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Structural optimization: An assessment approach of design procedures against the earthquake hazard

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ABSTRACT

Structural optimization problems are characterized by various objective and constraint functions, which are generally non-linear functions of the design variables. These functions are usually implicit, discontinuous and non-convex. The mathematical formulation of structural optimization problems with respect to the design variables, the objective and constraint functions depend on the type of the application. During the last three decades there has been a growing interest in problem solving systems based on algorithms which rely on analogies to natural processes. These systems have some selection process based on fitness of individuals and some recombination operators and they are used in this work for assessing design approaches against the earthquake hazard.

The first objective of this study is the assessment of the European seismic design codes and in particular of EC2 and EC8 with respect to the recommended behaviour factor q. The assessment is performed on two reinforced concrete multi-storey buildings, having symmetrical and non-symmetrical plan view respectively, which were optimally designed under four different values of the behaviour factor. In the mathematical formulation of the optimization problem the initial construction cost is considered as the objective function to be minimized while the cross sections and steel reinforcement of the beams and the columns constitute the design variables. The provisions of Eurocodes 2 and 8 are imposed as constraints to the optimization problem. Life-cycle cost analysis, in conjunction with structural optimization, is believed to be a reliable procedure for assessing the performance of structures during their life time.

The current state-of-practice static pushover methods as suggested in the provisions of European and American regulations are implemented in this comparative study. In particular the static pushover methods are: the displacement coefficient method of ASCE/SEI 41-06, the ATC-40 capacity spectrum method and the N2 method of Eurocode 8. Such analysis methods are typically recommended for the performance assessment of existing structures, and therefore most of the existing comparative studies are focused on the performance of one or more structures. Therefore, contrary to previous research studies, we use static pushover methods to perform design and we then compare the capacity of the outcome designs with reference to the results of nonlinear response history analysis. This alternative approach pinpoints the pros and cons of each method since the discrepancies between static and dynamic analysis are propagated to the properties of the final structure. All methods are implemented in an optimum performance-based design framework to obtain the lower bound designs for two regular and two irregular reinforced concrete building configurations. The outcome designs are compared with respect to the maximum interstorey drift and maximum roof drift demand obtained with the Incremental Dynamic Analysis method.

Keywords: performance-based design, life-cycle cost analysis, RC buildings, structural optimization