Research Article

Presplitting Blasting the Roof Strata to Control Large Deformation in the Deep Mine Roadway

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As the mining depth increases, under the influence of high ground stress, the surrounding rock of deep mine roadways shows soft rock characteristics. Under the influence of mining disturbance at the working face, large deformation of the roadway has occurred. To control the large deformation of the roadway, many mines have adopted the form of combined support, which has continuously increased the support strength and achieved a certain effect. However, since the stress environment of the surrounding rock of the roadway has not been changed, large deformation of the roadway still occurs in many cases. Based on the theoretical basis of academician Manchao He's "short cantilever beam by roof cutting," this paper puts forward the plan of "presplitting blasting + combined support" to control the large deformation of the deep mine roadways. Without changing the original support conditions of the roadway, presplitting blasting the roof strata of the roadway, by cutting off the mechanical connection of the roof strata between the roadway and gob, improves the stress distribution of the roadway to control the large deformation. Through field tests, the results show that after presplitting blasting the roadway roof, the roadway roof subsidence is reduced by 47.9%, the ribs displacement is reduced by 45.7%, and the floor heave volume is reduced by 50.8%. The effect is significant.

1. Introduction

China's coal resources buried below 1000 m are 2.95 trillion tons, accounting for 53% of the total coal resources [1, 2]. At present, there are more than 100 coal mines in China with a depth of more than 600 m, 38 coal mines with a depth of more than 1000 m, and the deepest is more than 1500 m [3, 4]. The existing research results show that with the increase in mining depth, the vertical stress continues to increase. The tectonic stress increases accordingly, forming a high stress condition of "high vertical stress and high tectonic stress" at a large buried depth, which easily leads to a series of problems such as large deformation, roof fall, rib spalling, and floor heave [5–7]. It brings hidden dangers to coal mine safety production.

As shallow coal resources are exhausted, the development of coal resources to deep is an objective and inevitable trend, and it is also a common problem faced by many mining countries in the world [8, 9]. Some mines in Germany and Russia have mining depths exceeding 1400 m, Canada has 30 mines exceeding 1000 m, and the United States has 11 mines exceeding 1000 m [10, 11]. China's coal mining depth is increasing year by year at a rate of 10–20 m per year [12, 13]. How to effectively control the large deformation of deep mine roadways has become a problem of the coal industry [14–16].

At present, domestic and foreign scholars have put forward many support theories for the deep mine roadway, such as the new Austrian tunneling method, the loose circle theory, the combined support theory, and the bolt shotcrete

arc plate support theory. [17–19]. These theories believe that due to the buried depth, the deep mine roadway has shown the characteristics of the soft rock roadway [20–22]. A single rigid or flexible support method cannot effectively control the large deformation of the deep mine roadway. Therefore, it is necessary to adopt a variety of support methods to control the large deformation of the deep mine roadway [23, 24]. These theories have played an important role in guiding the support of deep mine roadways. However, with the increase in mining depth, it has become more and more difficult to maintain the stability of the surrounding rock of deep mine roadways solely by supporting methods. To ensure the safety of deep mine roadways, many coal mines can only continuously increase the support strength and sometimes need to use passive methods such as roof ripping, rib expansion, and undercutting to ensure the section size of the roadway, which seriously restricts the transformation of coal mine enterprises to high production and efficiency [25–27].

Based on the theory of “short cantilever beam by roof cutting” proposed by academician Manchao He, this paper proposes a “presplitting blasting + combined support” scheme to control the large deformation of the deep mine roadway [28–30]. This paper takes the Xingcun Coal Mine of Shandong Tianan Mining Co., Ltd. as the engineering background to conduct research.

2. Engineering Background

Xingcun Coal Mine is located in Qufu City, Shandong Province. The west area of the minefield is the hanging wall of the Ziyang fault, the south is bounded by the Ziyang fault, the north and west are bounded by the minefield boundary, and the east is bounded by the F50 fault. The minefield area is about 36.86 km². The ground elevation of 3307 working face is 52–55 m, the underground elevation is –1110 to –1135, and the average buried depth is 1165 m. The roadway is affected by the pressure and geological conditions, and large deformation of the roadway appears. The most serious are the two shoulder sockets of the roadway. The top row of bolts at the top of the bank is covered by the top sinking, and there are phenomena such as steel strip tearing, bolt breakage, and anchor cable breakage. The floor heave of the roadway is large. This article takes the Xingcun Coal Mine 3307 ventilation roadway as the engineering background for research.

The main coal seam of 3307 working face is #3 coal. According to drilling data, the average coal thickness of #3 coal is 5.42 m, the coal seam inclination is 11°, the coal seam structure is simple, and the coal seam's proctor hardness $f=2$. The comprehensive histogram of rock formations is shown in Figure 1.

The section shape of the 3307 ventilation roadway is a straight wall arc arch type. The net width of the roadway is 4100 mm, the wall height is 2800 mm, and the middle height of the roadway is 3500 mm. The original support method is combined support of bolt, mesh, cable, and steel belt. KMG500-22-2400 type metal threaded anchor rod, SK18/8.0-1700Q type anchor cable, and metal diamond mesh

made of #8 iron wire were used. The specification is 2500 × 1350 mm, and the grid size is 70 × 70 mm. The anchor rod is used in conjunction with the W-shaped steel belt and was fastened on the steel belt with a special tray. The length of the steel belt is 4300 mm, the row distance of the steel belt is 800 mm, and the row distance between the bolts is 800 × 800 mm. The original support form of the roadway is shown in Figure 2.

3. Scheme Design

Without changing the original support scheme, this paper proposes a plan for presplitting blasting the roof strata of the roadway to control the large deformation of the deep mine roadway. First, the directional presplitting blasting method cuts off the force transmission path between the roof strata of the roadway and the gob, forcing the stress to transfer to the depth of the coal, which has the effect of pressure relief. Moreover, under the action of presplitting blasting, the impact of roof strata collapse on the surrounding rock of the roadway can be reduced. Then, cooperate with the original support method to achieve the purpose of controlling the large deformation of the roadway. The key technical parameters of presplitting blasting mainly include the depth, angle, and spacing of presplitting blasting holes.

Arrange presplitting blasting holes at the side of the gob on the roof of the 3307 ventilation roadway. According to the drilling data on site, there is a layer of fine sandstone of about 10 m above the roadway. In the mining process of the working face, the deformation and fracture process of this layer of fine sandstone have a great influence on the mine pressure appearance of the roadway. Therefore, the depth of the presplitting blasting hole should ensure that this layer of fine sandstone is cut so that it can collapse in a short time after the working face is mined. The depth of presplitting blasting hole is initially designed to be 17 m.

Presplitting blasting the roof strata of the roadway before the working face is mined, and the roof strata on the gob side and the roadway side is cut off at the presplitting blasting hole after the working face has been mined. The deflection angle of the presplitting blasting hole to the gob side is too small, which is not conducive to the stability of the roof strata of the roadway and will bring difficulties to the roadway support, while the angle is too large, and it is not conducive to the collapse of the gob roof strata. After presplitting blasting the roof strata of the roadway, the mechanical model of the roof strata can be simplified as Figure 3.

When the hinged structure is formed, the conditions for the rock mass to remain stable are as follows:

$$[T \cos \theta + (R - F) \sin \theta] \cdot \tan \varphi = (R - F) \cos \theta - T \sin \theta. \quad (1)$$

Equation (1) can be simplified as follows:

$$T \sin(\theta + \varphi) = (R - F) \cos(\theta + \varphi). \quad (2)$$

So, $\alpha = \arctan((R - F)/T) - \varphi$

Thickness (m)	Column	Lithology	Bulk (GPa)	Shear (GPa)	Tension (MPa)	Cohesion (MPa)	Friction angle (ϕ)	Density (kg/m^3)
6.75		Mudstone	0.97	1.45	1.92	1.88	33	2100
0.46		#1 coal	0.81	1.22	1.69	1.71	31	1400
0.55		Mudstone	0.97	1.45	1.92	1.88	33	2100
3.23		Fine sandstone	1.21	2.58	2.92	3.35	36	2300
3.52		Mudstone	0.97	1.45	1.92	1.88	33	2100
4.75		Fine sandstone	1.21	2.58	2.92	3.35	36	2300
5.76		Siltstone	2.81	3.22	4.53	3.82	41	2460
10.08		Fine sandstone	1.21	2.58	2.92	3.35	36	2300
0.45		#2 coal	0.81	1.22	1.69	1.71	31	1400
4.53		Siltstone	2.81	3.22	4.53	3.82	41	2460
0.39		Mudstone	0.97	1.45	1.92	1.88	33	2100
5.42		#3 coal	0.81	1.22	1.69	1.71	31	1400
1.43		Mudstone	0.97	1.45	1.92	1.88	33	2100
2.44		Siltstone	2.81	3.22	4.53	3.82	41	2460
11.13		Fine sandstone	1.21	2.58	2.92	3.35	36	2300
2.56		Mudstone	0.97	1.45	1.92	1.88	33	2100
3.53		Siltstone	2.81	3.22	4.53	3.82	41	2460
2.44		Fine sandstone	1.21	2.58	2.92	3.35	36	2300
1.66		Mudstone	0.97	1.45	1.92	1.88	33	2100

FIGURE 1: Coal seam stratum synthesis histogram.

FIGURE 2: Original support form of the 3307 ventilation roadway. (a) Front view of original support form of the roadway. (b) Top view of original support form of the roadway.

FIGURE 3: The mechanical model of the roof strata.

$$\begin{cases} f = \tau \times h \times 1, \\ R = \rho g h d, \end{cases} \quad (3)$$

where T is the horizontal force of the rock block in kN; R is the load of block B in kN; F is the working resistance of a single prop in kN; h is the height of roof cutting in m; φ is the friction angle of the rock block in $^\circ$; α is the angle of the presplitting blasting hole in $^\circ$; f is the shear force of the rock block in kN; ρ is the density of the rock strata in kg/m^3 ; and d is the width of the roadway in m.

For convenient calculation, a component of T can be approximated as f , where " $f = T \sin \alpha$ ". According to the actual conditions of the 3307 ventilation roadway, the field parameters were chosen as follows: $\varphi = 27^\circ$, $t = 0.13 \text{ MPa}$, $\rho = 2500 \text{ kg/m}^3$, $h = 16 \text{ m}$, and $d = 4.1 \text{ m}$.

According to the aforementioned theoretical calculation, when the angle of the presplitting blasting borehole is in the range of 10° – 15° , the roof strata of the roadway can remain stable. For comprehensive consideration of the convenience of construction and engineering experience of other mines, the angle between the presplitting blasting hole and the vertical is designed to be 15° .

Adopting bidirectional energy blasting technology, to pack the explosives in the tube, symmetrical openings on both sides of the energy collecting tube form a weak blasting surface [31–33]. As shown in Figure 4(a), after the explosive is detonated, the detonation wave will form a directional concentrated energy flow in the direction of the weak surface on both sides of the energy collecting tube, forming a cutting effect on the roof strata. As shown in Figure 4(b), the detonation wave generates concentrated tensile stress along the direction of the working face. The low tensile strength of the rock is used to force the presplitting blasting hole to penetrate along the energy-gathering direction to form a directional presplitting blasting section.

According to previous engineering experience, the bi-directional energy of concentrated blasting hole spacing is generally in the range of 400–600 mm, and the blasting effect is better. Numerical simulation was carried out on the roof strata formation of #3 coal in Xingcun Coal Mine, and LSDYNA software was used to numerically analyze the presplitting blasting hole spacing of 400 mm, 500 mm, and

600 mm to determine the best blast hole spacing. The simulation results are shown in Figure 5.

As shown in Figure 5, when the space between the presplitting blasting borehole was 400 mm, the stress superposition was too strong and easily caused the borehole to collapse. When the space between the presplitting blasting borehole was 500 mm, the stress superposition was strong enough to run through the roof strata. When the space between the presplitting blasting borehole was 600 mm, the stress superposition was too feeble to run through the roof strata. Based on the numerical simulation, considering the previous engineering experience and engineering quantity, the space between the presplitting blasting borehole was selected to be 500 mm.

The original support method of the roadway remains unchanged, and the combined support plan of "bolt + anchor + wire + steel + belt + shotcrete" is still selected. The support plan can be adjusted at the location where the local surrounding rock of the roadway is poor to increase the support strength.

4. Numerical Simulation

To understand the effect of pressure relief by presplitting blasting, Flac3D software was used to simulate the two working conditions of presplitting blasting and non-presplitting blasting the roof strata of the roadway. A numerical model was established according to the geological conditions of the #3 coal seam in the Xingcun Coal Mine. The mechanical parameters of the roof and floor rock strata are shown in Figure 1. The model length, width, and height were $600 \times 300 \times 70 \text{ m}$; the vertical boundary force was applied to the upper boundary; the lower boundary was fixed in the vertical direction; and the front, rear, left, and right boundaries were fixed in the horizontal direction [34–36]. The width of the simulated working face was 200 m, the thickness of the coal seam was 3.5 m, and the width and height of the roadway were $4.0 \times 3.5 \text{ m}$. The stress distribution for presplitting blasting the roof strata of the roadway is shown in Figure 6(a), and the stress distribution without presplitting blasting the roof strata of the roadway is shown in Figure 6(b).

FIGURE 4: Bidirectional energy blasting technology. (a) Principle of bidirectional energy blasting. (b) Presplitting blasting the roof strata.

FIGURE 5: Blasting effect of different blast hole spacing. (a) Blasting spacing 400 mm. (b) Blasting spacing 500 mm. (c) Blasting spacing 600 mm.

FIGURE 6: Stress distribution of two working conditions. (a) Presplitting blasting the roof strata. (b) Non-presplitting blasting the roof strata.

4.1. Characteristics of Stress Distribution in front of Working Face. To understand the influence of presplitting blasting on the stress distribution in front of the working face, stress measurement lines were arranged at the same position in front of the working face. As shown in Figure 6, #1–#3 survey lines were arranged perpendicular to the working face, and #4–#6 survey lines were arranged parallel to the working face. #1 survey line was 5 m away

from the mining side of the 3307 haulage roadway, #2 survey line was located in the middle of the working face, #3 survey line was 5 m away from the mining side of the 3307 ventilation roadway, #4 survey line was 20 m in front of the working face, #5 survey line was 10 m in front of the working face, and #6 survey line was 5 m in front of the working face. The stress monitoring curves are shown in Figure 7.

FIGURE 7: Continued.

FIGURE 7: Vertical stress curves of two working conditions. (a) Stress monitoring value of #1 survey line. (b) Stress monitoring value of #2 survey line. (c) Stress monitoring value of #3 survey line. (d) Stress monitoring value of #4 survey line. (e) Stress monitoring value of #5 survey line. (f) Stress monitoring value of #6 survey line.

By comparing and analyzing whether the roadway roof strata was presplitting blasted, the vertical stress changes in the front of the working face under the two working conditions; it can be seen that the change of stress of the #1 survey line and the #2 survey line was same, and the vertical stress of the #3 survey line under the presplitting blasting the roof strata is significantly smaller than the vertical stress without presplitting blasting. Comparing and analyzing the stress changes of #4–#6 survey lines, it can be seen that without presplitting blasting the roof strata of the roadway, the stress in front of the working face shows that the stress on both sides of the roadway is higher than that on the middle of the working face. The stress concentration area at both ends of the working face was close to the roadway. The presplitting blasting of the roof strata was carried out, and the stress concentration area on the side of the presplitting blasting of the working face is transferred to the depth of the coal seam, forming a stress reduction area of about 30 m.

4.2. Characteristics of Lateral Stress Distribution on Working Face. To understand the influence of presplitting blasting on the lateral stress distribution of the working face, five measuring lines were arranged at the same position on the working face. As shown in Figure 6, #7–#11 survey lines were located behind the working face, and the distances were 5 m, 10 m, 20 m, 50 m, and 100 m, respectively. The stress distribution cloud diagrams of #7–#11 survey lines are shown in Figure 8.

As shown in Figure 8, in the presplitting blasting the roadway roof strata, the average stress concentration area was 12.8 m away from the roadside, which is an increase of 56.3% compared with the roadway roof strata without presplitting blasting, which effectively improves the stress

distribution of the surrounding rock of the roadway, and the effect of pressure relief was good.

5. Engineering Application

To verify the pressure relief effect of presplitting blasting the roof strata of the roadway, a field test was carried out in the 3307 ventilation roadway. Before mining the working face, perform presplitting blasting on the roof strata of the 3307 ventilation roadway. The depth of the presplitting blasting hole is 17 m, the angle with the vertical direction is 15° , the distance is 500 mm, and the original support method remains unchanged. To further study the pressure relief effect of presplitting blasting the roof strata of the roadway, the ground pressure monitoring of the 3307 working face and the roadway was carried out.

5.1. Ground Pressure Monitoring of the 3307 Working Face.

The working resistance of hydraulic support in 3307 working face was monitored on site. A total of 128 hydraulic supports were installed in 3307 working face. To facilitate the analysis of the impact of presplitting blasting on the appearance of ground pressure, the hydraulic supports were divided into three areas, of which the #1–#30 hydraulic supports in the end of the working face are the upper area, the #31–#97 hydraulic supports in the middle of the working face are the middle area, and the #98–#128 hydraulic supports in the tail of the working face subjected to presplitting blasting are the lower area. The working resistance monitoring curves of the hydraulic support are shown in Figure 9.

The maximum pressure and average pressure of the hydraulic support in each area of the 3307 working face were, respectively, counted, as shown in Table 1.

FIGURE 8: Continued.

FIGURE 8: Lateral stress of working face of two working conditions. (a) #7 survey line with presplitting blasting. (b) #7 survey line without presplitting blasting. (c) #8 survey line with presplitting blasting. (d) #8 survey line without presplitting blasting. (e) #9 survey line with presplitting blasting. (f) #9 survey line without presplitting blasting. (g) #10 survey line with presplitting blasting. (h) #10 survey line without presplitting blasting. (i) #11 survey line with presplitting blasting. (j) #11 survey line without presplitting blasting.

The analysis shows that compared with the upper area and the middle area, the maximum pressure of the hydraulic support in the lower area affected by the presplitting blasting is reduced by 9.9 MPa and 7.7 MPa, respectively, by 26.5% and 21.9%, respectively; the average pressure was reduced by 14.9 MPa and 13.6 MPa, respectively, by 48.9% and 46.6%, respectively. The effect of pressure relief by presplitting blasting is good, which is consistent with the numerical simulation results.

5.2. Ground Pressure Monitoring of the Roadways. To understand the influence of presplitting blasting on the lead abutment pressure, the working resistance of single props in the 3307 ventilation roadway was monitored on site, and the 3307 haulage roadway which was not presplitting blasting was compared.

Install two single props in the 3307 ventilation roadway and haulage roadway at 50 m, 100 m, and 150 m positions in front of the working face, and install pressure monitors, of which the #1 and #2 props lead the working face by 50 m, the #3 and #4 props lead the working face by 100 m, and the #5 and #6 props lead the working face by 150 m. The

monitoring curves of the working resistance of the single props are shown in Figure 10.

As shown in Figure 10(a), the load of the single prop in 3307 haulage roadway increases significantly at 30 m ahead of the working face, and the load reached the maximum at 7 m ahead of the working face, and the maximum is 26.4 MPa. The load of the single prop in the 3307 ventilation roadway increases significantly at 20 m ahead of the working face, and the load reached the maximum at 5 m ahead of the working face, and the maximum is 22.7 MPa. Figures 10(b) and 10(c) show similar forces on the single props. The load of the single prop in the 3307 haulage roadway starts to increase at 80 m ahead of the working face, and the load increases significantly at 30 m ahead of the working face. The load reached the maximum at 7 m ahead of the working face, and the maximum is 27.2 MPa. The load of the single prop in the 3307 ventilation roadway starts to increase at 50 m ahead of the working face, and the load increases significantly at 20 m ahead of the working face. The load reached the maximum at 5 m ahead of working face, and the maximum is 22.8 MPa. After presplitting blasting the roof strata of the roadway, the influence range of the lead

FIGURE 9: Continued.

FIGURE 9: Working resistance monitoring curves of hydraulic support. (a) Working resistance monitoring curves of hydraulic support in the upper area. (b) Working resistance monitoring curves of hydraulic support in the middle area. (c) Working resistance monitoring curves of hydraulic support in the lower area.

TABLE 1: Working resistance of hydraulic support in the 3307 working face.

Partition	The maximum pressure (MPa)	The average pressure (MPa)
Upper area	37.4	30.5
Middle area	35.2	29.2
Lower area	27.5	15.6

- #1 single prop (3307 haulage roadway)
- #2 single prop (3307 haulage roadway)
- #1 single prop (3307 ventilation roadway)
- #2 single prop (3307 ventilation roadway)

- #1 single prop (3307 haulage roadway)
- #2 single prop (3307 haulage roadway)
- #1 single prop (3307 ventilation roadway)
- #2 single prop (3307 ventilation roadway)

FIGURE 10: Continued.

FIGURE 10: Working resistance of the single prop in front of the working face. (a) Monitoring curves of the single prop 50 m ahead of working face. (b) Monitoring curves of the single prop 100 m ahead of working face. (c) Monitoring curves of the single prop 150 m ahead of working face.

TABLE 2: The influence range and value of lead abutment pressure.

Position	Range		Peak stress		Average stress (MPa)
	Affected area (m)	Violent zone (m)	Ahead of the face (m)	Value (MPa)	
Haulage roadway	80	30	7	27.2	16.7
Ventilation roadway	50	20	5	22.7	15.3

FIGURE 11: Continued.

FIGURE 11: The on-site monitoring curves. (a) On-site monitoring curves of roof subsidence. (b) On-site monitoring curves of ribs displacement. (c) On-site monitoring curves of floor heave.

abutment pressure is reduced, the stress value is also reduced, and the effect of pressure relief is good. The results of monitoring data analysis are shown in Table 2.

In the 3307 ventilation roadway and haulage roadway, a monitoring point was arranged every 50 m to monitor the amount of roof subsidence, approaching of two ribs, and floor heave. For the convenience of analysis, this article only analyses the deformation of the roadway within 150 m from the open cut. The on-site monitoring curves are shown in Figure 11.

As shown in Figure 11, the deformation of the 3307 ventilation roadway is much smaller than that of the 3307 haulage roadway. Compared with the 3307 haulage roadway, the maximum value of the roof subsidence of the 3307 ventilation roadway is 219 mm, which is a reduction of 47.9%; the maximum value of the ribs displacement is 205 mm, which is a reduction of 45.7%; the maximum value of the floor heave is 312 mm, which is a reduction of 50.7%. It can be seen that after presplitting blasting of the roof strata of the roadway, the deformation of the roadway is significantly reduced, and the effect of controlling the roadway deformation is significant.

6. Conclusions

Based on the engineering background of the 3307 ventilation roadway of Xingcun Coal Mine, this paper studies the large deformation of the deep mine roadway through theoretical analysis, numerical simulation, and on-site monitoring. The main conclusions are as follows:

- (1) Using Flac3d software, the two working conditions of presplitting blasting and non-presplitting blasting of the roadway roof strata were numerically simulated. The results showed that

(a) After presplitting blasting the roadway roof strata, a pressure relief zone will be formed within 30 m of the blasting side of the working face and the surrounding rock stress reduced significantly.

(b) Because presplitting blasting cuts off the stress transmission path between the roof strata of the roadway and gob, it forces the stress concentration area to shift to the depth of the coal body. Without presplitting blasting, the stress concentration area of the surrounding rock of the roadway is about 8.2 m away from the roadside. After presplitting blasting, the stress concentration area of the surrounding rock of the roadway is about 12.8 m away from the roadside. The presplitting blasting the roof strata of the roadway has significantly improved the stress distribution of the surrounding rock.

- (2) The working face was divided into three areas for monitoring on site. The 30 hydraulic supports on the side without presplitting blasting are the upper area, the 30 hydraulic supports on the presplitting blasting side are the lower area, and the rest are the middle area. The results show that compared with the middle area, the maximum working resistance of the hydraulic support in the lower area is reduced by 21.9% and the average value is reduced by 46.6%; compared with the upper area, the maximum working resistance of the hydraulic support in the lower area is reduced by 26.5%; and the average value is reduced by 48.9%, and the pressure relief effect is significant.

- (3) On-site monitoring of the lead abutment pressure and the deformation of the 3307 ventilation roadway and haulage roadway. The results show that
 - (a) Compared with the 3307 haulage roadway, the 3307 ventilation roadway's lead abutment pressure influence zone is 50 m, a decrease of 37.5%, and the violent zone is 20 m, a reduction of 33.3%. The maximum value is 22.7 MPa, a decrease of 16.5%, and the average value is 15.3 MPa, reduced by 8.4%.
 - (b) Compared with the 3307 haulage roadway, the maximum value of roof subsidence of the 3307 ventilation roadway is 219 mm, which is reduced by 47.9%, the maximum value of the ribs displacement is 205 mm, which is reduced by 45.7%, and the maximum value of floor heave is 312 mm, which is reduced by 50.8%.
- (4) Through numerical simulation and field tests, it can be known that presplitting blasting the roof strata can effectively improve the stress distribution of the roadway and has a significant effect on controlling the large deformation of the roadway.

Data Availability

All the data used to support the findings of this study are available from Chaowen Hu upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Chaowen Hu and Xiaojie Yang were responsible for conceptualization of the study; Chaowen Hu was responsible for methodology; Chaowen Hu and Ruifeng Huang were responsible for software; Chaowen Hu and Xingen Ma were involved in data curation.

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