LOW STRAIN INTEGRITY & HIGH STRAIN DYNAMIC TESTING OF PILES - AN INDIAN OVERVIEW

By Ravikiran Vaidya[1]

ABSTRACT

High Strain Dynamic Pile Testing and Pile Integrity Testing have been in use in India since 1988 and the testing was conducted by few agencies. However, use of this technology was limited till 1998 as not enough data and work was actually done to justify its use and application on major infrastructure and real estate projects. The paper describes various actual field case studies, which were encountered across the country during the course of testing since 1998 and which have helped to establish confidence in this form of testing, and has helped in its increased usage throughout the country.

Since in a country like India where boring and concreting for piles is carried out using traditional equipments to hi-tech machines, the paper also describes very briefly about the need to deviate sometimes from the parameters generally recommended, based on site conditions / piling methods / nature of structure etc. to define pile integrity or to evaluate pile capacity.

1. INTRODUCTION

The paper describes typical case studies of Pile Integrity Tests (PIT) and High Strain Dynamic Tests conducted at various locations in India and how the benefits of testing have helped the client in saving time or costs or ensuring a safe and reliable foundation. Some of these case studies helped the industry in accepting these tests on major contracts although they are still not a part of the code provisions in India. For all the case studies that involve pile integrity testing, the Pulse Echo Method with single accelerometer was followed. Wherever high strain dynamic tests were conducted, CAPWAP analysis was conducted on the pile to correctly estimate the pile capacity and various other parameters.

2. CASE STUDIES

2.1 Case study 1

For a multistorey building in Mumbai, no specific previous records were available for 41 piles that were constructed 5 to 6 years ago. Before starting super structure work, client wanted to ascertain the depth of these piles, so as to enable him to proceed with further super structure construction activity.

Pile Integrity Tests were conducted on all the piles. A wave speed of 3700m/sec was assumed for the site. This was based on an assumption of concrete grade of M25. Although the manual mentions a wave speed of 4000m/sec, the local conditions and method of concreting at site indicated that assumption of slightly lower wave speed would be justified.

Figure 1 shows one such PIT record for the site. The estimated pile length was obtained as 11m with a variation of $\pm$ 5%. For all the 41 piles on site, the PIT inferred lengths to be around 10m to 11m. Actual coring was conducted on one of the piles to ascertain the PIT results.

[1] Ravikiran Vaidya, Managing Director, Geo Dynamics (India)

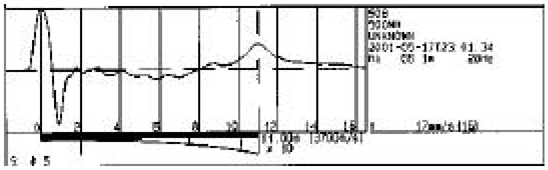


Figure 1. Typical velocity response of pile for the site in Mumbai

Coring conducted using NX size rotary drilling rig confirmed the pile depth as 10.5m. The graphical log for coring done is shown in Figure 2.

2.2 Case study 2

During piling for a star rated Hotel project in Mumbai, while concreting was being done for the pile A, an adjoining pile bore B (which was yet to be concreted) reported water and cement slurry coming out of it. Although concreting was continued for both the piles, it was suspected that some connection might have developed between both the piles. Further the integrity of the piles was also termed as suspect with more suspicion on Pile B. Pile Integrity tests were conducted on both the piles to evaluate the integrity. It was found that pile A had integrity problems, whereas no integrity problem was detected in Pile B. Coring was carried out on Pile A to confirm the finding deduced from the integrity test results. In this case the wave speed used was on higher side just because of the higher percentage reinforcement, higher concrete grade and liner being used. The PIT result for Pile A is shown in Figure 3 whereas the photograph of the cores found is shown in Figure 4. Confirmation of the core test results led the client in adopting PIT on many other piles at the site as well as for future projects.

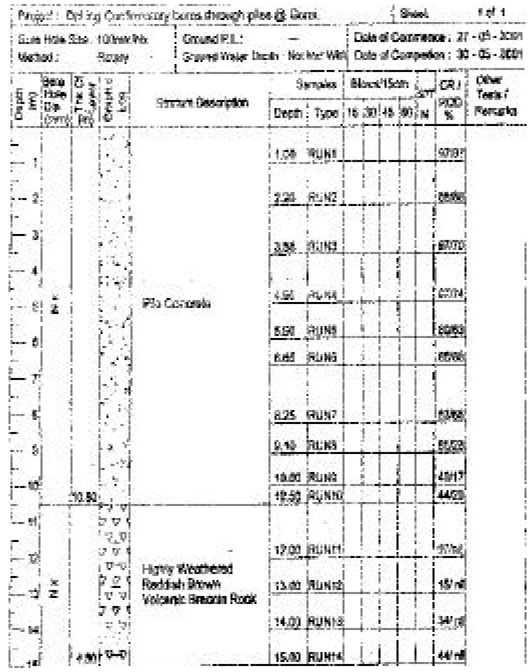


Figure 2. Graphical log for pile coring

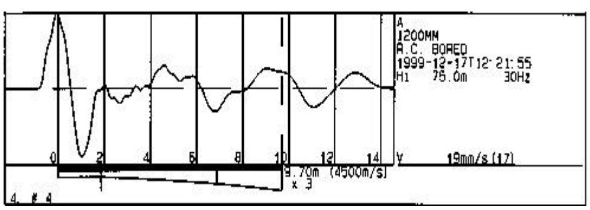


Figure 3. Typical velocity response of pile A

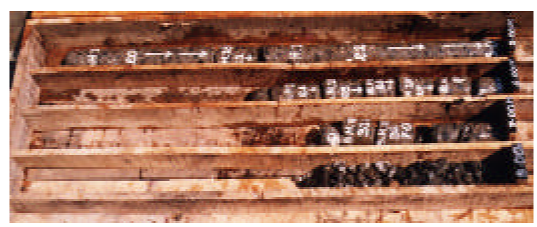


Figure 4. Photograph of the cores of pile A

2.3 Case study 3

For many flyovers constructed in a major metropolitan city in India, the clients had suspicion about the pile lengths much after the flyovers were complete and traffic moving over it. A total of 30 piles of 750mm diameter (L/D = 26) were tested at various flyovers. No previous details about pile lengths were provided to have a fair estimation of the pile lengths. Some of the details provided were concrete grade M35, no permanent liners used and the details of percentage reinforcement used in the pile. Integrity Tests were conducted on the piles by excavating pits and exposing the piles. Since not many details were made available, a wave speed of 3800m/sec was assumed in this case for all the piles and the lengths were reported to the clients accordingly. The graph for one such typical pile is shown in Figure 5.

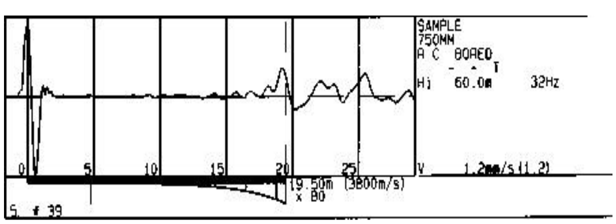


Figure 5. Typical velocity response of pile for the site

It was also explained that there maybe a variation of $\pm$ 5% to 10% in the reported lengths due to various parameters involved. The results and findings were later confirmed by the clients to be within the mentioned limits. Thus Low Strain Pile Integrity Testing method was used as an investigation tool in this case and helped in establishing confidence in the technology.

2.4 Case study 4

For one of the project sites in Mumbai, during course of routine integrity testing, one of the piles showed sharp tensile toe response at lower magnification. The record is shown in Figure 6. It can be seen that even at lower magnification the tensile and sharp nature of toe is clearly evident. It was suspected that this pile has a soft toe and maybe some loose material at pile bottom.

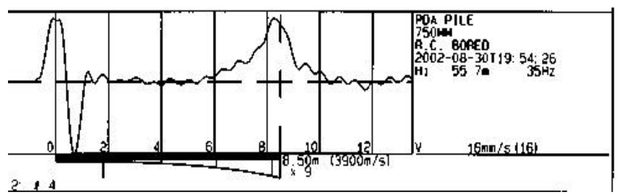
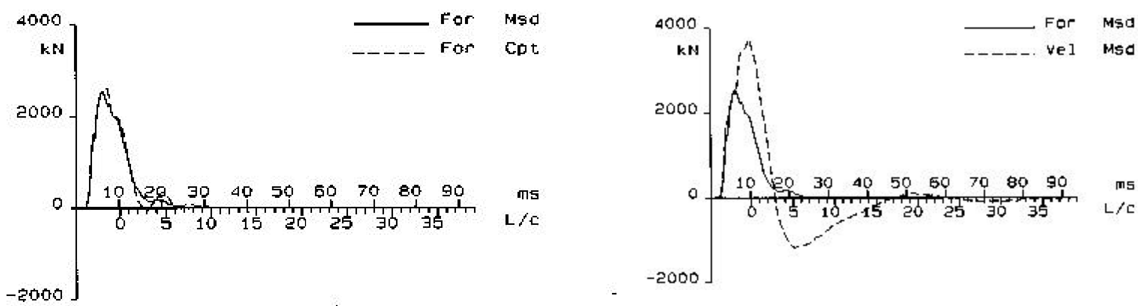


Figure 6. Typical velocity response of pile showing soft toe

High Strain Dynamic Test was conducted on the pile to evaluate its capacity. The design load for the pile was 120 tons and since it was a working pile, it was to be tested up to 180 tons. The pile was designed as an end bear ing pile socketed into rock.



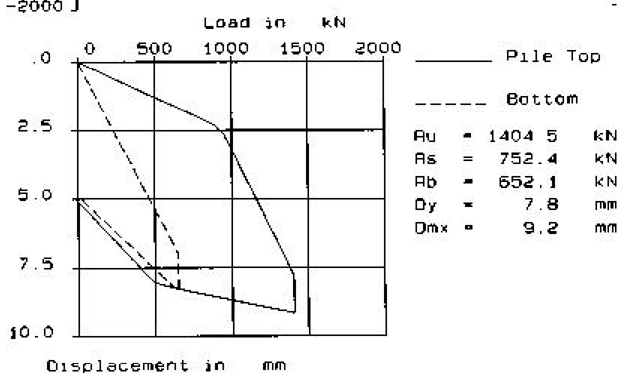


Figure 7. Typical High-Strain Dynamic Test Results

As evident from the dynamic testing results, the pile started to settle at 100 tons only and thus failed to achieve its required capacity. The results for high strain dynamic test are attached in Figure 7. Similar experiences were also observed at few other sites at later dates.

Thus it could be concluded that pile integrity testing can also be used in understanding the rock socket interaction. Although it is not possible to determine capacity of the pile using PIT, but it can be used to judge if the particular pile can potentially reach its capacity during static or high strain dynamic testing. The magnification factor can be an important value in assessing such a situation. If the peak of the toe response is same or more than that of the input signal at lower magnifications, then it possibly indicates a relatively lower capacity.

2.5 Case study 5

Figure 8 shows case study for 500mm diameter reinforced concrete. bored pile on an expressway project between two major cities Vadodara and Ahmedabad located in Western India. The clients located 128 piles that were abandoned by the previous contractor more than 10 years back. No technical data like pile depth or vertical load carrying capacity was available. A combination of high-strain dynamic test and pile integrity tests was used on the project site. Initially PIT conducted on the piles reported pile lengths about 20m. The wave speed again was assumed as 3500m/sec instead of

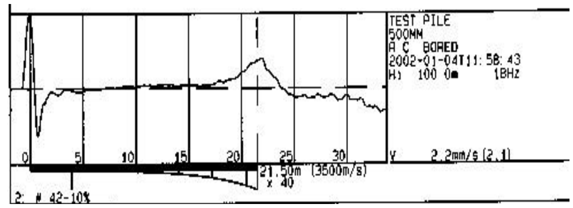


Figure 8. Typical velocity response of pile for expressway project

4000m/sec as the piling was done in early 90's with conventional method and with lower grade of concrete that could possibly be M20. Borehole taken adjacent to two such typical piles confirmed the findings that piles could have been possibly terminated in such stratum.

High-Strain dynamic testing on the pile helped in deciding its design load and was conducted upto a capacity that was more than design criterion. Static test was also conducted by the client on the same pile as a "proof test" but not upto the failure load. The co-relation between static and high strain dynamic testing is shown in Figure 9. As evident, the static and dynamic test results matched well and helped the client to save lot of time and money, since the piles could be used in further construction at no additional cost.

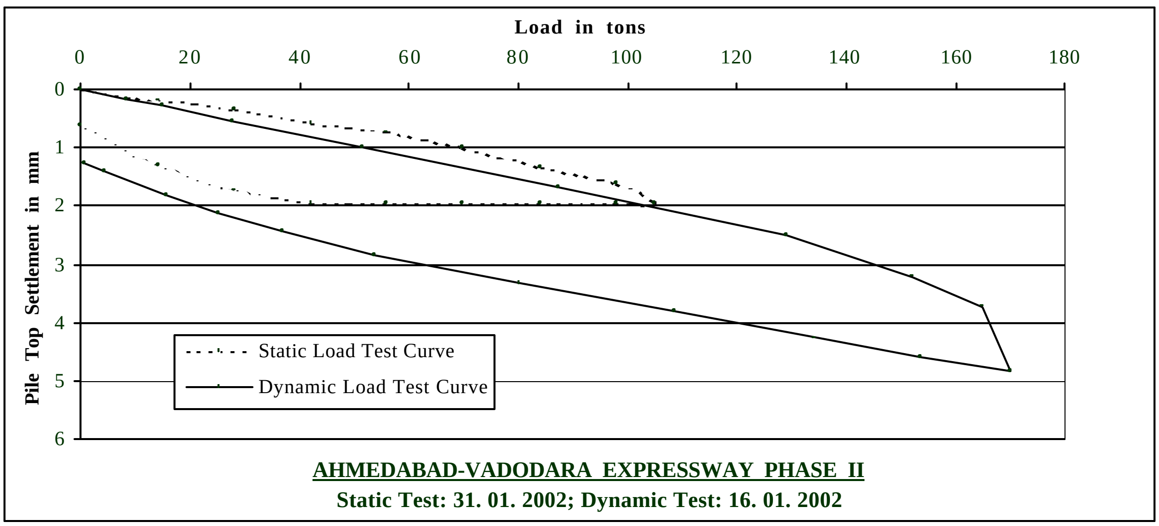


Figure 9. Co-relation between Static and High-Strain Dynamic Test on pile for expressway project

3. DISCUSSION ON INDIAN SCENARIO BASED ON ABOVE CASE STUDIES

High Strain Dynamic Pile Testing and Pile Integrity Testing have been in use in India since 1988. However, its use has been limited due to absence of specific documented case studies as well as co-relation studies between analyzed data and field information or between static and dynamic tests.

The above case studies established the confidence of the engineers in using these tools in the Indian construction industry. However, unlike the American scenario wherein the test agency only gives a factual report, in the Indian industry, the client / engineer wants a more specific report on whether to accept or reject the pile or do any remedial action based on the integrity and/or dynamic testing report. Hence the test agency in India must specifically mention whether the pile is acceptable or rejected based on his findings of the collected site data.

The piling industry in India uses modern tools like the rotary rigs and also uses the conventional winch and tripod system. Further concreting methods vary from volume batching using mixer machines to batch mix plants to ready mix concrete. This is done depending on the criticality of the structure and / or available resources near to site. There are still many remote areas and construction sites where it would be very difficult to procure ready mix concrete or setup batch mix plants. Thus these factors also need to be considered while assuming wave speeds. Perhaps an approach of assuming a standard wave speed for all the sites may not be appropriate in such a scenario, but a range of wave speed is a more suitable approach.

4. CONCLUSIONS

1. Low Strain Pile Integrity Testing has been proved as a powerful tool to evaluate defects and approximate pile lengths.
2. Knowledge about method of concreting, grade of concrete, time of test after concrete is in place and the percentage of reinforcement play an important role in determining wave speed. The normal range of wave speed in India may vary from 3500m/sec to 4200m/sec. Wave speed higher or lower than the above values may need specific justification or reasoning before use for evaluation.
3. The magnitude of toe response and the magnification factor can be used to evaluate the relative socketing of piles into rock or stiff stratum. In addition these parameters can be used to identify weak piles. Such piles can then be subjected to further testing thus ensuring more safe and reliable pile foundation.
4. High Strain Dynamic Testing is also now commonly used in the Indian construction industry and has served as an effective test that can be quickly accomplished compared to conventional static testing. Additional data like skin friction and end bearing is also available using CAPWAP analysis. More efforts need to be directed towards comparing these values in conjunction with instrumented pile load tests.