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Research on Optimization of Roadway Location in Close-Distance Coal Seam Mining

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Abstract

With the continuous exploitation of coal resources, close-distance coal seam mining has gradually become a crucial aspect in coal mine production. During close-distance coal seam mining, due to the small spacing between the upper and lower coal seams, the residual coal pillars and goaf areas left after the mining of the upper coal seam have a significant impact on the layout and stability of the roadways for mining the lower coal seam. Taking the 4203 working face of a certain coal mine as an example, this paper focuses on the optimization of roadway location in close-distance coal seam mining. Through a combination of theoretical analysis, numerical simulation, and on-site measurements, the paper investigates roadway layout schemes and determines a reasonable roadway position. The research findings indicate that adopting a staggered inward layout and determining an appropriate staggered distance can effectively avoid the influence of vertical stress above coal pillars and the vertical stress exerted by coal pillars on the floor roadway, thereby enhancing the stability and safety of the roadway.

Keywords

Close-distance coal seam; mining roadway; location optimization; staggered inward layout; numerical simulation.

1. Introduction

With the continuous exploitation of coal resources in China, the reserves of easily minable coal are gradually depleting, making close-distance coal seam mining an increasingly vital part of coal mine production [1-2]. During the mining of close-distance coal seams, due to the small spacing between the upper and lower coal seams, the residual coal pillars and goaf areas left after mining the upper seam significantly impact the layout and stability of the roadways for mining the lower seam [3]. A rational roadway layout not only enhances the stability and safety of the roadways but also effectively improves the recovery rate of coal resources and reduces production costs. Therefore, conducting research on the optimization of roadway location in close-distance coal seam mining holds significant theoretical and practical importance.

Currently, extensive research has been carried out by scholars both domestically and internationally on the optimization of roadway location in close-distance coal seam mining. Early studies primarily focused on the selection of roadway layout methods, such as staggered inward, staggered outward, and overlapping layouts [4-8]. With the advancement of computer technology, numerical simulation methods have gradually emerged as a crucial tool for studying roadway location optimization [9-10]. By establishing numerical models to simulate stress distribution and deformation under different roadway layout scenarios, scientific basis is provided for optimizing roadway positions. Additionally, on-site measurements serve as an important means to validate the results of theoretical analysis and numerical simulations.

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Hence, this paper primarily employs a combined approach of theoretical analysis, numerical simulation, and on-site measurements, taking a specific coal mine as an example, to determine the roadway layout scheme and reasonable roadway position for the mine's working face, thereby offering a theoretical reference for ensuring the stability and safety of the roadways.

2. Research Status on the Location of Roadways in Close-Distance Coal Seam Mining

Currently, research on downward mining in close-distance coal seam groups primarily focuses on roadway layout to avoid the concentrated stress from coal pillars in the upper coal seam. During downward mining, the concentrated stress formed by the residual section coal pillars and the mined-out coal body on one side of the upper coal seam is transmitted to the floor and deeper coal seams, altering the roof structure and stress environment in the mining area of the lower coal seam. The spatial positional relationships of mining roadways in close-distance coal seams mainly fall into three categories: staggered inward layout, staggered outward layout, and overlapping layout.

(1) Staggered Inward Layout. This layout is adopted when the width of the residual coal pillar in the upper coal seam working face is relatively small. In this case, the mining roadway of the lower coal seam is arranged on the inner side of the mining roadway of the upper coal seam, positioned within the stress-reduced zone beneath the goaf area of the upper coal seam. This results in lower pressure on the roadway, making it easier to maintain.

(2) Staggered Outward Layout. When the width of the residual coal pillar in the upper coal seam working face is large, a staggered outward layout can be employed. Here, the mining roadway of the lower coal seam is arranged on the outer side of the mining roadway of the upper coal seam, beneath the residual coal pillar of the upper coal seam. However, the surrounding rock of the roadway often lies within the abutment pressure zone of the coal pillar, which is unfavorable for roadway maintenance.

(3) Overlapping Layout. In an overlapping layout, the mining roadways of the upper and lower coal seams are arranged vertically, with a fixed working face length and an easily manageable direction. This layout can be adopted for the mining roadway of the lower coal seam when the upper coal seam employs a pillarless roadway protection method.

3. Determination of Layout Scheme and Position for the Working Face Gate Roads

3.1. Analysis of Roadway Layout Schemes

Based on the current research status regarding the positioning of gate roads in close-distance coal seams, there are primarily three layout schemes for the main and auxiliary transportation gate roads of the 4203 working face in this mine:

(1) Staggered Inward Layout

Both the main and auxiliary transportation gate roads of the 4203 working face are arranged on the side of the 4-1 coal goaf area, positioned at a certain distance directly below the edge of the 24m coal pillar. This arrangement effectively avoids the influence of vertical stress from the coal pillar and the vertical stress it exerts on the floor roadway. As a result, the roadway experiences less pressure and is easier to maintain.

(2) Overlapping Layout

The main and auxiliary transportation gate roads of the 4203 working face would theoretically be arranged directly below the edge of the 24m coal pillar in the upper seam. Although this position is within a zone of reduced vertical stress, considering the issues that arose after the

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layout of the 4201 main transportation gate road, there is a possibility that it may still be within the influence zone of the coal pillar's vertical stress on the floor roadway. Moreover, the overlapping layout is generally suitable when there are no coal pillars protecting the roadway in the upper seam. Therefore, it has been decided not to adopt this scheme.

(3) Staggered Outward Layout

The main and auxiliary transportation gate roads of the 4203 working face are arranged below the 24m coal pillar in the upper seam. In this scenario, the surrounding rock of the roadway lies within the abutment pressure zone of the coal pillar, which is unfavorable for roadway maintenance. After comprehensive consideration, it has been decided to adopt the staggered inward layout for the main and auxiliary transportation gate roads of the 4203 working face.

3.2. Determination of the Position of the Gate Roads

(1) Theoretical Analysis of Gate Road Position

Through the observation and analysis of rock pressure in nearly a hundred close-distance coal seam gate roads across different mining areas, a relationship between the deformation velocity v of the surrounding rock of the gate road and the coordinates x and z has been derived as follows:

$$v = [1 + 0.003(H - 300)]AC[1.15z^{-0.96}e^{-0.139x}] \tag{1}$$

In the formula: v — represents the approaching velocity of the surrounding rock in the adjacent coal roadway during the mining-induced influence period, measured in mm/d (millimeters per day). H — denotes the mining depth, measured in m (meters). x — signifies the horizontal distance between the roadway and the edge of the upper coal pillar, also measured in m (meters). z — indicates the vertical distance between the roadway and the edge of the upper coal pillar, measured in m (meters). A — is the influence coefficient of the surrounding rock stability of the roadway. C — represents the influence coefficient of the mining conditions around the coal pillar.

According to the principles of roadway layout, roadways should be positioned in zones where the approaching velocity of the surrounding rock is relatively gentle. In such areas, the roadway is less affected by the stress from the surrounding rock, and the deformation of the roof, floor, and surrounding rock is significantly smaller compared to zones with rapid rock movement. This makes the roadway easier to maintain. Based on the physical and mechanical properties of the surrounding rock in the 4-2 coal seam's 4203 main and auxiliary transportation gate roads, as well as the mining conditions of the 4-1 coal seam, the surrounding rock of the roadway is classified as moderately stable. Therefore, the influence coefficient A for the stability of the surrounding rock is taken as 6.7. Since the mining of the 4-1 coal seam has been completed, and both sides of the coal pillar are goaf areas, the influence coefficient C for the mining conditions around the coal pillar is taken as 5. The mining depth H of the 4-1 coal seam is approximately 150m. We consider coal seam spacings of 2m, 3m, and 4m. By substituting these parameters into Formula 1, we can obtain the relationship between the approaching velocity of the surrounding rock and the horizontal distance between the roadway and the edge of the upper coal pillar, as illustrated in Figure 1.

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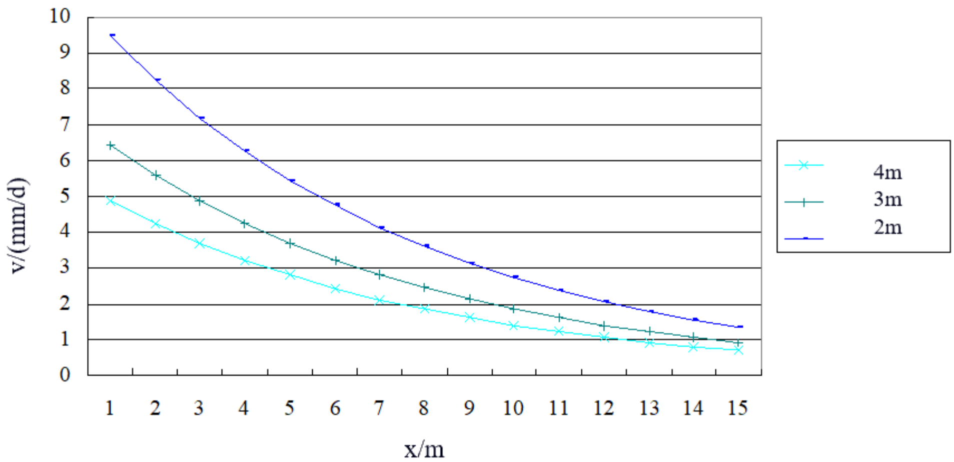

Figure 1. Relationship curve between v and x

From the Figure 1, when the coal seam spacings are 2m, 3m, and 4m respectively, the approaching velocity v of the surrounding rock in the adjacent coal roadway during the mining-induced influence period gradually decreases with an increase in the horizontal distance x between the roadway and the edge of the upper coal pillar. For all three curves, the rate of decrease in v tends to flatten out at around 6m. According to the theoretical analysis, when the approaching velocity of the surrounding rock becomes relatively gentle, the influence of concentrated stress on the surrounding rock diminishes. Therefore, the horizontal distance between the main and auxiliary transportation gate roads of the 4203 working face and the edge of the coal pillar is determined to be 6m. In other words, the theoretical staggered inward distance for the main and auxiliary transportation gate roads is set at 6m.

(2) Determination of Staggered Inward Distance under Numerical Simulation Conditions

When the coal pillar width is 24m, the distribution of vertical stress contours in the floor strata along the working face direction is illustrated in Figure 2. From the Figure2, the range of increased vertical stress in the strata located 2~4m below the coal pillar extends approximately 16m on either side of the coal pillar's centerline. This indicates that the stress reduction zone is situated about 4m horizontally from the edge of the coal pillar, with the angle of stress transfer influence being approximately 40°. Given the decision to adopt a staggered inward layout for the main and auxiliary transportation gate roads of the 4203 working face, the commonly used empirical formula for calculating the horizontal staggered distance is as follows:

$$S \geq \frac{Z}{\sin(\alpha+\theta)}\sin\beta \tag{2}$$

In the formula: S — represents the horizontal distance between the roadway in the lower coal seam and the edge of the coal pillar in the upper coal seam. Z — denotes the vertical distance between the roadway in the lower coal seam and the upper coal seam. α — signifies the dip angle of the coal seam. β — represents the angle of influence of the coal mass (also known as the angle of stress transfer influence), which typically ranges from 25° to 55°.

Currently, Formula (2) is widely applied in practical production as the primary calculation basis for determining the location of roadways in lower coal seams. For the 4203 working face, the vertical distance (Z) between the 4-1 coal seam and the 4-2 coal seam ranges from 2m to 4m. The average dip angle of the coal seam within the mine field is less than 15°. For conservative calculations, the maximum value is considered, which, in this case, is taken as 0° (indicating a nearly horizontal seam, simplifying the calculation). The angle of stress transfer influence (β)

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is determined to be 40° based on the results of numerical simulations. Using these parameters in Formula (2), the calculated staggered inward distance (S) ranges from approximately 1.68m to 3.36m. To account for potential calculation errors and ensure safety, a safety factor of 1.5 is applied. This results in an adjusted staggered inward distance range of 2.52m to 5.04m.

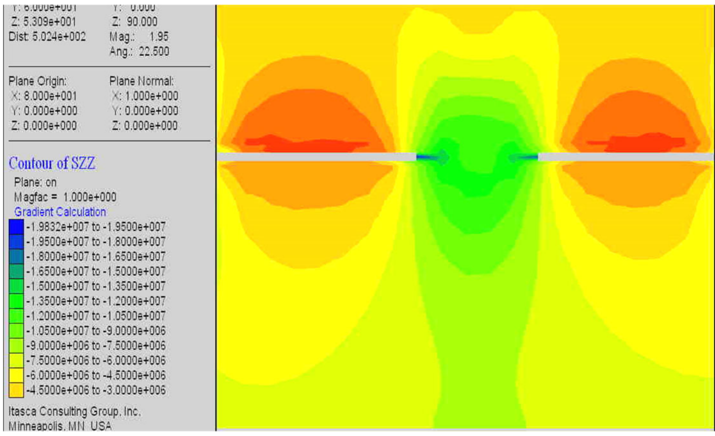

Figure 2. Contour map of vertical stress distribution along the floor strata of the working face (the coal pillar width is 24m)

(3) Final Determination of the Roadway's Position

Based on the results of theoretical analysis and numerical simulations, to ensure safety during roadway excavation and working face mining, it has been decided to adopt the maximum value of the staggered inward distance. Consequently, the staggered inward distance is set at 6m. The specific layout position is illustrated in Figure 3.

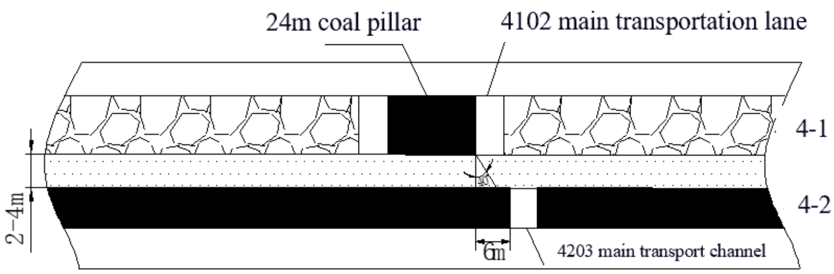

Figure 3. Final layout of 4203 main transport channel

4. Conclusion

Through the analysis of the roadway layout scheme and the study of the roadway position, this paper primarily draws the following conclusions:

(1) To avoid the influence of vertical stress above the coal pillar and the vertical stress exerted by the coal pillar on the floor roadway, it is advisable to adopt a staggered inward layout for the main and auxiliary transportation gate roads of the 4203 working face.

(2) Based on theoretical analysis of the roadway position, when the coal seam spacings are 2m, 3m, and 4m respectively, the approaching velocity (v) of the surrounding rock in the adjacent coal roadway during the mining-induced influence period gradually decreases with an increase in the horizontal distance (x) between the roadway and the edge of the upper coal pillar. For all cases, the rate of decrease in v tends to flatten out at around 6m, leading to the determination

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of a staggered inward distance of 6m. Additionally, through numerical simulations of the vertical stress distribution in the floor strata along the working face direction when the coal pillar width is 24m, the angle of stress transfer influence (β) of the coal mass is determined to be 40°, resulting in a calculated staggered inward distance range of 2.52m to 5.04m. By integrating the results of theoretical analysis and numerical simulations, the final staggered inward distance for the main transportation gate road of the 4203 working face is determined to be 6m.

(3) The staggered inward distance for the auxiliary transportation gate road of the 4203 working face is set at 8m, which is outside the range of stress influence and can effectively reduce the manifestation of ground pressure in the roadway. However, from the perspective of improving coal recovery rate, an additional 2m of coal pillar is left, resulting in a coal loss of approximately 11,519.2 tons. This calculation is based on a working face length of 847m, an average thickness of 4m for the 4-2 coal seam, and a coal density of $1.70t/m^3$.

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References

[1] Lu Guoqiang. Research on Close-Range Coal Seam Mining[J]. Inner Mongolia Coal Economy, 2022, (09): 12-14.

[2] Wei Weijie, Zhang Jinwang. Research Status and Prospects of Safe Mining in Close-Range Coal Seams[J]. Safety in Coal Mines, 2017, 48(10): 174-177.

[3] Xu Gang, Niu Hangyu, Zhao Haibo, et al. Study on Gas Emission Characteristics and Control Technology in Close-Range Coal Seam Group Mining Under Complex Geological Conditions[J]. Mining Research and Development, 2024, 44(08): 157-164.

[4] Zhang Jiangwei. Optimization Strategy of Mining Distance in Extremely Close-Range Coal Seams Under Complex Geological Conditions[J]. Energy and Energy Conservation, 2025, (03): 28-31.

[5] Wang Jin, Gao Xiangyu. Roadway Layout and Mining Distance Determination in Close-Range Coal Seam Mining in a Coal Mine[J]. Modern Mining, 2025, 41(03): 128-132.

[6] Guo Huiyu, Yang Tao. Classification Study of Internal Offset Roadways in Close-Range Coal Seam Mining[J]. Shandong Coal Science and Technology, 2023, 41(04): 4-6.

[7] Huang Hui, Hu Xiaolong, Zhang Jie, et al. Research on Section Optimization of Underlying Roadways Under External Offset Layout in Close-Range Coal Seam Mining[J]. Coal Technology, 2024, 43(12): 9-12.

[8] Qiao Jinlin, Guo Haijun, Wang Kai, et al. Study on Fracture Development Law of Overlying Strata in Overlapping Mining of Shallow Close-Range Coal Seam Group[J/OL]. China Mining Magazine, 1-11 [2025-05-20].

[9] Pei Bin. Numerical Simulation Research on Roadway Layout in Close-Range Coal Seam Mining[J]. Shandong Coal Science and Technology, 2019, (03): 65-66+69.

[10] Zhang Yanjing, Jin Shengyao, Wang Sujian. Numerical Simulation Analysis of Roadway Layout in Close-Range Coal Seam Mining[J]. Shaanxi Coal, 2020, 39(S1): 93-99.