Civil Engineering

Soil Mechanics and Foundation Engineering

Comprehensive Theory

with Solved Examples and Practice Questions

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CHAPTER 01

Soil Formation

1.1 Definition of Soil

Generally, the term 'soil', is used for upper layer of the earth surface which can support plants.

For engineering purposes, soil is defined as the uncemented aggregate of mineral grains and decayed organic matter (solid particles) with liquid and gas in the empty spaces between the solid particles.

Soil is an unconsolidated material that has resulted from the disintegration of rocks by various weathering agencies like water, air etc. The soil may contain inorganic or organic matter and can be represented as a three phase system containing solids, water and air. Soil is used as a construction material in various civil engineering projects and it supports structural foundations.

1.2 Definition of Soil Mechanics

Soil mechanics is the branch of science that deals with the study of physical properties of soil and the behaviour of soil masses subjected to various types of forces.

The term 'Soil Mechanics' was given by the Dr. Karl Terzaghi in 1925, who is also known as Father of Soil Mechanics. According to Terzaghi, "Soil mechanics is the branch of civil engineering that concerns the application of the principles of mechanics, hydraulics and chemistry to engineering problems related to the soil."

1.3 Definition of Soil Engineering

Soil Engineering is the application of principles of soil mechanics to practical purposes. It is a broader term including soil mechanics, geology, structural engineering and soil dynamics which are essential to obtain practical solution to problems related to the soil. It includes site investigation, lab testing, design, construction and maintenance of foundations and earth retaining structures.

1.4 Definition of Rock Mechanics

A natural aggregate of mineral particles bounded by strong and permanent cohesive force is called 'rock'. Rock Mechanics is the science dealing with the application of the principles of mechanics to understand the behaviour of rock masses.

1.5 Geotechnical Engineering

Geotechnical Engineering is the sub-discipline of civil engineering that involves natural materials found closer to the surface of the earth. It includes the application of the principles of soil mechanics and rock mechanics

to the design of foundations, retaining structure and earth structure. Geotechnical Engineering is a broader term which includes soil mechanics, rock mechanics, rock engineering, Geology and Soil Engineering.

1.6 Origin of Soil

Almost all the soils are formed by the disintegration of rocks either through physical or chemical weathering. If weathered sediments remain over parent rock, then soil is called 'Residual soil' and weathered sediments transported and deposited at some other place are called 'Transported soil'.

The process of soil formation is called 'Pedogenesis'.

The soil formation is cyclic which is called 'Geological cycle'.

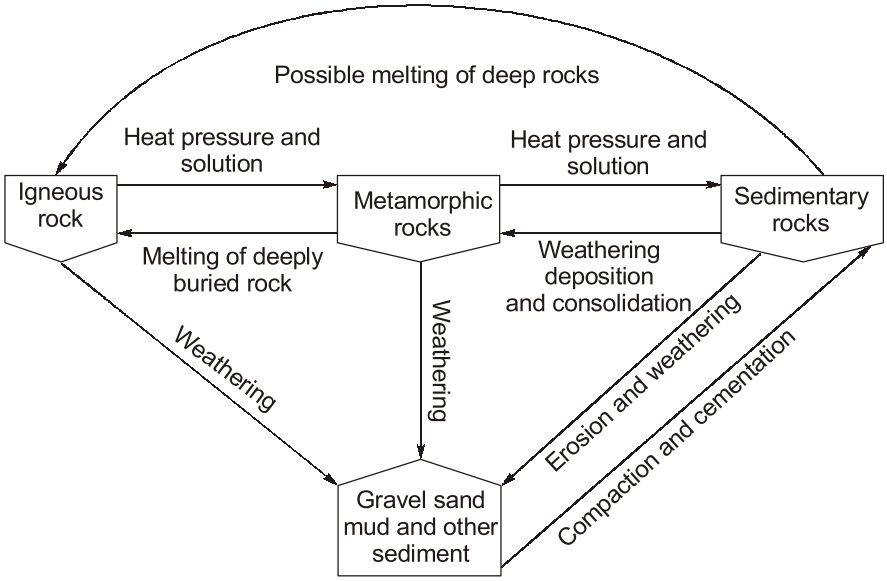

Fig. 1.1 *Geological cycle (suggested by Bowles, 1984)*

These are the stages in the geological cycle of soil formation in transported soil:

(1) weathering
(2) transportation
(3) deposition of weathered materials
(4) upheaval

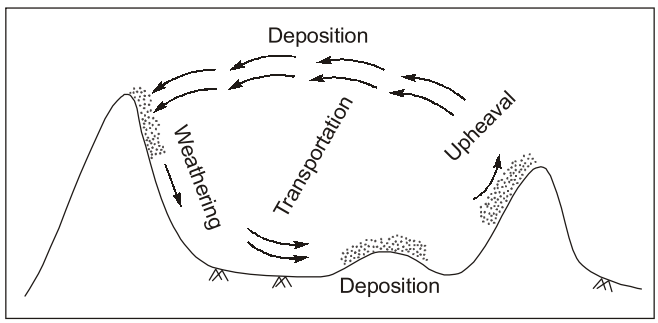

Fig. 1.2 *Stages of Geological Cycle in case of transported soil*

1.6.1 Weathering Stage

Rock disintegration, also called weathering, is one of the important geological process. Weathering may be physical (mechanical) or chemical.

Physical Weathering: In Physical weathering, rock disintegrates into smaller fragments due to various agencies like running water, heavy wind, temperature changes, rainfall, expansion due to freezing of water and human activities. Generally, sand and gravel fall in the category.

The mineral constituents remains same as that of parent rock, if soil is formed as a result of physical weathering.

Chemical Weathering: Fragmented rock materials obtained by physical weathering sometimes changes their mineral composition and new compounds are formed. This phenomenon is referred as 'Chemical Weathering'.

Chemical weathering is caused mainly by oxidation, hydration, carbonation, leaching water and organic acids.

Generally, clays and to some extent silts fall in this category.

1.6.2 Transportation and Deposition

The fragmented rock material obtained by weathering are transported by agents like running water (i.e. rivers), moving ice (i.e. glaciers) and blowing wind to new locations. The weathered fragmented materials transported and deposited at some other place are called 'Transported soil'.

On the basis of transporting agency, soil may be classified as:

Water transported soil: These sedimentary deposits are of three types

(i) Alluvial deposit
(ii) Lacustrine deposit
(iii) Marine deposit

(i) **Alluvial deposit (Alternate Layer of Sand + Silt + Clay):** Swift running water carry a large quantity of soil either in suspension or by rolling and sliding along the bottom of stream. When decrease in water velocity occurs, these sediments get deposited from suspension in running water. This type of soil is called 'Alluvial soil'.

Some of the examples of alluvial soil deposit are Alluvial cones, Natural levees and Delta.

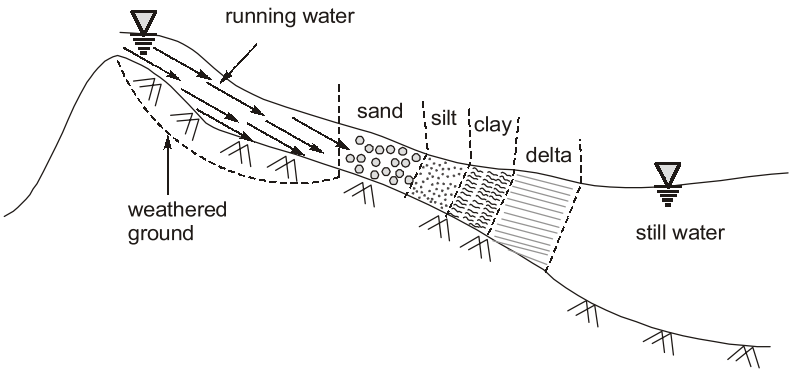

***Fig. 1.3** Alluvial deposit*

(ii) **Lacustrine deposit:** Soil carried by river, while entering a lake, deposits all the coarse particles because of a sudden decrease in velocity but the fine grained particles moves to the centre of the lake and settles when the water becomes still. Alternate layers are formed with season, and such lake deposits are called 'Lacustrine deposit'.

(iii) **Marine Soil:** These are soils that have been formed by sedimentation of soil particles in the deep sea water. The marine deposits have very low shearing strength and are highly compressible. They contain a large amount of organic matter. The marine clays are soft and highly plastic.

Wind Transported Soil: Like water, wind can erode, transport and deposit fine grain soils. The soils that have been transported and deposited by wind are called 'Aeolian deposits'. Dunes are formed due to accumulation of such wind deposited sand.

Loess: Loess is a silt deposit made by wind. These deposits have low density, slight cementation, high compressibility and poor bearing capacity when wet. The cementing is due to the presence of deposits of calcium carbonate, derived from decayed vegetable matter. When partially saturated, loess undergoes reduction in volume. This phenomenon, which occurs with increase in moisture content, without any charge in applied stress is termed as collapse compression, due to collapse of soil structure. Soils having susceptibility to collapse are called collapsible soils or metastable soils.

Glacial Deposits: Glaciers are large masses of ice formed by the compaction of snow. A glacier moves extremely slow but deforms and scour the surface and the bedrock over which it passes. Melting of a glacier cause deposition of all the materials and such a deposit is referred to as till. Drift is general term used for the deposits made by glaciers directly or indirectly.

The particles found in glacial deposits are generally angular, in contrast to the more rounded particles associated with typical waterborne deposits.

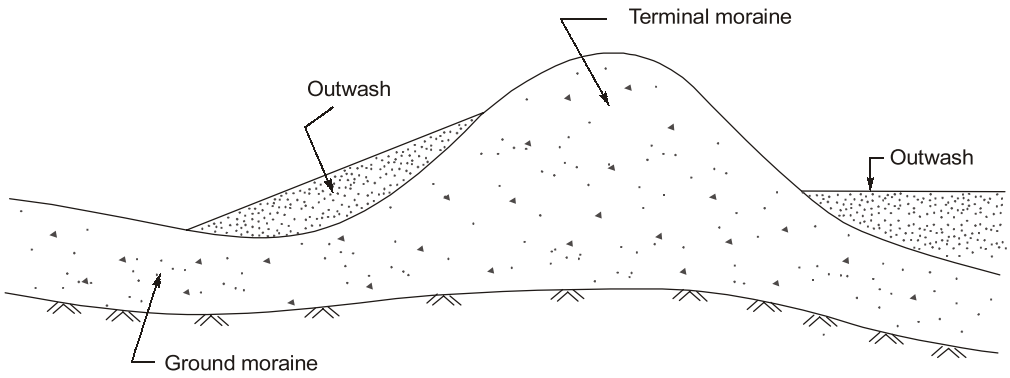

Fig. 1.4 *Glacier Deposited Soil*

Gravity Deposits: Gravity can transport materials for short distance. Gravity deposits are termed as colluvial soil or talus. These soils are found in mountain valley and formed by gravity force. On sloppy mountain due to moisture variation sediments start creeping down. Also due to swelling and shrinkage land slide may occur which may result into deposits in the valley. These soil consists of irregular particles of varying size.

Swamp and Marsh Deposits: In water stagnated areas where the water table is fluctuating and vegetational growth is possible, swamp and marsh deposits develop. These soils are soft, high in organic content and unpleasant in odour. Accumulation of partially or fully decomposed aquatic plants in swamps or marshes is termed 'muck or peat'. Muck soil is light in weight, highly compressible so this is not suitable for construction purpose.

1.7 Soil Deposits in India

India has been divided into five major soil groups

- Alluvial deposits
- Laterite soil
- Marine Deposits
- Black cotton soil
- Desert soil

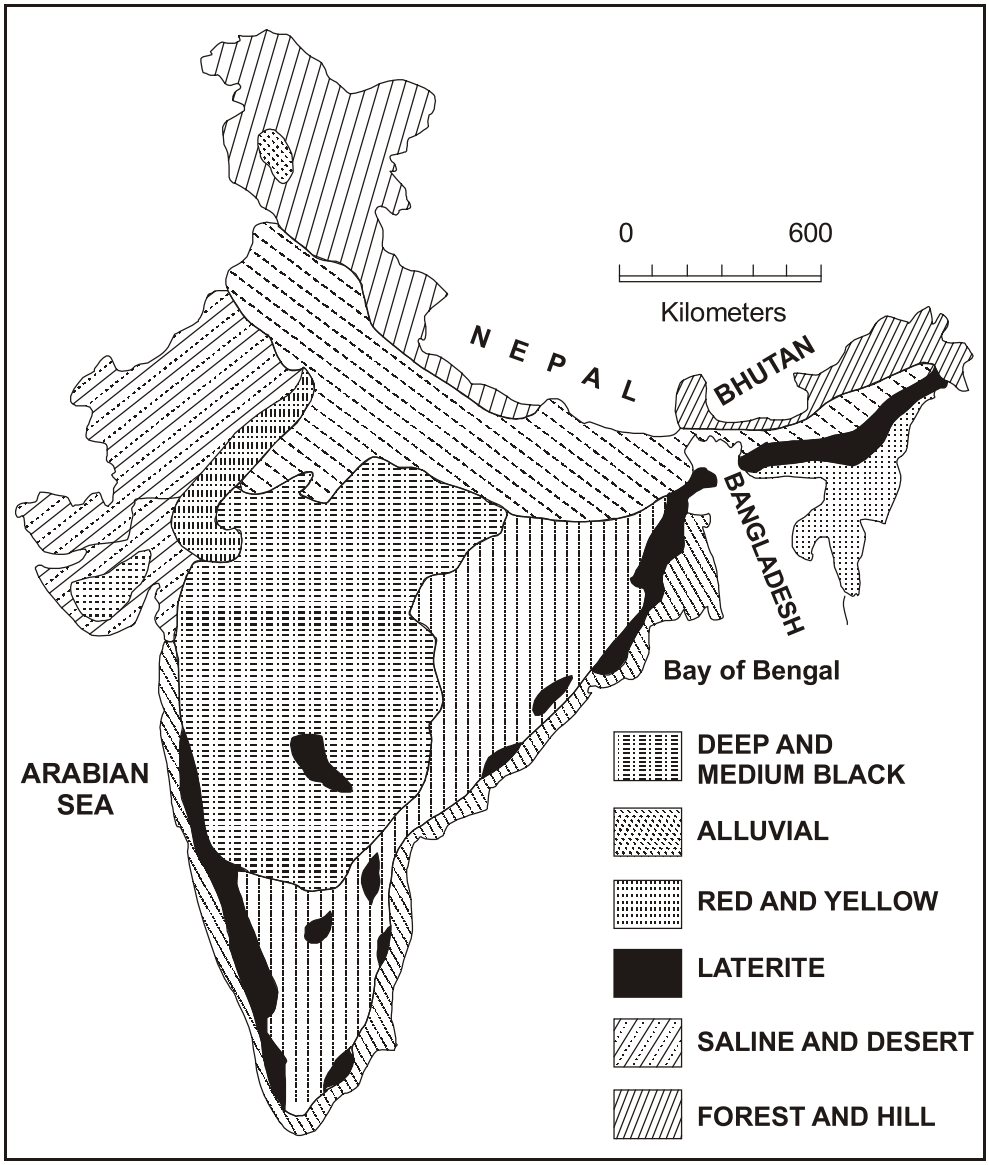

Fig. 1.5 *Soil map of India*

1.8 Organic and Inorganic Soils

Soils can also be classified as organic or inorganic soil.

- Organic soil are formed by growth and subsequent decomposition of plant. For example peat and mosses.
- In general, organic soil is that transported soil obtained from rock weathering which contains decomposed vegetable matter.
- Inorganic soils referred to ordinary soil obtain from rock disintegration due to weathering.

1.9 Common Types of Soils

- **Loess:** These are wind blown uniformly graded fine soil. Loess is formed in arid and semi-arid regions. Its colour is yellowish brown and deposits of this soil are found in Rajasthan and North Gujarat.

- **Caliche:** It is cemented soil rich in calcium carbonate consisting of gravel, sand and clays. These are also wind blown in semi-arid climate and later on cemented by the calcium carbonate left out from the evaporation of capillary water.
- **Loam:** It is a mixture of sand, silt and clay in definite proportion which in some cases may consist of organic matter.
- **Cumulose:** Peaty (organic) soils are also called cumulose soil or muck. These are formed due to accumulation of organic content under waterlogged condition. It is generally found in the areas having deficient sewerage facilities or found after overflooding of the rivers.
- **Gumbo:** These are highly sticky, plastic and dark coloured soil.
- **Marl:** These are fine grained calcium carbonated soil of marine origin. These are formed due to decomposition of cell mass and bones of aquatic life.
- **Humus:** Humus is a mixture of mud and dead plants. The tiny pieces of rock and humus joint to make various soils.
- **Peat:** It is highly organic soil containing almost decomposed vegetable matter.
- **Gravel:** Gravel is a type of coarse grain soil having particle size in the range of 4.75 mm to 80 mm.
- **Sand:** They are cohesionless aggregates of rounded, sub angular or angular sediment in the range of 0.075 mm to 4.75 mm.
- **Silt:** It is a fine-grained soil, with particle size between 0.002 mm and 0.075 mm.
- **Clay:** It is an aggregate of mineral particles of microscopic and submicroscopic range. Clay may be organic or inorganic.
- **Cobbles:** Cobbles are large size particles in the range of 80 mm to 300 mm.
- **Boulders:** Boulders are rock fragment of large size (more than 300 mm).
- **Tuff:** These are small grained slightly cemented volcanic ash that has been transported by wind or water.
- **Bentonite:** It is a clay formed by chemical weathering of volcanic ash which have high content of montmorillonite. Pulverized slurry of bentonite is highly plastic and is often used as a lubricant in drilling.
- **Kaolin (China Clay):** It is very pure form of white clay, which is extensively used in ceramic industry.
- **Hardpans:** Hardpans are types of soils that offer great resistance to the penetration of drilling tools during soil exploration. These are generally dense, well graded, cohesive aggregates of mineral particles.
- **Varved Clays:** These are sedimentary deposits consisting of alternate thin layer of silt and clay. These clays are the result of deposition in lakes during periods of alternate high and low waters.
- **Till:** It is formed by glaciers and iceberg and may contain mixture of gravel, sand, silt and clay. These soils are well graded.

Summary

- Soil is an unconsolidated material which consists of sediments derived from rocks.
- The soil formation process is cyclic, which is called 'Geological Cycle'.
- The process of soil formation is called 'Pedogenesis'.
- If weathered sediments remain over parent rock, then soil is called 'residual soil'.
- Weathered sediments transferred and deposited at other place are called transported soil.
- Major soil deposits of India are alluvial deposits, black cotton soil, laterite and lateritic soil, desert soil and marine deposits.

Objective Brain Teasers

Q.1 Glaciers are formed by
(a) Compaction and recrystallization of snow
(b) Continuous freezing of water
(c) A sudden drop in temperature below 0°C
(d) None of above process

Q.2 When the product of rock weathering are not transported as sediment but remain in place, then the soil is known as
(a) Alluvial soil (b) Glacial soil
(c) Residual soil (d) Aeolian soil

Q.3 Identify the true statements from the following
(a) A soil transported by gravitational force is called talus
(b) Lateritic soil is a category of organic soil
(c) Water held firmly to the clay particles has the same properties as ordinary water.
(d) A clay deposit which exibits no evidence of fissuring is described as intact.

Q.4 Bentonite is a material obtained due to the weathering of
(a) Lime stone (b) Quartzite
(c) Volcanic ash (d) Shales

Q.5 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I	List-II
A. Wind	1. Lacustrine
B. Lake	2. Loess
C. Gravity	3. Till
D. Glacier	4. Talus

Codes:

	1	2	3	4
(a)	A	C	B	D
(b)	B	A	D	C
(c)	C	A	C	D
(d)	D	B	A	C

Q.6 Match **List-I** (Type of soil) with **List-II** (Mode of transportation and deposition) and select the correct answer using the codes given below the lists:

List-I
A. Residual soil
B. Loess
C. Peat
D. Varved clays

List-II
1. Soil transported by wind
2. Organic soil
3. Deposition in lake during periods of alternate high and low waters
4. Soil left in place after weathering of parent rock

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	2	3	4	1
(c)	4	1	2	3
(d)	3	2	1	4

Q.7 Which of the following type of soil is transported by gravitational force?
(a) Loess (b) Talus
(c) Drift (d) Dune Sand

Q.8 Lacustrine soil are soils
(a) transported by rivers and streams
(b) transported by glaciers
(c) deposits in sea beds
(d) deposited in lake beds

Q.9 Which one of the following soils is the Aeolian?
(a) Volcanic soil
(b) Residual soil
(c) Weathered soil
(d) Transported soil

Q.10 **Assertion (A):** Black cotton soils are clay and exhibit characteristic property of swelling.
Reason (R): These clays contain Montmorillonite which attracts external water into its lattice structure.
Codes:
(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true but R is not the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Answers				
1. (a)	2. (c)	3. (a)	4. (c)	5. (b)
6. (c)	7. (b)	8. (d)	9. (d)	10. (a)

Hints and Explanations:

Ans.7 (b)

Soil carried and deposited by river water are alluvial soils. Deposits made in lakes are lacustrine deposits. Wind transported soils are aeoline deposits. Drifts are made by glaciers. Deposits directly made by melting of glaciers are called till. Talus are colluvial soil deposits, transported by gravity.

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