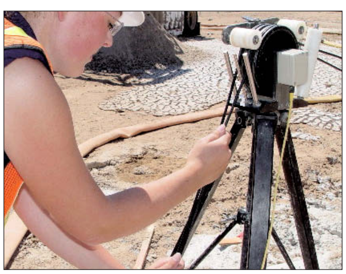
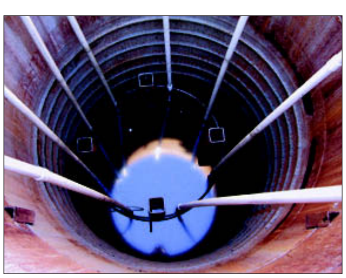
Crosshole Sonic Logging



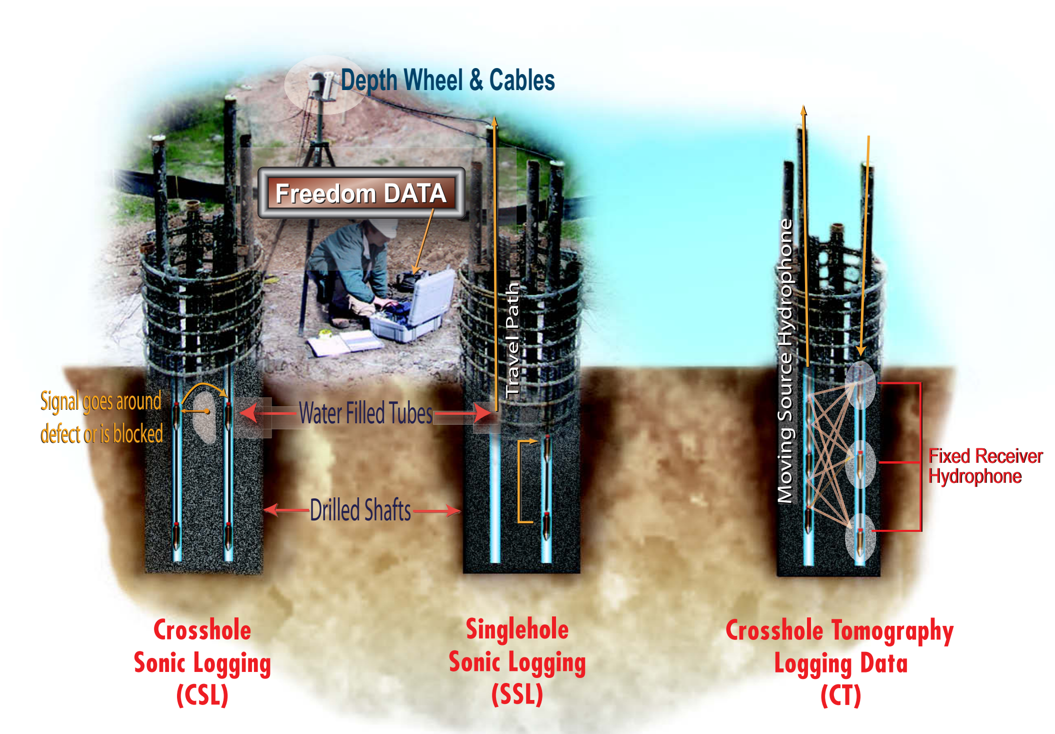


Application

Olson Engineering is a pioneer in the instrumentation and use of **CSL tests** for checking the integrity of newly placed drilled shafts, seal footings, and slurry or diaphragm walls. The CSL test relies on propagation of ultrasonic waves between two or more access tubes to measure the velocity and signal strength of the propagated waves. The testing can be performed on any concrete foundation provided two or more access tubes or coreholes capable of holding water are present in the foundation. CSL can also be used to check the integrity of underwater concrete piers and foundations by strapping access tubes to the sides. Crosshole Tomography can be performed to image critical anomalies found in CSL tests as discussed below.

A companion of the CSL test is the Singlehole Sonic Logging (SSL) test, which can be performed in one access tube or corehole to check the integrity of the concrete foundation around the tube in a fashion similar to Gamma-Gamma nuclear density tests.

CSL tests are typically performed on concrete, particularly concrete drilled shafts. Other materials, which support transmission of ultrasonic waves, can be tested, such as slurry, rock, grout, water-saturated media, and cemented radioactive wastes.



Standards

Standards for the CSL method include ASTM D6760-02 for integrity testing of concrete deep foundations and ACI 228.2R for NDE applications, and FLH 521.830 for determining pulse velocity through concrete in drilled shafts.

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

FIELD INVESTIGATION

ACCESS

Access tubes must be installed before the construction of the drilled shaft for quality assurance purposes, unless coreholes are to be drilled in a forensic case. PVC or black steel tubes (U.S. schedule 40) are typically used. The tubes are 1.5 (steel tubes only) to 2 inches (38 to 50 mm) in diameter, and are typically tied to the inside of the rebar cage to ensure close to vertical positions of the tubes. The tubes must extend about 3 feet (1 m) above the top of the shaft to compensate for the water displaced by the source, receiver, and cables and to allow for easy access. Tubes must be bonded to the concrete for good test results. In order to minimize debonding of tubes, water should be added immediately prior to or after concrete placement and the tubes should not be mechanically disturbed.

At least two tubes are needed to perform the CSL test. For good coverage of the test shaft, we recommend the following number of tubes be installed:

SHAFT DIAMETER	RECOMMENDED NUMBER OF TUBES	TUBE SPACING
D ≤ 2.5 ft (0.75m)	2 minimum	180 Degree
2.5 < D ≤ 3.5 ft (1.0 m)	3 minimum	120 Degrees
3.5 < D ≤ 5.0 ft (1.5 m)	4 minimum	90 Degrees
5.0 < D ≤ 8.0 ft (2.5 m)	6 minimum	60 Degrees
8.0 < D ≤	8 minimum	45 Degrees

The concrete in the shaft should normally be allowed at least 1-2 days to cure to hardened concrete prior to testing. If PVC tubes are used, testing should be done within 10 days after the placement of concrete due to possible tube-concrete debonding. If steel tubes are used, the testing can be done within 45 days after concrete placement as the steel tubes bond better than PVC tubes over a longer time.

COLLECTION OF DATA

In a CSL test, the source is lowered to the bottom of one of the tubes and the receiver is lowered to the bottom of another tube. The source and receiver are pulled simultaneously to allow the horizontal ultrasonic pulse velocity to be measured. A depth wheel controls the resolution of the collected data. Typically, the source is excited every 0.2 ft (6 cm) vertically and a measurement is taken. The source and receiver are pulled to the top of each shaft, thus giving a complete assessment of the concrete quality between the two tubes. CSL tests are typically performed between all the perimeter tubes to check the perimeter of the shaft. Additional opposing diagonal CSL tests are also performed to check the integrity of the inner core of the shaft. If there are more than 4 tubes and an anomaly is identified, CSL tests may be performed of subdiagonal tube pairs to further define an anomaly. A pair of tubes can be logged and the results displayed in less than approximately 5 minutes. Olson Engineering uses the Olson Instruments Freedom Data PC with the Crosshole and Singlehole Sonic Logging System (CSL-1 & CSL-2) for collection and analysis of CSL or SSL data.

CSL-1 SYSTEM: Includes components shown above.
CSL-2 SYSTEM: Includes components shown above with an additional hydrophone.

DATA REDUCTION

PROCESSING TECHNIQUES

The collected data from CSL measurements between two tubes at all depths are saved in one file. The file is scanned to determine first wave arrival times and energy levels at all depths. A CSL log shows both the arrival time (or velocity) and signal energy plots vs. depth (see next page).

INTERPRETATION OF DATA

In uniform, good quality concrete, the travel time between vertical equi-distant tubes will be relatively constant and correspond to a reasonable concrete pulse velocity from the bottom to the top of the foundation. The CSL test will also produce records with good signal amplitude and energy in good quality concrete. Longer travel times and lower amplitude/energy signals indicate the presence of irregularities such as poor quality concrete, void, honeycomb and soil intrusions. In some severe defects, the signal may be completely lost.

EFFECTIVENESS

The access tubes must be installed prior to concrete placement to perform CSL tests. For existing shafts or other concrete members, coreholes or drill holes must be drilled to allow access for the source and receiver hydrophones. CSL is best used for quality assurance. Tubes must be bonded to the concrete for good test results. In order to minimize debonding of tubes, water should be added immediately prior to or after concrete placement and the tubes should not be mechanically disturbed.

The CSL method is the most accurate quality assurance method for defect identification in drilled shafts. CSL testing provides assurance that the foundation concrete is sound and also hardened as velocity to the 4th power is proportional to concrete strength.

In areas where defects are identified in the CSL results, additional tests can be performed to better define the defect. The additional tests include angled CSL tests, Singlehole Sonic Logging (SSL) tests, and Crosshole Tomography (CT) analyses. Our CSL system is used to collect the tomography data. The data is subsequently analyzed to develop a velocity tomogram (an image) with better characterization of the defect in terms of its size and location. For forensic purposes, another test which can be used for condition evaluation is Sonic Echo/Impulse Response.

CSL VS SE/IR

One of the advantages of the CSL method over the surface Sonic Echo/Impulse Response method is that multiple defects can be identified in the same shaft using CSL, which may not be possible with the SE/IR method. In addition, the extent, nature, and the location of the defect can be determined with the CSL method as compared to only the depth of the defect from the SE/IR method. Finally, the CSL method is sensitive to smaller defects and yields more accurate depth information.

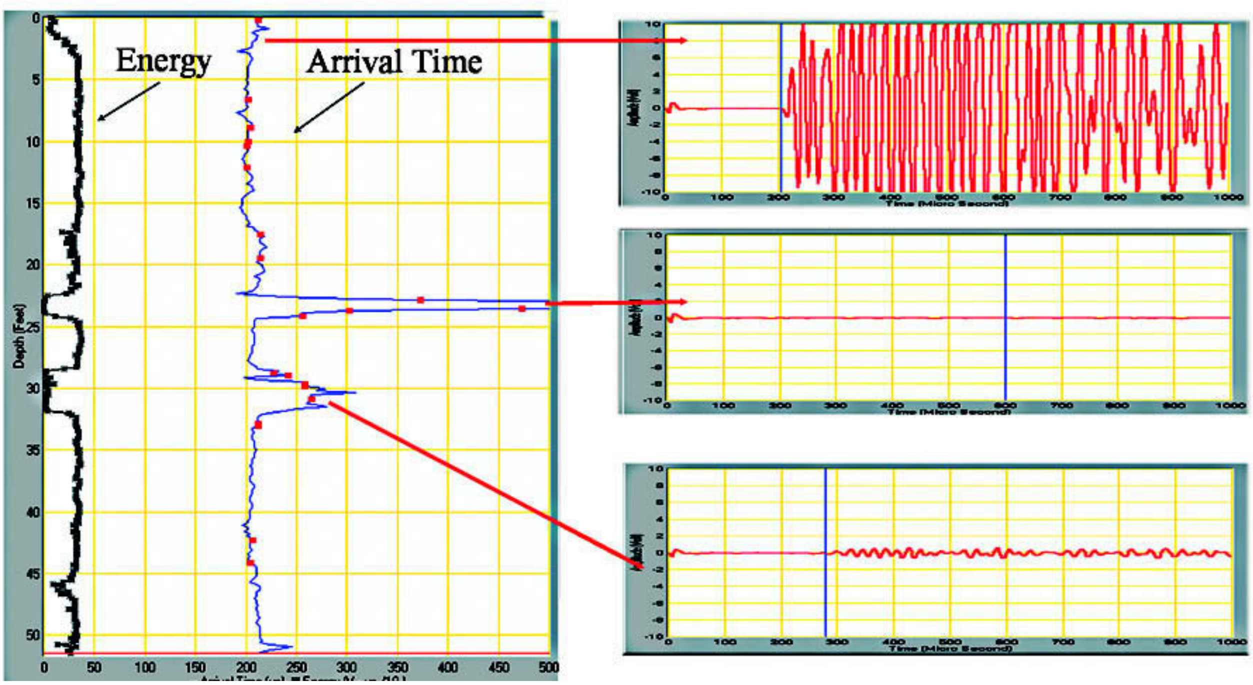
CSL VS GAMMA-GAMMA

When compared to Gamma-Gamma tests, the primary advantage of the CSL method is that CSL can locate defects that exist between tubes, which cannot be done with Gamma-Gamma tests. CSL testing is also much quicker, cheaper, and safer than Gamma-Gamma, and requires no special precautions which are required for the Gamma-Gamma tests. Also, Gamma-Gamma tests will falsely indicate sound concrete placement in terms of density when concrete is not cured if it is dense. The CSL test will indicate uncured or slow curing concrete as being a no signal to low velocity condition.

EXAMPLE RESULTS

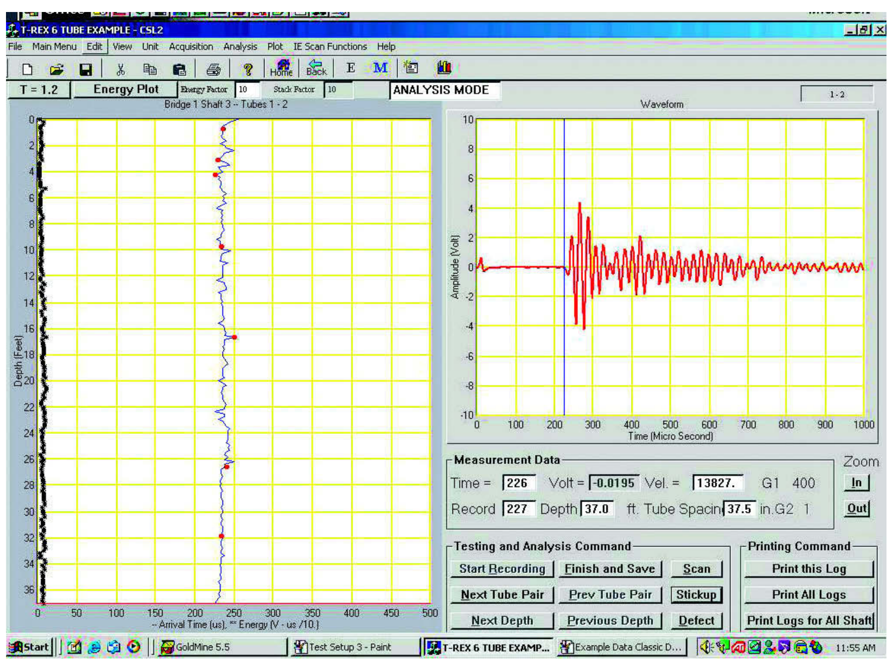
CSL LOG - PIER

The image below shows a more minor defect at about 30 ft. The ultrasonic signals (time vs. voltage) show sound, major defect and minor defect results.



CSL LOG - SOUND SHAFT

The image to the right shows a typical CSL log for what is known as a sound shaft. A consistent signal arrival time and signal energy level can be seen for the entire tested length of the shaft.



REFERENCES

Standards and Governmental Reports

- 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.
- ASTM D6760-02, "Standard Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing", Book of Standards Volume 04.09, ASTM International.
- FLH 521.830, "Standard Method for Determining Pulse Velocity Through Concrete in Drilled Shafts", Federal Lands Highway Division, Federal Highway Administration.

OLSON ENGINEERING PUBLICATIONS

- "Crosshole Sonic Logging and Tomographic Velocity Imaging of a New Drilled Shaft Bridge Foundation", *Larry D. Olson, P.E., David A. Hollema, Structural Materials Technology Topical Conference, Cincinnati, Ohio, September 10-13, 2002.*
- "Drilled Shaft Defect Detection and Resolution", *Larry D. Olson, P.E.*, Association of Drilled Shafts Contractors Drilled Shaft Foundation Symposium, Austin, Texas, January 30, 1998.
- "NDT Diagnosis of Drilled Shaft Foundations", *Larry D. Olson, P.E., Marwan F. Aouad, Ph.D., and Dennis A. Sack,* Transportation Research Board, 77th Annual Meeting, Washington, D.C., January 11-15, 1998.
- "Quality Assurance of Drilled Shaft Foundations with Nondestructive Testing", *Larry D. Olson, Marshall Lew, Greg C. Phelps, K.N. Murthy, B.M. Ghadiali*, Proceedings Federal Highway Administration Conference on Deep Foundations, Orlando, Florida, December 1994.
- "Nondestructive Testing of Deep Foundations with Sonic Methods", *Larry D. Olson, Clifford C. Wright*, ASCE Geotechnical And Construction Divisions - Foundation Engineering Conference, Northwestern University, Evanston, Illinois, June 1989.

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