Shear Wave Velocity Determination in Cumilla, Bangladesh, By Combined Analysis of Downhole Seismic and MASW Data

Mohammad Khairul Islam[1*], Md. Mahmood Hossain Khan[1], Mohammad Feruj Alam[1], Sarwat Jabeen[1], Faruk Hossain[1], Tahera Afrin[1], Mohammad Ashraful Kamal[1] and Nurun Nahar Faruqa[1]

[1]Geological Survey of Bangladesh, Dhaka, Bangladesh

*(*Corresponding E-mail: khairul.du2009@gmail.com)*

Abstract: Seismic wave amplification in shallow subsurface soils is governed by the local shear wave velocity (Vs) profiles. This study focuses on the assessment of 1-D dynamic soil properties, specifically Vs profiles, in Cumilla, Bangladesh. This study involves a variety of shallow seismic techniques, including 10 downhole seismic tests (DST), 12 non-invasive active multichannel analysis of surface waves measurements (MASW), and an equal number of passive microtremor array measurements (MAM).

Keywords: ***Shear wave velocity (Vs), Downhole seismic test (DST), Multichannel analysis of surface waves (MASW), Microtremor array measurement (MAM), Refraction microtremor (ReMi), Vs30, Seismic site classification.***

Introduction

Geotechnical characterization is essential for the designing foundations, particularly for evaluating the stiffness of the uppermost soil layers. These features have a major role in seismic ground motion, which influences earthquake damage. Seismic wave propagation techniques are commonly employed to assess the characteristics of shallow overburden soil, which are crucial for dynamic structural response (Matthews et al., 1997). The dynamic properties of soil, including shear wave velocity (Vs), compression wave velocity (Vp), shear modulus (G), and others, govern the response of the near-surface soil under seismic loading (Anbazhagan et al., 2016). In-situ geophysical methods offer advantages over traditional geotechnical investigation and laboratory testing because sampling disturbance is reduced and obtaining high-quality representative samples is difficult for the latter two methods. This study conducted downhole S-wave velocity measurements in 10 strategically selected boreholes, covering different geological units. Initially drilled for geotechnical and geological investigations, these boreholes were equipped with PVC casings for downhole surveys. Analysis of the seismic data provided time-depth curves and velocity-depth functions for S-waves, revealing 1-D Vs profiles in the upper 30 meters of the subsurface. The findings of this study will play a vital role in the evaluation of the ground suitability of the development of Cumilla city and its surrounding areas.

Data and Methods

Cumilla is situated on the bank of the Gumati River and belongs to the central foredeep province of the Bengal basin (Figure 1). It is located about 88 km southeast of Bangladesh's capital city Dhaka. The study area encompasses approximately 60 km^2 within the Cumilla city corporation territory, including adjacent regions surrounding its boundary.

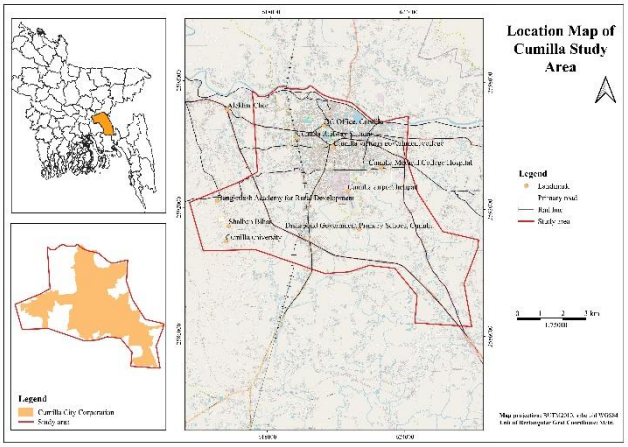

Figure 1, Location map of the study area.

Vertical profiles of the compression (P) and shear (S) wave-velocity-depth functions are effectively provided by DST (downhole seismic test). Rayleigh wave data is acquired by active MASW (Multichannel analysis of Rayleigh waves) and ReMi (Refraction Microtremor) techniques, which are inverted to obtain Vs profiles (Figure 2). The active MASW and ReMi methods were carried out for acquiring Rayleigh wave data in the frequency range ≥ 4.9 Hz and ≥ 2.4 Hz respectively. 7 MASW recordings were acquired at sites close to locations of standard penetration test (SPT) boreholes within the study area. The remaining 5 surveys were conducted at sites of downhole tests where the Vs profiles from both MASW and DST measurements, were compared to the SPT-N values. A good correlation was observed among the Vs profiles; the correlation equation from these data was further used in other boreholes to determine the Vs profiles (Figure 3). The geomorphic map of the study area was created by using Aerial Photographs, Spot image and Landsat TM image.

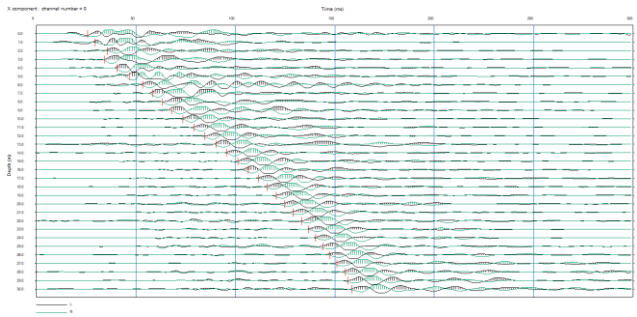

Figure 2, Example of time domain clear and strong traces of opposite polarity S waves.

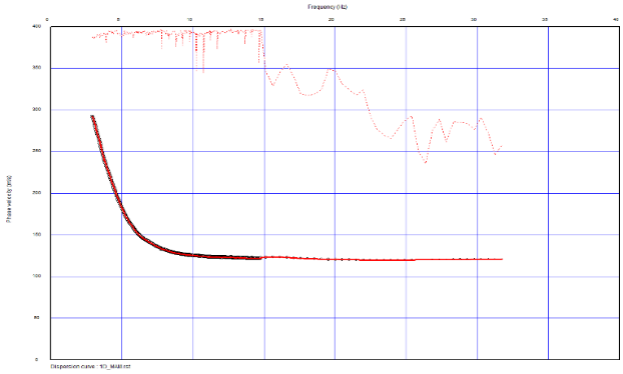

Figure 3, Example of dispersion curve derived from the active and passive MASW in the project area. Upper red dotted line represents the data quality.

Results and Discussion

The velocity models for most parts of the study area have low to medium Vs values ranging from 72 m/s to 585 m/s for the top 30 m of soil depth. The range of computed Vs30 values is 177 to 290 m/s (Figure 4).

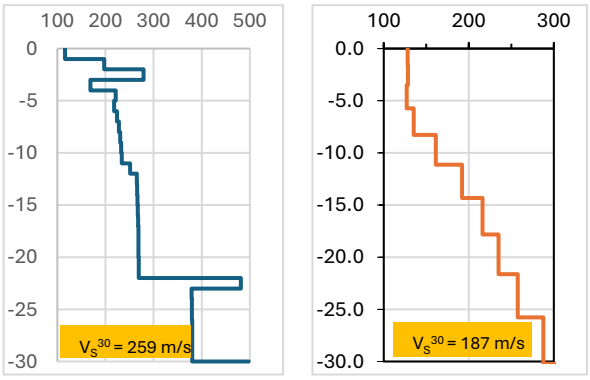

Figure 4, Example of shear wave velocity-depth profile derived with the P-S logging (left) and MASW (right) method in the project area.

Based on the Bangladesh National Building Code (BNBC) system, seismic soil classification and spatial distribution maps of Vs30 show that the entire study area belongs to site classes 'SC' and 'SD', which is in reasonable conformity with the geomorphological units of the region (Figure 5).

Conclusion

This study simultaneously concentrated on the PS logging and surface wave methods, in particular the execution of seismic downhole and MASW approaches for site characterization in Cumilla city corporation and surrounding areas. This study carried out a thorough comparison between borehole SPT-N values in the study region and Vs acquired from downhole seismic and MASW techniques. A strong connection between Vs and geotechnical soil strength was established by integrating data from SPT-N, MASW, and downhole seismic testing.

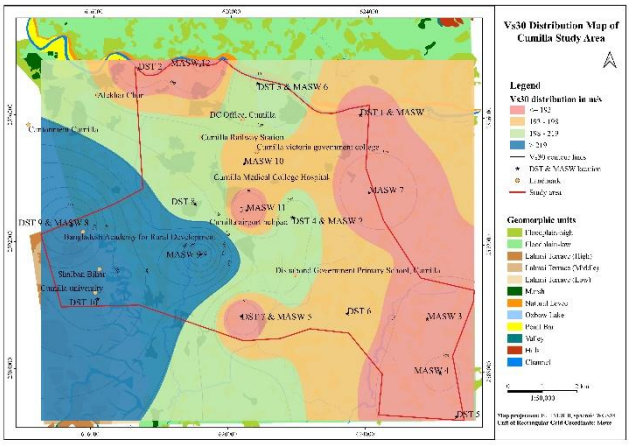

Figure 5, Map of Vs30 in the study area.

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