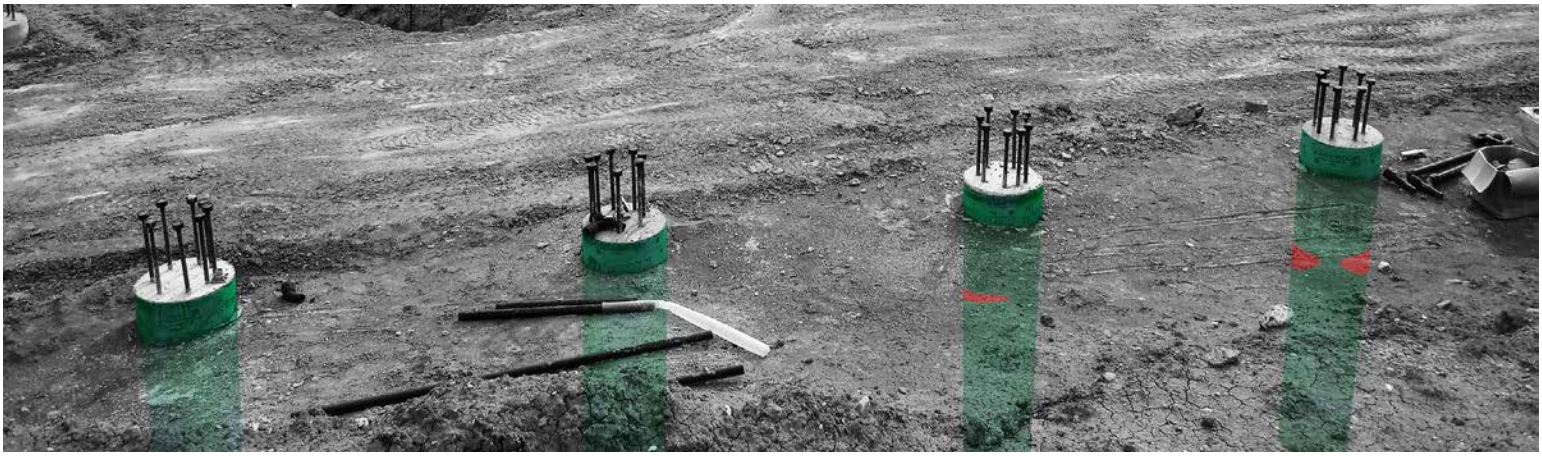
Olson ENGINEERING

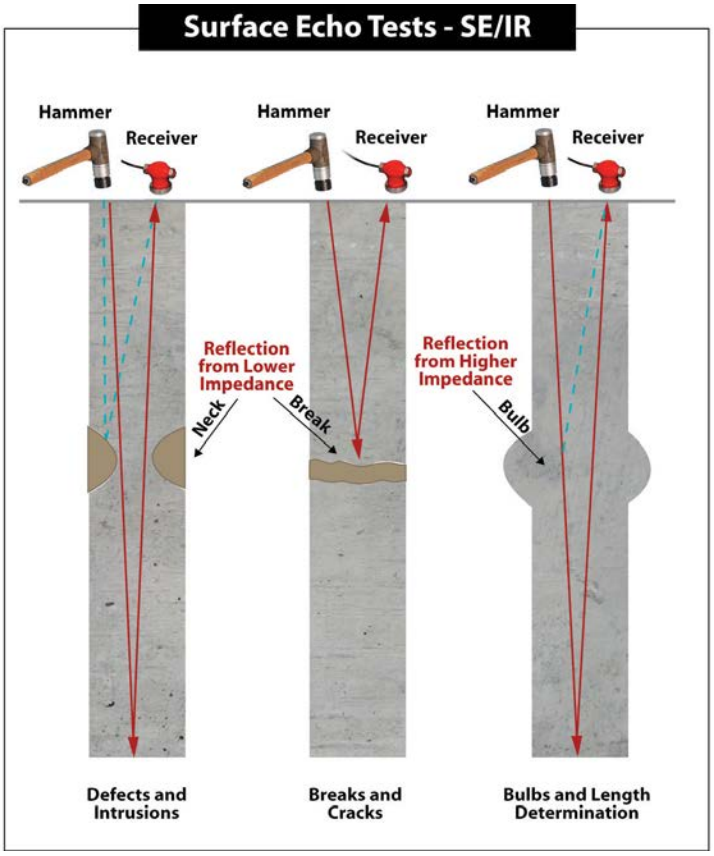
SONIC ECHO/IMPULSE RESPONSE (SE/IR)

METHOD BRIEF



APPLICATION

Sonic Echo/Impulse Response (SE/IR) tests (also called Low Strain Integrity [LSI], Pile Integrity Testing (PIT), etc.) are performed to evaluate the integrity and determine the length of deep foundations. SE/IR tests can be performed on drilled shafts and piles that are driven or auger-cast. 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 concrete-filled 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. 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 area and small cross-sectional area of these piles. Analysis of the Sonic Echo data is performed in the time domain, whereas analysis of the Impulse Response data is performed in the frequency domain. In both tests, compressional waves (the fastest of all wave types) are reflected and measured from the bottom of the tested structural element, or from a discontinuity – such as a crack, soil intrusion, or diameter change (bulb or neck). 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, whereupon the wave is reflected back, and is then measured by a receiver placed next to the hammer impact point.



STANDARDS

Standards for the SE/IR method include ASTM D5882 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 SE/IR tests can be performed on the side of the shaft, but this requires the upper 1-2 feet of the shaft to be exposed. For SE/IR testing on wall-like, shallow structures, the top of an abutment or a pier needs to 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 Sonic Echo/Impulse Response (SE/IR) System (shown below) records the hammer input and the receiver output. SE tests are typically performed with different frequency filtering functions, in order to optimize reflections coming from the bottom of the foundation and to reduce the effect of high-frequency surface waves. In IR tests, the time records of the hammer and the receiver are transformed to the frequency domain. The transfer and coherence functions are then automatically calculated by a digital analyzer.

SE/IR System

NDE 360

FDPC

FTG

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 can be exponentially amplified to enhance weak reflections and to compensate for acoustic energy damping.

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. Sonic Echo data can also be used to determine the existence of a bulb or a neck in a shaft or the end conditions of a 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, IR data provides information about the dynamic stiffness of a 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.

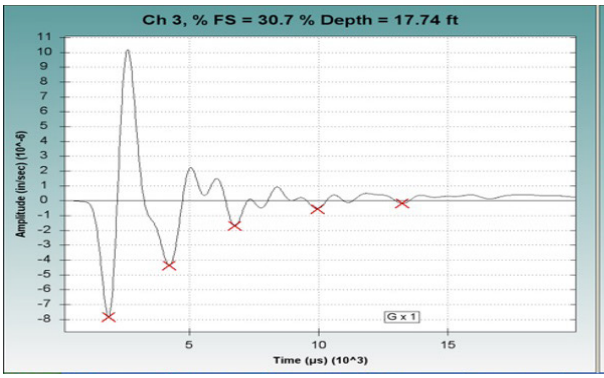
EFFECTIVENESS

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 two or more receivers may be used to track 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 cases where the wave velocity is assumed based on the material type, SE/IR tests are normally accurate to within about 10%.

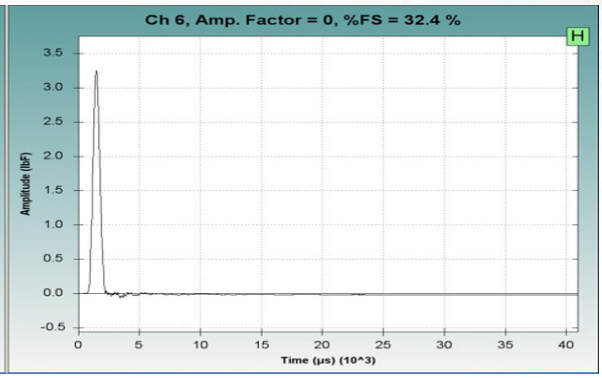
EXAMPLE RESULTS

SONIC ECHO DATA

The image below shows sample Sonic Echo data from a drilled shaft with a nominal length of 17.74 feet.



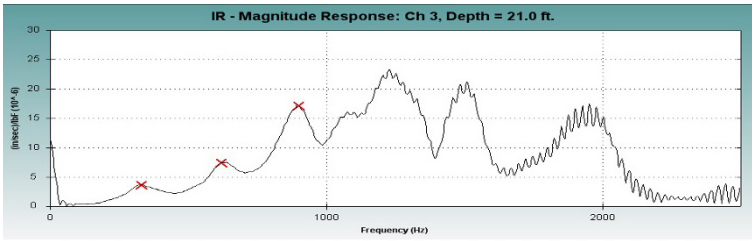
Accelerometer Receiver Data Trace



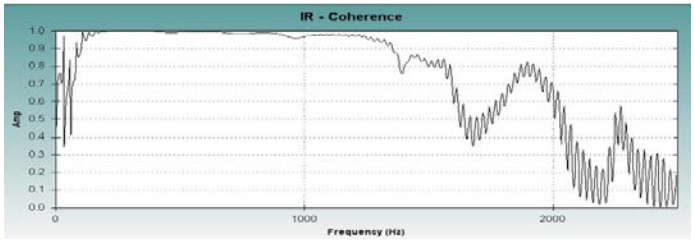
Hammer Data Trace

IMPULSE RESPONSE DATA

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



IR Transfer Function Amplitude Data



Frequency Domain IR Coherence Data

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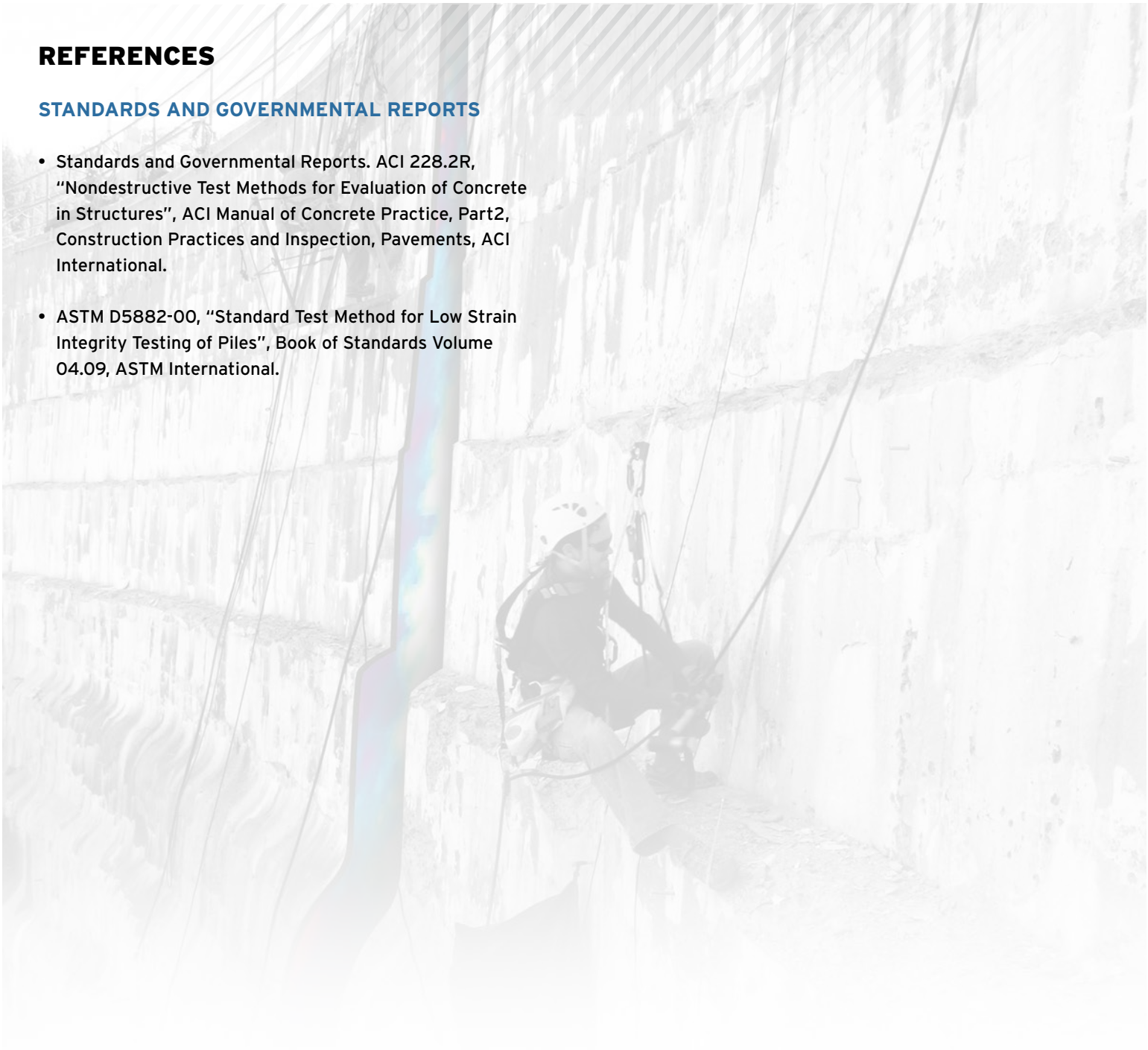
REFERENCES

STANDARDS AND GOVERNMENTAL REPORTS

- 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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