Research on deep foundation pit excavation based on numerical simulation

Cao Shiyong\textsuperscript{1}, Song Shuai\textsuperscript{1}, Qi Xili\textsuperscript{1, a}

\textsuperscript{1}GuiZhou Polytechnic Of Construction, Guiyang, Guizhou, 551400, China

\textsuperscript{a}gzjs1979@126.com

Abstract. The safety of deep foundation pit excavation has always been an important topic of urban construction safety. The traditional method is to control the construction safety by monitoring and adjusting the construction process, but the timeliness of monitoring makes it limited in the control of construction safety. In this paper, MIDAS / GTS software is used to simulate the excavation process of a hospital foundation pit in Guiyang. The maximum horizontal displacement in X direction is 4.03mm, and the minimum is -4.78mm. The maximum horizontal displacement in Y direction is 4.41mm, and the minimum horizontal displacement is -4.9mm. Through the study of the common horizontal X and Y displacement nephogram of crown beam, waist beam and anchor, the synergistic effect can be well expressed. The maximum horizontal displacement in X direction is 5.56mm. The minimum horizontal displacement is -3.54mm. The maximum horizontal displacement in Y direction is 6.56mm. The minimum horizontal displacement is -4.45mm. By comparing the numerical simulation results with the field measurement results, the reliability of the numerical simulation in the evaluation of the foundation pit is fully proved.

1. Preface

Numerical simulation is used to simulate the excavation process of foundation pit, and good results are obtained. Yin Shengbin, Ding Hongyan, etc. through numerical simulation of foundation pit excavation process, think that the surface settlement has obvious distribution law when the retaining structure rotates forward and backward and three basic deformations in downtown area, which can be simulated by exponential curve and empirical formula can be obtained. Luomei and Huahua used Midas GTS software to simulate a foundation pit in Shijiazhuang, analyzed the soil stress, supporting structure deformation and anchor axial force, and compared with the monitoring value. It was found that the anchor axial force was at the maximum value in the anchorage section near the free section. Jiang Yu used Midas GTS software to analyze the pile anchor supporting structure of a foundation pit in Wuhan. Through the analysis, it is concluded that the change trend of the surface outside the foundation pit is "spoon" shape, and the change trend of the water particle movement of the double row column is "big in the middle, small at both ends". The influence of various factors on the horizontal displacement and internal force of the supporting structure is analyzed, and it is found that the row spacing has the greatest influence. The purpose of this paper is to evaluate the safety of foundation pit excavation by studying the numerical simulation of specific excavation process, and verify the reliability of this method in evaluating the safety of foundation pit by means of on-site monitoring.
2. Computational constitutive model of numerical simulation
The finite element method is calculated by the following constitutive relation, and the following only introduces the linear elastic constitutive model:

2.1. The stress-strain expression of isotropic elastic model

\[
\begin{bmatrix}
\varepsilon_{11} \\
\varepsilon_{22} \\
\varepsilon_{33} \\
\gamma_{12} \\
\gamma_{13} \\
\gamma_{23}
\end{bmatrix} = \begin{bmatrix}
1/E & -\nu/E & -\nu/E & 0 & 0 & 0 \\
-\nu/E & 1/E & -\nu/E & 0 & 0 & 0 \\
-\nu/E & -\nu/E & 1/E & 0 & 0 & 0 \\
0 & 0 & 0 & 1/G & 0 & 0 \\
0 & 0 & 0 & 0 & 1/G & 0 \\
0 & 0 & 0 & 0 & 0 & 1/G
\end{bmatrix} \begin{bmatrix}
\sigma_{11} \\
\sigma_{22} \\
\sigma_{33} \\
\sigma_{12} \\
\sigma_{13} \\
\sigma_{23}
\end{bmatrix}
\] (2.1)

Where \(E\) is the modulus of elasticity and \(\nu\) is Poisson's ratio.

2.2. Orthotropic elastic model
The independent model parameters of orthotropic elastic model are young's modulus \(E_1, E_2\) and \(E_3\) in three orthogonal directions, Poisson's ratio \(\nu_{12}, \nu_{13}\) and \(\nu_{23}\) in three orthogonal directions, shear modulus \(G_{12}, G_{13}\) and \(G_{23}\) in three orthogonal directions, and the stress-strain expression is 2.2.

\[
\begin{bmatrix}
\varepsilon_{11} \\
\varepsilon_{22} \\
\varepsilon_{33} \\
\gamma_{12} \\
\gamma_{13} \\
\gamma_{23}
\end{bmatrix} = \begin{bmatrix}
1/E_1 & -\nu_{12}/E_2 & -\nu_{13}/E_3 & 0 & 0 & 0 \\
-\nu_{12}/E_1 & 1/E_2 & -\nu_{23}/E_3 & 0 & 0 & 0 \\
-\nu_{13}/E_1 & -\nu_{23}/E_2 & 1/E_3 & 0 & 0 & 0 \\
0 & 0 & 0 & 1/G_{12} & 0 & 0 \\
0 & 0 & 0 & 0 & 1/G_{13} & 0 \\
0 & 0 & 0 & 0 & 0 & 1/G_{23}
\end{bmatrix} \begin{bmatrix}
\sigma_{11} \\
\sigma_{22} \\
\sigma_{33} \\
\sigma_{12} \\
\sigma_{13} \\
\sigma_{23}
\end{bmatrix}
\] (2.2)

2.3. Anisotropic elastic model
The independent model parameters of fully anisotropic elastic model are 21, formula 2.3

\[
\begin{bmatrix}
\varepsilon_{11} \\
\varepsilon_{22} \\
\varepsilon_{33} \\
\gamma_{12} \\
\gamma_{13} \\
\gamma_{23}
\end{bmatrix} = \begin{bmatrix}
D_{11} & D_{12} & D_{13} & D_{14} & D_{15} & D_{16} \\
0 & D_{22} & D_{23} & D_{24} & D_{25} & D_{26} \\
0 & 0 & D_{33} & D_{34} & D_{35} & D_{36} \\
0 & 0 & 0 & D_{44} & D_{45} & D_{46} \\
0 & 0 & 0 & 0 & D_{55} & D_{56} \\
0 & 0 & 0 & 0 & 0 & D_{66}
\end{bmatrix} \begin{bmatrix}
\sigma_{11} \\
\sigma_{22} \\
\sigma_{33} \\
\sigma_{12} \\
\sigma_{13} \\
\sigma_{23}
\end{bmatrix}
\] (2.3)

3. The results of numerical simulation are compared with the monitoring data

3.1. Working condition setting and
According to the construction scheme of on-site construction, the excavation is simplified into six working conditions, and the working condition information is shown in table 1.

| Working condition | Excavation depth(m) | Support setting |
|-------------------|---------------------|-----------------|
| The first         | -3                  | Anti slide pile and crown beam |
The second -6 The first anchor rod and the first waist beam
The third -9 Second bolt
The fourth -12 The third anchor rod and the second waist beam
The fifth -15 The fourth bolt
The sixth -20 The fifth bolt

Figure 1. shows the model established according to the actual engineering case of foundation pit excavation in a hospital of traditional Chinese medicine in Guiyang. The model is properly optimized on the basis of the construction scheme, in which the existing building with greater impact on foundation pit excavation is replaced by load, because the building adopts shallow foundation.

3.2. Analysis of computational cloud image

3.2.1. Vertical displacement of pile
According to the conditions similar to the actual engineering excavation and properly optimized, the Seymour Coulomb model adopted in the soil calculation model in the software is a more practical one-way calculation model, and the calculation results of soil are shown in Figure 2.

In the construction stage-5, the simulation results have great changes, which are quite different from the actual situation, but the settlement trend is more consistent with the measured results. At this time, the influence of the surrounding buildings on the settlement is very small, and the fourth anchor has a great influence on the stability of the foundation pit. Showed in Figure 3.
3.2.2. Horizontal displacement of crown beam and waist beam

In the construction stage-1, Figure 4, it can be seen that the displacement of the component is consistent with the displacement of the pile as a whole, the maximum horizontal displacement in X direction is 0.38mm, the minimum is -0.81mm; the maximum horizontal displacement in Y direction is 0.56mm, the minimum is 0.63mm.
3.2.3. Bolt strain

Figure 5. Bolt strain nephogram

In the construction Stage-6, Figure 5., it can be seen that all the supporting structures in this stage have entered the working state, so the displacement level in this stage has not increased to a large extent, the maximum horizontal displacement in the X direction is 5.56mm, and the minimum horizontal displacement is -3.54mm; the maximum horizontal displacement in the Y direction is 6.56mm, and the minimum horizontal displacement is -4.45mm.

4. Summary

Through the analysis of the cloud image of soil settlement direction, in the process of excavation, the influence of foundation pit excavation on the surrounding soil can be seen clearly. Because there are shallow foundation buildings on the back of the foundation pit, in the first three layers of the foundation pit excavation, the influence on the surrounding of the foundation pit is still large. But with the completion of the fourth excavation, the cloud image shows that the place with the largest settlement at this time is no longer the back, but the foundation The record of the maximum and minimum value of each excavation shows that the settlement of the surrounding soil is a process of change and then gradually stable.

By studying the displacement nephogram of horizontal X and y of enclosing pile, the force of surrounding soil on enclosing pile during excavation can be clearly expressed, showing the overall role of pile in maintaining the stability of foundation pit. The maximum horizontal displacement in X direction is 4.03mm, and the minimum is -4.78mm; the maximum horizontal displacement in Y direction is 4.41mm, and the minimum is -4.9mm.

Through the study of the common horizontal X and Y displacement nephogram of crown beam, waist beam and anchor, the synergistic effect can be well expressed. The maximum horizontal displacement in X direction is 5.56mm, and the minimum horizontal displacement is -3.54mm; the maximum horizontal displacement in Y direction is 6.56mm, and the minimum horizontal displacement is -4.45mm.

Through the comparison between the numerical simulation results and the actual monitoring data, it is found that the error between the actual monitoring results and the numerical simulation results of each monitoring point is small, which fully verifies the reliability of the numerical simulation for the safety assessment of foundation pit excavation

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