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Response spectral attenuation relations for in-slab earthquakes in Indo-Burmese subduction zone

I.D. Gupta

Central Water and Power Research Station, Khadakwasla, Pune 411 024, India

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ABSTRACT

From an analysis of a limited number of strong-motion data recorded in northeast Indian region, the in-slab earthquakes along the Indo-Burmese subduction zone are found to be characterized by much larger ground motion amplitudes than that for the earthquakes along other subduction zones around the world. Specific type of source, propagation path and site geologic condition may perhaps simultaneously be responsible for such anomalous behaviour. The empirical attenuation relations developed by Atkinson and Boore [3] using a global database for subduction zone earthquakes have been therefore suitably modified to be more appropriate for the northeast India. The modified relationships are developed by combining the data for both horizontal and vertical components of motion. The response spectra of the accelerograms recorded in northeast India from earthquakes with widely varying magnitude and distance are, in general, found to match very well with the predictions from the modified attenuation model. The proposed model can thus be used to obtain more realistic estimate of the contribution of in-slab subduction zone earthquakes to seismic hazard in the northeast Indian region.

1. Introduction

Subduction zone earthquakes are characterized by significantly different attenuation characteristics [36] compared to the shallow crustal earthquakes [1]. Also, the ground motion amplitudes due to in-slab and interface types of subduction zone earthquakes are found to differ significantly. Using a global database of about 350 horizontal components, Youngs et al. [36] developed separate attenuation relations for the ground motion due to in-slab and interface earthquakes. Atkinson and Boore [3] have updated these relationships using a much bigger worldwide database of about 1200 horizontal components, which are termed as AB-2003 relationships in the subsequent description. The AB-2003 relations are based on the assumption that there are no detectable differences between ground motions among different regions of the world for the same earthquake magnitude and distance. However, Douglas et al. [16] and Douglas and Mohais [17] have shown that the AB-2003 model greatly under-predicts the ground motions in the Lesser Antilles. Thus, the applicability of this model to individual areas needs to be evaluated on a case-by-case basis.

The AB-2003 relations are also found to underestimate significantly the observed spectral amplitudes from a limited number of 56 three-component accelerograms recorded at 37 different sites in northeast India at large epicentral distances (greater than about 200 km) from three in-slab earthquakes along the Indo-Burmese subduction zone. The large amplification of ground motions recorded in northeast India can be considered akin to that in Mexico due to interface earthquakes along the Pacific coast as well as in-slab earthquakes in the subducted Cocos plate at very long distances [18]. Various studies subsequent to the Michoacan earthquake of 1985, which devastated the Mexico city at a distance of around 350 km, have established that the source and propagation path characteristics have contributed greatly to the large ground motion amplitudes during Mexico subduction zone earthquakes along with the local soil amplification effects (e.g., [9,20,18]).

The source characteristics like stress-drop and focal mechanism solutions, as well as the path effects like wave-guide action of the subducting plate, may perhaps be responsible for relatively larger ground motion amplitudes in northeast India. However, the available data are far less than adequate to analyze these effects in any details. As regards the site amplification effects, it is now well known that the use of shallow soil condition alone (for example, average shear wave velocity in the top 30 m of ground) is not adequate [23,10]. For more realistic description of the site effects, the ground motion regression relations are, in addition, required to consider explicitly the effect of local geological condition on a much bigger scale [32,19]. Atkinson and Boore [3] have also acknowledged the possibility of regional differences due to variation in the local geological condition. However, to quantify its effect for the northeast Indian region, an exact knowledge of the site geologic condition is lacking for the strong-motion database used in the present study.

E-mail address: idgrh4@gmail.com

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In view of the above, the available limited database in northeast India is used to consider the effects of source, path and site geology in an aggregate way only, by suitably modifying the AB-2003 relations. The methodology used for this purpose is very similar to that followed by Atkinson [2] for modifying a ground motion model for the western North America to make it better fit the observations in eastern North America. The modified relations are found to be of the highest rank as per the criteria of Scherbaum et al. [28], and are also seen to describe closely the behaviour of the recorded data at very long distances. These relations are thus expected to be very useful for estimation of more realistic seismic hazard in northeast India due to in-slab earthquakes along the Burmese subduction zone. A large and important area of northeast India may be affected significantly by such events beyond distances of about 200 km. However, no recorded strong-motion data are available to obtain the modified attenuation model for interface earthquakes in the northeast Indian region. It is therefore proposed to identify from the published literature a suitable model that matches most closely with the modified model for in-slab earthquakes, and use for northeast India the corresponding model for the interface earthquakes. If an unambiguous single choice becomes difficult, several models with suitable weight factors can be used in the probabilistic seismic hazard analysis [4]. It may be mentioned that very low level of interface seismicity is seen to occur in the Burmese subduction zone, and these earthquakes are not expected to contribute significantly to the seismic hazard in the northeast India, if any.

Table 1
Details of the recording sites in Northeast India for the strong motion data used in the present study.

Sl. No.	Name of site	Latitude	Longitude	Soil class
1.	Baigao	25.400	92.850	C
2.	Baithalangso	25.967	92.600	C
3.	Bamungao	25.883	93.000	C
4.	Berlongfer	25.767	93.250	C
5.	Bokajan	26.000	93.760	C
6.	Cherrapunji	25.267	91.733	B
7.	Dauki	25.183	92.010	C
8.	Diphu	25.917	93.430	C
9.	Doloo	24.917	92.780	C
10.	Gunjung	25.300	93.000	C
11.	Haflong	25.167	93.010	C
12.	Hajadisa	25.367	93.300	C
13.	Harengajao	25.100	92.850	C
14.	Hatikhali	25.650	93.100	C
15.	Hojai	25.983	92.850	C
16.	Jellalpur	25.000	92.450	C
17.	Jhirighat	24.800	93.100	C
18.	Kalain	24.967	92.560	C
19.	Katakhal	24.817	92.630	C
20.	Khliehriat	25.350	92.360	B
21.	Koomber	24.950	93.000	C
22.	Laisong	25.200	93.300	C
23.	Loharghat	25.967	91.467	C
24.	Maibang	25.300	93.130	C
25.	Mawkyrwat	25.367	91.467	B
26.	Mawphlang	25.450	91.767	B
27.	Mawsynram	25.283	91.583	B
28.	Nongkhlaw	25.683	91.633	B
29.	Nongstoin	25.500	91.267	B
30.	Panimur	25.650	92.800	C
31.	Pynursla	25.300	91.900	B
32.	Saitsama	25.717	92.380	C
33.	Shillong	25.550	91.900	B
34.	Silchar	24.817	92.800	C
35.	Ummulong	25.500	92.150	B
36.	Umrongso	25.500	92.610	C
37.	Umsning	25.733	91.883	B

2. Details of the database available

The database used in the present study has been recorded by an array of strong-motion instruments in northeast India, which is one of the most complex tectonic provinces in the world. This area is being over-thrusted from eastern as well as northeastern sides with a tectonically rigid block, the Shillong plateau, in-between. The overthrusting from the north has resulted in the formation of Eastern Himalayas, whereas the overthrusting from east has resulted in the formation of the Naga-Disang thrusts and Arakan-Yoma Fold Belt to the west of the eastern boundary of the Indian plate. Due to the horizontal forces acting from two sides, the Shillong plateau has been rising since early Tertiary period and all

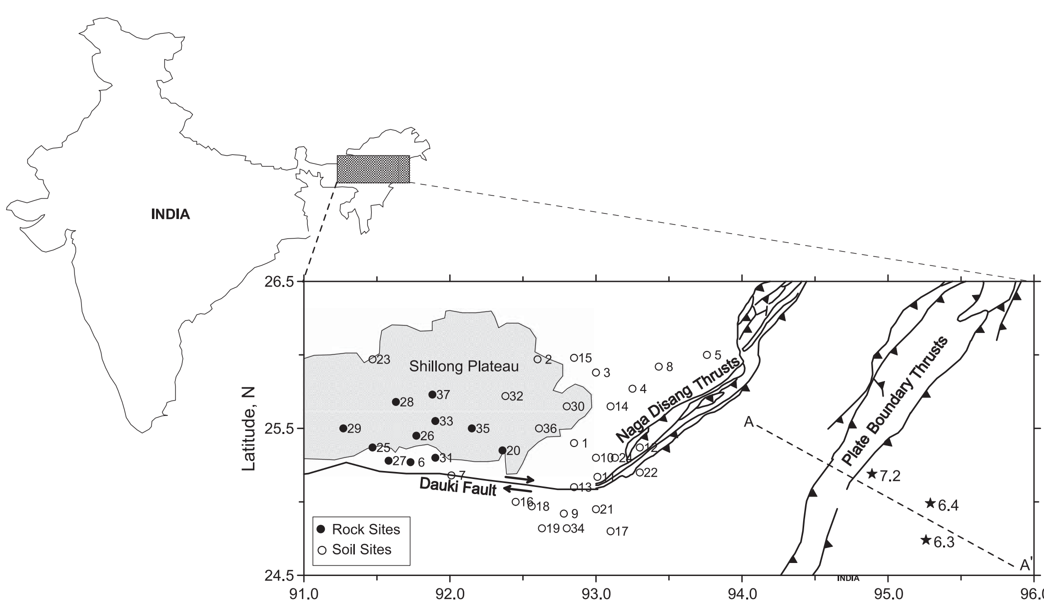

Fig. 1. Locations of recording sites for available strong-motion data in northeast India along with major tectonic features and the epicentral locations of the three contributing earthquakes.