

Supporting Mechanism and Technology of Roadway Overall along Goaf in Extremely Loose and Extra Thick Coal Seam

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ABSTRACT: Taking machinery roadway, ventilation passage of Roadway 8203 of Guobei Mine in Huaibei Mining Group as the research background, applying basic theory of modern solid mechanics, interaction mechanism between metal bracket and bolt were studied in the condition of large loose circle, high ground pressure soft-rock roadway. Several key technologies of extremely loose and extra thick coal seam in supporting overall along goaf roadway were introduced in detailed. The functional mechanism of key technologies was not only analyzed in detail, but also on-site industrial tests were conducted. Good action effect of bolt and double resistant cloth was demonstrated in roadway of extremely loose coal seam, emphasizing the comprehensive effect of the composite support structure “metal bracket + bolt + double resistant cloth”. On the one hand, the research results provided a significant effect, low-cost rock support technology; on the other hand, it also further improved the support theory of rock roadway. It has certain reference value for roadway supporting design in any case. It made the adjacent two mining areas into one and produced enormous economic benefits.

KEYWORD: the extremely loose and extra thick coal seam, Overall Roadway along Goaf, key technology, industrial test

1 INTRODUCTION

For a long time, the researches on the supporting technology of soft rock roadway with high ground pressure and loose coal seam have been more studied in the paper (Zhao Hongchao et al, 2011) (Liu Chaoru, 2011) (Wan Shiwen et al, 2011) (Li Jianmin et al, 2011) (Chen Baoyuan, 2010) (He Changhai et al, 2010) (Jing Laiwang et al, 2012) (Zhang Nong et al, 2009) (Wang Hezhi et al, 2008) (Zhao Yiming et al, 2008) (Wu Pengfei, 2010) (Zou Lei et al, 2010). Although some literatures which involved in supporting mechanism have made a lot of encouraging results (Jiang Yaodong et al, 2005) (Bai Jianbiao et al, 2008), there are still some aspects of mechanical mechanisms to be perfected. Some literatures (Sun Xiaoming et al, 2005) only use the numerical simulation for a certain degree of analysis. Because of the subjective factors in many cases, so it is difficult to accurately reflect the nature of the problem. However, in terms of supporting mechanism, most of the researches are partial to mechanism analysis of some single supporting condition, with combined supporting very little. Since the aspect of mechanical mechanism is a new mining and determine for supporting mechanisms and supporting effect, the research re-

sults have practical significance to supporting design of high stress soft rock roadways in the current domestic and foreign.

2 RESEARCH ON SUPPORTING MECHANISM

2.1 *Supporting mechanism of anchor frame combination*

Mechanical mechanism of anchor frame support lies in the organic combination of the advantages of the U-shaped scaffolding and anchor support, and they improve each other in terms of carrying capacity. By means of the larger bite force, which formed by the overall constraint function of metal support to the surrounding rock among the broken rock blocks, the anchoring effect of bolt that anchored in the loose circle of surrounding rock has been greatly improved. On the one hand, bolt imposed outward force from short beam to the metal support, so that the anti-side pressure of metal support improved larger. And the rigidity and strength also improved significantly by aggrandizing the fulcrum of U-shaped scaffolding. On the other hand, the improvement of stiffness and bearing capacity of metal scaffold in turn increased the bite force between the

broken rock, prompting increase of the anchoring force of bolt, eventually achieving the improvement purpose together between the bolt anchoring force and bearing capacity of the metal support. In addition, the effective range of the bolt increased shapely by means of large tray of metal support. The bearing capacity of bolt could be fully played, and ultimately got the supporting effect of $1+1 > 2$. The combined supporting structure of metal support and bolt was shown in Figure 1.

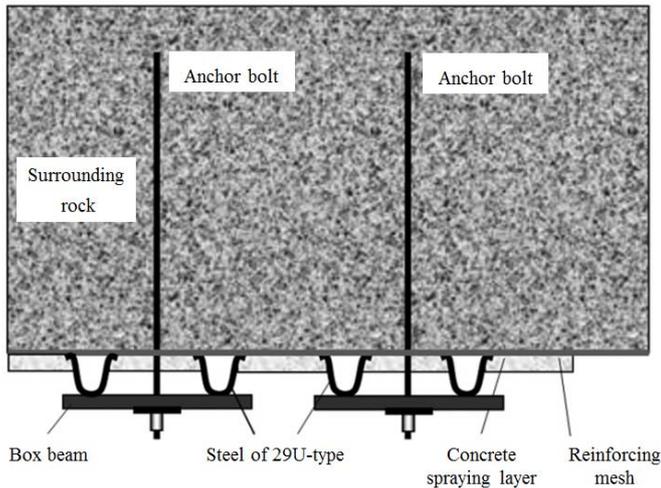


Fig.1 The combination structure of U-shaped scaffolding, short beam, bolt and concrete spray layer

2.2 The principle of “the stronger support, the weaker pressure; the weaker support, the stronger pressure”

When the support strength was stronger, the scope of loose circle was smaller and support pressure bear from the surrounding rock was lower. Conversely, when the support strength was weaker, the scope of loose circle was bigger and support pressure bear from the surrounding rock was larger.

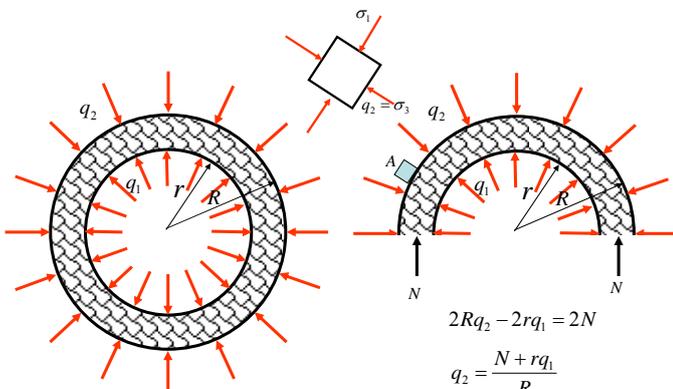


Fig. 2 Schematic diagram of the relationship between the strength of the support and the external pressure of the loose circle

It could be seen from Figure 2 (b), the pressure of $q_2 = \sigma_3$ acting on the external of the loose circle had a

linear relationship with the pressure of q_1 between supporting structure and rocks, which increased with q_1 . According to the Coulomb-Navier criteria of “ $\sigma_1[(f^2+1)^{1/2}-f] - \sigma_3[(f^2+1)^{1/2}+f]=2C$ ”, the greater the σ_3 , the more close to σ_1 , the more stable periphery rock mass. Otherwise, the loose circle would continue to expand. And the expansion of loose circle would lead to the increase of σ_1 . At this time, in order to suppress the loose circle continues to expand, the value of $q_2 = \sigma_3$ must improve according to the Coulomb-Navier criteria. According to the relationship of figure (b), it can be known that in the case of keeping the N constant, the balance state of the loose circle can be kept only by increasing the q_1 .

3 IN-SITE INDUSTRIAL TEST

3.1 Project overview

The occurrence of coal seams in Guobei Coal is stable, but the structure is complicated, and the mechanical characteristics are very special. Complex structure mainly manifested as containing many dirt band in coal seam. Mechanical characteristics of very special mainly manifested as extremely low strength of coal, which could broke with a little touch and belongs to category of extremely loose coal seam. On account of extremely loose and weak coal seam, the lateral pressure coefficient of coal is larger. Manifesting in aspect of roadway support, lateral pressure is very big, column leg is seriously inside moving and support is very difficult.

In 8203 roadway, the roadway section was 4628×3600 mm. The supporting form used 36U type steel bracket of circular arch with inclined legs and 36U type steel bracket of circular arch with arched legs respectively between December 2008 and March 2009. However, due to the extremely loose of coal seam, the floor was very weak and the support was difficult to maintain more than 10 days. The whole construction process was in the condition of digging before and repairing after. The footage of 2 month was less than 100m and the construction organization changed several.

3.2 Geological and hydrological conditions

The distance from upper limit of the surface to bottom mudstone of the third aquifuge and bottom margin of the fourth aquifer was about 200m. Therefore, the new layer aquifer had no direct effect on the surface mining. The main water sources which had influence on this surface were sandstone fissure water of Group 8 coal top and bottom floor. The upper roof in this section of Group 8 coal were siltstone-fine sandstone with thickness of 21.12 ~ 25.72m. The fracture was relatively developed, and had a relatively strong watery. The phenomena of roof raining and water spraying in a short time might be oc-

curred during the process of construction. The distance from “Taiyuan limestone” to Coal 8 floor was ranged 108m to 134.5m within the working range. The average distance was 121m. Normally, Taiyuan limestone water had no effect on production.

3.3 Geological characteristics of project

The corresponding dip angle (degree) of 8203 working face of coal seam was $19^{\circ}\sim 31^{\circ}$. And the average value was 26° with stable occurrence and more complex structure. Coal 81 was ranged from dark-gray to black, powder to fragment. It belonged to semi-dark type coal and contained thin layer dirt band partly with thickness of 0.20m. The thickness of Coal 81 was 4.28~6.84m, average of 5.55m. Coal 82 was ranged from black powder-like to fragment, scaly locally. It belonged to semi-dark type coal. It contained a thick layer of 0.20m dirt band in the part to bottom. The thickness of Coal 82 was 2.46~3.84m (an average of 3.23m). The dirt band between Coal 81 and Coal 82 was bulk mudstone of grey to dark-grey, siltstone in partly, brittle, and contained plant fossil. The thickness was 0.78~5.49m (an average of 2.30m). It had trend of outer section thick, internal section thin overall. And the outer section had tendency of thick in upper section and thin in bottom. The total thickness of coal (rock) layer was 8.78m. The bottom floor was soft-

weak mudstone. The original design of 8203 working face was 1200m of moving length, 148m of tendency length, an area of 173900 m², 2.1375 million tons of geological reserves and about 1.92 million of recoverable reserves.

3.4 Geological characteristics of project

Support parameters: the metal support are 600mm of row spacing and 36U-type steel in the above two schemes.

3.4.1 Main supporting technology parameters

(1) Component parameters of main body support

① Bracket: Metal bracket uses three sections of U36-type steel. The radius of semicircular arch is 2.3m. The width of roadway floor is 4993mm and the high is 3600mm. The basal area is 14.58m². The shed distance is 500mm. The top beam is a circular arc shape with arc length of 5236mm and shed leg length of 3265mm. The lap length of leg beam is 500mm and overlapping part connects with three snap rings.

② Bolt: Bolt uses non-longitudinal rib screw thread steel of high strength pre-stressed bolt of $\Phi 22\text{mm}\times 2400\text{mm}20\text{MnSi}$. Bolt tray is cold rolled steel of plate type tray of $10\times 150\times 150\text{mm}$. The arrangement of bolt is shown in figure 5.

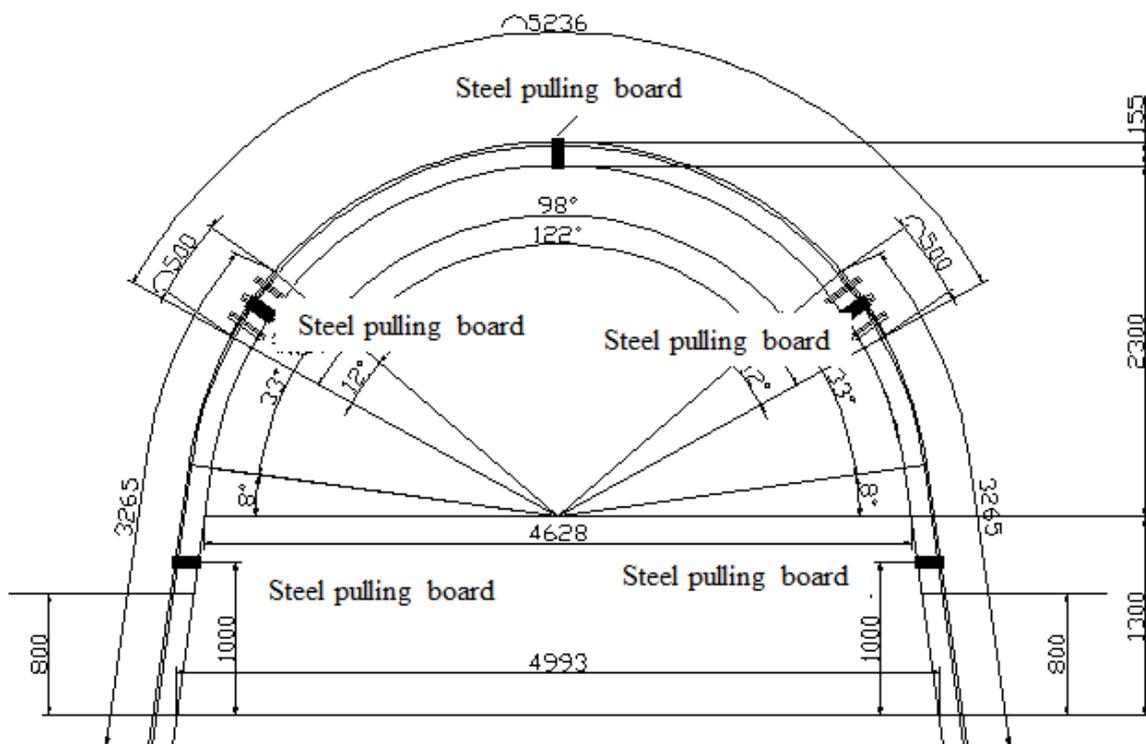


Fig. 3 The initial supporting scheme

Sectional drawing of machinery roadway , ventilation passage of Roadway 8203

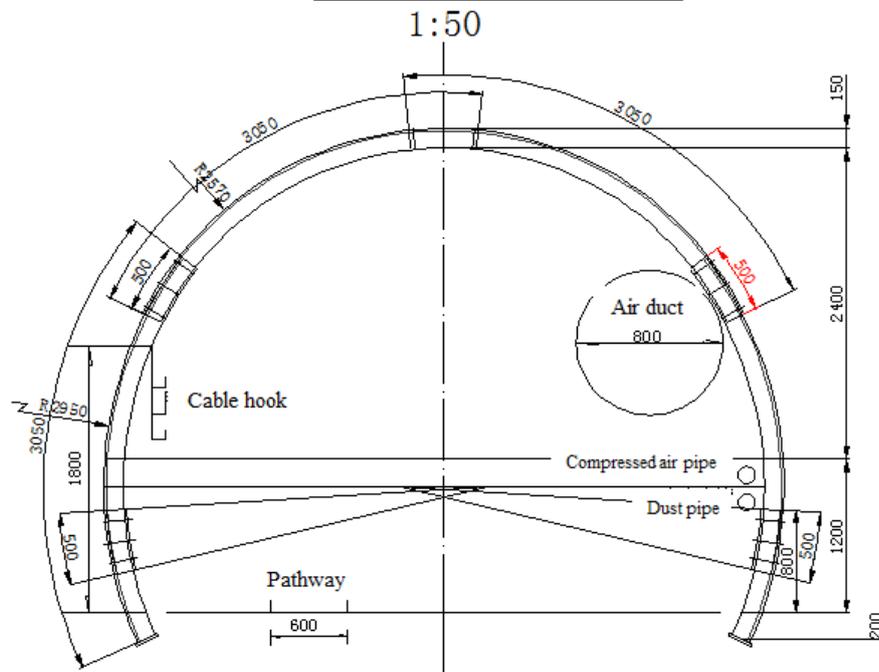


Fig. 4 Modified supporting scheme

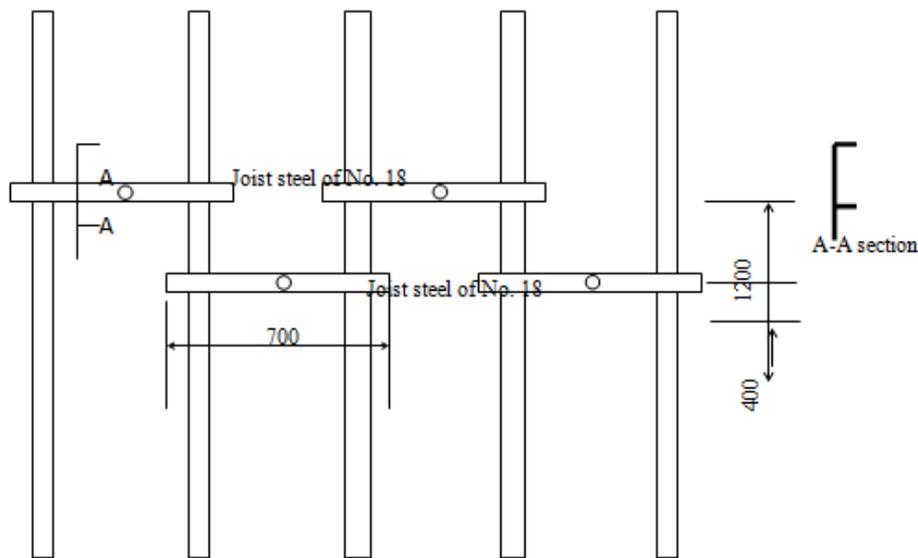


Fig. 5 Arrangement plan of roadway bolt in 8203 mining area

Table 1 the related supporting parameters

Tunnel name	Section shape	Surrounding rock type	Type of coal seam	Net height	Net width	Bracket		
						Shed distance	Shed beam segment number	Lap length
8203 machinery roadway	Skew arch	F>3	81, 82	3600	4993	500	3	500
Bracket					Top (help) material			
Cable spacing	Nut tightening torque	Depth of hamstring	material	Specifications	material	Specifications	spacing	Net lap length
230	≥300n.m	200	36USection steel	180×150	Steel bar net	700×1300	Fully closed	100mm

Description: 1 table in the parameters of the unit for the mm, bracket and its components, parts of the material, the quality must meet the requirements of the design and the relevant standards 2 leg tie angle 8°.

4 ROADWAY MONITORING OF INDUSTRIAL TEST

4.1 Layout of observation station

Mine pressure observation stations of totally eight were arranged in Roadway 8203 of Guobei Mine. The station spacing was 5m. The distance from observation station 8 to the head-on was 9m, as shown in Figure 6. Every observation station contained four observation points: roof observation point, the bot-

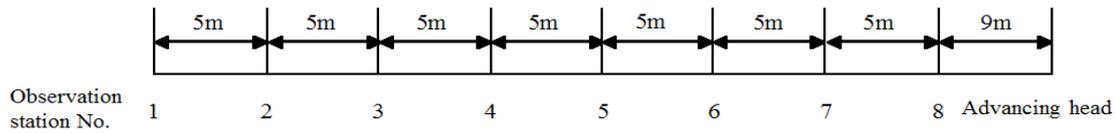


Fig. 6 Schematic diagram of instrument station layout (unit: m)

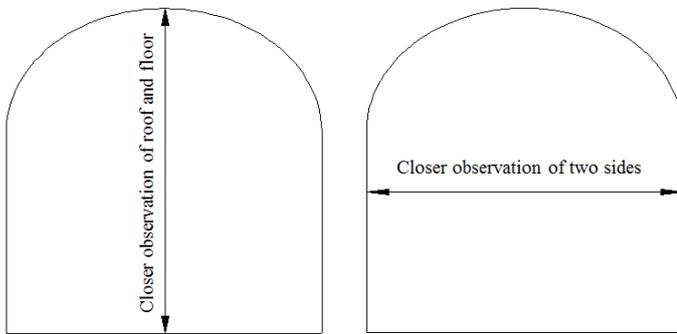


Fig. 7 Schematic diagram of measured point position in instrument station

4.2 Methods of observation

Roadway deformation test was divided into 5 stages, the first stage was the test of dynamic pressure impact stage, and the rest is the effect monitoring stage.

After arranged the observation points, it observed once a day for five days of continuous observation. The purpose was to understand the influence of dynamic pressure on roadway deformation. After five days, the roadway excavation excelled more than 30m and the roadway deformation was in stable stage. And then tested the well once every three days and filled in the test records at the end of test. The difference between the test results and the previous test results was the deformation value of roadway during the two tests. The difference between the test results and the test results of first time was the total deformation value of roadway throughout the total tests.

tom floor observation point and two side's observation point, as shown in Figure 7.

In these eight observation stations, the layout method of two sides and roof observation point were: the steel bar of diameter 10mm was bent to hook and welded in the nut which fixed on the U-shaped shed to act as observation point. The layout method of floor observation point were: the steel bar of diameter 10mm was bent to hook and welded in the crooked chisel of 10mm in diameter and 300mm in length, smashing into the floor to act as observation point.

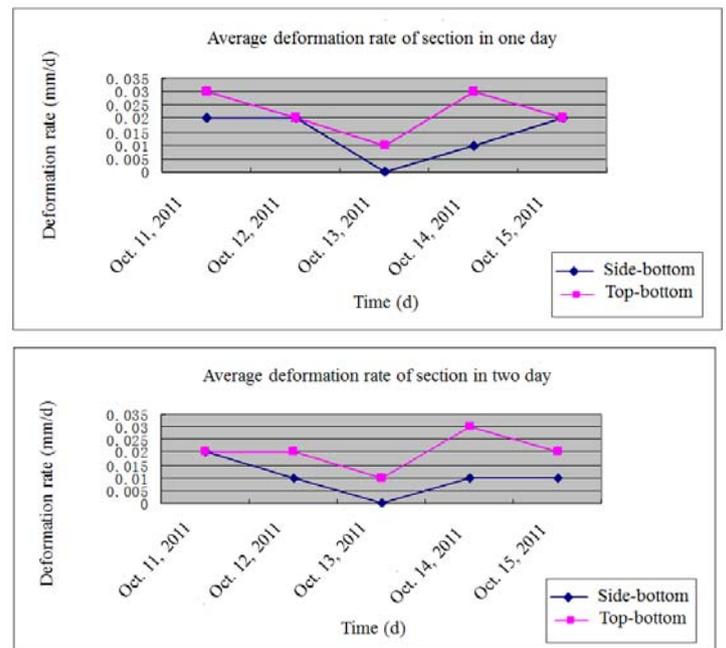


Fig. 8 Deformation rate of top-bottom and side-bottom in one day and two day

Dynamic pressure test lasted for 7 days in order to grasp the relationship between the dynamic pressure caused by the roadway deformation and the advance of the excavation working face. The second deformation stage observed 36 days. The main test content included the convergence of the roadway roof, the sides' bottom of U-shaped shed, the shed legs U-shaped shed and the convergence rate of the top and floor of the roadway. In the observation of third deformation stage, two sections were selected for monitoring effect and monitored continuously for 7 days. There were two kinds of monitoring content: the closer moving distance of side's bottom, the closer moving distance of roof and floor. In the observation of fourth deformation stage, two sections were selected for monitoring and monitored continuously for 6 days. There were two kinds of monitor-

ing content: the closer moving distance of side's bottom, the closer moving distance of roof and floor. In the observation of fifth deformation stage, two sections were selected for this monitoring effect and monitored continuously for 5 days. The monitoring content was the closer moving distance of side's bottom.

After nearly mining in the working face and through the five stages of monitoring data and on-site observation, the roadway was still intact. It realized zero rework record of 4 years for the first time in roadway of extremely loose and extra thick coal seam in domestic.

5 CONCLUSIONS

1) The principle of "the stronger support, the weaker pressure; the weaker support, the stronger pressure" and related key technologies better revealed the applicability in deep-thick extremely loose coal seam from the aspect of mechanical mechanism. Good application effect also fully demonstrated its relatively broad promotional value in roadway support of deep-thick extremely loose coal seam.

2) Aiming at pressure distribution characteristic of overall along goaf roadway, the reinforcing supporting scheme of anchor frame put forward. The monitoring results showed that the implementation of the scheme could be well controlled surrounding rock deformation and meet the requirements of safe production. It has great economic benefit and social benefit.

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