Research on deformation mechanism of super deep foundation pit on deep soft soil slope based on monitoring data

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Keywords: Monitoring data, Slope, Super deep foundation pit, Numerical simulation

Abstract: Because of the different slope angles of super deep FP (foundation pit) on the slope, different soil properties and lithology of excavation materials, seepage pressure of groundwater along the slope, pore water pressure in super deep FP and other factors, people don't know the deformation mode and failure mechanism of this kind of deep soft soil slope super deep FP. In this paper, Midas GTS software is used to simulate the deformation mechanism of a deep soft soil slope super deep FP in Qujing, Yunnan Province. The results show that the numerical simulation of the excavation process of this deep soft soil slope super deep FP is feasible and reasonable, which provides first-hand design information for similar projects in this area, and plays a good reference and guiding role in the construction of similar deep soft soil slopes in this area. It is particularly important and meaningful.

1. Introduction

In recent years, with the rapid development of urban underground space, the number of super deep FP (foundation pit) on deep soft soil slopes has increased sharply, and the FP excavation has gradually shifted from the stability problem to the deformation control problem of the surrounding environment. To solve these problems in urban development, we should make full use of urban underground space [1]. In the process of underground space development, the safety problems of construction and environment caused by the implementation of super deep FP project have become more and more prominent. However, underground projects, subject to the influence of geology, environment, weather, construction and other factors, often have many uncertain or unpredictable situations, resulting in frequent safety accidents of FPs.

Only by using digital simulation technology to study the failure mode and stability of super deep FP on deep soft soil slope, can we accurately grasp the pulse of engineering safety, nip the instability of FP in the cradle, and put an end to the safety accidents of super deep FP on deep soft soil slope [2]. Deep soft soil slope super deep FP is a problem that has to be faced in the design and construction of high-rise and super-high-rise buildings in China. Under the background of intelligent construction, it is of great scientific significance and application value to study the failure mode and stability of deep soft soil slope super deep FP to solve the instability problem of deep soft soil slope in China [3-4]. In this paper, the geotechnical engineering software Midas GTS is used to simulate the excavation process of a super deep FP project in Qujing, Yunnan, and compared with the actual monitoring data, the rationality and feasibility of the simulation parameters and the simulation construction process are demonstrated to ensure the stability of the FP and the surrounding environment.

2. Project overview

2.1 General situation of FP engineering

The reinforcement design is located on the south and east sides of the FP, with a total length of about 195m, of which the east side is about 90m long and the south side is about 105 long. The depth of FP on the east side is about 10.6~8.9m, and that on the south side is about 12.1~10.4m.

In this project, the north and east sides of the FP are excavated to the base elevation, and the east and south sides are excavated to the base elevation. Cracks of different degrees are found in the surrounding surface and buildings, which have been backfilled to 3m below the top of the pit. The

DOI: 10.25236/icmmct.2023.014

depth of the FP on the east side is about 10.6~8.9m.

The supporting type is a supporting pile+anchor cable structure system. The supporting pile is a rotary excavation construction technology with a pile diameter of 800mm and L = 23 m @ 1.3 m; There are 4 rows of anchor cables, L=16~30m@2.6m, and the number of cables is 2 and 3. Outside the pit, A500 deep mixing cement-soil pile is set to stop water, with L = 11m @ 0.3m. The whole project of FP is shown in Figure 1.

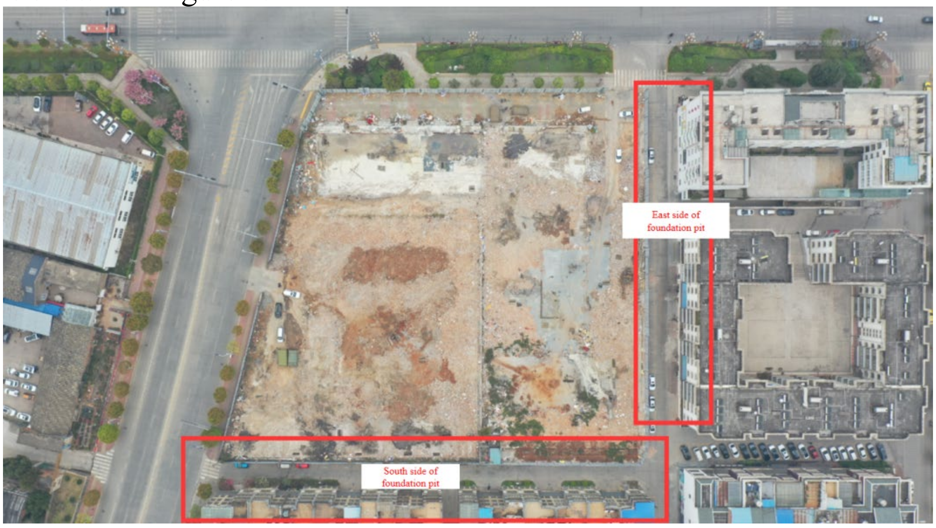

Figure 1: Engineering panorama of FP

The depth of the FP on the east side is about 10.6~8.9m. The supporting type is a supporting pile+anchor cable structure system. The supporting pile is a rotary excavation construction technology with a pile diameter of 800mm and L = 23 m @ 1.3 m; There are 4 rows of anchor cables, L=16~30m@2.6m, and the number of cables is 2 and 3. Outside the pit, A500 deep mixing cement-soil pile is set to stop water, with L = 11m @ 0.3m. The depth of the south FP is about 12.1~10.4m. The supporting type is a supporting pile+anchor cable structure system. The supporting pile is a rotary excavation construction technology with a pile diameter of 800mm and L = 26 m @ 1.3 m; There are 5 rows of anchor cables, L=18~42m@2.6m, and the number of cables is 2 and 3. Outside the pit, A500 deep mixing cement-soil pile is set to stop water, with L = 14m @ 0.3m.

On the east side of the FP, the supporting structures (supporting piles, water-stop piles and anchor cables) are all completed by construction. The construction of supporting piles and water-stop piles in the south side of the FP has been completed, but only three rows of anchor cables have been constructed, and the last two rows have not been constructed. The excavation line of the FP on the east side is about 3.5m away from the red line of the land (the site fence). Outside the red line, there are roads with a width of about 8m, and there are 5~6F houses (concrete structure, artificial digging pile foundation, about 17m); long) beside the roads. The excavation line of the FP on the south side is about 5m away from the red line (site fence) of the land. Outside the red line, there are roads with a width of about 6m, 4F houses (pile foundation, about 20m long) beside the roads, and parking areas outside the houses.

2.2 Support scheme

As the reinforcement height of this project is 8.9 ~ 12.1 m, according to the above analysis of the causes of cracks in the FP and the original design calculation results, it can be seen that the instability of the first-stage FP support project of this project is mainly caused by the insufficient anchoring force of the first-stage pile body and the insufficient stability against overturning. This reinforcement scheme takes into account the site construction requirements, the construction period, the surrounding environment of the FP, and from the safety and economic point of view, a reinforcement scheme of backfill back pressure+pit reinforcement (high-pressure jet grouting pile) is formed to increase the passive earth pressure of the soil.

2.3 Engineering geological conditions of site

The floor elevation of the site is 1887.91~1892.23m, with a relative height difference of about 4.32m m. The overall terrain is high in the south and low in the north. The proposed site is characterized by structural erosion and erosion.

The floor elevation of the site is 1887.91~1892.23m, with a relative height difference of about 4.32m m. The overall terrain is high in the south and low in the north. The proposed site is characterized by structural erosion and erosion. The plain fill in layer ① of the site belongs to permeable layer; ②, ③, ⑤, ⑥ layers of cohesive soil and ④ layers of peaty soil are relative water-resisting layers, ⑤1, ⑥1 layers of silty soil are pore aquifers, and the type of groundwater is upper stagnant water. The groundwater in the site is mainly supplied by the atmosphere and the surrounding domestic water, and the drainage mode is mainly to drain into the sunken ditch of the site in the form of groundwater seepage and runoff. The observed buried depth of groundwater level is 5.30~8.90m. The range of water level is 2 ~ 3m, and the elevation of water level is 1881.41~1885.71m

2.4 Monitoring content

According to Technical Specification for Monitoring of Building FP Engineering (GB50497-2009), this FP needs to be monitored for the following items: horizontal and vertical displacement of pile top, horizontal displacement of deep soil, settlement of surrounding ground (road), displacement of surrounding buildings and settlement of underground pipelines (Table 1).

Table 1: List of monitoring point information

Project name	Location of monitoring points	Monitoring purpose	monitoring method
Horizontal displacement of pile top	top beam	Monitor the horizontal and vertical displacement of pile top.	Total station and level
Vertical displacement of pile top	top beam(together with the layout of horizontal monitoring points)	Monitor the horizontal and vertical displacement of pile top.	Total station and level
Deep horizontal displacement of soil mass	In the pile or soil of supporting pile	Monitor the displacement at each depth of pile body.	Pre-measure the inclined pipe and monitor it with inclinometer
Settlement of surrounding roads (ground)	Road or ground	Monitoring the settlement of surrounding ground or roads	Total station and level
Peripheral pipeline displacement	Peripheral pipeline	Monitor the displacement of surrounding pipelines.	Into the benchmark total station, level
Displacement monitoring of surrounding buildings	Corner of building	Monitor the settlement, inclination and cracks of surrounding buildings.	Total station and level ruler

3. Research method

3.1 Basic assumptions of analysis

Midas GTS is a finite element analysis software developed by MIDAS IT Software Company of Korea for geotechnical engineering and tunnel engineering. Its core is Dinna, and its performance is very stable. It makes the software have the most basic geotechnical analysis function, and also has a very powerful geotechnical theoretical analysis function. Provide strong technical support for geotechnical engineering in the actual construction process, and ensure the safety and reliability of engineering quality.

There are many factors that affect the supporting effect in deep soft soil FP supporting engineering. In addition, the engineering conditions in the actual construction stage are also very complicated, so it is difficult to fully simulate the actual situation with finite element software. Therefore, the following assumptions are made in the simulation analysis [5-6]:

(1)The soil is assumed to be elastic-plastic, and the row pile supporting structure is assumed to be under linear elastic load.

(2)The soil is an ideal elastic-plastic material, and the modified Mohr-Coulomb criterion is adopted in the software.

(3) The supporting piles and anchors are ideal elastic bodies.

(4)The drainage consolidation of soil is not considered;

(5)The influence of supporting structure construction on soil disturbance is not considered.

3.2 Establishment of calculation model

On the basis of considering the elimination of boundary influence and the current computing power, the plane size of the two-dimensional plane finite element model is 138m ×93m; The plane size of the 3D model is 120m ×105m, the top elevation of the model is +5m, and the bottom elevation is -70m.

The soil layer is mainly simulated by DP material [7], and its failure criterion is Durckr-Prager criterion:

$$f = aI_1 + \sqrt{J_2} - k = 0$$
$$f = 3ap + \frac{1}{\sqrt{3}}q - k = 0 \quad (1)$$

Where I_1 is the first stress tensor invariant and J_2 is the deflection invariant.

In Midas GTS, the excavation and support of FP are realized by loading step, passivation and activation unit. Firstly, the original stratum model is established, the displacement constraint boundary conditions are imposed, and the iterative calculation is carried out under the initial in-situ stress condition to make the calculation model reach the initial stress balance, and the initial displacement is reset to zero, so as to simulate the consolidation settlement of soil before FP excavation [8-9]. Then passivate the excavated part of the soil according to the sequence of super deep FP construction, activate the supporting unit and unit prestress of the excavated part of the soil in the previous step, and passivate the excavated part of the soil in the next step, and so on until the end. The basic flow chart of modeling is shown in Figure 2 below:

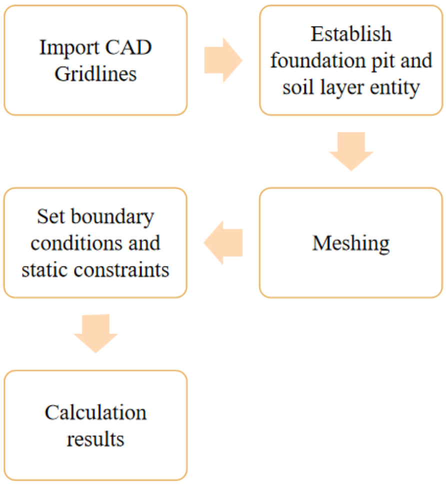

Figure 2: Basic modeling process

4. Numerical simulation analysis

4.1 Wall deformation analysis

The earth pressure acting on the wall can be as static as possible. With the excavation of the soil in the FP, the wall in the pit will face the empty surface, and the wall will be deformed into the pit. Under the action of the active earth pressure behind the wall, the wall will be deformed into the pit. Figure 3 shows the comparison curve between the calculated value of the lateral deformation of the middle wall in the east of the FP and the field monitoring data.

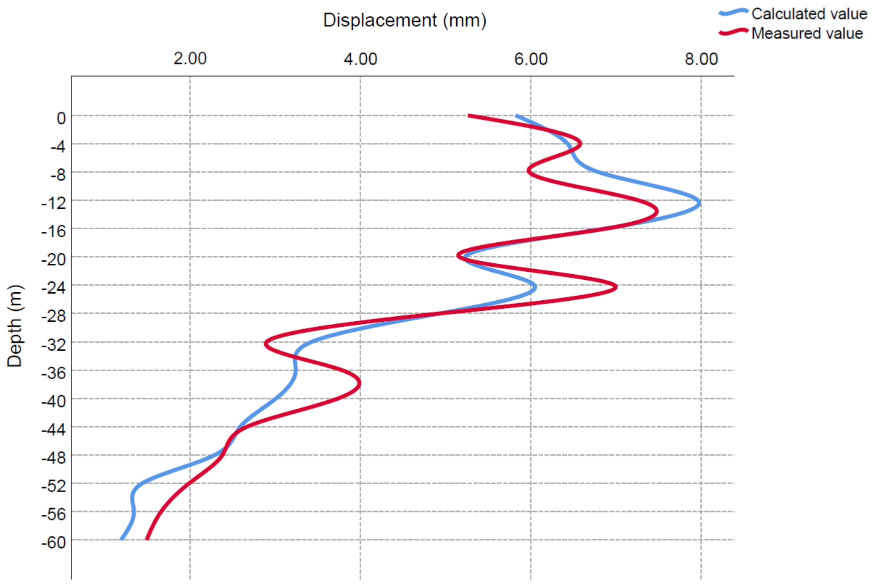

Figure 3: Lateral displacement of wall

On the whole, the two are basically coincident, but there are still errors between the local calculated values and the field monitoring data.) In actual engineering construction, the deformation of FP engineering will be affected by many factors, such as uncontrollable factors such as weather and temperature, but the uncontrollable factors cannot be considered in the numerical simulation process with finite element software, resulting in differences between the two results.

4.2 Comparative analysis of ground settlement displacement around FP

Fig. 4 is a comparative analysis curve between the numerical simulation results of ground settlement displacement around the FP and the field monitoring results after the FP excavation is completed.

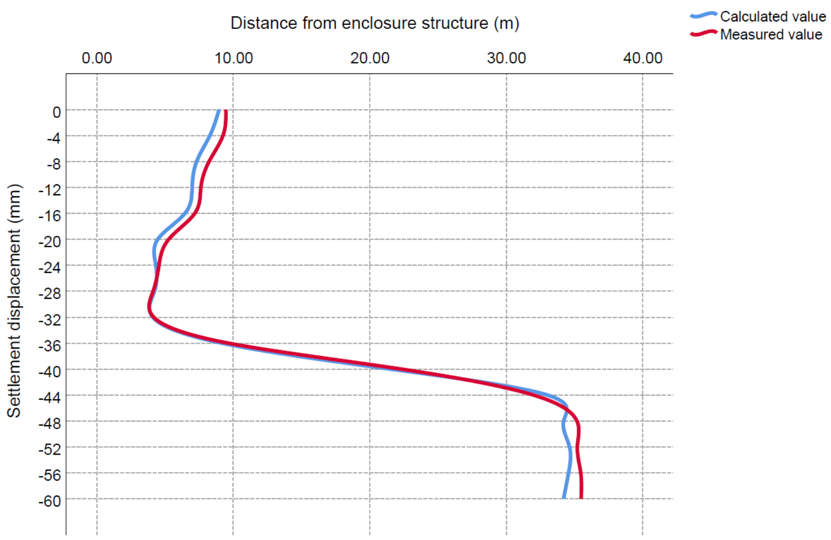

Figure 4: Contrast curve of surface subsidence and displacement

As can be seen from the figure, the change trend of simulation values is basically the same as that of monitoring data. It can be seen that the monitoring data is larger than the simulation value, which is due to the influence of many uncertain factors in the construction of FP engineering, resulting in differences in comparison results. The maximum value of settlement calculation value appears at 35m from the FP edge. However, the maximum position of monitoring data appears about 9 meters away from the FP, which is due to the influence of the construction factors of the FP.

5. Conclusions

In this paper, Midas GTS finite element software is used to simulate the excavation and deformation mechanism of the super deep FP project in Qujing, Yunnan, and the simulation results are analyzed. The monitoring results of wall deformation and ground settlement around the FP are compared with the simulation results. The main conclusions are as follows: With the excavation of the FP, the retaining structure is affected by the active and passive earth pressure, which makes the retaining structure horizontally displaced. With the increasing of the excavation depth, the horizontal displacement of the retaining structure gradually increases. The maximum value of settlement calculation value appears at 35m from the FP edge. However, the maximum position of monitoring data appears about 9 meters away from the FP, which is due to the influence of the construction factors of the FP. The deformation simulation value of the retaining structure is basically the same as the deformation trend of the actual monitoring data. It can be seen that the selection of various parameters is reasonable when using Midas GTS finite element software to model the FP engineering. It is reasonable to use software to simulate the deformation law of FP.

Acknowledgements

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