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INFLUENCE OF THE STRATIFICATION IN ROCK MASS ON THE STABILITY OF ROADWAYS IN VIETNAMESE COAL MINES

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ABSTRACT: When the excavation of roadways in the rock mass for underground mining the state of initial stress in the rock mass will be changed, otherwise established the new stress state in rock mass (the secondary stress state after excavation) around openings, respectively. The secondary stress state in rock mass has influence on the design and stability of roadways. Recently the estimation values of stress and deformation around roadways in underground mines when they are excavated in bedding rocks is limited problem. One of many factors concerns to the values and directions of the earth pressure on the steel supports is ratio between span of roadways and thickness of rock mass layers. This paper introduces the assessment of the stress and deformation around roadways and internal forces in the steel supports to determinate suitable locations of the friction joints of steel ribs in the roadways when consideration to change span ratio of roadways and thickness of rock mass layers in bedding rocks in the Quang Ninh underground mines of Viet Nam.

Keywords: Stress; deformation; roadways; steel ribs; Phase2

1. INTRODUCTION

According to the amount of roadways excavated along sedimentary rock masses in the Quang Ninh coal area is constantly increasing. Rock masses in Quang Ninh are characterized by a bedding between rock layers. Unlike the initial rock mass, the behaviour of sedimentary rock mass surrounding a tunnel depends on both initial rock and discontinuities between rock layers. The main characteristics of sedimentary rock mass is therefore heterogeneity and anisotropy. In the literature, the effect of discontinuities on the behaviour of rock mass surrounding the roadways and the other openings are usually considered through direct and indirect methods. In direct methods, bedding joints are added directly to the rock mass. In Jia and Tang (2008) [15], a finite element code was used to numerical investigate the influence of different dip angles of layered joints and of the lateral earth pressures factor on the stability of tunnel excavated along the strike of joints in rock mass. Numerical results indicated that both the dip angle and lateral earth pressure factor have considerable impact on the behaviour of roadways. They concluded that for horizontal layered joints, the failure mode is of ‘‘rock beam’’ type; for joints with dip angle rang from 30^0 to 45^0, the failure mode is sliding in of sidewall and the detaching, flexing and breaking of layered rock mass near the shoulder of roadways; for joints at a large dip angle, the failure mode is the sliding of rock mass along the interface of joints and rock mass. In their study, the gravity of rock mass was however not considered. In addition, it is impossible to make a general recommendation of the effect of joints on the roadways behaviour due to the limited number of performed calculations. He et al. (2012) in [16] adopted the distinct element method (UDEC software) to highlight the behaviour of a tunnel under the effect of bedding planes in rock mass. The authors recommend that an asymmetric support structure should be used to reinforce the geologically inclined bedding asymmetric load. Recently, a relatively comprehensive study of the anisotropic behaviour of stratified rock mass in tunnelling conducted by Fortsakis et al. (2012) pointed out the important role of the stratification planes and of the rock mass quality affecting the radial displacements around the tunnel. Only circular tunnels were mentioned in this study. With indirect methods, bedding joints are implicitly considered as transversely isotropic material (Forsakis et al. 2012; Tran et al. 2012). By comparing the displacement developed in a transversely isotropic rock mass with the one obtained in the corresponding anisotropic rock mass, Forsakis et al. (2015) emphasized that rock mass simulation as a transversely isotropic material does not lead to the same displacement field as in anisotropic rock mass due to the sliding effect along bedding joints.

In addition, the results of investigation during excavation roadways in underground mines in Viet Nam show that, they are driven in the rock mass or coal seams which have variable thickness and complex geological conditions. In recent times the solutions for these problems are limited not only in the documents but also in the experiences. Effects of structure factors on the state of stress and deformation of rock mass around roadways can not be simulated by analytical solutions. The numerical methods can be used widely to analysis the stability of rock mass around roadways because of attention to other input rock parameters. Using numerical softwares to design rock supports are obtained in many documents in Vietnam [1-10] and in the other countries [12-23]. However, the influences of the variable thickness of rock mass layers and the location of roadways on the stress and deformation in rock mass around roadways and the rock supports are limited not only in the theory but also in the actually excavation activities. The objective of this study is to highlight the field displacements, failure zones developed in rock mass surrounding roadways and the changing internal forces in the steel supports using a finite element method by Phase2 software [24] incase of consideration to change the span ratio of roadways and thickness of rock mass layers. The results of this studying are also to define appropriated locations of friction joints in the steel supports in roadways. The presence of bedding joints is explicitly simulated. The conclusions arising from numerical simulations contribute to estimate the asymmetry of the roadway behaviour after excavation.

2. ANALYSIS METHOD AND EVALUATION OF ROCK MASS PROPERTIES

It is assumed that span of roadways is 5.0 m and height 4.5 m, roadways with vertical wall and arc crown driven in joint rocks. These geological conditions are the conditions in the Nam Mau coal mine in Viet Nam [1]. The constitutive model using Hoek-Brown failure criterion has been adopted for the rock mass surrounding tunnel (Hoek et al, 2002). The joints strength was evaluated through the Barton and Bandis failure criterion (Barton and Bandis, 1990). In this paper, a range of *GSI* values changing from 10 to 80 has been adopted which covers rock mass quality varying from very poor to very good. The uniaxial compressive strength of intact rock was chosen from 10 to 80 MPa, the modulus ratio *MR* = 500 and the geomaterial constant *mi* = 7. The deformation modulus of intact rock E_i is determined by formula (Hoek and Diederichs, 2006):

$$E_i = MR \cdot \sigma_{ci} \tag{1}$$

The deformation modulus of rock mass (E_{rm}) was calculated base on the following relationship:

$$E_m / E_i = \left(0.02 + \frac{1 - D/2}{1 + e^{\frac{60+15D-GSI}{11}}} \right) \tag{2}$$

The shear modulus of initial rock (G_i) and rock mass (G_{rm}) can be estimated by formulas:

$$G_i = E_i / 2(1+\nu) \tag{3}$$

$$G_{rm} = E_m / 2(1+\nu) \tag{4}$$

Where ν is Poisson's ratio of rock mass.

The rock mass in Nam Mau coal mine is a combination of initial rock and discontinuities, the deformability properties of these elements can be calculated by equations (Barton, 1972; Goodman, 1989) as following:

$$\frac{1}{E_{rm}} = \frac{1}{E_i} + \frac{1}{s_p k_n} \tag{5}$$

$$\frac{1}{G_{rm}} = \frac{1}{G_i} + \frac{1}{s_p k_s} \tag{6}$$

Here s_p is the distance between bedding discontinuities, s_p = 0.5; k_n and k_s are the normal and shear stiffness of the discontinuities.

The other discontinuities strength parameters were obtained on the rock surface quality. The values of the joint roughness coefficient (*JRC*) changed range from 2 to 18. The joint compressive strength (*JCS*) varied from $0.1\sigma_{ci}$ to $0.8\sigma_{ci}$. The *GSI* value is assumed to change from 10 to 80. The parameters k_n, k_s are calculated based on the procedure mentioned above. All rock masses and discontinuities parameters can be shown in Table 1.

Table 1 Properties of the rock mass and joints

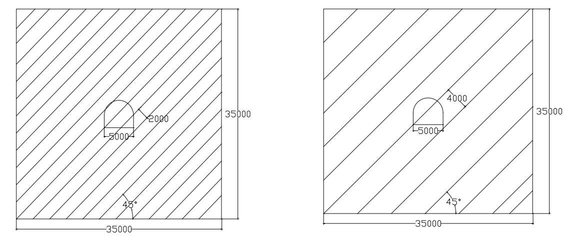
Parameters	Values	
	Sandstone	Siltstone
Unit weight of rock γ, MN/m^3	0.026	0.027
Uniaxial compressive strength of intact rock σ_{ci}, MPa	40	70
Tensile strength σ_t, MPa	0.5	0.7
Cohesion c, MPa	2	4
Friction angle φ	30	35
Young modulus E, MPa	1500	2000
Poisson ratio v	0.3	0.28
Dilation angle ψ, dgree	0	-
Residual tensile strength φ_{re}, dgree	28	32
Residual friction angle c_{re}, dgree	1	0.5
Span of roadways B, m	5	-
Depth of roadways H, m	100	-
Dip angle of rock mass layers α, dgree	45	45
Thickness of rock mass layers D, m	2; 4; 8; 16	2; 4; 8; 16
Lateral earth pressure coefficient K_0	1	
JCS	$0.1\sigma_{ci}$	
JRC	2; 6; 10; 14; 16; 18	

Numerical analyses in plane strain have been conducted using the finite element code Phase2 v.7.0

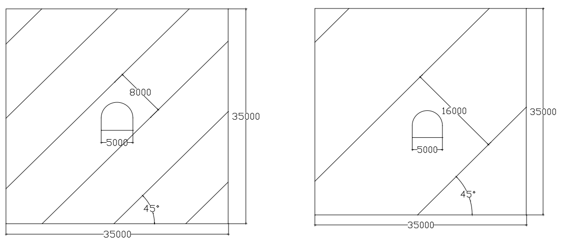
(Rocscience). Totally, there are 12 parametric calculations using the Phase2 software, thus covering most of the possible situation that could be encountered in practice.

3. NUMERICAL MODELING

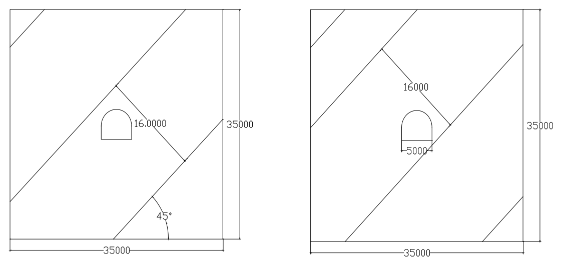
In this section shown the studying stress and displacement around roadways non - circular driven in joint and bedding rocks. The roadway cross section was assumed as an arch-profile crown and vertical sidewalls with dimension of 5.0 m wide and 4.5 m high, the width and height of model are all 35 m (Fig.1). It has been excavated at a depth of 100 m from the ground surface. The numerical analyses were performed for supported roadways. The first calculation step of the numerical excavation process consists in setting up the initial stress state taking into consideration the vertical stress under the effect of the gravity field. The ratio between lateral and vertical stresses is assumed $K_0 = 1$.



a) B/D = 5/2 b) B/D = 5/4



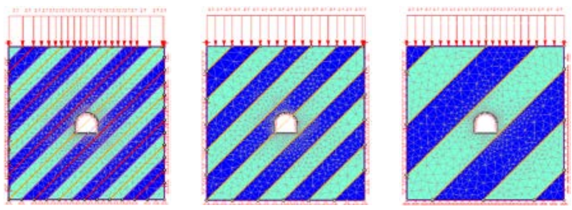
c) B/D = 5/8 d) B/D = 5/16 (1)



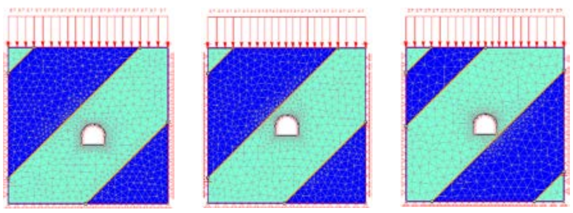
e) B/D = 5/16 (2) f) B/D = 5/16 (3)

Fig.1 Theory models

Using numerical method in the Phase2 software to simulate for this case, the results after analysis by Phase2 for two types of rocks, over burden of rock upper on the model will be added by surcharge load 1.78 MPa and can be seen as in the (Fig.2) and the failure zone of rock mass around roadways as in the (Fig.3).

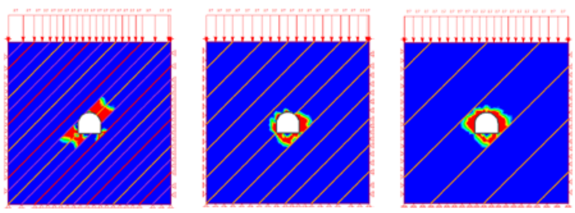


a) B/D = 5/2 b) B/D = 5/4 c) B/D = 5/8

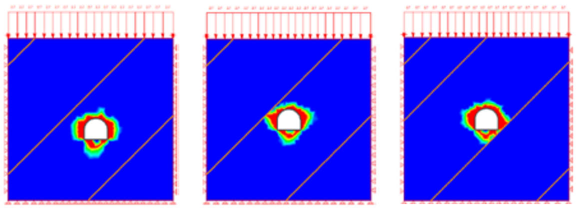


d)B/D=5/16 (1) e)B/D=5/16 (2) f)B/D= 5/16 (3)

Fig.2 Models by Phase2 with the alteration of B/D



a) B/D = 5/2 b) B/D = 5/4 c) B/D = 5/8



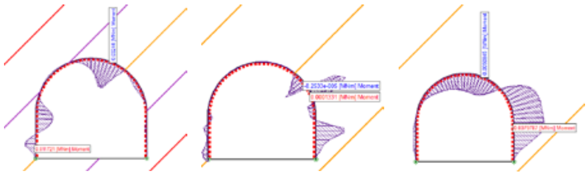
d)B/D=5/16 (1) e)B/D=5/16 (2) f)B/D= 5/16 (3)

Fig.3 Failure zones of rock mass around roadways with the changing ratio of B/D

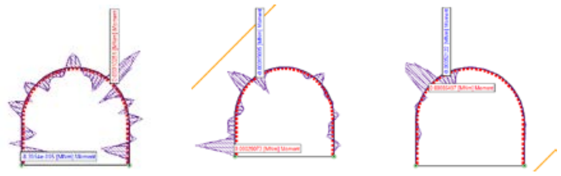
4. RESULTS AND DISCUSSION

Basing on the failure zones of rock mass around roadways with changing the thickness of rock mass layers and span of roadways can be seen that in case of D = 8 m; 6 m and 16 m (Fig.3) the failure zones of rock mass around roadways are the same as symmetry, the distribution of earth pressure surround roadways in this case is symmetry also too. When roadways are located in the one rock mass layer Sandstone, using the steel supports with I110x490, space of supports is 0.7 m the graphics of bending moments in the support can be received as in the (Fig.4). In this section it is assumed that at two corners of roadways restrain x, y are used, basing on this assuming the values of bending moments at locations will be zero.

From graphics of the bending moments in the steel supports and the failure zones of rock mass around roadways, location restrain x, y will be recommended so that the values of bending moment are modified and to raise the stability of roadways. The new locations of the friction joints are recommended as in the (Fig.5).

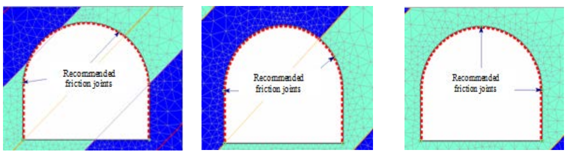


a) B/D = 5/2　　b) B/D = 5/4　　c) B/D = 5/8

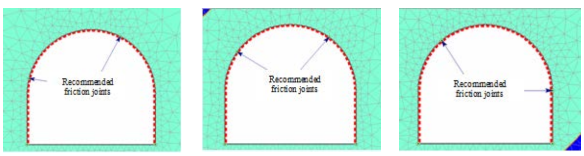


d) B/D=5/16(1)　　e) B/D=5/16(2)　　f) B/D= 5/16(3)

Fig.4 Graphics of bending moment in the supports with the varies thickness of rock mass layers



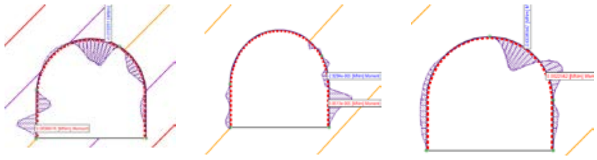
a) B/D = 5/2　　b) B/D = 5/4　　c) B/D = 5/8



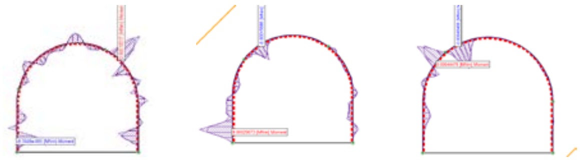
d) B/D=5/16(1)　　e) B/D=5/16(2)　　f) B/D= 5/16(3)

Fig.5 Recommendation of friction joints between arc and sidewalls of the steel supports in the roadways

The results in the (Fig.6) show that the values of bending moments are lower than these values in the steel supports before changing the other locations of friction joints between arc crown and sidewalls. The graphics of bending moment after analysis can be seen as in the (Figs.7-12).



a) B/D = 5/2　　b) B/D = 5/4　　c) B/D = 5/8



d) B/D=5/16(1)　　e) B/D= 5/16(2)　　f) B/D = 5/16(3)

Fig.6 Graphics of bending moment in the steel supports and other locations of the friction joints

By statistic analysis can be established the relationships the values of bending moment in the support for both of using the steel supports with two restrain x, y at two corners of roadways and recommendation solutions by changing location of friction joints. Here, the relationships of bending moment and length perimeter of roadways can be seen as in the (Figs.7-12).

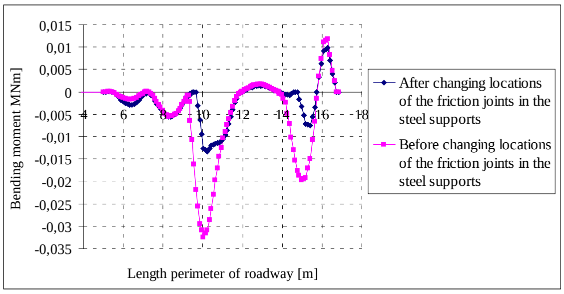


Fig.7 Bending moment in the steel supports in case of B/D = 5/2

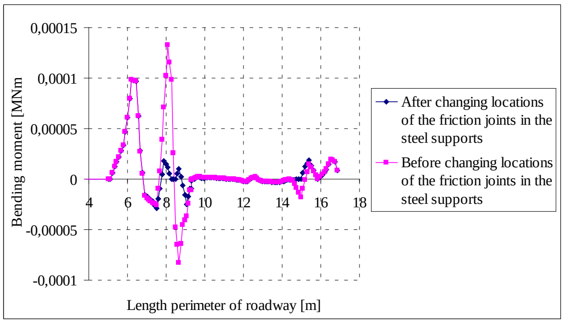


Fig.8 Bending moment in the steel supports in case of B/D = 5/6

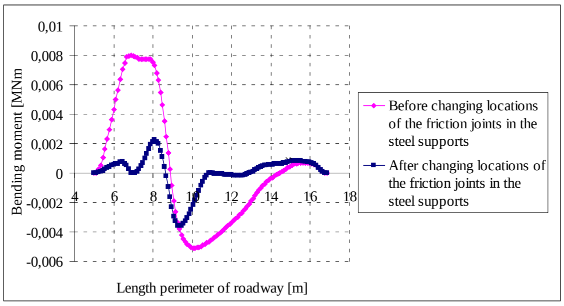


Fig.9 Bending moment in the steel supports in case of B/D = 5/8

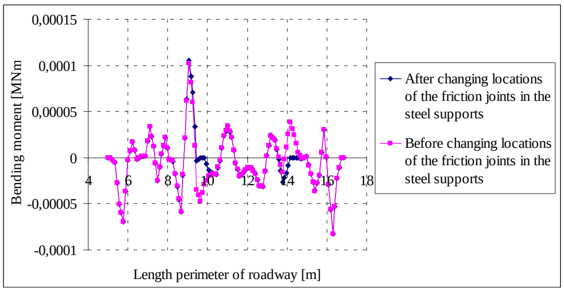


Fig.10 Bending moment in the steel supports in case of B/D = 5/16 (1)

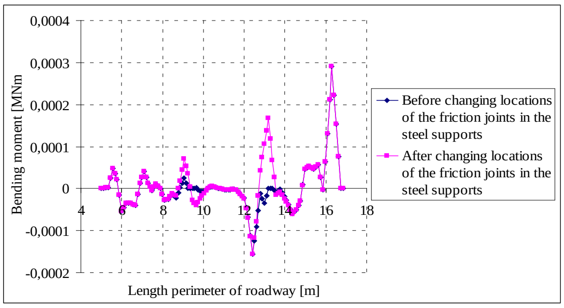


Fig.11 Bending moment in the steel supports in case of B/D = 5/16 (2)

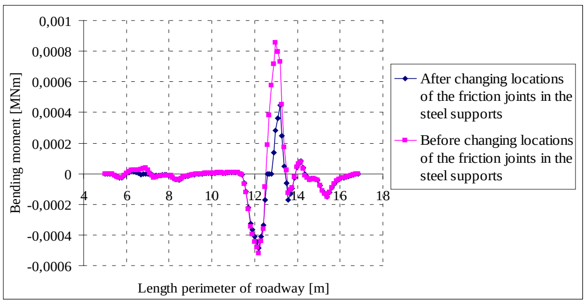


Fig.12 Bending moment in the steel supports in case of B/D = 5/16 (3)

5. CONCLUSIONS

By above analysis can be shown that the mechanical properties of rock mass, as well as the dip angles of rock layers and mechanical properties on the surface of layered rock mass have great influence on the distribution of the stress and displacement of the rock mass on the boundary of roadways and in the rock mass around the roadways. The values of internal forces of rock support in the steel supports are also changed due to changes in the bedding angles and the relationship between width and thickness of rock mass layers. The research results also show that the values of the stress and displacement are not symmetry, so that the pressure of rock mass is also not symmetry. The results of this analysis also indicated that when excavated roadways in practice in layered rock mass or in the surface of roadways have multiple layers of rock mass, the calculation and design of structures will be varies with the theories of the authors many years ago.

Basing on the results of this studying also show that the values of the bending moment can be reduced up to 80% at positions of the greatest values (Figs.7-12) when changing the suitable locations of friction joints in the steel ribs. This means that in practice, knowing the characteristics of layered rock mass should have reasonable design, analyzing and changing the appropriated locations of the friction joints between arc crowns and sidewalls. The results also indicate that, the designation of rock supports in other underground mines in Viet Nam currently is not appropriated by the installation the locations of friction joints in the steel supports. The results of research can be shown that, the rock pressure will be symmetry in case of roadways are located in the only type of Siltstone and Sandstone incase of the ratio between the width of roadways and the thickness of layered rock mass B/D = 5/8 and 5/16.

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