Large Deformation Control Principle and Reinforcement Technique for Solid Coal Rib of Large-Section Gob-side Tailentry in Thick Coal Seam buried Deeply

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Abstract

The large-section gob-side tailentry of the sublevel caving face often deforms heavily in the horizontal direction when driving and mining in deep mines, especially the side of solid coal, so it is difficult to support and needs several maintenances for the enough space. The control mechanism and technology is put forward based on the location of the main roof's lateral fracture to decrease the large deformation. And the field test and monitoring of gob-side roadway is done in 1306 coalface in Dongtan Mine. It is proved that the tailentry's horizontal deformation is obviously reduced..

Keywords: large-section tailentry driving

along goaf; large deformation; solid coal rib control; long anchor cable

1.Introduction

The tailentry is often driven along the next goaf to get the high recovery rate of coal reserve when adopting the fully mechanized caving method in deep mines. The roof of gob-side entry driving along floor is the top coal, the rock layer. The tailentry often deforms heavily because of the large buried depth and intensive mining effect, so it is hard to control. For the example of the 1305 tailentry(5.0m width, 3.8m height) in Dongtan Mine in China, the final horizontal deformation was 3.5m(the solid coal side 2.34m) and the vertical deformation was 1.5m

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according to the in-situ observation, especially the solid coal rib moved horizontally obviously. It seriously interfered with the normal mining work of the coal face.

The bolt-mesh-anchor is often adopted for the gob-side tailentry in deep mines recently^[1-4], but good effects are not obtained in fact. So it is necessary to research the control strategy and reinforcement technique for solid coal rib in large-section gob-side tailentry of deep fully-mechanized caving face.

2. Control mechanism and principle for solid coal rib in gob-side tailentry of deep fully mechanized caving face

According to the layout design principle of gob-side tailentry, it should be located in the stress-releasing zone (lower than the initial stress) while the side abutment pressure peak and the stress-concentrating zone (higher than the initial stress) is located in the side of the solid coal.

2.1 Side abutment pressure distribution feature and main roof fracture location

FLAC3D software is chosen to simulate the abutment pressure, stress and

displacement of surrounding rock for gob-side entry according to the geological condition of 1306 coalface in Dongtan Mine. According to the numerical simulation results, the phenomena that the side abutment pressure can be divided into internal stress field and external stress field according to the roof fracture line is found when the main roof's fracture line lies above the solid coal deeply in fully mechanized caving face as is shown in Fig.1.

From the Fig.1, the internal stress field peak from the basic roof fracture line is 2.6m, and the stress concentration factor is 0.86. The external stress field peak from the basic roof fracture line is 7.0m, and the stress concentration factor is 2.7. Research^[5] shows that the side abutment pressure consists of the internal and external stress field caused by the fracture of main roof is located in the solid coal. The gob-side entry should be developed in the internal stress field to avoid the high pressure, and the side abutment pressure was redistributed again after the excavation of entry, as is shown in Fig. 2.

Fig. 1 Vertical stress curve of Measurement line I when the horizontal distance between fracture line and tailentry rib is 16m

Fig. 2 Distribution of side abutment pressure and position of main roof fracture line in fully mechanized caving face

2.2 Control principles

The control principles of large deformation are put forward on the basis of the lateral abutment pressure distribution, breaking law of main roof and the fractured zone distribution of coal.

(1) The principle of large-section gob-side excavation

(2) The principles of adopt the high-strength, strongly anchored and yieldable long cable to strengthen the solid coal rib

(3) The principle that make the broken zone of solid coal stable and deform to some extent

(4) The principle combining the high-strength bolt and cable to produce the coupling action.

2.3 Reinforcement mechanism of solid coal rib

Based on control principles of the solid coal in deep large-section gob-side entry, the long anchor cable, bolt, mesh support method is put forward.

The functional mechanism of long anchor cable in the solid coal is that the long cable is fixed on the intact coal in the

external stress field, by using resin annulus and bearing plate with giving the pretension force in the end, then the cable constrains the deformation of coal in the plastic zone, finally the solid coal between the coal rib and the anchored end of long cable is compressed to one integrity. So the calculation formula of cable's length is as following:

$$L_s \geq L_{s1} + L_{s2} + L_{s3} \quad (1)$$

where L_{s1} is the length of the exposed cable end, m; L_{s2} is the width of the internal stress field which is equal to the distance between the main roof's fracture line and solid coal rib, for protecting rib, m; L_{s3} is the anchorage length of anchor cable outside internal stress field, at least 1.5m.

The functional mechanism of bolt-mesh-belt support in the solid coal rib is that the deformation of broken zone is restrained and the instability and rib spalling is prevented through the compression and consolidation of anchored zone; meanwhile, the anchored consolidation wall is formed by bolt,

metal mesh, steel belt and the coal in broken zone, therefore the mechanical property of coal in the broken zone is enhanced with a higher strength. Therefore, the length of rib bolt should be larger than the width of broken zone, and the formula for calculation is as following:

$$L_g \geq L_{g1} + h_1 \tan(45^\circ - \varphi / 2) + L_{g3} \quad (2)$$

where L_{g1} is the length of the exposed bolt end, m; h_1 is the height for protecting rib, m; φ is the internal friction angle, °; L_{g3} is

the length of anchored end, m.

The functional mechanism of combined support between long anchor and bolt-mesh-belt in the solid coal rib is that consolidation compressed wall is formed by bolt groups in the shallow part, the external bearing wall was formed by high-strength long anchor cable with a large diameter in the deep part, and these two structures combine together to form a yieldable thick structure with high strength, as is shown in Fig.3.

Fig. 3 Sketch map of reinforcing solid coal rib using bolts and long cables in gob-side entry

3. Support method and technology of large deformation of large-section gob-side tailentry

The solid coal rib of gob-side entry is broken largely, and the bolt and short cable make little use in the reinforcement of coal rib due to its small control area. Therefore, a combined reinforced technology for the solid coal rib of high strength large diameter long anchor cable with bolt-net-belt is put forward. The 1306 gob-side entry in Dongtan Mine is taken as an example to explain the design and application result.

3.1 Engineering background of 1306 tailentry

1306 tailentry is buried in the depth of 708.6m, and is close to the 1305 goaf. It is driven in Coal 3# along the floor by using fully mechanized excavation technology. Coal 3#($f=2-3$, f means Protodyaknov's number) is 8.80m thick averagely and stable. The immediate roof is siltstone (0-11.64m thick, $f=4-5$); the main roof is thin sandstone and medium sandstone (14.35-23.34m thick, $f=5-7$); the immediate floor is siltstone (1.00-2.65m thick, $f=4-6$).

3.2 Determination of support parameters of 1306 tailentry

(1) Shape and size of cross-section

The cross-section of 1306 tailentry is trapezoidal, with the height 3.8m, the upper width 4.8m and the down 5.2m.

(2) Cable parameters in the solid coal side

Based on field measurement of the main roof's lateral fracture position, it is 6.5m to the solid coal rib. The outside length of cable is 0.3m, the extra distance over the fracture line is 1.5m, the length of cable is 8.5m according to Formula (1). Two $\Phi 22\text{mm} \times 8.5\text{m}$ long anchor cables are lain out in the solid coal rib per row. The distance between two rows is 1.6m. In order to ensure the anchoring effect, the cable pretension is no less than 80KN, the anchorage force is no less than 200KN.

(3) Bolt parameters in the solid coal rib

According to Formula (2), the outside length of bolt is 0.10m, the anchored end 0.35m, the inner friction angle is 38° , the height 3.2m, the bolt length is 2.0m.

Five fully-thread steel bolts in equivalent strength with the size of $\Phi 20\text{mm} \times 2000\text{mm}$ are lain out per row in the solid coal rib, and the bolt interval is 800mm, the row interval is also 800mm.

(4) Wire mesh and steel channel

The double wire meshes are hung on the solid coal rib, which is located range 300mm below the dirt band. The wire mesh is made of galvanized iron wire with the grid size $50\text{mm} \times 50\text{mm}$.

The T-type steel channel is adopted in the

solid coal side to connect long cables in the vertical direction, which is 2 m long.

The final support design of solid coal side in 1306 tailentry is shown in Fig. 4.

Fig. 4 Support parameter of solid coal rib in 1306 tailentry

4. Support Result and Discussion

The gob-side tailentry rib of the sublevel caving face often deforms heavily especially the side of solid coal before the long anchor cable application. Satisfactory results were obtained by using the above control technology (long anchor cable and bolt-mesh-steel channel) and designed support parameters in reinforcing solid coal rib of 1306 entry. Based on the monitoring data of side displacement, the relation curve between the rib horizontal displacement and the distance to workface is provided, as is shown in the Fig. 5. From the relation curve, the final displacement of solid rib was 0.83m, the rib's convergence is 1.2m. Meanwhile, the tailentry kept stable and the useful width is 3.8m, so it can meet the requirement of the extraction of mechanized caving face.

Fig. 5 Rib horizontal displacement of 1306 tailentry during mining process

5. Conclusions

(1) The large-section gob-side tailentry of the deep fully mechanized sublevel caving face often deforms heavily in the horizontal direction, especially the side of solid coal, the combined reinforced technology of long cable with bolt-mesh-channel can control the deformation of solid coal rib effectively.

(2) Based on the lateral abutment pressure distribution and the fracture line's position of the main roof, a method for determining the length of long anchor cable in large-section gob-side tailentry rib of the deep sublevel caving face is presented, the length of anchor cable in the solid coal rib should exceeding 1.5 meter than the horizontal distance between fracture line of main roof and solid coal rib.

(3) The support system of solid coal in the 1306 tailentry of Dongtan consists of high intensive yieldable long anchor cables ($\Phi 22\text{mm}$, 8.5m long, 1.6m interval), high intensive bolts ($\Phi 22\text{mm}$, 2.0m long,

0.8m interval), the wire mesh and steel channel (2m long), which reduced deformation heavily and provided a good result after field test.

6. References

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