Strong Motion Impact of Large Earthquakes in the Seismic Zonation of NE Part of India

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Summary

A method of seismic zonation based on deterministic modeling of rupture plane is presented in this work. This method is based on the modeling of finite rupture plane along identified lineaments in the region using the semi empirical technique of Midorikawa (1993).The seismic zonation due to large earthquakes (M > 7) is prepared for technoeconomically important NE part of Indian subcontinent. On the basis of the value of expacted peak ground acceleration, the studied area is classified into three zones. The zone 1 is the area having expected peak ground acceleration of the order of more than 300 gals, the zone 2 is the area having expected peak ground acceleration of the order of 200 to 300 gals and the zone 3 with expected peak ground acceleration d" 200 gals. The study shows various zone can expect peak ground acceleration of the order >300 gals and Calcutta falls in a highly hazardous zone.

Introduction

Seismic hazard map serve a basic tool for demarcation and assessment of seismic parameters in an area having seismic potential. Peak ground acceleration is one of the important parameter that has been utilized for safe design of structure in any seismically active region. Attenuation relations are most commonly used tool for computing peak ground acceleration at any site. Although attenuation relation provide good estimate of peak ground acceleration, these relations are mainly controlled by the data used in their derivations. With the advancement of seismology several methods exist in which entire source of earthquake is modeled to obtain various strong motion parameters. These include i) Stochastic simulation technique, ii) Empirical Green Function technique (EGF) iii) composite fault modeling technique and iv) Semi empirical technique. In the stochastic simulation technique a band limited random white Gaussian noise is passed through number of filters representing earthquake process to get a synthetic ground motion (Housner and Jennings, 1964;Hanks and McGuire, 1981; Boore, 1983; McGuire et al., 1984; Boore and Joyner, 1991; Shinozuka and Sato, 1967 and Lai, 1982). This method lacks complete representation of earthquake source and wave propagation in the medium. In Empirical green function method records of aftershocks of the main event have been used to simulate ground motion at observation point, which has the record of aftershock data (Hartzell 1978, 1982; Kanamori 1979; Hadley and Helmberger 1980; Mikumo et al. 1981; Irikura and Muramatu 1982; Hadley et al. 1982; Irikura 1983; Coats et al. 1984; Houston and Kanamori 1984; Imagawa et al. 1984; Muguia and Brune 1984; Hutchings 1985 and Heaton and Hartzell, 1986). The advantage of this scheme is that there is no need to remove propagation effects (Fukuyama and Irikura, 1986). The small earthquakes needed in this method are located ideally near the source and recorded at a site for which a large event simulation is desired (Joyner and Boore, 1988). This is the most difficult condition to be met when applying this method and hence it is of limited use. In the composite fault modeling technique (Zeng et al., 1994; Yu, 1994 and Yu et al., 1995) detailed velocity structure of the regions together with the Q model is required for successful prediction. This is among the most difficult part of this method for those regions, which have very few earthquake records and limited seismic data. Recently a semi empirical method has been used for simulating earthquake ground motion due to rupture process (Midorikawa, 1993; Joshi (1997, 2000, 2001, 2003, 2004); Joshi and Midorikawa 2004, 2005; Kumar et.al.1997; Joshi and Patel 1997). This method has an advantage of both EGF technique and empirical relations based on recorded data. In the present work semi empirical method has been used for deterministic modeling of rupture plane to obtain strong motion parameter like peak ground acceleration .The modeled strong motion parameters is used for preparation of seismic zonation map. The approach is similar to that by Joshi and Patel (1997) except the method earlier used is now modified for its applicability for layered earth medium and slip duration of small and large earthquakes (Joshi et al., 2001; Joshi and Midorikawa, 2005).

Methodology of modeling rupture plane

Basis of modeling is semi empirical technique developed by Midorikawa and further modified by Joshi (1997, 1998, 2000 and Joshi and Midorikawa 2004, 2005). Detail of modeling technique is given in paper by Joshi and Patel (1997).

Method of seismic zonation

Method of seismic zonation is described in stepwise manner as follows:

(i) First step is identification of active lineaments based on various geological informations, satellite imageries and fieldwork. The length of a possible rupture along these lineaments is measured from the same map. By using the empirical relation of Araya and Kiureghian (1988), the lineaments, which are large enough to give rise to M > 6 earthquakes have been selected for further modeling. Using the relation of Kanamori and Anderson (1975), the ruptured area (A) is calculated, assuming the rectangular rupture model, this area is used to compute the width (D) of the rupture plane i.e, D= A/L. The values of parameters L, D, L_e and D_e for each rupture model are computed from applicable empirical relations and similarity relationship. The lowest range of magnitude of the elementary earthquake depends upon the scaling laws used in the studied region.

(ii) The entire region is divided into a grid consisting of several observation points at which peak ground acceleration (PGA) is simulated.

(iii) At each observation point peak accelerations are computed by modeling one by one, the rupture along each selected lineament. For 'n' number of lineaments n values of peak accelerations i.e, P_{a1}, P_{a2},......,P_{an} are obtained at that observation point. A new parameter 'E_{PGA}' is introduced which is defined as the maximum peak acceleration experienced at a particular site by earthquake of different magnitude and is named as Expected peak ground acceleration by Joshi and Patel (1997):

$$E_{PGA} = \mathrm{Max}\,\{P_{a1}, P_{a2},\ldots\ldots,P_{an}\}$$

Where P_{a1}, P_{a2}…….. is the peak ground acceleration at a particular site.

(v) The process is repeated for all observation points and the expected peak acceleration (E_{pga}) at each point is computed. The contours of the expected acceleration have been used for defining various zones. These zones are used to get the value of the peak ground acceleration in a region due to expected future earthquake. This parameter is finally used in the preparation of a zonation map.

For the purpose of preparation of the zonation map, computer software named 'EQZONE' in FORTRAN language has been developed. The input to this package is the parameters of rupture plane and velocity model of the region. The output is the expected acceleration at each specified location on the map. The detail of the methodology is given by Joshi and Patel (1997).

Case study: Zonation map for NE India

In NE Himalaya, collision of Indian Plate against Eurasian plate and suturing of the Indian plate against the Burmese plate along Tidding suture zone (Kumar, 1997) resulted in the formation of Assam syntaxial region (Which is also known as Mishmi thrust region), the Arkon Yoma folded belt on the eastern side and Naga Disang thrust belt to the South of the Assam valley (Fig.1).

Northeast region of Indian subcontinent had witnessed 18 large earthquakes (M > 7.0) including two great earthquakes during last 100 years (Kayal and Zhao, 1994). Detailed seismicity and seismotectonics of the region is reviewed by Kayal (1998). The collision and the continuous convergence of the Indian plate against the Eurasian plate produced the crustal shortening in this region resulting into the imbrications of the north margin of the Indian crustal along major intracrustal thrust such as Main Central Thrust (MCT), Main Boundary Thrust (MBT) and Main Frontal Thrust (MFT) (Gansser, 1964; Jain and Anand, 1988; Thakur, 1994 and Valdiya, 1980). Active faults and seismicity in the Himalaya are expression of recent and sub-recent crustal movements due to ongoing continental collision (Valdiya, 1980; Karunakaran and Ranga Rao, 1979). The four great earthquakes (M > 8) that have occurred in the last 100 years and related to this convergence are the 1897 Assam, 1905 Kangra, the 1935 Bihar Nepal and 1950 Eastern Assam (Chayu) earthquake.

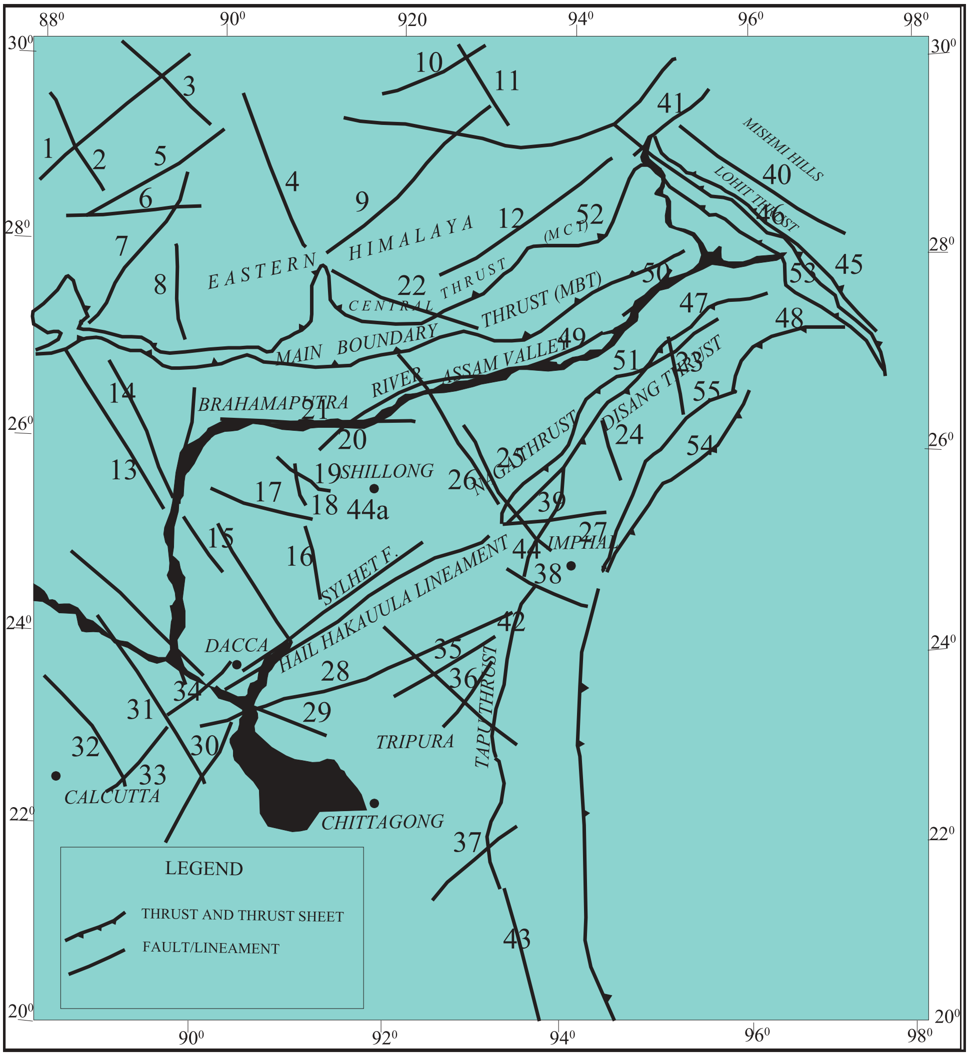

Fig.1: Major tectonic lineaments in NE region of India (Modified after Kayal, 1998)

The tectonic map of the region is taken after Kayal (1998), which was prepared on the basis of map published by Evans, 1964 and Krishnan, 1960). From this tectonic map, 55 lineaments have been identified and numbered in Fig. 1 Their length has been measured. The magnitude of an earthquake generated by rupture along these lineaments is calculated by using on the empirical relation between rupture length (L) and magnitude of the earthquake given by Araya and Kiureghian (1988) .The parameter like strike of rupture is measured from the tectonic map whereas the dip of modeled rupture plane is assumed as 45°. Assuming the magnitude of an elementary earthquake as 5.8, the values of parameters L, D, L_e and D_e for each rupture model are computed from applicable empirical relations. The rupture velocity is assumed as 2.7 km/sec whereas the velocity model is taken from Mukhopadhyay et al., (1997) and is given in Table 1.

The entire region is divided into 121 square grids and corner of each grid is used as observation point. The

Table1. Velocity model used for present work (After Mukhopadhyay et al.1997)

Depth to the top of the layer (km.)	Velocity V_s (km./sec.)
0.0	2.3
1.0	3.3
25.0	3.9
45.0	4.7

length of square grid is 50 km. By modeling each 55 lineaments, expected peak ground acceleration is calculated at 121 observation points. The value of E_{pga} at each observation point is used for preparation of contour map dividing region into different E_{pga}. Following three different zones of E_{pga} are assumed for preparing the zonation map in this region:

Zone1 E_{pga} > 300 gals
Zone2 200 d″ E_{pga} < 300 gals
Zone3 E_{pga} d″ 200gals

Based on deterministic modeling of rupture plane explained in earlier section, all 55 lineaments were modeled to prepare zonation map based on E_{pga} contour. The zonation map is shown in Fig.2. The prepared seismic zonation map shows that area surrounding both sides of Brahamputra river fall in zone 1. This indicates that Brahamputra valley is highly vulnerable to the seismic hazard. The places like Calcutta, Imphal, Chittagong and Dacca experience peak ground acceleration more than 300 gals.

Conclusions

A technique of zonation map based on deterministic modeling of rupture plane is presented in this paper and is applied to the technoeconomically important NE part of India. The seismic zonation map shows that the area surrounding both sides of Brahamputra river fall in zone 1. This indicates that Brahamputra valley is highly vulnerable to the seismic hazard. The places like Calcutta, Imphal, Chittagong and Dacca experience peak ground acceleration more than 300 gals. This study explains the utility of the proposed scheme for seismic zonation in any seismically active regions where the scarcity of digital seismic data poses hindrance to any seismic hazard studies.

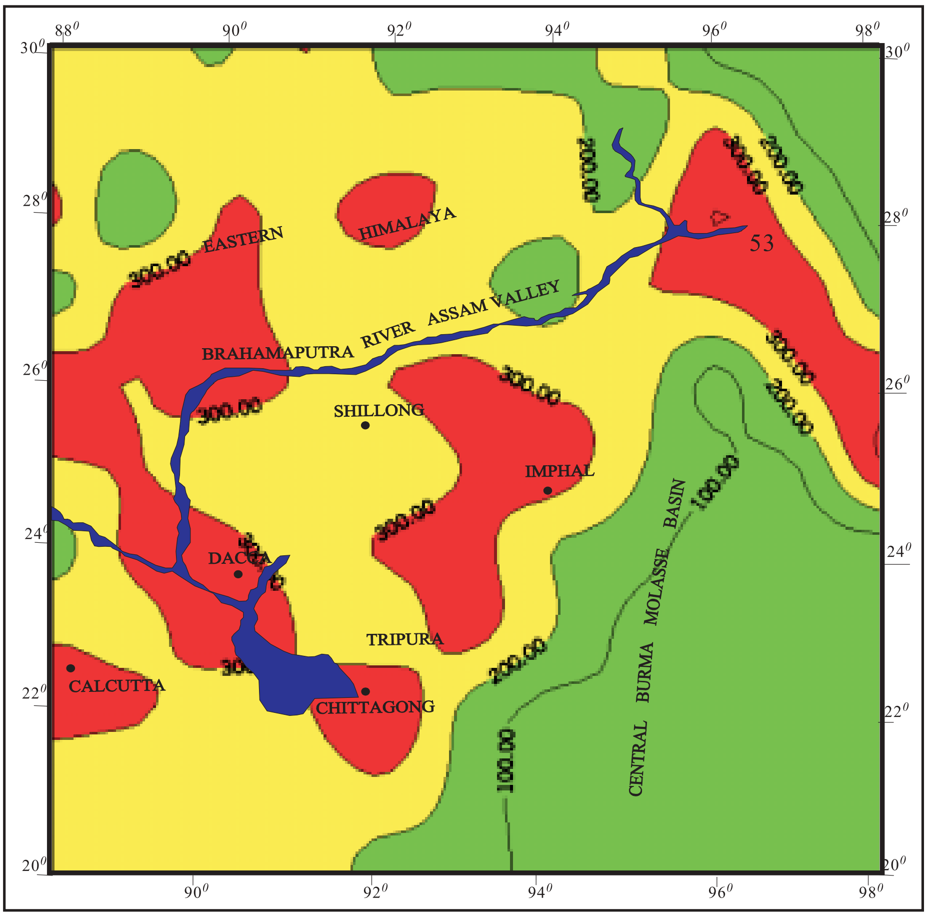

Fig. 2: Seismic zonation map of Brahamputra Valley. Zone1 stand for E_{pga} > 300 gals, Zone2 for 200 d″ E_{pga} < 300 gals and Zone3 for E_{ga} < 200 gals. Area covered by red colour denotes zone 1, yellow colour denotes zone 2 and green colour denotes zone 3.

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