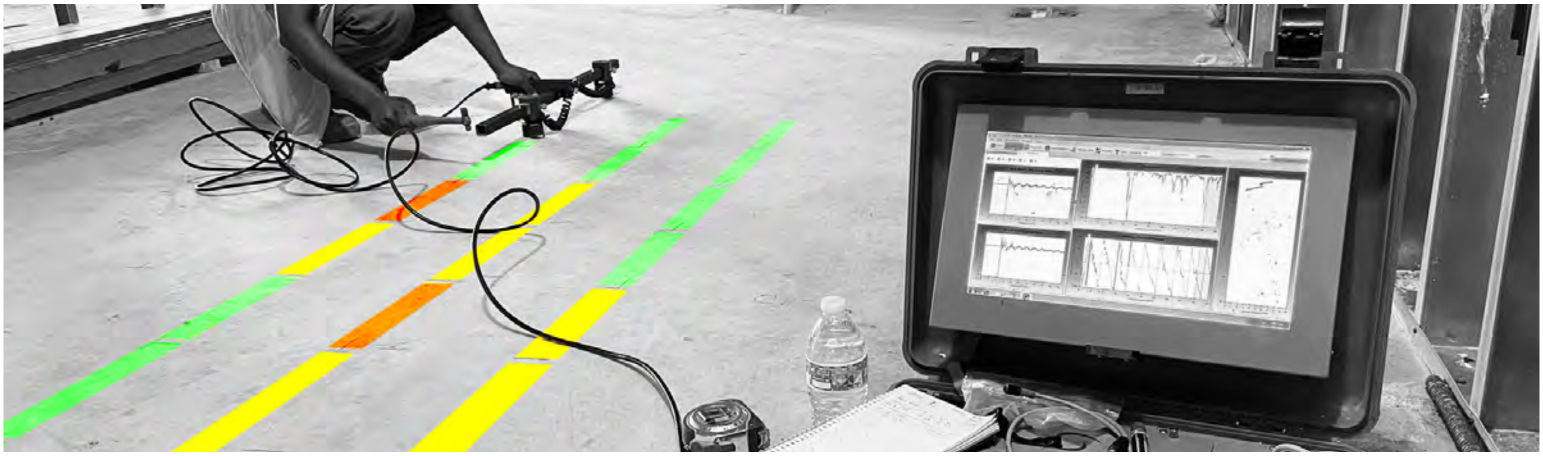
Olson ENGINEERING

SPECTRAL ANALYSIS OF SURFACE WAVES (SASW)

METHOD BRIEF

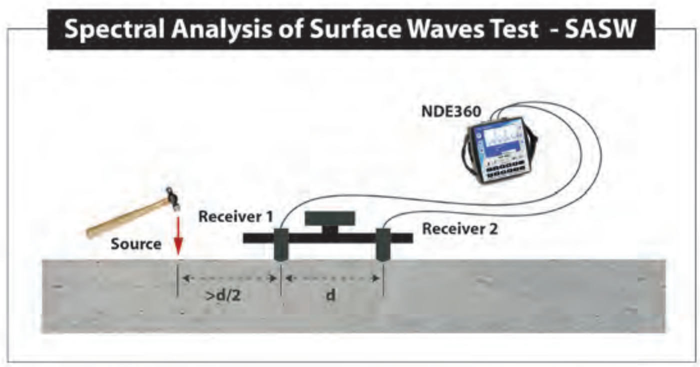


APPLICATION

The **Spectral Analysis of Surface Waves (SASW)** test method is used primarily to assess crack depths, material stiffness, material condition, and layer thickness. More specifically, the SASW method is used to determine:

1. Pavement system profiles including the surface layer, base and subgrade materials
2. Abutment depths of bridges
3. Condition of concrete liners in tunnels, slabs, and other structural concrete members
4. Tip depths of surface-opening cracks in concrete
5. Damage depths for freeze-thaw damage, fire damage, or chemical degradation

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 estimated 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 modelling or through an inversion process. The SASW method can be performed on any material provided there is an accessible surface for receiver attachments. Materials that can be tested include concrete, asphalt, soil, masonry, and wood.



STANDARDS

Standards for the SASW method include ASTM D6758 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.*

FIELD INVESTIGATION

ACCESS

The SASW method requires an accessible surface for the placement of 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 0.3 ft to +300 ft have been used in the field to investigate depths from 2 inches up to +300 ft.

COLLECTION OF DATA

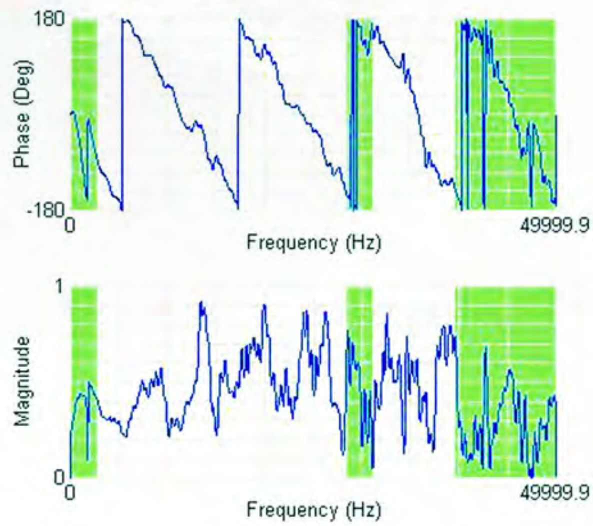
In SASW tests, two receivers are placed on the surface, and a hammer or other impactor is used to generate the acoustic energy. Other sources used in SASW measurements include solenoid-operated impactors and V-meters (high frequency sources). Short receiver spacings (typically our SASW bar system) are used to sample shallow layers while long receiver spacings (typically velocity transducers) are used to sample deep materials. The source and receiver signals are recorded by an Olson Instruments Data Collection Platform equipped with a SASW System and stored for further analysis. Two profiles, a forward profile and a reverse profile, can be obtained in SASW measurements where the accessible surface is struck by a hammer on opposite sides of the two 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)
(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 (if used) can also help in the interpretation of data.



The plot above shows a phase plot and coherence plot that have been masked for data collected on the top of a concrete drilled shaft. The masked out areas are unwanted boundary reflections from the round 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) = FXY (f) / 360 * f
2. VR (f) = D / t (f)
3. IR (f) = VR (f) / f

where t (f) = time delay between receivers as a function of frequency, f; FXY (f) = phase shift of the cross power spectrum in degrees; VR (f) = surface wave velocity; D = distance between receivers; and, IR (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 underlying layers are determined from the experimental dispersion curve through the forward modeling or inversion process. Even if the forward modelling process is not performed, a comparison between experimental dispersion curves of different sites produces valuable information about the existing conditions, but does not produce absolute values of the stiffnesses or thicknesses.

EFFECTIVENESS

The SASW method requires one surface to be accessible for testing. The depth that can be tested by SASW measurements is sometimes dictated by the lateral extent of the accessible surface. Note that a thin layer of slow velocity material lying between two thick high velocity layers often 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.

FDPC

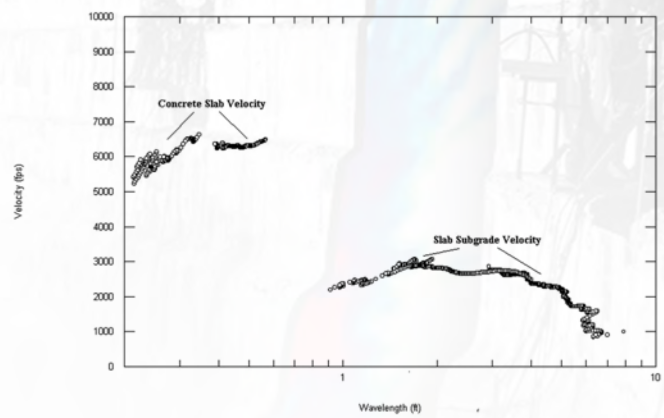
NDE 360

SASW System

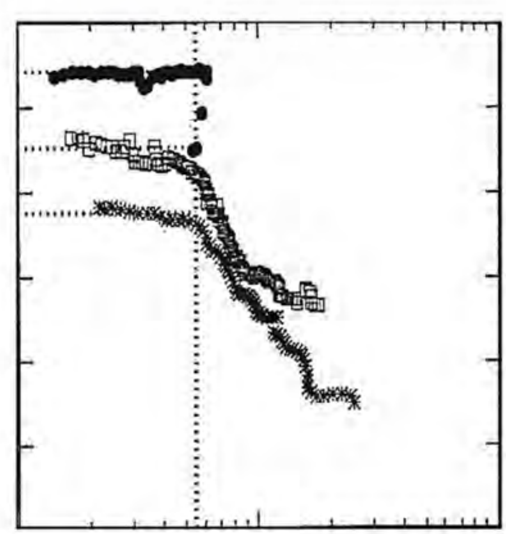
EXAMPLE RESULTS

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, or may indicate vertical cracking.



The figure below 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.



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REFERENCES

STANDARDS AND GOVERNMENTAL REPORTS

- ASTM D6758-02 "Standard Test Method for Measuring Stiffness and Apparent Modulus of Soil and Soil-Aggregate In Place by an Electro-Mechanical Method", Book of Standards Volume 04.09, ASTM International.

- ACI 228.2R, "Nondestructive Test Methods for Evaluation of Concrete in Structures", ACI Manual of Concrete Practice, Part 2, Construction Practices and Inspection, Pavements, ACI International.

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