

# The soil formation factors engineering essay



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In this chapter the formation, types and engineering properties of soil are discussed based on literature review . The main emphasis is on laterite soils, the definition, its formation and distribution. The chapter also includes engineering properties of lateritic soils observed and tested previously in various parts of the world. The reason to carryout literature review is to get an idea about lateritic soils and behaviour.

## **AN INTRODUCTION TO SOILS**

### **Definition of Soil**

The definition of soil depends upon the field in which it is studied. In Pedology, soil is defined as a material present on the surface, responsible for plant growth. The geologist takes the meaning of soil as the material formed due to past surface activities and actions and present in the thin zone of the Earth's face in which roots are contained.

In regard to civil engineering, the soil is assemblage of mineral particles which are product of rock weathering. These mineral particles are usually unbounded or weakly bounded. The void areas present between particles contains water or air or both. (Craig, 2004).

Terzaghi and Peck (1948) defined soil as aggregation of mineral grains naturally, that can be detached by lightly mechanical methods as agitation in water.

Hence the soil is mixture of mineral particles, containing void space which may be filled with air or water or both at same time.

## **Types of soil**

The types of soils can be presented in different forms which are shown below:-

### **Residual soils**

There is no specific or particular definition for residual soils, however all the definitions that are in literature do indicate that these soils are formed on site as a result of weathering of rocks and they remain at that same place. (Ahmed, et al. , 2006)

Venkataramaiah(2006) defined residual soils as ' soils which are formed by weathering of rocks may remain in position at the place of region' he further stated that these soils are found at large scale in area where the climate is hot and humid and cause the weathering of rocks easily. The sizes of grains of these soils are not specific and may break into smaller pieces by small amount of load.

### **Transported soils**

Gopal(2000) defined transported soil as ' Any soil that has been transported from its place of origin by wind, water or ice or any other agency and has been redeposit is called transported soil. He further explained that these soils are more common as compared to residual soils. The particles features such as size, shape, and texture of transported soils depends on source by which they were transported. These soils can further be categorized as alluvial, Lacustrine, Marine, Aeolian and Glacial deposits.

So it can be conclude that soils which remain at the place where they were created from weathering of rocks are known as residual soils and the soils

which are moved or blown from their original place of formation by different activities are transported soils.

## **Types of soils based on texture**

Soil texture refers to the particle size of each mineral present in soil. It also includes the proportion of each particle size in soil. Based on soil texture, the soils can be divided into three types 1) sand 2) silt and 3) clay.

### **Sand**

The particle size for sand is considered to be largest as compared to other types. Most classification systems consider the particle size of sand from 2mm to 0.05mm in diameter. The soils which consist of high proportion of sandy particles is known as sandy soils.

### **Clay**

Clay consists of particle size lesser than 0.002mm. The soil which contains higher proportion of clay particles is known as clayey.

### **Silt**

The particle size for silt is considered to be from 0.05mm to 0.002mm or in some countries it is also taken as 0.02mm. However in case of silt the soil containing higher proportion of silt are considered as loamy soils.

The loamy soils are further divided into different types based on proportion of clay, sand and silt particles. Soils with sand and silt particles in higher proportion are called sandy loams or loamy sands. Clayey particles in majority result in sandy clay loam or sandy clay. The soil containing approximately

the same quantity of clay, sand and silt particles is considered as clay loam. (Wiekco, 2006).

[http://www.uwsp.](http://www.uwsp.edu/geo/faculty/ritter/images/biosphere/soils/texture_triangle_large_2.jpg)

[edu/geo/faculty/ritter/images/biosphere/soils/texture\\_triangle\\_large\\_2.jpg](http://www.uwsp.edu/geo/faculty/ritter/images/biosphere/soils/texture_triangle_large_2.jpg)

Figure 2. 1 Soil classification based on texture

(Wiekco, 2006).

## **Soil Components**

The ideal soil consists of 50% solid particles, the solid part may consist of up to 5% of organic matters. The rest of 50% is shared equally among air and water contents which cover 25% each in soil composition.

### **Water**

Water makes up 25% of soil composition in ideal situation. The amount of water can vary based on conditions. In fully dry condition the water content is less as compared to saturated conditions.

### **Air**

Air is 25% of soil composition. Like water the air content also changes depending upon soil condition. For example as it rains the voids in soil filled with air are replaced by water thus reducing the quantity of air or when the soil becomes dry the void filled with water are occupied by air.( Reiley and Shry, 2002)

## **Organic matter**

The decaying process of living organisms such as plants and animals in soil results in formation of organic matter. (Bot and Benties, 2005).

The organs of dead animals, roots, leaves and wood of plants go through decaying process due to physical and chemical activities due to this decomposition the organic matter is formed.

Fine textured soils such as clay contain higher content of organic matter as compared to coarse textured soil such as sandy soils.( Bot and Benties, 2005 cited Prasad and Power, 1997).

Studies on the effect of organic content on certain properties have been carried out. Malkawi, et al. (1999) observed increase in the plastic limit and the liquid limit , the optimum water content of the illitic soil with increase in organic content and decrease maximum dry density.

## **Mineral particles.**

The solid components of soils consist of crystalline material called minerals. Mineral particles are categorized based on their structure and chemical composition. Oxygen and silicon minerals are most significant to geo-technical engineers. Fine grained soils consist of mineral particles which are platy in nature. (Budhu, 2007).

Figure 2. 2 Soil composition

(Reiley and Shry, 2002)

## Phases of soil

Soil is not a single phase substance but a multi phase.

Soil is a particulate material and not coherent like concrete and steel.

Naturally soil, comprises of three main components that are solid particles along with water and air present in the voids which occur among the particles. The water and air proportion in soil depend on location and environmental and climatic conditions. (Singh, n. d.)

Criag (2004) describing phase relations suggest that soil may have double or triple phase composition. Relating the degree of saturation and composition of soil he further explains that a fully dry or unsaturated soil composes of two phases that are solid particles and pore air. A completely saturated also like fully dry soil is two phase but has pore water instead of pore air.

A third category he describes is the partially saturated soil which is three phase comprising solid soil particles, pore water and pore air.

. <http://nptel.iitm.ac>.

[in/courses/Webcourse-contents/IIT-%20Guwahati/soil\\_mech/web/chap2final/s2\\_clip\\_image002\\_0000.jpg](http://nptel.iitm.ac/in/courses/Webcourse-contents/IIT-%20Guwahati/soil_mech/web/chap2final/s2_clip_image002_0000.jpg)

Figure 2. 3 Phases of soil

(Singh, n. d.)

## **Engineering Characteristics for soils**

### **Atterberg limits**

Atterberg was a Swedish soil physicist who in (1911) introduced a classification system and technique to establish the states of consistency of soil. The consistency states are liquid when the soil is wet, plastic state and ultimately the dry solid. The principle on which this method is based is to find the water content using the relation (mass of water/dry mass of soil) at particular transition point between different consistency states. The terms plastic limit, liquid limit and shrinkage limit which as a whole known as Atterberg limits were used to defined these transitions points.

Factors effecting Atterberg limits:-

Particle size.

Particular surface area of particles that can be occupied by water .

Particle size distribution. (Lal, 2005)

Sawangsurriya and Fratta(2006) indicated that index soil properties generally used for classification, description and identification of fine grained soils are called atterberg limits. Actually these index properties refer to water content, it is an indication that at a certain amount of water content the soil will flow as fluid, it will be plastic in nature or semi solid.

Dolinar, et al. (2007) stated that the consistency of a fine-grained soil varies from a semi-solid state to a plastic state and ultimately to a liquid state with an increase in water content.



He defined plastic, liquid limits as follows:-

### **Plastic limit**

The point at which the consistency, due to the soil water content, is altered from a semi-solid state to a plastic state is known as plastic limit. It is denoted by (PL).

### **Liquid limit**

The point upon which the consistency is changed from a plastic state to a liquid state is called liquid limit. It is denoted by (LL).

These limits are also known as consistency limit.

### **Shrinkage limit**

The water content upon which the soil is transformed from the semi solid state to the solid state is called shrinkage limit. The soils no more is saturated below the shrinkage limit . The voids of soils are filled with air . Moreover the volume of the soil does not alter due to capillary tension. Hence the soils maintain constant volume and stops shrinking further for water content at shrinkage limit. The water content at shrinkage limit is the lowest at which soil can remain fully saturated. (Arora, 2008).

### **Index of plasticity**

Water content between liquid and plastic limit is known as index of plasticity. It is denoted ( Ip). It is calculated by formula

$$IP = (LL - PL)$$

Where LL is liquid limit and PL is plastic limit. It shows the mechanical behaviour of soil towards changing amount of water (Lal, 2005).

Arora(2009) defined index of plasticity as ' numerical difference between liquid limit and plastic limit'. It may also be denoted by (PI).

Volume

Plastic state Liquid state

Solid state semi solid

State

SL PL LL

Water Content

Figure 2. 4 Different states of soil.

(Arora, 2008).

## **Specific gravity**

Specific gravity is defined as the ratio of weight of soil solid composition to the weight of water with the same volume.(Yalcin, 2007). The values of specific gravity of soil generally vary from 2. 60 to 2. 84.(Abdullahi, 2006). It is denoted by symbol  $G_s$ .

## Unconfined compressive strength

Reddy and Sastri(2002) state that ' unconfined compressive strength is defined as the ratio of axial failure load to cross sectional area of the soil sample when it is not subjected to any lateral pressure'.

Where

$q_u$  = Unconfined compressive strength

$P$  = axial load at failure

$A_c$  = corrected area at failure =  $A_o / (1 - \epsilon)$

$A_o$  = intial cross sectional area

$\epsilon$  = axial strain in sample  $L / L_o$

$L$  = change in length of sample

$L_o$  = initial length of sample

Table 2. 1 Unconfined compressive strength related to consistency

Consistency

Unconfined Compressive strenght

kPa

Very soft

<25

Soft

25-50

Medium stiff

50-100

Stiff

100-200

Very stiff

200-400

Hard

> 400

Source (serajuddin and chowdhury, 1996)

### **Particle-size distribution**

Particle size distribution gives the amount of different particles size present in particular soil. It is usually determine by sieve analysis. The particle-size distribution of soil provides the mean particle size and fines content which help in soil classifications and establishing soil property relationships (Vipulanandan and Ozgurel, 2009)

### **California bearing ratio**

As the name indicates California bearing ratio is bearing capacity of soil. California bearing ratio value is an important parameter when designing a  
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sub grade or base for roads. The potential strength of sub grade material is indicated California Bearing Ratio (CBR) and is a vital index to assess its performance in expressway.( Guang-qing, et al. , 2006).

## **Shear strength of soil**

For a soil mass a shear strength is a internal resistance per unit area that a soil mass can provide to oppose failure and sliding along the any plane within it .

The Mohr-coulomb failure criteria is fundamental equation to represent the shear strength of soil.

$c +$

Where

$C =$  cohesion

$=$  Angle of Internal friction.

The basic approximation in above equation is that shear stress is linear function of normal stress at failure plane.

For saturated soil the sum of effective stress and pore water pressure gives total normal at any particular point.

( Das, 2008).

The Mohr-Coulomb failure criteria equation in terms of effective strength parameters is given as

$$\tau = c' + (\sigma - u) \tan \phi'$$

$$\tau = c' + \sigma' \tan \phi'$$

'where

$\tau$  = the shear strength,

$c'$  = effective cohesion,

$\sigma$  = total stress,

$u$  = pore water pressure

$\phi'$  = effective angle of internal friction or shearing resistance. (Zhang, et al., 2001)

<http://www.ejge.com/2004/Ppr0478/Fig5.gif>

Figure 2. 5 Typical shear strength diagram

(yilmaz and Erzin, 2004).

## **Shear strength parameters**

There are two shear strength parameters

Angle of internal friction.

Cohesion

## **Angle of internal fraction**

The angle of contact between the particles of soil or unconsolidated mass and the underlying surface is called angle of internal friction. It is also known

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as angle of shearing resistance. It is denoted by  $\phi$ (phi). It is also regarded as slope angle

## **Cohesion**

The level to which particles or grains of soil are bounded together is denoted by cohesion or the ability of soil particles to adhere with each other is known as cohesion. (Huggett, 2007).

## **Factors effecting shear strength parameters**

Dry density, particle size distribution, particle shape, texture of surface and water content are the factors on which angle of internal friction is dependent where as the size of clayey particles, clay minerals types, valence or chemical bonds among particles, water content, and percentage of the clay are the factors on which cohesion is based.( Jain, et al., 2010).

## **Site investigation**

Site investigation is a significant element in construction industry and should be given due importance. One of the objectives of site investigation is to determine the ground conditions and type of soil lying on site of construction. The engineers should know the engineering properties of soil on basis on which they are going to design the foundations or any other structure. They can also suggest some solution for the properties of soils which do not meet requirements such as stabilization or addition of admixtures etc.

Some of major objectives of site investigation as mentioned in BS-5930:

1999+A2: 2010 are as follows:-

## Design

The site investigation can assist in creation of design which is economical and satisfying and safe, the results of investigation can help in planning the temporary works need for construction process.

## Site selection

The civil engineers can propose more appropriate and up to standard site for construction if option is available. Moreover they can advise suitable area for construction a particular site.

## Construction

To predict the preferred method of construction and to know the problems that may arise during construction such as delaying due to conditions of ground or water table etc.

## Effect of change

The results obtained from site investigations can help in determining the changes that can take place due to natural factors or as result of construction works and their effect on environment.

. Oloufa, et. al(1994) while highlighting the importance of site investigation stated that It is key feature to estimate and plan new construction projects. Site investigation gives indication about ground characteristics as well as underground conditions . These conditions in return allow engineers to make a choice of suitable construction methods and machinery. These factors affect the schedule and costing of projects.

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Hence the site characteristics should be observed carefully.

## **Soil formation**

The soil formation process involves the weathering of rocks. The weathering causes decomposition and disintegration of rocks and minerals into smaller and smaller particles. This weathering is caused due to natural or mechanical and chemical agents.

## **Mechanical weathering**

The mechanical weathering disintegrates the rock to soil, but soil retains most properties similar to rock material from which it was formed. The mechanical weathering agents include water, wind and glaciers etc.

## **Chemical weathering**

The effect chemical weathering is intense as compared to mechanical weathering. The soils minerals are partially or completely vanish in relation to rock materials they are formed from. Chemical weathering occurs at higher rate in tropical and humid climatic conditions. (Venkatramaiah, 2006).

## **Soil formation factors**

Soils are formed as result of five factors which are climate, organisms (biota) topography, parent material, and time. The soil formation is generally shown by Jenny's state factor equation that is  $S = f(C, O, R, P, T.)$  here (R) stands for relief depicting topography factor. (Demas, et al., 2001).

Climate refers the general climate conditions of the region where soil exists . The climate includes amount rainfall, moisture in air, temperature. The organism means the plants, animals and microorganisms that react with soil.

Topography refers landscape, terrain or geological features of location of soil deposit.

By parent material it means the original hard rock deposits where the soils are formed. For example, till is a parent material for soil created in glacial deposits similarly alluvium is a parent material for soil produced at the side of a river. Parent material influences the grain texture and mineral composition of soil,

Time depicts the duration of soil forming process. It shows that for how long chemical or mechanical weathering has taken place on rock or age of existing soil deposit. (Brevik, 1999)

Topographical characteristics such as curves, slope, steepness and other landforms affect the hydrological conditions of area where soil deposits are located and cause diverse soil moisture conditions and flow trends. Different types of slopes yield different conditions of drainage.( Seibert, et al., 2007).

Climatic conditions effect soil formation. For instance in tropical, hot and humid conditions the high temperature and humidity speed up weathering of rock and soil profiles with large depth are formed.(Noguchi et al, 2005).

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## **General Classification**

**Granular Materials (35% or less passing the 0.075 mm sieve)**

**Silt-Clay Materials (> 35% passing the 0.075 mm sieve)**

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, % passing

2. 00 mm (No. 10)

50 max

...

...

...

...

...

...

...

...

...

...

0. 425 (No. 40)

30 max

50 max

51 min

...

...

...

...

...

...

...

...

0. 075 (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 a subgrade

excellent to good

fair to poor

Source (Ranjan and Rao, 2005).