The effect of the additional load on the ground support on the settlement of the surrounding ground

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Abstract. Based on the existing engineering examples, this paper uses numerical simulation combined with the actual monitoring values on site to study the effect of the additional load on the support and the settlement of the surrounding ground, and the following conclusions are drawn: (1) When the enclosure structure is good, the settlement curve generally assumes a "spoon shape". As the distance from the foundation pit increases, the surface settlement curve first increases and then decreases. The distance between the location of the maximum surface settlement and the foundation pit is generally half of the maximum excavation depth of the foundation pit. (2) The existence of additional load accelerates the rate of change of surface settlement, making the soil settlement from the excavation of the first layer of soil as a whole smaller than the unacted additional load to the excavation to the bottom layer as a whole larger than the unapplied load. (3) There will be a certain gap between the numerical simulation and the actual monitoring value. This gap will become larger and larger as the excavation of the foundation pit continues, but the law of change between the two is the same.

1 Introduction

At this stage, due to the prosperous commerce and dense population in the city center, the land use is constantly in short supply. Therefore, the planning of three-dimensional transportation and three-dimensional cities has become an inevitable trend [1-2]. With the continuous implementation of these plans, the development of underground space is getting bigger and bigger. The most important project involved in underground space is foundation pit engineering. Therefore, the development of three-dimensional transportation and three-dimensional city leads to the development of foundation pit towards deep foundation pit or even ultra-deep foundation pit [3]. Most of the deep foundation pits and ultra-deep foundation pits are located in the prosperous areas of the city, and are often close to various buildings and underground pipe corridors, resulting in small construction operations. At this time, there may be a certain amount of piled load around the foundation pit, and even this piled load will act on the support, which will cause a certain disturbance to the surrounding soil, which will cause a certain risk.

Numerical simulation is an important method to study the mechanical characteristics of the deep foundation pit construction process. Aiming at solving realistic foundation pit stability problems, Lambe once pointed out that the use of engineering experience or numerical analysis can more effectively solve such problems[4,5]. The engineering ex perience method is highly subjective and has certain def ciencies on the theoretical basis, and it cannot accurately reflect the mechanical effects of deep foundation pits in the complex construction environment during the construction process. The problem to be solved is studied by numerical simulation in which analysis and prediction are more convenient and accurate [6-8].

The accurate prediction and calculation of surface settlement around a deep excavation pit are important for the safe and smooth development of a deep excavation project. Thus, different prediction methods and theories have been proposed [9-11]. In 1969， Peck pro-posed a method of estimating the surface subsidence in relation to the soil properties and excavation depth using engineering measurements. Referring to Peck and Schmidts theory, Xueyuan Hou (Tong ji University, Shanghai, China) developed the formation loss method deriving from the triangular settlement formula to estimate the ground tunnel settlement of shield tunnels. These widely used methods derive from elaste mechanics and the traditional.

In this paper, based on the problem of heap load in deep foundation pit excavation, the effect of additional load on the concrete support of the first layer is studied. Relying on the existing project, the site monitoring data and three-dimensional numerical simulation data are compared and analyzed, and the change law of Zhouwei's surface settlement is analyzed. Based on this research, the support system of deep foundation pits with such phenomena is optimized.

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2 Site characteristics

2.1 Project Background

The Jiluo Road Crossing Yellow Tunnel is located in the central part of Jinan City, connected to the Queshan area in the north (functionally positioned as a national tourist and leisure resort), the sub-center of Jibei, and the main road to the north, Jiluo Road in the south.

The open-cut and dark-buried section of the Nan'an Highway Tunnel is a three (four)-story, three-span box-frame structure system, and the deepest part of the floor is 32.30m. Use open-cut method for construction. Connect to the shield receiving shaft on the south bank of Jinan Yellow River Tunnel to the north.

Figure 1. Aerial view of construction area.

2.2 Foundation pit excavation construction method

Due to the limitations of the site, the site area for heavy machinery is insufficient during excavation of the foundation pit. According to the site design plan, a cover plate must be set on the first layer of concrete support to allow large machinery to work on the cover plate for earth excavation.

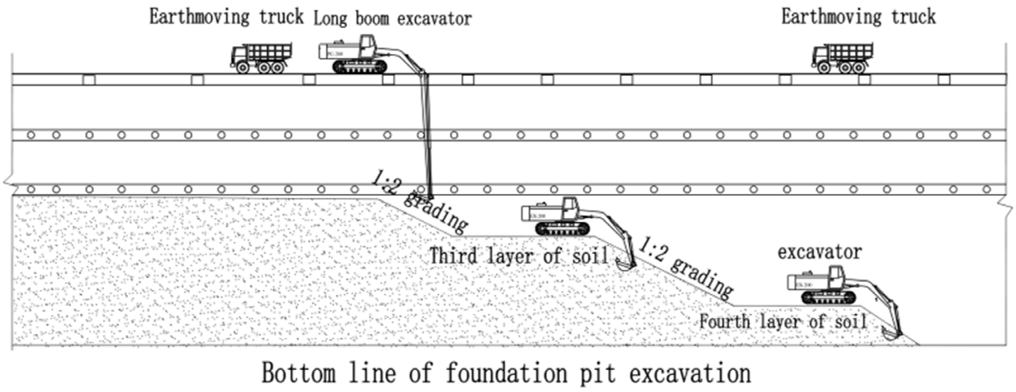


Figure 2. Sectional view of foundation pit excavation.

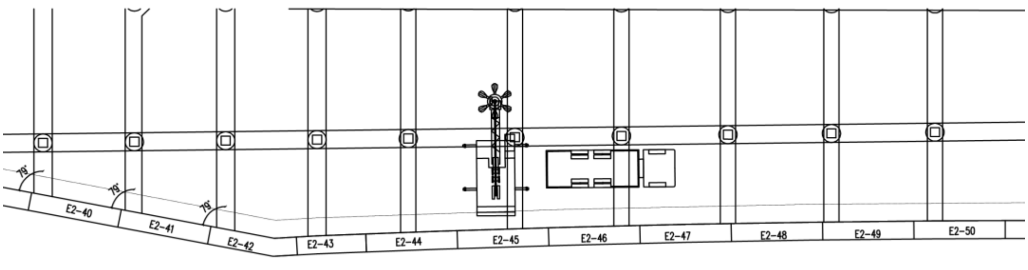


Figure 3. Plan of excavation of foundation pit.

2.3 Soil parameters

The main geological conditions of the main joint construction section of the site are obtained through site survey data and experiments, as shown in Table 1:

Table1. Various parameters of soil.

Soil type	$\gamma\left(KN/m^3\right)$	$c\left(kPa\right)$	$\varphi\left(^\circ\right)$	λ
①Miscellaneous fill		8.0	0.00	
②Silty clay	18.4	12.5	10.7	0.34
③$_2$ Clay silt	18.7	15.0	20.0	0.34
③Silty clay	18.6	22.0	10.0	0.34
④Silty clay	19.5	22.8	10.7	0.34
⑤Silty clay	19.7	22.7	11.4	0.34
⑥Silty clay	19.6	26.4	13.9	0.29
⑦Silty clay	19.3	35.0	18.0	0.29
⑧Silty clay	19.4	39.0	20.0	0.29
⑨Silty clay	20.0	40.0	22.0	0.29
⑬Fully Weathered Gabbro	22.0	38.0	0.00	0.29

3 method

3.1 Model building

3.1.1 Model building. Because the foundation pit is a deep and large foundation pit, the Mohr-Coulomb model in abaqus is used for analysis. The longitudinal length of the on-site foundation pit is too large, so the part with the cover plate is selected for analysis, and a pressure is used to simulate the additional force generated by the on-site heavy machinery. The pressure is selected as 84Kpa according to the actual situation and plan of the site. This calculation model is shown in Figure 3:

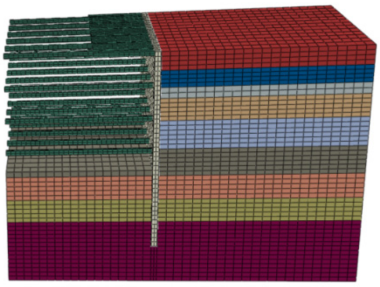


Figure 4. Numerical simulation calculation model.

3.1.2 Excavation plan. According to the site design plan and full consideration of the spatial effect during the excavation process, the excavation of the foundation pit is divided into four layers for excavation. The main excavation sequence is shown in the following table:

Table2. Simulated construction conditions.

Excavation stage	Working condition
1	Initial balance of ground stress and installation of enclosure structure
2	Pouring of the first layer of concrete support (including the upper cover of the concrete support) and excavation of the first layer of soil
3	Pouring of the second layer of concrete support and excavation of the second layer of soil
4	Pouring of the third layer of concrete support and excavation of the third layer of soil
5	Pouring of the fourth layer of concrete support and excavation of the fourth layer of soil

3.2 On-site monitoring

Select the on-site monitoring points corresponding to the simulation for comparative analysis. The layout of on-site monitoring points is shown in Figure 4:

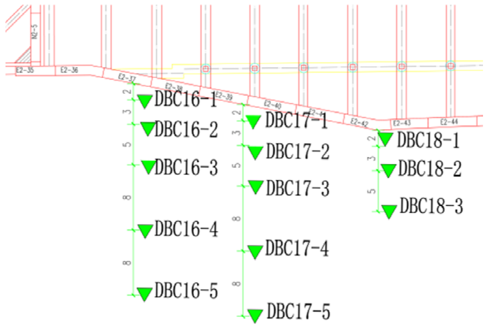
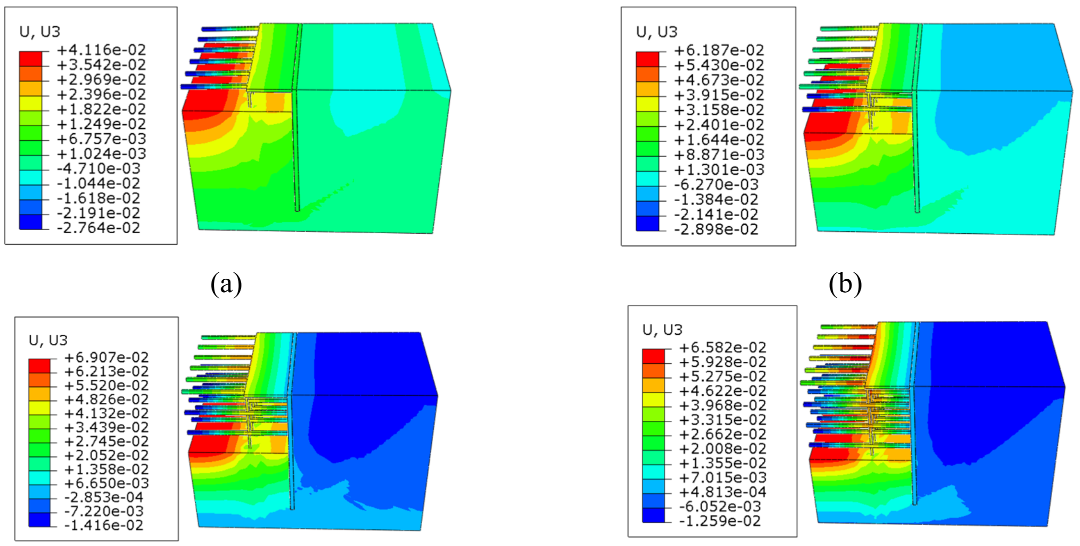


Figure 5. Layout of on-site monitoring points.

4 results and analysis



(a) (b)

(c) (d)

Figure 6. abaqus vertical displacement cloud map.

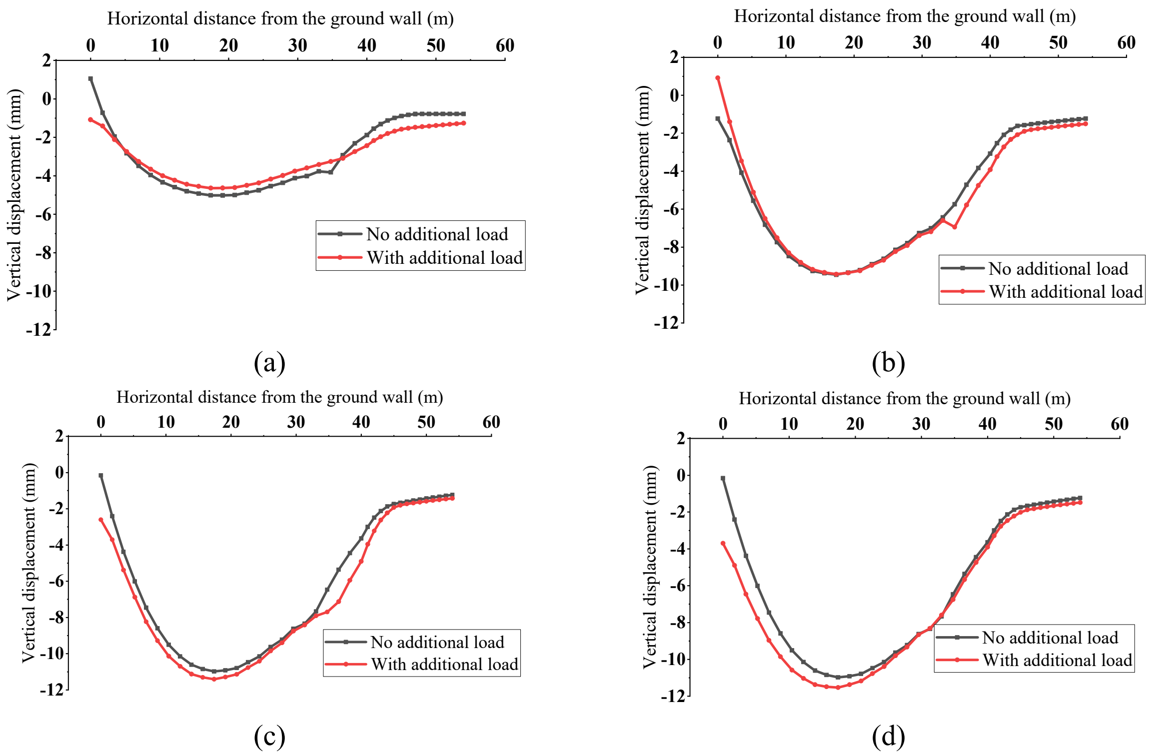


Figure 7. Settlement changes with and without additional load under various working conditions.

In Figure 7, a, b, c, and dare the comparison diagrams of surface settlement changes under four working conditions. As shown in Figure 7, the surrounding surface settlement curves of the foundation pit during excavation show a "spoon-shaped change", and additional The existence of the load makes the curve of surface settlement larger than the case without additional load. In the case of working condition 1, the maximum effect of no additional load is increased by about 7.5%, and in the case of working condition 2, it is increased by about 2.1%; In the case of an increase of about 4.5%; in the case of working condition 4, an increase of about 5.0%, and the maximum displacement is concentrated at a distance of 20m from the foundation pit (that is, 0.5 times of the excavation depth of the foundation pit). The erection of the support can restrain the deformation of the retaining structure to a certain extent and affect the deformation of the soil behind the wall, but with the deepening of the excavation of the foundation pit, the gap between the two continues to increase.

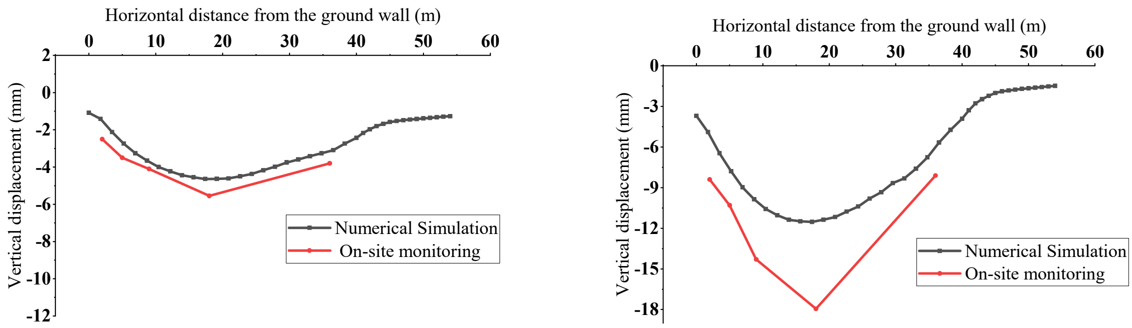


Figure 8. Comparison of simulated value and actual value.

Figure 8 shows the comparison between the simulated value and the actual value under Working Condition 1 and Working Condition 4. As shown in Figure 8, the monitoring value of the scene is larger than that due to the situation of the scene and the effect of the load is much more complicated than the numerical simulation. However, the deformation laws of the two are very similar. The surface settlement deformation is in a "spoon shape", and the distance between the maximum displacement and the ground wall is half of the excavation depth. With the continuous deepening of the excavation, the gap between the two continues to increase. When the excavation depth reaches a certain value, the numerical analysis is not applicable.

5 conclusion

Based on the existing foundation pit engineering examples, this paper analyzes the surrounding ground settlement during the excavation of deep foundation pits and the influence of additional loads on the first layer support through numerical simulation and on-site monitoring, and the following conclusions are obtained:

(1) With the continuous excavation of the foundation pit, the surrounding surface will be subsided to a certain extent. When the retaining structure is good, the subsidence curve is generally "spoon shaped". With the increasing distance from the foundation pit, the surface subsidence curve increases first and then decreases. The distance between the location of the maximum surface settlement and the foundation pit is generally half of the maximum excavation depth of the foundation pit.

(2) The effect of the additional load will have a certain impact on the change of ground settlement. The maximum change of the additional load is 5.95mm without the additional load, and the maximum change of the additional load is set to 6.89mm. The additional load can be seen by the time. The existence of, accelerates the rate of change of surface settlement, making the soil settlement from the excavation of the first layer of soil as a whole smaller than the unacted additional load to the excavation to the bottom layer as a whole larger than the unapplied load.

(3) There will be a certain gap between the numerical simulation and the actual monitoring value. This is caused by the incomplete consideration and application of the numerical simulation of the complex situation at the site. This gap will become larger and larger as the excavation of the foundation pit continues. But the law of change between the two is the same.

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