ISSN 2616-5767 Vol.3, Issue 5: 122-130, DOI: 10.25236/AJETS.2020.030516

Simulation Research on Grouting Spacing in Soft Rock Roadway

Qiang Su[1], Jianyong Pang[1], Hua Wang[2,*]

[1] School of Civil Engineering and Architecture, Anhui University of Science and Technology, Huainan 232001, China
[2]Mine Construction Branch, China Coal Research Institute, Beijing 100013, China
**Corresponding Author: E-mail.: 787577336@qq.com.*

ABSTRACT. *According to Gubei Coal Mine 1552 (3) working face soft rock roadway support has different degrees of roof subsidence, floor heaves, and slabs, accompanied by a large number of anchor cable breakage failures, through Flac3D numerical simulation, grouting for the roof With the two models of full-face grouting, the anchor cable spacing is 3m, 4m, 5m, 6m, and three new support schemes under different environments are obtained. The results show that the plastic zone range of 3m and 4m is the smallest and has the best control effect on the deformation and failure of the roadway. The spacing of 4m is more economical in cost control.*

KEYWORDS: *soft rock roadway, Flac3D, top grouting, full section grouting*

1. Introduction

Coal mine resources are an important foundation for global economic and social development [1-2]. The problem of soft rock roadway support in the process of coal mining resources is particularly prominent. Because the coal mine's soft rock roadway is in a very complex geological environment, the support technology seriously restricts the safe mining of coal mines. The normal development of coal mines and reasonable support methods have become an important technical guarantee for the development and utilization of coal mine resources[3-5].

At present, in the support of soft rock roadways in coal mines, the application of bolt shotcrete technology can strengthen the stability of the roadways. In the process of applying the bolt shotcrete technology, it is necessary to avoid the formation and destruction of loose rocks nearby, and then spray concrete on the surface of the stressed surrounding rock based on this as a prerequisite to make the overall closed surrounding rock form[6]. In addition to bolting and shotcreting technology, bolting and grouting support is another technology. When it is applied to soft rock roadway support, it should be sprayed and closed to prevent the soft rock roadway from being damaged or weathered. During the bolt joint support, reinforcement construction is required. Bolt grouting is used in the surrounding rock, combined with the grouting method to strengthen the surrounding rock of the soft rock roadway, and the

ISSN 2616-5767 Vol.3, Issue 5: 122-130, DOI: 10.25236/AJETS.2020.030516

inherently loose surrounding rock has sufficient bearing performance to ensure the soft The surrounding rock in the rock tunnel has a certain degree of compression resistance.

Aiming at the failure of supporting bolts and roof subsidence of soft rock roadway in Gubei Coal Mine, this paper uses Flac 3D numerical simulation to analyze the deformation and failure characteristics and the original support scheme is difficult to maintain the stability of the roadway mining surface. Three support schemes are proposed.

2. Project overview

2.1 Engineering geological conditions

Gubei Coal Mine of Huaizhe Coal and Electricity Co., Ltd. is located in the west of Fengtai County, Huainan City and is a large state-owned mine. The 1552(3) working face is located on the southwest side of the well bottom depot, and the east side is the wellfield boundary; the west side is the 13-1 coal seam wind oxidation zone; the north side is the F104 fault zone; the south side is the F109 fault. The face length is 170m, the coal thickness is 1.9m-6.1m, the average coal thickness is 4.5m, and the bulk density is 1.4t/m3. The coal seam mining method is a comprehensive mechanized coal mining method with inclined long walls, natural roof collapse, and retreat type one-time full-height mining. The direct roof is a composite roof composed of mudstone, sandy mudstone and coal line, with an average thickness of 4.7m and a compressive strength of 7.98-45.9Mpa. The direct bottom is mudstone and 13-1 coal, the average thickness is 1.9m, and the compressive strength is 8.74～19.36Mpa. The old bottom is sandy mudstone with an average thickness of 4.5m and compressive strength: 10.48-40.7Mpa.

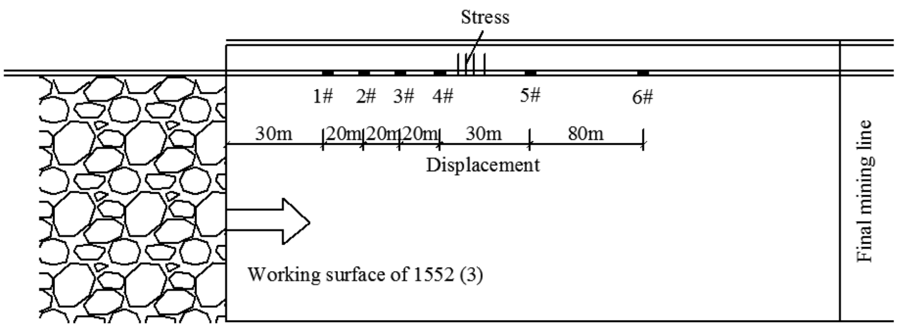


Fig.1 1552 (3) Position relation diagram of the mining face and the floor track main roadway

ISSN 2616-5767 Vol.3, Issue 5: 122-130, DOI: 10.25236/AJETS.2020.030516

1552(3) The designed mining length of the working face is 1222m, which has a fast advancing speed and strong mining intensity. The length of the mining face is 170m and the mining time is 12-15m per day. South 11-2 mining area floor track main roadway is located under the working face with a distance of about 68m. It is responsible for the transportation task of the south wing of the mine. It is the main transportation roadway of the mine. The total length of the roadway is 6850m. The spatial relationship between working face and roadway is shown in Figure 1.

2.2 Deformation characteristics of roadway

1552(3) The main roadway of the mining face floor track was originally designed for bolting and shotcrete support. Affected by the large dynamic pressure of the mining face in the vertical direction, the mine pressure of the main roadway of the track was very strong, and the anchor rods in the section failed. The roof sinks, bottom heaves, and slabs of the roadway are accompanied by a large number of anchor cable breakage failures. The deformation and destruction of the roadway will continue to increase, which affects the normal use of the roadway, and there are major safety hazards. In order to solve the above situation, the main method adopted by Gubei Mine is to repair and encrypt the anchor rods to increase the support strength. In order to ensure the safety of the roof, high-strength anchors are repeatedly installed on the roof and local surrounding rock is adopted. Grouting, but the control effect of the surrounding rock deformation of the roadway is still not ideal, the surrounding rock deformation is still large, and roof fall accidents still occur, as shown in Figure 2, which seriously affects the safety production of the mine. The physical and mechanical parameters of the surrounding rock of the mine roadway As listed in Table 1, the physical and mechanical parameters of anchor rods and anchor cables are listed in Table 2.

Table 1 Physical and mechanical parameters of surrounding rock of roadway

Rock formation type	Sandy mudstone	Medium-fine sandstone	Silty mudstone	Mudstone	Carbonaceous mudstone
density/(kg/m3)	2650	2600	2600	2700	2650
Elastic Modulus/GPa	9.6	18.6	9.0	7.5	7.5
tensile strength/MPa	2	9.6	2	0.3	0.25
Poisson's ratio	0.27	0.3	0.28	0.35	0.35
Cohesion/MPa	3.8	15.5	3.8	2.5	2.2
Internal friction angle/°	28.6	38.2	28.6	29.7	28

ISSN 2616-5767 Vol.3, Issue 5: 122-130, DOI: 10.25236/AJETS.2020.030516

Table 2 Physical and mechanical parameters of anchor rod and anchor cable

name	Elastic Modulus (Pa)	tensile strength (F)	Cross-sectional area(m^2)	Cement adhesion per unit length	Cement stiffness per unit length	Perimeter of cement slurry	Friction angle of grout
Anchor rod	2e11	1e20	0.000379	10e20	2e9	/	/
Anchor rope	2e11	1e20	0.000379	10e20	2e9	/	/
Grouting Anchor rod	2e11	1e20	0.00034			The grout diffusion radius is calculated according to about 1.3~1.8 of the grouting bolt/anchor cable length	35~40
Grouting Anchor rope	2e11	1e20	0.000379			The grout diffusion radius is calculated according to about 1.3~1.8 of the grouting bolt/anchor cable length	35~40

Fig.2 Deformation and failure characteristics of surrounding rock

3. Flacd3D simulation

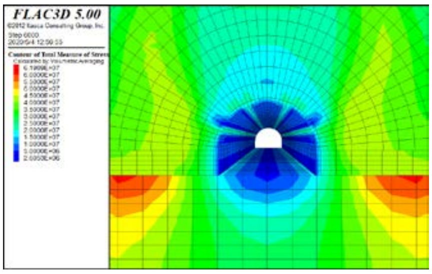
According to the actual geological conditions, the corresponding FLAC3D numerical model is established. The model size is 60000×40000×45000mm, which is divided into 33600 nodes and 38247 nodes, so as to simulate the force characteristics of the auxiliary lane of the 11-2 track lane. The horizontal principal stress here is 16MPa; the vertical principal stress is 10.2MPa. The in-situ stress field belongs to the σHv type stress field. The layout direction of the roadway should be at a certain angle with the direction of the maximum horizontal principal stress. In the process of modeling, a rectangular coordinate system was adopted in strict accordance with the size of the geological profile. The XOY plane was taken as the horizontal plane, the Z axis was taken as the vertical direction, and the upward direction was specified as positive. The entire coordinate system conforms to the right-handed spiral rule. The boundary conditions of the three-dimensional model

ISSN 2616-5767 Vol.3, Issue 5: 122-130, DOI: 10.25236/AJETS.2020.030516

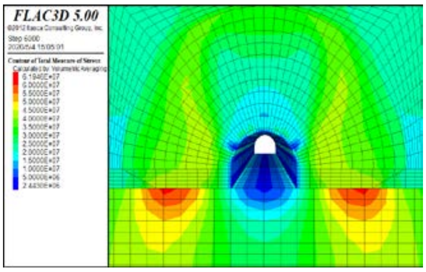
are taken as: the upper part is a free boundary, and the surrounding and bottom are hinged.

Using FLAC3D, three different types of models were made: top grouting model, and full-face grouting model. Among them, the top-side grouting model and the full-face grouting model each produced four models with grouting anchor cable spacing of 3m, 4m, 5m, and 6m, a total of nine models. The stress model is shown in Figure 3，The plastic zone model is shown in Figure 4,The top grouting model in the plastic zone is shown in Figure 5, and the full-section grouting model in the plastic zone is shown in Figure 6.

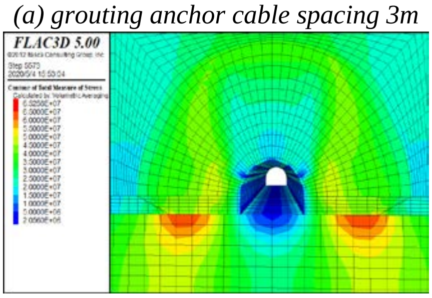
Based on the analysis of Figures 3 and 4, the maximum stress after the excavation of the roadway is mainly concentrated on the two sides, the minimum stress is concentrated on the center of the vault and the floor, and the maximum and minimum stresses both increase with the increase of the damage degree, which indicates that the roadway is damaged with the increase As the stress increases, the stress on the roadway becomes more and more serious. With the increase of the stress, the roadway will be squeezed and deformed. The uneven stress distribution will cause the roadway to appear shear stress and cause the inner wall of the roadway to crack or even collapse.



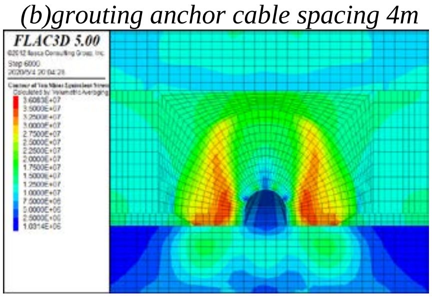
(a) grouting anchor cable spacing 3m



(b)grouting anchor cable spacing 4m



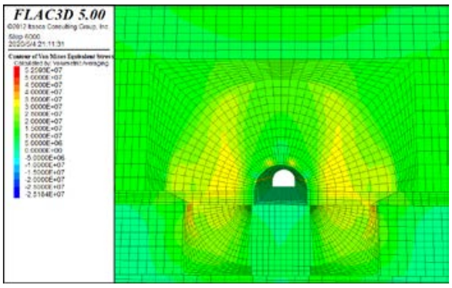
(c) grouting anchor cable spacing 5m

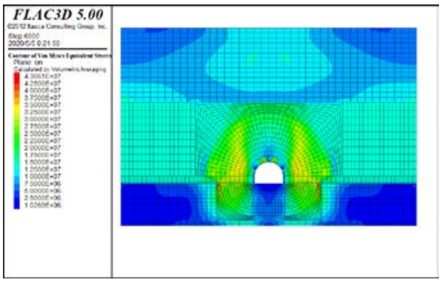


(d) grouting anchor cable spacing 6m

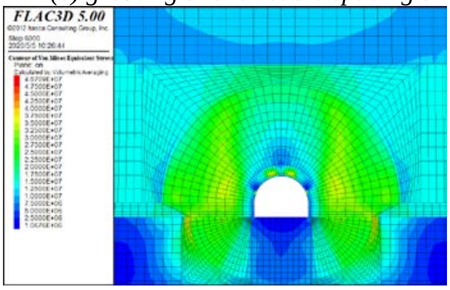
Fig.3 Top grouting stress model

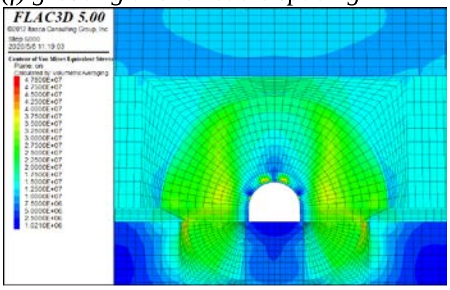
ISSN 2616-5767 Vol.3, Issue 5: 122-130, DOI: 10.25236/AJETS.2020.030516





(e) grouting anchor cable spacing 3m *(f) grouting anchor cable spacing 4m*





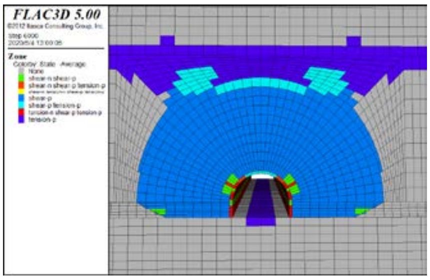
(g) grouting anchor cable spacing 5m *(h) grouting anchor cable spacing 6m*

Fig.4 Full-face grouting stress model

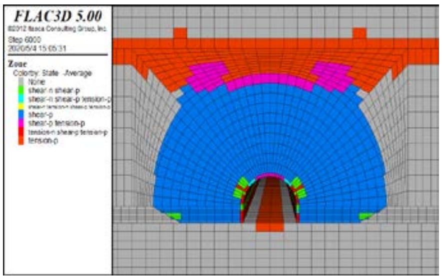
At the same time, it can be seen that the stress around the roadway reaches its maximum value at the two sides of the roadway, and the stress concentration coefficient is the largest. The maximum stress of the top-side grouting model is about 15MPa. After that, the horizontal stress of the roof first fluctuates at about 3.0-14.0MPa. The stress of the full-face grouting model is about 25MPa, and then the horizontal stress of the roof first fluctuates at about 2.0-20.0MPa. The surrounding of the roadway is a stress reduction zone, and the stress around the roadway can reach the original rock stress at a depth beyond the two sides of the roadway.

According to the above analysis, the overall law of stress distribution remains the same, and basically does not change with the change of the bolt spacing. This is because the stress distribution is affected by the shape and size of the roadway. When the roadway shape and size are the same, the surrounding rock stress of the roadway The distribution presents a basically similar law, which has nothing to do with the difference in support methods.

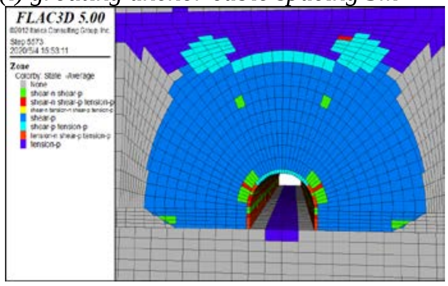
ISSN 2616-5767 Vol.3, Issue 5: 122-130, DOI: 10.25236/AJETS.2020.030516



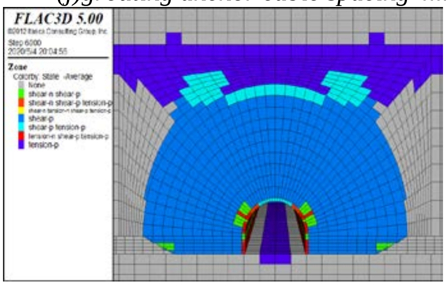
(i) grouting anchor cable spacing 3m



(j)grouting anchor cable spacing 4m

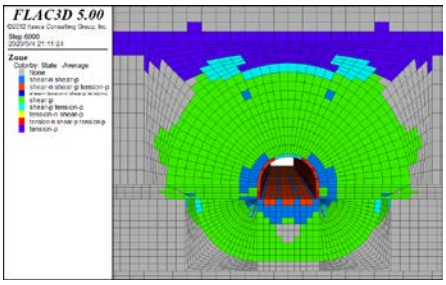


(k) grouting anchor cable spacing 5m

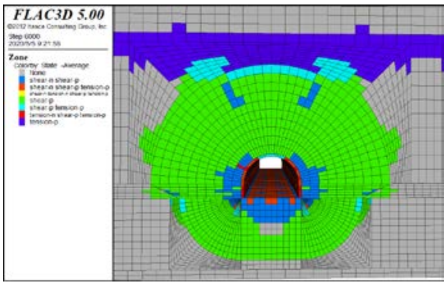


(l)grouting anchor cable spacing 6m

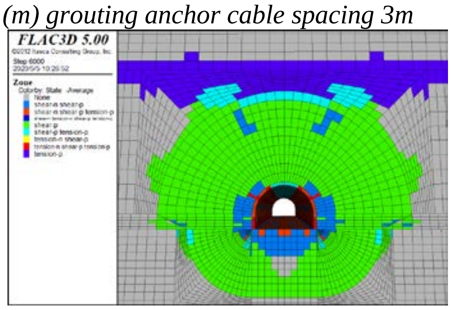
Fig.5 The top grouting model in the plastic zone is shown



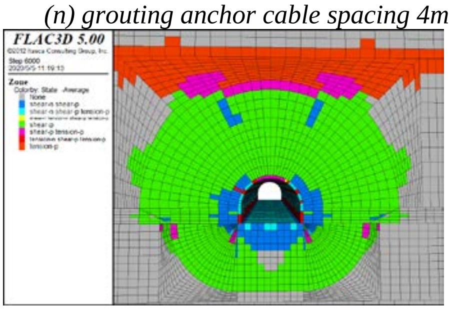
(m) grouting anchor cable spacing 3m



(n) grouting anchor cable spacing 4m



(o) grouting anchor cable spacing 5m



(p) grouting anchor cable spacing 6m

Fig.6 The full-section grouting model in the plastic zone is shown

It can be seen from the model plastic zone cloud diagrams in Figures 5 and 6 that the distribution of the plastic zone of the arched part of the roadway is dominated by shear stress failure, while the bottom plate is dominated by tensile stress failure. The zone depth reaches the maximum and is dominated by shear failure.

It can be seen that with the increase of the bolt spacing, the range of the plastic zone of the surrounding rock and the maximum damage depth gradually expand, indicating that the stability of the surrounding rock of the roadway is affected by the change of the bolt spacing. When the bolt spacing is increased from 3m to 4m, the increase in the degree of damage to the surrounding rock is relatively small. After that, as the spacing increases, the maximum depth of the plastic zone is still increasing, especially for the roof and floor. Therefore, the analysis believes that 4m spacing is more appropriate, which can increase the speed of excavation while reducing support costs.

4. Conclusion

According to the simulation results, three schemes are proposed.

(1) Roadway undamaged: ordinary bolt lining support.

(2) Serious damage to the top: grouting is added to the anchor rod lining support (the scope of grouting is the top and the upper part).

(3) Severe damage to the entire section: add grouting to the foundation of the bolt lining support (the grouting range is the top, side and bottom plate).

Acknowledgments

This work was financially supported by the Science and Technology Innovation and Entrepreneurship Special Fund of China Coal Technology & Engineering Group (Grant No.2018MS026)

References

[1] M.C. He , J. Yang and Q. Qi (2007). Optimal design and application of coupling support for deep soft rock roadway [J].Journal of Liaoning Technical University,vol.1, no.1, p.40-42.
[2] W.K. Zhang ,D.L. Liu and D.Z. Sun (2020).The destruction mechanism and active control technology of surrounding rock in deep roadway in Chengjiao coal mine[J].Mining Safety and Environmental Protection,vol.47, no.3, p.76-81+86.
[3] L. Fan,W.J. Wang and C. Yuan (2020). Evaluation method for supporting effect of inclined soft rock roadway based on extenics[J].Journal of Mining and Safety Engineering,vol.37, no.3, p.498-504.
[4] P.F. Jiang, H.P. Kang and Z.G. Wang (2020). The principle, technology and application of the coordinated control of anchoring and filling of surrounding

ISSN 2616-5767 Vol.3, Issue 5: 122-130, DOI: 10.25236/AJETS.2020.030516

rock in soft rock roadway in thousand-meter deep well[J].Journal of China Coal Society,vol.45, no.3, p.1020-1035.
[5] Y. Yang, Y.D. Sun and G.Y. Zhang (2020). Research on microseismic response characteristics and support of roadway surrounding rock under dynamic load [J].China Safety Science and Technology,vol.16, no.6, p.73-79.
[6] Q.L. Li and B.B. Wang (2020). Discussion on soft rock roadway excavation support technology [J].Science and Technology Innovation Guide, vol.17, no.15, p.13+15.