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RQD in Thin-layered Beddings

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The paper analyzes the possibility of RQD index application according to the definition of the example of thin-layered flysch beddings in the eastern part of Split. It also proposes the definition for thin-layered beddings that begins with the thickness of the thinnest layer and then points out the impossibility of applying it to subvertical and vertical layers, and illustrates the existence of chert nodules in beddings. The results of the RQD index should be analyzed in correlation with the information on the terrain structure in order to give an accurate interpretation of the results obtained by drilling boreholes.

Analizira se mogućnost primjene RQD indeksa prema definiciji na primjeru tankoslojevitih flišnih naslaga u istočnom dijelu Splita. Predlaže se za tankoslojevite naslage definicija koja polazi od debljine najtanjeg sloja i ukazuje na nemogućnost primjene u slučajevima subvertikalnih i vertikalnih slojeva, te postojanja nodula čerta u naslagama. Za što točniju interpretaciju rezultata bušenja, rezultate RQD indeksa treba analizirati u korelaciji s cjelokupnim saznanjima o građi terena.

INTRODUCTION

The drilling of boreholes is used as a part of the research which is carried out for the construction of different structures. The results yield important data which is used to make the decisions concerning the ground site preparation and then to design and built the structure.

The exploration borehole is a dotted datum whose results can be applied only in the analysis in the correlation with all other data obtained by lithostratigraphic, seismotectonic, engineering-geologic and hydrogeologic research. It is very important to correctly describe the core while applying the data obtained by drilling the boreholes (Deer, 1963). In this article great attention has been paid to discontinuities and to the type of filling between them, to the lithology and hardness, which is quite logical considering the application of drilling boreholes data in different classifications of the rock mass. In order to classify the rock mass, Deer (1963) introduced the term *»Rock Quality Designation«*, i. e. *RQD Index*. It is determined by analyzing the core so that, according to the definition, all pieces longer than 10 cm are totaled and the sum is divided by the total length of the analyzed core. The result is the index of the rock mass fracture expressed in a percentage which is useful in estimating the cut depth down to the »sound« rock. Although this index briefly and inexpensively provides a general insight into the rock mass quality at the borehole, Londe (1973) said that there were restrictions that influence the data accuracy, especially the type of drilling boreholes and the borehole diameter. By analyzing rock mass classifications for tunnel designs, Stojković (1983) discussed the disadvanteges of the RQD Index application since it does not take into account the orientation, the spacing of joints, the structure and the angle of the inner friction of the filling as well as the roughness of joint walls. In addition, while analyzing the Geomechanical classification or the Bieniawski's RMR system an example is given for categorizing tunnels in slighlty weathered quartzite which have a compressive strength of 160 MPa and RQD Index of 80—90 %. Stojković (1983) outlined other parametres necessary for ranking, i. e. determining categories. It should be pointed out here, that the compressive strength and RQD Index have no functional relation, for many flysch areas of the eastern part of Split with marl and marly limestones have low compressive strengths (lower than 20 MPa), while the RQD Index is very high (from 90 % to 100 %). Therefore, the disadvantages of the existing classifications containing the RQD Index refer to the use and comparison of that index with other measured and mesaurable parametres. Consequently, a serious analysis should be made of all parametres used in each actual case and the character of their relationship should be determined. Šestanović et al. (1984), wrote about further restrictions of the RQD Index application in marl flysch. This index cannot be applied, according to the definition, to thin layered beddings.

The average values presented in Table I were determined by analyzing 312 samples by the RQD Index in marl layers 30 cm thick and by taking into consideration other measurable parametres.

The RQD data indicate that the disintegration of marls decreases with an increase in depth. The greatest number of the examined samples with a $CaCO_3$ percentage of between 35 % and 75 % can be found from 4 m

Table I Average results obtained by measurable parametres in marls in the eastern part of Split (Šestanović et al., 1984)

Tabela I Prosječni rezultati nekih mjerljivih parametara u laporima istočnog dijela Splita (prema: Šestanović et al., 1984)

Drilling Depth Dubina bušenja (m)	RQD Indeks RQD Index (%)	Number of Samples in Marls with 35 % to 75 % $CaCO_3$ Broj uzoraka u laporima s 35 % do 75 % $CaCO_3$	Propagation Velocity of Longitudinal Waves (m/s) Brzina širenja longitudinalnih valova (m/s)	Compressive Strength Tlačna čvrstoća (MPa)
< 4	32	74	500	min 6.2
4—8	72	183	2000	max 78.5
> 8	92	55	> 2600	

to 8 m deep. The propagation velocity of longitudinal waves increases with the increase in depth, i. e., in relation to the lower rock mass disintegration. The compressive strength, examined on 120 samples, shows a wide range from 6.2 MPa to 78.5 MPa, but the majority of the samples (about 72 %) ranged from 10 MPa to 30 MPa.

The correlation of the mentioned parametres gave very good results only between the RQD Index and the propagation velocity of longitudinal waves. This could be expected since marls become more compact with an increase in depth. When the dependence of the RQD Index with the $CaCO_3$ percentage in marls and with the compressive strength were compared to the correlation coefficients were less than 0.5. This indicator shows that there is no link between them. Therefore, it should be mentioned that the compressive strengths were obtained on the samples which were not vertical to the beddings but which had less or greater structural deformations and were at an angle in natural conditions. In the future, in order to compare results and to draw proper conclusions the samples of the same kind should be compressed vertically to the bedding and the results should be compared as is the practice now. Propagation velocities of longitudinal waves were obtained at a certain angle in relation to the propagation direction. Consequently, the propagation velocity should be tested parallelly with the bedding and vertically to the layer in the field and laboratory.

The results gained by the analysis and a great number of borehole drillings in the flysch beddings in the eastern part of Split where thin-layered marls and sadstones mainly appear, have given an impetus to the authors of this paper to study in detail the application of that index.

MAIN CHARACTERISTICS OF FLYSCH BEDDINGS IN THE EASTERN PART OF SPLIT

In the Split area there are eocene flysch beddings — $E_{2,3}$ (Marinčić et al., 1971; Magaš et al., 1973; Marinčić, 1981) represented by brecciaconglomerates and breccias, sandstones, marl limestone and marls containing different proportions of $CaCO_3$. Marls interlayered with sandstones and marl limestones are dominant in the eastern part of Split. The thickenesses of marl layers are different. The most common are thinlayered marls, but sometimes the thickness of their layers can vary from 1 to 1.5 metres. Sandstones can have thicker when they are in contact with brecciaconglomerates and breccias. When they interchange with marls the thickness of the layers does not exceed 10 cm.

The layers of marls limestones are approximately 1 m thick, but they are thin-layered when they are interlayered with thin-layered marls. Brecciaconglomerates and breccias can be found inlayers of up to 1.5 m thick. Their fragments can be up to 5 cm, but in the area where these beddings gradually pass into sandstones, the fragments which do not exceed 5 cm can be found with an abundant foraminiferal fauna. Their connective tissue is calciferous and marly. The breccias and breccia-conglomerates fragments are of limestone origin with chert occurences on some places. The data obtained by research carried out in the eastern part of Split resulted in the division into three completely different vertical sections of the flysch bedding zones. The first zone is made of chemically weathered thin-layered marls that interchange with rare thin-layered sandstones and marly limestones. The second zone is made of marl which interlayers with thicker sandstone layers on some places and marly limestones as well as brecciaconglomerates and breccias. The third zone is made of thin-layered marls which often interchange with thin-layered sandstones and clayey interlayers.

RESTRICTIONS OF THE RQD INDEX APPLICATION IN THIN-LAYERED FLYSCH BEDDINGS

In applying the RQD Index in order to gather information on the rock mass fracture in depth and to define the foundation elevation of structures on flysch beddings in the eastern part of Split, some restrictions have been noted which should be added to those pointed out by L o n d e (1973) and S t o j k o v i ć (1983). They are specifically related to:

— layer thickness
— layer dip
— occurence of chert nodules

According to the definition, only core pieces longer than 10 cm are taken into account when defining the RQD Index, therefore this procedure cannot be applied (as suggested) to all those beddings which are thinner than those defined. In such situations the RQD is zero. Therefore, it is possible to get a wrong impression that the examined rock is highly disintegrated.

The examined flysch bedding layers in the eastern part of Split are partly very steep and sometimes vertical. Therefore, the possibility of applying the RQD Index and of getting an accurate interpretation of the drilling results is lessened, especially when the boreholes is drilled by a crown with a smaler profile. In order to obtain accurate data, an oblique drilling, which is vertical to the bedding, should be applied in such cases.

Chert nodules in breccias and mary limestones of flysch break the layers of weaker physical and mechanical characteristics during the drilling, forming new and fresh fractures also on the existing smaller discontinuities. Then the core looks completely fractured and it can lead an unexperienced researcher to wrong conclusions.

These restrictions, seen in thin-layered flysch beddings, can be characteristic for other thin-layered beddings: sedimentary or schistose metamorphic rocks. Therefore, the RQD Index, as it has been defined, has a limited application in thin-layered rocks. As the index by which the data of rock mass fracture are obtained is very important, it should be used wherever possible respecting all restrictions found in the field and during the borehole drilling.

L o k i n (1987) wrote about the disadvantages and restrictions of the RQD Index application as an indicator of the rock mass quality. He formulated estimation method for rock mass fracture based on the determination of homogeneous and semihomogeneous zones according to the degree of fracture. Therefore, this method can be applied to layered rock without regard to the thickness of the layers.

In analyzing the RQD Index special attention should be paid in all cases to the genetic origin of the defined joints. This datum included in evaluation of rock mass quality has a considerable influence on the interpretation of the state within the ground and the accuracy of the obtaine parametres.

CONCLUSION

The RQD Index is used in practice as an indicator of the rock mass quality and it yields results which help to draw conclusions on the degree of fractures. However, the reliability of data depends upon a profound and critical core analysis and a wider area of investigation. Consequently, the RQD Index itself does not yield a sufficient amount o reliable data without complete engineering geologic interpretations of the conditions in the field. The RQD Index, according to definition, is not applicable to thin-layered beddings. Thus, a modification of the definition is suggested, so that the RQD Index is computed according to the tchikness of the thinnest layer. That is, if the index is to be applied to thin-layered beddings, the definition should contain the sum of all the core pieces whose length is longer than the thickness of the thinnest layer in relation to the total length of the drilling interval. The reliability of data decreases with the dip of layers, therefore, the RQD Index cannot be used for subvertical and vertical layers. The RQD is not applicable either if there are chert nodules in layers which break and crush those beddings with weaker physical and mechanical properties (for example marls in flysch). Thus, great attention should be paid to the application of the analyzed indicator of the rock mass fracture. The interpretation of the results should be accomplished in correlation with a complete knowledge of the characteristics of the investigated area.

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REFERENCES

Deere, D. U. (1963): Technical Description of Rock Cores for Engineering Purposes. *Rock Mechanics and Engineering Geology, I/1*, 16—22, Wien.

Deere, D. U. (1968): Geologic consideration. In: Stagg, K. G. & Zienkiewicz, O. C. (eds.), Rock Mechanics in Engineering Practice, 1—20, New York.

Lokin, P. (1987): Metode ispitivanja ispucalosti neotkrivenih stenskih masa. U: Metodologija istraživanja ispucalosti stenskih masa u geotehnici (red. Janjić, M., Lokin, P. i Cvetković-Mrkić, S.). Seminar RGF Beograd, Katedra za geotehniku, 163—196, Beograd.

Londe, P. (1973): Rock Mechanics and Dam Foundation Design. International Commission on Large Dams. 104 p. Paris.

Magaš, N., Marinčić, S. i Borović, I. (1973): Osnovna geološka karta SFRJ, 1 : 100.000. Tumač za listove Split i Primošten. Savezni geološki zavod, 43 str., Beograd.

Marinčić, S. (1981): Eocenski fliš Jadranskog pojasa. *Geol. vjesnik 34*, 27—38, Zagreb.

Marinčić, S., Magaš, N., Borović, I., Blašković, I., Majcen, Ž., Raffaelli, P. i Magdalenić, Z. (1971): Osnovna geološka karta SFRJ, 1 : 100.000. List Split. Savezni geološki zavod, Beograd.

Stojković, B. (1983): Klasifikacije stijenskih masa kao osnova za projektiranje tunela. U: Mehanika stijena, temeljenje, podzemni radovi (red. Jašarević, I.). DGIT Zagreb i DMSPR Hrvatske, 1055—1082, Zagreb.

Šestanović, S., Čagalj, M. i Biloš, T. (1984): Neke značajke lapora u flišu istočnog dijela Splita. Zbornik ref. VIII jug. simp. o hidrogeol. i inž. geol., knjiga 2, 363—367, Budva.

RQD u tanskoslojevitim naslagama

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RQD indeks se veoma često koristi u praksi, jer na brzi i jeftini način daje podatke o stupnju razlomljenosti stijenske mase. No, pri njegovoj primjeni uočeno je više ograničenja, od kojih se u ovom radu analiziraju: debljina slojeva, nagib slojeva i pojava nodula čerta.

Na primjeru tankoslojevitih flišnih naslaga istočnog dijela Splita, uočena je nemogućnost primjene RQD indeksa s obzirom na definiciju, po kojoj se računaju samo komadi jezgre dulji od 10 cm. Stoga se predlaže modifikacija postojeće definicije koja bi u sebi sadržavala zbroj svih komada jezgre duljih od debljine najtanjeg sloja, u odnosu na interval bušenja. Takvom modifikacijom bi se RQD indeks mogao primjenjivati i u svim tankoslojevitim i škriljavim naslagama.

S obzirom na nagib slojeva, uočena je nemogućnost primjene u slučajevima subvertikalnih i vertikalnih slojeva, jer su dobiveni podaci nepouzdani. Za dobivanje pouzdanih podataka u takvim bi slučajevima trebalo primijeniti koso bušenje, okomito na slojevitost. Kvaliteta rezultata je manja ako se istražno bušenje obavlja s krunom profila manjim od 86 mm.

U flišnim naslagama istočnog dijela Splita su česte pojave nodula čerta. Prilikom bušenja, one drobe i lome naslage slabijih fizikalno-mehaničkih karakteristika, stvarajući uglavnom nove, svježe prijelome, ali i po postojećim manjim diskontinuitetima, zbog čega se dio intervala bušenja doima kao potpuno razlomljena stijenska masa. Usprkos detaljnim analizama takve jezgre, nemoguće je dobiti točnu sliku razlomljenosti, te u takvim slučajevima RQD index također ne bi trebalo primjenjivati.

Analizom istražnih bušotina, koje daju točkaste podatke, ne dobiva se cjelovit uvid u razlomljenost stijenske mase. Za interpretaciju razlomljenosti, nužno je podatke RQD indeksa analizirati u korelaciji sa svim podacima dobivenim inženjerskogeološkim i drugim istraživanjima i ispitivanjima, jer će tako stupanj pouzdanosti rezultata istraživanja biti bliži realnom. Pri tom značajnu ulogu ima i determinacija pukotina na stanovišta njihove genetske pripadnosti.