ROCK QUALITY ANALYSIS USING RMR AND Q-SYSTEM METHODS FOR DETERMINATION OF SUPPORTING HEADRACE TUNNEL IN HYDROELECTRIC POWER PLANT TANA TORAJA IN SOUTH SULAWESI

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Abstract - Geotechnical analysis below the surface of hydropower plant is one way to determine the stability of the opening holes in determining the supporting system. A discussion about supporting systems cannot be separated from the analysis of the construction of recommended supporting system based on the weighting value of the geomechanical classification of the RMR and Q-System. The aims of this study are: 1) understanding the quality and class types of rock, 2) determining the supporting of RMR and Q-system, 3) understanding the safety factor of opening hole using Phase2. This study was carried out by recording data directly in the field, which later were used to determine the number of rock bolt needed in the installation of the supporting. Based on geomechanical classification, the rock mass in headrace tunnel adit 1 up stream has an average RMR value of 58 (moderate rock quality) and Q-system value of 4.06 (moderate rock quality), while adit 2 up stream has an average RMR value of 47 (moderate rock quality) and Q-system value of 2.30 (poor rock quality). Based on these geomechanical classification data, each type of supporting types is obtained. Supporting headrace tunnel adit 1 and 2 type, RMR value of type 1 can be applied to the RMR (60-80). RMR value of type 2 can be applied to the RMR (40-60). Supporting headrace tunnel adit 1 and 2 type, Q-system value of type 1 can be applied to Q-value (4-10). Q-system value can be applied to Q-value (1-4). Based on the modeling results using phase2, the total displacement of headrace tunnel adit 1 up stream is 0.92 cm with safety factor value of 1.20 and the total displacement of headrace tunnel adit 2 up stream is 1.17 cm with safety factor value of 1.04.

Index Terms - geomechanics, supporting, RMR, Q-System, modeling, Phase2

I. INTRODUCTION

Geological conditions in a tunnel site have instability that can generate weak fields or zones, supported by types of rocks with many joint structures and the emergence of water seepage that enters through fractures into the tunnel which result in decreasing safety factors.

Wide joint surface is often found in the types of rocks during the implementation of a tunnel. If the direction is parallel or almost parallel to the axis of the tunnel, it can cause major problems in its implementation. A serious problem that occurs during excavation of tunnels is the presence of large amounts of water. The conditions of the groundwater are the main factor. For tunnels under a river or sea, leak must be avoided completely, because the amount of water that can enter the tunnel hole will be difficult to control.

The discussion of rock buffer system is an important part in manufacturing hydropower tunnels. Therefore, this study is also important considering the various characteristics of rocks and the possibility of the occurence of weak fields of rock that can cause rock instability such as debris occurence that hampers company's progress and results in the obstruction of the desired progress level. Self-support is defined as a system that helps rocks sustain themselves so that they can reach a balance after a disturbance in the form of opening holes is given.

The aims of this study is to analyze the characteristics of rocks in the study location, determine the supporting types, andexamine the stability of the tunnel roof.

II. METHODS AND MATERIALS

This study used direct field recording method. The data were directly collected from the technical geological mapping in the study area. At this stage, the data taken for the RMR system were the data of rock condition, rock strength, rock quality designation, spatial of discontinuous, condition of discontinuous, ground water, and orientation of discontinuous. As for the Q-system, the data taken were the data of rock quality designation, joint set number, joint roughness, joint alteration, ground water, and stress reduction factor.

Data obtained from the study field were then analyzed using statistical methods in phase2 to obtain corrected RMR and Q-system values as well as the analysis of opening hole stability. The data were

analyzed using several formulas as a suggestion in recommending a buffer system to obtain an effective and efficient buffer system.
The formulas used are:

RQD (Priest & Hudson, 1976):

$$RQD = 100e^{-0,1\lambda}(0,1\,\lambda + 1) \quad (1)$$

$$\lambda = \frac{L}{N} \quad (2)$$

Where : λ = Discontinuous frequency
L = Number of fractures
N = *Scanline* width

Calculation of ht, Prmr dan P (Unal, 1983) :

$$ht = \frac{100 - RMR}{100} \times B \quad (3)$$

$$P_{RMR} = \frac{100 - RMR}{100} \times B \times \gamma \quad (4)$$

$$P = B \cdot c \cdot P_{RMR} \quad (5)$$

Where :
ht = Collapse Height (ton/m2)
Prmr = Collapse Load (m)
P = Roof Area Load (ton)
B = Tunnel Width (m)
γ = Rock Density
c = Blasting Lenght Results (m)

All of the recorded and observed data from the study location were then taken and evaluated. Based on the evaluation result, tables were made and calculated using an existing formula. Microsoft Excel was used to simplify this calculation. The results of the classification was used to obtain the value of RMR and Q-system value and then make a cross section of openings from supporting tunnels, that is by inputting the data into phase2 to observe the transfer of rock mass and safety factor of the opening holes. Here are the explanation on how to operate Phase2:

To begin the operation, create a project setting to create data storage. The modeling begins by making a model based of the openings using Autocad, which will be later imported to Phase2. Before starting the modeling, the data about parameters such as elevation of each opening hole, groundwater analysis, and density must be inputted. The next step is to make boundaries (excavation, external, material, and stage) of the opening holes which can be done by importing data in dxf format.

The next step is to determine the material parameters of each opening location and the splitset and shotcrete parameters that we use. After all data are inputted, the program is executed by compute. The results of the opening holes and the supports used will be presented during interprete. Through these results, various information about openings and buffer systems used can be obtained such as total displacement, attraction experienced by rocks and splitsets, deformations, and safety factors.

III. RESULTS AND DISCUSSION

The study was done on headrace tunnel adit 1 up stream and headrace tunnel adit 2 up stream. Headrace tunnel is a development area as a water way of one of the hydropower plants in Indonesia. This area has openings of 6.5 x 7.3 meters. The headrace tunnel extends from inteck to power house with a total length of 9,100 meters.

Rock Rock mass rating system, known as the geomechanical classification method, was developed by Bieniawski in 1972 – 1973. RMR classification method is a simple method which can be obtained from both borehole data data and geotechnical mapping of underground structures. Here are six parameters used to classify rock masses using the RMR system:

a. Compressive strength of intact uniaxial rock
b. Rock Quality Designation
c. Spaces of discontinuous fields
d. Conditions of discontinuous fields
e. Groundwater conditions
f. Orientation of discontinuous fields

Based on the results of the parameter weighting above, the RMR value is obtained as follow:

Table 1. Results of RMR and Q-system Values

Adit	Blasting (M)	*Span/widht* (M)	RMR	Q System
Headrace 1 up	1.9	6.5	64	5.1
Headrace 1 up	1.6	6.5	52	1.4
Headrace 1 up	2.2	6.5	57	2.6
Headrace 1 up	1.8	6.5	64	11.9
Headrace 1 up	1.6	6.5	60	4.1
Headrace 1 up	2.4	6.5	55	2.1
Headrace 1 up	1.6	6.5	60	4.5
Headrace 1 up	2.2	6.5	58	1.8
Headrace 1 up	2.3	6.5	63	5.2
Headrace 1 up	1.7	6.5	52	1.9
Headrace 2 up	2.9	6.5	50	2.7
Headrace 2 up	3.0	6.5	49	1.4
Headrace 2 up	2.8	6.5	57	1.5
Headrace 2 up	3.2	6.5	44	1.4

Headrace 2 up	3.0	6.5	49	3.5
Headrace 2 up	2.5	6.5	42	2.5
Headrace 2 up	2.9	6.5	44	1.5
Headrace 2 up	3.3	6.5	43	1.2
Headrace 2 up	2.8	6.5	55	2.8
Headrace 2 up	2.6	6.5	44	3.5

Based on the formula of ht, Prmr, and P in the study method, the results are as follow:

Tabel 2. Calculation Results of ht, Prmr dan P

Adit	RMR	ht (M)	Prmr (Ton/M2)	P (Ton)
Headrace 1 up	64	2.34	5.616	69.357
Headrace 1 up	52	3.12	7.488	77.875
Headrace 1 up	57	2.79	6.708	95.924
Headrace 1 up	64	2.34	5.616	65.907
Headrace 1 up	60	2.60	6.240	64.896
Headrace 1 up	55	2.90	7.020	109.512
Headrace 1 up	60	2.60	6.240	64.896
Headrace 1 up	58	2.72	6.552	93.693
Headrace 1 up	63	2.40	5.772	86.291
Headrace 1 up	52	3.12	7.488	82.742
Headrace 2 up	50	3.25	7.637	143.957
Headrace 2 up	49	3.31	7.778	151.671
Headrace 2 up	57	2.79	6.556	119.319
Headrace 2 up	44	3.64	8.554	177.923
Headrace 2 up	49	3.31	7.778	151.671
Headrace 2 up	42	3.77	8.859	143.958
Headrace 2 up	44	3.64	8.554	161.242
Headrace 2 up	43	3.70	7.806	186.743
Headrace 2 up	55	2.92	6.862	124.888
Headrace 2 up	44	3.64	8.554	144.562

Above table is a benchmark in determining the number of rock bolts that will be used in the installation of rock supports.

a. Supporting based on RMR Value

Based on the results of all calculations, supporting types in this study are classified based on RMR value obtained from 6 weightings. The classification of supporting types of RMR value system is type 1 with RMR value of 61 – 80 and type 2 RMR value of 41 – 60.

1. Type 1 RMR 61 - 80

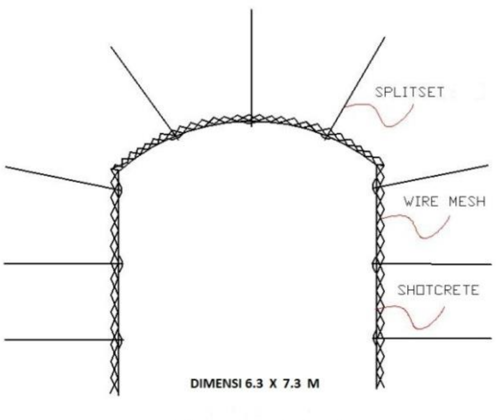

Figure 1. Supporting type 1 RMR 61-80 headrace tunnel

a. Blasting – smoke clearing – level muck – scalling – drill support
b. Install wire mesh + splitset (rock bolt) 3 meters in length, 9 pieces of rock bolts with space of 2.5 meters on left, right, and roof wall.
c. Muck out level
d. Install shotcrete 50 mm.

2. Type 2 RMR 41-60

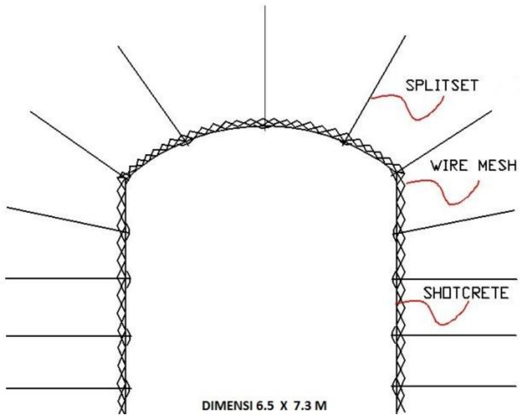

Figure 2. Supporting type 2 RMR 41-60 headrace tunnel

a. Blasting – smoke clearing – level muck – scalling – drill support
b. Install wire mesh + splitset (rock bolt) 4 meters in length, 13 pieces of rock bolts with space of 1.5 meters on left, right, and roof wall.
c. Muck out level
d. Install shotcrete 75 mm.

b. Supporting based on Q-System Values

Based on the results of all calculations, supporting types in this study are classified into 2 types based on Q-system value obtained from 6 weightings. The classification of supporting types of Q-Value System is type 1 with Q-value of 4 – 10 and type 2 with Q-value of 1 – 4.

1. Type 1 Q-value 4 – 10

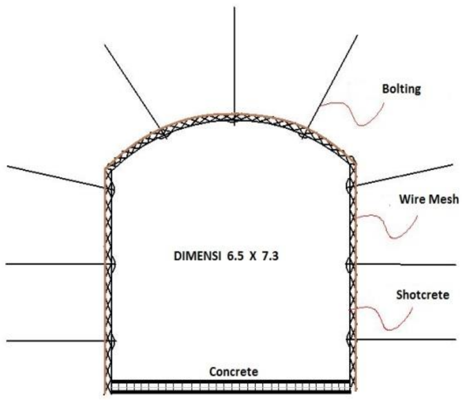

Figure 3. Supporting type 1 Q-value 4-10 headrace tunnel

a. Reinforced with loaded spray on the tunnel floor (concrete) 6-9 cm with the absorption energy of E500.
b. Bolting with length of 2.5 m + spot wire mesh
c. Bolting distance of 2.3 m
d. Shotcrete 2-3 cm

2. Tyspe 1 Q-value 1 – 4

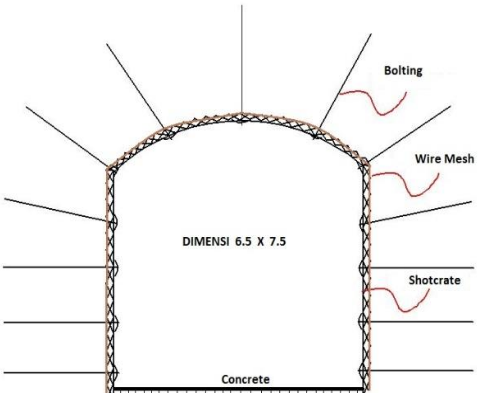

Figure 4. Supporting type 2 Q-value 1-4 headrace tunnel

a. Reinforced with loaded spray on the tunnel floor (concrete) 9-12 cm with the absorption energy of E700.
b. Bolting with length of 2.5 m + wire mesh
c. Bolting distance of 1.7 m
d. Shotcrete 3-5 cm

c. Total displacement of opening hole using Phase2

Modeling of opening hole support is done with the purpose to find out the condition of existing rocks after excavated, the movement of rock's mass around the opening hole, and force that applied to splitset. Furthermore, the most important thing is to model the most effective and the most efficient opening hole and its support by considering safety and total displacement that happened.

Modeling using Phase2 is done as one of consideration to determine the choice of splitset that will be used. Besides opening hole that haven't supported, the model is made from the experiment location for the comparison.

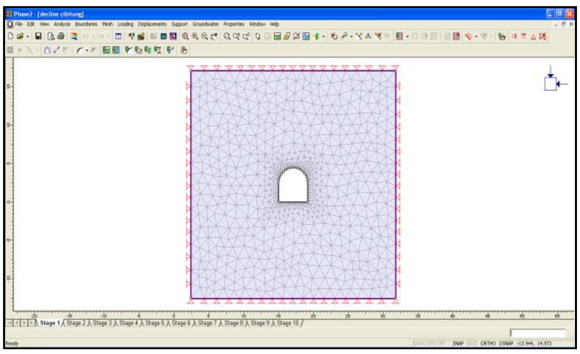

Figure 5. Propertice rock material input data in Phase2

After the model is made and all of the analysis parameters is done, the modeling is computed and analysis result will be displayed in the form of interprete.

From Headrace Tunnel model, a different total value of displacement and safety factor value is gained.

1. Headrace Tunnel 1 up Stream

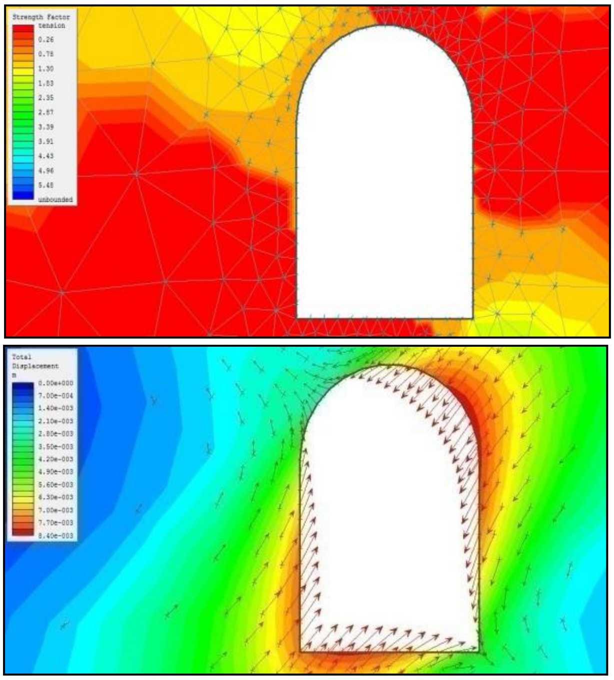

Figure 6. Interpret result of phase2 headrace tunnel adit 1 total Displacement and safety factor

2. Headrace Tunnel 2 up Stream

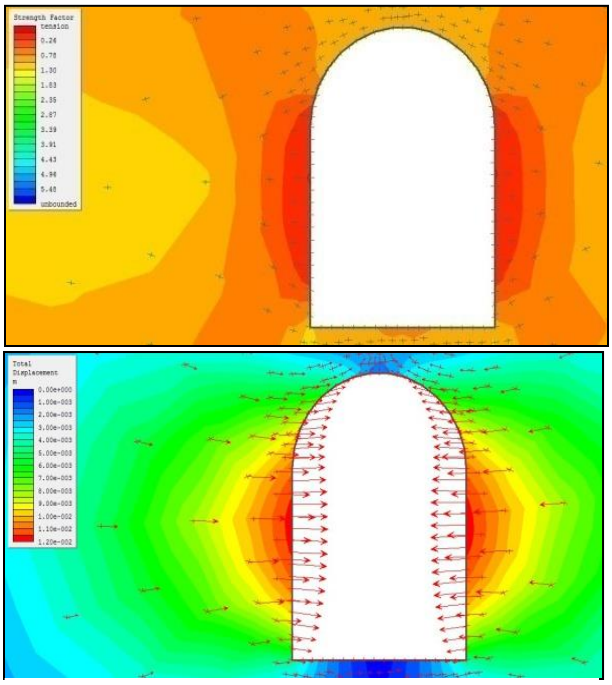

Figure 7. Interpret result of phase2 headrace tunnel adit 2 total Displacement and safety factor

Based on interpret result, the total of displacement and Headrace Tunnel safety factor can be discovered. Analysis of phase2 modeling on Headrace Tunnel is shown on the table below.

Table 3. Total displacement and safety factor rock ass from the study location

Adit	∑Total displacement	∑Safety factor
HTA 1 UP	0.0925435 M	1.20
HTA 2 UP	0.0117913 M	1.04

d. The impact of joint towards the tunnel condition

The impact of joint towards the tunnel condition analysis is useful to decrease accident risk such as falling rocks that could hurt workers or machinery below.

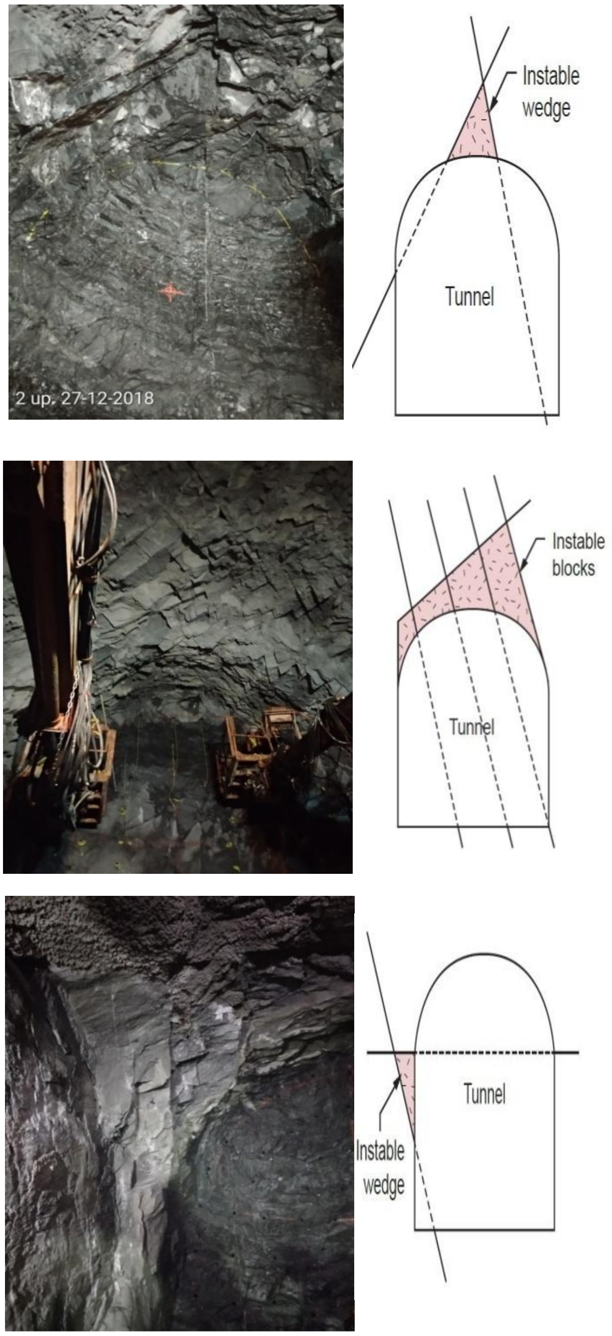

Figure 8. Effect Instable Wedge Joint Headrace Tunnel

Based on the figure above, the dangerous area is located in the intersection zone between joints. In this zone, it is possible to create weak fields thus making block on the rock could easily fell off. With the existence of such field, it is very recommended to conduct safety handling such as shotcrete before next excavation.

IV. CONCLUSION

The conclusion that can be drawn from this study includes:

1. Based on the geomechanics classification, the rock mass in Headrace Tunnel adit 1 upstream RMR classification is included in class II and III with rock types of good to medium and for Q-system classification is included in medium to bad class. The rock mass in Headrace Tunnel adit 2 upstream RMR classification is included in class III with rock types of medium and for Q-system classification is included in bad class.
2. Based on the RMR geomechanic system classification, Ground Support Recommendation for RMR type 1 is 61-80 with 1-1.5 m excavation length with 20 m support from face, 9 pcs rock bolts with 2.5 m space + 50 mm shotcrete thickness. Ground Support Recommendation for type 2 RMR is 41-50 with 1.5-3 m excavation length with 10 m support from face, 13 pcs rock bolts with 1.5 m space + 75 mm shotcrete thickness. Based on the Q-system geomechanics classification, Ground Support Recommendation for type 1 is Q-value 4-10, that is reinforced with loaded spray on the tunnel floor (concrete) 6-9 cm with E500 energy absorption, 2.5 m bolting length with 2.3 m space + 20-30 mm shotcrete thickness. Ground Support Recommendation for type 2 is Q-value 1-4, that is reinforced with loaded spray on the tunnel floor (concrete) 9-12 cm with E700 energy absorption, 2.5 m bolting length with 1.7 m space + 30-50 mm shotcrete thickness.
3. Based on the safety factor calculation using empirical method, safety factor value for Headrace Tunnel adit 1 upstream is included in safe or stable class with FK value of 1.7 to 2.7. Safety factor value for Headrace Tunnel adit 2 upstream is included in safe or stable class with FK value of 1.3 to 1.7.

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