

Analyze the deformation mechanism of foundation pit engineering and its influence on adjacent piers

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Abstract: With the development of china's aboveground engineering, large cities have long been lined with high-rise buildings, and the utilization rate of above-ground space in large cities has reached a very high level, and research has gradually turned to underground foundation pit engineering to make full use of underground space. Safety issues in the project are particularly important, and whether the progress of the foundation pit project will have a greater impact on the existing building, that is, it is necessary to fully understand the foundation pit project in order to better develop the foundation pit project. In this paper, the deformation mechanism of foundation pit engineering, the adverse effects of excavation of foundation pits on adjacent buildings, the innovation of foundation pit support technology, and the prospect of foundation pit engineering technology are briefly discussed.

Keywords: Foundation pit engineering, excavation of foundation pit, deformation, foundation pit support

1. Introduction

After the reform and opening up, China ushered in a stage of rapid development, with the continuous urbanization of China, the ground utilization rate of large cities is becoming less and less, which seriously affects the sustainable development strategy proposed by China. Some developed countries abroad have already begun to use underground space to build some storage warehouses, subways, tunnels, etc., which greatly reduces the occupancy rate of above-ground space and provides more space for the development of cities. China's foundation pit project has just started, and it still needs to be vigorously promoted.

This research group is using finite element to analyze the impact of foundation pit excavation on adjacent bridge piers through practical engineering, and provides reference significance for practical projects through this research. Through the collection of information through the review of literature, a brief review of the relevant literature viewed is provided.

2. Research status of foundation pit engineering at home and abroad

Foundation pit engineering has always been a course that keeps pace with the times, and as early as 1920 to 1929, Terzaghi^[1] began to study foundation pit engineering and wrote about soil mechanics, laying the foundation for foundation engineering. In 1970, Duncan James M^[2] studied the movement of the surrounding soil during the excavation of the deep foundation pit and one year after the excavation, and found that within a year the soil had undergone a huge deformation movement. In 1991, Richard J. Finno et al.^[3] studied the performance of the adjacent pile foundation next to the deep foundation pit and found that the additional bending moment of the excavation of the foundation pit was not enough to cause the pile to be damaged. In 1992, Japanese scholar Makoto KITO et al.^[4] explained the method of supporting structure design suitable for deep foundation pits through the comparison of theory and practice. Since the 21st century, due to the rapid development of computers, foreign scholars have continuously promoted theoretical development and proposed many models through finite element to reduce the impact of deep foundation pit excavation. In 2003, Y.M.A Hashash et al.^[5] proposed a new soil constitutive model of the underlying neural network that can be used for prospective prediction in the future or later excavation stages. In 2011, A. Krasiński et al.^[6] analyzed two simplified methods and found that the results were far apart, so he showed that the design safety of deep excavation support depended heavily on the choice of calculation method. In 2021, Piciullo Luca et al.^[7] proposed a GIBV

damage assessment method that considered short-term and long-term displacements in the evaluation, which was more reliable and had higher accuracy.

Domestic foundation pit engineering started relatively late, in the 1980s and 1990s only began to rise high-rise buildings, people slowly attach importance to foundation pit engineering, decades of development is mainly in the direction of structural improvement, to reduce the impact of foundation pit excavation on the surroundings. In 1994, Zhou Fanghong et al. ^[8] introduced the combined use of various supporting structures in the foundation pit project. Xu Guangyu et al. ^[9] adopt composite soil nail support, which expands the scope of application of soil nail support and has better comprehensive benefits. Wu Caide and other ^[10] proposed a double-row pile gantry plus anchor composite support structure, eliminating internal support, accelerating the construction progress, and suitable for excavation of foundation pits in soft soil areas. Yao Aijun et al. ^[11] Proposed an optimal calculation method for the cantilever double-row pile support structure of deep foundation pit through finite element simulation analysis. Wang Jie et al. ^[12] proposed a new type of pile-soil-bracing combined support system, which has no internal support structure, is convenient for construction, and is environmentally friendly and economical. Zhao Shengfeng et al. ^[13] proposed an HCMW construction method that combines the support inside the concrete ring, which can effectively protect the surrounding environment of the excavation of the foundation pit. Han Lei et al. ^[14] proposed that the variation law and final deformation value of the displacement of the top and pile body of the new H-type steel support area are basically consistent with the reinforced concrete support area, and the axial force of this support method is seriously affected by temperature.

3. Study the significance of the impact of foundation pit engineering on bridge piers

According to previous scholarly studies, the excavation of the foundation pit will unload the soil, resulting in horizontal displacement of the soil, which will have an adverse impact on the surrounding buildings, there are many scholars to study the harm of the excavation of the foundation pit on the surrounding houses, the ground, the impact of the foundation pit on the adjacent piers Is not much research results, but the interaction mechanism between the excavation of the foundation pit and the pile foundation of the adjacent bridge pier is very complex, in order to more scientifically, accurately and systematically analyze the impact of the excavation of the foundation pit on the bridge pier, better serve the actual project, Providing more reference value requires more scholars to work hard.

4. Research on foundation pit engineering problems

4.1 Deformation mechanism of excavation of foundation pits

The main reason for the deformation of the surrounding soil caused by the excavation of the foundation pit is the uplift at the bottom of the foundation pit and the horizontal displacement of the retaining wall due to the excavation, the main reason for which is the displacement of the retaining wall ^[15-16].

The process of excavation of the foundation pit is the unloading process of the original soil body, with the excavation of the original soil body, the release of the load causes the soil layer at the bottom of the foundation pit to produce a main upward vertical displacement, which forms a bulging part; the soil inside the retaining wall is excavated, resulting in a pressure difference between the inside and outside of the retaining wall, so that the retaining wall produces a horizontal displacement, so that the plastic area on the outside of the support structure expands, so that the soil on the outside of the support structure moves like the inside of the foundation pit, so that the bottom of the foundation pit is uplifted.

4.2 Effect of foundation pit works on adjacent piers

The adverse effects of close excavation on the pile foundation adjacent to the pier are manifested as horizontal displacement, vertical settlement and inclination, mainly reflected in horizontal displacement and vertical settlement.

The overall horizontal displacement of the piers caused by the excavation of the soft soil at close range is towards the excavation side of the foundation pit, and the excavation of the foundation pit can be restored due to the half-cycle unloading of the pier, but not the long cycle. The horizontal displacement of the top of the pier by excavation of the foundation pit will increase with the increase of

the excavation depth of the foundation pit, the settlement of the pier roof will decrease, and the maximum deformation position of the pile foundation will change with the depth of the excavation of the foundation pit, and the deformation of the general pile foundation will be "bow-shaped". The soil on the side of the pile foundation is unloaded due to the excavation of the foundation pit, resulting in the pressure on both sides of the pile foundation is inconsistent, resulting in a pressure difference, which increases with the increase of the excavation depth of the foundation pit, and the soil will produce an unbalanced horizontal force on the pier, resulting in the tilt of the pier, and the excavation will cause the friction resistance on both sides of the pile foundation to be inconsistent, resulting in a large initial additional bending moment of the pile foundation, although the degree of inclination caused by this excavation is very small, but it will affect the bearing capacity of the pile to a certain extent.

4.3 Factors affecting the impact of the foundation pit project on the adjacent bridge piers

The factors affecting the degree of influence of excavation of foundation pits on adjacent piers can be roughly divided into: the spacing between the foundation pit and the adjacent piers, the depth of excavation of the foundation pit, the excavation width of the foundation pit, the excavation sequence of the foundation pit, the load on the piers, and the stiffness of the pier.

The smaller the depth-to-width ratio of the excavated foundation, the smaller the impact of the pile foundation on the upper load, and the appropriate width-to-depth ratio should be selected when the foundation is excavated; the excavation of the foundation pit is given priority to excavating the soil far from the pier, and the impact of the excavation of the foundation pit on the pier will be greatly reduced, which is conducive to reducing the horizontal displacement and vertical settlement of the bridge pier, increasing the stability of the bridge pier, and the maximum deformation of the pier when the excavation reaches the pier pile. When the distance between the structure and the foundation pit is less than twice the excavation depth of the foundation pit, the horizontal impact of the excavation of the foundation pit on the structure is greater than the vertical impact, and when the distance is less than double the excavation depth, both reach the maximum value; when there are multiple foundation pits around the structure that need to be excavated, the excavation of the foundation pit on the same side has an obvious superposition effect, and when different side foundation pits are excavated at the same time, the impact on the level of the structure is reduced, and the vertical effect has a nonlinear superposition effect. It is about 2.5 times the impact of a single excavation pit; the excavation depth of the foundation pit has a particularly obvious impact on the structure, and when the excavation depth exceeds 10m, the sedimentation change is particularly obvious, and the closer to the foundation pit, the more significant the impact.

5. Conclusion

In summary, the excavation of the foundation pit has many influencing factors on the adjacent piers, which may seriously endanger the safety of the use of the piers, and the foundation pit project is a complex and highly distinctive project, that is, people need to have a deeper understanding of the impact of the excavation of the foundation pit, a deeper study of the role between the pile and the soil in the foundation pit project, and make full use of the finite element software for simulation and analysis to reduce engineering accidents and hazards.

References

- [1] Terzaghi K.. *Origin and Functions of Soil Mechanics*[J]. *Transactions of the American Society of Civil Engineers*, 1953, 118(2)
- [2] Chang ChinYung and Duncan James M.. *Analysis of Soil Movement Around a Deep Excavation*[J]. *Journal of the Soil Mechanics and Foundations Division*, 1970, 96(5)
- [3] Richard J. Finno et al. *Analysis of Performance of Pile Groups Adjacent to Deep Excavation*[J]. *Journal of Geotechnical Engineering*, 1991, 117(6) : 934-955.
- [4] Makoto Kito et al. *Study on design method for earth retaining structure having deep excavation* [J]. *proceedings of tunnel engineering, jsce*, 1992, 2 : 35-42.
- [5] Y.M.A Hashash et al. *Systematic update of a deep excavation model using field performance data*[J]. *Computers and Geotechnics*, 2003, 30(6) : 477-488.
- [6] A. Krasiński and M. Urban. *The Results of Analysis of Deep Excavation Walls Using Two Different*

- Methods of Calculation*[J]. *Archives of Civil Engineering*, 2011, LVII(1) : 59-72
- [7] Piciullo Luca et al. Assessment of building damage due to excavation-induced displacements: The GIBV method[J]. *Tunnelling and Underground Space Technology*, 2021, 108 : 103673-.
- [8] ZHOU Fanghong. Comprehensive application of multiple support methods in deep foundation pit engineering[J]. *Building Construction*, 1994(02):16-17.
- [9] Xu Guangyu, Yuan Peizhong, Zhang Xinle, Yang Renhua. Application of Composite Soil Nail Technology in Soft Soil Foundation Pit Engineering[J]. *Port Engineering Technology*, 2002 (02): 39-41.
- [10] Wu Caide, Gong Dikuai, Wang Jiedong. Application of gantry plus anchor composite structure in super large foundation pit[J]. *Chinese Journal of Geotechnical Engineering*, 2006(S1):1781-1784.
- [11] Yao Aijun, Li Haobo, Zheng Xuan, Zhang Jiantao, Zhou Jun, Lu Jian. Soil pressure analysis of cantilever double-row pile support structure in deep foundation pit[J]. *Construction Technology*, 2016, 45(S1):1-5.
- [12] Wang Jie, Li Di'an, Tian Baoji, Du Zuolong, Han Lei. Application of Engineering of New Pile-Soil-Bracing Support System[J]. *Chinese Journal of Geotechnical Engineering*, 2019, 41(S2):93-96.
- [13] Zhao Shengfeng, Chen Zhiyang, Cai Yun, Zhao Qianyun, Zhang Xin. HCMW construction method combined with support pit design in the ring [J]. *Building Structure*, 2019, 49(03): 120-124.
- [14] Han Lei, Sun Min, Huang Peilin, Chen Hua, Wang Qiang. Design analysis and engineering application of new H-beam support system [J]. *Building Structure*, 2021, 51(23):95-102.
- [15] LI Xiuxing. Analysis of deformation mechanism and prevention and control measures of foundation pit support[J]. *Building Materials and Decoration (Mid-10th Issue)*, 2008(06):196-197.
- [16] Tan Jinzhong, Chen Xinhua, Zhao Guijian. Deformation and control factor analysis of a soft soil deep foundation pit [J]. *Shanxi Architecture*, 2009, 35(21):95-96.
- [17] Zhang Zixin, Li Jiayu, Zhou Xiang, Li Wenyong. Study on the Response of Piers of Metro Viaducts Operated under Close Excavation and Unloading Conditions [J]. *Rock and Soil Mechanics*, 2015, 36(12):3531-3540.
- [18] Wang Duoyin, Xing Lei, Duan Lunliang. Study on the Displacement Evolution Law of Pier Top of Active Bridge Pier Considering the Near road Construction Process[J]. *Journal of Chongqing Jiaotong University (Natural Science Edition)*, 2021, 40(10):82-90.
- [19] Li Bing, Ma Ning. Analysis of the impact of deep excavation of subway foundation pit on adjacent bridge piles[J]. *Journal of Kunming University of Science and Technology (Natural Science Edition)*, 2018, 43(02):107-113.
- [20] Wang Muqun. Effect of excavation of foundation pit on piles of adjacent bridges and analysis of stability of foundation pits[J]. *Sino-Foreign Highway*, 2014, 34(03):197-200.
- [21] Zheng Mingxin, Xia Yiming, Yuan Zhao, Wu Gang. Analysis on the deformation of pile foundation of adjacent high-speed railway piers by deep excavation[J]. *Construction Technology*, 2017, 46(05):12-15+28.
- [22] Wang Cui, Yan Shuwang, Zhang Qibin. Study on the Influence Mechanism and Control Measures of Deep Excavation on Adjacent Bridge Piles[J]. *Chinese Journal of Rock Mechanics and Engineering*, 2010, 29(S1):2994-3000.
- [23] Yang Baozhu, Wang Li, Zheng Gang. Finite element analysis of vertical bearing characteristics when tilting adjacent piles caused by excavation of foundation pits[J]. *Chinese Journal of Geotechnical Engineering*, 2008, 30(S1):144-150.
- [24] Ran Qiren, Wang Xu, Wang Bolin, et al. Model test on the influence of excavation of foundation pit on bending moment and deformation of pile foundation of adjacent building[J]. *Chinese Journal of Geotechnical Engineering*, 2021, 43(S01):6.
- [25] Zheng Gang, Yan Zhixiong, Lei Huayang, Lei Yang. Measured and finite element numerical simulation analysis of the impact of excavation of foundation pit on adjacent pile foundation[J]. *Chinese Journal of Geotechnical Engineering*, 2007(05):638-643.
- [26] Ma Fenghai, Chen Huiru, Han Shuo. Analysis on the Influence of Excavation Sequence of Foundation Pit under Viaduct on Pier Deformation[J]. *Science Technology and Engineering*, 2020, 20(21):8750-8756.