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DETECTION OF DEFECTS IN BORED PILES BY NON-DESTRUCTIVE METHODS ON LRT CONSTRUCTION SITE

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ABSTRACT: This article presents the detection of defects in bored piles with cross-section $1.2\div 1.5$ m and length $10\div 53$ m. PIT and Cross-hole Sonic Logging (CSL) methods were used to detect defects in piles. These works were carried out in the city of Nur-Sultan on LRT construction site. Integrity inspections performed after installation are often the most reasonable alternative available to assess the pile quality. This paper discusses the similarities and differences, also advantages and disadvantages. Both Cross-hole Sonic logging and impact echo integrity testing indicated defects in several pile. Subsequent coring confirmed these defects. The results of the two test methods are presented and compared with each other.

KEYWORDS: bored pile, defect, Cross-hole Sonic logging, Pile load test, non-destructive method

1. INTRODUCTION

In Nur-Sultan city was constructed the construction public new transport system LRT (Light Railway Transport). LRT is an overhead road with two railway lines. At the first stage of construction included the construction of overhead road (bridge) with 22,4 km length and 18 stations which are under process. The foundation of bridge is the bored piles with cross-section $1.0\div 1.5$ m and length $8\div 55$ m. For boring of soil used a Chinese drilling rigs Zoomlion without casing. To maintain the walls of boreholes in sand and gravel soils to use a polymer slurry. In these conditions, very important to control integrity of concrete body of each bored piles. For checking integrity applying two methods - Low Strain Method (PIT) and Cross-Hole Sonic Logging (CSL).

The results field tests confirm that piles with defects over 20% have a low bearing capacity and are not allowed for exploitation. Details of the observations are discussed below.

2. EXPERIMENTAL DATA OF PIT AND CSL TEST

2.1 Low Strain Method

PIT-QV integrity testing system, manufactured by Pile Dynamics was employed for the integrity test performance. The system measures the wave response of a pile to a force input generated by a small hammer. This wave is reflected by any discontinuities within the pile shaft and the returning waves are detected by means of an accelerometer located at the pile head.

The depth from which these waves are returned is calculated by assuming the propagation velocity of the wave in the pile concrete. This method is normally referred to as the Sonic Echo method. The method can be used to check the depth of both pre-cast and cast-in-situ piles although pre-cast pile tend to have more internal stress due to the piling which



influences the quality of the return signals.

The Seismic echo method of assessing piles is able to analyze the following acoustic anomalies, like: Shaft restrains; Breaks; Cracks; Reductions in section; Zones of poor quality concrete.

For cast in-situ piles or concrete filled pipe piles, the integrity testing cannot be performed sooner than 7 days after casting the concrete or after the concrete achieves at least 75% of its design strength.

2.1.1 Interpretations of test data

Interpretation of the results obtained must take into account the specific pile circumstances, i.e. construction technique and localized soil conditions. For example, if all piles on a given site indicate an anomalous response, it is most likely that this is due to soil conditions or pile construction technique, although it is conceivable, that all the piles are defective. An anomaly does not necessarily indicate a deficiency in the pile, but would certainly merit further investigation to establish the cause of the anomaly. Full interpretation of the signal responses must only be undertaken by fully trained personnel.

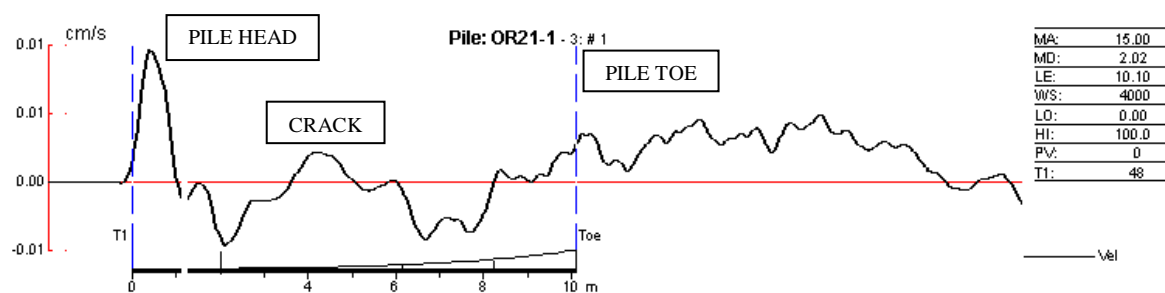


Fig. 1 Measurement signals as displayed in the Pit - W 2009-2 PC software

An assessment by this method can give a rapid and accurate appraisal of pile integrity. An integrity test will indicate when a pile should be investigated further but it cannot give information about any load carrying capacity of the pile.

The results of the PIT will show a graph per pile with the information as shown in the Figure 1 The Measurement signal will be displayed in the Pit-W 2009-2 PC software.

Shaft friction has a strong influence on the pile integrity testing results and has to be taken into account. The signals measured on the pile top are amplified linearly or exponentially to overcome the reduction of the amplitude of the stress wave while traveling to the pile toe and back. In case of unexpected signals, CPT information in the test area will help with processing the data and explain the observed phenomena.

To view the global shape of the signals smoothing is applied. It is taken into account that by smoothing information about discontinuities is lost. For the final interpretation and presentation of the signals, smoothing is reduced to a minimum.

2.2 Cross-Hole Sonic Logging

The work performed on the testing of bored piles by the method of transverse flaw detection using the CHAMP device was carried out in accordance with the procedure described in

standard TB 10218-2008. Pile testing was performed using the instrument: Cross-Hole-Analyzer, model: CHAMP, manufactured by Pile Dynamics Inc, USA.

CSL method is an accurate, cost-effective, and non-destructive that means of investigating the integrity of concrete in drilled shaft foundations. CSL establishes the homogeneity and integrity of concrete in a deep foundation and identifies anomalies, such as voids or soil intrusions, within the structure.

Ultrasonic logging, on the other hand, is intrusive and necessitates the prior installation of access tubes (usually two or more) in the pile. Before the test they have to be filled with water (to obtain good coupling) and two probes are lowered inside two of the tubes. One of these probes is “an emitter” and the other “a receiver” of ultrasonic pulses. Having been lowered to the bottom, the probes are then pulled simultaneously upwards to produce an ultrasonic logging profile. The transmitter produces a series of acoustic waves in all directions. Some of these waves do eventually reach the receiver. The testing instrument then plots the travel time between the tubes versus the depth. As long as this time is fairly constant, it shows that there is no change in concrete quality. If the travel time suddenly increase at any depth may indicate a weakness at this depth. The number of access tubes cast in the pile concrete is a function of the pile diameter, the importance of the pile and, of course, economic consideration. A good rule of thumb is to specify one tube per each 30 cm of pile diameter. For best effect, the tubes should be equally spaced inside the spiral reinforcement and rigidly attached to it by wire or spot welding. Tubes are extended below the reinforcement cage, they have stabilized by suitable steel hoops [1-2].

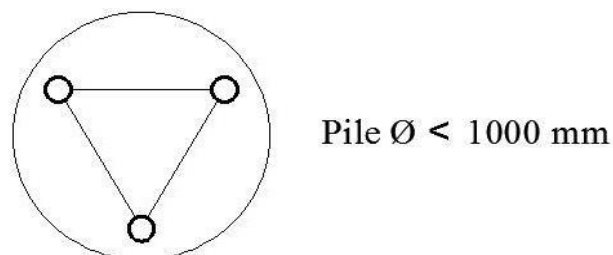


Fig. 2 Typical Access Duct Configuration

Everybody with experience in reinforced concrete construction has encountered columns that, upon dismantling of the forms, exhibit air voids and honeycombing. Although these columns may have been cast with good-quality concrete, in properly assembled forms and with careful vibration, they still exhibit defects. Cast-in-situ piles are also columns, but instead of forms made of wood or metal we have a hole in the ground. This hole may pass through layers of dumped fill, loose sand, organic matter, and ground water, which may be fast flowing or corrosive. Obviously, such conditions are not conducive to a high-quality end product.

2.2.1 Interpretations of test data

Usually the report includes presentation of Cross-Hole Sonic logs for all tested tube pairs including:

- Presentation of the traditional signal peak diagram as a function of time plotted versus depth.
- Computed initial pulse arrival time or pulse wave speed versus depth.
- Computed relative pulse energy or amplitude versus depth.

A Cross-Hole Sonic Logging will be presented for each tube pairs. Defect zones, if any, will be indicated on the logs and their extent and location discussed in the report text. Defect zones are defined by an increase in arrival time of more than 20 percent relative to the arrival time in a nearby zone of good concrete, indicating a lower pulse velocity [3-4]. The same procedure, which is carried out in two dimensions on a single profile can be used in three dimensions for the whole piles.

Testing bored piles using Cross-hole flaw detection at the construction site of the facility: “New transport system of the city of Nur-Sultan. LRT. 1st stage ”(section from the airport to the new railway station), the entry and exit line, foundation OR21 were carried out by KGS-Astana LLP on the instructions of the Branch of China Railway Asia-Europe Construction Investment Co., LTD in the Republic of Kazakhstan. Based on the testing a defect in the body of concrete of working pile number 1 (foundation OR21) was found to be defective at a depth of 3.75-4.75 m. The pile was classified as type III according to the classification of pile integrity, according to standard TV 10218-2008.

The field test result of the integrity of bored pile shows in Table 1 and defects on the pile body as shown in Figure 3.

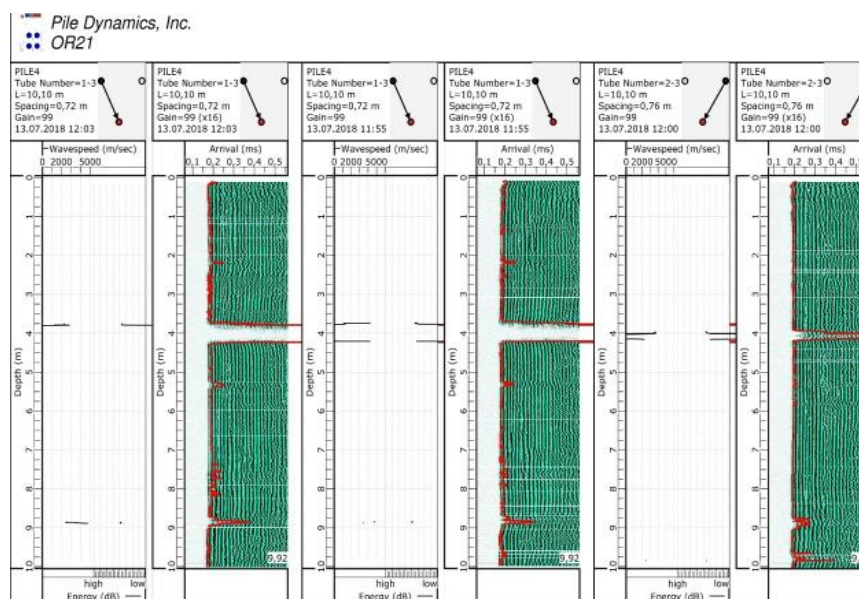


Fig. 3 A visual image of pile body OR21-4 from CSL test

A tomography is a mathematical procedure that is applied to the Cross-hole Sonic Logging (CSL) data, providing the user with a visual image of shaft's internal defects. The procedure involves solving a system of equations based on the first arrival times (FAT) in order to calculate wave speeds at various points within the shaft. Wave speeds of tomography distributed throughout the shaft are directly proportional to density, indicating concrete quality. For visual imaging are used a program PDI-TOMO is an extension of the CHA-W software designed for superior tomographic analysis results from CHAMP data with increased efficiency for the user.

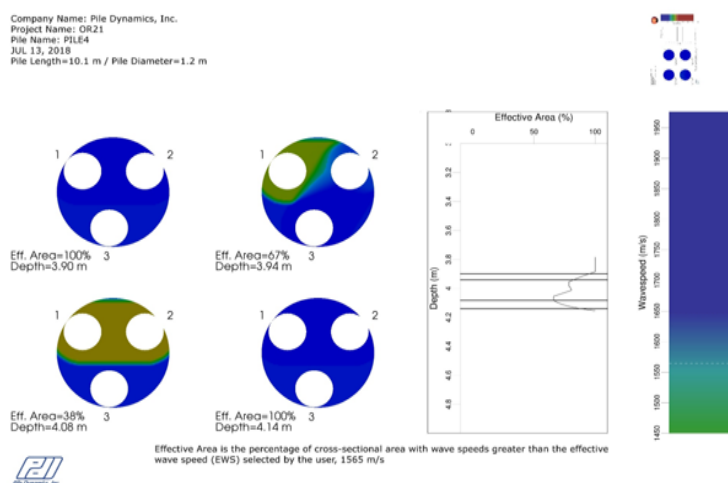


Fig. 4 Horizontal cross-sections of pile in PDI-TOMO software

Table 1 The results of the integrity of bored piles

Number pile	Pile diameter, (m)	Pile length, (m)	Speed of wave, (m/c)	Concrete class	Comments
Station 115-116, OR21-4	1.2	10.1	3200	B35	Anomaly at depth defected 3.75:4.75 m

3. COMPARISON TEST RESULTS OBTAINED BY TWO METHODS

In 2017 at the construction site of LRT in Nur-Sultan city, more than 1800 bored piles were integrity tested by using two methods: 45 % by Cross-Hole Sonic Logging and other 55 % by Low Strait Test. Chinese customer gives a technical assignment for integrity testing piles:

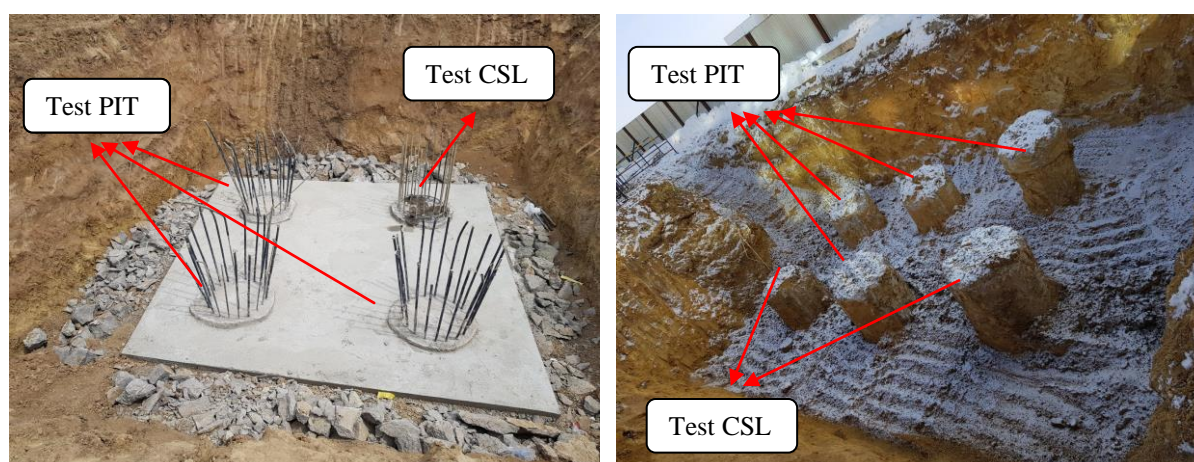


Fig. 5 The location of piles in the pit

- if one foundation of the bridge consists of four bored piles, then one pile is tested by Cross-Hole Sonic Logging (CSL) and other three piles tested by Low Strain Test (PIT).
- if one foundation of the bridge consists of six bored piles, then two pile is tested by Cross-Hole Sonic Logging (CSL) and other four piles tested by Low Strain Test (PIT).

4. CONCLUSION

The Low Strain test is a powerful quality-control tool, not so expensive and need about one minute for application but we must never forget that it is not omnipotent.

Pile testing included obtaining three measurement profiles in depth and processing the results using the specialized program CHA-W and PDI-TOMO, the results of processing the received information are presented in the appendix to this conclusion.

The results of field tests showed that piles with more than 20% defects have a low bearing capacity. Those piles are not approved for exploitation. Piles with defects are classified according to types of integrity of piles according to standard TV 10218-2008.

On the basis of investigations are given following recommendations: if defects of piles founded near top of piles needed to take a coring from pile body and analyze the concrete strength parameters at the laboratory, and secondly, if the length of the piles is deep needed to conduct a static test of pile with defects or improve the group piles by additional pile [6].

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