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The Feature of Deformation at Convex Corner of Deep Foundation Pit Based on FLAC3D

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Abstract. The study on the space-time feature of foundation pit deformation has important significance to ensure the stability of foundation pit engineering. In the present study, the relationship between the space-time fractal feature of foundation pit deformation and the stability of the foundation pit has not been studied adequately. By combining the concrete engineering example, used the FLAC3D software for numerical simulation, and the simulated values were compared with the actual value. Finally, we researched on the relationship between the foundation pit deformation and the stability of foundation pit. Research showed that FLAC3D could reveal the complex spatial and temporal characteristics of foundation pit deformation. But compared with the actual monitoring value, it still has some limitations.

Introduction

With the development of urbanization, a large number of foundation pits are emerging in China, and the foundation pits are becoming more and more complex. At present the safety and stability of foundation pit is a hot research topic. For the stability of foundation pit, the researchers mainly focus on the deformation of foundation pit. The researches on the deformation of foundation pit include the time effect and space effect.

For the time effect, the finite element simulation of the time effect of soft soil foundation pit was carried out by considering the rheological property of soft soil[1], At the same time, some researchers [2-9] have studied the space effect from different aspects. From the existing research, it's found that the deformation at the concave corner of foundation pit was smaller than the deformation at the convex corner which should be focused on in the construction of foundation pit. In particular, the convex corner should be avoided as much as possible in design phase. In comparison, the researches about the space effect on foundation pit deformation could considered the deformation characteristics of foundation pit under different construction state. In this paper, by combining the concrete engineering example, used the FLAC3D software for numerical simulation, and the simulated values were compared with the actual value. Finally, researched on the relationship between the foundation pit deformation and the stability of foundation pit

Engineering examples and numerical modeling analysis

The foundation pit built by Wuhan Wangjiadun CBD Construction& Investment Co., Ltd. located in Wuhan wangjiadun CBD. The plane shape of foundation pit is irregular. Combining the geological data and the surrounding environment of the engineering, the importance level of the foundation pit is the first level and the effective running time is 12 months. The perimeter is about 755m, the area is about 33569m^2, and the excavation depth is about 12m.In order to further analyze the deformation of the foundation pit, the FLAC3D software was used to model the foundation pit. Because the shape of the foundation pit is irregular, and the length-width ratio is closed to 1:1, the foundation pit can’t be simplified into plane strain model. In order to conveniently numerical simulate, the size of numerical model was reduced to 1/2 of original size. The excavation depth of the foundation pit is 12m and the excavation area is divided into 6 blocks, which are exca1, exca2, exca3, exca4, exca5, exca6.The size of numerical analysis model is 230 * 230 * 45m.The 3D model of foundation pit is shown in Fig.1.

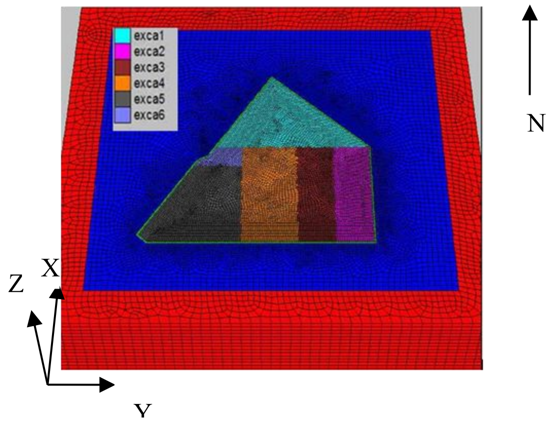

Fig.1. The 3D model of foundation pit

In order to improve the efficiency of model calculation, with the physical and mechanical properties of the soil provided by geotechnical investigation report, the homogeneous soil was merged and the foundation pit soil was divided into 5 layers from top to bottom. The mechanical parameters of the soil layers are shown in Table 1.

Table 1 The mechanical parameters of the soil layers

No.	Properties	Thickness(m)	Unit weight (kN/m^3)	Cohesive strength (kPa)	Internal friction angle (°)	Bulk modulus (MPa)	Shear modulus (MPa)
1	Plain fill	4	18.5	5	22	6	2.22
2	Silt clay	5	18.3	14	18	5	2.07
3	Fine sand	12	20	0	31	20	7.68
4	Sand gravel sand	9	20	0	35	26	10.08
5	Strong weathering mudstone	15	20	0	35	60	33.17

The solid element was used to simulate the underground continuous wall whose depth was 21m, thickness was 1m, density was 3000kg/m3, elastic modulus was 40GPa, and the Poisson's ratio was 0.25. The underground continuous wall was made of C40 concrete.

The excavation of the foundation pit was divided into ten construction states. The details are as follows:

Construction state 1: excavated exca1 and the depth of excavation was 12m.

Construction state 2: excavated exca2 and the depth of excavation was 12m.

Construction state 3: excavated exca3 and the depth of excavation was 12m.

Construction state 4: excavated exca4 and the depth of excavation was 12m.

Construction state 6: excavated exca5 and the depth range was -12m~-6m.

Construction state 7: excavated exca6 and the depth range was -3m~0m.

Construction state 8: excavated exca6 and the depth range was -6m~-3m.

Construction state 9: excavated exca6 and the depth range was -9m~-6m.

Construction state 10: excavated exca6 and the depth range was -12m~-9m.

The analysis of deformation at convex corner of deep foundation pit

From Fig.1 it can be clearly seen that there is a convex corner at the west side of the foundation pit and the degree is 150°.In engineering, the convex corner should be avoided and the convex corner which can't be avoided should be focused on in the deformation control of foundation pit. In order to explore the space effect of the deformation at convex corner of foundation pit, the deformation characteristics was studied by numerical simulation. The horizontal displacement of the foundation pit after the excavation is shown in Fig.2.

It can be seen from Figure 2 that the displacement of the B convex corner region significantly larger than the A and C concave corner regions, and there is obvious space effect. What's more, the displacement influence range of B convex corner region is also larger. In order to observe the deformation characteristics of the convex corner region, 7 monitoring points (1#, 2#, 3#, 4#, 5#, 6# and 7#) were set up, as shown in Fig.3.The horizontal displacement of the monitoring points at the end of the excavation is shown in Fig.4. From Fig.4 it can be seen that the two monitoring points with minimum displacement is close to A and C. The space effect of the B convex corner region with large range and complex form deformation is obvious. There are two shapes of the distribution of horizontal displacement-depth in Fig.4, the triangle and arched shapes.

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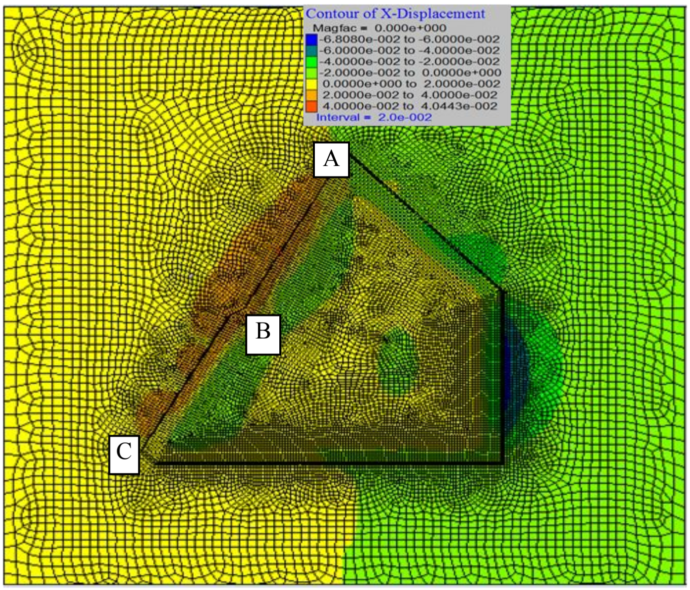

Fig.2. The horizontal displacement of foundation pit

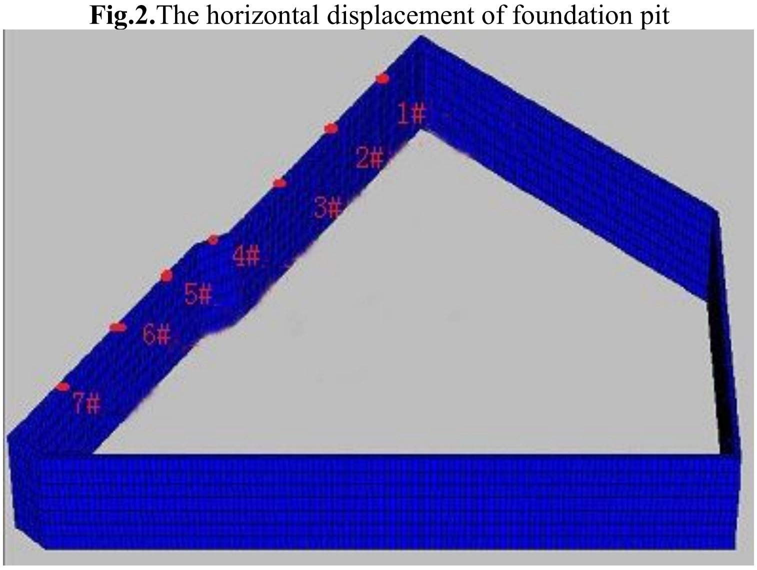

Fig.3. The Monitoring points arrangement of horizontal displacement of foundation pit

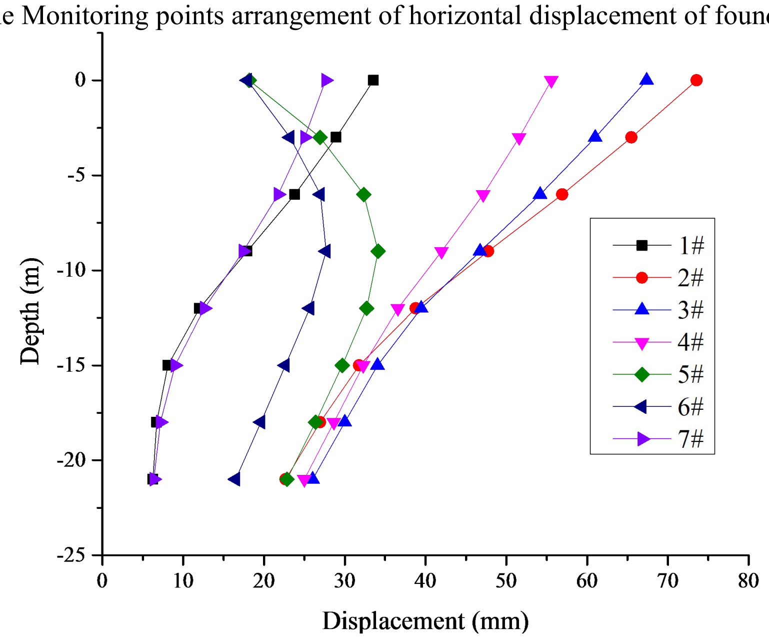

Fig.4. The curve of displacement-depth

In order to further analyze the deformation characteristics of the foundation pit, the relationship between the horizontal displacement at the top of the foundation pit of different monitoring points with the construction states was analyzed, as shown in Fig.5.From Figure 5 it can be seen that with the excavation of the foundation pit, the displacement the monitoring of points 3# and 4#continuously increase and there is a rising trend, which indicates that the dangerous areas are mainly concentrated in the area. Therefore the convex corner region need be focused on.

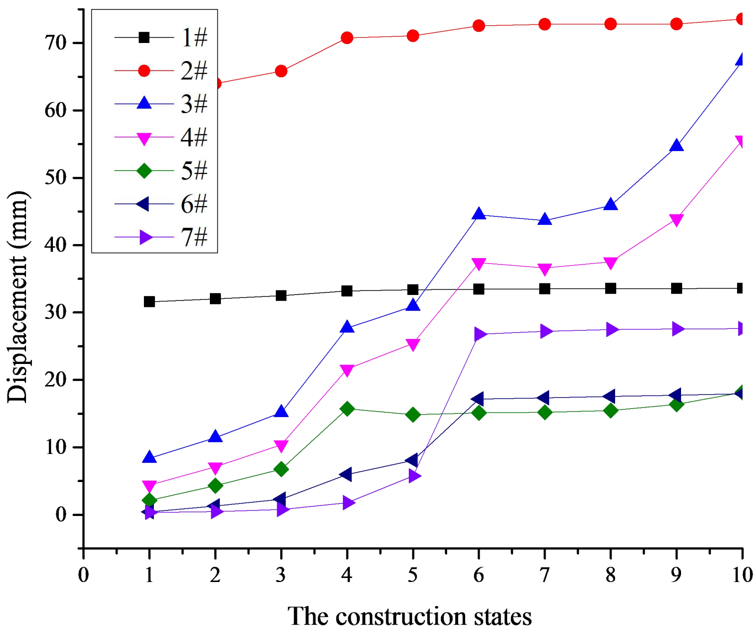

Fig.5. The relationship between the horizontal displacements at the top of the foundation pit of different monitoring points with the construction states

In the actual construction process, the measured displacement of the convex corner region peaked at 214.54mm, which caused the fracture of top beam and the cracks in the plant outside of the foundation pit. The construction company took the measures such as backfilling soil and applying diagonal brace in time, which limited the further development of the deformation at the convex corner region. And in the follow-up process of construction applied support to prevent the occurrence of a greater accident. According to the measured data, the risk area of the accident was in agreement with the numerical simulation. In the process of actual monitoring, the monitoring points C08, C09 close to the convex corner region were corresponding to the 4#, 5# in the numerical simulation. The actual monitoring date was from July 17, 2013 to June 16, 2014.The end date of foundation pit excavation was September 30, 2013, corresponding to construction state 10.The actual monitoring values were compared with the simulated values as shown in Fig.6.

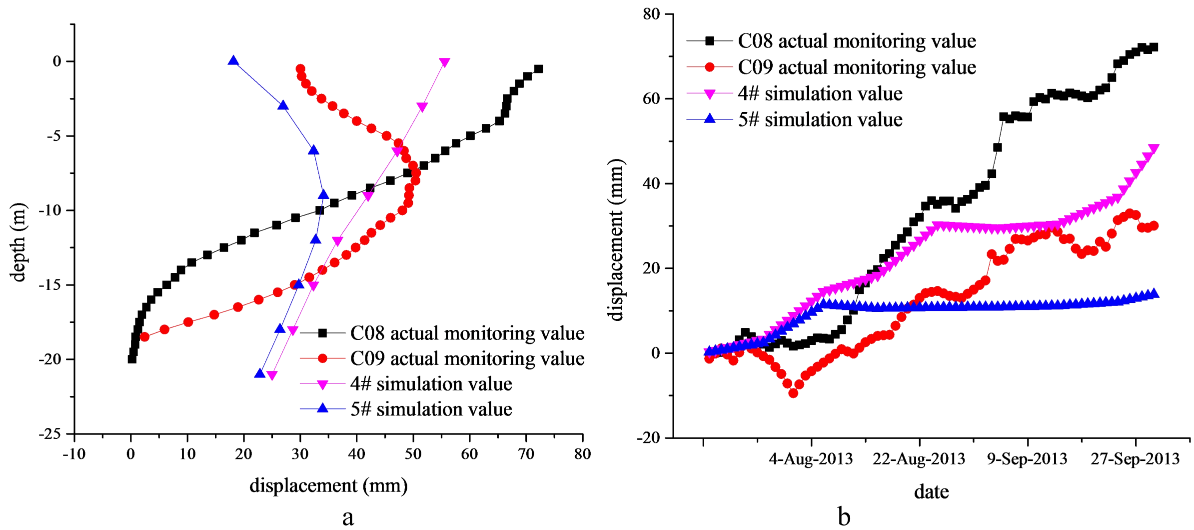

Fig.6. The contrast between the actual monitoring values with the simulated values. (a) The horizontal displacement of the foundation pit is the horizontal displacement at the end of the excavation which corresponds to the actual monitoring values and simulated values of construction state 10, (b) the difference with time between the actual monitoring values with simulated values.

FromFig.6, it is found that the numerical simulation of the foundation pit can partially reflect the space-time feature of deformation at convex corner. But compared with the numerical simulation, the actual deformation of the foundation pit is more complex. The detailed performances are that the actual monitoring values is more complex than the simulated values in different depth, and over time the actual monitoring values show the greater volatility and more obvious time effect.

Summary

The deformation of foundation pit is complex, and it is influenced by many factors. The Numerical simulation can calculate the potential unstable regions of foundation pit from the macro. However, with the simplification of actual construction states the numerical simulation can't accurately reflected the deformation characteristics of the foundation pit. In construction process, date mining from the monitoring data is an effective method to ensure the stability of foundation pit. Through the research, mainly conclusions are as follows:

1. With the simplification of actual construction states the numerical simulation can't accurately reflected the deformation characteristics of the foundation pit. In construction process, date mining from the monitoring data is an effective method to ensure the stability of foundation pit.

2. the actual monitoring values is more complex than the simulated values in different depth, and over time the actual monitoring values show the greater volatility and more obvious time effect.

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