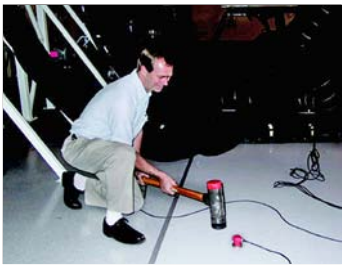
Sonic Echo/Impulse Response

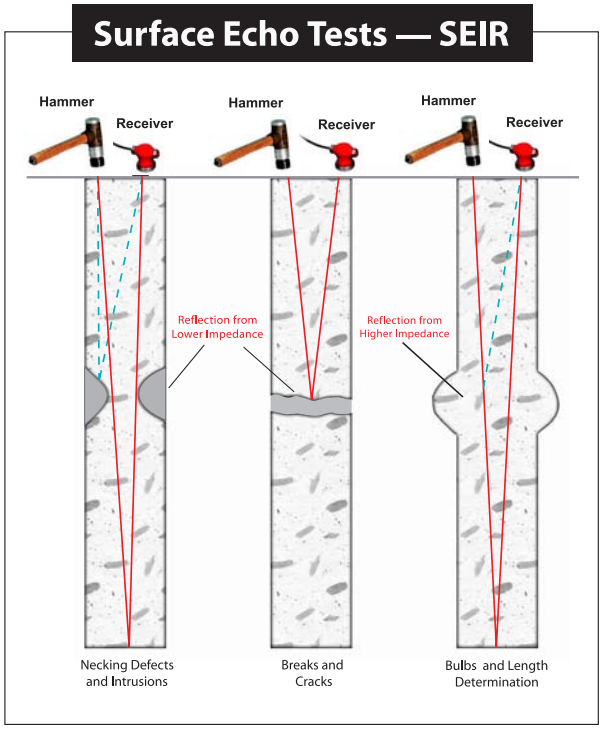


Application

Sonic Echo/Impulse Response tests are performed to evaluate the integrity and determine the length of deep foundations. SE/IR tests can be performed on drilled shafts and driven or auger-cast piles. The test can also be performed on shallow wall structures such as an abutment or a wall pier of a bridge provided the top of the wall is accessible.

Sonic Echo/Impulse Response tests can be performed on both concrete and wood foundations. Round steel pile foundations (pipe piles) can also be tested, but H-type piles generally cannot be tested. This is because damping of the signal energy in H-piles is often much greater than that of concrete and wood due to the large surface areas and small cross-sectional areas of these piles.

Analysis of the Sonic Echo data is performed in the time domain while analysis of the Impulse Response data is performed in the frequency domain. In both tests, the reflection of compressional waves (fastest of all wave types) from the bottom of the tested structural element or from a discontinuity such as a crack, soil intrusion, or diameter change (bulb or neck) is measured. In simple terms, the generated wave from an impulse hammer travels down in a shaft or a pile until a change in impedance is encountered, where the wave reflects back and is measured by a receiver placed next to the impact point.



Standards

Standards for the SE/IR method include ASTM D5882-00 for low strain integrity testing of piles and ACI 228.2R for NDE applications.

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

FIELD INVESTIGATION

ACCESS

For drilled shafts and piles, the best results from SE/IR tests are obtained if the top of the drilled shaft or the pile is exposed for receiver attachment and hammer hitting. If the top is not exposed, then the SE/IR tests are performed on the side, which requires at least the upper 1-2 feet of the shaft to be exposed. For wall-like shallow structures, the top of an abutment or a pier should be exposed for SE/IR testing.

COLLECTION OF DATA

In an SE/IR test, the foundation top is struck by a hammer and the response of the foundation is monitored by a receiver. An Olson Instruments Freedom Data PC Sonic Echo/Impulse Response (SE/IR-1) system (shown below) records the hammer input and the receiver output. SE tests are typically performed with different frequency filtering to optimize reflections coming from the bottom of the foundation and to reduce the effect of surface waves or reflections from a discontinuity at a shallow depth where the frequencies associated with these two conditions are high. In IR tests, the transfer and coherence functions are automatically calculated by the digital analyzer after transforming the time records of the hammer and the receiver to the frequency domain.

DATA REDUCTION

PROCESSING TECHNIQUES

To help interpret SE/IR data, some processing techniques can be applied to enhance weak echoes. First, the SE signals are integrated from acceleration to velocity and exponentially amplified to enhance weak reflections and to compensate for acoustic energy damping. Another processing technique for SE data is the Cepstrum technique in which an autocorrelation function is calculated to help determine better the time separation between two echoes. In simple cases, the SE data can be used to obtain an image of the shaft through a process called impedance imaging.

INTERPRETATION OF DATA

The Sonic Echo data is used to determine the depth of the foundation based on the time separation between the first arrival and the first reflection events or between any two consecutive reflection events (tP) according to the following equation:

$$D = VP \times tP / 2$$

where D is the reflector depth and VP is the velocity of compressional waves. A reflector can be the bottom of the foundation or any discontinuity along the embedded part of the foundation. Also, the Sonic Echo data can be used to determine the existence of a bulb or a neck in a shaft or the end conditions of the shaft based on the polarity of the reflection events.

The Impulse Response data is also used to determine the depth of reflectors according to the following equation:

$$D = VP / (2 \times \_f)$$

where _f is the distance between two peaks in the transfer function plot (velocity/force versus frequency) or between zero frequency and first peak for soft bottom conditions. In addition, the IR data provides information about the dynamic stiffness of the foundation. This value can be used to predict foundation behavior under working loads or correlated with the results of load tests to more accurately predict foundation settlement.

EFFECTIVENESS

The SE/IR method works best for columnar type foundations such as piles and drilled shafts. Reflection events are clearest if there is nothing on top of the foundations (such as a column). In cases where the superstructure is in place, the SE/IR data becomes more difficult to interpret because of the many reflecting boundaries and 2 or more receivers should be used to rack reflections.

Typically, SE/IR tests are performed on shafts or piles of length to diameter ratios of up to 20:1. Higher ratios (30:1 or greater) are possible in softer soils.

SE/IR tests are accurate to within 5% in the determination of the depth of the foundation provided an independent measurement of the wave velocity used in the depth calculation is made. In case the wave velocity is assumed based on the material type, SE/IR tests are normally accurate to within about 10%.

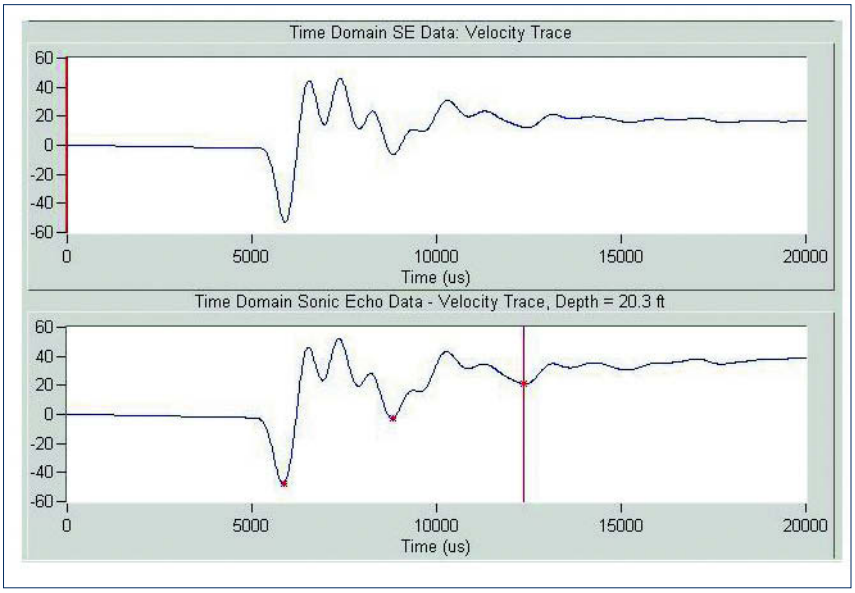
Example Results

Sonic Echo Data

The image at right shows sample Sonic Echo data from a drilled shaft with a nominal length of 21 feet.

Top Plot:
Raw Accelerometer Receiver Data Trace

Bottom Plot:
Receiver Data after Integration and Exponential Amplification

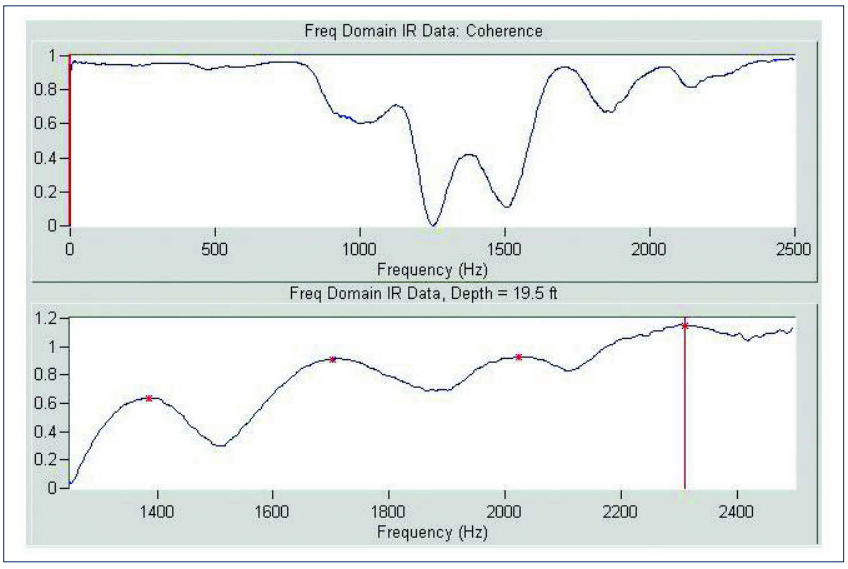


Impulse Response Data

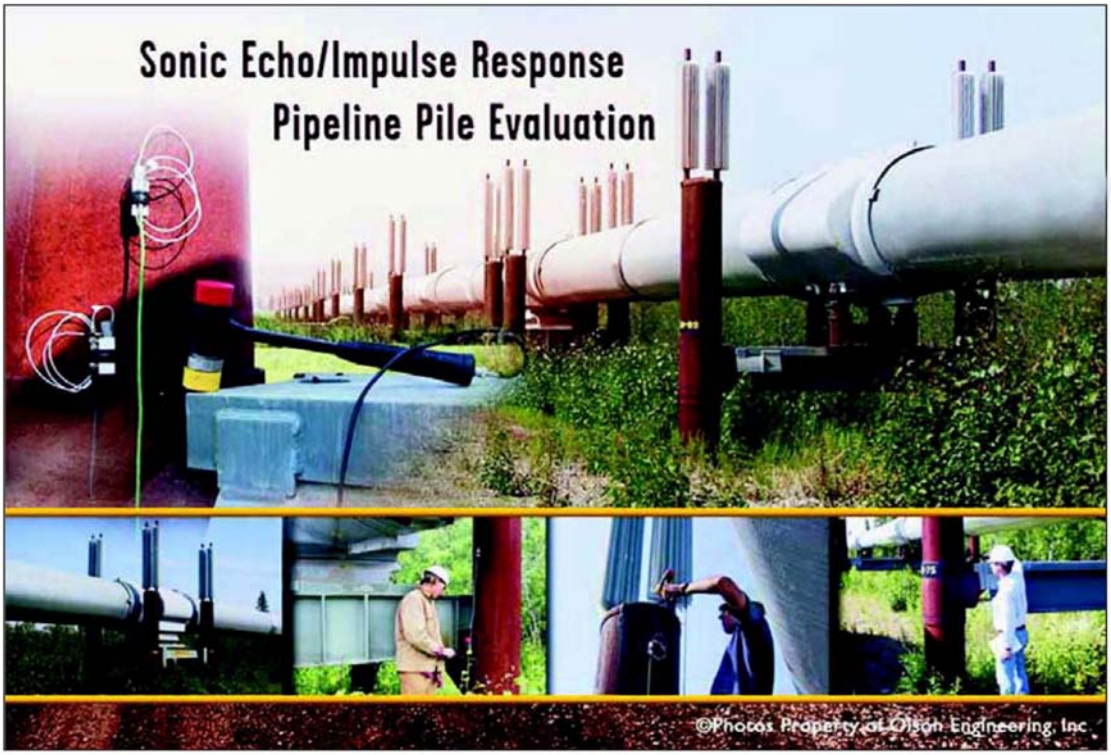
The image at right shows sample Impulse Response data from a drilled shaft with a nominal length of 21 feet.

Top Plot:
Frequency Domain IR Coherence Data

Bottom Plot:
IR Transfer Function Amplitude Data



EXAMPLE RESULTS



Olson Engineering performing SE/IR evaluation on the famous Alaskan Pipeline

Olson performed SE/IR evaluation on underground columns

Performing SE/IR evaluation on a drilled shaft top

Performing SE/IR evaluation on concrete foundation walls

REFERENCES

Standards and Governmental Reports.
ACI 228.2R, "Nondestructive Test Methods for Evaluation of Concrete in Structures", ACI Manual of Concrete Practice, Part2, Construction Practices and Inspection, Pavements, ACI International.

ASTM D5882-00, "Standard Test Method for Low Strain Integrity Testing of Piles", Book of Standards Volume 04.09, ASTM International.

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