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Research on the effective application of the foundation reinforcement technology in civil engineering

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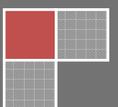
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ABSTRACT

Since 21st century, with the rapid development of science and technology, the construction industry has been booming. The advanced science and technologies have been fully applied in the construction of civil engineering, so the civil engineering has become the foundation engineering of the national economic strength, playing an important role in the social development. The foundation reinforcement technology has attracted more and more attention for the reason that it can not only effectively increase the strength and bearing capacity of civil engineering, but also improve the defective characteristics of the natural foundation so that the improving strength and stability of the foundation can satisfy the construction requirements of civil engineering. After introducing the concept of civil engineering, this research explains the concept of the foundation reinforcement technology and introduces the development history and status of the foundation reinforcement technology. Then, this research gives a technical analysis of its application and innovation, so the research proposes and prospects its development trend, aiming to have a comprehensive understanding of the foundation reinforcement technology and provide powerful technical support for the construction of civil engineering. Next, this research analyzes the strategies and requirements under the construction of the foundation reinforcement and discusses the normal foundation reinforcement technologies and their range of use and requirements. In the end, this research analyzes the current development trend of the foundation reinforcement technology.

KEYWORDS

Civil construction; Foundation; The reinforcement technology; Structural design.



INTRODUCTION

Closely connected with the daily life, civil engineering has already developed into the impetus of the national economic growth, playing a vitally important role in the improvement of living standards and qualities, so they are close and inseparable. As a result, there are demanding requirements for the quality of civil engineering, because it relates to people's security of life and property, which reflects that the civil engineering has an extraordinary meaning for social development. The structure and the foundation reinforcement technology affect the quality of civil engineering, so there must be a comprehensive consideration during the design. The modern foundation reinforcement technology has become the key element influencing the quality of civil engineering. Therefore, construction designers have to emphasize considering how to reasonably utilize different kinds of foundation reinforcement technologies to avoid adverse effects. This research analyzes the application of the foundation reinforcement technology for civil engineering and explains the means to ensure the construction quality of civil engineering and to ultimately improve the overall quality of civil engineering. The foundation reinforcement is the most basic groundwork and its related work contents are complicated, which involves how to choose the reinforcement technology based on different geological conditions, and so on. At the beginning of the design, the constructors shall check twice these most basic questions to ensure the accuracy of acquired data so that the best foundation reinforcement technology can be achieved.

BASIC CONCEPTS

Civil engineering

Civil engineering is a science and technology collecting all architecture and engineering facilities, whose main activities include reconnaissance survey, design, construction, maintenance, repair and so on. Besides, most construction objects are buildings, roads, railways, bridges, canals, dams, and etc. Civil engineering has positive effects on the social benefits and economic development and its quality has always been the center of social infrastructure, so the priority of constructors is to ensure the structure quality of civil engineering to meet the requirements in the construction process. Except for its own weight of civil engineering, civil engineering must bear load and wind action. Besides, hygral change has a great influence on civil engineering. Moreover, civil engineering structure lying in earthquake zone shall take into consideration earthquake resistance. The effects of artificial functions such as exploration and vibration on civil engineering cannot be ignored.

The foundation reinforcement technology

Early in the 20th century, the foundation reinforcement technology appeared in civil engineering and it fully developed in 1950s and 60s. The main reinforcement method was the dynamic consolidation first invented by the French back then. In 1990s, the reinforcement technology in China developed to some degree, the main method of which is the pile foundation technology. With the rapid development of Chinese economy, Chinese civil engineering has fully utilized these reinforcement methods. Moreover, China has introduced relevant laws and regulations to give institutional regulations to the foundation reinforcement technology, as shown in TABLE 1.

TABLE 1 : The institutional requirements of the foundation reinforcement technology

| Design Condition | Load Combination | Design Object | Choosing Range |
|----------------------------------|---|---------------|---|
| Limit stage of carrying capacity | Fundamental combination or simplified combination | Basement | The basic calculation about curve, shear and punching, and etc. |
| | | Foundation | Slip, overturning or stability, and etc. |
| Serviceability limit state | Characteristic combination, Frequent combination, Quasi-permanent combination | Basement | Crack, deflection, and etc. |
| | | Foundation | Settlement, differential settlement, inclination, and etc. |

Generally, the foundation reinforcement technology mainly aims to increase the shear capacity of the foundation, because shearing failure is one of the most quality detriments. It will cause serious consequences such as insufficient carrying capacity of the foundation, bad stability of the whole structure, decreasing the slope stability and so on. Moreover, it will influence the compressibility of the foundation soil and decreases the settlement degree of the foundation. On account that the scale of modern architecture is more than ever before, the requirements for the foundation are becoming increasing. Once the complicity exceeds standards, the settlement will occur. As a result, the low compressibility must be increased to decrease the differential settlement. Furthermore, it benefits to improve the dynamic characteristics of the foundation soil. It mainly presents that the foundation soil will be liquefaction as earthquake, which results the uneven sinking of the foundation. Thus, before the construction of civil engineering, the foundation liquefaction problem must be taken into consideration to improve the seismic capacity of the foundation.

The foundation reinforcement technology appeared in ancient times, and there is a long history in Chinese history. The technology mainly depended on people's long term practice accumulation. The normal means in China was ram crushed stone and other materials into the soft soil. The compacted lime soil and concrete were also widely used.

In general, there are two phases of Chinese modern foundation reinforcement technology development. The first phase is the initial stage in 1950s and 1960s. Most of technologies were learned from the former Soviet Union. The utilized method was the shallow treatments such as cushion, as shown in Figure 1; the second phase has developed fast since 1970s. A large number of advanced foreign foundation reinforcement technologies have been introduced into China, promoting greatly Chinese foundation reinforcement technology development. Moreover, according to the actual conditions, engineers research and develop and master several foundation reinforcement technologies which are suitable for Chinese conditions, such as vacuum preloading method and low intensity pile composite foundation technology.

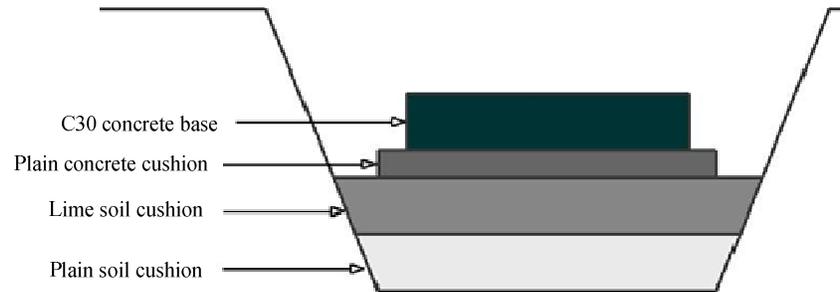


Figure 1 : Diagram of cushion reinforcement technology

The essential element related to the quality safety of modern civil engineering is the foundation reinforcement technology. All kinds of foundation reinforcement technologies have been applied in the foundation processing, so adopting measures suiting local conditions can avoid hidden danger in civil engineering construction caused by improper reinforcement technology. At present, the normal foundation reinforcement technologies are shown in Figure 2.

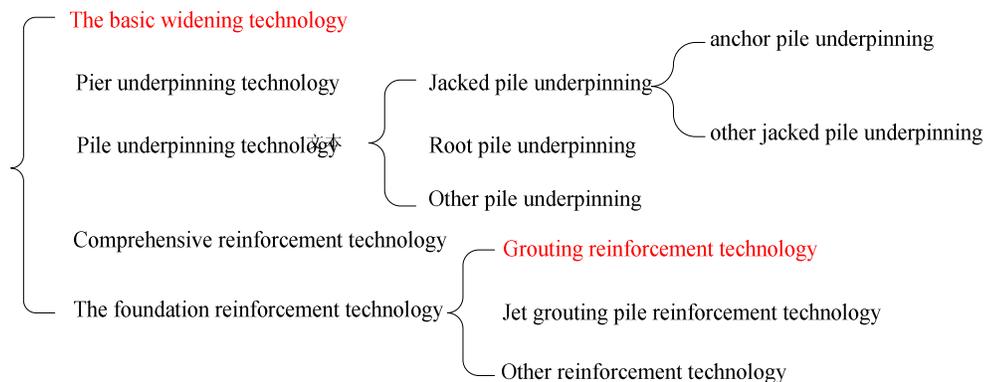


Figure 2 : Normal foundation reinforcement technologies

THE EFFECTIVE APPLICATION OF THE FOUNDATION REINFORCEMENT TECHNOLOGY IN CIVIL ENGINEERING

The requirements of civil engineering during construction

The elements in the engineering such as geology, water level and climate must be fully recognized and collected in the process of construction of civil engineering. For instance, a number of regions in China belong to geological clay layer and rubble layer under it, so the influence of rubble layer on the foundation reinforcement must be considered during foundation reinforcement. Normally, geological analysis is done by drill. First of all, information collection must be well done before foundation reinforcement, which includes contents as following:

- (1) Survey data of foundation engineering;
- (2) Observation data of settlement and differential settlement;
- (3) Superstructure data and basic design data of architecture;
- (4) Surroundings data (underground pipelines, adjacent building structure and basic information, and etc.)
- (5) Architectural construction data (avoid construction quality causing engineering accident, and etc.)

Besides, the detection of the following contents shall be paid attention during foundation reinforcement.

- (1) Settlement observation: settlement and sedimentation rate;
- (2) Observation and measurement of crack: with or without crack, and crack developing;

- (3) The change of groundwater level;
- (4) Detection of surrounding situation: surrounding roads, ground surface, water supply and sewerage, and etc.

Moreover, after a series of experimental tests, the best foundation reinforcement means in civil engineering can be achieved. Experimental program must be confirmed before tests, which demands that the tests shall be arranged based on geological conditions, architectural requirements and utilized materials. It is best to adopt actual construction conditions to do the tests to ensure that the experimental results are identical with the real construction situation to the largest extent. After finishing the tests, data shall be analyzed to search the weakness and possible defects, and then prioritizing the program.

While acquiring the construction speed and quality in the process of civil engineering, the real time monitoring shall be ensured which means to combine information management to detective and manage the whole construction. Normally, it is very difficult to apply the foundation reinforcement technology as construction. Some step was inappropriately dealt with would cause serious hidden danger. Thus, the existing problems can be found by the detection technology so that the results can be reflected in time and make corrections. The contents of construction detection include a few aspects as following: land subsidence, groundwater level, architectural lean, and etc.

The common foundation reinforcement technologies

Grouting reinforcement technology injects grouting into layers through grouting lines at a constant speed by adopting hydraulic pressure, atmospheric pressure or electrochemical theory. Then, grouting permeates into rock cracks or soil grains by the means of filling, permeability or compaction. As a result, grouting will squeeze water and gas in the layers, and the consolidations after hardening have some advantages including sound chemical stability, high strength and high waterproof. There are several categories of grouting reinforcement technology, including seep-in grouting, fracture grouting, compaction grouting, and electrochemical grouting. The application range of grouting is presented as following:

The foundation reinforcement of metro construction. There is few surface deformation by utilizing grouting method while construction. Besides, it also decreases groundwater flow and the deformation and displacement of construction soil, and etc;

- (1) Dam sandy gravels can prevent infiltration effectively;
- (2) Pulling anchor grouting is mainly applied for the anchoring section construction in the excavation of deep foundation pit;
- (3) Rectification and reinforcement of buildings;
- (4) Treating structural cracks of concrete and leaking stoppage of impounding reservoir.
- (5) The common grouting materials are shown in Figure 3.

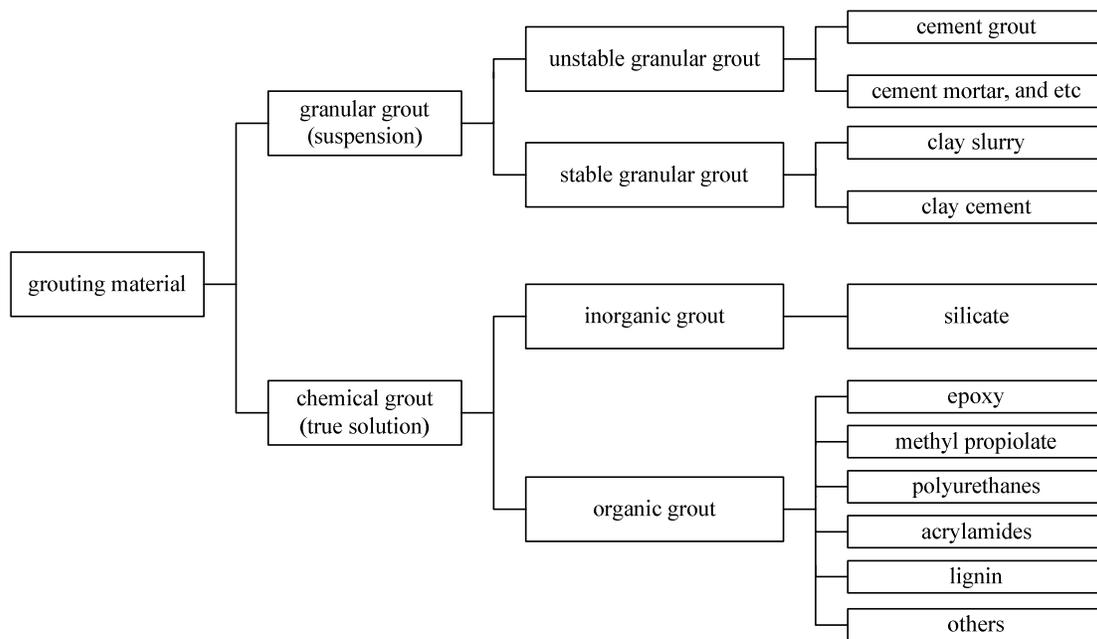


Figure 3 : The common grouting materials

Compaction grouting’s first step is to inject thick grout into the foundation. Then the soil surrounding the grouting points gradually forms the grouting bubbles caused by the pressure of grout. The increasing grouting bubbles will raise the ground surface or sinking buildings. This measure is usually adopted in sand foundation or clay foundation which has a good drainage capacity. Figure 4 is the diagram of the compaction grouting.

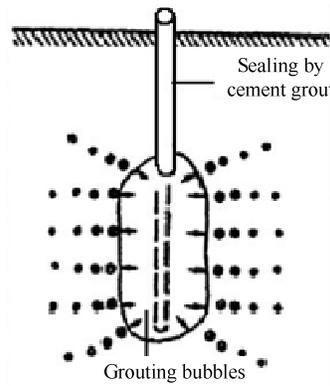


Figure 4 : The diagram of the compaction grouting

Dynamic compaction is an easy method. The free fall of heavy hammer constructs powerful impact energy for the foundation. Repeat the free fall several times until the action compacts the ground. It leads to the change of grainy structure in the foundation, so the denser solid can be acquired and the strength of the foundation can be improved a lot.

The main steps of the dynamic compaction process are as following:

- (1) Ground flat;
- (2) Inject hardcore bed;
- (3) Dynamic compact broken stones;
- (4) Flatten the rubble layer;
- (5) The second compaction;
- (6) Flatten and put geotechnical cloth;
- (7) Backfill weathered stones and vibrating compact several times.

Replacement cushion method means removing the foundation which does not meet the requirements and refilling and compacting appropriate soil so that the foundation with powerful bearing strength will be achieved and the resistance to deformation will be improved. Generally, there are plain soil cushion, lime soil cushion, sand-gravel cushion, hardcore cushion, and etc. Normally, the common construction methods are rolling machine, heavy tamping and flat-panel vibration. While the sand-gravel cushion shall be utilized insert vibration method, filling-shaking method, and etc.

Drainage consolidation method mainly used for draining void underground water, decreasing the volume of void and increasing the dense of soil. Therefore, the stress relief of soil will be greatly improved, and shear strength will be increased a lot. There are surcharge preloading method aiming to the depth about 10 meter and vacuum preloading method aiming to the depth about 15 meter.

Freezing method changes the characteristics of the foundation through controlling temperature. Consequently, frozen soil with good strength and waterproof can be acquired. It is realized by artificial refrigeration and widely applied in civil engineering such as railway, tunnel, and etc. There are two systems: cooling circulatory system and brine circulation system. The specific freezing installation is presented in Figure 5.

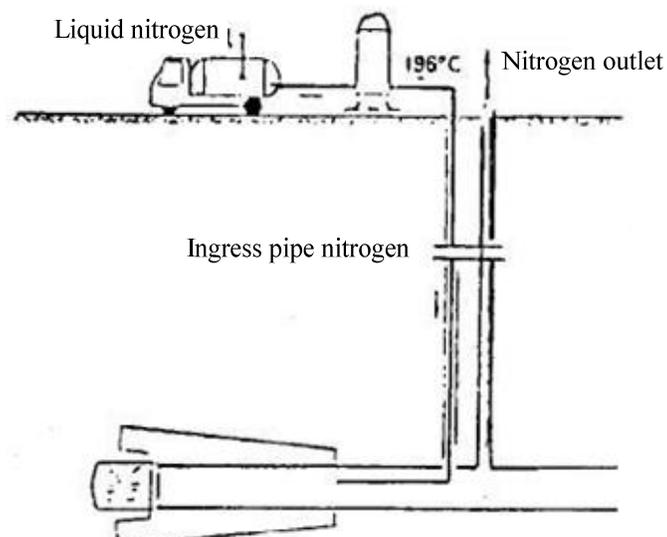


Figure 5 : The diagram of freezing installation

Comprehensive reinforcement method: the above methods have different advantages but comparatively narrow application range, so their limitations confine their utility. Generally speaking, the most basic principles of foundation reinforcement are safe and practical and at a reasonable cost. However, the current single reinforcement technology cannot satisfy all these principles, so the constructors combine different reinforcement technologies to play their different strength, making the foundation of civil engineering much solidier. The condition of adopting the comprehensive reinforcement method is to master fully parameters of the architecture and building land and compute scientifically. The design cannot be made until the result is calculated and concluded a comprehensive foundation characteristic. Then, combining different positive and negative features form a complete solution.

The development trend of current foundation reinforcement technology

On the whole, Chinese present foundation reinforcement technology has made significant progress and approached advanced international level. The development trend of foundation reinforcement technology mainly includes four points.

- (1) Widely adopt composite material foundation, which mainly presents that macromolecule composite materials of civil engineering are injected into the soft ground. Thus, high elasticity complex foundation can be obtained. The reinforcement foundation has the bearing capacity which is three or four times than before. It will prevent settlement of civil engineering and improve the stability at the same time;
- (2) During foundation reinforcement process, integrate more different construction technologies and make a better combination so that the better technology will be achieved;
- (3) The foundation reinforcement technology will be integrated and penetrate into the basic engineering construction so that the better and more stable and more reliable civil engineering can be acquired;
- (4) New materials will better reflect energy conservation and environment protection, and persist in the sustainable development way of environment protection.

CONCLUSION

As the base of civil engineering, the quality of foundation has always been the most crucial and important link. If there is no appropriate approach, the superstructure of architecture will have major potential risk. This paper introduces several common foundation reinforcement technologies with advantages and disadvantages, as a result, the using method shall be confirmed after further measurement and test by the construction designers. In recent years, Chinese has made great progress in the foundation reinforcement technology in the field of civil engineering, having excellent achievements. During the term, China has constantly absorbed advanced foreign technologies and theories and searched the experience suitable for Chinese geological environment, and then gradually has formed Chinese unique foundation reinforcement technology. That is to say, many aspects of Chinese reinforcement methods have already reached the world advanced level. However, confined with the development of instrumentation and machine building industry, there are many improvements of the foundation reinforcement technology demanding to work on and many fields are faced with innovation. The integration and penetration of the foundation reinforcement technology and the basic construction technology have gradually raised the stability and security of the quality of civil engineering. The future foundation reinforcement technology will develop forward the direction of energy conservation and environment protection. The environmental design with new technologies and new materials is the sustainable development road.

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