

Soil physical properties

Physical properties (mechanical behaviour) of a soil greatly influence its use and behaviour towards plant growth. The plant support, root penetration, drainage, aeration, retention of moisture, and plant nutrients are linked with the physical condition of the soil. Physical properties also influence the chemical and biological behaviour of soil. The physical properties of a soil depend on the amount, size, shape, arrangement and mineral composition of its particles. These properties also depend on organic matter content and pore spaces.

Important physical properties of soils.

1. Soil texture,
2. Soil structure,
3. Surface area,
4. Soil density,
5. Soil porosity,
6. Soil colour,
7. Soil consistence

Soil texture- Textural classes- Particle size distribution

Definition

Soil texture refers to the relative proportion of particles or it is the relative percentage by weight of the three soil separates viz., sand, silt and clay or simply refers to the size of soil particles. The proportion of each size group in a given soil (the texture) cannot be easily altered and it is considered as a basic property of a soil. The soil separates are defined in terms of diameter in millimeters of the particles. Soil particles less than 2 mm in diameter are excluded from soil textural determinations.

Stones and gravels may influence the use and management of land because of tillage difficulties but these larger particles make little or no contribution to soil properties such as WHC and capacity to store plant nutrients and their supply.

Gravels : 2 – 4 mm

Pebbles : 4 – 64 mm

Cobbles : 64 – 256 mm

Boulders : > 256 mm

Particles less than 2 mm is called fine earth, normally considered in chemical and mechanical analysis.

The components of fine earth: Sand, Silt and Clay (Soil separates). The size limits of these fractions have been established by various organizations. There are a number of systems of naming soil separates.

- (a) The American system developed by USDA
- (b) The English system or British system (BSI)
- (c) The International system (ISSS)
- (d) European system

i) USDA

Soil separates	Diameter (mm)
Clay	< 0.002 mm
Silt	0.002 – 0.05
Very Fine Sand	0.05 – 0.10
Fine Sand	0.10 – 0.25
Medium Sand	0.25 - 0.50
Coarse Sand	0.50 - 1.00
Very Coarse Sand	1.00 – 2.00

ii) BSI

Soil separates	Diameter (mm)
Clay	< 0.002 mm
Fine Silt	0.002 – 0.01
Medium Silt	0.01 – 0.04
Coarse Silt	0.04 – 0.06
Fine Sand	0.06 - 0.20
Medium Sand	0.20 - 1.00
Coarse Sand	1.00 – 2.00

iii) ISSS

Soil separates	Diameter (mm)
1. Clay	< 0.002 mm
2. Silt	0.002 – 0.02 mm
3. Fine sand	0.02 – 0.2 mm
4. Coarse sand	0.2 – 2.0 mm

iv) European System

S.No	Soil separates	Diameter (mm)
1	Fine clay	< 0.0002 mm
2	Medium clay	0.0002 – 0.0006
3	Coarse clay	0.0006 – 0.002
4	Fine silt	0.002 - 0.006

5	Medium silt	0.006 - 0.02
6	Coarse silt	0.02 - 0.06
7	Fine sand	0.06 - 0.20
8	Medium sand	0.20 - 0.60
9	Coarse sand	0.60 - 2.00

Sand

- Usually consists of quartz but may also contain fragments of feldspar, mica and occasionally heavy minerals viz., zircon, Tourmaline and hornblende.
- Has uniform dimensions
- Can be represented as spherical
- Not necessarily smooth and has jagged surface

Silt

- Particle size intermediate between sand and clay
- Since the size is smaller, the surface area is more
- Coated with clay
- Has the physico- chemical properties as that of clay to a limited extent
- Sand and Silt forms the SKELETON

Clay

- Particle size less than 0.002 mm
- Plate like or needle like in shape
- Belong to alumino silicate group of minerals
- Sometimes considerable concentration of fine particles which does not belong to alumino silicates. (eg). iron oxide and CaCO_3
- These are secondary minerals derived from primary minerals in the rock
- Flesh of the soil

Knowledge on Texture is important. It is a guide to the value of the land .Land use capability and methods of soil management depends on Texture

Particle size distribution/ determination

The determination of relative distribution of the ultimate or individual soil particles below 2 mm diameter is called as Particle size analysis or Mechanical analysis

Two steps are involved

- i) Separation of all the particles from each other i.e. Complete dispersion into ultimate particles
- ii) Measuring the amount of each group

Separation

S.No	Aggregating agents	Dispersion method
1	Lime and Oxides of Fe & Al	Dissolving in HCl
2	Organic matter	Oxidises with H_2O_2
3	High concn. of electrolytes (soluble salts)	Precipitate and decant or filter with suction
4	Surface tension	Elimination of air by stirring with water or boiling

After removing the cementing agents, disperse by adding NaOH

Measurement

Once the soil particles are dispersed into ultimate particles, measurement can be done

i) Coarser fractions – sieving – sieves used in the mechanical analysis corresponds to the desired particle size separation

For 2 mm, 1 mm and 0.5 mm – sieves with circular holes

For smaller sizes, wire mesh screens are used (screening)

ii) Finer fractions – by settling in a medium

The settling or the velocity of the fall of particles is influenced by

Viscosity of the medium

Difference in density between the medium and falling particles

Size and shape of object

Stokes' Law

Particle size analysis is based on a simple principle i.e. "when soil particles are suspended in water they tend to sink. Because there is little variation in the density of most soil particles, their velocity (V) of settling is proportional to the square of the radius 'r' of each particles.

Thus $V = kr^2$, where k is a constant. This equation is referred to as Stokes' law.

Stokes (1851) was the first to suggest the relationship between the radius of the particles and its rate of fall in a liquid. He stated that "the velocity of a falling particle is proportional to the square of the radius and not to its surface. The relation between the diameter of a particle and its settling velocity is governed by Stokes' Law:

$$V = \frac{2gr^2(ds - dw)}{9n}$$

Where ,

- V - velocity of settling particle (cm/sec.)
- g - acceleration due to gravity cm/ sec² (981)
- ds - density of soil particle (2.65)
- dw - density of water (1)
- n - coefficient of viscosity of water (0.0015 at 4oC)
- r - radius of spherical particles (cm).

Assumptions and Limitations of Stokes' Law

Particles are rigid and spherical / smooth. This requirement is very difficult to fulfill, because the particles are not completely smooth over the surface and spherical. It is established that the particles are not spherical and irregularly shaped such as plate and other shapes.

The particles are large in comparison with the molecules of the liquid so that in comparison with the particle the medium can be considered as homogenous. Ie the particles must be big enough to avoid Brownian movement. The particles less than 0.0002 mm exhibit this movement so that the rate of falling is varied.

The fall of the particles is not hindered or affected by the proximity (very near) of the wall of the vessel or of the adjacent particles. Many fast falling particles may drag finer particles down along with them.

The density of the particles and water and as well as the viscosity of the medium remain constant. But this is usually not so because of their different chemical and mineralogical composition.

The suspension must be still. Any movement in the suspension will alter the velocity of fall and such movement is brought by the sedimentation of larger particles (> 0.08 mm). They settle so fast and create turbulence in the medium.

The temperature should be kept constant so that convection currents are not set up.

Methods of Textural determination

Numerous methods for lab and field use have been developed

- i) Elutriation method – Water & Air ; ii)Pipette method

iii) Decantation/ beaker method ; iv) Test tube shaking method

v) Feel method – Applicable to the field – quick method – by feeling the soil between thumb and fingers

Feel Method

Evaluated by attempting to squeeze the moistened soil into a thin ribbon as it is pressed with rolling motion between thumb and pre finger or alternately to roll the soil into a thin wire.

η Four aspects to be seen – i) Feel by fingers, ii) Ball formation , iii) Stickiness and iv) Ribbon formation

Soil Textural Classes

To convey an idea of the textural make up of soils and to give an indication of their physical properties, soil textural class names are used. These are grouped into three main fractions viz., Sand, Silt and Clay.

According to the proportion of these three fractions a soil is given a name to indicate its textural composition. Such a name gives an idea not only of the textural composition of a soil but also of its various properties in general.

On this basis soils are classified into various textural classes like sands clays, silts, loams etc

Sands

The sand group includes all soils in which the sand separates make up at least 70% and the clay separate 15% or less of the material by weight. The properties of such soils are therefore characteristically those of sand in contrast to the stickier nature of clays. Two specific textural classes are recognized in this group sandy and loamy sand although in practice two subclasses are also used Loamy fine sand and loamy very fine sand.

Silt

The silt group includes soils with at least 80% silt and 12% or less clay. Naturally the properties of this group are dominated by those of silt. Only one textural class - Silt is included in this group.

Clays

To be designated a clay a soil must contain at least 35% of the clay separate and in most cases not less than 40%. In such soils the characteristics of the clay separates are distinctly dominant, and the class names are clay, sandy clay and silty clay. Sandy clays may contain more sand than clay. Likewise, the silt content of silty clays usually exceeds clay fraction.

Loams

The loam group, which contains many subdivisions, is a more complicated soil textural class. An ideal loam may be defined as a mixture of sand, silt and clay particles that exhibits the properties of those separates in about equal proportions. Loam soils do not exhibit dominant physical properties of sand, silt or clay. Loam does not contain equal percentage of sand, silt and clay. However, exhibit approximately equal properties of sand, silt and clay.

Determination of Textural Class

In the American system as developed by the United State Department of Agriculture twelve textural classes are proposed.

The textural triangle

It is used to determine the soil textural name after the percentages of sand, silt, and clay are determined from a laboratory analysis. Since the soil's textural classification includes only mineral particles and those of less than 2mm diameter, the sand plus silt plus clay percentages equal 100 percent. (note that organic matter is not included.) Knowing the amount of any two fractions automatically fixes the percentage of the third one.

To use the diagram, locate the percentage of clay first and project inward parallel to sand line. Do likewise for the per cent silt and project inward parallel to clay line and for sand, project inward parallel to silt. The point at which the projections cross or intersect will identify the class name. Some times, the intersecting point exactly fall on the line between the textural classes. Then it is customary to use the name of the finer fraction when it happens. (eg). Soil containing 40% clay, 30% sand.

Importance of Soil Texture

Presence of each type of soil particles makes its contribution to the nature and properties of soil as a whole

- Texture has good effect on management and productivity of soil. Sandy soils are of open character usually loose and friable.
- Such type of the texture is easy to handle in tillage operations.
- Sand facilitates drainage and aeration. It allows rapid evaporation and percolation.
- Sandy soils have very little water holding capacity. Such soils can not stand drought and unsuitable for dry farming.
- Sandy soils are poor store house of plant nutrients

- Contain low organic matter
- Leaching of applied nutrients is very high.
- In sandy soil, few crops can be grown such as potato, groundnut and cucumbers.
- Clay particles play a very important role in soil fertility.
- Clayey soils are difficult to till and require much skill in handling. When moist clayey soils are exceedingly sticky and when dry, become very hard and difficult to break.
- They have fine pores, and are poor in drainage and aeration.
- They have a high water holding capacity and poor percolation, which usually results in water logging.
- They are generally very fertile soils, in respect of plant nutrient content. Rice, jute, sugarcane can be grown very successfully in these soils.
- Loam and Silt loam soils are highly desirable for cultivation
- Generally, the best agriculture soils are those contain 10 – 20 per cent clay, 5 – 10 per cent organic matter and the rest equally shared by silt and sand and 30% silt - called as clay rather than clay loam.

