Challenges and Issues in Modern Day Piling: Indian Scenario

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ABSTRACT

Current contractual conditions focus on fast track piling. With the advent of infrastructural growth in India, rapid urbanization, and peculiar requirements for availing additional space, piling industry has gone through evolution and adapting itself to ever increasing challenges. This paper intends to address some of the issues and challenges of modern piling works, namely, high capacity pile requirements, problems under deep cut-off, drivability aspects, borehole stability issues, static load tests – techniques, modern pile evaluation techniques for capacity and integrity – their strength and limitations, problems of soft soils and high ground water table. A case study is undertaken describing the innovative techniques adopted to improve the progress and performances of bored cast-in situ piling works at Dahej located on western shores of India in Gujarat state.

1. INTRODUCTION

Recent contractual development focus on fast track piling, and these conditions gave birth to use of rapid drilling and boring rigs, innovative piling methodologies, specialized hammers for driving and advanced methods of pile evaluation for its capacity and integrity. With rapid urbanization, and peculiar requirements for availing additional space, high capacity, soft ground conditions, piling industry has geared itself in wake of demanding quality control / assurance and progress requirements.

With the above background, this paper attempts to address some of the issues and challenges involved with modern day piling. This theme is illustrated with a case study presented on the bored cast-in-situ piling operations carried out by authors’ firm at Dahej, a port town located in Gujarat.

2. SPECIAL CONSIDERATIONS IN CURRENT PILING PRACTICE

Although the fundamental process of piling have been retained even today. Recent years in India has seen a commendable improvement in quality, performance and speed of their construction. Piles today carry greater capacity vis-à-vis their size; they are constructed speedily thanks to high capacity hydraulic rigs with depth capability even greater than 60m. Technological developments in Impact hammers and Vibro-hammers has resulted in pre-cast and driven cast-in-situ piling operations being carried out in denser strata. With advancement in use of equipments and techniques, special considerations and attention arising out of the modern day piling are discussed in subsequent sections.

Constructional Issues of Piling

Concrete Pile types used frequently in India include Bored cast-in-situ, Driven cast-in-situ and Driven pre-cast. Use of Steel and Pre-stressed concrete piles is also finding increasing use in India these days.

Bored Cast-in-Situ Piles

Need for high capacity have been effectively addressed by large diameter and deep bored cast-in-situ piles. Increase in their geometric attributes has raised the benchmark of concerns related to quality and progress. Choice of boring techniques and tools has become decisive to achieve optimum progress. Concern still exists on effectiveness of conventional rotary drilling machines used in India (with maximum torque rating of 2500 kN.m) in rocks. While such machines can bore through weathered rocks with unconfined compressive strength of 10 MPa, socketing through granitic rocks, with high recovery ratios is still a difficult proposal with rotary machines currently being used; and conventional chisel-bailer system is resorted even today.
at the cost of progress rate.

Borehole stability with bentonite slurry system, even while maintaining desired quality norms like adequate specific gravity, viscosity and sand content; the slurry is found to be inadequate to stabilize boreholes under high ground water table, high permeability strata; or in areas of underwater currents or artesian conditions. Synthetic polymer based stabilizing slurry have entered the piling market in India. While the experiences abroad are very encouraging, their use and feedbacks in India are limited. While these slurry offer advantages of being environment friendly, having zero hydration time, and increased number of reusable cycles; concerns exists on their technoeconomical edge vis-a-vis the traditional bentonite based slurry.

Deep bored piles are bound to increase the waiting period because of higher time involved to lower long reinforcement cage, which at times require on-the-spot welding to join multiple lengths of such cages. Further, higher lead for concrete procurement or improper logistics during ready-mix concrete supply can increase the waiting period in piling. Concreting by Tremmie technique, which is considered most suitable under fluidy environment, is done bottom-upwards; and with the progress of concreting, segments of the long tremie pipes require removal, which are known to increase the piling time.

In light of utilizing the multi-level under-ground space to house utilities and parking, deep pile cut-off levels in excess of 10m are common nowadays. Such cut-off in bored piles demand alertness, and has stretched piling engineer’s skills to threshold in deciding exact instant to stop the concreting operations. In this connection, grey areas exist in determining exact concrete volume being poured through RMC truck; quick assessments of concrete level in borehole other than conventional sounding methods.

**Driven Cast-in-Situ Piles**

Driven Cast-in-Situ (DCIS) piles are becoming potential choice because of rapid construction; absence of splicing, and economy. With advent of heavier and efficient hammers (pneumatic and hydraulic), their speed and drivability aspects have seen quantum leap. These are best suited for a capacity range between 750 to 1250 kN, with lateral dimensions of pile varying from 400 to 600mm. Drivability aspects prevent higher capacities than these.

The working pile Set is used as a most vital field control for such piles. Confirmation of the validity of Set are usually made with the results of static load test on the pile before further proceeding with working piles.

Driving of such piles in cohesionless soils causes increasing compaction. With closely spaced piles, increasing compaction of sub-soil can result in refusals several meters above the toes of preceding piles. Overdriving of piles beyond the working sets merely to obtain closer toe parity with existing piles has damaging effects on the pile rig, hammer which lead to increasing maintenance and repairs resulting retarded progress. Such limitations pose serious challenge to the design approach, and based on field experiences drawn, it would be apt to use characteristics of virgin un-compacted ground to decide termination of initial piles; and with increasing effects of ground compaction, use quantified parameters of compacted ground to terminate progressive piles.

**Driven Pre-cast Piles**

This pile offers, by far a better quality since reinforcement cage fabrication and concrete casting are done in a controlled environment of the yard and are open to inspection. Typical lateral cross sectional dimension varies from 350 to 500mm, giving a safe capacity in the range of 1000 to 1250 kN.

Few of the issues affecting such piles are: waiting period between casting and driving (they have been reduced nowadays by adopting steam curing technique and use of early strength concrete), unseen pile damages during driving, splicing, time restrictions for shifting and stacking, tackling handling stresses.

In many of the sites, if a pre-determined depth is a strict criterion and pile driving to such depth is prohibitive then, initial pre-boring is resorted, followed by pitching and subsequent driving of the pile to the desired depth. Transportation restrictions limit the pile lengths in a range varying from 10 to 15m; hence to achieve greater depth, segmented pre-cast piles are used which are connected together on the spot by coupling arrangements. Variety of coupling arrangements exists which include Welded, Dowel types, Mechanical (example, Sure-Lock system), and Wedge types.

Precast driven piles are designed to meet pile load requirements which also includes considerations for stresses during driving in addition to meeting the bending moment and shear stress requirements during shifting, lifting, and transportation.

**Drivability Aspects**

Key factor governing the integrity of the pile during driving is the hammer energy imparted vis-à-vis the stratum encountered. Drivability analysis using advanced computational tools are available these days that give valuable insight into the stresses developed during driving. A drivability analysis produces a safe prescription for pile installation, including recommendations on cushion stiffness, hammer stroke and other driving system parameters that optimize blow counts and pile stresses during pile driving. For instance, drivability analysis can determine if a soft or hard layer causes excessive tensile or compressive stresses. Publications of such analysis and experiences in India are very limited, and therefore happens to be grey area in precast piling works.
Load Test Issues

Testing of piles by direct top loading still remains one of the best understood assessments of the pile load-displacement behaviour. Such tests are used to confirm the outcome of the fundamental pile design; and also form a part of quality assurance process on the contract piles. Many pile tests are carried out using Maintained load, but they rarely assist in determination of ultimate pile load. Maintained load is also common for determination of Pull-out and Lateral load capacity. Cyclic loading is more often used for piles tested under vertical compression for separation of skin and end bearing contributions. While the set-up for vertical compression and pull-out load tests model load-displacement of a single pile very satisfactorily; it is uncertain to what extent the lateral load test is able to model the behaviour of pile, particularly under real-life presence of pile caps and structural rigidity of foundation system.

Reaction sustaining arrangement for vertical compression load tests are either through kentledge system or by reaction piles / anchors. Maximum test load by kentledge system is limited to about 8000 kN; any additional test load requires a well designed anchor pile system. Instrumented load tests are used in areas where adequate case history of pile behaviour in soil / rock is available, and such tests incorporate multi-level strain gauge instruments with data acquisition systems to assess load-transfer behaviour of strata. High capacity piles are finding increasingly acceptance on use of bi-directional load tests these days, which incorporates single or multi-level Osterberg cells.

High Strain Dynamic Testing (HSDT) is an economical option for pile capacity and integrity assessment. These are particularly preferred in crowded or inaccessible areas where static load tests cannot be performed. HSDT incorporates CASE method encompassing measurement of force and velocity during a hammer blow and employs a reusable strain transducer, accelerometer and PDA software. The programme can evaluate static pile capacity, driving induced pile stresses, hammer / driving system performance parameters and structural pile integrity.

Marine Piling

These piles are used to support marine structures like jetties, wharves, dolphins, near- and off-shore structures. Essentially they are considered as slender piles subjected to very high lateral loads arising from waves, currents, wind, water pressures, and other operational forces during mooring, berthing etc. These are therefore heavily reinforced and are of higher diameters than land piles. Special design considerations include durability aspects since they are exposed to severe aggressive conditions. Marine piles are still based on IS: 2911 or BS 8004 which are primarily meant for land based piles. This fact necessitates need for special codes for marine pile design.

Lack of stable working area compels deployment of special arrangements for piling like use of fixed or cantilever platforms, jack-up barge and other floating arrangements. These constructional constraints prevent use of heavy rotary boring rigs, and hence percussion tools mounted on light weight rigs are commonly adopted. Advanced RCD rigs have also been employed by authors’ firm for marine piling works for a ship-lift facility at Karwar located in western India.

Quality Assurance

Use of Pile Integrity Testing (PIT) has become an inherent feature of quality assurance system. Such rapid tests are carried out over and above the traditional system of load testing (also called routine pile load tests, which are carried out on 0.5 to 2% of contract piles). PIT is known to analyze acoustic anomalies with respect to pile toe level, shaft restraints, over-break, cracks, reductions in section, and zones of poor quality concrete. Rausche (2004) describes various non destructive methods of testing piles which can serve as an effective tool for quality assurance. Among them, Cross Hole Sonic method gives assessment of concrete quality located throughout the length of testing tubes. Logging Pile concrete coring techniques and testing are also occasionally resorted for confirming in-situ strength of concrete; direct excavations to expose pile at shallow depths are also adopted.

The basic advantage of non-destructive methods lies in the fact that the testing can be carried out quickly and without significant disruption to the normal site activities. The costs are small by comparison with static load testing, coring or direct excavation, and large number of piles can be scanned for potential defects. However, such systems are not suitable for jointed precast piles in general (Fleming & Thornburn, 1983).

3. BORED CAST-IN-SITU PILING – DAHEJ CASE STUDY

Each piling site, unlike a common perception, involves unique challenges. On the spot innovative decisions, site specific fabrications, modifications in the tools, changes in driving and boring techniques have an element of research of its own, and very often such unique feats go un-published.

Authors’ firm is involved with variety of piling works, however a case study of bored cast-in-piling works carried out at a site at Dahej is reported on account of some unique approaches to piling carried out here.

Project Background

The project involved construction of bored cast-in-situ piles, diaphragm wall and civil works for Slip dock, Harbour components and Shiplift facilities at Dahej located in Gulf of Khambhat along West Gujarat Coastline.

Actual Sea Bed level in the piling area was observed ranging from +7.00m to -3.5 m. This marine site is known for being amongst the highest tidal range in India, namely
±10m. Schematic levels of the pile are reported in
Fig. 1.

**Fig. 1: Schematic of Pile and Levels**

**Piling Scheme**

Initially, marine piling was envisaged, since the piling area
was located away from the main landmass. This involved
use of gantry and typical marine piling scheme requiring
cantilever platform. However, speed and progress was
essential to this fast track project, and hence a scheme was
formulated to transform the marine piling into a typical
land piling scheme by constructing a temporary rockfill
cofferdam which surrounded the working pile area.

Considering the tidal variations, the area inside the coffer-
dam was filled up to +12 m level with locally available soil
and rock (shown as armour filling in Fig. 2). Subsequently
after construction of the platform, entire rockfill platform
was to be removed to facilitate shiplifting.

**Fig. 2: Cofferdam and Piling Scheme**

Based on the construction and design requirements of
the piles, it was decided to use guide casing of diameter
100mm excess of the proposed pile diameter so that the
permanent liner casing could be inserted conveniently and
further, it would cut valuable progress time required for
driving of liners. After initial boring and laying temporary
guide casing, boring operations was carried out upto a depth
of 21m which corresponded to the proposed dredging level.
Thereafter a permanent liner was inserted into this borehole
extending to -10m level (Fig. 1). The outer guide casing
was, thereafter extracted, and further boring operation was
carried out upto -25m elevation, with the borehole stability
maintained with bentonite based slurry.

The project also comprised 1200 and 1500mm diameter
raker piles, bored at a rake of 1 in 10. Raker bored cast-in-
situ piles were constructed by tilting the Kelly frame of the
hydraulic rig. On achievement of the desired rake, the kelly
frame was locked. Thereafter the rig was centered and after
surveying the final rake, piling operations were carried out
in the same sequences as stated in the preceding sections.

**Merits of Innovative Piling Scheme**

Speedy and faster construction rate was achieved by
transforming marine piling into a typical land piling
scheme. Further, since the entire area was filled up with
locally available fill material, a safe working platform for
bored piling operations was ensured, which also facilitated
effective lowering of permanent mild steel liner as deep as
21m. In addition to above, use of twin casing system ensured
that the permanent casing could be inserted conveniently
and this step resulted in saving of about 24 hrs per pile
thus enhancing the progress rate of construction.

The original plan of marine piling works with
traditional gantry system would have consumed 3 days for
a single pile construction. Whilst, under the deployed
scheme and with two hydraulic rotary rigs, productivity
was raised to 4 piles per day.

Further, since the bored piles were constructed with
permanent casing, a better degree of quality control could
be achieved at site comparative to gantry based marine
piling technique.

**4. EPILOGUE**

The foregoing account of prevalent piling practice indicates
that the while basic piling methodologies are still in vogue in
India, greater impetus is for faster quality control and quality
assurance measures; and meeting fast track progress
requirements of the piles. Newer piles like segmented pre-
stressed concrete spun piles are being explored and the Indian
piling industry are fully geared up to meet the future piling
challenges.

Further, important progress is made through use of
new computational tools, towards better understanding of
the behaviour of piles under complicated field conditions.
Increasing use of systems to investigate the capacity and
integrity of installed piles is now accompanied by a better
understanding of risks that are associated with construction
under various ground conditions, and by a desire to improve
specifications and site controls.

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