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INFLUENCES OF THE LAYER THICKNESS ON THE DISTRIBUTION OF STRESS AND DEFORMATION OF THE ROCK MASS AROUND ADITS – A CASE STUDY

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Abstract: Excavation of adits in the rock mass for underground mining will be changed the state of initial stress in the rock mass, besides established the new stress state in rock mass around openings, respectively. The secondary stress state has influence on the design of stability for adits. Nowadays the estimation of stress and deformation around adits in bedding rocks is limited. One of many factors concerns to the values and directions of earth pressure on supports is ratio between span of adits and thickness of rock mass layers. This paper refers to assessment of the stress and deformation around adits and internal forces in steel ribs when changing ratio span of adits and thickness of rock mass layers in bedding rocks in the Quang Ninh underground mines of Vietnam.

Key words: stress, deformation, adits, layer thickness, steel ribs.

1. Introduction

Nowadays the amount of adits and drifts 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 an adit 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 tunnel 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) [14], 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 tunnel. They concluded that for horizontal layered joints, the failure mode is of “rock beam” type; for joints with dip angle range 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 tunnel; 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 tunnel behaviour due to the limited number of performed calculations. He et al. (2012) in [15] 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) emphasised 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.

Additionally, the results of investigation during excavation adits and drifts 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. Nowadays 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 adits could not be simulated by analytical solutions. The numerical methods should be used widely to analysis the stability of rock mass around adits 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 [11-22]. However, the influences of the variable thickness of rock layers and location of adits on the stress and deformation in rock mass and rock supports are limited not only in the theory but also in the actual excavation activities. The objective of this study is to highlight the field displacements, failure zones developed in rock mass surrounding adits and the changing internal forces in the steel supports using a finite element method by Phase 2 software [23] incase of consideration to ratio of span of adits and thickness of rock mass layers. The results of this study are also to define appropriated locations of friction joints in the steel supports in adits. The presence of bedding joints is explicitly simulated. The conclusions arising from numerical simulations contribute to estimate the asymmetry of the adits behaviour after excavation.

2. Methods

It is assumption that span of adits is 5.0 m and height 4.5 m, adits with vertical wall and arc crown driven in joint rocks, properties of rock mass are shown in the Table 1. The properties of interface between the rock mass layers can be calculated by indirective methods. These geological conditions existed at the conditions in the Nam Mau coal mine in Viet Nam.

In this section shown the distribution of stress and displacement around adits non-cicular driven in joint and bedding rocks. In this case used model with depth of adit 100 m, width and height of model are all 35 m in the (Fig. 1). Numerical analyses in plane strain have been conducted using the finite element code Phase2 v.7.0 (Rocscience). The adit cross section was assumed as an arch-profile crown and vertical sidewalls with dimension of 5.0 m width and 4.5 m height. It has been excavated at a depth of 100 from the ground surface. The numerical analyses were performed for supported adits. The first calculation step of the numerical excavation process consists of 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 = 1.

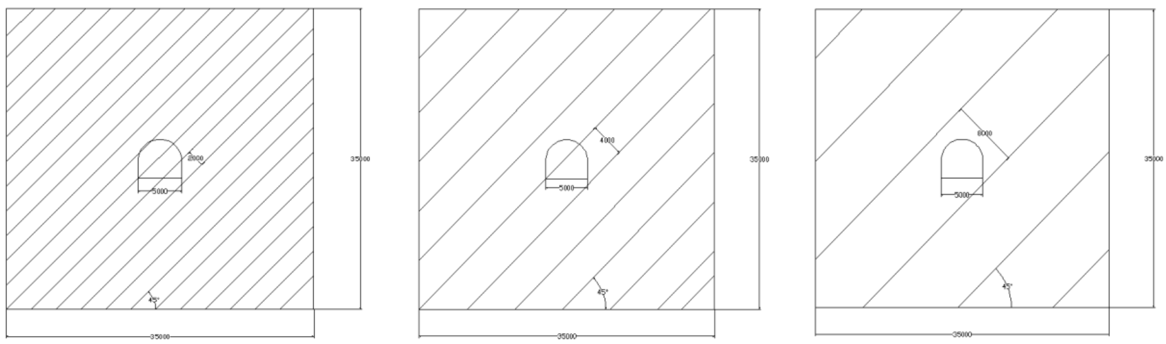
Table 1

Properties of the rock mass and joints

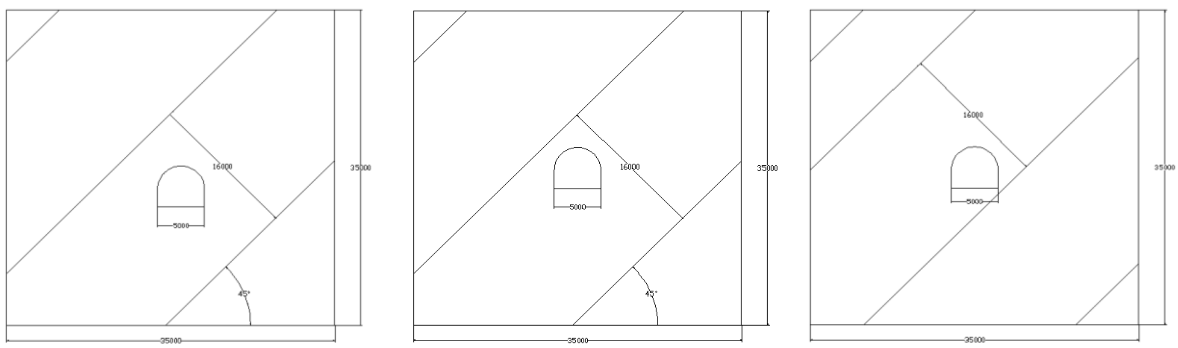
N_0	Parameters	Symbol	Values		Units
			Sandstone	Siltstone	
1	Unit weight of rock	γ	0.026	0.027	MN/m^3
2	Uniaxial compressive strength of intact rock	σci	60; 70	45; 50	MPa
3	Tensile strength	σt	0.5	0.7	MPa
4	Cohesion	c	2	4	MPa
5	Friction angle	φ	30	35	Degree
6	Young modulus	E	1500	2000	MPa
7	Poisson ratio	μ	0.3	0.28	-
8	Dilation angle	ψ	0	-	Degree

N_0	Parameters	Symbol	Values		Units
			Sandstone	Siltstone	
9	Residual tensile strength	φre	28	32	Degree
10	Residual friction angle	cre	1	0.5	MPa
11	Span of adits	B	5	-	m
12	Criterion of material	M-C	-	-	-
13	Ratio of initial stress	σ_3/σ_1	1	1	-
14	Depth of adits	H	100	-	m
15	Incline angle of rock mass layers	α	45	45	Degree
16	Thickness of rock mass layer	D	2; 4; 8; 16	2; 4; 8; 16	m
17	Strength tensile on the surfaces between two layers Sandstone / Siltstone	c’	0		MPa
18	Friction angle on the surfaces between two layers Sandstone/Siltstone	φ’	35		Degree
19	Normal stiffness on the surfaces between two layers Sandstone / Siltstone	σT	100000		MPa/m
20	Shear stiffness on the surfaces between two layers Sandstone/Siltstone	τ	10000		MPa/m

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



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

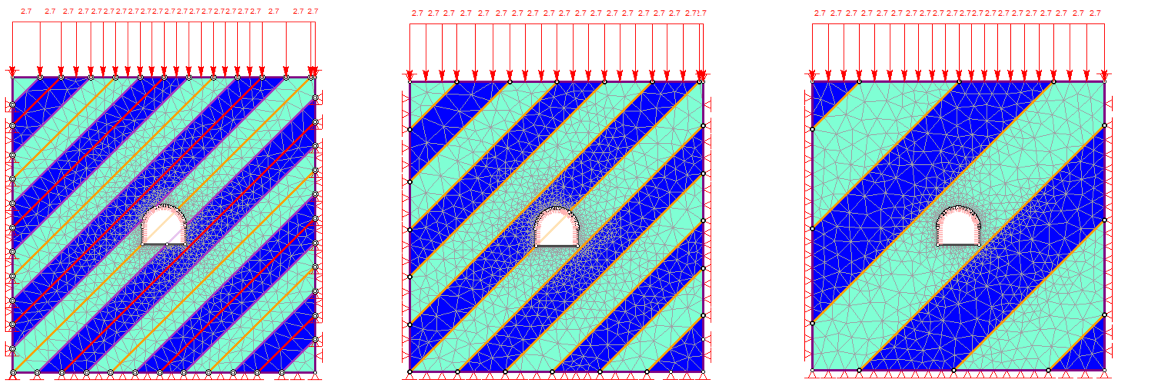


d) B/D = 5/16 Adit located in the center of rock mass layer

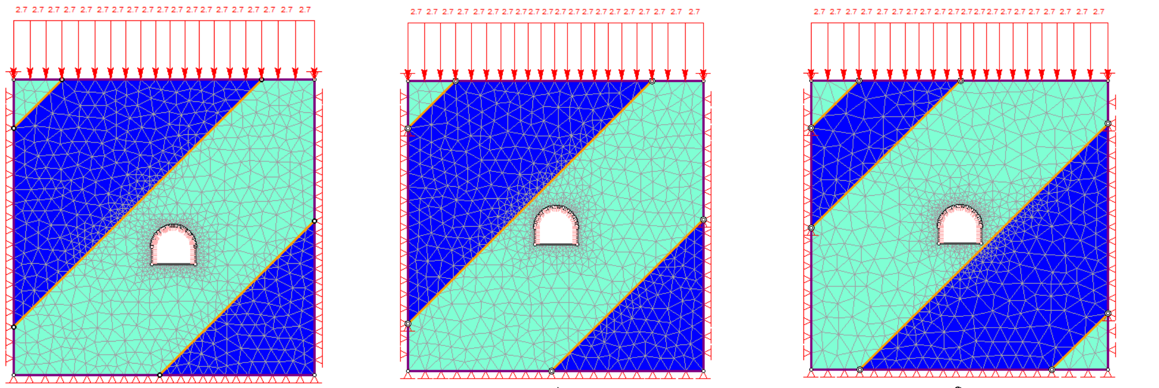
e) B/D = 5/16 Adit located on the top of rock mass layer

f) B/D = 5/16 Adit located on the bottom of rock mass layer

Fig. 1. Theory models in case of changing thickness of rock layers



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

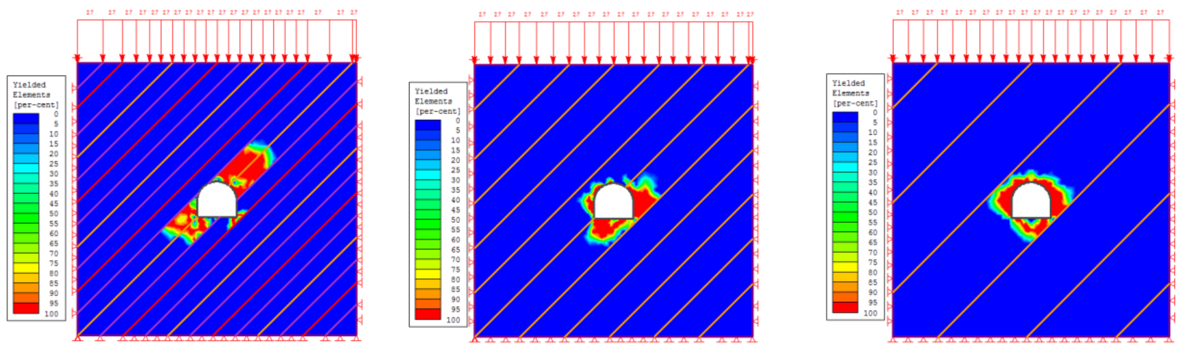


d) B/D = 5/16 adit located in the center of rock mass layer

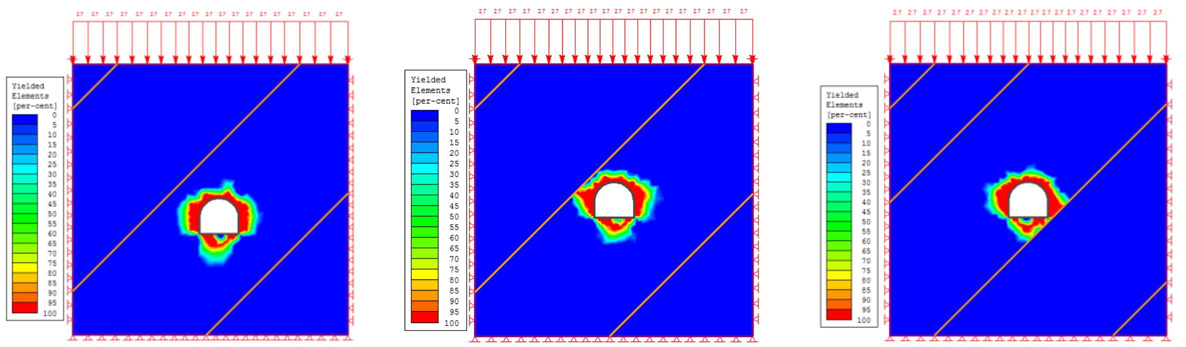
e) B/D = 5/16 adit located on the top of rock mass layer

f) B/D = 5/16 adit located on the bottom of rock mass layer

Fig. 2. Models by Phase 2 and the alteration of B/D



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



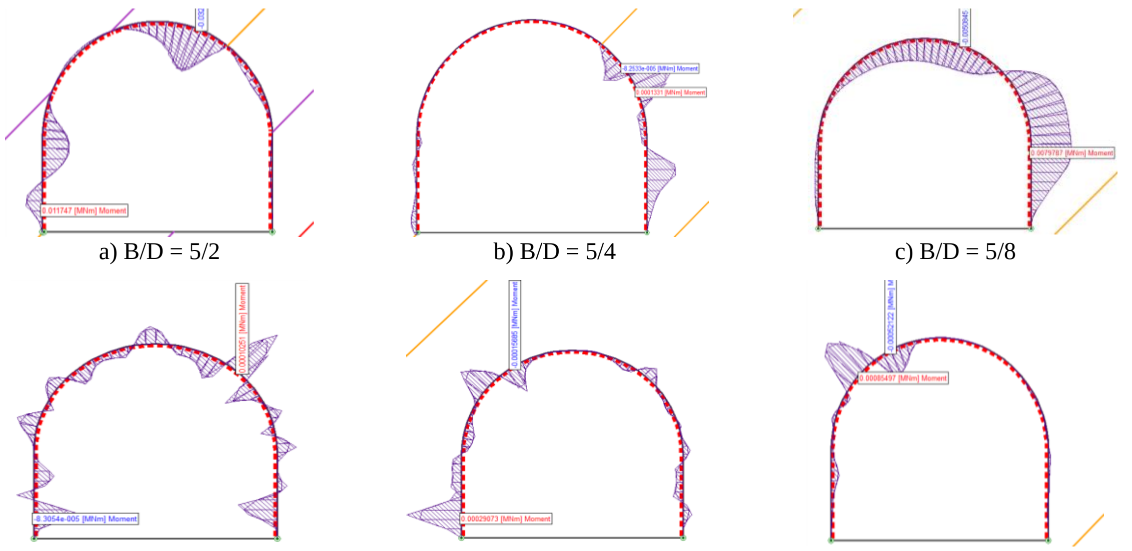
d) B/D = 5/16 adit located in center | e) B/D = 5/16 adit located on the top | f) B/D = 5/16 adit located on the bottom

Fig. 3. Failure zones of rock mass around adits

3. Results and Discussion

Base on the failure zones of rock mass around adits with the changing thickness of rock mass layer and span of adits can be shown that in case of D = 8 m; 6 m and 16 m (Figs. 3d, 3e, 3f) the failure zones of rockmass around adits are the same as symmetry, hence the earth pressure in this case is symmetry also too. When adits located in the one of rock mass layer sandstone, using steel supports with I110x490, spacing of supports is 0.7 m can be received graphics of bending moments in the support as in the (Fig. 4). In this section assume that at two corners of adits restrain x, y are used, by this assuming the values of bending moments at these locations will be zero.

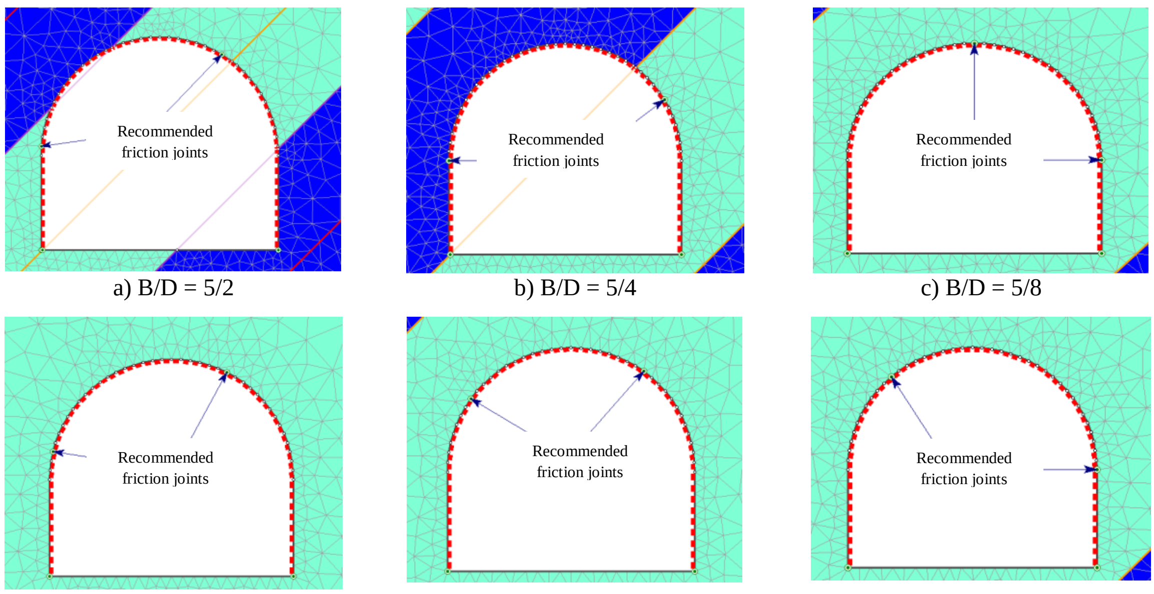
From graphics of the bending moments and the failure zones in this studying, the locations of restrain x, y will be recommended so that the values of bending moment are modified to raise the stability of adits. In this case the new locations of joints should be shown in the (Fig. 5), diagram of bending moment in the steel ribs with other recommended joint locations can be received in the (Fig. 6).



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

d) B/D = 5/16 adit located in the center of rock mass layer e) B/D = 5/16 adit located in the top of rock mass layer f) B/D = 5/16 adit located in the bottom of rock mass layer

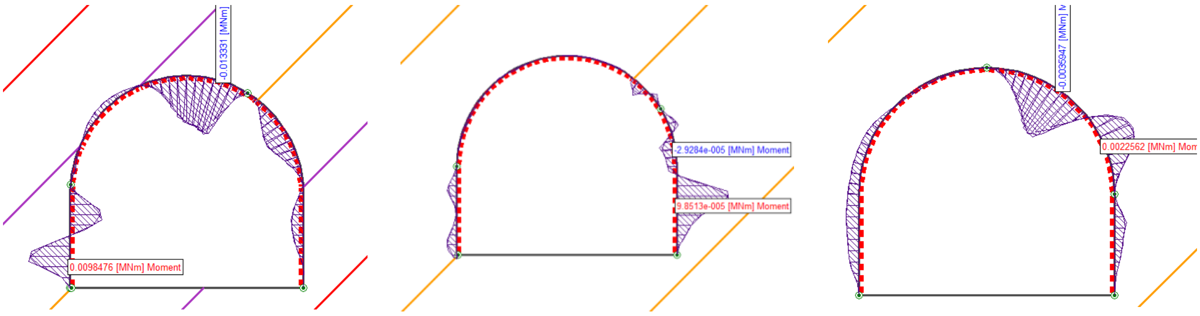
Fig. 4. Bending moments in the support with the varies thickness of rock mass layers



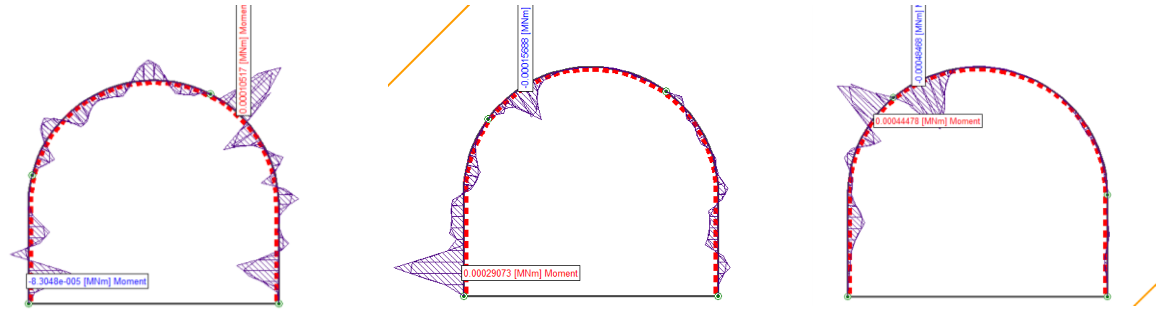
a) B/D = 5/2 b) B/D = 5/4 c) B/D = 5/8

d) B/D = 5/16 adit located in the center of rock mass layer e) B/D = 5/16 adit located on the top of rock mass layer f) B/D = 5/16 adit located on the bottom of rock mass layer

Fig. 5. Recommendation of friction joints between arc and wall of steel ribs in the adits



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



d) B/D = 5/16 adit located in the center of rock mass layer

e) B/D = 5/16 adit located on the top of rock mass layer

f) B/D = 5/16 adit located on the bottom of rock mass layer

Fig. 6. Bending moment in the steel ribs and other recommended locations of the friction joints

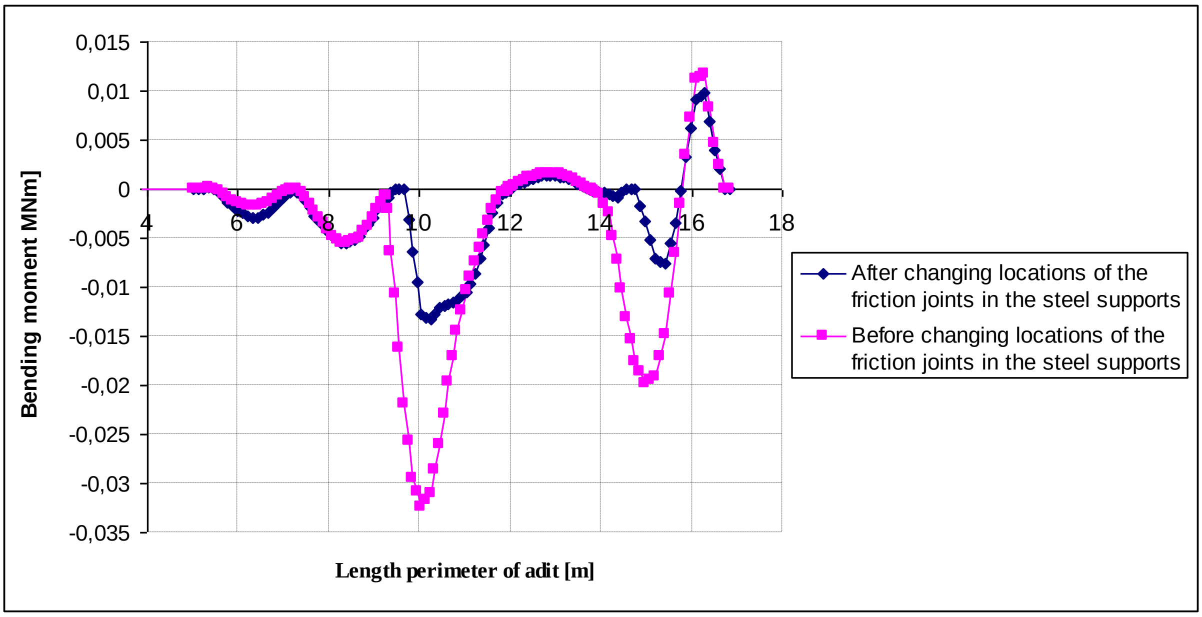


Fig. 7. Bending moment in the steel supports in case of B/D = 5/2

The results in the (Fig. 6) show that the values of bending moments are lower than these values in the steel supports before changing locations of friction joints between arc and side-walls. The graphics of bending moment after analysis can be shown in (Fig. 7).

4. Conclusion

By analysis can be established the relationships the values of bending moment in the support for both of using steel supports with two restrain x, y at two corners of adits and for recommendation solutions by changing location joints as in (Fig. 5). The relationships of bending moment and length perimeter of adits can be seen in the (Figs. 7-12).

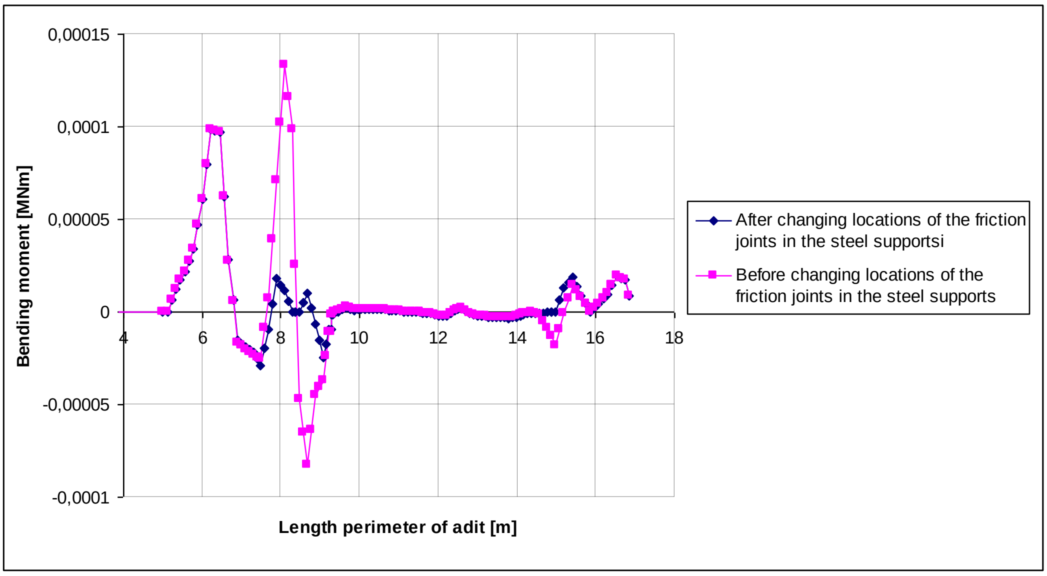


Fig. 8. Bending moment in the steel supports in case of B/D = 5/6

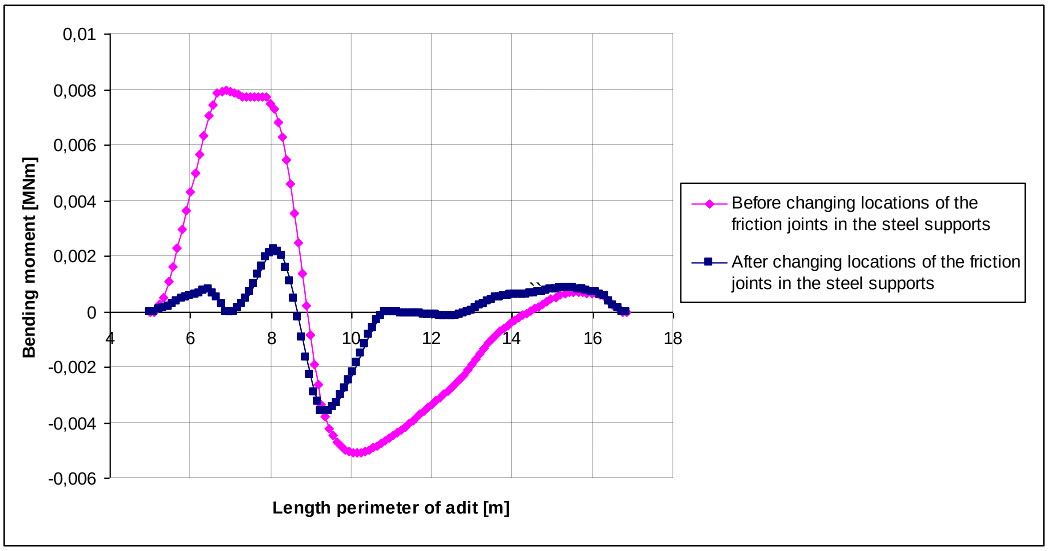


Fig. 9. Bending moment in the steel supports in case of B/D = 5/8

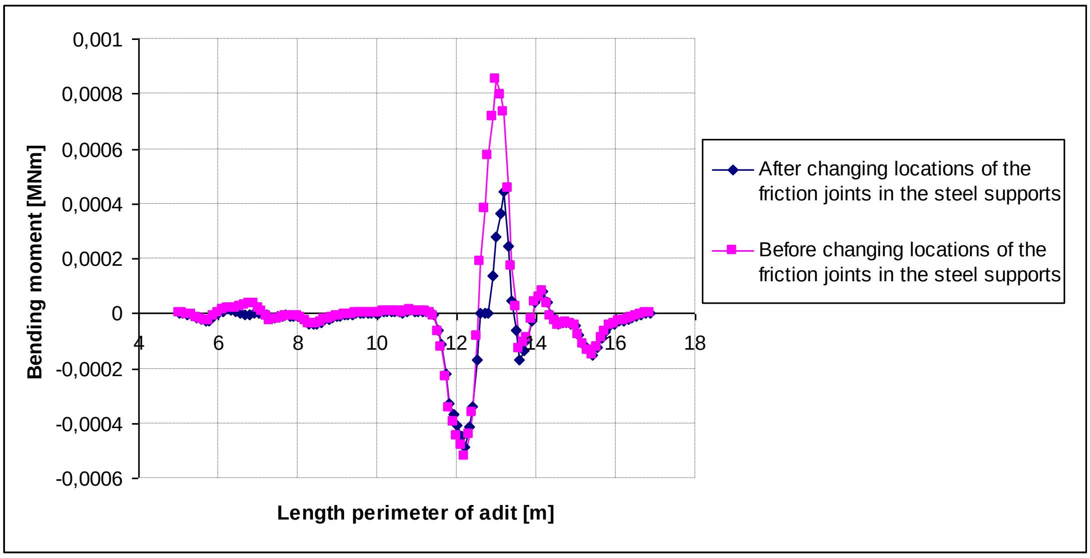


Fig. 10. Bending moment in the steel supports in case of B/D = 5/16
(adit located in the bottom of rock mass layer)

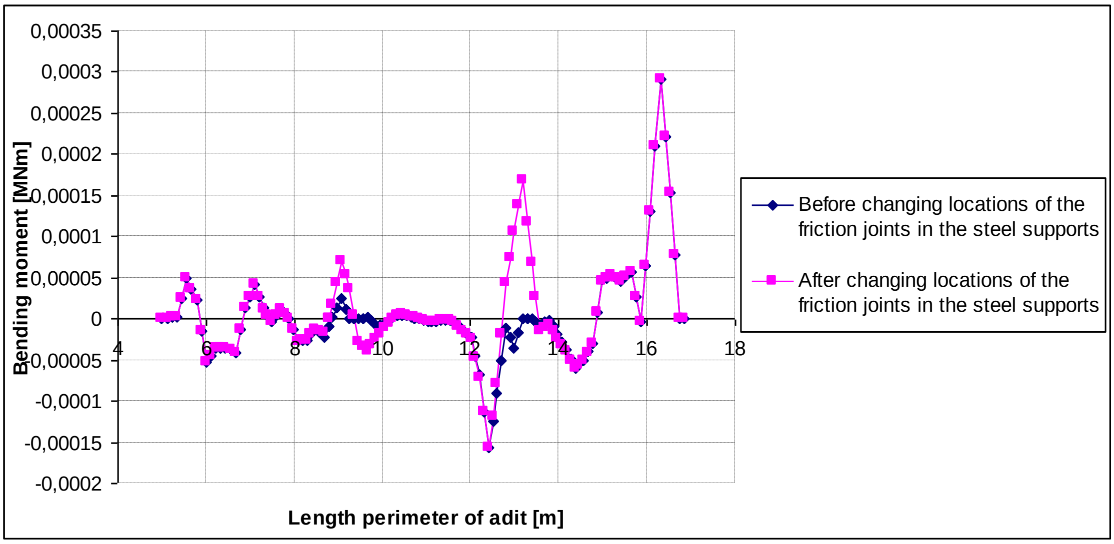


Fig. 11. Bending moment in the steel supports in case of B/D = 5/16
(adit located in the top of rock mass layer)

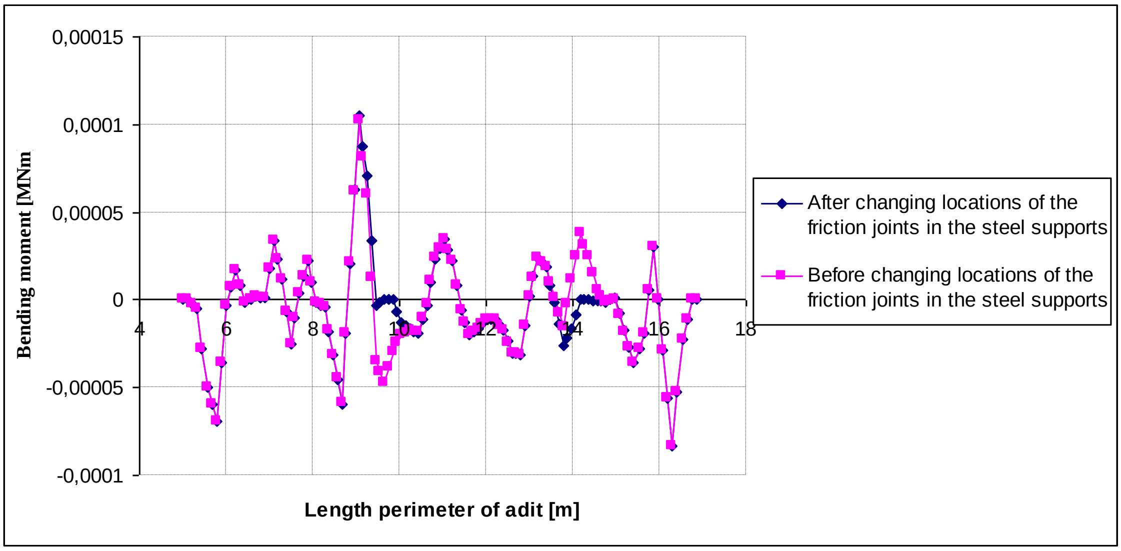


Fig. 12. Bending moment in the steel supports in case of B/D = 5/16
(adits located in the center of rock mass layer)

The results of analysis can be shown that the mechanical properties of rock mass, as well as the angle of layering and mechanical properties on the surface of layered rock mass have great influence on the distribution of stress and displacement of the rock mass on the boundary of adits and in the rock mass. The values of internal forces of structural in the steel supports are also changed due to changes in the bedding angles and the relationship between width and thickness of layered rock mass. The research results also show that the values of the stress and displacement are not symmetry, so the pressure of rock mass is also not symmetry. The results of this analysis also indicated that when excavated adits and drifts in practice in layered rock mass, the calculation and design of structures will be varies with the theories.

Base on the results of this study can see that the values of the bending moment can be reduced by up to 80% at positions of the greatest values by using recommended joint locations (Figs. 7-12). This means that in practice, knowing the characteristics of layered rock mass should have reasonable design. By analyzing of changing joints between arcs and columns could see that, the design of structures in the current mines using the steel supports using the joints between wall and arc are not appropriated. The results also show that, the rock pressure will be symmetry in case of adits located in the only type of Siltstone, the ratio between the width of adits and thickness of layered rock mass are B/D = 5/8 and 5/16, respectively.

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ВЛИЯНИЕ ТОЛЩИНЫ СЛОЯ НА РАСПРЕДЕЛЕНИЕ НАПРЯЖЕНИЙ И ДЕФОРМАЦИЙ МАССИВА ГОРНЫХ ПОРОД ВОКРУГ ШТОЛЕН – ПРИМЕР ИССЛЕДОВАНИЯ

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Аннотация: При выемке штольни в горном массиве для подземной разработки будет изменяться состояние начального напряжения в массиве горных пород, кроме того, установится новое напряженное состояние в горном массиве вокруг отверстий, соответственно. Вторичное напряженное состояние оказывает влияние на расчет устойчивости для штолен. В настоящее время оценка напряжений и деформаций вокруг штолен в слоистых породах ограничена. Одним из многих факторов, влияющих на величину и направление давления грунта на опоры, является соотношение между пролетом штолен и толщиной слоев массива горных пород. В данной работе рассматривается оценка напряжений и деформаций вокруг штолен и внутренних сил в стальных ребрах при изменении соотношения пролета штолен и толщины слоев массива горных пород в слоистых породах подземных шахт Куанг Нинь Вьетнама.

Ключевые слова: напряжение, деформация, штольни, толщина слоя, стальные ребра.