International Journal of Advance Research in Science and Engineering
Vol. No.5, Special Issue No. 01, March 2016
www.ijarse.com
IJARSE
ISSN 2319 - 8354

AN INVESTIGATION ON DISTRESSED CONCRETE PILES BY PIT AND THEIR REPAIR AND RETROFITTING

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ABSTRACT

Non-destructive testing (NDT) of piles has gained increased acceptance for various purposes, e.g., quality control/quality assurance, verification of existing conditions, and quantification of dimensions. The correct use of this technique can greatly simplify and expedite investigation, and be economical in addressing concerns or questions on pile conditions. Pile Integrity Testing (PIT) is one of the valuable testing tool of NDT method to locate major defects in concrete piles. It has demonstrated its worth in detecting defective piles when other methods are not practical. It requires no advanced planning and can be applied directly to any concrete pile after installation.This paper presents study on distress detected in concrete piles by use of PIT. Two case studies have been dealt with. In first case study, distress being at shallow depth, repairing methodology was undertaken, while for the other, retrofitting methodology was undertaken considering extent and location of distress.

Keywords: defects, evaluation, Micro piles, PIT, repairs, rehabilitation.

I. INTRODUCTION

Structural engineers are often faced with the question of pile integrity. Difficulties during installation, excavation procedures, slope failures or lateral movements due to accidental impact can create doubt about the integrity of any pile. In some cases lack of inspection on current installations leads the structural or geotechnical engineer to question the foundation adequacy. A process whereby confidence in the quality of the installed pile is expeditiously attained is essential to the contractor to confirm the adequacy of the deployed construction methods and vital to the engineer to verify the competence of the foundation installed. [1] The PIT method can be a valuable tool in rapidly making these evaluations as piles are constructed. Since the testing is quick, simple and can be performed on all piles. The cost per test is also quite reasonable. However, proper application and interpretation is essential to obtain reliable result.

II. PIT METHOD

PIT is a non-destructive testing technique, sometimes referred to as the sonic pulse echo method. It involves applying low strains to a foundation element using light hammer impacts and evaluating the collected force and velocity records to deduce qualitative and quantitative information for the foundation element. Standards

IJARSE
ISSN 2319 - 8354

covering PIT performance include ASTM D5882 (ASTM 2007). PIT development is based on the theory of wave propagation in media. For a linear elastic pile having a length an order of magnitude greater than its width, stress waves travel in the pile at a wave speed, c, such that,

$$c = E / \rho$$

where E is the pile material elastic modulus and ρ is its mass density. The applied force, F, imparted by hammer impact and the particle velocity, v, at any point are related such that,

$$F = Z v$$

Where Z is proportionality constant, also known as impedance; it is a measure of pile resisting change in velocity. Pile impedance for various size piles can be defined as,

$$Z = E A / c$$

Change in impedance is related to change in pile cross-sectional area, A, as well as pile material quality. Increase in pile impedance or soil resistance forces results in a decrease in measured pile top velocity. Conversely, decrease in pile impedance, results in increased velocity. By observing changes in impedance, pile quality can be assessed and dimensions estimated. [2].

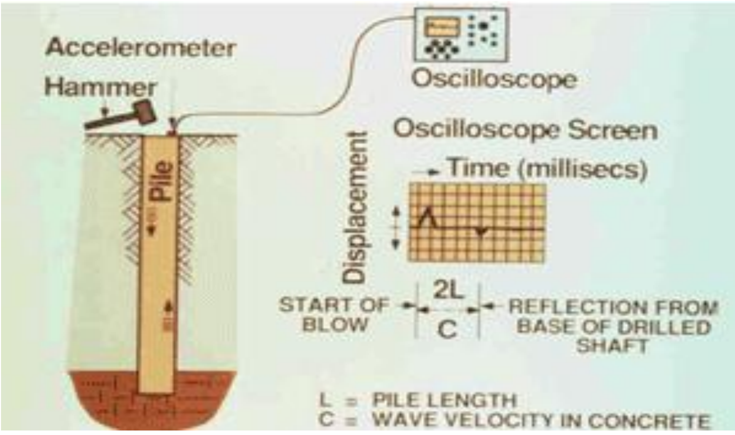
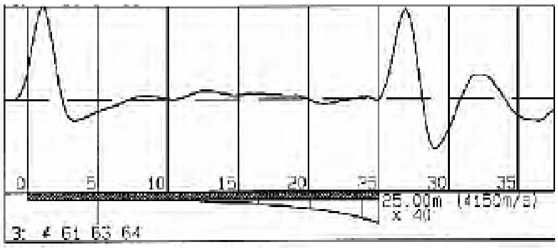
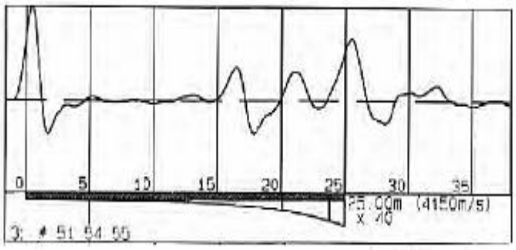


Fig. 1: Schematic View of PIT.

III. TESTING AND INTERPRETATION

Fig. 1, is a schematic view of PIT and its oscilloscope screen, which illustrates the relationship between the variations in the pile impedance, the traveling wave and the reflections recorded at the surface. A reflected tension wave indicates a decrease in impedance. Conversely, a reflected compression wave indicates an increase in impedance. At a time of 2L/C, where L is the pile length, the pile toe response can be identified by observing a reflected tension wave due to softer soil at the tip (signal is in opposite direction of impact pulse analogous to free end conditions) or a reflected compression wave due to denser soil at the pile tip (signal is in same direction as impact pulse analogous to a fixed end condition). One of the most difficult tasks in the interpretation of the velocity record is distinguishing between the velocity reflectors due to pile defects (e.g. crack, neck, void, poor) and velocity reflectors due to soil resistance.[3] Fig. 2, is a typical PIT record for piles, in which, (a), is a pile of sound integrity and (b), is of anomalous pile.





a) Pile considered to be of sound integrity. **b) Pile with anomalous reflections**

Fig. 2: Typical P.I.T Record.

IV. CASE STUDY-A

A 10 yrs Old foundation pile elements, at Pune, tested for their quality, integrity and length using Pile Integrity Test method.

V. DESCRIPTION OF THE STRUCTURE

One Multistoried residential building in Pune was under construction. Pile foundation work was at the verge of end, that, the legacy litigations became the hurdle in further construction work. On resolving the dispute after a period of ten years the owner decided to proceed with the construction work. Piles being exposed for ten years, the doubts regarding the shaft quality and other problems suspected in it propelled the owner, to go for pile assessment work before begin with the superstructure work.

VI. TEST PROGRAM

Pile Integrity Test Method was proposed and performed on the exposed piles to obtain information on pile quality and its length. In all 150 piles were tested. Fig.3. shows pile foundation at Pune site and Fig.4. shows PIT test equipment.

Fig. 3: Pile foundation at Pune Site. **Fig. 4: PIT Test Equipment**

To conduct the test successfully some initial preperations were carried out. Loose, contaminated or damaged concrete was removed by concrete breaker. Fig.5. shows braking of such damaged pile portion. To make a firm contact of accelerometer with concrete pile top, grinding process was carried out and then a thin layer of petro-wax or Vaseline between pile top and accelerometer was applied. Fig.6. shows such pile top grinding process.


Fig. 5: Breaking of damaged pile portion **Fig. 6: Pile top grinding process**

After this preparation, an impact with the hand held hammer is applied. The impact typically generates accelerations in the 10 to 100 g range, pile strains around 10^{-5}, velocities near 30 mm/s, and displacements less than 0.03 mm. Accelerations produced by several hammer blows are integrated and displayed as velocities on the processor's screen. Consistent records are selected, averaged, scaled and then redisplayed. Averaging reinforces the repetitive information from pile or soil effects while reducing random noise effect [4]. Fig. 7. shows Pile Integrity Test in progress. The test has been standardized as per ASlMD-5882 and is also a part of the Draft Indian specification IS: 2911 [5].

Fig. 7: Pile Integrity Test in progress

It is revealed from the PIT results that maximum of the total piles were satisfying the integrity criteria while few of them were found to be defective and three piles shown doubtful status. Test shows the piles have length ranging between 8 m to 9.5m and concrete grade, based on wave speed (3500m/s), would be of M20. Fig. 8. indicates one of the piles satisfying the integrity criteria.

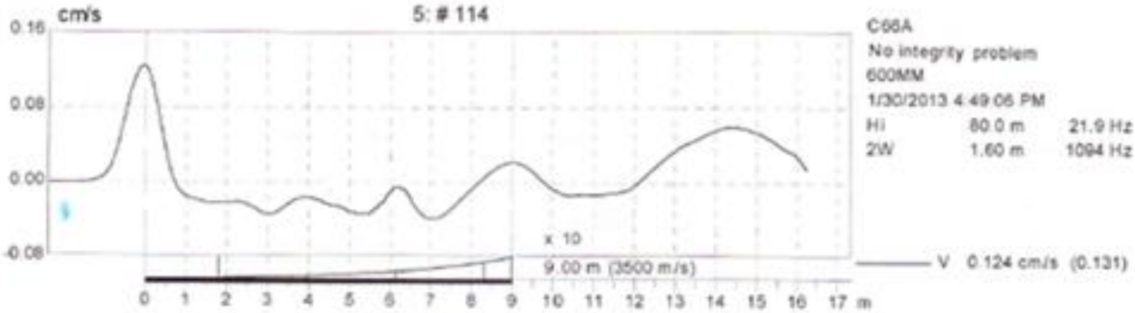


Fig. 8: PIT data for piles satisfying integrity.

Fig.No.9. and 10., both show PIT data from defective piles and indicate impedance change has occurred at 2 to 3m and 4m to 5m respectively. This implies that there is necking, reduction in cross sectional area due to soil inclusion or a crack as a defect in a pile. Fig.No.11 is a view of defective pile after excavation.

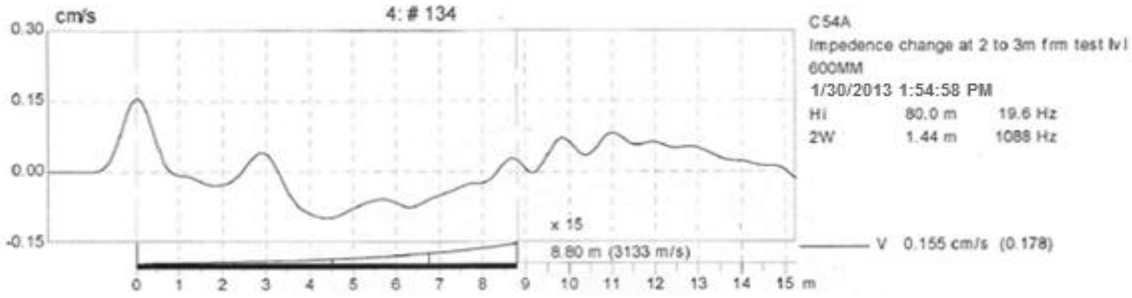


Fig. 9 : PIT Data for defective pile.

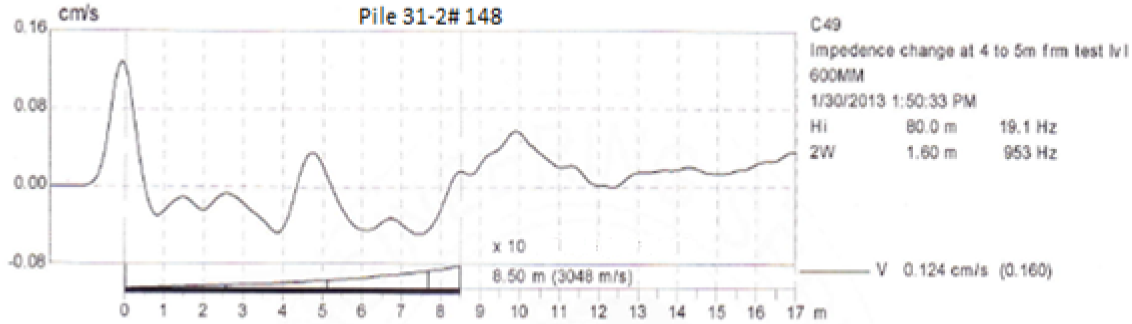


Fig. 10: PIT data for defective pile

Fig. 11: View of defective pile after excavation.

VII. REMEDIAL ACTIONS TO FIX THE DEFECTIVE SHAFTS

The remediation program for defective pile 4#134 is summarized as follows:

1. Excavate the defective pile as indicated by PIT method.
2. Excavation confirmed the defect was nearly at a depth of 4.9 m from top of pile which can be seen in PIT record at about 5m depth.

3. Break and remove the defective zone by breaker in combination with chisel. Clean dust and removing loose material from the defective zone.

Upon the completion of the cutting and breaking, defective zone was water blasted to break up inferior concrete. Fig.No.12, is a view of defective pile ready for repairs.

4. Enclose the defective pile, ready for repairs, with FX-70R Jacket. This jacket **is C**orrosion-Free Structural Repair and Protection System starts with a high-strength fiberglass interlocking jacket. The tongue-and groove seamed 4 mm thick jacket provides a corrosion resistant shell to the repair site, and is UV resistant.[6].
5. Fix the position of jacket properly and check the plumb and pour the FX-70-6 Hydro-Ester Multi-Purpose Marine Epoxy Grout mixed in a proportion 2A:1B, where A and B are the grout chemical components given by manufacture. Fig.No.13 is a view of defective pile after pouring of epoxy grout in an envelope of jacket.[7]

Fig.12. defective pile ready for repairing.

Fig.13. pouring of epoxy grout in an envelope of jacket.

6. It has following features –

- Special blend of "C" component promotes workability; easily pumped or poured.
- High-strength, low absorption, impact-resistant grout with extended pot life.
- Dewatering not required; can be placed underwater.
- Resistant to chemical and aggressive water environments.
- High-strength grout and can be used in dry or wet applications.

7. Seven days after the completion of the grout operation and curing, the defective shafts were retested by PIT.

It is clearly evident from the test result that, the defects in the pile were removed and at the same time concrete quality of the pile was improved. Fig.No.14. is the PIT record of pile after repairs.

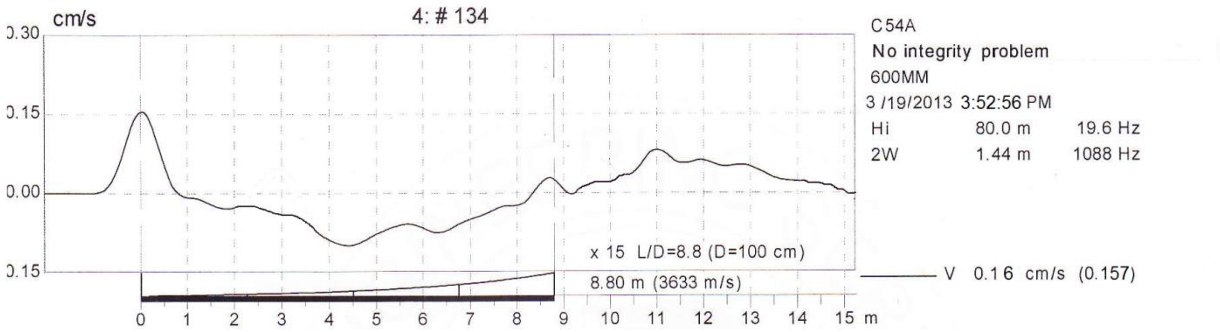


Fig. 14: PIT Record of Pile after Repairs.

VIII. CASE STUDY-B

Same site, as in a case study- A above, is considered for case study 2:

There were five piles showing defects well deep at a depth of 7.5 m to 8m. Fig.10 above, is one of such pile showing distress. It was decided that the rehabilitation of these piles was undertaken on account of defect being at considerable depth and new pile construction is uneconomic. Rehabilitation of these piles was required to avoid considerable future settlements.

Different possible remedy works are reviewed in this section are-

- Core cut Jet Grouting
- Bored piles
- Micro-piles

- **Micro-Pile Installation**

The third considered alternative for the remedy works was the use of the micro-piles system. This system was considered relatively new. It was seen as the most feasible solution. The proposed micro-pile solution is aimed at providing an alternative foundation system to transmit the structural load via the existing pile to a lower bearing stratum and isolate the building structure from the expected settlement. The proposed micro-pile consists of a steel pipe of 100 mm diameter that is lowered down an oversized hole of 150 mm diameter and sufficiently penetrated in the lower sand stratum. Fig.No.15. shows the kind of reinforcing bar used for micro pile.

Fig.15. Dywidag steel reinforcing bar used for micro pile.

Fig.16 : Installed micro pile.

A 30 mm diameter Dywidag steel bar and grout sleeve were placed in the center of the hole before the grout had set. The anchor zone was pressure-grouted through the grout sleeve under a low pressure. The purpose of pressure grouting the pile was to insure that the grout filled all voids and created an effective cylindrical bulb in the anchor zone, resulting in high values of skin friction between the pile and soil. After grouting the required grouted length, the inside part of the steel pipe is filled with the same cement grout. Fig 16 is a view of installed micro pile. At the location of the new column, a new pile cap was poured directly over the micro-piles including existing pile.

IX. ADVANTAGEOUS OF MICRO PILES

They can be installed rapidly and economically with small equipment. It is possible to predict the allowable load capacity of micro-piles by conventional analysis augmented by standard pile load test. Micro piles are used in rehabilitation projects or in new construction with physical constraints, such as limited headroom and restricted access, and in vibration or settlement sensitive areas. They have been installed directly through existing shallow foundation pile caps utilizing old piles. Higher load capacities will further their benefits and enhance their use.[8].

X. SUMMARY AND CONCLUSIONS

Low Strain Pile Integrity Testing has been proved as a powerful tool to evaluate defects and approximate pile lengths. Defects in the pile such as necking, discontinuities, honey-combing can be discovered at an early stage and remedial work undertaken. Testing can be carried out on any accessible pile. The method is quick, easy to perform, economical and reliable. A large number of piles can be tested in a single day. The wave speed measured can give a good indication of the concrete quality. A case history is given for repair of piles by use of fiberglass jacket with epoxy grout is feasible solution, when defect is at shallow level, and rehabilitation by micro pile underpinning the defective pile, of an existing building using small diameter pressure-injected piles, is effective efficient and economical remedy, when pile defects are at deep below the ground.

Many new applications for this advancement in construction techniques can be expected, both in new projects and for rehabilitation work.

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