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The Influence of Crack Leakage on the Stability of Foundation Pit and the Analysis of Reinforcement Effect of Grouting

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Abstract

In order to study the influence of water leakage on the stability of foundation pit during excavation, a numerical model was established based on the foundation pit project of Furong East Station of Xi'an Metro Line 8 with the help of three-dimensional finite element software, and the influence of water leakage at different positions of foundation pit on the lateral displacement of the envelope structure, surface settlement and bottom uplift was analyzed. The results show that with the increase of the distance between the crack location and the groundwater level, the lateral displacement of the enclosure structure increases gradually, and the maximum lateral displacement is located near the crack, and the surface settlement also increases gradually, and the maximum surface settlement is near the edge of the foundation pit. After plugging the leakage point by grouting, the dynamic hydraulic action in the formation is weakened, the lateral displacement and surface settlement of the envelope are reduced, but the uplift of the foundation pit bottom is increased.

Keywords

Foundation pit; Water leakage; Envelope structure; Surface settlement; Bottom uplift.

1. INTRODUCTION

In the process of foundation pit dewatering, excavation and support, due to improper construction operation, construction disturbance, groundwater and other factors, local leakage of the enclosure structure may occur[1-2]. If the treatment is not timely or improper, it may lead to excessive deformation of the foundation pit enclosure structure and difficult to control the surface settlement, which will lead to large-scale collapse of the foundation pit, causing casualties and huge economic losses[3-4]. Therefore, it is of great significance to study the influence of water leakage on the stability of foundation pit during excavation.

Juncheng Liu, Erxiao Sun, Zhuo Shang et al.[5-8] used three-dimensional finite element method to analyze the influence of foundation pit seepage on the displacement of envelope structure, surface settlement and uplift of pit bottom. Dongdong Fan et al.[9] summarized the causes of foundation pit leakage by analyzing the monitoring data of the foundation pit leakage section and the design of the enclosure structure based on the example of a deep foundation pit leakage accident in Nantong subway. Fan Huang et al.[10] used MIDAS/GTS numerical software to establish a three-dimensional foundation pit model, and analyzed the influence of whether the foundation pit envelope contains leakage defects and the size and location of the defects on the seepage path, pore water pressure and leakage of the foundation pit. Chaochao Yu[11] established a numerical model considering the seepage condition of the foundation pit wall with the finite element method, and analyzed the influence of soil parameters and wall insertion depth on the deformation of the surrounding soil and the enclosure structure.

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Based on this, 3D finite element software is used to establish a numerical model based on the actual project, and the influence of different leakage points of the enclosure structure on the lateral displacement, surface settlement and pit bottom uplift before and after reinforcement is analyzed, in order to provide reference for similar projects in the future.

2. MODEL BUILDING

2.1. Project Profile

Xi 'an Metro Line 8 is the main skeleton line of Xi 'an urban rapid rail transit network, and it is the only loop line in the line network. Furong East Road Station is an underground three-story island station with a length of 192.28m, a width of 23m in the standard section, a depth of 26.14m in the floor and a thickness of 3.20m in the soil cover. Through engineering investigation, the foundation soil of each layer of the project consists of: mixed fill, plain fill, new loess (on the water), paleosols, old loess (on the water), old loess (underwater, soft), old loess (underwater), paleosols (underwater) in sequence from top to bottom. The floor depth of the main structure of Furong East Road subway Station is about 26.14m, and the maximum depth is 29.15m. The main structure is mainly distributed from the mixed soil layer to the first ancient soil layer. During the preliminary exploration, drilling revealed that the buried depth of the stable water level of the underground diving in the East Furong Road subway station site was between 17.90 and 19.60m, and the corresponding elevation was 455.18 and 458.71m. During the detailed survey, drilling revealed that the buried depth of the stable underwater water level in the interior of the site was 17.70 ~ 20.30m, and the corresponding elevation was 455.18 ~ 457.00m. The main structure of the subway station was about 5.8~12.5m below the underground water surface, and the formation permeability coefficient was 3m/d.

2.2. Model Building

According to the engineering survey results, the subsoil of each layer of the project is simplified, and the sequence from top to bottom is divided into plain fill, new loess (on the water), old loess (on the water), old loess (underwater, soft), old loess (underwater), and paleosol (underwater), the three-dimensional numerical model established by this method is shown in Figure 1. The model size is 60m (length) ×20m (width) ×50m (height), the station width is 16m, the depth is 25m, the envelope structure is inserted 9m below the station floor, the groundwater level is 18m below the surface, and the crack is simulated according to the actual size, and the width is set at 5cm. Horizontal constraints are applied around the model and three directional constraints are applied at the bottom. Each layer of soil is regarded as an ideal elastoplastic body, which conforms to the Mohr-Coulomb criterion. The initial stress field of formation only considers the gravity stress.

2.3. Parameter Selection

According to the geological exploration report combined with laboratory tests, the physical and mechanical parameters of each soil layer in this model are shown in Table 1 below:

In the model, the envelope structure adopts solid unit simulation, and the steel support adopts beam unit simulation. The parameters and characteristics of the above materials are shown in Table 2 below:

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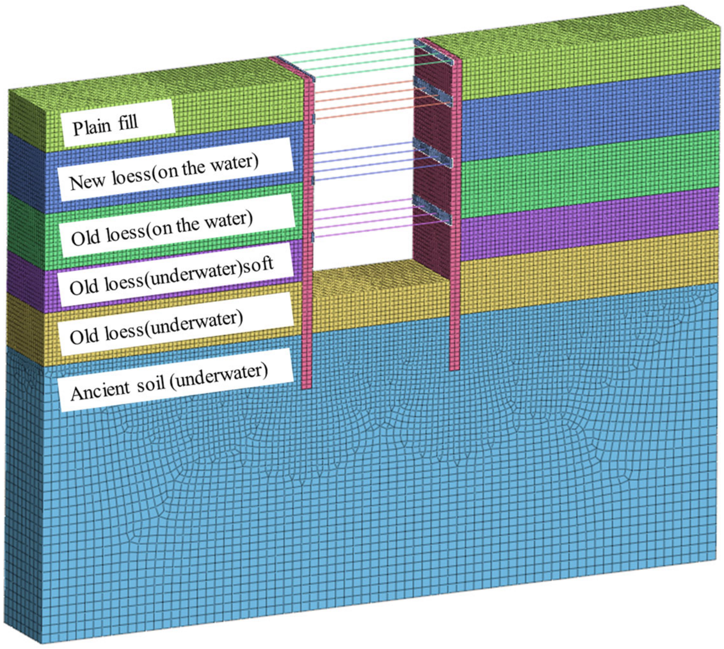

Figure 1. Three-dimensional numerical model

Table 1. Physical and mechanical parameters of soil layer

Soil layer	Thickness /m	Modulus of compression /MPa	Poisson's ratio	Soil natural density g/cm3	Void ratio	Cohesive force /kPa	Frictional angle /°
Plain fill	4.7	5.0	0.35	1.26	1.16	10.0	10.0
New loess (on the water)	6.9	10.3	0.28	1.35	1.04	23.0	20.0
Old loess (on the water)	6.4	12.4	0.29	1.42	0.93	23.0	21.0
Old loess (under water, soft)	4.8	6.57	0.33	1.46	0.90	36.0	20.5
Old loess (under water)	6.0	7.1	0.30	1.57	0.73	39.0	20.0
Ancient soil(under water)	31.2	7.4	0.30	1.59	0.72	41.0	20.0

Table 2. Material characteristics of support structure

Materials	Property	Elasticity modulus /GPa	Poisson's ratio	Volume-weight /kN·m-3
Envelope structure	Solid element	20.3	0.25	25.5
Steel support	Beam element	206	0.20	78.5

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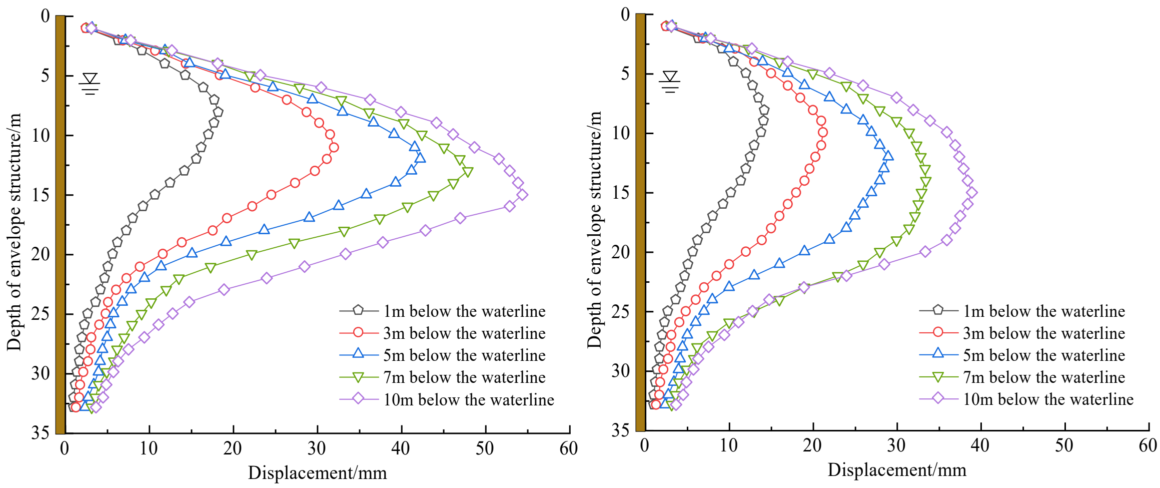
3. ANALYSIS OF SIMULATION RESULT

3.1. Displacement of envelope structure

The influence of water leakage from cracks at different positions of the envelope structure before and after reinforcement on its own lateral displacement is shown in Figure 2. It can be seen from the figure that with the increase of the distance between the crack and the groundwater level, the lateral displacement of the envelope structure also increases gradually. When the distance between the crack and the groundwater level increases from 1m to 10m, the maximum lateral displacement of the envelope structure increases significantly from 18mm to 55mm, and the maximum lateral displacement is all located at the leak of the crack. This is mainly because the greater the distance between the two, the corresponding pressure head also increases, more groundwater flows to the crack of the envelope structure, and the velocity increases. The effect of groundwater on the enclosure structure is more obvious. After the crack is reinforced and sealed by grouting method, the lateral displacement of the enclosure structure decreases obviously, which indicates that the grouting reinforcement has a certain effect on controlling the displacement of the enclosure structure.



(a)Before reforcement (b)After reforcement

Figure 2. Lateral displacement of envelope structure before and after reforcement

3.2. Ground surface settlement

The influence of water leakage from cracks at different positions of the envelope structure on the ground settlement around the foundation pit and the comparison before and after reinforcement are shown in Figure 3. As can be seen from the figure, the greater the distance between the crack and the groundwater level, the greater the surface settlement, and the maximum surface settlement is near the edge of the foundation pit. When the distance between the crack and the groundwater level increases from 1m to 10m, the maximum surface settlement increases from 30mm to 38mm. After cracks appear in the envelope structure, the surrounding groundwater flows to the crack, but the groundwater flow is blocked at other locations of the envelope structure, which will form a large vertical permeability near the edge of the foundation pit, resulting in a large surface settlement. After the crack is sealed, its permeability coefficient is reduced, and the influence of groundwater seepage on the formation is reduced, so the surface settlement is reduced.

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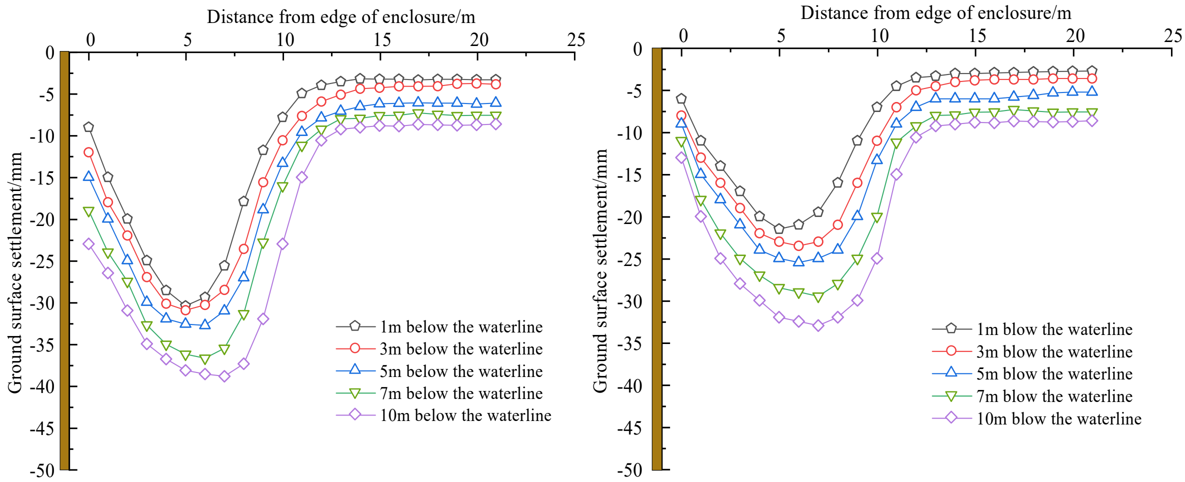
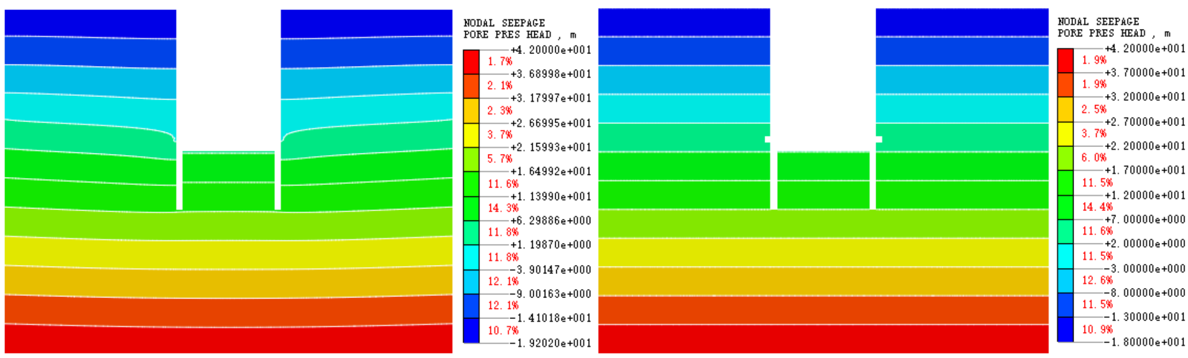


(a)Before reforcement (b) After reforcement

Figure 3. Ground surface settlement before and after reinforcement

3.3. Pore pressure head

The pore pressure water head of the formation before and after reinforcement is shown in Figure 4. Before the fracture reinforcement, the water outside the pit will percolate along the seepage point of the fracture, thus reducing the water level outside the pit and making the formation consolidation and settlement more obvious. After reinforcement, the permeability coefficient at the fracture is reduced, which weakens the action of dynamic hydraulic power and reduces the influence of groundwater on the formation.



(a)Before reforcement (b) After reforcement

Figure 4. Pore pressure water head before and after reinforcement

3.4. The uplift of foundation pit bottom

The uplift of foundation pit bottom before and after crack reinforcement is shown in Figure 5. It can be seen from the figure that before the reinforcement of cracks, due to the difference of water level inside and outside the foundation pit, groundwater will flow to the bottom of the foundation pit and the crack, and the maximum uplift of the bottom of the pit is 23mm. After the reinforcement, the permeability coefficient at the crack decreases, and more groundwater flows along the envelope to the bottom of the pit, resulting in upward permeability of the soil at the bottom of the pit, resulting in greater uplift.

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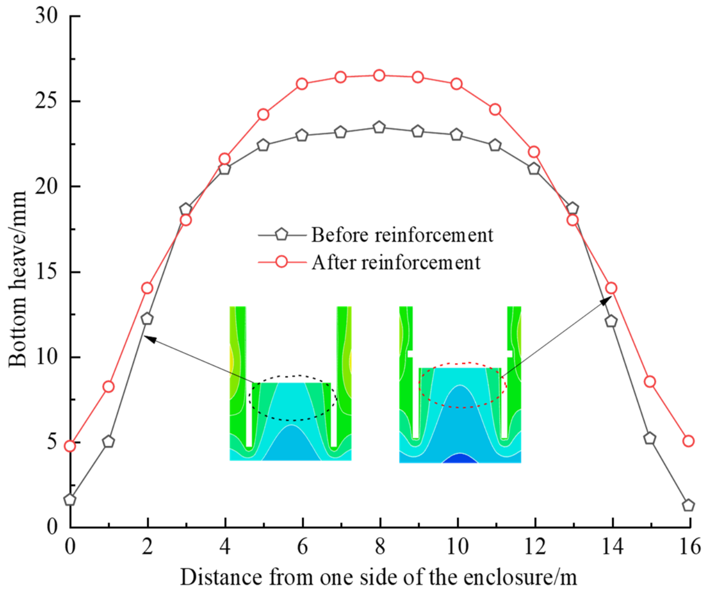

Figure 5. The uplift of foundation pit bottom before and after reinforcement

4. CONCLUSION

(1) The further the distance between the crack and the groundwater level, the greater the influence of groundwater seepage on the lateral displacement and surface settlement of the envelope structure, and the maximum lateral displacement of the envelope structure is located near the crack, and the maximum surface settlement is located near the edge of the foundation pit. After grouting reinforcement of the crack, the lateral displacement and surface settlement of the envelope structure can be significantly reduced.

(2) After grouting reinforcement of cracks where water leakage occurs, the permeability coefficient at the cracks decreases and the dynamic hydraulic action in the formation is weakened, but more groundwater will flow to the bottom of the foundation pit, resulting in greater upward permeability at the bottom of the pit, and greater uplift will be generated compared with that before the reinforcement of the cracks.

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