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Bin li [1 2 3 4]

[1]Tianjin Port Engineering Institute Ltd. CCCC First Harbor Engineering Company Ltd., Tianjin, China;[2]CCCC First Harbor Engineering Company Ltd., Tianjin, China; [3]Key laboratory of port geotechnical engineering, ministry of communications, PRC.Tianjin, China; [4]Key laboratory of port geotechnical engineering of Tianjin. Tianjin, China

Lee_binbin@163.com

Abstract. The effect of vacuum preloading on the existing road will be cracking. The mechanical model of vacuum preloading treatment in vacuum preloading area is established by FLAC 3D software, and the impact on the expressway under the conditions of high-pressure jet grouting pile and cast-in-place pile plus high-pressure jet grouting pile are simulated respectively. When the retaining structure is a high-pressure jet grouting pile, the impact of vacuum preloading on the expressway is 50m and the maximum settlement is 2.24 cm. When the retaining structure is cast-in-place pile and high-pressure jet grouting pile, the influence range is 45m and the maximum settlement is 2.37 cm. The cast-in-place pile and high-pressure rotary jet grouting pile retaining wall can weaken the adverse effect of vacuum preloading on the expressway.

1. Introduction

The rapid development of the city will inevitably lead to the shortage of urban land. With the continuous improvement of land reclamation capacity in the sea, the rise of large-scale reclamation will inevitably lead to the development of soft foundation treatment technology [1]. The impact of soft foundation treatment on existing buildings (structures) will be the key issue to be considered in the future soft foundation reinforcement process [2], which will affect the safety of people's lives and property and social stability.

Vacuum preloading is an effective method for soft soil foundation treatment. In recent years, this method is mostly used for airport, wharf yard, expressway and newly dredged fill foundation treatment [3]. Under the action of vacuum load, soft soil foundation will produce lateral shrinkage deformation facing the reinforcement area, and nearby buildings or structures may be affected and even an engineering accident may occur [4]. Vacuum preloading is the most important method in soft foundation treatment. According to the requirements of " Code for Building Foundation Treatment" (JGJ 79 - 2002) and on the basis of following the basic principles of geotechnical engineering [5], the simulation of vacuum preloading process by finite element method [6] is realized, and the safety evaluation of the supporting structure proposed in the design is carried out on this basis, which provides reference for similar projects in the future and has certain practical significance.

2. Project overview

A vacuum preloading area in Hengqin, Zhuhai is close to an expressway with large traffic flow, and the nearest distance between the sideline of the vacuum preloading area and the corridor of the expressway is 7m. In the vacuum preloading area, the surface layer is backfilled with plain soil, containing part of the stones, and the burial depth is large, making the construction of the flashboard difficult. Before inserting plate construction, it is necessary to excavate and replace it in the vacuum preloading area, and some areas need to be excavated to the elevation of 0m. Excavation and replacement construction has certain influence on the corridor of expressway. Therefore, rotary jet grouting piles are used for supporting before excavation and replacement, and in places with larger excavation and replacement depth on the east side, the continuous wall formed by high-pressure rotary jet grouting piles can be used as vacuum preloading sealing walls.

CFG piles are used for foundation treatment of expressway, and CFG piles with spacing of 1.8m square are used for road red line. The pipe gallery area is treated with CFG piles arranged in a regular triangle with a spacing of 2.0m .All CFG piles in the whole section are made of C15 commercial concrete with a diameter of 40 cm, the design elevation of the pile top is 2.0m, and the cushion layer is made of graded crushed stone with a thickness of 50 cm. CFG piles are drilled through silt and enter the bearing stratum not less than 1.0m.

The expressway is an existing structure. The distance between the vacuum preloading treatment sideline and the pipe corridor is only 7m. Whether the isolation protection measures between the vacuum preloading area and the expressway are reasonable and whether the influence of vacuum preloading on the expressway is small enough not to cause too much damage to the expressway needs to be analyzed and studied.

3. Basic parameters

The width of the vacuum preloading area for this soft foundation treatment is 25m. During the treatment, the site shall be leveled to an elevation of 2.2m first, and then a retaining structure shall be set up. Considering the most unfavorable situation, a section with the largest thickness of soft soil layer is selected as the calculation section.

Table 1 Material parameters of model

soil	Depth （m）	Density （g/cm^3）	compressibility （MPa）	cohesion (kPa)	friction (°)	permeability (cm/s)	
Plain fill	2.16	1.72	2.06	7	16.8	2.71E-05	2.95E-05
Silt	8	1.62	1.84	6.7	16.2	3.44E-07	4.56E-07
Silt	2	1.6	1.72	6.7	16.2	2.90E-07	4.37E-07
Silt	7.5	1.62	1.64	7	16	2.56E-07	3.38E-07
clay	4.3	1.71	2.29	8.8	16.5	7.21E-08	7.15E-08

In the preliminary design, vacuum preloading is used to treat the foundation, and the drain plate depth at the section is 17m, with plum-shaped layout and 1m spacing. The retaining structure between the vacuum preloading area and the expressway takes into account two structural forms: one is the high-pressure jet grouting pile, and the other is the combination of the grouting pile and the high-pressure jet grouting pile. The following two structures are analyzed numerically.

4. Simulation Analysis and comparison

According to the geological data in Table 1, a mechanical model was established using FLAC 3D, a large commercial software. Considering symmetry in the model, only half of the vacuum preloading area and one side of the expressway are selected. Because CFG piles in the pipe gallery are arranged in a regular triangle with a spacing of 2m, the model thickness is 1m, and the whole model size is 100m× 40m× 1m. CFG piles are staggered on the front and back of the model, and CFG is 1m deep into the 6 - 1 silty clay layers according to the design requirements.

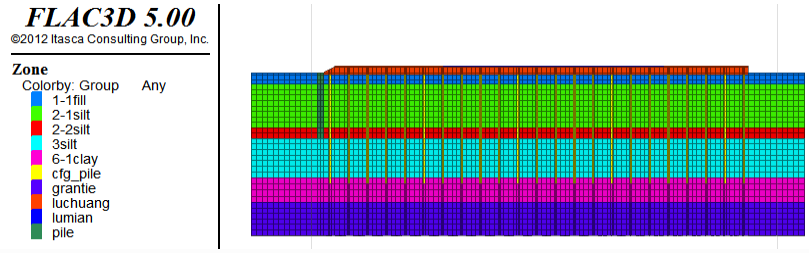

Figure.1 Mechanical model of vacuum preloading

The retaining structure between the vacuum preloading area and the expressway is divided into two types: high-pressure jet grouting pile and cast-in-place pile plus high-pressure jet grouting pile. The models under the two retaining structures will be analyzed below. In the figure, CFG _ PILE is a CFG pile in the subgrade of expressway, with a pile diameter of 40 cm and a pile body entering silty clay of 1m, which is simulated by solid unit. The west side retaining wall is composed of double rows of high-pressure jet grouting piles with a diameter of 700 mm, a lap joint of 200 mm and a retaining wall depth of 12m. On the east side of the retaining wall is cast-in-place pile and high-pressure jet grouting pile retaining wall. The diameter of the cast-in-place pile is 800 mm and the spacing is 1200 mm. The high-pressure jet grouting pile is filled between piles and the diameter of the high-pressure jet grouting pile is 600 mm. Cast - in - place piles are 13m ~ 23m deep and high-pressure jet grouting piles are 6m ~ 8m deep.

The fully weathered granite in the model is regarded as impervious elastic material, while other soil layers are regarded as Mohr - Coulomb material. The vacuum preloading area is subjected to vacuum pressure of 85 kPa, and the preloading time is calculated to be 120 days. The vacuum preloading area of plastic drainage plate is calculated by Chai Jinchun method [5],

After the vacuum preloading starts to be applied, the vacuum degree under the membrane reaches 80 kpa for a few days, and the loading time of vacuum preloading starts to be calculated. the loading time is planned to be 120 days. the consolidation degree and residual settlement are calculated according to the measured settlement value in the later stage of vacuum preloading, and the settlement trend is predicted. the design unit determines the specific preloading unloading time.

（1）Calculation results and analysis of model under high pressure jet grouting pile retaining structure

The result shows the lateral displacement of the foundation surface on the side of the expressway and the movement of the oriented retaining wall is positive. If the scope of influence is defined as the area where the expressway pile foundation has a lateral displacement of 5 cm, the scope of influence under this working condition is more than 50m.

According to the simulation results, the farther away from the high-pressure jet grouting pile retaining wall, the smaller the surface settlement, the smaller the foundation settlement at the retaining wall is about 7 cm, indicating that vacuum preloading has less influence on CFG pile foundation settlement. The depth curves of deep lateral displacement at different distances from the high-pressure jet grouting pile retaining wall are similar.

The influence range of foundation treatment in vacuum preloading area on expressway is 20m, the maximum lateral displacement of CFG pile near the expressway corridor to vacuum area is 8.3 cm, and the maximum lateral displacement of CFG pile at 15m away from vacuum area is 5.3 cm.

（2）Results and Analysis of Model Calculation under Supporting Structure of Cast - in - place Pile and High Pressure Jet Grouting Pile

According to the simulation results, the farther away from the retaining wall of cast-in-place pile and high-pressure jet grouting pile, the smaller the ground settlement, the less the foundation settlement at the retaining wall is 3 cm, and the smaller the settlement closer to the expressway, indicating that vacuum preloading has less influence on the foundation settlement of CFG pile. When the retaining structure in the vacuum preloading area is a combination of cast-in-place pile and high-pressure jet grouting pile, the influence range of foundation treatment on the expressway is 45m, the maximum lateral displacement of CFG pile in the immediate vicinity of the expressway corridor is

12.6 cm, and the maximum lateral displacement of CFG pile at 15m from the expressway to the vacuum area is 10.1 cm.

For convenience of comparison and analysis, the influence of vacuum preloading in vacuum preloading area on expressway under the conditions of high-pressure jet grouting pile and cast-in-place pile plus high-pressure jet grouting pile is can be seen from result, compared with the simple high-pressure rotary jet grouting pile retaining wall, the cast-in-place pile plus high-pressure rotary jet grouting pile retaining wall can weaken the adverse effect of vacuum preloading on the expressway. The analysis may be due to the fact that the depth of penetration of the cast-in-place pile and the high-pressure jet grouting pile structure is deeper, resulting in a higher ability to isolate the influence of vacuum preloading than that of the simple high-pressure jet grouting pile structure.

5. Conclusion

In this paper, the mechanical model of vacuum preloading treatment in vacuum preloading area is established by FLAC 3D software, and the influence of vacuum preloading on expressway is analyzed respectively when the retaining structure is high-pressure jet grouting pile and cast-in-place pile plus high-pressure jet grouting pile, and the following conclusions are obtained:

(1) When the retaining structure is a high-pressure jet grouting pile, the influence range of vacuum preloading foundation treatment in vacuum preloading area on the expressway is 50m, the maximum lateral displacement of CFG pile in the immediate vicinity of the expressway corridor is 21.4 cm, and the maximum lateral displacement of CFG pile at 15m away from the vacuum area is 12.9 cm.

(2) When the retaining structure is cast-in-place pile and high-pressure jet grouting pile, and the retaining structure in the vacuum preloading area adopts the combination of cast-in-place pile and high-pressure jet grouting pile, the influence range of foundation treatment on the expressway is 45m, the maximum lateral displacement of CFG pile near the expressway corridor is 12.6 cm, and the maximum lateral displacement of CFG pile 15m away from the vacuum area is 10.1 cm.

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