Short Communication

Rock Mass Classification System for Stability of under-Ground Metal Mines

by

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Introduction

The need for an engineering rock mass classification has been recognised for a long time in Mining and Civil Engineering professions for assessing the rock mass behaviour with reference to stability. The object of such classification is to assign a value, rather than a brief descriptive terminology, so that experienced field personnel can rapidly apply such system conveniently.

A number of classification systems have been developed for over the past 35 years and these have been progressively refined with the passage of time. Most of the systems described in the literature are applicable to the design of tunnels, and stand up times at shallow depths (i.e. less than 500 m) and only few apply specifically to mining operations (Laubscher and Taylor, 1976).

The classification system developed by Barton *et al.* (1974) is being used extensively for various practical civil and mining engineering problems. One of the principal concerns in the area of underground mining is the effect of the excavations on the state of stress in the rock adjacent to these excavations. As mining proceeds to depth, stress concentrations may be sufficiently high to cause in-elastic behaviour of the rock and yielding along joint surface. Most of the non-caving systems of mining rely on use of the rock pillars (shrinkage stoping method) and/or artificial cement fill (cut and fill method) to limit the ground control movement in the vicinity of excavation. Additional safety for men working inside the stope can be provided in the form of support, such as installation of rock bolts, cable bolts, dowels and wire mesh as required. Rock mass classification systems have been extensively used in the field for predicting the stable span of excavations in establishing support requirement and its effectiveness in different mining conditions.

Application of Geotechnical Investigations at Mochia Mines

History

Hindustan Zinc Limited's Mochia Mines at Zawar is located 42 km

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South East of Udaipur, Rajasthan. Current operations of the Zawar group of mines consist of three underground mines with a total annual production of about one million tonnes of Lead-Zinc Ore, among which Mochia Mines produce 2000 t per day with 5 per cent combined metal content. Exploration of Sulphide Ore bodies began 40 years ago and continued ever since. The discussions presented here relates to Mochia Mines, one of the major producing mines.

Mine Geology

Mochia deposit forms a part of the precambrian Aravalli group of rocks comprising phyllites, greywackes, quartzites and dolomites. Dolomite bears the concentration of Lead-Zinc mineralisation. The general strike of the formation is East-West with steep dips towards North.

Mining Method

The first four levels of the mine constitute the upper section and are at 32 to 36 m intervals. Production from these levels comes through conventional shrinkage stopes, which are of 45 to 75 m in length and 25 to 26 m in height with 9 m rib pillars in between stopes and 8 m sill pillar below IV level separates the lower levels of the mine from the upper section. The lower levels, viz. V to IX levels are at 67 m intervals and sub-level top slicing method of stoping is in practice.

The strike length of stopes ranges from 40 to 90 m with 9 to 20 m thick pillar. The sub-level interval varies from 6.7 to 9.6m. At present, the Mine being deepened to X level (-28MRL).

Stability Assessment

The first sign of rock mass distress presently experienced in Mochia Mines was associated with cracking, and spalling was observed in 1970's. Since that time due to progressive mining, more extensive rock mass failure, slabbing and ravelling occured in some sections of the mine due to redistribution of stresses. Prior to the analysis, data was collected on the "mining environment", "rock mass characteristics" and "state of stress".

Geotechnical mapping form an integral part of these investigations to assess the stability of rock masses for obtaining rock mass strength to devise satisfactory layouts, pillar extraction and design of suitable support systems.

Extensive geotechnical mapping was carried out covering all the accessible areas of the mine. The discontinuities were mapped on a 1 : 20 scale along the roof and walls. The objective in collecting data on rock mass characteristics are to assign a value to the strength of the rock mass for strength—stress analysis and to determine the orientation of discontinuities for structural tests of stability.

Rock Quality Rating

For the estimation of Rock Quality Rating, four parameters such as discontinuity spacing, discontinuity strength, intact rock strength (IRS) and rock quality designation (RQD) are used and with the help of power curve, each unit was converted into their weighting points, as shown in Table 1.

TABLE 1

Rock Mass Classification

Parameter	Units	Curve	Weighting range (points)
1. Intact Rock Strength	MPa	$Y=6.83 \log x^{16.63}$	0 to 20
2. Rock Quality Designation		$Y = 0.28x^{0.93}$	0 to 20
3. Discontinuity spacing	m	$Y = 20.35x^{0.38}$	0 to 30
4. Discontinuity condition			
(*a*) Roughness—R		$Y = 18.73 + 5.74 — Log (R/A)$	
(*b*) Alteration-A			0 to 30
		Total rating :	0 to 100

The intact rock strength is determined in the laboratory with the help of a point load tester. For Mochia dolomites, it is in the order of 60 to 140 MPa.

The Rock quality designation (RQD) is measured in the field after Deere (1964) from apparent discontinuity spacing along a scan line at every 1m length.

Discontinuity spacing is measured as distance along the scan line measured in meters to the point where the scan line and discontinuity interesect or to the intersect of the vertical projection of termination point.

Discontinuity condition is the ratio of joint roughness to joint alteration number. Ratings were taken from typical roughness profiles and alteration number for the discontinuities (Barton *et al*, 1974).

The point ratings from each parameter are simply summed in order to place the rock mass surveyed into one of the five classes ranging in quality from very good to very poor (Table 2) similar to Bieniawski (1973) rock mass classes determined from their total ratings.

TABLE 2

Rock Mass Rating and Description of Classes (after Bieniawski, 1973)

Class	1	2	3	4	5
Description	Very good	Good	Fair	Poor	Very poor
Rating	100-81	80-61	60-41	40-21	20-0

Rock Quality Rating Model

A computer program 'DISCON' was developed to analyse the discontinuity data collected as input obtained from underground mapping. The four basic parameters, as mentioned in Table 1 were used as input. The program computes the rock quality rating, for each scan line and gives the results in the form of output listing. A sample run of input and output is listed in Tables 3 to 5. The program enables the mass of field observations to be presented in a form useful for the analysis of rock quality.

TABLE 3

Input Header Card for DISCON Program

Column	Variable name
4 — 8	I.R.S.
9 —13	R.Q.D.
14 —18	Unit
19 —28	Mine
29 —46	Location
7 —60	Observer
61 —68	Date
9 —70	Bearing
71 —76	Scan line No.

TABLE 4

Input Data Card for DISCON Program

Column	Variable name
1 — 3	Number
4 — 8	Spacing
9 —13	Length
14 —16	Dip direction
17 —18	Dip amount
19 —22	Roughness number
23 —27	Alteration number

TABLE 5

Typical Output Results of a Scan line

Unit-Zawar-Mine Observer	Mine-Mochia-Mine	Hindustan Zine Ltd.—Udaipur					
		Location-III	Level 103 E Stope		Bearing-275 Scan line-83 Date		
Dip-Direction	Dip-Amount	Frequency	Av. R/A ratio	Av. Spacing	Number	Av. Length	Remark
1. 000 — 180	(A) 00—20		0.0000	0.0000		0.0000	
(22.5 to 337.5)	(B) 21—45		0.0000	0.0000		0.0000	
and	(C) 46—60		0.0000	0.0000		0.0000	
(157.5 to 202.5)	(D) 61—90	35	0.2905	0.0541	32	7.0914	
2. 090 — 270	(A) 00—20		0.0000	0.0000		0.0000	
(67.5 to 112.5)	(B) 21—45	4	0.5000	0.1167	3	3.0000	
and	(C) 46—60		0.0000	0.0000		0.0000	
(247.5 to 292.5)	(D) 61—90	15	0.7222	0.1950	10	3.5600	
3. 045 — 225	(A) 00—20		0.0000	0.0000		0.0000	
(22.5 to 67.5)	(B) 21—45		0.0000	0.0000		0.0000	
and	(C) 46—60	4	1.0000	0.1500	4	1.5000	
(202.5 to 247.5)	(D) 61—90		0.0000	0.0000		0.0000	
4. 135 — 315	(A) 00—20		0.0000	0.0000		0.0000	
(112.5 to 157.5)	(B) 21—45	6	0.5000	0.1400	5	5.2500	
and	(C) 46—60	9	0.7778	0.1000	7	3.2222	
(292.5 to 337.5)	(D) 61—90	2	0.5000	0.1000	1	4.4000	
	Total/Weighted Average	75	0.5067	0.0989	62	5.1853	

Intact Rock Strength	= 17.00
R.Q.D. (43.75)	= 9.40
Spacing	= 8.45
R/A Ratio	= 17.04
Rock Mass Rating	= 51.88

Conclusion : Quality = Fair

TABLE 6

Comparison of Observed Rock Mass Distress with Instrumentation Results

S. No.	Level Stope	Assigned Rock Rating	Observed Rock mass distress	Correlation with instrumentation results
1.	902 W 1302 W 1602 W (S) 402 W	50 50 48 30	Slight spalling or Stressing	Extensometers in 2nd Level, picking up minor activity
2.	1004 W 1704 W 1904 W	20 30 20	Rock yielding, Substantial evidence of spalling or stressing	Extensometers (11nos.) intstalled in these stope walls picked up activity, over this time (6 months) damage caused by cracks in the roof, producing high vault. Cracking of the floor and yielding of sill pillar of 1004W
3.	IE/1W main shaft cross cut pillar (5th level)	40	Slight spalling or stressing	Stressmeter installed in the main shaft cross cut pillar showed compression progressive yielding of shaft pillar.
	2W/3W Auxiliary shaft cross cut pillar (5th level)	45	Slight spalling or stressing	Extensometers (2 nos.) and Stressmeter indicated minor amount of activity. Minor danger noticed in the shaft pillar.
4.	IE/1W Main Shaft pillar (6th level)	40	Slight spalling or stressing	Extensometers installed in the stope walls picked up activity rapidly. Stressmeter indicated compresion. Area was cable bolted by artificial support and got stabilized.

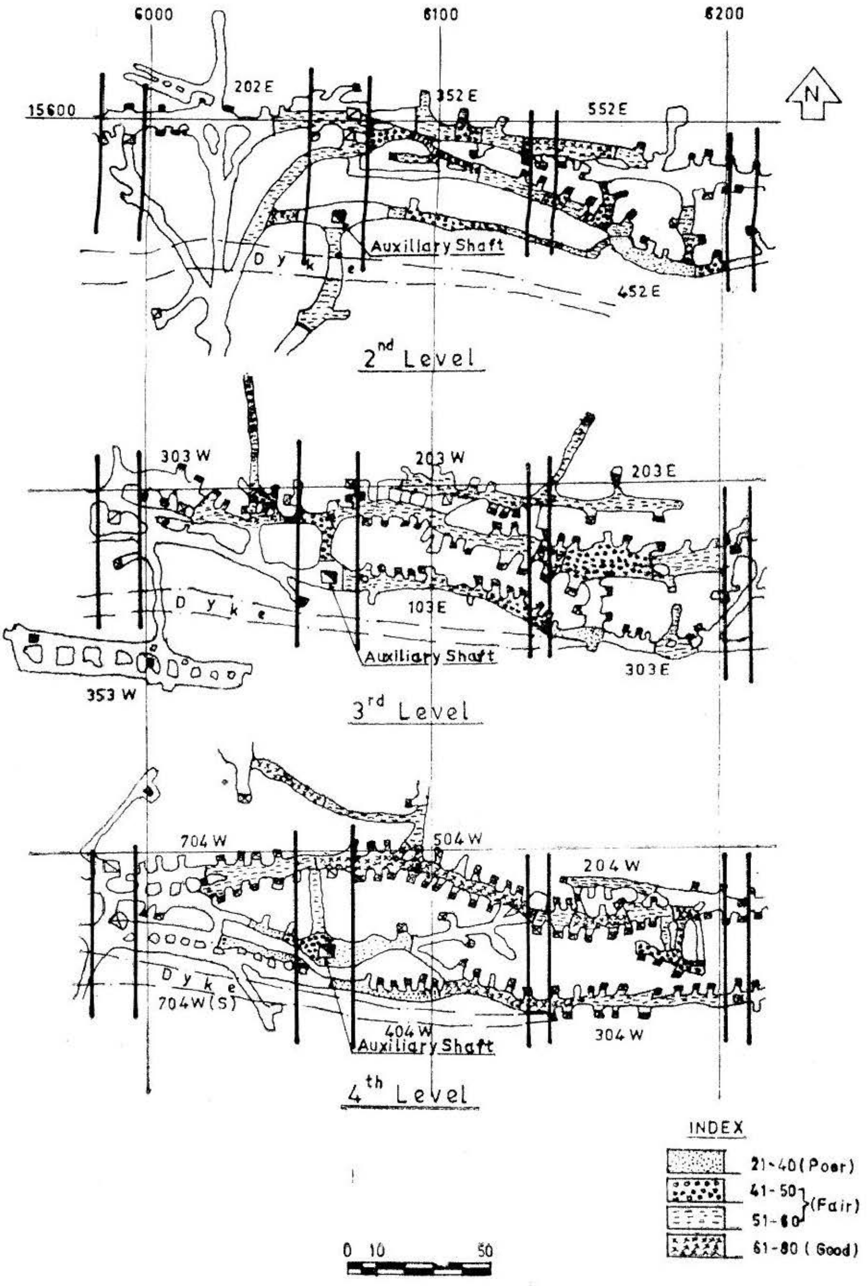

FIGURE 1 Rock Quality Map for Mochia Mine (Levels 2 to 4)

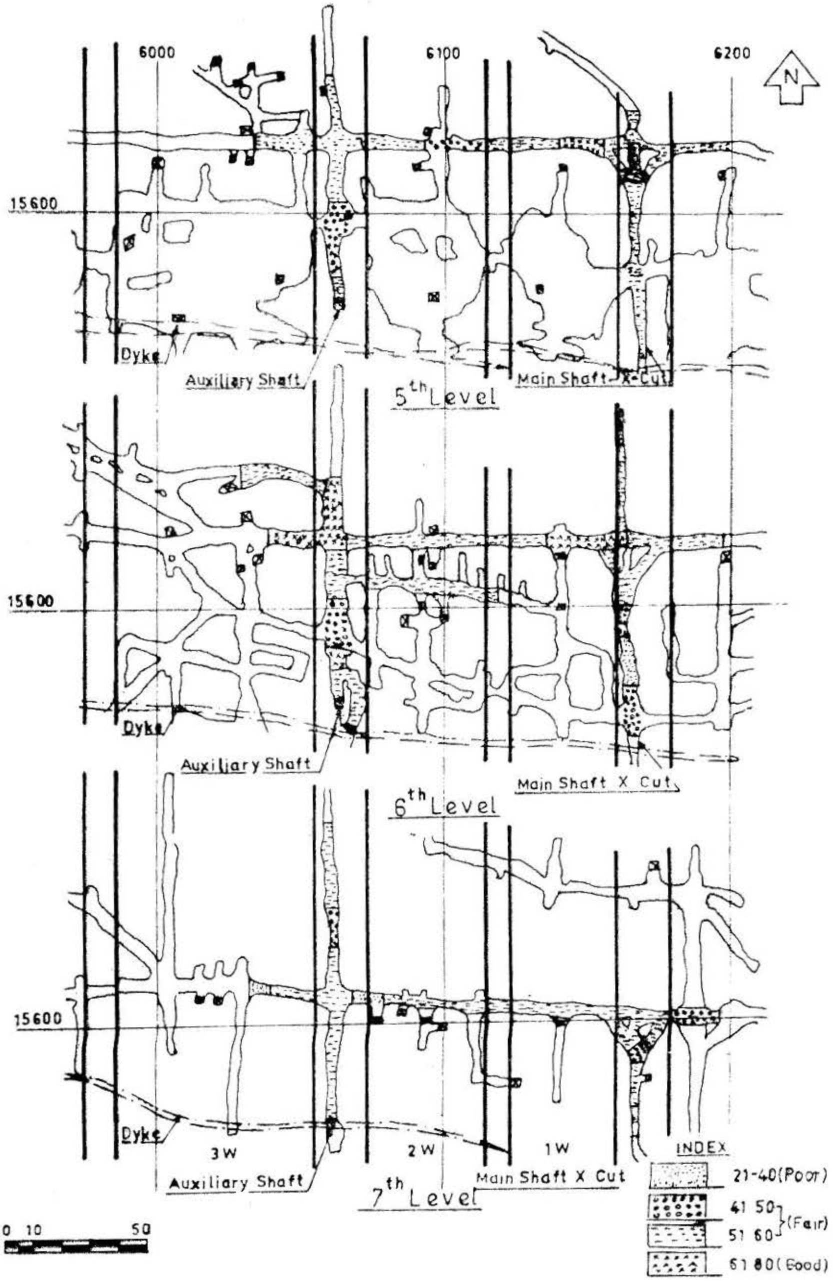

FIGURE 2 Rock Quality Map for Mochia Mine (Levels 5 to 7)

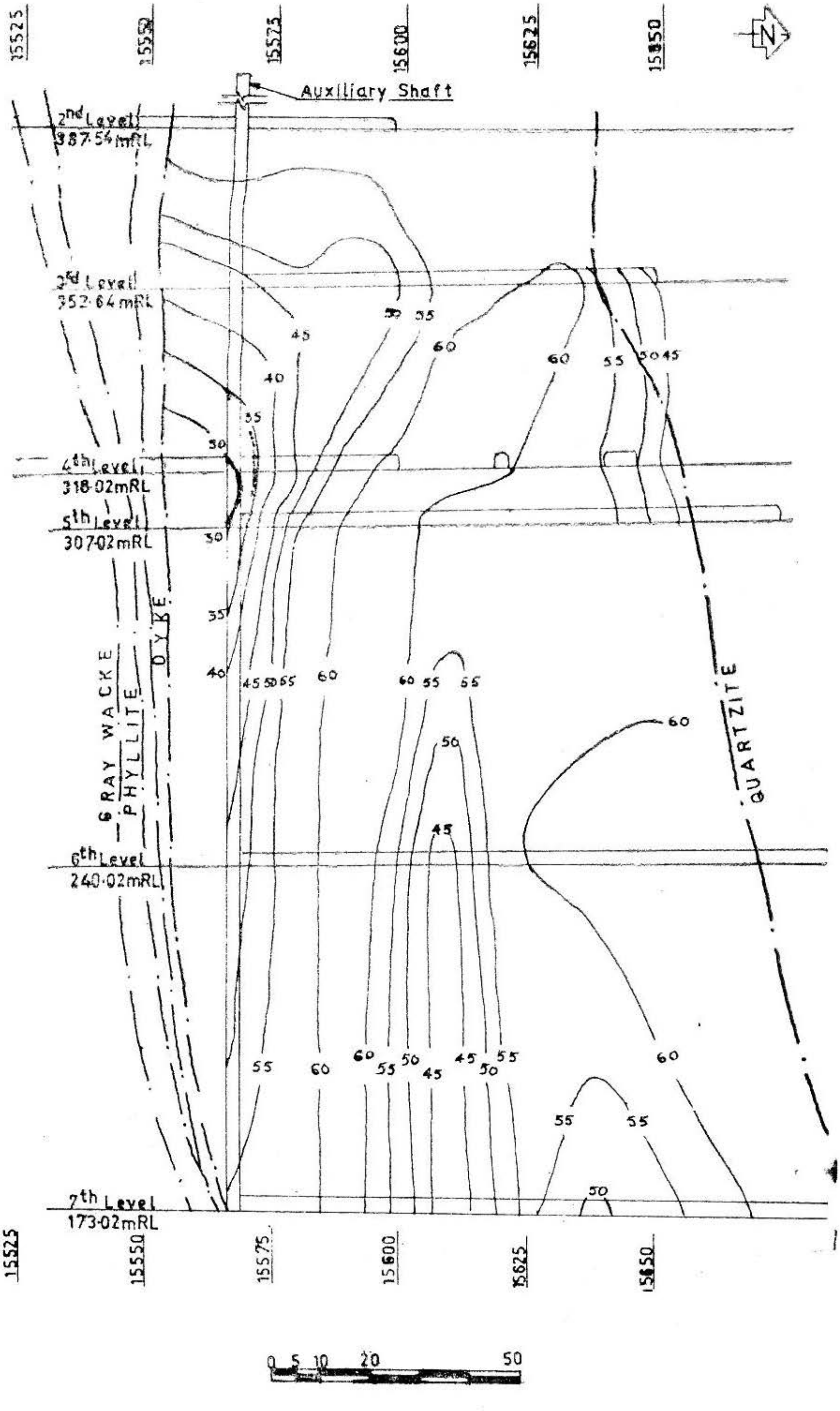

FIGURE 3 Rock Mass Qualitiy Contours along Auxiliary Shaft X—cut for Mochia Mine

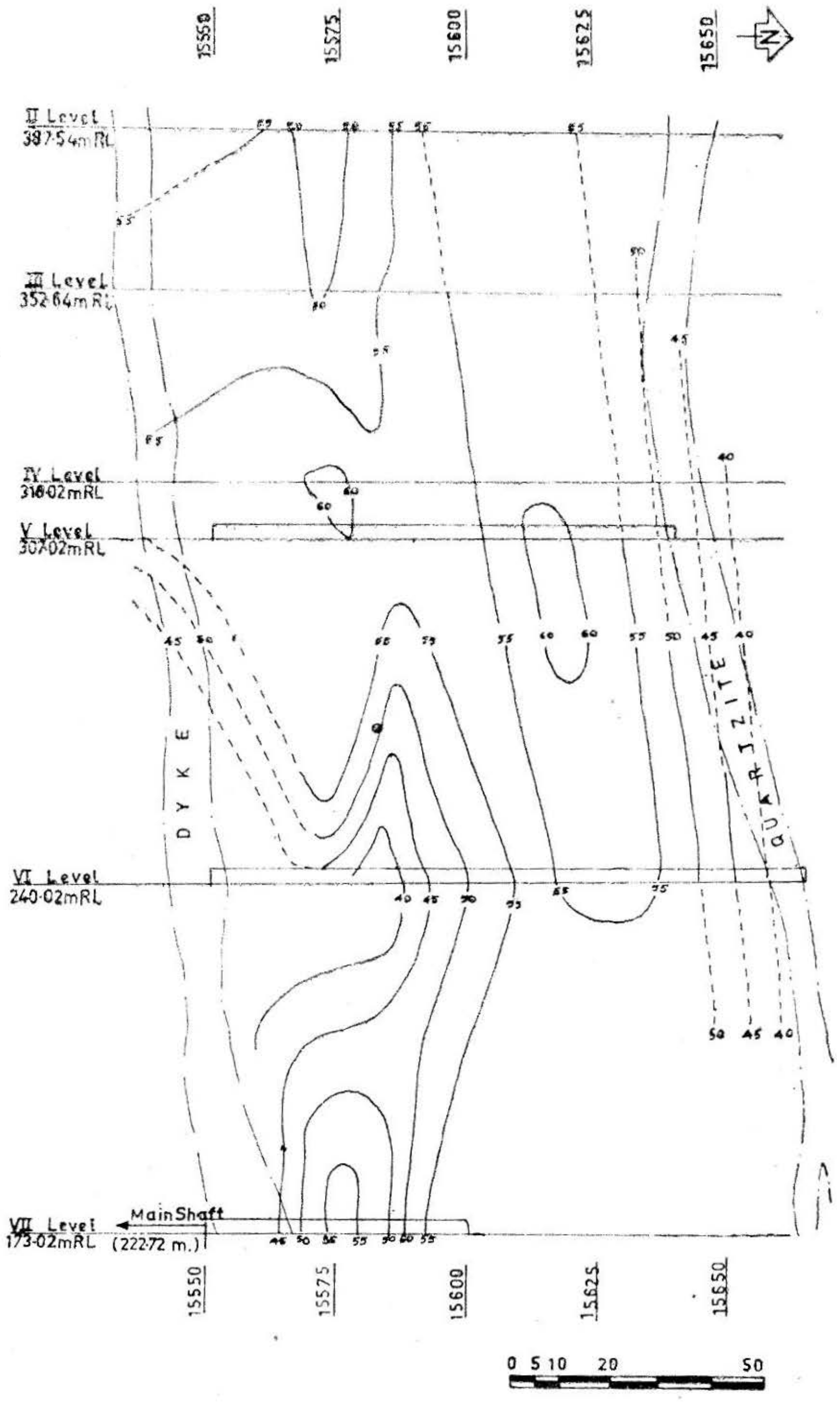

FIGURE 4 Rock Mass Quality Contour along Main Shaft X—cut for Mochia Mine

Once rock quality is determined the class boundary data was plotted on level plans (Figs. 1 and 2) and sections (Figs. 3 and 4) are contoured at 5 points interval for delineating the areas of good to poor ground conditions.

The areas of observed rock mass distress in the underground were in turn corroborated with the monitoring instruments installed in the adjacent areas and the results of the observations are summarised in Table 6.

A broad degree of correlation may be seen to exist between instrumentation results, observation of damage and assigned rock ratings.

The Rock Mass Strength (RMS) was calculated for the mine pillars based on the rock quality rating and with the help of insitu stress measurements (Laubscher, 1984) for deriving factor of safety and stability assessment of pillars.

Conclusions

The rock mass classification system followed at Mochia Mine, is a result of three years continuous geotechnical programme, for the evaluation of ground stability conditions. The rock mass rating thus obtained for the whole mine is a valuable input for the understanding of the general mine conditions and also to obtain relative rock mass strength of pillars, which in turn helped for support design. The monitoring instruments installed in at selected localities of the mine, reveal that there exist a close agreement between observed rock conditions and assigned rock mass rating. The rock mass strength will in turn be used as inputs for numerical mine modelling exercises.

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