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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.

[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.

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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 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* [illegible]

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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

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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)**.

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APPENDIX

(Nonmandatory Information)

X1. ADDITIONAL INFORMATION

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

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(**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*, ÖN 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.

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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°

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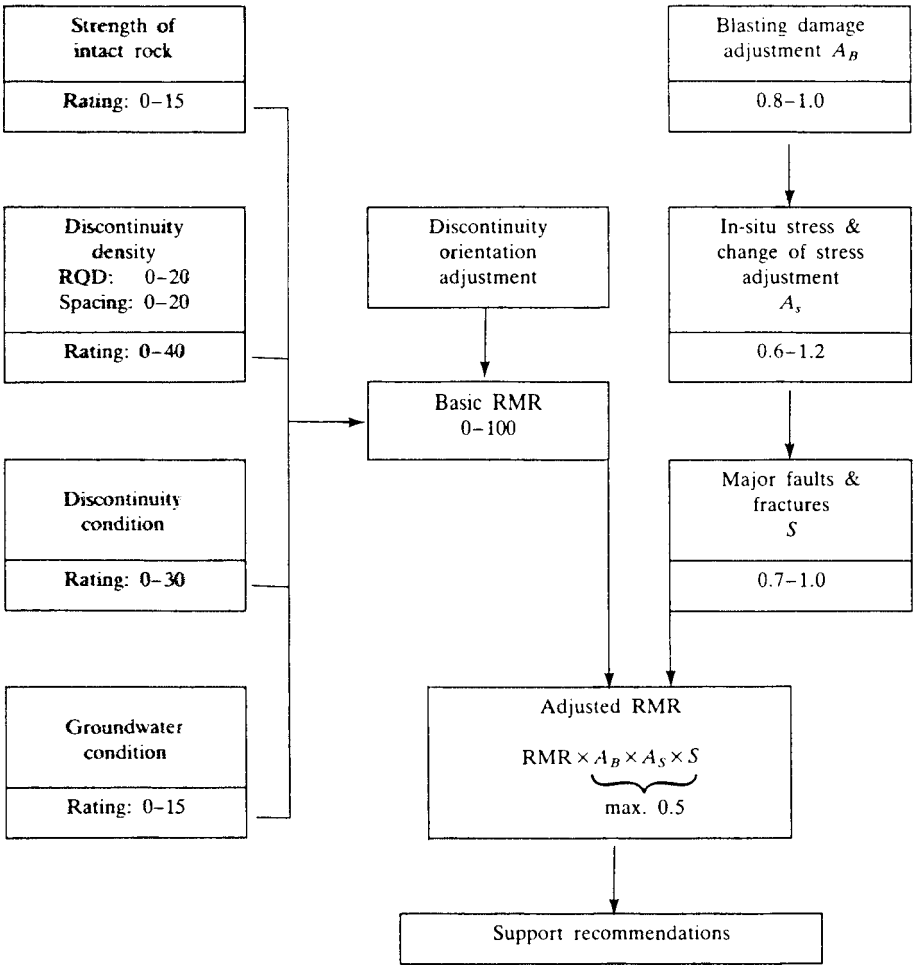
TABLE 2—*Effect of discontinuity strike and dip orientations in tunneling.*

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.*



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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.*		WALL ROCK OF DISCONTINUITIES
Excellent quality:	90 - 100%	Unweathered
Good quality:	75 - 90%	Slightly weathered
Fair quality:	50 - 75%	Moderately weathered
Poor quality:	25 - 50%	Highly weathered
Very poor quality:	<25%	Completely weathered
*R.Q.D. = Rock Quality Designation		Residual soil

GROUND WATER	STRENGTH OF INTACT ROCK MATERIAL			
INFLOW per 10 m of tunnel length litres/minute	Designation	Uniaxial compressive strength, MPa	OR	Point-load strength index, MPa
or	Very high:	Over 250		>10
WATER PRESSURE kPa	High:	100 - 250		4-10
or	Medium high:	50 - 100		2-4
GENERAL CONDITIONS (completely dry, damp, wet, dripping or flowing under low/medium or high pressure:	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

PERSISTENCE (CONTINUITY)		Set 1	Set 2	Set 3	Set 4
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.

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RSR

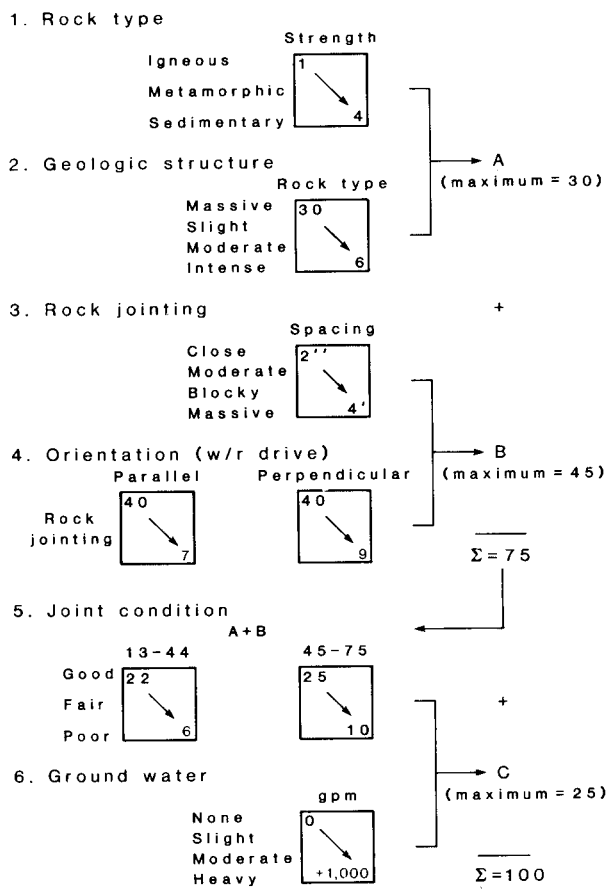

FIG. 1—*Schematic of Rock Structure Rating.*

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.*

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