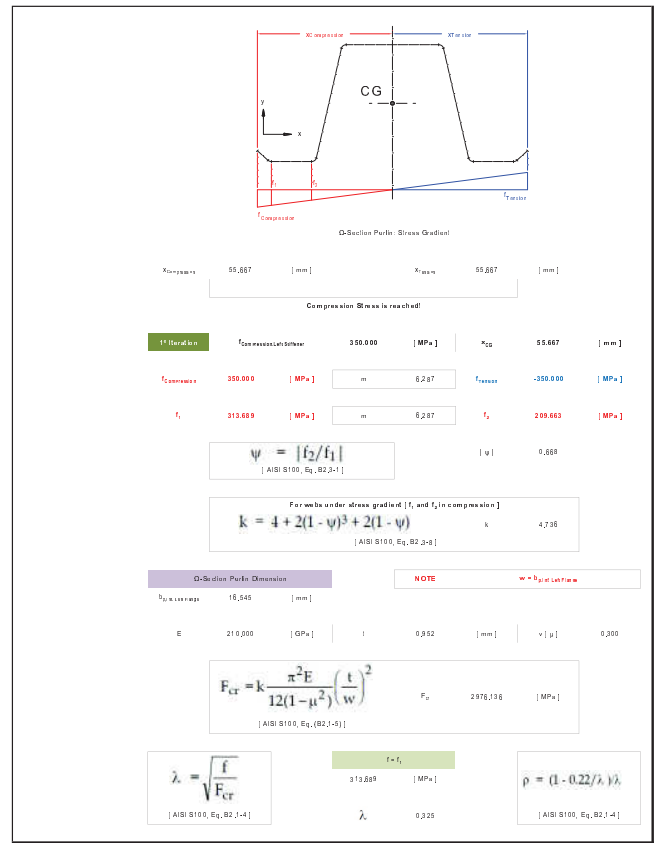
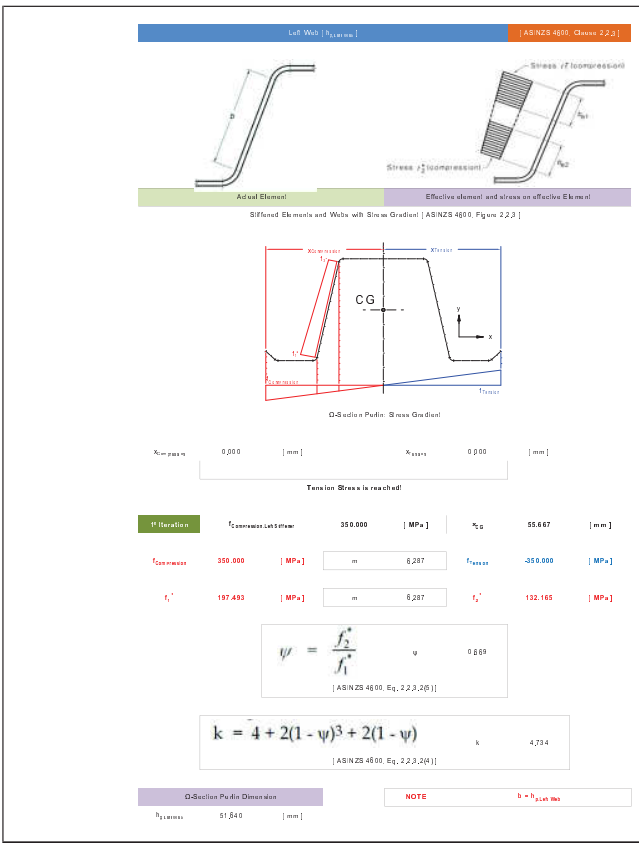
$p = 0,903$ → $b_{1,122 \text{ max. min.}} = 46,647$ [mm]

$b_w = b_{1,122 \text{ max. min.}} = 46,647$ [mm]

$b_1 = b_w / (3 - \psi)$ $b_1 = 20,013$ [mm] [AISI S100, Eq. B2.3-6]

$b_2 = b_w - b_1$ $b_2 = 26,633$ [mm] [AISI S100, Eq. B2.3-10]

$b_{1,122 \text{ max. min.}} = 20,013$ [mm] $b_{2,122 \text{ max. min.}} = 26,633$ [mm]



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$f_{cr} = 313.689$ [MPa] $f_{cr} = 299.643$ [MPa]

$$\psi = \frac{f_{cr}}{f_1} = 0.869$$

[AS/NZS 4600, Eq. 2.2.3.2(9)]

$$k = 4 + 2(1 - \psi)^3 + 2(1 - \psi)$$

[AS/NZS 4600, Eq. 2.2.3.2(6)] $k = 4.736$

D-Section Part Dimension		NOTE		*** $b_{eff} < b_{flange}$	
b_{flange}	16,545 [mm]				
E	210,000 [GPa]	λ	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. 2.2.3.2(9)] $f_{cr} = 2976,136$ [MPa]

$$\lambda = \left(\sqrt{\frac{f}{f_{cr}}} \right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)] $r = \lambda$ $\rho = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$ [AS/NZS 4600, Eq. 2.2.1.2(8)]

$\rho = 1,000$ $b_{flange, effective} = 16,545$ [mm]

$b_{c1} = \frac{b_e}{3 - \psi}$	$b_{c2} = \frac{b_e}{2}$	$b_{c2} = b_c - b_{c1}$
[AS/NZS 4600, Eq. 2.2.3.2(1)]	$\psi \leq -0,236$	$\psi > -0,236$
	$b_e = b_1 + b_2$	$b_e = b_1 - b_2$
$\psi \leq -0,236$ $b_1 = b_1/2$		$\psi > -0,236$ $b_1 = b_1 - b_2$ 9,249 [mm]
$b_{flange, effective} = 7,996$ [mm]		$b_{flange, effective} = 9,249$ [mm]

$b_{flange, effective} = 16,545$ [mm] $\psi = 0,869$ $b_{flange, effective} = 7,996$ [mm]

$\psi \leq -0,236$ $b_1 = b_1/2$ $b_{flange, effective} = 7,996$ [mm] $\psi > -0,236$ $b_1 = b_1 - b_2$ 9,249 [mm] $b_{flange, effective} = 9,249$ [mm]

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$$\lambda = \left(\sqrt{\frac{f}{f_{cr}}} \right)$$

[AS/NZS 4600, Eq. B2.1-4] $r = \lambda$ $\rho = (1 - 0,22/\lambda) \leq 1,0$ [AS/NZS 4600, Eq. B2.1-4]

$\rho = 1,000$ $b_{flange, effective} = 6,191$ [mm]

Left Edge Stiffener (f_{flange}) [AS/NZS 4600, Clause 2.3.2]

$f_{flange} = 350.000$ [MPa] $f_{flange} = 350.000$ [MPa] $f_{flange} = 350.000$ [MPa] $f_{flange} = 350.000$ [MPa]

$f_{cr} = 350.000$ [MPa] $f_{cr} = 322.474$ [MPa]

$$\psi = \frac{f_2}{f_1} = 0,921$$

[AS/NZS 4600, Eq. 2.2.2(1)]

$$k = 0,57 - 0,21\psi + 0,07\psi^2$$

[AS/NZS 4600, Eq. 2.2.2(3)]

D-Section Part Dimension		NOTE		*** $b < b_{flange}$	
b_{flange}	6,191 [mm]				
E	210,000 [GPa]	λ	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(9)] $f_{cr} = 1958,179$ [MPa]

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AISI S100, Effective Width [mm]	Compression = or ±	AS/NZS 4600, Effective Width [mm]
$b_{flange, effective} = 7,996$		$b_{flange, effective} = 7,996$
$b_{flange, effective} = 9,249$		$b_{flange, effective} = 9,249$

Left Edge Stiffener (f_{flange}) [AISI S100, Section B3.2]

$f_{flange} = 350.000$ [MPa] $f_{flange} = 350.000$ [MPa] $f_{flange} = 350.000$ [MPa] $f_{flange} = 350.000$ [MPa]

$f_{cr} = 350.000$ [MPa] $f_{cr} = 322.474$ [MPa]

$$\psi = \frac{f_2}{f_1} = 0,921$$

[AISI S100, Eq. B3.2-1]

$$k = 0,57 - 0,21\psi + 0,07\psi^2$$

[AISI S100, Eq. B3.2-3]

D-Section Part Dimension		NOTE		*** $b < b_{flange}$	
b_{flange}	6,191 [mm]				
E	210,000 [GPa]	λ	0,952 [mm]	ν	0,300
w	6,191 [mm]	w	$w \leq 60$ OK		

$$F_{cr} = k \frac{\pi^2 E}{12(1 - \mu^2)} \left(\frac{t}{w} \right)^2$$

[AISI S100, Eq. B3.2-4] $F_{cr} = 1958,179$ [MPa]

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$$\lambda = \left(\sqrt{\frac{f}{f_{cr}}} \right)$$

[AS/NZS 4600, Eq. 2.2.1.2(4)] $r = \lambda$ $\rho = (1 - 0,22/\lambda) \leq 1,0$ [AS/NZS 4600, Eq. 2.2.1.2(8)]

$\rho = 1,000$ $b_{flange, effective} = 6,191$ [mm]

AISI S100, Effective Width	Compression = or ±	AS/NZS 4600, Effective Width
$b_{flange, effective} = 6,191$		$b_{flange, effective} = 6,191$

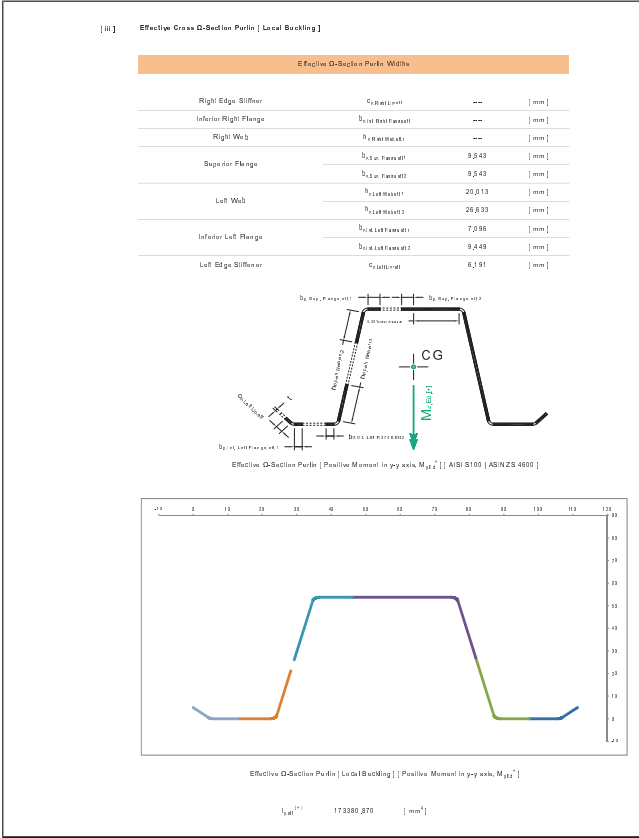
Effective D-Section Partin | Local Buckling

Effective D-Section Partin Widths | AISI S100 |		
Right Edge Stiffener	$b_{flange, effective} =$	--- [mm]
Inferior Right Flange	$b_{flange, effective} =$	--- [mm]
Right Web	$b_{flange, effective} =$	--- [mm]
Superior Flange	$b_{flange, effective} =$	38,171 [mm]
Left Web	$b_{flange, effective} =$	48,647 [mm]
Inferior Left Flange	$b_{flange, effective} =$	16,545 [mm]
Left Edge Stiffener	$b_{flange, effective} =$	6,191 [mm]

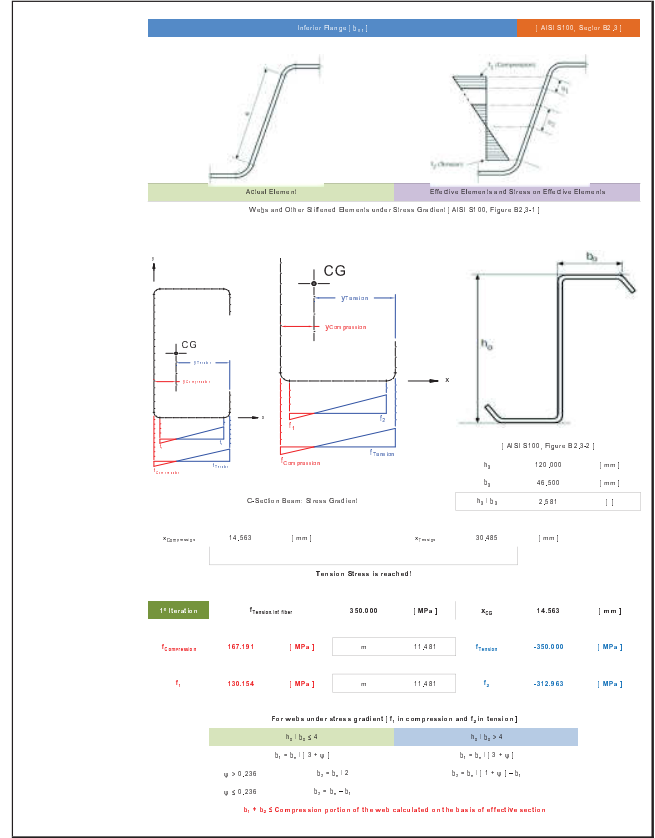
Effective D-Section Partin Widths | AS/NZS 4600 |		
Right Edge Stiffener	$b_{flange, effective} =$	--- [mm]
Inferior Right Flange	$b_{flange, effective} =$	--- [mm]
Right Web	$b_{flange, effective} =$	--- [mm]
Superior Flange	$b_{flange, effective} =$	38,171 [mm]
Left Web	$b_{flange, effective} =$	48,647 [mm]
Inferior Left Flange	$b_{flange, effective} =$	16,545 [mm]
Left Edge Stiffener	$b_{flange, effective} =$	6,191 [mm]

Effective D-Section Partin Widths | AISI S100 | AS/NZS 4600 |		
Right Edge Stiffener	$b_{flange, effective} =$	--- [mm]
Inferior Right Flange	$b_{flange, effective} =$	--- [mm]
Right Web	$b_{flange, effective} =$	--- [mm]
Superior Flange	$b_{flange, effective} =$	38,171 [mm]
Left Web	$b_{flange, effective} =$	48,647 [mm]
Inferior Left Flange	$b_{flange, effective} =$	16,545 [mm]
Left Edge Stiffener	$b_{flange, effective} =$	6,191 [mm]

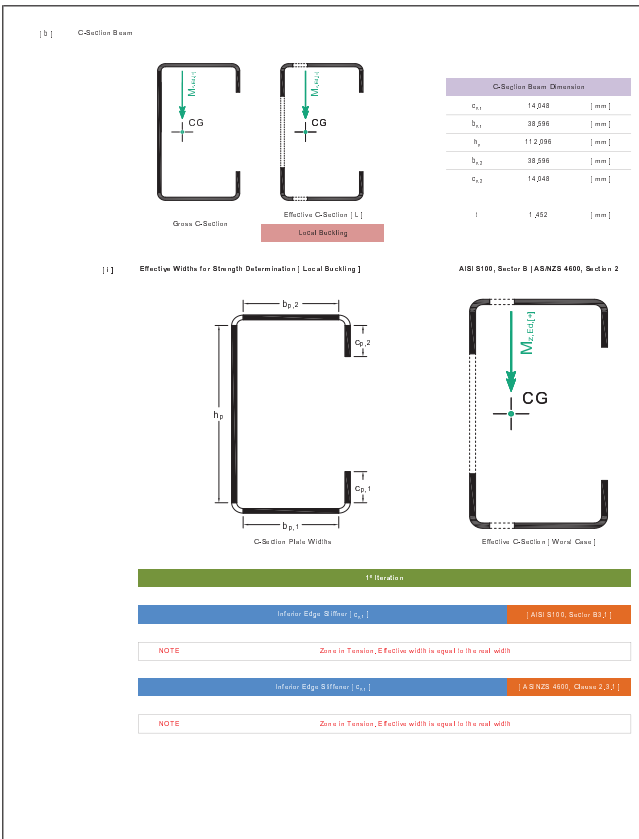
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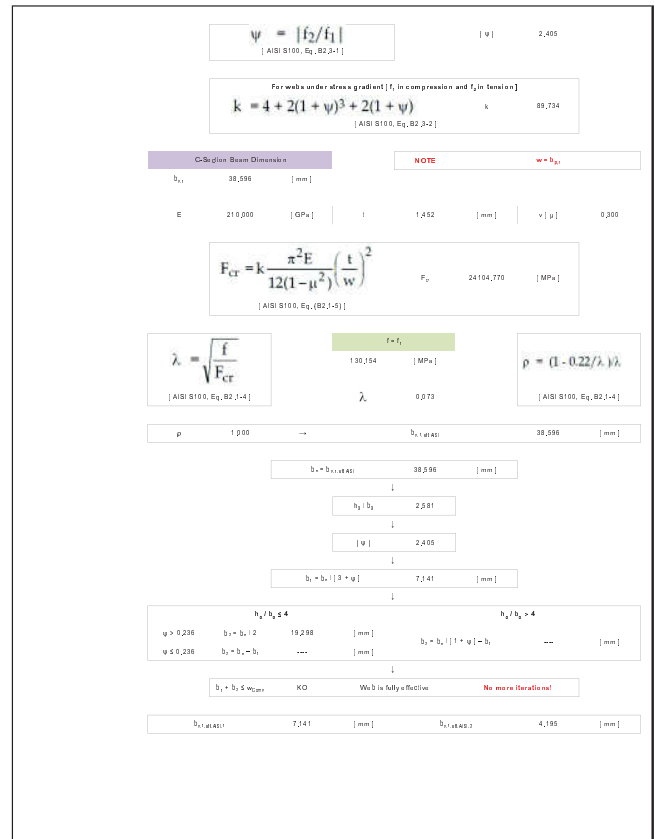
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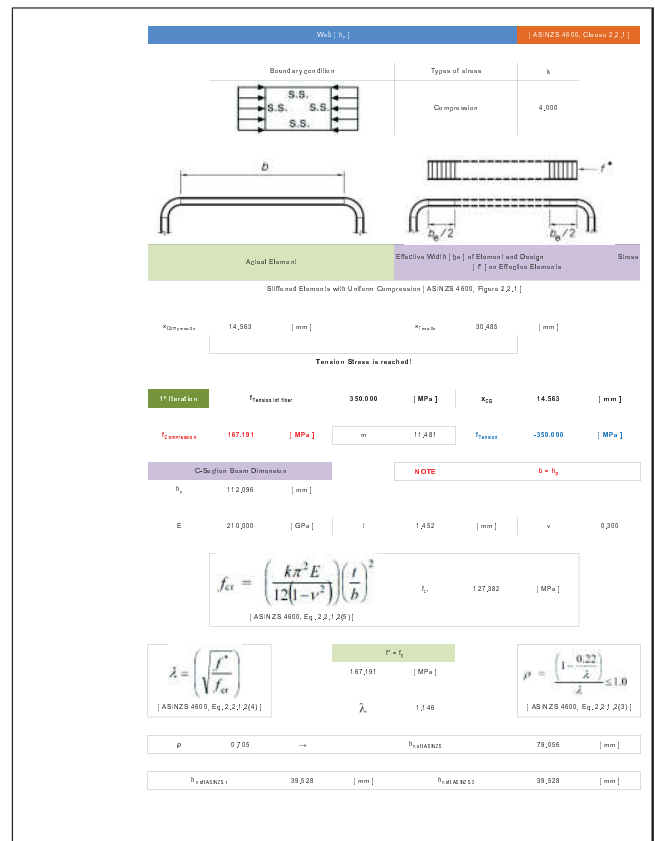
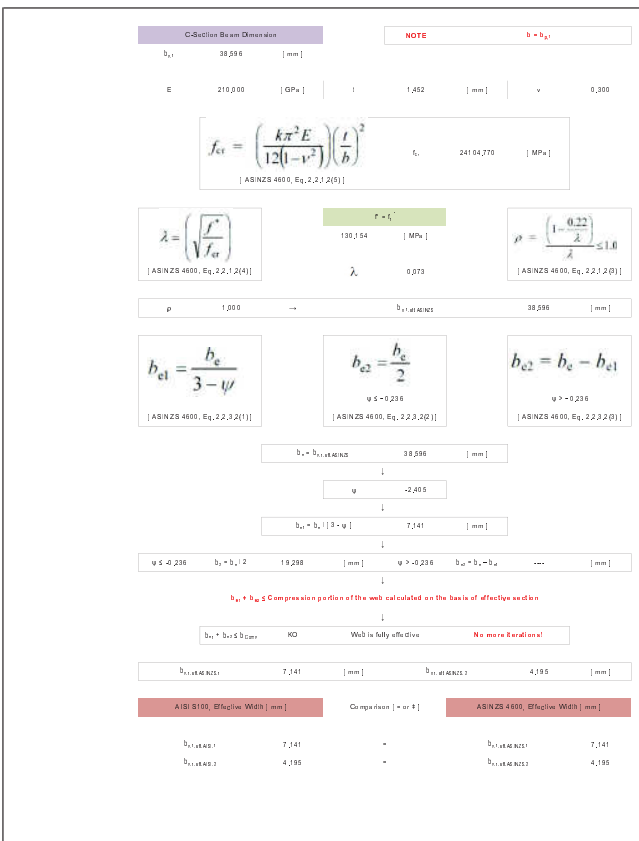
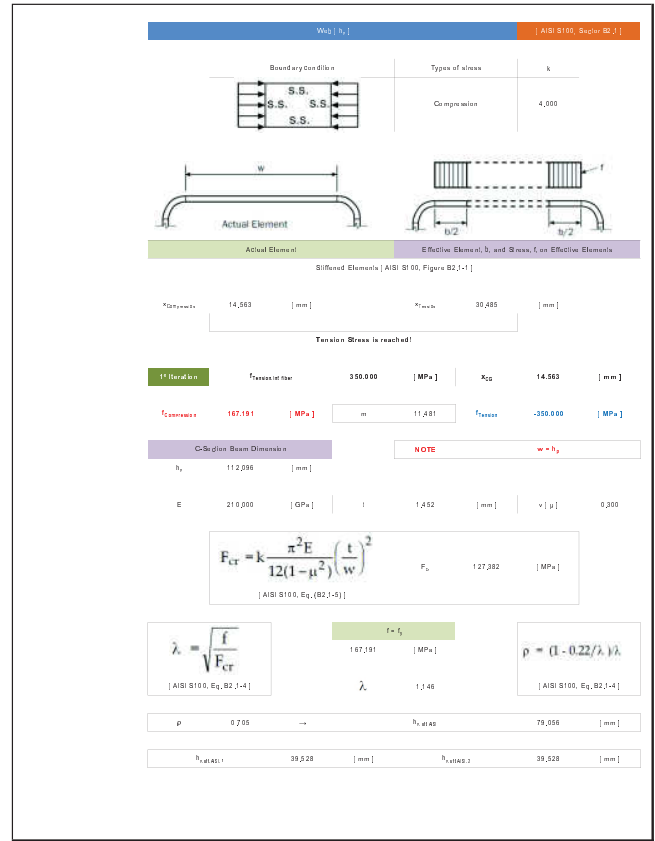
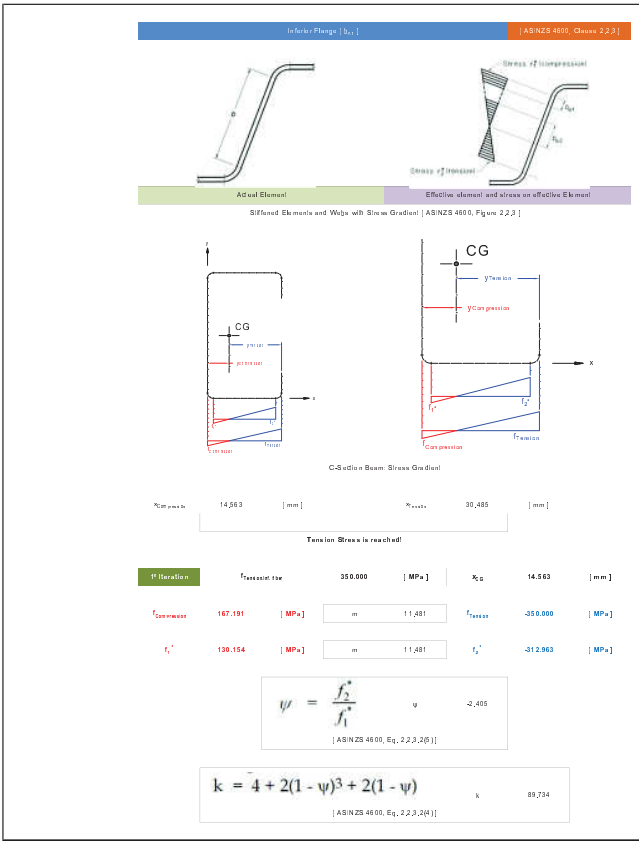


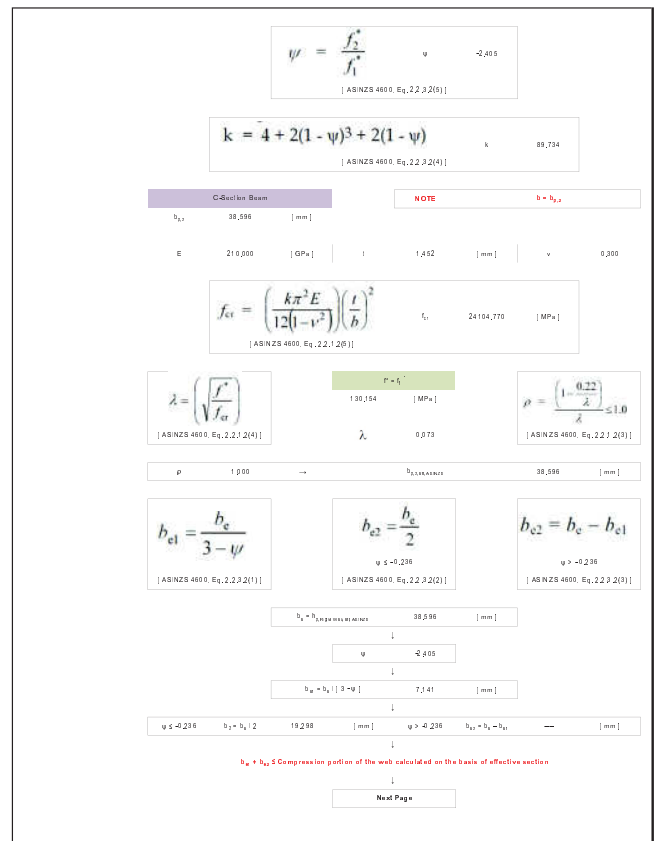
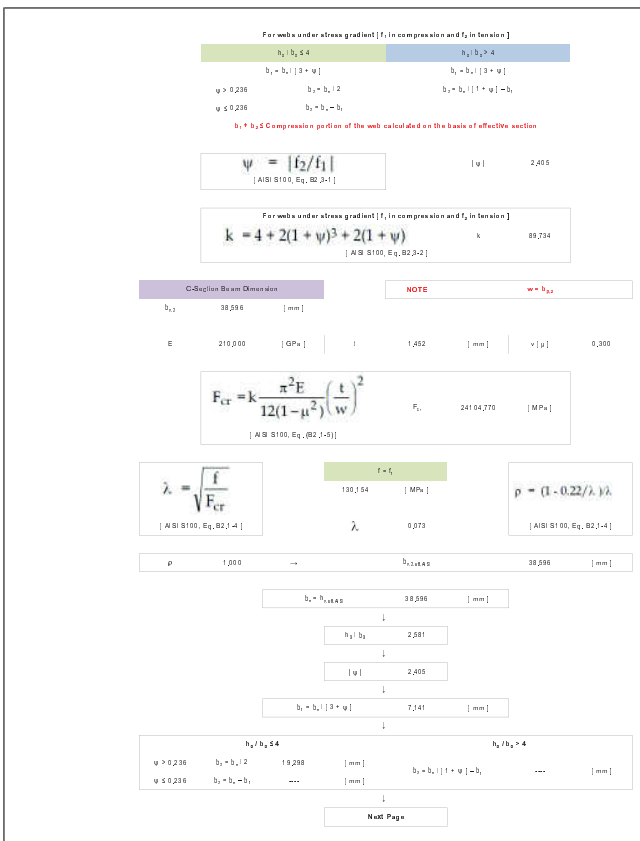
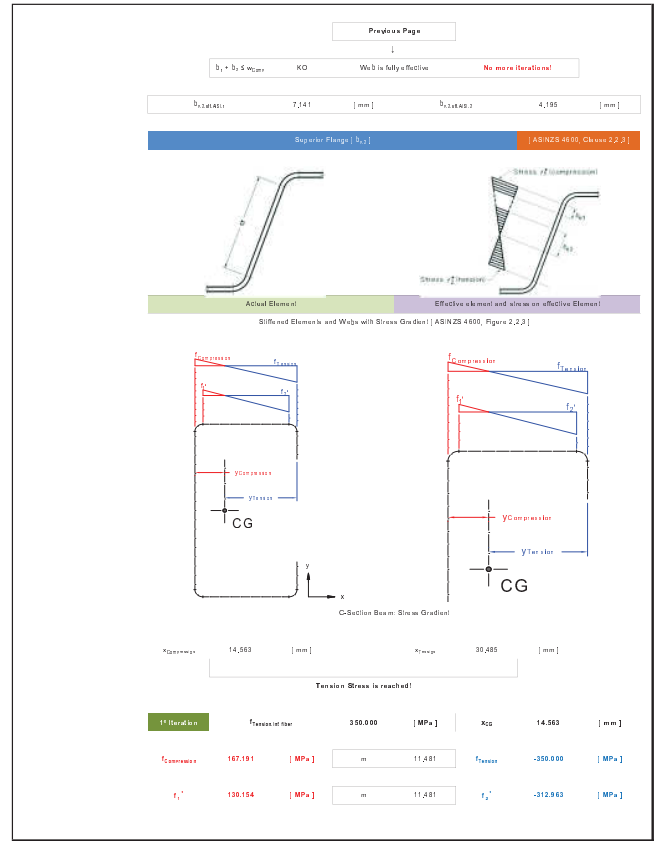
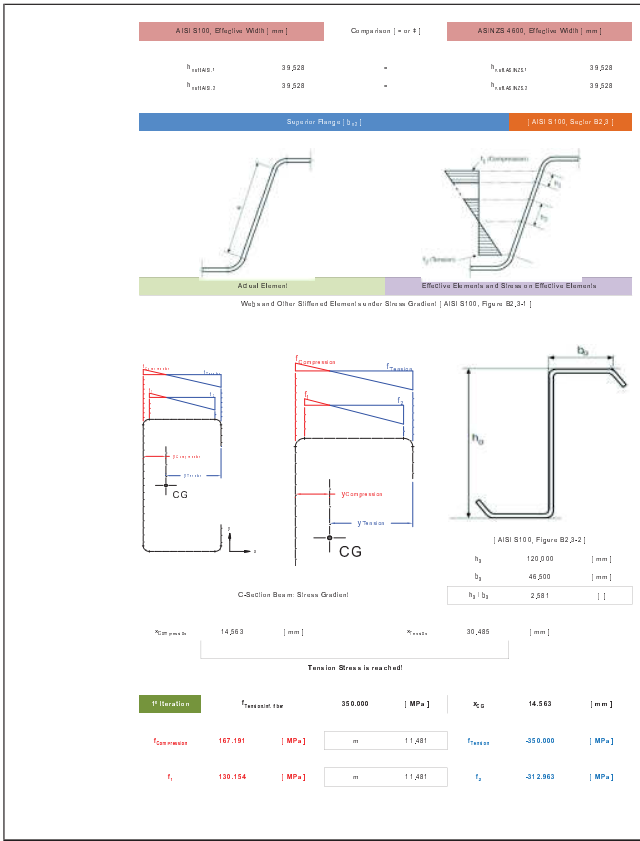
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Version: 1,000			



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$b_p + b_{p,5} b_{p,200}$ KO Web is fully effective **Notion Rational!**

$b_{EFFECTIVE}$	7,141	[mm]	$b_{EFFECTIVE}$	4,955	[mm]
-----------------	-------	------	-----------------	-------	------

AISI S100, Effective Width [mm] Comparison: + or 4 AS/NZS 4600, Effective Width [mm]

$b_{EFFECTIVE}$	7,141	-	$b_{EFFECTIVE}$	7,141
$b_{EFFECTIVE}$	4,955	-	$b_{EFFECTIVE}$	4,955

Superior Edge Stiffener [c_{y1}] AISI S100, Section B3.1

NOTE Zone in Tension, Effective width is equal to the real width

Superior Edge Stiffener [c_{y1}] 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	$c_{EFFECTIVE}$	---	[mm]
Inferior Flange	$b_{EFFECTIVE}$	38,596	[mm]
Web	$b_{EFFECTIVE}$	79,056	[mm]
Superior Flange	$b_{EFFECTIVE}$	38,596	[mm]
Superior Edge Stiffener	$c_{EFFECTIVE}$	---	[mm]

Effective C-Section Beam Widths [AS/NZS 4600]

Inferior Edge Stiffener	$c_{EFFECTIVE}$	---	[mm]
Inferior Flange	$b_{EFFECTIVE}$	38,596	[mm]
Web	$b_{EFFECTIVE}$	79,056	[mm]
Superior Flange	$b_{EFFECTIVE}$	38,596	[mm]
Superior Edge Stiffener	$c_{EFFECTIVE}$	---	[mm]

Effective C-Section Beam Widths [AISI S100 | AS/NZS 4600]

Inferior Edge Stiffener	$c_{EFFECTIVE}$	---	[mm]
Inferior Flange	$b_{EFFECTIVE}$	38,596	[mm]
Web	$b_{EFFECTIVE}$	79,056	[mm]
Superior Flange	$b_{EFFECTIVE}$	38,596	[mm]
Superior Edge Stiffener	$c_{EFFECTIVE}$	---	[mm]

[c] C-Section Columns

Drawn C-Section Effective C-Section [c_y] Local Buckling

C-Section Columns Dimension	
c_{y1}	13,048 [mm]
b_{p1}	38,596 [mm]
b_p	89,006 [mm]
b_{p2}	38,596 [mm]
c_{y2}	13,048 [mm]
l	2,452 [mm]

[II] Effective Widths for Strength Determination | Local Buckling

C-Section Plate Widths Effective C-Section | Worst Case

1st Iteration

Inferior Edge Stiffener [c_{y1}] AISI S100, Section B3.1

NOTE Zone in Tension, Effective width is equal to the real width

Inferior Edge Stiffener [c_{y1}] AS/NZS 4600, Clause 2.3.1

NOTE Zone in Tension, Effective width is equal to the real width

[III] Effective Cross C-Section Beam | Local Buckling

Effective C-Section Beam Widths

Inferior Edge Stiffener	$c_{EFFECTIVE}$	---	[mm]
Inferior Flange	$b_{EFFECTIVE}$	7,141	[mm]
	$b_{EFFECTIVE}$	4,955	[mm]
Web	$b_{EFFECTIVE}$	39,528	[mm]
	$b_{EFFECTIVE}$	39,528	[mm]
Superior Flange	$b_{EFFECTIVE}$	7,141	[mm]
	$b_{EFFECTIVE}$	4,955	[mm]
Superior Edge Stiffener	$c_{EFFECTIVE}$	---	[mm]

Effective C-Section Beam | Local Buckling | Bending Moment M_{y1} | AISI S100 | AS/NZS 4600

Effective C-Section Beam | Local Buckling | Bending Moment M_{y1}

$l_{eff}^{[1]}$ 9697,280 [mm]

Inferior Flange [b_{y1}] AISI S100, Section B2.3.1

Actual Element Effective Elements under Stress Gradient | AISI S100, Figure B2.3.1

Walls and Other Stiffened Elements under Stress Gradient | AISI S100, Figure B2.3.1

C-Section Column Stress Gradient

$x_{max,cs}$	16,159 [mm]	$x_{min,cs}$	27,889 [mm]
--------------	-------------	--------------	-------------

Tension Stress is reached!

1st Iteration

$f_{max,cs,tension}$	350.000 [MPa]	σ_{cs}	16,159 [mm]
$f_{compression}$	202,797 [MPa]	$f_{max,cs}$	-350.000 [MPa]
f_c	166,036 [MPa]	f_c	-303,239 [MPa]

For webs under stress gradient [f_c in compression and f_t in tension]

b_1$ | b_2 \leq 4$	b_1$ | b_2 > 4$
$b_1 = b_2$ | $3 + \psi$	$b_1 = b_2$ | $3 + \psi$
$\psi > 0,236$ | $b_2 = b_1 / 2$	$b_2 = b_1$ | $1 + \psi = b_1$
$\psi \leq 0,236$ | $b_2 = b_1 = b_1$	

$b_1 + b_2$ Compression portion of the web calculated on the basis of effective section

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$\psi = \frac{f_2/f_1}{}$ [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** | $w = b_{22}$

b_{22} | 36,596 | [mm]

E | 210,000 | [GPa] | t | 2,452 | [mm] | v | ν | 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1 - \mu^2)} \left(\frac{t}{w}\right)^2$ [AISI S100, Eq. B2.3-4] | F_{cr} | 51879,743 | [MPa]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ [AISI S100, Eq. B2.3-4] | $r = t$ | 156,036 | [MPa] | $\rho = (1 - 0,22/\lambda) \lambda$ [AISI S100, Eq. B2.3-4] | λ | 0,955

ρ | 1,000 | $b_{1,145AS}$ | 36,596 | [mm]

$b_1 = b_{1,145AS}$ | 36,596 | [mm]

$b_1/2$ | 1,8298 | [mm]

$|w|$ | 1,943 | [mm]

$b_2 = b_1(1 + \psi)$ | 7,493 | [mm]

$b_{22}/b_{21} \leq 4$ | $b_2/b_{21} > 4$

$\psi > 0,236$ | $b_2 = b_1/2$ | 1,8298 | [mm] | $b_2 = b_1(1 + \psi)$ | 7,493 | [mm]

$\psi \leq 0,236$ | $b_2 = b_1 = b_1$ | 36,596 | [mm]

$b_1 \leq b_{1,max}$ | KO | Web is fully effective. **No more iterations!**

$b_{1,145AS}$ | 7,493 | [mm] | $b_{1,145AS}$ | 5,030 | [mm]

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C-Section Column | **NOTE** | $b = b_{22}$

b_{22} | 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)] | $r = t$ | 156,036 | [MPa] | $\rho = \left(\frac{1 - 0,22}{\lambda}\right) \lambda \leq 1,0$ [AS/NZS 4600, Eq. 2.2.1.2(3)] | λ | 0,955

ρ | 1,000 | $b_{1,145AS}$ | 36,596 | [mm]

$b_{e1} = \frac{b_e}{3 - \psi}$ [AS/NZS 4600, Eq. 2.2.3.2(1)] | $b_{e2} = \frac{b_e}{2}$ | $b_{e2} = b_e - b_{e1}$ | $\psi \leq -0,236$ | $\psi > -0,236$ | $b_{e2} = b_e - b_{e1}$ | $\psi > -0,236$ | [AS/NZS 4600, Eq. 2.2.3.2(2)]

$b_{1,145AS}$ | 36,596 | [mm]

ψ | -1,943

$b_e = b_1(1 + \psi)$ | 7,493 | [mm]

$\psi \leq -0,236$ | $b_{e2} = b_e/2$ | 3,7465 | [mm] | $\psi > -0,236$ | $b_{e2} = b_{e1}$ | 3,7465 | [mm]

$b_e + b_{e2}$ Compression portion of the web calculated on the basis of effective section

$b_e + b_{e2} \leq b_{1,max}$ | KO | Web is fully effective. **No more iterations!**

$b_{1,145AS}$ | 7,493 | [mm] | $b_{1,145AS}$ | 5,030 | [mm]

AISI S100, Effective Width [mm] | **Compression | $\psi > 0$** | **AS/NZS 4600, Effective Width [mm]**

$b_{1,145AS}$ | 7,493 | | $b_{1,145AS}$ | 7,493

$b_{1,145AS}$ | 5,030 | | $b_{1,145AS}$ | 5,030

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Inferior Flange (b_{12}) | [AS/NZS 4600, Clause 2.2.3]

Actual Element | **Effective element and stress on effective Element**

Sifted 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!

1st Iteration | $f_{tension,max}$ | 350,000 | [MPa] | ρ_{cr} | 16,159 | [mm]

$f_{compression}$ | 202,797 | [MPa] | m | 12,550 | $f_{tension}$ | -350,000 | [MPa]

f_c | 156,036 | [MPa] | m | 12,550 | f_t | -303,239 | [MPa]

$\psi = \frac{f_2}{f_1}$ | ψ | -1,943 | [AS/NZS 4600, Eq. 2.2.3.2(3)]

$k = 4 + 2(1 - \psi)^3 + 2(1 - \psi)$ [AS/NZS 4600, Eq. 2.2.3.2(4)] | k | 60,887

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Web (b_{11}) | [AISI S100, Section B2.3.1]

Boundary condition | **Types of stress** | k

S.S. | S.S. | Compression | 4,000

Actual Element | **Effective Element, b_e , and Stress (σ) on Effective Elements**

Sifted Elements [AISI S100, Figure B2.3.1-1]

$x_{compression}$ | 16,159 | [mm] | $x_{tension}$ | 27,889 | [mm]

Tension Stress is reached!

1st Iteration | $f_{tension,max}$ | 350,000 | [MPa] | ρ_{cr} | 16,159 | [mm]

$f_{compression}$ | 202,797 | [MPa] | m | 12,550 | $f_{tension}$ | -350,000 | [MPa]

C-Section Column Dimension | **NOTE** | $w = b_{22}$

b_{22} | 36,596 | [mm]

E | 210,000 | [GPa] | t | 2,452 | [mm] | v | ν | 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1 - \mu^2)} \left(\frac{t}{w}\right)^2$ [AISI S100, Eq. B2.3-4] | F_{cr} | 711,501 | [MPa]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ [AISI S100, Eq. B2.3-4] | $r = t$ | 202,797 | [MPa] | $\rho = (1 - 0,22/\lambda) \lambda$ [AISI S100, Eq. B2.3-4] | λ | 0,934

ρ | 1,000 | $b_{1,145AS}$ | 36,596 | [mm]

$b_{1,145AS}$ | 40,048 | [mm] | $b_{1,145AS}$ | 40,048 | [mm]

Web b_w [AS/NZS 4600, Clause 2.2.3]

Boundary condition: S.S. S.S. S.S. S.S.

Types of stress: Compression

$k = 4,000$

Actual Element:

Effective Width b_e [of Element and Design f] (on Effective Elements)

Simplified Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.3]

$x_{Compress}$	16,359 [mm]	$x_{Tension}$	27,889 [mm]
----------------	-------------	---------------	-------------

Tension Stress is reached!

1st Iteration: $f_{Compress,ave} = 350,000$ [MPa], $\rho_{ave} = 16,159$ [mm]

$f_{Compress} = 202,797$ [MPa], $\lambda = 0,934$, $f_{Tension} = -350,000$ [MPa]

C-Section Column Dimension: NOTE $b = b_w$

b_f	80,096 [mm]	E	210,000 [GPa]	t	2,452 [mm]	v	0,300
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$f_{cr} = \left(\frac{k\pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$ [AS/NZS 4600, Eq.2.2.1.2(a)]

$f_c = 711,301$ [MPa]

$\lambda = \sqrt{\frac{f}{f_{cr}}}$ [AS/NZS 4600, Eq.2.2.1.2(a)], $\rho = \frac{f}{f_c} \leq 1,0$ [AS/NZS 4600, Eq.2.2.1.2(b)]

ρ	1,000	$b_{e,1,4600}$	80,096 [mm]
$b_{e,AS/NZS1}$	40,048 [mm]	$b_{e,AS/NZS2}$	40,048 [mm]

For webs under stress gradient f_1 in compression and f_2 in tension

$b_1/b_2 \leq 4$: $b_e = b_1 | 3 + \psi |$, $b_e = b_2 | 1 + \psi |$

$\psi > 0,236$: $b_2 = b_1 | 2$, $b_2 = b_1 | 1 + \psi | - b_1$

$\psi \leq 0,236$: $b_2 = b_1 - b_1$

$b_1 + b_2 \leq$ 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], $k = 69,887$

C-Section Column Dimension: NOTE $b = b_w$

$b_{e,1}$	36,096 [mm]	E	210,000 [GPa]	t	2,452 [mm]	v [v]	0,300
-----------	-------------	---	---------------	-----	------------	---------	-------

$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$ [AISI S100, Eq. (B2.3-4)], $F_c = 51879,743$ [MPa]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ [AISI S100, Eq. B2.3-4], $\lambda = 0,958$, $\rho = (1 - 0,22/\lambda) \lambda$ [AISI S100, Eq. B2.3-4]

$\rho = 1,000$, $b_{e,1,4600} = 36,096$ [mm]

$b_e = b_1 | 3 + \psi | = 36,096$ [mm]

$b_1/b_2 = 1,935$

$\psi = 1,943$

$b_2 = b_1 | 1 + \psi | = 7,403$ [mm]

$b_1/b_2 \leq 4$: $b_1 = b_1 | 2 = 18,298$ [mm], $b_2 = b_1 | 1 + \psi | = b_2$

$\psi > 0,236$: $b_2 = b_1 - b_1$

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AISI S100, Effective Width [mm]: $b_{e1,AS100} = 40,048$, $b_{e2,AS100} = 40,048$

AS/NZS 4600, Effective Width [mm]: $b_{e1,AS4600} = 40,048$, $b_{e2,AS4600} = 40,048$

Superior Flange b_{sf} [AISI S100, Section B2.3]

Actual Element:

Effective Elements and Stress on Effective Elements

Web and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.3-1]

C-Section Column Stress Gradient: $b_1 = 90,000$ [mm], $b_2 = 46,500$ [mm], $b_1/b_2 = 1,935$ []

$x_{Compress}$	16,359 [mm]	$x_{Tension}$	27,889 [mm]
----------------	-------------	---------------	-------------

Tension Stress is reached!

1st Iteration: $f_{Compress,ave} = 350,000$ [MPa], $\rho_{ave} = 16,159$ [mm]

$f_{Compress} = 202,797$ [MPa], $\lambda = 0,934$, $f_{Tension} = -350,000$ [MPa]

$f_c = 156,036$ [MPa], $f_1 = -303,239$ [MPa]

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$b_1 + b_2 \leq$ Web is fully effective. No more iterations!

$b_{e1,4600}$	7,403 [mm]	$b_{e2,4600}$	5,000 [mm]
---------------	------------	---------------	------------

Superior Flange b_{sf} [AS/NZS 4600, Clause 2.2.3]

Actual Element:

Effective Elements and Stress on Effective Elements

Simplified Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]

C-Section Column Stress Gradient: $b_1 = 90,000$ [mm], $b_2 = 46,500$ [mm], $b_1/b_2 = 1,935$ []

$x_{Compress}$	16,359 [mm]	$x_{Tension}$	27,889 [mm]
----------------	-------------	---------------	-------------

Tension Stress is reached!

1st Iteration: $f_{Compress,ave} = 350,000$ [MPa], $\rho_{ave} = 16,159$ [mm]

$f_{Compress} = 202,797$ [MPa], $\lambda = 0,934$, $f_{Tension} = -350,000$ [MPa]

$f_1 = 156,036$ [MPa], $f_2 = -303,239$ [MPa]

$$\psi = \frac{f_2}{f_1} = -0,943 \quad \text{[AS/NZS 4600, Eq. 2.2.3.2(6)]}$$

$$k = 4 + 2(1 - \psi)^3 + 2(1 - \psi) = 60,387 \quad \text{[AS/NZS 4600, Eq. 2.2.3.2(4)]}$$

C-Section Column Dimension		NOTE: $b_1 = b_{12}$	
b_{12}	36,596 [mm]		
E	210,000 [GPa]	I	2,452 [mm ⁴]
		v	0,300

$$f_{cr} = \left(\frac{k\pi^2 E}{12(1 - \nu^2)} \right) \left(\frac{t}{b} \right)^2 = 51879,743 \text{ [MPa]} \quad \text{[AS/NZS 4600, Eq. 2.2.1.2(5)]}$$

$\lambda = \sqrt{\frac{f}{f_{cr}}}$	$r = \sqrt{I/A}$	$\rho = \left(\frac{1 - 0,22}{\lambda} \right) \leq 1,0$
1,000	156,036 [MPa]	0,955
	λ	0,955

ρ	1,000	$b_{1,eff} = \rho b_1$	36,596 [mm]
--------	-------	------------------------	-------------

$$h_{el} = \frac{b_e}{3 - \psi} = 18,298 \text{ [mm]} \quad \text{[AS/NZS 4600, Eq. 2.2.3.2(1)]}$$

$$h_{c2} = \frac{b_e}{2} = 18,298 \text{ [mm]} \quad \text{[AS/NZS 4600, Eq. 2.2.3.2(2)]}$$

$$b_{c2} = b_e - b_{e1} = 18,298 \text{ [mm]} \quad \text{[AS/NZS 4600, Eq. 2.2.3.2(3)]}$$

$b_1 = b_{1,eff} = 36,596$ [mm]

$\psi = -0,943$

$b_{11} = b_1 [1 - \psi] = 7,403$ [mm]

$\psi < -0,236 \Rightarrow b_1 = b_1 / 2 = 18,298$ [mm]

$\psi > -0,236 \Rightarrow b_2 = b_1 = 18,298$ [mm]

$b_{11} \neq b_{12}$ Compression portion of the web calculated on the basis of effective section

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[3] Effective Cross-C-Section Column [Local Buckling]

Effective C-Section Column Widths			
Inferior Edge Stiffener	$s_{1,eff}$	---	[mm]
Inferior Flange	$b_{1,eff}$	7,403	[mm]
Web	$b_{w,eff}$	5,930	[mm]
	$b_{w,eff}$	40,948	[mm]
Superior Flange	$b_{2,eff}$	7,403	[mm]
	$b_{2,eff}$	5,930	[mm]
Superior Edge Stiffener	$s_{2,eff}$	---	[mm]

Effective C-Section Column [Local Buckling] | Bending Moment $M_{y,eff}$ | AISI S100 | AS/NZS 4600

Effective C-Section Column [Local Buckling] | Bending Moment $M_{y,eff}$

$I_{y,eff} = 153,816,866$ [mm⁴]

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$b_2 = b_{12} = b_{2,eff} = 5,930$ [mm] Web is fully effective **Not a Non-Rational!**

$b_{1,eff} = 7,403$ [mm]	$b_{2,eff} = 5,930$ [mm]
--------------------------	--------------------------

AISI S100, Effective Width [mm]	Comparison: \leq or \neq	AS/NZS 4600, Effective Width [mm]
$b_{1,eff} = 7,403$	=	$b_{1,eff} = 7,403$
$b_{2,eff} = 5,930$	=	$b_{2,eff} = 5,930$

Superior Edge Stiffener | $s_{1,eff}$ | AISI S100, Section B3.1

NOTE: Zone in Tension, Effective width is equal to the real width

Superior Edge Stiffener | $s_{2,eff}$ | AS/NZS 4600, Clause 2.3.1

NOTE: Zone in Tension, Effective width is equal to the real width

[3] Effective C-Section Column [Local Buckling]

Effective C-Section Column Widths | AISI S100			
Inferior Edge Stiffener	$s_{1,eff}$	---	[mm]
Inferior Flange	$b_{1,eff}$	7,403	[mm]
Web	$b_{w,eff}$	5,930	[mm]
Superior Flange	$b_{2,eff}$	7,403	[mm]
Superior Edge Stiffener	$s_{2,eff}$	---	[mm]

Effective C-Section Column Widths | AS/NZS 4600			
Inferior Edge Stiffener	$s_{1,eff}$	---	[mm]
Inferior Flange	$b_{1,eff}$	7,403	[mm]
Web	$b_{w,eff}$	5,930	[mm]
Superior Flange	$b_{2,eff}$	7,403	[mm]
Superior Edge Stiffener	$s_{2,eff}$	---	[mm]

Effective C-Section Column Widths | AISI S100 | AS/NZS 4600			
Inferior Edge Stiffener	$s_{1,eff}$	---	[mm]
Inferior Flange	$b_{1,eff}$	7,403	[mm]
Web	$b_{w,eff}$	5,930	[mm]
Superior Flange	$b_{2,eff}$	7,403	[mm]
Superior Edge Stiffener	$s_{2,eff}$	---	[mm]

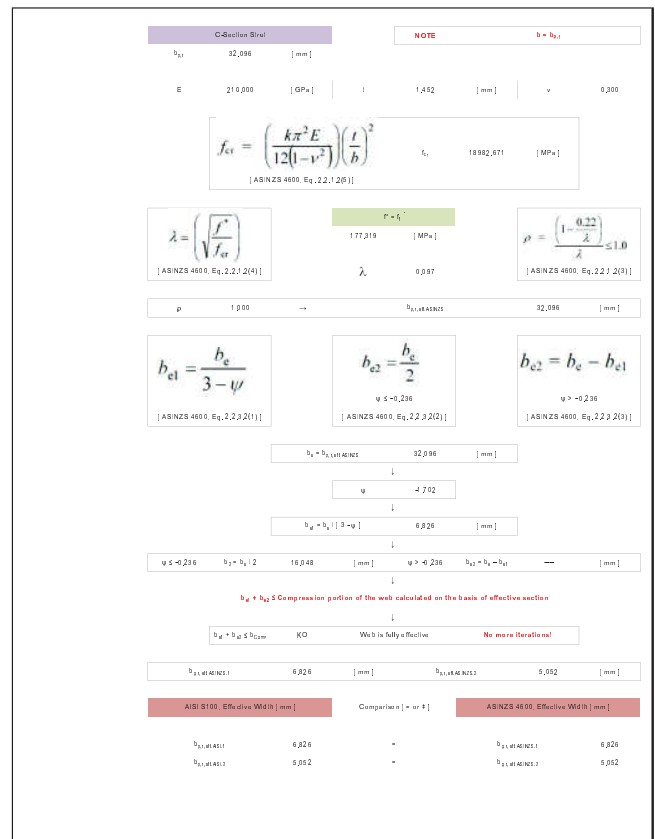
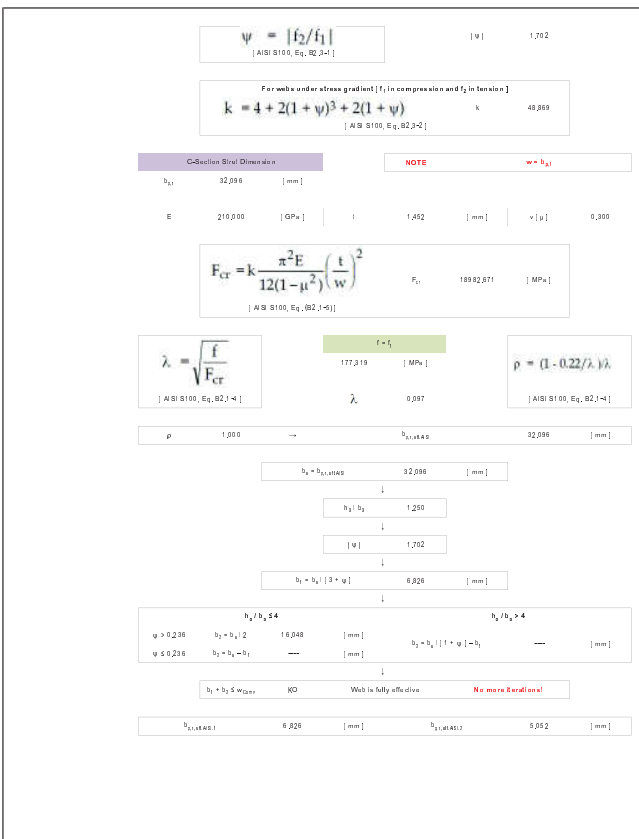
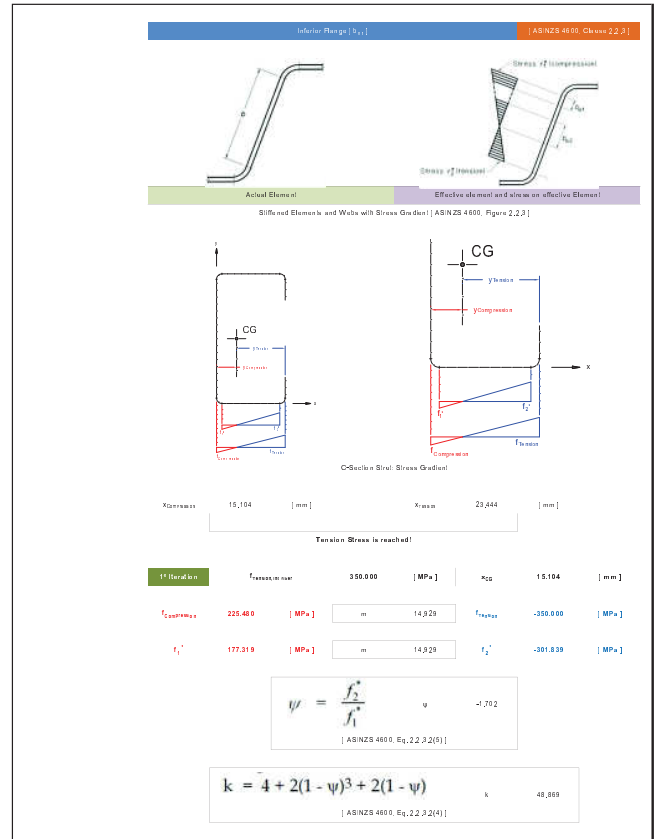
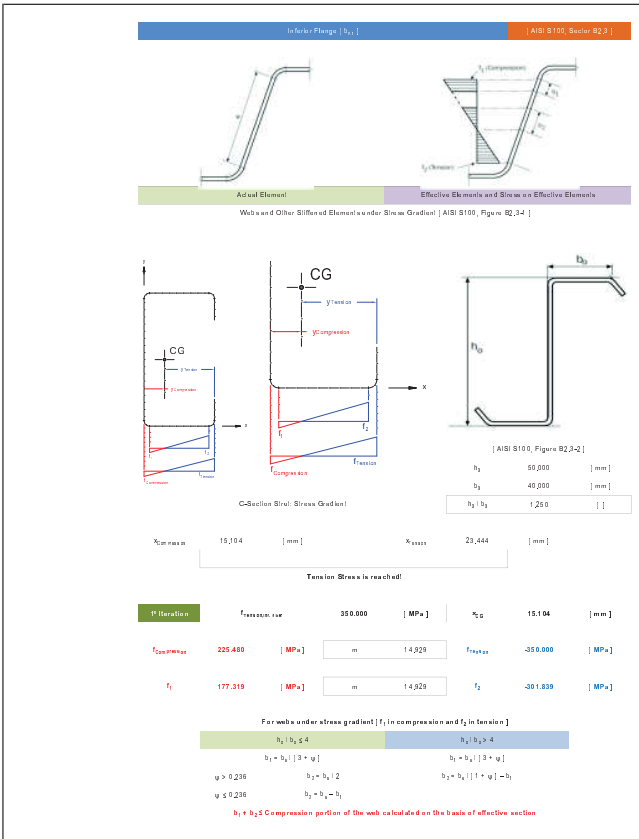
[4] C-Section Slit

C-Section Slit Dimension			
$s_{1,eff}$	6,948	[mm]	
$b_{1,eff}$	32,996	[mm]	
b_w	42,996	[mm]	
$b_{2,eff}$	32,996	[mm]	
$s_{2,eff}$	6,948	[mm]	
I	1,452	[mm]	

Original C-Section | Effective C-Section [L] | Local Buckling

[1] Effective Widths for Strength Determination | Local Buckling

Effective C-Section [Web] Case			
Inferior Edge Stiffener | $s_{1,eff}$	---	[mm]	AISI S100, Section B3.1
NOTE: Zone in Tension, Effective width is equal to the real width			
Inferior Edge Stiffener $s_{2,eff}$	---	[mm]	AS/NZS 4600, Clause 2.3.1
NOTE: Zone in Tension, Effective width is equal to the real width			



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Web (b_w) | AISI S100, Section B2.1

Boundary condition: S.S., S.S., S.S., S.S. | Types of stress: Compression | k : 4,000

Actual Element | Effective Element (b_w and Stress, f) on Effective Elements

Siffened Elements [AISI S100, Figure B2.1-1]

$x_{Compress}$ 15,104 [mm] | $x_{Tension}$ 23,444 [mm]

Tension Stress is reached!

Iteration: $f_{Tension, max}$ 350,000 [MPa] | ρ_{cr} 15,104 [mm]

$f_{Compress}$ 225,480 [MPa] | m 14,929 | $f_{Tension}$ -350,000 [MPa]

C-Section Size Dimension: NOTE $w = b_w$

b_w 42,096 [mm] | E 210,000 [GPa] | I 1,452 [mm⁴] | v [μ] 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w}\right)^2$ | F_{cr} 993,290 [MPa] | [AISI S100, Eq. B2.1-4]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ | $f = f_y$ 225,480 [MPa] | $\rho = (1 - 0.22/\lambda) \lambda$ | [AISI S100, Eq. B2.1-1]

ρ 1,000 --- | $b_{y,elastic}$ 42,096 [mm]

$b_{y,elastic}$ 21,048 [mm] | $b_{y,elastic}$ 21,048 [mm]

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AISI S100, Effective Width [mm] | Compression $\psi > 0$ | AS/NZS 4600, Effective Width [mm]

$b_{y,elastic}$ 42,096 | $b_{y,elastic}$ 21,048 | $b_{y,elastic}$ 21,048

Stuffer Flange (b_{st}) | AISI S100, Section B2.1

Actual Element | Effective Element (b_w and Stress on Effective Elements)

Web and Other Siffened Elements under Stress Gradient [AISI S100, Figure B2.1-1]

C-Section Size Dimension: NOTE $w = b_w$

b_w 42,096 [mm] | E 210,000 [GPa] | I 1,452 [mm⁴] | v [μ] 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w}\right)^2$ | F_{cr} 993,290 [MPa] | [AISI S100, Eq. B2.1-4]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ | $f = f_y$ 225,480 [MPa] | $\rho = (1 - 0.22/\lambda) \lambda$ | [AISI S100, Eq. B2.1-1]

ρ 1,000 --- | $b_{y,elastic}$ 42,096 [mm]

$b_{y,elastic}$ 21,048 [mm] | $b_{y,elastic}$ 21,048 [mm]

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Web (b_w) | AS/NZS 4600, Clause 2.2.1

Boundary condition: S.S., S.S., S.S., S.S. | Types of stress: Compression | k : 4,000

Actual Element | Effective Width (b_w) of Element and Design Stress (f) on Effective Elements

Siffened Elements with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

$x_{Compress}$ 15,104 [mm] | $x_{Tension}$ 23,444 [mm]

Tension Stress is reached!

Iteration: $f_{Tension, max}$ 350,000 [MPa] | ρ_{cr} 15,104 [mm]

$f_{Compress}$ 225,480 [MPa] | m 14,929 | $f_{Tension}$ -350,000 [MPa]

C-Section Size Dimension: NOTE $b = b_w$

b_w 42,096 [mm] | E 210,000 [GPa] | I 1,452 [mm⁴] | v 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1-\nu^2)} \left(\frac{t}{b}\right)^2$ | F_{cr} 993,290 [MPa] | [AS/NZS 4600, Eq. 2.2.1.2(a)]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ | $f = f_y$ 225,480 [MPa] | $\rho = \frac{1 - 0.22/\lambda}{\lambda} \leq 1.0$ | [AS/NZS 4600, Eq. 2.2.1.2(a)]

ρ 1,000 --- | $b_{y,elastic}$ 42,096 [mm]

$b_{y,elastic}$ 21,048 [mm] | $b_{y,elastic}$ 21,048 [mm]

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For webs under stress gradient (f_1 in compression and f_2 in tension)

$b_w/b_f \leq 4$ | $b_w/b_f > 4$

$b_w > b_f [1.3 + \psi]$ | $b_w > b_f [1.3 + \psi]$

$\psi > 0,236$ | $b_2 = b_f / 2$ | $b_2 = b_f [1 + \psi] - b_1$

$\psi \leq 0,236$ | $b_2 = b_f - b_1$

$b_1 + b_2$ Compression portion of the web calculated on the basis of effective section

$\psi = |f_2/f_1|$ | $|\psi|$ 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 Size Dimension: NOTE $w = b_w$

b_w 42,096 [mm] | E 210,000 [GPa] | I 1,452 [mm⁴] | v [μ] 0,300

$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w}\right)^2$ | F_{cr} 19,982,671 [MPa] | [AISI S100, Eq. B2.1-4]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ | $f = f_y$ 177,319 [MPa] | $\rho = (1 - 0.22/\lambda) \lambda$ | [AISI S100, Eq. B2.1-1]

λ 0,997

ρ 1,000 --- | $b_{y,elastic}$ 42,096 [mm]

$b_{y,elastic}$ 32,096 [mm]

b_w/b_f 1,250

$|\psi|$ 1,702

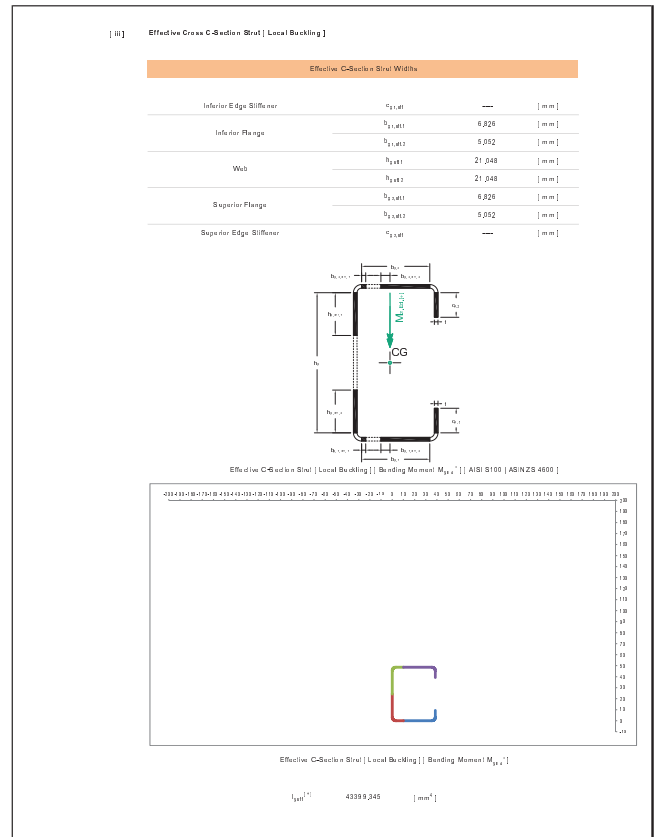
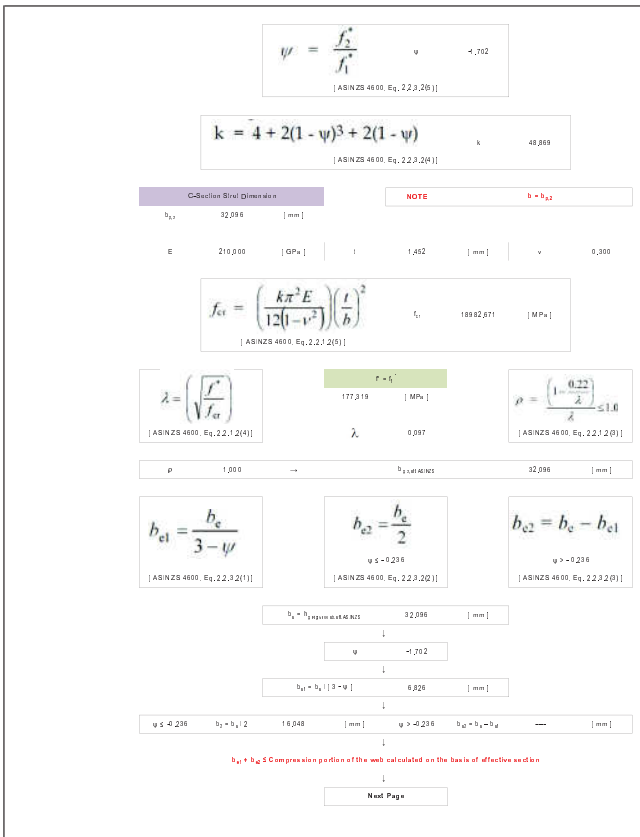
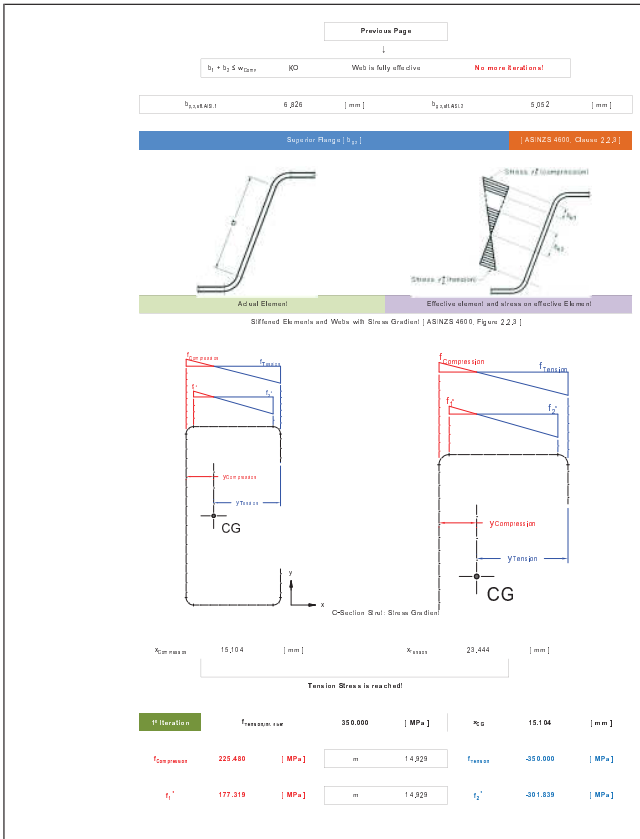
$b_w/b_f [1.3 + \psi]$ 6,826 [mm]

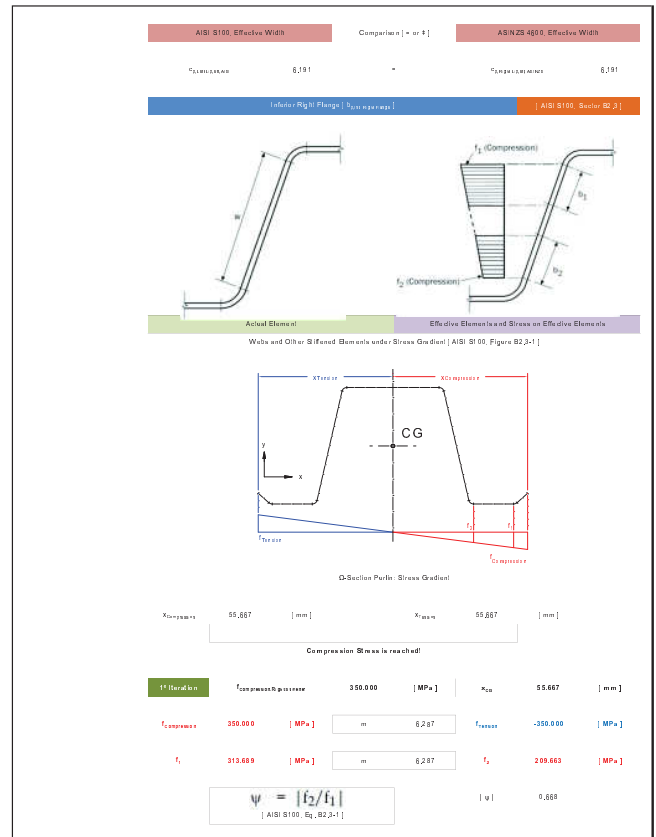
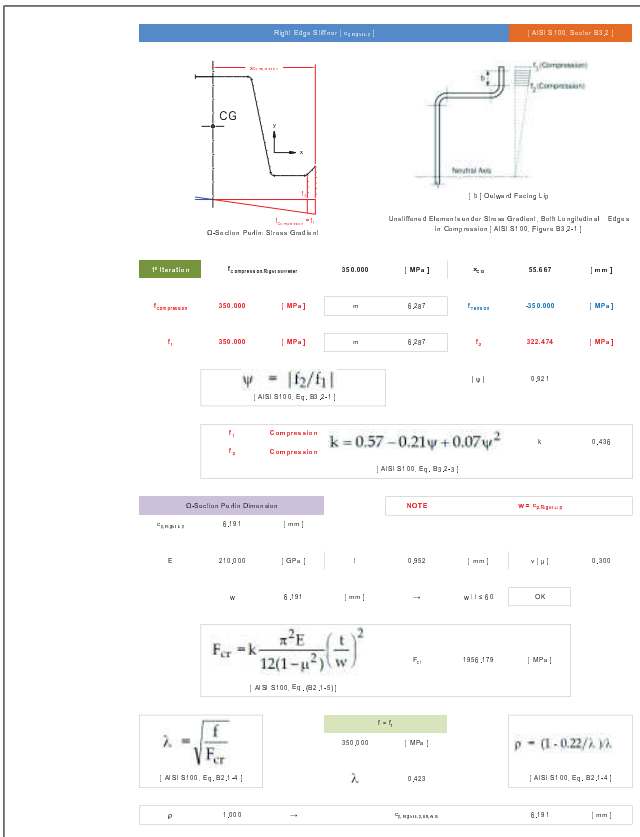
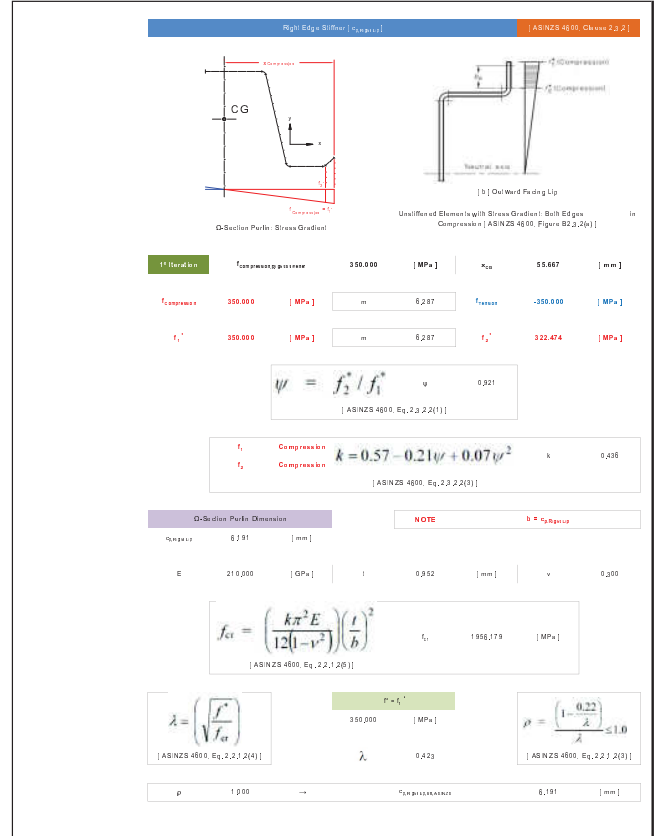
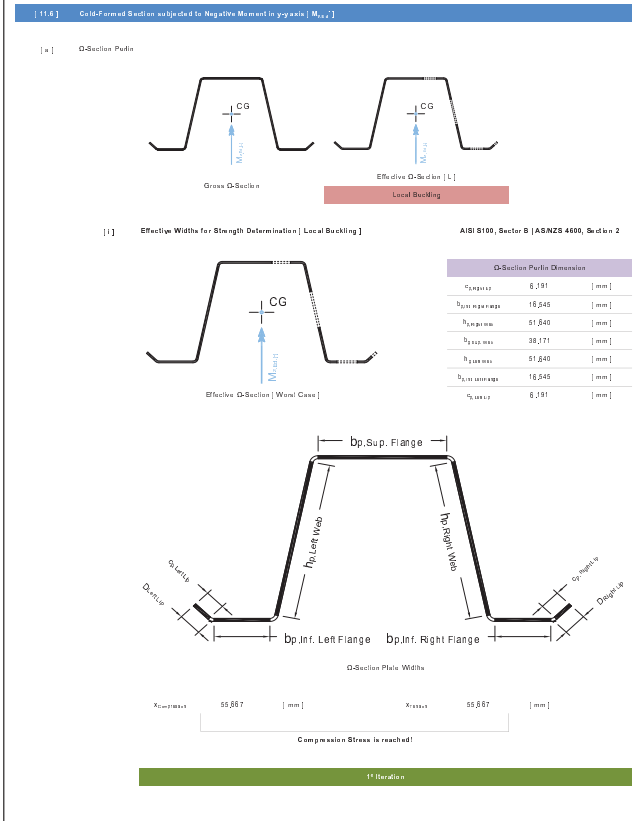
$b_w/b_f \leq 4$ | $b_w/b_f > 4$

$\psi > 0,236$ | $b_2 = b_f / 2$ 16,048 [mm] | $b_2 = b_f [1 + \psi] - b_1$ --- [mm]

$\psi \leq 0,236$ | $b_2 = b_f - b_1$ --- [mm]

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For webs under stress gradient (f_1 and f_2 in compression)

$$k = 4 + 2(1 - \psi)^3 + 2(1 - \psi) \quad k = 4,736$$

[AISI S100, Eq. B2.3-4]

D-Section Profile Dimension		NOTE	$W = b_w$ Required
b_w [mm]	16,245		
E [GPa]	210,000	t [mm]	0,952
v [μ]	0,300		

$$F_{cr} = k \frac{\pi^2 E}{12(1 - \mu^2)} \left(\frac{t}{w} \right)^2 \quad F_{cr} = 2970,136 \text{ [MPa]}$$

[AISI S100, Eq. B2.1-4]

$$\lambda = \sqrt{\frac{f}{F_{cr}}} \quad f = 313,689 \text{ [MPa]} \quad \rho = (1 - 0,22/\lambda) \lambda$$

[AISI S100, Eq. B2.1-4]

$\lambda = 0,225$ [AISI S100, Eq. B2.1-4]

$\rho = 1,000$ [AISI S100, Eq. B2.1-4]

$b_w = b_w$ [mm] 16,245

$b_1 = b_w / (3 - \psi)$ [AISI S100, Eq. B2.3-9] $b_1 = 7,996$ [mm]

$b_2 = b_w - b_1$ [AISI S100, Eq. B2.3-10] $b_2 = 8,249$ [mm]

b_w [mm] 16,245 b_w [mm] 16,245

b_w [mm] 7,996 b_w [mm] 8,249

Info: Right Flange (b_w is required) [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]

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$$\lambda = \left(\sqrt{\frac{f}{F_{cr}}} \right) \quad f = 313,689 \text{ [MPa]} \quad \rho = \left(\frac{1 - 0,22}{\lambda} \right) \lambda \leq 1,0$$

[AS/NZS 4600, Eq. 2.2.2(4)]

$\lambda = 0,225$

$\rho = 1,000$ [AS/NZS 4600, Eq. 2.2.2(5)]

$$b_{e1} = \frac{b_w}{3 - \psi} \quad b_{e2} = \frac{b_w}{2} \quad b_{e2} = b_w - b_{e1}$$

[AS/NZS 4600, Eq. 2.2.2(1)] [AS/NZS 4600, Eq. 2.2.2(2)] [AS/NZS 4600, Eq. 2.2.2(3)]

$b_w = b_w$ [mm] 16,245

$\psi = 0,868$

$b_w = b_w | 3 - \psi |$ [mm] 7,996

$\psi < -0,236$ $b_1 = b_1 | 2$ [mm] $\psi < -0,236$ $b_{e1} = b_w - b_{e1}$ [mm] 8,249

b_w [mm] 7,996 b_w [mm] 8,249

AISI S100, Effective Width [mm]	Comparison ($\psi < 0$)	AS/NZS 4600, Effective Width [mm]
b_{e1} [mm] 7,996	-	b_{e1} [mm] 7,996
b_{e2} [mm] 8,249	-	b_{e2} [mm] 8,249

Right Web (b_w is required) [AISI S100, Section 2.2]

Actual Element Effective Elements and Stress on Effective Elements

Webs and Other Stiffened Elements under Stress Gradient [AISI S100, Figure B2.1]

$x_{compression} = 55,667$ [mm] $x_{tension} = 55,667$ [mm]

Compression Stress is reached!

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D-Section Profile: Stress Gradient

$x_{compression} = 55,667$ [mm] $x_{tension} = 55,667$ [mm]

Compression Stress is reached!

f_1 Iteration	$f_{compression}$ [MPa]	350,000	ρ_{cr} [mm]	55,667
$f_{tension}$ [MPa]	350,000	m [mm]	8,287	$f_{tension}$ [-350,000] [MPa]
f_c [MPa]	313,689	m [mm]	8,287	f_c [209,463] [MPa]

$$\psi = \frac{f_2}{f_1} \quad \psi = 0,868$$

[AS/NZS 4600, Eq. 2.2.2(6)]

$$k = 4 + 2(1 - \psi)^3 + 2(1 - \psi) \quad k = 4,736$$

[AS/NZS 4600, Eq. 2.2.2(4)]

D-Section Profile Dimension		NOTE	$b = b_w$ Required
b_w [mm]	16,245		
E [GPa]	210,000	t [mm]	0,952
v [μ]	0,300		

$$F_{cr} = k \frac{\pi^2 E}{12(1 - \mu^2)} \left(\frac{t}{b} \right)^2 \quad F_{cr} = 305,382 \text{ [MPa]}$$

[AISI S100, Eq. B2.1-4]

$$\lambda = \sqrt{\frac{f}{F_{cr}}} \quad f = 197,493 \text{ [MPa]} \quad \rho = (1 - 0,22/\lambda) \lambda$$

[AISI S100, Eq. B2.1-4]

$\lambda = 0,264$

$\rho = 1,000$ [AISI S100, Eq. B2.1-4]

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D-Section Profile: Stress Gradient

$x_{compression} = 55,667$ [mm] $x_{tension} = 55,667$ [mm]

Tension Stress is reached!

f_1 Iteration	$f_{compression}$ [MPa]	350,000	ρ_{cr} [mm]	55,667
$f_{tension}$ [MPa]	350,000	m [mm]	8,287	$f_{tension}$ [-350,000] [MPa]
f_c [MPa]	197,493	m [mm]	8,287	f_c [132,163] [MPa]

$$\psi = |f_2/f_1| \quad \psi = 0,868$$

[AISI S100, Eq. B2.3-1]

$$k = 4 + 2(1 - \psi)^3 + 2(1 - \psi) \quad k = 4,736$$

[AISI S100, Eq. B2.3-4]

D-Section Profile Dimension		NOTE	$W = b_w$ Required
b_w [mm]	16,245		
E [GPa]	210,000	t [mm]	0,952
v [μ]	0,300		

$$F_{cr} = k \frac{\pi^2 E}{12(1 - \mu^2)} \left(\frac{t}{w} \right)^2 \quad F_{cr} = 305,382 \text{ [MPa]}$$

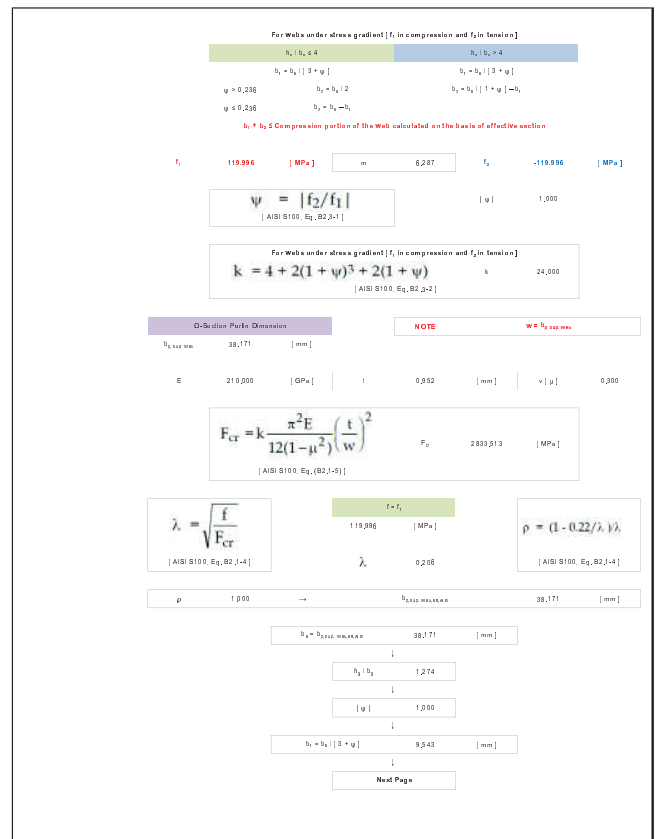
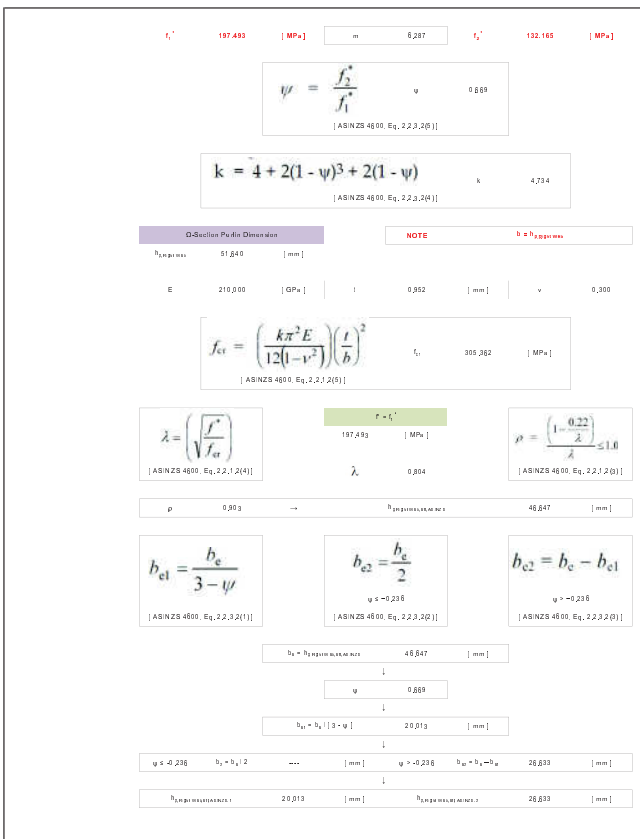
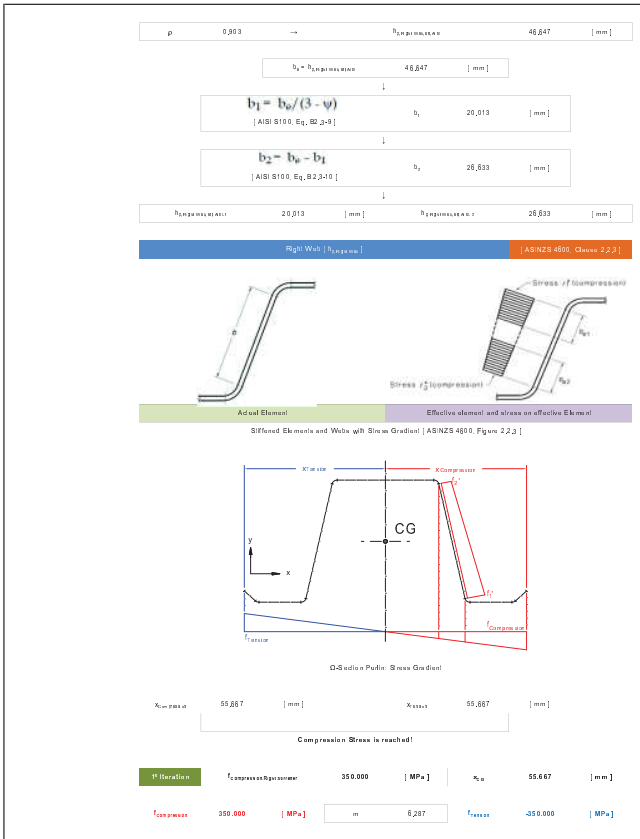
[AISI S100, Eq. B2.1-4]

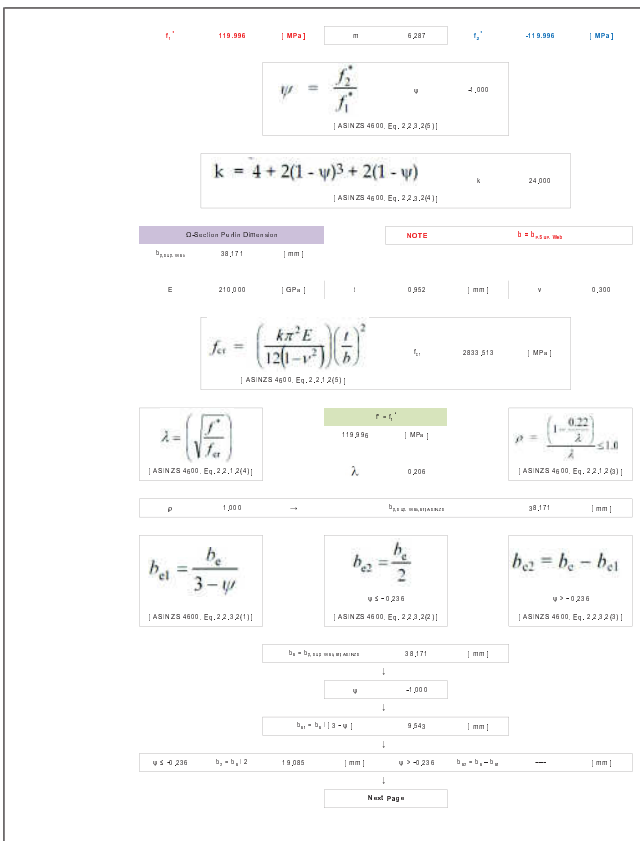
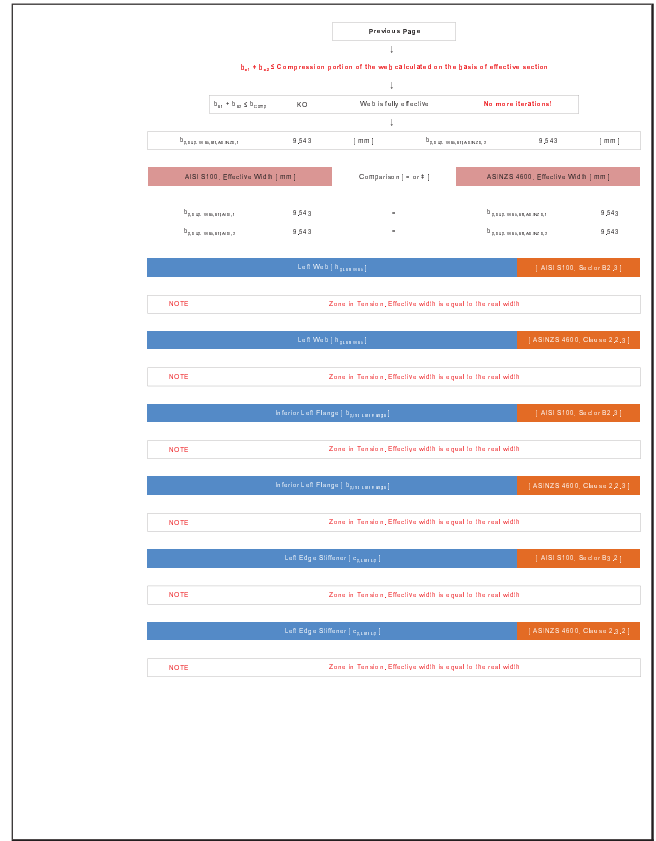
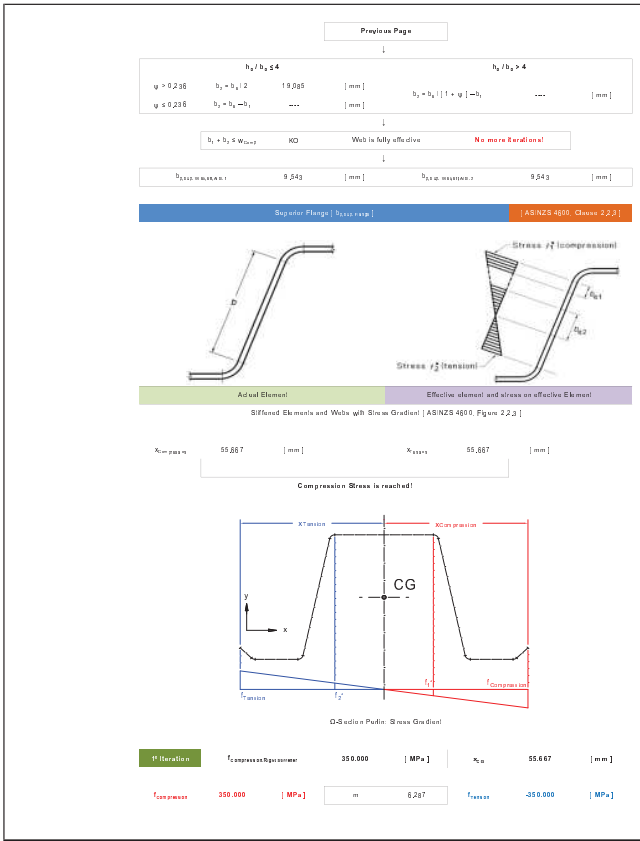
$$\lambda = \sqrt{\frac{f}{F_{cr}}} \quad f = 197,493 \text{ [MPa]} \quad \rho = (1 - 0,22/\lambda) \lambda$$

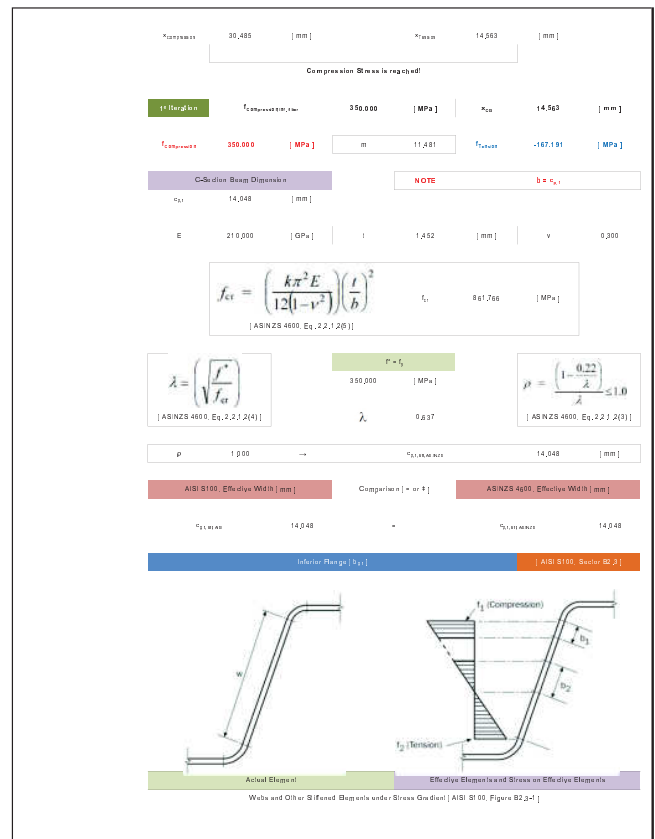
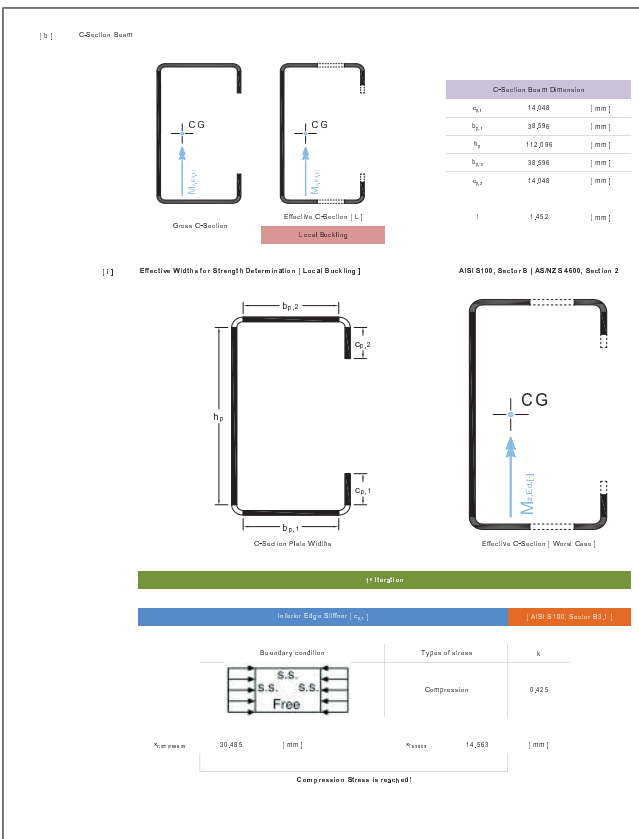
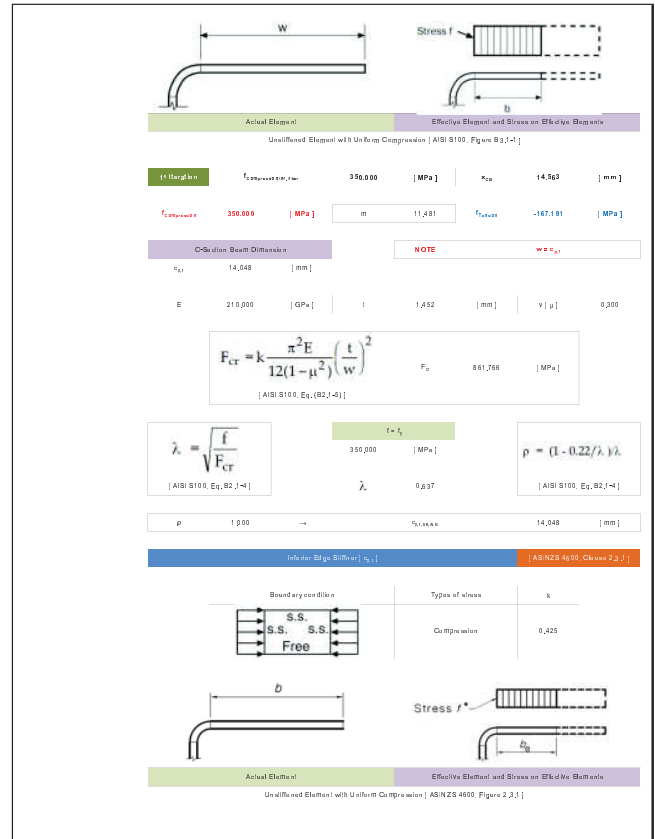
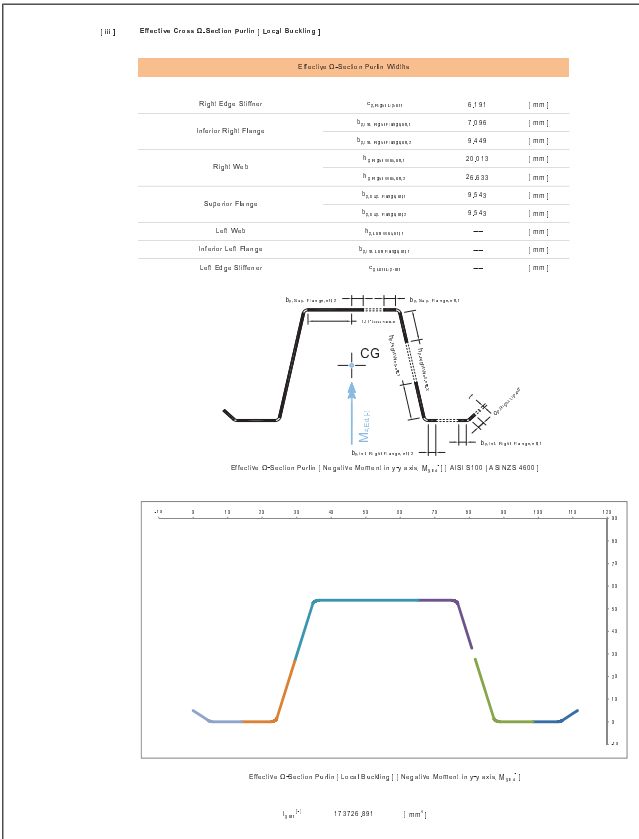
[AISI S100, Eq. B2.1-4]

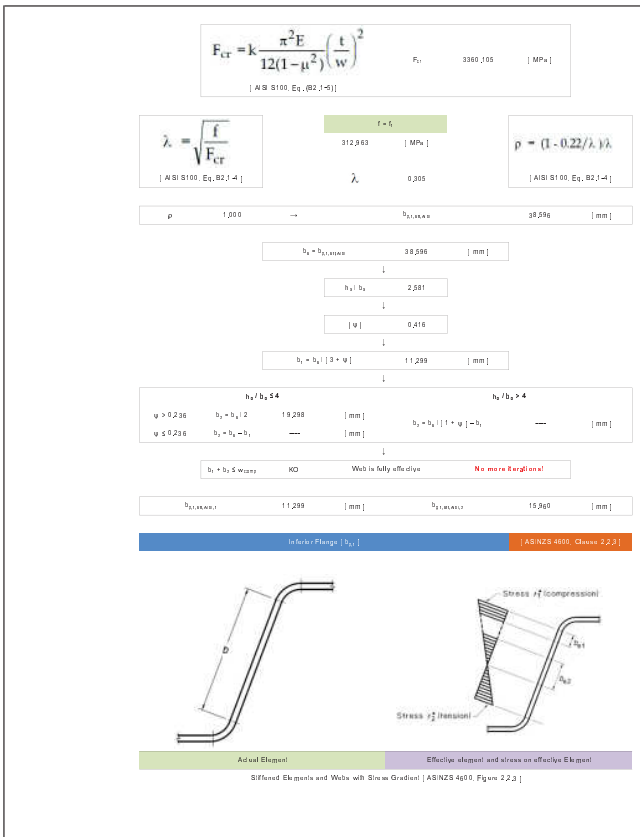
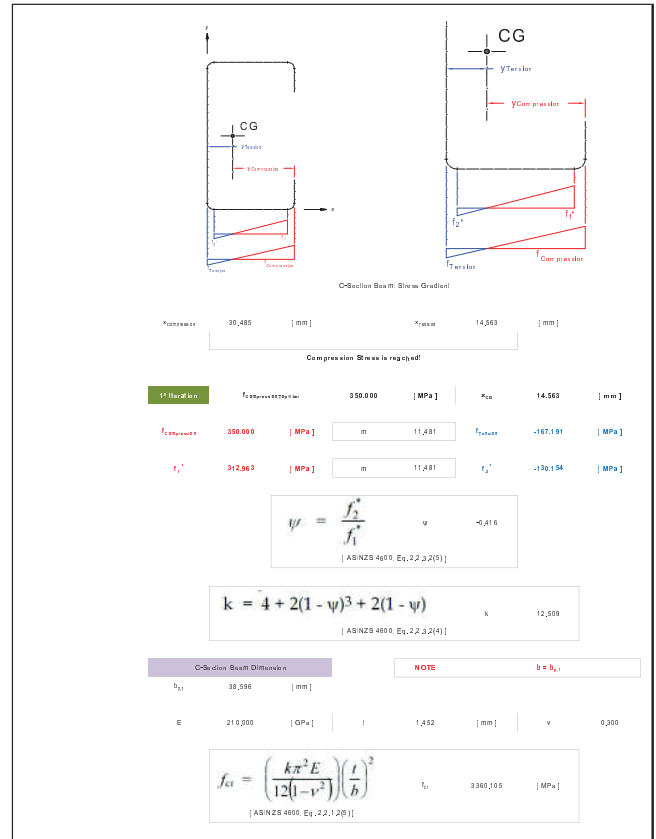
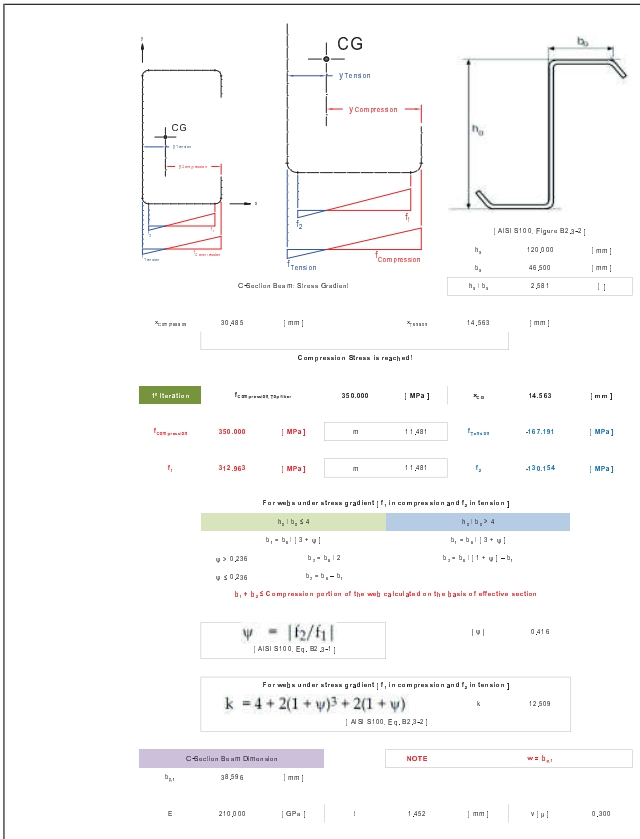
$\lambda = 0,264$

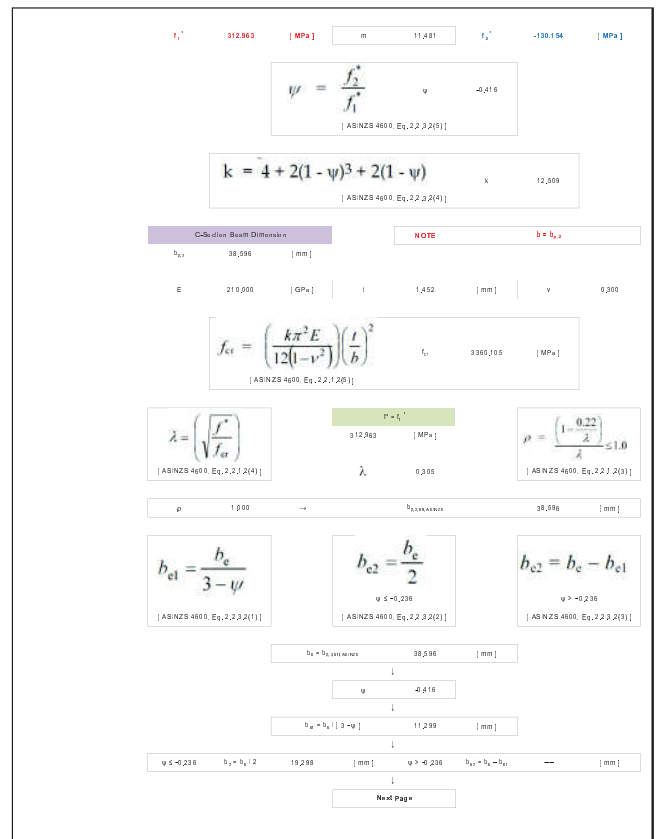
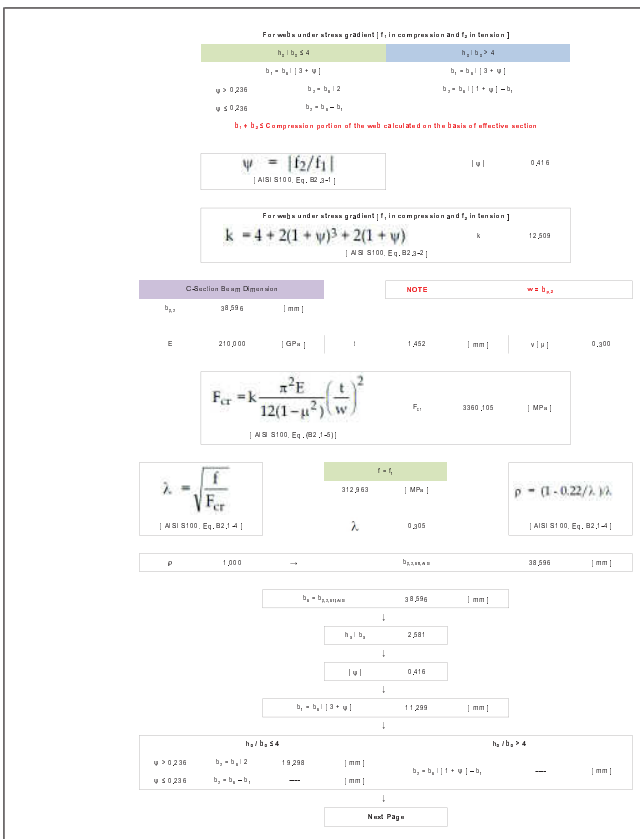
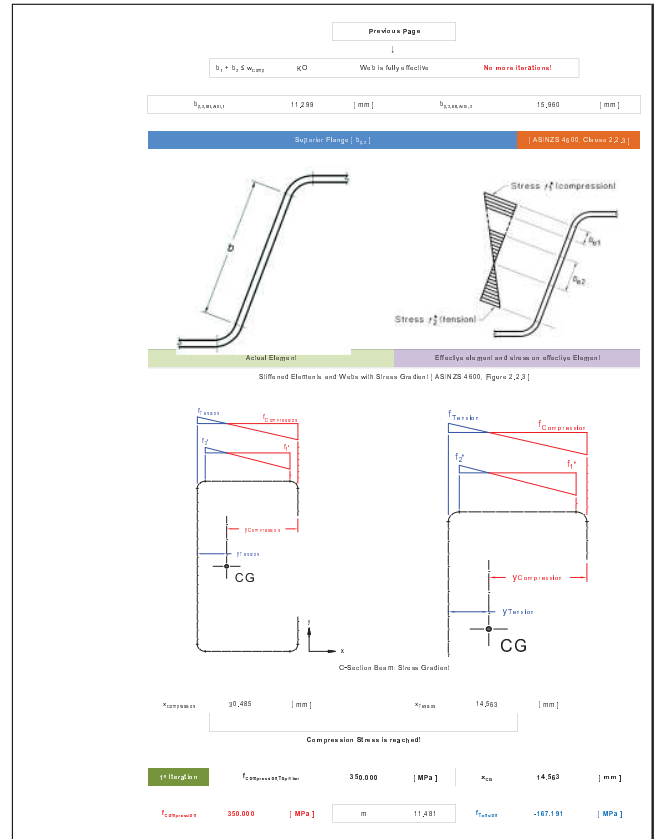
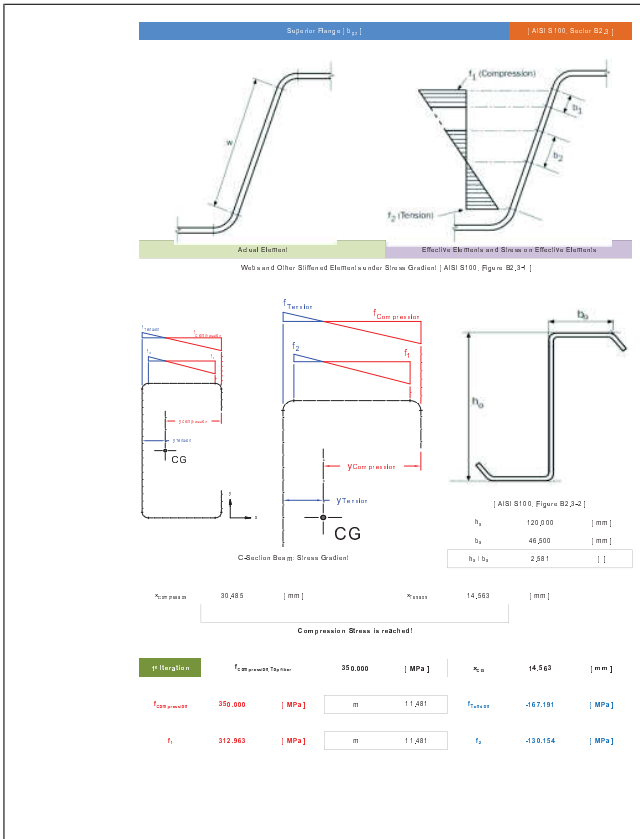
$\rho = 1,000$ [AISI S100, Eq. B2.1-4]











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$b_{eff} \neq b_{pl} \neq b_{comp}$ Compression portion of the web calculated on the basis of effective section

$b_{pl} \neq b_{pl} \neq b_{comp}$ Web is fully effective **No more Section!**

$b_{EFFECTIVE}$	11,289	[mm]	$b_{EFFECTIVE}$	15,960	[mm]
-----------------	--------	------	-----------------	--------	------

AISI S100_Effective Width [mm]	Computation = or ≠	AS/NZS 4600_Effective Width [mm]		
$b_{EFFECTIVE}$	11,289	≠	$b_{EFFECTIVE}$	11,289
$b_{EFFECTIVE}$	15,960	≠	$b_{EFFECTIVE}$	15,960

Superior Edge Stiffener ($c_{1,2}$) [AISI S100, Clause B3.1]

Boundary condition	Types of stress	k
S.S. S.S. S.S. Free	Compression	0,625

$b_{COMPRESS}$ 30,285 [mm] b_{TENSIL} 14,563 [mm]

Compression Stress is reached!

Actual Element Effective Element and Stress on Effective Elements

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1.4]

$f_{COMPRESSIVE}$	350,000	[MPa]	σ_{cr}	14,563	[mm]
$f_{TENSILE}$	350,000	[MPa]	m	11,481	f_{TENSIL} -167,191 [MPa]

C-Section Beam Dimension

$c_{1,2}$ 14,048 [mm] **NOTE** $b \neq c_{1,2}$

E	210,000	[GPa]	t	1,452	[mm]	v	0,300
---	---------	-------	---	-------	------	---	-------

$\lambda = \sqrt{\frac{f}{f_{cr}}}$ $f = f_c$ $\rho = \frac{1 - 0,22/\lambda}{\lambda} \leq 1,0$

350,000 [MPa] λ 0,637 [AS/NZS 4600, Eq. 2.2.2(4)] [AS/NZS 4600, Eq. 2.2.2(3)]

ρ 1,000 $c_{EFFECTIVE}$ 14,048 [mm]

AISI S100_Effective Width [mm] Computation = or ≠ AS/NZS 4600_Effective Width [mm]

$c_{EFFECTIVE}$	14,048	≠	$c_{EFFECTIVE}$	14,048
-----------------	--------	---	-----------------	--------

[B] Effective C-Section Beam | Local Buckling

Effective C-Section Beam Widths [AISI S100]

Inferior Edge Stiffener	$c_{EFFECTIVE}$	14,048	[mm]
Inferior Flange	$b_{EFFECTIVE}$	38,596	[mm]
Web	$b_{EFFECTIVE}$	---	[mm]
Superior Flange	$b_{EFFECTIVE}$	38,596	[mm]
Superior Edge Stiffener	$c_{EFFECTIVE}$	14,048	[mm]

Effective C-Section Beam Widths [AS/NZS 4600]

Inferior Edge Stiffener	$c_{EFFECTIVE}$	14,048	[mm]
Inferior Flange	$b_{EFFECTIVE}$	38,596	[mm]
Web	$b_{EFFECTIVE}$	---	[mm]
Superior Flange	$b_{EFFECTIVE}$	38,596	[mm]
Superior Edge Stiffener	$c_{EFFECTIVE}$	14,048	[mm]

Effective C-Section Beam Widths [AISI S100 | AS/NZS 4600]

Inferior Edge Stiffener	$c_{EFFECTIVE}$	14,048	[mm]
Inferior Flange	$b_{EFFECTIVE}$	38,596	[mm]
Web	$b_{EFFECTIVE}$	---	[mm]
Superior Flange	$b_{EFFECTIVE}$	38,596	[mm]
Superior Edge Stiffener	$c_{EFFECTIVE}$	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. B2.2(4)]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ $f = f_c$ $\rho = (1 - 0,22/\lambda)$

350,000 [MPa] λ 0,637 [AISI S100, Eq. B2.2(4)]

ρ 1,000 $c_{EFFECTIVE}$ 14,048 [mm]

Superior Edge Stiffener ($c_{1,2}$) [AS/NZS 4600, Clause 2.2.2]

Boundary condition	Types of stress	k
S.S. S.S. S.S. Free	Compression	0,625

$b_{COMPRESS}$ 30,285 [mm] b_{TENSIL} 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 2.2.1]

$f_{COMPRESSIVE}$	350,000	[MPa]	σ_{cr}	14,563	[mm]
$f_{TENSILE}$	350,000	[MPa]	m	11,481	f_{TENSIL} -167,191 [MPa]

C-Section Beam Dimension

$c_{1,2}$ 14,048 [mm] **NOTE** $b \neq c_{1,2}$

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. 2.2.2(4)]

[B] Effective Cross C-Section Beam | Local Buckling

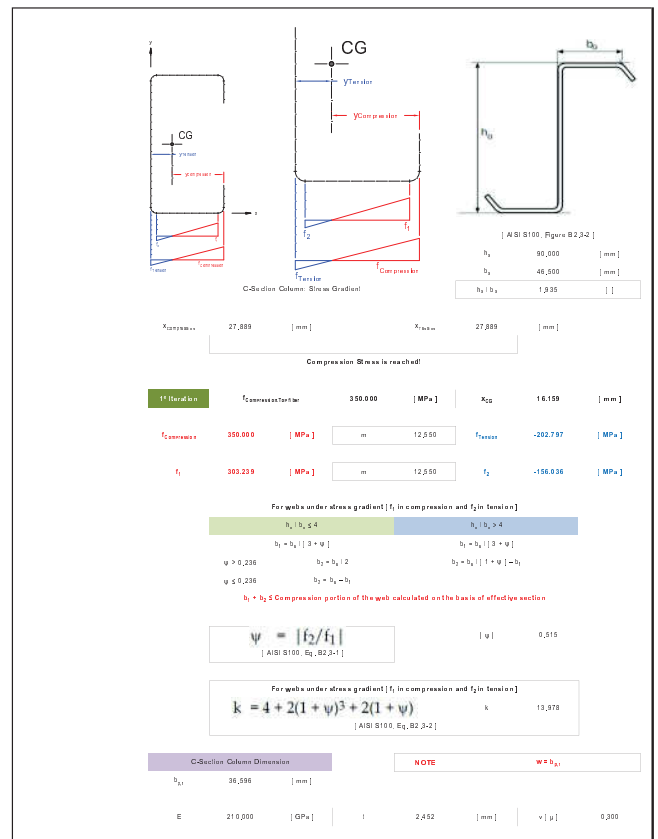
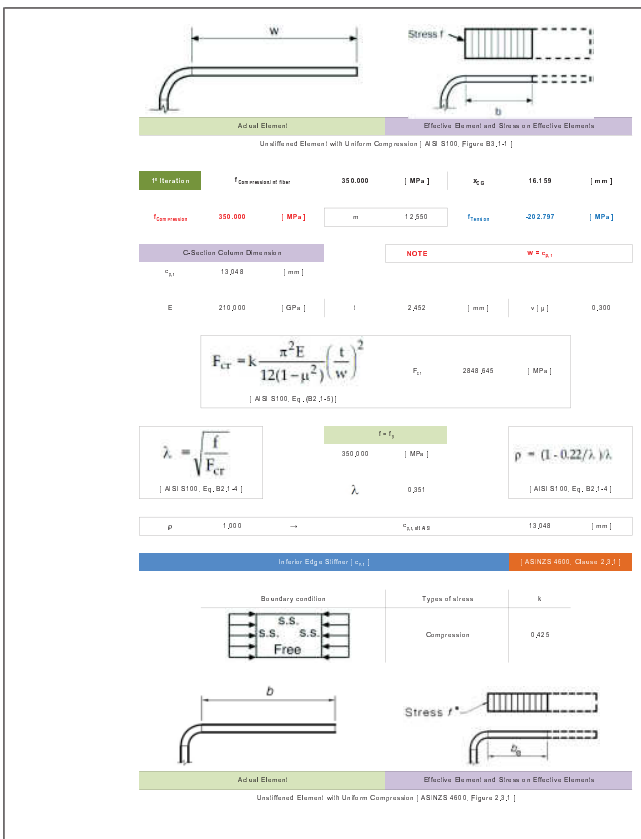
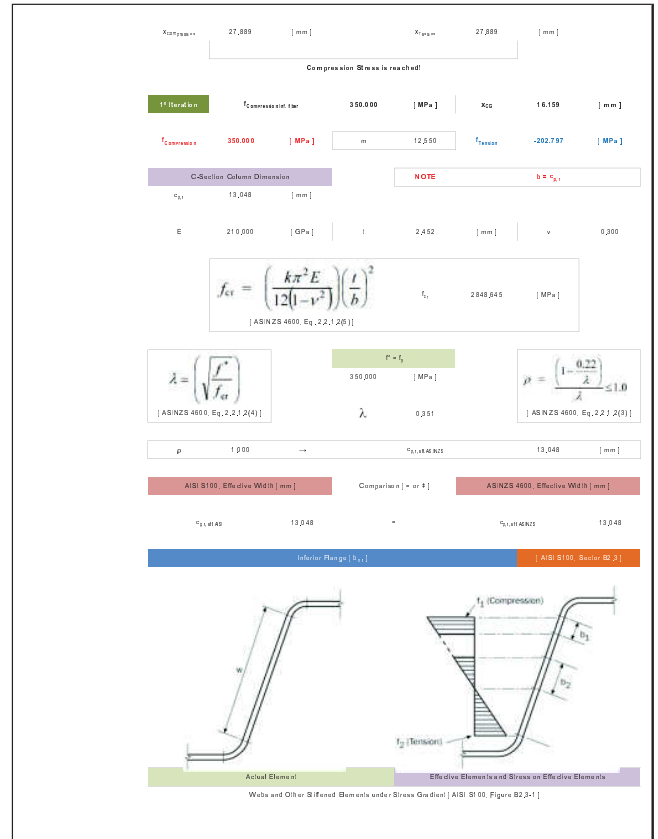
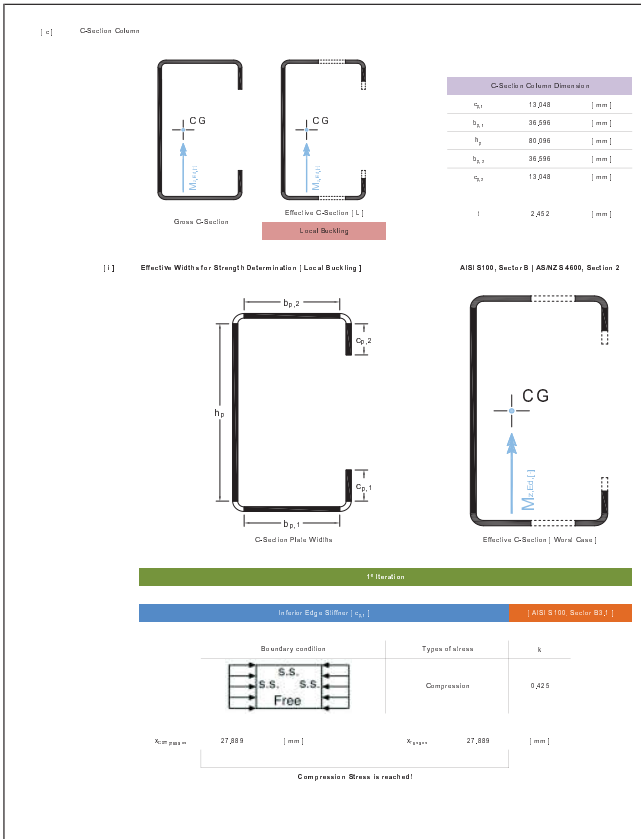
Effective C-Section Beam Widths

Inferior Edge Stiffener	$c_{EFFECTIVE}$	14,048	[mm]
Inferior Flange	$b_{EFFECTIVE}$	11,289	[mm]
Web	$b_{EFFECTIVE}$	15,960	[mm]
Superior Flange	$b_{EFFECTIVE}$	11,289	[mm]
Superior Edge Stiffener	$c_{EFFECTIVE}$	15,960	[mm]

Effective C-Section Beam | Local Buckling | Bending Moment $M_{y,y}$ [AISI S100 | AS/NZS 4600]

Effective C-Section Beam | Local Buckling | Bending Moment $M_{y,y}$

b_{eff} 108754,009 [mm]



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$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$$
 [AISI S100, Eq. B2.1.4] $F_{cr} = 119.09.792$ [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
 [AISI S100, Eq. B2.1.4] $f = 303.239$ [MPa] $\lambda = 0,160$ $\rho = (1 - 0,22/\lambda)$ [AISI S100, Eq. B2.1.4]

$\rho = 1,000$ $b_{1,eff} = 36,596$ [mm]

$b_1 = b_{1,eff}$ $b_1 = 36,596$ [mm]

$\psi = 0,515$

$b_1 = b_1 | 3 \cdot \psi$ $b_1 = 10,413$ [mm]

$b_{1,eff} \leq 4$ $b_2 = b_1 | 2$ $b_2 = 18,288$ [mm] $b_2 = b_1 | (1 + \psi) = b_1$ [mm]

$\psi > 0,236$ $b_2 = b_1 | 2$ $b_2 = 18,288$ [mm]

$\psi \leq 0,236$ $b_2 = b_1 = b_1$ [mm]

$b_1 = b_1 \leq 5w_{max}$ KO Web is fully effective. No more iterations!

$b_{1,eff} = 10,413$ [mm] $b_{1,eff} = 13,750$ [mm]

Infinite Flange ($b_{1,eff}$) [AS/NZS 4600, Clause 2.2.3]

Actual Element Effective element and stress on effective Element

Sifted Elements and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]

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$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$
 [AS/NZS 4600, Eq. 2.2.2(4)] $f = 303.239$ [MPa] $\lambda = 0,160$ $\rho = \frac{(1 - 0,22/\lambda)}{\lambda} \leq 1,0$ [AS/NZS 4600, Eq. 2.2.2(3)]

$\rho = 1,000$ $b_{1,eff} = 36,596$ [mm]

$$b_{e1} = \frac{b_c}{3 - \psi}$$
 [AS/NZS 4600, Eq. 2.2.2(1)] $b_{e2} = \frac{b_c}{2}$ $\psi > -0,236$ [AS/NZS 4600, Eq. 2.2.2(1)] $b_{e2} = b_c - b_{e1}$ $\psi > -0,236$ [AS/NZS 4600, Eq. 2.2.2(3)]

$b_1 = b_{1,eff} = 36,596$ [mm]

$\psi = -0,515$

$b_w = b_1 | 3 \cdot \psi$ $b_w = 10,413$ [mm]

$\psi > -0,236$ $b_2 = b_1 | 2$ $b_2 = 18,288$ [mm] $\psi > -0,236$ $b_2 = b_1 = b_{1,eff}$ [mm]

$b_w = b_w \leq 5w_{max}$ KO Web is fully effective. No more iterations!

$b_{1,eff} = 10,413$ [mm] $b_{1,eff} = 13,750$ [mm]

AISI S100, Effective Width [mm] Comparison $\rho = 1$ AS/NZS 4600, Effective Width [mm]

$b_{1,eff} = 10,413$ $b_{1,eff} = 10,413$

$b_{1,eff} = 13,750$ $b_{1,eff} = 13,750$

Web (b_1) [AISI S100, Section B2.1]

NOTE Zone in Tension, Effective width is equal to the real width

Web (b_1) [AS/NZS 4600, Clause 2.2.3]

NOTE Zone in Tension, Effective width is equal to the real width

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C-Section Column Stress Gradient

$x_{compression} = 27,889$ [mm] $x_{tension} = 27,889$ [mm]

Tension Stress is reached!

1st Iteration $f_{compression} = 350,000$ [MPa] $x_{cp} = 16,159$ [mm]

$f_{compression} = 350,000$ [MPa] $m = 12,550$ $f_{tension} = -202,787$ [MPa]

$f_1 = 303,239$ [MPa] $m = 12,550$ $f_2 = -156,036$ [MPa]

$$\psi = \frac{f_2}{f_1}$$
 [AS/NZS 4600, Eq. 2.2.2(9)] $\psi = -0,515$

$$k = 4 + 2(1 - \psi)^3 + 2(1 - \psi)$$
 [AS/NZS 4600, Eq. 2.2.2(8)] $k = 13,978$

C-Section Column Dimension NOTE $b = b_{1,eff}$

$b_{1,eff} = 36,596$ [mm]

$E = 210,000$ [GPa] $t = 2,652$ [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. 2.2.2(5)] $f_{cr} = 119.09.792$ [MPa]

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Superior Flange ($b_{1,eff}$) [AISI S100, Section B2.1]

Actual Element Effective Element in and stress on effective elements

Web and Other Sifted Elements under Stress Gradient [AISI S100, Figure B2.1.1]

C-Section Column Stress Gradient

$x_{compression} = 27,889$ [mm] $x_{tension} = 27,889$ [mm]

Compression Stress is reached!

1st Iteration $f_{compression} = 350,000$ [MPa] $x_{cp} = 16,159$ [mm]

$f_{compression} = 350,000$ [MPa] $m = 12,550$ $f_{tension} = -202,787$ [MPa]

$f_1 = 303,239$ [MPa] $m = 12,550$ $f_2 = -156,036$ [MPa]

[AISI S100, Figure B2.2.4] $b_1 = 99,500$ [mm] $b_2 = 46,500$ [mm] $b_1 = b_2 = 1,935$ [mm]

For Web under stress gradient [f₁ in compression and f₂ in tension]

$h_1/h_2 \leq 4$	$h_1/h_2 > 4$
$b_1 = b_2 [3 + \psi]$	$b_1 = b_2 [3 + \psi]$
$\psi > 0,236$ $b_2 = b_1 / 2$	$b_2 = b_1 [1 + \psi] - b_1$
$\psi \leq 0,236$ $b_2 = b_1 = b_1$	$b_2 = b_1 = b_1$

$b_1, b_2 \leq$ Compression portion of the web calculated on the basis of effective section

$\psi = |f_2/f_1|$ [AISI S100, Eq. B2.3-1] | $|\psi|$ 0,515

For Web under stress gradient [f₁ in compression and f₂ in tension]

$k = 4 + 2(1 + \psi)^3 + 2(1 + \psi)$ [AISI S100, Eq. B2.2-2] | k 13,978

C-Section Column Dimension | **NOTE** $W \leq b_{p2}$

b_{p2}	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. B2.1-4] | F_{cr} 11959,792 [MPa]

$\lambda = \sqrt{\frac{f}{F_{cr}}}$ [AISI S100, Eq. B2.1-4] | f 303,239 [MPa] | λ 0,60

$\rho = (1 - 0,22/\lambda) \lambda$ [AISI S100, Eq. B2.1-4]

ρ 1,000 | $b_{1,eff}$ 36,596 [mm]

$b_1 = b_{1,eff}$ 36,596 [mm]

b_1/h_1 1,939

$|\psi|$ 0,515

$b_2 = b_1 [3 + \psi]$ 10,413 [mm]

$h_1/h_2 \leq 4$	$h_1/h_2 > 4$
$\psi > 0,236$ $b_2 = b_1 / 2$ 18,288 [mm]	$b_2 = b_1 [1 + \psi] - b_1$ --- [mm]
$\psi \leq 0,236$ $b_2 = b_1 = b_1$ --- [mm]	$b_2 = b_1 = b_1$ --- [mm]

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f_1 303,239 [MPa] | f_2 -156,036 [MPa]

$\psi = \frac{f_2}{f_1}$ | ψ -0,515

[AS/NZS 4600, Eq. 2.2.2(9)]

$k = 4 + 2(1 - \psi)^3 + 2(1 - \psi)$ | k 13,978

[AS/NZS 4600, Eq. 2.2.2(9)]

C-Section Column Dimension | **NOTE** $W \leq b_{p2}$

b_{p2}	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)] | f_{cr} 11959,792 [MPa]

$\lambda = \left(\sqrt{\frac{f}{f_{cr}}}\right)$ [AS/NZS 4600, Eq. 2.2.1(4)] | f 303,239 [MPa] | λ 0,60

$\rho = \frac{1 - 0,22}{\lambda} \leq 1,0$ [AS/NZS 4600, Eq. 2.2.1(3)]

ρ 1,000 | $b_{1,eff}$ 36,596 [mm]

$b_{c1} = \frac{b_c}{3 - \psi}$ [AS/NZS 4600, Eq. 2.2.2(1)] | $b_{c2} = \frac{b_c}{2}$ | $b_{c2} = b_c - b_{c1}$

$\psi \leq -0,236$ $b_2 = b_1 / 2$ 18,288 [mm] | $\psi > -0,236$ $b_2 = b_1 = b_{p2}$ --- [mm]

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$b_1 = b_2 \leq W_{p0,2}$ KO | Web is fully effective | **No more Iterations!**

$b_{1,eff}$	10,413 [mm]	$b_{2,eff}$	13,750 [mm]
-------------	-------------	-------------	-------------

Support Edge Stiffness [k₁] [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

$x_{tension}$	27,889 [mm]	$x_{compression}$	27,889 [mm]
---------------	-------------	-------------------	-------------

Tension Stress is reached!

1st Iteration | $f_{tension}$ 350,000 [MPa] | λ_{cp} 16,159 [mm]

$f_{compression}$ 350,000 [MPa] | m 12,550 | $f_{tension}$ -292,797 [MPa]

Previous Page

$b_1 = b_2 \leq W_{p0,2}$ KO | Web is fully effective | **No more Iterations!**

$b_{1,eff}$	10,413 [mm]	$b_{2,eff}$	13,750 [mm]
-------------	-------------	-------------	-------------

AISI S100, Effective Width [mm] | Comparison $\lambda > \lambda_p$ | AS/NZS 4600, Effective Width [mm]

$b_{1,eff}$	10,413	$b_{2,eff}$	10,413
$b_{1,eff}$	13,750	$b_{2,eff}$	13,750

Support Edge Stiffness [k₁] [AISI S100, Section B3.1]

Boundary condition | Types of stress | k

S.S. S.S. Free	Compression	0,425
----------------	-------------	-------

$x_{tension}$ 27,889 [mm] | $x_{compression}$ 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]

1st Iteration | $f_{compression}$ 350,000 [MPa] | λ_{cp} 16,159 [mm]

$f_{tension}$ 350,000 [MPa] | m 12,550 | $f_{tension}$ -292,797 [MPa]

C-Section Column Dimension | **NOTE** $W \leq b_{p2}$

b_{p2}	13,048 [mm]
E	210,000 [GPa] | t 2,452 [mm] | v [μ] 0,300

Design of a Photovoltaic Structure, Partial configuration, according to AISI or AS/NZS	Office: ---	Author: JOSE ANTONIO
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$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$$

[AISI S100, Eq. B2.1-4]

$$F_{cr} = 2848,645 \quad [\text{MPa}]$$

$$\lambda = \sqrt{\frac{t}{F_{cr}}}$$

[AISI S100, Eq. B2.1-4]

$$\rho = (1 - 0.22/\lambda) \lambda$$

[AISI S100, Eq. B2.1-4]

ρ	1,000	→	$c_{1,eff}$	13,048	[mm]
--------	-------	---	-------------	--------	--------

Superior Edge Stiffener [$c_{1,1}$] [AS/NZS 4600, Clause 2.3.1]

Boundary condition	Types of stress	k	
	Compression	0,425	
$x_{e,comp}$	27,889 [mm]	$x_{e,comp}$	27,889 [mm]

Compression Stress is reached!

Actual Element

Effective Element and Stress in Effective Elements

Unflattened Element with Uniform Compression [AS/NZS 4600, Figure 2.3.1]

$f_{compression}$	350,000 [MPa]	σ_{cp}	16,159 [mm]
$f_{tension}$	350,000 [MPa]	$f_{tension}$	-202,797 [MPa]

C-Section Column Dimension **NOTE** $b \leq c_{1,eff}$

$c_{1,1}$	13,048 [mm]	i	2,452 [mm]	v	0,300
E	210,000 [GPa]				

$$f_{cr} = \left(\frac{k \pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$$f_{cr} = 2848,645 \quad [\text{MPa}]$$

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	Client: COIMBRA UNIVERSITY	
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[III] Effective Cross-C-Section Column [Local Buckling]

Effective C-Section Column Widths

Inferior Edge Stiffener	$c_{1,1,eff}$	13,048	[mm]
Inferior Flange	$b_{1,1,eff}$	10,413	[mm]
Web	$w_{1,1,eff}$	13,250	[mm]
Superior Flange	$b_{1,2,eff}$	10,413	[mm]
Superior Edge Stiffener	$c_{1,2,eff}$	13,250	[mm]

Effective C-Section Column [Local Buckling] [Bending Moment $M_{y,eff}$] [AISI S100 | AS/NZS 4600]

Effective C-Section Column [Local Buckling] [Bending Moment $M_{y,eff}$]

$I_{y,eff}$	153,816,866 [mm ⁴]
-------------	---------------------------------

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$$\lambda = \sqrt{\frac{t}{f_{cr}}}$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$$\rho = \frac{1 - 0.22/\lambda}{\lambda} \leq 1.0$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

ρ	1,000	→	$c_{1,eff}$	13,048	[mm]
--------	-------	---	-------------	--------	--------

AISI S100, Effective Width [mm]

Compression [$\rho = 1$]

AS/NZS 4600, Effective Width [mm]

$c_{1,1,eff}$	13,048	-	$c_{1,2,eff}$	13,048
---------------	--------	---	---------------	--------

[III] Effective C-Section Column [Local Buckling]

Effective C-Section Column Widths [AISI S100]

Inferior Edge Stiffener	$c_{1,1,eff}$	13,048	[mm]
Inferior Flange	$b_{1,1,eff}$	38,596	[mm]
Web	$w_{1,1,eff}$	--	[mm]
Superior Flange	$b_{1,2,eff}$	38,596	[mm]
Superior Edge Stiffener	$c_{1,2,eff}$	13,048	[mm]

Effective C-Section Column Widths [AS/NZS 4600]

Inferior Edge Stiffener	$c_{1,1,eff}$	13,048	[mm]
Inferior Flange	$b_{1,1,eff}$	38,596	[mm]
Web	$w_{1,1,eff}$	--	[mm]
Superior Flange	$b_{1,2,eff}$	38,596	[mm]
Superior Edge Stiffener	$c_{1,2,eff}$	13,048	[mm]

Effective C-Section Column Widths [AISI S100 | AS/NZS 4600]

Inferior Edge Stiffener	$c_{1,1,eff}$	13,048	[mm]
Inferior Flange	$b_{1,1,eff}$	38,596	[mm]
Web	$w_{1,1,eff}$	--	[mm]
Superior Flange	$b_{1,2,eff}$	38,596	[mm]
Superior Edge Stiffener	$c_{1,2,eff}$	13,048	[mm]

[III] Iteration

Inferior Edge Stiffener [$c_{1,1}$] [AISI S100, Section B]

Boundary condition	Types of stress	k	
	Compression	0,425	
$x_{e,comp}$	23,444 [mm]	$x_{e,comp}$	13,054 [mm]

Compression Stress is reached!

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[IV] C-Section Stud

Local Buckling

C-Section Stud Dimension	
$c_{1,1}$	6,848 [mm]
$b_{1,1}$	32,596 [mm]
w	42,096 [mm]
$b_{1,2}$	32,596 [mm]
$c_{1,2}$	6,848 [mm]
i	1,452 [mm]

[III] Effective Widths for Strength Determination [Local Buckling]

AISI S100, Section B [AS/NZS 4600, Section 2]

[III] Iteration

Inferior Edge Stiffener [$c_{1,1}$] [AISI S100, Section B]

Boundary condition	Types of stress	k	
	Compression	0,425	
$x_{e,comp}$	23,444 [mm]	$x_{e,comp}$	13,054 [mm]

Compression Stress is reached!

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Actual Element | Effective Element and Stress on an Effective Element

Unstiffened Element with Uniform Compression [AISI S100, Figure B3.1.4]

1st Iteration $f_{\text{compression}} = 350.000$ [MPa] $\lambda_{c0} = 15.164$ [mm]

$f_{\text{compression}} = 350.000$ [MPa] $m = 14.929$ $f_{\text{tension}} = -225.480$ [MPa]

C-Section Slab Dimension **NOTE** $w = c_{y1}$

$c_{y1} = 6.948$ [mm]

$E = 210.000$ [GPa] $t = 1.452$ [mm] $v [\mu] = 0,300$

$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$$

[AISI S100, Eq. B2.1.4] $F_{cr} = 4649,380$ [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1.4] $f = f_y = 350.000$ [MPa] $\lambda = 0,274$ $\rho = (1 - 0,22/\lambda) \lambda$ [AISI S100, Eq. B2.1.4]

$\rho = 1,000$ $c_{y,slab} = 6,948$ [mm]

Inflator Edge Stiffness [c_{y1}] [AS/NZS 4600, Clause 2.2.1]

Boundary condition	Types of stress	k
S.S. S.S.	Compression	0,425
S.S. Free		

Actual Element | Effective Element and Stress on an Effective Element

Unstiffened Element with Uniform Compression [AS/NZS 4600, Figure 2.2.1]

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Actual Element | Effective Element and Stress on an Effective Element

C-Section Slab Stress Gradient [AISI S100, Figure B2.3.2]

1st Iteration $f_{\text{compression}} = 350.000$ [MPa] $\lambda_{c0} = 15.164$ [mm]

$f_{\text{compression}} = 350.000$ [MPa] $m = 14.929$ $f_{\text{tension}} = -225.480$ [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]

$h_1 / b_1 \leq 4$ $h_1 / b_1 > 4$

$\psi = h_1 - h_2 / [3 + \psi]$ $h_1 - h_2 / [3 + \psi]$

$\psi > 0,236$ $h_2 = h_1 / 2$ $h_2 = h_1 / [1 + \psi] - h_1$

$\psi \leq 0,236$ $h_2 = h_1 - h_2$

$h_1 + b_1 \leq 5$ Compression portion of the web calculated on the b axis of effective section

$$\psi = [f_2 / f_1]$$

[AISI S100, Eq. B2.3.1] $|\psi| = 0,587$

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 Slab Dimension **NOTE** $w = b_1$

$b_{y1} = 32,996$ [mm]

$E = 210.000$ [GPa] $t = 1.452$ [mm] $v [\mu] = 0,300$

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$K_{\text{compression}} = 23,444$ [mm] $K_{\text{tension}} = 15,164$ [mm]

Compression Stress is reached!

1st Iteration $f_{\text{compression}} = 350.000$ [MPa] $\lambda_{c0} = 15.164$ [mm]

$f_{\text{compression}} = 350.000$ [MPa] $m = 14.929$ $f_{\text{tension}} = -225.480$ [MPa]

C-Section Slab Dimension **NOTE** $b = c_{y1}$

$c_{y1} = 6.948$ [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(6)] $f_{cr} = 4649,380$ [MPa]

$$\lambda = \sqrt{\frac{f}{f_{cr}}}$$

[AS/NZS 4600, Eq. 2.2.1.2(4)] $f = f_y = 350.000$ [MPa] $\lambda = 0,274$ $\rho = \frac{1 - 0,22}{\lambda} \leq 1,0$ [AS/NZS 4600, Eq. 2.2.1.2(5)]

$\rho = 1,000$ $c_{y,slab} = 6,948$ [mm]

AISI S100, Effective Width [mm] $c_{y,slab} = 6,948$ Comparison $\rho = \rho$ AS/NZS 4600, Effective Width [mm] $c_{y,slab} = 6,948$

Inflator Flange [b_{y1}] [AISI S100, Section B2.3]

Actual Element | Effective Element and Stress on an Effective Element

Stiffened Element and Webs with Stress Gradient [AISI S100, Figure B2.3.1]

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$$F_{cr} = k \frac{\pi^2 E}{12(1-\mu^2)} \left(\frac{t}{w} \right)^2$$

[AISI S100, Eq. B2.1.4] $F_{cr} = 5884,952$ [MPa]

$$\lambda = \sqrt{\frac{f}{F_{cr}}}$$

[AISI S100, Eq. B2.1.4] $f = f_y = 301,839$ [MPa] $\lambda = 0,226$ $\rho = (1 - 0,22/\lambda) \lambda$ [AISI S100, Eq. B2.1.4]

$\rho = 1,000$ $b_{y,slab} = 32,996$ [mm]

$b_{y1} = b_{y,slab} = 32,996$ [mm]

$h_1 / b_1 = 1,250$

$|\psi| = 0,587$

$h_1 = h_1 / [3 + \psi] = 8,947$ [mm]

$h_1 / b_1 \leq 4$ $h_1 / b_1 > 4$

$\psi > 0,236$ $h_2 = h_1 / 2 = 16,048$ [mm] $h_2 = h_1 / [1 + \psi] - h_1 = ---$ [mm]

$\psi \leq 0,236$ $h_2 = h_1 - h_2 = ---$ [mm]

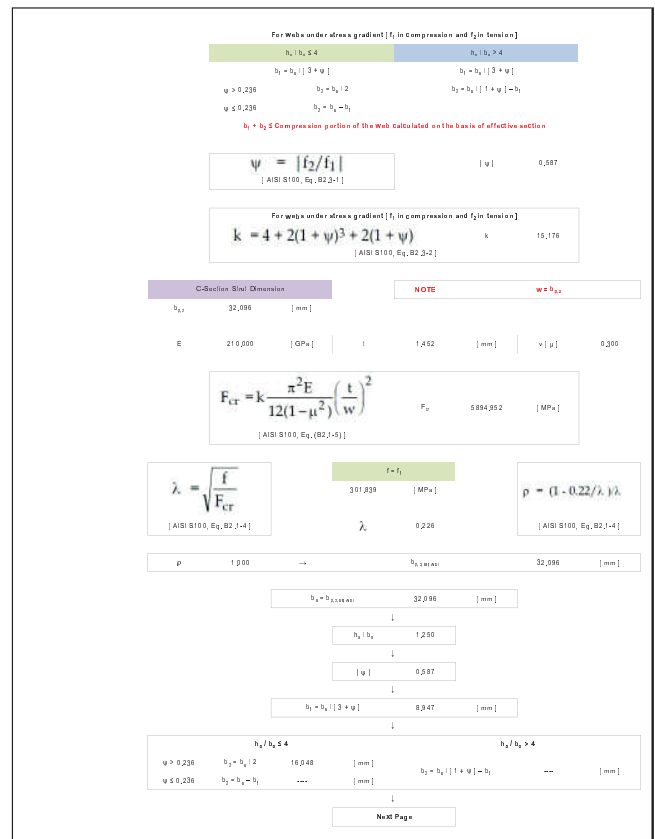
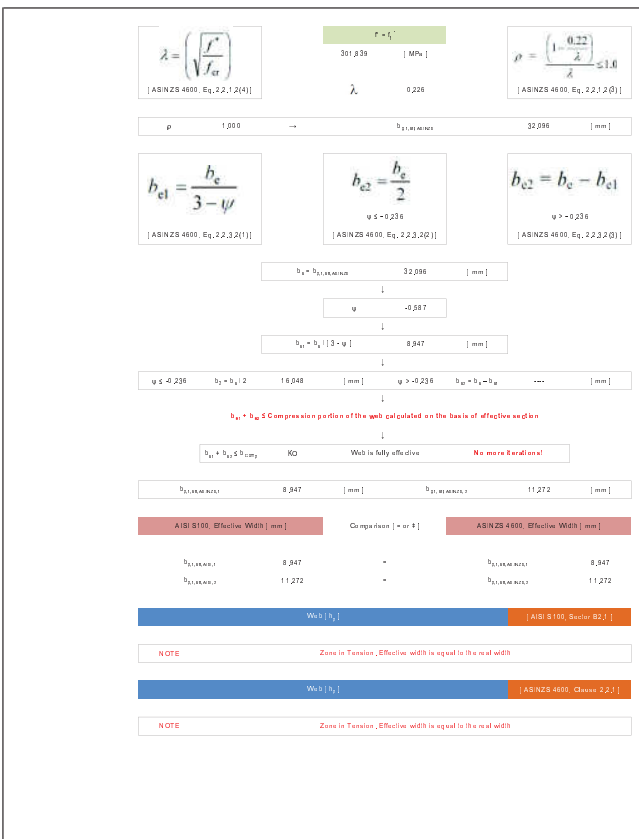
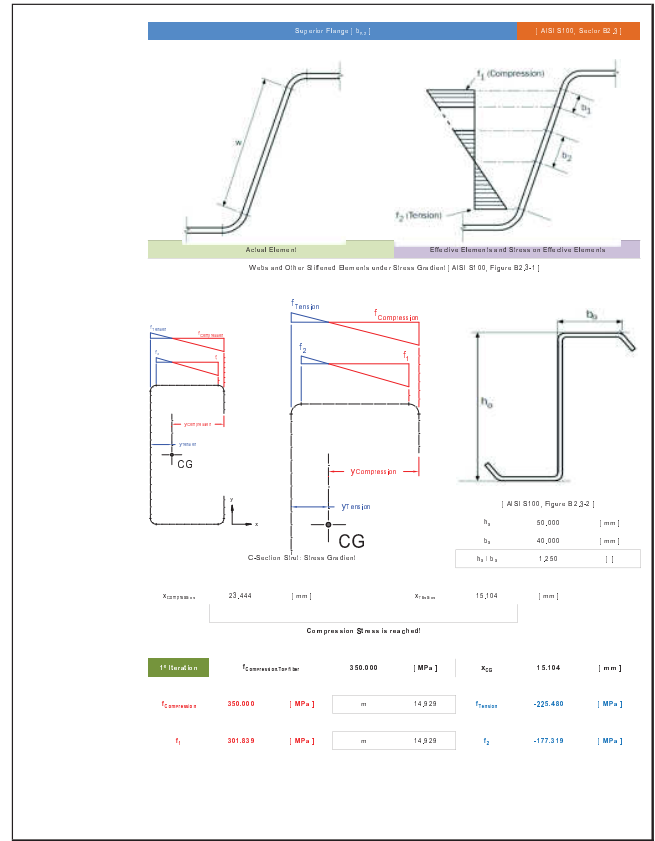
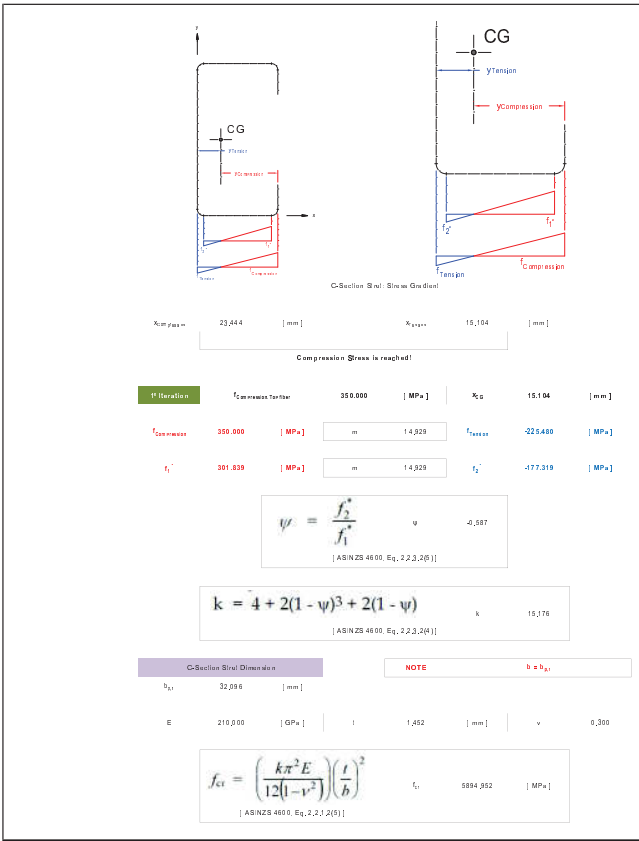
$b_1 + b_1 \leq 5$ Web is fully effective **No more iterations!**

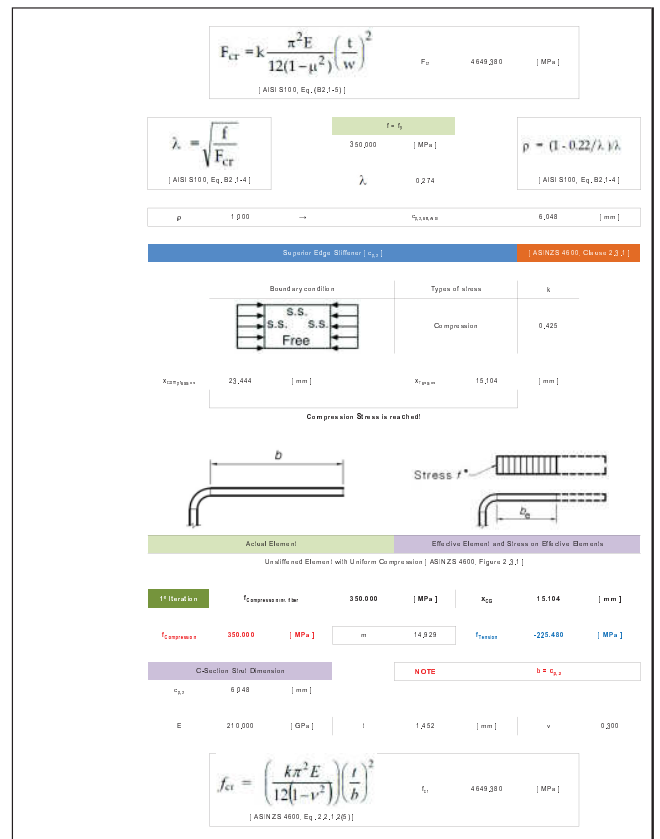
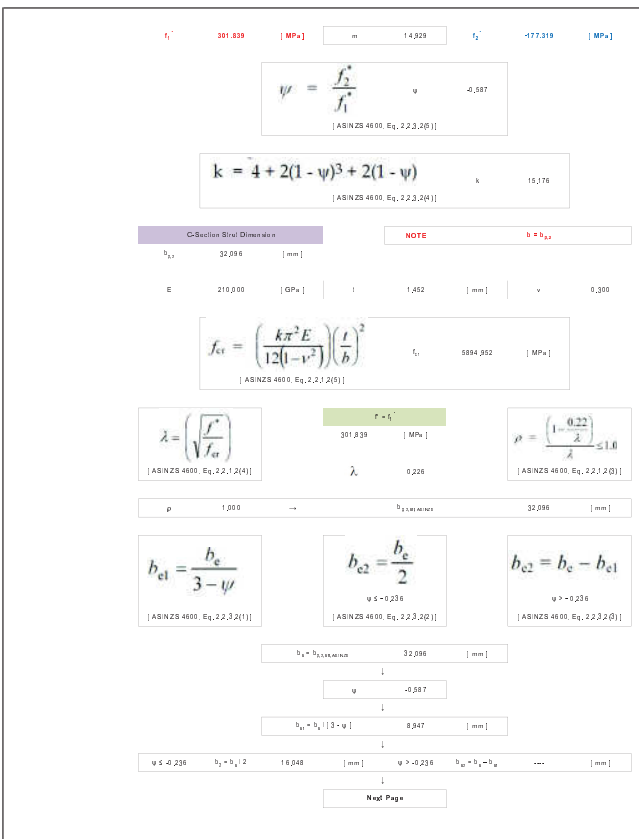
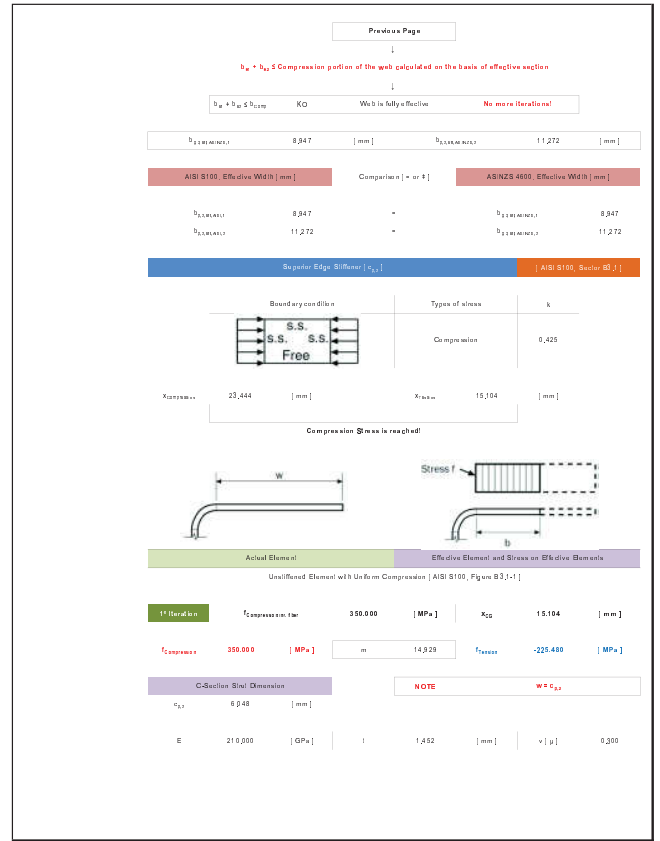
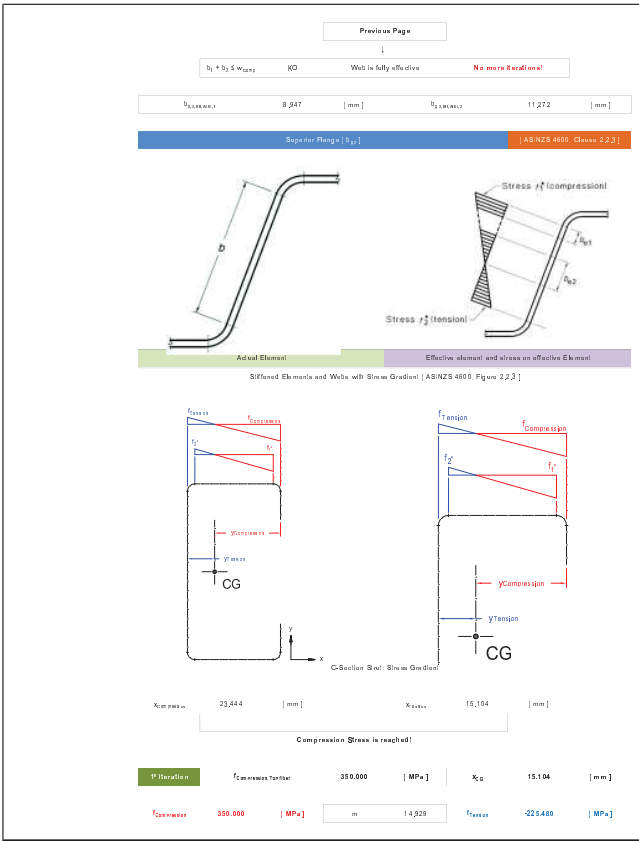
$b_{y,slab} = 8,947$ [mm] $b_{y,slab} = 11,272$ [mm]

Inflator Flange [b_{y1}] [AS/NZS 4600, Clause 2.2.1]

Actual Element | Effective Element and Stress on an Effective Element

Stiffened Element and Webs with Stress Gradient [AS/NZS 4600, Figure 2.2.3]





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$$\lambda = \sqrt{\frac{f}{f_{cr}}}$$

[AS/NZS 4600, Eq. 2.2.1.2(4)]

$F = \xi$

350,000 [MPa]

$\lambda = 0,274$

$$\phi = \frac{1 - 0,22}{\lambda} \leq 1,0$$

[AS/NZS 4600, Eq. 2.2.1.2(5)]

$\rho = 1,000$ $\xi_{resistance} = 0,948$ [mm]

AISI S100: Effective Width [mm]

Compression $\rho = 1$

AS/NZS 4600: Effective Width [mm]

$\xi_{compression}$

6,048

-

$\xi_{compression}$

6,048

[II] Effective C-Section Strut | Local Buckling

Effective C-Section Strut Widths | AISI S100 |

Inferior Edge Stiffener	$\xi_{E1,MIN}$	6,048	[mm]
Inferior Flange	$b_{E1,MIN}$	32,096	[mm]
Web	$b_{E1,MIN}$	--	[mm]
Superior Flange	$b_{E1,MIN}$	32,096	[mm]
Superior Edge Stiffener	$\xi_{E1,MIN}$	6,048	[mm]

Effective C-Section Strut Widths | AS/NZS 4600 |

Inferior Edge Stiffener	$\xi_{E1,MIN}$	6,048	[mm]
Inferior Flange	$b_{E1,MIN}$	32,096	[mm]
Web	$b_{E1,MIN}$	--	[mm]
Superior Flange	$b_{E1,MIN}$	32,096	[mm]
Superior Edge Stiffener	$\xi_{E1,MIN}$	6,048	[mm]

Effective C-Section Strut Widths | AISI S100 | AS/NZS 4600 |

Inferior Edge Stiffener	$\xi_{E1,MIN}$	6,048	[mm]
Inferior Flange	$b_{E1,MIN}$	32,096	[mm]
Web	$b_{E1,MIN}$	--	[mm]
Superior Flange	$b_{E1,MIN}$	32,096	[mm]
Superior Edge Stiffener	$\xi_{E1,MIN}$	6,048	[mm]

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[12] Cold-Formed Effective Section

[a] D-Section Profile

D-Section Profile subjected to Tension Force	$A_{tension}$	191,199	[mm ²]
D-Section Profile subjected to Compression Force	$A_{compression}$	156,435	[mm ²]
	ρ_{c1}	0,000	[mm]
	ρ_{c2}	-1,115	[mm]
D-Section Profile subjected to Positive Moment in yy axis | M_{yy}$ |	I_{yy,net}$	81881,327	[mm ⁴]
D-Section Profile subjected to Negative Moment in yy axis | M_{yy}$ |	I_{yy,net}$	85759,975	[mm ⁴]
D-Section Profile subjected to Positive Moment in zz axis | M_{zz}$ |	I_{zz,net}$	17338,070	[mm ⁴]
D-Section Profile subjected to Negative Moment in zz axis | M_{zz}$ |	I_{zz,net}$	17372,691	[mm ⁴]

[b] C-Section Beam

C-Section Beam subjected to Tension Force	$A_{tension}$	345,063	[mm ²]
C-Section Beam subjected to Compression Force	$A_{compression}$	287,460	[mm ²]
	ρ_{c1}	4,235	[mm]
	ρ_{c2}	0,000	[mm]
C-Section Beam subjected to Positive Moment in yy axis | M_{yy}$ |	I_{yy,net}$	76229,565	[mm ⁴]
C-Section Beam subjected to Negative Moment in yy axis | M_{yy}$ |	I_{yy,net}$	76229,565	[mm ⁴]
C-Section Beam subjected to Positive Moment in zz axis | M_{zz}$ |	I_{zz,net}$	9693,280	[mm ⁴]
C-Section Beam subjected to Negative Moment in zz axis M_{zz}	$I_{zz,net}$	10875,409	[mm ⁴]

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[III] Effective Cross C-Section Strut | Local Buckling

Effective C-Section Strut Widths

Inferior Edge Stiffener	$\xi_{E1,MIN}$	6,048	[mm]
Inferior Flange	$b_{E1,MIN}$	9,947	[mm]
	$\xi_{E1,MIN}$	11,272	[mm]
Web	$b_{E1,MIN}$	--	[mm]
Superior Flange	$b_{E1,MIN}$	9,947	[mm]
	$\xi_{E1,MIN}$	11,272	[mm]
Superior Edge Stiffener	$\xi_{E1,MIN}$	6,048	[mm]

Effective C-Section Strut | Local Buckling | Bending Moment: M_{yy} | [AISI S100 | AS/NZS 4600]

Effective C-Section Strut | Local Buckling | Bending Moment: M_{yy} |

$I_{yy,net} = 43399,345$ [mm⁴]

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[c] C-Section Column

C-Section Column subjected to Tension Force	$A_{tension}$	497,235	[mm ²]
C-Section Column subjected to Compression Force	$A_{compression}$	493,023	[mm ²]
	ρ_{c1}	0,138	[mm]
	ρ_{c2}	0,000	[mm]
C-Section Column subjected to Positive Moment in yy axis | M_{yy}$ |	I_{yy,net}$	62503,620	[mm ⁴]
C-Section Column subjected to Negative Moment in yy axis | M_{yy}$ |	I_{yy,net}$	62503,620	[mm ⁴]
C-Section Column subjected to Positive Moment in zz axis | M_{zz}$ |	I_{zz,net}$	15381,686	[mm ⁴]
C-Section Column subjected to Negative Moment in zz axis | M_{zz}$ |	I_{zz,net}$	15381,686	[mm ⁴]

[d] C-Section Strut

C-Section Strut subjected to Tension Force	$A_{tension}$	201,315	[mm ²]
C-Section Strut subjected to Compression Force	$A_{compression}$	201,315	[mm ²]
	ρ_{c1}	0,000	[mm]
	ρ_{c2}	0,000	[mm]
C-Section Strut subjected to Positive Moment in yy axis | M_{yy}$ |	I_{yy,net}$	8543,169	[mm ⁴]
C-Section Strut subjected to Negative Moment in yy axis | M_{yy}$ |	I_{yy,net}$	8543,169	[mm ⁴]
C-Section Strut subjected to Positive Moment in zz axis | M_{zz}$ |	I_{zz,net}$	4339,345	[mm ⁴]
C-Section Strut subjected to Negative Moment in zz axis | M_{zz}$ |	I_{zz,net}$	4339,345	[mm ⁴]

14 Reaction Values

D-Section Canopy Purlin				D-Section Middle Purlin			
N_{FE1}	0,000	[kN]		N_{FE1}	0,940	[kN]	
N_{FE2}	0,000	[kN]		N_{FE2}	0,940	[kN]	
V_{FE1}	0,170	[kN]		V_{FE1}	0,260	[kN]	
V_{FE2}	0,630	[kN]		V_{FE2}	1,010	[kN]	
M_{FE1-1}	0,220	[kN]		M_{FE1-1}	0,860	[kN]	
M_{FE1-0}	0,220	[kN]		M_{FE1-0}	0,860	[kN]	
M_{FE1-1}	0,060	[kN]		M_{FE1-1}	0,990	[kN]	
M_{FE1-0}	0,060	[kN]		M_{FE1-0}	0,990	[kN]	

C-Section Canopy Beam				C-Section Middle Beam			
N_{FE1}	0,520	[kN]		N_{FE1}	0,700	[kN]	
N_{FE2}	0,520	[kN]		N_{FE2}	1,030	[kN]	
V_{FE1}	0,040	[kN]		V_{FE1}	0,440	[kN]	
V_{FE2}	1,370	[kN]		V_{FE2}	2,000	[kN]	
M_{FE1-1}	0,840	[kN]		M_{FE1-1}	0,840	[kN]	
M_{FE1-0}	0,840	[kN]		M_{FE1-0}	0,840	[kN]	
M_{FE1-1}	0,020	[kN]		M_{FE1-1}	0,910	[kN]	
M_{FE1-0}	0,020	[kN]		M_{FE1-0}	0,910	[kN]	

C-Section Portal Column				C-Section Rear Column			
N_{FE1}	2,700	[kN]		N_{FE1}	3,340	[kN]	
N_{FE2}	4,140	[kN]		N_{FE2}	4,170	[kN]	
V_{FE1}	0,000	[kN]		V_{FE1}	0,000	[kN]	
V_{FE2}	1,780	[kN]		V_{FE2}	2,240	[kN]	
M_{FE1-1}	0,270	[kN]		M_{FE1-1}	0,350	[kN]	
M_{FE1-0}	0,270	[kN]		M_{FE1-0}	0,350	[kN]	
M_{FE1-1}	0,000	[kN]		M_{FE1-1}	0,000	[kN]	
M_{FE1-0}	0,000	[kN]		M_{FE1-0}	0,000	[kN]	

C-Section Steel			
N_{FE1}	2,280	[kN]	
N_{FE2}	1,470	[kN]	
V_{FE1}	0,000	[kN]	
V_{FE2}	0,020	[kN]	
M_{FE1-1}	0,010	[kN]	
M_{FE1-0}	0,010	[kN]	
M_{FE1-1}	0,000	[kN]	
M_{FE1-0}	0,000	[kN]	

9 C-Section Beam

11 C-Section Beam: Axial Tension [AISI S100, ASD]

$T_u = A_g \cdot F_u$	f_u	389,091	[MPa]	$T_s \leq T_u \leq \phi_t T_n$		
Yielding in gross section	A_g	349,063	[mm ²]			
[AISI S100, Eq. C2-1]	ϕ_t	1,670	[ASD]	[AISI S100, Eq. A4.1.1-1]		
T_u	124223,292	[N]	→	T_u	124,223	[kN]
$R = 0,700$	[kN]	0,700		Ratio	0,941	[%]
$R_u = T_u$	124,223	[kN]				

12 C-Section Beam: Axial Tension [AISI S100, LRFD]

$T_u = A_g \cdot F_u$	f_u	389,091	[MPa]	$T_s \leq \phi_t T_n$		
Yielding in gross section	A_g	349,063	[mm ²]			
[AISI S100, Eq. C2-1]	ϕ_t	0,900	[ASD]	[AISI S100, Eq. A4.1.1-1]		
T_u	124223,292	[N]	→	T_u	124,223	[kN]
$R = 0,700$	[kN]	0,700		Ratio	0,926	[%]
$R_u = T_u$	124,223	[kN]				

13 C-Section Beam: Axial Tension [AS/NZS 4600, LSD]

$N_u = A_g \cdot f_u$	f_u	389,091	[MPa]	$N_u \leq \phi_t N_n$		
[AS/NZS 4600, Eq. 3.2.2(1)]	A_g	349,063	[mm ²]			
ϕ_t	0,900	[ASD]		[AS/NZS 4600, Eq. 3.2.1]		
N_u	124223,292	[N]	→	N_u	124,223	[kN]
$N^* = 0,700$	[kN]	0,700		Ratio	0,926	[%]
N_u	124,223	[kN]				

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_u	124223,292	[N]	→	N_u	124,223	[kN]
$N^* = 0,700$	[kN]	0,700		Ratio	0,926	[%]
N_u	124,223	[kN]				

15 Members [AISI S100, C | AS/NZS 4600, 3]

15.1 Members subjected to Axial Tension [AISI S100, C2 | AS/NZS 4600, 3.2]

16 D-Section Purlin

17 D-Section Purlin: Axial Tension [AISI S100, ASD]

$T_u = A_g \cdot F_u$	f_u	389,092	[MPa]	$T_s \leq T_u \leq \phi_t T_n$		
Yielding in gross section	A_g	191,199	[mm ²]			
[AISI S100, Eq. C2-1]	ϕ_t	1,670	[ASD]	[AISI S100, Eq. A4.1.1-1]		
T_u	68562,518	[N]	→	T_u	68,563	[kN]
$R = 0,940$	[kN]	0,940		Ratio	0,997	[%]
$R_u = T_u$	68,563	[kN]				

18 D-Section Purlin: Axial Tension [AISI S100, LRFD]

$T_u = A_g \cdot F_u$	f_u	389,092	[MPa]	$T_s \leq \phi_t T_n$		
Yielding in gross section	A_g	191,199	[mm ²]			
[AISI S100, Eq. C2-1]	ϕ_t	0,900	[ASD]	[AISI S100, Eq. A4.1.1-1]		
T_u	68562,518	[N]	→	T_u	68,563	[kN]
$R = 0,940$	[kN]	0,940		Ratio	0,965	[%]
$R_u = T_u$	68,563	[kN]				

19 D-Section Purlin: Axial Tension [AS/NZS 4600, LSD]

$N_u = A_g \cdot f_u$	f_u	389,092	[MPa]	$N_u \leq \phi_t N_n$		
[AS/NZS 4600, Eq. 3.2.2(1)]	A_g	191,199	[mm ²]			
ϕ_t	0,900	[ASD]		[AS/NZS 4600, Eq. 3.2.1]		
N_u	68562,518	[N]	→	N_u	68,563	[kN]
$N^* = 0,940$	[kN]	0,940		Ratio	0,965	[%]
N_u	68,563	[kN]				

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_u	68562,518	[N]	→	N_u	68,563	[kN]
$N^* = 0,940$	[kN]	0,940		Ratio	0,965	[%]
N_u	68,563	[kN]				

20 C-Section Column

21 C-Section Column: Axial Tension [AISI S100, ASD]

$T_u = A_g \cdot F_u$	f_u	389,323	[MPa]	$T_s \leq T_u \leq \phi_t T_n$		
Yielding in gross section	A_g	487,235	[mm ²]			
[AISI S100, Eq. C2-1]	ϕ_t	1,670	[ASD]	[AISI S100, Eq. A4.1.1-1]		
T_u	183143,262	[N]	→	T_u	183,143	[kN]
$R = 3,340$	[kN]	3,340		Ratio	3,048	[%]
$R_u = T_u$	183,143	[kN]				

22 C-Section Column: Axial Tension [AISI S100, LRFD]

$T_u = A_g \cdot F_u$	f_u	389,323	[MPa]	$T_s \leq \phi_t T_n$		
Yielding in gross section	A_g	487,235	[mm ²]			
[AISI S100, Eq. C2-1]	ϕ_t	0,900	[ASD]	[AISI S100, Eq. A4.1.1-1]		
T_u	183143,262	[N]	→	T_u	183,143	[kN]
$R = 3,340$	[kN]	3,340		Ratio	2,028	[%]
$R_u = T_u$	183,143	[kN]				

23 C-Section Column: Axial Tension [AS/NZS 4600, LSD]

$N_u = A_g \cdot f_u$	f_u	389,323	[MPa]	$N_u \leq \phi_t N_n$		
[AS/NZS 4600, Eq. 3.2.2(1)]	A_g	487,235	[mm ²]			
ϕ_t	0,900	[ASD]		[AS/NZS 4600, Eq. 3.2.1]		
N_u	183143,262	[N]	→	N_u	183,143	[kN]
$N^* = 3,340$	[kN]	3,340		Ratio	2,028	[%]
N_u	183,143	[kN]				

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_u	183143,262	[N]	→	N_u	183,143	[kN]
$N^* = 3,340$	[kN]	3,340		Ratio	2,028	[%]
N_u	183,143	[kN]				

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Code: AISI AS/NZS	Reference: AISI S100 AS/NZS 4600 EN 1993		
Version: 1,000			

[1] C-Section Steel [AISI S100, ASD]

$T_x = A_g \cdot F_y$
Yielding in gross section [AISI S100, Eq. C2-4]

$f_y = 367,142$ [MPa]
 $A_g = 201,315$ [mm²]
 $Q_t = 1,570$ [ASD] [AISI S100, Eq. A4.1.1-1]

$T_x = 73911,492$ [N] → $T_x = 73911$ [kN]

$R = 2,280$ [kN]
 $R_x = T_x = 73,911$ [kN]

Ratio: 5/52 [%]

[II] C-Section Steel: Axial Tension [AISI S100, LRFD]

$T_x = A_g \cdot F_u$
Yielding in gross section [AISI S100, Eq. C2-4]

$f_u = 367,142$ [MPa]
 $A_g = 201,315$ [mm²]
 $\phi_t = 0,900$ [ASD] [AISI S100, Eq. A5.1.1-1]

$T_x = 73911,492$ [N] → $T_x = 73911$ [kN]

$R = 2,280$ [kN]
 $R_x = T_x = 73,911$ [kN]

Ratio: 3,428 [%]

[III] C-Section Steel: Axial Tension [AS/NZS 4600, LSD]

$N_x = A_g \cdot f_y$
[AS/NZS 4600, Eq. 3.2.2(1)]

$f_y = 367,142$ [MPa]
 $A_g = 201,315$ [mm²]
 $\phi_t = 0,900$ [ASD] [AS/NZS 4600, Eq. 3.2.1]

$N_x = 73911,492$ [N] → $N_x = 73911$ [kN]

$N^* = 2,280$ [kN]
 $N_x = 73,911$ [kN]

Ratio: 3,428 [%]

Table 1.6: Capacity Reduction Factor [AS/NZS 4600, 2.0.6]

Design Capacity	Clause Reference	Capacity Reduction Factor [ϕ_t]
Members subject to axial tension	3.2.1	0,900

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Negative Moment in x-x axis [M_{xx}]

$I_{xx} >$ 85759,975 [mm⁴]

$S_{xx,comp} = 3343,203$ [mm³]
 $S_{xx,tens} = 3563,334$ [mm³]

$I_{yy} >$ 85759,975 [mm⁴]

$S_{yy,comp} = 3343,203$ [mm³]
 $S_{yy,tens} = 3563,334$ [mm³]

Section is fully effective

$F_y = \dots$ [MPa]
 $F_u = 365,389$ [MPa]

$M_{xx,comp} <$ 122168,857 [Nmm]
 $M_{xx,tens} <$ 111589,737 [Nmm]

$M_{xx,comp} <$ 1,222 [kNm]
 $M_{xx,tens} <$ 1,116 [kNm]

Positive Moment in y-y axis [M_{yy}]

$I_{yy} >$ 17690,935 [mm⁴]

$S_{yy,comp} = 3177,386$ [mm³]
 $S_{yy,tens} = 3177,386$ [mm³]

$I_{xx} >$ 17380,870 [mm⁴]

$S_{xx,comp} = 3076,245$ [mm³]
 $S_{xx,tens} = 3163,378$ [mm³]

Section is not fully effective

$F_y = 350,000$ [MPa]
 $F_u = \dots$ [MPa]

$M_{yy,comp} <$ 107680,051 [Nmm]
 $M_{yy,tens} <$ 1103692,315 [Nmm]

$M_{yy,comp} <$ 1,077 [kNm]
 $M_{yy,tens} <$ 1,104 [kNm]

Negative Moment in y-y axis [M_{yy}]

$I_{yy} >$ 17690,935 [mm⁴]

$S_{yy,comp} = 3177,386$ [mm³]
 $S_{yy,tens} = 3177,386$ [mm³]

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[15.2] Members subjected to Bending [AISI S100, C] | AS/NZS 4600, 3.3]

[*] D-Section Profile

[1] D-Section Profile: Bending Moment [AISI S100, ASD]

[1] D-Section Profile: Nominal Section Strength [Resistance] [AISI S100, C3.1.2]

Procedure: 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:

- Member is not subject to twisting, lateral, or torsional buckling
- Effect of cold work or forming is not included in determining the yield stress F_y
- Ratio of the depth of the compressed portion of the web to its thickness not exceed A_1
- Shear force does not exceed:
 - $0,39F_y A_{SD}$ [lines web area] h_w - Stiffened elements [h_w - Unstiffened elements]
 - $0,60F_y I_{RFD}$ [lines web area] h_w - Stiffened elements [h_w - Unstiffened elements]
- The angle between any web and the vertical does not exceed 30

Sections with stiffened or partially stiffened compression flanges: $\phi_b = 1,570$

Procedure: I $M_x = S_x F_y$ [AISI S100, Eq. C3.1.2-1]

Positive Moment in x-x axis [M_{xx}]

$I_{xx} >$ 85759,975 [mm⁴]

$S_{xx,comp} = 3053,134$ [mm³]
 $S_{xx,tens} = 3343,203$ [mm³]

$I_{yy} >$ 81891,327 [mm⁴]

$S_{yy,comp} = 2844,717$ [mm³]
 $S_{yy,tens} = 3281,896$ [mm³]

Section is not fully effective

$F_y = 350,000$ [MPa]
 $F_u = \dots$ [MPa]

$M_{xx,comp} <$ 95651,0514 [Nmm]
 $M_{xx,tens} <$ 114859,066 [Nmm]

$M_{xx,comp} <$ 0,956 [kNm]
 $M_{xx,tens} <$ 1,149 [kNm]

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[2] D-Section Profile: Lateral-Torsional Buckling Strength [Resistance] [AISI S100, C3.1.2]

Provisions of this section are not applied to multiple-bay deck, U, closed box-type members, curved or arch members

[3] D-Section Profile: Distortional Buckling Strength [Resistance] [AISI S100, C3.1.4]

Provisions of this section are not applied to multiple-bay deck, U, closed box-type members, curved or arch members

[4] D-Section Profile: Bending Moment Verification [AISI S100, ASD]

$M_x \leq M_x \phi_b$ [AISI S100, Eq. A4.1.1-1] $M_x = MN [M_{xx,comp} - M_{xx,tens}]$

Positive Moment in x-x axis [M_{xx}]

$M_{xx,comp} <$ 0,950 [kNm]
 $M_{xx,tens} <$ 0,996 [kNm]

Ratio: 69,383 [%]

Negative Moment in x-x axis [M_{xx}]

$M_{xx,comp} <$ 0,950 [kNm]
 $M_{xx,tens} <$ 1,222 [kNm]

Ratio: 49,215 [%]

Positive Moment in y-y axis [M_{yy}]

$M_{yy,comp} <$ 0,950 [kNm]
 $M_{yy,tens} <$ 1,077 [kNm]

Ratio: 13,957 [%]

Negative Moment in y-y axis [M_{yy}]

$M_{yy,comp} <$ 0,950 [kNm]
 $M_{yy,tens} <$ 1,080 [kNm]

Ratio: 13,921 [%]

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Version:	1,000		

[0]	D-Section Portal - Bending Moment	[AISI S100, LRFD]																
[1]	D-Section Portal - Nominal Section Strength Resistance	[AISI S100, C3,J]																
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<p>Sections with stiffened or partially stiffened compression flanges $\Phi_c = 0.950$</p> <p>Procedure <input type="checkbox"/> I <input checked="" type="checkbox"/> II $M_x = S_x F_y$ [AISI S100, Eq. C3.J.1]</p>																		
<p>Positive Moment in x-x axis M_{xx} []</p> <table border="1"> <tr> <td>$I_{xx}(mm^4)$</td> <td>85759.975</td> <td>$I_{yy}(mm^4)$</td> <td>81891.327</td> </tr> <tr> <td>$S_{xx}(mm^3)$</td> <td>3053.134</td> <td>$S_{yy}(mm^3)$</td> <td>3281.886</td> </tr> <tr> <td>$I_{xx}(mm^4)$</td> <td>85759.975</td> <td>$I_{yy}(mm^4)$</td> <td>81891.327</td> </tr> <tr> <td>$S_{xx}(mm^3)$</td> <td>3053.134</td> <td>$S_{yy}(mm^3)$</td> <td>3281.886</td> </tr> </table> <p>$S_{xx}(mm^3)$ Section is not fully effective $S_{yy}(mm^3)$</p> <p>F_y 350.000 [MPa] F_u --- [MPa]</p> <p>$M_{xx}(kNm)$: 1079.646,074 [kNm] $M_{yy}(kNm)$: 110.6216,801 [kNm]</p> <p>$M_{xx}(kNm)$: 1.000 [kNm] $M_{yy}(kNm)$: 1.105 [kNm]</p>			$I_{xx}(mm^4)$	85759.975	$I_{yy}(mm^4)$	81891.327	$S_{xx}(mm^3)$	3053.134	$S_{yy}(mm^3)$	3281.886	$I_{xx}(mm^4)$	85759.975	$I_{yy}(mm^4)$	81891.327	$S_{xx}(mm^3)$	3053.134	$S_{yy}(mm^3)$	3281.886
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[0]	D-Section Portal - Bending Moment	[AISI S100, LRFD]																																
[1]	D-Section Portal - Nominal Section Strength Resistance	[AISI S100, C3,J]																																
[2]	D-Section Portal - Lateral-Torsional Buckling Strength Resistance	[AISI S100, C3.J.2]																																
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[0]	D-Section Portal - Bending Moment	[AISI S100, LRFD]																
[1]	D-Section Portal - Nominal Section Moment Capacity	[AISI S100, C3.J.2]																
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Version:	1,000		

[0]	D-Section Portal - Bending Moment	[AS/NZS 4600, LSD]																
[1]	D-Section Portal - Nominal Section Moment Capacity	[AS/NZS 4600, 3.3.2]																
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Negative Moment in x-x axis [M _{xx}]			
I _{xx} [mm ⁴]	85769,875		
Z _{xx} [mm]	3343,203	Z _{xx} [mm]	3053,334
I _{yy} [mm ⁴]	85769,875		
Z _{yy} [mm]	3343,203	Z _{yy} [mm]	3053,334
Z _{xx} [mm]		Section is fully effective	Z _{yy} [mm]
f _y [MPa]	---		
f _u [MPa]	365,389		
M _{xx} [Nmm]	1221968,857	M _{xx} [Nmm]	1158897,937
M _{xx} [kNm]	1,222	M _{xx} [kNm]	1,164
Positive Moment in y-y axis [M _{yy}]			
I _{xx} [mm ⁴]	176809,935		
Z _{xx} [mm]	3177,886	Z _{xx} [mm]	3177,886
I _{yy} [mm ⁴]	173380,870		
Z _{yy} [mm]	3076,745	Z _{yy} [mm]	3163,378
Z _{xx} [mm]		Section is not fully effective	Z _{yy} [mm]
f _y [MPa]	350,000		
f _u [MPa]	---		
M _{yy} [Nmm]	1076840,61	M _{yy} [Nmm]	1103682,315
M _{yy} [kNm]	1,077	M _{yy} [kNm]	1,104
Negative Moment in y-y axis [M _{yy}]			
I _{xx} [mm ⁴]	176809,935		
Z _{xx} [mm]	3177,886	Z _{xx} [mm]	3177,886

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[1]	C-Section Beam: Bending Moment	[AISI S100, ASD]								
[1]	C-Section Beam: Nominal Section Strength Resistance	[AISI S100, C1,1,1]								
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[5] The angle between any web and the vertical does not exceed 30°										
Sections with stiffened or partially stiffened compression flanges										
Q _w	1,870									
Procedure	I	M _n = Q _w F _y AISI S100, Eq. C1.7.1-1								
Positive Moment in x-x axis [M _{xx}]										
I _{xx} [mm ⁴]	762280,665									
S _{xx} [mm ³]	12860,454	S _{xx} [mm ³]	12860,454							
I _{yy} [mm ⁴]	762280,665									
S _{yy} [mm ³]	12860,454	S _{yy} [mm ³]	12860,454							
S _{xx} [mm ³]		Section is fully effective	S _{yy} [mm ³]							
F _y [MPa]	---									
F _u [MPa]	374,380									
M _{xx} [Nmm]	4814825,421	M _{xx} [Nmm]	4814825,421							
M _{xx} [kNm]	4,815	M _{xx} [kNm]	4,815							

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I _{xx} [mm ⁴]	173726,891		
Z _{xx} [mm]	3084,704	Z _{xx} [mm]	3157,762
Z _{xx} [mm]		Section is not fully effective	Z _{yy} [mm]
f _y [MPa]	350,000		
f _u [MPa]	---		
M _{xx} [Nmm]	1076840,61	M _{xx} [Nmm]	1105216,801
M _{xx} [kNm]	1,080	M _{xx} [kNm]	1,105
[2]	D-Section Purlin: Members subject to Lateral Buckling	[AS/NZS 4600, 3.3.2.2]	
Provisions of this clause are not applied to multiple web deck, U-box and covered arch members M _n = 0 kNm			
[3]	D-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 covered arch members M _n = 0 kNm			
[4]	D-Section Purlin: Bending Moment Verification	[AS/NZS 4600, LSD]	
M' ≤ φ _b M _n | AS/NZS 4600, Eq. 3.3.3.1(1)		M' ≤ φ _b M _n | AS/NZS 4600, Eq. 3.3.3.1(2)	
Positive Moment in x-x axis [M _{xx}]			
M _{xx} [Nmm]	0,980	Ratio	40,375 [%]
M _{xx} [kNm]	0,986		
Negative Moment in x-x axis [M _{xx}]			
M _{xx} [Nmm]	0,980	Ratio	32,745 [%]
M _{xx} [kNm]	1,232		
Positive Moment in y-y axis [M _{yy}]			
M _{yy} [Nmm]	0,980	Ratio	9,285 [%]
M _{yy} [kNm]	1,077		
Negative Moment in y-y axis [M _{yy}]			
M _{yy} [Nmm]	0,980	Ratio	9,282 [%]
M _{yy} [kNm]	1,080		

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Negative Moment in x-x axis [M _{xx}]			
I _{xx} [mm ⁴]	762280,665		
S _{xx} [mm ³]	12860,454	S _{xx} [mm ³]	12860,454
I _{yy} [mm ⁴]	762280,665		
S _{yy} [mm ³]	12860,454	S _{yy} [mm ³]	12860,454
S _{xx} [mm ³]		Section is fully effective	S _{yy} [mm ³]
F _y [MPa]	---		
F _u [MPa]	374,380		
M _{xx} [Nmm]	4814825,421	M _{xx} [Nmm]	4814825,421
M _{xx} [kNm]	4,815	M _{xx} [kNm]	4,815
Positive Moment in y-y axis [M _{yy}]			
I _{xx} [mm ⁴]	108754,099		
S _{xx} [mm ³]	7488,064	S _{xx} [mm ³]	3567,386
I _{yy} [mm ⁴]	96937,280		
S _{yy} [mm ³]	5791,742	S _{yy} [mm ³]	3445,072
S _{xx} [mm ³]		Section is not fully effective	S _{yy} [mm ³]
F _y [MPa]	350,000		
F _u [MPa]	---		
M _{yy} [Nmm]	2095889,557	M _{yy} [Nmm]	1205889,304
M _{yy} [kNm]	2,096	M _{yy} [kNm]	1,206
Negative Moment in y-y axis [M _{yy}]			
I _{xx} [mm ⁴]	108754,099		
S _{xx} [mm ³]	3567,386	S _{xx} [mm ³]	7488,064

$I_{xx} = 19874,009 \text{ [mm}^4\text{]}$

$S_{ix} = 3567,406 \text{ [mm}^3\text{]}$ | $S_{ix} = 7468,064 \text{ [mm}^3\text{]}$

Section is fully effective

$F_y = \dots$ [MPa] | $F_w = 374,300$ [MPa]

$M_{y,design} = 139,691,22$ [kNm] | $M_{x,design} = 2769,9824$ [kNm]

$M_{y,design} = 1,336$ [kNm] | $M_{x,design} = 2,796$ [kNm]

[2] C-Section Beam - Lateral-Torsional Buckling Strength [Resistance] [AISI S100, C3.J.2.J.1]

$C_b = 1,070$ | $M_y = S_y F_c$ [AISI S100, Eq. C3.J.2.J.1]

Singly-symmetric sections bending about the symmetry axis [xx]

C_b shall be permitted to be conservatively taken as unity for all cases. For cantilevers or overhangs where the free end is unrestrained, C_b shall be taken as unity.

$C_b = 1,000$ | $r_y = 47,051$ [mm]

$r_y = 17,763$ [mm] | $r_x = -97,355$ [mm]

$r_x = 62,668$ [mm]

$S_x = 12860,654$ [mm³] | $E = 210,000$ [GPa]

$\sigma_{ev} = \frac{\pi^2 E}{(K_y L_y / r_y)^2}$ | $\sigma_{ev,compression} = 3534,028$ [N/mm²] | $\sigma_{ev,tension} = 3520,291$ [N/mm²] [AISI S100, Eq. C3.J.2.J.8]

$\sigma_c = \frac{1}{A_g} \left[C_b + \frac{\pi^2 E C_b}{(K_x L_x)^2} \right]$ | $\sigma_{ev,compression} = 535,873$ [N/mm²] | $\sigma_{ev,tension} = 569,982$ [N/mm²] [AISI S100, Eq. C3.J.2.J.8]

$F_c = \frac{C_b F_y A}{S_y} \sqrt{\sigma_{ev} \sigma_c}$ | $F_{c,compression} = 2311,291$ [MPa] | $F_{c,tension} = 2379,420$ [MPa] [AISI S100, Eq. C3.J.2.J.8]

$F_y = \dots$ [MPa] | $F_w = 374,300$ [MPa]

$C_{TF} = 0.6 - 0.4 (M_1/M_2)$ | $C_{TF} = 1,000$ [AISI S100, Eq. C3.J.2.J.11]

$F_c = \frac{C_b A_g \sigma_{ev}}{C_{TF} S_y} \left[1 + C_b \sqrt{1 + r_y^2 (\sigma_y / \sigma_{ev})} \right]$ [AISI S100, Eq. C3.J.2.J.10]

$M_{y,design} = \dots$ | $C_b = 1,000$

$M_{x,design} = \dots$ | $C_b = -1,000$

$A_g = 345,063$ [mm²] | $r_y = 62,668$ [mm]

$S_y = 7468,064$ [mm³] | $S_y = 3567,406$ [mm³]

$\sigma_{ev,compression} = 535,873$ [N/mm²] | $\sigma_{ev,tension} = 569,982$ [N/mm²]

Console Beam [F_{y,design}]

$F_y \geq 2,780 * F_y$ [MPa] | $F_x \geq 2,780 * F_x$ [MPa]

Middle Beam [F_{y,design}]

$F_y \geq 2,780 * F_y$ [MPa] | $F_x \geq 2,780 * F_x$ [MPa]

$M_{y,design} = \dots$ | $F_y = \dots$ [MPa]

$M_{x,design} = \dots$ | $F_x = 374,300$ [MPa]

$F_y \geq 2,780 * F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_y . Available flexural strength [nominal resistance] shall be determined with Section C3.J.2.J.(c).

$2,780 * F_y > F_y > 0,560 * F_y$ | $0,560 * F_y \geq F_y$

$F_c = \frac{10}{9} F_y \left(1 - \frac{10 F_y}{36 F_c} \right)$ | $F_y = F_c$ [AISI S100, Eq. C3.J.2.J.3]

$S_y = 7468,064$ [mm³] | $S_y = 3567,406$ [mm³]

Console Beam [F_{y,design}]

$F_y \geq 2,780 * F_y$ | $2,780 * F_y > F_y > 0,560 * F_y$ | $0,560 * F_y \geq F_y$

Yes | No | No

C3.J.2.J.(c) [MPa] | --- [MPa] | --- [MPa]

$F_y \geq 2,780 * F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_y . Available flexural strength [nominal resistance] shall be determined with Section C3.J.2.J.(c).

$2,780 * F_y > F_y > 0,560 * F_y$ | $0,560 * F_y \geq F_y$

$F_c = \frac{10}{9} F_y \left(1 - \frac{10 F_y}{36 F_c} \right)$ | $F_y = F_c$ [AISI S100, Eq. C3.J.2.J.3]

$S_x = 12860,654$ [mm³]

Console Beam [F_{y,design}]

$F_y \geq 2,780 * F_y$ | $2,780 * F_y > F_y > 0,560 * F_y$ | $0,560 * F_y \geq F_y$

Yes | No | No

C3.J.2.J.(c) [MPa] | --- [MPa] | --- [MPa]

Middle Beam [F_{y,design}]

$F_y \geq 2,780 * F_y$ | $2,780 * F_y > F_y > 0,560 * F_y$ | $0,560 * F_y \geq F_y$

Yes | No | No

C3.J.2.J.(c) [MPa] | --- [MPa] | --- [MPa]

Console Beam [M_{y,design}]

$F_y \geq 2,780 * F_y$ | $2,780 * F_y > F_y > 0,560 * F_y$ | $0,560 * F_y \geq F_y$

4,815 [kNm] | --- [kNm] | --- [kNm]

Middle Beam [M_{y,design}]

$F_y \geq 2,780 * F_y$ | $2,780 * F_y > F_y > 0,560 * F_y$ | $0,560 * F_y \geq F_y$

4,815 [kNm] | --- [kNm] | --- [kNm]

$M_{y,design} = 4,815$ [kNm] | $M_{x,design} = 4,915$ [kNm]

Singly-symmetric sections bending about the axis perpendicular to the axis of symmetry [yy]

$C_b = 1 | 1,000 \rightarrow$ Moment causing compression on shear center side of section

$C_b = -1 | -1,000 \rightarrow$ Moment causing tension on shear center side of section

$\sigma_{ev} = \frac{\pi^2 E}{(K_y L_y / r_y)^2}$ | $\sigma_{ev,compression} = 4400,288$ [N/mm²] | $\sigma_{ev,tension} = 4680,583$ [N/mm²] [AISI S100, Eq. C3.J.2.J.14]

$I = \frac{1}{24} \int_{-h}^h x^3 dA + \int_{-h}^h x y^2 dA$ | $I = 65,750$ [mm⁴] [AISI S100, Eq. C3.J.2.J.14]

Console Beam [F_{y,design}]

$F_y \geq 2,780 * F_y$ | $2,780 * F_y > F_y > 0,560 * F_y$ | $0,560 * F_y \geq F_y$

Yes | No

C3.J.2.J.(c) [MPa] | --- [MPa] | --- [MPa]

Middle Beam [F_{y,design}]

$F_y \geq 2,780 * F_y$ | $2,780 * F_y > F_y > 0,560 * F_y$ | $0,560 * F_y \geq F_y$

Yes | No

C3.J.2.J.(c) [MPa] | --- [MPa] | --- [MPa]

Middle Beam [F_{y,design}]

$F_y \geq 2,780 * F_y$ | $2,780 * F_y > F_y > 0,560 * F_y$ | $0,560 * F_y \geq F_y$

Yes | No

C3.J.2.J.(c) [MPa] | --- [MPa] | --- [MPa]

Console Beam [M_{y,design}]

$F_y \geq 2,780 * F_y$ | $2,780 * F_y > F_y > 0,560 * F_y$ | $0,560 * F_y \geq F_y$

2,006 [kNm] | --- [kNm] | --- [kNm]

Console Beam [M_{y,design}]

$F_y \geq 2,780 * F_y$ | $2,780 * F_y > F_y > 0,560 * F_y$ | $0,560 * F_y \geq F_y$

1,336 [kNm] | --- [kNm] | --- [kNm]

Middle Beam [M_{y,design}]

$F_y \geq 2,780 * F_y$ | $2,780 * F_y > F_y > 0,560 * F_y$ | $0,560 * F_y \geq F_y$

2,006 [kNm] | --- [kNm] | --- [kNm]

Middle Beam [M_{y,design}]

$F_y \geq 2,780 * F_y$ | $2,780 * F_y > F_y > 0,560 * F_y$ | $0,560 * F_y \geq F_y$

1,336 [kNm] | --- [kNm] | --- [kNm]

Console Beam [M_{y,design}]

$M_{y,design} = 2,006$ [kNm] | $M_{x,design} = 1,336$ [kNm]

Middle Beam [M_{y,design}]

$M_{y,design} = 2,006$ [kNm] | $M_{x,design} = 1,336$ [kNm]

[3] C-Section Beam - Distortional Buckling Strength [Resistance] [AISI S100, C3.J.3]

$C_b = 1,070$

For C- and Z-Sections or any Open Sections with a Stiffened Compression Flange Extending to Side of the Web where the Stiffener is either a Single Lip or a Complex Edge Stiffener

[AISI S100, Figure B2.2-1] [AISI S100, Figure B4.4]

Dimensional Limits		
[1]	$50 \leq h_1$ [mm]	OK
[2]	$25 \leq h_2$ [mm]	OK
[3]	$6.25 \leq D$ [mm]	OK
[4]	$45^\circ \leq \theta$	OK
[5]	$8 \leq h_0$ [mm]	OK
[6]	$2 \leq h_1/h_2$	OK
	$h_1/h_2 \leq 8$	OK
	$0.94 \leq D^* \leq \min[8, h_1]$	OK
	$D^* \leq \min[8, h_2, 9.5\theta]$	OK

$$L_{cr} = \left(\frac{4\pi^4 h_0 (1-\mu^2)}{3} \left(I_{xt} (x_0 - h_x)^2 + C_{wtf} - E \frac{I_{yft}^2}{I_{yf}} (x_0 - h_x)^2 \right) + \frac{\pi^4 h_0^4}{720} \right)^{1/4}$$

[AISI S100, Eq.C3.7.4-12]

NOTE: Flanges with 90 Degree Lips

A_f	76,499	[mm ²]
I_x	1043,106	[mm ⁴]
I_y	1200,125	[mm ⁴]
I_{xy}	2927,982	[mm ⁴]
h_x	-24,448	[mm]
h_y	53,219	[mm]
J	53,219	[mm ⁴]
C_w	0,005	[mm ⁶]
v [μ]	0,005	[]
x_0	14,148	[mm]
y_0	-1,874	[mm]
h_0	12,000	[mm]
β	1,000	[]
$L = L_{cr}$	353,749	[mm]

$\lambda_p > 0.673$

$$M_n = M_y \left(1 - 0.22 \left(\frac{M_{end}}{M_y} \right)^{0.5} \right) \left(\frac{M_{end}}{M_y} \right)^{0.5} M_y$$

[AISI S100, Eq. C3.7.4-1] [AISI S100, Eq.C3.7.4-2]

M_x 4224619,304 [Nmm] M_y 4225 [Nmm]

[4] C-Section Beam: Bending Moment Verification [AISI S100, ASD]

M & M_y O_y [AISI S100, Eq.A4.1.1-1] $M_n = \min[M_{x(ASD)}, M_{y(ASD)}, M_{n(ASD)}]$

Positive Moment in x-axis [M_{x(ASD)}]

C-Section Cantilever Beam

$M_{x(ASD)}$	0,840	[kNm]	Ratio	33,255	[%]
$M_{x(ASD)max}$	4,225	[kNm]			

C-Section Middle Beam

$M_{x(ASD)}$	0,840	[kNm]	Ratio	33,255	[%]
$M_{x(ASD)max}$	4,225	[kNm]			

Negative Moment in x-axis [M_{x(ASD)}]

C-Section Cantilever Beam

$M_{x(ASD)}$	0,840	[kNm]	Ratio	33,255	[%]
$M_{x(ASD)max}$	4,225	[kNm]			

C-Section Middle Beam

$M_{x(ASD)}$	0,840	[kNm]	Ratio	33,255	[%]
$M_{x(ASD)max}$	4,225	[kNm]			

Positive Moment in y-axis [M_{y(ASD)}]

C-Section Cantilever Beam

$M_{y(ASD)}$	0,020	[kNm]	Ratio	1,065	[%]
$M_{y(ASD)max}$	2,006	[kNm]			

E 210,000 [GPa] G 80,769 [GPa]

$$k_{\phi fc} = \left(\frac{\pi}{L} \right)^4 \left(EI_{xt} (x_0 - h_x)^2 + EC_{wtf} - E \frac{I_{yft}^2}{I_{yf}} (x_0 - h_x)^2 \right) + \left(\frac{\pi}{L} \right)^2 GJ_t$$

[AISI S100, Eq.C3.7.4-13]

$$k_{\phi we} = \frac{Et^3}{12(1-\mu^2)} \left(\frac{3}{h_0} + \left(\frac{\pi}{L} \right)^2 \frac{19 h_0}{60} + \left(\frac{\pi}{L} \right)^4 \frac{h_0^3}{240} \right)$$

[AISI S100, Eq.C3.7.4-14]

h_{we} 1811,305 [N] h_{wc} 1659,922 [N]

$$\bar{k}_{\phi fc} = \left(\frac{\pi}{L} \right)^2 \left[A_f \left((x_0 - h_x)^2 \frac{I_{yft}^2}{I_{yf}^2} - 2y_0 (x_0 - h_x) \left(\frac{I_{yft}}{I_{yf}} \right) + h_x^2 + y_0^2 \right) + I_{xt} + I_{yf} \right]$$

[AISI S100, Eq.C3.7.4-15]

$$\bar{k}_{\phi we} = \frac{h_0 t n^2}{13440} \left(\frac{145360(1 - \zeta_{web}) + 62160 \left(\frac{L}{h_0} \right)^2 + 448\pi^2 + \left(\frac{h_0}{L} \right)^2 [53 + 3(1 - \zeta_{web})] \pi^4}{\pi^4 + 28\pi^2 \left(\frac{L}{h_0} \right)^2 + 42 \left(\frac{L}{h_0} \right)^4} \right)$$

[AISI S100, Eq.C3.7.4-16]

k_x 0,000 [N] $k_{\phi x}$ 2,000 []

$\bar{k}_{\phi fc}$ 5,074 [mm²] $\bar{k}_{\phi we}$ 0,665 [mm²]

$$F_{cr} = \beta \frac{k_{\phi fc} + k_{\phi we}}{\bar{k}_{\phi fc} + \bar{k}_{\phi we}}$$

[AISI S100, Eq.C3.7.4-16] F_c 614,924 [MPa]

$M_x = S_x \cdot F_c$ [AISI S100, Eq. C3.7.4-4] $M_y = S_y \cdot F_c$ [AISI S100, Eq. C3.7.4-4]

S_x 12889,464 [mm³] M_x 726629,491 [Nmm]

S_y 12889,464 [mm³] M_y 4507158,884 [Nmm]

$$\lambda_{ed} = \sqrt{M_y / M_{x(ASD)}}$$

[AISI S100, Eq.C3.7.4-4] λ_d 0,255

C-Section Middle Beam

$M_{x(ASD)}$	0,010	[kNm]	Ratio	1,259	[%]
$M_{x(ASD)max}$	1,336	[kNm]			

Negative Moment in y-axis [M_{y(ASD)}]

C-Section Cantilever Beam

$M_{y(ASD)}$	0,020	[kNm]	Ratio	2,001	[%]
$M_{y(ASD)max}$	1,336	[kNm]			

C-Section Middle Beam

$M_{y(ASD)}$	0,010	[kNm]	Ratio	1,259	[%]
$M_{y(ASD)max}$	1,336	[kNm]			

[8] C-Section Beam: Bending Moment [AISI S100, LRFD]

[9] C-Section Beam: Nominal Section Strength [Resistance] [AISI S100, LRFD]

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:

- Member is not subject to twisting, lateral, torsional, or flexure-torsional buckling
- Effect of cold work of forming is not included in determining the yield stress F_y
- Ratio of the depth of the compressed portion of the web to the thickness does not exceed A_1
- Stress does not exceed:
 - $0.85 F_y$ [ASD] times web area [h_s -Stiffened elements / h_u -Unstiffened elements]
 - $0.69 F_y$ [LRFD] times web area [h_s -Stiffened elements / h_u -Unstiffened elements]
- 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 $M_n = \phi_b F_y$ [AISI S100, Eq. C3.7.1-1]

Positive Moment in x-axis [M_{x(ASD)}]

$I_{x(ASD)}$ 76220,065 [mm⁴]

$S_{x(ASD)}$ 12889,464 [mm³] $S_{y(ASD)}$ 12889,464 [mm³]

Office: ---		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Design of a Photovoltaic Structure, Padraik configuration, according to AISI or AS/NZS			
Code: AISI | AS/NZS	Reference: AISI S100 | AS/NZS 4600 | EN 1993		
Version: 1,000	Client: COIMBRA UNIVERSITY		

$I_{x,eff}$	762280,665	[mm ⁴]	$I_{y,eff}$	762280,665	[mm ⁴]
$S_{x,eff}$	12860,454	[mm ³]	$S_{y,eff}$	12860,454	[mm ³]
Section is fully effective					
F_y	---	[MPa]	F_x	---	[MPa]
F_w	374,390	[MPa]	F_w	374,390	[MPa]
$M_{x,design}$	4814925,421	[Nmm]	$M_{y,design}$	4814925,421	[Nmm]
$M_{x,design}$	4,815	[kNm]	$M_{y,design}$	4,815	[kNm]
Negative Moment in x-z axis | M_{zz} |					
$I_{x,eff}$	762280,665	[mm ⁴]	$I_{y,eff}$	762280,665	[mm ⁴]
$S_{x,eff}$	12860,454	[mm ³]	$S_{y,eff}$	12860,454	[mm ³]
Section is fully effective					
F_y	---	[MPa]	F_x	---	[MPa]
F_w	374,390	[MPa]	F_w	374,390	[MPa]
$M_{x,design}$	4814925,421	[Nmm]	$M_{y,design}$	4814925,421	[Nmm]
$M_{x,design}$	4,815	[kNm]	$M_{y,design}$	4,815	[kNm]
Positive Moment in y-z axis | M_{zz} |					
$I_{x,eff}$	108754,009	[mm ⁴]	$I_{y,eff}$	96937,280	[mm ⁴]
$S_{x,eff}$	7468,064	[mm ³]	$S_{y,eff}$	3567,406	[mm ³]
$S_{x,eff}$	7468,064	[mm ³]	$S_{y,eff}$	3567,406	[mm ³]
$S_{y,eff}$	3567,406	[mm ³]	$S_{x,eff}$	7468,064	[mm ³]
F_y	---	[MPa]	F_x	---	[MPa]
F_w	374,390	[MPa]	F_w	374,390	[MPa]
$M_{x,design}$	1335931,22	[Nmm]	$M_{y,design}$	2795868,54	[Nmm]
$M_{x,design}$	1,336	[kNm]	$M_{y,design}$	2,796	[kNm]
[2] C-Section Beam: Lateral-Torsional Buckling Strength | Resistance | [AISI S100, C3.J.2.J-1]					
Φ_b	0,900		$M_n = \Phi_b F_c$	[AISI S100, Eq. C3.J.2.J-3]	
Bisymmetric sections bending about the symmetry axis | x_c |					
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_y	47,001	[mm]
			r_x	17,753	[mm]
			r_z	-37,355	[mm]
			r_o	62,658	[mm]
$r_{eff} = \sqrt{\frac{I_x + I_y + A r_o^2}{A}}$ [AISI S100, Eq. C3.J.2.J-7]					

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Date: 05/09/2019		Project: MASTER THESIS	
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Code: AISI AS/NZS	Reference: AISI S100 AS/NZS 4600 EN 1993		
Version: 1,000	Client: COIMBRA UNIVERSITY		

S_x	12860,454	[mm ³]	E	210,000	[GPa]
$\sigma_{xy} = \frac{\pi^2 E}{(K_y L_y / r_y)^2}$					
$\sigma_{1,design}$	3534,928	[N/mm ²]	$\sigma_{2,design}$	3520,291	[N/mm ²]
[AISI S100, Eq. C3.J.2.J-8]					
$\sigma_c = \frac{1}{A_g} \left[C_f + \frac{\pi^2 E C_{my}}{(K_y L_y / r_y)^2} \right]$					
$\sigma_{1,design}$	535,573	[N/mm ²]	$\sigma_{2,design}$	569,382	[N/mm ²]
[AISI S100, Eq. C3.J.2.J-8]					
$F_c = \frac{C_b F_y A}{S_f} \sqrt{\sigma_y \sigma_c}$					
$F_{c,design}$	2311,291	[MPa]	$F_{y,design}$	2379,520	[MPa]
[AISI S100, Eq. C3.J.2.J-4]					
F_y	---	[MPa]	F_x	374,390	[MPa]
$F_y \geq 2,780 \cdot F_x$					
Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_n					
Available flexural strength (moment resistance) shall be determined with Section C3.J.2(e)					
$2,780 \cdot F_y > F_x > 0,560 \cdot F_y$					
$F_c = \frac{10}{9} F_y \left(1 - \frac{10 F_y}{36 F_c} \right)$					
[AISI S100, Eq. C3.J.2.J-2]					
S_x	12860,454	[mm ³]			
Compact Beam | F_y |					
$F_y \geq 2,780 \cdot F_x$	Yes	No	$0,560 \cdot F_y \geq F_x$	Yes	No
C3.J.2(e)	[MPa]	---	[MPa]	---	[MPa]
Middle Beam | F_y |					
$F_y \geq 2,780 \cdot F_x$	Yes	No	$0,560 \cdot F_y \geq F_x$	Yes	No
C3.J.2(e)	[MPa]	---	[MPa]	---	[MPa]
Compact Beam | $M_{y,design}$ |					
$F_y \geq 2,780 \cdot F_x$	4,815	[kNm]	$0,560 \cdot F_y \geq F_x$	---	[kNm]
Middle Beam $M_{y,design}$					
$F_y \geq 2,780 \cdot F_x$	4,815	[kNm]	$0,560 \cdot F_y \geq F_x$	---	[kNm]

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Date: 05/09/2019		Project: MASTER THESIS	
Design of a Photovoltaic Structure, Padraik configuration, according to AISI or AS/NZS			
Code: AISI | AS/NZS	Reference: AISI S100 | AS/NZS 4600 | EN 1993		
Version: 1,000	Client: COIMBRA UNIVERSITY		

$S_{x,eff}$	Section is not fully effective		$S_{y,eff}$	
F_y	350,000	[MPa]	F_x	---
F_w	---	[MPa]	F_w	---
$M_{x,design}$	2009889,657	[Nmm]	$M_{y,design}$	1264953,04
$M_{x,design}$	2,006	[kNm]	$M_{y,design}$	1,206
Negative Moment in y-z axis | M_{zz} |				
$I_{x,eff}$	108754,009	[mm ⁴]	$I_{y,eff}$	7468,064
$S_{x,eff}$	3567,406	[mm ³]	$S_{y,eff}$	7468,064
$I_{y,eff}$	108754,009	[mm ⁴]	$S_{x,eff}$	3567,406
$S_{y,eff}$	3567,406	[mm ³]	$S_{y,eff}$	7468,064
Section is fully effective				
F_y	---	[MPa]	F_x	---
F_w	374,390	[MPa]	F_w	374,390
$M_{x,design}$	1335931,22	[Nmm]	$M_{y,design}$	2795868,54
$M_{x,design}$	1,336	[kNm]	$M_{y,design}$	2,796
[2] C-Section Beam: Lateral-Torsional Buckling Strength | Resistance | [AISI S100, C3.J.2.J-1]				
Φ_b	0,900		$M_n = \Phi_b F_c$	[AISI S100, Eq. C3.J.2.J-3]
Bisymmetric sections bending about the symmetry axis | x_c |				
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_y	47,001
			r_x	17,753
			r_z	-37,355
			r_o	62,658
$r_{eff} = \sqrt{\frac{I_x + I_y + A r_o^2}{A}}$ [AISI S100, Eq. C3.J.2.J-7]				

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Version: 1,000	Client: COIMBRA UNIVERSITY		

$M_{x,design}$	4,815	[kNm]	$M_{y,design}$	4,815	[kNm]
Bisymmetric sections bending about the axis perpendicular to the axis of symmetry | $y-z$ |					
C_b					
$C_b = 1,000 \rightarrow$ Moment causing compression on shear center side of coil end					
$C_b = -1,000 \rightarrow$ Moment causing tension on shear center side of coil end					
$\sigma_{cr} = \frac{\pi^2 E}{(K_y L_y / r_y)^2}$					
$\sigma_{1,design}$	4400,888	[N/mm ²]	$\sigma_{2,design}$	4690,583	[N/mm ²]
[AISI S100, Eq. C3.J.2.J-11]					
$i = \frac{1}{2I_x} \int_A x^2 dA + \frac{1}{2I_y} \int_A y^2 dA + x_o^2$					
[AISI S100, Eq. C3.J.2.J-11]					
$C_{TF} = 0,6 - 0,4 (M_1 / M_2)$					
[AISI S100, Eq. C3.J.2.J-11]					
$F_c = \frac{C_b A \sigma_{cr}}{C_{TF} S_f} \left[1 + C_b \sqrt{1 + r_o^2 (\sigma_y / \sigma_{cr})} \right]$					
[AISI S100, Eq. C3.J.2.J-10]					
M_{11}	---		C_b	1,000	
M_{21}	---		C_b	-1,000	
A_g	345,043	[mm ²]	r_y	62,658	
$S_{x,eff}$	7468,064	[mm ³]	$S_{y,eff}$	3567,406	
$\sigma_{1,design}$	535,573	[N/mm ²]	$\sigma_{2,design}$	569,382	
Compact Beam					
$F_y \geq 2,780 \cdot F_x$	27469,385	[MPa]	$0,560 \cdot F_y \geq F_x$	1574,931	
Middle Beam					
$F_y \geq 2,780 \cdot F_x$	29264,626	[MPa]	$0,560 \cdot F_y \geq F_x$	1600,427	
Middle Beam $M_{y,design}$					
F_y	350,000	[MPa]	F_x	---	
Middle Beam $M_{x,design}$					
F_y	---	[MPa]	F_x	374,390	

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$F_y \geq 2.780 \cdot F_y$

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 C3.3.3(a)

$2.780 \cdot F_y > F_y > 0.560 \cdot F_y$ $0.560 \cdot F_y \geq F_y$

$F_c = \frac{10}{9} F_y \left(1 - \frac{10 F_y}{36 F_c} \right)$ $F_c = F_y$ [AISI S100, Eq. C3.3.3-3]

[AISI S100, Eq. C3.3.3-2]

$S_{x1} = 7468,084$ [mm³] $S_{x2} = 3567,406$ [mm³]

Conside Beam | $F_{y,Ed}$ |

$F_y \geq 2.780 \cdot F_y$ $2.780 \cdot F_y > F_y > 0.560 \cdot F_y$ $0.560 \cdot F_y \geq F_y$

Yes No No

C3.3.3(a) [MPa] --- [MPa] --- [MPa]

Conside Beam | $F_{y,Ed}$ |

$F_y \geq 2.780 \cdot F_y$ $2.780 \cdot F_y > F_y > 0.560 \cdot F_y$ $0.560 \cdot F_y \geq F_y$

Yes No No

C3.3.3(a) [MPa] --- [MPa] --- [MPa]

Middle Beam | $F_{y,Ed}$ |

$F_y \geq 2.780 \cdot F_y$ $2.780 \cdot F_y > F_y > 0.560 \cdot F_y$ $0.560 \cdot F_y \geq F_y$

Yes No No

C3.3.3(a) [MPa] --- [MPa] --- [MPa]

Conside Beam | $M_{y,Ed}$ |

$F_y \geq 2.780 \cdot F_y$ $2.780 \cdot F_y > F_y > 0.560 \cdot F_y$ $0.560 \cdot F_y \geq F_y$

2,006 [kNm] --- [kNm] --- [kNm]

Conside Beam | $M_{y,Ed}$ |

$F_y \geq 2.780 \cdot F_y$ $2.780 \cdot F_y > F_y > 0.560 \cdot F_y$ $0.560 \cdot F_y \geq F_y$

1,336 [kNm] --- [kNm] --- [kNm]

Middle Beam | $M_{y,Ed}$ |

$F_y \geq 2.780 \cdot F_y$ $2.780 \cdot F_y > F_y > 0.560 \cdot F_y$ $0.560 \cdot F_y \geq F_y$

2,006 [kNm] --- [kNm] --- [kNm]

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$I_{xcr} = \left(\frac{4\pi^2 h_o (1-\mu^2)}{l^3} \left(I_{yd} (s_o - h_x)^2 + C_{wyt} - \frac{I_{xyt}^2}{I_{yt}} (s_o - h_x)^2 \right) + \frac{\pi^4 h_o^4}{720} \right)^{1/4}$

[AISI S100, Eq. C3.3.4-2]

NOTE Flanges with 90 Degree Lips

$A_x = 76,459$ [mm²]
 $I_y = 1083,305$ [mm⁴]
 $I_{xy} = 1258,125$ [mm⁴]
 $I_{yt} = 2027,882$ [mm⁴]
 $h_x = -24,448$ [mm]
 $h_o = 53,719$ [mm]
 $y_o = -4,374$ [mm]
 $C_{wyt} = 0,000$ [mm⁶]
 $\beta = 1,000$ $L+L_o = 353,259$ [mm]

$E = 210,000$ [GPa] $G = 82,759$ [GPa]

$k_{eff} = \left(\frac{\pi}{L} \right)^4 \left(EI_{yd} (s_o - h_x)^2 + EC_{wyt} - E \frac{I_{xyt}^2}{I_{yt}} (s_o - h_x)^2 \right) + \left(\frac{\pi}{L} \right)^2 GJ_f$

[AISI S100, Eq. C3.3.4-3]

$k_{pvc} = \frac{Et^3}{12(1-\mu^2)} \left(\frac{3}{h_o} + \left(\frac{\pi}{L} \right)^2 \frac{19 h_o}{60} + \left(\frac{\pi}{L} \right)^4 \frac{h_o^3}{240} \right)$

[AISI S100, Eq. C3.3.4-4]

$k_{xx} = 1811,205$ [N] $k_{yy} = 1650,822$ [N]

$\bar{k}_{eff} = \left(\frac{\pi}{L} \right)^2 \left[A_x \left(s_o - h_x \right)^2 \frac{I_{xyt}^2}{I_{yt}^2} - 2y_{cs} (s_o - h_x) \frac{I_{xyt}}{I_{yt}} + h_c^2 + y_{cs}^2 \right] + I_{yd} + I_{yt}$

[AISI S100, Eq. C3.3.4-5]

$\bar{k}_{pvc} = \frac{h_o t^3}{13440} \left(\frac{45360(1-\mu_{web}) - 62160 \left(\frac{L}{h_o} \right)^2 + 448t^2 + \left(\frac{h_o}{L} \right)^2 [53 - 3(1-\mu_{web})] t^4}{\pi^4 + 28t^2 \left(\frac{L}{h_o} \right)^2 + 420 \left(\frac{L}{h_o} \right)^4} \right)$

[AISI S100, Eq. C3.3.4-6]

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Middle Beam | $M_{y,Ed}$ |

$F_y \geq 2.780 \cdot F_y$ $2.780 \cdot F_y > F_y > 0.560 \cdot F_y$ $0.560 \cdot F_y \geq F_y$

1,336 [kNm] --- [kNm] --- [kNm]

Conside Beam | $M_{y,Ed}$ |

$M_{y,Ed}$ 2,006 [kNm] $M_{y,Ed}$ 1,336 [kNm]

Middle Beam | $M_{y,Ed}$ |

$M_{y,Ed}$ 2,006 [kNm] $M_{y,Ed}$ 1,336 [kNm]

[3] C-Section Beam: Distortional Buckling Strength | Resistance | [AISI S100, C3.3.4]

$\Phi_b = 0,900$

For C- and Z-Sections on any Open Section with a Stiffened Compression Flange, Extending to Side of the Web where the Stiffener is either a Single Lip or a Complex Edge Stiffener

[AISI S100, Figure B2.2-2] [AISI S100, Figure B4.1]

Dimensional Limits

[1]	$50 \leq h_o / t$	OK
	$h_o / t \leq 200$	OK
[2]	$25 \leq h_x / t$	OK
	$h_x / t \leq 100$	OK
[3]	$6.25 < D / t$	OK
	$D / t \leq 50$	OK
[4]	$45^\circ \leq \theta$	OK
	$\theta \leq 90^\circ$	OK
[5]	$2 \leq h_o / b_1$	OK
	$h_o / b_2 \leq 8$	OK
[6]	$0.94 \leq D' / t \leq 0.11 h_o$	OK
	$D' / t \leq 0.11 h_o \leq 0.90$	OK

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$k_{xx} = 0,900$ [N] $k_{yy} = 2,000$ [N]

$\bar{k}_{eff} = 5,074$ [mm²] $\bar{k}_{pvc} = 0,565$ [mm²]

$F_{Ed} = \beta \frac{k_{eff} + k_{pvc} + k_{\phi}}{k_{eff} + k_{pvc}}$ $F_y = 614,024$ [MPa]

[AISI S100, Eq. C3.3.4-6]

$M_y = S_{x1} \cdot F_y$ $M_x = S_{x2} \cdot F_y$

[AISI S100, Eq. C3.3.4-7] [AISI S100, Eq. C3.3.4-8]

$S_x = 12860,454$ [mm³] $M_x = 788629,691$ [kNm]

$S_y = 12860,454$ [mm³] $M_y = 4501159,984$ [kNm]

$\lambda_{cd} = \sqrt{M_y / M_{y,crd}}$ $M = 0,759$

[AISI S100, Eq. C3.3.4-9]

$\lambda_p \leq 0,673$ $\lambda_p > 0,673$

M_x, M_y $M_{Rd} = \left(1 - 0,22 \left(\frac{M_{y,crd}}{M_y} \right)^{0,5} \right) \left(\frac{M_{y,crd}}{M_y} \right)^{0,5} M_y$

[AISI S100, Eq. C3.3.4-1] [AISI S100, Eq. C3.3.4-2]

$M_x = 422619,134$ [kNm] $M_y = 4,225$ [kNm]

[4] C-Section Beam: Bending Moment Verification | [AISI S100, LRFD]

$M_x \leq \Phi_b \cdot M_{Rd}$ [AISI S100, Eq. A5.3.3-1] $M_y \leq \text{MIN} \{ M_{1,crd}, M_{2,crd}, M_{y,crd} \}$

Positive Moment in x-axis | $M_{x,Ed}$ |

C-Section Conside Beam

$M_{1,Ed} = 0,840$ [kNm] Ratio 22,093 [%]

$M_{1,Ed} \leq M_{1,crd}$ 4,225 [kNm]

C-Section Middle Beam

$M_{1,Ed} = 0,840$ [kNm] Ratio 22,093 [%]

$M_{1,Ed} \leq M_{1,crd}$ 4,225 [kNm]

Negative Moment in x-x axis [M _{xx}]			
C-Section Console Beam			
M _{MEMBER}	0,940	[Nm]	Ratio: 22,093 [%]
M _{ELASTOMER}	4,235	[Nm]	
C-Section Middle Beam			
M _{MEMBER}	0,940	[Nm]	Ratio: 22,093 [%]
M _{ELASTOMER}	4,235	[Nm]	
Positive Moment in y-y axis [M _{yy}]			
C-Section Console Beam			
M _{MEMBER}	0,920	[Nm]	Ratio: 1,164 [%]
M _{ELASTOMER}	2,906	[Nm]	
C-Section Middle Beam			
M _{MEMBER}	1,336	[Nm]	Ratio: 0,932 [%]
M _{ELASTOMER}	1,336	[Nm]	
Negative Moment in y-y axis [M _{yy}]			
C-Section Console Beam			
M _{MEMBER}	0,920	[Nm]	Ratio: 1,864 [%]
M _{ELASTOMER}	1,336	[Nm]	
C-Section Middle Beam			
M _{MEMBER}	0,910	[Nm]	Ratio: 0,932 [%]
M _{ELASTOMER}	1,336	[Nm]	
[0]	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

Section is fully effective			
f _y	---	[MPa]	
f _u	374,390	[MPa]	
M _{ELASTOMER}	4814825,421	[Nmm]	M _{ELASTOMER} : 4814825,421 [Nmm]
M _{ELASTOMER}	4,815	[kNm]	M _{ELASTOMER} : 4,815 [kNm]
Positive Moment in x-x axis [M _{xx}]			
I _{xx}	108754,009	[mm ⁴]	
Z _{xx}	7469,054	[mm ³]	Z _{xx} : 3567,406 [mm ³]
I _{yy}	86937,280	[mm ⁴]	
Z _{yy}	5731,142	[mm ³]	Z _{yy} : 3443,572 [mm ³]
Section is not fully effective			
f _y	350,000	[MPa]	
f _u	---	[MPa]	
M _{ELASTOMER}	2056899,057	[Nmm]	M _{ELASTOMER} : 1205999,304 [Nmm]
M _{ELASTOMER}	2,056	[kNm]	M _{ELASTOMER} : 1,206 [kNm]
Negative Moment in x-x axis [M _{xx}]			
I _{xx}	108754,009	[mm ⁴]	
Z _{xx}	3567,406	[mm ³]	Z _{xx} : 7469,054 [mm ³]
I _{yy}	108754,009	[mm ⁴]	
Z _{yy}	3567,406	[mm ³]	Z _{yy} : 7469,054 [mm ³]
Section is fully effective			
f _y	---	[MPa]	
f _u	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:

- Member is not subject to twisting, lateral, torsional, or flexural-torsional buckling
- Effect of cold work of forming is not included in determining the yield stress, f_y
- Ratio of the depth of the compressed portion of the web to its thickness not exceed A₁
- Shear force does not exceed 0.35f_y times web area
- The angle between any web and the vertical does not exceed 30

Table 1.9. Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Class Reference	Capacity Reduction Factor [Φ _c]
Sections with stiffened or partially stiffened compression flanges	3.3.2	0,85

Procedure: I M_x = Z_xf_y [AS/NZS 4600, Eq. 3.3.2.2]

Positive Moment in x-x axis [M _{xx}]			
I _{xx}	762289,565	[mm ⁴]	
Z _{xx}	12869,454	[mm ³]	Z _{xx} : 12869,454 [mm ³]
I _{yy}	762289,565	[mm ⁴]	
Z _{yy}	12869,454	[mm ³]	Z _{yy} : 12869,454 [mm ³]
Section is fully effective			
f _y	---	[MPa]	
f _u	374,390	[MPa]	
M _{ELASTOMER}	4814825,421	[Nmm]	M _{ELASTOMER} : 4814825,421 [Nmm]
M _{ELASTOMER}	4,815	[kNm]	M _{ELASTOMER} : 4,815 [kNm]
Negative Moment in x-x axis [M _{xx}]			
I _{xx}	762289,565	[mm ⁴]	
Z _{xx}	12869,454	[mm ³]	Z _{xx} : 12869,454 [mm ³]
I _{yy}	762289,565	[mm ⁴]	
Z _{yy}	12869,454	[mm ³]	Z _{yy} : 12869,454 [mm ³]

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M _{ELASTOMER}	1335601,22	[Nmm]	M _{ELASTOMER} : 279568,54 [Nmm]
M _{ELASTOMER}	1,336	[kNm]	M _{ELASTOMER} : 0,2796 [kNm]

[2] C-Section Beam - Member subject to Lateral Buckling [AS/NZS 4600, 3.3.2.1]

Table 1.9. Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Class Reference	Capacity Reduction Factor [Φ _c]
Member moment capacity, Members subject to lateral buckling	3.3.3.2	0,80

Procedure: I M_x = Z_xf_y [AS/NZS 4600, Eq. 3.3.2.2(1)]

Singly, doubly and point-symmetric sections bending about the symmetry axis [x-x]

Φ_c shall be permitted to be conservatively taken as unity for all cases, For cantilever or overhangs where the free and laced end, Φ_c shall be taken as unity

Φ _c	1,000		f _y	47,001	[MPa]
			f _u	17,759	[MPa]
			r _y	-37,355	[mm]
			y _c	0,000	[mm]
			r _x	62,688	[mm]
Z _x	12869,454	[mm ³]	E	210,000	[GPa]
I _{xx}	1335601,22	[mm ⁴]	I _{yy}	3534,038	[mm ⁴]
I _{yy}	3534,038	[mm ⁴]	I _{xx}	3500,281	[mm ⁴]
[AS/NZS 4600, Eq. 3.3.2.2(1)(1)]					
I _{xx}	1335601,22	[mm ⁴]	I _{yy}	3534,038	[mm ⁴]
I _{yy}	3534,038	[mm ⁴]	I _{xx}	3500,281	[mm ⁴]
[AS/NZS 4600, Eq. 3.3.2.2(2)]					
I _{xx}	1335601,22	[mm ⁴]	I _{yy}	3534,038	[mm ⁴]
I _{yy}	3534,038	[mm ⁴]	I _{xx}	3500,281	[mm ⁴]
[AS/NZS 4600, Eq. 3.3.2.2(3)]					
M _x	Z _x f _y	[AS/NZS 4600, Eq. 3.3.2.2(1)]	M _y	4501158,884	[Nmm]

$\lambda_{b1} = \sqrt{\frac{M_y}{M_{y0}}}$ [AS/NZS 4600, Eq. 3.3.2(7)]		$\lambda_{1,compression}$ 0.389 [] $\lambda_{1,tension}$ 0.284 []
$\lambda_b \leq 0.600$		$M_c = M_y$ [AS/NZS 4600, Eq. 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. 3.3.2(4)]
$\lambda_b \geq 1.336$		$M_c = M_y \left(\frac{1}{\lambda_b^2} \right)$ [AS/NZS 4600, Eq. 3.3.2(5)]
Channel Beam [M_y]		
$\lambda_b \leq 0.600$	$0.600 < \lambda_b < 1.336$	$\lambda_b \geq 1.336$
M _y	M _y	M _y
4501158,984 [Nmm]	---	---
Middle Beam [M_y]		
$\lambda_b \leq 0.600$	$0.600 < \lambda_b < 1.336$	$\lambda_b \geq 1.336$
M _y	M _y	M _y
4501158,984 [Nmm]	---	---
$f_{t,compression} = 350,000$ [MPa] $f_{t,tension} = 350,000$ [MPa] $Z_y = 12880,454$ [mm ³]		
$M_y = Z_y \cdot f_t$ [AS/NZS 4600, Eq. 3.3.2(1)]		
Channel Beam [M_z]		
$\lambda_b \leq 0.600$	$0.600 < \lambda_b < 1.336$	$\lambda_b \geq 1.336$
M _z	M _z	M _z
4501158,984 [Nmm]	---	---
Middle Beam [M_z]		
$\lambda_b \leq 0.600$	$0.600 < \lambda_b < 1.336$	$\lambda_b \geq 1.336$
M _z	M _z	M _z
4501158,984 [Nmm]	---	---
M _{y,compression} 4,501 [kNm]	M _{y,tension} 4,501 [kNm]	

$\lambda_b \leq 0.600$		$M_c = M_y$ [AS/NZS 4600, Eq. 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. 3.3.2(4)]
$\lambda_b \geq 1.336$		$M_c = M_y \left(\frac{1}{\lambda_b^2} \right)$ [AS/NZS 4600, Eq. 3.3.2(5)]
Channel Beam [M_y]		
$\lambda_b \leq 0.600$	$0.600 < \lambda_b < 1.336$	$\lambda_b \geq 1.336$
M _y	M _y	M _y
2613822,477 [Nmm]	---	---
Channel Beam [M_z]		
$\lambda_b \leq 0.600$	$0.600 < \lambda_b < 1.336$	$\lambda_b \geq 1.336$
M _z	M _z	M _z
1248592,193 [Nmm]	---	---
Middle Beam [M_y]		
$\lambda_b \leq 0.600$	$0.600 < \lambda_b < 1.336$	$\lambda_b \geq 1.336$
M _y	M _y	M _y
2613822,477 [Nmm]	---	---
Middle Beam [M_z]		
$\lambda_b \leq 0.600$	$0.600 < \lambda_b < 1.336$	$\lambda_b \geq 1.336$
M _z	M _z	M _z
1248592,193 [Nmm]	---	---
$f_{t,compression} = 350,000$ [MPa] $f_{t,tension} = 350,000$ [MPa] $Z_y = 5791,142$ [mm ³]		
$M_y = Z_y \cdot f_t$ [AS/NZS 4600, Eq. 3.3.2(1)]		
Z _y	5791,142 [mm ³]	Z _y

Singly-symmetric sections bending about the axis perpendicular to the axis of symmetry [99]

C_1
 $C_1 = +1 | 1.000 \rightarrow$ Moment causing compression on shear center side of axial load
 $C_1 = -1 | -1.000 \rightarrow$ Moment causing tension on shear center side of axial load

$$f_{cr} = \frac{\pi^2 E}{(U_{eff} / r_x)^2}$$
 $f_{cr,compression} = 4400,883$ [N/mm²]
 $f_{cr,tension} = 4680,583$ [N/mm²]
 [AS/NZS 4600, Eq. 3.3.2(4)]

$$B = \frac{1}{I_x} \int (y_x^2 dA + \int y_x^2 dA) - 2c_x$$
 $B_y = 65,760$ [mm]
 [AS/NZS 4600, Eq. 3.3.2(6)]

$$C_{T1} = 0.6 - 0.4 (M_y / M_z)$$
 $C_{T1} = 1.000$
 [AS/NZS 4600, Eq. 3.3.2(5)]

$$M_{y0} = \frac{C_1 M_{cr} \left[(B_y / 2) + C_1 \sqrt{(B_y / 2)^2 + r_x^2 (U_{eff} / f_{cr})} \right]}{C_{T1}}$$
 $M_{y0} = 10986269,904$ [Nmm]
 $M_{z0} = 10014807,992$ [Nmm]

Channel Beam

M_{y,compression} 10986269,904 [Nmm] M_{y,tension} 10014807,992 [Nmm]

Middle Beam

M_{y,compression} 117078076,727 [Nmm] M_{y,tension} 10677101,0 [Nmm]

M_z 2613822,477 [Nmm] M_z 1248592,193 [Nmm]
 $f_t = 350,000$ [MPa] $f_t = 350,000$ [MPa]

$$\lambda_{b1} = \sqrt{\frac{M_y}{M_{y0}}}$$
 $\lambda_{1,compression} = 0.364$ []
 $\lambda_{1,compression} = 0.353$ []
 $\lambda_{1,tension} = 0.449$ []
 $\lambda_{1,tension} = 0.442$ []

Channel Beam [M_y]

$\lambda_b \leq 0.600$ $0.600 < \lambda_b < 1.336$ $\lambda_b \geq 1.336$

M_y M_y M_y

2005989,557 [Nmm] --- [Nmm] --- [Nmm]

Channel Beam [M_z]

$\lambda_b \leq 0.600$ $0.600 < \lambda_b < 1.336$ $\lambda_b \geq 1.336$

M_z M_z M_z

1248592,193 [Nmm] --- [Nmm] --- [Nmm]

Middle Beam [M_y]

$\lambda_b \leq 0.600$ $0.600 < \lambda_b < 1.336$ $\lambda_b \geq 1.336$

M_y M_y M_y

2005989,557 [Nmm] --- [Nmm] --- [Nmm]

Middle Beam [M_z]

$\lambda_b \leq 0.600$ $0.600 < \lambda_b < 1.336$ $\lambda_b \geq 1.336$

M_z M_z M_z

1248592,193 [Nmm] --- [Nmm] --- [Nmm]

M_{y,compression} 2,056 [kNm] M_{y,tension} 1,249 [kNm]
 M_{z,compression} 2,056 [kNm] M_{z,tension} 1,249 [kNm]

[9] C-Section Beam - Members subject to Distortional Buckling [AS/NZS 4600, 3.3.3.1]

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity

Member moment capacity Members subject to distortional buckling 3.3.3 0.85

$$M_y = Z_{y0} f_{t0}$$
 [AS/NZS 4600, Eq. 3.3.2(1)]

Single Lipped Channel Models for Distortional Buckling [AS/NZS 4600, Figure D1]

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NOTE Flanges with 90 Degree Lips [AS/NZS 4600, D2]

b_p	120,000	[mm]	4	18,000	[mm]
b_f	46,800	[mm]	1	1,652	[mm]
A_f	93,654	[mm ²]	4	65,817	[mm ²]
\bar{I}	29,238	[mm ⁴]	I_y	2342,755	[mm ⁴]
\bar{I}^2	2,512	[mm ⁴]	I_x	22355,896	[mm ⁴]
E	210,000	[GPa]	I_{yy}	3942,737	[mm ⁴]

$$\lambda = 4.80 \sqrt{\frac{I_y b_f^3}{A_f^3}} \quad \lambda = 563,679 \quad [mm]$$

[AS/NZS 4600, Eq. D2(8)]

$$\eta = \left(\frac{\pi}{\lambda}\right)^2 \quad \eta = 3,106E-05 \quad []$$

[AS/NZS 4600, Eq. D2(7)]

$$I_x = \bar{I}^2 + \left(\frac{I_y + I_x}{4}\right) \quad I_x = 1147,338 \quad [mm^4]$$

[AS/NZS 4600, Eq. D2(9)]

$$\alpha_2 = \eta \left(I_y + \frac{2}{\beta_1} \beta_0 I_x \right) \quad \alpha_2 = 0,719 \quad []$$

[AS/NZS 4600, Eq. D2(3)]

$$\alpha_1 = \frac{\eta}{\beta_1} (I_y b_f^2 + 0.039 I_x^2) \quad \alpha_1 = 0,53 \quad []$$

[AS/NZS 4600, Eq. D2(6)]

$$\alpha_3 = \eta \left(\alpha_1 I_y - \frac{\eta}{\beta_1} I_x^2 b_f^2 \right) \quad \alpha_3 = 0,978 \quad []$$

[AS/NZS 4600, Eq. D2(4)]

$$f_{cr} = \frac{E}{\gamma_{M1}} \left(\alpha_1 - \alpha_2 + \sqrt{(\alpha_1 - \alpha_2)^2 + \alpha_3} \right) \quad f_{cr} = 227,821 \quad [MPa]$$

[AS/NZS 4600, Eq. D2(1)]

$$k_x = \frac{\pi^2}{100 + 0.5 \sqrt{1 + \frac{1.1 I_y}{I_x} \left(\frac{b_f}{L} \right)^2}} \quad k_x = 564,551 \quad [mm]$$

[AS/NZS 4600, Eq. D2(8)]

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Distortions (buckling) involves transverse bending of a vertical web with lateral displacement of the compression flange web

$$M_{y1} = Z_{y1} \quad Z_{y1} = 12860,454 \quad [mm^3]$$

[AS/NZS 4600, Eq. 3.3.3.3(9)]

$$M_{y2} = 4627091,321 \quad [Nmm]$$

$$\lambda_{y1} = \sqrt{\frac{M_{y1}}{M_{y2}}} \quad \lambda_{y1} = 0,986 \quad []$$

[AS/NZS 4600, Eq. 3.3.3.3(8)]

$$\lambda_{y2} \leq 0,590 \quad 0,590 < \lambda_{y2} \leq 1,700 \quad \lambda_{y2} = 1,700$$

$$M_{y1} = M_{y2} \quad M_{y2} = M_{y1} \left(\frac{0,59}{\lambda_{y2}} \right) \quad M_{y2} = M_{y1} \left(\frac{I_{y1}}{I_{y2}} \right)$$

[AS/NZS 4600, Eq. 3.3.3.3(5)] [AS/NZS 4600, Eq. 3.3.3.3(9)] [AS/NZS 4600, Eq. 3.3.3.3(7)]

$$\lambda_{y2} \leq 0,590 \quad 0,590 < \lambda_{y2} \leq 1,700 \quad \lambda_{y2} = 1,700$$

$$M_{y1} \quad M_{y2}$$

[Nmm] [Nmm] [Nmm] [Nmm]

$$f_t = M_y / Z_y \quad f_t = 259,359 \quad [MPa]$$

[AS/NZS 4600, Eq. 3.3.3.3(2)]

$$Z_{y,transverse} = 12860,454 \quad [mm^3]$$

$$M_y = Z_{y1} \quad [AS/NZS 4600, Eq. 3.3.3.3(1)]$$

$$M_{y1} = 2692577,569 \quad [Nmm]$$

$$M_{y2} = 2,693 \quad [kNm]$$

$$M_{y1} = 2692577,569 \quad [Nmm] \quad M_{y2} = 2,693 \quad [kNm]$$

[4] C-Section Beam: Bending Moment Verification [AS/NZS 4600, LSD]

$M_y \leq \phi_y \cdot M_{y1}$ [AS/NZS 4600, Eq. 3.3.1(7)] $M_y \leq \phi_y \cdot M_{y2}$ [AS/NZS 4600, Eq. 3.3.1(2)]

Positive Moment in xx axis [M_{xx1}]

C-Section Conside Beam

$M_{y1,EDM}$	0,840	[kNm]	Ratio	34,863	[%]
$M_{y2,EDM}$	2,693	[kNm]			

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$$\alpha_1 = \frac{\eta}{\beta_1} (I_y b_f^2 + 0.039 I_x^2) \quad \alpha_1 = 0,221 \quad []$$

[AS/NZS 4600, Eq. D2(6)]

$$\alpha_3 = \eta \left(\alpha_1 I_y - \frac{\eta}{\beta_1} I_x^2 b_f^2 \right) \quad \alpha_3 = 0,25 \quad []$$

[AS/NZS 4600, Eq. D2(4)]

$$f_{cr} = \frac{E}{\gamma_{M1}} \left(\alpha_1 - \alpha_2 + \sqrt{(\alpha_1 - \alpha_2)^2 + \alpha_3} \right) \quad f_{cr} = 359,792 \quad [MPa]$$

[AS/NZS 4600, Eq. D2(1)]

Distortions (buckling) involves rotation of a flange and lip about the flange/web junction of a channel

$K_x = 504,551 \quad [mm] \quad Z_{y1} = \text{Full section modulus}$

$Z_{y,transverse} = 12860,454 \quad [mm^3] \quad Z_{y,transverse} = --- \quad [mm^3]$

$$M_{y1} = Z_{y1} \quad Z_{y1} = 12860,454 \quad [mm^3]$$

[AS/NZS 4600, Eq. 3.3.3.3(9)]

$$M_{y2} = 4627091,321 \quad [Nmm]$$

$$\lambda_{y1} = \sqrt{\frac{M_{y1}}{M_{y2}}} \quad M_{y1} = 4697158,984 \quad [Nmm]$$

[AS/NZS 4600, Eq. 3.3.3.3(8)]

$$\lambda_{y2} = 0,986 \quad []$$

$$\lambda_{y2} \leq 0,674 \quad \lambda_{y2} > 0,674$$

$$M_{y1} = M_{y2} \quad M_{y2} = \frac{M_{y1}}{\lambda_{y2}} \left(1 - \frac{0,22}{\lambda_{y2}} \right)$$

[AS/NZS 4600, Eq. 3.3.3.3(5)] [AS/NZS 4600, Eq. 3.3.3.3(4)]

$$\lambda_{y2} \leq 0,674 \quad \lambda_{y2} > 0,674$$

$$M_{y1} \quad M_{y2}$$

[Nmm] [Nmm] [Nmm] [Nmm]

$$f_t = M_y / Z_y \quad f_t = 275,788 \quad [MPa]$$

[AS/NZS 4600, Eq. 3.3.3.3(2)]

$$M_y = Z_{y1} \quad [AS/NZS 4600, Eq. 3.3.3.3(1)]$$

$$M_{y1} = 3545730,794 \quad [Nmm]$$

$$M_{y2} = 3,546 \quad [kNm]$$

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C-Section Middle Beam

$M_{y1,EDM}$	0,840	[kNm]	Ratio	34,863	[%]
$M_{y2,EDM}$	2,693	[kNm]			

Negative Moment in xx axis [M_{xx2}]

C-Section Conside Beam

$M_{y1,EDM}$	0,840	[kNm]	Ratio	34,863	[%]
$M_{y2,EDM}$	2,693	[kNm]			

C-Section Middle Beam

$M_{y1,EDM}$	0,840	[kNm]	Ratio	34,863	[%]
$M_{y2,EDM}$	2,693	[kNm]			

Positive Moment in yy axis [M_{yy1}]

C-Section Conside Beam

$M_{y1,EDM}$	0,920	[kNm]	Ratio	1,700	[%]
$M_{y2,EDM}$	2,096	[kNm]			

C-Section Middle Beam

$M_{y1,EDM}$	0,910	[kNm]	Ratio	0,980	[%]
$M_{y2,EDM}$	2,096	[kNm]			

Negative Moment in yy axis [M_{yy2}]

C-Section Conside Beam

$M_{y1,EDM}$	0,910	[kNm]	Ratio	1,700	[%]
$M_{y2,EDM}$	1,249	[kNm]			

C-Section Middle Beam

$M_{y1,EDM}$	0,910	[kNm]	Ratio	0,980	[%]
$M_{y2,EDM}$	1,249	[kNm]			

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$C_{Tf} = 0.6 - 0.4 (M_1/M_2)$ $C_{Tf} = 1.000$
[AISI S100, Eq. C3.2.1-1-1]

$F_{cr} = \frac{C_s A_g \sigma_{cr}}{C_{Tf} S_x} \left[1 + C_s \sqrt{1 + \rho_0^2 (\sigma_1/\sigma_{cr})} \right]$
[AISI S100, Eq. C3.2.1-1-1]

$M_{zz}^* \rightarrow C_s = 1.000$
 $M_{zz}^* \rightarrow C_s = -1.000$

A_g	497,235	[mm ²]	r_x	56,347	[mm]
S_x^*	9518,806	[mm ³]	S_y^*	5515,375	[mm ³]
$\rho_{0,flexion}$	1762,839	[N/mm ²]	$\rho_{0,flexion}$	619,213	[N/mm ²]

Front Column

$F_{flexion}$	16291,289	[MPa]	$F_{flexion}$	3955,202	[MPa]
---------------	-----------	-------	---------------	----------	-------

Rear Column

$F_{flexion}$	4958,809	[MPa]	$F_{flexion}$	1349,456	[MPa]
---------------	----------	-------	---------------	----------	-------

M_{zz}^*

F_y	---	[MPa]	F_x	388,471	[MPa]
-------	-----	-------	-------	---------	-------

M_{zz}^*

F_y	---	[MPa]	F_x	388,471	[MPa]
-------	-----	-------	-------	---------	-------

$F_y \geq 2.780 \cdot F_x$

Member segment is not subject to lateral-torsional buckling if bending moments less or equal to M_y . Available flexural strength (no residual stresses) shall be determined with Section C3.2.1-2 (c).

$2.780 \cdot F_y > F_x > 0.560 \cdot F_y$ $0.560 \cdot F_y \geq F_x$

$F_c = \frac{10}{9} F_y \left(1 - \frac{10 F_y}{36 F_x} \right)$ [AISI S100, Eq. C3.2.1-2]

$S_x^* = 9518,806$ [mm³] $S_y^* = 5515,375$ [mm³]

Front Column | $F_{y,z}$

$F_y \geq 2.780 \cdot F_x$	$2.780 \cdot F_y > F_x > 0.560 \cdot F_y$	$0.560 \cdot F_y \geq F_x$
Yes	No	No
C3.2.1 (a)	[MPa]	[MPa]

Rear Column | $F_{y,z}$

$F_y \geq 2.780 \cdot F_x$	$2.780 \cdot F_y > F_x > 0.560 \cdot F_y$	$0.560 \cdot F_y \geq F_x$
Yes	No	No
C3.2.1 (a)	[MPa]	[MPa]

Front Column | M_{zz}

$F_y \geq 2.780 \cdot F_x$	$2.780 \cdot F_y > F_x > 0.560 \cdot F_y$	$0.560 \cdot F_y \geq F_x$
3,698	[kNm]	[kNm]

Front Column | M_{zz}

$F_y \geq 2.780 \cdot F_x$	$2.780 \cdot F_y > F_x > 0.560 \cdot F_y$	$0.560 \cdot F_y \geq F_x$
2,143	[kNm]	[kNm]

Rear Column | M_{zz}

$F_y \geq 2.780 \cdot F_x$	$2.780 \cdot F_y > F_x > 0.560 \cdot F_y$	$0.560 \cdot F_y \geq F_x$
3,698	[kNm]	[kNm]

Rear Column | M_{zz}

$F_y \geq 2.780 \cdot F_x$	$2.780 \cdot F_y > F_x > 0.560 \cdot F_y$	$0.560 \cdot F_y \geq F_x$
2,143	[kNm]	[kNm]

Front Column | M_{zz}

M_{zz}^*	3,698	[kNm]	M_{zz}^*	2,143	[kNm]
------------	-------	-------	------------	-------	-------

Rear Column | M_{zz}

M_{zz}^*	3,698	[kNm]	M_{zz}^*	2,143	[kNm]
------------	-------	-------	------------	-------	-------

[3] C-Section Beam - Distortional Buckling Strength Residuals [AISI S100, C3.1.4]

$\rho_0 = 1,670$

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For C- and Z-Sections or any Open Section with a Stiffener Compression Flange Extending to Sides of the Web where the Stiffener is either a Single Lip or a Complex Edge Stiffener

Dimensional Limits

[1]	$65 \leq h_o / t$	OK
[1]	$h_o / t \leq 200$	OK
[2]	$25 \leq h_o / t$	OK
[2]	$h_o / t \leq 100$	OK
[3]	$6.25 \leq D / t$	OK
[3]	$D / t \leq 50$	OK
[4]	$45^\circ \leq \theta$	OK
[4]	$6 \leq 90^\circ$	OK
[5]	$2 \leq h_o / h_w$	OK
[5]	$h_o / h_w \leq 8$	OK
[6]	$0.04 \leq D_o^* / (h_o / t) \leq 0.1$	OK
[6]	$D_o^* / (h_o / t) \leq 0.60$	OK

$I_{x,eff} = \left(\frac{4\pi^2 h_o (1-\mu^2)}{t^3} \left(I_{x,eff}(x_o - h_x)^2 + EC_{w,eff} - \frac{I_{y,eff}^2}{I_{y,eff}} (x_o - h_x)^2 \right) + \frac{\pi^4 h_o^4}{720} \right)^{1/4}$
[AISI S100, Eq. C3.1.4-1]

NOTE Flanges with 90 Degree Lips

A_g	121,227	[mm ²]
L_x	1652,668	[mm]
L_y	1791,120	[mm]
$I_{x,eff}$	2819,497	[mm ⁴]
$I_{y,eff}$	43,107	[mm ⁴]
k	243,953	[mm ³]
$C_{w,eff}$	0,000	[mm ⁶]
ρ_0	0,800	[]
β	1,000	[]
$L = L_x$	235,632	[mm]

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$E = 210,000$ [GPa] $G = 80,769$ [GPa]

$k_{d,eff} = \left(\frac{\pi}{L} \right)^4 \left(EI_{x,eff}(x_o - h_x)^2 + EC_{w,eff} - E \frac{I_{y,eff}^2}{I_{y,eff}} (x_o - h_x)^2 \right) + \left(\frac{\pi}{L} \right)^2 GJ_{eff}$
[AISI S100, Eq. C3.1.4-3]

$k_{\theta,we} = \frac{Et^3}{12(1-\mu^2)} \left(\frac{3}{h_o} + \left(\frac{\pi}{L} \right)^2 \frac{19 h_o}{60} + \left(\frac{\pi}{L} \right)^4 \frac{h_o^3}{240} \right)$
[AISI S100, Eq. C3.1.4-4]

$k_{d,eff} = \frac{\pi^2}{L^2} \left[A_g (x_o - h_x)^2 \left(\frac{I_{y,eff}}{I_{y,eff}} \right)^2 - 2y_o (x_o - h_x) \left(\frac{I_{y,eff}}{I_{y,eff}} \right) + h_x^2 + y_o^2 \right] + I_{x,eff} + I_{y,eff}$
[AISI S100, Eq. C3.1.4-5]

$k_{\theta,we} = \frac{h_o^{12}}{13440} \left(\frac{145560(1-\mu_{web}) + 62160}{h_o^2} + 448t^2 + \frac{h_o^2}{L^2} [53 + 3(1-\mu_{web})] \pi^4 \right)$
[AISI S100, Eq. C3.1.4-6]

$k_{d,eff}$	0,800	[N]	$k_{\theta,we}$	2,000	[]
$\tilde{k}_{d,eff}$	16,212	[mm ²]	$\tilde{k}_{\theta,we}$	0,897	[mm ²]
$F_{d,eff} = \beta \frac{k_{d,eff} + k_{\theta,we} + k_{\theta,we}}{k_{d,eff} + k_{\theta,we}}$	F_d	1393,322	[MPa]		
$M_y = S_y \cdot F_d$	$M_x = S_x \cdot F_d$				
[AISI S100, Eq. C3.1.4-4]	[AISI S100, Eq. C3.1.4-5]				
S_x	13921,309	[mm ³]	M_y	18839541,235	[Nmm]
S_y	13921,309	[mm ³]	M_x	4732458,074	[Nmm]
$\lambda_{d,eff} = \sqrt{M_y / M_{y,lim}}$	λ	0,501			
[AISI S100, Eq. C3.1.4-3]					

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Front Column | $F_{y,z}$

$F_y \geq 2.780 \cdot F_x$	$2.780 \cdot F_y > F_x > 0.560 \cdot F_y$	$0.560 \cdot F_y \geq F_x$
Yes	No	No
C3.2.1 (a)	[MPa]	[MPa]

Rear Column | $F_{y,z}$

$F_y \geq 2.780 \cdot F_x$	$2.780 \cdot F_y > F_x > 0.560 \cdot F_y$	$0.560 \cdot F_y \geq F_x$
Yes	No	No
C3.2.1 (a)	[MPa]	[MPa]

Front Column | M_{zz}

$F_y \geq 2.780 \cdot F_x$	$2.780 \cdot F_y > F_x > 0.560 \cdot F_y$	$0.560 \cdot F_y \geq F_x$
3,698	[kNm]	[kNm]

Front Column | M_{zz}

$F_y \geq 2.780 \cdot F_x$	$2.780 \cdot F_y > F_x > 0.560 \cdot F_y$	$0.560 \cdot F_y \geq F_x$
2,143	[kNm]	[kNm]

Rear Column | M_{zz}

$F_y \geq 2.780 \cdot F_x$	$2.780 \cdot F_y > F_x > 0.560 \cdot F_y$	$0.560 \cdot F_y \geq F_x$
3,698	[kNm]	[kNm]

Rear Column | M_{zz}

$F_y \geq 2.780 \cdot F_x$	$2.780 \cdot F_y > F_x > 0.560 \cdot F_y$	$0.560 \cdot F_y \geq F_x$
2,143	[kNm]	[kNm]

Front Column | M_{zz}

M_{zz}^*	3,698	[kNm]	M_{zz}^*	2,143	[kNm]
------------	-------	-------	------------	-------	-------

Rear Column | M_{zz}

M_{zz}^*	3,698	[kNm]	M_{zz}^*	2,143	[kNm]
------------	-------	-------	------------	-------	-------

[3] C-Section Beam - Distortional Buckling Strength Residuals [AISI S100, C3.1.4]

$\rho_0 = 1,670$

$\lambda_y = 0.873$ $\lambda_z = 0.873$

$$M_n = M_y = \left(1 - 0.22 \frac{M_{crd}}{M_y} \right)^{0.5} \frac{M_{crd}}{M_y} M_y$$

[AISI S100, Eq. C3.3.4-1] [AISI S100, Eq. C3.3.4-2]

$M_y = 4732.468,074$ [kNm] $M_z = 4.732$ [kNm]

[4] C-Section Column: Bending Moment Verification [AISI S100, ASD]

$M \leq M_n \cdot C_b$ [AISI S100, Eq. A4.3.1-1] $M_n = \min \{ M_{n1}, M_{n2}, M_{n3} \}$

Positive Moment in x-x axis [M_{x1}]

C-Section Front Column

$M_{d1(x-x)}$	0,270	[kNm]	Ratio	9,228	[%]
$M_{n1(x-x)}$	4,732	[kNm]			

C-Section Rear Column

$M_{d1(x-x)}$	0,300	[kNm]	Ratio	12,701	[%]
$M_{n1(x-x)}$	4,602	[kNm]			

Negative Moment in x-x axis [M_{x2}]

C-Section Front Column

$M_{d2(x-x)}$	0,270	[kNm]	Ratio	9,228	[%]
$M_{n2(x-x)}$	4,732	[kNm]			

C-Section Rear Column

$M_{d2(x-x)}$	0,300	[kNm]	Ratio	12,701	[%]
$M_{n2(x-x)}$	4,602	[kNm]			

Positive Moment in y-y axis [M_{y1}]

C-Section Front Column

$M_{d1(y-y)}$	0,300	[kNm]	Ratio	0,300	[%]
$M_{n1(y-y)}$	3,698	[kNm]			

$I_{xx}(mm^2) = 92009,020$

$S_{xx}(mm^3) = 13521,309$ $S_{yy}(mm^3) = 14278,205$

Section is fully effective

$F_y = ---$ [MPa] $F_u = 388,471$ [MPa]

$M_{x1}(kNm) = 525292,019$ $M_{x2}(kNm) = 554989,722$

$M_{y1}(kNm) = 5,253$ $M_{y2}(kNm) = 5,547$

Negative Moment in x-x axis [M_{x2}]

$I_{xx}(mm^2) = 92009,020$

$S_{xx}(mm^3) = 14278,205$ $S_{yy}(mm^3) = 13521,309$

$I_{yy}(mm^2) = 62503,020$

$S_{xx}(mm^3) = 14278,205$ $S_{yy}(mm^3) = 13521,309$

Section is fully effective

$F_y = ---$ [MPa] $F_u = 388,471$ [MPa]

$M_{x1}(kNm) = 554989,722$ $M_{x2}(kNm) = 525292,019$

$M_{y1}(kNm) = 5,547$ $M_{y2}(kNm) = 5,253$

Positive Moment in y-y axis [M_{y1}]

$I_{yy}(mm^2) = 153819,866$

$S_{xx}(mm^3) = 9519,375$ $S_{yy}(mm^3) = 5519,375$

$I_{xx}(mm^2) = 153819,866$

$S_{xx}(mm^3) = 9519,375$ $S_{yy}(mm^3) = 5519,375$

C-Section Rear Column

$M_{d1(y-y)}$	0,300	[kNm]	Ratio	0,300	[%]
$M_{n1(y-y)}$	2,143	[kNm]			

Negative Moment in y-y axis [M_{y2}]

C-Section Front Column

$M_{d2(y-y)}$	0,300	[kNm]	Ratio	0,300	[%]
$M_{n2(y-y)}$	2,143	[kNm]			

C-Section Rear Column

$M_{d1(y-y)}$	0,300	[kNm]	Ratio	0,300	[%]
$M_{n1(y-y)}$	2,143	[kNm]			

[0] C-Section Column: Bending Moment [AISI S100, LRFD]

[1] C-Section Column: Nominal Section Strength [Resistance] [AISI S100, C3.3.2]

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:

- Member is not subject to twisting, lateral, torsional, or flexural-torsional buckling
- Effect of cold work of forming is not included in determining the yield stress F_y
- Ratio of the depth of the compressed portion of the web to the thickness does not exceed 4.
- Shear force does not exceed:
 - $0.39F_y A_s$ [times web area] (h_s - Stiffened elements | w_s - Unstiffened elements)
 - $0.60F_y L$ [LRFD] [times web area] (h_s - Stiffened elements | w_s - Unstiffened elements)
- The angle between any web and the vertical does not exceed 30

Sections with 4 flared or partially flared compression flanges $\Phi_c = 0,950$

Procedure: I $M_n = \Phi_c F_y$ [AISI S100, Eq. C3.3.2-1]

Positive Moment in x-x axis [M_{x1}]

$I_{xx}(mm^2) = 625036,020$ [mm²]

$S_{xx}(mm^3) = 13521,309$ $S_{yy}(mm^3) = 14278,205$ [mm³]

Section is fully effective

$F_y = ---$ [MPa] $F_u = 388,471$ [MPa]

$M_{x1}(kNm) = 369776,967$ $M_{x2}(kNm) = 2142561,631$

$M_{y1}(kNm) = 3,698$ $M_{y2}(kNm) = 2,143$

Negative Moment in y-y axis [M_{y2}]

$I_{yy}(mm^2) = 153819,866$

$S_{xx}(mm^3) = 5519,375$ $S_{yy}(mm^3) = 9519,306$

$I_{xx}(mm^2) = 153819,866$

$S_{xx}(mm^3) = 5519,375$ $S_{yy}(mm^3) = 9519,306$

Section is fully effective

$F_y = ---$ [MPa] $F_u = 388,471$ [MPa]

$M_{x1}(kNm) = 2142561,631$ $M_{x2}(kNm) = 369776,967$

$M_{y1}(kNm) = 2,143$ $M_{y2}(kNm) = 3,698$

[2] C-Section Column: Lateral-Torsional Buckling Strength [Resistance] [AISI S100, C3.3.2]

$\Phi_b = 0,900$ $M_n = \Phi_b F_c$ [AISI S100, Eq. C3.3.2-1]

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

$C_b = 1,000$ $r_y = 35,455$ [mm]

$r_y = 17,588$ [mm]

$r_x = 40,108$ [mm]

$r_x = 58,347$ [mm]

$I_{yy} = \sqrt{\frac{I_x^2 + I_z^2}{2}}$

[AISI S100, Eq. C3.3.2-7]

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$S_x = 14278,705 \text{ [mm}^2\text{]} \quad E = 210,000 \text{ [GPa]}$

$$\sigma_{cr} = \frac{\pi^2 E}{(K_y L_y / r_y)^2} \quad \sigma_{cr,flexion} = 327,319 \text{ [N/mm}^2\text{]} \quad \sigma_{cr,compres} = 169,221 \text{ [N/mm}^2\text{]}$$

[AISI S100, Eq.C3.J.2.1-8]

$$\sigma_c = \frac{1}{A_g} \left[C_f + \frac{\pi^2 E C_{cr}}{(K_x L_x / r_x)^2} \right] \quad \sigma_{cr,flexion} = 1752,939 \text{ [N/mm}^2\text{]} \quad \sigma_{cr,compres} = 619,213 \text{ [N/mm}^2\text{]}$$

[AISI S100, Eq.C3.J.2.1-9]

$$F_c = \frac{C_b F_y A}{S_x} \sqrt{\sigma_{cr} \sigma_c} \quad F_{cr,flexion} = 1485,836 \text{ [MPa]} \quad F_{cr,compres} = 510,284 \text{ [MPa]}$$

[AISI S100, Eq.C3.J.2.1-4]

$F_y = \dots \text{ [MPa]} \quad F_u = 389,471 \text{ [MPa]}$

$F_c \geq 2,780 \cdot F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_p . Available flexural strength (moment resistance) shall be determined with Section C3.J.2(a)

$$2,780 \cdot F_y > F_c > 0,560 \cdot F_y \quad 0,560 \cdot F_y \geq F_c$$

$$F_c = F_u$$

$$F_c = \frac{10}{9} F_y \left(1 - \frac{10 F_y}{36 F_c} \right) \quad \text{[AISI S100, Eq.C3.J.2.1-9]}$$

[AISI S100, Eq.C3.J.2.1-2] $S_x = 13521,309 \text{ [mm}^2\text{]}$

Front Column Beam [F_y]

$F_c \geq 2,780 \cdot F_y$	Yes	No	No
Yes	No	No	No
$C_b J(\phi)$ [MPa]	---	---	---

Rear Column [F_y]

$F_c \geq 2,780 \cdot F_y$	No	Yes	No
---	---	---	---
$C_b J(\phi)$ [MPa]	---	---	---

Front Column [M_{cr,flex}]

$F_c \geq 2,780 \cdot F_y$	2,780 · F _y > F _c > 0,560 · F _y	0,560 · F _y ≥ F _c
5,253 [kNm]	---	---

Rear Column [M_{cr,comp}]

$F_c \geq 2,780 \cdot F_y$	2,780 · F _y > F _c > 0,560 · F _y	0,560 · F _y ≥ F _c
---	4,952 [kNm]	---

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$F_c \geq 2,780 \cdot F_y$

Member segment is not subject to lateral-torsional buckling at bending moments less or equal to M_p . Available flexural strength (moment resistance) shall be determined with Section C3.J(a)

$$2,780 \cdot F_y > F_c > 0,560 \cdot F_y \quad 0,560 \cdot F_y \geq F_c$$

$$F_c = F_u$$

$$F_c = \frac{10}{9} F_y \left(1 - \frac{10 F_y}{36 F_c} \right) \quad \text{[AISI S100, Eq.C3.J.2.1-9]}$$

[AISI S100, Eq.C3.J.2.1-2] $S_x = 9518,806 \text{ [mm}^2\text{]} \quad S_y = 5515,375 \text{ [mm}^2\text{]}$

Front Column [F_y]

$F_c \geq 2,780 \cdot F_y$	Yes	No	No
Yes	No	No	No
$C_b J(\phi)$ [MPa]	---	---	---

Rear Column [F_y]

$F_c \geq 2,780 \cdot F_y$	Yes	No	No
Yes	No	No	No
$C_b J(\phi)$ [MPa]	---	---	---

Front Column [M_{cr,flex}]

$F_c \geq 2,780 \cdot F_y$	2,780 · F _y > F _c > 0,560 · F _y	0,560 · F _y ≥ F _c
3,998 [kNm]	---	---

Rear Column [M_{cr,comp}]

$F_c \geq 2,780 \cdot F_y$	2,780 · F _y > F _c > 0,560 · F _y	0,560 · F _y ≥ F _c
2,143 [kNm]	---	---

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$M_{cr,flex} = 5,253 \text{ [kNm]} \quad M_{cr,comp} = 4,952 \text{ [kNm]}$

Singlysymmetric sections bending about the axis perpendicular to the axis of symmetry [y-y]

C₁

$C_1 = +1,000$ → Moment causing compression on outer center side of channel
 $C_1 = -1,000$ → Moment causing tension on outer center side of channel

$$\sigma_{cr} = \frac{\pi^2 E}{(K_x L_x / r_x)^2} \quad \sigma_{cr,flexion} = 2427,488 \text{ [N/mm}^2\text{]} \quad \sigma_{cr,compres} = 722,270 \text{ [N/mm}^2\text{]}$$

[AISI S100, Eq.C3.J.2.1-1]

$$i = \frac{1}{2I_x} \int_A x^2 dA + \frac{1}{A} x_c^2 dA \quad i = 55,317 \text{ [mm]}$$

[AISI S100, Eq.C3.J.2.1-1]

$$C_{TF} = 0,6 - 0,4 (M_1/M_2) \quad C_{TF} = 1,000$$

[AISI S100, Eq.C3.J.2.1-1]

$$F_{cr} = \frac{C_b A \sigma_{cr}}{C_{TF} S_x} \left[1 + C_s \sqrt{1 + r_{cr}^2 (\sigma_1 / \sigma_{cr})} \right]$$

[AISI S100, Eq.C3.J.2.1-10]

$M_{cr,flex} = \dots \quad C_1 = 1,000$
 $M_{cr,comp} = \dots \quad C_1 = -1,000$

$A_g = 497,235 \text{ [mm}^2\text{]} \quad r_x = 56,347 \text{ [mm]}$
 $S_x = 9518,806 \text{ [mm}^2\text{]} \quad S_y = 5515,375 \text{ [mm}^2\text{]}$
 $\sigma_{cr,flexion} = 1752,939 \text{ [N/mm}^2\text{]} \quad \sigma_{cr,compres} = 619,213 \text{ [N/mm}^2\text{]}$

Front Column

$F_{cr,flexion}$ [MPa]	15291,289	$F_{cr,compres}$ [MPa]	9975,292
------------------------	-----------	------------------------	----------

Rear Column

$F_{cr,flexion}$ [MPa]	4958,809	$F_{cr,compres}$ [MPa]	1349,456
------------------------	----------	------------------------	----------

$M_{cr,flex} = \dots$

F_y [MPa]	---	F_u [MPa]	389,471
-------------	-----	-------------	---------

$M_{cr,comp} = \dots$

F_y [MPa]	---	F_u [MPa]	389,471
-------------	-----	-------------	---------

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Rear Column [M_{cr,flex}]

$F_c \geq 2,780 \cdot F_y$	2,780 · F _y > F _c > 0,560 · F _y	0,560 · F _y ≥ F _c
2,143 [kNm]	---	---

Front Column [M_{cr,flex}]

$M_{cr,flex}$	3,998 [kNm]	$M_{cr,comp}$	2,143 [kNm]
---------------	-------------	---------------	-------------

Rear Column Beam [M_{cr,flex}]

$M_{cr,flex}$	3,998 [kNm]	$M_{cr,comp}$	2,143 [kNm]
---------------	-------------	---------------	-------------

[3] C-Section Column: Diagonal Buckling Strength [Resistance] [AISI S100, C3.J.1]

$\Phi_c = 0,900$

For C- and Z-Sections or any Open Section with a Slit Web of Compression Flange Extending to Side of the Web where the Slit Web is either a Single Lip or a Complex Edge Stiffener

[AISI S100, Figure B2-2] [AISI S100, Figure B4-1]

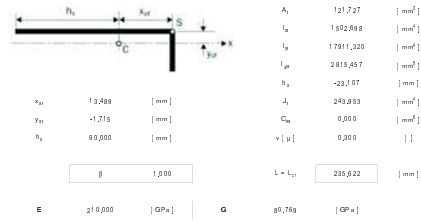
Dimensional Limits

[1]	$s_0 \leq h_1$	OK
	$b_2 \leq 200$	OK
	$2s \leq h_1$	OK
[2]	$b_2 \leq 100$	OK
	$6,25 < D$	OK
	$D \leq 50$	OK
[4]	$45 \leq s$	OK
	$s \leq 89$	OK
	$2 \leq h_1 / b_2$	OK
[5]	$h_2 / b_2 \leq 8$	OK
	$0,04 < D^* \leq 0,1$	OK
[6]	$D^* \leq 0,1$	OK

$$I_{xy} = \left(\frac{4\pi^4 h_o^4 (1-\mu^2)}{L^3} \left(I_{xt}(s_o - h_x)^2 + C_{xyt} - \frac{I_{xyt}^2}{I_{yt}} (s_o - h_x)^2 \right) + \frac{\pi^4 h_o^4}{720} \right)^{1/4}$$

[AISI S100, Eq.C3.J.12]

NOTE: Ranges with 90 Degree Lips



$$k_{eff} = \left(\frac{\pi}{L} \right)^4 \left(EI_{xt}(s_o - h_x)^2 + EC_{xyt} - E \frac{I_{xyt}^2}{I_{yt}} (s_o - h_x)^2 \right) + \left(\frac{\pi}{L} \right)^2 GJ_f$$

[AISI S100, Eq.C3.J.13]

$$k_{dive} = \frac{Et^3}{12(1-\mu^2)} \left(\frac{3}{h_o} + \left(\frac{\pi}{L} \right)^2 \frac{19 h_o}{60} + \left(\frac{\pi}{L} \right)^4 \frac{h_o^3}{240} \right)$$

[AISI S100, Eq.C3.J.14]

$k_{ax} = 12925,732$ [N] $k_{ay} = 10913,706$ [N]

$$\tilde{k}_{eff} = \left(\frac{\pi}{L} \right)^2 \left[A_x \left((s_o - h_x)^2 \frac{I_{xyt}^2}{I_{yt}^2} - 2y_o(s_o - h_x) \frac{I_{xyt}}{I_{yt}} \right) + h_x^2 + y_o^2 + I_{xt} + I_{yt} \right]$$

[AISI S100, Eq.C3.J.15]

$$\tilde{k}_{dive} = \frac{h_o \pi^2}{13440} \left(\frac{45360(1-\mu^2) - 62160 \left(\frac{L}{h_o} \right)^2 + 448t^2 \left(\frac{h_o}{L} \right)^2 [53 - 3(1-\mu^2) \left(\frac{L}{h_o} \right)^2] \right) + 420 \left(\frac{L}{h_o} \right)^4$$

[AISI S100, Eq.C3.J.16]

Negative Moment in xz axis | M_{xzz} |

C-Section Front Column

$M_{d,Ed}^{(1)}$	0,270	[kNm]		
$M_{d,Ed}^{(2)}$	4,732	[kNm]	Ratio	9,339 [%]

C-Section Rear Column

$M_{d,Ed}^{(1)}$	0,350	[kNm]		
$M_{d,Ed}^{(2)}$	4,892	[kNm]	Ratio	8,450 [%]

Positive Moment in yz axis | M_{yzz} |

C-Section Front Column

$M_{d,Ed}^{(1)}$	0,000	[kNm]		
$M_{d,Ed}^{(2)}$	3,998	[kNm]	Ratio	0,000 [%]

C-Section Rear Column

$M_{d,Ed}^{(1)}$	0,000	[kNm]		
$M_{d,Ed}^{(2)}$	2,143	[kNm]	Ratio	0,000 [%]

Negative Moment in yx axis | M_{yxx} |

C-Section Front Column

$M_{d,Ed}^{(1)}$	2,143	[kNm]		
$M_{d,Ed}^{(2)}$	2,143	[kNm]	Ratio	0,000 [%]

C-Section Rear Column

$M_{d,Ed}^{(1)}$	0,950	[kNm]		
$M_{d,Ed}^{(2)}$	2,143	[kNm]	Ratio	0,000 [%]

[0] 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

$k_x = 0,000$ [N] $k_{ax} = 2,000$ []

$\tilde{k}_{MG} = 16,212$ [mm²] $\tilde{k}_{dive} = 0,897$ [mm²]

$$F_{Ed} = \beta \frac{k_{dive} + k_{dive} + k_{dive}}{k_{MG} + k_{dive}} F_r = 1393,322$$

[AISI S100, Eq.C3.J.16]

$$M_x = \phi_y \cdot F_r$$

[AISI S100, Eq.C3.J.14]

$$M_y = \phi_x \cdot F_r$$

[AISI S100, Eq.C3.J.14]

$S_x = 13521,309$ [mm³] $M_x = 18838541,235$ [Nmm]

$S_y = 13521,309$ [mm³] $M_y = 4732458,074$ [Nmm]

$$\lambda_{Ed} = \sqrt{M_y / M_{crd}} = 0,61$$

[AISI S100, Eq.C3.J.14]

$$M_{Ed} = M_x \cdot \left(1 - 0,22 \left(\frac{M_{crd}}{M_y} \right)^{0,5} \right) \left(\frac{M_{crd}}{M_y} \right)^{0,5} M_y$$

[AISI S100, Eq.C3.J.14]

$M_x = 4732458,074$ [Nmm] $M_y = 4,732$ [kNm]

[4] C-Section Column - Bending Moment Verification | AISI S100, LRFD |

$$M \leq \phi_b \cdot M_n$$

[AISI S100, Eq.A5.J.1-1]

$$M_n = \min \{ M_{n1}, M_{n2}, M_{n3} \}$$

Positive Moment in xz axis | M_{xzz} |

C-Section Front Column

$M_{d,Ed}^{(1)}$	0,270	0,270	Ratio	9,339 [%]
$M_{d,Ed}^{(2)}$	4,732	[kNm]		

C-Section Rear Column

$M_{d,Ed}^{(1)}$	0,350	[kNm]		
$M_{d,Ed}^{(2)}$	4,892	[kNm]	Ratio	8,450 [%]

Procedure II - Based on Inelastic Reserve Capacity

- The inelastic reserve capacity shall be permitted to be used when:
- [1] Member is not subject to twisting, lateral, torsional, or flexure-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 the thickness does not exceed λ_c
 - [4] Shear force does not exceed $0,39F_y$ 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	0,850

$$M_n = Z_x \cdot f_y$$

[AS/NZS 4600, Eq.3.3.2.2]

Positive Moment in xz axis | M_{xzz} |

$I_{x,Ed} = 625039,020$ [mm⁴]

$Z_{x,Ed} = 13521,309$ [mm³] $Z_{x,Flx} = 14278,705$ [mm³]

$I_{y,Ed} = 625039,020$ [mm⁴]

$Z_{y,Ed} = 13521,309$ [mm³] $Z_{y,Flx} = 14278,705$ [mm³]

$Z_{x,Ed} = 13521,309$ [mm³] $Z_{x,Flx} = 14278,705$ [mm³]

$f_y = \dots$ [MPa]

$f_w = 388,471$ [MPa]

$M_{d,Ed}^{(1)} = 5252632,010$ [Nmm] $M_{d,Ed}^{(2)} = 5546559,722$ [Nmm]

$M_{d,Ed}^{(1)} = 5,253$ [kNm] $M_{d,Ed}^{(2)} = 5,547$ [kNm]

Negative Moment in xz axis | M_{xzz} |

$I_{x,Ed} = 625039,020$ [mm⁴]

$Z_{x,Ed} = 14278,705$ [mm³] $Z_{x,Flx} = 13521,309$ [mm³]

$I_{y,Ed} = 625039,020$ [mm⁴]

$Z_{y,Ed} = 14278,705$ [mm³] $Z_{y,Flx} = 13521,309$ [mm³]

$Z_{c,comp}$ Section is fully effective $Z_{c,tension}$			
f_y	--- [MPa]		
f_u	388,471 [MPa]		
$M_{y,design}$	5548,868 [22] [kNm]	$M_{x,design}$	252683,2913 [kNm]
$M_{y,design}$	5,547 [kNm]	$M_{x,design}$	5,259 [kNm]
Positive Moment in y-y axis | $M_{y,22}$ |			
I_{yy}	153816,866 [mm ⁴]		
$Z_{c,comp}$	9518,806 [mm ³]	$Z_{c,tension}$	9518,375 [mm ³]
I_{xx}	153816,866 [mm ⁴]		
$Z_{c,comp}$	9518,806 [mm ³]	$Z_{c,tension}$	9518,375 [mm ³]
$Z_{c,comp}$ Section is fully effective $Z_{c,tension}$			
f_y	--- [MPa]		
f_u	388,471 [MPa]		
$M_{y,design}$	3597776,867 [Nmm]	$M_{x,design}$	2142561,831 [Nmm]
$M_{y,design}$	3,698 [kNm]	$M_{x,design}$	2,143 [kNm]
Negative Moment in y-y axis | $M_{y,22}$ |			
I_{yy}	153816,866 [mm ⁴]		
$Z_{c,comp}$	9518,375 [mm ³]	$Z_{c,tension}$	9518,806 [mm ³]
I_{xx}	153816,866 [mm ⁴]		
$Z_{c,comp}$	9518,375 [mm ³]	$Z_{c,tension}$	9518,806 [mm ³]
$Z_{c,comp}$ Section is fully effective $Z_{c,tension}$			
f_y	--- [MPa]		
f_u	388,471 [MPa]		
Next Page			

$\lambda_b = \sqrt{\frac{M_y}{M_{cr}}}$		$\lambda_{b,compression}$	0,889	| |
[AS/NZS 4600, Eq. 3.3.2(7)]		$\lambda_{b,tension}$	0,228	| |
$\lambda_b \leq 0,600$		$M_y = M_x$ [AS/NZS 4600, Eq. 3.3.2(5)]		
$0,600 < \lambda_b < 1,336$		$M_y = 1,11 M_x \left[1 - \left(\frac{10 \lambda_b^2}{36} \right) \right]$ [AS/NZS 4600, Eq. 3.3.2(4)]		
$\lambda_b \geq 1,336$		$M_y = M_x \left(\frac{1}{\lambda_b^2} \right)$ [AS/NZS 4600, Eq. 3.3.2(5)]		
Front Column | $M_{y,22}$ |				
$\lambda_b \leq 0,600$	$0,600 < \lambda_b < 1,336$	$\lambda_b \geq 1,336$		
M_y	M_x	M_z		
4997546,647 [Nmm]	---	---		
Rear Column | $M_{y,22}$ |				
$\lambda_b \leq 0,600$	$0,600 < \lambda_b < 1,336$	$\lambda_b \geq 1,336$		
M_y	M_x	M_z		
---	[Nmm]	5441589,956 [Nmm]	---	
$f_c = M_y / Z_c$		$f_{c,compression}$	350,000 [MPa]	
[AS/NZS 4600, Eq. 3.3.2(2)]		$f_{c,tension}$	381,088 [MPa]	
Z_c		13521,309 [mm ³]	$M_y = Z_c \cdot f_c$ [AS/NZS 4600, Eq. 3.3.2(1)]	
Front Column | $M_{z,22}$ |				
$\lambda_b \leq 0,600$	$0,600 < \lambda_b < 1,336$	$\lambda_b \geq 1,336$		
M_y	M_x	M_z		
4732458,014 [Nmm]	---	---		
Rear Column | $M_{z,22}$ |				
$\lambda_b \leq 0,600$	$0,600 < \lambda_b < 1,336$	$\lambda_b \geq 1,336$		
M_y	M_x	M_z		
---	[Nmm]	5152948,812 [Nmm]	---	
$M_{y,design}$		4,732 [kNm]	$M_{z,design}$	
			5,153 [kNm]	

Previous Page			
$M_{y,design}$	2142561,831 [Nmm]	$M_{x,design}$	3597776,867 [Nmm]
$M_{y,design}$	2,143 [kNm]	$M_{x,design}$	3,698 [kNm]
[2] C-Section Column - Members subject to Lateral Buckling [AS/NZS 4600, 3.3.2.1]			
Table 1.9: Capacity Reduction Factor [AS/NZS 4600:2005]			
Design Capacity		Clause Reference	Capacity Reduction Factor | ϕ_c |
Member moment capacity - Members subject to lateral buckling		3.3.2	0,900
$M_y = \phi_c C_y$ [AS/NZS 4600, Eq. 3.3.2(1)]			
Singly, doubly and partially symmetric sections bending about the y-axis | ϕ_c |			
C_y shall be permitted to be conservatively taken as unity for all cases.			
For cantilevers or overhangs where the free end is unbraced, C_y shall be taken as unity.			
C_y	1,000	r_y	35,455 [mm]
		r_z	17,588 [mm]
		x_y	48,108 [mm]
		y_y	0,905 [mm]
		r_{yy}	56,347 [mm]
Z_c	14278,705 [mm ³]	E	210,000 [GPa]
$f_{cr} = \frac{\pi^2 E}{(L_{eff}/r_y)^2}$		$f_{cr,compression}$	927,119 [N/mm ²]
		$f_{cr,tension}$	109,221 [N/mm ²]
[AS/NZS 4600, Eq. 3.3.2(10)]			
$f_{cr} = \frac{GJ}{I_{yy}} \left(1 + \frac{\pi^2 E I_{yy}}{GJ L_{eff}^2} \right)$		$f_{cr,compression}$	1752,839 [N/mm ²]
		$f_{cr,tension}$	619,213 [N/mm ²]
[AS/NZS 4600, Eq. 3.3.2(12)]			
$M_{cr} = C_y \phi_c A_{eff} \sqrt{f_{cr} I_{yy}}$		$M_{y,tension}$	21215807,694 [MPa]
		$M_{y,compression}$	7295343,872 [MPa]
[AS/NZS 4600, Eq. 3.3.2(8)]			
$M_y = Z_c \cdot f_c$	[AS/NZS 4600, Eq. 3.3.2(7)]	M_x	4997546,647 [Nmm]

Singly-symmetric sections bent (top about) the axis perpendicular to the axis of symmetry | y-y |			
C_y			
$C_y = 1$ | 1,000 → Moment causing compression on shear center side of centroid			
$C_y = -1$ | -1,000 → Moment causing tension on shear center side of centroid			
$f_{cr} = \frac{\pi^2 E}{(L_{eff}/r_y)^2}$		$f_{cr,compression}$	2427,598 [N/mm ²]
		$f_{cr,tension}$	722,710 [N/mm ²]
[AS/NZS 4600, Eq. 3.3.2(10)]			
$R_y = \frac{I_z}{I_y} \left(\frac{y^2}{r_y^2} + \frac{z^2}{r_z^2} \right) - 2x_y$		β_y	55,317 [mm]
[AS/NZS 4600, Eq. 3.3.2(16)]			
$C_{TR} = 0,6 - 0,4 (M_y / M_x)$		C_y	1,000
[AS/NZS 4600, Eq. 3.3.2(15)]			
$M_{cr} = \frac{C_y A_{eff} \left(\beta_y / 2 + C_y \sqrt{\beta_y / 2} + r_{yy}^2 (f_{cr} / f_{cr}) \right)}{C_{TR}}$			
[AS/NZS 4600, Eq. 3.3.2(13)]			
$M_{y,tension}$	---	C_y	1,000
$M_{y,compression}$	---	C_y	-1,000
A	497,235 [mm ²]	r_y	56,347 [mm]
Z_c	9518,806 [mm ³]	Z_y	5518,375 [mm ³]
$f_{y,tension}$	1752,839 [N/mm ²]	$f_{y,compression}$	619,213 [N/mm ²]
Front Column			
$M_{y,tension}$	100726019,900 [Nmm]	$M_{y,compression}$	33398887,705 [Nmm]
Rear Column			
$M_{y,tension}$	31164908,332 [Nmm]	$M_{y,compression}$	11275971,224 [Nmm]
M_x	3331582,037 [Nmm]	M_z	1930381,138 [Nmm]
f_y	350,000 [MPa]	f_z	350,000 [MPa]
$\lambda_b = \sqrt{\frac{M_y}{M_{cr}}}$		$\lambda_{b,compression}$	0,82
		$\lambda_{b,tension}$	0,241
		$\lambda_{b,compression}$	0,327
		$\lambda_{b,tension}$	0,614

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$A_b \leq 0.600$ $M_x = M_y$
[AS/NZS 4600, Eq. 3.3.3.2(3)]

$0.600 < A_b < 1.336$ $M_c = 1.11 M_y \left[1 - \left(\frac{10 \lambda_b^2}{36} \right) \right]$
[AS/NZS 4600, Eq. 3.3.3.2(4)]

$A_b \geq 1.336$ $M_c = M_y \left(\frac{1}{\lambda_b^2} \right)$
[AS/NZS 4600, Eq. 3.3.3.2(5)]

Front Column [M_x]

$A_b \leq 0.600$	$0.600 < A_b < 1.336$	$A_b \geq 1.336$
M_x^*	M_x^*	M_x^*
3331582,037 [Nmm]	---	---

Front Column [M_y]

$A_b \leq 0.600$	$0.600 < A_b < 1.336$	$A_b \geq 1.336$
M_y^*	M_y^*	M_y^*
1930381,390 [Nmm]	---	---

Rear Column [M_x]

$A_b \leq 0.600$	$0.600 < A_b < 1.336$	$A_b \geq 1.336$
M_x^*	M_x^*	M_x^*
3331582,037 [Nmm]	---	---

Rear Column [M_y]

$A_b \leq 0.600$	$0.600 < A_b < 1.336$	$A_b \geq 1.336$
M_y^*	M_y^*	M_y^*
1930381,390 [Nmm]	---	---

$f_c = M_x / Z_x$ [AS/NZS 4600, Eq. 3.3.2(2)]

$f_{c,structure}^*$	350,000 [MPa]
$f_{c,structure}^*$	350,000 [MPa]
$f_{c,connection}^*$	350,000 [MPa]
$f_{c,connection}^*$	350,000 [MPa]

$M_x = Z_x \cdot f_c$ [AS/NZS 4600, Eq. 3.3.2(1)]

Z_x^*	9518,006 [mm ³]	Z_x^*	5519,376 [mm ³]
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NOTE Ring on with 90 Degree Lips [AS/NZS 4600, D₂]

b_a	90,000 [mm]	4	18,000 [mm]
b_b	46,000 [mm]	1	2,652 [mm]
A_x	193,154 [mm ²]	4	316,957 [mm ²]
\bar{Y}	29,738 [mm]	Y_p	3826,135 [mm ²]
\bar{Y}	2,672 [mm]	Y_p	9774,877 [mm ²]
E	210,000 [GPa]	E_{sp}	8668,321 [mm ²]

$\lambda = 4.80 \left(\frac{L_x A_b}{I_x} \right)^{0.5}$ λ 464,649 [mm]
[AS/NZS 4600, Eq. D₂(6)]

$\eta = \left(\frac{\pi}{\lambda} \right)^2$ η 6,028E-05 []
[AS/NZS 4600, Eq. D₂(7)]

$\beta_1 = \bar{Y}^2 + \left(\frac{L_x + L_y}{A} \right)$ β_1 1147,361 [mm²]
[AS/NZS 4600, Eq. D₂(5)]

$u_2 = \eta \left(L_x + \frac{2}{\beta_1} \bar{Y} L_y \right)$ u_2 2358 []
[AS/NZS 4600, Eq. D₂(3)]

$\eta_1 = \frac{\eta}{\beta_1} (L_x A_b^2 + 0.039 L_x^2)$ η_1 0,541 []
[AS/NZS 4600, Eq. D₂(3)]

$u_3 = \eta \left(u_2 L_x - \frac{\eta}{\beta_1} L_x^2 A_b^2 \right)$ u_3 0,928 []
[AS/NZS 4600, Eq. D₂(4)]

$f_c = \frac{\eta}{\beta_1} \left(\eta_1 L_x + \sqrt{\eta_1 L_x + \eta_1} \right)$ f_c 466,475 [MPa]
[AS/NZS 4600, Eq. D₂(1)]

$K_p = \frac{M_x}{1.040 + 0.040 \left(\frac{1.11 M_y}{M_x} \right) \left(\frac{Z_x}{Z_y} \right)}$ K_p 4189,587 [mm]
[AS/NZS 4600, Eq. D₂(8)]

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Front Column [M_{x,comp}]

$A_b \leq 0.600$	$0.600 < A_b < 1.336$	$A_b \geq 1.336$
M_x	M_x	M_x
3331582,037 [Nmm]	---	---

Front Column [M_{y,comp}]

$A_b \leq 0.600$	$0.600 < A_b < 1.336$	$A_b \geq 1.336$
M_y	M_y	M_y
1930381,390 [Nmm]	---	---

Rear Column [M_{x,comp}]

$A_b \leq 0.600$	$0.600 < A_b < 1.336$	$A_b \geq 1.336$
M_x	M_x	M_x
3331582,037 [Nmm]	---	---

Rear Column [M_{y,comp}]

$A_b \leq 0.600$	$0.600 < A_b < 1.336$	$A_b \geq 1.336$
M_y	M_y	M_y
1930381,390 [Nmm]	---	---

$M_{c,connection}^*$ 3,332 [kNm] $M_{c,structure}^*$ 1,930 [kNm]

$M_{c,connection}^*$ 3,332 [kNm] $M_{c,structure}^*$ 1,930 [kNm]

[9] C-Section Column Members subject to Distortional Buckling [AS/NZS 4600, 3.3.3.1]

Table 1.6. Capacity Reduction Factor [AS/NZS 4600, 2005]

Design Capacity	Class	Capacity Reduction Factor [Φ _c]
Member moment capacity: Members subject to distortional buckling	3,3,3,3	0,950

$M_x = Z_x \cdot f_c$ [AS/NZS 4600, Eq. 3.3.2(1)]

Single Lip Channel Model for Distortional Buckling [AS/NZS 4600, Figure D1]

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$u_1 = \frac{\eta}{\beta_1} (L_x A_b^2 + 0.039 L_x^2) + \frac{L_x}{\beta_1}$ u_1 0,929 []
[AS/NZS 4600, Eq. D₂(2)]

$u_3 = \eta \left(u_2 L_x - \frac{\eta}{\beta_1} L_x^2 A_b^2 \right)$ u_3 1,985 []
[AS/NZS 4600, Eq. D₂(4)]

$f_c = \frac{\eta}{\beta_1} \left(\eta_1 L_x + \sqrt{\eta_1 L_x + \eta_1} \right)$ f_c 818,295 [MPa]
[AS/NZS 4600, Eq. D₂(1)]

Distortional buckling (bending) relation of a flange and lip about the flange web junction of a channel

K_p 4189,587 [mm] Z_x Full section modulus

$Z_{x,flange}$ 13521,309 [mm³] $Z_{x,connection}$ --- [mm³]

$M_x = Z_x \cdot f_c$ Z_x 13521,309 [mm³]
[AS/NZS 4600, Eq. 3.3.2(8)] M_x 11064417,897 [Nmm]

$\lambda_b = \sqrt{\frac{M_x}{M_y}}$ M_y 4732458,074 [Nmm]
[AS/NZS 4600, Eq. 3.3.3(8)] λ_b 0,854 []

$\lambda_b \leq 0,674$ $\lambda_b > 0,674$

$M_x = M_y$ $M_c = \frac{M_x}{\lambda_b} \left(1 - \frac{0,22}{\lambda_b} \right)$
[AS/NZS 4600, Eq. 3.3.3(9)] [AS/NZS 4600, Eq. 3.3.3(10)]

$\lambda_b \leq 0,674$ $\lambda_b > 0,674$

M_x	4732458,074 [Nmm]	M_y	---
-------	-------------------	-------	-----

$f_c = M_x / Z_x$ f_c 350,000 [MPa]
[AS/NZS 4600, Eq. 3.3.2(2)]

$M_x = Z_x \cdot f_c$ [AS/NZS 4600, Eq. 3.3.2(1)]

M_x 4732458,074 [Nmm]

M_y 4,732 [kNm]

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Distortional buckling involves transverse bending of a vertical web

$M_{d1} = Z_{d1} \cdot f_{d1}$ [AS/NZS 4600, Eq. 3.3.3(8)]

$Z_{d1} = 13521,399$ [mm³]

$M_{d1} = 4732,459,974$ [Nmm]

$\lambda_d = \sqrt{\frac{M_{d1}}{M_{d2}}}$ [AS/NZS 4600, Eq. 3.3.3(8)]

$\lambda_d \leq 0.590$ $0.590 < \lambda_d \leq 1.700$ $\lambda_d > 1.700$

$M_{d1} = M_{d2}$ $M_{d1} = M_{d2} \cdot \left(\frac{0.59}{\lambda_d}\right)$ $M_{d1} = M_{d2} \cdot \left(\frac{1}{\lambda_d^2}\right)$

[AS/NZS 4600, Eq. 3.3.3(6)] [AS/NZS 4600, Eq. 3.3.3(8)] [AS/NZS 4600, Eq. 3.3.3(7)]

$\lambda_d \leq 0.590$ $0.590 < \lambda_d \leq 1.700$ $\lambda_d > 1.700$

M_{d1} M_{d2} M_{d3}

... [Nmm] 4269329,800 [Nmm] ... [Nmm]

$f_{d1} = M_{d1} / Z_{d1}$ $f_{d1} = 319,748$ [MPa]

[AS/NZS 4600, Eq. 3.3.3(2)]

$Z_{d1} = 13521,399$ [mm³]

$M_{d1} = Z_{d1} \cdot f_{d1}$ [AS/NZS 4600, Eq. 3.3.3(1)]

$M_{d1} = 4269329,800$ [Nmm]

$M_{d2} = 4,269$ [kNm]

$M_{d3} = 4269329,800$ [Nmm] $M_{d4} = 4,269$ [kNm]

[4] C-Section Column: Bending Moment Verification [AS/NZS 4600, LSD]

$M' \leq \phi_b \cdot M_u$ [AS/NZS 4600, Eq. 3.3.3(1)] $M' \leq \phi_b \cdot M_u$ [AS/NZS 4600, Eq. 3.3.1(2)]

Positive Moment in x-x axis [M_{1,22}']

C-Section Front Column

M _{1,22,EM(1)}	0,270	[kNm]	Ratio	7,927	[%]
M _{1,22,EM(2)}	4,269	[kNm]			

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[4] C-Section Beam

[1] C-Section Steel: Bending Moment [AISI S100, ASD]

[1] C-Section Steel: Nominal Section Strength (R) Resistance [AISI S100, CL1,1]

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:

- Member is not subject to twisting, lateral, torsional, or flexure-torsional buckling
- Effect of cold work of forming is not included in determining the yield stress F_y
- Ratio of the depth of the compressed portion of the web to its thickness does not exceed λ_p
- Shear force does not exceed $0.35 F_y$ ASD (times web area) λ_p - Stiffened elements λ_{ps} - Unstiffened elements
- $0.60 F_y$ LRFD (times web area) λ_p - Stiffened elements λ_{ps} - Unstiffened elements
- The angle between any web and the vertical does not exceed 30°

Sections with stiffened or partially stiffened compression flanges $\phi_b = 1,670$

Procedure I $M_u = \phi_b F_y$ [AISI S100, Eq. C3.1.1-1]

Positive Moment in x-x axis [M_{1,22}']

$I_{x,EM(1)}$	85495,109	[mm ⁴]
$S_{x,EM(1)}$	3320,364	[mm ³]
$S_{x,EM(2)}$	3519,814	[mm ³]
$I_{x,EM(3)}$	85495,109	[mm ⁴]
$S_{x,EM(3)}$	3320,364	[mm ³]
$S_{x,EM(4)}$	3519,814	[mm ³]
$S_{x,EM(5)}$	...	[mm ³]
F_y	...	[MPa]
F_u	378,145	[MPa]
$M_{1,22,EM(1)}$	1255804,644	[Nmm]
$M_{1,22,EM(2)}$	1330923,221	[Nmm]
$M_{1,22,EM(3)}$	1,256	[kNm]
$M_{1,22,EM(4)}$	1,331	[kNm]

Positive Moment in y-y axis [M_{2,22}']

$I_{y,EM(1)}$	85495,109	[mm ⁴]
$S_{y,EM(1)}$	3519,814	[mm ³]
$S_{y,EM(2)}$	3320,364	[mm ³]
$I_{y,EM(3)}$	85495,109	[mm ⁴]
$S_{y,EM(3)}$	3519,814	[mm ³]
$S_{y,EM(4)}$	3320,364	[mm ³]
$S_{y,EM(5)}$	...	[mm ³]
F_y	...	[MPa]
F_u	378,145	[MPa]
$M_{2,22,EM(1)}$	1330923,221	[Nmm]
$M_{2,22,EM(2)}$	1255804,644	[Nmm]
$M_{2,22,EM(3)}$	1,331	[kNm]
$M_{2,22,EM(4)}$	1,256	[kNm]

Negative Moment in y-y axis [M_{2,22}']

$I_{y,EM(1)}$	43399,245	[mm ⁴]
$S_{y,EM(1)}$	2873,459	[mm ³]
$S_{y,EM(2)}$	1851,157	[mm ³]
$I_{y,EM(3)}$	43399,245	[mm ⁴]
$S_{y,EM(3)}$	2873,459	[mm ³]
$S_{y,EM(4)}$	1851,157	[mm ³]
$S_{y,EM(5)}$	...	[mm ³]
F_y	...	[MPa]
F_u	378,145	[MPa]
$M_{2,22,EM(1)}$	1085889,872	[Nmm]
$M_{2,22,EM(2)}$	700004,8691	[Nmm]
$M_{2,22,EM(3)}$	1,087	[kNm]
$M_{2,22,EM(4)}$	0,700	[kNm]

Negative Moment in x-x axis [M_{1,22}']

$I_{x,EM(1)}$	43399,245	[mm ⁴]
$S_{x,EM(1)}$	1851,157	[mm ³]
$S_{x,EM(2)}$	2873,459	[mm ³]

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C-Section Rear Column

Positive Moment in x-x axis [M_{1,22}']

M _{1,22,EM(1)}	0,350	[kNm]	Ratio	9,199	[%]
M _{1,22,EM(2)}	4,269	[kNm]			

Negative Moment in x-x axis [M_{1,22}']

C-Section Front Column

Positive Moment in x-x axis [M_{1,22}']

M _{1,22,EM(1)}	0,270	[kNm]	Ratio	7,927	[%]
M _{1,22,EM(2)}	4,269	[kNm]			

Negative Moment in x-x axis [M_{1,22}']

C-Section Rear Column

Positive Moment in y-y axis [M_{2,22}']

M _{2,22,EM(1)}	0,350	[kNm]	Ratio	9,199	[%]
M _{2,22,EM(2)}	4,269	[kNm]			

Negative Moment in y-y axis [M_{2,22}']

C-Section Front Column

Positive Moment in y-y axis [M_{2,22}']

M _{2,22,EM(1)}	0,350	[kNm]	Ratio	9,199	[%]
M _{2,22,EM(2)}	4,269	[kNm]			

Negative Moment in y-y axis [M_{2,22}']

C-Section Rear Column

Positive Moment in x-x axis [M_{1,22}']

M _{1,22,EM(1)}	0,350	[kNm]	Ratio	9,199	[%]
M _{1,22,EM(2)}	3,332	[kNm]			

Negative Moment in x-x axis [M_{1,22}']

C-Section Front Column

Positive Moment in x-x axis [M_{1,22}']

M _{1,22,EM(1)}	0,350	[kNm]	Ratio	9,199	[%]
M _{1,22,EM(2)}	3,332	[kNm]			

Negative Moment in x-x axis [M_{1,22}']

C-Section Rear Column

Positive Moment in y-y axis [M_{2,22}']

M _{2,22,EM(1)}	0,350	[kNm]	Ratio	9,199	[%]
M _{2,22,EM(2)}	1,830	[kNm]			

Negative Moment in y-y axis [M_{2,22}']

C-Section Front Column

Positive Moment in y-y axis [M_{2,22}']

M _{2,22,EM(1)}	0,350	[kNm]	Ratio	9,199	[%]
M _{2,22,EM(2)}	1,830	[kNm]			

Negative Moment in y-y axis [M_{2,22}']

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Negative Moment in x-x axis [M_{1,22}']

$I_{x,EM(1)}$	85495,109	[mm ⁴]
$S_{x,EM(1)}$	3519,814	[mm ³]
$S_{x,EM(2)}$	3320,364	[mm ³]
$I_{x,EM(3)}$	85495,109	[mm ⁴]
$S_{x,EM(3)}$	3519,814	[mm ³]
$S_{x,EM(4)}$	3320,364	[mm ³]
$S_{x,EM(5)}$	...	[mm ³]
F_y	...	[MPa]
F_u	378,145	[MPa]
$M_{1,22,EM(1)}$	1330923,221	[Nmm]
$M_{1,22,EM(2)}$	1255804,644	[Nmm]
$M_{1,22,EM(3)}$	1,331	[kNm]
$M_{1,22,EM(4)}$	1,256	[kNm]

Positive Moment in y-y axis [M_{2,22}']

$I_{y,EM(1)}$	43399,245	[mm ⁴]
$S_{y,EM(1)}$	2873,459	[mm ³]
$S_{y,EM(2)}$	1851,157	[mm ³]
$I_{y,EM(3)}$	43399,245	[mm ⁴]
$S_{y,EM(3)}$	2873,459	[mm ³]
$S_{y,EM(4)}$	1851,157	[mm ³]
$S_{y,EM(5)}$	...	[mm ³]
F_y	...	[MPa]
F_u	378,145	[MPa]
$M_{2,22,EM(1)}$	1085889,872	[Nmm]
$M_{2,22,EM(2)}$	700004,8691	[Nmm]
$M_{2,22,EM(3)}$	1,087	[kNm]
$M_{2,22,EM(4)}$	0,700	[kNm]

Negative Moment in y-y axis [M_{2,22}']

$I_{y,EM(1)}$	43399,245	[mm ⁴]
$S_{y,EM(1)}$	1851,157	[mm ³]
$S_{y,EM(2)}$	2873,459	[mm ³]

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I_{xx}: 43399,345 [mm⁴]

S_{xx}top: 1851,957 [mm³] S_{xx}bot: 2873,453 [mm³]

Section is fully effective

F_y: --- [MPa] F_w: 378,145 [MPa]

M_{xx}max: 7000,04891 [Nm] M_{xx}min: 169589,872 [Nm]

M_{xx}design: 0,700 [kNm] M_{xx}res: 1,087 [kNm]

[2] C-Section Steel - Lateral-Torsional Buckling Strength [Resistance] [AISI S100, C3.J.2.1]

Q_s: 1,970 M_s = Q_sF_c [AISI S100, Eq. C3.J.2.1-1]

Single-symmetric sections bending about the symmetry axis [x-x]

C_s

C_s shall be permitted to be conservatively taken as unity for all cases.
For cantilevers or overhangs where the free end is unrestrained, C_s shall be taken as unity.

C_s: 1,000 r_y: 20,691 [mm] r_x: 14,863 [mm] r_y: -9,537 [mm] r_x: 43,921 [mm]

S_x: 3519,614 [mm³] E: 210,000 [MPa]

$\sigma_{cr} = \frac{\pi^2 E}{(K_y L_y / r_y)^2}$ $\sigma_{cr} = 117,489$ [N/mm²] [AISI S100, Eq. C3.J.2.1-8]

$\phi = \frac{1}{A_g} \left[C_f + \frac{\pi^2 K C}{(K_x L_x / r_x)^2} \right]$ $\phi = 67,264$ [N/mm²] [AISI S100, Eq. C3.J.2.1-9]

$F_e = \frac{C_b F_y A}{S_x} \sqrt{\phi \sigma_{cr}}$ F_{cr}res: 221,884 [MPa] [AISI S100, Eq. C3.J.2.1-11]

F_y: --- [MPa] F_w: 378,145 [MPa]

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A_g: 201,315 [mm²] r_y: 43,921 [mm]

S_{xx}: 2873,453 [mm³] S_{yy}: 1851,957 [mm³]

C_{xx}: 67,264 [N/mm²]

F_{cr}res: 221,884 [MPa] F_{cr}res: 152,780 [MPa]

M_{xx}design: --- [kNm] M_{xx}res: 1,087 [kNm]

F_y: --- [MPa] F_w: 378,145 [MPa]

M_{xx}design: --- [kNm] M_{xx}res: 1,087 [kNm]

F_y: --- [MPa] F_w: 378,145 [MPa]

F_y ≥ 2,780 * F_w

Member segment is not subject to lateral-torsional buckling at bending moments lesser equal to M_s
Available flexural strength (moment resistance) shall be determined with Section C3.J.2(x)

2,780 * F_w > F_y > 0,560 * F_w 0,560 * F_w ≥ F_w

F_c = F_w

$F_c = \frac{10}{9} F_y \left(1 - \frac{10 F_y}{36 F_e} \right)$ [AISI S100, Eq. C3.J.2.1-3]

[AISI S100, Eq. C3.J.2.1-2]

S_{xx}: 2873,453 [mm³] S_{yy}: 1851,957 [mm³]

F_y ≥ 2,780 * F_w 2,780 * F_w > F_y > 0,560 * F_w 0,560 * F_w ≥ F_w

Yes No Yes

C3.J.2(x) [MPa] --- [MPa] --- [MPa]

F_y ≥ 2,780 * F_w 2,780 * F_w > F_y > 0,560 * F_w 0,560 * F_w ≥ F_w

No Yes

--- [MPa] --- [MPa] 152,780 [MPa]

F_y ≥ 2,780 * F_w 2,780 * F_w > F_y > 0,560 * F_w 0,560 * F_w ≥ F_w

1,970 [kNm] --- [kNm] --- [kNm]

F_y ≥ 2,780 * F_w 2,780 * F_w > F_y > 0,560 * F_w 0,560 * F_w ≥ F_w

--- [kNm] --- [kNm] 0,283 [kNm]

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F_y ≥ 2,780 * F_w

Member segment is not subject to lateral-torsional buckling at bending moments lesser equal to M_s
Available flexural strength (moment resistance) shall be determined with Section C3.J.2(x)

2,780 * F_w > F_y > 0,560 * F_w 0,560 * F_w ≥ F_w

F_c = F_w

$F_c = \frac{10}{9} F_y \left(1 - \frac{10 F_y}{36 F_e} \right)$ [AISI S100, Eq. C3.J.2.1-3]

S_x: 3320,384 [mm³]

F_y ≥ 2,780 * F_w 2,780 * F_w > F_y > 0,560 * F_w 0,560 * F_w ≥ F_w

No Yes No

--- [MPa] 221,884 [MPa] --- [MPa]

F_y ≥ 2,780 * F_w 2,780 * F_w > F_y > 0,560 * F_w 0,560 * F_w ≥ F_w

--- [kNm] 0,283 [kNm] --- [kNm]

M_{xx}design: 0,283 [kNm]

Single-symmetric sections bending about the axis perpendicular to the axis of symmetry [y-y]

C_s

C_s = 1 | 1,000 → Moment causing compression on shear center side of centroid
C_s = -1 | -1,000 → Moment causing tension on shear center side of centroid

$\sigma_{cr} = \frac{\pi^2 E}{(K_y L_y / r_y)^2}$ $\sigma_{cr} = 231,286$ [N/mm²] [AISI S100, Eq. C3.J.2.1-11]

$\bar{y} = \frac{1}{A} \int_A x^2 dA + \bar{x}_c \int_A x dA$ $\bar{y} = 42,616$ [mm] [AISI S100, Eq. C3.J.2.1-11]

C_{TE} = 0,6 - 0,4 (M_y/M_x) C_{TE}: 1,000 [AISI S100, Eq. C3.J.2.1-11]

$F_e = \frac{C_s A \sigma_{cr}}{C_{TE} S_x} \left[1 + C_s \sqrt{1 + r_y^2 (\sigma_y / \sigma_{cr})} \right]$ [AISI S100, Eq. C3.J.2.1-10]

M_{xx}: --- C_s: 1,000

M_{yy}: --- C_s: -1,000

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M_{xx}design: 1,087 [kNm] M_{xx}res: 0,283 [kNm]

[3] C-Section Steel - Distortional Buckling Strength [Resistance] [AISI S100, C3.J.1]

Q_s: 1,970

For C- and Z-sections or any Open Section with a Stiffener of Compression Flange Extending to Side of the Web when the Stiffener is either a Single Lip or a Complex Edge Stiffener

D_o = Actual stiffener dimension

[AISI S100, Figure B2.2-1] [AISI S100, Figure B4-1]

Dimensional Limits

[1]	50 ≤ h _o [mm]	OK
	h _o [mm] ≤ 200	OK
	25 ≤ h _o [mm]	OK
[2]	h _o [mm] ≤ 100	OK
[3]	6,25 ≤ D _o [mm]	OK
	D _o [mm] ≤ 50	OK
[4]	45° ≤ θ	OK
	6 ≤ 90°	OK
	2 ≤ h _o / b _o	OK
[5]	h _o / b _o ≤ 8	OK
[6]	0,84 ≤ D _o / h _o ≤ 1,0	OK
	D _o / h _o ≤ 1,0	OK

$I_{yy} = \left(\frac{4h_o^3 b_o (1 - \alpha^2)}{3} \left[I_{yf} (S_o - h_o)^2 + C_{yf} - \frac{I_{yf}^2}{12} (S_o - h_o)^2 \right] + \frac{\pi^4 h_o^4}{720} \right)^{1/4}$ [AISI S100, Eq. C3.J.4-2]

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Section is fully effective

$S_{x,comp}$	---	$S_{x,comp}$	---		
F_y	---	[MPa]	---		
F_w	378,145	[MPa]	---		
$M_{y,comp}(z)$	1089,680,872	[Nmm]	$M_{y,tension}(z)$	7000,04,9591	[Nmm]
$M_{y,comp}(z)$	1.087	[kNm]	$M_{y,tension}(z)$	0.700	[kNm]

Negative Moment in y-y axis [M_{yy}]

$I_{yy}(z)$	43399,345	[mm ⁴]	---		
$S_{y,comp}$	1851,157	[mm ³]	$S_{y,tension}$	2873,453	[mm ³]
$I_{yy}(z)$	43399,345	[mm ⁴]	---		
$S_{y,comp}$	1851,157	[mm ³]	$S_{y,tension}$	2873,453	[mm ³]

Section is fully effective

$S_{x,comp}$	---	$S_{x,comp}$	---		
F_y	---	[MPa]	---		
F_w	378,145	[MPa]	---		
$M_{y,tension}(z)$	7000,04,9591	[Nmm]	$M_{y,comp}(z)$	1089,680,872	[Nmm]
$M_{y,tension}(z)$	0.700	[kNm]	$M_{y,comp}(z)$	1.087	[kNm]

[2] C-Section Steel: Lateral-Torsional Bending Strength | Resistance | [AISI S100, C3.1.2.1]

$\phi_b = 0,900$ | $M_y = \phi_b F_c$ [AISI S100, Eq. C3.1.2.1-1]

Singlysymmetric sections bending about the symmetry axis [xx]

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_y	20,601	[mm]
		r_z	14,683	[mm]
		r_x	-0,537	[mm]
		r_y	43,621	[mm]

$F_c = \frac{\sqrt{2}}{\sqrt{1 + \frac{r_y^2}{r_x^2} + \frac{r_z^2}{r_x^2}}}$ [AISI S100, Eq. C3.1.2.1-7]

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Section is fully effective

$\sigma_{cr} = \frac{\pi^2 E}{(K L_y / r_y)^2}$	$\sigma_{cr,xx}$	231,286	[N/mm ²]		
		[AISI S100, Eq. C3.1.2.1-1]			
$i = \frac{1}{2I_y} \int [I_x x^2 dA + I_y y^2 dA]$		42,516	[mm]		
		[AISI S100, Eq. C3.1.2.1-1]			
$C_{TF} = 0,6 - 0,4 (M_1 / M_2)$	C_T	1,000			
		[AISI S100, Eq. C3.1.2.1-1]			
$F_c = \frac{C_b A_g \sigma_{cr}}{C_{TF} S_x} \left[1 + C_s \sqrt{1 + r_y^2 (\sigma_y / \sigma_{cr})} \right]$					
		[AISI S100, Eq. C3.1.2.1-10]			
$M_{y,tension}$	---	C_y	1,000		
$M_{y,comp}$	---	C_y	-1,000		
A_g	201,215	[mm ²]	r_y	43,621	[mm]
$S_{y,tension}$	2873,453	[mm ³]	$S_{y,comp}$	1851,157	[mm ³]
$\sigma_{cr,xx}$	67,264	[N/mm ²]			

Steel

$F_{tension}(z)$	1476,276	[MPa]	$F_{compression}(z)$	152,780	[MPa]
$M_{y,comp}$	---	[MPa]	$M_{y,tension}$	---	[MPa]
F_y	---	[MPa]	F_w	378,145	[MPa]
$M_{y,comp}$	---	[MPa]	F_w	378,145	[MPa]

$F_y \geq 2,780 \cdot F_y$

Member segment is not subject to lateral-torsional buckling if bending moments have or equal to M_y .
Available flexural strength (moment resistance) shall be determined with Section C3.1.2.1(x)

$2,780 \cdot F_y > F_y > 0,560 \cdot F_y$ | $0,560 \cdot F_y \geq F_y$
 $F_y = F_y$

$F_c = \frac{10}{9} F_y \left(1 - \frac{10 F_y}{36 F_c} \right)$ [AISI S100, Eq. C3.1.2.1-2]

$S_{y,tension}$	2873,453	[mm ³]	$S_{y,comp}$	1851,157	[mm ³]
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Section is fully effective

S_x	3519,614	[mm ³]	E	210,000	[GPa]
$\sigma_{cr} = \frac{\pi^2 E}{(K_y L_y / r_y)^2}$	$\sigma_{cr,xx}$	117,489	[N/mm ²]		
		[AISI S100, Eq. C3.1.2.1-8]			
$\sigma_t = \frac{1}{A_g} \left[C_b \frac{\pi^2 E C_w}{(K L_y)^2} \right]$	$\sigma_{cr,yy}$	67,264	[N/mm ²]		
		[AISI S100, Eq. C3.1.2.1-9]			
$F_c = \frac{C_b F_y A}{S_x} \sqrt{\sigma_y \sigma_t}$	$F_{cr,yy}$	221,804	[MPa]		
		[AISI S100, Eq. C3.1.2.1-4]			
F_y	---	[MPa]	F_w	378,145	[MPa]

$F_y \geq 2,780 \cdot F_y$

Member segment is not subject to lateral-torsional buckling if bending moments have or equal to M_y .
Available flexural strength (moment resistance) shall be determined with Section C3.1.2.1(x)

$2,780 \cdot F_y > F_y > 0,560 \cdot F_y$ | $0,560 \cdot F_y \geq F_y$
 $F_y = F_y$

$F_c = \frac{10}{9} F_y \left(1 - \frac{10 F_y}{36 F_c} \right)$ [AISI S100, Eq. C3.1.2.1-2]

S_x	3320,364	[mm ³]
-------	----------	--------------------

Steel | $F_{tension}$

$F_y \geq 2,780 \cdot F_y$	2,780 · F _y > F _y > 0,560 · F _y	0,560 · F _y ≥ F _y
No	Yes	No
---	[MPa]	221,184
	[MPa]	---

Steel | $M_{y,comp}$

$F_y \geq 2,780 \cdot F_y$	2,780 · F _y > F _y > 0,560 · F _y	0,560 · F _y ≥ F _y
---	[kNm]	0,735
	[kNm]	---

$M_{y,comp}$

$M_{y,comp}$	0,735	[kNm]
--------------	-------	-------

Singlysymmetric sections bending about the axis perpendicular to the axis of symmetry [y-y]

C_b

$C_b = 1 > 1,000$ → Moment causing compression on shear center side of overhang
 $C_b = 1 > 1,000$ → Moment causing tension on shear center side of overhang

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Section is fully effective

$F_y \geq 2,780 \cdot F_y$	2,780 · F _y > F _y > 0,560 · F _y	0,560 · F _y ≥ F _y
Yes	No	Yes
C3.1.2.1(x)	[MPa]	---
	[MPa]	---

Steel | $F_{tension}$

$F_y \geq 2,780 \cdot F_y$	2,780 · F _y > F _y > 0,560 · F _y	0,560 · F _y ≥ F _y
No	Yes	Yes
---	[MPa]	131,289
	[MPa]	152,780

Steel | $M_{y,comp}$

$F_y \geq 2,780 \cdot F_y$	2,780 · F _y > F _y > 0,560 · F _y	0,560 · F _y ≥ F _y
1,087	[kNm]	---
	[kNm]	---

Steel | $M_{y,tension}$

$F_y \geq 2,780 \cdot F_y$	2,780 · F _y > F _y > 0,560 · F _y	0,560 · F _y ≥ F _y
---	[kNm]	0,243
	[kNm]	0,283


Steel | $M_{y,comp}$

$M_{y,comp}$	1,087	[kNm]
$M_{y,tension}$	0,283	[kNm]

[3] C-Section Steel: Diagonal Bending Strength | Resistance | [AISI S100, C3.1]

$\phi_b = 0,900$

For C- and Z-sections or any Open Section with a Slitweb Compression Flange Extending to Side of the Web where the Slitflange is either a Single Lip or a Complex Edge Slitflange



Diagonal Limits

[1]	$90 \leq h_1 / t$	OK
	$h_1 / t \leq 200$	OK
[2]	$25 \leq h_1 / t$	OK
	$h_1 / t \leq 100$	OK
[3]	$6,25 \leq D / t$	OK
	$D / t \leq 50$	OK

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Dimensional Limits

[4]	45° ≤ θ	OK
	0 ≤ β ≤ 90°	OK
[5]	2 ≤ h _o /b ₁	KO
	h _o /b ₂ ≤ 8	OK
[6]	0.04 ≤ D ⁺ sin θ [b] ≤ h _o	OK
	D ⁺ sin θ [b] ≤ 0.50	OK

$$I_{x,eff} = \left(\frac{4\pi^4 h_o^4 (1-\mu^2)}{3} \left(I_{x,fl} (s_o - h_x)^2 + C_{wfl} - \frac{I_{y,fl}^2 (s_o - h_x)^2}{I_{y,fl}} \right) + \frac{\pi^4 h_o^4}{720} \right)^{1/4}$$

[AISI S100, Eq. C3.3.4-12]

NOTE Flanges with 90 Degree Lips

A ₁	55,385	[mm ²]
I _x	102,528	[mm ⁴]
I _y	593,746	[mm ⁴]
I _{wp}	358,596	[mm ⁴]
h _x	-18,593	[mm]
A ₂	38,923	[mm ²]
C _w	0,000	[mm ³]
v [y]	0,000	[]

β = 1,000 L = L₁ = 148,214 [mm]

E = 219,000 [GPa] G = 81,769 [GPa]

$$k_{eff} = \left(\frac{\pi}{L} \right)^4 \left(EI_{x,fl} (s_o - h_x)^2 + EC_{wfl} - E \frac{I_{y,fl}^2}{I_{y,fl}} (s_o - h_x)^2 \right) + \left(\frac{\pi}{L} \right)^2 GJ_f$$

[AISI S100, Eq. C3.3.4-13]

$$k_{effve} = \frac{Et^3}{12(1-\mu^2)} \left(\frac{3}{h_o} + \left(\frac{\pi}{L} \right)^2 \frac{19 h_o}{60} + \left(\frac{\pi}{L} \right)^4 \frac{h_o^3}{240} \right)$$

[AISI S100, Eq. C3.3.4-14]

k_{xx} = 4938,273 [N] k_{yy} = 3937,292 [N]

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Positive Moment in x-axis [M_{xx}]

C-Section S100

M_{xx,Ed} = 0,910 [kNm] Ratio = 1,513 [%]

M_{xx,Ed,max} = 0,735 [kNm]

Negative Moment in x-axis [M_{xx}]

C-Section S100

M_{xx,Ed} = 0,910 [kNm] Ratio = 1,513 [%]

M_{xx,Ed,max} = 0,735 [kNm]

Positive Moment in y-axis [M_{yy}]

C-Section S100

M_{yy,Ed} = 0,900 [kNm] Ratio = 0,000 [%]

M_{yy,Ed,max} = 1,087 [kNm]

Negative Moment in y-axis [M_{yy}]

C-Section S100

M_{yy,Ed} = 0,900 [kNm] Ratio = 0,000 [%]

M_{yy,Ed,max} = 0,283 [kNm]

[0] C-Section S100 - Bending Moment [AS/NZS 4600, LSD]

[1] C-Section S100 - 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:

- Member is not subject to twisting, lateral, torsional, or flexure-torsional buckling.
- Effect of cold work of forming is not included in determining the yield stress f_y.
- Ratio of the depth of the compressed portion of the web to its thickness does not exceed 4.
- Shear force does not exceed 0.35F_y times web area.
- The angle between any web and the vertical does not exceed 30.

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$$\tilde{k}_{eff} = \left(\frac{\pi}{L} \right)^2 \left[A_1 (s_o - h_x)^2 \left(\frac{I_{y,fl}}{I_{y,fl}} \right)^2 - 2y_{o,fl} (s_o - h_x) \left(\frac{I_{y,fl}}{I_{y,fl}} \right) + h_x^2 + y_{o,fl}^2 \right] + I_{x,fl} + I_{y,fl}$$

[AISI S100, Eq. C3.3.4-15]

$$\tilde{k}_{effve} = \frac{h_o^4 (1-\mu^2)}{13440} \left(\frac{45360(1-\mu^2)}{h_o^4} + 62160 \left(\frac{L}{h_o} \right)^2 + 448 \pi^2 + \left(\frac{h_o}{L} \right)^2 [53 + 3(1-\mu^2)] h^4 \right)$$

[AISI S100, Eq. C3.3.4-16]

k_{xx} = 0,000 [N] k_{yy} = 2000 []

\tilde{k}_{eff} = 11,447 [mm²] \tilde{k}_{effve} = 0,233 [mm²]

$$F_d = \beta \frac{k_{eff} + k_{effve} + k_{fl}}{k_{eff} + k_{effve}}$$

[AISI S100, Eq. C3.3.4-18]

F_d = 761,623 [MPa]

M_x = S_x * F_d M_y = S_y * F_d

[AISI S100, Eq. C3.3.4-4] [AISI S100, Eq. C3.3.4-6]

S_x = 3320,984 [mm³] M_x = 252922,957 [Nmm]

S_y = 3320,984 [mm³] M_y = 1162337,256 [Nmm]

$$\lambda_{ed} = \sqrt{M_y / M_{y,Ed}}$$

[AISI S100, Eq. C3.3.4-3]

λ_{ed} ≤ 0.873 λ_{ed} > 0.873

$$M_n = \left(1 - 0.22 \left(\frac{M_{y,Ed}}{M_y} \right)^{0.5} \right) \left(\frac{M_{y,Ed}}{M_y} \right)^{0.5} M_y$$

[AISI S100, Eq. C3.3.4-1] [AISI S100, Eq. C3.3.4-2]

M_x = 1159170,279 [Nmm] M_y = 1,159 [kNm]

[4] C-Section S100 - Bending Moment Verification [AISI S100, LRFD]

M ≤ φ_t * M_n [AISI S100, Eq. A5.1.3-1] M_x ≤ MIN [M_{xx,Ed} ; M_{xx,Ed} ; M_{xx,Ed}]

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Table 1.6 - Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Class Reference	Capacity Reduction Factor [φ _t]
Sections with stiffened or partially stiffened compression flanges	3,3,2	0,950

Procedure I M_x = Z_x * f_y [AS/NZS 4600, Eq. 3.3.2.2]

Positive Moment in x-axis [M_{xx}]

I_{xx,Ed} = 85495,109 [mm⁴]

Z_{xx,Ed} = 3320,984 [mm³] Z_{xx,Ed} = 3519,814 [mm³]

I_{xx,Ed} = 85495,109 [mm⁴]

Z_{xx,Ed} = 3320,984 [mm³] Z_{xx,Ed} = 3519,814 [mm³]

Z_{xx,Ed} Section is fully effective Z_{xx,Ed}

f_y = --- [MPa]

f_w = 378,145 [MPa]

M_{xx,Ed,max} = 1255804,644 [Nmm] M_{xx,Ed,max} = 1330923,221 [Nmm]

M_{xx,Ed,max} = 1,256 [kNm] M_{xx,Ed,max} = 1,331 [kNm]

Negative Moment in x-axis [M_{xx}]

I_{xx,Ed} = 85495,109 [mm⁴]

Z_{xx,Ed} = 3519,814 [mm³] Z_{xx,Ed} = 3320,984 [mm³]

I_{xx,Ed} = 85495,109 [mm⁴]

Z_{xx,Ed} = 3519,814 [mm³] Z_{xx,Ed} = 3320,984 [mm³]

Z_{xx,Ed} Section is fully effective Z_{xx,Ed}

f_y = --- [MPa]

f_w = 378,145 [MPa]

M_{xx,Ed,max} = 1330923,221 [Nmm] M_{xx,Ed,max} = 1255804,644 [Nmm]

M_{xx,Ed,max} = 1,331 [kNm] M_{xx,Ed,max} = 1,256 [kNm]

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Positive Moment in y-y axis [M_{y,Ed}]

$I_{x,Ed}(\dots)$	43399,345	[mm ⁴]
$Z_{x,Ed}(\dots)$	2879,453	[mm ³]
$I_{y,Ed}(\dots)$	43399,345	[mm ⁴]
$Z_{y,Ed}(\dots)$	2879,453	[mm ³]

Section is fully effective

f_y	---	[MPa]
f_{yk}	378,145	[MPa]
$M_{Ed,Max}(\dots)$	1089,697,672	[Nmm]
$M_{Ed,Min}(\dots)$	1,087	[kNm]

Negative Moment in y-y axis [M_{y,Ed}]

$I_{x,Ed}(\dots)$	43399,345	[mm ⁴]
$Z_{x,Ed}(\dots)$	1851,197	[mm ³]
$I_{y,Ed}(\dots)$	43399,345	[mm ⁴]
$Z_{y,Ed}(\dots)$	1851,197	[mm ³]

Section is fully effective

f_y	---	[MPa]
f_{yk}	378,145	[MPa]
$M_{Ed,Max}(\dots)$	7000,049,991	[Nmm]
$M_{Ed,Min}(\dots)$	0,700	[kNm]

Table 1.6. Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Class	Reference	Capacity Reduction Factor [ϕ _c]
Member moment capacity. Member subject to lateral bracing	3,3,3,2		0,90

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$\lambda_y \geq 1,336$

$$M_c = M_y \left(\frac{1}{\lambda_y^2} \right)$$

[AS/NZS 4600, Eq. 3.3.2(8)]

Slenderness [λ_y]

$\lambda_y \leq 0,600$	$0,600 < \lambda_y < 1,336$	$\lambda_y \geq 1,336$
M_c	M_c	M_c
---	[Nmm]	[Nmm]

$f_c = M_c / Z_x$

[AS/NZS 4600, Eq. 3.3.2(2)]

$f_{c,Ed}$ 371,671 [MPa]

$M_c = Z_x \cdot f_c$ [AS/NZS 4600, Eq. 3.3.2(1)]

Z_x 3329,684 [mm³]

Slenderness [λ_y]

$\lambda_y \leq 0,600$	$0,600 < \lambda_y < 1,336$	$\lambda_y \geq 1,336$
M_c	M_c	M_c
---	[Nmm]	[Nmm]

$M_{c,Design}(\dots)$ 1,234 [kNm]

Singly-symmetric sections bending about the axis perpendicular to the axis of symmetry [y-y]

C_1

$C_1 = +1,000 \rightarrow$ Moment causing compression on the outer center side of centroid

$C_1 = -1,000 \rightarrow$ Moment causing tension on the outer center side of centroid

$f_{cr} = \frac{\pi^2 E}{(K_y L)^2}$

[AS/NZS 4600, Eq. 3.3.2(14)]

$f_{cr,Ed}$ 231,286 [N/mm²]

$\bar{A} = \frac{1}{I_y} \int (x^2 dA) - 2x_c$

[AS/NZS 4600, Eq. 3.3.2(16)]

β_y 42,216 [mm]

$C_{TF} = 0,6 - 0,4 (M_y / M_c)$

C_T 1,000

[AS/NZS 4600, Eq. 3.3.2(15)]

$$M_w = \frac{C_T \cdot f_{cr} \cdot \bar{A} \cdot (L_y / 2) + C_y \cdot \sqrt{\beta_y^2 + r_{01}^2 (f_{cr} / f_{cr,Ed})}}{C_{TF}}$$

[AS/NZS 4600, Eq. 3.3.2(13)]

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$M_y = Z_x \cdot f_c$ [AS/NZS 4600, Eq. 3.3.2(1)]

Singly, doubly and point-symmetric sections bending about the symmetry axis [x-x]

C_1

C_1 shall be permitted to be conservatively taken as unity for all cases.

For cantilevers or overhangs where the free end is unrestrained, C_1 shall be taken as unity

C_1 1,000

f_y 20,601 [MPa]

f_y 14,683 [MPa]

r_x -35,237 [mm]

r_y 0,900 [mm]

r_x 43,621 [mm]

$r_{ed} = \sqrt{r_x^2 + r_y^2 + r_z^2}$

[AS/NZS, Eq. 3.3.2(10)]

Z_x 3519,614 [mm³]

E 210,000 [GPa]

$f_{cr} = \frac{\pi^2 E}{(K_y L)^2}$

[AS/NZS 4600, Eq. 3.3.2(11)]

$f_{cr,Ed}$ 117,489 [N/mm²]

$f_{cr} = \frac{E I_y}{A r_{01}^2} \left(1 + \frac{\pi^2 E I_y}{C_y A r_{01}^2} \right)$

[AS/NZS 4600, Eq. 3.3.2(12)]

$f_{cr,Ed}$ 67,264 [N/mm²]

$M_c = C_{1b} A r_{01} \sqrt{f_{cr} f_{cr,Ed}}$

[AS/NZS 4600, Eq. 3.3.2(8)]

$M_{c,Ed}$ 79669,438 [MPa]

$M_y = Z_x \cdot f_c$ [AS/NZS 4600, Eq. 3.3.2(1)]

M_y 1231864,886 [Nmm]

$\lambda_b = \sqrt{\frac{M_y}{M_c}}$

[AS/NZS 4600, Eq. 3.3.2(7)]

λ_b 1,258 []

$\lambda_y \leq 0,600$

$M_c = M_y$

[AS/NZS 4600, Eq. 3.3.2(3)]

$0,600 < \lambda_y < 1,336$

$$M_c = 1,11 M_y \left[1 - \left(\frac{10 \lambda_y^2}{36} \right) \right]$$

[AS/NZS 4600, Eq. 3.3.2(4)]

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$M_{y,Ed}$ ---

$M_{y,Ed}$ ---

C_y 1,000

C_y -1,000

A	201,315	[mm ²]	r_x	43,621	[mm]
Z_x	2879,453	[mm ³]	Z_y	1851,197	[mm ³]
$f_{y,Ed}$	67,264	[N/mm ²]			

Slenderness

$M_{y,Ed}(\dots)$	2480084,644	[Nmm]	$M_{y,Ed}(\dots)$	486489,972	[Nmm]
M_y	1089708,619	[Nmm]	M_c	647,604,7887	[Nmm]
f_y	350,000	[MPa]	f_y	350,000	[MPa]

$\lambda_b = \sqrt{\frac{M_y}{M_c}}$

[AS/NZS 4600, Eq. 3.3.2(7)]

λ_b 0,639 []

λ_b 1,064 []

$\lambda_y \leq 0,600$

$M_c = M_y$

[AS/NZS 4600, Eq. 3.3.2(3)]

$0,600 < \lambda_y < 1,336$

$$M_c = 1,11 M_y \left[1 - \left(\frac{10 \lambda_y^2}{36} \right) \right]$$

[AS/NZS 4600, Eq. 3.3.2(4)]

$\lambda_y \geq 1,336$

$$M_c = M_y \left(\frac{1}{\lambda_y^2} \right)$$

[AS/NZS 4600, Eq. 3.3.2(8)]

Slenderness [λ_y]

$\lambda_y \leq 0,600$	$0,600 < \lambda_y < 1,336$	$\lambda_y \geq 1,336$
M_c	M_c	M_c
---	[Nmm]	[Nmm]

Slenderness [λ_y]

$\lambda_y \leq 0,600$	$0,600 < \lambda_y < 1,336$	$\lambda_y \geq 1,336$
M_c	M_c	M_c
---	[Nmm]	[Nmm]

$M_{c,Design}(\dots)$ 692,668,916 [Nmm]

$f_c = M_c / Z_x$

[AS/NZS 4600, Eq. 3.3.2(2)]

$f_{c,Ed}$ 384,599 [MPa]

$f_{c,Ed}$ 374,128 [MPa]

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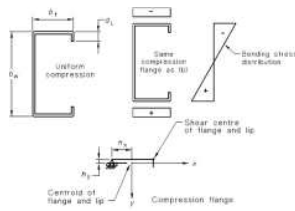
$M_x = Z_x \cdot f_t$ [AS/NZS 4600, Eq. 3.3.3.2(f)]																
Z_x	2873,453 [mm ³]	Z_y	1851,357 [mm ³]													
<table border="1"> <tr> <th colspan="3">S_{xx} M_{xx,Ed}</th> </tr> <tr> <td>$\lambda_p \leq 0,600$</td> <td>$0,600 < \lambda_p < 1,336$</td> <td>$\lambda_p \geq 1,336$</td> </tr> <tr> <td>$M_x$</td> <td></td> <td>$M_x$</td> </tr> <tr> <td>---</td> <td>[Nmm]</td> <td>110369,352 [Nmm]</td> <td>---</td> </tr> </table>				S _{xx} M _{xx,Ed}			$\lambda_p \leq 0,600$	$0,600 < \lambda_p < 1,336$	$\lambda_p \geq 1,336$	M_x		M_x	---	[Nmm]	110369,352 [Nmm]	---
S _{xx} M _{xx,Ed}																
$\lambda_p \leq 0,600$	$0,600 < \lambda_p < 1,336$	$\lambda_p \geq 1,336$														
M_x		M_x														
---	[Nmm]	110369,352 [Nmm]	---													
<table border="1"> <tr> <th colspan="3">S_{yy} M_{yy,Ed}</th> </tr> <tr> <td>$\lambda_p \leq 0,600$</td> <td>$0,600 < \lambda_p < 1,336$</td> <td>$\lambda_p \geq 1,336$</td> </tr> <tr> <td>$M_y$</td> <td></td> <td>$M_y$</td> </tr> <tr> <td>---</td> <td>[Nmm]</td> <td>62295,915 [Nmm]</td> <td>---</td> </tr> </table>				S _{yy} M _{yy,Ed}			$\lambda_p \leq 0,600$	$0,600 < \lambda_p < 1,336$	$\lambda_p \geq 1,336$	M_y		M_y	---	[Nmm]	62295,915 [Nmm]	---
S _{yy} M _{yy,Ed}																
$\lambda_p \leq 0,600$	$0,600 < \lambda_p < 1,336$	$\lambda_p \geq 1,336$														
M_y		M_y														
---	[Nmm]	62295,915 [Nmm]	---													
<table border="1"> <tr> <td>$M_{x,Ed,lim}$</td> <td>1,104 [kNm]</td> <td>$M_{y,Ed,lim}$</td> <td>0,593 [kNm]</td> </tr> </table>				$M_{x,Ed,lim}$	1,104 [kNm]	$M_{y,Ed,lim}$	0,593 [kNm]									
$M_{x,Ed,lim}$	1,104 [kNm]	$M_{y,Ed,lim}$	0,593 [kNm]													

[3] C-Section Steel: Member subject to Distortional Buckling [AS/NZS 4600, 3.3.3.3]

Table 1.6: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Class	Capacity Reduction Factor (ϕ_c)
Member moment capacity: Member subject to distortional buckling	3,3,3,3	0,900

$$M_y = Z_y \cdot f_t \quad [\text{AS/NZS 4600, Eq. 3.3.3.2(f)}]$$



Simple Liped Channel Model for Distortional Buckling [AS/NZS 4600, Figure D1]

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$$r_x = \frac{\sqrt{I_x (I_y + 0,039 I_x^2)}}{A} = 0,233 \quad []$$

$$r_y = \eta \left(r_1 I_x - \frac{\eta}{\beta_1} I_x^2 \beta_1^2 \right) = 0,269 \quad []$$

$$f_{cr} = \frac{\sigma_c}{\sqrt{1 + \eta \left(\frac{I_x}{I_y} + 0,039 \right)}} = 941,768 \quad [\text{MPa}]$$

Distortional buckling involves rotation of a flange, and tip about the flange web junction of a channel

K_x	1,661,393 [mm]	Z_x	Full section modulus
$Z_{x,Ed,lim}$	3320,364 [mm ³]	$Z_{y,Ed,lim}$	---

$M_x = Z_x f_t$	Z_x	3320,364 [mm ³]
[AS/NZS 4600, Eq. 3.3.3.2(f)]	M_x	1798193,159 [Nmm]

$\lambda_p = \sqrt{\frac{M_x}{M_{Ed}}}$	M_y	1162337,256 [Nmm]
[AS/NZS 4600, Eq. 3.3.3.2(g)]	λ_p	0,804 []

$\lambda_p \leq 0,674$	$\lambda_p > 0,674$
$M_x = M_y$	$M_x = M_y \left(1 - \frac{0,22}{\lambda_p} \right)$
[AS/NZS 4600, Eq. 3.3.3.3(c)]	[AS/NZS 4600, Eq. 3.3.3.3(d)]

$\lambda_p \leq 0,674$	$\lambda_p > 0,674$	
M_x	M_x	
---	1050239,643 [Nmm]	---

$f_t = M_x / Z_x$	f_t	316,264 [MPa]
[AS/NZS 4600, Eq. 3.3.3.2(f)]		

$M_y = Z_y f_t$	[AS/NZS 4600, Eq. 3.3.3.2(f)]
M_x	1050239,643 [Nmm]
M_y	1,050 [kNm]

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NOTE		Flanges with 90 Degree Lip		[AS/NZS 4600, D2]
b_w	50,000 [mm]	t	10,000 [mm]	
b_f	40,000 [mm]	t	1,652 [mm]	
A_x	72,800 [mm ²]	A_y	51,921 [mm ²]	
\bar{x}	24,000 [mm]	\bar{y}	421,604 [mm]	
\bar{y}	1,000 [mm]	\bar{x}	12392,451 [mm]	
E	210,000 [GPa]	I_{xx}	1161,800 [mm ⁴]	
$\lambda = 4,80 \sqrt{\frac{I_x b_w}{t}}$ [AS/NZS 4600, Eq. D2(f)]				
$\eta = \left(\frac{\pi}{\lambda} \right)^2$ [AS/NZS 4600, Eq. D2(f)]				
$\beta_1 = \bar{x}^2 + \left(\frac{I_x + I_y}{A} \right)$ [AS/NZS 4600, Eq. D2(f)]				
$r_x = \eta \left(I_x + \frac{2}{\beta_1} I_x^2 \right)$ [AS/NZS 4600, Eq. D2(f)]				
$r_y = \frac{\eta}{\beta_1} \left(I_x^2 + 0,039 I_x^3 \right)$ [AS/NZS 4600, Eq. D2(f)]				
$r_1 = \eta \left(r_1 I_x - \frac{\eta}{\beta_1} I_x^2 \beta_1^2 \right)$ [AS/NZS 4600, Eq. D2(f)]				
$f_{cr} = \frac{\sigma_c}{\sqrt{1 + \eta \left(\frac{I_x}{I_y} + 0,039 \right)}}$ [AS/NZS 4600, Eq. D2(f)]				
$K_x = \frac{M_x}{Z_x} = 1661,393$ [mm] [AS/NZS 4600, Eq. D2(f)]				

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Distortional Buckling involves transverse bending of a flange with lateral displacement of the compression flange		web	
$M_x = Z_x f_t$	Z_x	3320,364 [mm ³]	
[AS/NZS 4600, Eq. 3.3.3.2(f)]	M_x	1798193,159 [Nmm]	
$\lambda_p = \sqrt{\frac{M_x}{M_{Ed}}}$	M_y	1162337,256 [Nmm]	
[AS/NZS 4600, Eq. 3.3.3.2(g)]	λ_p	0,804 []	
$\lambda_p \leq 0,590$	$0,590 < \lambda_p \leq 1,700$	$\lambda_p > 1,700$	
$M_x = M_y$	$M_x = M_y \left(\frac{0,59}{\lambda_p} \right)$	$M_x = M_y \left(\frac{I_x}{I_y} \right)$	
[AS/NZS 4600, Eq. 3.3.3.3(c)]	[AS/NZS 4600, Eq. 3.3.3.3(e)]	[AS/NZS 4600, Eq. 3.3.3.3(f)]	
$\lambda_p \leq 0,590$	$0,590 < \lambda_p \leq 1,700$	$\lambda_p > 1,700$	
M_x	M_x	M_x	
---	853272,061 [Nmm]	---	
$f_t = M_x / Z_x$	f_t	256,317 [MPa]	
[AS/NZS 4600, Eq. 3.3.3.2(f)]			
	$Z_{x,Ed,lim}$	3320,364 [mm ³]	
$M_x = Z_x f_t$	[AS/NZS 4600, Eq. 3.3.3.2(f)]		
M_x	853272,061 [Nmm]		
M_y	0,853 [kNm]		
M_x	853272,061 [Nmm]	M_y	0,853 [kNm]

[4] C-Section Beam: Bending Moment Verification [AS/NZS 4600, LSD]

$M_x \leq \phi_c M_x$	[AS/NZS 4600, Eq. 3.3.3.1(f)]	$M_y \leq \phi_c M_y$	[AS/NZS 4600, Eq. 3.3.3.2(f)]
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Positive Moment (in kNm) | $M_{Ed,Ed}$

$M_{Ed,Ed}$	0,810 [kNm]	Ratio	1,372 [%]
$M_{Ed,Ed,lim}$	0,853 [kNm]		

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Negative Moment in x-axis [M_{xx}]

C-Section Size

M _{xx,Ed}	0.910 [kNm]	Ratio	1.002	%
M _{xx,Rd}	0.893 [kNm]			

Positive Moment in y-axis [M_{yy}]

C-Section Size

M _{yy,Ed}	0.900 [kNm]	Ratio	0.900	%
M _{yy,Rd}	1.007 [kNm]			

Negative Moment in y-axis [M_{zz}]

C-Section Size

M _{zz,Ed}	0.900 [kNm]	Ratio	0.900	%
M _{zz,Rd}	0.993 [kNm]			

[15.3] Shear [AISI S100, C3.2] [AS/NZS 4600, 3.3.4]

[*] D-Section Profile

[1] D-Section Profile: Shear [AISI S100, ASD]

[1] D-Section Profile: Shear Strength [Resistance] of Webs without Holes [AISI S100, C3.2.2]

Q _v	1.800	h _{we}	51.640 [mm]
v [μ]	0.300	l	0.952 [mm]
A _w = h * t	A _w 49.162 [mm ²]	Unreinforced Webs	
	[AISI S100, Eq. C3.2.2-5]	k _v	5.340
E	210.000 [GPa]	F _y	350.000 [MPa]

$$h/t \leq \sqrt{E k_v / F_y} \quad \sqrt{E k_v / F_y} < h/t \leq 1.51 \sqrt{E k_v / F_y} \quad h/t > 1.51 \sqrt{E k_v / F_y}$$

$$F_v = 0.60 * F_y \quad F_v = \frac{0.60 \sqrt{E k_v F_y}}{(h/t)} \quad F_v = \frac{\pi^2 E k_v}{12(1-\mu^2)(h/t)^2}$$

[AISI S100, Eq. C3.2.2-2] [AISI S100, Eq. C3.2.2-3] [AISI S100, Eq. C3.2.2-4]

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[10] D-Section Profile: Shear [AS/NZS 4600, LSD]

[1] D-Section Profile: Shear Strength [Resistance] of Webs without Holes [AS/NZS 4600, 3.3.4.1]

Table 1.5: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Design Reference	Capacity Reduction Factor	Factor
Web design: Shear	3.3.4	0.900	
d _v	51.640 [mm]	h _{we}	0.952 [mm]
Unstiffened Webs	k _v 5.340	v	0.300
E	210.000 [GPa]	f _y	350.000 [MPa]

$$d_v/t_w \leq \sqrt{E k_v / f_y} \quad d_v/t_w > 1.415 \sqrt{E k_v / f_y}$$

$$V_n = 0.6 F_y A_w \quad V_n = \frac{0.905 E k_v^2}{d_v}$$

[AS/NZS 4600, Eq. 3.3.4(1)] [AS/NZS 4600, Eq. 3.3.4(2)] [AS/NZS 4600, Eq. 3.3.4(3)]

$$\sqrt{E k_v / f_y} < d_v/t_w \leq 1.415 \sqrt{E k_v / f_y}$$

$$V_n = 0.6 A_w f_y \sqrt{E k_v / f_y}$$

[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 _n	110.1227 [kN]	φ _v	0.900	V _n	99.11 [kN/Web]
V _u	110.1227 [kN]	V _n	99.11 [kN/Web]	V _u	110.1227 [kN]

V' = φ_v V_n [AS/NZS 4600] V' 99.11 [kN/Web]

V _{u11}	1.010 [kN]	Ratio	0.900	%
V _u	10.022 [kN]			

[10] C-Section Beam

[1] C-Section Beam: Shear [AISI S100, ASD]

[1] C-Section Beam: Shear Strength [Resistance] of Webs without Holes [AISI S100, C3.2.2]

Q _v	1.800	h _{we}	112.956 [mm]
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$$h/t \leq \sqrt{E k_v / F_y} \quad \sqrt{E k_v / F_y} < h/t \leq 1.51 \sqrt{E k_v / F_y} \quad h/t > 1.51 \sqrt{E k_v / F_y}$$

F _v	F _v	F _v
210.000 [MPa]	---	10.324 [kN/Web]

$$V_n = A_w F_v \quad V_n 10.324 [kN/Web]$$

V _{u11}	1.010 [kN]	Ratio	7.248	%
V _u	20.648 [kN]			

[10] D-Section Profile: Shear [AISI S100, LRFD]

[1] D-Section Profile: Shear Strength [Resistance] of Webs without Holes [AISI S100, C3.2.2]

Q _v	0.950	h _{we}	51.640 [mm]
v [μ]	0.300	l	0.952 [mm]
A _w = h * t	A _w 49.162 [mm ²]	Unreinforced Webs	
	[AISI S100, Eq. C3.2.2-5]	k _v	5.340
E	210.000 [GPa]	F _y	350.000 [MPa]

$$h/t \leq \sqrt{E k_v / F_y} \quad \sqrt{E k_v / F_y} < h/t \leq 1.51 \sqrt{E k_v / F_y} \quad h/t > 1.51 \sqrt{E k_v / F_y}$$

$$F_v = 0.60 * F_y \quad F_v = \frac{0.60 \sqrt{E k_v F_y}}{(h/t)} \quad F_v = \frac{\pi^2 E k_v}{12(1-\mu^2)(h/t)^2}$$

[AISI S100, Eq. C3.2.2-2] [AISI S100, Eq. C3.2.2-3] [AISI S100, Eq. C3.2.2-4]

$$h/t \leq \sqrt{E k_v / F_y} \quad \sqrt{E k_v / F_y} < h/t \leq 1.51 \sqrt{E k_v / F_y} \quad h/t > 1.51 \sqrt{E k_v / F_y}$$

F _v	F _v	F _v
210.000 [MPa]	---	10.324 [kN/Web]

$$V_n = A_w F_v \quad V_n 10.324 [kN/Web]$$

V _{u11}	1.010 [kN]	Ratio	5.149	%
V _u	20.648 [kN]			

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v [μ]	0.300	l	1.452 [mm]
A _w = h * t	A _w 162.263 [mm ²]	Unreinforced Webs	
	[AISI S100, Eq. C3.2.2-5]	k _v	5.340
E	210.000 [GPa]	F _y	350.000 [MPa]

$$h/t \leq \sqrt{E k_v / F_y} \quad \sqrt{E k_v / F_y} < h/t \leq 1.51 \sqrt{E k_v / F_y} \quad h/t > 1.51 \sqrt{E k_v / F_y}$$

$$F_v = 0.60 * F_y \quad F_v = \frac{0.60 \sqrt{E k_v F_y}}{(h/t)} \quad F_v = \frac{\pi^2 E k_v}{12(1-\mu^2)(h/t)^2}$$

[AISI S100, Eq. C3.2.2-2] [AISI S100, Eq. C3.2.2-3] [AISI S100, Eq. C3.2.2-4]

$$h/t \leq \sqrt{E k_v / F_y} \quad \sqrt{E k_v / F_y} < h/t \leq 1.51 \sqrt{E k_v / F_y} \quad h/t > 1.51 \sqrt{E k_v / F_y}$$

F _v	F _v	F _v
---	193.071057 [MPa]	---

$$V_n = A_w F_v \quad V_n 25.041 [kN]$$

V _{u11}	2.050 [kN]	Ratio	12.260	%
V _u	25.041 [kN]			

[10] C-Section Beam: Shear [AISI S100, LRFD]

[1] C-Section Beam: Shear Strength [Resistance] of Webs without Holes [AISI S100, C3.2.2]

Q _v	0.950	h _{we}	112.956 [mm]
v [μ]	0.300	l	1.452 [mm]
A _w = h * t	A _w 162.263 [mm ²]	Unreinforced Webs	
	[AISI S100, Eq. C3.2.2-5]	k _v	5.340
E	210.000 [GPa]	F _y	350.000 [MPa]

$$h/t \leq \sqrt{E k_v / F_y} \quad \sqrt{E k_v / F_y} < h/t \leq 1.51 \sqrt{E k_v / F_y} \quad h/t > 1.51 \sqrt{E k_v / F_y}$$

$$F_v = 0.60 * F_y \quad F_v = \frac{0.60 \sqrt{E k_v F_y}}{(h/t)} \quad F_v = \frac{\pi^2 E k_v}{12(1-\mu^2)(h/t)^2}$$

[AISI S100, Eq. C3.2.2-2] [AISI S100, Eq. C3.2.2-3] [AISI S100, Eq. C3.2.2-4]

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$$\frac{h}{t} \leq \sqrt{E k_v / F_y} \quad \sqrt{E k_v / F_y} < h/t \leq 1.51 \sqrt{E k_v / F_y} \quad h/t > 1.51 \sqrt{E k_v / F_y}$$

F_v	---	F_v	---	F_v	---
---	[MPa]	153.9721057	[MPa]	---	[MPa]

$V_n = A_w F_v$ [AISI S100, Eq. C3.2.1-1] $V_n = 25.961$ [kN]

V_{nt}	2.900	[kN]	Ratio	0.401	[%]
V_n	25.961	[kN]			

[8] 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 (ϕ)	Factor
Web design - Shear	3.3.4	0.90	

d	112.096	[mm]	t_w	1.952	[mm]
-----	---------	------	-------	-------	------

Unreinforced Webs $k_v = 5.340$ $v = 0.300$

E	210.000	[GPa]	F_y	350.000	[MPa]
---	---------	-------	-------	---------	-------

$$\frac{d}{t_w} \leq \sqrt{E k_w / f_y} \quad \frac{d}{t_w} > 1.415 \sqrt{E k_w / f_y}$$

$$V_n = 0.64 \cdot f_y \cdot d \cdot t_w \quad V_n = \frac{0.905 E k_w t_w^2}{d}$$
[AIS/NZS 4600, Eq. 3.3.4(1)] [AS/NZS 4600, Eq. 3.3.4(3)]

$$\sqrt{E k_w / f_y} < d/t_w \leq 1.415 \sqrt{E k_w / f_y}$$

$$V_n = 0.64 t_w^2 \sqrt{E k_w f_y}$$
[AIS/NZS 4600, Eq. 3.3.4(2)]

---	[N]	26731.75701	[N]	---	[N]
-----	-----	-------------	-----	-----	-----

$V = \phi_n V_n$ [AS/NZS 4600] $V = 24.959$ [kN]

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$$\frac{h}{t} \leq \sqrt{E k_v / F_y} \quad \sqrt{E k_v / F_y} < h/t \leq 1.51 \sqrt{E k_v / F_y} \quad h/t > 1.51 \sqrt{E k_v / F_y}$$

F_v	---	F_v	---	F_v	---
---	[MPa]	---	[MPa]	---	[MPa]

$V_n = A_w F_v$ [AISI S100, Eq. C3.2.1-1] $V_n = 41.243$ [kN]

V_{nt}	2.240	[kN]	Ratio	5.717	[%]
V_n	41.243	[kN]			

[8] 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 (ϕ)	Factor
Web design - Shear	3.3.4	0.90	

d	80.096	[mm]	t_w	2.452	[mm]
-----	--------	------	-------	-------	------

Unreinforced Webs $k_v = 5.340$ $v = 0.300$

E	210.000	[GPa]	F_y	350.000	[MPa]
---	---------	-------	-------	---------	-------

$$\frac{d}{t_w} \leq \sqrt{E k_w / f_y} \quad \frac{d}{t_w} > 1.415 \sqrt{E k_w / f_y}$$

$$V_n = 0.64 \cdot f_y \cdot d \cdot t_w \quad V_n = \frac{0.905 E k_w t_w^2}{d}$$
[AIS/NZS 4600, Eq. 3.3.4(1)] [AS/NZS 4600, Eq. 3.3.4(3)]

$$\sqrt{E k_w / f_y} < d/t_w \leq 1.415 \sqrt{E k_w / f_y}$$

$$V_n = 0.64 t_w^2 \sqrt{E k_w f_y}$$
[AIS/NZS 4600, Eq. 3.3.4(2)]

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V_{nt}	2.900	[kN]	Ratio	0.313	[%]
V	24.959	[kN]			

[8] C-Section Column - Shear [AISI S100, ASD]

[1] C-Section Column - Shear Strength Resistance [of Webs without Holes] [AISI S100, C3.2.1]

D_n	1.900		t_{pmax}	80.096	[mm]
-------	-------	--	------------	--------	------

$v/p = 0.300$ $t = 2.952$ [mm]

$A_w = h \cdot t$	A_w	196.295	[mm ²]	Unreinforced Webs
				$k_v = 5.340$

E	210.000	[GPa]	F_y	350.000	[MPa]
---	---------	-------	-------	---------	-------

$$\frac{h}{t} \leq \sqrt{E k_v / F_y} \quad \sqrt{E k_v / F_y} < h/t \leq 1.51 \sqrt{E k_v / F_y} \quad h/t > 1.51 \sqrt{E k_v / F_y}$$

$$F_v = 0.60 \cdot F_y \quad F_v = \frac{0.60 \sqrt{E k_v F_y}}{(h/t)} \quad F_v = \frac{\pi^2 E k_v}{12(1-\mu^2)(h/t)^2}$$
[AISI S100, Eq. C3.2.1-2] [AISI S100, Eq. C3.2.1-3] [AISI S100, Eq. C3.2.1-4]

$$\frac{h}{t} \leq \sqrt{E k_v / F_y} \quad \sqrt{E k_v / F_y} < h/t \leq 1.51 \sqrt{E k_v / F_y} \quad h/t > 1.51 \sqrt{E k_v / F_y}$$

F_v	---	F_v	---	F_v	---
210.000	[MPa]	---	[MPa]	---	[MPa]

$V_n = A_w F_v$ [AISI S100, Eq. C3.2.1-1] $V_n = 41.240$ [kN]

V_{nt}	2.240	[kN]	Ratio	5.695	[%]
V_n	41.243	[kN]			

[8] C-Section Column - Shear [AISI S100, LRFD]

[1] C-Section Column - Shear Strength Resistance [of Webs without Holes] [AISI S100, C3.2.1]

D_n	0.950		t_{pmax}	80.096	[mm]
-------	-------	--	------------	--------	------

$v/p = 0.300$ $t = 2.952$ [mm]

$A_w = h \cdot t$	A_w	196.295	[mm ²]	Unreinforced Webs
				$k_v = 5.340$

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V_{nt}	2.240	[kN]	Ratio	5.695	[%]
V	39.593	[kN]			

[8] C-Section Beam - Shear [AISI S100, ASD]

[1] C-Section Beam - Shear Strength Resistance [of Webs without Holes] [AISI S100, C3.2.1]

D_n	1.900		t_{pmax}	42.096	[mm]
-------	-------	--	------------	--------	------

$v/p = 0.300$ $t = 1.952$ [mm]

$A_w = h \cdot t$	A_w	61.123	[mm ²]	Unreinforced Webs
				$k_v = 5.340$

E	210.000	[GPa]	F_y	350.000	[MPa]
---	---------	-------	-------	---------	-------

$$\frac{h}{t} \leq \sqrt{E k_v / F_y} \quad \sqrt{E k_v / F_y} < h/t \leq 1.51 \sqrt{E k_v / F_y} \quad h/t > 1.51 \sqrt{E k_v / F_y}$$

$$F_v = 0.60 \cdot F_y \quad F_v = \frac{0.60 \sqrt{E k_v F_y}}{(h/t)} \quad F_v = \frac{\pi^2 E k_v}{12(1-\mu^2)(h/t)^2}$$
[AISI S100, Eq. C3.2.1-2] [AISI S100, Eq. C3.2.1-3] [AISI S100, Eq. C3.2.1-4]

$$\frac{h}{t} \leq \sqrt{E k_v / F_y} \quad \sqrt{E k_v / F_y} < h/t \leq 1.51 \sqrt{E k_v / F_y} \quad h/t > 1.51 \sqrt{E k_v / F_y}$$

F_v	---	F_v	---	F_v	---
210.000	[MPa]	---	[MPa]	---	[MPa]

$V_n = A_w F_v$ [AISI S100, Eq. C3.2.1-1] $V_n = 12.836$ [kN]

V_{nt}	0.220	[kN]	Ratio	0.249	[%]
V	12.835	[kN]			

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[8] C-Section Steel: Shear [AISI S100, LRFD]

[1] C-Section Steel: Shear Strength Resistance of Webs without Holes [AISI S100, C3.2]

$\phi_w = 0,950$ $t_{yw} = 42,096$ [mm]

$v = 1,0$ $l = 1,952$ [mm]

$A_w = h \cdot t_w$ $A_w = 61,233$ [mm²] **Unreinforced Webs**

$k_v = 5,340$

$E = 210,000$ [GPa] $F_y = 350,000$ [MPa]

$h/t_w \leq \sqrt{E k_v / F_y}$ $\sqrt{E k_v / F_y} < h/t_w \leq 1,51 \sqrt{E k_v / F_y}$ $h/t_w > 1,51 \sqrt{E k_v / F_y}$

$F_v = 0,60 \cdot F_y$ $F_v = \frac{0,60 \sqrt{E k_v F_y}}{(h/t_w)}$ $F_v = \frac{n^2 E k_v}{12(1-\mu^2)(h/t_w)^2}$

[AISI S100, Eq. C3.2.1-2] [AISI S100, Eq. C3.2.1-3] [AISI S100, Eq. C3.2.1-4]

$F_v = 210,000$ [MPa] $F_v =$ $F_v =$ [MPa] $F_v =$ [MPa]

$V_n = A_w F_v$ [AISI S100, Eq. C3.2.1-1] $V_n = 12,836$ [kN]

$V_{nt} = 0,920$ [kN] **Relio = 0,64** [%]

$V_n = 12,836$ [kN]

[9] C-Section Steel: Shear [AS/NZS 4600, LSD]

[1] C-Section Steel: Shear Strength Resistance of Webs without Holes [AS/NZS 4600, 3.3.4]

Table 1.6. Capacity Reduction Factor [AS/NZS 4600, 2005]

Design Capacity	Class Reference	Capacity Reduction ϕ	Factor	
Web design: Shear	3.3.4	0,950		
t_w	42,096 [mm]	t_w	1,952 [mm]	
Unstiffened Webs	k_v	5,340	v	0,950
E	210,000 [GPa]	F_y	350,000 [MPa]	

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[8] D-Section Profile: Combined Bending and Shear [AISI S100, LRFD]

[1] D-Section Profile: Combined Bending and Shear | LRFD Method [AISI S100, C3.2]

$M_{tension} = 0,360$ [kNm] **Relio = 69,288** [%]

$M_{compression} = 0,996$ [kNm]

$V_{nt} = 1,010$ [kN]

$V_n = 20,648$ [kN]

$M_{tension} = 0,360$ [kNm] **Relio = 49,834** [%]

$M_{compression} = 1,222$ [kNm]

$V_{nt} = 1,010$ [kN]

$V_n = 20,648$ [kN]

$\sqrt{\left(\frac{M}{\phi_b M_{ntxo}}\right)^2 + \left(\frac{V}{\phi_v V_n}\right)^2} \leq 1,0$

Unreinforced Webs [AISI S100, Eq. C3.2.1]

$M_{tension} = 0,360$ [kNm] **Relio = 38,560** [%]

$M_{compression} = 0,996$ [kNm]

$V_{nt} = 1,010$ [kN]

$V_n = 20,648$ [kN]

$M_{tension} = 0,360$ [kNm] **Relio = 37,021** [%]

$M_{compression} = 1,222$ [kNm]

$V_{nt} = 1,010$ [kN]

$V_n = 20,648$ [kN]

$\sqrt{\left(\frac{M}{\phi_b M_{ntxo}}\right)^2 + \left(\frac{V}{\phi_v V_n}\right)^2} \leq 1,0$

Unreinforced Webs [AISI S100, Eq. C3.2.1]

$M_{tension} = 0,360$ [kNm] **Relio = 39,407** [%]

$M_{compression} = 0,996$ [kNm]

$V_{nt} = 1,010$ [kN]

$V_n = 20,648$ [kN]

$M_{tension} = 0,360$ [kNm] **Relio = 37,448** [%]

$M_{compression} = 1,222$ [kNm]

$V_{nt} = 1,010$ [kN]

$V_n = 20,648$ [kN]

Design of a Photovoltaic Structure, Partial configuration, according to AISI or AS/NZS		Office: ---	Author: JOSE ANTONIO
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	

$d/t_w \leq \sqrt{E k_v / f_y}$ $d/t_w > 1,415 \sqrt{E k_v / f_y}$

$V_n = 0,64 \cdot F_y \cdot A_w$ $F_v = \frac{0,905 E k_v t_w^2}{d}$

[AS/NZS 4600, Eq. 3.3.4(1)] [AS/NZS 4600, Eq. 3.3.4(3)]

$\sqrt{E k_v / f_y} < d/t_w \leq 1,415 \sqrt{E k_v / f_y}$

$V_n = 0,64 t_w^2 \sqrt{E k_v f_y}$

[AS/NZS 4600, Eq. 3.3.4(1)] [AS/NZS 4600, Eq. 3.3.4(2)] [AS/NZS 4600, Eq. 3.3.4(3)]

$V_n = 19,697,640$ [N] $V_n =$ [N] $V_n =$ [N]

$V' = \phi_w V_n$ [AS/NZS 4600] $V' = 12,322$ [kN]

$V_{nt} = 0,920$ [kN] **Relio = 0,762** [%]

$V' = 12,322$ [kN]

[15.4] Combined Bending and Shear [AISI S100, C3.1 | AS/NZS 4600, 3.3.5]

[*] D-Section Profile

[1] D-Section Profile: Combined Bending and Shear [AISI S100, ASD]

[1] D-Section Profile: Combined Bending and Shear | ASD Method [AISI S100, C3.2]

$M_{tension} = 0,360$ [kNm] **Relio = 60,383** [%]

$M_{compression} = 0,996$ [kNm]

$V_{nt} = 1,010$ [kN]

$V_n = 20,648$ [kN]

$M_{tension} = 0,360$ [kNm] **Relio = 49,215** [%]

$M_{compression} = 1,222$ [kNm]

$V_{nt} = 1,010$ [kN]

$V_n = 20,648$ [kN]

$\sqrt{\left(\frac{\Omega_b M}{M_{ntxo}}\right)^2 + \left(\frac{\Omega_v V}{V_n}\right)^2} \leq 1,0$

Unreinforced Webs [AISI S100, Eq. C3.2.1]

Design of a Photovoltaic Structure, Partial configuration, according to AISI or AS/NZS		Office: ---	Author: JOSE ANTONIO
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	

[8] D-Section Profile: Combined Bending and Shear [AS/NZS 4600, LSD]

[1] D-Section Profile: Combined Bending and Shear [AS/NZS 4600, 3.3.5]

$M_{tension} = 0,360$ [kNm] **Relio = 48,375** [%]

$M_{compression} = 0,996$ [kNm]

$V_{nt} = 1,010$ [kN]

$V_n = 20,648$ [kN]

$M_{tension} = 0,360$ [kNm] **Relio = 32,745** [%]

$M_{compression} = 1,222$ [kNm]

$V_{nt} = 1,010$ [kN]

$V_n = 19,822$ [kN]

$\sqrt{\left(\frac{M}{\phi_b M_s}\right)^2 + \left(\frac{V}{\phi_v V_n}\right)^2} \leq 1,0$

Unreinforced Webs [AS/NZS 4600, Eq. 3.3.5(1)]

$M_{tension} = 0,360$ [kNm] **Relio = 18,400** [%]

$M_{compression} = 0,996$ [kNm]

$V_{nt} = 1,010$ [kN]

$V_n = 22,024$ [kN]

$M_{tension} = 0,360$ [kNm] **Relio = 19,882** [%]

$M_{compression} = 1,222$ [kNm]

$V_{nt} = 1,010$ [kN]

$V_n = 22,024$ [kN]

[9] C-Section Beam

[1] C-Section Beam: Combined Bending and Shear [AISI S100, ASD]

[1] C-Section Beam: Combined Bending and Shear | ASD Method [AISI S100, C3.2]

$M_{tension} = 0,360$ [kNm] **Relio = 33,256** [%]

$M_{compression} = 0,996$ [kNm]

$V_{nt} = 1,010$ [kN]

$V_n = 20,648$ [kN]

$M_{tension} = 0,360$ [kNm] **Relio = 33,205** [%]

$M_{compression} = 1,222$ [kNm]

$V_{nt} = 1,010$ [kN]

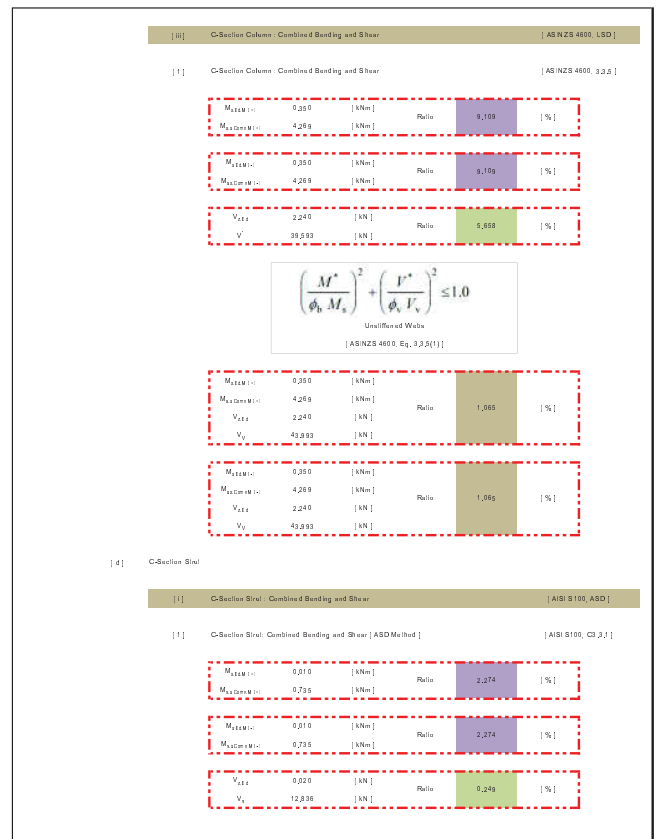
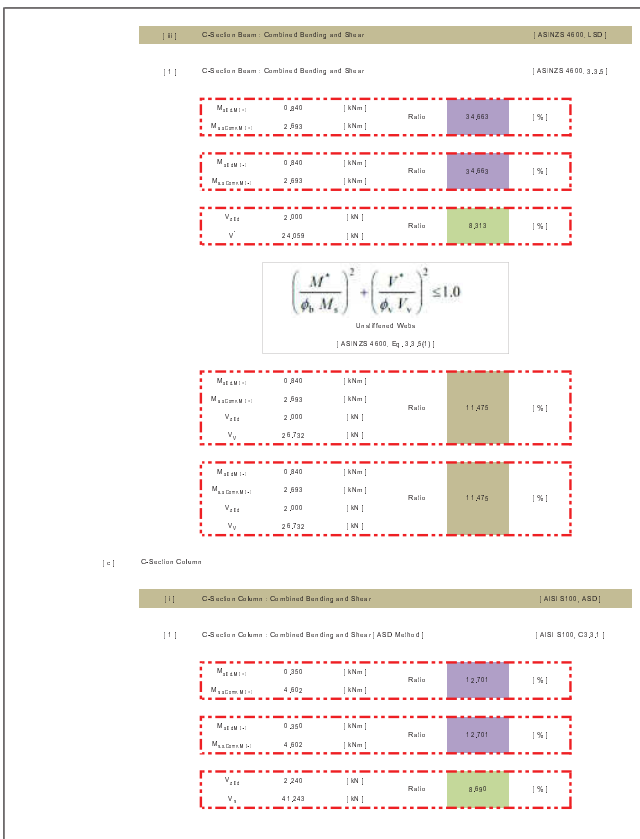
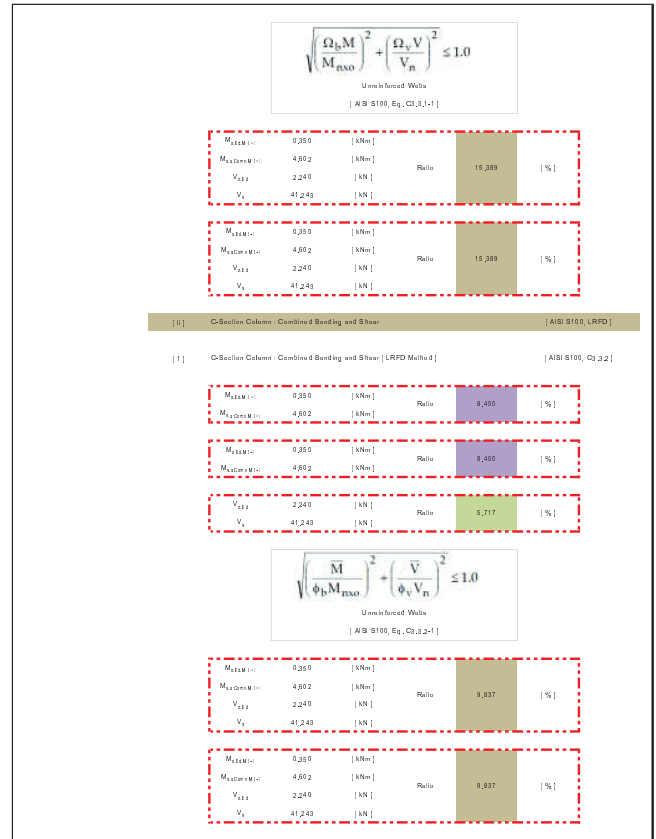
$V_n = 20,648$ [kN]

$M_{tension} = 0,360$ [kNm] **Relio = 12,759** [%]

$M_{compression} = 1,222$ [kNm]

$V_{nt} = 1,010$ [kN]

$V_n = 20,648$ [kN]



$$\sqrt{\left(\frac{\Omega_b M}{M_{RNSO}}\right)^2 + \left(\frac{\Omega_v V}{V_n}\right)^2} \leq 1.0$$

Unreinforced Webs
[AISI S100, Eq. C3.3.1-1]

$M_{Ed,Ed1(1)}$	0,910 [kNm]		
$M_{Ed,Ed1(1)}$	0,735 [kNm]	Ratio	2,287 [%]
$V_{Ed,Ed1(1)}$	0,920 [kN]		
V_n	12,836 [kN]		

$M_{Ed,Ed2(1)}$	0,920 [kNm]		
$M_{Ed,Ed2(1)}$	12,836 [kNm]	Ratio	0,360 [%]
$V_{Ed,Ed2(1)}$	0,920 [kN]		
V_n	12,836 [kN]		

[0] C-Section Steel: Combined Bending and Shear [AISI S100, LRFD]

[1] C-Section Steel: Combined Bending and Shear [LRFD Method] [AISI S100, C3.2]

$$\sqrt{\left(\frac{M}{\phi_b M_{RNSO}}\right)^2 + \left(\frac{V}{\phi_v V_n}\right)^2} \leq 1.0$$

Unreinforced Webs
[AISI S100, Eq. C3.3.2-1]

$M_{Ed,Ed1(1)}$	0,910 [kNm]		
$M_{Ed,Ed1(1)}$	0,735 [kNm]	Ratio	1,913 [%]
$V_{Ed,Ed1(1)}$	0,920 [kN]		
V_n	12,836 [kN]		

$M_{Ed,Ed2(1)}$	0,910 [kNm]		
$M_{Ed,Ed2(1)}$	0,735 [kNm]	Ratio	1,913 [%]
$V_{Ed,Ed2(1)}$	0,920 [kN]		
V_n	12,836 [kN]		

$M_{Ed,Ed1(1)}$	0,910 [kNm]		
$M_{Ed,Ed1(1)}$	0,735 [kNm]	Ratio	1,442 [%]
$V_{Ed,Ed1(1)}$	0,920 [kN]		
V_n	12,836 [kN]		

$M_{Ed,Ed2(1)}$	0,910 [kNm]		
$M_{Ed,Ed2(1)}$	0,735 [kNm]	Ratio	1,442 [%]
$V_{Ed,Ed2(1)}$	0,920 [kN]		
V_n	12,836 [kN]		

t	0,952 [mm]	Φ	78,393 [°]
$f_{y,Ed1(1)}$	350,000 [MPa]	$f_{y,Ed1(1)}$	--- [MPa]
$f_{y,Ed1(1)}$	--- [MPa]	$f_{y,Ed1(1)}$	350,389 [MPa]
R	1,500 [mm]	h	54,593 [mm]

Support Conditions: Fastened to Support

Load Cases: One-Flange Loading or Reaction

End Loading or Reaction: $\Phi_n = 2,000$

C	C_b	C_t	C_v
4,000	0,250	0,850	0,040

P_n	2278,954 [N]	P_n	2279 [kN]
-------	--------------	-------	-----------

$V_{Ed,Ed1(1)}$	1,010 [kN]	Ratio	88,937 [%]
P_n	2279 [kN]		

[0] D-Section Profile: Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, LRFD]

[1] D-Section Profile: Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, C3.4]

$$P_n = C_t^2 F_y \sin \theta \left(1 - C_R \sqrt{\frac{R}{t}} \right) \left(1 + C_N \sqrt{\frac{N}{t}} \right) \left(1 - C_h \sqrt{\frac{h}{t}} \right)$$

[AISI S100, Eq. C3.4.1-1]

t	0,952 [mm]	Φ	78,393 [°]
$f_{y,Ed1(1)}$	350,000 [MPa]	$f_{y,Ed1(1)}$	--- [MPa]
$f_{y,Ed1(1)}$	--- [MPa]	$f_{y,Ed1(1)}$	350,389 [MPa]
R	1,500 [mm]	h	54,593 [mm]

Support Conditions: Fastened to Support

Load Cases: One-Flange Loading or Reaction

End Loading or Reaction: $\Phi_n = 0,750$

C	C_b	C_t	C_v
4,000	0,250	0,850	0,040

P_n	2278,954 [N]	P_n	2279 [kN]
-------	--------------	-------	-----------

[0] C-Section Steel: Combined Bending and Shear [AS/NZS 4600, LSD]

[1] C-Section Steel: Combined Bending and Shear [AS/NZS 4600, 3.2.6]

$M_{Ed,Ed1(1)}$	0,910 [kNm]		
$M_{Ed,Ed1(1)}$	0,853 [kNm]	Ratio	1,302 [%]
$V_{Ed,Ed1(1)}$	0,920 [kN]		
V_n	12,822 [kN]		

$M_{Ed,Ed2(1)}$	0,910 [kNm]		
$M_{Ed,Ed2(1)}$	0,853 [kNm]	Ratio	1,302 [%]
$V_{Ed,Ed2(1)}$	0,920 [kN]		
V_n	12,822 [kN]		

$$\sqrt{\left(\frac{M^*}{\phi_b M_n^*}\right)^2 + \left(\frac{V^*}{\phi_v V_n^*}\right)^2} \leq 1.0$$

Unreinforced Webs
[AS/NZS 4600, Eq. 3.2.5(1)]

$M_{Ed,Ed1(1)}$	0,910 [kNm]		
$M_{Ed,Ed1(1)}$	0,853 [kNm]	Ratio	0,915 [%]
$V_{Ed,Ed1(1)}$	0,920 [kN]		
V_n	13,892 [kN]		

$M_{Ed,Ed2(1)}$	0,910 [kNm]		
$M_{Ed,Ed2(1)}$	0,853 [kNm]	Ratio	0,915 [%]
$V_{Ed,Ed2(1)}$	0,920 [kN]		
V_n	13,892 [kN]		

[15.5] Web Crippling [AISI S100, C3.4] [AS/NZS 4600, 3.2.6]

[1] D-Section Profile

[1] D-Section Profile: Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, ASD]

[1] D-Section Profile: Web Crippling Strength [Resistance] of Webs without Holes [AISI S100, C3.4.1]

$$P_n = C_t^2 F_y \sin \theta \left(1 - C_R \sqrt{\frac{R}{t}} \right) \left(1 + C_N \sqrt{\frac{N}{t}} \right) \left(1 - C_h \sqrt{\frac{h}{t}} \right)$$

[AISI S100, Eq. C3.4.1-1]

$V_{Ed,Ed1(1)}$	1,010 [kN]	Ratio	59,081 [%]
P_n	2279 [kN]		

[0] D-Section Profile: Bearing [Web Crippling Strength] of Webs without Holes [AS/NZS 4600, LSD]

D-Section Profile: Bearing [Web Crippling Strength] of Webs without Holes [AS/NZS 4600, 3.2.6]

$$R_b \leq \phi_b \cdot R_n$$

[AS/NZS 4600, Eq. 3.2.6(1)]

Table 3.2: Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Clause Reference	Capacity Reduction [ϕ_b]	Factor
Bearing: Single Hat Sections	Table 3.2.6(2)	0,750 - 0,900	

$$R_n = C_t^2 f_y \sin \theta \left(1 - C_t \sqrt{\frac{R}{t_w}} \right) \left(1 + C_f \sqrt{\frac{f_w}{t_w}} \right) \left(1 - C_w \sqrt{\frac{d_f}{t_w}} \right)$$

[AS/NZS 4600, Eq. 3.2.6.2]

t_w	0,952 [mm]	Φ	78,393 [°]
$f_{y,Ed1(1)}$	350,000 [MPa]	$f_{y,Ed1(1)}$	--- [MPa]
$f_{y,Ed1(1)}$	--- [MPa]	$f_{y,Ed1(1)}$	350,389 [MPa]
R	1,500 [mm]	d_f	54,593 [mm]

Support Conditions: Fastened to Support

Load Cases: One-Flange Loading or Reaction

End Loading or Reaction: $\Phi_n = 0,750$

C	C_b	C_t	C_v
4,000	0,250	0,850	0,040

R_b	2278,954 [N]	R_b	2279 [kN]
-------	--------------	-------	-----------

$V_{Ed,Ed1(1)}$	1,010 [kN]	Ratio	59,081 [%]
R_b	2279 [kN]		

[0] C-Section Beam

[1] 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]

$$P_n = C_t^2 F_y \sin \theta \left(1 - C_R \sqrt{\frac{R}{t}} \right) \left(1 + C_N \sqrt{\frac{N}{t}} \right) \left(1 - C_h \sqrt{\frac{h}{t}} \right)$$

[AISI S100, Eq. C3.2.1-1]

t	1,452	[mm]	Φ	90,000	[°]
F _{ymin}	---	[MPa]	F _{ymin}	374,390	[MPa]
F _{ymax}	---	[MPa]	F _{ymax}	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: → Φ_n 1,850

C	C _n	C _h	C _t
4,900	0,140	0,350	0,920

P _n	4634,307	[N]	P _n	4,634	[kN]
V _{rel}	2,900	[kN]	Ratio	79,839	[%]
P _n	4,634	[kN]			

[0] 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, CL 2.1]

$$P_n = C_t^2 F_y \sin \theta \left(1 - C_R \sqrt{\frac{R}{t}} \right) \left(1 + C_N \sqrt{\frac{N}{t}} \right) \left(1 - C_h \sqrt{\frac{h}{t}} \right)$$

[AISI S100, Eq. C3.2.1-1]

t	1,452	[mm]	Φ	90,000	[°]
F _{ymin}	---	[MPa]	F _{ymin}	374,390	[MPa]
F _{ymax}	---	[MPa]	F _{ymax}	374,390	[MPa]
R	2,500	[mm]	h	112,096	[mm]

[Previous Page]

End Loading or Reaction: → Φ_n 0,800

C	C _n	C _h	C _t
4,900	0,140	0,350	0,920

P _n	4634,307	[N]	P _n	4,634	[kN]
V _{rel}	2,900	[kN]	Ratio	53,845	[%]
P _n	4,634	[kN]			

[0] 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, CL 2.1]

$$P_n = C_t^2 F_y \sin \theta \left(1 - C_R \sqrt{\frac{R}{t}} \right) \left(1 + C_N \sqrt{\frac{N}{t}} \right) \left(1 - C_h \sqrt{\frac{h}{t}} \right)$$

[AISI S100, Eq. C3.2.1-1]

t	2,452	[mm]	Φ	90,000	[°]
F _{ymin}	---	[MPa]	F _{ymin}	388,471	[MPa]
F _{ymax}	---	[MPa]	F _{ymax}	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_n 1,250

C	C _n	C _h	C _t
7,500	0,080	0,200	0,940

P _n	17101,535	[N]	P _n	17,102	[kN]
V _{rel}	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_n 0,800

C	C _n	C _h	C _t
4,900	0,140	0,350	0,920

P _n	4634,307	[N]	P _n	4,634	[kN]
V _{rel}	2,900	[kN]	Ratio	53,845	[%]
P _n	4,634	[kN]			

[0] 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]

$$R_n = C_t^2 F_y \sin \theta \left(1 - C_R \sqrt{\frac{R}{t}} \right) \left(1 + C_N \sqrt{\frac{N}{t}} \right) \left(1 - C_h \sqrt{\frac{h}{t}} \right)$$

[AS/NZS 4600, Eq. 3.3.6.2]

t _n	1,452	[mm]	Φ	90,000	[°]
f _{ymin}	---	[MPa]	f _{ymin}	374,390	[MPa]
f _{ymax}	---	[MPa]	f _{ymax}	374,390	[MPa]
t	2,500	[mm]	h	112,096	[mm]

Support: Unfastened

Flange: Stiffened or Partially Stiffened Flanges

Load Cases: One-Flange Loading or Reaction

[Next Page]

[0] 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, CL 2.1]

$$P_n = C_t^2 F_y \sin \theta \left(1 - C_R \sqrt{\frac{R}{t}} \right) \left(1 + C_N \sqrt{\frac{N}{t}} \right) \left(1 - C_h \sqrt{\frac{h}{t}} \right)$$

[AISI S100, Eq. C3.2.1-1]

t	2,452	[mm]	Φ	90,000	[°]
F _{ymin}	---	[MPa]	F _{ymin}	388,471	[MPa]
F _{ymax}	---	[MPa]	F _{ymax}	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_n 0,850

C	C _n	C _h	C _t
7,500	0,080	0,200	0,940

P _n	17101,535	[N]	P _n	17,102	[kN]
V _{rel}	2,240	[kN]	Ratio	15,410	[%]
P _n	17,102	[kN]			

[0] 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]

$$R_n = C_t^2 F_y \sin \theta \left(1 - C_R \sqrt{\frac{R}{t}} \right) \left(1 + C_N \sqrt{\frac{N}{t}} \right) \left(1 - C_h \sqrt{\frac{h}{t}} \right)$$

[AS/NZS 4600, Eq. 3.3.6.2]

t _n	1,452	[mm]	Φ	90,000	[°]
f _{ymin}	---	[MPa]	f _{ymin}	374,390	[MPa]
f _{ymax}	---	[MPa]	f _{ymax}	374,390	[MPa]
t	2,500	[mm]	h	112,096	[mm]

Support: Unfastened

Flange: Stiffened or Partially Stiffened Flanges

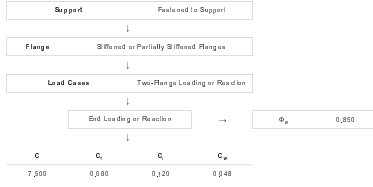
Load Cases: One-Flange Loading or Reaction

[Next Page]

$$R_b = C_{r1} f_y \sin \theta \left(1 - C_{r2} \sqrt{\frac{r_1}{r_w}} \right) \left(1 + C_{r3} \sqrt{\frac{r_2}{r_w}} \right) \left(1 - C_{r4} \sqrt{\frac{d_f}{r_w}} \right)$$

[AS/NZS 4600, Eq. 3.3.2.2]

r_w	2,452	[mm]	ϕ	90,000	[°]
f_{wy1}	---	[MPa]	f_{wy2}	389,471	[MPa]
f_{wy3}	---	[MPa]	f_{wy4}	389,471	[MPa]
r_1	2,500	[mm]	d_f	80,096	[mm]



C	C_1	C_2	C_3	C_4	
7,500	0,880	0,120	0,948		
R_b	171,01,535	[kN]	R_w	17,102	[kN]
V_{Ed}	2,240	[kN]	Ratio	15,410	[%]
R_b	17,102	[kN]			

[14] C-Section Beam

- [1] C-Section Beam: Web Crippling Strength | Resistance [of Webs without Holes] [AISI S100, ASD]
- [2] C-Section Beam: Web Crippling Strength | Resistance [of Webs without Holes] [AISI S100, LRFD]
- [3] C-Section Beam: Bearing | Web Crippling Strength | Resistance [of Webs without Holes] [AS/NZS 4600, LSD]

$$0,91 \left(\frac{P}{P_n} + \frac{M}{M_{tension}} \right) \leq 1,33 \phi$$

Unstiffened Webs
[AISI S100, Eq. C3.5.1.1]

M_{Ed1max}	0,380	[kNm]			
M_{Ed2max}	0,986	[kNm]	Ratio	101,883	[%]
V_{Ed}	1,010	[kN]			
P_b	2,279	[kN]			

M_{Ed1min}	0,380	[kNm]			
M_{Ed2min}	1,222	[kNm]	Ratio	93,867	[%]
V_{Ed}	1,010	[kN]			
P_b	2,279	[kN]			

[10] D-Section Profile: Combined Bending and Bearing [AS/NZS 4600, LSD]

[11] D-Section Profile: Combined Bending and Bearing | Web Crippling | LSD Method [AS/NZS 4600, 3.3.7]

M_{Ed1max}	0,380	[kNm]	Ratio	49,375	[%]
M_{Ed2max}	0,986	[kNm]			
M_{Ed1min}	0,380	[kNm]	Ratio	32,749	[%]
M_{Ed2min}	1,222	[kNm]			
V_{Ed}	1,010	[kN]	Ratio	59,091	[%]
R_b	2,279	[kN]			

$$1,07 \left(\frac{R'}{\phi_w K_b} + \frac{M'}{\phi_b M_r} \right) \leq 1,42$$

Unstiffened Webs
[AS/NZS 4600, Eq. 3.3.7(1)]

M_{Ed1max}	0,380	[kNm]	Ratio	103,493	[%]
M_{Ed2max}	0,986	[kNm]			
V_{Ed}	1,010	[kN]	Ratio	93,973	[%]
R_b	2,279	[kN]			

[15.6] Combined Bending and Web Crippling [AISI S100, C.3.5 | AS/NZS 4600, 3.3.7]

[*] D-Section Profile

- [1] D-Section Profile: Combined Bending and Web Crippling [AISI S100, ASD]
- [2] D-Section Profile: Combined Bending and Web Crippling | ASD Method [AISI S100, C3.5.1]

M_{Ed1max}	0,380	[kNm]	Ratio	69,383	[%]
M_{Ed2max}	0,986	[kNm]			
M_{Ed1min}	0,380	[kNm]	Ratio	49,215	[%]
M_{Ed2min}	1,222	[kNm]			
V_{Ed}	1,010	[kN]	Ratio	88,937	[%]
P_b	2,279	[kN]			

$$0,91 \left(\frac{P}{P_n} + \frac{M}{M_{tension}} \right) \leq \frac{1,33}{\Omega}$$

Unstiffened Webs
[AISI S100, Eq. C3.5.1.1]

M_{Ed1max}	0,380	[kNm]	Ratio	152,974	[%]
M_{Ed2max}	0,986	[kNm]			
V_{Ed}	1,010	[kN]	Ratio	139,800	[%]
P_b	2,279	[kN]			

[8] D-Section Profile: Combined Bending and Web Crippling [AISI S100, LRFD]

[1] D-Section Profile: Combined Bending and Web Crippling | LRFD Method [AISI S100, C3.5.2]

M_{Ed1max}	0,380	[kNm]	Ratio	39,060	[%]
M_{Ed2max}	0,986	[kNm]			
M_{Ed1min}	0,380	[kNm]	Ratio	31,021	[%]
M_{Ed2min}	1,222	[kNm]			
V_{Ed}	1,010	[kN]	Ratio	59,091	[%]
P_b	2,279	[kN]			

[9] C-Section Beam

- [1] C-Section Beam: Combined Bending and Web Crippling [AISI S100, ASD]
- [2] C-Section Beam: Combined Bending and Web Crippling | ASD Method [AISI S100, LRFD]

M_{Ed1max}	0,380	[kNm]	Ratio	33,205	[%]
M_{Ed2max}	4,225	[kNm]			
M_{Ed1min}	0,840	[kNm]	Ratio	33,205	[%]
M_{Ed2min}	4,225	[kNm]			
V_{Ed}	2,000	[kN]	Ratio	79,839	[%]
P_b	4,634	[kN]			

$$0,91 \left(\frac{P}{P_n} + \frac{M}{M_{tension}} \right) \leq \frac{1,33}{\Omega}$$

Unstiffened Webs
[AISI S100, Eq. C3.5.1.1]

M_{Ed1max}	0,840	[kNm]	Ratio	109,438	[%]
M_{Ed2max}	4,225	[kNm]			
V_{Ed}	2,000	[kN]	Ratio	109,438	[%]
P_b	4,634	[kN]			

[8] 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_{Ed1max}	0,840	[kNm]	Ratio	22,093	[%]
M_{Ed2max}	4,225	[kNm]			
M_{Ed1min}	0,840	[kNm]	Ratio	22,093	[%]
M_{Ed2min}	4,225	[kNm]			
V_{Ed}	2,000	[kN]	Ratio	53,845	[%]
P_b	4,634	[kN]			

$$0.91 \left[\frac{P}{P_n} + \frac{M}{M_{R500}} \right] \leq 1.33\phi$$

Unreinforced Webs
[AISI S100, Eq. C3.5.2.1]

$M_{MAXIMUM}$	0,350	[kNm]		
$M_{EFFECTIVE}$	4,225	[kNm]	Ratio	79,845
V_{MAX}	2,000	[kN]		
P_n	4,634	[kN]		

$M_{MAXIMUM}$	0,840	[kNm]		
$M_{EFFECTIVE}$	4,225	[kNm]	Ratio	79,845
V_{MAX}	2,000	[kN]		
P_n	4,634	[kN]		

[8] C-Section Beam - Combined Bending and Bearing [AS/NZS 4600, L8D]

[1] C-Section Beam - Combined Bending and Bearing/ Web Crippling [LSD Method] [AS/NZS 4600, 3.3.7]

$M_{MAXIMUM}$	0,840	[kNm]		
$M_{EFFECTIVE}$	2,693	[kNm]	Ratio	34,663

$M_{MAXIMUM}$	0,840	[kNm]		
$M_{EFFECTIVE}$	2,693	[kNm]	Ratio	34,663

V_{MAX}	2,000	[kN]	Ratio	53,845
R_n	4,634	[kN]		

$$1.07 \left(\frac{R^2}{\phi_w R_n} + \frac{M^2}{\phi_b M_n} \right) \leq 1.42$$

Unreinforced Webs
[AS/NZS 4600, Eq. 3.3.7(1)]

$M_{MAXIMUM}$	0,840	[kNm]		
$M_{EFFECTIVE}$	2,693	[kNm]	Ratio	92,385
V_{MAX}	2,000	[kN]		
R_n	4,634	[kN]		

$M_{MAXIMUM}$	0,840	[kNm]		
$M_{EFFECTIVE}$	2,693	[kNm]	Ratio	92,385
V_{MAX}	2,000	[kN]		
R_n	4,634	[kN]		

$$0.91 \left[\frac{P}{P_n} + \frac{M}{M_{R500}} \right] \leq 1.33\phi$$

Unreinforced Webs
[AISI S100, Eq. C3.5.2.1]

$M_{MAXIMUM}$	0,350	[kNm]		
$M_{EFFECTIVE}$	4,602	[kNm]	Ratio	22,970
V_{MAX}	2,240	[kN]		
P_n	17,102	[kN]		

$M_{MAXIMUM}$	0,350	[kNm]		
$M_{EFFECTIVE}$	4,602	[kNm]	Ratio	22,970
V_{MAX}	2,240	[kN]		
P_n	17,102	[kN]		

[8] C-Section Column - Combined Bending and Bearing [AS/NZS 4600, L8D]

[1] C-Section Column - Combined Bending and Bearing/ Web Crippling [LSD Method] [AS/NZS 4600, 3.3.7]

$M_{MAXIMUM}$	0,350	[kNm]		
$M_{EFFECTIVE}$	4,269	[kNm]	Ratio	9,109

$M_{MAXIMUM}$	0,350	[kNm]		
$M_{EFFECTIVE}$	4,269	[kNm]	Ratio	9,109

V_{MAX}	2,240	[kN]	Ratio	15,410
R_n	17,102	[kN]		

$$1.07 \left(\frac{R^2}{\phi_w R_n} + \frac{M^2}{\phi_b M_n} \right) \leq 1.42$$

Unreinforced Webs
[AS/NZS 4600, Eq. 3.3.7(1)]

$M_{MAXIMUM}$	0,350	[kNm]		
$M_{EFFECTIVE}$	4,269	[kNm]	Ratio	25,597
V_{MAX}	2,240	[kN]		
R_n	17,102	[kN]		

$M_{MAXIMUM}$	0,350	[kNm]		
$M_{EFFECTIVE}$	4,269	[kNm]	Ratio	25,597
V_{MAX}	2,240	[kN]		
R_n	17,102	[kN]		

[4] C-Section Column

[1] C-Section Column - Combined Bending and Web Crippling [AISI S100, ASD]

[1] C-Section Column - Combined Bending and Web Crippling [ASD Method] [AISI S100, C3.5.2]

$M_{MAXIMUM}$	0,350	[kNm]		
$M_{EFFECTIVE}$	4,602	[kNm]	Ratio	12,791

$M_{MAXIMUM}$	0,350	[kNm]		
$M_{EFFECTIVE}$	4,602	[kNm]	Ratio	12,791

V_{MAX}	2,240	[kN]	Ratio	22,972
P_n	17,102	[kN]		

$$0.91 \left[\frac{P}{P_n} + \frac{M}{M_{R500}} \right] \leq \frac{1.33}{\Omega}$$

Unreinforced Webs
[AISI S100, Eq. C3.5.2.1]

$M_{MAXIMUM}$	0,350	[kNm]		
$M_{EFFECTIVE}$	4,602	[kNm]	Ratio	34,168
V_{MAX}	2,240	[kN]		
P_n	17,102	[kN]		

$M_{MAXIMUM}$	0,350	[kNm]		
$M_{EFFECTIVE}$	4,602	[kNm]	Ratio	34,168
V_{MAX}	2,240	[kN]		
P_n	17,102	[kN]		

[8] 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]

$M_{MAXIMUM}$	0,350	[kNm]		
$M_{EFFECTIVE}$	4,602	[kNm]	Ratio	9,655

$M_{MAXIMUM}$	0,350	[kNm]		
$M_{EFFECTIVE}$	4,602	[kNm]	Ratio	9,655

V_{MAX}	2,240	[kN]	Ratio	15,410
P_n	17,102	[kN]		

[4] C-Section Beam

[1] C-Section Beam - Combined Bending and Web Crippling [AISI S100, ASD]

This verification isn't needed for this type of structural member

[8] C-Section Beam - Combined Bending and Web Crippling [AISI S100, LRFD]

This verification isn't needed for this type of structural member

[8] C-Section Beam - Combined Bending and Bearing [AS/NZS 4600, L8D]

This verification isn't needed for this type of structural member

[15.7] Stiffeners [AISI S100, C3.7 | AS/NZS 4600, 3.3.8]

[4] D-Section Purlin

[1] D-Section Purlin - Stiffeners [AISI S100, ASD]

[1] D-Section Purlin - Bearing Stiffeners [AISI S100, C3.7.1]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[2] D-Section Purlin - Bearing Stiffeners in C-Section Flange Members [AISI S100, C3.7.2]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[3] D-Section Purlin - Shear Stiffeners [AISI S100, C3.7.3]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[8] D-Section Purlin - Stiffeners [AISI S100, LRFD]

[1] D-Section Purlin - Bearing Stiffeners [AISI S100, C3.7.1]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

[2] D-Section Purlin - Bearing Stiffeners in C-Section Flange Members [AISI S100, C3.7.2]

Stiffeners weren't include on the structure definition, so, this verification isn't needed

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Version:	1,000		

[9]	D-Section Purlin: Shear Stiffeners	[AISI S100, C3.7.2]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[10]	D-Section Purlin: Stiffeners	[AS/NZS 4600, LSD]
[1]	D-Section Purlin: Transverse Stiffeners	[AS/NZS 4600, 3.3.3.1]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[2]	D-Section Purlin: Bearing stiffeners in channel-section flexural members	[AS/NZS 4600, 3.3.3.2]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[3]	D-Section Purlin: Shear Stiffeners	[AS/NZS 4600, 3.3.3.3]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[9]	C-Section Beam	
[1]	C-Section Beam: Stiffeners	[AISI S100, ASD]
[1]	C-Section Beam: Bearing Stiffeners	[AISI S100, C3.7.2]
	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, C3.7.2]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[1]	C-Section Beam: Stiffeners	[AISI S100, LRFD]
[1]	C-Section Beam: Bearing Stiffeners	[AISI S100, C3.7.2]
	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	

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[3]	C-Section Column: Shear Stiffeners	[AISI S100, C3.7.2]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[10]	C-Section Column: Stiffeners	[AS/NZS 4600, LSD]
[1]	C-Section Column: Transverse Stiffeners	[AS/NZS 4600, 3.3.3.1]
	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, 3.3.3.2]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[3]	C-Section Column: Shear Stiffeners	[AS/NZS 4600, 3.3.3.3]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[4]	C-Section Stud	
[1]	C-Section Stud: Stiffeners	[AISI S100, ASD]
[1]	C-Section Stud: Bearing Stiffeners	[AISI S100, C3.7.2]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[2]	C-Section Stud: 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 Stud: Shear Stiffeners	[AISI S100, C3.7.2]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[1]	C-Section Stud: Stiffeners	[AISI S100, LRFD]
[1]	C-Section Stud: Bearing Stiffeners	[AISI S100, C3.7.2]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[2]	C-Section Stud: 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	

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[3]	C-Section Beam: Shear Stiffeners	[AISI S100, C3.7.2]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[10]	C-Section Beam: Stiffeners	[AS/NZS 4600, LSD]
[1]	C-Section Beam: Transverse Stiffeners	[AS/NZS 4600, 3.3.3.1]
	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, 3.3.3.2]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[3]	C-Section Beam: Shear Stiffeners	[AS/NZS 4600, 3.3.3.3]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[4]	C-Section Column	
[1]	C-Section Column: Stiffeners	[AISI S100, ASD]
[1]	C-Section Column: Bearing Stiffeners	[AISI S100, C3.7.2]
	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, C3.7.2]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[1]	C-Section Column: Stiffeners	[AISI S100, LRFD]
[1]	C-Section Column: Bearing Stiffeners	[AISI S100, C3.7.2]
	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	

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[3]	C-Section Stud: Shear Stiffeners	[AISI S100, C3.7.2]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[10]	C-Section Stud: Stiffeners	[AS/NZS 4600, LSD]
[1]	C-Section Stud: Transverse Stiffeners	[AS/NZS 4600, 3.3.3.1]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[2]	C-Section Stud: Bearing stiffeners in channel-section flexural members	[AS/NZS 4600, 3.3.3.2]
	Stiffeners weren't include on the structure definition, so, this verification isn't needed	
[3]	C-Section Stud: Shear Stiffeners	[AS/NZS 4600, 3.3.3.3]
	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]
[*]	D-Section Purlin	
	This verification isn't needed for this type of structural member	
[9]	C-Section Beam	
[1]	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]
	Bisly-Symmetrical 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	
	r_x	37,355 [mm]
	r_y	62,658 [mm]
	β	1 - $(k_x/k_y)^2$ [AISI S100, Eq. C4.1.2-3]
		0,644

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$\sigma_{\text{compression}}$	4400,888	[N/mm ²]	$\sigma_{\text{compression}}$	4400,888	[N/mm ²]
$\sigma_{\text{compression}}$	595,873	[N/mm ²]	$\sigma_{\text{compression}}$	595,882	[N/mm ²]

F _{compression}	
[AISI S100, Eq. C4.1.2-1]	[AISI S100, Eq. C4.1.2-2]
F _{compression}	511,706 [N/mm ²]
F _{compression}	477,547 [N/mm ²]

F _{compression}	
[AISI S100, Eq. C4.1.2-1]	[AISI S100, Eq. C4.1.2-2]
F _{compression}	544,922 [N/mm ²]
F _{compression}	508,224 [N/mm ²]

$\lambda_c = \sqrt{\frac{F_y}{F_c}}$	F _y	350,000	[MPa]
[AISI S100, Eq. C4.1-4]	$\lambda_{\text{compression}}$	0,927	[]
	$\lambda_{\text{compression}}$	0,902	[]

$F_n = \left(0,658^{\lambda_c^2} \right) F_y$	$F_n = \left[\frac{0,877}{\lambda_c^2} \right] F_y$
$\lambda_c \leq 1,50$	$\lambda_c > 1,50$
[AISI S100, Eq. C4.1-2]	[AISI S100, Eq. C4.1-3]

F _{compression}	362,967	[N/mm ²]	→	[AISI S100, Eq. C4.1-2]
F _{compression}	367,442	[N/mm ²]	→	[AISI S100, Eq. C4.1-2]

P _y = A _y F _y	[AISI S100, Eq. C4.1-4]	Q _y	1,800			
P _{compression}	70306,541	[N]	→	P _{compression}	70,307	[kN]
P _{compression}	71530,102	[N]	→	P _{compression}	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 Side of the Web where the Stiffener is either a Single Lip or Complex Edge Stiffener

[AISI S100, Figure B2.2-2] [AISI S100, Figure B4.1]

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$$\bar{k}_{\phi wg} = \left(\frac{\pi}{L} \right)^2 \left[A_1 (k_{\phi} - h_x)^2 \left(\frac{I_{xy}}{I_y} \right)^2 - 2y_{cg} (k_{\phi} - h_x) \left(\frac{I_{xy}}{I_y} \right) + h_x^2 + y_{cg}^2 \right] + I_{xt} + I_{yt}$$

[AISI S100, Eq. C4.1-14]

$$\bar{k}_{\phi wg} = \left(\frac{\pi}{L} \right)^2 \frac{th_{\phi}^3}{60}$$

[AISI S100, Eq. C4.1-12]

$\bar{k}_{\phi wg}$	43,47	[mm ²]
$\bar{k}_{\phi wg}$	2,959	[mm ²]

$$F_{\phi} = \frac{k_{\phi gg} + k_{\phi ww} + k_{\phi}}{k_{\phi gg} + k_{\phi ww}}$$

[AISI S100, Eq. C4.2-9]

F _y	350,000	[MPa]	A _y	345,043	[mm ²]
P _y = A _y F _y	[AISI S100, Eq. C4.2-4]	→	P _y	120,772,187	[N]
P _{yy} = A _y F _y	[AISI S100, Eq. C4.2-6]	→	P _{yy}	113,075,214	[N]

$$\lambda_{\phi} = \sqrt{P_y / P_{crit}}$$

[AISI S100, Eq. C4.2-3]

λ_{ϕ}	1,039	Q _y	1,800
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P _y = P _y	$\lambda_{\phi} \leq 0,561$	→	P _{yy} = $\left(1 - 0,25 \left(\frac{P_{crit}}{P_y} \right)^{0,667} \right) \frac{P_{crit}}{P_y} P_y$
[AISI S100, Eq. C4.2-4]			[AISI S100, Eq. C4.2-2]

P _{yy}	80194,422	[N]	→	[AISI S100, Eq. C4.2-2]		
P _{compression}	70,307	[kN]	→	P _{compression}	71,530	[kN]

[8] 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]

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Dimensional Limits		
[1]	50 ≤ h _x / t	OK
	h _x / t ≤ 200	OK
[2]	25 ≤ b _x / t	OK
	b _x / t ≤ 100	OK
[3]	6,25 ≤ D / t	OK
	D / t ≤ 50	OK
[4]	45° ≤ θ	OK
	θ ≤ 90°	OK
[5]	2,5 h _x / b _x	OK
	h _x / b _x ≤ 8	OK
[6]	0,94 ≤ D ^{0,4} sin θ / [b _x]	OK
	D ^{0,4} sin θ / [b _x] ≤ 0,50	OK

$$L_{cr} = \left(\frac{6\pi^4 h_{\phi}^4 (1 - \mu^2)}{t^3} \left[I_{xy} (x_{\phi} - h_x)^2 + C_{wif} - \frac{I_{xy}^2}{I_y} (x_{\phi} - h_x)^2 \right] \right)^{1/4}$$

[AISI S100, Eq. C4.2-13]

NOTE: Ranges with 90 Degree Lips

x _u	14,348	[mm]	A _y	76,438	[mm ²]
y _u	-1,874	[mm]	I _y	1083,105	[mm ⁴]
h _x	129,000	[mm]	I _x	12526,125	[mm ⁴]
L = L ₀	391,333	[mm]	I _{xy}	2027,982	[mm ⁴]
			h _y	-24,448	[mm]
			J _w	53,719	[mm ⁴]
			C _w	0,000	[mm ³]
			v _y	0,300	[]
E	210,000	[GPa]	G	80,769	[GPa]

$$k_{\phi fg} = \left(\frac{\pi}{L} \right)^4 \left[EI_{xy} (x_{\phi} - h_x)^2 + EC_{wif} - \frac{E I_{xy}^2}{I_y} (x_{\phi} - h_x)^2 \right] + \left(\frac{\pi}{L} \right)^2 GJ$$

[AISI S100, Eq. C4.1-13]

$$k_{\phi wc} = \frac{Et^3}{6h_{\phi}(1 - \mu^2)}$$

[AISI S100, Eq. C4.2-11]

P _{yy}	120,772	[N]
P _{yy}	981,772	[N]
v _y	0,000	[N]

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$$F_e = \frac{\sigma_t \sigma_{ex}}{\sigma_t + \sigma_{ex}}$$

[AISI S100, Eq. C4.1-2-2]

NOTE: Eq. C4.1-2-2 gives a conservative estimate of F_e

x _u	-37,355	[mm]	v _y	62,658	[mm]
----------------	---------	------	----------------	--------	------

$$\beta = 1 - (h_{\phi}/t)^2$$

[AISI S100, Eq. C4.1-2-3]

β	0,844
---	-------

$\sigma_{\text{compression}}$	4400,888	[N/mm ²]	$\sigma_{\text{compression}}$	4400,888	[N/mm ²]
$\sigma_{\text{compression}}$	595,873	[N/mm ²]	$\sigma_{\text{compression}}$	595,882	[N/mm ²]

F _{compression}	
[AISI S100, Eq. C4.1.2-1]	[AISI S100, Eq. C4.1.2-2]
F _{compression}	511,706 [N/mm ²]
F _{compression}	477,547 [N/mm ²]

F _{compression}	
[AISI S100, Eq. C4.1.2-1]	[AISI S100, Eq. C4.1.2-2]
F _{compression}	544,922 [N/mm ²]
F _{compression}	508,224 [N/mm ²]

$\lambda_c = \sqrt{\frac{F_y}{F_c}}$	F _y	350,000	[MPa]
[AISI S100, Eq. C4.1-4]	$\lambda_{\text{compression}}$	0,927	[]
	$\lambda_{\text{compression}}$	0,902	[]

$F_n = \left(0,658^{\lambda_c^2} \right) F_y$	$F_n = \left[\frac{0,877}{\lambda_c^2} \right] F_y$
$\lambda_c \leq 1,50$	$\lambda_c > 1,50$
[AISI S100, Eq. C4.1-2]	[AISI S100, Eq. C4.1-3]

F _{compression}	362,967	[N/mm ²]	→	[AISI S100, Eq. C4.1-2]
F _{compression}	367,442	[N/mm ²]	→	[AISI S100, Eq. C4.1-2]

P _y = A _y F _y	[AISI S100, Eq. C4.1-4]	Q _y	0,850			
P _{compression}	70306,541	[N]	→	P _{compression}	70,307	[kN]
P _{compression}	71530,102	[N]	→	P _{compression}	71,530	[kN]

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[2] | Distortional Buckling Strength | Resistance | | AIS1100, C4.2 |

For C and Z-sections or any Open Section with a Stiffened Compression Flange Extending to Side of the Web where the Stiffener is either a Single Lip or a Complex Edge Stiffener

[AIS1100, Figure B2.2-1] | [AIS1100, Figure B4.1]

Dimensional Limits		
[1]	$50 \leq h_0$ [mm]	OK
[2]	$25 \leq h_0$ [mm]	OK
[3]	$6.25 < D$ [mm]	OK
[4]	$45^\circ \leq \theta$	OK
[5]	$8 \leq 90^\circ$	OK
[6]	$2 \leq h_0/h_1$	OK
[7]	$0.24 \leq D \cdot \sin(\theta) \leq h_0$	OK
[8]	$D \cdot \sin(\theta) \leq h_0 \leq 9.5D$	OK

$$L_{cr} = \left(\frac{6\pi^4 h_0^4 (1-\mu^2)}{L^3} \left[I_{xt}(x_0 - h_x)^2 + EC_{wf} - \frac{I_{yf}^2}{I_{xt}} (x_0 - h_x)^2 \right] \right)^{1/4}$$

[AIS1100, Eq. C4.2-13]

NOTE: Flanges with 90 Degree Lips

A_x	76,439	[mm ²]
I_x	1093,056	[mm ⁴]
I_y	1260,125	[mm ⁴]
I_{xy}	2027,882	[mm ⁴]
x_0	14,148	[mm]
y_0	-1,874	[mm]
h_x	120,000	[mm]
$L \cdot L_y$	391,223	[mm]
E	210,000	[GPa]
G	80,769	[GPa]

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[03] | C-Section Beam - Concentrically Loaded Compression Members | | AS/NZS 4600, LSD |

Table 1.6 - Capacity Reduction Factor [AS/NZS 4600:2005]

Design Capacity	Class Reference	Capacity Reduction Factor, ϕ_c
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 |

$$f_{ocr} = \frac{1}{2\beta} \left[(f_{ox} + f_{or}) - \sqrt{(f_{ox} + f_{or})^2 - 4\beta f_{ox} f_{or}} \right]$$

[AS/NZS 4600, Eq. 3.4.3(1)]

$$f_{ocr} = f_{ox} f_{or} / (f_{ox} + f_{or})$$

[AS/NZS 4600, Eq. 3.4.3(2)]

NOTE: Eq. 3.4.3(2) gives a conservative estimate of f_{ocr}

x_0	-37,355	[mm]	y_0	62,658	[mm]
-------	---------	------	-------	--------	------

$$\beta = 1 - (x_0 / r_{y0})^2$$

[AIS1100, Eq. C4.1.2-3] | β | 0.644

$f_{t,compression}$	400,888	[N/mm ²]	$f_{t,tension}$	480,583	[N/mm ²]
$f_{c,compression}$	535.673	[N/mm ²]	$f_{c,tension}$	569.982	[N/mm ²]

[AS/NZS 4600, Eq. 3.4.3(1)] | [AS/NZS 4600, Eq. 3.4.3(2)]

$f_{t,compression}$	511,206	[N/mm ²]	$f_{t,tension}$	477,547	[N/mm ²]
$f_{c,compression}$	544,922	[N/mm ²]	$f_{c,tension}$	509,224	[N/mm ²]

[AS/NZS 4600, Eq. 3.4.3(1)] | [AS/NZS 4600, Eq. 3.4.3(2)]

$$f_{oc} = \frac{\pi^2 E}{(L_e / r)^2}$$

[AS/NZS 4600, Eq. 3.4.2(1)]

r_x	17,259	[mm]
E	210,000	[GPa]
$L_{compression}$	1020,000	[mm]
$L_{tension}$	988,000	[mm]

[AS/NZS 4600, Eq. 3.4.2(1)]

$f_{t,compression}$	627,863	[N/mm ²]	$f_{t,tension}$	669,293	[N/mm ²]
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$$\lambda_{ec} = \sqrt{\frac{f_y}{f_{oc}}}$$

[AS/NZS 4600, Eq. 3.4.1(9)]

f_y	350,000	[MPa]
$\lambda_{t,compression}$	0.747	[]
$\lambda_{c,tension}$	0.723	[]

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$$k_{dfe} = \left(\frac{\pi}{L} \right)^4 \left[EI_{xt}(x_0 - h_x)^2 + EC_{wf} - E \frac{I_{yf}^2}{I_{xt}} (x_0 - h_x)^2 \right] + \left(\frac{\pi}{L} \right)^2 GJ_f$$

[AIS1100, Eq. C3.1.4-13]

$$k_{\phi we} = \frac{Et^3}{6h_0(1-\mu^2)}$$

[AIS1100, Eq. C4.2-11]

k_{dfe}	1269,814	[N]
$k_{\phi we}$	991,712	[N]
k_d	0,000	[N]

$$\tilde{k}_{dfe} = \left(\frac{\pi}{L} \right)^2 \left[A_x \left[(x_0 - h_x)^2 \frac{I_{yf}}{I_{xt}} \right] - 2y_0(x_0 - h_x) \left(\frac{I_{xy}}{I_{xt}} \right) + h_x^2 + y_0^2 \right] + I_{xt} + I_{yf}$$

[AIS1100, Eq. C3.1.4-15]

$$\tilde{k}_{\phi we} = \left(\frac{\pi}{L} \right)^2 \frac{th_0^3}{60}$$

[AIS1100, Eq. C4.2-12]

\tilde{k}_{dfe}	4,247	[mm ²]
$\tilde{k}_{\phi we}$	2,895	[mm ²]

$$F_{d1} = \frac{k_{dfe} + k_{\phi we} + k_d}{\tilde{k}_{dfe} + \tilde{k}_{\phi we}}$$

[AIS1100, Eq. C4.2-20]

F_d	327,894	[MPa]
-------	---------	-------

F_y	350,000	[MPa]	A_y	345,083	[mm ²]
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[AIS1100, Eq. C4.2-4]

$P_y = A_y F_y$	120772,887	[N]
-----------------	------------	-----

[AIS1100, Eq. C4.2-4]

$P_{y,c} = A_y F_{y,c}$	113076,314	[N]
-------------------------	------------	-----

[AIS1100, Eq. C4.2-4]

$$\lambda_{d1} = \sqrt{P_y / F_{d1}}$$

[AIS1100, Eq. C4.2-3]

λ_{d1}	1,033	ϕ_c	0,850
----------------	-------	----------	-------

$$P_y = P_y \left[1 - 0.25 \left(\frac{P_y}{P_{y,c}} \right)^{0.6} \right] \left[\frac{P_{y,c}}{P_y} \right]^{0.6}$$

[AIS1100, Eq. C4.2-2]

$P_{y,c}$	881,94422	[N]	$P_{y,max}$	71,530	[N]
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[AIS1100, Eq. C4.2-2]

$P_{t,compression}$	70,207	[N]	$P_{t,tension}$	71,530	[N]
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$$f_m = (0.658^{\lambda_{ec}}) f_y$$

[AS/NZS 4600, Eq. 3.4.1(1)]

$$f_m = (0.877 / \lambda_{ec}^2) f_y$$

[AS/NZS 4600, Eq. 3.4.1(2)]

$f_{t,compression}$	550,936	[N/mm ²]	$f_{t,tension}$	569,982	[N/mm ²]
---------------------	---------	----------------------	-----------------	---------	----------------------

[AS/NZS 4600, Eq. 3.4.1(1)] | [AS/NZS 4600, Eq. 3.4.1(2)]

[2] | Singly-Symmetric Sections subject to Distortional Buckling | | AS/NZS 4600, 3.4.6 |

$$f_m = \frac{E}{2.4} \left[(f_y + \sigma_1) - \sqrt{(f_y + \sigma_1)^2 - 4\sigma_1 f_y} \right]$$

[AS/NZS 4600, Eq. D1(1)]

The value of N_d in Equation 3.4.1(2) shall be the lesser of:

f_y	359,792	[MPa]	$f_y > f_{1,2}$	5119.5 f _{1,2}
-------	---------	-------	-----------------	-------------------------

[AS/NZS 4600, Eq. 3.4.6(1)]

$f_{1,2}$	359,792	[MPa]	$f_y > f_{1,2}$	OK
f_y	350,000	[MPa]	$f_y \leq f_{1,2}$	KD
$A_y f_y$	91400,884	[N]	$f_y \geq 1.3 f_y$	OK

[AS/NZS 4600, Eq. 3.4.6(1)] | [AS/NZS 4600, Eq. 3.4.6(2)]

[3] | Concentrically Loaded Compression Members | | AS/NZS 4600, 3.4.1 |

$$N_c = A_c f_y$$

[AS/NZS 4600, Eq. 3.4.1(1)]

$$N_c = A_c f_m$$

[AS/NZS 4600, Eq. 3.4.1(2)]

$N_{t,compression}$	93611,001	[N]	$N_{t,tension}$	93,611	[kN]
$N_{c,compression}$	91400,884	[N]	$N_{c,tension}$	91401	[kN]

$N_{t,compression}$	93611,001	[N]	$N_{t,tension}$	93,611	[kN]
$N_{c,compression}$	91400,884	[N]	$N_{c,tension}$	91401	[kN]

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[c] C-Section Column

[1] 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

$$F_e = \frac{1}{2\beta} \left[(\sigma_{ex} + \sigma_y) - \sqrt{(\sigma_{ex} + \sigma_y)^2 - 4\beta\sigma_{ex}\sigma_y} \right]$$

[AISI S100, Eq. C4.1.2.1]

$$F_e = \frac{\sigma_y \sigma_{ex}}{\sigma_y + \sigma_{ex}}$$

[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]	y_0	58,347 [mm]
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$\beta = 1 - (h_0/h_x)^2$ [AISI S100, Eq. C4.1.2.3] → $\beta = 0,493$

Distortions	2427,408 [Nmm ²]	Distortions	722,710 [Nmm ²]
Distortions	1752,839 [Nmm ²]	Distortions	619,213 [Nmm ²]

Flexure cases

$F_{flexure}$	1183,015 [Nmm ²]	$F_{flexure}$	1017,848 [Nmm ²]
---------------	------------------------------	---------------	------------------------------

Flexure cases

$F_{flexure}$	389,163 [Nmm ²]	$F_{flexure}$	333,485 [Nmm ²]
---------------	-----------------------------	---------------	-----------------------------

$\lambda_c = \sqrt{\frac{F_y}{F_e}}$ [AISI S100, Eq. C4.1.4]

F_y	359,000 [MPa]	$\lambda_{flexure}$	0,544 []
$\lambda_{flexure}$	0,948 []	$\lambda_{flexure}$	0,948 []

$$F_n = \left(0,658^{\lambda_c^2} \right) F_y$$

[AISI S100, Eq. C4.1.2]

$$F_n = \left(\frac{0,877}{\lambda_c^2} \right) F_y$$

[AISI S100, Eq. C4.1.2]

$F_{flexure}$	399,236 [Nmm ²]	→	[AISI S100, Eq. C4.1.2]
$F_{flexure}$	249,207 [Nmm ²]	→	[AISI S100, Eq. C4.1.2]

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NOTE Flanges with 90 Degree Lips

A_y	121,227 [mm ²]	A_x	1552,898 [mm ²]
I_x	17911,320 [mm ⁴]	I_y	2015,457 [mm ⁴]
I_{xt}	-23,067 [mm ⁴]	A	243,953 [mm ²]
x_0	19,489 [mm]	C_{yt}	0,000 [mm ³]
y_0	-1,715 [mm]	C_{xt}	0,000 [mm ³]
h_x	99,000 [mm]	v	0,300 []
$L = L_y$	200,071 [mm]	E	210,000 [GPa]
		G	80,769 [GPa]

$$k_{tfc} = \left(\frac{\pi}{L} \right)^4 \left[EI_{xt}(x_0 - h_x)^2 + EC_{wt} - E \frac{I_{yt}^2}{I_{yt}} (x_0 - h_x)^2 \right] + \left(\frac{\pi}{L} \right)^2 GJ_t$$

[AISI S100, Eq. C4.1.4.3]

$$k_{\phi wc} = \frac{Et^3}{6h_x(1-\mu^2)}$$

[AISI S100, Eq. C4.1.11]

v_{w1}	9164,255 [N]
v_{w2}	6300,072 [N]
v_1	0,000 [N]

$$\tilde{k}_{tfc} = \left(\frac{\pi}{L} \right)^2 \left[A_y \left[(x_0 - h_x)^2 \left(\frac{I_{xt}}{I_{yt}} \right)^2 - 2y_0(x_0 - h_x) \left(\frac{I_{xt}}{I_{yt}} \right) - h_x^2 + y_0^2 \right] + I_{xt} + I_{yt} \right]$$

[AISI S100, Eq. C4.1.4.5]

$$\tilde{k}_{\phi wg} = \left(\frac{\pi}{L} \right)^2 \frac{th_0^3}{60}$$

[AISI S100, Eq. C4.1.12]

\tilde{k}_{tfc}	13,267 [mm ²]
$\tilde{k}_{\phi wg}$	4,331 [mm ²]

$$F_d = \frac{k_{tfc} + k_{\phi wc} + k_g}{\tilde{k}_{tfc} + \tilde{k}_{\phi wg}}$$

[AISI S100, Eq. C4.1.20]

F_y	359,000 [MPa]	A_y	497,235 [mm ²]
$P_y = A_y F_y$	[AISI S100, Eq. C4.2-4]	→	P_y 174932,262 [N]
$P_{wy} = A_y F_d$	[AISI S100, Eq. C4.2-6]	→	P_{wy} 437219,937 [N]

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$P_y = A_y F_y$ [AISI S100, Eq. C4.1-4]

$P_{flexure}$	152460,330 [N]	→	$P_{flexure}$ 152,460 [kN]
$P_{flexure}$	118427,973 [N]	→	$P_{flexure}$ 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 Sides of the Web where the Stiffener is either a Single Lip or a Complex Edge Stiffener

[AISI S100, Figure B2.2-2] [AISI S100, Figure B4.1]

Dimensional Limits

[1]	$50 \leq h_0/l$	OK
[1]	$h_0/l \leq 200$	OK
[2]	$25 \leq h_0/l$	OK
[2]	$h_0/l \leq 100$	OK
[3]	$6,25 < D/l$	OK
[3]	$D/l \leq 50$	OK
[4]	$45^\circ \leq \theta$	OK
[4]	$\theta \leq 90^\circ$	OK
[5]	$2,5 h_0/b_1$	OK
[5]	$h_0/b_2 \leq 8$	OK
[6]	$0,94 \leq D^* \sin(\theta) \leq 1,1 h_0$	OK
[6]	$D^* \sin(\theta) \leq 1,1 h_0 \leq 0,90$	OK

$$L_{cr} = \left(\frac{6\pi^4 h_0 (1-\mu^2)}{l^3} \left[I_{xt}(x_0 - h_x)^2 + C_{wt} - \frac{I_{yt}^2}{I_{yt}} (x_0 - h_x)^2 \right] \right)^{1/4}$$

[AISI S100, Eq. C4.2-13]

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$\lambda_{cd} = \sqrt{F_y / F_{cr,d}}$ [AISI S100, Eq. C4.2-3]

λ_{cd}	0,931	ϕ_c	1,000
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$P_y = P_y$

$\lambda_c < 0,961$ [AISI S100, Eq. C4.1-4]

$P_y = \left(1 - 0,25 \frac{P_{cr,d}}{P_y} \right) \left(\frac{P_{cr,d}}{P_y} \right)^{0,75} P_y$ [AISI S100, Eq. C4.2-2]

$P_{cr,d}$ 171044,947 [N] → [AISI S100, Eq. C4.2-2]

$P_{flexure}$	152,460 [kN]	$P_{flexure}$	118,428 [kN]
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[1] C-Section Column: Concentrically Loaded Compression Members [AISI S100, LRFD]

[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

$$F_e = \frac{1}{2\beta} \left[(\sigma_{ex} + \sigma_y) - \sqrt{(\sigma_{ex} + \sigma_y)^2 - 4\beta\sigma_{ex}\sigma_y} \right]$$

[AISI S100, Eq. C4.1.2.1]

$$F_e = \frac{\sigma_y \sigma_{ex}}{\sigma_y + \sigma_{ex}}$$

[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]	y_0	58,347 [mm]
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$\beta = 1 - (h_0/h_x)^2$ [AISI S100, Eq. C4.1.2.3] → $\beta = 0,493$

Distortions	2427,408 [Nmm ²]	Distortions	722,710 [Nmm ²]
Distortions	1752,839 [Nmm ²]	Distortions	619,213 [Nmm ²]

Flexure cases

$F_{flexure}$	1183,015 [Nmm ²]	$F_{flexure}$	1017,848 [Nmm ²]
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Flexure cases

$F_{flexure}$	389,163 [Nmm ²]	$F_{flexure}$	333,485 [Nmm ²]
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$$\lambda_{c,c} = \sqrt{\frac{F_y}{F_{c,c}}}$$

[AISI S100, Eq. C4.2-4]

$$F_n = \begin{cases} 0.658^{A_s} F_y & A_s \leq 1.50 \\ 0.877 \sqrt{F_y} & A_s > 1.50 \end{cases}$$

[AISI S100, Eq. C4.2-2]

$F_{tension,c}$	39,236	[Nmm ²]	→	[AISI S100, Eq. C4.2-2]
$F_{tension,c}$	249,207	[Nmm ²]	→	[AISI S100, Eq. C4.2-2]

$P_n = A_g F_n$	[AISI S100, Eq. C4.2-4]	ϕ_c	0.950			
$P_{tension,c}$	152,460,330	[N]	→	$P_{tension,c}$	152,460	[kN]
$P_{tension,c}$	118,427,873	[N]	→	$P_{tension,c}$	118,428	[kN]

F_y	350,000	[MPa]
$\lambda_{tension,c}$	0.944	[]
$\lambda_{tension,c}$	0.948	[]

[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 Sides of the Web where the Stiffener is either a Simple Lip or a Complex Edge Stiffener.

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$$\lambda_{c,c} = \sqrt{\frac{F_y}{F_{c,c}}}$$

[AISI S100, Eq. C4.2-4]

$$F_n = \left(0.658^{\lambda_{c,c}^2} \right) F_y$$

[AISI S100, Eq. C4.2-2]

$$F_n = \left(\frac{0.877}{\lambda_{c,c}^2} \right) F_y$$

[AISI S100, Eq. C4.2-3]

$F_{cr,c} = 48,793$ [N/mm²] → [AISI S100, Eq. C4.2-3]

$P_n = A_c F_n$ [AISI S100, Eq. C4.2-4] → $\phi_c = 0,950$

$P_{cr,c} = 9814,866$ [N] → $P_{cr,c} = 9,815$ [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 Side of the Web where the Stiffener is either a Single Lip or a Complex Edge Stiffener. One

[AISI S100, Figure B2.2-2] [AISI S100, Figure B4-1]

Dimensional Limits		
[1]	$50 \leq h_x / t$	OK
	$h_x / t \leq 200$	OK
[2]	$25 \leq b_x / t$	OK
	$b_x / t \leq 100$	OK
[3]	$6.25 < D / t$	OK
	$D / t \leq 50$	OK
[4]	$45^\circ \leq \theta$	OK
	$\theta \leq 90^\circ$	OK
[5]	$2.5 h_x / b_x$	OK
	$h_x / b_x \leq 8$	OK
[6]	$0.84 \leq D^{*sin(\theta)} / t$	OK
	$D^{*sin(\theta)} / t \leq 5,00$	OK

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$$L_{cr} = \left(\frac{6\pi^4 h_o (1-\mu^2)}{L^3} \left[I_{xf} (x_o - h_x)^2 + C_{wf} - \frac{I_{yxf}^2}{I_{yf}} (x_o - h_x)^2 \right] \right)^{1/4}$$

[AISI S100, Eq. C4.2-13]

NOTE Flanges with 90 Degree Lips

$x_o = 13,503$ [mm]

$y_o = -0,479$ [mm]

$h_x = 50,000$ [mm]

$L = L_y = 163,264$ [mm]

$E = 210,000$ [GPa]

$G = 80,769$ [GPa]

$$k_{eff,c} = \left(\frac{\pi}{L} \right)^4 \left(EI_{xf} (x_o - h_x)^2 + EC_{wf} - E \frac{I_{yxf}^2}{I_{yf}} (x_o - h_x)^2 \right) + \left(\frac{\pi}{L} \right)^2 GJ_f$$

[AISI S100, Eq. C3.1-13]

$$k_{\phi we} = \frac{E t^3}{6 h_o (1-\mu^2)}$$

[AISI S100, Eq. C4.2-11]

$$\tilde{k}_{eff,c} = \left(\frac{\pi}{L} \right)^2 \left[A_f (x_o - h_x)^2 \left(\frac{I_{yxf}}{I_{yf}} \right)^2 - 2 y_o (x_o - h_x) \left(\frac{I_{yxf}}{I_{yf}} \right) + h_x^2 + y_o^2 \right] + I_{xf} + I_{yf}$$

[AISI S100, Eq. C3.1-16]

$$\tilde{k}_{\phi we} = \left(\frac{\pi}{L} \right)^2 \frac{t h_o^3}{60}$$

[AISI S100, Eq. C4.2-12]

$$F_c = \frac{k_{eff,c} - k_{\phi we} - k_{\phi w} + k_{\phi w}}{k_{eff,c} + k_{\phi we}}$$

[AISI S100, Eq. C4.2-20]

$F_y = 350,000$ [MPa]

$A_y = 201,315$ [mm²]

$P_n = A_c F_n$ [AISI S100, Eq. C4.2-4] → $P_n = 7546,387$ [N]

$P_{cr,c} = A_c F_{cr,c}$ [AISI S100, Eq. C4.2-6] → $P_{cr,c} = 112799,494$ [N]

$$\lambda_{c,d} = \sqrt{F_y / F_{cr,d}}$$

[AISI S100, Eq. C4.2-3]

$A_y = 0,950$ → $\phi_y = 0,950$

$P_n = P_y$ → $P_n = \left(1 - 0,25 \frac{F_{cr,d}}{F_y} \right) \left(\frac{F_y}{F_y} \right) A_y P_y$

$A_y \leq 0,561$ → $A_y = 0,561$ [AISI S100, Eq. C4.2-2]

$P_{cr,d} = 62469,618$ [N] → [AISI S100, Eq. C4.2-2]

$P_{cr,d} = 9,815$ [kN]

[1] C-Section Biral | Concentrically Loaded Compression Members | [AS/NZS 4600, LSD]

Table 1.5. Capacity Reduction Factor | AS/NZS 4600:2005 |

Design Capacity	Capacity Reference	Capacity Reduction Factor | ϕ_c |
Concentrically loaded compression members	3,4	0,950

[1] Singly-Symmetric Sections subject to Torsional or Flexural-Torsional Buckling | [AS/NZS 4600, 3.4.3]

$$f_{ow} = \frac{1}{2\beta} \left((f_{ox} + f_{ow}) - \sqrt{(f_{ox} + f_{ow})^2 - 4\beta f_{ox} f_{ow}} \right)$$

[AS/NZS 4600, Eq. 3.4.3(1)]

$$f_{ox} = f_{ox} f_{ox} / (f_{ox} + f_{ox})$$

[AS/NZS 4600, Eq. 3.4.3(2)] **NOTE** Eq. 3.4.3(2) gives a conservative estimate of f_{ow}

$x_o = -35,537$ [mm]

$f_{ox} = 43,621$ [mm]

$$\beta = 1 - (x_o / r_{yo})^2$$

[AISI S100, Eq. C4.1-2-3]

$\beta = 0,336$

$f_{cr,ox} = 231,286$ [N/mm²]

$f_{cr,oy} = 67,264$ [N/mm²]

$f_{cr,ow} = 55,590$ [N/mm²]

$f_{cr,ow} = 52,059$ [N/mm²]

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$$f_{oc} = \frac{\pi^2 E}{(L_e / r)^2}$$

[AS/NZS 4600, Eq. 3.4.2(1)]

$$\lambda_{c,c} = \sqrt{\frac{F_y}{F_{c,c}}}$$

[AS/NZS 4600, Eq. 3.4.2(2)]

$$F_n = \left(0.658^{\lambda_{c,c}^2} \right) F_y$$

[AS/NZS 4600, Eq. 3.4.2(3)]

$$F_n = \left(\frac{0.877}{\lambda_{c,c}^2} \right) F_y$$

[AS/NZS 4600, Eq. 3.4.2(4)]

$f_{cr,c} = 103,038$ [N/mm²] → [AS/NZS 4600, Eq. 3.4.2(4)]

[2] Singly-Symmetric Sections subject to Distortional Buckling | [AS/NZS 4600, 3.4.6]

$$f_{oa} = \frac{E}{2,4} \left((c_1 + c_2) - \sqrt{(c_1 + c_2)^2 - 4c_1 c_2} \right)$$

[AS/NZS 4600, Eq. D0(1)]

The value of N_x in Equation 3.4.1(2) shall be the lesser of:

[A_{f1} substituted in accordance with Equations 3.4.1(3) and 3.4.1(6)]

$$A_{f1} = A_f \left(1 - \frac{f_y}{4 f_{oa}} \right)$$

[AS/NZS 4600, Eq. 3.4.5(1)]

$$A_{f2} = A_f \left(0,055 \sqrt{\frac{L_e}{f_{oa}}} - 3,6 \right) + 0,237$$

[AS/NZS 4600, Eq. 3.4.5(2)]

$f_{oa} = 541,268$ [MPa]

$f_{oa} > f_{y1,2}$ OK

$f_{oa} = 350,000$ [MPa]

$f_{y1,2} > f_{oa}$ KO

$f_{y1,3} > f_{oa}$ OK

$A_{f1} = 59089,462$ [N] → [AS/NZS 4600, Eq. 3.4.5(1)]

[3] Concentrically Loaded Compression Members | [AS/NZS 4600, 3.4.3]

$$N_c = A_c f_y$$

[AS/NZS 4600, Eq. 3.4.1(1)]

$$N_c = A_c f_n$$

[AS/NZS 4600, Eq. 3.4.1(2)]

$r_{yo} = 14,853$ [mm]

$E = 210,000$ [GPa]

$L_{e,ox} = 1950,333$ [mm]

$L_{e,oy} = 117,489$ [mm]

$F_y = 350,000$ [MPa]

$A_{cr,c} = 1,208$ []

$F_n = (0.658^{\lambda_{c,c}^2}) F_y$

$F_n = (0.877 / \lambda_{c,c}^2) F_y$

$A_y \leq 0,50$

$A_y \leq 0,561$

[AS/NZS 4600, Eq. 3.4.2(3)]

[AS/NZS 4600, Eq. 3.4.2(4)]

$f_{cr,c} = 103,038$ [N/mm²] → [AS/NZS 4600, Eq. 3.4.2(4)]

[2] Singly-Symmetric Sections subject to Distortional Buckling | [AS/NZS 4600, 3.4.6]

$$f_{oa} = \frac{E}{2,4} \left((c_1 + c_2) - \sqrt{(c_1 + c_2)^2 - 4c_1 c_2} \right)$$

[AS/NZS 4600, Eq. D0(1)]

The value of N_x in Equation 3.4.1(2) shall be the lesser of:

[A_{f1} substituted in accordance with Equations 3.4.1(3) and 3.4.1(6)]

$$A_{f1} = A_f \left(1 - \frac{f_y}{4 f_{oa}} \right)$$

[AS/NZS 4600, Eq. 3.4.5(1)]

$$A_{f2} = A_f \left(0,055 \sqrt{\frac{L_e}{f_{oa}}} - 3,6 \right) + 0,237$$

[AS/NZS 4600, Eq. 3.4.5(2)]

$f_{oa} = 541,268$ [MPa]

$f_{oa} > f_{y1,2}$ OK

$f_{oa} = 350,000$ [MPa]

$f_{y1,2} > f_{oa}$ KO

$f_{y1,3} > f_{oa}$ OK

$A_{f1} = 59089,462$ [N] → [AS/NZS 4600, Eq. 3.4.5(1)]

[3] Concentrically Loaded Compression Members | [AS/NZS 4600, 3.4.3]

$$N_c = A_c f_y$$

[AS/NZS 4600, Eq. 3.4.1(1)]

$$N_c = A_c f_n$$

[AS/NZS 4600, Eq. 3.4.1(2)]

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$N_{1,101}$	70460,287	[kN]	→	$N_{1,100}$	70460	[kN]
$N_{2,101}$	20743,083	[kN]	→	$N_{2,100}$	20743	[kN]

[159] Combined Axial Load and Bending [AISI S100, C5] [AS/NZS 4600, 3.5]

[a] D-Section Profile

This verification isn't needed for this type of structural member.

[b] C-Section Beam

[1] C-Section Beam - Combined Axial Load and Bending [AISI S100, ASD]

[1] Combined Tensile Axial Load and Bending [AISI S100, C5.2.1]

$$\frac{\Omega_b M_x}{M_{ntx}} + \frac{\Omega_b M_y}{M_{nty}} + \frac{\Omega_b T}{T_n} \leq 1.0$$

[AISI S100, Eq. C5.2.1-1]

$$\frac{\Omega_b M_x}{M_{ntx}} + \frac{\Omega_b M_y}{M_{nty}} - \frac{\Omega_b T}{T_n} \leq 1.0$$

[AISI S100, Eq. C5.2.1-2]

Ω_b	1,870	Ω_b	1,870
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Members whose ends are unrestrained

C_{t1}	1,000	C_{t2}	1,000
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C_{t1}	1,000	C_{t2}	0,950
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P_{1x}	1518,285	[kN]	P_{1y}	1279,264	[kN]
α_x	0,999		α_y	0,999	

P	0,520	[kN]	Ratio	35,974	[%]
P_x	70,207	[kN]	ϕ_x	0,999	
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,020	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	2,006	[kNm]
$M_{1,101,103}$	0,020	[kNm]	$M_{1,101,103}$	1,249	[kNm]
$M_{1,101,104}$	2,006	[kNm]	$M_{1,101,104}$	0,840	[kNm]

P	0,520	[kN]	Ratio	36,202	[%]
P_x	70,207	[kN]	ϕ_x	0,999	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,020	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	2,006	[kNm]
$M_{1,101,103}$	0,020	[kNm]	$M_{1,101,103}$	1,249	[kNm]
$M_{1,101,104}$	2,006	[kNm]	$M_{1,101,104}$	0,840	[kNm]

P	0,520	[kN]	Ratio	36,202	[%]
P_x	70,207	[kN]	ϕ_x	0,999	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,020	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	2,006	[kNm]
$M_{1,101,103}$	0,020	[kNm]	$M_{1,101,103}$	1,249	[kNm]
$M_{1,101,104}$	2,006	[kNm]	$M_{1,101,104}$	0,840	[kNm]

P	0,520	[kN]	Ratio	36,884	[%]
P_x	70,207	[kN]	ϕ_x	0,999	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,020	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	2,006	[kNm]
$M_{1,101,103}$	0,020	[kNm]	$M_{1,101,103}$	1,249	[kNm]
$M_{1,101,104}$	1,336	[kNm]	$M_{1,101,104}$	0,840	[kNm]

P	0,520	[kN]	Ratio	37,037	[%]
P_x	70,207	[kN]	ϕ_x	0,999	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,020	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	1,336	[kNm]
$M_{1,101,103}$	0,020	[kNm]	$M_{1,101,103}$	2,814	[kNm]
$M_{1,101,104}$	2,814	[kNm]	$M_{1,101,104}$	0,020	[kNm]

P	0,520	[kN]	Ratio	37,037	[%]
P_x	70,207	[kN]	ϕ_x	0,999	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,020	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	1,336	[kNm]
$M_{1,101,103}$	0,020	[kNm]	$M_{1,101,103}$	2,814	[kNm]
$M_{1,101,104}$	2,814	[kNm]	$M_{1,101,104}$	0,020	[kNm]

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Middle Beam

R = T	0,700	[kN]	Ratio	32,444	[%]
$R_x + T_x$	124,223	[kN]	$M_{1,101,101}$	1,336	[kNm]
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	4,901	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	1,249	[kNm]
$M_{1,101,103}$	0,010	[kNm]	$M_{1,101,103}$	2,814	[kNm]

R = T	0,700	[kN]	Ratio	33,515	[%]
$R_x + T_x$	124,223	[kN]	$M_{1,101,101}$	1,336	[kNm]
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	4,901	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	1,249	[kNm]
$M_{1,101,103}$	0,010	[kNm]	$M_{1,101,103}$	2,814	[kNm]

[2] Combined Compressive Axial Load and Bending [AISI S100, C5.2.2]

$$\frac{\Omega_c P}{P_n} + \frac{\Omega_c M_x}{M_{nx}} + \frac{\Omega_c M_y}{M_{ny}} \leq 1.0$$

[AISI S100, Eq. C5.2.2-1]

$$\frac{\Omega_c P}{P_n} + \frac{\Omega_c M_x}{M_{nx}} - \frac{\Omega_c M_y}{M_{ny}} \leq 1.0$$

[AISI S100, Eq. C5.2.2-2]

$$\Omega_c (P/P_n) \leq 0.15 \quad \frac{\Omega_c P}{P_n} + \frac{\Omega_b M_x}{M_{nx}} + \frac{\Omega_b M_y}{M_{ny}} \leq 1.0$$

[AISI S100, Eq. C5.2.2-3]

Ω_c	1,800	Ω_c	1,870
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$$\alpha_x = 1 - \frac{\Omega_c P}{P_{Ex}} > 0$$

[AISI S100, Eq. C5.2.2-4]

Members whose ends are restrained

C_{t1}	0,850	C_{t2}	0,850
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Members whose ends are unrestrained

C_{t1}	1,000	C_{t2}	1,000
----------	-------	----------	-------

C_{t1}	1,000	C_{t2}	0,950
----------	-------	----------	-------

P_{1x}	1518,285	[kN]	P_{1y}	1279,264	[kN]
α_x	0,999	||	α_y	0,999	||

P	0,520	[kN]	Ratio	35,974	[%]
P_x	70,207	[kN]	ϕ_x	0,999	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,020	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	2,006	[kNm]
$M_{1,101,103}$	0,020	[kNm]	$M_{1,101,103}$	1,249	[kNm]
$M_{1,101,104}$	2,006	[kNm]	$M_{1,101,104}$	0,840	[kNm]

P	0,520	[kN]	Ratio	36,202	[%]
P_x	70,207	[kN]	ϕ_x	0,999	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,020	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	2,006	[kNm]
$M_{1,101,103}$	0,020	[kNm]	$M_{1,101,103}$	1,249	[kNm]
$M_{1,101,104}$	2,006	[kNm]	$M_{1,101,104}$	0,840	[kNm]

P	0,520	[kN]	Ratio	36,202	[%]
P_x	70,207	[kN]	ϕ_x	0,999	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,020	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	2,006	[kNm]
$M_{1,101,103}$	0,020	[kNm]	$M_{1,101,103}$	1,249	[kNm]
$M_{1,101,104}$	2,006	[kNm]	$M_{1,101,104}$	0,840	[kNm]

P	0,520	[kN]	Ratio	36,884	[%]
P_x	70,207	[kN]	ϕ_x	0,999	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,020	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	2,006	[kNm]
$M_{1,101,103}$	0,020	[kNm]	$M_{1,101,103}$	1,249	[kNm]
$M_{1,101,104}$	1,336	[kNm]	$M_{1,101,104}$	0,840	[kNm]

P	0,520	[kN]	Ratio	37,037	[%]
P_x	70,207	[kN]	ϕ_x	0,999	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,020	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	1,336	[kNm]
$M_{1,101,103}$	0,020	[kNm]	$M_{1,101,103}$	2,814	[kNm]
$M_{1,101,104}$	2,814	[kNm]	$M_{1,101,104}$	0,020	[kNm]

P	0,520	[kN]	Ratio	37,037	[%]
P_x	70,207	[kN]	ϕ_x	0,999	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,020	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	1,336	[kNm]
$M_{1,101,103}$	0,020	[kNm]	$M_{1,101,103}$	2,814	[kNm]
$M_{1,101,104}$	2,814	[kNm]	$M_{1,101,104}$	0,020	[kNm]

Office: ...		Author: JOSE ANTONIO	
Date: 05/09/2019		Project: MASTER THESIS	
Client: COIMBRA UNIVERSITY			
Design of a Photovoltaic Structure, Portal configuration, according to AISI or AS/NZS			
Code: AISI AS/NZS	Reference: AISI S100 AS/NZS 4600 EN 1993		
Version: 1,000			

Middle Beam

C_{t1}	0,850	C_{t2}	0,850
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P_{1x}	1618,248	[kN]	P_{1y}	1244,724	[kN]
α_x	0,999		α_y	0,998	

P	1,030	[kN]	Ratio	31,558	[%]
P_x	71,530	[kN]	ϕ_x	0,998	
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,010	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	2,006	[kNm]
$M_{1,101,103}$	0,010	[kNm]	$M_{1,101,103}$	2,814	[kNm]
$M_{1,101,104}$	2,006	[kNm]	$M_{1,101,104}$	0,840	[kNm]

P	1,030	[kN]	Ratio	36,830	[%]
P_x	71,530	[kN]	ϕ_x	0,998	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,010	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	2,006	[kNm]
$M_{1,101,103}$	0,010	[kNm]	$M_{1,101,103}$	2,814	[kNm]
$M_{1,101,104}$	2,006	[kNm]	$M_{1,101,104}$	0,840	[kNm]

P	1,030	[kN]	Ratio	36,830	[%]
P_x	71,530	[kN]	ϕ_x	0,998	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,010	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	2,006	[kNm]
$M_{1,101,103}$	0,010	[kNm]	$M_{1,101,103}$	2,814	[kNm]
$M_{1,101,104}$	2,006	[kNm]	$M_{1,101,104}$	0,840	[kNm]

P	1,030	[kN]	Ratio	37,913	[%]
P_x	71,530	[kN]	ϕ_x	0,999	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,010	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	1,336	[kNm]
$M_{1,101,103}$	0,010	[kNm]	$M_{1,101,103}$	2,814	[kNm]
$M_{1,101,104}$	1,336	[kNm]	$M_{1,101,104}$	0,840	[kNm]

P	1,030	[kN]	Ratio	37,913	[%]
P_x	71,530	[kN]	ϕ_x	0,999	||
$M_{1,101,101}$	0,840	[kNm]	$M_{1,101,101}$	0,010	[kNm]
$M_{1,101,102}$	4,225	[kNm]	$M_{1,101,102}$	1,336	[kNm]
$M_{1,101,103}$	0,010	[kNm]	$M_{1,101,103}$	2,814	[kNm]
$M_{1,101,104}$	2,814	[kNm]	$M_{1,101,104}$	0,010	[kNm]

[0] C-Section Beam - Combined Axial Load and Bending [AISI S100, LRFD]

[1] Combined Tensile Axial Load and Bending [AISI S100, CS,1,2]

$$\frac{\bar{M}_x}{\phi_b M_{ntx}} + \frac{\bar{M}_y}{\phi_b M_{nty}} + \frac{\bar{T}}{\phi_b T_n} \leq 1.0$$

[AISI S100, Eq. C5.1.2.1]

$\phi_b = 0.900$ $\phi_b = 0.950$

$$\frac{\bar{M}_x}{\phi_b M_{ntx}} + \frac{\bar{M}_y}{\phi_b M_{nty}} + \frac{\bar{T}}{\phi_b T_n} \leq 1.0$$

[AISI S100, Eq. C5.1.2.2]

Concrete Beam

R = T	0,520	[kN]	Ratio	22,956	[%]
R _y = T _y	124,223	[kN]			
M _{xx(beam)}	0,840	[kNm]	M _{xx(beam)}	2,056	[kNm]
M _{yy(beam)}	4,815	[kNm]	M _{yy(beam)}	4,951	[kNm]
M _{zz(beam)}	0,020	[kNm]	M _{zz(beam)}	1,249	[kNm]

[AISI S100, Eq. C5.1.2.1]

R = T	0,520	[kN]	Ratio	20,058	[%]
R _y = T _y	124,223	[kN]			
M _{xx(beam)}	0,840	[kNm]	M _{xx(beam)}	1,336	[kNm]
M _{yy(beam)}	4,815	[kNm]	M _{yy(beam)}	4,951	[kNm]
M _{zz(beam)}	0,020	[kNm]	M _{zz(beam)}	2,814	[kNm]

Middle Beam

R = T	0,700	[kN]	Ratio	22,218	[%]
R _y = T _y	124,223	[kN]			
M _{xx(beam)}	0,840	[kNm]	M _{xx(beam)}	2,056	[kNm]
M _{yy(beam)}	4,815	[kNm]	M _{yy(beam)}	4,951	[kNm]
M _{zz(beam)}	0,010	[kNm]	M _{zz(beam)}	1,249	[kNm]

[AISI S100, Eq. C5.1.2.1]

R = T	0,700	[kN]	Ratio	19,823	[%]
R _y = T _y	124,223	[kN]			
M _{xx(beam)}	0,840	[kNm]	M _{xx(beam)}	1,336	[kNm]
M _{yy(beam)}	4,815	[kNm]	M _{yy(beam)}	4,951	[kNm]
M _{zz(beam)}	0,010	[kNm]	M _{zz(beam)}	2,814	[kNm]

P	0,520	[kN]	Ratio	21,202	[%]
P _y	70,307	[kN]			
M _{xx(beam)}	0,840	[kNm]	φ _b	1,000	[]
M _{yy(beam)}	4,815	[kNm]	M _{xx(beam)}	0,020	[kNm]
M _{zz(beam)}	0,020	[kNm]	C _{u1}	0,950	[]
M _{zz(beam)}	2,056	[kNm]	C _{u2}	0,950	[]

P	0,520	[kN]	Ratio	21,363	[%]
P _y	70,307	[kN]			
M _{xx(beam)}	0,840	[kNm]	M _{xx(beam)}	0,020	[kNm]
M _{yy(beam)}	4,815	[kNm]	M _{yy(beam)}	2,056	[kNm]

P	0,520	[kN]	Ratio	21,363	[%]
P _y	70,307	[kN]			
M _{xx(beam)}	0,840	[kNm]	M _{xx(beam)}	0,020	[kNm]
M _{yy(beam)}	4,815	[kNm]	M _{yy(beam)}	2,056	[kNm]

P	0,520	[kN]	Ratio	21,075	[%]
P _y	70,307	[kN]			
M _{xx(beam)}	0,840	[kNm]	φ _b	1,000	[]
M _{yy(beam)}	4,815	[kNm]	φ _b	1,000	[]
M _{zz(beam)}	0,020	[kNm]	C _{u1}	1,000	[]
M _{zz(beam)}	1,336	[kNm]	C _{u2}	0,950	[]

P	0,520	[kN]	Ratio	21,919	[%]
P _y	70,307	[kN]			
M _{xx(beam)}	0,840	[kNm]	M _{xx(beam)}	0,020	[kNm]
M _{yy(beam)}	4,815	[kNm]	M _{yy(beam)}	1,336	[kNm]

P	0,520	[kN]	Ratio	21,919	[%]
P _y	70,307	[kN]			
M _{xx(beam)}	0,840	[kNm]	M _{xx(beam)}	0,020	[kNm]
M _{yy(beam)}	4,815	[kNm]	M _{yy(beam)}	1,336	[kNm]

Middle Beam

C _{u1}	0,850	C _{u2}	0,950
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P _{Ex}	1618,248	[kN]	P _{Ey}	1214,224	[kN]
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φ _x	0,999	[]	φ _y	0,999	[]
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[2] Combined Compressive Axial Load and Bending [AISI S100, CS,2,2]

$$\frac{\bar{P}}{\phi_c P_n} + \frac{C_{mx} \bar{M}_x}{\phi_b M_{ntx}} + \frac{C_{my} \bar{M}_y}{\phi_b M_{nty}} \leq 1.0$$

[AISI S100, Eq. C5.2.2.1]

$$\frac{\bar{P}}{\phi_c P_n} + \frac{\bar{M}_x}{\phi_b M_{ntx}} + \frac{\bar{M}_y}{\phi_b M_{nty}} \leq 1.0$$

[AISI S100, Eq. C5.2.2.2]

$P \parallel \phi_c \leq 0,15$ $\frac{\bar{P}}{\phi_c P_n} + \frac{\bar{M}_x}{\phi_b M_{ntx}} + \frac{\bar{M}_y}{\phi_b M_{nty}} \leq 1.0$

[AISI S100, Eq. C5.2.2.3]

$\phi_c = 0,850$ $\phi_c = 0,900$

$\alpha_x = 1 - \frac{\bar{P}}{P_{Ex}} > 0$ **Concrete Beam** $\alpha_y = 1 - \frac{\bar{P}}{P_{Ey}} > 0$

[AISI S100, Eq. C5.2.2.4] P [kN]: 0,520 [AISI S100, Eq. C5.2.2.4]

$P_{Ex} = \frac{\pi^2 EI_x}{(K_x L_x)^2}$ **Middle Beam** $P_{Ey} = \frac{\pi^2 EI_y}{(K_y L_y)^2}$

[AISI S100, Eq. C5.2.2.4] P [kN]: 1,030 [AISI S100, Eq. C5.2.2.7]

Members whose ends are restrained

C _{u1}	0,850	C _{u2}	0,950
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Members whose ends are unrestrained

C _{u1}	1,000	C _{u2}	1,000
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Concrete Beam

C _{u1}	1,000	C _{u2}	0,950
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P _{Ex}	1518,885	[kN]	P _{Ey}	1219,464	[kN]
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φ _x	1,000	[]	φ _y	1,000	[]
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P	1,030	[kN]	Ratio	19,651	[%]
P _y	71,530	[kN]			
M _{xx(beam)}	0,840	[kNm]	φ _b	0,999	[]
M _{yy(beam)}	4,815	[kNm]	φ _b	0,999	[]
M _{zz(beam)}	0,010	[kNm]	C _{u1}	0,950	[]
M _{zz(beam)}	2,056	[kNm]	C _{u2}	0,950	[]

P	1,030	[kN]	Ratio	21,633	[%]
P _y	71,530	[kN]			
M _{xx(beam)}	0,840	[kNm]	M _{xx(beam)}	0,010	[kNm]
M _{yy(beam)}	4,815	[kNm]	M _{yy(beam)}	2,056	[kNm]

P	1,030	[kN]	Ratio	21,633	[%]
P _y	71,530	[kN]			
M _{xx(beam)}	0,840	[kNm]	M _{xx(beam)}	0,010	[kNm]
M _{yy(beam)}	4,815	[kNm]	M _{yy(beam)}	2,056	[kNm]

P	1,030	[kN]	Ratio	19,688	[%]
P _y	71,530	[kN]			
M _{xx(beam)}	0,840	[kNm]	φ _b	0,999	[]
M _{yy(beam)}	4,815	[kNm]	φ _b	0,999	[]
M _{zz(beam)}	0,010	[kNm]	C _{u1}	0,950	[]
M _{zz(beam)}	1,336	[kNm]	C _{u2}	0,950	[]

P	1,030	[kN]	Ratio	21,911	[%]
P _y	71,530	[kN]			
M _{xx(beam)}	0,840	[kNm]	M _{xx(beam)}	0,010	[kNm]
M _{yy(beam)}	4,815	[kNm]	M _{yy(beam)}	1,336	[kNm]

P	1,030	[kN]	Ratio	21,911	[%]
P _y	71,530	[kN]			
M _{xx(beam)}	0,840	[kNm]	M _{xx(beam)}	0,010	[kNm]
M _{yy(beam)}	4,815	[kNm]	M _{yy(beam)}	1,336	[kNm]

[0] C-Section Beam - Combined Axial Load and Bending [AS/NZS 4600, LSD]

[1] Combined axial tension and bending [AS/NZS 4600, 3.5.2]

$$\frac{M'_x}{\phi_b M'_{bx}} + \frac{M'_y}{\phi_b M'_{by}} + \frac{N'}{\phi_b N'_t} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.2(1)]

$$\frac{N^*}{\phi_t N_c} + \frac{M_x^*}{\phi_b M_{c,x}} + \frac{M_y^*}{\phi_b M_{c,y}} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.2(2)]

$\phi_t = 0.900$ $\phi_b = 0.950$

Concave Beam

N*	0,520	[kN]	Ratio	20,052	[%]
N _c	124,223	[kN]			
M _{Ed,x}	0,840	[kNm]	M _{Ed,y}	2,056	[kNm]
M _{Ed,y}	4,815	[kNm]	M _{Ed,x}	4,901	[kNm]
M _{Ed,x}	0,020	[kNm]	M _{Ed,y}	1,248	[kNm]

Middle Beam

N*	0,520	[kN]	Ratio	22,036	[%]
N _c	124,223	[kN]			
M _{Ed,x}	0,840	[kNm]	M _{Ed,y}	1,336	[kNm]
M _{Ed,y}	4,815	[kNm]	M _{Ed,x}	4,901	[kNm]
M _{Ed,x}	0,020	[kNm]	M _{Ed,y}	2,614	[kNm]

Front Column

N*	0,700	[kN]	Ratio	19,346	[%]
N _c	124,223	[kN]			
M _{Ed,x}	0,840	[kNm]	M _{Ed,y}	2,056	[kNm]
M _{Ed,y}	4,815	[kNm]	M _{Ed,x}	4,901	[kNm]
M _{Ed,x}	0,010	[kNm]	M _{Ed,y}	1,248	[kNm]

Back Column

N*	0,700	[kN]	Ratio	21,754	[%]
N _c	124,223	[kN]			
M _{Ed,x}	0,840	[kNm]	M _{Ed,y}	1,336	[kNm]
M _{Ed,y}	4,815	[kNm]	M _{Ed,x}	4,901	[kNm]
M _{Ed,x}	0,010	[kNm]	M _{Ed,y}	2,614	[kNm]

[2] Combined Compressive Axial Load and Bending [AS/NZS 4600, 3.5.1]

$$\frac{N^*}{\phi_t N_c} + \frac{C_{m1} M_x^*}{\phi_b M_{c,x}} + \frac{C_{m2} M_y^*}{\phi_b M_{c,y}} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.1(1)]

$$\frac{N^*}{\phi_t N_c} + \frac{M_x^*}{\phi_b M_{c,x}} + \frac{M_y^*}{\phi_b M_{c,y}} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.1(2)]

N*	0,520	[kN]	Ratio	21,476	[%]
N _c	91,401	[kN]			
M _{Ed,x}	0,840	[kNm]	φ _w	1,000	[]
M _{Ed,y}	4,815	[kNm]	φ _w	0,999	[]
M _{Ed,x}	0,020	[kNm]	C _{u1}	1,000	[]
M _{Ed,y}	1,336	[kNm]	C _{u2}	0,950	[]

N*	0,520	[kN]	Ratio	21,702	[%]
N _c	93,611	[kN]			
M _{Ed,x}	0,840	[kNm]	M _{Ed,y}	0,020	[kNm]
M _{Ed,y}	4,815	[kNm]	M _{Ed,x}	1,336	[kNm]

N*	0,520	[kN]	Ratio	21,718	[%]
N _c	91,401	[kN]			
M _{Ed,x}	0,840	[kNm]	M _{Ed,y}	0,020	[kNm]
M _{Ed,y}	4,815	[kNm]	M _{Ed,x}	1,336	[kNm]

Middle Beam

C _{u1}	0,850	C _{u2}	0,950
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N _{Ed}	1618,548	[kN]	N _{Ed}	1214,324	[kN]
φ _w	0,999	[]	φ _w	0,999	[]

N*	0,700	[kN]	Ratio	17,666	[%]
N _c	91,401	[kN]			
M _{Ed,x}	0,840	[kNm]	φ _w	0,999	[]
M _{Ed,y}	4,815	[kNm]	φ _w	0,999	[]
M _{Ed,x}	0,010	[kNm]	C _{u1}	0,950	[]
M _{Ed,y}	2,056	[kNm]	C _{u2}	0,950	[]

N*	0,700	[kN]	Ratio	20,816	[%]
N _c	93,611	[kN]			
M _{Ed,x}	0,840	[kNm]	M _{Ed,y}	0,010	[kNm]
M _{Ed,y}	4,815	[kNm]	M _{Ed,x}	2,056	[kNm]

N*	0,700	[kN]	Ratio	20,840	[%]
N _c	91,401	[kN]			
M _{Ed,x}	0,840	[kNm]	M _{Ed,y}	0,010	[kNm]
M _{Ed,y}	4,815	[kNm]	M _{Ed,x}	2,056	[kNm]

[4] C-Section Column

[1] C-Section Column: Combined Axial Load and Bending [AISI S100, ASD]

[1] Combined Torsional Axial Load and Bending [AISI S100, CS 1.1]

$$\frac{\Omega_c M_x}{M_{c,x}} + \frac{\Omega_c M_y}{M_{c,y}} + \frac{\Omega_c T}{T_n} \leq 1.0$$

[AISI S100, Eq. CS 1.1-1]

$$\frac{\Omega_c M_x}{M_{c,x}} + \frac{\Omega_c M_y}{M_{c,y}} + \frac{\Omega_c T}{T_n} \leq 1.0$$

[AISI S100, Eq. CS 1.1-2]

Ω _c	1,670	Ω _c	1,670
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Front Column

R = T	2,256	[kN]	Ratio	11,484	[%]
R = T _y	183,743	[kN]			
M _{Ed,x}	0,270	[kNm]	M _{Ed,y}	3,998	[kNm]
M _{Ed,y}	4,732	[kNm]	M _{Ed,x}	4,998	[kNm]
M _{Ed,x}	0,000	[kNm]	M _{Ed,y}	1,930	[kNm]

$N^* | \phi_t N_c | \leq 0,15$ $\frac{N^*}{\phi_t N_c} + \frac{M_x^*}{\phi_b M_{c,x}} + \frac{M_y^*}{\phi_b M_{c,y}} \leq 1.0$

[AS/NZS 4600, Eq. 3.5.1(3)]

$\phi_t = 0,850$ $\phi_b = 0,900$

$\alpha_{c1} \alpha_{c2} = 1 - \left(\frac{N^*}{N_c} \right)^2$ $N_c = \frac{\pi^2 EI_b}{(l_{cb})^2}$

[AS/NZS 4600, Eq. 3.5.1(5)] [AS/NZS 4600, Eq. 3.5.1(6)]

Members whose ends are restrained

C _{u1}	0,850	C _{u2}	0,950
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Members whose ends are unrestrained

C _{u1}	1,000	C _{u2}	1,000
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Concave Beam

C _{u1}	1,000	C _{u2}	0,950
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N _{Ed}	1518,585	[kN]	N _{Ed}	1219,464	[kN]
φ _w	1,000	[]	φ _w	0,999	[]

Concave Beam

N*	0,520	[kN]	Ratio	21,052	[%]
N _c	91,401	[kN]			
M _{Ed,x}	0,840	[kNm]	φ _w	1,000	[]
M _{Ed,y}	4,815	[kNm]	φ _w	0,999	[]
M _{Ed,x}	0,020	[kNm]	C _{u1}	1,000	[]
M _{Ed,y}	2,056	[kNm]	C _{u2}	0,950	[]

Middle Beam

N*	0,520	[kN]	Ratio	21,146	[%]
N _c	93,611	[kN]			
M _{Ed,x}	0,840	[kNm]	M _{Ed,y}	0,020	[kNm]
M _{Ed,y}	4,815	[kNm]	M _{Ed,x}	2,056	[kNm]

Front Column

N*	0,520	[kN]	Ratio	21,762	[%]
N _c	91,401	[kN]			
M _{Ed,x}	0,840	[kNm]	M _{Ed,y}	0,020	[kNm]
M _{Ed,y}	4,815	[kNm]	M _{Ed,x}	2,056	[kNm]

N*	0,700	[kN]	Ratio	19,066	[%]
N _c	91,401	[kN]			
M _{Ed,x}	0,840	[kNm]	φ _w	0,999	[]
M _{Ed,y}	4,815	[kNm]	φ _w	0,999	[]
M _{Ed,x}	0,010	[kNm]	C _{u1}	0,950	[]
M _{Ed,y}	1,336	[kNm]	C _{u2}	0,950	[]

N*	0,700	[kN]	Ratio	21,066	[%]
N _c	93,611	[kN]			
M _{Ed,x}	0,840	[kNm]	M _{Ed,y}	0,010	[kNm]
M _{Ed,y}	4,815	[kNm]	M _{Ed,x}	1,336	[kNm]

N*	0,700	[kN]	Ratio	21,317	[%]
N _c	91,401	[kN]			
M _{Ed,x}	0,840	[kNm]	M _{Ed,y}	0,010	[kNm]
M _{Ed,y}	4,815	[kNm]	M _{Ed,x}	1,336	[kNm]

[4] C-Section Column

[1] C-Section Column: Combined Axial Load and Bending [AISI S100, ASD]

[1] Combined Torsional Axial Load and Bending [AISI S100, CS 1.1]

$$\frac{\Omega_c M_x}{M_{c,x}} + \frac{\Omega_c M_y}{M_{c,y}} + \frac{\Omega_c T}{T_n} \leq 1.0$$

[AISI S100, Eq. CS 1.1-1]

$$\frac{\Omega_c M_x}{M_{c,x}} + \frac{\Omega_c M_y}{M_{c,y}} + \frac{\Omega_c T}{T_n} \leq 1.0$$

[AISI S100, Eq. CS 1.1-2]

Ω _c	1,670	Ω _c	1,670
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Front Column

R = T	2,256	[kN]	Ratio	11,484	[%]
R = T _y	183,743	[kN]			
M _{Ed,x}	0,270	[kNm]	M _{Ed,y}	3,998	[kNm]
M _{Ed,y}	4,732	[kNm]	M _{Ed,x}	4,998	[kNm]
M _{Ed,x}	0,000	[kNm]	M _{Ed,y}	1,930	[kNm]

[MEMBER_Eq_CS2.1.2]	<table border="1"> <tr><td>R = T</td><td>2,700</td><td>[kN]</td><td>Ratio</td><td>7,065</td><td>[%]</td></tr> <tr><td>R_y = T_y</td><td>183,343</td><td>[kN]</td><td></td><td></td><td></td></tr> <tr><td>M_{MAXIMUM}</td><td>0,270</td><td>[kNm]</td><td>M_{MAXIMUM}</td><td>2,43</td><td>[kNm]</td></tr> <tr><td>M_{MINIMUM}</td><td>4,732</td><td>[kNm]</td><td>M_{MINIMUM}</td><td>4,732</td><td>[kNm]</td></tr> <tr><td>M_{AVG}</td><td>0,000</td><td>[kNm]</td><td>M_{AVG}</td><td>3,332</td><td>[kNm]</td></tr> </table>	R = T	2,700	[kN]	Ratio	7,065	[%]	R _y = T _y	183,343	[kN]				M _{MAXIMUM}	0,270	[kNm]	M _{MAXIMUM}	2,43	[kNm]	M _{MINIMUM}	4,732	[kNm]	M _{MINIMUM}	4,732	[kNm]	M _{AVG}	0,000	[kNm]	M _{AVG}	3,332	[kNm]
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[2]	<p>Combined Compressive Axial Load and Bending [AISI S100, CS 2.2]</p> $\frac{\Omega_c P}{P_n} + \frac{\Omega_c C_{mx} M_x}{M_{nx}} + \frac{\Omega_c C_{my} M_y}{M_{ny}} \leq 1.0$ <p>[AISI S100, Eq. CS 2.1-1]</p> $\frac{\Omega_c P}{P_{no}} + \frac{\Omega_b M_x}{M_{nx}} + \frac{\Omega_b M_y}{M_{ny}} \leq 1.0$ <p>[AISI S100, Eq. CS 2.1-2]</p> $\Omega_c \cdot P \leq 0.5 \cdot \frac{\Omega_c P}{P_n} + \frac{\Omega_b M_x}{M_{nx}} + \frac{\Omega_b M_y}{M_{ny}} \leq 1.0$ <p>[AISI S100, Eq. CS 2.1-3]</p> <table border="1"> <tr><td>Ω_c</td><td>1,000</td><td>Ω_b</td><td>1,970</td></tr> </table> $\alpha_x = 1 - \frac{\Omega_c P}{P_{EX}} > 0$ <p>[AISI S100, Eq. CS 2.1-4] P [kN]: 4,340</p> $\alpha_y = 1 - \frac{\Omega_c P}{P_{EY}} > 0$ <p>[AISI S100, Eq. CS 2.1-4]</p>	Ω _c	1,000	Ω _b	1,970																										
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	$P_{EX} = \frac{\pi^2 EI_x}{(K_x L_x)^2}$ <p>[AISI S100, Eq. CS 2.1-4] P [kN]: 4,370</p> $P_{EY} = \frac{\pi^2 EI_y}{(K_y L_y)^2}$ <p>[AISI S100, Eq. CS 2.1-4]</p>																																				
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[MEMBER_Eq_CS2.1.2]	<table border="1"> <tr><td>P</td><td>4,340</td><td>[kN]</td><td>Ratio</td><td>14,416</td><td>[%]</td></tr> <tr><td>P_y</td><td>152,460</td><td>[kN]</td><td></td><td></td><td></td></tr> <tr><td>M_{MAXIMUM}</td><td>0,270</td><td>[kNm]</td><td>M_{MAXIMUM}</td><td>0,000</td><td>[kNm]</td></tr> <tr><td>M_{MINIMUM}</td><td>4,732</td><td>[kNm]</td><td>M_{MINIMUM}</td><td>3,999</td><td>[kNm]</td></tr> </table>	P	4,340	[kN]	Ratio	14,416	[%]	P _y	152,460	[kN]				M _{MAXIMUM}	0,270	[kNm]	M _{MAXIMUM}	0,000	[kNm]	M _{MINIMUM}	4,732	[kNm]	M _{MINIMUM}	3,999	[kNm]												
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Rear Column			
R + T	3,340	[kN]	Ratio 9,201 [%]
R _y + T _y	183,143	[kN]	
M _{MAXIMUM}	0,350	[kNm]	M _{MINIMUM} 2,143 [kNm]
M _{MAXIMUM}	4,732	[kNm]	M _{MINIMUM} 4,988 [kNm]
M _{MAXIMUM}	0,000	[kNm]	M _{MINIMUM} 3,332 [kNm]

Rear Column			
R + T	3,340	[kN]	Ratio 9,531 [%]
R _y + T _y	183,143	[kN]	
M _{MAXIMUM}	0,350	[kNm]	M _{MINIMUM} 2,143 [kNm]
M _{MAXIMUM}	4,602	[kNm]	M _{MINIMUM} 4,732 [kNm]
M _{MAXIMUM}	0,000	[kNm]	M _{MINIMUM} 3,332 [kNm]

[2] Combined Compressive Axial Load and Bending [AISI S100, CS.2.2]

$$\frac{\bar{P}}{\phi_p P_n} + \frac{C_m \bar{M}_x}{\phi_b M_n \alpha_x} + \frac{C_m \bar{M}_y}{\phi_b M_n \alpha_y} \leq 1.0$$

[AISI S100, Eq. C5.2.2a]

$$\frac{\bar{P}}{\phi_p P_n} + \frac{\bar{M}_x}{\phi_b M_n} + \frac{\bar{M}_y}{\phi_b M_n} \leq 1.0$$

[AISI S100, Eq. C5.2.2c]

P | $\alpha_x > P_x$ | $\alpha_y > P_y$

$$\alpha_x = 1 - \frac{\bar{P}}{P_{Ex}} > 0$$

[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. C5.2.2.4] | Rear Column | P [kN] | 4,170

$$P_{Ex} = \frac{\pi^2 EI_x}{(K_x L_x)^2}$$

[AISI S100, Eq. C5.2.2.4] | Rear Column | P [kN] | 4,170

$$P_{Ey} = \frac{\pi^2 EI_y}{(K_y L_y)^2}$$

[AISI S100, Eq. C5.2.2.4] | Rear Column | P [kN] | 4,170

Members whose ends are unrestrained

C _{u1}	0,850	C _{u2}	0,950
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Rear Column			
C _{u1}	0,850	C _{u2}	0,950
P _{u1}	359,357	[kN]	P _{u2} 54,359 [kN]
α_x	0,990		α_y 0,935

Rear Column			
P	4,170	[kN]	Ratio 11,937 [%]
P _y	118,428	[kN]	
M _{MAXIMUM}	0,350	[kNm]	α_x 0,990 | |
M _{MAXIMUM}	4,602	[kNm]	α_y 0,935 | |
M _{MAXIMUM}	0,000	[kNm]	C _{u1} 0,850 | |
M _{MAXIMUM}	2,143	[kNm]	C _{u2} 0,950 | |

Rear Column			
P	4,170	[kN]	Ratio 12,563 [%]
P _y	118,428	[kN]	
M _{MAXIMUM}	0,350	[kNm]	M _{MINIMUM} 0,000 [kNm]
M _{MAXIMUM}	4,602	[kNm]	M _{MINIMUM} 2,143 [kNm]

Rear Column			
P	4,170	[kN]	Ratio 11,937 [%]
P _y	118,428	[kN]	
M _{MAXIMUM}	0,350	[kNm]	α_x 0,990 | |
M _{MAXIMUM}	4,602	[kNm]	α_y 0,935 | |
M _{MAXIMUM}	0,000	[kNm]	C _{u1} 0,850 | |
M _{MAXIMUM}	2,143	[kNm]	C _{u2} 0,950 | |

Rear Column			
P	4,170	[kN]	Ratio 12,563 [%]
P _y	118,428	[kN]	
M _{MAXIMUM}	0,350	[kNm]	M _{MINIMUM} 0,000 [kNm]
M _{MAXIMUM}	4,602	[kNm]	M _{MINIMUM} 2,143 [kNm]

Rear Column			
P	4,170	[kN]	Ratio 12,563 [%]
P _y	118,428	[kN]	
M _{MAXIMUM}	0,350	[kNm]	M _{MINIMUM} 0,000 [kNm]
M _{MAXIMUM}	4,602	[kNm]	M _{MINIMUM} 2,143 [kNm]

Members whose ends are unrestrained

C _{u1}	1,000	C _{u2}	1,000
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Front Column			
C _{u1}	1,000	C _{u2}	0,950
P _{u1}	1206,983	[kN]	P _{u2} 162,455 [kN]
α_x	0,997		α_y 0,978

Front Column			
P	4,140	[kN]	Ratio 9,552 [%]
P _y	152,480	[kN]	
M _{MAXIMUM}	0,270	[kNm]	α_x 0,997 | |
M _{MAXIMUM}	4,732	[kNm]	α_y 0,978 | |
M _{MAXIMUM}	0,000	[kNm]	C _{u1} 1,000 | |
M _{MAXIMUM}	3,988	[kNm]	C _{u2} 0,950 | |

Front Column			
P	4,140	[kN]	Ratio 9,534 [%]
P _y	152,480	[kN]	
M _{MAXIMUM}	0,270	[kNm]	M _{MINIMUM} 0,000 [kNm]
M _{MAXIMUM}	4,732	[kNm]	M _{MINIMUM} 3,988 [kNm]

Front Column			
P	4,140	[kN]	Ratio 9,534 [%]
P _y	152,480	[kN]	
M _{MAXIMUM}	0,270	[kNm]	M _{MINIMUM} 0,000 [kNm]
M _{MAXIMUM}	4,732	[kNm]	M _{MINIMUM} 3,988 [kNm]

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P	4,140	[kN]	Ratio 9,534 [%]
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P	4,140	[kN]	Ratio 9,534 [%]
P _y	152,480	[kN]	
M _{MAXIMUM}	0,270	[kNm]	M _{MINIMUM} 0,000 [kNm]
M _{MAXIMUM}	4,732	[kNm]	M _{MINIMUM} 2,143 [kNm]

[10] C-Section Column - Combined Axial Load and Bending [AS/NZS 4600, 3.5.2]

[1] Combined axial tension and bending [AS/NZS 4600, 3.5.2]

$$\frac{M'_x}{\phi_b M'_n} + \frac{M'_y}{\phi_b M'_n} + \frac{N'}{\phi_t N'_t} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.2(1)]

$$\frac{N'}{\phi_t N'_t} + \frac{M'_x}{\phi_b M'_n} + \frac{M'_y}{\phi_b M'_n} \leq 1.0$$

[AS/NZS 4600, Eq. 3.5.2(2)]

α_x	0,990	α_y	0,950
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Front Column			
N'	2,700	[kN]	Ratio 5,475 [%]
N _y	183,143	[kN]	
M _{MAXIMUM}	0,270	[kNm]	M _{MINIMUM} 3,332 [kNm]
M _{MAXIMUM}	4,269	[kNm]	M _{MINIMUM} 4,988 [kNm]
M _{MAXIMUM}	0,000	[kNm]	M _{MINIMUM} 1,930 [kNm]

Front Column			
N'	2,700	[kN]	Ratio 7,891 [%]
N _y	183,143	[kN]	
M _{MAXIMUM}	0,270	[kNm]	M _{MINIMUM} 1,930 [kNm]
M _{MAXIMUM}	4,269	[kNm]	M _{MINIMUM} 4,732 [kNm]
M _{MAXIMUM}	0,000	[kNm]	M _{MINIMUM} 3,332 [kNm]

Rear Column			
N'	3,340	[kN]	Ratio 7,169 [%]
N _y	183,143	[kN]	
M _{MAXIMUM}	0,350	[kNm]	M _{MINIMUM} 3,332 [kNm]
M _{MAXIMUM}	4,269	[kNm]	M _{MINIMUM} 4,988 [kNm]
M _{MAXIMUM}	0,000	[kNm]	M _{MINIMUM} 1,930 [kNm]

Rear Column			
N'	3,340	[kN]	Ratio 19,137 [%]
N _y	183,143	[kN]	
M _{MAXIMUM}	0,350	[kNm]	M _{MINIMUM} 1,930 [kNm]
M _{MAXIMUM}	4,269	[kNm]	M _{MINIMUM} 4,732 [kNm]
M _{MAXIMUM}	0,000	[kNm]	M _{MINIMUM} 3,332 [kNm]

[2] Combined Compressive Axial Load and Bending [AS/NZS 4600, 3.5.1]

$$\frac{N^*}{\phi_c N_c} + \frac{C_m M_x^*}{\phi_b M_{rx}} \leq 1.0$$

$$\frac{N^*}{\phi_c N_c} + \frac{M_y^*}{\phi_b M_{ry}} \leq 1.0$$

$N^* \leq \phi_c N_c$ [AS/NZS 4600, Eq.3.5.3(1)]

$N^* \leq \phi_c N_c$ [AS/NZS 4600, Eq.3.5.3(1)]

$\phi_c = 0.850$ $\phi_b = 0.850$

Members whose ends are restrained

C_{m1}	0.850	C_{m2}	0.850
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Members whose ends are unrestrained

C_{m1}	1.000	C_{m2}	1.000
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Fixed Column

C_{m1}	1.000	C_{m2}	0.850
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$N_{x1} = 1208.993$ [kN] $N_{y1} = 162.856$ [kN]

$\alpha_{m1} = 0.997$ [] $\alpha_{m2} = 0.974$ []

[AS/NZS 4600, Eq.3.5.1(1)]

N^*	4,170	[kN]	Ratio	11,952	[%]
N_c	172,558	[kN]			
$M_{rx1(max)}$	0,350	[kNm]	$M_{rx1(max)}$	0,000	[kNm]
$M_{rx1(min)}$	4,269	[kNm]	$M_{rx1(min)}$	3,332	[kNm]
$M_{ry1(max)}$	0,000	[kNm]	α_w	0,988	[]
$M_{ry1(min)}$	0,000	[kNm]	α_w	0,923	[]
$M_{ry1(max)}$	1,930	[kNm]	C_{m1}	0,850	[]
$M_{ry1(min)}$	0,000	[kNm]	C_{m2}	0,850	[]

[4] C-Section Steel

[1] C-Section Steel Combined Axial Load and Bending [AISI S100, ASD]

[1] Combined Tensile Axial Load and Bending [AISI S100, CS 1.1]

$$\frac{\Omega_c M_x}{M_{rx}} + \frac{\Omega_c M_y}{M_{ry}} + \frac{\Omega_c T}{T_n} \leq 1.0$$

$$\frac{\Omega_c M_x}{M_{rx}} + \frac{\Omega_c M_y}{M_{ry}} + \frac{\Omega_c T}{T_n} \leq 1.0$$

$\Omega_c = 1.670$ $\Omega_c = 1.670$

[AS/NZS 4600, Eq.3.5.1(1)]

N^*	4,170	[kN]	Ratio	11,952	[%]
N_c	172,558	[kN]			
$M_{rx1(max)}$	0,350	[kNm]	$M_{rx1(max)}$	0,000	[kNm]
$M_{rx1(min)}$	4,269	[kNm]	$M_{rx1(min)}$	3,332	[kNm]
$M_{ry1(max)}$	0,000	[kNm]	α_w	0,988	[]
$M_{ry1(min)}$	0,000	[kNm]	α_w	0,923	[]
$M_{ry1(max)}$	1,930	[kNm]	C_{m1}	0,850	[]
$M_{ry1(min)}$	0,000	[kNm]	C_{m2}	0,850	[]

[AS/NZS 4600, Eq.3.5.1(1)]

N^*	4,170	[kN]	Ratio	9,648	[%]
N_c	172,558	[kN]			
$M_{rx1(max)}$	0,270	[kNm]	$M_{rx1(max)}$	0,000	[kNm]
$M_{rx1(min)}$	4,269	[kNm]	$M_{rx1(min)}$	3,332	[kNm]
$M_{ry1(max)}$	0,270	[kNm]	α_w	0,997	[]
$M_{ry1(min)}$	4,269	[kNm]	α_w	0,974	[]
$M_{ry1(max)}$	0,000	[kNm]	C_{m1}	1,000	[]
$M_{ry1(min)}$	3,332	[kNm]	C_{m2}	0,850	[]

[AS/NZS 4600, Eq.3.5.1(1)]

N^*	4,170	[kN]	Ratio	10,161	[%]
N_c	155,423	[kN]			
$M_{rx1(max)}$	0,270	[kNm]	$M_{rx1(max)}$	0,000	[kNm]
$M_{rx1(min)}$	4,269	[kNm]	$M_{rx1(min)}$	3,332	[kNm]
$M_{ry1(max)}$	0,270	[kNm]	α_w	0,997	[]
$M_{ry1(min)}$	4,269	[kNm]	α_w	0,974	[]
$M_{ry1(max)}$	0,000	[kNm]	C_{m1}	1,000	[]
$M_{ry1(min)}$	3,332	[kNm]	C_{m2}	0,850	[]

[AS/NZS 4600, Eq.3.5.1(1)]

N^*	4,170	[kN]	Ratio	11,055	[%]
N_c	155,423	[kN]			
$M_{rx1(max)}$	0,270	[kNm]	α_w	0,997	[]
$M_{rx1(min)}$	4,269	[kNm]	α_w	0,974	[]
$M_{ry1(max)}$	0,000	[kNm]	C_{m1}	1,000	[]
$M_{ry1(min)}$	1,930	[kNm]	C_{m2}	0,850	[]

[AS/NZS 4600, Eq.3.5.1(1)]

N^*	4,170	[kN]	Ratio	9,648	[%]
N_c	172,558	[kN]			
$M_{rx1(max)}$	0,270	[kNm]	$M_{rx1(max)}$	0,000	[kNm]
$M_{rx1(min)}$	4,269	[kNm]	$M_{rx1(min)}$	1,930	[kNm]
$M_{ry1(max)}$	0,270	[kNm]	α_w	0,997	[]
$M_{ry1(min)}$	4,269	[kNm]	α_w	0,974	[]
$M_{ry1(max)}$	0,000	[kNm]	C_{m1}	1,000	[]
$M_{ry1(min)}$	3,332	[kNm]	C_{m2}	0,850	[]

[AS/NZS 4600, Eq.3.5.1(1)]

N^*	4,170	[kN]	Ratio	10,161	[%]
N_c	155,423	[kN]			
$M_{rx1(max)}$	0,270	[kNm]	$M_{rx1(max)}$	0,000	[kNm]
$M_{rx1(min)}$	4,269	[kNm]	$M_{rx1(min)}$	1,930	[kNm]
$M_{ry1(max)}$	0,270	[kNm]	α_w	0,997	[]
$M_{ry1(min)}$	4,269	[kNm]	α_w	0,974	[]
$M_{ry1(max)}$	0,000	[kNm]	C_{m1}	1,000	[]
$M_{ry1(min)}$	3,332	[kNm]	C_{m2}	0,850	[]

Fixed Column

C_{m1}	0.850	C_{m2}	0.850
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$N_{x1} = 359.397$ [kN] $N_{y1} = 54.309$ [kN]

$\alpha_{m1} = 0.988$ [] $\alpha_{m2} = 0.923$ []

[AS/NZS 4600, Eq.3.5.1(1)]

N^*	4,170	[kN]	Ratio	10,900	[%]
N_c	155,423	[kN]			
$M_{rx1(max)}$	0,350	[kNm]	α_w	0,988	[]
$M_{rx1(min)}$	4,269	[kNm]	α_w	0,923	[]
$M_{ry1(max)}$	0,000	[kNm]	C_{m1}	0,850	[]
$M_{ry1(min)}$	3,332	[kNm]	C_{m2}	0,850	[]

[AS/NZS 4600, Eq.3.5.1(1)]

$R = T$	2,280	[kN]	Ratio	6,507	[%]
$R_x = T_x$	73,911	[kN]			
$M_{rx1(max)}$	0,010	[kNm]	$M_{rx1(max)}$	1,087	[kNm]
$M_{rx1(min)}$	0,735	[kNm]	$M_{rx1(min)}$	1,232	[kNm]
$M_{ry1(max)}$	0,000	[kNm]	$M_{ry1(max)}$	0,648	[kNm]
$M_{ry1(min)}$	0,000	[kNm]	$M_{ry1(min)}$	1,006	[kNm]

[AS/NZS 4600, Eq.3.5.1(1)]

$R = T$	2,280	[kN]	Ratio	-3,878	[%]
$R_x = T_x$	73,911	[kN]			
$M_{rx1(max)}$	0,010	[kNm]	$M_{rx1(max)}$	0,283	[kNm]
$M_{rx1(min)}$	0,735	[kNm]	$M_{rx1(min)}$	1,162	[kNm]
$M_{ry1(max)}$	0,000	[kNm]	$M_{ry1(max)}$	1,006	[kNm]
$M_{ry1(min)}$	0,000	[kNm]	$M_{ry1(min)}$	1,006	[kNm]

[2] Combined Compressive Axial Load and Bending [AISI S100, CS 2.1]

$$\frac{\Omega_c P}{P_n} + \frac{\Omega_c C_m M_x}{M_{rx} \alpha_x} + \frac{\Omega_c C_m M_y}{M_{ry} \alpha_y} \leq 1.0$$

$$\frac{\Omega_c P}{P_{n0}} + \frac{\Omega_c M_x}{M_{rx}} + \frac{\Omega_c M_y}{M_{ry}} \leq 1.0$$

$\Omega_c P / P_n \leq 0.15$ $\frac{\Omega_c P}{P_n} + \frac{\Omega_c M_x}{M_{rx}} + \frac{\Omega_c M_y}{M_{ry}} \leq 1.0$

$\alpha_x = 1 - \frac{\Omega_c P}{P_{Ex}} > 0$ $\alpha_y = 1 - \frac{\Omega_c P}{P_{Ey}} > 0$

$P_{Ex} = \frac{\pi^2 EI_x}{(K_x L_x)^2}$ $P_{Ey} = \frac{\pi^2 EI_y}{(K_y L_y)^2}$

Members whose ends are restrained

C_{m1}	0.850	C_{m2}	0.850
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Members whose ends are unrestrained

C_{m1}	1.000	C_{m2}	1.000
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Office	---	Author	JOSE ANTONIO
Date	05/09/2019	Project	MASTER THESIS
Client	COIMBRA UNIVERSITY		

Design of a Photovoltaic Structure, Pedestal configuration, according to AISI or AS/NZS

Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993

Version: 1,000

Office	---	Author	JOSE ANTONIO
Date	05/09/2019	Project	MASTER THESIS
Client	COIMBRA UNIVERSITY		

Design of a Photovoltaic Structure, Pedestal configuration, according to AISI or AS/NZS

Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993

Version: 1,000

Strut	C_{u1}	1,000	C_{u2}	0,950	
P_{u1}	46,561	[kN]	P_{u2}	23,552	[kN]
q_u	0,943	[]	q_v	0,888	[]
P	1,470	[kN]	Ratio	24,070	[%]
P_{u1}	9,815	[kN]	q_u	0,943	[]
M_{u1max}	0,910	[kNm]	q_v	0,888	[]
M_{u1min}	0,735	[kNm]	C_{u1}	1,000	[]
M_{u1mid}	0,000	[kNm]	C_{u2}	0,950	[]
M_{u1end}	1,087	[kNm]	C_{u1}	0,950	[]

$$\alpha_x = 1 - \frac{\bar{P}}{P_{Ex}} > 0$$

$$\alpha_y = 1 - \frac{\bar{P}}{P_{Ey}} > 0$$

$$P_{Ex} = \frac{\pi^2 EI_x}{(K_x L_x)^2}$$

$$P_{Ey} = \frac{\pi^2 EI_y}{(K_y L_y)^2}$$

Members whose ends are restrained

C_{u1}	0,950	C_{u2}	0,950
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Members whose ends are unrestrained

C_{u1}	1,000	C_{u2}	1,000
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Strut	C_{u1}	0,950	C_{u2}	0,950	
P_{u1}	46,561	[kN]	P_{u2}	23,552	[kN]
q_u	0,973	[]	q_v	0,947	[]
P	1,470	[kN]	Ratio	16,942	[%]
P_{u1}	9,815	[kN]	q_u	0,973	[]
M_{u1max}	0,910	[kNm]	q_v	0,947	[]
M_{u1min}	0,735	[kNm]	C_{u1}	0,950	[]
M_{u1mid}	0,000	[kNm]	C_{u2}	0,950	[]
M_{u1end}	1,087	[kNm]	C_{u1}	0,950	[]

Office	---	Author	JOSE ANTONIO
Date	05/09/2019	Project	MASTER THESIS
Client	COIMBRA UNIVERSITY		

Design of a Photovoltaic Structure, Pedestal configuration, according to AISI or AS/NZS

Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993

Version: 1,000

Office	---	Author	JOSE ANTONIO
Date	05/09/2019	Project	MASTER THESIS
Client	COIMBRA UNIVERSITY		

Design of a Photovoltaic Structure, Pedestal configuration, according to AISI or AS/NZS

Code: AISI | AS/NZS References: AISI S100 | AS/NZS 4600 | EN 1993

Version: 1,000

[0] C-Section Strut - Combined Axial Load and Bending [AISI S100, LRFD]

[1] Combined Tensile Axial Load and Bending [AISI S100, CS 1.2]

$$\frac{\bar{M}_x}{\phi_b M_{ntx}} + \frac{\bar{M}_y}{\phi_b M_{nty}} + \frac{\bar{T}}{\phi_t T_n} \leq 1.0$$

$$\frac{\bar{M}_x}{\phi_b M_{ntx}} + \frac{\bar{M}_y}{\phi_b M_{nty}} + \frac{\bar{T}}{\phi_t T_n} \leq 1.0$$

Strut	$R = T$	2,280	[kN]	Ratio	4,144	[%]
$R_x = T_x$	73,911	[kN]	M_{u1max}	1,087	[kNm]	
M_{u1min}	0,910	[kNm]	M_{u1mid}	1,232	[kNm]	
M_{u1end}	0,735	[kNm]	M_{u1end}	0,848	[kNm]	

[2] Combined Compressive Axial Load and Bending [AISI S100, CS 2.2]

$$\frac{\bar{P}}{\phi_c P_n} + \frac{C_{m1} \bar{M}_x}{\phi_b M_{ntx}} + \frac{C_{m2} \bar{M}_y}{\phi_b M_{nty}} \leq 1.0$$

$$\frac{\bar{P}}{\phi_c P_n} + \frac{\bar{M}_x}{\phi_b M_{ntx}} + \frac{\bar{M}_y}{\phi_b M_{nty}} \leq 1.0$$

$$P | \phi_c \cdot P_n | \leq 0,15$$

Strut	$R = T$	2,280	[kN]	Ratio	1,734	[%]
$R_x = T_x$	73,911	[kN]	M_{u1max}	0,283	[kNm]	
M_{u1min}	0,910	[kNm]	M_{u1mid}	1,162	[kNm]	
M_{u1end}	0,735	[kNm]	M_{u1end}	1,056	[kNm]	

Strut	\bar{P}	0,850	[kN]	ϕ_c	0,950
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[0] C-Section Strut - Combined Axial Load and Bending [AS/NZS 4600, LSD]

[1] Combined axial tension and bending [AS/NZS 4600, 3.5.2]

$$\frac{M'_x}{\phi_b M'_n} + \frac{M'_y}{\phi_b M'_n} + \frac{N'}{\phi_t N'_t} \leq 1.0$$

$$\frac{N'}{\phi_t N'_t} + \frac{M'_x}{\phi_b M'_n} + \frac{M'_y}{\phi_b M'_n} \leq 1.0$$

Strut	$R = T$	2,280	[kN]	Ratio	1,942	[%]
$R_x = T_x$	73,911	[kN]	q_u	0,973	[]	
M_{u1max}	0,910	[kNm]	q_v	0,947	[]	
M_{u1min}	0,735	[kNm]	C_{u1}	0,950	[]	
M_{u1mid}	0,000	[kNm]	C_{u2}	0,950	[]	
M_{u1end}	1,087	[kNm]	C_{u1}	0,950	[]	

Strut	$R = T$	2,280	[kN]	Ratio	19,133	[%]
$R_x = T_x$	73,911	[kN]	M_{u1max}	0,000	[kNm]	
M_{u1min}	0,910	[kNm]	M_{u1mid}	0,283	[kNm]	
M_{u1end}	0,735	[kNm]	M_{u1end}	0,283	[kNm]	

Strut	$R = T$	2,280	[kN]	Ratio	17,021	[%]
$R_x = T_x$	73,911	[kN]	M_{u1max}	0,000	[kNm]	
M_{u1min}	0,910	[kNm]	M_{u1mid}	0,283	[kNm]	
M_{u1end}	0,735	[kNm]	M_{u1end}	0,283	[kNm]	

Strut	N'	2,280	[kN]	Ratio	1,345	[%]
N_x	73,911	[kN]	M_{u1max}	1,087	[kNm]	
M_{u1min}	0,910	[kNm]	M_{u1mid}	1,232	[kNm]	
M_{u1end}	0,735	[kNm]	M_{u1end}	0,848	[kNm]	

Strut	N'	2,280	[kN]	Ratio	4,233	[%]
N_x	73,911	[kN]	M_{u1max}	0,693	[kNm]	
M_{u1min}	0,910	[kNm]	M_{u1mid}	1,162	[kNm]	
M_{u1end}	0,735	[kNm]	M_{u1end}	1,056	[kNm]	

Strut	\bar{P}	0,850	[kN]	ϕ_c	0,950
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Design of a Photovoltaic Structure, Portal configuration, according to ASB or AS/NZS			Office: ...	Author: JOSÉ ANTONIO
Code: AS [AS/NZS]	Reference: AS15100 [AS/NZS 4600] EN 1993	Date: 05/09/2019	Project: MASTER THESIS	
Version: 1,000		Client: COIMBRA UNIVERSITY		

[2] Combined Compressive Axial Load and Bending [AS15100, CS 2.2]

$$\frac{N^*}{\phi_c N_s} + \frac{C_m M_x^*}{\phi_b M_{sx} \alpha_{cb}} + \frac{C_m M_y^*}{\phi_b M_{sy} \alpha_{cb}} \leq 1.0$$

[AS/NZS 4600, Eq.3.5.1(f)]

$$\frac{N^*}{\phi_c N_s} + \frac{M_x^*}{\phi_b M_{sx}} + \frac{M_y^*}{\phi_b M_{sy}} \leq 1.0$$

[AS/NZS 4600, Eq.3.5.1(g)]

$N^* \leq \phi_c N_s$ [5.0.1.5]

$$\frac{N^*}{\phi_c N_s} + \frac{M_x^*}{\phi_b M_{sx}} + \frac{M_y^*}{\phi_b M_{sy}} \leq 1.0$$

[AS/NZS 4600, Eq.3.5.1(f)]

$\phi_c = 0.950$ $\phi_b = 0.950$

$$\alpha_{cbx}, \alpha_{cby} = 1 - \left(\frac{N^*}{N_s} \right)^2$$

[AS/NZS 4600, Eq.3.5.1(f)]

$$N_s = \frac{\pi^2 EI_b}{(L_{cb})^2}$$

[AS/NZS 4600, Eq.3.5.1(f)]

Members whose ends are restrained

C_{m1}	0.950	C_{m2}	0.950
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Members whose ends are unrestrained

C_{m1}	1.000	C_{m2}	1.000
----------	-------	----------	-------

Strut

C_{m1}	0.950	C_{m2}	0.950
----------	-------	----------	-------

$N_{s1} = 46,261$ [kN] $N_{s2} = 23,652$ [kN]

$\alpha_w = 0.968$ [] $\alpha_w = 1.000$ []

N^*	1,870	[kN]	Ratio	9,800	[%]
N_s	20,743	[kN]			
$M_{11(Load)}^*$	0.910	[kNm]	α_w	0.968	[]
$M_{11(Design)}^*$	0.953	[kNm]	α_w	1.000	[]
$M_{12(Load)}^*$	0.900	[kNm]	C_{m2}	0.950	[]
$M_{12(Design)}^*$	1.087	[kNm]	C_{m2}	0.950	[]

[AS/NZS 4600, Eq.3.5.1(f)]

Design of a Photovoltaic Structure, Portal configuration, according to ASB or AS/NZS			Office: ...	Author: JOSÉ ANTONIO
Code: AS [AS/NZS]	Reference: AS15100 [AS/NZS 4600] EN 1993	Date: 05/09/2019	Project: MASTER THESIS	
Version: 1,000		Client: COIMBRA UNIVERSITY		

[AS/NZS 4600, Eq.3.5.1(f)]	<table border="1"> <tr> <td>N^*</td> <td>1,870</td> <td>[kN]</td> <td>Ratio</td> <td>9,757</td> <td>[%]</td> </tr> <tr> <td>N_s</td> <td>70,460</td> <td>[kN]</td> <td></td> <td></td> <td></td> </tr> <tr> <td>$M_{11(Load)}^*$</td> <td>0.910</td> <td>[kNm]</td> <td>$M_{11(Design)}^*$</td> <td>0.950</td> <td>[kNm]</td> </tr> <tr> <td>$M_{12(Load)}^*$</td> <td>0.953</td> <td>[kNm]</td> <td>$M_{12(Design)}^*$</td> <td>1.087</td> <td>[kNm]</td> </tr> </table>	N^*	1,870	[kN]	Ratio	9,757	[%]	N_s	70,460	[kN]				$M_{11(Load)}^*$	0.910	[kNm]	$M_{11(Design)}^*$	0.950	[kNm]	$M_{12(Load)}^*$	0.953	[kNm]	$M_{12(Design)}^*$	1.087	[kNm]												
N^*	1,870	[kN]	Ratio	9,757	[%]																																
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[AS/NZS 4600, Eq.3.5.1(f)]	<table border="1"> <tr> <td>N^*</td> <td>1,870</td> <td>[kN]</td> <td>Ratio</td> <td>9,840</td> <td>[%]</td> </tr> <tr> <td>N_s</td> <td>20,743</td> <td>[kN]</td> <td></td> <td></td> <td></td> </tr> <tr> <td>$M_{11(Load)}^*$</td> <td>0.910</td> <td>[kNm]</td> <td>$M_{11(Design)}^*$</td> <td>0.900</td> <td>[kNm]</td> </tr> <tr> <td>$M_{12(Load)}^*$</td> <td>0.953</td> <td>[kNm]</td> <td>$M_{12(Design)}^*$</td> <td>1.087</td> <td>[kNm]</td> </tr> </table>	N^*	1,870	[kN]	Ratio	9,840	[%]	N_s	20,743	[kN]				$M_{11(Load)}^*$	0.910	[kNm]	$M_{11(Design)}^*$	0.900	[kNm]	$M_{12(Load)}^*$	0.953	[kNm]	$M_{12(Design)}^*$	1.087	[kNm]												
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