Study on Optimization of Support of Whole Coal Roadway Using Numerical Simulation

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Abstract. Roadway is a necessary channel for mining, and smooth and stable roadways are the guarantee for safe and efficient mining. Due to the diversity of roadway support modes and support parameters, this paper aims to analyze the influence of different support modes and different support parameters on the whole coal roadway using numerical simulation method.

1. Introduction
The support modes and parameters of roadway play a significant function in safe and efficient mining [1]. This paper aims to analyze the influence of different support modes and different support parameters on whole coal roadway using numerical simulation. The model is established in the background of 8105 working face of No.3~5 coal seam in Datong mining area. The influence of different support parameters on the support effect of the working face are studied by changing the relevant support parameters.

2. Model establishment and stopping simulation
2.1. Model and parameters
The three-dimensional model of the original rock in this paper is built in FLAC 3D. The geological structure of the 8105 working face of the No. 3~5 coal seam in the Datong mining area consists of three parts: coal, mudstone and sandstone. The shape of the roadway is rectangular, and the height and width of the roadway are 3.0m and 4.0m respectively. The origin point of the model is at the center of the coal excavated; the stratum model is made up of sandstone, mudstone, coal, mudstone, coal, sandstone and mudstone from bottom to top in the vertical Z direction, and corresponding thicknesses are 5m, 4m, 14m, 4m, 1m, 16m and 8m respectively; the longitudinal length of model in the Y direction is 50m, and the longitudinal depth of the three roadway is 36m; the horizontal length of model in the X direction is 132m; the right side of the roadway 1 is located 20m to the left of the origin point; the left side of the roadway 2 is located 44m to the right of the origin point; the middle of the roadway 1 and the roadway 2 is a reserved coal pillar.
The model uses a displacement boundary condition allowing only the upper surface to move. The buried depth of the roadway is about 280m, and the bottom surface of model adopts the stress boundary condition, and the self-weight stress of the overlying rock is applied. By formula $\sigma_z = \gamma h$, $\rho = 2.65 \times 10^3 \text{ kg/m}^3$, $g = 9.8 \text{ m/s}^2$ and $\gamma = \rho g$, it is obtained that $\sigma_z = 7.5\text{ MPa}$. The model applies a horizontal tectonic stress ($\sigma_x = 5.8\text{ MPa}$) with a lateral pressure coefficient of 0.77 along the X direction, and it also applies a horizontal tectonic stress ($\sigma_y = 5.2\text{ MPa}$) with a lateral pressure coefficient of 0.69 along the Y direction. The displacements at the bottom and two sides of the model are fixed at zero.

The two sides and the roof of the three roadways are supported by bolts. The length of the bolts is 1.8m and the spacing is 1m, which are perpendicular to the surface of the roadway. In order to accord with the actual project as possible, the bolts are set as pre-stressed bolts \[2\]. According to the on-site geostress test and geological survey report, the mechanical parameters of the surrounding rock and support in models are shown in Table 1. Because the Mohr-Coulomb model is more suitable for the simulation of the mechanical problems of rock and soil during underground excavation \[3\], this paper adopts the Mohr-Coulomb model.

| name  | Bulk modulus (GPa) | Shear modulus (GPa) | Cohesion (MPa) | Internal friction angle ($) | tensile strength (MPa) |
|-------|-------------------|---------------------|---------------|---------------------------|----------------------|
| sandstone | 0.54              | 0.31                | 7.5           | 40                        | 1                    |
| mudstone  | 0.55              | 0.31                | 3.5           | 29                        | 0.8                  |
| coal     | 0.4               | 0.133               | 2.4           | 18                        | 0.6                  |

2.2. Stopping simulation
The mining is carried out under the action of the self-heavy stress of the surrounding rock, and the displacement and stress of the three roadways are recorded. From the change of the displacement value of the monitoring point, it is known that the deformation of roadway has happened. The settlement of rock in the roof of the roadway is large, and it is mainly vertical settlement. The surrounding rock at two sides are subjected to lateral compressing due to shear stress. The results of numerical simulation of roadways show the sinking of the large area roof and the large amount of deformation. And most of bolts are in the tension state, which is the same as the bolts in the actual roadway \[4\].

3. Change related parameters of the simulation
3.1. Numerical simulation of different the lengths of bolts
The length and the spacing of bolts have a significant influence on the support effect of the roadway \[5\]. The numerical simulation method is used to investigate the influence of different the lengths and different spacing of the bolts on the support. The amount of changes at length and spacing of bolts are reduced by 20%, reduced by 10%, and reduced by 5%, increased by 5%, increased by 10%, increased by 20% respectively. By observing the displacement and stress, it is obtained that the influence of different parameters of bolts on the support effect.

Since the roadway 1 and the roadway 2 are similar in mechanical mechanism, the roadway 1 is only analyzed in the paper. From the monitoring point data, it can be concluded that when the roadway support effect is weakened (the length of bolts is reduced or the spacing of bolts is increased), the displacement curve of the roof corresponding to different parameters is shown in Fig. 1. The displacement curves of the two side are shown in Figure 2. The maximum stress curve of the roof is shown in Figure 3. The maximum stress curve of the surrounding rock is shown in Figure 4. It can be seen from these figures that the influence of the length of the bolts on the support effect is greater than the influence of the spacing of bolts on the support effect, but the degree of influence of the two is very small.
3.2. Numerical simulation of different widths of coal pillars

The width of the coal pillars reserved between the roadways is also a major factor affecting the roadway support effect. The numerical simulation method is used to explore the influence on the support effect of the roadway by changing the width of the reserved coal pillars between the roadways. The width of the reserved coal pillar between the roadway 2 and the roadway 3 is 20m. Then, carry out the numerical simulation with different the widths of the coal pillar which is reduced by 20%, 10%, by 5% and increased by 20%, 10%, by 5%. By recording and observing the displacement of the monitoring points, analyze the influence of different widths of the coal pillar on support effect.

It can be seen from Table 2 that as the width of the coal pillar is reduced, the amount of subsidence of the roof increases gradually and the displacement of the two sides increases gradually, and the subsidence of roof and the deformation of the two sides of the roadway 3 are the most obvious.

| Actual width of coal pillars | Subsidence of roof /mm | Displacement of two sides /mm | Subsidence of roof /mm | Displacement of two sides /mm | Subsidence of roof /mm | Displacement of two sides /mm |
|-----------------------------|------------------------|-------------------------------|------------------------|-------------------------------|------------------------|-------------------------------|
| Reducing width of coal pillars by 5% | 38.88 | 34.78 | 39.61 | 35.25 | 11.79 | 12.47 |
| Reducing width of | 38.91 | 34.82 | 39.76 | 35.37 | 12.68 | 12.77 |
Reducing width of coal pillars by 10%  
Reducing width of coal pillars by 20%  

| Parameter Change | coal pillars by 10% | coal pillars by 20% |
|------------------|---------------------|---------------------|
| 0.00             | 38.94               | 38.95               |
| 0.05             | 34.87               | 35.56               |
| 0.10             | 39.95               | 34.56               |
| 0.15             | 14.55               | 13.97               |
| 0.20             | 13.97               | 13.97               |

Therefore, the displacement of the roof curve corresponding to different parameters can be obtained when the support effect of the roadway is weakened in Figure 5. As shown in Figure 6, it can be seen that the displacement curves of the two sides. From the two figures, it is known that the influence degree of the bolt length on the support effect is greater than that of the bolt spacing and the coal pillar width on the support effect in roadway 1.

It can be seen from Figure 7 and Figure 8 that the influence degree of the coal pillar width on the support effect is greater than that of the bolt spacing and the bolt length on the supporting effect in the roadway 3.

4. CONCLUSION
Under this condition, the following conclusions can be drawn:

The influence degree of bolt length on the support effect is greater than that of bolt spacing and coal pillar width on the support effect in roadway 1.

The influence of the width of the coal pillar on the support effect is greater than that of the bolt spacing and the length of the bolt on the support effect in roadway 3.
The above conclusion has much guiding significance for actual engineering projects. However, there are still many factors affecting the support effect. In the future research, we can continue to study the influences of other factors separately or together on the support effect of roadway.

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