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ROCK MASS CHARACTERISATION AT THE CORRXGBXHALT MZME NORTHERN IRELAND

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ABSTRACT: This paper presents the host rock mass characterisation of the mineralisation zone at the Currighinalt Mine, Northern Ireland using the modified classification scheme of RMR (RMR2) on the basis of the inclusion of abrasivity as a factor incorporating either quartz content or aggregate abrasion value. Also, the geomechanical properties determined based on RMR2 (i.e. elastic and shear properties) of the following materials existed in the mine site are discussed : Semi-pelite, graphitic pelite, quartz semi-pelite and psammite.

I. INTRODUCTION

At the initial engineering design stage of a mining project, material characterisation procedures can be used as a design tool for investigating and determining the engineering properties of the orebody and surrounding host rock masses. Existing classification systems use a number of geotechnical parameters to characterise the rock mass and to relate the quality of the rock mass to the stability of the proposed structures. These parameters are either measured directly or scaled against descriptive scales. Also, the classification systems were devised as a means of quantifying the often subjective parameters describing the properties of a rock mass. These systems form the backbone of the empirical design methods in rock mechanics during a mine design.

A rock mass classification scheme is analogous to a large but semi-quantitative index text, in which the rock mass is rated according to the values of a variety of input parameters (Hudson, 1989). An engineering rock mass classification is designed for a specific purpose, such as feasibility, stability or support requirements. Therefore, in order to built an engineering rock mass classification, a number of engineering factors should be considered in constructing the structure of a classification scheme. On the other hand, a rock mass classification scheme built may produce a methodology to determine the mechanical behaviour of rock masses. This may.be established by a set of numerical correlations from the analysis of field data.

The geomechanical properties (i.e. elastic and shear properties, Young's Modulus, Cohesion, Internal Friction Angle, m and s values etc.) of rock masses are required at the initial design stage of a mining project. Therefore, the need arises to determine these properties for the orebody and the host rock masses in a mine structure. In recent years, researchers have proposed several relationships liking the geomechanical properties of rocks with the current rock mass classification schemes. The geomechanical properties of rock masses to be used in a mine design could be determined in three ways;

- ***by analysing and evaluating field scanline survey of rock mass dala using any one of engineering rock mass classification systems currently available,***
- ***by analysing the laboratory test results of intact rock specimens,***
- ***m by using a database of geomechanical properties of rock masses.***

The principle sketch of a technical analysis of rock mass data based on the above approaches is simplified in Figure 1.

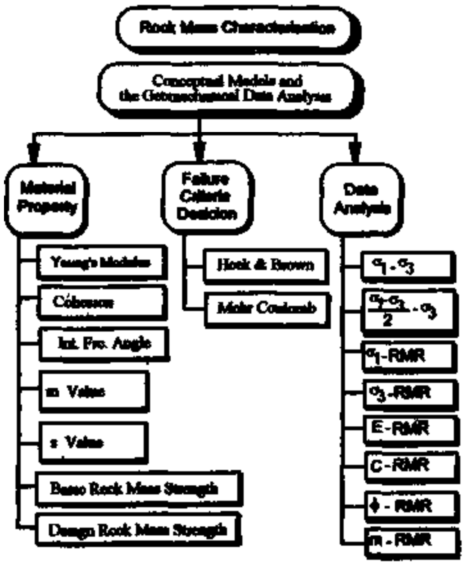

Figure 1. Analysis process of rock mass data.

An experimental research was undertaken to assess the relationship between selected rock mass parameters and the performance of various non-explosive excavation techniques for cut-and-fill mining in hard rock without the use of explosives at Curríghinalt Mine in Northern Ireland. The field measurements to collect rock mass information have been made at the mine and the laboratory work to obtain rock material data was carried out The rock mass data was obtained from scanline surveys and the rock material data from laboratory analysis of blocks or cores taken from me mine. The rock mass data consisted of such features as RQD, joint spacing , intact rock strength (as measured by Schmidt Hammer), joint wall condition and water inflows as well as the orientation of the discontinuities present

The scanline data has been used to rate the rock mass by means of the CSIR Rock Mass Rating (RMR) scheme developed by Bieniawski. In an attempt to improve the determination of geomechanical properties of rock mass, some modifications were made to the original RMR scheme, which is designed to predict tunnel support requirements.

This paper presents the rock characterisation at the Curríghinalt Mine, Northern Ireland using the modified classification scheme of RMR (RMR2) on the basis of the inclusion of abrasivity as a factor incorporating either quartz content or aggregate abrasion value. Also, the geomechanical properties determined based on RMR2 (i.e. elastic and shear properties) of the following rocks encountered in the Mine are discussed : *Semi-pelite, graphitic peine, quartz semi-pehte andpsammtte.*

2. GEOTECHNICALDATA

The scanline surveys consisted of the establishment of a scanline along which the following rock mass measurements were made:

- Distance from partal, or along adit,
- Nature of discontinuity (joint, fault etc.),
- Orientation of discontinuity (strike and dip),
- Spacing of discontinuities (JS),
- Rock Quality Designation (RQD),
- Planarity of discontinuities,
- Openness of discontinuity,
- Infilling of discontinuities (clay, quartz, calcite etc.),
- Roughness of discontinuity surface,
- Persistence of discontinuity,
- Presence of ground water (level of inflow, if any),
- Schmidt Hammer Readings (1RS).

Samples of the rock material were also collected either from drill core or as blocks taken from the mine wall. These samples were men tested to provide further data. The tests performed included determination of;

- Point Load Index,
- Uniaxial Compressive Strength,
- Quartz Content (by means of thin sections).

The results of these tests and the obtained geotechnical data were then incorporated into a database and were used to determine their geomechanical properties and to evaluate their rock mass characteristics.

The deposit at the Curríghinalt is hosted in Dalradian metasediments of Cambrian age. These sediments are made up of a series of petites (mudstones), semi-pelites, graphitic petites, graphitic semi-pelites, quartz semi-pelites and. psammites (sandstone). The classification into these groups is made upon the distribution of quartz, micas, feldspars and graphite.

The mineralisation is mainly associated with quartz veins. Apart from the gold mineralisation, sulphides are also found in concentrations of around 10%. Pyrite is the most common, however, arsenopyrite, chalcopyrite, bornite, galena, sphalerite and native copper have been found

The rocks at Curnghinalt were found to fall into classes two to four in the rock mass classification scheme (RMR). The relative proportions of each class found along 291m of the exploration adit are shown in Figure 2. Each of these rock classes has been correlated to a rock mass class given in Table 1. This length of the adit was studied in conjunction with the assessment of the DOSCO Roadheader. The geotechnical data and RMR index values are given in Figure 3.

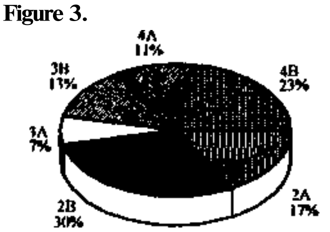

Figure 2. Distribution of rock classes encountered in exploration adit at Curnghinalt.

Table 1 Correlation of rock classes-actual rock types.

Rock Class	Characteristic Rock Types
IA&1B	Not yet Encountered at Curnghinalt
2A	Psammite, joint spacing > lm
2B	Psammite, joint spacing <" lm
3A	Quart/ semi-pelite, joint spacing < lm
3B	Semi-pelite (SO MPa), loint spacing < lm
4A	Semi-pelite (30 MPa), joint spacing < 0,1m
4B	Graphitic semi-pelite and graphitic pelite
5A&5B	Not yet Encountered at Currighinalt

3. ROCK MASS CHARACTERISATION WITH RMR2

The data has been mainly analysed using advanced micro-computer based statistical programs, namely; Data Desk Professional run on an Apple Macintosh SE. This program was used to provide statistical descriptions and scatter-plots of all the data, to perform correlations using the Spearman rank technique and the multiple linear regression.

Also, the scanline data has been used to rate the rock mass by means of the CSIR Rock Mass Rating (RMR) scheme developed by Bieniawski.

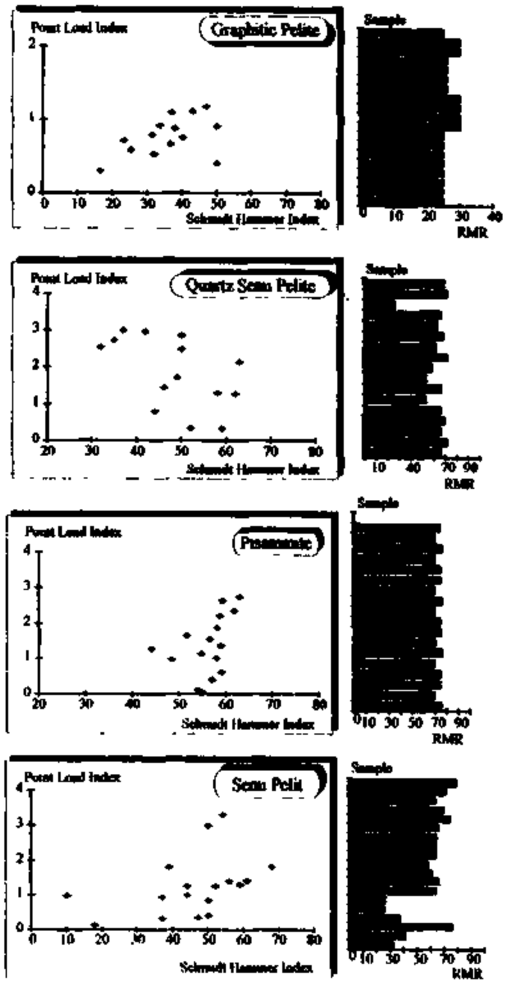

Figure 3. Geotechnical data obtained.

In an attempt to improve the determination of geomechanical properties of rock masses as well as providing a tool for the assessment of roadheader performance in hard, abresive rocks, some modifications were made to the original RMR scheme. The most fundamental change made was the inclusion of abrasivity as a factor using either quartz content or aggregate abrasion value. Other changes involved adjustments of the weightings used for the various factors.

The Modified Rock Mass Rating scheme (RMR2) is given in Table 2. Using the modified rock mass classification scheme, the rock masses at the Main Adit and the T17 development, separated into vein (> 1.0m thick) and the non-vein development, were characterised by constructing the adjusted RMR2 values. Tables 3 and 4 summarise the results of the analysis for rock mass characterisation at the Currighinalt Mine.

The modified scheme of RMR as named RMR2 uses the basic RMR approach of Bieniawski (1979) with some of the modifications for the initial ratings. The modified rating for strength of the intact rock, fracture spacing, discontinuity density (Rock Quality Designation, RQD), discontinuity conditions are used to determine the initial rating value of RMR2. On the other hand, the additional rating value for the inclusion of abrasivity as a factor using either quartz content or aggregate abrasion value is also considered in correlating the initial rating of RMR2. Therefore, key differences lie in the arrangement of the initial rating terms. Rock mass characterisation system using RMR2 as an integral conceptualised model is depicted in Figure 4. As shown in the figure that, in the first stage of the characterisation scheme, the summation of the four parameter ratings m Table 2 will give the unadjusted rock mass rating. The second stage is the assignment of numerical adjustments to the unadjusted RMR2 value as a reduction factor for strike and dip onentations of discontinuities. After applying the adjustments, the final value of RMR2 is obtained.

Table 2. Modified rock mass rating scheme (RMR2)

Strength							
Intact Rock Strength	>200	100-200	100-50	50-25	25-10	10-3	3-1
Point Load Index	>g	g-4	4-2	2-1	useUCS		
Rating	30	24	14	g	4	2	1
Rock Type							
Quartz Content %	100-gO	80-60	60-50	50-40	40-20	20-10	
Aggregate Abrasion Value	<5	5-7 5	7 5-10	10-12 5	12 5-15	>15	
Raun«	20	17	14	11	g	5	
Fracture Spacing							
RQD(%)	100-90	90-75	75-50	50-25	<25		
Rating	30	26	18	12	5		
Joint Condition							
Very rough surfaces Not continuous No separation Hard joint wail rock	**Slightly rough surfaces Separation < 1mm Hard joint wall rock**	**Slightly rough surfaces Separation < 1mm Soft joint wall rock**	**Shckensided surfaces or Gouge < 1 mm thick or Joints open 1-5 mm Continuous joints**				
20	15	10	5				

Table 3. Rock mass characterisation

Quartz Vein Development					
	RQD (%)	1RS	JS (mm)	RMR	RMR2
Observations	60	60	60	60	60
Mean	47 8	47 2	lg7	46 6	58 2
Std Deviano n	32 9	143	24 8	126	82
Maximum	100	64	100	74	77
Minimum	0	2	1	24	39

Table 4 Rock mass characterisation.

Non-Quartz Vein Development					
	ROD (%)	1RS	JS (mm)	RMR	RMR2
Observations	432	432	432	432	432
Mean	43 2	33 8	29 6	43 6	47 0
Std.Deviatıo n	45 1	193	412	18 J	173
Maximum	100	80	300	79	70
Minimum	0	2	1	14	23

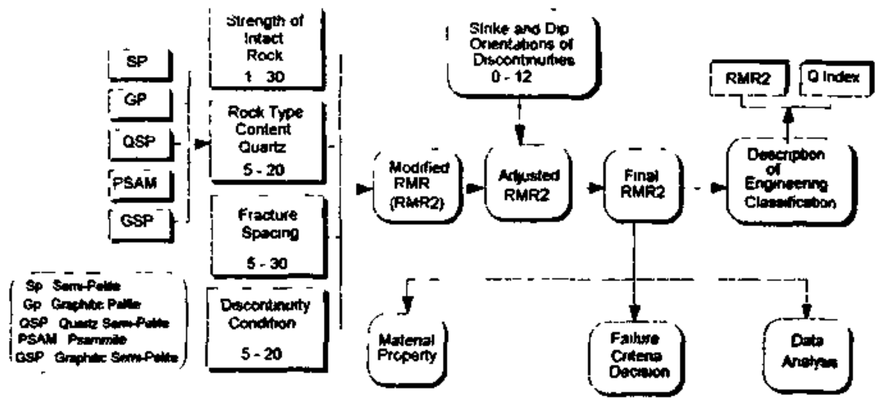

Figure 4 Rock Mass Characterisation using the RMR2.

4 GEOMECHANICAL PROPERTIES OF ROCK MASSES

The rock mass data obtained from scanline survey and the rock material data from laboratory analysis of blocks or cores taken from the mine was analysed using a variety of graphical and statistical techniques and correlations established between certain parameters. The data has been analysed using a statistical program, namely NONPAK run on a micro-computer. This program was written by a research group of Mining Engineering Department at Süleyman Demirel University, Turkey The program was run to provide statistical descriptions and to perform regressions using the non parametric rank techniques and multiple linear regression analysis. The scanline survey data rated by means of RMR2 to define the geomechanical properties of rock masses. The Spearman rank correlation technique was used to establish the relationship between selected geolcchnical parameters and RMR2 ratings for rock masses. It is a non-parametric measure of the relationship between two variables (i e. it makes no assumptions regarding linearity and is therefore appropriate for use with this type of data Linear rank correlation parameters for scanline survey data and laboratory test results based on Spearman rank correlation technique are given in Tables 5 and 6, respectively.

According to high rank correlation factors obtained, the rank analysis findings showed that RMR2 variables are the strong indicators to perform the rock mass characteristics based on the field data sets. The geomechanical properties of the rock masses at the main Adit and the T17 development at the Currighinalt Mine was determined on the basis of correlated RMR2 values for the rock masses Figure S shows the correlated RMR2 versus quartz content for various rock types encountered at the mine site. Elastic and shear properties of rock masses at the mine were determined by RMR2 ratings obtained based on a multiple linear regression techniques. The research findings are depicted in Figures 6 and 7.

Table 5 Linear rank correlation factors
(Scanline Survey).

SEUIPEUTE	RQD	RS	JS	RMR2
RQD	1000			
1RS	-0 029	1000		
JS	0 568	0 248	1000	
RMR2	0417	0 649	0 752	1000
QUARTZ SEUIPEUTE	RQD	1RS	JS	RMR2
RQD	1 000			
1RS	-0 789	1000		
JS	-0 149	-0 237	1000	
RMR2	-0 501	0 334	0 587	1000
PSAUUITE	RQD	1RS	JS	RMR2
RQD	1000			
1RS	-0 500	1.000		
JS	0998	-0 500	1000	
RMR2	0400	-0 500	0400	1000
GRAPHITIC PEUTE	RQD	1RS	JS	RMR2
RQD	1 000			
1RS	-0150	1000		
JS	0 997	-0 150	1000	
RMR2	-0 150	0 700'	-0150	1000

Table 6 Linear rank correlation factors
(Laboratory Tests)

SEMI PEUTE	11 Load Index	Vlab in/s	Quartz Cont%	U C S MPa
i Pt Load Index	1000			
ι Vlab m/s	0 369	1000		
Quartz Com %	-0 127	-0 091	1000	
U C S **MPa**	0 331	0S88	-0 672	1000
QtMRTZ *SEMI PEUTE*	PlLoad Index	Vlab m/s	Quartz Cont%	U C S MPa
Pt Load Index	1000			
Vlab m/s	-0 028	1000		
Quartz Com %	0 085	0 085	1000	
ÜC S **MPa**	0 028	0 371	0 943	1000

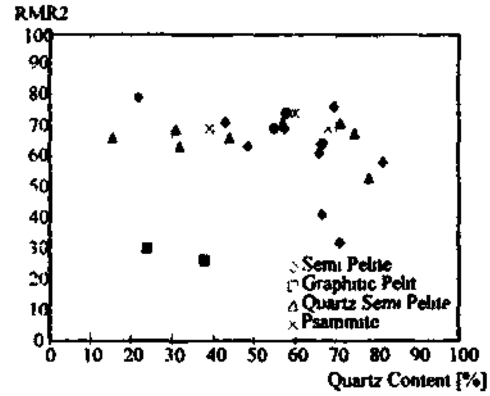

Figure 5. RMR2 versus Quartz content for various rock types at Currighinalt.

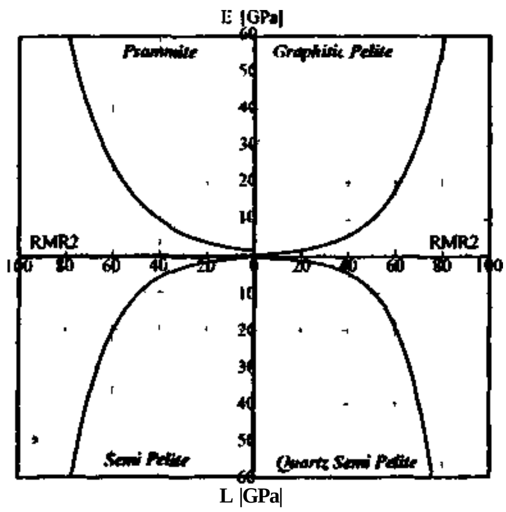

Figure 6. Elastic characteristics of rock masses.

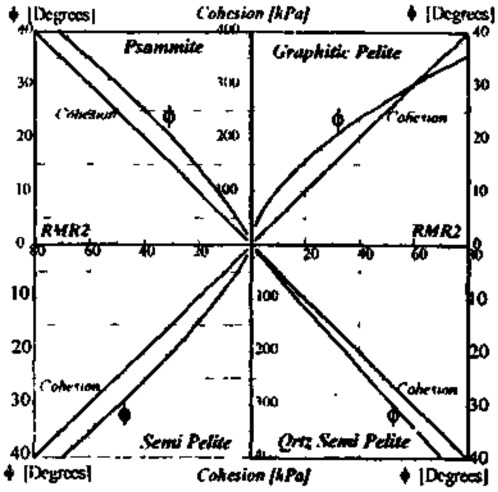

Figure 7 Shear properties of rock masses

The m-situ strength of the rock mass is best defined using an empirical equation. The empirical equations given m Murrell (1965) and Hoek and Brown (1980) both take into account the influence of the tnaxial state of stress in a rock mass. The empirical criterion proposed by Hoek and Brown (1980) enables estimation of the strength of rock masses In recent years, the applications have been shown that the estimated rock mass strengths were reasonable when used for slope stability studies in which the rock mass is usually distributed and loosened by relaxation due to excavation of the slope However, the estimated rock mass strengths generally appeared to be too low in applications involving underground excavations where the confining stresses do not permit the same degree of loosening as Would occur in a slope (Hoek & Brown, 1988). In an attempt to overcome the limitations of predicting the strength of the rock mass on the basis of direct shear tests, Hoek and Brown (1980) attempted to link the empirical Hoek and Brown strength criterion parameters, m and s with existing rock mass classifications. Brown and Hoek (1988) proposed a revised set of relationships between the rock mass rating (RMR) from Bieniawski's (1974) rock mass classification and the constants m and s. Using this analogy, the combinations were also made for the material constants of "m" for rock masses at Currighinalt mine (Figure 8).

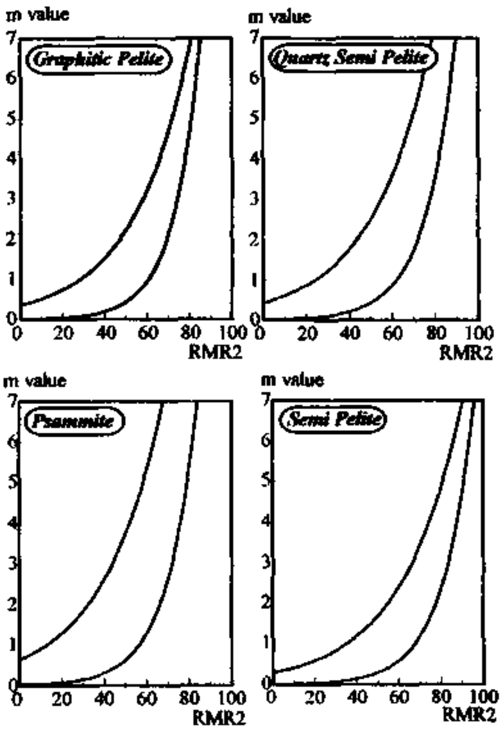

Figure 8 m value versus RMR2 for rock masses.

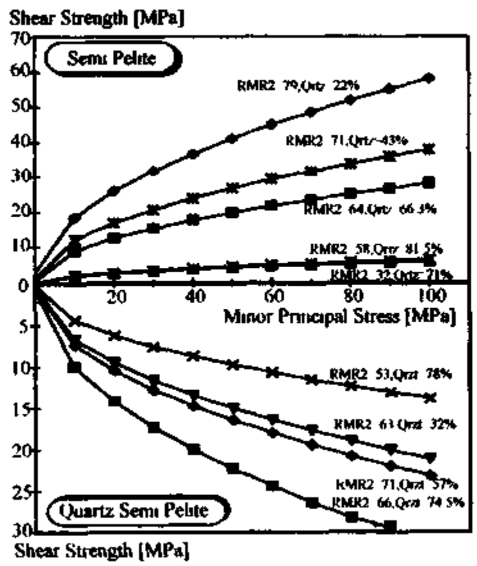

Figure 9 Strength Envelopes for rock masses.

When the elastic and shear properties of rock masses are determined, the geotechnical data can be analysed to evaluate for the strength requirement and/or development of rock masses. The basic combinations for this analysis are depicted in Figure 4. An example of the evaluation is given as follows; using the equations proposed for Hoek & Brown empirical criteria (Hoek & Brown, 1988), the strength envelopes can be constructed for rock masses. Figure 9 shows the strength envelopes constructed for semi-pelite and quartz semi-pelite at the Currighinall Mine rating with RMR2.

5. CONCLUSIONS

The modified scheme of RMR (RMR2) was described and its practical implications for rock mass characterisation were presented as given the analysis results conducted on semi-pelite, graphitic peilte, quartz semi-pelite, graphitic semi-pelite and psammite from the Currighinalt Mine. The RMR2 was linked with the correlations corresponding with the engineering rock mass classification schemes in determining the geomechanical properties of host rock masses. According to the concepts presented in this paper, it was recognised that the RMR2 scheme can be a useful tool for characterising the host rock mass response with the knowledge of engineering sense.

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