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UNIFIED SOIL CLASSIFICATION SYSTEM — TEST PROCEDURES

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16. ABSTRACT

The Third Edition (1988) of the Earth Manual contains new or revised soil testing procedures as compared to the Second Edition (1974). This report documents the changes in the soil classification procedures, as follows:

USBR 5000 - Determining Unified Soil Classification (Laboratory Method)

USBR 5005 - Determining Unified Soil Classification (Visual Method)

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UNIFIED SOIL CLASSIFICATION SYSTEM - TEST PROCEDURES

by

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Denver, Colorado

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UNITED STATES DEPARTMENT OF THE INTERIOR ★ Bureau of Reclamation

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.

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SECTION I

INTRODUCTION

This report documents the rationale used in preparing the following test procedures for soil classification as presented in the Third Edition of the Earth Manual:

USBR 5000 "Determining Unified Soil Classification (Laboratory Method)"

USBR 5005 "Determining Unified Soil Classification (Visual Method)"

Copies of these procedures are included in the appendix.

Volume II of the Third Edition of the Earth Manual was developed during 1986-87. That volume is a compilation of procedures used by the Bureau of Reclamation for investigating, sampling, and testing soils and performing construction quality control of soils. The procedures are written and presented in a significantly different format from that used in the Second Edition of the Earth Manual published in 1974. During the writing of those procedures, many decisions were made to (1) either modify or expand the previously published version, or (2) prepare a new procedure not included in the Second Edition. The procedures were written to conform, as much as possible, with current ASTM (American Society for Testing and Materials) standards and to reflect current soil mechanics technology and concepts.

This report serves as a background reference for requirements of the procedures for soil classification as presented in the Third Edition.

The previous version of procedures discussed in this report was Designation E-3, "Visual and Laboratory Methods for Identification and Classification of Soils" [1].[1]

USBR 5000 on laboratory classification is almost identical to ASTM D 2487-85, "Standard Test Method for Classification of Soils for Engineering Purposes" [2]. The 1985 ASTM version of this test standard was significantly revised from the previous version. A paper presented in the Geotechnical Testing Journal documented the changes [3]. A copy of that paper is included in this report in section II and serves as documentation for the changes from Bureau Designation E-3 to USBR 5000. There are some minor differences between ASTM D 2487-85 and USBR 5000, and these are discussed in section IV of this report.

USBR 5005 on visual classification is almost identical to ASTM D 2488-84, "Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)" [4]. The 1984 ASTM version of this standard was also significantly revised from its previous version. A paper presented in the Geotechnical Testing Journal documented the changes [5]. A copy of that paper is included in this report in section III and serves as documentation for the changes from Bureau Designation E-3 to USBR 5005. There are some minor differences between ASTM D 2488-84 and USBR 5005, and these are discussed in section IV of this report.

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[1]Numbers in brackets refer to entries in the Bibliography.

SECTION II

Reprint of

"The Revised ASTM Standard on the Unified Soil Classification System"

by Amster K. Howard

Published in the Geotechnical Testing Journal, vol. 7, No. 4,
American Society for Testing and Materials, Philadelphia, Pennsylvania,
December 1984

TECHNICAL NOTE

Amster K. Howard[1]

The Revised ASTM Standard on the Unified Classification System

REFERENCE: Howard, A. K., **"The Revised ASTM Standard on the Unified Soil Classification System,"** *Geotechnical Testing Journal,* GTJODJ, Vol. 7, No. 4, Dec. 1984, pp. 216-222.

ABSTRACT: ASTM Test Method for Classification of Soils for Engineering Purposes (D 2487) was significantly revised in 1983. The revisions require that soil is to be classified by using both a symbol and a name, and the group names were standardized. Organic silts and clays were redefined to recognize that organic soils occur that plot above the "A" line on the plasticity chart. More precise guidelines were established, particularly with regard to plasticity, so that only one particular classification will result. If boarderline classifications are used, the classification symbols are separated with a slash with the classification symbol indicated using the standard appearing first. Appendixes give example written descriptions, preparation of soil for testing, and guidelines for using the system for materials such as shale, mudstone, crushed rock, and slag

KEYWORDS: soil classifications, soils, sands, clays, silts

Introduction

Classification is the mirror in which the present condition of science is reflected; a series of classifications reflect the phases of its development, Aristocristane, 98 A.D.

ASTM Test Method for Classification of Soils for Engineering Purposes (D 2487) was significantly revised in 1983. The modifications were the result of several years of discussion by ASTM Subcommittee D18.07 on Identification and Classification of Soils and a special meeting of Federal agencies using the Unified Soil Classification System (USCS) held in Denver, CO, in 1980.

The USCS has become the most popular and widely used soil classification system for engineering purposes. The Federal Aviation Administration (FAA) recently adopted the use of the USCS in place of the system they had developed earlier. Personnel using the American Association of State Highway and Transportation Officials (AASHTO) soil classification system for highway construction are seriously looking at using the USCS. The USCS began as the Airfield Classification System developed by Arthur Casagrande during World War II. With the adoption of the system by the U.S. Bureau of Reclamation and the Corps of Engineers in 1952, with standardized terms and procedures, it became known as the "Unified" system.

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In the ensuing years, it became apparent that certain approaches in the system needed to be better defined and standardized. Where insufficiencies or gaps existed, various organizations and agencies found it necessary to develop their own standards or practices. In an attempt to bring uniformity to this important means of communicating engineering information, ASTM Subcommittee D18.07 sought to refine and standardize the ASTM version of the system.

The significant changes and revisions adopted include the following:

1. Soil classification consists of both a name and a symbol.
2. The names were standardized.
3. Organic silts and clays were redefined.
4. More precise classification was established.

In addition, information presented in appendixes gives example written descriptions to encourage uniformity, detail methods of preparation and testing, and shows how the system can be used to assist in describing materials such as shale, siltstone, crushed rock, and so forth.

ASTM Recommended Practice for Description of Soils (Visual-Manual Procedure) (D 2488-69) is currently undergoing similar revisions.

Classification—Name and Symbol

The classification of a soil should consist of both a name and a symbol. Often only a symbol is used, and this can be misleading. For example, the symbol CL is used for the following three soils:

(1) 100% fines,
(2) 55% fines, 45% fine-to-medium sand, and
(3) 55% fines, 25% fine and coarse gravel, 20% fine to coarse sand.

These are three different materials based on their gradation and on their engineering properties. The new ASTM D 2487-83 would classify the soils as follows:

(1) CL—lean clay,
(2) CL—sandy lean clay, and
(3) CL—gravelly lean clay with sand.

It is obvious that the name and symbol together give a better indication of what the soil is like.

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

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

FIG. 1—*Soil classification chart (ASTM D 2487-69).*

Standardization of Group Names

On Figure 1 of ASTM D 2487-69 (see Fig. 1, this paper), one column of the soil classification chart shows "group symbols" and the adjacent column "typical names." The typical names were more like descriptions of the soil, but some of the descriptions evolved in time to become a name associated with the symbol. The committee decided to formalize these names with a single unique name for each symbol (except for organic silts and clays). The names and corresponding symbols are:

GW well-graded gravel
GP poorly graded gravel
GM silty gravel
GC clayey gravel
SW well-graded sand
SP poorly graded sand
SM silty sand
SC clayey sand
CL lean clay
ML silt
OL organic silt or organic clay
CH fat clay
MH elastic silt
OH organic silt or organic clay
PT peat

Although some of the names were often unpalatable (for example, fat clay and elastic silt), it was decided to go with the venacular that had evolved, recognizing that it would be impossible to change.

In addition, modifiers to the basic group name were standardized. Most engineering organizations recognized the need to change the soil name or modify it to better reflect the characteristics of the soil. However, the names varied widely between users. For example, soil with 20% sand, 15% gravel, and 65% fines has been variously described as:

lean clay,
sandy clay,
sandy gravelly clay,
sandy lean clay,
sandy gravelly lean clay,
lean sandy clay,
lean clay with sand and gravel, or
clay with well-graded sand and gravel.

Since only the symbol, CL, does not convey enough information, a group name should be associated with the symbol and that group name should be standardized. According to the revised standard, every user would describe this soil as

sandy lean clay with gravel, CL

Thus, the name and symbol alone relate the facts that the fines are clayey with a liquid limit less than 50; there is between 30 and 49% coarse-grained particles, predominantly sand, with at least 15% gravel.

The standard group name is listed in Table 1 of the new standard (see Fig. 2, this paper) for each group symbol and information given as to what to add to the group by a "with" statement. The flow charts, Figs. 1 and 2, also illustrate the use of the group name and "withs" (see Figs. 3 through 5, this paper).

Organic Silts and Clays Redefined

In ASTM D 2487-69, organic silts (OL) and organic clays (OH) could only occur below the "A" line. A liquid limit of 50 was the dividing line between OL and OH (see Fig. 1 ASTM D 2487-69).

The standard was changed so that OL and OH soils can be both below and above the "A" line. A liquid limit of 50 remains as the division between the symbols OL and OH (see Fig. 6, this paper). However, the group name will depend on whether the soil plots above or below the "A" line. The group names "organic clay" will apply to soils on or above the "A" line and "organic silt" will apply to soils below the "A" line. The possible classifications then are

organic clay, OL,
organic silt, OL,
organic clay, OH, or
organic silt, OH.

The criterion for determining whether or not a soil is organic remains as the comparison of the liquid limit values of an oven-dried specimen and a nondried specimen. The change was made for the following reasons:

1. Organic soils occur that plot above the "A" line. The following comments are by A. Casagrande [1].

> Originally the A-line was defined by the writer as an empirical boundary between typical inorganic clays and plastic organic soils. He was then not aware of the existence of fairly tough organic clays which fall above the A-line. (They have more the characteristics of inorganic clays except for the substantial loss in plasticity due to drying.) It was suggested to move the A-line so as to assure that all organic soils would fall below it. However, this would also bring most inorganic soils below the A-line. The writer believes that the A-line has proven its value as an important reference line and that it should be kept essentially in its original position, but that in the expanded system a new group should be provided for the organic soils located above the A-line.

The following are comments by R. A. Barron [2]:

> After a year's use, comments were sent in from the various field offices to the Office of the Chief of Engineers. There were a few comments on the system which indicated some minor revisions may be necessary. One, for instance, is the fact that some organic soils plot above the "A" line of the plasticity charts.

In addition, Richard S. Ladd, of Woodward-Clyde Consultants of Clifton, NJ, reported in subcommittee meetings of D18.07 that his laboratory has encountered organic soils that plot above the "A" line.

2. For inorganic soils, the "A" line is the division between clays and silts. This division is now logically extended to organic soils.

3. The name "organic clay" according to ASTM D 2487-69 could have been applied to a soil with a liquid limit (LL) > 50 and a plasticity index (PI) < 10. For a soil with such low plasticity, the name organic "clay" is inappropriate.

More Precise Classification

ASTM D 2487-69 recommended giving a soil a borderline classification if the LL and PI values plotted "on or practically on" the "A" line or the LL = 50 line.

CRITERIA FOR ASSIGNING GROUP SYMBOLS AND GROUP NAMES USING LABORATORY TESTS [a]				SOIL CLASSIFICATION: GROUP SYMBOL	SOIL CLASSIFICATION: GROUP NAME [b]
COARSE-GRAINED SOILS more than 50% retained on No. 200 sieve	GRAVELS More than 50% of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS Less than 5% fines [c]	$C_u \geq 4$ and $1 \leq C_c \leq 3$ [e]	GW	Well-graded gravel [f]
			$C_u < 4$ and/or $1 > C_c > 3$ [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]	$C_u \geq 6$ and $1 \leq C_c \leq 3$ [e]	SW	Well-graded sand [i]
			$C_u < 6$ and/or $1 > C_c > 3$ [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 passed 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 and/or boulders, add "with cobbles and/or boulders" 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. $C_u = D_{60}/D_{10}$ $\qquad C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$
f. If soil contains $\geq$ 15% sand, add "with sand" to group name.
g. If fines classify as CL-ML, use dual symbol GC-GM, SC-SM.
h. If fines are organic, add "with organic fines" to group name.
i. If soil contains $\geq$ 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 $\geq$ 30% plus No. 200, predominantly sand, add "sandy" to group name.
m. If soil contains $\geq$ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.
n. PI $\geq$ 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. 2—*Soil classification chart (ASTM D 2487-83).*

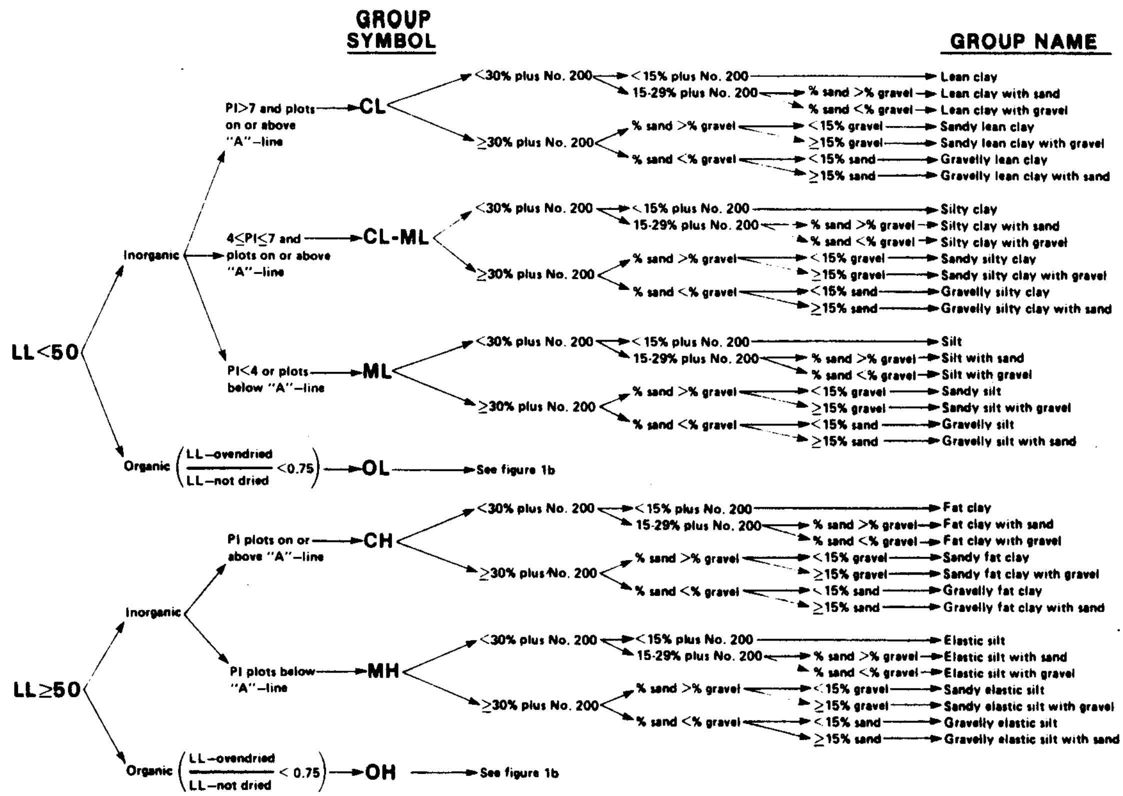

FIG. 3—*Flow chart for classifying fine-grained soil.*

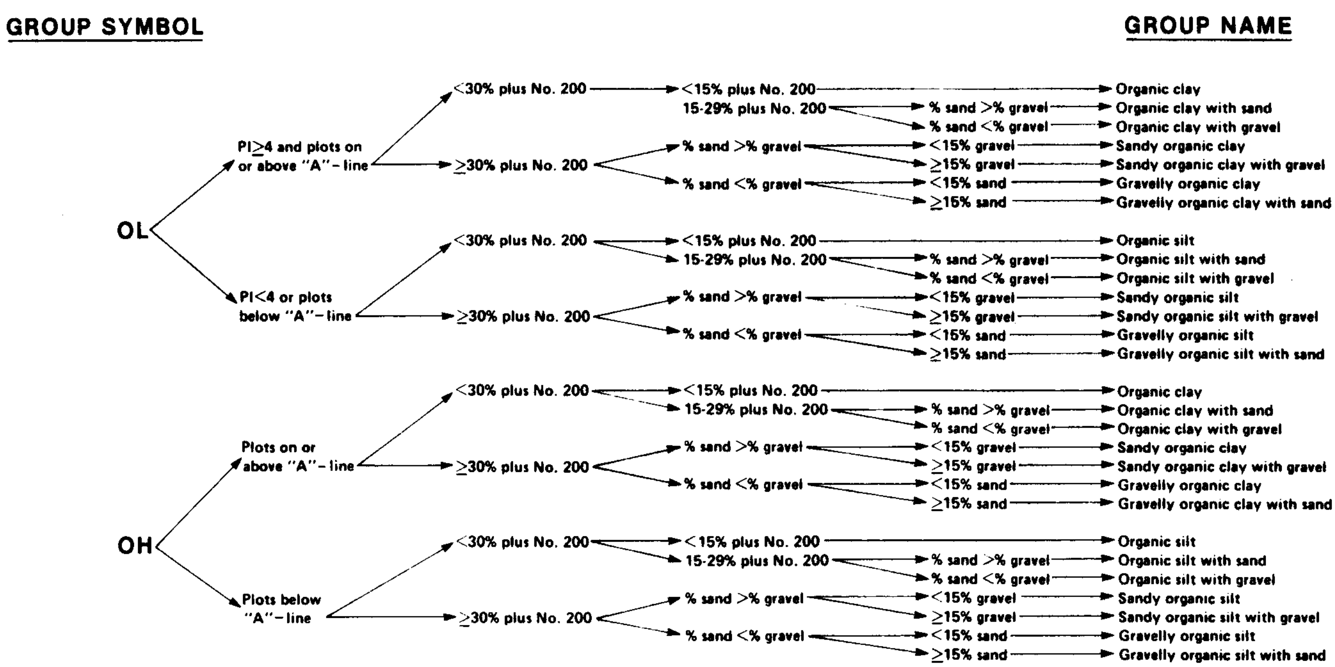

FIG. 4—*Flow chart for classifying organic soil.*

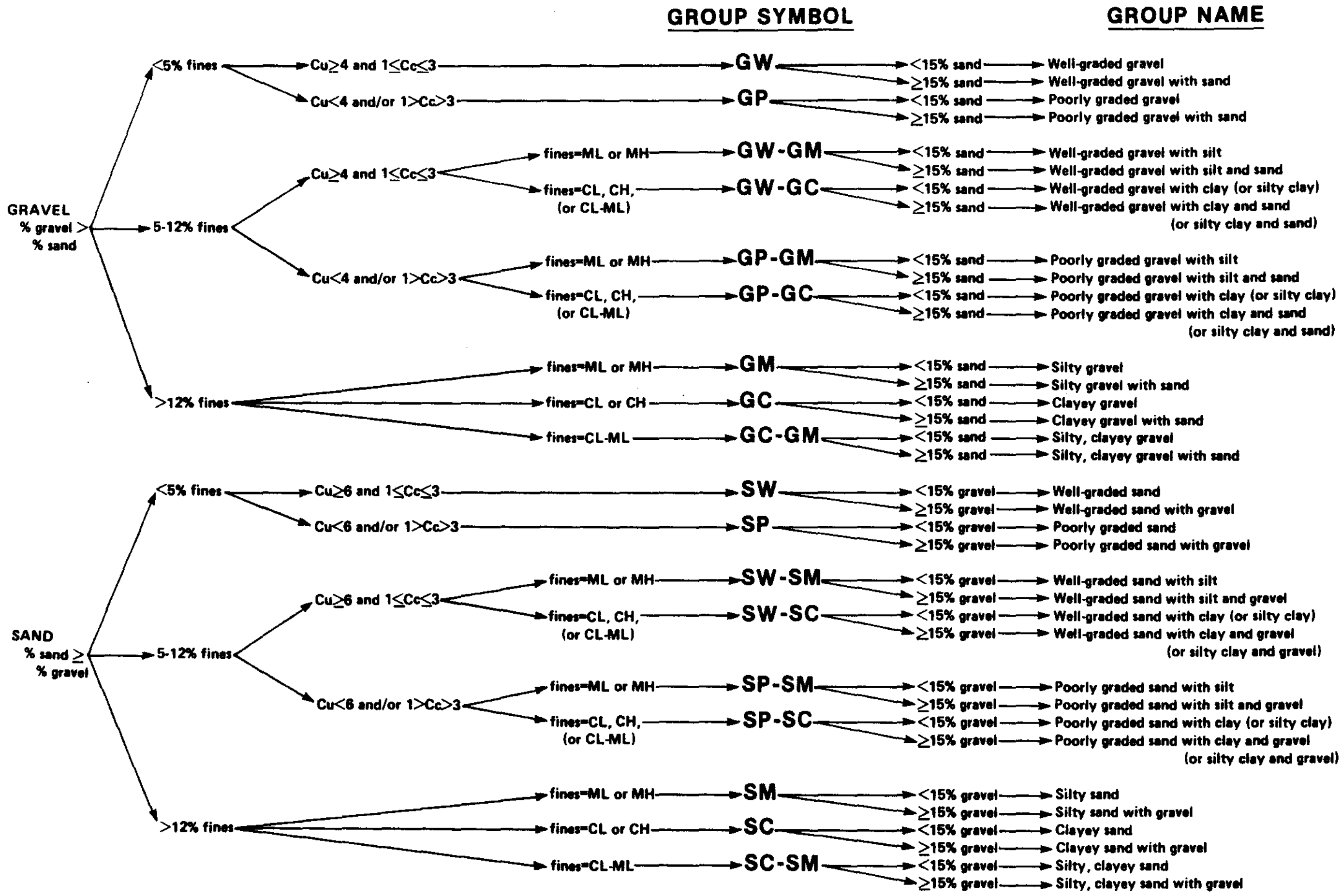

FIG. 5—*Flow chart for classifying coarse-grained soil.*

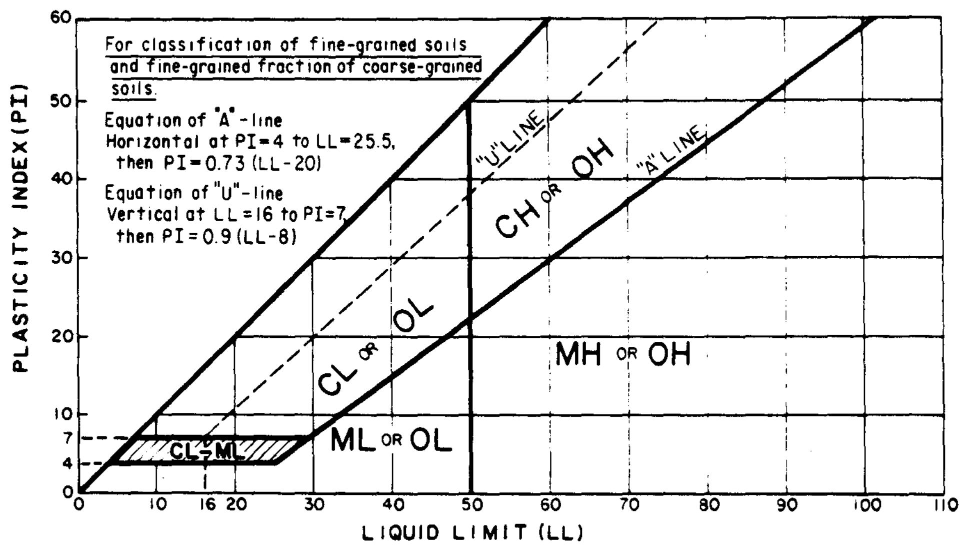

FIG. 6—*Plasticity chart.*

The standard was changed so that these borderline classifications are eliminated. Fines to be described as clay have an LL and PI value that plot on or above the "A" line while fines to be described as silt would plot below the "A" line. The symbols CH, MH, and OL refer to soils with a liquid limit of 50 or greater; and CL, ML, and OL refer to soils with a liquid limit less than 50.

The change was made for the following reasons:

(1) to eliminate the confusion and profusion of using borderline classifications,

(2) so people using the same laboratory test results would classify the soil exactly the same, and

(3) so inexperienced personnel and computer programs would have a set of prescribed rules to follow.

Dual Versus Borderline Symbols

The USCS requires some soils to have dual symbols. Soils with 5 to 12% fines must have a dual symbol composed of a clean, coarse-grained symbol followed by a coarse-grained soil with fines symbol (for example, SP-SM and GW-GC). Soils with LL and PI values that plot in the cross-hatched area of the plasticity chart must have a dual symbol of CL-ML, SC-SM, or GC-GM. These classifications are a required part of the system as presented in ASTM D 2487-83.

However, it is often desired to indicate that a soil is close to the boundary or borderline between two different soil classifications. When the laboratory tests indicate that a soil is close to a borderline (either plasticity or gradation values), it can be given a borderline symbol of two symbols separated by a slash. The first symbol is the one based on ASTM D 2487 (for example, CL/CH, CL/ML, ML/CL, and GP/SP).

Emphasis Placed on More Plastic Classification

The new standard emphasizes or favors the more plastic classification or the finer-grained classification.

1. ASTM D 2487-69 defined fine-grained soils as "50% or more passes the No. 200 sieve" and coarse-grained soils as "more than 50% retained on No. 200 sieve" while sands were soils with "more than 50% of coarse fraction passes No. 4 sieve" and gravels as "50% or more of coarse fraction retained on No. 4 sieve." In the former case, the fine-grained material was favored while in the latter case the coarse-grained material was favored. The new standard changes the latter case to describe sands as "50% or more of coarse fraction passes the No. 4 sieve" and gravels as "more than 50% of coarse fraction retained on No. 4 sieve."
2. ASTM D2487-69 favored the less plastic classification in one note (Note 5), while another note (Note 6) stated the more plastic classification was to be favored.

The new standard favors the more plastic classification in the following ways:

1. New Note 7 (old Note 5) was changed to favor the more plastic classification.
2. When the LL and PI for a soil fall on the "A" line, the soil is classified as a clay, not a silt.
3. When the LL = 50, the soil is to be classified as a CH, not CL, and MH, not ML, emphasizing the more compressible material.
4. A soil with LL and PI plotting in the hatched area of the plasticity chart is to be classified as a CL-ML, silty clay.

Use of the System as a Secondary Classification System

The USCS is often used for classifying and describing materials such as shale, siltstone, claystone, mudstone, sandstone, crushed rock, slag, cinders, shells, and so forth.

Lithified or partially lithified material (shale, claystone, and so forth), is sometimes classified as a soil after the material has been processed (grinding, slaking, and so forth). The material should be "classified" according to its original state. A secondary classification according to USCS can be reported. However, as presented in Appendix X2 in ASTM D 2487-83, it is suggested that the group name and symbol be in quotation marks to distinguish them from the classification of true soils.

Material, such as shells and slag, should not be considered as soil, but the USCS can be used to describe the material. Again, the primary classification should be shells or slag with a secondary USCS classification in quotation marks.

Crushed rock is not a naturally occurring soil and any classification should also be in quotation marks.

Examples of written descriptions were included in Appendix X2, some of which are shown below:

1. *Shale Chunks*—retrieved as 50- to 101-mm (2- to 4-in.) pieces of shale from power auger, 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.
2. *Crushed Rock*—processed gravel and cobbles from Pit 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.

"U" Line

The upper limit or "U" line was added to the plasticity chart (Fig. 6) to aid in the evaluation of test data. This line was recommended by Casagrand as an empirical boundary for natural soils. It provides a check against erroneous data, and any test results that plot above or to the left of it should be verified.

There is no formal documentation as to the origin of the "U" line. Students in classes given by Casagrande reported that it was presented as part of his lectures, and they have the sketch in their class notes. The Corps of Engineers does include the "U" line, described as the upper limit line, in their manual *Laboratory Soils Testing*. Casagrande served as a consultant for this manual and did review it. The Corps' manual states that the "U" line begins at an LL of 8 and PI of 0 and rises on a slope of 0.9 (PI − 0.9 [LL = 8]). However, the line is not shown on their plasticity chart below a PI of 7 (the top of the cross-hatched area).

The 1983 revision of ASTM D 2487 also shows the "U" line on the plasticity chart, but below a PI of 7 the line is vertical at LL = 16. LL's below 16 are felt to be unreasonable values as the soil is probably sliding on the surface of the cup rather than a flowing or shearing of the material. A computer search revealed that of over a thousand soil specimens tested and reported by the USBR geotechnical laboratory, four had LL = 17, one had LL = 16, and none had LL below 16.

Expanded Liquid Limit Scale

Stopping the LL scale at 100 on the plasticity chart tends to reinforce the erroneous assumption that the LL of a soil cannot be greater than 100. Expanding the scale to 110 to help correct this misunderstanding was incorporated in the 1983 revision of ASTM D 2487 (Fig. 6).

Symbol for Coefficient of Curvature

The most controversial charge in the revised standard was the symbol for the coefficient of curvature. In the USCS, as adopted by the Corps of Engineers and the Bureau of Reclamation, the symbol used was C_c. Unfortunately, this is also the soil mechanics symbol for the compression index; the slope of the linear portion of the pressure-void ratio curve on a semilog plot. In ASTM 2487-69, the symbol C_z was used for the coefficient of curvature in order to avoid the confusion of using the same symbol for two different terms. During the balloting process preceding the 1983 version, it became apparent that a strong and vociferous faction wanted to return to the traditional C_c as the symbol. After a ballot incorporating the C_c symbol went out, it became obvious that the advocates of not using the C_c symbol were also indeed numerous and vocal. Following hours of deliberating, cogitating, and arbitrating, the symbol Cc, with the lower case c on the same line (not a subscript) was selected as the symbol that least offended all the parties involved.

Cobbles and Boulders

Although the soil that is classified is the 75-mm (3-in.) minus material, the new standard requires that if plus 75-mm (3-in.) particles (cobbles or boulders) were present in the field sample, then the name of the soil should reflect their presence (for example, silty gravel with cobbles, GM). Suggested criteria for what is a cobble or a boulder were given.

Summary

ASTM D 2487 was significantly revised in 1983. The revisions include:

1. Requiring soil to be classified by stating both a symbol and a name.
2. Standardizing the names associated with the symbols and what modifiers or additional terms must be included in the name.
3. Redefining organic silts and clays to recognize that organic soils occur that plot above the "A" line on the plasticity chart.
4. More precise guidelines were established, particularly with regard to plasticity, to eliminate borderline classifications. Using the standard, only one particular classification will result. In the case of soils with 5 to 12% fines or plotting in the hatched area of the plasticity chart, dual symbols are used (for example, SP-SM, and CL-ML). However, if it is desired to indicate that the soil properties are close to another classification group, the two groups can be indicated using a slash, for example, CL/CH, with the classification indicated from the standard appearing first.
5. Provision was made to apply the classification system to materials such as shale, mudstone, crushed rock, slag, and so forth.

References

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SECTION III

Reprint of

"The Revised ASTM Standard on the Description and Identification of Soils (Visual-Manual Procedure)"

by Amster K. Howard

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TECHNICAL NOTE

Amster K. Howard[1]

The Revised ASTM Standard on the Description and Identification of Soils (Visual-Manual Procedure)*

REFERENCE: Howard, A. K., "**The Revised ASTM Standard on the Description and Identification of Soils (Visual-Manual Procedure),**" *Geotechnical Testing Journal,* GTJODJ, Vol. 10, No. 4, Dec. 1987, pp. 229-234.

ABSTRACT: ASTM Practice for Description and Identification of Soils (Visual-Manual Procedure) (D 2488) was significantly revised in 1984. Revisions were made to parallel the recent changes in ASTM Classification of Soils for Engineering Purposes (D 2487) and to reflect more of current practices used for visual-manual description and identification. Where possible, the number of terms for descriptive information (dry strength, moisture condition, and so forth) was reduced, and the criteria for deciding which term to use were made less subjective. Criteria for describing particle shape and for describing cementation of coarse-grained soils were added. Appendixes give example written descriptions, procedures for estimating particle size distribution, and guidelines for using the system for materials such as shale, mudstone, crushed rock, and slag.

KEYWORDS: soil classification, soils, sands, clays, silts

ASTM Practice for Description and Identification of Soils (Visual-Manual Procedure) (D 2488) was revised in 1984 following the adoption of significant revisions to ASTM Classification of Soils for Engineering Purposes (D 2487). This technical note is to document the changes and revisions to D 2488 similar to the previous documentation for the revised D 2487 [*1*].

The primary purpose of D 2488 is to standardize the terms to be used when describing a soil for engineering purposes. As part of the description, the soil may be identified based on the classification system established in D 2487.

The basic reason for most of the changes was that no one in the subcommittee knew of any group, agency, or organization that was using the standard in the 1969 version (reapproved 1975). The criteria and terms being used by members of the subcommittee were substituted, and the revised standard sent to the committee for comments. There were no objections. In general, there were no strong technical reasons for many of the changes; revisions were basically made to conform with current practices.

*ASTM Practice for Description and Identification of Soils (Visual-Manual Procedure) (D 2488).

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The subcommittee also felt it necessary to reduce the vagueness of the descriptive criteria, where possible, in order for the description of the soil to be less subjective. The terms and descriptive criteria were also reduced to the minimum number practicable to simplify the procedure.

Descriptive Terms

The criteria used for the terminology for describing soil samples are now presented in a series of tables at the end of the standard instead of being in the main body of the standard. This was done to make all of the terms easier to refer to and to locate.

The descriptive terms and any revisions are as follows:

Criteria for Describing Angularity of Coarse-Grained Particles

This was previously referred to as "grain shape." However, "shape" was felt to better describe another characteristic as discussed in the next item. The terms to be used and the criteria for describing angularity (angular, subangular, subrounded, rounded) were not changed.

Criteria for Describing Particle Shape

Gravel particles with unusual shapes may cause difficulty in scalping and screening, may segregate easily, may be difficult to compact, and can significantly affect concrete mix design. When appropriate, the particles are to be described as flat, elongated, or flat and elongated. The terms "flat" and "elongated" were taken from ASTM Definition of Terms Relating to Concrete and Concrete Aggregates (C 125). The term "flat and elongated," plus the criteria for determining which (if any) term should be used, were taken from the Corps of Engineers Standard CRD-C 119-53 [*2*].

The particle shape is to 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.

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The shape of the particles is to be mentioned only if they meet the above criteria. The fraction of the sample with the particular shape should be given, such as one-third of gravel particles are flat. A thorough discussion of particle shape is given in Ref *3*.

Moisture Condition

The previous standard described the moisture condition of a soil with four terms, and the criterion for each term was related to the optimum moisture for compaction of the soil. While the relationship to optimum moisture is useful for a soil description, it becomes a very subjective criteria, which depends on the user having considerable experience with the moisture-density relationship of soils. In the interest of reducing subjectivity and the number of terms, the terms and criteria were changed as follows:

Previous Criteria

- Dry—requires addition of considerable moisture to attain optimum for compaction.
- Moist—near optimum moisture content.
- Wet—requires drying to attain optimum moisture content.
- Saturated—comes from below the water table.

Revised 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.

"Saturated" was eliminated since it implies a 100-percent degree of saturation which is impossible to judge from a visual examination.

Color

It was recommended in the previous version that the color be described in accordance with a standard color chart, and in a note, the Munsell color notation was suggested. While this sounds beneficial for standardization and uniformity, no one knew of anyone or any organization who used the Munsell color chart for describing soils, and the Munsell charts are expensive. The color chart recommendation was eliminated. The standard now just states "describe the color."

Odor

In the previous version, the odor was to be described for dark-colored soils as organic, earthy, or none. Describing the odor as "earthy" was felt to not have any significance. An "organic" odor should be described regardless of the color of the soil. Odor should also be described if it is unusual, such as a petroleum product odor, chemical odor, and so forth. A description of an organic or unusual odor then becomes a "red flag" to indicate a special or unusual situation that may require additional investigation.

Cementation and HCl Reaction

Some soils exhibit some cementation in the intact state. In the previous standard, cementation was detected by the reaction with dilute hydrochloric acid (HCl). The revised standard now makes a distinction between cementation and the reaction with HCl (which detects calcium carbonate). There are cementing agents other than calcium carbonate. Some soils may not appear to be cemented but have a distinct reaction with HCl.

The revision states that the reaction with HCl is to detect the presence of calcium carbonate. The same terms are used as before (none, weak, or strong), but a description of the criteria for each was added as follows:

- None—no visible reaction.
- Weak—some reaction, with bubbles forming slowly.
- Strong—violent reaction, with bubbles forming immediately.

A separate category of cementation was added for intact, coarse-grained soils that are cemented in their natural state, such as a sandstone, but could be processed for use as a construction material. The following terms and criteria for cementation were added

- 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.

Consistency

In the previous standard, consistency was to be described for cohesive soils based on the penetration of the thumb or thumbnail into the soil. Shear strength values were listed for correlation with pocket penetrometers or shear gages.

"Cohesive soils" was felt to be too broad a term, and the presence of gravel can affect the results. Consistency was changed to be described for intact fine-grained soils with a warning added that the observation is inappropriate for soils with significant amounts of gravel.

The quantitative values of shear strength were dropped. If a pocket penetrometer or shear gage is used, the values should be reported but not related to consistency terms such as soft or hard. It was also felt that someone might use the shear strengths based on only the "thumb" test for design purposes.

The consistency terms were changed to reflect what most organizations were using, as follows:

Previous Criteria

- Soft—easily penetrated several inches by thumb.
- Firm (medium)—penetrated several inches by thumb with moderate effort.
- Stiff—readily indented by thumb, but penetrated only with great effort.
- Very stiff—readily indented by thumbnail.
- Hard—indented with difficulty by thumbnail.

Revised 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 1/4 in. (6 mm).
- Hard—thumb will not indent soil but readily indented with thumbnail.
- Very hard—thumbnail will not indent soil.

Structure

No changes were made.

Dry Strength

There were six terms used to describe dry strength (crushing a lump of soil between the fingers) in the previous standard. The term "very low" was eliminated and "high" was defined less subjectively.

The revised criteria are

• None—the dry specimen crumbles into powder with mere pressure of handling.
• Low—the dry specimen crumbles into powder with some finger pressure.
• Medium—the dry specimen breaks into pieces or crumbles with considerable finger pressure.
• High—the dry specimen cannot be broken with finger pressure; specimen will break into pieces between thumb and a hard surface.
• Very High—the dry specimen cannot be broken between the thumb and a hard surface.

Dilatancy

No changes were made.

Toughness

Toughness is the resistance to deformation of the soil at the plastic limit moisture content. The previous terms and criteria were as follows:

• Weak and Soft—only slight pressure required to roll thread, thread has little or no strength, and after crumbling the thread, the pieces cannot be formed into a coherent mass.
• Medium Stiff—medium pressure required to roll thread, thread will support its own weight when a few inches long, and after crumbling the thread pieces can be molded into a lump which crumbles with slight kneading.
• Very Stiff—considerable pressure required to roll thread, thread will easily support its own weight when several inches long, and after crumbling the thread pieces can be formed into a lump which is coherent and tough.

The terms were changed to low, medium, and high for simplicity. The criteria for the thread supporting its own weight were eliminated. If the thread crumbles at the plastic limit, how can the length of a thread supporting its own weight be determined when the soil is at the plastic limit?

The revised terms and criteria are as follows:

• 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.

Plasticity

The plasticity was to be described based on the results of the dry strength, dilatancy, and toughness tests. Subcommittee members had difficulty agreeing with the correlation between the terms as stated.

The plasticity is best described as the behavior of the soil during the performance of the toughness test. The following terms and criteria were approved:

• Nonplastic—a 1/8-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.

Identification of Soils

The other application of D 2488 is to identify the soil by assigning a group name and group symbol using the principles of the classification system established in D 2487.

In place of the laboratory tests prescribed in D 2487, visual-manual techniques are described in D 2488 for evaluating the plasticity characteristics of the soil and estimating the percent of gravel, sand, and fines in the soil. Since visual-manual procedures are used, the precise classification that would result from D 2487 cannot be extended in all details to D 2488. For example, identifying a soil as CL-ML (soil with a LL [liquid limit] and PI [plasticity index] that plot in the crosshatched area of the plasticity chart) is not recommended in D 2488, since CL-ML classification covers such a small portion of the plasticity chart and is visually difficult to identify. Although it is true that a person with considerable experience with soils in a specific area may be able to distinguish a CL-ML soil; in general, a visual identification of CL-ML is difficult and should not be attempted by the general user of the standard. The same situation exists for the OL and OH classifications in D 2487. For the revised D 2488, the soil is to be identified as an ORGANIC SOIL OL/OH. Further classification into the OL or OH categories should be done based on laboratory tests.

Group Names and Symbols

The identification criteria and the accompanying flow charts for assigning a group symbol and a group name had to be presented differently in D 2488 than those stated in D 2487 because the exact values for the particle-size distribution and the Atterberg limits are not determined. In addition, not identifying the soil as a CL-ML or OL or OH required separate flow charts for D 2488. The flow charts for assigning a group name and symbol using the visual-manual procedure are shown on Figs. 1 through 3.

Estimating Particle-Size Distribution

In place of a gradation analysis, the visual-manual identification of a soil requires estimation of the percent of gravel, sand, and fines in the soil being examined. Several suggested procedures for doing this are now given in Appendix X4 in D 2488. The percent-

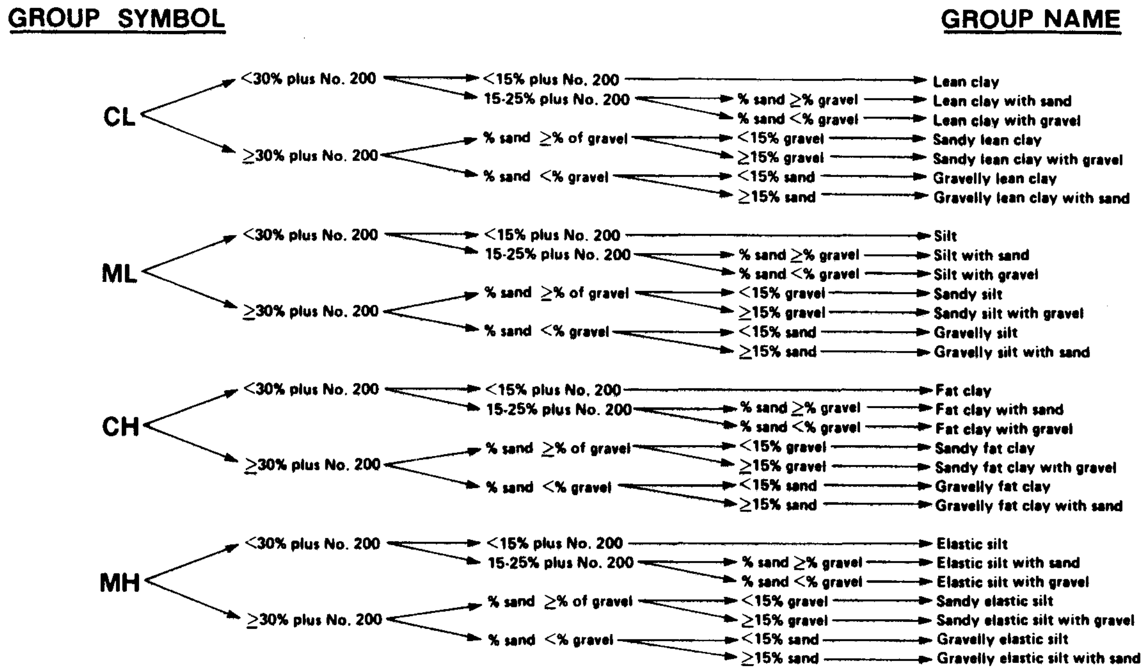

FIG. 1—*Flow chart for identifying inorganic fine-grained soil (50% or more fines).*

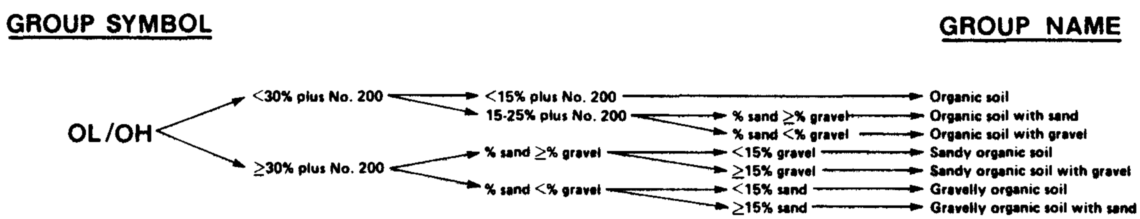

FIG. 2—*Flow chart for identifying organic fine-grained soil (50% or more fines).*

ages are to be estimated to the closest 5%. These percentages are then used to identify the group as to the appropriate group name and group symbol. In the report, or the written description of the soil, the estimated percentages may be stated in terms other than a percent value as indicated in Note 15, 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%.

Estimating Plasticity Characteristics

In D 2487, the Atterberg limits determined for the soil dictate whether the fine-grained portion of the soil is CL, ML, CH, or MH. In place of the Atterberg limits, D 2488 gives guidelines for identifying the soil as ML, CL, MH, or CH based on the results of the dilatancy, dry strength, and toughness manual tests. The guidelines are given in Table 1.

Table 1 replaces the portion of the previous standard that described identifying the soil as a "silt" or "clay" with appropriate adjectives of "sandy," "clayey," or "silty." The adjective of "sandy" was felt to be more related to the percent of sand in the soil rather than a result of the manual tests. In addition, no one was using the table as published, and the identification guidelines as presented in the above table were being used by several organizations.

Appendixes

The appendixes that were included in the revised D 2487 on "Examples of Descriptions Using Soil Classification" and "Using Soil Classification as a Descriptive System for Shale, Claystone, Shells, Slag, Crushed Rock, etc." were also included in D 2488 with appropriate changes to fit the visual-manual descriptive and identification procedure. An appendix was added "Suggested Procedure for Using a Borderline Symbol for Soils with Two Possible Identifications."

Trouble

The most interesting and controversial issue that arose during the subcommittee and committee balloting was the title. It began as Classification and Description of Soils (Visual-Manual Proce-

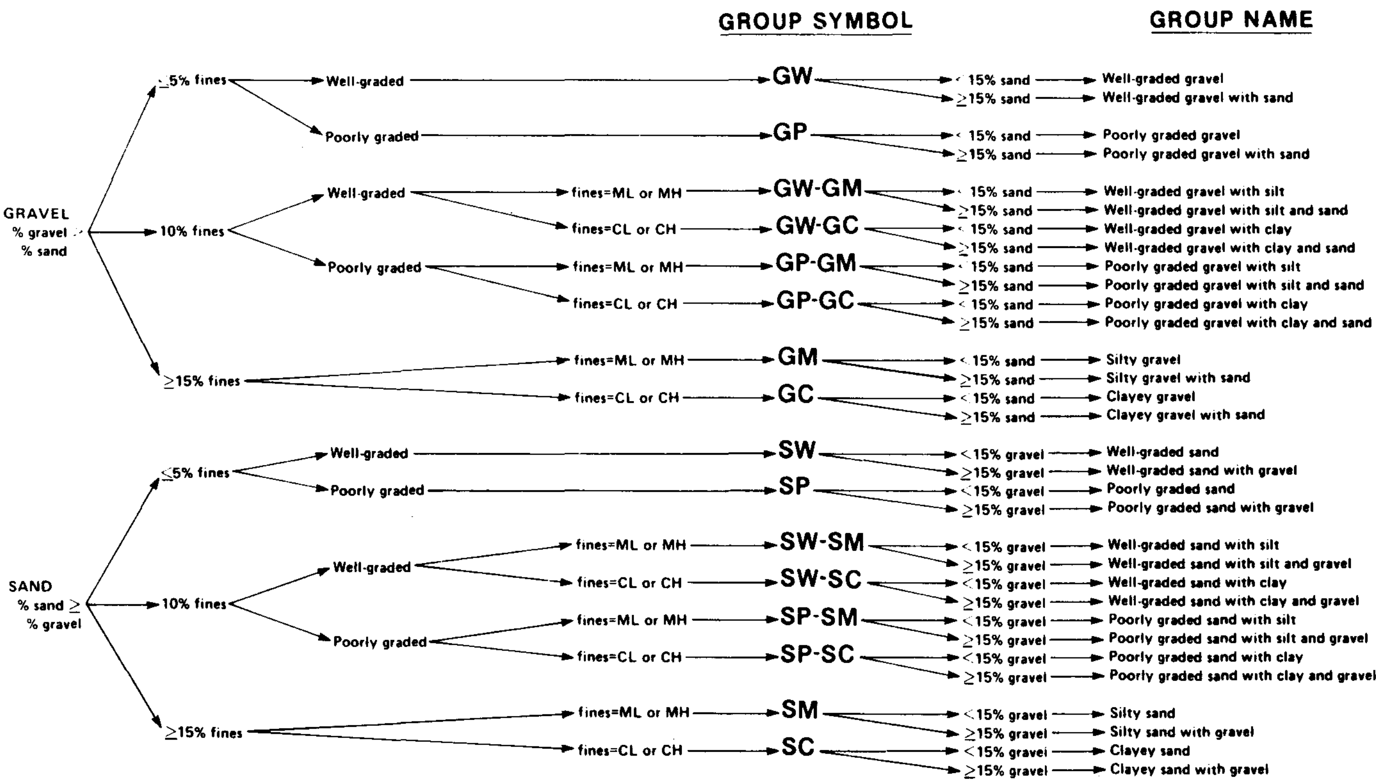

FIG. 3—*Flow chart for identifying coarse-grained soils (less than 50% fines).*

TABLE 1—*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

dure). Whether the standard was for classification or for identification was a major concern for some, and the order of the words classification (or identification) and description was challenged.

In D 2487, it is stated that a soil is classified when it is given a group symbol and a group name. D 2487 also establishes the classification system for soils using the results of laboratory tests. In the process of using visual-manual techniques in D 2488 to arrive at a group name and group symbol, is the soil being classified or is it being identified according to the classification system established in D 2487? A quick poll of interested and disinterested parties revealed that most people use the words "classification" and "identification" interchangeably and consider the words synonymous. In the *New American Webster's Dictionary*, "classification" was listed as a meaning for "identification."

In fact, all three words (identification, classification, and description) came under attack. There are some strong feelings about what the words denote, and the opinions are varied.

These issues were raised in the past about D 2488 and will probably be raised again in the future. Identification was selected to be used in the standard and remained in the final approved version after considerable negotiating, cajoling, and threats. To forestall (or perhaps encourage) future deliberations on the matter, the following rationale is stated for the record:

1. Identification was used in the previous version and is thus familiar and comfortable.
2. Since D 2487 establishes the classification system, then D 2488 identifies the soil in accordance with the classification system of D 2487. This is consistent with most dictionary definitions. After consulting 23 various dictionaries, the definitions of classification and identification were paraphrased as follows:

- Classification—the systematic arrangement into groups according to established procedures by reason of common characteristics.
- Identification—the state of being recognized as being a particular thing (general)—to determine to what group a given specimen belongs (technical).

As to the order of the terms "identification" and "description" in the title and in the standard, the following arguments persuaded the majority of the subcommittee to place description before identification:

- Alphabetical order.
- The standard is primarily for a procedure to describe soils. Identifying the soil by giving it a name and symbol is optional and is part of the description of the soil.

Summary

ASTM Practice for Description and Identification of Soils (Visual-Manual Procedure) (D 2488) was significantly revised in 1984. Revisions were made to parallel the recent changes in ASTM Classification of Soils for Engineering Purposes (D 2487) and to reflect more of current practices used for visual-manual description and identification purposes.

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SECTION IV

DIFFERENCES BETWEEN BUREAU AND ASTM STANDARDS FOR THE UNIFIED SOIL CLASSIFICATION SYSTEM

A. USBR 5000 and ASTM D 2487

In conformance with Bureau policy for presentation of test procedures, the following wording is different from that used by ASTM:

1. The titles are different.

2. "Moisture content" is used instead of "water content."

3. "Mass" is used instead of "weight."

4. References are made to other Bureau procedures as well as ASTM standards.

The following items are related to technical differences:

5. Note 1 in ASTM D 2487 discusses the possibility of using borderline classifications. As a note, it is nonmandatory and is provided only for information. The user of the standard may or may not elect to use borderline classifications.

   In the Bureau test procedure, the statement on borderline soil classifications is a required section. The Bureau has found borderline soil classifications extremely useful and, as a required section, use of such classifications is emphasized.

6. In the Bureau designation, the "dry" method of preparation for testing is to be used except for special cases. The two procedures for preparing the soil specimen for testing are given in appendixes. Appendix X3 describes a "wet" preparation method where the soil is not allowed to become drier than its natural moisture content. Appendix X4 describes a "dry" preparation method that uses air-dried soil for testing.

In ASTM, the last sentence of subsection 9.2 states:

> "Appendix X3 describes the wet preparation method and is the preferred method for cohesive soils that have never dried out and for organic soils."

In USBR 5000, this was changed to read:

> "Appendix X3 describes the wet preparation method and is the preferred method for organic soils and for special cases. Normally, the procedure described in appendix X4 will be used."

This wording was changed to emphasize that the "dry" method is the standard method to be used, and the "wet" method is the exception. Since the Bureau operates only in the arid, western United States, most of the soils encountered have been through natural wetting and drying cycles, and air-drying for testing should not affect test results. Since the dry method is simpler and less time consuming, it is more suited for a production-type system of classifying the large quantities of soils handled in Bureau laboratories. However, Bureau personnel are encouraged to perform a few comparison tests using both the wet and dry methods if there is any indication or suspicion that the method of sample preparation would affect test results.

7. The set of sieves required in subsection 9.7 of ASTM D 2487 for gradation analysis was changed to accommodate the set normally used in Bureau laboratories as shown below:

ASTM D 2487	USBR 5000
3 in (75 mm)	3 in (75 mm)
3/4 in (19.0 mm)	1-1/2 in (37.5 mm)
No. 4 (4.75 mm)	3/4 in (19.0 mm)
No. 10 (2.00 mm)	3/8 in (9.5 mm)
No. 40 (425 µm)	No. 4 (4.75 mm)
No. 200 (75 µm)	No. 8 (2.36 mm)
	No. 16 (1.18 mm)
	No. 30 (600 µm)
	No. 50 (300 µm)
	No. 100 (150 µm)
	No. 200 (75 µm)

The set of sieves described in ASTM D 2487 is referred to as the "soil mechanics" sieves while the ones listed in USBR 5000 are known as the "concrete" sieves. The Bureau has historically used only one set of sieves so that the numerous field laboratories established at the various project sites would not to have maintain two separate sets of sieves.

8. The minimum specimen sizes required for testing listed in ASTM subsection 7.2 were changed to conform with Bureau policy as follows:

Maximum particle size (sieve opening)	ASTM D 2487	USBR 5000
No. 4 (4.75 mm)	0.25 lb	0.2 lbm
3/8 in (9.5 mm)	0.5 lb	0.5 lbm
3/4 in (19.0 mm)	2.2 lb	2.5 lbm
1-1/2 in (37.5 mm)	18 lb	20 lbm
3 in (75 mm)	132 lb	150 lbm

A discussion of the Bureau's required specimen sizes is presented in GR-88-2 [6].

9. Appendix X5 titled "Abbreviated Soil Classification Symbols" was added to USBR 5000.

ASTM D 2487 states that a soil classification consists of assigning both a group symbol and a group name (subsec. 3.2). This was done because the soil symbol alone does not fully identify the soil in terms of other components that may be present. While the intent is strongly supported, there are some instances where numerous "stick" logs need to be presented; but space is insufficient to show both a group symbol and a name. For this reason, a "shorthand" method of adding single-letter prefixes and suffixes to the basic soil classification symbol was developed that indicates the full group name.

10. Maximum particle size is described in millimeters rather than inches (see item 8 under sec. IV.B. in this report).

11. The Bureau-adopted definitions of cobbles and boulders are included in USBR 5000. ASTM D 2487, Note 4 under subsection 5.1, gives suggested definitions for cobbles and boulders that are more appropriate for soil classification than the definitions given in ASTM D 653 [7]. Therefore, the Bureau formally adopted the definitions from ASTM Note 4 and uses them as a required part of USBR 5000 [8].

12. In conjunction with both Bureau and ASTM revised procedures, a new "plasticity chart" was developed as shown on figure 1 [form No. 7-1461 (11-85)]. This format was approved for Bureau use starting January 1, 1984 [9]. The only difference between this form and the ASTM figure in D 2487 is the addition of vertical and horizontal lines in increments of 2, rather than 10, to facilitate hand-plotting of data.

B. <u>USBR 5005 and ASTM D 2488</u>

In conformance with Bureau policy for presentation of test procedures, the following wording or format is different from that used by ASTM:

1. Items 1 through 4 in section IV.A. of this report also apply here.

2. There is a difference in the numbering system between the two documents. Although both were the responsibility of the author of this report, editorial changes were made by ASTM that were not paralleled by the Bureau. Primarily, a section on "Reagents" appears in the ASTM standard but is not presented separately in USBR 5005.

The following items are related to technical differences:

3. Note 3, which is nonmandatory in ASTM D 2488, was made a required part of the Bureau test procedure, subparagraph 3.3 in USBR 5005 (see item 5 under sec. IV.A. of this report).

4. Item 8 under section IV.A. of this report also applies here.

5. Item 11 under section IV.A. of this report also applies here.

6. For the Bureau procedure, the specimens for the dry strength test are about 1/4 inch in diameter (subpar. 13.2) rather than 1/2 inch required by ASTM (subsec. 14.2). The 1/4-inch size has been historically used in the Bureau, and personnel have become "calibrated" to the descriptive terms for dry strength using this size.

7. Note 15 in ASTM D 2488 was not included in USBR 5005. The note allows words to be used in the description of the soil in place of stating estimated percentages, as follows:

> "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%."

8. In USBR 5005, the maximum particle size is to be stated in millimeters rather than inches as used in ASTM D 2488.

USBR 5005 was written using metric units because, at that time, the Bureau was committed to using the SI system. However, at the time of this writing, use of the SI system is <u>not</u> being emphasized within the Bureau. However, ASTM is encouraging the use of metric units in its standards. ASTM D 2488 is to be reapproved soon, and if it is approved maintaining the inch-pound system, then USBR 5005 should be revised accordingly.

SECTION V

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7-1461 (11-85)
Bureau of Reclamation

PREPARED BY ____________ CHECKED BY ____________

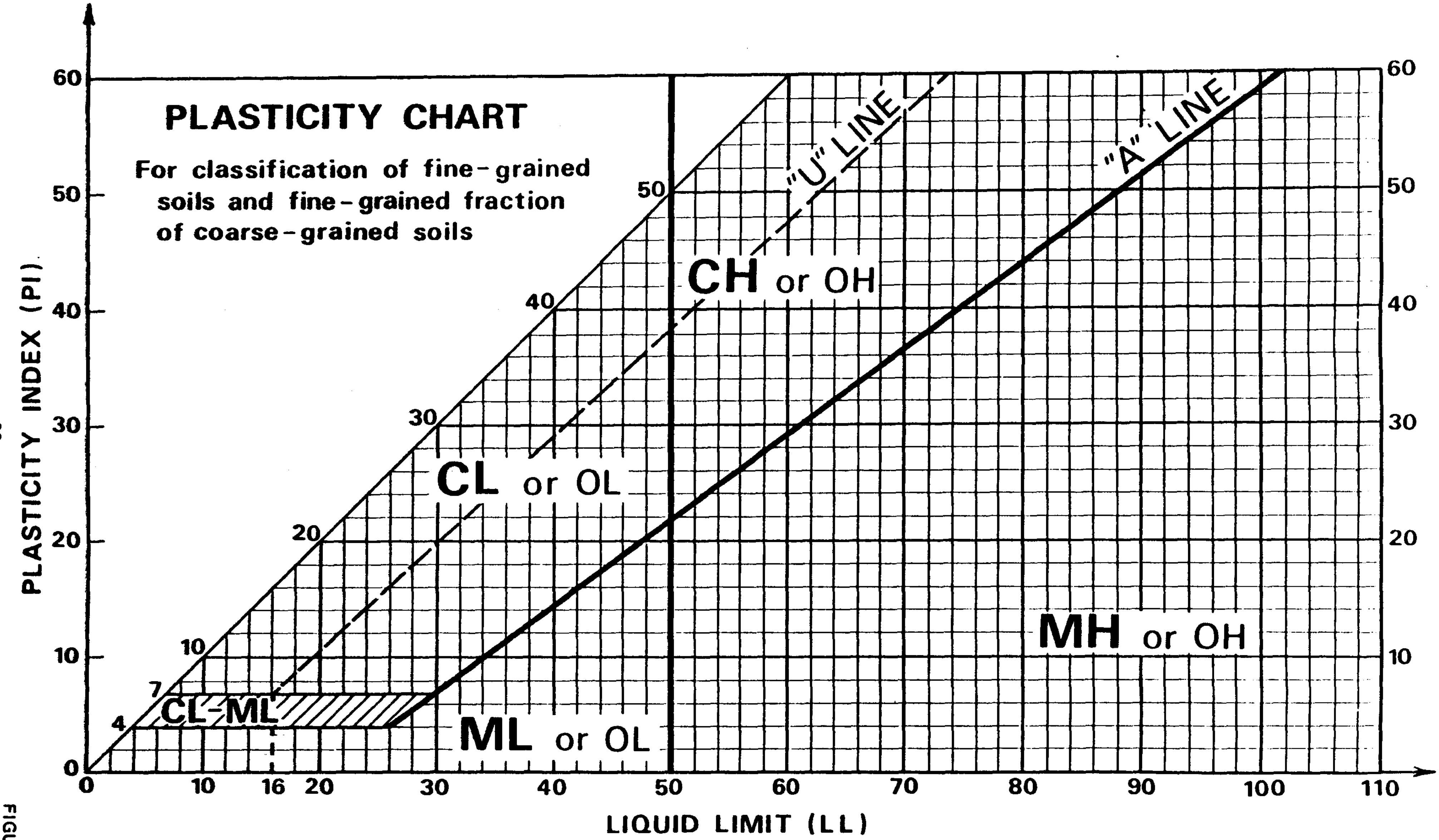


FIGURE 1

APPENDIX

TEST PROCEDURES USBR 5000 AND USBR 5005

USBR 5000-86

PROCEDURE FOR

DETERMINING UNIFIED SOIL CLASSIFICATION (LABORATORY METHOD)

INTRODUCTION

This procedure is under the jurisdiction of the Geotechnical Branch, code D-1540, Division of Research and Laboratory Services, E&R Center, Denver, Colorado. The procedure is issued under the fixed designation USBR 5000. The number immediately following the designation indicates the year of acceptance or the year of last revision.

This procedure is similar to ASTM D 2487 Standard Test Method for Classification of Soils for Engineering Purposes, except for the following: (a) change in title and format, (b) references to USBR procedures, (c) note 1 in ASTM D 2487 is a required section in this procedure, (d) the dry method of preparation (app. X4) should be used except for special cases, (e) maximum particle size is to be expressed in millimeters, (f) the set of sieves required in subparagraph 9.7 was changed to the sieves normally used in USBR laboratories, (g) addition of appendix X5 on "Abbreviated Soil Classification Symbols," (h) moisture content is used instead of water content and mass is substituted for weight, and (i) the minimum specimen sizes required in subparagraph 7.2 were changed to conform with USBR policy.

For circumstances where it may be required or expedient to use ASTM standards, the use of ASTM D 2487 or D 2488 may be substituted for USBR 5000 or 5005. However, it must be stated clearly in written discussions, tables, figures, and logs that the ASTM standards were used.

1. Scope

1.1 This 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.

1.2 Use of this procedure will result in a single classification group symbol and group name except when a soil contains 5 to 12 percent fines or when the plot of the liquid limit and plasticity index values falls into the cross-hatched area of the plasticity chart (see fig. 3). In these two cases, a dual symbol is used (e.g., GP-GM, CL-ML). When 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 (e.g., 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.

1.3 The group symbol portion of this system is based on laboratory tests performed on the portion of a soil sample passing the 3-inch U.S.A. Standard series sieve (75-mm sieve, see ASTM E 11).

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

NOTE 1.-The group names and symbols used in this procedure may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (see app. X2).

1.5 This method is for qualitative application only.

NOTE 2.-When quantitative information is required for detailed designs of important structures, this procedure must be supplemented by laboratory tests or other quantitative data to determine performance characteristics under expected field conditions.

1.6 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 Casagrande[1].[1]

2. Applicable Documents

2.1 *USBR Procedures*:

USBR 3900 Standard Definitions of Terms and Symbols Relating to Soil Mechanics
USBR 5005 Determining Unified Soil Classification (Visual Method)
USBR 5205 Preparing Soil Samples by Splitting or Quartering
USBR 5300 Determining Moisture Content of Soil and Rock by the Oven Method
USBR 5325 Performing Gradation Analysis of Gravel Size Fraction of Soils
USBR 5330 Performing Gradation Analysis of Fines and Sand Size Fraction of Soils, Including Hydrometer Analysis
USBR 5335 Performing Gradation Analysis of Soils Without Hydrometer — Wet Sieve

[1] Number in brackets refers to the reference.

USBR 5350 Determining the Liquid Limit of Soils by the One-Point Method
USBR 5355 Determining the Liquid Limit of Soils by the Three-Point Method
USBR 5360 Determining the Plastic Limit and Plasticity Index of Soils

2.2 *ASTM Standards*:
C 117 Test for Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
C 136 Method for Sieve Analysis of Fine and Coarse Aggregates
D 1140 Method for Amount of Material in Soils Finer Than the No. 200 (75-μm) Sieve
D 2217 Method for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants
D 2487 Classification of Soils for Engineering Purposes
D 2488 Description of Soils (Visual-Manual Procedure)
E 11 Standard Specification for Wire-Cloth Sieves for Testing Purposes

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 3 divisions are further subdivided into a total of 15 basic soil groups.

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

4. Significance and Use

4.1 The procedure described classifies soils from any geographic location into categories representing the results of prescribed laboratory tests to determine the particle-size characteristics and the liquid limit and plasticity index.

4.2 The assigning of a group name and symbol(s) along with the descriptive information required in USBR 5005 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 procedure provides a useful first step in any field or laboratory investigation for geotechnical engineering purposes.

4.4 The procedure may be used as an aid in training personnel in the use of USBR 5005.

5. Terminology

5.1 Definitions are in accordance with USBR 3900. Terms of particular significance are:

5.1.1 *Boulder.*–A particle of rock that will not pass a 12-inch (300-mm) square opening.

5.1.2 *Cobble.*–A particle of rock that will pass a 12-inch (300-mm) square opening and be retained on a 3-inch (75-mm) U.S.A. Standard sieve.

5.1.3 *Peat.*–A soil composed primarily of vegetable tissue in various stages of decomposition with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous (ASTM 2487-83).

5.1.4 *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 percent finer on the cumulative graduation curve, respectively.

5.1.5 *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 percent finer on the cumulative graduation curve, respectively.

5.2 *Terms Specific to This Designation*:

5.2.1 *Gravel.*–Particles of rock that will pass a 3-inch (75-mm) U.S.A. Standard sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

Coarse —Passes 3-inch (75-mm) sieve and retained on 3/4-inch (19.0-mm) sieve
Fine —Passes 3/4-inch (19.0-mm) sieve and retained on No. 4 (4.75-mm) sieve

5.2.2 *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 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
Fine —Passes No. 40 (425-μm) sieve and retained on No. 200 (75-μm) sieve

5.2.3 *Clay.*–Soil passing the No. 200 (75-μm) U.S.A. Standard sieve that exhibits plasticity (putty-like properties) within a range of moisture contents, and which exhibits considerable strength when air-dried. 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.

5.2.4 *Silt.*–Material passing the No. 200 (75-μm) U.S.A. Standard sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air-dried (ASTM). 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.

5.2.5 *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 ovendrying is less than 75 percent of its liquid limit value before ovendrying.

5.2.6 *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 ovendrying is less than 75 percent of its liquid limit value before ovendrying.

6. Apparatus

6.1 In addition to the apparatus that may be required

Table 1. – Soil classification chart – laboratory method.

Criteria for assigning group symbols and group names using laboratory tests [a]				Soil classification: Group symbol	Soil classification: Group name [b]
COARSE-GRAINED SOILS more than 50% retained on No. 200 sieve	GRAVELS More than 50% of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS Less than 5% fines [c]	$Cu \geq 4$ and $1 \leq Cc \leq 3$ [e]	GW	Well-graded gravel [f]
			$Cu < 4$ and/or $1 > Cc > 3$ [e]	GP	Poorly graded gravel [f]
		GRAVELS WITH FINES More than 12% fines [c]	Fines classify as ML or MH	GM	Silty gravel [f,g,h]
			Fines classify as CL or CH	GC	Clayey gravel [f,g,h]
	SANDS 50% or more of coarse fraction passes No. 4 sieve	CLEAN SANDS Less than 5% fines [d]	$Cu \geq 6$ and $1 \leq Cc \leq 3$ [e]	SW	Well-graded sand [i]
			$Cu < 6$ and/or $1 > Cc > 3$ [e]	SP	Poorly graded sand [i]
		SANDS WITH FINES More than 12% fines [d]	Fines classify as ML or MH	SM	Silty sand [g,h,i]
			Fines classify as CL or CH	SC	Clayey sand [g,h,i]
FINE-GRAINED SOILS 50% or more passes the No. 200 sieve	SILTS AND CLAYS Liquid limit less than 50	inorganic	PI > 7 and plots on or above "A" line [j]	CL	Lean clay [k,l,m]
			PI < 4 or plots below "A" line [j]	ML	Silt [k,l,m]
		organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	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 and/or boulders, add "with cobbles and/or boulders" 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 $\geq$ 15% sand, add "with sand" to group name.
g. If fines classify as CL-ML, use dual symbol GC-GM, SC-SM.
h. If fines are organic, add "with organic fines" to group name.
i. If soil contains $\geq$ 15% gravel, add "with gravel" to group name.
j. If the liquid limit and plasticity index plot in hatched area on plasticity chart, 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 $\geq$ 30% plus No. 200, predominantly sand, add "sandy" to group name.
m. If soil contains $\geq$ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.
n. PI $\geq$ 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.

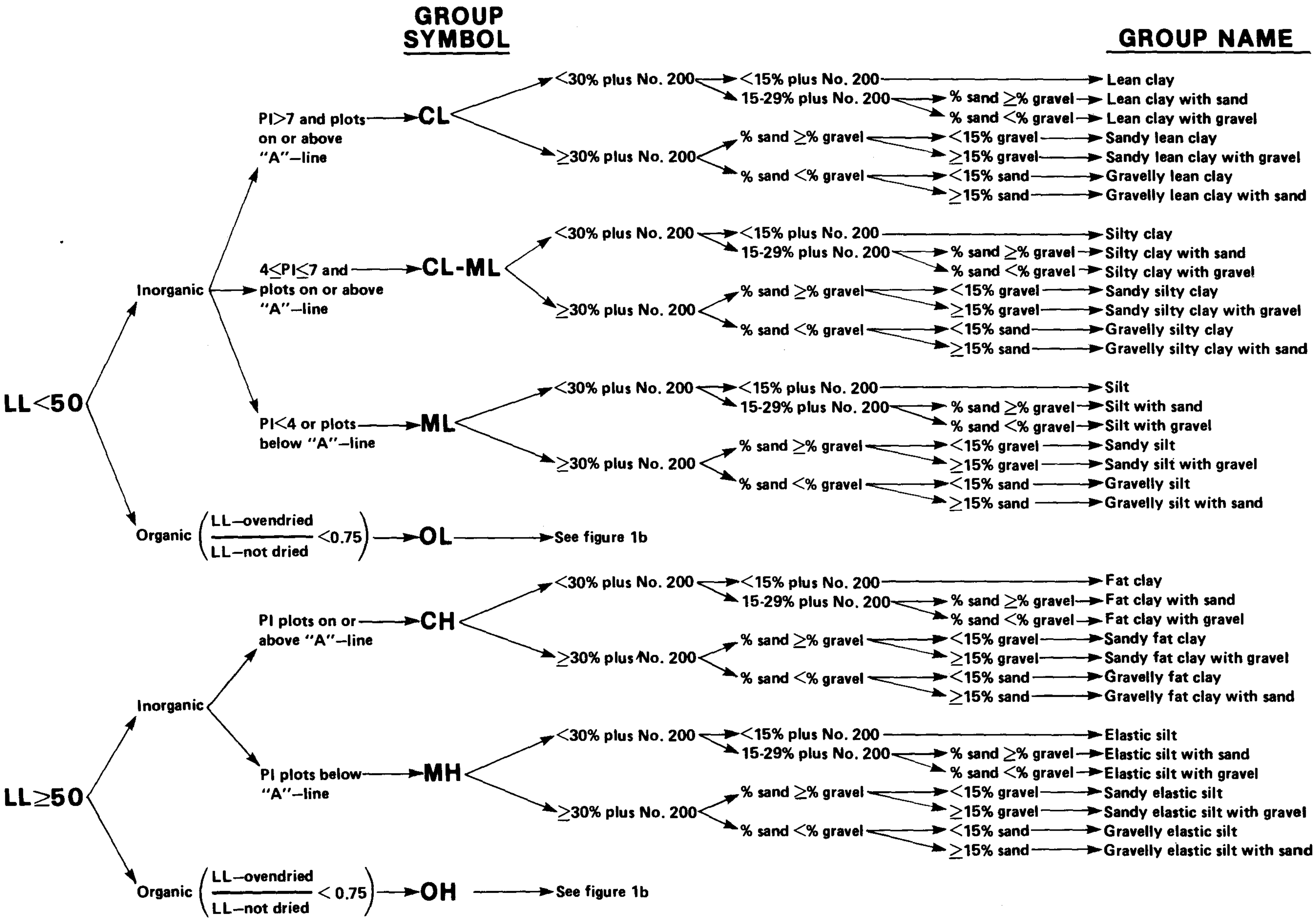


Figure 1a. – Flow chart for classifying inorganic fine-grained soils – laboratory method (50% or more passes No. 200 sieve).

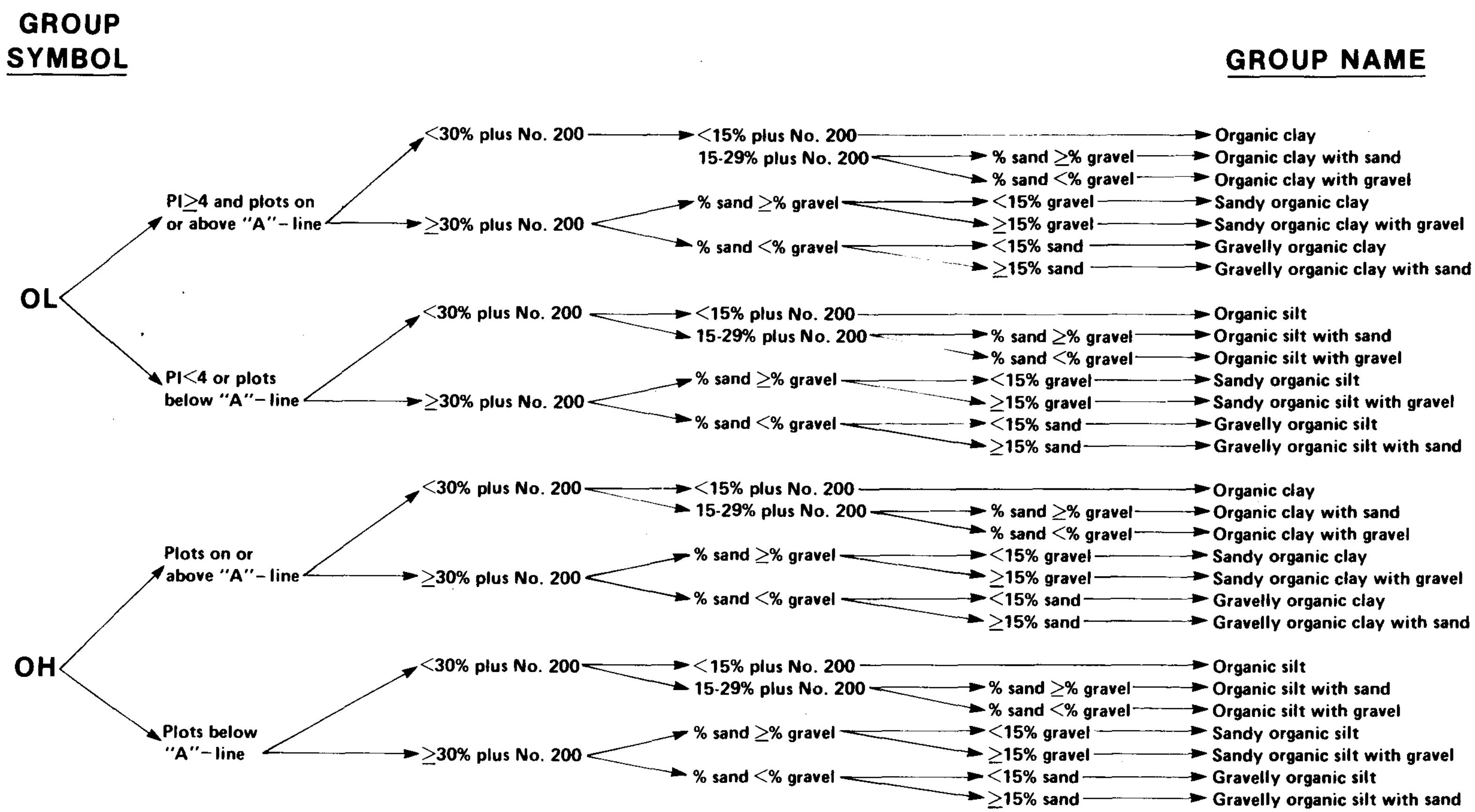


Figure 1b. – Flow chart for classifying organic fine-grained soils – laboratory method (50% or more passes No. 200 sieve).

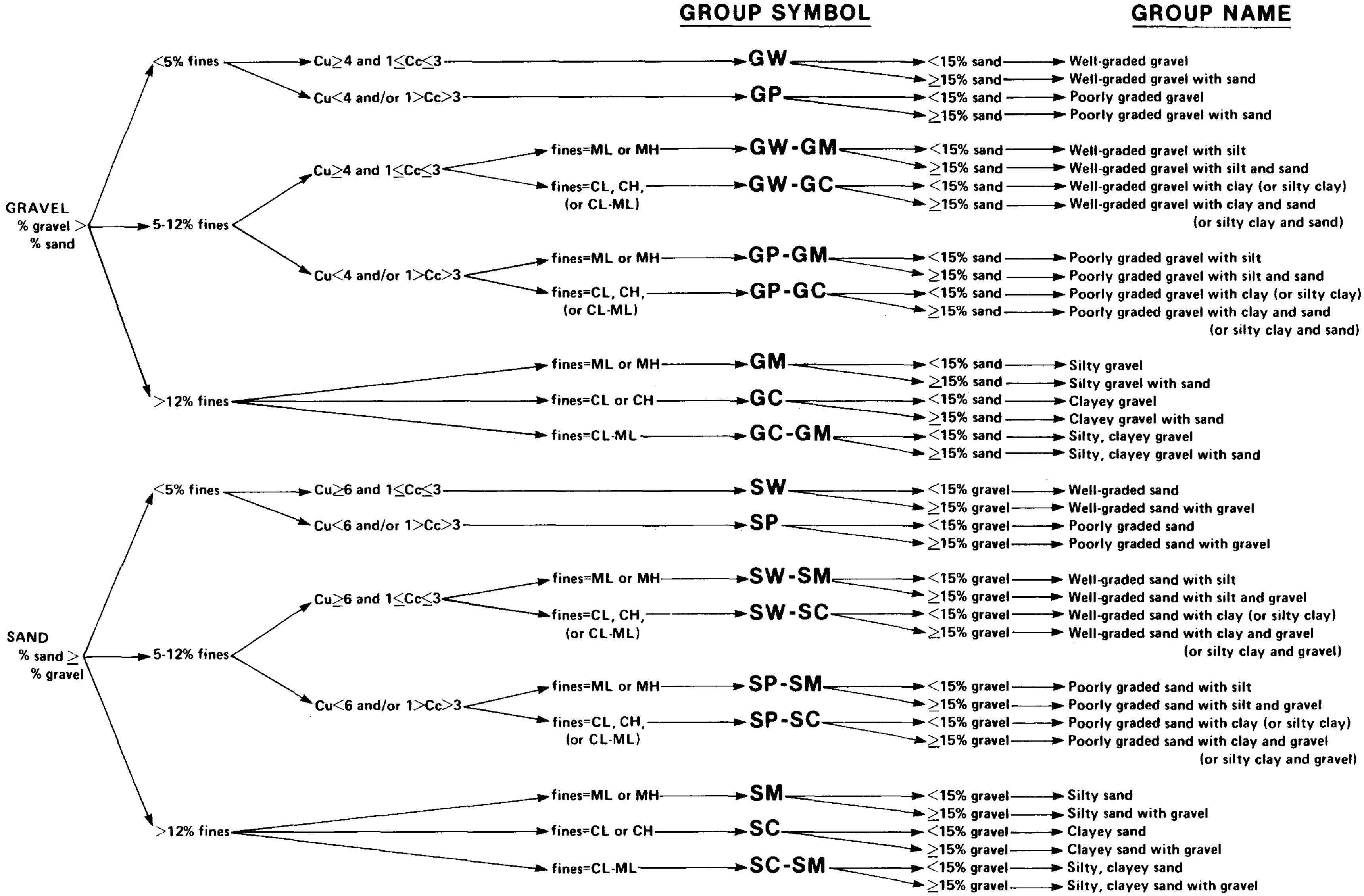


Figure 2. – Flow chart for classifying coarse-grained soils – laboratory method (more than 50% retained on No. 200 sieve).

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 3.-The "U"-line shown on figure 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, Test Specimens, and Test Units

7.1 Samples shall be obtained and identified in accordance with a USBR procedure or ASTM standard or other appropriate standard or procedure.

7.2 For accurate identification, the minimum amount of test sample required for this procedure 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 masses are required:

Maximum particle size, sieve opening		*Minimum specimen size, dry mass*	
mm	in	kg	lbm
4.75	No. 4	0.1	0.2
9.5	3/8	0.25	0.5
19.0	3/4	1.1	2.5
37.5	1-1/2	10	20
75.0	3	70	150

Whenever possible, the field sample should have a mass two to four times larger than shown.

7.3 When the liquid and plastic limit tests also must be performed, additional material will be required sufficient to provide 150 to 200 grams 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. Specimen Preparation for Classification

9.1 Before a soil can be classified according to this procedure, generally the particle-size distribution curve of the minus 3-inch (75-mm) material and the plasticity characteristics of the minus No. 40 (425 μm) material must be determined. (See subpar. 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 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 organic soils and for special cases. Normally, the procedure described in appendix X4 will be used.

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

9.4 Although the 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 mass) of any plus 3-inch (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 curve is required, a set of sieves shall be used which includes 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:

U.S.A. Standard series sieve			
mm	in	μm	No.
75	3	600	30
37.5	1-1/2	300	50
19.0	3/4	150	100
9.5	3/8	75	200
4.75	No. 4		
2.36	No. 8		
1.18	No. 16		

9.8 The tests required to be performed in preparation for classification follow:

9.8.1 For soils estimated to contain less than 5 percent 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 on figure 4.

9.8.2 For soils estimated to contain 5 to 15 percent fines, a cumulative particle-size distribution curve, as described in subparagraph 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 USBR 5005 and so noted in the report.

9.8.3 For soils estimated to contain 15 percent 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 percent fines or more, the percent fines, percent sand, and percent gravel may be estimated using the procedures described in USBR 5005 and so noted in the report.

10. Preliminary Classification Procedure

10.1 Designate the soil as fine-grained if 50 percent or more by dry mass of the test specimen passes the No. 200 (75-μm) sieve and follow paragraph 11.

10.2 Designate the soil as coarse-grained if more than 50 percent by dry mass of the test specimen is retained on the No. 200 (75-μm) sieve and follow paragraph 12.

11. Procedure for the Classification of Fine-Grained Soils [50 percent or more by dry mass 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 and the plasticity index is greater than 4 and presence of organic matter does not influence the liquid limit as determined in subparagraph 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 the plasticity chart (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 the plasticity chart (fig 3).

NOTE 4.–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 the plasticity chart (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 subparagraph 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 the plasticity chart (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 the plasticity chart (fig. 3).

11.3 The soil is an organic silt or clay if organic matter is present in sufficient amounts to influence the soil properties as determined in subparagraph 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 ovendried at 110±5 °C to a constant mass, typically overnight.

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

11.3.3 Classify the soil as an *organic silt* or *organic clay, OL,* if the liquid limit (not ovendried) 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

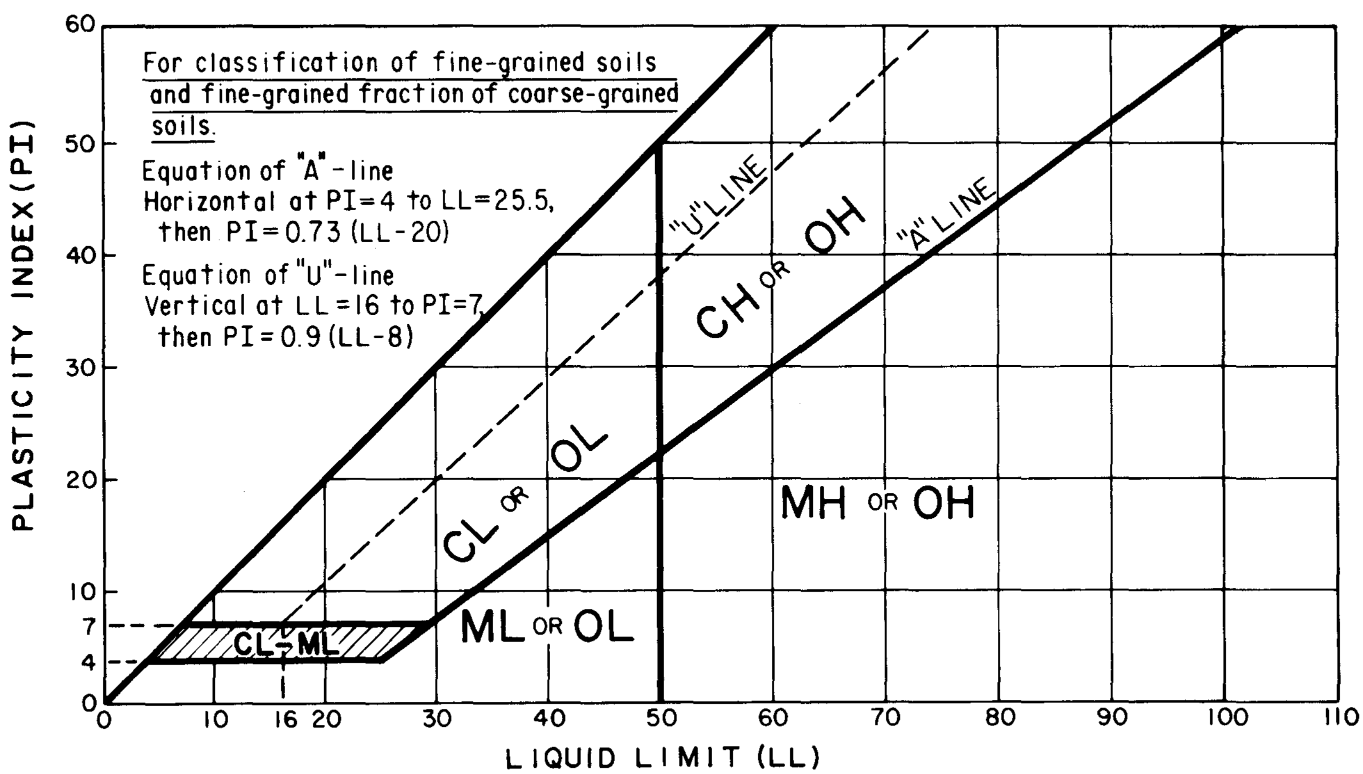


Fig. 3. – Plasticity chart.

liquid limit plot falls on or above the "A"-line. See area identified as OL (or CL-ML) on the plasticity chart (fig. 3).

11.3.4 Classify the soil as an *organic clay* or *organic silt, OH,* if the liquid limit (not ovendried) 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 the plasticity chart (fig. 3).

11.4 If less than 30 percent but 15 percent or more of the test specimen is retained on the No. 200 (75-μm) sieve, the words "with sand" or "with gravel" (whichever is more predominant) shall be added to the group name (e.g., 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 percent 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 percent 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 percent or more of the test specimen is retained on the No. 200 (75-μm) sieve and the coarse-grained portion is predominantly gravel (e.g., 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 the Classification of Coarse-Grained Soils [more than 50 percent by dry mass retained on the No. 200 (75-μm) sieve]

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

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

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

$$Cu = \frac{D_{60}}{D_{10}} \tag{1}$$

$$Cc = \frac{(D_{30})^2}{D_{10}\,D_{60}} \tag{2}$$

where D_{10}, D_{30}, and D_{60} are the particle-size diameters corresponding to 10, 30, and 60 percent passing on the cumulative particle-size distribution curve (fig. 4).

NOTE 5.–It may be necessary to extrapolate the curve to obtain the D_{10} diameter.

12.3.1 If less than 5 percent 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 percent 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 percent 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 the plasticity chart (fig. 3). (If sufficient material for testing is not available, see subpar. 9.8.2.1.)

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 percent of the test specimen passes the No. 200 (75-μm) sieve, assign the soil a dual classification using two group symbols separated by a hyphen.

12.5.1 The first group symbol shall correspond to that for a gravel or sand having less than 5 percent fines (GW, GP, SW, SP), and the second symbol shall correspond to a gravel or sand having more than 12 percent 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 (e.g., well-graded gravel with clay, GW-GC; poorly graded sand with silt, SP-SM). (If sufficient material for testing is not available, see subpar. 9.8.2.1.)

NOTE 6.–If the fines plot as a silty clay, CL-ML, the second group symbol should be either GC or SC (e.g., a poorly graded sand with 10 percent 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 percent or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name (e.g., poorly graded gravel with sand, GP; clayey sand with gravel, SC).

12.7 If the field sample contained any cobbles and/or boulders, the words "with cobbles," or "with cobbles and boulders" shall be added to the group name (e.g., 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 USBR 5005. 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 procedures used shall be referenced.

NOTE 7.–Example: CLAYEY GRAVEL WITH SAND AND COBBLES (GC): Sample from interval had 46 percent fine to coarse, hard, subrounded gravel; 30 percent fine to coarse, hard, subrounded sand; 24 percent clayey fines; weak reaction with HCl; original field sample had 2 percent hard, subrounded cobbles; maximum dimension, 150 mm. LL = 38, PI = 19.

In-place conditions — firm, homogeneous, dry, brown
Geologic interpretation — alluvial fan

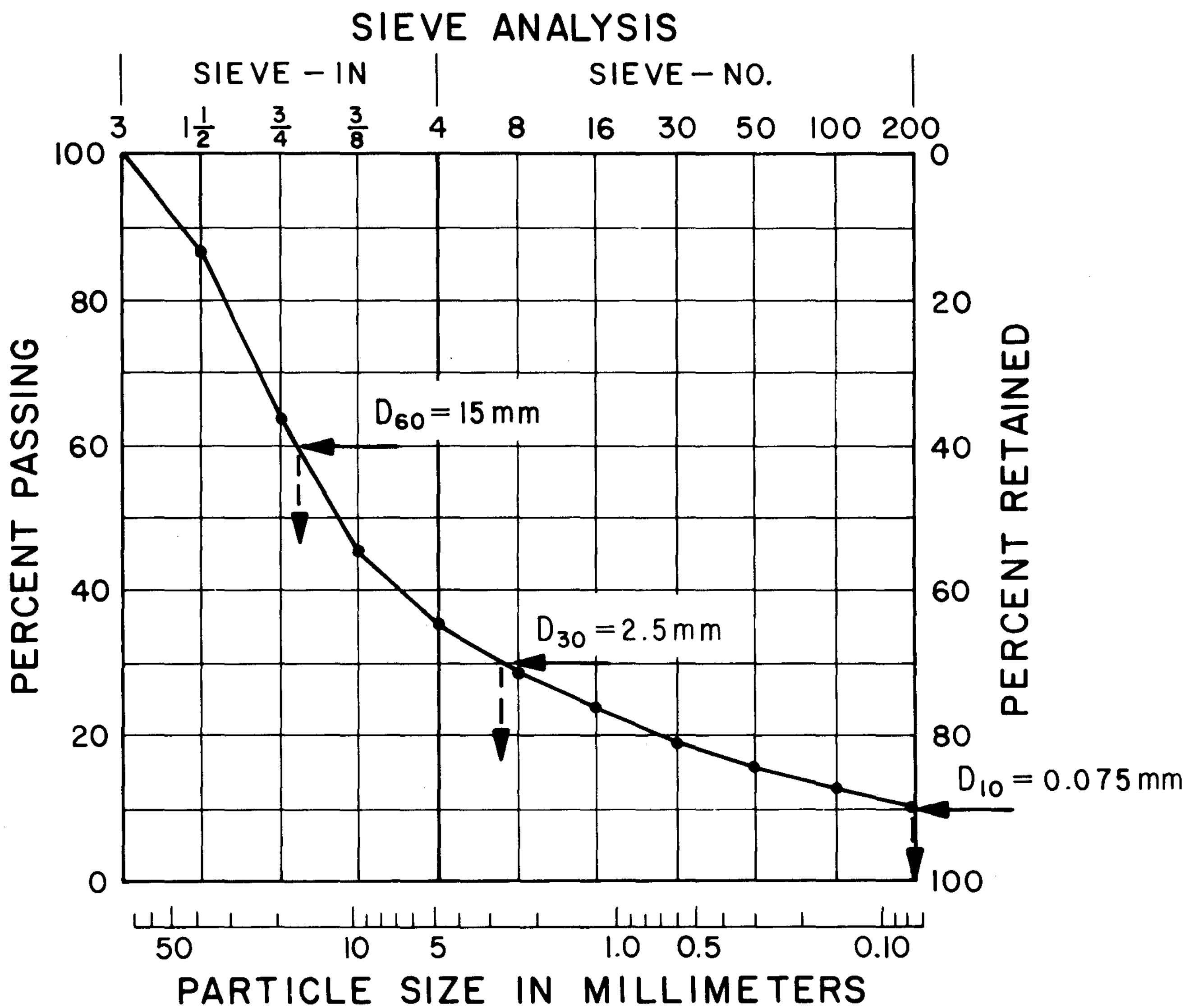
NOTE 8.–Other examples of soil descriptions are given in appendix X1.

14. Precision and Accuracy

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

15. Reference

[1] Casagrande, A., "Classification and Identification of Soils," *Trans. of the Am. Soc. of Civil Engineers*, p. 901, 1948.



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

Figure 4. – Gradation plot.

APPENDIXES

X1. EXAMPLES OF DESCRIPTIONS USING SOIL CLASSIFICATION

X1.1 The following examples show how the information required in subparagraph 13.1 can be reported. The appropriate descriptive information from USBR 5005 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.

Example 1: WELL-GRADED GRAVEL WITH SAND (GW): Sample had 73 percent fine to coarse, hard, subangular gravel; 23 percent fine to coarse, hard, subangular sand; 4 percent fines; maximum size, 75 mm; moist, brown; no reaction with HCl. $Cc = 2.7$, $Cu = 12.4$.

Example 2: SILTY SAND WITH GRAVEL (SM): Sample from interval had 61 percent predominantly fine sand; 23 percent silty fines; 16 percent fine, hard, subrounded gravel; maximum size, 20 mm; no reaction with HCl. Note: field sample smaller than recommended. LL = 33, PI = 6.

In-place conditions — firm, stratified, and contains lenses of silt 1 to 2 inches thick; moist, brown to gray; in-place dry unit weight = 106 lbf/ft^3 and in-place moisture = 9 percent.

Example 3: ORGANIC CLAY (OL): Sample had 100 percent fines, LL (not dried) = 32, LL (ovendried) = 21, PI (not dried) = 10; wet, dark brown, organic odor; weak reaction with HCl.

Example 4: SILTY SAND WITH ORGANIC FINES (SM): Sample had 74 percent fine to coarse, hard, subangular reddish sand; 26 percent organic and silty dark brown fines, LL (not dried) = 37, LL (ovendried) = 26, PI (not dried) = 6; maximum size, coarse sand; wet; weak reaction with HCl.

Example 5: POORLY GRADED GRAVEL WITH SILT, SAND, COBBLES, AND BOULDERS (GP-GM): Sample from interval had 78 percent fine to coarse, hard, subrounded to subangular gravel; 16 percent fine to coarse, hard, subrounded to subangular sand; 6 percent silty (estimated) fines; moist, brown; no reaction with HCl; original field sample had a trace of hard, subrounded cobbles and a trace of hard, subrounded boulders with a maximum dimension of 500 mm. $Cc = 0.8$, $Cu = 40$.

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 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 particle-size and plasticity characteristics may be used in the description of the material. If desired, a classification according to this 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 following 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 follow:

Example 1: SHALE CHUNKS: Retrieved as 2- to 4-inch pieces of shale from power auger hole; dry, brown; no reaction with HCl. After a sample was laboratory processed by slaking in water for 24 hours, the sample was classified as "SANDY LEAN CLAY (CL)" — 61 percent clayey fines, LL = 37, PI = 16; 33 percent fine to medium sand; 6 percent gravel-size pieces of shale.

Example 2: CRUSHED SANDSTONE: Product of commercial crushing operation; "POORLY GRADED SAND WITH SILT (SP-SM)" — sample had 91 percent fine to medium sand; 9 percent silty (estimated) fines; dry, reddish-brown; strong reaction with HCl.

Example 3: BROKEN SHELLS: Sample from interval had 62 percent gravel-size broken shells; 31 percent sand and sand-size shell pieces; 7 percent fines. Would be classified as "POORLY GRADED GRAVEL WITH SAND (GP)."

Example 4: CRUSHED ROCK: Processed gravel and cobbles from Pit No. 7; "POORLY GRADED GRAVEL (GP)" — sample had 89 percent fine, hard, angular gravel-size particles; 11 percent 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 moisture 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 method assume that the field sample contains fines, sand, gravel, and plus 3-inch (75-mm) particles, and the cumulative particle-size distribution plus the liquid limit and plasticity index values are required (see subpar. 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 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-inch (75-mm) sieve, the plus 3-inch (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-inch (75-mm) sieve shall be obtained as follows:

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

X3.6.2 Determine the air-dry or ovendry mass of the fraction retained on the 3-inch (75-mm) sieve. Determine the total (wet) mass of the fraction passing the 3-inch (75-mm) sieve.

X3.6.3 Thoroughly mix the fraction passing the 3-inch (75-mm) sieve. Determine the moisture content, in accordance with USBR 5300, of a representative specimen with a minimum dry mass as required in subparagraph 7.2. Save the moisture content specimen for determination of the particle-size analysis in accordance with subparagraph X3.8.

X3.6.4 Compute the dry mass of the fraction passing the 3-inch (75-mm) sieve based on the moisture content and total (wet) mass. Compute the total dry mass of the sample and calculate the percentage of material retained on the 3-inch (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 USBR 5205.

X3.7.1.1 If the soil contains coarse-grained particles coated with and bound together by tough clayey material, extreme care has to be taken in obtaining a representative portion of the minus No. 40 (425-μm) fraction. Typically, a larger portion than normal has to be selected, such as the minimum masses required in subparagraph 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 3/4-inch (19.0-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 ASTM: D 2217.

X3.7.3 Perform the liquid limit test in accordance with USBR 5350 or 5355, except the soil shall not be air-dried prior to the test.

X3.7.4 Perform the plastic limit test in accordance with USBR 5360, 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 moisture content of the fraction passing the 3-inch (75-mm) sieve was required (subpar. X3.6.3), use the moisture content specimen for determining the particle-size distribution. Otherwise, select a representative specimen in accordance with USBR 5205 with a minimum dry mass as required in subparagraph 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 USBR 5330 (see subpar. 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 USBR 5335 (see subpar. 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 ASTM 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 ASTM C 117, being sure to soak the specimen long enough to soften all clayey aggregations, followed by USBR 5335 using a set of sieves which shall include a No. 4 (4.75-mm) and a No. 200 (75-μm) sieve.

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

X4. PREPARATION AND TESTING FOR CLASSIFICATION PURPOSES BY THE AIR-DRIED METHOD

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 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-inch (75-mm) sieve, the plus 3-inch (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-inch (75-mm) sieve shall be obtained as follows:

X4.4.1 Air-dry and determine the mass of the field sample.

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

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

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

X4.5.1 Thoroughly mix the fraction passing the 3-inch (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 USBR 5330. (See subpar. 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 USBR 5335. (See subpar. 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 ASTM Method D 1140 followed by ASTM Method C 136 using a set of sieves which shall include a No. 4 (4.75-mm) 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 USBR 5350 (or USBR 5355) and USBR 5360.

X5. ABBREVIATED SOIL CLASSIFICATION SYMBOLS

X5.1 In some cases, because of lack of space, an abbreviated system may be used to indicate the soil classification symbol and name.

X5.2 The abbreviated system should consist of the soil classification symbol based on this designation with appropriate lower case letter prefixes and suffixes as:

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

X5.3 The soil classification symbol is to be enclosed in parenthesis. Some examples would be:

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

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

USBR 5005-86

PROCEDURE FOR

DETERMINING UNIFIED SOIL CLASSIFICATION (VISUAL METHOD)

INTRODUCTION

This procedure is under the jurisdiction of the Geotechnical Branch, code D-1540, Division of Research and Laboratory Services, E&R Center, Denver, Colorado. The procedure is issued under the fixed designation USBR 5005. The number immediately following the designation indicates the year of acceptance or the year of last revision.

This procedure is similar to ASTM D 2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) except for the following: (1) change in title and format, (2) references to USBR procedures, (3) note 2 in ASTM D 2488 is required in this procedure, (4) note 4 in ASTM D 2488 is required in this procedure, (5) the maximum particle size is in millimeters with prescribed increments of measurement, (6) the specimens for the dry strength test are one-fourth inch (6 mm) in diameter rather than one-half inch (12 mm), (7) note 14 is not used, and (8) moisture content is used here instead of water content and mass is substituted for weight.

For circumstances where it may be required or expedient to use ASTM standards, ASTM D 2487 or D 2488 may be substituted for USBR 5000 or 5005, respectively. However, it must be clearly stated in written comments, tables, figures, and logs that the ASTM standards were used.

1. Scope

1.1 This designation outlines the procedures for the description of soils for engineering purposes.

1.2 This designation outlines procedures for visually identifying soils for engineering purposes based on the classification system described in USBR 5000. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on the visual-manual processes.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures required in USBR 5000 shall be used.

1.2.2 The identification portion of this procedure — in assigning a group symbol and name — is limited to soil particles smaller than 3 inches (75 mm); that is, passing a U.S.A. Standard series 3-inch sieve.

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

NOTE 1.-This procedure may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (see app. X2).

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

2. Applicable Documents

2.1 *USBR Procedures*:

USBR 3900 Standard Definitions of Terms and Symbols Relating to Soil Mechanics

USBR 5000 Determining Unified Soil Classification (Laboratory Method)

2.2 *ASTM Standards*:

D 2487 Classification of Soils for Engineering Purposes

D 2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

3. Summary of Method

3.1 Using visual examination and simple manual tests, this procedure gives standardized criteria and processes for describing and identifying soils.

3.2 Soil can be given an identification by assigning a group symbol(s) and name. The flow charts (figure 1 for fine-grained soils and figure 2 for coarse-grained soils) can be used to determine the appropriate group symbol(s) and name. If the soil has visually determined properties that do not distinctly place it into a specific group, borderline symbols may be used (see app. X3).

3.3 A distinction must be made between *dual symbols* and *borderline symbols*.

3.3.1 A *dual symbol* (two symbols separated by a hyphen, e.g., GP-GM, SW-SC, CL-ML) should be used to indicate the soil has been identified as having the properties of a classification as required by USBR 5000 where two symbols are required. Two symbols are required when the soil has between 5 and 12 percent fines and where the liquid limit and plasticity index values plot in the CL-ML (cross hatched) area of the plasticity chart.

3.3.2 A *borderline symbol* (two symbols separated by a slash, e.g., CL/CH, GM/SM, CL/ML) should be used to indicate the soil has been identified as having properties

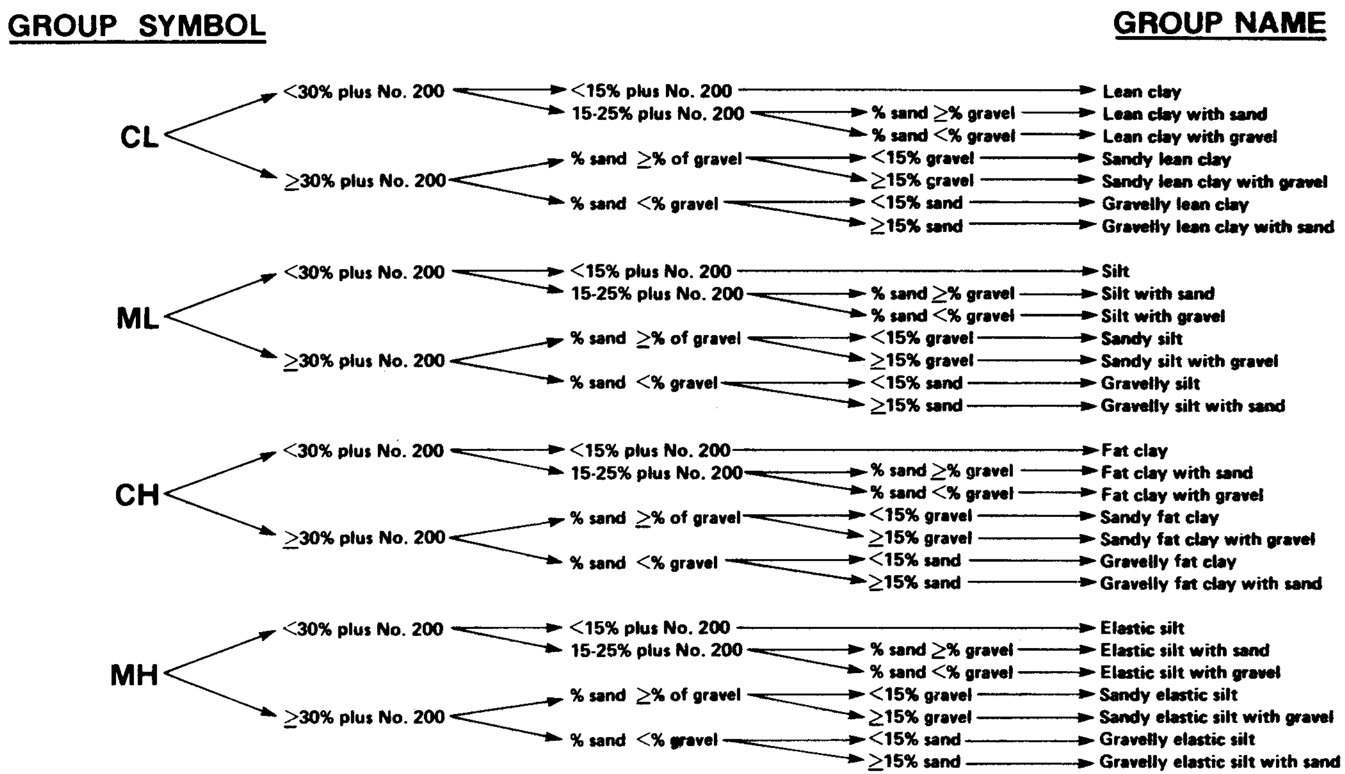


Figure 1a. – Flowchart for identifying inorganic fine-grained soil (50% or more fines) — visual-manual method.

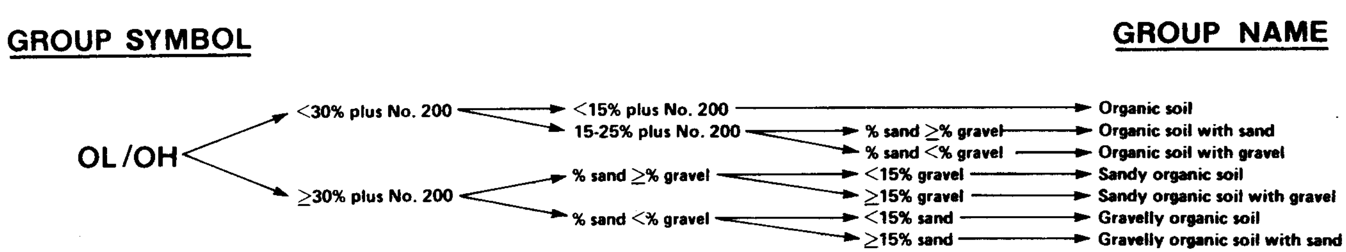


Figure 1b. – Flowchart for identifying organic fine-grained soil (50% or more fines) — visual-manual method.

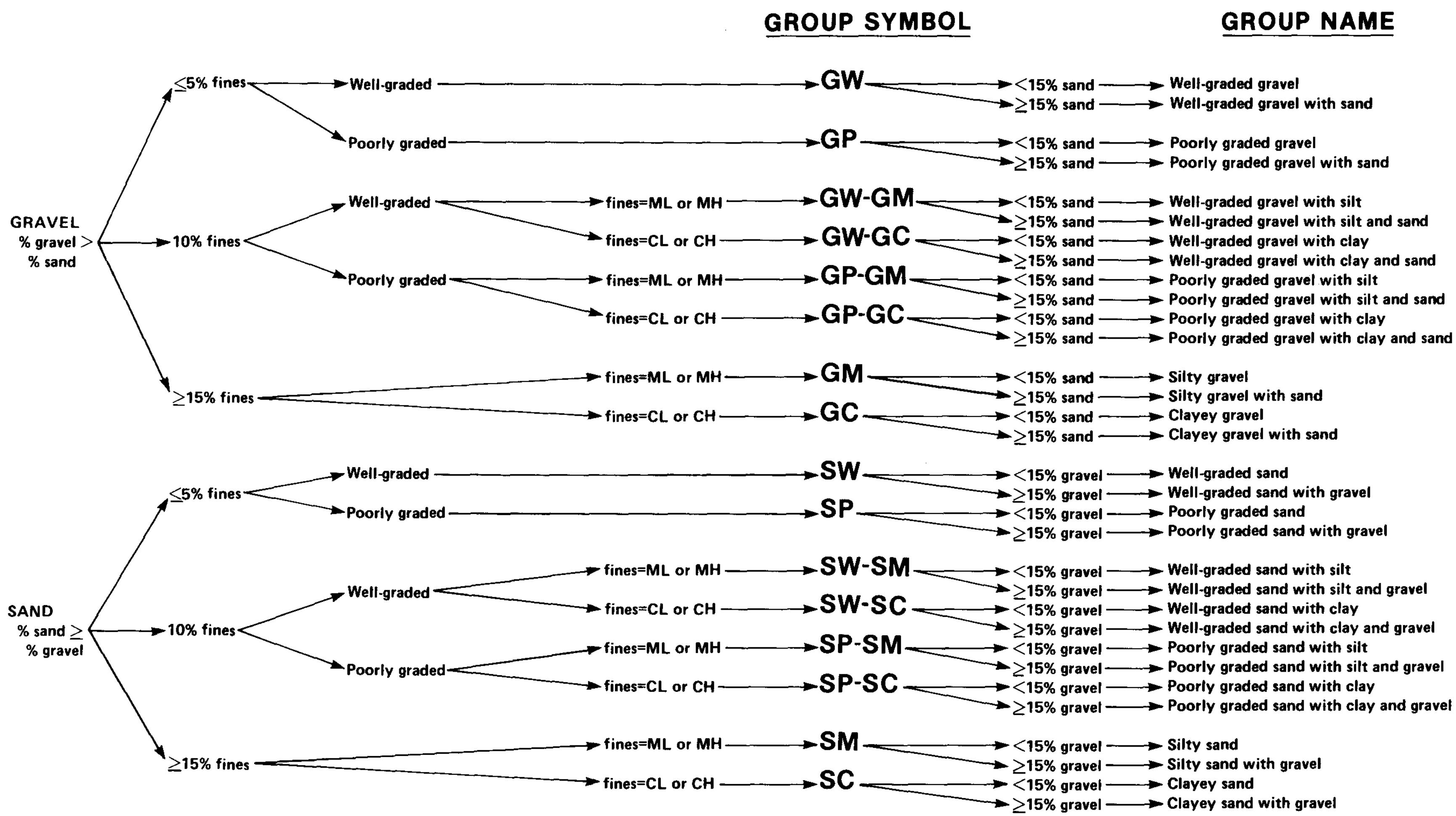


Figure 2. - Flowchart for identifying coarse-grained soils (less than 50% fines) — visual-manual method.

that do not distinctly place the soil into a specific group (see app. X3).

4. Significance and Use

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

4.2 The descriptive information required in this procedure should be used to supplement the classification of a soil as determined in USBR 5000.

4.3 This procedure may be used in identifying soils using the classification group symbols and names as prescribed in USBR 5000. Since the names and symbols used in this procedure to identify the soils are the same as those used in USBR 5000, it shall be clearly stated in reports, etc., that the classification symbol and name are based on the visual-manual procedures.

4.4 This procedure is to be used not only for identification of soils in the field but also in the office, in the laboratory, or wherever soil samples are inspected and described.

4.5 The procedure 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 2.-The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it also may be acquired systematically by comparing numerical laboratory test results for typical soils of each type with their visual and manual characteristics.

4.6 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 processes in this procedure for every sample. Soils which appear to be similar can be grouped together. One sample from the group can be completely described and identified, with the others referred to "as similar" based on performing only a few of the descriptive and identification processes described in this procedure.

5. Terminology

5.1 Definitions are in accordance with USBR 3900. Terms of particular significance are:

5.1.1 *Boulder*.-A particle of rock that will not pass a 12-inch (300-mm) square opening.

5.1.2 *Cobble*.-A particle of rock that will pass a 12-inch (300-mm) square opening and be retained on a 3-inch (75-mm) U.S.A. Standard sieve.

5.1.3 *Peat*.-A soil composed primarily of vegetable tissue in various stages of decomposition with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous (ASTM D 2487-83).

5.2 *Terms Specific to This Designation*:

5.2.1 *Gravel*.-Particles of rock that will pass a 3-inch (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

Coarse	— Passes 3-inch (75-mm) sieve and retained on 3/4-inch (19.0-mm) sieve
Fine	— Passes 3/4-inch (19.0-mm) sieve and retained on No. 4 (4.75-mm) sieve

5.2.2 *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 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
Fine	— Passes No. 40 (425-μm) sieve and retained on No. 200 (75-μm) sieve

5.2.3 *Clay*.-Soil passing the No. 200 (75-μm) U.S.A. Standard sieve that exhibits plasticity (putty-like properties) within a range of moisture contents, and which exhibits considerable strength when air-dried. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, having 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, USBR 5000).

5.2.4 *Silt*.-Material passing the No. 200 (75-μm) U.S.A. Standard sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air-dried (ASTM). For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, having a plasticity index less than 4 or if the plot of plasticity index versus liquid limit falls below the "A"-line (see fig. 3, USBR 5000).

5.2.5 *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 ovendrying is less than 75 percent of its liquid limit value before ovendrying.

5.2.6 *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 ovendrying is less than 75 percent of its liquid limit value before ovendrying.

6. Apparatus

6.1 *Required Apparatus*:

6.1.1 Small supply of water.

6.1.2 Pocket knife or small spatula.

6.2 *Useful Auxiliary Apparatus*:

6.2.1 Small bottle of dilute hydrochloric acid, one part HCl (10 N) to three parts distilled water.

6.2.2 Small test tube and stopper, or jar with a lid.

6.2.3 Dish for wash test.

6.2.4 Small hand lens.

6.2.5 Ruler.

7. Precautions

7.1 When preparing the dilute HCl (hydrochloric acid) solution of one part concentrated HCl (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 in contact with skin, rinse thoroughly with water.

CAUTION.-Do not add water to acid.

8. Sampling

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

NOTE 3.-The sampling procedure should be identified as having been conducted in accordance with a USBR procedure or an ASTM standard, or other appropriate standard or procedure.

8.2 The sample shall be carefully identified as to origin.

NOTE 4.-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, grid system, or station number and offset with respect to a stated centerline, and a depth or elevation.

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

Maximum particle size, sieve opening		*Minimum specimen size, dry mass*	
mm	in	kg	lbm
4.75	No. 4	0.1	0.2
9.5	3/8	0.25	0.5
19.0	3/4	1.1	2.5
37.5	1-1/2	10	20
75.0	3	70	150

NOTE 5.-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 above schedule.

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

9. Descriptive Information

9.1 Describe the *angularity* of the sand (coarse sizes only), gravel, cobbles, and boulders as rounded, subrounded, subangular, or angular as indicated by the criteria in table 1 and on figure 3. A range of angularity may be stated such as subrounded to rounded.

9.2 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 on figure 4; otherwise, do not remark. Indicate the fraction of particles having that shape such as one-third of gravel particles are flat.

9.3 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 should be noted and all representative colors should be described. Color should be described for moist samples. If color represents a dry condition, this should be stated in the report.

9.4 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

Table 1. - Criteria for describing angularity of coarse-grained particles (see fig. 3).

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

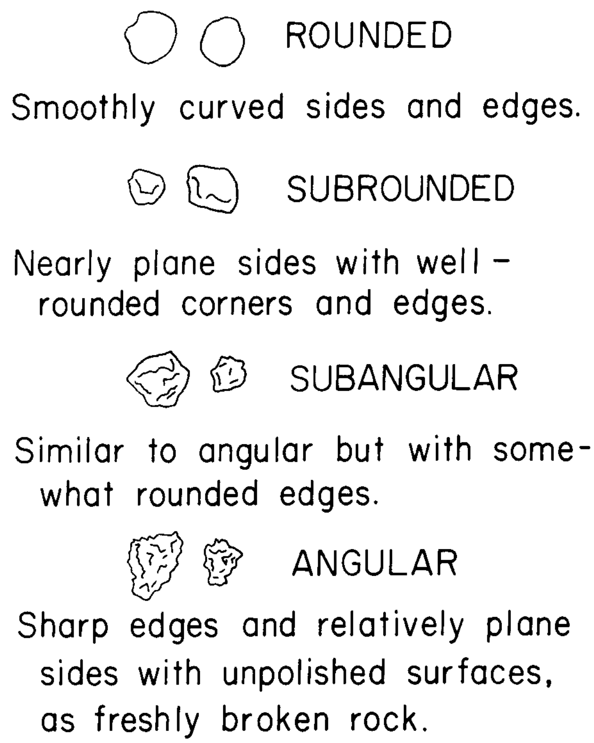
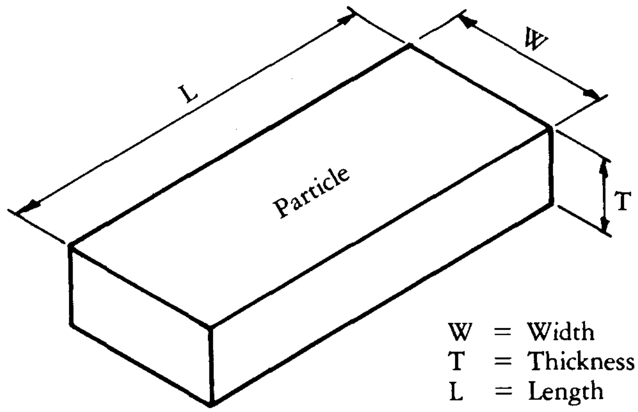


Figure 3. - Typical angularity of coarse-grained particles.

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 $\frac{\text{width}}{\text{thickness}} > 3$
Elongated	- Particles with $\frac{\text{length}}{\text{width}} > 3$
Flat and elongated	- Particles meet criteria for both flat and elongated



Flat: $W/T > 3$
Elongated: $L/W > 3$
Flat and Elongated: meets both criteria

Figure 4. - Criteria for particle shape.

Table 3. - Criteria for describing moisture condition.

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

Table 4. - Criteria for describing the reaction with HCl.

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

Table 5. - Criteria for describing consistency.

Very soft	- Thumb penetrates soil more than 1 inch (25 mm)
Soft	- Thumb penetrates soil about 1 inch (25 mm)
Firm	- Thumb indents soil about 1/4 inch (6 mm)
Hard	- Thumb cannot indent soil but readily indented with thumbnail
Very hard	- Thumbnail cannot indent soil

Table 6. - Criteria for describing cementation.

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

Table 7. - Criteria for describing structure.

Stratified	- Alternating layers of varying material or color with layers at least 1/4 inch (6 mm) thick; note thickness
Laminated	- Alternating layers of varying material or color with the layers less than 1/4 inch (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

are dried, the odor may often be revived by heating a moistened sample. Describe the odor if unusual (petroleum product, chemical, etc.).

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

9.6 Describe the *reaction with HCl* as none, weak, or strong as indicated by the criteria in table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute HCl is important.

9.7 For intact fine-grained soil, describe the *consistency* as very soft, soft, firm, hard, or very hard as indicated by the criteria in table 5. This observation is inappropriate for disturbed soils or soils with significant amounts of gravel.

9.8 Describe the *cementation* of intact coarse-grained soils as weak, moderate, or strong as indicated by the criteria in table 6.

9.9 Describe the *structure* of intact soils according to the criteria in table 7.

9.10 For gravel and sand components, describe the range of particle sizes within each component as defined in subparagraphs 5.2.1 and 5.2.2 (for example: about 20 percent fine to coarse gravel, about 40 percent fine to coarse sand).

9.11 Describe the *maximum particle size* found in the sample.

9.11.1 If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in subparagraph 5.2.2 (for example: maximum size, medium sand).

9.11.2 If the maximum particle size is a gravel size, describe maximum particle size in millimeters as the smallest sieve opening that the particle would pass [for example: maximum size, 37.5 mm (would pass 37.5-mm-square opening but not a 19.0-mm-square opening)].

9.11.3 If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle (for example: maximum dimension, 400 mm). Use 25-mm increments from 75 to 300 mm (cobbles) and 100-mm increments for particles larger than 300 mm (boulders).

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

9.13 Additional comments should be noted such as:
Presence of roots or root holes
Difficulty in drilling or augering hole
Caving of trench or hole
Presence of mica

9.14 A local or commercial name and/or a geologic interpretation for the soil may be added if identified as such.

9.15 A classification or identification of the soil according to other classification systems may be added if identified as such.

10. Identification of Peat

10.1 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 should be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the identification procedures described hereafter.

11. Specimen Preparation for Identification

11.1 The soil identification portion of this procedure is based on the minus 3-inch (75-mm) particle sizes. The plus 3-inch (75-mm) particles must be removed, manually, for a loose sample, or mentally evaluated, for an intact sample before classifying the soil.

11.2 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 6.-Since the percentages of the particle-size distribution in USBR 5000 are by dry mass and the estimates of percentages for gravel, sand, and fines in this procedure are by dry mass, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

11.3 Of the fraction of the soil smaller than 3 inches (75 mm), estimate and note the percentage, by dry mass, of the gravel, sand, and fines. (See app. X4 for suggested procedures.)

NOTE 7.-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 mass. Frequent comparisons with laboratory gradation analyses should be made.

11.3.1 The percentages shall be estimated to the nearest 5 percent. The percentages of gravel, sand, and fines must add up to 100 percent.

11.3.2 If one of the components is present, but not in sufficient quantity to be considered 5 percent of the minus 3-inch (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 percent for the components.

12. Preliminary Identification Procedure

12.1 The soil is *fine grained* if it contains 50 percent or more fines; follow paragraph 13.

12.2 The soil is *coarse grained* if it contains less than 50 percent fines; follow paragraph 14.

13. Procedure for Identifying Fine-Grained Soils

13.1 *Selection.*-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.

13.2 *Dry Strength.*-From the specimen, select enough material to mold into a ball about 1 inch (25 mm) in diameter. Mold the material until it has the consistency of putty; add water if necessary.

13.2.1 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about 1/4 inch (6 mm) in diameter. Allow the test specimens to dry in air or sun or dry by artificial means as long as the temperature does not exceed 140 °F (60 °C).

13.2.2 If the test specimen contains natural dry lumps, those that are about 1/4 inch (6 mm) in diameter may be used in place of the molded balls.

NOTE 8.-The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

13.2.3 Test the strength of the dry balls or lumps by crushing between the fingers and note the strength as none, low, medium, high, or very high according to 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.

13.2.4 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate usually can be detected from the intensity of the reaction with dilute hydrochloric acid (see subpar. 9.6).

13.3 *Dilatancy.*-From the specimen, select enough material to mold into a ball about 1/2 inch (12 mm) in diameter. Mold the material; add water if necessary until it has a soft, but not sticky, consistency.

13.3.1 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

Table 8. - Criteria for describing dry strength.

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.

by closing the hand or pinching the soil between the fingers and note reaction as none, slow, or rapid according to the criteria in table 9. The reaction is the speed at which water appears while shaking and disappears while squeezing.

13.4 *Toughness*.-Following completion of the dilatancy test, shape the test specimen into an elongated pat and roll by hand on a smooth surface or between the palms into a thread about 1/8 inch (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread out 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 1/8 inch (3 mm). The thread will crumble at a diameter of 1/8 inch (3 mm) 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.

13.4.1 Describe the toughness of the thread and lump as low, medium, or high according to the criteria in table 10.

13.5 *Plasticity*.-On the basis of observations made during the toughness test, describe the plasticity of the material according to the criteria given in table 11.

13.6 *Inorganic/Organic*.-Decide whether the soil is an *inorganic* or an *organic* fine-grained soil (see subpar. 13.8). If inorganic, follow subparagraph 13.7.

13.7 *Identification of Inorganic Fine-Grained Soils*:

13.7.1 Identify the soil as a *lean clay*, CL, if the soil has medium to high dry strength, none to slow dilatancy, and medium toughness and plasticity (see table 12).

13.7.2 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).

13.7.3 Identify the soil as a *silt*, ML, if the soil has none to low dry strength, slow to rapid dilatancy, and low toughness and plasticity or is nonplastic (see table 12).

Table 9. - Criteria for describing dilatancy.

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.

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.

Nonplastic	- A 1/8-inch (3-mm) thread cannot be rolled at any moisture content.
Low	- The thread can be barely 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 close to 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

13.7.4 Identify the soil as an *elastic silt*, MH, if the soil has low to medium dry strength, none to slow dilatancy, and low to medium toughness and plasticity (see table 12).

NOTE 9.-These properties for elastic silt are similar to those for a lean clay. However, the silt will dry much faster on the hand and have a smooth, silky feel when dry. Some soils which would classify as elastic silt, MH, according to the criteria in USBR 5000 are visually difficult to distinguish from lean clay, CL. It may be necessary to perform laboratory testing for proper identification.

13.8 *Identification of Organic Fine-Grained Soils*:

13.8.1 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, e.g., black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air dried. Normally, organic soils would not have a high toughness or plasticity. The thread for the toughness test will be spongy.

NOTE 10.-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, and toughness tests and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

13.9 If the soil is estimated to have 15 to 25 percent sand or gravel or both, the words "with sand" or "with gravel" shall be added to the group name (see figs. 1a and 1b) (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."

13.10 If the soil is estimated to have 30 percent 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 (see figs. 1a and 1b) (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."

14. Procedure for Identifying Coarse-Grained Soils (contains less than 50 % fines)

14.1 The soil is a *gravel* if the percent gravel is estimated to be more than the percent sand.

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

14.3 The soil is a *clean gravel* or *clean sand* if the percent fines is estimated to be 5 percent or less.

14.3.1 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.

14.3.2 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 if it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

14.4 The soil is either a *gravel with fines* or a *sand with fines* if the percent fines is estimated to be 15 percent or more.

14.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in paragraph 13.

14.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in paragraph 13.

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

14.5.1 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).

14.5.2 The group name shall correspond to the first group symbol plus "with clay" or "with silt" to indicate the plasticity characteristics of the fines (see fig. 2) (for example: well-graded gravel with clay, GW-GC; poorly graded sand with silt, SP-SM).

14.6 If the specimen is predominantly sand or gravel but contains an estimated 15 percent or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name (see fig. 2) (for example: poorly graded gravel with sand, GP; clayey sand with gravel, SC).

14.7 If the field sample contained any cobbles and/or boulders, the words "with cobbles," or "with cobbles and boulders" shall be added to the group name (for example: silty gravel with cobbles, GM).

15. Report

15.1 The report shall include information as to sample origin as well as the items indicated in table 13.

NOTE 11.–Example: CLAYEY GRAVEL WITH SAND AND COBBLES (GC): About 50 percent fine to coarse, subrounded to subangular gravel; about 30 percent fine to coarse, subrounded sand; about 20 percent fines with medium plasticity, high dry strength, no dilatancy, medium toughness; original field sample had trace of hard, subrounded cobbles; maximum size, 150 mm; weak reaction with HCl.

In-place conditions: firm, homogeneous, dry, brown
Geologic interpretation: alluvial fan

NOTE 12.–Other examples of soil descriptions and identifications are given in appendixes X1 and X2.

15.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in USBR 5000, it must be distinctly and clearly stated in log forms, summary tables, reports, etc., that the symbol and name are based on visual-manual procedures.

16. Precision and Accuracy

16.1 This method provides qualitative information only; therefore, a precision and accuracy statement is nonapplicable.

Table 13. - Checklist for description of soils.

1. Group name
2. Group symbol
3. Percent of cobbles and/or boulders (by volume)
4. Percent of gravel, sand and/or fines (by dry mass)
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

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 excavation
Etc.

APPENDIX

X1. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show how the information required in subparagraph 15.1 can be reported. The information that is included in descriptions should be based on individual circumstances and need.

Example 1: WELL-GRADED GRAVEL WITH SAND (GW): About 75 percent fine to coarse, hard, subangular gravel; about 25 percent fine to coarse, hard, subangular sand; trace of fines; maximum size, 75 mm; dry, brown; no reaction with HCl.

Example 2: SILTY SAND WITH GRAVEL (SM): About 60 percent predominantly fine sand; about 25 percent fines with low plasticity, low dry strength, rapid dilatancy, low toughness; about 15 percent fine, hard, subrounded gravel (a few gravel-size particles fractured with hammer blow); maximum size, 20 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 inches thick, moist, brown to gray; in-place dry unit weight was 106 lbf/ft^3 and in-place moisture was 9 percent.

Example 3: ORGANIC SOIL (OL/OH): About 100 percent fines with low plasticity, slow dilatancy, low dry strength, low toughness; wet, dark brown, organic odor; weak reaction with HCl.

Example 4: SILTY SAND WITH ORGANIC FINES (SM): About 75 percent fine to coarse, hard, subangular reddish sand; about 25 percent organic and dark brown nonplastic fines, no dry strength, slow dilatancy; wet; maximum size, coarse sand; weak reaction with HCl.

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

X2. USING THE IDENTIFICATION METHOD AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, ETC.

X2.1 The identification 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 processes used in this procedure 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 method 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 could be incorporated into a descriptive system for materials that are not naturally occurring soils follow.

Example 1: SHALE CHUNKS: Retrieved as 2- to 4-inch pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 hours, material identified as "SANDY LEAN CLAY (CL)" — About 60 percent fines with medium plasticity, high dry strength, no dilatancy, medium toughness; about 35 percent fine to medium sand; about 5 percent gravel-size pieces of shale.

Example 2: CRUSHED SANDSTONE: Product of commercial crushing operation; "POORLY GRADED SAND WITH SILT (SP-SM)" — About 90 percent fine to medium sand; about 10 percent nonplastic fines; maximum size, medium sand; dry, reddish-brown; strong reaction with HCl.

Example 3: BROKEN SHELLS: Natural deposit of shells; "POORLY GRADED GRAVEL WITH SAND (GP)" — About 60 percent gravel-size broken shells; about 35 percent sand and sand-size shell pieces; about 5 percent fines.

Example 4: CRUSHED ROCK: Processed from gravel and cobbles in Pit No. 7; "POORLY GRADED GRAVEL (GP)" — About 90 percent fine, hard, angular gravel-size particles; about 10 percent coarse, hard, angular sand-size particles; maximum size, 20 mm; 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, CL/CH).

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

X3.1.2 A borderline symbol may be used when the percent sand and the percent gravel is estimated to be about the same (for example: GP/SP, SC/GC, GM/SM). It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

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 should be made to place the soil into a single group.

X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENT 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 seconds. 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 then can be estimated from the wash test (see subpar. 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-inch (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 mass, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

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

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In-place conditions — firm, stratified and contains lenses of silt 1 to 2 inches thick, moist, brown to gray; in-place dry unit weight was 106 lbf/ft^3 and in-place moisture was 9 percent.

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X2.2 Materials such as shells, crushed rock, slag, etc., should be identified as such. However, the processes used in this procedure 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 method may be assigned to aid in describing the material.

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X3.1.2 A borderline symbol may be used when the percent sand and the percent gravel is estimated to be about the same (for example: GP/SP, SC/GC, GM/SM). It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

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X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENT 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 seconds. 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 then can be estimated from the wash test (see subpar. 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-inch (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 mass, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

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

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Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.