Engineering Geophysics for Site Characterization for Local Seismic Hazard Assessment in Barishal City, Bangladesh

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Abstract: Various engineering geophysical methods are available for seismic site characterization, including invasive and non-invasive techniques. Multichannel analysis of surface waves (MASW), downhole seismic testing (DST) and Standard Penetration Tests (SPT) were carried out for local seismic site effect (amplification) analysis in the mapped area. A regional seismic hazard map based on a probabilistic seismic hazard assessment (PSHA) for Bangladesh was prepared by Azari et al. (2021), reflecting regional Peak Ground Acceleration (PGA) at bedrock with an exceedance probability of 10 % in 475 years. The mapped area covers an area of approximately 92 km² and is characterized by very thick deposits of unconsolidated or loosely consolidated late Holocene to recent age fluvial and deltaic sediments. The research presented in this contribution gives an estimation of the near surface one-dimensional (1D) shear (S) wave velocity (Vs) models at every 1 m depth interval, limited to the upper 30 m of soil deposits at various locations in Barishal city using DST which was done in the framework of the GPAC project carried out by BGR, LIAG and GSB. MASW results were cross-checked with DST data. 13 boreholes with DST and SPT information were used to establish a regression model to calculate shear wave velocity using the SPT data at each SPT location. A SAGA (system for Automated Geoscientific Analyses)-ISEG (the Information System Engineering Geology)-based algorithm is used to correlate each SPT N-value (uncorrected/1.5 m interval) with the corresponding measured shear wave velocity (mean value). The two parameters, shear wave velocity and SPT are thus correlated and the resulting exponential regression formula of Barishal is $y = 107.9x^{0.192}$ with R^2 = 0.6308. The local site conditions are classified using the mean shear wave velocity value representative for the top 30 m soil column (VS_{30} value in m/s). The VS_{30} values range between 145 m/s and 216 m/s. Based on VS_{30}, the studied areas are classified into two seismic site classes, SC and SD according to the national building code.

Keywords: Shear wave velocity, Seismic hazard, Seismic soil classification.

Introduction

Geotechnical characterization of the subsurface material, especially the stiffness of the topmost soil layers, is usually the first task for any foundation design activity at a given site. Nature of seismic ground motion at a site significantly depends on the stiffness properties of the topmost part of the earthen materials in the subsurface (Foti et al., 2014). These properties are considered as important parameters in the field of geotechnical studies because the earthquake induced ground motion and resulting damages are mainly influenced by the local soil properties. Generally, the shallow overburden soil properties largely contribute to the dynamic response of the structure placed on the ground surface. In this setting, geophysical techniques are considered reliable methods to estimate the elastic properties or stiff behavior of subsurface soils. In recent years measurement of these soil properties by conducting seismic wave propagation methods have become common approach for site response analysis (Matthews et al., 1997). The main objectives of research are to derive the average shear wave velocity of the upper 30 m depth (VS_{30}) of the ground for each of the test sites and correlate with SPT value in Barishal city

Methodology

DST (PS logging) is considered as a very efficient way of evaluating the Vs-depth profiles using a single borehole in the field. Vs_{30} (i.e., the layer weighted average shear wave velocity in the uppermost 30 m) is widely used for seismic geotechnical site characterization studies in local seismic hazard assessment. This study involves determination of shallow subsurface Vs-depth profiles and Vs_{30} over various geomorphic units across the investigated area. The tests were conducted using a downhole system comprising surface sources of a horizontally polarized shear beam, a pair of downhole probes equipped with 3-component geophone packages as receivers and a digital seismograph as the data recording device. The test was carried out at 13 selected sites where standard penetration tests (SPT) were conducted on geotechnical boreholes up to a depth of about 30 m and a 3-inch PVC pipe installed as the casing at all these test wells. The data were recorded with 6 active channels mounted within two separate in-line probes from receivers of 10 Hz resonant frequency inserted into the boreholes. Horizontally polarized shear (SH) wave data were recorded by generating two repeated reverse polarity horizontal hits from two opposite directions on the wooden shear plank at the same respective test depth level. The downhole data are analyzed by the interval method primarily to evaluate the Vs-depth profiles. The recorded time-depth seismic waveform data are analyzed by using the SeisImager/Pickwin software package from Geometrics Inc. SH waves are identified on corresponding sensor components by selecting their arrival times on the time axis for each 1 m interval depth level. In-situ 1D shallow shear wave interval velocity (ΔVs)-depth profiles are deducted from the SH wave interval travel time data. An ISEG-based algorithm is used to correlate each SPT N-value (uncorrected/1.5 m interval) with the corresponding measured shear wave velocity (mean value). The two parameters, shear wave velocity and SPT are thus correlated by resulting exponential regression formula. In some locations (12 sites) we have carried out active and passive multichannel analysis of surface wave for shear wave velocity to compare with the PS logging results.

Results and Discussion

The resulting velocity models from the PS logging of the topmost 30 m show that most of the study area have very low ΔVs values mainly ranging from 80 m/s to slightly more than 250 m/s. The calculated VS_{30} values throughout the area range between 152 m/s and 177 m/s. The combination of MASW active and passive Remi results show the shear wave velocity (VS_{30}) varies from 151 m/s to 184 m/s but finally this data was not used for regression analysis. This exponential regression formula was used to calculate the shear wave velocity from the SPT information within the 92 remaining boreholes. The VS_{30} values range between 145 m/s and 216 m/s. Based on VS_{30}, the studied areas are classified into two seismic site classes, SC and SD (Figure 1). *SC* class covers 10% of the area whereas *SD* class covers 90% area.

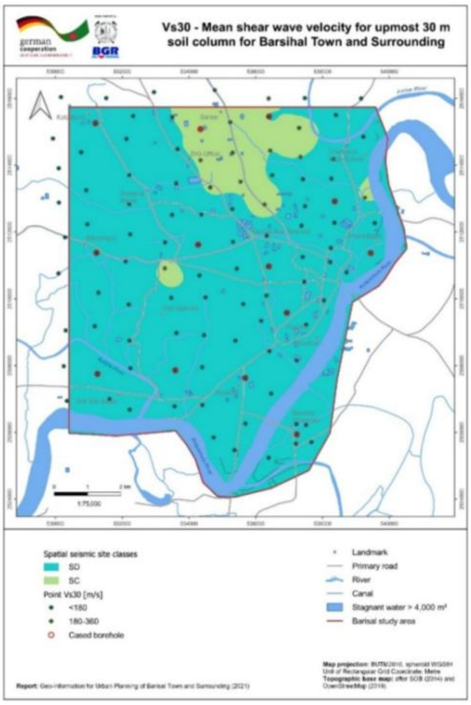

Figure 1, Seismic site class map at Barishal area based on VS30; cased geotechnical boreholes for P-S logging are marked with red circle.

For the calculation of site-specific amplification factors, an empirical method implemented in the National Earthquake Hazard Reduction Program (NHERP) of the USA was employed (Seyhan & Steward, 2014), and local PGA maps are computed from regional PGA data with the VS_{30}-based amplification data.

Conclusion

Passive seismic measurements with the analysis of H/V for fundamental frequencies and array microtremor measurement for shear wave velocity profiles and identification of the depth of the engineering bedrock are important information for site characterization, especially for seismic microzonation. Therefore, we will integrate geophysical and geotechnical data in the future with the results from passive seismic measurements. If we can incorporate well planned (500 m to 200 m spacing H/V and spiral galaxy array survey) microtremor data will help in details site characterization of the area.

Acknowledgement

The authors are grateful to the German–Bangladesh technical cooperation project Geo-information for the Implementation of a Climate-Change-Resilient Urbanization (GICU), funded by the Government of the Federal Republic of Germany through its commissioning Federal Ministry for Economic Cooperation and Development (BMZ) and by the Government of the People's Republic of Bangladesh through the Ministry of Power, Energy and Mineral Resources (MPEMR), and implemented jointly by the Federal Institute for Geosciences and Natural Resources (BGR) and the Geological Survey of Bangladesh (GSB).

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