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Rock Material Field Classification Procedure

Second Edition

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PREFACE

This document was developed to satisfy the needs of the Soil Conservation Service (SCS) in classifying and describing information on rock materials for engineering purposes. The procedure is used to classify rock for a specific engineering purpose by assessing the rock material, rock mass, and geohydrologic properties. Performance assessment of the rock is shown for five engineering purposes most commonly used in SCS activities. These are erosion resistance, excavation characteristics, construction quality, fluid transmission and rock mass stability.

This is not a new classification system. It uses established methods, procedures, and tests which have previously been developed and proven useful. The Unified Rock Classification System by D.A. Williamson, US Forest Service, has been included in its entirety because it is a major part of two performance assessment tables.

This document was originally issued in 1984. It was twice revised in 1986 to reflect the latest data from a study on erosion resistance. This edition resulted from work done by John S. Moore, Engineering Geologist, Northeast National Technical Center, Chester, Pennsylvania clarifying many items and providing classification elements for rock material in Class II in Tables 3, 4, and 5.

CONTENTS

DEFINITIONS

Bedrock - A general term for in-place (in-situ), usually solid rock that is exposed at the surface of the earth or overlain by unconsolidated material (see: Rock, and Rock mass).

Discrete rock particles - Discrete particles may be pieces of rock resting in the place of origin, such as fractured, broken, or jointed bedrock. They may be particles that have been moved from their place of origin, such as stream gravel, talus, glacial boulders, or riprap. The median particle size (d_{50}) is the size for which 50 percent of the sample is finer or coarser by weight. The mean particle diameter of a discrete rock particle too large to weigh is assumed to be the cube root of the product of its three dimensions of length, width, and thickness.

Durability - The resistance of rock particles to break down due to weathering processes, hard wear, abrasion, and erosion during the design life of the structure. Durability can be quantified by methods given in NEH-20, Material Specification 523, Rock for Riprap, or equivalent ASTM C-127 and ASTM C-88. Durability of rock may be established by documenting a specific case history of satisfactory durability and performance under comparable climatic conditions, uses, and time of exposure.

Outcrop confidence - Knowledge of the consistency of the lithologic character of a rock unit from one exposure to another or to the proposed site of investigation.

Outcrop Confidence Levels

I. High - Massive homogeneous rock units with large vertical and lateral extent. History of low tectonic stress levels.

II. Intermediate - Rock characteristics are generally predictable but with expected lateral and vertical variability. Systematic tectonic stress features.

III. Low - Extremely variable rock conditions due to depositional processes, structural complexity, mass movement or buried topography. Frequent lateral and vertical changes can be expected. Frequent and variable tectonic stress features.

Rock - A naturally occurring aggregate of one or more minerals (e.g., granite, shale, or marble); or a body of undifferentiated mineral matter (e.g., obsidian); or solid organic matterial (e.g., coal).

Rock discontinuity - A rock mass feature characterized by a surface of real or potential discontinuity. Examples include extension and shear joints, bedding, banding, contacts, cleavage, foliation, and faults.

Rock Mass - Rock mass is comprised of the rock, its network of discontinuities, and its weathering profile. The behavior of the rock mass reflects all of these components as well as water and stress regimes, strength, durability, and permeability, which may be largely unrelated to rock material properties (see: description of classification elements, under: Classification).

Rock Quality Designation (RQD) -

$$\frac{\text{Length of core pieces} > 0.10\text{m}}{\text{Length of core run}} \times 100$$

URCS - Unified Rock Classification System: A rock classification system developed by the U.S. Forest Service that allows a rapid preliminary assessment of rock conditions by simple field tests that establish basic engineering properties. Elements evaluated by the URCS include: (1) weathering, (2) strength, (3) discontinuities, and (4) unit weight.

Weathering - The destructive process or group of processes by which earth and rock materials exposed to atmospheric agents at or near the earth's surface are changed in color, texture, composition, density, or form, with little or no transport of the loosened or altered material; specifically, it is the physical disintegration and chemical decomposition of rock that produce an in-situ mantle of disaggregated material.

(210-VI, TR-71, 2nd Ed., Feb. 1987)

ROCK MATERIAL FIELD CLASSIFICATION PROCEDURE

SCOPE

This classification procedure is to be used for describing rock material in support of Soil Conservation Service (SCS) engineering activities. It is a field classification to be used by geotechnically trained personnel. The procedure does not preclude or replace laboratory testing for specific design requirements.

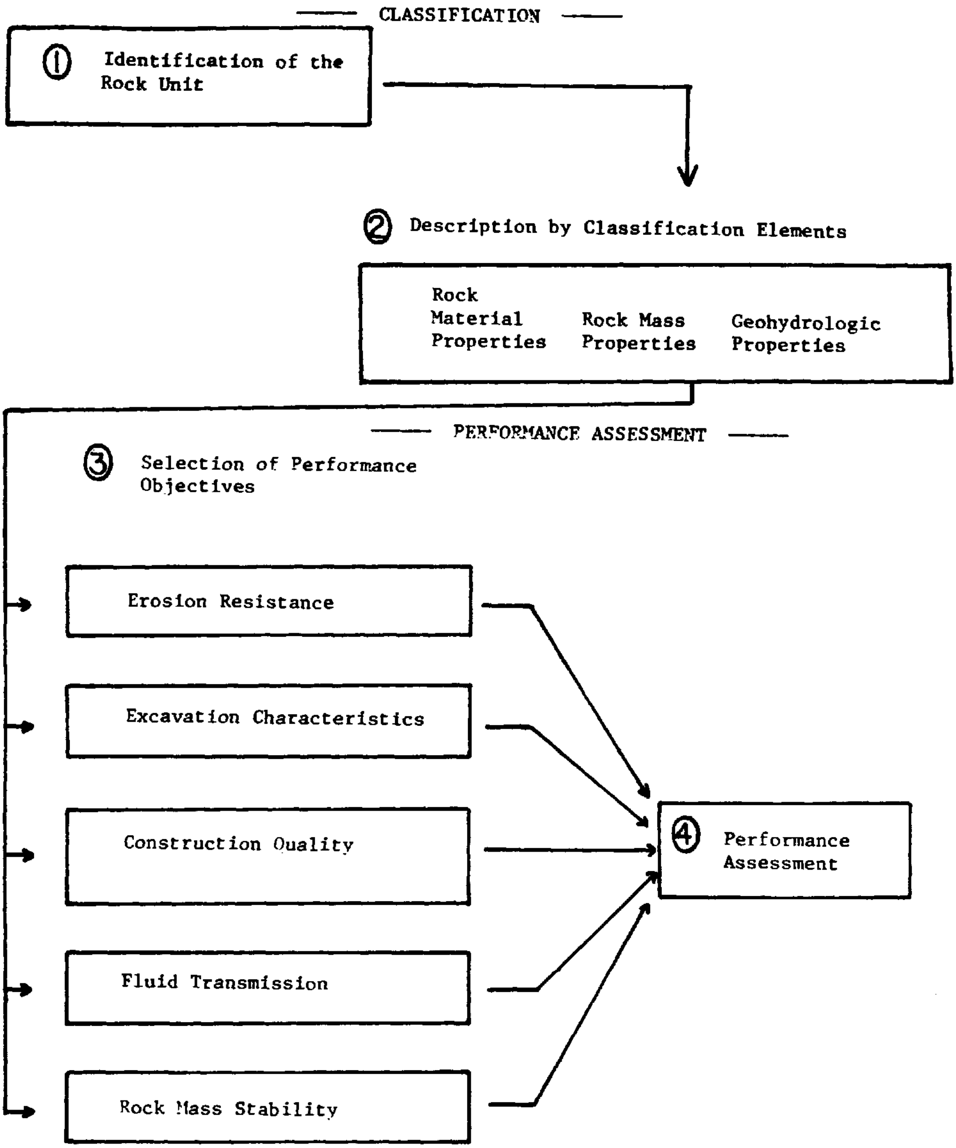
INTRODUCTION

The rock material field classification procedure consists of two primary steps: the classification process and the performance assessment. The classification process includes (1) the identification of the ROCK UNIT and (2) the description of the rock in terms of CLASSIFICATION ELEMENTS. The classification elements describe the physical properties of the rock units that are most relevant to engineering activities. These elements include rock material, rock mass, and geohydrologic properties of the rock units.

The performance assessment includes the selection of PERFORMANCE OBJECTIVES related to project requirements. Rock performance with respect to the identified objective is determined from the performance assessment tables.

A major component in the classification process is the Unified Rock Classification System (URCS) included in Appendix I. The URCS terminology and symbols are utilized in both the classification process and performance assessment.

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" (see: Definitions).

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.

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: (see: Definitions)

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 piezometers 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)

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 in this Technical Release:

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.

PERFORMANCE ASSESSMENT TABLES

TABLE 1 - EROSION RESISTANCE

CLASSIFICATION ELEMENTS	CLASS I	CLASS II	CLASS III
	Definition: Rock material that will sustain extended flow velocities of at least 3 m/s (10 ft/s) without significant erosion. Must fulfill <u>all</u> conditions below.	Definition: Rock material is intermediate between Classes I and III.	Definition: Rock material that will be severely eroded when subjected to velocities greater than 1.2 m/s (4 ft/s). Must fulfill <u>at least one</u> of the conditions below.
ROCK MATERIAL PROPERTIES			
Discrete rock particle size	> 75 % of the particles have mean diameters greater than 0.61 m (2.0 ft).		> 75 % of the particles have mean diameters less than 0.15 m (6.0 in).
ROCK MASS PROPERTIES			
Planar orientation	Planar features are interlocking (not at or near 90°) and are not coincident (+/- 10°) with either the direction of flow or the surface gradient or both.		Planar features are in three directions, and at or near 90° with the direction of flow or the surface gradient.
Planar separation	95 % or more of the planar features are cemented or less than 0.003 m (1/8 in) in width.		10% or more of the planar features are uncemented or greater than 0.016 m (5/8 in) in width.
Rock unit thickness	> 0.30 m (1.0 ft)		< 0.076 m (3.0 in)
Rock unit attitude	Horizontal or dips upstream.		Dips downstream ≥ surface gradient.

TABLE 2 - EXCAVATION CHARACTERISTICS

CLASSIFICATION ELEMENTS	CLASS I	CLASS II	CLASS III
	Definition: Rock material that will require explosive or impact procedures for excavation. Must fulfill <u>one or more</u> of the conditions below.	Definition: Rock material is intermediate between Classes I and III.	Definition: Rock material that can be excavated as common material by earthmoving or ripping equipment (SCS Construction Spec. No 21). Must fulfill <u>all</u> of the conditions below.
ROCK MATERIAL PROPERTIES			
Discrete rock particle size	> 75% of the particles have mean diameters greater than 0.9 m (36 in).		> 75% of the particles have mean diameters less than 0.3 m (12 in).
RQD	> 75		< 25
ROCK MASS PROPERTIES			
Dip of rock unit	> 60°		< 10°
Discontinuities (URCS)	A, B, or C	D	E
Rock unit thickness	> 0.9 m (36 in)		< 0.3 m (12 in).
Planar separation	Cemented or < 0.003 m (1/8 in) in width.		Uncemented and > 50% are < 0.025 m (1.0 in) in width.
Planar spacing	> 0.9 m (36 in)		< 0.3 m (12 in)
Seismic velocity	> 3000 m/s (10,000 ft/s)		< 2300 m/s (7500 ft/s)

TABLE 3 - CONSTRUCTION QUALITY

CLASSIFICATION ELEMENTS	CLASS I	CLASS II	CLASS III
	Definition: High grade construction quality. Suitable for high stress aggregate, filter and drain material, riprap, and other construction applications which require high durability. Must fulfill <u>all</u> conditions below.	Definition: Rock material is intermediate between Classes I and III.	Definition: Low grade construction quality. Not suitable for aggregate, filter and drain material, or riprap. Essentially reacts as a soil in embankments. Must fulfill <u>one or more</u> conditions below.
ROCK MATERIAL PROPERTIES			
Degree of weathering (URCS)	A or B	C	D or E*
Estimated strength (URCS)	A or B	C	D or E
Unit weight (URCS)	A, B, or C	D	E
ROCK MASS PROPERTIES			
Discontinuities (URCS)	A or B	C	D or E

* Analyze by Unified Soil Classification System ASTM D-2488 when used as a soil material.

TABLE 4 - FLUID TRANSMISSION

CLASSIFICATION ELEMENTS	CLASS I	CLASS II	CLASS III
	Definition: Low capability to transmit fluids. Must fulfill <u>all</u> conditions below.	Definition: Rock material is intermediate between Classes I and III.	Definition: Rock material having a high capability to transmit fluids through inter-connected pores, open fractures, or voids. <u>At least one</u> of the following conditions exists.
ROCK MATERIAL PROPERTIES			
Mineralogy	No soluble rock (e.g., lime-stone, dolomite, marble, gyp-sum or halite).	Soluble rock occurs.	Soluble rock occurs.
Degree of weathering (URCS)	A, B, E (plastic)	C, D (plastic), E (non-plastic)	D (non-plastic)
Primary porosity	Micro pores, not free drain-ing.		Pores visible under 10X hand lens, free-draining.
ROCK MASS PROPERTIES			
Discontinuities (URCS)	A, B, C	D	E
Fracture separation	< 0.001 m (1/32 in) and comprising < 0.2% of rock unit cross-sectional area.		> 0.003 m (1/8 in) and comprising >4% of rock unit cross-sectional area.
Voids (depositional, solutional)	No such voids occur.	No karst features or obvious evidence of solution.	Occurrence of karst features (e.g., caverns, solutionally enlarged joints, sinkholes), lava tubes or interbedded gravel and lava beds, vugs, tectonic features (open, systematic joints or faults), or valley stress relief joints.
GEOHYDROLOGIC PROPERTIES			
Hydraulic conductivity (dams)	< 10^{-6} m/s (0.3 ft/day)		> 10^{-5} m/s (3 ft/day)
Transmissivity (wells)	< 10^{-3} m^2/s (10^3 ft^2/day)		> 10^{-1} m^2/s (10^5 ft^2/day)

TABLE 5 - ROCK MASS STABILITY

CLASSIFICATION ELEMENTS	CLASS I	CLASS II	CLASS III
	Definition: Very low potential for instability. No natural or cutslope failures occur within rock unit. Must fulfill <u>all</u> of the following conditions.	Definition: Rock material is intermediate between Classes I and III.	Definition: Significant potential for rock instability exists. Failures of natural or cutslopes occur within the rock unit. Must fulfill <u>at least one</u> of the following conditions.
ROCK MATERIAL PROPERTIES			
Degree of weathering (URCS)	A or B	C	D or E
Estimated strength (URCS)	A or B	C or D	E
RQD	> 75		< 25
ROCK MASS PROPERTIES			
Discontinuities (URCS)	A or B, or <u>no</u> adverse component of dip	C	D or E, or adverse component of dip
GEOHYDROLOGIC PROPERTIES			
Aquifer type	Unconfined		Confined

REFERENCES

Barton, N., Lien, R., and Lunde, J., 1974, Engineering Classification of Rock Masses for the Design of Tunnel Support: Rock Mechanics, Vol. 6, No. 4, pp. 189-236.

Bates, R. L., and Jackson, J. A., Editors, 1980, Glossary of Geology: 2nd ed, American Geological Institute, Falls Church, VA.

Bieniawski, Z. T., 1976, Rock Mass Classification in Rock Engineering: Proc. Symposium on Exploration for Rock Engineering, Johannesburg, Vol. 1, pp. 97-106.

Bureau of Reclamation, USDI, 1977, Ground Water Manual: U. S. Govt. Printing Office, Denver.

Caterpillar Tractor Company, 1978, Handbook of Ripping: 6th ed., Publication AEDQ4007, Peoria, IL.

Compton, R. C., 1962, Manual of Field Geology: Wiley, NY.

Deere, D. U., 1964, Technical Description of Rock Cores for Engineering Purposes: Rock Mechanics and Engineering Geology, Vol. 1, pp. 17-22.

Ernst, W. G., 1969, Earth Materials: Prentice-Hall, Englewood Cliffs, NJ.

Freeze, R. A., and Cherry, J. A., 1979, Ground Water: Prentice-Hall, Englewood Cliffs, NJ.

Goodman, R. E., 1976, Methods of Geological Engineering in Discontinuous Rocks: West Publishing Co., St. Paul.

__________, 1980, Introduction to Rock Mechanics: Wiley, New York.

Hoek, E., and Brown, E. T., 1980, Underground Excavations in Rock: The Institution of Mining and Metallurgy, London, pp. 7-37.

Krynine, D. P., and Judd, W. R., 1957, Principles of Engineering Geology and Geotechnics: McGraw-Hill, NY.

Soil Conservation Service, USDA, 1968, Ground Water: National Engineering Handbook - Section 18, Superintendent of Documents, U. S. Govt. Printing Office, Washington, D. C., 20401.

__________, 1978, Engineering Geology: NEH-8, U. S. Govt. Printing Office, Washington, D.C., 20401.

__________, 1984, Specifications for Construction Contracts: NEH-20, U. S. Govt. Printing Office, Washington, D. C., 20401.

__________, 1987, Excavated Rock Spillway Classification and Layout: NENTC Engineering - Geology Technical Note No. 4 (rev. 2), Chester, PA. 19013.

Williamson, D. A., 1984, Unified Rock Classification System: Bulletin of the Association of Engineering Geologists, Vol. XXI, No. 3, pp. 345-354.

APPENDIX I

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Unified Rock Classification System[1]

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ABSTRACT

The Unified Rock Classification System (URCS) provides a reliable and rapid method of communicating detailed information about rock conditions pertinent to design and construction of civil engineering projects. The URCS consists of four fundamental physical properties: 1) weathering, 2) strength, 3) discontinuities and 4) density. A general assessment of rock performance is then based on a grouping of the four key elements to aid in making engineering judgments. These individual properties are estimated in the field with the use of a hand lens, a 1-pound ballpeen hammer, a spring-loaded "fish" scale and a bucket of water. Each property is divided into five ratings which convey uniform meaning to engineering geologists, design engineers, inspectors and contractors as well as contract appeal board members.

Subjective terminology, such as "slightly weathered, moderately hard, highly fractured and lightweight," varies widely in meaning, depends on individual and professional experience, and cannot be quantified with any reliability. The URCS is not intended to supplant existing geologic classifications but it does offer a suitable alternative to ambiguous descriptive terminology, since it is verifiable and reproducible.1/

INTRODUCTION

The Unified Rock Classification System (URCS) allows rapid preliminary assessments of rock conditions by simple field tests that establish basic engineering properties. The URCS is useful for all earth-associated design and construction projects. Pertinent natural conditions related to design parameters are documented in a convenient manner which can be understood at a glance.

The URCS is engineering shorthand which can be used to convey maximum information. With the URCS, rock is classified in simple, easily understood terms that convey evidence of strength and behavior. The URCS terms convey uniform meaning to engineering geologists, design engineers, inspectors, contractors and contract appeal board members.

Geotechnical field reports or drill logs sometimes lack uniformity of notation to assure that sufficiently identical interpretations will be made by designers. A working classification system based on simple field tests which can be refined by laboratory test results can provide this needed uniformity. The URCS is not intended to replace existing geologic classifications but rather to supplement them with engineering design parameters.

The URCS was conceived in 1959 in simplified form in conjunction with investigations and explorations for design and construction of major flood-control dams by the Portland District of the U.S. Army Corps of Engineers. Use of the URCS was found to materially increase efficiency and produce

[1] Modified by the Symposium editor from papers written by Williamson (1978, 1980).

1/ personal communication with author

reliable rock information that resulted in successful design and construction as well as post-construction evaluations. The URCS in its present form dates from 1975 and is used by the U.S. Forest Service in Region 6 and parts of Regions 1 and 5. It has been found to be a reliable method of communicating rock conditions (including those in quarries, retaining walls, and extensive rock excavations) for the design of forest access roads.

PURPOSE AND NEED

The purpose of the URCS is to establish a means of making rapid initial assessments of rock conditions related to design and construction by simple field tests that permit direct estimation of natural strength parameters. The purpose of this report is threefold: 1) to present a rock classification for use in engineering geology and geotechnical investigations, 2) to outline field procedures that require simple equipment, and 3) to establish the relationship between the classification and design and performance.

Experienced professionals who deal with rock can, and often do, apply the principles of rock mechanics without any formally accepted rock classification. Organizations comprised of employees of many experience levels commonly have a designated rock classification system. Rock information is frequently collected in the field by geologists but utilized in design by engineers. The URCS is intended to supplement, not supplant, existing geologic classifications; its specific goal is to provide a means by which the inherent confusion of subjective terminology can be eliminated when applied in civil engineering.

Classification is not the chief aim of geotechnical investigations, but a uniform working classification is necessary to effectively supply the needs of a large organization of diverse professional disciplines. The assertion that there is no need for another classification is easily discounted with the statement that a classification is always needed until one is found that meets general approval and acceptance and is used.

The following statements are unfortunately still true: "There are as many classifications as there are geologists," and "No two geotechnical investigators will give the same name to the same rock." Because of the number of geotechnical personnel working in the field, it is vital that some uniformity of data exist. Even now, when one reads geotechnical reports, drilling logs, or contract documents, it is not possible to be sure that two different geotechnical specialists who are discussing the same rock are describing sufficiently identical design characteristics. A working classification requires uniform symbols, abbreviations, notations, and definitions that are established to be acceptable procedures.

The URCS fulfills basic needs of any classification:

1) Definitions are developed by simple field tests.
2) Information is presented in simple, understandable, non-technical terms.
3) Field conditions are related to design and construction.
4) Notations are flexible to scale of sample, outcrop or large excavation area and are appropriate to evaluation.
5) Collected data are verifiable, reproducible and independent of experience but not training.
6) The system is useful to all levels of experience.
7) The system allows immediate assessment, both directly and on notes or documents.

BASIC ELEMENTS

The URCS consists of four basic elements which are major physical properties of rock material and are related to design and construction. The elements are: 1) degree of weathering, 2) estimated strength, 3) discontinuities or directional weaknesses, and 4) unit weight or density.

By establishing limiting values of these four basic elements by using uniform field tests and observations, terminology, notations, and abbreviations, the URCS provides a means for recording and communicating reliable indications of rock properties and performance. The URCS permits a useful estimate of compressive strength, permeability and shear strength—the three primary properties of rock masses. When combined with other geotechnical information (stress history and water table location), the URCS permits an estimate of rock performance such as foundation suitability, excavation methods, slope stability, material use, blasting character and water transmittal.

The equipment used for the field tests and observations is simple and available: one's fingers, a 10-power hand lens, a 1-pound (0.5-kg) ballpeen hammer, a spring-loaded "fish" scale of the 10-pound (5 kg) range, and a bucket of water. Fingers are used in determining the degree of weathering and the lower range of strength. The hand lens is used in defining the degree of weathering. The ballpeen hammer is used to estimate the range of unconfined

WILLIAMSON–UNIFIED ROCK CLASSIFICATION

DEGREE OF WEATHERING

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

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

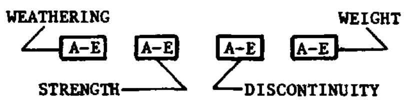


Figure 1. Basic elements of the unified rock classification system.

compressive strength from impact reaction. The spring-loaded scale and bucket of water are used to measure the weight of samples for determining apparent specific gravity.

The URCS design notation consists of underlined groups of four letters ranging from A through E which represent the five categories or design-limiting conditions of each of the basic elements of the system. The limiting conditions of the basic elements are described below in the order that they appear in the symbol.

Degree of Weathering

The degree of weathering in the URCS is restricted to chemical processes. The five design-limiting conditions of weathering are: 1) micro fresh state (MFS) designated by A, 2) visually fresh state (VFS) designated by B, 3) stained state (STS) designated by C, 4) partly decomposed state (PDS) designated by D, and 5) completely decomposed state (CDS) designated by E. These five weathering states are listed in the top line of Figure 1.

Micro Fresh State (MFS)

MFS is determined in the field by examining rock samples with the aid of a 10-power hand lens. This condition is characterized by absence of oxidation alteration of any mineral components. MFS will generally apply only to crystalline rocks, some volcanic rocks, and chemical sedimentary rocks. Investigations of crushed rock and concrete aggregate sources may require MFS rock, but ordinary rock-design evaluations usually do not require such high quality rock.

Visually Fresh State (VFS)

VFS is determined in the field by examining rock samples with the unaided eye. This condition is characterized by a uniform color of the rock material. VFS will apply to all rock types including some clastic sedimentary rocks. VFS samples commonly exhibit maximum unit weight, maximum specimen strength and least water absorption for the site from which comparisons to STS are made. The VFS is generally representative of the standard quality acceptable for all foundation and excavation designs.

Stained State (STS)

STS is determined in the field by examining rock samples with the unaided eye. This condition is characterized by partial or complete discoloration due to oxidation alteration of mineral components, but the specimen cannot be remolded with finger pressure. STS will apply to all rock types and commonly is the highest weathering state of Cenozoic clastic sedimentary rocks. STS specimen strength may or may not vary from that of VFS specimens; unit weights are usually lower and water absorptions are usually higher than VFS specimens.

Partly Decomposed State (PDS)

PDS is determined in the field by applying finger pressure to discolored specimens. The material is solid rock when in place but can be disaggregated into gravel or larger size rock fragments in a matrix of soil.

1/ The relative percentage of rock fragments is estimated and the quality of individual fragments is assessed with URCS. The soil fines are determined to be plastic or nonplastic.

The in-place strength is estimated by manual consistency values or by size, shape, and gradation of the remolded aggregate (Terzaghi and Peck, 1948). The remolded aggregate is tested for dilatency, dry strength, and toughness and classified according to field procedures of the Unified Soil Classification System (USCS) (Casagrande, 1948).

Completely Decomposed State (CDS)

CDS is determined in the field by applying finger pressure to discolored specimens in a manner similar to that for PDS specimens. CDS specimens disaggregate or remold to soil* without gravel or larger size fragments of intact rock. The remolded material is determined to be plastic or nonplastic, and dry strength, dilatency, and toughness tests are performed. The in-place strength is estimated by manual consistency values. Both URCS and USCS symbols are recorded. Note that the URCS boundary separating rock from soil is the No. 4 sieve which is the gravel/sand division. Most investigators, as well as lay persons, generally accept that gravel is composed of rock fragments but sand is composed of mineral grains.

Estimated Strength

A reasonable estimate of specimen strength can be made by striking a sample, piece of rock core, or outcrop with the round end of a ballpeen hammer (or with the rounded head end of a 20-penny nail if the specimen is to be preserved). The resulting characteristic impact reaction indicates a range of unconfined compressive strength (Williamson,

1/ personal communication with author

* sand, silt or clay--personal communication with author

1961). The rock specimen or outcrop is struck several times to permit evaluation of uniformity of response, and a quality is assigned based on the distinct reaction. The five kinds of reaction are illustrated in Figure 2.

The reaction of a rock specimen to the impact of a ballpeen hammer is distinct and characteristic depending on the range of unconfined compressive strength. The *nature* of the reaction, *not* the *magnitude* of the reaction is used to assign a strength quality to the specimen. Therefore, the reaction is independent of the intensity of the blow within the limitations of the tool used and the investigator's strength.

The five design-limiting conditions of strength based on impact reaction are: 1) rebound quality (RQ) designated by A, 2) pit quality (PQ) designated by B, 3) dent quality (DQ) designated by C, 4) crater quality (CQ) designated by D, and 5) moldable quality (MQ) designated by E. These five strength states are listed in the second line of Figure 1. The range of unconfined compressive strength in terms of pounds per square inch (psi) and megapascals (MPa) for each of the strength states is also listed in Figure 1.

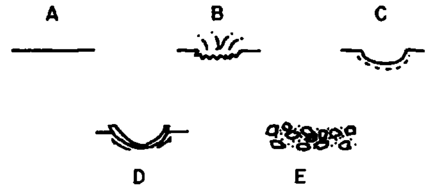


Figure 2. Reaction to impact of ballpeen hammer. A) Rebound quality, no reaction; B) Pit quality, rough pit; C) Dent quality, smooth depression; D) Crater quality, depression with upthrust material around perimeter; E) Moldable quality, crumbles with finger pressure.

Rebound Quality (RQ)

RQ rock material shows no reaction under the point of impact and is a true brittle-elastic substance in a mechanical sense. The estimated unconfined compressive strength of RQ material is greater than 15,000 psi (103 MPa). The exact strength value is seldom significant in typical civil engineering applications once the strength reaches this magnitude. RQ rock material produces free-draining fill that is suitable for road aggregate; however, it is often sharp and angular due to its brittleness and therefore may produce a less desirable material than PQ material. RQ rock material has a very high energy transfer in response to blasting and may be difficult to drill and break in the absence of planar separations.

Pit Quality (PQ)

PQ rock material produces a shallow rough pit under the point of impact due to explosive departure of mineral grains. This quality of specimen has an estimated unconfined compressive strength ranging from 8,000 to 15,000 psi (55 to 103 MPa) and is considered to be hard rock by the construction industry. PQ rock material produces free-draining fill and is suitable for road surfacing material. It has high energy transfer in response to blasting which produces generally good fragmentation and satisfactory excavation slopes. No special blasting design procedure is generally necessary.

Dent Quality (DQ)

DQ rock material produces a dent or depression under the point of impact indicating the presence of pore spaces between mineral grains. This quality of specimen has an estimated unconfined compressive strength ranging from 3,000 to 8,000 psi (21 to 55 MPa) and is approximately equivalent to the strength range of concrete. DQ rock material usually does not meet absorption specifications for road aggregate and has a relatively low energy transfer in response to blasting. Special blasting design may be necessary to avoid creating over-size blocks. DQ material is usually not suitable for road fill or surfacing and is not free-draining.

Crater Quality (CQ)

CQ rock material produces a shearing and upthrusting of mineral grains surrounding the point of impact resulting in a depression which resembles a moon crater. This quality of specimen has an estimated unconfined compressive strength ranging from 1,000 to 3,000 psi (7 to 21 MPa). CQ material can usually be recovered during diamond-core drilling operations, has high absorption, and will respond to freeze-thaw stresses by at least cracking and checking. It has very low energy transfer when blasted and can be excavated by means of machinery, produces poorly drained embankments, and is not suitable for road fill or surfacing material.

Moldable Quality (MQ)

MQ rock is in a condition which can be molded by finger pressure but retains the fabric of intact rock. The unconfined compressive strength for this quality of specimen is less than 1,000 psi (7 MPa). MQ material must be examined and tested as a soil and a dual classification (URCS and USCS) is given. The material usually cannot be recovered by diamond-core drilling, can be excavated by machinery, and must be evaluated as a soil for design purposes.

Discontinuities

Directional weaknesses of a rock mass or rock material are termed planar or linear features. Planar separations are open separations that already exist in the rock mass and are defined by relative capacity to transmit water. Linear features are directional weaknesses due to visible or nonvisible alignments of mineral grains in an otherwise solid rock mass or material that usually require blasting or mechanical crushing to produce a separation.

For purposes of design evaluations, linear features are defined by breakage characteristics. Planar features or open planes of separation are defined by the scale dimension of the rock mass examined and by the geometric determination that defines a plane or shape.

The five design-limiting conditions of discontinuities are: 1) solid random breakage (SRB) designated by A, 2) solid preferred breakage (SPB) designated by B, 3) latent planar separations (LPS) designated by C, 4) two-dimensional open planar separations (2-D) designated by D, and 5) three-dimensional open planar separations (3-D) designated by E. These five discontinuity states are listed in the third line of Figure 1.

Solid Random Breakage (SRB)

SRB represents ideal design conditions in which planar and linear features have no effect within the dimensions of the rock mass examined. The specimen strength equals the mass strength so that the strength value of any individual sample tested is directly representative of the entire rock-mass strength. Needless to say, this is seldom the case, except in very limited foundation dimensions.

Solid Preferred Breakage (SPB)

SPB indicates that a nonvisible alignment of mineral grains has resulted in a directional weakness in the rock mass or material. The rock breaks consistently along a uniform angle or direction. SPB rock material may produce an undesirable shape or size for rock aggregate or may prevent the achievement of a desired slope in an excavation. It may be an adverse quality in the production of dimension stone.

Latent Planar Separations (LPS)

LPS indicates a visible alignment of mineral grains or infilling material which may or may not affect the strength or breakage character of the rock mass or material during excavation or crushing. The latent planes may be stronger or weaker than the rock mass. The reaction of LPS material to impact defines the strength estimate. Latent planes occur in patterns or at random and are continuous or discontinuous; the planes may be of measurable thickness. In all cases, the infilling material in the latent plane of separation has an unconfined compressive strength greater than 1,000 psi (7 MPa).

LPS material is usually not a foundation design consideration because the material is, for practical purposes, a solid. In consideration of rock slope design or road aggregate source, blasting energy will, in most cases, be reflected by the latent plane and produce a separation and breakage at right angles to the plane alignment.

Two-Dimensional Open Planar Separations (2-D)

The 2-D category indicates the presence of one or more parallel open planes of separation that pass through the rock mass at the point of examination. The 2-D planar separations may vary in frequency and spacing but do not intersect. The attitude, relief, and continuity of the plane or planes are fundamental elements of design analysis. Water transmission along the open planes can be determined by observations of the drilling operation or by water testing.

Three-Dimensional Open Planar Separations (3-D)

The 3-D category indicates the presence of two or more intersecting planar discontinuities or open planes of separation that pass through the rock mass at the point of examination. The planar separation may form patterns or may be random in occurrence. Internal planar separations (IPS) terminate within the rock mass; mass planar separations (MPS) pass entirely through the rock mass and are infinite in extent in terms of design.

By geometric definition, three dimensions form a shape. This shape is often referred to as a joint block which has an average size and weight that can be estimated. The degree of interlock between joint blocks can be used to estimate the strength-of-foundation or the stability-of-excavation factor.

In the case of MPS, the attitude of the planes with respect to the slope or excavation is the chief design factor. The ability of the planes to transmit water is estimated or measured as in the 2-D category above.

Unit Weight

Density or unit weight has been found to be one of the most useful and reliable means of communicating rock quality to design engineers and contractors, due to their past experience with rock. The unit weight is determined in the field with the aid of a spring-loaded "fish" scale and a bucket of water. A suitable sample is fastened to the scale with a short piece of string. The weight of the sample is determined first in air and then submerged in water. The weight of the string (wet and dry) is ignored. The unit weight is calculated by the following equation:

$$\text{Unit Weight} = [Wa/(Wa - Ww)]Dw$$

where Wa is the weight of the sample in air, Ww is the weight of the sample in water, and Dw is the density of water (62.4 pounds per cubic foot, pcf, 1.0 g/cc). The weight of the sample in air and water can be measured in either pounds or grams since the mathematical operation with the weights produces a dimensionless number.

The five categories of unit weight are: 1) greater than 160 pcf (2.55 g/cc) designated by A, 2) 150 to 160 pcf (2.40 to 2.55 g/cc) designated by B, 3) 140 to 150 pcf (2.25 to 2.40 g/cc) designated by C, 4) 130 to 140 pcf (2.10 to 2.25 g/cc) designated by D, and 5) less than 130 pcf (2.10 g/cc) designated by E. These five unit weight conditions are listed in the bottom line of Figure 1.

The unit weight design evaluation establishes the driving force in problems of slope stability, the relative usefulness of the rock material as a surface course or concrete aggregate, of the weight-volume relationship for estimates of haul cost. Unit weight establishes the degree of change due to change of weathering state.

As a general rule, the author has found that rock material having a unit weight greater than 160 pcf (2.55 g/cc) is suitable more than 50 percent of the time for use as road aggregate, concrete aggregate, riprap, or jettystone without laboratory testing. Rock material having a unit weight of 150 to 160 pcf (2.40 to 2.55 g/cc) may be acceptable for these uses but requires laboratory testing for confirmation. Rock having a unit weight less than 150 pcf (2.40 g/cc) is usually not acceptable for these uses, typically does not produce free-draining fill, and will probably degrade. Rock having a unit weight less than 130 pcf (2.10 g/cc) can usually be excavated by machinery but will likely degrade during excavation under abrasion of excavation equipment.

Symbols and Notations

The URCS employs a simple system of notation for graphic representation on geotechnical inventories, boring logs, maps, and sections. The notation registers rapidly in the mind and minimizes the required drafting effort. The letter design symbols for the four basic elements described above and shown in Figure 1 are grouped together in a four-letter notation.

The four letters are upper case and are underlined. The letter "A" denotes that the least design evaluation is generally required, while the letter "E" denotes the greatest design evaluation. The letter "O" in sequence indicates that no determination of that basic element was made; a lower case "e" after an upper case letter indicates that the value of the basic element was estimated.

The field notation should include both the letter symbol and the abbreviated basis written under the letter. For example:

Symbol on log: BCAD

Field notebook: $\frac{B}{\text{VFS}}\ \frac{C}{\text{DQ}}\ \frac{A}{\text{SRB}}\ \frac{D}{130}$

Explanation:
B—Visually fresh state
C—Dent quality
A—Solid random breakage
D—Unit weight of 130 pcf

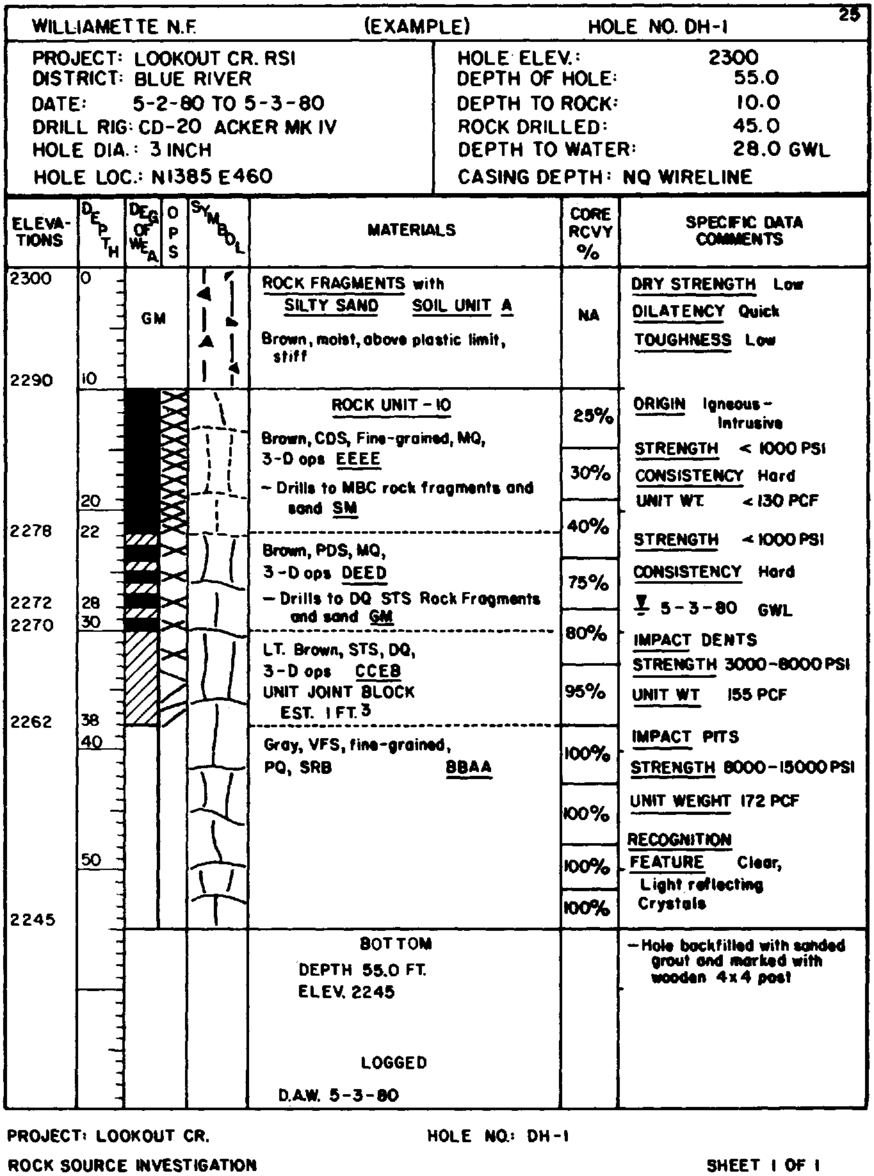
Design values can then be established for this material for the intended purpose.

Some combinations of states or qualities do not occur. For example, the CDS weathering state could not occur with RQ strength or 160 pcf (2.55 g/cc) unit weight. Neither could MQ strength material occur with MFS weathering.

Design values of the four basic elements are not equivalent even though the same letter notation might apply. In general, rock material designated AAAA will require the least design evaluation while EEEE will require the most.

DISCUSSION

Information pertaining to rock material or rock masses in current contract specifications or design memoranda is sketchy and ambiguous, to say the least, even when supported by laboratory test data. The terminology used in drilling logs and geologic



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WILLIAMETTE N.F (EXAMPLE) HOLE NO. DH-1

PROJECT:	LOOKOUT CR. RSI	HOLE ELEV.:	2300
DISTRICT:	BLUE RIVER	DEPTH OF HOLE:	55.0
DATE:	5-2-80 TO 5-3-80	DEPTH TO ROCK:	10.0
DRILL RIG:	CD-20 ACKER MK IV	ROCK DRILLED:	45.0
HOLE DIA.:	3 INCH	DEPTH TO WATER:	28.0 GWL
HOLE LOC.:	N1385 E460	CASING DEPTH:	NQ WIRELINE

ELEVATIONS	DEPTH	DEG OF WEA	OPS	SYMBOL	MATERIALS	CORE RCVY %	SPECIFIC DATA COMMENTS
2300 – 2290	0 – 10	GM			ROCK FRAGMENTS with SILTY SAND SOIL UNIT A Brown, moist, above plastic limit, stiff	NA	DRY STRENGTH Low DILATENCY Quick TOUGHNESS Low
2290 – 2278	10 – 22				ROCK UNIT - 10 Brown, CDS, Fine-grained, MQ, 3-D ops EEEE – Drills to MBC rock fragments and sand SM	25% 30% 40%	ORIGIN Igneous - Intrusive STRENGTH < 1000 PSI CONSISTENCY Hard UNIT WT < 130 PCF
2278 – 2272 – 2270	22 – 28 – 30				Brown, PDS, MQ, 3-D ops DEED – Drills to DQ STS Rock Fragments and sand GM	75%	STRENGTH < 1000 PSI CONSISTENCY Hard 5-3-80 GWL
2270 – 2262	30 – 38				LT. Brown, STS, DQ, 3-D ops CCEB UNIT JOINT BLOCK EST. 1 FT.³	80% 95%	IMPACT DENTS STRENGTH 3000-8000 PSI UNIT WT 155 PCF
2262 – 2245	38 – 40 – 50				Gray, VFS, fine-grained, PQ, SRB BBAA	100% 100% 100% 100%	IMPACT PITS STRENGTH 8000-15000 PSI UNIT WEIGHT 172 PCF RECOGNITION FEATURE Clear, Light reflecting Crystals
					BOTTOM DEPTH 55.0 FT. ELEV. 2245 LOGGED D.A.W. 5-3-80		– Hole backfilled with sanded grout and marked with wooden 4x4 post

PROJECT: LOOKOUT CR. HOLE NO.: DH-1

ROCK SOURCE INVESTIGATION SHEET 1 OF 1

Figure 3. Example of boring log utilizing URCS notation.

WILLIAMSON—UNIFIED ROCK CLASSIFICATION

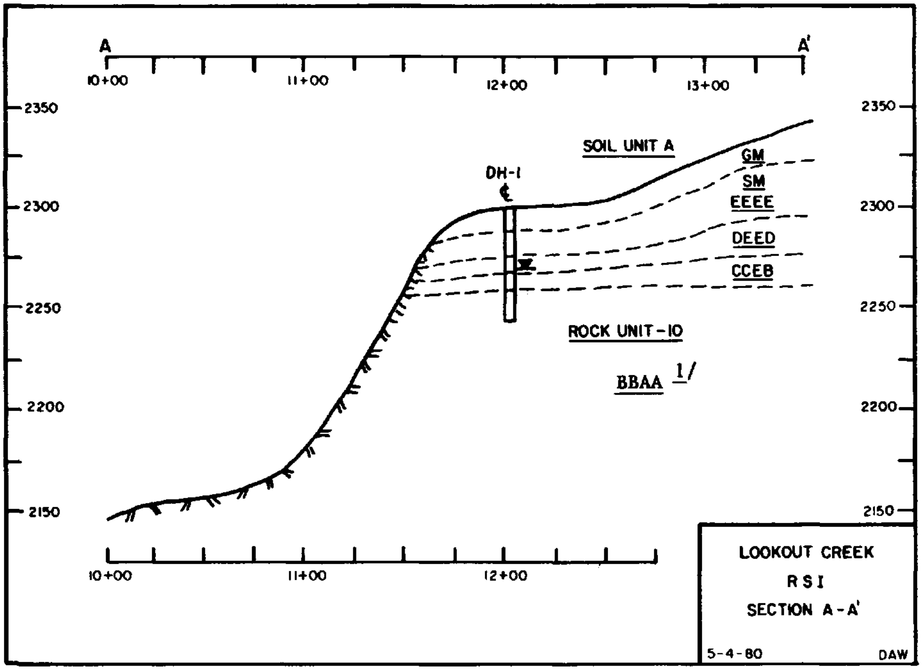


Figure 4. Example of geotechnical section utilizing URCS notation.

sections usually fails to provide understandable information to the contractor for purposes of bid estimates.

Here is an example of a rock description found in a typical contract specification or design memorandum:

> "Slightly weathered, moderately hard, highly fractured, lightweight rhyolitic rock."

This information is sincerely intended to portray actual conditions existing at a site and will provide the basis of the design, the cost estimate, and the judgment of the construction method required as well as the basis for defending the owner from future construction claims or extras.

Descriptive terms such as these vary widely in meaning, depending on both individual and professional experience, and cannot be quantified with any degree of precision or uniformity. Consequently, design decisions, cost estimates, or construction methods based on such information also vary widely.

The URCS offers a suitable alternative to this ambiguous, descriptive approach. The term "unified" refers to the necessary unification of geology and engineering for geotechnical purposes. The URCS equivalent of the typical rock description for contract specifications and design memoranda is CCED. This simple notation is based on uniform acceptable procedures used to define design conditions.

The CCED notation indicates that the degree of weathering of the rock is the stained state (STS) or not representative of the standard design condition that exists at the site and that comparative data will have to be determined. The strength of the rock material is dent quality (DQ) and has a range of unconfined compressive strength of 3,000 to 8,000 psi (21 to 55 MPa), which is comparable to the

1/ personal communication with author

strength of concrete. The rock mass has three-dimensional planar separations (3-D), which will be the primary design and construction consideration with respect to stability, excavation, and material use. The size, shape, volume and weight of the unit joint block have not been defined and will have to be determined as well as the continuity and attitude of the planes and degree of interlock of the joint blocks. Water transmission will have to be estimated or measured. The unit weight of the rock material is 130 to 140 pcf (2.10 to 2.25 g/cc), which indicates that there will be full loads for hauling equipment but that the material is probably not free draining nor can it be used in load-bearing fills or for surfacing.

This simple but well-defined verifiable design notation is suitable for graphic abstracts, boring logs, plans and sections, and other documentation. Since it is based on basic design elements, the notation provides a reliable means for decision. The notation registers rapidly in the mind during scanning and allows rapid comparison with several rock conditions. Similarities and differences can be established immediately. The simple notation minimizes drafting effort. The notation prevents subjective connotation and allows recording of the significant information on a scale appropriate to the investigation. The information can be checked and verified.

Examples of the notation in actual use on a boring log and on a section are presented as Figures 3 and 4, respectively.

CONCLUSION

The URCS furnishes a means by which persons from professional and technical disciplines who have different experience levels can communicate in a reliable and unambiguous manner about rock conditions.

REFERENCES

Casagrande, A., 1948, Classification and identification of soils: *American Society of Civil Engineers Transactions*, Vol. 113, pp. 901–930.

Terzaghi, K. and Peck, R. B., 1948, *Soil Mechanics in Engineering Practice:* John Wiley and Sons, Inc., New York, NY, 729 p.

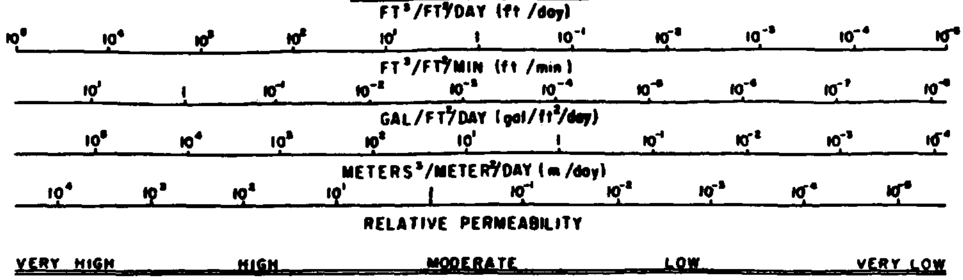
Williamson, D. A., 1961, Rock classification for engineering investigations, *20th Annual Meeting:* Oregon Academy of Science, Portland, OR, 6 p.

Williamson, D. A., 1978, *Unified Rock Classification System*, United States Department of Agriculture Forest Service Field Notes, Vol. 10, No. 11: U.S. Government Printing Office, Washington, DC, pp. 6–18.

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

APPENDIX II*

Hydraulic Conductivity



REPRESENTATIVE MATERIALS

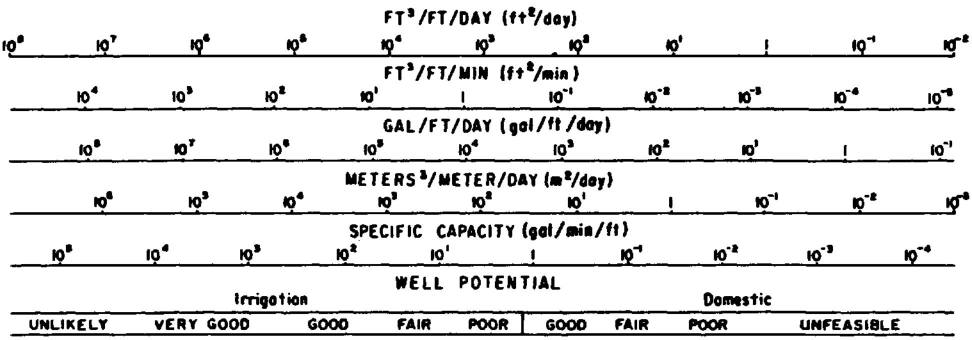
Clean gravel — Clean sand and sand and gravel — Fine sand — Silt, clay and mixtures of sand, silt and clay — Massive clay

Vesicular and scoriaceous basalt and cavernous limestone and dolomite — Clean sandstone and fractured igneous and metamorphic rocks — Laminated sandstone shale, mudstone — Massive igneous and metamorphic rocks

Figure 1 - Comparison of hydraulic conductivity and representative aquifer materials.

*Tables after Ground Water Manual, pp. 28-29.

TRANSMISSIVITY



NOTES: Transmissivity (T) = KM where
K = Permeability
M = Saturated thickness of the aquifer
Specific capacity values based on pumping period of approximately 8-hours but are otherwise generalized.

APPENDIX III

Geologic Rock Classification Systems

Geologic classification will be made using standard published systems for igneous, sedimentary, and metamorphic rocks. While the geologic classification may not always relate directly to engineering or other discipline needs, it serves two important purposes. First, the geologic terminology communicates mineralogic and textural characteristics to the geotechnical reader. Second, the geologic description indicates rock origin and mode of emplacement. Both of these are necessary requirements for the evaluation of rock units for engineering uses.

There are many geologic rock classification tables and systems; the decision of which to use is left to the discretion of the geologist. Some widely used examples include:

American Geological Institute, Data Sheets for Geology in the Field, Laboratory, and Office: ISBN 0-913312-38-X, Alexandria, VA. 22302.

Travis, Russell B., 1955, Classification of Rocks: Quarterly of the Colorado School of Mines, Vol. 50, No. 1.

Kemp, J. F., 1940, A Handbook of Rocks (for Use without the Petrographic Microscope): 6th ed., Revised and Edited by F. F. Grout, Van Nostrand, New York.

APPENDIX IV

ROCK UNIT CLASSIFICATION
(EXAMPLE)

Project: <u>Sandy Branch</u>
Date: <u>August 10-13, 1987</u>
Geologist: <u>Clay E. Stone</u>

1. <u>ROCK UNIT IDENTIFICATION</u>.

    (a) Designation: LA-3

    (b) Location: Left abutment between centerline stations 275+00 and 325+00 and extending throughout the reservoir pool area and down the valley between elevations 282 and 297 meters (925 and 975 feet) above MSL.

    (c) Outcrop confidence level: II

2. <u>CLASSIFICATION ELEMENTS</u>.

    (a) **ROCK MATERIAL PROPERTIES:**

    Rock name: sandstone bed (contained within the St. Peter sandstone).

    Mineralogy: 100 % quartz grains with carbonate cement.

    Texture: poorly graded, medium sand.

    Primary porosity: micro pores not free-draining.

    Discrete rock particle size: 80 % > 1.2 m (4 ft)

    Bedding thickness: 0.3-1.0 m (1-3 ft)

    Rock unit thickness: 12 m (40 ft)

    Rock hardness: moderately hard.

    Micro structures: ripple marks.

    Degree of weathering (URCS): B

    Estimated strength (URCS): B

    Unit weight (URCS): A

(b) **ROCK MASS PROPERTIES:**

Discontinuities (URCS): B

Strike and dip of formation: Strike: N 45 E. Dip: 5 SE. Measured at Station 280+00, uniform over entire site.

Joint analysis:
Spacing: Set 1: 1-2 m (3-6 ft, avg. 4)
Set 2: 2-3 m (6-10 ft, avg. 8)
Orientation: Set 1: N-S, vertical
Set 2: E-W, vertical
Length: Set 1: 12-23 m (40-75 ft)
Set 2: 9-15 m (30-50 ft)
Separation: Set 1: > 0.016 m (5/8 in), comprising 4 % cross-sectional area of rock unit.
Set 2: None
Joint wall rock: smooth
Joint tightness: Set 1: open
Set 2: tightly calcite cemented.

Other structures: Cross-bedded, beach type.

Geomorphic features: outcrop is well exposed and forms a prominent, broad, low ridge above left abutment.

Voids: none

RQD: 80

Seismic velocity: 4000 - 4300 m/s
(13,000 - 14,000 ft/s)

URCS: BBBA

(c) **GEOHYDROLOGIC PROPERTIES.**

Primary porosity: see above.

Secondary porosity: the two joint sets intersect at right angles, but Set 2 joints are well cemented. Angle hole drilling in abutment did not indicate stress relief joints. Secondary porosity not well developed in this rock unit.

Hydraulic conductivity: 10^{-7} m/s (10^{-1} ft/day)

Transmissivity: 10^{-4} m^2/s (10^2 ft^2/day)

Specific yield: 0.10

Aquifer type: unconfined

Water table: at Station 275+00, W.T. elev. was 286.8 m (882.0 ft) above MSL on 8/13/87. See map for water table contours.

3. <u>Photographic Documentation</u>.

(a) Photos nos. 1-11 show rock unit in outcrop between Stations 275+00 and 325+00 in 1.5 m (5 ft) increments.
(b) Photos nos. DH-275-1 through DH-275-10 show rock unit in core samples.

4. <u>PERFORMANCE ASSESSMENT</u>*.

Erosion Resistance:	Class I
Excavation Characteristics	Class I
Construction Quality	Class I
Fluid Transmission	Class II (fracture separation)
Rock Stability	Class I

* This example is for illustration only. Usually a rock unit is assessed for only one or two performance objectives rather than all five.

*U.S. Government Printing Office : 1987 - 180-917/60148