Numerical analysis on a new pressure-type anchor cable with precast anchor head based on FLAC3d

Jian Li[1, a], Lijie Li[2, b]

[1]Railway Engineering Research Institute, China Academy of Railway Sciences, Beijing 100081, China;

[2]State Key Laboratory of Railway Traffic Control & Safety, School of Traffic Transportation, Beijing Jiaotong University, Beijing 100044, China.

[a]517158105@qq.com, [b]yajiemodeai@163.com

Abstract. The prestressed anchoring technology is applied extensively to the geotechnical projects. Due to the limitations of conventional prestressed anchorage cable, such as stress concentration on the head of anchor-root and distribution nonuniformity of shear stress, a new pressure-type anchor cable with precast anchor head is proposed. A number of numerical simulations based on FLAC3d are conducted to understand the technology systematically. The results show that the compressive stress concentrated on anchor-root is low; the superposition of axial compressive stress and shear stress in the grouting are not obvious; and the stress distribution is uniform. The new pressure-type anchor cable with precast anchor head can overcome the defects of conventional prestressed anchorage cable effectively and improve the reliability of cable significantly. The result can provide an alternative in selecting anchorage system in geotechnical projects.

1 Introduction

Anchorage technology in geotechnical projects which can make full use of the self-strength and self-stabilization capacity of rocks and soils, and reduce the retaining structure system and weight, improve the stabilization of the structural system, moreover it has the characteristic of small floor area, safety construction, shortening building-shaft cycle and reducing project costs. At present, the pressure-type cable which widely used in China has the disadvantages of the stress concentration on leading end anchorage segment and the irregular stress distribution, and they reduce the quality of anchorage seriously due to the installation process, jet grouting denseness of anchorage and the intensity of the board in pressure in engineering practice. To solve this problem, developing a new pressure-type anchor cable with precast anchor head for making full use of the anchor cable tensile strength will be of great importance in practical engineering application and saving cost. So this paper introduces a new pressure-type anchor cable with precast anchor head, makes a study of its effect through the numerical simulation. The result can provide an alternative in selecting anchorage system in geotechnical projects[1, 2].

2 A new pressure-type anchor cable with precast anchor head

Due to the limitations of conventional prestressed anchorage cable, such as stress concentration on the head of anchor-root and distribution nonuniformity of shear stress, a new pressure-type anchor cable with precast anchor head is designed, as shown in figure 1.
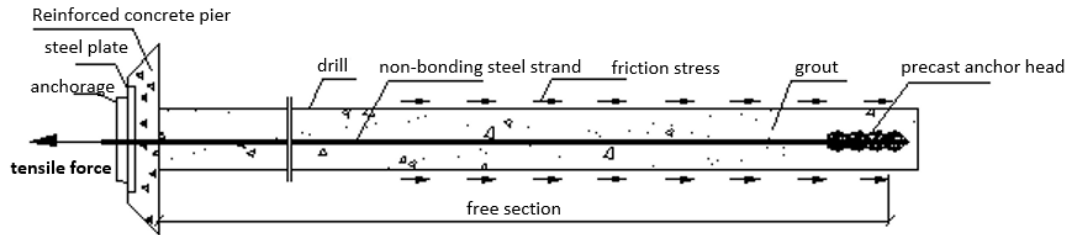
Fig.1 Precast anchor head structural schematic diagram

The precast anchor head adopts high-strength concrete which has two specifications, Φ90mm*250mm and Φ90mm*500mm. The steel plate which has a diameter of 75mm and a thickness of 20 mm, and there are four boreholes for anchor cable which has a diameter of 18mm on the quadrature-axis. The isolating tray adopts typical nylon rod, which has a diameter of 98mm and a thickness of 10 mm, to set the boreholes for anchor cable and the steel plate in a corresponding consistent condition and to reserve grouting holes which has a diameter of 75mm and location hole which has a diameter of 8mm in the surrounding area.

3 Numerical analysis of anchorage mechanism

Anchorage mechanism of conventional pressure-type anchorage cable has world-wide been researched massively, the results can be summarized as (1) the pressure-type cable has the disadvantages of the stress concentration; (2) the shear stress mainly impact the first half of anchorage section, and decay rapidly in the second half [3, 4].

Numerical analysis of the new pressure-type anchor cable with precast anchor head is based on the FLAC3d, computational models include the rock mass, grouting, the precast anchor head, the steel plate. The model dimension is 5000×800×800mm, the length of the grouting is 4500 millimeters, drilling diameter is 150 millimeters, the precast anchor head is 25 centimeters long. A quarter model is adopted because of the symmetry, and there are 11628 units and 13763 nodes in total, as shown in figure 2.
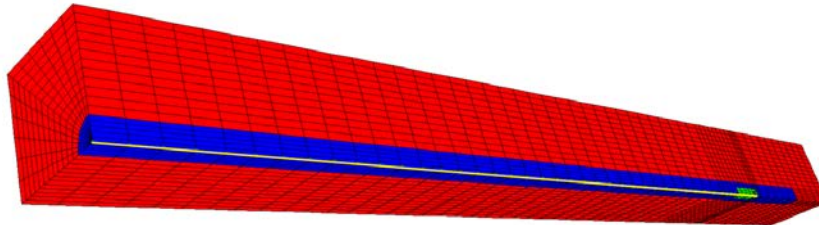

Fig.2 numerical analysis model

The Interface between rock mass and grouting and the Interface between precast anchor head and grouting are modeled as interface element with Coulomb Shear Model. The rock mass, grouting, the precast anchor head are modeled as solid elements with Mohr-Coulomb Model and the steel plate are modeled as solid element with Elastic Model. The mechanical parameters are shown in Table 1.

Table 1 Numerical simulation of mechanical parameters

Model	modulus of elasticity E/GPa	Poisson's ratio	unit weight γ/kg/m³	Equivalence cohesion c/MPa	Equivalence internal friction angleφ/°	contact surface internal friction angleφ/°	contact surface cohesion c/MPa
Rock mass	34.5	0.16	2450	7.00	51.99	49	1.0
Grouting	25	11.5	2550	7.14	49.96		
Steel plate	210	0.28	7800				
Precast anchor head	34.5	0.16	2450	7.00	51.99	49	1.0

No interaction between steel strand and the grouting. Cohesiveness and friction between steel strand and the precast anchor head, the cohesional strength is 3.4MPa, so it can calculate the single strand cohesive force per unit length is 162.28 KN, friction angle is 35°. Steel strand anchor cable element node and nodes connected by fixed unit.

The simulated respectively exert tension load on the anchor end of 100 kN, 200 kN, 300 kN,400 kN, 500 kN, 600 kN, 700 kN,800 kN,900 kN and 1000 kN.

3.1 The grouting along the axial stress distribution rule

It can be seen from Fig . 3 that ① The grouting axial stress is compressive stress, and with the increase of load, stress increases gradually; ② Grouting stress is mainly concentrated in the front of the 0.5 m of the precast anchor head and the grouting between the precast anchor head end and steel plate. The compressive stress of the steel plate after close to zero; ③ the biggest compressive stress is in the grouting in the front of the precast anchor head and stress concentration is very obvious.
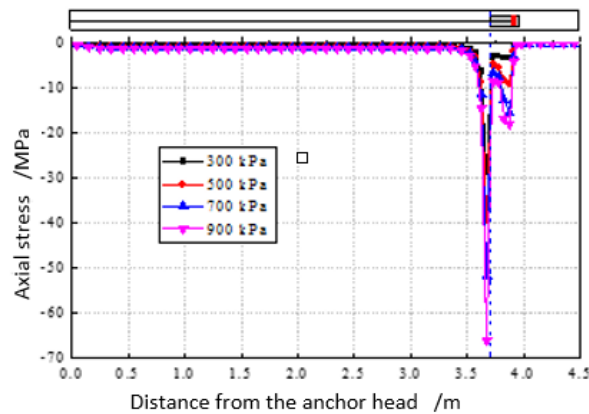

Fig.3 The grouting axial stress (Minus mean the compressive stress)

3.2 The axial strain distribution of grouting

It can be seen from Fig . 4 that ① the compressive strain in the front of the precast anchor head is concentrated; The compressive strain mainly in the grouting which is at side of the precast anchor head, but the order of magnitude was smaller; the tensile strain is concentrated at the steel plate and the small scope at the back of the steel plate.
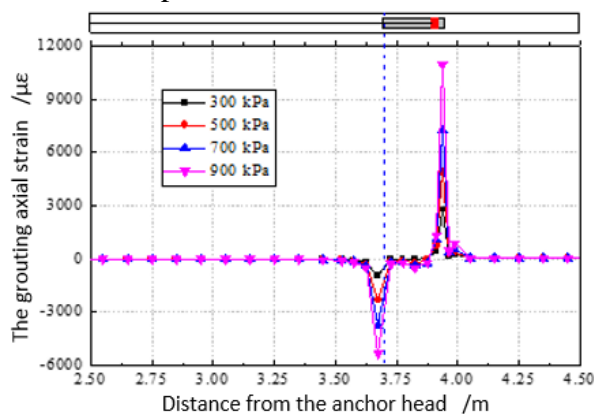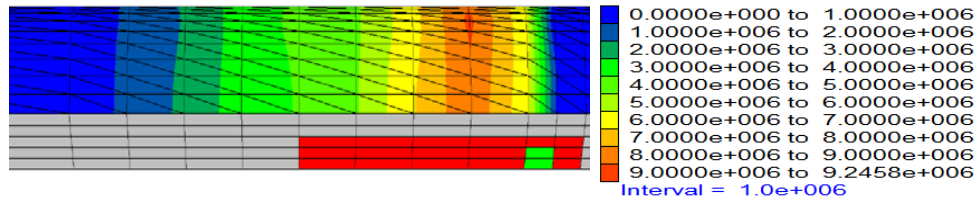

Fig.4 The grouting axial strain

3.3 The shear stress distribution of the contact surface between grouting and wall of hole

Figure 5 shows the shear stress distribution nephogram of the contact surface between grouting and wall of hole under the tension load of 900 kN. Figure 6 shows the shear stress distribution curve of the contact surface between grouting and wall of hole under the different tension load. It can be seen from Fig . 5 and Fig . 6 that ① the shear stress of the contact surface between grouting and wall of hole is mainly concentrated in the precast anchor head and in the front of the 0.5 m of the precast anchor head.

And some of the contact surface takes a large proportion of the tensile load; ② the maximum shear stress of the contact surface between grouting and wall of hole is about 9.00 MPa; ③ With the increase of the tensile load, the shear stress of the contact surface between grouting and wall of hole increases gradually, but the distribution of shear stress changes little.

(a) The shear stress distribution nephogram of the contact surface between grouting and wall of hole (Whole Model)

(b) The shear stress distribution nephogram of the contact surface between grouting and wall of hole (partial model)

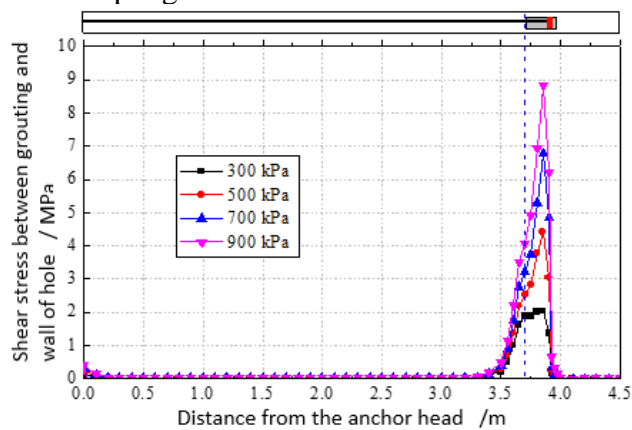Fig.5 Shear stress distribution nephogram of the contact surface between grouting and wall of hole

Fig.6 Shear stress curve changing with load of the contact surface between grouting and wall of hole

3.4 The shear stress of the contact surface between the precast anchor head and grouting

Figure 7 shows the shear stress distribution nephogram of the contact surface between the precast anchor head and grouting under the tension load of 900 kN, the red area units is the steel plate. It can be seen from Fig . 7 that ① The biggest shear stress between the precast anchor head and grouting is near the steel plate and it Can be up to 23.12 MPa. ② As shown in figure in the blue circle section, there are some relative shear slip in the middle of the precast anchor head on the contact surface between the precast anchor head and grouting, but shear sliding region is smaller.
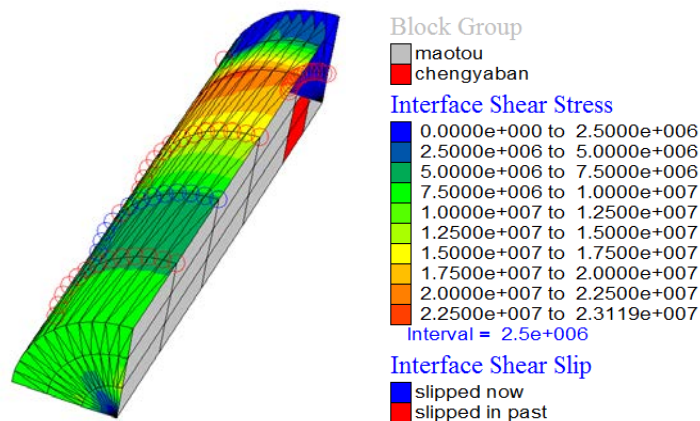

Fig.7 The shear stress distribution and shear slip of the contact surface between the precast anchor head and grouting

4 Conclusion

In view of the insufficiency of the pressure-type cable, a new pressure-type anchor cable with precast anchor head is proposed, makes a study of its effect through the numerical simulation, the main results are as follows:

(1) Grouting stress is mainly concentrated in the front of the 0.5 m of the precast anchor head and the grouting between the precast anchor head end and steel plate. The biggest compressive stress is in the grouting in the front of the precast anchor head and stress concentration is very obvious.

(2) The compressive strain in the front of the precast anchor head is concentrated; The compressive strain mainly in the grouting which is at side of the precast anchor head, but the order of magnitude was smaller; the tensile strain is concentrated at the steel plate and the small scope at the back of the steel plate.

(3) The shear stress of the contact surface between grouting and wall of hole is mainly concentrated in the precast anchor head and in the front of the 0.5 m of the precast anchor head. And some of the contact surface takes a large proportion of the tensile load.

(4) Compared with the traditional pressure-type anchor cable, the new pressure-type anchor cable with precast anchor head has the advantage of stress concentration value is smaller, axial compressive stress and shear stress superposition in the grouting is not obvious, the stress distribution is more homogeneous, and it can overcome the defects of conventional prestressed anchorage cable effectively and improve the reliability of cable significantly.

References

[1] ZHANG Desheng, LIN Ge, GONG Faxiong, et al. Primary discussing on familiar questions of prestressed anchor cable construction in Xiaowan hydropower station [J]. Construction Technology, 2006, 35(9): 67-70. (in Chinese)

[2] GAO Qian, WU Shunchuan, WU Xuemin. Application of prestressed cable in supporting for nonworking slope in the west open pit of Pingzhuang coal mine [J]. Journal of Engineering Geology, 2005, 13(2): 257-262. (in Chinese)

[3] LI Yingyong, ZHANG Dingli, WANG Songgen. Research on numerical simulation of anchoringmechanism of prestressed anchor cables [J]. Rock and Soil Mechanics, 2006, 27(Supp.1): 921-925. (in Chinese)

[4] DING Xiuli, SHENG Qian, HAN Jun, et al. Numerical simulation testing study on reinforcement mechanism of prestressed anchorage cable[J].Chinese Journal of Rock Mechanics and Engineering, 2002, 21(7): 980-988. (in Chinese)