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REVIEW ARTICLE

APPLICABILITY OF THE GEOLOGICAL STRENGTH INDEX (GSI) CLASSIFICATION FOR THE TRUSMADI FORMATION AT SABAH, MALAYSIA

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ABSTRACT

During the feasibility and preliminary design stages of a project, when very little detailed information on the rock mass and its geomechanic characteristics is not available, the use of a Rock Mass Classification Scheme (RMCS) can be of considerable benefit. Various parameters were used in order to identify the RMCS. The parameter comprised of Rock Quality Designation (RQD), Rock Mass Rating (RMR), Rock Structure Rating (RSR), Geological Strength Index (GSI), Slope Mass Rating (SMR), etc. In this paper, we present the results of the applicability of the Geological Strength Index (GSI) classification for the Trusmadi Formation in Sabah, Malaysia. The GSI classification system is based on the assumption that the rock mass contains a sufficient number of "randomly" oriented discontinuities such that it behaves as a homogeneous isotropic mass. In this study, the GSI relates the properties of the intact rock elements/blocks to those of the overall rock mass. It is based on an assessment of the lithology, structure and condition of discontinuity surfaces in the rock mass and is estimated from visual examination of the rock mass exposed in outcrops or surface excavations. A total of ten (10) locations were selected on the basis of exposures of the lithology and slope condition of the Trusmadi Formation. The Trusmadi Formation regionally experienced of two major structural orientations NW-SE and NE-SW. It consists mostly of dark grey shale with thin bedded sandstones, typical of a turbidite deposit. This unit has been subjected to low grade of metamorphism, producing slates, phyllites and meta-sediments and intense tectonic deformation producing disrupted or brecciated beds. Quartz vein are quite widespread within the joints on sandstone beds. The shale is dark grey when fresh but changes light grey to brownish when weathered. The results are classified as "Poor Rock" to "Fair Rock" in term of GSI. The poor categories (TR2 and TR7) represent slickensided, highly weathered surfaces with compact coatings or fillings or angular fragments. It is also characterized as blocky/ disturbed/seamy, which folded with angular blocks formed by many intersecting discontinuity sets. The fair categories can be divided into two (2) types; type 1 (TR1, TR6 and TR8) which represent as smooth, moderately weathered and have altered surfaces. It is also characterised as very blocky rock, which indicates interlocked, partially disturbed ass with multi-faceted angular blocks formed by 4 or more joint sets. Type 2 (TR3, TR4, TR5, TR9 and TR10) which represent as smooth, moderately weathered and have altered surfaces but characterized as blocky/disturbed/seamy, which folded with angular blocks formed by many intersecting discontinuity sets. It also has persistence of bedding planes or schistosity.

KEYWORDS

Geological Strength Index (GSI), Rock Mass Classification Scheme (RMCS) & Trusmadi Formation.

1. INTRODUCTION

The Geological Strength Index (GSI) was introduced by (Hoek et al., 1992; Hoek, 1994; Hoek et al., 1995). This index was subsequently extended for weak rock masses in a series of papers by (Hoek et al., 1998; Marinos and Hoek, 2000). Later, proposed a chart of the GSI for heterogeneous rock masses, such as flysch, which is frequently composed of tectonically disturbed alternations of strong and weak rocks (sandstone and siltstone, respectively) (Marinos and Hoek, 2001). This chart was modified later (Marinos et al., 2007). The GSI relates the properties of the intact rock elements/blocks to those of the overall rock mass. It is based on an assessment of the lithology, structure and condition of discontinuity surfaces in the rock mass and is estimated from visual examination of the rock mass exposed in outcrops, surface excavations such as road cuts, tunnel faces and borehole cores. It utilizes two fundamental parameters of the geological process (blockiness of the mass and condition of

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discontinuities), hence takes into account the main geological constraints that govern a formation. In addition, the index is simple to assess in the field.

The Geological Strength Index (GSI) classification system is based on the assumption that the rock mass contains a sufficient number of “randomly” oriented discontinuities such that it behaves as a homogeneous isotropic mass. The behavior of the rock mass is independent of the direction of the applied loads. Therefore, it is clear that the GSI system should not be applied to those rock masses in which there is a clearly defined dominant structural orientation or structurally dependent gravitational instability. However, the Hoek-Brown criterion and the GSI chart can be applied with caution if the failure of such rock masses is not controlled by such anisotropy (e.g., in the case of a slope when the dominant structural discontinuity set dips into the slope and failure occurs through the rock mass) (Marinos and Hoek, 2001). For rock masses with a structure such as that shown in the bottom row of the GSI chart, anisotropy is not a major issue, as the difference in the strength of the rock and that of the discontinuities within it is often small.

Therefore, it is important to understand that the use of a GSI cannot replace some of the more elaborate design procedures. However, the use of these design procedures requires access to relatively detailed information on in situ stresses, rock mass properties and planned excavation sequence, none of which may be available at an early stage in the project. As this information becomes available, the use of this GSI classification should be updated and used in conjunction with site specific analyses.

2. Background of Study Area

Study area is located about 110km from Kota Kinabalu city center. It is bounded between longitude line E 116^{o} 30’ to E 116^{o} 40’ and latitude line N 06^{o} 09’ to N 06^{o}15’ (Figure 1). Due to this study only concentrated on the Trusmadi Formation, all activities such mapping, sampling, observation and monitoring is more focused on the slopes under this formation. Trusmadi Formation is Paleocene to Eocene in aged. The Trusmadi Formation generally shows two major structural orientations NW-SE and NE-SW. Trusmadi Formation is characterized by the present of dark colour argillaceous rocks, siltstone and thin-bedded turbidite in well-stratified sequence.

Some of the Trusmadi Formation rocks have been metamorphosed to low grade of the greenish-schist facies; the sediment has become slate, phyllite and metarenite. Cataclastic rocks are widespread and occur as black phyllonite enclosing arenitic and lutitic boudins with diameter up to a meter or demarcating thin to thicker fault zones or as flaser zones with hardly any finer grain matrix or as zones of closely spaced fractures. Quartz and calcite veins are quite widespread within the crack deformed on sandstone beds. The shale is dark grey when fresh but changes light grey to brownish when weathered (Rodeano et al., 2010; Norbert et al., 2016; Rodeano et al., 2018).

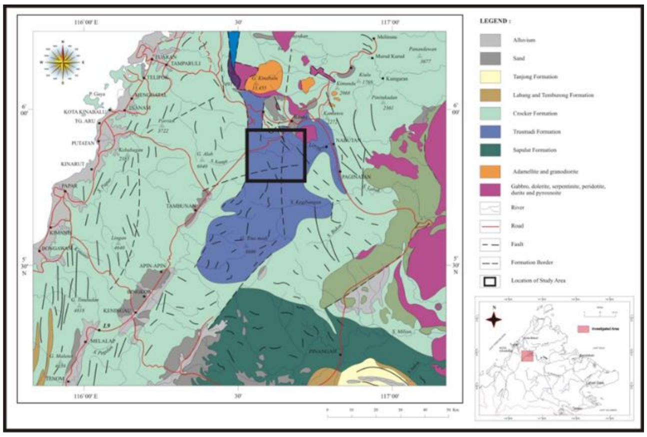

Figure 1: Location of study area

3. Determination of Geological Strength Index (GSI)

Field studies have been carried out to study the lithological and structural variations in rock slopes. A total of ten (10) locations were selected on the basis of exposures of the lithology and slope condition of the Trusmadi Formation (Figure 2). Slopes at these locations were studied and classified for their GSI classification. GSI was calculated by using below equation:

$$GSI = RMR - 5 \text{ (Bieniawski, 1989)} \qquad (1)$$

Where, RMR is mean rock mass rating = Parameter A + Parameter B + Parameter C + Parameter D + Parameter E

The Rock Mass Rating (RMR) system is a rock mass quality classification developed by South African Council for Scientific and Industrial Research (CSIR), which are closed associated with excavation for the mining industry (Bieniawski, 1973). The RMR system in use now incorporates five (5) basic parameters below:

a. Strength of intact rock material (Parameter A): Uniaxial compressive strength is preferred. For rock of moderate to high strength, point load index is acceptable.

b. RQD (Parameter B): Rock quality designation (RQD) was introduced in 1960s, as an attempt to quantify rock mass quality. RQD only represents the degree of fracturing of the rock mass. It does not account for the strength of the rock or mechanical and other geometrical properties of the joints.

c. Spacing of joints (Parameter C): Average spacing of all rock discontinuities is used.

d. Condition of joints (Parameter D): Condition includes joint aperture, persistence, roughness, joint surface weathering and alteration, and presence of infilling.

e. Groundwater conditions (Parameter E): It is to account for groundwater inflow in excavation stability.

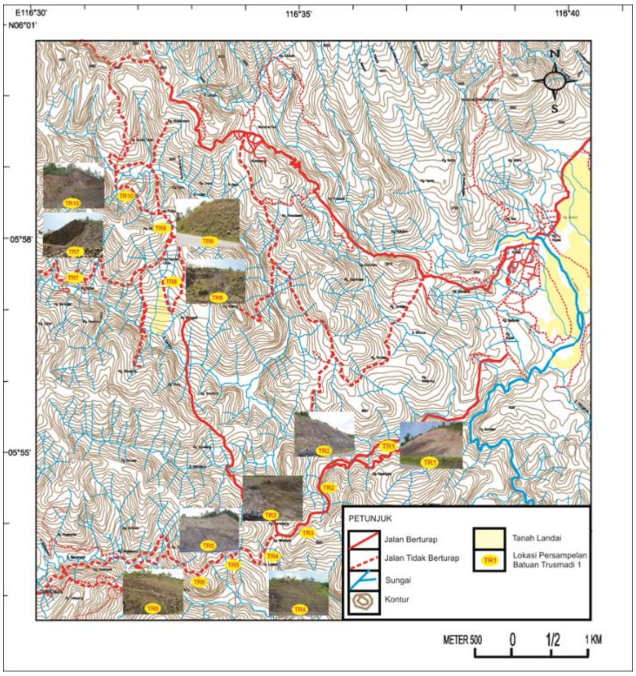

Figure 2: Selected rock slopes location with their photographs

Table 1 is the RMR system classification updated in 1989. Part A of the table shows the RMR system classification with the 5 parameters. Individual rate for each parameter is obtained from the property of each parameter. The weight of each parameter has already considered in the rating. The overall basic RMR system rate is the sum of individual rates. Influence of joint orientation on the stability of excavation is considered in Part B of the same table. Explanation of the descriptive terms used is given table Part C. With adjustment made to account for joint orientation, a final

RMR system rating is obtained it can be also express in rock mass class, as shown in Tables 1 and 2. The Table 2 also gives the meaning of rock mass classes in terms of stand-up time, equivalent rock mass cohesion and friction angle. Part D indicate the meaning of rock classes and Part E described the guidelines for classification of discontinuity conditions.

<table>
<tr><th colspan="10">Table 1: Rock mass classification RMR system (Bieniawski, 1989)</th></tr>
<tr><td colspan="10">A. CLASSIFICATION PARAMETERS AND THEIR RATINGS</td></tr>
<tr><td colspan="3">Parameter</td><td colspan="7">Range of values</td></tr>
<tr><td rowspan="3">1</td><td rowspan="2">Strength of intact rock material</td><td>Point-load strength index</td><td>>10MPa</td><td>4 – 10MPa</td><td>2 – 4MPa</td><td>1 – 2MPa</td><td colspan="3">For this low range – uniaxial compressive test is preferred</td></tr>
<tr><td>Uniaxial compression strength</td><td>>250MPa</td><td>100 – 250MPa</td><td>50 – 100MPa</td><td>25 – 50MPa</td><td>5-25 MPa</td><td>1-5 MPa</td><td><1 MPa</td></tr>
<tr><td colspan="2">Rating</td><td>15</td><td>12</td><td>7</td><td>4</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">2</td><td colspan="2">Drill core quality RQD</td><td>90% - 100%</td><td>75% - 90%</td><td>50% - 75%</td><td>25% - 50%</td><td colspan="3">< 25%</td></tr>
<tr><td colspan="2">Rating</td><td>20</td><td>17</td><td>13</td><td>8</td><td colspan="3">3</td></tr>
<tr><td rowspan="2">3</td><td colspan="2">Spacing of discontinuities</td><td>>2m</td><td>0.6 – 2m</td><td>200 – 600mm</td><td>60 – 200mm</td><td colspan="3"><60mm</td></tr>
<tr><td colspan="2">Rating</td><td>20</td><td>15</td><td>10</td><td>8</td><td colspan="3">5</td></tr>
<tr><td rowspan="2">4</td><td colspan="2">Condition of discontinuities (See E)</td><td>Very rough surfaces
Not continuous
No separation
Unweathered wall rock</td><td>Slightly rough surfaces
Separation <1mm
Slightly weathered walls</td><td>Slightly rough surfaces
Separation <1mm
Highly weathered walls</td><td>Slickensided surfaces or gouge <5mm thick or
Separation 1-5mm continuous</td><td colspan="3">Soft gouge >5mm thick
or Separation >5mm continuous</td></tr>
<tr><td colspan="2">Rating</td><td>30</td><td>25</td><td>20</td><td>10</td><td colspan="3">0</td></tr>
<tr><td rowspan="4">5</td><td rowspan="3">Ground water</td><td>Inflow per 10m tunnel length (l/m)</td><td>None</td><td><10</td><td>10 – 25</td><td>25 – 125</td><td colspan="3">>125</td></tr>
<tr><td>(Joint water press)/ (major principal σ)</td><td>0</td><td><0.1</td><td>0.1 – 0.2</td><td>0.2 – 0.5</td><td colspan="3">>0.5</td></tr>
<tr><td>General conditions</td><td>Completely dry</td><td>Damp</td><td>Wet</td><td>Dripping</td><td colspan="3">Flowing</td></tr>
<tr><td colspan="2">Rating</td><td>15</td><td>10</td><td>7</td><td>4</td><td colspan="3">0</td></tr>
<tr><td colspan="10">B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)</td></tr>
<tr><td colspan="3">Strike and dip orientations</td><td>Very Favourable</td><td>Favourable</td><td>Fair</td><td>Unfavourable</td><td colspan="3">Very Unfavourable</td></tr>
<tr><td colspan="2" rowspan="3">Ratings</td><td>Tunnels and mines</td><td>0</td><td>-2</td><td>-5</td><td>-10</td><td colspan="3">-12</td></tr>
<tr><td>Foundations</td><td>0</td><td>-2</td><td>-7</td><td>-15</td><td colspan="3">-25</td></tr>
<tr><td>Slopes</td><td>0</td><td>-5</td><td>-25</td><td>-50</td><td colspan="3">-60</td></tr>
<tr><td colspan="10">C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS</td></tr>
<tr><td colspan="3">Rating</td><td>100 ← 81</td><td>80 ← 61</td><td>60 ← 41</td><td>40 ← 21</td><td colspan="3"><21</td></tr>
<tr><td colspan="3">Class number</td><td>I</td><td>II</td><td>III</td><td>IV</td><td colspan="3">V</td></tr>
<tr><td colspan="3">Description</td><td>Very good rock</td><td>Good rock</td><td>Fair rock</td><td>Poor rock</td><td colspan="3">Very poor rock</td></tr>
<tr><td colspan="10">D. MEANING OF ROCK CLASSES</td></tr>
<tr><td colspan="3">Class number</td><td>I</td><td>II</td><td>III</td><td>IV</td><td colspan="3">V</td></tr>
<tr><td colspan="3">Average stand-up time</td><td>20 yrs for 15m span</td><td>1 year for 10m span</td><td>1 week for 5m span</td><td>10 hrs for 2.5m span</td><td colspan="3">30 min for 1m span</td></tr>
<tr><td colspan="3">Cohesion of rock mass (kPa)</td><td>>400</td><td>300 – 400</td><td>200 – 300</td><td>100 – 200</td><td colspan="3"><100</td></tr>
<tr><td colspan="3">Friction angle of rock mass (deg)</td><td>>45</td><td>35 – 45</td><td>25 – 35</td><td>15 – 25</td><td colspan="3"><15</td></tr>
<tr><td colspan="10">E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY CONDITIONS</td></tr>
<tr><td colspan="3">Discontinuity length (persistence)
Rating</td><td><1m
6</td><td>1.3m
4</td><td>3 – 10m
2</td><td>10 – 20m
1</td><td colspan="3">>20m
0</td></tr>
<tr><td colspan="3">Separation (aperture)
Rating</td><td>None
6</td><td><0.1mm
5</td><td>0.1 – 1.0mm
4</td><td>1 – 5mm
1</td><td colspan="3">>5mm
0</td></tr>
<tr><td colspan="3">Roughness
Rating</td><td>Very rough
6</td><td>Rough
5</td><td>Slightly rough
3</td><td>Smooth
1</td><td colspan="3">Slickensided
0</td></tr>
<tr><td colspan="3">Infilling (gouge)
Rating</td><td>None
6</td><td>Hard filling <5mm
4</td><td>Hard filling >5mm
2</td><td>Soft filling <5mm
2</td><td colspan="3">Soft filling >5mm
0</td></tr>
<tr><td colspan="3">Weathering
Rating</td><td>Unweathered
6</td><td>Slightly weathered
5</td><td>Moderately weathered
3</td><td>Highly weathered
1</td><td colspan="3">Decomposed
0</td></tr>
</table>

Table 2: Rock mass classes determined from total ratings and meaning (Bieniawski, 1989)

RMR Ratings	81 – 100	61 – 80	41 – 60	21 – 40	< 20
Rock mass class	A	B	C	D	E
Description	very good rock	good rock	fair rock	poor rock	very poor rock
Average stand-up time	10 year for 15 m span	6 months for 8 m span	1 week for 5 m span	10 hours for 2.5 m span	30 minutes for 0.5 m span
Rock mass cohesion (KPa)	> 400	300 – 400	200 – 300	100 – 200	< 100
Rock mass friction angle	> 45°	35° – 45°	25° – 35°	15° – 25°	< 15°

4. Estimation of Geological Strength Index (GSI)

Geological Strength Index (GSI) is required a thorough field in-situ observation to assess the Rock Mass Classification Scheme (RMCS) of the study area. Whether the RMCS of the area would be strong or weak depend on their 5 basic parameters (in rock mass rating) minors to value 5 as mentioned at section above (Bieniawski, 1989). The calculation of GSI results for all 10 rock slopes selected is shown in Table 3 and Figure 3. According to the Table 3 and Figure 3, GSI rating values is ranged from 28 to 45. This result can be classified as “Poor Rock” to “Fair Rock” in term of GSI classification. Based on the Figure 3, the poor categories (TR2 and TR7) represent as slickensided, highly weathered surfaces with compact coatings or fillings or angular fragments.

It’s was also characterised as blocky/disturbed/seamy, which folded with angular blocks formed by many intersecting discontinuity sets. They have persistence of bedding planes or schistosity. The fair categories can be divided into two (2) types; type 1 (TR1, TR6 and TR8) represent as smooth, moderately weathered and have altered surfaces. It’s was also characterised as very blocky rock, which indicates interlocked, partially disturbed mass with multi-faceted angular blocks formed by 4 or more joint sets. Whereas type 2 (TR3, TR4, TR5, TR9 and TR10) represent as smooth, moderately weathered and have altered surfaces but characterised as blocky/disturbed/seamy, which folded with angular blocks formed by many intersecting discontinuity sets. It’s was also had persistence of bedding planes or schistosity.

Table 3: The total summarizes rating for the Geological Strength Index (GSI) results

Station	TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8	TR9	TR10
Strength of intact rock material rating	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
RQD rating	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Spacing of joints rating	8.0	10.0	8.0	10.0	8.0	10.0	8.0	8.0	10.0	10.0
Condition of joints rating	20.0	10.0	20.0	10.0	10.0	20.0	10.0	20.0	10.0	10.0
Groundwater conditions rating	7.0	0.0	0.0	4.0	7.0	4.0	0.0	4.0	7.0	4.0
TOTAL RMR rating	50.0	35.0	43.0	39.0	40.0	49.0	33.0	47.0	42.0	39.0
TOTAL GSI rating	**45.0**	**30.0**	**38.0**	**34.0**	**35.0**	**44.0**	**28.0**	**42.0**	**37.0**	**34.0**
GSI Classification	**Fair rock**	**Poor rock**	**Fair rock**	**Fair rock**	**Fair rock**	**Fair rock**	**Poor rock**	**Fair rock**	**Fair rock**	**Poor rock**

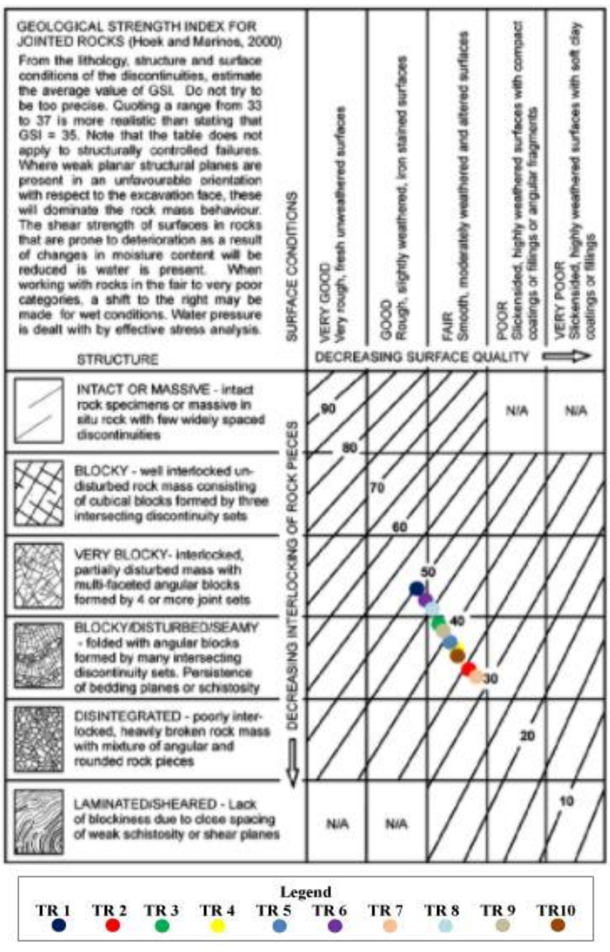

Figure 3: The GSI estimation chart from the geological observations (Diagram above is based on Hoek & Karzulovic, 2000).

5. Conclusion

In light of available information, the following conclusions may be drawn from the present study:

1. A total of 10 selected critical slope failures were studied. The results are classified as **“**Poor Rock” to “Fair Rock” in term of GSI. The poor categories (TR2 and TR7) represent slickensided, highly weathered surfaces with compact coatings or fillings or angular fragments. It is also characterized as blocky/ disturbed/seamy, which folded with angular blocks formed by many intersecting discontinuity sets.

2. The fair categories can be divided into two (2) types; type 1 (TR1, TR6 and TR8) which represent as smooth, moderately weathered and have altered surfaces. It is also characterised as very blocky rock, which indicates interlocked, partially disturbed ass with multi-faceted angular blocks formed by 4 or more joint sets. Type 2 (TR3, TR4, TR5, TR9 and TR10) which represent as smooth, moderately weathered and have altered surfaces but characterized as blocky/disturbed/seamy, which folded with angular blocks formed by many intersecting discontinuity sets. It also has persistence of bedding planes or schistosity.

3. The GSI classification has recently been extended to accommodate some of the most variable of rock masses, including extremely poor qualities sheared rock masses of weak schistose materials (such as shales or phyllites) sometime inter-bedded with strong rock (such as sandstones or slate). In such cases, the use of the GSI chart for the ‘‘blocky’’ or ‘‘massive’’ rock masses for Trusmadi Formation is applicable. The discontinuities, although they are limited in number, cannot be better than fair (usually fair or poor) and hence the GSI values tend to be in the range of 40–60. However, when these rocks form continuous masses with no discontinuities, the rock mass can be treated as intact with engineering parameters given directly by laboratory testing. In such cases the GSI classification is not applicable.

Acknowledgements

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References

Bieniawski, Z.T., 1973. Engineering classification of jointed rock masses. South African Inst. Civil Eng., 15, Pp. 335 – 344.

Bieniawski, Z.T., 1989. Engineering rock mass classification. New York: Jonh Wiley & Sons.

Hoek, E., 1994. Strength of Rock and Rock Masses. ISRM News Journal, 2, Pp. 4-16.

Hoek, E., Karzulovic, A., 2000. Rock mass properties for surface mines. In: Hustralid WA, McCarter MK, van Zyl DJA (eds). Slope stability in surface mining. Society for Mining, Metallurgical and Exploration (SME), Littleton,

Hoek, E., Wood, D., Shah, S., 1992. A modified Hoek-Brown criterion for jointed rock masses. In J. Hudson (ed.), Rock Characterization: ISRM Symp, Eurock '92, Chester, UK. London: Thomas Telford.

Hoek, E., Kaiser, P.K., Bawden, W.F., 1995. Support of Underground Excavations in Hard Rock. Rotterdam: Balkema

Hoek, E., Marinos, P., Benissi, M., 1998. Applicability of the geological strength index (GSI) classification for weak and sheared rock masses-the case of the Athens schist formation. Bull Eng Geol Env., 57 (2), Pp. 151–160.

Marinos, P., Hoek, E., 2000. GSI: A geologically friendly tool for rock mass strength estimation. In: Proceedings of the GeoEng2000 at the international conference on geotechnical and geological engineering. Melbourne. Technomic publishers, Lancaster.

Marinos, P., Hoek, E., 2001. Estimating the geotechnical properties of heterogeneous rock masses such as flysch. Bull Eng Geol Env., 60, Pp. 82–92.

Marinos, P., Marinos, V., Hoek, E., 2007. Geological Strength Index (GSI). A characterization tool for assessing engineering properties for rock masses. Published in: Underground works under special conditions, eds. Romana, Perucho & Olalla. Lisbon: Taylor and Francis.

Norbert, S., Rodeano, R., Abdul, G.R., Goh, T.L., Noran, N.N.A., Kamilia, S., Nightingle, L. M., Azimah, H., Lee, K.E., 2016. Rock Mass Assessment using Geological Strength Index (GSI) along the Ranau-Tambunan Road, Sabah, Malaysia. Research Journal of Applied Sciences, Engineering and Technology, 12 (1), Pp. 108-115.

Rodeano, R., 2020. Geological Assisted on Water Resources Planning in Mountainous Catchments In Kundasang, Sabah, Malaysia. Malaysian Journal of Geosciences, 4 (1), Pp. 26-31.

Rodeano, R., Sanudin, T., Baba, M., Omang, S.A.K.S., 2010. Geological inputs for Landslide Hazard Identification (LHI) in the Trusmadi Formation slopes, Sabah, Malaysia. Borneo Science, 26, Pp. 37-51.

Rodeano, R., Felix, T., 2018. Engineering Geological Mapping on Slope Design in the Mountainous Area of Sabah Western, Malaysia. Pakistan Journal of Geology, 2 (2), Pp. 1-10.