Location Selection and Control Technology of New Driving Roadway in Upward Mining Roof

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Abstract. Based on the engineering background of the belt conveyance roadway in the north wing of Zhuxianzhuang Coal Mine, this paper puts forward and analyses the existing problems in the optimization of the roof roadway location in upstream mining, and studies the movement law of overlying strata under different mining heights by FLAC3D numerical analysis software. On this basis, the orthogonal test is used to analyze the optimization of different location of roadway in overlying strata, determine the weights of three factors affecting the selection of roadway location, and put forward a reasonable roadway location for belt conveyance roadway in the north wing of Zhuxianzhuang Mine. According to the occurrence and use of surrounding rock of belt conveyance roadway in North Wing of Zhuxianzhuang Mine, two schemes of zonal support are put forward. Industrial test shows that the support effect is greatly strengthened and the support condition is improved, which can be used as a reference for the location selection of coal mine roadway and surrounding rock control under similar geological conditions.

1. Introduction
The roadway in Zhuxianzhuang Mine is seriously damaged due to the combined action of ground pressure, tectonic stress and mining stress, which directly threatens the safety of mine production. 7 coal seam is 1-2.5 m thick, while 8 coal seam is 6-8 m thick. With the increase of mining depth, the mining stress concentration is higher, the mining influence scope is larger, the mining influence time is longer, the space stability of mine roadway engineering is worse, and the difficulty of roadway maintenance is aggravated. The difficulty of roadway maintenance has become the "bottleneck" restricting upward mining, and the restrictive role is increasingly prominent. To maintain the safety, high production and efficiency and sustainable development of the mine, it is necessary to solve the problem of location selection and stability control of roof roadway in upward mining of coal seam group.

Aiming at the location selection of roadway in overlying strata, scholars at home and abroad mainly focus on the location of high extraction roadway [1-4]. However, due to the differences of using function, mining conditions and geological conditions, the location selection of upward mining roadway under
high mining height is seldom involved. Therefore, this paper takes the belt conveyance roadway in the north wing of Zhuxianzhuang Coal Mine as the research background, uses FLAC3D numerical simulation analysis to study the movement law of overlying strata under different mining height conditions, combines orthogonal test to select the location of roadway, determines the weight of factors affecting the location of roadway, and puts forward zonal support scheme. The research on soft rock roadway treatment technology under such conditions will help enrich the technical route and theoretical system of roadway surrounding rock control in mining area. Hence it can further guide the engineering practice of surrounding rock treatment in mining area.

2. Migration law of overlying strata under different mining heights

2.1. Establishment of Numerical Model and Simulation Scheme

Taking the belt conveyance roadway on the north wing of Zhuxianzhuang Coal Mine as the simulation model, this paper selects 1/4 model for calculation and analysis. The shape size of the model is 200 m × 200 m × 200 m, 208 000 units. The upper boundary of the model is loaded uniformly according to the thickness of the overlying strata, the vertical displacement of the lower boundary is fixed, and the horizontal displacement of the left and right sides is fixed. The constitutive relation of the surrounding rock used in the model is the Mohr-Coulomb model. The mechanical parameters of rock are selected according to Table 1. From the upper boundary to the surface of the model, the surrounding rock is added to the upper boundary in the form of uniform load, the load size is $P=2500\text{kg} \cdot \text{m}^{-3} \times 10\text{m} \cdot \text{s}^{-2} \times 500\text{m}=12.5\text{MPa}$. Through comprehensive analysis and simplified calculation model, the failure law and stress distribution law of overlying strata under mining height of 2 m, 3 m, 4 m, 5 m, 6 m and 7 m are simulated. Layout of monitoring lines as shown in Figure 1[5].

![Figure 1. Simulation Model and Roof Monitor Lines Layout (unit: m)](image)

| Lithology            | Bulk modulus (GPa) | Shear modulus (GPa) | density (kg/m³) | Cohesion (MPa) | Internal friction angle (°) | tensile strength (MPa) |
|----------------------|--------------------|---------------------|-----------------|----------------|-----------------------------|------------------------|
| Fine sandstone       | 2.56               | 2.17                | 2600            | 2.4            | 42                          | 2.5                    |
| Medium sandstone     | 2.73               | 1.38                | 2500            | 2.3            | 40                          | 2.3                    |
| Siltstone            | 2.68               | 1.84                | 2700            | 2.0            | 32                          | 2.0                    |
| Mudstone             | 3.03               | 1.56                | 2200            | 1.2            | 27                          | 1.0                    |
| Oblique porphyry coal| 2.42               | 1.32                | 2700            | 1.6            | 35                          | 2.3                    |
| Coal                 | 1.19               | 1.17                | 1400            | 0.8            | 23                          | 0.7                    |
2.2. Analysis of Failure Law of Overburden Strata

(1) The plastic zone of the working face is a saddle-shaped distribution with high end and low middle. The working face is symmetrical along the direction of strike and inclination. The plastic zone in the middle of the goaf is smaller than that in the upper part of the working face, which is caused by the tension stress above the mining boundary because of the subsidence of overlying strata on the side of the goaf due to the support of coal pillars, which makes the damage scope larger than that in the middle part of the goaf.

Figure 2. Plastic Zone Distribution along Strike Direction and Dip Direction while Advance is 100 m with Various Mining Heights

(2) With the increase of mining height, the difference between the plastic area above the mining boundary and the plastic area in the middle decreases. From the bottom to the top of the roof, the order is tensile failure area, shear failure area, shear failure area and undamaged area. The tension failure zone is mainly distributed in the strata of the tension stress zone above the goaf, and is divided into caving zone; There are tension fissure zones on the upper part, which produce unidirectional or bi-directional fissures and divide them into fissure zones; The elastic and plastic deformation zones of the model can be divided into bending subsidence zones because of the overall movement, small subsidence, plastic deformation caused by certain cracks and local shear failure of the rock strata in the bending subsidence zone.

| Mining height | 2m  | 3m  | 4m  | 5m  | 6m  | 7m  |
|---------------|-----|-----|-----|-----|-----|-----|
| Caving zone height | 10m | 10m | 33.7m | 34.6m | 38.7m | 40.4m |
| Fissure zone height | 36m | 36.8m | 54.9m | 62.7m | 84.8m | 90m |

2.3. Analysis of Distribution Law of Mining Stress

Through the analysis of monitoring line 1 and monitoring line 2 diagrams under different mining heights, it can be seen that:

(1) There is no obvious rule of the vertical stress of the leading support stress and the lateral support stress on the side of the goaf, which indicates that the rock mass after roof collapse loses continuity and falls irregularly over the floor of the goaf, and the subsidence of the overlying strata does not compact the rock mass falling in the goaf.

(2) Along the advancing direction of the working face, the roof overburden of the goaf undergoes the state of high stress compression, pressure relief expansion and re-compression, and this process appears periodically with the continuous advance of the work. Therefore, in the roof strata of goaf, roadways are arranged parallel to the working face. In the normal mining stage, roadways are firstly subjected to advance supporting stress. Surrounding rocks produce fissures and enter the goaf. The stress level of surrounding rocks decreases sharply, the mining fissures are released and expanded, and the surrounding rocks are fragmented and deformed seriously, resulting in the instability of roadways.
3. Selection of Roadway Location

3.1. Selection Scheme of Roadway Location

After studying the movement law of overlying strata and the division of "three zones" under different mining heights, this paper is aimed at mining heights of 2m, 4m, 5m, 6m and 7m; Normal distance is 40m, 60m, 80m, 100m, 120m; the numerical models of horizontal stopping line - 40m, - 20m, 0m, 20m and 40m are established respectively. The simulation models are shown in Figure 4. Orthogonal test chooses three indexes: mining height, normal distance and horizontal distance. The orthogonal test table of six factors and five levels (L25_5_6) was selected.

3.2. Test Results of Optimum Selection of Roadway Location

Through 25 kinds of simulated test roadway surrounding rock displacement (Table 3), it can be seen that because the overlying strata are affected by coal seam mining, the secondary mining of overlying strata Roadway after roadway excavation makes the roadway displacement close to the stope large, and the roadway displacement far from the stope small. The displacement of the two sides of the roadway develops from large to small in the direction of the back of the fan face to the stope. Therefore, the location far away from the stope should be chosen as far as possible to carry out roadway construction when the site engineering and replacement work permit. The roof subsidence and floor heave of the roadway near the stope are larger. The location of roadway 16 and 11 is in the stress increasing area, and the roadway is not suitable for the location. Due to the limitation of space, only a few characteristic displacement nephograms of test schemes are given in this paper, as shown in Figure 5.
Table 3. Displacement of various test schemes/mm

|          | Roof sinking | Floor heave | Left-side | Right-side | Total   | Roof sinking | Floor heave | Left-side | Right-side | Total   |
|----------|--------------|-------------|-----------|------------|---------|--------------|-------------|-----------|------------|---------|
| Test1    | 256.30       | 298.31      | 138.07    | 172.15     | 864.83  | 220.00       | 226.23     | 129.22    | 217.43     | 792.88  |
| Test2    | 251.52       | 267.40      | 145.50    | 179.21     | 843.63  | 220.38       | 226.23     | 129.22    | 217.43     | 792.88  |
| Test3    | 234.09       | 251.25      | 135.72    | 179.21     | 843.63  | 220.38       | 226.23     | 129.22    | 217.43     | 792.88  |
| Test4    | 220.76       | 220.00      | 137.57    | 110.00     | 864.83  | 220.38       | 226.23     | 129.22    | 217.43     | 792.88  |
| Test5    | 210.00       | 203.61      | 119.85    | 136.03     | 669.49  | 220.38       | 226.23     | 129.22    | 217.43     | 792.88  |
| Test6    | 281.61       | 291.64      | 165.42    | 187.35     | 926.02  | 220.38       | 226.23     | 129.22    | 217.43     | 792.88  |
| Test7    | 265.09       | 275.98      | 150.14    | 237.46     | 926.02  | 220.38       | 226.23     | 129.22    | 217.43     | 792.88  |
| Test8    | 241.95       | 253.61      | 132.87    | 230.12     | 926.02  | 220.38       | 226.23     | 129.22    | 217.43     | 792.88  |
| Test9    | 222.33       | 228.51      | 108.91    | 100.00     | 659.75  | 220.38       | 226.23     | 129.22    | 217.43     | 792.88  |
| Test10   | 215.18       | 194.13      | 140.91    | 160.00     | 710.22  | 220.38       | 226.23     | 129.22    | 217.43     | 792.88  |
| Test11   | 290.00       | 306.03      | 170.65    | 343.83     | 1110.51 | 220.38       | 226.23     | 129.22    | 217.43     | 792.88  |
| Test12   | 260.00       | 270.00      | 141.52    | 231.72     | 903.24  | 220.38       | 226.23     | 129.22    | 217.43     | 792.88  |
| Test13   | 236.08       | 255.75      | 126.53    | 214.04     | 832.40  | 220.38       | 226.23     | 129.22    | 217.43     | 792.88  |

The displacement fields of 25 test schemes are obtained as follows:

1. The roof displacement of the roadway inclines to the stope direction and the floor heave inclines to the coal pillar direction, and it spreads outward in the form of "oblique sole". (2) In addition to the normal distance of 140 m, the surrounding rocks of other roadways have different degrees of sharp corners at the right bottom corner, which indicates that the deformation of surrounding rocks in the right bottom corner is large. (3) In normal distance direction, floor heave is the main approach distance from the stope, while roof subsidence is the main approach distance from the stope. According to the above rules and from the angle of controlling the deformation of surrounding rock, the roadway reinforcement scheme should use asymmetric reinforcement, and the support should be strengthened at the right shoulder angle and the right bottom angle. If the roadway location is located near the stope, the area with serious floor heave should also be strengthened at the left bottom corner of the roadway.

![Figure 5. Displacement Contours of the Pilot Program](attachment:image.png)

3.3. Orthogonal Test to Optimize the Location Selection of Roadway

Comparing these three columns, we can see that the influence of normal distance factor is the greatest, followed by horizontal distance factor and mining height factor is the smallest. According to the minimum principle, the optimal roadway location is selected when the mining height is 2 m, the normal distance is 140 m and the horizontal distance is -20 m.

Table 4. ANOVA Table

| Factor         | Sum of squares of deviations | Free degree | F ratio | F critical value | Significance |
|----------------|------------------------------|-------------|---------|-----------------|--------------|
| Mining height  | 23582.096                    | 4           | 1.000   | 6.390           | (*)          |
| Normal distance| 391199.257                   | 4           | 16.589  | 6.390           |              |
| Horizontal distance | 38088.061                  | 4           | 1.615   | 6.390           |              |
| Error          | 23582.10                     | 4           |         |                 |              |
However, due to the restriction of production replacement requirements and design and construction conditions of coal mines, roadways should be laid at a normal distance of more than 80 m from the stope under the condition of 7 m or 6 m high mining height, which plays a vital role in the control of surrounding rock and later maintenance of the roadway. If the floor heave of roadway should be controlled in the near normal distance, the floor bolt may be added in the design of bolt support or the bottom arch should be added in the design of roof support so as to optimize the shape of cross-section to make the pressure uniform to achieve the purpose of optimizing the design of support. In the stope, the location of 60 m distance and 20-40 m horizontal distance is the stress increasing area, so the roadway can not be arranged in this position.

4. Roadway Surrounding Rock Control Technology

4.1. General situation of Roadway Engineering
The northern belt conveyance roadway is located from the upper coal hole of the second belt conveyor roadway to the lower part of the tenth belt conveyor roadway. It is the southern part of the main conveyance roadway in the tenth mining area. The design length of this section is 1741.098m and the elevation is -414.38～-380m. The roadway main body project is located above the goaf of 8415 working face, and the mining height of No. 8 coal is relatively high. Although the lithology of the overlying strata is good and the surrounding rock activity above the goaf is stable, the mining of No. 8415 working face has certain destructive effect on the overlying strata. North wing belt conveyance roadway is the main mine roadway, which has a relatively long service life and requires high deformation control.

4.2. Support parameter design

4.2.1. Support in a relatively stable surrounding rock area. The IV grade special screw steel high performance bolt is adopted. 7 bolts are constructed at the top of the roadway. The bolt specifications are M22-20×L2500mm, the row spacing is 800mm×800mm, the pre-tightening force is not less than 80 kN, and the anchoring force is not less than 150 kN. Six bolts are arranged in the upper part, with a row spacing of 700 mm ×800 mm and other bolts on the same top. Each bolt is anchored by two Z2360 resin cartridges. The specifications of cold-drawn arc welded steel mesh are 6-100mm × 100mm. Three anchor cables are constructed at the top, with the specifications of 17.8 ×6300mm. The middle row is in the center of the roof, the distance between rows is 1400mm ×1600mm, and the pretension force is 120kN. A roll of K2350 and three rolls of ZZ2360 resin cartridges are used in each hole when installing the anchor cable. Shotcrete to seal surrounding rock in time to prevent cracks from developing, the thickness of shotcrete layer is 50mm; concrete ratio, cement: yellow sand: stone = 1:2:2.
4.2.2. Regional Support with Poor Stability of Surrounding Rock. The surrounding rocks are sandy mudstone and medium-grained sandstone with low degree of cementation, poor self-stabilization ability after excavation and fracture development area. The support of "retractable bracket + grouting + grouting" is adopted. The support adopts 29# U-shaped steel shed with direct shed spacing of 500 mm, shed beam joints of 4, lap length of 400 mm, cable spacing of 200 mm, depth of pillar socket of 350 mm, roof (side) close connection of 700 mm \times 300 mm steel bar bars.

4.3. Analysis of Supporting Effect
The roadway is 446 mm and the maximum absolute convergence of the roof and floor is 314 mm at the end of the observation. The convergence rate in the first 7 days is the period of intense deformation after roadway excavation. The deformation rate is very high, and the rate decreases gradually with the increase of time. When the convergence rate is about 2 weeks, it begins to enter the stage of stable deformation, and the convergence rate is basically stable within 1 mm/d.

![Figure 7. Deformation Curve of Surrounding Rock](image)

5. Conclusion
(1) Through FLAC3D simulation, the law of movement and failure of overlying strata in stope under different mining heights is analyzed, and the corresponding height of caving zone and fissure zone is obtained. Along the advancing direction of the working face, the roof overburden of the goaf undergoes the state of high stress compression, pressure relief expansion and re-compression, and this process appears periodically with the continuous advance of the work.

(2) According to the orthogonal test, the weights of influencing factors from large to small are normal distance, horizontal distance and mining height. Due to the restriction of production replacement requirements and design and construction conditions of coal mines, roadways should be laid at a normal distance of more than 80 m from the stope under the condition of 7 m or 6 m high mining height, which plays a vital role in the control of surrounding rock and the later maintenance of the roadway. In the stope, the location of 60 m distance and 20-40 m horizontal distance is the stress increasing area, so the roadway can not be arranged in this position.

(3) Through the regional control and reinforcement support test of belt conveyance roadway in North Wing of Zhuxianzhuang Coal Mine, the reliable basis is provided for exploring effective control scheme and determining reasonable support form and parameters for roadway support under similar conditions.

Acknowledgments
This work was financially supported by Scientific Research Foundation Project of Yunnan Education Department: Multiscale Fractal Analysis of Unloading Fracture Propagation Law of Damaged Rock Mass (2019J0891) fund.
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