DID YOU KNOW:
Cross Hole Sonic Logging is standardized by ASTM D6760.

Pile Dynamics, Inc.

GRL engineers, inc.
Dynamic Measurements and Analyses

Criteria for Evaluating CSL Data

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Cross Hole Sonic Logging (CSL) evaluates the concrete quality and construction adequacy of drilled shafts. CSL may identify poor quality concrete due to mixing with drilling slurry, honeycombing, necking, soil intrusions, and soft toe conditions.

CSL is performed on drilled shafts built with access tubes by lowering a transmitter into one access tube while simultaneously lowering a receiver into a second tube. The transmitter generates ultrasonic pulses that travel through the concrete to the receiver. Received signals are processed and displayed by CSL equipment such as Pile Dynamics' Cross-Hole Analyzer, and evaluated by a test engineer. The test generates shaft profiles and is repeated for each pair of tubes.

The most common criterion for evaluating CSL data in the USA is the First Arrival Time (FAT). FAT is defined as the time elapsed between when the signal is generated and when it is first sensed by the receiver. The concrete wave speed is calculated by dividing the distance between tubes by FAT. A higher than expected (or delayed) FAT results in a lower concrete wave speed. Concrete wave speed is related to concrete quality.

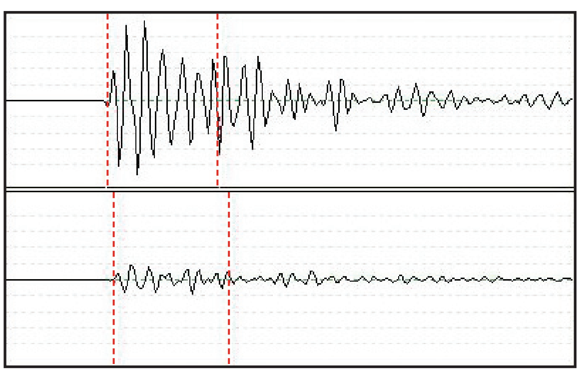

Figure 1: Signal from location with good concrete (top) and signal from location of known defect at 5 m depth (bottom).

One problem with using only FAT as a method of interpretation is demonstrated in Figures 1 and 2, from a 12m long shaft purposely built with a defect at 5 m. Figure 1 shows the received signals versus time (time 0 corresponds to the time when the signal is generated by the transmitter) at two different depths. While both plots show well defined, and nearly identical, FATs (first dotted red line) the signal on the bottom has significantly lower strength (or "energy", indicated by the signal amplitude). This is an indication of an interruption on the transmission path or of transmission through contaminated concrete.

An improved drilled shaft evaluation criterion was proposed for use in the USA by Likins et al (2007). Similar to French and Chinese standards, it considers not only FAT, but also the reduction in signal energy which, like FAT, is related to the quality of the concrete between transmitter and receiver. Once the FAT increase and signal energy reduction have been determined for the entire profile, the shaft may be evaluated according to the following criterion:

Evaluation	FAT increase		Energy reduction
(G) Good	0 to 10%	**and**	< 6 dB
(Q) Questionable	11 to 20%	**or**	6 to 9 dB
(P/F) Poor/Flaw	21 to 30%	**or**	9 to 12 dB
(P/D) Poor/Defect	> 31%	**or**	> 12 dB

This evaluation builds on a FAT based defect classification used by several USA Departments of Transportation. It refines that classification by distinguishing Flaws from more serious Defects, and it adds a quantitative Energy Reduction criterion to the evaluation.

Likins et al (2007) recommended that Flaws (P/F) be addressed if present in more than half of the profiles, while Defects (P/D) be addressed if present in two or more profiles. Addressing a flaw or defect should include tomography evaluation and could require excavation (if near the top of the shaft), core drilling, or pressure grouting. Defects or flaws present over the entire cross section usually require repair or shaft replacement.

Figure 2 further exemplifies the proposed evaluation criterion. The bold line on the left side of the figure plots FAT, and the thin line energy, both versus depth. While there is little FAT variation - less than 10% - over the entire length of the shaft, the energy decreases by 8.4dB at 5 m (red horizontal line). The waterfall diagram on the right side of the figure confirms the existence of a signal of low energy at about 5 m depth. A FAT-only criterion would evaluate this shaft as "Good". Under the proposed FAT and Energy based criterion, however, the 8.4 dB energy reduction places this knowingly defective shaft at the upper end of the "Questionable" evaluation, closer in fact to an evaluation of Poor/Flaw.

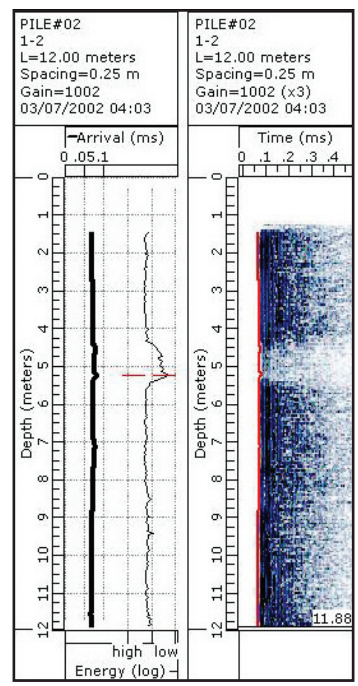

Figure 2: output of a CSL test between tubes 1 and 2 of the same 12m long defective at 5m shaft.

By contributing to a more positive identification of defects, this new criterion enhances CSL based quality control practices in drilled shaft construction.

Reference: Likins, G. E., Rausche, F., Webster, K., Klesney, A., February, 2007. Defect Analysis for CSL Testing. Geo-Denver 2007 New Peaks in Geotechnics: Denver, CO. (CD-ROM). Available at www.pile.com/reference