HOW TO COMPARE THE SEISMIC PERFORMANCE OF STRUCTURES

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ABSTRACT

The process of structural design is based on the selection of the top alternative designs from a group of viable choices, ideally choosing the one that best satisfies the requirements. With the emergence of performance-based earthquake engineering, such comparisons now need to be performed on the basis of the seismic performance, preferably at several limit-states. Such a direct evaluation can become cumbersome, requiring seismic hazard information. Therefore, shortcuts and simpler techniques have been introduced that are generally based on the concept of system fragility, as estimated through the various methods of structural analysis. Still, there is no general consensus on the metrics that can be used for such an evaluation. To help with such assessments, we offer a discussion of the available choices for analysts that can employ nonlinear dynamic analysis methods. It is shown that having the complete description of limit-state fragility is sufficient for a reliable comparison, with few exceptions, while lesser information may lead to erroneous results.

INTRODUCTION

The performance comparison of different structural designs, be they alternate structural configurations or simply differently proportioned versions of the same type, is a common, yet little-understood operation in earthquake structural engineering, both in practice and in research. Although it may not explicitly appear in typical engineering calculations,it is a fundamental task that every professional engineer sooner or later encounters. It is essentially the basic premise of seismic design, needed to rationally select, e.g., one structural system or rehabilitation strategy over another, especially when little relevant experience is available.

Limiting ourselves to a given limit-state, the mean annual frequency (MAF) of violating the limit-state is a very powerful way to achieve a robust comparison. Still, there are significant disadvantages that may preclude the wider use of such a method, the most important being the need for seismic hazard information. While it is conceivable, many people would not agree that a comparison of two different designs might shift one way or another based on the site characteristics. It may happen for two relatively close candidates when comparing them at two very different sites, but that is probably not the issue that will trouble most comparisons. Therefore the logical question arrives of whether we can drop the hazard info and focus just on fragility-level information.

This is further motivated by a simplification of the integrals to estimate the MAF into the closed-form solutions developed for SAC/FEMA by Cornell et al. (2002). Thus, if $H(s)$ is the hazard function of the scalar IM represented by variable s, then it can be approximated as

$$H(s) \cong k_0 (s)^{-k} \tag{1}$$

where k is a positive constant, indicative of the local hazard slope at the range of interest. We need also assume that the relationship of IM and EDP, the latter represented by the variableθ, is approximately a power law: