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Application of T-PHC Bamboo Joint Pile in Foundation Engineering in Coastal Areas

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Abstract

Taking the pile foundation design and construction of a project in Pudong New Area of Shanghai as an example, the principle and feasibility of T-PHC bamboo pile as a Pile foundation in coastal soft soil areas are verified through the analysis of geological conditions. Based on the actual situation of the project, the main process parameters, construction process and applicable conditions, as well as some problems encountered during the construction process and solutions and prevention methods are introduced. As the foundation of the underground reservoir is located in the original river channel and adjacent to the newly opened river channel, T-PHC bamboo joint piles have good uplift resistance and bearing capacity, meet relevant requirements and have high economic efficiency.

Keywords

Prefabricated Piles; Coastal Soft Soil Foundation; T-PHC Type Bamboo Joint Pile; Pile Foundation Engineering.

1. Introduction

At present, prefabricated piles in various types of building foundations have the advantages of low pre production cost, low reinforcement ratio, steel saving, environmentally friendly hollow piles, small diameter, large specific surface area, large bearing capacity of single concrete, simple construction, and low technical difficulty. Its production cycle is short, its turnover is high, and it has the characteristics of related Prefabricated building, so it has high economy. Especially in coastal soft soil foundation, it has unique advantages in application. Compared to ordinary prefabricated pipe piles, the application of T-PHC bamboo joint piles in coastal soft soil foundation not only meets the relevant requirements for bearing capacity, but also has high economic efficiency. T-PHC type bamboo joint pile can be understood as a deformed prestressed pipe pile that uses its diameter changing principle to change the cross-sectional area of the pile body, achieving the goal of improving uplift resistance and bearing capacity.

2. Overview of Engineering Geology and Feasibility Analysis of Prefabricated Piles

The project is located in Caolu Town, Pudong New Area, Shanghai, reaching Gutang Road in the east and Qinjiagang Road in the north. The proposed project consists of three student apartments with 14 floors above the ground, 1 floor underground and a maximum height of 49.90m. The frame structure, Pile foundation, and two teacher apartments with 14 floors above the ground, 1 floor underground and a maximum height of 48.60m are proposed. The frame shear wall structure, Pile

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foundation, 6 floors above the ground, and 1 floor underground are proposed. The maximum height is 16.95m. The frame structure, Pile foundation, One comprehensive canteen has 5 floors above ground, with a maximum height of 17.25m. It is planned to adopt a frame structure, and the excavation depth of the foundation pit is about 4.85-6.45m. The site is located in the East China Plain, belonging to alluvial and marine low plains.

1) Miscellaneous fill soil is mainly composed of cohesive soil mixed with miscellaneous bricks, stones, cement blocks, and garbage, with a complex composition. The site is widely distributed, with a layer of cement floor distributed on the surface or at a depth of 0.4m in some sections, with a thickness of approximately 0.3m.

2) The gray black creek soil is mainly composed of silt, containing a large amount of black organic matter, humus, etc. The soil is weak and mainly distributed at the bottom of the open creek on the site.

3) Brown yellow to grayish yellow silty clay contains iron oxide spots and ferromanganese nodules, and the soil becomes soft from top to bottom. It is widely distributed on the site except for Mingbang area.

4) Grey muddy silty clay contains mica, organic matter, and locally contains a small amount of thin layer of silt blocks and a small amount of muddy clay. It is distributed throughout the site and is stable in distribution.

5) Grey sandy silt contains mica and quartz, mixed with a thin layer of cohesive soil, with uneven soil quality and stable distribution throughout the site.

6) Grey muddy silty clay contains mica, organic matter, and locally contains a small amount of thin layers of silt and small amounts of muddy clay. The site is widespread and stably distributed.

7) Grey muddy clay contains mica and organic matter, locally mixed with thin layered silt and silty soil blocks. The site is widespread and stably distributed.

8) Grey clay contains mica and organic matter, mixed with calcareous nodules, and locally mixed with a small amount of thin layer of silty soil. The site is widespread and stably distributed.

9) Grey silty clay mixed with clayey silt contains mica and organic matter, with uneven soil quality. Silty clay and silty soil are interlayered.

10) Grey silty clay contains mica, organic matter, a small amount of semi humus, muddy patches, and thin layers of silty soil.

11) Blue gray to grayish green silty clay contains iron oxide spots and iron manganese nodules.

12) Grey green to grass yellow clayey silt contains mica and quartz, mixed with a thin layer of cohesive soil, and the soil quality is uneven.

13) The particle composition of grass yellow to gray silty sand is mainly composed of mica, feldspar, and quartz, with uneven soil quality and locally composed of silty soil with a thin layer of cohesive soil.

14) The composition of gray silt particles is mainly composed of mica, feldspar, and quartz, with local fine sand. Widely distributed, but with a relatively deep burial depth, some boreholes have not been exposed.

15) Grey silty clay contains ferromanganese nodules, partially mixed with silty soil. Widely distributed, but with a relatively deep burial depth, some boreholes have not been exposed.

The northwest side of the proposed site is a school, and the hammer method construction will have a significant impact on the surrounding environment. It is recommended to use static pressure method for construction. To ensure smooth pile sinking, reasonable construction equipment should be selected during design and construction. If necessary, trial pile sinking can be carried out to determine construction control parameters. During the construction of prefabricated piles, the pile sinking should be controlled by combining the pile pressure with the elevation.

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When designing prefabricated piles, the spacing between piles should be reasonably arranged. During construction, reasonable construction techniques and sequences should be selected to prevent soil compaction effects.

Table 1. Characteristic values of bearing capacity of foundation soil

sequence	Soil layer name	specific penetration resistance	severe	Direct shear fast peak strength		Fak(b=3.0m,d=0.5m)
		Ps(MPa)	γ (KN/m³)	C(kPa)	ψ(°)	Fak(kPa)
②	clay	0.6	18.7	24	15.5	75
③1	Silty Silty Clay	0.39	17.8	10	*16.8	50
③2	Sandy silt	2.2	19.3	4	31.5	100
③3	Silty Silty Clay	0.68	17.3	13	15.5	55
④	muddy clay	0.7	16.8	14	11	60

3. Analysis of Bearing Capacity of Prefabricated Pile Foundation Selection and Test Piles

On the premise of determining the use of prefabricated piles, the following pile types were selected for off-site pile testing. The pile types were selected as follows: ① Pile type 1 prestressed pipe pile PHC 500 AB 125-12 (upper), 12 (middle), 13 (middle), 13 (lower); ② Pile type 2 prestressed pipe pile PHC 500 AB 125-11 (upper), 12 (middle), 12 (middle), 13 (lower); ③ Pile type 3 prestressed pipe pile PHC 400 AB 95-13 (upper), 13 (middle), 14 (lower), with pile tip; ④ Pile type 4 T-PHC-B 400-370 (95) -12 (upper), 11 (lower), with pile tip. Each of the above pile types is equipped with 3 test piles, and the test pile numbers are numbered S1 to S12 in the order of pile types. The test pile position is shown in Figure 1.

The test adopts the slow maintenance load method to load in equal quantities step by step. The static load test of 12 test piles in this project has a loading value of 150kN per level, and the final load is until failure.

1) The process of pile number s1~s3 test was normal during the loading level 1-8 test, and the settlement increased during the 9th level loading (1500kN). The Q-s curve shows a turning point, and the tail of the s-lgt curve shows a significant downward bend, indicating obvious failure characteristics. The test is over. According to the specifications, the standard value of the vertical compressive ultimate bearing capacity of the single pile for the s1~s3 test pile is 1350kN, and the characteristic value is 675kN. The Q-s curve, s-lgt curve, and s-1gQ curve of the s1 test pile are shown in Figure 2.

2) The process of pile numbers s4~s6 test is normal during the loading level 1-9 test. When the 10th level load is applied (1650kN), the settlement increases, the Q-s curve shows a turning point, and the tail support of the s-lgt curve shows a significant downward bending, indicating the end of the test with obvious failure characteristics. According to the specifications, the standard value of the vertical compressive ultimate bearing capacity of s4~s6 single piles is 1500kN, and the characteristic value is 750kN. The Q-s curve, s-lgt curve, and s-1gQ curve of the s4 test pile are shown in Figure 3.

3) The process of pile number s7 test was normal during the loading level 1-11 test. Apply load at the 12th level (1950kN).

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As the settlement increases, a turning point appears on the Q-s curve, and the tail support of the s-lgt curve bends significantly downwards, indicating obvious failure characteristics. The test is over. According to the specifications, the standard value of the vertical compressive ultimate bearing capacity of s7 single pile is 1800kN, and the characteristic value is 900kN.

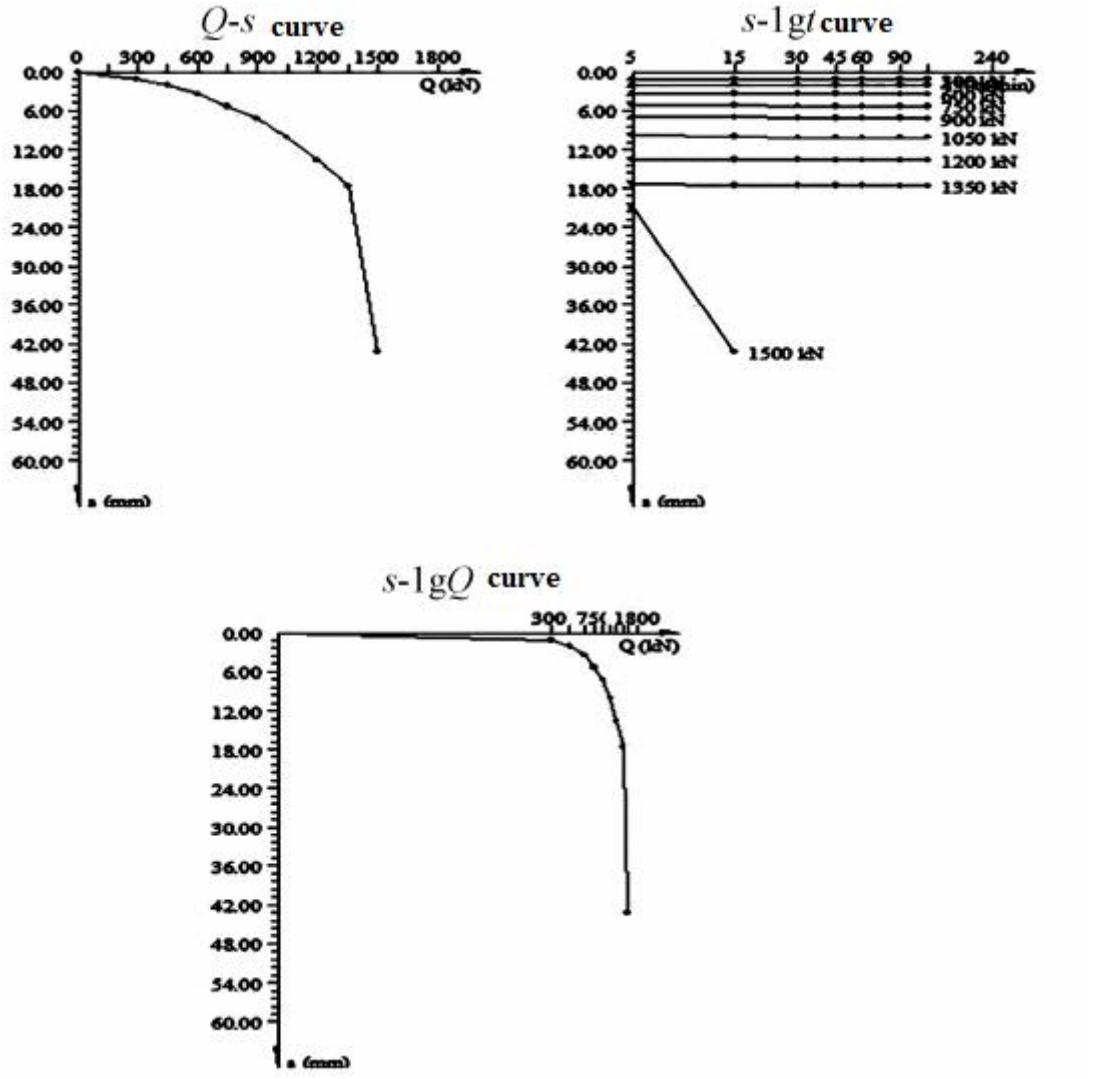

Figure 1. Q-s curve, s-lgt curve, s-lgQ curve of s1 test pile

4) The process of pile number s8 test was normal during the loading level 1-10 test. At the 11th level loading (1800kN), the settlement increased and the Q-s curve showed a turning point, while the tail support of the s-lgt curve showed a significant downward bend, indicating the end of the test with obvious failure characteristics. According to the specifications, the standard value of the vertical compressive ultimate bearing capacity of s8 single pile is 1650kN, and the characteristic value is 825kN.

5) The process of pile No. s9 test was normal during the loading level 1-11 test. When the 12th level load was applied (1950kN), the settlement increased, the Q-s curve showed a turning point, and the tail support of the s-lgt curve showed a significant downward bending, indicating the end of the test with obvious failure characteristics. According to the specifications, the standard value of the vertical compressive ultimate bearing capacity of s9 single pile is 1800kN, and the characteristic value is 900kN.

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6) The process of pile No. s10 during the loading level 1-10 test is normal. When the 11th level load is applied (1800kN), the settlement increases. The Q-s curve shows a turning point, and the tail support of the s-lgt curve shows a significant downward bending, indicating the end of the test with obvious failure characteristics. According to the specifications, the standard value of the vertical compressive ultimate bearing capacity of s10 single pile is 1650kN, and the characteristic value is 825kN.

7) The process of pile numbers s11 to s12 test was normal during the loading level 1-11 test. When the 12th level load was applied (1950kN), the settlement increased, the Q-s curve showed a turning point, and the tail support of the s-lgt curve showed a significant downward bending, indicating the end of the test with obvious failure characteristics. According to the specifications, the standard value of vertical compressive ultimate bearing capacity for single piles in s11 and s12 is 1800kN, and the characteristic value is 900kN.

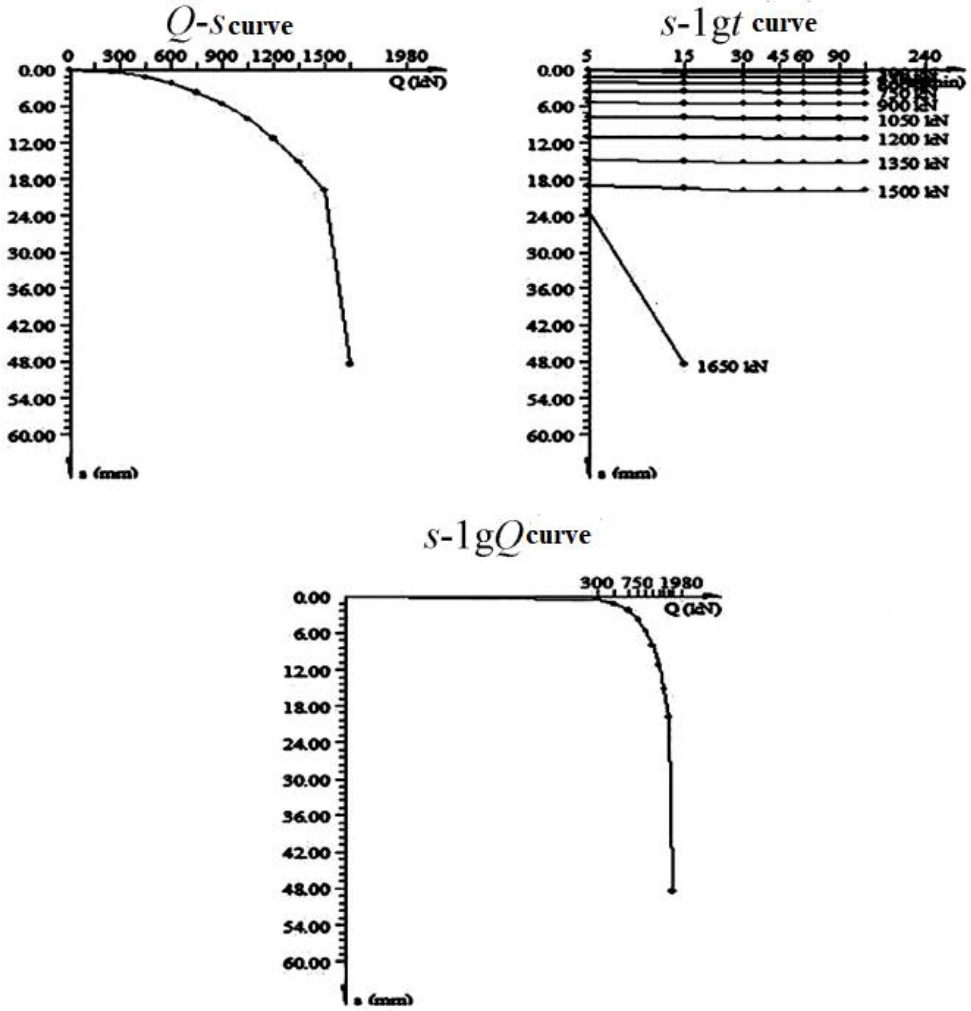

Figure 2. Q4 test pile Q-s curve, s-lgt curve, s-lgQ curve

The ultimate vertical compressive bearing capacity of a single pile in this site was determined through the static load test of 15 single piles tested outside the pile foundation inspection project site. The ultimate bearing capacity of test piles s1~s3 is 1350kN; The ultimate bearing capacity of test piles s4~s6 is 1500kN; The ultimate bearing capacity of test piles s8 and s10 is 1650kN; The ultimate bearing capacity of test piles s7.s9, s11, and s12 is 1800kN.

According to the geological report, it was found that the plot is a silt layer, and this layer was used as the bearing layer for the design and testing of piles. According to the test pile data, the bearing

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capacity of bamboo joint piles has increased by nearly 30% compared to other pile types, indicating better economic performance.

4. T-PHC Bamboo Joint Pile Construction Technology

4.1 Construction Technology.

The construction process of bamboo joint piles is basically similar to that of prestressed pipe piles, and the specific construction process is shown in Figure 3.

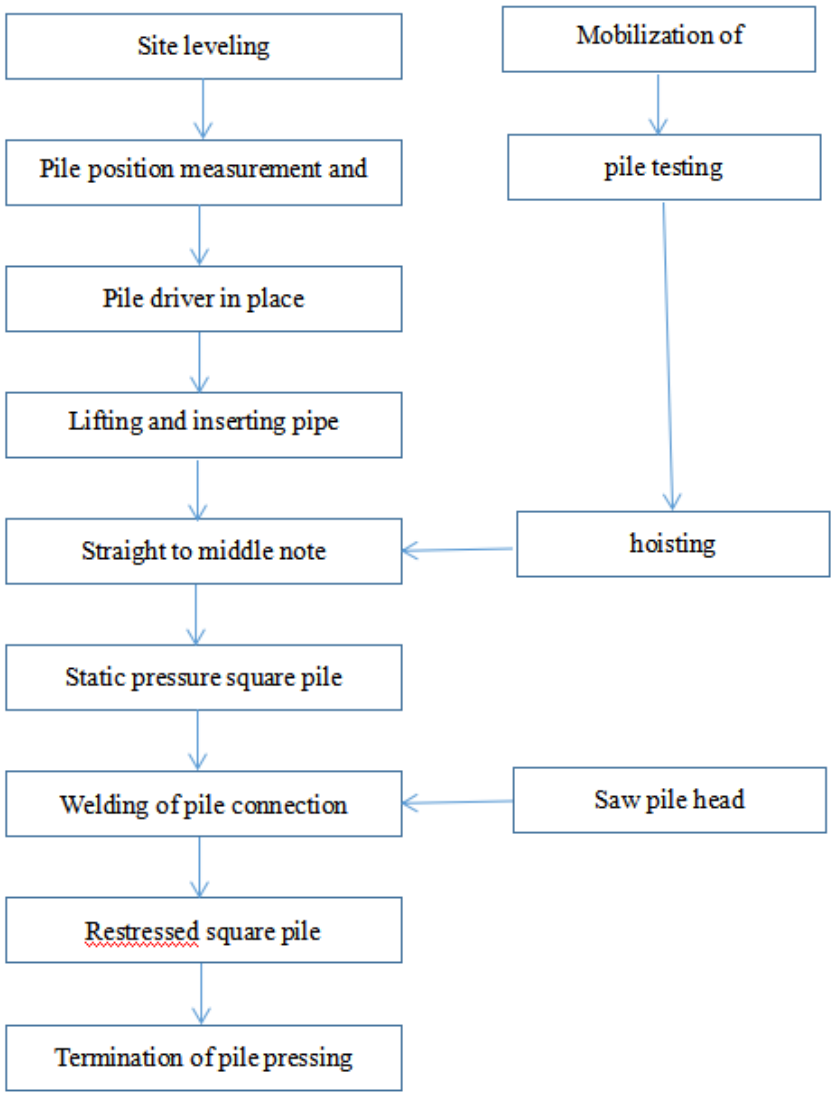

Figure 3. Construction technology

4.2 Pile Head Treatment.

(1) Pile cutting: During the excavation process, after the pile body exposes the soil surface for a certain length, a unified elevation is taken on each pile and marked with red paint. After the excavation position is determined, the concrete is chiseled off along the steel bars around the pile body. The stirrups inside the pile body are cut open using gas welding along this position, and the steel bars are pulled out outside the pile body. After the pile cutting is completed, it is necessary to

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work with relevant departments to compare the drawings and count the number and position of pile heads one by one for accuracy, in order to prevent omissions and pile displacement.

(2) Pile head treatment: Use pneumatic picks and manual drills to clean and chisel the pile head. It is required that the pile body below the design pile top elevation is not damaged, and the surface of the pile head is flat. The loose concrete and concrete laitance on the pile head must be cleaned up to a dense layer of concrete, with no damage to the steel bars, bending less than the specified value, and the exposed length to the design length ratio within a range of plus or minus 5cm.

4.3 Preparation for Pile Sinking Construction.

(1) Before pile pressing, pile foundation construction drawings, drawing review minutes, construction plans, and relevant materials should be prepared;

(2) Familiar with and proficient in the detailed geological survey report of the construction site, especially the fluctuation of the bearing layer elevation and the situation of local hard and soft interlayers;

(3) Before pressing the pile, site investigation work should be carried out, and corresponding measures should be taken according to relevant requirements based on the information provided by Party A regarding underground pipelines and obstacles;

(4) The axis and elevation control points should be firmly marked, and the survey site should be located 15m away from the construction site and not affected by pile sinking. Before each survey of the pile position, the pile position guidance point and the movement of the pile position should be rechecked based on the control points for correction;

(5) The cross-section of the pile driver should be consistent with the shape of the pipe pile cross-section, and have sufficient length, stiffness, and strength. The surface should have anti slip strips, and the end face (contact surface with the pile top surface) should be flat and perpendicular to the central axis of the pile driver;

(6) The construction site shall be equipped with truck crane, gas cutting tools, rigging, lifting hammer, Total station, level, hammer, crowbar, wire brush, pile breaker and other construction machinery;

(7) The construction water supply and power supply should meet the equipment requirements.

4.4 Preparation before Pile Pressing.

Survey and remove underground pipelines and obstacles in the press area before pile pressing; Before pile foundation construction, the site should be cleaned and leveled. The construction site within the pile driving area should be leveled to a unified elevation as much as possible, and the site should be compacted to ensure the verticality and safety of the pile foundation. Special treatment should be given to hidden ponds and areas that have not been backfilled recently. Do a good job in leveling and setting out, set up no less than 2 benchmark points on site, establish construction axes, control networks, and set up no less than 6 extension points for control axes. Both benchmark points and control axis points are set up in areas not affected by the construction of compressed piles and properly protected; The benchmark and control axis points must be reviewed and confirmed by the owner and supervisor. The pile stacking site should be flat and solid, and the piles should be neatly stacked with drainage measures in place. During the installation process of the pile press, each component should be inspected once; The oil pressure gauge needs to be calibrated.

4.5 Precautions for Pile Pressing.

(1) Before starting the operation, the foreman should conduct a comprehensive safety and technical briefing to the team, and there should be signature procedures.

(2) All processes should comply with safety operating procedures.

(3) Before the captain operates, he/she should clarify the division of labor, unify signals, and command.

(4) Non production personnel are not allowed to approach the piling operation area.

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(5) When lifting pile components, collision is not allowed, and no one is allowed to pass under the lifting object.

(6) When the pile driver is moving, the site should be flat, solid, and unobstructed.

(7) Seasonal construction shall be carried out in accordance with relevant regulations, and night shift construction shall have sufficient lighting.

(8) Double shift operations should have a safe handover record. Construct according to the flow section of the plan to ensure safe production.

(9) Piling operators are prohibited from drinking excessively, and should concentrate during operation. If any abnormalities are found, the machine should be stopped immediately. In case of adverse weather, the operation should be stopped according to regulations.

(10) During pile driving operations, maintenance and upkeep are not allowed. All electrical equipment and non electricians are not allowed to move around to prevent electric shock. High altitude and ground operations must comply with safety regulations.

(11) When the pile driving operation stops, the power supply should be immediately cut off, and the pile driver should be parked in a suitable position.

(12) New workers should receive safety education when entering the site. Safety personnel should regularly inspect the site and promptly resolve any unsafe factors.

4.6 Precautions for Pile Connection.

4.6.1 Welding Pile Connection

The pipe pile connection adopts the steel end plate welding method, and the top of the pile end can be connected to the pile about 1m from the ground. Before connecting the pile, clean the top of the lower section of the pile, add a positioning plate, and then adjust the upper section of the pile to the end plate of the lower section of the pile. Use the positioning plate to straighten the upper and lower sections of the pile. If there are gaps at the joints, wedge-shaped iron sheets should be used to fill and weld them firmly. The welding of the groove at the joints should be carried out symmetrically in layers. Measures should be taken to reduce welding deformation during welding, and the welding should be continuous and full. After welding, welding slag should be removed and the fullness of the weld should be checked.

The welding requirements are as follows: Carbon dioxide gas shielded welding should be used for welding. When manual welding is used, the welding wire should be ER50-6, and the weld quality level should not be lower than level 2. The welded pile joints should be naturally cooled before continuous pile sinking. The natural cooling time for static pressure pile sinking should not be less than 3 minutes, and water cooling should not be used. The welding leakage part of the pile body joint should be treated with rust prevention.

4.6.2 Mechanical Connection Pile Extension (Suitable for Anti Uplift Piles at Underground Storage Locations)

(1) When the pipe pile is mechanically connected, the gap should be filled with asphalt filler:

Before connecting the pile, check the size deviation and connectors made at both ends of the pile, and lift the construction only after there is no damage. The pile head of the lower section of the pile should be 0.8m~1.0m higher than the ground;

When connecting piles, after removing the protective devices at both ends of the upper and lower sections of the pile, the residual material at the joints should be cleaned;

Align the upper and lower sections of the pile with a dedicated joint taper and tighten the connection; A dedicated chain wrench can be used to tighten, and there should still be a gap of 1mm~2mm between the two end plates after locking.

(2) When using mechanical engagement joints to connect piles, the following steps need to be followed:

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Before connecting, the pile end plate at the connection must be cleaned thoroughly, and the connection pins fully coated with asphalt paint must be screwed into the bolt holes of the perforated end plate of the pipe pile one by one with a wrench. The orientation of the connection pins must be checked and adjusted using a steel model plate;

Remove the foam plastic protective block filled in the connecting groove of the pipe pile with groove end plate at the lower side. Fill the connecting groove with asphalt paint not less than 0.5 times the groove depth. Apply asphalt paint with width of 20mm and thickness of 3nn along the outer periphery of the grooved end plate. When the foundation soil and groundwater of the pipe pile foundation are medium or more corrosive, the surface of the grooved end plate shall be fully coated with asphalt paint with thickness not less than 2mm;

Lift the upper section of the pipe pile so that the connecting pins align with the various connecting ports of the slotted end plate soil, and then insert the connecting pins into the connecting slots:

Apply pressure to make the pile end plates of the upper and lower pile sections contact, and the pile connection is completed.

(3) When using other mechanical methods to connect piles, they should comply with the requirements of the corresponding mechanical connection method operation, and be fixed correctly and firmly.

(4) The cutting of pipe piles should use a pile saw. It is strictly prohibited to use a sledgehammer to horizontally strike or forcibly pull the cutting of piles.

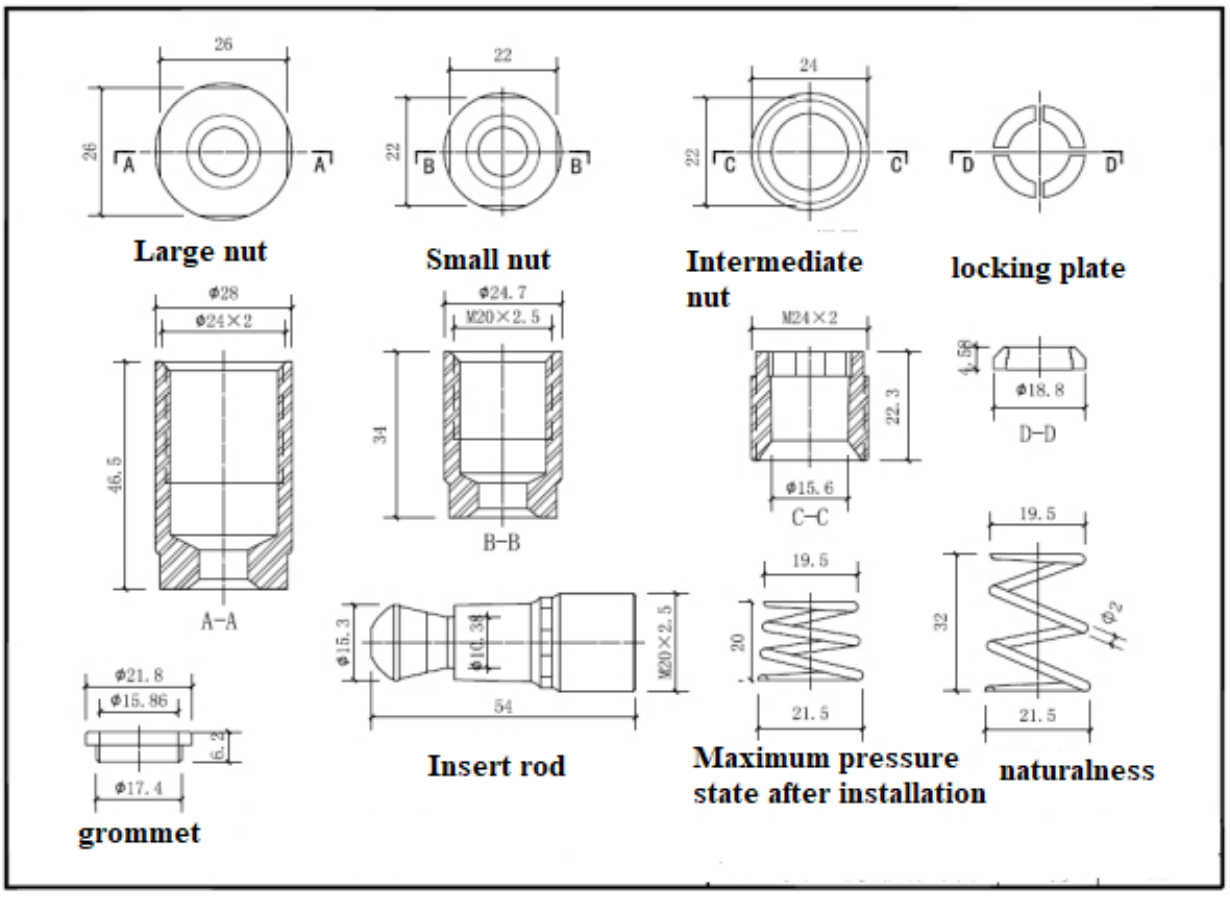

Figure 4. Detailed drawing of compression connectors for steel bars with diameters of 9.1 and 9.5

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5. Key Points and Related Problems of Quality Control During the Construction Process and Improvement Suggestions

5.1 Quality Control before Construction.

(1) During transportation, the distance between the support point of the mechanically connected bamboo joint pile and the pile end should not be greater than 0.2 times the pile length, and wedges should be placed at the bottom of the bamboo joint pile to prevent its sliding or misalignment.

(2) The pile sinking sequence is carried out from the center to the surrounding area. If the pile is inserted from the surrounding area to the center, it may cause difficulties in delivering the pile.

(3) When the elevation of the pile top is lower than the natural ground, the positioning deviation of the pile top should be rechecked and recorded when the last section of the pile is about 1000mm above the natural ground during construction.

(4) It is strictly prohibited to use internal triangular guiding devices for the positioning of pile machines and pile caps.

5.2 Quality Control During Construction.

5.2.1 Pile Body Fracture

Before construction, the bending of the pile body and whether the pile tip deviates from the longitudinal axis should be checked;

When there are obstacles underground in the site, they should be removed before construction;

When tilting occurs during initial sinking, it should be corrected in a timely manner.

5.2.2 The Pile Sinking Cannot Meet the Requirements

Select the correct bearing layer or pile tip elevation.

If there is a hard interlayer in the soil, the method of drilling first and then pressing can be used, that is, the pile tip is first inserted into a depth of 4D (D is the pile diameter) before proceeding with the pile sinking operation.

Determine the control standards for pile sinking construction based on engineering geology. In general, two control standards are determined, one being the primary and the other being a reference.

Reasonably select the machine model.

Adopt double compaction and control the pile sinking rate well.

5.2.3 Pile Top Displacement

Underground obstacles in the pile sinking area should be removed before construction;

Control the rate of pile sinking;

Reduce pore water pressure by using bagged sand wells, plastic water hoses, etc.

5.2.4 Pile Inclination

The construction site should be leveled and compacted, and reinforcement measures should be taken for weak foundations. To ensure the stability of the pile driving machine chassis, a pad can be added under the walking device of the pile driving machine if necessary.

When encountering shallow obstacles, the obstacles can be excavated first, and then filled with soil before pile replacement or pressure treatment.

The contact surface between the pile cap and the pile top should be kept horizontal to prevent the pile from being tilted due to eccentric loads.

In saturated soft clay areas, the speed of pile sinking should be controlled and measures should be taken to divert and drain pore water.

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6. Conclusion

Taking a project in Pudong New Area of Shanghai as an example, this paper expounds the feasibility of using T-PHC bamboo pile as Pile foundation instead of traditional PHC pipe pile in soft soil areas, combined with the geological conditions, surrounding environment, construction technology and other factors of the project.

Based on the geological characteristics of the project and the primary characteristics of the muddy soil. This article provides a detailed introduction to geological conditions, selection of pile bearing capacity for testing, construction process flow, relevant parameters and construction points of the construction process, as well as existing problems and corrective measures, providing practical guarantees for the smooth implementation of the project and quality control.

The project plan should be tailored to local conditions, ensuring safety while also being practical and feasible. The successful experience of this case provides new ideas for similar projects in the future, which has certain reference significance.

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