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## Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)<sup>1</sup>

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

*This standard has been approved for use by agencies of the Department of Defense.*

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<sup>ε1</sup> NOTE—Table 1 was editorially reformatted in August 2008.

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### 1. Scope\*

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

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

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

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

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

1.4 This standard is for qualitative application only.

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

1.5 This standard is the ASTM version of the Unified Soil Classification System. The basis for the classification scheme is the Airfield Classification System developed by A. Casagrande in the early 1940's.<sup>2</sup> It became known as the Unified Soil Classification System when several U.S. Government Agencies adopted a modified version of the Airfield System in 1952.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

### 2. Referenced Documents

2.1 *ASTM Standards:*<sup>3</sup>

C 117 Test Method for Materials Finer Than 75- $\mu\text{m}$  than 75-m (No. 200) Sieve in Mineral Aggregates by Washing

<sup>1</sup> This standard is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

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<sup>2</sup> Casagrande, A., "Classification and Identification of Soils," *Transactions*, ASCE, 1948, p. 901.

<sup>3</sup> Annual Book of ASTM Standards, Vol 04.02.

\*A Summary of Changes section appears at the end of this standard.

TABLE 1 Soil Classification Chart

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

<sup>A</sup> Based on the material passing the 3-in. (75-mm) sieve.

<sup>B</sup> If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

<sup>C</sup> 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

<sup>D</sup>  $Cu = D_{60}/D_{10}$   $Cc = (D_{30})^2 / D_{10} \times D_{60}$

<sup>E</sup> If soil contains  $\geq 15$  % sand, add "with sand" to group name.

<sup>F</sup> If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

<sup>G</sup> If fines are organic, add "with organic fines" to group name.

<sup>H</sup> 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

<sup>I</sup> If soil contains  $\geq 15$  % gravel, add "with gravel" to group name.

<sup>J</sup> If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

<sup>K</sup> If soil contains 15 to 29 % plus No. 200, add "with sand" or "with gravel," whichever is predominant.

<sup>L</sup> If soil contains  $\geq 30$  % plus No. 200, predominantly sand, add "sand" to group name.

<sup>M</sup> If soil contains  $\geq 30$  % plus No. 200, predominantly gravel, add "gravelly" to group name.

<sup>N</sup>  $PI \geq 4$  and plots on or above "A" line.

<sup>O</sup>  $PI < 4$  or plots below "A" line.

<sup>P</sup>  $PI$  plots on or above "A" line.

<sup>Q</sup>  $PI$  plots below "A" line.

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 702 Practice for Reducing Field-Samples of Aggregate to Testing Size

D 420 Guide to Site Characterization for Engineering, Design and Construction Purposes

D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants—Guide to Site Characterization for Engineering Design and Construction Purposes

D 422 Test Method for Particle-Size Analysis of Soils

D 653 Terminology Relating to Soil, Rock, and Contained Fluids

D 1140 Test Methods for Amount of Material in Soils Finer than the No. 200 (75- $\mu$ m)(75-m) Sieve

D 2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

- D 2217 Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
- D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
- D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)
- D 4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- D 4427 ~~Classification of Peat Samples by Laboratory Testing~~<sup>4</sup> Classification of Peat Samples by Laboratory Testing
- D 6913 Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis
- E 11 ~~Specification for Wire-Cloth Sieves for Testing Purposes~~ Specification for Wire Cloth and Sieves for Testing Purposes

### 3. Terminology

3.1 *Definitions*— Except as listed below, all definitions are in accordance with Terminology D 653.

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

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

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

3.1.1 *clay*—soil passing a No. 200 (75-μm) U.S. standard sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents and that exhibits considerable strength when air dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the “A” line.

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

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

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

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

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

3.1.5 *peat*—a soil composed of vegetable tissue in various stages of decomposition usually with an organic odor, a dark-brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

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

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

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

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

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *coefficient of curvature, C<sub>c</sub>*—the ratio  $(D_{30})^2 / (D_{10} \times D_{60})$ , where  $D_{60}$ ,  $D_{30}$ , and  $D_{10}$  are the particle sizes corresponding to 60, 30, and 10 % finer on the cumulative particle-size distribution curve, respectively.

3.2.2 *coefficient of uniformity, C<sub>u</sub>*—the ratio  $D_{60} / D_{10}$ , where  $D_{60}$  and  $D_{10}$  are the particle diameters corresponding to 60 and 10 % finer on the cumulative particle-size distribution curve, respectively.

### 4. Summary

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

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests <sup>A</sup>				Soil Classification	
				Group Symbol	Group Name <sup>B</sup>
COARSE-GRAINED SOILS	Gravels	Clean Gravels	$C_u \geq 4$ and $1 \leq C_c \leq 3^C$	GW	Well-graded gravel <sup>D</sup>
	More than 50% retained on No. 200 sieve	Less than 5% fines <sup>E</sup>	$C_u < 4$ and/or $1 > C_c > 3^C$	GP	Poorly-graded gravel <sup>D</sup>
	More than 50% of coarse fraction retained on No. 4 sieve	Gravels with Fines	Fines classify as ML or MH	GM	Silty gravel <sup>D, F, G</sup>

TABLE 1—Continued

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

<sup>A</sup>Based on the material passing the 3-in. (75-mm) sieve.

<sup>B</sup>If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

<sup>C</sup> $Cu = D_{60}/D_{10}$   $Cc = (D_{30})^2 / D_{10} \times D_{60}$

<sup>D</sup>If soil contains  $\geq 15\%$  sand, add "with sand" to group name.

<sup>E</sup>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

<sup>F</sup>If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

<sup>G</sup>If fines are organic, add "with organic fines" to group name.

<sup>H</sup>If soil contains  $\geq 15\%$  gravel, add "with gravel" to group name.

<sup>I</sup>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

<sup>J</sup>If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

<sup>K</sup>If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

<sup>L</sup>If soil contains  $\geq 30\%$  plus No. 200, predominantly sand, add "sand" to group name.

<sup>M</sup>If soil contains  $\geq 30\%$  plus No. 200, predominantly gravel, add "gravelly" to group name.

<sup>N</sup> $PI \geq 4$  and plots on or above "A" line.

<sup>O</sup> $PI < 4$  or plots below "A" line.

<sup>P</sup> $PI$  plots on or above "A" line.

<sup>Q</sup> $PI$  plots below "A" line.

4.2 Based on the results of visual observations and prescribed laboratory tests, a soil is catalogued according to the basic soil groups, assigned a group symbol(s) and name, and thereby classified. The flow charts, Fig. 1 for fine-grained soils, and Fig. 3 for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name.

## 5. Significance and Use

5.1 This standard classifies soils from any geographic location into categories representing the results of prescribed laboratory tests to determine the particle-size characteristics, the liquid limit, and the plasticity index.

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

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

5.4 This standard may also be used as an aid in training personnel in the use of Practice D 2488.

5.5 This standard may be used in combination with Practice D 4083 when working with frozen soils.

NOTE 5—Notwithstanding the statements on precision and bias contained in this standard: The precision of this test method is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D 3740 does not in itself assure reliable testing. Reliable testing depends on several factors; Practice D 3740 provides a means for evaluating some of those factors.

## 6. Apparatus

6.1 In addition to the apparatus that may be required for obtaining and preparing the samples and conducting the prescribed laboratory tests, a plasticity chart, similar to Fig. 4, and a cumulative particle-size distribution curve, similar to Fig. 5, are required.

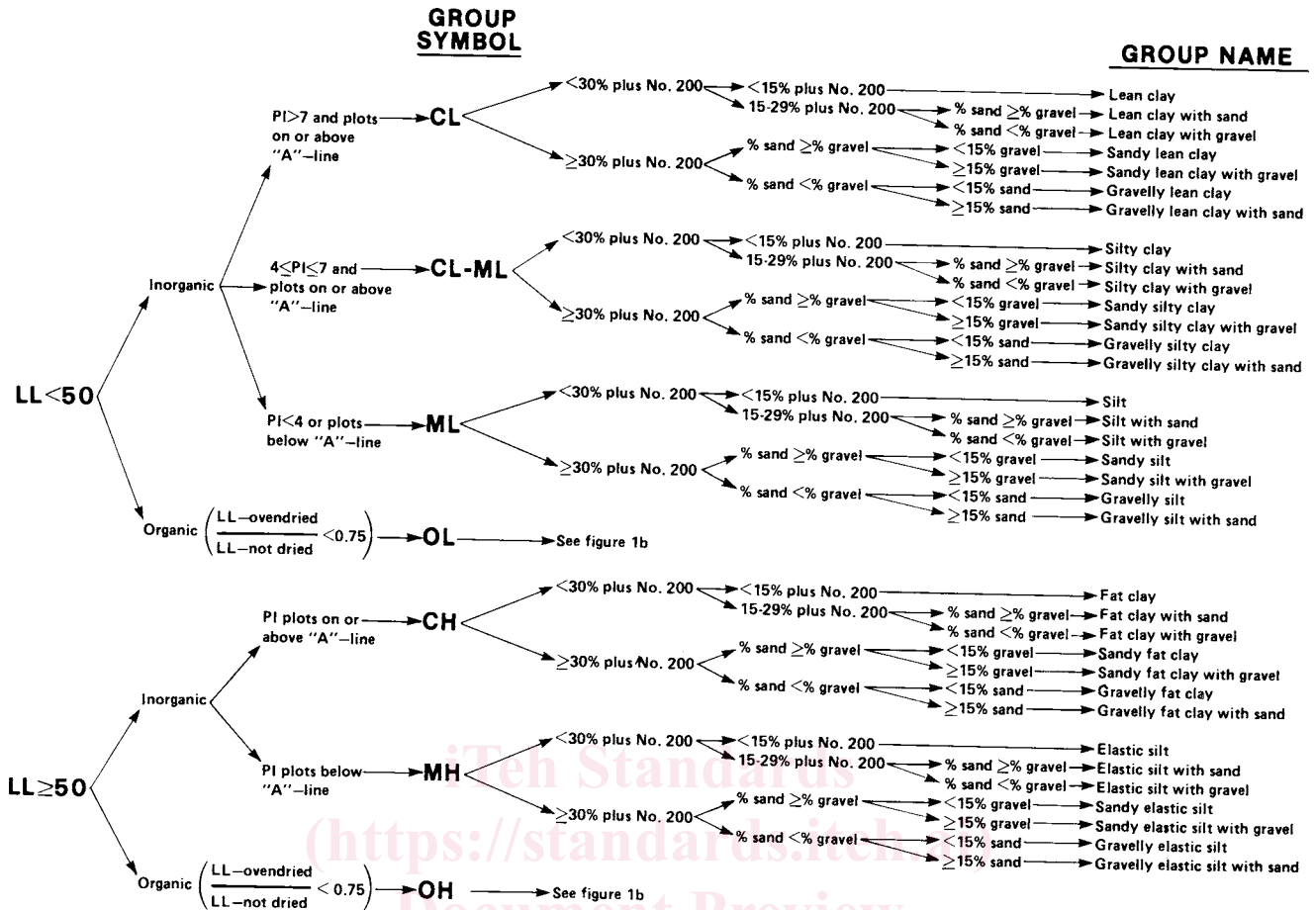


FIG. 1 Flow Chart for Classifying Fine-Grained Soil (50% or More Passes No. 200 Sieve)

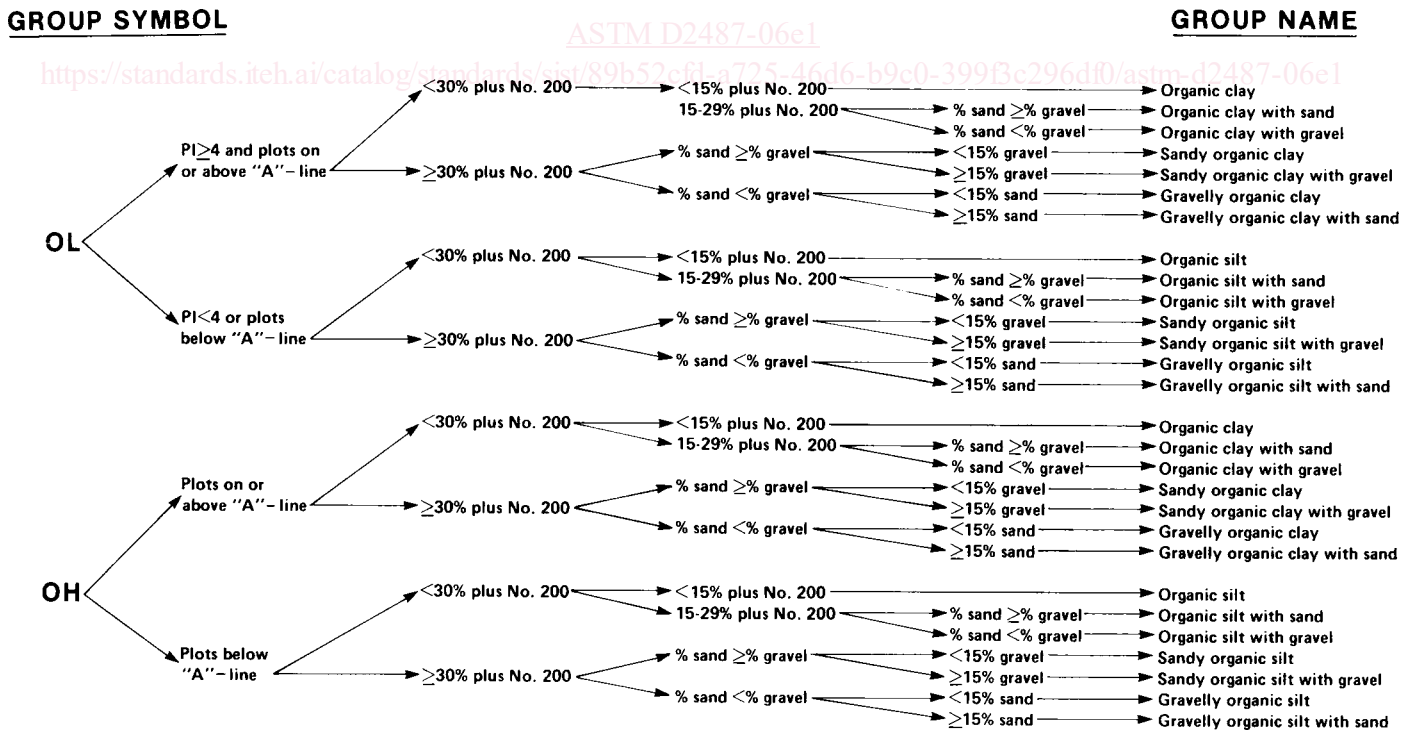


FIG. 2 Flow Chart for Classifying Organic Fine-Grained Soil (50% or More Passes No. 200 Sieve)

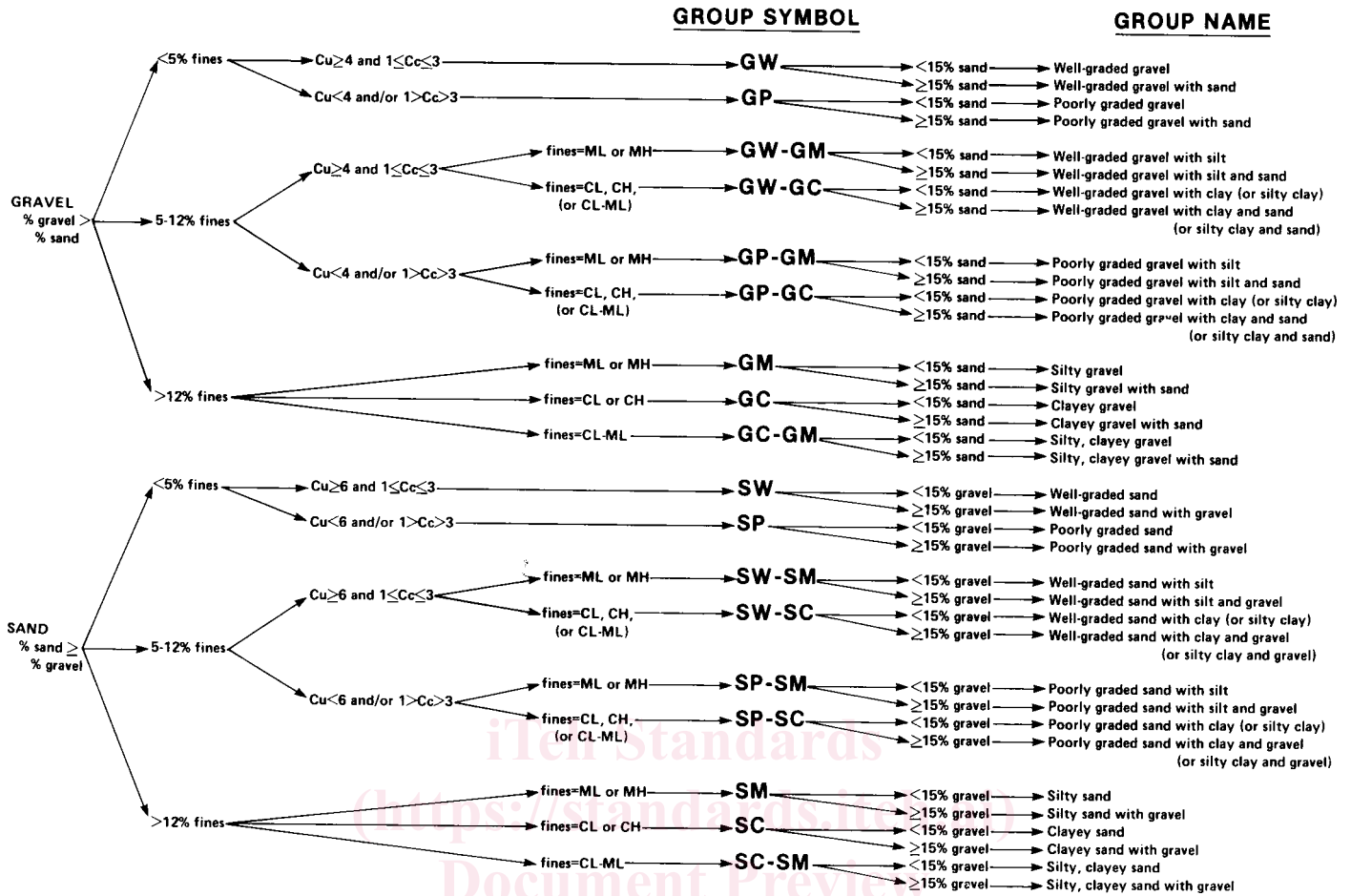


FIG. 3 Flow Chart for Classifying Coarse-Grained Soils (More Than 50 % Retained on No. 200 Sieve)

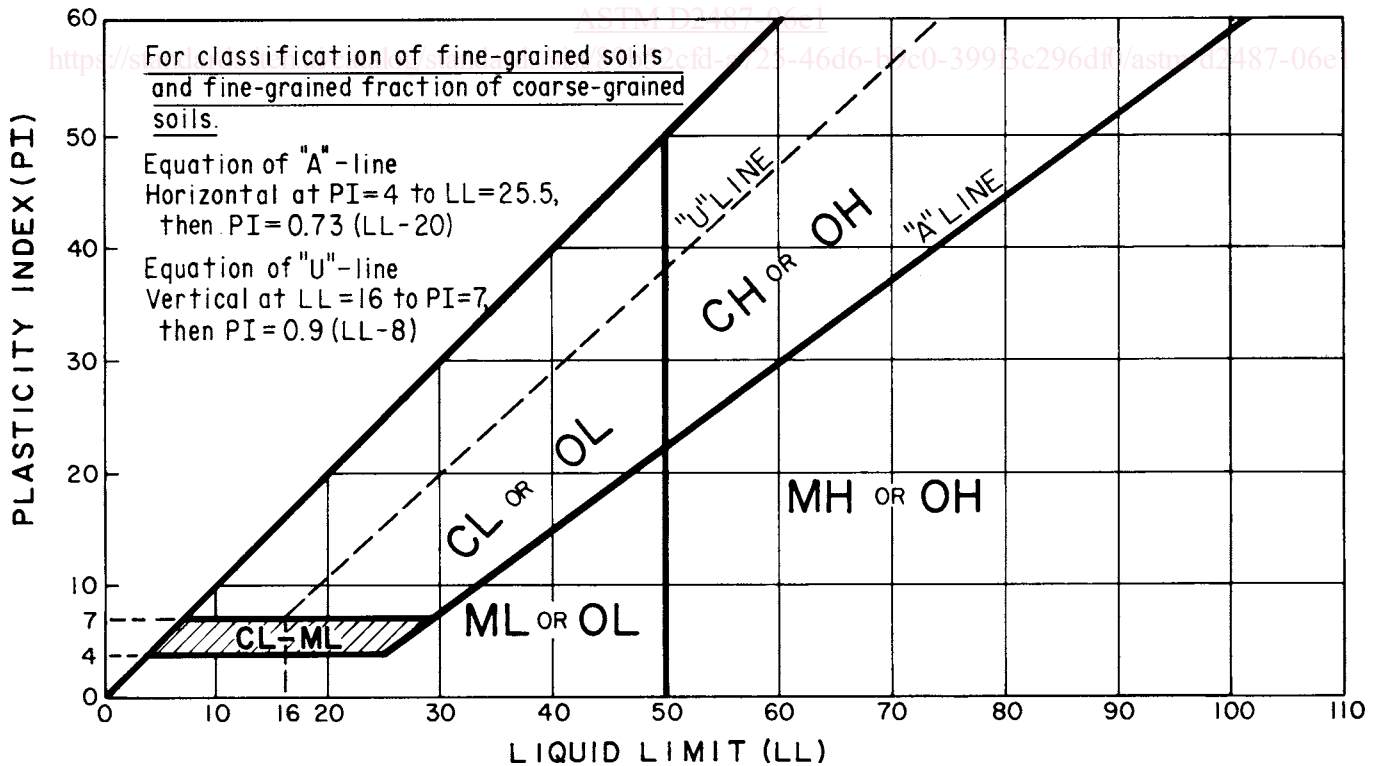


FIG. 4 Plasticity Chart