Rock mass characterization: a comparison of the MRMR and IRMR classification systems

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Synopsis

The MRMR classification system was developed specifically for mining applications, namely caving operations, and is one of three rock mass classification systems used in the South African mining industry today. Increased usage of the MRMR classification system has raised concerns that it does not adequately address the role played by discontinuities, veins and cemented joints in a jointed rock mass. To address these concerns, Laubscher and Jakubec introduced the In-Situ Rock Mass Classification System (IRMR) in the year 2000. Although the IRMR system is more applicable to a jointed rock mass than the MRMR system, a quantitative comparison of the MRMR and IRMR classification systems indicates that there is not a significant difference between the resultant rock mass rating values derived from the two classification systems.

Introduction

The mining out of shallow mineral reserves in South Africa and resultant increase in the mining depth precipitated a change in the mining industries, and investors' perceptions of the risks associated with mining-induced instability. The increased risk of mining-induced instability within the mining industry was initially addressed through the adoption of empirical methods to quantifying the quality of the *in situ* rock mass. Although numerical stress analysis programs have subsequently become readily available, rock mass classification still forms an integral part of pre-feasibility, feasibility and bankable feasibility mining geotechnical investigations, both as a stand alone method of estimating rock mass stability, support requirements in underground excavations and rock mass deformability, and as input data into complex numerical models.

Definition of a rock mass

A rock mass may be defined as 'a discontinuous medium made up of partitioned solid bodies or aggregates of blocks, more or less separated by planes of weakness, which generally fit together tightly, with water and soft and/or hard infilling materials present or absent in the spaces between the blocks' (Piteau, 1970). Slope stability in open pit mines is principally a function of the structural discontinuities within the rock mass, and not the strength of the intact rock (Piteau, 1970), requiring a detailed knowledge of the effect of discontinuities on the rock mass. Pit slopes are seldom developed in a single lithological unit; typically they are a complex association of several lithological units having inherently different engineering properties in terms of *in situ* strength, structural composition, texture, fabric bonding strength and macro- and micro-structure respectively.

Quantification of a rock mass

Notwithstanding the difficulties associated with quantitatively classifying a rock mass, empirical techniques have been developed over the years to facilitate the assessment of the behaviour of a massive rock mass and the behaviour of a rock mass modified by structural discontinuities. Used correctly, rock mass classification systems constitute a powerful design tool and may, at times, provide the only practical basis for design, having been successfully used in Canada, Chile, the Philippines, Austria, Europe, India, South Africa, Australia and America (Laubscher, 1990). Laubscher's (1990) Mining Rock Mass Rating (MRMR) classification system is one of three rock mass classification systems in common usage in South Africa, the other two being the Geomechanics Classification System (Bieniawski, 1973) and the Norwegian Geotechnical Institute's Q-System (Barton *et al.*, 1974).

Mining rock mass rating classification system

Application of the MRMR system involves assigning *in situ* ratings to a rock mass based

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on measurable geological parameters (Laubscher, 1990). The geological parameters are weighed according to their relative importance, with a maximum possible total rating of 100. Rating values between 0 and 100 cover five rock mass classes comprising ratings of 20 per class, ranging from very poor to very good, which are a reflection of the relative strengths of the rock masses (Laubscher, 1990). Each rock mass class is further sub-divided into a division A and B.

One of the major industry concerns relating to the application of the MRMR system is its inability to adequately address the influence of fractures/veins and cemented joints on the competency of a rock mass.

The *in situ* rock mass rating classification system

Laubscher and Jakubec introduced the IRMR classification system in 2000 to address the concerns about the application of the MRMR system to a jointed rock mass, recognizing the fact that the competency of a jointed rock mass is a function of the nature, orientation and continuity of the discontinuities. The revised MRMR system, termed the In-Situ Rock Mass (IRMR) Classification System, introduced the following new concepts:

- Rock block strength (RBS)
- Cemented joint adjustment
- Joint condition (Jc) adjustment modifications
- A water adjustment parameter.

Rock block strength (RBS)

Using the unconfined compressive strength (UCS) of the rock mass, an appropriate intact rock strength (IRS) rating value is assigned to the rock mass with the corrected IRS being determined by estimating the percentage of weak rock in the rock block from a nomogram. If the rock block is devoid of fractures or veins, a factor of 0.8 is applied to adjust for the small- to large-scale specimen effect (Laubscher and Jakubec, 2000). In those instances where fractures and veins are developed, use is made of the Moh's hardness number to define the frictional properties of the infill material. In adjusting for infilled fractures and veins, the inverse of the hardness index is multiplied by the fracture/vein frequency per metre to derive a number reflecting the relative weakness between different rock masses (Laubscher and Jakubec, 2000). The percentage IRS adjustment value is determined with the RBS rating value being obtained from a nomogram.

Cemented joint adjustments

The effect of open joints is considered in the RBS calculation. Use is made of a nomogram to down-rate the joint spacing rating value of cemented joints where the strength of the cementing material is less than that of the host rock.

Joint condition (JC) adjustment modifications

Although the joint condition ratings for single joints remain unchanged, the joint condition adjustments were adjusted. In the case of multiple joints, use is made of a nomogram to derive realistic average joint condition rating values.

Water adjustment parameter

The water/ice adjustment was added due to its effect on reducing the frictional properties and effective stress of the rock mass.

Rock mass rating value

The resultant rock mass rating value is the sum of the RBS and the overall joint rating. Apart from the effect of water and/or ice, the IRMR classification system also takes the effect of the proposed mining activities on the *in situ* rock mass into account, namely weathering, joint orientation, induced stress and blasting.

Quantitative analysis

The quantitative analysis was carried out on a geotechnical database comprising 72 rock mass rating values, derived from direct field measurements, from the in-pit mapping of three open pit mining operations in South Africa and Zimbabwe. The geotechnical database included sedimentary, igneous and metamorphic rock. Rock mass rating values were calculated using both the MRMR and IRMR systems, with the resultant rock mass rating values being quantitatively analysed using statistical techniques.

Quantitative analysis results

Scatter plots of the MRMR and IRMR sedimentary, igneous and metamorphic data bases are presented as Figures 1, 2 and 3. A scatter plot of the combined MRMR and IRMR data bases is presented as Figure 4.

The correlation coefficient values for the sedimentary, igneous and metamorphic rock MRMR and IRMR data-sets are presented as Table I.

The correlation coefficients indicate:

- A linear relationship and an imperfect, yet significant, correlation between the MRMR and IRMR sedimentary rock data sets
- A linear relationship, albeit with a relatively wide scatter, and an imperfect, moderate correlation between the MRMR and IRMR igneous rock data sets
- A linear relationship and an imperfect, yet good, correlation between the MRMR and IRMR metamorphic data sets.
- A linear relationship and an imperfect, yet good, correlation between the combined MRMR and IRMR data-sets.

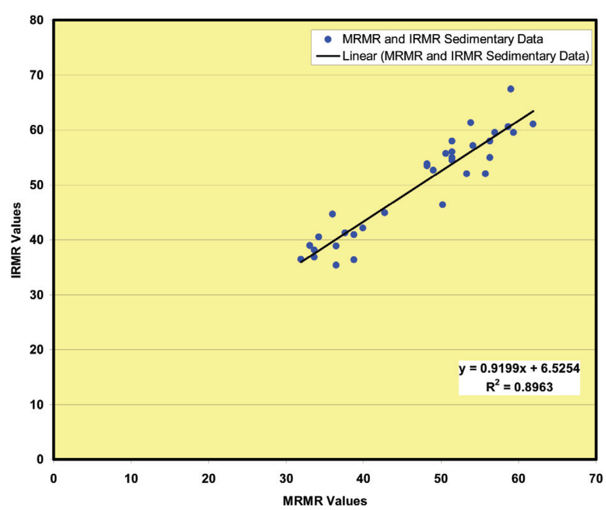

Figure 1—Scatter graph of sedimentary rock MRMR and IRMR values

Rock mass characterization:

Table I

MRMR and IRMR correlation coefficient values

Measures of relationship	Correlation coefficient values			
	Sedimentary	Igneous	Metamorphic	Combined
Correlation Coefficient	0.97	0.73	0.76	0.90

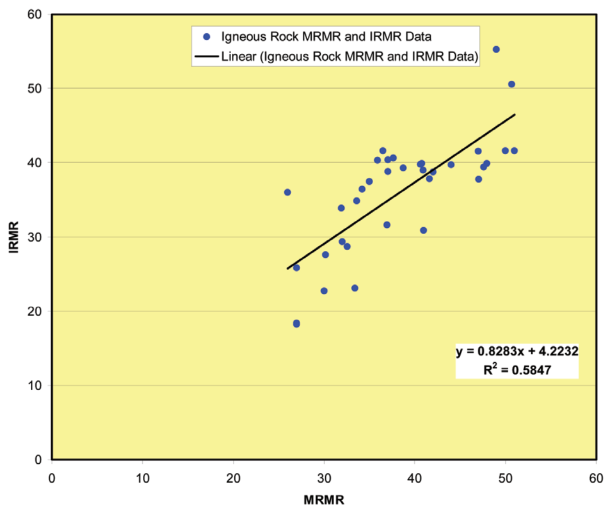

Figure 2—Scatter graph of igneous rock MRMR and IRMR values

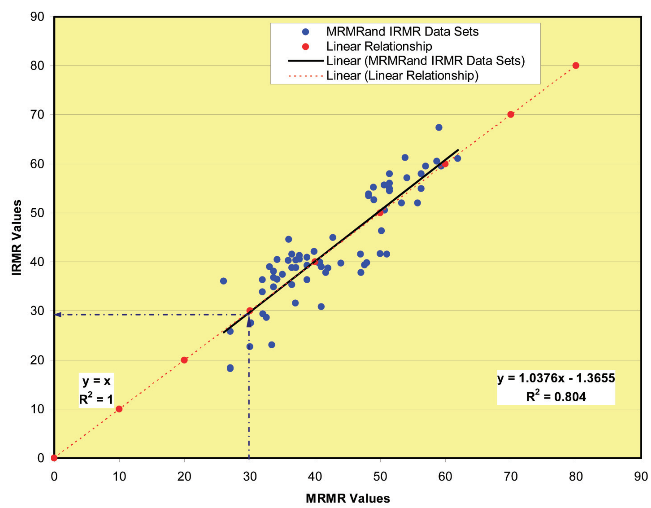

Figure 4—Scatter graph of combined MRMR and IRMR databases

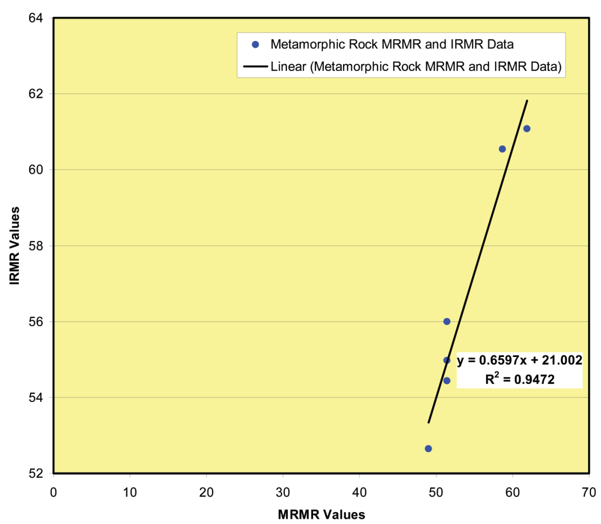

Figure 3—Scatter graph of metamorphic rock MRMR and IRMR values

Table II

Equivalent IRMR values from MRMR values

Rock type	Applicable equation
Sedimentary	IRMR = 0.9199MRMR + 6.5
Igneous	IRMR = 0.8283MRMR + 4.2
Metamorphic	IRMR = 0.6597MRMR + 21.0

Regression analysis indicates that equivalent IRMR values, for sedimentary, igneous and metamorphic rock, may be predicted with an acceptably high degree of confidence using MRMR values, through application of the regression equations in Table II.

A general regression equation may also be used to predict equivalent IRMR values from MRMR values, where:

$$\text{IRMR} = 1.0376\ \text{MRMR} - 1.3655\ [\pm 0.24] \qquad [1]$$

Conclusions

There is a linear, good, yet imperfect, relationship between the MRMR and IRMR data-sets. Equivalent IRMR values can be derived from a MRMR database with a satisfactory degree of confidence, in terms of sedimentary, metamorphic or igneous rock, or through the application of a general equation.

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