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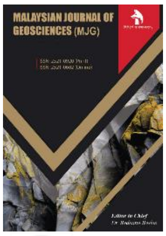

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RESEARCH ARTICLE

TUNNEL SUPPORT BY ROCK QUALITY INDEX (Q) SYSTEM FOR ULTRABASIC ROCK: A CASE STUDY IN TELUPID, SABAH, MALAYSIA

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ABSTRACT

The study area is underlain by the ultrabasic rock of partly Sabah Ophiolite Complex of Cretaceous ages. The objectives of this study are to determine the Q-value and to estimate the permanent support measures for 20m span, 10m high and eastern direction of the proposed tunnel in the study area. Engineering geological mapping (lithological and surface mapping and discontinuity survey), laboratory study (petrographical study) and testing (Uniaxial Compressive Strength testing) and data analysis (stereographic plots, Q system parameters evaluation and support estimation) was used in this study. The results show that the rock mass is classified as lherzolite, strong, excellent quality, more than four joint sets, slightly altered discontinuity wall, dry excavation and favourable stress condition. The equivalence dimension (D_e) are 15.4 for the permanent roof. The Q-value for permanent roof and wall of the proposed tunnel are 1.4 (Class D or poor and type 5) and 3.5 (Class D or poor and type 3), respectively. The permanent and temporary supports for the roof and wall are systematic bolting, 700J energy absorption of fiber reinforce sprayed concrete, 9-12 and 5-6 cm thick fiber reinforce shotcrete, respectively.

KEYWORDS

Q-system, ultrabasic rock, Telupid, Tunnel support, Rock bolts, reinforce sprayed concrete.

1. INTRODUCTION

The Q-system was developed at NGI between 1971 and 1974 (Barton et al., 1974). Since the introduction of the Q-system in 1974 there has been a considerable development within support philosophy and technology in underground excavations. The types of rock bolts and fiber reinforced technology had been introduced and continuous develops as support procedure. Two revisions of the support chart have been carried out and published in conference proceedings. An extensive updating in 1993 was based on 1050 examples mainly from Norwegian underground excavation (Grimstand and Barton, 1993). Analytical research updating with respect to the thickness, spacing and reinforcement of reinforce ribs of sprayed concrete (RRS) as a function of the load and rock mass quality have been done (Grimstand et al., 2002). The most updated guideline for RRS in the support chart based on case histories in Norway can be found (NGI, 2015). The Q-system can be used as a guideline in rock support design decisions and for documentation of rock mass quality. The Q-value is most precise when mapped in underground openings. However, the system can also be used for field mapping, core logging and investigations in borehole, but it is important to have in mind that such cases some of the parameters may be difficult to estimate. The majority of the case histories are derived from hard, jointed rocks. From weak rocks with few or no joints there are only few examples and by evaluation of support in such types of rocks, other methods should be used in addition to the Q-system for support design. It is important to combine application of the Q-system with deformation measurement and numerical simulation in squeezing rock or very weak rock (Q<1).

Sabah, Malaysia is a country that underline by complex geological rocks unit and tectonic history. The infrastructure development growth was contribute to construction of public transport especially the major road or highway which is important for communication and transportation. In Sabah, ultrabasic rock are the rock unit that should being involved when constructing west-east highway. In some cases, tunneling could be necessary for some reason. The application of Q-system for tunneling in ultrabasic rock in Sabah, Malaysia is never been documented. Then this study was conducted to determine the Q-value and to estimate the support measures for a propose 20m span, 10m high and eastern direction of a tunnel in ultrabasic rock in Telupid area (Figure 1)

2. GEOLOGICAL BACKGROUND

The Telupid area consists of igneous and sedimentary rocks with minor occurrence of metamorphic rocks (Kirks, 1968; Sanudin and Baba, 2007). The oldest dated sedimentary rocks are radiolarian cherts of Early Cretaceous age (Jasin, 1991). These thinly bedded cherts are closely associated with basic igneous of basaltic/spilitic type. Also closely associated with these two types of rocks are ultrabasic rocks (serpentinites/peridotites), intrusive rocks (dolerites) and metamorphic rocks (hornblendes schists and gneiss). This association of rock types, which resembles an ophiolite sequence is interpreted to represent an oceanic crust of Mesozoic age and it forms the basement rock here. The study area is only represented part of this ophiolite complex i.e. peridotite and basaltic rocks and quaternary alluvium along the river (Figure 1). The Telupid area is also dominated by NE-SW and NW-SE ridges. The NW-SE ridges represent bedding strikes of the Crocker formation and Kulapis formation in western and eastern part of the area, respectively. These ridges are cut through by NE-SW ridges, representing elongate bodies of ophiolitic rocks. The boundary of two trends are characterizes by a

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disrupted zone. Several horizontal and thrust faults, mostly trending NW-SE dissect of ophiolitic rocks, exposing slivers of sedimentary rock mostly from the Crocker formation. Thrusting to the northeast affect the Kulapis, Crocker and ophiolotic rocks (Tongkul, 1997).

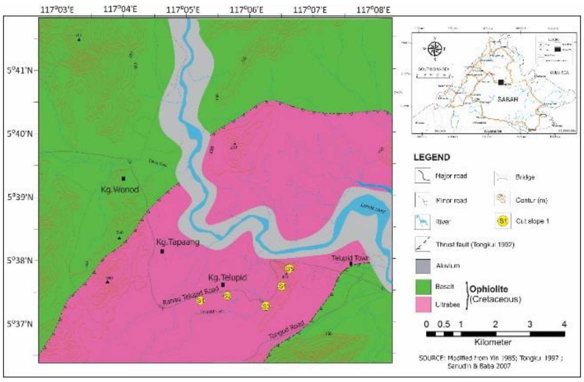


Figure 1: The geological map, location of the study area and slope studies.

3. Methodology

This study is about the proposal to build a 20m span and 10m high tunnel of East direction in ultrabasic rock and was conducted with the assumption bellows;

a. This study was concentrated on ultrabasic rock only and ignoring the basaltic rocks, then study area is relatively small in size and contains uniform discontinuities patterns even though experiencing poly-phase tectonic compression in NW-SE and NE-SW direction (Tongkul, 1997).

b. The rock mass characteristics of the study area are represented by combining and analyzing data from fives (5) outcrops (Figure 1 and Photo 1).

The methodology of this study includes field study (geological mapping, discontinuity survey and rock sampling), laboratory study and testing (petrographical study and uniaxial compressive strength test) and data analysis (evaluation of field and laboratory studies results and Q-system parameters and support design calculation and determination). In data analysis, the Q-system were fully applied in determining the Q-value and support procedure for the proposed tunnel in study area (Barton et al., 1974; NGI, 2015). The Q-system is a quantitative classification system based on a numerical assessment of the rock mass quality using the following six parameters:

i. RQD, Rock quality designation.

ii. Jn, number of joint sets.

iii. Jr, roughness of the most unfavourable joint or discontinuity.

iv. Ja, degree of alteration or filling along the weakest joint.

v. Jw, water inflow.

vi. SRF, stress reduction factor

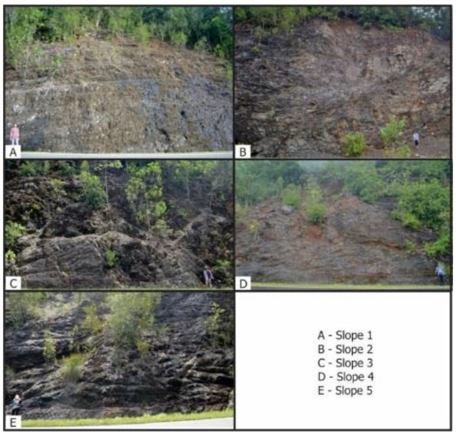


Photo 1: Rock cut slope of the ultrabasic rock (peridotite) in study area.

The above six parameters are grouped into three quotients to give the overall rock mass quality (Equation 1),

$$Q = (RQD/J_n) \times (J_r/J_a) \times (J_w/SRF) \quad (1)$$

The ratings of the various input parameters to the Q-value are given in Barton et al., (1974). The Q-value is related to tunnel support requirement by defining the equivalent dimensions (D_e) of the underground opening (Equation 2).

$$D_e = D_t / ESR \quad (2)$$

Where;

D_t = diameter or wall height

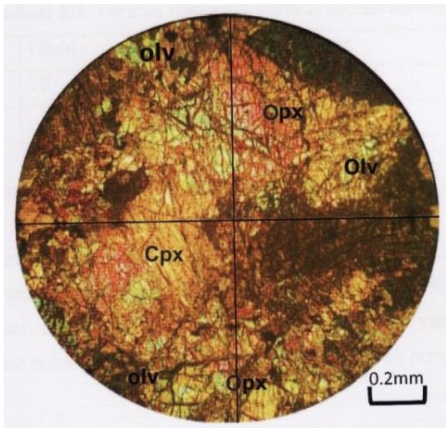
ESR = excavation support ratio (ESR)

The important permanent roof support is a pressure roof, P_{roof} which also can be estimated from Q, J_n and J_r by the Equation 3.

$$P_{roof} = (2\sqrt{J_n} Q^{-1/3})/3J_r \quad (3)$$

4. Result and Discussion

The result of lithological and petrographical study shows that the ultrabasic rock is a massive rock mass and identified as peridotite. The color is greenish black, holocrystalline, medium to coarse grained and slightly altered. The mineralogy is dominated by olivine (78%), followed by orthopyroxene (10%), clinopyroxene (8) and other minor mineral such as serpentine, talc and iron oxides (8%) (Microphotograph 1). This peridotite can be classified as Lherzolite (Le Bas and Streckeisen, 1991; Mohamad, 2018). Result of the UCS test shows that the peridotite can be classified as strong rock (ISRM, 1981). This strong characteristic may due to the occurrences of olivine and pyroxene as well as less micro fracture on and in the rock forming minerals. Summary of the Q-system's parameters and their ratings, Q value and related design parameters are shown in Table 1. RQD is classified as excellent quality because 88.1% of the discontinuities more than 10cm in distance (Deere, 1963). This shows that the blocks size are medium to big. The joint set number (J_n) was rated as 15 because there are more than four discontinuities sets found in stereographic plots.



Microphotograph 1: Mineralogy and texture of ultrabasic rock under cross polarized light (XPL) in 10x objectives. Note: Oli-olivine; Opx-orthopyroxene; Cpx-clinopyroxene.

The rock mass was classified as a rock-wall contact type and discontinuities roughness that observed by scanline are smooth, slightly rough, slickensides, planar and undulating. But the overall roughness (J_r) have been given as smooth, planar with 1 rating value. Field study also shows that the contact between discontinuities walls are clean and slightly altered. Then the discontinuities alteration (J_a) is classified as experiencing discontinuities softening or low friction clay mineral coatings i.e. kaolinite, mica, chlorite, talc, gypsum, graphite and small quantities of swelling clay with 2 rating value. The joint water reduction factor (J_w) was selected as dry excavation or minor inflow, i.e. < 5 l/min locally according to discontinuity survey result. The rock mass is observed as competent rock with stability problem due to high stresses or lack of stresses category which characterized as low stress, near surface and open joints. Then, this category is suitable for 1 value of Stress Reduction Factor (SRF).

Table 1: Summary of the Q-system's parameters and ratings, Q-value and related design parameters.

Parameters	Remarks	Notes / Rating			
UCS	92.88 MPa	Strong			
RQD	Excellent quality	88.1			
Jn	Four or more joint sets	15			
Jr	Smooth planar	1			
Ja	Softening or low friction clay mineral coatings	4			
Jw	Dry excavation, or minor inflow dry	1			
SRF	Low stress, near surface and open joints	1			
ESR	Minor road and railway tunnels	1.3			
Span	20m				
Height	10m				
D_e	Span or height in m / ESR	Roof		Wall	
		15.4		7.69	
Q	Type	Permanent		Temporary	
	Position	Roof	Wall	Roof	Wall
	Value	1.4	3.5	7	17.5
P_{roof}	3.05 MN				

The proposed tunnel span is 20m and 10m high. The category of underground opening type and use are road tunnels with little traffic and rated as 1.3 for Excavation Support Ratio (ESR). Then, the D_e value for the proposed permanent tunnel roof is 15.4. The calculated Q-value for permanent roof and wall tunnel are 1.4 (Class D or poor and type 5) and 3.5 (Class D or poor and type 3), respectively. Then the Q-value for temporary roof and wall are 7 and 17.7, respectively (Figure 2). The support for the permanent and temporary roof and wall tunnel are shown in Figure 2 and Table 2. The permanent support on the roof are 20mm diameter, 2.5m space and 4 length bolts and 9-12 cm thick and 700J energy absorption of fiber reinforce sprayed concrete as well as 20mm diameter, 4m space and 2.75m length and 6-9 cm thick fiber reinforce shotcrete for the wall. The temporary support for the roof are 20mm diameter, 4m space and 4m length bolts and 6cm thick fiber reinforce shotcrete but 20mm diameter, 4.5m space and 2.75m length bolts and 5-6cm thick fiber reinforce shotcrete in the wall, respectively. The support pressure for proposed tunnel roof (P_{roof}) is 3.05MN.

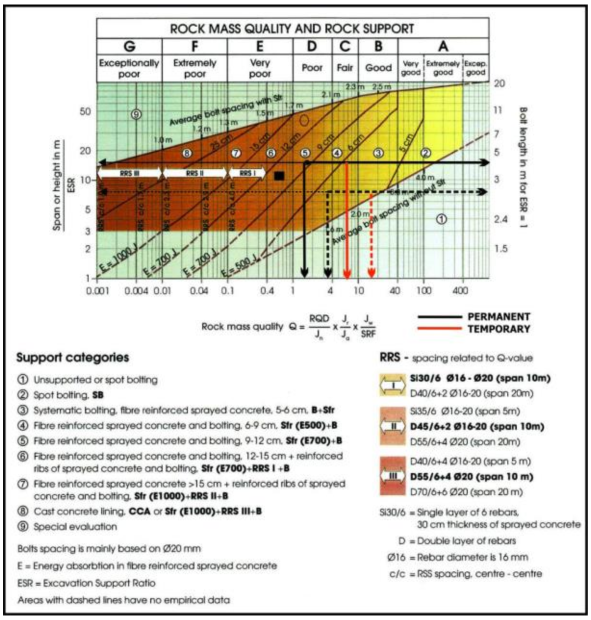


Figure 2: Lines of the result of Q-value and permanent and temporary support design requirement of tunnel roof (solid lines) and wall (dot lines).

Table 2: Summary of the result of permanent and temporary support design requirement of tunnel roof and wall.

Position in Tunnel	Rock Mass Quality	Symbols	Rock support	Remarks
Permanent support				
Roof	D / Poor / 5	Sfr (E700) + B	Systematic bolting , fibre reinforce sprayed concrete, 9-12 cm	20mm diameter, 2.5m space & 4 length bolts 9-12cm thick fibre reinforce shotcrete, 700J energy absorption in fibre reinforce shotcrete
Wall	D / Poor / 3	B + Sfr	Systematic bolting , fibre reinforce sprayed concrete, 5-6 cm	20mm diameter, 4m space & 2.75m length bolts 6-9cm thick fibre reinforce shotcrete
Temporary support				
Roof	D / Fair / 3	B + Sfr	Systematic bolting , fibre reinforce sprayed concrete, 6 cm	20mm diameter, 4m space & 4m length bolts 6cm thick fibre reinforce shotcrete
Wall	D / Good / 3	B + Sfr	Systematic bolting , fibre reinforce sprayed concrete, 5-6 cm	20mm diameter, 4.5m space & 2.75m length bolts 5-6cm thick fibre reinforce shotcrete

5. Conclusion

The conclusions of this study are:

1. The Q-values are 1.4 (Class D or poor and type 5) and 3.5 (Class D or poor and type 3), for permanent roof and wall of the proposed tunnel, respectively.

2. The support measures are systematic bolting and 9-12 cm thick and 700J energy absorption in fiber reinforce sprayed concrete as permanent support for roof but systematic bolting and 6-9 cm thick fiber reinforce shotcrete for the wall.

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