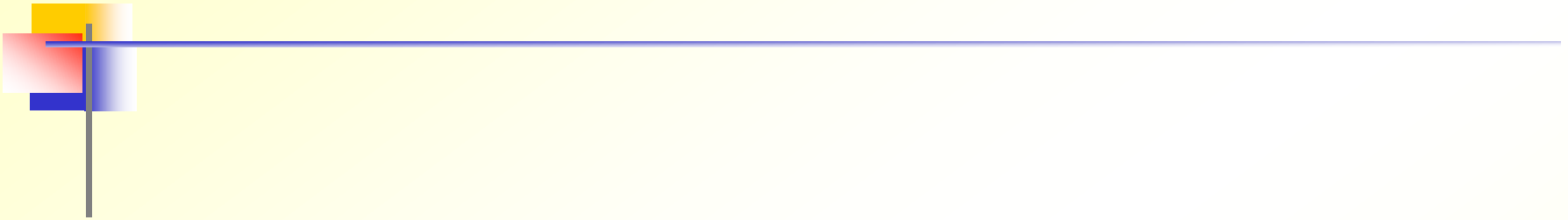


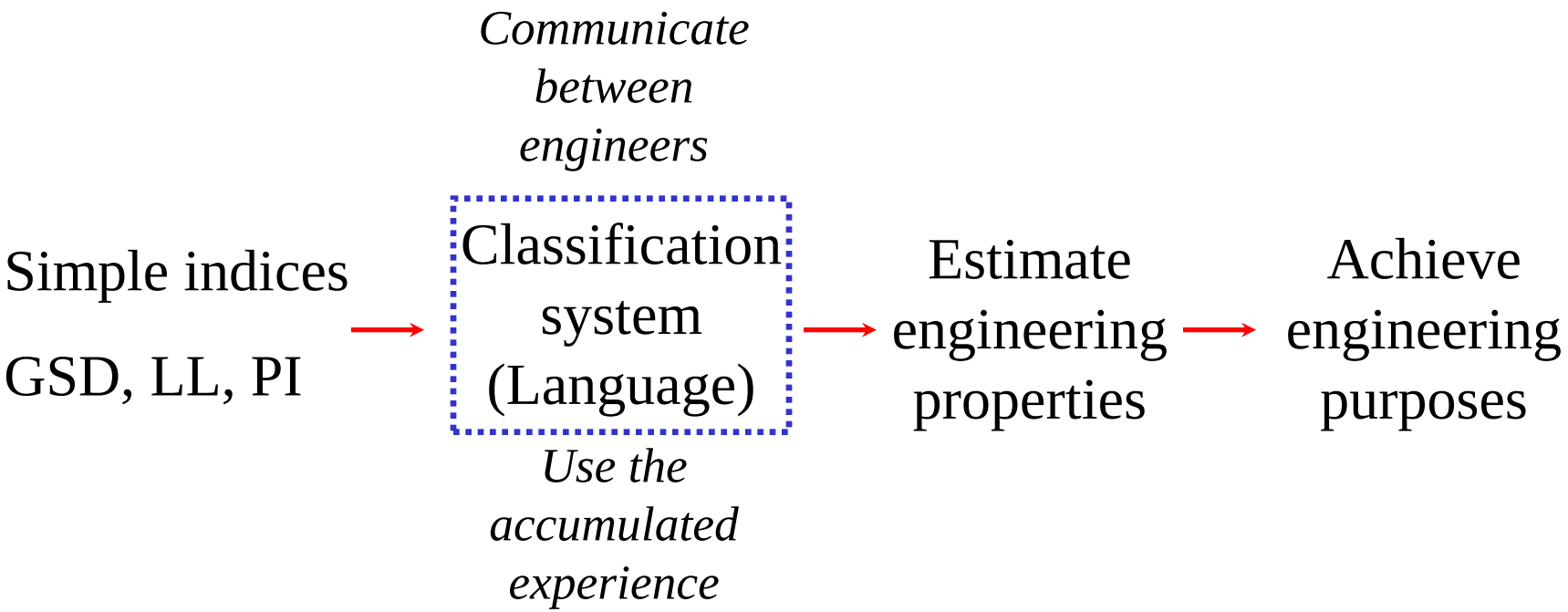
Soil Classification

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. Suggested Homework

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)

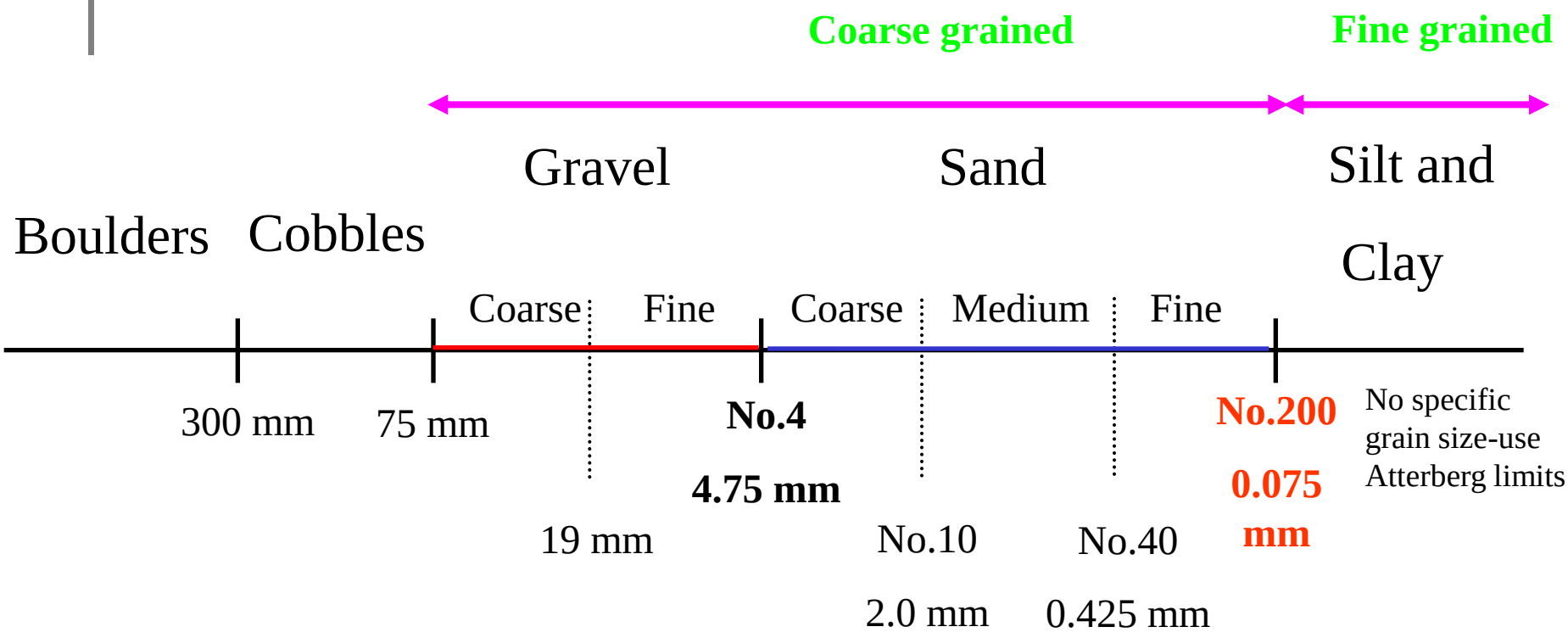
Origin of USCS:

This system was first developed by Professor A. Casagrande (1948) for the purpose of airfield construction during World War II. Afterwards, it was modified by Professor 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).

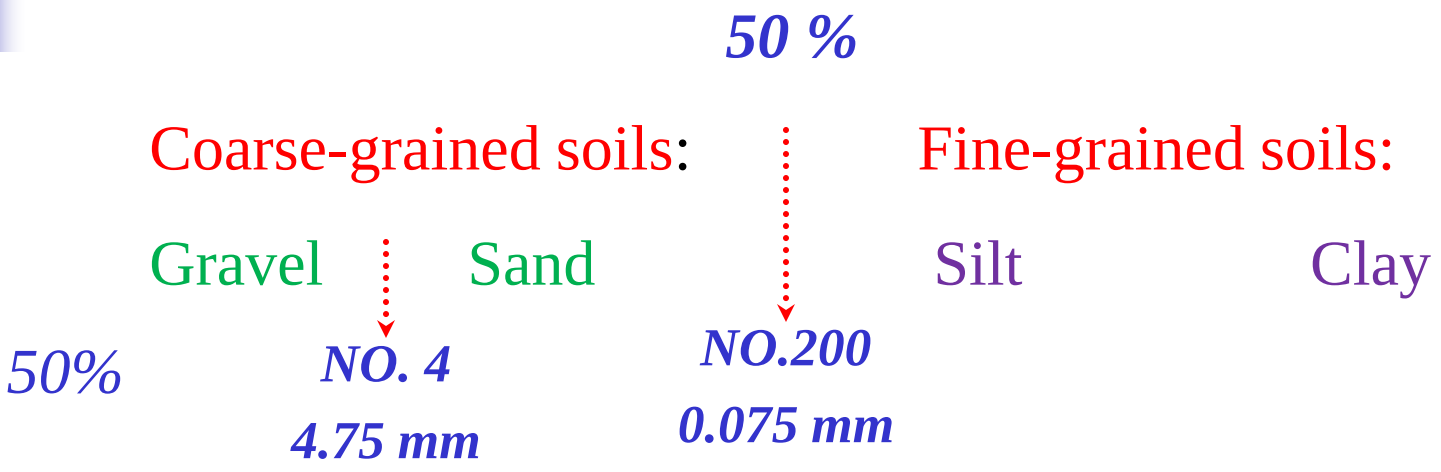
Four major divisions:

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

3.1 Definition of Grain Size



3.2 General Guidance



- Grain size distribution
- C_u
- C_c

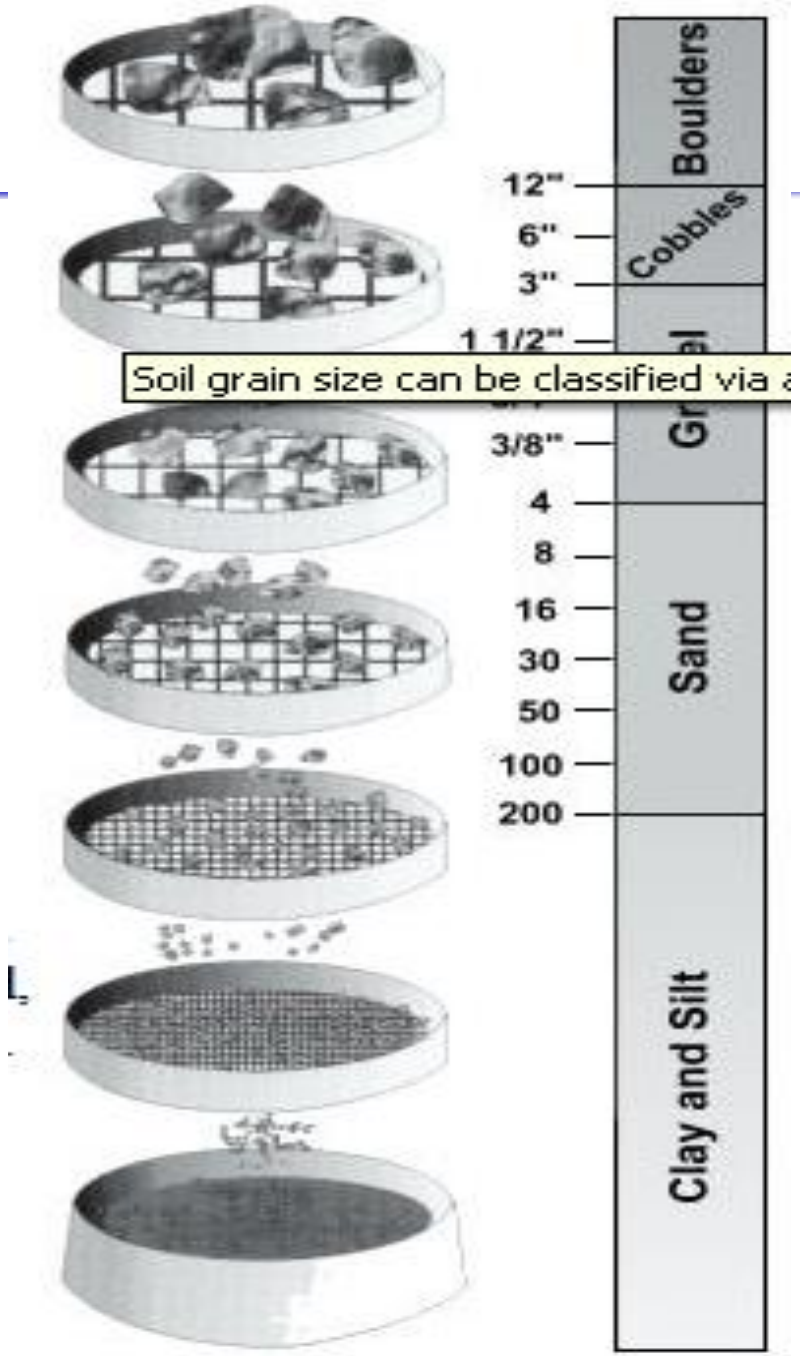
- PL, LL
- Plasticity chart

LL>50
LL <50

Required tests: Sieve analysis

Atterberg limit

Sieve Test

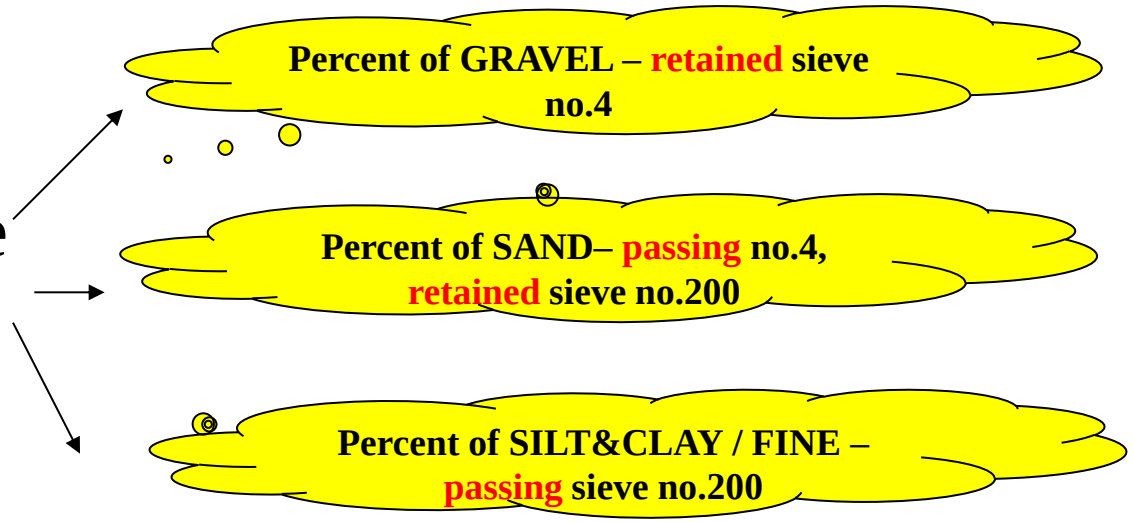


Soil grain size can be classified via a

Information needed

***some or all of this information need to be known:**

- Grain size



- Cu
- Cc
- PI & LL

3.3 Symbols

Soil symbols:

G: Gravel

S: Sand

M: Silt

C: Clay

O: Organic

Pt: Peat

Liquid limit symbols:

H: High LL (LL>50)

L: Low LL (LL<50)

Gradation symbols:

W: Well-graded

P: Poorly-graded

Example: SW, Well-graded sand

SC, Clayey sand

SM, Silty sand,

MH, Elastic silt

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

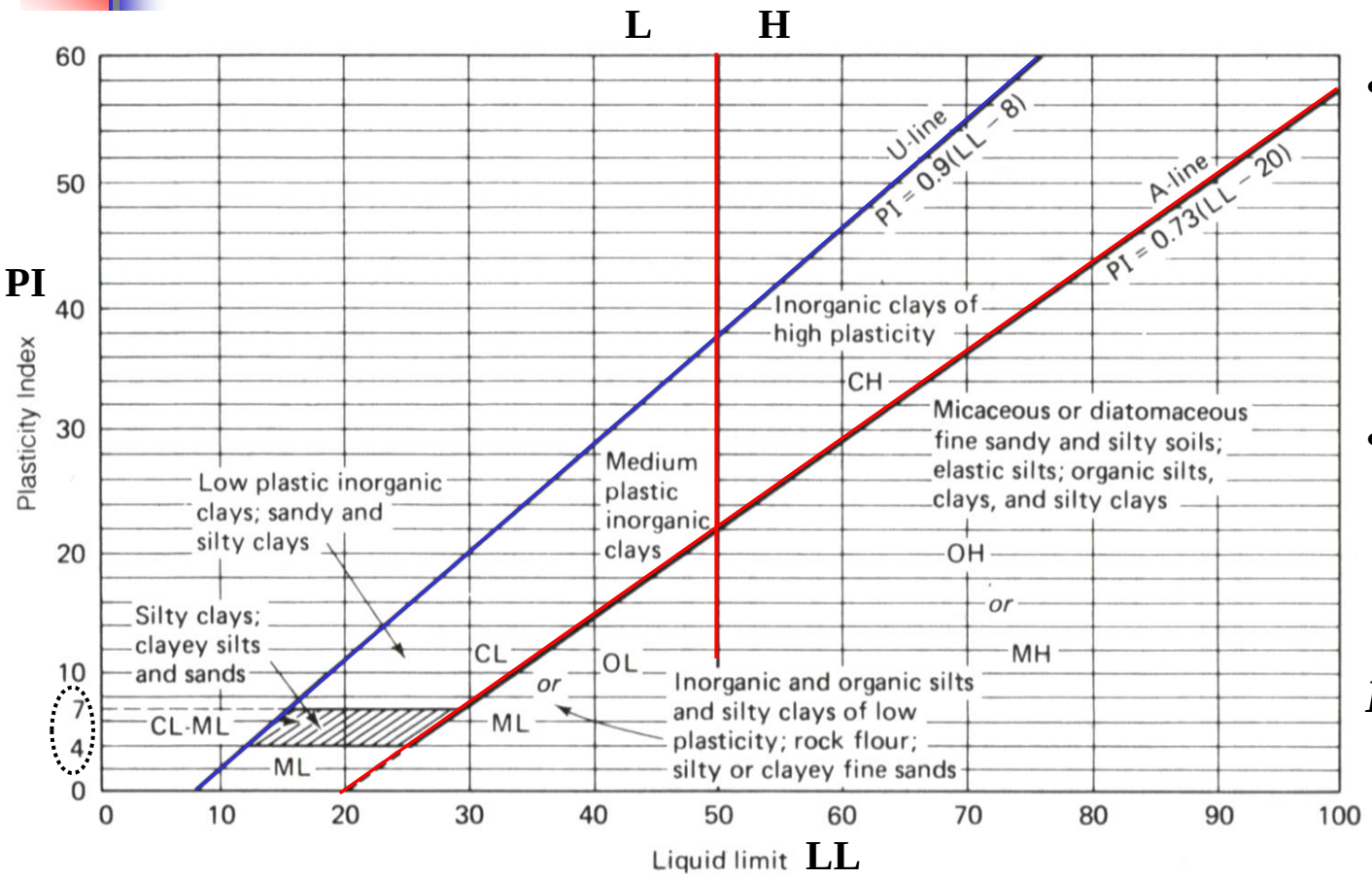


Fig. 3.2 Casagrande's plasticity chart, showing several representative soil types (developed from Casagrande, 1948, and Howard, 1977).

(Holtz and Kovacs, 1981)

- 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.

3.5 Procedures for Classification

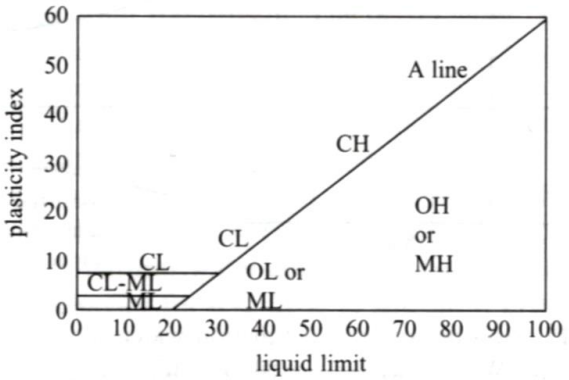
Coarse-grained material

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)

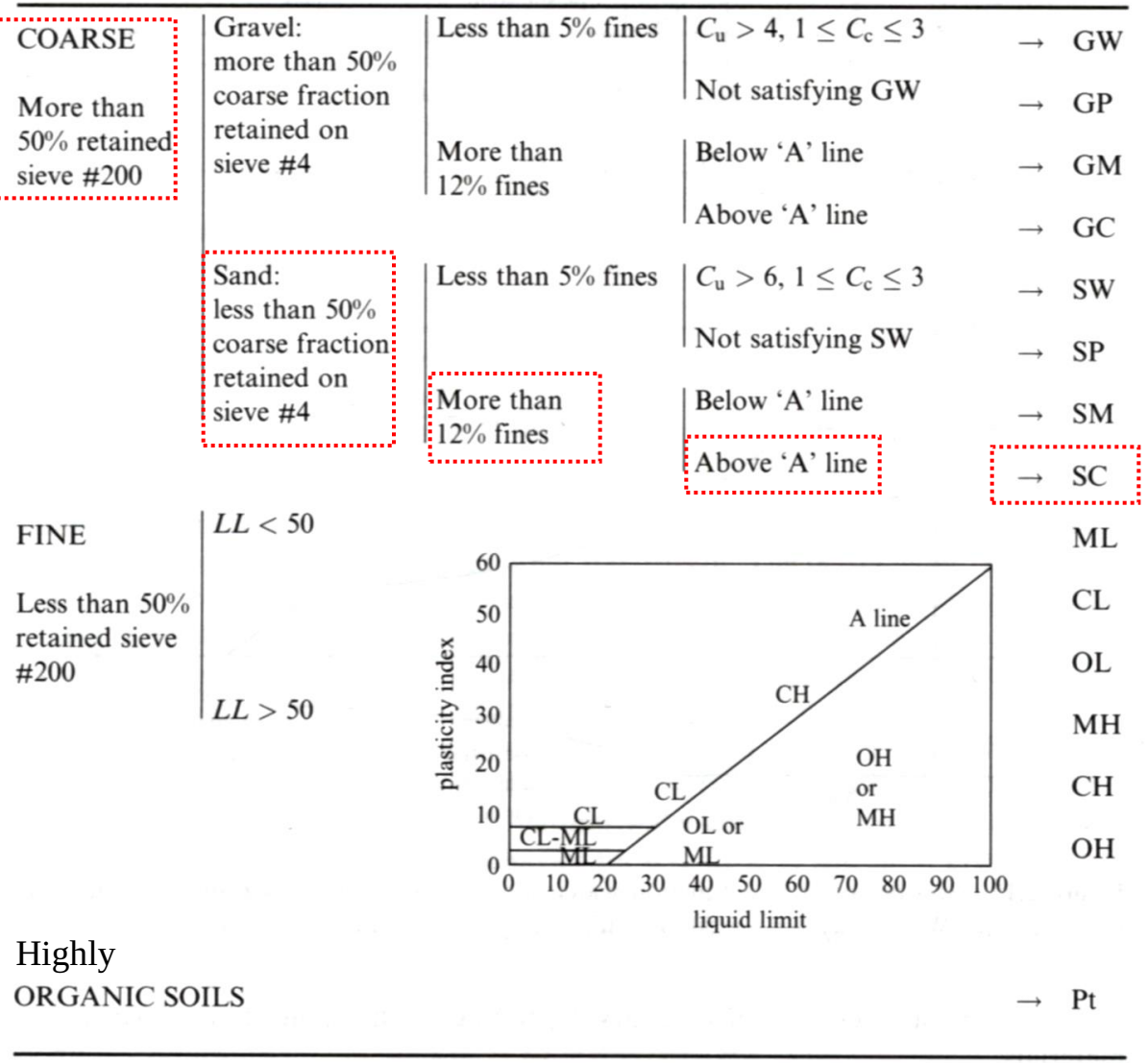
3.6 Example

Passing No.200 sieve 30 %

Passing No.4 sieve 70 %

LL= 33

PI= 12



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

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

(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.

- Soil contain similar fines and coarse-grained fractions.
  - possible dual symbols GM-ML
- 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.

Borderline Cases (Dual Symbols)

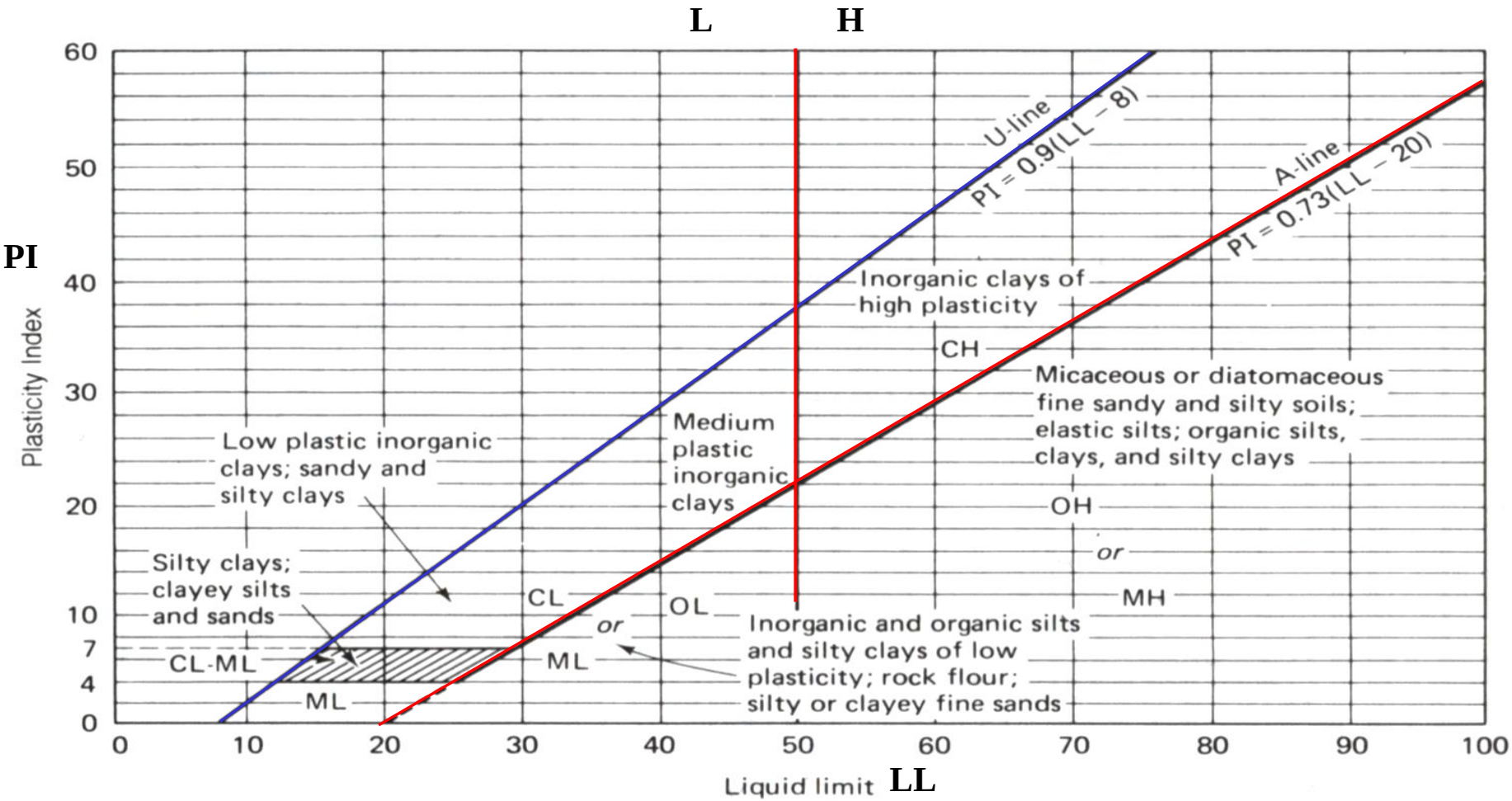
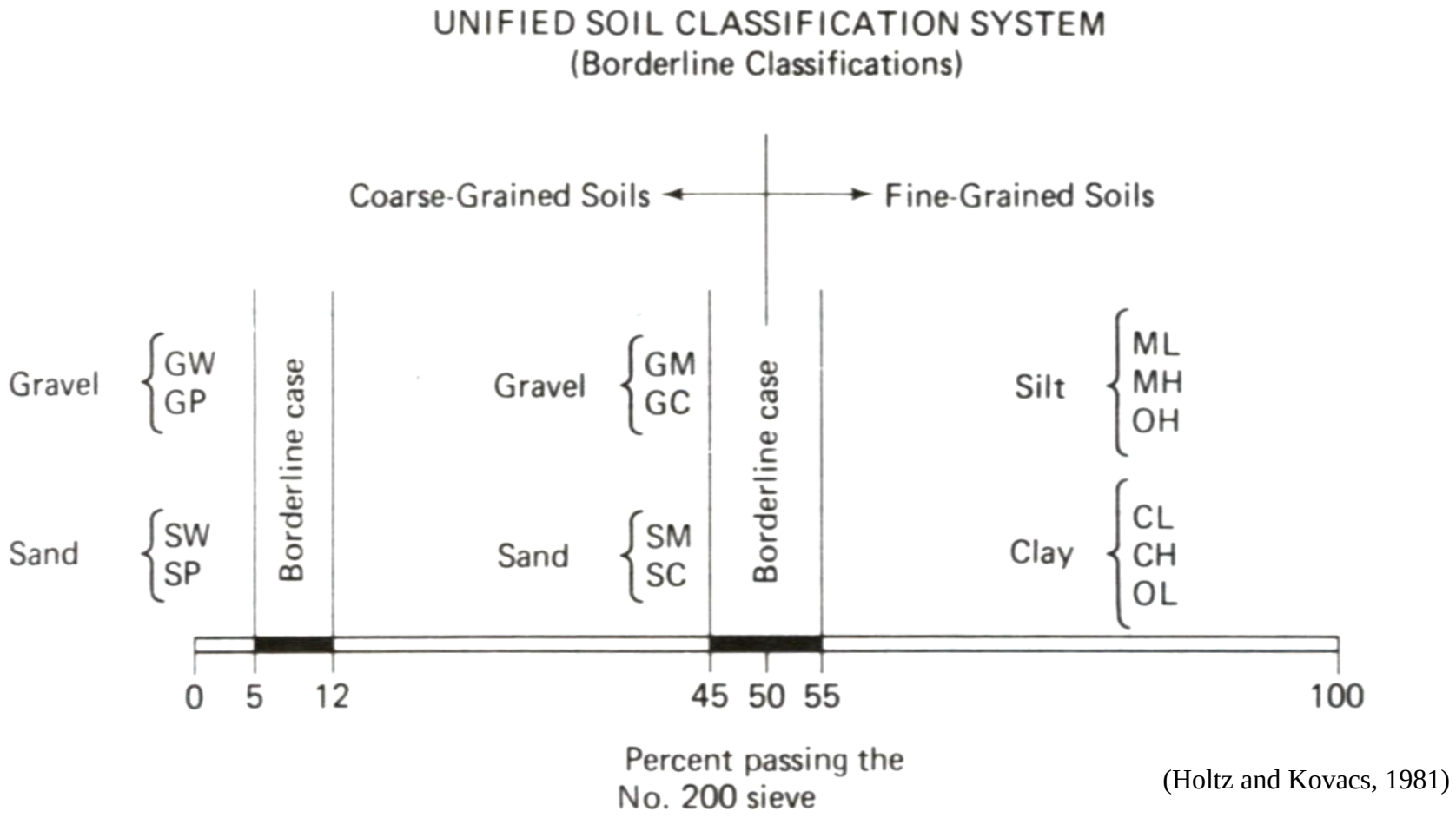


Fig. 3.2 Casagrande's plasticity chart, showing several representative soil types (developed from Casagrande, 1948, and Howard, 1977).

(Holtz and Kovacs, 1981)

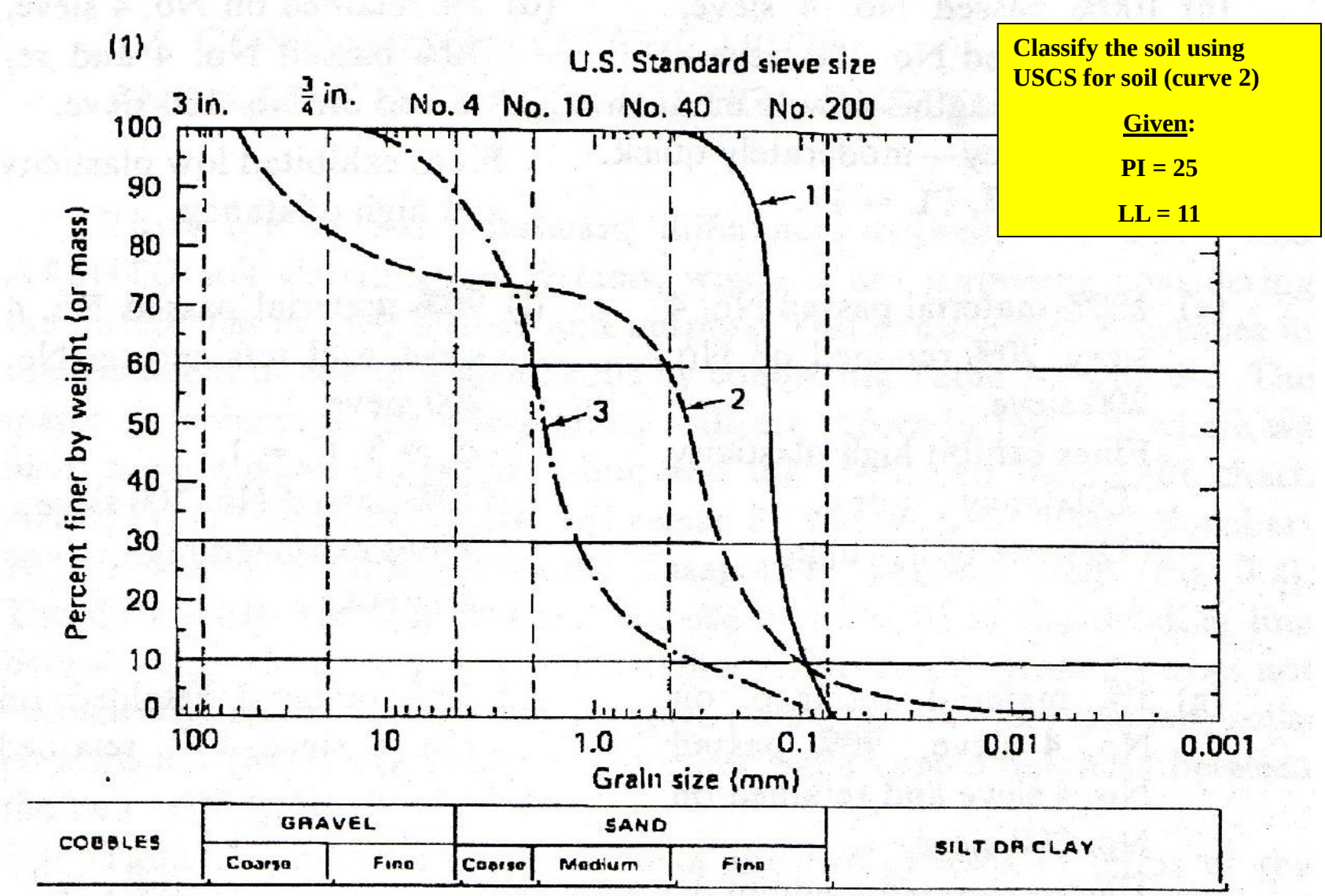
3.8 Borderline Cases (Summary)



(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.

Example USCS (Borderline Cases)



Classify the soil using USCS for soil (curve 2)

Given:

PI = 25

LL = 11

Solution…

Silt & Clay /Fine

% passing no.200 (F) = 8% < 50% ∴coarse grained soil

Sand

% passing no.4 = 75%; thus
retained no.4 = 25%

Gravel

% passing no.4, retained no.200 (F_1) = 67% > 50% ∴sandy soil

% fines lies between 5 to 12% , thus refer *dual symbols*

- **Based on the grading characteristic, curve of size distribution is considered as well graded (SW),**
- **Based on plasticity information, atterberg limits plot above A-line and PI greater than 7 ∴meets criteria for SC, therefore type of soil is…..**

SW-SC

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 General Guidance

- 7 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).

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

Using LL and PI separates silty materials from clayey materials

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

4.2 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.

Determination of GI

Some rules for determining GI value:

- If GI is negative, taken as 0
- GI value is rounded off to the nearest number
- GI for A-1-a, A-1-b, A-2-4, A-2-5 and A-3 always 0
- Use the partial GI for PI, when calculate the GI belong to group A-2-6 and A-2-7

4.3Classification

Coarse Grained

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.)

Fine Grained

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

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

$$= 33.47 \cong 33 \quad \textit{Round off}$$

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, $PI > LL - 30$

5. Suggested Homework

1. Please read Chapter 3 (Holtz's Book).
2. Read ASTM D2487 and D 2488.
3. Please go over Example 3.1 and 3.2.

6. References

Main References:

Das, B.M. (1998). *Principles of Geotechnical Engineering*, 4th edition, PWS Publishing Company. (Chapter 3)

Holtz, R.D. and Kovacs, W.D. (1981). *An Introduction to Geotechnical Engineering*, Prentice Hall. (Chapter 3)

Others:

Santamarina, J.C., Klein, K.A., and Fam, M.A. (2001). *Soils and Waves*, John Wiley & Sons, LTD.