Rock Engineering Properties of Jurong Formation

Rueda J.

Master of Numerical Methods in Engineering

Communications Skills II

Introduction

The purpose of this study is to demonstrate that properties such as the rock's strength, stiffness and anisotropy, with a particular focus on the rocks of the Jurong Formation, can be empirically correlated to laboratory test classification and/or strength indices.

The design of underground excavations in rock demands engineers to be able to predict the behavior of the rock mass under certain imposed actions.

Two key properties that control this behavior are rock mass' strength and stiffness. Bieniawski [2] pointed out uniaxial compression strength and triaxial strength of rock as two suitable tests for characterisation of rock mass strength and stiffness. However, these are both relatively expensive tests and time-consuming, and since ground investigation programmes are typically under time and budget constraints, engineers tend to sacrifice accuracy on results in behalf of cheaper, quicker and simpler testing methods: Point load strength index [7] and uniaxial compressive strength test [3 and 11].

Methodology

I - Normalization of results

The rock specimen shape, dimensions and weathering grade have a considerable influence on the rock strength indices ([1], [4], [5], [6], [8], [10], [12]), [13]). Thus, normalizing the test results becomes even more critical for comparison and development of relationships between different strength indexes.

II - Relationships studied

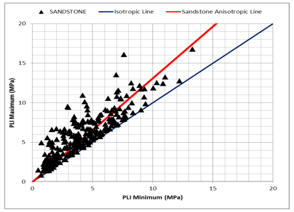
- Unconfined compression strength and dry bulk density.
- Rock anisotropy and point load strength index.
- Unconfined compression strength and point load strength index, where previous relationships, proposed by Broch E. et al [3] and Leung C. F. et al [9], respectively, are compared with the data.
- *Tangent Young Modulus and unconfined compressive strength*

III - Confidence measured with the coefficient of determination.

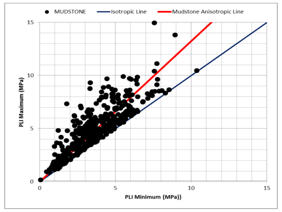
Results

I - Background

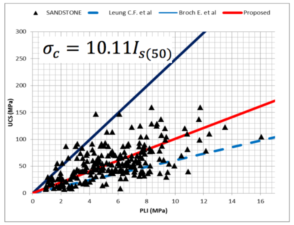
Data – The present work has relied on a total of 2,721 tests, comprising classification and strength index testing, on two major rock units (i.e. sandstones and mudstones of the Ayer Chawan facies) of the Jurong Formation of Singapore.



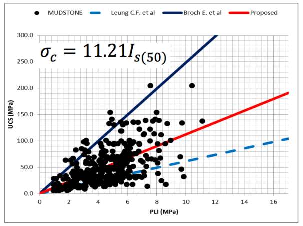
SANDSTONE – ANISOTROPY BASED ON POINT LOAD STRENGTH INDEX



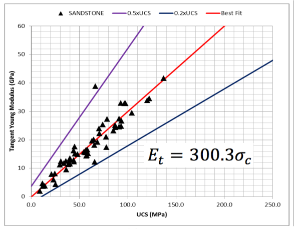
MUDSTONE – ANISOTROPY BASED ON POINT LOAD STRENGTH INDEX



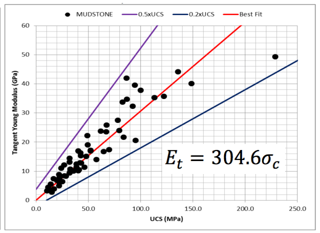
SANDSTONE – UNIAXIAL COMPRESSION STRENGTH VERSUS POINT LOAD STRENGTH INDEX



MUDSTONE – UNIAXIAL COMPRESSION STRENGTH VERSUS POINT LOAD STRENGTH INDEX



SANDSTONE – TANGENT YOUNG'S MODULUS VERSUS UNIAXIAL COMPRESSIVE STRENGTH



MUDSTONE – TANGENT YOUNG'S MODULUS VERSUS UNIAXIAL COMPRESSIVE STRENGTH

Conclusions

Rock Anisotropy and PLI – The approach taken to derive the anisotropy has given consistent results between sandstones and mudstones.

UCS versus PLI – Moderate relationships have been derived. Equation (1.5) is not applicable to rocks of the Jurong Formation, as it overestimates the strength. Equation (1.4) seems reasonable on general highly weathered rocks of Jurong Formation, while equations (1.8) and (1.9) may be more adequate on moderately to slightly weathered rock units.

E versus UCS – The present paper has established that a strong relationship exists between uniaxial compression strength and tangent young modulus, with equations (1.12) to (1.15) defining that relationship.

Generally the strength and stiffness are slightly greater for the mudstones, this might be related to the grain size, for which a decrease in grain size leads to an increase in strength and stiffness. The bonding between particles and the fact that a much larger number of grains have to fail, might be the reason behind that slight difference between sandstones and mudstones.

Recommendations

Shape effects must be considered and strength test results normalized (e.g. at a reference diameter of 50mm) according to latest standards or state-of art procedures. This is critical for comparison and assessment between different strength indexes.

To adequately assess the reliability of point load strength data it is recommended to ensure the GI Contractor included photographs, as well as description of the specimen's mode of failure (i.e. failure through joint, lamination, intact rock). At the same tame we recommend to filter any anomalous values and treat point load strength index values lower than 1MPa with suspicion.

Point load strength tests on shaley mudstones might yield unrepresentative results, and hence customized testing must be specified and results carefully reviewed on such fissile materials.

Point load strength index must be used in conjunction with uniaxial compressive strength tests, when possible. This approach allows engineers to verify and confirm the reliability of proposed empirical relationships or even establish site-specific relationships.

References

[1] Akram M. and Bakar M. Z. A. (2007) *Correlation between uniaxial compressive strength and point load index for Salt-Range rocks*. Pak. J. Eng. Appl. Sci. 1

[2] Bieniawski Z. T. (1974) *Estimating the strength of rock materials*. JSAIMM.

[3] Broch E. and Franklin J.A. (1972) *The point-load strength test*. IJRMMSG Vol. 9, No.2, pp 669-697

[4] Chang C., Zoback M. D., Khaksar A. (2006) *Empirical relations between rock strength and physical properties in sedimentary rocks*. JPSE 51, pp 223-237

[5] Gu D.X., Tamblyn W., Lamb I. and Ramsey N. (2008) *Effect of weathering on strength and modulus of basalt and siltstone*. ARMA

[6] Hoek E. and Brown E.T. (1980) *Underground excavations in rock*. IMM.

[7] International Society of Rock Mechanics Commission on Testing Methods. (1979 & 1985) IJRMMSG.

[8] Jeyatharan K., Lee K. W., Pakianathan L. J. and She C. P. (2003) *Limestones of the Jurong Formation*. Underground Singapore

[9] Leung C.F. and Radhakrishnan R. (1990) *Geotechnical properties of weathered sedimentary rocks*. Geotechnical Engineering, Vol. 21

[10] Macklin S., Schult M., Terzic Z. and Chu D. (2014) Strain-dependent stiffness of the weathered Melbourne Formation. 15th ATC 2014

[11] Pells P. J. N. (1975) The use of the point load test in predicting the compressive strength of rock materials. Australian Geomechanics Journal

[12] Thuro K., Plinninger R. J., Zah S. and Schutz S. (2001) Scale effects in rock strength properties. Part 1. Rock Mechanics – a Challenge for Society, Sarkka & Eloranta (eds.),

[13] Zhao J., Ng W.L., Cai J.G., Zhang X. H. and Bian H. Y. (2004) Feasibility of Underground Hydrocarbon Storage at Jurong Island. Proceedings of WTC