Underwater Application of Spectral Analysis of Surface Waves

L. Paoletti[1], E. Mouton[2], and M. Maraschini[3]

[1]D'Appolonia S.p.A, Via S. Nazaro 19, 16145 Genova, Italy, email lorenzo.paoletti@dappolonia.it
SismOcean SARL 132 rue Pauline RAMART, 34070 Montpellier, France, email edouard.mouton@sismocean.com
[3]D'Appolonia, S.p.A, Via S. Nazaro 19, 16145 Genova, Italy, email margherita.maraschini@dappolonia.it

Abstract

The spectral analysis of surface waves (SASW) technique is frequently used on land to measure the shear wave velocity profile. This paper presents an application of the methodology for underwater site investigations. Field data are collected using a bottom-towed acoustic source and a streamer of hydrophones. Multichannel data are processed by slant-stacking and fast Fourier transform to find the relation between phase velocity and frequency. Inversion processing of these dispersion curves is used to generate a continuous profile of soil stiffness below sea floor. An example case of a site investigation in the Adriatic Sea is presented. Comparison of shear wave velocity profiles obtained with downhole seismic cone and the underwater surface waves technique shows good agreement confirming the reliability of the multichannel analysis of surface waves (MASW) underwater.

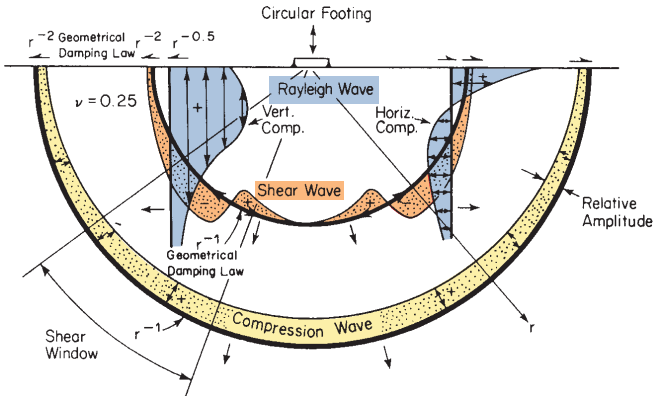
Background on Surface Waves

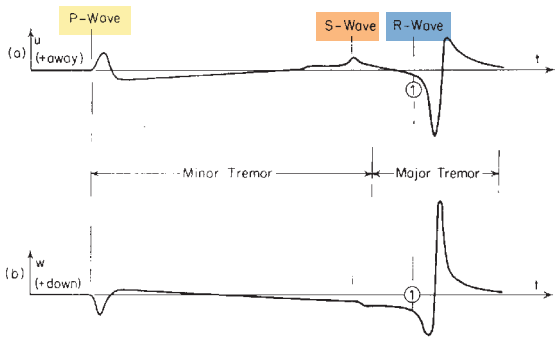
Surface waves properties

- Confined near the surface (amplitude decreases exponentially with depth)
- Energy greater than body waves (P and S)
- Geometrical damping less than body waves
- Penetration proportional to wavelength

Each wavelength travels at different velocity depending on soil stiffness profile (dispersivity)

Soil stiffness profile can be determined from surface waves survey

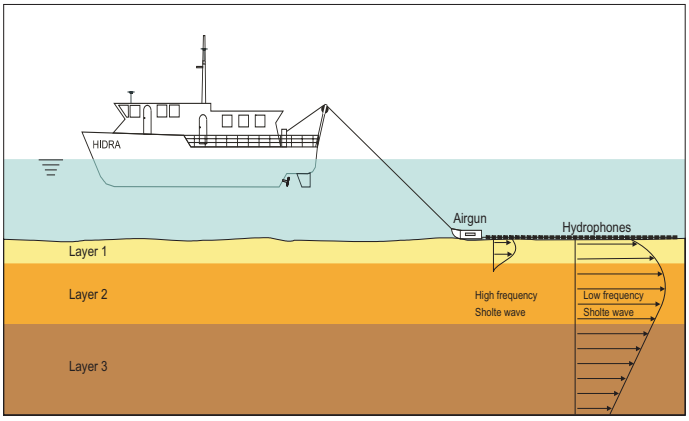




From Woods 1968 and Lamb 1904 cited in Richart, F. E., Woods, R. D. and Hall J. R. (1970). *Vibration of Soils and Foundations,* Prentice-Hall.

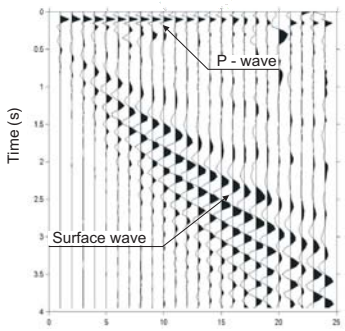
Field Operations

- An airgun and an array of hydrophones are deployed on the seafloor.
- The airgun impulse generates seismic waves.
- The hydrophones measure pressure changes induced by travelling waves.



Data Processing

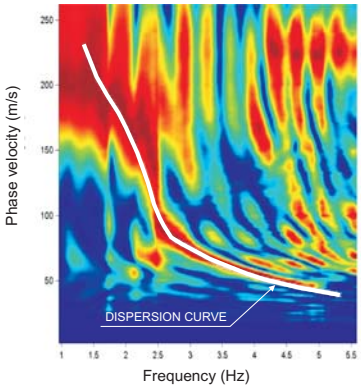
EXAMPLE OF RECORDED SIGNAL



Data is recorded during field operations and filtered. Example refers to a survey in the Adriatic Sea in 28 m water depth.

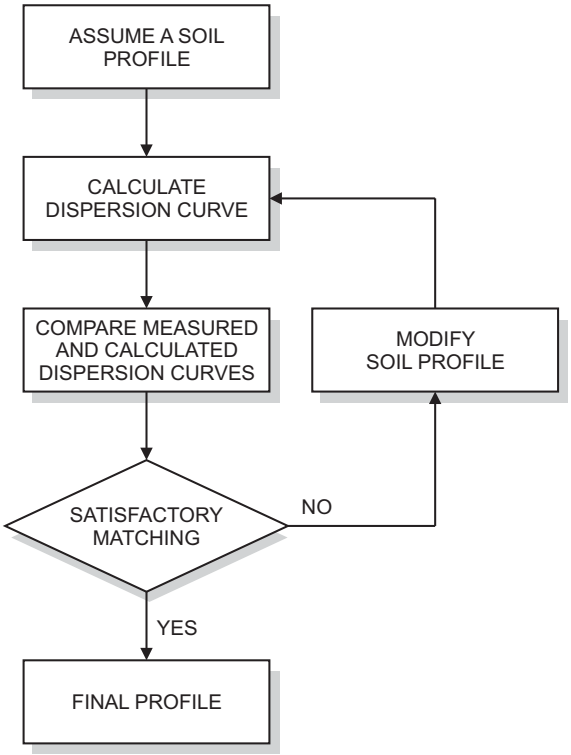
Data is processed by means of Fourier transform and plotted in frequency - velocity space.

TRANSFORMED SIGNAL



The dispersion curve is taken passing through the peaks of energy.

Evaluation of Soil Stiffness Profile

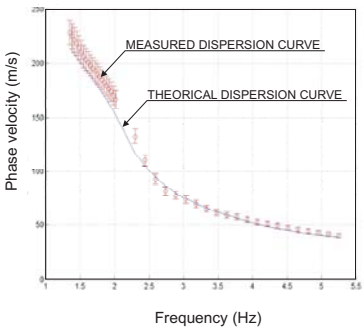


The soil stiffness profile is obtained by means of an iterative inversion process.

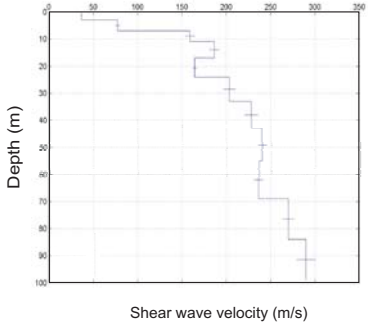
- An initial soil profile is assumed.
- The theoretical dispersion curve is computed and compared to the measured dispersion curve.
- The soil profile is modified and the process is repeated until convergence.

The results of analysis of the example signal shown in the upper panel are given below.

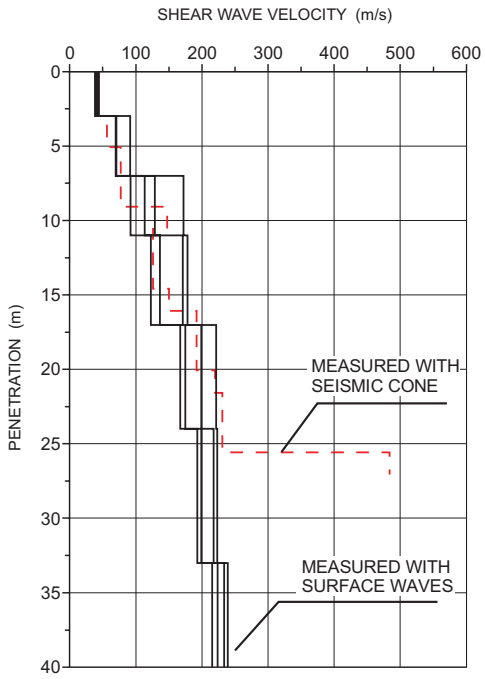
DISPERSION CURVE



SHEAR WAVE VELOCITY PROFILE



Comparison with Seismic CPT



Shear wave velocity profiles at a site in the Adriatic sea are shown on the left.

Data has been obtained by means of :

- seismic CPT on a geotechnical borehole
- a series of surface waves measurements in a 100 m radius from the borehole.

Surface waves results match very well seismic CPT data.

Conclusions

THE UNDERWATER SURFACE WAVES SURVEY OFFERS SEVERAL ADVANTAGES WITH RESPECT TO THE SEISMIC CONE MEASUREMENTS:

- underwater surface waves survey can provide shear wave velocity profiling along several kilometers of route in few days of operations. Anomalous site conditions can be identified during the survey;
- there is no need to drill a borehole to advance the cone in the ground. A conventional geophysical vessel can be used. Consequently, survey costs are considerably lower.

AND RESPECT TO THE CONVENTIONAL OFFSHORE GEOPHYSICAL SURVEYS:

- penetration of surface waves is not limited by the water depth, while conventional methods are affected by multiple reflections which mask the acoustic signal in shallow water;
- surface waves penetrate in the soil also in the cases of a stiff layer overlying soft layers, and in presence of gas charged sediments.

THESE ADVANTAGES MAKE THE UNDERWATER SASW PARTICULARLY ATTRACTIVE IN OFFSHORE SURVEYS.