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Site Characterization by Ambient Noise Geophysical and by Geotechnical Investigations at Mirpur, Dhaka, Bangladesh

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Abstract: Seismic site effects are critical in seismic hazard assessment and earthquake-resilient urban planning, as they strongly influence the intensity and characteristics of ground shaking during earthquakes. Geophysical approaches based on ambient seismic vibrations, particularly the Horizontal-to-Vertical spectral ratio (H/V) method and array techniques, offer cost-effective and noninvasive means to estimate fundamental resonance frequency and one-dimensional shear-wave velocity (Vs) profiles. These parameters are directly linked to sediment thickness and the amplification potential of a site. Geomorphologically, Dhaka, including the Mirpur area, lies in the southern part of the Madhupur Tract and is surrounded by extensive river floodplains. Mirpur, located in northern Dhaka, falls within Seismic Zone II (Z = 0.20g) as per the Bangladesh National Building Code (2020), indicating moderate seismic risk. In this study, 17 H/V measurements were conducted using OYO McSEIS-MT NEO three-component sensors and processed with Geopsy. The results were integrated with borehole Standard Penetration Test (SPT) data, lithological logs, Multichannel Analysis of Surface Waves (MASW), and downhole PS logging data from the Dhaka Urban Geo-information Atlas (2023). Previous studies, such as Helaly and Ansary (2021), reported fundamental frequencies ranging from 0.5 to 4 Hz in Mirpur, suggesting significant spatial variability. However, the present analysis indicates a narrower range of 0.5 to 1.2 Hz, implying relatively lower resonance frequencies. These findings suggest that generalized seismic zonation may overestimate local site response, underscoring the importance of site-specific microtremor investigations for accurate and reliable seismic site characterization.

Keywords: ***Site characterization, Microtremor, H/V spectral ratio, Climate-Change Resilient Urbanization.***

Introduction

Dhaka is one of the most seismically vulnerable megacities in South Asia due to its dense population (~34,000 people / sq. km), rapid urbanization and location within an active tectonic setting (Rahman et al., 2021). The Mirpur area is composed of two main geological units, Pleistocene Madhupur Clay and Recent alluvium (Monsur, 1994). The presence of soft alluvial deposits increases the susceptibility of the area to local site amplification (Farazi et al., 2023). Reliable geo-information is therefore essential for seismic microzonation, earthquake-resistant design, and disaster risk reduction (Schmitz et al., 2020).

Methodology

Seventeen microtremor measurements were carried out using OYO McSEIS-MT NEO three-component sensors following the SESAME (2004) guidelines. Data were processed using the horizontal-to-vertical (H/V) spectral ratio method (Nakamura, 1989; Hobiger et al., 2021) in the Geopsy software. Ambient noise analysis was integrated with borehole PS logging, standard penetration test (SPT) results, and lithological information to construct a site model for Mirpur. This combined approach enabled cross-validation of engineering soil parameters and resonance frequencies, providing a more robust characterization of local site effects.

Results and discussion

The integrated datasets unveil that the investigated area is composed of thick unconsolidated to semi-consolidated sedimentary deposits. The shear wave velocity (Vs) is 85 m/s at the surface that increases to nearly 360 m/s at depth of 30m, while the compressional wave velocity (Vp) increases from 100 to 1700 m/s from surface to 30 m depth. The Vp/Vs ratio is decreasing with depth indicating increasing stiffness and reduced saturation conditions. The SPT values are very low (N=3 to 9, soft-loose strata) in upper 7.5 m but increased sharply (N=25 to 55) at 7.5 to 12 m depth and exceeds 90 beyond 19m depth reflecting presence of dense sandy strata. H/V analysis show a clear fundamental resonance frequency (f_0) of 0.5 to 1.2 Hz., across all stations. This resonance corresponds to a fundamental frequency associated with the impedance contrast between soft silty clay layers and the deeper dense sandy layers or shallow basements. Representative H/V curves from selected stations in Mirpur are shown in Figure 1.

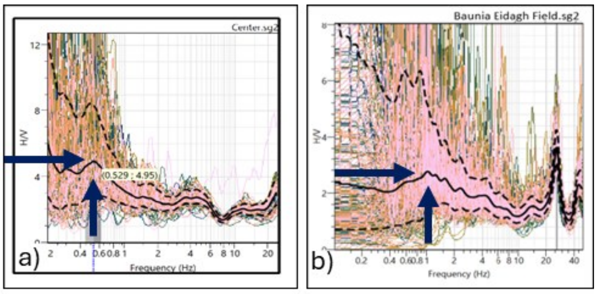

Figure 1, H/V spectral ratio curves from Mirpur: (a) Mirpur Center (f_0 = 0.53 Hz; A = 5.0) and (b) Baunia Eidagh Field (f_0 = 1.0 Hz; A = 2.5). Fundamental peaks are marked by arrows.

According to NEHRP site classification (based on Vs30), the computed average Vs30 is 211 m/s from MASW, and 250 m/s from PS log, corresponding to Site Class D (stiff soil). However, local amplification effects from the thick clayey top layer should be considered in seismic design.

Conclusion

The study reveals that site specific ambient noise surveys can enhance seismic hazard understanding in Dhaka. The area is characterized by a soft silty clay up to 7.5 m overlying sandy deposits and producing a fundamental resonance frequency of 0.5 to 1.2 Hz., which is lower than the resonance frequency (0.5 to 4.0 Hz.) reported in earlier microzonation assessments. The multiple approach from the SPT, MASW, Vs and H/V analysis show consistent results. Based on the Vs30 values 200 to 250 m/s the area falls in seismic site class D of NEHRP classification. The current assessment reveals that integration of ambient noise methods with geotechnical data is an effective way to characterize seismic sites in urban area. The findings provide valuable input for earthquake hazard assessment and urban resilient planning.

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