The Stability Analysis of Cross Roadway Support of Gaojialiang Coal Mine

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ABSTRACT: For further research of effect on coal mine soft rock of cross roadway and structural mechanics behavior of early support by dynamic construction process; the construction of the vertical cross-range of auxiliary-roadway and crossheading of Gaojialiang coal mine in Erdos is studied. The cross-tunnel excavation process is simulated by three-dimensional elastic-plastic finite element MIDAS/GTS software; the impact of crossheading dynamic construction process for the structural mechanics behavior of auxiliary roadway surrounding rock and the initial supporting is analyzed. The excavation of crossheading tunnel leads to the stress release and secondary distribution of the main roadway surrounding rock and the supporting structure; the results showed that crossheading excavation has something to do with stress and displacement of the surrounding rock. Combined with the site monitoring results, it provides a reliable basis for the program optimization and security controls of cross roadway construction.

KEYWORDS: Soft rock, Cross-tunnel, Combined support, MIDAS software

1 INTRODUCTION

Gaojialiang coal mine lies in the south of Wangli digging area in Ordos, which located 8 kilometers away from southeast of Ordos. It is a type of soft rock mine geology. Rock strength is low, joint fissure is well developed; the expansion deformation is large, so supporting is difficult. The general geological structure is tilted horizontal occurrence of monoclinic structure to southwest, formation dip less than 5°. Crossheading or contacts the channel excavated causes the formation of cross conformation among the main tunnel, crossheading and contacts the channel. Especially it makes the structure that lies the unilateral of the crossheading or horizontal channel in a very bad condition and deformation characteristics of the force. So we must take some measures to strengthen. The paper uses the element software MIDAS/GTS to simulate the excavation and support when the main tunnel and crossheading cross in the level. The paper studies the discipline of mechanical changes in the progress of dynamic construction, the stability of tunnel and the validity of the support measures. The excavation of crossheading has great influence on the stress and displacement of surrounding rock. According to the site monitoring results, it provides a reliable basis for the construction scheme optimization and security control. And it also comes to a conclusion that the strength on the special soft rock is feasible in technique and acceptable in economic in Gaojialiang mining area.

2 SURROUNDING ROCK DEFORMATION MONITORING OF ROADWAY

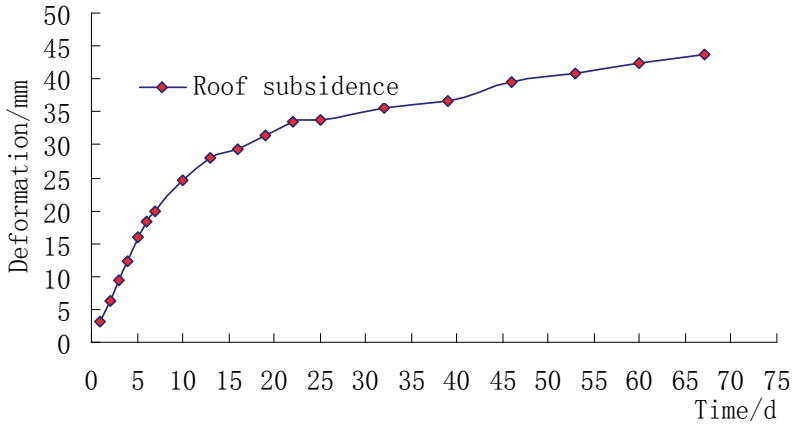

Figure 1 Roof subsidence curve with time

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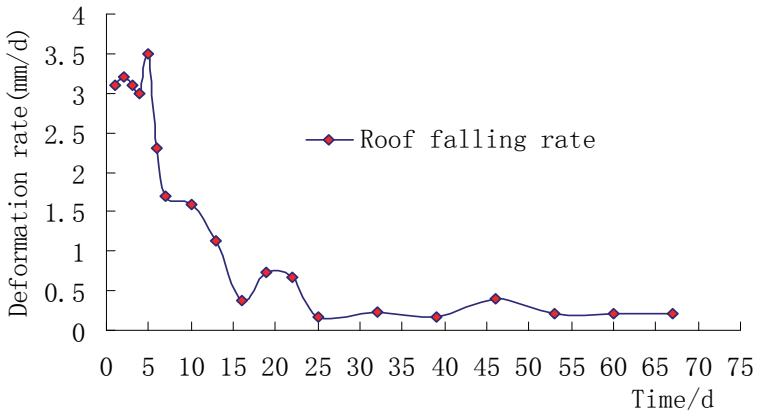

Figure 2 Roof falling rate of curve with time

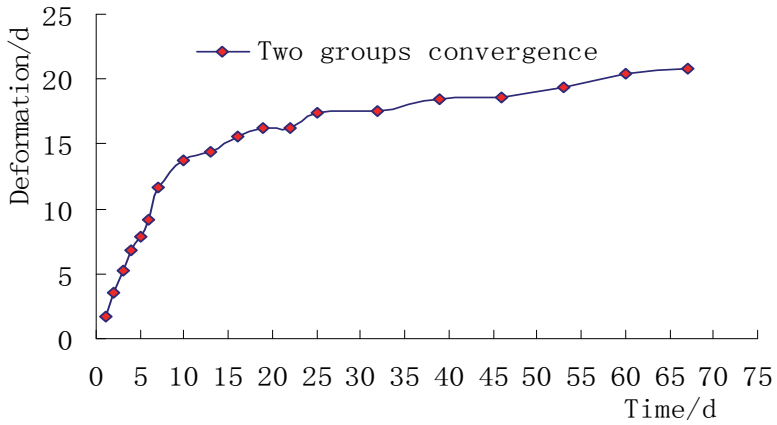

Figure 3 Two groups convergence with time

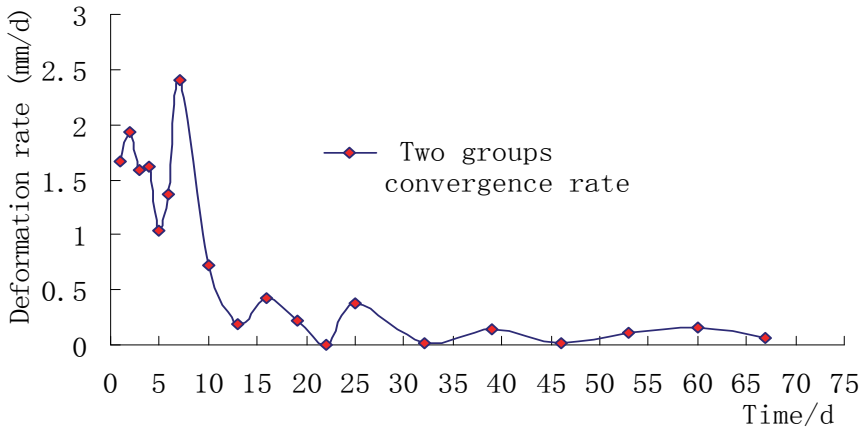

Figure 4 Two groups convergence rate with time

The main performances of roadway's surrounding rock consist of roof separation, sinking, caving, spalling of two groups, slip, backplane muster and so on. As it is shown in Figure 1 and Figure 3 that the deformation of the roof and the two groups is linear relationship with time. Characterized by flowing deformation, which made up of plastic flow and viscous flow, the deformation of the roof and the two groups both decreased slowly with time. As it is shown in Figure 2 and Figure 4 that the convergence rate of roof and two groups characterized by elastic after effect, which decreased slowly with time.

3 THE FINITE ELEMENT MODEL OF CROSS ROADWAY

The model based on the calculation of cross section of auxiliary-roadway and through level of Gaojialiang coals mine. The depth of roadway is 120m, cross section shape is arched besides vertical wall, excavation height is 4.2m, and width is 5.2m. Regarding the overburden stress as the model of vertical load, and lateral pressure coefficient is 1.6.

3.1 Model and boundary conditions

The model size as follows: length is 36m; width is 36m, and height is 24m. And the finite element model shown in Figure 5; There are 68 294 units and 12 920 nodes in total; Shot concrete takes the unit of plate provided by GTS, achieved by the use of disjunctive feature. Anchor bolt with resin anchorage, and diameter is 22mm, the length is 2.5m. Spacing and exclusion are both 800mm. Each anchor node is divided into three implanted with a truss element. The roadway excavation and support achieved by the active and passive function of GTS (as shown in Figure 6), the footage of excavation is 2m. The displacement surface of model constrained by X and Z positive direction. The bottom surface of the boundary displacement constrained by Y negative direction. The state surrounding rock stress is reflected by the lateral pressure coefficient.

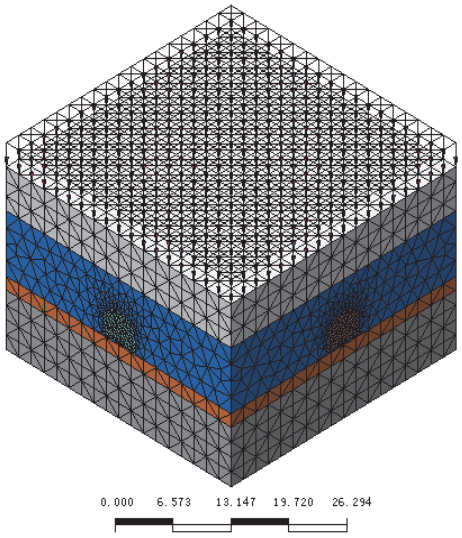

Figure 5 Model trellis

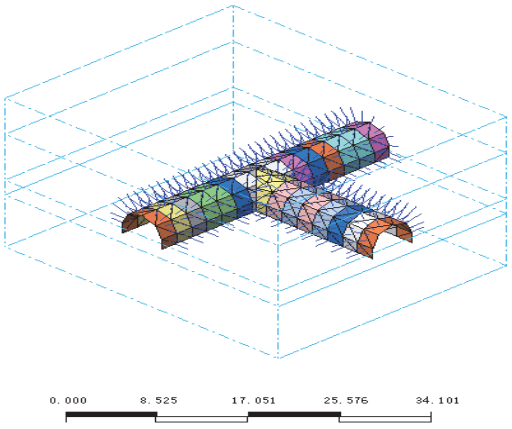

Figure 6 Models supporting unit map

3.2 Rock material model

Rock material is assumed to be isotropic, without considering the impact of ground water and temperature. And rock material stress - strain relationship to the ideal elastic, with M-C strength criterion. Constitutive equation as follows:

$$f=\alpha I_1+\sqrt{J_2}-K=0 \tag{1}$$

$I_1=\sigma_{ii}=\sigma_1+\sigma_2+\sigma_3=\sigma_x+\sigma_y+\sigma_z$ is the first stress invariant.

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$$J_2 = \frac{1}{2} s_i s_j = \frac{1}{6}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^3 + (\sigma_3 - \sigma_1)^2 \right]$$

is the second stress invariant.

$\alpha = \frac{2\sin\varphi}{\sqrt{3}(3-\sin\varphi)}$ $K = \frac{6\cos\varphi}{\sqrt{3}(3-\sin\varphi)}$ α, K are experimental constants which related to internal friction angle and the cohesive force of rock.

3.3 Material parameters

Table 1 Physical and mechanical parameters of surrounding rock

Parameters	*P* (Kg/m^3)	*E* (MPa)	μ	C	φ
Sandy mudstone	2581	9320	0.26	1.06	29.6
Siltstone	2736	13000	0.30	2.47	22.6
Coal	1449	3500	0.32	1.32	40
Fine sandstone	2592	3180	0.2	1.56	37.2

Table 2 Physical and mechanical parameters of retaining structure

Parameters	*P* (Kg/m^3)	*E* (MPa)	μ	Thickness /length (m)	Diameter (m)	Row spacing (m)	Tensile strength (Mpa)
Shot concrete	2 400	20 000	0.2	0.1			1.78
Anchor	7 850	200 000	0.3	2.5	0.022	0.8×1	235

4 ANALYSIS OF SIMULATION RESULTS

4.1 Analysis of stress features

A: Stress characteristics of surrounding rock

After excavation of roadway, the primary stress supported by surrounding rock was compressive stress, two groups and the part of floor were subject to tensile stress, the maximum tensile stress appears at the Intermediate place of baseboard, the maximum tensile stress is 5 930 KN/m^2, more than the tensile strength of alleviate, this also is one of the main reasons why inverted arch generate; The centre of two groups support local tensile stress, the maximum tensile stress is 78 KN/m^2, it is easy to cause rib spalling, which is coincide with the results of field measurement.

After the anchor nets gush combination supporting come into use in Gaojialiang coal mine, anchor rod has changed the stress state of roadway surrounding rock, the stress of two groups of roadway reduced significantly, two arch Angle just second to two groups of roadway. The tensile stress in surrounding rock overall declined, the tensile stress of two groups reduced to 20% of no supporting, the stress concentration phenomenon is also effectively improve but not fundamentally solved, so the local support should be strengthened based on the simulation results.

B: Stress characteristics of support structure

The simulation results show that the shot concrete are basically compressed and pressure values are within the scope of compressive strength, tensile stress occurs in cross-site, the maximum was 13 360 KN/m^2, far more than the shot concrete tensile strength, it is very easily lead to rupture of shot concrete If not reinforce supporting system, the stress concentration increased, lead to the loss of support role.

The results from the anchor stress can be seen that all the anchors are tensed, the waist position shoulder a larger arch pull, and its value is between 70 – 80 KN, which both within the anchor tensile strength and site tests results are consistent with the simulation results, Cross Anchor area significantly greater than other parts of the axial force, maximum axial force reaches to 127.2 KN, taking into account the volume resin anchoring agent drug strength, cross-anchoring site should be improved.

4.2 Analysis of displacement features

A: Characteristics of the vertical displacement

Figure 7 shows that the results of the roof subsidence, the actual deviation is 4.8% compared with Figure 1. Which is site monitoring result. And reach the basic agreement. After auxiliary roadway excavation, the maximum vertical displacement of surrounding rock occurs in the middle floor, the amount of the bottom of arch is 64.2mm; Roof subsidence maximum occurs in cross-site, the amount is 45.5mm, the largest non-cross-site roof subsidence value is 41.6mm. The simulated results provide a reliable basis for stability of surrounding rock of roadway, because the simulation results extracted from the main roof section of roadway just sinking excavation results, far away from the cross-roadway, free from cross-effects roadway excavation.

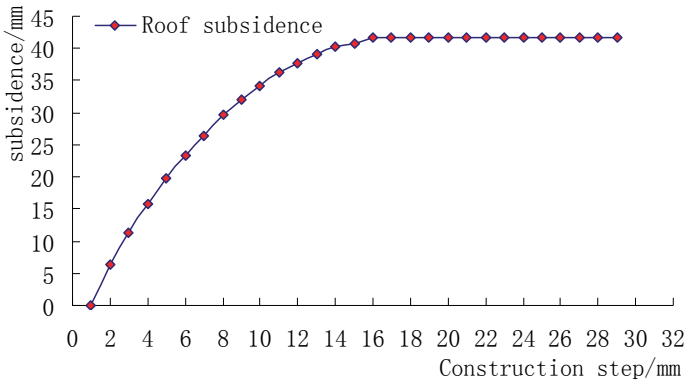

Figure 7 The amount of roof subsidence simulation results map

B: Characteristics of the lateral displacement

The analysis results shows that the horizontal displacement of x direction occurs in the middle between two groups after excavating of the auxiliary transport roadway, which consistent with the monitoring results, both sides are basically symmetrical, the largest convergence is 56.7mm on the cross part of roadway, so the roadway need to strengthen support, and the largest non-cross-site convergence value is 39mm.

C: Displacement analysis of cross-site

The roadway intersection is a key component of construction support; auxiliary roadway is a single one before the tunnel operation, the existing support measures meet stability requirements, for the study of roadway excavation trough cross to the impact of the original roadway, we should focus on cross-site analysis to identify the weak links and to strengthen support so that avoid a partial collapse or the whole stability of the roadway.

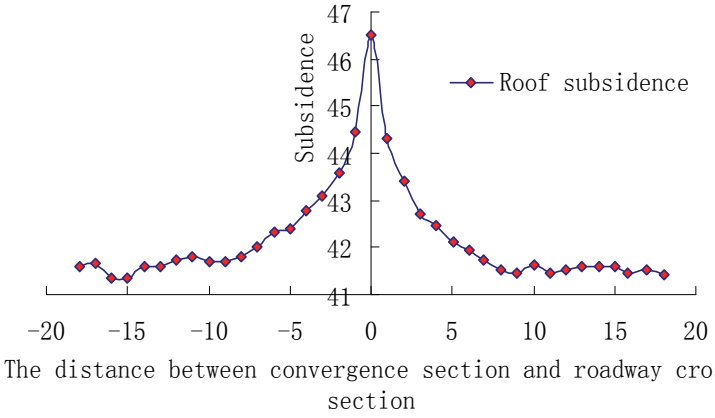

Figure 8 The main roadway vertical displacement curve

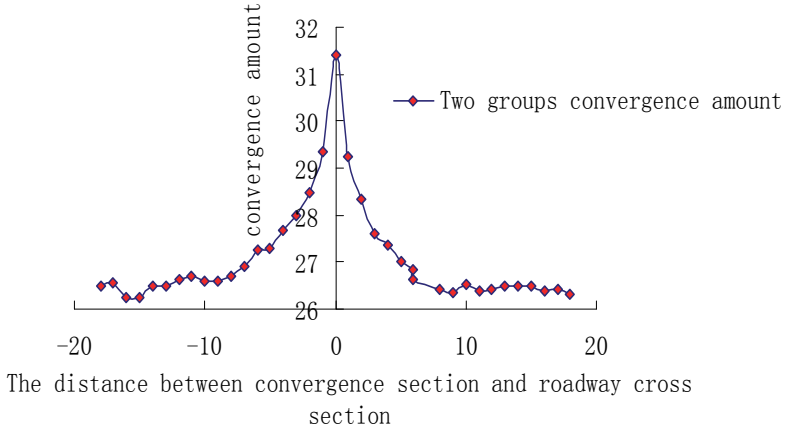

Figure 9 The main roadway transverse displacement curve

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Figure 8 shows that the surrounding rock vertical displacement influenced by the intersection of roadway after the excavation of the main roadway, we can see from the figure that the main roadway is closer the crossroad, the roof subsidence is greater, indicating that the roof sinking is greatly impacted by the excavation of cross-road, the range is -7 - 7meters, to the intersection of roof subsidence occurred at the maximum value of 43.7mm.

Figure 9 shows that the surrounding rock lateral displacement of X positive direction influenced by the intersection of roadway after the excavation of the main roadway, we can see from the figure that as the cross tunnel excavation, the closer the distance to cross-roadway, the greater the lateral displacement. The range is -6 - 6 meters, the lateral displacement increase significantly in the intersections of cross-roadway and main roadway, it is easy to destroy the surrounding rock, we should focus on supporting to this site.

5 CONCLUSION

A: The rock in the mining area of Gaojialiang has a big deformation, the initial deformation rate is large, duration of deformation is long, the stability is related to the stress difference and the form of the tunnel cross-section.

B: Through the maximum principal stress dug distribution and the maximum principal stress distribution after anchor support contrast shows that the impact on tunnel roof and the two sides extension board is obvious, which has great improve the support ability and the support scope of the two sides extension board, Tensile stress of the two sides is reduced to 20% of unsupported. The quantity of heaving floor is the main part in the displacement of the rock, which greater than the convergence of the rock two sides and the deflection of the roof respectively. And it is matched up to the practical situation, and keeps the consistence with the results investigated and surveyed in the site.

C: Through site survey and computer simulation, most of shot concrete support roadway measures meet the stability requirements, conventional methods cannot meet the support requirements of rock stability in roadway cross-site, the roadway excavation has a big impact on the stability of original main surrounding rock, the range is 3 meters or so, we should focus on strengthening support.

D: Obtained by numerical analysis of the amount of dome subsidence was consistent with the on-site monitoring, proving the correctness of the numerical analysis results. Shot concrete support body stress analysis shows that the main roadway and the cross-roadway meet the requirements of intensity, cross-sectional stress concentration is serious, shot concrete is seriously tensed, far more than its tensile strength, so need to strengthen support. Anchor axial force analysis shows that the two groups of main roadway and cross-roadway shoulder great force. The maximum axial force reaches to 70 - 80KN, and other parts of reaches to 40 - 50KN, the overall cross-section of anchor force is too large, the maximum axial force value reaches to 120KN, we need to improve support measures.

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