Thi_ Qar University
College of Engineering/Civil Engineering Department

Highway Lectures

Fourth Class

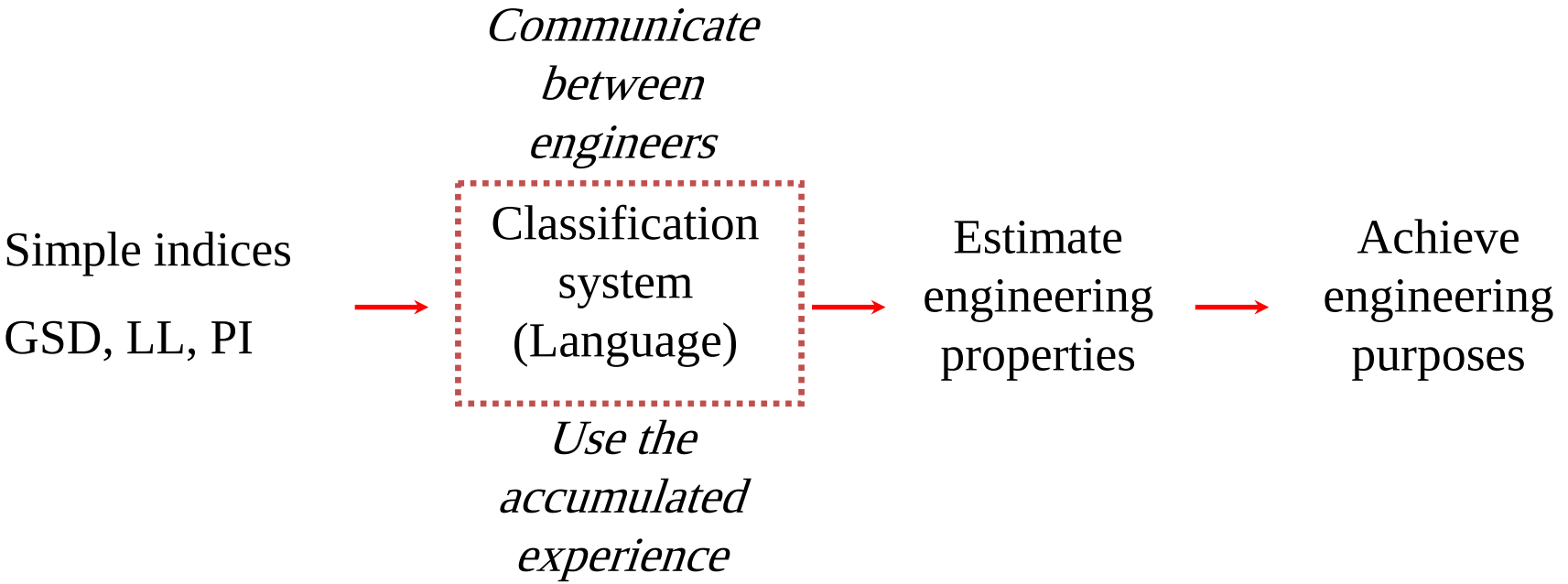
Part #2: - Subgrade Soil

Lecture #2
Soil Classification
DAS, Chapter 4, Engineering Classification of Soil

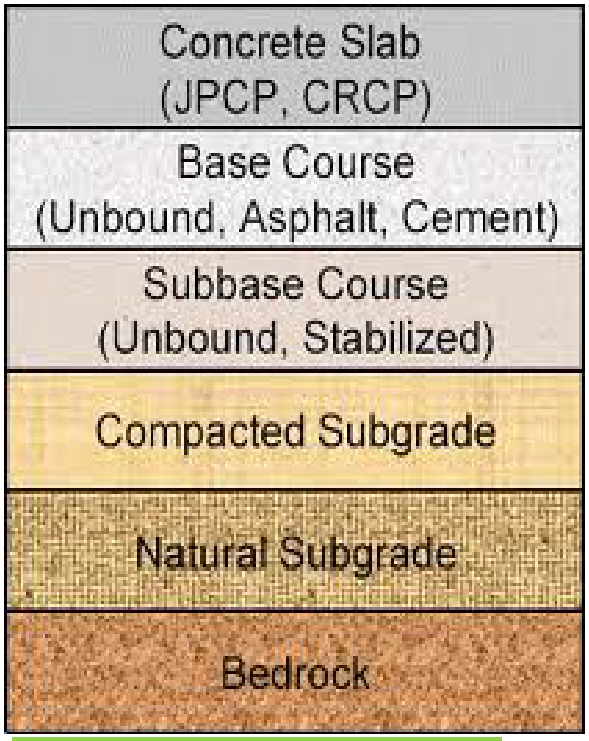
Prepared By
Dr. Haider Habeeb Aodah

Purpose

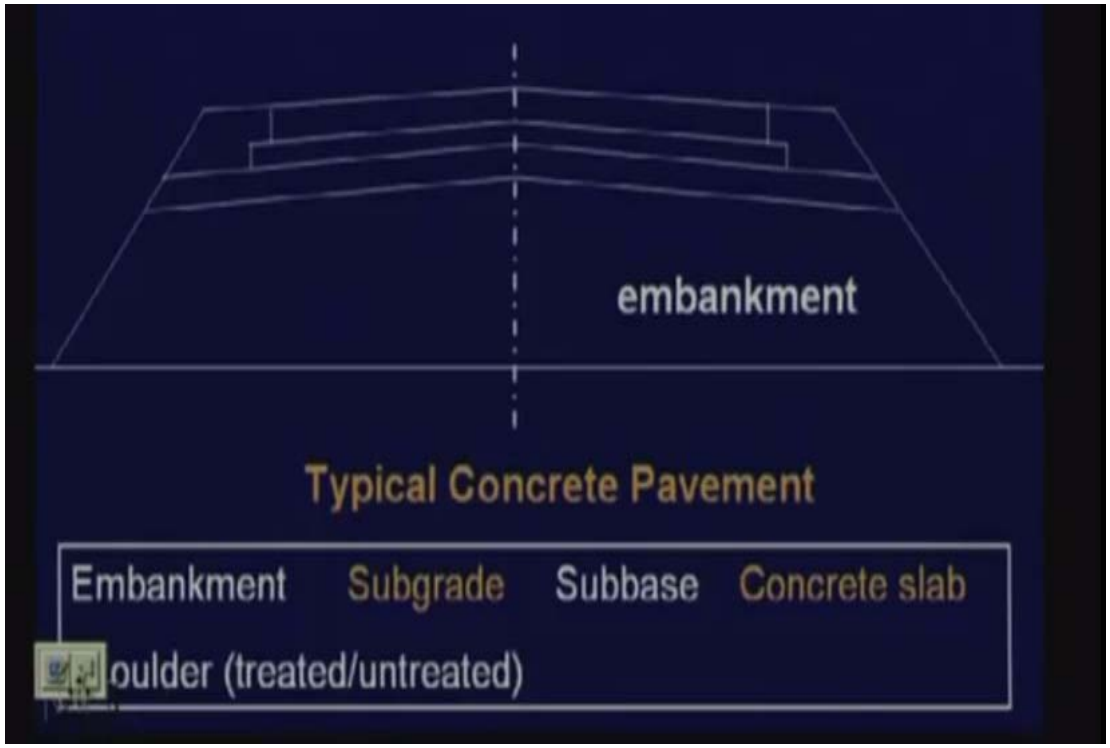
- Classifying soils into groups or sub-groups with similar engineering behavior.
- Classification systems were developed in terms of *simple* indices (Grain Size Distribution (GSD) and plasticity (LL, PL, PI)).
- These classifications can provide geotechnical engineers with general guidance about engineering properties of the soils through the *accumulated experience*.



Purpose



Typical section in rigid pavement



Typical section in flexible pavement

Classification Systems

Two commonly classification system used are:

1. American Association of State Highway and Transportation Officials (AASHTO) System (preferred by Transportation engineers).

2. Unified Soil Classification System (USCS) (preferred by geotechnical engineers).

AASHTO SYSTEM

➢This system was originally developed by Hogentogler and Terzaghiin 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)

➢The system is based on the following three soil properties:

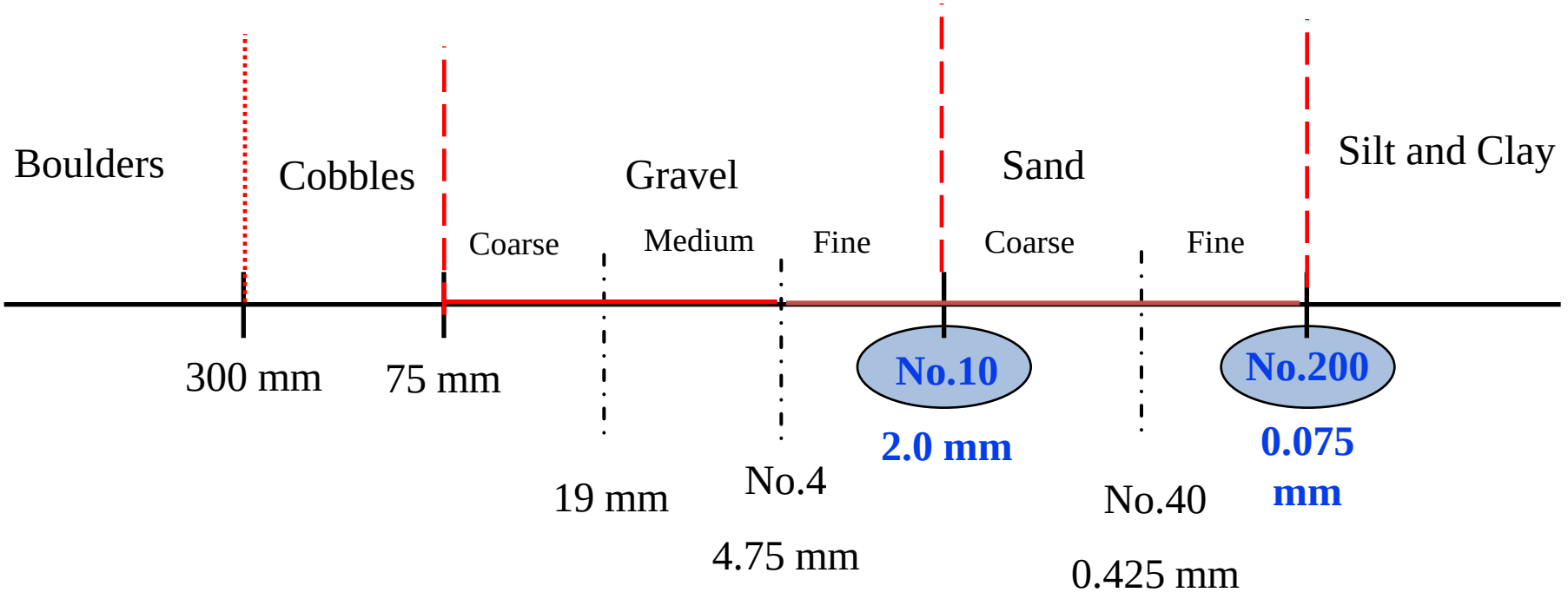
i. Particle-size distribution (AASHTO T-11 and AASHTO T-27 test)
ii. Liquid Limit (AASHTO T-89 test).
iii. Plasticity Index (AASHTO T-90 test).

AASHTO SYSTEM

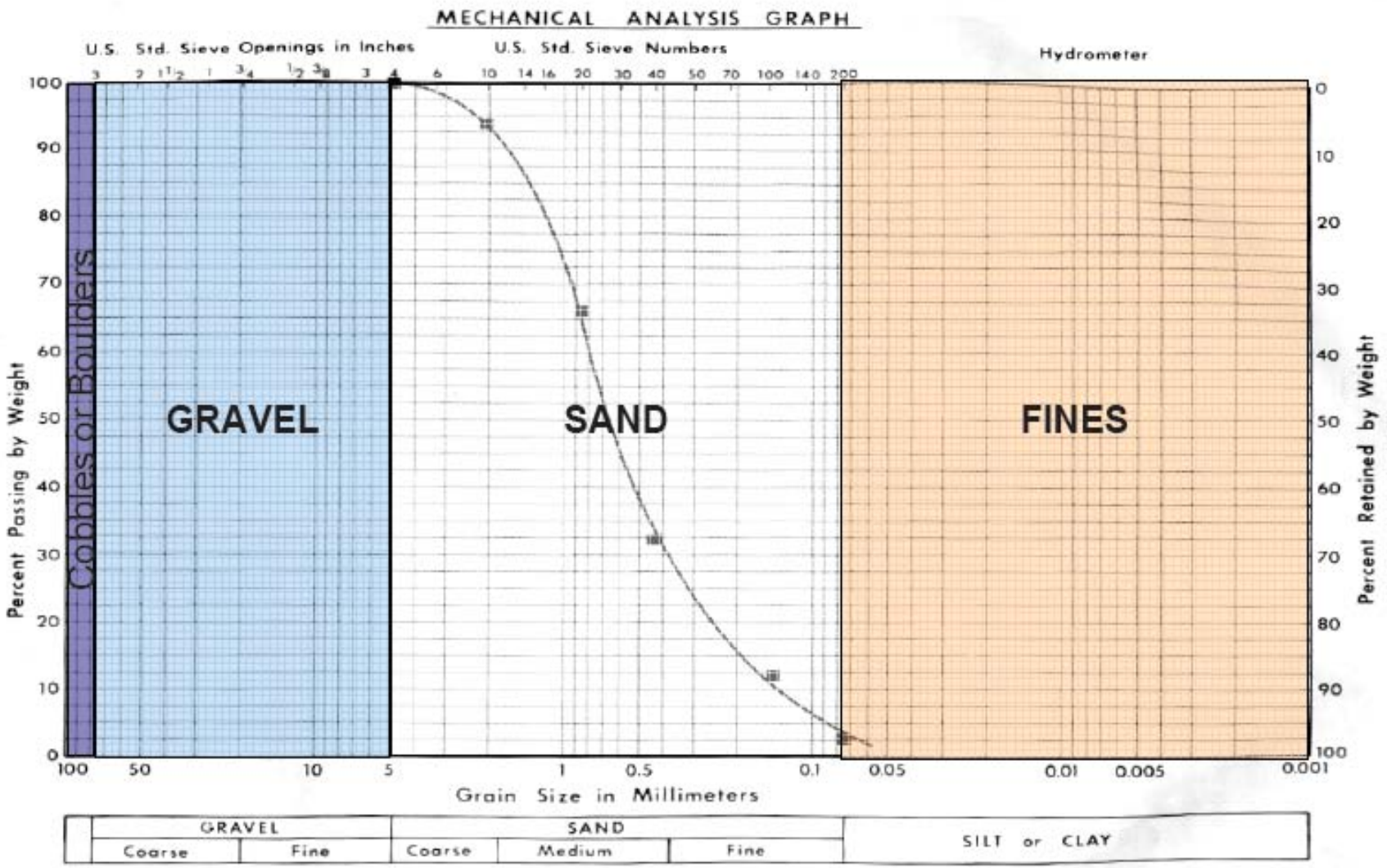
Definition of Grain Size

No specific grain size-use

Atterberg limits



Grain Size Distribution Curve



AASHTO SYSTEM

Key Elements:-

1.Grain Size:

- ***Gravel***: Fraction passing 75mm sieve and retained on #10 (2mm) US sieve
- ***Sand***: Fraction passing #10 sieve and retained #200 sieve
- ***Silt*** and ***Clay***: Fraction passing #200 sieve.

2.Plasticity:

- Term ***silty*** is applied when fine fractions have a $PI \leq 10$
- Term ***clayey*** is applied when fine fractions have $PI > 10$

3.Groups: (see Tables)

- Soils are classified into eight groups, **A-1** through **A-8**.
- The major groups**A-1**,**A-2**, and **A-3** represent the coarse grained soils.
- The **A-4**, **A-5**, **A-6**, and **A-7** represent fine grained soils.
- The **A-8** are identified by visual inspection.

AASHTO SYSTEM

Table:-

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						

Classification starts from left to right

AASHTO SYSTEM

Table:-

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 SYSTEM

Table:-

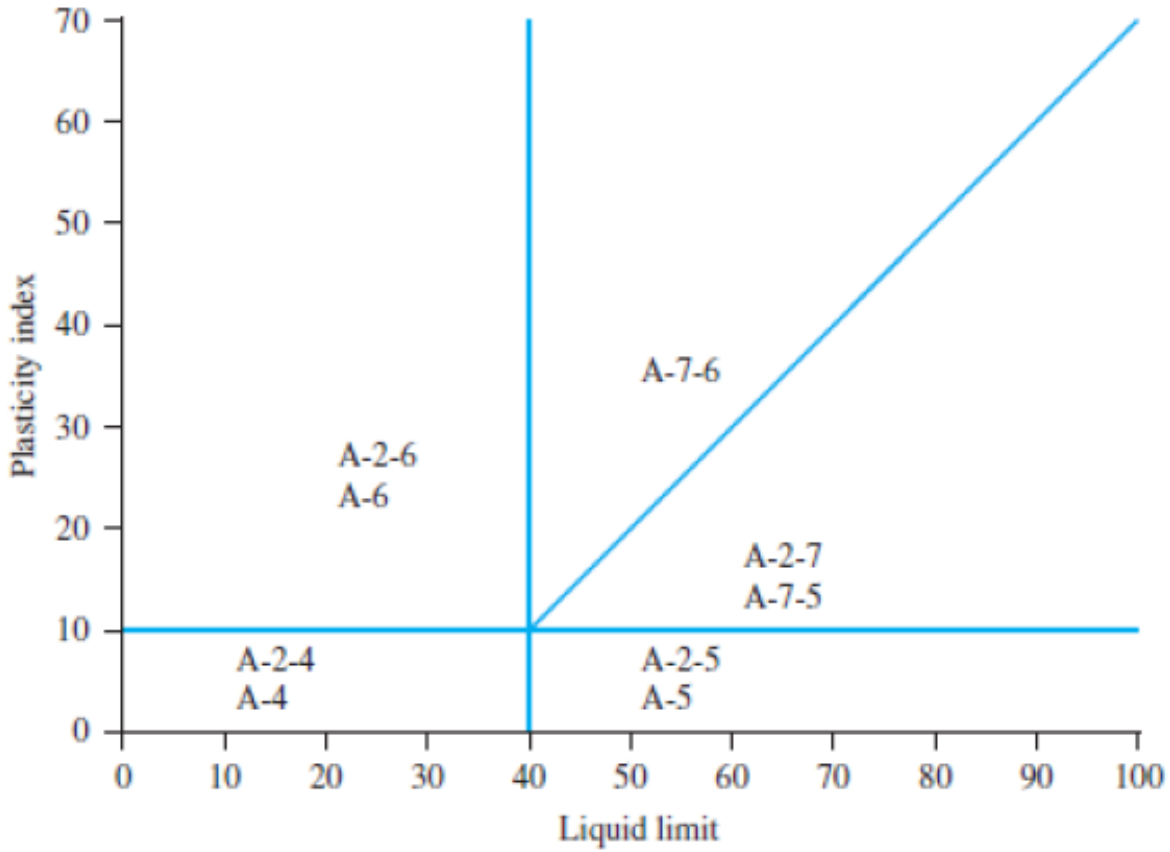
TABLE V-1
CLASSIFICATION OF SOILS AND SOIL-AGGREGATE MIXTURES

General Classification	Granular Materials (35% or less passing 0.075 mm) ~200							Silt-Clay Materials (More than 35% passing 0.075 mm)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis, Percent Passing											
2.00 mm (No. 10)	50 max	---	---	---	---	---	---	---	---	---	---
0.425 mm (No. 40)	30 max	50 max	51 min	---	---	---	---	---	---	---	---
0.075 mm (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of Fraction Passing 0.425 mm (No. 40)											
Liquid Limit	---		---	40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity Index	6 max		N.P.	10 max	10 max	11 min	11 min	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				Silty Soils		Clayey Soils	
General Rating as Subgrade	Excellent to Good							Fair to Poor			

Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30 (see Figure V-2).

AASHTO SYSTEM

- The ranges of the *LL* and *PI* for groups **A-2** , **A-4**, **A-5** , **A-6** and **A-7**:



AASHTO SYSTEM

Group Index (GI):-

- To evaluate the quality of a soil as a highway subgrade material, one must incorporate a number called the ***Group Index (GI)*** *with the groups and subgroups of the soil.* This index is written in parentheses after the group or subgroup designation. The group index is given by the equation:

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

The first term is determined by the LL

The second term is determined by the PI

where:

F_{200}: % passing #200 sieves expressed as whole number

LL: liquid limit of soil

PI: Plasticity Index of soil

AASHTO SYSTEM

Group Index (GI):-

i. A soil having ***GI*** of zero is considered as the best.

ii. 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. The higher the value of GI the weaker will be the soil and vice versa. Thus, quality of performance of a soil as a subgrade material is *inversely proportional* to GI.

iii. If Eq. (1) yields a negative value for GI, it is taken as 0.

iv. The group index 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).

v. There is no upper limit for the group index.

AASHTO SYSTEM

Procedure:-

- Determine the percentage of soil passing the #200 sieve
- Determine the subgroups

i. For coarse-grained soils (gravel and sand), determine the percent passing the #10, 40, and 200 sieves.

ii. Determine the liquid limit and plasticity index

iii. THEN, determine soil group or subgroup from Table.

iv. Determine the Group Index (usually reflects the relative strength of the material, where low values have the greatest shear strength).

AASHTO SYSTEM

Example #1:-

Classify the following soils by the AASHTO classification system.

Description	Soil A	B	C	D	E
Percent finer than No. 10 sieve	83	100	48	90	100
Percent finer than No. 40 sieve	48	92	28	76	82
Percent finer than No. 200 sieve	20	86	6	34	38
Liquid limit[a]	20	70	—	37	42
Plasticity index[a]	5	32	Nonplastic	12	23

AASHTO SYSTEM

Example #1:-

Passing No.200 86%
LL=70, PI=32
LL-30=40 > PI=32

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

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

AASHTO SYSTEM

Example #2:-

The following are the characteristics of two soils. Classify the soils according to the AASHTO system.

Soil A:

Percent passing No. 4 sieve	= 98
Percent passing No. 10 sieve	= 90
Percent passing No. 40 sieve	= 76
Percent passing No. 200 sieve	= 34
Liquid limit	= 38
Plastic limit	= 26

Soil B:

Percent passing No. 4 sieve	= 100
Percent passing No. 10 sieve	= 98
Percent passing No. 40 sieve	= 86
Percent passing No. 200 sieve	= 58
Liquid limit	= 49
Plastic limit	= 28

AASHTO SYSTEM

Example #2:-

Solution

Soil A:

1. The soil has 34% (which is less than 35%) passing through No. 200 sieve. So this is a coarse-grained soil.
2. For this soil, the liquid limit = 38.
   From Equation (7.2), plasticity index, $PI = LL - PL = 38 - 24 = 12$.
   From Table 9–1, by matching, the soil is found to belong to subgroup *A-2-6*.
3. From Equation (9.1)
   $$GI = 0.01(F_{200} - 15)(PI - 10)$$
   $$= 0.01(34 - 15)(12 - 10) = (0.01)(19)(2)$$
   $$= 0.38 \approx 0$$
4. So, the soil can be classified as *A-2-6(0)*.

AASHTO SYSTEM

Homework:-

- Classify the following soil Using AASHTO System.
- Given:
- % passing No. 10 = 100;
- % passing No. 40 = 80;
- '% passing No.200 = 58
- LL = 30; PI = 10.

AASHTO SYSTEM

DESCRIPTION OF GROUPS & SUBGROUPS

Group A-1: Well-graded mixtures of stone fragments or gravel ranging from coarse to fine with a non-plastic or slightly plastic soil binder**.** However, this group also includes coarse materials without soil binder.

Subgroup A-1-a: Materials consisting predominantly of stone fragments or gravel, either with or without a well graded soil binder**.**

Subgroup A-1-b: Materials consisting predominantly of coarse sand either with or without a well-graded soil binder.

AASHTO SYSTEM

DESCRIPTION OF GROUPS & SUBGROUPS

Group A-3: Material consisting of sands deficient in coarse material and soil binder. Typical is fine beach sand or fine desert blow sand, without silt or clay fines or with a very small amount of non-plastic silt. This group also includes stream deposited mixtures of poorly graded fine sand and limited amounts of coarse sand and gravel. These soils make suitable subgrades for all types of pavements when confined and damp. They are subject to erosion and have been known to pump and blow under rigid pavements. (Information: They can be compacted by vibratory, pneumatic-tired, and steel-wheeled rollers but not with a sheeps foot roller.)

Group A-2: This group includes a wide variety of "granular" materials that are borderline between the materials falling in Groups A-1 and A-3 and silt-clay materials of Groups A-4, A-5, A-6 and A-7. It includes all materials containing 35 percent or less passing the 75-μm (No. 200) sieve that cannot be classified as A-1 or A-3.

AASHTO SYSTEM

DESCRIPTION OF GROUPS & SUBGROUPS

Group A-4: The typical material of this group is a non-plastic or moderately plastic silty soil usually having 75 percent or more passing the 75 μm (No. 200) sieve. The group includes also mixtures of fine silty soil and up to 64 percent of sand and gravel retained on the 75-μm (No. 200) sieve

Group A-5: The typical material of this group is similar to that described under Group A-4, except that it is usually of diatomaceous or micaceous character and may be highly elastic as indicated by the high liquid limit

.

Group A-6: The typical material of this group is plastic clay soil usually having 75 percent or more passing the 75-μm (No. 200) sieve. The group includes also mixtures of fine clayey soil and up to 64 percent of sand and gravel retained on the 75-μm (No. 200) sieve.

AASHTO SYSTEM

DESCRIPTION OF GROUPS & SUBGROUPS

Group A-7: The typical materials and problems of this group are similar to those described under Group A-6, except that they have the high liquid limits characteristic of the A-5 group and may be elastic as well as subject to high volume change.

Subgroup A-7-5: Includes those materials with moderate Plasticity Indexes in relation to Liquid Limit and which may be highly elastic as well as subject to considerable volume change.

Subgroup A-7-6: Includes those materials with high Plasticity Indexes in relation to Liquid Limit and which are subject to extremely high volume change.

Subgroup A-8: Highly organic soils such as peat or muck are not included in this classification. Because of their many undesirable properties, their use should be avoided, if possible, in all types of construction.

Unified Soil Classification System (USCS)

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

$$\text{Well}-\text{graded soil}$$

$$1 < C_c < 3 \text{ and } C_u \geq 4$$

$$(\text{for gravels})$$

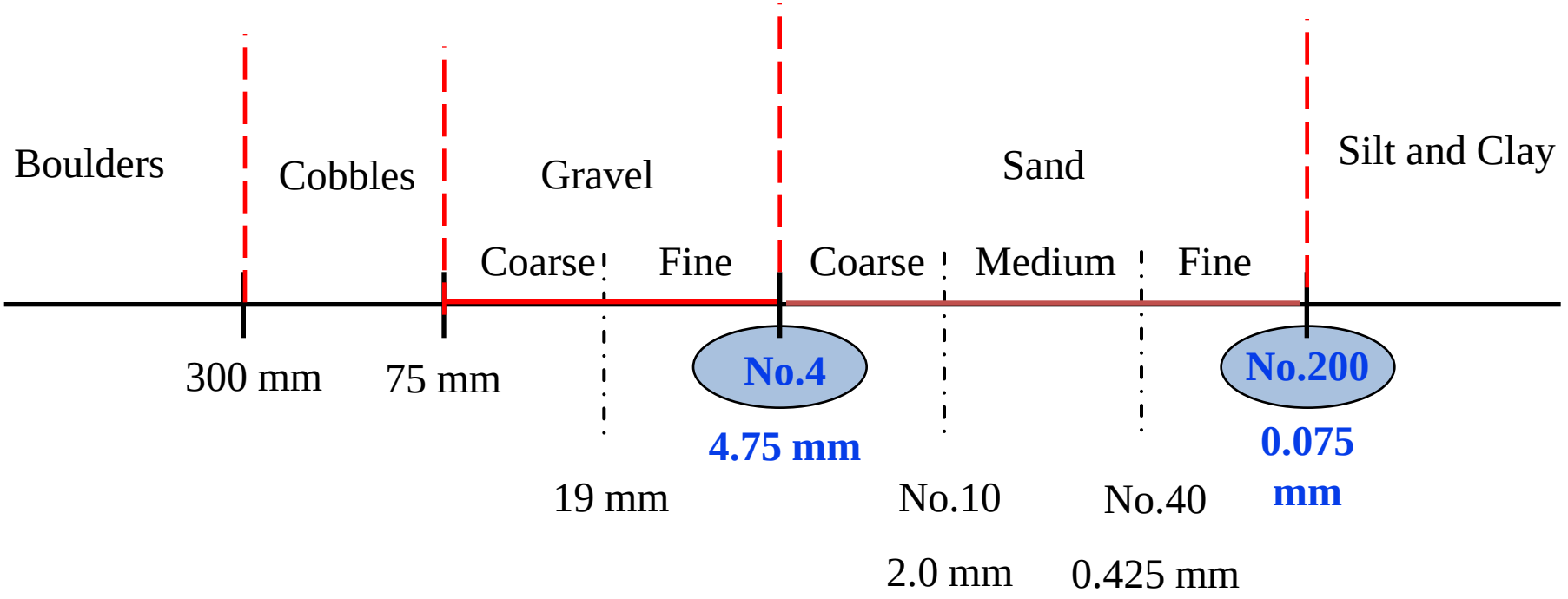
$$1 < C_c < 3 \text{ and } C_u \geq 6$$

$$(\text{for sands})$$

Unified Soil Classification System (USCS)

Definition of Grain Size

No specific grain size-use Atterberg limits



Unified Soil Classification System (USCS)

% Passing sieve No. 200 (0.075 mm)

< 50%

Coarse-grained soils

•Grain size distribution

> 50%

Fine-grained soils

Silt (M)

Clay (C)

•Use Plasticity chart

•LL, PL

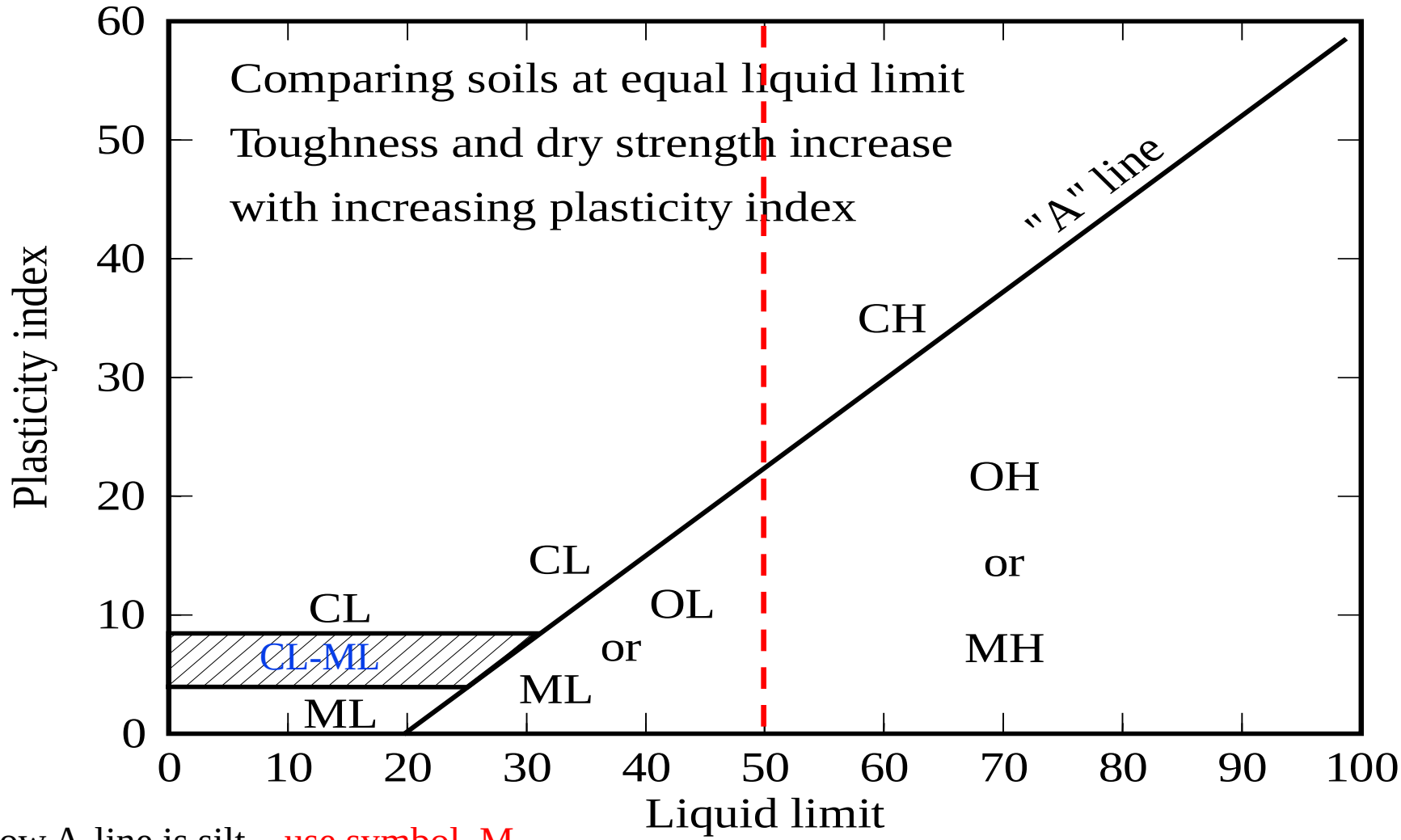
•Use Plasticity chart

ML, MH, CL, CH

Required tests: Sieve analysis

Atterberg limit

Unified Soil Classification System (USCS)



Plasticity chart

Below A-line is silt – use symbol M

Above A-line is clay – use symbol C

Unified Soil Classification System (USCS)

% Passing sieve No. 200 (0.075 mm)

< 50%

Coarse-grained soils

% Coarse soil (Co) = 100 - % Passing # 200

% Gravel (G) = 100 - % Passing # 4

G > 1/2 Co

Gravel (G)

G < 1/2 Co

Sand (S)

% Passing sieve No. 200

- < 5% — GW, GP, SW or SP — Use → C_u, C_c — W : well graded P: poorly graded
- 5% -12 % — GW-GM, GW-GC, GP-GM, GP-GC, SW-SM, SW-SC, SP-SM, SP-SC
- > 12% — GM, GC, SM, SC — Use → plasticity charts

> 50%

Fine-grained soils

Silt (M)

Clay (C)

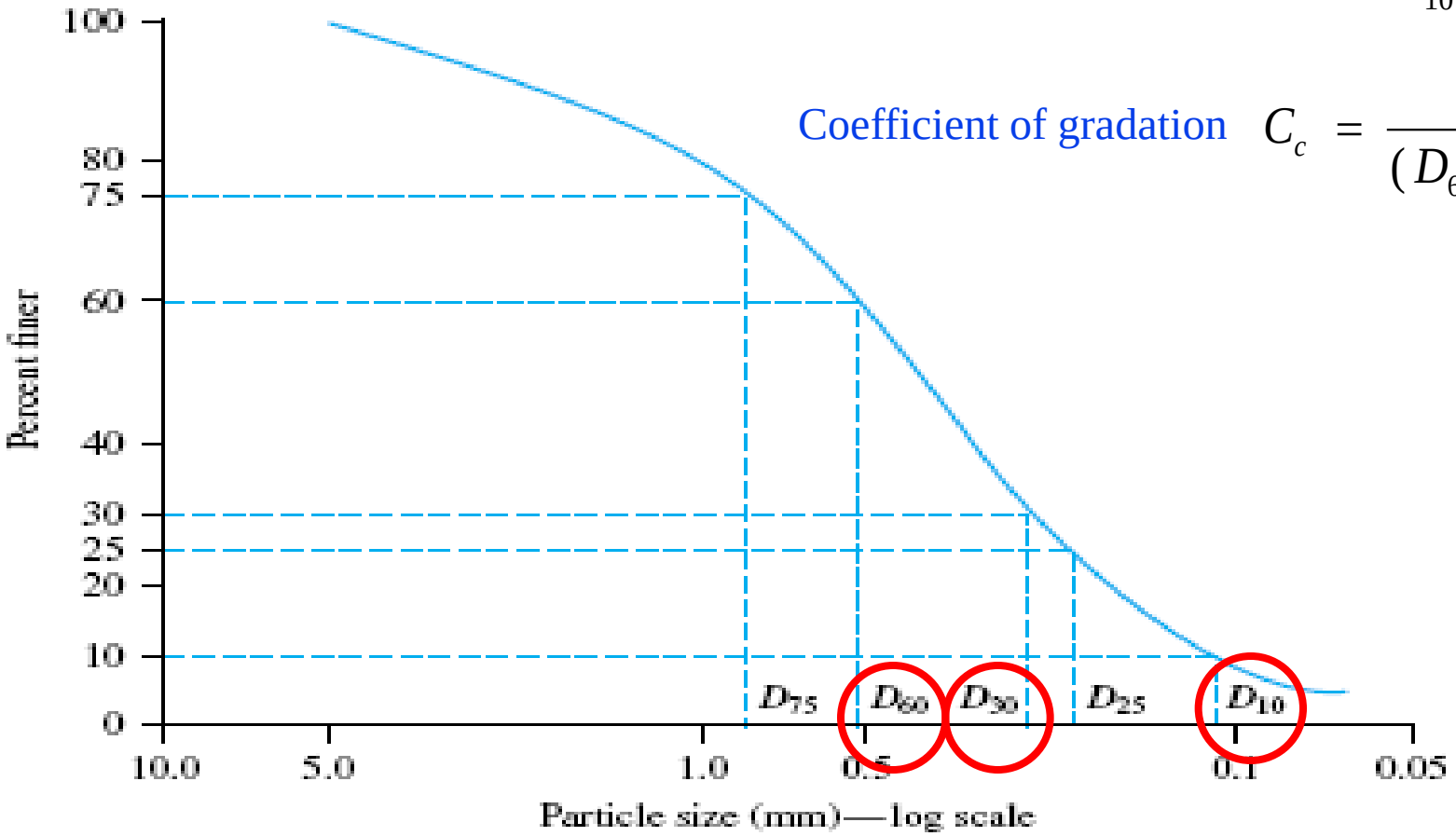
- Use Plasticity chart
- LL, PL

Unified Soil Classification System (USCS)

To determine if well graded (W) or poorly graded (P), calculate C_u and C_c

Coefficient of uniformity $C_u = \frac{D_{60}}{D_{10}}$

Coefficient of gradation $C_c = \frac{D_{30}^2}{(D_{60} \times D_{10})}$



Unified Soil Classification System (USCS)

Coefficient of uniformity $$C_u = \frac{D_{60}}{D_{10}}$$

Coefficient of gradation $$C_c = \frac{D_{30}^2}{(D_{60} \times D_{10})}$$

Conditions for **Well-graded soils**

For ***gravels*** → $C_u > 4$ **and** C_c is between 1 and 3

For ***Sand*** → W if $C_u > 6$ **and** C_c is between 1 and 3

1. Unified Soil Classification System (USCS)

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

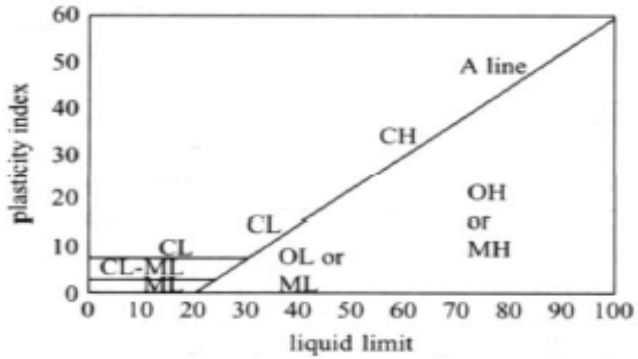
[d] If $4 \leq PI \leq 7$ and plots in the hatched area in Figure 5.3, use dual symbol GC-GM or SC-SM.

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

Unified Soil Classification System (USCS)

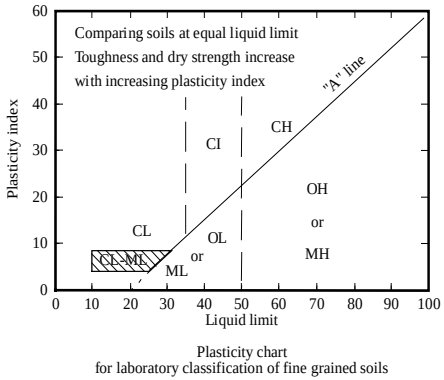
Procedures for Classification

Coarse-grained material **Grain size distribution**	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-grained material **LL, PI**	FINE Less than 50% retained sieve #200	$LL < 50$			→ ML → CL → OL
		$LL > 50$			→ MH → CH → OH
	Highly ORGANIC SOILS				→ Pt



Unified soil classification (including identification and description)

Field identification procedures (Excluding particles larger than 75mm and basing fractions on estimated weights)					*Group symbols 1*	*Typical names*	*Information required for describing soils*	*Laboratory classification criteria*
Coarse grained soils More than half of material is larger than .075mm sieve size The .075mm sieve size is about the smallest particle visible to the naked eye	*Gravels More than half of coarse fraction is larger than 2.36mm*	*Clean gravels (little or no fines)*	Wide range of grain size and substantial amounts of all intermediate particle sizes		GW	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical names: indicate approximate percentages of sand and gravel: maximum size: angularity, surface condition, and hardness of the coarse grains: local or geological name and other pertinent descriptive information and symbol in parentheses. For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics. *Example:* Silty sand, gravelly; about 20% hard angular gravel particles 12.5mm maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic lines with low dry strength; well compacted and moist in places; alluvial sand; (SM)	Use grain size curve in identifying the fractions as given under field identification Determine percentages of gravel and sand from grain size curve Depending on percentages of fines (fraction smaller than .075mm sieve size) coarse grained soils are classified as follows Less than 5% GW, GP, SW, SP More than 12% GM, GC, SM, SC 5% to 12% Bordeline case requiring use of dual symbols $C_U = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 Not meeting all gradation requirements for GW Atterberg limits below "A" line or PI less than 4 — Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols Atterberg limits above "A" line with PI greater than 7 $C_U = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 Not meeting all gradation requirements for SW Atterberg limits below "A" line or PI less than 4 — Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols Atterberg limits above "A" line with PI greater than 7
		Gravels with fines (appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)		GM	Silty gravels, poorly graded gravel-sand-silt mixtures		
			Plastic fines (for identification procedures see CL below)		GC	Clayey gravels, poorly graded gravel-sand-clay mixtures		
	Sands More than half of coarse fraction is smaller than 2.36mm	*Clean sands (little or no fines)*	Wide range in grain sizes and substantial amounts of all intermediate particle sizes		SW	Well graded sands, gravelly sands, little or no fines		
			Predominantely one size or a range of sizes with some intermediate sizes missing		SP	Poorly graded sands, gravelly sands, little or no fines		
		Sands with fines (appreciable amount of fines)	Non-plastic fines (for identification procedures, see ML below)		SM	Silty sands, poorly graded sand-silt mixtures		
			Plastic fines (for identification procedures, see CL below)		SC	Clayey sands, poorly graded sand-clay mixtures		
Fine grained soils More than half of material is smaller than .075mm sieve size	*Identification procedure on fraction smaller than .425mm sieve size*		*Dry strength crushing characteristics*	*Dilatency (reaction to shaking)*	*Toughness (consistency near plastic limit)*			
	Silts and clays liquid limit less than 50		None to slight	Quick to slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains: colour in wet condition, odour if any, local or geological name, and other pertinent descriptive information, and symbol in parentheses For undisturbed soils add information on structure, stratification, consistency and undisturbed and remoulded states, moisture and drainage conditions *Example* Clayey silt, brown: slightly plastic: small percentage of fine sand: numerous vertical root holes: firm and dry in places; loess; (ML)
			Medium to high	None to very slow	Medium	CL,CI	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	
			Slight to medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity	
	Silts and clays liquid limit greater than 50		Slight to medium	Slow to none	Slight to medium	MH	inorganic silts, micaceous or dictomaceous fine sandy or silty soils, elastic silts	
			High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays	
			Medium to high	None to very high	Slight to medium	OH	Organic clays of medium to high plasticity	
Highly organic soils			Readily identified by colour, odour spongy feel and frequently by fibrous texture			Pt	Peat and other highly organic soils	



Plasticity chart
for laboratory classification of fine grained soils

Unified Soil Classification System (USCS)

Example#1

Passing No.200 sieve 30 %

Passing No.4 sieve 70 %

LL= 33

PI= 12

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

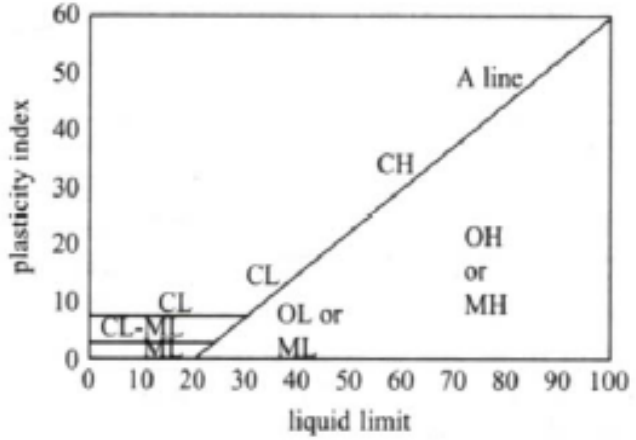
PI=0.73(33-20)=9.49

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



Unified Soil Classification System (USCS)

Example#2

Classify Soils A and B as given in Example 9–1 and obtain the group symbols and group names. Assume Soil B to be inorganic.

Soil A:

Percent passing No. 4 sieve	= 98
Percent passing No. 10 sieve	= 90
Percent passing No. 40 sieve	= 76
Percent passing No. 200 sieve	= 34
Liquid limit	= 38
Plastic limit	= 26

Soil B:

Percent passing No. 4 sieve	= 100
Percent passing No. 10 sieve	= 98
Percent passing No. 40 sieve	= 86
Percent passing No. 200 sieve	= 58
Liquid limit	= 49
Plastic limit	= 28

Unified Soil Classification System (USCS)

Solution

Soil A:

Step 1. $F_{200} = 34\%$

Step 2. $R_{200} = 100 - F_{200} = 100 - 34 = 66\%$

Step 3. $R_{200} = 66\% > 50\%$. So it is a coarse-grained soil.

Skip Step 4.

Step 5. $R_4 = 100 - F_4 = 2\%$

$R_4 < 0.5R_{200} = 33\%$

So it is a sandy soil (Step 5b). $F_{200} > 12\%$. Thus C_u and C_c values are not needed.

$PI = LL - PL = 38 - 26 = 12$

$PI = 12 < 0.73(LL - 20) = 0.73(38 - 20) = 13.14$

From Table 9–6, the *group symbol* is **SM**.

$GF = R_4 = 2\%$ (which is $< 15\%$)

From Table 9–6, the *group name* is **silty sand**.

Soil B:

Step 1. $F_{200} = 58\%$

Step 2. $R_{200} = 100 - F_{200} = 100 - 58 = 42\%$

Step 3. $R_{200} = 42\% < 50\%$. So it is a fine-grained soil.

Unified Soil Classification System (USCS)

Soil B:

Step 1. $F_{200} = 58\%$

Step 2. $R_{200} = 100 - F_{200} = 100 - 58 = 42\%$

Step 3. $R_{200} = 42\% < 50\%$. So it is a fine-grained soil.

Step 4. From Table 9–3, $LL = 49 < 50$

$PI = 49 - 28 = 21$

$PI = 21 < 0.73(LL - 20) = 0.73(49 - 20) = 21.17$

So the *group symbol* is **ML**.

Again, $R_{200} = 42\% > 30\%$

$R_4 = 100 - F_4 = 100 - 100 = 0\%$

So $GF = 0\% < 15\%$

$SF = R_{200} - GF = 42 - 0 = 42\%$

$SF/GF > 1$

So the *group name* is **sandy silt**.

Unified Soil Classification System (USCS)

Example #3

Soil A

Coarse = 100-48 = 52% (retained on N o. 2 0 0), so COARSE-GRAINED SOIL

8% retained on No. 4, vs. 52% coarse,

8/52 = 15% (<50%), so SAND

Using the LL and PL values in the USAC

Atterberg limits above line A, so Clay

Classification SC, clayey sand

Soil B

Coarse = 100 - 76 = 24%, so FINE-GRAINED SOIL

LL = 60, and P I = 32 Using Casagrandi Chart

Classification CH, inorganic clay with high plasticity

Soil C

Coarse = 100 - 35 = 65%, so COARSE-GRAINED SOIL

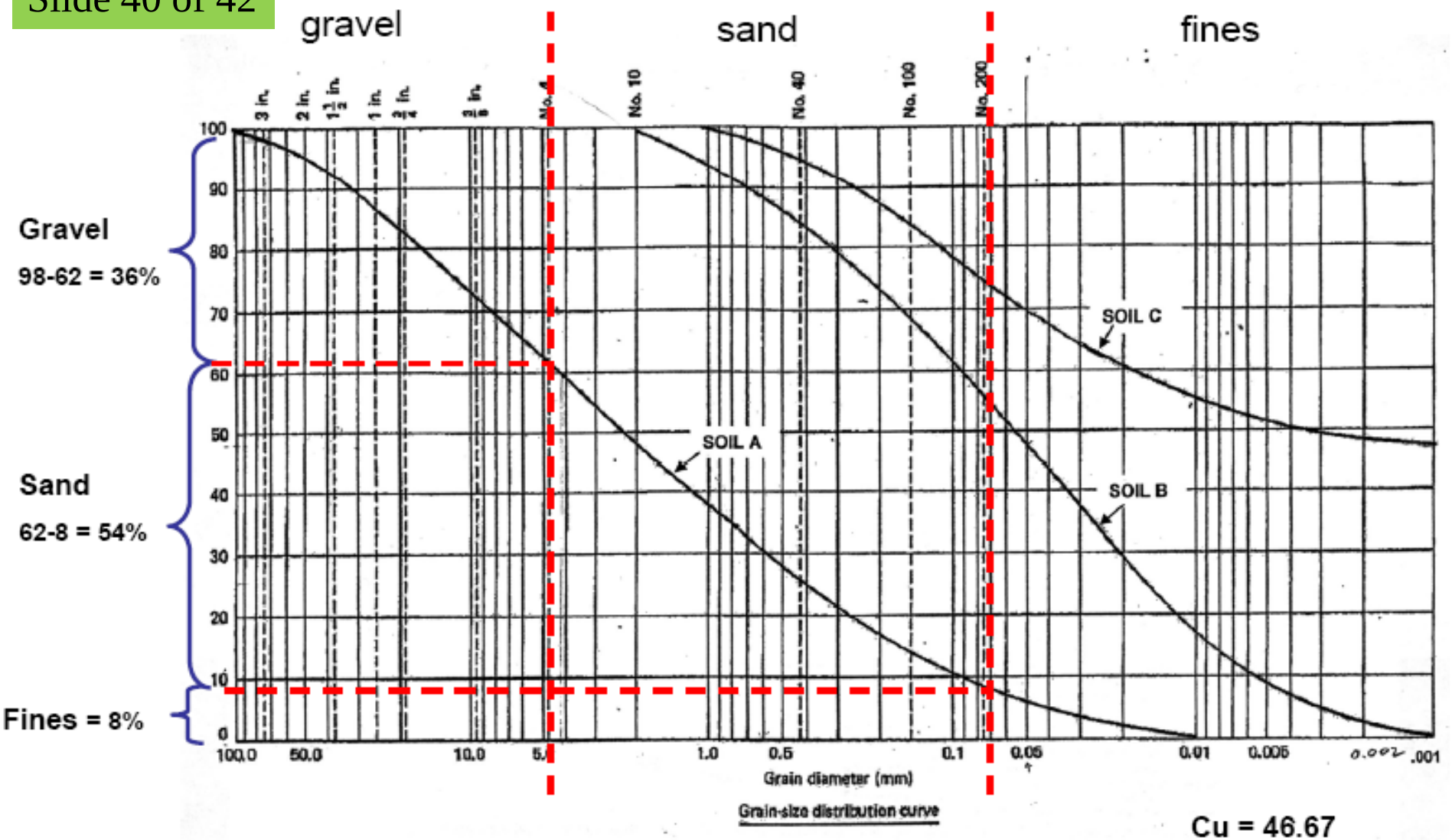
20% retained on No. 4, vs. 65%

coarse, 20/65 = 31% (<50%), so SAND

Using Casagrandi Chart

Classification SM, Silty sand

Example 3 – Soil A



Gravel
98-62 = 36%

Sand
62-8 = 54%

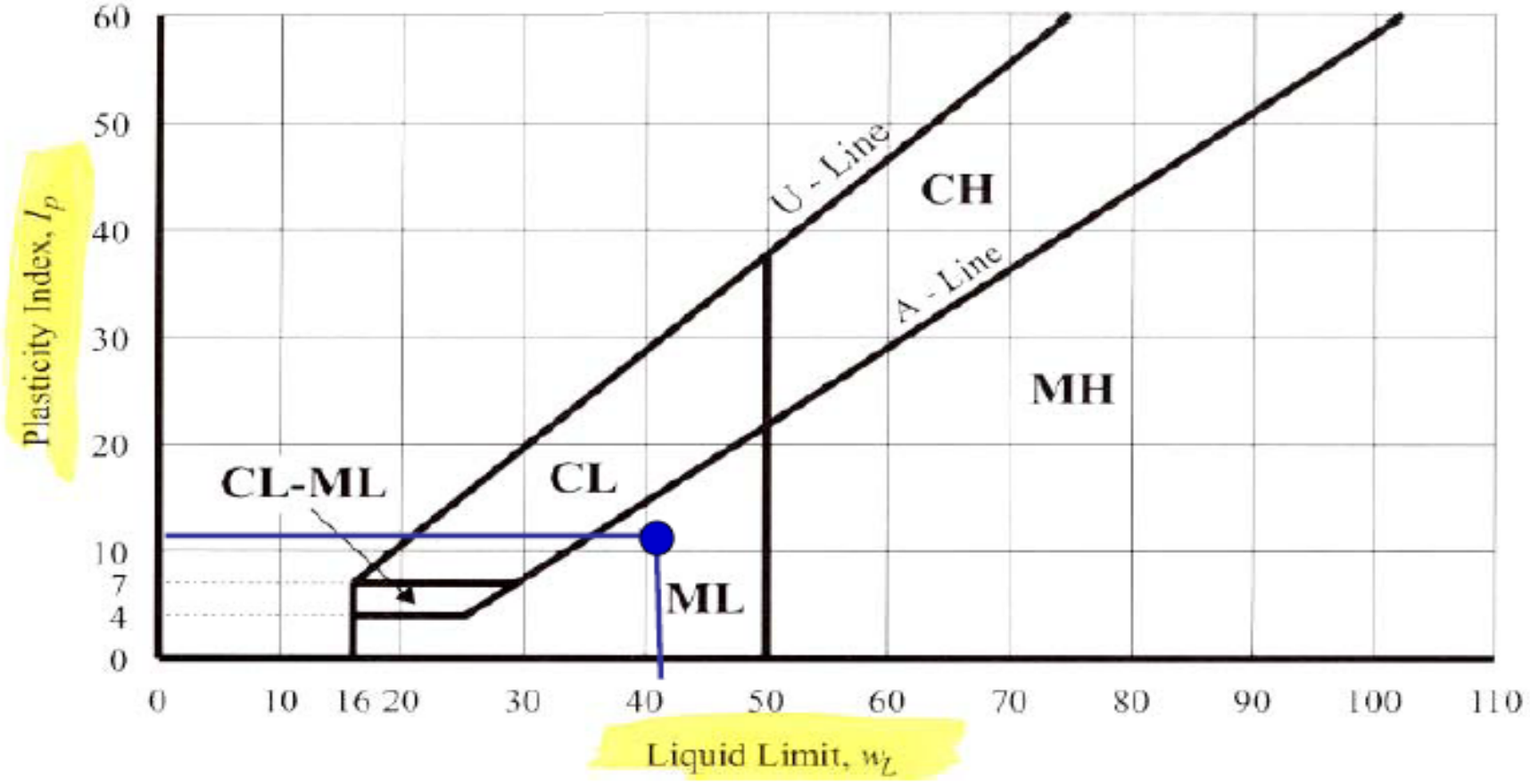
Fines = 8%

Soil A: D_{60} = 4.2 mm , D_{30} = 0.6 mm, D_{10} = 0.09 mm

Cu = 46.67
Cc = 0.95

LL = 42
PL = 31
PI = 42-31 = 11

Example 3 – Soil A (Cont.)



LL = 42
PL = 31
PI = 42-31 = 11

→ **ML**

Unified Soil Classification System (USCS)

HOMEWORK:

Classify the following soils by both the AASHTO and Unified Systems, and give the group index for the AASHTO system.

	Sieve Analysis -- % finer than				
Soil Sample	#10	#40	#200	Liquid Lmt	Plastic Lmt
A	95	79	53	36	21
B	100	95	78	65	26
C	100	80	62	35	20
D	90	55	45	28	20
E	90	71	60	40	26

Soil Fractions

AASHTO M-145:-

Boulders and Cobbles – material retained on the 75 mm (3 in.) sieve. They should be excluded from the portion of a sample to which the classification is applied, but the percentage of such material should be recorded.

Gravel – materials passing sieve with 75 mm (3 in.) and retained on the 2.0 mm (No. 10)

Coarse Sand – materials passing the 2.0 mm (No. 10) sieve and retained on the 425-μm (No. 40) sieve.

Fine Sand – materials passing the 425-μm (No. 40) sieve and retained on the 75-μm (No. 200)

Combined Silt and Clay – material passing the 75-μm (No. 200) sieve. The word “silty” is applied to a fine material having a Plasticity Index of 10 or less, and the term “clayey” is applied to fine material having a PI of more than 10.

Questions - ?

References

1) Braja M. DAS,(2006), “ Engineering Classification of Soil”, Chapter 4,
2) Internet websites.