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Research on Damage Repair and Reinforcement of Deep Foundation Pit Support Structure Based on Fractal Dimension Theory

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Foundation pit engineering refers to the excavation in the ground below the underground space and its supporting support system. The foundation pit support is used to ensure the excavation of the foundation pit, the smooth construction of the foundation and the safety of the surrounding environment. The support and reinforcement measures are also used for the side wall safety of the foundation pit and the surrounding environment. With the rapid development of China's high-rise buildings, deep foundation pit support is the current construction of a wide range of important applications. This has a direct impact on the safety and quality of construction. Therefore, it is of great significance to strengthen the research on the damage of deep foundation pit support. This paper introduces a kind of repair and reinforcement of deep foundation pit support which is based on fractal dimension theory. According to the complex environmental effects of foundation pit engineering, the reinforcement of foundation pit support should not only ensure the safety and stability of the foundation pit itself, but also effectively control the movement of the surrounding strata and protect the surrounding environment.

1. Introduction

The foundation pit engineering is an important research direction in the current foundation of our country. However, with the development of China's construction industry, the emergence of high-rise buildings in the city has greatly promoted the theory of deep foundation pit engineering design and the development of deep foundation pit engineering (Kayan et al., 2017). In the end of the 1980s, Construction technology continues to develop, but also has produced a large number of deep foundation pit support design and construction problems. A lot of engineering practice show that the most dangerous stages of many projects are not necessarily in the normal use stage, but in the construction stage and the aging stage (Sheng et al., 2017). Many engineering accidents often occur in the construction phase, the reason is that the construction quality is not guaranteed, the construction method of unreasonable changes, one of the important reasons is fit to the environment, geology, load and other factors. Because we lack of design, construction is caused by some mistakes and omissions.

Deep foundation pit engineering is a comprehensive technology related to many factors, and it is also a systematic engineering problem (Ursyn, 2015). Deep foundation pit has a wealth of construction experience. Combined with the proposed site of the soil and the surrounding environment, it is closely related to site engineering survey, support structure design, construction excavation, foundation pit stability, precipitation, construction management, on-site monitoring and mutual construction of adjacent sites. Many complex problems are related to geological conditions, geotechnical properties, geotechnical properties, site environment, engineering requirements, climate change, groundwater dynamics, construction procedures and methods which are the comprehensive technical disciplines and theoretically perfect, mature (Boje et al., 2016). The premise of guaranteeing stability is also an important problem of foundation pit. Therefore, in the foundation pit engineering design and construction, the need is rigorous, careful analysis and calculation.

For decades, the existing foundation pit support frame structure is more and more reinforced by the relevant scientific research and engineering technical personnel attention, which has played a great role in promoting

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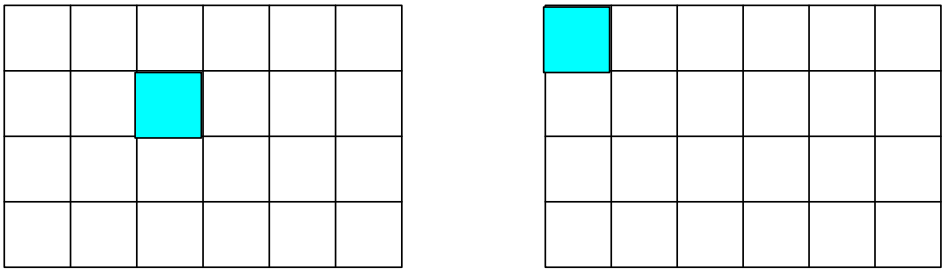
the development and application of frame structure reinforcement technology (Verdiere et al., 2014). At the same time, people are accustomed to the existing reinforcement method, and the foundation pit support structure reinforcement project is often on the matter, the lack of deeper theoretical research, so that the level of reinforcement technology helps to improve unhappy. Chinese foundation pit support frame structure reinforcement method has formed a more systematic, supporting the construction technology and technology. But in general, the construction technology and technology is still relatively backward (Barceló et al., 2015). Such as carbon fibre as the representative of the new material in the reinforcement project has not yet universal application, and its related design, construction, there are still many problems. Secondly, compared with foreign developed countries, China's testing equipment, the technical level is relatively low, in the detection software and equipment systems, there is a big gap (Ai, 2016). Therefore, the theory of reinforcement and damage of foundation damage is also of great practical significance.

2. Research on foundation support based on fractal dimension theory

The method of meta-fractal dimension has more research on geomorphic features, but less in damage of foundation pit structure. In this paper, the method of elemental fractal analysis is introduced into the degree of repair and reinforcement of the damage of foundation pit. The basic starting point of the element fractal model is that for each spatial element of the fractal object (Shao, 2016). The closer the spatial nature is, the more similar. In the process of damage repair and repair of the foundation pit structure, the closer the distance is, the more the choice of travel choice is. In order to describe the change of the damage of the foundation pit structure, the local difference of the research target and the continuity of the whole dimensional model of the analytical ideas are necessary (Xu et al., 2012). In the development of the elemental fractal dimension theory, the expression of the "sliding window" theory evolution grid is divided into the square grid with the length of r along the x and y axes according to the projection area within the land use research. The object of this paper is not limited to the target itself, but rather to the surrounding area adjacent to the target which is also included in the scope of the study.

First, the range is divided into the square grid with the length of r, and the grid is used as the local object (the grid), and the characteristic value of the object is represented by the feature of the neighboring grid (Xiao et al., 2016). The degree of damage to the foundation pit structure of each grid is related to the grid which adjacent to its surroundings, using the repair degree of damage to the foundation pit structure of the adjacent grid of the target grid.



(a) (b)

Figure 1 Mesh area and edge area of the grid calculation

3. Model establishment

3.1 Stability analysis of foundation pit

In the excavation of the foundation pit, due to the excavation of the soil in the pit, the stress field and the deformation field of the foundation are changed, which may lead to the instability of the foundation pit. So the overall pit or local landslide, foundation pit uplift and piping lead to engineering accidents (Otto et al., 2015). Therefore, in the design of foundation pit support, the need to check the stability of the foundation pit, if necessary, should take appropriate measures to strengthen the prevention, so that the stability of the foundation pit has a certain degree of security (Chen et al., 2015). We can ensure the safety of the entire excavation process.

Horizontal rib configuration gives us the horizontal ribs minimum rate requirements.

$$f_y = 0.24 f_t / f_y = 0.24 \times 1.27/300 = 0.1\% \tag{1}$$

When $h \geq 800mm$, and s=200mm, so A_{sv}=565mm^2

Table 1: Reinforcement Chart See

Type of reinforcement	Level	The real value of steel	Calculated area (mm2/m)
Longitudinal reinforcement in	HRB335	D25@150	3272[2593]
Longitudinal reinforcement out	HRB335	D25@150	3272[2593]
Horizontal reinforcement	HRB335	D12@200	565
Tie bar	HPB235	d6@100	283

3.2 Foundation stability of the anti-uplift

The bottom surface of the wall as the ultimate bearing capacity of the reference plane, slip line shape see the calculation diagram, with reference to Prandtl foundation bearing capacity formula. Regardless of the size of the foundation pit (Liu et al, 2015).
Figure 2 for the calculation and analysis of the diagram:

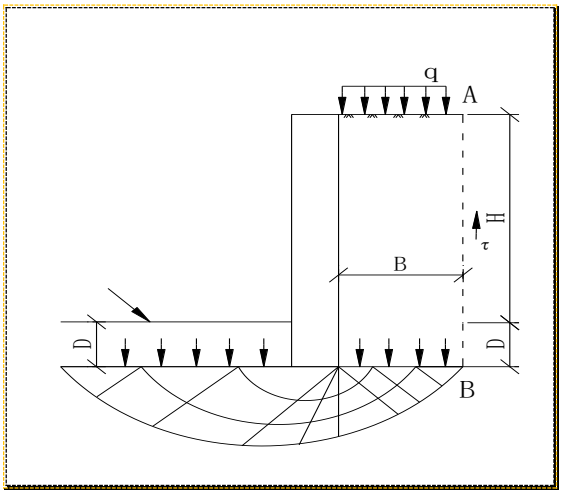


Figure 2: For the calculation and analysis of the diagram:

Calculation and analysis diagram is shown as follows.

$$K = \frac{\gamma_2 D N_q + c N_c}{\gamma_1 (H + D) + q} \tag{2}$$

D - Wall depth (m); H - Excavation depth (m); γ_1, γ_2 - Wall lateral and bottom soil gravity (kN/);
q - Bottom Overload (kN /m); N_c, N_q - The coefficient of foundation bearing capacity.
With Prandtl formula, N_c, N_q respectively means in forma (3).

$$\begin{cases} N_q = tg^2(45^0 + \frac{\varphi}{2}) e^{\pi tg\varphi} \\ N_c = (N_q - 1) \big/ tg\varphi \end{cases} \tag{3}$$

Using this method to check the anti-uplift safety factor, the requirement is $K_s \geq 1.10 \sim 1.20$. Note: The safety factor from the "construction pit engineering technical specifications".
Calculation process is as follows.

$$H = 17.4m \quad D = 11.9m \quad C = 33.4kPa \quad \varphi = 24.1^0$$

$$N_q = tg^2(45^0 + \frac{24.1}{2}) e^{\pi tg 24.1^0} = 9.61 \tag{4}$$

$$N_c = \frac{N_q - 1}{tg24.1^0} = 19.25 \tag{5}$$

When the anti-uplift safety factor is checked by this method, it is assumed that the outer side of the wall and the bottom of the pit are heavy and due to the shearing strength $\gamma_1 = \gamma_2 = 30kPa$ of the AB surface.

Solutions have to satisfy with K=4.48>1.10~1.20.
We can fulfill requirements.

3.3 Estimation and control of foundation pit damage by fractal dimension theory

Deep excavation should not only ensure the safety and stability of the foundation pit itself, but also effectively control the displacement of the foundation around the foundation pit and ensure the surrounding environment. The ground pit around the traffic is busy, and the geological conditions are poor, it is necessary to do strict control of the deformation of the foundation pit, that is, deformation estimation and deformation control.
The excavation depth of the foundation pit is 17.4m.
1) Horizontal displacement estimation

$$\delta = \frac{H^2 L}{10DB}\xi = \frac{17.4^2 \times 60}{10 \times 11.9 \times 0.8} \times 0.8 = 152.65mm \tag{6}$$

H—Depth of excavation; B—Wall thickness; D—Retaining wall depth; L—Section excavation length; δ – Displacement wall factor, selection is 0.8
2) Estimation of foundation pit uplift
According to the actual situation, using Tongji University proposed simulation test empirical formula:

$$\delta = -29.17 - 0.167\gamma H' + 12.5\left(\frac{D}{H}\right)^{-0.5} + 5.3\gamma c^{-0.04}(tg\varphi)^{-0.54} \tag{7}$$

$$H' = H + \frac{P}{\gamma} \tag{8}$$

δ- foundation pit uplift; *H* - depth of excavation; *P* - the bottom of the pit is overloaded;
c, φ, γ - cohesion of soil, internal friction angle, bulk density *D* - continuous wall depth.
δ=-29.17-0.167×18.1×18+12.5×1.21+5.3×18.1×0.86×1.54=61.43mm

4. Results and discussion

In the construction project, the foundation pit support frame structure is one of the relatively wide application forms. From the middle of the last century, the frame structure has been widely used. The purpose of strengthening the existing frame structure is used to improve the strength, stiffness, ductility, stability and durability of the frame structure. And the existing foundation pit support frame structure helps to take the corresponding reinforcement measures which can reduce a lot of infrastructure investment and bring huge economic social benefits (Maksimović et al., 2017). At the present stage, with the deepening of the research on the structural reinforcement of the building, the method of strengthening the foundation pit frame structure is more. The reinforcement method commonly used in the project is as follows.
1) Increased section reinforcement method
Increasing the cross-section reinforcement method is a reinforcement method to increase the cross-sectional area of the support structure of the foundation pit or to increase the bearing capacity to improve its bearing capacity and to meet the normal use or to change its natural frequency. In this way, while the bearing capacity of the component is improved, the original strong beam weak column is changed to strong column weak beam to a certain extent. The results show that the increase of one or two closed stirrups in the core area will effectively reduce the cracking of the foundation pit support in the joint area, and it will also improve the seismic capacity of the joints. At the same time, the ductility of the components can be improved by the treatment of the encryption zone. To a certain extent, the cross-sectional size will use the space to reduce, and sometimes also be subject to restrictions on the use.
2) Outsourcing steel reinforcement method
Outer steel reinforcement method refers to the foundation pit support column or internal perfusion adhesive to achieve the overall force of a reinforcement method. Compared with the large section reinforcement method, the steel cladding method can make the original parts section basically unchanged, and the construction is convenient, but the bearing capacity of the foundation pit support can be greatly improved.

3) Change the structure of the force system reinforcement method

Change the structure of the force system reinforcement method that the middle part of the structural components to add fulcrums, joists or multi-span simple beam into a continuous beam and other methods. In the frame structure, the method is actually through the appropriate parts of the additional shear wall, the original frame structure into a framework - shear wall structure. The method of adding shear wall is a kind of reinforcement method which is widely used at present. When using this method, two aspects should be considered first. On the one hand, the position and quantity of the shear wall are determined, and then the new shear wall and the original frame structure.

4) Pre-stressed reinforcement method

Pre-stressed reinforcement method is the use of external pre-stressed steel rod or steel brace, so that the original structure or component of the force to improve or adjust the indirect reinforcement method. Reinforced frame beams with pre-stressing are already subjected to reinforcement and have been cracked before reinforcement. After the reinforcement of the pre-stressed rod, the crack of the original beam is reduced or even closed, and the original frame beam is generated to reverse the load deflection of the part of the original beam, thus improving the mechanical performance of the frame beam structure.

5) Bonded steel reinforcement method

Bonded steel reinforcement method is the use of high-performance steel structure which is bonded to the surface of the foundation support components, so that steel and foundation pit support helps to form a whole, we can strengthen and enhance the original structure of the effective improvement and bearing capacity. This reinforcement method construction period is short, sticky steel space is very small, almost no change in the original shape of the component (Yang, YY., 2015). The technology is mainly used in foundation pit support broken beam, broken column, shock absorption and lifeline building seismic reinforcement.

6) Sticky carbon fiber cloth reinforcement method

Carbon fiber reinforcement method is a new, high-tech structural reinforcement method. Carbon fiber strength is generally ten times the strength of ordinary steel, elastic modulus is several times the steel, is an excellent structural reinforcement material. So you can use high-performance structural adhesive to the carbon fiber material paste and the original component surface, to the original structural components of the reinforcement and improve the original components of the seismic performance. At the same time, carbon fiber reinforcement method has the characteristics of high strength and high efficiency, thin material, light weight, convenient construction and durable corrosion resistance. However, the use of carbon fiber reinforced method of adhesive performance requirements are relatively high, whether it is carbon fiber cloth or adhesive with a major dependence on foreign imports, the corresponding high cost, such as large-scale promotion of this method there are still some difficulties.

7) Foundation pit support replacement technology

When the beam, plate or column and other components of the foundation pit support strength can not meet the design requirements or a lot of difference, can not meet the quality requirements of the pit support chisel, replaced with the requirements of the new pit support, for Beam plate as long as the set of templates and support, while adjusting the steel is easier to achieve. However, for the column, the whole root or a region, especially when it has been built above the multi-layer pillars, the pit support replacement is very difficult. So must do a good job supporting the design to meet the strength requirements at the same time should meet the requirements of stable deformation, the construction process must be monitored to ensure the absolute safety of the reinforcement process. And the replacement of the foundation pit support should be compared with the original building foundation pit support strength level, while the use of micro-expansion of the pit support.

5. Conclusion

Deep foundation pit is based on the construction of wide applications and its complex, variability. In the construction program which is not considered, it can easily lead to sudden problems, to the property and personnel security to bring a greater threat. This requires engineering staff according to the actual conditions, which is combined with engineering experience, the various possible support programs have to compare and optimize. In order to ensure the safety and applicability of the support structure in engineering applications, deep foundation pit excavation and support belongs to the underground structure of the construction mechanics category, the program design involves engineering structure, construction knowledge, and rely on experience which has technology and theory between the close combination. There are many ways to reinforce and repair the existing frame structure. The choice of reinforcement method should be based on the results of reliability identification and the characteristics of structure. The factors such as reinforcement effect, construction simplicity and economy should be taken into account. At the same time, the identification and reinforcement of the building is a long way to go, do a good job of each reinforcement project design and

construction, to ensure the quality of reinforcement works, we engaged in building identification and reinforcement workers duty-bound.

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