Study on the Influenced Zones for Deformation of Existing Masonry Buildings Adjacent to the Metro Foundation Pit Kicking in the Soft Soil Area

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Abstract: There is a high risk of metro foundation pit construction in the soft soil area, where foundation pit kicking occurs frequently. In this paper, by using the material point method, the failure modes and mechanism of foundation pit kicking are studied. Parametric study is performed to further analyze the effects of pit excavation depth, location of the adjacent building. As a result, the scope and intensity of the influenced zones are proposed.

Introduction

The foundation pit kicking not only involves the foundation pit's own security, and will lead to uneven settlement and even the failure of the surrounding buildings. The Study on the influenced zones for deformation of existing masonry buildings adjacent to the metro foundation pit kicking in the soft soil area is very meaningful ,especially for some of the old historic buildings.

Due to the large deformation of soils occurs in the metro foundation pit kicking, if the finite element method was applied to bulid the model, the mesh distortion would ultimately lead to the termination of the calculation. To overcome this problem, the material point method was employed in an innovative way, for it can avoid mesh distortion problems and suitably analyze large deformation of the metro foundation pit[1].

In this study, a simplified model of the metro foundation pit kicking is built based on the material point method. Through controlling variables of pit excavation depth and location of adjacent buliding, the effect rules of the metro foundation pit kicking on adjacent buildings in the soft soil area are proposed.

Computing model

In order to achieve precise analysis of the deformation of adjacent buildings, a fine model of the building was shown in Fig.1(a). The building is a typical masonry structure, such as historical buildings. E=220 Mpa, $\mu=0.2$. To simplify the calculation, the length in the y direction is 1m, and the width and height of the building are 12m and 8m respectively. The length of each layer and each truss are both 4m, and the opening size of doors and windows are both 2.0m×2.0m.

For the metro foundation pit is long but narrow, it the can be analyzed by the assumption of plane strain. Considering the symmetry of the model, half the width of foudation pit is suitbly to be analyzed .The simplified model of the metro foundation pit was shown in Fig.1(b). The diaphragm wall is used in the foundation pit supporting, where the length and thickness of diaphragm are 24m and 1m respectively. $E=3\times10^6 N/m^2$, $\mu=0.2$. The lateral bracings are located at -1m、-5m、-9m, of

which the length and thickness are 20m and 1m respectively. E= 3×10^{7}N/m^2.

The horizontal and vertical displacement is constained at the bottom of the model, and the horizontal displacement is constrained at the two sides. Meanwhile, the masonry building and soil are simulated based on the Drucker-Prager model, while the diaphragm wall and the lateral bracing are based on the linear elasticity constitutive model[2]. According to the related inspection report of the soft soil area, the physical and mechanical indexes of soil are shown in Table 1.

The model simulated the practical construction process and then dynamically analyzed the effect of the metro foundation pit kicking on the adjacent buliding, just as follows:

（a）The number of material points and material types are counted.

（b）Background grid is divided, where the mesh size is x (0,80), y (0,1), z (0,60), and the unit is m.

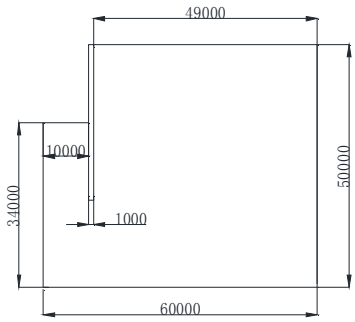
（c）Boundary conditions are constrained.

（d）Physical mechanical parameters are assigned to the diaphragm wall, the lateral bracings, soils and the building.

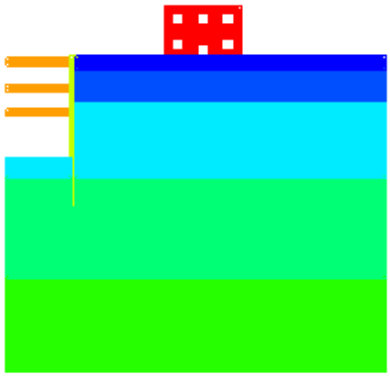
（e）Geometric models of the metro foundation pit and adjacent building are built, and the parameters of pit excavation depth and location of adjacent buliding are controlled to simulate different types of metro foundation pit kicking accidents. For example, when *He* (pit excavation depth) =16m and *d*=15m, the model is shown in Fig.1(c).

（f）Initial stress is balanced.

(a) The model of the masonry building.



(b) The model of the foundation pit.



(c) The basic computing model.

Fig.1 Network diagram of the model.

Table 1. Physical and mechanical parameters of soils[3].

Soils	*h*/m	*ρ*/kg/m3	*c*/kpa	*Φ*/°	*E*/MPa
Filling soil	2	1900	16.2	18.1	30
Clayey silt	5	1900	10.2	31.8	30
Silt clay	12	1710	15.3	13.0	10
Mucky silty clay	16	1710	13.5	13.6	15
Silty clay silt	15	1790	14.4	16.5	60

Parameter analysis

the influence of pit excavation depth

In the model, *d*=15m, the pit excavation depth was varied among 12m,14m,16m,18m,20m and 22m. The equivalent plastic strain is calculated based on the distortion energy theory (the fourth strength theory). This theory consider that when the distortional energy density storaged in unit body (*vd*) is approximation to uniaxial tensile yield distortion energy density (*vds*), the material enters the plastic yield[4]. As shown in Fig.2, with the He increasing, the plastic deformation zone near the bottom of the pit expands, forming a huge shear failure band to the ground when the *He*>20m, which will cause serious damage to the adjacent masonry buildings. Fig.3 displays the variation trend of settlement and differential settlement of the floor, as the *He* increases, the settlement and differential settlement nonlinearly increases. As shown in Fig.4, there is monolithic translation to the side close to the pit and transverse tension strain appears on the first floor, while almost no relative lateral displacement appear on the second floor. When the *He*>14m, the operating condition could be regarded as exceeded excavation.with the *He* increasing, the influenced zone for deformation of existing masonry buildings expands.

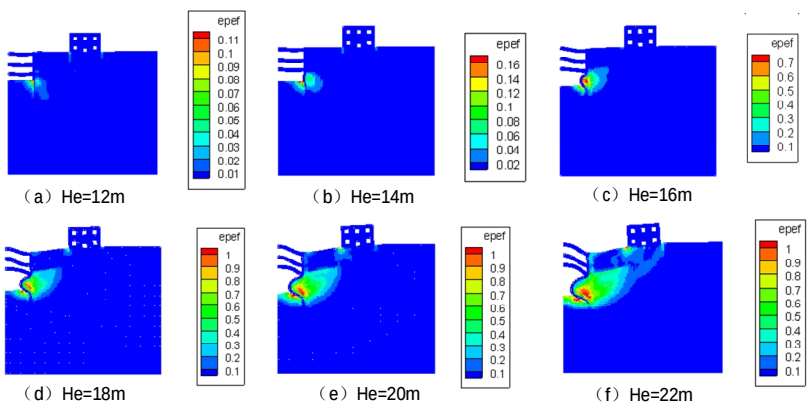


Fig. 2 Equivalent plastic strain cloud diagram under different pit excavation depths.

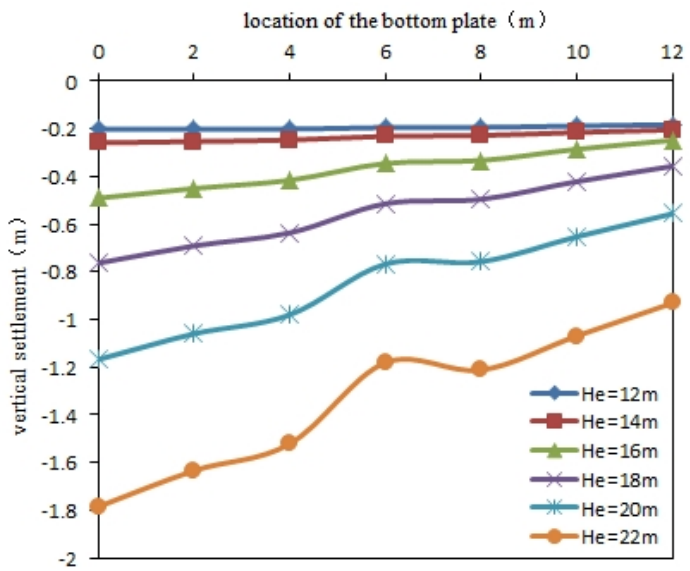


Fig. 3 Vertical settlement of the floor under different pit excavation depths.

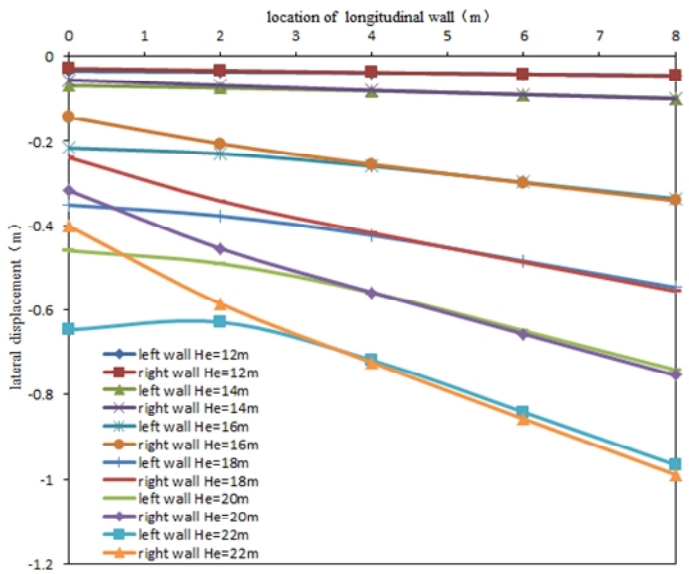


Fig. 4 Lateral displacemen of longitudinal wall under different pit excavation depths.

the influence of location of adjacent buliding

In the model, *He*=16m, the insertion ratio of the diaphragm wall is 0.5, the location of adjacent buliding was varied among 5m,10m,15m,20m,25m and 30m. As shown in Fig.5, with the d decreasing, the settlement and differential settlement nonlinearly increases. According to the code for design of building foundation[5], for the building in the high compressibility of foundation, the local dip limit is 2‰~3‰, thus the limit differential settlement of the buiding is 24mm. As shown in Fig.6, with the d increasing, the transverse tension strain emerges immediately and then decreases gradually. When the *d*=0.5*He*, the tension strain appears the maximum value. When the *d* increases to the 1.5*He*, the tension strain goes away. Thus, the main influenced zones within a range of 1.5*He*.

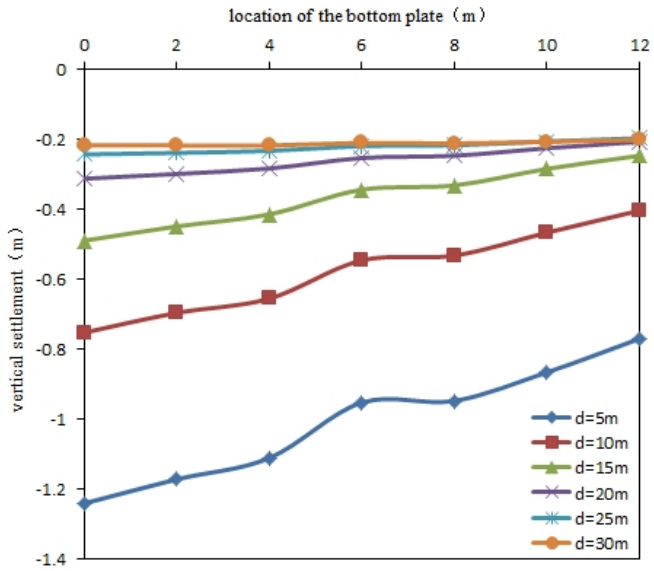


Fig. 5 Vertical settlement of the floor under different location of adjacent buliding.

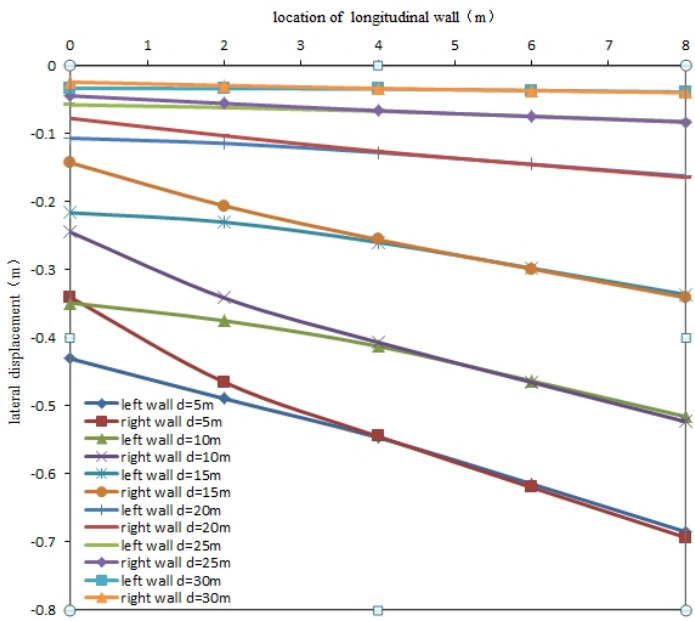


Fig. 6 Lateral displacemen of longitudinal wall under different location of adjacent buliding.

As shown in Fig.7, there is synergistic effect between the settlement of the building itself and the displacement of adjacent soil caused by foudation pit kicking. and the synergistic effect decreases as the *d* incrases[6]. When the *d*=1*He*, the settlement of the building itself virtually has no effect on the displacement of the diaphragm wall.

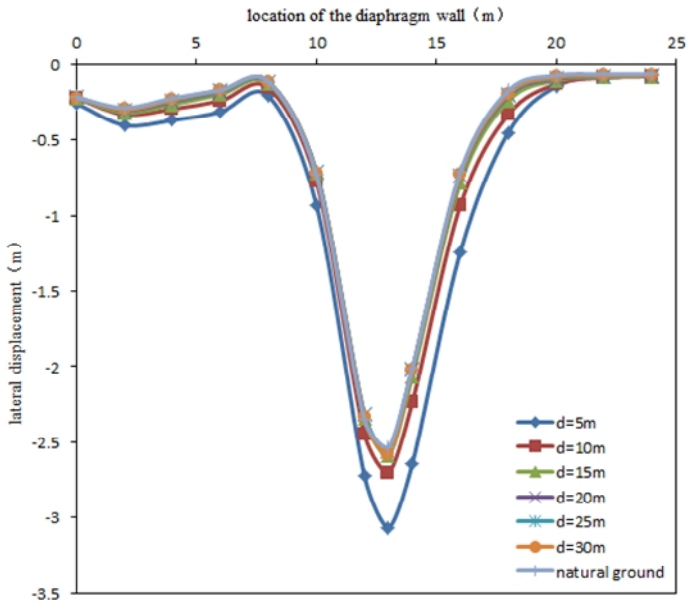


Fig. 7 Lateral displacemen of diaphragm wall.

Conclusions

In conclusion, in a certain foundation pit supporting condition, with the excavation depth increasing, the kick-resistant stability decreases, and the influenced zone for deformation of existing masonry buildings expands. When the pit is exceeded excavation, as the building gets closer to the foudation pit, the deformation caused by the foudation pit kicking is larger, and the main influenced zones within a range of 1.5*He*.

References

[1]Lian,Y.P., Zhang,F., liu,Y., 2013, "Theory and application of the material point method."Advances in Mechanics,02:237-264.

[2]Deng,F.H., 2009, "The shield tunnel segment displacement response analysis in the subway operation period." ScienceTechnology and Engineering, 07:3684-3688.

[3]Zheng,G., Li,Z.W., 2012, " Comparison analysis of the effects of foundation pit excavation on adjacent buildings."Chinese Journal of Geotechnical Engineering, 969-977.

[4]Zheng,Y.R., Qiu,C.Y., 2008, "The exploration of soil tunnel surrounding rock stability analysis method." Chinese Journal of Rock Mechanics and Engineering:27(10).

[5] GB 50007—2002 Code for design of building foundation[S]. Beijing: China Architecture and Building Press, 2002.

[6] Hsieh P G, Ou C Y. Shape of ground surface settlement profiles caused by excavation[J].

Canadian Geotechnical Journal, 1998,35(6): 1004-1017.