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Professional paper

STABILITY CHECK AND SUPPORT DESIGNING FOR THE GR-2011 EXPLORATION DRIFT

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Abstract: As part of the mining exploration activities on the "Grabova reka" site, an exploration drift GR-2011 has been designed. The designed room has been analyzed in terms of stress-strain and structural stability. After determination of instability and the obtained field results, a support construction, which provides stability and secure work areas of employees, has been designed.

Key words: stress-deformation stability analysis, finite element stress analysis, structural stability analysis, new Austrian tunnelling method

1. INTRODUCTION

In the site "Grabova reka" near Majdanpek, as part of the mining exploration activities of the "Murex-mining and Geology" Ltd. Belgrade, an exploration drift, 150 m long, with the cross section shown in Figure 1, has been designed. Geological field exploration revealed that the working environment is made from dominantly actinolite shales. Data about the cracks that appear in the massif have been collected, so the geological strength index (GSI) has been estimated.

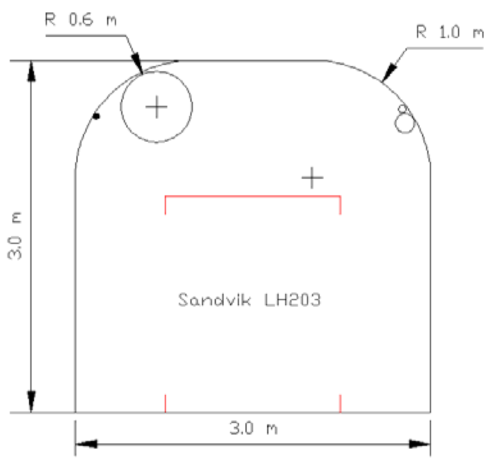

Figure 1 - Cross-section of the exploration drift

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In order to estimate the dynamics of progress of the working forehead and installation of roof support, the basic principles of the "New Austrian Method" have been used.

The support has been designed according to the criteria of the most unfavourable conditions expected in the massif, as well as in terms of structural and stress-strain stability.

2. STRESS-DEFORMATION STABILITY ANALYSIS USING FINITE ELEMENT METHOD

Due to the lack of measured data on physical-mechanical properties of the monolith, the input parameters for the stress-deformation analysis have been estimated using software RocData (Rocscience Inc., 2005). The estimated parameters for the Hoek-Brown's fracture criteria are shown in Table 1. The stress-deformation analysis has been performed using Phase2 software (Rocscience Inc., 2008).

The vertical component of stress has been determined, based on the maximum depth and the normal gravity value for actinolite shales. As the field court observed folding chains, sideways to the direction of the room, it has been assumed that the lateral stresses could have intensities greater than usual. As the practice has shown, lateral components of stress in lower depths can be of multiple bigger intensity than vertical, analysis of a series of expected values of lateral stress have been realized and, finally, the least favourable expected has been accepted.

Table 1 - Rock mass strength parameters

Rock mass strength based on the Hoek-Borwn's fracture criteria	
Uniaxial compressive strength	60 Mpa
Geological strenght index (GSI)	50
Module strain	5809.48 Mpa
mb	0.647
and	0.506
with	0.0013
I	7
Disturbance factor	0.5

In order to simulate the spatial progress of the underground room and analyze the changes in stress state in the room, due to the length of the room, the finite element model has been constructed and processed into ten phases. The first phase simulates state of rock mass before beginning of the works, in a manner that uniform workload has been inflicted on the contour of the room, which evens out the all-over load in the massif. In the stages 2-9, this burden has been reduced in certain percentages, and in the tenth stage, this burden has had the value of 0. In this way, in the tenth stage, flat stress state for the room of arbitrary length has been simulated.

The results obtained after models processing, indicated the necessity of supporting of the exploration drift. This is evident in Figure 2, where it can be seen that the rooms have safety factor values below 1, and the elements in which fracture will occur are presented.

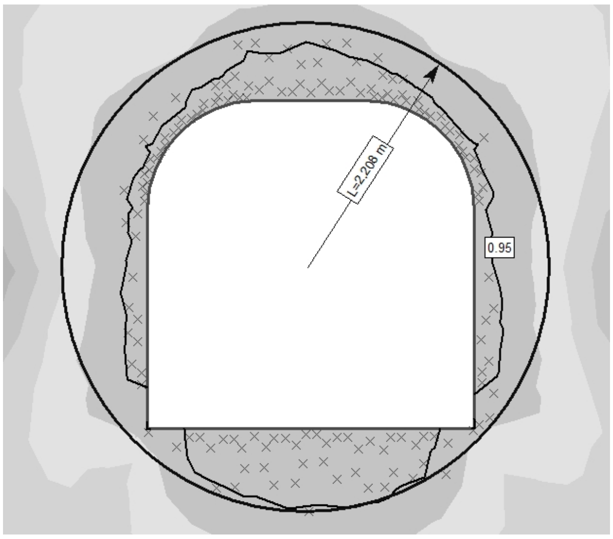

Figure 2 - Safety factor on the edge of the room-drift, coating radius and elements in which a fracture occurred

In order to determine the exact moment for roof support installation, i.e. determining the deformation of the wall of the room at the time of installation of roof supports, the graphics based on the Diedrichs and Vlachopoulos equation, have been constructed. Using (Hoek et al. 2008) Figure 3, in the tenth stage of the coating and the estimated radius of maximum deformation of the wall of the room, have been estimated. A diagram of the stages of deformation has also been designed, and shown in Figure 4.

Table 2 - Estimated and measured parameters after model processing

Estimated and measured values	
Coating radius (Rp)	2.20 m
The radius of the room (Re)	1.50 m
The maximum deformation (u_{max})	0.002 m
Advancement step (x)	1.50 m

The deformation of the room sidewall in the moment of support installation has been calculated based on estimated values with maximum values of deformation, observed from diagram shown in Figure 3. In order to perform observation from the diagram, it is necessary to calculate the following relations:

$$\frac{x}{R_e} = 1; \qquad \frac{R_p}{R_e} = 1,47 \approx 1,5 \tag{1}$$

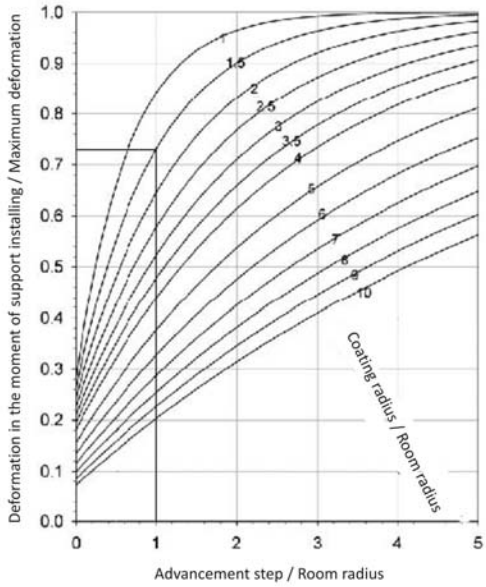

Figure 3 - The diagram is constructed based on equations suggested by Diedrichs and Vlachopoulos

Based on the point of intersection on the ordinate of the diagram, a relationship u/u_{max} has been read and deformation in the moment of support installing is calculated:

$$\frac{u}{u_{\max}} = 0,73 \tag{2}$$

so:

$$u = 0,73 \cdot u_{\max} = 0,0015m \tag{3}$$

The calculated value of the deformation of the room wall before installation of support corresponds to the fourth stage of the simulation, which can be seen from the diagram in Figure 4.

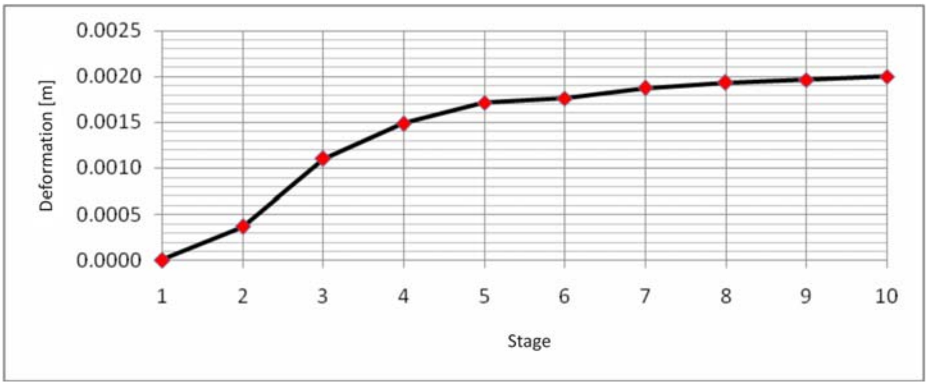

Figure 4 - Diagram of deformation according to the simulation stages

Using an analogue procedure a convergence diagram has been established (Figure 5), from which it can be seen that after a certain length of the unsupported room, deformation values gravitate to the close values.

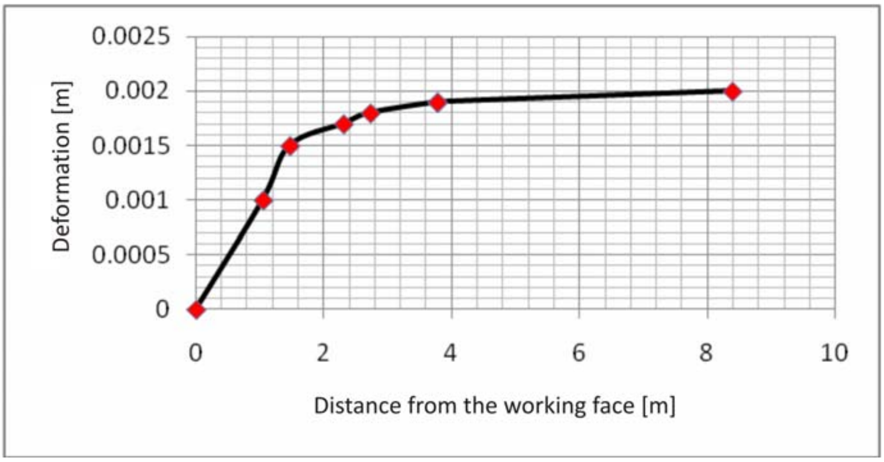

Figure 5 - Diagram of convergence

The next phase is the construction of a new model, in which the support installation has been simulated. The composite support, consisting of anchors and steel mesh, has been simulated in this model. Scheme of installation of the roof support, with maximum loads that occur in anchors, is given in Figure 6, and the mechanical properties of support elements are shown in Table 3.

Table 3 - Elements of support mechanical properties

Anchors	Type	End anchored bolt
	Quantity	7 pcs.
	Length	1 m
	Diameter	19 mm
	Tear strength	0.1 MN
	Modulus of elasticity	200,000 Mpa
	The distance in row	1 m
	The distance between rows	1 m
Mesh products	Type	Wire Mesh (Canada)
	Diameter	4 mm
	Poissons' ratio	0.25
	Modulus of elasticity	200,000 Mpa

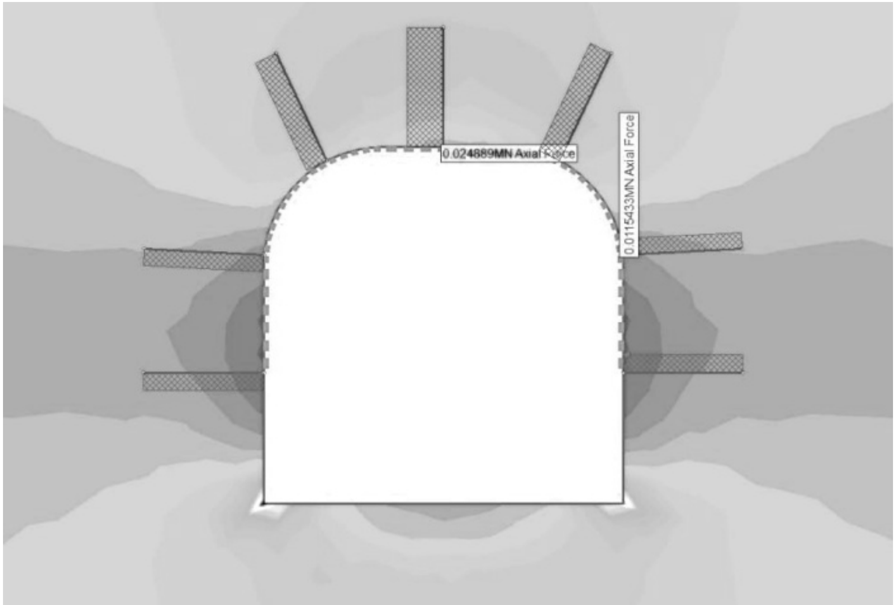

Figure 6 - Installation of anchors scheme and their load

The analysis confirms that the maximum force that occurs in anchors has not exceeded the value of breaking force, while mesh security coefficients have values above 1.4 (Figure 7).

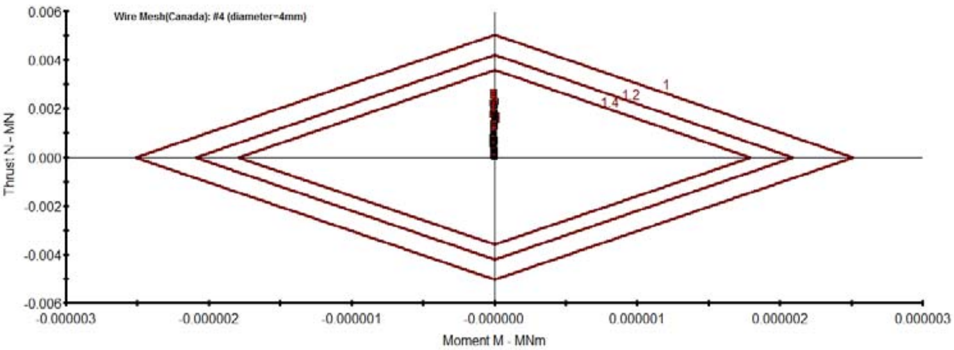

Figure 7 - Anvelopes of mesh security coefficients

3. STRUCTURAL ANALYSIS OF THE STABILITY

Stress-deformation analysis of rock massif is modelled as an isotropic, homogeneous and continuous. In this way, a significant simplification of the actual situation, in order to simplify the mathematical apparatus, has been made. As the rock massif has cracked in different directions, i.e. mechanical discontinuities of different genesis, mechanical characteristics, different directions and length, there is a possibility of forming triangular kinematic pins with the ability to slip into the excavated space. Therefore, a structural stability analysis has been performed, using Unwedge software (Rocscience Inc., 2003).

By the geological studies of certain elements of the fall of the dominant system of cracks in the trajectory of the designed rooms, have been determinated - Table 4 (Pavlović, 2011). As dominants, distinct gaps cleavage systems, foliation and two cracked shear systems have been determined. Based on the genesis of the fill material in the cracks, the parameters and their strength are estimated and shown in Table 5. The estimation is made according to the Bandise Barton's criteria.

Table 4 – Elements of the crack fall

Genetic type of discontinuity	Elements of dip (Dip/Dip Direction)
Shearing 1	76/260
Shearing 2	70/318
Foliation	45/118
Cleavage	82/42

Tabela 5 - Mechanical properties of discontinuity

Genetic type of discontinuity	Strenght parameters	
	C (MPa)	φ (°)
Shearing 1	0.06	20
Shearing 2	0.06	20
Foliation	0.19	37
Cleavage	0.08	25

The analysis has been realized on all the varieties of the crack systems, and it is proved that the most unfavourable combination has been the one of shear cracks with cracks foliation. Directions of these crack systems dip, related to the direction of the room, are shown in Figure 8.

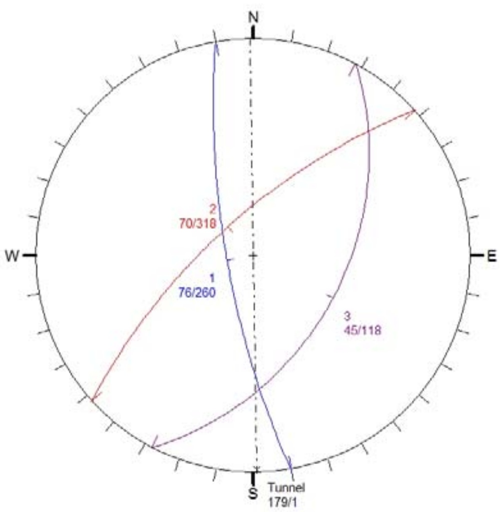

Figure 8 - Relationship between crack system dip and the direction of the room

In this case, there is a possibility of forming large unstable wedges in the arch of the drift (Figure 9). As it can be observed, there is also a possibility of forming the wedges in the sides and floor of the room. However, the stability of the room–drift remains undisturbed, and these factors do not compromise the safety of work.

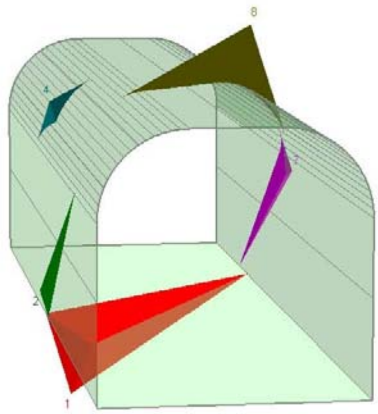

Figure 9 - Possible triangular wedges

In order to prevent the possible movement of unstable wedges through planes which have been formed by the crack systems, analysis of the possible interaction of the wedges and roof supports, is made (Figure 10).

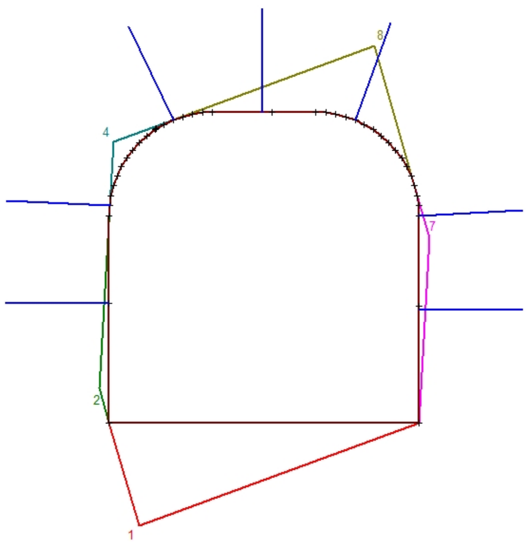

Figure 10 – The relationship between formed wedges and installed roof supports

As from the selected image can be seen, the selected anchor bolts length is long enough to connect the unstable with more stable parts of the massif. Support itself has contributed to the safety factor of possible unstable wedges, increase the value above 6, and safety factor of selected anchors remained within the required value, satisfying the criterion of structural analysis.

4. CONCLUSION

Exploration drift GR-2011, designed in the environment dominated by actinolite shale and in which there are three types of mechanical genetic discontinuity distinguished, is subsumed to the deformation stress stability and structural analysis.

Stress-deformation analysis has identified the necessity for drift roof support. The basic parameters needed to be implemented for the "New Austrian method" have been estimated, and support structures have been dimensioned to satisfy these requirements.

As in the site of drift occur cracks systems, the structural analysis has been carried out. It turned out that there is a possibility of structural instability, which can be prevented by installing designed support construction.

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