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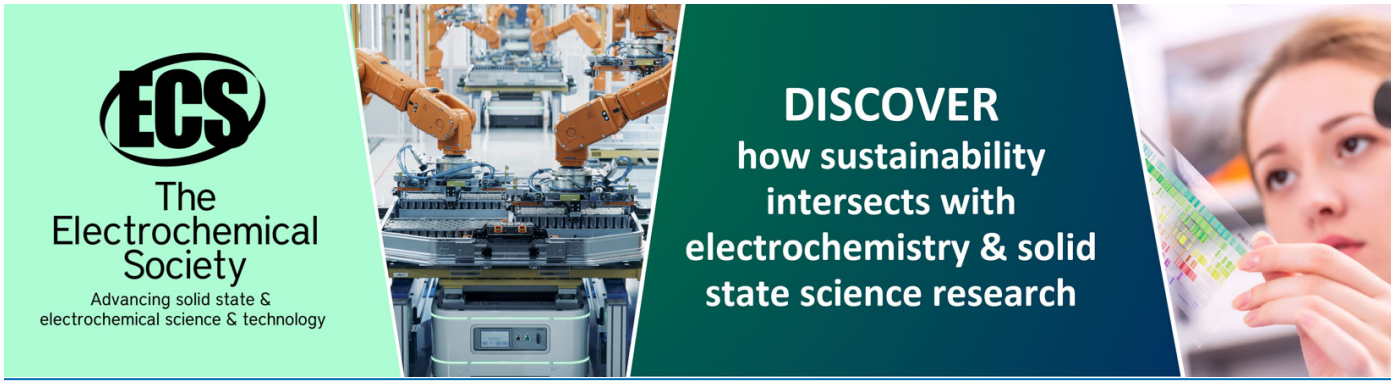

Study on Optimization of Deep Foundation Pit Support Scheme under the Influence of Traffic Dynamic Load in the Reconstruction and Expansion of Jiqing Expressway

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Abstract. In this paper, based on the deep foundation pit support of the reconstruction and expansion project of Jiqing expressway, the FLAC3D software is used to establish the numerical calculation model of the deformation support of deep foundation pit under the influence of traffic dynamic load. The numerical calculation results are consistent with the actual project monitoring results. By changing the key support parameters such as pile diameter and pile distance, pile length, the level of piles under different support schemes is analyzed. The results show that the ideal diameter of bored pile is 0.8-1.2m, the spacing is 1.1-1.3m, the length of pile is 23m-28m. The horizontal displacement of pile body and ground settlement decrease with the increase of length and diameter of support pile. Considering the safety of foundation pit and the reduction of project cost, the pile with length 23m and diameter 0.8m is chosen in the practical engineering.

1. Introduction

With the rapid development of China's economy, the links between different places are increasingly close, and the transportation industry is also facing opportunities and challenges. At the same time, the substantial increase in vehicle ownership has also led to a sharp increase in road transport volume. Since 1980, the mileage of highway construction in China has increased year by year, which has greatly improved the total mileage of highway transportation in China. According to the statistics of the transportation department, by 2017, the mileage of China's expressways opened to traffic and planned to be built reached 136000 km, ranking first in the world [1]-[3]. But, the expressways of early construction has now appeared many problems such as low pavement quality, traffic capacity reduced and lower service level. Today, with the rapid expansion of transportation, the expressway built in advance has been unable to meet the needs of modern society large traffic demand. Therefore, it is the most feasible solution to reconstruct and expand the expressway construction in the early stage and reduce the project investment. The reconstruction and expansion on the basis of the original expressway can not only improve the transportation capacity, but also reduce the construction cost and the occupancy rate of land resources [3]-[5].

The reconstruction and extension project of Jiqing expressway' length is 309km, which is the first expressway widening project without traffic interruption in Shandong Province. During the reconstruction and expansion project, the traffic is normal. Due to the influence of traffic load during

construction, the support of deep foundation pit becomes very important. At present, many scholars have carried out a lot of research work in the field of deep foundation pit support and traffic loads. For example, through the foundation pit support engineering practice in Xining area of Qinghai Province, the paper compares and analyzes the action mechanism and application scope of common support structures, and puts forward corresponding optimization scheme of foundation pit support; Someone analyzes the theoretical calculation method and monitoring technical measures of deep foundation pit In some paper, the advantages and disadvantages of reinforced concrete support and steel pipe support in deep foundation pit are compared and analyzed, and the feasibility of foundation pit support scheme under different soil conditions is discussed [6]-[10].

Based on the actual deep foundation pit engineering of the fourth bid section of Jiqing expressway reconstruction and expansion project, this paper establishes FLAC^{3D} numerical calculation model according to the engineering characteristics of deep foundation pit support under traffic dynamic load, analyzes the influence of key factors such as pile diameter, pile distance and pile length on foundation pit deformation and settlement, and then puts forward the design scheme of foundation pit support.

2. Engineering overview and numerical simulation model

2.1. Engineering overview

The length, width and width of the depth foundation pit under construction in Jiqing expressway Reconstruction and Expansion Project are 12.4m, 6m and 16.8m respectively. Its support scheme is designed as bored pile with inner support, in which the diameter of the pile is 800mm, the spacing between the piles is 1100mm, and the length of the pile is 23000mm. The steel is used in the inner support, whose length and diameter are 600mm and 14mm respectively, the horizontal spacing is 3000mm and vertical spacing is 5000mm. There are three inner supports located underground-0.6m, -5.6 m and -10.6 m respectively. There is an expressway on one side of the foundation pit and the vehicle is driving normally. The soil layer in the site includes plain filling, clay, pebble soil and powder clay. The parameters of each soil layer are shown in the table below.

Table 1. Soil parameters of foundation pit

Soil Layer	Thickness /m	Density Kg/m^3	Elastic Modulus MPa	Poisson ratio	Cohesion /kPa	Internal friction angle
Plain filling	1.5	1810	10	0.43	6.4	16.5
Clay	5	1785	18	0.41	18.2	18.9
Pebble soil	18.4	1965	23	0.35	17.8	18.2
Powder clay	12.3	1980	27	0.37	25.8	17.5

2.2. Numerical simulation model

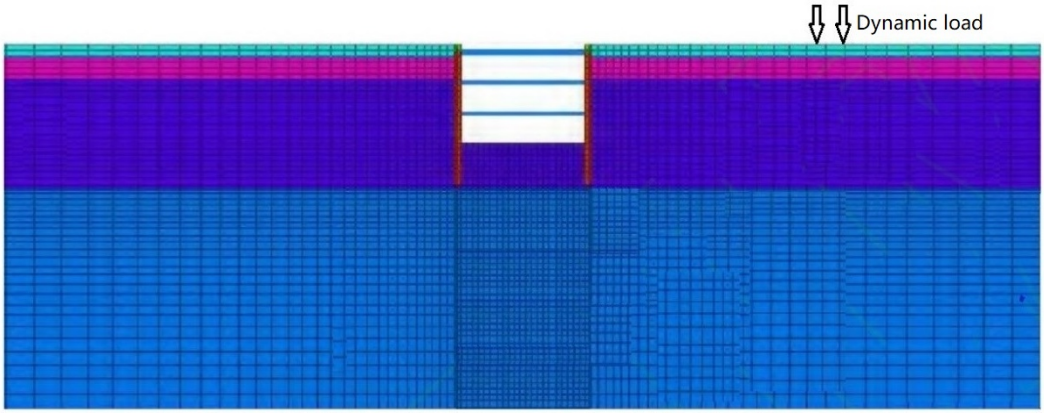


Figure 1. Numerical calculation model

According to geological conditions and investigation data of the deep foundation pit, a FLAC^{3D} numerical calculation model is established, which is shown in Figure 1. The length, depth and thickness of the model are 160m, 68m and 2m respectively. The load produced by the traffic vehicle is taken as external force and embedded into the numerical model in the form of additional dynamic load. Bored piles and top beams that are reinforced concrete structures are set as solid element in the numerical model. Steel supports are set as structural element. The excavation steps in the numerical model are divided into 4 steps from top to bottom.

In order to compare and optimize the supporting scheme of foundation pit, four different supporting schemes are designed, whose pile diameter, pile distance and pile length are different, as shown in the table below.

Table 2. Supporting schemes

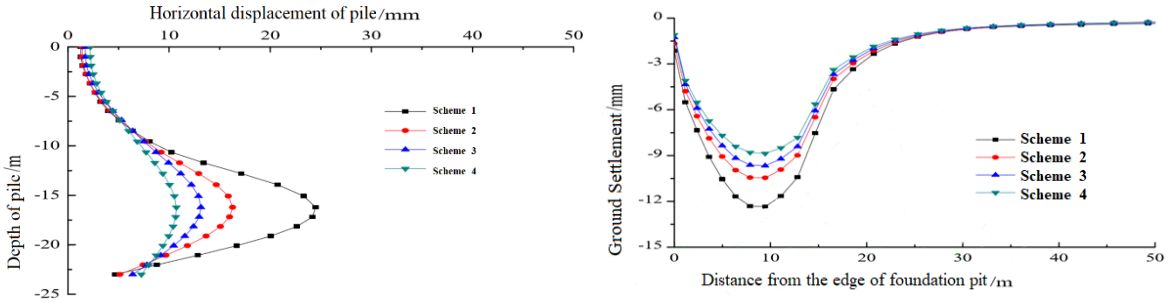
Scheme	Diameter /m	Distance /m	Length /m
1	0.6	0.9	18
2	0.8	1.1	23
3	1.0	1.3	28
4	1.2	1.4	33

3. Optimum analysis of support scheme for foundation pit

3.1. Analysis of Pile Diameter and Pile Distance

Considering the traffic dynamic loads, the supporting effects of deep foundation pit under different pile diameters and distance between piles are compared and analyzed. The results are shown in Figure 2. As can be seen from the results, (1) The horizontal displacement in Scheme 1 is the largest, reaching 25.8mm, while that in Scheme 4 is the smallest, only 11.6mm; therefore, with the increase of pile diameter and distance, the maximum horizontal displacement gradually decreases.(2) As the distance from the edge of the foundation pit increases, the deformation of the soil outside the foundation pit firstly increases, then decreases, and finally tends to zero. The settlement value reaches the maximum at 9m outside the edge of the foundation pit; the ground settlement of the soil around the deep foundation pit changes to the maximum of -13.3mm in Scheme 1. With the increase of pile diameter and distance between the piles, the ground settlement gradually decreases, and the minimum is -8.2mm in Scheme 4.It can be seen from the above that under the same pile length and inner support spacing, the support effect of deep foundation pit gradually decreases with the increase of pile

diameter and spacing between piles. Considering the variation of horizontal displacement of pile body and ground settlement with pile diameter and spacing, the selection of diameter of bored pile of 0.8-1.2m and distance of 1.1-1.4m can effectively limit the deformation of soil around foundation pit.

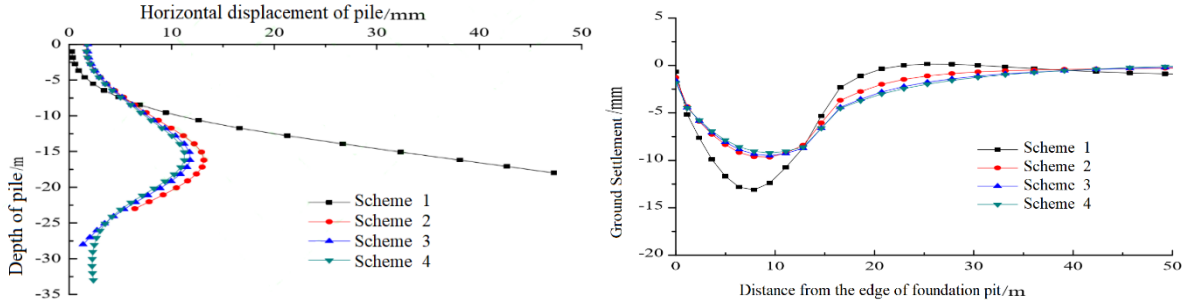


(a) Pile position displacement (b) Ground settlement

Figure 2. Deformation curve of foundation pit and supporting structure in different pile diameters and distance

3.2. Design Analysis of Pile Length

Under the influence of traffic dynamic loads, the supporting effects of deep foundation pit with different pile lengths are compared and analyzed under the same pile diameter, distance and inner support spacing. The diameter of supporting piles is 0.8m, distance is 1.1m and spacing is 5m. The deformation simulation results of supporting structure and soil of foundation pit under different pile lengths are shown in Figure 3. As can be seen from the curves, (1) When the length of piles is 18m, the change trend of horizontal displacement of piles gradually increases. The increase trend from top to bottom indicates that the support pile can not restrain the foundation, which results in kicking destruction of the support pile and destabilization of the foundation pit. When the length of the pile is 23, 28 and 33 m, the deformation trend of the horizontal displacement of the pile is consistent with the actual monitoring results. When the length of the pile is 28 and 33 m, the pile body can remain stable without kicking destruction; when the length of the pile is 23 m, the deformation trend of the horizontal displacement of the pile is consistent with the actual monitoring results. (2) The deformation trend of the soil outside the foundation pit is the same as that in the previous section, but when the length of the pile is more than 23m, the difference of the maximum settlement of the soil is smaller. At the same time, it can also be seen that when the pile length meets the requirements of structural stability, increasing the pile length has no obvious control effect on the horizontal displacement of the pile and ground settlement. From the above results, it is appropriate to choose 23-28m long piles in this paper.



(a) Pile position displacement (b) Ground settlement

Figure 3. Deformation curve of foundation pit and supporting structure in different pile lengths

4. Conclusion

Based on the support project of deep foundation pit in the Jiqing expressway reconstruction and expansion project, the calculation model is established by FLAC^{3D} numerical calculation software, and the support schemes of deep foundation pit are simulated numerically. The calculated results are in good agreement with the actual monitoring results. On this basis, the influence laws of pile diameter and distance between piles, length of piles on deformation and settlement of foundation pit are analyzed, and the optimized design method is put forward. The main conclusions are as follows:

(1) The horizontal displacement of pile body and ground settlement decrease with the increase of pile diameter and pile distance. In practical engineering, it is better to select support piles with diameter of 0.8-1.2m and pile distance of 1.1-1.3m.

(2) When the length of piles is less than or equal to 18m, the slope of foundation pit will lose stability; when the length of piles is longer than 28m, the effect of reinforcement by increasing the length of piles is not obvious.

(3) The horizontal displacement of pile body and ground settlement decrease with the increase of length and diameter of support pile. Considering the safety of foundation pit and the reduction of project cost, the pile with length 23m and diameter 0.8m is chosen in the practical engineering.

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