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The Behaviors of Connections in Segmental Precast Concrete Pile Systems

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Abstract
A continuously reinforced segmental precast concrete underpinning pile using a method of installation where a high strength strand aligns the precast segments during installation, provides a means for measurement of pile penetration depth, and continuously reinforces the pile when bonded or anchored upon completion. The results from the laboratorytesting and the finite element analysis indicate that the failure mode of the pile segment was attributed to the concrete cross- section. The laboratory testing also indicated that exposure of the reinforcement at the connection as the bending moment approached the ultimate limit state, may be cause for concern with regard to durability.

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I. INTRODUCTION

Precast concrete pile are displacement pile that are one of the most economical pile system on a cost per lineal foot per load supported basis. Geostructures provides precast concrete pile on a design build basis with allowable capacities ranging from 125 to over 750 kips for pile or as needed as your project. Precast Concrete Piles are the most common type of deep foundation used, to transmit loads through the upper zones of the poor soil to a depth where the soil is capable of providing adequate support. The precast concrete pile is a reinforced concrete pile which can be circular, rectangular, square, or octagonal in shape. The steel reinforcement in a precast concrete pile is provided to resist the stresses produced due to its handling, driving and loading which the pile is finally expected to receive.These piles are constructed by conventionally reinforcing the concrete with internal reinforcement cage made up of several longitudinal and lateral steel bars and in the form of individual ties or a spiral. The precast piles are constructed in a casting yard to a specified length, cured and then transported to the construction site. If space is available and a large quantity of piles are needed, a casting yard is provided at the site to reduce transportation cost. Precast piles are driven similarly as timber piles using pile drivers.

Types of Precast Concrete Piles

There are two types of precast concrete piles such as,

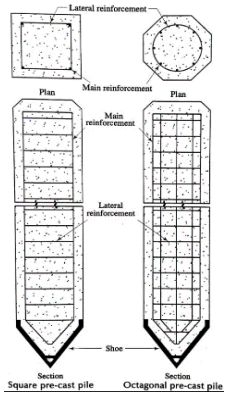
Driven Precast Concrete Piles

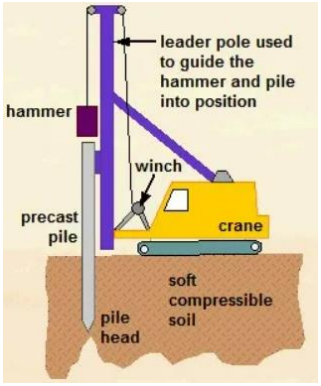
Driven precast concrete pile is constructed of reinforced concrete in a casting yard and once it attains sufficient strength it is hammered into the ground to a depth of more than 40m using a hammer.

Bored Precast Concrete Piles

- Bored precast concrete pile is a type of precast pile which is constructed in reinforced concrete in a casting yard and subsequently lowered into pre bored holes. Later, the space between the pre bored holes and piles is grouted.
- Bored precast concrete piles have advantage over the driven precast concrete piles, in following locations and situations,
- Where the vibrations and noise caused by the driving of piles are to be avoided.
- The strata of adequate bearing capacity are so deep that they are difficult to reach by driven piles.

Images





Description

FIELD OF THE INVENTION

The invention relates to the repair of building foundations by underpinning. More specifically, it relates to a method for aligning pile segments during installation, inspecting pile penetration depth, and continuously reinforcing an improved segmental precast concrete pile used for underpinning repairs.

There is a type of precast concrete pile used in the underpinning of building foundations comprised of vertically stacked, unconnected, precast concrete segments. These segments are pressed or driven vertically into the soil one at a time until adequate load capacity is obtained. This type of pile is distinctive in that it can be installed with almost no clearance, usually beneath an existing structure.

Although serviceable, this pile has several significant disadvantages:

(a) the pile segments are not aligned, other than being stacked on each other, and detrimental misalignments can occur,

(b) independent inspection of the installed pile depth is only possible by providing full-time inspection personnel during installation to monitor the quantity of precast segments used at each pile location, (c) the completed pile is an unreinforced stack of precast concrete segments.

Misalignment of the segments as they are installed can produce several conditions detrimental to future pile stability. Lack of proper independent inspection of pile depth can lead to inadequate pile penetration, which in highly expansive soils produces an unstable installation subject to continued movements caused by seasonal changes in soil moisture. An unreinforced or non-continuously reinforced pile is subject to permanent separation at segment joints or breakage at segment midpoints when installed in clay soils having high shrink-swell potentials.

This separation of segments occurs when clay soils swell due to an increase in moisture content. This soil expansion exposes the pile to tension forces. This is especially detrimental to an unreinforced pile because even slight soil intrusion into the gaps between segments prevents closing of the gaps when soil moisture decreases. Over a period of years, this cyclical shrink-swell effect can lift the upper portion of the pile and the supported structure. This lifting effect at pile support locations falsely appears as settlement of adjacent unsupported areas.

II. SUMMARY OF THE INVENTION

Briefly, the invention provides a method for aligning precast concrete pile segments as they are installed, while furnishing a means for rapid inspection of pile installation depth, and upon completion of installation provides a continuously reinforced segmental precast concrete underpinning pile.

The above attributes are accomplished in the preferred embodiment by using a precast concrete starter segment with a graduated high strength steel strand extending from the center of one end. This starter segment is driven into the soil while using a bending template with a restraining anchor. The bending template curves and protects the strand, and the restraining anchor keeps the strand taut to prevent misalignment of the segments as they are driven. Improved precast concrete pile segments constructed with strand ways are then threaded onto the graduated strand and aligned for installation in the same manner as the starter segment.

Installation of subsequent segments continues until adequate load capacity and depth is obtained. Upon completion of segment installation, a pile cap is threaded onto the strand for distributing structural loads to the pile. The pile penetration depth can be easily inspected upon completion by simply reading the graduated strand. After inspection of the pile penetration depth, the excess length of strand is trimmed flush. The annular space between strand and concrete is then injected with a structural adhesive to bond all components of the pile.

This method of installation provides an aligned, continuously reinforced, concrete underpinning pile of verifiable depth, installed under conditions with almost no clearance, such as beneath an existing building.

BENEFITS OF DESIGN-BUILD

■ Contractor/Designer Committed to Pile Performance
■ Multiple Design Options Results in Best Value
■ All Piles is not the only answer – Can Combine with Ground Improvement Options

APPLICATIONS FOR PRECAST CONCRETE PILES

■ Building Foundations – Heavy Loads and Soft Soils
■ Tall buildings subject to earthquake loading
■ Industrial buildings with significant horizontal or bending stresses
■ Tank Foundations
■ Embankment and MSE Wall Support
■ Warehouses with heavy floor loading
■ Power Plants

ADVANTAGES OF PRECAST CONCRETE PILES

- Minimal spoils – great for Brownfield Sites
- Pile Capacity Confirmed on Every Pile
- Design/Build process – provides highest value through efficient design
- Mechanical Splices provide Faster Installation and Minimal Waste
- Precast concrete piles compact the soil. Therefore, the main advantage of using these piles is increasing the **bearing capacity of the soil**.
- These piles can be made in various sizes, shapes and lengths and used at the site. As a result, the progress of project work will be faster.
- The position of the reinforcement in these piles is not disturbed from its original position.
- The construction of these piles can be well supervised, and any defect detected can be rectified before use.
- **The Precast Concrete Piles can also be driven underwater**.
- Precast piles can be immediately loaded after they have been driven.
- The driving of an adjacent pile does not produce an adverse effect on the already driven piles.
- These piles are highly resistant to the biological and chemical action of the subsoil.
- No waste generation on the site.
- It is not affected by the groundwater.
- It is the most economical form of deep foundation
- Precast concrete piles can withstand high pressure vertical loads as well as high tension

Disadvantage of Precast Piles

- Precast Concrete piles are heavy. Therefore, they require special types of equipment for handling, transportation and driving.
- If sufficient care is not taken, these piles may break during transport or driving.
- Precast piles require heavy pile driving machinery for installation.
- It requires extra reinforcement to bear handling and driving stresses which otherwise are not needed. Hence these piles are costly.
- The length of the pile has to be limited since it depends upon the transport facilities.
- It is difficult to increase the length of the pile based on previously estimated borehole data.
- If the pile is found to be too long, during driving, it is difficult and uneconomical to cut the pile.
- These piles are not available at short notice. Hence delay of work will occur for projects having emergency and when changes are needed.

BEST GEOTECHNICAL APPLICATIONS

■ Heavy Loading Conditions and Tight Settlement Criteria
■ Deep Soft or Organic Soils over dense sands or bedrock
■ Soft or Loose soils over 30 feet deep

NSTALLATION CONSIDERATIONS VIBRATIONS

Because **Hydraulic Hammers** are used, piles can be installed very close to buildings and rail lines.
Hydraulic Hammers have a high frequency and a low drop height and can be adjusted to limit vibrations when needed adjacent to critical structures.

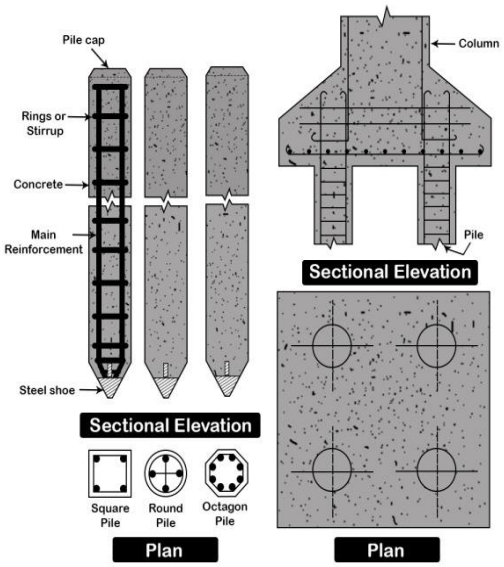
Necessary Information About Precast Concrete Piles

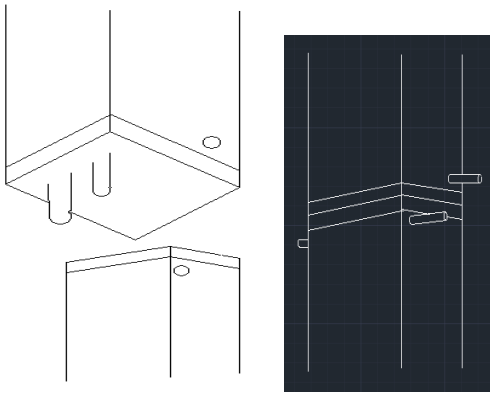
According to '**Swami Saran**' (Author of Analysis and Design of Substructures Limit State Design), these things are to be kept in mind while opting for precast concrete piles.

- Precast Concrete piles are used in lengths up to about 20 m. The length of the pile depends on the soil condition and position of the water table. To increase the length of pre-cast piles, two piles are connected with the help of fish plates and bolts.
- The piles are driven by hammering them at the top. Hence maximum stresses are developed at the top due to direct strokes, and at the point in overcoming the resistance to penetration, therefore additional reinforcement should be provided.
- The minimum grade of concrete used in construction of precast concrete pile is M25.

As per Indian Standard Code, for satisfactory design and construction of precast concrete piles, the following information would be necessary,

- Site investigation data has to be carried out as per Indian standard code (IS – 1892).
- Based on appropriate tests of strength, compressibility etc., the nature of the soil around and beneath the proposed pile should be assessed.
- Groundwater level and artesian conditions also need to be mentioned.
- Chemical properties of soil should be evaluated and studied so that there is no loss after constructing them.
- All loads including seismic, wind and forces due to water current, etc. should be indicated separately.
- In the case of bridge foundation, data on high flood level, maximum scouring depth, normal water level during the working season, etc. along with other hydrological data should be provided.
- Sufficient Information of nearby existing structure and experience of piles in the area close to the proposed site should be carried out, to determine the level of the foundation.
- Design of driven precast concrete piles should conform to **Indian Standard Code -2911 – Part -I/ Sec-III** and Design of bored precast concrete piles conform including sequence of works to **Indian Standard Code -2911 – Part -I/ Sec-IV**.
- Prepare complete working drawings for the execution of work.





Procedure for Casting Precast Concrete Piles

- Prepare formwork for the pile.
- The cage of reinforcement is prepared as per the design, and this cage is then placed in formwork.
- Prepare the grade of concrete which is specified in the design.
- The concrete is laid in formwork and well compacted using vibrators.
- The piles are then shifted to a curing tank, and after the curing, they become ready for use.

Precast Concrete Pile Installation

The operation of forcing a pile into the ground is known as pile driving or installation of pile. Pile driver is an equipment used to lift the hammer and allow it to fall on to the head of a pile.

The piles are driven into the ground by means of hammers or vibratory drivers. In certain situation, piles can also be inserted by jetting or partial augering. The type of hammer used for pile driving are

- Drop Hammer
- Single-acting hammer
- Double-acting hammer
- Diesel Hammer
- Vibratory Hammer

in the pile driving operation, a pile cap is placed on the top of the pile. The primary function of a pile cap is to support the **superstructure of a building**. The cap has to be designed with care so that there is no failure of structure.

To know more about the installation of the precast concrete pile, watch this online documentary by **McDonnell**. (It is a Company that provide a range of geotechnical solution for any ground condition in Ireland and investigate, review and recommended then give practical and realistic advice.)

There are various types of pile driving machines built for different types of soil and the pile material. However, all of them basically consist of a heavy weight placed between guides so that it can move up and down in straight line. The driving force comes from the repeated hammering action as the weight is dropped on the pile head, raised and dropped again using hydraulic or compressed air for the operation.

Final Thought

Pile foundation is the oldest method of providing a safe, sound and a dependable foundation. A pile is an element of construction consisting of timber, concrete, or steel or combination of these. It is either driven into the soil or formed on-site by excavating a hole and grouting bore with concrete.

A pile foundation usually consists of several piles, which together support a structure. **Selection of type of pile** depends upon the nature of the structure, loading conditions, type of soil and its properties, groundwater table, facilities available for pile driving, maintenance cost etc.

III. CONCLUSIONS

Based on the literature review undertaken it was found that thestructural competency of the connections in segmental piles is a cause for concern. The literature review established that limited scientific data is available. The results of the laboratorytesting indicate that the configuration of the pile joint that wastested is structurally sound and the failure of the concrete crosssection was the primary mode of failure. Neither the end platenor the locking peg in the joint configuration that was tested exhibited any sign of yielding or plastic deformation. The FEAand hand calculations support the results of the laboratory testing. However, it was observed in the laboratory testing thatthe effects of the bending moment on the connection and the resulting deflections caused exposure of the reinforcing steel atthe connection as the magnitude of the bending moment approached the ultimate limit state.

This may be a cause for concern for the long term durability of the connection. Furtherresearch would be required for confidence in the joint in all configurations.

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