Non-destructive Testing for Integrity Testing of Concrete Piles

Shedding light on the hidden parts of concrete piles

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The inspection and evaluation of concrete piles and deep foundations are often challenging, mainly because these elements are not easily accessible for visual inspection. The process of quality control and quality assurance for this group of elements is very much through indirect measurement of other parameters, such as resistance of a pile to driving or drilling. In other words, the process of quality control in pile construction is somewhat blind and comes down to the inspector's experience and pile installer's know-how. Non-destructive testing (NDT) and evaluation can shed light on this hidden part of concrete piles.

Inconsistency in pile materials, structural deficiencies and damages during pile construction or driving can affect the performance of these elements. Depending on pile materials, and how the pile system transfers the load to the subsoils, deficiencies in materials, design, construction and/or installation can reduce the load bearing capacity of piles. An effective transmission of superstructure loads is performed when no major issue accompanies the piles such as cracks, voids, soil intrusion or necking occurs. The consequence of such deficiencies might be challenging when a superstructure stands on weak piles and deep foundations. This might vary from partial settlement to significant damage or

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collapse of the superstructure. The consistency and integrity of piles and deep foundations need to be regularly evaluated from the beginning.

Over the past two decades, various NDT solutions have been developed for different applications in geotechnical engineering. The article will briefly discuss three NDT methods that are widely used for evaluating the integrity of concrete piles and deep foundations.

NDT of piles and foundations

As discussed earlier, visual examination of piles is nearly impossible, due to the fact that a large section of pile systems is often buried under ground. Whether it is a driven concrete pile or bored cast-in-place pile, contractors and geotechnical engineers are looking for methods to quantitatively assess the load bearing capacity of piles, as well as quality and integrity.

NDT techniques provide a practical and convenient solution for testing piles and deep foundations (2010). In contrast to traditional intrusive methods such as drilling and coring, NDT methods are relatively fast, repeatable and accurate (when conducted properly), which makes them very popular (ACI 228.2R). Different NDT solutions have been developed and commercialized over the years.

Integrity evaluation is a constant challenge in concrete pile construction. Cast-in-place piles can suffer from deficiencies in materials and pour quality, while precast concrete piles may experience damages during transportation and installation. NDT methods can be used to evaluate the integrity and consistency of piles. This article presents and briefly discusses three different methods of integrity evaluation:

- Low strain impact integrity testing (ASTM D5882)
- Ultrasonic cross hole testing (ASTM D6760) for piles with an accessible tip
- Parallel seismic (ACI 228.2R) for piles covered up by a pile-cap

Low strain impact integrity testing

Low strain impact integrity testing provides acceleration or velocity data that can be used to assess the integrity and consistency of piles. The test is also applicable to long structural elements that function in a manner similar to any deep foundation unit – such as driven piles, augured piles or drilled shafts.

A hand-held hammer – or instrumented hammer – is used to impact the pile head. The impact should be applied axially and perpendicularly to the pile head surface. A motion transducer, capable of detecting and recording the reflected echoes, is placed over the pile head. The distance between the impact location and the sensor should be no larger than 300 mm. It is recommended to collect a minimum of 10 measurements for every single pile to have a better understanding of the pile's integrity problems.

The test results can be used to evaluate the pile cross-sectional area and length, determining the integrity and continuity of piles and assessing the consistency of pile materials. However, this method has certain inherent limitations: pile integrity testing does not provide any information on the load bearing capacity of piles. This test cannot be conducted over pile caps and is not reliable for evaluation of unfilled steel pipe piles, H-piles or steel sheet piles. In some cases, it is difficult to distinguish the soil response and the pile toe response.

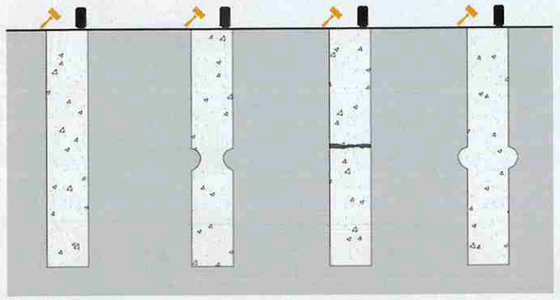

Figure 1

OR

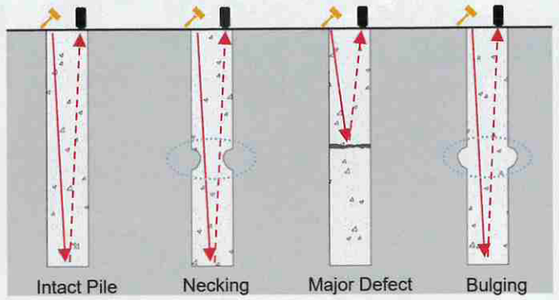

Figure 2

Ultrasonic cross hole testing

Ultrasonic cross hole testing provides information about the homogeneity and integrity of concrete. This method is used to identify the regions of poor quality concrete and overcomes the limitation of low strain impact integrity testing.

This method requires a number of vertical holes (tubes) made during concrete placement using parallel metal or plastic tubes. Depending on the pile diameter, the number and configuration of these holes can be determined (see ASTM D6760). The holes should be filled with water. An acoustic wave emitter transducer is lowered to the bottom of one tube while another acoustic wave receiving transducer is placed at the bottom of second tube. Both transducers are pulled upward at the same rate. The signals from the transmitter and receiver probes and the depth-measuring device are transmitted to a field computerized apparatus for recording, processing and displaying the data in the form of an ultrasonic profile. This profile is used for the integrity evaluation of the pile along the pile length (Fig. 2).

The signals are analyzed to determine the location of defects, as well as identifying the extent of the defects. The test can be expanded using several holes, enabling a full cross section analysis of the pile. Ultrasonic cross hole testing is an ideal test when evaluating large diameter piles.

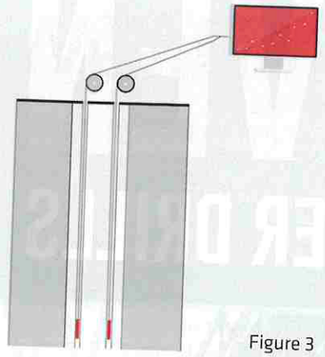

Figure 3

Parallel seismic testing

The low strain impact integrity and ultrasonic cross hole testing methods need clear access to the tip of the pile. The parallel seismic method is mostly developed for integrity evaluation of concrete piles for existing structures, as the superstructure has been built upon the foundation. For integrity evaluation, a borehole is drilled close and parallel to the pile. Boreholes are lined with a plastic tube and filled with water for coupling between the transducer and the surrounding surface. An acoustic wave receiver is placed at the bottom of the tube, moving upward at a constant speed. The pile-cap is struck by a hand-held hammer. The signals from the receiver probe and the depth-measuring device are recorded and analyzed from the form of an acoustic wave profile. The profile is then used to evaluate the integrity of piles (Fig. 3).

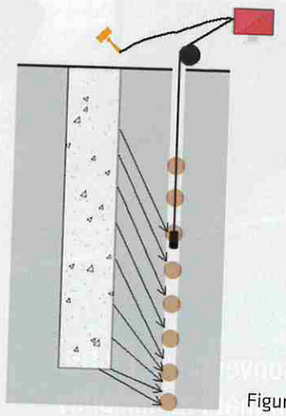

Figure 4

Summary

NDT of piles and deep foundation work is one of the best solutions for evaluating the consistency and integrity of piles. Among existing technologies, techniques based on acoustic wave theory are widely used for integrity assessment. Low strain impact integrity testing and ultrasonic cross hole testing are commonly used for piles and deep foundations when the pile-tip is accessible; parallel seismic testing is mostly recommended for existing and old structures. Selecting the most appropriate technique for every specific project is key to a successful evaluation.

About the authors

Drs. Farid Moradi and Hamed Layssi are co-founders of FPrimeC Solutions Inc. They are passionate entrepreneurs for developing new technology for structural health monitoring purposes.

FPrimeC Solutions Inc. is a technology startup in Canada, developing innovative testing solutions for cost-effective and reliable assessment of infrastructure facilities. Research and development is at the core of FPrimeC business and its identity as a technology company. FPrimeC is committed to bringing leading technologies and making the next generation of testing solutions that help their customers succeed.

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