EFFECTIVENESS OF MODAL/SPECTRAL *Versus* TIME-HISTORY METHODS IN OPTIMIZATION OF CABLE-STAYED BRIDGES UNDER SEISMIC ACTION

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Extended Summary

In countries of high seismicity, the structural safety of large structures such as cable-stayed bridges against earthquake vibrations is a major concern of the design.

This means that, if the application of some optimization technique at a preliminary design stage is to be considered, the usefulness and reliability of their results will depend upon the consideration of this action.

The application of optimization techniques to improve the design of cable-stayed bridges undergoing earthquake vibrations requires the development of appropriate structural and sensitivity analysis programs. A three-dimensional modelling and the capability of handling geometric non-linearities are required for such study.

The vibrational characteristics of this type of structure are highly dependant on the stiffness and mass distribution and there is not an explicit form for this relation.

The usual methods for seismic analysis are either modal/spectral analysis or time-history (step-by-step) process.

Both methods were extensively described in literature and practically checked by a number of actual designs. Also their relative advantages and inconvenients are well known. Modal superposition behaves well only in linear or mild non-linear problems, while step-by-step methods generate a large amount of data which makes the post-processing stage expensive unless some filtering is provided. The unsuitability of modal/spectral approach for structures with close frequencies and strong mode coupling used to be a major inconvenient for cable-stayed bridges, where these are typical features of its behaviour. With the advent of the Complete Quadratic Combination (CQC) method for the modal effects combination, however, this limitation was overcome. As to processing time, modal/spectral analysis spends most of the time at the stage of the eigenvalue problem solution, while time-history computational cost results essentially from the time integration and analysis cycle. Modal/spectral solution is usually less expensive, at least when only a moderate number of the most significant vibration modes is used to compute the pseudo-loads set.

Sensitivity analysis for modal/spectral approach was formulated after the derivation of the expressions concerning both the maximum modal forces and the CQC combination rule. Eigenvalues and eigenvectors derivatives are required for this purpose and its determination results on a significant increase in computational time.

The direct integration procedure of Newmark's method was considered in the step-by-step procedure, due to its effectiveness and formal simplicity. Sensitivity analysis, in this case, is evaluated from the sequential solution in time of the derivatives of the dynamic equilibrium equations with respect to the design variables. This represents most of the computational cost increase for the step-by-step approach. However, the cost of the preliminary limited eigenvalue problem sensitivity analysis, giving the frequencies and its derivatives for Rayleigh's damping, cannot be neglected.

The optimization objectives to minimise stresses, material cost/volume and displacements, in order to achieve some global cost reduction. This is a minimax optimization problem which can be solved indirectly by the solution of a continuously differentiable scalar function, derived by using Shannon's maximum entropy principle.

The main issue of this paper is to observe the general behaviour and, particularly, the global and partial costs associated with each method throughout the optimization process. For that purpose, several starting designs are solved by both methods and the results discussed.