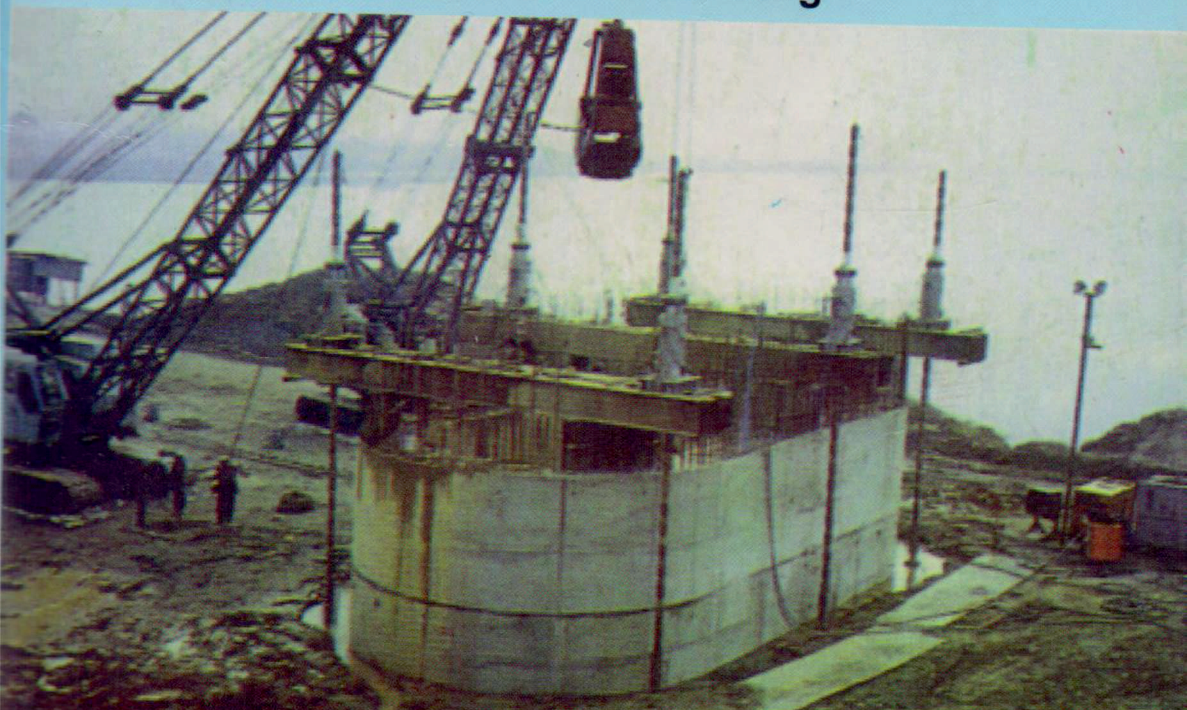
GEOTECH ENGINEERING

Soil Mechanics and Foundation Engineering

(In S.I. Units)

Santosh Kumar Garg



KH1283919
Khanna Publishers

KHANNA PUBLISHERS
Investing in Learning

GEOTECH ENGINEERING

SOIL MECHANICS AND FOUNDATION ENGINEERING

For

[Civil Engineering Degree Students ; AMIE (Section B) Exams ; GATE Exams ; U.P.S.C. and Other State Service Competitions ; and for Professional Field Engineers.]

(Containing Solved Questions of Civil Services, Engineering Services, and Gate Exams.)

By

Santosh Kumar Garg

B.Sc. Engg. (Civil)
First Class First (Delhi University)
Life Member—Indian Water Resources Society

FORMERLY

Superintending Engineer
Flood Control and Irrigation Department,
Govt. of NCT of Delhi

(Thirteenth Revised Edition)

KHANNA PUBLISHERS®
Investing in Learning®
Operational Office :
4575/15, Onkar House, Opp. Happy School,
Ground Floor, Daryaganj, New Delhi 110 002
Phones : 011-45033819 • *Mob.* 09811541460
email : contactus@khannapublishers.in

Published by :

Romesh Chander Khanna & Vineet Khanna
for **KHANNA PUBLISHERS**
2-B, Nath Market, Nai Sarak
Delhi- 110 006 (India)

Visit us at : www.khannapublishers.in

© 1987 and onward

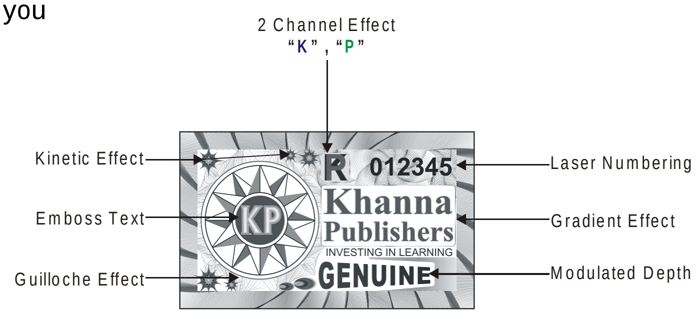
This book or part thereof cannot be translated or reproduced in any form without the written permission of the Author and the Publishers. The right to translation, is however, reserved with the author alone.

Copyright : Author and Publishers Jointly.

Hologram & Description

To all readers of our books: In order to prevent yourself from being defrauded by pirated books, please make sure that there exists a Hologram on the top cover of the book with the specifications indicated below. If you find any book without Hologram of this description, please do not buy that pirated copy, and inform us through e-mail at *contactus@khannapublishers.in*

Thanking you



ISBN No. 978-81-7409-275-5

First Edition : 1987
Thirteenth Revised Edition : March 2020

PREFACE

SECOND EDITION

This brand new 2nd edition has not only been enormously revised but has been enlarged to virtually double of the size of its first edition. The previous edition, infact, did contain only the principles of "Soil Mechanics", but did not contain much on the "Foundation" side, and that is why the book was titled as "Soil Mechanics", in its first edition.

The present edition, however contains full detailed descriptions of the foundations, in so far as they are designed w.r. to the load carrying capacities of the soils, on which the structures are to be rested and founded. The bearing capacity of *Shallow foundations, pile foundations*, as well as *well foundations*, have now been described in sufficient details in separate chapters. One full chapter has also been added on the principles dealing with the **foundations of the machines**, which vibrate and produce dynamic forces in addition to the static loads. The name of the book has accordingly been modified as "*Soil Mechanics and Foundation Engineering*".

The chapter on "*Pavements*" has been enlarged and revised to include detailed *designs of flexible as well as rigid pavements*. Not only this, the entire text has been thoroughly and enormously revised, and explanations at several places rewritten, to make this tough subject, look much simpler to the average students.

Additionally, the MKS Units adopted in the previous edition have been changed to **S.I. Units**, because the questions in the GATE as well as in the Civil Services Examinations in this subject, are mostly being set in the S.I. Units these days. The numerical questions, in the Engineering Services Exams, however, are still being set in the MKS as well as in the S.I. Units. Efforts have therefore been made to keep the solutions of their previous years problems in the MKS system itself, as to keep the students well conversant with both the systems of units.

About 400 **Chapterwise Multichoice Objective Questions** have been given in a separate chapter, from various competitive, Universities, and AMIE Exams. The **objective questions of the Engineering Services Competitions** from the year 1993 to 1997 have been given in a separate chapter. Similarly, the **Objective Questions of the Gate Exams** are given in another chapter. All these objective questions have been supported with **Answers** and **Hints** required for solving difficult *starred questions*. No other book except this one, provides Hints for solving objective questions.

The **numerical and other conventional questions of the Civil Services as well as of the Engineering Services Competitions** have been given and solved in a separate chapter. Similarly, the conventional **numerical questions of the GATE Exams** for the last 7 years have been fully solved in another chapter.

All out efforts have been made by the author to lift the standard of the book at par with his other popular titles like "*Irrigation Engg. and Hydraulic Structures*" and "*Environmental Engineering (Vol. I and II)*". It is expected that this title will receive an equally enthusiastic response from the student and the teaching community, as has been received by the other titles of this author. *The author assures his readers that they will certainly not be loosers in purchasing this publication, and they will certainly gain enormously in knowledge, concepts, and in their University as well as Competitive Exams.*

The author will like to thank all those who have helped in the publication of this title. *Mr. Vineet Khanna* of Khanna Publishers and *Mr. Harish* (an employee of Khanna Publishers) merits mention of their names at the top, since they have largely encouraged the author to revise this publication. My wife, *Mrs. Rajeshwari Garg*, also deserves mention, for her tolerance, help and encouragement. My elder son, *Neeraj Garg*, has also been helpful in this publication to some extent. The author invites comments, observations, and suggestions from the students, teachers, and other professional engineers, for further improvement of this publication.

June 1, 1998

THIRTEENTH REVISED EDITION

In this 13th adition the book has further been revised; and corrections & changes have been affected at various places, particularly in the chapter No. 14 on "Stability Analysis of Earthen Slopes". Besides, Typographical errors of the previous edition at certain places have been removed. The chapter on *Rigid and Flexible Pavement* has been removed, since this topic is now-a-days not included in "Soil Mechanics & Foundation Engg.", but is included in "Transportation Engineering". This has helped in reducing the thickness of the book to some extent.

The question banks of the Engineering Services as well as those of Civil Services Exams have also been updated. The present edition will certainly prove to be more useful to the students in clearing these competitions, since the subject of Soil Mechanics gets a larger weightage in these competitions.

The author will entertain further suggestions and comments on this edition for making further improvements in its future editions.

December, 01, 2019

Santosh Kr Garg
Res. : 3A/2 WEA, Sat Nagar
KAROL BAGH,
New Delhi-110005
Mobile for sms : (+91) 9873067343

Contents

—1

Introduction to the Subject

1.1. Soils and Soil Mechanics—Defined

In civil engineering literature, a **soil** or a **soil deposit** may be defined as an uncemented or weakly cemented accumulation of mineral particles, which are formed by the weathering (disintegration) of rocks. The void space between these particles contains water and/or air. Weak cementation of the soil particles may either be caused by the carbonates and oxides precipitated between the particles, or by the organic matter. If the products of weathering remain at their original location, they constitute a *residual soil*. If, however, the products are transported and deposited in a different location, they constitute a *transported soil*. The various agents of transportation being gravity, wind, water, and glaciers. During transportation, the size and shape of the particles may undergo vast changes, and the particles may be sorted out into various size ranges. Depending upon such particle size ranges, the soils may be classified as boulders, gravels, sands, silts, clays, etc. ; in the decreasing order of size range.

The study of the engineering behaviour of the different types of soils, is extremely important to civil engineers, because every engineering structure such as a building, a road, a bridge, a monument, etc. will have to be rested and founded on the ground *i.e.* on some kind of soil deposit. The sub-structure or the foundation portion of every such engineering structure will have to be taken below the ground and rested on the foundation soil, in such a manner that the structure does not get settled or tilted, or damaged due to some kind of failure of the foundation soil. The strength of the soil to withstand loads, under different site conditions, therefore, becomes an important factor, in designing safe foundation for the structure.

The study of the soils is not only required for the design of safe foundations as stated above, but is also required for using the soils as building material, such as for construction of earthen dams and dykes, etc.

The science which deals with the study of the engineering properties and behaviour of the soils, is known as the 'Soil Engineering', or the 'Soil Mechanics', or the 'Geotech Engineering'.

1.2. History of Development of the Subject of Soil-Mechanics

The systematic, rational and scientific study of the soils is comparatively of recent origin, say about the year 1925 or so. It was **Mr. Karl Terzaghi**, who spent about 50 years (1913-1963) in doing pioneering research on soils and bringing out his first book titled *Erdbaumechanik* (means Soil Mechanics) in 1925. This was the first attempt in the world to treat soil mechanics on the basis of the physical properties of the soils, since prior to this, all the designs were used to be based on intuition, experience and empirical formulas, which never provided full confidence about the safety and economy of the design. No wonder then, Mr. Karl Terzaghi, is known as the father of the Soil Mechanics.

Although of course, the foundations for the engineering structures in the past, were not designed on such scientific study of the properties of the soils, yet the fact remains that some excellent foundations were provided to various notable structures, since the ancient times.

Say for example, the greatest structure, which was built in the ancient times, was the famous **hanging gardens,** built in Babylon (Iraq) by the famous King *Nebuchadnezzar II*, in the 6th century B.C. The big retaining walls constructed to support the terraces of this garden must have required knowledge of the earth pressure, even though such a knowledge must have only remained empirical, based on common sense and experience.

The Romans also built notable engineering structures, such as harbours, break waters, aqueducts, bridges, large public buildings, and a vast network of durable and excellent roads. It appears that Roman engineers, such as *Vitruvious*, had acquired a large scale knowledge on the behaviour of the different kinds of soils. His famous work titled *'Ten Books on Architecture',* written sometimes in the first century B.C., is said to have discussed the stability of the buildings, the swelling characteristics of the soils, the use of closely driven piles in loose or marshy lands, etc., which amply exhibit the understanding of the ancient man about the soils and foundations. In India also, several books were written, to lay down rules for construction and one of them titled *"Silpa Sastra"*, written sometimes in the sixth or the seventh century, is said to have become very popular. *Mansar* also wrote a popular book, which is said to have recommended compaction of the soils by cows and oxen, and dewatering of the foundations.

Many structures were again built during the medieval period (about 400 to 1400 AD), and many of them faced problems of compression of soils, and subsequent settlement of buildings, several heavy structures like cathedrals had to face large scale settlements. The famous *Leaning Tower of Pisa*, In Italy, constructed during 1174 to 1350 AD, provides an ample testimony of the insufficient knowledge of the compressible soils, as this famous 179 ft high tower has largely tilted on one side, making its top out of plumb, by as much as 17 ft (Pl. see Fig. 1.1).

Another case of successful foundations related to the famous *Taj Mahal of India* at Agra city which was constructed by the Mughal emperor *Shahjahan* in the 17th century A.D. Because of its proximity to river Yamuna, unique foundation design was adopted in supporting the terrace, the minarets and the mausoleum building on one firm compact bed of masonry supported on masonry cylindrical wells sunk at close intervals.

The first major contribution to the scientific study of the behaviour of the soil deposits was made at the end of the 18th century, when **Coulomb** (1776), a Frenchman, Published his wedge theory of lateral earth pressure. He was the first person to introduce the concept of shearing resistance of soil, consisting of two components, *i.e.* the *cohesion* and the *friction*. The Coulomb's theory of lateral earth pressure was subsequently extended by investigators like

Fig. 1.1. The Leaning Tower of Pisa, Italy.
The tilting is partly the result of subsidence due to removal of ground water.

Poncelet (1788-1867), *K. Kulmann* (1866), *Rebhann* (1871) and *Weyrauch* (1878) to work out graphical solutions for computations of active and passive earth pressures. The important **Darcy's law** relating to the flow of water through the soils, and the **Stoke's law** for the settlement of the solid particles in a liquid, were enunciated in the year 1856. These laws play very important roles even today, in soil engineering. It was **Rankine**, who in 1857, presented his simple theory of active and passive earth pressures, and of the safe bearing capacity of the foundations. He, at that time, did not accounted cohesion of the clay soils in his calculations, although he knew its existence. In 1871, **O. Mohr** produced a graphical representation of stress at a point in a soil mass, by the popular *Mohr's stress circle*. Such Mohr's stress circles are now vastly used in Soil Mechanics, in analysing the shear strength of soils. A little later, in the year 1885, another investigator—**Mr. Boussinesq**, produced analysis of stress distribution in a semi-infinite elastic medium under vertical surface loads, which again constitute, a major contribution, as it helps in computing stresses in soils, due to loadings.

It was only at the beginning of the 20th century, however, that the basic physical properties of the clay soils in general, were understood, when **Mr. Alterberg**, a Swedish soil scientist, brought out in 1911, the soil properties like liquid limit, plastic limit, plasticity index, etc., which may cause a clayey soil to exist in different stages of consistency, depending upon its water content. To measure the shear strength of sands (cohesionless soils), shear box was first developed in France in 1885 by *Leygue*, and later improved by *Krey* (1918) in Germany.

The Rankine's theory of lateral earth pressures was also extended by *Terzaghi* and *Casagrande* in USA (1910) and by *Bell* (1915), to include soils having both cohesion and friction. *Bell* also suggested a method of calculating the bearing capacity of cohesive soils. Theories were also developed for stability analysis of soil mass piled up in an embankment by *Petterson* and *Hultin* (1916), and later by *Fellenius* (1926). **Fellenius** method, known as *Swedish method of slope analysis*, is still used these days in Soil Mechanics. In 1920, L. Prandtl, enunciated his theory of plastic equilibrium, which forms the backbone of various bearing capacity theories developed later. In 1923, Dr. Terzaghi published his most important *theory of consolidation*. He also enunciated the science of Soil Mechanics, through his book *Erdbaumechanik* published in 1925.

In 1930, **Proctor** brought out the principles of *Soil compaction*. In 1922-23, *Pavlovsky* of Russia solved the complex problems of seepage below the hydraulic structures, and enunciated the electrical analogy method for seepage computations. His work, which was in Russian language, however, remained hidden, till *Weaver* (1934) and *Mr. Khosla* (1936) solved some of the seepage problems in English literature. During the second world war (1939-45) and subsequent to that, large scale efforts have been made by various scientists and engineers of the world to develop the science of soil-engineering ; and today, this science is a fully recognised and well established branch of engineering, and can help to rationally and optimally design the foundations and earthen embankments, with full confidence.

We, through this book, only intend to explain the theories and concepts worked out by all these great pioneers and soil scientists, in a common man's language, so as to make them easily understandable for their better and better utilisation in our practical life.

—2

Soils, Their Origin, Formation and Types

2.1. Definition of Soil

Soils are the earthy materials (weathered rocks), *inorganic* (such as sand, clay, silt etc.) or *organic* (such as peat), in nature. A *soil is thus a natural aggregate of mineral grains, which are separable by gentle mechanical means* ; and is thus distinguishable from a rock, which is a natural aggregate of minerals connected by strong and permanent cohesive forces.

Table 2.1 stipulates the specific gravities of the most important minerals, which are generally found available in different types of soils. Table 2.2, at the same-time, indicates the specific gravities of the common soils.

Table 2.1. Sp. Gravities of Important Mineral Constituents of Soils

S. No.	*Mineral name*	*Sp. Gravity*	*S. No.*	*Mineral name*	*Sp. Gravity*
1.	Hematite	4.9 to 5.3	16.	Pyrophyllite	2.84
2.	Magnetite	5.17	17.	Illite	2.84
3.	Hematite hydrous	4.30	18.	Montmorillonite	2.74
4.	Siderite	3.83 to 3.88	19.	Calcite	2.72 to 2.90
5.	Limonite	3.8	20.	Talc	2.70 to 2.90
6.	Hornblende	3.2 to 3.5	21.	Serpentine	2.20 to 2.70
7.	Olivene	3.27 to 3.37	22.	Na-Ca-Felspars	2.62 to 2.76
8.	Augite	3.2 to 3.4	23.	K-Felspars	2.54 to 2.57
9.	Anhydrite	3.00	24.	Quartz	2.65
10.	Biotite	2.8 to 3.2	25.	Kaolinite	2.61
11.	Micas	2.7 to 3.1	26.	Gibbsite	2.30 to 2.40
12.	Muscovite	2.7 to 3.1	27.	Halloysite	2.55
13.	Aragonite	2.94	28.	Gypsum	2.32
14.	Chlorite	2.6 to 2.9	29.	Attapulgite	2.30
15.	Dolomite	2.85 to 2.87	30.	Bentonite	2.13 to 2.18

Table 2.2. Specific Gravities of Important Soils

S. No.	*Soil type—name*	*Sp. Gravity*	*S. No*	*Soil type—name*	*Sp. Gravity*
1.	Clay	2.44—2.92	9.	Silt with organic admixture	2.40—2.50
2.	Chalk	2.63—2.81			
3.	Loess	2.65—2.75	10.	Bentonite clay	2.34
4.	Silt	2.68—2.72	11.	Peat	1.26—1.80
5.	Lime	2.70	12.	Humus	1.37
6.	Quartz and Sand	2.64—2.65	13.	Peat, sphagnuna 25% decomposed	0.50—0.80
7.	Quartzite	2.65			
8.	Kaolin	2.47—2.58			

2.2. Origin and Formation of Soils

Soils are formed by the disintegration (technically called *weathering*), of rocks. The disintegrated or weathered material may either be found deposited at its own place of origin, or may get transported by agents like water, wind, ice, etc., before deposition. In the first case, the resultant soil is called a **residual soil ;** and in the second case, it is called a **transported soil.** Moreover depending upon whether the sediments are transported by *water, ice,* or *wind*, the soils are called as *alluvial, glacial*, or *aeolin*, respectively.

The three stages involved above, in the formation of transported soils, can thus be described as follows :

(*i*) *weathering* ;

(*ii*) *transportation* ; and

(*iii*) *deposition of weathered materials*.

These three stages are briefly discussed below :

(*i*) **Weathering.** *Mechanical weathering* disintegrates a pre-existing rock into smaller fragments ; and *chemical weathering* acting on these small fragments, rearranges the elements into new minerals, and thus *decomposes* them.

Mechanical weathering or *erosion* is done mainly by the forces produced by various agencies, like atmospheric gases, temperature changes, running water, expansion due to freezing of water, etc. ; and to a lesser extent by such things as forces of growing roots, burrowing animals, lightening, and work of man. The products of mechanical weathering include everything from huge boulders found beneath the cliffs to the smallest silt particles.

These fragmented rock materials, produced by mechanical weathering may change their mineral composition by **chemical weathering**. In general, the rate of chemical weathering depends on temperature, the surface area, and the amount of water. Except in cold or very dry climates, the chemical weathering keeps pace with the mechanical weathering, and the two can be separated only in theoretical concept. Mechanical weathering provides the large surface area necessary for chemical activity to take place near the surface of the fragmented rock. [Fig. 2.1 shows how mechanical weathering increases the surface area, and thus helps to increase the chemical weathering.

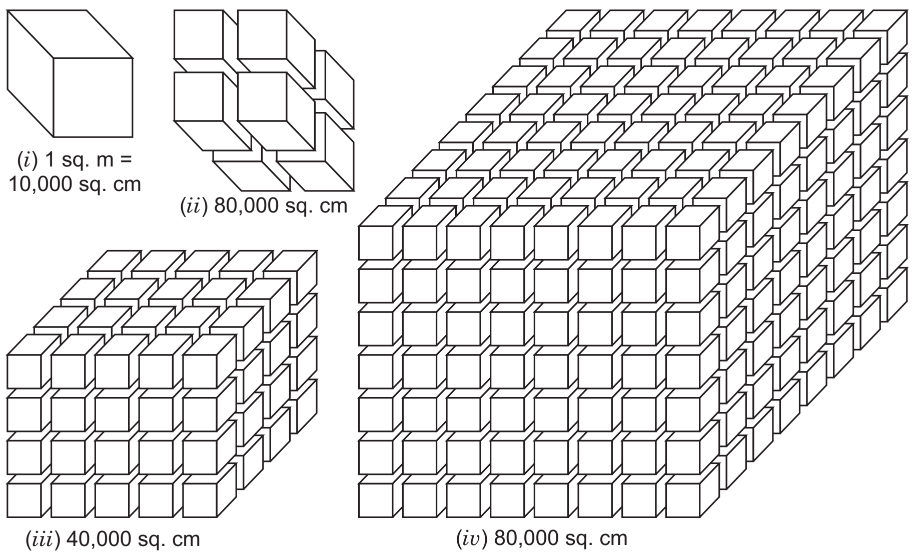


Fig. 2.1

The main reactions involved in the process of chemical weathering can, infact, be divided into : *Oxidation ; hydrolysis* ; and *carbonation*. **Oxidation** is the reaction with atmospheric oxygen to form an oxide ; **hydrolysis** is the reaction with water ; and **carbonation** is the reaction with atmospheric carbon dioxide to form a carbonate. The carbonation reaction begins with the uniting of carbon dioxide and water to form carbonic acid ; *i.e.*

$$CO_2 + H_2O \longrightarrow H_2CO_3 \text{ (Carbonic acid)}$$

The carbonic acid plays an important role in many weathering reactions, which ultimately result in the production of new minerals. In all these reactions, substances are added, so that the total volume gets increased. The details as to how exactly these reactions take place are, at present, not well understood and are an important area of current research in 'soil science'.

It can, however, be stated that these reactions take place slowly, and are probably influenced by the composition of the water films that surround the particles, and by the organic material present (particularly the acids). Another process through which chemical weathering may occur is **leaching,** under which the water-soluble material is removed by water. Limestones, Rock Salt, and Rock Gypsum, are largely weathered by water. The leaching and consequent washing away of limestones will be more rapid, if carbon dioxide is also present in water. An interesting discovery that has been made in this field is that if these reactions are able to continue to completion (*i.e.* erosion does not remove the immature soil), *the type of soil produced is determined more by the composition of the parent rock*.

(*ii*) **Transportation.** The products of rock weathering are generally transported in large amounts by the running waters (*i.e. rivers*), moving ice (*i.e. glaciers*), and blowing *winds*. Out of these three transporting agents, running water, *i.e.* the rivers, are the most important. The fragmented rock particles are carried by water in suspension, and the products which are dissolved by water are carried in solution. These agents of erosion and transportation, and the work done by each, has been discussed in details under chapter 4 of the book titled "Engineering and Physical Geology", written by the same author, and can be referred to in special needs.

The effects produced on the size and shape of the sediments, by the important transportation agents, are, however, summarised in Table 2.3.

Table 2.3. Effects of Transportation on Sediments

Property of sediments affected in transportation	*Effects produced by transporting agents*				
	Water	*Air*	*Ice*	*Gravity*	*Organisms*
SIZE	Reduction through solution, little abrasion in suspended load, some abrasion and impact in traction load	Considerable reduction	Considerable grinding and impact	Considerable impact	Minor abrasion effects from direct organic transportation

Contd...

SHAPE AND ROUND-NESS	Rounding of sand and gravel	High degree of rounding	Angular, solid particles	Angular, non-spherical	
SURFACE TEXTURE	*Sand :* smooth, polished, shiny *Slit* : little effect	Impact prod-uces frosted surfaces	Striated surfaces	Striated surfaces	
SORTING	Considerable sorting	Very consider-able sorting (progressive)	Very little sorting	No sorting	Limited sorting

(*iii*) **Deposition of weathered material.** The transportation of the weathered products continues as the velocity of the transporting medium remains unchecked. But when these products are brought at rest into big water bodies like oceans and lakes, their deposition will start. Of the weathered products carried in suspension, the coarser and heavier pieces will settle first, followed by lighter and finer particles. The weathered products carried in solution may precipitate out at a later stage, which may form a separate layer on deposition.

2.3. Types of Soils

As stated earlier, the soils, on the basis of their origin, may be broadly classified into two categories, *viz* :

(*A*) *Residual soils* ; and

(*B*) *Transported soils*, as defined below :

(*A*) **Residual Soil.** A soil that is formed by weathering of the parent rock and still occupies the position of the rock from which it has been formed, is called a residual soil. Residual soils are not as common as transported soils.

(*B*) **Transported Soil.** Any soil that has been transported from its place of origin by wind, water, ice or some other agency, and has been re-deposited, is called a transported soil. Transported soils, are classified according to the transporting agency and method of deposition, as follows :

(*a*) *Alluvial deposits* ; (*b*) *Lacustrine deposits* ;
(*c*) *Marine deposits* ; (*d*) *Aeolin deposits* ; and
(*e*) *Glacial deposits*.

The above types of soil deposits or soils are defined below :

(*a*) **Alluvial soils** are those soils that have been deposited from suspension in running water.

(*b*) **Lacustrine soils** are those soils that have been deposited from suspension in quiet fresh water lakes.

(*c*) **Marine soils** are those soils that have been deposited from suspension in sea water.

(*d*) **Aeolin soils** are those soils that have been transported by wind. Usually, fine sand deposited in dunes, or silt which forms Loess, fall in this category.

(*e*) **Glacial soils** are those that have been transported by ice.

2.3.1. Organic and Inorganic Soils. Soils in general can also be classified as *organic* or *inorganic*. Soils of organic origin are generally formed by growth and subsequent decay of plants, such as peat mosses. They may also be formed by the accumulation of fragments of the inorganic skeletons or shells of organisms. Hence, a soil of organic origin can be either organic or inorganic. The term organic soil ordinarily refers to a transported soil, consisting of the products of rock weathering with a more or less conspicuous admixture of decayed vegetable matter.

2.3.2. Certain Important Commonly Available Soils. Depending upon the weathered rocks and the different methods of transportation and deposition, different soils are formed. These soils have been differently named. Some of the important soils, so found in general practice, are summarised in Table 2.4.

Table 2.4. Commonly Found Soils

S. No.	*Name of soil*	*Definition*
(1)	*(2)*	*(3)*
(1)	*Sand and Gravel*	They are cohesionless aggregates of rounded sub-angular or angular fragments of almost unaltered rocks of minerals. Particles of size varying from 0.075 to 4.75 mm are termed as sand, and those with a size from 4.75 to 80 mm as gravel. Fragments with diameters more than 80 mm and less than 300 mm are known as **cobbles**.
(2)	*Inorganic Silt*	It is fine grained soil with little or no plasticity. The least plastic varieties generally consist of almost uniformly sized grains of quartz, and are sometimes called **rock flour.** On the other hand, the plastic types contain a considerable percentage of flake shaped particles and are referred to as **plastic silts**.
(3)	*Organic silt*	It is a fine grained, almost plastic soil with an admixture of finely divided particles of organic matter.
(4)	*Clay*	It is an aggregate of mineral particles of microscopic and sub-microscopic range. The soil may be organic or inorganic. Inorganic clays are generally more plastic than the *organic clays* ; whereas, the organic clays are more compressible because of the presence of finely divided organic matter.
(5)	*Bentonite*	It is a clay formed by the decomposition of volcanic ash with a high content of montmorillonite (a clay mineral). It exhibits the properties of clay to an extreme degree.
(6)	*Verved Clays*	They are alternative thin layers of silt and clay deposited in fresh water glacial lakes by outwash from glacials. The silt is deposited in warm weather of summer during heavy runoff, and clay is deposited during cool weather of autumn and spring during small runoff. Generally, one band of silt and clay is deposited each year. They possess the undesirable properties of both silt and clay.
(7)	*Kaolin (China clay)*	A very pure form of white clay used in ceramic industry.
(8)	*Calcareous Soil*	It is a soil containing calcium carbonate. Such a soil effervescences when tested with dilute hydrochloric acid.
(9)	*Loess*	It is a loose deposit of wind blown silt that has been weakly cemented with calcium carbonate and montmorillonite (clay min-

(1)	*(2)*	*(3)*
		eral). Loess is formed in arid and semi-arid regions where the dust deposited by wind is cemented by a small amount of calcium carbonate left by the evaporation of seepage water or by montmorillonite. This soil is characterised by very uniform grain size, and high void ratio. The size of particles vary between 0.01 to 0.05 mm. This soil can stand deep vertical cuts because of cementation between particles. It, however, erodes badly in flowing water because of its inappreciable cohesion and higher porosity. Roads in this soil will readily pulverise and become dusty, and constructions are prone to sudden collapse, when the Loess saturates. There are enough deposits of this soil in Rajasthan and North Gujarat. Its colour is yellowish brown.
(10)	*Modified Loess*	It is that Loess that has been made denser by the collapse of the loess structure from immersion in water or by decomposition.
(11)	*Adobe*	It is the wind blown clay similar to Loess, except with a different structure that is formed by deposition in shallow water.
(12)	*Caliche*	It is a soil (not calcareous silt stone) whose grains are rather strongly cemented with a fairly large amount of calcium carbonate. Caliche, like Loess, was probably deposited by wind in a semiarid climate, and later on cemented by the calcium carbonate left out from the evaporation of capillary water. It contains much more calcium carbonate as compared to Loess.
(13)	*Tuff*	It is a small grained slightly cemented volcanic ash, that has been transported by wind or water.
(14)	*Shale*	This is a material in the state of transition from clay to shale. Shale itself is sometimes considered a rock, but when it is exposed to the air or has a chance to take in water, it may rapidly decompose.
(15)	*Marl*	Very fine grained calcium carbonated soil of marine origin is known as Marl.
(16)	*Lake Marl or Boglime*	It is a white fine grained powdery calcareous deposit, precipitated by plants in ponds. It is commonly associated with beds of peat.
(17)	*Peat*	It is a highly organic soil, consisting almost entirely of vegetable matter in varying stages of decomposition. It is brown to black in colour, and possesses a strong organic odour. Peat in general, is highly compressible, and hence one should be cautious while using it for supporting foundations of structures.
(18)	*Muck*	It is a mixture of finely particled, inorganic soil and black decomposed organic matter. It is usually found accumulated under conditions of imperfect drainage—for example in swamps, or is deposited by overflowing rivers.
(19)	*Humus*	Humus is a mixture of mud and dead plants. The tiny pieces of rock and humus join together to make various soils.
(20)	*Loam*	It is a mixture of sand, silt and clay, sometimes containing some organic matter, such as humus.
(21)	*Gumbo*	Sticky, plastic dark coloured clay is called gumbo.

Soil Mechanics and Foundation Engineering

About the Book

This is comparatively a new book from our popular Author, who has turned the difficult subject of *Geotech. Engineering* into a simple one, by adopting his unmatchable skills and lucid language, as is the case with his other publications, titled **"Water Resources Engineering Vol. I & Vol. II"** as well as **"The Environmental Engineering Vol. I & Vol. II"**.

This book provides detailed description of the various properties and analysis of the behaviours of different types of Soils and Soil deposits, over which are rested the foundations of the different types of structures, like buildings, bridges, roads, machines, etc.

The design of the different types of foundations to be adopted to suit particular soil deposit and the proposed structure, without causing excess differential or total settlement or any other failure of the underneath soil, to ensure the safety of the structure, has been explained in this volume in a simple language. The design of stable shapes of earthen embankments has also been exhaustively covered. The *soil reinforcements* and **geotextiles,** being used in modern days, have also been described in details with practical examples. The **expansive and collapsible soils** have also been described giving details of special precautions required to be taken in proving structures on such soil deposits.

The text matter is further supported by more than **700 Objective Questions,** including those from the Engineering Services, Civil Services (IAS), AMIE, and GATE Exams., giving **Hints** for solving difficult questions. **The numerical questions of the past more than 15 years** from these Competitive Examinations have also been solved, making the book highly useful for the Degree level engineering courses as well as for the Competitive Examinations.

About the Author

The Author, **Santosh Kumar Garg**, retired as Superintending Engineer from the Irrigation & Flood Control Deptt. of the Govt. of Delhi, obtained his basic degree in civil engineering from the University of Delhi in 1969, securing a **First Rank at the University** with **Record breaking percentage of marks**, getting ***Certificates of merit in seven subjects***. He since remained closely associated with the planning, design and maintenance of several water resources and drainage projects of the Delhi Govt., including the preparation of the Master Plan of Drainage.

Shr. Garg, in fact, is a veteran in the field of Civil and Environmental Engineering, and has eight widely acclaimed books to his credit. His book on *Water Resources Engineering (Vols. I & II)*, and *Environmental Engineering (Vols. I & II)*, are being followed in almost all the engineering colleges in India, including the prestigious IITs and NITs, and also in certain Asian and African Countries. His three other publications titled, *Soil Mechanics and Foundation Engineering, Physical and Engineering Geology*, and *Ecology & Environmental Studies*, have also gained a lot of popularity with the students and teachers alike.

KHANNA PUBLISHERS®
ISO 9001:2015
4575/15, Onkar House, Opp. Happy School,
Ground Floor, Daryaganj, New Delhi-110002
Phones: 011-45033819, 9811541460
E-mail: contactus@khannapublishers.in

Website:
www.khannapublishers.in

9788174092755

"image: Freepik.com". This cover has been designed using assets from Freepik.com