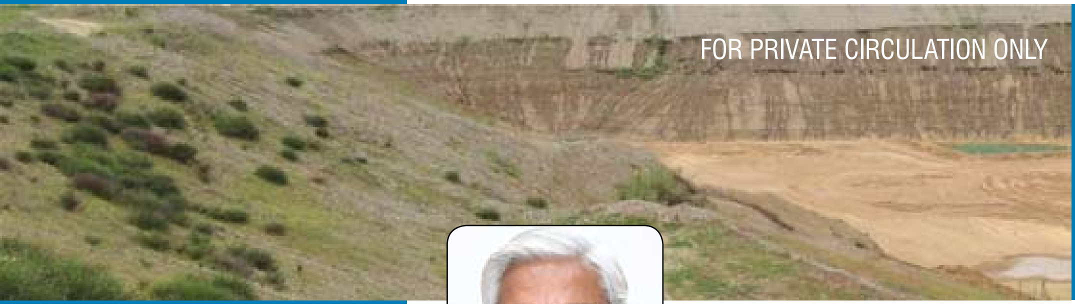
Volume **54**
No.
01
January-March 2022

IGS NEWS

A Bulletin of the Indian Geotechnical Society



Contents

Message from President

Popular Methods for Testing of Pile Foundations - Overview and Case Studies

Summary of Ph.D Theses

Call for Sponsorship

Conference Reports and Chapter News

Call for Entries for Best Ph.D. Thesis

Activity Report - A Short Course on ‘Pile Foundations’

Awards for Professional Practice - Call for Nominations

Young Geotechnical Engineer (YGE) Best Paper Awards-2022

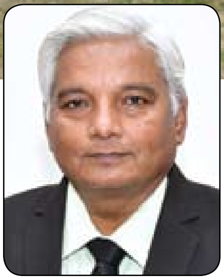
Guidelines for Professional Forum

IGS Election-2022 Schedule

Call for Nominations for IGS Awards

Geotechnical Events Calendar

Welcome to New Members



Message from President

Dear distinguished colleagues,

I hope and wish that all of you and your families are safe and healthy. The IGS local chapters have conducted many activities during this quarter on varied topics including Laboratory Investigations, Field Investigations for Infrastructure Projects, Non Destructive Testing, Geotechnical Earthquake Engineering, Ground Improvement, Rock Engineering, Towards Better Practices in Geotechnical Engineering, Landslides, Geo-environmental, Geothermal Piles and Field Visits to Construction Sites. Some of these programs had the presence of experts from different countries also. A very successful workshop was held on 4th March 2022, by IGS Delhi Chapter in Collaboration with IGS SC 10 Committee, on Cone Penetration Test: Current Practices & Codes. Ms. Madhurima from Bureau of Indian Standards representing CED 43 of BIS graced the occasion. The recommendations of the workshop will be shared with BIS for revision of the code. I am happy to share that out of 48 chapters, most of the chapters are active. I would like to appreciate the SC-6 committee members for all the efforts put in for making this to happen. It is heartening to see that there has been growth in the number of student chapters of IGS. Four chapters have been inaugurated under the aegis of Pune chapter during this quarter. Pune Chapter also organized One Day Seminar to honour very senior and esteemed members of IGS: Dr. B.J. Kasmalkar and Er. V.V. Abhyankar on 11th March 2022. The event was very well attended. On behalf of IGS, I wish to thank IGS chapters in Aurangabad, Baroda, Chandigarh, Coimbatore, Delhi, Goa, Hyderabad, Jabalpur, Kochi, Mumbai, Pune, Roorkee, Vellore and Warangal.

The Student Chapter Activities and Continuing Education Sub-committee (SC: 7) of IGS has organized a short course on “Pile Foundations” between 11th February and 5th March 2022 to impart the field knowledge and technical skills to the geotechnical fraternity, especially young geotechnical engineers, students through the leading practicing engineers and professionals. The short course has covered various topics on pile foundations, such that these concepts supplement the available knowledge in the field of pile foundations. Each lecture was organized in association with different student chapters of IGS local chapters located at Guntur, Hyderabad, Jabalpur, Roorkee, Surat, Surathkal, Tirupati, and Trichy. I would like to thank each individual for their help.

The 230th meeting of the Executive Committee (EC) of the Indian Geotechnical Society was held online on Zoom platform (in virtual mode) on 12th March 2022. Various subcommittees presented the progress. I am happy to inform that the refundable grant up to the maximum amount of Rs. 2 Lakhs will be given to the IGS Local Chapter for organizing IGC and Rs. 30,000/- will be given as non-refundable Grant to IGS Local Chapters for organizing physical activities. You may be aware that the election of office bearers for the two-year term of 2023-2024 is due this year. I would earnestly request the enthusiastic members to take part in the elections and contribute in further strengthening the society. Nominations have also been invited for various awards to be given during IGC 2022 at Kochi. I am sure we will receive lot of nominations for the respective categories.

I would also like to inform you that from 2022, the first article in each issue of IGJ will be a “Feature Article” by Editors’ Choice. This article will be an open access article freely available for download.

We are looking forward to the IGS-Ferroco Terzaghi orations 2020 and 2022 at IIT Bombay on October 02, 2022 and IGC 2022 in December 2022 at Kochi.

At the end, I request the professionals to contribute technical articles to be published in IGS News.

Wishing you all a safe, healthy and fruitful time ahead.

Prof. N.K. Samadhiya

POPULAR METHODS FOR TESTING OF PILE FOUNDATIONS – OVERVIEW AND CASE STUDIES

Ravikiran Vaidya, Principal Engineer
Geo Dynamics, Vadodara – 390023 Email: ravikiran@geodynamics.net

ABSTRACT

Low Strain PileIntegrity testing (LSIT), Cross-hole Sonic Logging testing (CSL) and High Strain Dynamic pile testing (HSDPT) are now routinely conducted on various infrastructure and real estate projects across the country. The trend which started with the "MSRDC 55 Flyovers Scheme" in Mumbai has now been adoptedby almost all major bodies in the country that includes metro rail bodies, NHAI, NTPC, Railways, state and central PWD and majorreal estate projects across the country. These pile testing methods have been valuable tools in ascertaining integrity and capacity of small and large diameter piles. This article tries to highlight the usefulness of these methods to assess the quality of pile foundations at the initial stages of the project. Several case studies are presented in this article,which illustrates how these tests helped the Engineer take quick decisions at the project site, in some cases avoiding a potential catastrophe. The article also presents a case study that shows the inadequacy of ISO/IEC:17025:2017 in ensuring good quality at construction projects.

1. INTRODUCTION

LSIT,CSL and HSDPT are now beingcommonly used for all major projects in the country to provide a quick and reliable information on pile quality and capacity. The practice in early 2000 was to conduct static load testing on 0.5-2% of the piles based on IS:2911 (Part:4). However, the current trend includes conducting either 100% low strain tests or a combination of CSL and LSIT tests at project sites. The use of CSL testing has increased in the recent times and it is observed that CSL is now being used on 50%-100% of the piles for critical projects like sea or river bridges, nuclear projects, etc. High Strain Dynamic testing is now accepted more widely based on the studies presented by the author in various literature and it is commonly used for assessment of load capacity and integrity of working piles at projectsfor loads of 5000T or even more. When properly used, these methods have resulted in early information on pile quality to the contractor, Engineer and Owner to take the right decisions in the interests of the project. The methods have helped modify construction practices and resulted in improved QA/QC at projects which otherwise was not possible two decades ago.

It is important to note that, although the use of these methods has been wide spread, these technologies require experts with good knowledge of wave mechanics, soil structure interaction, piling processes and also high professional integrity in assessment of the available data. In absence of any of these qualities, the methods are prone to misuse, false reporting and may mislead Engineers to accept pile foundations which otherwise were questionable.

2. OVERVIEW OF TEST METHODS

2.1 LOW STRAIN INTEGRITY TESTING

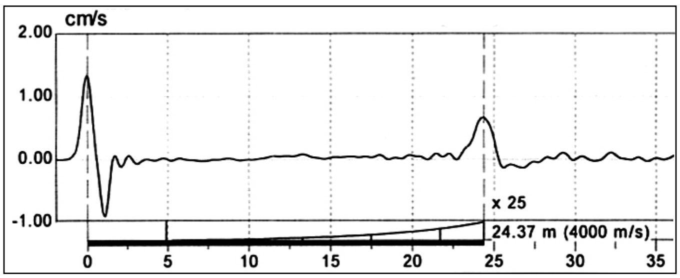
The method is a quick tool to assess pile integrity once a concrete drilled shaft or a bored concrete pile is cast.The test can be conducted after 75% of concrete strength is achieved, requires minimal preparation and generates a cardiogram of pile health. As the method requires minimal advance pile preparation and is cheap, it has become very popular in India and is widely used. The recent IS:14893-2021[1] and the ASTM D5882-2016[2] provide considerable information about the method, data collection, processing and final output from this method.

Although there are several variants of low strain integrity testing, the pulse echo method is the easiest, more reliable and hence most widely used. The process involves impacting the pile with a series of blows and then averaging similar blows (minimum 3 blows) to obtain a record of velocity versus time. Upon impact the p-wave travels down through concrete and reflects back from the pile bottom and also from the pile sides. During its return, it carries reflections not only from concrete but from pile soil interface at the sides, the bottom of the pile and also from any sudden changes in elastic modulus or cross-section area along the pile length. The surface wave carries reflections from pile surface and also from the rebars sticking out of the pile.

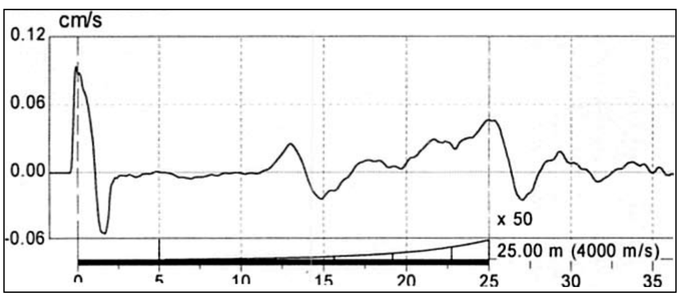
Figure 1 : LSIT data collection in progress

Thus since the wave carries several reflections, it is important to process it before further comparisons with soil, concrete pour card, drilling time and any other event at sites before arriving at a conclusion on pile integrity[3]. Data processing of the graph may include amplification, magnification, filters to remove noise and a check on the pile wave speed before its final presentation[4]. Figure 1 shows a typical data collection at the project site.

Figures 2a and 2b shows a standard data sets for a good and defective pile based on LSIT.



(a) Typical Velocity Trace - Good Pile



(b) Typical Velocity Trace - Damaged Pile

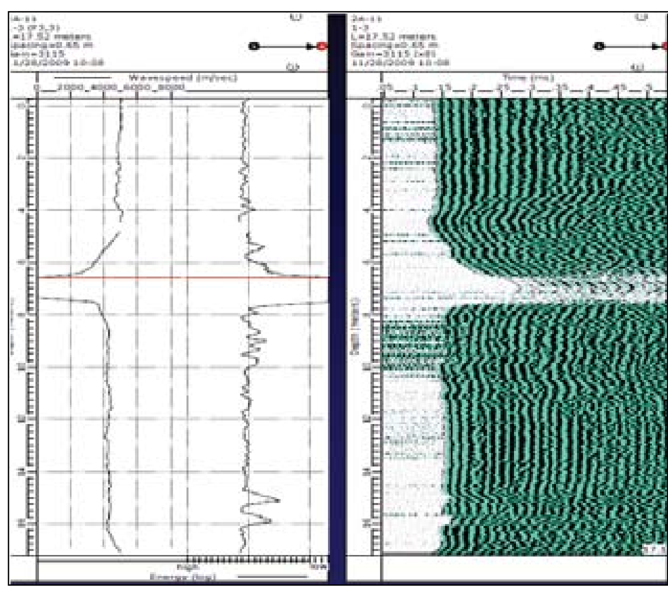
Figure 2 : Low Strain Integrity Testing by Pulse Echo Method

2.2. Cross Hole Sonic Logging

The cross hole sonic logging is a much more refined tool to assess pile integrity for concrete bored piles. The method assesses the integrity between pre-installed pipes along the entire pile length with scans typically obtained at every 50mm along the pile length unlike the low strain which depends on interpretation of the wave form. Scans between two adjoining pair of pipes and between diagonals can then be obtained using a CSL equipment and ultrasonic probes to evaluate pile integrity along the entire length of the pile. The method is standardized as per ASTM D6760-2017 [5] and various codes, specifications worldwide [6]. There is no BIS code currently available although a committee is expected to be formed soon to provide an Indian code for cross hole sonic logging.

The method requires that 38mm-50mm internal diameter mild steel(MS) pipes be installed inside the pile before concreting. To obtain adequate data from the test, in general one MS pipe is installed for every 300mm diameter of pile. Thus 4 pipes are installed for a 1200mm piles, 5 pipes for 1500mm piles and so on. The number of scans will depend on the number of pipes and six scans will be available if four pipes are used. It is important that the pipes are rough from outside, are properly connected to each other on the inside of the cage at equal angles from the centre, have no leakages and are sealed at the top and bottom during installation. Water must be filled inside the pipes before concreting or immediately after concreting within two hours and then the pipes are sealed at top. Data is obtained by lowering transmitter into one pipe and receiver into another pipe along the entire depth and then obtaining scans between two pipes that are embedded within concrete. Figure 3a shows a standard test in progress at a project site and Figure 3b shows a standard output from CSL testing that includes waterfall diagram, first arrival time and the wave speed.

(a) CSL Test in Progress on 3m pile



(b) Typical Output from CSL test

Figure 3 : Cross Hole Sonic Logging Test

The method also requires knowledge of wave propagation, use of proper parameters or settings inside the equipment, and high professional integrity to present factual reports. It is observed that the Engineer to the project or contractors do expect in several cases that the test expert also indicate possible further action to be taken in case defects are reported. A two dimensional tomography on defective piles further provides additional information about the location and extent of defects [7].

2.3. High Strain Dynamic Pile Testing

The method is a replacement of static load testing and hence has been widely used for routine piles and in some cases for initial piles to ascertain the pile capacity and integrity. It is also used when CSL or Low Strain testing shows anomalies to further evaluate and arrive at a conclusive decision on pile acceptability. High Strain dynamic testing is standardized as per ASTM D4945-2017 [8] and various codes worldwide. The BIS also has constituted a committee and the draft version is currently under discussion.

For bored concrete piles or drilled shafts, the method involves impacting the pile top with a hammer whose weight is 1-2% of the test load and 7-10% of the self-weight of the pile, whichever is higher. The purpose of the hammer is to generate a force which is equal to or more than the test load and ensure that there is adequate energy to move the pile or compress the pile. Heavier hammers are often used for longer piles and hammer weights upto 0.7% of the test load have also been used for shorter piles socketed in rock. Hammers upto 50T weight have been used by the author to generate load in excess of 8000T. The measurements are conducted by fixing one or two pairs of strain gages and accelerometers each to the sides of the pile at a distance equal to 1.5 times the pile diameter from the top. The pile head is usually extended with fresh concrete after removing the top laitance and it is allowed to set until its strength is equal to the grade of concrete inside the pile. The sensors are then fixed to the pile. The strains induced by hammer impacts are converted to forces and accelerations are converted to velocity and displacements. Data quality checks [9] need to be considered before data acceptance. The pile capacity (Rs) on field is then computed using the Case Method equation as below.

$$Rs = (1 - Jc)[P_1 + Zv_1/2] + (1 + Jc)[P_2 - Zv_2]/2$$

Here P_1, V_1, P_2, V_2 are forces and velocities measured from strains and accelerations at times T1 and T2 respectively and Jc is the Case Damping factor. Correction to this method maybe required in case the return force is more than the applied force which is likely the case for piles installed into fixed end rock socket or for piles installed into soils with high friction and when sets are nominal. The basic assumption in all the cases is that concrete is an elastic material. The testing is continued till either the target pile capacity is achieved or the pile settles atleast 3mm-4mm per blow for three or more consecutive blows.

The data then available is broadly the field capacity assuming correct Case damping, area, wave speed, elastic modulus etc. A signal matching technique commonly known as CAPWAP™ is then used to further refine the pile capacity for the above parameters and to have an estimate of the capacity in friction and end bearing. The CAPWAP is a complex signal matching technique that needs expertise and experience in understanding pile geotechnical and structural behavior and involves modeling several parameters like damping, quakes, soil plug, tension cracks etc. [10].

The final output from CAPWAP generally requires that the Match Quality is less than 5 unless otherwise justified by valid explanations in very specific cases.

Figure 4 shows a high strain dynamic test in progress on a bored and cast in-situ concrete pile.

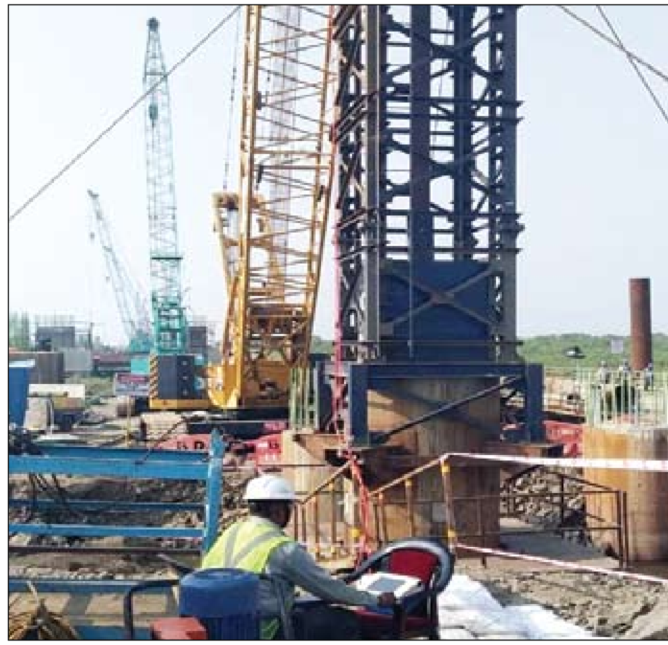


Figure 4 : High Strain Dynamic Pile Test in progress

3. CASE STUDIES

A few selected case studies are presented below to demonstrate their effective use on construction projects.

3.1. CASE STUDY 1: A project in Northern India

At a project site in Northern India 1500mm and 1600mm diameter piles were installed. The depth of the piles ranged from 40m to 48m. The proposed construction method was top down construction and after the piling was completed, piles were partially exposed in order to serve as building columns. As described in geotechnical report, the soil at the site consists of alternating layers of clayey silt and sandy silt up to the exploration depth. A plot indicating variation of SPT along the depth is presented as Figure 5.

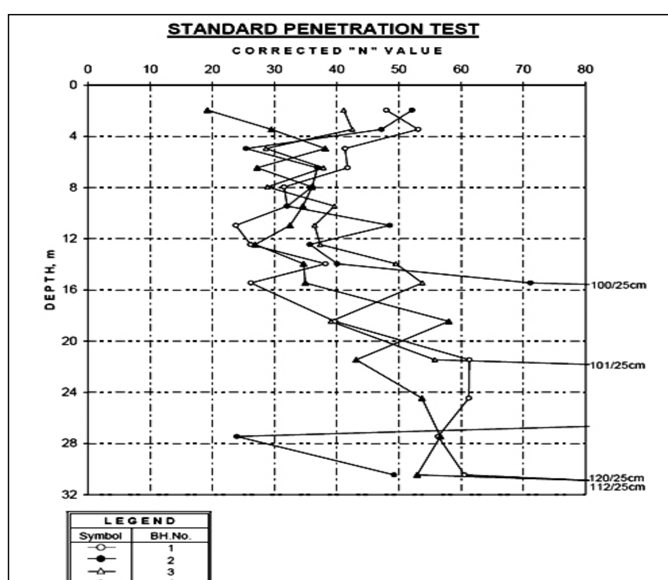


Figure 5 : Variation of SPT along the depth

The safe loads on the piles were estimated to be around 1250 tons and 1425tons for 1500mm and 1600mm piles respectively. After completion of piling, the author was engaged to perform the LSIT on the piles before initiating the excavation. From the LSIT data it was apparent that some of the piles have defects. LSIT output for a typical pile is presented as Figure 6.

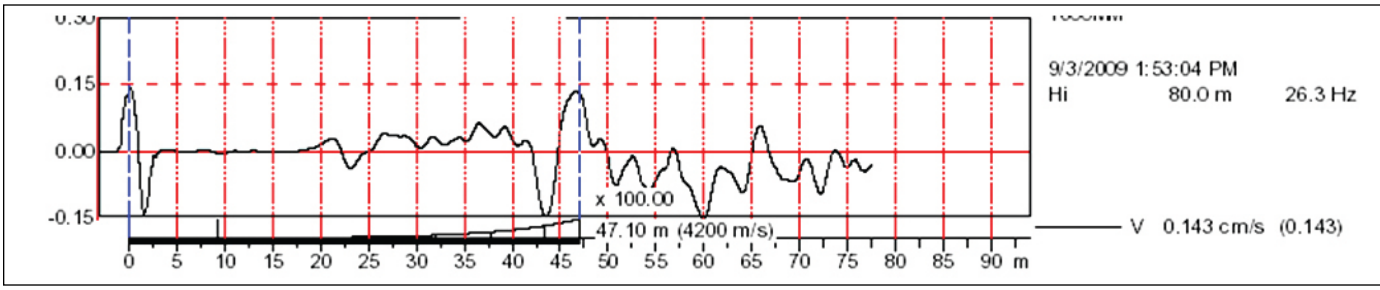


Figure 6 : L LSIT data collected at a site in Northern India

HSDPT was performed on selected piles for load carrying capacity assessment. Two pairs of strain gages and accelerometers were attached to the pile head at 900. A 35 ton hammer was used for the testing. A picture showing HSDPT in progress is presented as Figure 7.

Figure 7 HSDPT in progress using 35 ton hammer

Three piles of 1600mm diameter and two piles of 1500mm diameter were selected for the dynamic testing. All the tested piles were unable to achieve the required test load and settlement of piles were more than 3mm per blow for several consecutive blows indicating piles have reached ultimate capacities [6]. Eventually additional piles were tested. Some of these piles did not achieve even design load. Three piles were identified as having major defect and may have been one of the causes of pile failures. A picture of the excavated pile is presented in Figure 8.

Figure 8 Picture of Defect post LSIT and Excavation

Results of the HSDPT and CAPWAP analysis are summarized in Table 1 to explain the magnitude of the problem. A bi-directional static load test conducted at the project to verify HSDPT also indicated similar results

Table 1: CAPWAP results for the HSDPT performed at a site in Northern India

Sr. No.	Pile Diameter (mm)	Pile Length (m)	Design Load (Tons)	Ultimate Pile Capacity (Tons)	Set (mm)	Defect	Defect Location
1	1500	48	1242	1810	3	Major	Upper 9 m
2	1500	44.5	1242	837	9	Minor	17 m-22 m
3	1600	48	1423	852	4	Major	Upper 12 m
4	1600	48	1423	2064	4	Minor	22 m
5	1600	46	1423	722	6	Major	6 m-12 m

Test load was 1.5 times the design load for working piles

Set is the amount of pile settlement for a blow on which CAPWAP was performed.

One of the possible reasons for defects was construction inadequacy, longer drilling times and issues with tremie concrete that lead to pile failures. Since the number of piles was limited at the project and the authors only got involved at the end of piling, modification to piling and concreting processes was not possible.

3.2. CASE STUDY 2 : A project for a High Rise Tower on Rock Socketed Piles

For a major multi-storey tower project in Mumbai, rock socketed piles were proposed for the construction. The site consists of shallow rock (basalt) which was varying significantly across the site. The top of rock was varying from 4.5m to 10m. The upper soil consists of filled up material up to 2-3m followed by silty sand of varying consistency upto top of the rock. A subsurface profile is presented as Figure 9.

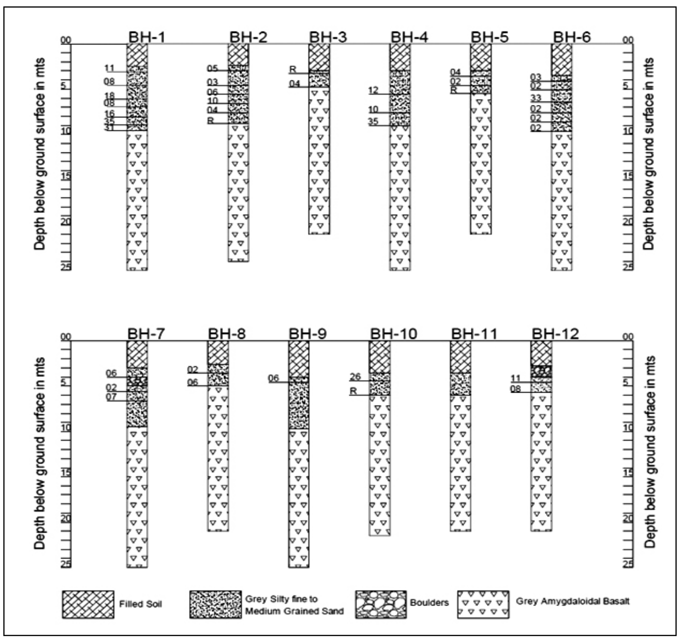


Figure 9 : Subsurface profile – A site in Mumbai

Reinforced concrete bored and cast in-situ piles with rock socket and having diameter of 750mm and a design load of 280 tons were installed at the site. The lengths of piles were varying significantly due to variation in the depth of rock. Thus the contractor had to be careful while drilling and ensure he had terminated the piles into the correct stratum.

LSIT was conducted on these piles and several piles indicated possible soft toe condition. Graphical output for two such piles is presented as Figure 10indicating a toe response not in rock.

Note that soft toe identification can be difficult and it requires site specific calibration, knowledge of local geology, construction practices etc. In addition, some of the piles were also reported as short and few piles also seemed to have defects.

After retests and several discussions, it was agreed by all the stakeholders viz. contractor, consultant and owner to conduct HSDPT on 24 piles that included both acceptable and questionable piles to ensure validation of defects, soft toe conditions and also to have estimate of in-situ pile capacity. The high strain dynamic tests showed very low capacity and very high settlements for most of the soft toe piles and the prediction of soft toe was accurate to the extent of 90%. Table 2 presents HSDPT test results of few piles. As evident the capacity was much lower than the required test load of 420T (280T x 1.5 times = 420T) for working piles.

Table 2: HSDPT findings on piles classified as soft toe for Mumbai Project

Pile Length (m)	Pile Capacity (Tons)	Set (mm)
7.8	124	5
8.5	52	8
7.4	99	14
8.2	188	10
9.6	134	10
5.2	153	12

After HSDPT, coring of two piles through its length revealed sand at the pile bottom conforming soft material at toe. Several theories were floated to explain pile failure including a doctoral thesis that claimed Rhyzner Index which causes sudden corrosion in piles due to abrasive and sewage water [11]. The findings were disputed by the author and the geotechnical engineer to the project.

Later new piles were installed at the same jobsite with proper care. It was ensured that the bore was not left open for more than 30 minutes after flushing, the drilling was into proper rock sockets with samples collected at every stage. Proper flushing was done before and after cage lowering to ensure no soft toe conditions. Due to space constraints, the new piles then were designed to 440T of safe load instead of 280T. With improved construction practices and monitoring, the integrity tests did not reveal soft toe. All the new piles took much more than the required test load and were monitored with HSDPT. The results for some of the new piles are presented in Table: 3.

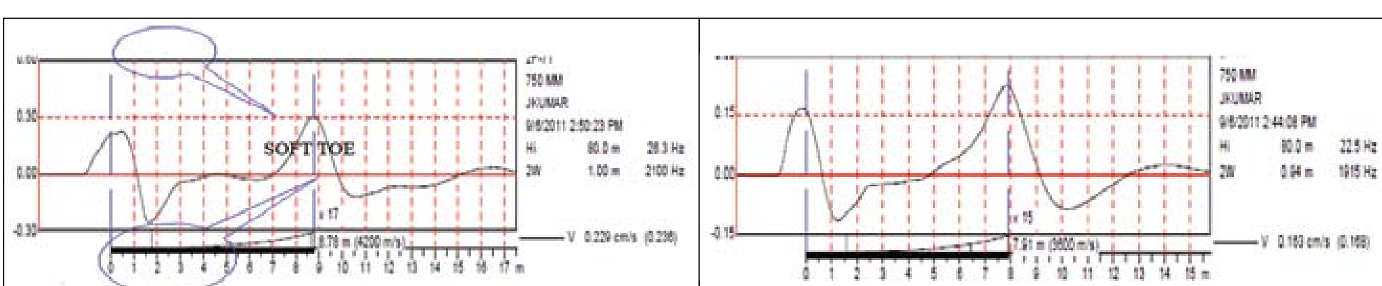


Figure 10 Soft Toe – LSIT data for piles tested at a site in Mumbai

Table: 3 HSDPT findings on replaced piles classified for Mumbai Project

Pile Length (m)	Pile Capacity (Tons)	Set (mm)
10.8	807	1
10.6	576	0.3
8.5	948	0.1

Thus the theory of Ryzner Index was also negated as otherwise the new piles would have also been under attack of corrosion with similar logic that was earlier floated. The author had to take huge pressure to justify the results at every stage and eventually questions on the LSIT and HSDPT technology were all answered resulting in a safe foundation for this 50 storey tower which otherwise would have led to a dangerous situation post construction. The cost of rectification exceeded Rs. 20 million but was worth the cost to ensure safety of the structure.

3.3. CASE STUDY 3: CSL findings compared with PIT/ HSDPT for an Infra Project

For a major infrastructure project in Delhi, cross hole sonic logging was part of the contractfor construction of 1200mm diameter bored piles with a depth of 31.5m from cutoff level. Four mild steel pipes with a thickness of 3mm were installed inside the pile to obtain CSL scans and verify the pile integrity. The CSL test results showed defect at 11.2m to 12.6m and for bottom 0.3m. Refer to Figure 11. Since the CSL showed defect, the contractor insisted on conducting low strain integrity tests at the project site.

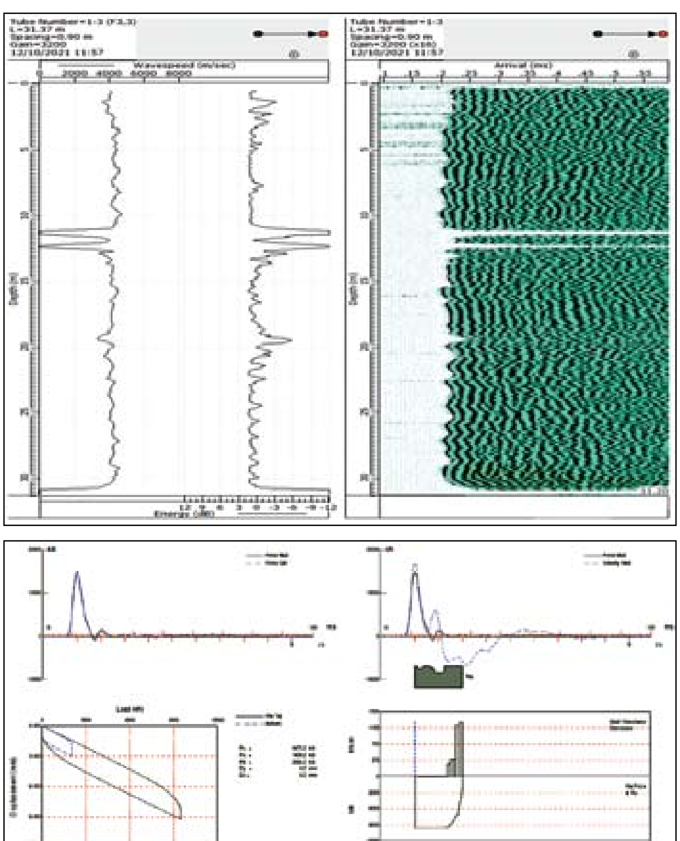


Figure 11 : CSL & HSDPT results on the same pile

The LSIT results also confirmed a defect at 12.5m although the defect was not as clear as evident in CSL tests. Refer to Figure 12. The low strain test results however did not provide any information about the defect at the pile bottom due to known method limitations as it is not possible to evaluate defects in the bottom 5-10% due to uncertainties in wave speed.

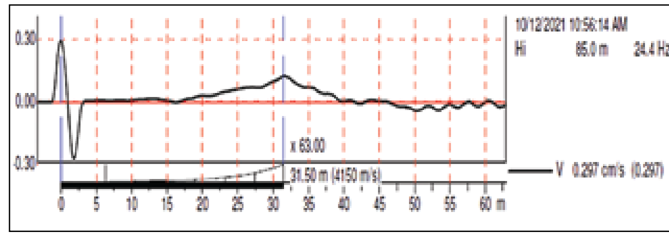


Figure 12 : PIT results on the same pile

Finally, it was decided to conduct High Strain Dynamic load test on this pile as recommended in ASTM D6760 to further evaluate the integrity and pile capacity. Note that the piles were installed in sand with SPT values ranging from 30-50. The test load for the pile was 763.5T. A 12T hammer was used to test the pile and the maximum drop height was 1.5m. The HSDPT results showed that the pile had a defect of approximately 30% at 14m from test level. The pile achieved a test load of 966 T (9475 kN), which was more than the required test load. The pile set was only 1mm for the blow and the total displacement was 9.2mm(Figure 11). Thus both the values of net and permanent displacement were very much within the specified limits of IRC:78 and IS:2911 (Part:4). The defect at bottom as shown by CSL was not validated from HSDPT and this could be due to the fact that high friction near the bottom absorbed most of the energy response and hence the HSDPT could not detect the defect which might have been present.

The defect from CSL was thus validated with both PIT and HSDPT for the project. It was difficult to decide on the acceptance or rejection of the pile purely based on the test results in such a case, as the pile had achieved the required test load although a defect was clearly evident which may compromise the long term durability and capacity. A static load test in this case would not have revealed a defect and a durability issue. None of the Indian codes address this issue of pile acceptance or rejection if the pile takes the load inspite of a defect. Thus this presented the Engineer a unique challenge on whether to accept the pile on the basis of capacity or reject the pile on the basis of integrity. The author is of the opinion that several factors may be evaluated including possible long term effects, life cycle analysis, location of defect with respect to water table etc., before a final decision can be taken. The case study was an excellent example of collating findings from various NDT tests to evaluate defects inside the pile which otherwise would not be known from a conventional static load test.

4. TESTING PROFICIENCY

There is a trend to accredit testing companies with ISO/ IEC:17025-2017 norms and in general various bodies like metro rails, highway authorities insist on such an accreditation before permission for testing and evaluation is granted. This is a good practice but note that most accreditation audits work more towards standardization of processes rather than improvement of quality of work which is very important in field testing and expert based testing. Standardization is always possible for laboratory samples or testing which is in controlled environment and where processes are defined, the output is expected to remain reasonably the same within tolerances and room for manual error needs to be eliminated. That the methods described in this article require expertise is also mentioned in ASTM standards and thus is known. However, the non-destructive testing industry for super structures and sub-structures in civil engineering is based on understanding of the structure, proper data collection and proper interpretation which is based on experience, technical logic, knowledge of concrete for super-structures and pile-soil interaction for pile foundations. Since neither soil nor concrete have a constant property, and data collection as well as analysis involves several parameters which are not necessarily the same, the expertise of the testing expert becomes much more vital than anISO certification. However an ISO certification misleads the end user into thinking that they have invested into a correct testing company for getting a genuine report. A simple example is a wave speed of 3700m/sec with UPV is classified as good as per IS:516 Section 5/Part 1 (2018). However, this wave speed maybe good for regular structures but might be low for critical structures like concrete inside nuclear complexes, structures with 100 year life cycle etc. Thus it is upto the expert to get proper data and interpret on acceptance rather than merely specify the concrete as good as per a code or ISO requirements.

Figure: 13 shows two such graph from an NABL accredited laboratory and is also an example of abuse of the technology which otherwise would have provided correct information if properly used.

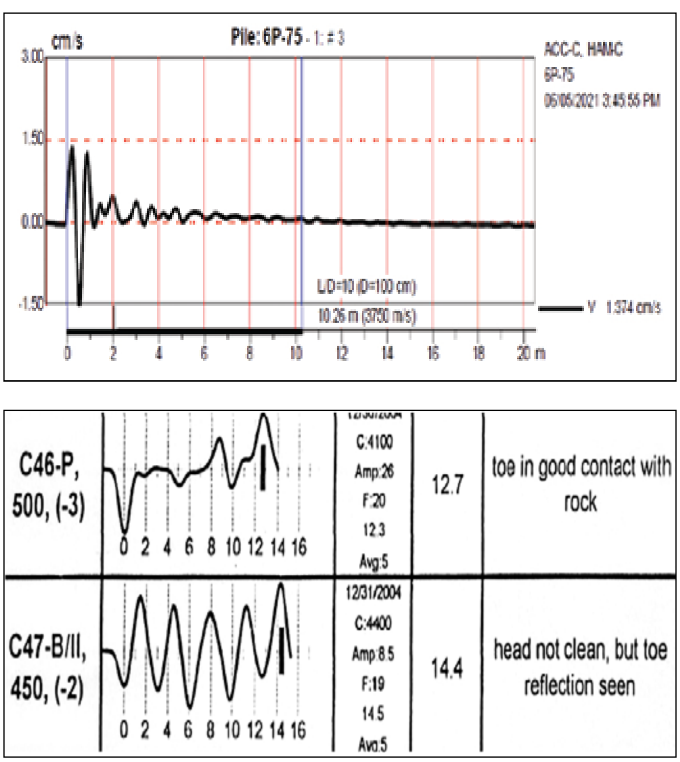


Figure 13 PIT results of some ISO companies

In both the cases, the data collection, processing and interpretation is incorrect. The graphs do not provide any interpretation on the pile integrity and mislead the owner of the foundations with a false sense of belief about the acceptability of these piles. This can also have dangerous consequences for the country as several important structures may simply be classified as acceptable by a testing company who then claim legitimacy by having an ISO certification. Thus, adequate care must be exercised before granting accreditation to field testing and interpretation and also for methods where several variables are involved and the output not standardized nor can be reproduced. This is even cited in the ASTM for all the three methods wherein the quality of the results is based on the competence of the personnel performing the test and is also dependent on equipment and facilities used. The ASTM also does not provide any precision or bias with these methods and thus repeatability of the method in field conditions is not guaranteed. Emphasis while granting accreditation should be more on quality of work and output rather than following standard systems and processes which do not guarantee a reliable output as evident from above examples.

5. SUMMARY OF FINDINGS

The case studies demonstrate the effectiveness of Low strain integrity testing, high strain dynamic testing and cross hole sonic logging for evaluating quality and capacity of pile foundations. These testing methods when used properly, provide solutions to foundation assessment with a high degree of reliability. The HSDPT provides significant additional information within quick time and at much lesser cost than a conventional static load test. The statement does not imply that static load tests are irrelevant but that HSDPT and other methods can definitely improve construction quality at projects which otherwise was not possible only with conventional static load testing.

These methods of pile testing are not like laboratory test methods. These require significant knowledge of wave mechanics, pile soil interaction, construction procedures and in some cases knowledge of geotechnical design before a final decision or an outcome can be available from the tests. That the integrity of the testing personnel is a pre-requisite or is mandatory if good findings are to be obtained and thus it is also a limitation of these tests.

Interaction with all the stake holders viz. the contractor, consultant and owner is important before final pile acceptance and rejection which otherwise may lead to conflicts. Thus these methods need an expert to analyze and discuss the findings of the method that will enable the Engineer to take a proper decision in the interests of the structure and the project.

There have been several instances apart from the case studies presented above, wherein the author was involved with repeat testing which otherwise were certified as acceptable piles by some of the ISO:17025-2015 accredited test expert. Since the tests are expert based, good data collection and integrity of the testing personnel/agency is a necessary pre-requisite and that the final outcome shall also be based on findings like purpose of testing, type of soil, construction records etc.,rather than solely from the output of the tests. This implies that selecting a test expert for a project just on the basis of ISO qualification is not recommended as some of the expertise documentation is beyond the scope of ISO. Thus, it is strongly recommended that the Engineer and contractor evaluate expertise based on documented studies, past experience and criticality of the project before accepting or allowing an expert to make predictions on the basis of these methods.

6. CONCLUDING REMARKS

LSIT, CSL and HSDPT are proven tools when it comes to QA practices for pile foundations. It is essential that these tools are used properly and judiciously for the benefit of the industry. Use of these methods at the start of the project may provide confirmation of design and avoid huge rectification costs later if the workmanship does not match with geotechnical design parameters. Care needs to be taken to train the contractors and even the Engineer's representative to monitor and handle piling projects as a piling job is not merely boring and putting concrete inside the bore but is a complex process which requires experience and dedication. The consequences of poor execution can be catastrophic.For several projects, the entire effort during the project is to cut costs and thoughtless actions lead to major foundation failures. Use of PDA, PIT and Cross Hole Sonic Tests should be encouraged, yet at the same time malpractices should be specifically reported and highlighted with action taken if the overall construction quality has to improve in the country. Also it should be noted that, use of these technologiesrequires expertise and accreditation of reputed organization such as ISO or NABL does not always guarantee a reliable result and hence Engineers should assess all requirements of the project including applicability of ISO norms before selecting a testing expert at his project.

REFERENCES

1. IS:14893-2021, Low Strain Non Destructive Integrity Testing of Piles
2. ASTM D5882-2017,Standard Test Method for Low Strain Impact Integrity Testing of Deep Foundations
3. "Pile Integrity by Low and High Strain Impacts", Proceedings of the Third International Conference on Stress Wave Theory on Piles, Rausche, F., Likins, G.E., and Hussain, M., Ottawa, Canada, May 1988.
4. Vaidya Ravikiran & Shah D.L., "Pile Diagnostics By Low Strain Integrity Testing", IGC 2001, "The New Millenium Conference", Indore, India, December 2001
5. ASTM D6760-2016, Standard Test Method for Integrity Testing of Concrete Deep Foundation by Ultrasonic Crosshole Testing
6. Jorge Beim et al Standardization and Codification of Dynamic Pile Testing A Worldwide Review, 8th International Conference on the Application of Stress Wave Theory to Piles, Lisbon, Portugal, September 2008.
7. Vaidya Ravikiran, "Evaluation of Pile Integrity Testing using Cross Hole Sonic Logging Testing"IGC 2010, GeoTrendz, Mumbai, December 2010
8. ASTM D4945-2017, Standard Test Method For High Strain Dynamic Testing of Deep Foundations
9. Vaidya Ravikiran and Likins Garland "Guidelines for successful High Strain Dynamic Load Tests & Low Strain Integrity Tests for Bored Piles", Deep Foundation Technologies for Infrastructure Development in India, Mumbai, India. November 2013.
10. Vaidya Ravikiran & Kulkarni Sujan "CAPWAP Complexities and Case Studies for Pile Foundation Testing in India", 5th International Conference on Forensic Geotechnical Engineering, December 2016, Bangalore, India
11. Ganpule V.T. et al. Deterioration of Bored Cast in Situ Piles due to Aggressive Water, 6th Intnl Conf. on Case Histories in Geotechnical Engineering, USA, 2008.
12. Berger J.A. and Cotton D.M., "Low Strain Integrity Testing of Deep Foundations", Proceedings of Deep Foundation Institute Annual Meeting, Seattle, October 1990.
13. PIT & PDA Users Manual, May 1998, Pile Dynamics, Inc.
14. Rausche F. and Goble G.G., "Determination of Pile Damage by Top Measurements." Behaviour of Deep Foundations, ASTM Symposium, Boston, 1978

Presidential's Message 1

ISSMGE Time Capsule Project 16

TC Corner 17

- *TC309/ TC304/TC222: 3rd ML Dialogue*
- *TC107 reestablishment*

Conference Reports 23

- *Engineering Challenges in Rehabilitation of Damaged Historical Monuments in Mosul, Iraqi*
- *Eurasian Forum on Seismology Engineering, Geotechnics and Structural Dynamics, SEISMO-SIBGEOTECH-2021*
- *International Conference on Geocryological Engineering Research*

Event Diary 35

Corporate Associates 42

Foundation Donors 45