Effect of the Size of Shillong Plateau on Relative Weightage of Selected Attenuation Relations for Seismic Hazard Analysis

B. Olympa[1] and K. Abhishek, Ph.D.[2]

[1]Research Scholar, Dept. of Civil Engineering, Indian Institute of Technology Guwahati, India. E-mail: okay4aec@gmail.com
[2]Dept. of Civil Engineering, Indian Institute of Technology Guwahati, India. E-mail: abhiak@iitg.ernet.in

ABSTRACT

The Shillong Plateau (SP) located in northeast India covers an area of 25,000 km^2. Recent study found that seismic hazard of the SP is affected by four different seismic source zones viz. Shillong Plateau-Assam Valley Zone (SP-AVZ), Indo-Burma Ranges Zone (IBRZ), Bengal Basin Zone (BBZ), and Eastern Himalaya Zone (EHZ). The hypocentral distances from the above mentioned source zones to different parts of the SP are significantly varying. Present study found that this variation in hypocentral distance affects the weights of applicable ground prediction equations (GMPEs) for different parts (based on information theoretic approach) and consequently the seismic hazard of the SP. It is found that the GMPE having the highest weight in the western part of the SP has a lower weight in the eastern part and vice versa. These findings suggest seismic hazard analysis of larger areas like the SP should be attempted by dividing into sub-regions rather a single study area.

INTRODUCTION

The northeastern region of India is a hotbed of seismic activity. This seismic activity of the region can be attributed to its close proximity to two very active plate boundaries viz. the Indian & Eurasian plate boundary to the north and the Indian & Burmese plate boundary to the east. Approximately 60 million years ago (Mya), this tectonic movement of the plates led to the formation of the Shillong Plateau (SP) in south-western part of the region. The SP comprises of the present day Indian state of Meghalaya as shown in Figure 1. The SP is spread across an area of 25,000 km^2 and extends for 302 km in the east-west direction and 105 km in the north-south direction. Thus, the SP is relatively elongated in the east-west direction compared to the north-south direction. This plateau has experienced several earthquakes (EQs) throughout its existence, the 1897 Assam EQ (M_W-8.1) being the most damaging. As per Bilham and England (2001), the 1897 Assam EQ triggered landslides at various locations across the SP. The shaking also caused damages across a wide radial extent. Other major EQs ($M_W \geq 7.0$) that had occurred in and around the SP are the 1869 Cachar EQ(M_W-7.5), 1923 Meghalaya EQ(M_S-7.1), 1930 Dhubri EQ(M_S-7.1) and 1943 Assam EQ(M_S-7.2). Oldham (1882) reported that the 1869 Cachar EQ generated ground fissures, sand vents and also caused damages to government buildings in the cities of Guwahati and Shillong located in Assam and Meghalaya respectively. The 1923 Meghalaya EQ was felt across the Indian states of Meghalaya, Assam, West Bengal as well as in Bangladesh (CNDM 2002; Baro and Kumar 2015 a, b). The 1930 Dhubri EQ caused damages to the towns of Dhubri and Tura located in Assam and Meghalaya respectively (Gee 1934; Baro and Kumar 2015 a, b). The 1943 Assam EQ also led to the occurrence of fissures, ground unevenness and building damages at several locations (CNDM 2002).

Shillong city and Tura located in the eastern and western parts of the SP. Some GMPEs which are found applicable to Shillong city are not applicable to Tura and vice versa. Similarly, there are relatively different weights to be given to same GMPEs for Shillong city in comparison to Tura. These differences are the attributes of variation in the hypocentral distance range for same seismic sources from Tura in comparison to Shillong city which significantly alters the PGA proposed by selected GMPEs and subsequently its weights and ranks. More number of similar studies can be attempted in the future to quantify the minimum size of study area for which weights and ranks of GMPEs changes within the study area.

Table 1 (b) LLH values, DSI values, ranks and weights (w_j) of GMPEs for Tura

Zone	GMPEs	LLH values	DSI values	Rank	Weights
SP-AVZ	Toro (2002)	2.82	-26.45	3	-
	Kanno et al. (2006)	4.19	-71.58	4	-
	NDMA (2010)	2.80	-25.12	2	-
	Anbazhagan et al. (2013)	1.22	123.16	1	1
IBRZ	Toro (2002)	6.13	11.56	2	0.31
	Kanno et al. (2006)	7.66	-61.46	4	-
	NDMA (2010)	6.26	1.83	3	0.28
	Anbazhagan et al. (2013)	5.72	48.06	1	0.41
BBZ	Toro (2002)	8.37	20.47	1	0.35
	Kanno et al. (2006)	9.52	-45.71	4	-
	NDMA (2010)	8.38	19.63	2	0.35
	Anbazhagan et al. (2013)	8.56	5.60	3	0.31

REFERENCE

Anbazhagan, P., Kumar, A. and Sitharam, T.G. (2013). "Ground motion prediction equation considering combined dataset of recorded and simulated ground motions."*Soil. Dyn. Earthq. Eng.*, 53, 92–108.

Anbazhagan, P., Bajaj, K. and Patel, S. (2015a). "Seismic hazard maps and spectrum for Patna considering region-specific seismotectonic parameters." *Nat. Hazards*, 10.1007/s11069-015-1764-0.

Anbazhagan, P., Sreenivas, N., Ketan, B., Moustafa, S.S.R. and Al-Arifi, N.S.N. (2015b). "Selection of Ground Motion Prediction Equations for Seismic Hazard Analysis of Peninsular India." *J Earthquake Eng*, 20, 699-737.

Baro, O. and Kumar, A. (2015a). "A review on the tectonic setting and seismic activity of the Shillong plateau in the light of past studies." *Disaster Advances*, 8(7), 34-45.

Baro, O. and Kumar, A. (2015b). "An insight into the Shillong plateau seismicity: a review."*Proc., Indian Geotechnical Conference*, College of Engineering, Maharashtra, India.

Baro, O. and Kumar, A. (2017). "Seismic source characterization for the Shillong plateau in northeast India." *J. Seismol.*, 10.1007/s10950-017-9664-2.

Bilham, R. England, P. (2001). "Plateau Pop-up during the 1897 Assam earthquake."*Nature*, 410(6830), 806-809.

CNDM (Centre for Natural Disaster Management). (2002). *Scenario of seismic hazard in Assam*, A report by the Assam Administrative Staff College, Guwahati, Assam, India

Delavaud, E., Cotton, F., Akkar, S., Scherbaum, F., Danciu, L., Beauval, C., Drouet, S., Douglas J., Basili, R., Sandikkaya, M. A., Segou, M., Faccioli, E. and Theodoulidis, N. (2012).

Toward a ground-motion logic tree for probabilistic seismic hazard assessment in Europe. *J. Seismol.*, 16, 451–473.
Gee, E.R. (1934). “The Dhubri earthquake of the 3rd July 1930.” *Memoir Geol. Surv. India*, 65(1), 1-106.
IMD (Indian Meteorological Department). http://www.imd.gov.in/pages/earthquake_prelim.php, (May. 6, 2016).
Kanno, T., Narita, A., Morikawa, N., Fujiwara, H. and Fukushima, Y. (2006). “A new attenuation relation for strong ground motion in Japan based on recorded data.” *Bull. Seismol. Soc. Am.*, 96, 879–897.
Kayal, J.R. (2008). *Microearthquake Seismology and Seismotectonics of South Asia*. McGraw Hill Publication, India.
Kayal, J.R., Arefiev, S.S., Baruah, S., Tatevossian, R., Gogoi, N., Sanoujam M., Gautam, J.L., Hazarika, D. and Borah D. (2010). “The 2009 Bhutan and Assam felt earthquakes M_W (6.3 and 5.1) at the Kopili fault in the northeast Himalaya region.”*Geomatics. Nat. Hazards. Risk*, 1, 273–81.
Kijko, A. and Sellevoll, M.A. (1989). “Estimation of earthquake hazard parameters from incomplete data files. Part I. Utilization of extreme and complete catalogs with different threshold magnitudes.” *Bull. Seismol. Soc. Am*. 79, 645–654.
Kijko, A. and Graham, G. (1998). “Parametric-historic Procedure for Probabilistic Seismic Hazard Analysis Part I: Estimation of Maximum Regional Magnitude mmax.” *Pure Appl. Geophys*., 152, 413–442.
Kijko, A. Smit, A. and Sellevoll, M.A. (2016). “Estimation of Earthquake Hazard Parameters from Incomplete Data Files. Part III. Incorporation of Uncertainty of Earthquake-Occurrence Model.” *Bull. Seismol. Soc. Am.*, 106 (3), 1210–1222.
Kumar, A., Anbazhagan, P. and Sitharam, T.G. (2013). “Seismic hazard analysis of Lucknow considering local and active seismic gaps.” *Nat. Hazards*, 69, 327–50.
Kundu, B. and Gahalaut, V.K, (2013). “Tectonic geodesy revealing geodynamic complexity of the Indo-Burmese arc region, North East India.” *Curr. Sci.*, 104 (7), 920-933.
Maurin, T. and Rangin, C. (2009). “Structure and kinematics of the Indo-Burmese Wedge: Recent and fast growth of the outer wedge.” *Tectonics*, 10.1029/2008TC002276.
Mittal, H., Kumar, A. and Ramhmachhuani, R. (2012). “Indian national strong motion instrumentation network and site characterization of its stations.” *Int. J. Geosci.*, 10.4236/ijg.2012.326117.
Mohanty, W.K., Verma, A.K., Vaccari, F. and Panza, G.F. (2013). “Influence of epicentral distance on local seismic response in Kolkata City, India.” *J. Earth. Syst. Sci.*, 10.1007/s12040-013-0275-1.
Nath, S.K., Adhikari, M.D., Maiti, S.K., Devaraj, N., Srivastava, N. and Mohapatra, L.D. (2014). “Earthquake scenario in West Bengal with emphasis on seismic hazard microzonation of the city of Kolkata, India.” *Nat. Hazards. Earth. Syst. Sci.*, 10.5194/nhess-14-2549-2014.
NDMA (National Disaster Management Authority). (2010). *Development of Probabilistic Seismic Hazard Map of India*, Technical report by National Disaster Management Authority, Government of India.
Oldham, T. (1882). “The Cachar earthquake of 10th January, 1869, by the late Thomas Oldham edited by Oldham RD.” *Memoir. Geol. Surv. India*, 19, 1-98.
Reasenberg, P.A. (1985). “Second order moment of central California seismicity, 1969–1982.” *J. Geophys. Res.*, 90, 5479–5495.

Ristau, J., Rogers, G.C. and Cassidy, J.F. (2005). "Moment magnitude-local magnitude calibration for earthquakes in western Canada." *Bull. Seismol. Soc. Am.*, 95, 1994–2000.

Scherbaum, F., Delavaud, E. and Riggelsen, C. (2009). "Model selection in seismic hazard analysis: An information-theoretic perspective." *Bull. Seismol. Soc. Am.*, 99, 3234–3247.

Scordilis, E.M. (2006). "Empirical global relations converting M_S and mb to moment magnitude." *J. Seismol.*, 10, 225–36.

Sitharam, T.G. and Sil, A. (2014). "Comprehensive seismic hazard assessment of Tripura and Mizoram states." *J. Earth Syst. Sci.*, 123,837–57.

Srinivasan, V. (2003). "Deciphering differential uplift in Shillong Plateau using remote sensing." *J. Geol. Soc. India*, 612, 773 – 777.

Srivastava, H.N., Verma, M., Bansal, B.K. and Sutar, A.K. (2015). "Discriminatory characteristics of seismic gaps in Himalaya." *Geomatics. Nat. Hazards. Risk.*, 6(3), 224–242.

Stepp, J.C. (1972). "Analysis of completeness of the earthquake sample in the Puget sound area and its effect on statistical estimates of earthquake hazard." *Proc., Int. Conf. on microzonation*, Seattle, USA, 2, 897–910.

Toro, G.R. (2002). *Modification of the Toro et al. (1997) attenuation equations for large magnitudes and short distances*, Technical Report, Risk Engineering.

USGS (United States Geological Survey).http://earthquake.usgs.gov/earthquakes/search/ (May. 6. 2016).

Wang, Yu., Sieh, K., Soe, T.T., Lai, K-Y. and Than, Myint. (2014). "Active tectonics and earthquake potential of the Myanmar region." *Journal of Geophysical Research: Solid Earth*, 10.1002/2013JB010762.

Wiemer, S. and Wyss, M. (2000). "Minimum Magnitude of Completeness in Earthquake Catalogs: Examples from Alaska, the Western United States, and Japan." *Bull. Seismol. Soc. Am.*,90(4), 859–869.