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Study on Passive Soil Arching Effect in Front of Cantilever Pile Based on FLAC^{3D}

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Abstract

Based on FLAC^{3D} finite difference soft armor, the arching effect of passive soil arching in front of cantilever pile was studied, and the influence of the change of pile depth direction and the soil strength of different embedded sections on the passive soil arching effect in front of pile was analyzed.The results show that the passive soil arching effect can occur in the soil of two adjacent piles, and it decreases along the depth of the pile. However, when the strength of the embedded soil is small, the pile displacement is too large, and the passive soil arching effect cannot occur in the surface soil, but can occur in the deeper soil.

Keywords

Cantilever pile; FLAC^{3D}; Passive soil arching effect; Strength of soil in fixed section.

1. INTRODUCTION

As a kind of horizontal load-bearing pile, cantilever pile plays a vital role in the field of disaster control and engineering construction because of its advantages such as clear force, strong retaining ability, land saving and simple construction. It is one of the main forms of slope support. As a kind of horizontal load-bearing pile, cantilever pile mainly transfers the earth pressure behind the pile to the soil in the fixed section through the pile body, so as to achieve the supporting effect. Therefore, the interaction between pile and soil has always been a hot topic in the research of cantilever pile. Under the action of horizontal load, soil arching effect will occur due to the relative displacement due to the great difference of stiffness between pile and soil. The phenomenon of soil arching was first discovered by Terzaghi [1] through trapdoor test. Ladanyi B and Wang WL [2-3] etc. verified the existence of soil arching effect through theoretical calculation and experimental methods.

Many scholars have conducted in-depth studies on the role of soil arching effect in cantilever pile. Ye Xiaoming [4-5] etc. studied the relationship between soil pressure on the baffle between cantilever piles and soil arching effect, and based on this, obtained the earth pressure on the baffle between piles and proposed the calculation formula of unloaded arch method. Li Xinzhe etc.[6] studied the existence of vertical arches between cantilever piles and reasonable pile spacing, and concluded that the arch of vertical arches is catenary, the arch span of vertical arches increases with the increase of soil cohesion and internal friction Angle, and the change of arch height decreases with the increase of soil load between piles. Lin Bin and Lin Zhihang etc. [7-8] studied reasonable pile spacing according to soil arching effect behind and around piles. Most of the research on soil arching effect of cantilever piles focuses on the soil arching effect generated behind the piles. In this paper, the soil arching effect of the soil embedded in front of the cantilever piles supporting structure of a backfill subgrade is studied by FLAC3D.

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2. MODEL ESTABLISHMENT

2.1. Basic Assumptions

1) Considering plane strain, the numerical simulation model is shown in Figure 1.Size for length x width x height = 40m×35m×24m cantilever pile retaining structure of cantilever section 14 m high, the constraints of the model: in the x axis displacement in x is equal to 0 m and x is equal to 40 m, fixed constraint in the y direction, the displacement in the y equals 0 m and y equals 24 m for fixed constraint, only the bottom displacement in the z axis direction constraints in z is equal to -35 m, top of freedom.

2) In this paper, the Mohr-Coulomb model in the plastic model group is adopted for the soil element model, and the Elastic model is adopted for the pile and baffle element models.

3) Contact surfaces are set between pile and soil and pile and baffle, as shown in Figure 2.

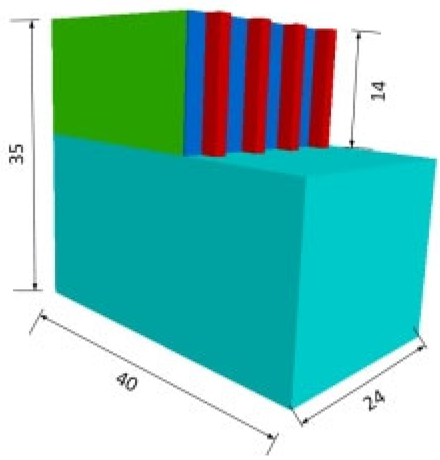

Figure 1. Cantilever pile

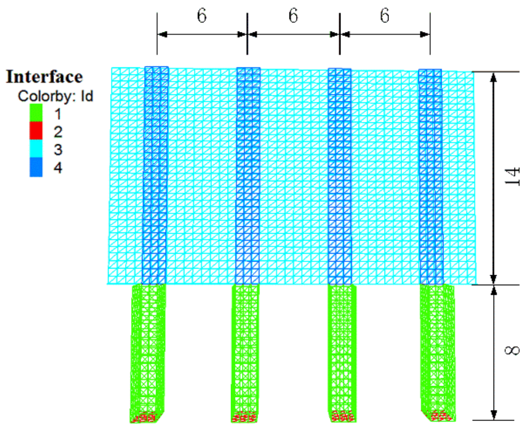

Figure 2. Contact surfaces

2.2. Parameter Selection

1) Soil parameters

Physical and mechanical parameters of soil within the calculation range of this model are shown in Table 1, and parameters of contact surface are shown in Figure 2.

Table 1. Physical and mechanical parameters of soil layer

Name of the soil	Thick (m)	Severe γ (kN/m³)	Cohesive force c (kPa)	Angle of internal friction φ (°)
Backfill soil	14	19.5	18	28
The soil in the fixed section	21	22	80	23

Table 2. Parameters of the interface

Contact number	k_n/Pa	k_s/Pa	c/kPa	φ/°
Interface 1	1.5×109	0.5×107	30	20
Interface 2	1.5×109	0.5×107	30	20
Interface 3	0.7×108	1.0×107	10	10
Interface 4	5×109	5×109	30	20

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2) Concrete parameter

The pile body and the baffle between piles are made of C35 concrete, with elastic modulus E=3.15×10^4Mpa, Poisson's ratio μ=0.2.

3. COMPARATIVE ANALYSIS OF SIMULATION RESULTS

3.1. Reverse Variation Law of Passive Soil Arch Along Depth

In this excerpt, the variation of passive soil arching effect in front of piles with depth is studied by taking the soil parameters in Table 1 and taking the stress σx in the x direction (horizontal direction) of the symmetrical line between the center of two piles. Figure. 3 is the stress nephogram of horizontal stress σx of the soil at a depth of 0~3m in front of the embedded surface. It can be clearly seen from the figure that there are obvious stress arches at the embedded surface and 1m below the embedded surface, and the stress arches at 2m and 3m below the embedded surface are weakened. At the same time, it can be seen from Figure 3 that the compressive stress of soil in front of piles radiates outward fan-shaped from the starting point in front of piles, forming a stress arch at the intersection of horizontal fan-shaped radiation areas of the two piles. A simplified diagram of passive soil arch in front of piles is shown in Figure 4.

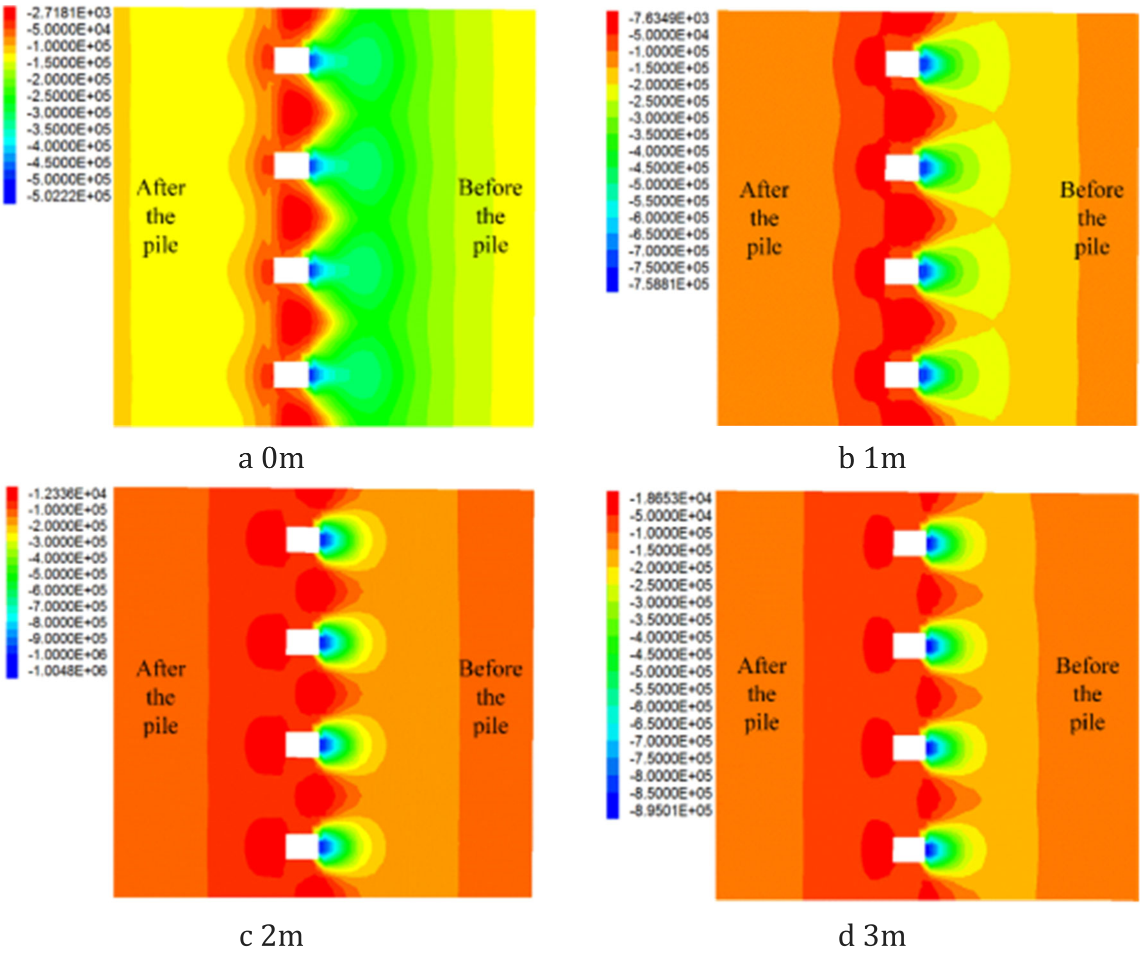

Figure 3. Sigma x stress nephogram at different depths below the embedded surface

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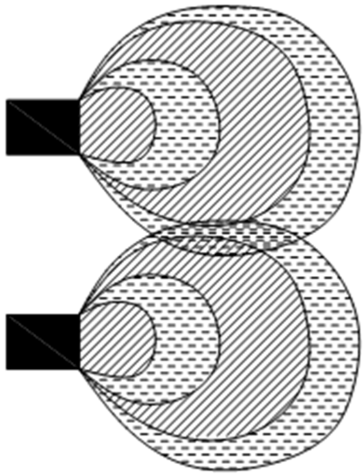

Figure 4. Diagram of passive soil arch in front of pile

Figure. 5 shows the horizontal displacement of the pile body of the fixed segment. The horizontal displacement of the turn of 0~3m below the fixed surface is 12.45mm, 9.3mm, 6.6mm and 4.3mm respectively.Figure 6 for pile former passive soil arch effect in the change at different depth of the curve, the figure 6 shows that the pile before passive soil arch effect in 0 ~ 2 m depth, in 2 m of the horizontal stress of soil before pile flatten out, combined with five horizontal displacement of pile body, the horizontal displacement of pile in 4.3 mm, the soil arch effect no longer obvious, with a gradual increase in the pile body displacement, passive earth arch is more and more obvious.Moreover, with the increase of depth, the maximum value of passive soil arch in front of pile gradually moves towards the pile body.

Combined with the pre-pile stress and stress radiation diagram shown in Figure. 4, it can be concluded that when the horizontal displacement of the pile is small, the horizontal stress of the soil in front of the pile is small, the range of stress radiation is small, and the stress zone between the two piles does not overlap.As the horizontal displacement of the pile increases, the horizontal stress of the soil in front of the pile gradually increases, and the range of stress radiation becomes larger. As the stress area between the two piles overlaps, the passive soil arching effect occurs and increases with the increase of the displacement.

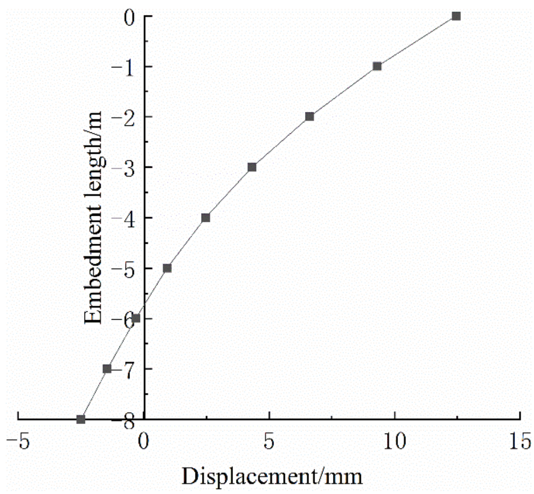

Figure 5. Horizontal displacement curve of fixed pile body

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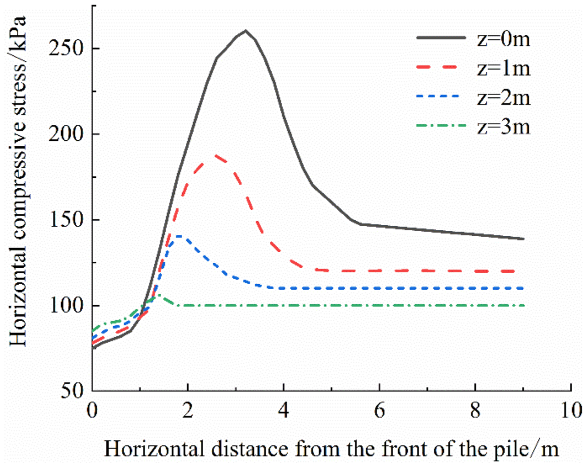

Figure 6. Horizontal variation trend of passive soil arching effect at different depths

3.2. Effect of Soil Strength on Passive Soil Arching in Front of Pile

Due to the complex and changeable site conditions, different geological conditions will inevitably be encountered in the actual project.Based on the soil parameters in the embedded section in Table 1, this section increases and decreases the soil in the embedded section respectively to study the influence of soil strength in different embedded sections on the passive soil arch in front of the pile. The specific parameters are shown in Table 3.

Table 3. Rock and soil physical and mechanical parameters

Type of soil	Thickness (m)	Unit weight (KN/m³)	Cohesion (kPa)	Internal fricti angle(°)
Type 1 of soil mass in fixed section	21	22	80	20.5
Type 2 of soil mass in fixed section	21	22	120	22.5
Type 3 of soil mass in fixed section	21	22	160	24.5

Figure 7 shows the horizontal displacement curves of cantilever piles in the soil of different embedded sections. It can be seen from the figure that the pile displacement decreases with the increase of the soil strength of embedded sections, and the displacement of piles in the soil of three embedded sections is 30mm, 12.45mm and 6.52mm, respectively.

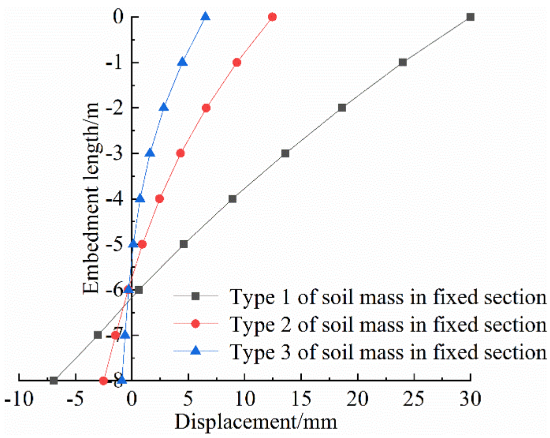

Figure 7. Horizontal displacement of piles in different embedded sections

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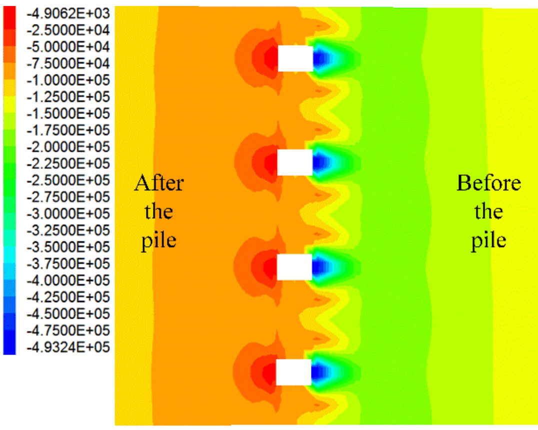
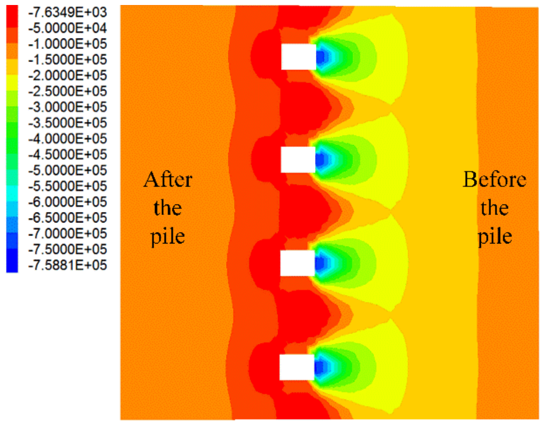
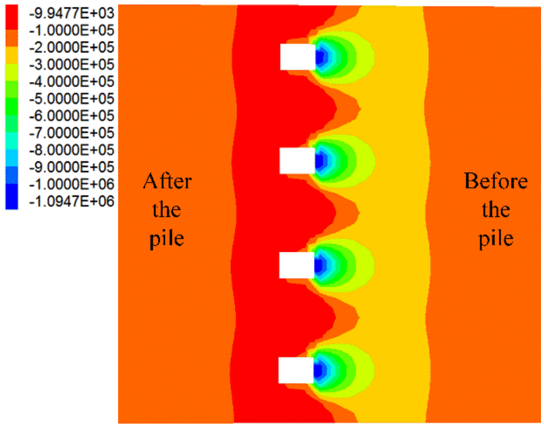
Figure 8 shows the horizontal stress nephogram of soils in different embedded sections in front of piles at 1m below the embedded surface. In combination with Figure 7, it can be seen that in the soil in the embedded section 1, due to the low strength of the soil in the embedded section, no soil arch was formed at 1m below the embedded surface, while passive soil arch was formed in the soil in the embedded section 2 and 3.This is due to the large displacement of the pile body and the large plastic deformation of the surface soil in the fixed section 1.



a Type 1 of soil mass in fixed section



b Type 2 of soil mass in fixed section

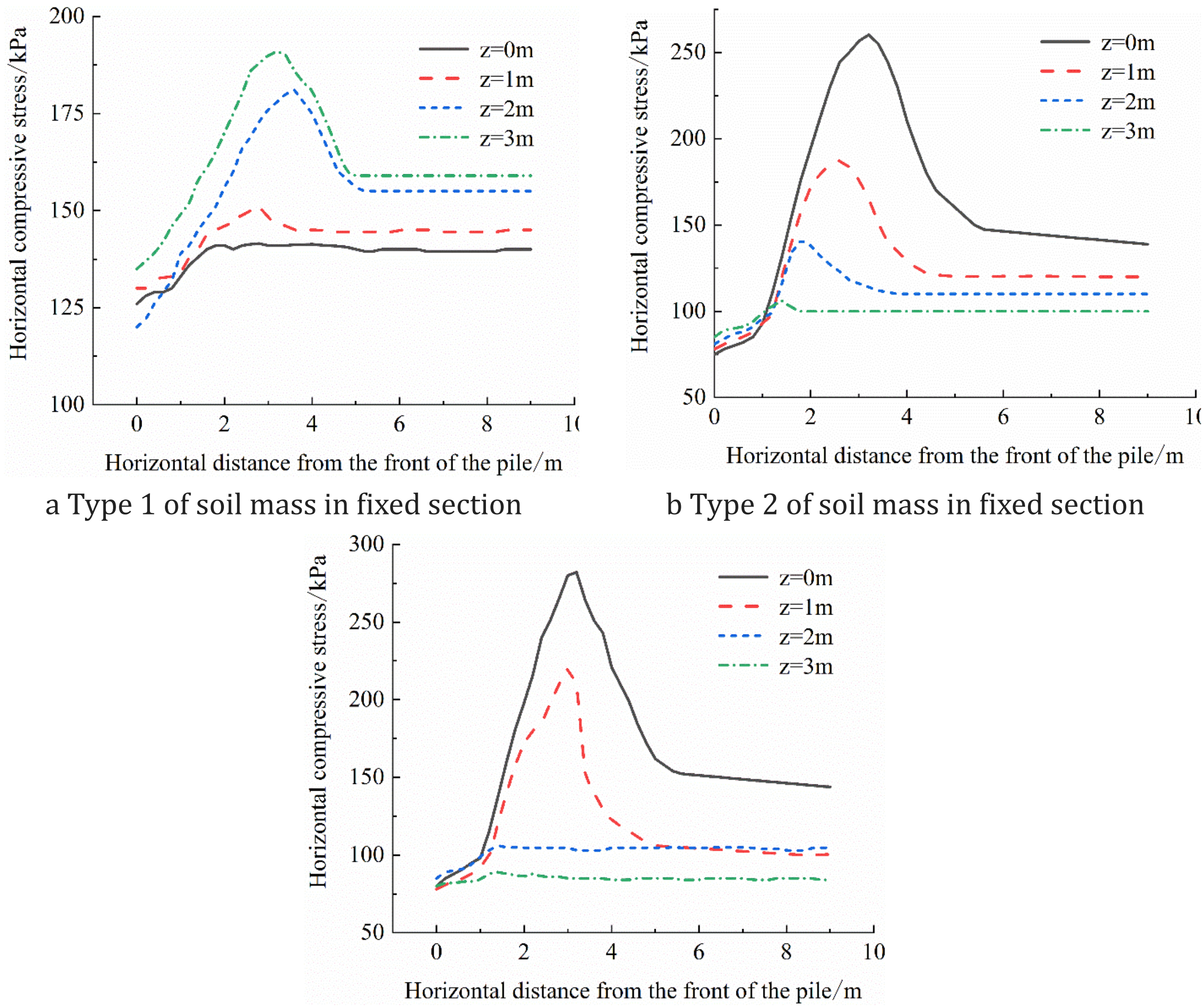


c Type 3 of soil mass in fixed section

Figure 8. Horizontal stress nephogram at 1m depth under the embedded surface of soils in different embedded sections

Figure 9 shows the variation curves of passive soil arching effect in front of piles at different depths. As can be seen from Figure 9, passive soil arching effect in front of piles is not obvious in the depth range of 0~1m, but is obvious in the position of 2m and 3m.In the soil 2 of the embedded section, the passive soil arching effect in front of the pile is obvious in the depth range of 0~2m, and the horizontal stress tends to be gentle at 3m.The passive soil arching effect in front of the pile is obvious in the depth range of 0~1m, and the horizontal stress of the soil in front of the pile tends to be gentle at 2m and 3m.

Combined with 7 and 8, shows that when excessive horizontal displacement of pile, pile the former passive earth arch cannot be formed by plastic deformation of the soil is too large, when the horizontal displacement of pile through the hours, before the pile soil stress zone of intercourse, still unable to form the passive soil arch, visible, pile former passive soil arch is closely related to the horizontal displacement of pile body.



a Type 1 of soil mass in fixed section

b Type 2 of soil mass in fixed section

c Type 3 of soil mass in fixed section

Figure 9. The variation trend of passive soil arching effect in horizontal direction at different depths of soil in different embedded sections

4. CONCLUSION

In this paper, FLAC3D numerical simulation is used to study the passive soil arching effect of cantilever pile in front of fixed section from two aspects: the change of passive soil arching with depth and the soil strength of fixed section. The following conclusions are drawn:

(1) Under the action of earth pressure behind the pile, the cantilever anti-slide pile produces horizontal deflection. As for the parametric compressive stress of the soil in the fixed section in front of the pile, with the increase of displacement, the compressive stress zone of the soil in front of the pile overlaps with the parametric passive soil arch.

(2) When the horizontal displacement of the pile is small, the passive soil arching effect in front of the pile gradually weakens along the depth of the pile until it becomes gentle.

(3) When the horizontal displacement of the pile is large, the surface soil of the fixed section in front of the pile cannot form a passive soil arch due to the excessive deformation of the parameters. Along the direction of the pile depth, the passive soil arch effect occurs with the decrease of the displacement, and the passive soil arch effect disappears with the deepening of the depth.

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