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Reliability-Based Design of Large Scale Structural Models under Stochastic Excitation

Hector Jensen*, Alvaro Muñoz†, Marcos Valdebenito†

* Department of Civil Engineering, Federico Santa Maria University
Casilla 110 V, Valparaiso, Chile
hector.jensen@usm.cl

† Department of Civil Engineering, Federico Santa Maria University
Casilla 110 V, Valparaiso, Chile

ABSTRACT

This work presents a general framework for the reliability-based design of large scale structural models under stochastic excitation. The variability of future ground motions is modeled as a non-stationary stochastic process. The design process is written in terms of a constrained nonlinear optimization problem with reliability constraints. For structural systems under stochastic excitation the reliability constraints are associated with high dimensional reliability problems which are difficult to estimate. Overall the solution of the reliability-based optimization problem is computationally very demanding due to the large number of dynamic finite element analyses required during the optimization process. To cope with the computational burden associated with the design process a model reduction technique is implemented to define a reduced-order model for the structure. In particular, a substructure coupling technique for dynamic analysis is considered here [1]. This technique is integrated into the optimization process by defining two groups of substructures. The first group comprises the substructures that do not depend on the design variables while the second group is defined by the substructures that depend explicitly on the design variables. In this setting only the matrices related to the substructures that depend on the vector of design variables need to be recomputed in each iteration of the optimization process. This repeated computation, however, is usually confined to a small number of substructures in many practical applications. Thus, a significant saving arises during the optimization process under these conditions. The solution of the optimization problem is carried out by an efficient nonlinear interior point algorithm [2]. Starting from a feasible design the objective of the optimization scheme is to determine a direction vector followed by a step length along this direction which gives a new improved design point. The process continues until convergence is achieved.

The effectiveness of the proposed strategy is demonstrated by the reliability-based design of a large scale bridge finite element model. Numerical results show that the computational effort for designing the reduced-order model is decreased drastically by two or three orders of magnitude with respect to the unreduced model without compromising the accuracy of the final design.

REFERENCES

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