Designation: D 5878 – 00

Standard Guide for Using Rock-Mass Classification Systems for Engineering Purposes[1]

This standard is issued under the fixed designation D 5878; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This guide covers the selection of a suitable system of classification of rock mass for specific engineering purposes, such as tunneling and shaft-sinking, excavation of rock chambers, ground support, modification and stabilization of rock slopes, and preparation of foundations and abutments. These classification systems may also be of use in work on rippability of rock, quality of construction materials, and erosion resistance. Although widely used classification systems are treated in this guide, systems not included here may be more appropriate in some situations, and may be added to subsequent editions of this standard.

1.2 The valid, effective use of this guide is contingent upon the prior complete definition of the engineering purposes to be served and on the complete and competent definition of the geology and hydrology of the engineering site. Further, the person or persons using this guide must have had field experience in studying rock-mass behavior. An appropriate reference for geological mapping in the underground is provided by Guide D 4879.

1.3 This guide identifies the essential characteristics of seven classification systems. It does not include detailed guidance for application to all engineering purposes for which a particular system might be validly used. Detailed descriptions of the first five systems are presented in STP 984 **(1)**,[2] with abundant references to source literature. Details of two other classification systems and a listing of seven Japanese systems are also presented.

1.4 The range of applications of each of the systems has grown since its inception. This guide summarizes the major fields of application up to this time of each of the seven classification systems.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education ore experience and should be used in conjunction with professional judgement. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[3]

D 2938 Test Method for Unconfined Compressive Strength of Intact Rock Core Specimens[3]

D 4879 Guide for Geotechnical Mapping of Large Underground Openings in Rock[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *classification*, *n*—a systematic arrangement or division of materials, products, systems, or services into groups based on similar characteristics such as origin, composition, properties, or use (*Regulations Governing ASTM Technical Committees*).[4]

3.1.2 *rock mass (in situ rock)*, *n*—rock as it occurs in situ, including both the rock material and its structural discontinuities (Modified after Terminology D 653 [ISRM]).

3.1.2.1 *Discussion*—Rock mass also includes at least some of the earth materials in mixed-ground and soft-ground conditions.

3.1.3 *rock material (intact rock, rock substance, rock element)*, *n*—rock without structural discontinuities; rock on which standardized laboratory property tests are run.

3.1.4 *structural discontinuity (discontinuity)*, *n*—an interruption or abrupt change in a rock's structural properties, such

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.12 on Rock Mechanics.

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[2] The boldface numbers given in parentheses refer to a list of references at the end of the text.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

[4] Available from ASTM Headquarters, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

*A Summary of Changes section appears at the end of this standard.

as strength, stiffness, or density, usually occurring across internal surfaces or zones, such as bedding, parting, cracks, joints, faults, or cleavage.

NOTE 1—To some extent, 3.1.1, 3.1.2, and 3.1.4 are scale-related. A rock's microfractures might be structural discontinuities to a petrologist, but to a field geologist the same rock could be considered intact. Similarly, the localized occurrence of jointed rock (rock mass) could be inconsequential in regional analysis.

3.1.5 For the definition of other terms that appear in this guide, refer to STP 984, Guide D 4879, and Terminology D 653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *classification system, n*—a group or hierarchy of classifications used in combination for a designated purpose, such as evaluating or rating a property or other characteristic of a rock mass.

4. Significance and Use

4.1 The classification systems included in this guide and their respective applications are as follows:

4.1.1 *Rock Mass Rating System (RMR) or Geomechanics Classification*—This system has been applied to tunneling, hard-rock mining, coal mining, stability of rock slopes, rock foundations, borability, rippability, dredgability, weatherability, and rock bolting.

4.1.2 *Rock Structure Rating System (RSR)*—This system has been used in tunnel support and excavation and in other ground support work in mining and construction.

4.1.3 *The Q System or Norwegian Geotechnical Institute System (NGI)*—This system has been applied to work on tunnels and chambers, rippability, excavatability, hydraulic erodibility, and seismic stability of roof-rock.

4.1.4 *The Unified Rock Classification System (URCS)*—This system has been applied to work on foundations, methods of excavation, slope stability, uses of earth materials, blasting characteristics of earth materials, and transmission of ground water.

4.1.5 *The Rock Material Field Classification Procedure (RMFC)*—This system has been used mainly for applications involving shallow excavation, particularly with regard to resistance to erosion, excavatability, construction quality of rock, fluid transmission, and rock-mass stability.

4.1.6 *The New Austrian Tunneling Method (NATM)*—This system is used for both conventional (cyclical, such as drill-and-blast) and continuous (tunnel-boring machine or TBM) tunneling. This is a tunneling procedure in which design is extended into the construction phase by continued monitoring of rock displacement. Support requirements are revised to achieve stability.

NOTE 2—The Austrian code **(7)** specifies methods of payment based on coding of excavation volume and means of support.

4.1.7 *The Coal Mine Roof Rating (CMRR)*—This system applies to bedded coal-measure rocks, in particular with regard to their structural competence as influenced by discontinuities in the rock mass. The basic building blocks of CMRR are unit ratings. The units are rock intervals defined by their geotechnical properties, and are at least 0.15 m (6 in.) thick. The unit ratings are combined into roof ratings, using additional geotechnical characteristics **(8)**.

4.1.8 *Japanese Rock Mass Classification Systems*—The Japanese Society of Engineering Geology has recognized seven major classification systems in use in Japan **(9)**. These are summarized in 4.1.8.1-4.1.8.7, without additional details in this guide.

4.1.8.1 *Rock-Mass Classification for Railway Tunnels by Railway Technical Research Institute*—Rock-masses are classified based on the values of *P*-wave velocity, unconfined compressive strength and unit weight. Support patterns for tunnels, such as shotcreting and rock bolting, is recommended depending upon the rock-mass classification obtained.

4.1.8.2 *Rock-Mass Classification for Tunnels and Slopes by Japan Highway Public Corporation*—This system classifies the rock-mass using RQD, *P*-wave velocity, unconfined compressive strength and unit weight.

4.1.8.3 *Rock-Mass Classification for Dam Foundations by Public Works Research Institute, Ministry of Construction*—In this system, the rock-masses are classified by observing spacing of joints, conditions of joints and strength of rock pieces.

4.1.8.4 *Rock-Mass Classification for Water Tunnel Design by The Ministry of Agriculture, Forestry and Fisheries*—The rock-mass is classified into four categories based on values of *P*-wave velocity, compressive strength and Poisson ratio as well as rock type.

4.1.8.5 *Rock-Mass Classification by Central Research Institute of Electric Power Industry*—This system classifies rock-mass based on rock type and weathering characteristics.

4.1.8.6 *Rock-Mass Classification by Electric-Power Development Company*—This system is somewhat similar to the system developed by the Central Research Institute of Electric Power Industry (see 4.1.8.5). The three factors used for classifying rock-mass are weathering, hardness and joint spacing.

4.1.8.7 *Rock-Mass Classification for Weathered Granite for Bridge Foundation by Honshu-Shikoku Bridge Authority*—This system uses results of visual observations of rock-mass in situ, geophysical logging, laboratory tests on rock samples, pressuremeter tests or other forms of in-situ tests or a combination thereof, to estimate strength and stiffness.

4.2 Other classification systems are described in detail in the general references listed in the appendix.

4.3 Using this guide, the classifier should be able to decide which system appears to be most appropriate for the specified engineering purpose at hand. The next step should be the study of the source literature on the selected classification system and on case histories documenting the application of that system to real-world situations and the degree of success of each such application. Appropriate but by no means exhaustive references for this purpose are provided in the appendix and in STP 984 **(1)**. *The classifier should realize that taking the step of consulting the source literature might lead to abandonment of the initially selected classification system and selection of another system, to be followed again by study of the appropriate source literature.*

5. Bases for Classification

5.1 The parameters used in each classification system follow. In general, the terminology used by the respective author or authors of each system is listed, to facilitate reference to STP 984 **(1)** or source documents.

5.1.1 *Rock Mass Rating System (RMR) or Geomechanics Classification*

Uniaxial compressive strength (see Test Method D 2938)
Rock quality designation (RQD)
Spacing of discontinuities
Condition of discontinuities
Ground water conditions
Orientation of discontinuities

5.1.2 *Rock Structure Rating System (RSR)*

Rock type plus rock strength
Geologic structure
Spacing of joints
Orientation of joints
Weathering of joints
Ground water inflow

5.1.3 *Q-System or Norwegian Geotechnical Institute (NGI) System*

Rock quality designation (RQD)
Number of joint sets
Joint roughness
Joint alteration
Joint water-reduction factor
Stress-reduction factor

5.1.4 *Unified Rock Classification System (URCS)*

Degree of weathering
Uniaxial compressive strength (see Test Method D2938)
Discontinuities
Unit weight

5.1.5 *Rock Material Field Classification Procedure (RMFC)*

Discrete rock-particle size
Uniaxial compressive strength (see Test Method D 2938)
Joint orientation
Joint-aperture width
Geologic structure
Rock-unit thickness
Seismic velocity
URCS rating
Rock quality designation (RQD)
Mineralogy
Porosity and voids
Hydraulic conductivity and transmissivity

5.1.6 *New Austrian Tunneling Method (NATM)*

A:1.Stable
2.Overbreaking
B:1.Friable
2.Very friable
3.Rolling/running
C:1.Rock bursting
2.Squeezing
3.Heavily squeezing
4.Flowing
5.Swelling

5.1.7 *Coal Mine Roof Rating (CMRR)*

Unit Ratings
Shear strength of discontinuities
Cohesion
Roughness
Intensity of discontinuities
Spacing
Persistence
Number of discontinuity sets
Compressive strength
Moisture sensitivity
Roof Ratings
Strong bed adjustment
Unit contact adjustment
Groundwater adjustment
Surcharge adjustment

5.2 Comparison of parameters among these systems indicates some strong similarities. It is not surprising, therefore, that paired correlations have been established between RMR, RSR, and Q **(2)**. Some of the references in the appendix also present procedures for estimating some in situ engineering properties from one or more of these indexes **(2, 3, 4**, and **5**).

NOTE 3—Reference **(2)** presents step-by-step procedures for calculating and applying RSR, RMR, and Q values. Applications of the first five systems are discussed in STP 984 **(1)**, as is a detailed treatment of RQD.

6. Procedures for Determining Parameters

6.1 The annex of this guide contains tabled and other material for determining the parameters needed to apply each of the classification systems. These materials should be used in conjunction with detailed, instructive references such as STP 984 **(1)** and Ref **(2)**. The annexed materials are as follows:

6.1.1 *RMR System*

Classification parameters (five) and their ratings (Sum ratings)
Rating adjustment for discontinuity orientations (Parameter No. 6) *(RMR = adjusted sum)*
Effect of discontinuity strike and dip in tunneling
Adjustments for mining applications
Input data

6.1.2 *RSR System*

Schematic of the six parameters
Rock type plus strength, geologic structure (“A”)
Joint spacing and orientation (“B”)
Weathering of joints and ground water inflow (“C”)

$$(RSR = A + B + C) \quad (1)$$

6.1.3 *Q-System*:

RQD
Joint set number, J_n
Joint roughness number, J_r
Joint alteration number, J_a
Joint water reduction factor, J_W
Stress reduction factor SRF

$$(Q = (RQD/J_n) \times (J_r/J_a) \times (J_W/SRF) \quad (2)$$

6.1.4 *URCS*

Degree of weathering (*A*–*E*)
Estimated strength (*A*–*E*)

Discontinuities (*A–E*)

Unit weight (*A–E*)

Schematic of notation (*results* = *AAAA* through *EEEE*)

6.1.5 *RMFCP*

Schematic of procedure through performance assessment

Classification (description and definitions),

Rock unit

Classification Elements—Including rock material properties, rock mass properties, and hydrogeologic properties.

Performance Assessment—Performance objectives

Erosion resistance

Excavation Characteristics

Construction Quality

Fluid Transmission

Rock Mass Stability

6.1.6 *NATM*

Rock mass types

Calculation of support factor

Excavation class matrix for conventional tunneling (The excavation class matrix for continuous (TBM) tunneling is determined by standup time and the support factor, the latter calculated in the same way as for conventional tunneling, although there may be some differences in the way in which rating factors are assigned.)

Support elements and rating factors

NOTE 4—Standup time is the length of time following excavation that an active span in an underground opening will stand without artificial support. An active span is the largest unsupported span between the face and artificial supports **(10)**.

6.1.7 *CMRR*

CMRR calculation

Immersion test

Field data sheet

Directions for field data sheet

Cohesion-roughness rating

Spacing-persistence rating

Multiple discontinuity set adjustment

Strength rating

Moisture sensitivity rating

Unit rating calculation sheet

Roof rating calculation sheet

Strong bed adjustment

Unit contacts adjustment

Groundwater adjustment

Surcharge adjustment

CMRR values

7. Precision

7.1 Precision statements will be available for some components of some of the classification systems, such as uniaxial compressive strength and rock quality designation.

8. Keywords

8.1 classification; classification system; coal mine roof rating (CMRR); Japanese rock mass classification systems; new Austrian tunneling method (NATM); Q-system (NGI); rock mass; rock mass rating system (RMR); rock material field classification procedure (RMFCP); rock quality designation (RQD); rock structure rating system (RSR); unified rock classification system (URCS)

ANNEX

(Mandatory Information)

A1. Classification System Material

A1.1 The materials presented in this Annex for RMR, RSR, URCS, and RMFCP have been extracted from STP 984 **(1)**. The materials for Q (NGI) are from Ref **(4)**. The materials for NATM are from Ref. **(6)**. The materials for CMRR are from Ref. **(8)**.

APPENDIX

(Nonmandatory Information)

X1. ADDITIONAL INFORMATION

Afrouz, A. A., *Practical Handbook of Rock Mass Classification Systems and Modes of Ground Failure*, CRC Press, Boca Raton, 1992.

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Williamson, D. A., "Uniform Rock Classification for Geotechnical Engineering Purposes," *Transportation Research Record 783*, National Academy of Sciences, Washington, DC, 1980, pp. 9–14.

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(**2**) Bieniawski, Z. T., *Rock Mechanics Design in Mining and Tunneling*, Balkema, A. A., Rotterdam, 1984.

(**3**) Barton, N., Lien, R., and Lunde, J., "Engineering Classification of Rock Masses for the Design of Tunnel Support," *Rock Mechanics*, Vol 6, No. 4, 1974, pp. 189–236.

(**4**) Barton, N., and Grimstad, E., "The Q-System Following Twenty Years of Application in NMT Support Selection," *Felsbau*, Vol 12, No. 6, 1994, pp. 428–436.

(**5**) Bieniawski, Z. T., *Engineering Rock Mass Classifications*, Wiley-Interscience, New York, 1989.

(**6**) Lauffer, H., "Rock Classification Methods Based on the Excavation Response," *Felsbau*, Vol 15, No. 3, 1997, pp. 179–182.

(**7**) *Austrian Code, Ő*N B2203/1994.

(**8**) Molinda, G. M., and Mark, C., "Coal Mine Roof Rating (CMRR): A Practical Rock Mass Classification for Coal Mines," *Information Circular 9387*, U.S. Bureau of Mines, Pittsburgh, PA, 1994.

(**9**) "Rock Mass Classification in Japan," Japanese Society of Engineering Geology, 1992.

(**10**) Hoek, E. and Brown, E. T., *Underground Excavations in Rock*, Institution of Mining and Metallurgy, London, 1980.

SUMMARY OF CHANGES

The principal changes to this guide that have been incorporated since the last issue, D 5878–95, are information on additional rock-mass classification systems, as follows:

(*1*) New Austrian Tunneling Method (NATM).
(*2*) Coal Mine Roof Rating (CMRR).
(*3*) A listing and brief descriptions of seven Japanese systems.

RMR

TABLE 1—*Geomechanics Classification of jointed rock masses.*

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

	PARAMETER		RANGES OF VALUES						
1	Strength of intact roack material	Point-load strength index	> 10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range – uniaxial compressive test is preferred		
		Uniaxial compressive strength	>250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5-25 MPa	1-5 MPa	< 1 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core quality RQD		90% - 100%	75% - 90%	50% - 75%	25% - 50%	< 25%		
	Rating		20	17	13	8	3		
3	Spacing of discontinuities		>2 m	0,6 - 2 m	200 - 600 mm	60 -200 mm	<60 mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities		Very rough surfaces. Not continuous No seperation Unweathered wall rock.	Slightly rough surfaces. Separation < 1 mm Slightly weathered walls	Slightly rough surfaces. Separation < 1 mm Highly weathered walls	Slickensided surfaces OR Gouge < 5 mm thick OR Separation 1-5 mm. Continuous	Soft gouge > 5 mm thick OR Separation > 5 mm. Continous		
	Rating		30	25	20	10	0		
5	Ground water	Inflow per 10 m tunnel length	None	<10 litres/min	10-25 litres/min	25 - 125 litres/min	> 125		
		Ratio $\frac{\text{joint water pressure}}{\text{major principal stress}}$	OR 0	OR 0,0-0,1	OR 0,1-0,2	OR 0,2-0,5	OR > 0,5		
		General conditions	OR Completely dry	OR Damp	OR Wet	OR Dripping	OR Flowing		
	Rating		15	10	7	4	0		

B. RATING ADJUSTMENT FOR JOINT ORIENTATIONS

Strike and dip orientations of joints		Very favourable	Favourable	Fair	Unfavourable	Very unfavourable
Ratings	Tunnels	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	-60

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Rating	100← 81	80← 61	60← 41	40← 21	< 20
Class No.	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING OF ROCK MASS CLASSES

Class No	I	II	III	IV	V
Average stand-up time	10 years for 15 m span	6 months for 8 m span	1 week for 5 m span	10 hours for 2,5 m span	30 minutes for 1 m span
Cohesion of the rock mass	> 400 kPa	300 - 400 kPa	200 - 300 kPa	100 - 200 kPa	< 100 kPa
Friction angle of the rock mass	> 45°	35° - 45°	25° - 35°	15° - 25°	< 15°

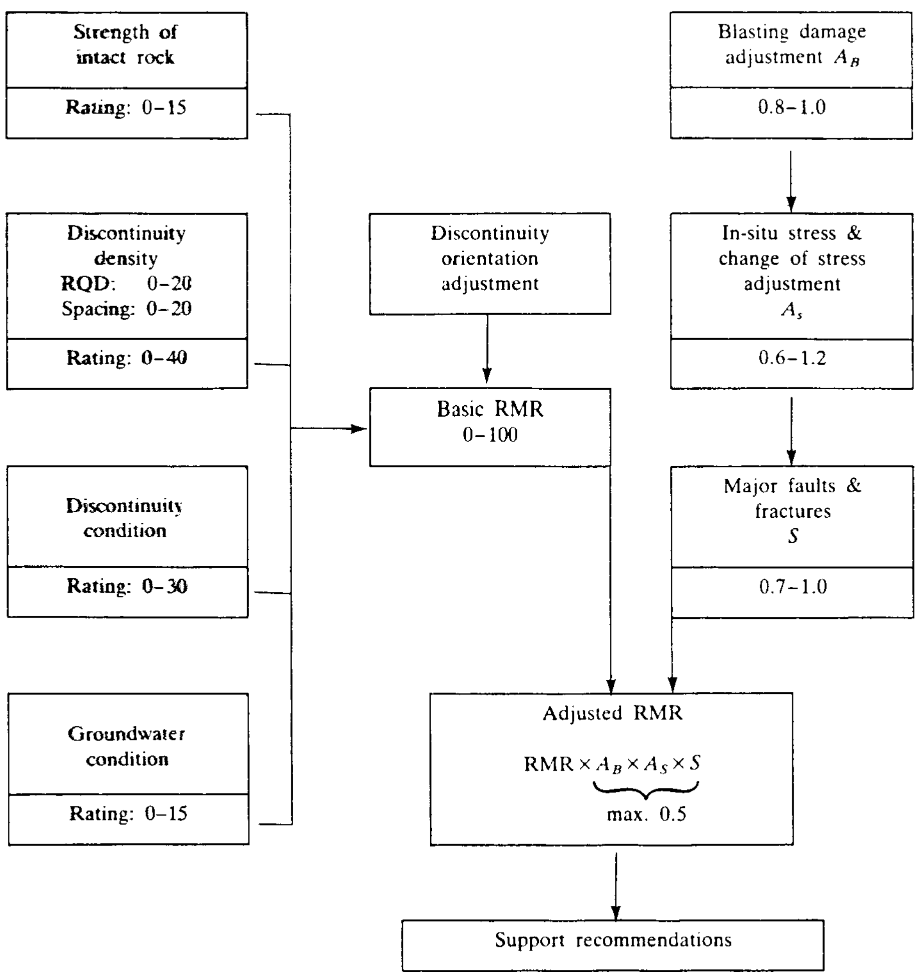
RMR

TABLE 2—*Effect of discontinuity strike and dip orientations in tunneling.*

Strike Perpendicular to Tunnel Axis			
Drive with Dip		Drive against Dip	
Dip 45–90°	Dip 20–45°	Dip 45–90°	Dip 20–45°
Very favorable	Favorable	Fair	Unfavorable

Strike Parallel to Tunnel Axis		Irrespective of Strike
Dip 20–45°	Dip 45–90°	Dip 0–20°
Fair	Very unfavorable	Fair

TABLE 3—*Adjustments to the Geomechanics Classification for mining applications.*



RMR

Input data form for the Geomechanics Classification (RMR System)

Name of project:

Site of survey:

Conducted by:

Date:

STRUCTURAL REGION	ROCK TYPE AND ORIGIN

DRILL CORE QUALITY R.Q.D.*

Excellent quality:	90 - 100%	....
Good quality:	75 - 90%	....
Fair quality:	50 - 75%	....
Poor quality:	25 - 50%	....
Very poor quality:	<25%	....

*R.Q.D. = Rock Quality Designation

WALL ROCK OF DISCONTINUITIES

Unweathered	....
Slightly weathered	....
Moderately weathered	....
Highly weathered	....
Completely weathered	....
Residual soil	....

GROUND WATER

INFLOW per 10 m of tunnel length litres/minute ....

or

WATER PRESSURE kPa ....

or

GENERAL CONDITIONS (completely dry, damp, wet, dripping or flowing under low/medium or high pressure:

....

STRENGTH OF INTACT ROCK MATERIAL

Designation	Uniaxial compressive strength, MPa	OR	Point-load strength index, MPa
Very high:	Over 250		>10
High:	100 - 250		4-10
Medium high:	50 - 100		2-4
Moderate:	25 - 50		1-2
Low:	5 - 25		< 1
Very low:	1 - 5		

SPACING OF DISCONTINUITIES

		Set 1	Set 2	Set 3	Set 4
Very wide:	Over 2 m	....	....	....	....
Wide:	0,6 - 2 m	....	....	....	....
Moderate:	200 - 600 mm	....	....	....	....
Close:	60 - 200 mm	....	....	....	....
Very close:	<60 mm	....	....	....	....

NOTE: These values are obtained from a joint survey and not from borehole logs.

STRIKE AND DIP ORIENTATIONS

Set 1	Strike: .... (average)	(from .... to ....)	Dip: .... (angle) .... (direction)
Set 2	Strike:	(from .... to ....)	Dip: ....
Set 3	Strike:	(from .... to ....)	Dip: ....
Set 4	Strike:	(from .... to ....)	Dip: ....

NOTE: Refer all directions to magnetic north.

CONDITION OF DISCONTINUITIES

		Set 1	Set 2	Set 3	Set 4
PERSISTENCE (CONTINUITY)					
Very low:	<1 m	....	....	....	....
Low:	1 - 3 m	....	....	....	....
Medium:	3 - 10 m	....	....	....	....
High:	10 - 20 m	....	....	....	....
Very high:	> 20 m	....	....	....	....
SEPARATION (APERTURE)					
Very tight joints:	<0,1 mm	....	....	....	....
Tight joints:	0,1 - 0,5 mm	....	....	....	....
Moderately open joints:	0,5 - 2,5 mm	....	....	....	....
Open joints:	2,5 - 10 mm	....	....	....	....
Very wide aperture	> 10 mm	....	....	....	....
ROUGHNESS (state also if surfaces are stepped, undulating or planar)					
Very rough surfaces:		....	....	....	....
Rough surfaces:		....	....	....	....
Slightly rough surfaces:		....	....	....	....
Smooth surfaces:		....	....	....	....
Slickensided surfaces:		....	....	....	....
FILLING (GOUGE)					
Type:		....	....	....	....
Thickness:		....	....	....	....
Uniaxial compressive strength, MPa		....	....	....	....
Seepage:		....	....	....	....

MAJOR FAULTS OR FOLDS

Describe major faults and folds specifying their locality, nature and orientations.

GENERAL REMARKS AND ADDITIONAL DATA

NOTE:

(1) For definitions and methods consult ISRM document: *'Quantitative description of discontinuities in rock masses.'*

(2) The data on this form constitute the minimum required for engineering design. The geologist should, however, supply any further information which he considers relevant.

RSR

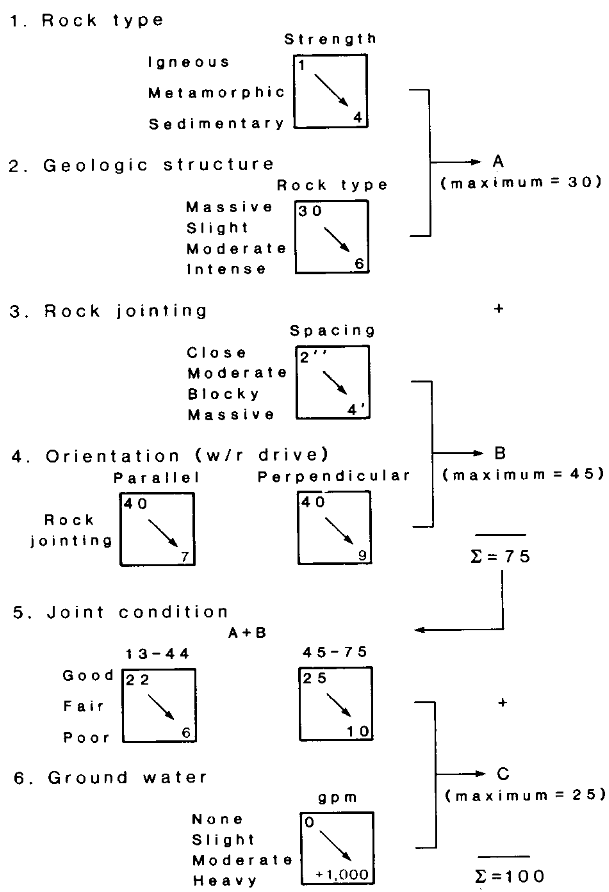


FIG. 1—*Schematic of Rock Structure Rating.*

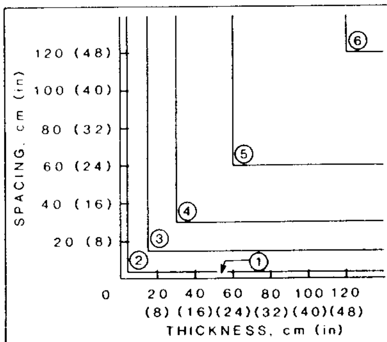
Parameter A
Rock structure rating
Rock type, strength index and geologic structure
Maximum value 30

Basic rock type	Hard	Medium	Soft	Decomp
Igneous	1	2	3	4
Metamorphic	1	2	3	4
Sedimentary	2	3	4	4

	Geological structure			
	Massive	Slightly faulted or folded	Moderately faulted or folded	Intensely faulted or folded
Type 1	30	22	15	9
Type 2	27	20	13	8
Type 3	24	18	12	7
Type 4	19	15	10	6

FIG. 2—*Parameter A.*

RSR



Parameter B
Rock structure rating
Joint pattern and direction of drive

Maximum value 45

	Strike perpendicular to axis					Strike parallel to axis		
	Direction of drive					Direction of drive		
	Both	With dip		Against dip		Both		
	Dip of prominent joints					Dip of prominent joints		
	Flat	Dipping	Vertical	Dipping	Vertical	Flat	Dipping	Vertical
(1) Very closely jointed	9	11	13	10	12	9	9	7
(2) Closely jointed	13	16	19	15	17	14	14	11
(3) Moderately jointed	23	24	28	19	22	23	23	19
(4) Moderate to blocky	30	32	36	25	28	30	28	24
(5) Blocky to massive	36	38	40	33	35	36	34	28
(6) Massive	40	43	45	37	40	40	38	34

Flat: 0-20°; Dipping: 20-50°; Vertical: 50-90°

FIG. 3—*Parameter B.*

Parameter C
Rock structure rating
Ground water and joint condition

Maximum value 25

Anticipated water inflow m3/min/300m (gpm/1,000 ft)	Sum of parameters A + B					
	13-44			45-75		
	Joint condition					
	Good	Fair	Poor	Good	Fair	Poor
None	22	18	12	25	22	18
Slight <0.75 m3/min (<200 gpm)	19	15	9	23	19	14
Moderate 0.75-3.8 m3/min (200-1,000 gpm)	15	11	7	21	16	12
Heavy >3.8 m3/min (>1,000 gpm)	10	8	6	18	14	10

Joint condition: Good = Tight or cemented; Fair = Slightly weathered or altered; Poor = Severely weathered, altered or open

FIG. 4—*Parameter C.*

Q (NGI)

Ratings for the six Q-system parameters

1. Rock Quality Designation		RQD
A	Very poor	0 - 25
B	Poor	25 - 50
C	Fair	50 - 75
D	Good	75 - 90
E	Excellent	90 - 100

Note: i) Where RQD is reported or measured as ≤ 10 (including 0), a nominal value of 10 is used to evaluate Q.
ii) RQD intervals of 5, *i.e.*, 100, 95, 90, *etc.*, are sufficiently accurate.

2. Joint Set Number		J_n
A	Massive, no or few joints	0.5 - 1.0
B	One joint set	2
C	One joint set plus random joints	3
D	Two joint sets	4
E	Two joint sets plus random joints	6
F	Three joint sets	9
G	Three joint sets plus random joints	12
H	Four or more joint sets, random, heavily jointed, "sugar cube", *etc.*	15
J	Crushed rock, earthlike	20

Note: i) For intersections, use $(3.0 \times J_n)$
ii) For portals, use $2.0 \times J_n$)

3. Joint Roughness Number		J_r
a) Rock-wall contact, and b) rock-wall contact before 10 cm shear		
A	Discontinuous joints	4
B	Rough or irregular, undulating	3
C	Smooth, undulating	2
D	Slickensided, undulating	1.5
E	Rough or irregular, planar	1.5
F	Smooth, planar	1.0
G	Slickensided, planar	0.5
Note: i) Descriptions refer to small scale features and intermediate scale features, in that order.		
c) No rock-wall contact when sheared		
H	Zone containing clay minerals thick enough to prevent rock-wall contact	1.0
J	Sandy, gravelly or crushed zone thick enough to prevent rock-wall contact	1.0

Note: i) Add 1.0 if the mean spacing of the relevant joint set is greater than 3m.
ii) J_r = 0.5 can be used for planar slickensided joints having lineations, provided the lineations are oriented for minimum strength.

4. Joint Alteration Number		ϕ_r approx.	J_a
a) Rock-wall contact (no mineral fillings, only coatings)			
A	Tightly healed, hard, non-softening, impermeable filling, *i.e.*, quartz or epidote		0.75
B	Unaltered joint walls, surface staining only	25-35°	1.0
C	Slightly altered joint walls. Non-softening mineral coatings, sandy particles, clay-free disintegrated rock, *etc.*	25-30°	2.0
D	Silty- or sandy-clay coatings, small clay fraction (non-softening)	20-25°	3.0
E	Softening or low friction clay mineral coatings, *i.e.*, kaolinite or mica. Also chlorite, talc, gypsum, graphite, *etc.*, and small quantities of swelling clays.	8-16°	4.0
b) Rock-wall contact before 10 cm shear (thin mineral fillings)			
F	Sandy particles, clay-free disintegrated rock, *etc.*	25-30°	4.0
G	Strongly over-consolidated non-softening clay mineral fillings (continuous, but <5mm thickness)	16-24°	6.0
H	Medium or low over-consolidation, softening, clay mineral fillings (continuous, but <5mm thickness)	12-16°	8.0
J	Swelling-clay fillings, *i.e.*, montmorillonite (continuous, but <5mm thickness). Value of J_a depends on percent of swelling clay-size particles, and access to water, *etc.*	6-12°	8-12
c) No rock-wall contact when sheared (thick mineral fillings)			
KLM	Zones or bands of disintegrated or crushed rock and clay (see G, H, J for description of clay condition)	6-24°	6, 8, or 8-12
N	Zones or bands of silty- or sandy-clay, small clay fraction (non-softening)	-	5.0
OPR	Thick, continuous zones or bands of clay (see G, H, J for description of clay condition)	6-24°	10, 13, or 13-20

5. Joint Water Reduction Factor		approx water pres. (kg/cm²)	J_w
A	Dry excavations or minor inflow, *i.e.*, <5 l/min locally	<1	1.0
B	Medium inflow or pressure, occasional outwash of joint fillings	1-2.5	0.66
C	Large inflow or high pressure in competent rock with unfilled joints	2.5-10	0.5
D	Large inflow or high pressure, considerable outwash of joint fillings	2.5-10	0.33
E	Exceptionally high inflow or water pressure at blasting, decaying with time	>10	0.2-0.1
F	Exceptionally high inflow or water pressure continuing without noticeable decay	>10	0.1-0.05

Note: i) Factors C to F are crude estimates. Increase J_w if drainage measures are installed.
ii) Special problems caused by ice formation are not considered.

6. Stress Reduction Factor		SRF
a) Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated		
A	Multiple occurrences of weakness zones containing *clay* or chemically disintegrated rock, very loose surrounding rock (any depth)	10
B	Single weakness zones containing *clay* or chemically disintegrated rock (depth of excavation ≤ 50m)	5
C	Single weakness zones containing *clay* or chemically disintegrated rock (depth of excavation > 50m)	2.5
D	Multiple shear zones in competent rock (*clay-free*), loose surrounding rock (any depth)	7.5
E	Single shear zones in competent rock (*clay-free*) (depth of excavation ≤ 50m)	5.0
F	Single shear zones in competent rock (*clay-free*) (depth of excavation > 50m)	2.5
G	Loose, open joints, heavily jointed or "sugar cube", *etc.* (any depth)	5.0

Note: i) Reduce these values of SRF by 25-50% if the relevant shear zones only influence but do not intersect the excavation.

b) Competent rock, rock stress problems		σ_c/σ_1	σ_θ/σ_c	SRF
H	Low stress, near surface, open joints	>200	<0.01	2.5
J	Medium stress, favourable stress condition	200-10	0.01-0.3	1
K	High stress, very tight structure. Usually favourable to stability, may be unfavourable for wall stability.	10-5	0.3-0.4	0.5-2
L	Moderate slabbing after > 1 hour in *massive* rock	5-3	0.5-0.65	5-50
M	Slabbing and rock burst after a few minutes in *massive* rock	3-2	0.65-1	50-200
N	Heavy rock burst (strain-burst) and immediate dynamic deformations in *massive* rock	<2	>1	200-400

Note: ii) For strongly anisotropic virgin stress field (if measured): when $5 \le \sigma_1/\sigma_3 \le 10$, reduce σ_c to $0.75\sigma_c$. When $\sigma_1/\sigma_3 > 10$, reduce σ_c to $0.5\sigma_c$, where σ_c = unconfined compression strength, σ_1 and σ_3 are the major and minor principal stresses, and σ_θ = maximum tangential stress (estimated from elastic theory).
iii) Few case records available where depth of crown below surface is less than span width. Suggest SRF increase from 2.5 to 5 for such cases (see H).

c) Squeezing rock: plastic flow of incompetent rock under the influence of high rock pressure		σ_θ/σ_c	SRF
O	Mild squeezing rock pressure	1-5	5-10
P	Heavy squeezing rock pressure	>5	10-20

Note: iv) Cases of squeezing rock may occur for depth $H > 350\ Q^{1/3}$ (Singh *et al.*, 1992). Rock mass compression strength can be estimated from $q \approx 0.7\ \gamma\ Q^{1/3}$(MPa) where γ = rock density in kN/m³ (Singh, 1993).

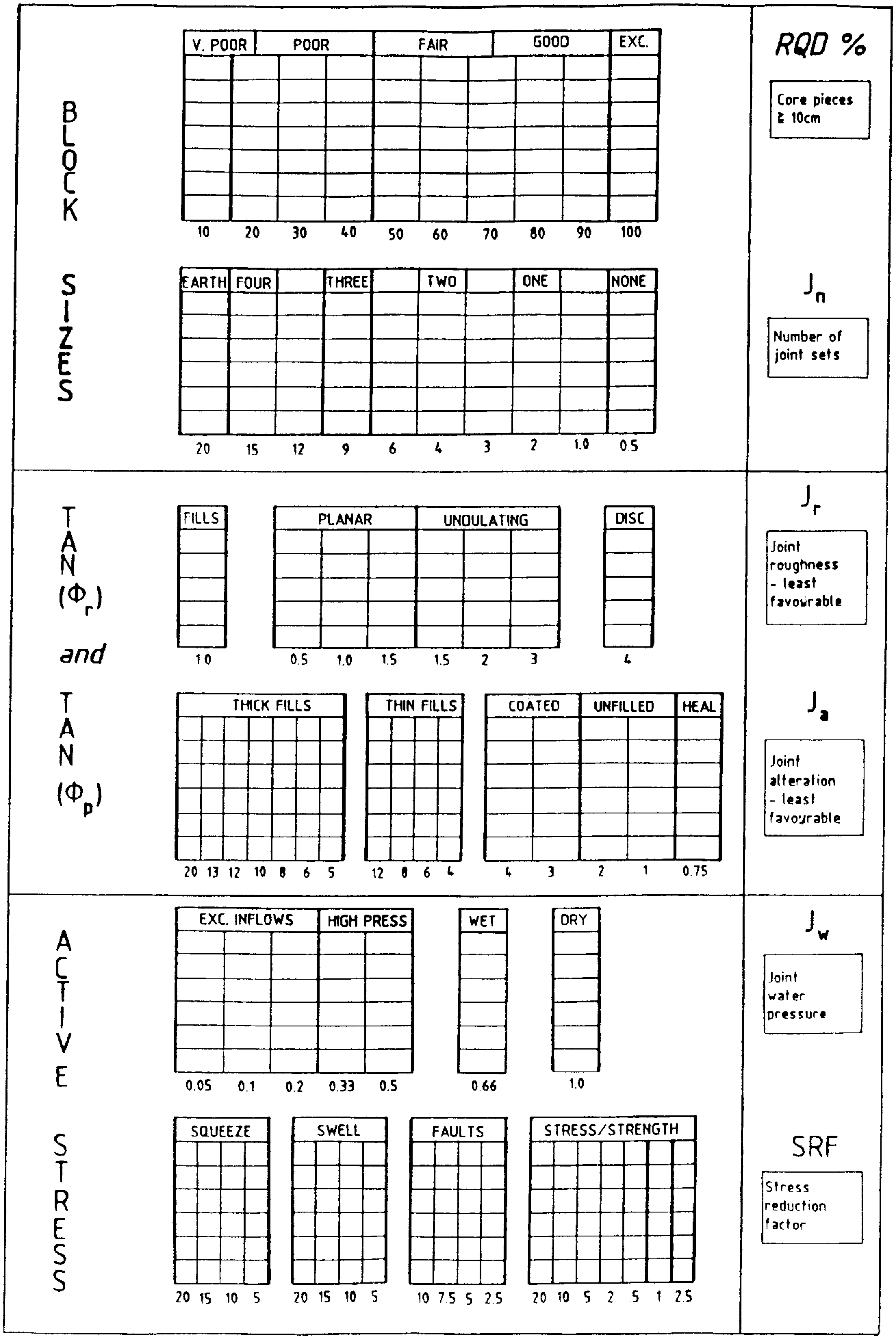
d) Swelling rock: chemical swelling activity depending on presence of water		
R	Mild swelling rock pressure	5-10
S	Heavy swelling rock pressure	10-15

Note: J_r and J_a classification is applied to the joint set or discontinuity that is least favourable for stability both from the point of view of orientation and shear resistance, τ (where $\tau \approx \sigma_n \tan^{-1}(J_r/J_a)$). Choose the most likely feature to allow failure to initiate.

$$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SRF}$$

Q (NGI)

Logging chart for assembling Q-parameter statistics



URCS

DEGREE OF WEATHERING

<table>
<tr><th colspan="2" rowspan="2">REPRESENTATIVE</th><th rowspan="2">ALTERED</th><th colspan="4">WEATHERED</th></tr>
<tr><th colspan="2">>GRAVEL SIZE</th><th colspan="2"><SAND SIZE</th></tr>
<tr><td>Micro Fresh State (MFS)
A</td><td>Visually Fresh State (VFS)
B</td><td>Stained State (STS)
C</td><td colspan="2">Partly Decomposed State (PDS)
D</td><td colspan="2">Completely Decomposed State (CDS)
E</td></tr>
<tr><td colspan="2">UNIT WEIGHT RELATIVE ABSORPTION</td><td>COMPARE TO FRESH STATE</td><td>NON-PLASTIC</td><td>PLASTIC</td><td>NON-PLASTIC</td><td>PLASTIC</td></tr>
</table>

ESTIMATED STRENGTH

REACTION TO IMPACT OF 1 LB. BALLPEEN HAMMER				REMOLDING[1]
"Rebounds" (Elastic) (RQ) A	"Pits" (Tensional) (PQ) B	"Dents" (Compression) (DQ) C	"Craters" (Shears) (CQ) D	Moldable (Friable) (MQ) E
>15000 psi[2] >103 MPa	8000-15000 psi[2] 55-103 MPa	3000-8000 psi[2] 21-55 MPa	1000-3000 psi[2] 7-21 MPa	<1000 psi[2] <7 MPa

(1) Strength Estimated by Soil Mechanics Techniques
(2) Approximate Unconfined Compressive Strength

DISCONTINUITIES

VERY LOW PERMEABILITY			MAY TRANSMIT WATER	
Solid (Random Breakage) (SRB) A	Solid (Preferred Breakage) (SPB) B	Solid (Latent Planes Of Separation) (LPS) C	Nonintersecting Open Planes (2-D) D	Intersecting Open Planes (3-D) E
			ATTITUDE	INTERLOCK

UNIT WEIGHT

Greater Than 160 pcf 2.55 g/cc A	150-160 pcf 2.40-2.55 g/cc B	140-150 pcf 2.25-240 g/cc C	130-140 pcf 2.10-2.25 g/cc D	Less Than 130 pcf 2.10 g/cc E

DESIGN NOTATION

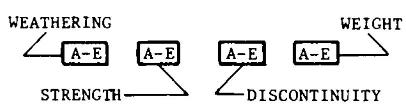
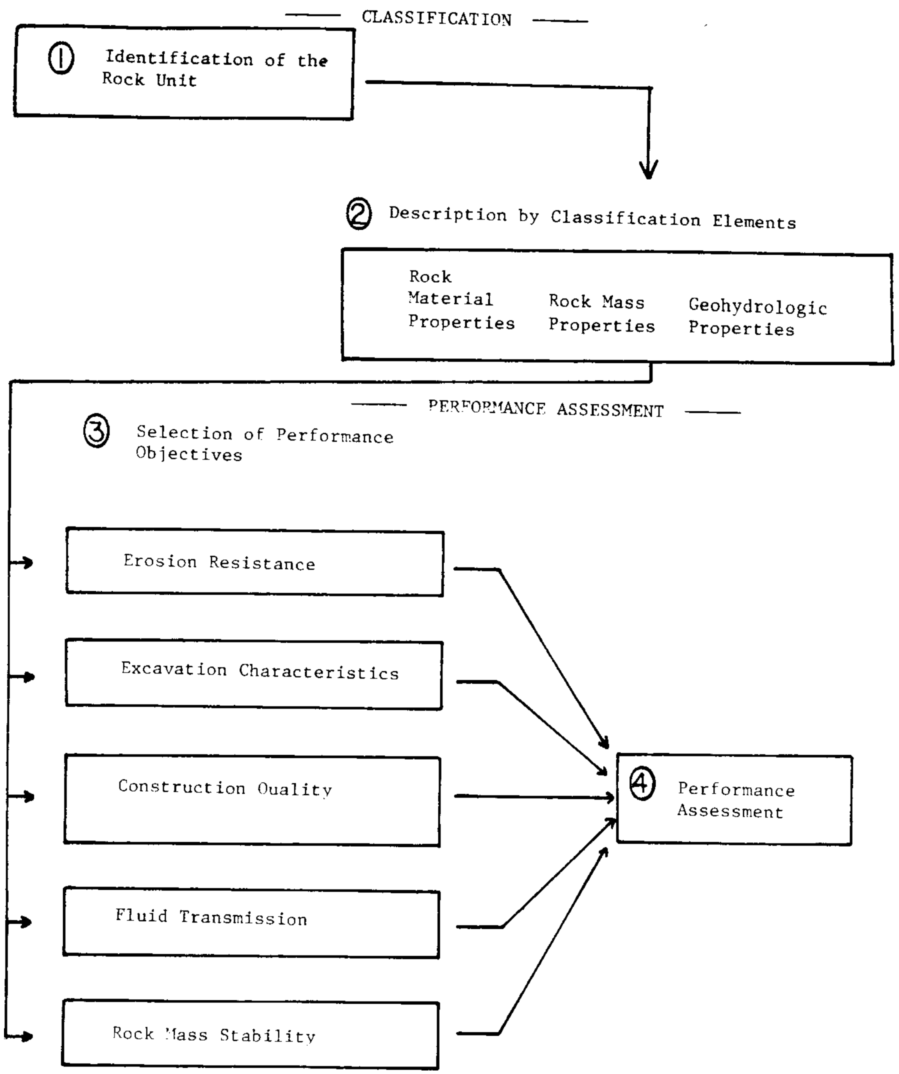


Figure 1. Basic elements of the unified rock classification system.

RMFCP

The following diagram illustrates the procedure:



CLASSIFICATION

ROCK UNIT. A rock unit is an identifiable rock that is consistent in mineral, structural, and hydraulic characteristics. A rock unit can be considered essentially homogeneous for project analysis and for descriptive and mapping purposes. The degree of homogeneity of the rock units at the site of investigation is indicated by assignment of an "outcrop confidence level".

Rock units are delineated by observable and measurable physical features. When a rock unit has been established it can be defined by classification elements and analyzed for performance in relation to selected performance objectives.

CLASSIFICATION ELEMENTS. Classification elements are objective physical properties of the rock unit that define the characteristics of the material. Engineering classification of a rock unit reflects not only the material properties of the rock itself but the structural characteristics of the rock mass in the field, and the interactions between the rock and its system of discontinuities.

(1) Rock Material Properties: The lithologic properties of the rock that can be evaluated in hand specimen (and in many instances, in outcrop) and thus can be subject to meaningful inquiry in the laboratory. They include characteristics such as mineralogic composition, grain size, rock hardness, degree of weathering, unconfined compressive strength, porosity, unit weight, and other index properties.

(2) Rock Mass Properties: The lithologic properties of the rock that must be evaluated on a macroscopic scale in the field. They include description of tectonic features that are too large to be observed directly in their entirety, such as regional structure, karst features, and lineaments. Rock mass properties include features that cannot be sampled for laboratory analysis, such as fractures, joints, and faults, bedding, schistosity, lineations, as well as the lateral and vertical extent of the rock unit.

(3) Geohydrologic Properties: The lithologic properties of the rock that affect the mode of occurrence, location, distribution and flow characteristics of subsurface waters; these properties may include primary and secondary porosity, hydraulic conductivity, transmissivity, and other fluid transmission characteristics.

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ROCK CLASSIFICATION PROCESS

The rock classification process involves identifying the rock units at the site of investigation and describing appropriate classification elements. The following outline can be used as a guide in the process. Primary and secondary levels of description are indicated. Additional levels or factors may be added as required for further clarification. Appropriate appendixes are referred to. See Appendix IV for an example of a completed outline.

ROCK UNIT CLASSIFICATION

Project: ______________
Date: ______________
Geologist: ______________

1. ROCK UNIT IDENTIFICATION.

The description of each rock unit should include the location and extent of the unit in outcrop or in stratigraphic section which, in turn, should provide an indication of outcrop confidence level. The rock unit can be identified either by name or alpha-numeric designation.

(a) Designation: (Vishnu schist, Rock Unit L-6, etc.)
(b) Location: (geographic, station, depth, etc.)
(c) Outcrop Confidence Level:

2. CLASSIFICATION ELEMENTS.

(a) Rock Material Properties: To be determined by examination and classification of hand specimens, core sections, drill cuttings, outcroppings, and disturbed samples, using standard geological terminology. Typical elements may include:

Rock formation name: (primary, secondary). See Appendix III
Mineralogy: (principal and accessory minerals, estimate percent; type of cement; note presence of alterable minerals)
Texture and fabric:
Primary porosity: (free-draining or not)
Discrete rock particle size: (See: Definitions)
Rock hardness: (See NEH-8, p. 1-13)
Micro structures: (bedding, foliation, etc.)
Degree of weathering (URCS): See Appendix I
Estimated strength (URCS): See Appendix I
Unit weight (URCS): See Appendix I

c (b) Rock Mass Properties: To be determined by geologic mapping, geophysical survey, remote imagery interpretation, core sample analysis, and geomorphic evaluation. Typical elements may include:

Discontinuities (URCS): See Appendix I
Strike and dip of formation: (show where measured)
Joint analysis: (spacing, orientation, separation, description of wall rock: wavy, rough, smooth, or slickensided)
Joint tightness: (open, cemented, filled, cavernous)
Other structures: (folds, faults, unconformities, rock unit contacts, random fractures, etc.)
Geomorphic features: (karst topography, lava flows, lineaments, etc.)
Voids: (caverns, vugs, sinkholes, lava tubes, etc.: include shape, orientation, type of filling)
Rock quality designation (RQD):
Seismic velocity:
Unified Rock Class: See Appendix I

(c) Geohydrologic Properties: To be determined by pressure testing; water wells, observation wells, drill holes, and/or piezometer data; review of published maps and reports; interpretation of rock material and rock mass properties; dye tests. Typical elements may include:

Primary porosity: (see: Rock Material Properties)
Secondary porosity: (see: Rock Material Properties)
Hydraulic conductivity: See Appendix II
Transmissivity: See Appendix II
Storativity/specific yield:
Soluble rock: (occurrence of limestone, gypsum, or dolomite; also see: Rock Material Properties)
Water table/potentiometric surface: (contour map, dated)
Aquifer type: (confined or unconfined)

RMFCP

PERFORMANCE ASSESSMENT

PERFORMANCE OBJECTIVES. Performance objectives are selected operational elements or conditions that require an assessment of rock material performance. Five performance objectives are considered.

1. **Erosion Resistance:** Evaluation of the rock to resist erosion in spillways, channels, or other areas where rock material must withstand the stress of flowing water.

2. **Excavation Characteristics:** Evaluation of rock excavation characteristics, including the type of procedure required (rock, common, etc.) and the fragmentation characteristics and blasting response anticipated.

3. **Construction Quality:** Analysis of rock quality for riprap, aggregate, embankment fill, foundation, and other construction requirements.

4. **Fluid Transmission:** Evaluation of rock unit potential for fluid transmission through primary and secondary pores; for investigations concerning reservoir, canal, and dam foundation seepage losses, excavation dewatering, engineering subdrainage for slope stability, point and non-point source pollution, ground water yield for development (water wells, springs, aquifers, and basins), ground water recharge or disposal, and other ground water conditions of concern.

5. **Rock Mass Stability:** Evaluation of rock mass stability in relation to natural and constructed slopes, adequacy as a foundation material, seismic effects, and other construction requirements.

The performance assessment of rock material is developed through the following process:

1. Classification of the rock unit in terms of the CLASSIFICATION ELEMENTS.

2. Selection of appropriate PERFORMANCE OBJECTIVES based upon project requirements or structure conditions.

3. Identification of the levels of rock capability and limitations using the Performance Assessment Tables 1-5.

4. Further description or amplification of the rock capabilities and limitations as required to provide specific performance assessments in support of planning, design, and construction of project elements.

NATM

Table 1 Rock Mass Types.

Type	Main Rock Mass Types
A Stable to Overbreaking	Stresses acting on rock mass do not cause major failures
B Friable	Disintegration due to structural weakness and/or lack of interlocking
C Squeezing	Strength of rock mass is exceeded to great depth; this type also includes rock bursts and swelling rock

Type	Rock mass behaviour	Demands on excavation and support for conventional tunnel driving
Rock Mass Types in Detail		
A 1 Stable	Minor deformations that decline rapidly, no spalling	No support required, unlimited round length
A 2 Overbreaking	Minor deformations that decline rapidly; some spalling at the crown due to discontinuities	Support required in places; round length governed by overbreak
B 1 Friable	Minor deformations that decline rapidly; structural weakness and blasting operations lead to loosening and the separation of blocks in the crown and upper wall	Small quantities of systematic support; reduced round length governed by stand-up length; possible support ahead of face
B 2 Very Friable	Deformations decline rapidly; poor structural strength, little interlocking, high mobility of rock mass and blasting operations lead to rapid and deep loosening where unsupported	Systematic support except in invert; support of face; subdivision of cross section; systematic support ahead of face (forepoling); round length is dependent on reduced stand-up time and stand-up length
B 3 Rolling	Excavation even in small cross sections leads to inflow of rock material; lack of cohesion and interlocking are responsible for insufficient stability	Support ahead of face (forepoling) and improvement of rock mass quality are required to allow advance in small cross sections; systematic support of all excavation surfaces
C 1 Rock Bursting	Sudden release of energy leads to explosive rock failure	Closely spaced short rock bolts; stress relief by drilling and relief blasting
C 2 Squeezing	Pronounced deformations that take long to decline; development of failure zones and plastic zones in plastic, cohesive rock mass	Systematic support around the cross section; tunnel face is generally stable
C 3 Heavily Squeezing	Large deformations, rapid at the beginning, taking long to decline; development of deep reaching failure zones and plastic zones	Extensive support of all excavated surfaces; deformable support is generally necessary, round length is governed by the degree of stability of the face and deformation speed
C 4 Flowing	Very low cohesion, low friction, soft and plastic consistency of rock mass; material will flow into the tunnel even through very small unsupported areas	Improvement of rock mass by advance support or special methods is necessary to allow excavation in small sections
C 5 Swelling	Rock mass with mineral content that increases in volume by absorbing water, e.g. swelling clay-minerals, salts, anhydrite	Provision of supports capable of resisting the swelling pressure or of reserve space to allow volume increase due to swelling

NATM

CALCULATION OF SUPPORT FACTOR (SF)

SF = [Σ(SQxRF)]/AR

Where
SQ=support quantities (from SQ/m)
RF=rating factors (Table 3)
AR=rating area= CxW/4 in which
C=circumference of excavated section without invert
W=maximum width of the cross-section

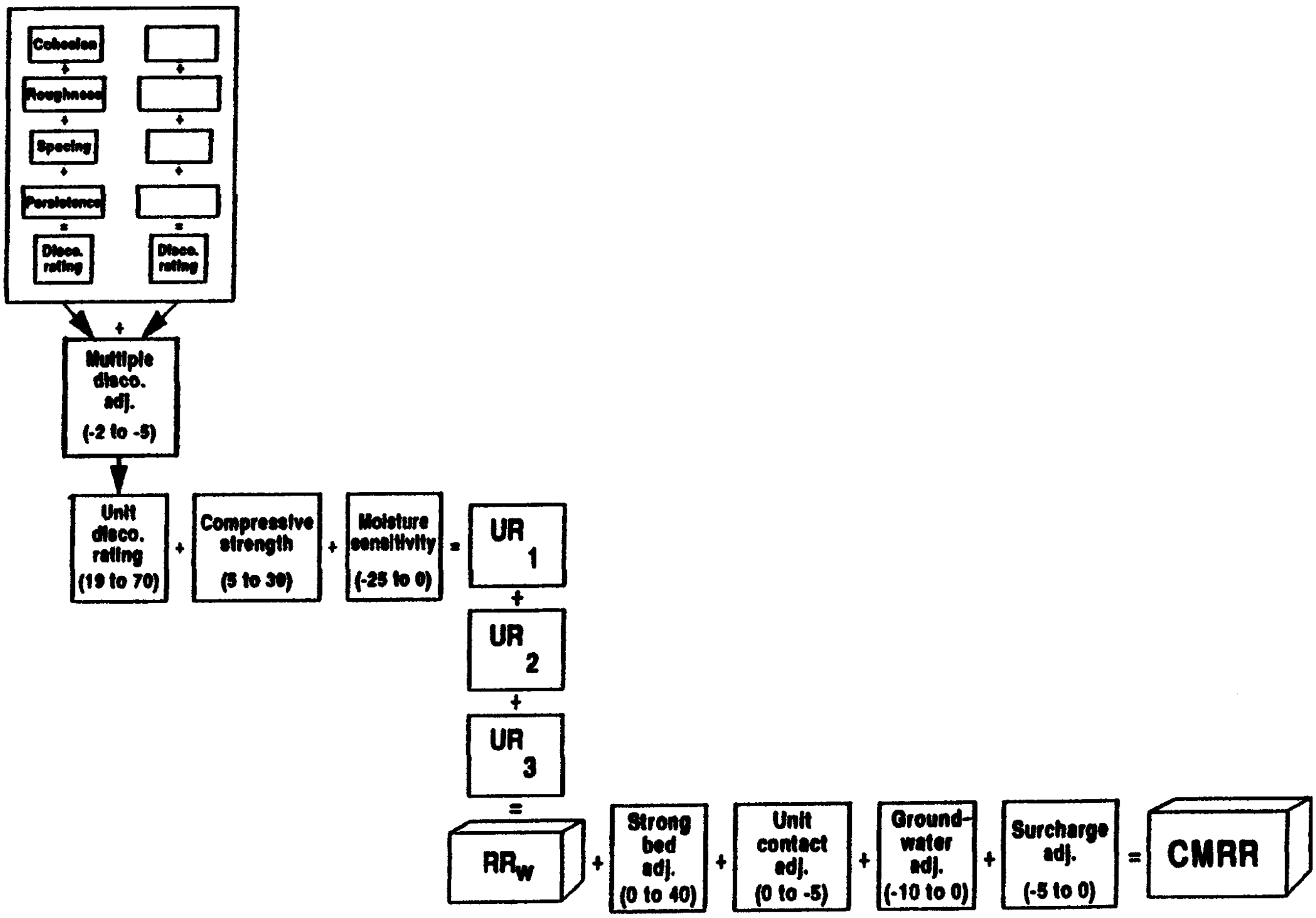
Table 3 Support Elements and Rating Factors.

Support element			Rating factor
Rock Bolts	Swellex and expansion bolts	m	1
	SN mortar bolts	m	1.5
	Selfdrilling bolts	m	2.0
	Grouted bolts	m	2.5
	Prestressed-mortar bolts	m	3.0
Wire Mesh	First layer	m^2	1.0
	Second layer	m^2	1.5
	Invert	m^2	0.5
Steel arch and load distribution beam		m	2.0
Shotorete (theoretical quantity)		m^3	15.0
Deformation slots		m	4.0
Spiles (forepoling)	Not mortar embedded spiles	m	0.7
	Mortar embedded spiles	m	1.0
	Selfdrilling spiles	m	1.5
	Grouted spiles	m	2.0
	Grouting spiles	m	3.0
Liner plates	Lagging	m^2	2.5
	Forepoling	m^2	4.0

Table 2 Excavation Class Matrix for Cyclical Tunnelling.

		2	3	4	5	6	7	8	9	
Maximum Round length		Support Factor								
		1.0	2.0	3.0	4.5	6.8	10.0	15.0	23.0	
1	no limit									
2	4.00 m									
3	3.00 m									
4	2.20 m									
5	1.70 m									
6	1.30 m									
7	1.00 m									
8	0.80 m									
9	0.60 m									
10	0.48 m									

CMRR



–CMRR calculation.

CMRR

IMMERSION TEST

Mine ________________ *Date* ________________

Unit No. ________________ *Tester* ________________

Sample Description (lithology, bedding, etc.)

Immersion		Breakability	
Observation	**Rating**	**Observation**	**Rating**
Appearance of Water Clear = 0 Misty = -2 Cloudy = -5	____	No Change = 0 Small Change = -3 Large Change = -10	
		Total	____
Talus Formation None = 0 Minor = -2 Major = -5	____		
Cracking of Sample None = 0 Minor-Random = -2 Major-Preferred Orientation = -5 Specimen Breakdown = -15	____		
Total	____		

IMMERSION TEST

Procedure for Immersion Test

1. Select sample(s) ≈ hand-sized.
2. Test for hand breakability.
3. Rinse specimen (to remove surface dirt, dust, etc.).
4. Immerse in water for 24 h.
5. Observe and rate water appearance, talus formation, and cracking of sample.

    Sum Rating for Immersion Test Index.

6. Retest for hand breakability.

    Determine Breakability Index.

7. Use the larger negative value of the Immersion Test Index or the Breakability Index as the Weatherability Rating.

Immersion test data sheet.

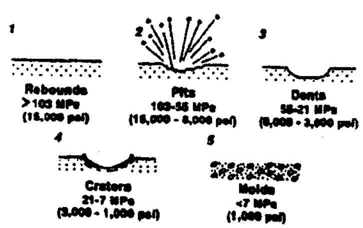
CMRR

DATE______ MINE______________ LOCATION____________________ PAGE______ OF_______ CMRR______

TYPE OF EXPOSURE________________________ NAME________________________

UNIT

Unit No.	Unit Thickness	Strip Log	Description	Strength	Moisture Sensitivity
3					
	CONTACT				
2					
	CONTACT				
1					
			1	Rebounds	Not Sensitive
			2	Pits	Slightly Sensitive
			3	Dents	Moderately Sensitive
			4	Craters	Severely Sensitive
			5	Molds	



Groundwater (inflow/10 m (33 ft) of entry length) (Circle)

L/min (gal/min)

Dry 0	1	Heavy Drip 10-50 (2.7-12.2)	4
Damp 0-5 (0-1.3)	2	Flowing >50 (13.2)	5
Light Drip 5-10 (1.3-2.7)	3		

Describe condition in vicinity of fall (circle one)

1. Good
2. Scaly
3. Heavy
4. Failed

UNIT DISCONTINUITIES

Disco. I.D.	Description	Cohesion	Roughness	Spacing	Persistence Lateral/Vert	Orientation Strike	Orientation Dip
A.							
B.							
C.							
A.							
B.							
C.							
A.							
B.							
C.							
	1	Strong (>7)**	Jagged	>1.8 m (6 ft)	0-0.9 m (0-3 ft)	N.	Horiz.
	2	Moderate (4-7)	Wavy	0.6-1.8 m (2-6 ft)	0.9-3 m (3-10 ft)	NE.	Subhoriz.
	3	Weak (1-3)	Planar	20-60 cm (8-24 in)	3-9 m (10-30 ft)	E.	45°
	4	Slickensided (0)		6-20 cm (2.5-8 in)	>9 m (30 ft)	SE.	Subvert.
	5			<6 cm (2.5 in)		S.	Vert.

** Hammer blows necessary to split bedding with 9-cm (3.5-in) chisel.

COMMENTS: (Roof Support, etc.)

CMRR field data sheet.

COAL MINE ROOF RATING (CMRR) FIELD DATA SHEET DIRECTIONS

1. *Apply classification to entire roof exposure (use several sheets if necessary).*
2. *Use criteria below each category to classify that category.*
3. *Begin with a description of each unit and use "strength," "moisture sensitivity," and "persistence" to describe each bed.*
4. *Next, describe each discontinuity (bedding plane, slickenside, inclusion, crossbed, etc.) within the bed by the criteria provided below each column.*
5. *Three rows are provided for up to three discontinuities.*

Unit - Any distinct rock bed >15 cm (>6 in) thick that forms a structural member in the roof.

Discontinuity - Any surface that interrupts the lateral or vertical continuity of a unit or sequence of units (bedding planes, slickensides, shears, joints).

Contact - The interface between roof strata, which may be described as sharp or gradational.

Strength - The compressive strength of the intact rock within a hand sample as indicated by a hammer impact test.

Moisture sensitivity - Immerse sample in water for 24 h to determine its degree of disintegration.

Spacing - Indicate how closely spaced the discontinuities are.

Cohesion - An estimation of the ability of a surface (bedding plane, discontinuity) to resist separation or shear estimated by the number of blows necessary to split the discontinuity with a 9-cm (3.5-in) chisel.

Roughness - Describe the shape of the discontinuity surface as jagged, wavy, or planar.

Orientation - Estimate the orientation of the discontinuity relative to the heading orientation (quadrants). Estimate the dip on the discontinuity.

CMRR field data sheet—Continued.

CMRR

Table 1.—Cohesion-roughness rating

Roughness	(1) Strong cohesion	(2) Moderate cohesion	(3) Weak cohesion	(4) Slickensided
(1) Jagged . .	35	29	24	10
(2) Wavy . . .	35	27	20	10
(3) Planar . . .	35	25	16	10

NOTE.—If unit has no bedding or discontinuities, then apply test to the intact rock. Strong cohesion implies that the discontinuities have no weakening effect on the rock.

Table 2.—Spacing-persistence rating

Persistence, m (ft)	(1) >1.8 m (>6 ft)	(2) 0.6 to 1.8 m (2 to 6 ft)	(3) 20 to 61 cm (8 to 24 in)	(4) 6 to 20 cm (2.5 to 8 in)	(5) <6 cm (<2.5 in)
(1) 0 to 0.9 (0 to 3)	35	30	24	17	9
(2) 0.9 to 3 (3 to 10)	32	27	21	15	9
(3) 3 to 9 (10 to 30)	30	25	20	13	9
(4) >9 (>30)	30	25	20	13	9

NOTE.—If unit has no bedding or discontinuities, then enter 35. If cohesion is strong, then enter 35.

Table 3.—Multiple discontinuity set adjustment

Two lowest individual discontinuity ratings both lower than—	*Adjustment*
30	-5
40	-4
50	-2

Table 4.—Strength rating

Strength, MPa (psi)	*Rating*
(1) >103 (>15,000)	30
(2) 55 to 103 (8,000 to 15,000) . .	22
(3) 21 to 55 (3,000 to 8,000) . . .	15
(4) 7 to 21 (1,000 to 3,000)	10
(5) <7 (<1,000)	5

Table 5.—Moisture sensitivity rating

Moisture sensitivity	*Rating*
(1) Not sensitive	0
(2) Slightly sensitive	-3
(3) Moderately sensitive . . .	-10
(4) Severely sensitive	-25

NOTE.—Use immersion test for better accuracy. Apply adjustment only if the unit is exposed as the immediate roof or flowing groundwater is present and if the anticipated service life of entry is long enough to allow decomposition to occur.

CMRR

UNIT RATING (UR)
CALCULATION SHEET

Mine Name ______________________ *Date* ______________

Location ______________________ *Data Collected by* ________

1) Calculate the Individual Discontinuity Rating *Unit No.* __________

	Discontinuity Set 1	Discontinuity Set 2	Discontinuity Set 3
Cohesion-Roughness (table 1)	☐	☐	☐
	+	+	+
Spacing-Persistence (table 2)	☐	☐	☐
Individual Discontinuity Ratings	☐	☐	☐

2) Enter the lowest of the Individual Discontinuity Ratings ☐

\+

3) If there is more than one Discontinuity set, enter the Multiple Discontinuity Adjustment from table 3. Otherwise, enter 0. ☐

\+

4) Calculate the Unit Strength (table 4) ☐

\+

5) Calculate the Unit Moisture Sensitivity (table 5) (this applies only to Unit 1, or if upper Unit is exposed to water) ☐

☐ *= Unit Rating (UR)*

Unit rating calculation sheet.

CMRR

ROOF RATING (CMRR) CALCULATION SHEET

Mine Name ______________________ *Date* ____________

Location ______________________ *Data Collected by* ____________

1) Calculate the weighted average of the Unit Ratings (RR_w)

	UR		Unit Thickness (m (in))		
1.	☐	×	☐	=	☐
			+		+
2.	☐	×	☐	=	☐
			+		+
3.	☐	×	☐	=	☐
			+		+
4.	☐	×	☐	=	☐
Bolted Interval (BI) (m (in))			☐		☐

☐ / ☐ *(BI)* = ☐ *(RR_w)*

☐ *(RR_w)*

2) Calculate Strong Bed Difference (SBD)

Largest (UR) = ☐ *Strong Bed (SB)*

☐ *(SB) -* ☐ *RR_w =* ☐ *(SBD)*

3) Calculate the Strong Bed Adjustment (table 6) + ☐

4) Calculate the Unit Contact Adjustment (table 7) + ☐

5) Calculate the Groundwater Adjustment (table 8) + ☐

6) Calculate the Surcharge Adjustment (table 9) + ☐

☐ *= CMRR*

Roof rating calculation sheet.

CMRR

Table 6.—Strong bed adjustment

Thickness of strong bed, m (ft)	Strong bed difference							
	5-9	10-14	15-19	20-24	25-29	30-34	35-40	>40
0.3 to 0.6 (1 to 2)	0	2	4	5	7	8	9	10
0.6 to 0.9 (2 to 3)	2	4	7	9	12	14	17	20
0.9 to 1.2 (3 to 4)	3	5	10	14	18	21	25	30
>1.2 (>4)	4	8	13	18	23	28	34	40

NOTE.—The strong bed adjustments should be reduced to account for the weight of the weaker rock suspended from it as follows:

Thickness of weaker rock, m (ft)	*Multiply strong bed adjustment by—*
0-0.9 (0-3)	1.0
0.9-1.8 (3-6)	0.7
>1.8 (>6)	0.3

Table 7.—Unit contacts adjustment

Number of major contacts	*Adjustment*
0	0
1 to 2	-2
3 to 4	-4
>4	-5

NOTE.—Apply only if unit contacts are significant planes of weakness (persistent, low cohesion).

Table 8.—Groundwater adjustment

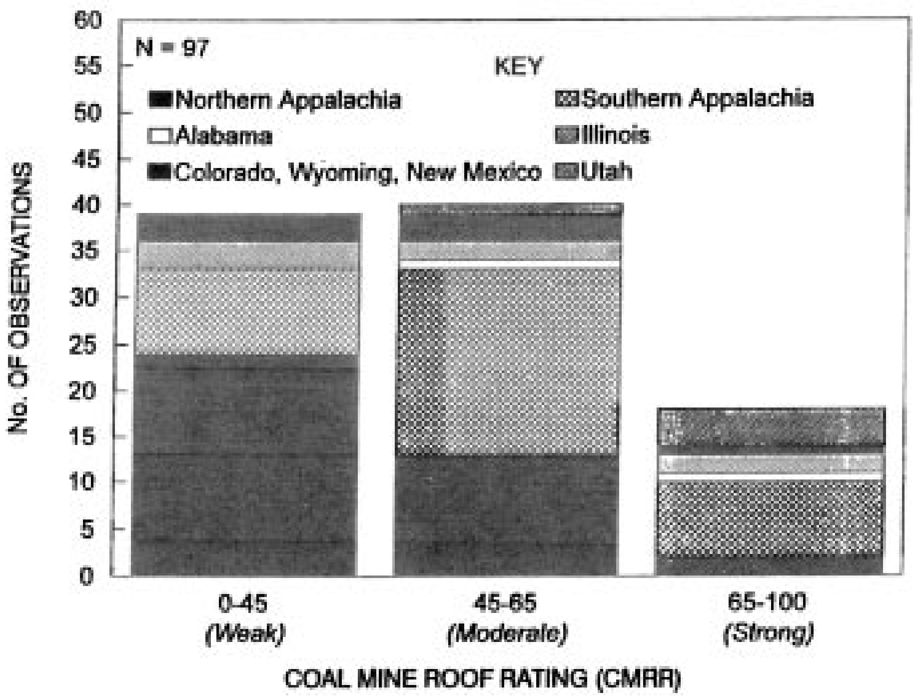
Condition	*Adjustment*
Dry	0
Damp	-2
Light drip	-4
Heavy drip	-7
Flowing	-10

NOTE.—Applies only to groundwater present in roof (not floor or ribs).

Table 9.—Surcharge adjustment

Condition	*Adjustment*
Upper units approximately equal in strength to bolted interval	0
Upper units significantly weaker than bolted interval	-2 to -5

CMRR


N = 97
KEY
Northern Appalachia
Southern Appalachia
Alabama
Illinois
Colorado, Wyoming, New Mexico
Utah
No. OF OBSERVATIONS
60
55
50
45
40
35
30
25
20
15
10
5
0
0-45
(Weak)
45-65
(Moderate)
65-100
(Strong)
COAL MINE ROOF RATING (CMRR)