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RECENT ADVANCES OF CAST-IN-SITU PILE INTEGRITY TEST IN INDONESIA

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Abstract

Deep foundations, especially cast-in-situ piles became popular and key support for most structures in limited land, so as Jakarta. The piles quality became highly dependent on the soil condition and the skill of the contactors. It's underneath the ground and this makes inspection to its quality became much more difficult. There is many methods for inspection, either by destructive method, i.e. coring, to non-destructive method like low strain integrity test (PIT), cross-hole sonic logging (CSL) and latest is thermal integrity profiler (TIP). Some advances in applicating and evaluating the pile integrity discussed here as well as its advantages and limitations.

Keywords : *Integrity Testing; PIT; CSL; TIP; Bored Pile*

Abstrak

Pondasi yang dalam, terutama tiang galian di tempat menjadi populer dan dukungan utama untuk sebagian besar struktur di lahan terbatas, seperti Jakarta. Kualitas tumpukan menjadi sangat tergantung pada kondisi tanah dan keterampilan kontaktor. Itu berada di bawah tanah dan ini membuat pemeriksaan terhadap kualitasnya menjadi jauh lebih sulit. Ada banyak metode untuk inspeksi, baik dengan metode destruktif, yaitu coring, hingga metode non-destruktif seperti uji integritas beban rendah (PIT), penebangan silang sonik (CSL) dan yang terbaru adalah thermal integrity profiler (TIP). Beberapa kemajuan dalam menerapkan dan mengevaluasi integritas tumpukan dibahas di sini serta kelebihan dan keterbatasannya.

Kata kunci : *Pengujian Integritas; PIT; CSL; TIP; Tumpukan Bosan*

Introduction

Integrity testing is a routine works for cast-in-situ piles quality control. There are types of procedure to evaluate, start from the old-fashion way by doing a destructive 'test' where coring conducted directly to the piles and a visual condition can obtain. This method of course very costly and can cover only a small area of the pile itself. Imagine when we have a 2.5 m diameter bored pile or 3 m x 0.8 m barette pile. This lead us to numerous research for pile non-destructive test (NDT) such as determination of pile damage by top measurement introduce by late 70's (Rausche & Goble, 1988), follow with ultrasonic test on early 90's and by early 2000, thermal profiler (Mullins & Kranc, 2004) was introduced.

Literature Review

Low Strain Integrity Test (pulse echo method or pit, pile integrity test)

This test method first use in Europe and USA (Steinbach, et. al., 1975) and since then, became the most popular integrity test all over the world, include in Indonesia. The simplicity in its procedure where it only need a compact field personal computer (PC), accelerometer and hand held hammer (ASTM 4945) makes almost every one in the construction site prefer this test. Test only conducted by struck the pile head with the hand held hammer and wave travelling measured by the accelerometer and recorded with the field PC. Figure 1 present the standard equipment for PIT. Since this NDT known as the first of its kind, people always refer and thought this type of test can do everything and know everything.

Figure 1
PIT Equipments and Test Preparation

Results will present an impact wave and toe reflection at time 2L/c showing pile condition acceptable with assumption of its pile length and wave speed is correct. An early tension reflection with same direction with its impact wave, before time 2L/c indicate a major defect to the piles. Figure 2 shows a sample graph of acceptable and potentially major defect to piles. The first record shows correct wave travelling time for 25 m piles, while the second record shows a tension reflection at about 15 m measured from pile top.

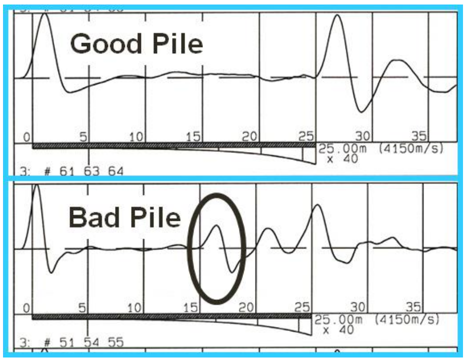

Figure 2
Sample PIT Record for (2) Different Piles. 'Good' Pile (Top Record) and 'Bad' Pile (bottom record)

There is a lot of advantages from this test where it only needs a very compact equipment, a sound concrete pile top surface, and quick application and of course those (3) will lead to cheaper cost. Where there is advantages, of course, there will follow disadvantages with the system. The preparation itself for a sound concrete surface is not as easy as write or talk about it, especially when the pile Cut-Off-Level (COL) located deep below the ground level for the purpose of underground structure such as basement. Small hammer and wave propagation also become challenging when dealing with a very slender piles, high friction soil, multiple defects, and the accuracy of distance of anomaly or pile length caused by assumed wave speed. A very compact equipment and simple interpretation will actually lead us to a superb understanding about its theory or else it will only lead us to garbage output and these means, the result highly depends on the qualified and experienced engineer behind it.

Crosshole Sonic Logging (CSL)

CSL also known as ultrasonic concrete test with requirement of water filled pipes along its full length (ASTM 6760). The test itself somewhat easy enough to conduct where it only needs transmitter and emitter lower down to the bottom of the access pipes and later pull-up simultaneously at about same elevation while the sensors continously send and receive the ultrasonic signal. Some number of pipes required for better result and analysis. Figure 3 shows the test equipment and its test.

Figure 3
CSL Test and Preparation

The result presented the First Arrival Time (FAT) at every 5 cm depth yielding to assessment of concrete quality along pile entire length for every combination of pipes. Analysis of data briefly explain by Likins et al. (2007) where the basic concept came from formula of velocity equal to the distance over time. When constant FAT achieved at the entire pile effective length, pile will consider in good condition, while vice versa when the FAT delayed the pile considered have decreased to its quality.

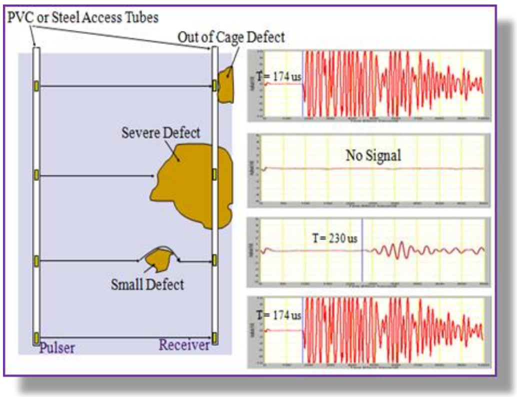

Figure 4
CSL Typical Record at Specific Level (Olson, 2007)

Figure 4 shows typical record of CSL result. Left sketch show ideas of possibly defect location to pile, while right sketch show its typical record. First record (start from bottom to top) shows if there is no defect between the access pipes then the ultrasonic signal will arrive in specific constant time while the next record with small defect will need more time to transmit. When severe defect exist, the signal will delay more and due to its time filter, it will consider 'no signal' or no FAT recorded at the time range. The interesting things come from the results that if the defect located outside the piles reinforcement or outside the pipes path, the ultrasonic signal will give same result as there is no defect. Figure 5 below, shows the CSL final result plotting the FAT over depth. The delay time shows potential defect of pile at certain depth.

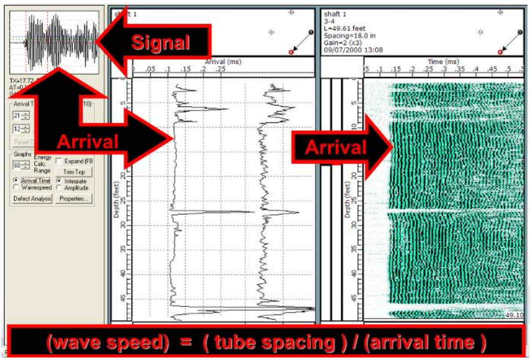

Figure 5
CSL Graph Final Result

Seeing the result, it is clearly shown that CSL could find defect on its direct perimeter path, at all specific depth and quadrant. Other advantages, it is independent to its pile length and surrounding soil. There also a psychology advantage, since the test need some pre-work by installing the access pipes, this will inspire the contractor to work more carefully to get better result.

Yet, the disadvantages always follows; it needs special pre-work for pipes preparation and it will not detect any defect outside its direct path, therefore it can't detect concrete cover problem (or bulge). Other consideration, the CSL needs more then 7 days time after concreting to do the test; and this might significant for the project schedule.

Thermal Integrity Profiler

Mullins & Kranc, (2004) introduce the use of hydration heat to analyze concrete quality at pile length. Its base on assumption that standard heat in piles will depends on pile diameter, soil surround, concrete mix, and time. Average temperature consider proportionally to the effective radius of the piles at any depth, except for the top and bottom where the opening much larger and the heat dissipation goes to its top and bottom section instead its radial area. This measurement will present a thermal profile which can evaluate concrete consistency and anomaly to its shape (both necking and bulging). Typical test equipment for test is illustrated in Figure 6.

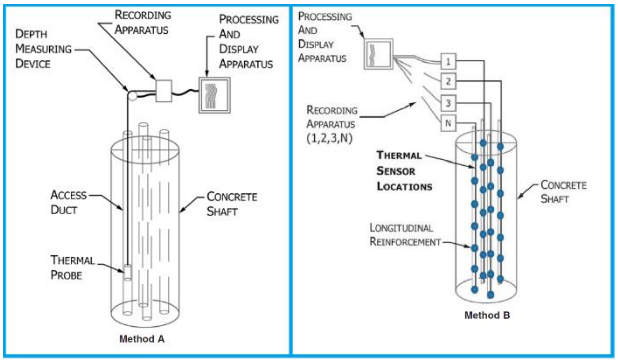

Figure 6
Schematic TIP Equipment & Test (ASTM D 7949)

The test could done by (2) method, using access pipes with probe-depth measuring device and the other cames with signal measuring cable (ASTM D7949). Temperature measure by both system with sensors attach near reinforcement, will be lower then the core due to the heat dissipation. Which means a defect will produce less heat than normal concrete. Vice versa, pile bulge with larger area will produce higher temperature. Figure 7 illustrated the result of TIP test where (5) cables sensor attached to the reinforcement and result showed a relatively good pile with a potentially cage shifting at the depth of 2 m to 9 m. The relatively offset heat between north and south sensors compare to its mean temperature indicate it. While the heat loss at top and bottom cage indicates the high heat dissipation due to the geometry of the pile.

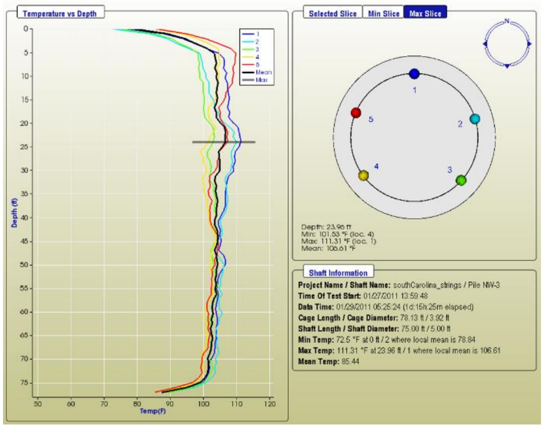

Figure 7
TIP Final Result (PDI, 2011)

The main advantages from TIP is its capability to check for bulge potential without affected by surrounded soil for its entire length. Since the test need heat from concrete hydration, TIP can perform and give result in 24 hours after concreting.

Disadvantages from this test method comes from its equipment. The use of embedded cable made a potential problem where it might damage during the installation or concreting process. When using an access pipes, it needs to empty the access pipes from water and this will also takes a lot of work to vacuum the water out.

Result and Discussion

On February 2016, a bored pile constructed with 120 cm diameter and 32 m effective length. The soil at the project dominated with loose sand with high potential to collapse during construction. After 6.5 hours boring, the shaft checked by ultrasonic drilling monitoring where result showed there is a possibility of soil collapsing at the depth of about 21 m – 23 m depth. Later, concreting continue with overbreak of about 15% of its theoretical volume 36 m3. All integrity test discussed before, performs in the same pile.

TIP measured as soon as the concreting finished, follow by CSL after 3 days when the water inside access pipe already have a stable temperature and PIT as the latest test perform after 8 days from concreting time.Below are discussions for each integrity test performed to the test pile. PIT results (Figure 8) shows a relatively good pile without any anomaly. Impact wave and toe reflection says nothing but good pile.

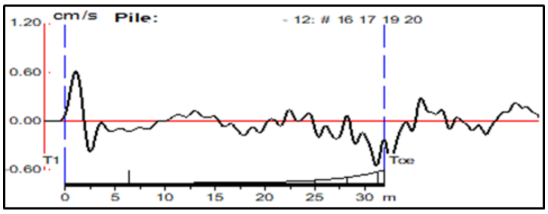

Figure 8
Test Pile PIT Result (Geotech Efathama, 2016)

CSL test also conducted to the same pile and it shows promising pile condition as reported by the PIT test except for potentially soft toe found with 2 m thickness at 1/3 (nearby access pile #03) of the toe area and this is the interesting part, where it found soft toe condition when PIT says nothing.

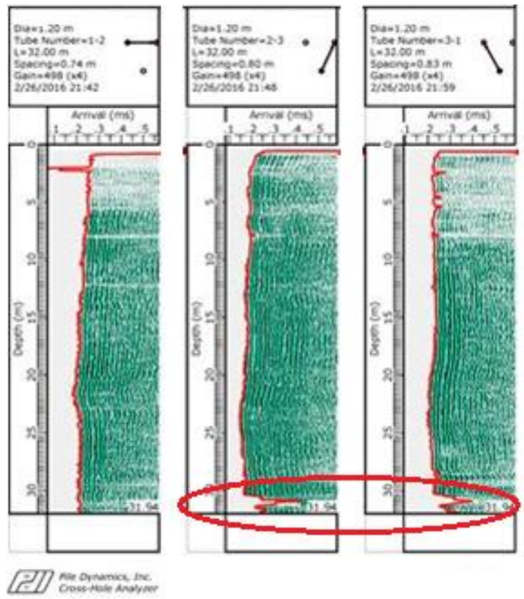

Figure 9
Test Pile CSL Result (Geotech Efathama, 2016)

The last integrity result from TIP showed a confirmed result with CSL where 2 m thickness of potential soft-toe was found. It also found the bulge condition indicated by the previous ultrasonic drilling monitor located at 21 m – 24 (Figure 10).

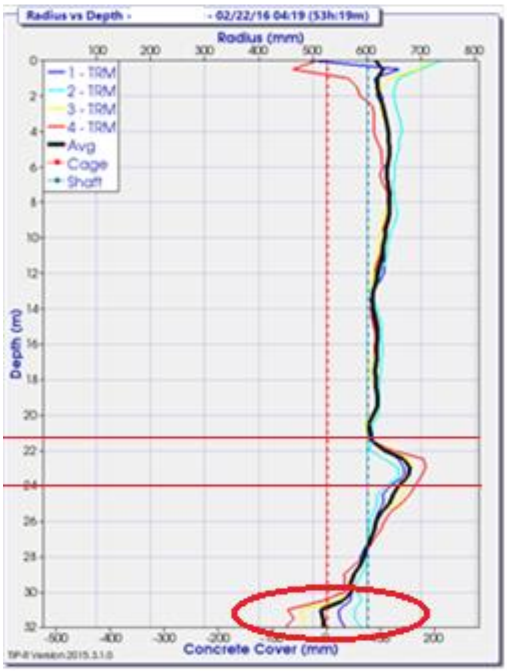

Figure 10
Test Pile TIP Result (Geotech Efathama, 2016)

This result show the capability of recent integrity test to find the bulge potential without the interference of soil resistance around the pile itself.

Conclusion

Recent advances for cast-in-situ integrity test are all effective as a tools for quality assurance however it require good knowledge for interpretation and experienced for conduct and analyze the test result. PIT, which only need minimal pile preparation could perform at almost pile for its low price. But, result highly affected by soil around the shaft, pile head condition, and it can't detect multiple defect in pile.CSL, even with it needs for more preparation works, it can provide direct result for pile entire length without affected by the soil surround. Unfortunately, it can't detect any defect outside the reinforcement and access pipe path.While TIP, could cover the disadvantages of both method, where it could get pile integrity, both necking and bulge, for the entire length without affecting by the surround soil.

It is clearly shown how the advances of integrity test in Jakarta can help to increase construction work quality assurance. Of course, all results shall always interpret by certified and experienced geotechnical engineer to avoid mis-interpretation. Since all integrity test discussed here are NDT, it should be always consider there is a possibility that interpretation was limited or even can't get interpreted due to lack of quality.Knowing the correct test method, its advantages and limitations will lead for better results.

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