Spectral Analysis of Surface Waves



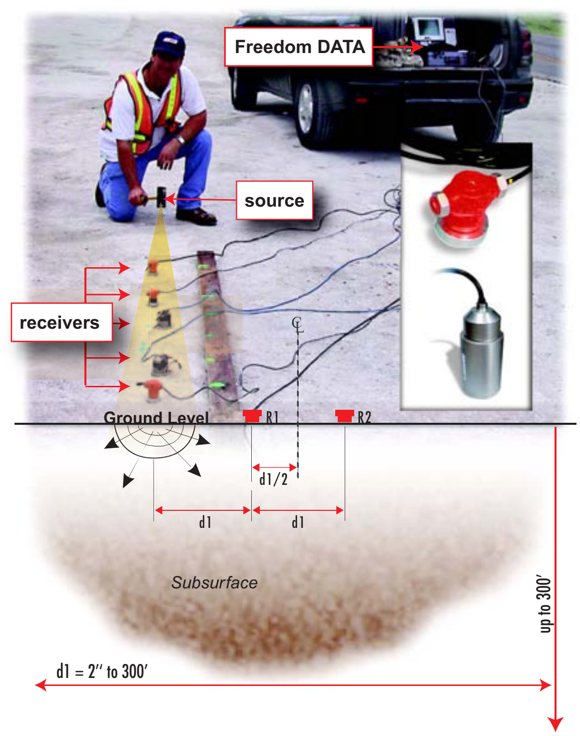



Application

Spectral Analysis of Surface Waves test method is applied primarily to assess material stiffness and condition, and layer thickness. More specifically, the SASW method is applied to:

1. determination of pavement system profiles including the surface layer, base and subgrade materials.
2. determination of abutment depths of bridges.
3. condition assessment of concrete liners in tunnels, slabs, and other structural concrete members.

SASW - Spectral Analysis of Surface Waves
Determination of Pavement and Soil Velocity Profiles



The SASW method uses the dispersive characteristics of surface (Rayleigh) waves to determine the variation of the shear wave velocity (stiffness) of layered systems with depth. The SASW testing is applied from the surface which makes the method nondestructive and noninstrusive. Once the shear wave velocity profiles are determined, shear and Young's moduli of the materials can be calculated through the use of simple mathematical equations. The shear wave velocity profiles are determined from the experimental dispersion curves (surface wave velocity versus wavelength) obtained from SASW measurements through a process called forward modeling or through an inversion process. The SASW method can be performed on any material provided there is an accessible surface for receiver attachments. Materials include concrete, asphalt, soil, masonry, and wood. SASW is also used for geophysical purposes in estimating shear wave velocity of soils and rock.

Standards

Standards for the SASW method include ASTM D6758-02 for measuring stiffness and apparent modulus of soil and soil-aggregate in-place by an electro-mechanical method and ACI 228.2R for NDE applications.

- **See end of document for full references.**

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FIELD INVESTIGATION

ACCESS

The SASW method requires an accessible surface for receiver attachments. The extent of the accessible surface limits the investigation depth. As a rule of thumb, if one is interested in material properties to a depth D, then the accessible surface should extend in the line of receivers direction to a distance equal to 1.5D, preferably 2D. The diagram on the front page shows the general field arrangement used in SASW testing. Receiver spacings ranging from 0.5 ft to +300 ft have been used in the field to investigate depths from 2 inches up to +300 ft.

COLLECTION OF DATA

In SASW tests, two receivers are placed on the surface, and a hammer is used to generate the acoustic energy. Other sources used in SASW measurements include solenoid-operated impactors and V-meters (high frequency sources). Short receiver spacings (typically accelerometers) are used to sample the shallow layers while long receiver spacings (typically velocity transducers) are used in sampling the deep materials. The source and receiver signals are recorded by an Olson Instruments Freedom Data PC Spectral Analysis of Surface Waves System for Concrete and Masonry (SASW-1S) and stored for further analysis. Two profiles, a forward profile and a reverse profile, are typically obtained in SASW measurements where the accessible surface is struck by a hammer on two opposite sides of the receivers. A signal analyzer is used to collect and transform the receiver outputs to the frequency domain. Two functions in the frequency domain (spectra) are of great importance in SASW tests:

(1) the cross power spectrum between the two receivers (used in the preparation of the experimental dispersion curve) and,

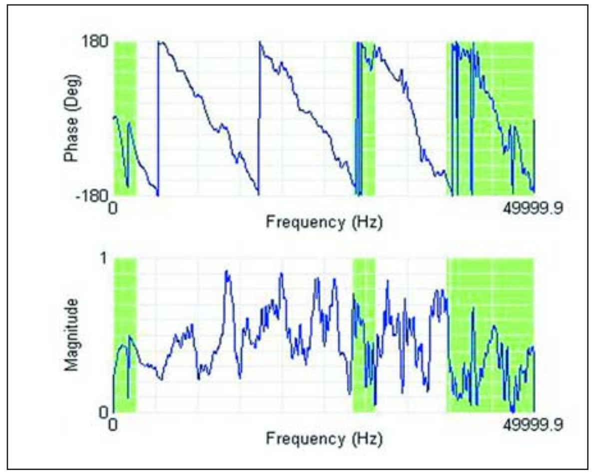
(2) the coherence function (used to ensure that high signal-to-noise ratio data is being collected).

DATA REDUCTION

PROCESSING TECHNIQUES

Exponential windowing can help in the interpretation of the SASW results as unwanted reflections from nearby boundaries are reduced due to the windowing process. Averaging of SASW data from the forward and reverse profiles can also help in the interpretation of data.

The plot at right shows a phase plot and coherence plot that have been masked for data collected on a concrete drilled shaft. The masked out areas are unwanted boundary reflections from the cylindrical shape of the drilled shaft.



INTERPRETATION OF DATA

The phase shift of the cross power spectrum between the two receivers is used to determine the experimental dispersion curve as follows:

1. $t(f) = \Phi XY(f) / 360° * f$
2. $V_R(f) = D / t(f)$
3. $\lambda_R(f) = V_R(f) / f$

where $t(f)$ = time delay between receivers as a function of frequency, f; $\Phi XY(f)$ = phase shift of the cross power spectrum in degrees; $V_R(f)$ = surface wave velocity; D = distance between receivers; and, $\lambda_R(f)$ = wavelength.

The experimental dispersion curve can be used to determine the thickness and the stiffness of the top uniform layer such as the asphalt concrete layer in a pavement system. The thicknesses and stiffnesses of the underlying layers are determined from the experimental dispersion curve through the forward modeling or inversion process. Even if the forward modeling process is not performed, a comparison between experimental dispersion curves of different sites gives relatively valuable information about the existing conditions but not absolute values of the stiffnesses or thicknesses.

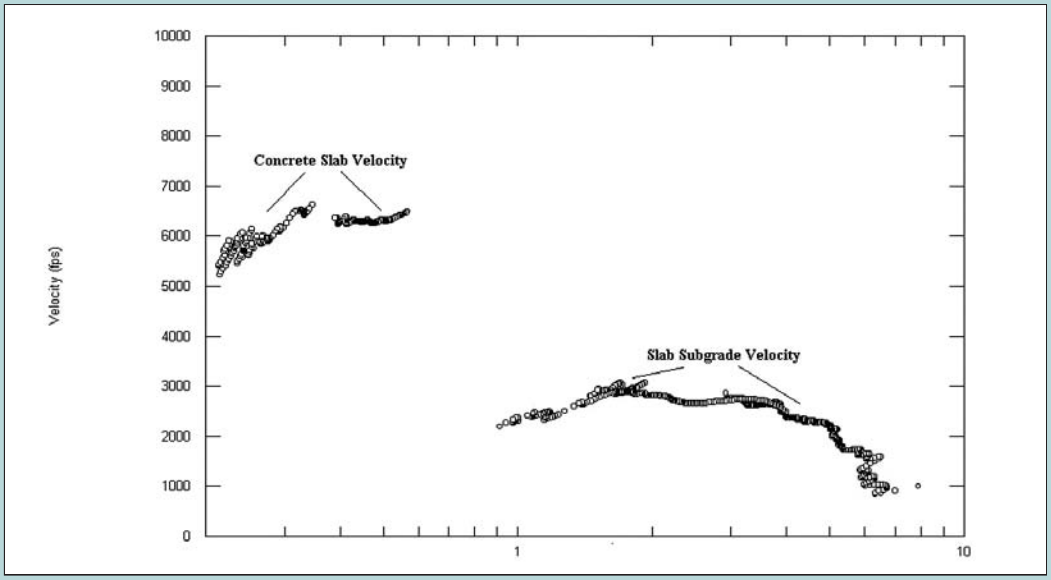
EFFECTIVENESS

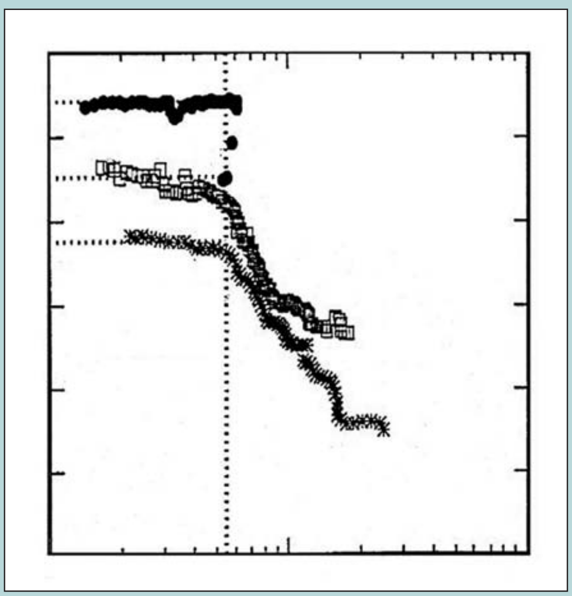
SASW measurements require one surface to be accessible for testing. The depth that can be tested by SASW measurements is sometimes controlled by the accessible surface lateral extent. A thin layer of slow velocity material lying between two thick high velocity layers cannot be identified, particularly if this layer is deep.

SASW measurements are accurate to within 5% for the determination of the thickness and stiffness of the top layer in a pavement system or of the concrete liner of a tunnel.

STRUCTURAL — SLAB ON GRADE

Example results from SASW tests to determine the thickness and stiffness of the surface layer (slab) and the base material (subgrade) for a slab-on-grade are shown in the figures below. Degraded concrete can also be identified near the surface of the slab. This damage may be typical of freeze-thaw or fire damage.





The figure at left shows dispersion curves determined from SASW measurements on asphalt pavement. The shift of the surface wave velocity (or modulus) curves is due to changes in temperature. The SASW measurements also determined the thickness of the surface layer.