

Prospects of Grouted Steel Anchor Pipe and Cable Structures in Fractured Rock Slope Applications

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Abstract

The split grouting prestressed steel anchor pipe and cable composite structure is a technology with promising long-term development prospects. It combines prestressed anchor cable framework beams with multiple-section controlled grouting technology, exhibiting superior shear and tensile resistance. The structure is novel and technologically advanced. This technology enhances the strength and stability of rock and soil masses through split grouting, effectively avoiding the problem of corrosion in prestressed steel strands. The construction process is simple and does not require additional construction machinery, making it suitable for slope protection in weak geological conditions. Field practices have demonstrated its high prestress and stability characteristics. Its successful application provides a new solution for landslide geological disaster control, enhancing slope stability and anti-sliding capabilities with the advantages of speed and reliability. The article combines specific examples to introduce the construction methods and techniques of grouted steel anchor pipe and cable structures in fractured rock slope reinforcement. It expands the application and prospects of reinforcement mechanisms, providing reference examples for similar slope support technologies.

Keywords

Steel Anchor Pipe and Cable; Split Grouting; Prospects.

1. Introduction

With the continuous development of China's economic construction and the implementation of the "Belt and Road" national strategy, the construction of highways and railways has extended on a large scale to rugged and complex mountainous areas. During the construction process, slope disasters have become increasingly prominent[1-2]. The large number, scale, severity, and difficulties in treating these slope hazards pose a significant challenge in quickly and efficiently addressing slope diseases and proposing effective slope remediation plans[3]. This is currently an urgent issue that needs to be addressed in the construction of highways and railways in mountainous regions.

In the mid-19th century, research on landslides and landslide disaster management began both domestically and internationally. So far, landslide prevention and control have developed mature means and formed a comprehensive technical system for landslide disaster prevention and control[4]. Traditional methods of slope prevention and control can effectively address most of the slope disaster issues in highways and railways when used appropriately. However, these methods also have some significant issues, such as high construction safety risks, long construction periods, high economic costs, and limited applicability in complex geological conditions. For example, the construction of retaining piles requires manual drilling, which is time-consuming and poses construction safety risks, making it difficult to meet the requirements of emergency projects in highways and railways. In

addition, in coal-bearing formations or formations with abundant groundwater, the durability of ordinary anchor cables in pre-stressed anchor systems may fail to meet the reinforcement duration due to the potential corrosion of prestressed steel strands. Therefore, research on emergency disposal techniques for landslide geological disasters has become an important focus in infrastructure construction fields such as civil engineering, water conservancy, and transportation. It is also a current research hotspot in the field of geotechnical and geological engineering[5-6].

2. Split Grouting Steel Anchor Pipe and Cable Composite Structure

2.1 Structural Style

The split grouting prestressed steel anchor pipe and cable composite structure is a technology with promising long-term development prospects. It is essentially a prestressed anchor rod, but compared to conventional anchor rods or prestressed anchor cables, it exhibits superior shear resistance and tensile resistance. The structure is novel and technologically advanced. The specific structural form can be referred to as shown in Fig.1.

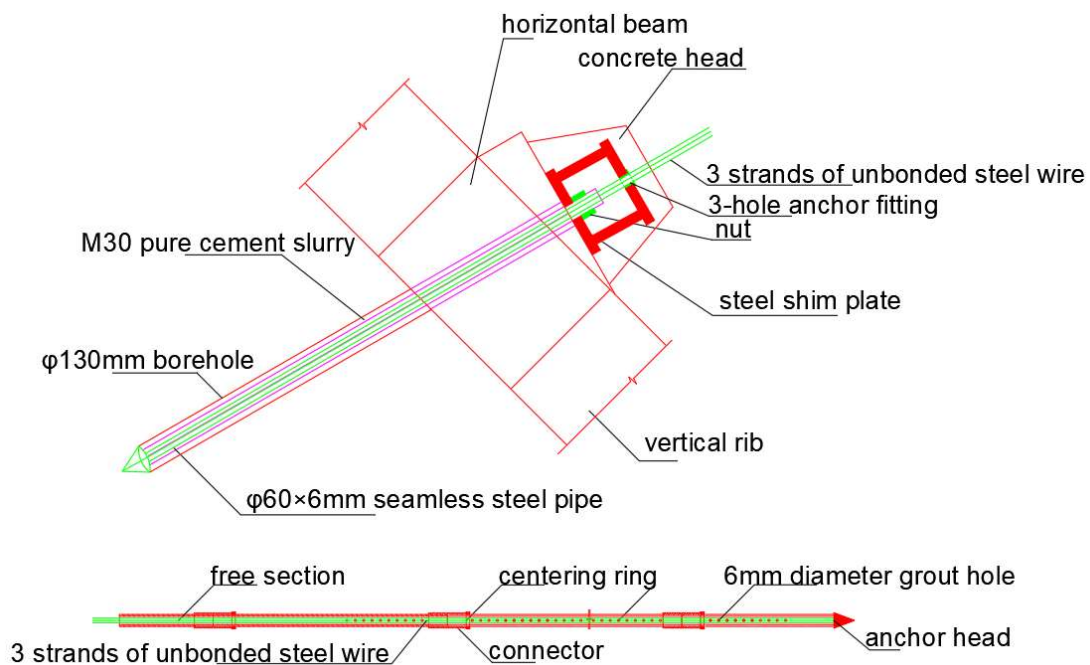


Fig.1 Schematic Diagram of Split Grouting Prestressed Steel Anchor Pipe and Cable Composite Structure

The key points of the Split Grouting Prestressed Steel Anchor Pipe and Cable Composite Structure are as follows:

- (1) The technique combines the prestressed anchor cable framework beam with multiple segmented controlled grouting techniques. The steel flower tube itself has sufficient flexural strength, especially when combined with grouting, it can act as mini-piles to resist landslide thrust. The steel flower tube has sufficient sealing properties, and by drilling grouting holes and temporarily sealing them, it can also serve as a multi-segmented split grouting tube to perform split grouting on the surrounding soil.
- (2) This technique employs secondary split grouting through steel anchor pipes to compact and improve the strength of crushed rock and soil slopes, enhancing their overall integrity. With multiple segmented controlled split grouting, the bonding between the steel pipe and the surrounding rock and soil becomes tighter, and the splitting effect is more thorough. In coal-bearing formations or formations with abundant groundwater, the durability of ordinary anchor cables may fail to meet the required reinforcement duration due to the potential corrosion of prestressed steel strands. However,

the split grouting steel anchor pipe and cable composite structure, with its multiple segmented controlled grouting technique, can improve the properties of the surrounding soil, enhancing its strength and stability. This helps to mitigate the issue of corrosion in prestressed steel strands.

(3) This technique utilizes anchor cables as prestressing transfer elements, which are implanted inside the grouted steel anchor pipes. By applying prestressing at the appropriate time, it fully harnesses the increased strength of the rock and soil mass achieved through split grouting, providing high prestress to the slope.

In the composite structure of prestressed steel anchor pipes and cables, the tensioned section of the prestressed steel anchor pipe applies prestressing to the anchor cables. Then, the free section of the anchor cables elongates and transfers the prestressing to the combined body of the steel anchor pipe and anchor cables in the anchorage section. Finally, the prestressing is transmitted to the surrounding stable rock layers through the anchorage section. Compared to traditional prestressed steel anchor pipe structures, steel strands exhibit superior load-bearing capacity.

2.2 Construction Process

The construction process of the split grouting steel anchor pipe and cable composite structure is as follows: Firstly, drilling is performed using a drilling machine, and the steel anchor pipe is inserted into the borehole together with the first-stage grouting pipe. Each section of the steel anchor pipe is connected by welding and mid-rings are installed at regular intervals. Then, during the first-stage grouting, the grout is filled between the steel anchor pipe and the borehole wall. After an 8-hour waiting period, the steel anchor pipe is used as the split grouting pipe for the second-stage split grouting. During the split grouting, the grout is sprayed out from the grouting holes on the surface of the steel anchor pipe, splitting the surrounding first-stage grout and rock and soil mass, thereby compacting the surrounding rock and soil mass and forming a "root-like" grout body. Once the split grouting is completed, the second-stage grouting pipe is removed, and the grouting holes are sealed. Then, the prepared anchor cables are quickly inserted into the steel anchor pipe and mid-rings are installed at certain intervals to ensure the central placement of the anchor cables. Finally, the framework beams and anchor abutments are constructed, and prestressing is applied after the curing period is reached.

The construction process of the split grouting steel anchor pipe and cable composite structure is relatively simple, and it does not require additional construction machinery. All materials can be produced on-site. Additionally, high-pressure split grouting has excellent effectiveness, especially for weak formations such as crushed granite, for slope protection.

3. Field Application and Practice

The technology has been successfully applied in landslide remediation projects such as the Guangle Expressway in Guangdong, the North Third Ring Road in Guangzhou, and the Chaohui Expressway in Guangdong. Compared to ordinary anchor cables and conventional prestressed steel anchor pipes, the split grouting steel anchor pipe and cable composite structure demonstrates high prestressing and stability in on-site applications. Through the split grouting action of the steel anchor pipe, geotechnical parameters such as shear strength (c) and internal friction angle (φ) are improved. The partial prestressing transfer in the steel anchor pipe and cable composite structure becomes more stable, reducing the probability of anchor cable pullout or failure, and greatly enhancing the shear resistance capacity of the prestressed elements.

In the on-site slope test of the Guangzhou Zengcheng Shazhuang to Huadu Beixing Highway Phase II Project (Licheng to Huadu Northbound section) at K42+265 to K42+630[7], a comparative test and analysis were conducted between ordinary anchor rods and prestressed grouting steel anchor pipes under the same conditions. The results showed that as a prestressed element, the maximum anchoring force of the grouting steel anchor pipe reached 193KN, while the prestress of the ordinary anchor rod was only 120KN. In addition, when steel strand wires were used as prestressed elements,

compared to ordinary prestressed anchor cables, the single-bundle steel strand wire prestressed anchor cable had a 17.5% increase in bearing capacity, the two-strand steel strand wire prestressed anchor cable had a 28.14% increase in bearing capacity, and the three-strand steel strand wire prestressed anchor cable had a 28.65% increase in bearing capacity.

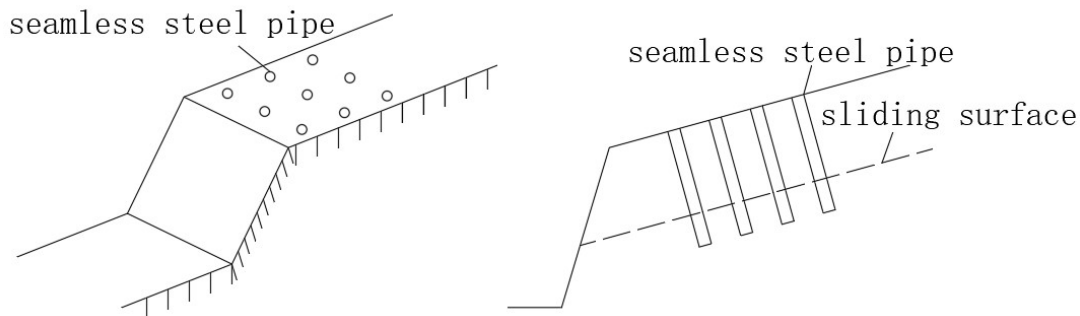


Fig.2 Schematic Diagram of Split Grouting Steel Anchor Pipe Model Test

Zhang YF[8] conducted large-scale model tests to verify the micro pile group effect of the split grouting steel anchor pipe. The design diagram is shown in Fig.2. By applying an active thrust to the sliding body, the sliding movement along the sliding surface was induced to evaluate the shear performance of the split grouting steel anchor pipe. The test results showed that high-pressure grouting can split the surrounding soil of the pile, forming a root-like consolidated body in the sliding zone. This significantly improved the mechanical performance of the landslide soil, enhanced its resistance to deformation, reduced the bending deformation of the shaft, and increased the shear strength of the sliding zone soil. Compared to gravity-grouted micro piles, the adoption of high-pressure grouting steel anchor pipe micro piles or pile groups for landslide reinforcement increased the horizontal ultimate load by 37.8% and 71.2%, respectively.

4. Conclusion

The split grouting steel anchor pipe and cable composite structure is a slope disaster prevention and control technology with broad application prospects. By controlling the application of grouting and steel anchor pipes, it can significantly improve the stability and anti-sliding capacity of slopes, providing engineers with a feasible option for slope disaster prevention and control. Moreover, this technology aligns with the important concerns of infrastructure construction in civil, hydraulic, and transportation fields and corresponds to the current research focus in the geotechnical and geological engineering disciplines.

Currently, the application of the split grouting steel anchor pipe and cable composite structure technology in new slope control techniques is not widespread. However, with the increasing difficulty in slope support, especially for coal formations and gravel formations, the continuous maturation of the split grouting steel anchor pipe and cable composite structure technology will lead to its wider application in slope support. This innovative technology can meet the needs of various engineering projects and provide different construction schemes for different geological conditions and construction requirements, showcasing its increasing adaptability.

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