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DEEP FOUNDATIONS: BELIEVING WITHOUT SEEING

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As we all know, deep foundations are expensive. And if you pay a lot of money, you expect the highest quality foundation. Ironically, no matter how much you pay for your foundations, you don't get to see what the final product looks like... To an increasing number of owners, engineers and contractors, the answer is to rely on quality assurance methods. When judiciously chosen and properly applied, these methods save time, money and frustration:

The low strain **PIT** method utilizes one-dimensional wave propagation. A small hand held hammer impacts the top of the shaft, and an accelerometer measures the ensuing shaft top motion. The motion record is then analyzed for relevant reflections from the pile toe or major shaft anomalies. A record that shows a clear reflection from the pile toe and no major reflections from intermediate points indicates a sound shaft. Generally, shafts that contain major anomalies show a significant wave reflection from a shorter length and no toe reflection.

PIT can be applied to practically every pile on site due to its low cost and minimal pile preparation. It is often the first alternative when questions of pile acceptability arise after the installation is completed, or if lateral movements from slope failure, lateral impacts or excavations were experienced. PIT is useful for selecting piles for further testing. If it determines obviously good or obviously bad piles, the solution is clear. For tests indicating marginal conditions further testing of another type may be desired. Pile integrity testing has been assigned ASTM standard D5882.

Pile integrity evaluation may also be performed using the high strain method with the Pile Driving Analyzer® (**PDA**). Pile force and velocity are measured during the impact of a pile driving hammer or a large drop weight. Although this test method often gives a better defined integrity evaluation than the low strain PIT method, it requires larger and more expensive equipment and therefore costs significantly more to perform. This test method has the advantage of also evaluating hammer performance (by measuring transferred energy), pile compressive and tension stresses, and ultimate pile capacity. High strain testing using the Pile Driving Analyzer has ASTM standard D4945.

CSL (Cross Hole Sonic Logger) requires that tubes be installed in the shaft prior to concreting. After the concrete has hardened, a pulse transmitter and a receiver are lowered into neighboring tubes. The arrival time and magnitude of the received wave are a measure of the concrete quality and homogeneity. Measurements are typically done at 1 or 2 inch intervals. An ASTM committee is presently preparing a Crosshole Sonic Logging standard.

The Pile Installation Recorder™ for Augercast (or CFA) piles, called **PIR-A**, helps prevent problems before they actually develop. It records grout or concrete pumped versus depth which, according to the Deep Foundations Institute, is the most important parameter for good augercast pile integrity. If the volume pumped is less than required, a graphic display alerts the operator, so that an immediate corrective action can be taken while the grout is fluid. Optional pressure sensors can measure pressure in the grout line or rig hydraulics (proportional to the drilling torque). The PIR-A has recently won the Ohio New Product Award which is given by the Ohio Society of Professional Engineers to acknowledge engineering and technology innovations.

Obviously, all methods have strengths and weaknesses. Table 1 presents a summary.

Because of uncertainties due to the construction methods, these non-destructive integrity test methods have proven to be indispensable tools to evaluate the integrity of drilled shafts, augercast piles and driven piles. With the PIR-A equipment, more confidence can be gained in the quality of augercast piles during construction. The need for additional integrity testing may therefore be reduced. Of course, PIT is still useful for integrity evaluation of augercast piles after excavation, or for any pile with excessive lateral movement, or to test a percentage of randomly selected production piles for additional quality assurance.

Method	Benefits ☺	Limitations ☹
PIT	No special preparation needed; quick, simple and inexpensive; yields information on major variations of quality or size.	Test interpretation limited if toe cannot be seen due to excess length or multiple section changes.
PDA	Structural and geotechnical evaluation; yields bearing capacity and therefore overall suitability.	Requires substantial impact mass.
CSL	Works on drilled shafts of unlimited size or length. Clear identification of defects even at great depth.	Inspection tubes installed during shaft construction. Tube debonding sometimes prevents wave transmission; important to wait for concrete hardening. Not for most driven piles.
PIR-A	Works during construction thus can be used to reduce waste of grout or to detect problems while grout is fluid. No length limitation.	Limited to monitoring augercast (CFA) type piles during installation.

Table 1

No matter which method of quality assurance is used, it is important that all parties involved in the construction process have a clear understanding of what to do should a problem be uncovered. For example, one course of action may be to core drill a shaft when a problem is detected and use the hole for injection of grout to remedy the foundation. Alternatively, the PDA method may be used on questionable piles detected by PIT or CSL to check their performance under realistic loads.

Quality assurance methods may help the project owners get their money's worth and the engineer sleep well at night. However, they must be used with caution. These methods require experience for data collection and even more so for data interpretation. In order for the construction industry to believe in the foundations it cannot see, quality assurance procedures must be in the right hands. Professional engineers with specialized training in this field should always review the test results.