Research on Green Geotechnical Engineering Design and Construction Technology

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Abstract. Since the 21st century, China's economic industrialization and urbanization have rapidly advanced, and the quality and speed of urban comprehensive construction have significantly improved. The geotechnical engineering industry has also ushered in unprecedented development opportunities. With the increase of key engineering projects such as urban underground complexes and rail transit, the geotechnical engineering industry is facing multiple challenges including complex construction environments, large project scales, and high resource consumption. It not only restricts the high-quality development of cities, but also puts forward higher requirements for the iterative upgrading of geotechnical engineering technology and equipment. This article focuses on the challenges faced by the geotechnical engineering industry under the dual carbon target, and introduces green technologies and practices in geotechnical engineering from the aspects of green geotechnical engineering design, engineering construction, and recycling. Finally, it is pointed out that future geotechnical engineering needs to integrate multidisciplinary knowledge, explore theoretical development, promote collaborative innovation and development of green geotechnical engineering design, construction technology, and equipment, construct an industrial system for geotechnical engineering, and provide strong support for the green development of the geotechnical engineering industry.

Keywords: Green geotechnical engineering, Carbon Peaking and Carbon Neutrality, Green geotechnical engineering design, Green geotechnical construction

1 Introduction

With the increasing severity of global climate change, achieving the goal of carbon peaking and carbon neutrality has become a common responsibility and mission of all countries. In this context, geotechnical engineering, as an important branch of civil engineering, plays a crucial role in promoting the low-carbon and green development

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of the construction industry. The urban spatial development is facing a shortage of land resources, traditional construction machinery and methods are no longer able to meet the actual construction needs of the project, with low intelligence, poor data fidelity, and deep mining effects, seriously affecting the progress and quality of engineering construction[1-3]. The higher requirements have been put forward for urban geotechnical engineering construction equipment and machinery. Therefore, the in-depth exploration of green geotechnical engineering design and construction technology is of great significance for promoting the sustainable development of the geotechnical engineering industry.

Based on the background of the carbon peaking and carbon neutrality evolution, this paper firstly reveals the main problems faced by the geotechnical engineering industry in the process of green and low-carbon transformation; Secondly, from the aspects of green geotechnical engineering design and construction, combined with relevant engineering cases, this paper explores the countermeasures and suggestions for green geotechnical engineering in terms of technological innovation and construction management; Finally, looking forward to the future development trend of green geotechnical engineering, providing theoretical support and practical guidance for the industry to achieve the carbon peaking and carbon neutrality goals.

2 Background of dual carbon evolution and challenges faced by geotechnical engineering

2.1 Background of dual carbon evolution

Due to the impact of global climate change, the frequency, intensity, and scope of various extreme weather events such as floods, extreme rainfall, glacier melting, sea level rise, and drought are increasing, posing a threat to human survival[4-5]. Extreme weather can significantly alter the water content, stress field, and engineering properties of rock and soil, leading to geological disasters and posing numerous new challenges to the current geotechnical engineering industry.

2.2 Challenges faced by geotechnical engineering in the dual carbon strategy

The contradiction between engineering construction and ecological environmental protection is prominent. The problems caused by engineering construction activities such as environmental pollution, the imbalance between man and land, and engineering disasters are very prominent. The difficulty of engineering construction control increases sharply under the rigid constraint of ecological environment.

The contradiction between traditional construction methods and green and low-carbon technologies. The traditional construction industry has backward construction methods and large resource consumption, and the demand for green construction technology innovation such as low-carbon technology is gradually increasing.

The contradiction between engineering practice preceding theory and fundamental research. The current data on the energy consumption of raw materials for green geotechnical engineering construction is extremely scarce, and the relevant basic theories relied on in geotechnical engineering technology practice are not clear enough, which increases the difficulty of applying green geotechnical technology.

3 Theory and methods of green geotechnical engineering

3.1 Connotation of Green Geotechnical Engineering

Green geotechnical engineering refers to the implementation of the concept of green, low-carbon, and sustainable development throughout the entire life cycle of geotechnical engineering survey, design, construction, operation, and recycling[6-7]. It aims to save resources, protect the environment, reduce pollution, improve efficiency, and enhance quality, ultimately achieving harmonious coexistence between site formation planning, underground space construction, environmental geotechnical engineering, geological disaster management, and the natural environment.

3.2 Green geotechnical engineering design

Overall design combining support structure and main structure. During the construction period, the external walls of the underground structure or the beams, slabs, and columns of the underground structure can be used as support structures for the foundation pit. Therefore, it is possible to not set up or only set up partial temporary support systems, which can effectively save project costs and control the deformation of the surrounding rock during excavation[8]. At present, the design concept of main and temporary combination has been gradually promoted and applied. However, in practical production, methods such as design, deformation control, and construction technology between the support structure and the main structure still need to be improved (Fig. 1).

Fig. 1. Schematic diagram of support design for Wuhan Tianyue Xingchen foundation pit project

Problem and environment oriented solution design. The determination of the support design scheme based on the severity of the surrounding environment of the foundation pit, as well as the depth of excavation, engineering geology, and hydrogeological conditions, is actually a design method guided by problems. Thus, different safety thresholds are assigned to foundation pits under different environmental constraints, and different support design methods are selected based on the characteristics of the problem. Similarly, the selection of construction methods also needs to consider constraints such as surrounding space, geological conditions, and environmental limitations. The foundation pit of Wuhan Zheshang Building is located in a bustling urban area, with a large excavation depth of 14m. It adopted underground continuous walls, three ring beam support structures, groove walls, and passive area reinforcement and backfilling technology. During the construction process, the foundation pit was successfully dewatered without any problems such as inrushing and seepage (Fig. 2).

Fig. 2. Schematic diagram of foundation pit support design for Zhejiang Commercial Building

Dynamic conceptual design of partitioning and blocking. For ultra large and deep foundation pits, the design concept of zoning, segmented design, and combination of light and heavy is mainly adopted. This can effectively control deformation and ensure safe operation in the case of ultra large foundation pits. However, corresponding effective measures need to be taken to reduce the unbalanced force and differential deformation between adjacent sections. In addition, it meets the progress construction requirements of the owner for different individual units during the construction process. For the division of key protection areas and non key protection areas, targeted design of support measures should be carried out to achieve economic and reasonable goals.

3.3 Green geotechnical engineering construction

In recent years, the rapid development of urban infrastructure construction has promoted the development of geotechnical engineering construction equipment and technology. It is particularly evident in deep foundation pit engineering. The urban land is expanding and foundation pit construction faces more complex environmental conditions. The increasing number of deep foundation pits and construction costs have posed severe challenges to foundation pit engineering construction, and higher requirements have been put forward for foundation pit engineering construction. The foundation pit support technology is mainly reflected in the following aspects.

Vertical enclosure technology. The vertical support structure of foundation pits includes composite steel pile support technology, leg type underground continuous wall, and inclined pile support technology. Among them, PC construction pile technology is widely used in the field of foundation pit support in municipal, subway, and industrial structures, and has achieved good application results. Due to its prefabricated structure, fast construction speed, no mud production, connection through locking buckles, and ability to resist lateral pressure, it also serves as a water stop (Fig. 3).

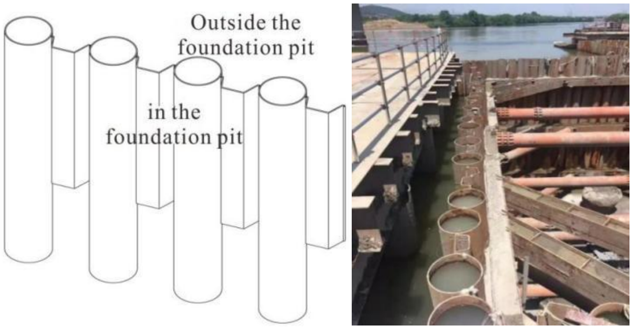

Fig. 3. Schematic diagram of vertical enclosure structure for PC construction method piles (a. schematic diagram of enclosure structure; b. on-site construction diagram)

Horizontal support technology. In the horizontal support technology of foundation pits, the application of section steel combination support technology is relatively wide, mainly including types such as section steel combination, tension string beam, and fish belly beam. The steel composite support structure includes supporting beams, stress conversion components, support battens and other components, which have advantages such as fast construction speed, stable stress, multiple application scenarios, and minimal environmental impact. In the actual construction process, the combination technology of steel profiles is a prefabricated structure, with fast construction speed, high degree of reusability, and good stability. The combination of steel sections adopts node rigid connection, with a large spacing between supports and a relatively open construction surface. It is suitable for most foundation pits and can be mixed with reinforced concrete supports (Fig. 4).

Fig. 4. Schematic diagram of horizontal support enclosure structure

Freezing method construction technology. The artificial ground freezing method is mainly used as a special reinforcement technology for water rich and weak strata, and is widely used in rail transit construction and mine construction. Its principle is mainly to use artificial refrigeration technology to freeze the water in the surrounding soil in the work area into ice, and bond it with the surrounding soil to form a frozen soil wall or sealed frozen body. Under its protection, it is used to resist external soil and isolate groundwater, improving the construction progress of underground engineering. The freezing method construction can efficiently isolate groundwater, has strong resistance to permeability, and high frozen soil strength. It can effectively control construction deformation and the impact of adjacent underground construction, and has relatively less environmental pollution to the work area, effectively shortening the construction period. At present, the freezing method has a wide range of applications, and is more commonly used in scenarios such as subway shield tunnel excavation construction, underground engineering leak sealing and rescue construction.

Ecological restoration of slopes. According to the comprehensive needs of slope safety, ecological sustainability, landscape coordination and engineering economy, the interaction of plants, rock and soil is used to protect the surface of slope, so that it can not only meet the requirements of slope surface stability, but also restore the destroyed natural ecological environment[9-10].

3.4 Recycling

Recycling mainly refers to the process of collecting, processing, and reusing waste or abandoned resources to reduce negative impacts on the environment. It mainly includes the recycling of construction waste and the recycling of abandoned underground spaces[11]. This paper mainly introduces from the following two aspects:

Solid waste grouting filling technology. By moderately crushing, processing, and testing solid waste such as urban construction waste and coal gangue, they are produced as recycled filling materials for goaf filling, achieving a dual effect of environmental protection reuse of solid waste and reducing the cost of engineering materials (Fig. 5).

Fig. 5. Solid waste grouting filling process

Secondary development and utilization of abandoned mines. The secondary development and utilization of abandoned mines aims to transform abandoned mine resources into new uses with economic and environmental benefits[12] (Fig. 6). This process is mainly based on the unique spatial structure characteristics of the mine and possible residual resources, and through scientific planning and reasonable transformation, the maximum utilization of resources is achieved. A common way of secondary development and utilization is to transform it into a pumped storage power station. Utilizing the goaf formed by coal mining to save some coal mine production water for the construction of distributed coal mine underground reservoirs, while fully utilizing the abundant solar and wind energy resources as well as abundant electricity in the western region, achieving multiple goals such as water storage, energy storage and power generation, and mine water recycling, and achieving coordinated development of renewable energy development and green mining of coal resources.

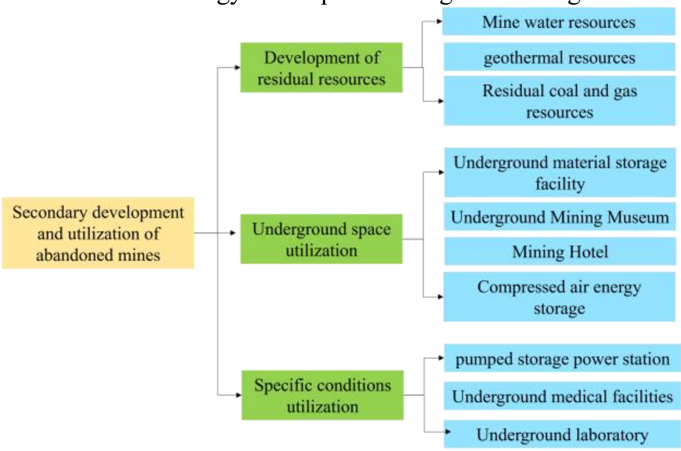

Fig. 6. Classification of Secondary Development and Utilization of Abandoned Mines

4 Outlook and suggestions for green geotechnical engineering

(1) Integration of multidisciplinary knowledge to explore theoretical development and innovation. It is necessary to focus on geotechnical engineering mechanics

experiment and theoretical analysis, integrate the theoretical innovation of geotechnical engineering in microbiology, physical mechanics, material chemistry and other related fields, and further develop green, low-carbon and recycled geotechnical engineering technology and construction process methods.

(2) Advocate the concept of green survey, improve the green and low-carbon technology system, and encourage the application of green building materials and low-carbon technology in the whole life cycle of engineering construction.

(3) Actively build a digital geotechnical engineering application system based on integrated technologies such as BIM (information), GIS (positioning), big data, cloud computing, 5G, BeiDou GPS, RS, so as to achieve both green and digital transformation of geotechnical engineering.

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