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Probabilistic Seismic Hazard Analysis and Synthetic Ground Motion Generation for Seismic Risk Assessment of Structures in the Northeast India

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ABSTRACT

This article outlines the performance-based seismic risk assessment (PBSRA) of structures requiring probabilistic seismic hazard analysis (PSHA) to obtain hazard curves and an evaluation of the demand model by a nonlinear structural response analysis under properly selected ground motion records. Unfortunately, such site-specific information is not readily available for Northeast region of India. The present study focuses on these two aspects to supplement the PBSRA. The estimations of hazard curves are demonstrated by considering the seismicity within 300 km radius around the considered locations and specified exposure period. Due to limited availability of natural records in this region, synthetic accelerograms are generated using stochastic point source models by identifying the most contributing magnitude distance combinations from disaggregation of the PSHA results. The significant variabilities observed in the estimated hazard, synthetic accelerograms and nonlinear building responses in the various locations indicate the need of explicit site-specific analysis for PBRSA of structures in the region.

KEYWORDS

Disaggregation, Hazard Curve, Nonlinear Seismic Response, Northeast India, Seismic Hazard Analysis, Site Amplification, Synthetic Accelerograms

INTRODUCTION

An increasing number of casualties, damage and loss to human life and economy have been observed worldwide in the last few decades due to earthquakes. After 1994 Northridge earthquake and 1995 Kobe earthquake, it was observed that even with the structures designed based on the available design practice, the amount of damage, economic loss, repairing and retrofitting cost of structures in the aftermath of earthquakes are unacceptably high. As a result, the earthquake engineering community felt the need for a major revision of the traditional seismic design philosophy. The development of performance based seismic risk assessment (PBSRA) of structures has its root in this realization. In recent years, the performance based earthquake engineering (PBEE) methodology has attracted considerable research interest and significant progress has been made towards the development of PBSRA of new and existing structures. The evaluation of seismic risk of structure basically involves

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evaluation of failure limit state probability. In the context of PBEE, it is the probability of exceedance of structural demand (*D*) to its capacity (*C*) i.e. $P_{LS} = P[D \geq C]$. For estimating the limit state probability analytically, the equation is decomposed into two parts with respect to an interface variable using the concept of total probability theorem (Jalayer & Cornell, 2003). For example, considering the spectral acceleration at the fundamental period of the structure (S_a) as an interface variable, it is expressed as:

$$P_{LS} = P[D \geq C] = \sum_{x} P[D \geq C \,|\, S_a = x].P[S_a = x] = \int_{x} F_R(x).\left| d\lambda_{S_a}(x) \right| \tag{1}$$

In the above, $F_R(x)$ is the seismic fragility conditioned on $S_a = x$ which is usually modelled by a lognormal cumulative distribution function (CDF) and $\lambda_{S_a}\left(x\right) = P[S_a \geq x]$ is the seismic hazard function. Thus, the evaluation of P_{LS} needs the solutions of two problems in sequence. In the first step, a detailed probabilistic seismic hazard analysis (PSHA) is carried out considering the seismicity around the location of the study area to estimate the hazard curve corresponding to a specified hazard level. The second problem is to obtain the conditional probability $F_R(x)$ which is customarily termed as the seismic fragility analysis (SFA).

It can readily be realized from the above that the PBSRA of structure largely hinges on two site-specific information features. In the first step, the PSHA is required to perform to obtain the hazard curve providing the variation in the mean annual frequency of exceedance of a selected intensity measure. The other important aspect is the estimation of the displacement demand, usually measured in terms of maximum responses of a structure. The ground motion record is the most important variable in this regard, governing the response outcome. Therefore, hazard analysis also includes the selection of adequate numbers of ground motion time histories compatible to a target hazard level to provide meaningful statistical demand data obtained through nonlinear time history analysis (NLTHA). In order to be consistent with the PSHA, the selected ground motions should be compatible with the magnitude (M_j) and distance (R_i) combinations which dominate the hazard for a particular hazard scenario. This should be provided on a site specific or mapped regional basis. But, such site-specific information is not readily available for Northeast (NE) region of India. The present study focuses on these two aspects of PSHA to supplement the PBSRA of structures in the NE region of India.

The NE India is located approximately within a geographical area between latitude 20°N to 28°N and longitude 88°E to 98°E. The region is well known for its seismo-tectonic activities. It falls under the zone of highest seismicity corresponding to the seismic zonation map of the country. The Global Seismic Hazard Assessment Programme (GSHAP) has also classified this region such as associated with high peak ground acceleration (PGA) hazard in the order of 0.3g to 0.4g (Bhatia et al, 1999). The region has experienced two great earthquakes of magnitude $\geq$ 8.0 (1897 Shillong Earthquake, M = 8.0 and 1950 Assam-Tibet border, M = 8.6) and almost 16 large earthquakes of magnitude $\geq$ 7.0 over a period of 150 years (Raghukanth, 2011). The reason for high seismicity is mainly due to the complex tectonic and geological set up of the region. This region marks the boundary between the Indian and Eurasian plates. Due to the highly oblique continental convergence of the northward moving Indian plate at the rate of 20+3mm/year, earthquakes of magnitudes 8.0 and above have occurred in the past and may recur. Furthermore, there has been a phenomenal increase in the population density and infrastructural developments in the region which further increases the seismic vulnerability of human population and structures. However, most of the existing seismic assessment studies in this region are simplified evaluations in the deterministic framework (Sarkar et al., 2004; Pathak, 2008). The behaviour assessment of structure in the context of PBEE considering the uncertainty and randomness in the influencing parameters is not well addressed. Thus, realistic seismic risk analyses of existing structures in the region for an urgent and sustained mitigation measure seems