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Talking about the influence of foundation pit excavation on surrounding buildings

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Abstract: *Foundation pit engineering is one of the important systems studied in geotechnical engineering. The study of foundation pit not only studies its own stability during excavation, but also analyzes its influence on surrounding building structures. This paper analyzes and summarizes the influence rules of foundation pit excavation on adjacent bridge piles, subway tunnels and houses from the aspects of influence principle, theoretical analysis method, selection of supporting structure and influence factors.*

Keywords: *foundation pit engineering; supporting structure; bridge pile; tunnel; house; influence law*

1. Introduction

With the continuous development of my country's economy, the process of urbanization is accelerating, and the population is increasing rapidly, which makes the construction land increasingly tight, traffic becomes congested, and the contradiction between supply and demand of urban space intensifies. Due to the non-renewability of land, it is required to rationally plan the construction layout of the city under the existing pattern, and develop towards high-rise buildings and underground space.

The utilization of underground space is directly related to the excavation of foundation pits. Since foundation pit projects are mostly located in urban areas, there are often underground pipelines, subway tunnels, houses, bridges and other buildings around. cluster and underground facilities. Only by studying the influence of foundation pit excavation on surrounding buildings can some serious engineering accidents be avoided.

The research on foundation pit engineering started relatively early abroad. In the 1940s, Peck [1] proposed a method for estimating the support force of the cofferdam structure and the excavation stability of the foundation pit, and the total stress method. After continuous improvement and revision, it has been used till now. In the 1970s, based on Peck theory, Duncan [2] studied the interface behavior relationship between foundation pit backfill and retaining wall by using two-dimensional finite element analysis, which opened up the extensive application of finite element method in the field of foundation pit engineering. In the 21st century, with the rapid improvement of the utilization rate of underground space in China and the continuous development of the theory of foundation pit excavation technology, various theoretical studies on the construction of foundation pit excavation in China are also emerging. For example, Hou Xueyuan [3] proposed the theory of space-time effect of deep foundation pit, which is widely used in engineering practice.

2. Influence of foundation pit excavation on adjacent bridge piles

At present, there are three main methods for solving the influence of foundation pit excavation on pile foundation buildings: one is the foundation reaction force method based on the Winkle: model, including linear and nonlinear load transfer method (PY curve method), and the method is The core other methods [4]; the second is the finite difference method or the finite element method [5]; the third is the elastic theory analysis method [6]

The influence principles of foundation pit excavation on adjacent pile foundations are roughly as follows: 1) Foundation pit excavation causes lateral displacement of soil mass, which produces horizontal thrust on adjacent pile foundations, resulting in additional bending moment, axial force, and deflection of the pile body. In severe cases, the pile gene can be deformed too much and damaged,

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thereby causing the instability of the superstructure supported by it; 2) The vertical settlement of the soil caused by the excavation of the foundation pit produces negative frictional resistance to the pile body. As a result, the pile body sinks or lifts up, thereby weakening the bearing capacity of the pile foundation. When the pile body settles unevenly, additional stress is generated on the supporting superstructure, resulting in cracking and damage [7].

It can be seen from the above influence principles that when the foundation pit is excavated, the adjacent pile foundation structure will be deformed by the corresponding horizontal and vertical displacement, bending moment and axial force of the pile body due to the earth pressure of the surrounding soil. Therefore, it is necessary to do a good foundation pit supporting structure during the excavation process of the foundation pit, and the advantages, disadvantages and adaptability of different supporting structures are also different, and it is necessary to choose according to the specific environmental conditions:

1) When the foundation pit is under the bridge (such as the excavation of the foundation pit on the road under the viaduct), due to the restriction of the clearance under the bridge and the construction space of the piers on both sides, the construction method and support plan that require a large construction space are not applicable. For example, the supporting structure of the underground diaphragm wall requires certain construction environment requirements for the layout of the support, and the space is too small to be constructed. It is suitable for foundation pit engineering in complex environments such as narrow construction space, poor site conditions and dense buildings.

2) When the area of the excavation foundation pit is large or narrow, not all excavation sections are close to the pile foundation. Considering the economy of the support scheme, different support structures should be arranged according to the actual situation. In the secondary affected area far away from the pile foundation, the stability of the foundation pit itself is mainly considered, and a supporting scheme with relatively low cost and weak supporting effect can be adopted for supporting (such as grading excavation, soil nailing wall) and ordinary cement-soil walls, etc.); and in the main affected area close to the pile foundation, not only the stability of the foundation pit itself, but also the influence of the excavation of the foundation pit on the adjacent pile foundation should be considered. A good support plan should be used for foundation pit support (such as SMW construction method, pile row, underground diaphragm wall, etc.).

Of course, the influence of foundation pit excavation on the pile foundation is also related to various other factors, such as the distance or positional relationship between the two, the hardness of the stratum, the depth-to-width ratio of the foundation pit, the Foundation burial depth, foundation pit excavation construction methods and support schemes, etc. Generally speaking, as the distance between the excavated foundation pit and the pile foundation increases, after the foundation pit is excavated, the displacement and deformation of the pile foundation will decrease accordingly, and the maximum bending moment of the pile body will move up [8]; When the pile foundation is excavated and unloaded in a full circle, the vertical displacement generated by the pile foundation will not rebound after the excavation is completed, and when the pile foundation is unloaded in a half circle, it will take a period of time after the excavation ends. The vertical displacement generated by the pile foundation will partially rebound. When the excavation foundation pit is in the hard soil layer, the adjacent pile foundation will produce vertical settlement, and when the excavation foundation pit is in the soft soil layer, the pile foundation may produce vertical upward displacement after excavation [9]. Usually, the displacement and deformation of the adjacent pile foundation will increase with the increase of the depth-to-width ratio of the excavated foundation pit, and decrease with the increase of the buried depth of the pile foundation itself.

Moreover, the use of different supporting schemes has a significant impact on the pile foundation, increasing the strength and stiffness of the supporting structure, increasing the burial depth of the retaining pile and wall structure, and adding supports and anchors, etc. The deformation and displacement of the pile foundation during the excavation of the foundation pit will be reduced accordingly.

3. Influence of foundation pit excavation on adjacent tunnels

The influence principle of foundation pit excavation tunnel is: the foundation pit excavation leads to the unloading of the stress at the bottom of the pit, the enclosure structure will move into the pit, and the horizontal pressure on the side of the tunnel close to the foundation pit decreases, which in turn causes the horizontal displacement of the tunnel into the pit. When the excavation depth of the

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foundation pit is shallow and less than a certain critical depth, the tunnel will generate upward additional force, and the tunnel will be uplifted and deformed; when the excavation depth is greater than another critical depth, a downward additional force will be generated, and vertical settlement deformation will occur. When the excavation depth is between these two critical depths, the tunnel may undergo subsidence or uplift deformation [10].

Due to the rapid development of my country's subway transportation in recent years, research related to subway tunnels has also ushered in an explosion, and many valuable results have been achieved. At present, there are three main methods that can be used to analyze such problems:

1) Finite element numerical simulation method: The advantage of the finite element numerical simulation method is that the analysis problem is more comprehensive, the results are intuitive, and the soil constitutive relationship can be fully considered. However, the rationality of the numerical simulation results largely depends on the selected constitutive model and parameter values, and the modeling workload of this method is relatively large;

2) Residual stress method: The residual stress method (RSM) [11] is based on the idea of the layered sum method, and analyzes the soil spring back deformation at the tunnel location according to the residual stress field caused by excavation. The advantage of this method is that it is easy to understand and use, but the disadvantage is that only the free displacement of soil at the tunnel position is regarded as the displacement of the tunnel structure, and the effect of tunnel stiffness is not considered.

3) Two-stage method based on elastic foundation beam: The two-stage method based on elastic foundation beam is an analytical method,

In the first stage, the additional stress field of soil caused by external loads is obtained by analytical solution or finite element method; in the second stage, the tunnel is regarded as an elastic foundation beam, and the additional stress field is applied to the research system as a known condition to solve. The two-stage method has clear mechanical relationship and fast calculation speed. However, the calculation results of different foundation models selected in the second stage of this method are quite different. The more complex the foundation model, the more reasonable the calculation, but the more and more difficult the foundation parameters are. Sure. In addition, this method regards the foundation soil layer as a homogeneous soil mass, and cannot consider the natural layering of the foundation soil.

The two factors that affect the normal use of subway tunnels during foundation pit excavation are absolute deformation and non-uniform deformation. The absolute deformation leads to the change of the tunnel orientation and the overall curvature of the track, which affects the normal operation of the subway train. The uneven deformation leads to cracks in the tunnel segments, expansion of the segment joints, and structural damage to the tunnel [12].

1) The absolute deformation of the subway tunnel generally cannot exceed 20mm, the maximum floating displacement does not exceed 15mm, and the relative bending does not exceed 1/2500. When the total upward force of the soil is greater than the sum of the gravity of the subway station and the static frictional resistance between the station and the soil, the overall upward displacement of the station; when the total upward force of the soil is less than the sum of the gravity of the subway station and the static frictional resistance between the station and the soil, the station generally sinks.

2) The force between the side near the foundation pit and the side far from the foundation pit is uneven, the station will tilt to a certain extent, and the station may sink as a whole but the side near the foundation pit floats [13]. Due to the horizontal unloading and the lateral movement of the foundation pit enclosure into the pit, the soil layer above the uplift area will subside, resulting in the subsidence of the subway tunnel in the soil layer. When the connecting part of the subway station and the tunnel floats up and the tunnel sinks, the damage to the subway tunnel structure caused by this difference in settlement is extremely serious.

The main reasons for the structural damage of the tunnel caused by the excavation of the foundation pit are the difference of settlement and the difference of horizontal displacement. After the excavation of the foundation pit, the horizontal displacement generated by the adjacent subway tunnels generally faces the foundation pit. When there is a subway tunnel around the foundation pit, the foundation pit support mostly adopts pile structures such as mixing piles or cast-in-place piles. While the foundation pit support is carried out, it can also play a certain role in strengthening the soil around the tunnel . The horizontal displacement of the adjacent existing subway tunnels can be reduced when the tunnel is arranged or close to the foundation pit, and the distance between the piles and tunnels has the greatest influence on the horizontal displacement and surface settlement of the adjacent existing subway tunnels

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[14].

4. Influence of foundation pit excavation on adjacent houses

Large number of studies have shown that the influence of the foundation pit on the surrounding building structures is mainly indirect. This leads to the destruction of the building. The surface settlement caused by the excavation of the foundation pit has the characteristics of large displacement on the side close to the foundation pit and small displacement on the side far from the foundation pit. This displacement usually includes the lateral displacement of the soil behind the pile. When the indirect action of the body toward the inside and bottom of the foundation pit is applied to the building, the building often shows some unique characteristics. The response of the building to the excavation of the foundation pit mainly includes the following aspects [15]:

1) Due to the large settlement of the building close to the foundation pit and the small displacement away from the foundation pit, the buildings with good integrity will mainly tilt as a whole under the effect of this uneven settlement; for buildings with poor integrity , and local inclination often occurs within the range of settlement influence.

2) The horizontal displacement of the soil causes the building to be subjected to lateral strain. Under this action, lateral displacement often occurs. When the internal tensile strain of the component exceeds a certain limit, cracks will occur in the components of the building structure.

The response law of buildings to uneven settlement caused by excavation is mainly controlled by settlement difference and ultimate tensile strain. Therefore, when considering the design of the foundation pit supporting structure of the adjacent building, the influence of the foundation pit excavation on the building can be controlled by controlling the development of the bending moment and displacement in the building. For the multi-storey building structure, under the influence of foundation pit excavation, the horizontal displacement of the building shows the law that each floor is different and the same floor is similar, and the vertical displacement of the building shows the law that each span is different and the same span is similar.

For frame structures, the maximum horizontal displacement in buildings generally occurs at the corners of beams and columns on the top floor of the building near the foundation pit, the maximum vertical displacement occurs at the first-floor beams, and the maximum bending moment response occurs at the first-floor beams [16].

Due to the excavation of the foundation pit, the uneven settlement of the house structure occurs, and the uneven settlement has a great impact on the stability and safety of the house. When carrying out foundation pit support, it is not only necessary to consider the stability of the foundation pit itself, but more importantly, to control the uneven settlement of the building structure. Previous studies have shown that, according to the environmental conditions of different projects, choosing piles and wall structures of different sizes to enclose the foundation pit can effectively reduce the deformation of the surrounding soil, thereby reducing the impact on adjacent houses. In addition, adding isolation piles between the foundation pit and the building can reduce the settlement of the nearby house, increase the overall stiffness of the house, and effectively adjust the uneven settlement of the house [17].

5. Summary and outlook

With the continuous development of science and technology and the continuous improvement of underground engineering technology, many scholars have conducted research on foundation pit engineering through field measurement, experimental research and finite element analysis, and have also achieved some results. However, in recent years, due to the excavation of foundation pits, the cracking of adjacent roads and pavements, and the structural deformation and damage of bridges and houses are not uncommon. Therefore, it is necessary to conduct more comprehensive and in-depth research on the stability of the excavation of the foundation pit and its impact on the surrounding buildings and the environment, and continuously optimize the support scheme to ensure the safety and stability of the foundation pit and surrounding buildings.

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