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Soft rock roadway collaborative support technology and research

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Abstract

In order to solve the problems of large roadway deformation, serious roof subsidence and difficult support in the west wing transportation roadway, a collaborative support scheme of "anchor bolt+anchor cable+anchor net+shotcrete" was proposed based on the research background of the west wing transportation roadway in Yuandian No.2 Coal Mine. The Flac3 D numerical simulation is used to simulate and compare the original support scheme and the collaborative support scheme respectively. The results show that compared with the original support scheme, the plastic zone of the roof of the collaborative support scheme is reduced by 33.33 %, the floor is reduced by 51.74 %, the maximum roof subsidence is reduced by 65.57 %, the maximum floor heave is reduced by 61.11 %, and the maximum two sides are reduced by 76.79 %. The collaborative support effect is good. The field engineering test and monitoring show that the surface displacement monitoring of the roadway after the adoption of the collaborative support scheme shows that the maximum roof-bottom displacement and the two-side displacement are only 113.62 mm and 86.78 mm. Compared with the original support, the maximum roof-bottom displacement of the collaborative support scheme is reduced by 236.23 mm, and the two-side displacement is reduced by 263.07 mm. It can effectively control the stability of the roadway, improve the self-bearing capacity of the surrounding rock, and maintain the long-term stability of the roadway. The collaborative support scheme has certain reference value for other similar roadways.

Keywords

Soft rock roadway, roadway support, collaborative support, numerical simulation.

1. Introduction

With the rapid development of social economy, China 's demand for coal is also growing. In order to increase the output of coal to meet the needs of economic development [1, 2], the depth of mine mining in China has continued to extend downward since the 1980 s, and the difficulty of mining has also increased [3, 4]. At present, the shallow coal in Huaibei mining area has been exhausted, and the buried depth of the roadway is also increasing. The geological conditions are complex and changeable with the increase of the buried depth of the roadway [5, 6], especially the high-stress soft rock roadways are numerous. The traditional anchor bolt support often causes large deformation of the roadway, long deformation duration and poor safety, which brings great hidden dangers to the roadway safety [7, 8].

In order to solve the problem of surrounding rock support in deep high ground pressure soft rock roadway, domestic and foreign scholars have carried out a lot of research on the theory and method of surrounding rock support in deep high ground pressure soft rock roadway [9, 10], and put forward the use of active support as a primary support, and then timely secondary support to improve the support strength to ensure the stability of deep high stress soft rock roadway [11, 12]. However, in order to ensure the stability of deep high ground pressure soft rock roadway, primary support and secondary support need to form a community with the surrounding rock of the roadway. X.H. Kong, et al. [13] proposed and adopted the combined reinforcement technology of grouting and anchor cable to reinforce the roadway. L.F. Zhang, et al. [14] used ANSYS to study the failure mechanism of roadway and the mechanism of bolt-grouting support, put forward the combined support technology of "anchor, belt, net, cable and grouting", and implemented comprehensive control on the field application of roadway. H.P. Kang, et al. [15] put forward the concept of collaborative control of support-modification-pressure relief for roadway in kilometer deep well, soft rock and strong mining. Numerical simulation was used to compare the stress, deformation and failure laws of roadway surrounding rock in four schemes : no support, bolt support, bolt support-grouting modification, bolt support-grouting modification-hydraulic fracturing pressure relief. The principle of collaborative control of roadway support-modification-pressure relief was expounded. Li Haiyan et al. [17] proposed a joint control technology with a new type of high prestressed anchor cable and grouting anchor as the core. The above research results have fully analyzed the surrounding rock support of high ground pressure soft rock roadway, and enriched the research on surrounding rock support of high ground pressure soft rock roadway.

In order to solve the problems of large roadway deformation, serious roof subsidence and difficult support in the west wing transportation roadway, this paper takes the west wing transportation roadway of Yuandian No.2 Coal Mine as the research background, and puts forward the "bolt+anchor cable+anchor net+shotcrete" collaborative support scheme. The FLAC 3D numerical simulation is used to simulate and compare the original support scheme and the collaborative support scheme, and the field engineering test is carried out to verify the reliability of the support scheme. The collaborative support scheme has certain reference value for other similar roadways.

2. Engineering background

2.1. Engineering status.

The elevation of the west wing transportation roadway in Yuandian No.2 Coal Mine is -745~-740.7m, and the average dip angle is 20°. The roadway construction horizon is 39m of the 6 coal roof, and the lithology is mainly mudstone, siltstone, sandstone, and carbonaceous mudstone. The columnar diagram of the roadway surrounding rock is shown in Fig. 1.

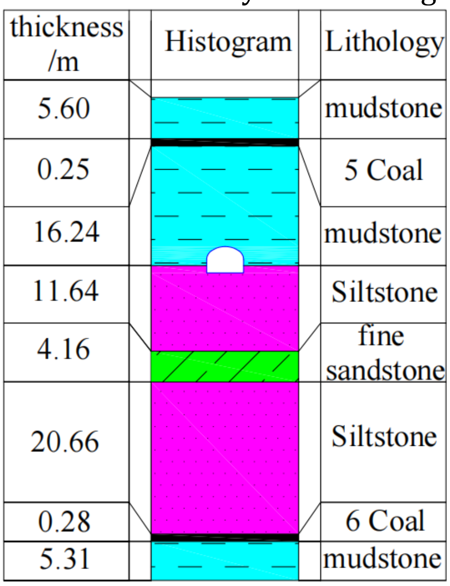


Fig. 1 Columnar diagram of surrounding rock of west wing transport roadway

2.2. Deformation characteristics of roadway.

In the early stage after the excavation of the west wing transportation roadway, the roof and side of the roadway are seriously broken under the original support scheme, the two sides are close to each other, and the roof subsidence is serious, which seriously affects the stability of the roadway. The failure characteristics of the roadway are shown in Fig. 2.

(a) (b)

Fig. 2 Failure characteristics of west wing transport roadway

2.3. Analysis of roadway failure mechanism.

Through the field observation and research of the west wing transportation roadway, combined with the analysis of similar roadways at home and abroad, it can be seen that the specific influencing factors of the deformation and instability of the west wing transportation roadway are : the elevation of the west wing transportation roadway is 740 m, and the surrounding rock pressure of the roadway is large, which makes the surrounding rock loose and difficult to control. The surrounding rock of the west wing transportation roadway is mainly mudstone, sandstone and siltstone, with low strength and poor stability. The original support scheme of the west wing transportation roadway adopts the support method of bolt, anchor net and shotcrete to reinforce the surrounding rock of the roadway, which cannot fully mobilize the deep self-bearing capacity of the surrounding rock. In summary, the original support scheme has been difficult to maintain the long-term stability of the roadway, and reasonable support measures are urgently needed to maintain the stability of the roadway.

3. Comparative study on numerical simulation of support scheme

3.1. Numerical simulation model establishment.

In order to solve the support problem faced by the west wing transportation roadway, the numerical simulation model is established by FLAC 3D based on the west wing transportation roadway of Yuandian No.2 Mine. The model size is 60×20×68m, with a total of 503810 cells and 534693 nodes. The simulated roadway is a three-center arch, with a wall height of 1.8m, a roadway width of 5m, and a depth of 740m. The load is applied to the top of the model at 18.5MPa, and the displacement constraints in the y-direction and x-direction are applied to the front and back, left and right, respectively. The displacement constraints in the z-direction are applied at the bottom. The mechanical parameters of the surrounding rock are shown in Table 1, and the parameters of the anchor bolt and anchor cable are shown in Table 2.

Table 1. Mechanical parameters of surrounding rock of west wing transport roadway

Rock stratum	K/ GPa	G/ GPa	Q/ (Kg/m3)	t/ GPa	c/ MPa	φ/ (°)
Coal	1.2	0.6	1380	0.5	0.8	32
Mudstone	1.6	1.0	2890	0.9	1.6	39
Fine sandstone	3.4	1.5	2690	2.0	2.8	36

Siltstone	2.8	1.2	2800	1.2	1.8	35

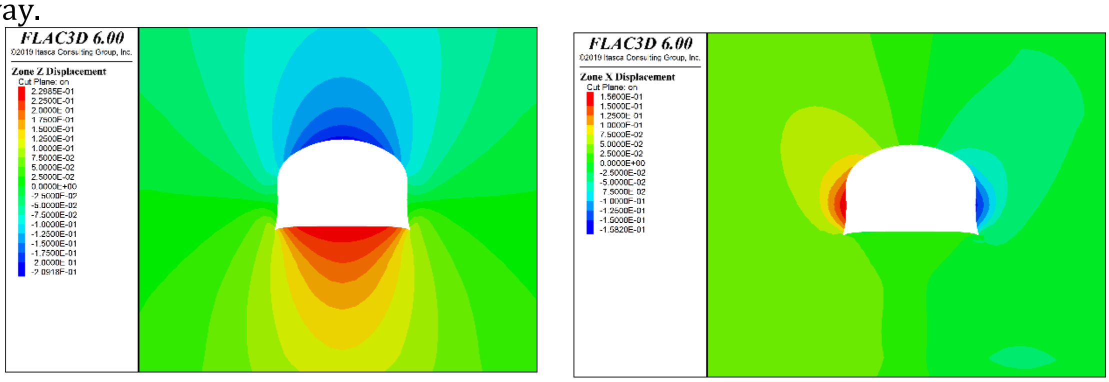
Table 2. Simulation parameters of anchor bolt and anchor cable

Category	Length/mm	Elastic modulus/ GPa	Aperture/mm	Rod diameter/mm	Tensile strength/t
Anchor bolt	6200	210	28	22	10.5
Anchor cable	2800	210	28	22	23.2

3.2. Simulation and analysis of support scheme.

3.2.1. Simulation of "anchor bolt + anchor net + shotcrete" support.

The original support scheme of the west wing transportation roadway is anchor bolt+anchor net+shotcrete combined support. The displacement cloud diagram of the original support scheme is shown in Fig. 3, and the plastic zone distribution is shown in Fig. 4. According to the numerical simulation analysis of the original support, it can be seen that the roof subsidence of the roadway is serious, the floor heave is obvious, and the convergence of the two sides is large. The plastic zone of the roof is 1.2m, the floor is 4.2m, the maximum roof subsidence is 209.18mm, the maximum floor heave is 229.8mm, and the maximum two sides are 316.2mm.Therefore, under the condition of soft rock roadway, the original support scheme bolt + anchor net + shotcrete combination support has no obvious control effect on the plastic zone, roof and floor and two sides of the roadway, and can not effectively maintain the stability of the roadway.



(a)vertical displacement (b)horizontal displacement

Fig. 3 Anchor bolt + anchor net + shotcrete displacement nephogram

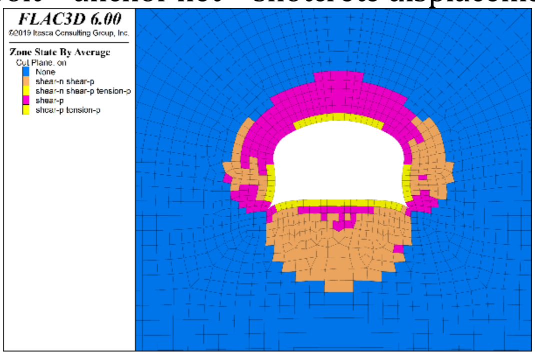


Fig. 4 Distribution of plastic zone of anchor bolt + anchor net + shotcrete

3.2.2. Simulation of "anchor bolt + anchor cable + anchor net + shotcrete" collaborative support scheme.

The displacement cloud diagram of "anchor bolt+anchor cable+anchor net+shotcrete" collaborative support scheme is shown in Fig. 5, and the distribution of plastic zone is shown in Fig. 6. According to the numerical simulation analysis of "anchor bolt+anchor cable+anchor

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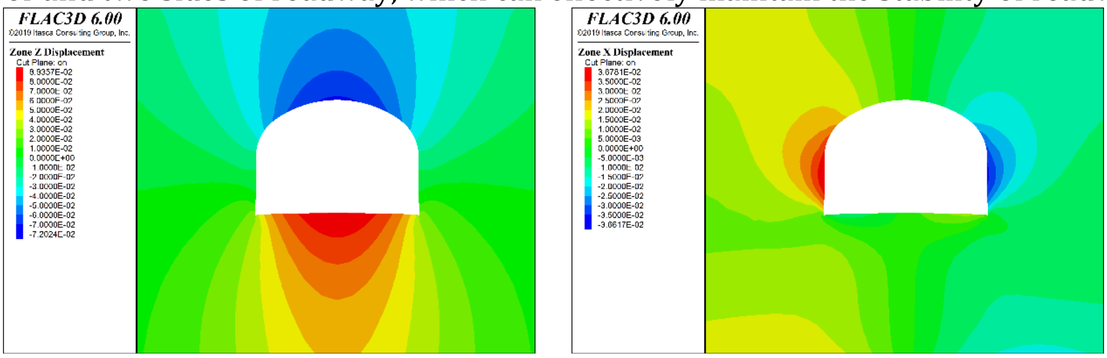
net+shotcrete" cooperative support, it can be seen that the displacement of the roof and floor of the roadway and the two sides is small, the plastic zone of the roof is 0.8m, the floor is 1.8m, the maximum roof subsidence is 72.02mm, the maximum floor heave is 89.36mm, and the maximum two sides are close to 73.39mm. Compared with the original support scheme, the roof plastic zone of the "anchor bolt+anchor cable+anchor net+shotcrete" collaborative support scheme is reduced by 33.33%, the floor is reduced by 51.74%, the maximum roof subsidence is reduced by 65.57%, the maximum floor heave is reduced by 61.11%, and the maximum two-side convergence is reduced by 76.79%. Therefore, the synergistic support scheme of anchor bolt + anchor cable + anchor net + shotcrete has obvious control effect on the plastic zone, roof and floor and two sides of roadway, which can effectively maintain the stability of roadway.



(a)vertical displacement (b)horizontal displacement

Fig. 5 displacement nephogram of anchor bolt + anchor cable + anchor net + shotcrete collaborative support scheme

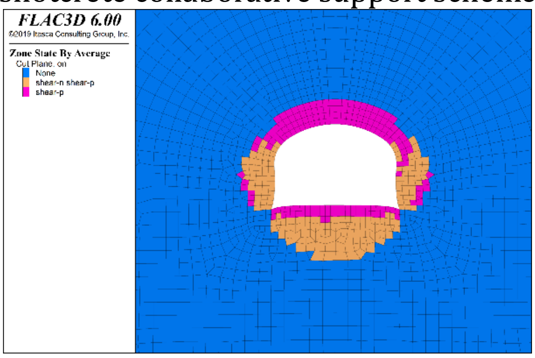


Fig. 6 Plastic zone distribution of anchor bolt + anchor cable + anchor net + shotcrete collaborative support scheme

4. Engineering applications

4.1. Collaborative support scheme design.

Based on the background of the west wing transportation roadway of Yuandian No.2 Coal Mine, this paper puts forward the coordinated support scheme of "anchor bolt+anchor cable+anchor net+shotcrete", and the support section is shown in Fig. 7. The whole section of the west wing transport roadway is supported by Φ22×2800 mm high strength screw steel anchor bolt, the row spacing is 500 × 800 mm, and each anchor bolt is anchored by 2 K2950 resin anchoring agent. The Φ22×6200 mm anchor cable is driven into the two sides, and the row spacing is 1600×1600 mm. Each anchor cable is anchored by one K2950 type and two Z2950 type anchoring agents. Using 100×100mm steel bar welding warp and weft mesh ; the surrounding rock of the concrete closed roadway with a strength grade of C20 is used. The thickness of the initial spray layer is 30-50 mm, and the secondary spray is 100 mm.

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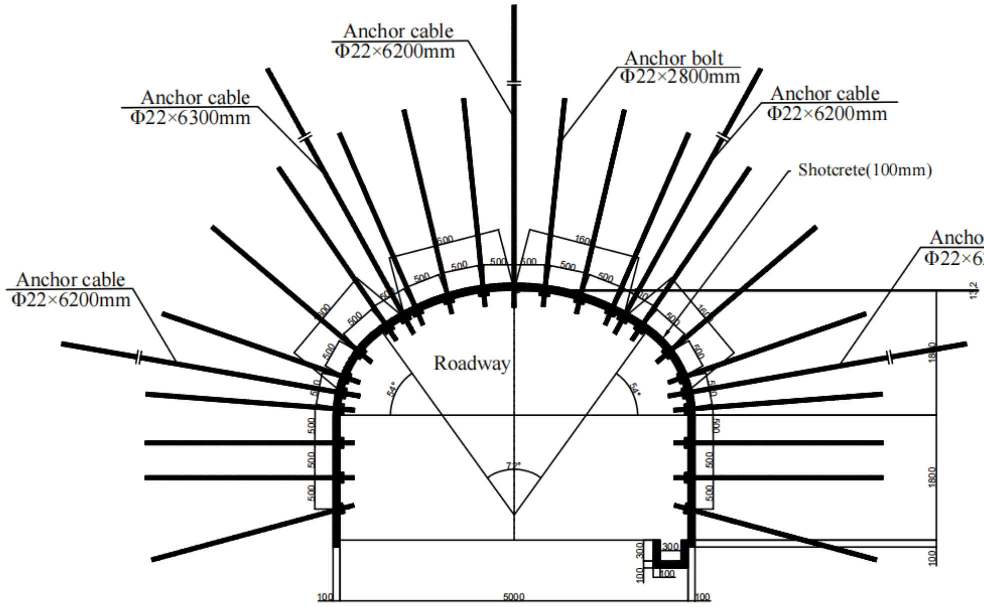
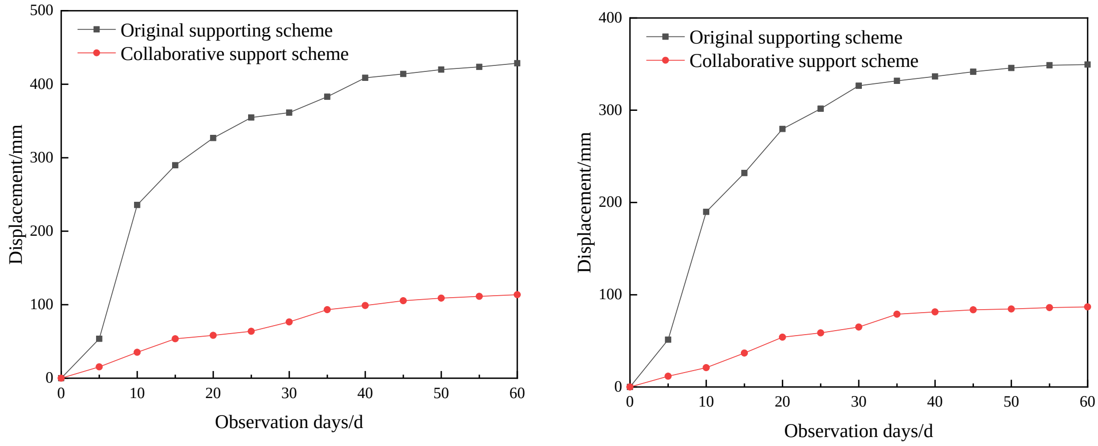


Fig. 7 Anchor bolt + anchor cable + anchor net + shotcrete collaborative support section of West wing transport roadway

4.2. Test site monitoring and analysis.

According to the above FLAC 3D numerical simulation analysis, the original support scheme and the “anchor bolt+anchor cable+anchor net+shotcrete” collaborative support scheme were selected for engineering test comparison. Through the monitoring of 60 days, the displacement monitoring curves of the original support scheme and the cooperative support scheme of “anchor bolt+anchor cable+anchor net+shotcrete” are shown in Fig. 8.



(a)top-and-bottom displacement (b)two-sided displacement

Fig. 8 Displacement monitoring curve

It can be seen from Fig. 8 that the deformation and deformation rate of the roof and floor and the two sides of the roadway in the first 30 days of the two support schemes are large, and then tend to be stable. The maximum top-bottom displacement of the original support scheme is 428.56 mm, and the maximum two-side displacement is 349.85 mm. The maximum top-bottom displacement and two-side displacement of the “anchor bolt+anchor cable+anchor net+shotcrete”collaborative support scheme are only 113.62 mm and 86.78 mm. Compared with the original support, the maximum top-bottom displacement of the “anchor bolt+anchor cable+anchor net+shotcrete” collaborative support scheme is reduced by 236.23 mm, and the two-side displacement is reduced by 263.07 mm. It shows that the synergistic support of “anchor bolt+anchor cable+anchor net+shotcrete” has a significant effect on the control of roadway roof and floor and two sides. Compared with the support effect of “anchor bolt+anchor net+shotcrete", it can better mobilize the self-bearing capacity of deep surrounding rock and improve the stability of roadway. The field effect of synergistic support of "anchor bolt+anchor cable+anchor net+shotcrete" is shown in Fig. 9.

(a)

(b)

Fig. 9 Collaborative support site

5. Conclusion

(1) Under the original support scheme of the west wing transport roadway, the roof subsidence of the roadway is serious, and the displacement of the two sides is large. The specific influencing factors of its instability are large buried depth, low surrounding rock strength and unreasonable roadway support mode, which cannot fully mobilize the deep self-bearing capacity of the surrounding rock.

(2) FLAC 3D numerical simulation shows that compared with anchor bolt + anchor net + shotcrete, the plastic zone of roof of "anchor bolt+anchor cable+anchor net+shotcrete" is reduced by 33.33 %, the floor is reduced by 51.74 %, the maximum roof subsidence is reduced by 65.57 %, the maximum floor heave is reduced by 61.11 %, and the maximum two-side convergence is reduced by 76.79 %.

(3) The field monitoring shows that the maximum roof-to-floor convergence and the two-side convergence are only 113.62 mm and 86.78 mm after the collaborative support scheme of "anchor bolt+anchor cable+anchor net+shotcrete" is adopted. Compared with the original support, the maximum roof-to-floor convergence of the collaborative support scheme of "anchor bolt+anchor cable+anchor net+shotcrete" is reduced by 236.23 mm, and the two-side convergence is reduced by 263.07 mm. It can effectively control the stability of roadway, improve the self-bearing capacity of surrounding rock and maintain the long-term stability of roadway. The collaborative support scheme has certain reference value for other similar roadways.

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