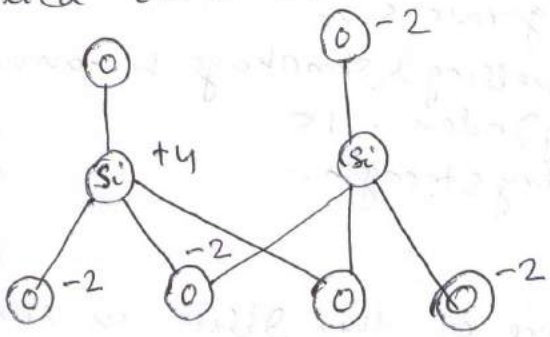
CLAY MINEROLOGY :-

(i) Silica tetrahedral unit :-



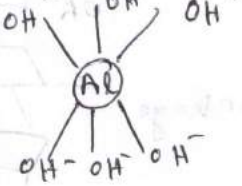
Silica sheet

→ 1 unit of silica atom is bonded with 4 units of oxygen atoms to form a silica tetrahedral unit. The structure of this unit is a trapezium.

→ The individual unit cannot exist freely so they are bonded together to form a silica sheet.

(ii) Octahedral unit :-

— 1 unit of aluminium react with 6 units of hydroxil ion



(Gibsite sheet)

There are basically 3 types of clay minerals present in clay

(i) Kaolinite
(ii) Illite
(iii) Montmorilonite

Kaolinite :- The structural unit is formed when one octahedral unit combines with 1 tetrahedral unit. & resulting in the formation of open book like structure.

→ The thickness is 7A° (10^{-10} m)

$1A^0 = 10^{-10}$ m

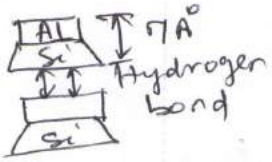
→ several such units are combined together by hydrogen bond. Hence it is very difficult to displace such units i.e. why kaolinite shows less Shrinkage & swelling characteristics.

Ex. China clay for making Chinaware

- It is used as an intestinal absorbent in anti-diarrhoeal medicines

- The bonding with hydrogen bond results in considerable strength & stability with little tendency on the inter layers to allow water & swell

Properties :- - Largest grain size
- Smallest swelling & shrinkage behaviour
- Plasticity Index = 15
- Lowest dry strength.



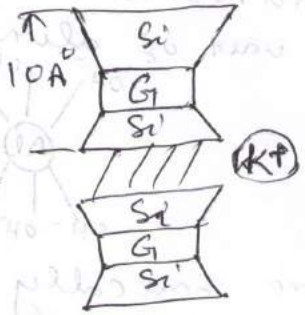
1:1 clay mineral

(ii) Illite :- Structure of this Illite is similar as montmorillonite. 1 structural unit of Illite is formed with 1 octahedral unit in between 2 tetrahedral units.

→ The thickness is 10 A°

→ Each unit of Illite is bonded with potassium ion.

Ex :- Alluvial soil



2 : 1 mineral

Properties
- Intermediate grain size
- Intermediate swelling & shrinkage behaviour
- PI = 30
- Intermediate dry strength.

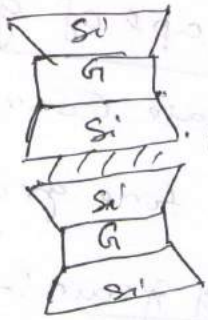
~~Montmorillonite :- Also called Smectite~~
- ~~Composed of two silica sheets & one~~

→ potassium ion occupy position between the adjacent base planes
- Potassion ion bonds the two layers together more firmly than in case of montmorillonite, Illite therefore doesnot swell as much in presence of water as montmorillonite but it does much more than Kaolinite

Montmorillonite :- also called Smectite

- Composed of two silica sheets and one alumina (Gibbsite) sheet so called 2:1 mineral
- Thickness of basic layer is about 9.6 A°
- The interlayer bonding between the tops of silica sheets is mainly due to vanderwaals forces and is thus very weak compared to hydrogen or other ion bonding.
- Further it has the largest specific surface among major clay minerals.
- All these factors lead to extremely high swelling properties in montmorillonite. They swell as the water gains entry into the lattice structure & shrink if the water is removed because of same reason.

Example - Expansive soil, Blackcotton soil, Bentonite



- High swelling & shrinkage nature of soil is normally considered as problematic soil for construction work.

properties :-
- Smallest grain size
- Largest swelling & shrinkage behaviour
- PI = 300
- Highest dry strength.

Halloysite :-
- Another 1:1 mineral of kaolin group
- The 7 A° basic layers are separated by water molecules
- In contrast to other clay minerals halloysite particles are tubular & rod like.
- Dehydration by heat will convert it to approximately kaolinite
- kaolinite & halloysite clays are used for making chinaware

SOIL STRUCTURE

The index properties of soils can be divided into two categories.

1. Soil grain properties
2. Soil aggregate properties

Soil grain properties :- are those properties which are dependent on the individual grains of the soil & are independent of the manner of soil formation e.g mineralogical composition, Sp. gr. of solids, size & shape of grains

Soil aggregate properties :- are those properties which are dependent on the soil mass as a whole & represent the collective behaviour of the soil. These properties are influenced by soil stress history, mode of soil formation & the soil structure.

Shape of grain / Particle

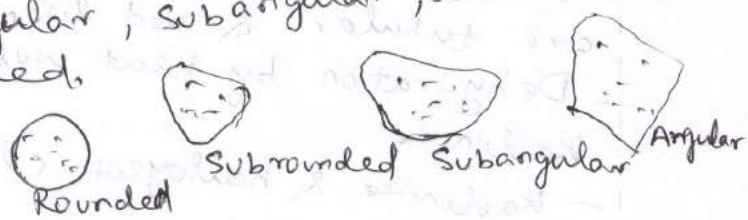
In case coarse grained soil shape of grain examined with naked eye

For fine grained soil — shape of grain require microscopic examination.

Bulky grain :- are soil grains where all dimensions of a grain are more or less the same. These are characteristic of sand & gravel.

- Individual particles are frequently irregular in shape depending on the parent rock, the stage of weathering & the agents of weathering

The particle shape of bulky grains may be described by terms such as angular, subangular, subrounded, rounded & well rounded.



Shape of bulky grains is described in terms of their sphericity $S = \frac{De}{L}$

De = equivalent dia. of particle

L = Length of the particle

Assuming to be a sphere

$De = \left(\frac{6V}{\pi}\right)^{1/3}$

V = Volume of the particle.

Flaky grain / plate shaped grains:-

are the ones in which one dimension of grain, its thickness bears no relationship with the other two lateral dimensions which are much bigger. Ex. clay mineral

Needle shaped grains: are the grains in which one dimension of the grain is fully developed & is much larger than the other two. Such grains are characteristic of clay mineral kaolinite.

Shape of particle

1. Angular shape – Ex. Gravel
2. Round shape – Ex Gravel, sand
3. Flaky – Silt, clay
4. Needle shape – clay

Force

Force

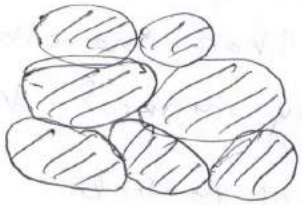
- **Gravity force**
  - → It is depend on particle size of soil
  - PS↑ GF↑ SF↓
  - ↓
  - Gravel
- **Surface force**
  - → It is depends on the shape of particle and its surface area
  - SA(↑) SF(↑) GF(↓)
  - silt & clay

Soil structure:-

(i) Single grain structure
(ii) Honey comb structure
(iii) Flocculent structure
(iv) Dispersse structure
(v) Coarse grain skeleton
(vi) clay matrix
(vii)

(a) Single grained structure :-

- Cohesion less soil (gravel, sand) are composed to form such type of structure
- Here the gravity force is predominant over surface force
- Depending upon the relative position of the particles the structure is divided into 2 parts.
  (a) Loose structure
  (b) Dense structure



(i) Loose structure :-

$e = 0.9$

Shear strength (↓)
Compressibility (↑)
Permeability (↑)

→ Unstable structure
→ affected by vibration

(a iv) Dense structure :-

→ $e = 0.35$

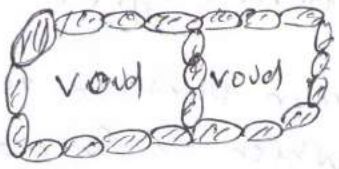
Shear strength (↑)
Compressibility (↓)
Permeability (↓)

* Stable structure
* not affected by vibration
*

(a ii) Honeycomb Structure :-

- It occurs in fine grained soil (silt, clay, sand)
- Particle to particle contact over a large mass of soil which is developed while settling occurs.
- Soil masses skeletons remain in stable condition
- The particle size is usually 0.002mm - 0.02mm
- It occurs in smaller granular particles of soil which have cohesion according to their fineness.
- Particles are placed by mutual attraction due to cohesion
- But the particles does not have any plasticity characteristic

- The soil structure is normally loose & it can supports loads under the static condition
- On vibration the structure may collapse & large deformation takes place
- When water is added to dry fine sand the structure is like honey comb structure (Bulking of sand)

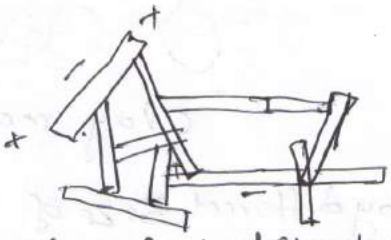


Compressibility high (↑)
Permeability high (↑)

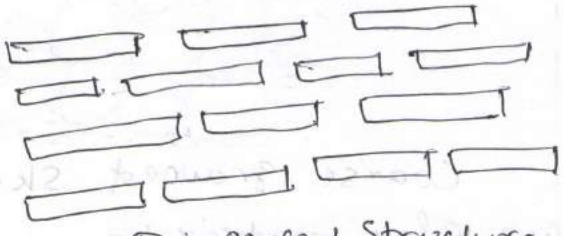
(iii) Flocculent structure :-

- It occurs in clay only
- As it has large surface area so the surface force is predominent over gravity force
- It has -ve charge on surface and +ve charge on edge so the arrangement is edge to face
- The structure is form when there is a net attractive force in between the particles.
- Degree of flocculation depends on the type of Concentration of clay and the presence of salt in water.

Salt (↑) Flocculent structure (↑)
wt (↓) Compressibility (↑)
e (↑) Permeability (↓)
Shear strength (↑)



Flocculent structure



Dispersed structure

(iv) Dispersed structure :-

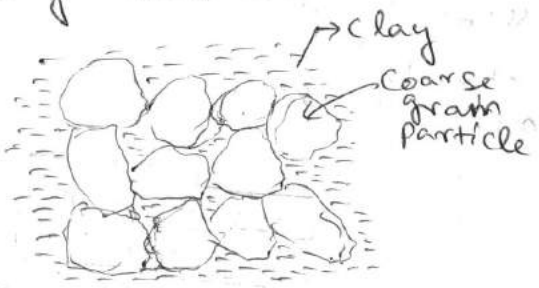
- It developed in clay & it is a remoulded structure particles are parallelly arranged.
- The arrangement is edge to edge

- The arrangement is possible due to net repulsive force.

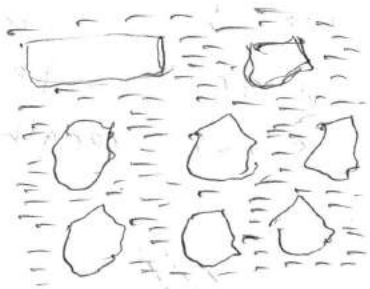
Salt (↓) flocculent (↓)
Wt. (↑) Compressibility (↓)
e (↓) Permeability (↑)

(V) Coarse grained Structure (Skeleton) :-

- Soil contains particles of different type (clay coarse grain)
- The space between the coarse grain particle is occupied by clayey particles which is formed a frame like structure / skeleton.
- In nature the coarse grain particles are deposited first during the sedimentation process & the binder is deposited later.
  (Binder material = clayey particles)
- When the soil structure is not disturbed it can take a heavy load without any deformation
  * As the entire load is carried out by the coarse grain particles.
- When the soil is disturbed the load is transfered to the clayey particles & the stability of soil is gradually reduced.



Coarse grained skeleton



Clay matrix

(VI) Clay matrix :-

- The soil structure is formed by different size of particles
- The amount of clayey particles of very high as compare to coarse grain particles
- The clayey particles form a matrix in which coarse grain particles are floating without touching each other
- The clay matrix is very similar as clay.

SOIL CLASSIFICATION

- The purpose of soil classification is to arrange various types of soils into specific groups based on physical properties & engineering behaviour of soils with the objective of finding the suitability of soils for different engineering applications such as in the construction of earth dams, highways & foundations of buildings etc.
- It is done to arrange the soil in different groups of soils to analysis their property

There are different methods of classification of soil.

a. Particle size classification
b. Textural classification
c. Highway Research Board classification
d. Unified soil classification
e. IS classification

(a) Particle size classification :-

300mm 80mm 4.75mm 75μ 2μ

boulder cobbler Gravel Sand silt clay

Particle size analysis

Gravel

Fine grain (4.75 to 20mm) | Coarse grain (20 to 80mm)

Notations: Gravel – G
Sand – S
Silt – M
Clay – C

GP – Poorly graded gravel
SP – Poorly graded sand
MP – Poorly graded silt
CP – Poorly graded clay

Sand

Fine (75μ – 425μ) | medium (425μ – 2mm) | Coarse (2 – 4 mm)

GW – well graded gravel
SW – well graded sand
MW – well graded silt
CW – well graded clay

Coarse grained soil

Gravel

GW ($C_u > 4$) ($G > S$) ($C_c = 1$ to 2)
GP ($G > S$)

Sand

SW $S > G$ $C_u > 6$ $C_c = 1$ to 3
SP ($S > G$)

IS Classification:

- Indian standard classification system is normally based on unified soil classification system.
- This was 1st developed in 1959 & later modified in 1970 IS 1498 - 1970 The revised version based on USCS.
- It is for classification and identification of soil for general engineering purpose.
- In this system soil are broadly divided into 3 groups

(i) Coarse grained soil - If more than 50% by mass of soil sample is retained by 75μ sieve

(ii) Fine grained soil - If more than 50% by mass of soil sample passes through 75μ IS sieve

(iii) Highly organic soil or some other kind of soil These soil contain high percentage of organic matter, (decomposed vegetation), non soil material and peat

- In certain soils the concretions, shell and other nonsoil materials, in sufficient quantities are also grouped in this divisions

Coarse grained soil:-

GW - well graded gravel $C_u \geq 4$, C_c - 1 to 3

GP - poorly graded gravel $C_u \geq 4$, C_c - Null

GC - clayey gravel $I_p > 7$

GM - silty gravel $I_p < 4$

SW - well graded sand $C_u \geq 6$ C_c 1 to 3

SP - poorly graded sand $C_u \geq 6$

SC - clayey sand $I_p > 7$

SM - silty sand $I_p < 4$

Fine grained soil:- The fine grained soils are again subdivided into 3 groups on basis of liquid limit which is a good index of compressibility

(i) Low compressibility (L)

(ii) Intermediate compressibility (I)

(iii) High compressibility (H)

For organic soil (O) is used

ML – Low compressibility silt, low plasticity

MI – Intermediate compressibility silt medium plasticity

MH – High compressibility silt ; Plasticity ~~high~~

CL – Low compressibility clay Low Plasticity

CI – Medium plasticity

CH – High plasticity

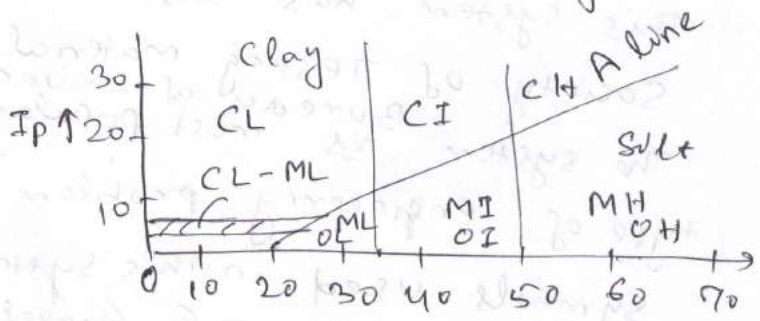
OH – High compressibility organic clay High plasticity

OI – Intermediate compressibility (clay) (silt, clay) Plasiticity medium

OL – Low compressibility organic soil (silt) Low plasticity

*** GW – GC – well graded gravel with clay

Plasticity Chart



Equation for A line

$$I_p = 0.73 (W_L - 20)$$

(v) Silt & clay of low compressibility having a liquid limit less than 35 & represented by symbol (L)

(vi) Silt & clay of medium compressibility :- having liquid limit LL > 35 < 50 is represented by symbol (I)

(vii) Silt & clays of high compressibility having a liquid limit > 50 is represented by symbol (H)

Basic requirement for soil classification :-

1. It should be based on the engineering properties which are most relevant for the purpose for which the classification has been made
2. It should have minimum number of groups
3. It should be simple and should use the terms which are easily understood

Unified soil classification system :- (USCS)

- Ist developed by Casagrande in 1948 & later in 195 was modified by Bureau of Reclamation & the crops of Engineers of the united states of America (USA) This system has also been adopted by American Society of Testing materials (ASTM) & later by Bureau of Indian Standard.

The system is most popular system for use to all type of engineering problem.. It was used for air field construction during world war II.

Symbols used in this system

primary symbols (Prefix) →
- G Gravel
- S Sand
- M - Silt
- C - Clay
- O organic
- Pt Peat

Secondary symbols ↓ Suffix
- W - well graded
- P - Poorly graded
- M - Non plastic
- C - plastic fines
- L - Low plasticity
- H - High plasticity

The system uses both particle size analysis & plasticity characteristics of soils in this system soils are classified into 15 groups

— According to USCS the coarse grained soils are classified on the basis of grain size distribution whereas the fine grained soils are classified on the basis of their plasticity.

Various soils are classified into 4 major groups

(i) Coarse grained
(ii) Fine grained
(iii) Organic soil
(iv) Peat

In USCS system there are 15 groups of soil in which 8 groups are coarse grained soil, 6 groups are of fine grained soils and one group for peat

Coarse grained soil :- If more than 50% of the soil is retained on No. 200 US sieve (0.075 mm or 75μ IS sieve) it is designated as coarse grained soil. A coarse grained soil is designated as gravel (G) if 50% or more of the coarse fraction is retained on No 4 US sieve (4.75 mm IS sieve), otherwise it is termed as sand (S)

Fine grained soil :- If 50% of the soil sample is passed through No 200 US sieve then it is designated as fine grained soil. It is subdivided into silt (M) and clay (C) Based on there liquid limit & Plasticity Index. organic soil are also included in this group.

Highway Research Board Classification (HRB)

The HRB classification system is also known as Public Road Administration (PRB) According to this system the classification of soil is based on both the particle size composition as well as plasticity characteristics. The system is mostly used for pavement construction. The soils are divided into 7 primary groups designated as A-1, A-2, A-3 . . . . A-7

Here group A-1 is divided into two subgroups & group A-2 is divided into four subgroups

- A characteristic group index is use to describe the performance of the soils when used for pavement construction. The higher the value of group index the poorer is the quality of the material. The group index of a soil depends upon

(i) The amount of material passing through 75 μ IS sieve
(ii) Liquid limit
(iii) Plastic limit

Group index can be find out by following equation

$$\text{Group Index} = 0.2a + 0.005ac + 0.01bd$$

where a = that portion of %age passing 75 μ IS sieve greater than 35 & not exceeding 75 (0 to 40)

b = That portion of %age passing 75 μ greater than 15 and not exceeding 55 (0 to 40)

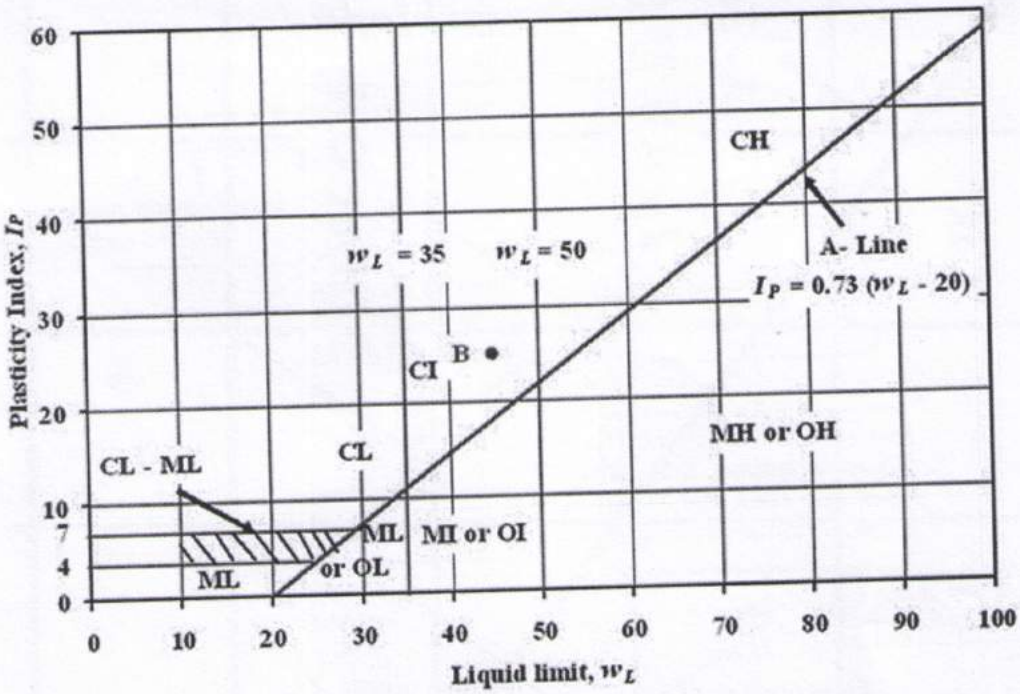
c = that portion of liquid limit greater than 40 and not exceeding 60 (0 to 20)

d = that portion of plasticity index greater than 10 and not exceeding 30 (0 to 30)

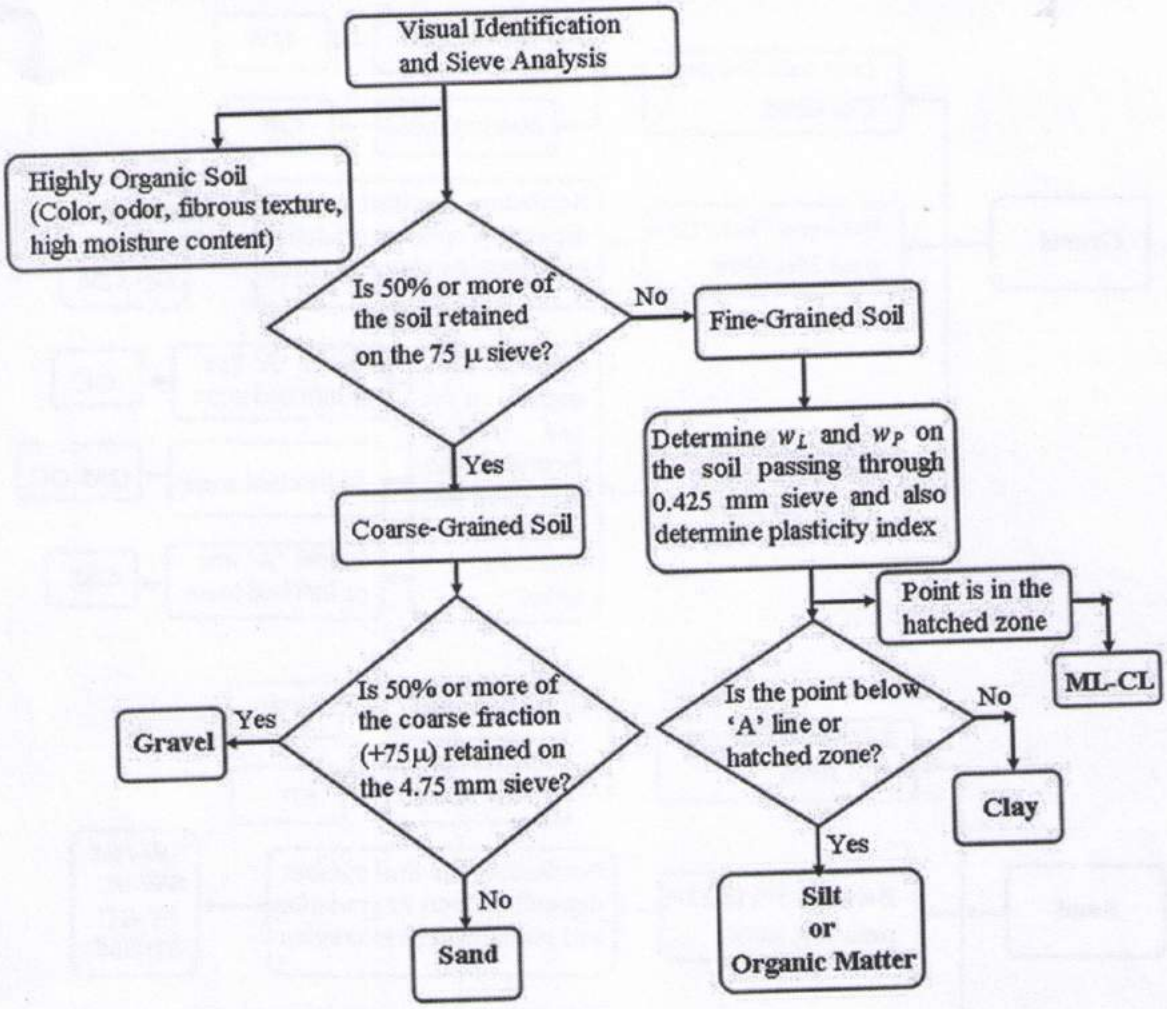
e.g. classification of Indian black cotton soils.

According to Central Road Research Laboratory New Delhi A classification of black cotton soil has been suggested by extending the maximum value of group index from 20 to 50. Accordingly the factors for the calculation of group index such as

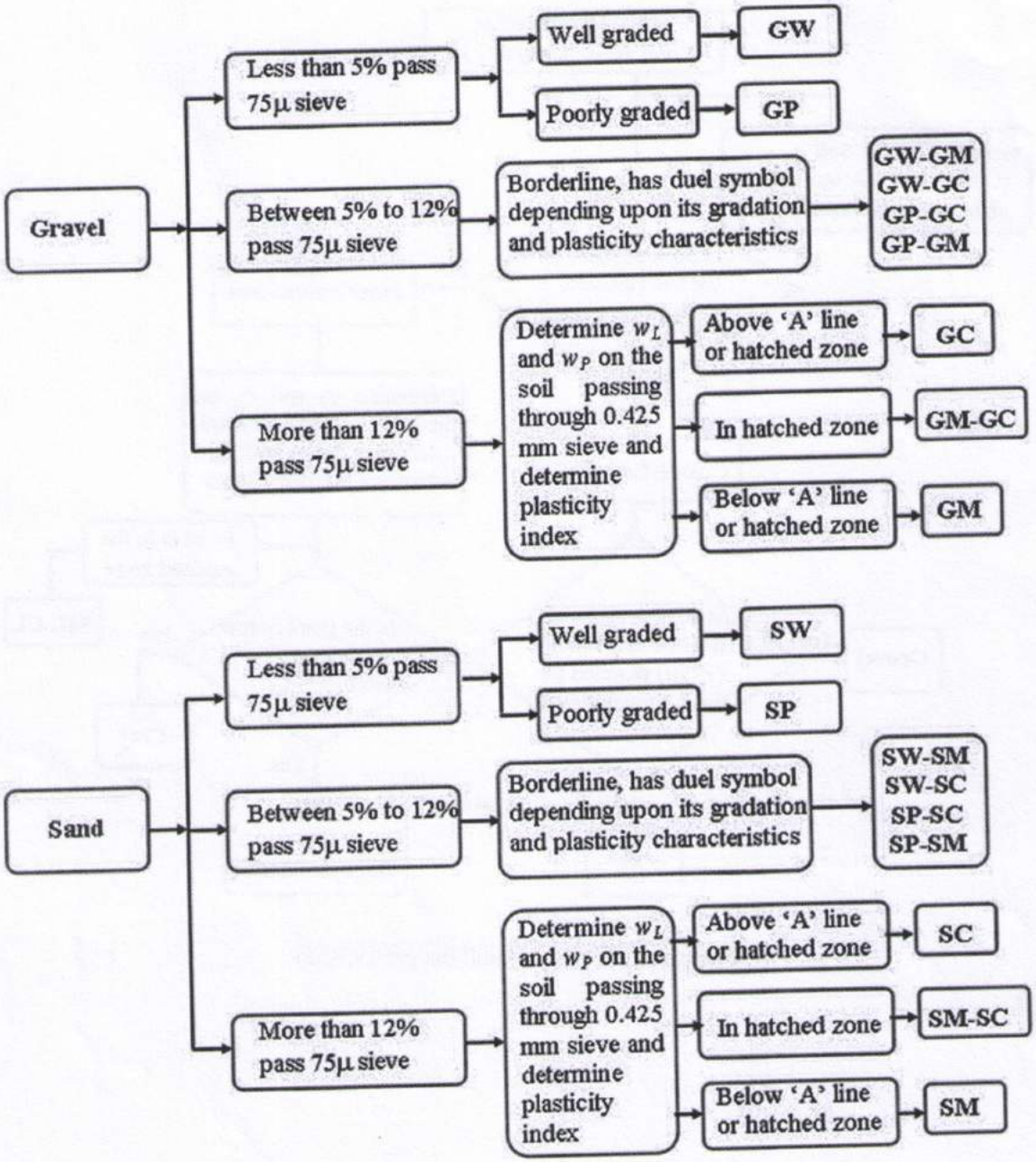
a = 65, b = 65, c = 45, d = 34.



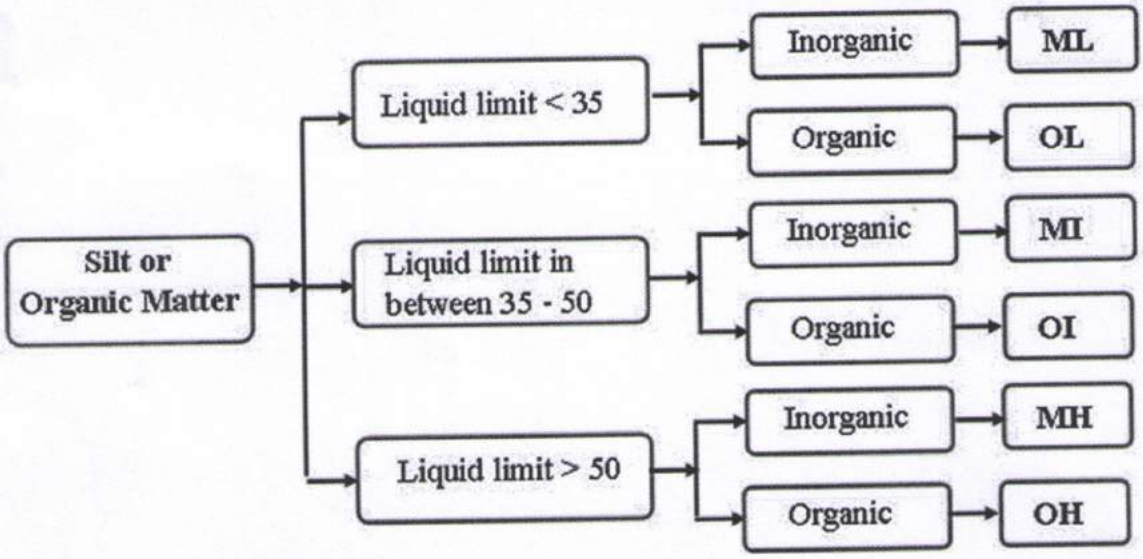
Plasticity chart as per Indian Standard Soil Classification System



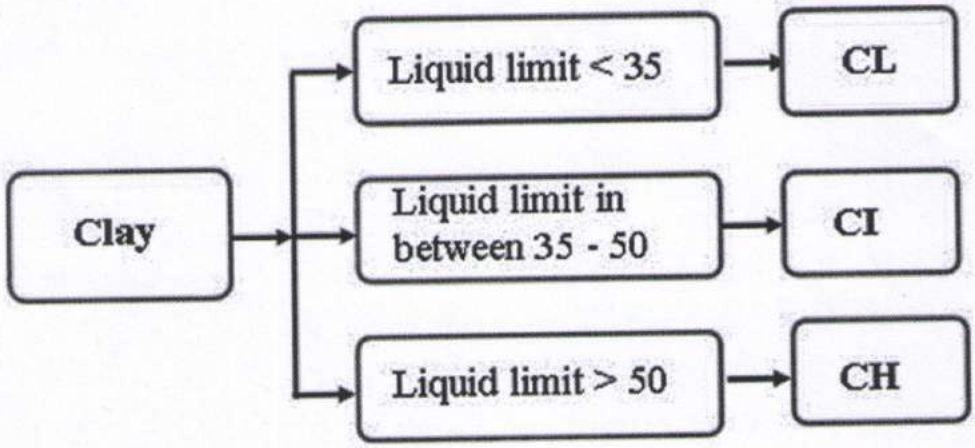
Flow chart to classify soil (as per ISSCS)



Classification of coarse-grained soil: (a) Gravel (b) Sand (as per ISSCS).



(a)



(b)

Classification of fine-grained soil: (a) Silt or Organic matter (b) Clay (as per ISSCS).