Effect of A-priori Information on the Uncertainties in MASW Test

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Abstract. Seismic site characterization is an extremely crucial task in geotechnical earthquake engineering. Although several methods are available for that, the most popular method currently is the multi-channel analysis of surface waves (MASW) method. Its results are useful in many applications such as seismic microzonation, site response analysis, etc. However, there are several uncertainties in the measurement and interpretation of this test. In this paper, an attempt has been made to find out how much these uncertainties can be reduced when prior information is available before the MASW test. The a-priori information is taken in the form of soil layering and their thicknesses in this paper. The results indicate that the availability of a-priori information certainly helps in restraining the final shear wave velocity profile of the soil. In this way, the uncertainties in the MASW test results can be reduced to a great extent when prior information about the soil profile is available.

Keywords: Site Characterization, Shear Wave Velocity, Prior Information.

1 Introduction

Seismic surface wave methods have emerged as the most adopted techniques to carry out site characterization currently. Site characterization is the procedure which provides important information regarding the soil behaviour under dynamic loading. This becomes useful for the earthquake resistant design of structures. The surface wave methods basically render the shear wave velocity (V_s) profile of the soil which is required for carrying out site characterization. The V_s profile becomes useful in the assessment of seismic site response, site classification, soil liquefaction potential, foundation settlement and many other applications [1-6]. Numerous methods are available to carry out site characterization. However, the surface wave methods are preferred because they are cheaper and require less time compared to conventional methods such as standard penetration test (SPT) and cone penetration test (CPT). Among the surface wave methods, the spectral analysis of surface waves (SASW) and the multichannel analysis of surface waves (MASW) are primarily used currently. The SASW test was proposed initially [7]. Subsequently, some modifications were incorporated and the MASW test was proposed [8,9].

The surface wave methods are based on the principle of the dispersion property of Rayleigh type surface waves. In the dispersion phenomenon, the Rayleigh waves having different frequencies travel with different speeds and penetrate to different depths in layered media. The Rayleigh waves having higher frequencies penetrate up to shallow depths and those having lower frequencies penetrate up to higher depths. This property is useful for retrieving important soil properties such as the V_s profile and shear modulus of soil. Once this information is available, it can be utilized for many applications pertaining to geotechnical earthquake engineering. However, the final results obtained from the surface wave methods contain certain uncertainties. A considerable amount of research has been carried out throughout the world on the uncertainties in the MASW test [10-14]. One of the uncertainties is due to the non-uniqueness of the surface wave inversion process. When the dispersion curve is inverted, a number of V_s profiles are generated having equivalent match to the dispersion curve. This creates ambiguity in the results. Hence, it's needed to make some efforts to reduce these uncertainties or to account for them in the subsequent analyses.

Regarding this, an assessment of how the availability of a-priori information about the number of soil layers and their thicknesses affects the results can provide important inferences. Earlier, some researchers have employed the use of MASW along with some other methods to get better results or to assess the MASW results. Fatehnia et al. [15] developed an equation to correlate SPT-N and V_s values for North Florida soils. Xia et al. [16] found that the results of MASW and borehole measurements were quite similar, having differences of 15% or less. Schwenk et al. [17] used MASW along with S_H wave refraction traveltime tomography as the a-priori information. They concluded that this resulted in better constrained final V_s profile with less non-uniqueness. Garofalo et al. [18] made a comparison of different surface wave methods. After getting all the results, they felt that a-priori information in the form of bore logs and/or local geology would have helped in better constraining the results. However, there is a lack of numerical analyses on how a-priori information can affect the MASW results. In this study, an attempt has been made to assess the impact of the availability of a-priori information on the final outcomes of MASW test using numerical simulations.

2 Model considered

Table 1 shows the considered synthetic V_s profile. It has 3 soil layers having an increase in V_s with the depth and the halfspace at the depth of 24 m. Soil density and Poisson's ratio are kept constant because their effect on Rayleigh wave dispersion is insignificant.

Table 1. Typical shear wave velocity profile of a site considered

Layer	Thickness (m)	V_s (m/s)	Density (kg/m^3)	ν (Poisson's ratio)
1	5	180	1800	0.3
2	7	240	1800	0.3

3	12	300	1800	0.3
Halfspace	-	700	1800	0.3

The V_s profile shown above was used to obtain the dispersion curve. For that, the ABAQUS software [19] was used which is based on the finite element method. Fig. X shows the considered model in ABAQUS. The model size was kept 400 m*400 m. The model type considered in ABAQUS was axisymmetric. In the model, at the bottom boundary, the horizontal and vertical movement was restrained. At the left and right boundaries, the horizontal movement was restrained.

3 Analysis and results

The considered V_s profile was given as input in ABAQUS and half-sine pulse load was applied. It had a peak value of 12 kN. The time for loading was 0.025 s and the time for simulation was 1 s. The sampling frequency was 500 Hz. The size of the mesh was decided based on Kuhlemeyer & Lysmer [20]. At the surface, the mesh was kept smaller and at higher depths, the mesh size was increased gradually. After applying the load, the displacement time histories were obtained at 30 locations spaced at 1 m from one another. These time histories were fed as input in the software GEOPSY [21]. It is a software based on the frequency-wavenumber (f-k) method. The f-k method is a useful technique for carrying out dispersion analyses. Hence, using GEOPSY, the dispersion curve was obtained which is shown in Fig. 1.

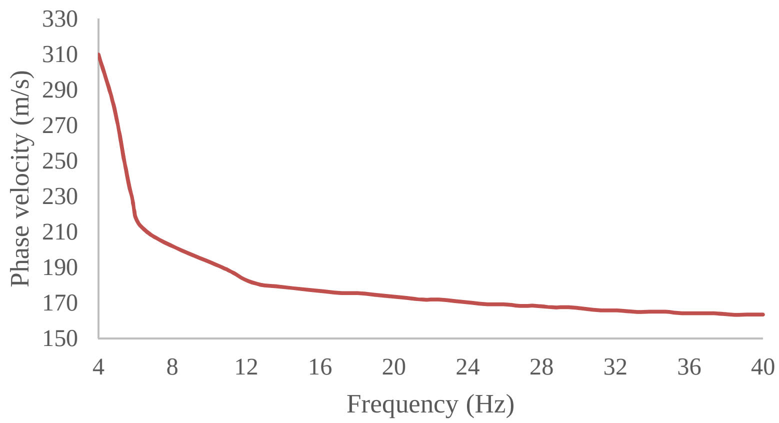

Fig. 1. Dispersion curve of the soil profile considered

This dispersion curve was then used for inversion and to assess the effect of the a-priori information on the MASW test results. 3 cases were considered while carrying out the inversion process. The first 2 were the cases when no a-priori information is available. So, randomly 3 and 5 soil layers were considered in case 1 and case 2 respectively. The third case is when a-priori information is available in the form of a number of layers and layer thicknesses. The inversion process was carried out in GEOPSY software for all the 3 cases and the V_s profiles and corresponding dispersion curves were obtained. Figures 2 to 4 show the results of these analyses. In these figures, it can be very clearly observed that in case 3, when the a-priori information is available, the number of V_s profiles generated is very less compared to the cases when there is no a-priori information. Also, it can be seen that when a-priori information is available, the generated V_s profiles have comparatively quite lower misfit values than the previous two cases.

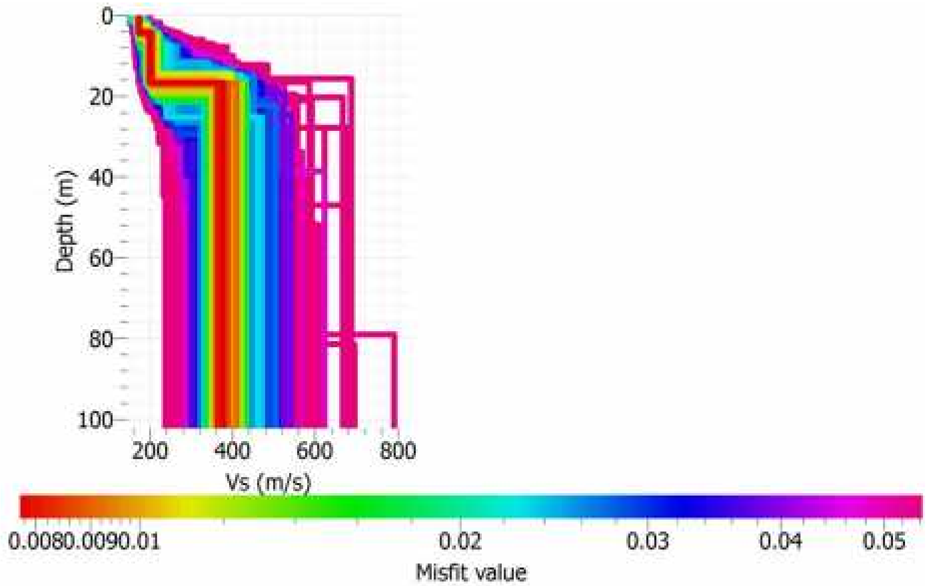

Fig. 2. V_s profiles obtained by considering 3 soil layers (In absence of a-priori information) (Case 1)

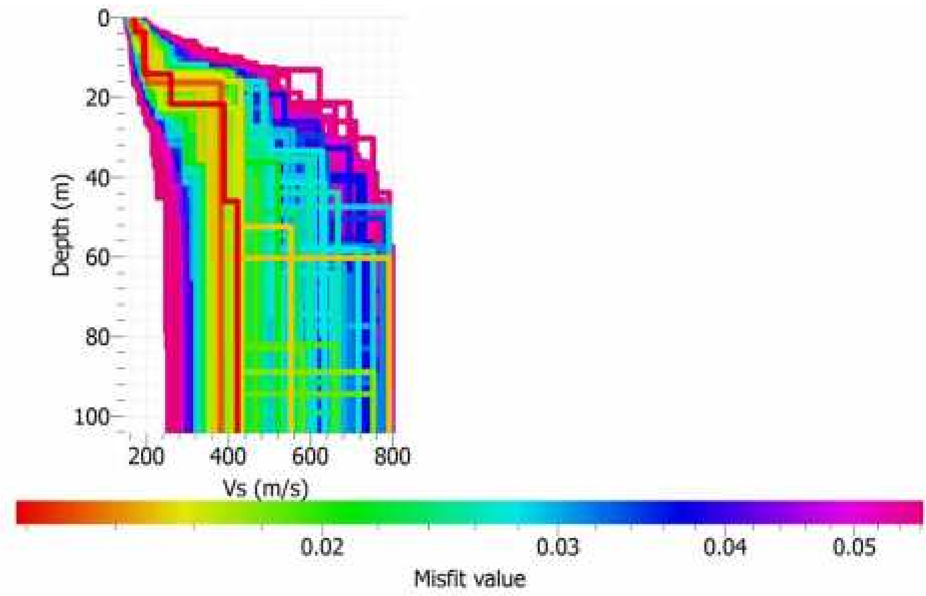

Fig. 3. V_s profiles obtained by considering 5 soil layers (In absence of a-priori information) (Case 2)

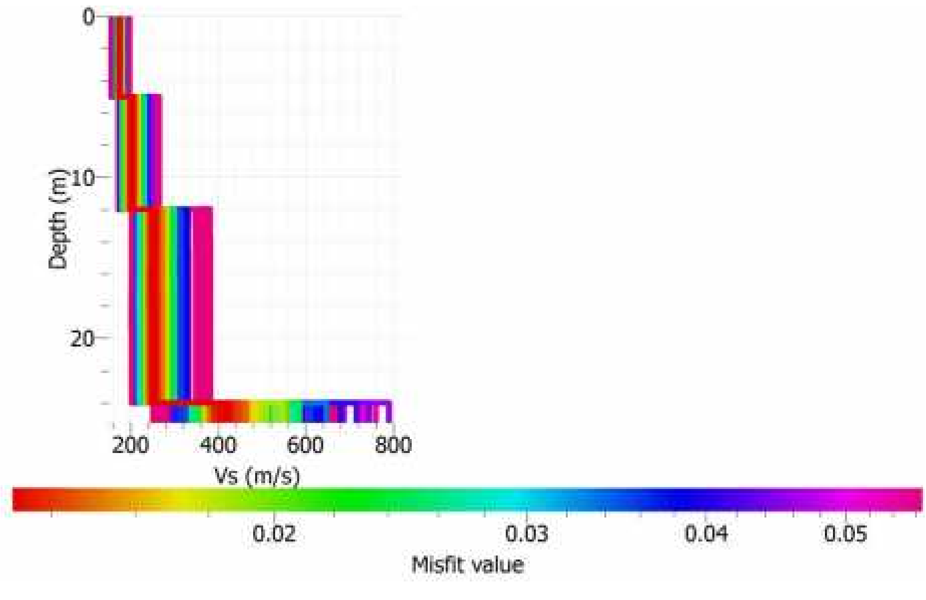

Fig. 4. V_s profiles obtained by considering 4 soil layers (In presence of a-priori information) (Case 3)

4 Conclusions

Whenever a-priori information is available in the form of a number of soil layers and thickness of soil layers from other investigations, the number of V_s profiles obtained after inversion is quite small compared to the case of no a-priori information. In the presence of a-priori information, the final V_s profiles would be having less non-uniqueness and better constrained. Hence, a-priori information plays a crucial role in restraining the number of V_s profiles. In this way, the uncertainty in the MASW test results is considerably reduced by using a-priori information.

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