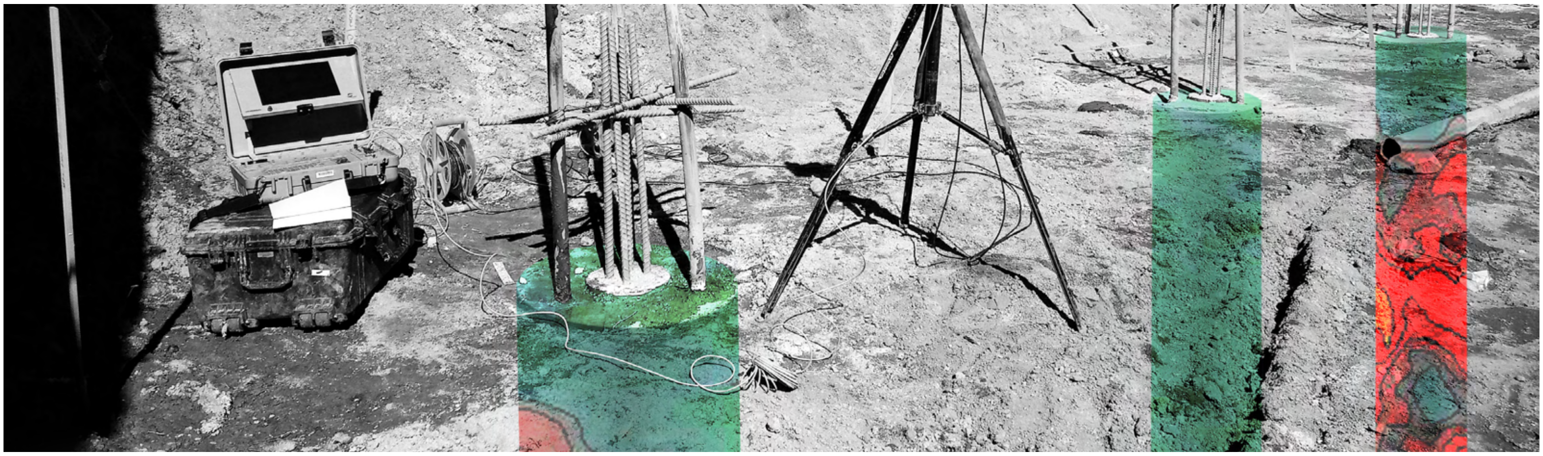
Olson ENGINEERING

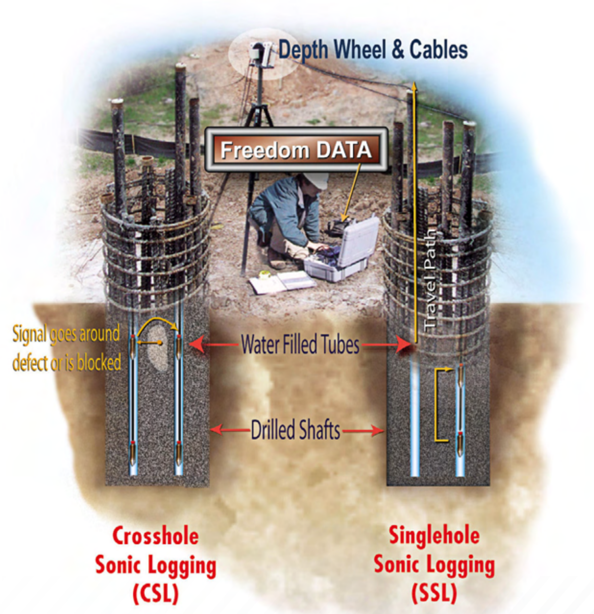
CROSSHOLE SCONIC LOGGING (CSL)

METHOD BRIEF



APPLICATION

Olson Engineering is a pioneer in the instrumentation and use of **Crosshole Sonic Logging (CSL)** tests for checking the integrity of newly placed drilled shafts, seal footings, and slurry or diaphragm walls. The CSL test relies on the propagation of ultrasonic waves between two or more access tubes to measure the velocity and signal strength of the waves. The testing can be performed on any concrete foundation, provided that 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 of the concrete members.



Crosshole Tomography can be performed to image critical anomalies found in CSL tests. 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 the 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 for integrity testing of concrete deep foundations, 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 a drilled shaft for quality assurance purposes, unless coreholes are to be drilled in a forensic case. PVC or (preferably) 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 inside diameter, and are typically tied to the inside of the rebar cage to ensure near-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 immediately 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	180º
2.5< D≤ 3.5 ft (1.0 m)	3 minimum	120º
3.5< D≤ 5.0 ft (1.5 m)	4 minimum	90º
5.0< D≤ 8.0 ft (2.5 m)	6 minimum	60º
8.0< D≤	8 minimum	45º

The concrete in the shaft should normally be allowed at least 1-2 days to cure and harden prior to testing. If PVC tubes are used, testing should be done within 10 days after the placement of concrete (this is due to possible tube-concrete debonding). If steel tubes are used, the testing can be done within 45 days after concrete placement as steel tubes bond better than PVC tubes over a longer time. Note that steel access tubes are strongly recommended for this testing.

COLLECTION OF DATA

In a CSL test, the source is lowered to the bottom of one tube and the receiver is lowered to the bottom of the other tube. The source and receiver are pulled up 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 perimeter tubes in order 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 5 minutes. Olson Engineering uses the Olson Instruments Freedom Data PC with the CSL System for collection and analysis of CSL or SSL data.

IE scanning measurements are performed with the Olson Instruments Scanner. The scanner is pushed across an accessible surface of the structural element and measurements are taken every inch. A calibrated distance wheel allows the impactor to hit the surface with precise timing and accurate positioning. The data are then automatically processed for identification of thickness echo peaks and signal energy. The identified peaks or energy are processed to calculate thicknesses and the thicknesses are plotted out on a graph of thickness versus location.

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). to cracks, voids/debonds or the back side of the concrete.

INTERPRETATION OF DATA

In uniform, good quality concrete, the travel time between vertical equi-distant tubes will be relatively constant from the bottom to the top of the foundation and correspond to a reasonable concrete pulse velocity. The CSL test will also produce records with good signal amplitude and energy in good quality concrete. Longer travel times and (usually) lower amplitude/energy signals indicate the presence of irregularities such as poor quality concrete, void, honeycomb and soil intrusions. In the case of severe defects, the signal may be completely lost.the presence of possible defects or other interfaces in the concrete. Shape effects due to beam boundaries, or from an elevated slab positioned directly on a beam, can influence thickness measurements. When round void/debond areas exist, the thickness echo peak is often shifted to a lower frequency. This causes the slab to appear thicker as a result of a later arrival time around the void/debond area.

EFFECTIVENESS

The access tubes must be installed prior to concrete placement to perform CSL tests. For testing 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 the Sonic Echo/Impulse Response method.

CSL System

FDPC

CSL vs SE/IR

One of the advantages of the CSL method over the surface SE/IR 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.

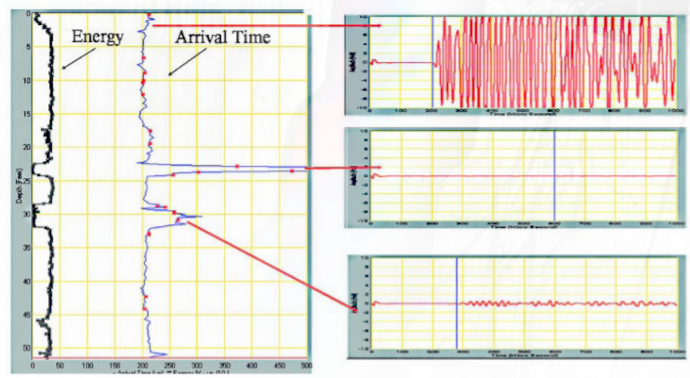
CSL vs Gamma-Gamma

When compared to Gamma-Gamma tests, the primary advantage of the CSL method is that CSL can locate defects that exist between tubes and in the shaft center, which cannot be done with Gamma-Gamma tests. CSL testing is also much quicker, cheaper, and safer and requires no special precautions which are required for Gamma-Gamma tests. Also, Gamma-Gamma tests will falsely indicate sound concrete placement (in terms of density) when concrete is not cured. The CSL test will clearly indicate areas of uncured or slow-curing concrete.

EXAMPLE RESULTS

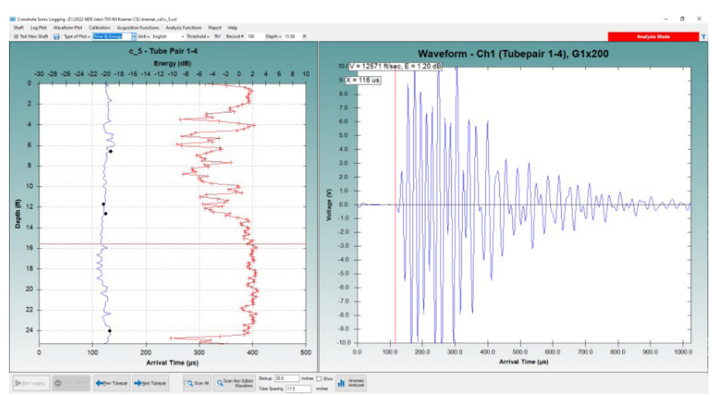
CSL LOG – PIER

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



CSL – SOUND SHAFT

The image below 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.



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REFERENCES

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.

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

Metro Denver Corporate Office:
Olson Engineering Inc.
12401 W. 49th Ave.
Wheat Ridge, CO 80033
Phone: (303) 423-1212
Fax: (303) 423-6071

Metro Washington D.C. Office:
Olson Engineering Inc.
7529 Standish Place, Suite 102
Rockville, MD 20855
Phone: (240) 477-7738
Fax: (240) 801-9951

www.olsonengineering.com | www.olsoninstruments.com