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# Investigation S20-brittleness index of limestone and effective parameters on it at dry and saturated states

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## Abstract

Brittleness is an important problem in rock boring. So far, various methods have been introduced for determining rock brittleness but no method has yet been standard to measure it. In this paper, an empirical study was done to provide a reliable method for predicting the S20 brittleness index. The S20 brittleness test was done for 35 limestone blocks pick out from different parts of Iran in a dry and saturated state. Besides, physical (dry density, porosity, electrical resistivity, Schmidt rebound hardness number, and water absorption), mechanical (uniaxial comprehensive strength and point load index) and dynamical properties (P and S wave velocity) were measured. Finally, the classification of the samples was done based on the studying of petrography and mineralogy and statistical studies were done for each class. According to the results, predicting S20 based on the provided classification has a high degree of certainty. Also, by studying the brittleness of the samples in a dry and saturated state, it was determined that the presence of Montmorillonite clay mineral causes a decrease of brittleness and the presence of intergranular micro-cracks and high porosity leads to an increased brittleness in the saturation state relative to a dry state.

***Key words**: S20 brittleness index, Rock boring, Montmorillonite, Petrography, Limestone.*

## Extended Abstract:

### 1. Introduction

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Brittleness is one of the most important mechanical properties of rock. Nowadays, many tunnel boring projects are underway using Tunnel Boring Machine (TBM) and Roadheader (Yarali and Soyer). Methods of predicting TBM costs have been studied by many researchers (Ozdemir and Wang, 1979, Farmer and Glossop, 1980, Bamford, 1984, Nelson et al., 1985, Bruland, 1999, Blindheim et al., 2002, Bieniawski and Grandori, 2007, Genis et al., 2007, Armaghani et al., 2017, Macias et al., 2017, Koopialipoor et al., 2018, Salimi et al., 2018, Frough et al., 2019). Among them, CSM and NTNU models have been used in many projects. NTNU/SINTEF experiments have been used in many underground excavations projects. This method is an international acceptable tool for determining rock boring capability (Dahl et al., 2012).
The methods for determining rock brittleness by Meng et al. (Meng et al., 2015) are divided into two general groups, based on the stress-strain curve and based on the physical and mechanical properties of rocks. Another method for determining rock brittleness is a punch penetration test, which is very expensive and time-consuming (Yagiz, 2009). There is a general acceptance of NTNU / SINTEF tests. Therefore, the purpose of this study was to determine the best method for predicting the S20 brittleness criterion based on the index characteristics, petrography, and other criteria of brittleness.

## 2. Materials and methods

### *2.1 Petrographic characteristics of samples*

35 limestone blocks were collected with approximate dimensions of 30 * 30 * 20 cm from different parts of Iran. Petrographic studies were done and samples classified according to Dunham, 1962 and Embry and Klovan, 1971 classification (Dunham, 1962, Embry and Klovan, 1971). Accordingly, samples were divided into 3 major classes. Class 1, 2 and 3 are limestone without a trace of dolomitization and quartz mineral, sandy limestone and dolomitic limestone, respectively. Class 1 and 3 were divided into 2 subclasses based on detailed petrographic studies. Subclass 1A and 1B are mud supported and grain supported limestone, respectively. Class 1B was divided into two subclasses of 1BM and 1BS based on the dominant of the matrix or sparry cement, respectively. Class 3B is dolomudstones and class 3A including other types of dolomitic limestone.

### *2.2 Engineering properties*

Determination of Schmidt rebound number and physical properties including dry density and porosity of samples were performed according to standard (ISRM, 1981). The electrical resistivity of the samples was measured based on electrical resistance and sample dimensions. Ultrasonic wave velocity was determined according to the International Society for Rock Mechanics (ISRM, 2007). Also, the point load index and uniaxial comprehensive strength of the samples were measured according to standard (ISRM, 1985).

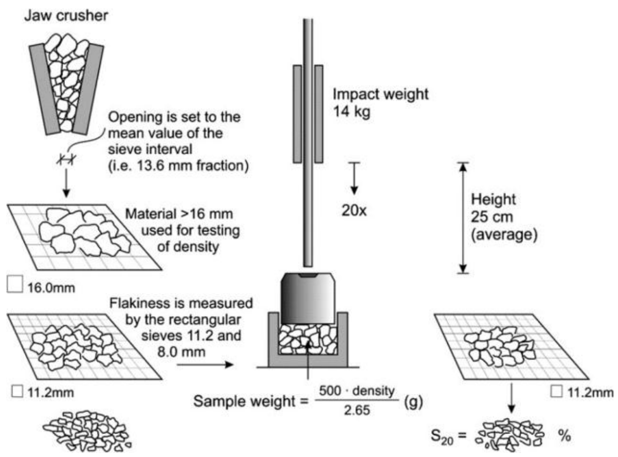

Fig. 1. S20-Brittleness test (Dahl et al., 2012)

Then, the brittleness test was done with 20 repeated impacts. Finally, the S20 was measured as the percentage of particles passing through the 11.2 mm square sieve.

## 3. Tests results

The S20 brittleness index of some samples in the dry state gets less or more. The presence of clay minerals, especially montmorillonite, is the main reason for reducing brittleness in a saturated state. Montmorillonite clay mineral can contain sodium and calcium ions (positive cations). In the presence of water, sodium and calcium ions dissolved easily and as a result, clay minerals sheets are separated. This process increases ductability of the rock and thus reduces brittleness.

## 4. Conclusion

In this paper, an experimental study was carried out to predict limestone S20-brittleness under dry and saturated states. Besides, the reason for the decrease and increase in the amount of it was analyzed under dry and saturated states. The following are the results:
1- Linear/nonlinear regression by using the petrographic classification, provides high correlation relations.
2- Presence of clay minerals in the rock, especially montmorillonite, reducing the brittleness in saturated states concerning dry states.
3- High porosity and microcracks in the rock grains are the factors that increase the brittleness in saturated states for dry states.

## References:

Armaghani, D. J., Mohamad, E. T., Narayanasamy, M. S., Narita, N., Yagiz, S. 2017. Development of hybrid intelligent models for predicting TBM penetration rate in hard rock condition. Tunnelling and Underground Space Technology, 63: 29-43.
Bamford, W., 1984. Rock test indices are being successfully correlated with tunnel boring machine performance. Fifth Australian Tunnelling Conference: State of the Art in Underground Development and Construction; Preprints of Papers. Institution of Engineers, Australia, 218p.
Bruland, A., 1999. Hard rock tunnel boring advance rate and cutter wear. Norwegian Institute of Technology (NTNU), Trondheim, Norway.

Bieniawski, Z., Grandori, R., 2007. Predicting TBM excavability-part II. Tunnels and Tunnelling International.

Blindheim, O., Grov, E., Nilsen, B., 2002. The effect of mixed face conditions (MFC) on hard rock TBM performance. AITES-ITA Downunder 2002: 28th ITA General Assembly and World Tunnel Congress, Sydney, Australia, 2-8.

Dahl, F., Bruland, A., Jakobsen, P. D., Nilsen, B., Grov, E., 2012. Classifications of properties influencing the drillability of rocks, based on the NTNU/SINTEF test method. Tunnelling and Underground Space Technology, 28: 150-158.

Dunham, R. J., 1962. Classification of carbonate rocks according to depositional textures. AAPG Bulletin, 1: 80-121.

Embry, A. F., Klovan, J. E., 1971. A late Devonian reef tract on northeastern Banks Island, N.W.T. Bulletin of Canadian Petroleum Geology, 19: 730-781.

Genis, M., Basarir, H., Ozarslan, A., Bilir, E., Balaban, E., 2007. Engineering geological appraisal of the rock masses and preliminary support design, Dorukhan Tunnel, Zonguldak, Turkey. Engineering Geology, 92: 14-26.

ISRM 1981. Rock characterization, testing and monitoring, Oxford, Pergamon press.

ISRM 1985. Suggested method for determining point load strength. International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts, Elsevier, 51-60.

ISRM 2007. The complete ISRM suggested methods for rock characterization, testing and monitoring: 1974-2006. Suggested methods prepared by the commission on testing methods., Ankara, International Soc. for Rock Mechanics, Commission on Testing Methods.

Farmer, I., Glossop, N., 1980. Mechanics of disc cutter penetration. Tunnels and Tunnelling, 12: 22-25.

Frough, O., Khetwal, A., Rostami, J., 2019. Predicting TBM utilization factor using discrete event simulation models. Tunnelling and Underground Space Technology, 87: 91-99.

Koopialipoor, M., Nikouei, S. S., Marto, A., Fahimifar, A., Armaghani, D. J., Mohamad, E. T., 2018. Predicting tunnel boring machine performance through a new model based on the group method of data handling. Bulletin of Engineering Geology and the Environment, 1-15.

Macias, F., Dahl, F., Bruland, A., Tunnelling, I., Association, U. S., 2017. Applicability of the new rock abrasivity test method (RIAT) to cutter life assessments in hard rock tunnel boring. World Tunnel Congress, 1-10.

Meng, F., Zhou, H., Zhang, C., Xu, R., Lu, J. 2015. Evaluation methodology of brittleness of rock based on post-peak stress–strain curves. Rock Mechanics and Rock Engineering, 48, 1787-1805.

Nelson, P., Ingraffea, A., O'rourke, T., 1985. TBM performance prediction using rock fracture parameters. Intl J of Rock Mech and Mining Sci and Geomechanic Abs, 22.

Salimi, A., Faradonbeh, R. S., Monjezi, M., Moormann, C., 2018. TBM performance estimation using a classification and regression tree (CART) technique. Bulletin of Engineering Geology and the Environment, 77: 429-440.

Yagiz, S., 2009. Assessment of brittleness using rock strength and density with punch penetration test. Tunnelling and Underground Space Technology, 24: 66-74.

Yarali, O., Soyer, E., 2011. The effect of mechanical rock properties and brittleness on drillability. Scientific Research and Essays, 6: 1077-1088.

OZDEMIR, L., and WANG, F. D., 1979. Mechanical tunnel boring prediction and machine design. Nasa Sti/Recon Technical Report N, 80p.