Study on the subdivision support and rapid tunneling technology of coal mine roadway

Shuan-cheng Gu¹, Wei Sun¹* and Bin Wang¹

¹School of Architecture and Civil Engineering, Xi’an University of Science and Technology, Xi’an, Shaanxi, 710054, China

*Corresponding author’s e-mail: sunwei1205 @163.com

Abstract: In the existing forming support technology of the existing coal mine roadway, the support cost time of the anchor (cable) accounts for a large proportion of the total time at the roadway excavation, and the deformation characteristics and variation regular patterns of the surrounding rock and support structure of the roadway are not fully considered, thus limiting roadway excavation rate cannot achieve rapid tunneling, which affects production efficiency. In the one-time forming support technology of coal mine roadway, the support time of bolt (cable) occupies 60~70% of the tunneling time of the whole roadway, which greatly restricts the rapid tunneling of the roadway and does not fully consider the coordinated deformation of the surrounding rock and supporting structure of the roadway. The characteristics, therefore, can not ensure the economic rationality of the support scheme, resulting in an increase support costs and maintenance schedules. This article takes the transportation of 22202 working face in Zhang Jia Mao coal mine as the research object, and combines theoretical analysis and numerical simulation to study the technology of roadway sub-support and rapid excavation, and comprehensively consider the surrounding rock of the roadway in combination with the existing research shortage. With the stability of the supporting structure, a design scheme of the sub-support is proposed to ensure the economic and reasonable support scheme and better serve the safe and efficient production of the mine.

1. Introduction

The roadway excavation code requires that the support be followed by the work surface. But in the actual excavation cannot meet this requirement due to various factors, resulting in the excessive distance between the roof and the roof in the roadway excavation, which does not meet the requirements of the specification and is not conducive to the safety and stability of the roadway. At present, in the one-time forming support technology of coal mine roadway, roadway excavation, transportation, support and so on can not work in parallel and the support time accounts for 60~70% of the tunneling time of the whole roadway excavation, which greatly restricts the rapid tunneling of the roadway. The reason is that the one-time forming support does not fully consider the coordinated deformation characteristics of the surrounding rock and supporting structure of the roadway and the deformation regular pattern of the surrounding rock, which cannot ensure the economic rationality of the supporting scheme, and is not conducive to the support cost and the supporting work efficiency. control.

Aiming at the existing roadway rock control theory research and support technology analysis, the article analyzes the surrounding rock deformation and support coordination regular pattern of the roadway and proposes the sub-support technology. The fractional support technology makes full use of...
the self-supporting ability of the surrounding rock, which not only ensures the safety and stability of the surrounding rock of the roadway during excavation, but also improves the support effect of the anchor (cable), and at the same time ensures the personal safety of the excavation site; The secondary support technology uses the real-time monitoring data feedback as the basis for the design and excavation of the roadway support. The support scheme is more targeted, ensuring the safety and stability of the roadway and making the support more economical and reasonable. It saves the economy from personnel, materials and processes, so time cost increases the efficiency of tunneling [1-6].

2. Factors analysis of influencing roadway rapid tunneling
After the roadway excavation is completed, if the support form and parameter selection are unreasonable, the support strength is too high, not only the support material is wasted, but also the excavation speed is affected; or the support strength is not enough, the surrounding rock deformation cannot be effectively controlled, and a roof accident occurs. The deformation regular pattern of surrounding rock and the coordination of anchor, and surrounding rock deformation are not fully considered, which leads to the failure of bolt support to play the role of anchor, increase the workload of support and prolong the support time.

According to the existing roadway excavation and support situation of Zhang Jia Mao coal mine, the following shortages are obtained:

- For the control of roadway surrounding rock deformation, the excavation specification requires that the support be followed by the work surface, but the design concept of one support cannot meet this requirement, resulting in an excessively large empty top distance and failing to meet the requirements of coal mine safety regulations.
- In the one-time forming support technology of coal mine roadway, the anchor (cable) support time takes up too much time, which greatly restricts the rapid tunneling of the roadway.
- The idea of support economic rationality, the supporting theory mainly based on the theory of broken-rock circle on a molding supporting, without fully considering the deformation characteristics of roadway surrounding rock and supporting structure coordination, timeliness of bolt (cable), the rheological deformation of surrounding rock and so on, there is no ensure that the economic rationality of supporting schemes, resulting in the increase of roadway supporting cost and time limit for a project.

3. Design and implementation of roadway bolt (rope) sub-support scheme
In the roadway excavation stage, the support should be followed by the excavation working face to control the deformation of the roof and ensure that the surrounding rock of the roadway is basically stable. The first support of the roof of the roadway is carried out to minimize the distance between the roadway and the top of the roadway, and the “end effect” of the roadway is used to ensure that the roof of the roadway is basically stable during the tunneling process. In the subsequent support process, the data is monitored through the on-site monitoring. The analysis determines the deformation characteristics of the surrounding rock of the roadway, and reinforces the area with large deformation and poor stability of the roadway, so that the whole deformation of the roadway can be effectively controlled to ensure the stability of the surrounding rock. The surrounding rock structure of the roadway is determined during the mining impact stage. Destroy the form and determine the support reinforcement program. The roadway support technology is decomposed into several stages for sub-support. According to the “New Austrian Tunneling Method” idea and the joint support theory, the deformation regular pattern of surrounding rock after roadway excavation is analyzed, and the surrounding rock deformation monitoring adjustment design supporting intensity and frequency, so as to continuously improve the safety and stability of the surrounding rock, and shortens the proportion of the total time of support in the roadway excavation process [7-11].

On the basis of the original support design of the rubber conveyor in the Zhang Jia Mao 22202 fully mechanized mining face, as shown in figure 1 below, two kinds of split support schemes are
proposed to achieve the purpose of safe and efficient roadway support.

Figure 1. Supporting schematic diagram of the original 22202 fully-mechanized mining face with glue transportation and trough section

The sub-supporting operation can closely follow the excavation working face in time to effectively reduce the empty top distance of the roadway, and meet the requirements of the relevant operational procedures for supporting the working face in the coal mine safety regulations. In order to study the secondary support and rapid excavation of the roadway, the support cost of the surrounding rock and the supporting structure should be fully considered to ensure the economic rationality of the supporting scheme and the safety and stability of the roadway, so as to reduce the support cost of the roadway. Starting from the support period, improve the efficiency of excavation and production, make the support scheme more efficient and economical, and realize the rapid excavation of the roadway and put it into production. Specific embodiments and support parameters are shown in Table 1.

Table 1. Design table of support scheme parameters in different stages

| Scheme | Name of bolt | Amount | Size       | Row spacing between |
|--------|--------------|--------|------------|----------------------|
| Original scheme | Left-hand unreinforced screw bolt + plate | 6      | Φ 18×2600mm | 1040×1200mm          |
|         | Fiberglass bolt+ plate | 5      | Φ 18×1800mm | 1000×1200mm          |
| first support | Left-hand unreinforced screw bolt + plate | 3      | Φ 18×2600mm | 1040×1200mm          |
| second support | Left-hand unreinforced screw bolt + plate | 2      | Φ 18×2600mm | 1040×1200mm          |
|         | Fiberglass bolt+ plate | 4      | Φ 18×1800mm | 1000×1200mm          |
| first support | Left-hand unreinforced screw bolt + plate | 4      | Φ 18×2600mm | 1040×1200mm          |
| second support | Left-hand unreinforced screw bolt + plate | 2      | Φ 18×2600mm | 1040×1200mm          |
|         | Fiberglass bolt+ plate | 4      | Φ 18×1800mm | 1000×1200mm          |

Both scheme 1 and scheme 2 can effectively improve the roadway excavation rate, ensure the safety of the surrounding rock of the roadway, and realize safe and rapid tunneling of the roadway. Compared with scheme 2, scheme 1 has the following characteristics:

- Due to the small number of bolts in the first support, the proportion of the tunneling cycle is small, which effectively increases the excavation rate.
- In the first support, the strength of the roof support of the pair of roadways is weak, so the
amount of subsidence of the surrounding rock of the roof is larger than that of the second plan, which is not conducive to the stability of the roof of the roadway.

Compared with the original scheme, the fractional support scheme has outstanding advantages in reducing the unsupported top distance, improving the tunneling speed and the surrounding rock stability of the roadway:

- It is beneficial to the rapid excavation of roadway, decomposing the traditional primary support into multiple supports, reducing the time proportion in the whole excavation process, improving the efficiency of roadway tunneling, and realizing rapid roadway excavation;
- The sub-supporting fully exerts the supporting effect of the supporting structure, effectively controls the deformation of the surrounding rock in the early stage of the roadway, and ensures the stability of the surrounding rock of the roadway;
- To improve economic efficiency, the sub-support technology is based on real-time monitoring data feedback for roadway support design and excavation. The support scheme is more targeted and more economical and reasonable under the premise of ensuring the safety and stability of the roadway.

4. Numerical simulation and result analysis of roadway anchorage (cable) support in different stages

The model range is determined according to the specific section size of the roadway. The surrounding rock model of the roadway section includes three types of surrounding rock, mainly medium and coarse sandstone, siltstone and coal seam. The model is established according to the actual surrounding rock distribution, as shown in Table 2.

| Rock Type       | Severe (kN/m³) | Elastic modulus (GPa) | Poisson's ratio | Cohesive force (MPa) | Angle of internal friction (°) |
|-----------------|----------------|-----------------------|-----------------|-----------------------|-------------------------------|
| Medium grained sandstone | 23             | 2.3                   | 0.21            | 10                    | 37                            |
| Fine sandstone  | 24.2           | 2.8                   | 0.24            | 12                    | 38                            |
| Siltstone       | 24.46          | 2.5                   | 0.19            | 14                    | 39                            |
| 2° coal         | 13.1           | 0.53                  | 0.47            | 1.5                   | 30                            |

4.1 Sub-support simulation of bolt (rope) in excavation roadway

- Scheme 1 roadway change regular pattern
Figure 2. Displacement diagram of surrounding rock of the first supporting roadway with anchor rod (cable) in scheme 1

Figure 3. Displacement diagram of surrounding rock of the second supporting roadway with anchor rod (cable) in scheme 1

The maximum subsidence of the first support roof is 22.47 mm, the maximum displacement of the two gangs is 4.99 mm, the maximum subsidence of the second support roof is 24.51 mm, and the maximum migrating amount of the two gangs is 5.45 mm.

• Scheme 2 roadway change regular pattern

Figure 4. Displacement diagram of surrounding rock of the first supporting roadway of plan 2 bolt (cable)

Figure 5. Displacement diagram of surrounding rock of the second supporting roadway of plan 2 bolt (cable)

The maximum subsidence of the first support roof is 21.04 mm, the maximum displacement of the two sets is 4.68 mm, the maximum subsidence of the second support roof is 26.70 mm, and the maximum displacement of the two sides is 5.93 mm.

4.2 Simulation analysis

Considering the rapid excavation of the roadway, the first support is carried out after the excavation of the roadway, and the top plate of the roadway is followed by the work. Under the support condition, the roof does not fall overall, and the maximum sinking amount is 22.47 mm. The roof can remain basically stable during tunneling. After the second reinforcement, with the tunneling progress, the deformation of the surrounding rock continues to increase, but the deformation rate decreases until the surrounding rock of the roadway reaches the final stability. The maximum subsidence of the roof of the roadway after stabilization is 24.51 mm.

After the first support, the maximum subsidence of the roof is 21.04 mm, and the maximum
subsidence of the roof after the surrounding rock reaches the final stability is 26.70 mm. The surrounding rock remains stable during the whole roadway excavation process, indicating that the support scheme is it can keep the surrounding rock stable and ensure safe and rapid roadway driving operation.

5. Conclusion

- In this article, the research on the fractional rapid support of the 22202 working face in Zhang Jia Mao coal mine is carried out, and the coordination deformation characteristics of the surrounding rock and supporting structure of the roadway are fully considered to ensure the economic rationality of the supporting scheme and the premise of safe and stable roadway. Next, reduce the support cost and support period of the roadway, make the support plan efficient and economical, realize the rapid tunneling of the roadway and put it into production.

- The numerical simulation analysis shows that the first support is carried out after the excavation of the roadway, and the top plate of the roadway is followed by the work. Under the support condition, the roof does not fall overall, and the maximum sinking amount is 22.47 mm. After the second reinforcement, the deformation of the surrounding rock continues to increase with the roadway excavation, but the deformation rate decreases until the surrounding rock of the roadway reaches the final stability. The maximum subsidence of the roof of the roadway after stabilization is 24.51 mm; after the first support, the maximum subsidence of the roof is 21.04 mm, and the maximum subsidence of the roof after the surrounding rock reaches the final stability is 26.70 mm. The surrounding rock remains stable throughout the roadway excavation process. The surrounding rock of the roadway can be kept stable and the roadway driving operation can be safely and quickly carried out.

Acknowledgments

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