BOLTING SUPPORT OF ROADWAY IN FULLY MECHANIZED TOP-COAL CAVING FACE

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ABSTRACT

This paper aims to introduce bolting support of roadways in fully mechanized top-coal caving faces under specific geo-mechanical conditions. With the change of roadway layout and mining environment, support of entries becomes complicated, especially when meeting the following case: solid roadway, static gob-side entry with a narrow pillar reserved in between and gob-side entry driving head-on adjacent advancing coalface occur one after the other. Corresponding bolting supporting principle and rational supporting technology were put forward. Meanwhile the special structure of surrounding rock of gob-side entry and its failure pattern were explored. Lastly supporting results were demonstrated by an engineering instance.

Key words: bolting support, roadway, fully mechanized top-coal caving faces, gob-side entry.

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INTRODUCTION

Great changes have taken place in China's coal mines in recent fifteen years. China University of Mining and Technology, Central Coal Mining Research Institute and mining administrations have cooperated with each other in solving many key problems .Great breakthroughs have been made as a result. Bolting has become an important support pattern of roadways for its technological and economic superiority, the usage of which is up to more than 80% in Xingtai, Yanzhou, Huainan, Lu'an, and other large Mining Administrations. The so-called difficult and complex conditions occupy about 40% of all roadways in China, namely "three soft" surrounding rock (soft roof, soft walls and soft floor), deep shaft, compound roof, gob edge roadway, mining roadway for fully mechanized mining face with top-coal caving and so on. A lot of practical technologies have been developed and successfully applied to these conditions.

THE THREE DISTINGUISHED STATES OF ROADWAY IN A FULLY MECHANIZED TOP-COAL CAVING FACE

Affected by adjacent coalfaces’ mining activities, a fully mechanized top-coal caving face often falls into totally different states. Take the No.7 coal seam of Sanhejian coalmine in Xuzhou Coal Industry Group as an example (it has a 5.5~6.5 m thickness, a 5~80 seam pitch and a 700~750 m working depth, accomplished by strong tectonic stress), its immediate roof is made of 0.5~2.5m-thick siltstone which is broken and easy to fall off at any time; its main roof is made of sandstone and its floor is made of 2.5~3.0 m thick sandy shale which will swell when meeting water. This main coal seam is mined by a fully mechanized top-coal caving method and the entries are driven along the floor with a 2.5~ 3.5 meter- thick- top coal seam reserved.

Roadways driving along next gob are an unavoidable phenomenon of China’s energy policy and roadway layout principle. Gob-side entries are generally laid out in stable coal body along the gob with a 3 ~ 8m-wide narrow coal pillar reserved in between. And there are also occasions of entries that must be head-on driven during the adjacent coalface’s advancing. This fact makes supporting much more difficult than that of the general stable state. It sets a big obstacle to the advancing speed of the coalface and makes the roadway unsafe when driving close to the open-off cut. The same goes for the Coalface 7405, whose air entry must be driven while the adjacent coalface 7401 is being advanced for the need of replacement of coalface.

So there are three distinguished states of roadways in a fully mechanized top-coal caving face: the first state occurs when the roadway is driven along the bottom of the solid coal seam; the second state occurs when the roadway is driven along next stable gob and the gob is static; and the third state occurs when the roadway is driven while the next caving face is being advanced. A gob is formed as a narrow 3~8-meter-wide pillar is purposely reserved in between and the surrounding rock of roadway becomes active. Obviously the third state is special and seldom occurs.

BOLTING SUPPORT OF SOLID ROADWAYS

The basic supporting principle

The roadways of coalface 7401 are in deep shaft and tectonic stress zone, so the occurrence of broken zone is inevitable. The mechanic properties of rockmass are notably improved by bolting, because bolts can provide lateral pressure to bolted rock; enhance the strength of rock surrounding roadway, especially in post-peak zone. Based on regression analysis of the simulated laboratory tests results, the formula of the peak strength of bolted rockmass(σ_b) and the residual strength of bolted rockmass(σ^*_b) are given as follows:

$\sigma_b = 0.4+15.89\sigma_m+2\, C \tan(45^0+\varphi/2)$ (r=0.968) (1)

$\sigma^*_b = 0.4+26.4\sigma_m+2\, C^* \tan(45^0+\varphi^*/2)$ (r=0.967) (2)

Where: σ_m = the axial power per square given by bolt (mean load density)

According to formula (1) and (2), the increase of σ_b and σ^*_b are related to the increase of σ_m, meanwhile the increase of σ_m can cause the increase of C, C*, φ, and φ*, then further enhance the value ofσb and σ^*_b. Here σ^*b increases much faster than σ_b. In other words, the acting effect of bolting to the broken zone is more notable than that to the plastic or elastic zone. So increase of mean load density (σ_m) may enhance the strength of surrounding rock, thus to keep the roadway stable.

The supporting of 7401 haul roadway

Nowadays high and super high strength bolts have replaced the low-strength metal bolts used in the past. They are made of 20SiMn twist steel with the body made in left-handed rotation way. Based on field measurement and coupling numerical analysis, the rational mean load density should be 0.2~0.3 MPa. Once the mean load density of bolting is less than 0.2 MPa, strengthened supporting methods should be applied, such as cable anchor and prop-supporting ahead of mine face.

The section of the 7401 haul roadway is rectangular and its width and height are 4.0 m and 3.0m respectively. Supporting is designed as high-quality bolts with M steel belts because high-quality bolts can be mechanically installed and provide greater pretension force than the other bolts. The specification of bolts in the roof is M22 (nut, mm)-φ20 (diameter of rebar, mm)-2500 (length of rebar, mm) and that of side bolts is M22-φ20-2000. The anchored length of all bolts exceeds half the length of the bolt body by resin. The pretension force of bolts shouldn't be lower than 150N•M. The spacing and pitch of the array is 900 × 900mm. The pretensioned high-quality bolt can immediately act on the coal seam of the roof, and timely strengthen the surrounding coal of the entry.

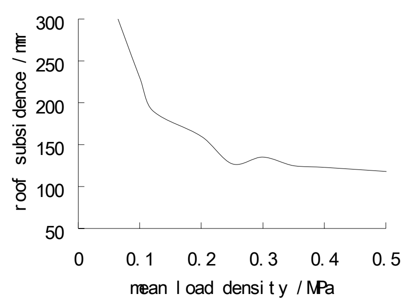

Figure1.: The relative curve of the roof subsidence and the mean load density.

Field observations show that obvious deformation of the roadway occurs within 4~6 days after the roadway excavation and then the surrounding rock tend to be stable. The stable subsidence velocity of the roof is about 0.23~0.25 mm/d, and the final surface displacement value of the roof is about 175~440 mm. While the displacement velocity between the two walls is 0.2~0.3 mm/d, the total displacement of walls can reach 235~365 mm. The bearing force of some wall-bolts is usually lower than 35 kN and this suggests the possibility of simplifying the wall supporting. The bearing force of the roof-bolts is usually about 56~78 kN, even up to 90 kN, suggesting the rationality of roof supporting. In-situ supporting state is shown by Figure two.

Figure 2.: In-situ support state of solid roadway in 7401 coalface.

BOLTING SUPPORT OF ROADWAY DRIVEN ALONG NEXT STABLE GOB

The basic supporting principle

According to key stratum theory, the key roof strata essentially determine the structure and stability of roadway driven in bedded rockmass. With the advancing of coal face and the formation of gob, the key strata will gradually develop into cantilever beam, and then the beam breaks, rotates and subsides. This long breaking process will finally result in an arc-triangle structure, i.e. the “big structure”. The so-called “big structure” consists of top coal, the immediate roof, the main roof and the soft strata attached to the main roof. One bearing point of this arc-triangle big structure is solid coal and immediate roof rock, while the other is waste rock. Beneath it is the “small structure” which is composed of bolts and the anchored zone of the surrounding rock. The “big structure” not only bears the upper soft strata, but also stops abutment pressure from transmitting to the coal body beneath and the immediate roof, and keep the roof of the “small structure” stable. Analysis of big-small structure can explain the structure stability of surrounding rock of the gob-side entries.

The adjacent coalface has been mined for a long time, and the gob is already in stable state. A typical gob-side roadway is driven in the stress-relief zone of big structure, the excavation of which has little effect on the stability of the “big structure”. Deformation during this period comes mainly from expansion of the shallow surrounding rocks, and the maintenance of the roadway is relatively easy. But during the leading mining influencing period, the rotation and subsidence of the key arc-triangle strata directly affect the small structure and make the roadway violently deformed. So the supporting in the small structure is required not only be able to adapt to the deformation of the “big structure”, but also to effectively control the deformation of the small structure.

The supporting of 7405 rib roadway driven along next stable gob

According to the stability analyses of big-small structure, good use of the big-structure equilibrium should be made. While the next gob is in stable state, the small aperture anchor cable may effectively integrate the top coal and the "big-structure" as a whole, thus to keep the roof safe. This is shown in figure 3. The basic layout and parameters of bolting are similar to those of the solid roadways under same conditions only with the array pitch of bolting decreased from 900 mm to 800 mm, and two additional sets of small aperture anchor cable are installed to strengthen the roof strata. The effective length of cable is 5.0 m, the array pitch is 2400 mm, and the pretension force is 60~80 kN. In practice, the stable subsidence velocity and the surface displacement value is less than that of solid roadway in the period of excavation.

Figure 3.: In-situ support state of roadway along next stable gob (width of pillar, 4m).

BOLTING SUPPORT OF ROADWAY DRIVING HEAD-ON ADJACENT ADVANCING COALFACE

The basic supporting principle

When the gob-side roadway must be driven head-on adjacent advancing coalface, the entry driving and adjacent coalface advancing are carried out face to face with only a narrow pillar reserved in between. The shape of the gob-side entry cannot be completely formed until the two coalfaces adjoin. During the period of adjacent mining influence, the stress around the roadway and the deformation of the surrounding rocks increase continuously because of serious deformation and subsidence of the overlying strata structure. Practice indicates that the damage of the afterward abutment is far more serious than that of the previous abutment, and the value of the deformation during this period is 5 ~ 10 times greater than that during the period of roadway excavation. Apparently the afterward abutment stress will take effect several months until the gob is entirely stationary. As a result, special attention should be paid when the big-structure equilibrium of rock strata is badly disturbed. The surrounding rock of roadway is severely subject to the whole breaking process of lateral main roof strata, which will unavoidably lead to the separation of the coal seam from the roof and collapse of the reserved narrow coal pillar. The collapse of the pillar can cause up to 1000 mm displacement as shown in Figure four.

Figure 4.: The collapse of narrow pillar.

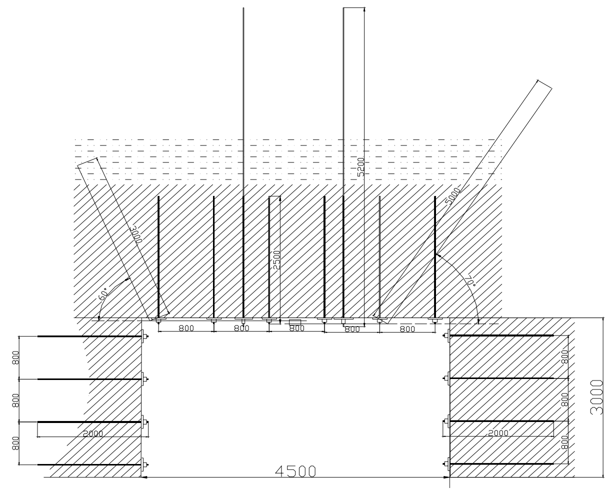

Figure 5.: Bolting design of 7405 gob roadway.

Supplementary support is necessary in this case. Only by improving the supporting structure and choosing more reliable anchorage point can roof falling be avoided. The big-structure is unstable because of the key strata's rotation and subsidence. The small aperture anchor cables system, which must have its inner anchorage points installed in the strata of the big-structure, cannot keep the roof safe. So it cannot be individually used. However, the steel strand pretension truss system whose anchorage points have been adjusted from the roof to upper corner rockmass of roadway may successfully solve the problem and worth recommending. It can make the small structure self-stable during the strong deformation period. Truss bearing structure is entirely contained in the small structure. Its needed anchorage depth is shallower than that of cables, so it won't lose efficacy in the broken process of the big structure. This kind of truss can control the separation of top coal and other soft roof from the key strata, and take precautions against any collapse of the roof.

The supporting of 7405 air-return roadway driven head-on adjacent advancing coalface

The entry size is designed as 4.5m (width) × 3.0m (height). The initial supporting methods and specific parameters are the same as those of 7405 air-return roadway driven along next stable gob. Additional truss system can prevent the top coal and other soft rockmass from collapsing in the strong deformation period. The truss is directly fixed on every other line of M-belts. The array pitch is 1600mm.The supporting pattern and parameters are shown in Figure 5.

Observation results show that there are four obvious deformation periods in the air-return roadway driven head-on adjacent advancing coalface, of which the period of adjacent gob's formation is the most serious one. Only in this single period the displacement of two walls can reach 950~1100 mm, 60% of which comes from the coal pillar; the displacement from roof to floor is 1350~1460 mm, 65% of which comes from the floor. However, the use of truss system can maintain the shape of the roadway but meet production needs only after certain reparations. Actual supporting state is shown in Figure 6. after the adjacent gob is stable.

Figure 6.: In-situ support state of entry driven head-on adjacent advancing coalface (width of pillar, 4m).

CONCLUSIONS

High-quality bolts and small aperture anchor cables have been widely used in China’s coal roadways while the use of pretension steel strand truss is still in its infancy. By fully considering the special mining environment, bolting has been successfully used in the three distinguished states of the fully mechanized top-coal caving face in Sanhejian coal mine. But how to further control the deformation of the gob-side entries, especially when they are driven head-on adjacent advancing coalfaces, remains a question.

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