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SELECTION OF PRIMARY SUPPORT SYSTEM FOR THE RIVER "MALI PEK" TUNNEL

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Abstract
The open-pit "Juzni revir" in Majdanpek is threatened by an active landslide on the north and northwest sides. The landslide threatens production at the open-pit and the "Mali Pek" riverbed. By building a tunnel, we would shift the riverbed and thus eliminate the danger posed by an active landslide. Before starting tunnel construction, it is necessary to define the condition of the rock mass and determine the support system for each working environment.

Keywords: *landslide, tunnel, support system*

1. INTRODUCTION

Numerous authors have attempted to define the quality of the field under consideration using basic data on the properties of the rock mass (compressive strength, modulus of elasticity, angle of internal friction, etc.) and to propose a support system based on the rock characteristics. This is a complex task because each work environment has its own specific characteristics. Various classification systems have been developed such as GSI, RMR, Q, etc. For this paper, the required primary support was determined based on the known GSI value and known correlations between GSI and RMR system. The secondary support will be made of monolithic concrete. The thickness of the concrete support will vary depending on the lithological area and will range from 25 - 45 cm. Determining the secondary support will not be the topic in this paper. The selected primary support was tested by the Convergent-Confinement Method.

2. ROCK MASS CLASSIFICATION

2.1 Geological Strength Index (GSI)

The Geological Strength Index (GSI) is a system of rock-mass characterization that has been developed in engineering rock mechanics to meet the need for reliable input data, particularly those related to rock-mass properties required as inputs into numerical analysis or closed form solutions for designing tunnels, slopes, or foundations in rocks [1].

2.2 The Rock Mass Rating (RMR)

The Rock Mass Rating (RMR) system, otherwise known as the Geomechanics Classification, was developed by the Bieniawski during 1972-1973. It was modified over the years as more case histories became available and to conform with international standards and procedures [2]. The following relationship has been established between the GSI and RMR classifications [3]:

$$GSI = RMR_{89} - 5 \tag{1}$$

Table 1. Guidelines for Excavation and Support of Rock Tunnels in Accordance with the Rock Mass Rating System [2]

Rock Mass Class	Excavation	Rock Bolts (20 mm Dia, Fully Grouted)	Shotcrete	Steel Sets
Very good rock, I, RMR: 81-100	Full face 3 m advance	Generally, no support required except for occasional spot bolting		
Good rock, II, RMR: 61-80	Full face 1-1.5 m advance. Complete support 20 m from face	Locally, bolts in crown 3 m long, spaced 2.5 m, with occasional wire mesh	50 mm in crown where required	None
Fair rock, III, RMR: 41-60	Top heading and bench 1.5-3 m advance in top heading. Commence support after each blast. Complete support 10 m from face	Systematic bolts 4 m long, spaced 1.5-2 m in crown and walls with wire mesh in crown	50-100 mm in crown and 30 mm in sides	None
Poor rock, IV, RMR: 20-40	Top heading and bench 1.0-1.5 m advance in top heading. Install support concurrently with excavation 10 m from face	Systematic bolts 4-5 m long, spaced 1-1.5 m in crown and wall with wire mesh	100-150 mm in crown and 100 mm in sides	Light to medium ribs spaced 1.5 m where required
Very poor rock, V, RMR: <20	Multiple drifts, 0.5-1.5 m advance in top heading. Install support concurrently with excavation. Shotcrete as soon as possible after blasting	Systematic bolts 5-6 m long, spaced 1-1.5 m in crown and walls with wire mesh. Bolt invert	150-200 mm in crown, 150 mm in sides, and 50 mm on face	Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required. Close invert

The route of the designed tunnel passes through the following lithological units: 1. Granitoid gneisses, 2. Amphibole-biotite gneisses and mica schists, 3. Limestones and 4. Andesites and tectonic breccias. According to relation (1) values of RMR was determined and shown in Table 2.

Table 2. Correlation values between different classification of rock mass

Lithological area	GSI	RMR
Amphibole-biotite gneisses and mica schist	34	39
Limestones	49	54
Andesites and tectonic breccias	20.76	25.76
Granitoid gneisses	41	46

3. SELECTED PRIMARY SUPPORT SYSTEM

According to the recommendations from Table 1, the following primary support system was selected and shown in Table 3.

Table 3. Selected primary support system

Lithological area	Primary support system
Amphibole-biotite gneisses and mica schist	Mesh reinforced concrete, thickness 15 cm in crown and sides, Tensioned bolts 4 m long, spaced 1.5x1 m in crown and wall, Steel sets at a distance of 1 m (as needed).
Limestones	Mesh reinforced concrete, thickness 10 cm in crown and sides, Bolts 4 m long, spaced 2x2m in crown and wall.
Andesites and tectonic breccias	Mesh reinforced concrete, thickness 15 cm in crown and sides, Tensioned bolts 5 m long, spaced 1x1 m in crown and wall, Steel sets at a distance of 1 m (as needed).
Granitoid gneisses	Mesh reinforced concrete, thickness 10 cm in crown and sides, Bolts 4 m long, spaced 2x2m in crown and wall.

3.1 Determination of the required pressure of the primary support system

Considering the original Unal equation, substituting the GSI for RMR, and considering the reduction factor for rock mass quality through disturbance and strength factors, the new equation to estimate the support pressure was proposed [4]:

$$P = \frac{100 - ((1 - \frac{D}{2})\sqrt{\frac{\sigma_{cr}}{100}}\ GSI)}{100} C_s S_q D_e \gamma \qquad (2)$$

where is:
D – disturbance factor
D_e – equivalent diameter of the excavation
$\sigma_{cr} = s_r \cdot \sigma_{ci}$, $s_r =$ post-peak strength reduction factor. $s_r = 1$ for poor rock masses (GSI<27).
S_q – correction factor for squeezing ground condition, $S_q = 1$
C_s – stress correction factor, $C_s = 1.4$.
Required pressure of the primary support system according to different lithological area are shown in Table 4.

3.2 Convergence-Confinement Method

The Convergent-Confinement Method is based on an elastoplastic model that allows for closed mathematical solutions. Stresses and the displacement in the rock mass around the tunnel and in the support depend on the properties of the rock mass, the primary state of stress, the stiffness of the support, as well as the time of its installation. The Convergent-Confinement Method consists of two characteristic lines: the characteristic line of the Ground reaction Curve and Support Characteristic Curve (Figure 1). These lines represent the relationship between radial stress and radial deformation in the rock mass around the underground opening and in the surrounding area [5]. The support stiffness, maximum pressure support system and safety factor of support system are shown in Table 4.

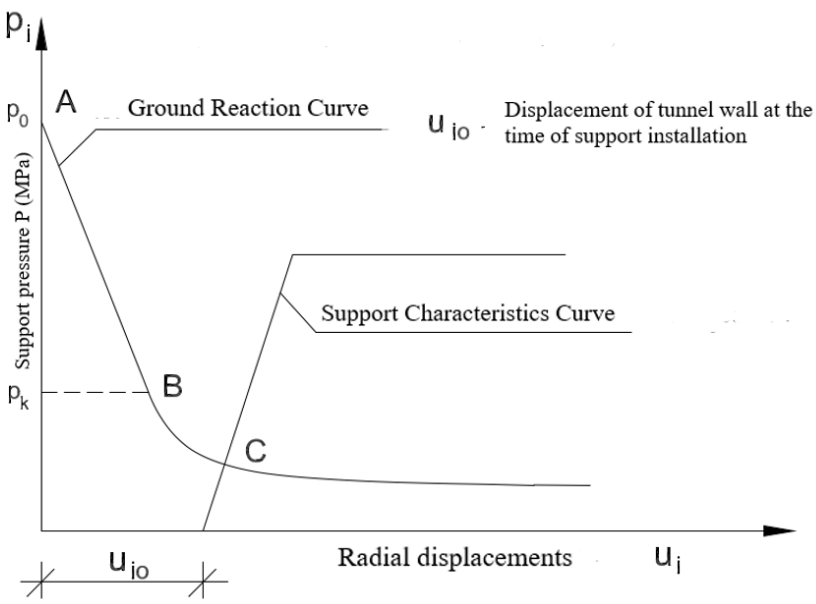

Figure 1. Convergence-confinement curves [5]

Table 4. Characteristics of selected primary support system

Lithological area	P – Required pressure of the primary support system [MPa]	K – Support stiffness [MPa]	Pmax – Maximum pressure support system [MPa]	SF = Pmax/P – Safety factor of support system
Amphibole-biotite gneisses and mica schist	0.225	673.87	1.75	7.78
Limestones	0.211	397.3	1.41	6.7
Andesites and tectonic breccias	0.196	638.93	1.64	8.37
Granitoid gneisses	0.22	426.26	1.46	6.64

4. CONCLUSION

The mentioned recommendation for support can serve as a good guide for supporting when we are still unsure about what rock mass we will work with. During the construction of any underground space, it is necessary to conduct exploratory work to obtain information about the rock, and in this way, we will adapt our support system.

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