جامعة بيرزيت
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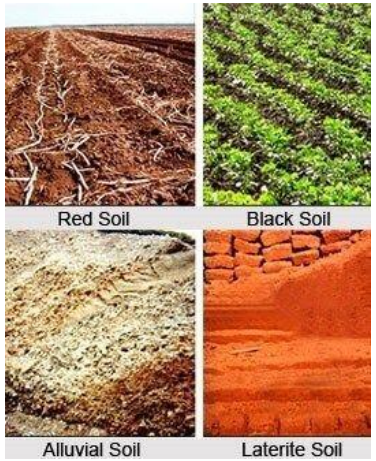
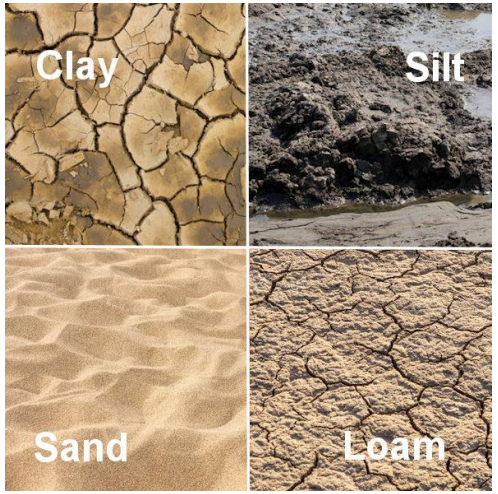
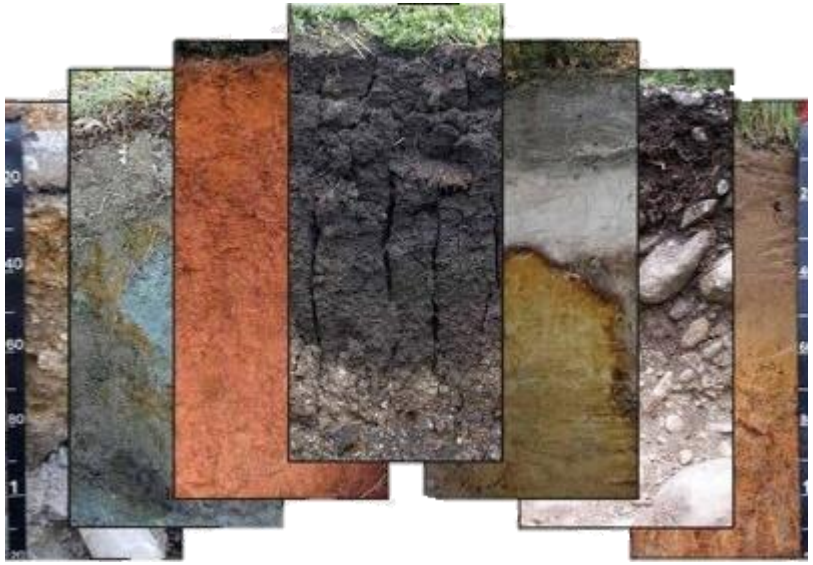
ENCE 331: Soil Classification

Why Classify soil?

- Different soils with similar properties may be classified into, groups and subgroups according to their engineering behavior.
- Classification systems provide a common language to concisely express the general characteristics of soils
- Engineering purposes are based on simple index properties such as particle-size distribution and plasticity







Classifications systems

- Textural Classification
  - Texture of soil refers to its surface appearance.
  - It is influenced by the size of the individual particles
  - Major classification system is US dept. of Agriculture (USDA)

- Engineering behavior of soil
  - Takes into consideration the particle-size distribution and the plasticity
  - Major systems
    - American Association of State Highway and Transportation Officials (AASHTO)
    - Unified Soil Classification System (USCS)

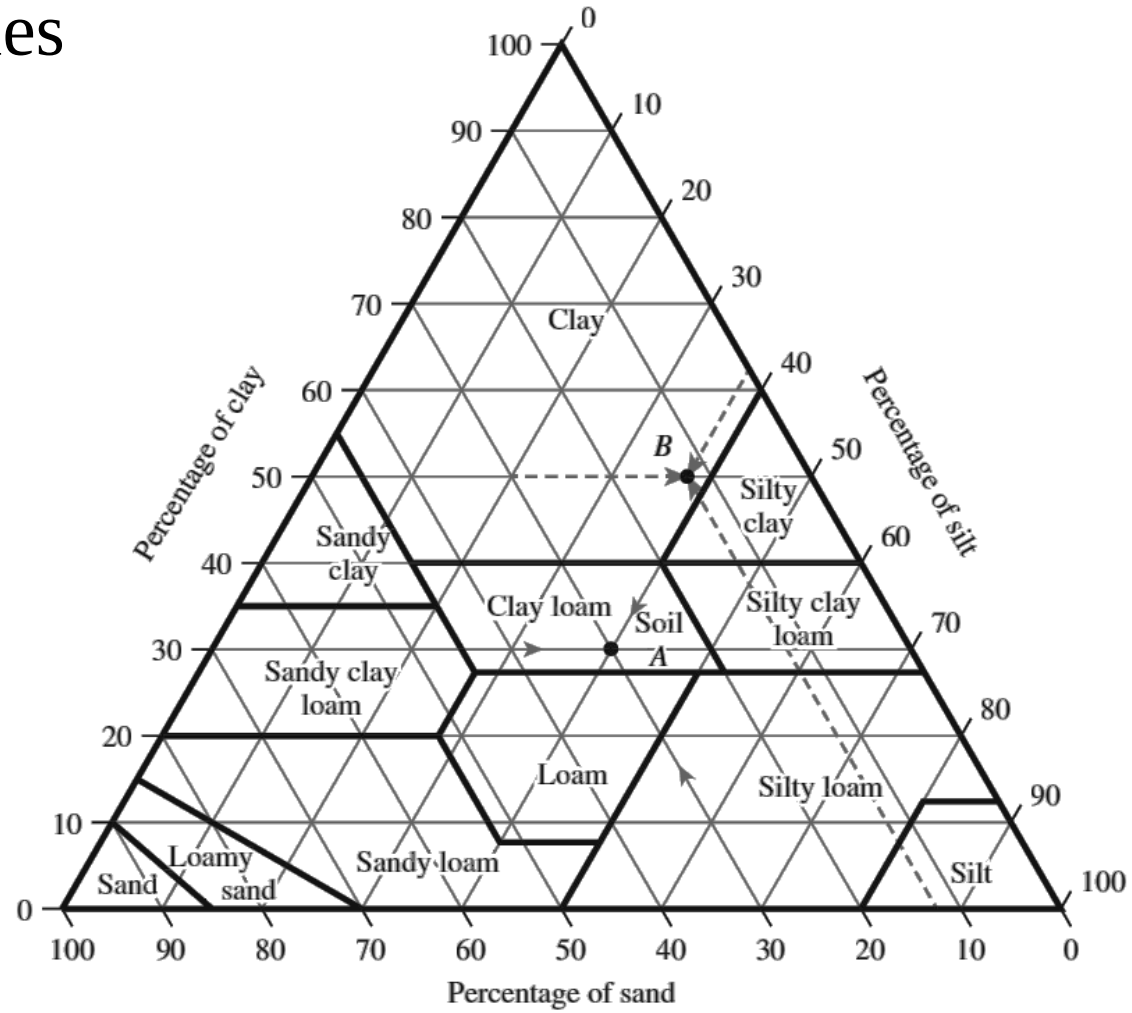
Textural systems: USDA System

- Soil is Classified into three Major Categories
  - 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

- From grain-size distribution curve
  - Example:

    Soil A: 30% Sand, 40% Silt, and 30% Clay

    Soil B: 20% Gravel, 10% sand, 30% Silt, 40% Clay



Engineering behavior Systems

- Textural classification of soil is relatively simple, it is based entirely on the particle-size distribution.
- The amount and type of clay minerals present in fine-grained soils dictate to a great extent their physical properties.
- The Geotechnical engineer must consider ***plasticity***, which results from the presence of clay minerals.

AASHTO Classification system

- ASTM designation D-3282; AASHTO method M145
  - Soil is classified into seven major groups: A-1 through A-7.
  - Soils classified under groups A-1, A-2, and A-3 are granular materials.
  - Soils of which more than 35% pass through the No. 200 sieve are classified under groups A-4, A-5, A-6, and A-7. These soils are mostly silt and clay-type materials

  - This classification system is based on the following criteria:
    - Grain size
      - Gravel: fraction passing the 75-mm (3-in.) sieve and retained on the No. 10 (2-mm).
      - Sand: fraction passing the No. 10 (2-mm) U.S. sieve and retained on the No. 200 (0.075-mm) U.S. sieve
      - Silt and clay: fraction passing the No. 200 U.S. sieve
    - Plasticity
      - The term silty is applied when the fine fractions of the soil have a plasticity index of 10 or less.
      - The term clayey is applied when the fine fractions have a plasticity index of 11 or more.

AASHTO Classification system

- ASTM designation D-3282; AASHTO method M145
  - Group Index:
    - The Group index (GI) is used to evaluate the quality of a soil as a highway subgrade material

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

    - If Equation above yields a negative value for GI, it is taken as 0.
    - The group index is rounded off to the nearest whole number
    - 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

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

AASHTO Classification system

- ASTM designation D-3282; AASHTO method M145

General classification	Granular materials (35% or less of total sample passing No. 200)						
	A-1			A-2			
Group classification	A-1-a	A-1-b	A-3	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						

AASHTO Classification system

- ASTM designation D-3282; AASHTO method M145

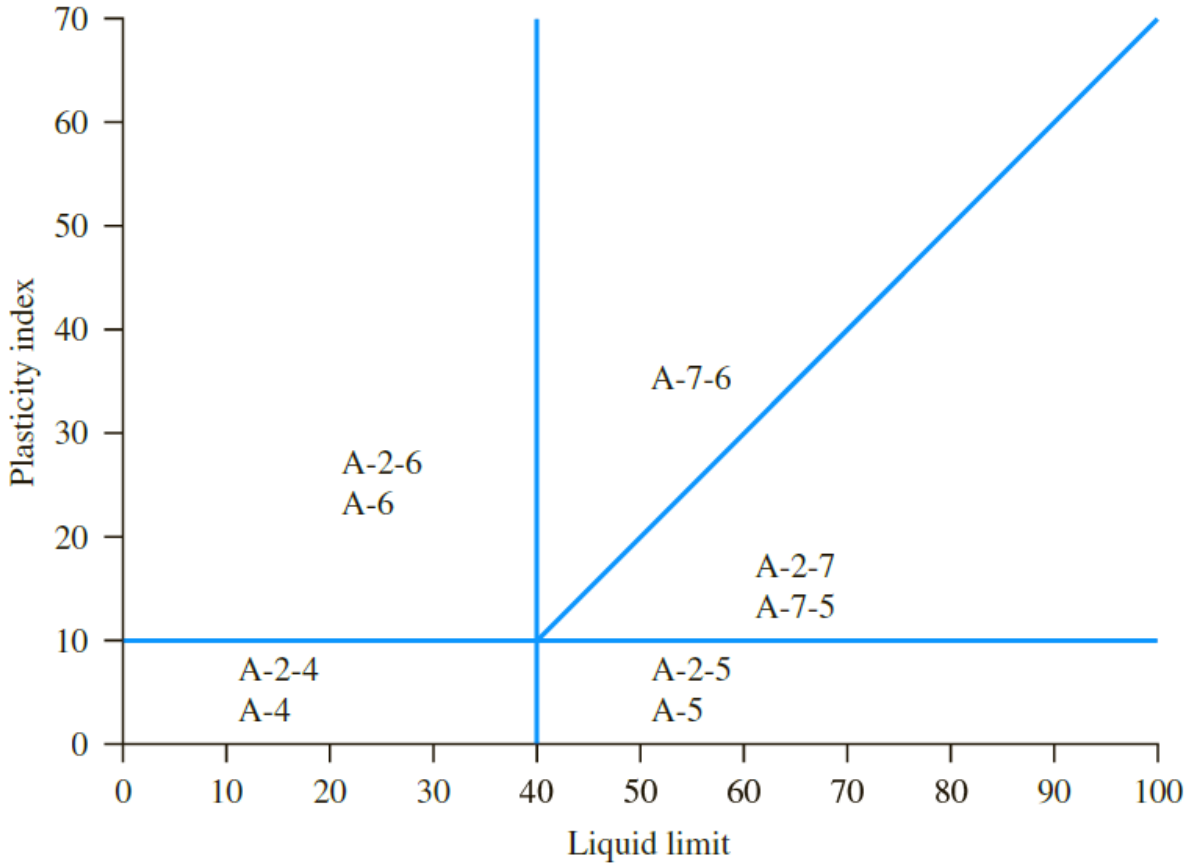
General classification	Silt-clay materials (more than 35% of total sample passing No. 200)			
Group classification	A-4	A-5	A-6	A-7 A-7-5[a] A-7-6[b]
Sieve analysis (percentage passing)				
No. 10				
No. 40				
No. 200	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No. 40				
Liquid 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			

[a]For A-7-5, $PI \leq LL - 30$

[b]For A-7-6, $PI > LL - 30$

AASHTO Classification system

- ASTM designation D-3282; AASHTO method M145



AASHTO Classification system

Example:

Classify the following soils using the AASHTO classification system

Soil A:

- Percent passing the No. 10 sieve = 42
- Percent passing the No. 40 sieve = 35
- Percent passing the No. 200 sieve = 20

The liquid limit and plastic limit of the minus No. 40 fraction of the soil are 25 and 20, respectively.

Soil B:

Ninety-five percent of a soil passes through the No. 200 sieve and has a liquid limit of 60 and plasticity index of 40.

Unified Soil Classification system (USCS)

- ASTM Test Designation D-2487
- This system classifies soils into two broad categories:
  - **Coarse-grained soils** that are gravelly and sandy in nature with less than 50% passing through the No. 200 sieve. The group symbols start with a prefix of
    - G: Gravel, passing the 76.2-mm sieve and retained on the No. 4 sieve (4.75-mm opening)
    - S: Sand, passing the No. 4 sieve (4.75-mm opening) and retained on the No. 200 sieve (0.075-mm opening)
  - **Fine-grained soils** are with 50% or more passing through the No. 200 sieve. The group symbols start with prefixes of
    - M: Inorganic silt,
    - C: Inorganic clay
    - O: Organic silts and clays.
  - **The Second Symbol** used for the classification are
    - W: Well graded: $C_u \geq 4$ for Gravel and $C_u \geq 6$ for Sand. $1 < C_c < 3$
    - P: Poorly graded if the any condition above is not satisfied
    - L: Low plasticity (liquid limit less than 50)
    - H: High plasticity (liquid limit more than 50)
  - Soil is further given a **group name** after Assigning the Group symbol based on Sand and Gravel Fractions for Coarse soils and Plasticity index and fine fraction.

Unified Soil Classification system (USCS)

Criteria for assigning group symbols				Group symbol
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[a]	$C_u \geq 4$ and $1 \leq C_c \leq 3$[c]	GW
			$C_u < 4$ and/or $C_c < 1$ or $C_c > 3$[c]	GP
		Gravels with Fines More than 12% fines[a,d]	$PI < 4$ or plots below "A" line (Figure 5.3)	GM
			$PI > 7$ and plots on or above "A" line (Figure 5.3)	GC
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[b]	$C_u \geq 6$ and $1 \leq C_c \leq 3$[c]	SW
			$C_u < 6$ and/or $C_c < 1$ or $C_c > 3$[c]	SP
		Sands with Fines More than 12% fines[b,d]	$PI < 4$ or plots below "A" line (Figure 5.3)	SM
			$PI > 7$ 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

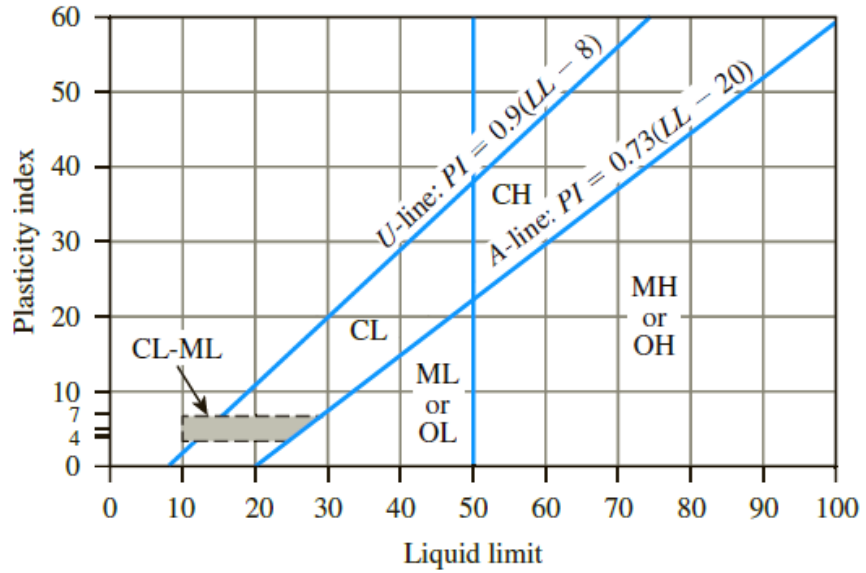
[a]Gravels with 5 to 12% fine require dual symbols: GW-GM, GW-GC, GP-GM, GP-GC.

[b]Sands with 5 to 12% fines require dual symbols: SW-SM, SW-SC, SP-SM, SP-SC.

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

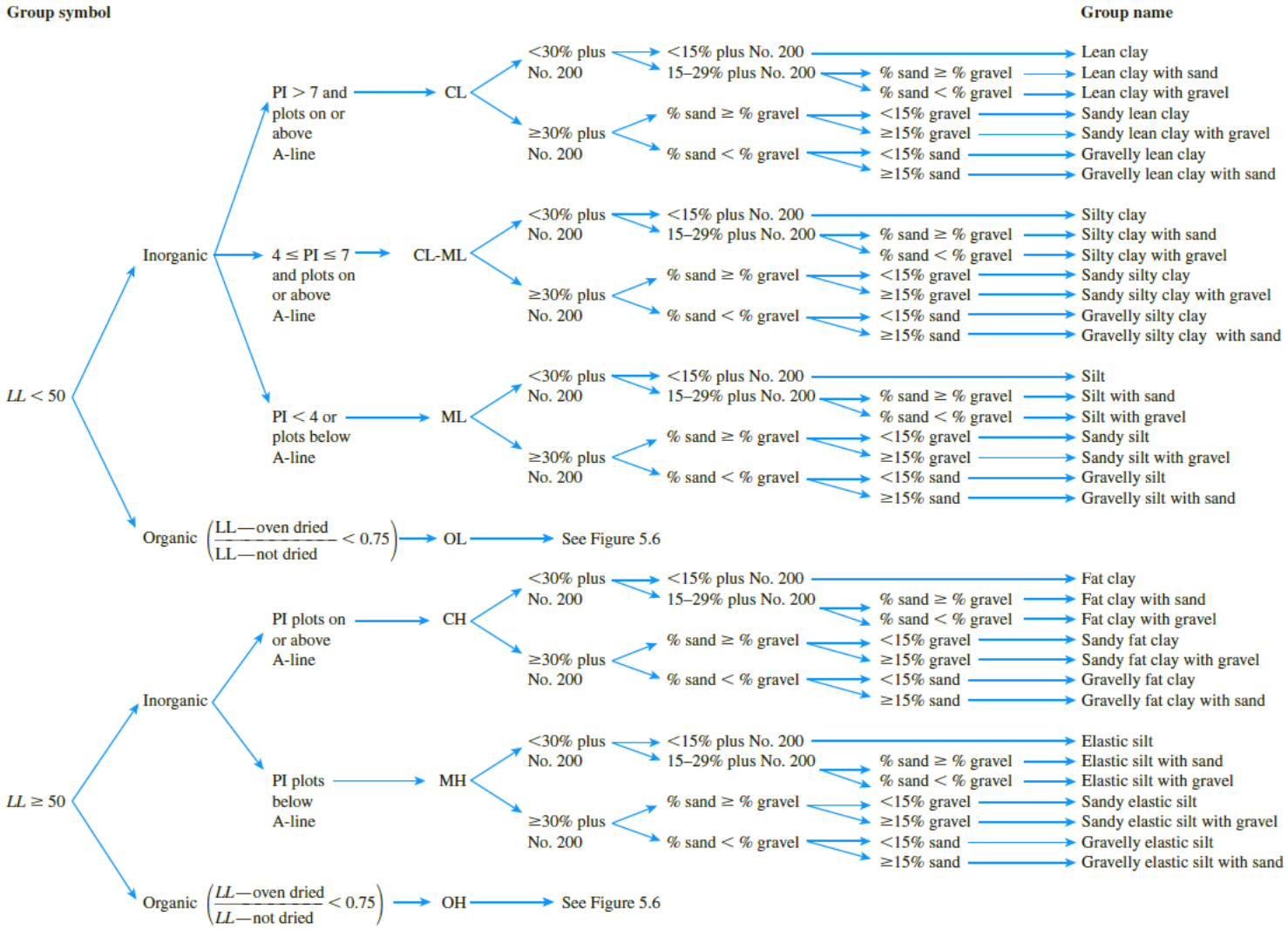
[d]If $4 \leq PI \leq 7$ and plots in the hatched area in Figure 5.3, use dual symbol GC-GM or SC-SM.

[e]If $4 \leq PI \leq 7$ and plots in the hatched area in Figure 5.3, use dual symbol CL-ML.

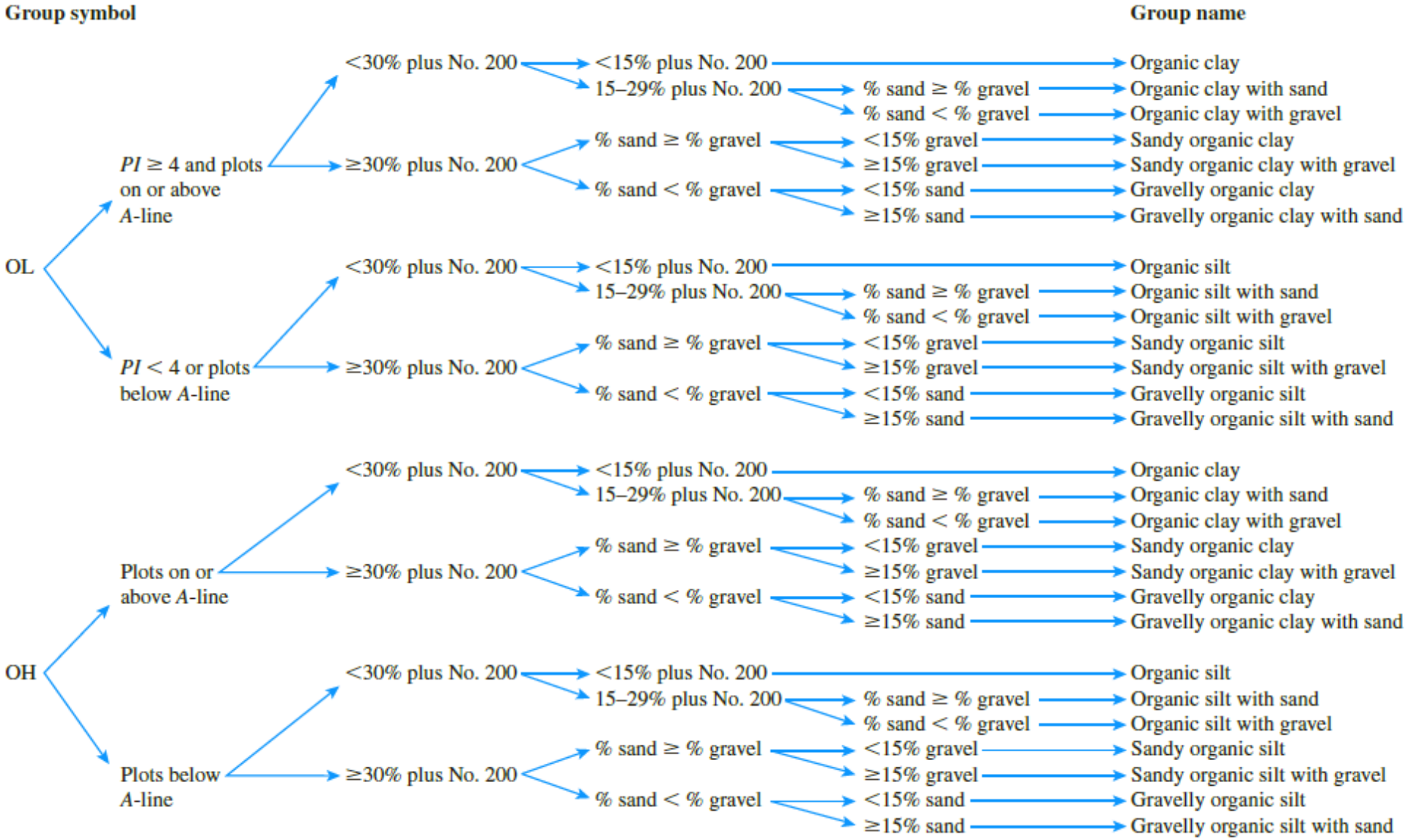


Unified Soil Classification system (USCS)

Group symbol		Group name
GW	<15% sand	Well-graded gravel
	≥15% sand	Well-graded gravel with sand
GP	<15% sand	Poorly graded gravel
	≥15% sand	Poorly graded gravel with sand
GW-GM	<15% sand	Well-graded gravel with silt
	≥15% sand	Well-graded gravel with silt and sand
GW-GC	<15% sand	Well-graded gravel with clay (or silty clay)
	≥15% sand	Well-graded gravel with clay and sand (or silty clay and sand)
GP-GM	<15% sand	Poorly graded gravel with silt
	≥15% sand	Poorly graded gravel with silt and sand
GP-GC	<15% sand	Poorly graded gravel with clay (or silty clay)
	≥15% sand	Poorly graded gravel with clay and sand (or silty clay and sand)
GM	<15% sand	Silty gravel
	≥15% sand	Silty gravel with sand
GC	<15% sand	Clayey gravel
	≥15% sand	Clayey gravel with sand
GC-GM	<15% sand	Silty clayey gravel
	≥15% sand	Silty clayey gravel with sand
SW	<15% gravel	Well-graded sand
	≥15% gravel	Well-graded sand with gravel
SP	<15% gravel	Poorly graded sand
	≥15% gravel	Poorly graded sand with gravel
SW-SM	<15% gravel	Well-graded sand with silt
	≥15% gravel	Well-graded sand with silt and gravel
SW-SC	<15% gravel	Well-graded sand with clay (or silty clay)
	≥15% gravel	Well-graded sand with clay and gravel (or silty clay and gravel)
SP-SM	<15% gravel	Poorly graded sand with silt
	≥15% gravel	Poorly graded sand with silt and gravel
SP-SC	<15% gravel	Poorly graded sand with clay (or silty clay)
	≥15% gravel	Poorly graded sand with clay and gravel (or silty clay and gravel)
SM	<15% gravel	Silty sand
	≥15% gravel	Silty sand with gravel
SC	<15% gravel	Clayey sand
	≥15% gravel	Clayey sand with gravel
SC-SM	<15% gravel	Silty clayey sand
	≥15% gravel	Silty clayey sand with gravel



Unified Soil Classification system (USCS)



Unified Soil Classification system (USCS)

Example:

The grain-size distribution of two soils are shown . The liquid and plastic limits of minus No. 40 sieve fraction of the soil are as follows:

	Soil *A*	Soil *B*
Liquid limit	30	26
Plastic limit	22	20