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Performance-Based Design Optimization of Structures Under Seismic Demands, Incorporating Passive Control Devices

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ABSTRACT

The general objective of performance-based design of structures, under different seismic demands, is to obtain values for several design parameters which result in the satisfaction of performance requirements with specified minimum reliabilities while, at the same time, achieving a minimum total cost. The problem includes uncertain intervening variables, some associated with the structure itself while others are associated with the earthquake ground motions. In this context, the problem involves an optimization for the different design parameters (for example, the mean value of some of those variables). This optimization [1] has the objective of minimum total cost, with constraints related to the minimum reliabilities with which the different performance levels must be met.

The problem requires first the definition of the intervening variables and their uncertainty. The performance requirements are formulated in terms of maxima for structural responses like displacements, relative deformations or damage parameters, quantities that require a nonlinear dynamic analysis of the structure for combinations of the variables under different ground motions. This discrete set of values is given a continuous representation, in order to interpolate responses for combinations not studied. In this work artificial neural networks [2] are used to represent the mean and the standard deviation of the structural responses over a range corresponding to a set of different, possible ground motions at the site. This approach facilitates also the task of numerical simulations required for 1) the estimation of the probabilities of exceeding a performance limit, and 2) the implementation of a robust, search-based, optimization algorithm. To facilitate the verification of the constraints during the optimization, artificial neural networks are also used to represent the achieved reliabilities in terms of the design parameters. The cost objective function includes not only the initial cost of the structure and the dissipation devices, but also those costs associated with their repair for damage due to earthquakes occurring at random times during the economic life of the structure, plus costs corresponding to the social consequences of the earthquakes.

As an example, a four-story, reinforced concrete office building in the city of Mendoza, Argentina, is considered. Devices which dissipate energy by yielding are installed at each story. It is shown how the general methodology presented permits the optimization of the device parameters, the dimensions of the structure and the steel reinforcement ratios in beams and columns. Conclusions are offered regarding the initial cost of the devices and the cost of their replacement, in relation to the initial cost of the main structure and its repair cost.

REFERENCES

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