SOIL AND ROCK CLASSIFICATION MANUAL

OREGON DEPARTMENT OF TRANSPORTATION

HIGHWAY DIVISION

1987

SOIL AND ROCK CLASSIFICATION MANUAL

FORWARD

Detailed descriptions and classifications of soil and rock are an essential part of the geologic interpretation process and the geotechnical information developed to support design and construction. This manual contains standardized procedures and guidelines for describing and evaluating soil and rock materials and for preparing exploration logs.

The Unified Soil Classification System provides a conventional system for categorizing soils by gradation and plasticity characteristics. However, it alone does not provide adequate descriptive terminology for identifying soils. The enclosed descriptive terminology is not intended to replace the USCS, but to expand it in order to make the classification more precise and better understood.

Various rock description systems exist; however, no one system is universally used. This manual contains a composite procedure that incorporates significant descriptive terminology relevant to geotechnical design and construction.

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ODOT SOIL/ROCK CLASSIFICATION MANUAL

CLASSIFICATION FORMAT

The description and classification of soil and rock includes consideration of the physical characteristics and engineering properties of the material. The detail of description is dictated to some degree by the complexity and objectives of the project; however, an attempt should always be made to describe the soil/rock as completely as possible. The soil and rock descriptions on boring logs should be based on factual information. Interpretive information should be provided elsewhere, such as in the text of geologic, geotechnical, and foundation reports. The general descriptive sequence for soil and rock materials follows:

SOIL

Soil Name

USCS Designation

Color

Plasticity

Moisture

Consistency/Relative Density

Texture

Cementation

Structure

Fill Materials

Other Constituents/Characteristics as applicable (unit weight, sensitivity, quality of coarse-grained constituents)

Origin

ROCK

Rock Name

Color

Degree of Weathering

Relative Hardness

Structure (joints, stratification, faults attitude, separation, filling, continuity, voids)

Core Recovery and RQD

Other Characteristics as applicable (mineralization, slaking, field unit weight, discontinuity surface condition, voids)

Formation Name

An important facet of classification is the determination of what constitutes rock, as opposed to extremely weathered, partially cemented or altered material which approaches soil in its character and engineering characteristics.

Extremely soft or decomposed rock that is friable and can be reduced to gravel size or smaller by normal hand pressure should be classified as a soil. The soil classification would be followed by the parent rock name (in parentheses).

The inferred contacts between differing soil types (overburden) and the underlying rock should be noted on exploration logs, interpreted profiles and cross sections.

SOIL CLASSIFICATION

Introduction

The soil description and classification is based on the distribution and behavior of fine-grained (passing No. 200 sieve) and coarse-grained (retained on the No. 200 sieve) soil constituents, as described in ASTM D 2487 and D 2488.

Soil descriptions contained on exploration logs and in field/laboratory reports should be consistent with the visual-manual procedure of ASTM D 2488. The visual-manual method employs visual observations and simple manual tests (index tests) to estimate the size and distribution of the coarse-grained soil fractions and to indicate the plasticity characteristics of fine-grained fractions. These index tests should be performed on representative samples from each soil unit.

Soil classifications are determined based on soil descriptions and laboratory testing. Representative soil samples that are submitted for laboratory testing should be classified using the procedure of ASTM D 2487, which generally requires grain size and plasticity testing (Atterberg limits).

The definitions for various soil constituents are presented on Table 1.

TABLE 1: SOIL CONSTITUENTS-DEFINITIONS

(Ref.4)

Boulders	Particles of rock that will not pass a 12-inch square opening.
Cobbles	Particles of rock that will pass a 12-inch square opening and be retained on a 3-inch sieve.
Gravel	Particles of rock that will pass a 3-inch sieve and be retained on a No. 4 sieve.
Sand	Particles of rock that will pass a No. 4 sieve and be retained on a No. 200 sieve.
Silt	Soil passing a No. 200 sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry.
Clay	Soil passing a No. 200 sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air dry.
Organic Soil	A soil with sufficient organic content to influence the soil properties.
Peat	A soil composed primarily of vegetable matter in various stages of decomposition usually with an organic odor, or dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

Soil Name

The first step in describing a soil is to determine whether it is predominantly fine-grained, coarse-grained, or peat. A mixed-grained soil (containing both fine-grained and coarse-grained constituents) is categorized by determining its predominant engineering behavior and by visually estimating the percentages of fine-grained and coarse-grained constituents. There are three techniques available for estimating the percentage of gravel, sand, and fines in a sample: the jar method, the visual method, and the wash test, as described in Appendix X4 of ASTM D 2488. Soils containing more than 50 percent visible particles are coarse-grained soils. After the sample is determined to be predominantly fine-grained or coarsegrained, the next step is to determine the primary, secondary, and additional constituents. For rapid and easy identification, the primary constituent should be written in upper case letters, i.e., GRAVEL, SAND, SILT, CLAY. The procedures for describing and classifying fine-grained and coarse-grained soils are described in the following subsections.

Fine-Grained Soils Fine-grained soils are described by their engineering behavior considering such physical characteristics as dilatancy, dry strength, toughness, dispersion, and plasticity, as summarized on Table 2. The index tests used to determine these characteristics are described in ASTM D 2488. Examples of soil descriptions based on index tests are shown on Table 3. The Plasticity Chart, Figure 1, is used in the classification process to determine if the soil behaves primarily as a silt or clay: it also provides a measure of the plasticity as well as compressibility of the soil. Table 4 summarizes the subclassification order for fine-grained soils. For instance, a soil which contains 80% fine-grained constituents (medium dry strength, slow dilatancy, medium toughness, low plasticity) and 20% sand would be classified as "clayey SILT with some sand." It is possible to have two secondary constituents. For instance, a soil with 40% sand and 60% fine-grained constituents (medium plasticity, no dilatancy, medium toughness, and medium dry strength) would be described as "sandy, silty CLAY."

TABLE 2: SILT AND CLAY CHARACTERISTICS

(After Ref.24)

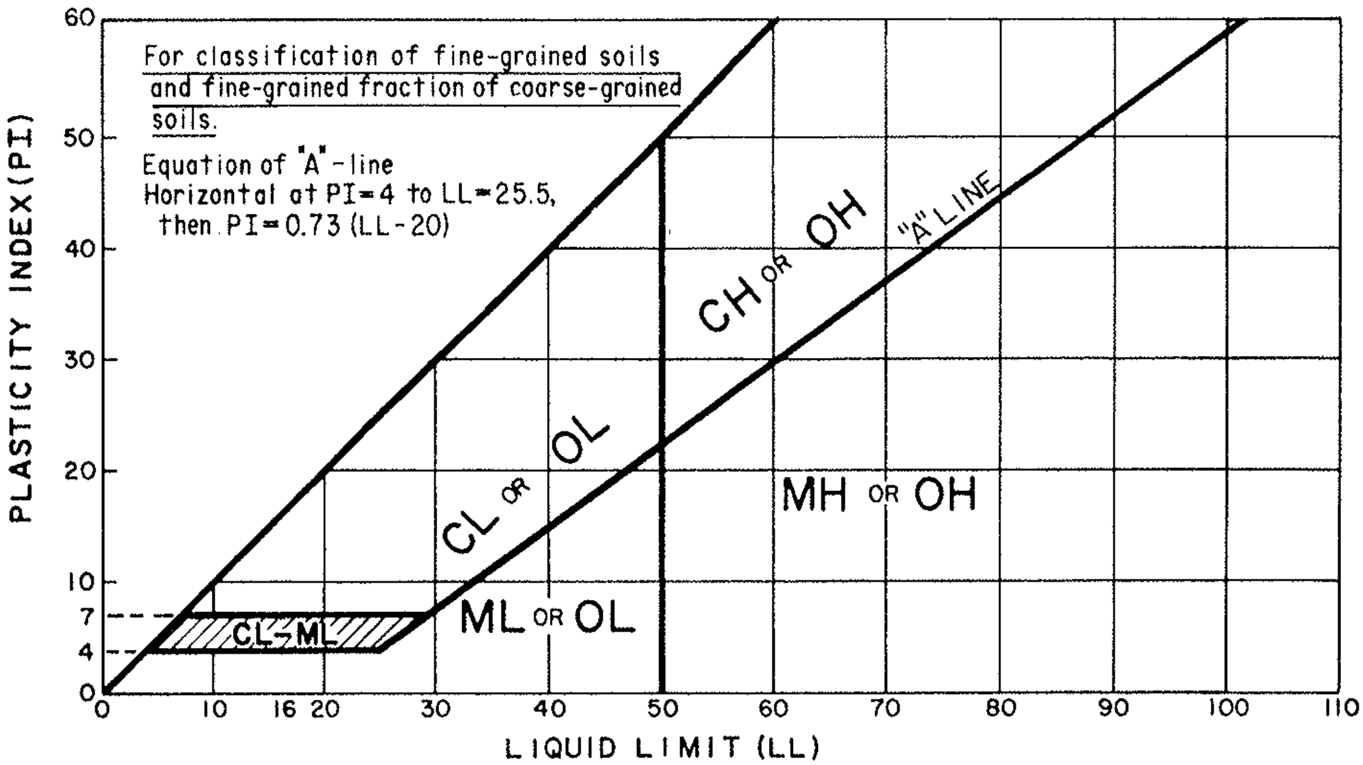
CHARACTERISTICS	SILTS	CLAYS
DILATANCY (reaction to shaking. Movement of water in voids). • None • Slow • Rapid	Rapid reaction. Water appears on the surface to give a livery appearance when shaken. Squeezing the soil causes water to disappear rapidly.	Sluggish or no reaction. Surface of the samples remain lustrous. Little or no water appears when hand is shaken. Sample remains lustrous during squeezing.
DRY STRENGTH (Cohesiveness in dry state). • None • Low • Medium • High • Very High	None to low. Even oven-dry strength is low. Powder easily rubs off surface of the sample. Little or no cohesive strength-will crumble and slake readily.	High to very high. Exceptionally high if oven-dry. Powder will not rub off the surface. Crumbles with difficulty. Slakes slowly.
TOUGHNESS (Plasticity in moist state). • Low • Medium • High	Plastic thread has little strength. Dries quickly. Crumbles easily as it dries below plastic range. Seldom can be rolled to 1/8" thread without cracking.	Plastic thread has high strength. Dries slowly. Usually stiff and tough as it dries below plastic range. Can easily be rolled to 1/8" thread without cracking.
DISPERSION (Settlement in water).	Settles out of suspension in 15 to 60 minutes. (Sands settle in 30 to 60 seconds).	Settles in several hours or days, unless it flocculates (rapidly precipitates out in small clumps).
VISUAL INSPECTION AND FEEL	Only coarsest individual silt grains are visible to the naked eye. Feels slightly gritty when rubbed in fingers. Dries quickly and dusts off easily.	Individual grains cannot be observed by the naked eye. Feels smooth and greasy when rubbed in fingers. Dries slowly and does not dust off, must be scraped off.
BITE TEST (Caution:Eating contaminated soil may be hazardous to your health)	Gritty feeling between the teeth, does not stick to the teeth.	No gritty feeling between the teeth; tends to stick to the teeth.

TABLE 3: EXAMPLES OF FINE-GRAINED SOIL FIELD IDENTIFICATION

Typical Name	FIELD INDEX TESTS			
	Dry Strength	Dilatancy Reaction	Toughness of Plastic Thread	Plasticity
SILT SILT w/some clay	none, low low, medium	rapid rapid, slow	low low, medium	nonplastic, low low
clayey SILT silty CLAY	medium medium, high	slow slow, none	medium medium, high	low, medium medium
CLAY w/some silt CLAY	high very high	none none	high high	high high
organic SILT organic CLAY	low, medium medium to very high	slow none	low, medium medium, high	nonplastic, low medium, high

FIGURE 1: PLASTICITY CHART

(After Ref.4)



Note: The symbols CL,ML,OL,CL,CH and OH are Unified Soils classification symbols. For definitions refer to Table 7.

TABLE 4: FINE-GRAINED SOIL SUBCLASSIFICATION

(After Ref.4)

Terms	Percent (by weight) of Total Sample	
SILT, CLAY	*	PRIMARY CONSTITUENT
Clayey, Silty	*	Secondary fine-grained Constituents
w/some silt, some clay	*	Additional fine-grained Constituents
Sandy, Gravelly	30 - 50	Secondary coarse-grained Constituents
w/some sand, some gravel	15 - 30	Additional coarse-grained Constituents
w/trace sand, trace gravel	5 - 15	

* The relationship of clay and silt constituents is based on plasticity and normally determined by performing index tests. Refined classifications are based on Atterberg Limits tests and the Plasticity Chart (Figure 1).

Coarse-Grained Soils   Coarse-grained soils are described on the basis of particle-size distribution, as shown on Table 5. In the absence of grain size test results, the percent distribution of the various constituents should be visually estimated. Where no constituent exceeds 50% of the total sample, then the coarse-grained constituent having the largest percentage becomes the primary constituent. If the soil does not include any discernible fines, then describe soil as "clean." Where the secondary or additional constituent is fine-grained, the term "clay" or "silt" is selected based on the predominant plasticity characteristics from index tests (Tables 2 and 3). For instance, a soil with 48% sand, 42% gravel and 10% fine-grained constituents (non-plastic, low dry strength) would be described as "gravelly SAND with some silt."

TABLE 5: COARSE-GRAINED SOIL SUBCLASSIFICATION

(After Ref.4)

Terms	Percent (by weight) of Total Sample	
GRAVEL, SAND	Predominant constituent	PRIMARY CONSTITUENT
Gravelly, sandy	30 - 50	Secondary Coarse-Grained Constituents
w/some (gravel, sand)	15 - 30	Additional Coarse-Grained Constituents
w/trace (gravel, sand)	5 - 15	
Silty, Clayey *	12 - 50	Secondary Fine-Grained Constituents
w/some (silt, clay) *	5 - 12	Additional Fine-Grained Constituents
w/trace (silt, clay) *	< 5	

* Index tests and/or plasticity tests are performed to determine whether the term "silt" or "clay" is used.

Where stratified soils are encountered, each layer should be classified. The significant dimensions of the lenses/layers should be noted. For instance, a soil that is predominantly fine-grained (low dry strength, medium plasticity) with thin (1-inch) layers of clean sand would be described as "clayey SILT with 1-inch layers of clean sand."

<u>Organics</u> Organics can generally be identified by their distinctive dark color and by their spongy feel. Fresh, wet organic soils usually have a distinctive odor of decomposed organic matter. This odor can be made more noticeable by heating the wet sample. The estimated percent and type of organic material present should be included in the sample description. An estimation of percent organics is based on a <u>percent by volume</u> of the total sample and may be obtained through visual comparison of the sample to a standardized comparison chart, Figure 2. The organic material subclassification is shown on Table 6.

FIGURE 2: COMPARISON CHART (PERCENT BY VOLUME)

(Ref.19)

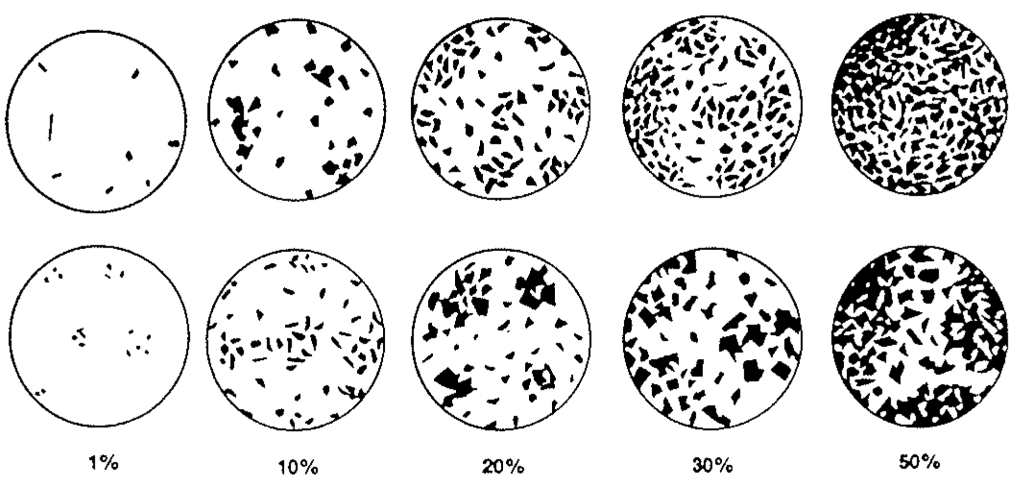


TABLE 6: ORGANIC MATERIAL SUBCLASSIFICATION

Term	Organic Percent (by volume) Of Total Sample	
PEAT	50 - 100	PRIMARY CONSTITUENT
organic (soil name)	15 - 50	Secondary Organic Constituent
(soil name) w/some organics	5 - 15	Additional Organic Constituents

Secondary soil constituents should be described for peats. For example, if a soil contains greater than 50% organics by volume and more than 12% silt by weight, the material would be described as a "silty PEAT". The term "silty PEAT" would also apply to a material having greater than 50% organics by volume and a significant percentage of silt (i.e. 80%) by weight.

The type of organic material (i.e., peat, wood fibers, carbonized wood, grass, leaves, roots) should be identified if possible, or referred to as organics. An example would be: "silty SAND with trace clay; some carbonized wood."

Organics may be fibrous and/or amorphous. Organic material may be very finely divided and hard to identify if a strong organic odor is not present. Consider the location when describing samples (i.e., former stream channel, flood plain). If you cannot identify organic material, but suspect its presence (due to color, odor, etc.), then indicate "organics may be present" or "organic odor". A natural moisture content determination or liquid limit tests on samples before and after oven drying may verify your assumption (Atterberg limits tests are not applicable for peat).

Unified Soil Classification System (USCS) Designation

The USCS designation should be determined by following the procedures specified in ASTM D 2487. The USCS designation as reported on exploration logs will be an approximation based on the visual-manual soil description (ASTM D 2488). Where classifications are based on grain-size and Atterberg limits tests (such as laboratory test classifications), the USCS designation will be more precise. Table 7 presents a simplified summary of the USCS system.

TABLE 7: UNIFIED SOIL CLASSIFICATION SUMMARY

(Ref.12)

UNIFIED SOIL CLASSIFICATION

MAJOR DIVISIONS			GROUP SYMBOLS ‡	TYPICAL NAMES
COARSE GRAINED SOILS More than half of material is larger than No 200 sieve size	GRAVELS More than half of coarse fraction is larger than No 4 sieve size	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, poorly graded gravel-sand-silt mixtures.
			GC	Clayey gravels, poorly graded gravel-sand-clay mixtures.
	SANDS More than half of coarse fraction is smaller than No 4 sieve size.	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 More than half of material is smaller than No. 200 sieve size.	SILTS AND CLAYS	Liquid limit less than 50	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			OL	Organic silts and organic silt-clays of low plasticity
	SILTS AND CLAYS	Liquid limit greater than 50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			CH	Inorganic clays of high plasticity, fat clays.
			OH	Organic clays of medium to high plasticity.
HIGHLY ORGANIC SOILS			PT	Peat and other highly organic soils.

‡ Boundary classifications. Soils possessing characteristics of two groups are designated by combinations of group symbols For example GW-GC, well graded gravel-sand mixture with clay binder

Color

Soil color is not in itself a specific engineering property, but may be an indicator of other significant properties such as soil chemistry, ground water (e.g., mottling indicating wet/dry cycles), alteration/weathering, or relative natural moisture content. Color may also be an aid in subsurface correlation.

The color should be field-determined from fresh soil samples at their natural moisture content. Use common colors (such as white, yellow, red, brown, green, gray, blue, or black) because they are basic and easier for others to understand. Standard color charts can be used, when available, for more uniform and precise descriptions. For variations use hyphenated combinations such as red-brown. Do not use "ish", or unusual colors. For example: instead of turquoise or aqua, use green-blue or blue-green, respectively. Describe the "net" color, that is, for a sand with white and dark gray grains, the net color would be gray, not white and dark gray. Avoid listing more than two colors. To describe tint use the following example, demonstrated with brown: pale brown, light brown, brown, dark brown. When color variations are observed and considered significant, additional adjectives such as "mottled" or "streaked" may be used. For instance:

SAND, SW, brown, [mottled / streaked] gray, etc.

Plasticity

Plasticity is a significant indicator property for cohesive soils. Field estimates of plasticity should be based on dry strength and toughness tests (ASTM D 2488). The relationships between these index tests and the plasticity are shown on Table 8. An accurate measurement of plasticity is normally made in the laboratory by means of the Atterberg limits tests (ASTM D 4318). A series of Atterberg limits tests should be performed on representative samples to confirm visual soil descriptions and for engineering purposes.

TABLE 8: DEGREE OF PLASTICITY

(Ref.4,18)

Term	Plasticity Index, PI%	Dry Strength	Field Test (approximation)
Nonplastic	0 - 3	Very low	Dry specimen ball falls apart easily. Cannot be rolled at any moisture content.
Low Plasticity	3 - 15	Low	Dry specimen ball easily crushed with fingers. 1/8" thread can barely be rolled within its plastic range.
Medium Plasticity	15 - 30	Medium	Difficult to crush dry specimen ball when dry. 1/8" thread is easy to roll.
High Plasticity	30 or more	High	Impossible to crush dry specimen ball with fingers. 1/8" thread takes considerable time to roll/knead to reach plastic limit. Can be rerolled several times without breaking after reaching plastic limit.

Atterberg limits may be higher than expected if calcium carbonate or iron oxides are present. Correlations using the Atterberg limits may not be reliable for soils high in organic content.

Moisture

A visual estimation of relative moisture content should be made during field classification (ASTM D 2488). Natural moisture contents should be determined in the laboratory for all soils containing more than 5 percent fine-grained material. The typical classifications are presented in Table 9.

TABLE 9: MOISTURE DESIGNATIONS

(After Ref.4,15)

Term	Field Identification
Dry	Absence of moisture. Dusty. Dry to the touch.
Damp	Soil has moisture. Cohesive soils are below plastic limit (BPL) and usually moldable.
Moist	Grains appear darkened, but no visible water. Silt/clay will clump. Sand will bulk. Soils are often at or near plastic limit.
Wet	Visible water on larger grain surfaces. Sand and cohesionless silt exhibit dilatancy. Cohesive silt/clay can be readily remolded. Soil leaves wetness on the hand when squeezed. "Wet" indicates that the soil is much wetter than the optimum moisture content and above plastic limit (APL).

Consistency/Relative Density of Soils

An important index property of cohesive (plastic) soil is its consistency. The consistency of cohesive soil is expressed qualitatively by terms such as very soft, soft, medium stiff, stiff, hard, and very hard. Similarly, a significant index property of a cohesionless (non-plastic) soil is its relative density. Relative density terms include very loose, loose, medium dense, dense, and very dense.

__Consistency__ is an indicator of the shear strength (S_u) of a cohesive soil. The shear strength can be estimated from manual and mechanical field tests (i.e., Standard Penetration Test [SPT], Torvane, and pocket penetrometer), or determined by laboratory testing (i.e., unconfined compressive or triaxial shear strength). Normally, the above tests are performed on undisturbed materials. Pocket penetrometer tests on cohesive samples from SPT tests will generally underestimate the undisturbed shear strength. These results, although conservative, may still be useful in preliminary design. Correlation of consistency terms with various parameters determined from both field and laboratory tests, are summarized in Table 10.

TABLE 10: CONSISTENCY OF COHESIVE SOILS

(After Ref.10,14,18,20)

Consistency	SPT N-value blows/ft.	Approx. undrained Shear Strength, S_u, tsf. *	Field Approximation
Very soft	< 2	< 0.125	Squeezes between fingers when fist is closed; easily penetrated several inches by fist.
Soft	2 - 4	0.125 - 0.25	Easily molded by fingers; easily penetrated several inches by thumb.
Medium stiff	4 - 8	0.25 - 0.50	Molded by strong pressure of fingers; can be penetrated several inches by thumb with moderate effort.
Stiff	8 - 15	0.50 - 1.0	Dented by strong pressure of fingers; readily indented by thumb but can be penetrated only with great effort.
Very stiff	15 - 30	1.0 - 2.0	Readily indented by thumb nail.
Hard	30 - 60	> 2.0	Indented with difficulty by thumb nail.
Very hard	> 60		

* Pocket penetrometer and unconfined compression tests yield q_u. Torvane yields S_u; $S_u = q_u \div 2$.

Relative density of uncemented granular or cohesionless soils is a measure of the compactness of the soil. Nonplastic SILT soils which exhibit general properties of granular soil are given a relative density description. Relative density can be estimated from a simple manual field test, or evaluated with the Standard Penetration Test, SPT (ASTM D 1586, AASHTO T206). Relative density terms are related to SPT N-values and rudimentary field tests, as shown in Table 11.

TABLE 11: RELATIVE DENSITY FOR GRANULAR (COHESIONLESS) SOILS

(After Ref.1,10)

Relative Density	SPT N-value blows/foot	Field Approximation
Very loose	0 - 4	Easily penetrated many inches (>12) with 1/2 inch rebar pushed by hand.
Loose	4 - 10	Easily penetrated several inches with 1/2 inch rebar pushed by hand.
Medium dense	10 - 30	Easily to moderately penetrated with 1/2 inch rebar driven by 5 lb. hammer.
Dense	30 - 50	Penetrated 1 foot with difficulty using 1/2 inch rebar driven by 5 lb. hammer.
Very Dense	> 50	Penetrated only a few inches with 1/2 inch rebar driven by 5 lb. hammer.

Texture

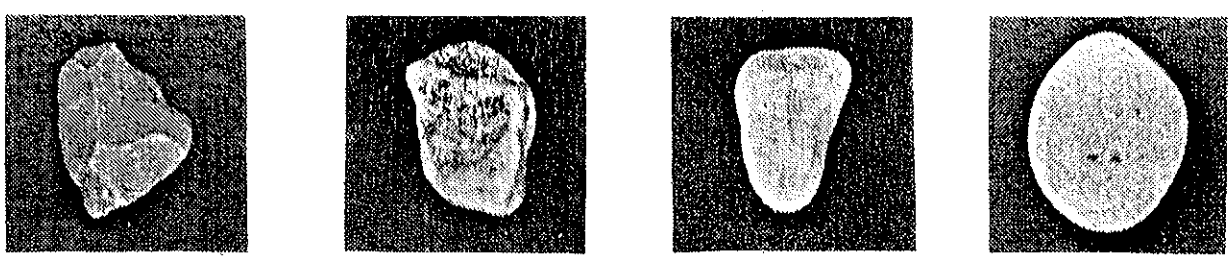
Texture refers to the actual size, shape, and gradation of the constituent grains. Table 12 defines the most common grain size terms. The maximum coarse-grained size recovered in soils should be noted. Figure 3 shows various shapes of bulky (granular) grains and their corresponding classification. The gradation definitions are presented in Table 13, and a gradation chart is shown on Figure 4. Coarse-grained soils having less than 12 percent passing the no. 200 sieve require gradation descriptions, i.e., well-graded, poorly-graded (uniform or gap-graded).

TABLE 12: GRAIN SIZE DEFINITIONS

(Ref.1)

Term	Grain Size (inches, or sieve #)
Boulders	> 12 in.
Cobbles	3-12 in.
Gravel	
Coarse	3/4-3 in.
Fine	#4-3/4 in.
Sand	
Coarse	#10-#4
Medium	#40-#10
Fine	#200-#40

FIGURE 3: TYPICAL SHAPES OF BULKY GRAINS



Angular Subangular Subrounded Rounded

TABLE 13: GRADATION CATEGORIES

(After Ref.1,4)

Gradation Term (USCS)	Description	Example
Well-graded (GW, SW)	Full range and even distribution of grain sizes present.	Coarse to fine SAND with trace silt, SW
Poorly-graded (GP, SP)	Narrow range of grain sizes present.	Fine to medium SAND, SP
Uniformly-graded (GP, SP)	Consists predominantly of one grain size.	Clean fine SAND, SP
Gap-graded (GP, SP)	Within the range of grain sizes present, one or more sizes are missing.	Fine SAND with some coarse gravel, SP

Uniformity coefficients:

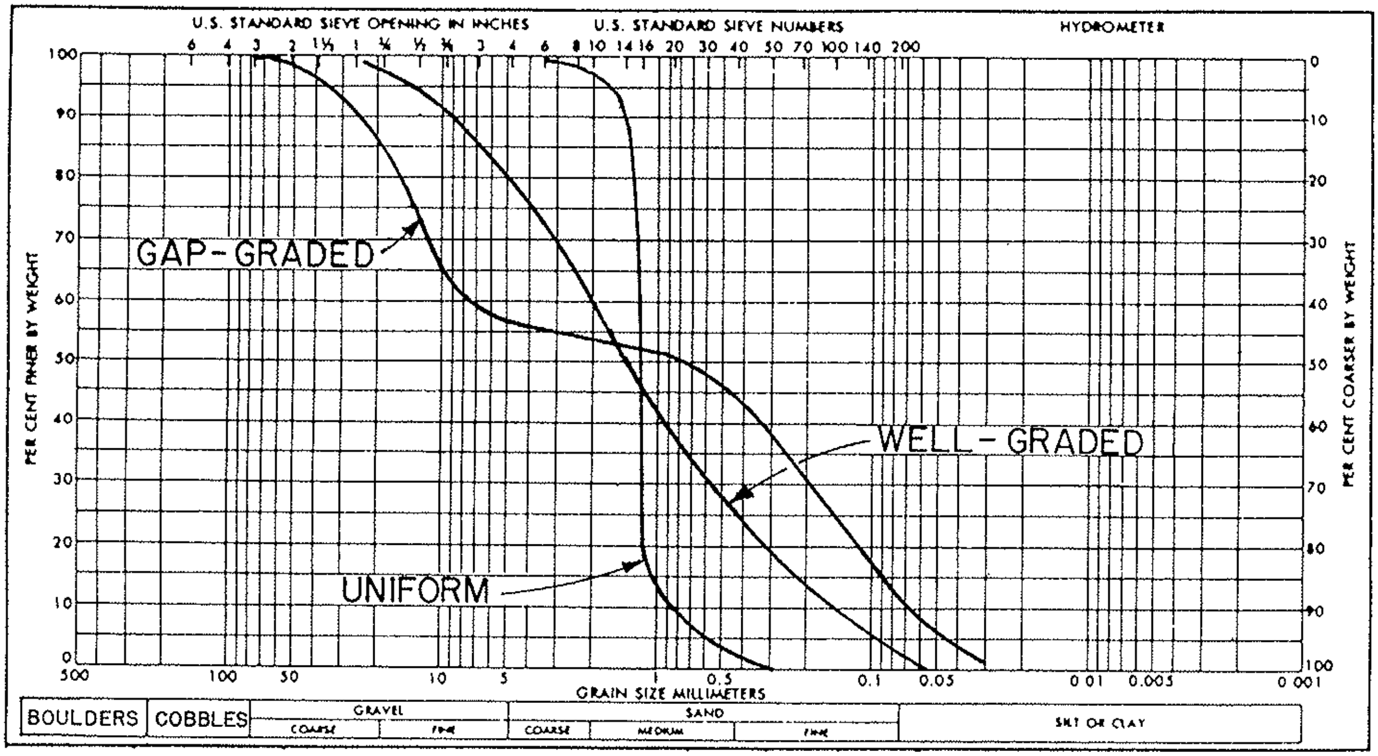
$$C_u = \frac{D_{60}}{D_{10}} \qquad C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

USCS Term	% Passing No.200 Sieve	Uniformity Coefficient Requirements
SW	$\leq$ 5%	$C_u > 6$ and $C_c = 1$ to 3
GW	$\leq$ 5%	$C_u > 4$ and $C_c = 1$ to 3

Note: If 5 to 12% passes the No. 200 sieve, then use a dual classification with the predominant fine-grained constituent, i.e., SW-SM, etc.

FIGURE 4: GRADATION CHART

(After Ref.18,22)



Cementation

Cementation is the bonding of grains by secondary minerals (e.g., calcite) or degradation products (e.g., clay). The presence of calcium carbonate cementation can be detected by its reaction to hydrochloric acid. The relative degree of cementation of undisturbed soil samples is defined in Table 14:

TABLE 14: CRITERIA FOR DESCRIBING CEMENTATION

(Ref.4)

TERM	CRITERIA
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

Structural features include stratifications, varves, lenses, fissures, seams, slickensides, striations, blocky structure, relict rock structure, voids (root or worm holes, cavities). The thickness, frequency, and inclination of these features should be noted. Table 15 presents criteria for describing structure.

TABLE 15: CRITERIA FOR DESCRIBING STRUCTURE
(Ref.4)

TERM	CRITERIA
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	Contains shears or separations along planes of weakness.
Slickensided	Shear planes appear polished or glossy, sometimes striated.
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown.
Lensed	Inclusion of small pockets of different soils, such as small lenses of clay; note thickness.
Homogeneous	Same color and appearance throughout.

Fill Materials

All soils should be examined to see if they contain foreign materials indicative of man-made fills. Nonstructural fills are often a problem in design. Man-made and other foreign fill items should be listed in each of the soil descriptions. Common man-made items include glass, brick, dimensioned lumber, concrete, metal, plastics, plaster, etc. Other items that could suggest fill include buried vegetation mats, tree limbs, stumps, etc. The soil description for a fill material should be followed by the term "(Fill)", i.e., for a clayey silt fill with some brick fragments the description would be "clayey SILT, ML, with brick fragments (Fill)." The size and distribution of miscellaneous items should be noted. The limits (depth range) of fill material should be determined and identified at each exploration location.

Other Constituents/Characteristics

Additional constituents and/or pertinent characteristics not included in the previous categories should be described, depending on the scope and objectives of the project. Some of these other constituents/characteristics include the following:

<u>Unit Weight</u> The total unit weight should be determined on undisturbed soil samples, and may sometimes be determined in-situ. When the moisture content is determined, the dry unit weight should also be shown.

<u>Sensitivity</u> Sensitivity refers to the significant loss of strength when a fine-grained soil is remolded. A sensitive soil may be highly compressible, and the natural moisture content often is above its liquid limit. Sensitivity is a

function of the primary structure of the soil, i.e., dispersed, dense or flocculated; strength of grain bonding; and water content. A measure of the sensitivity, S_t, is the ratio of the undisturbed, undrained shear strength to the remolded shear strength, or:

$$S_t = \frac{S_u\text{(undisturbed)}}{S_u\text{(remolded)}} = \frac{q_u\text{(undisturbed)}}{q_u\text{(remolded)}}$$

[Where S_u = shear strength
q_u = unconfined compressive strength]

The shear strengths can be determined by in situ tests (vane shear or less accurately by Torvane and pocket penetrometer) or by laboratory tests (UU triaxial test or less accurately by unconfined compression test). When it is noticed in the field that a fine-grained soil might be sensitive, it should be so noted on the field log as "potentially sensitive".

Quality of Coarse-grained Constituents Where the soil is predominantly coarse-grained, the nature and condition of the coarse grains should be described. For instance, the parent rock type(s), hardness (soft or hard) and weathering (fresh, weathered, or decomposed).

Origin

The origin of the soil is generally interpreted based on a knowledge of geologic site conditions and soil description. A generic name for the soils origin may be provided at the end of the soil description (in parentheses), such as (Alluvium), (Colluvium), (Terrace deposit), (Decomposed [rock name]), (Fill), etc. Where known, the formation name may be included at the end of the description.

ROCK CLASSIFICATION

Rock classification for engineering purposes consists of two basic assessments: that for intact character, such as a hand specimen or small fragment; and in situ character, or engineering features of rock masses (Ref.1):

> **Intact character:** classification of the intact rock, such as hand specimens or core, is in terms of its origin, mineralogical makeup, texture, and degree and nature of chemical and physical weathering or alteration.
>
> **In situ character:** classification of in-place rock masses includes the nature and orientation of its constituent interlocking blocks, plates, or wedges formed by bounding discontinuities such as bedding, foliation planes, joints, shear planes, shear zones and faults.

Both assessments are essential for design. Both characteristics are the basis for rock slope design and excavation and many facets of rock anchorage and bearing capacity determinations.

Rock Name

Rocks are classically divided into three general categories: igneous, sedimentary and metamorphic.

Igneous rocks are classified based on mineralogy and genetic occurrence (intrusive or extrusive). Texture is the most conspicuous feature of genetic occurrence.

Sedimentary rocks are classified on the basis of grain size, mineralogy and on the relationship between grains.

The most conspicuous features of metamorphic rocks are generally their structural features, especially foliation.

The complete name of a rock specimen or rock unit should include texture and lithologic name. The rock name should be in simple geologic terms. The rock name should be completely written in capital letters. The following tables present common rock names and their characteristics.

TABLE 16: COMMON IGNEOUS ROCKS

(Ref.9)

Intrusive (coarse-grained)	Essential Minerals	Common Accessory Minerals	Extrusive (fine-grained)
Granite	Quartz K-feldspar	Plagioclase Mica Amphibole Pyroxene	Rhyolite
Diorite	Plagioclase	Mica Amphibole Pyroxene	Andesite
Gabbro	Plagioclase Pyroxene	Amphibole	Basalt

TABLE 17: IGNEOUS ROCK TEXTURES

(Ref.9)

Texture	Grain Size	Rock Type
Pegmatitic	Very large; diameters measured in inches or feet. Wide range of sizes.	Intrusive
Phaneritic	Can be seen with naked eye	Intrusive or Extrusive
Aphanitic	Cannot be seen with naked eye	Extrusive or Intrusive
Glassy	No grains present	Extrusive
Porphyritic	Grains of two widely different sizes	Intrusive and Extrusive

TABLE 18: PYROCLASTIC ROCKS

(After Ref.2)

ROCK NAME	CHARACTERISTICS
Cinders	Uncemented glassy and vesicular ejecta 4-32 mm size
Tuff Breccia (agglomerate)	Composed of ejecta >32 mm size, in ash/tuff matrix, indurated
Lapilli Tuff	Composed of ejecta 4-32 mm size, in ash/tuff matrix, indurated
Tuff	Cemented volcanic ash particles <4 mm size, indurated
Pumice	Excessively vesiculated glassy lava

TABLE 19: COMMON SEDIMENTARY ROCKS

(Ref.9)

A. Mechanical Sedimentary Rocks	
Rock Name	**Original Sediment**
Conglomerate	Gravel, or sand and gravel
Sandstone	Sand
Siltstone	Silt
Claystone	Clay
Mudstone	Silt, clay, possibly with sand and/or gravel inclusions, nonoriented
Shale (laminated claystone/siltstone)	Oriented, laminated, fissile, clay and silt
B. Chemical Sedimentary Rocks	
Rock Name	**Main Mineral**
Limestone	Calcite
Dolomite	Dolomite
Chert	Quartz

A modifier may be necessary to describe a sedimentary rock formed from a combination of different soil types, i.e., a "silty SANDSTONE" would be predominantly composed of sand grains with a lesser amount of silt grains. This distinction is only necessary when the modifier has engineering significance. The term mudstone could be used when the composition of the sedimentary rock is uncertain or variable.

TABLE 20: COMMON METAMORPHIC ROCKS

(After Ref.9)

A. Foliated Metamorphic Rocks			
Rock Name	**Texture**	**Formed From**	**Main Minerals**
Slate	Platy, fine-grained	Shale	Mica, quartz
Schist	Irregular layers, medium-grained	Slate, igneous rocks	Mica, quartz, feldspar, amphibole
Gneiss	Layered, coarse-grained	Igneous rocks, schist, sandstone	Mica, quartz, feldspar, amphibole
B. Nonfoliated Metamorphic Rocks			
Rock Name	**Texture**	**Formed From**	**Main Minerals**
Marble	Crystalline	Limestone, dolomite	Calcite dolomite
Quartzite	Crystalline	Sandstone	Quartz
Serpentinite	Massive to layered, fine to coarse-grained	Ultramafic rocks, i.e., peridotite, gabbro	Serpentine

Vesicularity Vesicles in volcanic rocks are rounded cavities due to gas bubbles in molten lava. Cavities or openings in other rocks (e.g., intergranular space) should be described in other terms, such as porosity (e.g., porous sandstone).

The occurrence of vesicles are to be reported using the Comparison Chart (Figure 5) to estimate relative percent area occupied by vesicles and the designations in Table 21.

FIGURE 5: DEGREE OF VESICULARITY COMPARISON CHART (PERCENT BY VOLUME)

(Ref.19)

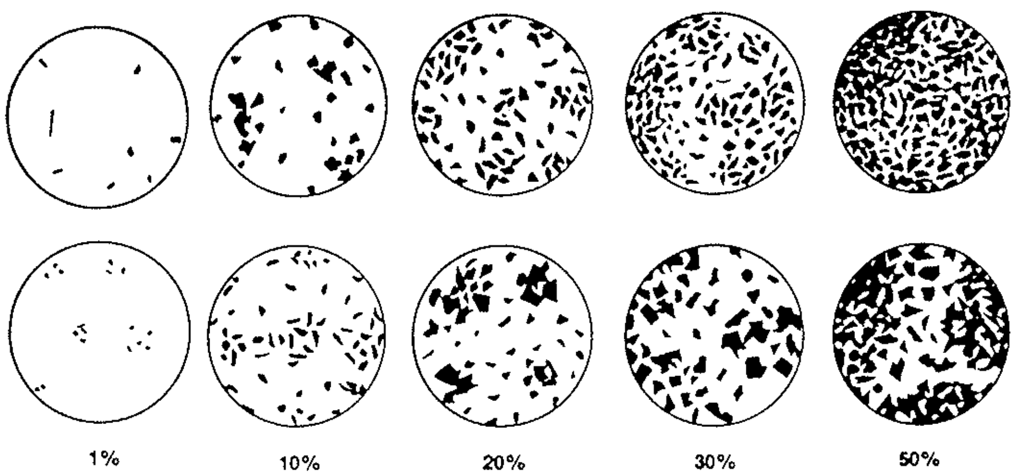


TABLE 21: DEGREE OF VESICULARITY

Term	Percentage (by volume) of Total Sample
Some Vesicles	5 - 25%
Highly Vesicular	15 - 50%
Scoriaceous	> 50%

Color

Rock color is not in itself a specific engineering property, but may be an indicator of the influence of other significant conditions such as groundwater (e.g., mottling indicating wet/dry cycles), and alteration/weathering. Color may also be an aid in subsurface correlation.

The color should be determined from fresh samples. Describe the "net" color of the rock mass. Wetting the rock sample may be necessary if drying has occurred. Use common colors (such as white, yellow, red, brown, green, gray, blue, or black) because they are basic and easier for others to identify. For variations use hyphenated combinations such as red-brown. Do not use "ish", or unusual colors. For example: instead of turquoise or aqua, use green-blue or blue-green, respectively. Avoid listing more than two colors.

Degree of Weathering

Weathering and alteration should be described as part of the rock classification. Weathering is the process of mechanical and/or chemical breakdown of rocks through exposure to the elements, which include rain, wind, plant action, groundwater, ice, and changes of temperature. In general, the strength of rock tends to decrease as the degree of weathering increases. In the earliest stages, weathering is manifested by discoloration of intact rock and only slight changes in rock texture. With time, significant changes in rock hardness, strength, compressibility and permeability occur, and the rock mass is altered until the rock is decomposed to soil. For determining stages of weathering for rock, use Table 22, Scale of Relative Rock Weathering. For example, a basalt that is more than 50 percent decomposed (but not completely) would be described as: "BASALT; predominantly decomposed." The degree of weathering should be determined for each rock core sample: multiple designations would be required for variable rock conditions.

In select cases, the term alteration may be used, which applies specifically to changes in the chemical or mineral composition of rock due to hydrothermal or metamorphic activity. Alteration may occur as zones and pockets and can be found at depths far below that of normal rock weathering. Separate the terms weathering and alteration, since alteration does not strictly infer a reduction in rock strength. For example, a gray basalt that is closely jointed with extensive hydrothermal alteration and secondary mineralization, may exhibit only slight weathering along joint surfaces and would be described as: "BASALT; gray; slightly weathered; close jointed; extensive hydrothermal alteration with secondary mineralization".

TABLE 22: SCALE OF RELATIVE ROCK WEATHERING

(Modified, After Ref.3,11)

Designation	Field Identification
Fresh	Crystals are bright. Discontinuities may show some minor surface staining. No discoloration in rock fabric.
Slightly Weathered	Rock mass is generally fresh. Discontinuities are stained and may contain clay. Some discoloration in rock fabric. Decomposition extends up to 1 inch into rock.
Moderately Weathered	Rock mass is decomposed 50% or less. Significant portions of rock show discoloration and weathering effects. Crystals are dull and show visible chemical alteration. Discontinuities are stained and may contain secondary mineral deposits.
Predominantly Decomposed	Rock mass is more than 50% decomposed. Rock can be excavated with geologist's pick. All discontinuities exhibit secondary mineralization. Complete discoloration of rock fabric. Surface of core is friable and usually pitted due to washing out of highly altered minerals by drilling water.
Decomposed	Rock mass is completely decomposed. Original rock "fabric" may be evident. May be reduced to soil with hand pressure.

Relative Hardness of Rock

Differentiating between rock and soil, for engineering purposes, is based primarily on values of unconfined compressive strength. Rock hardness is a measure of rock strength, and is controlled by many factors including degree of induration, cementation, crystal bonding, and/or degree of weathering. Determination of rock hardness may be estimated through manual field tests yielding a "field classification", which can be refined through further field and laboratory testing. The scale of rock hardness to be used is presented on Table 23. The relative hardness of rock should be determined for each rock core sample: multiple designations would be required for variable rock conditions, such as changes in weathering and joint filling.

TABLE 23: SCALE OF RELATIVE ROCK HARDNESS
(Modified, After Ref.3,12,17)

Term	Hardness Designation	Field Identification	Approximate Unconfined Compressive Strength
Extremely Soft	R0	Can be indented with difficulty by thumbnail. May be moldable or friable with finger pressure.	< 100 psi
Very Soft	R1	Crumbles under firm blows with point of a geology pick. Can be peeled by a pocket knife. Scratched with finger nail.	100-1000 psi
Soft	R2	Can be peeled by a pocket knife with difficulty. Cannot be scratched with fingernail. Shallow indentation made by firm blow of geology pick.	1000-4000 psi
Medium Hard	R3	Can be scratched by knife or pick. Specimen can be fractured with a single firm blow of hammer/geology pick.	4000-8000 psi
Hard	R4	Can be scratched with knife or pick only with difficulty. Several hard hammer blows required to fracture specimen.	8000-16000 psi
Very Hard	R5	Cannot be scratched by knife or sharp pick. Specimen requires many blows of hammer to fracture or chip. Hammer rebounds after impact.	> 16000 psi

Structure

Structure refers to large-scale (megascopic) planar or oriented features which are significant to the overall strength, permeability, and breakage characteristics of the rock unit. Planar structural features include joints, bedding, and faults. These terms are defined below. Other oriented structural features include mineral/grain orientation (i.e., foliation, flow banding and folded originally planar features) or root holes.

<u>Joints</u> Planar breaks or fractures in rock along which <u>no movement has occurred</u> parallel to the fracture surface are defined as joints. They may range from perpendicular to parallel in orientation with respect to bedding. Repetitive patterns of more or less parallel joints is called a <u>joint set</u>. Two or more joint sets or a pattern of joints define a <u>joint system</u>. The number of joint sets is most reliably obtained from rock exposures.

<u>Stratification</u> Stratification of rock is evidenced by changes in texture, composition, age or unique forms. Bedding applies primarily to sedimentary and pyroclastic rocks. Other terms related to stratification are defined in Table 24.

TABLE 24: STRATIFICATION TERMS

TERM	CHARACTERISTICS
laminations	thin beds (< 1 cm.)
fissile	tendency to break along laminations
parting	tendency to break parallel to bedding, any scale
foliation	non-depositional, e.g., segregation and layering of minerals in metamorphic rocks

Joint or Bedding Spacing In determining the range of distances between individual joints or beds, care must be taken to distinguish between joints and mechanical breaks that are caused by handling or drilling. These types of mechanical breaks are typically rough and irregular, showing a fresh rock surface and are disregarded for description. Some mechanical breaks, though, may be caused by handling or drilling, but occur along existing joints or fractures, and should be described accordingly. Joint/bedding spacing is based on Table 25.

TABLE 25: JOINT AND BEDDING SPACING TERMS
(After Ref. 3, 12, 18)

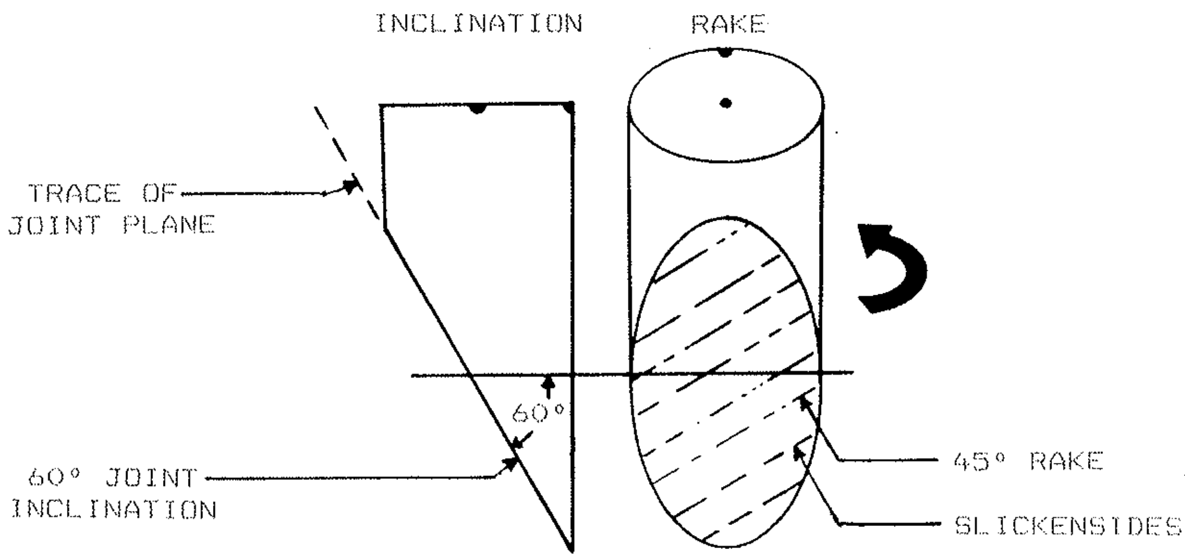
Spacing	Joint spacing Terms	Bedding/Foliation Spacing Terms
Less than 2 in.	Very close	Very thin (laminated)
2 in. - 1 ft.	Close	Thin
1 ft. - 3 ft.	Moderately close	Medium
3 ft. - 10 ft.	Wide	Thick
More than 10 ft.	Very wide	Very thick (massive)

Faults Planar breaks or fractures, along which displacement has occurred parallel to the fracture surface are termed as faults. The presence of gouge (pulverized rock), bedding offset, and/or slickensided surfaces (commonly with mineral or clay coating), may be indicators of fault movement. However, not all slickensides are caused by faulting: slickensides can be caused by deformation (i.e., folds, flows) or landsliding.

Attitude The inclination of a joint, fault, or bedding plane or other linear feature is measured from horizontal. Figure 6 presents joint features that should be identified/measured. The angle that striations (slickensides) make with a horizontal line is known as the "rake", as shown on Figure 6.

FIGURE 6: MEASUREMENT OF JOINTS

(After Ref.13)



Strike and dip of joint and bedding planes are usually measured in test pits or on outcrops, since core obtained in most drilling operations will not be properly oriented. Joint and bedding planes should be described in terms of orientation, i.e., strike and dip. Primary and secondary joint sets should be defined where possible and appropriate. Typically in rock, one joint set may yield slabs, two intersecting joint sets may yield wedges, and three or more intersecting joint sets may yield blocks or highly fragmented rock.

Separation The separation or relative openness of joints may be described as:

a) open, an existing planar surface that is separated or separates easily when handled, and may have mineralization or staining/weathering on the joint surfaces. Where measurable, identify the opening width (aperture). Open joints are possible groundwater drainage paths.

b) closed, an existing planar surface that separates with greater difficulty, seen as a "hairline" trace on the outside of the sample/core, and usually does not have soil or mineral surface coating.

c) healed, breaks open easily or with difficulty, seen either as a hairline trace or seam of some thickness on the outside of the sample/core, and usually contains soil or minerals as a filling between joint surfaces.

Filling This term refers to the material in the space between adjacent surfaces of a discontinuity. The filling material may consist of weathered or hydrothermally altered products, secondary mineral precipitates, mylonite or gouge. The material description and thickness of the filling material should be reported.

Continuity Continuity is an expression of the lateral extension of the discontinuity, as measured or projected along its strike and dip. Continuity is a very important property of the rock mass, as a single continuous joint may actually control the behavior of the entire mass. Whether or not joints are continuous may require test pit, outcrop, or additional borehole information for confirmation. Description of joint continuity, as defined in Table 26, should include an indication of certainty and the method of observation.

TABLE 26: DEGREE OF CONTINUITY

(Ref.12)

Term	Length
Discontinuous	0 - 5 ft.
Slightly continuous	5 - 10 ft.
Continuous	10 - 40 ft.
Highly continuous	> 40 ft.

Core Recovery and Rock Quality Designation (RQD)

Core recovery and the Rock Quality Designation are measured indicators of the quality and structure of rock. Both the percent core recovery and the RQD should be determined and recorded on the field boring log for each core run. The core recovery is calculated by dividing the length of core retained (recovered) in the core barrel by the total run length expressed as a percent.

The RQD provides a subjective estimate of rock mass quality/ structure. The RQD is a modified core recovery percentage in which only pieces of intact rock core 4 inches or greater in length are measured (average length). The smaller pieces are considered to be the result of close jointing, fracturing or weathering in the rock mass, and are therefore excluded from the RQD determination. The RQD is defined as the cumulative total length of all pieces 4 inches long or longer divided by the total run length, expressed as a percentage. Mechanical breaks, such as caused by handling or drilling, should be noted as such and not included in the RQD calculations.

In some cases, where significant soil is encountered at one end of the core run, the RQD should be determined on the basis of rock core length recovered: where this is done it should be clearly defined. RQD is not applicable to fissile rocks such as shales. Difficulties such as distinguishing natural fractures in the rock core from mechanical breaks and the insensitivity of the RQD to the tightness of individual joints may limit the use of the RQD in evaluating in situ rock properties.

Other Rock Characteristics

Other physical characteristics should be described, depending on the scope and objectives of the project. These may include the following:

Mineralization Secondary mineralization is the introduction of new minerals to a rock mass from an outside source, or through alteration of existing minerals. Mineralization may occur in voids, along joints or within the ground mass.

Iron-oxide staining usually indicates the static groundwater level may fluctuate within the discolored zone. The iron oxide may only be a discoloration of surfaces, or an accumulation of bright orange material several inches thick and varying in hardness. Sulfide or carbonate minerals, such as pyrite or calcite, may be present and could denote groundwater of high mineral or bicarbonate content. Alteration products may indicate an increase in hardness/brittleness (i.e., silicification, usually due to hydrothermal alteration), or reduction of rock strength if soft clay minerals have developed along joints or replaced major constituent minerals (e.g., the feldspar crystals in basalt altered to clay).

Slaking The tendency for rock to disintegrate under conditions of wetting and drying, or when exposed to air is called slaking. This behavior is related primarily to the chemical composition of the material. It may be identified in the field if samples shrink and crack, or otherwise degrade upon drying, or being exposed to the air for several hours. If degradation occurs, and slaking is suspected, an air-dried sample may be placed in clean water to observe a reaction. The greater the tendency for slaking, the more rapidly degradation will occur. This tendency should be expressed on field logs as "potential for slaking", and can be confirmed through laboratory testing.

Field Unit Weight The unit weight of rock can be important and useful in engineering design and practice. The unit weight can be determined by performing a field bulk specific gravity test and multiplying by the unit weight of water to get the rock unit weight. The procedure consists of weighing the sample in air (B) and then weighing it in water (C).

$$\text{field unit weight} = \left[\frac{B}{B - C}\right] \times (62.4), \text{ lbs. per. cu. ft.}$$

Discontinuity Surface Condition If applicable to the project, the joint/fault surfaces should be inspected and the surface condition described. Joint surface roughness can be defined in terms of a Joint Roughness Coefficient (JRC), which requires estimation or measurement of the surface unevenness, i.e., rough or smooth undulating, rough or smooth nearly planar. The JRC should be determined in the direction of anticipated block movement. Surface roughness is best determined on in-place discontinuities rather than core samples. For further detail, see References 5, 6, and 13.

Voids Open spaces in sedimentary and metamorphic rock are generally caused by chemical dissolution or the action of running water. Since most of these voids result from the action of groundwater, the openings are usually elongate in the horizontal plane. The size of voids, where significant, should be measured and recorded with the rock classification.

Formation Name

Various rock units are generally known by formational names (i.e., Columbia River Basalt Formation, Astoria Formation, Umpqua Formation) and can be identified within project boundaries by examination of core samples, rock outcrops, and geologic literature. Where the formation name is known, it should be included at the end of the rock classification (in parentheses).

SOILS AND GEOLOGIC EXPLORATION LOG

General

A "Soils and Geological Exploration Log" should be made for each exploratory boring, hand-auger hole, probe hole and test pit. The log can also be used to describe inspected cut slopes. Information provided on the final logs should be either typed or neatly printed so that legible copies can be made. Soil and rock descriptions/classifications and terminology should be consistent with this manual. Abbreviations are to be avoided unless thay are defined in this manual. Sample descriptions are shown on pages 45 through 48.

The logs should contain basic reference information at the top, including project name, purpose, specific location and elevation, exploration hole number, date, drilling equipment, procedures, drilling fluid, etc. Each sample should be fully described. Referencing a previous sample is not recommended since rarely are any two samples identical. The depth of each stratum contact, discontinuity, and lens should be recorded. The reason for exploratory hole termination and a list/description of instrumentation installed should be written at the end (bottom) of each exploration log.

Field Log

The field log is a record which should contain all of the information obtained from an exploratory hole whether or not it may seem important at the time of exploration. It is important to record all information in an accurate manner. All soil and rock samples are to be fully described immediately on recovery. Depths of samples, top and bottom of each stratum/layer, discontinuities, field tests, and groundwater level(s) should be measured to the nearest 0.1-foot. The depth(s) of drilling stoppage and date/time (i.e., end of shift) should be recorded.

Drilling Remarks

The material that is not recovered is frequently significant in the design of foundations, excavations, performance of fills, and other geotechnical designs. Subsurface conditions are not always fully described by depending solely on material descriptions. Therefore, any comments with regard to the character of drilling and difficulties encountered while advancing the boring should be included on the exploration log. Drilling remarks may include:

- obstructions
- difficulties in drilling (caving, surging sands, caverns, etc.)
- estimated percent water return and applied water pressure
- color of water return
- return water constituents
- relative drilling down-pressure and exact depth of major pressure changes
- drilling action, i.e. drill chatter, smooth, bouncy, etc.
- length of time for each core run
- explanation for incomplete recoveries (SPT, Shelby, Core)
- artesian water pressure or elevation head, and depth where encountered
- reasons for using drilling muds, casing, or special drill bits

Final Log

The final log is prepared from the field log after completing routine laboratory tests (such as moisture contents and check classifications) and comparing with other exploration records for the same project. The final log includes descriptions of all materials, conditions, drilling remarks, and results of field tests and any instrumentation. Where groundwater observation wells or piezometers are installed, several measurements are usually necessary following drilling to verify that measured groundwater levels or pressures have achieved equilibrium. For instance, if drill water is used in fine-grained soils, and the exploratory hole is not bailed, then the observation well levels will be initially high, dropping with time to the actual groundwater level. It is desirable that final logs include measurements of groundwater levels during winter and summer months in order to establish the range of groundwater fluctuation.

Depth, ft.	Test Type No.	Driving Resistance	Measured Recovery,	% Recovery	Hardness / R.Q.D.	Graphic Log	% Natural Moisture	Material Description (Color, Consistency, Plasticity, Organic Content, Wet-Dry, Jointed-Broken, Angular-Rounded, Drill Remarks, etc.)
22	C-1		2.0'	40	N/A	GW 26'		(C-1) 22' - 27' 22'-26': Recovered 12" consisting of coarse gravel and two cobble sized core pieces each 4" long. Interpret material to be same as recovered in N-4.
					R0 / 100	TUFF 27'		26'-27': 12" recovery. TUFF, Yellow-brown, Predominately decomposed, Extremely soft, Massive (Little Butte Series).
27	C-2		5.0'	100	R1 / 100	AGGLOMERATE		(C-2) 27' - 32' AGGLOMERATE, Blue-brown, Moderately weathered, Very soft, Massive (Little Butte Series).
32	C-3		5.0'	100	R2 / 100			(C-3) 32' - 37' AGGLOMERATE, Blue-brown, Moderately weathered, Soft, Massive, (Little Butte Series).
37	C-4		5.0'	100	R3 / 100	42'		(C-4) 37' - 42' AGGLOMERATE, Yellow-brown, slightly weathered, Medium hard, Massive, (Little Butte Series).
								End of hole at 42'. Hole terminated after 15 feet of core recovery. Hole was bailed upon completion. A 3/4-inch stand-pipe piezometer tube was installed to bottom of hole, slotted from 14' to 25' with a two-foot bentonite seal from 11'-13'. Backfilled above and below seal with clean coarse sand. A one-foot bentonite seal placed at collar.

SAMPLE

SOILS AND GEOLOGICAL EXPLORATION LOG

HIGHWAY DIVISION

Project	Battle Creek Bypass	Hole No.	TB 87-1
Highway	Pioneer Express (12) MP 73 — County Lane	Prefix	C000-1400
Purpose of Work	Bridge Replacement	Bridge No.	B461
Equipment	Mobile B 50 (#87-001)	Tube Elev.	181.2
Geologist	Rocky Hammer — Driller Curly Auger	Recorder	Gee Won
Hole Location	L, Line, Sta. 110 + 35 Lt. 12' C.L. Rt.	Ground Elev.	179.8

Tests		Drilling Method		Groundwater Level Date	Depth
"N" — Standard Penetration,	No. 4	Auger Depth		8-12-86	15.0'
"M" — Oregon Miniature Pile,	No.	HQWL Casing Depth		8-19-86	16.3'
"C" — Core, Barrel Type HQWL	No. 4	Open Depth	42'		
"U" — Undisturbed Sample, Size	No. 1	Total Depth	42'		

Date Started 8-12-86 | Date Completed 8-12-86 | Sample Data Sheet No. A-00000

Depth, ft.	Test Type No.	Driving Resistance	Measured Recovery	% Recovery	Hardness / R.Q.D.	Graphic Log	% Natural Moisture	Material Description (Color, Consistency, Plasticity, Organic Content, Wet-Dry, Jointed-Broken, Angular-Rounded, Drill Remarks etc.)
								0-5' advanced H.Q.W.L. drill action smooth-soil, water return-grey
5	U-1		1.8'	92		MH		(U-1) 5'-7' Clayey SILT with some fine sand and some organics, MH, Grey, Medium plasticity, Wet, Soft, Torvane .25 TSF (Alluvium).
						7.0'		
7	N-1	2-3-4-7	1.5'	75		CH	55	(N-1) 7'-9' Silty CLAY, CH, Grey, High plasticity, Wet, Medium stiff, (Aluvium).
						9.5'		7'-10' advanced casing. Smooth drilling.
10	N-2	5-5-8-11	2.0'	100		MH	57	(N-2) 10'-12' Clayey SILT, MH, Brown-grey, Medium plasticity, Wet, Stiff, (Alluvium).
						12.5'		12'-15' advanced casing. Smooth drilling. Lost drill water return at 12.5'.
15	N-3	6-8-8-14	2.0'	100		SP		(N-3) 15'-17' SAND, SP, Pale brown, Non-plastic, Wet, Medium dense, Fine sand, with 1-inch layer of clayey silt at 15.5'.
						18.0'		17'-20' advanced casing. Smooth drilling to 18'. Drill bouncing 18'-20'.
20	N-4	14-50/0.2'	0.5'	25		GW		(N-4) 20'-22' Sandy GRAVEL with some cobbles GW, Grey, Wet, Coarse sand to 4" cobbles, (Alluvium). SPT bouncing on cobble.
								Install core barrel at 22'.

734-3976 (REV. 12-82)

SAMPLE

SOILS AND GEOLOGICAL EXPLORATION LOG

HIGHWAY DIVISION

Project	Raliegh - Old Tooth Rd.	Hole No.	TB 85-1
Highway	Mountain Pass (482) MP 37 — County: Kaplan	Prefix	C000-1200
Purpose of Work	Highway Realignment	Bridge No.	—
Equipment	Mobile B 53, #84-199	Tube Elev.	4216'
Geologist	G. Runyan — Driller: J. Smith	Recorder	M. Jones
Hole Location	L2 Line, Sta. 488 + 25 Lt. C.L. Rt. 50'	Ground Elev.	4214'

Tests	No.
"N" — Standard Penetration,	4
"M" — Oregon Miniature Pile,	
"C" — Core, Barrel Type HQ	3
"U" — Undisturbed Sample, Size	

Drilling Method		
6" Hollow Stem	Auger Depth	9.5'
HQWL	Casing Depth	
Drilling Fluid	Open Depth	15'
WATER	Total Depth	24.5'

Groundwater Level

Date	Depth
10-10-85	9.5'
10-12-85	7.0'
10-20-85	7.0'

Date Started 10-7-85 | Date Completed 10-8-85 | Sample Data Sheet No.

Depth, ft.	Test Type No.	Driving Resistance	Measured Recovery	% Recovery	Hardness / R.Q.D.	Graphic Log	% Natural Moisture	Material Description (Color, Consistency, Plasticity, Organic Content, Wet-Dry, Jointed-Broken, Angular-Rounded, Drill Remarks etc.)
								Top 3 feet of soil removed for access road. Clayey SILT, ML, Brown, Low plasticity, Moist (Decomposed Basalt).
								Advanced auger to 3.5'. Drill action smooth.
3.5	N-1	10 - 31 - 27	1.5	100			18	(N-1) 3.5 - 5.0' Clayey SILT with trace fine sand, ML, Brown, Low plasticity, Damp, Hard, (Decomposed Basalt).
								Advanced auger to 5.5'. Drill action smooth.
5.5	N-2	12 - 41 - 22	0.8	50			28	(N-2) 5.5' - 7.0' Clayey SILT with trace fine sand and trace of coarse gravel size subangular basalt fragments, ML, Brown, Low plasticity, Moist, Hard, (Decomposed Basalt).
								Advanced auger to 7.5' Ocassional drill chatter.
7.5	N-3	10 - 19 - 22	1.5	100		ML	30	(N-3) 7.5' - 9.0' Clayey SILT with some fine sand and trace of fine gravel size angular basalt fragments, ML, Grey-brown, Low plasticity, Moist, Hard, (Decomposed Basalt).
						9.5'		Advanced auger to 9.5' Ocassional drill chatter.
9.5	N-4	50/0.1'	0	0		BASALT		(N-4) 9.5' - 9.6' No recovery. SPT bouncing. Basalt contact at 9.5'.

Depth, ft.	Test Type No.	Driving Resistance	Measured Recovery,	% Recovery	Hardness / R. Q. D.	Graphic Log	% Natural Moisture	Material Description (Color, Consistency, Plasticity, Organic Content, Wet-Dry, Jointed-Broken, Angular-Rounded, Drill Remarks etc.)
								Installed H.O.W.L. through hollow stem auger. Begin coring at 9.5'.
9.5	C-1		5.0	100	R-3 / 50			(C-1) 9.5' - 14.5' Basalt with trace of vesicules, Brown-Grey, Moderately weathered, Medium hard, Closely jointed at 45° and 90°, Joints are open with calcite on surfaces, (Columbia River Basalt).
14.5	C-2		5.0	100	R-4 / 100			(C-2) 14.5' - 19.5' BASALT with trace of vesicules, Grey, Slightly weathered, Hard, Widely jointed, one 45° open joint at 16.0' with calcite on surface, (Columbia River Basalt).
19.5	C-3		5.0	100	R-4 / 100			(C-3) 19.5' - 24.5' BASALT with trace of vesicules, Grey, Fresh, Hard, Widely jointed with one 45° open joint at 20.4', (Columbia River Basalt).
								End of hole at 24.5', five feet below proposed grade. One-inch open standpipe piezometer tube installed to bottom of hole, slotted from 10 to 24 feet with a two-foot bentonite seal from 8 to 10 feet. Backfilled above and below seal with clean coarse sand. A one-foot bentonite seal placed at collar. Hole was bailed upon completion.

REFERENCES

1. AASHTO, Manual on Foundation Investigations, 1978

2. American Geological Institute, Dictionary of Geologic Terms, Doubleday, 1974

3. ASCE, "Subsurface Investigation for Design and Construction of Foundations of Buildings," ASCE Manual on Engineering Practice No. 56, 1976, 61 p.

4. ASTM, Annual Book of ASTM Standards: Section 4, Vol. 04.08 "Soil and Rock Building Stones," Philadelphia, 1986, 1076 p.

5. Bandis, S., Lumsden, A.C., and Barton, N.R., "Experimental Studies of Scale Effects on the Shear Behavior of Rock Joints," Int. Journal of Rock Mechanics and Mining Sciences, Vol. 18, 1981, pp 1-21

6. Barton, N.R., Bandis, S., and Bakhtar, K., "Strength, Deformation and Conductivity Coupling of Rock Joints," Int. Journal of Rock Mechanics and Mining Sciences, Vol. 22, 1985, pp 121-140

7. Bell, F.G., Engineering Properties of Soils and Rocks, 2nd Edition, 1983, 149 p.

8. Billings, M.P., Structural Geology, Second Edition, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1954, 514 p.

9. Brownlow, A.H., and Reinhard, M.J., Laboratory Manual: Geology for Engineers, W.C. Brown Co., Iowa, 1965, pp 6-17

10. Cooling, L.F., Skempton, A.W., and Glossop, R., "Discussion: Classification and Identification of Soils (Casagrande, A.) Transactions, ASCE, 1948

11. Deere, D.U., and Patton, F.D., "Slope Stability in Residual Soils", Fourth Pan American Conference on Soil Mechanics and Foundation Engineering, Puerto Rico, Vol. 1, June 1971, p. 87-170.

12. Haley and Aldrich, Manual on Subsurface Investigations, NCHRP, TRB, Project 24-1, July, 1984

13. Hoek, E., and Bray, J., "Rock Slope Engineering", revised Second Edition, The Institute of Mining and Metallurgy, London, 1977, 402.p.

14. Naval Facilities Engineering Command, Soil Mechanics Design Manual 7.1, May 1982

15. Ontario Ministry of Transportation and Communications, Soil Classification Manual, Ontario, Canada, 1980

16. Ontario Ministry of Transportation and Communications, A Guide to the Description of Rock for Engineering Purposes, Ontario, Canada, 1982

17. Piteau, D.R., "Methods of Obtaining Geologic Structural Strength and Related Engineering Geology Data", Rock Slope Engineering, Part B, Federal Highway Administration FHWA-TS-79208, 1979

18. Sowers, G.B.and Sowers, G.F., "Introductory Soil Mechanics and Foundations"; Geotechnical Engineering, Fourth Edition, Macmillan Publishing Co. Inc., New York, 1979, 621 p.

19. Terry, R.D., and Chillingar, G.V., "Comparison Charts for Visual Estimation of Percentage Composition", Journal Sed. Petrol., Vol. 25, No. 3, Sept. 1955, pp 229-234

20. Terzaghi, K., and Peck, R.B., Soil Mechanics in Engineering Practice, 2nd Ed., Wiley, 1967

21. U.S. Department of the Army, Corps of Engineers North Pacific Division, "Inspectors Manual for Subsurface Investigations", Portland, Oregon, Oct. 1960

22. U.S. Department of the Army, Waterways Experiment Station, Laboratory Soils Testing Manaual EM 1110-2-1906, Washington D.C., Nov. 1970

23. U.S. Department of the Interior, Water and Power Resources Service, "Earth Manual", reprinted Second Edition, U.S. Government Printing Office, Washington, D.C., 1980, 810 p.

24. Welch, R.C., and Thornton, S.I., Arkansas Bridge Foundations: Field Procedures, Arkansas DOT, March, 1978

APPENDIX A

REFERENCE CLASSIFICATION PROCEDURES

1. ASTM D2487

2. ASTM D2488

Designation: D 2487 - 85

Standard Test Method for CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES[1]

This standard is issued under the fixed designation D 2487; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This test method has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

1. Scope

1.1 This test method describes a system for classifying mineral and organo-mineral soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit, and plasticity index and shall be used when precise classification is required.

NOTE 1—Use of this standard will result in a single classification group symbol and group name except when a soil contains 5 to 12 % fines or when the plot of the liquid limit and plasticity index values falls into the crosshatched area of the plasticity chart. In these two cases, a dual symbol is used, for example, GP-GM, CL-ML. When the laboratory test results indicate that the soil is close to another soil classification group, the borderline condition can be indicated with two symbols separated by a slash. The first symbol should be the one based on this standard, for example, CL/CH, GM/SM, SC/CL. Borderline symbols are particularly useful when the liquid limit value of clayey soils is close to 50. These soils can have expansive characteristics and the use of a borderline symbol (CL/CH, CH/CL) will alert the user of the assigned classifications of expansive potential.

1.2 The group symbol portion of this sytem is based on laboratory tests performed on the portion of a soil sample passing the 3-in. (75-mm) sieve (see Specification E 11).

1.3 As a classification system, this test method is limited to naturally occurring soils.

NOTE 2—The group names and symbols used in this test method may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. See Appendix X2.

1.4 This test method is for qualitative application only.

NOTE 3—When quantitative information is required for detailed designs of important structures, this test method must be supplemented by laboratory tests or other quantitative data to determine performance characteristics under expected field conditions.

1.5 The system is based on the widely recognized Unified Soil Classification System which was adopted by several U.S. Government agencies in 1952 as an outgrowth of the Airfield Classification System developed by A. Casagrande.[2]

1.6 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Applicable Documents

2.1 *ASTM Standards:*

C 117 Test Method for Material Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing[3]

C 136 Method for Sieve Analysis of Fine and Coarse Aggregates[3]

C 702 Methods for Reducing Field Samples of Aggregate to Testing Size[3]

D420 Recommended Practice for Investigating and Sampling Soil and Rock for Engineering Purposes[4]

D421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and De-

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

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[2] Casagrande, A., "Classification and Identification of Soils," *Transactions*, ASCE, 1948, p. 901.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

[4] *Annual Book of ASTM Standards*, Vol 04.08.

termination of Soil Constants[4]

D422 Method for Particle-Size Analysis of Soils[4]

D653 Terms and Symbols Relating to Soil and Rock[4]

D1140 Test Method for Amount of Material in Soils Finer than the No. 200 (75-μm) Sieve[4]

D2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[4]

D2217 Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[4]

D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[4]

D4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[4]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

3. Summary of Method

3.1 As illustrated in Table 1, this classification system identifies three major soil divisions: coarse-grained soils, fine-grained soils, and highly organic soils. These three divisions are further subdivided into a total of 15 basic soil groups.

3.2 Based on the results of visual observations and prescribed laboratory tests, a soil is catalogued according to the basic soil groups, assigned a group symbol(s) and name, and thereby classified. The flow charts, Fig. 1 for fine-grained soils, and Fig. 2 for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name.

4. Significance and Use

4.1 This test method 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.

4.2 The assigning of a group name and symbol(s) along with the descriptive information required in Practice D 2488 can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

4.3 The various groupings of this classification system have been devised to correlate in a general way with the engineering behavior of soils. This test method provides a useful first step in any field or laboratory investigation for geotechnical engineering purposes.

4.4 This test method may also be used as an aid in training personnel in the use of Practice D 2488.

5. Terminology

5.1 *Definitions*—Except as listed below, all definitions are in accordance with Terms and Symbols D 653.

NOTE 4—For particles retained on a 3-in. (75-mm) U.S. standard sieve, the following definitions are suggested:

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

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

5.1.1 *gravel*—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 3-in. (75-mm) sieve and retained on ¾-in. (19-mm) sieve, and

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

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

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

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

Fine—passes No. 40 (425-μm) sieve and retained on No. 200 (75-μm) sieve.

5.1.3 *clay*—soil passing a No. 200 (75-μm) U.S. standard sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents and that exhibits considerable strength when air dry. 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.

5.1.4 *silt*—soil passing a No. 200 (75-μm) U.S. standard 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 if the plot of plasticity index versus liquid limit falls below the "A" line.

5.1.5 *organic clay*—a clay with sufficient organic content to influence the soil properties. 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 % of its liquid limit value before oven drying.

5.1.6 *organic silt*—a silt with sufficient organic content to influence 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 % of its liquid limit value before oven drying.

5.1.7 *peat*—a soil composed of vegetable tissue 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.

5.2 *Descriptions of Terms Specific to This Standard:*

5.2.1 *coefficient of curvature*, Cc—the ratio $(D_{30})^2/(D_{10} \times D_{60})$, where D_{60}, D_{30}, and D_{10} are the particle diameters corresponding to 60, 30, and 10 % finer on the cumulative particle-size distribution curve, respectively.

5.2.2 *coefficient of uniformity*, Cu—the ratio D_{60}/D_{10}, where D_{60} and D_{10} are the particle diameters corresponding to 60 and 10 % finer on the cumulative particle-size distribution curve, respectively.

6. Apparatus

6.1 In addition to the apparatus that may be required for obtaining and preparing the samples and conducting the prescribed laboratory tests, a plasticity chart, similar to Fig. 3, and a cumulative particle-size distribution curve, similar to Fig. 4, are required.

NOTE 5—The "U" line shown on Fig. 3 has been empirically determined to be the approximate "upper limit" for natural soils. It is a good check against erroneous data, and any test results that plot above or to the left of it should be verified.

7. Sampling

7.1 Samples shall be obtained and identified in accordance with a method or methods, recommended in Recommended Practice D 420 or by other accepted procedures.

7.2 For accurate identification, the minimum amount of test sample required for this test method will depend on which of the laboratory tests need to be performed. Where only the particle-size analysis of the sample is required, specimens having the following minimum dry weights are required:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (3/8 in.)	200 g (0.5 lb)
19.0 mm (3/4 in.)	1.0 kg (2.2 lb)
38.1 mm (1½ in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

Whenever possible, the field samples should have weights two to four times larger than shown.

7.3 When the liquid and plastic limit tests must also be performed, additional material will be required sufficient to provide 150 g to 200 g of soil finer than the No. 40 (425-µm) sieve.

7.4 If the field sample or test specimen is smaller than the minimum recommended amount, the report shall include an appropriate remark.

8. Classification of Peat

8.1 A sample composed primarily of vegetable tissue in various stages of decomposition and has a fibrous to amorphous texture, a dark-brown to black color, and an organic odor should be designated as a highly organic soil and shall be classified as peat, PT, and not subjected to the classification procedures described hereafter.

9. Preparation for Classification

9.1 Before a soil can be classified according to this test method, generally the particle-size distribution of the minus 3-in. (75-mm) material and the plasticity characteristics of the minus No. 40 (425-µm) sieve material must be determined. See 9.8 for the specific required tests.

9.2 The preparation of the soil specimen(s) and the testing for particle-size distribution and liquid limit and plasticity index shall be in accordance with accepted standard procedures. Two procedures for preparation of the soil specimens for testing for soil classification purposes are given in Appendixes X3 and X4. Appendix X3 describes the wet preparation method and is the preferred method for cohesive soils that have never dried out and for organic soils.

9.3 When reporting soil classifications determined by this test method, the preparation and test procedures used shall be reported or referenced.

9.4 Although the test procedure used in determining the particle-size distribution or other considerations may require a hydrometer analysis of the material, a hydrometer analysis is not necessary for soil classification.

9.5 The percentage (by dry weight) of any plus 3-in. (75-mm) material must be determined and reported as auxiliary information.

9.6 The maximum particle size shall be determined (measured or estimated) and reported as auxiliary information.

9.7 When the cumulative particle-size distribution is required, a set of sieves shall be used which include the following sizes (with the largest size commensurate with the maximum particle size) with other sieve sizes as needed or required to define the particle-size distribution:

3-in. (75-mm)
¾-in.(19.0-mm)
No. 4 (4.75-mm)
No. 10 (2.00-mm)
No. 40 (425-µm)
No. 200 (75-µm)

9.8 The tests required to be performed in preparation for classification are as follows:

9.8.1 For soils estimated to contain less than 5 % fines, a plot of the cumulative particle-size distribution curve of the fraction coarser than the No. 200 (75-µm) sieve is required. The cumulative particle-size distribution curve may be plotted on a graph similar to that shown in Fig. 4.

9.8.2 For soils estimated to contain 5 to 15 % fines, a cumulative particle-size distribution curve, as described in 9.8.1, is required, and the liquid limit and plasticity index are required.

9.8.2.1 If sufficient material is not available to determine the liquid limit and plasticity index, the fines should be estimated to be either silty or clayey using the procedures described in Practice D 2488 and so noted in the report.

9.8.3 For soils estimated to contain 15 % or more fines, a determination of the percent fines, percent sand, and percent gravel is required, and the liquid limit and plasticity index are required. For soils estimated to contain 90 % fines or more, the percent fines, percent sand, and percent gravel may be estimated using the procedures described in Practice D 2488 and so noted in the report.

10. Preliminary Classification Procedure

10.1 Class the soil as fine-grained if 50 % or more by dry weight of the test specimen passes the No. 200 (75-µm) sieve and follow Section 11.

10.2 Class the soil as coarse-grained if more than 50 % by dry weight of the test specimen is retained on the No. 200 (75-µm) sieve and follow Section 12.

11. Procedure for Classification of Fine-Grained Soils (50 % or more by dry weight passing the No. 200 (75-µm) sieve)

11.1 The soil is an inorganic clay if the position of the plasticity index versus liquid limit plot, Fig. 3, falls on or above the "A" line, the plasticity index is greater than 4, and the presence of organic matter does not influence the liquid limit as determined in 11.3.2.

11.1.1 Classify the soil as a *lean clay*, CL, if the liquid limit is less than 50. See area identified as CL on Fig. 3.

11.1.2 Classify the soil as a *fat clay*, CH, if the liquid limit is 50 or greater. See area identified as CH on Fig. 3.

NOTE 6—In cases where the liquid limit exceeds 110 or the plasticity index exceeds 60, the plasticity chart may be expanded by maintaining the same scale on both axes and extending the "A" line at the indicated slope.

11.1.3 Classify the soil as a *silty clay*, CL-ML, if the position of the plasticity index versus liquid limit plot falls on or above the "A" line and the plasticity index is in the range of 4 to 7. See area identified as CL-ML on Fig. 3.

11.2 The soil is an inorganic silt if the position of the plasticity index versus liquid limit plot, Fig. 3, falls below the "A" line or the plasticity index is less than 4, and presence of organic matter does not influence the liquid limit as determined in 11.3.2.

11.2.1 Classify the soil as a *silt*, ML, if the liquid limit is less than 50. See area identified as ML on Fig. 3.

11.2.2 Classify the soil as an *elastic silt*, MH, if the liquid limit is 50 or greater. See area identified as MH on Fig. 3.

11.3 The soil is an organic silt or clay if organic matter is present in sufficient amounts to influence the liquid limit as determined in 11.3.2.

11.3.1 If the soil has a dark color and an organic odor when moist and warm, a second liquid limit test shall be performed on a test specimen which has been oven dried at 110 ± 5°C to a constant weight, typically over night.

11.3.2 The soil is an organic silt or organic clay if the liquid limit after oven drying is less than 75 % of the liquid limit of the original specimen determined before oven drying (see Procedure B of Practice D 2217).

11.3.3 Classify the soil as an *organic silt* or *organic clay*, OL, if the liquid limit (not oven dried) is less than 50 %. Classify the soil as an *organic silt*, OL, if the plasticity index is less than 4, or the position of the plasticity index versus liquid limit plot falls below the "A" line. Classify the soil as an *organic clay*, OL, if the plasticity index is 4 or greater and the position of the plasticity index versus liquid limit plot falls on or above the "A" line. See area identified as OL (or CL-ML) on Fig. 3.

11.3.4 Classify the soil as an *organic clay* or *organic silt*, OH, if the liquid limit (not oven dried) is 50 or greater. Classify the soil as an *organic silt*, OH, if the position of the plasticity index versus liquid limit plot falls below the "A" line. Classify the soil as an *organic clay*, OH, if the position of the plasticity index versus liquid-limit plot falls on or above the "A" line. See area identified as OH on Fig. 3.

11.4 If less than 30 % but 15 % or more of the test specimen is retained on the No. 200 (75-μm) sieve, the words "with sand" or "with gravel" (whichever is predominant) shall be added to the group name. For example, lean clay with sand, CL; silt with gravel, ML. If the percent of sand is equal to the percent of gravel, use "with sand."

11.5 If 30 % or more of the test specimen is retained on the No. 200 (75-μm) sieve, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if 30 % or more of the test specimen is retained on the No. 200 (75-μm) sieve and the coarse-grained portion is predominantly sand. Add the word "gravelly" if 30 % or more of the test specimen is retained on the No. 200 (75-μm) sieve and the coarse-grained portion is predominantly gravel. For example, sandy lean clay, CL; gravelly fat clay, CH; sandy silt, ML. If the percent of sand is equal to the percent of gravel, use "sandy."

12. Procedure for Classification of Coarse-Grained Soils (more than 50 % retained on the No. 200 (75-μm) sieve)

12.1 Class the soil as gravel if more than 50 % of the coarse fraction [plus No. 200 (75-μm) sieve] is retained on the No. 4 (4.75-mm) sieve.

12.2 Class the soil as sand if 50 % or more of the coarse fraction [plus No. 200 (75-μm) sieve] passes the No. 4 (4.75-mm) sieve.

12.3 If 12 % or less of the test specimen passes the No. 200 (75-μm) sieve, plot the cumulative particle-size distribution, Fig. 4, and compute the coefficient of uniformity, Cu, and coefficient of curvature, Cc, as given in Eqs 1 and 2.

$$Cu = D_{60}/D_{10} \quad (1)$$

$$Cc = (D_{30})^2/(D_{10} \times D_{60}) \quad (2)$$

where:

D_{10}, D_{30}, and D_{60} = the particle-size diameters corresponding to 10, 30, and 60 %, respectively, passing on the cumulative particle-size distribution curve, Fig. 4.

NOTE 7—It may be necessary to extrapolate the curve to obtain the D_{10} diameter.

12.3.1 If less than 5 % of the test specimen passes the No. 200 (75-μm) sieve, classify the soil as a *well-graded gravel*, GW, or *well-graded sand*, SW, if Cu is greater than 4.0 for gravel or greater than 6.0 for sand, and Cc is at least 1.0 but not more than 3.0.

12.3.2 If less than 5 % of the test specimen passes the No. 200 (75-μm) sieve, classify the soil as *poorly graded gravel*, GP, or *poorly graded sand*, SP, if either the Cu or the Cc criteria for well-graded soils are not satisfied.

12.4 If more than 12 % of the test specimen passes the No. 200 (75-μm) sieve, the soil shall be considered a coarse-grained soil with fines. The fines are determined to be either clayey or silty based on the plasticity index versus liquid limit plot on Fig. 3. (See 9.8.2.1 if insufficient material available for testing).

12.4.1 Classify the soil as a *clayey gravel*, GC, or *clayey sand*, SC, if the fines are clayey, that is, the position of the plasticity index versus liquid limit plot, Fig. 3, falls on or above the "A" line and the plasticity index is greater than 7.

12.4.2 Classify the soil as a *silty gravel*, GM, or *silty sand*, SM, if the fines are silty, that is, the position of the plasticity index versus liquid limit plot, Fig. 3, falls below the "A" line or the plasticity index is less than 4.

12.4.3 If the fines plot as a silty clay, CL-ML, classify the soil as a *silty, clayey gravel*, GC-GM, if it is a gravel or a *silty, clayey sand*, SC-SM, if it is a sand.

12.5 If 5 to 12 % of the test specimen passes the No. 200 (75-μm) sieve, give the soil a dual classification using two group symbols.

12.5.1 The first group symbol shall correspond to that for a gravel or sand having less than 5 % fines (GW, GP, SW, SP), and the second symbol shall correspond to a gravel or sand having more than 12 % fines (GC, GM, SC, SM).

12.5.2 The group name shall correspond to 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 (See 9.8.2.1 if insufficient material available for testing).

NOTE 8—If the fines plot as a *silty clay*, CL-ML, the second group symbol should be either GC or SC. For example, a poorly graded sand with 10 % fines, a liquid limit of 20, and a plasticity index of 6 would be classified as a poorly graded sand with silty clay, SP-SC.

12.6 If the specimen is predominantly sand or gravel but contains 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, clayey sand with gravel.

12.7 If the field sample contained 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.

13. Report

13.1 The report should include the group name, group symbol, and the results of the laboratory tests. The particle-size distribution shall be given in terms of percent of gravel, sand, and fines. The plot of the cumulative particle-size distribution curve shall be reported if used in classifying the soil. Report appropriate descriptive information according to the procedures in Practice D 2488. A local or commercial name or geologic interpretation for the material may be added at the end of the descriptive information if identified as such. The test procedures used shall be referenced.

NOTE 9—*Example: Clayey Gravel with Sand and Cobbles* (GC)—46 % fine to coarse, hard, subrounded gravel; 30 % fine to coarse, hard, subrounded sand; 24 % clayey fines, LL = 38, PI = 19; weak reaction with HCl; original field sample had 4 % hard, subrounded cobbles; maximum dimension 150 mm.

In-Place Conditions—firm, homogeneous, dry, brown,

Geologic Interpretation—alluvial fan.

NOTE 10—Other examples of soil descriptions are given in Appendix X1.

14. Precision and Bias

14.1 This test method provides qualitative data only; therefore, a precision and bias statement is nonapplicable.

TABLE 1 Soil Classification Chart

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification	
				Group Symbol	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	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	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	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	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

[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥ 15 % sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ≥ 15 % gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29 % plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains ≥ 30 % plus No. 200, predominantly sand, add "sandy" to group name.

[M] If soil contains ≥ 30 % plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ≥ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.

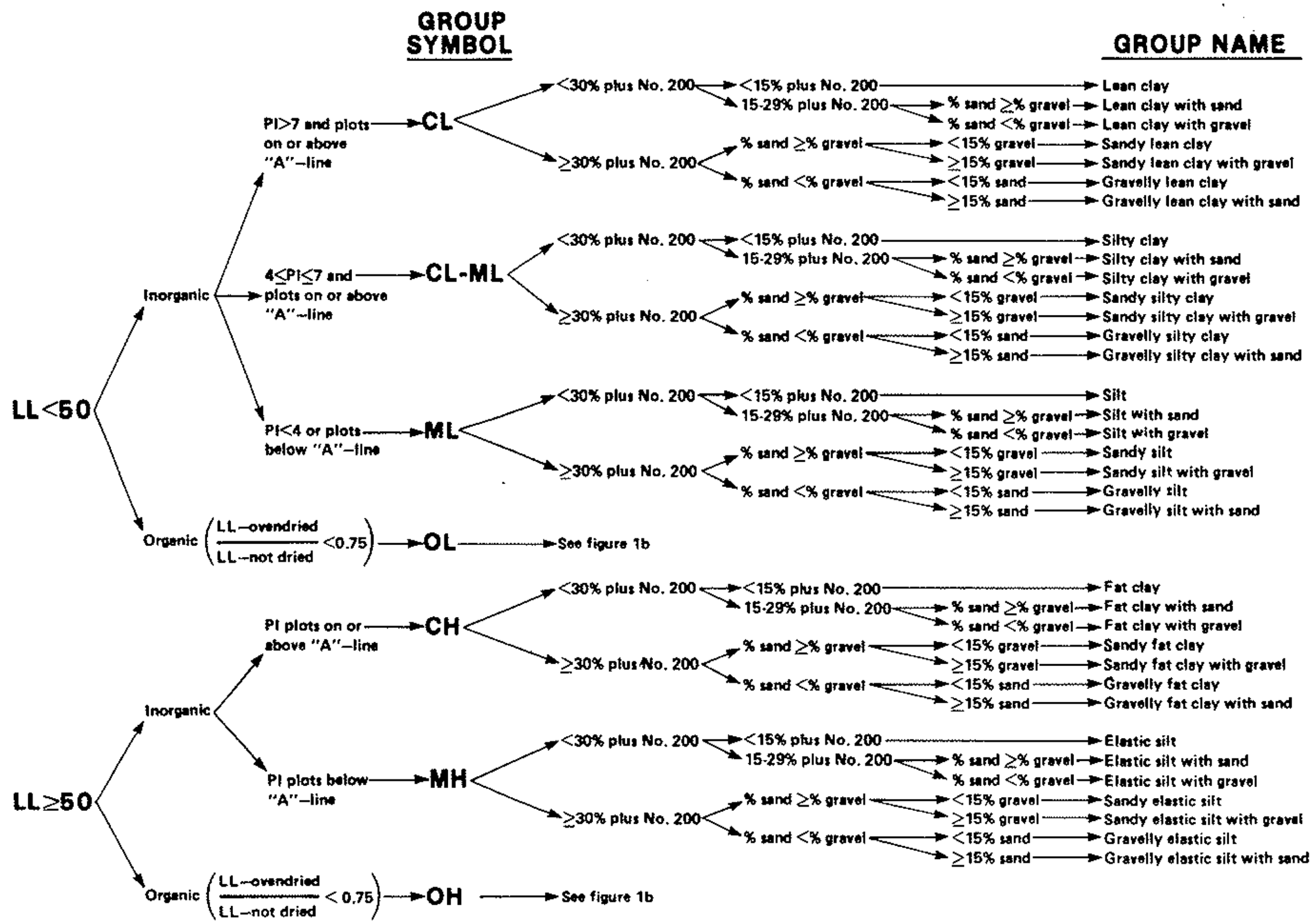


FIG. 1a Flow Chart for Classifying Fine-Grained Soil (50 % or More Passes No. 200 Sieve)

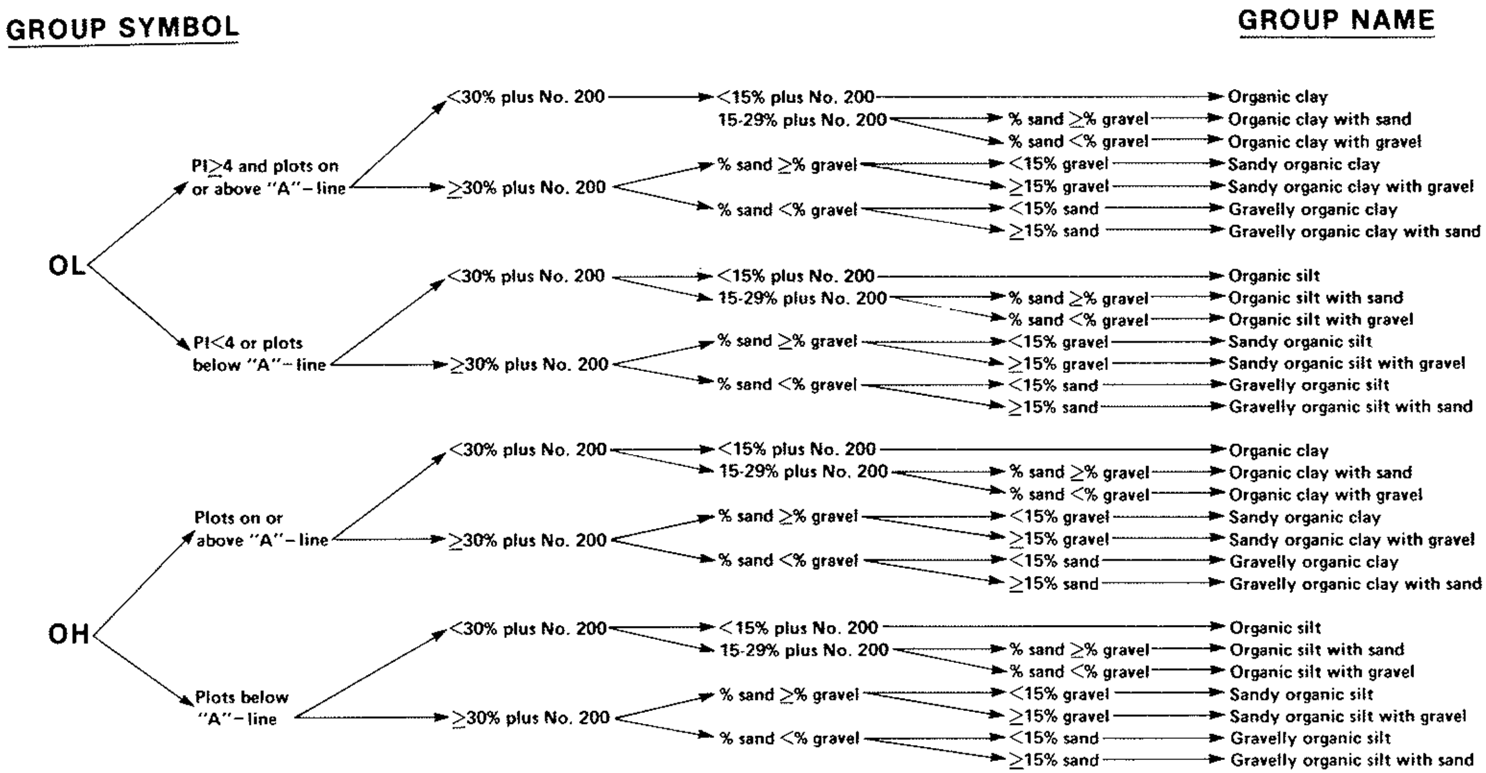


FIG. 1b Flow Chart for Classifying Organic Fine-Grained Soil (50 % or More Passes No. 200 Sieve)

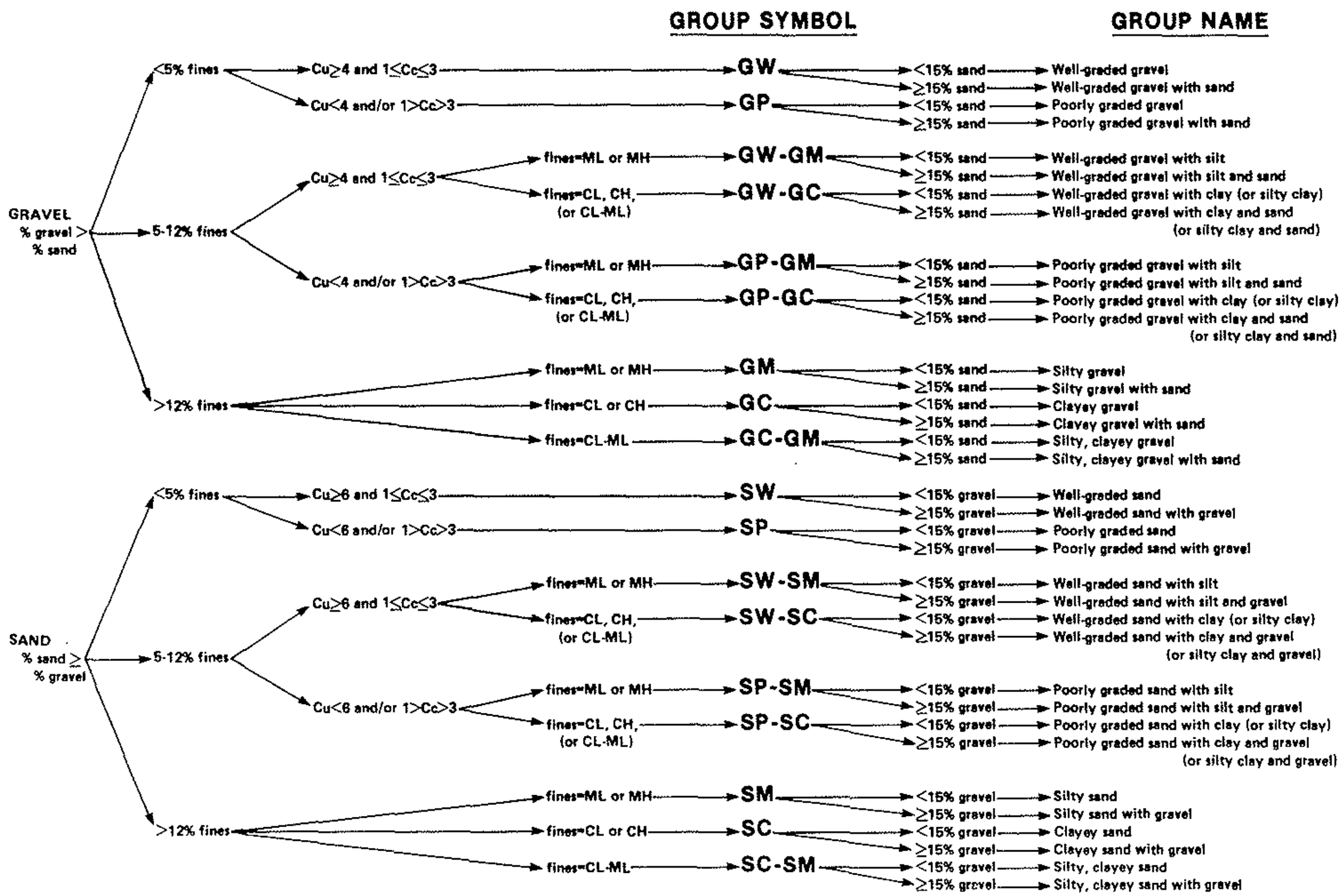


FIG. 2 Flow Chart for Classifying Coarse-Grained Soils (More Than 50 % Retained on No. 200 Sieve)

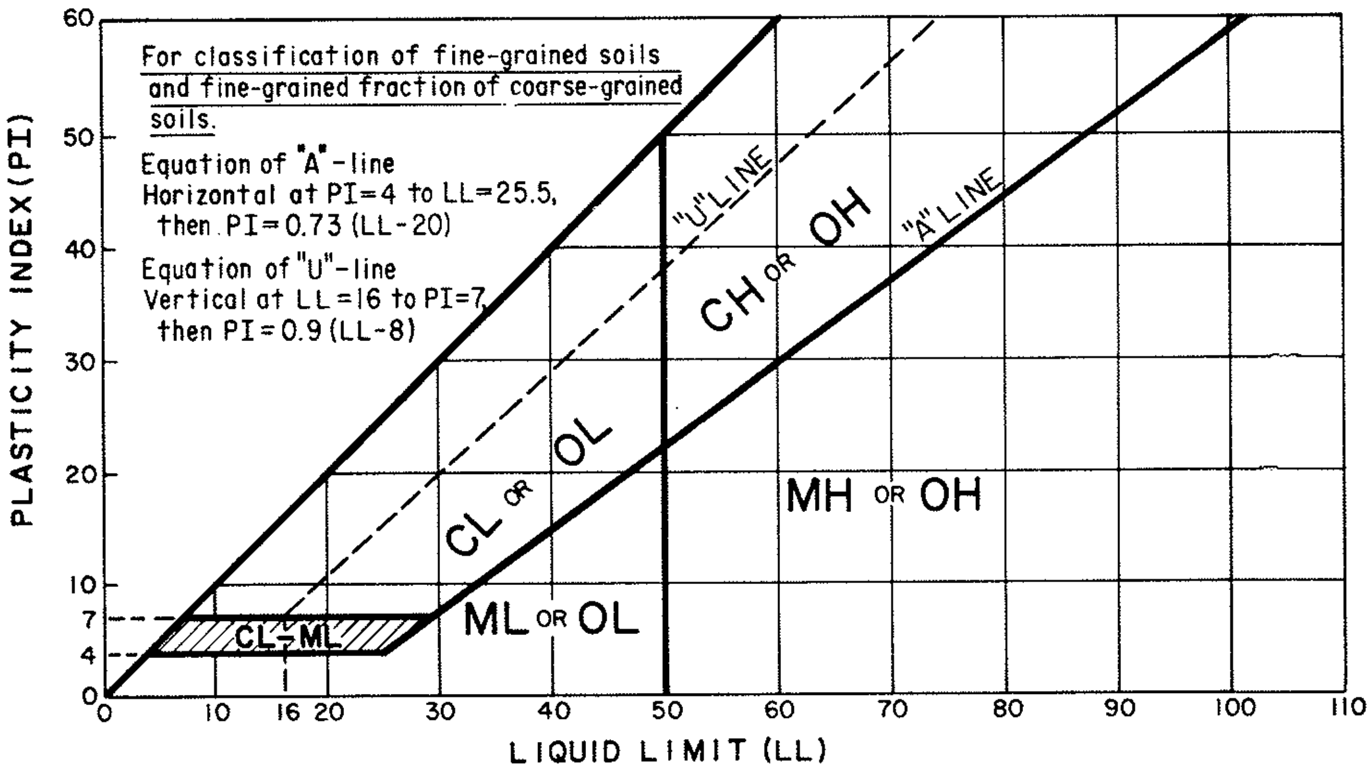
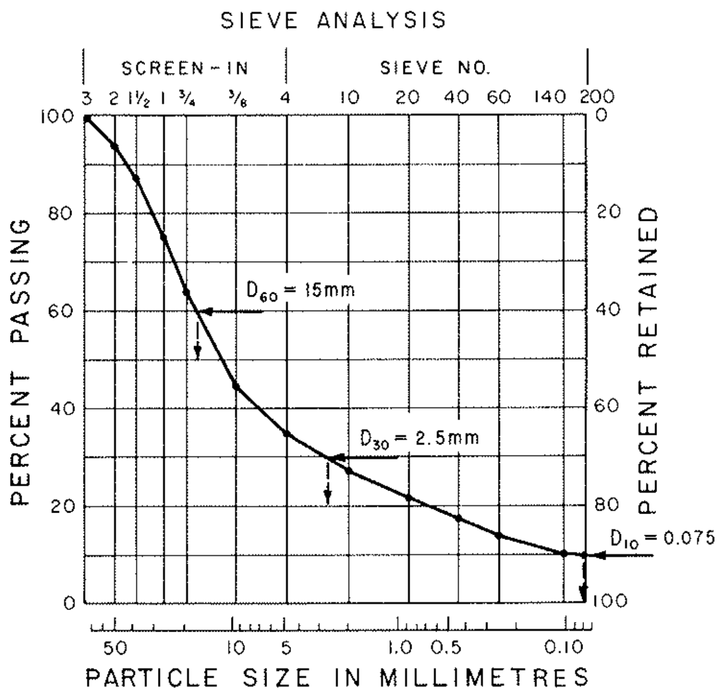


FIG. 3 Plasticity Chart



$$Cu = \frac{D_{60}}{D_{10}} = \frac{15}{0.075} = 200 \qquad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{(2.5)^2}{0.075 \times 15} = 5.6$$

FIG. 4 Cumulative Particle-Size Plot

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF DESCRIPTIONS USING SOIL CLASSIFICATION

X1.1 The following examples show how the information required in 13.1 can be reported. The appropriate descriptive information from Practice D 2488 is included for illustrative purposes. The additional descriptive terms that would accompany the soil classification should be based on the intended use of the classification and the individual circumstances.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—73 % fine to coarse, hard, subangular gravel; 23 % fine to coarse, hard, subangular sand; 4 % fines; Cc = 2.7, Cu = 12.4.

X1.1.2 *Silty Sand with Gravel (SM)*—61 % predominantly fine sand; 23 % silty fines, LL = 33, PI = 6; 16 % fine, hard, subrounded gravel; no reaction with HCl; (field sample smaller than recommended). *In-Place Conditions*—Firm, stratified and contains lenses of silt 1 to 2 in. thick, moist, brown to gray; in-place density = 106 lb/ft^3 and in-place moisture = 9 %.

X1.1.3 *Organic Clay (OL)*—100 % fines, LL (not dried) = 32, LL (oven dried) = 21, PI (not dried) = 10; wet, dark brown, organic odor, weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—74 % fine to coarse, hard, subangular reddish sand; 26 % organic and silty dark-brown fines, LL (not dried) = 37, LL (oven dried) = 26, PI (not dried) = 6, wet, weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—78 % fine to coarse, hard, subrounded to subangular gravel; 16 % fine to coarse, hard, subrounded to subangular sand; 6 % silty (estimated) fines; moist, brown; no reaction with HCl; original field sample had 7 % hard, subrounded cobbles and 2 % hard, subrounded boulders with a maximum dimension of 18 in.

X2. USING SOIL CLASSIFICATION AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, ETC.

X2.1 The group names and symbols used in this test method may be used as a descriptive system applied to materials that exist in situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, etc.).

X2.2 Materials such as shells, crushed rock, slag, etc., should be identified as such. However, the procedures used in this method for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, a classification in accordance with this test method may be assigned to aid in describing the material.

X2.3 If a classification is used, the group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how soil classifications could be incorporated into a description system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. pieces of shale from power auger hole, dry, brown, no reaction with HCl. After laboratory processing by slaking in water for 24 h, material classified as "Sandy Lean Clay (CL)"—61 % clayey fines, LL = 37, PI = 16; 33 % fine to medium sand; 6 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; "Poorly Graded Sand with Silt (SP-SM)"—91 % fine to medium sand; 9 % silty (estimated) fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—62 % gravel-size broken shells; 31 % sand and sand-size shell pieces; 7 % fines; would be classified as "Poorly Graded Gravel with Sand (GP)".

X2.4.4 *Crushed Rock*—Processed gravel and cobbles from Pit No. 7; "Poorly Graded Gravel (GP)"—89 % fine, hard, angular gravel-size particles; 11 % coarse, hard, angular sand-size particles, dry, tan; no reaction with HCl; Cc = 2.4, Cu = 0.9.

X3. PREPARATION AND TESTING FOR CLASSIFICATION PURPOSES BY THE WET METHOD

X3.1 This appendix describes the steps in preparing a soil sample for testing for purposes of soil classification using a wet-preparation procedure.

X3.2 Samples prepared in accordance with this procedure should contain as much of their natural water content as possible and every effort should be made during obtaining, preparing, and transporting the samples to maintain the natural moisture.

X3.3 The procedures to be followed in this test method assume that the field sample contains fines, sand, gravel, and plus 3-in. (75-mm) particles and the cumulative particle-size distribution plus the liquid limit and plasticity index values are required (see 9.8). Some of the following steps may be omitted when they are not applicable to the soil being tested.

X3.4 If the soil contains plus No. 200 (75-μm) particles that would degrade during dry sieving, use a test procedure for determining the particle-size characteristics that prevents this degradation.

X3.5 Since this classification system is limited to the portion of a sample passing the 3-in. (75-mm) sieve, the plus 3-in. (75-mm) material shall be removed prior to the determination of the particle-size characteristics and the liquid limit and plasticity index.

X3.6 The portion of the field sample finer than the 3-in. (75-mm) sieve shall be obtained as follows:

X3.6.1 Separate the field sample into two fractions on a 3-in. (75-mm) sieve, being careful to maintain the natural water content in the minus 3-in. (75-mm) fraction. Any particles adhering to the plus 3-in. (75-mm) particles shall be brushed or wiped off and placed in the fraction passing the 3-in. (75-mm) sieve.

X3.6.2 Determine the air-dry or oven-dry weight of the fraction retained on the 3-in. (75-mm) sieve. Determine the total (wet) weight of the fraction passing the 3-in. (75-mm) sieve.

X3.6.3 Thoroughly mix the fraction passing the 3-in. (75-mm) sieve. Determine the water content, in accordance with Method D 2216, of a representative specimen with a minimum dry weight as required in 7.2. Save the water-content specimen for determination of the particle-size analysis in accordance with X3.8.

X3.6.4 Compute the dry weight of the fraction passing the 3-in. (75-mm) sieve based on the water content and total (wet) weight. Compute the total dry weight of the sample and calculate the percentage of material retained on the 3-in. (75-mm) sieve.

X3.7 Determine the liquid limit and plasticity index as follows:

X3.7.1 If the soil disaggregates readily, mix on a clean, hard surface and select a representative sample by quartering in accordance with Methods C 702.

X3.7.1.1 If the soil contains coarse-grained particles coated with and bound together by tough clayey material, take extreme care in obtaining a representative portion of the No. 40 (425-μm) fraction. Typically, a larger portion than normal has to be selected, such as the minimum weights required in 7.2.

X3.7.1.2 To obtain a representative specimen of a basically cohesive soil, it may be advantageous to pass the soil through a ¾-in. (19-mm) sieve or other convenient size so the material can be more easily mixed and then quartered or split to obtain the representative specimen.

X3.7.2 Process the representative specimen in accordance with Procedure B of Practice D 2217.

X3.7.3 Perform the liquid-limit test in accordance with Test Method D 4318, except the soil shall not be air dried prior to the test.

X3.7.4 Perform the plastic-limit test in accordance with Test Method D 4318, except the soil shall not be air dried prior to the test, and calculate the plasticity index.

X3.8 Determine the particle-size distribution as follows:

X3.8.1 If the water content of the fraction passing the 3-in. (75-mm) sieve was required (X3.6.3), use the water-content specimen for determining the particle-size distribution. Otherwise, select a representative specimen in accordance with Methods C 702 with a minimum dry weight as required in 7.2.

X3.8.2 If the cumulative particle-size distribution including a hydrometer analysis is required, determine the particle-size distribution in accordance with Method D 422. See 9.7 for the set of required sieves.

X3.8.3 If the cumulative particle-size distribution without a hydrometer analysis is required, determine the particle-size distribution in accordance with Method C 136. See 9.7 for the set of required sieves. The specimen should be soaked until all clayey aggregations have softened and then washed in accordance with Test Method C 117 prior to performing the particle-size distribution.

X3.8.4 If the cumulative particle-size distribution is not required, determine the percent fines, percent sand, and percent gravel in the specimen in accordance with Test Method C 117, being sure to soak the specimen long enough to soften all clayey aggregations, followed by Method C 136 using a nest of sieves which shall include a No. 4 (4.75-mm) sieve and a No. 200 (75-μm) sieve.

X3.8.5 Calculate the percent fines, percent sand, and percent gravel in the minus 3-in. (75-mm) fraction for classification purposes.

X4. AIR-DRIED METHOD OF PREPARATION OF SOILS FOR TESTING FOR CLASSIFICATION PURPOSES

X4.1 This appendix describes the steps in preparing a soil sample for testing for purposes of soil classification when air-drying the soil before testing is specified or desired or when the natural moisture content is near that of an air-dried state.

X4.2 If the soil contains organic matter or mineral colloids that are irreversibly affected by air drying, the wet-preparation method as described in Appendix X3 should be used.

X4.3 Since this classification system is limited to the portion of a sample passing the 3-in. (75-mm) sieve, the plus 3-in. (75-mm) material shall be removed prior to the determination of the particle-size characteristics and the liquid limit and plasticity index.

X4.4 The portion of the field sample finer than the 3-in. (75-mm) sieve shall be obtained as follows:

X4.4.1 Air dry and weigh the field sample.

X4.4.2 Separate the field sample into two fractions on a 3-in. (75-mm) sieve.

X4.4.3 Weigh the two fractions and compute the percentage of the plus 3-in. (75-mm) material in the field sample.

X4.5 Determine the particle-size distribution and liquid limit and plasticity index as follows (see 9.8 for when these tests are required):

X4.5.1 Thoroughly mix the fraction passing the 3-in. (75-mm) sieve.

X4.5.2 If the cumulative particle-size distribution including a hydrometer analysis is required, determine the particle-size distribution in accordance with Method D 422. See 9.7 for the set of sieves that is required.

X4.5.3 If the cumulative particle-size distribution without a hydrometer analysis is required, determine the particle-size distribution in accordance with Test Method D 1140 followed by Method C 136. See 9.7 for the set of sieves that is required.

X4.5.4 If the cumulative particle-size distribution is not required, determine the percent fines, percent sand, and percent gravel in the specimen in accordance with Test Method D 1140 followed by Method C 136 using a nest of sieves which shall include a No. 4 (4.75-mm) sieve and a No. 200 (75-μm) sieve.

X4.5.5 If required, determine the liquid limit and the plasticity index of the test specimen in accordance with Test Method D 4318.

Designation: D 2488 - 84

Standard Practice for
DESCRIPTION AND IDENTIFICATION OF SOILS (VISUAL-MANUAL PROCEDURE)[1]

This standard is issued under the fixed designation D 2488; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D 2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D 2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils.

NOTE 1—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (See Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements see Section 8.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Applicable Documents

2.1 *ASTM Standards:*

D 653 Terms and Symbols Relating to Soil and Rock[2]

D 1452 Practice for Soil Investigation and Sampling by Auger Borings[2]

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils[2]

D 1587 Practice for Thin-Walled Tube Sampling of Soils[2]

D 2113 Practice for Diamond Core Drilling for Site Investigation[2]

D 2487 Test Method for Classification of Soils for Engineering Purposes[2]

3. Definitions

3.1 Except as listed below, all definitions are in accordance with Terms and Symbols D 653.

NOTE 2—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:

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

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

3.1.1 *clay*—soil passing a No. 200 (75-μm) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents,

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[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

Current edition approved Oct. 3, 1984. Published December 1984. Originally published as D 2488 - 66 T. Last previous edition D 2488 - 69 (1975).

[2] *Annual Book of ASTM Standards*, Vol 04.08.

and that exhibits considerable strength when air-dry. 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 (see Fig. 3 of Test Method D 2487).

3.1.2 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) 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 No. 4 (4.75-mm) sieve.

3.1.3 *organic clay*—a clay with sufficient organic content to influence the soil properties. 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 % of its liquid limit value before oven drying.

3.1.4 *organic silt*—a silt with sufficient organic content to influence 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 % of its liquid limit value before oven drying.

3.1.5 *peat*—a soil composed primarily of vegetable tissue 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.

3.1.6 *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 No. 200 (75-μm) sieve.

3.1.7 *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 (see Fig. 3 of Test Method D 2487).

4. Summary of Practice

4.1 Using visual examination and simple manual tests, this practice gives standardized criteria and procedures for describing and identifying soils.

4.2 The soil can be given an identification by assigning a group symbol(s) and name. The flow charts, Figs. 1a and 1b for fine-grained soils, and Fig. 2, for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name. If the soil has properties which do not distinctly place it into a specific group, borderline symbols may be used, see Appendix X3.

NOTE 3—It is suggested that a distinction be made between *dual symbols* and *borderline symbols.*

Dual Symbol—A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, CL-ML used to indicate that the soil has been identified as having the properties of a classification in accordance with Test Method D 2487 where two symbols are required. Two symbols are required when the soil has between 5 and 12 % fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

Borderline Symbol—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D 2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D 2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D 2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to 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.

5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test results for typical soils of each type with their visual and manual characteristics.

5.6 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 practice.

6. Apparatus

6.1 *Required Apparatus:*

6.1.1 *Pocket Knife or Small Spatula.*

6.2 *Useful Auxiliary Apparatus:*

6.2.1 *Small Test Tube and Stopper* (or jar with a lid).

6.2.2 *Small Hand Lens.*

7. Reagents

7.1 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean water from a city water supply or natural source, including non-potable water.

7.2 *Hydrochloric Acid*—A small bottle of dilute hydrochloric acid, HCl, one part HCl (10 *N*) to three parts water (This reagent is optional for use with this practice). See Section 8.

8. Safety Precautions

8.1 When preparing the dilute HCl solution of one part concentrated hydrochloric acid (10 *N*) to three parts of distilled water, slowly add acid into water following necessary safety precautions. Handle with caution and store safely. If solution comes into contact with the skin, rinse thoroughly with water.

8.2 **Caution**—Do not add water to acid.

9. Sampling

9.1 The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted, or standard procedure.

NOTE 5—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D 1452, D 1587, or D 2113, or Method D 1586.

9.2 The sample shall be carefully identified as to origin.

NOTE 6—Remarks as to the origin may take the form of a boring number and sample number in conjunction with a job 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 with respect to a stated centerline and a depth or elevation.

9.3 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	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (⅜ in.)	200 g (0.5 lb)
19.0 mm (¾ in.)	1.0 kg (2.2 lb)
38.1 mm (1½ in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

NOTE 7—If random isolated particles are encountered that are significantly larger than the particles in the soil matrix, the soil matrix can be accurately described and identified in accordance with the preceeding schedule.

9.4 If the field sample or specimen being examined is smaller than the minimum recommended amount, the report shall include an appropriate remark.

10. Descriptive Information for Soils

10.1 *Angularity*—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 1 and Fig. 3. A range of angularity may be stated, such as: subrounded to rounded.

10.2 *Shape*—Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet the criteria in Table 2 and Fig. 4. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

10.3 *Color*—Describe the color. Color is an important property in identifying organic soils, and within a given locality it may also be useful in identifying materials of similar geologic origin. If the sample contains layers or patches of varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

10.4 *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 may often be revived by heating a moistened sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as none, weak, or strong, in accordance with the critera in Table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

10.7 *Consistency*—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.7. For example: maximum particle size, medium sand.

10.11.2 *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. (will pass a 1½-in. square opening but not a ¾-in. square opening).

10.11.3 *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. (450 mm).

10.12 *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, some gravel-size particles crumble with hammer blow. "Hard" means particles do not crack, fracture, or crumble under a hammer blow.

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

10.14 A local or commercial name or a geologic interpretation of the soil, or both, may be added if identified as such.

10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

11. Identification of Peat

11.1 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 the identification procedures described hereafter.

12. Preparation for Identification

12.1 The soil identification portion of this practice is based on the portion of the soil sample that will pass a 3-in. (75-mm) sieve. The larger than 3-in. (75-mm) particles must be removed, manually, for a loose sample, or mentally, for an intact sample before classifying the soil.

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 8—Since the percentages of the particle-size distribution in Test Method D 2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 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 (see Appendix X4 for suggested procedures).

NOTE 9—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term *trace*, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

14. Procedure for Identifying Fine-Grained Soils

14.1 Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dry strength, dilatancy, and toughness tests.

14.2 *Dry Strength:*

14.2.1 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.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about ½ in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 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 10—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 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 accorance with the criteria in Table 8. 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.

14.2.5 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 hydrochloric acid (see 10.6).

14.3 *Dilatancy:*

14.3.1 From the specimen, select enough material 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.

14.3.2 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 9. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

14.4 *Toughness:*

14.4.1 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 ⅛ 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.) Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about ⅛ in. The thread will crumble at a diameter of ⅛ in. when the soil is near 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.

14.4.2 Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in Table 10.

14.5 *Plasticity*—On the basis of observations made during the toughness test, describe the plasticity of the material in accordance with the criteria given in Table 11.

14.6 Decide whether the soil is an *inorganic* or an *organic* fine-grained soil (see 14.8). If inorganic, follow the steps given in 14.7.

14.7 *Identification of Inorganic Fine-Grained Soils:*

14.7.1 Identify the soil as a *lean clay*, CL, if the soil has medium to high dry strength, no or slow dilatancy, and medium toughness and plasticity (see Table 12).

14.7.2 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 (see Table 12).

14.7.3 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 (see Table 12).

14.7.4 Identify the soil as an *elastic silt*, MH, if the soil has low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity (see Table 12).

NOTE 11—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. Some soils that would classify as MH in accordance with the criteria in Test Method D 2487 are visually difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing for proper identification.

14.8 *Identification of Organic Fine-Grained Soils:*

14.8.1 Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a 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. Some organic soils will lighten in color significantly when air dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

NOTE 12—In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

14.9 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" or "silt with gravel, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percentage of gravel, use "with sand."

14.10 If the soil is estimated to have 30 % or more sand or gravel, or both, the words "sandy" or "gravelly" shall be 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", or "sandy silt, ML" (see Figs. 1a and 1b). If the percentage of sand is equal to the percent of gravel, use "sandy."

15. Procedure for Identifying Coarse-Grained Soils (Contains less than 50 % fines)

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

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

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

15.3.1 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 the intermediate particle sizes.

15.3.2 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).

15.4 The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

15.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

15.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in Section 14.

15.5 If the soil is estimated to contain 10 % fines, give the soil a dual identification using two group symbols.

15.5.1 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).

15.5.2 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" or "poorly graded sand with silt, SP-SM" (see Fig. 2).

15.6 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" or "clayey sand with gravel, SC" (see Fig. 2).

15.7 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."

16. Report

16.1 The report shall include the information as to origin, and the items indicated in Table 13.

NOTE 13—*Example: Clayey Gravel with Sand and Cobbles, GC*—About 50 % fine to coarse, subrounded to subangular gravel; about 30 % fine to coarse, subrounded sand; about 20 % fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown

Geologic Interpretation—Alluvial fan

NOTE 14—Other examples of soil descriptions and identification are given in Appendixes X1 and X2.

NOTE 15—If desired, the percentages of gravel, sand, and fines may be stated in terms indicating a range of percentages, as follows:

Trace—Particles are present but estimated to be less than 5 %

Few—5 to 10 %

Little—15 to 25 %

Some—30 to 45 %

Mostly—50 to 100 %

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D 2487, it must be distinctly and clearly stated in log forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

17. Precision and Bias

17.1 This practice provides qualitative information only, therefore, a precision and bias statement is not applicable.

TABLE 1 Criteria for Describing Angularity of Coarse-Grained Particles (see Fig. 3)

Description	Criteria
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

TABLE 2 Criteria for Describing Particle Shape (see Fig. 4)

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

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
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

TABLE 4 Criteria for Describing the Reaction With HCl

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

TABLE 5 Criteria for Describing Consistency

Description	Criteria
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

TABLE 6 Criteria for Describing Cementation

Description	Criteria
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

TABLE 7 Criteria for Describing Structure

Description	Criteria
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 small angular lumps which resist further breakdown
Lensed	Inclusion 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

TABLE 8 Criteria for Describing Dry Strength

Description	Criteria
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

TABLE 9 Criteria for Describing Dilatancy

Description	Criteria
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

TABLE 10 Criteria for Describing Toughness

Description	Criteria
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

TABLE 11 Criteria for Describing Plasticity

Description	Criteria
Nonplastic	A ⅛-in. (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 rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit

TABLE 12 Identification of Inorganic Fine-Grained Soils from Manual Tests

Soil 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

TABLE 13 Checklist for Description of Soils

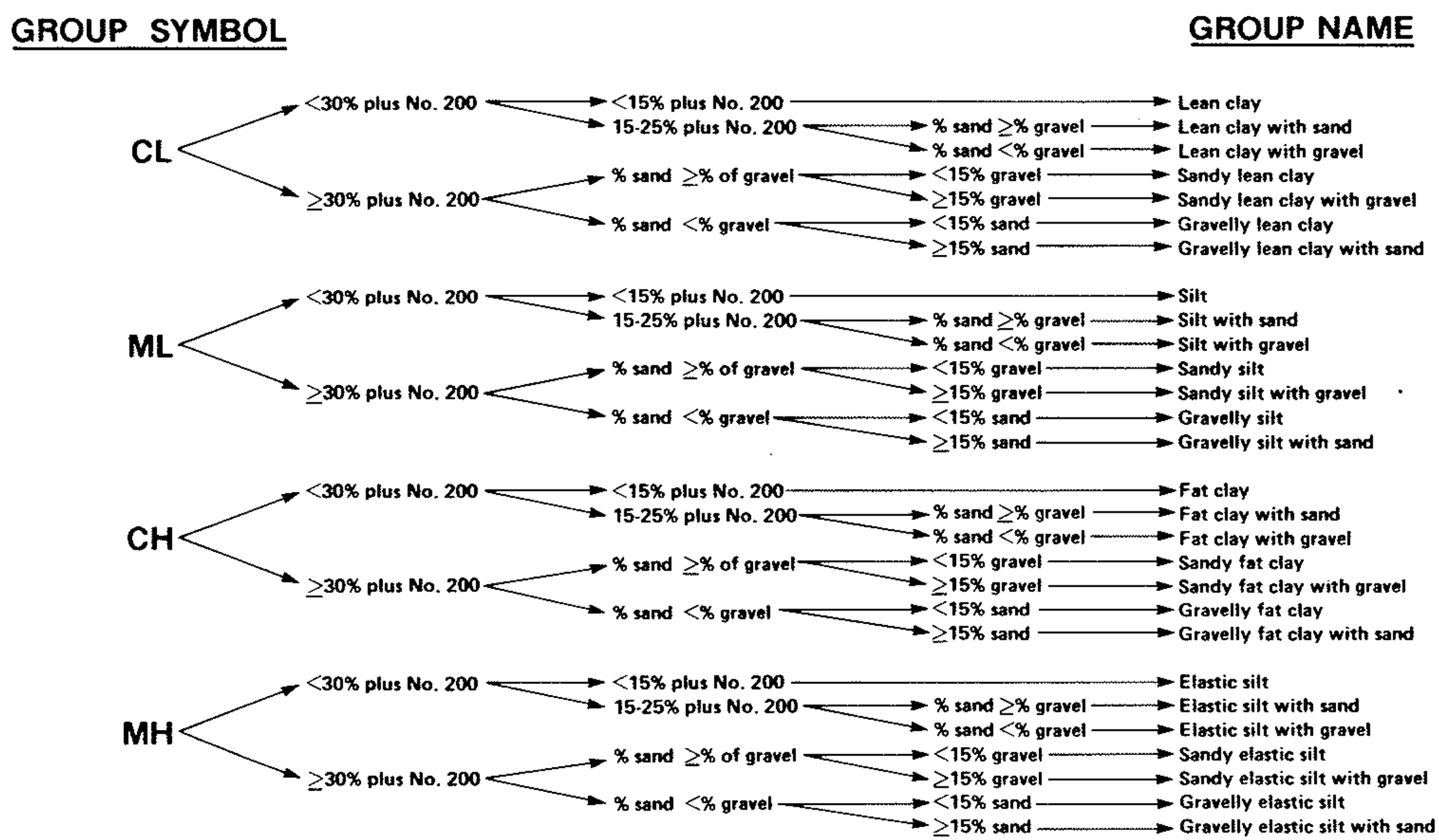
1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range:

   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: nonplastic, 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 (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong

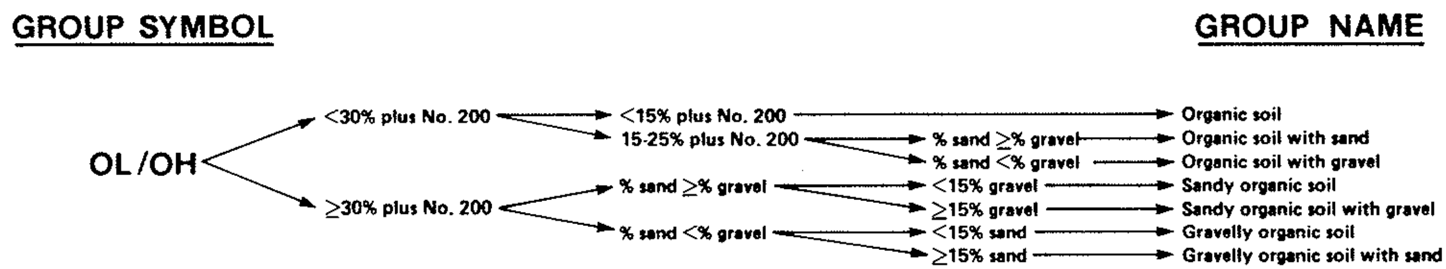
For intact samples:

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, etc.



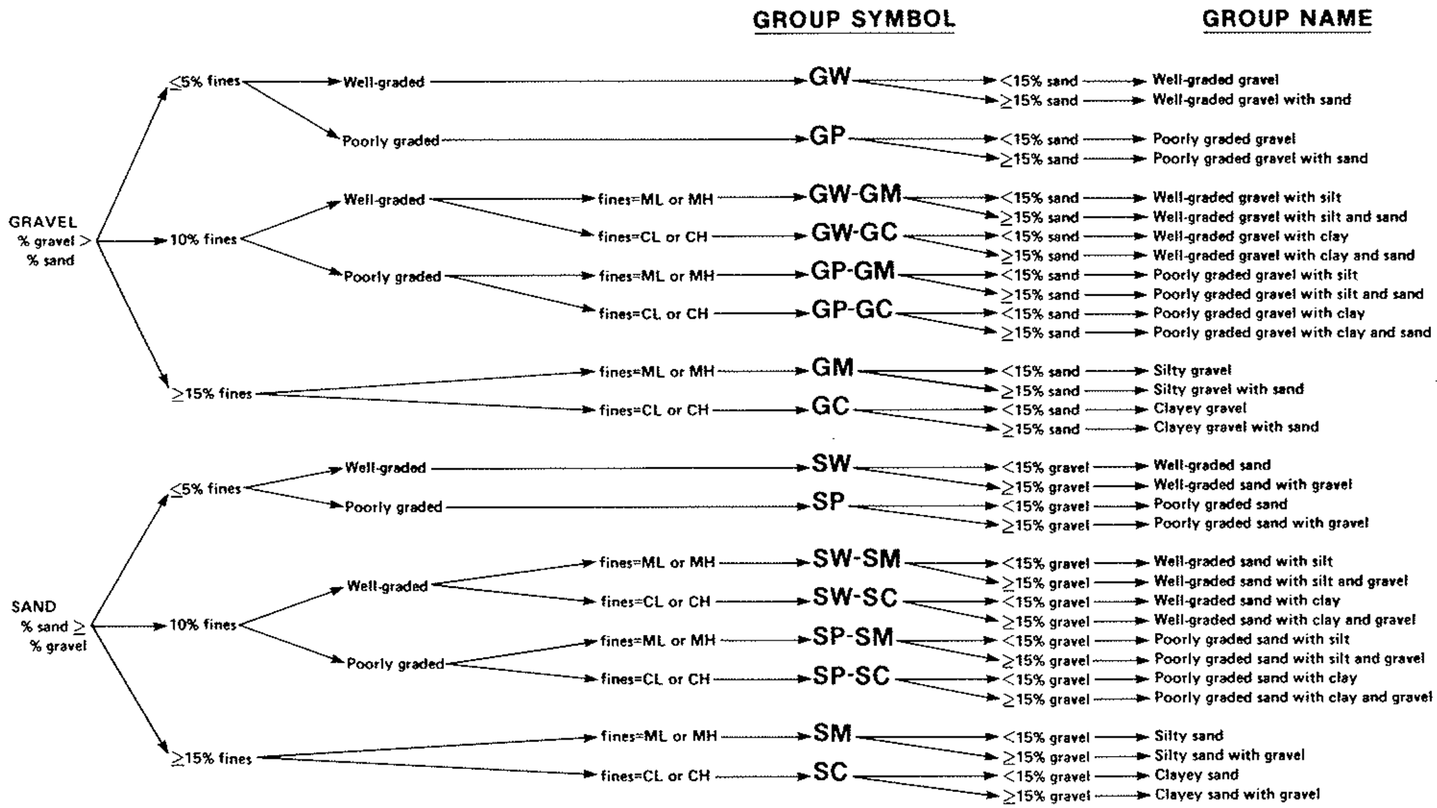
NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1b Flow Chart for Identifying Organic Fine-Grained Soil (50 % or more fines)



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5%.

FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

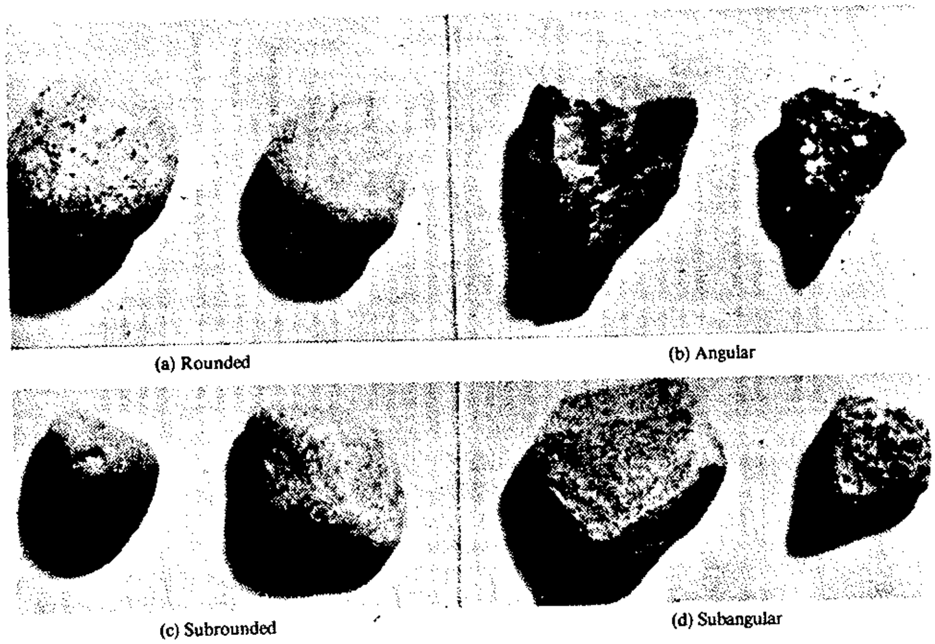
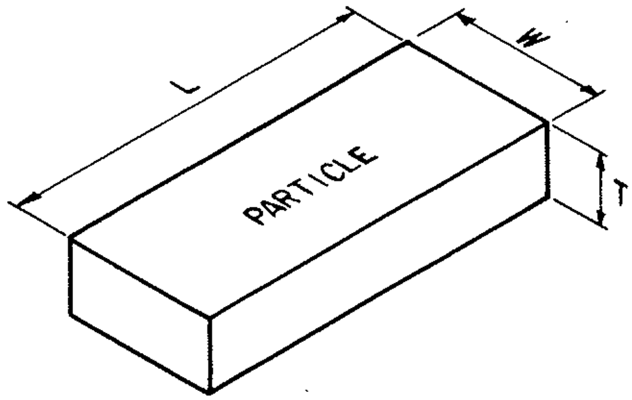


FIG. 3 Typical Angularity of Bulky Grains

PARTICLE SHAPE

W = WIDTH
T = THICKNESS
L = LENGTH



FLAT: W/T > 3
ELONGATED: L/W > 3
FLAT AND ELONGATED:
– meets both criteria

FIG. 4 Criteria for Particle Shape

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show how the information required in 16.1 can be reported. The information that is included in descriptions should be based on individual circumstances and need.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—About 75 % fine to coarse, hard, subangular gravel; about 25 % fine to coarse, hard, subangular sand; trace of fines; maximum size, 75 mm, brown, dry; no reaction with HCl.

X1.1.2 *Silty Sand with Gravel (SM)*—About 60 % predominantly fine sand; about 25 % silty fines with low plasticity, low dry strength, rapid dilatancy, and low toughness; about 15 % fine, hard, subrounded gravel, a few gravel-size particles fractured with hammer blow; maximum size, 25 mm; no reaction with HCl (Note—Field sample size smaller than recommended).

In-Place Conditions—Firm, stratified and contains lenses of silt 1 to 2 in. (25 to 50 mm) thick, moist, brown to gray; in-place density 106 lb/ft^3; in-place moisture 9 %.

X1.1.3 *Organic Soil (OL/OH)*—About 100 % fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown, organic odor; weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—About 75 % fine to coarse, hard, subangular reddish sand; about 25 % organic and silty dark brown nonplastic fines with no dry strength and slow dilatancy; wet;

maximum size, coarse sand; weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—About 75 % fine to coarse, hard, subrounded to subangular gravel; about 15 % fine, hard, subrounded to subangular sand; about 10 % silty nonplastic fines; moist, brown; no reaction with HCl; original field sample had about 5 % (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders, with a maximum dimension of 18 in. (450 mm).

X2. USING THE IDENTIFICATION PROCEDURE AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, AND THE LIKE

X2.1 The identification procedure may be used as a descriptive system applied to materials that exist in-situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, and the like).

X2.2 Materials such as shells, crushed rock, slag, and the like, should be identified as such. However, the procedures used in this practice for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, an identification using a group name and symbol according to this practice may be assigned to aid in describing the material.

X2.3 The group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how group names and symbols can be incororated into a descriptive system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. (50 to 100-mm) pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 h, material identified as "Sandy Lean Clay (CL)"; about 60 % fines with medium plasticity, high dry strength, no dilatancy, and medium toughness; about 35 % fine to medium, hard sand; about 5 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; "Poorly Graded Sand with Silt (SP-SM)"; about 90 % fine to medium sand; about 10 % nonplastic fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—About 60 % gravel-size broken shells; about 30 % sand and sand-size shell pieces; about 10 % fines; "Poorly Graded Gravel with Sand (GP)."

X2.4.4 *Crushed Rock*—Processed from gravel and cobbles in Pit No. 7; "Poorly Graded Gravel (GP)"; about 90 % fine, hard, angular gravel-size particles; about 10 % coarse, hard, angular sand-size particles; dry, tan; no reaction with HCl.

X3. SUGGESTED PROCEDURE FOR USING A BORDERLINE SYMBOL FOR SOILS WITH TWO POSSIBLE IDENTIFICATIONS.

X3.1 Since this practice 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. For example: SC/CL or CL/CH.

X3.1.1 A borderline symbol may be used when the percentage of fines is estimated to be between 45 and 55 %. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil. For example: GM/ML or CL/SC.

X3.1.2 A borderline symbol may be used when the percentage of sand and the percentage of gravel are 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.

X3.1.3 A borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil could either be a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-grained soil has properties that indicate that it is at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. For example: soils in a borrow area have been identified as CH. One sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol should be CH/CL.

X3.3 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

X3.4 The use of a borderline symbol should not be used indiscriminately. Every effort shall be made to first place the soil into a single group.

X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 *Jar Method*—The relative percentage of coarse- and fine-grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing 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 20 to 30 s. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory determinations.

X4.2 *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 sieve size and minus No. 4 sieve size present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (X4.3).

X4.3 *Wash Test (for relative percentages of sand and fines)*—Select and moisten enough minus No. 4 sieve size material to form a 1-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. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.