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Comparative Study of Pile Pillared Support and Pile-anchor Retaining in Deep Pit

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Abstract. Support pattern is the most important factor affecting the stability of foundation pit. In order to study the stable state of deep foundation pit, this paper selects pile pillared support and pile-anchor retaining which are high accident rate for comparison, and optimizes the construction scheme combined with the actual deep foundation pit project. The deformation of the supporting structure and the settlement of the foundation pit of Huiquan Square are used to analyze by FLAC3D. The variation range and trend of the internal force of the steel support and the axial force of the anchor cable are analyzed under the different values of the soil layer parameters, such as elastic modulus, cohesion and internal friction angle. The results show that the internal force of pile pillared support is greatly affected by the change of cohesion and the anchor axial force is greatly affected by the change of elastic modulus and internal friction angle. Meanwhile, the influence degree of each soil layer parameter on the internal force of support structure is different, which provides reference suggestions for the selection of support pattern of deep foundation pit.

1.Introduction

The deep foundation pit support scheme is the main measure to ensure the deep foundation pit deformation. Choosing an appropriate support scheme is the key to the stability of the foundation pit. Pile pillared support and pile-anchor retaining account for 14% and 11.1% of all foundation pit support accidents respectively, so the study of the two support methods is particularly important. Some scholars have conducted a series of studies on the mechanism of various support methods. Gao et al[1] proposed a method for determining the parameters of the soil constitutive model, and proposed an optimized design scheme for the protection of surrounding buildings. Cui et al[2] pointed out the key parameters affecting the deformation and stability of the foundation pit. Ye et al[3] compared the simulated values with the actual monitoring values under different excavation conditions of deep foundation pits, and pointed out that with the increase of the excavation depth, the surface settlement and the horizontal displacement of the retaining structure also increased. Li et al[4] analysed the interaction mechanism between the supporting axial force and the horizontal displacement of the pile.

At present, the researches focus mainly on the mechanism of support, and few studies on the influence of soil layer parameters on the support method. We analyse by FLAC3D the internal force of the steel support and the axial force of the anchor cable under the different values of the soil layer parameters, such as elastic modulus, cohesion and internal friction angle.

2.Actual working conditions and model establishment

2.1 Actual working conditions

The foundation pit of Huiquan Square has a depth of 17.5m and a width of 18.9m. The soil design parameters of Huiquan Square are shown in Table 1.

Table 1. Design parameters of soil

Layer	Name of soil	Soil thickness(m)	Weight (kN/m^3)
1	Plain fill	1.80	17.5
2	Silt	1.00	19.6
3	Medium sand	3.00	19.5
4	Cohesive soil	3.00	19.5
5	Gravel	1.40	21.5
6	Strong decomposed rock 1	3.00	22.5
7	Strong decomposed rock 2	3.00	22.0

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8	Strong decomposed rock 3	6.70	24.5
9	Medium weathering rock	2.80	26.0

2.2 Calculation model

FLAC3D was used as the simulation software. In the calculation model shown in Figure 1. The x, y and z direction represent the width direction, length direction, depth direction, respectively.

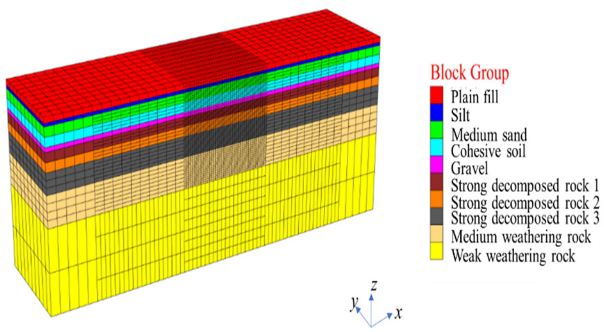

Fig. 1 Calculation model

2.3 Support schemes for pile support and pile anchor support

2.3.1 Pile pillared support

Excavation conditions of pile pillared support as follow:

(1) The first step is excavation and reinforcement. The excavation depth is 2.9m.

(2) In the second step of excavation and reinforcement, the excavation depth is 9.3m.

(3) The third step is excavation and reinforcement. The excavation depth is 13.8m.

(4) The fourth step is excavating to the bottom of the foundation pit with a depth of 17.5m. After the main structure was constructed, a rigid hinge was constructed at 9.95m to remove the second support.

(5) A rigid hinge is applied at 3.8m and the first support is removed.

2.3.2 Pile anchor support

Excavation conditions of pile-anchor retaining as follow :

(1) The first step is excavation and reinforcement. The excavation depth is 2.3m.

(2) The second step of excavation and reinforcement, the excavation depth is 6.3m. the first and second bolts are vertically spaced 4m, and the horizontal space is 1.7m.

(3) The third step is excavation and reinforcement. The excavation depth is 10.3m. The vertical distance between the second and third anchors is 4m and the horizontal distance is 1.7m.

(4) The fourth step is excavation and reinforcement. The excavation depth is 14.3m.

(5) The fifth step is to dig to the bottom of the foundation pit with a depth of 17m.

3.Comparative analysis of supporting axial force

The parameters that determine the strength of the soil layer generally include soil gravity, elastic modulus, Poisson's ratio, and internal friction angle, etc[5]. Rock and soil mechanical parameters can describe the quality, stress state, failure mode and properties of rock and soil, and provide basic data for safety and stability analysis of deep foundation pit engineering. By comparing the changes of elastic modulus, internal friction angle and cohesive force, the advantages and disadvantages of the two schemes in engineering practice are compared. Mechanic parameters of soil layer is shown in Table 2.

Table 2. Elastic modulus values

Soil layer	Young modulus E(MPa)	Poisson ratio μ	Cohesion C(kPa)	Friction angle φ(°)
Plain fill	15	0.35	20	15
Silt	10	0.35	18.75	36
Medium sand	25	0.3	20	38
Cohesive soil	17	0.3	24.35	15
Gravel	60	0.3	30	30
Strong decomposed rock 1	45	0.3	90	30
Strong decomposed rock 2	60	0.28	100	45
Medium weathering rock	90	0.28	170	45

3.1 Influence of changes in elastic modulus

The elastic modulus is an indicator of the strength of the soil layer. The elastic modulus is taken as a multiple of the elastic modulus of the survey, and the multiples are: 0.1E, 0.2E, 0.5E, E, 2E, 5E.

Figure 4 is the change curve of the maximum value of the support internal force when different elastic modulus values are taken. It can be concluded that when the elastic modulus is small (0.1E and 0.2E), the maximum value of the internal force of the steel support appears in the early stage of excavation. During the excavation and support construction, the internal force of the steel support gradually decreased and reached equilibrium. The elastic modulus was large (E, 2E, 5E), the internal force of the steel support increased with the excavation of the deep foundation pit, and reached the maximum value when the excavation was completed.

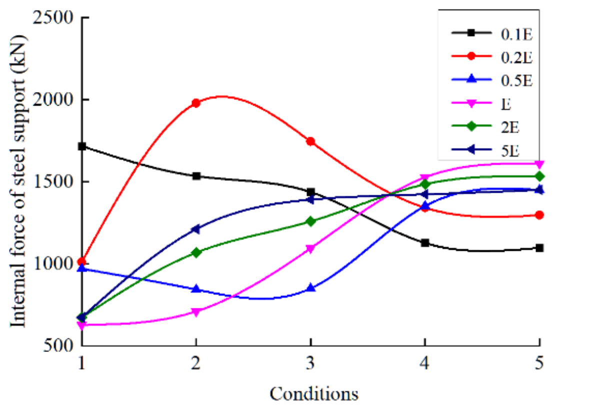

Fig.2. The steel support force (max) curve at different situation of the elastic modulus values

Fig.3 is the change curve of the maximum value of the axial force of the anchor cable when different elastic modulus values are taken. The axial force of the anchor cable shows a completely different trend of pile pillared support. It shows a similar growth law, and generally reaches a maximum value and tends to stabilize after the excavation of the deep foundation pit is completed.

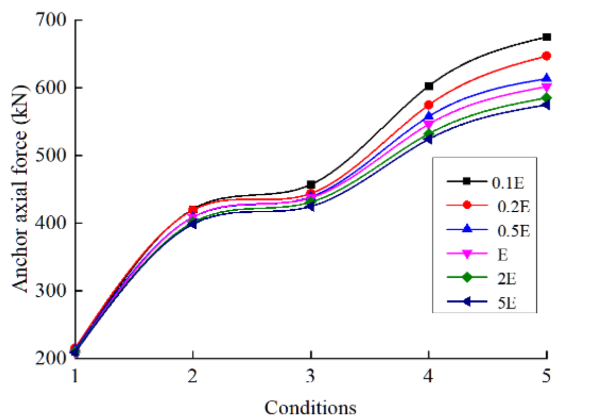

Fig.3. The anchor axial force (max) curve at different situation of the elastic modulus values

3.2 Effect of cohesion changes

Cohesion is an important parameter reflecting the characteristics of the soil layer[6]. Generally, the cohesive strength of the cohesive soil layer determines its shear strength. The change of cohesive force is 0.1C, 0.2C, 0.5C, C, 2C, 5C.

Figure 6 is the change curve of the internal support force (maximum value) when different cohesion values are taken. The following conclusions can be drawn:

When the cohesive force values are 0.1C and 0.2C, the internal force of the steel support increases rapidly during the second step of the excavation condition, and decreases in the subsequent conditions. When the cohesion value is 0.5C, C, 2C and 5C, the internal force of the steel support decreases with the increase of the cohesion value, increases with the depth of the excavation, and eventually stabilizes. The internal force changes in the four cases are consistent, which indicates that the steel support internal force is relatively less sensitive to cohesion.

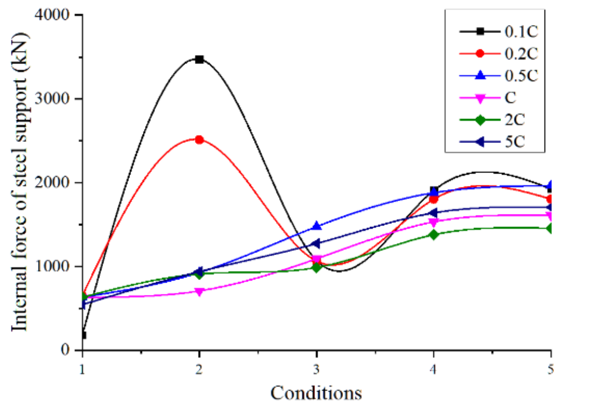

Fig.4 . The steel support force (max) curve at different situation of the cohesion values

Fig.5 is the variation curve of the maximum axial force of anchor cable under different cohesion force values. The axial deformation of anchor cable has a strong regularity and tends to increase. When the cohesion value is 0.1C and 0.2C, the axial force of anchor cable increases rapidly from the third step of excavation. When the cohesion value is 0.5C, C, 2C and 5C, the axial force of anchor cable increases gradually and the value difference is small. It can be seen that the axial force of prestressed anchor cable is less affected by the change of cohesive force.

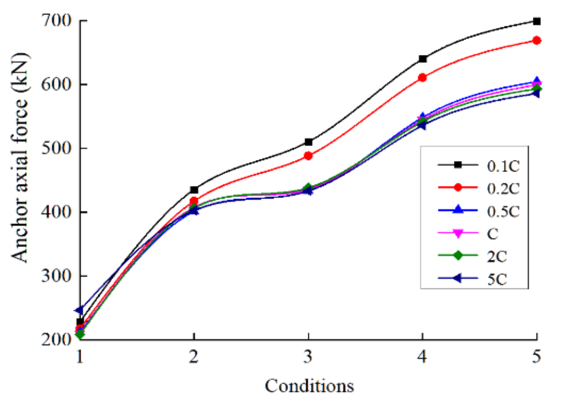

Fig.5. The anchor axial force (max) curve at different situation of the cohesion values

3.3 The effect of internal friction Angle change

Internal friction angle is an important index to describe the nature of soil friction and shear strength, which directly affects the horizontal resistance of soil, is closely related to the sliding failure of foundation soil, and affects the safety and stability of deep foundation pit.

Fig. 6 is change curve of the maximum internal force of steel support under different values of internal friction Angle. It can be obtained that: the change of internal force of steel support presents an overall increasing trend. The friction angle in the soil decreased by 10° on the whole, and the internal force of steel support increased rapidly in the excavation of the 3rd and 4th working conditions, and the maximum value was significantly higher than other conditions. Under other values, the internal force of steel support increases regularly with the increase of internal friction Angle.

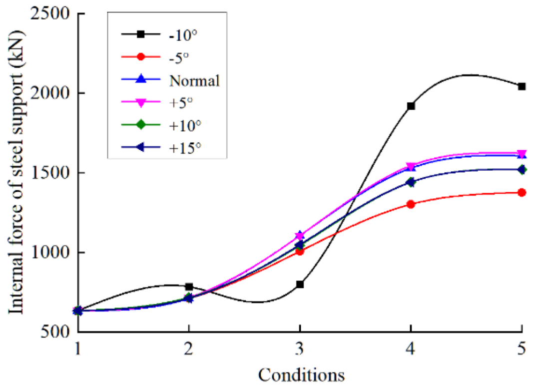

Fig.6. The steel support force (max) curve at different situation of the friction angle values

Fig.7 shows the variation curve of axial force of anchor cable under different internal friction angles. Under different values of internal friction angles, the variation of axial force of anchor cable presents an overall increasing trend. When the friction Angle in the soil decreases by 10°, the axial force of anchor cable increases rapidly in the third step of excavation, and the increasing trend is obviously different from other cases.

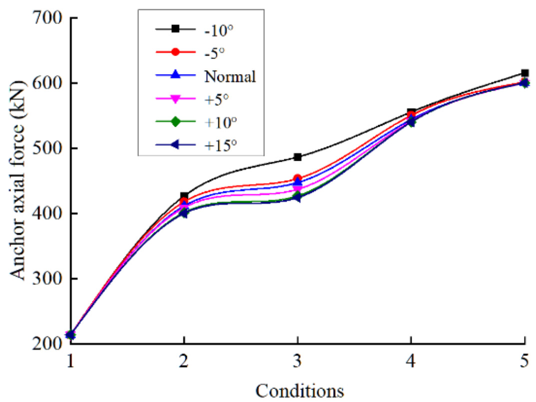

Fig.7. The anchor axial force (max) curve at different situation of the friction angle values

Conclusions

Through optimization analysis, the main findings can be summarized as follows:

1. The internal force of steel support is greatly affected by the change of cohesion, and the axial force of anchor cable is greatly affected by the change of elastic modulus and internal friction angle;

2.The sensitivity of foundation to soil parameters is different, cohesion is greater than elastic modulus while elastic modulus is greater than internal friction.

3. Anchor axial force shows a completely different trend of internal force of steel support, which decreases with the increase of elastic modulus and increases with the increase of excavation depth. Pile anchor support should be used in projects with great influence of elastic modulus.

4. The internal force of steel support and the axial force of anchor cable increase with the increase of internal friction angle.

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