Designation: D5878 – 08

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

This standard is issued under the fixed designation D5878; 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 These guides offer 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 standard, 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 standard 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 standard must have had field experience in studying rock-mass behavior. An appropriate reference for geological mapping in the underground is provided by Guide D4879.

1.3 This standard 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 standard summarizes the major fields of application up to this time of each of the seven classification systems.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are mathematical conversions to inch-pounds units that are provided for information only and are not considered standard.

1.6 *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.*

1.7 *This standard 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 standard 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:*[3]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D4879 Guide for Geotechnical Mapping of Large Underground Openings in Rock

D6026 Practice for Using Significant Digits in Geotechnical Data

D6032 Test Method for Determining Rock Quality Designation (RQD) of Rock Core

D7012 Test Methods for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures

[1] These guides are under the jurisdiction of ASTM Committee D18 on Soil and Rock and are 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] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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 D653 [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 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 standard, refer to STP 984, Guide D4879, and Terminology D653.

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 standard 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 groundwater.

4.1.5 *The Rock Material Field Classification System (RMFCS)*—This system has been used mainly for applications involving shallow excavation, particularly with regard to hydraulic erodibility in earth spillways, excavatability, construction quality of rock, fluid transmission, and rock-mass stability (**2**).

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 (**3**).

NOTE 2—The Austrian code (**4**) 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 (**5**).

4.1.8 *Japanese Rock Mass Classification Systems*—The Japanese Society of Engineering Geology has recognized seven major classification systems in use in Japan (**6**). 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

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

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 standard, 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.*

NOTE 3—The quality of the results produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing, sampling, inspection, etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself ensure reliable results. Reliable results depend on many factors. Practice D3740 provides a means for evaluating some of these factors.

5. Basis 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 D7012, Method C)
- Rock quality designation (RQD) (see D6032)
- Spacing of discontinuities
- Condition of discontinuities
- Groundwater 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
- Groundwater inflow

5.1.3 *Q-System or Norwegian Geotechnical Institute (NGI) System* Rock quality designation (RQD) (see D6032)
- 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 D7012, Method C)
- Discontinuities
- Unit weight

5.1.5 *Rock Material Field Classification System (RMFCS)*
- Rock Material Properties
  - Principal rock type
  - Mineralogy
  - Primary porosity, voids
  - Discrete rock particle size
  - Hardness
  - Unconfined composite strength (see D7012, Method C)
  - Unit weight
  - Color
- Rock Mass Properties
  - Discontinuity type
  - Joint set spacing
  - Joint persistence
  - Aperture
  - Joint count number
  - Joint wall roughness
  - Joint infilling
  - Type of large geomorphic or structural feature
  - Seismic velocity
  - Rock quality designation (RQD) (see D6032)
- Geohydraulic Properties
  - Primary porosity
  - Secondary porosity
  - Hydraulic conductivity
  - Transmissivity
  - Storativity
  - Water table/potentiometric surface
  - Aquifer type

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 (**7**). Some of the references in the appendix also present procedures for estimating some in situ engineering properties from one or more of these indexes (**7**, **8**, **9**, and **10**).

NOTE 4—Reference (**7**) 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 standard 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 (**7**). The annexed materials are as follows:

6.1.1 *Guide A—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 *Guide B—RSR System*

Schematic of the six parameters

Rock type plus strength, geologic structure (“A”)

Joint spacing and orientation (“B”)

Weathering of joints and groundwater inflow (“C”)

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

6.1.3 *Guide C—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 *Guide D—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 *Guide E—RMFCS*

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

Hydraulic Erodibility in Earth Spillways

Excavation Characteristics

Construction Quality

Fluid Transmission

Rock Mass Stability

6.1.6 *Guide F—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 5—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 (**11**).

6.1.7 *Guide G—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

6.2 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

6.2.1 The method used to specify how data are collected, calculated, or recorded in this standard is not directly related to the accuracy with which the data can be applied in design or other uses, or both. How one applies the results obtained using this standard is beyond its scope.

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 system (RMFCS); 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, and URCS have been extracted from STP 984 (**1**). The materials for Q (NGI) are from Ref (**9**). The materials for NATM are from Ref. (**3**). The materials for CMRR are from Ref. (**5**). The materials for RMFCS are from Ref. (**2**).

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.

Bell, F. G., *Engineering Properties of Soils and Rocks*, Butterworth-Heinemann, Oxford, 1992.

Bieniawski, Z. T., "Engineering Classification of Jointed Rock Masses", *Transactions of the South African Institution of Civil Engineers*, Vol 15, 1973, pp. 335–344.

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Sauer, G. and Gold, H.," NATM Ground Support Concepts and their Effect on Contracting Practices," *Proceedings*, Rapid Excavation and Tunneling Conference, Los Angeles, June 1989, Sect. 2, Chapt. 5, pp. 67–86.

Wickham, G. E., Tiedemann, H. R., and Skinner, E. H., "Ground Support Prediction Model, RSR Concept," in *Proceedings*, Second Rapid Excavation and Tunneling Conference, San Francisco, June 1974, Vol I, pp. 691–707.

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

RMR

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

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

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

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

Ratings	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°

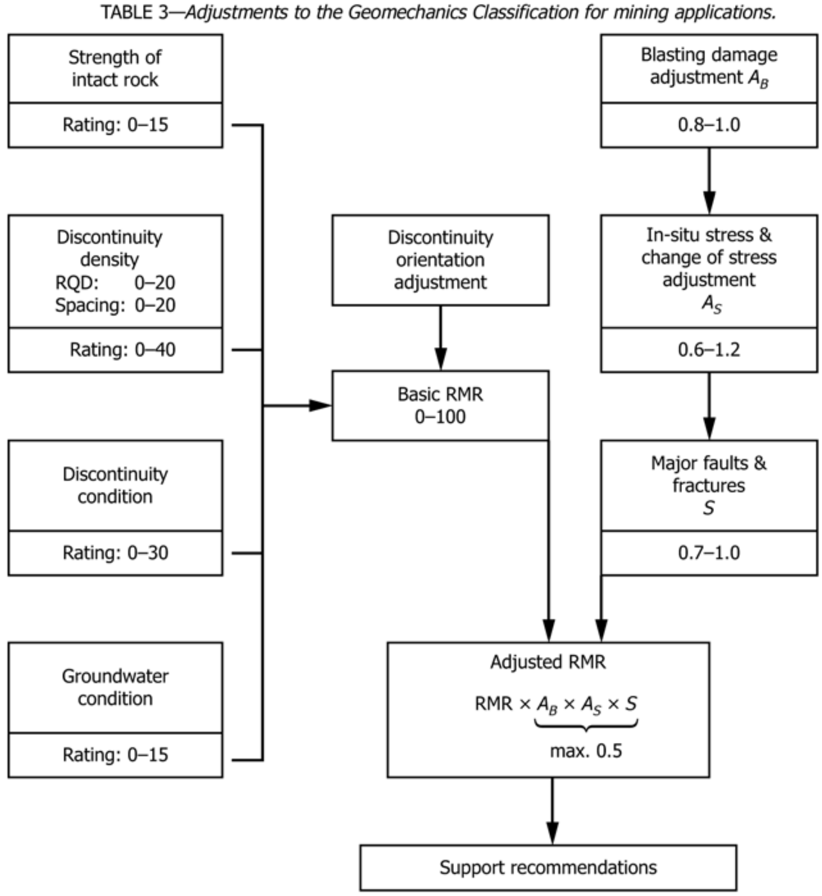
RMR

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

	Strike		Dip	
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

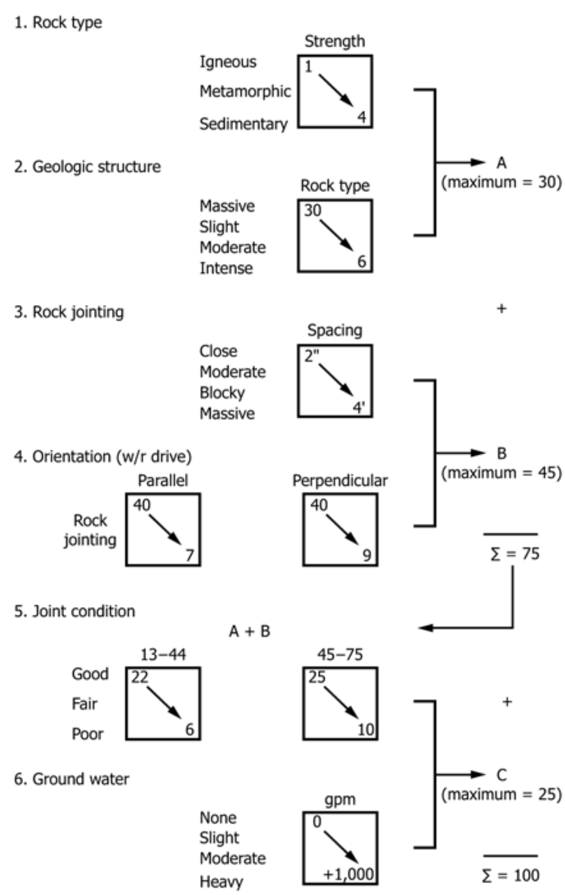


FIG. 1—*Schematic of Rock Structure Rating.*

Parameter A
Rock structure rating

Rock type, strength index and geologic structure

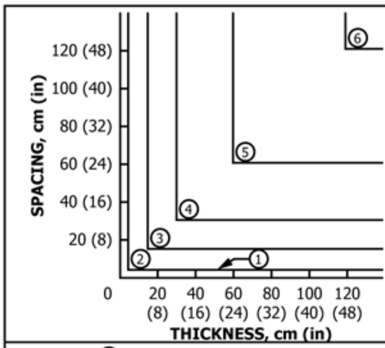
Maximum value 30

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 m^3/min/300 m (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 m^3/min (<200 gpm)	19	15	9	23	19	14
Moderate 0.75 – 3.8 m^3/min (200 – 1,000 gpm)	15	11	7	21	16	12
Heavy >3.8 m^3/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 3 m. 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 <5 mm thickness)	16-24°	6.0
H	Medium or low over-consolidation, softening, clay mineral fillings (continuous, but <5 mm thickness)	12-16°	8.0
J	Swelling-clay fillings, *i.e.*, montmorillonite (continuous, but <5 mm 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.			

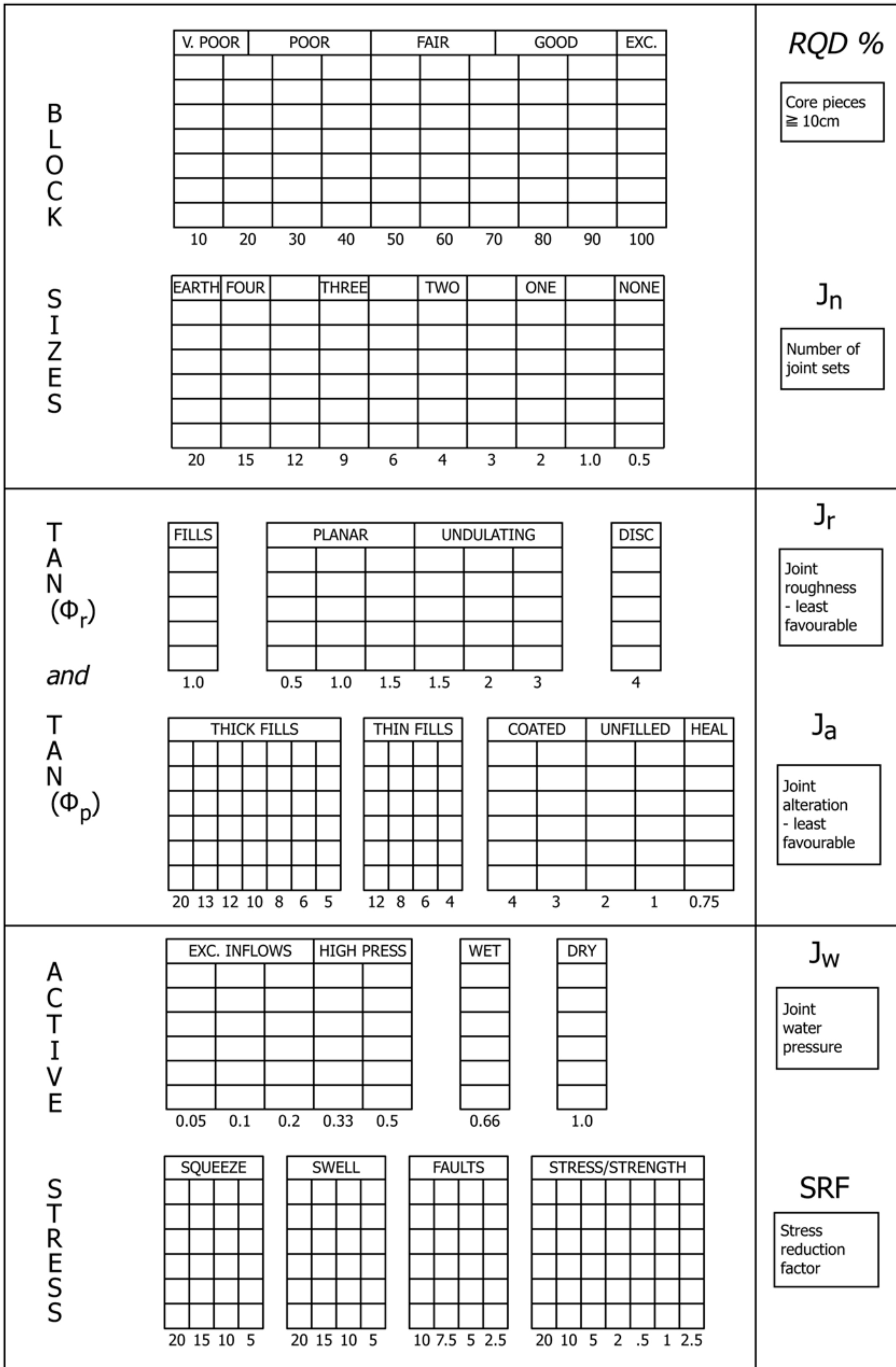
6.	**Stress Reduction Factor**			**SRF**
a) Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated				
A	Multiple occurrences of weakness zones containing *clay* or chemically disintegrated rock, very loose surrounding rock (any depth)			10
B	Single weakness zones containing *clay* or chemically disintegrated rock (depth of excavation ≤ 50 m)			5
C	Single weakness zones containing *clay* or chemically disintegrated rock (depth of excavation > 50 m)			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 ≤ 50 m)			5.0
F	Single shear zones in competent rock (*clay-free*) (depth of excavation > 50 m)			2.5
G	Loose, open joints, heavily jointed or "sugar cube", *etc.* (any depth)			5.0
Note: i) Reduce these value of SRF by 25-50% if the relevant shear zones only influence but did not intersect the excavation.				
b) Competent rock, rock stress problems		σ_c/σ_1	σ_φ/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_φ/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 $\sigma \approx 0.7\ \gamma\ Q^{1/3}$ (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, r (where $r \approx \sigma_n \tan^{-1}(J_r/J_a)$). 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><td colspan="2">REPRESENTATIVE</td><td>ALTERED</td><td colspan="4">WEATHERED</td></tr>
<tr><td colspan="2"></td><td></td><td colspan="2">>GRAVEL SIZE</td><td colspan="2"><SAND SIZE</td></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

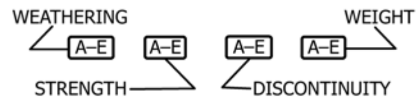


Figure 1. Basic elements of the unified rock classification system.

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Table 1 Hydraulic erodibility in earth spillways

Classification elements	Class I	Class II	Class III
	Highly erosion resistant	**Erosion resistant**	**Moderately erosion resistant**
	Rock material experiences headcut erosion rates less than 0.3 m/hr (1 ft/hr) at a unit discharge of 9.2 $m^3/s/m$ (100 $ft^3/s/ft$) and 9 m (30 ft) of energy head. Must fulfill the following condition:	Rock material experiences headcut erosion rates from 0.3 to 3.0 m/hr (1 to 10 ft/hr) at a unit discharge of 9.2 $m^3/s/m$ (100 $ft^3/s/ft$) and 9 m (30 ft) of energy head. Must fulfill the following condition:	Rock material experiences headcut erosion rates greater than 3.0 m/hr (10 ft/hr) at a unit discharge of 9.2 $m^3/s/m$ (100 $ft^3/s/ft$) and 9 m (30 ft) of energy head. Must fulfill the following condition:
Headcut erodibility index, k_h (NEH 628.52), which comprises: Material strength Block size Discontinuity shear strength Relative ground structure	$k_h \geq 100$	$10 < k_h < 100$	$1 \leq k_h \leq 10$

RMFCS

Table 2 Excavation characteristics

Classification elements	Class I	Class II	Class III
	Very hard ripping to blasting	**Hard ripping**	**Easy ripping**
	Rock material requires drilling and explosives or impact procedures for excavation may classify [1] as rock excavation (NRCS Construction Spec. 21). Must fulfill all conditions below:	Rock material requires ripping techniques for excavation may classify [1] as rock excavation (NRCS Construction Spec. 21). Must fulfill all conditions below:	Rock material can be excavated as common material by earthmoving or ripping equipment may classify [1] as common excavation (NRCS Construction Spec. 21). Must fulfill the all conditions below:
Headcut erodibility index, k_h (NEH 628.52)	$k_h \geq 100$	$10 < k_h < 100$	$k_h \leq 10$
Seismic velocity, approximate (ASTM D 5777 and Caterpillar Handbook of Ripping, 1997)	≥2,450 m/s (≥8,000 ft/s)	2,150-2,450 m/s (7,000-8,000 ft/s)	≤2,150 m/s (≤7,000 ft/s)
Minimum equipment size (flywheel power) required to excavate rock. All machines assumed to be heavy-duty, track-type backhoes or tractors equipped with a single tine, rear-mounted ripper.	260 kW (350 hp), for $k_h < 1,000$ 375 kW (500 hp). for $k_h \leq 10,000$ Blasting, for $k_h > 10,000$	185 kW (250 hp)	110 kW (150 hp)

1/ The classification in no way implies the actual contract payment method to be used or supersedes NRCS contract documents. The classification is for engineering design purposes only.

RMFCS

Table 3 Construction quality

Classification elements	Class I	Class II	Class III
	High grade	**Medium grade**	**Low grade**
	Rock material is suitable for high stress aggregate, filter and drain material, riprap, and other construction applications requiring high durability. Must fulfill all conditions below:	Rock material is potentially suitable for construction applications. May require additional evaluation if at least one condition below is fulfilled:	Rock material is unsuitable for aggregate, filter, and drain material, or riprap. Reacts essentially as a soil material in embankments. Must fulfill at least one condition below:
Strength (NEH 628.52, table 52-4)	> 50 MPa (> 7,250 lb/in^2)	12.5-50 MPa (1,800-7,250 lb/in^2)	< 12.5 MPa (< 1,800 lb/in^2)
Hardness (NEH 628.52, table 52-4)	Hard to extremely hard rock	Moderately hard rock	Moderately soft to very soft rock
Unit weight (NEH 628.52, appendix 52C, table 3)	> 2.24 g/cm^3 (> 140 lb/ft^3)	2.08-2.24 g/cm^3 (130-140 lb/ft^3)	< 2.08 g/cm^3 (< 130 lb/ft^3)

RMFCS

Table 4 Fluid transmission

Classification elements	Class I	Class II	Class III
	Slowly permeable	**Moderately permeable**	**Highly permeable**
	Rock material has low capability to transmit water. Must fulfill all conditions below.	Rock material has potential to transmit water, generally through primary porosity. May require additional evaluation if at least one condition below is fulfilled.	Rock material has high capability to transmit water, generally through secondary porosity. Must fulfill at least one condition below.
Soluble rock	No soluble rock occurs in the rock mass.	Soluble rock, if present, occurs as a minor or secondary constituent in the rock mass	Soluble rock, such as lime stone, gypsum, dolomite, marble, or halite, is the predominant rock type.
Primary porosity	Very low primary porosity: pores not interconnected or free draining	Pores visible under 10× hand lens; slowly free draining	Pores visible to naked eye; rapidly free draining
Number of joint sets (include bedding plane partings)	1 joint set and random fractures; or rock mass intact and massive	≤ 2 joint sets and random fractures	≥ 3 interconnecting joint sets
Joint aperture category (NEH 628.52, appendix 52C, table 14)	Extremely narrow, hairline (<2 mm)	Very narrow to narrow (2.6 mm)	Narrow to wide (≥6 mm)
Infilling (gouge)	Joints tight or filled with cohesive. plastic clay or swelling fines matrix	Joints open or filled with nonplastic, nonswelling fines matrix	Joints open or filled with sand or gravel with < 15% cohesionless, nonplastic fines matrix
Major voids, solutional (caverns, sinkholes, enlarged joints), depositional (lava tubes or interbedded gravels and lava beds) or structural/tectonic (faults, stress relief joints)	No major voids occur in rock mass		Any types of major voids occur in rock mass
Hydraulic conductivity (dams)	$< 10^{-6}$ m/s (< 0.3 ft/d)		$> 10^{-6}$ m/s (> 3 ft/d)
Transmissivity (irrigation wells)	$< 10^{-3}$ m^2/s ($< 10^3$ ft^2/d)		> 1 m^2/s ($> 10^5$ ft^2/d)
Transmissivity (domestic/stock wells)	$< 10^{-6}$ m^2/s (< 1 ft^2/d)		$> 10^{-4}$ m^2/s ($> 10^2$ ft^2/d)

RMFCS

Table 5 Rock mass stability

Classification elements	Class I	Class II	Class III
	Stable	**Potentially unstable**	**Unstable**
	Rock material has very low potential for instability. Must fulfill all conditions below:	Rock material has potential for instability. May require additional evaluation if at least one condition below is fulfilled:	Rock material has significant potential for instability. Must fulfill at least one condition below:
Strength (NEH 628.52. table 52-4)	> 50 MPa (>7,250 lb/in^2)	12.5-50 MPa (1,800-7,250 lb/in^2)	< 12.5 MPa (< 1,800 lb/in^2)
Hardness (NEH 628.52, table 52-4)	Hard to extremely hard rock	Moderately hard rock	Moderately soft to very soft rock
RQD (ASTM D 6032)	> 75	25–75	< 25
Number of joint sets in rock mass (include bedding plane partings)	1 joint set and random fractures, or rock mass intact and massive; no adverse component of dip	≤ 2 joint sets plus random fractures; no set contains adverse component of dip	≥ 3 interconnecting joint sets; and ≥ 1 set contains adverse component of dip
Joint water condition	Unconfined	Unconfined	Confined

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 basis 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 or 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 plastio 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 plastio 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 of 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(SQ×RF)]/AR

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

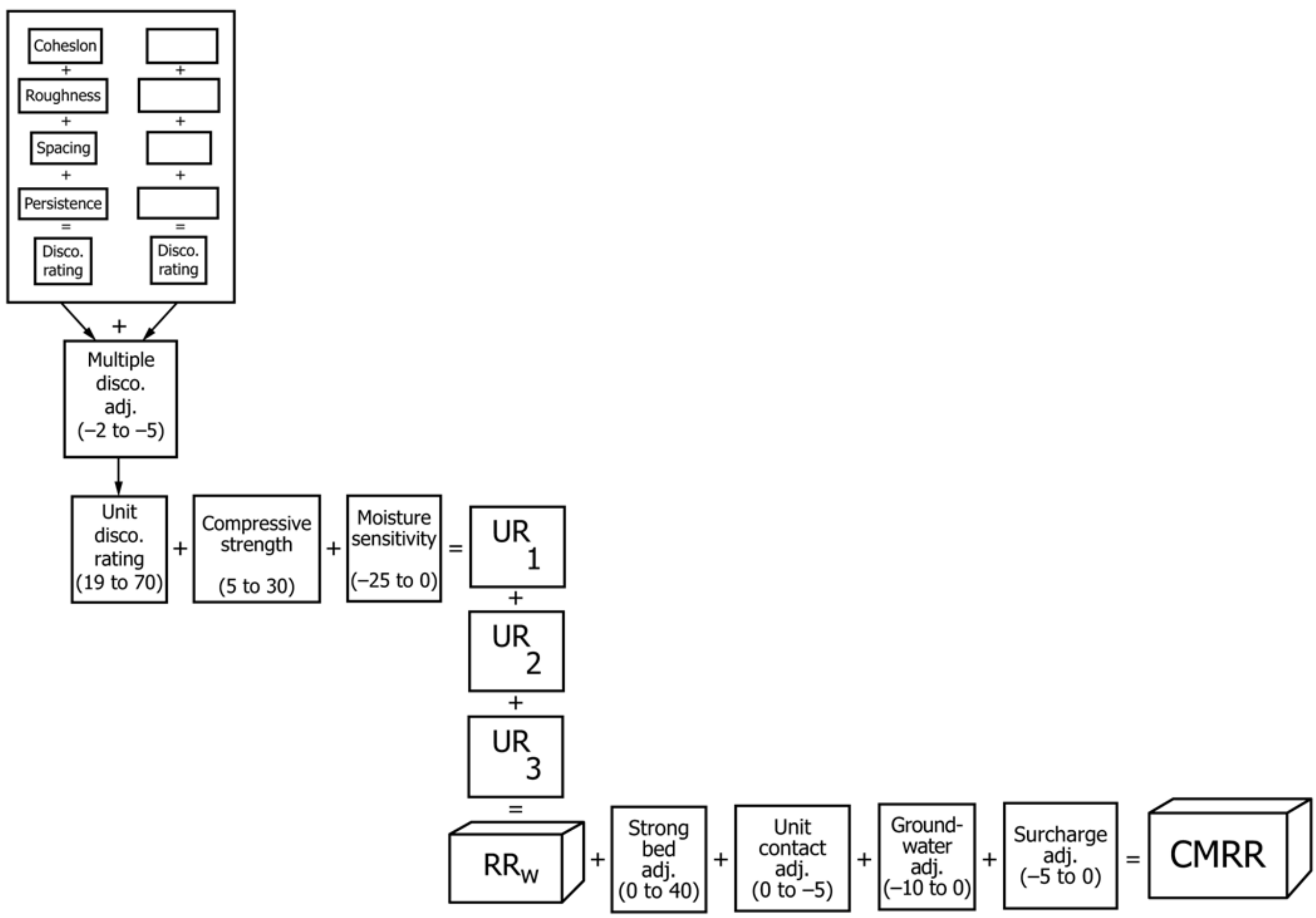
Table 2 Excavation Class Matrix for Cyclicat Tunnelling

		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	0.80 m									
10	0.45 m									

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
Shotarete (theoretial 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

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	_____	*No Change= 0*	
Misty = −2		*Small Change = −3*	
Cloudy = −5		*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.*

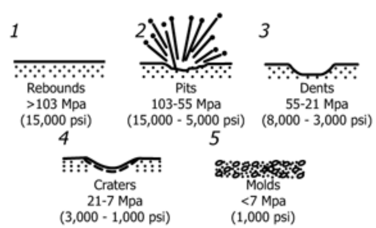
Immersion test data sheet.

CMMR

DATE ________ MINE ____________________ LOCATION ________________________________ PAGE ________ OF ___________ CMRR _______

TYPE OF EXPOSURE ____ NAME ____

UNIT						UNIT DISCONTINUITIES							
Unit No.	Unit Thickness	Strip Log	Description	Strength	Moisture Sensitivity	Disco. I.D.	Description	Cohesion	Rough-ness	Spacing	Persistence Lateral/Vert	Orientation Strike	Dip
3						A.							
						B.							
						C.							
	CONTACT												
2						A.							
						B.							
						C.							
	CONTACT												
1						A.							
						B.							
						C.							
			1	Rebounds	Not Sensitive		1	Strong (>7)**	Jagged	>1.8 m (6 ft)	0-0.9 m (0-3 ft)	N.	Horiz.
			2	Pits	Slightly Sensitive		2	Moderate (4-7)	Wavy	0.6-1.8 m (2-6 ft)	0.9-3 m (3-10 ft)	NE.	Subhoriz.
			3	Dents	Moderately Sensitive		3	Weak (1-3)	Planar	20-60 cm (8-24 in)	3-9 m (10-30 ft)	E.	45°
			4	Craters	Severely Sensitive		4	Slicken-sided (0)		6-20 cm (2.5-8 in)	>9 m (30 ft)	SE.	Subvert.
			5	Molds			5			<6 cm (2.5 in)		S.	Vert.



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 3. Heavy
2. Scaly 4. Failed

COMMENTS: ** Hammer blows necessary to split bedding with 9-cm (3.5-in) chisel. (Roof Support, etc.)

CMMR 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 dlscontinuities 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	*Set 2*	*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

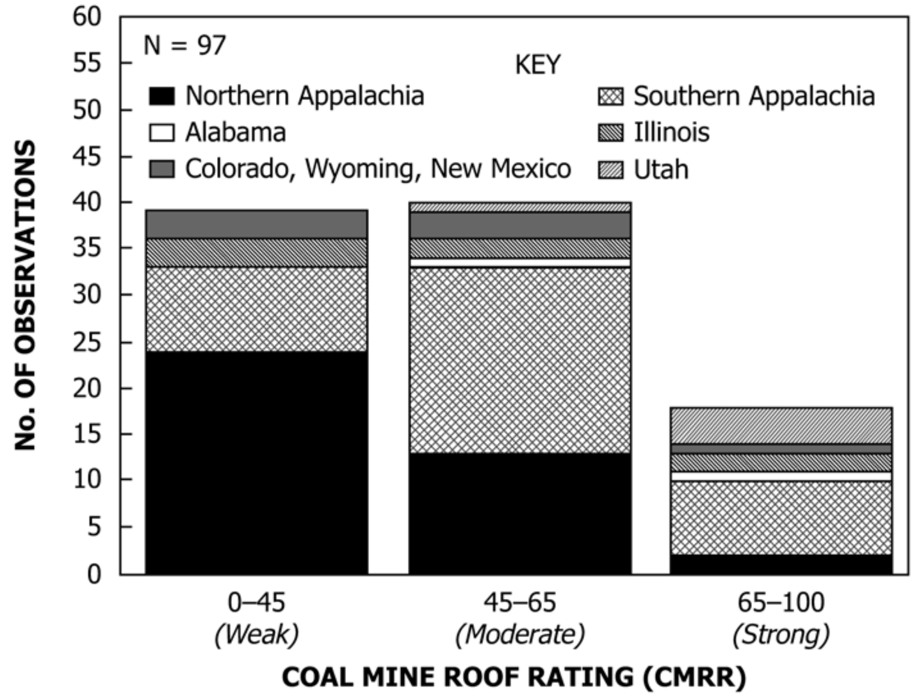
Condition	*Adjustment*
Dry	0
Damp	–2
Light drip	–4
Heavy drip	–7
Flowing	–10

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



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SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this standard since the last issue (D5878 – 05) that may impact the use of this standard. (Approved July 1, 2008.)

(1) Edited Section 1.5 on units.