Soil Identification and its Classification (4 hrs)

3.1 Purpose of Soil Classification
3.2 Field Identification of Soil
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Soil Classification

It is the arrangement of soils into different groups such that soils in a particular group shows similar behavior.

Purpose of Soil Classification

- When a soil is classified as per some standard classification system, its behavior and properties can be estimated based on the experience gained from similar soils elsewhere.
- It provides a common language between engineers dealing with soils.
- It is useful in exchange of information and experience between the geotechnical engineers. Eg: If a soil has been classified as SW according to Unified Soil Classification System, the geotechnical engineer anywhere would know that the soil is well graded sand.

Basic Requirements of Soil Classification

- It should have limited number of groups.
- It should be based on engineering properties and should fit purpose for which classification is done.
- It should be simple and should use easy terms.

Field Identification of Soils

According to consistency

Consistency	**Field Inspection**
Very Stiff	Brittle or very hard
Stiff	Can not be moulded in fingers
Firm	Can be moulded in fingers by strong pressure
Soft	Easily moulded in fingers
Very Soft	Excludes between the fingers when squeezed in the fist.

Gravel Vs. Sand

Gravel (4.75 – 75 mm)
Sand (0.075mm – 4.75mm)
If percentage of gravel is more than the percentage of sand, then the soil is known as gravel, otherwise sand.
If more than 50% of particles retain on 4.75mm sieve, soil is gravel else sand.

Sand Vs. Silt

- It is difficult to distinguish between fine sand and silt. Both look like dust but silt looks slightly darker than sand.
- They can be distinguished by dispersion test.

Dispersion Test:

This test is used for making rough estimation of sand and silt. Small quantity of soil is taken in a glass cylinder and then particles are allowed to settle and time required for settling of particles is noted down.

- Sand particles settle within 30 secs for 10cm depth of water column.
- Silt particles take longer time of about 30 secs to 240 min.
- Clay particles or smaller may remain in suspension for hours-day.

Silt Vs. Clay

It is difficult to distinguish silt and clay by visual examination, so a microscopic examination is required. Some simple tests which can fairly distinguish them are:

1) Visual examination
2) Wet and manipulated strength test
3) Thread test
4) Dilatancy test
5) Dry Strength test
6) Toughness test

Visual Examination

It should be carried out with respect to size, angularity and grading characteristics. (Difficult to distinguish by visual examination only).

Wet and manipulated strength test

Small quantity of moistened soil is taken in hand and work it with fingers and feel it.

- If moisture comes out after squeezing between fingers and soapy touch – silty soil.
- If feeling of roughness occurs – sandy soil.
- If sticks to fingers and dries slowly – clay.
- If sticks to fingers and dries quickly and can dust off fingers leaving a stain – silt.

This test helps to distinguish predominant soil characteristics i.e. sandy, silty or clayey.

Thread Test

1 cm^2 of specimen of soil is taken and moistened if necessary and is rolled on a smooth glass plate to about 3mm diameter (plastic limit test). If crumbling does not occur, fold the thread, knead and roll again until the moisture of the soil reduces by drying during manipulation to plastic limit, which is indicated by crumbling that occurs during rolling. Characteristics of thread approaching

plastic limit offers means of identification of soil. Plastic clays can be easily rolled and its plasticity can be easily found but if soil contains much silt, it can't be rolled or becomes difficult to roll.

Dilatancy Test (Shaking Test)

The test assists in identifying fineness characteristics of soils. Particles retained on IS Sieve 40 are removed and a pat of soil of size $2cm^3$ is prepared. Enough water is added to make soil soft but not sticky. Pat is placed in the palm of one hand and shaking vigorously against other hand several times. Glossy appearance or appearance of water on surface of pat implies positive reaction. Then the sample is squeezed between the fingers, the water or gloss disappears from the surface and pat stiffens and then finally cracks.

Quickest and most distinct reaction – Sand

Moderate reaction – Inorganic Silt

No reaction – Plastic Clay

Dry Strength Test

Dry strength can be estimated by crumbling of a 3mm sized dried fragment between thumb and fore fingers. Dry strength is an indication of cohesion and hence nature of soil. Clay fragment can be broken with a great effort, but silt fragments crushes easily. Sand and silts can be distinguished by feeling of powdered specimen. Fine sand feels gritty, whereas typical silt has a smooth feel.

Toughness Test

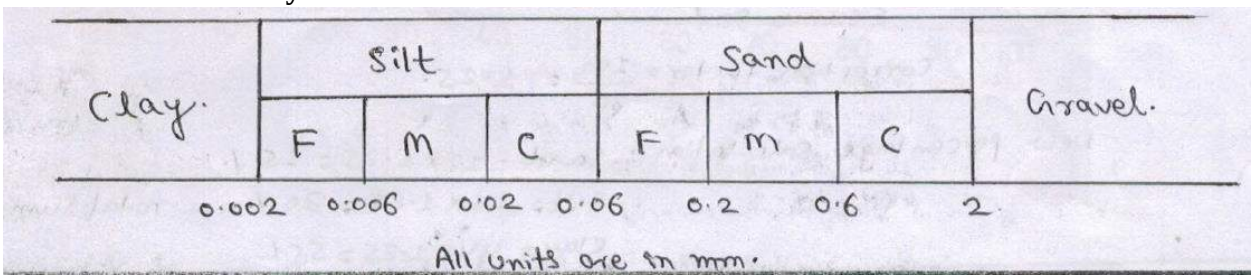
After crumbling of soil at 3mm diameter (at plastic limit), the pieces of soil are again taken, remoulded and kneaded to form the lump of soil. If the soil can be easily lumped at water content below plastic limit it implies that the toughness of soil is higher. Such soils contain much amount of clay or colloidal matters otherwise they contain much silt.

Soil Classification System

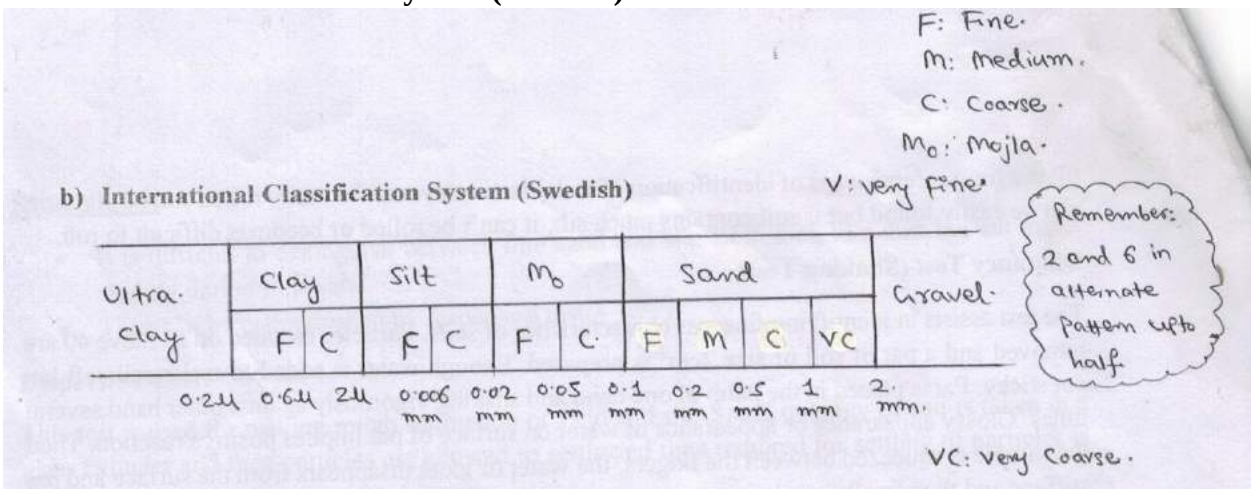
1. Particle Size Classification

The size of individual particles has an important influence on the behavior of soils. Any system of classification based only on particle size may be misleading for fine-grained soils. The behavior of such soils depends on the plasticity characteristics and not on the particle size. However, classification based on particle size is of immense value in the case of coarse-grained soils, since the behavior of such soils depends mainly on the particle size.

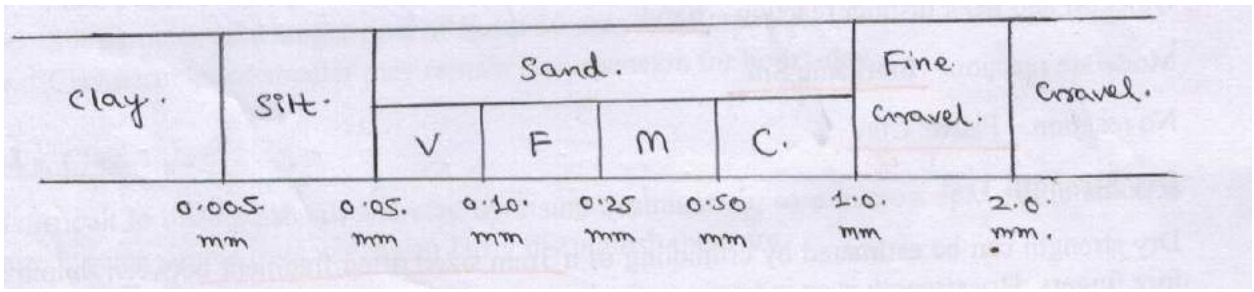
a) MIT Classification System



b) International Classification System (Swedish)



c) US Bureau of Soil Classification



2. Textural Classification of Soil

a. Triangular system of classification suggested by U.S. Bureau of Public Roads.
b. Texture refers to visual appearance of soil which refers to particle size, shape and gradation of particles. But in this classification system we only look at particle size.
c. First the given soil sample is sieved and the % of sand, silt and clay are determined.
d. Then % of sand, silt and clay are plotted along 3 sides of an equilateral triangle which is divided into 10 zones.
e. The soil is classified according to zone in which it lies.
f. This classification system is much suitable for describing coarse grained soil than clay which properties are less dependent on particle size distribution.

g. Eg: 30% sand, 20% silt and 50% clay – Soil is clay.

30% sand, 60% silt and 10% clay – Silty loam.

45% sand, 30% silt and 25% clay – Clay loam.

- If the soil contains significant amount of particles, gravel > 2mm, then a correction factor is needed since there soil is assumed to have no gravel fraction.

Example: Sand = 12%, Silt = 24%, Clay = 44%.

Σ sum = 80%

Correction factor = $\frac{100}{80}$ = 1.25.

New percentage calculation: Sand = 12 x 1.25 = 15%.

Silt = 24 x 1.25 = 30%. Total Sum = 100%.

Clay = 44 x 1.25 = 55%.

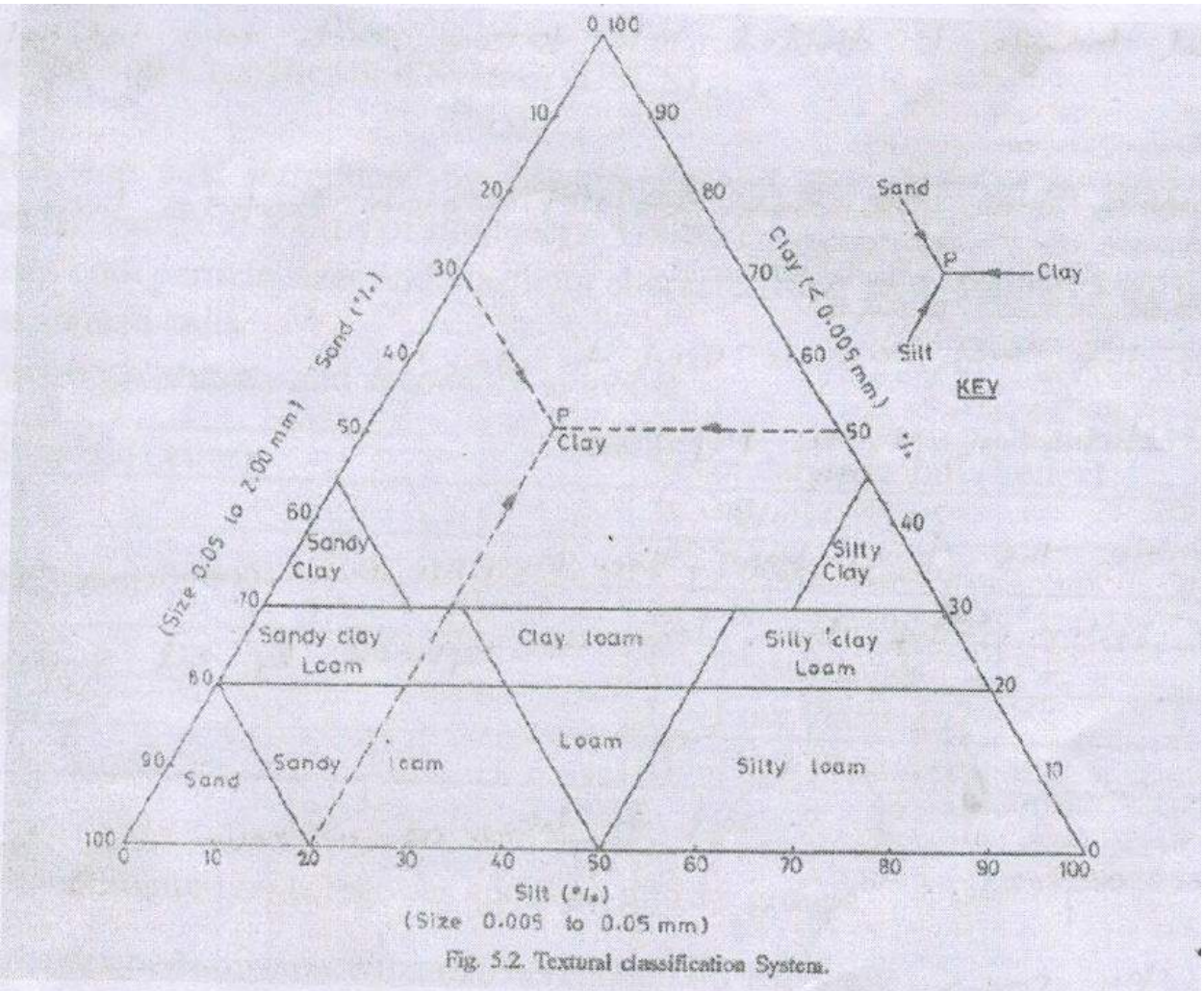


Fig. 5.2. Textural classification System.

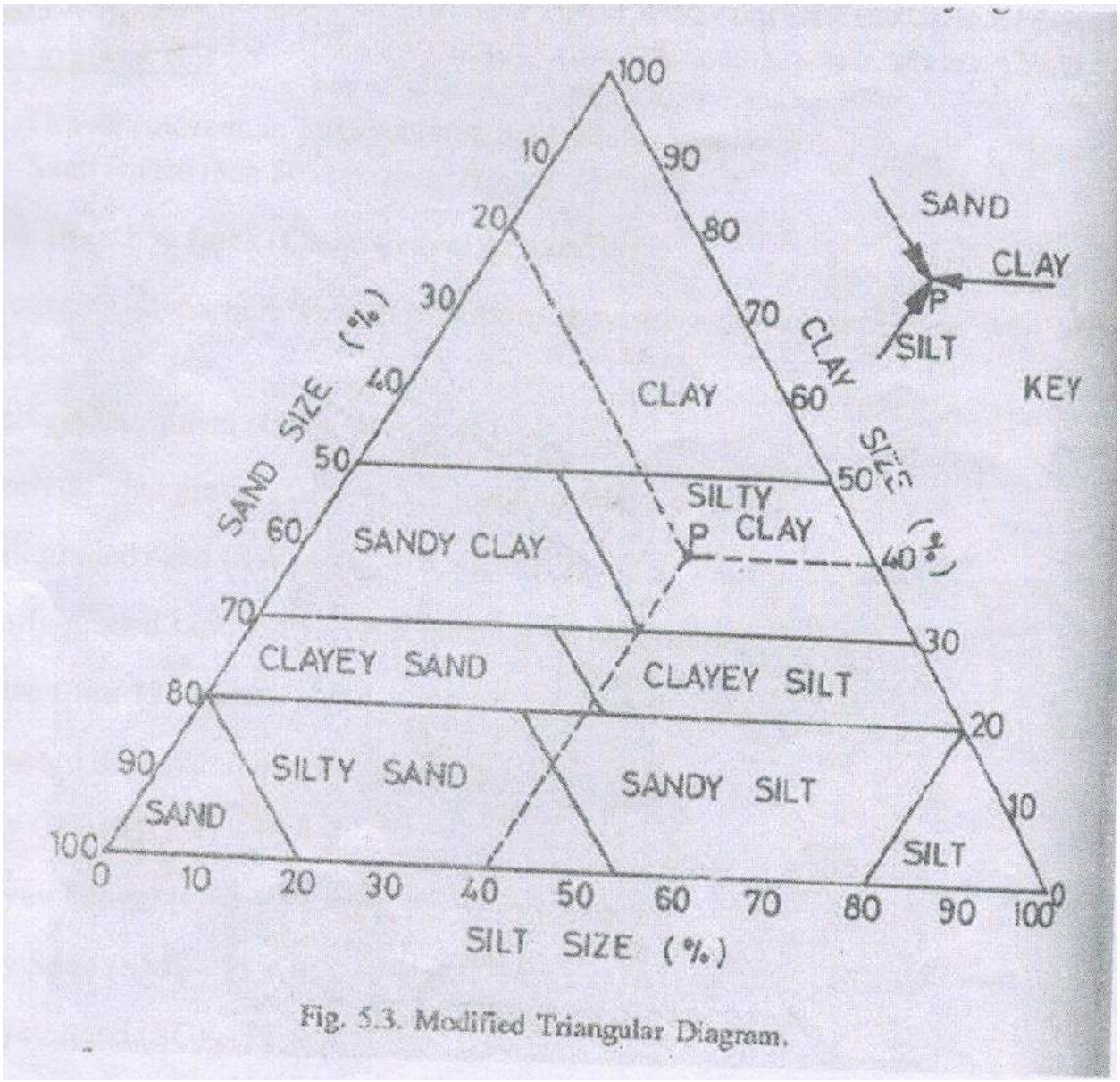


Fig. 5.3. Modified Triangular Diagram.

→ Percentage of sand, silt and clay are plotted along the three sides of an equilateral triangle.

→ The equilateral triangle is divided into 10 zones, each zone indicates a type of soil.

→ The system assumes that the soil does not contain particles larger than 2.0mm size.

→ In this system, the term loam is used to describe a mixture of sand, silt and clay particles in various proportions.

In order to eliminate the term loam, the Mississipi River Commission (USA) proposed a modified trangular system. The term loam is replaced by soil engineering terms such as silty clay.

The principal component of a soil is taken as a noun and less prominent component as an adjective.

Eg; Silty clay contains mainly particles of clay, but some silt particles are also present.

3. Unified Soil Classification System (USCS)

a) USCS was first introduced by Casagrande and was modified in 1952 by 'Bureau of Reclamation' and 'Corps of Engineers' USA.
b) It uses both particle sizes and plasticity characteristics, so it is suitable for both coarse- and fine-grained soils.
c) It uses both primary and secondary symbols.

Primary Symbol (Letter)	Secondary Symbol (Letter)
G – Gravel	W – Well Graded
S – Sand	P – Poorly Graded
M – Silt	M – Non-plastic fines
C – Clay	C – Plastic Fines
O – Organic	L – Low Plasticity
P_e – Peat	H – High Plasticity

Soil is first divided into two categories and then into 18 groups.

a) Coarse grained soil (more than 50% retained on 75μ sieve)
b) Fine grained soil (more than 50% passing from 75μ sieve)

Coarse grained soil

a) Gravel (more than 50% retained on 4.75mm sieve)
b) Sand (more than 50% passing from 4.75mm sieve)

Less than 5% fines (Clean gravel or sand)

According to particle size distribution, they are again classified as well graded or poorly graded.

Well graded gravel (GW) – ($C_u > 4$, $C_c = 1\text{-}3$)

Poorly graded gravel (GP) – (Not meeting above criteria)

Well graded sand (SW) – ($C_u > 6$, $C_c = 1\text{-}3$)

Poorly graded sand (SP) – (Not meeting above criteria)

More than 12% fines

They are designated as silty or clayey

Silty Gravel (GM) – PI < 4

Clayey Gravel (GC) – PI > 7

Silty Sand (SM) – PI < 4

Clayey Sand (SC) – PI > 7

For 5-12% of fines

They are given dual symbol as:

GM – GC (Between silty gravel and clayey gravel)

SM – SC (Between silty sand and clayey sand)

Fine Grained Soils

They are further divided as:

a) Soil of low plasticity (W_L < 50%)
b) Soil of high plasticity (W_L > 50%)

They are also classified as clayey and silty (or organic) according to their consistency limits.

Consistency limits above A – line: Clayey

Consistency limits below A – line: Silty or Organic

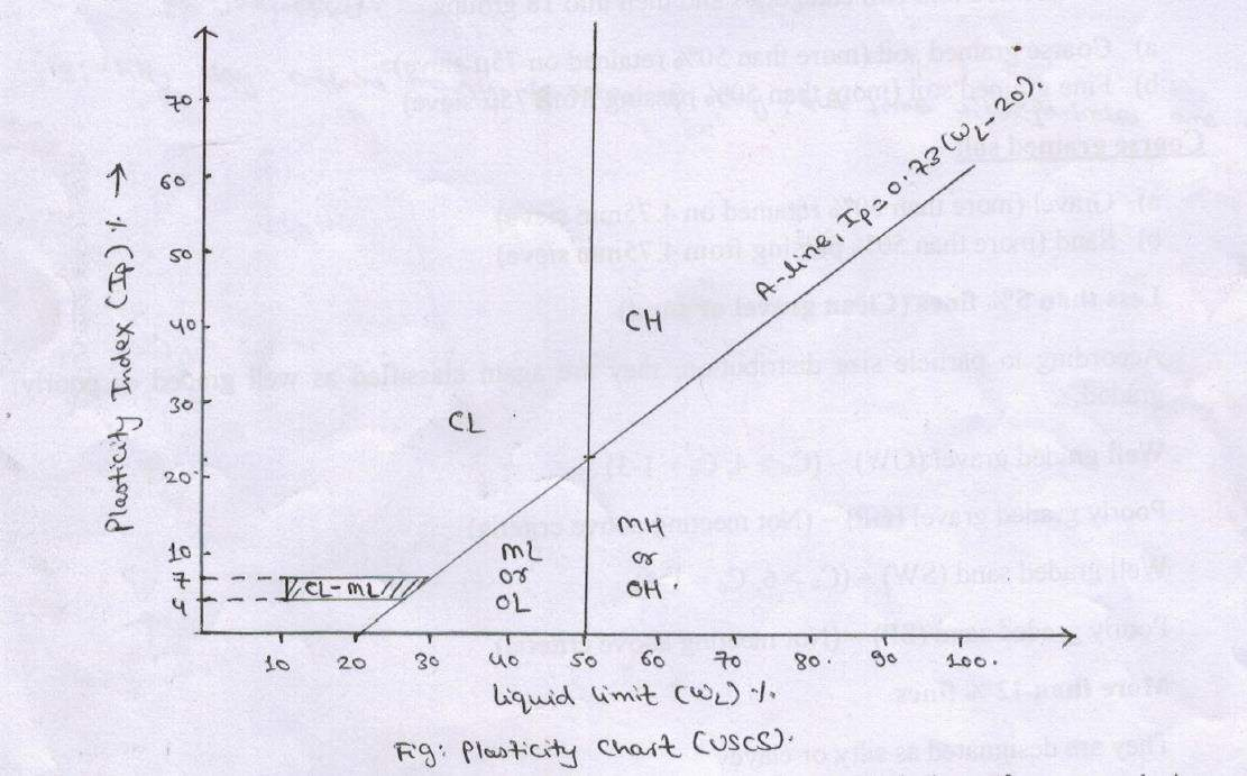


Fig: Plasticity Chart (USCS).

The distinction between inorganic and organic soil is made by oven-drying. If on oven-drying liquid limit (W_L) decreases by 30% or more soil is organic otherwise silt (organic soils have dark color, high compressibility and permeability and presence of organic matter).

Highly organic soils: Identified by visual examination (fibrous texture) and termed as Peat (P_e).

4. Indian Soil Classification System (IS)

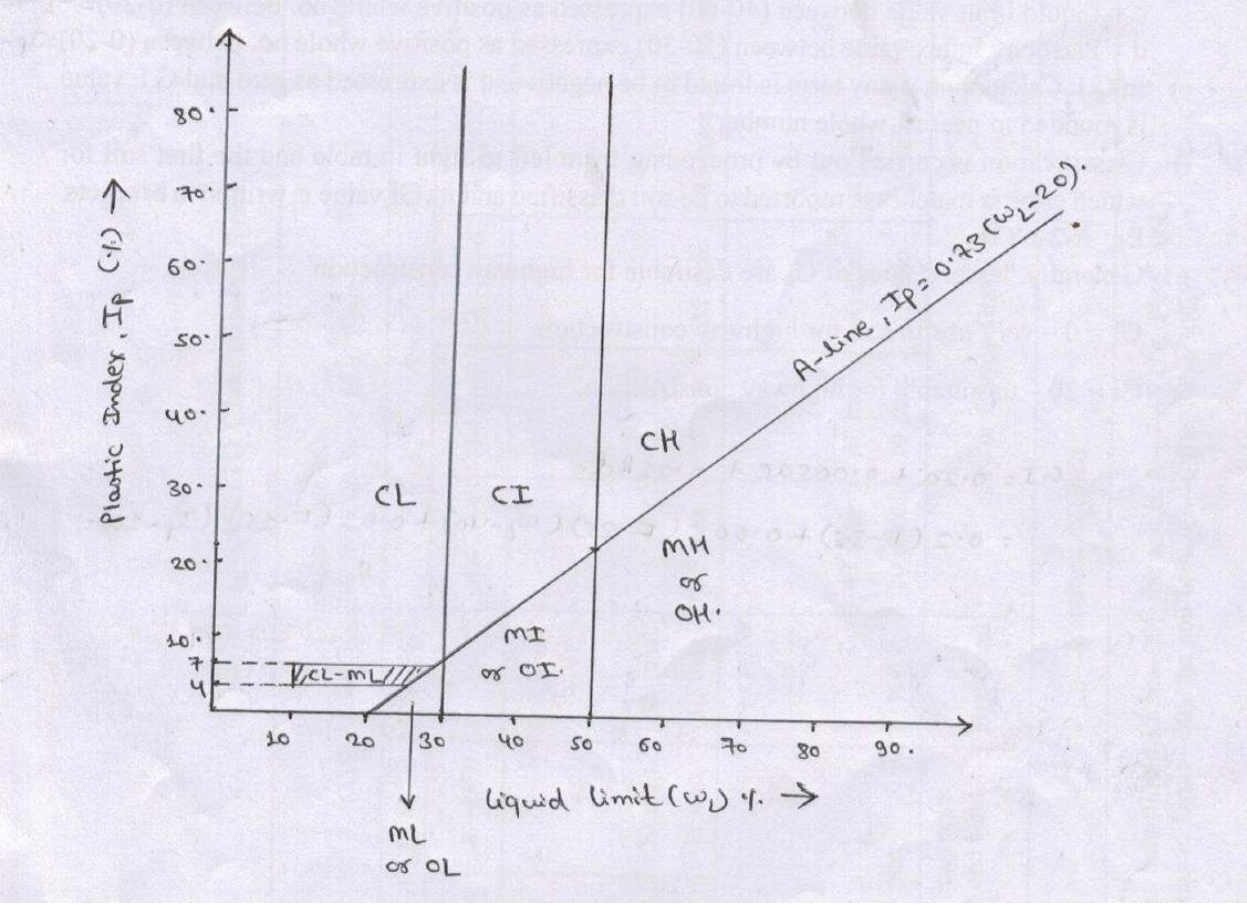
This system is adopted by BIS (Bureau of Indian Standard) and is similar in many respects to USCS system. The basic difference is in classification of fine-grained soils.

Classification of coarse-grained soil is same as in USCS.

Fine Grained Soils

Fine grained soils are first classified into 3 categories as low, medium and high compressibility, instead of two categories as low and high in USCS.

So, there are total 18 groups.



5. AASHTO Soil Classification

a) Federal highway administration developed this classification system mainly for road construction.
b) System is based on both particle size and plasticity characteristics (W_L, W_P, I_P).
c) Soil is classified into 8 groups. A_1 – A_7 and A_8 for peat or muck.
d) System is based on group index given by: G.I. = 0.2a + 0.005ac + 0.01bd
   a = % passing through 75μ sieve between (35-75) expressed as positive whole no. between (0-40)
   b = % passing through 75μ sieve between (15-55) expressed as positive whole no. between (0-40)
   c = Liquid limit value between (40-60) expressed as positive whole no. between (0-20)
   d = Plasticity Index value between (10-30) expressed as positive whole no. between (0-20)
e) In G.I. Calculation if any term is found to be negative, it is expressed as zero and G.I. value is rounded to nearest whole number.
f) Classification is carried out by proceeding from left to right in table and the first soil for which criteria matches is reported to be soil classified and its GI value is written in brackets. Eg: A-2-6 (3).
g) Generally, lesser values of GI are desirable for highway construction.

   GI = 0 – very useful soil for highway construction.

   GI ≥ 20 – unsuitable for highway construction.

$$GI = 0.2a + 0.005ac + 0.01bd.$$
$$= 0.2(F-35) + 0.005(F-35)(w_L-40) + 0.01(F-15)(I_p-10).$$

Table 5.1. AASHTO Classification System

General Classification	Granular materials (35% or less passing No. 200 Sieve (0.075 mm))							Silt-clay Materials More than 35% passing No. 200 Sieve (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
(a) Sieve Analysis: Percent Passing											
(i) 2.00 mm (No. 10)	50 max										
(ii) 0.425 mm (No. 40)	30 max	50 max	51 min								
(iii) 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
(b) Characteristics of fraction passing 0.425 mm (No. 40)											
(i) Liquid limit				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
(ii) Plasticity index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min*
(c) Usual types of significant Constituent materials	Stone Fragments Gravel and sand		Fine Sand	Silty or Clayey Gravel Sand				Silty Soils		Clayey Soils	
(d) General rating as subgrade.	Excellent to Good							Fair to Poor			

* If plasticity index is equal to or less than (liquid Limit—30), the soil is A—7—5 (*i.e.* PL > 30%)
If plasticity index is greater than (Liquid Limit—30), the soil is A—7—6 (*i.e.* PL < 30%)

Table 5.3. Unified Soil Classification System

Major Division			*Group Symbols*	*Typical names*	*Classification criteria*		
Coarse-Grained Soils. [More than 50% retained on No. 200 sieve (0.075 mm)]	Gravel [50% or more of coarse fraction retained on No. 4 sieve (4.75 mm)]	Clean Gravels	GW	Well graded gravels	Percentage of fines (a) Less than 5% passing No. 200, GW, GP, SW, SP (b) more than 12% passing No. 200, GM, GC, SM, SC (c) 5 to 12% passing No. 200 use of dual symbols as GW—GM, SP—SC.	$C_u > 4$ $C_c = 1$ to 3	
			GP	Poorly graded gravels		Not meeting both criteria for GW	
		Gravels with fines	GM	Silty gravels		Atterberg Limits below A-line or plasticity index less than 4	Atterberg Limits in hatched area GM—GC
			GC	Clayey gravels		Atterberg Limits above A-line and plasticity index greater than 7	
	Sand [more than 50% of coarse faction passing No. 4 sieve (4.75 mm)]	Clean Sands	SW	Well-graded sands		$C_u > 6$ $C_c = 1$ to 3	
			SP	Poorly graded sands		Not meeting both criteria for SW	
		Sands with fines	SM	Silty sands		Atterberg Limits below A-line or plasticity index less than 4	Atterberg Limits in hatched area SM—SC
			SC	Clayey sands		Atterberg Limits above A-line and plasticity index greater than 7	
Fine grained soils [50% or more passing No. 200 sieve (0.075 mm)]	Silts and clays Liquid Limit 50% or less		ML	Inorganic silts of low plasticity	See Plasticity Chart (Fig. 5.5)		
			CL	Inorganic clays of low to medium plasticity			
			OL	Organic silts of low plasticity			
	Silts and clays Liquid Limit greater than 50%		MH	Inorganic silts of high plasticity			
			CH	Inorganic clays of high plasticity			
			OH	Organic clays of medium of high plasticity			
Highty organic Soils			Pt	Peat, muck and other highly organic soils	Visual-manual identification		

Field Identification Tests

Table 5.8. Field Identification Tests

Test	*ML*	*CL*	*OL*	*MI*	*CI*	*OI*	*MH*	*CH*	*OH*
(*a*) Dilatancy	Quick	None to very slow	Slow	Quick to slow	None	Slow	Slow to none	None	None to very slow
(*b*) Toughness	None	Medium	Low	None	Medium	Low	Low to medium	High	Low to medium
(*c*) Dry strength	None of low	Medium	Low	Low	Medium to high	Low to medium	Low to medium	High to very high	Medium to high

General Characteristics of Soils of Different Groups

The general characteristics of the soils of various groups as classified by ISCS and USCS are given in the table. The information given in the table should be considered as a rough guidance about the engineering properties of soil. For complete information, the tests should be conducted and the engineering properties need to be determined.

Table 5.9. General Propeties of Soils

Soil Group	*Permeability*	*Compressibility*	*Shear Strength*	*Workability*
(*a*) *Gravels*				
GW	Pervious	Negligible	Excellent	Excellent
GP	Very pervious	Negligible	Good	Good
GM	Semi-pervious to impervious	Negligible	Good	Good
GC	Impervious	Very low	Good to fair	Good
(*b*) Seeds				
SW	Pervious	Negligible	Excellent	Excellent
SP	Pervious	Very low	Good	Fair
SM	Semi-pervious to impervious	Low	Good	Fair
SC	Impervious	Low	Good to fair	Good
(*c*) Low & medium Plasticity silt & clays				
ML, MI	Semi-pervious to impervious	Medium	Fair	Fair
CL, CI	Impervious	Medium	Fair	Good to fair
OL, OI	Semi-pervious to impervious	Medium	Fair	Fair
(*d*) High- plasticity silts & clays				
MH	Semi-pervious to impervious	High	Fair to poor	Poor
CH	Impervious	High	Poor	Poor
OH	Impervious	High	Poor	Poor

Note. Highly organic soils [Peats] are not used in engineering works.

Differences between USCS and AASHTO System

According to AASHTO system, a soil is termed as fine-grained if more than 35% passes No. 200 (0.075mm) sieve, whereas in the USC system, if more than 50% passes that sieve. In this respect, the AASHTO system is somewhat better because the soil behaves as fine-grained when the percentage of fines is 35%, and the limit of 50% in USC system is somewhat higher.

In AASHTO system, sieve No. 10 (2.0mm size) is used to divide the soil into gravel and sand, whereas in USC system, sieve No. 4 (4.75mm size) is used.

In USC system, the gravelly and sandy soils are clearly separated, whereas in AASHTO system, clear demarcation is not done. The soil A-2 in the latter system contains a large variety of soils.

Symbols used in USC system are more descriptive and are more easily remembered than those in AASHTO system.

Organic soils are also classified as OL and OH and as peat (P_t) if highly organic in USCS. In AASHTO, there is no place for organic soils.

USCS is more convenient to use than the AASHTO system. In the latter, the process of elimination is required which is time-consuming.

Table 5.4. Approximate Equivalence Between AASHTO and USC System

AASHTO System	*USC system (most probable)*
A-1-a	GW, GP
A-1-b	SW, SM, GM, SP
A-2-4	GM, SM
A-2-5	GM, SM
A-2-6	GC, SC
A-2-7	GM, GC, SM, SC
A-3	SP
A-4	ML, OL, MH, OH
A-5	MH, OH, ML, OH
A-6	CL
A-7-5	OH, MH, CL, OL
A-7-6	CH, CL, OH