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Seismic hazard assessment for eastern Nepal using 1934 and 1988 earthquakes

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ABSTRACT

The Himalayan arc is widely considered as one of the hot spots in terms of earthquake disaster. Nepal, which is centrally located in the Himalayan region, has witnessed many medium to large earthquakes in the past, e.g., 1934 Bihar-Nepal earthquake, 1988 Udayapur earthquake. Because of lack of income resources in rural area, considerable number of population has already migrated to the major urban areas of the country and the trend is still continued. With such population pressure and also economic constrains, major part of population is residing in weak and non-engineered structures of the unplanned urban areas. Consequently, it has put large population at high risk of earthquake disaster. It is, therefore, necessary to assess the seismic hazard so that proper mitigation measures may be adopted for the safeguard of the population, property and infrastructures under risk.

In this contribution, preliminary Probabilistic Seismic Hazard Analysis (PSHA) for eastern Nepal is carried out taking two point sources, i.e. 1934 Bihar-Nepal and 1988 Udayapur earthquakes. For Bihar-Nepal earthquake Peak Ground Acceleration (PGA) of 100 gal is computed for southeastern Nepal and exceeds as much as 350 gal near the epicenter. The 1988 Udayapur earhtquake having smaller magnitude than 1934 Bihar-Nepal earthquake has given maximum 300 gal of PGA. The computed intensities for both earthquakes almost correspond with the observed values. The study, for the first time, provides strong ground motion data at local level and may be useful in designing engineering structures, upgradation of building code and most importantly to formulate policy for earthquake risk management in eastern Nepal.

Keywords: Seismic Hazard Assessment, Point Sources, Peak Ground Acceleration, eastern Nepal

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INTRODUCTION

Among the natural disasters, earthquake is considered as a peculiar and the most destructive because it has almost no onset time and can cause massive and wide spread damages to life and property in a few seconds. In addition, it can induce several secondary disasters like flood, fire, landslide, land subsidence, tsunami, etc. There are several incidents of devastating earthquakes that have claimed thousands of people and caused loss of billions of dollars disrupting the structure and functioning of the society both in developed and developing worlds. The first decade of twenty-first century witnessed five catastrophic earthquakes namely Sumatra earthquake (2004), Pakistan earthquake (2005), Sichuan earthquake (2008), Haiti Earthquake (2010) and Chile earthquake (2010). In these calamities at least 616,025 people have been killed and another 60,654,479 were affected. Further, these earthquakes have caused economic damage of more than 132 billion US dollars. In this regard, appropriate assessment of seismic hazard is necessary to plan for safer society particularly for rapidly urbanizing developing world.

Recently, seismic hazard assessment has become one of the essential tools to estimate probable hazard level to be induced by the impending earthquake in any area. It mainly reflects the level of ground motion for a particular earthquake in a particular site. The seismic hazard mapping has become inevitable to assess the seismic risk and is necessary in detailing building codes and damage and loss estimation. Despite such significances there are limited studies in regional as well as local levels in Nepal. In this contribution, therefore, it is aimed to estimate the level of seismic hazard in eastern Nepal taking Bihar-Nepal earthquake (1934) and Udayapur earthquake (1988) as the major scenario earthquakes. This study may provide basis for design of earthquake resistant structures. Further, such study can equally contribute to effective and apposite formulation of earthquake disaster management plan for rapidly urbanizing cities of eastern Nepal.

GEO-SEISMOTECTONIC SETTING

The Himalaya arc is a result of collision between the Indian Plate in the south and the Eurasian Plate in the north. The large-scale seismo-tectonic structures have revealed that the entire Himalayan arc is composed of basically three intra-crustal thrusts namely from north to south; Main Central Thrust (MCT), Main Boundary Thrust (MBT) and Main Frontal Thrust (MFT). The northern most fault; South Tibetan Detachment System is a system of normal faults that predates above-mentioned thrust faults. These all faults are believed to merge with the Main Himalayan Thrust (MHT) that marks the boundary between the two colliding plates (Zhao et al. 1993). The geophysical and seismological studies have shown that the MHT and its associated faults in the Himalaya are responsible for the ongoing seismicity (Seeber and Armbuster 1981, Baranowski et al. 1984, Pandey et al. 1995, Pandey et al. 1999).

Beside these older tectonic structures, there are significant numbers of active faults along the strike of the range. These are mainly associated with the older tectonic elements and are classified into four groups (Nakata 1982): the Main Central Active Fault system, active faults in Lower Himalayas, the Main Boundary Active Fault system and active faults along the Himalayan Frontal Fault (equivalent to MFT). Among these, active faults along the MBT and MFT are most active, and have the potential to produce large earthquakes in future (Lave and Avouac 2000; Chamlagain et al. 2000). The Himalayan front in eastern Nepal is largely characterized by landforms produced by active faulting, along both the MBT and MFT. Near the Timai Khola in eastern Nepal, active faults trending NW–SE along the MBT merge with the active faults striking E–W along the MFT and extending farther south into the Gangetic Plain. These active faults exhibit down-throw towards the north. In the Lesser Himalaya of Udayapur area, active neotectonic movement is characterized by pressure ridges and fault scarps. These faults are inferred to join the MHT beneath the Himalaya. The Mid-crustal ramp beneath the Higher Himalaya behaves as a geometrical asperity accumulating stress and strain in interseismic periods. Numerical models of tectonic stress have clearly indicated that there is a continuous shear stress accumulation at the ramp and southern flat of MHT which may reactivate MHT and its associated faults generating devastating earthquakes in the region, particularly, in the "central seismic gap" (Chamlagain and Hayashi 2007).

SEISMICITY

Over the last century, the Himalayan arc has been struck by six devastating earthquakes e.g., 1897 (M8.1) Shillong earthquake, 1905 (M7.8) Kangra earthquake, 1934 (M8.2) Bihar-Nepal earthquake, 1950 (M8.7) Assam earthquake, 1988 (M6.6) Udayapur earthquake, and 1991 (M6.9) Uttarkashi earthquake claiming lives of thousands of people in the region. Beside these earthquakes, in 2005, western Himalaya was hit by an earthquake with magnitude 7.4 killing more than 74,000 people from Pakistan and India. The 1905 Kangra earthquake produced severe damage in the Kangra area and, about 100 km to the east, in the Dehradun area. The estimated ruptured is about 280 km long segment, from Kangra to Dehradun, that must have extended eastward to about 78^{0}E, near the border with Nepal (Chander 1988; Yeats and Lillie 1991; Gahalaut and Chander 1997). The 1934 Bihar-Nepal earthquake was believed to rupture a 200-300 km long segment to the east of Kathmandu (Pandey and Molnar 1988).

Microseimicity is particularly clustered in eastern, central and far- western Nepal (Pandey et al. 1999). In western Nepal, cluster lies between 80.5˚ E and 82.5˚E whereas in central Nepal it is bounded between longitudes 82.5˚E and 86.5˚E (Fig. 1). The eastern Nepal cluster is characterized by higher level of events between 86.5˚E and 88.5˚E. The general trend consists of a narrow belt of predominantly moderate-sized earthquakes beneath the Lesser Himalaya just south of the Higher Himalayan front (Ni and Barazangi 1984) where all available fault-plane solutions indicate thrusting. The great Himalayan earthquakes, however, occur along the basal décollement beneath the Siwalik and Lesser Himalaya. The focal depth for the Himalayan earthquake varies from 10-20 km. The basic mechanism of crustal earthquake generation in the Himalaya is largely explained by mid-crustal ramp model which states that during the interseismic period due to locking of the southern ramp-flat segment of MHT strain is being accumulated, when it exceeds its threshold value, stress will be released in the form of great earthquake along the MHT propagating the deformation towards MFT, a southern expression of MHT (Pandey et al. 1999). However, Himalaya has also been hit by the mantle earthquake (e.g. 1988 Udayapur earthquake) for which such model is quite silent.

SCENARIO EARTHQUAKE

In this study, "scenario earthquake" refers to a given earthquake having a probability of exceedence higher, equal or lower than that of the design earthquake specified in the seismic code in force and provides a comprehensive description of what happens when such an earthquake occurs. As the eastern Nepal witnessed two devastating earthquakes namely Bihar-Nepal earthquake (1934) and Udayapur earthquake (1988), among which former earthquake ruptured hundreds of kilometers in eastern Nepal causing wide spread damage in the region, considering magnitude, severity and probability of recurrence of similar earthquake in the region, these two earthquakes are taken as "scenario earthquake" for hazard assessment. The details of the earthquakes are summarized in Table 1 and described below.

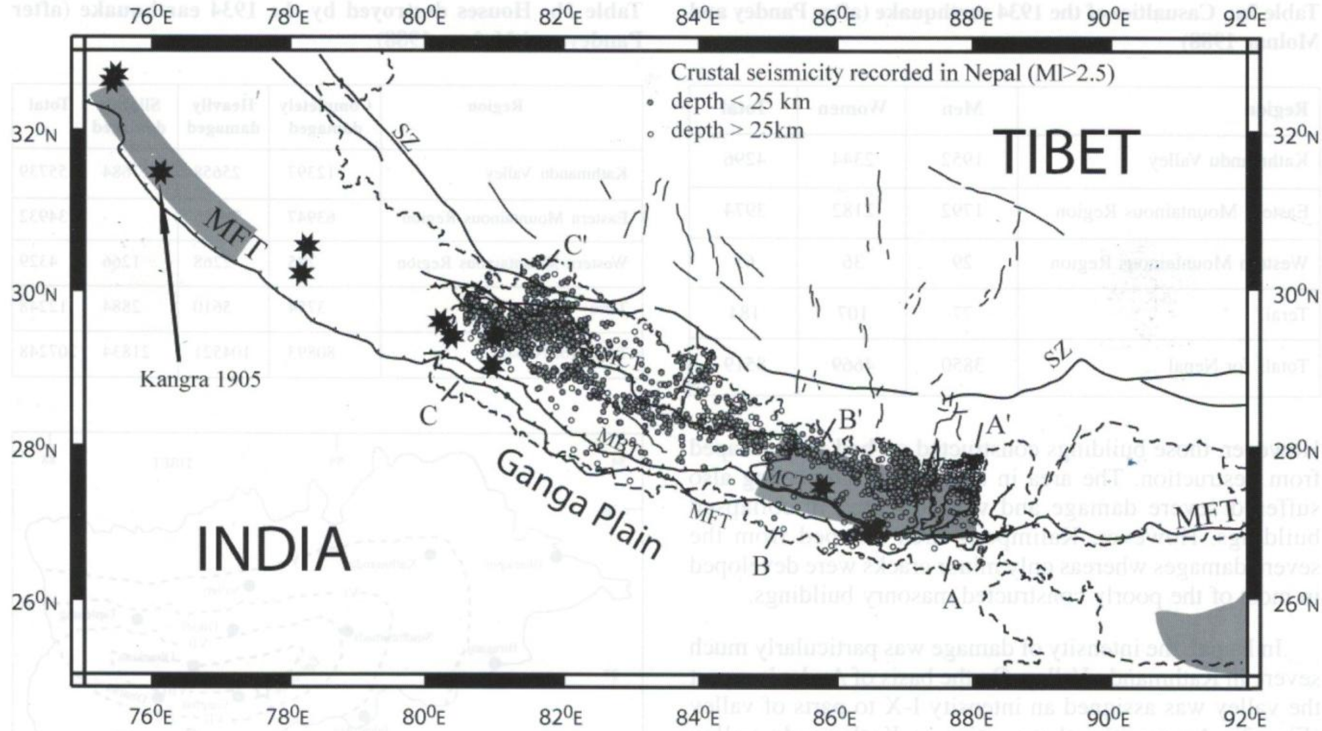

Fig. 1: Seismicity in the Himalayas of Nepal (after Jouanne et al. 2004). The intense microseismicity (monitered between 1985-1998) drawn with small grey circles, tend to cluster south of the Higher Himalayas (Pandey et al. 1999) at a mid-crustal level. Star represents medium size earthquake.

Table 1: Details of the scenario earthquakes

Earthquake	Magnitude	Location		G-R constant	
				a	b
1934 Bihar-Nepal	8.2	27.55	87.09	3.07	0.77
1988 Udayapur	6.6	26.77	86.61	3.07	0.77

BIHAR-NEPAL EARTHQUAKE 1934

The Bihar-Nepal earthquake that occurred on 15 January 1934 is one of the deadly earthquakes in the history of south Asia. Among the great earthquakes that struck the Himalaya in twentieth century, the Bihar-Nepal earthquake has still remained in ambiguity in terms of its location, nature and intensity. According to Rana (1935) and Dunn et al. (1939) the damage of earthquake was very uneven and much of the destruction was due to slumping, fissuring, and tilting of the ground. The records of damage have shown two parallel belts of severe damage in northern belt of India (Fig. 2). First, the slump belt where damage was severe due to extensive slumping, ground fissuring, tilting and ground sinking. According to Dunn et al. (1939) not a single house escaped tilting and sinking and fissuring of the ground was so severe that sand emission covered the houses, streets and side drains of the roads. Nearly 1500 km of railway lines belonging to the Bengal and Northwestern Railway traversing northern India was damaged. The second narrow belt was mainly in Monghyr and Patna areas which fall on intensity of IX and X (RFI scale) (Fig. 2.). Lying on Indo-Gangetic Plain Monghyr City of Bihar was the worst affected by the earthquake. Devastation was reflected by huge number of collapsed buildings founded on soft soil.

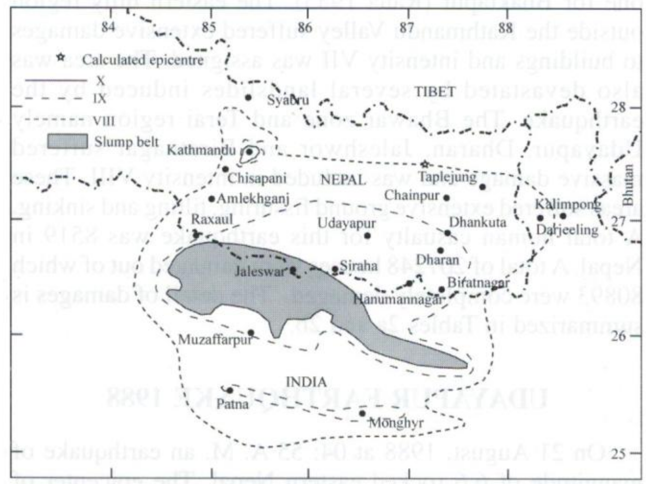

Fig. 2: Observed intensity for 1934 Bihar-Nepal earthquake (Redrawn from Pandey et al. 1988)

Table 2a: Casualties of the 1934 earthquake (after Pandey and Molnar 1988)

Region	Men	Women	Total
Kathmandu Valley	1952	2344	4296
Eastern Mountainous Region	1792	2182	3974
Western Mountainous Region	29	36	65
Terai	77	107	184
Totals for Nepal	3850	4669	8519

Table 2b: Houses destroyed by the 1934 earthquake (after Pandey and Molnar 1988)

Region	Completely damaged	Heavily damaged	Slightly damaged	Total
Kathmandu Valley	12397	25658	17684	55739
Eastern Mountainous Region	63947	70985	-	134932
Western Mountainous Region	795	2268	1266	4329
Terai	3754	5610	2884	12248
Totals for Nepal	80893	104521	21834	207248

However, those buildings constructed on bed rock escaped from destruction. The area in and around Darjeeling also suffered severe damage and was reflected in collapsed buildings. However, Kalimpong area escaped from the severe damages whereas only minor cracks were developed in most of the poorly constructed masonry buildings.

In Nepal, the intensity of damage was particularly much severe in Kathmandu Valley. On the basis of Auden's report the valley was assigned an intensity I-X to parts of valley (Fig. 2). Among the three cities in Kathmandu valley Bhaktapur city and adjacent villages in eastern part of the valley suffered widespread destruction. This is evidenced partly from the ratio of "totally destroyed" house to the number of those "much fractured" house which is more than one for Bhaktapur (Rana 1935). The eastern hilly region outside the Kathmandu Valley suffered extensive damages to buildings and intensity VII was assigned. The area was also devastated by several landslides induced by the earthquake. The Bhawar zone and Terai region namely Udayapur, Dharan, Jaleshwor and Biratnagar suffered massive damage and was included in intensity VIII. These areas suffered extensive ground fissuring, tilting and sinking. A total human casualty for this earthquake was 8519 in Nepal. A total of 207248 houses were damaged out of which 80893 were completely damaged. The detail of damages is summarized in Tables 2a and 2b.

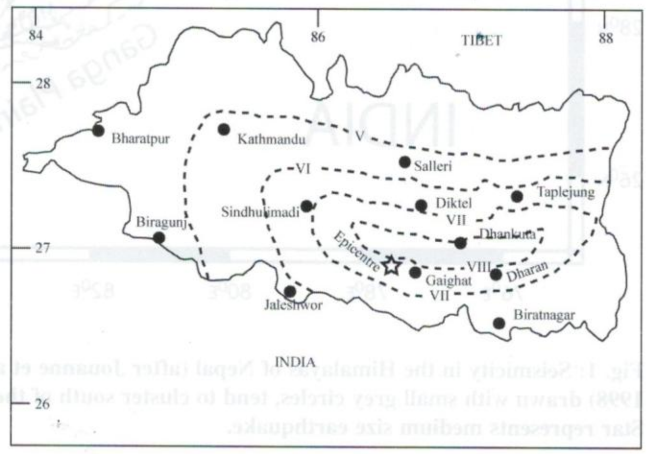

Fig. 3: Observed intensity for 1988 Udayapur earthquake (Redrawn from Dixit 1991)

UDAYAPUR EARTHQUAKE 1988

On 21 August, 1988 at 04: 55 A. M. an earthquake of magnitude of 6.6 rocked eastern Nepal. The epicenter of the earthquake was located in Udayapur district to the south of Siwalik and depth was 57 km. The tremor was so strong that it was also felt in northern India up to Delhi, Burma and parts of Bangladesh. The earthquake extensively devastated eastern Nepal particularly Udayapur, Dharan, Dhankuta, Khotang, Panchthar, Ilam, and Morang. To the west, it caused destruction up to the Kathmandu Valley. Damages were so widespread and were also observed in Darjeeling, Gangtok, and several cities in northern India. The intensity up to VII was estimated in eastern Nepal (Fig. 3). The earthquake caused ground fissuring, liquefaction, sinking and titling in the eastern Nepal, particularly, in Indo-Gangetic Plain. Several landslides were triggered in the hilly region. The earthquake claimed lives of 717 people and injured 6445. Beside these, there were huge devastation of infrastructures; the eastern city of Dharan was almost turned into rubble leaving thousands of people homeless. A total of 65145 building including both public and private were damaged.

SEISMIC HAZARD ANALYSIS

Seismic hazard mapping is a new approach for Nepal. Pandey et al. (2002) has performed PSHA to prepare Seismic Hazard Map of Nepal by using software CRISIS99 developed by Institutede Ingenieria UNAM, Mexico. They have divided entire region of Nepal into ten areal sources and approximately 40 km length of 24 number linear segments. For the purpose of calculation of Peak Ground Acceleration (PGA) they have used attenuation relationship proposed by Youngs et al. (1997). However, their work did not consider point sources. They have calculated PGA only for bedrock, which could assess the hazard level on bed rock only and is not useful for the purpose of design earthquake force calculation unless the suitable relation on amplification is established on the basis of local site effect

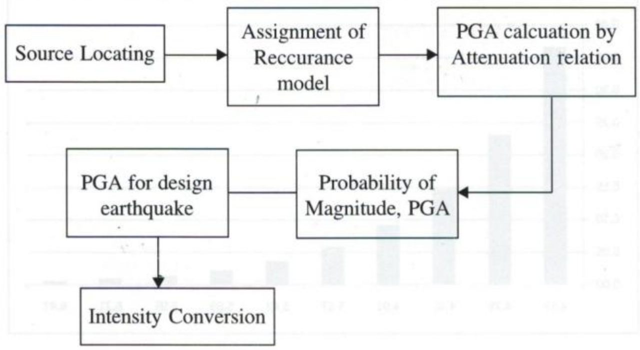

Fig. 4: Detail flow chart showing different steps of seismic hazard assessment

consideration. Therefore, a new method of predicting the ground motion parameter for particular event is conceptualized in this research. Unlike Pandey et al. (2002) to predict design basis earthquakes from all possible sources; this work is mainly focused on prediction of ground motion parameter for individual point sources considering 1934 Bihar-Nepal and 1988 Udayapur earthquakes.

METHODOLOGY

Seismic hazard analysis specifies the level of ground shaking due to impending earthquakes in the particular site. There are mainly two approaches of seismic hazard assessment namely Deterministic Seismic Hazard Analysis (DSHA) and Probabilistic Seismic Hazard Analysis (PSHA). DSHA involves to a particular earthquake scenario, it does not use the condition of likelihood of maximum possible ground motion. The ground motion parameters predicted by the method of DSHA is generally of maximum value. In PSHA uncertainties in earthquake size, location, and time of occurrence are considered. In this method, probability of exceedence of some particular value of ground motion parameter like PGA or spectral acceleration is calculated. Attenuation relationship is used to calculate the mean value of PGA and their standard deviations. Generally, ground motion parameters are log normally distributed. The probability of exceeding the mean value by targeted ground acceleration is calculated. In this study, a PSHA approach of hazard assessment is adopted for calculation of the peak ground acceleration due to scenario earthquakes event occurring at the source. The basic steps adopted in this study are shown in Fig. 4.

The maximum magnitude of scenario earthquakes sources are assigned as the values recorded or calculated in each event. The study area is divided into small grids of size 0.5^0 X 0.5^0 as shown in Fig. 5.

Characterization of seismicity or temporal distribution of earthquake recurrence is done after locating the epicentres of scenario earthquakes. A reccurance relationship which

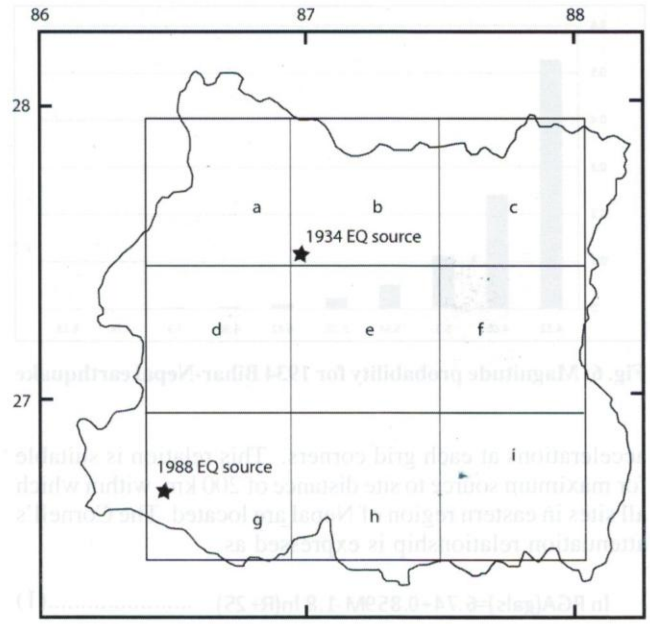

Fig. 5: Study area showing rectangular grids and point sources

specifies average rate of exceedance of minimum significant magnitude of 4 is used to characterize the seismicity of each source. Gutenberg-Richter Law for earthquake reccurance, which can expressed as, Log λ_m= a-bm, where λ_m is the mean annual rate of exceedance of magnitude m, 10^a is the mean yearly number of earthquakes of magnitude greater than or equal to zero, and b also called b-value describes the relative likelihood of large and small earthquakes is used to calculate the recurrence interval.

ADOPTED ATTENUATION RELATIONSHIP

Predictive relationship also known as attenuation relationship usually expresses ground motion parameter like PGA as function of magnitude and source to site distance in other variables too. For example: $Y= f(M,R,P_i)$, where Y is ground motion paramenters of interest, M is the magnitude of earthquake, R is the source to site distance and P_i is source path and local soil effect which may or may not be considered. Generally with attenuation relationship, uncertainity assosiated with the expression (standard deviation) is also specified.

The attenuation relationship is usually based on the regional values. In Nepal where attenuation relationship has not been developed due to lack of earthquake data, the relationships proposed by Young's et al. (1997), and Cornell et al. (1979) can be used to predict ground motion parameter (Maskey and Mishra 2005). Since other attenuation except defined by Cornell et al. (1979) relationships needs geological region based coefficients which have not clearly defined yet for Nepal, the attenuation relationship proposed by Cornell et al. (1979) is used in predicting the peak ground

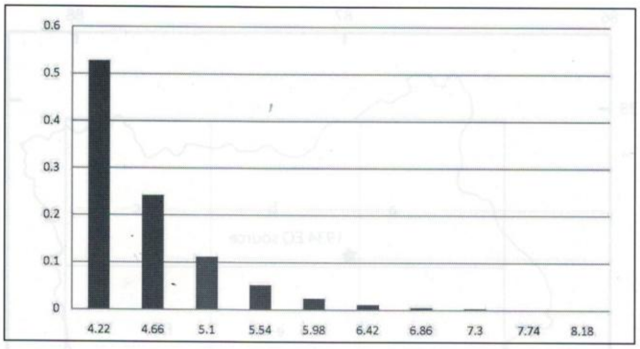

Fig. 6: Magnitude probability for 1934 Bihar-Nepal earthquake

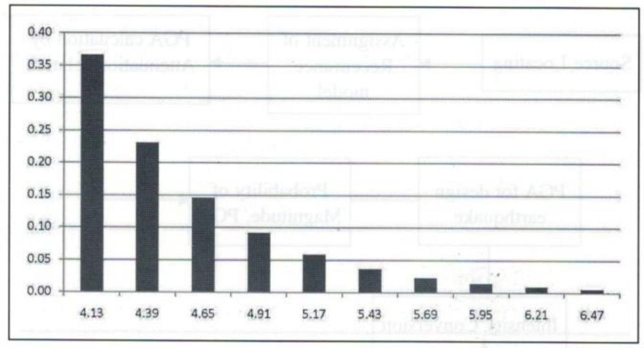

Fig. 7: Magnitude probability for 1988 Udayapur earthquake

accelerations at each grid corners. This relation is suitable for maximum source to site distance of 200 km, within which all sites in eastern region of Nepal are located. The Cornell's attenuation relationship is expressed as

$$\ln PGA(gals)=6.74+0.859M-1.8\ln(R+25) \quad \text{.....................(1)}$$

$\sigma_{lny} = 0.57$, where, PGA is peak Ground Acceleration, M is magnitude in Richter scale, R is source to site distance in km and σ_{lny} is natural log of standard deviation for the uncertainty associated with this ground motion parameter (y) predicting expression.

PROBABILITY CONSIDERATION

Magnitudes of 1934 and 1988 earthquakes are assigned as the maximum characterized magnitude of these sources for seismic hazard analysis. For the purpose of dynamic analysis the minimum threshold magnitude that may cause damage to structures is considered as 4. The magnitude is divided into equal number of intervals. In between these two limits of maximum and minimum magnitudes and the probability of each interval of magnitudes is calculated. The point source which has a single source to site distance, the probability of source to site distance is considered as a unity. Attenuation relationship proposed by Cornell et al. (1979) is used to find PGA in each interval of magnitude and distance. The probability of exceedence of expected PGA is computed from the normal distribution of lognormal of peak ground accelerations. Finally, the mean annual rate of exceedence of ground motion parameter of interest (y*) is calculated by using the expression given by equation (2).

$$\lambda y * - \sum_{i=1}^{ns} fM(m) * \sum_{j=1}^{nm} fR(r) * \sum_{k=1}^{nR} \Delta m \, \Delta r * \; vi \, P[Y > y * \backslash mj, rk] \quad (2)$$

where, λy^* is annual rate of exceedence of peak ground acceleration y* occurring at source from 1 to number n_S in between magnitudes of total n_M numbers at source to site distances ranging from 1 to n_R number, vi is annual rate of exceedence of minimum threshold earthquake (M=4) at source i derived using G-R recurrence relationship and $P[Y>y^*/m_j, r_k]$ is the probability of exceedence of specified PGA Y to the value y* obtained using attenuation relationship for given magnitude m_j and distance r_k. $f_M(m)$ is the function of magnitude probability as given by truncated G-R relationship with upper and lower bound expressed in equation (3) (McGuire 2004).

$$f_M(m) = \beta \exp[-\beta(m-m_o)]/\{1-\exp[-\beta(m_{max}-m_o)] \quad \text{...............................(3)}$$

where m_{max} is maximum magnitude and m_0 is minimum level of magnitude which is responsible to cause damage in structure. $f_R(r)$ is the uniform probability of source to site distance ranging from 1 to n_R numbers.

PGA induced at bed rock level of site due to each source can be expressed by the hazard curves plotted between λy^* and y*. Poisson's model represented by equation (4) is used to compute PGA values from hazard curves, at exceedence probability of 10% in 50 years. This represents probability of at least one exceedence of particular value of annual rate λy in period of t years.

$$P(N\geq 1) = 1-e^{-\lambda y.t} \quad \text{...(4)}$$

Where, $P(N\geq 1)$ is probability of exceedence of least one particular value of annual rate λy in period t years.

RESULTS

Magnitude probability calculated from equation (3) is represented by Figs. 6 and 7 for 1934 Bihar-Nepal and 1988 Udayapur earthquakes, respectively. It is found that the probability of occurrence of smaller magnitude is more than the larger magnitude. Distance probability [fR(r)] of source to each site distance in this case is 1, because each of the sources, being point sources, have a single measured distance from the selected site.

Seismic hazard in the form of annual rate of exceedence of specified level of ground motion acceleration occurring at each corner of grids named as a to i in the map (Fig. 5) is calculated using the attenuation relation of Cornell (1979) (Eq. 1).The temporal distribution or earthquake recurrence above minimum threshold level of magnitude of 4 is computed using equation log λm=3.07-0.77 M. From the probabilistic seismic hazard analysis firstly the seismic hazard curves are drawn for all grid corners. From these hazard curves the exceedence of peak ground accelerations for 10% probability in 50 years is computed. Finally, these values are assigned in each site (the corners of grid in Fig. 5) and interpolation is performed to represent in contours that connects equal values of ground acceleration.

The simulated values of ground shakings are derived for design basis earthquakes which have 10% probability in 50 years (i.e. return period of earthquake event of 475 years) and are represented by PGA. For the Bihar-Nepal earthquake PGA value ranges from 100 to 350 gal (Fig. 8). The highest PGA value (i.e. 350 gal) is found to the east of epicenter, i.e. border between Sankhuwasabha and

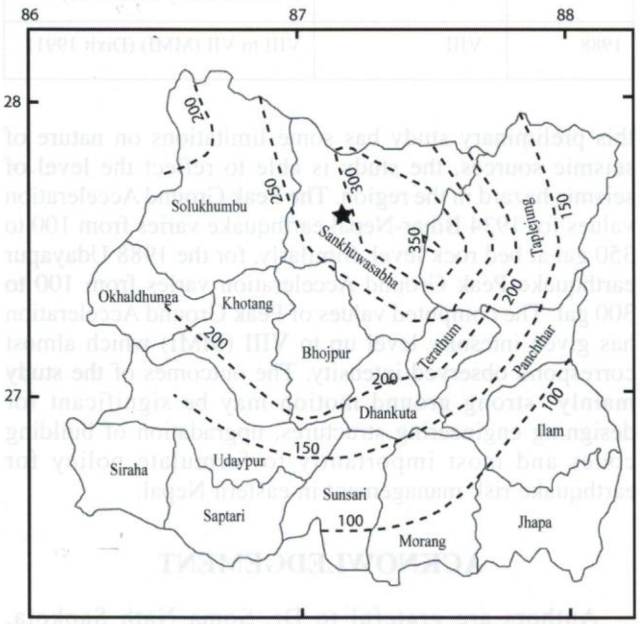

Fig. 8: Seismic hazard map simulating 1934 Bihar-Nepal earthquake ground motion. Star shows epicenter. Peak Ground Acceleration is in gal.

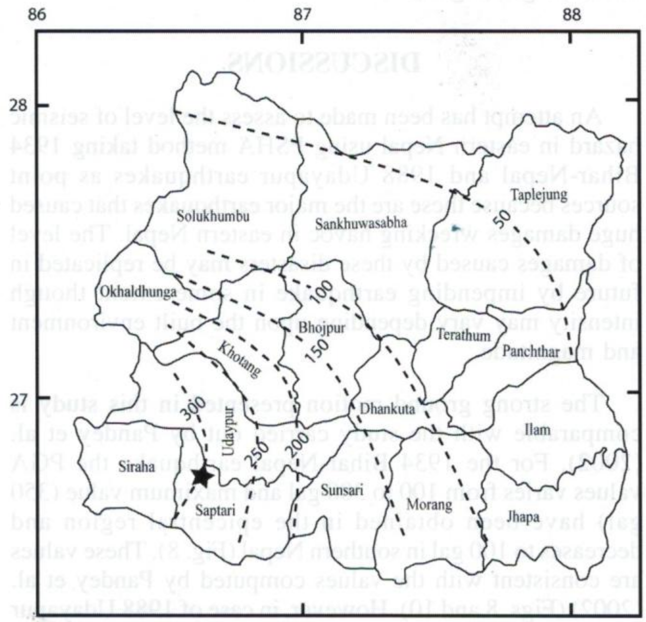

Fig. 9: Seismic hazard map simulating 1988 Udayapur earthquake ground motion. Star shows epicenter. Peak Ground Acceleration is in gal.

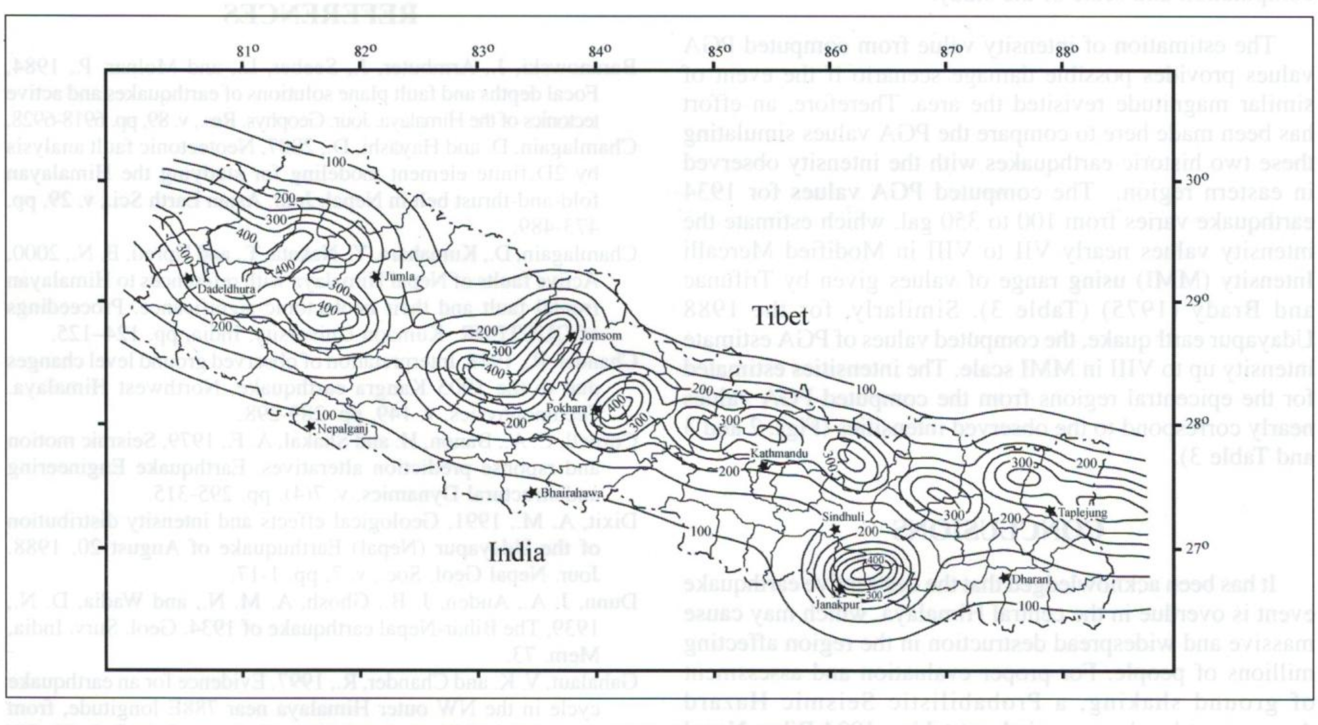

Fig. 10: Seismic hazard map (Redrawn from Pandey et al. 2002). Peak Ground Acceleration is in gal.

Taplejung districts. These two districts have moderate to high PGA values i.e. 150 to 350 gal. However, the PGA value decreases towards southeast and reaches down to 100 gal in Sunsari, Morang and Ilam districts. For the Udayapur earthquake, the highest value of PGA (300 gal) is found for the epicentral region, i.e. Udayapur and Saptari districts and is decreased towards northeast where the minimum value is found 50 gal (Fig. 9).

DISCUSSIONS

An attempt has been made to assess the level of seismic hazard in eastern Nepal using PSHA method taking 1934 Bihar-Nepal and 1988 Udayapur earthquakes as point sources because these are the major earthquakes that caused huge damages wrecking havoc in eastern Nepal. The level of damages caused by these disasters may be replicated in future by impending earthquake in some extent though intensity may vary depending upon the built environment and magnitude.

The strong ground motion presented in this study is comparable with the study carried out by Pandey et al. (2002). For the 1934 Bihar-Nepal earthquake the PGA values varies from 100 to 300 gal and maximum value (350 gal) have been obtained in the epicentral region and decreases to 100 gal in southern Nepal (Fig. 8). These values are consistent with the values computed by Pandey et al. (2002) (Figs. 8 and 10). However, in case of 1988 Udayapur earthquake the computed values were lower than that of Pandey et al. (2002) (Figs. 9 and 10). This difference may be attributed to number of sources considered for computation and scale of the study.

The estimation of intensity value from computed PGA values provides possible damage scenario if the event of similar magnitude revisited the area. Therefore, an effort has been made here to compare the PGA values simulating these two historic earthquakes with the intensity observed in eastern region. The computed PGA values for 1934 earthquake varies from 100 to 350 gal, which estimate the intensity values nearly VII to VIII in Modified Mercalli Intensity (MMI) using range of values given by Trifunac and Brady (1975) (Table 3). Similarly, for the 1988 Udayapur earthquake, the computed values of PGA estimate intensity up to VIII in MMI scale. The intensities estimated for the epicentral regions from the computed PGA values nearly correspond to the observed intensities (Figs. 2 and 3 and Table 3).

Table 3: Comparisons of PGA and Earthquake Intensity at epicenter

Earthquake	Intensity calculated (MMI)	Observed intensity
1934	VII to VIII	VIII (RFI), VII to VIII (MMI) (Pandey et al. 1988)
1988	VIII	VIII to VII (MMI) (Dixit 1991)

CONCLUSIONS

It has been acknowledged that the destructive earthquake event is overdue in the central Himalaya, which may cause massive and widespread destruction in the region affecting millions of people. For proper evaluation and assessment of ground shaking, a Probabilistic Seismic Hazard Assessment has been carried out taking 1934 Bihar-Nepal and 1988 Udayapur earthquakes as point source. Although this preliminary study has some limitations on nature of seismic sources, the study is able to reflect the level of seismic hazard in the region. The Peak Ground Acceleration values for 1934 Bihar-Nepal earthquake varies from 100 to 350 gal at bed rock level. Similarly, for the 1988 Udayapur earthquake Peak Ground Acceleration varies from 100 to 300 gal. The computed values of Peak Ground Acceleration has given intesnity level up to VIII (MMI) which almost correspond observed intensity. The outcomes of the study mainly strong ground motion may be significant for designing engineering structures, upgradation of building codes and most importantly to formulate policy for earthquake risk management in eastern Nepal.

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