Research on Deformation Control Technology of Broken Soft Rock Pre-mining Roadway

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Abstract. This paper takes the right third pre-mining roadway of Double-river Coal Mine as the research object. Based on the analysis of the deformation law of soft rock broken roadway, a composite support technology scheme combining one-time reinforcement support and surrounding rock grouting reinforcement scheme is proposed. The application shows that the deformation of the composite support roadway is significantly lower than that of the conventional support roadway used in the same environment. The deformation of the roadway is effectively controlled, which greatly reduces the amount of repair and maintenance of the roadway, and achieves safe mining of the working face.

1. Introduction
Roadway in deep mine, soft rock roadway and development roadway with broken rock are an emphasis of research on mine roadway support in recent years, and also a technical problem that puzzles production of many mines. Double-river Coal Mine is a medium-sized mine put into production in 1959 at an annual output of 60t, and after exploitation for over 50 years, as of now the mine has been exploited to -520 level, 3# and 2# coal seams are mainly exploited, the burial depth of the exploited coal seams is more than 700m, and the verified production capacity of the mine is 1,100,000t. This mine is one of typical mines in which coal seams are difficult to exploit due to soft and broken rock in China. Control and maintenance of ground pressure of roadways in stope seriously puzzles safe production of the mine, heading is very difficult, and each heading need be supported independently, and even special advanced support measures shall be taken to pass individual sections safely, and more seriously maintenance is very difficult due to fast speed and large amount of deformation of roadways and short service time, as a result, deformation and inbreak of a lot of roadways are caused, and the backstopping work is hard to proceed normally, so steady improvement of both yield and economic benefit of Double-river Coal Mine are seriously affected and restricted. Therefore, exploration and settlement of heading and supporting problems of development roadways with high-stress soft and broken rock are of great significance to increase of economic benefit and improvement of conditions for safe production of the mine.

2. Engineering geological conditions of test stope

2.1. Structure of surrounding rock stratum
The right No.3 roadway in new district of Double-river Coal Mine is located in No. 3 coal seam of the mine at -520 level, the mining depth in the middle of two goafs in south and north wings of the field is up to 780m, mine pressure appears violently. The dip angle of coal seams in the roadway is -8°, the average thickness of coal seams is 3.8m, and the height of the roadway is 3.5m. the roof is made of...
16m middle-fine sandstone, fracture and its structural plane development, many faults and folds exist at a density of 20~30 faults and folds/m, between fractures clay minerals are filled, which swell, soften and disintegrate when touching water so as to exhibit very poor self-stabilization, the physical and mechanical properties and change rules are reflected in inbreak with mining.

2.2. Rock mechanics parameters
The rock mechanics parameters obtained by measuring the rock cores extracted from the right No.3 roadway by means of MTS815.03 electro-hydraulic servo rock testing system in laboratory are shown in Table 1, and the full stress-strain curves obtained from the test are shown in Fig.1 and Fig.2.

Table 1. Measured rock mechanics parameters

| Samples | Dimensions of sample | Uniaxial compressive strength/MPa | Elastic modulus/MPa | Poisson’s ratio |
|---------|----------------------|-----------------------------------|---------------------|----------------|
|         | Diameter/mm x Height/mm |                                   |                     |                |
| No.1    | 50 x 69.43           | 4.5                               | 8723.852            | 0.2428         |
| No.2    | 50 x 68.69           | 2.9                               | 6370.365            | 0.14272        |
| Average |                      | 3.6                               | 7547.1085           | 0.19426        |

As shown in Table 1, Fig.1 and Fig.2, the surrounding rock in the right No.3 roadway is typical soft and broken rock.

3. Deformation rules of development roadways with soft and broken rock and principles for design of support

3.1. Deformation rules of development roadways with soft and broken rock
The service life of development roadways is short, and their service period is in general 2 years, and even 4—5 months, so they are temporary works. In accordance with a large number of the site monitoring data of Double-river Coal Mine, and in combination with the mechanism of mine pressure that appears, the general form of the curve deformation of surrounding rock of roadways vs time is shown in Fig.3, and main process can be roughly divided into three stages:

(1) Stage of decelerated deformation. The characteristic is deceleration of surface displacement with increase of time, which is mainly reflected in a period of time from roadway excavation to end of support, and is a comprehensive reflection of deformation of surrounding rock with heading and bearing capacity at initial stage of support. The duration and amount of deformation are closely related to promptness of roadway support and initial rigidity of support.

(2) Stage of linear growth. The amount of deformation of surrounding rock shows linear (or approximate linear) increase with continuity of time, and mainly appears in the periods of development and mining preparation before cutting.
(3) Stage of accelerated growth. Deformation of surrounding rock accelerates with continuity of time, and mainly happens after completion of heading or in the period of backstopping of working face. In general, during heading construction deflection of the roof of upper roadways is 0.5m, and displacement of both sides is up to 0.5m; during backstopping of working face deflection of the roof increases to 0.9-1.5m, and the advanced pressure reaches approximate 100m.

3.2. Principles for design of support
Main principles for design of support are as follows:
(1) Improve the stress state of surrounding rock near the surface that degrades due to roadway excavation, and restrict radial expansion deformation of surrounding rock along free face or structural surface of roadways.
(2) High-strength or ultrahigh-strength anchor cables are adopted at roof, floor, spandrel and side walls to increase self-strength of surrounding rock so as to improve the shear strength of surrounding rock, mobilize the bearing capacity of deep surrounding rock and restrict slippage of key blocks along potentially ruptured slip plane.
(3) Solidify the surrounding rock in rupture zone to recover and improve integrity and overall strength of surrounding rock, and enlarge the range of effective bearing ring of supporting structure in coordination with anchor cables and meshes.
(4) Adjust and optimize roadway support methods continuously according to the application effect at the site.

4. Control of deformation of roadways and technical measures for support
The right No.3 roadway of Double-river Coal Mine is “a roadway (category IV) with unstable surrounding rock”, due to breaking rules and characteristics of such surrounding rock, general support of anchor cables and meshes is insufficient, so composite support technology shall be adopted available locally to the site conditions so as to reduce the cost of roadway support on the premise of guaranteeing reasonable and safe support of the roadway. The composite support measures taken for heading construction on working face are hereby described as follows:
(1) Implement reinforced support at one time
During construction at the site follow the support guiding ideology of “deepening inside, densifying outside and reinforcing surface” to improve integrity of the rock mass in loose zone to enhance the resistance of plastic zone, and meanwhile increase the length of part of anchor bolts to restrain and restrict overall displacement of loose zone by means of deformation difference between plastic zone and loose zone. In accordance with different stope roadways, conditions of surrounding rock and requirement for convenient construction, etc., combined support of anchor cables and meshes is adopted in construction.
The roof is supported by Ф20mm×2000mm high-strength resin anchor bolts and diamond reinforcing meshes pressure spot welded by means of W type steel strips, 5 anchor bolts are arranged on each row at a space of 900mm×1000mm, and the depth of each anchor bolt is 1.9m. Ф15.24mm×9000mm steel stranded anchor cables are adopted, 3 anchor cables are arranged on each row at a space of 1000mm×1000mm, and the depth of each anchor cable is 5m. The left and right sides are supported by whole course anchor bolts, FRP anchor bolts and diamond reinforcing meshes pressure spot welded by means of anchor cables in combination, in which two whole course anchor bolts and FRP anchor bolts at the size of Ф20mm×2000mm are arranged on each row and each side, and the anchorage depth is 1.9m. The size of anchor cables is Ф15.24mm×9000mm, the space between anchor bolt and anchor cable rows is 1000mm×1200mm, 1 roll of CK2360 resin anchoring agent is filled into each anchor bolt hole, and 3 rolls of CK2360 resin anchoring agent are filled into each anchor cable hole. The sections of support are shown in Fig.4, Fig.5 and Fig.6.
Figure 6. Schematic diagram of support on both sides

(2) Grouting reinforcing support of surrounding rock of roadway

When the zone of high-stress concentration or crushed zone through faults is encountered, the surrounding rock grouting reinforcing technology is adopted. After grouting reinforcement of soft and broken rock, the fractures in rock mass around the roadway are filled with cement mortar, and after setting of cement mortar, bearing capacity of rock mass itself is strengthened effectively so that the speed and amount of deformation of the reinforced surrounding rock of the roadway are controlled effectively. The specific implement scheme is as follows:

The grouting reinforcing support of surrounding rock is implemented at a distance of 5m from the crushed zone. Arrangement of grouting anchor bolts is shown in Fig.4, the row spacing of grouting anchor bolts in axial direction of the roadway is designed at 1200 mm. The grouting materials are cement mortar and Malison, respectively, the cement mortar is made of 425# cement at water-cement ratio of 1:1, the grouting pressure is 10MPa, and the grouting pressure time is 3～5min. For Malison grouting, two materials are mixed uniformly, and sufficient reaction is guaranteed, under normal conditions Malison foaming lasts for 85s, and the expansion ratio is 2.

Parameters of grouting anchor bolts are as follows:

YB242-63 international welded tubes at the size of Φ24×2000 mm are adopted as grouting anchor bolts, the depth of anchor bolts into rock mass is 1900mm, the exposed 100mm is provided with threads for connection with high-pressure quick couplings of grouting pump, and meanwhile the requirement for installation of supporting boards; the length of middle grouting segment is 1400 mm, the bolt end is 300mm long, and is flattened and twisted into Chinese doughnut shape; 15 Φ6 mm grouting holes are arranged crosswise on anchor bolts at a space of 100mm; hollow rapid-hardening expansion cement cartridge that can set within 1～5 min and can provide sufficient anchorage force is adopted as anchor sealing material.
5. Effect of comprehensive control for deformation of roadway in stope

(1) Effect of control for deformation of roadway with composite support

In order to investigate the effect of composite support of the roadway, 3 observation sections for convergence deformation of the roadway are set in the segments of the right No.3 roadway with and without composite support, respectively, and the distance between the sections is 10 m. The convergence deformation curves of the roadway with and without composite support are shown in Fig.8 (a) and (b), respectively.

![Figure 7. Arrange of grouting anchor bolts](image)

![Figure 8. Comparison of convergence deformation of roadway](image)

As shown by comparison of convergence deformation of the roadway in Fig.8, the amount of deformation of the roadway with composite support is reduced significantly in comparison with the amount of deformation of the roadway with conventional support in the same environment, so deformation of the roadway is under effective control.

(2) Comparative analysis of strength of rock samples before and after grouting of broken surrounding rock

For further inspection of the grouting effect, rock cores are extracted at the site for mechanical pressure test of the rock samples before and after grouting reinforcement, and the comparison of strength is shown in Table 2.
Table 2. Comparison table of improvement percentage of strength of rock samples before and after grouting reinforcement

| Name of samples | Post-peak residual strength before grouting/MPa | Strength of samples after grouting reinforcement/MPa | Improvement percentage |
|-----------------|-----------------------------------------------|-------------------------------------------------|------------------------|
| 1# rock sample  | 0.1                                           | 1.22                                           | 1120%                  |
| 2# rock sample  | 3.5                                           | 4.5                                            | 29%                    |
| 3# rock sample  | 2.1                                           | 4.3                                            | 105%                   |
| 4# rock sample  | 3.3                                           | 6.5                                            | 97%                    |

The results of mechanical test show that the strength of rock samples after grouting in comparison with that before grouting is improved at different degrees, and the higher degree of broken rock samples, the higher the improvement percentage of strength after grouting.

(3) Evaluation of comprehensive effect

During service of the whole right No.3 development roadway, the ground pressure of the roadway weakens obviously, and the surrounding rock of the roadway in high stress zone and fault crushed zone maintains perfect safety and stability. Although, in the backstopping period, swelling and cracking appear on both sides of some roadway sections, the roof is kept intact all the time and does not affect normal backstopping, and collapse and inbreak in the heading process are completely eradicated.

6. Conclusion

The results of site test of support of the roadways with soft and broken rock in Double-river Coal Mine for more than two years prove that the strategy of composite support of “deepening inside, densifying outside and reinforcing surface” proposed and the scheme of reinforcing support at one time and support by grouting reinforcing surrounding rock adopted in the research are correct, and greatly reduce the amount of repair and maintenance of the roadways on the premise of guaranteeing safe backstopping of working face so as to exhibit remarkable economic effect, and meanwhile to provide successful experiences for reference by support of similar roadways in this mine and other mines.

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