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Synthetic Accelerograms due to Moderate/ Strong Earthquakes in National Capital (Delhi) Region

S. S. Teotia , Manisha* and Dinesh Kumar
Department of Geophysics , Kurukshetra

Summary

The National Capital Region (NCR) of India lies in the geological realm of the Peninsular India and is about 200 km from the India plate boundary (Himalaya).Devastating events have occurred in Peninsular India in the recent past which points towards the seismic hazard of the densely populated city with weak structures as in NCR .Besides its own seismotectonic setup , NCR is also vulnerable to great earthquakes from the Central Seismic Gap (CSG) of Himalaya and/or by moderate/strong earthquake in NCR .We have identified the five source zones in the region based on geology and past seismicity which have the potential of generating the earthquakes of magnitude 5.5 and above. The accelerograms have been generated at bed rock level from hypothetical moderate/strong earthquakes (M 5.5 – 6.5) in the National Capital Region to estimate the seismic hazard and risk from such events . The acclerograms have been generated at specific locations. A semi- empirical technique has been used for this purpose .The peak ground acceleration (PGA) values have been extracted from the simulated accelerograms from each zone .The maximum PGA value considering all the zones is .22g ,which is due to the Sohna Fault. We have also observed that the source zone I and II ,i.e. Mathura Fault zone and Sohna Fault Zone contributing maximum PGA values for the NCR. These results may vary when empirical transfer function is incorporated as values computed are at bed rock level.

Introduction

Since historical past, the NCR have experienced earthquakes of magnitude 6.0 and above which are capable of destroying the whole infrastructure within few seconds. Recent disastrous earthquakes of Bhuj (26 Jan., 2001),Chamoli (March 29,1999)and Uttarkashi (Oct. 20,1991) have demonstrated large amount of damage and consequent loss of life.

The seismotectonic set up of NCR and its position in the neighbourhood of Himalaya makes it vulnerable to high seismic hazard zone as shown in Figure 1(a-b). The losses due to damaging earthquakes can be minimized by comprehensive assessment of seismic hazard and risk. First step to minimize the earthquake hazard is to estimate the hazard of the region itself. In order to assess seismic hazard past records of earthquakes provide valuable information, but in many regions such records are few or absent at the site of interest .To overcome this problem one needs to simulate synthetic accelerograms. There are number of techniques to simulate ground motion(1)ARMA (Auto Regressive Moving Average) methods(2)Composite Source Model (3)Empirical Greens Function approach to synthesis the strong ground motion which is advantageous as it takes the complex heterogeneity of the path into account .However , the small event record ,foreshock or aftershock ,from the source region of the main earthquake may not be available for the site of interest. We use the fast semi empirical method proposed by Khattri(1998) which was

Department of Geophysics , Kurukshetra University Kurukshetra 136 119 India
teotia_ss@rediffmail.com, san553@yahoo.co.in, dineshk5@rediffmail.com

extension of Midorikawa (1993) procedure for obtaining synthetic accelerograms for large earthquakes.

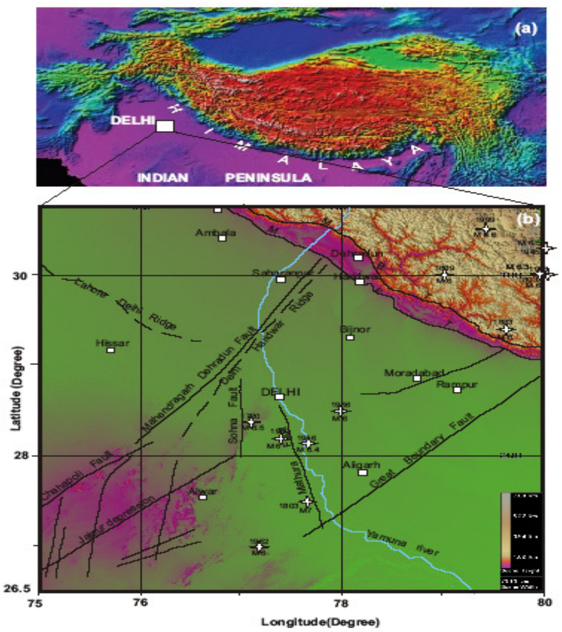

Figure 1(a) :Map showing the position of Delhi w.r.t Himalayas
1(b): Seismotectonic map of NCR

Methdology

The fault plane of target earthquake is divided into n x n subfaults where size of each subfault corresponds to a small earthquake . Here n is a scaling parameter given by the relation by (Midorikawa,1993).

$$N=10^{0.5(M-M')} \qquad \text{---- (1)}$$

Where M and M' are earthquake magnitudes of the large and small earthquakes respectively. To simulate the peak acceleration from large earthquakes, Midorikawa adopted the following envelope function used by Kameda and Sugito(1978)

$$e_{ij}=(a_{ij}t/d_{ij})*\exp(1-t/d_{ij}) \qquad \text{------(2)}$$

where $e_{ij}(t)$ is the envelope function corresponding to the (i,j)th element of the fault plane. a_{ij} and d_{ij} are the peak acceleration and duration parameters respectively,determined fron the exiting empirical relations for these parameters , t is the time .The acceleration envelope waveform e(t)of the target earthquake can be synthesized by the summation of the envelope e_{ij} as follows

$$e(t)=[\sum_{i}\sum_{j} e^2_{ij}(t-t_{ij})]^{1/2} \qquad \text{---------(3)}$$

where t_{ij} is the time delay due to rupture propagation and travel time of seismic waves.Now the envelope waveform generated above is multiply with the band limited white noise to get the accelerogram at the site .The steps involved in synthesizing the accelerogram are shown in figure 1 below.

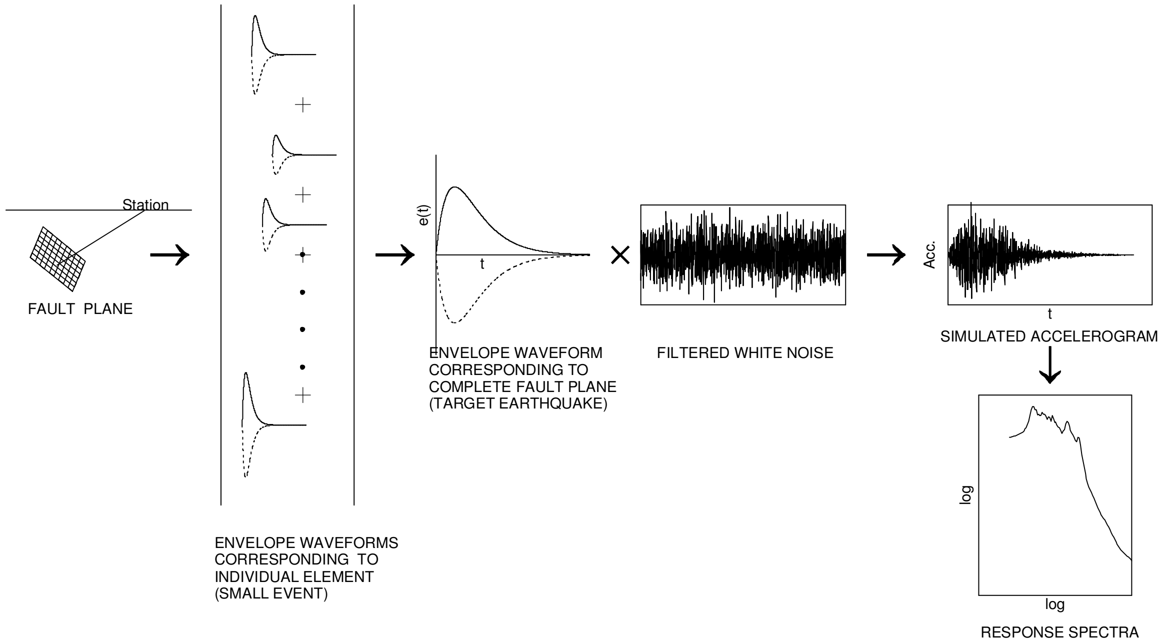

Figure 2: Schematic illustration of steps for synthesizing accelerogram used in proposed technique (after Dinesh et al., 1999)

Results and Discussion

To compute the envelope waveform corresponding to the elements on the fault plane using eq. (2) the peak acceleration and the duration parameters are required .The peak acceleration is determined from the attenuation relation for the region where the envelope waveform due to target earthquake is required. A seismo-tectonic region is characterized by its specific attenuation relation. The relation developed by Abrahamson and Litehiser (1989) based on 585 strong motion records from 76 worldwide earthquakes has been adopted in this study. The attenuation relation for horizontal acceleration is as follows:

$$\log(a)=-0.62+0.177M_s-0.982\log(R+\exp(0.284M_s))+0.132F-0.0008ER$$

where a is acceleration in g , M_s is the earthquake surface wave magnitude and R is the hypocentral distance in km. F is 1 for reverse fault and 0 otherwise. E is a parameter equal to 1 for interplate and 0 for intraplate events.

The duration parameter has been estimated using the following relation given by Midorikawa (1993) and modified by Dinesh et. al. (1999) :

$$d=0.015*10^{0.05M'}+0.12\ x^{0.75}$$

where d is the duration parameter ,M' is the earthquake magnitude of the small event, x is the distance (in km) of the element from the site .

The acclerograms have been generated at some specific locations around the source zones. The parameters used for simulating accelerograms due to different source zones are given in Table I. The number of elements in which the fault plane is divided are four for the Sohna Fault zone

,Moradabad Fault zone, Delhi Haridwar ridge zone ,Great Boundary Fault zone and nine for the Mathura Fault zone. The synthetic accelerograms thus generated are shown in Figures 3(a-e). We note that the pga values are varying from .015g -.22g and maximum pga value ,i.e. .22g is contributed by Sohna Fault . The maximum pga values are contributed from source zone I & II ,Sohna Fault zone and Mathura Fault zone (as shown in Table I). It is to mention here that these values are computed at bed rock level and may vary when empirical transfer function is incorporated (in progress).

Table I

MAJOR FAULTS in NCR CAPABLE OF PRODUCING EARTHQUAKES OF MAGNITUDE ≥6.0

S.No.	Name of the Fault	Earthquake Occurred in past	Magnitude of Occurred Earthquake	Magnitude of Target Earthquake	Latitude	Longitude	Fault Dimension (kmxkm)
1.	Sohna Fault	1720	6.5	6.0	28.37	77.1	16 x 6
2.	Mathura Fault	1803	7.0	6.5	27.5	77.67	30 x 10
3.	Moradabad Fault	1956	6.0	6.0	28.5	78	16 X 6
4.	Delhi-Haridwar Ridge	1720	6.5	6.0	28.37	77.1	16 X 6
5.	Rajasthan Great Boundary Fault	1952	6.0	6.0	27	77.2	16 X 6

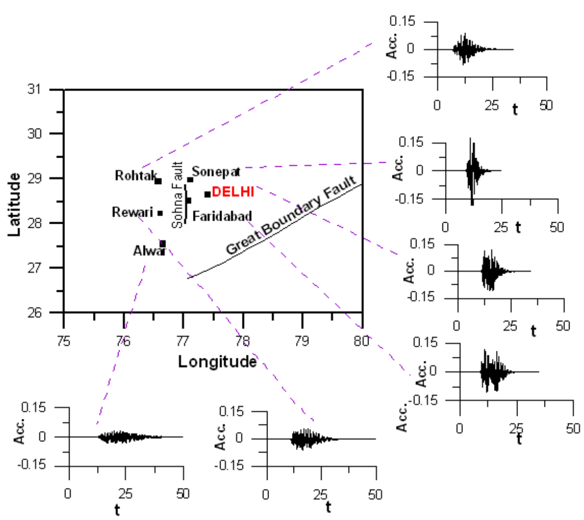

Figure 3(a) Synthetic Acclerograms generated in NCR at specific location marked by dashed lines due to Earthquake of M 6.0 from Sohna Fault zone

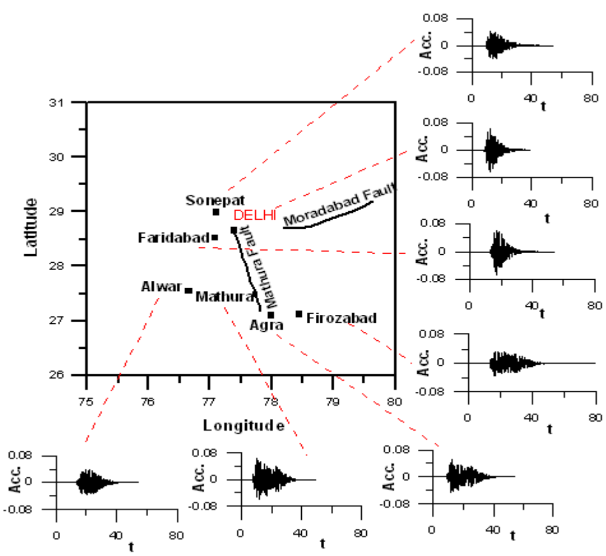

Figure 3(b) Synthetic Acclerograms generated in NCR at specific locations marked by dashed lines due to Earthquake of M 6.5 from Mathura Fault zone

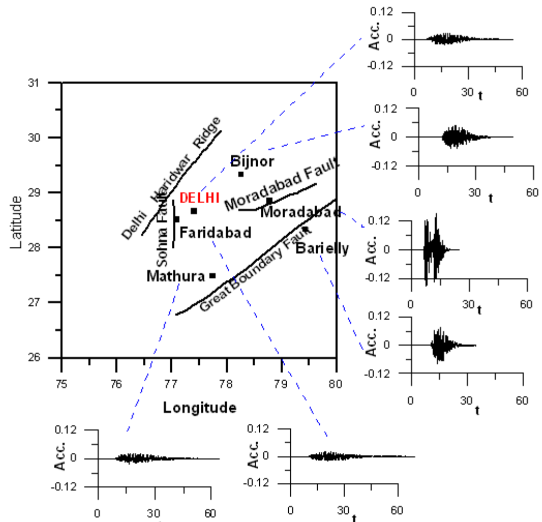

Figure 3(c) Synthetic Accelerograms generated in NCR ay specific location marked by dashed lines due to Earthquake of M 6.0 from Moradabad Fault zone

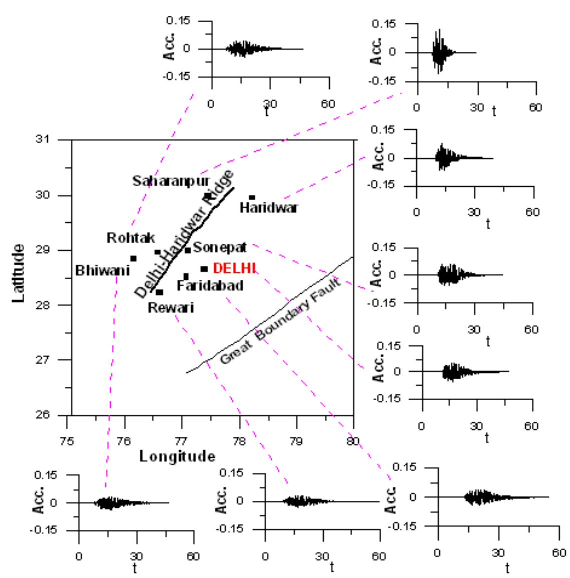

Figure 3(d) Synthetic Accelerograms generated in NCR at specific location marked by dashed lines due to Earthquake of M 6.0 from Delhi-Haridwar Ridge Zone

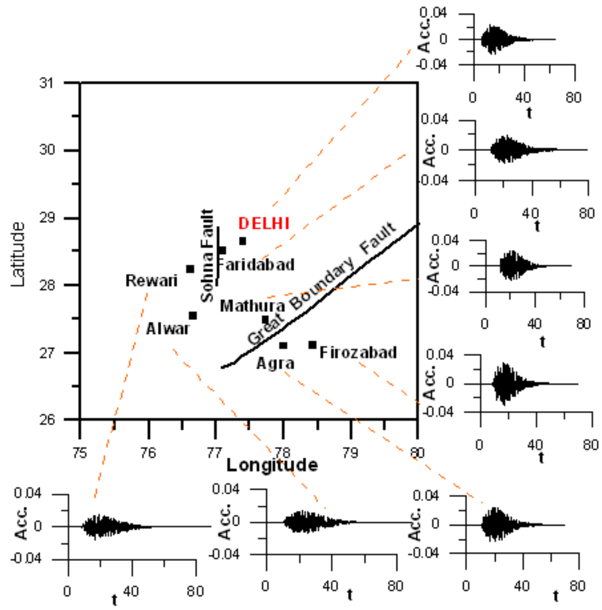

Figure 3(e) Synthetic Acclerograms generated in NCR at specific location marked by dashed lines due to Earthquake of M 6.0 from Great Boundary Fault zone

Conclusions

A fast semi-empirical method to generate synthetic accelerograms for the NCR has been used. For NCR the five seismogenic sources have been identified for the potential of generating an earthquake of magnitude 6.0 and above. The pga values have been extracted from the simulated acclerograms which corresponds to each source zone . The maximum pga value considering all the source zones is .22g ,which is due to Sohna Fault zone. We have also observed that the source zone I and II ,i.e. Sohna Fault zone and Mathura Fault zone contribute maximum pga values for the NCR .These values are computed at the bed rock level and may vary when soil amplification factor is incorporated.

Acknowledgements

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