Site-specific earthquake hazard characterization for Dhaka City, Bangladesh

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ABSTRACT

Seismic hazard characterization is the foremost module for earthquake risk management in a seismically vulnerable region. The mega city Dhaka in Bangladesh is considered by many researchers as one of the riskiest cities in the world due to many non-engineered construction practices and poorly studied tectonic boundary conditions. The city is built on a Plio-Pleistocene terrace, located within the subsiding Bengal basin. The records of historical earthquakes indicate that three large magnitude earthquakes occurred during the last 150 years within and in close proximity to Bangladesh. Magnitudes of these earthquakes ranged from 6.9 to 8.7 occurring between 1885 and 1918. These events caused moderate damage to buildings and other infrastructures in Bangladesh, but the damage in Dhaka city were negligible. It is believed that the 6.9 magnitude Bengal earthquake occurred at about 50 km from the city, although there are multiple controversies about the location of the epicenter. Many consider that the epicenter of this earthquake was 170 km away from Dhaka city and others inferred the epicenter to be somewhere along Madhupur fault, approximately 50 km away. The 1885 Bengal, 1897 Great Indian, and 1918 Srimangal Earthquakes are considered as the seismic sources for site-specific seismic hazard characterization. The peak ground acceleration (PGA), peak ground velocity (PGV), spectral accelerations (SA) of different periods have been calculated at the ground surface based on recently developed ground motion prediction equations and site amplification factors. The amplification factors are predicted from the average shear wave velocity to a depth of 30 m (V_s^{30}), which are estimated using various geophysical and geotechnical investigations. The study reveals that the city is built on a very firm ground where seismic risks are manageable provided the engineering structures adhere to the norms of seismic regulations and building codes.

Generalized geology of Dhaka city

The Mega City of Dhaka occupies an unique geological location. The subsurface geology is firm and almost homogenously consistent. Geologically it is an old terrace raised considerably about 6m above sea level (AMSL). The surrounding floodplains are at about 4m AMSL. The ground is composed of Madhupur Clay. The Clay is Over-consolidated. The shear strength properties are considerably high. The Thickness of Madhupur Clay is about 6 m and it overlies a firm sandstone bed, geologically known as Dupitila Formation (Upper Dupitila Sandstone). It may be considered as very dense bedrock. The Madhupur Clay and Dupitila Sandstone are very much suitable for construction of underground structure, even for development of underground transportation system for this growing city. The study reveals that the city has been developed on an advantageous geological location consisting of raised Madhupur Clay Formation or older alluvium in respect to the surrounding floodplains of young alluvial deposits

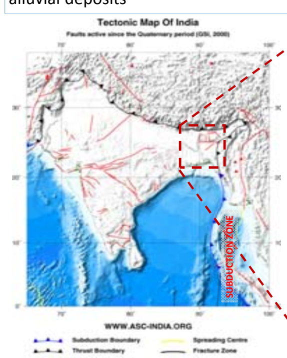

Figure 1. Tectonic and relief map of Indian Subcontinent

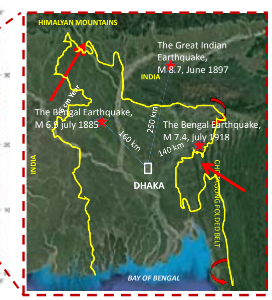

Figure 2. Map showing three historical events that did not cause significant damages in Dhaka city

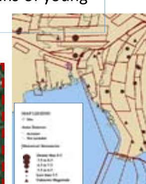

Figure 3. Seismic source areas are located >100 km away from Dhaka city.

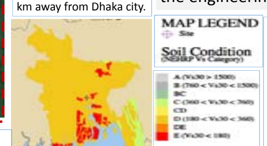

Figure 4. Generalized soil condition map by seismic wave velocity ranking

Figure 6. Satellite image of Dhaka city showing very dense urban settlement

Figure 7. 3D Block model of Dhaka city surface morphology and thick two top layers of very stiff to hard clay and moderately lithified sanstone showing very dense urban settlement

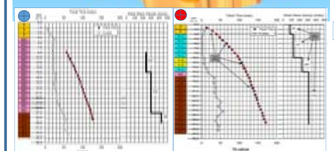

Figure 8. Two borehole logs from two location showing SPT logs (N), Travel Time and Shear Wave Velocity logs.

Geotechnical and seismic properties of Dhaka ground

Formation	Average Thickness, meter	Consistency and Material	Average Moisture content, w_n %	Dry unit Weight, γ_d kN/m^3	Average Undrained Shear Strength, s_u, kPa	N value Range (SPT count)	Shear Wave Velocity, m/sec
Madhupur Clay	6	Stiff Clay-SILT	25	16	150	10 - 30	>200 <300
Dupi Tila Sandstone	> 90	Very dense Sandstone with occasional clay beds	< 20	> 16	ϕ > 30^o	Often Refusal	> 350 <450

Deterministic and probabilistic seismic hazard analyses

The deterministic and probabilistic seismic hazard analyses were performed for Dhaka City using EZ-FRISK software of Risk Engineering, USA. The earthquake catalogue that was prepared by the Global Seismic Hazard Assessment Program (GSHAP) was used for seismic sources. The Next Generation of Ground Motion Attenuation Models for the western United States (NGA West) were used in the analysis to estimate ground motion intensity measures (IM), i.e., peak ground acceleration (PGA), peak ground velocity (PGV), spectral acceleration (SA) for the periods of 0.2 and 1.0 second, and uniform hazard spectra. The mean values of IM that were estimated using four ground motion prediction equations (GMPE) that are proposed by Abrahamson-Silva (2008), Boore-Atkinson (2008), Campbell-Bozorgnia (2008), and Chiou-Youngs (2008).

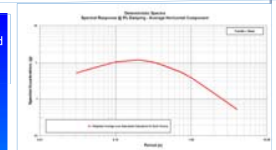

Figure 9. Deterministic spectral response

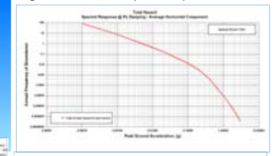

Figure 10. Probabilistic total hazard

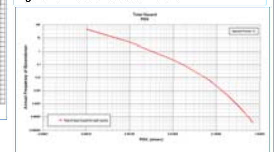

Figure 11. Probabilistic PGV

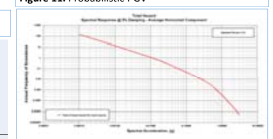

Figure 12. Probabilistic spectral responsefor 0.2 sec period

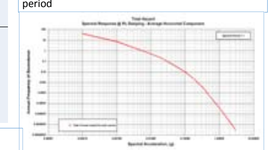

Figure 13. Probabilistic spectral response for 1.0 sec period

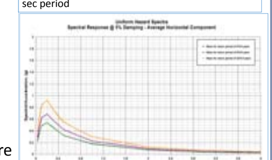

Figure 14. Probabilistic uniform hazard spectra

Concluding remarks: The event based earthquake study for Dhaka reveals that there is no longer faults close to the city to generate large earthquakes. The city is built on a very firm ground where the increase of density, shear strength and shear wave velocity (>350m/s below 20 ft.) with depth are strong advantages for expecting lower seismic risk in vicinity. The seismic risks posed by faults located more than 140 km away are manageable provided the engineering structures adhere to the norms of seismic regulations and building codes.

References:

Abrahamson, Norman, and Walter Silva. "Summary of the Abrahamson & Silva NGA ground-motion relations." *Earthquake spectra* 24.1 (2008): 67-97.

Boore, David M., and Gail M. Atkinson. "Ground-motion prediction equations for the average horizontal component of PGA, PGV, and 5%-damped PSA at spectral periods between 0.01 s and 10.0 s." *Earthquake Spectra* 24.1 (2008): 99-138.

Campbell, Kenneth W., and Yousef Bozorgnia. "NGA ground motion model for the geometric mean horizontal component of PGA, PGV, PGD and 5% damped linear elastic response spectra for periods ranging from 0.01 to 10 s." *Earthquake Spectra* 24.1 (2008): 139-171.

Chiou, BrianS-J., and Robert R. Youngs. "An NGA model for the average horizontal component of peak ground motion and response spectra." *Earthquake Spectra* 24.1 (2008): 173-215.

Karim, M F. "Some basic considerations for seismic hazard assessment in a complex geological environment like Bangladesh." Workshop on Earthquake Disaster Preparedness and Mitigation Organized by Identification Mission Consultants to the EU Delegation-Bangladesh, February 18, 2004, Dhaka, Bangladesh (https://www.academia.edu/14000774/Some_basic_considerations_for_seismic_hazard_assessment_in_a_complex_geological_environment_like_Bangladesh._Mir_Fazlul_Karim_

Karim, M. F. and Rahman M. Z. Possible Effect of Moderate Earthquake on Existing Infrastructures of Dhaka City: A Geological-Geotechnical Overview. Bangladesh Journal of Science and Technology, Vol. 4(2), July 2002. pp 193-203.

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