Study on the Influence of Step-by-step Excavation of Foundation Pit on Supporting Structure

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Abstract. Aiming at the influence of step-by-step excavation of foundation pit on the internal force and deformation of supporting structure, this paper summarizes the research status of domestic and foreign scholars on this issue, introduces the calculation method of internal force of supporting structure, and uses GEO5 software and ABAQUS finite element analysis software to solve the internal force and deformation of supporting structure in the process of step-by-step excavation, and compares it with the measured results.

Keywords: Foundation pit engineering; Step by step excavation; GEO5; ABAQUS.

1. Introduction

With the continuous development of China's economy, many high-rise buildings have sprung up, and the population in urban areas is increasing. The contradiction between population growth and land use has arisen in urban areas, which is not conducive to creating a livable environment. The development of underground space can introduce many people into the ground, reduce the number of people on the ground, and improve the quality of life in urban areas. When developing underground space, it also involves foundation pit engineering, and many urban areas develop very fast. The development efforts are constantly increasing, and the depth is also increasing. Usually, the excavation depth is more than 5m, which belongs to the deep foundation pit [2], and the subway foundation pit generally belongs to the deep foundation pit. The deep foundation pit project has the characteristics of strong space-time effect and environmental effect, and it is risky [3]. The foundation pit project is related to many aspects, and its influence on the structure should be taken into account while considering the geotechnical problems [4]. The subway foundation pit is usually located in a relatively prosperous urban area. The excavation of foundation pit is usually supported excavation, and more than 40% of the accidents in foundation pit engineering are caused by design factors. Therefore, it is very important to calculate the supporting structure reasonably. Because of the particularity of the load, it is related to the change of earth pressure during excavation, and influenced by the excavation method and the amount of earthwork excavation, the stress situation is complicated. If the structural design of excavation process is considered to be safe, the study of step-by-step excavation is therefore carried out.

2. Overview of Development Status of Foundation Pit Engineering

The theoretical research on foundation pit engineering began in 1930s, and Terzaghi and others obtained the calculation method, which can roughly estimate the stress of the support. After that, many scholars all over the world began to study foundation pit engineering, and new achievements emerged constantly, such as the analysis method of foundation pit bottom uplift, the empirical estimation method of surface settlement behind the wall, and the finite element analysis method of foundation pit excavation [6-8]. Up to now, there are some super-high-rise buildings in China, such as Zifeng Building in Nanjing, 117 Building in Tianjin, Shanghai Center Building, etc., and the depth of foundation pit has also increased a lot compared with the last century, and the development of underground space such as urban subway stations has been increasing. How to solve the problem of the influence of excavation in urban areas on the surrounding environment has given the topic of
foundation pit a flavor of the times. When there is not enough space for slope excavation, enclosure excavation is produced. There are various types of enclosure structures, such as steel sheet piles, double-row piles, bored piles, high-pressure jet grouting piles, casing bite piles, underground continuous walls and SMW construction piles, and the design theory and analysis methods have also been continuously improved [9].

3. Research Status at Home and Abroad

In 1971, Clough and others used the finite element method to analyze and study the deformation of foundation pit excavation for the first time. It is concluded that the deformation of soil is nonlinear, and the influence of space-time effect of foundation pit on supporting structure is also discussed [10]. In 1981, Thoms compared the results of physical experiments with a large number of engineering test conclusions, and obtained the function of lateral deflection and vertical displacement of the ground behind the wall [11]. In 2003, Mana Al summarized some laws of horizontal displacement of the structure [12]. In 2014, Based on a foundation pit project, Ching Hung et al. used the enhanced non-associated anisotropic boundary surface model to analyze the excavation of deep foundation pit in soft clay by finite element method. The results show that it is reasonable to use this model to simulate the excavation of deep foundation pit. In China, in 1997, Li Xiangfeng calculated and analyzed the supporting structure of a foundation pit project in Wuhan, and obtained the influence of different application orders of foundation pit support on the deformation of retaining piles, and proposed that strengthening the soil in the passive area can effectively reduce the bending moment and lateral deformation of retaining piles [13]. In 1998, Liu Xingwang and others combined the calculation method proposed with the actual project on site, and obtained the general law of the change of supporting system during construction [14], 2000. Lou Yihong and others made dynamic analysis, and the calculation model established by him can calculate the deformation and internal force of the supporting system at any position and at any time [15]. In 2001, Zhou Jun analyzed the influence of various factors on the internal force and deformation of the supporting structure of the foundation pit, and also discussed the optimization principle of the supporting scheme of the deep foundation pit project, and obtained the main methods and approaches for optimal design [16]. In 2003, Wang Xiaohui adopted Duncan-Zhang soil model and proposed the foundation pit. In 2004, Qi Liang observed the deformation, stress and rebound of a foundation pit project for four months. Considering the defects in the design of the existing supporting structure, a new design method was proposed, which considered the internal force and deformation of the supporting structure under different excavation conditions and improved the design accuracy. In 2004, Yang Xiaoping and others regard the excavation surface of foundation pit as the surface of elastic semi-infinite body, and use Mindlin solution in elastic semi-infinite body under horizontal load to calculate internal force and deformation [19]. In 2007, Wang Ruike used ANSYS software to carry out numerical simulation on the whole excavation process of the foundation pit, and studied the thickness of the retaining structure and its variation law during layered excavation [20]. In 2011, Wang Chang carried out numerical analysis on different working conditions of the foundation pit excavation process. Considering the interaction between structure and soil, the numerical simulation results are basically consistent with the monitoring data, which proves the rationality of the calculation model [21]. In 2013, Chen Yanbin and others deduced the finite difference decomposition based on the elastic foundation beam theory, and the calculation results were close to the actual project, which made the solution simple and provided a new idea for the design of supporting structure of foundation pit engineering [22]. In 2015, Duan Xin established soil-support. The deformation and internal force of retaining pile under different working conditions during excavation are studied. The results show that with the increase of excavation depth, the bending moment, shear force and horizontal displacement of retaining pile increase obviously, and the supporting axial force gradually increases and tends to be stable [23]. In 2015, Li Tao and others calculated the distribution of bending moment and displacement of pile
along the depth. After comparing this calculation method with the standard method, it was found that it was closer to the measured value [24]. In 2016, Liu Kai used FLAC3D software to study the changes of lateral displacement and stress of the supporting structure during excavation. The results show that the lateral deflection of the pile is convex along the depth [25].

4. Summary

Even though the finite element method is so powerful, it still needs to be improved: soil is a complex body composed of three phases, and although many constitutive models of soil have been put forward by scholars from all over the world, the simulation of soil is only an approximate simulation, so the selection of appropriate models and accurate parameters remains to be studied; How to simplify the complex interaction and displacement boundary needs further study; How to consider many factors that affect the stress of foundation pit supporting structure is also to be studied.

References


