



INS 3121

SOIL MECHANICS

Classification of Soils

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5.1 Textural Classification

➤ texture of soil: **surface appearance**

➤ In most cases, **natural soils are mixtures of particles from several size groups.**

➤ USDA system in Table 2.3 ;

- Sand size: **2.0 to 0.05 mm** in diameter
- Silt size: **0.05 to 0.002 mm** in diameter
- Clay size: **smaller than 0.002 mm** in diameter

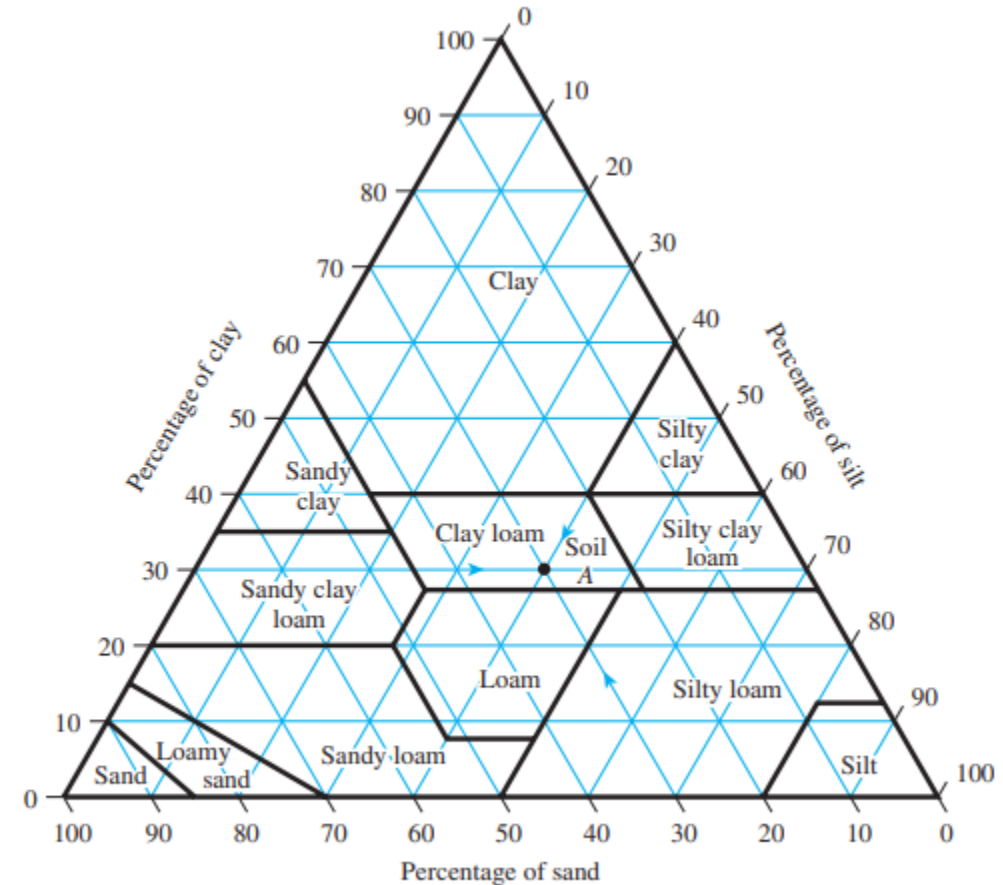


Figure 5.1 U.S. Department of Agriculture textural classification

5.2 Classification by Engineering Behavior

- textural classification: based entirely on the particle-size distribution.
- It is necessary to consider plasticity, which results from the presence of clay minerals, in order to interpret soil characteristics.
- Three Classification System :
 1. AASHTO Classification System – Highways
 2. Unified Classification System - Geotechnical Engineers
 3. TS1500/2000 Turkish Soil Classification System

5.3 AASHTO Classification System

- Developed in 1929 as the Public Road Administration Classification system.
- Proposed by the Committee on Classification of Materials for Subgrades and Granular Type Roads of the Highway Research Board in 1945 (ASTM designation D-3282; AASHTO method M145).
- Incorporate a number called the group index(GI): Particle size analysis, Atterberg Limit using USCS classification.
- Soil is classified into seven major groups : A-1~A-7

5.3 AASHTO Classification System

- A-1, A-2, and A-3 :

Granular materials where 35% or less of the particles pass through the No. 200 sieve.

- A-4, A-5, A-6 and A-7 :

More than 35% pass through the No. 200 sieve.

5.3 AASHTO Classification System

➤ A-1, A-2, and A-3 :

Table 5.1 Classification of Highway Subgrade Materials

General classification	Granular materials (35% or less of total sample passing No. 200)						
Group classification	A-1		A-3	A-2			
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7
Sieve analysis (percentage passing)							
No. 10	50 max.						
No. 40	30 max.	50 max.	51 min.				
No. 200	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.
Characteristics of fraction passing No. 40							
Liquid limit				40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.		NP	10 max.	10 max.	11 min.	11 min.
Usual types of significant constituent materials	Stone fragments, gravel, and sand		Fine sand		Silty or clayey gravel and sand		
General subgrade rating				Excellent to good			

5.3 AASHTO Classification System

➤ A-4, A-5, A-6 and A-7 :

General classification	Silt-clay materials (more than 35% of total sample passing No. 200)			
Group classification	A-4	A-5	A-6	A-7 A-7-5 ^a A-7-6 ^b
Sieve analysis (percentage passing)				
No. 10				
No. 40				
No. 200	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No. 40				
Liquid limit	40 max.	41 min.	40 max.	41 min.
Plasticity index	10 max.	10 max.	11 min.	11 min.
Usual types of significant constituent materials	Silty soils		Clayey soils	
General subgrade rating	Fair to poor			

^aFor A-7-5, $PI \leq LL - 30$

^bFor A-7-6, $PI > LL - 30$

5.3 AASHTO Classification System

➤ A-2, A-4, A-5, A-6, and A-7:

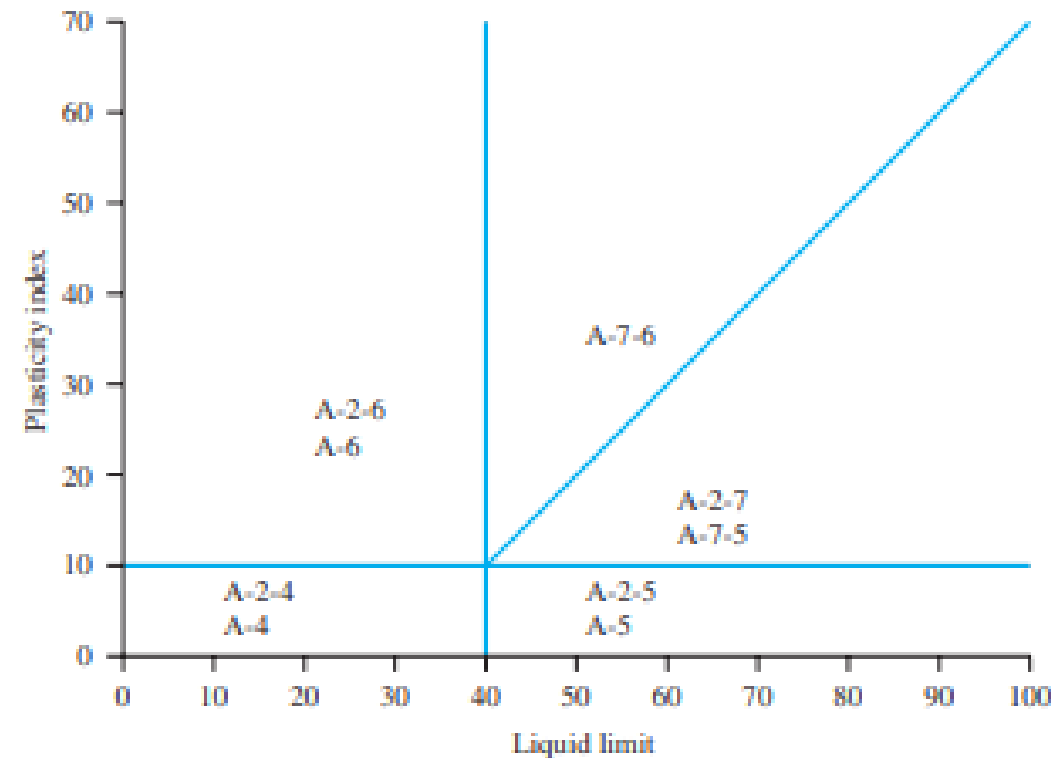


Figure 5.2 Range of liquid limit and plasticity index for soils in groups A-2, A-4, A-5, A-6, and A-7

5.3 AASHTO Classification System

- To classify a soil according to the Table, one must apply the test data from left to right. By process of elimination, the first group from the left into which the test data fit is the correct classification.
- To evaluate the quality of a soil as a highway subgrade material, one must also incorporate a number called the group index (GI) with the groups and subgroups of the soil.

$$GI = (F_{200} - 35)[0.2 + 0.005(LL - 40)] + 0.01(F_{200} - 15)(PI - 10)$$

where F_{200} = percentage passing through the No. 200 sieve

LL = liquid limit

PI = plasticity index

5.3 AASHTO Classification System

- $GI = (F_{200} - 35)[0.2 + 0.005(LL - 40)] + 0.01(F_{200} - 15)(PI - 10)$
 - $(F_{200} - 35)[0.2 + 0.005(LL - 40)]$: the first term is the partial group index determined from **the liquid limit**
 - If the equation yields a negative value for GI, it is taken as 0.
 - The group index calculated from the equation is **rounded off** to the nearest whole number (for example, GI = 3.4 is rounded off to 3; GI = 3.5 is rounded off to 4).
 - There is no upper limit for the group index.
 - The group index of soils belonging to groups A-1-a, A-1-b, A-2-4, A-2-5, and A-3 is always 0.
 - When calculating the group index for soils that **belong to groups A-2-6 and A-2-7, use the partial group index for PI, or**

$$GI = 0.01(F_{200} - 15)(PI - 10)$$

5.4 Unified Soil Classification System

- The most widely used system.
- Proposed by Casagrande in 1942 during World war II for the US army.
- ASTM designation D-2487
- Soil classification system to determine the group symbols (symbol, letter).

5.4 Unified Soil Classification System

➤ For proper classification according to this system, some or all of the following need to be known :

1. **Percent of gravel** – that is, the fraction passing the 76.2 mm opening sieve and retained on the No.4 sieve (4.75 mm opening)
2. **Percent of sand** – that is, the fraction passing the No.4 sieve (4.75 mm opening) and retained on the No.200 sieve (0.075 mm opening)
3. **Percent of silt and clay** – that is, the fraction finer than the No.200 sieve (0.075 mm opening)
4. Uniformity coefficient(C_u) and the coefficient of Gradation(C_c)
5. **Liquid limit and plasticity index of the portion of soil passing the No.40 sieve**

5.4 Unified Soil Classification System

Primary letter		Secondary letter	
Gravel	G	W } #200 passing < 5%	
#4	$\frac{< 50\%}{\geq 50\%}$	5 ~ 12 %	dual symbol (GP-GM) SW-SM
Sand	S	M : Non plastic] #200 passing > 12%
#200	$\frac{< 50\%}{\geq 50\%}$	C : Plastic	
Silt	M	L : Low plasticity (LL < 50%)	
Clay	C	H : High plasticity (LL \geq 50%)	
O (organic silts and clays)			
P_t (peat, muck and highly organic soils)			

5.4 Unified Soil Classification System

1. Sieve analysis: $\left[\begin{array}{c} G, S \\ or \\ M, C, O \end{array} \right]$
2. #4(4.76mm) passing or retained: (G, S)
3.

If GW, $C_u > 4$	$1 < C_c < 3$	} If not,	GP
SW, $C_u > 6$	$1 < C_c < 3$		SP

5.4 Unified Soil Classification System

- Proposed by Casagrande in 1942
 - SM, GM; Below A line , $IP < 4$
 - SC, GC; Above A line , $IP > 7$
- } # 200 passing > 12%

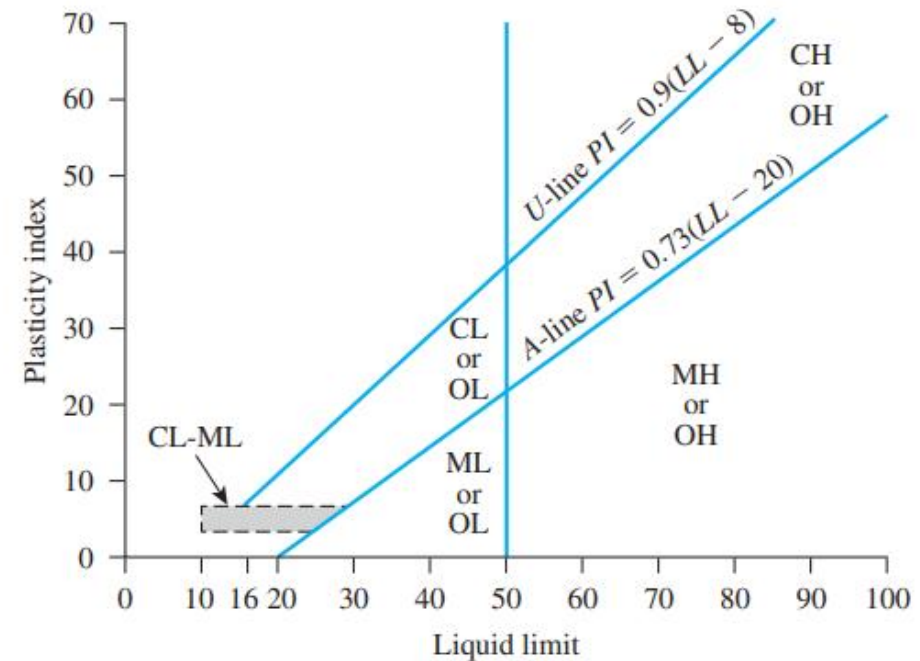


Figure 5.3 Plasticity chart

Table 5.2 Unified Soil Classification System (Based on Material Passing 76.2-mm Sieve)

ASTM designation D-2487

Criteria for assigning group symbols				Group symbol
Coarse-grained soils More than 50% of retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels	$C_u \geq 4$ and $1 \leq C_c \leq 3^c$	GW
		Less than 5% fines ^a	$C_u < 4$ and/or $C_c < 1$ or $C_c > 3^c$	GP
		Gravels with Fines	$PI < 4$ or plots below "A" line (Figure 5.3)	GM
		More than 12% fines ^{a,d}	$PI > 7$ and plots on or above "A" line (Figure 5.3)	GC
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands	$C_u \geq 6$ and $1 \leq C_c \leq 3^c$	SW
		Less than 5% fines ^b	$C_u < 6$ and/or $C_c < 1$ or $C_c > 3^c$	SP
		Sands with Fines	$PI < 4$ or plots below "A" line (Figure 5.3)	SM
		More than 12% fines ^{b,d}	$PI > 7$ and plots on or above "A" line (Figure 5.3)	SC
Fine-grained soils 50% or more passes No. 200 sieve	Silts and clays Liquid limit less than 50	Inorganic	$PI > 7$ and plots on or above "A" line (Figure 5.3) ^e	CL
			$PI < 4$ or plots below "A" line (Figure 5.3) ^e	ML
		Organic	$\frac{\text{Liquid limit—oven dried}}{\text{Liquid limit—not dried}} < 0.75$; see Figure 5.3; OL zone	OL
	Silts and clays Liquid limit 50 or more	Inorganic	PI plots on or above "A" line (Figure 5.3)	CH
			PI plots below "A" line (Figure 5.3)	MH
		Organic	$\frac{\text{Liquid limit—oven dried}}{\text{Liquid limit—not dried}} < 0.75$; see Figure 5.3; OH zone	OH
Highly organic soils	Primarily organic matter, dark in color, and organic odor			Pt

^aGravels with 5 to 12% fine require dual symbols: GW-GM, GW-GC, GP-GM, GP-GC.

^bSands with 5 to 12% fines require dual symbols: SW-SM, SW-SC, SP-SM, SP-SC.

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

^dIf $4 \leq PI \leq 7$ and plots in the hatched area in Figure 5.3, use dual symbol GC-GM or SC-SM.

^eIf $4 \leq PI \leq 7$ and plots in the hatched area in Figure 5.3, use dual symbol CL-ML.

ASTM designation D-2487

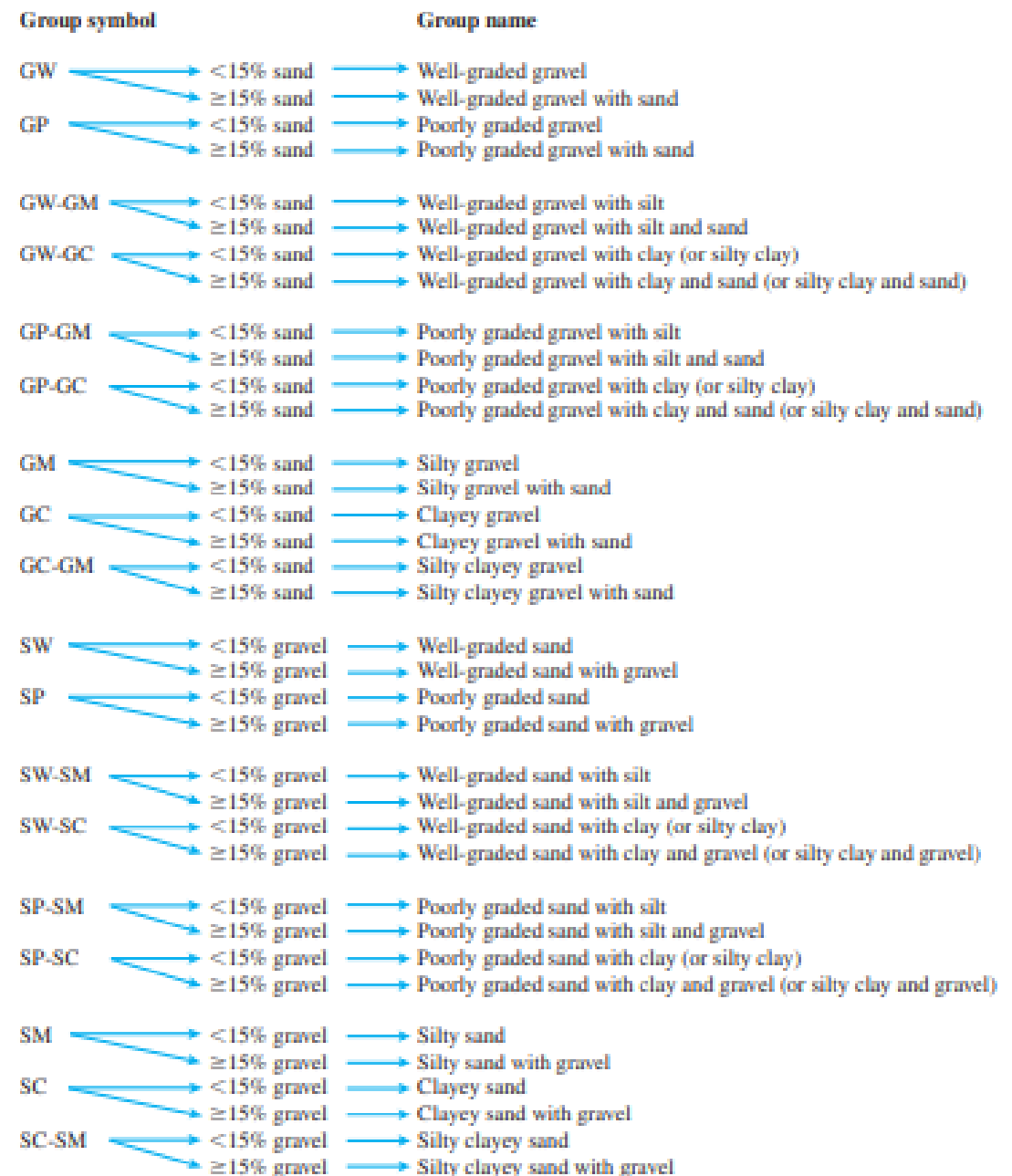


Figure 5.4 Flowchart group names for gravelly and sandy soil (Source: From "Annual Book of ASTM Standards, 04.08." Copyright ASTM INTERNATIONAL. Reprinted with permission.)

ASTM designation D-2487

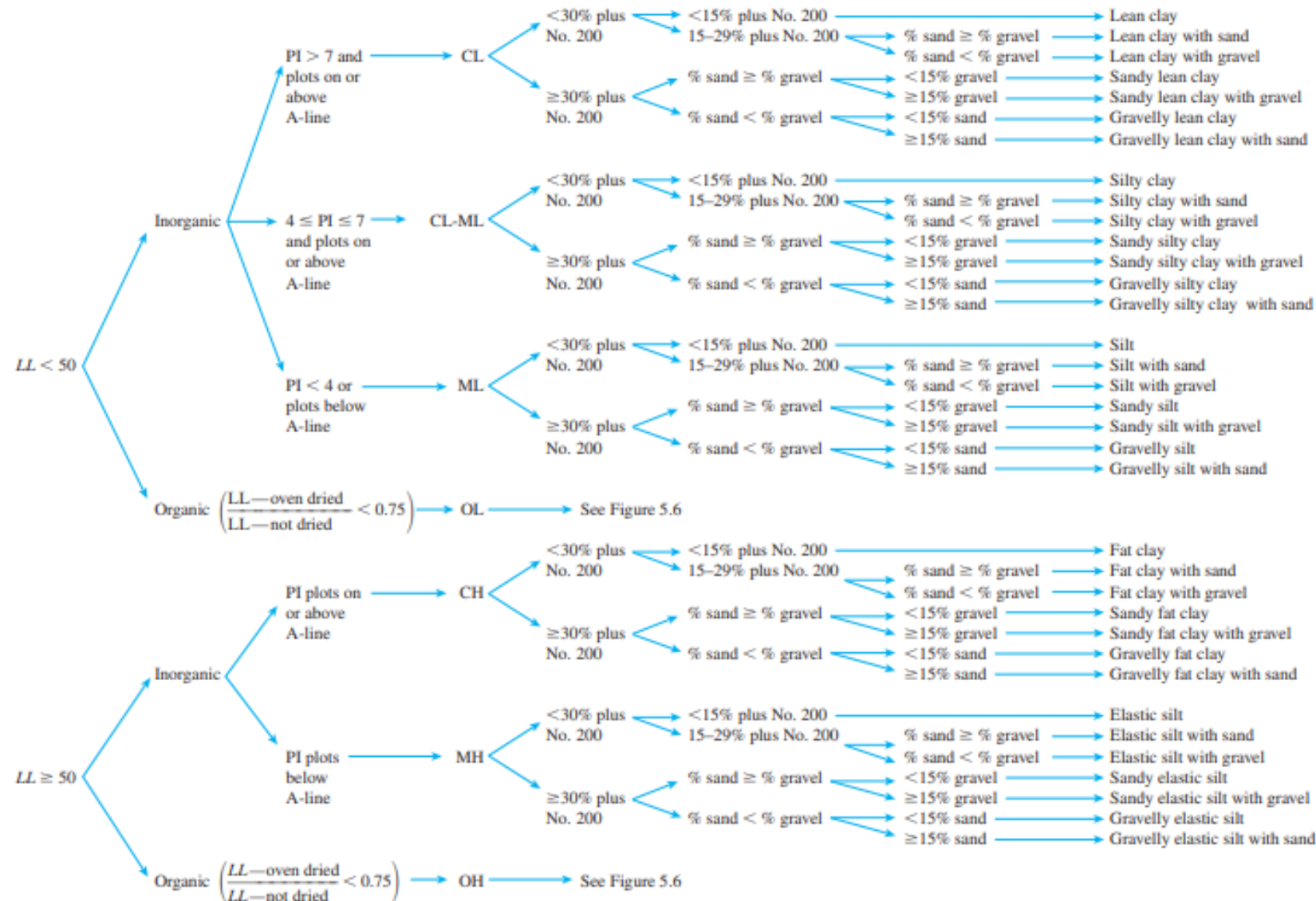


Figure 5.5 Flowchart group names for inorganic silty and clayey soils (Source: From “Annual Book of ASTM Standards, 04.08.” Copyright ASTM INTERNATIONAL. Reprinted with permission.)

ASTM designation D-2487

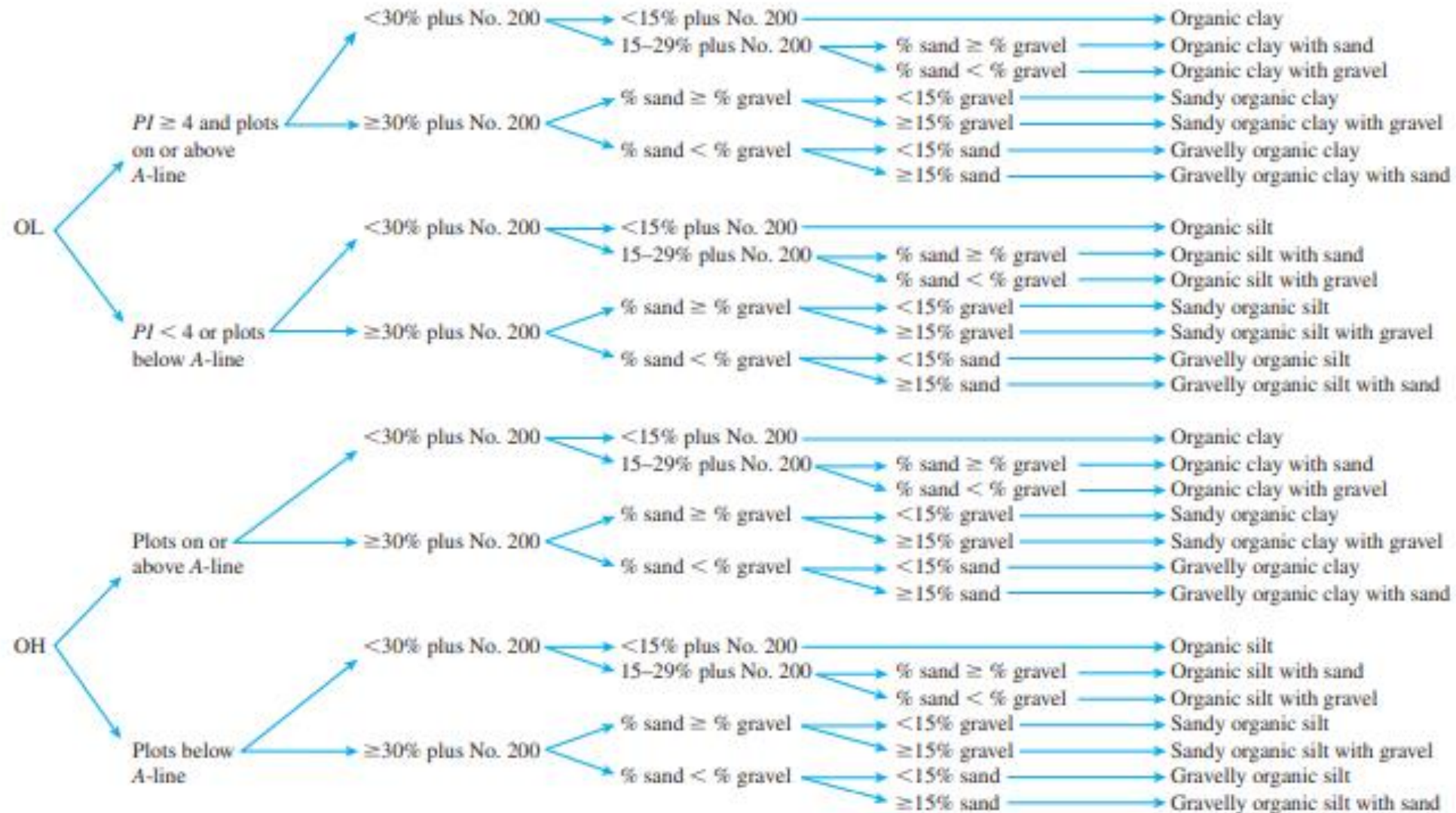


Figure 6.6 Flowchart group names for organic silty and clayey soils (Source: From "Annual Book of ASTM Standards, 04.08.")

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5.5 TS1500/2000 Turkish Soil Classification System

➤ Based on USCS classification system. However, some differences includes.

- Transition between GRAVELS and SANDS: #10 sieve (2 mm) instead of #4 sieve (4.76 mm).
- Medium plasticity on the Plasticity Chart for fine grained soils added (CI and MI)

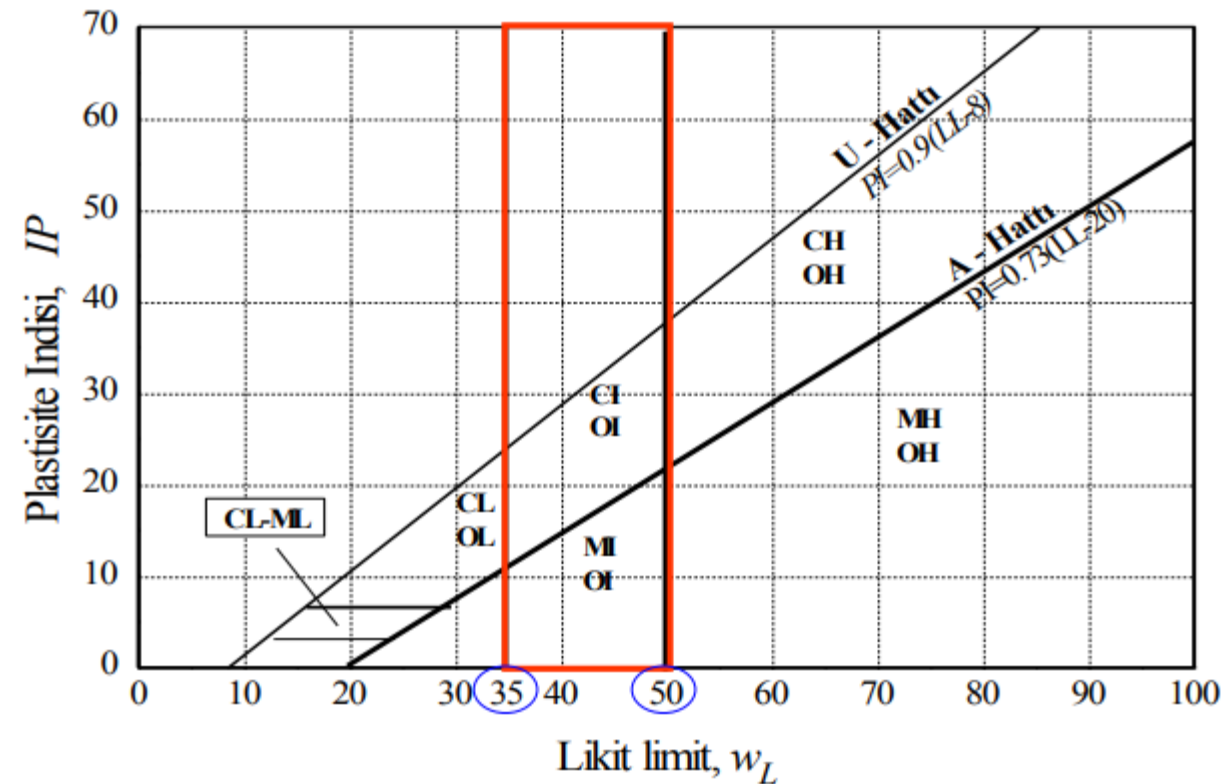
$w_L < 35$ -> Low plasticity

$35 \leq w_L < 50$ -> Medium plasticity

$w_L \geq 50$ -> High plasticity

5.5 TS1500/2000 Turkish Soil Classification System

- Medium plasticity on the Plasticity Chart for fine grained soils added (CI and MI)



Summary&Essential Points

➤ AASHTO system :

- 35% passes through the No. 200 sieve
- No. 10 sieve is used to separate gravel from sand.
- Gravelly and sand soils are not clearly separated.

(The A-2 group, in particular, contains a large variety of soils)

➤ Unified system :

- 50% passes through the No. 200 sieve.
- No. 4 sieve is used to separate gravel from sand.
- Gravelly and sandy soils are clearly separated.

Summary&Essential Points

- Symbols like **GW, SM, CH**, and others that are used in the Unified system **are more descriptive** of the soil properties than the A symbols used in the AASHTO system.
- The classification of organic soils as OL, OH, and Pt is provided in the Unified System. **Under the AASHTO system, there is no place for organic soils.**
- The classification of coarse and fine soil based on the particle size distribution of the soil and the amount of passing through #200 sieve is the same, but USCS uses 50%, AASHTO uses 35%.
- AASHTO and TS1500/2000 use sand and gravel as a standard of 2.0mm, but USCS uses a limit of 4.76mm.
- USCS classifies sand and gravel in detail, but AASHTO classifies it roughly.
- Organic soil is available in USCS, but AASHTO NOT