Research on the Bearing Characteristics of a New Type of Prefabricated Internal Anchor Head and Its Application in Transportation Engineering

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Abstract. The new type of anchor cable structure with prefabricated internal anchor head has advantages such as high anchoring force and good durability, and has great application prospects in transportation engineering and civil engineering. However, there is currently a lack of systematic research on its load-bearing characteristics. In this paper, the numerical analysis method was used to study the bearing characteristics of the prefabricated inner anchor cable under different sizes of the prefabricated inner anchor head. The stress mechanism and influencing factors were revealed. The results show that the new type anchor cable with prefabricated inner anchor head can effectively improve the ultimate anchoring force of the anchor cable.

Keywords: prefabricated inner anchor head, anchor cable, numerical analysis, bearing characteristics, transportation engineering

1 Introduction

With the rapid development of the economy, transportation has become an important factor restricting economic development. In order to meet the needs of economic construction, China's basic transportation construction has developed on a large scale. Due to the complex terrain, high embankments and deep cutting slopes often occur. Among them, the durability and anchoring effect of the slope pre-stressed anchoring system are particularly prominent, posing a great threat to the safety of highway and railway operations. After years of development, there are various structural types of anchor cables, with traditional ones mainly including tension type, pressure type, dispersed tension type, dispersed pressure type, etc. [1]. In order to improve the performance of anchor structures and adapt to increasingly complex geological and engineering conditions,

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various new types of anchor structures have emerged one after another, such as tension compression combined anchor cables [2], release compression anchor rods [3,10], enlarged head anchor rods[4,9], recyclable anchor cables[5,8], double anchoring segment anchor cables[6], and so on. However, there is a significant drawback to various existing anchor cables. In coal strata, corrosive strata, and strata with rich groundwater, the bearing plate at the bottom of the anchor cable is often difficult to achieve effective compression of the grouting body throughout the entire hole of the anchor cable due to factors such as installation technology, grouting density, strength of the pressure bearing plate itself, and durability of the pressure bearing plate during actual construction, leading to loss or failure of the anchor cable anchoring force. Yuan Kun, Zhang Yufang, etc. [7] developed a prefabricated internal anchor head anchor cable structure (Figure 1) to address the disadvantage of pressure type anchor cable compression plates being prone to failure, and conducted model experiments. Compared to traditional pressure type anchor cables, the new prefabricated internal anchor head anchor cable structure has advantages such as large anchoring force and good durability, which can effectively improve the stability and safety of slopes and significantly reduce engineering costs. This article focuses on this new type of structure. Based on model experiments, numerical simulation methods are used to further systematically study its bearing characteristics under different geological conditions and different sizes of prefabricated internal anchor heads. The main research objective of this article is to reveal the stress mechanism of new anchor cables and the influence of various factors on the bearing characteristics of the structure, providing a theoretical basis for the design and engineering application of prefabricated internal anchor head anchor cable structures.

2 Model Establishment

Referring to physical engineering, the horizontal spacing of anchor cables is 2.5m, and the vertical spacing is 3.5m. Based on symmetry, the numerical model selects the range of influence of an anchor cable. The geometric dimensions of the simulated object are 5000mm×2500mm×3500mm.

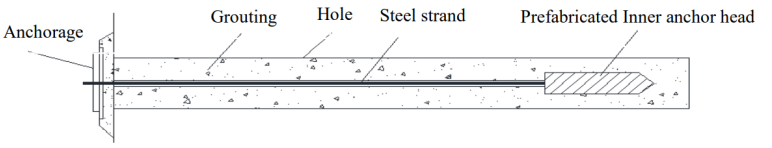


Fig. 1. Anchor cable with prefabricated head

Table 1. Simulated working conditions of anchor cable with prefabricated anchor head

Model Number	Anchor diameter /mm	Anchor length /cm	type of pre-stressed anchor cables
G3-1	90	0	ordinary pressure type anchor cables
G3-2		25	pre-stressed anchor cables with prefabricated anchor head
G3-3		50	
G3-4		100	

Four types of pre-stressed anchor cables were considered. The model number and detailed parameters are shown in Table 1.

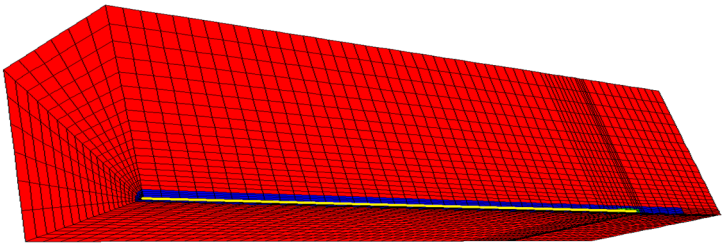


Fig. 2. Mesh generation diagram of model used in numerical calculation

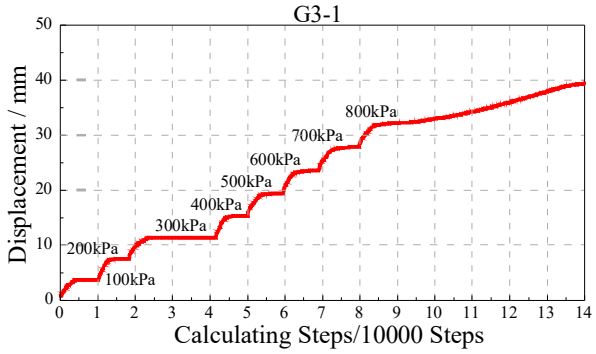
The establishment of the model is based on the principle of improving computational efficiency while ensuring real simulation. The rock mass, grouting body, bearing plate, and prefabricated anchor head use solid units, and the Mohr Coulomb constitutive model is used. The interface between the rock mass and grouting body, as well as the interface between anchor head and grouting body, uses contact surface elements. Based on the symmetrical characteristics of the model, take 1/4 of the model for calculation. The model mesh adopts a step-by-step subdivision method, and the mesh division of the solid elements and contact surfaces of the rock mass and grouting body near the pressure bearing plate is relatively fine. The specific grid division is shown in Figure 2, with a total of 15732 units and 18287 nodes in the model.

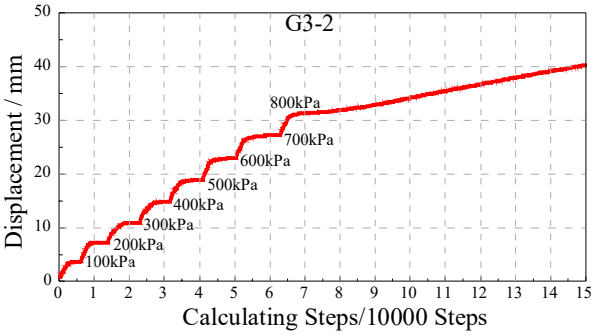
3 Bearing Characteristics

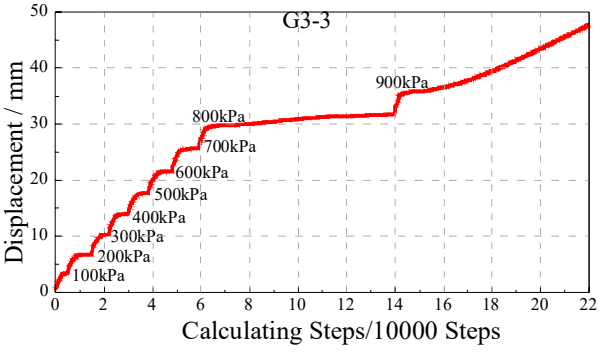
The displacement of the anchor head of traditional pressure type anchor cables and new types of anchor cables with different prefabricated anchor head lengths under graded loads varies with the number of calculation steps and load. As shown in Figure 3 and Figure 4, the longer the length of the prefabricated inner anchor head, the greater the ultimate anchoring force of the anchor cable under the same conditions, and the smaller the displacement of the anchor head under the same load, indicating that the prefabricated inner anchor head anchor cable can effectively improve the anchoring force compared to traditional pressure type anchor cables (with only a pressure plate) , and increasing the length of prefabricated anchor heads can improve the overall elastic modulus of the anchoring system.

Comparative analysis was conducted on the axial stress distribution of the grouting body center of traditional pressure type anchor cables and new anchor cables with different prefabricated anchor head lengths under a tension load of 700kN. As shown in Figure 5, the axial stress of the grouting body of traditional pressure type anchor cables is significantly concentrated at the pressure plate, with a peak size of about 3.5 times that of the new anchor cables with prefabricated anchor heads. This indicates that the stress state of the anchoring system of the new anchor cables is greatly improved compared to traditional pressure type anchor cables.

Figure 6 shows the distribution curves of shear stress and normal stress on the indirect contact surface between the grouting body and the hole wall under a tension load of 700kN, with different lengths of prefabricated anchor heads. As shown in Figure 6, the shorter the length of the prefabricated anchor head, the greater the peak shear stress and normal stress, and the smaller the distribution range, the more obvious the stress concentration phenomenon. For traditional pressure type anchor cables, the concentration of shear stress and normal stress on the contact surface is the most severe. This indicates that the new anchor cables have significantly improved stress conditions.







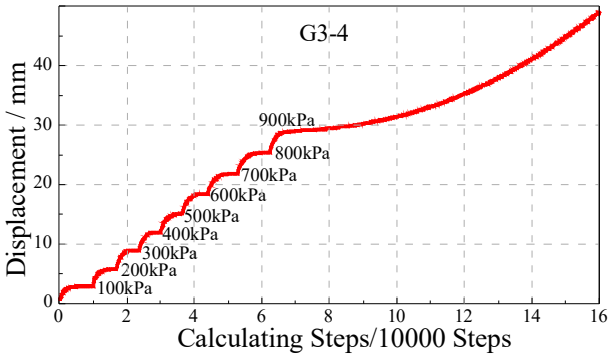


Fig. 3. Variation of anchor head displacement with calculation steps and load

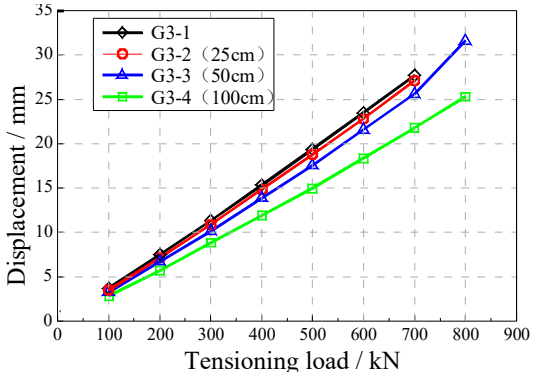


Fig. 4. Displacement-load curve of anchor head of anchor cable

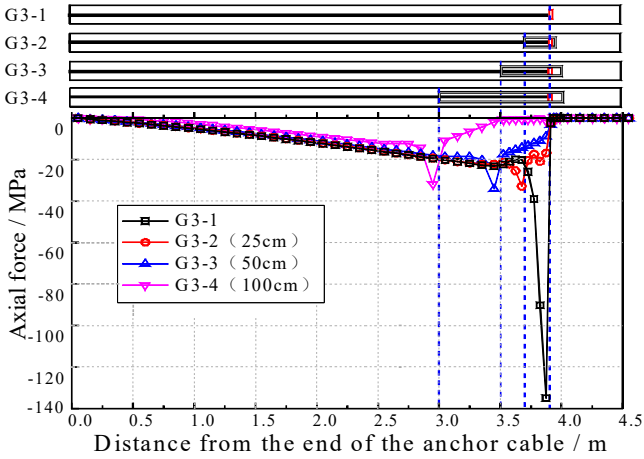


Fig. 5. Axial stress of grouting body and bearing plate under 700kN load

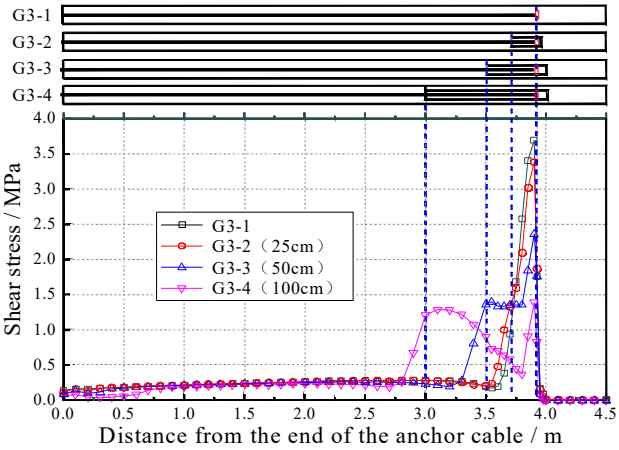


Fig. 6. Stress curve of contact surface between grouting body and hole wall

Figure 7 shows the yield state of the grouting body in front of the pressure bearing plate or prefabricated anchor head. As shown in Figure 7, the shorter the length of the prefabricated anchor head, the larger the yield range of the grouting body. For traditional pressure type anchor cables, the yield range of the grouting body is the largest, and the yield degree is the most severe.

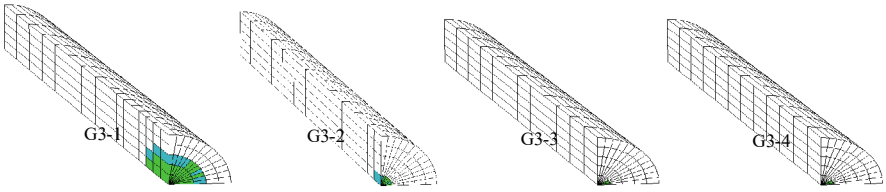


Fig. 7. Yield state of grouting body in front of bearing plate or precast anchor head

4 Engineering Application

The slope on the right side of the K102+130~K102+330 section of the Guangle Expressway is composed of Quaternary silty clay, siltstone, carbonaceous shale, coal seams, etc. It belongs to a typical coal bearing strata slope. The slope height is about 35.0m, the length is about 210.0m. The slope is supported by stainless steel prefabricated internal anchor head anchor cables with a length of 32m~40m. The total cost of the project is 12139820.96 yuan, saving 2.19 million yuan compared to conventional anti-skid piles, with a savings rate of 15%, indicating significant economic advantages.

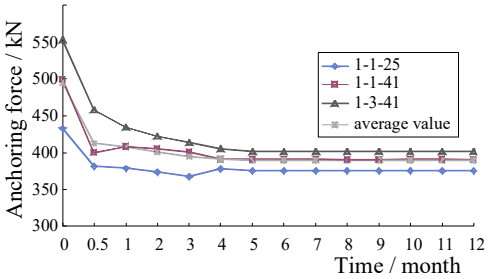


Fig. 8. Anchoring force-time curve of anchor cable

During the construction process, stress monitoring was conducted on the prefabricated internal anchor cables at three locations of the construction site (Figure 8). The average locking force of the prefabricated internal anchor cables was 413.1kN, the minimum value was 389.1kN, the average pre-stress loss was 24.0kN, and the pre-stress loss was 5.81%. The pre-stress loss of ordinary anchor cables in coal bearing soft rock formations is generally 10-15%, or even greater. Overall, the application of prefabricated internal anchor head anchor cables in corrosive or weak and fractured formations has shown good results, solving the problem of bearing body corrosion, improving the anchoring force of anchor cables, and achieving significant economic benefits.

5 Conclusion

Compared with traditional pressure type anchor cables, the new prefabricated internal anchor head anchor cable effectively improves the ultimate anchoring force of the anchor cable, reduces the displacement of the anchor cable, and significantly improves the ability to resist shear sliding between the grouting body and the hole wall; The peak values of shear stress and normal stress on the indirect contact surface between the grouting body and the hole wall are smaller, and the phenomenon of stress concentration is significantly alleviated; The smaller the yield range of the grouting body in front of the prefabricated anchor head.

For traditional pressure type anchor cables, the axial stress of the grouting body is significantly concentrated at the pressure plate, with a peak size of about 3.5 times that of the new anchor cables. This indicates that the stress state of the anchoring system of the new anchor cables with prefabricated anchor heads is greatly improved compared to traditional pressure type anchor cables.

This article studies the bearing characteristics of a new type of prefabricated internal anchor cable with different anchor head lengths. However, the bearing performance of this anchor cable in different strata still needs to be studied. At present, the practical engineering application of this anchor cable is relatively limited, and its calculation and design method is not yet mature, which needs to be summarized in more practical engineering applications.

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