Analysis of Instability Mechanism and Support Technology of Surrounding Rock in High Stress Soft Rock Mining Roadway

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Abstract: Based on the on-site investigation and monitoring of the working face of Yannan Mine 10128023, by using FLAC 3D numerical simulation software, the mechanism of deformation and instability of roadway surrounding rock is analyzed, and it is concluded that the existing support method has been unsuitable for the soft rock roadway and technical requirements. Aiming at this problem, propose a new technology of hollow grouting anchor support. The support parameters and support process are optimized through field experiments. The results of mine pressure observation show that the technology has achieved the goal of maintaining roadway stability.

1. Introduction
Shenhua Dayan Company Yannan Coal Mine is located in the southwest of Dayan Mining Area. The coal-bearing strata belongs to the Middle Jurassic Upper Tiezhu nuoer Group Damoguaihe Formation and Yimin Formation. The middle part of the Damoguahe Formation is coal-bearing. The area mainly contains coal section. The lithology of the top and bottom of the coal seam is loose and fractured, belonging to rock mass with low strength, weak cementation, strong expansion and large deformation. The weak layer between the sandy mudstone layers has low shear strength, and it is easy to muddy when exposed to water, which is unfavorable to the stability of the roadway, which is one of the typical expansive soft rock mining areas in China. With the increase of mining depth and the increase of stress, the technical difficulties of soft rock support are becoming more obvious. During the production process, the deformation of the mining roadway is severely damaged. The form of the bolt body is broken, the pallet fails, and the bonding fails, anchorage failure, etc., the roadway renovation rate has reached more than 50% of the total mine roadway in the mine, and some mining roadways even have 3 to 4 repeated renovations. The traditional anchor bolt support has poor control effect on the roadway deformation, bring great hidden dangers to the mine safety, and at the same time increased the cost of mine support, which severely restricted the production of Yannan Coal Mine. How to solve the support problem of high-stress soft rock mining roadway has become a difficult problem in Yannan Mine.

2. Establishment of Numerical Simulation of Working Face Mining Roadway
The numerical simulation is based on the 10128023 working area and taken the mining roadway of No.28-2 coal seam as the research object, and the numerical simulation model is established. The shape of the roadway section is rectangular, and the section size is net width×net height=3.5×3.0m.
The roadway is 376-540m away from the surface, the vertical stress is 10MPa, and the maximum horizontal stress is 14MPa. The coal mining method is fully mechanized top coal caving, the coal caving step is 1.20m, adopting “two mining and one release”, the coal seam thickness is 5.5m, the mining height is 3.0m, the average strike length is 1037m, the inclined length is 200m, and the coal seam inclination angle is 11°. The roadway support method is the anchor net and cable joint support: the roof plate adopts anchor net and anchor cable support, the two sets adopt anchor and net support, the roof bolt adopts strong threaded anchor such as φ20×2200mm, and the two sets of anchors adopt φ18×2200mm and other strong threaded anchors, the spacing between anchors is 800×800mm, the cable specifications are 17.8×6000mm, the space between anchors is 800×1600mm; and there also are 4 bolts in each section and 5 anchors in the roof Rod, 2 anchor cables.

The numerical model size is: 400m×400m×20.1m, there are 200,000 units, a total of 214221 nodes, the simulated working face and roadway excavation design figure is shown in Figure 1-1; the mining roadway model is shown in Figure 1-2.

3. Numerical Simulation Results and Analysis of Mining Roadway

3.1. Numerical Simulation and Analysis of Deformation and Instability of Surrounding Rock in Roadway Excavation

3.1.1. Roadway Displacement Variation Law

According to the different excavation time of the roadway, the numerical simulation of the displacement law of the surrounding rock of the roadway is carried out. The simulation results of the displacement law of the surrounding rock of the roadway are shown in Figure 2-1.
**Figure 1-2 Numerical model of mining roadway**

- **t=1d roadway surrounding rock displacement cloud map**
- **t=15d roadway surrounding rock displacement cloud map**
- **t=30d roadway surrounding rock displacement cloud map**
By analyzing the above simulation results, we can see that:

1. With the extension of the excavation time of the roadway, the displacement of the surrounding rock of the roadway gradually increases. When the excavation is 60d, the displacement of the surrounding rock of the roadway tends to be gentle.

2. The displacement of the surrounding rock of the roadway is mainly represented by the roof and the two gangs. The maximum displacement of the two gangs occurs near the shoulder angle, and the maximum displacement is 1.67m. The displacement of the bottom plate is relatively small, generally about 1m.

3. The deformation speed of the surrounding rock in the excavation and excavation is large. With the continuous advancement of the excavation, the displacement deformation speed of the surrounding rock in the later roadway is significantly slowed down and gradually stabilized.

4. The deformation of the roadway is manifested by the sinking of the roof of the roadway, the squeezing of the two gangs into the roadway and the bulging of the floor.

3.1.2. Law of Change of Plastic Zone in Roadway
According to the different excavation time of the roadway, the variation law of the plastic zone of the surrounding rock of the roadway is numerically simulated. The simulation results are shown in Figure 2-2.

![t=45d roadway surrounding rock displacement cloud map](image1)

![t=60d roadway surrounding rock displacement cloud map](image2)

Figure 2-1 Surrounding rock displacement cloud map of different time periods of roadway excavation

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3. The deformation speed of the surrounding rock in the excavation and excavation is large. With the continuous advancement of the excavation, the displacement deformation speed of the surrounding rock in the later roadway is significantly slowed down and gradually stabilized.

4. The deformation of the roadway is manifested by the sinking of the roof of the roadway, the squeezing of the two gangs into the roadway and the bulging of the floor.
By analyzing the above simulation results, we can see that:

1. The damage of the surrounding rock of the roadway begins with the roof and the corner of the roadway, showing the form of shear failure; the top and bottom of the roadway and the two gangs first have local shear failure zones, and then the local shear failure zone penetrates each other gradually. A plastic damage zone with a wide range is formed.

2. From the perspective of the development of the plastic zone, the depth of the roadway is generally 1 to 2 m. After the tunnel is excavated for 60 days, there is basically no major change in the plastic zone, which is basically close to or reaches a stable trend.

3.1.3. Law of Stress Variation of Surrounding Rock in Roadway

According to different excavation time of the roadway, the numerical simulation of the stress variation law of the surrounding rock of the roadway is carried out. The simulation results are shown in Figure 2-3.
By analyzing the above simulation results, we can see that:

1. With the excavation of the roadway, the surrounding rock stress is redistributed and the surrounding rock stress is continuously increased.

2. With the deformation of the surrounding rock of the roadway, the surrounding rock of the roadway has a stress reduction zone. The roof of the roadway is the main pressure relief zone with a depth of about 2m. The depth of the roadway and the depth of the floor of the floor are about 1.0m pressure relief zone.

3. From the surface of the surrounding rock to the deep part of the roadway, the stress distribution is expanded and the surrounding rock stress is further increased.

4. Combined with the plastic zone and the displacement cloud map, the main stress relief zone occurs in the plastic zone of loose failure.

3.2. Analysis of Influence Law of Working Area Mining on Surrounding Rock Deformation of Roadway

Under the influence of mining dynamic pressure on the working face, the surrounding rock deformation of the mining roadway is affected to some extent. The deformation of the surrounding rock in the mining roadway is analyzed within 30m from the front of the work. The deformation law is shown in Figure 3-4.
It can be seen from Fig. 2-4 that the maximum damage area is formed between the upper and lower channels of the mining roadway due to the advancement of the working surface. Through the variation of the surrounding rock displacement of the 30m, 20m, 10m and 5m mining roadway in front of the working face, the closer the distance from the working face, the greater the degree of roadway damage.

4. Support Technology Design
Yannan Coal Mine currently adopts the support structure of “cluster + anchor cable + net + steel strip” in the mining roadway. The rock bolt roadway adopts the “bolt + concrete” support structure method, which has not met the technical requirements of mine soft rock roadway support. Therefore, for the large deformation and difficult support of the Yannan soft rock roadway due to the weak surrounding rock properties, high ground stress, support mode and unreasonable parameters, the hollow grouting anchor cable support technology is designed.

4.1. Support Mechanism
(1) Grouting can be used to reinforce the surrounding rock, and it can also be used to block the cracks of the surrounding rock, to isolate the air, to prevent weathering of the surrounding rock, and to prevent the surrounding rock from being wetted by water and to reduce the strength of the surrounding rock.

(2) After grouting, the slurry material is cemented with the loosely broken surrounding rock, which improves the cohesion, internal friction angle and elastic modulus of the rock mass, thereby improving the strength of the rock mass and realizing the surrounding rock itself as a part of...
supporting structure.

(3) After grouting, the wall of the spray layer is filled and compacted, so that the load can be uniformly applied to the spray layer and the support to avoid stress concentration and first damage.

(4) After grouting, the pressure acting on the vault can be effectively transmitted to the two walls, and the reinforcement can be applied to the bottom plate by reinforcing the wall. Due to the increase of the thickness of the combined arch, the load concentration on the bottom plate can be reduced, thereby reducing the stress in the rock of the floor, weakening the plastic deformation of the bottom plate, and reducing the stability of the bottom drum and the bottom plate. It helps to stabilize the two walls. In the case of the bottom plate and the two walls being stable, the stability of the vault can be maintained. The stability of the roof depends not only on the roof load, but also depends on the stability of the bottom plate and the two walls in the fracture zone. One of the key points of grouting support is to ensure the stability of the two slabs and the bottom plate, thus ensuring the stability of the entire support structure.

4.2. Support Parameter Design

The grouting anchor cable engineering test is carried out under the working surface of I0128203, and the technical parameters of grouting anchor cable support are determined according to the actual geological conditions. That is, +294 contact lane grouting anchor support parameters: 5 φ22×7000mm grouting anchor cables are arranged in the whole section of the roadway, one is installed in the tunnel archway, and one hollow anchor is arranged symmetrically in the shoulder and the gangway. The anchor cable has an interval of 1600×1800mm, and the top plate and the two sets use ACZ-1 additive cement slurry. There are 3 bottom plates arranged, one hollow anchor bolt cable is arranged in the bottom plate lane, the distance between the two sides is 1200×1200mm, which is arranged perpendicular to the bottom plate, and the bottom plate adopts organic chemical slurry-anchoring agent.

4.3. Construction Effect

Eight monitoring points are set in the section of the +294 contact road. According to the data of the mine pressure monitoring system, the stress of the bolt, the separation of the roof and the stress of the surrounding rock are small, and the amount of the roof is 1.5 to 2.6 mm; the force of the bolt is 1 There was almost no change in the measuring point of No.6, and the force on the No. 7 measuring point increased by 3 MPa, and the force on the No. 8 measuring point increased by 7 MPa; the monitoring data of the surrounding rock stress did not change.

5. Conclusion

By determining reasonable support methods as well as supporting parameters and strictly controlling the engineering quality, hollow grouting anchor cable support technology can change the stress state of surrounding rock, strengthen roadway support effect, control roadway deformation and reduce roadway failure rate. Practice has proved that the hollow grouting anchor cable technology is a new type of support technology suitable for the geological conditions of Yannan Coal Mine, and has a strong promotion value.

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