RECLAMATION

Managing Water in the West

Rock Manual
Part 2 (Introduction)

First Edition

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

Revised 2015

Mission Statements

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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prepared by

Technical Service Center
Geotechnical Services Division

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Preface

The Rock Manual provides common technical information on properties of rocks, field and laboratory investigations, and testing of rocks used as foundations and materials for dams, tunnels, canals, and many other types of structures built for Bureau of Reclamation (Reclamation) projects in the Western United States. The Rock Manual contains standardized, specialized, and general procedures that have been determined to be generally acceptable in the rock mechanics community for securing uniform results throughout Reclamation. It includes general guidelines intended to complement but not to substitute for sound engineering judgment and training to do the test or a strong background in rock mechanics. While many aspects of Rock Mechanics tests are covered in this manual, this manual is by no means all encompassing. For example, testing frozen rock is not covered specifically and only some of the many geophysical rock mechanics methods are covered.

The Web-based format is so the manual can be personalized and both the printed and the Web-based portions of the manual can be updated in a timely manner and uniformly Reclamation-wide. Computer links to sites outside Reclamation's jurisdiction should be used with caution as any content change will be outside Reclamation's control and will need to be more closely monitored on an individual basis. Custodians for this manual will make a good faith effort to keep the manual accurate and updated. Such efforts will be controlled by both available funding and personnel. Therefore, users will also be responsible for making sure they are using the correct or most update version of any portion of this manual. The Rock Manual is presented in two parts:

- Part 1 (to be developed) will provide the principles, contexts, and the general rock and foundation technology applicable to investigating and constructing water resources structures. Included in Part 1 will be chapters on the properties of rocks, principles and stages of rock investigations, and quality control of rock investigations.

- Part 2 contains standard, specialized, and general procedures for investigating and testing rock materials for engineering design, construction, and operation and maintenance of water resources structures. Research and development continue to produce improvements in the knowledge of geotechnical materials and methods in which those materials are evaluated. Therefore, users benefit from the latest technologies. Thus, the Rock Manual is presented in a Web-based format where technical material, regardless of the source, can be updated in a more timely and uniform manner and take advantage of the combined resources such as ASTM-International,

International Society for Rock Mechanics (ISRM), non-government sources, and other government agencies.

In a departure from the Earth Manual, and the original draft of the Rock Manual, where all the procedures were presented in a step-by-step format, most of the rock testing procedures in this manual are presented in a general format when possible. This was to simplify use, easily update, and cross correlate with other methods, as well as maintain uniformity in rock testing activities. Therefore, the more general the format, the more comprehensive background in rock mechanics principles and the specific tests a user must have.

Furthermore, consensus or other available standards are used where possible, which has the added benefit of complying with the Office of Management and Budget (OMB) Circular A-119 and the National Technology Transfer and Advancement Act of 1995, which direct all government agencies to use industry standards as much as possible in lieu of developing in-house standards to conserve government resources and to provide standardized practices. Specialized Reclamation standards are presented when no such standard exists in the industry or our requirements are such that none of the existing standards are applicable. These specialized Reclamation standards may consist of earlier, more detailed, standards developed under the original Rock Manual protocol. Similar standards by other resources are listed and when possible will have a hyperlink available to the user.

Attempts to standardize rock testing procedures are often frustrated by the complex nature of rock testing and in the materials themselves. Furthermore, it must be realized that rock and soil are often referred to as if they are two separate entities when in fact they are a continuum with many rocks being soil like and lending themselves to more soil like test methods and vice versa. Unlike testing of other construction materials such as concrete, steel, and asphalt, rock testing does not always lend itself to strict standardization and sometimes require significant professional judgment by the testing professionals with regards to the testing procedures. If variations from standard procedures outlined in this manual are deemed necessary, the alternative procedures must be described in detail when reporting the test data so proper interpretations are possible. The specialized procedures described in this manual are provided primarily for Reclamation. However, engineers and technicians from other government agencies, foreign governments, educational institutions, and private firms, should find them useful as well.

Acknowledgements

Preparing this manual was an imposing task requiring contributions and suggestions from engineers, scientists, and technicians (past and present) from many disciplines throughout and outside of Reclamation. The effort of all those who contributed to this work, both past and present is greatly appreciated.

Special recognition is accorded Jack Touseull whose resolute efforts were instrumental in completing Part 2 of the manual. W.G. Austin, J. Montgomery, H. Horton, and Dr. R. A. Sinha provided early coordination and development of the first of many drafts of the manual. Others contributors are R. Stansbury, B. Harper, J. Bowen, T. Strauss, and Z. Erdogan. Field and office personnel who participated or contributed are also appreciated. Part 2 of this First Edition was edited and coordinated by Deena Larsen and Cindy Gray.

ASTM-International participation and support by D-18 committee staff and membership is especially appreciated.

Acronyms

ASTM	American Society of Testing and Materials (now referred to as ASTM-International)
DSC	Differing Site Conditions
ISRM	International Society for Rock Mechanics
MDN	Modified Decimal Numbering
OMB	Office of Management and Budget
Reclamation	Bureau of Reclamation
USACE	U.S. Army Corps of Engineers

Contents

Using Standards

General

The Rock Manual is comprised of two Parts. Part 1, to be completed, will include chapters on the properties of rocks and general principles as well as stages of rock investigations. Part 2, which is this manual, is a compilation of the rock testing procedures currently recommended to be used by the Bureau of Reclamation. Specialized Reclamation standards are presented when no such standard exists in the industry or Reclamation requirements are such that none of the existing standards are applicable. Standards may consist of an earlier, more detailed, type standard developed under the original Rock Manual protocol. Reclamation specific standards tend to be much more detailed than comparable ASTM standards.

Earlier procedures that described instrumentation for monitoring dams for this manual were removed because there were redundant in other Reclamation publications (e.g., the Embankment Dam Instrumentation Manual or the Concrete Dam Instrumentation Manual).

OMB Circular-119 "Federal Participation in the Development and use of Voluntary Consensus Standards and in Conformity Assessment Activities" and section 12(d) of Public Law 104-113 "The National Technology Transfer and Advancement Act" direct government agencies to use industry standards as much as possible in lieu of developing in-house standards to conserve government resources. As a result, when appropriate, many of the Reclamation Standards were replaced with suitable standards that were already available in the private domain. Whenever possible, ASTM, ISRM standards, and other standards were either consulted or used in lieu of specialized USBR procedures and are listed under the appropriate USBR series number. Procedures specifically developed by USBR are written in a more detailed step-by-step format and include example data forms and work sheets.

The format for presentation of standard Reclamation laboratory procedures follows a Modified Decimal Numbering (MDN) System and a sequence of presentation similar to that ASTM uses. Each procedure has a four-digit number corresponding to the following categories:

Category USB	**R Series**
Equipment calibration	1000
Equipment specifications	2000
General test methods and definitions	3000
Cement and concrete test methods (Concrete Manual-Part 2)	4000
Soil test methods (Earth Manual-Part 2)	5000

Rock test methods	6000
Drilling and sampling methods	7000
General standards	9000
Accreditation and certification	9000
Equipment (list, inventory)	9100
Laboratory buildings	9200
Quality assurance, documentation, and reporting	9300

The Rock Manual Part 2 covers standards in the series: 1000, 3000, 5000, 6000, and 9300. Standards or methods for some categories are not yet developed, are under development, or are found in other Reclamation publications such as the Earth Manual (Part 2). A list of all the rock testing resources available under the ISRM Suggested Methods and a list of resources from the U.S. Army Corps of Engineers (USACE) Rock Testing Manual can be found on the "Rock Manual" Web site via Reclamation's Technical Service Center Web site at: http://www.usbr.gov/tsc/.

Modifications to Test Procedures

Test procedures were prepared to maintain testing conformance and consistency throughout Reclamation. Modifying a test procedure may be required because of the type of material to be tested or for a specific design or construction requirement. Modifications must be based on sound engineering judgment; a description of a modification must be included on the test data form(s) and when reporting the test data.

The test procedures described in Part 2 are standard methods and must be performed exactly as prescribed unless modifications are justified and approved by management. Any variation in procedure is considered a modification, for example:

- A change in conditioning or testing time
- A test specimen that is more soil like
- A change in the specimen size or the maximum particle size allowed

Although test procedure steps may need to be varied, the equipment specified for the tests in this manual may not be modified under any circumstance without written approval of management. For Reclamation, that approval would come from the Technical Service Center at the Denver Office. Any deviations must be documented and reported with the test results so that proper interpretations can be made.

Contract Specifications

When a significant difference exists between the information in Part 2 and contract specifications, the contract specifications always take precedence.

Terminology

Due to the multiple sources for the standards the uniformity in terminology and symbols is maintained as much as possible throughout the Rock Manual by use of USBR 3900, "Standard Definitions of Terms and Symbols Relating to Rock Mechanics" and which references ASTM and ISRM terminology. Unless otherwise noted, the terms and symbols used in this Manual conform to USBR 3900.

Applicability and Use of Test Results

The test procedures describe how a test is to be performed. Note that only brief references are cited concerning the reasons tests are performed and how test results are used. These topics are discussed in more detail in Part 1. However, both the author(s) of the test program and the testing personnel should be aware of how a procedure applies for the material to be tested. Before a material is tested, it should be determined whether the test procedure is appropriate for a given situation or if the test procedure must be modified for the specific rock to be tested. In some cases, this may not be apparent until the test is begun, at which time a decision either to discontinue the test or to modify the procedure is needed by the project engineer and/or the contracting officer or their designated representative.

For some materials, such as shale, sandstone, siltstone, conglomerate, non-planar discontinuities etc., test results may not reflect the in-place properties of the material due to changes that may occur during the sampling process or due to the scale of the test specimen.

When a procedure is modified, or if test results are considered inappropriate, explanations must be included on the test data forms and when reporting the test data. Explanatory statements are required, for example, when:

(1) Changes in the sample size or sampling techniques Specified in a standard should be explained.

(2) The properties of some materials are irreversibly affected by air or oven drying. Rocks and discontinuities containing organic matter, certain clay materials (such as allophane or halloysite) or hydrous minerals (such as gypsum or actinolite) have different properties after being air dried even though water is later added to bring them back to their original moisture content. When results of tests on these rocks are critical, the samples should not be allowed to dry below their *in-situ* (in-place) moisture content.

Other examples and more detailed discussions of the applicability of test results will be given in Rock Manual Part 1.

Calibration

Separate procedures were prepared for equipment calibration. Regular, careful calibration and inspection of equipment are as important as adhering to proper testing procedures to ensure acceptable accuracy of test results. Results of rock testing can be only as accurate as the procedures and equipment used in performing the tests. These procedures are shown in the USBR 1000 series.

Balances or Scales

In almost every test procedure, a balance or scale is listed in the "Apparatus" paragraph with the load capacity required to measure the mass for that procedure. The readability specified for each balance or scale is normally that required within the procedure to obtain measurements of sufficient accuracy for reliable test results. In some cases, there may be differences between the balance capacity stated and the requirements of the procedure. The intent throughout the Rock Manual Part 2 is to limit the number of balances or scales required for a particular laboratory. Therefore, the capacities of balances or scales used in a typical geotechnical laboratory were cited. If the balances or scales available in a given laboratory are different from those typically required, the capacities must be compared with those described in the procedure to ascertain if sufficient capacity is available to perform the test.

The precision or accuracy required for a balance or scale is not given in the individual procedures, but acceptable tolerance for any error difference is specified in USBR 1012 "Calibrating Balances or Scales."

Tare Mass

In many test procedures, the mass of a container is to be determined and later subtracted from the mass of the container plus its contents. It is permissible to use a tare mass or tare setting equal to the mass of the container so that the mass of the container need not be recorded.

Data Forms and Checking

Where available, test procedures in Part 2 include example data forms and illustrate what data are required and where they are to be recorded. Checking data computations is as important as performing the test; the test is not considered

complete until the data form has been checked. Checkmarks are not shown on the example data forms so that required data could be illustrated in a neat and legible fashion. Instructions for checking, and an example of a typically checked data form are presented in USBR 9300, "Checking, Rounding, and Reporting of Laboratory Data." This document should be reviewed and understood as it is considered part of every test procedure.

Proprietary Materials

Occasionally, references are made to proprietary materials or products; references must not be construed as an endorsement. Reclamation does not and cannot endorse proprietary products or processes of manufacturers or the services of commercial firms for advertising, publicity, sales, or other purposes.

ASTM standards are copyrighted and a legal, current copy must be obtained by the user. Copies contained in this manual are for reference only and are not necessarily the most current copy. Reclamation staff can obtain copies through the Reclamation's library, which has a license for downloading the most current edition off the ASTM Web site.

Legal Reasons

Valid laboratory data can be valuable for reasons ranging from simply determining the actual engineering properties for engineering design studies to the establishment of an information data bank for later use in possible litigation. Damage claims arising from dam construction and/or ancillary structures, both during or post construction, from adverse events or contractor claims of differing site conditions (DSC) can reach many millions of dollars. Laboratory data can help determine rock substance mechanical properties (e.g., Stillwater Dam, Central Utah Project, Utah; crushing cost claim) and other causes of adverse events, so that proper legal adjudication can be accomplished or prevented.

Future Revisions

Each test procedure has a fixed USBR procedure number followed by the year of acceptance or the year of last revision. Revisions will be issued and custodians for this manual will make a good faith effort to keep the manual accurate and updated. Such efforts will be controlled by both available funding and personnel. Therefore, users must ascertain if the correct or most update version of any portion of this manual is being used.

After each Reclamation test procedure was written, it was checked, validated whenever practical, and extensively reviewed. However, because the procedures are presented in a new format covering both new procedures and revisions to

existing procedures, possible errors and omissions may exist. User comments and suggestions for improvement are invited and should be directed to the Bureau of Reclamation; Denver Office; Technical Service Center.

It is important for users to realize that ASTM standards are required to be reapproved and/or revised a minimum of every 5 years and are dropped after the eighth year if neither of these actions occurs. Therefore, any standard older than 5-8 years is potentially outdated and should be used with caution. Dates associated with ASTM standards provide the user with the following information:

- The date immediately after the ASTM numerical designation indicates the year of original adoption or, in the case of revision, the year of last revision year the standard was technically revised.

- Any date between parentheses is the year of last reapproved, but without any technical revisions.

- A new date for any ASTM standard that was revised may or may not be truly updated technically as the revision could range from something insignificant, like correcting an error on one figure, to a major rewrite of the standard. Some, but not all, ASTM committees have a "summary of changes" at the end of the standard to help the user to address the significance of the changes that were made.

- The number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision.

- A superscript epsilon "ε" following any numerical date means that only editorial changes were made.

- A superscript epsilon "ε" in the text indicates an editorial change since the last revision or re-approval.

What this means is that the user may have to use professional judgment to determine if the standard is actually current. If needed, users may order a redline edition of any ASTM standard which show the changes on the current version of the standard, from the previous version.

Denver Office Organization

Bureau of Reclamation organizational units are noted in the introduction of each test procedure and within the text of others. Recent organizational changes make those references obsolete; where those references are cited, inquiries should be directed to:

Bureau of Reclamation
Technical Service Center
PO Box 25007
Denver, Colorado 80225-0007

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