Soil Classification

Measuring of fundamental soil Properties

- Permeability
- Compressibility
- Strength

- Difficult
- Time consuming
- Expensive

Soil Classification

A Soil Classification scheme provides a method of identifying soils in a particular group that would likely

- To exhibit similar characteristics
- Suitable for a given application

Approximate analysis for the preliminarily soil selection

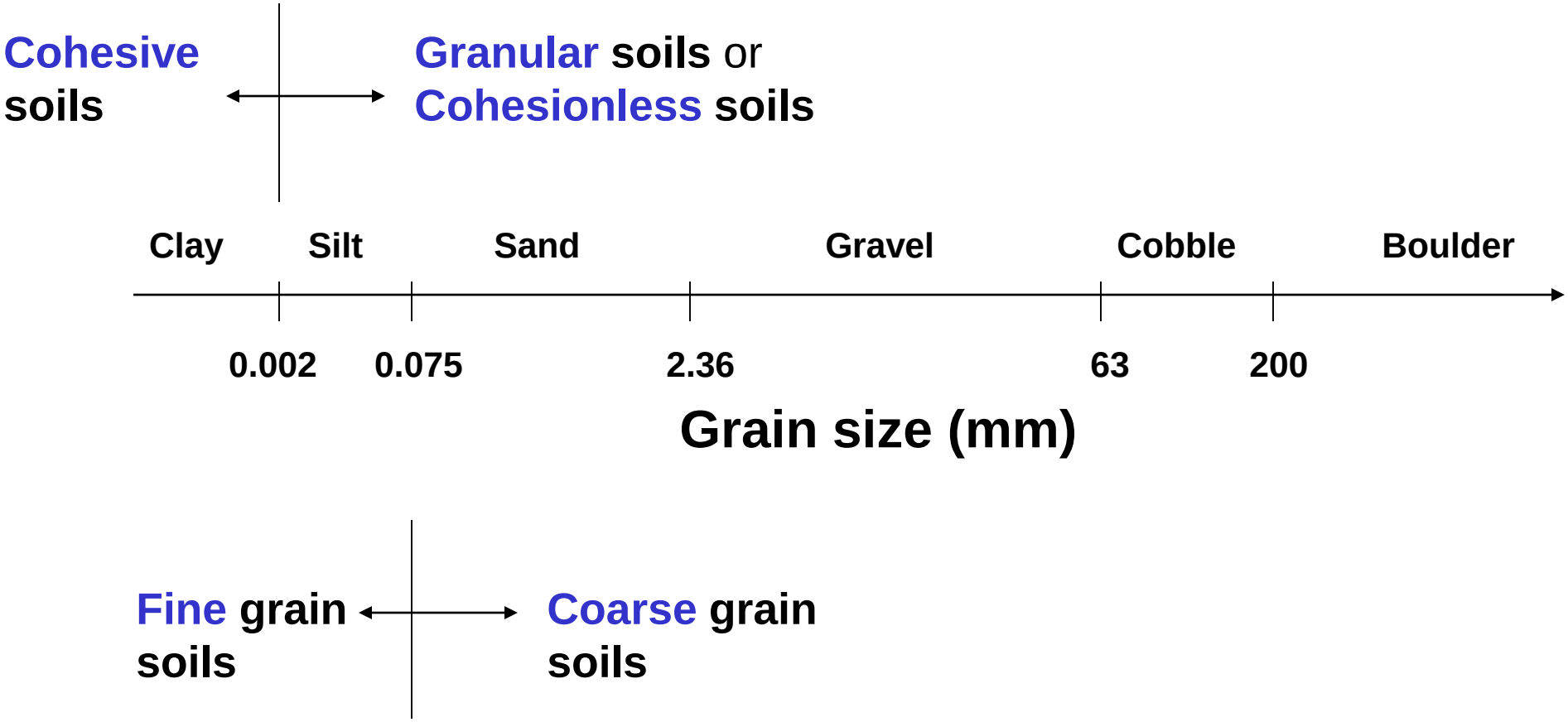
Possible Criteria for Classifying Soils and their Utility

S. No. (*1*)	*Criteria* (*2*)	*Utilitity* (*3*)
(*i*)	Origin	Provides useful information, but too complicated to assess.
(*ii*)	Colour	Knowledge not sufficient to indicate probable engineering behaviour.
(*iii*)	Smell	— do —
(*iv*)	Porosity	— do —
(*v*)	Water content	— do —
(*vi*)	Sulphate content	Of little relevance to soil engineer.
(*vii*)	Ability to sustain plant life	— do —
(*viii*)	Strength	Too complicated to determine, and once known, no need to classify.
(*ix*)	Permeability	— do —
(*x*)	Compressibility	— do —
(*xi*)	Size of particles	Useful criteria for classification.
(*xii*)	Stickiness or plasticity	— do —

Classifications on basis of size

It has been thought that a soil largely containing small sized particles, will differ in its engineering behavior from a soil mainly containing relatively larger particles

Major Soil Groups



Note:

Clay-size particles

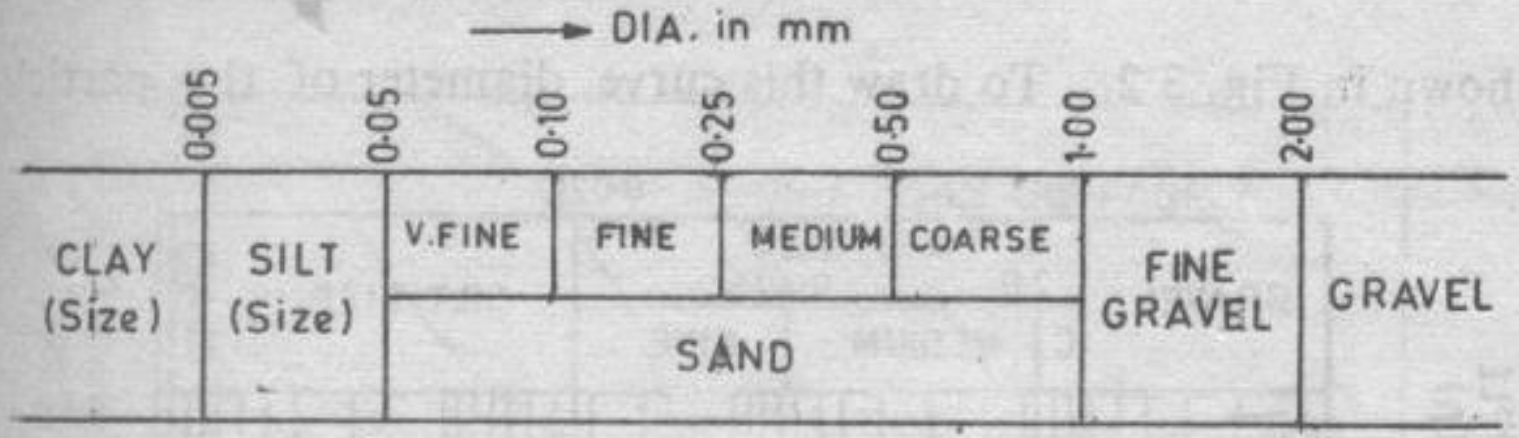
For example:

A small quartz particle may have the similar size of clay minerals.

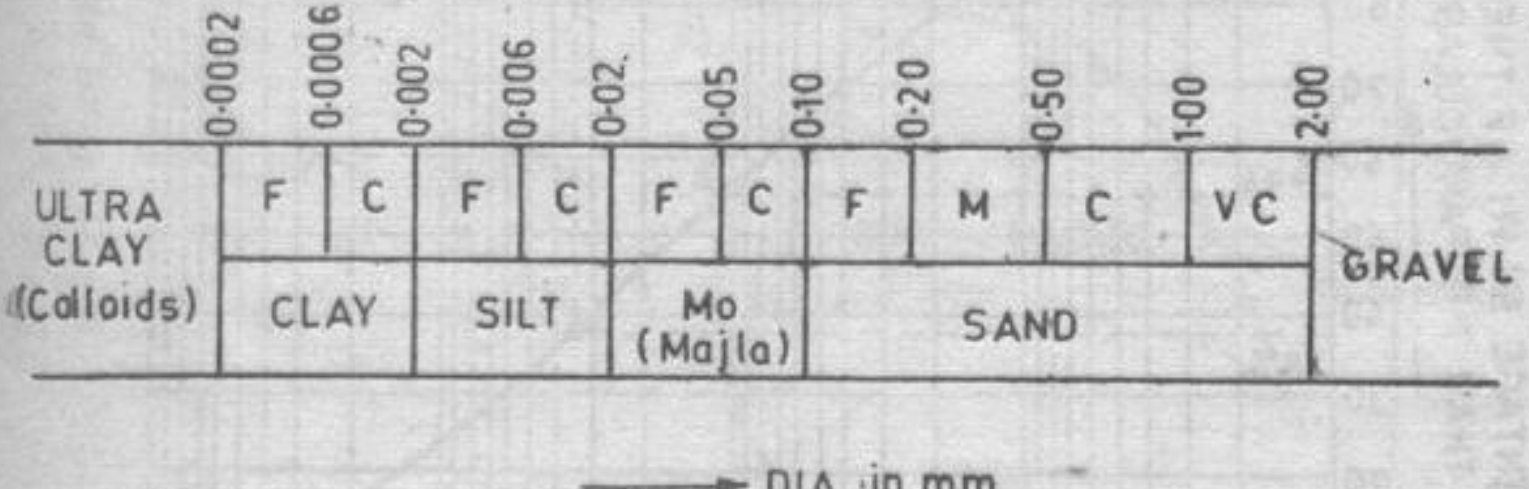
Clay minerals

For example:

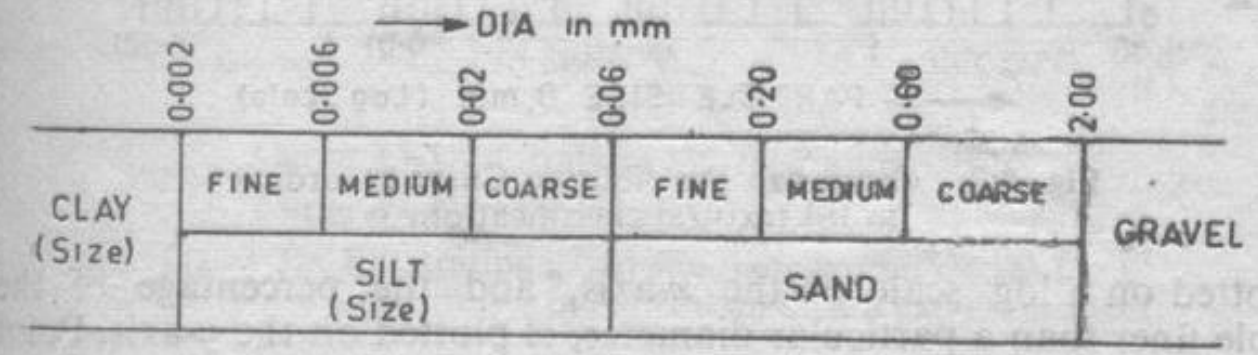
Kaolinite, Illite, etc.



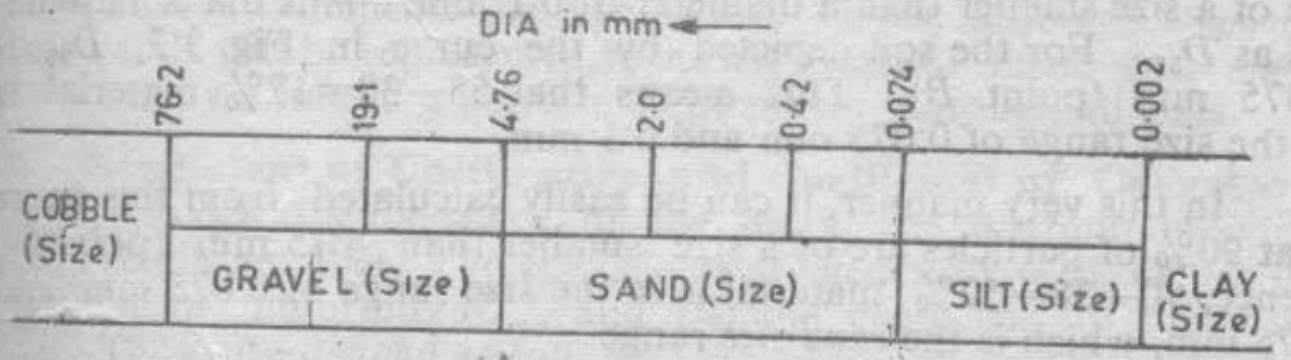
(*a*) U.S. Bureau of Soil and PRA classification.



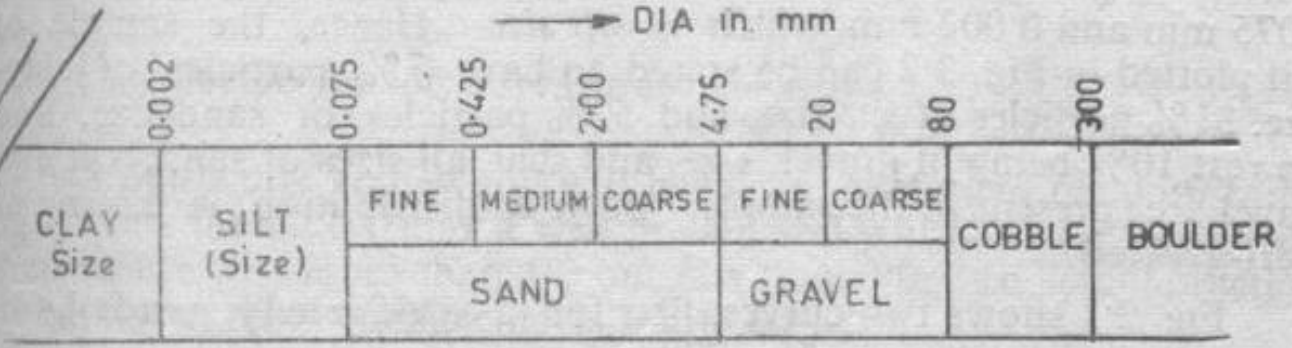
(*b*) International clarsification.



(*c*) M.I.T. classification.

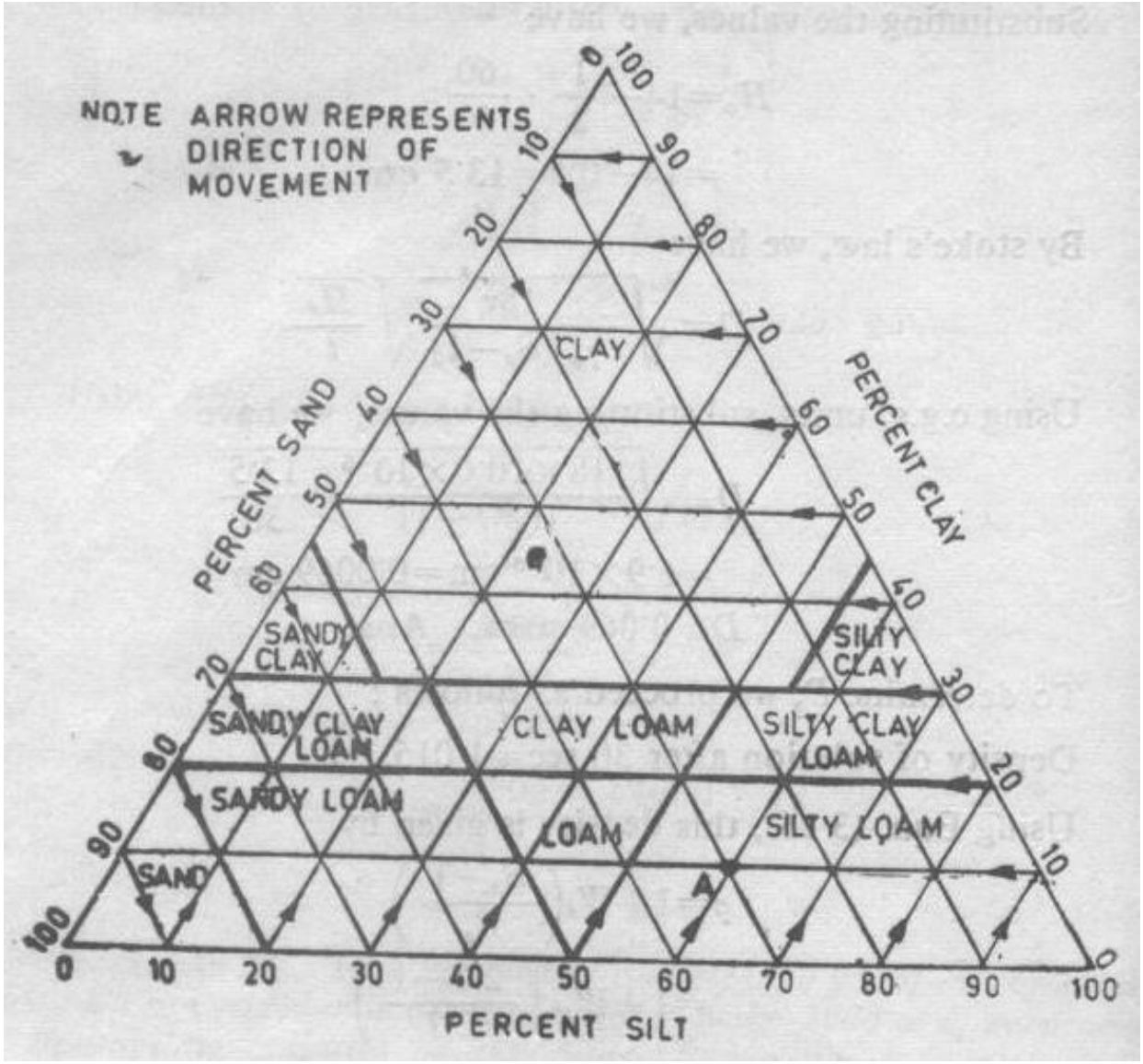


(*d*) Unified Soil Classification System followed by U.S.B.R. (U.S.A.), Army Coops of Engineers ASTM and ASCE.



(*e*) Indian Standard classification.

Textural Classification of U.S. Bureau of Soils



Classification of soils on basis of its plasticity

Clay (Plastic) (can be molded at certain water content)

Sand (Non-Plastic) (Very difficult to mould)

These physical difference between the behavior of clay and sand, helps us in determining that physical property of the given soil (Plasticity) and thus classify the soil on its basis

Public Road Administration Classification

Highway Research Board

Particle Size

Plasticity

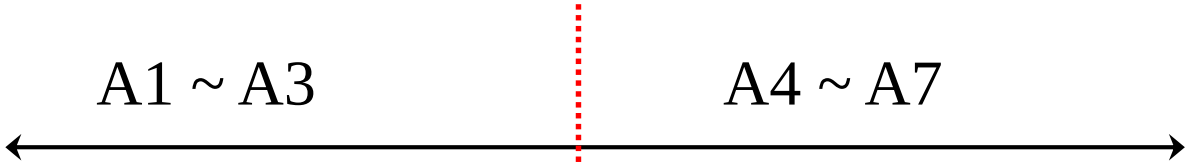
Generally used for Pavement construction

Table 3·9. Public Roads Administration Classification Incorporating Highway Research Board Modifications

General classification	*Granular materials (35 per cent or less passing No. 200)*							*Silt-clay materials (More than 35 per cent passing No. 200)*			
Group classification	*A-1*			*A-2*							*A-7*
(1)	*A-1-a (2)*	*A-1-b (3)*	*A-3 (4)*	*A-2-4 (5)*	*A-2-5 (6)*	*A-2-6 (7)*	*A-2-7 (8)*	*A-4 (9)*	*A-5 (10)*	*A-6 (11)*	*A-7-5 A-7-6 (12)*
Sieve analysis per cent passing											
2·0 mm IS	50 (max.)										
425 μ sieve	30 (max.)	50 (max.)	51 (min.)								
75 μ sieve	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 425 μ sieve											
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 (max.)	10 (max.)	10 (max.)	11 (min.)	11 (min.)
Group index	0		0	0		4 (max.)		8 (max.)	12 (max.)	16 (max.)	20 (max.)
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			

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

Group Index= GI=0.2a + 0.005 a c + 0.01 bd

a= that portion of the percentage of the soil passing 75 micron sieve, greater than 35 and not exceeding 75; expressed as positive whole number (0 to 40)

b=that portion of the percentage of the soil passing 75 micron sieve, greater than 15 and not exceeding 55; expressed as positive whole number (0 to 40)

c= that portion of the liquid limit, greater than 40 and not exceeding 60; expressed as positive whole number (0 to 20)

d= that portion of the plasticity index, greater than 10 and not exceeding 30; expressed as positive whole number (0 to 20)

- Group index is not used to place the soil in a particular group, but is actually means of rating the value soil as a sub-grade material
- The higher is the value of index, the poorer is the quality of the material

A sample of inorganic soil has the following grain size characteristics

Size mm	2	0.075
% Passing	95	78

LL= 55% and P.I= 24%

Classify the soil according to PRA

a=40, b=40, c=15, d=14

G.I= 16.6 (17)

On the basis of % fine grained soil (i.e soil passing 75 micron sieve), LL, P.I (A-7 Group)

A-7…….A-7-5 or A-7-6

PL=31

A-7-5(17)

Soil is poor for road construction

Unified Soil Classification System (USCS)

- Originally developed for use in air field
- Later modified for general used
- Very commonly used
- Nor too elaborate
- Nor too simple
- Grain size+ Plasticity+Gradation

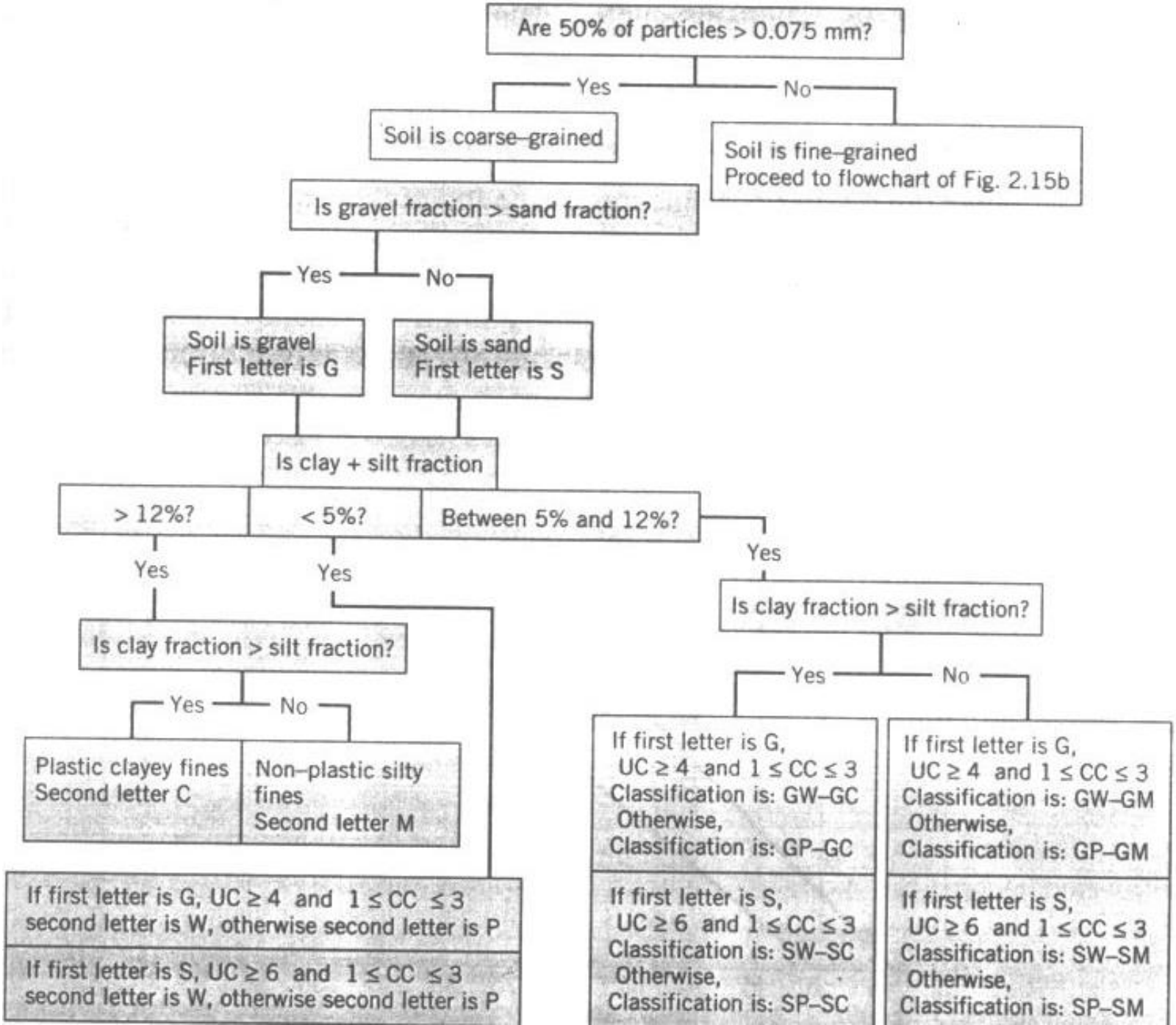
Symbols in USCS

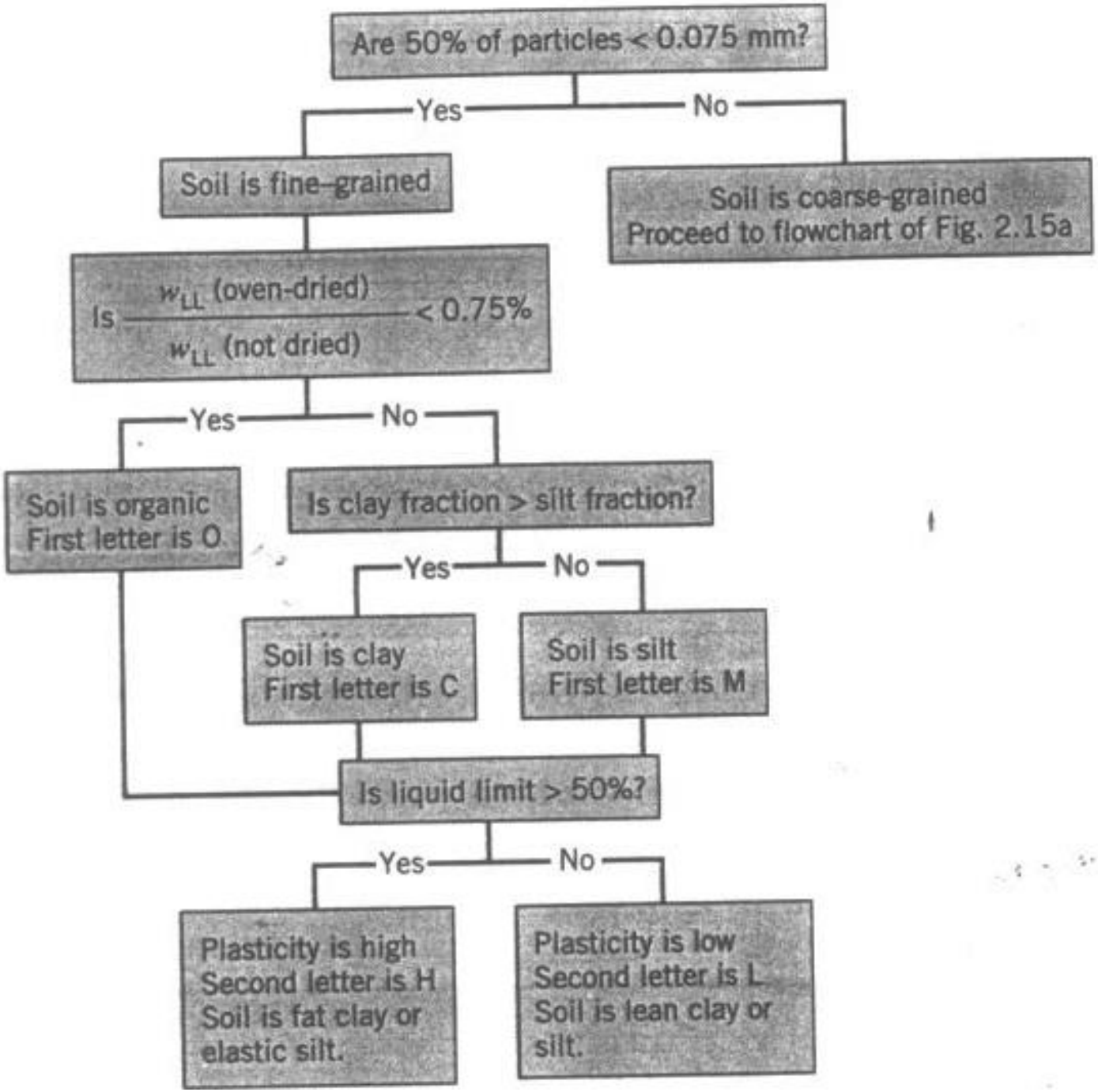
Particle size	Gradation	Plasticity
G: Gravel S: Sand M: Silt C: Clay	W: Well graded P: Poorly graded	H: High Plastic L: Low Plastic

O: Presence of Organic Material

I: Inorganic

CL, SP


Are 50% of particles > 0.075 mm?
Yes
No
Soil is coarse–grained
Soil is fine–grained
Proceed to flowchart of Fig. 2.15b
Is gravel fraction > sand fraction?
Yes
No
Soil is gravel
First letter is G
Soil is sand
First letter is S
Is clay + silt fraction
> 12%?
< 5%?
Between 5% and 12%?
Yes
Yes
Yes
Is clay fraction > silt fraction?
Is clay fraction > silt fraction?
Yes
No
Yes
No
Plastic clayey fines
Second letter C
Non–plastic silty fines
Second letter M
If first letter is G, UC ≥ 4 and 1 ≤ CC ≤ 3
second letter is W, otherwise second letter is P
If first letter is S, UC ≥ 6 and 1 ≤ CC ≤ 3
second letter is W, otherwise second letter is P
If first letter is G,
UC ≥ 4 and 1 ≤ CC ≤ 3
Classification is: GW–GC
Otherwise,
Classification is: GP–GC
If first letter is G,
UC ≥ 4 and 1 ≤ CC ≤ 3
Classification is: GW–GM
Otherwise,
Classification is: GP–GM
If first letter is S,
UC ≥ 6 and 1 ≤ CC ≤ 3
Classification is: SW–SC
Otherwise,
Classification is: SP–SC
If first letter is S,
UC ≥ 6 and 1 ≤ CC ≤ 3
Classification is: SW–SM
Otherwise,
Classification is: SP–SM


Are 50% of particles < 0.075 mm?
Yes
No
Soil is fine-grained
Soil is coarse-grained
Proceed to flowchart of Fig. 2.15a
Is $\frac{w_{LL}\text{ (oven-dried)}}{w_{LL}\text{ (not dried)}} < 0.75\%$
Yes
No
Soil is organic
First letter is O
Is clay fraction > silt fraction?
Yes
No
Soil is clay
First letter is C
Soil is silt
First letter is M
Is liquid limit > 50%?
Yes
No
Plasticity is high
Second letter is H
Soil is fat clay or
elastic silt.
Plasticity is low
Second letter is L
Soil is lean clay or
silt.

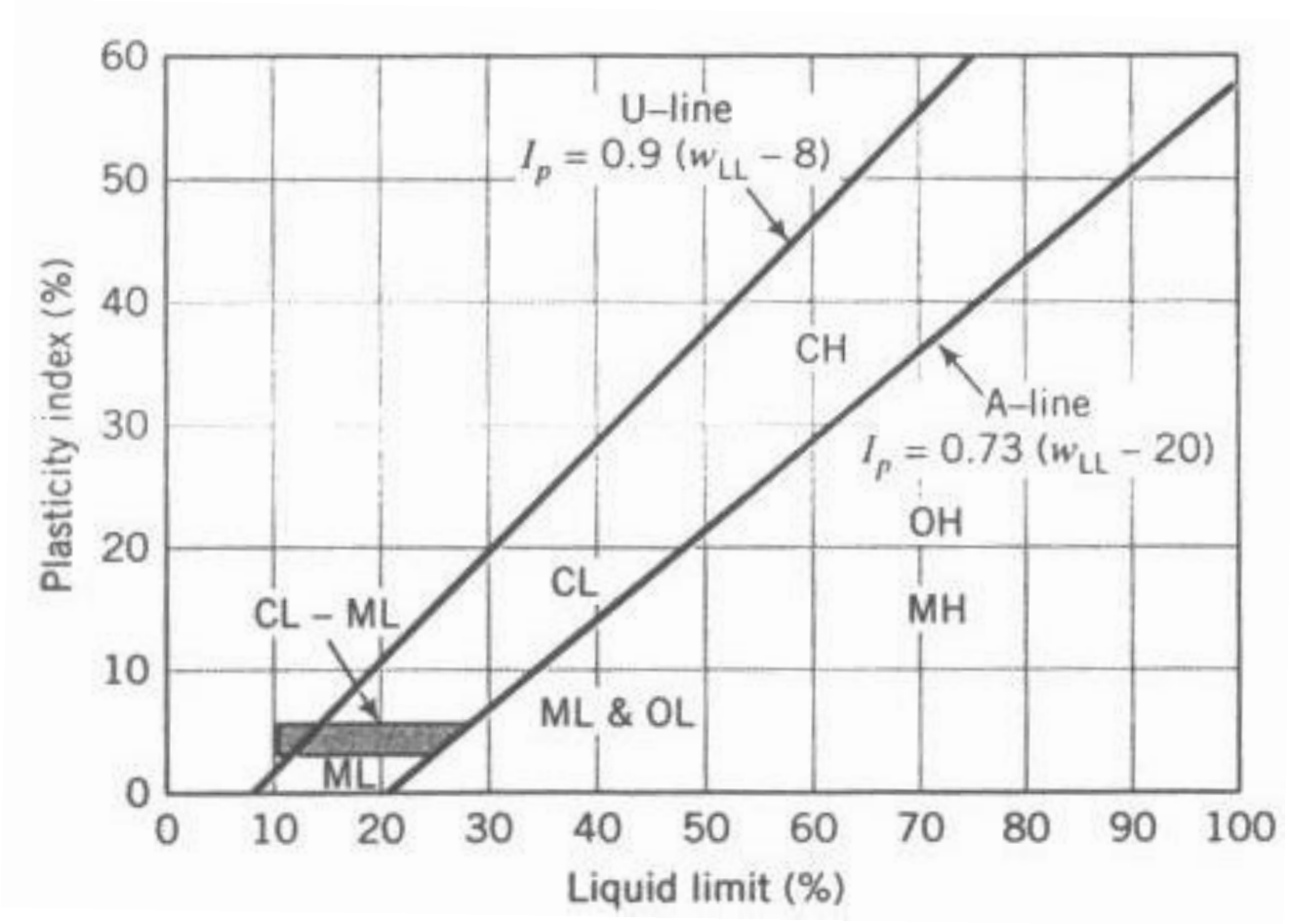
Major divisions			Group symbol	Typical names	Classification criteria for coarse-grained soils	
Coarse-grained soils (more than half of material is larger than No. 200)	Gravels (more than half of coarse fraction is larger than No. 4 sieve size)	Clean gravels (little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	$C_U \geq 4$ $1 \leq C_C \leq 3$	
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines	Not meeting all gradation requirements for GW ($C_U < 4$ or $1 > C_c > 3$)	
		Gravels with fines (appreciable amount of fines)	GM $\frac{d}{u}$	Silty gravels, gravel-sand-silt mixtures	Atterberg limits below *A* line or $I_p < 4$	Above *A* line with $4 < I_p < 7$ are borderline cases requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures	Atterberg limits above *A* line with $I_p > 7$	
	Sands (more than half of coarse fraction is smaller than No. 4 sieve size)	Clean sands (little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines	$C_U \geq 6$ $1 \leq C_C \leq 3$	
			SP	Poorly graded sands, gravelly sands, little or no fines	Not meeting all gradation requirements for SW ($C_U < 6$ or $1 > C_C > 3$)	
		Sands with fines (appreciable amount of fines)	SM $\frac{d}{u}$	Silty sands, sand-silt mixtures	Atterberg limits below *A* line or $I_p < 4$	Limits plotting in hatched zone with $4 \leq I_p \leq 7$ are borderline cases requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures	Atterberg limits above *A* line with $I_p > 7$	

Fine-grained soils (more than half of material is smaller than No. 200)	Silts and clays (liquid limit < 50)	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity	1. Determine percentages of sand and gravel from grain-size curve. 2. Depending on percentages of fines (fraction smaller than 200 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%–Borderline cases requiring dual symbols
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	
		OL	Organic silts and organic silty clays of low plasticity	
	Silts and clays (liquid limit > 50)	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	
		CH	Inorganic clays or high plasticity, fat clays	
		OH	Organic clays of medium to high plasticity, organic silts	
	Highly organic soils	Pt	Peat and other highly organic soils	

$$C_U = \frac{D_{60}}{D_{10}}$$

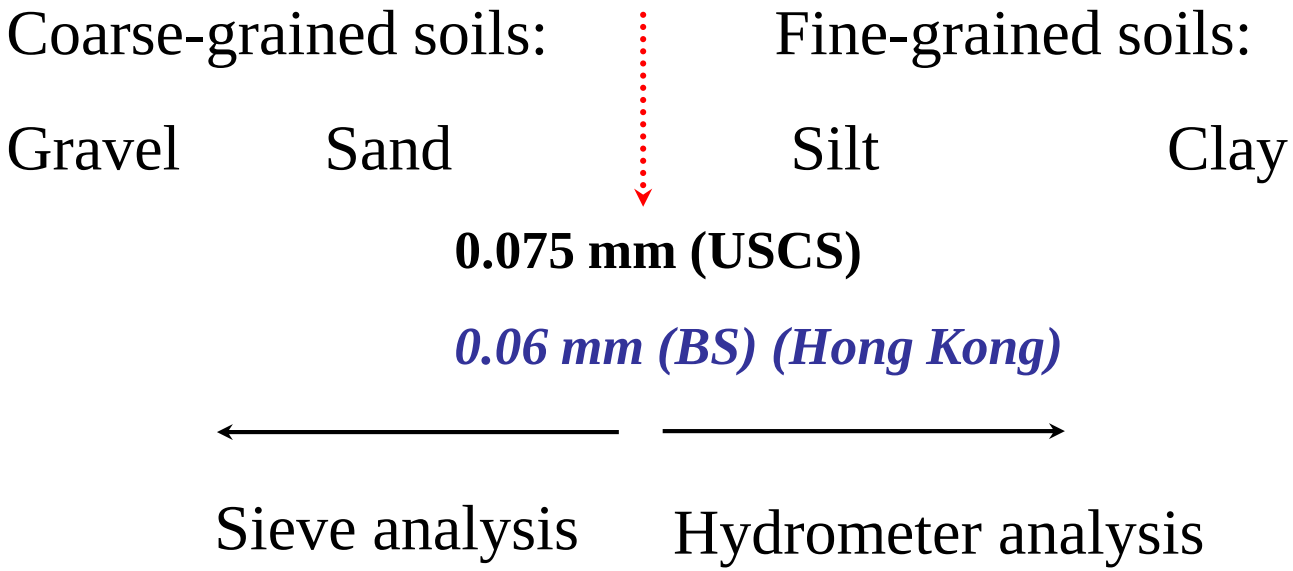
$$C_C = \frac{D_{30}^2}{D_{10} D_{60}}$$

Plasticity Chart



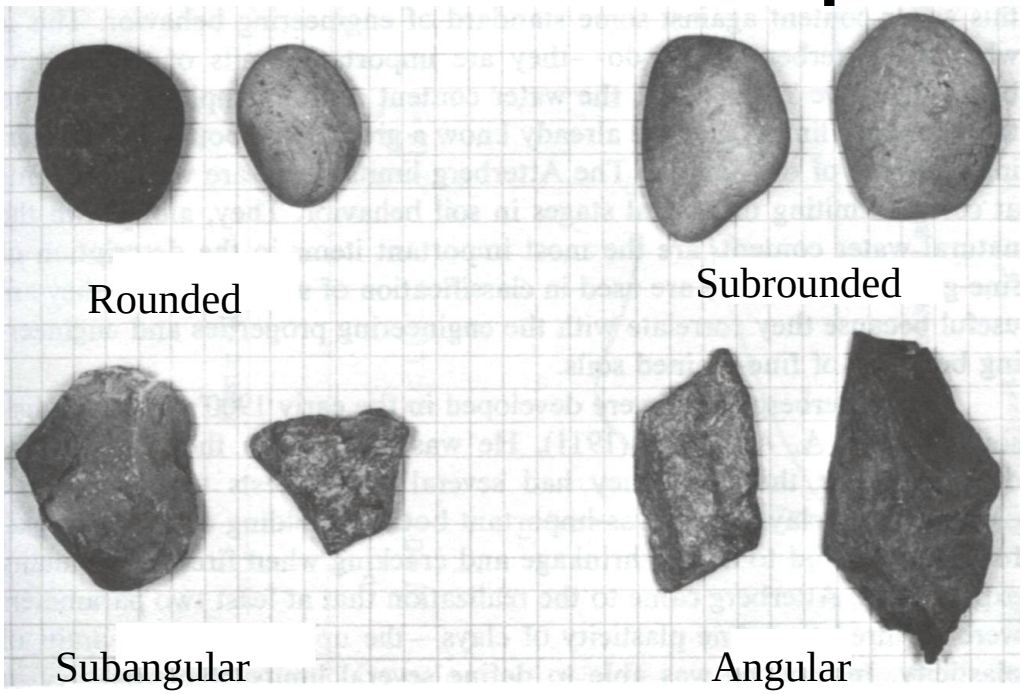
Soil Texture

- The texture of a soil is its appearance or "feel" and it depends on the relative sizes and shapes of the particles as well as the range or distribution of those sizes.



3. Particle Shape

Coarse-grained soils



- Important for granular soils
- Angular soil particle → higher friction
- Round soil particle → lower friction
- Note that clay particles are sheet-like.

(Holtz and Kovacs, 1981)