OLSON ENGINEERING, INC.

Experts in Nondestructive Evaluation

CT Method

N D E

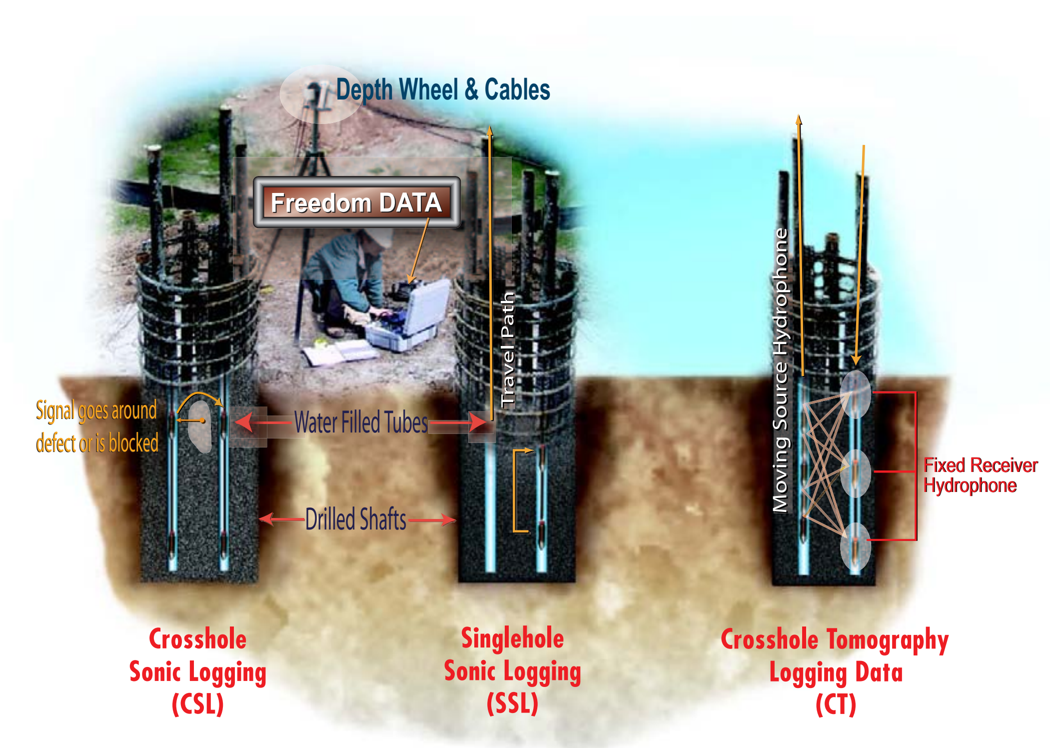
CROSSHOLE TOMOGRAPHY

Application

Crosshole Tomography testing is used to accurately characterize the size, location and severity of defects commonly found within newly place drilled shafts, seal footings, and slurry or diaphragm walls. The CT test relies on propagation of ultrasonic waves between two or more access tubes to measure the velocity and signal strength of the propagated waves. This 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. CT can also be used to image critical anomalies in underwater piers and foundations by strapping access tubes to the sides.

The CT test is most commonly used when a defect has been identified by an initial test, such as Crosshole Sonic Logging (CSL), and requires further analysis. Unlike the CSL test where only horizontal data is collected, the CT test collects data at various angles (vertically and horizontally), thus providing the user with a more detailed understanding of the defect in question.

CT tests are typically performed on concrete, particularly concrete drilled shafts, other materials which support transmission of ultrasonic waves, such as slurry, rock, grout, water-saturated media, and cemented radioactive wastes, and anywhere a CSL or Singlehole Sonic Logging (SSL) has already been completed.



Standards

No standards for United States currently exist.

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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 CT 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

Tomography data is collected in a procedure similar to that for standard CSL testing, except that many more data sets are collected with different source and receiver depths. Typically the receiver is first fixed at the lowest depth of interest (usually 3-5 meters below the suspected defect), and the source pulled from this depth (Do) to the top of the shaft over the depth wheel. Typically, the source is excited every 6 cm vertically and a measurement is taken. Note that the receiver is not pulled up with the source, but is left fixed at the same depth while the source moves. The receiver is then raised to the next depth (typically fixed increments of 2-6 increments) and the source is again pulled up from the initial depth (Do) to the top. This process is repeated until the receiver is at the shaft top or is 3-5 meters above the suspected defect zone. Because CT tests require raising and lowering the hydrophones many times during a single test, recording data over just three (3) meters of depth in a single tube pair can take up to one half hour. Due to time constraints, it is typical to only test tube pairs that help isolate the suspected defect. 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 CT data.

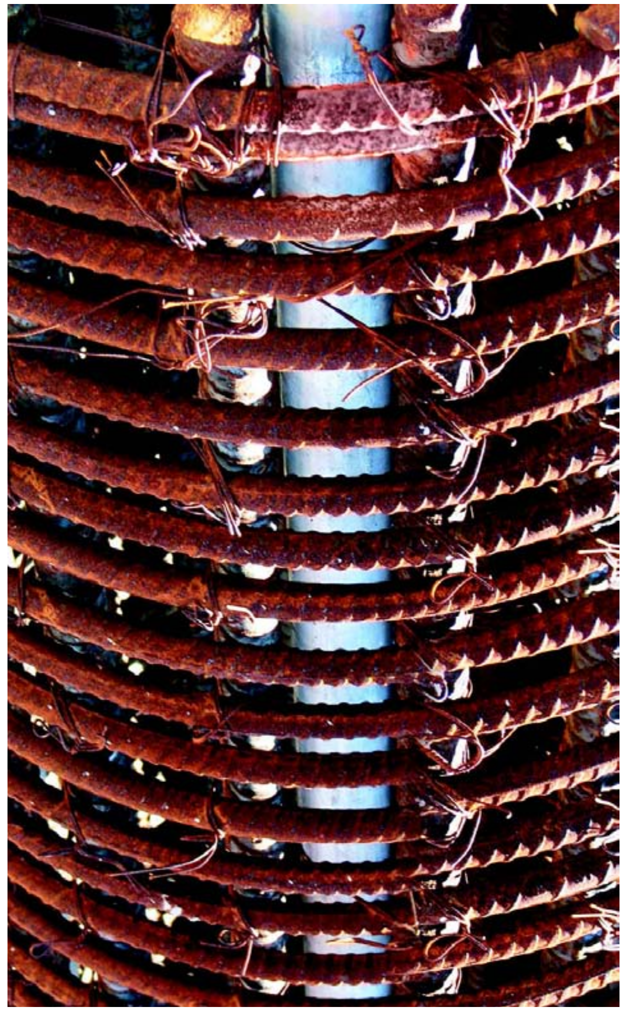
CSL-1 SYSTEM: Includes components shown above

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

DATA REDUCTION

PROCESSING TECHNIQUES

The collected data from the CT measurements between tubes for individual tube pairs are saved as a single data file. However, data collected at each receiver depth within a tube pair are saved in their own tomography (.tom) files. The file is scanned in the CSL2 software to determine first wave arrival times and energy levels at all depths. The CT logs within CSL2 show both the arrival time (or velocity) and signal energy vs. depth. These files are then imported into the GeoTomCG® tomography software where a model file (2-D slice) can be created. Using the Slicer Dicer® software within GeoTomCG® allows the user to display an inverted tomography set with a full 3-D visualization effect.



INTERPRETATION OF DATA

In uniform, good quality concrete, the velocities displayed by the Slicer Dicer® software will be equal to each other. Any defects will show up in the 3-D plot as slower velocities thus allowing them to be easily pinpointed by removing the higher velocity (good quality) sections of the shaft from the plot. This visualization allows for easy determination of the volume and location of the suspected defect.

EFFECTIVENESS

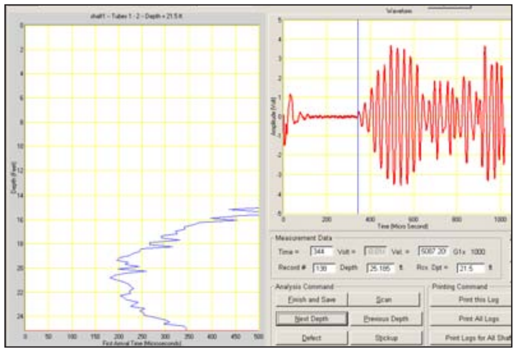
The access tubes must be installed prior to concrete placement to perform CSL tests. For existing shafts or other concrete members, coreholes or drill holes must be drilled to allow access for the source and receiver hydrophones. CSL is best used for quality assurance. Tubes must be bonded to the concrete 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.

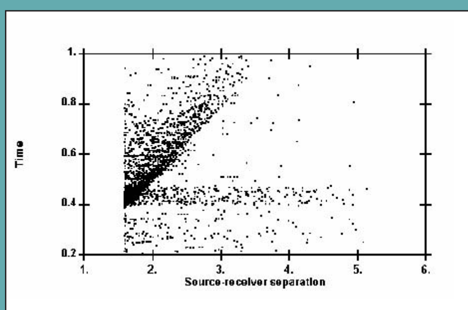
In areas where defects are identified by preliminary testing such as Crosshole Sonic Logging (CSL), the CT method proves to be a very useful tool in accurately characterizing the defects. Using the data from these preliminary tests allows the CT method to achieve a far greater level of detail than any other method, such as coring, thus allowing one to more accurately determine the volume of a suspected defect.

EXAMPLE RESULTS

CSL2 SOFTWARE - CT LOG

The figure at right shows the data collected from one receiver depth. The record log shows first arrival times and signal amplitudes.



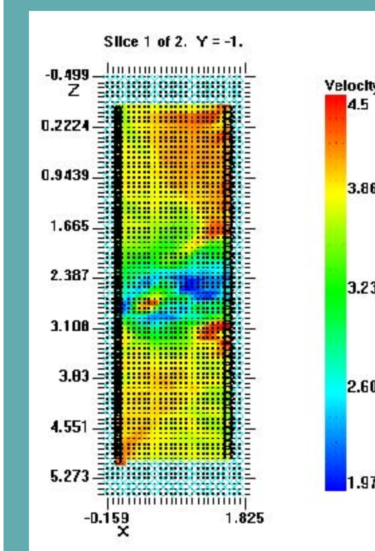


GEOTOMCG® DATA PLOT

The image to the left displays a time vs. source-receiver distance plot which allows the user to check the quality of the data.

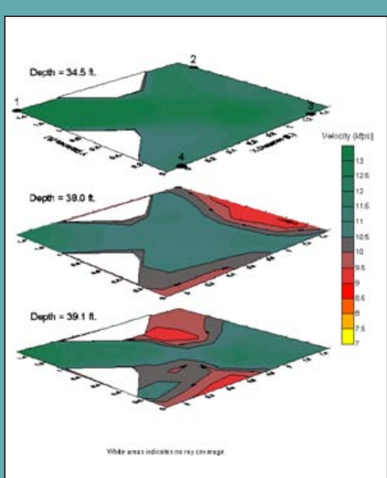
GEOTOMCG® 2-D SLICE

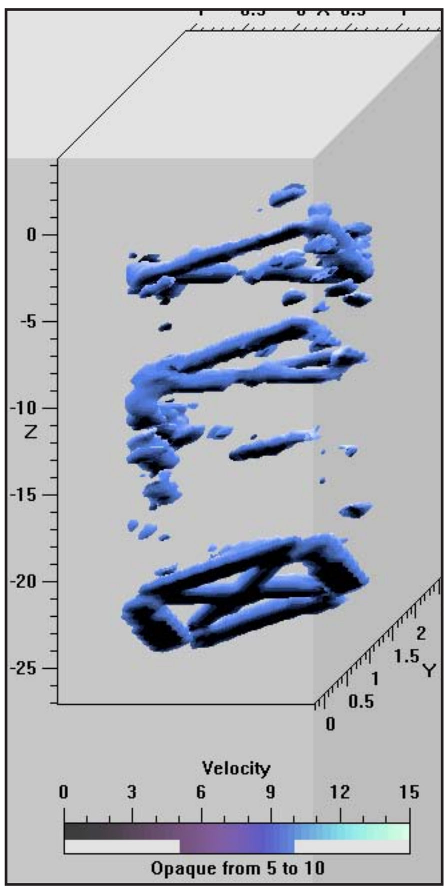
The image below displays a 2-D "slice" of data from a signal tube pair. Different colors show different velocities. Defect zones are depicted by lower velocity colors



GEOTOMCG® 2-D SLICE

Displays several 2-D horizontal slices of data. Note that red colors indicate areas of low velocity and therefore low strength.





SLICER DICER® 3-D VISUALIZATION

Image at left shows a 3-D visualization where the higher velocity sections of the shaft have been removed leaving only the lower velocity areas for easy viewing of defects.

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REFERENCES

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