Effect of anchor-injected support of the dip heads adjacent rock stability based on the distinct element

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Abstract: Due to the direct roof structured by sandy mudstone and the direct floor structured by carbon mudstone in three closed slant roadways in one coal mine, the intensity of direct roof and floor is poor which is acted as the extreme instable steam. The extreme instable steam has brought heavy effects on safe construction and normal utilization in roadway. Mechanism of the bolting and bolt-grouting support wall-rock has been analyzed further by the distinct element method. Comparing bolting support with bolt-grouting support by numerical simulation UDEC, all mechanical, displacement and damage character of the wall-rock have been put forward. In the end, the influence of stability on the slant wall-rock from bolting support and bolt-grouting reinforcement has been indicated. The article utilizes the discrete element method conferring adjacent rock action mechanism of the bolting and anchor-injected support, and proceeds numerical simulation to this two types of support method by using the discrete element software UDEC, and then deeply researches mechanical character, displacement character, and damage character of the dip heads adjacent rock after the bolting and anchor-injected reinforcement, after that it analyses the effect of bolting and anchor-injected support stability of influence the dip heads adjacent rock with the constrating method, thus it provides a reference basis for suitable support of the dip heads adjacent rock.

Key words: the closed slant, distinct element, reinforcement of grouting and bolting, mechanical character of surrounding rock

1.Geomechanics of the dip heads

Two-one coal bed thickness is about 3.2m in the Mine Coal, appears on pulverescent structure and has about 0.07m thickness dirt in it. The immediate roof is sandy mud stone of 5.74m thickness, contains a little of amount carbon and uncompleted phytopaleontology and thin carbon mud stone and some laminated mica in local. The main roof is medium-grain sandrock about 9.57m thickness, appears on medium-grain structure which mainly contains quartz, black mineral next, and also contians some laminated mica on bedding surface. The immediate bottom is carbon mud stone of 1.0m thickness, appears on lamellar and foliated structure, and contains a little amount of phytopaleontology in it. The main bottom is sandy mud stone of 5.44m thickness, and contains carbon and phytopaleontology on upper part and sandyrock smuggle in local place. The three dip heads arranged on the same coal bed is shown in Fig.1. Return dip head, rail dip head and transport dip head all exhibit on arch cross-section. Furthermore, they are of the same size, width of the tunnels is 1.5m, height of the stalk is 1.5m, and height of the arched-type is 1.5m. In order to erase boundary, spacing intervals among the three dip heads in horizontal direction are set for 133m when the dipheads are advancing along bottom of the coal bed.

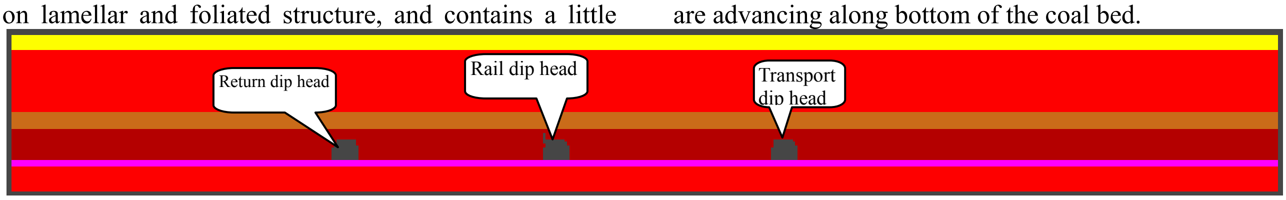

Fig.1 Two-dimension model graticule figure of arrangement of the dip heads

Because the three dip heads are arranged on the same coal bed, coal bed appears on cloddy pulverescent structure, and the geological condition is very simple. But from the geological condition of the dip heads we can see that the immediate roof of the dip heads are sandy mud stone, self-strength is low, rock stratum contains water, consolidation is weak, easily forms loose stuff, and will melt further when rock stratum meets efflorescence, which belongs to the unstable incompetent bed[1]. Adjacent rock will cause serious destruction and bring many difficulties to the tunnel driving, support and maintenance when the dip heads are advancing. The immediate bottom of the dip heads is carbon mud stone of which is very low, and often causes large floor-drum in underground pressure. Observation in the scene indicates that adjacent rock seriously changes the form, even some-

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times may cause caving accident in this tectonic complex zone when the dip heads are advancing, and seriously affects safety construction and regular service of the dip heads.

This actual geological status extracts a difficult problem to the scene bolting design, and whether it can meat suitable supporting demand if tunnel driving uses pure bolt support. The article utilizes the method of combining theoretical analysis with numerical simulation, analyses stability effectiveness of the bolting and anchor-injected support with comparing method, confers support parameter of the dip head adjacent rock, to prevent large changing shape of the adjacent rock, and thus provides a reference basis for suitable support of the dip heads adjacent rock.

2. Theoretical analysis of the dip head adjacent rock via the discrete element method

2.1.Mechanics summarization of the anchor injected support

Bolting and anchor-injected support are the basic support form of support in the rock-soil engineering, such as tunnels, It is a new path to solve the difficult problem which realizes the anchor-injected integration with bolt concurrenting injected pipe[2].

1)Using the anchor-injected support manner, the adjacent rock of loosening fracture will be cemented whole body by serous fluid after adopting the anchor-injected method, thus enhance strength of the rock mass, effectively change mechanical physical characteristics of the rock mass, achieve to utilize self-adjacent rock as a section of support structure, and full swap self-supporting ability of the adjacent rock.

2) Using the anchor-injected support manner can utilize cap adjacent rock crack,with serious fluid isolate air, prevent adjacent rock decency, inhibit adjacent rock by water soaking to reduce self-strength of the adjacent rock, and then improve stability of the adjacent rock.

3) Using the anchor-injected support to fill adjacent rock crack can form a multiplex effective combination arch, bolt compressing combination arch, and serous fluid diffuse strengthening arch, and thus enlarge effective loading scope of the support structure, then improve entirety and loading ability of the support structure[3]~[5].

2.2.Adjacent rock action mechanism of the anchor-injected support with the discrete element method

The discrete element method is a numerical method of the explicit solution. When the explicit method is used to count, all the equation unilateral variable are known, and the other unilateral can solute it as long as use the simple substitution method, that is to say, assumed in every substitution hour-pace, every bolck unit causes force influence only to its adjacent rock bolck unit, so, the hour-pace need get enough small to keep the explicit method stability[6].

Bolting anchoring rock mass mainly relies on its axial tensile force, and bending distortion of the bolt is not considered. Therefore, it is agreed that seeing bolt as one dimension unit bar, and when the block of bolt anchoring causes advection and rotary movement, see the equation:

$$\{X\} = [T]^{-1}\left[\bar{K}\right][T]\{\mu\} = [K]\{\mu\} \tag{1}$$

In equation: $\{X\}=[X_1\ Y_1\ X_2\ Y_2]^T$; $\{\mu\}=[\mu_1\ \nu_1\ \mu_2\ \nu_2]^T$; $\{X\}$ is general force vector matrix of acting on rod end; $\{\mu\}$ is general displacement vector matrix of acting on rod end; $[K]$ is stiffness matrix; $[T]$ is transformation matrix.

Count creating force of bipolar of the blot, and then proceed the discrete element method iterative computing by stressing force on the block centre of form.

Anchoring ability of the bolt count according to an equation counting:

$$F \le \frac{\pi d^2}{4}\sigma_b \tag{2}$$

In equation: F is axial tensile force of the bolt; d is bolt diametric; σ_b is yielding limit of strength of the bolt.

The anchor-injected support to anchoring effectiveness of its anchoring body can be simulated with two spring element in the discrete element. It is shown in Fig.2.

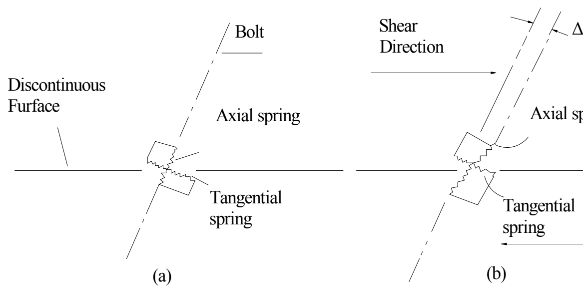


Fig.2 The anchor-injected bolt contrast figure in forward (a) and rear (b)

One spring element parallels effective length to supply axial force, the other one to supply shear force, axial force and shear force of the bolt can be counted by displacing increment of effective length end:

$$\left.\begin{aligned} F_a &= \kappa_a \Delta\mu_a \\ F_s &= \kappa_s \Delta\mu_s \end{aligned}\right\} \tag{3}$$

In equation: F_a, F_s are axial force and shear force; κ_a , κ_s are axial rigidity and shear rigidity; $\Delta\mu_a$, $\Delta\mu_s$ are axial displacement and shear displacement of effective length end.

Final axial loading ability (P_{ult}) of the bolt can be determined by extreme value of the rock compression strength σ_c and yield ultimate strength of the bolt σ_b .that is to say:

$$P_{ult} = \min\{0.1\sigma_c \pi d_2 l \quad 0.25\pi d_1^2 \sigma_b\} \qquad (4)$$

In equation: l is consolidated length; $d1$、$d2$ are bolt diametric and drilled diametric.

Tangential shear ability of the bolt is:

$$F_s = 0.25\pi d_1^2 \sigma_b \qquad (5)$$

The article aims at the purpose of study, on the theoretical basis of the dip head adjacent support of the discrete element, utilizes the discrete element software UDEC proceeding numerical simulation analyze the stability of bolting and anchor-injected support.

3.Numerical simulation model establishment and parameter set

3.1.Numerical simulation content

We utilize the discrete element software UDEC proceeding numerical simulation to analyze mechanical character, displacement character, and damage character of the dip heads adjacent rock after the bolting and anchor-injected reinforcement.

3.2. Numerical simulation parameter set

Model calculation the Mohr-Coulomb criterion is used as rock damage criterion. Every horizon nature in the model mainly is base on test result obtained in lab, of which parameter is shown on Table 1.

Table 1 Coal and rock physical mechanical parameter

	main roof	main roof	Immediate roof	Two-one coal bed	Im-medi-ate bottom	main botto-m
Tensile (MPa)	4.31	3.21	2.21	0.2	1.35	3.21
Elastic (GPa)	20.56	18.37	15.37	2.12	10.25	18.37
Con (MPa)	5.45	5.62	5.32	4.96	5.21	5.62
Friction (°)	28.0	29.0	31.0	31.0	30.0	29.0

Vertical stress along tunnel depth of burial appears lineal change in experiment plot, tunnel depth of burial is about 520m, terrene average bulk is about $2500 kg/m^3$, besides, the two-side of return dip head and rail dip head are both goaf, vertical stress central coefficient is 2, correspondent to 1040m of depth of burial. So applied vertical stress on model upward side is -13Mpa, and considering tectonic stress influence, horizontal stress takes more 1.4 fold than vertical stress. Bolt length of the dip head immediate roof is 2.4m and end-bolt length is 1.8m. The anchor-injected scope is among 1.5~2.0.

3.3.Calculating process

(1) Model vest original rock stress;

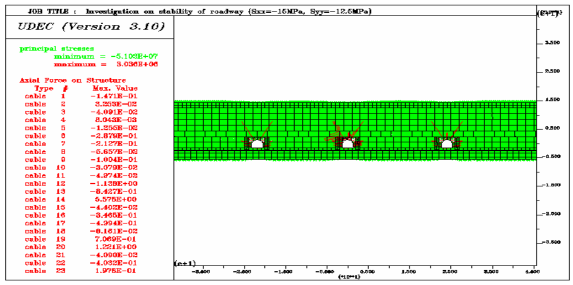
(2)Cutting dip head and bolt construction (bolt and anchor-injected);

(3) Applied inherent stress.

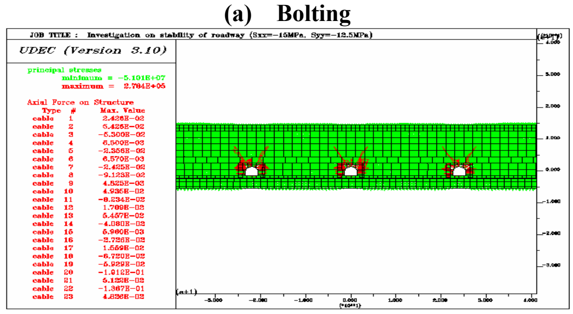
4.Numerical simulation result analysis

4.1.Mechanical character analysis in addition to bolting and anchor-injected support

From Fig.3 we can see that obvious distinguish with bolting in the three dip heads adjacent wall rock. Firstly,



(a) Bolting



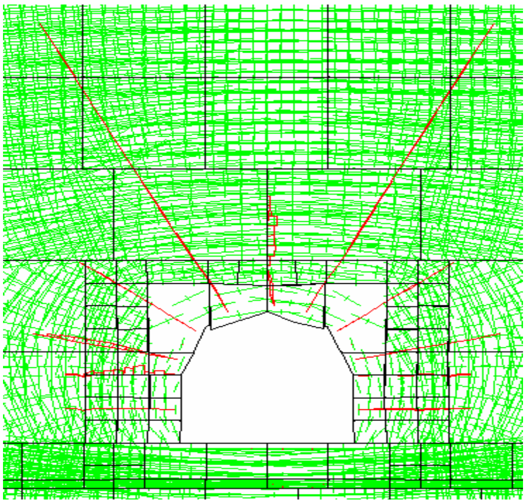
(b) Anchor-injected support

Fig.3 Mechanical character full figure of the dip head adjacent rock

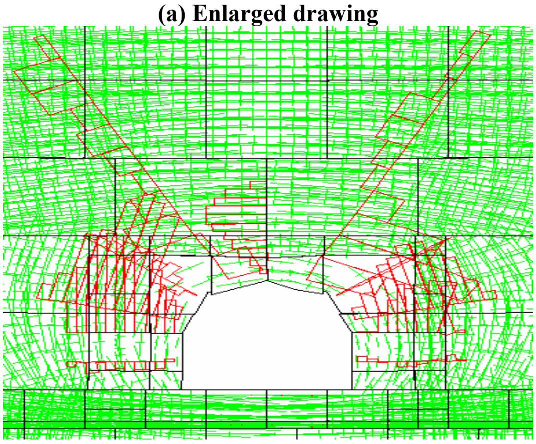
stress influence scopes in bolting are greater than anchor-injected support. Max and min primary stress of the dip heads adjacent stability under bolting are all less than those under anchor-injected support.

From Fig.4 we can see that the return dip head tunnel is not only bolting but also anchor-injected support, adjacent rock anchoring body stress is maximum. After anchoring body stability of every dip head under anchor-injected support, adjacent rock locates in high some stress state, but stress of bolting is lower. It indicates that a large extent damage occurs to the roadway near the surface of coal and rock mass after bolting reinforcement such large deformation of roadway, result a lot of bolted lost capacity of carrying, cause severe roadway deformation, affecting production.

Because when model was established, was set 133m distance among the three dip head, and erase boundary effect, they are almost mutually influence. Therefore, the three dip heads adjacent rock have the same mechanical character, and do not repeat here. Following



(a) Enlarged drawing



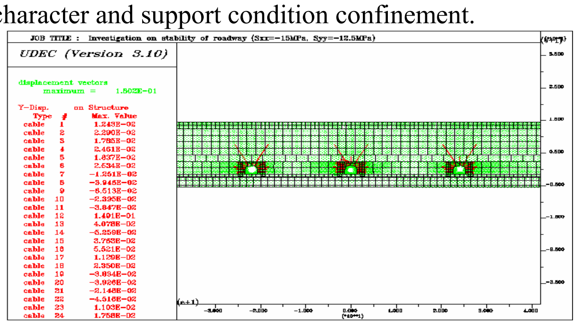
（b）Enlarged drawing under bolting anchor-injected support

Fig.4 Mechanical character enlarged contrast figure of the dip head adjacent rock

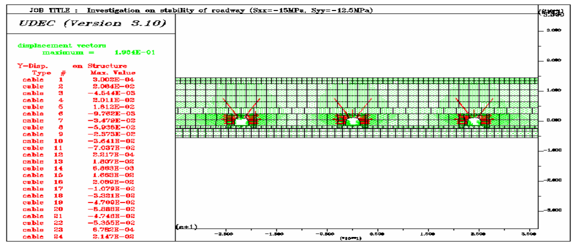
the same method to analyze displacement character and destruction character of the dip head adjacent rock.

4.2.Displacement character analysis of bolting and anchor injected support

The dip head adjacent rock changing shape is the result of comprehensive action in which stress gives off and stop to effect after cutting, is external behavior which the adjacent rock not only suffered from external engineering effecting, but also suffered from self-physical mechanical character and support condition confinement.



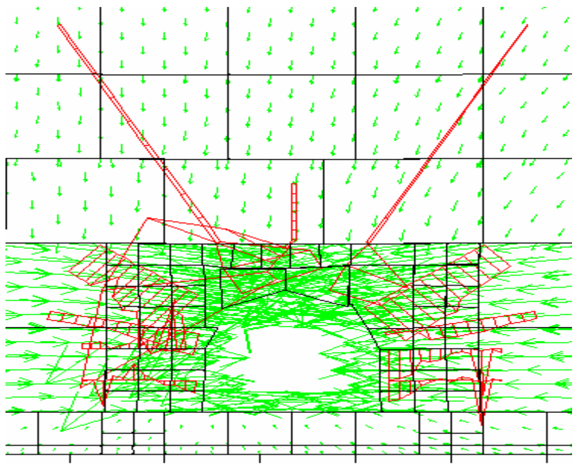
(a) Bolting



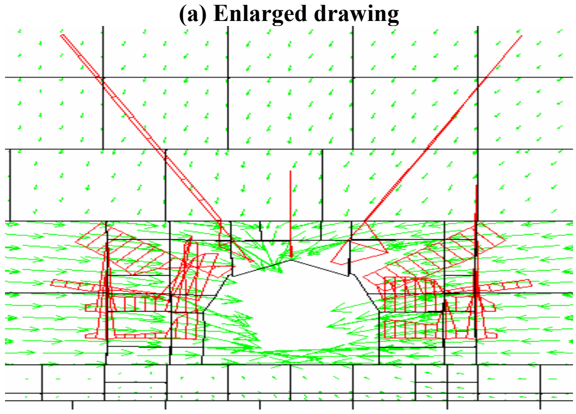
(b) Anchor-injected support

Fig.5 Displacement character full figure of the dip head adjacent rock

In order to research more clearly and comprehend outcome after every dip head anchor-injected support, we take the displacement character of the anchoring body enlargement to the return dip head, which is shown on Fig.6. We can understand that the return dip head adjacent rock changing shape of anchor-injected support is more serious than bolting. Roof coal rock mass appears on slough phenomenon in bolting of the return dip head condition and corresponding to anchor-injected support does not appear on slough phenomenon. Obviously, the anchor-injected supports superiority and effectiveness have few externalizations on the adjacent rock displacement.



(a) Enlarged drawing

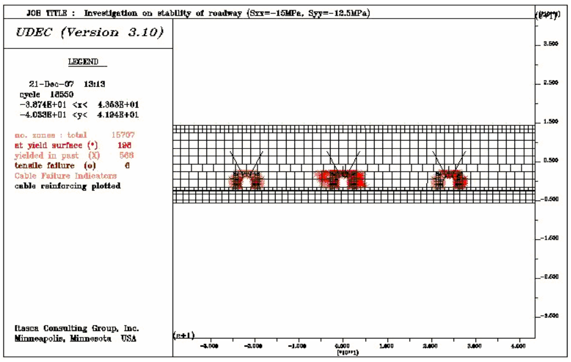


（b）Enlarged drawing under bolting anchor-injected support

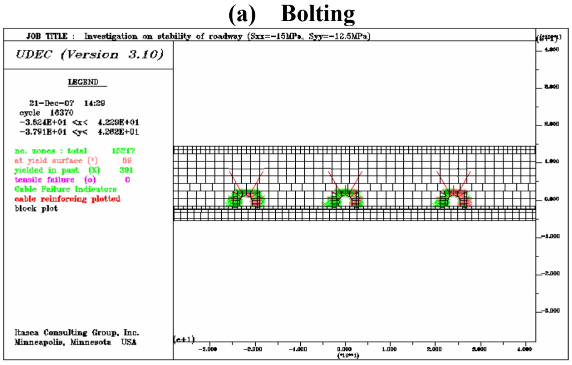
Fig.6 Displacement character enlarged contrast figure of the dip head adjacent

4.3.Damage character contrast analysis of bolting and anchor-injected support

Every dip head adjacent rock damage character of bolting and anchor-injected support is shown on Fig.7. From macroscopic view, the dip head adjacent rock damage scope of bolting is larger than that under anchor-injected support.

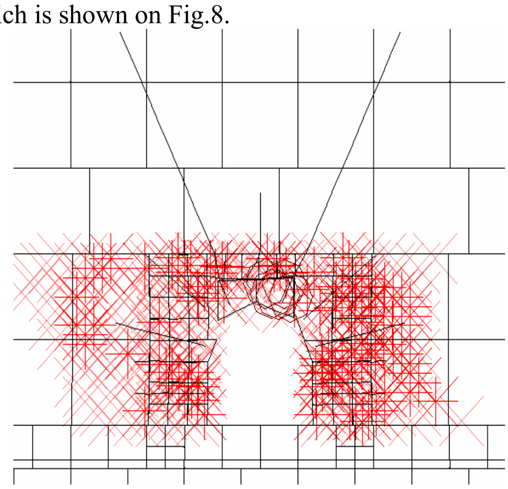


(a) Bolting

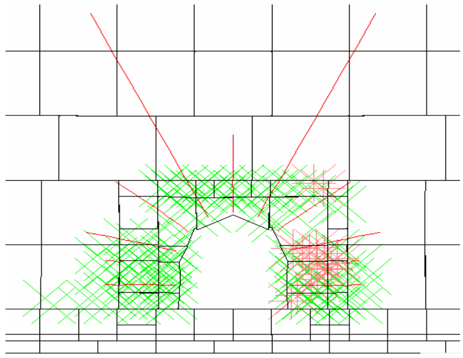


(b) Anchor-injected support
Fig.7 Damage character
full figure of the dip head adjacent rock

The dip head adjacent rock and anchoring bulk damage character proceed contrast analysis in local enlargment, which is shown on Fig.8.



(a) Enlarged drawing



（b）Enlarged drawing under bolting anchor-injected support
Fig.8 Damage character
enlarged contrast figure of the dip head adjacent

From the fig.8 we can get that the adjacent rock yield surface amount, tensile failure scope and slip inactivation amount of bolting are all more than anchor-injected support. Especially, the return dip head roof coal rock is obvious to appears large scope destruction and emerges some local caving line in condition of bolting and does not appear this phenomenon with anchor-injected support.

5.Conclusions

(1) Utilizing discrete element tunnel support theory to make stability analysis of the dip head abjection rock in condition that in bolting and anchor-injected support, and then provides a theoretical basis for suitable support of the dip heads adjacent rock.

(2) Through numerical simulation analysis we obtain that: anchoring bulks of the dip heads adjacent rock on character of mechanical, displacement and damage all show that anchor-injected support is more suitable reinforcement this heavily stressed soft tunnel than bolting.

(3) Using anchor-injected support technology can take loosening cracking adjacent rock to cementation integrality, improve the rock bulk strength, and then keep the tunnels stability and uneasily cause destruction. Therefore, the anchor-injected support technology adapts to support and harness in the Mine Coal.

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