TENOM TUNNEL SUPPORT ESTIMATE BY THE ROCK MASS CLASSIFICATION SYSTEMS

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ABSTRACT. *Objectives of this study are to determine the rock mass quality and support estimate for a single lane railway tunnel by using rock mass classification system at km 137.1 Tenom, Sabah. The study area is underlain by the Late Eocene – Early Miocene Crocker Formation. Rock Structure Rating (RSR), Rock Mass Rating (RMR) and Rock Mass Quality (Q) systems are selected rock mass classification for this study. Field study includes geological mapping and discontinuity survey. Laboratory analysis are petrographic study and point load test. Data analysis are kinematic analysis and RSR, RMR and Q systems parameter values evaluation and calculation. The result shows that rock mass quality of RSR, RMR and Q systems are 80, 77 (good) and 2.12 (poor), respectively. Support estimate for RSR is 25mm diameter spot rock bolts. RMR are 20mm diameter, 3m length and 2.5m spacing systematic rock bolts with occasional wire mesh and 50mm shotcrete on crown. Installation of steel sets are unnecessary. Support estimate for Q system are 1.5 space of systematic rock bolts with 5cm shotcrete and 1.6-2m space without shotcrete on crown and wall, respectively. Thus, support estimate based on rock mass classification for the tunnel in study area are 20mm diameter, 3m length and 2m spacing of rock bolts, 50mm thick shotcrete on crown and weep hole in western section.*

KEYWORDS. Rock Mass Rating (RMR), Rock Structure Rating (RSR), Q system, Crocker Formation, Tenom.

INTRODUCTION

The study area is located at km 137.1 Tenom railway tunnel and is underlain by Late Eocene-Early Miocene Crocker formation (Figure 1). This Crocker formation is divided into thick amalgamated sandstone unit and interbedded sandstone and shale unit (Photo 1). Thick sandstone are classified as medium grain lithic wacke (Microphoto 1), less than 3m thick and slightly weathered to fresh. The thickness of interbedded sandstone and shale unit is about 10-50cm. The sandstone is fine grain lithic wacke (Microphoto 2) and slightly weathered.

Landslide or major rock fall occurrences were never been reported since the construction of 42.69m length, 4.4m width dan 4.6m height railway tunnel in 1896. Nevertheless, the presence of moderately open discontinuity planes (Photo 2) and seepage on the wall and rail track (Photo 3 dan 4) have become a turning point to conduct this study.

The objectives of this study are to determine the rock mass quality and to estimate the support for this tunnel by using rock mass classification systems i.e. Rock Structure Rating, RSR (Wickham *et al.,* 1972), Rock Mass Rating, RMR (Bieniawski, 1989) and Q system (Barton *et al.,* 1974).

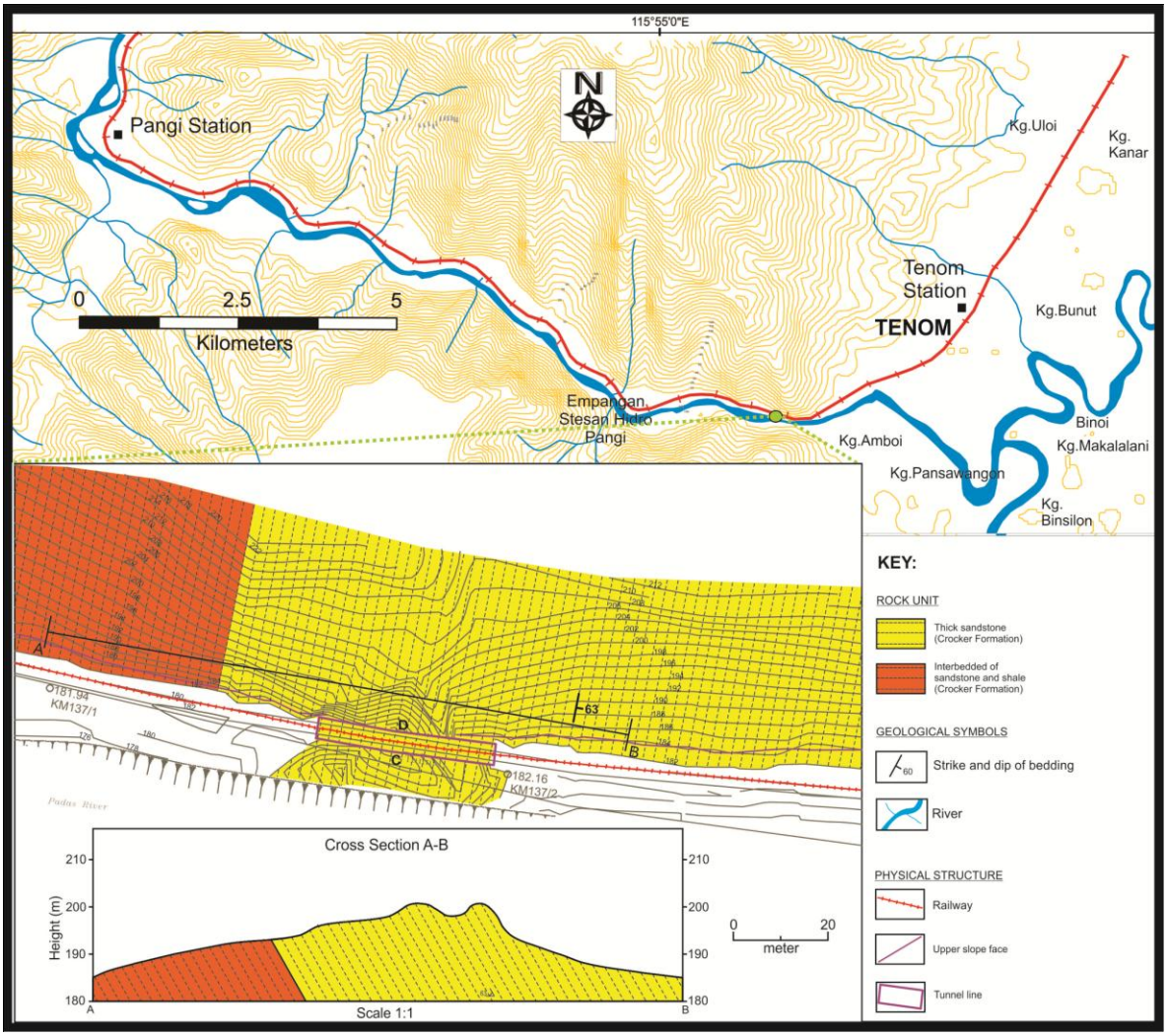
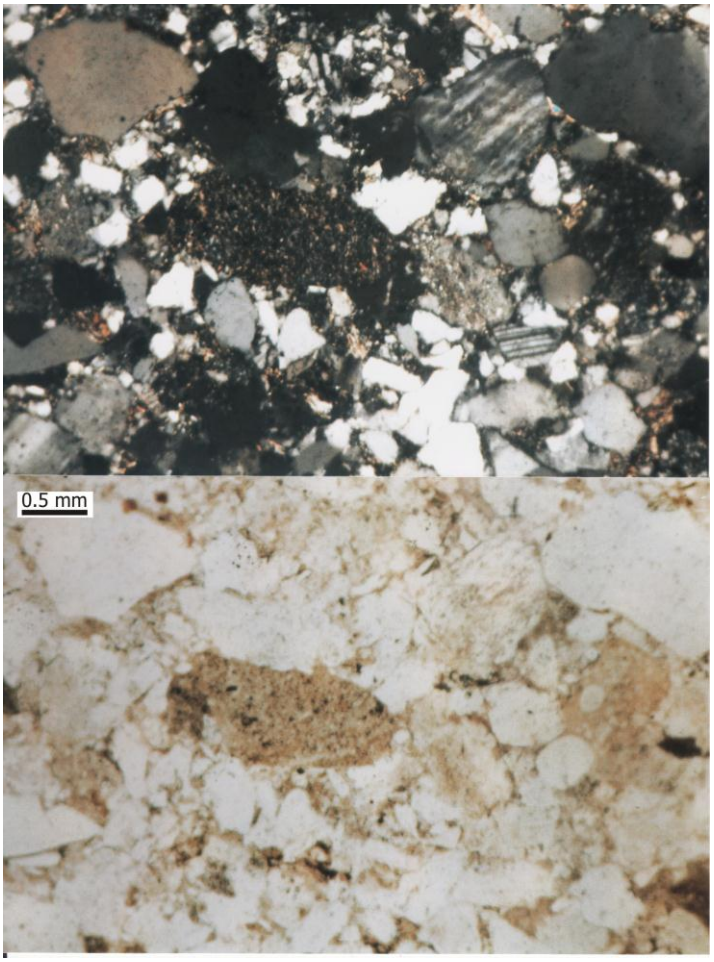
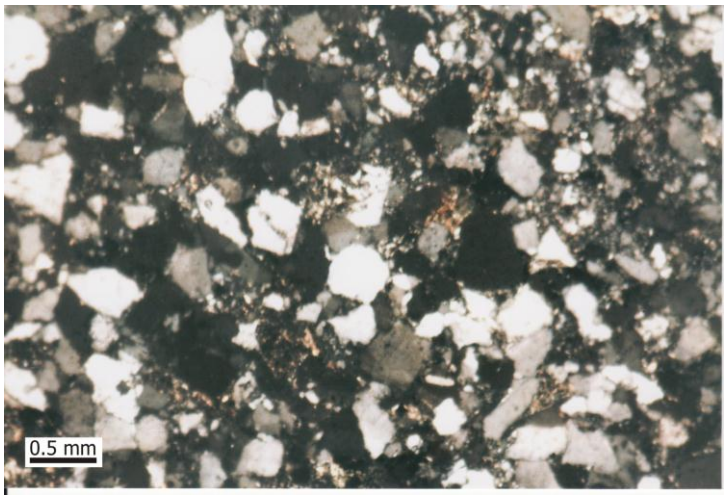


Figure 1. Location and geological map of the study. Note: C - right side wall; D - left side wall of the tunnel.

Photo 1. Amalgamated thick sandstone unit of the Crocker formation. Photo direction – east southeast (ESE) to west northwest (WNW).



Microphoto 1. Medium grain lithic wacke. XPL (upper) and PPL (below).



Microphoto 2. Fine grain lithic wacke. XPL.

Photo 2. Moderately open joint.

Photo 3. Seepage activities on the wall (white circle) (left) and on railway track (right).

METHODOLOGY

The methodology consists of desk study, field study, laboratory and data analysis. Desk study includes preparation of base map and discontinuity data sheet as well as aerial photograph study. Field study involved geological mapping and discontinuity survey (ISRM, 1981). Laboratory analysis were petrographic study and point load test (ISRM, 2007), while data analysis consist of kinematic analysis (Markland, 1972), evaluation and calculation of RSR, RMR and Q systems parameters.

Three (3) parameters were determined in RSR system i.e. general geology of the area, geometry (effect of discontinuity pattern) and groundwater and discontinuity condition. Six (6) parameters for RMR system include uniaxial compressive strength (UCS), Rock Quality Designation (RQD), discontinuity spacing, discontinuity condition, groundwater condition and discontinuity orientation.

In RMR, UCS is referred to intact rock strength for rock forming material which calculated from intact rock strength for rock material by point load test and Lithological Unit Thickness (LUT) approach (Ismail Abd Rahim *et al.*, 2009). RQD were calculated by using Deere *et al.* (1967) procedure. Discontinuity spacing was determined by weighted average of discontinuity set spacing approach (Ismail Abd Rahim, 2011). Both discontinuity condition

and water flow using weighted average method (Ismail Abd Rahim, 2011). Bieniawski (1976) procedure was used to analysis discontinuity orientation.

The main parameters in Q system are block size (RQD/J_n), inter block shear strength (J_r/J_a) and active stress (J_w/SRF), where J_n - the joint set number; J_r - the joint roughness number; J_a - the joint alteration number; J_w - the joint water reduction factor; and SRF - the stress reduction factor.

Support estimate for rock mass classification system was determined by using existing scheme in Rock Structure Rating, RSR (Wickham *et al.*, 1972), Rock Mass Rating, RMR (Bieniawski, 1989) and Q (Barton *et al.*, 1974) systems. For Q system, support for crown is using actual Q value but the wall need to multiple with 2.5 (Palmstorm *at al.*, 2002).

Finally, the support estimates from these three rock mass classification systems has been evaluated to propose support estimate for the tunnel in study area.

RESULT AND DISCUSSIONS

There are five (5) discontinuity sets along this tunnel (Figure 2, 3 and 4). Markland test (Markland, 1972) shows that potential mode of failure are wedge failure (intersection of joint 2 and 4) and planar failure (joint 2) in left and right sided of the tunnel (Figure 4). Intersection of three or more set of discontinuities in the tunnel crown will theoritically potential for rock fall or complex wedge rock block failure as shown by the intersection of joint 2, joint 3 and joint 4 (J2J3J4), joint 2, joint 3, joint 4 and bedding B (J2J3J4B), joint 1, joint 2, joint 3 and joint 4 (J1J2J3J4) and joint 1, joint 2, joint 3 and bedding B (J1J2J3B) in Figure 4.

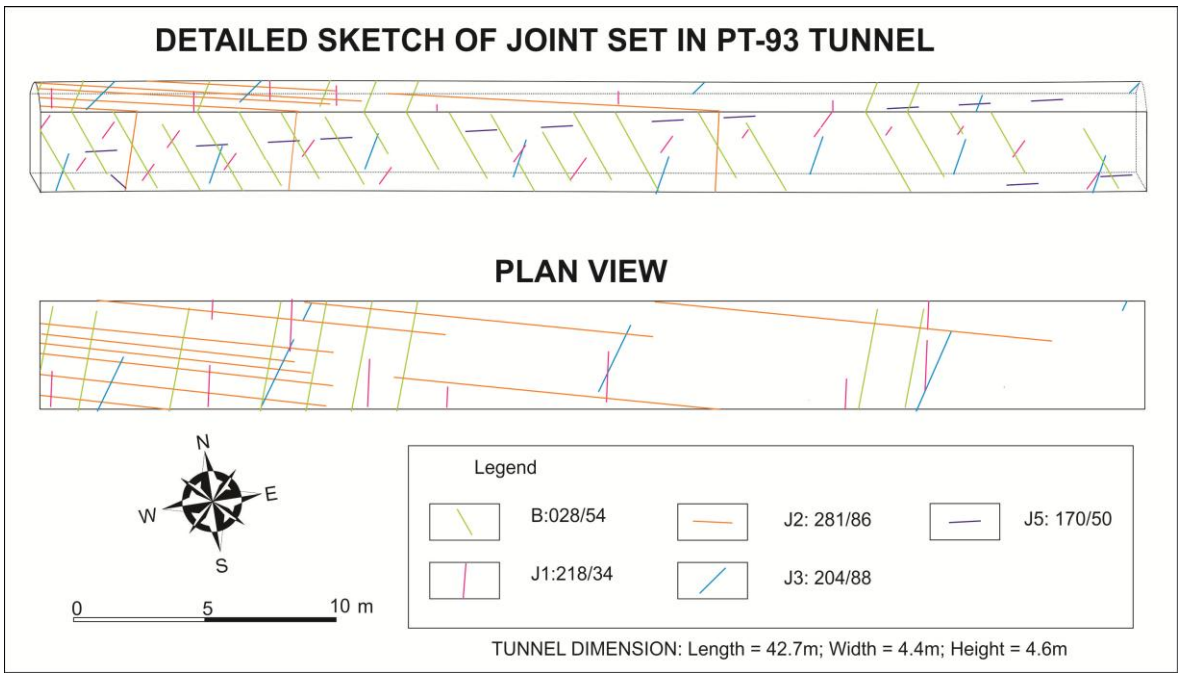


Figure 2. Sketch, joint sets in three dimension and plan view of the tunnel.

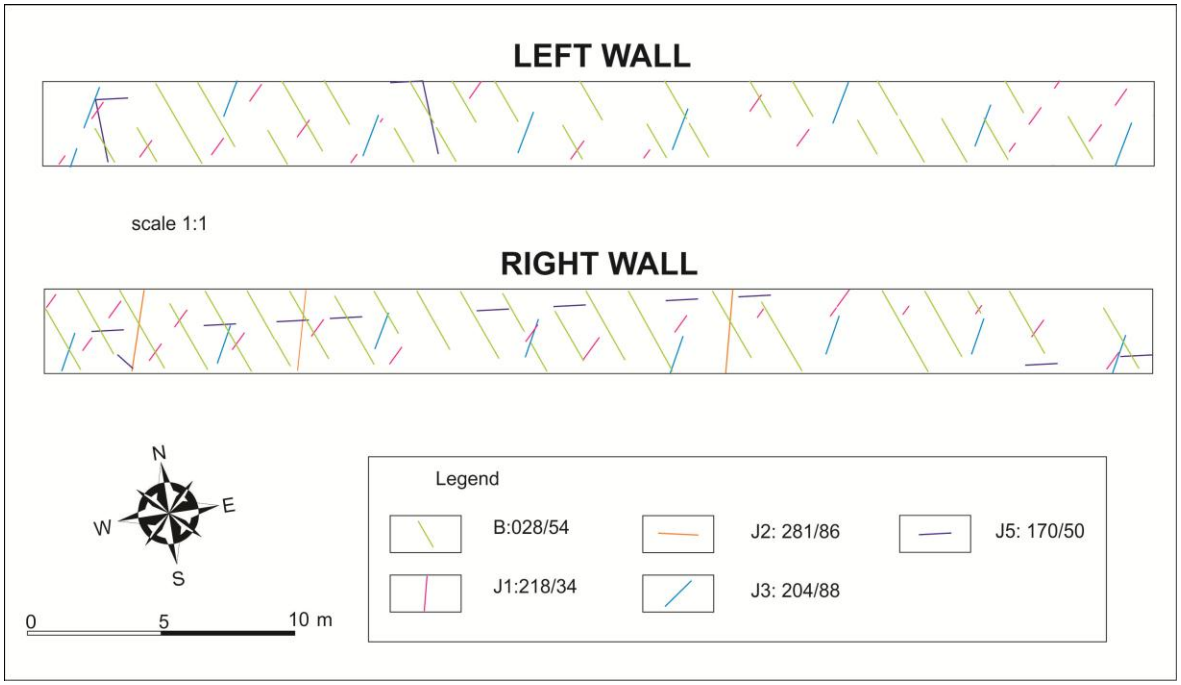
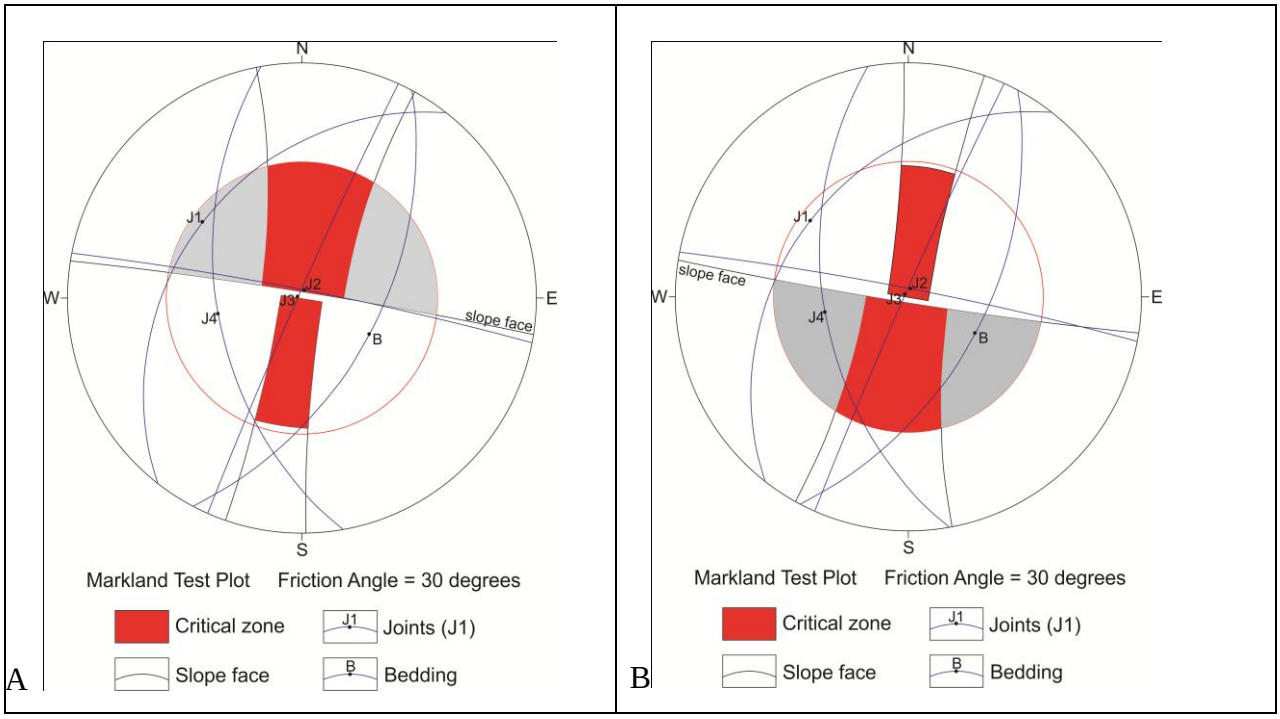


Figure 3. Sketch and joint sets in left and right wall of the tunnel.



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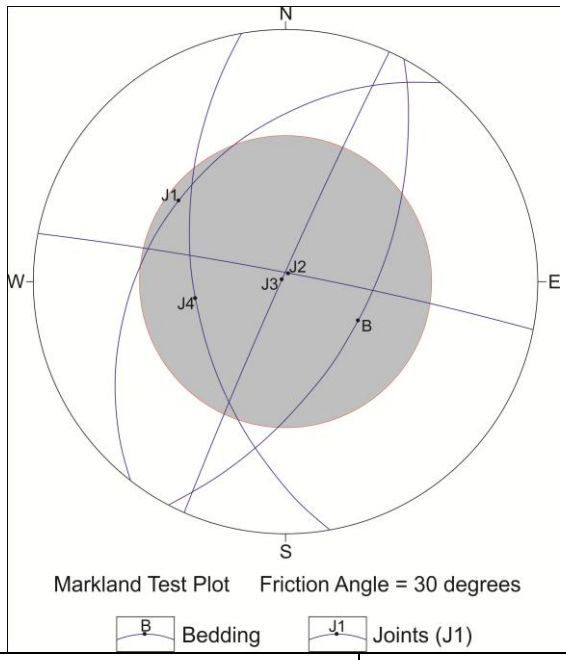

Section	Type of failures	Discontinuities
Left wall	Planar	J2
Right wall	Wedge	J2J4
Crown	rock fall or complex wedge block	J2J3J4; J2J3B; J1J2J3J4; J1J2J3B

Note: J1-joint 1; J2J3B- intersection of joint 2, joint 3 and bedding B.

Figure 4. Markland test, type of failure and related discontinuities. A-left wall section; B-right wall section;C–crown section of the tunnel.

The value of rock mass quality for RSR, RMR dan Q in the study area were calculated as 80, 77 (good) and 2.12 (poor), respectively (Table 1).

Based on RSR value (80), the study area is underlain by the sedimentary rock, strong rock material, moderately folded and faulted, more than 1 m discontinuity spacing, dip direction of dominan discontinuity are parallel to tunnel exis and dipping, without water flow (dry) and moderate discontinuity condition.

The rock mass quality for RMR is good (Class II) with high uniaxial compressive strength (UCS) value, moderate block size and very wide discontinuity spacing. Discontinuity condition is represented by rough surface, high persistency, closely separated and unweathered wall. No water flow in and on discontinuity planes as well as fair discontinuity orientation.

Poor quality (2.12) of the Q system shows that the rock mass in study area is moderate block size (Palmstorm *et al.*, 2002) with very good quality of RQD (98%) and more than four (4) discontinuity sets. Inter block shear strength is high due to rough and unweathered discontinuity surface. Joint water reduction (J_w) factor is 1 due to absent of water. The ‘fine tunning’ stress reduction factor (SRF) (Palmstorm & Broch, 2006) of the tunnel is 2.5 because it was constructed in competent rock mass with low stress condition, near surface and open joint. Then, the active stress experienced by the tunnel is 0.4.

According to Wickham *et al.* (1972), Grimstand & Barton (1993) and Palmstorm *at al.*, (2002) support estimate for RSR with 80 rating value is 25mm diameter spot rock bolt (Figure 5). For good RMR class (Bieniawski, 1989), the support are 20mm diameter, 3m length and 2.5m spacing systematic rock bolts with occasional wire mesh and 50mm thick shotcrete on tunnel crown. Installation of steel sets are unnecessary (Table 2). Support estimate for Q system are 1.5 m spacing systematic rock bolts with 5cm shotcrete and 1.6-2m space without shotcrete on crown and wall, respectively (Figure 6).

Occurrences of water seepage are seasoning and indicating a periodical load accumulation and infiltration in and along discontinuity planes from upper part of the tunnel (Photo 3). This shows that the load will potentioally rised by water and the strength of rock material can be reduced during rainy season especially in the western section of the tunnel. Then, installation of weep hole is necessary in that section (Figure 7).

Based on three rock mass classifications, the support estimate for the tunnel in the study area are 20mm diameter, 3m length and 2m spacing of rock bolts, 50mm thick shotcrete on crown and weep hole in western section (Table 3).

Table 1. Rating value and rock mass quality for RSR, RMR and Q systems.

System	Parameter	Description	Rating
RSR	A	Sedimentary rock; moderately strong; moderately folded and faulted	15
	B	>4 feet joint DC spacing; DC orientation parallel with tunnel axis and dipping	43
	C	Overal rock mass quality (A + B) is 58; no water inflow; fair DC condition	22
	Total Rating		**80**
RMR	UCS	94.88 MPa (moderately strong)	7
	RQD	98% (very good quality)	20
	DC spacing	4.97m (very wide)	20
	DC condition	High persistence; tight DC; slightly rough surface; unweathered	20
	Water flow	Dry	15
	DC Orientation	Fair DC srtike and dip orientation	-5
	Total Rating (Class)		**77 (Good)**
Q	RQD	98% (very good quality)	20
	J_n	4 DC sets plus random	15
	J_r	Rough and irregular; undulating	3
	J_a	Tightly healed; hard; non-softening; impermeable filling	0.75
	J_w	Dry excavation	1
	SRF	low stress condition, near surface and open joint	2.5
	ESR	Railway	1.3
	Total Rating (Class)		**2.12 (Poor)**

Note: DC-discontinuity; l-liter; m-meter

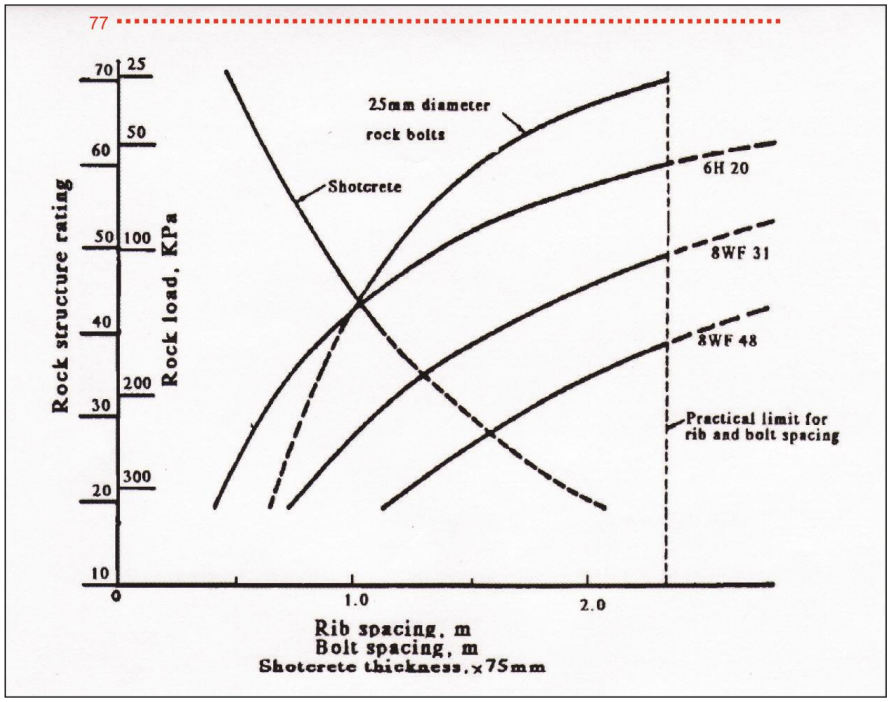

Figure 5. Support estimate for RSR (Wickham *et al.*, 1972). Red line shows study area value.

Table 2. Support estimate for RMR (Bieniawski, 1989). Shaded grey represent study area.

Rock Mass Class	**Excavation**	**Support**		
		Rock Bolts (20mm Dia, Fully Grouted)	Shotcrete	Steel Sets
Very good rock I RMR: 81 - 100	Full face 3m advance	Generally, no support required except for occasional spot bolting		
Good rock II RMR: 61 - 80	Full face 1.0-1.5 m advance Complete support 20 m from face	Locally, bolts in crown 3 m long, spaced 2.5 m with occasional wire mesh	50 mm in crown where required	None
Fair rock III RMR: 41 - 60	Top heading and bench 1.5- 3 m advance in top heading Commence support 10 m from face Commence support after each blast	Systematic bolts 4 m long, spaced 1.5-2 m in crown and walls with wire mesh in crown	50-100 mm in crown and 30 mm in sides	None
Poor rock IV RMR: 21 - 40	Top heading and bench 1.0-1.5 m advance in top heading. Install support concurrently with excavation 10m from face	Systematic bolts 4-5 m long, spaced 1-1.5 m in crown and wall with wire mesh	100-150 mm in crown and 100 mm in sides	Light to medium ribs spaced 1.5 m where required
Very poor rock V RMR: < 20	Multiple drifts 0.5-1.5 m advance in top heading Install support concurrently with excavation. Shotcrete as soon as possible after blasting	Systematic bolts 5-6 m long, and walls with wire mesh spaced 1-1.5 m in crown Bolt invert	150-200 mm in crown, 150 mm in sides, and 50 mm on face	Medium to heavy ribs spaced 0.75 m with steel lagging and forepolling if required. Close invert

Note: Shape: horseshoe; width: 10 m; vertical stress: <25 MPa; construction: drilling and blasting

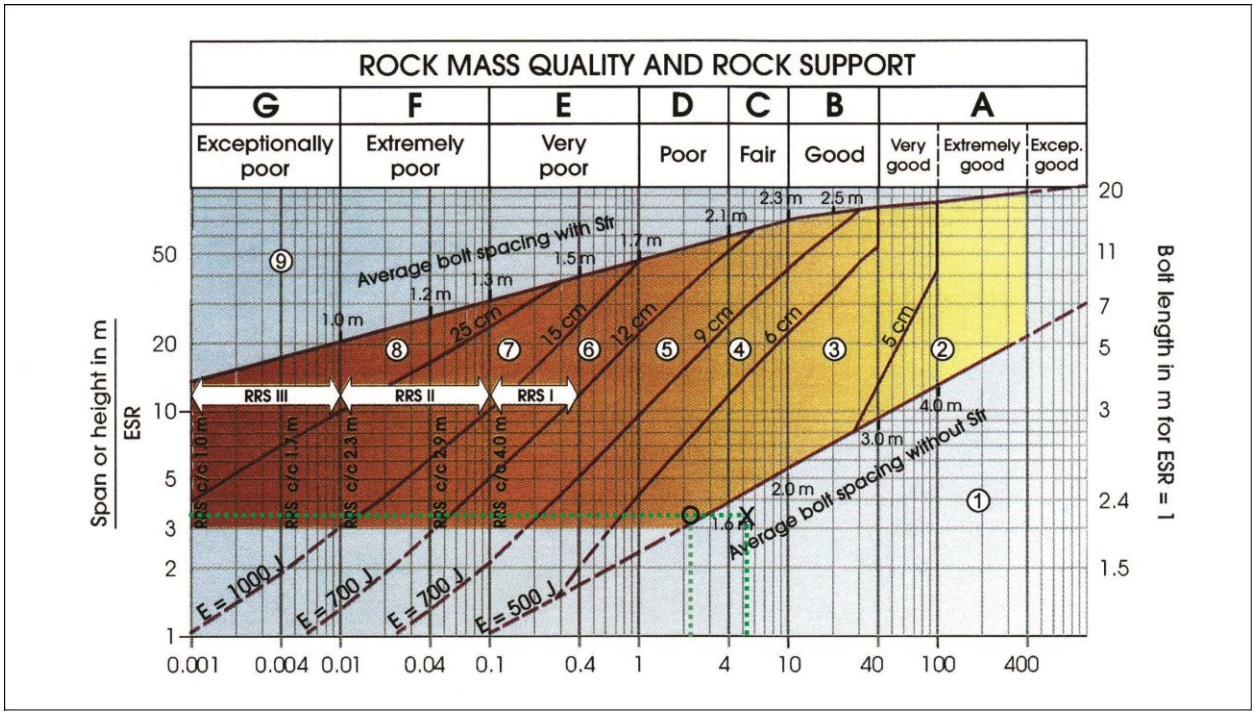

Figure 6. Support estimate for Q (Grimstand & Barton, 1993). Note: Green line shows study area; O - actual Q value; X - Q value for wall support.

Table 3. Support estimate for RSR, RMR, Q system and suggested for the study area.

Classification system	Support estimate	
RSR	Shotcrete – spot, diameter 25mm	
RMR	Rock bolt – systematic, 20mm diameter, 3m length and 2.5m spaced on the crown Shotcrete - 50mm thick on crown . Steel set - none	
Q	Crown	Rock bolt - 1.5m spacing Shotcrete – 50mm
	Wall	Rock bolt - 1.6-2m spacing Shotcrete – none
Suggested	Rock bolt - 20mm diameter, 3m length and 2m spacing Shotcrete - 50mm thick on crown Weep hole – western section	

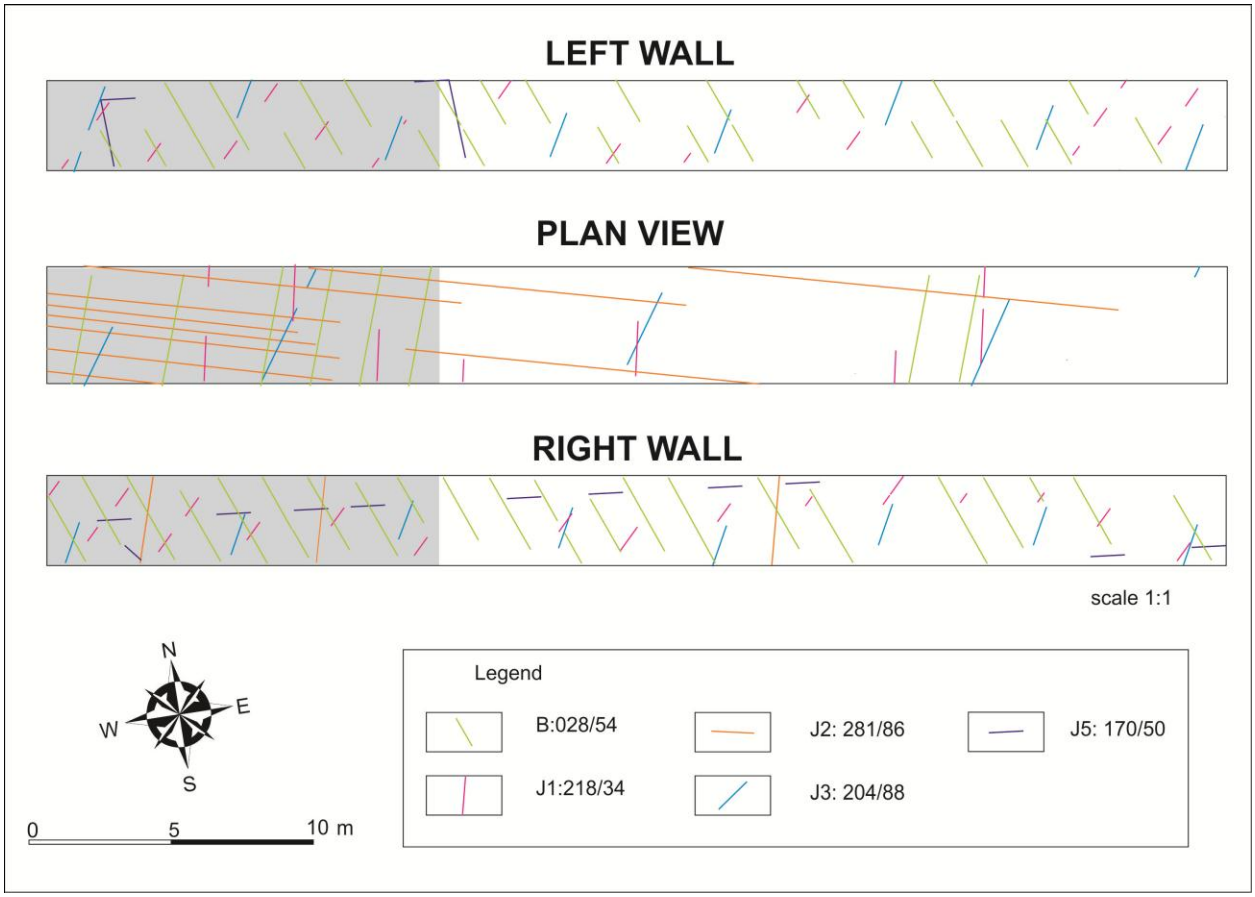

Figure 7. Suggested section for weep hole installation.

CONCLUSION

Conclusions of this study are:

1. Rock mass quality for RSR, RMR and Q systems are 80, 77 (good) and 2.12 (poor), respectively.
2. Support estimate for RSR is 25mm diameter spot rock bolts.
3. Support estimate for RMR are 20mm diameter, 3m length and 2.5m spaced systematic rock bolts on the crown and without steel set.
4. Support estimate for Q system are 1.5 spacing systematic rock bolts with 5cm shotcrete and 1.6-2m space without shotcrete on crown and wall, respectively
5. Support estimate based on rock mass classification for the tunnel in study area are 20mm diameter, 3m length and 2m spacing of rock bolts, 50mm thick shotcrete on crown and weep hole in western section.

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