# 11.0 Visual-Manual Identification of Soil

## 11.1 Introduction

Soil classification is used to systematically group soils with similar physical characteristics in the same classification category. The use of a soil classification system produces a consistent description of soil samples that can be readily understood by engineers, geologists, drillers and other members of the project team. Soil classification systems groups soils based upon physical characteristics (e.g. grain size, gradation, plasticity, etc.). General engineering and hydrologic properties of soils can be estimated from these physical characteristics allowing rapid preliminary assessment of site conditions during a field investigation program when little time is available for laboratory analyses.

A systematic grouping of similar soil types based upon physical characteristics aids in the identification and correlation of subsurface stratigraphy. Accurate identification of subsurface structures of heterogeneities can have a significant impact on rates and directions of contaminant movement.

## 11.2 Purpose

Soils are classified on the basis of visual-manual tests and laboratory tests. The purpose of this SOP is to present standardized criteria for describing and identifying soils in the field. With proper training, experience, and regular feedback (correlation to laboratory tests), it is possible to accurately and consistently classify soils on the basis of visual-manual field observations/tests. The comparison of these field classifications to laboratory grain-size analyses or to pre-sieved standards in the office are necessary to confirm and refine the field descriptions.

Fluor Daniel GTI uses the Unified Soil Classification System (USCS) to describe soil samples. This classification system is the industry standard which is used throughout the environmental consulting and regulatory world. Using this standard will assist in our ability to communicate easily with our customers, regulatory officials, and fellow consultants.

## 11.3 References

The following ASTM Standards were consulted in the preparation of this SOP:

C 136-92 Test Method for Sieve Analysis of Fine and Coarse Aggregates
D 421-85(93) Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants
D 422-63(90) Test Method for Particle-Size Analysis of Soils
D 2217-85(93) Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants
**D 2487-92** Classification of Soils for Engineering Purposes (Unified Soil Classification System)
**D 2488-93** Practice for Description and Identification of Soils (Visual-Manual Procedure)

Note: an ASTM serial designation in bold type denotes a major reference used in the preparation of this SOP. Non-bold serial designations denote references useful in obtaining additional information pertinent to the subject matter.

The following additional references were also used in the preparation of this document:

Driscoll, F.G., 1986, *"Groundwater and Wells"*, Johnson Division, St. Paul, Minnesota.

Massachusetts Department of Environmental Protection (DEP), 1991, *"Standard References for Monitoring Wells"*, Publication #WSC-310-91, Section 3.5, "Soil Classification".

Mohr, H.A., 1962, *"Exploration of Soil Conditions and Sampling Operations"*, Boston, Massachusetts.

US Army Corps of Engineers, 1953, *"The Unified Soil Classification System"*, Waterways Experiment Station, Vicksburg, Mississippi.

US Department of the Interior, Bureau of Reclamation, 1986, *"Procedure for Determining Unified Soil Classification"* (Laboratory Method), USBR #5000-86.

US Department of the Interior, Bureau of Reclamation, 1986, *"Procedure for Determining Unified Soil Classification"* (Visual Method), USBR #5005-86.

## 11.4 Background

The basis of field soil classification used by FDGTI (and the environmental industry in general) is the Unified Soil Classification System (USCS). The basis for the USCS classification scheme is the Airfield Classification System developed by A. Casagrande in the 1940s. The USCS classifies soils from any geographic location into categories representing the results of prescribed laboratory tests to determine the particle-size characteristics, the liquid limit, and the plasticity index. For the purpose of this classification scheme, the following definitions apply:

**coefficient of uniformity**, $C_u$ (D) - the ratio $d_{60}/d_{10}$, where $d_{60}$ is the particle diameter corresponding to 60% finer on the cumulative particle size distribution curve, and $d_{10}$ is the particle size diameter corresponding to 10% finer on the cumulative particle-size distribution curve.

**liquid limit**, *LL*, $L_W$, $w_L$ (D) - (a) the water content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil. (b) the water content at which a pat of soil, cut by a groove of standard dimensions, will flow together for a distance of ½ in. (12.7 mm.) under the impact of 25 blows in a standard liquid limit apparatus.

**plasticity index**, $I_p$, *PI*, $I_W$ (D) - numerical difference between the liquid limit and the plastic limit.

**plastic limit**, $w_p$, *PL*, $P_W$ (D) - (a) the water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistency of a soil. (b) water content at which a soil will just begin to crumble when rolled into a thread approximately   in. (3.2 mm) in diameter.

Figures 11-1 through 11-3 present flow charts for classifying fine-grained soils, organic fine-grained soils and coarse-grained soils, respectively, using the USCS classification scheme. Figure 11-4 is a plasticity chart for the classification of fine-grained soils which shows how these soils are classified according to their liquid limit and plasticity index. Figure 11-5 is an example of a cumulative particle-size plot which is used to classify coarse-grained soils. Table 11-1, attached, is a summary of the USCS soil classification groups with typical descriptors, arranged according to categories and sub-categories used to define them. This table is a handy reference when performing field classification. And Table 11-2 is a USCS soil classification chart which summarizes the criteria used in assigning group symbols and group names based on laboratory tests.

## 11.5 Procedure

### 11.5.1 General

Care should be taken to assure that samples to be classified are representative of the soil strata from which they were obtained. The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted or standard procedure. The sample shall be carefully identified as to its origin. If the visual-manual soil method is used solely to identify soils (i.e., without laboratory confirmation) it shall be so stated in reports and all other appropriate documents. This practice has a particular value in grouping similar soil samples so that only a minimum number of laboratory tests need to be run for positive soil identification.

When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together; one sample completely described and identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this SOP.

Useful equipment that will aid in field identification and description of soils include:
a pocket knife or small spatula,
a small test tube and stopper (or a jar with a lid),
a hand lens,
a small squeeze bottle of dilute HCl,
a grain-size chart,
a Munsell color chart, and
a USCS Soil Classification Chart.

Table 11-1, attached, contains a summary of USCS soil classification groups.

For accurate description and identification, the minimum amount of the specimen to be examined shall be in accordance with the following schedule:

| Maximum Particle Size, Sieve Opening | Maximum Specimen Size, Dry Weight |
| --- | --- |
| 4.75 mm (No. 4) | 100g (0.25 lb.) |
| 9.5 mm (  in.) | 200g (0.5 lb) |
| 19.0 mm (¾ in.) | 1.0kg (2.2lb.) |
| 38.1 mm (1½ in.) | 8.0 kg (18 lb.) |
| 75.0 mm (3 in.) | 60.0 kg (132 lb.) |

### 11.5.2 Preliminary Classification

A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as **peat, PT**, and not subjected to further identification procedures.

Soil identification is based on the portion of the soil sample that will pass a 3-in. (75-mm) sieve (i.e., less than cobble size grains). The larger than 3-in. (75-mm) particles must be removed manually or mentally before classifying the soil. Estimate and note the percentage of cobbles and boulders. These estimates will be based on volume percentage.

Of the fraction of the soil smaller than 3-in. (75-mm), estimate and note the percentage, by dry weight, of the gravel, sand and fines. The following methods can be used to make this estimate:

*Jar Method* - Place a mixture of the soil sample and water in a test tube or a jar, apply a stopper or a lid, thoroughly shake the mixture, then allow the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 10 to 30 seconds. The relative proportions can be estimated from the relative volume of each size separate.

*Visual Method* - Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then do the same with the sand size particles and the fines. Then, mentally compare the number of sacks to estimate the percentage of plus No. 4 (larger than sand) sieve size and minus No. 4 (smaller than gravel) sieve size present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from a wash test.

*Wash test (for relative percentages of sand and fines)* - Select and moisten enough minus No. 4 sieve size material to form a 10 in. (25-mm) cube of soil. Cut the cube in half, set one half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. The percentage should be based on weight, not volume, however volume comparison will provide a reasonable indication of grain size percentages.

The soil is **fine-grained** if it contains 50% or more fines, and **coarse-grained** if it contains less than 50% fines. Once this preliminary classification has been made, more detailed identification will be performed in order to place the sample into a USCS group.

The following procedures provide instruction regarding the proper field classification of fine-grained (i.e., cohesive) and coarse-grained (granular) soils. Granular soils are typically classified through visual inspection. Cohesive soils, because the primary constituents are not visible, are typically classified through manual field tests.

The order of soil sample descriptors which FDGTI uses when classifying soils in the field is:

1. color,
2. moisture condition,
3. density/consistency,
4. hardness,
5. angularity,
6. shape,
7. size gradation:
   *for fine-grained soils:*
   7a. dry strength,
   7b. dilatancy,
   7c. toughness,
   7d. plasticity,
8. USCS classification based on No. 7,
9. structure,
10. reaction with HCl,
11. odor,
12. evidence of contamination (if any), and
13. other special conditions or notes.

The Unified Soil Classification two letter descriptor is placed in the appropriate column on the drilling log or in the field log.

The following procedures are presented in the order consistent with the order of the actual description shown above.

### 11.5.3 Color

Color is probably the most obvious feature of soil and is easily seen by laypersons. An observer experienced in a given area can often relate soil color to specific chemical, physical, and/or biological properties of the soils in that area. Some broad generalizations are also possible. Black soil color usually indicates the presence of organic matter. Red colors indicate the presence of free iron oxides common in well-oxidized soil. Upon the removal of free iron under reducing conditions, the soil mineral grains usually appear gray or bluish gray in color.

Mottling is indicative of soil which has experienced, or is experiencing a variety of conditions which affect the soil color. Thus, mottling in soil is a clue which should be evaluated in terms of depositional environments, groundwater fluctuations, or contaminant transport. Mottling is described in terms of three basic characteristics: abundance (few, common, many), contrast (faint, distinct, prominent), and size (fine, medium, coarse). In expressing color, it is customary to list the dominant color first, followed by a description of abundance, contrast, and size of other colors in the mottled pattern.

Gleization is the reduction of iron under anaerobic (oxygen depleted and usually water-saturated), soil conditions, with the production of bluish to greenish-gray matrix colors, with or without yellowish-brown, brown, and black mottles, and ferric and manganiferous concretions.

Describe the color. A standard color chart such as a Munsell Color Chart is useful in choosing standard color names, although it is generally not necessary to get overly-specific in naming a specific shade (i.e., “dark brown” is good enough). If the sample contains layers, patches or mottling of varying colors, note this and describe all of the representative colors. The color should be described for moist samples. If the color represents a dry sample, note this.

11.5.4 Moisture Condition

The percentage of pore space occupied by water determines the moisture content of the soil. The moisture condition of a soil sample at the time of sampling can shed important light on groundwater conditions. Near the water table, increasing moisture condition is indicative of the capillary fringe, which cannot be measured once the boring is completed as a monitoring well. This information can also have significant bearing on the movement of separate phase contaminants in the subsurface. Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 1.

**Table 1 Criteria for Describing Moisture Condition**

| | Description |
|---|---|
| Dry | Absence of moisture, dusty, dry to the touch |
| Moist | Damp, but no visible water |
| Wet | Visible free water, usually soil is below water table |

11.5.5 Density/Consistency

The soil classification flow charts (see Figures 11-1 through 11-3) indicate that the procedures for classifying granular and cohesive soils separate at this point. This separation results from the requirement that cohesive soils be classified through manual tests, because the soil grains are not visible to the naked eye.

The primary means for *in situ* measurement of soil density is the standard penetration test (SPT), which is described in detail in SOP No.10. The SPT yields an “N” value for the soil which represents a standard density. Thus, **any modification to the SPT procedures (such as use of a wire cable or winch) must be noted on the boring log, as it may affect the “N” value**.

The "N" value is used to apply standard density/consistency modifiers. There are different modifiers for granular and for cohesive soils. Also, if SPT is not performed, a manual test can be performed to yield a consistency modifier for fine-grained soils that do not contain significant amounts of gravel. Describe the density/consistency in accordance with criteria in Table 2.

**Table 2 Criteria for Describing Density/Consistency**

SPT, coarse-grained/granular soil:

| Description | |
|---|---|
| Very loose | |
| Loose | 4 - 1 |
| Medium dense | |
| Dense | 30 - 5 |
| Very dense | > 5 |

SPT, fine-grained/cohesive soil:

| Description | |
|---|---|
| Very soft | |
| Soft | 2 - 4 |
| Medium stiff | |
| stiff | |
| Very stiff | |
| Hard | > 3 |

Manual, fine-grained/cohesive soil:

| Description | |
|---|---|
| Very soft | Thumb will penetrate soil more than 1 in. (25 mm) |
| Soft | Thumb will penetrate soil about 1 in. (25 mm) |
| Firm | Thumb will indent soil about ¼ in. (6 mm) |
| Hard | Thumb will not indent soil but readily indented with thumbnail |
| Very Hard | Thumbnail will not indent soil |

*Geotechnical Implications*:

The SPT is used by civil and geotechnical engineers to calculate bearing strength of soil strata. FDGTI's customers may use our boring logs to design a rebuild or an expansion of an existing facility. Therefore, it is critical that the SPT methodology be followed exactly or modifications noted in the well log notes. It is important to remember:

- Logs may develop "a life of their own": if you record blowcounts, make sure you are following the SPT protocols.

- SPT results are used by engineers to determine bearing strength and other soil properties.
- FDGTI well logs may be used by customers for other purposes (e.g., preliminary foundation design).

*Hydrogeologic Implications:*

The density of a soil stratum influences the ability of that stratum to transmit water. The hydraulic conductivity of a soil stratum can be estimated from the mean grain size of the soil and the density as determined by the SPT. This method is described in Driscoll (1986), pages 737-738.

11.5.6 Hardness

Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer, for example, "gravel-size particles fracture with considerable hammer blow", or "some gravel-size crumble with hammer blow". "Hard" means particles do not crack, fracture or crumble under a hammer blow.

11.5.7. Angularity

The relative angularity of a soil sample can provide some insight into the mode of deposition of the geologic unit. Water transport usually rounds the sample grains. The degree roundness of a soil sample is directly proportional to the porosity of the soil.

Describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded in accordance with the criteria in Table 3 and in Figure 11-6, attached. A range of angularity may be stated, such as "rounded to subrounded".

**Table 3 Criteria for Describing Angularity of Coarse-Grained Particles**

| | Description |
|---|---|
| Angular | Particles have sharp edges and relatively plane sides with unpolished surfaces |
| Subangular | Particles are similar to angular description but have rounded edges |
| Subrounded | Particles have nearly plane sides but have well-rounded corners and edges |
| Rounded | Particles have smoothly curved sides and no edges |

11.5.8 Shape

Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet criteria in Table 4 and in Figure 11-7, attached. Otherwise, do not mention shape. Indicate the fraction of the particles that have the shape, such as "one-third of the gravel particles are flat".

**Table 4 Criteria for Describing Particle Shape**

The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.

Flat Particles with width thickness > 3
Elongated Particles with length width > 3
Flat and Elongated Particles meet criteria for both flat and elongated

11.5.9 Size Gradation

As discussed previously, the size gradation of a soil sample will be determined through visual means for coarse-grained soils and through field tests and manual methods for fine-grained soils. The boundaries between grain size categories (e.g., clay, silt, sand, gravel, cobble, and boulder) are described in the definitions, below, and are shown for the USCS on Table 11-1 and Figure 11-4, attached.

**clay** - fine-grained soil or the fine-grained portion of soil that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. The term has been used to designate the percentage finer than 0.002 mm (0.005 mm in some cases), but it is strongly recommended that this usage be discontinued, since there is ample evidence from an engineering standpoint that the properties described in the above definition are many times more important. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line.

**silt** - soil passing a No. 200 (75-µm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4, or the plot of plasticity index versus liquid limit falls below the "A" line.

**sand** - particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75-µm) sieve with the following subdivisions:

*coarse* - passes a No. 4 (4.75-mm) sieve and is retained on a No. 10 (2.00-mm) sieve.

*medium* - passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425-µm) sieve.

*fine* - passes a No. 40 (425-µm) sieve and is retained on a retained on a No. 200 (75-µm) sieve.

**gravel** - rounded or semirounded particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) U.S. standard sieve with the following subdivisions:

*coarse* - passes a 3-in. (75-mm) sieve and is retained on a ¾-in. (19-mm) sieve.

*fine* - passes a ¾-in. (19-mm) sieve and is retained on a retained on a No. 4 (4.75-mm) sieve.

**cobbles** - rock fragments, usually rounded or semirounded, that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve.

**boulders** - rock fragments, usually rounded by weathering or abrasion, that will not pass a 12-in. (300-mm) square opening.

*Range of Particle Sizes:*

For gravel and sand components, describe the range of particle sizes within each component as presented in the definitions, above. For example, "about 20% fine to coarse gravel" or "about 40% fine to medium sand".

*Maximum Particle Size:*

Describe the maximum particle size found in the sample in accordance with the following information:

- *sand size* - if the maximum particle size is a sand size, describe as fine, medium or coarse;
- *gravel size* - if the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass, for example, "maximum particle size 1½ in."; and
- *cobble or boulder size* - if the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle, for example "maximum dimension, 18 in."

*Primary Component:*

The first step in grain size classification is to determine the primary constituent or component (>50% by weight). One method to assist in field classification is the bag concept. The field scientist examines the soil sample and imagines the different size categories being placed in bags. The size/weight of the bags should help develop a consistent classification. The primary component should be capitalized.

*Secondary Components:*

Secondary components are described in a specific way according to USCS protocol, depending on their percentages. Figures 11-1 through 11-3 shows how to state the secondary component in the group name based on its percentage. Sections 11.5.10 and 11.5.11, below, also present protocol for choosing the proper secondary component descriptors based on percentages.

Care should be taken to ensure that the percentages used or inferred do not exceed 100%. The secondary components are not capitalized.

*Grading vs. Sorting:*

Grading and sorting are terms which refer to the range of grain sizes in a soil sample. Sorting is the term used by geologists and soil scientists and is the opposite of grading, which is the term used by engineers. The terms are described below:

**well graded (= "poorly sorted")** - composed of a wide range of grain sizes.

**poorly graded (= "well sorted")** - composed of a narrow range of grain sizes.

11.5.10 Identification of Fine-Grained Soils

Fine-grained or cohesive soil is defined as the soil which passes the #200 sieve. The USCS categories for cohesive soils are **silt** and **clay**. The classification of cohesive soil depends on manual tests because the soil grains can not be seen with the naked eye.

One of the primary means of classifying fine-grained soil is to determine its plasticity. Plasticity generally increases with clay content, so for the purpose of field classification, one can determine whether the fine fraction of a soil stratum is primarily silt or clay by determining the relative plasticity of the soil. This is a generalization which may lead to erroneous classification of plastic silts as clays. If the distinction between silt and clay is important on a project, a sample should be submitted to a soils lab for a hydrometer analysis to accurately classify the fine fraction of the soil.

The primary field tests for fine-grained soils are *dry strength*, *dilatancy* (mobility of pore water), and *toughness* tests. These are described below. Prior to testing a sample, remove particles that are medium sand-size and larger. Use about a handful of material.

*Dry Strength:*

1. From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.
2. From the molded material, make at least three test specimens which consist of a ball of material about ½ in. (12 mm) in diameter. Allow the test specimen to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 140$^{o}$ F (60$^{o}$ C).
3. If the test specimen contains natural dry lumps, those that are about ½ in. (12 mm) in diameter may be used in place of the molded balls. Note: the process of molding and drying usually produces higher strengths than in natural dry lumps of soil.
4. Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accordance with the criteria in Table 5. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain coarse sand.
5. The presence of high-strength water-soluble cementing materials, such as calcium carbonate, can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see Section 11.5.14, below).

Upon completion of the test, if the specimen is easy to crush it is probably a silt, and if it is hard to crush it is probably a clay.

**Table 5 Criteria for Describing Dry Strength**

| | Description |
|---|---|
| None | The dry specimen crumbles into powder with mere pressure of handling |

| | |
|---|---|
| Low | The dry specimen crumbles into powder with some finger pressure |
| Medium | The dry specimen breaks into pieces or crumbles with considerable finger pressure |
| High | The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface |
| Very high | The dry specimen cannot be broken between the thumb and a hard surface |

*Dilatancy:*

1. From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.
2. Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in Table 6. The reaction is the speed with which water appears while shaking and disappears while squeezing.

Upon completion of the test, if the specimen has a glassy, wet look, it is probably a silt, and if it has a dry look, it is probably a clay.

**Table 6 Criteria for Describing Dilatancy**

| | Description |
|---|---|
| None | No visible change in the specimen |
| Slow | Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing |
| Rapid | Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing |

*Toughness:*

1. Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about in. (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.)

2. Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about  in. The thread will crumble at a diameter of  in. when the soil is near the plastic limit.
3. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading.
4. Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in Table 7.

Upon completion of the test, if a thread can't be rolled, it is probably a silt, and if the specimen can be rolled into a thin thread, it is probably a clay. Note: some silts are plastic (i.e., able to be rolled into a thread), so above generalization should be confirmed by other tests.

**Table 7 Criteria for Describing Toughness**

| | Description |
|---|---|
| Low | Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft |
| Medium | Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness |
| High | Considerable pressure is required to roll the thread near the plastic limit. The thread and the lump have very high stiffness |

*Plasticity:*

On the basis of observations made during the toughness test, describe the plasticity of the soil in accordance with the criteria given in Table 8.

Soil moisture affects plasticity: higher moisture content yields higher plasticity. One should use a soil sample with moderate moisture content (this may require adding water to the sample if it has dried out or was collected from the vadose zone.

**Table 8 Criteria for Describing Plasticity**

| | Description |
|---|---|
| Nonplastic | a -in. thread cannot be rolled at any water content |
| Low | The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit |

Medium — The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.

High — It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

*Identification of Inorganic Fine-Grained Soils :*

- Identify the soil as a **lean clay, CL**, if the soil has medium to high strength, no or slow dilatancy, and medium toughness and plasticity.

- Identify the soil as a **fat clay, CH**, if the soil has high to very high dry strength, no dilatancy, and high toughness and plasticity.

- Identify the soil as a **silt, ML**, if the soil has no to low dry strength, slow to rapid dilatancy, and low toughness and plasticity, or is nonplastic.

- Identify the soil as and **elastic silt, MH**, if the soil has low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity. Note: these properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry.

Table 9 summarizes the identification of inorganic fine-grained soils based on manual tests.

**Table 9 Identification of Inorganic Fine-Grained Soils from Manual Tests**

| Soil Symbol | Dry Strength | Dilatancy | Toughness |
|---|---|---|---|
| ML | None to low | Slow to rapid | |
| CL | Medium to high | None to slow | Medium |
| MH | Low to medium | None to slow | Low to medium |
| CH | High to very high | None | High |

*Identification of Organic Fine-Grained Soils :*

- Identify the soil as a **organic soil, OL/OH**, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have dark brown to black color and may have an organic odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Organic soils will normally not have a high toughness or plasticity. The thread for the toughness test will be spongy.

If the soil is estimated to have 15 to 25% sand or gravel, or both, the words **"with sand"** or **"with gravel"** (whichever is more predominant) shall be added to the group name, for example, "lean clay with sand, CL". If the percentage of sand is equal to the percentage of gravel, use "with sand".

If the soil is estimated to have 30% or more sand or gravel, or both, the words **"sandy"** or **"gravelly"** (whichever is more predominant) shall be added to the group name, for example, "sandy lean clay, CL". If the percentage of sand is equal to the percentage of gravel, use the word "sandy".

11.5.11 Identification of Coarse-Grained Soils

Coarse-grained or granular soil is defined as the soil retained on the #200 sieve. The USCS categories for granular soils are **sand**, **gravel**, **cobbles**, and **boulders**. The classification of granular soil depends upon visual inspection because the soil grains can be seen by the naked eye. One should remember while classifying soil samples retrieved from a split-barrel sampler that the maximum size grain which can enter the spoon is 1 inch. An approximation of the larger fraction can sometimes be made from the auger cuttings or the resistance to drilling. The only accurate method to determine the larger fraction (coarse gravel and larger) is through test pit exploration.

The soil is a **gravel** if the percentage of gravel is estimated to be more than the percentage of sand.

The soil is a **sand** if the percentage of gravel is estimated to be equal or less than the percentage of sand.

The soil is a **clean gravel** or **clean sand** if the percentage of fines is estimated to be 5% or less.

Identify the soil as a **well-graded gravel, GW**, or as a **well-graded sand, SW**, if it has a wide range of particle sizes and substantial amounts of intermediate particle sizes.

Identify the soil as a **poorly graded gravel, GP**, or as a **poorly graded sand, SP**, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing ("gap" or "skip" graded).

The soil is either a **gravel with fines** or a **sand with fines** if the percentage of fines is estimated to be between 5 and 12%.

Identify the soil as a **clayey gravel, GC**, or a **clayey sand, SC**, if the fines are greater than 12% and are clayey as determined by the procedures in Section 11.5.10, above.

Identify the soil as **silty gravel, GM**, or **silty sand, SM**, if the fines are greater than 12% and are silty as determined by the procedures in Section 11.5.10, above.

If the soil is estimated to contain greater than 5% fines, give the soil a dual identification using two group symbols:

- The first group symbol shall correspond to a clean gravel or sand (GW GP, SW, SP) and the second symbol shall correspond to a gravel or sand with fines (GC, GM, SC, SM).
- The group name shall correspond to the first group symbol plus the words **"with clay"** or **"with silt"** to indicate the plasticity characteristics of the fines, for example "well graded gravel with clay, GW-GC" (see Figure 11-3).

If the specimen is predominantly sand or gravel but contains an estimated 15% or more of the other coarse-grained constituent, the words **"with gravel"** or **"with sand"** shall be added to the group name, for example, "poorly graded gravel with sand, GP" (see Figure 11-3).

If the field sample contains any cobbles or boulders, or both, the words **"with cobbles"** or **"with cobbles and boulders"** shall be added to the group name, for example "silty gravel with cobbles, GM".

### 11.5.12 USCS Classification

The USCS is summarized in Tables 11-1 and 11-2. The USCS consists of a set of boundaries between the different soil types, and a two-letter designation which described the major characteristics of the soil. The two letters describe the major components based upon the following abbreviations:

| Abbreviation | Description |
|---|---|
| **G** | Gravel |
| **S** | Sand |
| **M** | Silt |
| **C** | Clay |
| **W** | Well-Sorted |
| **P** | Poorly-Sorted |
| **L** | Low Plasticity |
| **H** | High Plasticity |
| **O** | Organic |

The two-letter USCS symbols are presented below:

| USCS Symbol | Soil Description |
|---|---|
| **GW** | well-graded gravels; gravel-sand mixtures; little or |
| **GP** | poorly-graded gravels; little or no fines |
| **GM** | silty gravels; gravel-silt-sand mixtures |
| **GC** | clayey gravels; gravel-clay-sand mixtures |
| **SW** | well-graded sands; sand-gravel mixtures; little or no fines |
| **SP** | poorly-graded sands; little or no fines |
| **SM** | silty sands; sand-silt mixtures |
| **SC** | clayey sands; sand-clay mixtures |
| **ML** | inorganic silts; silt-fine sand mixtures with slight plasticity |
| **CL** | inorganic clays w |
| **OL** | organic silts and organic silty clays with low plasticity |
| **MH** | inorganic silts with high plasticity, micaceous or diatomaceous silts |
| **CH** | inorganic clays with high plasticity; "fat" clays |
| **OH** | organic clays with medium to high plasticity; |

| | |
|---|---|
| | organic silts |
| **PT** | peat, humus, swamp soils with high organic content |

The two-letter symbols are particularly important to FDGTI because the GTGS graphics package, which is a computer program used to generate finished drilling logs, chooses the appropriate graphical pattern for a soil on drilling logs and cross-sections from the USCS two-letter symbol. (See SOP No. 10 for operation of the GTGS program).

11.5.13 Structure

The structure of a soil sample is a critical, yet often unrecorded characteristic which can yield valuable insight into depositional environments and structure-enhanced hydraulic conductivity. The field scientist should examine the sample, cut a section with a field knife, and describe the structure in accordance with criteria contained in Table 10. This examination should ideally be performed before the sample is removed for the split-barrel sampler, so that the structure is intact while classifying it.

**Table 10 Criteria for Describing Structure**

| | Description |
|---|---|
| Stratified | Alternating layers of varying material or color with layers at least 6 mm thick; note thickness |
| Laminated | Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness |
| Fissured | Breaks along definite planes of fracture with little resistance to fracturing |
| Slickensided | Fracture planes appear polished or glossy, sometimes striated |
| Blocky | Cohesive soil that can be broken down into smaller angular lumps which resist further breakdown |
| Lensed | Inclusions of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness |
| Homogeneous | Same color and appearance throughout |

11.5.14 Reaction with HCl

Use the following concentration of dilute hydrochloric acid to conduct tests: one part HCl (10 *N*) to three parts distilled water.

**Note**: when preparing this solution, slowly add the acid into water following necessary safety precautions. **Do not add the water to the acid.** Handle the acid with caution and store it safely. If the solution comes in contact with the skin, rinse thoroughly with water.

Place several drops of the dilute HCl solution onto the sample. Describe the reaction as none, weak, or strong in accordance with the criteria in Table 11. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction of the sample with dilute HCl is important.

**Table 11 Criteria for Describing the Reaction with HCl**

| | Description |
|---|---|
| None | No visible reaction |
| Weak | Some reaction, with bubbles forming slowly |
| Strong | Violent reaction, with bubbles forming immediately |

11.5.15. Odor

Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples. If the odor is unusual (petroleum product, chemical, etc.), particularly if it indicates the presence of a contaminant, describe it.

11.5.16. Evidence of Contamination

In addition to any odor that indicates the presence of contamination, describe any other physical indicators of contaminants such as visible product or staining.

11.5.17 Other Conditions or Notes

Additional comments shall be noted such as the presence of roots and root holes, shells or other recognizable inclusions, the occurrence of fill material or topsoil layers, difficulty in drilling or augering, caving of the trench or hole, etc. A local or commercial name or a geologic interpretation of the soil, or both, may be added if identified as such.

11.6 Checklists

As an aid in following the above procedures to properly identify and classify soils in the field, two checklists have been prepared. Table 11-3 is a checklist for the description of soils. It summarizes all of the descriptive elements that are detailed in the above sections. Table 11-4 is a soil classification checklist which provides a quick reference to some of the major characteristics that are used to classify a sample into the USCS groups. Copies of both of these checklists should be taken into the field and referred to as soil classification is performed.

**TABLE 11-1**
**USCS SOIL CLASSIFICATION GROUPS**

| **MAJOR DIVISIONS** | | | | |
|---|---|---|---|---|
| COARSE-GRAINED SOILS: More than 50% retained on No. 200 sieve* | GRAVELS: 50% or more of coarse fraction retained on a No. 4 sieve | CLEAN GRAVELS | GW | Well-graded gravels & gravel-sand mixtures, little or no fines. |
| | | | GP | Poorly graded gravels & gravel-sand mixtures, little or no fines. |
| | | GRAVELS WITH FINES | GM | Silty gravels, gravel-sand-clay mixtures. |
| | | | GC | Clayey gravels, gravel-sand-clay mixtures. |
| | SANDS: more than 50% of coarse fraction passes a No. 4 sieve | CLEAN SANDS | SW | Well-graded sands & gravelly sands, little or no fines. |
| | | | SP | Poorly graded sands & gravelly sands, little or no fines. |
| | | SANDS WITH FINES | SM | Silty sands, sand-silt mixtures. |
| | | | SC | Clayey sands, sand-clay mixtures. |
| FINE-GRAINED SOILS: 50% or more passes a No. 200 sieve* | SILTS & CLAYS: liquid limit 50% or less | | ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands. |
| | | | CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. |
| | | | OL | Organic silts & organic clays of low plasticity. |
| | SILTS & CLAYS: liquid limit greater than 50% | | MH | Organic silts, micaceous or diatomaceous fine sands or silts, elastic silts. |
| | | | CH | Inorganic clays of high plasticity, fat clays. |
| | | | OH | Organic clays of medium to high plasticity. |
| HIGHLY ORGANIC SOILS | | | PT | Peat, muck & other highly organic soils. |

*Based on material passing the 3-in. (75-mm) sieve.

**TABLE 11-2**
**USCS SOIL CLASSIFICATION CHART**

| Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A] | | | | | Soil Classification: Group Symbol | Soil Classification: Group Name [B] |
|---|---|---|---|---|---|---|
| COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve | Gravels More than 50% of coarse fraction retained on No. 4 sieve | Clean Gravels Less than 5% fines [C] | $Cu \geq 4$ and $1 \leq Cc \leq 3$ [E] | | GW | Well-graded gravel [F] |
| | | | $Cu < 4$ and/or $1 > Cc > 3$ [E] | | GP | Poorly graded gravel [F] |
| | | Gravels with Fines More than 12% fines [C] | Fines classify as ML or MH | | GM | Silty Gravel [F, G, H] |
| | | | Fines classify as CL or CH | | GC | Clayey Gravel [F, G, H] |
| | Sands 50% or more of coarse fraction passes No. 4 sieve | Clean Sands Less than 5% fines[D] | $Cu \geq 6$ and $1 \leq Cc \leq 3$ [E] | | SW | Well-graded sand [I] |
| | | | $Cu < 6$ and/or $1 > Cc > 3$ [E] | | SP | Poorly graded sand [I] |
| | | Sands with Fines More than 12% fines[D] | Fines classify as ML or MH | | SM | Silty sand [G, H, I] |
| | | | Fines classify as CL or CH | | SC | Clayey sand [G, H, I] |
| FINE-GRAINED SOILS 50% or more passes the No. 200 sieve | Silts and Clays Liquid limit less than 50 | inorganic | PI > 7 and plots on or above "A" line [J] | | CL | Lean clay [K, L, M] |
| | | | PI < 4 or plots below "A" line [J] | | ML | Silt [K, L, M] |
| | | organic | Liquid limit - oven dried / Liquid limit - not dried | < 0.75 | OL | Organic clay [K, L, M, N] |
| | | | | | | Organic silt [K, L, M, O] |
| | Silts and Clays Liquid limit 50 or more | inorganic | PI plots on or above "A" line | | CH | Fat clay [K, L, M] |
| | | | PI plots below "A" line | | MH | Elastic silt [K, L, M] |
| | | organic | Liquid limit - oven dried / Liquid limit - not dried | < 0.75 | OH | Organic clay [K, L, M, P] |
| | | | | | | Organic silt [K, L, M, Q] |
| HIGHLY ORGANIC SOILS | | Primarily organic matter, dark in color, and organic odor | | | PT | Peat |

[A]Based on the material passing the 3-in. (75-mm) sieve.
[B]If field sample contained cobbles or boulders, or both, add “with cobbles or boulders, or both” to group name.
[C]Gravels with 5 to 12% fines require dual symbols:
GW-GM well-graded gravel with silt
GW-GC well-graded gravel with clay
GP-GM poorly graded gravel with silt
GP-GC poorly graded gravel with clay
[D]Sands with 5 to 12% fines require dual symbols:
SW-SM well-graded sand with silt
SW-SC well-graded sand with clay
SP-SM poorly graded sand with silt
SP-SC poorly graded sand with clay
Cc = {(D SUB 30) SUP 2} OVER {D SUB 10 x D SUB 30}

[E]Cu = $D_{60}/D_{10}$

**TABLE 11-3**
**CHECKLIST FOR DESCRIPTION OF SOILS**

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range:
   Gravel - fine, coarse
   Sand - fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape: (if appropriate) flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: non-plastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition
15. Odor: none, organic, hydrocarbon, other
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong

    *For intact samples:*
18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
20. Cementation: weak, moderate, strong
21. Local name
22. Geologic interpretation
23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc., surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, presence of contaminants

# TABLE 11-4
## Soil Classification Checklist

| Color | Moisture Content | Density/ Consistency | Plasticity (Cohesive) | Angularity (Granular) | Size Gradation | Structure | Evidence of Contamination | Special Conditions | Unified Class. |
|---|---|---|---|---|---|---|---|---|---|
| Various | Dry | Granular | Not | Very angular | Granular | Homogeneous | Various | Various | GW |
| | Damp | | | | | | Slightly | Angular | |
| | | | | | | Heterogeneous | | | GP |
| | Moist | Very loose | Moderately | Subangular | Fine sand | Stratified | | | GM |
| | Wet | Loose | Highly | Subrounded | Medium sand | Laminated | | | GC |
| | Saturated | Med. dense | | Rounded | Coarse sand | Lens | | | SW |
| | | Dense | | Well rounded | Fine gravel | Root holes | | | SP |
| | | Very dense | | | Coarse gravel | Varves | | | SM |
| | | | | | Cobble | Occasional | | | SC |
| | | Cohesive | | | Boulder | Interbedded | | | ML |
| | | | | | | Mottled | | | CL |
| | | Very soft | | | Cohesive | Topsoil | | | OL |
| | | Soft | | | | | | | MH |
| | | Med. stiff | | | Silt | | | | CH |
| | | Stiff | | | Clay | | | | OH |
| | | Very stiff | | | | | | | PT |
| | | Hard | | | | | | | |

## EXAMPLES

Gray, damp, medium dense, angular, coarse to fine SAND, little fine gravel, trace silt (SW)

Brown, wet, very soft, slightly plastic, SILT and fine sand, trace clay (ML). Note: sample spoon advanced with weight of hammer only.

Notes:

Do not attempt to determine the relative sand sub-fractions in a sample unless there is a predominant size. For example, one should use "coarse to fine SAND" rather than "coarse SAND and medium sand, trace fine sand"

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**INSERT FIGURE 1a FROM ASTM D 2487 AS FIGURE 11-1**
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**INSERT FIGURE 1b FROM ASTM D 2487 AS FIGURE 11-2**
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**INSERT FIGURE 2 FROM ASTM D 2487 AS FIGURE 11-3**
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**INSERT FIGURE 3 FROM ASTM D 2487 AS FIGURE 11-4**
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**INSERT FIGURE 4 FROM ASTM D 2487 AS FIGURE 11-5**
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**INSERT FIGURE 3 FROM ASTM D 2488 AS FIGURE 11-6**
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**INSERT FIGURE 4 FROM ASTM D 2488 AS FIGURE 11-7**
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