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Study of Numerical Simulation of Dynamic Replacement Soft Soil Foundation Pit

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Abstract

The strength of natural soft soil is low, so there is a problem of stability when the foundation pit is excavated directly in soft soil, and the replacement of dynamic compaction can improve the strength of soft soil. Through numerical simulation, the effect of dynamic replacement on the horizontal displacement of soft soil foundation pit is studied. The results show that the maximum horizontal displacement of slope is located at 1/2 of the excavation depth of slope surface rather than the top Angle, and the internal horizontal displacement of slope body decreases in a divergent gradient from the maximum displacement of slope surface to the slope body. After dynamic compaction displacement treatment of soft soil, the horizontal displacement in the excavation process can be reduced. The research results of this paper can provide reference for the design and construction of foundation pit engineering in areas with wide distribution of soft soil and large thickness.

Keywords

Soft soil; Pit; Dynamic replacement method; Numerical simulation.

1. INTRODUCTION

In recent years, the construction scale of coastal cities is constantly expanding, and the demand for land is increasing day by day.Soft soil in coastal areas is characterized by high natural moisture content, large pore ratio, high compressibility, high sensitivity, low strength, poor water permeability and high rheological property. Therefore, many serious problems are faced when foundation pit excavation is carried out in soft soil.

For this reason, many scholars have studied the problems related to foundation pit excavation in soft soil by using numerical simulation test method. Gao Bing analyzed and predicted the creep in the process of excavation of soft soil foundation pit by PLAXIS numerical model based on creep theory. According to the analysis, the soil around the foundation pit will creep and deform in or out of the pit during excavation, which redistributes the soil and increases the possibility of instability [1]. Zhang Yue simulated the excavation process of foundation pit in deep soft soil area with Mohr-Coulomb model through ANSYS finite element software, and concluded that the influence range of surface settlement after deep foundation pit excavation is about 4 times of the excavation depth [2]. The influence range of surface horizontal displacement is about 6 times of the excavation depth, and the supporting force gradually increases with the increase of the depth. Zhou Bin used MIDAS GTS NX finite element software to simulate the excavation and supporting process of soft soil foundation pit, and the simulation results were in good agreement with the actual construction monitoring data [3].

Slope excavation is an economic support scheme for foundation pit slope, but the strength of soft soil is low, so it is impossible to excavate the slope directly in soft soil. Compared with soft soil, the strength of composite reinforcement formed by dynamic compaction replacement treatment is improved [4-7]. At present, only a few scholars have carried out researches on

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dynamic consolidation displacement combined with slope excavation. Yan Xingang theoretically demonstrated the application of dynamic compaction replacement method in soft soil foundation pit support from the perspective of mechanical properties, and believed that this method was applicable to the situation where the strength of unmodified soil was low, the site was open, the underground water level was not high, and there was no important building or municipal pipeline near the foundation pit, etc [8]. Xiong Xinfu carried out slope excavation of soft soil foundation pit replaced by dynamic compaction combined with pillar hammer, medium hammer and flat hammer in practical engineering, and found that slope stability and no crack could be maintained if excavated at a 1:0.5 slope [9].

In this paper, a three-dimensional finite element numerical model is established to study the effect of dynamic tamping displacement on horizontal displacement of soft soil foundation pit.

2. STUDY OF NUMERICAL SIMULATION

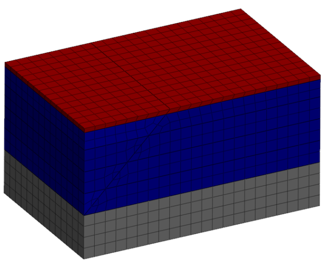
2.1. Soil Hardening Model and Parameter Selection

2.1.1 Sub-section Headings

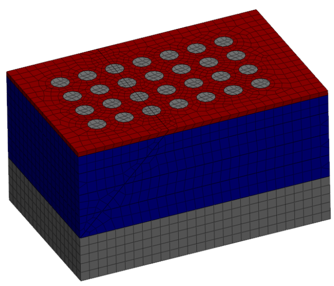
The modified Cam-clay model is an elastoplastic model of normally consolidated or over consolidated saturated Clay, which adopts the cap yield surface and the corresponding flow criterion, and takes the plastic volume strain as the hardening parameter [10-12]. The modified Cambridge model has different energy equations with the Cambridge model, but the model parameters are the same [13]. There are three model parameters: the slope M of the critical state line, the slope λ of the normal consolidation line, and the slope k of the rebound line, which are measured by the consolidation undrained triaxial shear test (CU test) and the anisotropic isopressure consolidation test. In the numerical simulation, the modified Cambridge model is adopted for the soft soil model. The Mohr-Coulomb model is used for plain fill, broken stone pier and completely weathered rock.

2.2. Finite Element Numerical Model

According to the parameters in Table 1 [14-16], a three-dimensional finite element numerical model was established to simulate the excavation process of silty clay replaced by dynamic compaction, as shown in Figure.1. Model length×width×height =11m×7m×6m, and the shape of the pier was obtained through laboratory tests and idealized [17], as shown in Figure. 2.The pier spacing is 1.2m, and the displacement rate of dynamic tamping is 27.5%.The excavation slope ratio of foundation pit is 1:1, the excavation depth is 4m, and the excavation depth of each layer is 1m.In order to improve the accuracy of calculation, the hybrid mesh (hexahedral mesh and tetrahedral mesh combination) was used to divide the soil and pier. In this paper, the foundation pit excavation is simulated before and after dynamic compaction displacement, but the dynamic displacement process of dynamic compaction displacement is not studied. After dynamic tamping replacement, the strength parameters of soil between piers are increased to 1.5 times of those without replacement [18-20].



a) Before dynamic replacement



b) After dynamic replacement

Figure 1. Foundation pit model entirety

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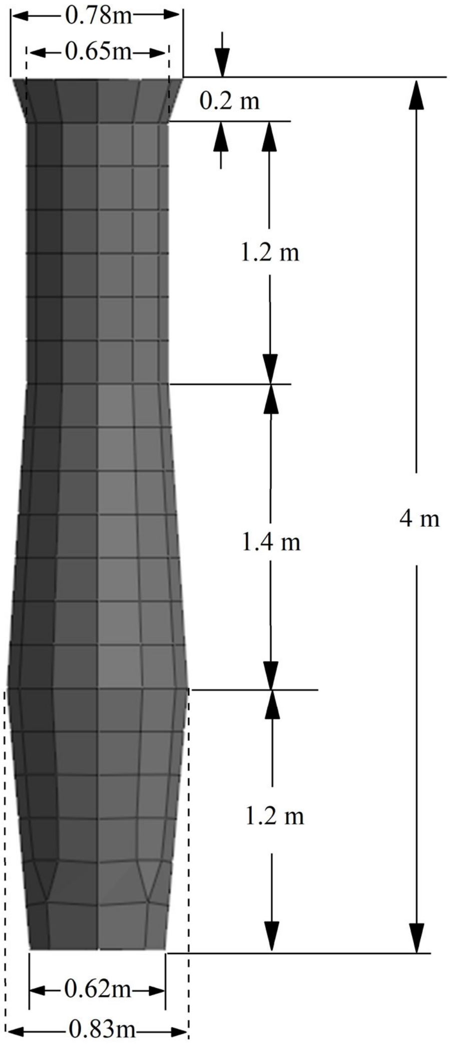

Figure 2. Model piers

Table 1. Soil of parameters

	Symbol	Plain fill	Fully weathered rock	Crushed stone	Silty silty clay
Model type	—	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Modified Cam-Clay
Thickness degree (m)	D	0.2	4	4	3.8
Unit weight(kN/m3)	γ	18.2	21.5	22.0	17.9
Poisson's ration	M	0.35	0.30	0.30	0.32
elastic modulus (MPa)	E	15.0	60.0	20.0	32.0
Coefficient of permeability(m/s)	kx*ky*kz	1.0*10-3	4.2*10-2	1.2*10-3	1.0*10-6
effective angle of internal friction(°)	φ'	10.0	40.0	38.0	—
effective cohesion(kPa)	c'	12.0	35.0	2.0	—
Overconsolidatio-n ratio	OCR	1.0	1.0	1.0	1.0
The slope of the critical state line	M	—	—	—	1.657
Compressed parameters	λ	—	—	—	0.132
The springback parameters	k	—	—	—	0.048

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3. RESULTS AND DISCUSSION

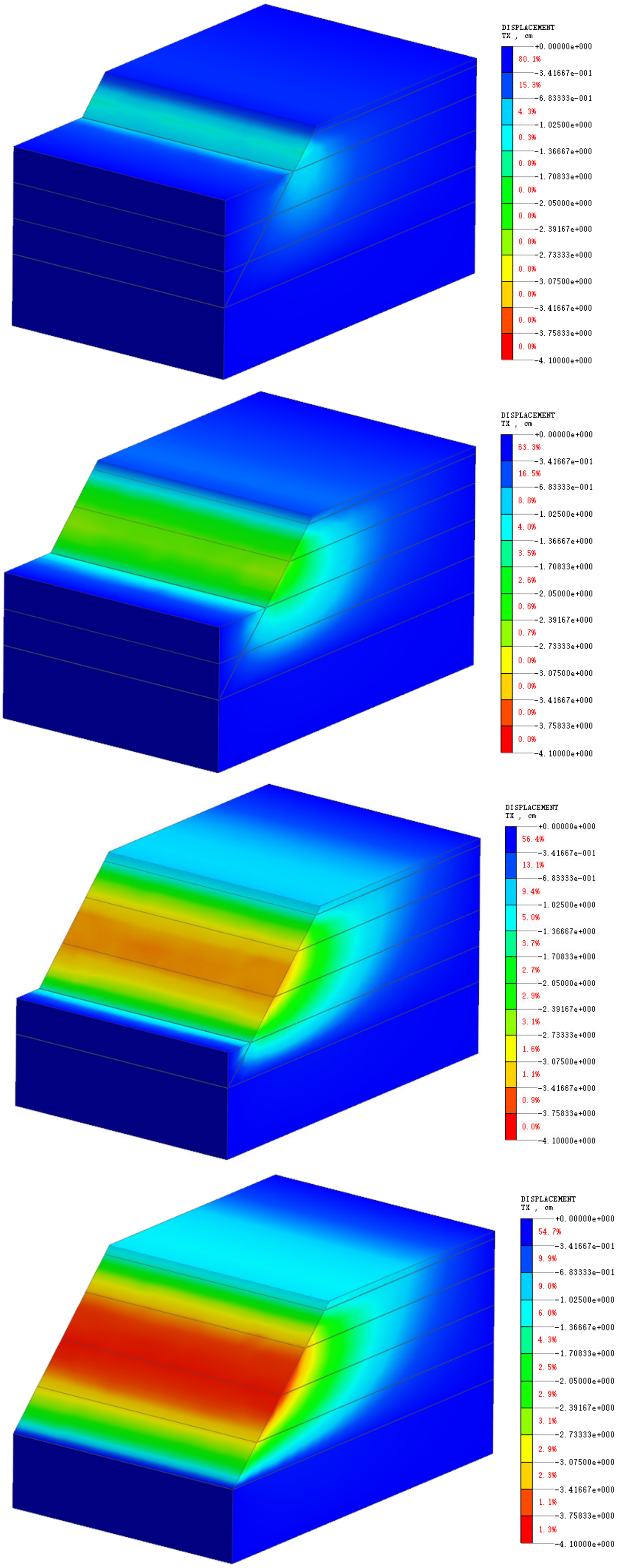

Figure 3. Horizontal displacement cloud of foundation pit excavation with replacement rate of 0% and slope rate of 1:1

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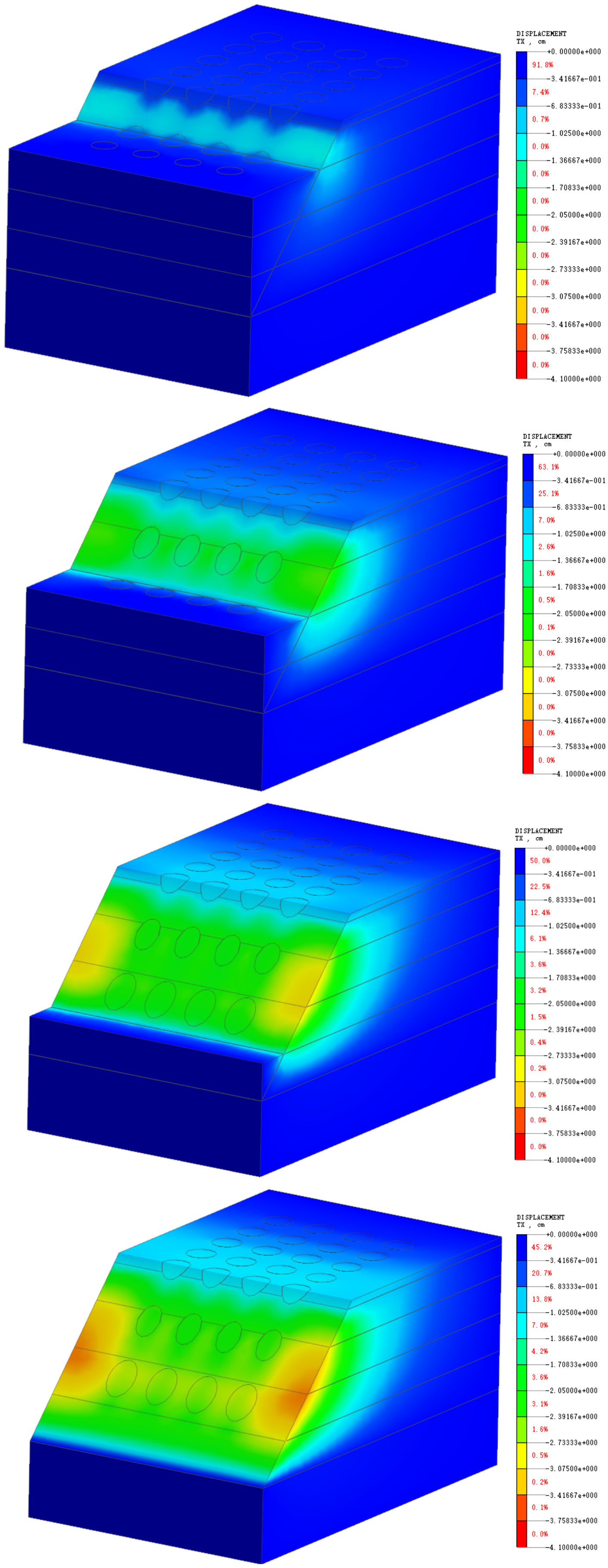

Figure 4. Horizontal displacement cloud of foundation pit excavation with replacement rate of 27.5% and slope rate of 1:1

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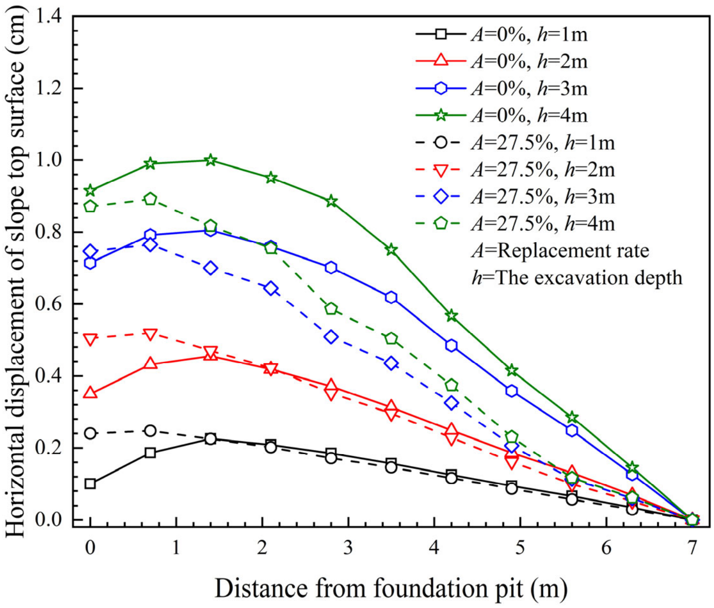

Figure 5. Horizontal displacement of foundation pit top surface

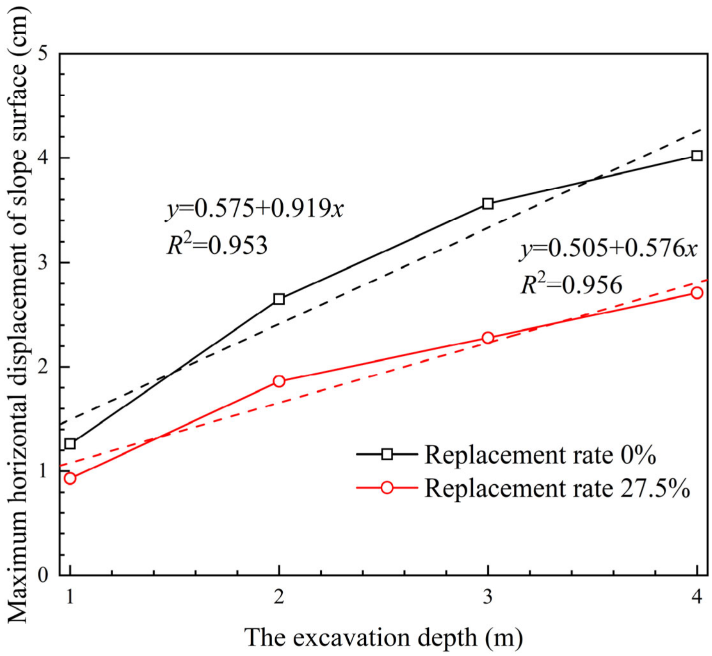

Figure 6. Maximum horizontal displacement of slope surface

In Figure 3 and Figure 4, after excavation of foundation pit, the maximum horizontal displacement point is not located at the top Angle or foot of the foundation pit, but at 1/2 excavation depth of the slope surface. I n Figure 5, the horizontal displacement of the top surface of the slope decreases with the increase of the distance from the foundation pit, indicating that the excavation of the foundation pit has an impact on the soil within a certain distance from the foundation pit. When the depth of the foundation pit is less than 2m, the horizontal displacement at the top Angle of the foundation pit with a displacement rate of 27.5% is greater than that with a displacement rate of 0%. When the distance from the foundation pit is 1.5m, there is no significant difference between the two horizontal displacements. When the excavation depth is greater than 2m, there is a small difference between the horizontal displacement at the top Angle of the foundation pit with a displacement rate of 27.5% and that with a displacement rate of 0%. With the increase of the distance from the foundation pit, the difference between the horizontal displacement and the horizontal displacement increases first

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and then decreases. As can be seen from Figure. 6, during the excavation process, the maximum horizontal displacement of the slope increases with the increase of the excavation depth. Within a certain excavation depth, the maximum horizontal displacement of the slope between piers shows a linear growth relationship with the excavation depth. When the excavation of slope foundation pit is carried out directly in soft soil layer, the maximum horizontal displacement of slope reaches 4cm when the excavation depth is 4m, and the slope body is prone to instability due to its large horizontal displacement. After dynamic tamping replacement treatment of soft soil, crushed stone piers are tamped into soft soil, and the surrounding soft soil is squeezed to form drainage channels at the same time. The strength of soft soil is improved, and the strength of soft soil is enhanced and the composite foundation is formed with crushed stone piers. In the composite foundation, the foundation pit excavation with the same slope rate is carried out, and the maximum horizontal displacement of slope surface is significantly reduced. It shows that dynamic compaction replacement can be used to treat the soft soil foundation when the soft soil is thick and widely distributed, which can not only meet the strength requirements but also save the cost of foundation pit support.

4. CONCLUSION

(1) In the numerical simulation, after the excavation of the foundation pit, the maximum horizontal displacement of the slope surface is located at 1/2 of the excavation depth.

(2) The maximum horizontal displacement of slope increases with the increase of excavation depth, and the relationship between the two increases linearly.

(3) The horizontal displacement of the top surface of the slope decreases with the increase of the distance from the foundation pit, and the excavation of the foundation pit only affects the soil within a certain range.

(4) Dynamic compaction replacement can improve the strength of soft soil and reduce the horizontal displacement of slope surface and top surface after excavation.

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