Study on Supporting Technology of Shallow Buried Mining Gateway with Weak Surrounding Rock

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KEYWORD: Shallow buried depth; Weak surrounding rock; Mining gateway; Support optimizing; FLAC3D numerical simulation

ABSTRACT: Taking the project field as background, the paper studied the supporting technology of mining gateway with weak surrounding rock in 3-1 shallow seam mining of a coal mine, and solved problems of mining gateway slide and roof deformation and failure. The shortage of original supporting system was simulated and analyzed, and by theoretical analysis and field investigation, a support optimizing program was put forward, which was adding the strength and length of rock bolts, and using the combined support system with rock bolts, cables, nets, and rebar trays, and by using FLAC3D numerical simulation software, the rationality of support optimizing program was analyzed. Field test showed that the support optimizing program can guarantee compound mining face with shallow buried depth producing safely and efficiently, and the paper provided a basis for the supporting technology of mining gateway in mine working faces of the coal mine and mines with similar condition.

Introduction

There exist a large number of shallow buried coal seams within 150m in west China, and during mining shallow coal seams there are the phenomena of main roof cracking to the earth surface directly, overlying rocks completely cut down, huge intensity and short duration time of roof weighting, certain amount of impact load to the roof support and so on, so the working face and mining roadways will present new characteristics of strata behavior and roof movement during longwall mining shallow buried coal seams, especially when the surrounding rocks of roadway are soft. In order to realize working face advancing normally and the mine producing safety and efficiently, it has great significance to study reasonable supporting technology of mining roadway during mining shallow buried coal seams.

In order to solve the problems of roadway's sides and roof severe damage of 3-1 coal seam 1136 working face of a certain shallow buried coal mine, depending on the existing supporting method of 1136 working face's haulage roadway, the paper analyzed the characteristics and reasons of roadway's damage and deformation under the original supporting way using $FLAC^{3D}$ numerical simulation software, and the original supporting way was optimized. The rationality of optimized supporting way was confirmed by field observation, and it provided a basis for similar condition mines to design supporting way of working face's roadway.

Project summary

The buried depth of 3-1 coal seam was 103m～143m, which belonged to shallow buried seam. 1136 working face's roadway was located in 3-1 seam, and the all high comprehensive mechanized mining method was used in the working face to mining 3-1 seam of yan'an formation. The strike and inclination length of the face were separately 1128m and 200m, and the average thickness of the seam was 3.2m. The thickness of the coal seam in the mining field changed little with simple structure, whose hardness coefficient f=2～3. And the seam was stable and minable coal seam, whose roof strata were mainly powder sandstone, sandy mudstone and mudstone; floor strata were mainly fine grained sandstone, siltstone and mudstone with the characteristics of argillaceous cementation, parallel bedding

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structure and water softening and abating. The comprehensive stratigraphic column of the working face was shown as Figure 1.

Coal or rock seams	Synthetic columna 1:300	Thickness (m)	Petrographic description
Sandstone or sand and mudstone interbedding		6~26	Hard and compact.
mudstone		1.35~1.5	Gray, bedding is development, slightly crispy, easy caving.
3-1coal seam		3.2	The thickness is 1.2m to 3.5 m, no dirt band.Coal is black, brittle, grease ~ vitreous luster, shells or jagged fracture, and crack is well developed, coal hardness coefficient is 1.03 to 1.28, macroscopic coal and rock type is half dark~ half bright.
Mudstone or sandy mudstone		0~1.3	Relatively soft, easy to clay under the influence of water
Middle-fine sandstone		15~28.92	Hard and compact.

Figure 1. Mining working face strata histogram.

1136 working face's haulage roadway was tunnelled along the floor of the coal seam, and the roadway's section was rectangular with 3600mm clear width, 3000mm clear height and 10.8m2 net sectional area. The roadway was originally supported by anchor bolt and net. 5 Φ18×1800mm metal resin bolts with 800mm×800mm yow & line space were used to support the roof, and 4 Φ16×1800mm glass fiber reinforced plastic resin bolts with 800mm×1000mm yow & line space were used to support the two sides, and the bolt fastening force was 120N·m. The supporting way was as Figure 2 shown. Under this supporting way, roadway's two sides appeared to rib spalling and roof appeared to distortion and breakage severely, forming crushed coal nets. Roadway's roof appeared subsidence integrally, and the maximal subsidence was as large as 425mm, and roof fall severely happened in some sites.

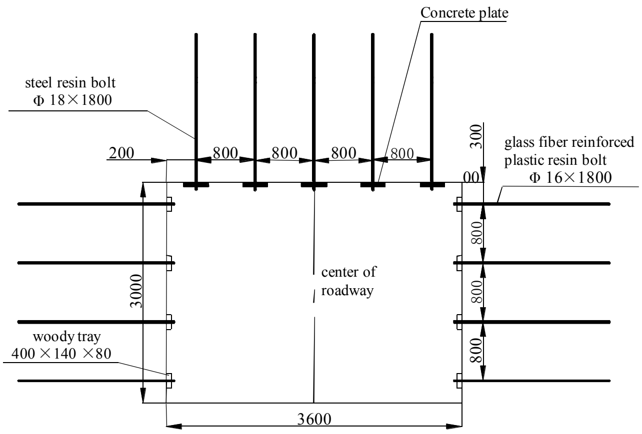


Figure 2. Original supporting way of 1136 working face haulage roadway.

Analysis of surrounding rock characteristics under original roadway supporting way

Numerical simulation analysis under original supporting way

According to the occurrence of coal and rock seams, finite difference numerical simulation software FLAC^{3D} was used to simulate and analyze the original roadway supporting way, and detailed mechanical parameters of coal and rock seams were listed in Table 1.

Table 1. Rock mechanics parameter of every stratum.

Lithology	Bulk modulus/Gpa	Shear modulus/Gpa	Compressive strength/Mpa	Tensile strength/Mpa	Cohesion/Mpa	Inner angular/°	Density /(Kg/m^3)
Sand-mudstone	11.5	9.5	48.9	3.2	13.0	33	2600
Mudstone	4.3	3.9	27.2	1.0	3.5	31	2500
3-1 seam	2.3	2.0	10.3	0.6	3.5	27	1470
Mudstone	4.7	3.9	27.2	1.0	3.5	31	2500
Medium-sandstone	12.5	9.5	48.9	3.2	13.0	33	2630

According to the simulation result, as Figure 3 shown, after the balance of supporting, there was a large range of the stress reducing area around roadway's roof and floor, and there was no anchorage effect in roadway's two sides. Stress concentration of roof bolt support section was 0.3Mpa, and the maximal roof subsidence by monitoring record was about 400mm. The phenomenon of stress concentration in roof and two sides was not obvious, so that the effect of roof overall supporting could not be achieved, and anchor bolts' suspension function could not make roadway's roof soft rock stratum anchored in deep-seated stable and solid rock. Bolts' anchoring and supporting effect was not obvious, as a result, roadway could not be effectively supported, and safe and efficient production in mining working face could not be ensured.

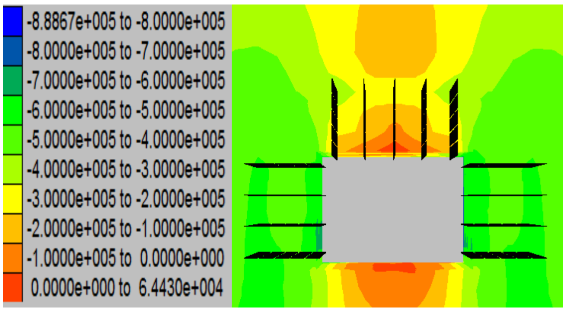


Figure 3. Simulated result of original supporting way.

Analysis of roadway damage under original anchor supporting way

Because 3-1 coal seam was shallow buried seam, as the working face advancing, the main roof cracked easily to the earth surface, which would cause the phenomena of overlying rock cutting down as a whole and large roof weighting, as a result, the stability of roadway would be affected during roof weighting. Anchor supporting could whether control the roof effectively or not, the main point is that whether the coordination of anchor's actual working feature and roof stratum's self-bearing capacity could achieve or not, making the roof turn from load body to supporting body. The surrounding rock of 1136 working face's haulage roadway was soft, and two sides were entitative coal, on the other hand, original anchors arranged perpendicular to the roadway, and the anchoring depth was no more than 2000mm, so that the intensity of skewbacks didn't get strengthened, as a result, shear failure occurred firstly, and then gradually expanded to the deeper, and faulted fracture appeared in roadway's two sides, especially obvious when roof weighting came during working face advancing; compression failure happened in the roof under the effect of upper load and skewback shear stress, and because the upper roof was soft stratum, anchor supporting effect ran out, and anchorage zone formed isolated broken zone, as a result, coal seam appeared overall falling around anchorage area.

Optimization design of roadway supporting system

Calculation of anchor supporting parameters

Calculation of anchor length

Roof anchor worked through suspension, and in order to achieve the condition of supporting effect, according to the suspension theory of anchor supporting, anchor length should satisfy the following formula:

$$L \geq L_1 + L_2 + L_3 \qquad (1)$$

where L = anchor total length; L_1 = anchor exposed length (including the thickness of the steel belt, supporting plate and nut); L_2 = effective length (the length of roof anchor took the falling height of loose range of surrounding rock b); L_3 = depth anchoring into the rock (coal) layer.

Thereinto, the falling height of loose range of surrounding rock was as following:

$$b = \frac{\frac{B}{2} + H\tan(45° - \frac{w}{2})}{f_{floor}} \qquad (2)$$

$$c = H\tan\left(45° - \frac{w}{2}\right) \qquad (3)$$

where B = Drivage width (3.6m); H = Drivage height (3.2m); f_{roof} = Roof rock protodyakonov coefficient (2.5); w = Two sides' surrounding rock internal friction angle.

After calculation, the following results were got: L_1=0.1m, L_2=1.0m, L_3=0.8m, L=1.9m. So 2m mining roadway's anchor bolt length was taken.

Calculation of inter-row spacion of anchor bolts

Inter-row spacion of anchor bolts should satisfy the following:

$$a < \sqrt{\frac{G}{kL_2r}} \qquad (4)$$

where a = anchor bolts' row spacing and column spacing, m; G = designed anchoring force, KN, 70KN was taken; k = security coefficient, 2 was taken as normal; L_2 = effective length, (b was taken for roof blots length); r = density of rock mass, 24KN/m^3 was taken.

Taking the values above into the formula, a<1.2 was got.

In practice, according to features of roadway's surrounding rock and the adding anchor cables, 0.8m anchor bolts' inter-row spacion was taken.

Design of roadway two sides' bolt supporting parameters

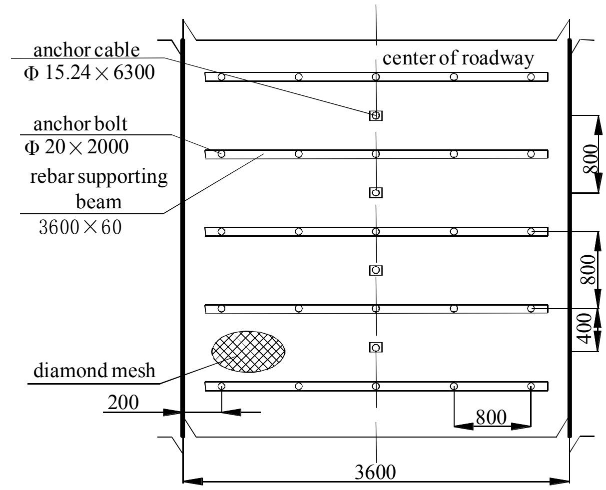
Combining with large deformation of two sides in field and the non-ideal result of existing supporting way, roadway's two sides were all changed to use 4 Φ18×2000mm glass fiber reinforced plastic resin anchor bolts.

So as to adding bolt strength, the diameter of roof and two sides' anchor bolts was redesigned seperately to 20mm and 18mm. In addition, according to the characters of roadway's defomation and failure, and the control area of the supporting, the supporting key places should be the roadway's vertex corner and base corner, so sloping anchor bolts arrangement way was used to them, which could achieve the goal of making the tangential bearing capacity play to the largest, and the development scope of the plastic zone or damage area in roadway's corner decrease; on the other hand, corner bolts could be anchored into stable rock, restricting the further development of roof breakage.

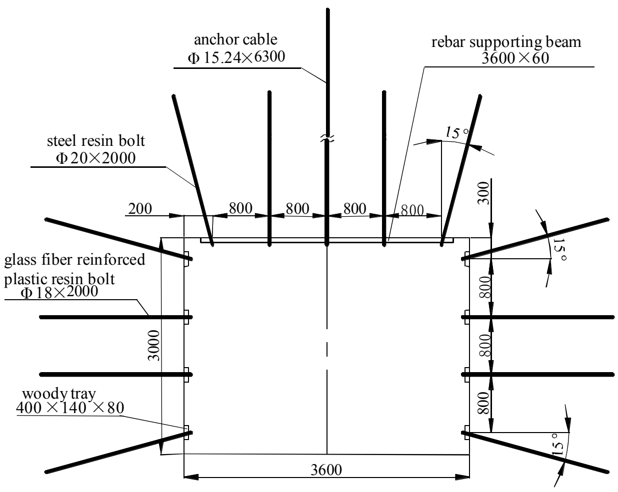
Optimizing of roadway's supporting technology

According to theoretical analysis and actual situation on site, the optimized supporting plan of 1136 working face's roadway was made as following. Bolt-mesh-anchors and rebar supporting beams were used to support roadway roof. 5 Φ20×2000mm screw-thread steel bolts with 800mm×800mm interval were used, cooperating with 3600mm×60mm rebar supporting beams, whose pretightening force was as large as 120N·m. One Φ15.24×6300mm anchor cable was used between two rows of anchor bolts, with single-row layout along roadway center line, and the row spacing was 800mm. Except that two roof corner bolts inclined 75° to the sides, others were all perpendicular to the roof, and wedgy trays must be used correctly on corner bolts. The anchor way of roof bolts was resin extending anchoring, and mating with screw-thread steel bolts was one CK2340 and one Z2340 resin anchoring cartridges. And one CK2340 and three Z2340 resin anchoring cartridges were used on every anchor cable, with a gasket made by 300mm×300mm×10mm steel plate.

4 Φ16×2000mm glass fiber reinforced plastic resin anchor bolts with 800mm×800mm interval were used in roadway's each side, mating with them were 400mm×140mm×80mm trays. Except that sides' upper corner bolts inclined 15° upward, and lower corner bolts inclined 15° downward, others were all perpendicular to the two sides. The anchor way of sides bolts was resin terminal anchoring, mating with them were K2355 resin anchoring cartridges. The plane and section of optimized supporting plan was as Figure 4 shown.



(a) Plane view



(b) sectional view

Figure 4. Optimized supporting way of 1136 working face haulage roadway.

Numerical simulation analysis of optimized supporting plan

Effect of roadway's optimized supporting plan was simulated using FLAC^{3D} numerical software, and the result was as Figure 5 shown. Supporting section's concentrated stress of roof anchor bolts and cables was 0.5Mpa, and recorded roof subsidence was about maximum 90mm. What can be got from the distribution of stress concentration was that supporting intensity of the optimized supporting way got higher comparing with the original supporting way; what can be got from the vertical displacement of roof and floor was that roof and floor's control effect of the optimized supporting way was obviously better than the original. Supporting section's concentrated stress of two sides anchor bolts was as large as 0.7Mpa, which got a large promotion. And what can be got from the integrality of supporting stress was that anchorage section of anchor bolts and cables could easily add up and forming stress-concentrated area, which could strengthen the supporting force to roof rock mass, and reduce the influence of roof weighting during shallow buried coal mining. So effective action area of roadway roof by optimized supporting way was large, and overall effect was better, which could help the stability of roadway.

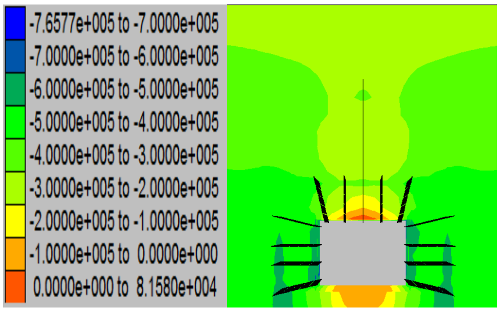


Figure 5. Simulated result of optimized supporting way.

Field observation and analysis of the results

In order to analyse roadway deformation regular after supporting plan optimized, 1136 working face roadway's deformation was observed using cross measurement. Every 15m set a observation station, and 5 stations were set totally; in every station, middle of roadway's two sides, roof and floor set one observation point respectively, aiming at observing convergence displacement of two sides and deformation of roof and floor. The observing result was as Figure 6 shown.

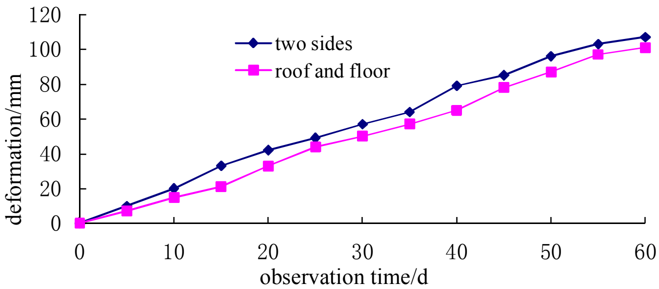


Figure 6. Result of Field observations.

What can be got by analysing the observation values was that in the 60 observation days, the maximal deformation of roof and floor was about 100mm, 75% less than the deformation of original supporting way, and the maximal deformation of two sides was about 120mm, making two sides convergence displacement effectively controlled, and supporting effect was obvious.

Conclusions

(1) By field observation and numerical simulation, the deformation and destruction way of shallow buried coal seam 1136 working face haulage roadway with soft surrounding rock under the original supporting way was analyzed, and the shortcomings were pointed out.

(2)According to field geological condition and theoretical analysis, optimized supporting plan was proposed, which was adding anchor bolts' strength and length, and using bolt-mesh-anchors and and rebar supporting beams. The active area by optimized supporting way to roadway's roof was large, and overall effect was very good, which could help the stability of roadway.

(3)Roadway deformation and stress state under original and optimized supporting way were simulated and contrasted using FLAC^{3D} numerical simulation software, mating with field measurement, and the result showed that optimized supporting plan "anchor bolt + anchor cable + anchor net + steel joist" could ensure the roadway supported safely, which could provide a basis for working face roadway supporting of the mine and other similar condition coal mines.

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1 FOUNDATION ITEMS

Chongqing Science and Technology Commission(item number: cstc2012jjA90003); Natural Science Foundation of China(item number: 51304237).

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