Control design of roof rock for advance blasting in roof on gob-side entry without roadside support

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Abstract

In order to solve the problem that when using gob-side entry retaining, the overall cost of roadside support was expensive, the construction technology was very complicated and the stability of roof rock destroyed easily, gob-side entry retaining without roadside support that based upon the roof control theory was presented. According to the analysis of the roof movement process accompanied with advance blasting in roof on gob-side entry retaining without roadside support, the paper summed up a conclusion that roof movement consisted of two periods, which was active period and stable period. The motion state of roof was dominated by revolving in active period, while parallel subsidence in stable period. For roof, in order to improve the capability of resisting deformation, the roadway support was required high strength and constructed timely, so the super-long anchor cable with high strength combined with concrete filled steel tube was a better choice. Then, the basic mechanical model was built up, and maximum roadway support force was solved. Additionally, the research results were applied to practice successfully.

Key words: gob-side entry without roadside support, advance blasting in roof, roof movement, strata control, roadway support.

1. Introduction

Frequently, the roadway excavation and supporting are crucial techniques in mining engineering and usually a large pillar is essential to the traditional mining method [1]. Unfortunately, this mode not only waste lots coal resource, but also bring an effort which is to have painful repercussions ---a great challenge in the roadway support, increase roadway driftage ratio, that is not in the interest of anybody. As a new way, gob-side entry retaining without roadside support has been studied and applied recently for the reason that it could avoid many pitfalls. Meanwhile it is indicated that this method will be a very important mining trend in the future. [2].
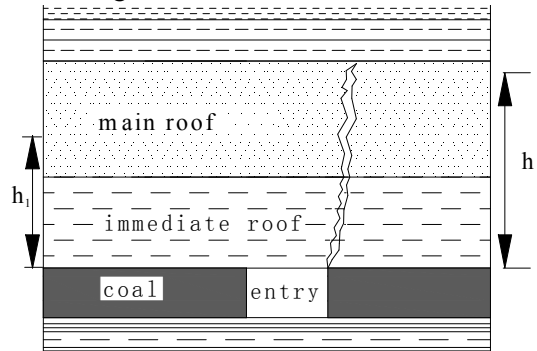
The present study shows that roadside support system is partly proposed for effective controlling entry stability. But it's not likely to be a wise choice as a result of reality that they have to adapt themselves to the movement of the roof passively [3, 4]. The support resistance bears the load of immediate roof and cantilever at initial stage of roof movement, yet it is unthinkable that never a significant role on roof structure and stability does it play at late stage [5]. While gob-side entry retaining without roadside support attracts people's interest for it's advantage such as improve the coal recovery ratio, cut down the per ton

coal cost and prevent underground accidents cased by the reason of protecting coal pillar and losing coal.
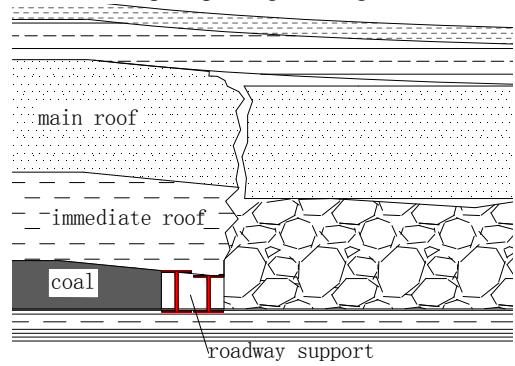
2. Description of gob-side entry retaining without roadside support

Based upon the similar pre-splitting blasting technique, the gob-side entry retaining without roadside support was a technology that sever the roof above the entry with a certain height along the border of gob before the coal mining, which could control the caving condition of roof along the gob while maintain the integrity of the whole system [6]. The roof structure followed the pre-splitting blasting was shown in Fig. 1(a). The coal body alongside entry and roadway support system combined together to prevent rotational deformation of the roof over entry when the roof above gob spontaneous caving gradually. In the early stage of roof movement, the friction force between the waste rock in the border of gob and roof above entry, cased by the horizontal force that had the waste rock as their source, increased gradually. The complex stress that came from the coal body alongside entry, roadway support system, the waste rock and underground pressure as well, forced the roof above entry to achieve a balance in mechanics. All the caving waste rock could be regarded as a whole support system in gob, which would support a majority of the weight of overburden strata progressively. Obviously the overburden strata movement tended to suspend owing to the lack of space for sinking and the stable balance state in mechanics. Finally, the roof structure reached a steady-state process, this state was shown in Fig. 1(b). Some technical processing was essential

to the waste rock before the entry could be used again.

(a) The roof structure followed the pre-splitting blasting

(b) Final state of roof structure

Fig. 1 The different state of roof structure

In order to achieve the ideal condition that the whole support system in gob bore underground pressure as much as possible, the blasting design parameter H should use the following form:

$$H = \frac{M}{K'_P - 1}$$

Where M is the thickness of coal seam,

K'_P is final coefficient of bulk increase.

$K'_P = 1.1 \sim 1.25$

3. Characteristics of roof movement in gob-side entry retaining without roadside support

Measurement curves of roof subsidence curve accompanied with advance blasting in roof on gob-side entry retaining without roadside support in coal face 20916 of Long fen colliery was shown in

Fig. 2. These data showed that roof movement features in gob-side entry retaining without roadside support differed from that in traditional gob-side entry with roadside support. The whole stage of roof movement in this mode could be divided into two parts: the active period and the steady period.
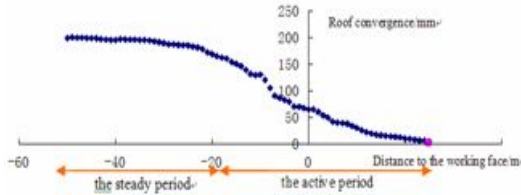

Fig. 2 Measurement curves of roof subsidence curve

The surface of gap through blasting turned a sound unaltered rock into two independent structural, which had few mechanical contact except friction force with each other. As a result, the overlying strata's bearing condition changed. Followed the working face, the gob could be filled with large numbers of waste rock that came from the rapid spontaneous caving roof strata. So long as the pre-splitting gap's height sufficed requirement of the design, the gob near the entry might be full of waste rock completely. In the process of roof's spontaneous caving in gob, owing to the complex stress which was largely due to the friction force from the waste rock and underground pressure from overlying strata, there would be some subsidence motion to this general trend in the roof above entry, as shown in Fig. 2. Roof subsidence during this period accounted for 60 percent of all subsidence process. This time was therefore called the active period of roof deformation. Throughout this period in gob, roof's caving height h_1 was represented concisely

$$h_1 = \frac{M}{K_p - 1}$$

Where h_1 is roof's caving height in gob, K_p is initial coefficient of bulk increase, and it's dominated by waste rock's morphology and density. $K_P = 1.3 \sim 1.5$

During the subsequent process of roof's spontaneous caving, changing stresses brought about more overlying strata cracking and rock deformation. Simultaneously the underground pressure that loaded by the coal body alongside entry and the whole waste rock support system increased exponentially, as a result that when it came to sharing stress in the mechanical aspect, the one whose hardness was stronger than others would take more [7]. It was corroborated that response of whole waste rock became stable after period of loading. At the same time the ability of friction force and horizontal force offered by waste rock to prevent roof subsidence increased with variable increasing length of time [8]. Eventually, the whole waste rock's height became steady and the horizontal forces as well as friction force would be equal to the whole system. So the equilibrium condition of forces experienced by the roof above the entry. This phase was known as the steady period of roof deformation. Thanks to the waste rock alongside the entry, only a small amount of parallel sinkage emerged during the roof movement at this stage.

4. Design of roadway strengthen support

4.1 The basic principles of roadway strengthen support design

In the active period of roof deformation, while underground pressure from overlying strata stayed at a lower level, the friction force between the waste rock in the border of gob and roof above entry aggravated roof's subsidence deformation. Consequently, roadway strengthen support should have the ability to prevent roof from this deformation trend. So a powerful support resistance to keep the whole roof structure stable and avoid separation inside of roof as soon as possible would be an optimal choice.

During the steady period of roof deformation, the passive support configuration could not make an appreciable difference to prevent roof's subsidence deformation trend until the roof reach the equilibrium condition of forces. So it was a better option to enhance the roof strength and improve the anti deformation capacity through initiative support in time.

In short, in terms of roadway strengthen support, control in advance and high strength in time to achieve favorable effect was basic requirement, also a combination of passive support and initiative support with other methods would be suitable.

4.2 Selection of support material

Two types of support pattern were classified in consideration of properties: passive support and initiative support [9]. Passive support controlled breaking surrounding rock, prevented roof leakage, caving and wall caving. However the anchor cable and bolt-net supporting should be displayed together. On the basis

main drawback was that it had to contact with round irregularly, leading to the deformed of surrounding rock accelerating, pressed unbalance, and the support period was short. Initiative support could timely reinforce rock, prevent wall rock from disintegrating, enhance different kinds of roof rock grow one integer, improve the integrality of shoring configuration and extend the adaptability

Due to the reason that roof contained many strata of different nature, there would be a number of initiate fissure and separation layer after mining in the interior of roof. Super-long prestressed anchor cable with high strength could be used in conjunction with shed shoring based on concrete filled steel tube to achieve the desired support effect. Super-long anchor cable was an initiative shoring configuration, it contributed the strata rock in the range of anchorage to an ensemble, timely reinforced rock, raised stability and bearing capacity of rock, prevented abscission layer and roof caving. Concrete filled steel tube provided higher strengthens than common single prop. Considering the shear capability, support strength, support effect and influence on production, concrete filled steel tube seems to be the better choice of all the passive support material available at present. Its advantages include superior performance, easy to operate, the broad scope of application, small covered area and possessed space, and low prices as well.

4.3 Calculation support Parameters

For the implementation of bolting support to roof as composite girder, super-long of usual active support, super-long anchor cable arms would be embedded deeply

above the main roof. It acted with the roof rock to support the roof above the entry actively. Additionally all the active support would keep and increase the strength of the whole roof. The main parameters of super-long anchor cable could be written as follows.

$$L \geq h_0 + l\text{a}$$

$$F_n \geq \gamma_z \cdot V_z$$

Where L is the length of super-long anchor cable, h_0 is the height of composite girder. $l\text{a}$ is the length of hanging outside and anchorage zone in rock. F_n is the effective prestressing of super-long anchor cable. γ_z is body force of immediate roof. V_z is the volume that a anchor cable support.

According to existing research, roof above entry that under super-long anchor cable's length could be regarded as a composite girder, and this composite girder should rotation and sink at the juncture of the elastic-plastic in coal near the entry. While ignoring the possible separation layer between immediate roof and main roof, the basic mechanical model of gob-side entry retaining without roadside support were built up, as Fig. 3 below.
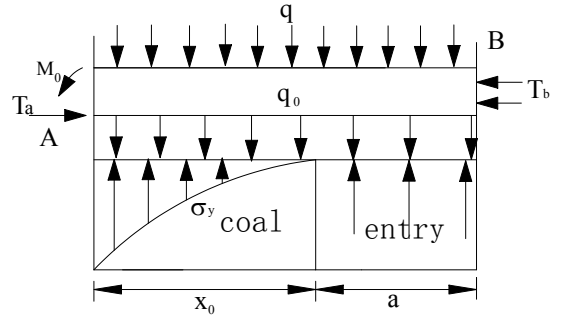

Fig.3 Mechanical model of gob-side entry retaining without roadside support

There would be the maximum roadway support force in active period. Using self-balanced method, mechanical equation was shown as follow.

$$\sum F_{y=0}, \quad (x_0+a)(q+q_o)+T_b\mu - x_o\sigma_y - p = 0, \quad \sum M_a = 0$$

$$p(x_o + a/2) + \int_0^{x_o}\sigma_y(x_o - x) + M_o + T_b(h_m/2 - \beta) - \frac{(q+q_o)(x_o+a)^2}{2} = 0$$

Combining these formulas, the maximum roadway support force p was obtained.

$$p = \frac{\frac{(x_o+a)^2(q+q_o)}{2} - (\frac{h_m/2 - \beta}{\mu} - 1)\int_0^{x_o}\sigma_y(x_o - x) - M_o + (h_m/2 - \beta)\frac{(x_o+a)(q+q_o)}{\mu}}{(1 - \frac{h_m/2 - \beta}{\mu})}$$

Where x_o is the length of elastic-plastic. a is the length of entry. q is the weight of main roof and overburden strata that had an obvious effect on the entry. q_0 is the weight of immediate roof. T_b is horizontal force offered by waste rock. μ is the friction coefficient. σ_y is abutment pressure that offered by coal near entry. h_m is the thickness of main roof. β is the subsidence value of B point.

5. Field application

Linhua colliery was a low gas mine, and the average coal thickness was 3.1 meters in No.20916 working face. In order to alleviate the tense situation of drivage and mining, reduce coal pillar loss, the technology of advance blasting in roof on

gob-side entry without roadside support was applied to the ventilation roadway, whose size was 4 meters wide and 3.2 meters high. The roof characters of ventilation roadway in No.20916 coal face were given in Table 1. To realize stable, the design depth of blasting gap was 14 meters. According to the geological data, the mechanics parameters were listed in Table 2. Subsequently, analysis of date by the formula above was done, and the maximum roadway support force p $\geq 2.93 MPa$. In order to meet this requirement, the support configuration system consists of bolt-net-anchor coupling support and concrete filled steel tube. Among them the anchor cable is 15 meters long, 2 meters row & line space, and the diameter is 21.6 mm. Concrete filled steel tubes contains Q235 seamless steel tube of 168 mm diameter as well as 10 mm wall thickness and concretes of C40.

Table 1: Roof rock characters of ventilation roadway

Name	Kinds of rock	Thickness（m）
Overburden strata	Limestone	25
Main roof	Siltstone	6.3
Immediate roof	The mixed Mudstone and siltstone	3.1
	Mudstone	4.6
False roof	Expansion slime	0.5

Table 2: The mechanics parameters of the roof rock

Mechanics parameters		Numerical value
Average elastic modulus	E	16.5GPa
Average body force	γ_z	23.8 KN/m^3
Initial coefficient of bulk increase	K_p	1.40
Final coefficient of bulk increase	K_P'	1.15
Length of the elastic-plastic	x_o	9.4m

The process of roof movement were analyzed and monitored in the whole construct courses. Here was the curve of anchor cables in Fig. 4. All the result showed that the movement of the roof became strong and prompt within a range of 20 meters in the rear of the working face, but turned steady 50 meters beyond. And then the surrounding rock remained steady again soon. The maximum subsidence is 223 mm, far below the numerical value of traditional gob-side entry retaining mode. The photo of ventilation roadway after the roof return stable again was shown in Fig. 5. So this mode was scientific in theory and feasible in practice.
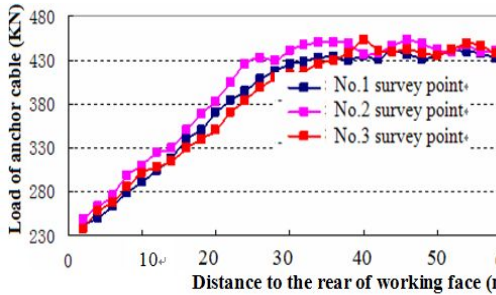

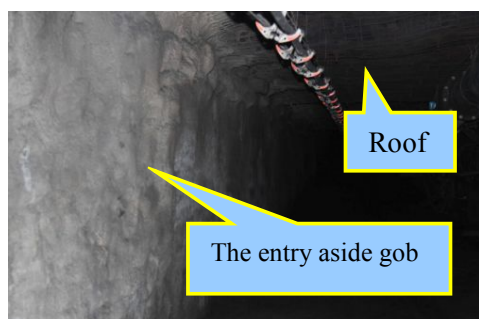Fig.4 The bearing curve of anchor cables

Fig.5 The photo of ventilation roadway after the roof return stable again

6 Conclusions

Thanks to the advantage that gob-side entry retaining without roadside support attached, it is an important entry support developing trend nowadays. In terms of roadway strengthen support, control in advance and high strength in time is the basic requirement, also a combination of passive support and initiative support with other methods is an ideal choice. In summary, advance blasting in roof on gob-side entry without roadside support is scientific in theory and feasible in practice.

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