Numerical simulation study on support design of deep roadway

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Abstract. In order to solve the problem of large deformation in deep roadway mining, the stress and deformation of surrounding rock after roadway excavation and support are studied by numerical simulation. The results show that the displacement of roof and two sides is large after the roadway excavation. After adopting bolt support technology, the displacement of the roof and two sides of the roadway decreases obviously. The displacement decreases with the decrease of bolt spacing, the range of plastic zone decreases greatly, and the overall strength of the surrounding rock of the roadway increases obviously. The research results can provide reference for other deep roadway support.

1. Introduction
With the increase of coal mining depth, geological conditions become more complex, and bolt support, as an economical and effective roadway support technology, has been widely applied in coal mine production [1]. Dengyun Hao used field measurement, theoretical analysis and numerical simulation as the research means to study the instability mechanism of mining roadway in close distance extra thick coal seam under goaf, and concluded that roadway layout, dynamic pressure on mining and excavation, and roadway support scheme were the main factors affecting roadway deformation and instability [2]. Yukai Fu tested the mechanical properties of warp and weft networks, diamond shaped networks and steel reinforcement networks under static and dynamic pressures [3]. In order to solve the problem of deep roadway support, Renlong Fu proposed the bolt-injection combined support technology with grouting bolt as the core [4]. Jianbiao Bai proposed an active controlled pressure relief method [5], which effectively controlled the deformation of the western roadway of the Guhanshan mine. Metallurgical Coal Company combined analysis, numerical and empirical modeling, proposed a set of roof support design [6] methods. In addition, many scholars at home and abroad have studied bolt support technology [7-12]. In this paper, the author takes numerical simulation as the research method to discuss the deformation and stress distribution of roadway after excavation. After putting forward various support schemes, the better support schemes are selected according to the simulation results. The research results can be used for reference for other roadway support designs.

2. Numerical Simulation

2.1. Model Building
(1) Model building establish a layered model, the top layer is L2 limestone with a height of 10m; the second layer is L1 limestone with a height of 12m; the third layer is a coal seam with a height of 3m;
the fourth layer is sandy mudstone with a height of 10m; the bottom layer is mudstone 15 m high; the roadway is located in the coal seam, 4 m wide and 3 m high. As shown in Figure 1.

(2) The destruction criterion conforms to Mohr Coulomb criterion.

(3) Except for the top surface, all other surfaces are set as fixed displacement boundaries, the top surface is subjected to a stress of 20 MPa, and the lateral pressure coefficient is taken as 1.

![Figure 1 Strata division](image)

2.2. Support Scheme

The support design scheme is shown in Table 1.

| Scheme number | Roof support | Two sides of support |
|---------------|--------------|----------------------|
|               | Row spacing (m) | Column spacing (m) | Row spacing (m) | Column spacing (m) |
| 1             | 0.8           | 0.8                  | 0.8            | 0.8               |
| 2             | 1.0           | 1.0                  | 1.0            | 1.0               |
| 3             | 1.2           | 1.2                  | 1.2            | 1.2               |
| 4             | 1.4           | 1.4                  | 1.4            | 1.4               |

3. Results Analysis

Figure 2 shows the result nephogram without support.

![Figure 2: (a) Vertical displacement (b) Lateral displacement](image)
It can be seen from Figure 2 that when there is no support, the maximum sinking amount of the roof is 10 cm, the maximum upper bulging volume of the bottom plate is 1.2 cm, the maximum bulging volume of the two sides is 22.7 cm, and there is a large plastic circle around the roadway. Meanwhile, there is a phenomenon of stress concentration at the corners, in order to ensure the smooth progress and safety of the project, it is necessary to adopt a reasonable support scheme.

Figure 3 shows the vertical displacement nephograms of different schemes.

Comparing the simulation results of each supporting scheme in Figure 3, it is found that compared with the excavation without support, the roof displacement of scheme 1 is reduced from 10 cm to 2.95 cm, and the displacement is reduced by 70.5%; The roof displacement of scheme 2 is reduced from 10 cm to 2.95 cm, and the displacement is reduced by 70.5%; The roof displacement of scheme 3 is reduced from 10 cm to 2.95 cm, and the displacement is reduced by 70.5%; The roof displacement of scheme 4 is reduced from 10 cm to 2.95 cm, and the displacement is reduced by 70.5%;
cm to 4.13 cm, and the displacement is reduced by 58.7%; The roof displacement of scheme 3 is reduced from 10 cm to 5.26 cm, and the displacement is reduced by 47.4%; The roof displacement of scheme 4 is reduced from 10 cm to 6.2 cm, and the displacement is reduced by 38.0%. By comparison, it is found that with the decrease of the bolt spacing, the amount of roof displacement gradually decreases, and the scheme 1 has the best protection effect.

Figure 4 shows the lateral displacement nephogram of different schemes.

Comparing the simulation results of each supporting scheme in Figure 4, it is found that compared with the excavation without support, the displacement of the two sides of scheme 1 is reduced from 22.7 cm to 6.4 cm, and the displacement is reduced by 71.8%; the displacement of the two sides of scheme 2 is reduced from 22.7 cm to 8.4 cm, and the displacement is reduced by 63.0%; the displacement of the two sides of scheme 3 is reduced from 22.7 cm to 10 cm, and the displacement is reduced by 55.9%; the displacement of the two sides of scheme 4 is reduced from 22.7 cm to 14 cm, and the displacement is reduced by 38.3%. With the decrease of bolt spacing, the displacement of both sides decreases gradually, and the support effect of scheme 1 is the best.

It can be concluded that scheme 1 is the best scheme.

Figure 5 shows the maximum principal stress nephogram and plastic zone nephogram of scheme 1.
Figure 5 Scheme 1 result nephograms

(a) maximum principal stress  (b) plastic zone

It can be seen from Figure 5 that after adopting scheme 1, it can be seen from the figure that the plastic zone area of the roadway is significantly reduced after supporting, indicating that the overall strength of the surrounding rock of the roadway is significantly improved after supporting, and only a small part of surrounding rock is in shear.

4. Conclusion
After the excavation of the roadway, the displacement and the plastic zone of the roof and the two sides are both larger, and the corners have stress concentration. After the bolt support technology is adopted, the displacement of the roof and the two sides of the roadway is significantly reduced. Among them, the displacement decreases with the decrease of the bolt spacing. Therefore, the scheme 1 is the optimal scheme in this working condition. After adopting the scheme 1 support, the plastic zone range is greatly reduced, indicating that the overall strength of the surrounding rock of the roadway is obviously improved after the support.

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