Challenges and problems faced to Quality Control in Cast-In-Place Bored Piling by Rotary Bored Machine at Lalitpur, NEPAL

Abstract

In a construction project of G+19 Hotel & Residence, there have been parking problem due to lack of sufficient land. So to minimize these problem double basement have been designed for parking floor. The basement excavation is not easy to excavate without proper protection work for retaining deep excavations. Soil at its natural form, in a construction site is not suitable to completely bear heavy surcharge loads. For such situations, the soil stability needs to be improved to enhance its strengthen capacity and decrease the expected landslide. There are some techniques for retaining deep excavations for basements which are used at site to take surcharge load during excavation. Depending upon the loading conditions and nature of soil at site, a Cast-In-Place Bored Piling by Rotary Bored Machine technique have been adopted. This paper gives the overview and concept of Cast-In-Place Bored Piling by Rotary Bored Machine, discusses their practical applications and problems faced to Quality Control.

1. Introduction

Urbanization growth of Kathmandu valley with increasing density of people require necessities of construction of multi-storey residence & hotel building. The built up area is not sufficient due to compact settlement throughout Lalitpur which results in imposing high surcharge loads during excavation for basement and foundation work. Cast-In-Place Bored Piling by Rotary Bored Machine is the most suitable for protection piling Kathmandu valley[1–5]. In Lalitpur the roads are very steepy and narrowed, traffic flows are more due compact settlement due to this there are restriction of vehicles running during days’ time and timings for construction machinery vehicles is from 9 p.m. onwards to 5 a.m. Because of these restrictions time, quick progress is impossible to achieve. Foundation work needs to be done as quickly as possible[6–8]. Geo-tech designer and sub-contractor have faced many challenges in maintaining quality of Cast-In-Place piling in relating to all aspects of pile work at site[9]. The problems they have faced are related to equipment selection for boring, boring machine erection on line & level, neighbor issues during boring, interrupt of boring due to obstruction like rock, trees root etc. and concreting of pile without any disturbance and interruption. Concreting without interruptions[10,11]. There was also challenges for shoring during excavation for pile cap which was below 2 meter from original ground level. We have used MS Pipe of 150mm Medium size thick and 5mm MS sheet for shoring work to protect the deflection of neighbor’s boundary wall. All the interruption faced during the work are mentioned in this paper based on my experience during site work.

1.1 Methods of Cast-In-Place Bored Piling by Rotary Bored Machine

The sequence of construction of Cast-In-Place bored pile is as follows.

1.1.1 Establishment of Reference Pegs and Datum Level- Prior to the setting up the center point peg reference pegs and datum level will be established and maintained to facilitate installation of temporary casing to correct location.

1.1.2 Setting up of The TMR Machine- The machine will be set up at the location of the center point peg by
suspending a plumb bob and the auger is centered exactly over the center peg.

1.1.3 Boring

1.1.3.1 Installation of Casing
A steel casing of length around 1.2 m (the length may be increased depending upon the soil encountered at site) will be installed at the location of piling to stabilize the upper portion of borehole. A hole of will be drilled by machine using solid stem auger. Position and verticality of the temporary casing will then be checked with respect to reference points installed previously. About 300 mm of the top the casing will be left protruding above the ground[12,13].

1.1.3.2 Advancement of Borehole- The borehole will be advanced further mechanically by means of a truck mounted solid stem auger. Truck mounting rotary machine are made using kill bar with auger attachment on it. The hole is then drilled up to 1m depth and the casing is placed to support the auger in boring. During boring bentonite will be added and when required to minimize the collapse of the borehole as much as possible. The level of bentonite is maintained within 1000 mm below the top of the casing pipe. The depth of excavation will be checked by the length of the auger and the extension rods. When the boring is advanced further by another piece of drill rod is added. In this way the boring work will be progressed. When the pile toe level is reached, boring will be stopped. The bored pile hole will be cleaned by washing with clean water to expel out loosen soil, mixed soil or disturbed subsoil from the base to top of pile boring. The depth of the borehole must be confirmed prior to placing the reinforcement cage.

1.1.4 Fabrication & Installation of Reinforcement Cage

1.1.4.1 Fabrication of Cages- Cutting and bending of rebar will be carried out in accordance with approved bar bending schedules on site and cages fabricated. Binding wires are used to bind main bar with the stirrups links and control bar. Circular concrete spacers made up of sand and cement with rich mix are placed on stirrups on every 1m spacing with 5 numbers of blocks on each placed stirrups links. The cover blocks are made up of same grade of concrete as of bored pile to be done.

1.1.4.2 Installation of cages- The reinforcement cages up to the length of 12m will be lowered into the borehole manually or by means of the tripod & winch using steel slings and shackles. Finally the complete cage will rest on the founding base of the borehole and or be supported from the top of the temporary casing while the correct concrete cover to reinforcement is assured by concrete spacers. About 2 m of rebar cage will be left projected above the ground level for constructing piling above the ground level.
1.1.5 Concreting

Concreting of the required grade and slump will be supplied from batching plant or mixed in the concrete mixer locally at site. All concrete delivered shall be visually inspected and checked against delivery note before being tested and used. Concreting is to be commenced soon after the completion of the borehole and maximum time of concreting should not be greater than two hours to minimize the cave-in of the borehole. Concrete will be placed using tremie pipes of 200mm diameter. The tremie pipes are of lengths 2 m per piece (at least 10 no’s of pipe). The tremie pipes are joined one piece at a time and lowered into the borehole. The pipe are raised using pulley in order to flow of concrete into the borehole. The concrete will be discharged from the delivery truck to a hopper connected to the tremie pipes. Initially, a layer of thermocol balls or similar may be placed to separate the stabilizing fluid from the concrete. When the concrete level get raised in the tremmie pipe, the pipe are then removed. The concrete poring is done accordingly. The bentonite slurry obtained during concreting of pile in the borehole is to be collected in a sump pit suitable at the site and after drying the bentonite along with the excavated material, subsequently, be removed to designated location. The tremie will however always be embedded two meters into the concrete. Sections of the tremie pipe will be dismantled from the top as the pipe is withdrawn. During concreting the level of concrete inside the borehole will be monitored either with a weighted tape or chain. Concrete will be casted at least one meter above cut-off level to ensure sound and homogeneous concrete at cut-off level. As part of the bored pile concrete record, the actual and theoretical concrete volume placed will be plotted for each bored pile.

1.2 Guidelines for Micro-Piles.

• To design the micro piles IRC SP-109-2015 should be used.
• For shoring work if there is use of micro-piles then it should be provided with metallic sheet liner and supported by MS pipes or props.
• The gap in between the shoring pipe must be filled with skinning concrete or MS plates to minimize the effect of seepage problem and soil erosion from the gaps into excavated area.
• Foundation drawing and details must be understood. For ensuring trial pits should be taken near neighbor building. The foundation details of adjoining buildings
• Anchoring must be avoided if the neighbour building is on piles or nearby piles.
• Subsidence ground surface on neighbour plot should be hardened and good for stability.

1.3 The Pile Integrity Tester (PIT TEST) conducted to ensure pile Integrity.

Integrity refers to the change in physical dimension, continuity of a pile, consistency of pile material. Pile integrity test is non-destructive test for evaluation of integrity in concrete piles[14–16]. This procedure explains in detail the method statement conducting pile integrity test of cast in situ pile of diameter 800mm Summit Hotel Protection Piles, Lalitpur. The purpose of pile integrity test is
To determine the length of pile
To evaluate the integrity of pile
To check the consistency of pile material.

The Pile Integrity Tester (PIT) is an instrument for integrity testing of deep foundations by low-strain surface-impact methods. It acquires, processes, enhances, and reports data. The test engineer must interpret the data according to wave propagation theory. The results obtained are only as meaningful and reliable as the testing engineer's understanding of the physical principles involved. The PIT is available in four models, namely, PIT-X, PIT-V, PIT-XFV and PIT-FV. The four models can be distinguished from each other on the basis of their size, portability, number of input data channels and wireless transmission of data from the sensing device to the electronic units. All PIT models support the “Low Strain Integrity Test” Method (see ASTM 5882) also called the Pulse-Echo Method (PEM), while PIT-XFV and PIT-FV additionally support the Transient Response Method (TRM)[17]. The user should become thoroughly proficient in PEM and TRM in order to achieve a higher level of confidence needed during data interpretation. Some theory is discussed in this user manual as it relates to the PIT operation, but this discussion is neither definitive nor exhaustive. Test applications for PIT include integrity and/or length determination of most types of concrete deep foundations such as drilled shafts or bored piles, Continuous Flight Auger (CFA) or Augered-Cast-in-Place (ACIP) piles, driven concrete piles, individual concrete wall panels (barrettes), concrete filled pipe piles, and timber piles. For simplicity we will refer to all of these foundation types as “piles”. Please note that the Pulse Echo Method has pile length limitations which are a function of pile material type, pile uniformity, soil elastic properties (elastic modulus), soil density etc. Also data taken on cylindrical piles, steel piles, jointed piles and timber piles have either greater length limitations than solid ones or do not support clear and/or reliable data interpretation[16,18–24]. Similarly individual piles within a bored pile wall or panels of a diaphragm wall usually do not provide satisfactory integrity assessments with the Pulse Echo Method. Other methods such as the Thermal Integrity Profiler (TIP) or Cross Hole Sonic Logging are then much more successful.

2. Test Method

Pile Integrity Test is applied to any type of concrete pile. The test is performed with a hand held hammer, a geophone or accelerometer and data acquisition and interpretation electronic instrument. Hammer is used to induce impact of low strain. An accelerometer or geophone measures the response of hammer impact. Data acquisition and interpretation electronic instrument display results. The test is based on wave propagation theory. The name "low-strain dynamic test" stems from the fact that when a light impact is applied to a pile it produces a low strain. The impact produces compression wave that travels down the pile at a constant wave speed. Changes in cross sectional area - such as a reduction in diameter - or material -such as a void in concrete - produce wave reflections.

### Pit equipment

2.1 Hammer:

2.1.1 The hammer: Diverse types are available, ranging from small hand held hammers to large, heavy-duty machines. The hammer is designed to deliver a controlled impact to the pile. The hammer must be held firmly and used in a consistent manner to ensure accurate results.

2.1.2 Accelerometer: The accelerometer is placed on the pile head using suitable, or temporary, thin layer of bonding material (that is, wax, Vaseline, putty etc.) and have their sensitive axis parallel with the pile axis. It is generally placed near the center of the pile.

2.1.3 Data acquisition and interpretation electronic instrument: The apparatus include a graphic display of velocity and a data storage capability for retrieving records for further analysis. The apparatus is capable of averaging data of several blows to reinforce the repetitive information from soil and pile effects while reducing random noise effects. The apparatus is capable of transferring all data to a permanent storage medium. The apparatus shall allow for a permanent graphical output of the records.

2.1.4 PIT-QV: It supports the “Low Strain Integrity Test” Method also called the Pulse-Echo Method (PEM). This models provide output both in time and frequency domain, using Fast Fourier Transform(FFT). Data collected by the PIT-QV is further analyzed using the PIT-W software for a more through data interpretation and report quality output.
2.2 Test Procedure of PIT

2.2.1 Test preparation: For cast in place piles, integrity testing is performed on a pile cured for a minimum of 14 days and the head trimmed down to cut-off level, unless otherwise approved by the Engineer. The pile head shall be free from water, dirt or other debris. The concrete at the pile top surface must be relatively smooth and provide sufficient space for attaching the motion sensing device and for the hammer impact area.

Fig 7: Pile Surface Prepared for PIT Test

2.2.2 Measurement: Several impacts are recorded in the form of each individual impact or the average, as required. The low strain impact is applied to the pile head within a distance of 300 mm from the motion sensor. If only the individual impacts are recorded, ensure that the apparatus for recording, reducing, and displaying data is capable of averaging up to 10 individual records (normally, 4 to 6). Record the number of impacts for a specific averaged record. Take, record, and display a series of velocity measurements.

2.2.3 Interpretation and Reporting

Based on these record categories, the following decisions may be made.

a. For Category PD records, contingency plan must be in place which allows the engineer-in-charge to choose from a menu of additional tests or corrective measures such as retesting at a later time, retesting by other methods such as dynamic load testing, replacing the pile, core drilling, pressure injection, etc. It may also be possible to accept the pile, maybe with a reduced capacity, based on the reduced length.

b. For Category PF records, a reduced pile capacity may be assessed based on Conservative shaft property assumptions, including consideration of a reduced Length. Also, the shaft may be retested later or by other methods (e.g. dynamic load testing).

c. For Category AB records where the test is inconclusive due to a great length or embedment, it may be sufficient to accept the shaft if the upper shaft portion appears to be of good quality.

d. For Category IV and IR records, additional PIT testing may be scheduled after removing poor pile top concrete, after allowing concrete to achieve greater strength or when the vibration disturbance has been eliminated.

e. For Categories PF, PD indicating flaws or defects near the top, excavation around the pile may be done for pile
2.3 Basic Testing Recommendations

Velocity of the pile top surface is in most instances the most important data collected during a pile integrity test. It requires a light hammer impact and the recording of acceleration. In order to obtain an accurate record of the pile top surface motion the location where the acceleration is measured has to be a sound, clean pile material. Contamination by soil, loose debris or surface layers, poorly hardened pile material a very rough surface are among the conditions that provide poor records which are difficult or in most instances impossible to interpret clearly. Obviously, the concrete has to be hardened to a point where it is much harder (or having a higher elastic modulus) than the surrounding soil. For clean impact pulses without ringing or other spurious signals the impact surface also has to be of clean and preferably smoothened. Thus grinding down to good concrete several impact and accelerometer locations is the best assurance to obtain meaningful results. It saves on data interpretation time and/or a repeat trip to the site. The accelerometer should be bonded to the pile top surface with a thin layer of a “sticky” material. Depending on pile temperature and/or moisture content, different materials may have to be tried. Under no circumstances should a thick layer of bonding material separate the sensor from the pile material. In fact, pressing the accelerometer down far enough until one feels it touching the concrete makes for the best records.

Ideally, the hammer impact would cause the whole pile diameter to achieve a uniform axial motion. However, only a small pile top area is subjected to the impact causing a non-plane deformation of the pile cross sections below the pile top. Thus testing on the west side of the pile top will not reveal what is happening on the east side within one or two pile diameters below the pile top and for larger piles it is therefore strongly recommended that the pile top is tested and impacted at several locations. Ideally impacting and testing is done at the third points of the pile top surface. The worst location for testing is the edge of the pile. However, the larger the pile diameter the greater the motions generated at the pile top by shear (or Rayleigh) waves. These pile top motions may appear as noise in the basic compressive wave record. Spurious record components can also be created by reinforcement extending above the pile toe or small cracks within a short distance below the pile top. Larger hammers or more cushioned hammers possibly improve the record appearance in such cases.

Longer piles produce weaker pile toe signals than shorter ones because of losses of wave energy due to pile internal or soil external damping. However, hammer impact pulses with lower frequency contents (those that have longer lasting impact pulses either because of a greater hammer weight or a softer cushioning) travel longer distances with less energy dissipation than those that are sharper and shorter[23–25]. Unfortunately, the smoother longer pulses do not allow for as clear a resolution as the sharper ones. It is best practice, therefore, to test with several hammers, for example, using hammer weights of 5, 10, 30 N (0.5, 1, and 3 kg or 1, 2 and 6 lb) for more and clearer information.

Results of Pit

From the resulting graphs of the data collected following results have been found out:

- Pile 1c has sound shaft integrity also no major defects have been observed and the estimated depth of the pile is 22.20 m which was 22m.
- Pile 2c indicates a probable flaw of minor necking but which can also be caused due to change in material, unplanned reduction of size otherwise the pile is sound. The apparent depth of the pile is 21.85 m which was 22m.
- Pile 3b shows no major cracking but there are slight indication of bulging at 7.6 m and reduction of size at 4.3 m and 11.2 m. The depth of the pile is 22.40 m which was 22m.
- Pile 4a shows no cracking but there are slight indication of bulging at 9.6 m and reduction of size at 14.5 m. The depth of the pile is 23.80 m which was 24m.
- Below is the pile type cb 7.1 & cb 9.3 result which is 12m depth on the lowest excavation part I.e. north side:
3.1 Difficulties faced in construction of caste-in-situ protection pile for basement works.

The apartment & hotel basement have free floor area ratio. There is huge requirements for parking in apartment and hotel building which means that the developer should have to build 2 floor basement in order to provide parking to buyers. The basement area covers around 80-90% site area which means that the leftover land is 2m from the boundary line on each side. Protection pile get necessary to build up to retain the surcharge and neighbor area. Caste-in-situ protection pile have been used to solve out these problems to excavate basement and foundation level. Micro Anchor piling have been done in 4-5 layers so as to restrain the pile on each side. While doing the work we have faced lots of problem in quality control of work. Following are the problem we have faced during construction:

a. Truck mounting rotary machine was very difficult to move at center point of pile due to loose moisture content soil surface.

b. However, TMR machine was setup at center point, there was a big challenges in leveling the hydraulic jack of machine to erect auger vertically on the center point.

c. As the pile cap level was given 2m below the Original ground level, there was a major issues in placing the rebar cage into the boring pile.

d. Concreting at required pile cap level which was 2m below the ground level was very difficult to figure out and it lead to concreting up-to OGL; It encounter the losses and difficult to pile cap work.

e. As the boring work was started in rainy season which creates disturbance in work at site.

f. Leveling the auger while boring was a major issues during rainy season which sometimes leads deflection of TMR and the piling boring used for angular; it leads to touch the Completed pile about the bottom level and required pile boring was difficult to get.

g. Pile spacing was 200 mm only from external face; at the inner level sand strata was found at 8m,12m, 16m etc. on the east and west side which used to erode sand during wash boring. During Concreting the sand used to bond with cement and gets hardened.

h. Work timing is very critical we have faced as it was from 8 a.m.to 7 p.m. As boring was done the concreting should be done within 3 hours otherwise there was chances of pile collapse.

I. Machinery problem have occurred during concreting many times in the site.

j. Site management and material management was also critical due access road and compact community areas.

k. Quality in aggregates was also issued due there was lack of storage areas in the field.

I. Safety in handling and getting the site free of injuries and accident was also a challenge in site. However no accident happened during work as safety was taken seriously by both contractor and consultant.
3.2 Summary Guidelines for Cast-In-Place Bored Piling by Rotary Bored Machine

For the quality control of Cast-In-Place bored piles done at construction of hotel summit & residence, Lalitpur areas are mentioned in this paper. For the study purpose some guidelines have been mentioned below:

• At first selecting the auger frame is done considering of soil structure and soil report.
• Ensuring truck mounting machine stability using spirit level machine.
• Cleaning the pile tip zone by washing method.
• Checking to be done on each pile whether the required depth is obtained or not.
• Soil test report must be available at site so that it will be easy to identify the soil layers while working.
• PIT Test must be done to ensure the pile depth and quality of concrete poured.
• For the movement of TMR to center point excavator and loader have been used to pull.
• For vertical leveling with respect to earth surface spirit level should be checked before starting the boring and each intervals of boring i.e. 2m.
• As pile cap level was 2m below, for concrete quality and required pouring was done using tremmie pipe and checking the depth of concreting by means of wooden stick which was inserted to bored and when it get stuck below 2m concrete pouring was stopped in that bore.
• As rainy season was there in the working time, 2-3 pond on site areas was dug out to collect rain water and with the help of submersible pump it was drained quickly in order to keep the subsoil dry.
• In order to maintain immediate machinery equipment there was 2 mechanics available at the site during the working hours.
• For stocking the sand and aggregate first two layers of plastic sheet has been placed at areas and for reinforcement it was covered using sheet. If the reinforcement stock was large cement slurry was used to spray over rebar.
• For minimizing the work time the boring was used to start from morning first half and then concreting was done in second half. Due timing we faced lots of problem. It took us 2 months to complete 270 no’s of pile for Apartment areas which is half of the site areas.
• HR manger was appointed to solve neighbor issues and discussion.
• In order to material management there was 5 container have been placed in one of the corner of site areas for cement, silica etc. storage.

Conclusions

Construction of Multi-storey buildings and hotels are increasing rapidly in Kathmandu valley. The Ground coverage in Lalitpur is 60% only, FAR is about 4 and for higher structures 5m setback must be left in order to run emergent vehicles during hazards. Due to this parking areas get smaller and the developer must to make underground basement which means they can utilize 80-90% of their property without disturbing setback areas the cast in place protection piling is done to build basement without making any hazards to other properties. Pile defects or collapse cannot be accepted. So Quality Control in Cast-In-Place Bored Piling is most important in site. For the quality control of Cast-In-Place bored piles done at construction of hotel summit & residence, Lalitpur areas are mentioned in this paper for the study purpose and to minimize the problems occurred during construction.

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REFERENCES
