Subsurface shear-wave velocity determination using Multi-channel Analysis of Surface Wave (MASW)

Overview:

Active and passive surface-wave techniques are relatively new insitu seismic methods for determining shear wave velocity (Vs) profiles. Testing is performed on the ground surface, allowing for less costly measurements than with traditional borehole methods or where access may be difficult for drill rigs. The basis of surface-wave techniques is the dispersive characteristics of surface-waves when travelling through a layered medium. Surface-wave velocity is directly related to the material properties (primarily shear-wave velocity, but also to a lesser degree compression wave velocity and material density) of the subsurface to a depth of approximately 1 to 2 wavelengths. Longer wavelengths penetrate deeper and their velocity is affected by the material properties at greater depth. Surface-wave testing consists of measuring the surface-wave dispersion curve at a site and modelling it to obtain the corresponding shear-wave velocity profile.

Applications:

The MASW system gives a good estimation of shear-wave velocity is a geotechnical parameter that is used to evaluate site response and site amplification. The 2D shear-wave velocity profiles can also be used for bedrock profiling, locating paleo-channels and other stratigraphic features, compaction testing, and a range of other problems.

Field Methodology:

Multiple sensors (usually 24 or more) are deployed with even spacing along a linear survey line and the sensors are connected to a multichannel recording device (seismograph). Each channel is dedicated to recording vibrations from one sensor. One multichannel record (commonly called a shot gather) consists of a multiple number of time series (called traces) from all the receivers in an ordered manner. There are two MASW methods, active MASW and passive MASW. Active MASW is used when the target depth is 30 meters or less, and a large area needs to be covered. Passive MASW can penetrate up to 100 meters depth, but acquisition is slower and less manoeuvrable than active MASW.

Active MASW:

The most common MASW method is active MASW, where seismic energy is generated using an Accelerated Weight Drop (AWD), sledge hammer or other point source. The MASW system is designed for mobility – the sensors are connected to a towable array that can be towed behind a vehicle, with shot gathers being collected along a line at set distances.

Southern Geophysical Ltd (SGL) normally runs an active MASW survey with the following progression:

- Preliminary site visit to determine if site conditions are suitable for MASW and plan layout and placement of MASW lines.
- Job Safety Analysis and other health and safety procedures.
- Establishing a safe work site.
- Collection of active MASW shot gathers and surveying of shot gather locations.

It normally takes about 30 minutes to set up the MASW system at the start of the operational period, and 10 to 30 minutes to move the array from one line to the next. The most commonly used MASW array consists of 24 receivers spaced 1 meter apart, the AWD is offset from the array by 10 meters, and the AWD and towing vehicle add an additional 5 to 10 meters of length – the total length of the system is typically around 40 meters (Figure 2). A shot gather involves striking the ground with the AWD or sledge hammer, and recording data for 1.5 seconds. During the recording period there should be no moving vehicle or pedestrian traffic in the vicinity of the MASW system to eliminate contamination of the

surface wave data. An entire shot gather normally takes between 0.5 minutes and 3 minutes, depending on how much background noise is present. After a shot gather, the system is towed forward by a particular distance, which depends on the desired lateral resolution. Typically it is either 5 m or 10 m for a 23 m MASW array, where the objective is to achieve maximum depth penetration (normally 15 to 30 meters depth, depending on site conditions and geology). The system rolls along in this fashion, stopping every spacing distance to collect a shot gather.

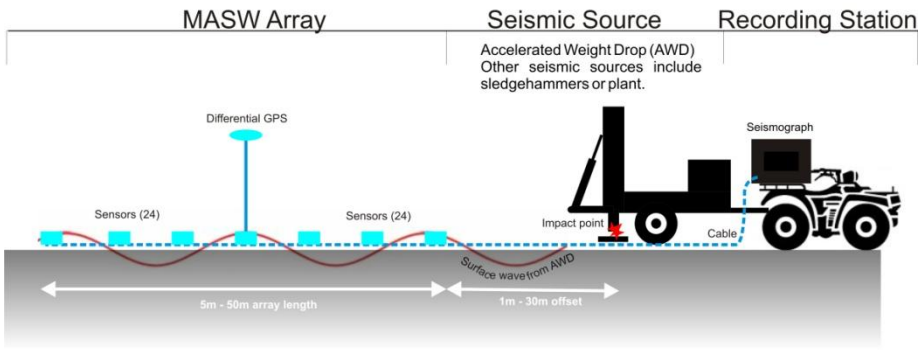
Passive MASW:

Passive MASW differs from active MASW, in that the seismic source is ambient noise, rather than an AWD or sledge-hammer. Generally, the receivers are planted in the ground to ensure optimal ground coupling, and the system is not designed to be towed. A typical array might have 48 sensors spaced 2 meters apart, but there is considerable flexibility in the receiver spacing and the length of the system. Ambient noise is often generated by driving large vehicles or plant around the array in set patterns.

Southern Geophysical Ltd (SGL) normally runs a passive survey with the following progression:

- Preliminary site visit to determine if site conditions are suitable for MASW and plan layout and placement of MASW lines.
- Job Safety Analysis and other health and safety procedures.
- Establishing a safe work site.
- Collection of passive MASW shot gathers.

It normally takes about 60 minutes to set up the MASW system at the start of the operational period, and 30 to 40 minutes to move the array from one location to the next. A shot gather involves recording ambient noise or deliberately generated surface wave noise for a period 15 to 30 seconds. An entire shot gather normally takes around 5 minutes, depending on the character of the background noise.



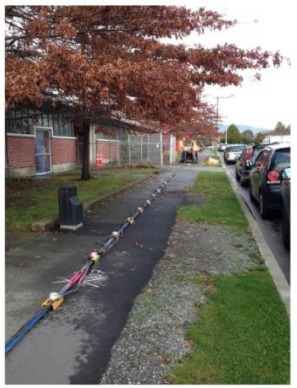


Figure 1: Active MASW Field Methodology: Graphical Representation and Field Photographs

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Data processing:

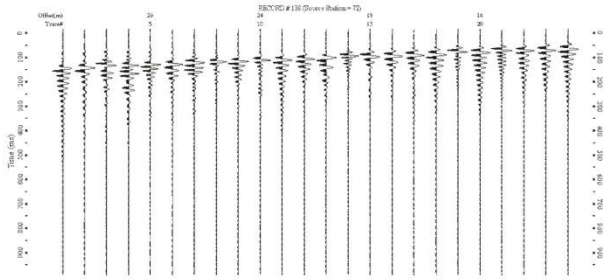
Data processing for both active and passive MASW consists of 5 steps:

1. Preliminary detection of surface waves.
2. Constructing the dispersion image panel and extracting the signal dispersion curve.
3. Back-calculating Vs variation with depth.
4. Interpolation of Vs variation data points into a 2D MASW profile.
5. Generation of a site map showing the location of MASW lines and chainage along MASW lines.

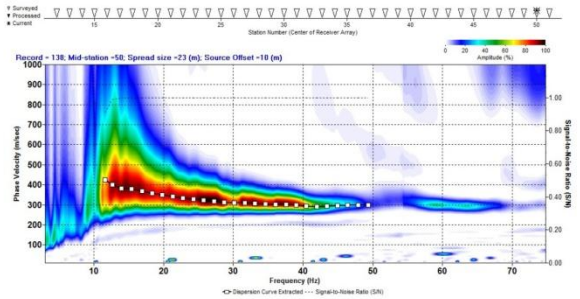
The first three steps are automated and computed in a specialized software package. The output from the software package is a text file with the Vs model for each shot gather. The text file is combined with the differentially corrected GPS data to produce a CSV file with the easting, northing, chainage, depth and Vs at for each layer of each shot gather. This data is gridded using the Kriging gridding method, and a 2D profile is produced.

Figure 2: Sample MASW Processing Flow

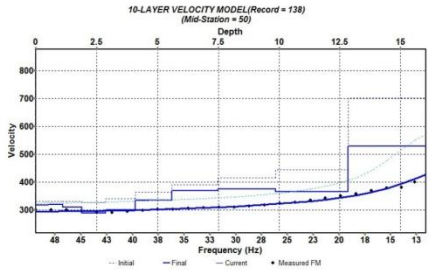
1.) Raw field record

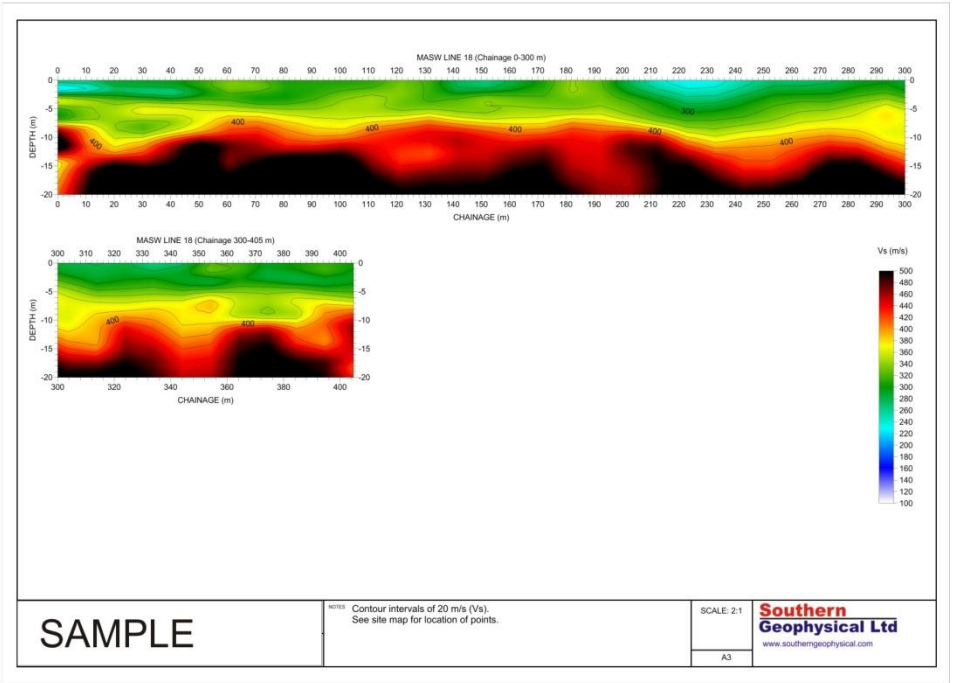


2.) Dispersion curve



3.) Inversion





4.) 2D MASW Profile

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