Geoscience Frontiers 6 (2015) 847–859

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Geoscience Frontiers

journal homepage: www.elsevier.com/locate/gsf

Research paper

Probabilistic assessment of surface level seismic hazard in India using topographic gradient as a proxy for site condition

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ARTICLE INFO

Article history:
Received 9 September 2013
Received in revised form
12 June 2014
Accepted 23 June 2014
Available online 5 July 2014

Keywords:
PSHA
PGA
Topography
Site amplification
India

ABSTRACT

This paper presents spatial variation of seismic hazard at the surface level for India, covering 6–38° N and 68–98° E. The most recent knowledge on seismic activity in the region has been used to evaluate the hazard incorporating uncertainties associated with the seismicity parameters using different modeling methodologies. Three types of seismic source models, viz. linear sources, gridded seismicity model and areal sources, were considered to model the seismic sources and different sets of ground motion prediction equations were used for different tectonic provinces to characterize the attenuation properties. The hazard estimation at bedrock level has been carried out using probabilistic approach and the results obtained from various methodologies were combined in a logic tree framework. The seismic site characterization of India was done using topographic slope map derived from Digital Elevation Model data. This paper presents estimation of the hazard at surface level, using appropriate site amplification factors corresponding to various site classes based on V_{S30} values derived from the topographic gradient. Spatial variation of surface level peak horizontal acceleration (PHA) for return periods of 475 years and 2475 years are presented as contour maps.

1. Introduction

Earthquakes are known to have occurred in the region of Indian subcontinent from ancient times. Large magnitude earthquakes have occurred in the northern subcontinent and in the Andaman and Nicobar regions. In the southern peninsula, damaging earthquakes have occurred but less frequently and with lower magnitudes than at the plate boundaries. The rapid drifting of Indian plate towards Himalayas in the north east direction with a high velocity along with its low plate thickness might be the cause for high seismicity of the Indian region. Bureau of Indian Standard has published seismic zonation map in 1962 and revised it during 1966, 1970, 1984 and 2002. The map was entirely based on past earthquake history, seismotectonics and geophysical data, not based on a detailed hazard analysis.

Various researchers have attempted to evaluate the expected ground motion due to future earthquakes in and around India. Khatri et al. (1984) developed Peak Horizontal Acceleration (PHA) hazard map with 10% annual probability of exceedance in 50 years with the use of the ground motion prediction equation developed by Algermissen and Perkins (1976). PHA hazard map for entire India, with 10% annual probability of exceedance in 50 years was presented by Bhatia et al. (1999) using the ground motion prediction equation of Joyner and Boore (1981). However the results obtained in the studies of Khatri et al. (1984) and Bhatia et al. (1999) were debatable because of the use of single ground motion prediction equation for the entire country. Iyengar et al. (2010) developed probabilistic seismic hazard map for Indian landmass using linear seismic sources and attenuations relations developed by them using ground motion simulations for various parts of the country. There were several other efforts by various researchers to estimate the seismic hazard for various isolated regions in the country using different methodologies. Most of the past works on estimating the seismic hazard for various parts of India focused on a small region without extending it to the adjoining areas that

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Peer-review under responsibility of China University of Geosciences (Beijing).

http://dx.doi.org/10.1016/j.gsf.2014.06.002

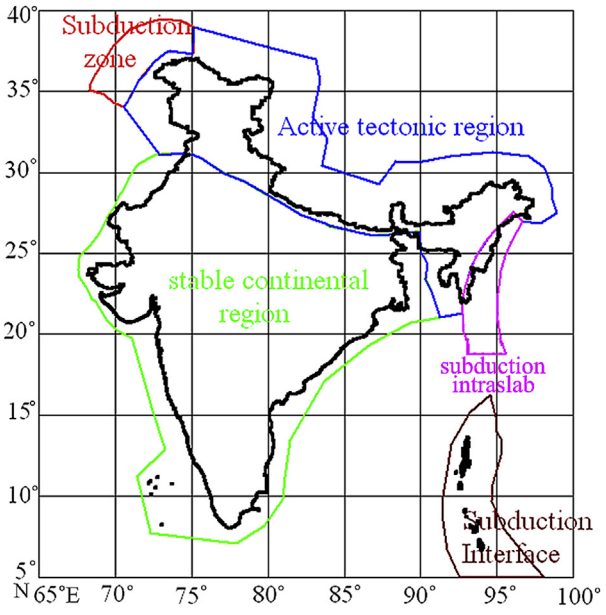

Figure 1. Tectonic provinces in and around India.

exhibits different seismotectonic characteristics. The few works that focused on entire country either use only one specific source model or a single ground motion prediction equation without taking into account varied attenuation properties of different tectonic provinces in the country. This necessitates the need for a comprehensive seismic hazard analysis for entire country considering various source models and different ground motion predictions to suit various tectonic provinces with varied seismotectonic characteristics.

Estimation of PHA is done using different sets of ground motion prediction equations specific to various tectonic provinces in the country. In context of recent development in seismic hazard assessment and its application to earthquake engineering, it is clear that we cannot bestow completely with either probabilistic or deterministic elements, but both are equally important (Bommer, 2003). Deterministic Seismic Hazard Analysis (DSHA) adopts a transparent process, whereas Probabilistic Seismic Hazard Analysis (PSHA) deals with various uncertainties. PSHA gives a richer description of the expected ground motions since it provides the probability of exceeding a specific ground motion level whereas the ground motions given by DSHA are associated with an unknown probability of exceedance. PHA estimated from probabilistic method handles various uncertainties, where as deterministic approach generates distinct value of ground motion parameter for a specific scenario.

When seismic wave travels from bedrock to ground surface, it undergoes modification due to impedance contrast and this modification is termed as the local site effects. Thus local geology and soil conditions have significant effect on the intensity of ground shaking due to earthquake. In most of the buildings where foundation is not extending to bedrock, local site effect becomes crucial in dictating the damage intensity. The estimation of intensity of

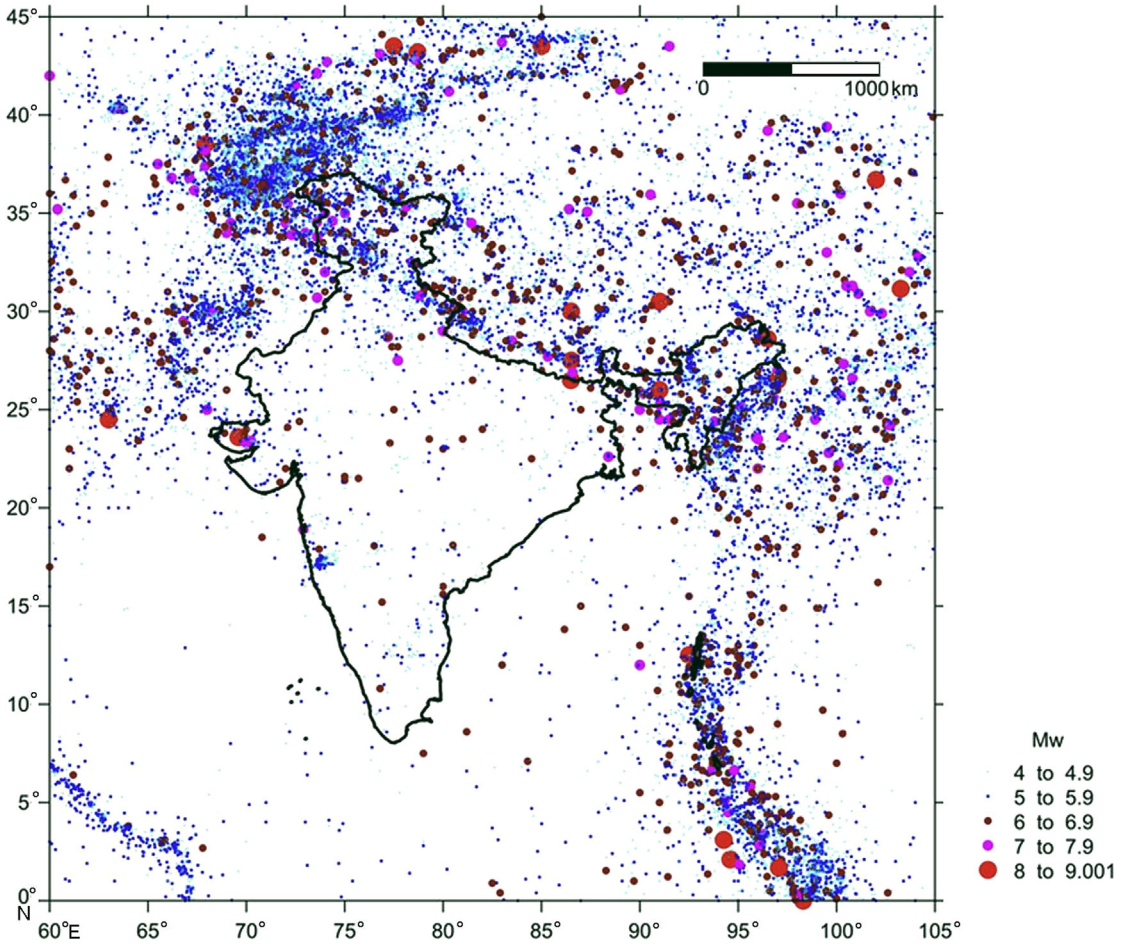

Figure 2. Distribution of Earthquake events (mainshocks only) in and around India (Kolathayar and Sitharam, 2012).