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Technical Lead
Scott Stovall

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LABORATORY INVESTIGATIONS OF SOILS AND ROCKS FOR ENGINEERING ANALYSIS AND DESIGN OF NUCLEAR POWER PLANTS

A. INTRODUCTION

Purpose

This guide describes laboratory investigations and testing practices acceptable to the staff of the U.S. Nuclear Regulatory Commission (NRC) for determining soil and rock properties and characteristics needed for engineering analysis and design of foundations and earthworks for nuclear power plants. Existing standards reflect the state of the art of laboratory practices for testing soils and rocks; where appropriate, this guide discusses and references such standards.

Applicable Regulations

- Appendix A to Title 10, Part 50, of the *Code of Federal Regulations* (10 CFR Part 50), "Domestic Licensing of Production and Utilization Facilities" (Ref. 1) governs the licensing of nuclear power plants and provides general design criteria (GDC).

- 10 CFR Part 52 "Licenses, Certifications, and Approvals for Nuclear Power Plants," (Ref. 2) governs the issuance of early site permits, standard design certifications, combined licenses, standard design approvals, and manufacturing licenses for nuclear power facilities licensed under Section 103 of the Atomic Energy Act of 1954, as amended (68 Stat. 919), and Title II of the Energy Reorganization Act of 1974 (88 Stat. 1242).

- 10 CFR Part 100, "Reactor Site Criteria" (Ref. 3), requires the NRC to consider the physical characteristics of a site including seismology and geology in determining the site's acceptability for a nuclear power reactor. In particular, 10 CFR 100.20(c), 10 CFR 100.21(d), and 10 CFR 100.23, establish requirements for conducting site investigations for nuclear power plants license applications submitted after January 10, 1997. The evaluation of a site for seismic response analyses and engineering design requires information about the static and dynamic engineering properties of the site's soil and rock materials.

Written suggestions regarding this guide or development of new guides may be submitted through the NRC's public Web site under the Regulatory Guides document collection of the NRC Library at http://www.nrc.gov/reading-rm/doc-collections/reg-guides/contactus.html.

Electronic copies of this regulatory guide, previous versions of this guide, and other recently issued guides are available through the NRC's public Web site under the Regulatory Guides document collection of the NRC Library at http://www.nrc.gov/reading-rm/doc-collections/. The regulatory guide is also available through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html, under ADAMS Accession No. ML14289A600. The regulatory analysis may be found in ADAMS under Accession No. ML14289A602. No public comments were received on this revision of RG 1.138.

Related Guidance

- Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations" (Ref. 4), discusses characteristics that affect a site's suitability.

- Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants" (Ref. 5), discusses programs of field studies, exploratory borings, and sampling needed to provide geotechnical data for site evaluation and engineering analysis and design.

Purpose of Regulatory Guides

The NRC issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations and compliance with them is not required. Methods and solutions that differ from those set forth in regulatory guides are acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license.

Paperwork Reduction Act

This regulatory guide contains information collection requirements covered by 10 CFR Part 50, 10 CFR Part 52, and 10 CFR Part 100 that the Office of Management and Budget (OMB) approved under OMB control number 3150-0011, 3150-0151, and 3150-0093, respectively. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

B. DISCUSSION

Reason for Revision

The guide was revised to reflect the current standards for testing procedures. Much of this revision involved updating of references. The most significant change is in Section C.6.3, "Resonant Column Tests," which provides an alternative method for resonant column and torsional shear testing of soil and rock samples.

Background

In the course of site investigations and analyses for nuclear power plant facilities, the purpose of a laboratory-testing program is to identify and classify soils and rocks, and to evaluate their physical and engineering properties. The NRC staff reviews the information obtained from site investigations and laboratory tests and considers the safety aspects of applying the data to the design and construction of nuclear plants. Consideration of public safety imposes particularly stringent requirements on the design and construction of nuclear power plant facilities. Therefore, it is essential that investigators carefully plan and carry out all phases of a site investigation program to ensure that the associated field and laboratory testing realistically determine the properties of the soil and rock.

The site and laboratory investigations will depend on actual site conditions, the nature of problems encountered or suspected at the site, site parameters defined by the design of the nuclear power plant to be built on the site, and design requirements for foundations and earthworks. Therefore, the site investigation program should be flexible and tailored to each site and plant design as the site and laboratory investigations proceed. Experienced engineers and geologists who have demonstrated competence in the field of soil and rock mechanics testing and familiarity with the site should direct the site investigation program. Specific testing requirements and details of testing procedures will depend on the nature of the soils and rocks encountered. Normally, the investigation should follow testing procedures that are generally known and accepted because they are easy to reproduce and their effects on test results are well understood. Depending on the nature of the soil and rock material, it may be more appropriate and desirable to modify existing standard procedures; however, it is important to describe such test procedures fully so that other investigators can reproduce the test and verify the results. Appendix A shows the laboratory procedures for some of the most common tests, with related references.

NUREG/CR-5739, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Facilities" (Ref. 6) provides the technical basis for this guide. The NRC developed NUREG/CR–5739 to reflect current and state-of-the-art techniques for laboratory testing of soils and rock. It summarizes the processes for a laboratory testing program, ranging from storage, selection, handling of test specimens to static, and dynamic testing methods and equipment.

Harmonization with International Standards

The International Atomic Energy Agency (IAEA) has established a series of safety guides and standards constituting a high level of safety for protecting people and the environment. IAEA safety guides present international good practices and increasingly reflect best practices to help users striving to achieve high levels of safety. Pertinent to this regulatory guide, IAEA Safety Guide NS-G-6, "Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants," (Ref. 7) provides guidance on the methods and procedures for analyses to support the assessment of the geotechnical aspects of the safety of nuclear power plants.

Documents Discussed in Staff Regulatory Guidance

This regulatory guide endorses the use of one or more codes or standards developed by external organizations and other third-party guidance documents. These codes, standards and third-party guidance documents may contain references to other codes, standards, or third-party guidance documents ("secondary references"). If a secondary reference has itself been incorporated by reference into NRC regulations as a requirement, then licensees and applicants must comply with that standard as set forth in the regulation. If the secondary reference has been endorsed in a regulatory guide as an acceptable approach for meeting an NRC requirement, then the standard constitutes a method acceptable to the NRC staff for meeting that regulatory requirement as described in the specific regulatory guide. If the secondary reference has neither been incorporated by reference into NRC regulations nor endorsed in a regulatory guide, then the secondary reference is neither a legally-binding requirement nor a "generic" NRC-approved acceptable approach for meeting an NRC requirement. However, licensees and applicants may consider and use the information in the secondary reference, if appropriately justified, consistent with current regulatory practice and applicable NRC requirements.

C. STAFF REGULATORY GUIDANCE

1. Laboratory Testing Program

1.1. Laboratory Facilities

Laboratory facilities for soil and rock testing should include adequate test space, temperature-controlled areas, and adequate ventilation and airflow. Separate areas, and preferably separate rooms, are desirable for dust- and vibration-producing activities such as sieve analyses, compaction tests, and sample processing. Normally, samples should be tested on arrival from the field, or as soon as possible. If storage is required, investigators should consider storing samples in a separate room with the relative humidity maintained at or near 100 percent. The facility should have the proper equipment necessary to perform the types of tests for which the facility is designed.

1.2. Laboratory Equipment

When standard laboratory testing procedures are used, the test apparatus should conform to the published specifications. When the testing apparatus does not satisfy published specifications, investigators should supply a complete description of the essential characteristics of the apparatus with appropriate references to published papers, reports, or monographs. To ensure that essential characteristics (such as dimensions, mating of parts, piston friction, and fluid seals) are not significantly altered by wear, handling, corrosion, dirt, or deterioration of materials, all testing apparatus should be inspected and maintained regularly.

For additional information, U.S. Army Corps of Engineers Engineering Manual (EM) 1110-2-1906, “Laboratory Soils Testing” (Ref. 8), issued in 1986, Das (1992, Ref. 9), and Head (1992, Ref. 10) discuss the use and care of laboratory equipment in detail. American Society for Testing and Materials (ASTM) Standard D4753, “Standard Specification for Evaluating, Selecting and Specifying Balances and Scales for Use in Soil, Rock, and Construction Materials Testing” (Ref. 11), describes specifications for balances and scales. In addition, IAEA Safety Guide NS-G-6 contains valuable discussions of common problems, precautionary measures, and control of errors in the testing of soils. Scholey et al. (1995, Ref. 12) present a review of instruments for measuring small strain. Germaine and Ladd (1988, Ref. 13) discuss problems associated with triaxial testing of saturated cohesive soils, including errors caused by the equipment or the procedures used.

1.3. Calibration

a. Investigators should calibrate all test apparatus and instruments used for quantity measurement against certified calibration standards before putting them into service. Thereafter, they should verify the calibration at regular intervals. The necessary frequency for recalibration varies according to the susceptibility of the apparatus to change and the required precision of measurement. Physical length or volume measuring apparatus such as metallic tapes, rules, pycnometers, cylinders, or graduated cylinders need not be calibrated unless altered by visible wear or damage.

b. An external agency with equipment directly traceable to the National Institute of Standards and Technology should periodically recalibrate weights and other equipment used as standards to calibrate test instruments.

c. Instrument calibrations may be performed in house using the specific laboratory’s own standards of references.

For additional information on calibration, U.S. Army Corps of Engineers EM 1110-2-1909, "Calibration of Laboratory Soils Testing Equipment" (1986, Ref. 14), recommends procedures for calibrating testing equipment. ASTM D3740, "Standard Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction" (Ref. 15) and Sallfors (1989, Ref. 16) offer information on equipment calibration and its importance, respectively.

1.4. Reagents and Water

Chemical testing in a soil laboratory is usually limited to routine tests and the methodology should be documented. These tests determine such constituents as organic matter, chlorides, pH value, and sulfates.

For additional information on chemical testing, Head (1992, Ref. 10) provides information on the most widely used chemical tests for soils and groundwater.

2. Handling and Storage of Samples

a. The laboratory should verify the identification markings of all samples immediately upon their arrival and maintain an inventory of all samples received.

b. Since the handling and storage of samples can affect their material properties, it needs to be considered in analyzing their properties.

For further information on storage and reconsolidation procedures see Graham et al. (Ref. 17); for prevention of sample deterioration see Brown and Chow (Ref. 18); and for preserving and transporting soil samples see ASTM D4220 (Ref. 19). It is important that the laboratory examines and tests disturbed samples as soon as possible after they arrive; however, large testing programs may require storage of the samples for several days or weeks. Samples to be used for fluid content determinations, however, should be protected against change in water content.

2.1. Undisturbed Samples

Undisturbed samples should be protected from vibration, shock, significant temperature changes, and changes in water content. Moisture seals should be checked periodically and renewed as needed. Even the most careful sealing and storing of undisturbed samples cannot prevent physical and chemical changes. Therefore, the samples should not be retained for long periods, particularly if in contact with unprotected steel tubes. Storage for long periods may discredit any subsequent determination of their engineering properties. The duration of storage before testing should be recorded for each sample test. Samples that have been stored for long periods should not be considered to have the characteristics of undisturbed samples and, therefore, should not be tested as such. Delays between sampling and testing and the control kept over specimen volumes during storage affect the strength and compressibility of clay specimens measured in the laboratory.

2.2. Rocks

Rock samples should be treated as fragile material and protected from excessive changes in humidity and temperature. Like soil samples, rock samples should be examined and tested as soon as possible. For a large testing program, the rock specimens may be stored, but every effort should be made to protect the stored samples against damage.

3. Initial Identification and Examination of Samples

The initial description of a sample should include, but should not be limited to, what investigators can see, feel, and smell.

For additional information, ASTM D2488, "Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)" (Ref. 20), describes procedures necessary to describe and identify a soil sample based on visual identification and manual testing. ASTM D4452, "Standard Methods for X-Ray Radiography of Soil Samples" (Ref. 21), describes procedures before x-ray testing of soil samples for the detection of inherent abnormalities and disturbances. This guidance is especially useful for undisturbed samples. ASTM D2487, "Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)" (Ref. 22), describes the various soil groups in detail and discusses the method of identification so that those who use the system can follow a uniform classification procedure. U.S. Army Corps of Engineers Rock Testing Handbook (RTH) Standard 102-93, "Recommended Practice for Petrographic Examination of Rock Cores" (Ref. 23), describes procedures to use in the petrographic examination of rock core samples. Petrographic examinations determine the physical and chemical properties of a material, describe and classify a sample, and determine the amount of specific materials that may affect the specimen's intended use.

4. Selection and Preparation of Test Specimens

4.1. <u>General</u>

a. Undisturbed samples of earth fill should be taken for confirmatory testing during construction and in the testing and re-evaluation of existing structures.

b. Procedures for preparing soil samples for testing should be documented. Details of procedures depend on the nature of the test and the specimen.

For additional information, EM 1110-2-1906 describes procedures for preparing soil samples for testing, and ASTM D4452 can be used to determine the quality of a sample before testing. Regulatory Guide 1.132 discusses methods of determining the in situ density of cohesionless soils.

c. The selection of soil and rock specimens for laboratory testing requires careful examination of records of borings and available samples. To permit establishment of the soil profile, investigators should ensure that test specimens are representative of the soil or rock unit to be tested and should describe them accurately. The number of test specimens should be sufficient to produce statistically meaningful test results. Investigators should identify average test values of material properties as well as the range of values that identify their variability. In addition to the most representative samples, investigators should also test samples that have extreme properties and represent critical zones.

For additional information, Regulatory Guide 1.132 offers guidelines for spacing of borings and frequency of sampling. Additional boring and sampling may be required when laboratory examination of the samples reveals an inadequate number or distribution of suitable samples to meet testing requirements.

4.2. Undisturbed Samples

a. Undisturbed test samples should be prepared to preserve the natural structure and water content of the material. The sample should always be prepared in a humid room. Trimming instruments should be sharp and clean and the sample adequately supported.

b. Investigators should examine undisturbed tube samples of soils for evidence of disturbance. A serious source of damage to undisturbed soil samples is the extrusion of the samples from the sample tubes. One method that may minimize damage during the removal of samples from thin-wall tubes is to split the tube lengthwise by milling. Another method is to saw the tube transversely into segments of sufficient length to extrude a single test specimen from each and then trim off the ends. It is important, however, to consider the fact that milling may cause disturbance and changes in the void ratio in some soils, particularly in loose sand. Dressing the cut tube edges before extruding samples from the tube sections reduces disturbance of the sample. Reuse of thin-walled sample tubes is not recommended if they have been damaged in the process of retrieving or extruding samples. Undisturbed tube samples should satisfy the following criteria:

(1) The specific recovery ratio should be between 90 and 100 percent; a tube with less recovery may be acceptable if it appears that the sample was broken off, but appears otherwise undisturbed. Investigators should record and document the actual recovery obtained.

(2) The surface or sliced sections of the sample should have no visible distortions, planes of failure, pitting, discoloration, or other signs of disturbance that can be attributed to the sampling operation or handling of the sample.

(3) The net length and weight of the sample and the results of other control tests should not have changed during shipment, storage, and handling of the sample.

c. In addition to the above, samples that have been subjected to violent mechanical shocks or to accidental freezing and thawing should not be considered undisturbed, even if other evidence of disturbance is absent.

d. To permit establishment of the soil and geologic profiles, investigators should ensure that test specimens are representative of each discrete soil or rock unit to be tested and are accurately described on the basis of classification tests. Physical and engineering property tests of in situ soils, whether cohesive or cohesionless, should use the highest quality and most representative undisturbed samples available.

e. Trimming and shaping of test specimens of soils require great care to prevent disturbance and changes in water content. Frozen samples should be prepared under conditions that will prevent premature thawing.

f. Laboratory personnel should record a complete detailed description of the specimen that includes, but is not limited to, the material, color, consistency, and brittleness of the material and any indication that the boring samples were disturbed. Personnel should not use disturbed samples for any test other than classification and tests that do not require an undisturbed sample. When a sample is disturbed, its seal may be broken and that sample cannot be used for water content.

4.3. Reconstituted or Remolded Samples

All tests of strength and dynamic responses of in situ soils, whether cohesive or cohesionless, should use high-quality, undisturbed samples. In some instances, however, reconstituted or remolded samples may be used when representative undisturbed samples cannot be obtained. Remolded samples are also used as representative of compacted fill or backfill material for new construction. Reconstituted specimens representative of in situ material should be molded to the in situ density and moisture content as determined from actual field measurements.

4.4. Scalping of Large Particles

Since standard-size laboratory testing equipment will not readily accommodate gravel and large particles, such materials should be removed from the total sample, and the finer fraction tested.

For additional information on accounting for large particles, Torrey and Donaghe (1991, Ref. 24) discuss fractional analysis of density for compaction control measures to account for scalped gradation, and Evans and Zhou (1995, Ref. 25) report the effects on cyclic strength of the inclusion of gravel size particles in various gradations of granular soils.

4.5. Laboratory Testing Program

a. The study of soil and rock mechanics covers the investigation, description, classification, testing, and analysis of soil and rock to determine their interaction with structures built in, upon, or with them. The physical properties of soils and rocks should be determined by carrying out tests on samples of soil in a laboratory. These tests fall into two main categories: classification tests and engineering properties tests. Classification tests indicate the general type of soil and the engineering category to which it belongs. Specific tests to determine engineering properties require careful consideration of field conditions, various design loading conditions, material properties, and possible problems at the site. The focus of laboratory investigations should depend on the design requirements and nature of problems encountered or suspected at the site.

b. In addition to the usual geotechnical engineering considerations, the investigation and evaluation of sites for nuclear power plants requires an evaluation of the site’s response to earthquake loading and other dynamic loading conditions. Such analyses include the evaluation of wave propagation characteristics of subsurface materials with interaction effects of structures, analysis of the potential for soil liquefaction, settlement under dynamic loading, and analysis of the effects of earthquake loading on the stability of slope and embankments.

c. The basic parameters required as input for dynamic response analyses of soils include total mass density, relative density, Poisson’s ratio, static soil strength, initial stress conditions, shear and compressional wave velocities, and the dynamic shear modulus and damping ratio. Such analyses also need the variation of strength, moduli, and damping with strain.

5. Testing Procedures for Determining Static Soil Properties

5.1. General

Laboratory tests on soil and rock material should be thorough and of sufficient documented quality to permit a realistic estimate of soil and rock properties and subsurface conditions. Personnel experienced in laboratory practices for soil testing should be responsible for handling samples, preparing test specimens, specifying testing procedures and operations, and completing all related documentation.

5.2. Soil Testing

a. Laboratory personnel should perform classification tests and engineering properties tests according to an accepted and published method. Appendix A shows laboratory procedures for some of the most common tests, along with other related references. These include the following:

(1) water content
(2) permeability
(3) unit weights
(4) consolidation
(5) void ratio
(6) direct shear
(7) porosity
(8) triaxial compression
(9) saturation
(10) unconfined compression
(11) Atterberg limits
(12) relative density
(13) specific gravity
(14) grain size analysis
(15) erodibility
(16) compaction

b. The number of tests required in a laboratory investigation program will depend on the type of material, the quality of samples, the purpose and relative importance of the test, and the scatter of test data. In general, investigators should first identify and classify all soils and rocks sampled at the site using appropriate index and classification tests. The Unified Soil Classification System (ASTM D2487) should be used to describe soils and prepare soil profiles, while ASTM D5878, "Standard Guide for Using Rock Mass Classification Systems for Engineering Purposes" (Ref. 26) should be used to classify rock mass for specific engineering purposes. Further tests required to establish physical and engineering properties should be sufficient to define the range of values for material properties. The number of tests should be sufficient to cover the range of values expected under field conditions.

c. Standard test procedures, when followed without deviation and performed on standard equipment, require documentation by reference only. For tests for which no standard procedures are available or for which modified or alternative procedures are appropriate, laboratory personnel should document the details of the test procedures for evaluation and future reference. Personnel should document the technical basis for deviating from standard testing procedures. Use of nonstandard equipment, even if it is used with standard testing procedures, should also be documented.

5.3. Tests of Groundwater or Surface Waters

Testing of groundwater and surface water depends on the nature of potential problems identified at the site. Acid water, for example, may cause the degradation of carbonate rocks and concrete foundations. Standard methods of testing water for physical, chemical, radioactive, and microbiological properties are described in "Standard Methods for the Examination of Water and Wastewater" (American Public Health Association, American Water Works Association, and Water

Environment Federation, 1999, Ref. 27). This reference also describes methods of testing polluted water, wastewater, effluent, bottom sediment, and sludge. Investigators should use standard testing methods unless they encounter special problems that require modifications or alternative methods.

6. Testing Procedures for Determining Dynamic Soil Properties

6.1. General

To ensure a realistic assessment of soil properties, it is important that the laboratory tests represent field conditions as closely as is practical. Before performing dynamic tests, laboratory personnel should determine the initial state of stress in the soil and perform a series of static consolidated-drained and consolidated-undrained triaxial compression tests to determine static strength. The dynamic testing program should include tests to determine the soil parameters needed as input for reference analyses and studies of soil structure interaction and to determine the dynamic strength characteristics and liquefaction potential of soils.

For additional information, Appendix A lists some laboratory investigations and testing procedures for determining dynamic soil properties and soil behavior, with related references. Dynamic soil property testing includes cyclic triaxial tests and resonant column tests.

6.2. Cyclic Triaxial Tests

a. Investigators should use laboratory cyclic tests only to establish parametric effects on cyclic strength behavior. Because test equipment is readily available and the preparation of undisturbed specimens is relatively easy, the most common cyclic loading technique for investigating liquefaction resistance historically has been the cyclic triaxial test—in spite of wide recognition of the test's inability to accurately represent field earthquake stresses and boundary conditions (Seed and Idriss, 1982, Ref. 28). Other research studies have demonstrated that laboratory-determined cyclic triaxial strengths (in fact, strengths determined from any unidirectional loading test) are higher than those expected to produce equivalent effects in the field (Seed, 1976, Ref. 29). Research also has shown that estimation of field cyclic test results may not be possible by universal application of sample factors (e.g., gradation, density, and soil type) (Koester, 1992, Ref. 30).

b. Since the cyclic triaxial test does not accurately model the stress conditions in situ, investigators should exercise caution when using laboratory-obtained soil cyclic strengths and should make appropriate downward adjustments of cyclic stress values obtained from triaxial tests, as required. Documentation should present and reference the rationale behind the adjustment and the data supporting its magnitude.

For additional information, see Tatsuoka et al. (1994 Ref. 31), on cyclic triaxial tests of sand and gravel and Vucetic and Dobry (1991 Ref. 32), on cyclic triaxial tests in clays.

6.3. Resonant Column Tests

a. ASTM D4015, "Standard Test Methods for Modulus and Damping of Soils by the Resonant-Column Method" (Ref. 33), provides acceptable testing procedures to determine the shear modulus, shear damping, rod modulus (Young's modulus), and rod damping for solid cylindrical specimens of soil in undisturbed and remolded conditions by vibration using the resonant column.

b. As an alternative, "Technical Procedures for Resonant Column and Torsional Shear Testing of Soil and Rock Samples," Procedure PBRCTS-1 (University of Texas at Austin, 2000, Ref. 34) can also be used.

For additional information, Appendix A discusses the limitations and applicability of these tests and gives related references.

7. Testing Procedures for Determining the Engineering Properties of Rock

Investigators should perform testing procedures for determining the engineering properties of rock according to accepted and published methods.

For additional information, Appendix A outlines and gives references for common testing procedures.

D. IMPLEMENTATION

The purpose of this section is to provide information on how applicants and licensees[1] may use this guide and information regarding the NRC's plans for using this regulatory guide. In addition, it describes how the NRC staff complies with 10 CFR 50.109, "Backfitting," and any applicable finality provisions in 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

Use by Applicants and Licensees

Applicants and licensees may voluntarily[2] use the guidance in this document to demonstrate compliance with the underlying NRC regulations. Methods or solutions that differ from those described in this regulatory guide may be deemed acceptable if they provide sufficient basis and information for the NRC staff to verify that the proposed alternative demonstrates compliance with the appropriate NRC regulations. Current licensees may continue to use guidance the NRC found acceptable for complying with the identified regulations as long as their current licensing basis remains unchanged.

Licensees may use the information in this regulatory guide for actions which do not require NRC review and approval such as changes to a facility design under 10 CFR 50.59, "Changes, Tests, and Experiments." Licensees may use the information in this regulatory guide or applicable parts to resolve regulatory or inspection issues.

Use by NRC Staff

The NRC staff does not intend or approve any imposition of the guidance in this regulatory guide. The NRC staff does not expect any existing licensee to use or commit to using the guidance in this regulatory guide, unless the licensee makes a change to its licensing basis. The NRC staff does not expect or plan to request licensees to voluntarily adopt this regulatory guide to resolve a generic regulatory issue. The NRC staff does not expect or plan to initiate NRC regulatory action which would require the use of this regulatory guide, including issuance of an order requiring the use of the regulatory guide, requests for information under 10 CFR 50.54(f) as to whether a licensee intends to commit to use of this regulatory guide, generic

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1 In this section, "licensees" refers to licensees of nuclear power plants under 10 CFR Parts 50 and 52, and the term "applicants" refers to applicants for licenses and permits for (or relating to) nuclear power plants under 10 CFR Parts 50 and 52, and applicants for standard design approvals and standard design certifications under 10 CFR Part 52.

2 In this section, "voluntary" and "voluntarily" means that the licensee is seeking the action of its own accord, without the force of a legally binding requirement or an NRC representation of further licensing or enforcement action.

communication, or promulgation of a rule requiring the use of this regulatory guide without further backfit consideration.

During regulatory discussions on plant-specific operational issues, the staff may discuss with licensees various actions consistent with staff positions in this regulatory guide as one acceptable means of meeting the underlying NRC regulatory requirement. Such discussions would not ordinarily be considered backfitting even if prior versions of this regulatory guide are part of the licensing basis of the facility. However, unless this regulatory guide is part of the licensing basis for a facility, the staff may not represent to the licensee that the licensee's failure to comply with the positions in this regulatory guide constitutes a violation.

If an existing licensee voluntarily seeks a license amendment or change and (1) the NRC staff's consideration of the request involves a regulatory issue directly relevant to this new or revised regulatory guide and (2) the specific subject matter of this regulatory guide is an essential consideration in the staff's determination of the acceptability of the licensee's request. Then the staff may request that the licensee either follow the guidance in this regulatory guide or provide an equivalent alternative process that demonstrates compliance with the underlying NRC regulatory requirements. This is not considered backfitting as defined in 10 CFR 50.109(a)(1) or a violation of any of the issue finality provisions in 10 CFR Part 52.

Additionally, an existing applicant may be required to comply with new rules, orders, or guidance if 10 CFR 50.109(a)(3) applies.

If a licensee believes that the NRC is either using this regulatory guide or requesting or requiring the licensee to implement the methods or processes in this regulatory guide in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfit appeal with the NRC in accordance with the guidance in NUREG-1409, "Backfitting Guidelines," (Ref. 35) and the NRC Management Directive 8.4, "Management of Facility-Specific Backfitting and Information Collection" (Ref. 36).

REFERENCES[3]

1. *U.S. Code of Federal Regulations*, "Domestic Licensing of Production and Utilization Facilities," Part 50, Chapter I, Title 10, "Energy."[4]

2. *U.S. Code of Federal Regulations*, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Part 52, Chapter I, Title 10, "Energy."

3. *U.S. Code of Federal Regulations*, "Reactor Site Criteria," Part 100, Chapter I, Title 10, "Energy."

4. U.S. Nuclear Regulatory Commission (NRC), "General Site Suitability Criteria for Nuclear Power Stations," Regulatory Guide 4.7, Washington, DC.

5. NRC, "Site Investigations for Foundations of Nuclear Power Plants," Regulatory Guide 1.132, Washington, DC.

6. NRC, "Laboratory Investigations of Soils and Rock for Engineering Analysis and Design of Nuclear Power Plants," NUREG/CR–5739, Washington, DC, January 2000, ML003686696.

7. International Atomic Energy Agency (IAEA) Safety Guide NS-G-6, "Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants."[5]

8. U.S. Army Corps of Engineers, Engineering Manual (EM) 1110-2-1906, "Laboratory Soils Testing," Washington, DC, 1986.[6]

9. Das, B.M., *Soil Mechanics Laboratory Manual*, 8th ed., Oxford University Press, NY, NY, 2012.[7]

10. Head, K.H., *Manual of Soil Laboratory Testing*, Volume 1: Soil Classification and Compaction Tests, 2nd ed., Halstead Press: an imprint of John Wiley & Sons Inc., New York, Toronto, 1992.[8]

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3 Publicly available documents from the U.S. Nuclear Regulatory Commission (NRC) are available electronically through the NRC Library on the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/. The documents can also be viewed on-line for free or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or (800) 397-4209; and e-mail pdr.resource@nrc.gov.

4 The code of Federal Regulations is available electronically from the U.S. Government Printing Office at: http://www.gpo.gov/fdsys/browse/collectionCfr.action?collectionCode=CFR.

5 Copies of International Atomic Energy Agency (IAEA) documents may be obtained through their Web site: WWW.IAEA.Org/, or by writing to the International Atomic Energy Agency, P.O. Box 100 Wagramer Strasse 5, A-1400 Vienna, Austria. Telephone (+431) 2600-0, Fax (+431) 2600-7, or E-Mail at Official.Mail@IAEA.Org.

6 Copies of U.S. Army Corps of Engineers documents may be obtained from the Corps at: Headquarters, U.S. Army Corps of Engineers, 441 G Street, NW, Washington, DC 20314-1000, or electronically from their web site: http://publications.usace.army.mil/publications/.

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APPENDIX A

LABORATORY TESTING METHODS FOR SOIL AND ROCK

NAME OF TEST	STANDARD OR PREFERRED METHOD	APPENDIX A REFERENCES	PROPERTIES OR PARAMETERS DETERMINED	REMARKS/SPECIAL EQUIPMENT REQUIREMENTS
SOILS—INDEX AND CLASSIFICATION TESTS				
Gradation analysis	ASTM D421-85(1998) D422-63(2007) D2217 D4221-99(2005)	Refs. 1, 2, 3, 4	Particle size distribution	Methods are applicable to some rocks, after disaggregation.
Percent fines	ASTM D1140-00(2006)	Refs. 1, 4, 5	Percent of weight of material finer than No. 200 sieve	
Atterberg limits	ASTM D4318-10 D4943-08	Refs. 2, 3, 5, 6, 7, 8	Liquid and plastic limit, plasticity index, shrinkage factor (limit)	
Specific gravity	ASTM D854-10 D5550-06 C127-07	Refs. 2, 4	Specific gravity, apparent specific gravity, bulk unit weight sufficiently fine to eliminate internal voids in the intact rock	Boiling should not be used for de-airing. Method can be used for rock, after grinding.
Radiography	ASTM D4452-06	Ref. 9	Qualitative test of sample quality	
Description of soil and rock	ASTM D2487-10 D2488-09a D4452-06 C294-05		Description of soil from visual-manual examination	
SOILS—MOISTURE-DENSITY RELATIONS				
Bulk unit weight	ASTM C127-07		Bulk unit weight (bulk density)	Methods are applicable to some rocks, with some obvious modifications.
Water (moisture) content	ASTM D425-88(2008) D1558-99(2004) D2216-10 D2974-07a D4643-80 D4959-07	Refs. 2, 12, 13	Water content as a percent of dry weight	Method is applicable to rock.

NAME OF TEST	STANDARD OR PREFERRED METHOD	APPENDIX A REFERENCES	PROPERTIES OR PARAMETERS DETERMINED	REMARKS/SPECIAL EQUIPMENT REQUIREMENTS
Relative density	ASTM C127-07		Maximum and minimum density of cohesionless soils	Requires vibration table. In vibration table testing, both amplitude and frequency should be adjusted to values that yield greatest density. However, treatment that produces breakage of grains should be avoided, and mechanical analyses should be performed as a check on grain breakage.
Compaction	ASTM D698-07 D1557-09 D4253-00(2006) D4254-00(2006) D5080-08	Refs. 2, 4, 14	Maximum dry unit weight of soil	Method for earth-rock mixtures is given in Ref. 15.
SOILS—CONSOLIDATION AND PERMEABILITY				
Consolidation	ASTM D2435-04 D4186-06	Refs. 2, 4, 14	One-dimensional compressibility, permeability of cohesive soil	
Permeability	ASTM D2434-68(2006) D5084-10	Refs. 2, 4, 16	Permeability	Suitable for remolded or compacted soils. For natural, in situ soils, field test should be used.
SOILS—PHYSICAL AND CHEMICAL PROPERTIES				
Mineralogy		Refs. 17, 18, 19	Identification of minerals	Applicable to rock. Requires x-ray diffraction apparatus. Differential thermal analysis apparatus may also be used.
Organic Content	ASTM D2974-07	Ref. 20	Organic and inorganic carbon content as percent of dry weight	Dry combustion methods (ASTM D2974) are acceptable, but where organic matter content is critical, data so obtained should be verified by wet combustion tests.
Soluble salts	ASTM D4542-07	Ref. 21		Concentration of soluble salts in soil pore water
Erodibility tests	ASTM D5852-00(2007)			
Pinhole test	ASTM D4221-99(2005) D4647-06e1	Refs. 22, 23		Significant in evaluation of potential erosion or piping
Crumb test	ATSM D6572-06			Qualitative indication of the natural dispersive characteristics of clayey soils

NAME OF TEST	STANDARD OR PREFERRED METHOD	APPENDIX A REFERENCES	PROPERTIES OR PARAMETERS DETERMINED	REMARKS/SPECIAL EQUIPMENT REQUIREMENTS
Cylinder dispersion		Ref. 1		
SOILS—SHEAR STRENGTH AND DEFORMABILITY				
Unconfined compression	ASTM D2166-06	Ref. 1	Strength of cohesive soil in uniaxial compression	
Direct shear, consolidated-drained	ASTM D3080-04	Ref. 4	Cohesion and angle of internal friction under drained conditions	
Triaxial compression, unconsolidated-undrained	ASTM D2850-03a(2007)	Refs. 2, 4, 25	Shear strength parameters; cohesion and angle of internal friction for soils of low permeability	
Triaxial compression, consolidated-drained	ASTM D7181-11	Refs. 2, 4, 25	Shear strength parameters; cohesion and angle of internal friction; for long-term loading conditions	Circumferential drains, if used, should be slit to avoid stiffening the test specimen.
Triaxial compression, consolidated-undrained	ASTM D4767-04	Refs. 2, 4, 25	Shear strength parameters; cohesion and angle of internal friction for consolidated soil. With pressure measurements, cohesion and friction may be obtained.	Circumferential drains, if used, should be slit to avoid stiffening of test specimen.
Cyclic triaxial	ASTM D3999-91(2006) D5311-92(2004)	Refs. 8, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35	Local strain, modulus and damping	
Cyclic simple shear		Refs. 30, 36	Shear modulus and damping values and cyclic strength of cohesive and cohesionless soils	Tests may be run with either stress control or strain control. Two different types of apparatus, NGI and Roscoe devices, are described in Refs. 35 and 37, respectively.
ROCKS—ENGINEERING PROPERTIES				
Water content	ASTM D2216-10		Water Content	
Specific gravity	ASTM C127-07			
Porosity	ASTM D4612-08 D4404-10	Refs. 10, 41	Bulk unit weight, specific gravity, and total porosity (Melcher method) or effective porosity (Simmons or Washburn-Bunting methods)	Soil testing methods are generally applicable with minor modification.

NAME OF TEST	STANDARD OR PREFERRED METHOD	APPENDIX A REFERENCES	PROPERTIES OR PARAMETERS DETERMINED	REMARKS/SPECIAL EQUIPMENT REQUIREMENTS
Permeability	ASTM D4525-08	Refs. 10, 41	Permeability of intact rock	Laboratory permeability values are not normally representative of in situ permeability of shallow jointed rock masses.
Degradation resistance	ASTM C535-09		Percent of weight of rock greater than 3/4 in. (19 mm)	
Seismic velocity	ASTM D2845-08		Compressional and shear wave velocities in intact rock	Requires signal generator, transducers, oscilloscope
Direct tensile strength	ASTM D2936-08		Uniaxial tensile strength of intact rock	
Splitting tensile strength	ASTM D3967-08		Indirect measure of tensile strength of intact rock	
Modulus of rupture		Ref. 15	Indirect measure of tensile strength of intact rock	
Unconfined compression	ASTM D7012-10		Young's moduli and unconfined compression strength of intact rock	
Uniaxial compression	ASTM D7012-10 D7070-08		Young's moduli, Poisson's ratio	
Triaxial compression undrained	ASTM D7012-10		Young's moduli, cohesion friction parameters of failure envelope	
Triaxial compression without pore pressure measurements	ASTM D7012-10	Ref. 42	Young's moduli, cohesion friction parameters	
Triaxial compression with pore pressure measurements		Ref. 42	Young's moduli, cohesion friction parameters of effective stress conditions	
Slake durability	ASTM D4644-08	Ref. 37	Index of resistance to slaking	
Direct shear	ASTM D5607-08		Shear strength	

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