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A Bayesian Method to Form the Best Probabilistic Model to Estimate the Seismic Demand of Steel Moment-Resisting Frames

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Abstract

In this article, using a Bayesian statistics method, in order to estimate the seismic demand of Steel Moment-Resisting Frames (SMRFs) at any given Intensity Measure (IM), two probabilistic models, Probabilistic Seismic Demand Model (PSDM), not included collapse probability, and Collapse Probability Model (CPM), are developed. With the aim of selecting the best PSDM, 13 different IM parameters consist of one or more spectral accelerations are defined and evaluated. The Bayesian regression results show that for all defined IM, a linear relation between the logarithm of IM and the logarithm of demand parameter, drift here, is the best form to define the PSDM, but if a single spectral acceleration is used to define the IM, it is impossible to introduce a unique parameter as IM for all type of SMRFs, because a specific spectral acceleration with the most accuracy to estimated the seismic demand of a stiff frame, may change to the weakest estimator in a deformable frame and vice versa. On the other hand, if the IM is defined by using the combination of two or more spectral acceleration, one can find a unique IM with almost same accuracy for all modeled frames. Also the results show that a normal distribution is the best probabilistic model to define the CPM.

Keywords: Probabilistic Seismic Demand Analysis, Bayesian, Steel Moment-Resisting Frame.

1. INTRODUCTION

In recently developed performance based design engineering frameworks, estimation of seismic demand is an essential part to describe the performance of structure. The most challenging in this estimation is the large uncertainty associated with the seismic events and structural response demands. Because of this uncertainty, can be described in term of those originating from randomness (aleatory) and modeling errors (epistemic), using a probabilistic method to treatment of both randomness and uncertainty is required in estimation of seismic demand. This method is generally known as Probabilistic Seismic Demand Analysis (PSDA).

PSDA is an approach for calculating the mean annual frequency (or annual probability) of exceeding a specified seismic demand for given structure at a designated site [1]. PSDA combines a ground motion Intensity Measure (*IM*) hazard curves for designated site with the demand results from Nonlinear Dynamic Analysis (NDA) of the given structure under a suite of earthquake ground motion records through the application of the total probability theorem [2]. If the maximum inter story drift (denoted by *DR*) is selected as the demand parameter, the following mathematical expression can be used to calculate the probability that the drift exceeds the value x, $P[DR > x]$:

$$P[DR > x] = \int_0^\infty P[DR > x \mid IM = y].\,|\,dH_{IM}(y)\,| \tag{1}$$

In this equation the term $H_{IM}(y)$ means annual frequency that *IM* at a given site will equal or exceed the value *y* and notation $|d\ldots|$ means its differential with respect to *IM*, evaluated at *y*. This term is usually computed through a probabilistic seismic hazard analysis and it is not the object of this study. The main object of this study is the term $P[DR > x \mid IM=y]$, which means the probability of *DR* exceeding the value *x* given (i.e., conditioned on knowing) that *IM* equals *y*. In order to calculate this probability in a reliable manner, along with the probability of exceeding, the probability of total collapse of structure at any given *IM* level must be considered. Hence the following two part equation is proposed to calculate this probability [3]:

$$P[DR > x \mid IM = y] = (1 - P_{C|IM}).P_{NC|IM}(DR > x \mid IM = y] + P_{C|IM} \tag{2}$$