

FLAC^{3D} simulation of combined support effect under different prestress parameters of deep soft rock roadway

Jie Li^{1,*}, Xinghua Li¹, Fuguang Liu²

¹College of Energy and Mining Engineering, Shandong University of Science and Technology, Qingdao 266590, Shandong Province, China

²Shandong Ding 'an Testing Technology Co., Ltd, Jinan 250031, Shandong Province, China

Abstract. In coal mining, as the mining depth increases, a complex mechanical environment of "high ground stress", "high ground temperature", "high karst water pressure", and "mining disturbance", namely "three highs and one disturbance" appears. Many roadways have the characteristics of soft rock roadways with large deformation, large ground pressure, difficult support, and high support cost, which brings severe challenges to the safe and efficient production of coal mines. Therefore, it is very important to explore the support technology and support parameters of deep soft rock roadways. In this paper, numerical simulation is used to study the influence of different prestress on the displacement, axial force and vertical stress of the surrounding rock of the roadway in the joint support of deep soft rock roadway. The results show that in the simulation of prestressing 20KN, 40KN, 60KN, and supporting method of bolt and anchor cable combined support, the comprehensive support effect of 60KN prestressed bolt + anchor cable is the best.

1 Model establishment

1.1 Analog variable parameter setting

In order to simulate the influence of different prestress parameters of bolts and cables on the displacement, axial force and vertical stress of the surrounding rock of the roadway in the combined support technology of bolting and spraying + U-shaped steel retractable support, and bolting and spraying + arc plate support. I set up an engineering condition of deep mine soft rock condition, and set up a numerical simulation model for it. The buried depth of the roadway is 1000m, and the size of the roadway is 5m×3.5m.

(1) Model: The anchor rod and anchor cable combined support adopt 8m long anchor cable and 1.4m long anchor rod, the design is shown in Figure 1.

(2) Different prestresses are applied: 20KN, 40KN, 60KN.

(3) Simulation evaluation indicators: roof displacement, roof surrounding rock anchoring force, roof vertical stress distribution.

1.2 Boundary condition setting

The numerical simulation model is 40m×1m×29.5m, which is divided into 2800 units and 5822 nodes. The lower surface of the model is fixed, a vertical stress is applied to the upper surface to simulate the buried depth of the roadway, and the Mohr-Coulomb criterion is used for simulation. The quality conditions of the roadway are shown in Table 1.

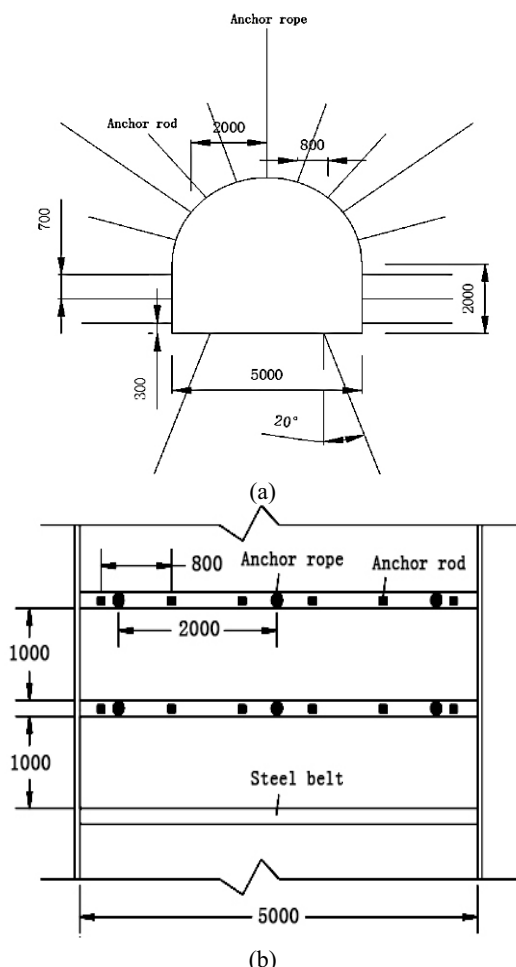


Fig. 1. Supporting method diagram

* Corresponding author: E-mail: 980652377@qq.com

Table1. Uniaxial compressive strength of rock

Lithology	Elastic Modulus (MPa)		Poisson's ratio		Uniaxial compressive strength (MPa)	
	Test value	Average value	Test value	Average value	Test value	Average value
	11687.0		0.3589		11.89	
Mudstone	11083.0	11417.8	0.2788	0.3648	12.57	12.46
	11483.4		0.4568		12.93	
	4198.1		0.2984		5.37	
Coarse sandstone	4185.7	4194.3	0.3133	0.3043	5.46	5.38
	4199.1		0.3012		5.31	
	6524.5		0.3729		15.71	
Fine sandstone	6223.7	6250.2	0.3813	0.3789	15.52	15.62
	6002.4		0.3825		15.63	
	3789.3		0.4876		4.89	
coal	3734.6	3776.3	0.5023	0.4798	4.03	4.52
	3805.0		0.4495		4.64	
	4897.3		0.4819		6.74	
Sandy mudstone	4312.0	4251.4	0.4512	0.4698	7.38	6.89
	3544.9		0.4762		6.55	

Combining the uniaxial test and the triaxial test can obtain the molar strength envelope of various rocks, so that the mechanical parameter values of the cohesive force C and the internal friction angle of each lithology can be obtained:

- Coal: C=1.59MPa;
- Mudstone: C=2.35MPa;
- Fine sandstone: C=2.39MPa;
- Coarse sandstone: C=2.37MPa;
- Sandy mudstone: C=2.18MPa.

According to the above parameters, a numerical simulation model is established as shown in Figure 2:

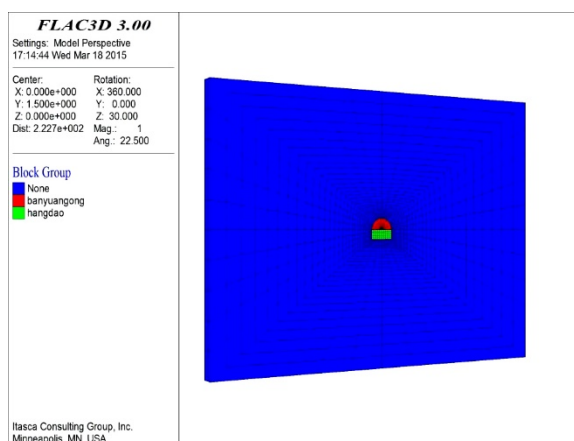
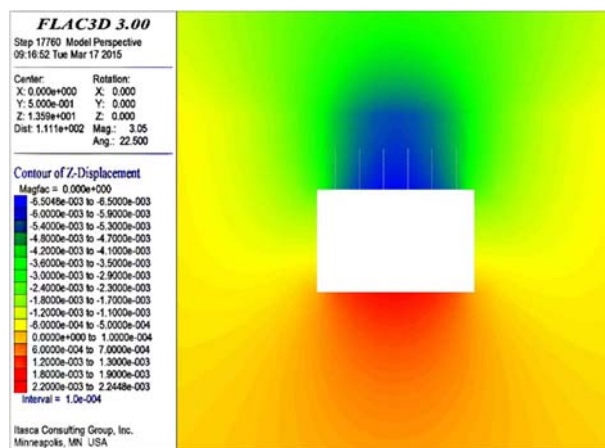


Fig. 2. numerical model diagram

a tensile strength of 500Mpa was selected. The anchor cable with a modulus of elasticity of 205Gpa and a tensile strength of 1860Mpa is simulated under three prestressing conditions.

2.1 Change of roof displacement under different prestress

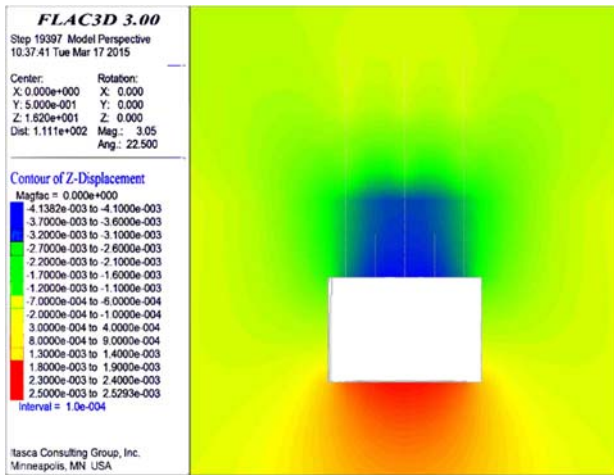
Under the condition of 20KN applied bolt and anchor cable prestress, the displacement of the roof is 5.1mm, the prestress of the roof bolt and anchor cable is 4.1mm



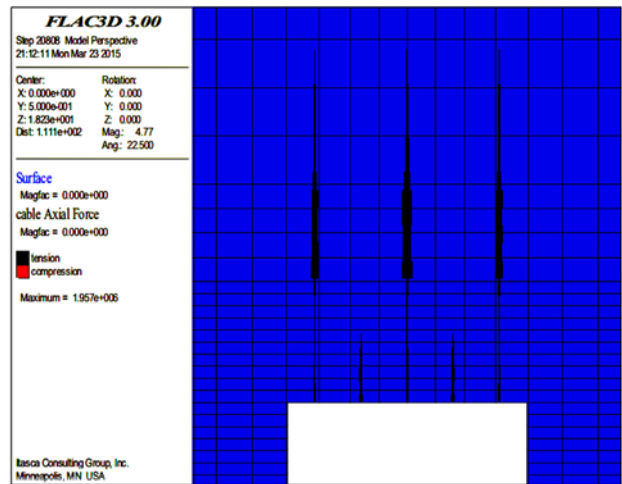
(a)The prestress applied is 20KN

2 FLAC^{3D} numerical simulation

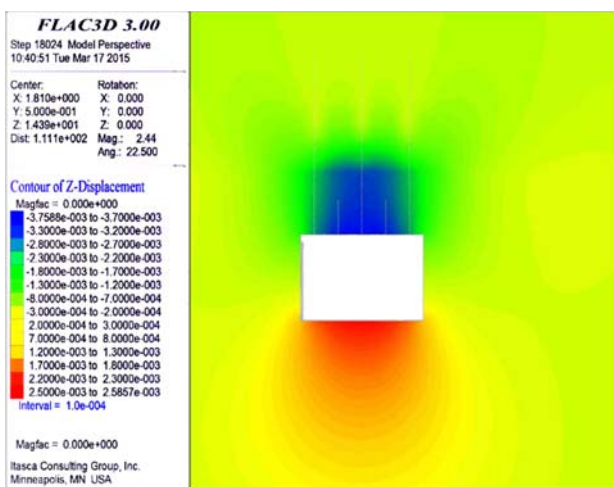
Analysis of Stress and Strain of Prestressed Cable and Anchor Rods under Combined Prestress: In order to verify the control effect of the combined application of the anchor cable and the anchor rod on the surrounding rock of the roadway under different prestress, the anchor rod with a length of 1.4m, an elastic modulus of 210Gpa and



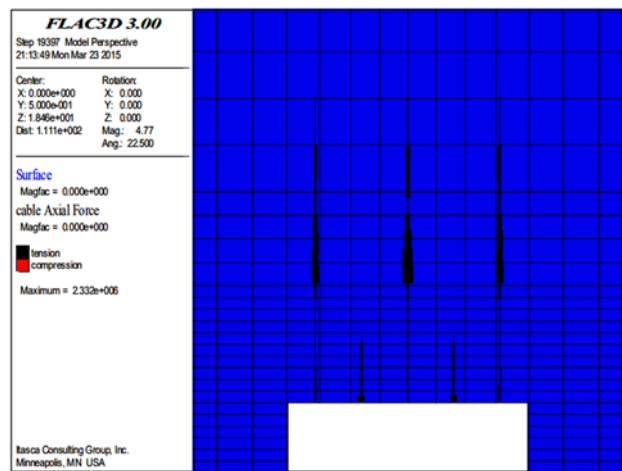
(b) The prestress applied is 40KN



(a)The prestress applied is 20KN



(c) The prestress applied is 60KN



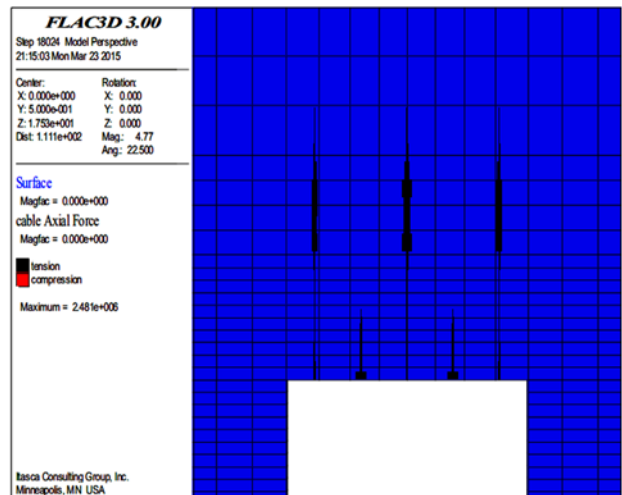
(b) The prestress applied is 40KN

Fig. 3. Different prestress displacement changes

when the prestress of the roof bolt and anchor cable is 40KN, and the roof bolt is 3.7mm when the prestress of the roof bolt is 60KN. When 60KN prestress is applied to the cable, the roof subsidence of the roadway is the smallest, and the vertical deformation of the roadway is within the allowable deformation range.

2.2 Change of roof axial force under different prestress

From Figure 4 of the axial force distribution change, it can be obtained that under the application of 20KN prestress, the maximum anchoring force provided by the bolt and anchor cable to the surrounding rock is 1957KN. When 40KN prestress is applied, the bolt and anchor cable joint support provide the anchoring force to the surrounding rock of the roof is 2332KN, and it is 2481KN when 60KN prestress is applied.

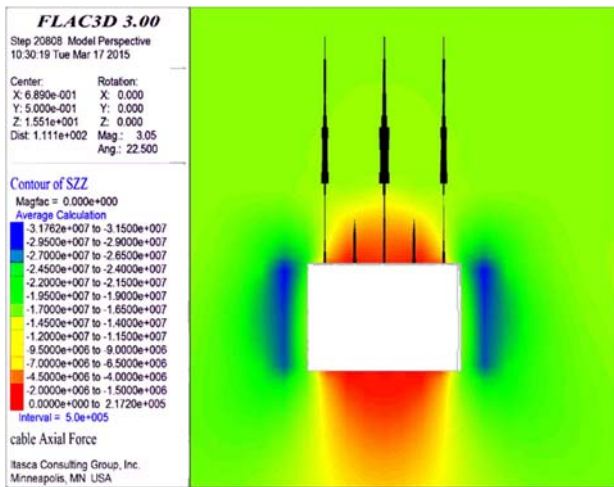


(c) The prestress applied is 60KN

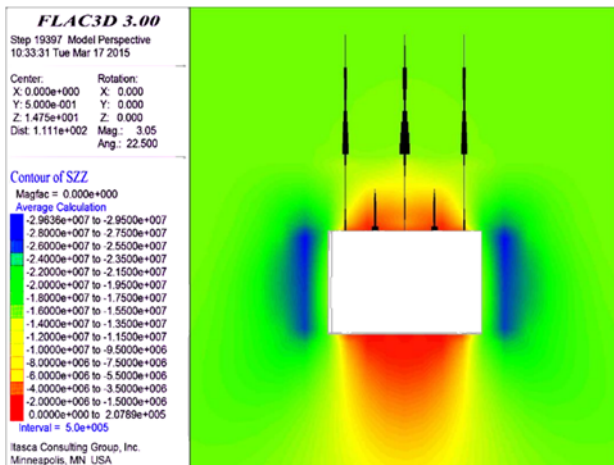
Fig. 4. Different prestressed axial force variation diagram

The peak position of the maximum anchoring force appears in the middle of the length of the anchor cable. With the increase of the prestress, the radial force provided by the anchor rod and anchor cable combined support to the surrounding rock also increases, and the corresponding radial restraint ability provided to the surrounding rock also increases.

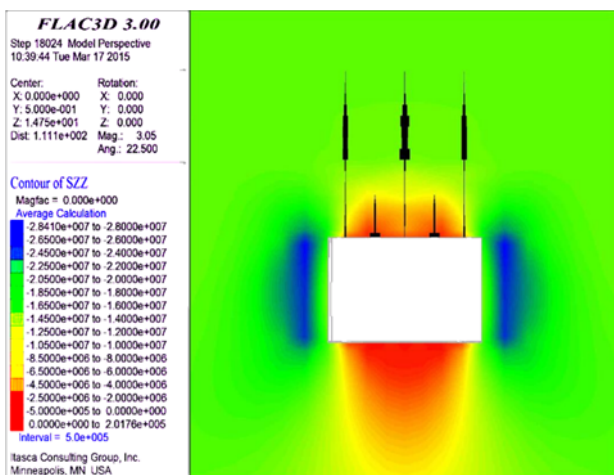
2.3 Vertical stress change of roof under different prestress



(a) The prestress applied is 20KN



(b) The prestress applied is 40KN



(c) The prestress applied is 60KN

Fig. 5. Different prestress vertical stress change diagram

As shown in the figure, when the prestress of the roof anchor cable is 20KN, it is 0.217MPa, when the prestress is 40KN, it is 0.207MPa, and when the prestress of the anchor cable is 60KN, it is 0.201MPa. Based on the above analysis, the following conclusions can be drawn: when

the prestress is 60KN, the vertical stress of the roof improves most obviously, and 60KN is the best value for the prestress of the roof anchor.

Through simulation, it can be found that the combined support of bolt and cable has obvious effects in controlling the subsidence of the roof of the roadway, reducing the stress value at the roof, and increasing the anchoring force to the surrounding rock. The greater the prestress, the greater the impact on the deep mine. The better the supporting effect of the soft rock roadway.

3 Conclusion

In this paper, numerical simulation technology is used to analyze and study the supporting effects of different prestresses in the joint supporting of soft rock roadways in deep mines. The main conclusions are as follows:

(1) For deep mine soft rock roadway support, the application of bolts and cables to apply prestress can significantly increase the compressive stress value in the anchoring area, forming an effective and large active support area in the anchoring area, and the surrounding rock of the roadway Effective control.

(2) Through the numerical simulation analysis of this paper, it can be concluded that the greater the prestress, the better the support effect, and the prestress in practical applications is not limited to the maximum value of 60KN. Therefore, it is suggested to use the combined support of higher prestressed bolt and anchor cable when supporting deep soft rock roadway.

References

1. M .C. He, X.M. Sun. Science Press.M.(2004)
2. K.W. Rong, A.X. Wu, S.H. Yin. Mining Research and Development.J.40, 94-97(2020)
3. X.P. Guo, D.Y. Hao. Mining, **28 (12)**: 123-127 (2019)
4. J. Cao, S.L. Guan, Z.X. Wang, etc. China Mining.J. **28 (S1)**,200-204 + 208 (2019)
5. L.C. Han, Y. Liu, S. Wang, X.T. Kang, Y.Y. Wang, Mining Research and Development.J.39,87 (2019)
6. H.J. Zhang, H.Y. Li, S.C. Li, etc. Journal of Mining and Safety Engineering.J. **32(6)**, 955-962 (2015)
7. H.J. Zhang, H.Y. Li, T.P.Zhang, etc. J. Journal of China Coal Society. 44 (2),409(2019)
8. C.R. Duan, Q. Zheng, G.F. Yu, etc. J. Industry and Mine Automation, **6**, 69(2020)