

Subsidence Displacement Analysis of Bridge Pier under Approaching Excavation Load

Shuai Huang, Yuejun Lv, Yanju Peng, Liwei Xiu

Institute of Crustal Dynamics, China Earthquake Administration, No.1 Anning zhuang Road, Haidian District, Beijing 100085, China

huangshuai3395@163.com

Abstract. Based on the finite element model of approaching excavation of foundation pit, the influence laws of excavation depth and distance on the bridge pier deformation are studied. The results show that subsidence displacement of the bridge pier increases with the increasing of the approaching excavation depth. The axial force of the steel pipe near the bridge pier is greater than that far away from the bridge pier. The influence of approaching excavation distance on foundation pit decreases with the approaching excavation distance increasing. The maximum sedimentation deformation appears at the location of $0.5B$ (B is the lateral width of the pier). When the approaching excavation distance is less than $1B$, sedimentation deformation of the pier is dangerous. When the approaching excavation distance is greater than $1B$, sedimentation deformation of the pier is safe.

1. Introduction

Approaching excavation problems in the process of rapid urbanization in China has been more and more common. Many new development project is close to the existing public facilities of the city, and how to ensure the normal construction conditions to minimize the impact of public facilities is an important issue. Bridge is the important part of urban traffic and components, and it is often required to maintain normal operation when the surrounding approaching excavation is constructed. In addition, the bridge is more sensitive to the change of surrounding environment, which makes approaching excavation of the Bridges being particularity and complexity. Thus, researching the bridge safety is necessary.

About the approaching excavation, Peck^[1] recommended to use the relation between the subsidence degree and the distance from edge of foundation pit to estimate subsidence. Li Fangming^[2] studied the surrounding ground surface settlement laws caused by coupling effect of foundation pit excavation. Linya Tian^[3] performed a settlement monitoring and trend prediction method, and built a prediction model, and this model can be applied to settlement predictions for buildings surrounding foundation pits. Hence, this model can be applied to settlement predictions for buildings surrounding foundation pits. Yang Min^[4] performed the numerical simulation of foundation pit excavation based on the four basic deformation modes of retaining structures put forward by Goldberg^[5], and found that the deformation of the maintenance structure has a linear relation with the maximum ground subsidence. Ning-wei Wang^[6] derived a superposition calculation formula to calculated the surface settlement around deep excavation retaining structure. However, most researches are focused on safety evaluation of approaching construction, and there is less research about the influence of approaching construction on mechanic behavior of surrounding building. Thus, based on the finite element model



of approaching excavation of bridge, and studied the influence laws of excavation depth and distance on the bridge pier deformation.

2. Analysis of the bridge pier subsidence and approaching excavation on support system deformation.

2.1. Three-dimensional finite element model and pier subsidence.

Software MIDAS/GTS is used to simulate the excavation of foundation pit. The soil constitutive model used Mohr-Coulomb. The boundaries of the left and right sides are fixed the X displacement, and the bottom of the model is fixed. The site sizes are $64 \times 14.5 \times 30\text{m}$, and the pier is simulated by solid element, and pile foundation is simulated by beam element. Elasticity modulus of the pier is C30, and the density is 25kN/m^3 . The pier is simulated by elasticity constitutive model. Length of the pile is 14.5m. The finite element model is shown in Figure 1. The influence laws of excavation depth on the bridge pier subsidence, as shown in Figure 2.

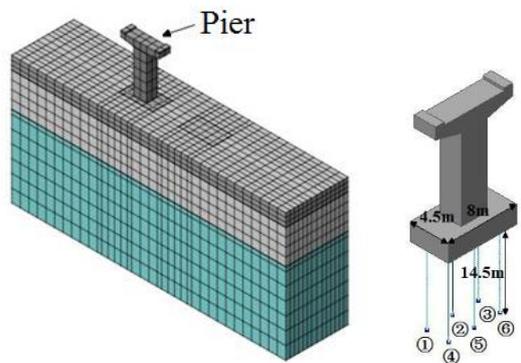


Figure 1. Finite element model of the pier

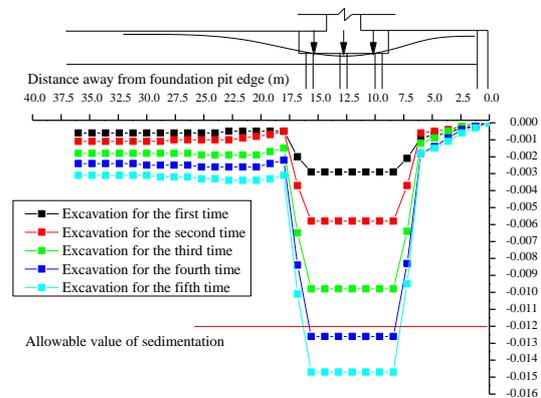


Figure 2. Bridge pier subsidence

As shown in Figure 2, the bridge pier subsidence increases with the increasing of excavation depths. The maximum subsidence displacement appears the last excavation, and the displacement is 1.47cm, which have exceeded the subsidence limiting value 1.2cm. Thus, when the approaching excavation depth is one time width of the pile caps, the bridge is dangerous.

2.2. Deformation analysis of the retaining wall.

The influence laws of excavation depth on the displacement of the left retaining wall, as shown in Figure 3 and Figure 4.

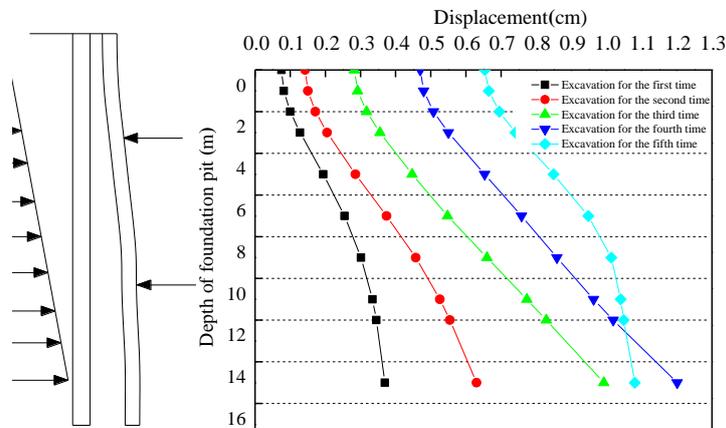


Figure 3. Influence laws of excavation depth on the displacement of the left retaining wall

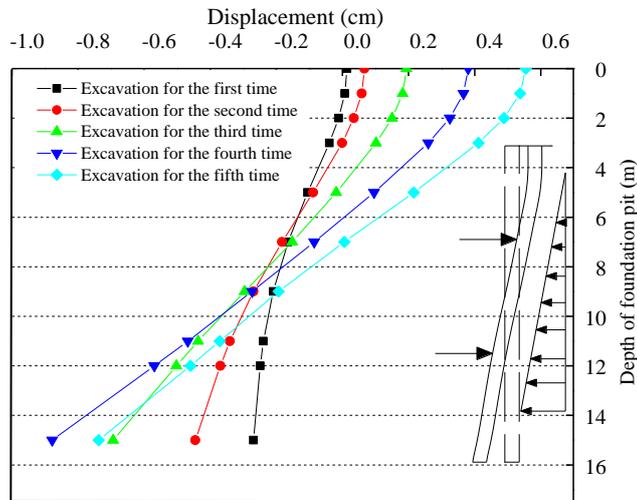


Figure 4. Influence laws of excavation depth on the displacement of the right retaining wall

As shown in Figure 3 and Figure 4, the displacement of the left retaining wall increases with the increasing of excavation depths. The maximum displacement of the left retaining wall is 1.2cm. The displacement of the right retaining wall increases with the increasing of excavation depths. The top of the right retaining wall extends outward of the foundation pit. The maximum displacement of the top of the retaining wall is 0.6cm. The maximum displacement at the bottom of the retaining wall is 0.9cm.

Axial force diagram of the top two layers of steel pipe support are show in Table 1 and Table 2.

Table 1. Axial force of steel pipe support considering approaching excavation

Number	First layers of steel pipe support	Second layers of steel pipe support
1	-328 KN	-1248 KN
2	-528 KN	-1500 KN
3	-528 KN	-1500 KN
4	-328 KN	-1248 KN

Table 2. Axial force diagram of steel pipe support not considering approaching excavation

Number	First layers of steel pipe support	Second layers of steel pipe support
1	-415KN	-1123 KN
2	-467 KN	-1173 KN
3	-467 KN	-1173 KN
4	-415 KN	-1123 KN

As show in Table 1 and Table 2, the maximum axial force appeared on the second layer steel pipe support after the excavation, and the axial force of the first layer is less. The axial force of the steel pipe support considering approaching excavation is not uniform, and the axial force of the steel pipe near the bridge pier is greater than that far away from the bridge pier. The reasons are that the soil at the bottom of the pier appeared additional stress and produced the extrusion and thrust to the retaining wall and support system.

3. Influence of approaching excavation distance on deformation of bridge pier.

By changing the approaching excavation distance of the foundation pit and the pier, the deformation of the pier is calculated, as shown in Figure 5 and Figure 6. The distance (D_0) are set as $0B$, $0.5B$, $1B$, $1.5B$, $2B$, $2.5B$, $3B$ (B is the lateral width of the pier).

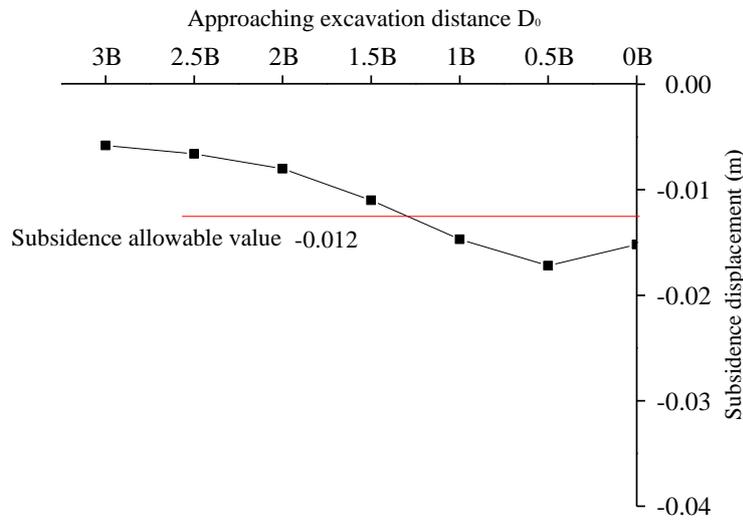


Figure 5. Change rules of pier deformations with approaching excavation distance

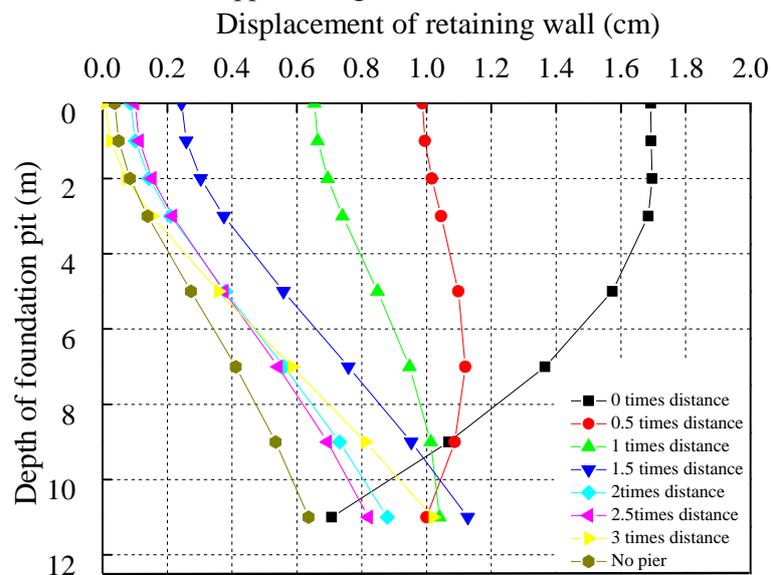


Figure 6. Change rules of foundation pit deformations with approaching excavation distance

As shown in Figure 5 and Figure 6, the influence of approaching excavation distance on foundation pit decreases with the approaching excavation distance increasing. The maximum sedimentation deformation appear at the location of 0.5B. When the approaching excavation distance is less than 1B, sedimentation deformation of the pier excelled the alarm value, and the pier is dangerous. When the approaching excavation distance is greater than 1B, sedimentation deformation of the pier is under the alarm value, and the pier is safe. The displacement of the foundation pit walls top appears the maximum value which is 1.7cm when the approaching excavation distance is 0B. With the increasing of the approaching excavation distance, when the approaching excavation distance is 2B, the influence of approaching excavation distance on deformation of the foundation pit seems to be disappearing.

4. Conclusions.

(1) Subsidence displacement of the bridge pier increases with the increasing of the approaching excavation depth. When the approaching excavation depth is one time width of the pile caps, the bridge is dangerous.

(2) The maximum axial force appeared on the second layer steel pipe support after the excavation, and the axial force of the first layer is less. The axial force of the steel pipe near the bridge pier is greater than that far away from the bridge pier.

(3) The influence of approaching excavation distance on foundation pit decreases with the approaching excavation distance increasing. The maximum sedimentation deformation appear at the location of 0.5B. When the approaching excavation distance is less than 1B, sedimentation deformation of the pier excelled the alarm value, and the pier is dangerous.

Acknowledgments

This work is financially supported by the National Natural Science Foundation of China (Grant No. 51708516), Beijing Natural Science Foundation (Grant No. 8174078), National Key R&D Program of China (2017YFC1500400), research grant from Institute of Crustal Dynamics, China Earthquake Administration (No. ZDJ2017-28) and Beijing talents Fund (2015000057592G270).

5.References

- [1] Peck R B. Deep exeavations and tunneling in soft ground.state-of-the-art report[C].7th Int. Conf. soil Mechanics and Foundation Engineering, Mexieo, 1969 pp 225-290.
- [2] Li Fangming,Chen Guoxing. Study of Ground Surface Settlement of Foundation Pit with Suspended Waterproof Curtain in Yangtze River Floodplain[J]. Tunnel Construction, 2018, 38(1) pp 33-40.
- [3] Lin ya Tian, Xi sheng Hua. Settlement Prediction for Buildings Surrounding Foundation Pits Based on a Stationary Auto-regression Model[J]. Journal of China University of Mining and Technology, 2007, 17(1) pp 78-81.
- [4] Yang Min, Lu Jun-yi. Estimation of ground settlement aroused by deep excavation[J]. Chinese Journal of Geotechnical Engineering, 2010, 32(12) pp 1821-1828.
- [5] Goldberg D T, Jaworski W E, Gordon M D. Lateral support systems and underpinning (Vol.II): design fundamentals. 1976 pp 6-27.
- [6] Ning wei Wang, Xu Han. Analysis of the surface settlement adjacent to deep foundation pit in soft soil[J]. Journal of Civil Engineering and Construction,2014,3(1) pp 31-37.