Research on Roadway Surrounding Rock Control Technology Using O-arch Combination Support Scheme

WANG Mao-yuan[1,a*],LIN Tian-shu[1,b],YIN Lei-jia [1,c], YANG Yang[1,d],YANG Lei [2,e]

[1]China University of Mining and Technology (Beijing), Beijing 100083, China,

[2]HeXi Mine, FenXi Mining Group Company，LvLiang 033300, China

[a]595952504@qq.com, [b]fayeleen@gmail.com, [c]1507590882@qq.com, [d]519485237@qq.com, [e]1511135489@qq.com

Keywords: Soft rock roadway ; Deformation of surrounding rock ; Combined support ; Numerical Simulation

Abstract： According to the soft rock roadway geological, productive conditions and the actual project features in Zhengling Coal-mine, from the theory with practical point of view， this study analysis the key damage factors of the soft rock roadway. A new kind of support scheme, O-arch combination support scheme, is designed and used in central substation in Zhengling Coal Mine. FLAC^{3D} software is used to simulate two different support programs. The roadway surrounding rock deformation is monitored. The results show that new support program can effectively control stability of complex soft rock roadway.

Roadway plays an important role in transportation and production in coal mine. The roadway stability and surrounding rock deformation have a direct influence on the safety of coal mine[1]. Appreciate support design is one of the most important method to control the growth of plastic zone and prevent the deformation and failure of roadway[2-3].

The geological conditions of Zhengling Coal Mine, is complicated as a typical “three-soft” coal seam. There is a wide distribution range of soft rock in this area, and with a high in-situ stress, which lead to the original support design can’t control the deformation of roadway surrounding rock effectively. This problem affects the safety and production of Zhengling Coal Mine seriously. According to the field situation, this study analyzed the reason of roadway surrounding rock damage and designed a new support scheme for Zhengling Coal Mine. Both Flac^{3D} numerical simulation and field monitor were used in this study. Results shown the new support scheme is effect.

Engineering Situation

The central substation of Zhengling Coal Mine is excavated in 2# coal seam, which depth is 650m. Both roof and floor of central substation are sandy mudstone, which is mixed with a small amount of powder sandstone. The Protodyakonov coefficient of mudstone is from 3 to 6. Joint, bedding developed heavily and easy to weathering in this area, at the same time this area exist broken rock mass, soft lithology and poor cementing properties. Thus, the surrounding rock of central substation belongs to high stress, swelling and physicochemical soft rock. The deformation and failure mechanism of the surrounding rock is extremely complex[4].

Analysis on key factor of roadway damage

Mechanics mechanism which affect deformation of soft rock roadway is relatively complex. Many factors, as the physical and mechanical properties of rocks, mineral composition, the mechanical environment and support design will all influence the deformation of roadway surrounding rock[5]. By field observation and measured data analysis, this study conclude the main factors affect the roadway surrounding rock stability and lead to the damage of roadway are as follows: 1. The large buried depth and high stress of roadway; 2. The insufficient supporting strength of the two sides and floor of roadway, and restraining measures is not enough; 3. The high repair rate lead to the badly damage of roadway;4. The original support scheme is not scientific.

These reasons result in there are some coupling phenomenon between support system and roadway surrounding rock, which cause the deformation and failure of roadway.

Optimization of original support design

Original support design

Original support design of Zhengling Coal Mine chose the straight wall semicircle arch scheme, which is with some kind of helping for roadway supporting. The specific way of this scheme is using bolt and anchor cable, and base plate is equipped with the base anchor, with a dip angle of 38°. The diameter of bolt is 20mm and the length is 2400mm. Reinforcing anchor cable is used in the shoulder angle of roof. And the two sides of roadway are spray processing, spraying thickness is 200mm, supporting profile as shown in figure 1. During the supporting progress of underground cavern some roadway infrastructure as water pump suffer with damage like crack, tilt, which increase the cost of secondary supporting progress and lead to the poor effect of support, the higher labor intensity of workers. Thus, there exist some problems in the original support scheme of Zhengling Coal Mine.

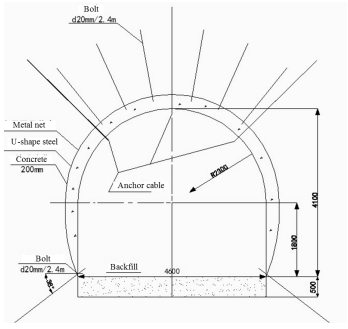


Fig. 1 Supporting profile of original support scheme

Spray anchor net cable and O-arch combination supporting scheme

There is a lot of advantages of O-arch combination supporting scheme: on the one hand, O-arch combination supporting scheme can avoid the problem faced by rigid support, its good scalability and circular cross section can control the deformation of surrounding rock in a small range; on the other hand, its effective supporting for surrounding rock can inhibit the crushing inflation of surrounding soft rock effectively; in addition, it can control the bottom drum up effectively[6].

Support parameters are as follows: rebar bolt, with diameter of 20mm and length of 2400mm, is used in this support scheme. Both spacing and row spacing of bolt is 800mm. Steel strand anchor cable is used, the diameter is 17.8mm, length is 600mm, spacing is 1600mm and row spacing is 2400mm. Bolt and anchor cable are used in both the sides and floor of the roadway, arrangement for radiation rectangle. Bar-mat reinforcement is used closed to the face of two sides and floor of roadway. The bar-mat reinforcement is inside of steel pallet, whit a size of Φ6mm×2000mm×1000

mm, grid of 100×100mm. 36# U-shape steel is chose to make the O-arch. Supporting profile is shown in figure 2.

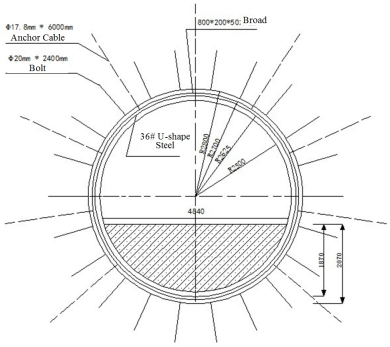


Fig. 2 Supporting profile of O-arch combination support scheme

Numerical simulation analysis

FLAC^{3D} (Fast Lagrangian Analysis of Continua in 3 Dimensions) software is used in numerical simulation. FLAC^{3D} is explored by Itasca, which can well simulate the damage or plastic flow mechanical behavior of geological material when is reached the ultimate strength or yield limit. Thus it is especially suitable for the analysis of progressive damage, instability and simulate the large deformation[7].

Model building

According to the size of roadway, the size of entire model is 50m×10m×38m. From top to bottom of the model in turn to K8 sandstone, fine sandstone, sandy mudstone, 2# coal seam, sandy mudstone, sandstone, sand mud rock. For the convenience of study, the rock mass can be assumed as a homogeneous and isotropic medium[8]. According to the analysis of rock mechanics theory, and combined with field engineering geological data, this numerical simulation analysis use Moore Coulomb constitutive relation. The physical and mechanical parameter of rock is shown in table 1 below:

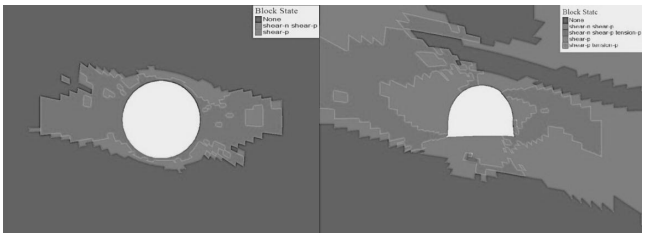
Table 1 Physical and mechanical parameter of rock

	Density /kg•m^{-3}	Coh /MPa	Fric /°	UCS /MPa	Elastic modulus /GPa	Poisson ratio	Tensile strength /MPa
K8 sandstone	2727.15	12.76	36.6	86.09	21.66	0.22	15.28
fine sandstone	2649.56	7.01	40.40	65.06	16.73	0.22	9.31
sandy mudstone	2579.44	3.06	42.93	51.79	10.61	0.24	7.28
2# coal seam	1386.72	0.62	43.27	9.38	3.10	0.30	0.87
sandy mudstone	2579.44	3.06	42.93	51.79	10.61	0.24	7.28
sandstone	2649.56	7.01	40.40	65.06	16.73	0.22	9.31
sand mud rock	2582	11.35	38.6	40.91	18.85	0.16	6.46

Plastic zone analysis of roadway surrounding rock

The rock stress state can be judged according to the different plastic zone, so the distribution of plastic zone of surrounding rock after excavation of roadway can evaluate the effect of roadway support effectively[9]. Some results can be obtained from figure 3: a large range of tensile plastic zone apparent around the roof, floor and two sides of roadway. The plastic zone of roof surrounding rock is with a thickness of 1.4m, of floor with a thickness of 2.8m and of two sizes with a thickness up to a dozen meters. The plastic zone of roadway surrounding rock decreases greatly after using the O-arch combination support scheme. the plastic zone of roof surrounding rock is with a

thickness of 0.64m, of floor with a thickness of 0.47m and of two sizes with a thickness of 5.15m. The deformation of roadway decreases greatly.



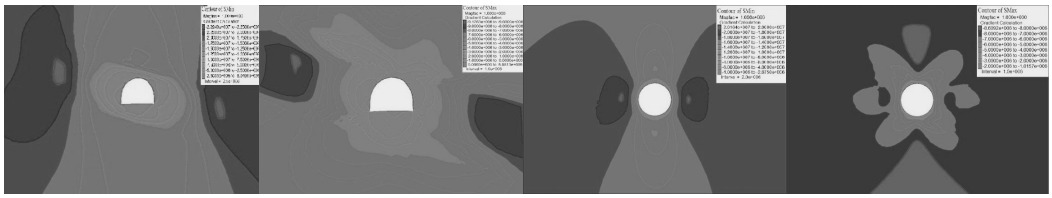
a. O-arch combination support scheme b. Original support scheme

Fig.3 Plastic zone of roadway surrounding rock

Stress analysis of roadway surrounding rock

Under the original support scheme, stress concentration appeared in the deep area of two sides roadway surrounding rock. The distribution cloud image of the maximum principal stress of roadway surrounding rock (figure 4-a) shows that the maximum principal stress of extreme area of roadway surrounding rock is beside the left side of roadway, and the distance to the roadway surface is around 7.6m. The extreme stress value is 23.7MPa with the stress concentration factor of 1.48. The distribution cloud image of the minimum principal stress of roadway surrounding rock (figure 4-b) shows that most of the roadway surrounding rock surface is in the tensile stress state, when floor and two sides are particularly serious, and the tensile stress is in the range of 0.5MPa.

Under the O-arch combination support scheme, stress concentration still appeared in the deep area of two sides roadway surrounding rock, and the maximum principal stress of extreme area of roadway surrounding rock is also beside the left side of roadway. Bud the distance to the roadway surface is decrease to around 2.24m. And the extreme stress value is as less as 20.2MPa with the stress concentration factor of 1.26, as shown in figure 4-c. The distribution cloud image of the minimum principal stress of roadway surrounding rock (figure 4-d) shows that just a small part of roadway surrounding rock is in the tensile stress state, with the O-arch combination support scheme. Thus, compared with the original support scheme, stress state of roadway surrounding rock under the O-arch combination support scheme is of greatly improve.

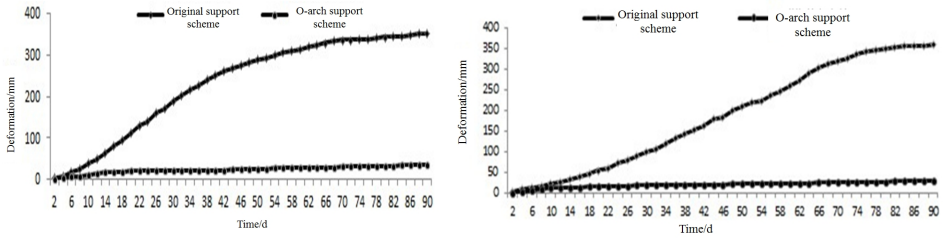


a.σ_{max} of original support scheme b.σ_{min} of original c. σ_{max} of O-arch support scheme d. σ_{max} of O-arch

Fig. 4 The stress distribution cloud image of roadway surrounding rock

Roadway deformation monitoring analysis

To verify the effect of O-arch combination support scheme, the field observation of roadway deformation is carried out. The compared of side-to-side and roof-to-floor deformation situation under two kinds of support scheme are shown in figure 5:



a. Deformation of size-to-size b. Deformation of roof-to-floor

Fig. 5 Deformation of roadway

Figure 5-a shows that under the original support scheme in the 90th day of monitoring the deformation of side-to-side and roof-to-floor is 345mm and 351mm respectively, and the deformation of the roadway is still rising. This shows that the original support scheme have been unable to control the deformation of roadway surrounding rock effectively.

After the using of O-arch combination support scheme, the deformation of side-to-side and roof-to-floor increase slightly in the first 20 days of monitoring, and keep basic stable agter 30days. The maximum of deformation in this support scheme of side-to-side and roof-to-floor is just about 29mm and 34mm respectively. The results of monitoring show that O-arch combination support scheme has a good effect in the control of roadway surrounding rock.

Conclusion

1.Aimed at the specific situation of soft rock roadway in Zhengling Coal Mine, this study put forward of the support mechanism of “soft first” of O-arch combination support scheme. Through the mechanism analysis this study concluded that this support scheme is more reasonable when all around of the roadway is under high pressure.

2.Using FLAC^{3D} numerical simulation, rock stress, rock strain and the plastic zone are analysis and comparison between two kinds of support scheme. Results show that, compared with the original support scheme, the deformation of roadway under O-arch combination support scheme reduced obviously. The O-arch combination support scheme support effectively.

3.A field support experiment is done in the central substation repair soft roadway in Zhengling Coal Mine, and with the roadway deformation monitoring. Results show that the deformation of roadway das been controlled effectively under the O-arch combination support scheme. This study provides a reliable reference for similar projects.

References

[1]SHEN Jie, LIANG Wen-xue. Test and measurement study on released ring in full seam gateway of island coal mining face[J].Coal Science and Technology，2007（6）

[2]WANG Qin-di, JING Hong-wen, WANG Meng. Analysis on support results of different pre-stressed bolt/anchor in seam gateway along goaf of fully mechanized top coal caving mining face[J]. Coal Science and Technology，2009（9）

[3]XUE Shun-xun. Study of deep soft rock tunnel supporting technology [M].China coal press，2002:12-19

[4]SUN Yan. Soft rock roadways using spray anchor net cable and type O arch support analysis

[J].Shanxi Coking Coal Science & Technology，2012（8）

[5]HE Man-chao, Introduction of soft rock tunnel engineering[M]，China University of Mining and Technology Press，1993.

[6]ZHOU Jun-fan, LI Da-wei, LI Deng-yue, Application of high strength U section steel support in soft rock roadway[J]. Coal Technology, 2010（12）, Vol.29,No.12:80-82.

[7]LIU Bo, HAN Yan-hui, Principle, instance and application guide of FLAC[M].China Communications Press，2005.09

[8]WANG Mao-yuan, XUE Hua-jun, BAI Xiao-sheng. Optimization and application of roadway support program based on FLAC3D[J],Chian coal，2012,9:40-42.

[9]MA Shi-jin, The softening deformation analysis and simulation calculation of dilatancy in the soft rock tunnel[D],Liaoning Technical University,2002.