CHARACTERIZATION OF GROUND PROFILE USING MULTICHANNEL ANALYSIS OF SURFACE WAVE AT SOMNATH TEMPLE

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ABSTRACT

Site characterization involves taking samples of soil, testing the samples, and evaluation of subsurface features, subsurface material types and their properties. The accuracy of characterization depends on ground features, subsoil condition and changes in geological aspects. In order to get the geotechnical properties of the soil stratum, it is necessary to carry out experiments both in the laboratory and field. The laboratory and field tests produce information especially about the type and strength of soils which are vital for the economic and safe design of infrastructure facilities and buildings. In the Multi-channel Analysis of Surface Waves (MASW) test, concepts of refraction analysis, time term method and tomographic inversion are used to calculate the seismic wave velocity with respect to depth for full of temple complex. The shear wave velocities are generated for 2D profiles layer and classified the soil layer are made using the results of average shear wave velocity up to top 30 m of the overburden (Vs)30

Keywords: Refraction Analysis, Time Term Method, Multi-channel Analysis of Surface Waves and Shear Wave Velocity.

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1. INTRODUCTION
In characterizing the soil stratum, there are many methods being adopted by geotechnical engineers. Among these, the geophysical methods are the most robust methods that can be performed without actually accessing the stratum physically. These methods provide the profiles of continuous sections. Some of the techniques can also provide stiffness properties of the ground, which are useful for seismic microzonation. Geophysical techniques also help in locating cavities, backfilled mine shafts and subsurface geological features such as faults and discontinuities. Currently, Multi-channel Analysis of Surface Waves (MASW) test is used in geotechnical engineering profession for the measurement of dynamic properties, soil profiling, microzonation and site response studies. In particular, the MASW test is widely used in the measurement of shear wave velocity (Vs), identification of interface between the strata and spatial variation of ground etc. Another advantage of MASW test is that it is a non-invasive, low cost, rapid and moreover it consistently provides reliable shear wave velocity profiles [6, 7, 8, 9, 10]. The MASW test is used for near surface materials and can be used for getting stiffness data needed in earthquake analysis of geotechnical structures and also for liquefaction assessment.

2. MASW CONCEPT AND PROCEDURE
The MASW method is widely used in near-surface seismology as well as in reflection surveying for oil exploration and utilizes multi-channel recording and processing concepts. The fundamental mode is the Rayleigh which is one of the most troublesome types of source generated noise on reflection surveys. Rayleigh-wave energy is defined as signal in MASW analysis, and needs to be enhanced during both data acquisition and processing steps. In all kinds of surface seismic surveys using vertical sources, ground roll takes more than two thirds of total generated seismic energy and usually appears with the most prominence on the multi-channel records. Therefore, generation of ground roll is easiest among all other types of seismic waves. The field setup is shown schematically in Figure 1. The method first requires measurement of seismic surface waves generated from various types of seismic sources such as sledge hammer and the propagation velocities of those surface waves is analyzed, and finally the shear wave velocity (Vs) variations below the surveyed area that is most responsible for the analyzed propagation velocity pattern of surface waves is calculated.

3. FIELD TEST SET UP AND INSTRUMENTATION

3.1 Instrumentation Used for Carrying Out Masw Test
1. The Digital seismograph: DMT summit 24-channels
2. Adopter connected to laptop
3. 24 Geophones, natural frequency 4.5 Hz
4. Sledgehammer
5. Steel plate to drop weight from sledgehammer(8 kg)
6. 12 volt battery
7. Sampling rate=0.125 ms
8. Record length=0.25 s
3.2 Data Acquisition

The MASW data were collected from linear array at the temple complex at a particular location using single Geode and 24-channel of geophones are used with a spacing of 2 m between them with the natural frequency of 4.5 Hz. The offset distances i.e., distance between the source and the nearest geophone is fixed to 2 m at both ends, also the source is shifted among first, last and in between them (Figure 1) and these configurations are fixed for conducting several tests. This made the total survey length to be 48 m and in other places less than 48 m. Seismic energy is generated using a sledge hammer of 8 kg weight which would be manually impacted on 150 cm$^2$ aluminum plate at an offset distance and the source is shifted every time with first, last and in-between of them for total of 5 shots are made at each location. Also the trigger geophone is used to initialize the recording. The generated Rayleigh wave data is recorded at all the shot points. Data for each shot is digitally recorded and saved in a laptop computer through software called seismic controller, and the data is recorded in the SEG-2 format. Figure 2 shows the typical test program of field test set up along with data files [2, 3].

![Figure 1 Schematic Illustration of a Typical Field Configuration of the MASW Test](image-url)
a) Test setup and MASW test accessories at different sites in SMT
Characterization of ground profile Using multichannel analysis of surface wave at Somnath temple

Figure 2 Shows the typical test program of field test set up along with data files.

3.2 Processing and Inversion

The collected MASW data would be first processed to remove any bad records, such as a geophone with poor response. Data can also be time filtered to remove any spurious noise on the seismic records at times before or after the source energy, to reduce their effect on the calculated phase velocities. Some processing techniques transform the whole data set from the time-offset domain where it has been acquired into domains where the energy is mapped as a function of other parameters, such as frequency, slowness, and wavenumber. There is a common method to generate a dispersion curve, through frequency-wavenumber plots and the field data are processed to estimate the experimental dispersion curve, which is the relationship between phase velocity and frequency [4, 5].

The inversion is the last step of the seismic wave method, and it is the step that produces the final result. After finishing the dispersion analysis, the inversion algorithm is applied to characterize soil profiles from the dispersion curves. Inversion of Rayleigh wave dispersion curve is a process for determining the shear wave velocity profile from frequency-phase velocity dispersion relationship ([2, 3]. An inversion can however be made for the first higher mode or for any other mode. As well, for a given Vs profile, inversion for different modes should lead to exactly the same Vs profile if the assumed compression wave profile is correct. Subsequently, one can get dispersion curve i.e., phase velocity versus frequency by using transformation process. Finally in the inversion analysis is carried out to obtain the 1D S- and P-wave velocity profiles.

4. RESULTS AND DISCUSSION
4.1 1D Seismic Wave Velocity Profile from Masw Tests

The MASW tests were conducted in Somanath, at different locations, with 24 receivers with a spacing of 2, 5 meters over a total spread of 48 meters along the survey line. The description of each layer has been obtained based on the average shear wave velocity for each of the layers as per NEHRP site classification. The data analyzed is for the Somanath temple and the subsurface identified is the dense soil to hard rock. The shear wave velocity corresponding to this soil varies from 320 to 500 m/s and the compressional wave velocity varies from 1600 to 1900 m/s [1, 2, 3, 11, 12] up to a depth of 50 m from the ground level (GL).

Line 1 (Figure 3) at source position at -4 meter away from the first geophone was processed using a stack of 3 shots of a sledgehammer. The source of impact was at a distance of 4m from the first geophone of the survey line. The resulting profile indicates the presence of a low velocity layer near the surface underlain by approximately 50 meters of sediments having shear wave velocity approximately equal to 628 m/s as shown in Figure 3. Table 1 presents the results of average S- and P-wave velocities for the identified layers.

Table 1 Calculated S- and P-wave velocities for a site at right side of Somanath temple, SE direction

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>S-wave velocity (m/s)</th>
<th>P-wave velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2.78</td>
<td>323.46</td>
<td>1649.04</td>
</tr>
<tr>
<td>2.78-6.25</td>
<td>579.64</td>
<td>1933.41</td>
</tr>
<tr>
<td>6.25-10.42</td>
<td>676.43</td>
<td>2040.84</td>
</tr>
<tr>
<td>10.42-15.28</td>
<td>662.40</td>
<td>2025.26</td>
</tr>
<tr>
<td>15.28-20.83</td>
<td>574.05</td>
<td>1927.20</td>
</tr>
<tr>
<td>20.83-27.08</td>
<td>449.19</td>
<td>1788.60</td>
</tr>
<tr>
<td>27.08-34.02</td>
<td>457.38</td>
<td>1797.70</td>
</tr>
<tr>
<td>34.02-41.67</td>
<td>484.44</td>
<td>1827.73</td>
</tr>
<tr>
<td>41.67-66.67</td>
<td>628.11</td>
<td>1987.20</td>
</tr>
</tbody>
</table>

Figure 3 Inversion for P- and S-wave velocity profiles
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Line 1 (Figure 4) at source position at 52 meter i.e., away from the last geophone was processed using a stack of 3 shots of a sledgehammer. The source of impact was at a distance of 4m from the first geophone of the survey line. The resulting profile indicates the presence of a low velocity layer near the surface underlain by approximately 50 meters of sediments having shear wave velocity approximately equal to 480m/s as shown in Figure 4. Table 2 presents the results of average S- and P-wave velocities for the identified layers.

Table 2 Calculated S- and P-wave velocities for a site at right side of Somanath temple, SW direction

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>S-wave velocity (m/s)</th>
<th>P-wave velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2.78</td>
<td>301.97</td>
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<td>411.70</td>
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<td>15.28-20.83</td>
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<tr>
<td>20.83-27.08</td>
<td>367.10</td>
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<tr>
<td>27.08-34.02</td>
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<tr>
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<td>1750.03</td>
</tr>
<tr>
<td>41.67-66.67</td>
<td>484.40</td>
<td>1827.69</td>
</tr>
</tbody>
</table>

Figure 4 Inversion for P- and S-wave velocity profiles

5. CONCLUSION
Overall, the MASW test has been carried out few locations in the Somnath temple as part of the development of 2D subsurface profile. The 1D P- and S-waves analyses show that the compressional/primary wave velocity varies from 1600 to 1900 m/s and shear wave velocity varies from 300 to 600 m/s up to a depth of 10 m from the ground level [1, 12]. The soil deposit up to 5 m depth from the ground level is residual soil and from 5 to 50 m depth it is a weather rock/hard rock. From the value of $V_{S30}$ for the Somnath temple soil, the soil can be classified as “site class C” and in some places “site class B and A” as per the NEHRP classification [12]. A fairly good match is obtained between the measured shear wave velocity profiles by MASW tests and those evaluated from the predictive equation developed for all
soils of the Somanath city. The mapped depth to bedrock values have been cross validated with the measured shear wave velocities from the MASW test and derived regression equations. Depth to bedrock matches well with obtained from the selected boreholes and layer depth estimated from the MASW test.

REFERENCES


