Construction Technology of Pipe Pile in the Reclamation Project

ZhiXiong Xu
Fuzhou Polytechnic Fujian, Fuzhou, Fujian Province, P. R. China
1069067985@qq.com

Abstract. Combining the successful experience on the formation of same kind, bore-making technique in the pipe pile construction of reclamation project and its solution are put forward, such as the selection of construction machines, construction technology, which provides reference for the project of the same kind.

1. Introduction
In recent years, coastal developed areas have witnessed a great upsurge in land reclamation, that is, encircling the sea to make land, just like the reclamation project phase I of Tianjin Harbor Industrial Park. This project is going to make a land of 50 sq.km, being the largest urban reclamation project nationwide then. Since 1980s, nearly 20 million hectares of land have been made in Guangdong’s Pearl River Estuary; 80% of the land in Panyu District, Guangdong is made from reclamation of past ages. Lands made from encircling the sea serve for urban construction and agricultural production, relieving the contradiction between economic development and lack of construction land. When it comes to Fujian province, a large number of reclamation projects are under construction in ports such as Luoyuan Bay, Quanzhou Bay and Meizhou Bay, wharves and large-scale industrial building in recent years. In those projects, sand is filled on top of beach soil with preloading drainage, then hill stone is paved on the top. It is a commonly discussed issue that how to perform the pile foundation construction under such geological conditions. there are some problems need to be addressed: 1. Determine hole-forming pile foundation process. 2. Control the weight of pile body in intertidal zone. 3. How to prevent the concrete structure from corrosion of surface sea water. 4. How to eliminate the negative friction of pile body under the situation that the silt has not fully consolidated, which will be discussed based on the geological characteristics of a power plant project in Luoyuan Bay.

2. Project’s geological conditions
The plant site and surrounding area are a zone connecting tectonic erosion hill, bay intertidal zone and neritic geomorphic unit. Main plant site is a parcel of vacuum-surcharge preloading backfill, the rest area is plastic drainage board + surcharge backfill, the surface is rubble backfill, elevation of local theoretically lowest tide level is around 8.5m. According to drilling results, the site’s upper formation mainly comprises plain fill, quaternary system marine deposition and proluvium formation (Q4 a1-m), its lithologic character features silt, mucky soil, clay, silty clay mixed with gravel and gravel, the introduction is shown as follows:

First layer, plain fill: recent backfill, land is formed by reclamation in upland of the plant, hill stone: the layer is formed through backfill of hill stone in hilly mountain. The diameter of stone varies from
30cm to 80cm, they are not compacted, with poor grain composition, big porosity and high water permeability, the average thickness of the formation is 5.50m.

Second layer, silt: dark grey, saturation, current-formed, putrefactive odor, purer texture, a bit of shell is contained in local area, there is thin fine sand layer interbedded in silt layer in local horizon, phase transition happens in local section, silt changes into mucky soil. The soil is high-compressibility and unconsolidated soft soil, but not organic matter soil, the average thickness of the formation is 9.50m.

Third layer, clay: red brown, yellowish brown, plastic, wet, hard plastic or soft plastic in local area, phase transition happens in local section, clay changes into silty clay, the soil texture is not pure, mixed with a little gravel, the average thickness is 3.1m, presenting a form of lens.

Fourth layer, silty clay mixed with gravel: purplish grey, grayish yellow, brown yellow, wet, plastic, hard plastic in local area. Soil texture is uneven, the content of gravel is 3.4%-39.3%; there is clay, silty clay and mucky soil interbedded in the formation, presenting a form of lens. The average thickness of the formation is 20.70m.

Fifth layer, gravel: there is a mixed color and mixed composition in this formation, it is dominated by tufflava fragment, the particle size is 2cm-9cm, while the largest ones can be 11cm-20cm. The gradation is good, filled with gravelly sand, coarse sand and a little cohesive soil. The average thickness of the formation is 20.55m.

Sixth layer, tufflava: the average thickness of the formation is 3.45m; intense weathering tufflava: purplish grey, fuchsia, grayish yellow, bulk solid and fracture, tufflava has a clear protolith texture, its mineral composition includes: feldspar and quartz, most feldspars have been weathered to secondary mineral, the rock is extremely fractured and belongs to extremely soft rock, basic quality grade of the rock mass is class V. Moderately weathering tufflava: representing a massive structure, the rock is compact and hard, rock mass is complete, basic quality grade of the rock is class III. The thickness of the formation is not exposed. Plant site is located in intertidal zone, which is a humid region and close to waterfront. Underground water mainly occurs in quaternary system formation and hole and fracture of bottom bedrock, laterally recharged by surface sea wa, surface water and underground water, while sea water has a major influence on the proposed project. Surface sea water has moderate corrosion to concrete structure; and has weak corrosion to the steel bar in the concrete structure if they are immersed in water for a long time, it has strong corrosion to the steel bar in the concrete structure if they are in the situation of alternate drying-wetting. Water level of the sea water varies with tide. Mean sea level: 4.06m; the largest tidal range: 7.64m; the smallest tidal range: 2.27m.

3. Selection of hole-forming process
Through comparison and selection and based on the successful experience on the formation of same kind, impact drill hole-forming cast-in-place pile is formed through the process that impact drill or winch hangs the chopping pit (hammer) to impact up and down repeatedly to fracture the hard soil or terrane and form a hole, part of the slag and slurry are squeezed into the wall of hole, most of them turns into sludge, then slag dredge is used to pull out them and concrete is filled to form a pile. Characteristics of impact drill hole-forming cast-in-place pile: simple equipment structure, wide range of application, easy operation, the wall of hole is solid and stable with less hole collapse, less limitation to construction site, no noisy and vibration influence, so it can be widely applied to construction. This process is applicable to the loess, cohesive soil or silty clay in the industrial and civil construction and the project where impact drill hole-forming cast-in-place pile is applied to sand gravel layer containing boulder, boulder layer, hard soil layer and rock foundation. There are two types of impact drills used at home currently, impact drill, which is equipped with drilling rig, winch, drilling hammer, distribution box, slurry pump and pipe; and CZ and YKC automatic impact drill. With construction experience on nearly 5000 piles under such geological condition, I consider this process is feasible. Impact drill hole-forming cast-in-place pile is successfully formed under the situation that the particle size of backfill hill stone is 800-2000mm, the thickness is 20m and the length
of pile is 80m. A large number of constructions have proven that: CZ and YKC automatic impact drill are applicable to such geological characteristics.

4. The weight of pile body in intertidal zone

The project is located in Luoyuan Bay’s reclamation land, the highest tide level is 8.05m, the lowest tide level is -0.21m; the largest tide range is 7.64m and the smallest tide range is 2.27m. The site can be influenced by the tide, and the strength of pile body can be also largely decreased because in the solidification process of the concrete, cementitious materials, especially cement slurry can be taken away by the sea water due to high head and fast flow velocity in intertidal zone. It is indicated that the strength is strongly reduced to above 50%. Countermeasures, e.g. add steel shield are taken in the construction of same kind in intertidal zone, but the measure costs too much and has some disadvantages (when the shield is pulled out after initial setting, the pile will be disturbed and negative friction of the soil around the pile occurs. The full of concrete and horizontal stiffness and stability of pile body). It is proven that this issued can be addressed through controlling the slurry proportion and making material, maintaining water-bearing pressure in the hole and paying more attention to liquid level change of slurry with the change of tide. The slurry control index is provided as follows for reference of construction of same kind.

| No. | Item                                      | Performance index          |
|-----|-------------------------------------------|----------------------------|
| 1   | Viscosity                                 | 10-25s                     |
| 2   | Sand factor                               | < 6%                       |
| 3   | Colloid fraction                          | > 95%                      |
| 4   | Water loss                                | < 30mL/30min               |
| 5   | Mudcake thickness                         | 1-2mm/30min                |
| 6   | Gel strength                              | 1min20-30mg/cm² 10min50-100mg/cm² |
| 7   | Stability                                 | < 0.03g/cm²                |
| 8   | PH value                                  | 7-9                        |
| 9   | Slurry proportion in different soil layer |                            |
| 10  | Backfill stone layer and sand layer        | 1.3-1.5                    |
| 11  | Silt layer                                | 1.2-1.3                    |
| 12  | Gravel clay layer                         | 1.3-1.4                    |
| 13  | Weathered stone layer                     | 1.25-1.35                  |

5. The concrete structure from corrosion of sea water

Description on main corrosion mechanism is not given here. The salt in the sea water reacts with concrete chemically, which leads to a reduction on concrete strength due to its decomposition, and salt in the sea water invades pores of concrete to form saturated solution, then the volume of crystal that separates out when temperature decreases in drying-wetting area expands, which damages the concrete structure. Therefore, the following index should be controlled: increase the concrete class (degree of density), control the chlorine ion content in the raw material, prevent early strength, strengthen the thickness of steel protect layer, reduce water cement ratio, alkali-prevention aggregate (prevent chemical expansion), control the tricalcium aluminate index in the cement (prevent chemical expansion with ettringite), add corrosion inhibitor in the steel bar. Comprehensive test is conducted to test the corrosion inhibition performance of concrete (salt water immersion test, dry-immers and comprehensive electrochemical test) and concrete performance (degradation of compressive strength, permeability resistance and difference in setting time). The raw material meeting the relevant index is selected with adding additive to test the change of corrosion-inhibition ability and concrete
performance through experiment. The control index of the construction is provided for reference: concrete class: C40, thickness of protect layer: 60mm, limit concentration of acid, alkali and salt resistance of cement: 15000mg/L, water cement ratio: 0.45, low water-binder ratio of large amount of mineral admixture, colloid use: 320kg-420kg/m³, tricalcium aluminate <5%, content of water-soluble chlorine ion in concrete is less than 0.1% of colloid weight, mixing of superplasticizer, corrosion inhibitor, salt water immersion test: 0-250Mv, no rust, salt dry-wet test: corrosion area of steel bar reduces more than 95% after mixing additive, comprehensive electrochemical test: electric current is lower than 150μA, degradation of compressive strength: less than 90%, impermeability: remain unchanged, difference of setting time: less than 120min.

6. Conclusion
As the value of negative friction is largely dependent on backfill material, compactness, thickness and degree of consolidation of bottom slurry layer, it has no reference value to the construction. This issue is just proposed in the paper, negative friction is commonly existed in such geological condition, and relevant personnel should exercise caution. Through extensive construction test, a value (20-50%) is proposed for design and construction personnel’s reference, and the value can be determined through typical test in specific project.

Acknowledgments
This work was financially supported by the natural science foundation of Fujian Province (2016J01726).

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