Coal Operators' Conference

Faculty of Engineering and Information Sciences

2011

Stability Assessment and Support Design for Water Deviation Binary Tunnels of Bakhtiyari Dam-Iran

Said Mahammad Hossaini
University of Tehran, Iran

Farshad Nezhadshahmohamad
University of Oromeih, Iran

Mojtaba Dadkhah
Iran Water and Power Resource Development Co., Iran

Publication Details

S. M. F. Hossaini, F. Nezhadshahmohamad and M. Dadkhah, 11th Underground Coal Operators' Conference, University of Wollongong & the Australasian Institute of Mining and Metallurgy, 2011, 99-104.

STABILITY ASSESSMENT AND SUPPORT DESIGN for Water Deviation Binary Tunnels of Bakhtiyari Dam-Iran

Saied Mohammad Farouq Hossaini[1], Farshad Nezhadshahmohamad[2] and Mojtaba Dadkhah[3]

ABSTRACT: Analysis of the stability of deviations binary tunnels at Bakhtiyari dam situated in the southwest of Iran is presented. The diameter of each tunnel is 13.7 m and they are around 1000 m long. The tunnels are excavated in steps of consecutive cuts. The tunnels pass through seven different geological zones with various specifications. To study the characteristics of these zones nine boreholes of total length of 904 m were drilled and around 140 various laboratory tests were conducted on the core samples. Testing and analysis of the cores from the boreholes have resulted in series of data required for the investigation. These data present physical and mechanical properties of the seven various rock zones, including RQD, joint sets and joint properties. Based on these data the values of RMR and Q and therefore the class of the rocks of all seven zones were determined. Stability analysis has been conducted and appropriate supports were suggested for both tunnels by RMR and Q methods. Based on the ratings ascribed to each zone by the two methods a relationship has been driven between RMR and Q for this particular project.

INTRODUCTION

Rock mass characterization is normally carried out through the application of empirical classification systems, which use a set of geotechnical data and provide an overall description of the rock properties. Moreover, they provide other important information like support needs, stand-up time, geotechnical parameter among others (Sing and Goel, 1999).

Different classification systems have well known drawbacks and limitations, due mainly to their empirical base (Palmstrom, 1995). However, they are still very useful in practice. Therefore, there is a need to improve their efficiency. Two of the most used classification systems are the RMR-Rock Mass Rating and the Q-system (Sing and Goel, 1999). The RMR and Q systems have evolved over time to better reflect the perceived influence of various rock mass factors on excavation stability (Rajnish and Bhawani, 2006). This paper discusses the evolution of these systems, as well as problems associated with estimating the Q, RMR indices for water deviation binary tunnels in the Bakhtiyari dam of Iran.

SITE GEOLOGY

Bakhtyari dam site is in the South West of Iran, almost 70 km North-East of Andimeshk town (Khuzestan province) and some 65 km South-West of Doroud town (Lorestan province). The dam axis lays at 290725 E and 3648729 N points. Figure1 shows the Location of the project area (Iran Water and Power Resourced Development Co, 2006).

The geological formation consists of a series of asymmetric folding and faults. The project area is covered by the sedimentary bedrocks of Sarvak and Garau formations. The Sarvak Formation is divided into 7 units from SV1 (oldest) to SV 7 (youngest). At project site the Garau Formation is younger than the Sarvak Formation and is divided into two units (Iran Water and Power resourced Development Co, 2008). Figure 2 shows longitudinal geological section of right diversion tunnel.

[1] *Assistant Professor, School of Mining Engineering, University of Tehran, Tehran, Iran, mfarogh@ut.ac.ir*
[2] *Lecturer, Shahid Bakeri Branch,University of Oromieh, Miandoab, Iran*
[3] *Project Expert, Iran Water and Power Resource Development Co., Tehran, Iran*

Figure 1 - Location of the project area on Iran map (Iran Water and Power Resourced Development Co, 2006)

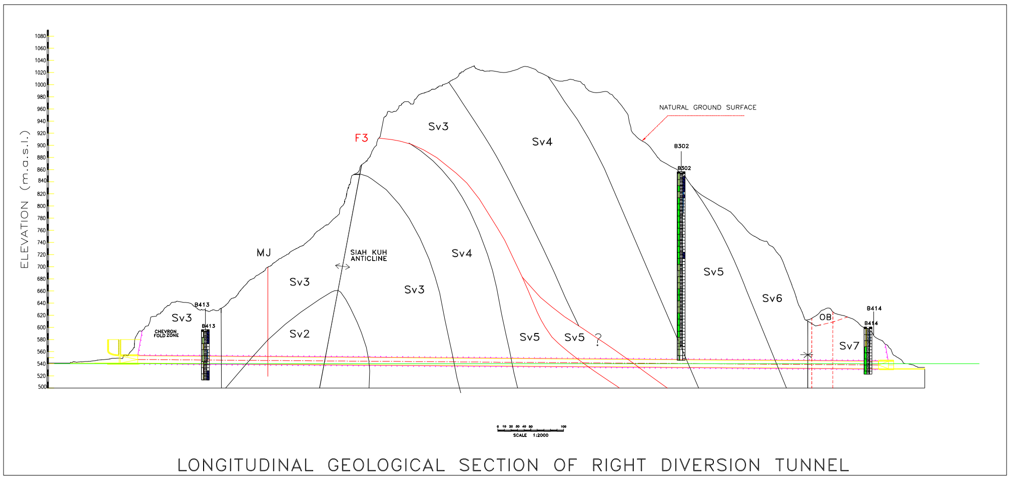

Figure 2 - Longitudinal geological section of right diversion tunnel (Iran Water and Power Resourced Development Co, 2006)

PROJECT DESCRIPTION

Deviation system of Bakhtiyari dam includes two tunnels, namely upper and lower tunnels. The diameter of circular cross section of the upper tunnel is 13.7 m and the length of this tunnel is 1181 m. The cross section of the lower tunnel is D-shaped with 13.2 m width and 13.7 m height. This tunnel is 1151 m long. Both tunnels are approximated with a diagonal pattern that is excavated with heading and benching method (Iran Water and Power resourced Development Co, (2006).

A number of nine boreholes were drilled with five boreholes at the upstream and downstream cofferdams and four boreholes along the diversion tunnels path. Total drilling length was 904.1 m consisting of 7.30 m in overburden and 811.78 m in the bedrock.

DISCONTINUITIES SYSTEM

Rock mass in the Bakhtiari dam diversion section consists of four set of discontinuities. The characteristics of these discontinuities have been studied in the galleries and boreholes located in the dam site. Stereographic plot of discontinuities along the diversion tunnel is shown in the Figure 3.

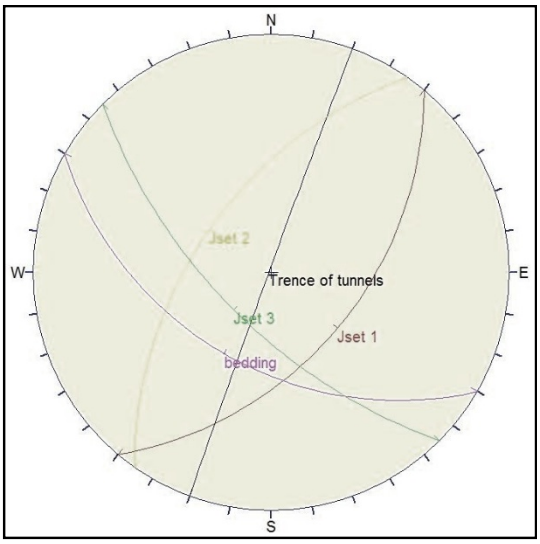

Figure 3 - Stereographic plot of discontinuities, along the diversion tunnel (Iran Water and Power Resourced Development Co, 2006)

EVALUATION OF ROCK MASS QUALITY IN THE BOREHOLES

The first set of the information taken from the freshly recovered drill cores was Rock Mass Quality or RQD parameter. It is defined as the ratio of the total length of intact, sound core pieces longer than 10 cm to the length of the core run.

Thus, the RQD is a direct measurement of the degree of the bedrocks fracturing and by this also an indirect account of the grade of weathering. Technical fractures, produced during drilling and recovery of the cores from the core barrel therefore have been disregarded. The RQD value is significantly depending on the relationship between orientation of the discontinuities and the borehole axis. In the project area tectonic structures such as faults, kink bands, the joint sets and in some cases the lithological bedding planes have a remarkable effect on the RQD value. Figure 4 shows the variation of RQD versus the elevation (m.a.s.l) for the boreholes number B435 and B302 (Iran Water and Power resourced Development Co, 2008).

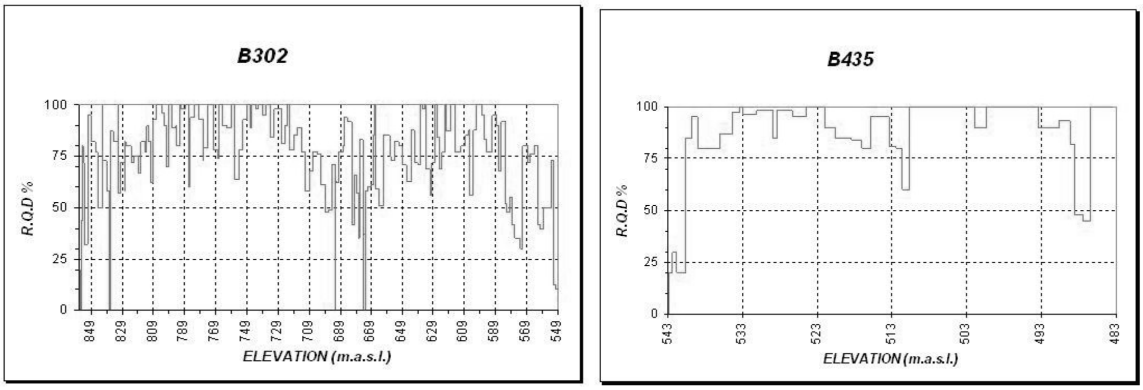

Figure 4 - Variation of RQD values versus elevation for boreholes number B435 and B302 (Iran Water and Power Resourced Development Co, 2008)

Studying all the boreholes, RQD values in the seven zones have been calculated and presented in Table 1.

Table 1 - RQD values in diversion tunnels (Iran Water and Power resourced Development Co, 2008)

parameter	SV3(Disturbed)	SV3-SV2	SV4	SV5	SV6	SV7
RQD(%)	40-60	55-75	65-75	75-90	65-85	50-80
Description	Poor-fair	fair	fair	good	good	Fair

Table 2 - The Ratings and values of the various rock mass parameters in two systems

INPUT PARAMETERS			SV3 (disturbed)			SV2&SV3			SV4			SV5			ems SV6			SV7		
			RMR		Q	RMR		Q	RMR		Q	RMR		Q	RMR		Q	RMR		Q
ROCK	UCS(Mpa)		10		-	12		-	9		-	8		-	11		-	8		-
DEGREE OF JOINTING	RQD(%)		11-15		40-60	14-17		55-75	16-17		65-75	17-20		75-90	16-19		65-85	13-18		50-80
	Average joint spacing(m)		9		-	10		-	15		-	15		-	10		-	9		-
JOINTING PATTERN	Orientation of main joint set		-5		-	-5		-	-5		-	-5		-	-5		-	-5		-
	Number of joint sets		-		J_n=12	-		J_n=9	-		J_n=6	-		J_n=6	-		J_n=6	-		J_n=12
JOINT CHARAC-TERISTICS	Smoothness	joint roughness	0	10	J_r=2	3	14	J_r=3	0	14	J_r=3	5	20	J_r=3	3	13	J_r=1.5	1	11	J_r=2
	Undulation		-			-			-			-			-			-		
	Joint alteration	weathering	5		Ja=2	5		Ja=2	5		Ja=2	6		Ja=1	6		Ja=1	5		Ja=2
		filling	2			2			2			4			2			1		
	Joint separation		2		-	0		-	2		-	1		-	1		-	2		-
	Joint separation		1		-	4		-	1		-	4		-	1		-	2		-
GROUND WATER			13		Jw=1	10		Jw=0.6	7		Jw=0.6	13		Jw=1	10		Jw=0.6	10		Jw=0.6
STRESSES AROUND TUNNEL			-		2.5	-		2.5	-		2.5	-		2.5	-		2.5	-		2.5
TOTAL			48-52		1.3-2	55-58		2.4--3.3	56-57		4.3-4.95	61		4.3-5.6	55-58		4.3-5.6	46-51		1.1-1.76
CLASS DESCRIPTION			Fair Rock		Poor Rock	Fair Rock		Poor Rock	Fair Rock		Fair Rock	Good Rock		Good Rock	Fair Rock		Fair Rock	Fair Rock		Poor Rock

RMR AND Q CLASSIFICATION OF THE CASE

The main classification systems for rock support estimates, Q and the RMR, use the most important ground features or parameters influencing on stability as inputs. Each of these parameters is classified and each class given a value or rating to express its influence on tunnel stability (Palmstrom, 2008), Table 2 shows the values of the various rock mass parameters in the two systems.

Although the rating methods of RMR and Q-system are additive and multiplicative, respectively, the basic Concepts of both schemes are similar. Both schemes allocate the ratings to the properties that influence the rock mass behavior and then quantitative figures such as total-RMR and Q-value are produced. These values would be used to judge the goodness of rock mass for construction (Rajnish and Bhawani, 2006). Table 2 indicates that in both systems the least quality is due to the zone SV7 and the maximum quality due to the zone SV5.

COMPARISON BETWEEN THE TWO CLASSIFICATION SYSTEMS

Figure 5 depicts the results from comparisons conducted. Table 3 shows correlation equations between maximum, minimum and average values found for RMR and Q systems. Comparison of the average values obtained by the two systems was done through regression. The result showed that average difference between the two systems was not more than 2%. The maximum difference was about 3% which was due to minimum values estimated by the two systems.

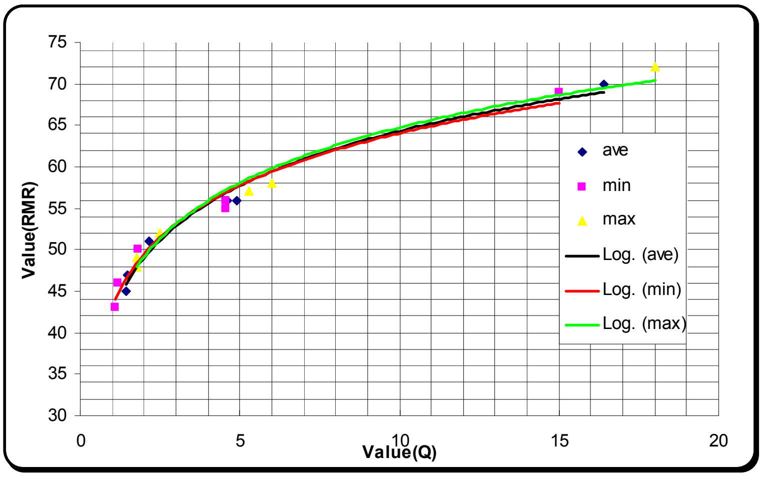

Figure 5 - Comparison between RMR and Q systems

Table 3 - Correlation equations between the values found for RMR and Q

Parameter	Equation	R^2
Average	$RMR = 9.52Ln(Q) + 42.39$	0.9815
Maximum	$RMR = 9.65Ln(Q) + 42.52$	0.9749
Minimum	$RMR = 9.1Ln(Q) + 43.23$	0.9733

CONCLUSIONS

The following conclusions could be drawn from the current study:

- RMR classification system ranks the various units of rock mass of Bakhtiari dam tunnel as medium to good where Q system ranks it as poor to good.
- In most cases the class of "medium", estimated by RMR coincides with the class of "poor" offered by Q.
- Both classifications suggest "good" class for SV5 unit.

- In both systems most of the rock units hosting the tunnel fall into medium class.
- The results obtained from both classifications demonstrate a high correlation where the differences between the values suggested by them are around 2% for medium values and 3% for minimum values.

REFERENCES

Sing B, Goel R k, 1999. *Rock Mass Classification*, University of Roorke India, published by Elsevier.

Palmstrom A, 1995. A rock mass classification system for rock engineering purposes, PhD Thesis, University Of Oslo, Chapter 5.

Rajnish K, Bhawani S G, 2006. *Tunneling in weak rocks*, ELSEVIER GEO-ENGINEERING BOOK SERIES.

Iran Water and Power Resourced Development Co, 2006. *Geological report of bakhtiari dam*.

Iran Water and Power Resourced Development Co, 2008. In-situ and laboratory rock mechanics tests of Bakhtiari Dam.

Palmstrom A, 2008. *Comparing the RMR, Q and RMi classification system*s, Internet web site: www.rockmass.net. Rock Mass AS, Oslo, Norway.