Tunnel Design for Fractured Rocks and Suitable Support Selection

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Abstract: This research focused on design of a tunnel in highly fractured rocks, and to propose suitable support classes, based on the study carried out at the Upper Kotmale Hydro Power project location. The necessity arises in order to cope up the unpredictable changes in geological patterns which highly influence the continuity of tunnel works. Present tunnelling method in fractured rocks need to be further evaluated to suit the engineering geological patterns and rock types of the area. The rock strength and the fracture intensity are assessed through field and laboratory works, including tunnel mapping and joint intensity surveys. The suitable support class selected based on Q-value system formulated by Nick Barton (Norway) in mid 70's.The data and the borehole samples obtained from site location facilitated to propose a proper support design, suitable to Sri Lankan geotechnical conditions. The variation in the rock mass from unweathered to highly weathered, sound to heavily fractured along a tunnel was accounted in selecting a suitable supporting method to avoid disastrous consequences and to provide a secure working environment. The results of the study were used to develop a model for tunnel design, and to propose modifications to the existing support classes in fractured rocks at Upper Kotmale Hydro Power Project. And it was understood Q-value evaluation could be more suitable than RMR, for Sri Lankan terrain.

Key words- Fracture, geotechnical, Q-value, RMR, tunnel

1. Introduction

Sri Lanka is underlain with Precambrian metamorphic rocks having a ragged terrain concentrated central hilly areas, although we have a long history of tunneling in hydropower, transportation and Irrigation.

In tunneling it is important to develop rock properties, characteristics for Sri Lanka for more suitable designing of tunnels as well as other rock structures.

Designing a tunnel in fractured rocks is somewhat bewildering. Rock quality is one of the formative factors, which determine the design of the tunnel. If an investigation reveals that the location consists of fractured rocks the whole designing process has to be re-evaluated to suit the conditions. The unavailability

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of developed theoretical methodologies in application complicate the excavation design in fractured rocks hence tunneling in fractured areas has to be handled with great care.

This study is aimed at developing a detailed methodology to design tunnels in fractured rock through rock mass classifications; this will also provides better alternatives for the selection of tunnel support systems.

2. Methodology

2.1 Study area

Three locations of Upper Kotmale Hydro Power (UKHP) tunnel (Figure 1) were selected for the study. The selected adit locations are as follow.

Adit I- Headrace tunnel (Talawakale)
Adit II- Dunsinan Estate
Adit VI-Switchyard (Pundloya-outlet)

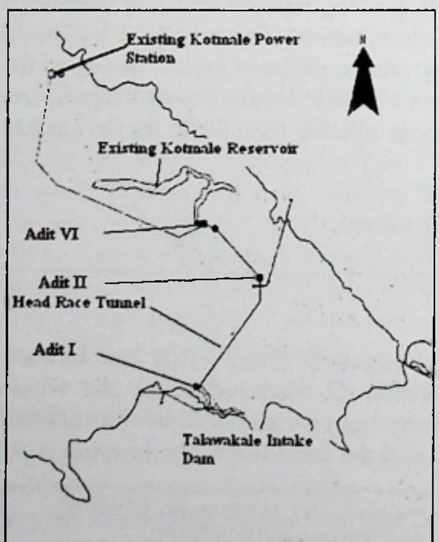

Figure 1- Study locations of UKHP tunnel

2.2 Field studies and observations

The studies and observations on the key areas selected including geological variations along tunnel axis, continuous tunneling process, support selection and support installation were covered during the time of fieldwork. Three representative samples were obtained for laboratory testing and, borehole drive data were gathered for the considered locations of UKHP project.

2.2 Engineering geological mapping

Complete engineering geological mapping of face, crown and wall of the tunnel were performed in the exposed areas along the tunnel axis. The mapping data serve to evaluate support selection under the classification systems of Rock Mass Rating (RMR) and Rock Mass Quality (Q-Value), hence full attention was paid on tunnel mapping and face logging, which performed at selected areas of UKHP tunnel along different sections including Adit I, Adit II, Adit VI and head race tunnel.

2.3 Physical model for shape selection

A proper physical model test for tunnel shape selection was developed under the theories of equiangular strain rosette. The moulds for different shape evaluation were formed and tested under compressive stress to select the suitable shape, which characterise maximum stability.

2.4 Lab testing

Core samples were prepared from the field samples, and standard lab tests performed, at the mineral processing laboratory of University of Moratuwa.

2.5 Data analysis

The data were analysed to classify rock mass of the study areas performed under the systems of RMR, Q-Value. These quantitative values use to select the support systems interpreted with the existing support systems of UKHP tunnels.

3. Results

Based on RMR and Q-value evaluation, following tunnel supports were selected. Since the project location exhibit good, fair quality rocks, Adit 2 is the only exposed area with considerable variations of rock conditions. Support selection under Q- value almost similar for the first two sections from 100-110m chainage, while RMR evaluation contradicts the proposals of Q-Value.

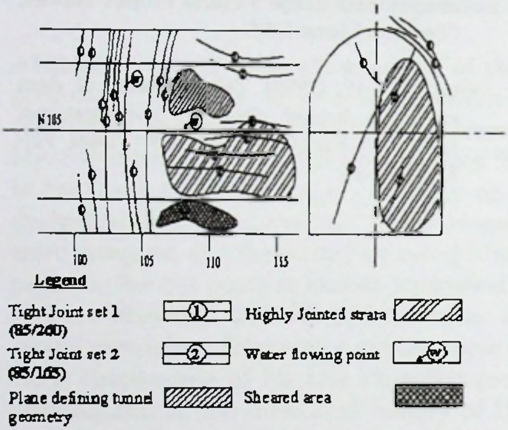

Figure 2- Tunnel mapping Adit 2

Table 1- Q-value results Adit 2

Parameter \ Chainage	100-105m	105-110m	110-115m
RQD	Poor (48%)	Fair (69%)	Fair (64%)
Jn	C-3	E-6	C-3
Jr	E-1.5	E-1.5	E-1.5
Ja	K-6	L-8	K-6
Jw	A-1.0	C-0.5	A-1.0
SRF	Shear-5.0	Shear-5.0	Shear-5.0
Q-Value	0.8	0.22	1.06

Table 2- RMR evaluation Adit2

Parameter \ Chainage	100-105m	105-110m	110-115m
Strength of intact rock material	14.6 Mpa 15	12.3 Mpa 15	12.3 Mpa 15
RQD	Poor(48) 8	Fair (69) 13	Fair (64) 13
Spacing of joints	0.9m/ 0.48m 20	0.9m/ 0.48m 20	0.9m/ 0.48m 20
Condition of joints	Slicken sided 6	Slightly rough 12	Slightly rough 12
Ground water	Water under P 4	Completel y dry 10	Water under P 4
Rating adj for joint Orientation	Fair 64-5=59	Unfavour 83-10=73	Fair 64-5=59
Rock mass class	Class 111 Fair rock	Class 11 Good rock	Class 111 Fair rock

Table 3- Support selection Adit 2

Parameter \ Chainage	100-105m	105-110m	110-115m
Q-Value	0.8	0.22	1.06
Support Class	Tensioned grouted bolt (1m) with 5cm thick Shotcrete mesh reinforce	Tensioned grouted bolt (1m) with 5cm thick Shotcrete mesh reinforce	Tensioned Systematic Bolt (1m spacing) Shothcrete mesh reinforce

4. Discussion

Rock characteristics exhibit regional variations, which complicate the objective of having a universal classification system. Hence, the existing classification systems, which are already in application, have to be further evaluated and developed to ensure their suitability for local conditions.

In this study we have selected both RMR, Q-Value which are widely acknowledged for their simplicity, measurability of parameters quantitative outcome hence exhibit better suitability to Sri Lankan characteristics. Especially the Q-value, selected as reference for our support selection was originally developed for Norwegian tunnels, which reflect similar geological characteristics to Sri Lankan terrain.

Shape selection consists of a more empirical approach. Shape of a tunnel

will have a greater bearing on controlling regional stresses.
in common application where there are external factors including expected capacity, manuarability, and maintenance influences the shape design. Instances where tunneling has to done in fractured rock, attention should paid for the effective redistribution of regional stresses to attain optimum stability.

5. Conclusion

Though the rock quality of UKHP project was, quite sound, small fractured regions with varying intensity were encountered along the tunnel axis. Such regions were thoroughly analysed and the recommendations were made which were validated by laboratorial testing and field observations.

According to the results obtained from the physical model testing, we can propose extended horseshoe shape for vertical stress governing areas while vertical elongated horseshoe shape to horizontal stress prominence areas for optimum stability.

In this regard, it is more suitable to conclude that for Sri Lankan geotechnical conditions, support selection based on Q-Value is more suitable than RMR value.

Acknowledgments

The authors would like to thank Mr. Shavinda Fernando (Project Manager, UKHP) for granting permission and providing facilities to carry out the field works. They also acknowledge the contributions made by the mining engineers of UKHP who were helpful and supportive during the field works and provided necessary data and information.

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