The Application of Slow Setting Prestressed Pullout Pile in Foundation Engineering

Boshi Pang\textsuperscript{a}, Yun Gao\textsuperscript{b} and Baoan Zhang\textsuperscript{c}

China Construction Fourth Engineering Bureau No.6 Construction Co., Ltd., Shanghai 201100, China
\textsuperscript{a}1730920231@qq.com, \textsuperscript{b}2014286859@qq.com, \textsuperscript{c}1442920691@qq.com

Abstract

In construction engineering, in areas with high groundwater level, when the upper structural load cannot balance the groundwater buoyancy, the whole or part of the structure will be subject to upward buoyancy. In order to offset the upward buoyancy of groundwater on the structure, uplift piles are generally set in the pile foundation. Ordinary uplift piles use the friction force of the pile body to counteract the buoyancy of groundwater. To improve the uplift capacity of ordinary uplift piles, it is necessary to increase the diameter of the pile, which increases the amount of concrete and steel bars used, resulting in increased engineering costs. If bonded prestressed technology is used, it also faces the problem of complex construction process and difficulty in ensuring grouting quality. In order to solve these problems, slow bonded prestressed uplift piles are used in pile foundation. The slow bonding prestressed anti pull pile improves the pile's anti pull bearing capacity and reduces the amount of steel bars while maintaining the same pile diameter, and has been successfully applied in engineering. This provides new ideas and choices for the construction of other pile foundation projects.

Keywords

Friction; Slow Bonding Prestressed Anti Pulling Pile; Bearing Capacity; A Steel Bar.

1. Introduction

In today’s rapidly developing world, engineering projects under construction are becoming increasingly complex, and the performance requirements for foundations are constantly increasing. The anti floating technologies used in engineering now include anti floating plates, anti floating piles, and anti floating anchor rods. These anti floating technologies are increasingly unable to meet people's needs for engineering safety, economy, and durability. Therefore, slow setting pre-stressed anti pulling piles have emerged, further increasing the selectivity in the field of building anti floating. The current slow bonding prestressed technology is a relatively advanced prestressed technology, which avoids the disadvantages of complex construction and difficult to ensure grouting quality of bonded prestressed technology. At the same time, it also absorbs the advantages of less construction process and faster progress of unbonded prestressed technology. Slow bond pre-stressing is the third generation pre-stressing technology after bonded pre-stressing and unbonded pre-stressing. Nowadays, slow bond pre-stressing technology is also becoming mature, but it is rarely applied in foundation engineering. This project's slow bond pre-stressing anti uplift pile is the application of slow bond pre-stressing technology in the field of foundation anti floating, which can provide experience and reference for the use of slow bond pre-stressing technology in subsequent projects.
2. Project Overview

The project is located in Hangzhou. Lishui Road under construction is to the east of the site, Gongxie Road is to the north, Grand Canal is to the west, and Jinchang Road is to the south. It is close to the Beijing Hangzhou Grand Canal and Hanggang River, only 50m away from the Grand Canal and 90m away from Hanggang River. The project is located at a high groundwater level of 0.8~2.1m. The total land area of the project is 49952 m², and the total building area is 175650 m², of which the aboveground building area is about 107700 m², and the underground structure area is about 67950 m². The building is divided into 2 underground floors and 15 above ground floors. The total height of the building is 70m. Basement structure type: frame shear wall structure, podium structure type: small wall large-span steel structure, main building structure type: frame shear wall structure+core tube.

![Fig 1. On site pile foundation construction](image)

The perimeter of the project foundation pit is 950m, and the excavation depth is 12.8m-13.3m. The strata within the exploration depth range of the project surface are mainly Quaternary overburden layers, which can be divided into 12 engineering geological layers, totaling 26 sub layers. From top to bottom, the rock and soil layers are mainly miscellaneous fill, plain fill, silty clay, silt and muddy clay, clay silt, gravel sand, completely weathered tuff, strongly weathered tuff, moderately weathered tuff, moderately weathered altered tuff, strongly weathered altered tuff, moderately weathered altered tuff. The moderately weathered tuff and moderately weathered tuff are selected as the bearing stratum of the foundation.

3. Construction Technology of Slowly Bonded Prestressed Anti Pull Pile

3.1 Composition of Slow Bonding Prestressed Anti Pull Pile Materials

3.1.1 Slow Bonding Prestressed Reinforcement

Slow bonding prestressed steel bars are composed of steel strands, coated with slow bonding adhesive, and wrapped with PE.

![Fig 2. Slow setting prestressed reinforcement](image)
Steel strand: The prestressed steel strand is mainly made of cold drawn high carbon steel, and the number of steel wires in the steel strand can be divided into 2 wire steel strand, 3 wire steel strand, 7 wire steel strand, and 19 wire steel strand. The steel strand used in the project is a high-strength and low relaxation steel hinge wire with a diameter of 15.2mm, and the standard tensile strength value is fptk=1860MPa.

Slow bonding adhesive: Through the solidification of slow bonding adhesive, the transition from non bonding to bonding between prestressed steel strands and concrete is gradually achieved. During the construction phase, the prestressed steel bars can expand and deform freely, without bonding with the surrounding slow setting adhesive. However, during the predetermined period after the construction is completed, the prestressed steel strands bond with the surrounding concrete through the solidified slow setting adhesive. The prestressed steel strands form an integral part with the surrounding concrete and work together to achieve a cohesive effect. The standard tensioning period of the adhesive used in the project is 180 days, and the standard curing time is 540 days.

External PE: The surface of the external PE is mechanically pressed into a corrugated tube like indentation. After the slow setting adhesive is fully cured, it is bonded to the steel strand through the slow setting adhesive, and the uneven indentations of the PE sheath bite into the concrete. The prestressed steel bars cannot slide freely in the concrete, and the slow bonding pre-stress produces the mechanical effect of bonded pre-stress.

3.1.2 Parameters Related to Slow Bond Prestressing

<table>
<thead>
<tr>
<th>Table 1. Parameters related to slow bond prestressing</th>
</tr>
</thead>
<tbody>
<tr>
<td>specifications</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>15.2</td>
</tr>
</tbody>
</table>

3.2 Construction of Slowly Bonded Prestressed Pullout Pile

The slowly bonded prestressed anti pull pile is composed of the following parts: slowly bonded prestressed steel strand, upper anchor end clip anchor, lower anchor fixed end compression anchor, steel cage, and together with pouring concrete and surrounding foundation soil to form the anti pull pile solid.

<table>
<thead>
<tr>
<th>Table 2. Design parameters of slowly bonded anti uplift piles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pile diameter (mm)</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>700</td>
</tr>
</tbody>
</table>

Upper anchoring end clip anchor: It is a key component for tensioning and sealing anchor in the later stage of slow setting. Composed of single hole anchor, pressure plate, spiral reinforcement, and cavity mold.

Lower anchor fixed end compression anchor: It is an enlarged fixed anchor head set to ensure better stress on the anchor body during the later prestressed tensioning process. Adopting a single bundle compression anchor, composed of compression anchor, anchor plate, and spiral reinforcement.
The prestressed steel strand used in this project is a high-strength and low relaxation steel strand with a diameter of 15.2mm, and the standard value of tensile strength is $f_{ptk}=1860\text{MPa}$. The tension control stress of prestressed reinforcement is $\sigma_{con}=0.75f_{ptk}=1395\text{Mpa}$. The standard tensioning period of the delayed adhesive is 180 days, and the standard curing time is 540 days. The product is marked as RPSR-180-540 15.2-1860 JG/T 369-2012. Slow bonding prestressed steel bars are composed of steel strands, coated with slow bonding adhesive, and wrapped with PE. The tensioning end adopts clip type anchorage, and the fixed end adopts extrusion type anchorage. The strength grade of concrete is C40. When the strength of the prestressed pile concrete reaches 100% or more (based on the test report of the concrete test block under the same conditions), tensioning can only be carried out.

The use of slowly bonded prestressed steel bars instead of the main reinforcement of the anti-pulling pile reduces the amount of steel bars used in the pile, causing the pile concrete to be subjected to compressive stress first, indirectly increasing the tensile strength or ultimate tensile strain of the pile concrete. This fundamentally improves the easy cracking characteristics of the pile concrete, reduces the occurrence of cracks, and enhances the durability of the anti-pulling pile.

![Fig 3. Detailed drawing of tension end and fixed end](image1)

![Fig 4. Detailed drawing of slowly bonded prestressed uplift pile](image2)
3.3 Construction of Slowly Bonded Prestressed Pullout Pile

3.3.1 Construction Process

1) Pile foundation drilling: Through the construction process of pile foundation positioning, steel casing production and burial, mud preparation, rotary excavation construction, hole cleaning, hole inspection and acceptance, the pile foundation drilling is completed. It should be noted that total station or RTK setting out shall be used for pile foundation positioning to determine the position of the pile body, and then the center point method shall be used, and the re-inspection work shall be done after the pile casing is buried. The allowable deviation of the pile diameter is 50mm, the allowable deviation of the perpendicularity is less than 1%, and the allowable deviation of the pile position is 100mm. During the drilling process, it is necessary to regularly measure the specific gravity, sand content, viscosity, and pH value of the protective mud slurry, at least once every 10m depth. The specific gravity of the mud should be controlled according to the soil layer being crossed, and the sand content of the mud should be less than 6%; The viscosity of the mud slurry is 18-20s, and the pH value is 7-9. After the rotary excavation reaches the design depth, organize relevant personnel to inspect and accept the hole depth, aperture, sediment, verticality, etc., and sign acceptance opinions.

2) Processing of prestressed steel bars: Slow bonded prestressed steel bars are produced in professional slow bonded steel bar production workshops. According to the structural dimensions and quantities on the detailed construction drawings, taking into account factors such as the length of prestressed reinforcement, tensioning elongation value, and concrete compression deformation, a tensioning length of no less than 1m is reserved at each tensioning end of each prestressed reinforcement for cutting. The cutting of prestressed tendons should be done using a grinding wheel cutting machine, and the use of electric welding and gas welding is strictly prohibited.

3) Extrusion anchor production: Install threaded spring bushings and extrusion sleeves at the end of the prestressed steel strand. Apply aluminum disulfide grease or paraffin on the outside of the assembled extrusion sleeve. Insert the assembled end into the extrusion mold, start the pump to supply
oil (with an oil pressure of no less than 20MPa), and complete the assembly of the anchor end of the extrusion anchor. After the extrusion of the anchor is completed, it is advisable to expose the prestressed reinforcement of the extrusion anchor with a length of 1-5mm.

4) Laying of prestressed steel bars: The steel bar worker ties the framework of the steel bar cage, and the prestressed construction unit marks the position of the prestressed steel bars evenly on the steel bar cage according to the designed number of prestressed steel bars. According to the embedded length of the prestressed reinforcement shown in the construction drawing, it has been uniformly numbered, and the prestressed reinforcement is arranged according to the layout method of the prestressed reinforcement group bundle in the section according to the construction drawing. Before laying prestressed reinforcement, special attention should be paid to coordinating and coordinating with the laying direction and position of non prestressed reinforcement. The laying sequence and position of prestressed steel bars should be coordinated with the laying sequence and position of ordinary steel bars; The prestressed reinforcement should be laid according to the requirements of the construction drawings, and its plane and section positions should be accurately positioned during the laying process. When multiple slowly bonded prestressed steel bars are arranged, each bar should maintain a parallel direction. Install steel strand protective sleeves before pouring concrete.

![Fig 6. Slow setting prestressed steel strand protection](image)

5) Finished product protection of prestressed steel bars: The outer skin of prestressed steel bars should be laid again and arranged for special personnel to take care of it. If any damage is found, tape should be used for winding and repairing in a timely manner. The overlapping width of the tape should not be less than half of the tape width, and the winding length should exceed the damaged length. When breaking piles, it is strictly prohibited to use a pile breaking machine. Manual pile breaking methods should be used to prevent damage to the steel strand caused by the pile breaking machine, which may cause the inability to tension.

6) Concrete pouring and vibration: After the laying of prestressed reinforcement is completed, the construction unit, quality inspection department, and supervision unit should conduct hidden inspection and acceptance. Only after confirming that it is qualified can concrete be poured. After the placement of the pouring concrete conduit is completed, retest the hole depth, empty bottom sediment, etc. If the thickness of the sediment at the bottom of the hole exceeds the specified value, reverse circulation cleaning should be carried out using the pouring catheter after the reinforcement cage and conduit are installed. The second cleaning time should not be less than 30 minutes, and the sediment at the bottom of the hole should be measured to be \( \leq 50 \) mm before stopping the cleaning. Measure the sediment at the bottom of the hole and use a heavy hammer to test. The reading on the measuring rope must be accurate. The civil engineering unit should carefully vibrate and ensure the compactness of the concrete when pouring it. Especially for the concrete around the pressure bearing plate and anchor plate, it is strictly prohibited to leak vibration, and there should be no honeycomb or holes. When vibrating, it is necessary to avoid stepping and colliding with the prestressed reinforcement, support frame, and end embedded components as much as possible. When pouring concrete in the civil engineering unit, two sets of concrete test blocks are reserved. The two sets of test blocks and
prestressed pile concrete are cured under the same conditions, and pressure testing is conducted before tensioning as the basis for tensioning.

7) Pre tensioning: The tensioning of prestressed reinforcement can only be carried out after the concrete reaches 100% of the designed tensile strength. Before tensioning, a strength test report for concrete test blocks cured under the same conditions should be provided. Before the prestressed tensioning construction, first calculate the stretching elongation value of the prestressing force, and then calculate the oil pressure gauge reading corresponding to the tensioning force of this project based on the calibration curve of the prestressed tensioning equipment. The tensioning of prestressed reinforcement adopts dual control, with the main focus on controlling the tensioning force and the elongation value as the verification. The tensioning of prestressed reinforcement can be symmetrically tensioned according to the plan and concrete strength. Single end reinforcement, tension at one end. After each prestressed tendon is tensioned, the elongation value should be immediately measured and calibrated. If any abnormalities are found, the tensioning should be suspended until the cause is identified and measures are taken before continuing the tensioning. Technicians and safety personnel are present throughout the entire process.

8) Anti corrosion treatment: After the tensioning of the prestressed reinforcement is completed, the exposed prestressed reinforcement should be cut off with a grinder, and the length of the exposed prestressed reinforcement retained on the outside of the anchor should not be less than 3cm. The tensioning end and its surrounding area should be cleaned, and the tensioning end anchor and pad should be coated with anti-rust paint or epoxy resin for anti-corrosion treatment. Finally, the anchor should be sealed with C40 micro expansion fine stone concrete.
4. Conclusion

Slow bonded prestressed uplift piles have the following advantages compared to other uplift piles:

1) The slow bonding prestressed anti pulling pile avoids the disadvantages of complex construction and difficult to ensure grouting quality with bonded prestressed technology, and also absorbs the advantages of less construction process and fast progress of unbonded prestressed technology.

2) Compared with ordinary uplift piles, slow bonded prestressed uplift piles have higher tensile strength, reduce the amount of concrete and steel bars used in cast-in-place piles, shorten the construction period, and create considerable economic and social benefits.

3) Slow setting pre-stress can resist the temperature stress caused by temperature changes, control the temperature shrinkage and surface cracks of the structure, and improve the durability of the uplift pile.

In summary, the delayed setting pre-stressed uplift pile can not only reduce the economic cost of the project, but also play a low-carbon, energy-saving, and environmentally friendly role, providing new construction ideas for future projects.

Acknowledgments

Thanks for the project support of CSCEC4B-2023-KTA-10, the key construction technology research of the Beijing Hangzhou Grand Canal Museum in China.

References


