



FUGRO

SURFACE WAVE SEISMIC

Surface wave investigation can be used to determine in situ variations in stiffness and detect and map cavities, solution features and/or areas prone to subsidence.

Multi-channel analysis of surface waves (MASW) is a non-intrusive seismic technique that can provide considerable cost and logistical advantages over traditional physical sampling strategies. Investigations can typically provide shear velocity (V_s) values to depths of up to 20 metres.

Shear velocity is a key indicator of small strain ground stiffness (shear modulus); MASW can therefore be used to determine stiffness at discrete locations such as wind turbine bases, or as a mapping technique across large areas.

By mapping variations in ground stiffness the technique may be used to highlight areas of anomalous response resulting from subsurface cavities, solution features and/or weak and less dense subsurface areas.

1D, 2D and 3D data presentation can be used to understand the near surface stiffness characteristics of a site.

SITE CONSIDERATIONS

Good quality seismic data may be difficult to obtain where there is a high level of ambient acoustic noise, for example, construction or traffic noise. Consequently surveying may need to be done at a quiet time of day or by restricting vehicular movement.

Most equipment is hand portable, however good access is required to allow safe and efficient deployment of cables. Contact with the ground is required to ensure good quality data so vegetation clearance may be necessary.

The MASW method is relatively insensitive to small (<5-10 m) lateral variations in shear wave velocities and therefore careful consideration of the target feature must be made. The method is often used as a reconnaissance mapping technique to target areas of specific interest for further investigation using other geophysical or intrusive methods.

PRINCIPLES

Surface wave energy can be generated by an impact at the ground surface via a seismic source such as a sledgehammer or an accelerated weight-drop. Surface waves propagate outwards from the impact with cylindrical wavefronts. Rayleigh waves are a common type of surface wave which arise from the interference of compressional (P) waves and vertically polarised shear waves (Sv).

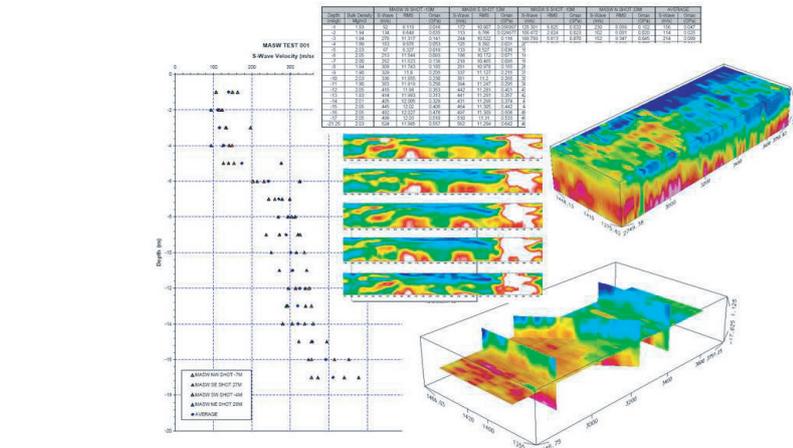
Rayleigh wave behaviour is influenced by several factors including P/S-wave velocity, density, layer thickness and depth, but the most significant factor is the S-wave velocity. Rayleigh waves, assuming a Poisson's Ratio of 0.25, travel at a speed of about 0.9 times the S-wave velocity for a medium.

In most geological situations, layering or gradual velocity changes are present near the Earth's surface. In these circumstances, velocity will vary with frequency (dispersive behaviour) because higher frequencies generated by the source travel in the shallow layers only, whilst lower frequencies travel in both shallow and deep layers. The lowest frequency-velocity at which coherent dispersive energy is identified is known as the fundamental mode.

Often multi-modal behaviour occurs and care must be taken to identify fundamental mode energy. Critically the MASW method provides a reliable means of discriminating fundamental mode energy from secondary and tertiary modes (as shown in the data example), offering a distinct advantage over other surface wave methods.

METHOD

MASW data are collected in the time-distance domain in a similar manner to seismic refraction or reflection data (MASW survey design can often be tailored to



Data can be acquired and combined into 2D or 3D datasets

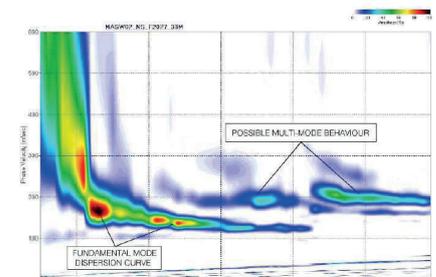
simultaneously provide refraction and reflection data without the need for additional acquisition). A seismic source is activated at or near the ground surface, usually a sledgehammer or accelerated weight drop for shallow engineering studies. An array of geophones is connected to an engineering seismograph. Fugro offer bespoke landstreamer recording spreads that can improve production by as much as 10 times compared to traditional static spreads.

Data are transformed to the velocity-frequency domain using well established signal processing workflows. The relationship between phase, velocity and frequency facilitates the discrimination of a dispersion curve. Dispersion curve data inversion is carried out to provide S wave velocity values as a function of depth. A priori information can be incorporated as necessary to constrain and improve the inversion process.

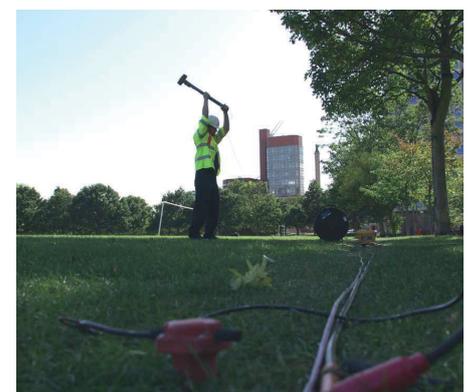
Data are normally acquired and processed on a station basis, however, 1-D depth-velocity data may be combined to produce 2-D and 3-D representations of velocity distribution as required to meet the project objectives.

APPLICATIONS

- Risk mapping of areas of 'weak' ground
- Dissolution zone detection and other karstic features
- Determination of ground stiffness for foundation design
- Bedrock profiling
- Overburden thickness profiling
- Embankment stability assessment.



Phase velocity-frequency plot showing typical dispersive characteristics and multi-modal behaviour



MASW is widely used for near surface cavity detection and surface mapping

