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Discussion on Research Status of Prestressed Anchor Reinforcement Technology

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Abstract: The technology of prestressed anchor bolt reinforcement is to strengthen the friction resistance to prevent the rock mass from sliding by burying the anchor bolt or the anchor bolt under the stratum and closely fitting the rock mass. With the continuous development and progress of science and technology, prestressed anchor reinforcement technology has been widely used in slope, tunnel, underground cavern, foundation pit, dam and anti-tipping, anti-floating and other engineering construction, with remarkable results. According to the current theoretical research status of prestressed anchor reinforcement technology and the experimental research status of prestressed anchor reinforcement technology, this paper analyzes the current design concept, theory and method of prestressed anchor reinforcement technology, the understanding of engineering characteristics and design ideas, and other development trends of rock and soil mass anchorage design.

1. Introduction

With the vigorous development of China's infrastructure, more and more complex engineering geological problems come into view. Most of China's terrain is relatively complex, with many mountainous and hilly areas. It is the basic policy of social development to carry out infrastructure construction in these mountainous and hilly areas so as to make the life of the people in those mountainous areas more convenient. Among them, the stability of rock mass has always been the focus and difficulty of infrastructure construction[1]. At present, prestressed anchor reinforcement technology is used for most rock masses whose stability cannot meet the requirements. Prestressed anchor reinforcement technology is an important branch of geotechnical engineering in recent years. This technology gives full play to the bearing capacity of rock mass, closely connects solid and rock mass, and uses the shear strength of anchor and rock mass to transfer the tensile force of solid to control the deformation of rock mass and ensure the stability of rock mass. The rock mass after reinforcement is an important guarantee for construction safety, so the in-depth study on the mechanism of prestressed anchorage has significant economic and social benefits.

2. Theoretical research status of prestressed anchor reinforcement technology

Prestressed anchor reinforcement technology has been widely used in engineering. Prestressed anchorage is not passively subjected to the load generated by the rock and soil mass, but makes full use of the high tensile strength of the prestressed steel strand to actively strengthen the rock and soil mass, effectively inhibit the deformation of the rock and soil mass, prevent the collapse and slip of the rock and soil mass, and ensure its stability. From the 1960s, according to the method of material mechanics to establish the model and calculation, gradually formed a variety of anchoring support theory. Among them, suspension theory, composite beam theory, extrusion reinforcement theory, rock strength theory, pin theory and so on have been recognized in the engineering and theoretical circles.

(1) Suspension theory. The principle of suspension theory is as follows: the rock bolt support suspended the weak, loose and unstable rock mass in the stable rock mass through the anchor rod to prevent it from falling off the layer. The anchor bolt mainly provides enough tension to overcome the gravity or sliding force of the sliding rock body and maintain the stability of the rock and soil body. This kind of effect is especially prominent in underground engineering anchorage.

(2) Composite beam theory. The principle of the composite beam theory is to regard the thin layered rock mass without anchorage as simply supported beams superimposed together, and the shear resistance between layers is very small. Therefore, when the load is applied, a single thin layer beam will produce bending moment deformation, and the lower edge and the upper edge will be strained and compressed respectively. After anchoring, the individual thin layers are fastened together, each layer is squeezed, the friction resistance between the layers increases and the internal stress and deflection are greatly reduced, so the bending strength of the thin layer assembly after anchoring is greatly enhanced. When the anchor bolt is inserted into the rock body to a certain depth, the beam superimposed with several layers becomes a composite beam, thus improving the bearing capacity of the rock and soil body. Each anchor rod added to a simple beam is equivalent to adding a support span to reduce by half, so the bending moment stress is equivalent to 1/4 of the full-span beam, and the deflection is equivalent to 1/16 of the full-span beam. This composite beam is more suitable for thin rock and soil body.

(3) Extrusion reinforcement theory. The compressive reinforcement theory is to verify the effect of compressive reinforcement of bolt through experiment. In the experiment, after the prestressed bolt is installed on the elastic body, a conical compression belt is formed in the elastic body, and the prestressed bolt is arranged according to a certain distance, so that the adjacent compression area of the bolt overlaps to form a continuous compression belt with a certain thickness. The General Research Institute of Metallurgical Construction in China has simulated the effect of prestressed anchor bolt reinforcement in broken strata. In the laboratory, crushed stone and concrete fragments were used as materials to build a broken zone model. After the reinforcement of prestressed anchor rod, the mechanical properties of the model were greatly improved, and the gravel without cohesive force became an integral structure bearing considerable loads. The theory also emphasizes for the first time that the function of prestressed anchor is to improve the mechanical properties of rock mass and enhance the strength of rock mass so as to enhance the stability of rock mass.

(4) Rock loose circle theory. The theory of loose zone of surrounding rock is put forward for bolting and shotcrete support[2]. The loosening zone is caused by the roadway advancing destroying the original stress state of the rock mass. When the strength of the rock mass in the range of the surrounding rock stress increasing is lower than its stress, the yield failure occurs. The development range of loose ring is the basis of bolt support design, and the supporting parameters based on the range of loose ring are also proposed. In the theory of loose circle, the rock mass which loses its stability in surrounding rock is regarded as the support object, and the range of loose

circle is determined based on acoustic wave test. The important breakthrough of the loose ring theory is that it is clear that the support object of the roadway is the loose soft broken rock mass around the roadway, and it emphasizes the gradual development of the time of the formation of the loose ring and the interaction and dynamic change of the stress and property of the surrounding rock.

(5) Pin theory. The pin theory was put forward by Ge X.R., a researcher at the Institute of Rock and Soil Research of the Chinese Academy of Sciences. The theory holds that the anchor rod can enhance the shear resistance of the sliding surface when it passes through the sliding surface[3-4].

3. Experimental research status of prestressed anchor reinforcement technology

In the field of laboratory model analysis and research of prestressed anchorage reinforcement effect, Cheng L.K. and others of the General Institute of Building Research of the Ministry of Metallurgy in China began to gradually carry out in the 1970s[5-6]. In order to simulate the working condition of fractured rock, Cheng Liangkui et al. built an arch with irregular concrete blocks and reinforced it with 10 8mm anchor rods. The measured data showed that the bearing capacity of the model was nearly 7 times higher than that before reinforcement, and the deflection in the model was also significantly lower than that before reinforcement.

In the late 1980s, in order to study the influence of bolt and bolt Angle on the shear performance of joint surface, Ge X.R. analyzed and discussed through indoor simulation experiments, and the experimental results concluded that the shear strength of bolt body can be fully responded under small shear displacement[7-8].

Chen A.M. and others studied the reinforcement effect of prestressed bolt on massive rock mass through model experiments, and concluded the factors affecting the reinforcement effect of bolt, among which the distance, length and prestress of bolt were the most important influencing factors. The optimization of bolt layout scheme was also obtained through the experiment, and the experiment believed that the cross-layout scheme could enhance the anchoring effect[9].

In terms of the influence of bolt arrangement on rock mass strength, Wu D.H. conducted an indoor model experiment study[10]. According to the study, when the anchor Angle is perpendicular to the rock joint direction, the model strength is the highest and the anchoring effect is the best. The more favorable the anchoring Angle is to the model strength, the larger the deformation range of the model will be when failure occurs: the higher the location of single anchor, the greater the cracking load and failure load of the model.

In terms of field test research, Zhu Jibing et al. conducted a follow-up investigation and study on the prestressed anchor construction of the high slope of the Three Gorges Dam permanent ship lock[11]. Through monitoring and analysis of the deformation, elastic modulus, wave velocity and other parameters of the rock mass before and after the reinforcement of the high slope, it was found that the stress state of the rock mass was greatly improved after the prestressed reinforcement. In particular, the stress state in the local area of the anchor pier attachment changes from zero stress to compressive stress. With the increase of the anchoring range, the stress region expands from point to plane.

According to the field test study, Zhang Faming divided the first and second effect zones of group anchors[12]. The study believes that compressive stress anchorage will form a certain compressed zone on the surface of rock mass, which is called the "first effect zone" of group anchors. Under the action of compressive stress, the tension fracture zone at the bottom of the anchoring section will be produced, which is called the "second effect zone" of group anchoring.

Japanese scholars set up a jointed rock mass model to carry out an experimental study on the reinforcement effect[13]. In the experiment, three reinforcement methods were simulated: no support, anchor reinforcement and mixed anchor plate reinforcement. The experimental results

show that the jointed rock mass model is generally in a continuous state after the mixed reinforcement of bolt and plate, and the bolt greatly improves the uniaxial compressive strength and deformation coefficient of the model, while the plate further improves the compressive strength of the model.

4. Research and development trend of rock and soil mass anchoring design

With the wide application of anchoring technology, its design theory and method have been studied more deeply. At present, many scholars have carried out numerical analysis methods, deeply studied its mechanism, and optimized its design parameters, which has been greatly developed in the past ten years. The theoretical and numerical analysis of anchorage design is an indispensable part. Similarly, engineering experience and on-site monitoring and feedback on construction and operation are also indispensable means. Theoretical analysis method, numerical analysis method and engineering construction experience feedback method are indispensable methods in rock and soil mass anchorage design. Compared with traditional design methods, the design theory of geotechnical anchoring engineering has made great progress and breakthroughs in design concepts, theories and methods, understanding of engineering characteristics and design ideas, which are mainly reflected in the following aspects:

(1) Breakthrough of anchorage design concept in geotechnical engineering. The stability state and failure mode of geotechnical engineering are different from other engineering, which not only depends on the characteristics of geotechnical engineering (project scale, support type, parameters and geological conditions), but also depends on the engineering construction technology (construction sequence, blasting method and construction time). Therefore, the anchorage design of rock mass engineering is not only limited to the design of anchorage parameters, but also must include the determination of construction methods and technological parameters. Therefore, modern anchoring design theory has extended the concept of structural engineering design to include "anchoring parameters" and "construction technology" two aspects of the broad "design concept".

(2) Progress in design theory and method. Due to the inherent characteristics of rock engineering, people have not fully mastered all the characteristics of rock and soil, and some aspects are still very vague, so there is no calculation theory or technology, method can be completely and accurately solved the problem of rock and soil anchorage. At present, various design theories analyze and discuss anchorage engineering from different angles and different entry points, and verify and analyze engineering experience and monitoring data fed back by monitoring means, constantly exploring the characteristics of geotechnical anchorage engineering. Therefore, it has become one of the means of modern anchoring design to take advantage of the advantages of various theoretical methods and apply them to the design of anchoring engineering.

(3) Breakthroughs in the understanding of geotechnical anchoring engineering characteristics. Geotechnical anchoring engineering has dynamic change, engineering design and construction personnel constantly understand the dynamic change of geotechnical anchoring with the development of engineering. The stable state of rock and soil is determined by the interaction of surrounding rock and anchoring measures, so it changes with the change of any factor. In addition, with the progress of different processes in the construction of geotechnical anchoring engineering, people are constantly deeply understanding the characteristics of anchoring engineering. The dynamic change of engineering and the gradual deepening of people's understanding determine the dynamic nature of modern anchoring design theory.

(4) Breakthroughs in design ideas. Traditional anchoring design basically uses static design and local information, but with the development and application of more and more anchoring shotcrete support technology, modern anchoring design has gradually developed. Great changes have taken

place in the design theory from the understanding of engineering characteristics, and the design idea has changed from the static and local in the past to the dynamic design and the use of comprehensive information. Since the advent of the "new Austrian Law", it has attracted the attention of related engineering circles. With the application of this method, scholars have a deeper understanding of the meaning and function of rock and soil anchoring design, and the essence of this new method is reflected in different degrees in the design. Therefore, the development direction of anchoring technology design is gradually developing to program and standardization.

5. Conclusions

Many experts and scholars have carried out research and exploration on prestressed anchor bolt. Due to the very complex stress situation of prestressed anchor bolt in rock and soil media, the research development in this aspect is slow, and many anchoring technology design and theoretical calculation are also derived from experience. In order to break the existing bottleneck, experts and scholars in relevant fields at home and abroad need to further summarize the stress characteristics of prestressed anchor rods, and carry out further verification through various practices.

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