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Research Article

Stability Analysis and Reasonable Layout of Floor Drainage Roadway above Confined Water and under Mining Influence

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The surrounding rock failure range of floor drainage roadway under the mining influence and its effect on the aquiclude are the key to determine the aquiclude thickness of the floor. This paper studied the distribution characteristics of the surrounding rock plastic zone by the numerical simulation when the floor drainage roadway was located at different positions under the working face and determined the rational position. Results show that (1) when the floor drainage roadway is staggered inward, the floor surrounding rock is prone to appear the butterfly plastic zone under single work face mining. And the butterfly plastic zone increases sharply after being affected by secondary mining of adjacent working face. (2) When the floor drainage roadway is staggered outward, the floor surrounding rock plastic zone extends gently affected by a single working face. And the depth of the plastic zone has no obvious change after being affected by secondary mining of adjacent working face. (3) According to the risk of water inrush, the three layout schemes can be ranked as follows: stagger inward 25 m > stagger inward 80 m > stagger outward 15 m. (4) Considering the floor stress environment, gas extraction efficiency, and water prevention and control, the reasonable location of floor drainage roadway below the No. 11060 working face of Zhaogu No. 2 Coal Mine was finally determined. It was arranged in the sandy mudstone layer on the upper part of L9 limestone under the middle part of coal pillar and was drived along the seam floor.

1. Introduction

To prevent the occurrence of coal and gas accidents, floor rock roadway is sometimes designed to extract gas from upper coal through layers [1–4]. If the coal seam floor is adjacent to the aquifer, digging the roadway under the coal seam floor will damage the floor and it is prone to water inflow accidents [5, 6]. Therefore, when it is necessary to excavate the floor drainage roadway for regional gas control, the key point of the research is to select the reasonable position so as to reduce the risk of water inrush from the floor.

Currently, the main floor water inrush theory is divided into a complete floor and a structurally defective floor water inrush mechanism. The complete floor water inrush mechanism mainly includes the "down three zones" theory [7], the "down four zones" theory [8], the "site crack and no-destruction" theory [9], the "thin plate theory" [10], the "key strata theory" [11, 12], the "progressive derivation" theory [13], and the "water inrush preferred plane" theory [14]. In addition, based on the semi-infinite theory, limit equilibrium theory, and thin plate theory, combined with numerical simulation and similar simulation, the water inrush caused by fault and collapse column is studied in detail [15–21]. Since floor drainage roadways are excavated under coal seam, the rocks around the roadways are damaged under the influence of the mine stress field. The damage extent of the rocks around the drainage roadway directly determines the risk of floor water inrush.

The research on stress environment and failure characteristics of surrounding rock in floor roadway mainly focuses on obtaining the stress distribution in floor rock mass by using elastic mechanics theory and calculating the maximum failure depth of floor combining with relevant failure criteria [22–25]. According to the statistics of field data, many scholars studied the relationship between floor roadway, coal pillar, and stope [26–28]. At the same time, many scholars have studied the failure mechanisms and the deformation characteristics of the floor roadways affected by mines [29–31]. The stress environment of the rocks around the floor roadways is not uniform [32–34]. However, most previous studies focused on the changes of abutment pressure and ignored the influence of stress in different directions on the failure of surrounding rock.

In this study, based on the contradiction between gas drainage demand and floor water inrush risk in Zhaogu No. 2 Coal Mine, the plastic zone distribution characteristics of surrounding rock in different positions under the working face were studied by numerical simulation, and the reasonable position of floor drainage roadway was determined.

2. Case Engineering Background

2.1. Project Overview. Zhaogu No. 2 Coal Mine is a new mine of Jiaozuo Coal Industry Group. At present, the main mineable coal seam is 2-1 coal seam, which is a coal seam with a thickness of 6.0 m~6.59 m and an average of 6.32 m. To succeed in production, exploration depth is increasing. When the mining is gradually moving towards deep, the gas content in the coal seam is also gradually increasing, leading to the transformation of the mine from a low gas mine to a high gas mine. Now, the mine is taking preventive and control measures to extract gas from the upper coal seam by digging the floor drainage roadway.

Due to the difficulty in drilling and low efficiency of roof drainage roadway, the coal mine decided to adopt the floor drainage roadway to conduct gas preextraction on 11060 working face. Therefore, the development roadway of No. 1 panel had to be changed from coal seam roadway to floor rock roadway. Two parallel permanent roadways were developed under the coal seam of No. 1 panel: one was the West belt transportation roadway and the other was the floor gas measure roadway. At the same time, in order to effectively eliminate the gas outburst risk in the working face coal seam, the floor drainage roadway of working face was opened under 11060 working face. The floor drainage roadway studied in this paper is the floor drainage roadway of 11060 working face which is excavated to relieve gas outburst in dangerous working face.

2.2. The Geological Conditions. According to the field geological exploration results, multilayer aquifers were commonly found under the 2-1 coal seam in Zhaogu No. 2 Coal Mine [35], as shown in Figure 1. L9 limestone and L8 limestone are the closest floor aquifer to coal seam. Due to the thin rock layer and small water storage capacity of L9 limestone, the water inrush risk has been eliminated by means of drainage, while L8 limestone layer is thick with strong water bearing capacity, and the water pressure reaches 3.24-6.84 MPa, which is the main aquifer threatening floor roadway seriously. There are mudstone and sandy mudstone between 2-1 coal seam and L8 limestone with good water resistance, which is a natural aquiclude. Due to the existence of L8 limestone, there is a serious water inrush risk in the driving and the whole service cycle of the floor drainage roadway. In Zhaogu No. 2 Coal Mine, due to the large buried depth, the underlying confined aquifer, and the mining influence, it is necessary to study the failure law and reasonable location of floor drainage roadway.

3. Numerical Simulation Method

3.1. Layout Scheme of Floor Drainage Roadway

3.1.1. Vertical Position of Floor Drainage Roadway. According to the histogram of floor rock stratum, the distance between coal seam floor and L8 limestone is 26 m~28.67 m, and the optional layout range of floor drainage roadway in longitudinal direction is very small. The lithology of L9 limestone is hard and stable. If the roadway is excavated in L9 limestone, the roadheader will cut the hard rock, and the excavation amount will undoubtedly increase. If the floor drainage roadway is excavated under the L9 limestone, it will be too close to the aquifer, and the gas drainage borehole in the later stage needs to cross the L9 limestone, increasing the drilling work quantity. Therefore, the floor drainage roadway should be arranged above the L9 limestone. If L9 limestone is used as the floor of the floor drainage roadway, its strong lithology will increase the floor stability of the floor drainage roadway and reduce the maintenance work quantity of the floor. Its stable occurrence can be used as a marker layer for the excavation of floor drainage roadway to ensure the vertical distance between roadway and coal seam. Therefore, the longitudinal layer layout of the floor drainage roadway is selected to drive along the bottom in the sandy mudstone above the L9 limestone. According to the comprehensive histogram of rock strata, the center of the roadway of floor drainage roadway is about 13 m away from the coal seam floor in the longitudinal horizon direction.

3.1.2. Layout Scheme of Horizontal Position of Floor Drainage Roadway. The floor drainage roadway serves for the upper working face of regional danger relief. The floor drainage roadway is arranged before the working face, and the floor drainage roadway is bound to be affected by the mining-induced stress of the upper working face when mining in the later stage. According to the field investigation, the length of the working face of Zhaogu No. 2 Coal Mine is 160 m generally, and the coal pillar size of adjacent working face is 30 m. In order to study the failure characteristics of roadway surrounding rock under the influence of mining above and to select a reasonable layout location, the following three schemes are designed to simulate the failure characteristics of roadway surrounding rock when the floor drainage roadway is arranged in different positions (as shown in Figure 2) (scheme I: the floor drainage roadway is arranged in the middle of the 1# working face, i.e., stagger inward 80 m; scheme II: the floor drainage roadway is arranged at 25 m away from the coal wall, i.e., stagger inward 25 m; and scheme III: the floor drainage roadway is arranged in the middle of the coal pillars of two working faces, i.e., stagger outward 15 m). Considering the influence of adjacent working face mining, combined with the actual situation of the

Lithology	Bore histogram	Thickness (m)	Remarks
2-1 Coal Seam		6.12	Black, with submetallic luster, massive, containing a small amount of powder, coal seam structure is simple, some contain a layer of gangue.
Mudstone	Aquiclude	7.54	Dark gray, with horizontal bedding, with siderite mudstone, fracture development and calcite filling.
Sandy mudstone	Aquiclude	7.46~9.73	Argillaceous cementation, the occurrence of rock strata is stable, and there are small changes in some parts.
L9 limestone	Permeable layer	1.5~1.9	Dark gray, with some fusulinidae fossils and developed fissures filled with calcite veins.
Mudstone	Aquiclude	4.7	Dark gray, with thin siderite mudstone in the upper part, brittle and hard.
Sandy mudstone	Aquiclude	4.8	Gray black and contains a small amount of muscovite. There is a layer of siderite mudstone in the middle and lower part, and the fractures are filled with calcite.
L8 limestone	Aquifer	6.8~10.11	Dark gray, aphanitic texture, local fissures and calcite veins, with star like pyrite.

Figure 1: The comprehensive histogram of rock strata in coal seam.

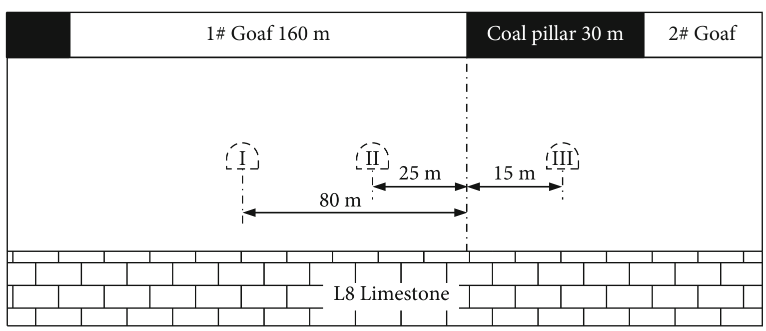


Figure 2: Simulation layout scheme of floor drainage.

site, 30 m coal pillar will be reserved after mining in 1# working face, and then 2# working face will be mined.

3.2. Numerical Simulation Model. According to the simulation scheme, and based on the actual occurrence of surrounding rock, FLAC3D numerical simulation software is used to establish the model as shown in Figure 3. The size of the model is length × width × height = 560 × 520 × 200 m, and the excavation size of the middle floor drainage roadway is 5 × 520 × 4 m, which is fixed in the middle of the model. By changing the coordinates of different working faces in the upper coal seam, the position between the floor drainage roadway and the two working faces is changed, so as to simulate the surrounding rock failure law of the floor drainage roadway under the conditions of 80 m internal dislocation, 25 m internal dislocation, and 15 m external displacement between the floor drainage roadway and No. 1 working face. Based on the site engineering conditions, the length of working face in the model is 160 m, and a 30 m coal pillar is set between the two working faces. After the stress of primary rock is calculated and balanced, the floor drainage roadway is excavated first, then the 1# working face with corresponding coordinates is excavated, and finally the 2# working face with corresponding coordinates is excavated.

3.3. Materials and Boundary Conditions. The Mohr Coulomb constitutive model is adopted in the model, and the rock mechanical parameters of each rock stratum in the model refer to the existing test results of the mine [35]. Detailed mechanical parameters of surrounding rock are shown in Table 1.

Combined with the actual geological structure of Zhaogu mining area, some scholars have used the hollow inclusion strain relief method to carry out crustal stress measurement in Zhaogu No. 1 mine shaft bottom and heading of West return air roadway. The measurement results are shown in Table 2 [35]. Because Zhaogu No. 2 Coal Mine is adjacent to Zhaogu No. 1 Coal Mine and belongs to the same coalfield, the distribution of strata and geological structure in the area are basically the same. The boundary conditions of numerical simulation are determined as follows: the horizontal displacement of x-axis and y-axis boundary and the vertical displacement of z-axis boundary were fixed. The compensation

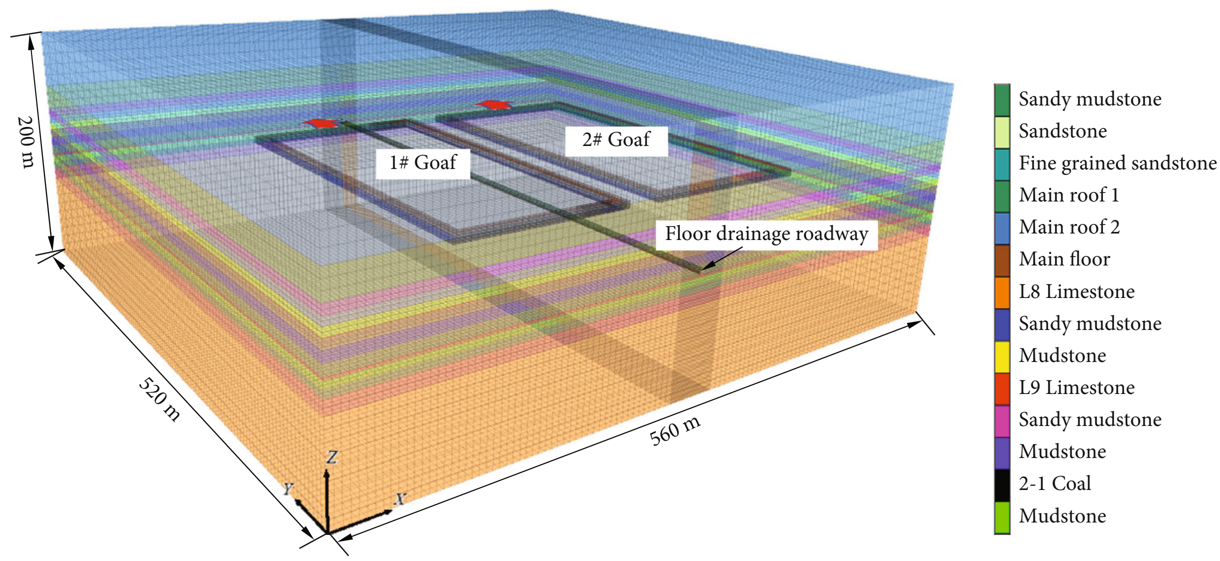


Figure 3: The simulation model of the floor extraction roadway at different locations.

Table 1: Rock mechanic parameters used in the model.

Rock stratum	Thickness (m)	Density ($kg{\cdot}m^{-3}$)	Elastic modulus (GPa)	Bulk modulus (GPa)	Internal friction angle (°)	Cohesion (MPa)	Tensile strength (MPa)
Main roof	20	2500	7.60	6.50	35	13	4.5
Fine-grained sandstone	7	2500	7.60	6.50	35	13	4.5
Sandstone	5.8	2700	10.20	9.00	38	16	7.5
Sandy mudstone	6	2500	10.44	4.54	28	5.36	2.60
Mudstone	0.8	2200	8.82	5.04	30	5.24	1.48
2-1 coal	6.2	1500	5.4	4.8	25	2.8	1.5
Mudstone	7.5	2200	8.82	5.04	30	3.24	1.48
Sandy mudstone	7.5	2500	10.44	4.54	28	5.36	2.60
L_9 limestone	2	2700	12.6	8.3	40	10	8.71
Mudstone	5.2	2200	8.82	5.04	30	3.24	1.48
Sandy mudstone	5.3	2500	10.44	4.54	28	5.36	2.60
L_8 limestone	10	2700	12.6	8.3	40	10	8.71
Main floor	70	2700	12.6	8.3	40	10	8.71

Table 2: Analysis of ground stress component results.

Measure point	σ_y (MPa)	σ_x (MPa)	σ_z (MPa)	τ_{yz} (MPa)	τ_{xy} (MPa)	τ_{zx} (MPa)	σ_y/σ_z	$(\sigma_x+\sigma_y)/\sigma_z$
1	29.42	16.70	15.37	-0.11	-1.99	0.41	1.91	1.50
2	26.26	16.90	15.34	-6.09	-3.29	0.81	1.71	1.41

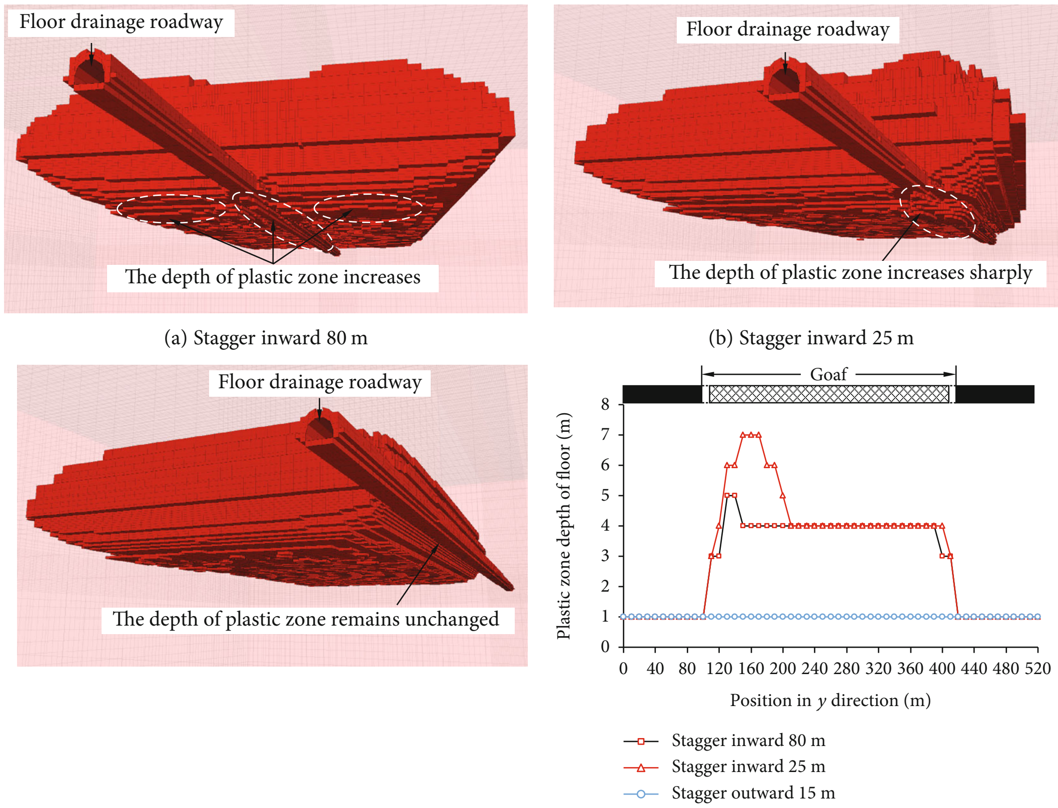
load was 17.5 MPa on the upper boundary, and the initial stress was $szz = 17.75$ MPa and $sxx = syy = 23.075$ MPa.

4. Results and Discussions

4.1. Surrounding Rock Failure Law of Floor Drainage Roadway under Mining Influence

4.1.1. Surrounding Rock Failure Law of Floor Drainage Roadway Affected by Single Working Face Mining. Figure 4 shows the distribution of the plastic zone after the influence of single working face mining. From the figure, we can see the floor failure situation of floor drainage roadway in different schemes and obtain the maximum failure depth in each scheme.

As shown in Figure 4(a), after the excavation of 1# working face, the floor failure depth of floor drainage roadway remains 1 m within the projection range of coal wall, while it increases from 1 m to 5 m at the distance of 0~30 m away from the open-off cut within the projection range of goaf



(a) Stagger inward 80 m

(b) Stagger inward 25 m

(c) Stagger outward 15 m

(d) Plastic zone depth of floor

FIGURE 4: The plastic zone depth in floor extraction roadway affected by single working face.

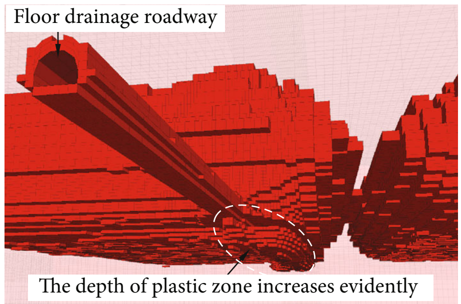
and keeps 5 m within the range of 30~40 m. With the increase of the distance from the open-off cut position, the floor maximum failure depth of the floor drainage roadway is basically kept at 4 m, and it is reduced to 3 m at 340 m; then, it is gradually decreased to 1 m within the range of 0~30 m from the working face.

As shown in Figure 4(b), after the excavation of 1# working face, the floor failure depth of floor drainage roadway remains 1 m within the projection range of coal wall, while it increases from 1 m to 7 m at the distance of 0~50 m away from the open-off cut within the projection range of goaf and keeps 7 m within the range of 50-70 m. Finally, with the increase of the distance from the open-off cut, the maximum floor failure depth of the floor drainage roadway is maintained at 4 m, and it is gradually reduced to 1 m within the range of 0~20 m from the working face.

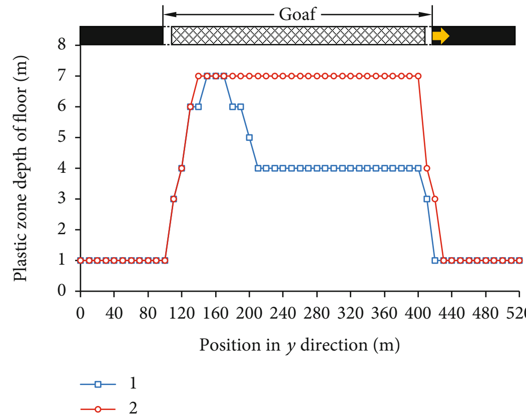
As shown in Figure 4(c), it can be seen that the floor failure depth of the floor drainage roadway is always kept at 1 m when the floor drainage roadway is arranged at an outer stagger of 15 m. According to the floor failure under the influence of a single working face, it can be concluded that the maximum floor failure depth of floor drainage roadway is 1 m in the projection range of the coal wall.

4.1.2. The Expansion Law of Plastic Zone under Disturbance of Adjacent Working Face Again. Because in the actual mining process, the working faces are sequential adjacent mining, if the floor drainage roadway is arranged closer to the next working face, it is bound to be affected by the mining stress of the adjacent working face. Therefore, this section analyzes the surrounding rock failure and the maximum floor failure depth of the floor drainage roadway when it is staggered inward 25 m and staggered outward 15 m.

Figure 5 shows the plastic zone distribution of the surrounding rock of the floor drainage roadway under the disturbance of the adjacent working face again when the floor drainage roadway is arranged with an internal stagger of 25 m. It can be concluded that when affected by the mining of the second adjacent working face, the surrounding rock failure scope of the floor drainage roadway increases significantly under the goaf. In the projection range of coal wall, the failure range of surrounding rock of floor drainage roadway is basically the same as that after one mining, and the maximum failure depth is 1 m. However, in the projection range of goaf, the maximum failure depth of floor is 7 m, which is distributed in the distance of 50~70 from the open-off cut. When the mining of 2# working face is finished, the maximum failure depth of the floor is still 7 m, but its distribution range has changed greatly, which is widely distributed in the range of 30 m behind the open-off cut projection and 20 m behind the working face projection. When the floor drainage roadway is arranged with an internal stagger of 25 m, although there is a distance of up to 55 m from the coal wall of 2# working face on the transverse horizon, the influence range of single working face on the stress in the coal pillar is 50~60 m. Therefore, the influence of 2# working face



(a) The plastic zone distribution



(b) The plastic zone depth

FIGURE 5: The plastic zone depth under the influence of two working faces arranged at an internal stagger of 25 m.

mining on the surrounding rock of the floor drainage roadway is very weak at this time. Since the plastic zone of the floor drainage roadway has been in a very dangerous malignant expansion state after the completion of mining in 1# working face, even if the influence of mining stress on the stress field is extremely small, the plastic zone of the floor drainage roadway will appear larger extension. Therefore, when the floor drainage roadway is arranged at an internal stagger of 25 m, the surrounding rock within the projection range of the goaf is highly sensitive, even if the small change of stress will lead to large-scale failure of the plastic zone.

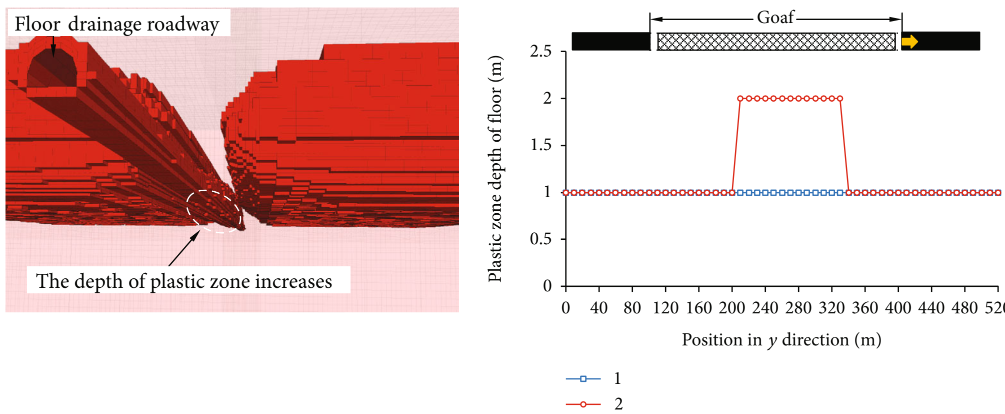
Figure 6 shows the plastic zone distribution of the floor drainage roadway under the disturbance of the adjacent working face again when the floor drainage roadway is arranged at an external stagger of 15 m. It can be concluded that after the mining influence of the second adjacent working face, the surrounding rock failure range of floor drainage roadway has increased to a certain extent in the middle of the goaf projection, and that the maximum failure depth increases to 2 m in the range of 110~220 m from the coal wall projection. The plastic zone of floor drainage roadway is only in the state of "linear slow growth" with gentle expansion after the completion of mining in 1# working face, so even when the mining stress of 2# working face has a great influence on the surrounding rock of the floor drainage roadway, the plastic zone depth of floor rock does not appear a huge increase. Therefore, when the floor drainage roadway is arranged at an external stagger of 15 m, the plastic zone of the surrounding rock is relatively safe. Even if the mining stress of the adjacent working face is relatively large, it is difficult to cause the large-scale malignant rapid expansion of the plastic zone of the floor drainage roadway.

4.2. Risk Analysis of Water Inrush from Floor under the Influence of Mining. Through the previous analysis, it can be seen that the water inrush risk of the coal seam floor is closely related to the safe aquiclude thickness of the floor. Except for the L9 limestone which is a permeable layer in the floor rock of Zhaogu No. 2 Coal Mine, the rest are all aquicludes with good water resistance. Therefore, the disturbance and failure of the aquiclude under the influence of mining directly determines the safe aquiclude thickness of the Zhaogu No. 2 Coal Mine and thus affects the risk of water inrush from the working face and the floor of the floor drainage roadway.

Figure 7 shows the failure of the rock when the coal seam floor is without the floor drainage roadway. It can be seen that since the floor rock is mainly mudstone and sandy mudstone, although its water resistance property is good, due to its poor lithology, the rock layer below the coal seam is directly destroyed to the upper boundary of the L_9 limestone layer under the influence of the stress field. Therefore, when there is no floor drainage roadway in the floor rock, the original failure depth of the coal floor is 15 m. Since the L_9 limestone is a permeable layer, the safe aquiclude thickness of the coal floor is 10.5 m.

According to the previous text, it can be seen that when the floor drainage roadway is internally staggered by 80 m, the maximum failure of the floor is within 30~40 m from the opening cut. Therefore, cutting the plane of $y = 130$ m in the model can get the failure of the floor rock at this time, the situation is shown in Figure 8. At this time, the floor drainage roadway as a whole is within the mining-induced influence damage range of the working face, the floor damage depth of the floor drainage roadway is 5 m. It can be seen that the existence of the floor drainage roadway does not significantly change the original floor damage of the working face. With the existence of the floor drainage roadway, a wide range of elongated and narrow damage occurred in the mudstone layer below its floor. Since the L_9 limestone is a permeable layer, the safe aquiclude thickness of the working face and the floor of the floor drainage roadway is only 7.3 m.

When the floor drainage roadway is internally staggered by 80 m, the maximum damage depth of the floor of the floor drainage roadway is distributed in the middle of the goaf after both the upper two working faces are mined. Therefore, cutting the plane of $y = 260$ m after both working faces are mined can get the failure of the floor rock at this time, as shown in Figure 9. It can be seen that the floor drainage roadway as a whole is within the mining-induced influence damage range of the working face, the damage depth of the floor of the floor drainage roadway has reached 7 m; due to the



(a) The plastic zone distribution

(b) The plastic zone depth

FIGURE 6: The plastic zone depth under the influence of two working faces arranged at an outer stagger of 15 m.

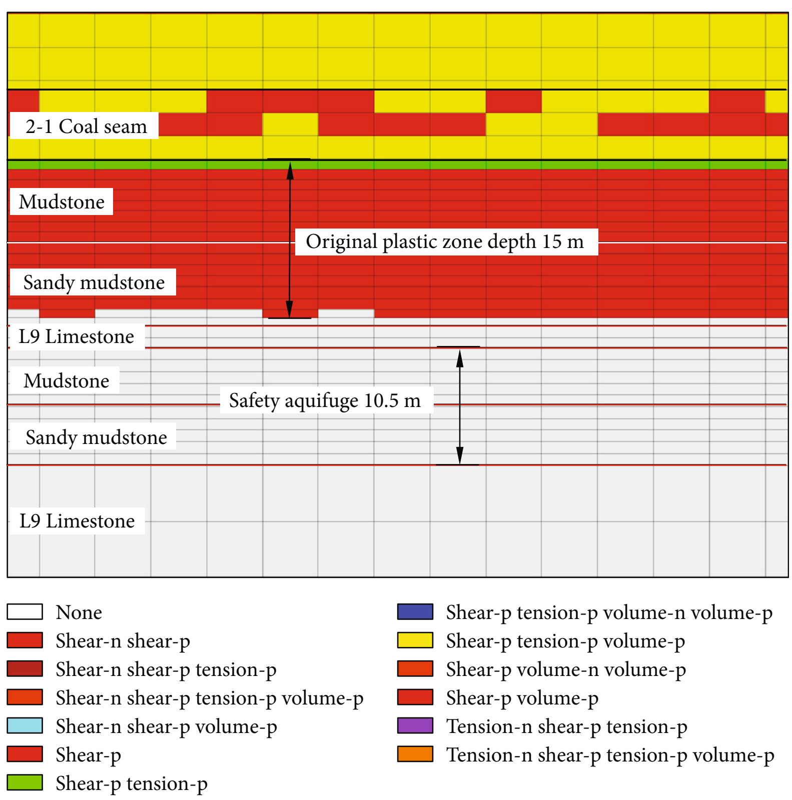


FIGURE 7: Failure of bottom floor rock stratum without floor drainage roadway.

existence of the floor drainage roadway, large-scale damage occurred in the mudstone 7 m below the floor. At this time, the safe aquiclude thickness of the working face and the floor of the floor drainage roadway is only 5.3 m.

When the floor drainage roadway is externally staggered by 15 m, the maximum damage depth of the floor of the floor drainage roadway is distributed in the middle of the goaf after both the upper two working faces are mined. Therefore, cutting the plane of $y = 260$ m after the two working faces are mined can get the failure of the floor rock at this time, as shown in Figure 10. It can be seen that the surrounding rock stress environment of the floor drainage roadway makes the plastic failure of the roadway roof and the two sides of surrounding rock appear obvious nonuniform distribution characteristics. Because the lithology of the floor is stronger than that of the roof and two sides, the plastic failure in the floor presents a small range of nonuniform distribution characteristics, but the damage range of the roof is not connected to the damage range of the coal seam floor on both sides. The maximum damage depth of the floor is only 2 m, and the damage mainly occurs in the limestone permeable layer of the floor L_9. Thus, the failure of the surrounding rock of the

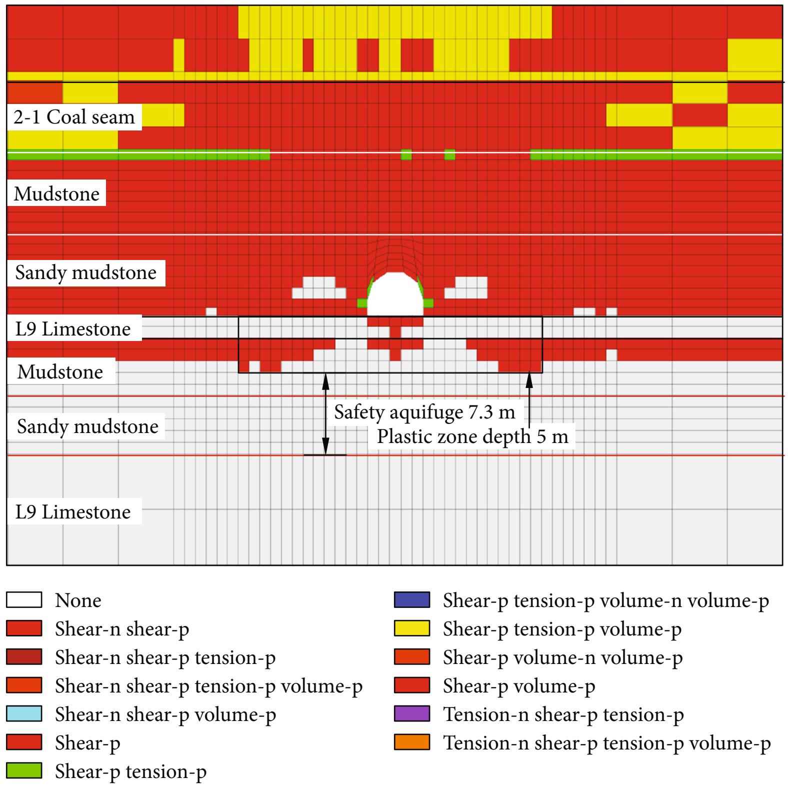


Figure 8: Failure of bottom rock stratum at $y = 130$ m in the floor drainage roadway when roadway internal is 80 m.

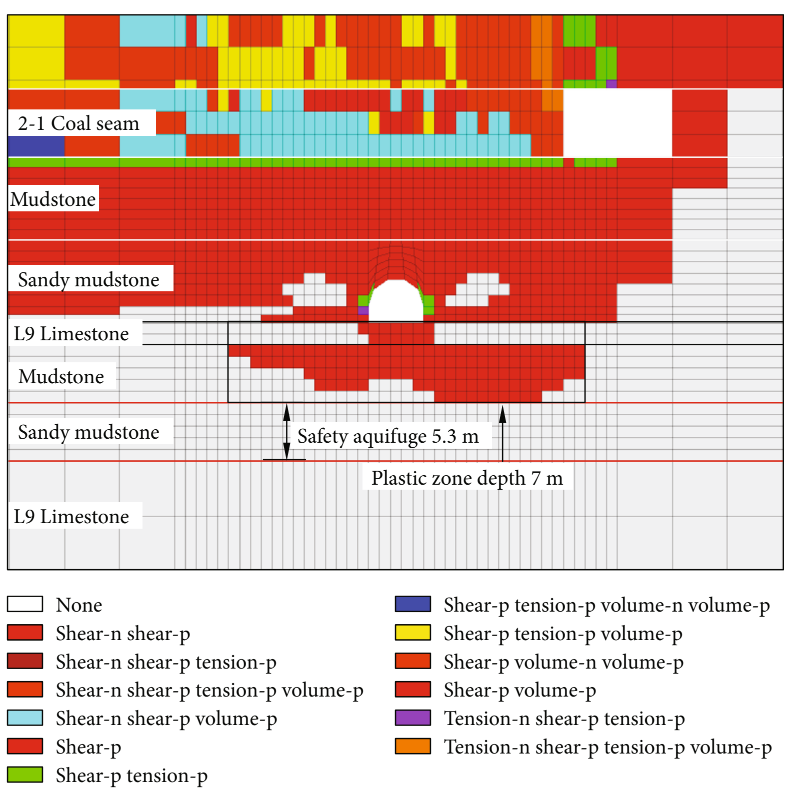


Figure 9: Failure of bottom rock stratum at $y = 260$ m in the floor drainage roadway at an internal stagger of 25 m.

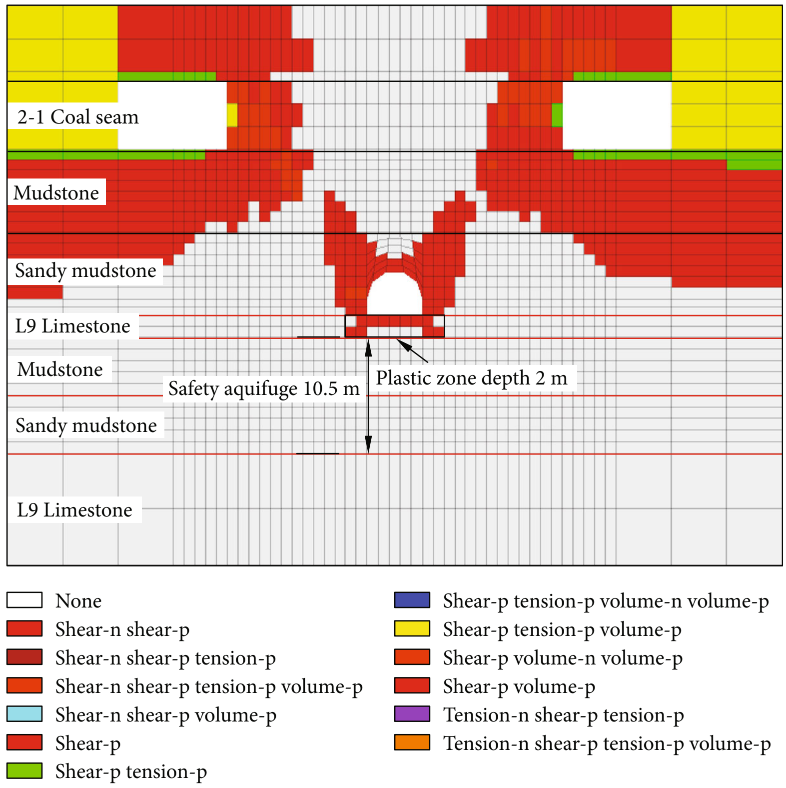


FIGURE 10: Failure of bottom rock stratum at $y = 260$ m in the floor drainage roadway at an external of 15 m.

floor drainage roadway does not affect the safe aquiclude thickness of the working face and the floor, and its thickness is maintained at the best state of 10.5 m.

In conclusion, under the mining-induced influence of the upper working face, when the floor drainage roadway is internally staggered, the three layout schemes can be sorted according to the risk of water inrush and can be sorted as follows: internally staggered by 25 m > internally staggered by 80 m > externally staggered by 15 m.

4.3. Reasonable Location Selection of the Floor Drainage Roadway

(1) Since the main task of the floor drainage roadway is to relieve the methane in the upper coal seam, there are different methods of methane drainage and relief when the floor drainage roadway of Zhaogu No. 2 Coal Mine is arranged in different positions. Because the length of the drainage borehole and the density of the drainage borehole in the floor drainage roadway can be increased to achieve a larger range of drainage, it is restricted by the efficiency of the drainage borehole construction, the density of the borehole, and the requirements of the drainage equipment. And the best relief range of the floor drainage roadway in Zhaogu No. 2 Coal Mine is not more than 80 m. If the floor drainage roadway is arranged below the working face to be mined, although the risk of gas outburst in the working face area can be eliminated, the methane drainage efficiency in the gateway area will be reduced, and the gateway is mined before the working face. If the floor drainage roadway is arranged under the coal pillar of the working face to be mined, the methane in the gateway can be relieved in advance, and then the gas is drained out from the working face by excavating the upper gateway and drilling along the layer. Therefore, from the perspective of methane drainage and regional risk relief, the floor drainage roadway should give priority to the relief of the danger of gas outburst in the gateway area, and the horizontal position should not be far away from the roadway to be excavated. If the floor drainage roadway is arranged directly under the coal pillar, it can be as close as possible to the roadway to be excavated above. At this time, the gas drainage distance is relatively small, the predrainage effect is better, and the gas outburst danger in the gateway area of the two working faces can be solved, and the efficiency is high

(2) As Zhaogu No. 2 Coal Mine is faced with the severe danger of water inrush from the floor, the floor drainage roadway can also provide a place for floor grouting transformation. Therefore, it is necessary to maintain good surrounding rock stability and ensure that there is no water inrush accident under the influence of mining stress. So, it is necessary to minimize the plastic failure range of the surrounding rock of the floor drainage roadway under the

influence of mining stress on the upper working face, considering comprehensively the condition can only be met if it is arranged in the middle of the large coal pillar above

Considering the choice of floor stress environment to reduce the damage of the surrounding rock of the floor drainage roadway and increase the safe aquiclude thickness of the floor, the layout of the floor drainage roadway under the middle of the coal pillar is the best. In consideration of the priority relief of the gateway area, increasing the drainage effect and improving the drainage efficiency, the floor drainage roadway should also be arranged under the coal pillars between the two working face gateways. From the perspective of preventing water inrush from the working face floor, it is considered to provide a place for floor grouting transformation in the early stage of the working face and treatment of water inrush grouting from the working face floor in the late stage. Only when it is arranged under the coal pillars can maintain the maximum stability of the floor drainage roadway and reduce its own water inrush risk. Therefore, the optimal location of the floor drainage roadway on the 11060 working face of Zhaogu No. 2 Coal Mine is to be arranged along the normal direction of the working face to be mined, and to drive along the floor in the sandy mudstone layer above the L_9 limestone below the central part of the planned coal pillar.

5. Conclusions

The surrounding rock failure depth of floor drainage roadway under the mining influence and its effect on the aquiclude are the key to determine the aquiclude thickness of the floor. This study studied the distribution law of plastic zone in surrounding rock of floor drainage roadway in three typical positions affected by mining, compared the water inrush risk of three schemes, and then determined the reasonable position of floor drainage roadway. Based on the work presented in this paper, the following conclusions are made:

(1) When the floor drainage roadway is staggered inward, the floor surrounding rock is prone to appear the butterfly plastic zone under single work face mining. Then, the butterfly plastic zone increases sharply after being affected by secondary mining of adjacent working face

(2) When the floor drainage roadway is staggered outward, the floor surrounding rock plastic zone extends gently affected by a single working face. And the depth of the plastic zone has no obvious change after being affected by secondary mining of adjacent working face

(3) According to the risk of water inrush, the three layout schemes can be ranked as follows: stagger inward 25 m > stagger inward 80 m > stagger outward 15 m

(4) Considering the floor stress environment, gas extraction efficiency, and water prevention and control, the reasonable location of floor drainage roadway below the No. 11060 working face of Zhaogu No. 2 Coal Mine was finally determined. It was arranged in the sandy mudstone layer on the upper part of L9 limestone under the middle part of coal pillar and was drived along the seam floor

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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