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RELIABILITY OF RMR CLASSIFICATION DURING THE CONSTRUCTION OF ZENICA TUNNEL

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SUMMARY

Construction of underground tunnels in the rock mass is a very complex task from the aspect of stability of the rock mass in the secondary state of stress and defining the method of support. The method of excavation and the construction of the primary support are adapted to the state of the rock mass, which is why an adequate analysis of the rock mass as a work environment is of great importance. In order to define as precisely as possible, the quality of the rock mass as a work environment, classifications of the rock mass have been developed in recent times. The classifications are based on which the condition is assessed and its characteristics important for design are defined. In tunnel construction in Bosnia and Herzegovina, the RMR classification is most often used, the reliability of which varies depending on the characteristics of the rock mass in which the room is made. The paper analyzed the reliability of the RMR classification for the construction of the "Zenica" road tunnel, which was built in complex geotechnical conditions.

Key words: rock mass, uniaxial compressive strength, reliability, RMR classification

1. GEOLOGICAL AND HYDROGEOLOGICAL CONDITIONS OF THE ZENICA TUNNEL CONSTRUCTION

The Zenica road tunnel is located on the route of corridor Vc, it passes under the Vepar mountain, it is 3360 m long, while the maximum upper layer of the tunnel is approx. 478 m. The tunnel has 13 cross connections, 11 for pedestrians and 2 for motor vehicles. The distance between the shafts of the tunnel tubes is 25 m, and the tunnel has 3 parking spaces in each tunnel tube.

The geological characteristics of the massif in which the Zenica tunnel was excavated are determined by the Jurassic-Cretaceous fiche (2J,K) of the "Vrandučke serije", which consists of sedimentary rocks with a dominant presence of sandstone. In addition to sandstone, there are compact sandy and silicified clays, limestones and marls (2J;K). The rock massif is significantly layered, with layers from 5 to 100 cm thick and thin clay layers from 1 to 30 cm thick. The repetition of the sequence of layers occurs at intervals of 5-10 m. The flysch of the „Vrandučke serije“ is an extremely heterogeneous rock mass and is heavily folded, so it was a big challenge to define the engineering geological and geomechanical conditions for such rock mass. There is no clearly expressed rules of layers and folding mechanism change, which makes it difficult to determine the engineering geological conditions. Altogether, in combination with faults and folds, results in the degradation of the geomechanical properties of the rock mass, which makes their adequate definition significantly more difficult.

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Figure 1. The head of the Zenica tunnel excavation

During the excavation of the tunnel, large amounts of underground water were recorded, and they were constantly measured. During the measurement of groundwater inflow, it was sometimes difficult to capture all the water in one point.

Table 1. Part of the inspection of water inflow measurement in the Zenica tunnel

08.06.2020.	0+555.62	47.00 l/s
15.06.2020.	0+562.60	62.50 l/s
23.06.2020.	0+578.00	51.00 l/s
24.06.2020.	0+583.24	30.00 l/s
26.06.2020.	0+585.65	60.00 l/s
30.06.2020.	0+594.426	29.00 l/s
10.07.2020.	0+603.710	30.00 l/s
15.07.2020.	0+611.880	20.00 l/s
17.07.2020.	0+611.880	15.00 l/s
21.07.2020.	0+612.041	13.00 l/s
23.07.2020.	0+612.041	15.50 l/s
04.08.2020.	0+626.270	10.00 l/s
07.08.2020.	0+629.640	7.50 l/s
17.02.2021.	1+083.000	1,80 l/s
01.10.2021.	2+117.230	5,50 l/s

Figure 2. The emergence of underground water in the Zenica tunnel

In certain sections of the Zenica tunnel, the presence of large amounts of water significantly affected the classification of rock mass according to the RMR classification, and due to the significant influence of groundwater in some situations, the classification of rock mass according to the RMR classification was unreliable.

2. GEOTECHNICAL CONDITIONS IN THE ZENICA TUNNEL

The rock mass in certain sections was weakened and tectonized, which significantly affected the stability of the newly constructed part of the tunnel. Tectonic activity in the soft lithological members of the mentioned complex was most often reflected through the disintegration of the softer lithological members, while a large number of discontinuities were present in the hard lithological members. In tectonically disturbed zones, the rock mass is mostly defined as highly eroded and disintegrated, and the primary conditions are only partially preserved. The structure of the rock mass in the tectonically disturbed zone showed that the layering relationship and discontinuities systems have a wide range of spatial orientation element values, which posed a problem when classifying the rock mass according to the RMR classification.

The discontinuities are mostly filled with soft clay and hard calcite filling, and some discontinuities are open and without filling. The walls of fissures filled with calcite are slightly rough, while the walls of fissures filled with clay are smooth to slippery.

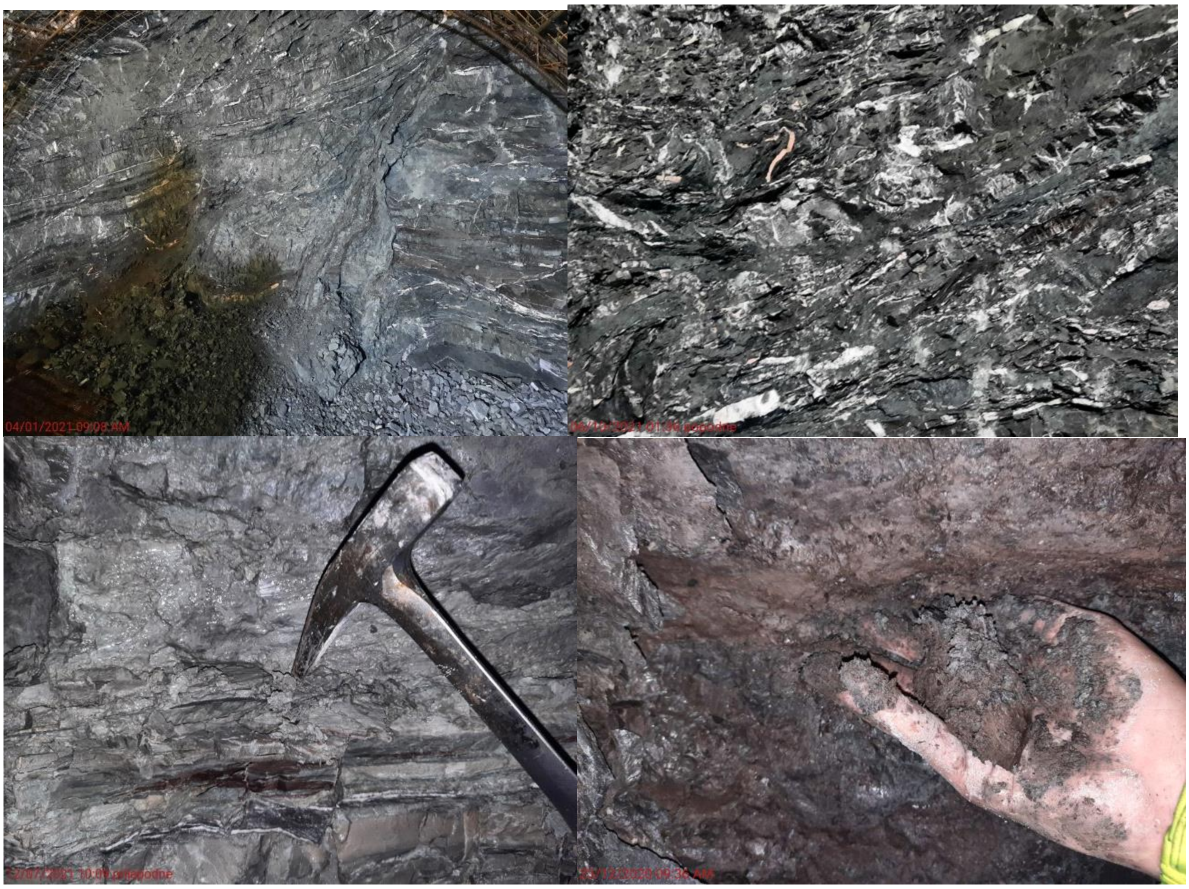

Figure 3. Structural properties (folding) of J/K flysch of the “Vrandučke serije” in the Zenica tunnel

3. OVERVIEW OF THE CATEGORIZATION OF THE ROCK MASS ACCORDING TO THE RMR CLASSIFICATION IN THE ZENICA TUNNEL

During the construction of the Zenica tunnel, lower RMR values were determined compared to those projected in the Main Project of the Zenica tunnel. Continued research during the construction of the tunnel showed that the rock mass is of lower quality, and a significantly higher content of category IV and category V according to RMR was determined. Therefore, the share of category III rock mass on the tunnel route was significantly reduced (almost by half), which is why it was necessary to approach with different type of the construction in the tunnel.

The cause of this change is the real geotechnical characteristics of the terrain where the excavation is being carried out, primarily the heterogeneity of the structure, i.e. the changing values of the physical-mechanical characteristics of the rock mass and the unfavorable hydrogeological conditions in which the tunnel was built. Low values of the basic parameters of uniaxial strength, the presence of clayey materials, constant vertical and horizontal changes of soft and hard rocks, and the unfavorable orientation of the discontinuity, had a significant impact on the reduction of the rating points of the rock mass along the route.

Table 2. Prognostic percentage of rock mass categories according to RMR classification in the Zenica tunnel

Left and right tunnel tube Zenica- projected		
Categorization of rock mass	**Length (m)**	**Percentage (%)**
II category	-	-
III category	6376,18	96,43
IV category	181,00	2,74
V category	54,66	0,83
Total length	6611,84	100,00

By monitoring the excavation of both tunnel tubes of the "Zenica" tunnel, it was determined that out of the total observed 4835.50m of tunnel excavation length, the tunnel excavation through the rock of the III RMR category was 2211.07m or 45.72%, the excavation through the rock of the IV RMR category in length of 2172.42m or 44.93%, and excavation through V RMR category 452.01m or 9.35%, which is shown in table no. 4.

Table 4. Overview of the representation of RMR categories according to the actual condition of the Zenica tunnel

Left and right tunnel tube Zenica- constructed		
Categorization of rock mass	**Length (m)**	**Percentage (%)**
II category	-	-
III category	2211,07	45,72
IV category	2172,42	44,93
V category	452,01	9,35
Total length	4835	100,00

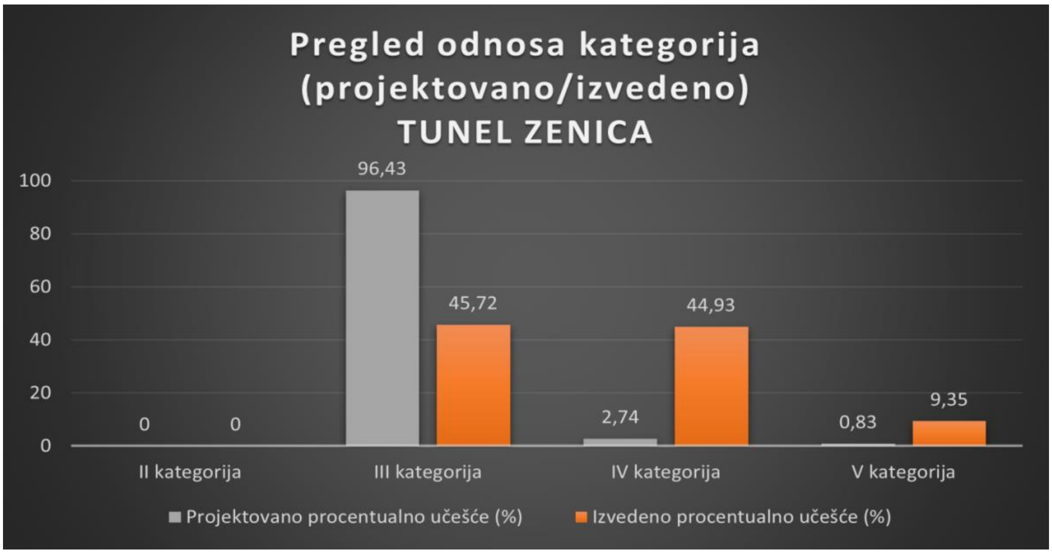

Figure 4. Overview of designed (gray) categories of rock mass and categories determined during construction (orange)

4. RELIABILITY OF THE RMR CLASSIFICATION DURING THE CONSTRUCTION OF THE ZENICA TUNNEL

Considering the geological, engineering geology, geotechnical, hydrogeological and other data collected during the design and construction of the Zenica tunnel, it can be stated that the Zenica tunnel was built in extremely complex geological, engineering geological and geotechnical conditions. The geotechnical conditions in which the Zenica tunnel was built are significantly less favorable than those assumed in the Main Geotechnical Project, as shown by the results presented in Tables 3 and 4.

The reliability of the RMR classification of the rock mass during the preparation of the Main Project was very low, which was shown during the 3,558 scoring of the rock material of the excavation face of the Zenica tunnel, including both tunnel tubes. The differences in what was defined in the project and during the construction of the tunnel can be seen in Figure 4, where the correlation between the predicted categorization and the categorization determined during construction, according to RMR, is shown. Such differences may also be a consequence of the insufficient scope of investigative work during design.

Figure 5. Fallout of rock blocks in the Zenica tunnel

However, the application of the RMR classification during tunnel construction was limited and often impossible. Defining input parameters for rock mass classification was very complicated, considering the wide range of values of individual input parameters. Sudden unexpected occurrences of groundwater, large differences in discontinuity characteristics and significant differences in the uniaxial strength of individual lithological members often forced contractors to classify the rock mass in a lower category, which in some cases was justified. In certain zones, due to a wrong assessment of some of the input parameters, it was necessary to carry out additional work to ensure the stability of the excavation, because some parameters did not correspond to the actual situation. The most common question is how and to what extent the parameters of one lithological member affect the complete stability of the excavation. As an example, one can cite the uniaxial compressive strength of individual lithological members, which can affect the deformation characteristics of the rock mass during excavation. The position, orientation and representation of individual lithological members in the excavation zone affected in different ways the very stability of the rock mass. Also, differences in uniaxial strength in the same lithological member, presented a problem for engineers. The position of a certain lithological member in the flanks or head of the excavation had an impact on the deformation characteristics of the excavation itself. Because of all this, the engineers who did the classification of the rock mass, very often based on their own assessment made the choice of input parameters for the classification, so often e.g. the choice of uniaxial compressive strength was an uncritically chosen mean value obtained in the laboratory. The reliability of the taken strength parameter often depended solely on the judgment of the engineer. In addition, the presence of lithological members with very low uniaxial compressive strength led to difficulties in the selection of this input parameter. The question arose as to what percentage of the presence of a lithological member with low uniaxial compressive strength in the excavation has an impact on the stability of the excavation and when to take that strength as relevant. Defining other input parameters was, in such complex geotechnical conditions, significantly more difficult, which forced engineers to often include the rock mass in a lower category. In spite of the fact that the engineers often classified the rock mass in a lower category, in order to ensure the unquestionable stability of the excavation, blocks fall out and part of the excavation collapsed. It was difficult to adjust the excavation step and the substructure of the Zenica tunnel, so that the excavation of the tunnel would be safe, without unforeseen blocks falling out and convergences, without over-dimensioning the substructure of the tunnel. All this shows that the reliability of RMR classification in complex geotechnical conditions is significantly reduced and depends solely on the experience of the engineer in the field. Introduction of reduction factors for certain input parameters, e.g. uniaxial compressive strength and the development of additional guidelines for the selection of individual parameters in complex geotechnical conditions would increase the reliability of the RMR classification.

CONCLUSION

The RMR classification is the most commonly used classification in Bosnia and Herzegovina when constructing road tunnels. Its reliability directly depends on geological, engineering geological and geomechanical conditions, that is, geotechnical conditions in the rock mass. Research works for the development of the main project should be carried out in an optimal scale, in order to reduce the differences between what is designed and what can be realistically expected in the rock mass. Only the experience of engineers in the field and adequate assessment of each of the input parameters enables optimal construction in the rock mass.

The scoring of rock material according to the RMR classification, in the complex geotechnical conditions of the Zenica tunnel, clearly showed that: "The RMR classification should be used in the cases for which it was developed, and not as an answer to all design problems" (Bieniawski 1989). The problem of the reliability of the categorization of rock material according to RMR calcification during the construction of the Zenica tunnel is a consequence of the complex geotechnical conditions in J/K “Vrandučki fliš”. A special problem is the relation to the test results and uniaxial strength values of the rock material, which resulted in often unrealistic scoring of the rock material according to the RMR classification. Considering the heterogeneity of the rock material, at the head of the excavation and the content of thin layers of clays, the question arises from which lithological member to take the value of uniaxial compression strength.

Due to the fact that the RMR classification is the most used classification, it is necessary to refine the classification in more detail, which would make the selection of input parameters easier. Correction factors for uniaxial compressive strength represent one of the steps to increase the reliability of RMR classification in complex geotechnical conditions.

LITERATURE

1. Barton, N.R. 1987. Predicting the behaviour of underground openings in rock. Manuel RochaMemorial Lecture, Lisbon. Oslo: Norwegian Geotech. Inst.
2. Barton, N.R., Lien, R. and Lunde, J. 1974. Engineering classification of rock masses for the design of tunnel support. Rock Mech. 6(4), 189-239.
3. Barton, N., (2000), TBM Tunnelling in Jointed and Faulted Rock, Balkema 172.p.
4. Barton, N., (2007), Rock Quality, Seismic Velocity, Attenaution and Anisotropy, Taylor & Francis 729.p.
5. Bieniawski Z.T. 1989. Engineering Rock Mass Classifications. Wiley, New York. 251pages.
6. Bieniawski, Z.T. 1967. Mechanism of brittle fracture of rock, parts I, II and III. Int. J. RockMech. Min. Sci. & Geomech. Abstr. 4(4), 395-430.
7. Bieniawski, Z.T. 1976. Rock mass classification in rock engineering. In Exploration for rockengineering, proc. of the symp., (ed. Z.T. Bieniawski) 1, 97-106. Cape Town: Balkema.
8. Bieniawski, Z.T. 1979. The geomechanics classification in rock engineering applications. Proc. 4th. congr., Int. Soc. Rock Mech., Montreux 2, 41-48.
9. Franklin J.A., Dusseault, M.B., (1989), Rock Engineering, McGraw-Hill Publishing Company,
10. Hoek, E., Carranza-Torres, C., Corkum, B. (2002) Hoek-Brown Failure Criterion-2002 Edition, Proc. North American Rock Mechanics Society Meeting in Torinto in July 2002.
11. Hoek, E., Kaiser, P.K., Bawden, W.F., (1995), Support of Underground Excavations in Hard Rock, Balkeme, 215 p 27-47 O.K.
12. Hoek, E., Rock Engineering (a course) http://www.rocscience.com/ 40-58 O.K of rock jointing. Proc. 4th congr. Int. Assn Engng Geol., Delhi 5, 221-228.
13. Mandžić E., (1999), Mehanika stijena, Autorizovana predavanja, RGGF Tuzla
14. Singh, B., Goel, R.K., (1999), Rock Mass Classification, A practical approach in civil engineering, Elsevier, 267 p.
15. Riedmuller, G., Schubert, W., (1999), Critical Comments on quantitative Rock Mass Classifications, Felsbau, 17, Nr.3
16. Singh, B., Goel, R.K., (1999), Rock Mass Classification, A practical approach in civil engineering, Elsevier, 267 p.
17. Selimović M., (2004), Rock Mechanics (Research of Rock Mass), Faculty of Civil Engineering, University of Mostar, Mostar
18. Selimović M., (2004), Rock Mechanics (Basic theory), Faculty of Civil Engineering, University of Mostar, Mostar
19. Selimović M., (2014), Rock Mechanics (Application in engineering practice), Faculty of Civil Engineering, University of Mostar, Mostar
20. Group of authors, (2022), Final engineering geological report on the excavation of "Zenica" tunnel, Zenica
21. Group of authors, (2022), Final engineering geological report on the excavation of "Vranduk", Zenica