Chapter 3

ENGINEERING CLASSIFICATION AND DESCRIPTION OF SOIL

General

Application

Soil investigations conducted for engineering purposes that use test pits, trenches, auger and drill holes, or other exploratory methods and surface sampling and mapping are logged and described according to the Unified Soil Classification System (USCS) as presented in Bureau of Reclamation (Reclamation) standards USBR 5000 [1] and 5005 [2]. Also, bedrock materials with the engineering properties of soils are described using these standards (chapter 2). The Reclamation standards are consistent with the American Society for Testing Materials (ASTM) Designation D2487 and 2488 on the USCS system [3,4]. Descriptive criteria and terminology presented are primarily for the visual classification and manual tests. The identification portion of these methods in assigning group symbols is limited to soil particles smaller than 3 inches (in) (75 millimeters [mm]) and to naturally occurring soils. Provisions are also made to estimate the percentages of cobbles and boulders by volume. This descriptive system may also be applied to shale, shells, crushed rock, and other materials if done according to criteria established in this section. Chapter 11 addresses the logging format and criteria for describing soil in test pits, trenches, auger holes, and drill hole logs.

All investigations associated with land classification for irrigation suitability, data collection, analyses of soil and substratum materials related to drainage investigations, and Quaternary stratigraphy (e.g., fault and paleoflood studies) are logged and described using the

U.S. Department of Agriculture terminology outlined in appendix I to *Agriculture Handbook No. 436 (Soil Taxonomy),* dated December 1975 [5].

All soil classification descriptions for particle sizes less than No. 4 sieve size are to be in metric units.

Performing Tests and Obtaining Descriptive Information

The USCS groups soils according to potential engineering behavior. The descriptive information assists with estimating engineering properties such as shear strength, compressibility, and permeability. These guidelines can be used not only for identification of soils in the field but also in the office, laboratory, or wherever soil samples are inspected and described.

Laboratory classification of soils [1] is not always required but should be performed as necessary and can be used as a check of visual-manual methods. The descriptors obtained from visual-manual inspection provide valuable information not obtainable from laboratory testing. Visual-manual inspection is always required. The visual-manual method has particular value in identifying and grouping similar soil samples so that only a minimum number of laboratory tests are required for positive soil classification. The ability to identify and describe soils correctly is learned more readily under the guidance of experienced personnel, but can be acquired by comparing laboratory test results for typical soils of each type with their visual and manual characteristics. When identifying and describing soil samples from an area or project, all the procedures need not be followed. Similar soils may be grouped together; for example, one sample should be identified and described completely, with the others identified as similar based on performing only a few of the identification and descriptive procedures.

Descriptive information should be evaluated and reported on every sample.

The sample used for classification must be representative of the stratum and be obtained by an appropriate accepted or standard procedure. The origin of the material must be correctly identified. The origin description may be a boring number and depth and/or sample number, a geologic stratum, a pedologic horizon, or a location description with respect to a permanent monument, a grid system, or a station number and offset.

Terminology for Soils

Definitions for soil classification and description are in accordance with USBR 3900 Standard Definitions of Terms and Symbols Relating to Soil Mechanics [6]:

Cobbles and boulders—particles retained on a 3-inch (75-mm) U.S. Standard sieve. The following terminology distinguishes between cobbles and boulders:

- Cobbles—particles of rock that will pass a 12-in (300-mm) square opening and be retained on a 3-in (75-mm) sieve.

- Boulders—particles of rock that will not pass a 12-in (300-mm) square opening.

Gravel—particles of rock that will pass a 3-in (75-mm) sieve and is retained on a No. 4 (4.75-mm) sieve. Gravel is further subdivided as follows:

- Coarse gravel—passes a 3-in (75-mm) sieve and is retained on 3/4-in (19-mm) sieve.

- Fine gravel—passes a ¾-in (19-mm) sieve and is retained on No. 4 (4.75-mm) sieve.

Sand—particles of rock that will pass a No. 4 (4.75-mm) sieve and is retained on a No. 200 (0.075-mm or 75-micrometer [µm]) sieve. Sand is further subdivided as follows:

- Coarse sand—passes No. 4 (4.75-mm) sieve and is retained on No. 10 (2.00-mm) sieve.

- Medium sand—passes No. 10 (2.00-mm) sieve and is retained on No. 40 (425-µm) sieve.

- Fine sand—passes No. 40 (425-µm) sieve and is retained on No. 200 (0.075-mm or 75-µm) sieve.

Clay—passes a No. 200 (0.075-mm or 75-µm) sieve. Soil has plasticity within a range of water contents and has considerable strength when air-dry. For classification, clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index greater than 4 and the plot of plasticity index versus liquid limit falls on or above the "A"-line (figure 3-5, later in this chapter).

Silt—passes a No. 200 (0.075-mm or 75-µm) sieve. Soil is nonplastic or very slightly plastic and that exhibits little or no strength when air-dry is a silt. 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 (figure 3-5).

Organic clay—clay with sufficient organic content to influence the soil properties is an organic clay. For classification, an organic clay is a soil that would be classified as a clay except that its liquid limit value after oven-drying is less than 75 percent of its liquid limit value before oven-drying.

Organic silt—silt with sufficient organic content to in-flu-ence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven-drying is less than 75 percent of its liquid limit value before oven-drying.

Peat—material composed primarily of vegetable tissues in various stages of decomposition, usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous. Classification procedures are not applied to peat.

Classifications of Soils

Group Names and Group Symbols

The identification and naming of a soil based on results of visual and manual tests is presented in a subsequent section. Soil is given an identification by assigning a group symbol(s) and group name. Important information about the soil is added to the group name by the term "with" when appropriate (figures 3-1, 3-2, 3-3, 3-4). The group name is modified using “with” to stress other significant components in the soil.

Figure 3-2 is a flow chart for assigning typical names and group symbols for inorganic fine-grained soils; figure 3-3 is a flow chart for organic fine-grained soils; figure 3-4 is a flow chart for coarse-grained soils. Refer to tables 3-1 and 3-2 for the basic group names without modifiers. If the soil has properties which do not distinctly place it in

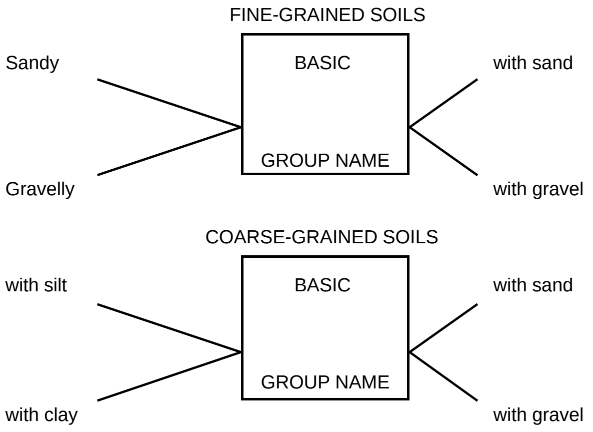

Figure 3-1.—Modifiers to basic soil group names (for visual classification).

a specific group, borderline symbols may be used. There is a distinction between *dual symbols* and *borderline symbols*.

Dual Symbols.—Dual symbols separated by a hyphen are used in laboratory classification of soils and in visual classification when soils are estimated to contain 10 percent fines. A dual symbol (two symbols separated by a hyphen, e.g., GP-GM, SW-SC, CL-ML) should be used to indicate that the soil has the properties of a classification where two symbols are required. Dual symbols are required when the soil has between 5 and 12 percent fines from laboratory tests (table 3-2), or fines are estimated as 10 percent by visual classification. Dual symbols are also required when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (figure 3-5, later in this chapter).

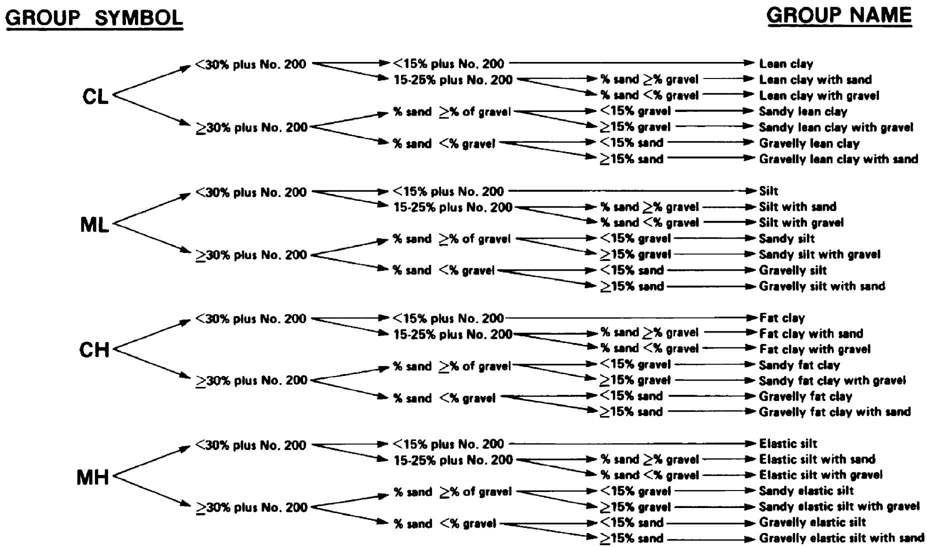

Figure 3-2.—Flow chart for inorganic fine-grained soils, visual method.

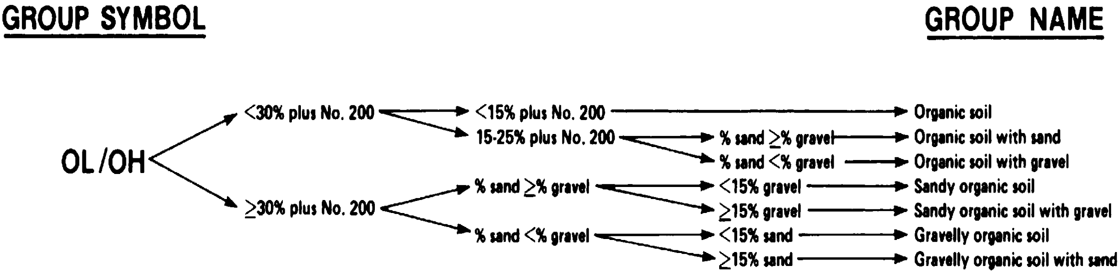

Figure 3-3.—Flow chart for organic soils, visual method.

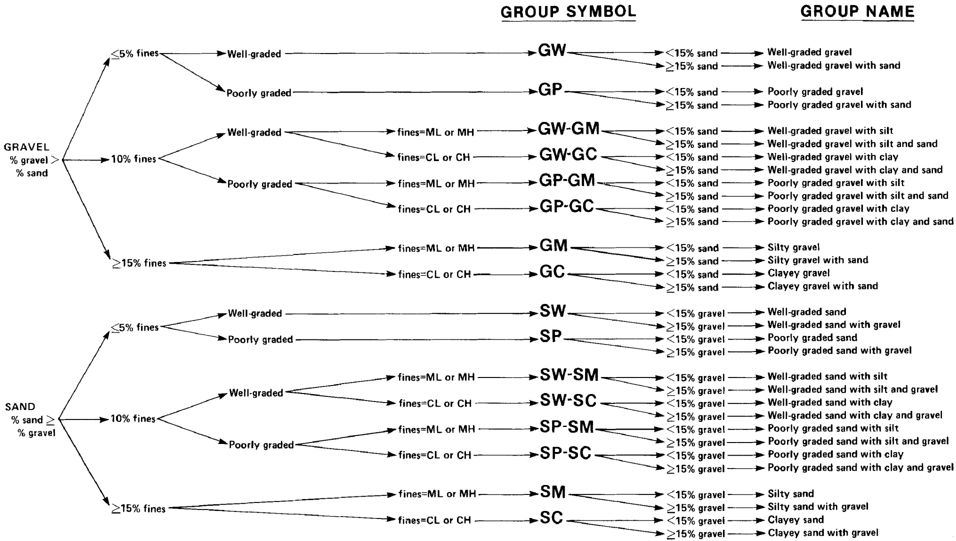

Figure 3-4.—Flow chart for coarse-grained soils, visual method.

Table 3-1.—Basic group names, primary groups

Coarse-grained soils	Fine-grained soils
GW - Well graded gravel	CL - Lean clay
GP - Poorly graded gravel	ML - Silt
GM - Silty gravel	OL - Organic clay (on or above A-line
GC - Clayey gravel sand	- Organic silt (below A-line)
SW - Well graded sand	CH - Fat clay
SP - Poorly graded sand	MH - Elastic silt
SM - Silty sand	OH - Organic clay (on or above A-line)
SC - Clayey sand	- Organic silt (below A-line)

Basic group name—hatched area on Plasticity Chart (Laboratory Classification)		
CL-ML	-	Silty clay
GC-GM	-	Silty, clayey gravel
SC-SM	-	Silty, clayey sand

Table 3-2.—Basic group names, 5 to 12 percent fines (Laboratory Classification)

GW-GM	-	Well graded gravel with silt
GW-GC	-	Well graded gravel with clay (if fines = CL-ML) Well graded gravel with silty clay
GP-GM	-	Poorly graded gravel with silt
GP-GC	-	Poorly graded gravel with clay (if fines = CL-ML) Poorly graded gravel with silty clay
SW-SM	-	Well graded sand with silt
SW-SC	-	Well graded sand with clay (if fines = CL-ML) Well graded sand with silty clay
SP-SM	-	Poorly graded sand with silt
SP-SC	-	Poorly graded sand with clay (if fines = CL-ML) Poorly graded sand with silty clay

Borderline Symbols.—Borderline symbols are used when soil properties indicate the soil is close to another classification group. Two symbols separated by a slash, such as CL/CH, SC/CL, GM/SM, CL/ML, should be used to indicate that the soil has properties that do not distinctly place the soil into a specific group. Because the visual classification of soil is based on estimates of particle-size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. A borderline classification symbol should not be used indiscriminately. Every effort should be made first to place the soil into a single group. Borderline symbols can also be used in laboratory classification, but less frequently.

A borderline symbol may be used when the percentage of fines is visually estimated to be between 45 and 55 percent. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil. For example: GM/ML, CL/SC.

A borderline symbol may be used when the percentage of sand and the percentage of gravel is estimated to be about the same, for example, GP/SP, SC/GC, GM/SM. It is practically impossible to have a soil that would have a borderline symbol of GW/SW. However, a borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

A borderline symbol may be used when the soil could be either a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

A borderline symbol may be used when a fine-grained soil has properties at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

The order of the borderline symbol should reflect similarity to surrounding or adjacent soils. For example, soils in a borrow area have been predominantly identified as CH. One sample has the borderline symbol of CL and CH. To show similarity to the adjacent CH soils, the borderline symbol should be CH/CL.

The group name for a soil with a borderline symbol should be the group name for the first symbol, except for:

CL/CH - lean to fat clay
ML/CL - clayey silt
CL/ML - silty clay

Preparation for Identification and Visual Classification

A usually dark-brown to black material composed primarily of vegetable tissue in various stages of decomposition with a fibrous to amorphous texture and organic odor is a highly organic soil and classified as peat, PT. Plant forms may or may not be readily recognized. In general, the greater the organic content, the greater the water content, void ratio, and compressibility of peat. Organic soils are often identified by their odor. To check for organic content, the soil can be subjected to the laboratory classification liquid limit test criteria. Organic soils can also be identified through laboratory loss-on-ignition tests. Materials identified as peat are not subjected to the following identification procedures.

Soil identification procedures are based on the minus 3-in (75-mm) particle sizes. All plus 3-in (75-mm) particles must be manually removed from a loose sample, or mentally for an intact sample, before classifying the soil. Estimate and note the percent by volume of the plus 3-in (75-mm) particles, both the percentage of cobbles and the percentage of boulders.

> Note: Because the percentages of the particle-size distribution in laboratory classification (ASTM: D 2487) are by dry weight and the estimates of percentages for gravel, sand, and fines are by dry weight, the description should state that the percentages of cobbles and boulders are by volume, not weight, for visual classification. Estimation of the volume of cobbles and boulders is not an easy task. Accurate estimating requires experience. While experienced loggers may be able to successfully estimate the minus 3-in fraction to within 5 percent, the margin of error could be larger for oversize particles. Estimates can be confirmed or calibrated with large scale field gradation tests on critical projects. Given the large possible errors in these estimates, the estimates should not be used as the sole basis for design of processing equipment. Large scale gradations should be obtained as part of the process plant designs.

In most cases, the volume of oversize is estimated in three size ranges, 3 to 5, 5 to 12, and 12 inches and larger. Cobbles are often divided into two size ranges, because in roller compacted fill of 6-in compacted lift thickness, the maximum size cobble is 5 inches. If the purpose of the investigation is not for roller compacted fill, a single size range for cobbles can be estimated.

Estimate and note the percentage by dry weight of the gravel, sand, and fines of the fraction of the soil smaller than 3 in (75-mm). The percentages are estimated to the closest 5 percent. The percentages of gravel, sand, and fines must add up to 100 percent, excluding trace amounts. The presence of a component not in sufficient quantity to be considered 5 percent in the minus 3-in (75-mm) portion, is indicated by the term "trace." For example: trace of fines. A trace is not considered in the total of 100 percent for the components.

The first step in the identification procedure is to determine the percentages of fine-grained and coarse-grained materials in the sample. The soil is fine-grained if it contains 50 percent or more fines. The soil is coarse-grained if it contains less than 50 percent fines. Procedures for the description and classification of these two preliminary identification groups follow.

Procedures and Criteria for Visual Classification of Fine-Grained Soils

Select a representative sample of the material for examination and remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of representative material is available. Use this specimen for performing the identification tests.

Identification Criteria for Fine-Grained Soils.—The tests for identifying properties of fines are dry strength, dilatency, toughness, and plasticity.

> 1. *Dry strength.*—Select from the specimen enough material to mold into a ball about 1 in (25 mm) in diameter. Mold or work the material until it has the consistency of putty, adding water if necessary.

From the molded material, make at least three test specimens. Each test specimen should be a ball of material about ½ in (12 mm) in diameter. Allow the test specimens to dry in air or sun, or dry by artificial means, as long as the temperature does not exceed 60 degrees Centigrade (EC). In most cases, it will be necessary to prepare specimens and allow them to dry over night. If the test specimen contains natural dry lumps, those that are about ½ in (12 mm) in diameter may be used in place of molded balls. (The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil). Test the strength of the dry balls or lumps by crushing them between the fingers and note the strength as none, low, medium, high, or very high according to the criteria in table 3-3. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

Table 3-3.—Criteria for describing dry strength

None	The dry specimen crumbles with mere pressure of handling.
Low	The dry specimen crumbles 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 thumb and a hard surface.

The presence of high-strength, water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrocloric acid (HCl). Criteria for reaction with HCl are presented in a subsequent paragraph.

2. Dilatancy.—Select enough material from the specimen to mold into a ball about ½ in (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency. Smooth the soil ball in the palm of one hand with the blade of a knife or spatula. Shake horizontally (the soil ball), striking the side of the hand vigorously against the other hand several times. Note the reaction of the water appearing on the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers and note reaction as none, slow, or rapid according to the criteria in table 3-4. The reaction criteria are the speeds with which water appears while shaking and disappears while squeezing.

Table 3-4.—Criteria for describing dilatancy

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

3. Toughness.—Following completion of the dilatancy test, the specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about **c** in (3 mm) diameter. (If the sample is too wet to roll easily, spread the sample out into a thin layer and allow some water loss by evaporation). Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about **c** in (3 mm) when the soil is near the plastic limit. Note the time required to reroll the thread to reach the plastic limit. 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.

Describe the toughness of the thread and lump as low, medium, or high according to the criteria in table 3-5.

Table 3-5.—Criteria for describing toughness

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 to near the plastic limit. The thread and the lump have very high stiffness.

4. Plasticity.—On the basis of observations made during the toughness test, describe the plasticity of the material according to the criteria given in table 3-6 (figure 3-5).

Table 3-6.—Criteria for describing plasticity

Nonplastic	A 3-mm 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 rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

After the dry strength, dilatency, toughness, and plasticity tests have been performed, decide on whether the soil is an organic or an inorganic fine-grained soil.

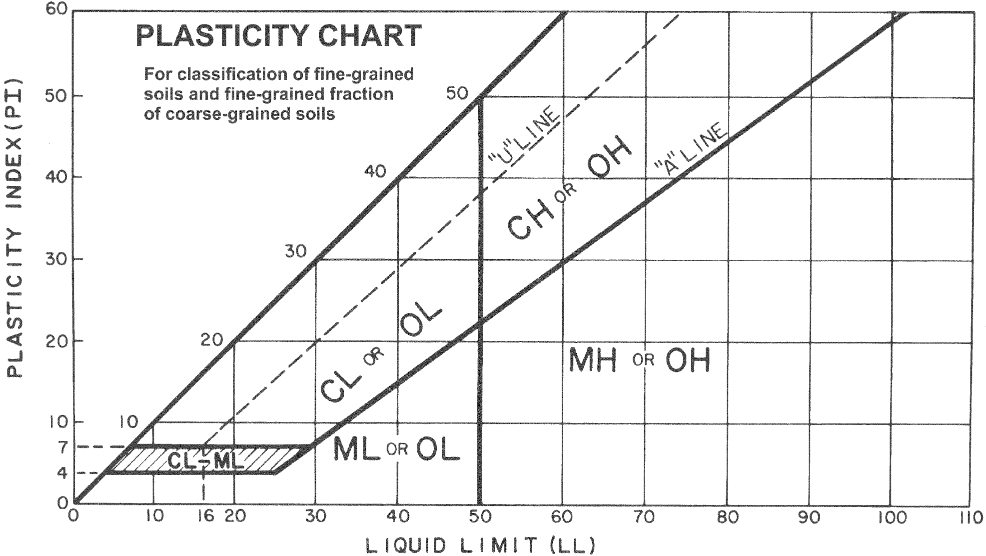

Figure 3-5.—Plasticity chart.

Identification of Inorganic Fine-Grained Soils.—Classify the soils using the results of the manual tests and the identifying criteria shown in table 3-7. Possible inorganic soils include lean clay (CL), fat clay (CH), silt (ML), and elastic silt (MH). The properties of an elastic silt 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. Some soils which classify as MH according to the field classification criteria are difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing to ensure proper classification.

Table 3-7.—Identification of inorganic fine-grained soils from manual tests

Group symbol	Dry strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot be formed
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

Some soils undergo irreversible changes upon air drying. These irreversible processes may cause changes in atterberg limits and other index tests. Even unsuspected soils such as low plasticity silts may have differing atterberg limits due to processes like disaggregation. When tested at natural moisture, clay particles cling to silt particles resulting in less plasticity. When dried, the clay disaggregates, making a finer and more well graded mix of particles with increased plasticity.

For foundation studies of existing or new structures, natural moisture atterberg limits are preferred because the in-place material will remain moist. Natural moisture atterberg limits are especially important in critical studies, such as earthquake liquefaction evaluation of silts. On some foundation studies, such as for pumping plant design, consolidation tests will govern, and natural moisture atterbergs are not required. For borrow studies, soils will likely undergo moisture changes, and natural moisture atterberg limits are not required unless unusual mineralogy is encountered.

Identification of Organic Fine-Grained Soils.—If the soil contains enough organic particles to influence the soil properties, classify the soil as an *organic soil*, OL or OH. Organic soils usually are dark brown to black and usually have an organic odor. Often organic soils will change color, (black to brown) when exposed to air. Organic soils normally do not have high toughness or plasticity. The thread for the toughness test is spongy. In some cases, further identification of organic soils as organic silts or organic clays, OL or OH is possible. Correlations between the dilatancy, dry strength, and toughness tests with laboratory tests can be made to classify organic soils in similar materials.

Modifiers for Fine-Grained Soil Classifications.—If based on visual observation, the soil is estimated to have 15 to 25 percent sand and/or gravel, the words "with sand and/or gravel" are added to the group name, for example, LEAN CLAY WITH SAND, (CL); SILT WITH SAND AND GRAVEL (ML). Refer to figures 3-2 and 3-3. If the soil is visually estimated to be 30 percent or more sand and/or gravel, the words "sandy" or "gravelly" are added to the group name. Add the word "sandy" if there appears to be more sand than gravel. Add the word "gravelly" if there appears to be more gravel than sand, for example, SANDY LEAN CLAY (CL); GRAVELLY FAT CLAY (CH);

SANDY SILT (ML). Refer to figures 3-2 and 3-3. Note that the Laboratory Classification follows different criteria.

Procedures and Criteria for Visual Classification of Coarse-Grained Soils

A representative sample containing less than 50 percent fines is identified as a coarse-grained soil.

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

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

The soil is a clean gravel or clean sand if the percentages of fines are visually estimated to be 5 percent or less. A clean gravel or sand is further classified by grain size distribution.

The soil is classified as a WELL GRADED GRAVEL (GW), or as a WELL GRADED SAND (SW), if a wide range of particle sizes and substantial amounts of the intermediate particle sizes are present. The soil is classified as a POORLY GRADED GRAVEL (GP) or as a POORLY GRADED SAND (SP) if the material is predominantly one size (uniformly graded) or the soil has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

The soil is identified as either gravel with fines or sand with fines if the percentage of fines is visually estimated to be 15 percent or more.

Classify the soil as a CLAYEY GRAVEL (GC) or a CLAYEY SAND (SC) if the fines are clayey as determined by the procedures for fine-grained soil identification.

Identify the soil as a SILTY GRAVEL (GM) or a SILTY SAND (SM) if the fines are silty as determined by the procedures for fine-grained soil identification.

If the soil is visually estimated to contain 10 percent fines, give the soil a dual classification using two group symbols. The first group symbol should correspond to a clean gravel or sand (GW, GP, SW, SP), and the second symbol should correspond to a gravel or sand with fines (GC, GM, SC, SM). The typical name is the first group symbol plus "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example, WELL GRADED GRAVEL WITH CLAY (GW-GC); POORLY GRADED SAND WITH SILT (SP-SM). Refer to figure 3-4.

If the specimen is predominantly sand or gravel but contains an estimated 15 percent or more of the other coarse-grained constituent, the words "with gravel" or "with sand" are added to the group name. For example: POORLY GRADED GRAVEL WITH SAND (GP); CLAYEY SAND WITH GRAVEL (SC). Refer to figure 3-4.

If the field sample contained any cobbles and/or boulders, the words "with cobbles" or "with cobbles and boulders" are added to the group name, for example, SILTY GRAVEL WITH COBBLES (GM).

Abbreviated Soil Classification Symbols

If space is limited, an abbreviated system may be used to indicate the soil classification symbol and name such as in logs, data bases, tables, etc. The abbreviated system is not a substitute for the full name and descriptive information but can be used in supplementary presentations. The abbreviated system consists of the soil classification system based on this chapter, with prefixes and suffixes as listed below.

Prefix:	s = sandy	g = gravelly
Suffix:	s = with sand	g = with gravel
	c = with cobbles	b = with boulders

The soil classification symbol is enclosed in parentheses. Examples are:

CL, sandy lean clay	s(CL)
SP-SM, poorly graded sand with silt and gravel	(SP-GM)g
GP, poorly graded gravel with sand, cobbles, and boulders	(GP)scb
ML, gravelly silt with sand and cobbles	g(ML)sc

Description of the Physical Properties of Soil

Descriptive information for classification and reporting soil properties such as angularity, shape, color, moisture conditions, and consistency are presented in the following paragraphs.

Angularity

Angularity is a descriptor for coarse-grained materials only. The angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, are described as angular, subangular, subrounded, or rounded as indicated by the criteria in table 3-8. A range of angularity may be stated, such as: sub-rounded to rounded.

Table 3-8.—Criteria for describing angularity of coarse-grained particles

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

Shape

Describe the shape of the gravel, cobbles, and boulders as "flat, elongated" or "flat and elongated" if they meet the criteria in table 3-9. Indicate the fraction of the particles that have the shape, such as: one-third of gravel particles are flat. If the material is to be processed or used as aggregate for concrete, note any unusually shaped particles.

Color

Color is an especially important property in identifying organic soils and is often important in identifying other types of soils. Within a given locality, color may also be useful in identifying materials of similar geologic units. Color should be described for moist samples. Note if color

Table 3-9.—Criteria for describing particle shape

The particle shape is 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.

represents a dry condition. If the sample contains layers or patches of varying colors, this should be noted, and representative colors should be described. The Munsel Color System may be used for consistent color descriptions.

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, but if the samples are dried, the odor often may be revived by heating a moistened sample. If the odor is unusual, such as that of a petroleum product or other chemical, the material should be described and identified if known. The material may be hazardous, and combustion or exposure should be considered.

Moisture Conditions

Describe the moisture condition as dry, moist, or wet, as indicated by the criteria in table 3-10.

Table 3-10.—Criteria for describing moisture condition

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.

Reaction with HCl

Describe the reaction with HCl as none, weak, or strong, as indicated by the criteria in table 3-11. Calcium carbonate is a common cementing agent. The reaction with dilute hydrochloric acid is important in determining the presence and abundance of calcium carbonate.

Table 3-11.—Criteria for describing reaction with HCl

None	No visible reaction.
Weak	Some reaction, with bubbles forming slowly.
Strong	Violent reaction, with bubbles forming immediately.

Consistency

Describe consistency (degree of firmness) for intact fine-grained soils as very soft, soft, firm, hard, or very hard, as indicated by the criteria in table 3-12. This observation is inappropriate for soils with significant amounts of gravel. Pocket penetrometer or torvane testing may supplement this data.

Table 3-12.—Criteria for describing consistency of in-place or undisturbed fine-grained soils

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 1/4 in (5 mm).
Hard	Thumb will not indent soil but readily indented with thumbnail.
Very hard	Thumbnail will not indent soil.

Cementation

Describe the cementation of intact soils as weak, moderate, or strong, as indicated by the criteria in table 3-13.

Table 3-13.—Criteria for describing cementation

Weak	Crumbles or breaks with handling or little finger pressure.
Moderate	Crumbles or breaks with considerable finger pressure.
Strong	Will not crumble or break with finger pressure.

Structure (Fabric)

Describe the structure of the soil according to criteria described in table 3-14. The descriptors presented are for soils only; they are not synonymous with descriptors for rock.

Table 3-14.—Criteria for describing structure

Stratified	Alternating layers of varying material or color; note thicknesses.
Laminated[1]	Alternating layers of varying material or color with layers less than 6 mm thick; note thicknesses.
Fissured[1]	Breaks along definite planes with little resistance to fracturing.
Slickensided[1]	Fracture planes appear polished or glossy, sometimes striated.
Blocky[1]	Cohesive soil that can be broken down into small angular lumps which resist further breakdown.
Lenses	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thicknesses.
Homogeneous	Same color and textural or structural appearance throughout.

[1] Do not use for coarse-grained soils with the exception of fine sands which can be laminated.

Particle Sizes

For gravel and sand-size components, describe the range of particle sizes within each component as defined in the previous terminology paragraph. Descriptive terms, sizes, and examples of particle sizes are shown in table 3-15.

Table 3-15.—Particle sizes

Descriptive term	Size	Familiar example within the size range
Boulder	300 mm or more	Larger than a volleyball
Cobble	300 mm to 75 mm	Volleyball - grapefruit - orange
Coarse gravel	75 mm to 20 mm	Orange - grape
Fine gravel	20 mm to No. 4 sieve (5 mm)	Grape - pea
Coarse sand	No. 4 sieve to No. 10 sieve	Sidewalk salt
Medium sand	No. 10 sieve to No. 40 sieve	Openings in window screen
Fine sand	No. 40 sieve to No. 200 sieve	Sugar - table salt, grains barely visible

Describe the maximum particle size found in the sample. For reporting maximum particle size, use the following descriptors and size increments:

Fine sand
Medium sand
Coarse sand
5-mm increments from 5 mm to 75 mm
25-mm increments from 75 mm to 300 mm
100-mm increments over 300 mm

For example: "maximum particle size 35 mm"
"maximum particle size 400 mm"

If the maximum particle size is sand size, describe as fine, medium, or coarse sand; for example, maximum particle size, medium sand.

If the maximum particle size is gravel size, describe the maximum particle size as the smallest sieve opening that the particle would pass.

If the maximum particle size is cobble or boulder size, describe the maximum dimension of the largest particle.

Particle Hardness

Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer; e.g., gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. Hard means particles do not fracture or crumble when struck with a hammer. Remember that the larger the particle, the harder the blow required to fracture it. A good practice is to describe the particle size and the method that was used to determine the hardness.

Additional Descriptive Information

Additional descriptive information may include unusual conditions, geological interpretation or other classification methods, such as:

> Presence of roots or root holes or other organic material or debris;
>
> Degree of difficulty in drilling or augering hole or excavating a pit; or
>
> Raveling or caving of the trench, hole, pit, or exposure;
>
> *or*
>
> Presence of mica or other predominant minerals.

A local or commercial name and/or a geologic interpretation should be provided for the soil.

A classification or identification of the soil according to other classification systems may be added.

Narrative Descriptions and Examples

The description should include the information shown in tables 3-16 and 3-17, a checklist for the description of soils. Example descriptions follow.

Table 3-16.—Checklist for the description of soil classification and identification

1. Group name and symbol
2. Percent gravel, sand, and/or fines
3. Percent by volume of cobbles and boulders
4. Particle size
   Gravel - fine, coarse
   Sand - fine, medium, coarse
5. Particle angularity
   angular subangular subrounded rounded
6. Particle shape
   flat elongated flat and elongated
7. Maximum particle size or dimension
8. Hardness of coarse sand and larger particles
9. Plasticity of fines
   nonplastic low medium high
10. Dry strength
    none low medium high very high
11. Dilatancy
    none slow rapid
12. Toughness
    low medium high
13. Color (when moist)
14. Odor (if organic or unusual)
15. Moisture
    dry moist wet
16. Reaction with HCL
    none weak strong

Table 3-17.—Checklist for the description of in-place conditions

In-place conditions:

1. Consistency (fine-grained soils only)
   very soft   soft   firm   hard   very hard
2. Cementation
   weak   moderate   strong
3. Structure
   stratified   laminated   fissured   slickened lensed   homogeneous
4. Geologic interpretation and/or local name, if any
5. Additional comments and description
   Presence of roots or root holes
   Presence of mica, gypsum, etc.
   Surface coatings
   Caving or sloughing of excavation
   Excavation difficulty

Example 1: CLAYEY GRAVEL WITH SAND AND COBBLES (GC)—Approximately 50 percent fine to coarse, sub-rounded to subangular gravel; approximately 30 percent fine to coarse, subrounded sand; approximately 20 per-cent fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak reaction with HCl; original field sample had about 5 percent (by volume) subrounded cobbles, maximum size 150 mm.

IN-PLACE CONDITIONS: firm, homogeneous, dry, brown.

GEOLOGIC INTERPRETATION: alluvial fan.

Abbreviated symbol is (GC)sc.

Example 2: WELL GRADED GRAVEL WITH SAND (GW)—Approximately 75 percent fine to coarse, hard, sub-angular gravel; approximately 25 percent fine to coarse, hard, subangular sand; trace of fines; maximum size 75 mm, brown, dry; no reaction with HCl.

Abbreviated symbol is (GW)s

Example 3: SILTY SAND WITH GRAVEL (SM)—Approximately 60 percent predominantly fine sand; approximately 25 percent silty fines with low plasticity, low dry strength, rapid dilatancy, and low toughness; approximately 15 percent fine, hard, subrounded gravel, a few gravel-size particles fractured with hammer blow; maximum size 25 mm; no reaction with HCl.

IN-PLACE CONDITIONS: firm, stratified, and contains lenses of silt 1- to 2-in thick, moist, brown to gray; in-place density was 106 pounds per cubic foot (lb/ft^3), and in-place moisture was 9 percent.

GEOLOGIC INTERPRETATION: ALLUVIUM

Abbreviated symbol is (SM)g.

Example 4: ORGANIC SOIL (OL/OH)—Approximately 100 percent fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown, organic odor, weak reaction with HCl.

Abbreviated symbol is (OL/OH).

Example 5: SILTY SAND WITH ORGANIC FINES (SM)—Approximately 75 percent fine to coarse, hard, subangular reddish sand, approximately 25 percent organic and silty dark-brown nonplastic fines with no dry strength and slow dilatancy; wet; maximum size, coarse sand; weak reaction with HCl.

Abbreviated symbol is (SM)

Example 6: POORLY GRADED GRAVEL WITH SILT, SAND, COBBLES, AND BOULDERS (GP-GM)—Approximately 75 percent fine to coarse, hard, subrounded to subangular gravel; approximately 15 percent fine, hard, subrounded to subangular sand; approximately 10 percent silty nonplastic fines; moist, brown; no reaction with HCl; original field sample had approximately 5 percent (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders with a maximum dimension of 500 mm.

Abbreviated symbol is (GP-GM)scb.

Use of Soil Classification as Secondary Identification Method for Materials Other Than Natural Soils

General

Materials other than natural soils may be classified and their properties identified and described using the same procedures presented in the preceding subsections. The following materials are not considered soils and should not be given a primary USCS soil classification:

<u>Partially lithified or poorly cemented materials</u>

Shale	Claystone
Sandstone	Siltstone
Decomposed granite	

<u>Processed, manmade, or other materials</u>

Crushed rock	Slag
Crushed sandstone	Shells
Cinders	Ashes

Identification criteria may be used for describing these materials, especially for describing particle sizes and shapes and identifying those materials which convert to soils after field or laboratory processing. Description format and classification for these materials are discussed individually in the following paragraphs.

Partially Lithified or Cemented Materials

Partially lithified or poorly cemented materials may need to be classified because the material will be excavated, processed, or manipulated for use as a construction material. When the physical properties are to be determined for these materials for classification, the material must be processed into a soil by grinding or slaking in water (shale, siltstone, poorly indurated ash deposits).

The physical properties and resulting classification describe the soil type as created by reworking the original material. Soil classifications can then be used as a secondary identification. However, the classification symbol and group name must be reported in quotation marks in any 1ogs, tables, figures, and reports. If laboratory tests are performed on these materials, the results must be reported as shown in figure 3-6.

An example of a written narrative for either a test pit or auger hole log based on visual classification is as follows:

Symbol	Description
Shale Fragments	3.4- to 7.8-foot (ft) Shale Fragments—Retrieved as 2- to 4-in pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 hours, material classified as "SANDY CLAY (CH)"—

SUMMARY OF PHYSICAL PROPERTIES TEST RESULTS (Inplace Density)

SI METRIC

PROJECT__________ FEATURE__________

TABLE 5-3/18
SHEET 1 of 1

IDENTIFICATION				PARTICLE SIZE FRACTIONS IN PERCENT						CONSISTENCY LIMITS			SPECIFIC GRAVITY				INPLACE DENSITY			
				FINES										PLUS NO. 4						
SAMPLE NUMBER	HOLE NUMBER	DEPTH - m	CLASSIFICATION SYMBOL	SMALLER THAN 0.005 mm	0.005 TO 0.075 mm	SAND NO. 200 TO NO. 4 (0.075 TO 4.75 mm)	GRAVEL NO. 4 TO 3 in (4.75 TO 75 mm)	COBBLES 3 TO 5 in (75 TO 127 mm)	COBBLES LARGER THAN 5 in (127 mm)	LIQUID LIMIT - %	PLASTICITY INDEX - %	SHRINKAGE LIMIT - %	MINUS NO. 4	BULK	APPARENT	ABSORPTION - %	DRY DENSITY - kg/m³	WATER CONTENT - %	DEGREE OF SATURATION - %	
	Example 1																			
12	AP-13	4.7-6.2	shale fragments (as received)																	
		*	"CL"	53	30	17														
	Example 2																			
13	DH 319-8	27.2-28.7	siltstone	(as received)													118	18	17	19
		*	"ML"	50	41	9				27	3									
	Example 3																			
14	Commercial Source		Crushed Sandstone (as received)																	
			"SP-SM"	5	4	91				22	2									
	Example 4																			
15	DH No. 3		Crushed	Rock																
			"GP"	0	0	11	89													
	Example 5																			
16	Waste Pile	78	Slag																	
	CP and I		"GP"	2	1	25	72													
		*	properties of material after processing in laboratory																	

Figure 3-6.—Sample of test results summary.

Approximately 60 percent fines with high plasticity, high dry strength, no dilatancy and high toughness; approximately 35 percent fine to medium, hard sand; approximately 5 percent gravel-size pieces of shale.

Processed or Manmade Materials

Processed, manmade, or other materials are also used as construction materials, and classification can be used as a secondary identification. However, for these processed materials, the group name and classification symbol are to be within quotation marks. If laboratory tests are performed on these materials, the results must be reported as shown in table 3-6.

An example of a written narrative for logs for visual classification is as follows:

Symbol	Description
CRUSHED ROCK	Stockpile No. 3 CRUSHED ROCK— processed gravel and cobbles from P.T. NO. 7; "POORLY GRADED GRAVEL (GP)"—approximately 90 percent fine, hard, angular, gravel-size particles; approximately 10 percent coarse, angular, sand-size particles; dry, tan, no reaction with HCl.

Special Cases for Classification

Some materials that require a classification and description according to USBR 5000 [1] or USBR 5005 [2] should not have a heading that is a classification group name.

SOIL

When these materials will be used in, or influence, design and construction, they should be described according to the criteria for logs of test pits and auger holes and the classification symbol and typical name placed in quotation marks similar to the previous discussion on secondary identification method for materials other than natural soils. The heading should be as follows:

Topsoil
Landfill
Road surfacing Uncompacted or Compacted
Fill

For example:

Classification

Symbol	Description
TOPSOIL	0.0-0.8 meter (m) TOPSOIL—would be classified as "ORGANIC SILT (OL)." Approximately 80 percent fines with low plasticity, slow dilatancy, low dry strength, and low toughness; approximately 20 percent fine to medium sand; wet, dark brown, organic odor, weak reaction with HCl; roots present throughout.

Some material should be described but not given a classification symbol or group name, such as landfill (trash, garbage, etc.) or asphalt road. All of the above listed terms are only examples; this is not a complete list. If the above materials are not to be used and will not influence design or construction, only the basic term listed above need be shown on the logs without a complete description or classification.

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[3] American Society for Testing and Materials, ASTM D-2487, "Standard Classification of Soils for Engineering Purposes," *ASTM Annual Book of Standards*, Volume 04.08 on Soil and Rock, Section 4 - Construction, West Conshohocken, PA, 1996.

[4] American Society for Testing and Materials, ASTM D-2488, "Standard Practice for Description and Identification of soils (Visual-Manual Procedure)," *ASTM Annual Book of Standards*, Volume 04.08 on Soil and Rock, Section 4 - Construction, West Conshohocken, PA, 1996.

[5] U.S. Department of Agriculture, *Agriculture Handbook No. 436*, Appendix I (Soil Taxonomy), December 1975.

[6] Bureau of Reclamation, U.S. Department of the Interior, USBR 3900, "Standard Definitions of Terms and Symbols Relating to Soil Mechanics," *Earth Manual*, Part II, 3rd edition, 1990.