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Stability Analysis of Surrounding Rock with the Tilted Weak Intercalation Throughout Roadway

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Abstract: In order to research to the influence of the tilted weak intercalation throughout roadway form different site on stability of surrounding rock,analyse the influence of the weak intercalation on the displacement field, stress field and plastic zone of surrounding rock of which no weak intercalation,weak intercalation throughout roadway on top, middle, bottom four models under the same condition by using numerical simulation software Flac^{3D}. Comparison of numerical results show that existence of weak intercalated layers lead to overall roadway surrounding rock displacement field, stress field non-uniform distribution, the increased scope of plastic zone, the parts of weak intercalated tend to large deformation. Relatively the roadway roof stability of the worst when the weak intercalated through the top of roadway. Based on the roadway deformation observation in the field also verify the results of the numerical simulation analysis. If there is weak intercalated layers throughout the roadway,it should take corresponding support measures to control displacement, stress concentration and the increase in plastic zone caused by weak intercalation, having the definite guiding significance for support measures under appropriate conditions in the future.

Key words: Tilt occurrence, weak intercalation, throughout roadway, large deformation, stability of surrounding rock

INTRODUCTION

Considering that deposit conditions for geological stratums of different categories differ, the surrounding rock of roadway during mining process is not intact rock but is composite in structure made up of rocks of different categories. These rocks with different composite structure differ significantly in terms of strength and mechanics characteristics. Such surrounding rock of roadway as contains rock of low strength and large deformation is entitled as weak structure or weak intercalation (Zhang *et al*., 2005; Zhang, 2009; Chang and Xie, 2009). At present, scholars at home and abroad have conducted a great deal researches on support of weak rock, producing fruitful results. However, no effective means of support has been found for support of with surrounding rock with weak intercalation throughout roadway. In actual mining activities, roadway with weak intercalation is supported according to support theory and experience for ordinary soft rock roadway, producing no satisfactory results. In this research, mechanics characteristic of surrounding rock with tilted weak intercalation throughout semicircle arch straight wall roadway have been taken as the research object and numerical simulation software Flac^{3D} has been employed to investigate the effects of weak intercalation throughout roadway at different positions on the stress, deformation and destruction of the surrounding rock in the hopes of generalizing the influencing roles and providing references for security evaluation and construction design of the roadway under the same conditions (Liu *et al*., 2004; Zhou, 1993;Yang *et al*., 2008; Guan and Jia, 2006; Wang *et al*., 2007; Fan and Zhuo, 2004).

Infrastructures of shaft of Damoling mine in Xinmi city are under construction at the moment. The western air return way is located 426.5m below the ground, the tilt of surrounding rock approximately 26° and the section of the roadway designed to be straight wall semicircle arch with net width, net height and wall height being 5100, 4350 and 1800 mm, respectively. The western air return way has been seriously deformed due to effects of sliding structure of geological stratum. In addition, weak intercalation has been detected in many places through roadway, resulting in severe destruction to some positions of roadway. Hence, it is of high necessity to conduct theoretical research and analysis regarding

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effects of tilted weak intercalation through roadway at different positions on stability of surrounding rock of roadway.

VALUE CALCULATION MODEL AND ANALYSIS OF LABORATORY TEST RESULTS

Establishment of the model: The research is based upon Damoling mine in Xinmi city. The roadway is designed to be embedded 500 m underground with net width, net height and wall height being 5100, 4350 and 1800 mm, respectively. The weak intercalation, 400 m in thickness, is titled 30°. The design model has been reserved to be large enough to eliminate boundary effect with length, width and height of 50, 30 and 30 m, respectively. The upper boundary of the model is stress boundary and the load equals dead weight of overlaying strata, approximately 12.5 Mpa. The model is horizontally bounded by horizontal displacement and the horizontal stress is calculated with help of formula $\lambda = 1$. The lower boundary of the model is designed to be bounded by vertical displacement. The model is simulated by Mohr-Coulomb strength theory.

Four models have been established to investigate the effects of tilted weak intercalation through roadway at different positions on mechanics characteristics of surrounding rock of roadway. Model 1 is for zero weak intercalation, model 2 for weak intercalation throughout the top of roadway, model 3 for weak intercalation throughout the middle of roadway and model 4 for weak intercalation throughout the bottom of roadway (Fig. 1). All the numerical values of rock coefficients are simulated (Table 1) on the basis of laboratory test results with suitable deductions as per the reference book (Wang *et al*., 2003).

Effects of location of weak intercalation on deformation of surrounding rock of roadway: In the course of excavation of roadway, deformation of the surrounding rock could best demonstrate the change of rock mechanics state and stability of the surrounding rock. In order to eliminate effects of boundary effect, roadway section at 15 m on y axis has been selected to take top point, left springing, right springing and middle bottom point to trace and monitor the displacement and deformation of roadway. Tracing points have been

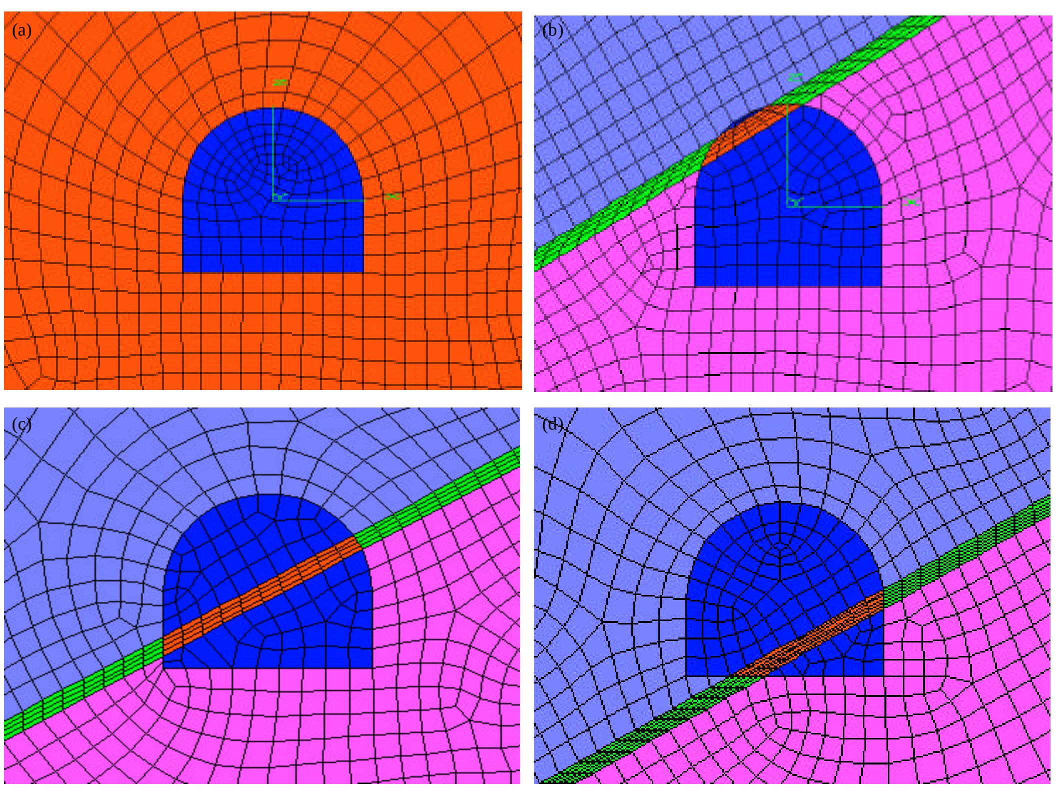

Fig. 1(a-d): Laboratory models for four categories of weak intercalations through roadway at different positions (a) Model 1 (b) Model 2 (c) Model 3 and (d) Model 4

Table 1: Physio-mechanics characteristics of surrounding rock and rock with weak intercalation

Name	Modulus of Elasticity E/GPa	Poisson ratio/μ	Internal friction angle φ/°	Cohesion c/MPa	densitykg m^{-3}
Surrounding rock	1	0.23	46.2	1.2	2500
Weak intercalation	0.075	0.38	25	0.05	1400

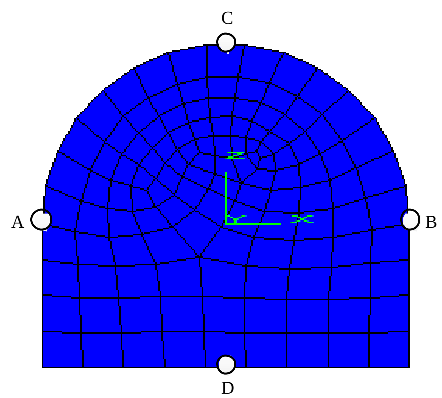

Fig. 2: Positions of tracing points for deformation of roadway

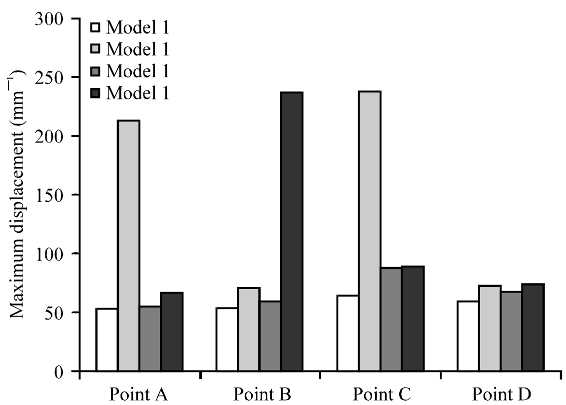

Fig. 3: Column chart of maximum displacement of roadway with weak intercalation at different positions

indicated in Fig. 2 and the treatment results of data are given in Fig. 3.

As shown by Fig. 3, the displacements at points A and C in model 2 (weak intercalation throughout the top of roadway) are approximately 4 times as much as displacements in model 1 (zero weak intercalation); the displacements at points B and D in model 2 is 1.2-1.3 times as much as those in model 1. The displacements of the four tracing points in model 3 (weak intercalation throughout the middle of roadway) have risen slightly by 1.02-1.34 times in contrast with the displacements in model 1. The displacements at point B in model 4 (weak intercalation throughout the bottom of roadway) are approximately 1-4 time(s) as much as displacements of model 1 (zero weak intercalation) and the displacements at points A, C and D in model 4 are 1.24-1.36 times as much as those in model 1.

Based on the above analysis, it could be learnt that the existence of weak intercalation is the cause for instability and deformation of roadway and roadway with weak intercalation is easily susceptible to large deformation as weak area of roadway and key position for support.

Effects of location of weak intercalation on displacement field of surrounding rock of roadway: In order to eliminate effects of boundary effect, roadway section at 15 m on y axis has been selected to analyze changes of the displacement filed of roadway. Displacement vectors of the surrounding rock have been indicated in Fig. 4.

It could be seen from Fig. 4 that the roadway without weak intercalation has stable symmetric displacement which is favorable for support and weak intercalation at different positions could affect the roadway deformation differently. Relatively speaking, in the case that weak intercalation appears at the top of roadway, the effects on stability of roadway could be enormous as shown in Fig. 4b. Deformations of roadway are distributed asymmetrically and the surrounding rock at the top tends to slip along the weak surface and there is high possibility of sloughing at the joint between the roadway and weak intercalation where the deformation is relatively large. In this case, it is difficult to maintain the top and support the roadway. When weak intercalation appears at the middle of roadway, the area surrounding weak intercalation has more deformation in comparison with the deformation of roadway with intercalation at the top. However, in this circumstance, the stability of the roadway is not considerably affected. When weak intercalation appears at the bottom of roadway, deformation of weak intercalation area is increased significantly and the projection on the bottom of roadway could affect the roadway as well. However, in this circumstance, the stability of the roadway is not considerably affected in comparison with the deformation of roadway with intercalation at the top.

Effects of location of weak intercalation on stress field of surrounding rock of roadway: Excavation of roadway has changed the stress of surrounding rock from tridimensional stress to near dimensional tress, resulting

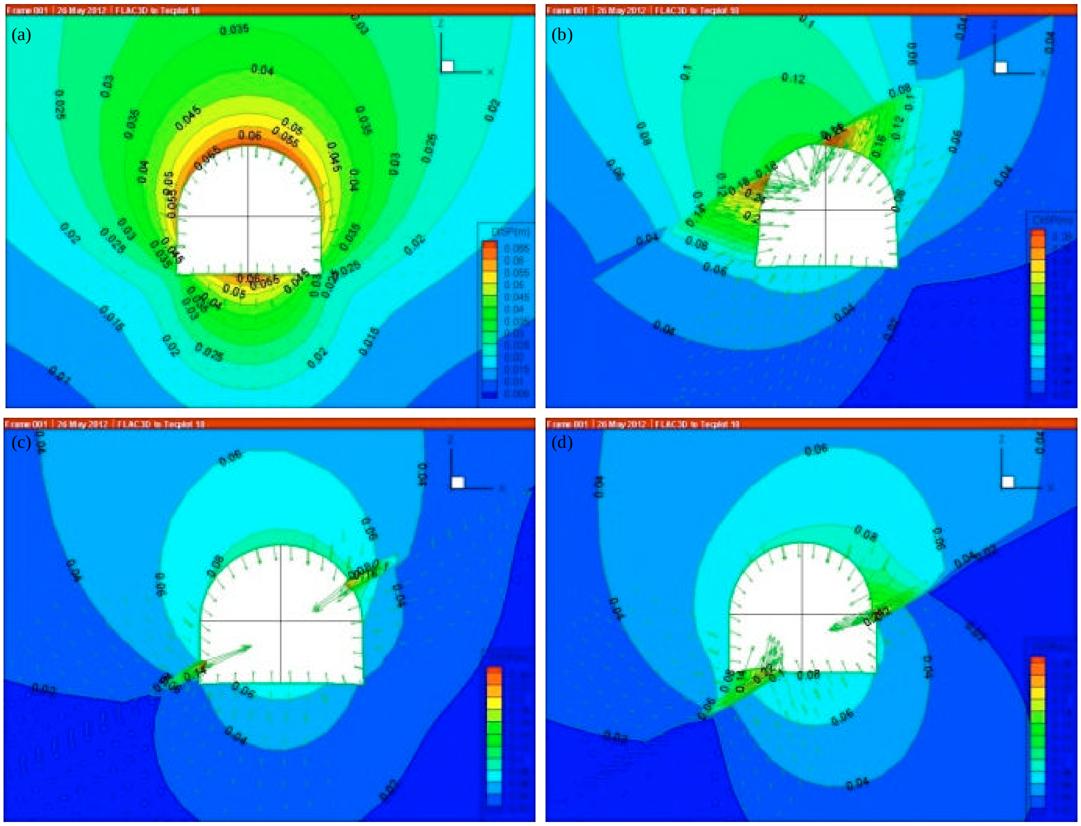

Fig. 4(a-d): Displacement vector of surrounding rock of roadway with weak intercalation at different positions (a) Model 1 (b) Model 2 (c) Model 3 and (d) Model 4

in big drop of rock strength and redistribution of rock stress (Dong, 2001; Zhang *et al*., 2000; Fairhrust and Pei, 1990).

Weak intercalation could be first destroyed due to its low strength and other reasons. In addition, the system of surrounding rock and weak intercalation could be easily interrupted to become unstable. Changes of maximum stress field, horizontal stress and vertical stress could demonstrate the overall stability of surrounding rock of roadway.

Based on comparative analysis, it could be learnt that the maximum stress of surrounding rock without weak intercalation is distributed symmetrically, evenly and does not cluster (Fig. 5). The horizontal and vertical stresses are also distributed symmetrically, clustering within approximately 1 m area on the top and sides of roadway respectively.

For the roadway with weak intercalation, stress field is distributed unevenly with low stress area larger near roadway and stress clustering apparently at weak intercalation. In contrast, the high stress field moves toward weak intercalation, having larger area but lower maximum value. In addition, when weak intercalation is located on the top of roadway, the low stress field is increased in area and the stability of roadway is the worst. Weak intercalation at different positions of roadway has different effects on stability of the surrounding rock. Weak intercalation is weak area of roadway. With weak intercalation at the top of roadway, the stability of rock could be interrupted which could easily result in sloughing. With weak intercalation at the belt lines of roadway, cluster of stress could be intensified and deformation of the belt lines could be multiplied. With weak intercalation at the bottom of roadway, high stress area could be enlarged and the projection at the bottom increased.

Effects of location of weak intercalation on plastic zone of surrounding rock of roadway: Plastic zone is formed after the excavation of roadway as final redistribution of rock under stress. The size of plastic zone could be taken as a major factor to evaluate the stability of roadway, whose four models have been given in Fig. 6.

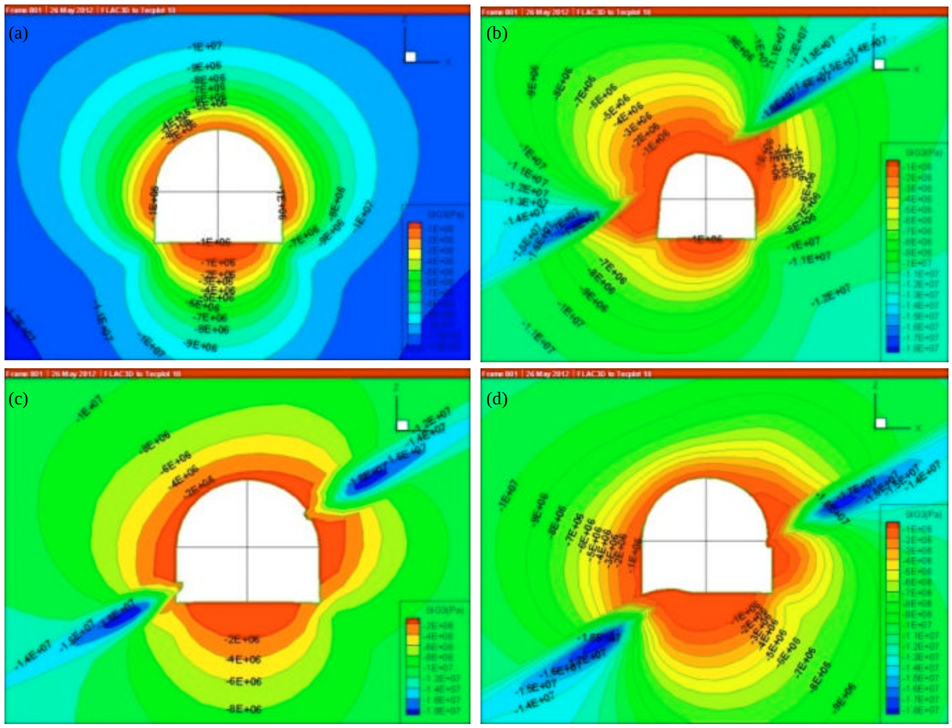

Fig. 5(a-d): Distribution of maximum stress of surrounding rock of roadway with weak intercalation at different positions (a) Model 1 (b) Model 2 (c) Model 3 and (d) Model 4

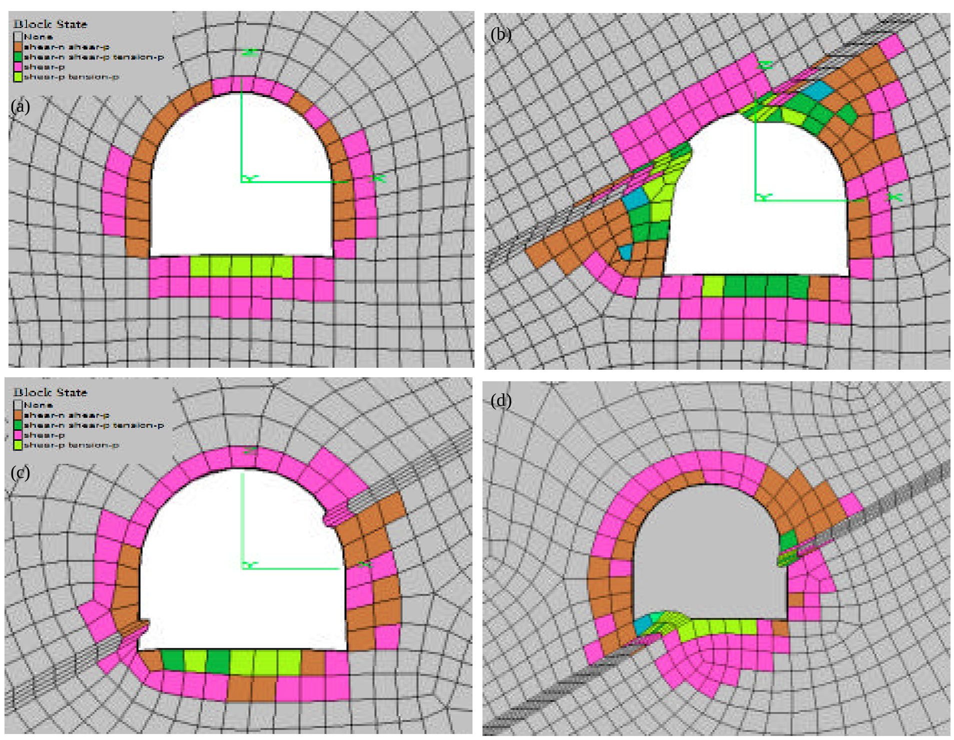

Fig. 6(a-d): Distribution of plastic zone of surrounding rock of roadway with weak intercalation at different positions (a) Model 1 (b) Model 2 (c) Model 3 and (d) Model 4

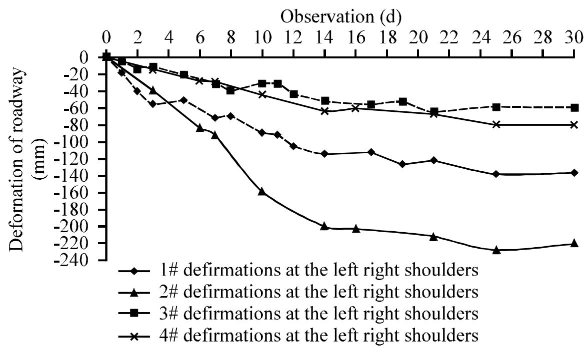

Fig. 7: Curves of deformations of roadway

Based on comparative analysis of laboratory test results, it could be learnt that the plastic zone of surrounding rock without weak intercalation is distributed symmetrically and evenly. Existence of weak intercalation has lead to rise of area of plastic zone and the plastic zone for roadway with weak intercalation has been increased, by 2-4 times in comparison with that for roadway without weak intercalation. Hence, the through position of weak intercalation is key position for support of roadway.

ENGINEERING PRACTICE

According to design of Damoling mine in Xinmi city, coal II_1 is mainly mined and approximately 15 m above it lies coal of 0.5 m in average thickness. Coal II_3 is not fully developed due to slide phenomenon in the area. Coal II_3 has the characteristics of complex structure, instability and soft coal. Coal II_3 has appeared in area from 370 to 410 m near west air return way, going thought top of the roadway and giving difficulty to support the top. Deformations of roadway without coal II_3 and with coal II_3 have been measured at site. In the course of excavation, waste rock has been found and scrapper used to locate the observation points. Observation results of a month has been recorded on site and treated as listed below.

No. 1 point is the section without coal II_3 and No. 2 the section with coal II_3. As the curves graph show in Fig. 7, the section without coal II_3 has the maximum sediment of approximately 60 mm at the top of roadway and the deformation of 137 mm at the shoulder. However, the section with coal II_3 has the maximum sediment of approximately 80 mm, about 1.3 times of the section without coal II_3; the deformations at the left and right shoulders are 220 mm, 1.6 times as much as those for the section without coal II_3.

The complex conditions at site may result in error in simulation results, but the bigger increase of deformations of roadway with weak intercalation agrees with results of numerical value simulation results. Hence, the existence of weak intercalation leads to multiple increases of deformations of roadway, having affected overall stability of surrounding rock.

CONCLUSIONS

In this research, numerical contrast and analysis of laboratory test results have been conducted to investigate the effects of tilted weak intercalation through roadway at different positions on stability of surrounding rock. The following main conclusions could be generalized with help of simulation results of observed data at site.

- The existence of weak intercalation leads to instability of roadway and the area with weak intercalation could easily be susceptible to deformation
- The existence of weak intercalation leads to uneven distribution of stress on surrounding rock of roadway. The movement of high stress field toward weak area with weak intercalation results in cluster of stress
- Relatively speaking, weak intercalation throughout the top of the roadway has the maximum effects on stability of the roadway
- The existence of weak intercalation leads to increase in area of entire plastic zone of surrounding rock and the increase is more apparent near the weak intercalation
- Site monitor of deformations of the roadway has testified the simulation results of numerical values: the existence of weak intercalation affects overall stability of roadway

In general, the existence of weak intercalation has apparent effects on displacement field, stress field, plastic field and other aspects of roadway. For roadway with weak intercalation, support measures are of high necessity and support for weak areas shall be reinforced to improve overall stability of roadway. In the research, comparison and analysis are made only to a particular condition and effects of weak intercalation with different tilts, thickness and geological conditions have not been investigated and shall be explored further in future research.

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