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Research and application of technology of gob-side entry retaining by roof cutting pressure relief in Jiaozishan coal mine

Combined the mechanism of gob-side entry retaining by roof cutting pressure relief and the geological conditions of Jiaozishan coal mine, the influence of gob-side entry retaining from the depth of blasting bore in the process of roof cutting pressure relief was studied by the method of FLAC3D numerical simulation. When the depth of blasting bore was 4m, it was most significant that the surrounding rock stress of roadway transferred to the roadway deep; meanwhile, the surrounding rock deformation was also the minimum. And the result was applied to an industrial practice in the intake airflow roadway of the 9706 working face. When the working face was mined, the surrounding rock deformation was basically identical between the coal-side entry in front of the working face and the gob-side entry behind the working face, which met the requirements of retaining roadway and production in the next working face. It successfully reduced the difficulty of protecting roadway and the loss of coal pillar, and achieved remarkable economic and social benefits.

Keywords: *Roof cutting pressure relief; gob-side entry retaining; numerical simulation; surrounding rock control; ground pressure monitoring.*

1. Introduction

The technology of gob-side entry retaining is a major reform of mining roadway support technology, and it is one of the main technologies of no-pillar mining. Practice has proved that the technology of gob-side entry retaining can bring obvious economic and social benefits [1~3]. Gob-side entry retaining by roof cutting pressure relief has been developed in recent years, and is an advanced technology of protecting roadway without coal pillar. The surrounding rock structure, movement characteristics, stability mechanism and control technology of gob-side entry retaining were further explored by Wei Xuesong and Chen Yong [4~5]. Combined with the motion characteristics of overlying strata in stope, the key technologies of surrounding rock control of gob-side entry retaining were put forward by Zhang Nong, et al [6~7], such as presplitting blasting pressure relief, partition management, structure parameters optimization, "trinity" surrounding rock control and the quick construction of wall, etc. Based on the directional blasting theory, a way of gob-side entry retaining through roof presplitting was given by Zhang Kaizhi [8], and according to the fracture mechanics theory, the calculation formulas of the charge amount of single blasting bore and the distance of every two bores were derived. Using the method of numerical simulation, the key parameters of gob-side entry retaining through blasting and roof cutting pressure relief were researched by Hao Shengpeng, Zhang Guofeng and Sun Xiaoming, et al [9~11]. Some field industrial tests, in Zhuzhuang coal mine in Huaibei, Tucheng coal mine of Panjiang Refined Coal, Halagou coal mine of Shenhua Group and Baijiao coal mine, were conducted by Li Baoyu, Gu Youfu, Yang Hanhong and Song Runquan, et al [12~15].

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2. Engineering situation

The 9706 working face was in 9# coal seam of Jiaozishan mine, and its average buried depth was 329.911m. The length of the working face was 180m, and the length of intake airflow roadway and ventilation roadway was respectively 760m and 765m. The section of roadway was rectangular, and the size was 4.0 (width) ×1.8m (height). The coal seam was relatively stable, and the average thickness was 1.8m, and the dip angle was 3~5°. The characteristics of roof and floor were listed in Table 1. It is expected that the intake airflow roadway of the 9706 working face would be retained to serve the 9707 working face as ventilation roadway.

3. Mechanism of gob-side entry retaining by roof cutting pressure relief

In the process of conventional gob-side entry retaining, the roof must naturally break under the ground pressure. And the

TABLE 1: CHARACTERISTICS OF ROOF AND FLOOR

	Lithology	Thickness /m	Signalment
Basic roof	Chert limestone	10.4	Light gray, dense and hard, strong stability
Immediate roof	Siltstone	3.5	Gray-black thin clay
False roof	Clay rock	0~0.55	Dark gray-black thin carbon mud, no significant bedding, rich in plant fossils
Immediate floor	Mudstone or clay rock	0.8	Containing pyrite accretion and plant fragment fossils
Basic floor	Fine sandstone	11	Grey and dark gray calcareous, dense, bulk and thin bedded, level and slow-wave bedding, joint development, containing pyrite accretion

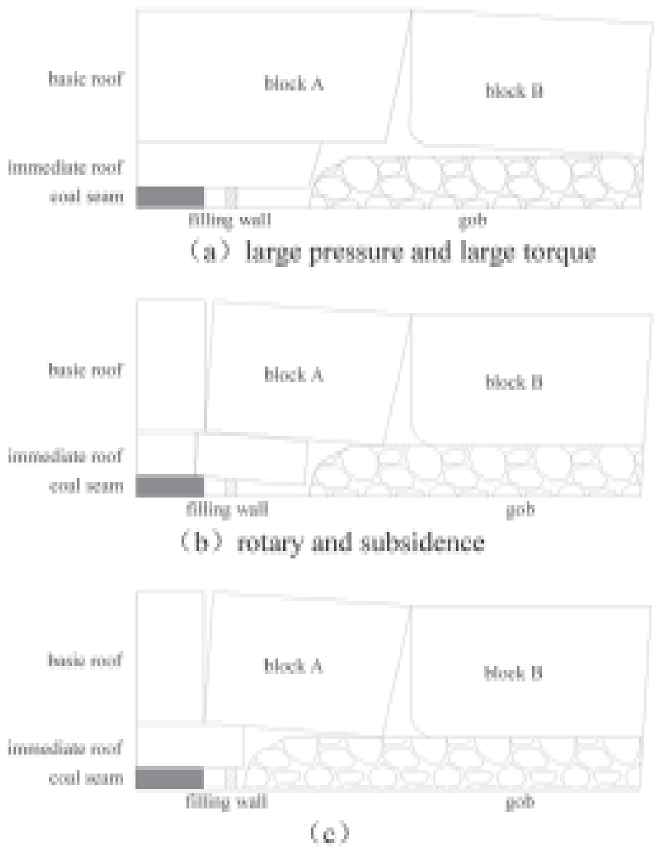

Fig.1 Section of roof breaking in the gob-side entry retaining

gob-side of retained roadway would appear the phenomena of large roof areas or roof rotary and subsidence, as shown in Figs.1(a) and (b). Due to being unevenly loaded, the filling wall next to the side of roadway loses stability and is broken, which ultimately results in the failure of retaining roadway. In Fig.1(c), the technology of gob-side entry retaining by roof cutting pressure relief cuts off the cantilevers of immediate roof and basic roof and the connection between roadway roof and gob roof, and it also reduces the rock load that the filling wall bears; in the meantime, the caving immediate roof has a support action to the basic roof, and it reduces the influence of the basic roof's rotary and subsidence. Therefore, the measure of blasting and roof cutting can change the strata structure and physical and mechanical properties of roadway roof; what is more, it also can weaken the correlation between the roof of retained roadway and the immediate roof and basic roof of the stope. Besides, the stress concentration around roadway is transferred to surrounding rock deep and the surrounding rock stress environment where the roadway was located is improved, which creates a probability for gob-side entry retaining [6~7, 16~17].

4. Design of blasting parameters

4.1 Determination of the depth of blasting bore

The depth of blasting bore is one of important factors that influence the effect of roof cutting pressure relief and retained roadway support. In order to determine the reasonable depth of blasting bore for presplitting and roof cutting in the 9706 working face, the software of FLAC3D numerical simulation was used. Five models of gob-side entry retaining by roof cutting pressure relief, whose depths of blasting bore were respectively 0m (no blasting), 3m, 4m, 5m and 6m, were built and analyzed. And the calculated results were as shown in Figs.2 and 3.

It could be seen from Figs.2 and 3 that for different depth of blasting bore, the distribution laws of horizontal stress and vertical stress existing in the roadway surrounding rock were similar. The roof and floor of roadway in the gob-side were the stress reduction areas, and a stress concentration was formed in the solid coal side deep. But because of the different depth of blasting bore, the concentration extent of the surrounding rock stress distributing in the roadway was also of difference, as shown in Fig.4.

It made clear that in the geological conditions of Jiaozishan coal mine, the unloading effect of gob-side entry first increased and then decreased with the depth of blasting bore increasing. When the depth of blasting bore was less than 4m, there was a positive correlation between the maximum of surrounding rock stress, stress concentration coefficient and it; and moreover, the stress concentration developed to roadway deep. When the depth of blasting bore was over 4m, the maximum of surrounding rock stress and stress concentration coefficient both presented a trend of decreasing, and but the stress concentration rapidly transferred towards roadway surface.

Similarly, the surrounding rock displacement of the different depth of blasting bore was shown in Fig.5.

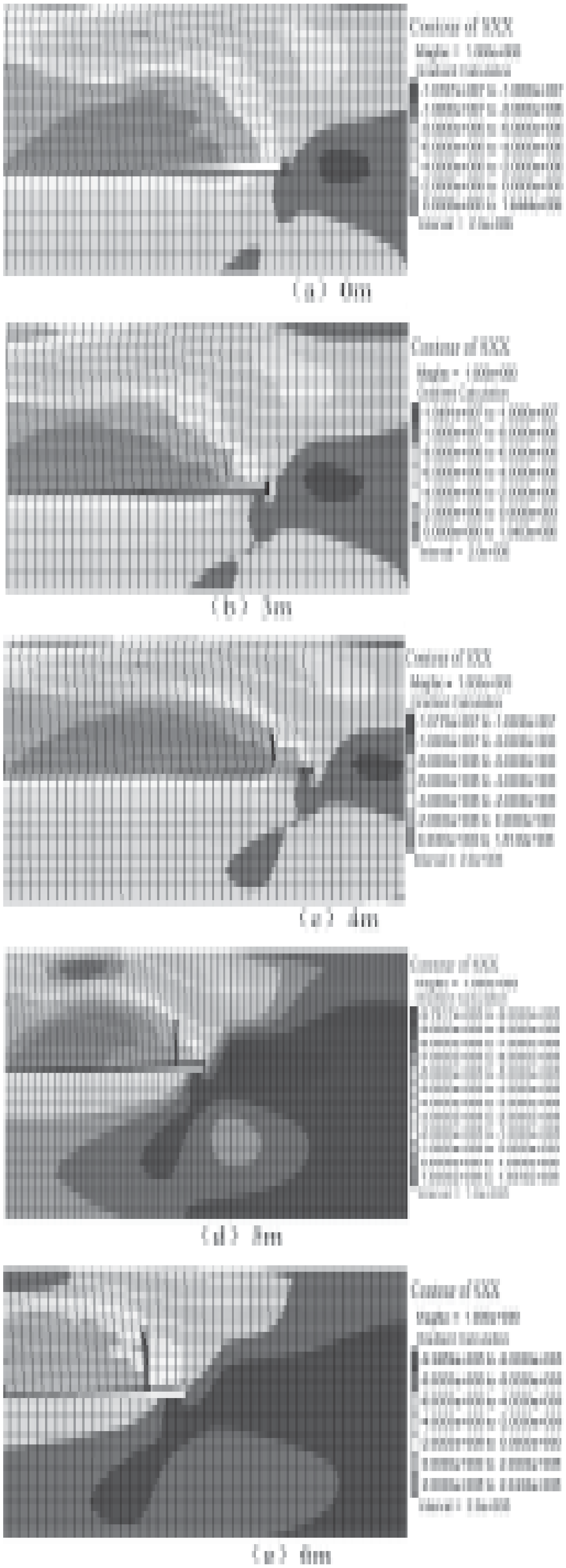

Fig.2 The horizontal surrounding rock stress distribution of different depth of blasting bore

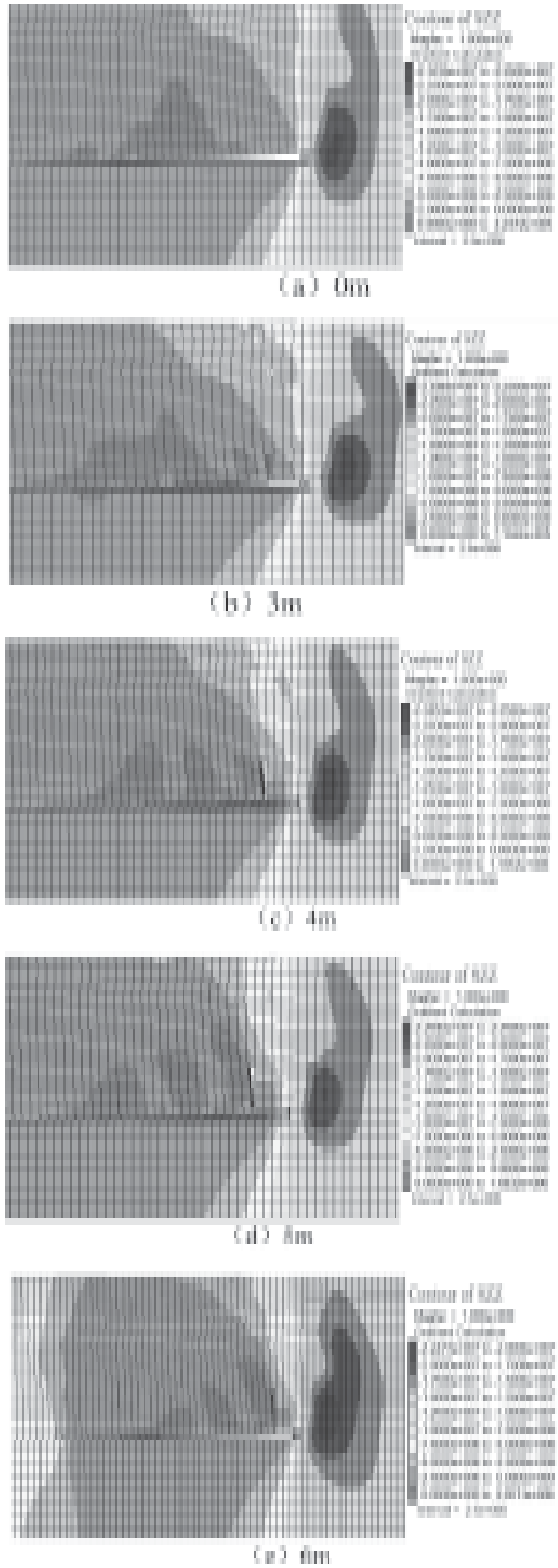

Fig.3 The vertical surrounding rock stress distribution of different depth of blasting bore

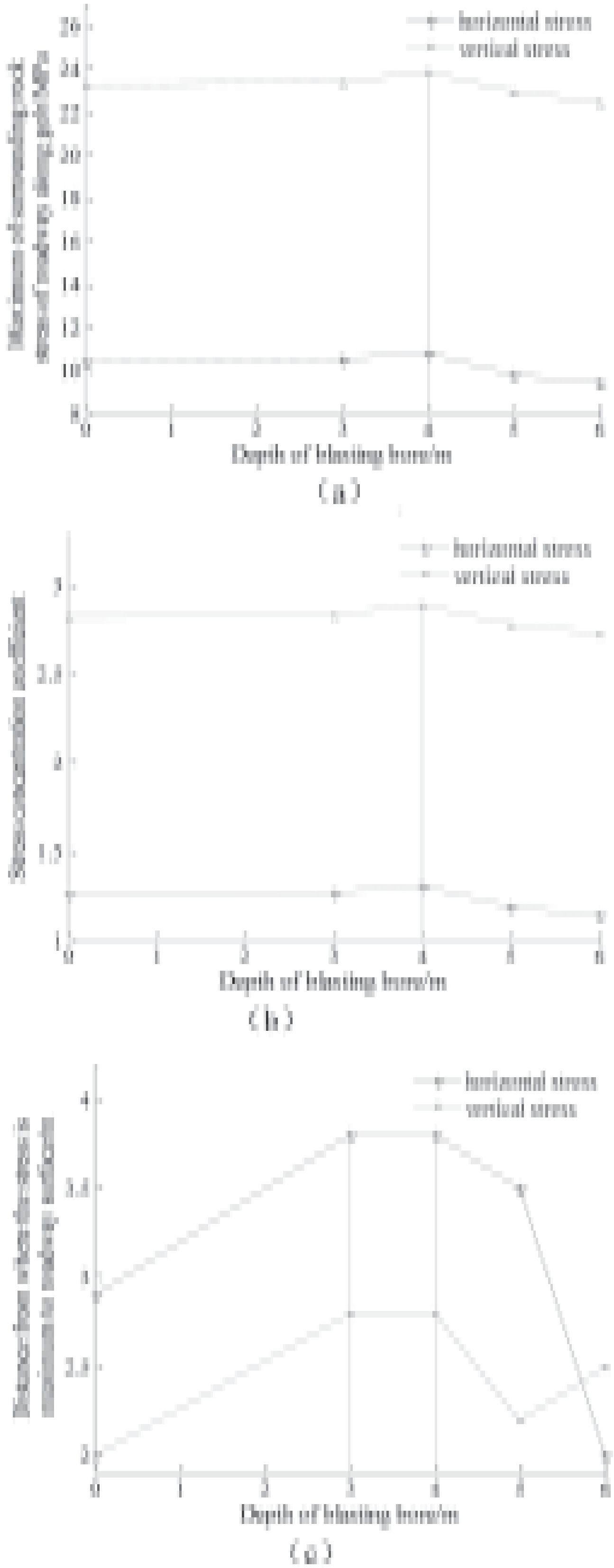

Fig.4 The characteristics of surrounding rock stress of different depth of blasting bore

According to Fig.5 knowing the roof subsidence was given an absolute priority in the surrounding rock deformation of roadway. When the depth of blasting bore was 4m, the roof subsidence of gob-side entry was the minimum, compared to no measures of blasting and roof cutting, its value decreased by 203.7mm. So the surrounding rock deformation of roadway had been effectively controlled.

In summary, the depth of blasting bore should be 4m in the construction process of gob-side entry retaining by presplitting blasting and roof cutting pressure relief in Jiaozishan coal mine.

4.2 Blasting technology

Ahead of the working face, the measure of presplitting blasting and roof cutting pressure relief was put into effect step by step along the advance direction. According to the actual situation underground, along the mining side, the blasting bore that was perpendicular to the roof was arranged where there was a 1.7-meter distance from the center line of roadway. Its depth was 4.0m, and the spacing of every two blasting bores were 0.5m. Each group was less than 8 blasting bores and required to finish a continuous detonation. Before blasting, the advance distance to the working face was asked for being more than 10m, as seen in Fig.6. The charge of single bore needed six volumes emulsion explosive and two millisecond delay electric detonators, and the blasting way of a large series was adopted.

The procedure of blasting construction was as follows: (1) If the roof had a good integrity, it would be that the construction of gob-side entry retaining, coal cutting and advancing support; (2) If the roof was broken, it would be that advancing support, the construction of gob-side entry retaining and coal cutting.

5. Industrial test

5.1 Design of the support parameters of roadway retained

In the period of excavating, the roof support used the ordinary bolt of F18×1800mm and the steel net whose size was 1000×2100mm, and the bolt spacing was 800×800mm. The coal sides were nude roadway (no support). Before the working face being mined, the roadway was given a supplement support [18]. On the basis of the original support, the anchor cable of F15.24×6000mm was constructed every 2.4m along the center line of roadway (in the excavating period, the anchor cable could be constructed lagging bolt). The hydraulic single prop of DW22-25 and the articulated beam of HDJB-1200 were used together as advance support. There were 3 props in every row, and its spacing was 1300×1200mm. The advance distance to the working face was more than 30m. Behind the working face, when the blasted roof was into the gob, the temporary support should be added in time forming a wall support. The metal net clung to the filling wall, and a strengthening support of single prop was done close to the wall, as shown in Fig.6.

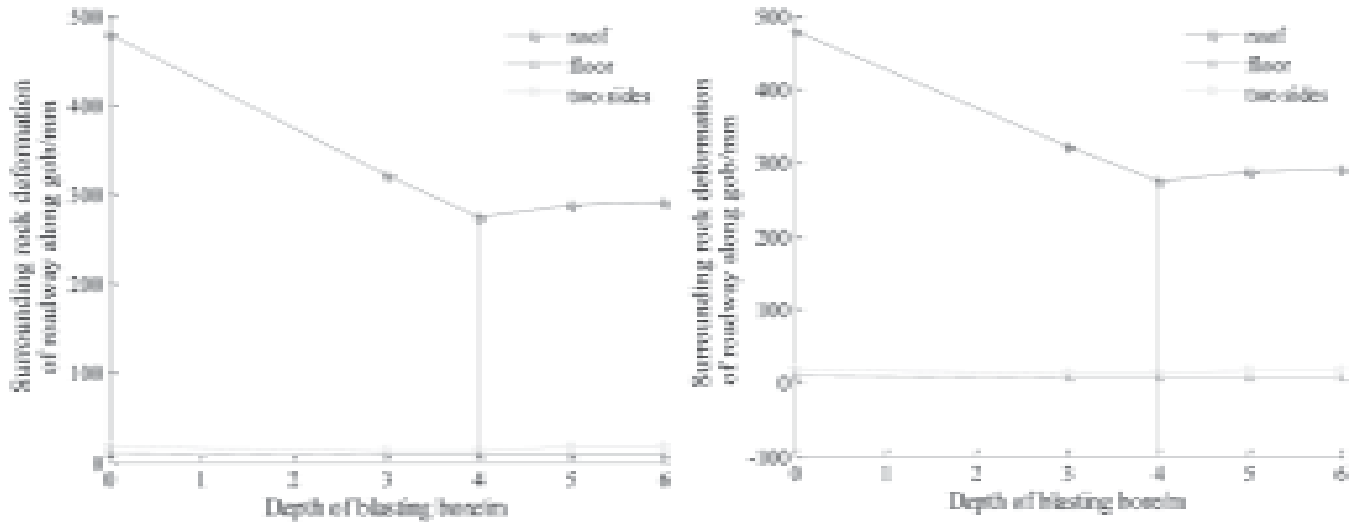

Fig.5 The surrounding rock deformation of different depth of blasting bore

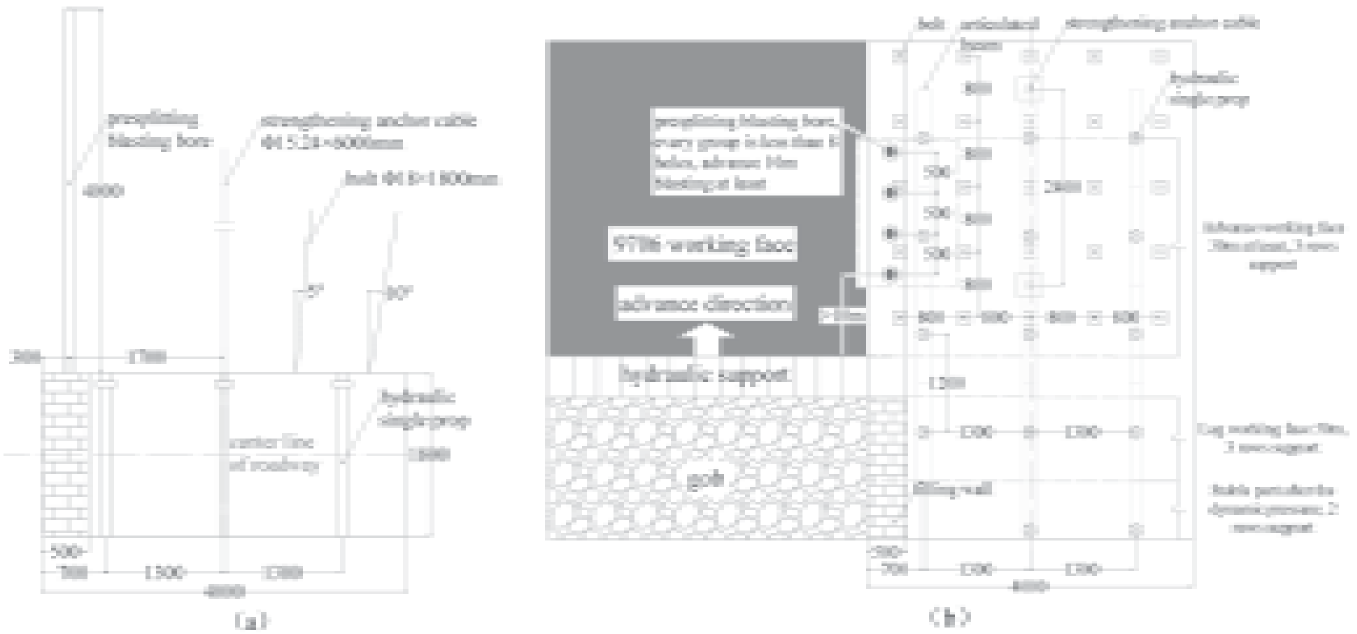

Fig.6 Layout of presplitting blasting bore and sketch of support for roadway

5.2 Mine pressure monitoring of roadway retained

To analyze the surrounding rock support effect of gob-side entry retaining, the ground pressure monitoring was carried out. The surface displacement station 1 was built in advancing working face of 120m, and it was used to monitor the mining influence on the roadway surrounding rock. The surface displacement station 2 was arranged lagging working face a little and it was aimed at monitoring the surrounding rock deformation of retained roadway. The data acquisition frequency of station 1 was once in every 2 days in the initial period, after the rate of surrounding rock deformation increase, the frequency was updated once a day. On the contrary, with regard to the station 2, the early choice once a day, after the surface displacement of retained roadway being in the basic stability state, the frequency of once every 2 days was accepted. The monitoring results were given in Figs.7 and 8.

As is told in Fig.7, the large deformation of intake airflow roadway was lead because of the mining influence of the working face. The cumulative total displacement of roof and floor was 245mm, and two sides of roadway cumulatively moved 124mm. With the advancement of working face, the rate of surrounding rock deformation gradually increased in the station 1. When the distance between the station 1 and the working face was about 50m, the deformation rate sharply increased; when the distance was 15m, the deformation rate reached the maximum, and respectively equaled 25mm/d (roof and floor) and 16mm/d (two sides). Namely, the dramatic range

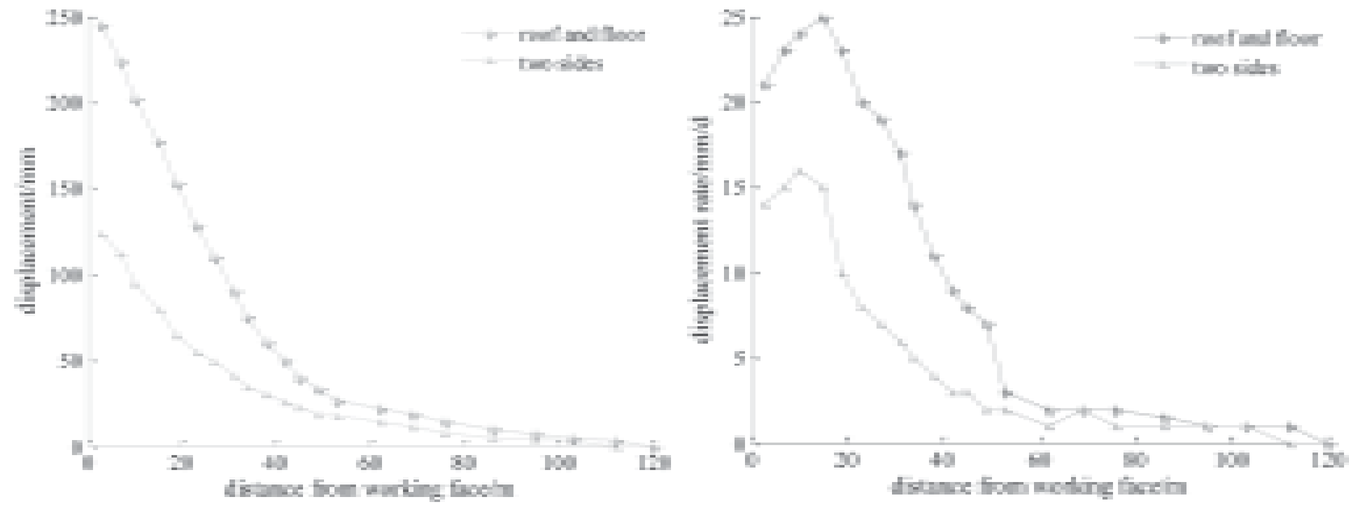

Fig.7 Monitoring data of station 1

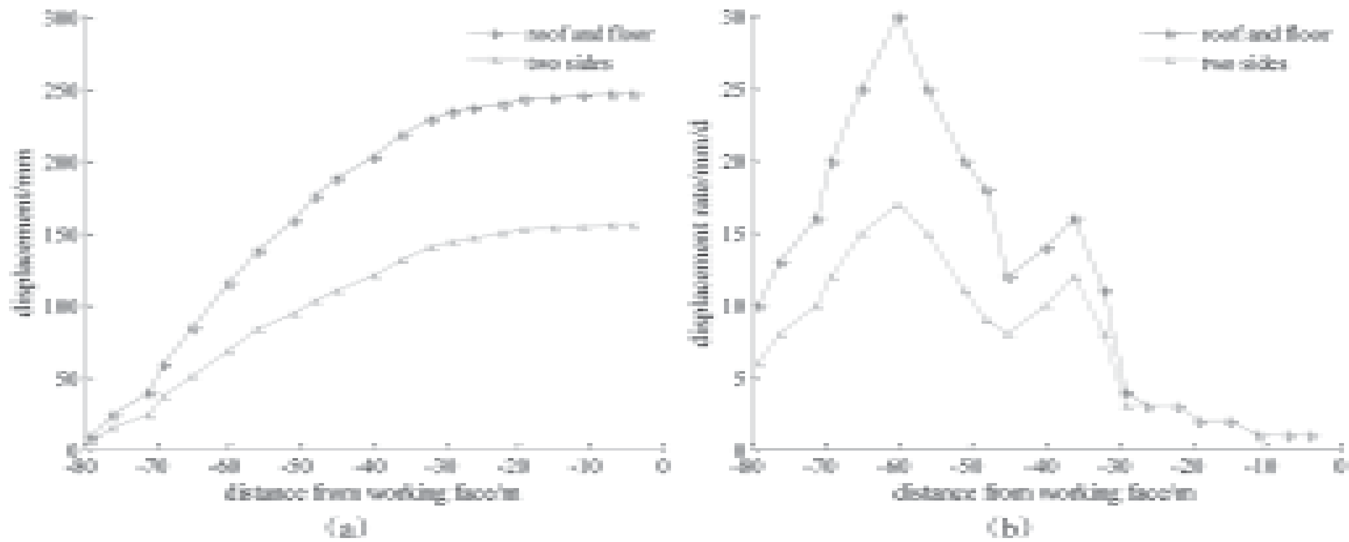

Fig.8 Monitoring data of station 2

affected by the working face's mining was 50m. The section of roadway narrowed by 16.67% and it could satisfy the production requirements of the working face.

As can be seen in Fig.8, after the working face being mined, the surrounding rock of gob-side entry actively moved. And the cumulative total displacement of roof and floor was 247mm, and two sides' was 156mm. When the station 2 was in the rear 20m of the working face, the rate of surrounding rock deformation was the maximum, and separately 30mm/d (roof and floor) and 17mm/d (two sides). In the rear 50m of the working face, the rate of surrounding rock deformation visibly decreased. Behind the working face for 50~80m, the surrounding rock deformation seemed to become gentle and basically tended to be stable. That is to say, the mining influence range acting on gob-side entry was 50m. The section of gob-side entry shrank by 17.57%. Compared to the coal-side entry, the surrounding rock deformation of gob-side entry was slightly larger, but it still could accord with the demand of retaining roadway and returning air next working face [19]. Consequently, the key parameters and technology of gob-side entry retaining by roof cutting pressure relief were reasonable and effective, and the possibility and foundation were made for successfully gob-side entry retaining.

6. Conclusions

By comparing the characteristics of conventional gob-side entry retaining and gob-side entry retaining by roof cutting pressure relief, the mechanism and advantages of the latter were analyzed. Combined with the geological conditions of Jiaozishan coal mine, the influences on gob-side entry retaining from the depth of presplit blasting bore were further studied by FLAC3D numerical simulation software. And then a 4-meter depth was determined for the blasting bore. Industrial test showed that during mining, the section of roadway in front of the working face was narrowed by 16.67%, and the section of roadway behind the working face was narrowed 17.57%; the deformation extent of surrounding rock was approximately the same, and it satisfied the requirements of retaining roadway and production next working face. The technology of gob-side entry retaining by roof cutting pressure relief effectively reduced the difficulty of protecting roadway and the loss of coal pillar, which had achieved remarkable economic and social benefits, and laid a foundation of no-pillar, safe and efficient mining for mines.

Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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