Numerical Simulation of Double Row Piles Prestressed Anchor Cable Support Based on ABAQUS

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Abstract. With the development of urban construction, there are more and more high-rise buildings, and excavation support methods have emerged. Traditional support methods have the drawbacks of a small range of safety factors and high economic requirements. Based on this, this article proposes a new type of support method using double row piles and prestressed anchor cables, and establishes a numerical model using ABAQUS software. The results indicate that: (1) As the excavation depth increases, the horizontal displacement of the foundation ditch continues to increase, and the displacement of the piles also continues to increase. (2) After soil excavation, there is a bottom bulge phenomenon at the bottom of the foundation ditch, and the piles move upwards, causing the soil around the foundation ditch to decrease.

Keywords: Double row piles, Prestressed, ABAQUS, Anchor cable support, numerical simulation.

1. Introduction

The research on deep foundation ditch support by domestic and foreign scholars has a long history, Hou et al. [1] studied the excavation of foundation ditchs using anchor rods and underground continuous wall support. Through the analysis of a large amount of on-site monitoring data, three-dimensional numerical simulation software was used for back analysis. Xu et al. [2] analyzed the deformation of foundation ditch support structures under different working conditions (depth of foundation ditch and thickness of weak soil layer). Wu et al. [3] analyzed the variation law of the internal force of the foundation ditch support structure and found that the two important factors affecting the internal force of the support structure are the excavation depth of the foundation ditch and the pre stress of the anchor rod. Li et al. [4] believe that the lateral displacement of piles and the rate of surface settlement are proportional to time, and the lateral displacement of piles changes more significantly compared to the rate of surface settlement. Hu [5] optimized the design of deep foundation ditch support structure and conducted construction monitoring, and the results showed that the optimized support design can effectively improve the stability of the foundation ditch. To optimize the design parameters of the foundation ditch support structure. Yang et al. [6] used orthogonal experiments to study the effects of three parameters, namely the embedded depth of the underground continuous wall, the thickness of the underground continuous wall, and the stiffness of the internal support, on the deformation of the foundation ditch. The above research results indicate that suitable support technologies should be adopted according to local conditions and geological environment during construction [7-10]. Based on this, this article proposes a double row pile prestressed anchor cable support scheme for a deep foundation ditch project. Using ABAQUS software, establish a numerical model for excavation of foundation ditchs to analyze the feasibility of the double row pile prestressed anchor cable support scheme.

2. Model Establishment

This chapter establishes a numerical model of double row piles prestressed anchor cables. The unit type is C3D8R, with a total of 32000 grids divided. Using static static analysis, the model was excavated in three stages. The first excavation is 2.5m, the second excavation is 2.5m, and the third excavation is 3m. In the numerical simulation process, the element deletion algorithm is used to achieve soil excavation [11-13].

2.1. Geological Conditions

The geological conditions of deep foundation ditch are complex, which are divided into five types of soil layers. The specific geological conditions and related parameters are shown in Table 1.

Table 1. Physical and mechanical parameters of soil layer

Stratum No.	Stratum name	Internal friction angle/(°)	ρ (kg/m³)	μ
1	Coarse sand	30	2000	0.3
2	Silty soil	11.76	1930	0.25
3	Fine sand 1	28	1900	0.25
4	Fine sand 2	32	2070	0.25
5	Plain soil	10	1650	0.38

2.2. Layout of Supporting Structure

The specific method is thermal loading method. Thermal loading method is a method of applying prestress in the application of simulated welding process. By applying heating load, the temperature gradient is caused, and the prestress is generated. The steps are as follows:

(1) Define a temperature field, which can be applied by defining the node temperature or by importing the temperature field.

(2) The thermal load is applied and the corresponding thermal load is introduced into the model.

(3) Under thermal load, apply mechanical load to maintain balance.

(4) Save the data as needed.

Front row pile adopts Φ 1200@1600 Bored cast-in-place pile, 32.8m long, 0.8m diameter, and 2.0m spacing. The rear row pile adopts Φ 1200@3200. The bored pile is 22.8m long, 0.8m in diameter, 2.0m apart, and the concrete material is C35. Prestressed anchor cable is set behind the front row piles, one pile and one anchor, and the anchor cable is set at 6 Φ 15.2@1000 With an inclination of 22.5 degrees and 7 anchor cables (Figure 1).

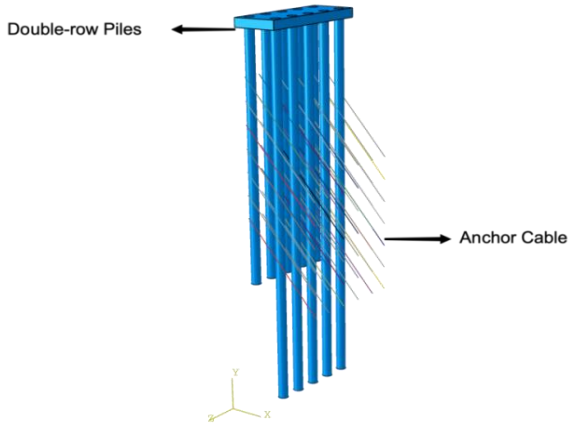


Figure 1. Prestressed anchor cable model of double row piles

Table 2. List of design parameters of prestressed anchor cable

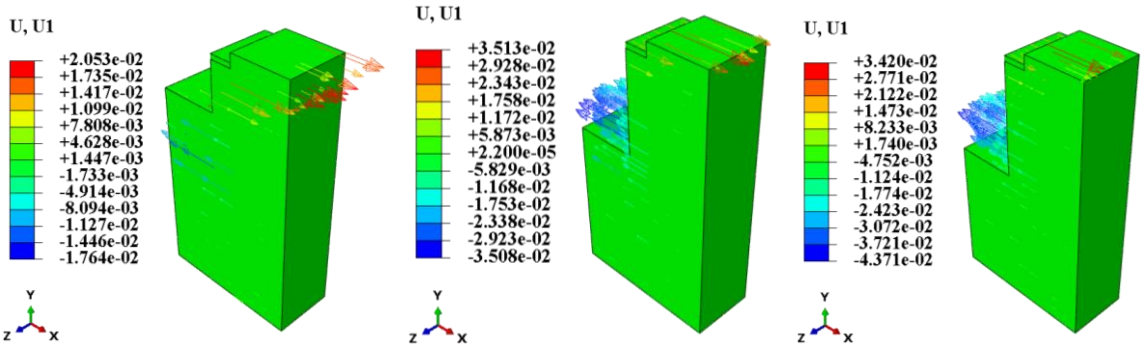
Anchor cable No	Relative Elevation/m	Prestress /kN	Total Length/m	Anchor Section Length/m	Axial inner design value/kN
1	-2.20	150.0	21.00	12.00	231.13
2	-5.20	200.0	18.00	10.00	304.07
3	-6.70	250.0	22.00	15.00	390.24
4	-8.20	250.0	22.00	15.00	390.24
5	-11.20	250.0	26.00	20.00	367.27
6	-14.20	300.0	28.00	23.00	502.33
7	16.70	300.0	24.00	19.00	482.38

3. Result analysis

3.1. Horizontal displacement

As shown in Figure 2, after the excavation of the first layer, the soil around the foundation ditch undergoes horizontal displacement, with a horizontal displacement value of 30mm. In addition, the horizontal displacement of the foundation ditch is 11.2mm.

Excavation of the second layer diagram, the horizontal displacement of the foundation ditch is 35.08mm, and the horizontal displacement of the piles is 35.13mm. The displacement direction of the foundation ditch and pile is opposite, and the displacement is close. After the second excavation, apply prestressed anchor cables to the soil. Continuing the excavation of the third layer of soil, the horizontal displacement of the foundation ditch increased to 43.71mm, and the pile displacement was 34.20mm. Therefore, during the construction process, special attention should be paid to controlling the horizontal displacement of the foundation ditch.

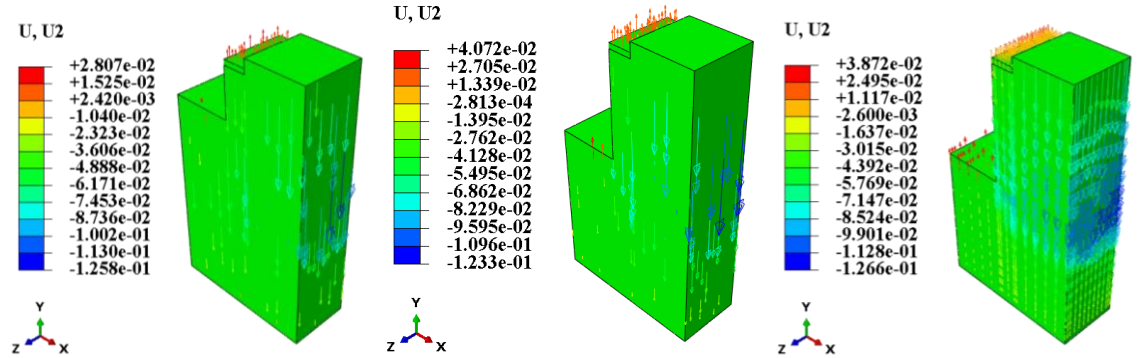


(a) First excavation (b) Second excavation (c) Third excavation

Figure 2. Horizontal displacement of foundation ditch excavation

3.2. Vertical displacement

As shown in Figure 3, during the excavation process, the excavation surface of the foundation ditch shows a rebound state, and the soil behind the support structure settles. After the initial excavation, the rebound displacement of the pile is 28.07mm, and the rebound amount at the bottom of the foundation ditch is 15.25mm. The rebound amount of the pile is greater than the rebound amount at the bottom of the foundation ditch. After the second excavation, the maximum rebound at the bottom of the foundation ditch is 40.72mm. After applying anchor cables, the third excavation was carried out, and the rebound amount at the bottom of the foundation ditch was reduced to 38.72mm. After the application of anchor cables, the rebound amount at the bottom of the foundation ditch decreases, and the anchor cables have a good control effect on the rebound of the foundation ditch.



(a) First excavation (b) Second excavation (c) Third excavation

Figure 3. Vertical displacement of foundation ditch excavation

4. Conclusion

To improve the support conditions of a deep foundation pit and enhance the safety of excavation, a numerical model of double row pile-prestressed anchor cable was established using ABAQUS. The study showed that:

(1) Research has found that after applying prestressed anchor cables, the decrease in horizontal displacement of piles is greater than that of foundation pits. During the construction process, corresponding measures should be taken to control the horizontal displacement of the foundation pit.

(2) Until all excavation of the foundation pit is completed, the foundation pit rebounds by 40.72mm and the pile displacement value is 38.72mm. This indicates that the proposed double row pile-prestressed anchor cable support method has good control effect.

(3) The soil around the foundation pit tends to settle, and monitoring should be strengthened during construction to prevent adjacent buildings from collapsing.

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