Classification of Soils for Excavations

Method number:	ID-194
Version:	3.1
OSHA regulation:	Earth material that is excavated must be properly sloped or supported for construction and safety purposes. The applicable regulation is 29 CFR Part 1926, Subpart P – Excavations.[1] The specifications for classifying soil are outlined in 29 CFR Part 1926, Subpart P, Appendix A – Soil Classification. The instructions for the proper sloping, shoring, and bracing of excavations are contained in 29 CFR Part 1926, Subpart P, Appendix B – Sloping and Benching. This is a prescriptive regulation.
Procedure:	A bulk soil (excavated earth material) sample is collected and placed in a one-gallon clear plastic storage bag. Refer to Section 2.3 for detailed specifications on soil sample collection, packaging, and compliance with United States Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS) regulations for shipping soils and earth materials. Various visual and manual analyses are performed to classify the soil sample.
Minimum sample size:	Two pounds, which is approximately one third to one half of a one-gallon clear plastic storage bag.
Special requirements:	See section 2.4. Questions on excavation sampling should be directed to the OSHA Salt Lake Technical Center (SLTC). For samples submitted from outside the continental United States, see Appendix A.
Status:	Approved procedure.

November 2001	Alan Peck
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[1] Excavations. *Code of Federal Regulations*, Part 1926, Subpart P. Title 29, 1989.

1. General Discussion

For assistance with accessibility problems in using figures and illustrations presented in this method, please contact Salt Lake Technical Center (SLTC) at (801) 233-4900. These procedures were designed and tested for internal use by OSHA personnel. Mention of any company name or commercial product does not constitute endorsement by OSHA.

1.1 Background

1.1.1 History

When a trench or other excavation is made in the earth, the force of gravity works to bring the material in the excavation to a stable configuration. When the mechanical and chemical forces holding the walls of the excavation in place are less than the force of gravity, a cave-in occurs. There are numerous and complex factors that determine the stability of a given excavation. In basic terms, the particles that constitute soil and other earth materials can bond by chemical and mechanical forces that resist the force of gravity. Chemical bonding refers to the chemical forces that bond soil particles; such bonding can be the result of carbonates, iron oxides, salts, water, or even organic material. Mechanical bonding refers to the physical forces such as friction that hold particles in place. It has been determined empirically that soil, when sloped appropriately, will resist the force of gravity, and will remain safely stable during the excavation period. The required angle of the slope depends upon the properties of the soil in which the excavation has been made.

The evaluation of soil conditions and structure is crucial to safe operation in and around excavations, therefore an excavation requirement was included in the construction standard, which was among the first promulgated by OSHA in 1971.[2] In that standard, soils were classified into three types called running, unstable, and hard compact. Historically, these terms were generally misunderstood and later changed.

In a 1975 study, based primarily on a previous study of newspaper articles and other data made available from OSHA files, it was estimated that more than 100 persons were killed in excavation cave-ins each year.[3] Responding to this high incidence rate, OSHA promulgated the current excavation standard and it has the following requirements:[4]

1) Classification of soil and rock deposits: Each soil and rock deposit shall be classified by a competent person as Stable Rock, Type A, Type B, or Type C in accordance with the definitions set forth in 29 CFR 1926, Subpart P, Appendix A.
2) Basis of classification: The classification of the deposits shall be made based on the results of at least one visual and at least one manual analysis. Such analyses shall be conducted by a competent person using tests described in 29 CFR 1926, Subpart

[2] *Federal Register*, Vol. 36, No. 75, pp 7339-7410. U.S. Government Printing Office, Washington, DC, 20402-9328, April 17, 1971.

[3] Thompson, L.J.;Tanenbaum, R.J. *Excavations, Trenching and Shoring: The Responsibility for Design and Safety*; Project Number RF-3177 for Department of Civil Engineering Texas A&M University College Station, Texas 77843, TX, 1975, pp 50-55.

[4] *Federal Register*, Vol. 54, No. 209, pp 45893-45992. U.S. Government Printing Office, Washington, DC, 20402-9328, October 31, 1989.

P, Appendix A, or in other recognized methods of soil classification and testing such as those adopted by the American Society for Testing Materials, or the U.S. Department of Agriculture textural classification system.

3) Visual and manual analyses: The visual and manual analyses, such as those noted as being acceptable in 29 CFR 1926, Subpart P, Appendix A, shall be designed and conducted to provide sufficient quantitative and qualitative information as may be necessary to identify properly the properties, factors, and conditions affecting the classification of the deposits.
4) Layered systems: In a layered system, the system shall be classified in accordance with its weakest layer. However, each layer may be classified individually where a more stable layer lies under a less stable layer.
5) Reclassification: If, after classifying a deposit, the properties, factors, or conditions affecting its classification change in any way, the changes shall be evaluated by a competent person. The deposit shall be reclassified as necessary to reflect the changed circumstances.

In its 1989 rule making, OSHA relied heavily on a classification system developed in 1982 by the National Bureau of Standards (now the National Institute of Standards and Technology – NIST). OSHA also used ASTM standards and public commentary from industry organizations. The 1989 standard introduced new terms for structural classification. The new terms are cohesive, granular cohesionless, granular, and cemented. In addition to these fundamental references, SLTC used The Unified Soil Classification System[5], the Engineering Geology Field Manual of the U.S. Bureau of Reclamation[6], and other documents in the development of this method.[7,8,9,10]

OSHA Method ID-194 was developed to emphasize the performance and engineering properties of soil and is consistent with the objectives and requirements of the 1989 OSHA excavation regulations. Most of the tests published in this method are the same visual and manual analyses that must be performed by a competent person at the excavation site.

Only minor changes to the method were made for Version 2.0. In March 2014, the United States Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS) imposed new requirements for soil sterilization. In order to prevent the introduction and spread of harmful or invasive organisms into the local environment, the SLTC was thereafter required to sterilize all soil samples at a minimum temperature of 110 °C for a minimum of 16 hours. All previous references to the initial drying of the sample were changed from 60 °C to 110 °C to meet the new requirements and maintain a USDA APHIS permit.

[5] U.S. Department of the Interior, Bureau of Reclamation. *Earth Manual, Part 1, 3d ed*, Earth Sciences and Research Laboratory Geotechnical Research Technical Service Center, Denver, CO, 1998, pp 1-4.
[6] U.S. Bureau of Reclamation. *Engineering Geology Field Manual*, Volume 1, 2d ed. U.S. Government Printing Office, Washington, DC, 2001, Chapter 3.
[7] Dunn, I.S. *Fundamentals of Geotechnical Analysis*; John Wiley & Sons, Ltd.; West Sussex, U.K., 1980; p 33.
[8] *Compendium 13 Slopes: Analysis and Stabilization,* p 141; National Academy of Sciences, U.S. Government Printing Office: Washington, DC, 1980.
[9] Wilun, Z.; Starzewski, K. *Mechanics in Foundation Engineering;* Surrey Press/450 Edgeware Rd. London: U.K., 1972; p 77.
[10] Deere, D.U.; Miller, R.P. *Engineering Classification and Index Properties of Intact Rock*; Technical Report No. AFWL-TR-65-116 for Air Force Weapons Laboratory Research and Technology Division Air Force Systems Command: Kirtland Air Force Base, NM, 1966.

Substantial changes to style and content have been made to Version 3.0 of this method. The format has been changed to maintain consistency with the style of other OSHA method publications. Additional details on history and more statistics have been added. More explicit information about USDA APHIS requirements has been included. Version 3.0 also provides more details on sample collection and on the steps performed during laboratory analysis. Some explanatory photographs have also been added. The most significant change is the elimination of the textural classification from the analytical results. This textural classification was only descriptive and not used in the classification of soil samples for purposes of regulatory compliance; therefore, it has been deleted.

Minor changes were made to Version 3.1 in August 2022. These changes add clarification to the discussion of rock fragments and angular gravel. A photo of angular gravel was added. Appendix B, "Analytical Worksheet" was removed.

1.1.2 Hazardous effects (This section is for information only and should not be taken as the basis of OSHA policy.)

Trenching and excavation work presents serious hazards to all workers involved. Cave-ins pose the greatest risk and are more likely than some other excavation-related incidents to result in worker fatalities. Other potential hazards associated with trenching work include falling loads, hazardous atmospheres, and hazards from mobile equipment.[11] There is no reliable warning before an excavation fails; the walls can collapse suddenly, and workers will not have time to escape.[12]

One cubic yard of soil can weigh more than 3,000 pounds, which can fatally crush or suffocate workers.[13] Death by asphyxiation or suffocation may occur if the employee is engulfed. Potential non-fatal injuries from an excavation collapse include blunt force trauma and fractures. Drowning may occur when an excavation collapse is combined with a broken pipeline or other means of flooding.

1.1.3 Workplace exposure

Trenching and excavation take place during a wide variety of employment activities, including water, sewer, pipeline, and power line construction and for the purpose of installing and repairing foundations and other structural elements.[14] Such activity is typically of short duration, after which the excavation is typically backfilled.

During 1992 to 2001, data from the Bureau of Labor Statistics Census of Fatal Occupational Injuries identified 542 fatalities associated with trenching and excavation, excluding data from New York City. Annual totals ranged from a low of 44 in 1993 to a high of 65 in 1996 and averaged 54 fatalities per year. Cave-ins accounted for 76% of

[11] *Trenching and Excavation Safety, Publication 2226-10R*; U.S. Department of Labor Occupational Safety and Health Administration (OSHA), U.S. Government Printing Office: Washington, DC, 2015.

[12] Lentz, T.J.; Afanuh, S.; Gillen, M. Workplace Solutions Protecting Worker Deaths from Trench Cave-Ins, 2011. National Institute for Occupational Safety and Health (NIOSH) Web site. https://www.cdc.gov/niosh/docs/wp-solutions/2011-208/pdfs/2011-208.pdf (accessed March 2019).

[13] Deatherage, J.H.; Furches, L.K.; Radcliffe, M.; Schriver, W.R.; Wagner, J.P. Neglecting Safety Precautions May Lead to Trenching Fatalities. *Am J Ind Med*, **2004**, *45(6)*, 522-527.

[14] Boone, J.L.; Broderick, T.A.; Casini, V.J.; Storms, C. Occupational Fatalities During Trenching and Excavation Work – United States, 1992-2001. *Morb Mortal Wkly Rep*, **2004**, *53(15),* 311-314.

fatalities.[15] In addition, analysis of OSHA data from 1997 to 2001 showed that 64% of fatalities in trenches occurred at depths less than ten feet.[16] From 2000 to 2009, 350 workers died in trenching or excavation cave-ins. This is an average of 35 fatalities per year.[17] In November 2016, OSHA published data indicating that, from 2012 through 2015, there had been 33 trench-related reported injuries and 45 trench-related fatalities.[18]

A Regulatory Review of 29 CFR 1926, Subpart P – Excavations, conducted in March 2007, found that "There is a continued need for the standard … Although the standard has improved safety, it remains needed in light of the ongoing occurrence of related fatalities most of which result from violations of the standard."[19]

1.1.4 Physical properties and other descriptive information

The soil types and structural classifications defined in Appendix A of the regulation are based on site conditions, as well as on the structure and composition of the earth deposits. Appendix A contains definitions, sets forth requirements, and describes acceptable visual and manual tests for use in classifying soils in excavations. The soil classification system means a method of categorizing soil and rock deposits in a hierarchy of Stable Rock, Type A, Type B, and Type C, in decreasing order of stability. For the purposes of the regulation and for performance of this method, "excavation" means any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal. Soils are evaluated as being cohesive, granular, granular cohesionless, or cemented, as well as being evaluated as Stable Rock, Type A, Type B, or Type C.

Stable Rock: natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed. Excavations made in rock must be evaluated on site. This determination cannot be made at the SLTC.

Type A means cohesive soils with an unconfined compressive strength of 1.5 tons per square foot (tsf) (144 kPa) or greater. Cemented soils such as caliche and hardpan are also considered Type A. However, no soil is Type A if:

i. The soil is fissured; or
ii. The soil is subject to vibration from heavy traffic, pile driving, or similar effects; or
iii. The soil has been previously disturbed; or
iv. The soil is part of a sloped, layered system where the layers dip into the excavation on a slope of four horizontal to one vertical (4H:1V) or greater; or

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[15] *NIOSH analyses of the Bureau of Labor Statistics' Census of Fatal Occupational Injuries special research file*; U.S. Department of Health and Human Services, CDC, National Institute for Occupational Safety and Health (NIOSH): Morgantown, West Virginia, 2004.

[16] Arboleda, C.A.; Abraham, D.M. Fatalities in Trenching Operations — Analysis Using Models of Accident Causation. *J Const Eng Mgmt*, **2004**, *130(2)*, 273-280.

[17] *Census of Fatal Occupational Injuries (2000-2009);* U.S. Bureau of Labor Statistics, U.S. Government Printing Office: Washington, DC, 2010.

[18] OSHA News Release – Region 5. OSHA investigates trench collapse after 28-year-old worker becomes 13th worker injured while working underground in 2016, 2016. Occupational Safety and Health Administration (OSHA) Web site. https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=NEWS_RELEASES&p_id=33444 (accessed March 2019).

[19] *Regulatory Review of 29 CFR 1926, Subpart P: Excavations, Pursuant to Section 610 of the Regulatory Flexibility Act and Section 5 of Executive Order 12866*; Occupational Safety and Health Administration (OSHA), U.S. Government Printing Office: Washington, DC, 2007.

v. The material is subject to other factors that would require it to be classified as a less stable material.

Type B means:

i. Cohesive soil with an unconfined compressive strength greater than 0.5 tsf (48 kPa) but less than 1.5 tsf (144 kPa); or
ii. Granular cohesionless soils includes angular gravel (similar to crushed rock).
iii. Previously disturbed soils except those which would otherwise be classed as Type C soil.
iv. Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subject to vibration; or
v. Dry rock that is not stable; or
vi. Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less than four horizontal to one vertical (4H:1V), but only if the material would otherwise be classified as Type B.

Type C means:

i. Cohesive soil with an unconfined compressive strength of 0.5 tsf (48 kPa) or less; or
ii. Granular soils including gravel and sand; or
iii. Submerged soil or soil from which water is freely seeping; or
iv. Submerged rock that is not stable, or
v. Material in a sloped, layered system where the layers dip into the excavation or a slope of four horizontal to one vertical (4H:1V) or steeper.

Cohesive soil means clay, or soil with a high clay content, which has cohesive strength. Cohesive soil does not crumble, can be excavated with vertical sideslopes, and is plastic when moist.

Granular soil means gravel, sand, or silt with little or no clay content. Granular soil has no cohesive strength, though some moist granular soils exhibit apparent cohesion. Granular soil cannot be molded when moist and crumbles easily when dry.

Granular cohesionless soil means soil that contains less than 85% sand and gravel[20] but does not contain enough clay to be molded.

Cemented soil means a soil in which the particles are held together by a chemical agent, such that a hand-size sample cannot be crushed into powder or individual soil particles by finger pressure. Cemented soils are a special case. They are typically too dry to test for unconfined compressive strength, but if they are cemented and not fissured, and not subject to other factors that would require them to be classified as a less stable material, they are classified as Type A.

[20] U.S. Bureau of Reclamation. *Engineering Geology Field Manual*, Volume 1, 2d ed. U.S. Government Printing Office, Washington, DC, 2001, Chapter 3.

The IMIS code associated with soil classification is S777.[21]

2. Sampling Procedure

All safety practices that apply to the work area being sampled should be followed.

2.1 Apparatus

- Scoop or shovel, or other safe means of obtaining a representative sample.
- One-gallon re-sealable plastic bags.
- Moisture resistant tape.

2.2 Reagents

None required.

2.3 Technique

A bulk soil (excavated earth material) sample is collected and placed in a clear plastic storage bag. Take care not to break up clumps. The minimum sampling size is 1 kilogram (approximately 2 pounds), which is approximately one third to one half of a one-gallon clear plastic storage bag.

Obtain a representative sample for each soil layer in the excavation by using any safe means. Place the sample inside an airtight plastic bag and seal across the length of the opening with moisture resistant tape. Place this bag inside a second airtight plastic bag and again seal across the length of the opening with moisture resistant tape. Place Form OSHA-21 across the seal lengthwise. Figure 2.3 shows a properly packaged, sealed, and labeled excavation sample.

Figure 2.3. A properly packaged, sealed, and labeled excavation sample.

Submit the sample and an associated Form OSHA-91A for analysis. Request IMIS code S777 for soil analysis by OSHA Method ID-194. Do not place the Form OSHA-91A or any other accompanying documentation inside the sample bag with the soil. IMIS code S777 includes all

[21] Soil (Excavation) (OSHA Occupational Chemical Database), 2018. United States Department of Labor, Occupational Safety & Health Administration (OSHA) Web site. https:// https://www.osha.gov/chemicaldata/943 943 (accessed Feb 2022).

the tests prescribed in the regulation as well as a quantitative gradation to determine sand and gravel content, as described in Section 3, Analytical Procedure. Quantitative moisture and specific gravity tests on soils are not performed at SLTC.

2.4 Special considerations

The United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) regulates the movement of plant pests and other harmful organisms. The OSHA Salt Lake Technical Center (SLTC) maintains Permits to Receive Soil in accordance with 7 CFR Part 330.

Because potentially harmful organisms might be present in a sample sent from any of the fifty states or U.S. territories, the SLTC has agreed with the USDA APHIS to follow two specific protocols as part of the permit agreement. First, the SLTC will sterilize all excavation samples. Second, it is imperative that Compliance Safety and Health Officers (compliance officers or CSHOs) package and seal all excavation samples as described in this procedure. A sample that is leaking or has broken in transit, or that is otherwise packaged so it presents a risk of exposure, will be sterilized immediately, discarded, and reported as “Not Analyzed.”

Any sample sent from outside the continental United States (OCONUS) must be packaged in accordance with the instructions described in this method, and in addition must include a copy of the current soil permit and have a USDA PPQ Form 550 attached to the outside of the container. See Appendix A for instructions on how to obtain the current permit and detailed instructions on sending samples from OCONUS.

The OSHA SLTC cannot make a determination of Stable Rock. This must be done at the excavation site by observing the excavation walls and current environmental factors in accordance with the regulation. Any sample consisting entirely of rock fragments greater than approximately 7 cm (3 in.) will be reported as Granular Cohesionless, Type B. Rock fragments, when part of a sample containing clay, sand, or gravel, will be reported as part of the gravel component of the sample.

If an excavation contains a substantial amount of rock fragments, the CSHO must evaluate the overall composition carefully when selecting a representative sample. The proportions of any sample containing large rock fragments greater than 7 cm (3 in.) must be representative of the material in the excavation, and therefore the sample needed may be larger and heavier than the recommended sample size as discussed in Section 2.3.

All samples are analyzed as received at the SLTC. The analysts are not aware of site conditions such as surcharge loads or whether the soil was subject to vibration. Therefore, the analyst may report a soil type that is correct based on the laboratory analysis but would need to be modified by the compliance officer based on conditions observed during the inspection. For example, the analyst may report a soil sample as Cohesive, Type A, but if the compliance officer noted pile-driving activity nearby during the inspection, the compliance officer may reclassify the material as Cohesive, Type B, because the material was subject to vibration.

Use universal safety precautions when obtaining samples from excavations where there may be chemical or biological hazards. Do not submit samples that are obviously chemically or biologically contaminated to the SLTC. Notations on the Form OSHA-91A should be made as to the potential for any possible chemical or biological exposure to sample receiving staff as well as analytical staff.

3. Analytical Procedure

3.1 Apparatus

- Numbered metal pans approximately 13 cm W × 23 cm L (5” W × 9” L), used as drying pans.
- Numbered metal bowls of at least 2 L capacity, used for gradation analysis.
- Vented, forced air ovens that will dry samples at 110 °C.
- Laboratory balance of at least 3 kg capacity with a readability of 0.1 g. An Ohaus Adventurer is used at SLTC.
- A dial penetrometer with a readability of 0.1 tsf. A Gilson Geotester Pocket Penetrometer is used at SLTC.
- Spatula for slicing clumps.
- Utility knife for opening sample bags.
- Wire brush for cleaning drying pans and bowls.
- Soft bristle brush for cleaning sieves.
- Blank sample labels, with 1-inch scale bar.
- Ruler.
- Permanent markers for filling out sample labels.
- Digital camera for photographing samples.
- Rubber-tipped pestle for disaggregating soil clumps for plasticity testing.
- Gloves sufficient to protect skin from abrasion, for use as needed.
- Gloves for handling hot pans and bowls, for use as needed.
- Wash bottles.
- Digital thermometer with probe, for measuring sample temperature.
- A 3-in. wire grid.

The following USA standard testing sieves, ASTM E-11[22] specifications, 8-inch diameter:

[22]ASTM Standard E11, 2020, “Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves”, ASTM International, West Conshohocken, PA, DOI: 10.1520/E0011-20.

- No. 4 mesh, with lid, 4.75 mm (0.187 in), for gradation analysis.
- No. 6 mesh, 3.35 mm (0.132 in), for separating larger material during wet sieving (optional).
- No. 40 mesh, 425 µm (0.0167 in), for separating the finer soil fraction for the remolded plasticity test.
- No. 200 mesh, 75 µm (0.0029 in), high sided wet sieve for washing.
- No. 200 mesh, with catch pan, 75 µm (0.0029 in), for gradation analysis.

3.2 Reagents

- DI Water.
- Hydrochloric acid (HCl), [CAS no. 7647-01-0], reagent grade.
- Ethanol (C_2H_6O), [CAS no. 64-17-5], reagent grade.
- Hydrochloric acid solution in DI water 50% (v/v) hydrochloric acid/water in used for determining carbonate cementation.
- Sterilization solution with a minimum concentration of 70% (v/v) (ethanol/water) is used for sterilizing tools and surfaces exposed to a soil sample before it is dried.

3.3 Sample preparation

No sample preparation is required. All samples are analyzed as received.

3.4 Analysis

3.4.1 The analysis consists of opening the sample, photographing the sample, testing for unconfined compressive strength, testing for natural plasticity (cohesiveness), noting the physical characteristics of the sample, testing for fissuring, drying and sterilizing the sample, and gradation.

- **Open the Sample:**

Samples with odors of sewage or of petroleum distillates, or similar conditions, may constitute a health or safety concern. Follow the laboratory chemical hygiene plan.

If any form of living organism is found—including, but not limited to, ants, spiders, beetles, or nematodes—immediately kill the organism, then contain and isolate the sample by any means necessary. It may be necessary to contact the local USDA APHIS representative in such cases.

Generate a soil classification worksheet on which to record the data and observations from the tests prescribed below.

Record the lab sample identifier on the sample label.

Select a drying pan and record the drying pan number.

Break the seal and open the sample. Use a utility knife to cut the bag open if necessary.

Transfer the sample into the drying pan. If the entire sample will not fit into the drying pan, select a representative aliquot.

Place the sample label atop the sample so that the sample identifier and 1-inch scale bar are clearly visible. See Figure 3.4.1.1.

● **Photograph the sample:**

Take a color photograph of the sample using a digital camera to document some of its visual characteristics. Record that the photograph was taken. Ensure the photograph is representative of the sample and that its features such as loose sand, gravel, soil clumps, and fine soil are clearly visible. Figure 3.4.1.1 shows an ideal photograph, with the excavated material filling the photo frame and the lab sample identifier clearly visible.

Figure 3.4.1.1. Ideal photo of an excavation sample.

● **Test the sample for unconfined compressive strength:**

Immediately after taking a photograph, test the unconfined compressive strength of the sample. Select a suitable clump or clumps, if available. A suitable clump will be approximately 7 cm (3 in.) or greater in diameter and generally rounded in shape. The clump should be soft enough to slice cleanly with a spatula and not so dry that it crumbles when cut. The desired result after slicing the clump or clumps should be at least one portion with a flat face suitable for penetrometer testing and enough depth to avoid crumbling. Figures 3.4.1.2 and 3.4.1.3 illustrate a clump of suitable size and texture being tested with a penetrometer.

Figure 3.4.1.2. Flat face of sample ready for testing.

Figure 3.4.1.3. Testing with a penetrometer.

Zero the dial penetrometer. Take a minimum of three readings on the faces of the freshly exposed interior of the clump or clumps to obtain a set of values for calculating an average. This is accomplished by pressing the flat face of the penetrometer cylinder against a freshly cut flat face of the soil clump, holding it perpendicular to the exposed face, and pressing slowly and steadily until the cylinder has penetrated as far as the indicator ring engraved on the cylinder. Stop pressing and read the value directly from the penetrometer dial. Record the value in tsf on the analytical worksheet. Zero the penetrometer between each reading. Calculate the average of the values; round to one decimal place and record this value.

It is not always possible to obtain a clump of suitable size or texture for a reliable penetrometer test. If this is the case, note that the unconfined compressive strength is unavailable. Also note one of the following reasons why the reading was unavailable:

No appropriately sized clumps available: This statement applies if the clumps in the sample were too small for testing, if fewer than three penetrometer readings were obtained, or if the sample consisted of fine soil or sand.

The material was very dry or otherwise too difficult to cut cleanly with a spatula: This statement applies if the sample was too difficult to cut with a spatula, it crumbled when cut, or it contained so much gravel that it could not be cut evenly.

The material crumbled when tested with the penetrometer: Sometimes the sample can be cut cleanly but may still crumble or fracture when the penetrometer is pressed against it, thus preventing a reliable reading.

The material was freely seeping water: A sample that is freely seeping water will provide almost no resistance to the penetrometer, giving values near 0 tsf. A sample is Type C if it is freely seeping water.

Note: Part of the definition of Type A soil is that the material must have an unconfined compressive strength greater than or equal to 1.5 tsf; therefore, if a reading cannot be obtained for any of the reasons above, the analyst cannot classify the material as a Type A soil.

- **Test the sample for natural plasticity (cohesiveness):**

Immediately after testing for unconfined compressive strength, test for natural plasticity in the sample as received. Take a portion of the material and roll it into a ball having a diameter of approximately one-half inch, if possible. Attempt to roll the sample out into a thread 3 mm (1/8 in.) in diameter and at least 5 cm (2 in.) long. When a thread of the correct size is created, hold it up by one end. If it holds together, it passes the test and is classified as plastic and cohesive. If it breaks, it fails the test. Record the results of the natural plasticity test. Note that some silty or sandy materials may roll out into a thread, but that thread may not remain intact when held up vertically by one end.

- **Note the physical characteristics of the sample:**

Next, record the observed characteristics of the sample. With a few exceptions, most of these observations are not used in the final analysis of soil structure and type. Rather, they support any observations the compliance officer made and provide a general description of the material for the record. The details of each characteristic are explained below.

Plant matter: Record if the sample contains plant matter. This includes leaves, grass, flowers, seed pods, and other plant parts. This is a qualitative assessment.

Non-soil foreign material: Record if the sample contains manufactured debris. This is a wide-ranging category that includes glass, brick, asphalt, metal fittings, and any other synthetic items that are not soil, rock, plant, or animal matter. The presence of such material supports the premise that the soil was previously disturbed. This is a qualitative assessment.

Rock fragments > 3 inches: Record if the sample contains rock fragments greater than approximately 7 cm (3 in.) in diameter. The 3-in. wire grid can be used to make this determination. To determine structural classification, rock fragments will be included with the gravel component of the soil sample.

Hydrocarbon odors: Record if the sample has the odor of petroleum distillates such as gasoline, fuel oil, diesel fuel, or other such compounds. This is a qualitative assessment.

Sewage odors: Record if the sample has an odor of sewage. Compliance officers are advised not to send contaminated samples to SLTC. However, in the event this does occur, isolate the sample. SLTC does not analyze such samples. This is a qualitative assessment.

Aquatic matter (shells, etc.): Record if the sample has visible aquatic matter. For the purposes of this method, aquatic matter is defined as shells, coral, or other durable material formed by freshwater or saltwater organisms. Aquatic matter is common in excavated materials from coastal areas. This is a qualitative assessment.

Damp or wet: Record if the soil is palpably damp or wet but not freely seeping water. Material that is very wet typically has a low or very low unconfined compressive strength. This is a qualitative assessment.

Freely seeping water: Record if the sample is freely seeping water. Some signs of this condition are free water or mud in the sample bag, water running or seeping from the sample as it is handled, and what can be described as a “muddy” texture. Samples of this type typically have a very low unconfined compressive strength, or even register as 0 tsf on the penetrometer dial. In many cases it is not possible to obtain a clean cut with a spatula because the material will slump or collapse. It is useful to document this assessment with additional photographs of both the sample and the original sample container. If a sample is freely seeping water, it is Type C.

Angular gravel: Record if the sample contains visible angular gravel. Angular gravel is uncommon in nature, due to the chemical and mechanical weathering of rock fragments over time. However, freshly crushed quarry rock is sometimes used as fill, and this will often qualify as angular gravel. Angular gravel has sharp edges and relatively flat faces that allow the individual pieces to interlock and remain more stable than rounded gravel. This is a qualitative assessment. Figure 3.4.1.4 illustrates an example of angular gravel.

Figure 3.4.1.4. Angular gravel has relatively flat faces and generally sharp interfacial angles.

Cemented: Record if the material is cemented. Earth material may be cemented with carbonates, salts, iron oxides, or other chemical agents such that a hand-sized sample cannot be crushed into powder or individual soil particles by finger pressure. Such materials are sometimes called “caliche” or “hardpan.” These terms are colloquial and do not have explicit meanings for the purposes of this method. Cemented soils may be Type A, depending upon other factors. This is a qualitative assessment.

Fizzes with acid: This test is optional. It is useful on soils that appear to be cemented, because bubbling or fizzing indicates cementation by carbonates. This test may also be useful if the analyst suspects that carbonates are a significant component of the sample, whether or not it is cemented. A hydrochloric acid solution in DI water 50% (v/v) hydrochloric acid/water is used to conduct the test. This is a qualitative assessment.

● **Test the sample for fissuring:**

Next, test the sample for fissuring. There are two indicators of fissuring, as described in the regulation. If the material breaks along definite planes of fracture under finger pressure with little resistance, it is fissured. The material may exhibit open cracks in an exposed surface, which also indicates fissuring. If either or both of these conditions are true, note that the sample is fissured, and record the characteristics that indicate fissuring. If neither of these conditions is met, record that the sample is not fissured. If the material was sandy, consisted of fine soil and very small clumps, or was otherwise not able to be tested for fissuring, record that the material was not of sufficient size or composition to determine fissuring. If the test for fissuring cannot be performed, then the material cannot be classified as Type A by the analyst.

● **Dry and sterilize the sample:**

Set the oven to 110 °C and place the sample into the drying oven. Dry the sample for a minimum of 16 hours. Use the temperature probe and digital thermometer, as necessary, to monitor the temperature.

Decontaminate all equipment used in the analysis with the ethanol sterilization solution.

● **Gradation:**

After the sample has been dried and sterilized for a minimum of 16 hours at 110 °C, perform the gradation analysis. Remove the sample from the drying oven and select a numbered bowl for use in gradation analysis. Record the bowl number.

Zero the balance and place the bowl on the balance. Tare the balance with the bowl on it.

Select a representative aliquot from the drying pan. Use a minimum of 100 g of sample. The amount chosen will vary based upon the homogeneity of the material. For instance, a relatively homogeneous sample that consists mostly of sand requires approximately 100 g to 150 g for gradation analysis. A different sample that consists of sand, fine soil, and large gravel may require 400 g or more in order to capture a representative aliquot. Record the mass of the sample aliquot.

Fill the bowl with hot water. Use care not to spill any water or splash any sample material out of the bowl. If any water or material is lost from the bowl, select another aliquot from the original sample and begin again. Allow the sample to stand for a minimum of 2 hours.

Attach a sprayer hose to the faucet and select the No. 200 wet sieve. If the sample contains coarse material or large gravel, the No. 6 sieve can be used to protect the No. 200 sieve from damage by larger material. Place the No. 6 sieve atop the No. 200 wet sieve as needed.

Ensure that the sieve screens are free of tears, holes, or clogging.

Transfer the sample material from the bowl into the top sieve - either the No. 6 sieve nested on top of the No. 200 sieve, or the No. 200 sieve alone. Transfer material gently to avoid damage to the mesh screens.

Put on rubber gloves. Use the sprayer with hot water to wash the soil material such that the silt and clay fractions pass through the No. 200 sieve openings. Stir the material gently. Check the water running from the sieve frequently. Stop washing when the effluent water runs continuously clear. Carefully wash the material from the sieve back into the bowl. If the No. 6 sieve was used to catch large material, remove it from the No. 200 sieve first and return the material to the bowl, then return the remaining material from the No. 200 sieve to the bowl.

Pour excess water from the bowl. Make certain that none of the sample is lost during this process. Observe the residual water in the bowl and make certain it is clear. If not, it is necessary to wash the material through the sieve again.

Dry the remaining sample material in the drying oven at 110 °C for a minimum of two hours or until the sample is dry. Remove the sample from the drying oven and place it on a table to cool.

Stack a No. 4 sieve on top of a No. 200 sieve and attach a catch pan underneath the No. 200 sieve.

Place the dried material from the bowl on to the No. 4 sieve and place the lid on the sieve. Use a wire brush to make certain all the sample material is transferred from the bowl into the sieve.

Zero the balance and place the bowl on the balance. Tare the balance with the bowl on it.

Tap and shake the stacked sieves vigorously. Check the catch pan periodically and discard any residual material. Continue to agitate the stacked sieves vigorously until no more residual material falls into the catch pan.

Remove the lid and then remove the No. 4 sieve from the stack. Transfer the gravel fraction from the No. 4 sieve into the bowl. Use a soft brush to make sure all material from the inside of the sieve is transferred. Record the mass of the gravel fraction.

Remove the No. 200 sieve from the catch pan and transfer the sand fraction from the No. 200 sieve into the bowl. Use a soft brush to make sure all material from inside the sieve is transferred. Record the combined mass of the sand and gravel fractions.

Calculate the percent gravel and percent sand and gravel for the sample. See Section 3.5.

3.4.2 Structural component classification

After the gradation is complete and all mass fractions have been recorded, the structural component classification is determined. This will be either **Cemented**, **Granular**, **Cohesive**, or **Granular Cohesionless**. It may be necessary to conduct a second test for plasticity if the sample failed the previous natural plasticity test.

Cemented soils are very hard and do not crumble under hand pressure. These samples may not dissolve in water and may react by fizzing when acid is applied. If this condition is met, record that the structural component is cemented and proceed to the "Type Determination" section. In most cases natural plasticity is absent in cemented soils. Rarely, residual fine material from cemented soils can be molded into a plasticity thread.

Granular soils have a sand and gravel content that is greater than 85% and the gravel is not angular. If both these conditions are met, record that the structural component is granular and proceed to the "Type Determination" section. In rare cases, the fine material sieved from granular soils will have plasticity. If the sand and gravel content is greater than 85%, the material is categorically classified as granular regardless of the plasticity of the fine material.

Cohesive soils have a sand and gravel content of less than or equal to 85% and have plasticity. If a sample has a sand and gravel content of less than or equal to 85% and was determined to have natural plasticity, record that the structural component is cohesive and proceed to the "Type Determination" section. However, if a sample has a sand and gravel content of less than or equal to 85% but was determined to not have natural plasticity, a second plasticity test is needed before the structural component can be classified. This second plasticity test is a remolded plasticity and is performed as follows:

Disaggregate a representative aliquot of the sample using a rubber-tipped pestle and a small pan.

Using a #40 sieve and a catch pan, sieve the disaggregated fine material and recover what passes through the sieve.

Take a small portion of the material in the catch pan and wet it with DI water. Attempt to roll it into a ball and then roll it out into a plasticity thread as described earlier. Use various amounts of water as necessary.

If the material was remolded successfully into a plasticity thread, record the results of the remolded plasticity test, and record that the material is cohesive. Proceed to the "Type Determination" section.

Granular Cohesionless soils are those that have a sand and gravel content of less than or equal to 85% but lack plasticity on both the natural plasticity and the remolded plasticity tests. These soils also include those samples where the sand and gravel content is greater than 85% but where the sand and gravel content is mostly composed of angular gravel. Record granular cohesionless as the structural component and proceed to the "Type Determination" section.

3.4.3 Type Determination

After the structural component is recorded, the soil type can be determined. This will be either **Type C**, **Type B**, or **Type A**.

Type C: All granular soils are Type C. Cohesive soils that have an unconfined compressive strength less than or equal to 0.5 tsf are Type C. Any soil that is freely seeping water is classified as Type C regardless of the results of all other tests.

Type B: All granular cohesionless soils are Type B. Cohesive soils that have an unconfined compressive strength greater than or equal to 1.5 tsf but are fissured (or fissuring cannot be determined) are also Type B. Cohesive soils that are not fissured but have an unconfined compressive strength greater than 0.5 and less than 1.5 tsf are also Type B.

Type A: All cemented soils are classified as Type A. Cohesive soils may be Type A if both the following conditions are met: they are not fissured, and they have an unconfined compressive strength greater than or equal to 1.5 tsf.

3.5 Calculations

The percent gravel and the percent sand and gravel can be calculated using the following formulas.

$$P_g = \frac{M_g}{M_a} \times 100\ \%$$

where P_g is the percent gravel
M_g is the mass in grams from the No.4 sieve
and M_a is the mass in grams of the aliquot of sample used in the gradation analysis

$$P_{s,g} = \frac{M_{s,g}}{M_a} \times 100\ \%$$

where $P_{s,g}$ is the percent sand and gravel
$M_{s,g}$ is the mass in grams from the No. 4 and No. 200 sieves combined
and M_a is the mass in grams of the aliquot of sample used in the gradation analysis

4. Method Validation

OSHA does not have validation guidelines for the development of analytical methods designed to measure physical properties. Therefore, the tests employed to validate this method were designed for this purpose only and are presented and explained herein.

4.1 Reproducibility

To show that results obtained using this method are repeatable, 27 compliance samples were randomly selected from those submitted to SLTC. Samples were split into two portions. The first portion was classified (for both structural classification and soil type) by a first soils analyst according to the tests and instructions in this method. The second portion was independently classified in a similar manner by a different, second soils analyst. The results for both the structural component and type determined by the analysts are presented in Table 4.1 along with the percent sand and gravel found. Of the 27 samples, 26 showed agreement in structural classification and soil type.

Table 4.1. Reproducibility data.

sample no.	structural component (analyst 1)	structural component (analyst 2)	soil type (analyst 1)	soil type (analyst 2)	sand & gravel (%) (analyst 1)	sand & gravel (%) (analyst 2)
1	g. cohesionless*	g. cohesionless*	B	B	84.4	82.6
2	granular	granular	C	C	89.2	89.9
3	granular	granular	C	C	93.5	93.4
4	granular	granular	C	C	85.9	86.5
5	granular	granular	C	C	95.5	94.8
6	granular	granular	C	C	96.6	95.8
7	granular	granular	C	C	94.3	95.8
8	granular	cohesive	B	B	55.7	57.1
9	g. cohesionless*	granular	B	C	84.4	85.4
10	cohesive	cohesive	B	B	38.5	35.4
11	granular	granular	C	C	92.5	90.4
12	granular	granular	C	C	95.3	94.3
13	cohesive	cohesive	B	B	61.4	56.6
14	cohesive	cohesive	C	C	23.2	18.6
15	cohesive	cohesive	B	B	14.6	16.7
16	cohesive	cohesive	B	B	8.7	5.2
17	cohesive	cohesive	B	B	7.4	2.7
18	cohesive	cohesive	A	A	6.1	5.0
19	cohesive	cohesive	A	A	8.2	6.2
20	cohesive	cohesive	B	B	3.0	1.6
21	cohesive	cohesive	B	B	12.3	10.6
22	cohesive	cohesive	B	B	6.4	4.6
23	cohesive	cohesive	B	B	27.9	27.6
24	cohesive	cohesive	B	B	47.1	48.2
25	granular	granular	C	C	91.0	90.7
26	cohesive	cohesive	B	B	37.1	29.8
27	cohesive	cohesive	B	B	6.5	7.9

*granular cohesionless

4.2 Sieve Test

Sieve performance was verified using a NIST traceable sieve calibration standard SS398. Four No. 200 mesh (75 µm) sieves were tested with the standard. Two were heavily used sieves, which had been used in the collection of validation data for this method, and two were unused sieves. The results of the test are the mean aperture sizes of the sieves. The heavily used sieves had mean aperture sizes of 78.0 µm and 72.9 µm. The unused sieves had mean aperture sizes of 74.7 µm and 75.2 µm. All these results were within published ASTM E-11[23] tolerances of ±5 µm.

4.3 Compressive Strength Test

The penetrometer gauge has graduation marks in units of kg/cm^2 which is nearly equal to tons per square foot (tsf). In most instances these measurements are regarded as equal. The soil type can be determined, and structural component can be classified without conversion. In cases where conversion is necessary the following equation is used.

$$M_{tsf} = M_{kg/cm^2} \times 1.024$$

where M_{tsf} is the compressive strength in tsf
and M_{kg/cm^2} is the penetrometer dial reading in kg/cm^2

Because a measurement of compressive strength near 0.5 and 1.5 kg/cm^2 can be the distinguishing feature to determine the soil type of cohesive soil samples, a test was created to determine the precision of the penetrometer used in the analysis. A jig was designed to house both a balance and a penetrometer in such a way that the penetrometer could be pressed down onto the balance pan using an inverted jack above the balance. The jack was a simple lab support scissor jack. After the balance was properly checked and tared, the jack was used to press the penetrometer toward the balance pan until the piston on the penetrometer began to be compressed. The adjustment screw on the jack was then used to adjust the force on the balance until the dial of the penetrometer read 0.5 kg/cm^2, 1.5 kg/cm^2, and 2.5 kg/cm^2. (2.5 kg/cm^2 was included at the recommendation of the penetrometer manufacturer.) When the desired penetrometer reading was obtained, the force on the balance was read in pounds and converted to tsf. The test was repeated 20 times. The data were used to calculate a standard deviation (SD) a coefficient of variation (CV) and an inaccuracy. The data are included in Table 4.2 and summarized in Table 4.3.

[23] ASTM Standard E11, 2020, “Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves”, ASTM International, West Conshohocken, PA, DOI: 10.1520/E0011-20.

Table 4.2. Data for the compressive strength test.

replicate	0.488 (tsf)	1.465 (tsf)	2.441 (tsf)
1	0.480	1.478	2.475
2	0.488	1.500	2.439
3	0.494	1.483	2.436
4	0.492	1.508	2.460
5	0.491	1.466	2.441
6	0.495	1.467	2.451
7	0.487	1.469	2.457
8	0.489	1.536	2.474
9	0.517	1.568	2.542
10	0.565	1.485	2.460
11	0.553	1.511	2.458
12	0.517	1.445	2.578
13	0.461	1.474	2.407
14	0.499	1.487	2.452
15	0.484	1.462	2.449
16	0.507	1.510	2.507
17	0.493	1.480	2.377
18	0.517	1.465	2.458
19	0.507	1.514	2.485
20	0.489	1.497	2.460

Table 4.3. Summary data for the compressive strength test.

	0.488 (tsf)	1.465 (tsf)	2.441 (tsf)
mean (tsf)	0.501	1.490	2.463
SD	0.024	0.029	0.043
CV (%)	4.790	1.929	1.746
mean/calc	1.027	1.017	1.009
inaccuracy (%)	2.7	1.7	0.90

Appendix A

Submitting Samples from Outside the Continental United States (OCONUS)

A.1 Background

The USDA APHIS governs the sending of soil samples from OCONUS. Any facility authorized to receive and store OCONUS soil samples maintains one or more USDA APHIS Permits to Receive Soil. Each permit is issued to an individual at the facility and must be renewed every three years. Compliance officers sending soils from OCONUS to the SLTC must read the permit in its entirety and comply with all applicable conditions.

A.2 Procedure

Ship soil samples in a securely closed, watertight container, enclosed in a second, durable, watertight container. Do not ship more than 1.3 kg (3 lbs.), the authority of the permit specifies samples three pounds or less. Ensure the shipment is free of foreign matter or debris, plants and plant parts including noxious weeds and infestations by other macro-organisms.

Obtain and print a copy of the current permit by going to OSHA's Intranet, then CSHO's Resources, and it can be found under Inspection Preparation. A copy of the permit must accompany all OCONUS shipments.

Request a shipping label (PPQ Form 550 Black/White) from the SLTC Excavation Laboratory before sampling. Request one label for each package you expect to send. The labels take up to five days to prepare. The labels are serialized for one-time use only and will be e-mailed to the SLTC permit holder as a PDF file. The permit holder will then forward the PDF file to the requestor.

Attach a shipping label to the exterior of each package being imported under this permit with clear tape. The labels will include detailed shipping instructions. Enclose the following supplemental information inside each shipment: permittee name, permit number, and label number.