ROADBED SOILS-D

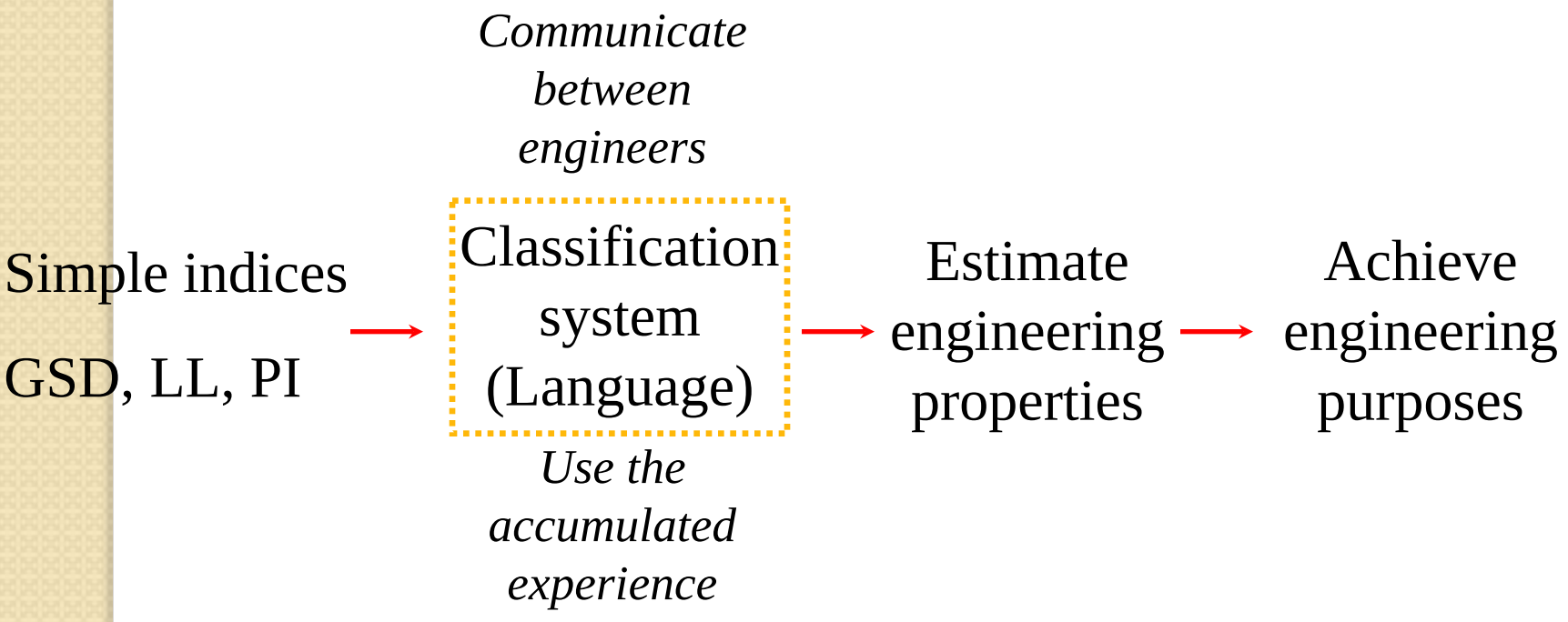
Soil Classification

Outline

1. Purpose
2. Classification Systems
3. The Unified Soil Classification System (USCS)
4. American Association of State Highway and Transportation Officials System (AASHTO)
5. Home Assignment-1

1. Purpose

Classifying soils into groups with similar behavior, in terms of *simple* indices, can provide geotechnical engineers a general guidance about engineering properties of the soils through the *accumulated experience*.



2. Classification Systems

Two commonly used systems:

- Unified Soil Classification System (USCS).
- American Association of State Highway and Transportation Officials (AASHTO) System

3. Unified Soil Classification System (USCS)

Origin of USCS:

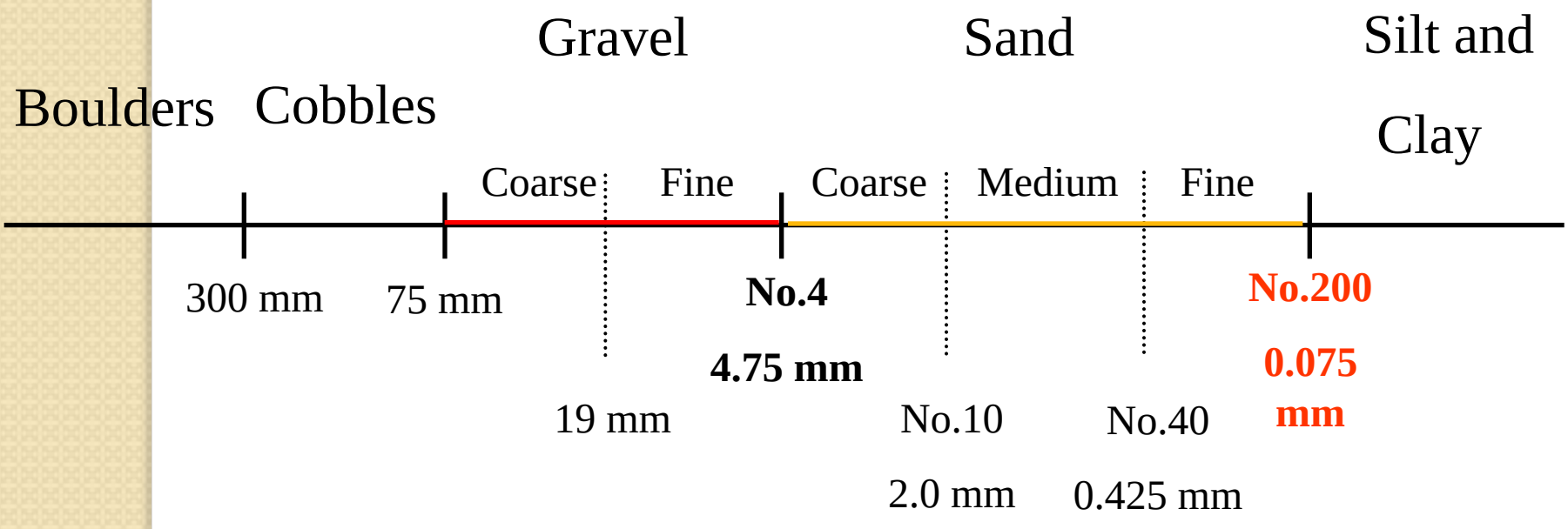
This system was first developed by Professor A. Casagrande for the purpose of airfield construction during World War II. Afterwards, it was modified by Professor A. Casagrande, the U.S. Bureau of Reclamation, and the U.S. Army Corps of Engineers to enable the system to be applicable to dams, foundations, and other construction (Holtz and Kovacs, 1981).

Four major divisions:

(1) Coarse-grained
(2) Fine-grained
(3) Organic soils
(4) Peat

3.1 Definition of Grain Size

No specific grain size-use Atterberg limits



3.2 General Guidance

50 %

Coarse-grained soils: Fine-grained soils:

Gravel Sand Silt Clay

50%

NO. 4

4.75 mm

NO.200

0.075 mm

- Grain size distribution
- C_u
- C_c

- PL, LL
- Plasticity chart

LL>50

LL <50

Required tests: Sieve analysis

Atterberg limit

3.3 Symbols

Soil symbols:

G: Gravel

S: Sand

M: Silt

C: Clay

O: Organic

Pt: Peat

Example: SW, Well-graded sand

SC, Clayey sand

SM, Silty sand,

MH, Elastic silt

Liquid limit symbols:

H: High LL (LL>50)

L: Low LL (LL<50)

Gradation symbols:

W: Well-graded

P: Poorly-graded

Well – graded soil

$1 < C_c < 3$ and $C_u \geq 4$

(for gravels)

$1 < C_c < 3$ and $C_u \geq 6$

(for sands)

3.4 Plasticity Chart

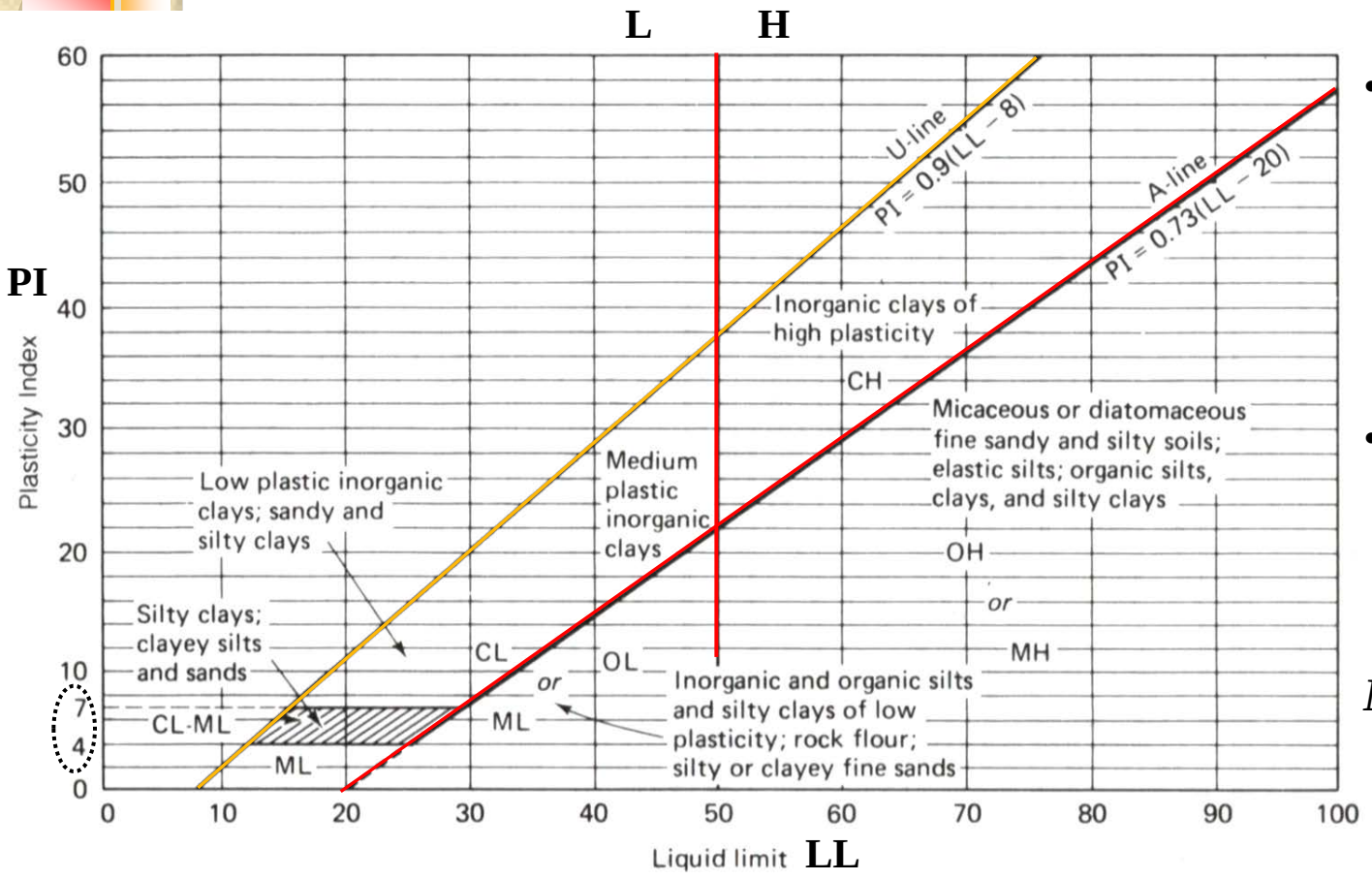


Fig. 3.2 Casagrande's plasticity chart, showing several representative soil types (developed from Casagrande, 1948, and Howard, 1977).

- The A-line generally separates the more claylike materials from silty materials, and the organics from the inorganics.
- The U-line indicates the upper bound for general soils.

Note: If the measured limits of soils are on the left of U-line, they should be rechecked.

(Holtz and Kovacs, 1981)

3.5 Procedures for Classification

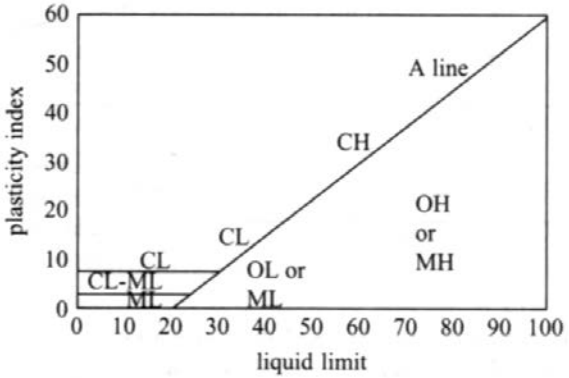
Coarse-grained material

Grain size distribution

Fine-grained material

LL, PI

COARSE More than 50% retained sieve #200	Gravel: more than 50% coarse fraction retained on sieve #4	Less than 5% fines	$C_u > 4,\ 1 \le C_c \le 3$	→ GW
			Not satisfying GW	→ GP
		More than 12% fines	Below 'A' line	→ GM
			Above 'A' line	→ GC
	Sand: less than 50% coarse fraction retained on sieve #4	Less than 5% fines	$C_u > 6,\ 1 \le C_c \le 3$	→ SW
			Not satisfying SW	→ SP
		More than 12% fines	Below 'A' line	→ SM
			Above 'A' line	→ SC
FINE Less than 50% retained sieve #200	$LL < 50$			ML CL OL
	$LL > 50$			MH CH OH
Highly ORGANIC SOILS				→ Pt



(Santamarina et al., 2001)

3.6 Example

Passing No.200 sieve 30 %

Passing No.4 sieve 70 %

LL= 33

PI= 12

Passing No.200 sieve 30 %

Passing No.4 sieve 70 %

LL= 33

PI= 12

PI= 0.73(LL-20), A-line

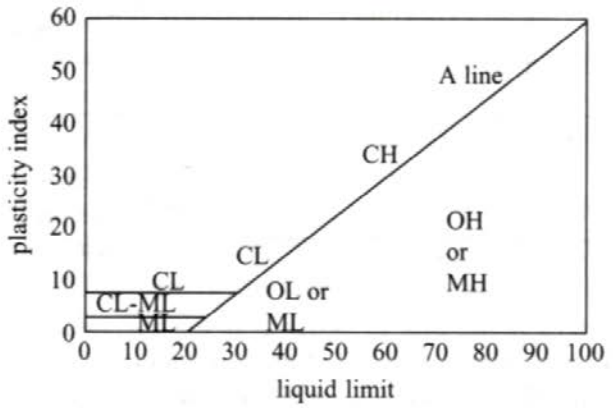
PI=0.73(33-20)=9.49

SC

(≥15% gravel)

Clayey sand with gravel

COARSE More than 50% retained sieve #200	Gravel: more than 50% coarse fraction retained on sieve #4	Less than 5% fines	$C_u > 4, 1 \le C_c \le 3$	→ GW
			Not satisfying GW	→ GP
		More than 12% fines	Below 'A' line	→ GM
			Above 'A' line	→ GC
	Sand: less than 50% coarse fraction retained on sieve #4	Less than 5% fines	$C_u > 6, 1 \le C_c \le 3$	→ SW
			Not satisfying SW	→ SP
		More than 12% fines	Below 'A' line	→ SM
			Above 'A' line	→ SC
FINE Less than 50% retained sieve #200	$LL < 50$			→ ML → CL → OL
	$LL > 50$			→ MH → CH → OH
Highly ORGANIC SOILS				→ Pt



(Santamarina et al., 2001)

3.7 Organic Soils

- **Highly organic soils- Peat (Group symbol PT)**
  - 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.

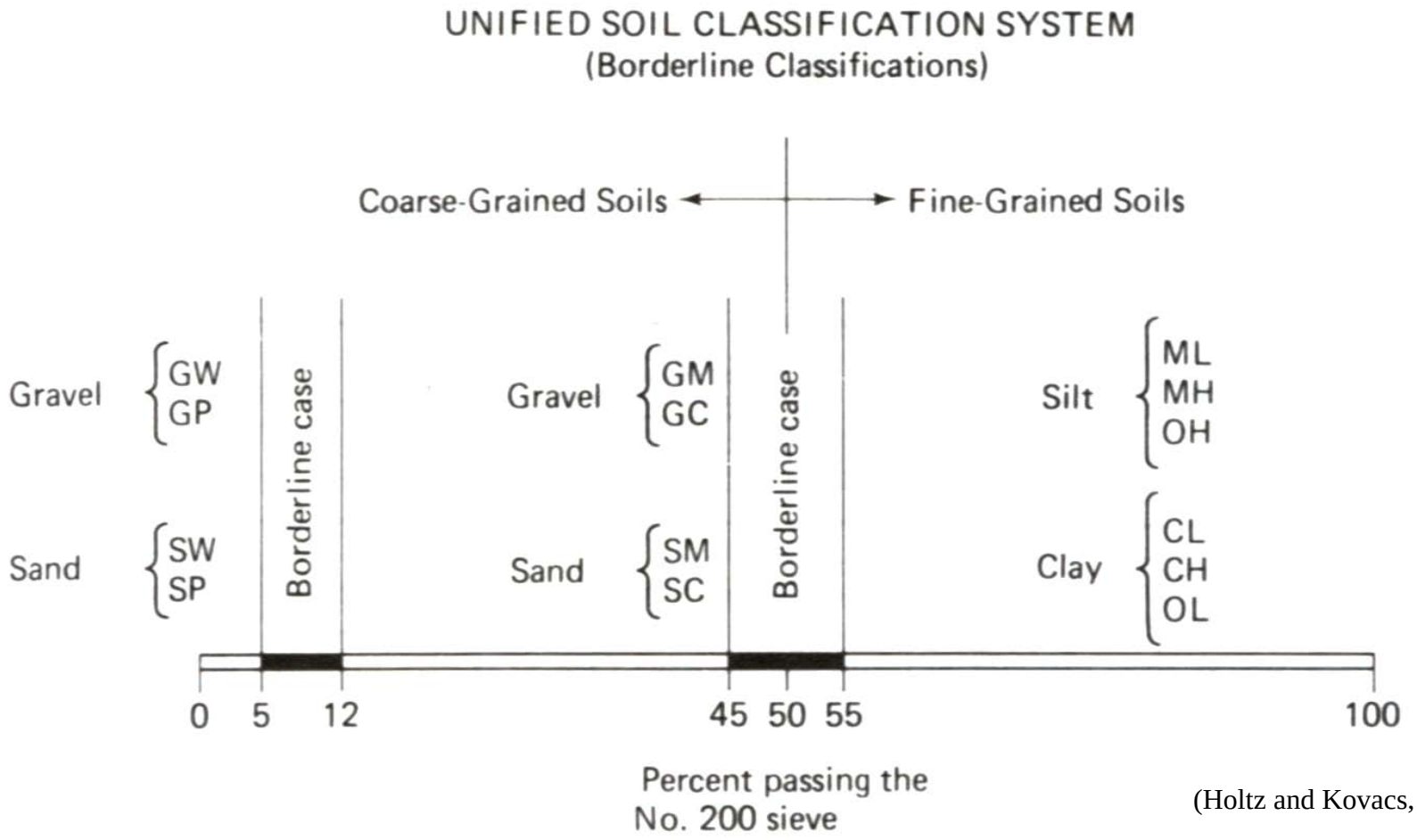
- **Organic clay or silt(group symbol OL or OH):**
  - "The soil's liquid limit (LL) after oven drying is less than 75 % of its liquid limit before oven drying." If the above statement is true, then the first symbol is O.
  - The second symbol is obtained by locating the values of PI and LL (not oven dried) in the plasticity chart.

3.8 Borderline Cases (Dual Symbols)

For the following three conditions, a dual symbol should be used.

- Coarse-grained soils with 5% - 12% fines.
  - **About 7 % fines can change the hydraulic conductivity of the coarse-grained media by orders of magnitude.**
  - The first symbol indicates whether the coarse fraction is well or poorly graded. The second symbol describe the contained fines. For example: SP-SM, poorly graded sand with silt.
- Fine-grained soils with limits within the shaded zone. (PI between 4 and 7 and LL between about 12 and 25).
  - It is hard to distinguish between the silty and more claylike materials.
  - CL-ML: Silty clay, SC-SM: Silty, clayed sand.
- Soil contain similar fines and coarse-grained fractions.
  - possible dual symbols GM-ML

3.8 Borderline Cases (Summary)



(Holtz and Kovacs, 1981)

Note: Only two group symbols may be used to describe a soil.
Borderline classifications can exist within each of the above groups.

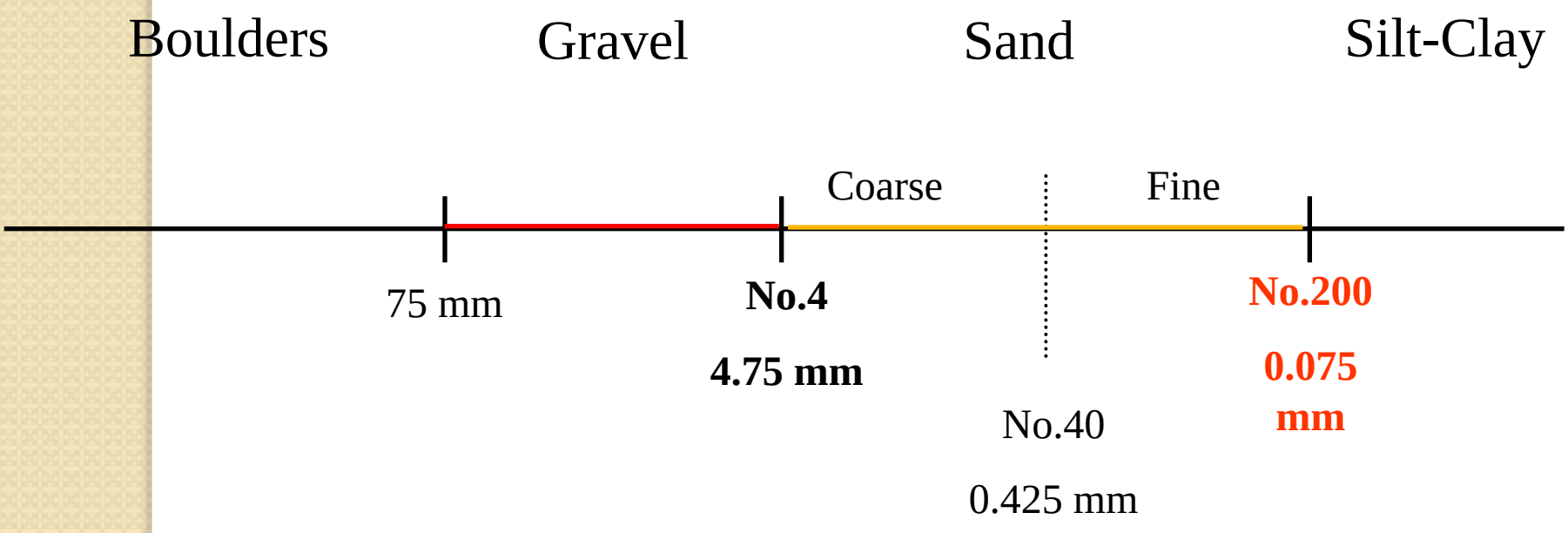
4. American Association of State Highway and Transportation Officials system (AASHTO)

Origin of AASHTO: (For road construction)

This system was originally developed by Hogentogler and Terzaghi in 1929 as the Public Roads Classification System. Afterwards, there are several revisions. The present AASHTO (1978) system is primarily based on the version in 1945. (Holtz and Kovacs, 1981)

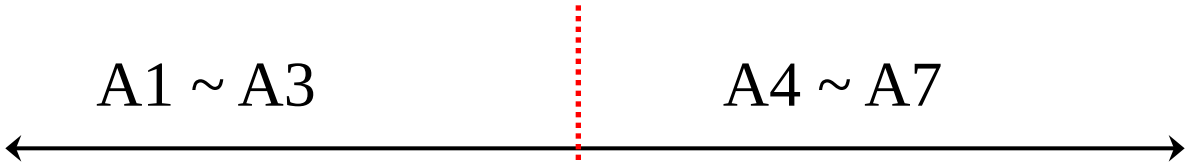
4.1 Definition of Grain Size

No specific grain size-use Atterberg limits



4.2 General Guidance

- 8 major groups: A1 ~ A7 (with several subgroups) and organic soils A8
- The required tests are sieve analysis and Atterberg limits.
- The group index, an empirical formula, is used to further evaluate soils within a group (subgroups).



Granular Materials

≤ 35% pass No. 200 sieve

Using LL and PI separates silty materials from clayey materials (only for A2 group)

Silt-clay Materials

≥ 36% pass No. 200 sieve

Using LL and PI separates silty materials from clayey materials

- The original purpose of this classification system is used for road construction (subgrade rating).

4.3 Group Index

The first term is determined by the LL

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

The second term is determined by the PI

For Group A-2-6 and A-2-7

$$GI = 0.01(F_{200} - 15)(PI - 10)$$ use the second term only

F200: percentage passing through the No.200 sieve

In general, the rating for a pavement subgrade is inversely proportional to the group index, GI.

4.4 Classification

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						

Das, 1998

4.4 Classification (Cont.)

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, $PI > LL - 30$

Note:

The first group from the left to fit the test data is the correct AASHTO classification.

Das, 1998

4.4 Example

Passing No.200 86%

LL=70, PI=32

LL-30=40 > PI=32

Passing No.200 86%

LL=70, PI=32

LL-30=40 > PI=32

$$GI = (F_{200} - 35)\left[0.2 + 0.005(LL - 40)\right] + 0.01(F_{200} - 15)(PI - 10) = 33.47 \cong 33$$ *Round off*

A-7-5(33)

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, $PI > LL - 30$

CLASS EXERCISE – SOIL CLASSIFICATION

Example

The results of the particle-size analysis of a soil are as follows:

- Percent passing the No. 10 sieve = 100
- Percent passing the No. 40 sieve = 80
- Percent passing the No. 200 sieve = 58

The liquid limit and plasticity index of the minus No. 40 fraction of the soil are 30 and 10, respectively. Classify the soil by the AASHTO system.

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, $PI > LL - 30$

From Eq. (5.1)

$$\begin{aligned} GI &= (F_{200} - 35)[0.2 + 0.005(LL - 40)] + 0.01(F_{200} - 15)(PI - 10) \\ &= (58 - 35)[0.2 + 0.005(30 - 40)] + (0.01)(58 - 15)(10 - 10) \\ &= 3.45 \simeq 3 \end{aligned}$$

So, the soil will be classified as A-4(3).

Example

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

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, $PI > LL - 30$

According to Table 5.1, this soil falls under group A-7 (proceed in a manner similar to Example 5.2). Since

$$\begin{array}{ccc} 40 & > & 60 - 30 \\ \uparrow & & \uparrow \\ PI & & LL \end{array}$$

this is an A-7-6 soil.

$$\begin{aligned} GI &= (F_{200} - 35)[0.2 + 0.005(LL - 40)] + 0.01(F_{200} - 15)(PI - 10) \\ &= (95 - 35)[0.2 + 0.005(60 - 40)] + (0.01)(95 - 15)(40 - 10) \\ &= 42 \end{aligned}$$

So, the classification is **A-7-6(42)**.

Example

Classify the following soil by the AASHTO Classification System:

- Percentage passing No. 10 sieve = 90
- Percentage passing No. 40 sieve = 76
- Percentage passing No. 200 sieve = 34
- Liquid limit (–No. 40 fraction) = 37
- Plasticity index (–No. 40 fraction) = 12

Table 5.1 Classification of Highway Subgrade Materials

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						

Example

The percentage passing through the No. 200 sieve is less than 35, so the soil is a granular material. From Table 5.1, we see that it is type A-2-6. From Eq. (5.2),

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

For this soil, $F_{200} = 34$ and $PI = 12$, so

$$GI = 0.01(34 - 15)(12 - 10) = 0.38 \approx 0$$

Thus, the soil is type **A-2-6(0)**.

Rules for determining GI

1. If Eq. (5.1) yields a negative value for *GI*, it is taken as 0.
2. The group index calculated from Eq. (5.1) 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).
3. There is no upper limit for the group index.
4. 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.
5. 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

$$GI = 0.01(F_{200} - 15)(PI - 10) \tag{5.2}$$

In general, the quality of performance of a soil as a subgrade material is inversely proportional to the group index.

USCS System

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

1. Percent of gravel—that is, the fraction passing the 76.2-mm 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

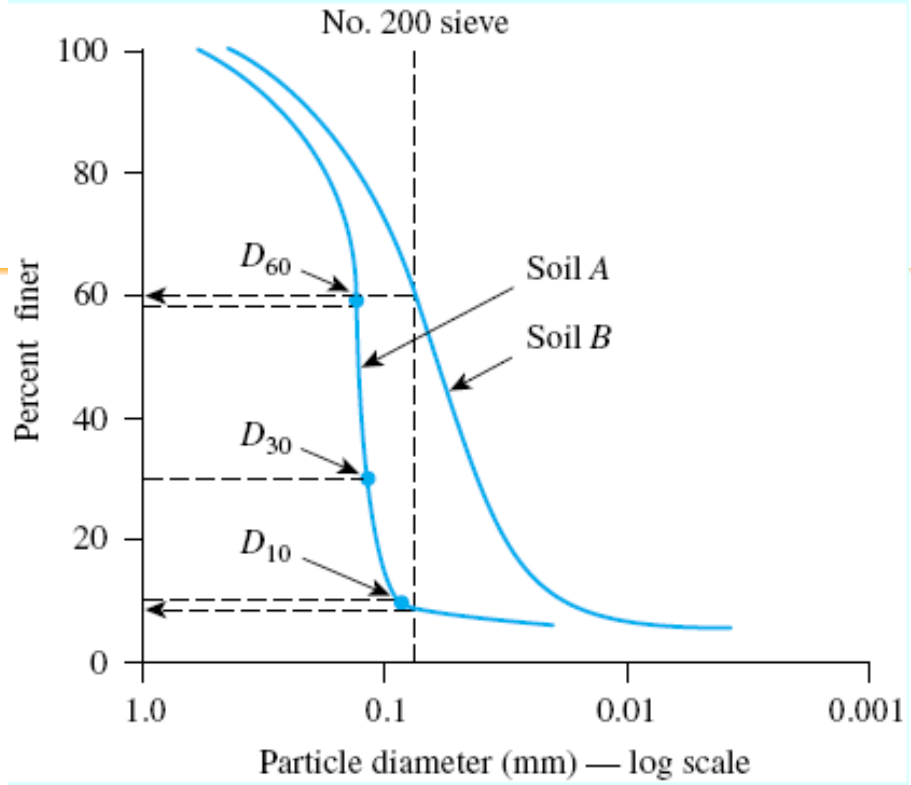


Figure 5.7 Particle-size distribution of two soils

Figure 5.7 gives the grain-size distribution of two soils. 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

Determine the group symbols and group names according to the Unified Soil Classification System.

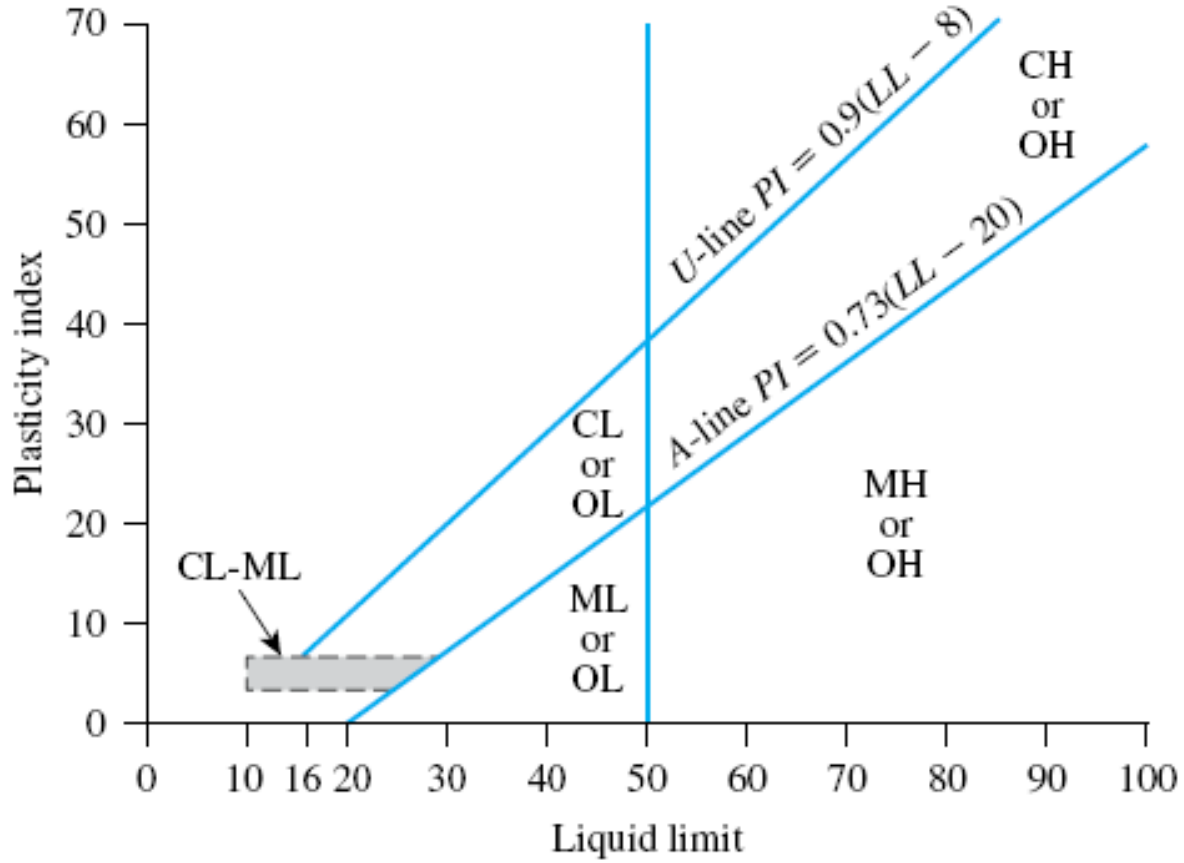

Plasticity index
70
60
50
40
30
20
10
0
0
10
16
20
30
40
50
60
70
80
90
100
Liquid limit
U-line PI = 0.9(LL − 8)
A-line PI = 0.73(LL − 20)
CH
or
OH
CL
or
OL
MH
or
OH
ML
or
OL
CL-ML

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

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 Less than 5% fines[a]	$C_u \geq 4$ and $1 \leq C_c \leq 3$[c]	GW
			$C_u < 4$ and/or $1 > C_c > 3$[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 $1 > C_c > 3$[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] $C_u = \frac{D_{60}}{D_{10}}; \quad C_c = \frac{(D_{30})^2}{D_{60} \times D_{10}}$

[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.

Solution

Soil *A*

The grain-size distribution curve (Figure 5.7) indicates that percent passing No. 200 sieve is 8. According to Table 5.2, it is a coarse-grained soil. Also, from Figure 5.7, the percent retained on No. 4 sieve is zero. Hence, it is a sandy soil.

From Figure 5.7, $D_{10} = 0.085$ mm, $D_{30} = 0.12$ m, and $D_{60} = 0.135$ mm. Thus,

$$C_u = \frac{D_{60}}{D_{10}} = \frac{0.135}{0.085} = 1.59 < 6$$

$$C_c = \frac{D_{30}^2}{D_{60} \times D_{10}} = \frac{(0.12)^2}{(0.135)(0.085)} = 1.25 > 1$$

With $LL = 30$ and $PI = 30 - 22 = 8$ (which is greater than 7), it plots above the *A*-line in Figure 5.3. Hence, the group symbol is **SP-SC**.

In order to determine the group name, we refer to Figure 5.4.

$$\text{Percentage of gravel} = 0\,(\text{which is} < 15\%)$$

So, the group name is **poorly graded sand with clay**.

Soil *B*

The grain-size distribution curve in Figure 5.7 shows that percent passing No. 200 sieve is 61 (>50%); hence, it is a fine-grained soil. Given: $LL = 26$ and $PI = 26 - 20 = 6$. In Figure 5.3, the *PI* plots in the hatched area. So, from Table 5.2, the group symbol is **CL-ML**.

For group name (assuming that the soil is inorganic), we go to Figure 5.5 and obtain Plus No. 200 sieve $= 100 - 61 = 39$ (which is greater than 30).

Percentage of gravel = 0; percentage of sand $= 100 - 61 = 39$

Thus, because the percentage of sand is greater than the percentage of gravel, the soil is **sandy silty clay**. ■

Example

For a given soil, the following are known:

- Percentage passing No. 4 sieve = 70
- Percentage passing No. 200 sieve = 30
- Liquid limit = 33
- Plastic limit = 12

Classify the soil using the Unified Soil Classification System. Give the group symbol and the group name.

Refer to Table 5.2. The percentage passing No. 200 sieve is 30%, which is less than 50%. So it is a coarse-grained soil. Thus,

$$\text{Coarse fraction} = 100 - 30 = 70\%$$

Gravel fraction = percent retained on No. 4 sieve = 100 − 70 = 30% Hence, more than 50% of the coarse fraction is passing No. 4 sieve. Thus, it is a sandy soil. Since more than 12% is passing No. 200 sieve, it is SM or SC. For this soil, $PI = 33 - 12 = 21$ (which is greater than 7). With $LL = 33$ and $PI = 21$, it plots above the A-line in Figure 5.3. Thus, the group symbol is **SC**.

For the group name, refer to Figure 5.4. Since the percentage of gravel is more than 15%, it is **clayey sand with gravel**.

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

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 Less than 5% fines[a]	$C_u \geq 4$ and $1 \leq C_c \leq 3$[c]	GW
			$C_u < 4$ and/or $1 > C_c > 3$[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 $1 > C_c > 3$[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] $C_u = \frac{D_{60}}{D_{10}}; \quad C_c = \frac{(D_{30})^2}{D_{60} \times D_{10}}$

[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.

5. Suggested Homework

1. Read ASTM D2487 and D 2488.