

Soil Characteristics

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Course Description

This is a 4-hour continued education course on Soil Characteristics. This course outlines soil formation and characterization. Soil is commonly used in engineering and construction projects. It is important to learn about its properties and characteristics, so it can be utilized effectively. Understanding the behavior of soil under different conditions, its composition, and its response to external forces is essential for engineers and construction professionals to make informed decisions and ensure the stability and longevity of structures.

Course Objectives

- Classify rocks as igneous, sedimentary, or metamorphic
- Outline the process of soil formation
- Differentiate between the types of soil
- Identify the particles found in soils, based on their size
- Explain the composition of clay minerals
- Characterize the groups of clay minerals
- Examine the relationship between clay particles and water
- Describe the properties of soil

Introduction

The meaning of the word 'soil' differs depending on the profession. For instance, to an agriculturist, soil refers to the top layer of earth that contains organic forces and supports plant life. On the other hand, to a geologist, soil is the material found within the top thin zone where roots occur. To a pedologist, soil is a substance that exists on the surface to support plant life. From an engineer's perspective, soil encompasses all organic and inorganic earth materials within the zone above the rock crust.

The properties of the soil materials on which a structure rests determine its behavior. These properties are dependent on the properties of the rocks from which the soil materials are derived.

Soil Mechanics

Soil Mechanics is a specialized field within Civil Engineering that studies soil, how it behaves, and its use as a construction material. Soil is made up of solid particles, air, and water, and its unique properties affect how it responds to mechanical and hydraulic forces. Engineers focus on the mechanical properties of soil, such as how easily it allows water to pass through it (permeability), how much it can be compressed without losing its shape (stiffness), and how much force it can withstand before breaking apart (strength). These properties depend on the type of soil, the amount of water it contains, and the amount of pressure it is under.

Properties of Soil

Soil has the following properties:

- **Adhesion:** The attraction of substances of unlike characteristics.
- **Cohesion:** The attraction of substances of like characteristics.
- **Capillarity:** The ability of soil to transmit moisture in all directions, no matter the gravitational force. It depends on the pressure which forces water into the soil, which increases as the size of the soil particles decreases.
- **Permeability:** The rate at which water flows through the soil. It generally decreases as cohesion increases.
- **Plasticity:** The ability of moist soil to change shape when force is applied and to retain its shape after the force is removed. It depends on the cohesion and adhesion of soil materials.
- **Elasticity:** The ability of a soil to change shape when a load is applied but recover quickly when the load is removed.
- **Compressibility:** The decrease in volume of soil when pressure is increased. Gravels, sands, and silts are less compressible than clay. The compressibility of sand and silt

varies depending on their density, while the compressibility of clay is directly affected by its water content and inversely affected by its cohesive strength.

- **Erodibility:** How easily soil can be broken down by wind or water. Silt and sand are looser materials that are easier to erode compared to cohesive soils.

Engineers take additional items into consideration when evaluating soil, which include:

- **Cleavage:** Breaking or splitting of soil particles.
- **Angle of Internal Friction:** This influences the resistance in sliding of soil grain particles. It is dependent on the density of the particles.
- **Specific Gravity:** The ratio of a material's unit weight to water's unit weight. This is similar to density but unitless.
- **Shear Strength:** The amount of force that can be applied to soil without causing it to break apart.
- **Bulk Density:** A measure of soil compaction and porosity. It is calculated by dividing dry weight of soil and volume.
- **Total Stress:** The weight of all the soil above a certain layer, divided by the surface area of the soil. It increases with depth and unit weight.
- **Pore Water Pressure:** Water pressure inside the soil's pores, which depends on the depth below the water table and conditions of seepage flow.
- **Compaction:** The compression of soil using mechanical energy. It rearranges the particles in the soil and reduces the amount of empty space between them.

Soil Engineers

Soil Engineers are essential for designing structures like buildings, bridges, levees, roads, and reservoirs. They take soil samples and investigate its composition and grade, among other factors, to calculate the foundation's design. Soil engineers are also needed when retrofitting existing structures.

For soil engineers to do their work, they need to have a good understanding of soil and its properties mentioned above. In order to understand soil, it is important to have deep knowledge of the rocks that formed it.

Classification of Rocks

Rock refers to a compact natural material that is semi-hard to hard and is composed of one or more minerals. Rocks can be classified into three groups based on their modes of origin, namely igneous, sedimentary, and metamorphic rocks.

Igneous rocks are considered to be the primary rocks that are formed by the cooling of molten magmas or by the recrystallization of older rocks under heat and pressure. These rocks have been formed on or at various depths below the earth's surface. Igneous rocks can be further classified into two main classes - extrusive and intrusive. Extrusive rocks pour out at the surface of the earth, while intrusive rocks are large rock masses that have not been formed in contact with the atmosphere.

Both classes of igneous rock, extrusive and intrusive, begin in a molten state. But they solidify differently. Extrusive rocks are formed due to volcanic eruptions and are characterized by their glass-like structure. On the other hand, intrusive rocks are formed at great depths under pressure containing entrapped gases, resulting in wholly crystalline texture.

Some important rocks in the igneous group are granite and basalt, which are used as building stones. Granite is made up of feldspar, quartz, and mica and has a massive structure, while basalt is a dark-colored fine-grained rock dominated by plagioclase and characterized by the absence of quartz.

The formation of sedimentary rocks occurs when the products of the disintegration and decomposition of a rock type are transported, redeposited, and consolidated into a new rock type. These rocks are typically arranged in horizontal layers, or strata, and are classified based on grain size, texture, and structure. Some of the most important sedimentary rocks for engineering purposes are sandstones, limestones, and shales.

Metamorphic rocks, on the other hand, are formed by the recrystallization of igneous or sedimentary rocks due to high temperatures, pressures, and shearing stresses. These rocks can display a range of features, from complete and distinct foliation to a fine, partially crystalline state caused by direct compressive stress. Some examples of metamorphic rocks include gneiss, schist, slate, and marble. Each of these rocks has unique characteristics and uses in construction and engineering. For example, gneiss is known for its elongated mineral grains and banding, while slate is used for roofing due to its easy cleavage. Marble, on the other hand, is dense and used for facing walls and floors.

Rock-Forming Minerals

The study of rock-forming minerals is crucial as all soils are formed from the breakdown or decomposition of a parent rock. A mineral is a natural inorganic substance with a specific structure and chemical composition. Physical properties of minerals such as crystal form, color, hardness, cleavage, luster, fracture, and specific gravity are important, with only specific gravity and hardness relevant to foundation engineering. The specific gravity of most rock-forming minerals ranges from 2.1 (salt) to 5.2 (magnetite).

According to some reports, igneous rocks make up about 95% of the lithosphere, the rigid outer part of the earth, while sedimentary rocks account for only 5%, and hence soil formation is

primarily due to the disintegration of igneous rock. The primary minerals that make up igneous rock are feldspars and quartz, which typically have specific gravities ranging from 2.50 to 2.65.

Soil Formation

Soil refers to a natural collection of mineral grains, with or without organic constituents, that can be gently separated from one another by mechanical means such as agitation in water. On the other hand, rock is considered to be a naturally occurring aggregate of mineral grains that are bound together by strong and permanent cohesive forces. The cohesive forces binding the mineral grains in a rock formation can be decreased through the process of weathering, leading to the disintegration of larger masses of rock into smaller and smaller particles. Soils are formed as a result of the weathering process acting on the parent rock, which can occur through mechanical disintegration or chemical decomposition. Overall, the formation of soil is intricately connected to the process of weathering, which has the potential to transform larger rock formations into the smaller particles that make up soil.

Mechanical Weathering Versus Chemical Weathering

Mechanical weathering can break rocks down into smaller particles due to the action of various agents, such as the expansive forces of freezing water in fissures, temperature changes, and the abrasion of rock by moving water or glaciers. When the temperature changes, it causes changes in the volume of rocks in the earth's crust, resulting in expansion and contraction. This volume change creates tensile and shear stresses in the rock that can eventually cause even large rocks to fracture. This type of rock weathering is particularly significant in arid climates where extreme atmospheric radiation brings about significant temperature variations at sunrise and sunset. Erosion caused by wind and rain is also a major factor, as is the cracking force generated by growing plants and roots in voids and fissures of rock.

Chemical weathering, on the other hand, is a natural process that can transform hard rock minerals into soft, easily erodable matter. This process occurs through different types of decomposition, including hydration, oxidation, carbonation, desilication, and leaching. Rock elements can readily combine with oxygen and carbon dioxide in the presence of water, leading to chemical reactions that alter the rock's structure and properties. For example, when water comes into contact with granite, the feldspar crystals inside the rock react chemically, forming clay minerals.

Types of Soil

As previously mentioned, soil is formed by the process of physical and chemical weathering. The size of the constituent parts of a weathered rock can range from colloidal to boulders. However, not all weathered constituents of a parent rock can be considered soil. The classification of soil particles is based on their grain size, which includes cobbles, gravel, sand, silt, and clay.

Residual vs Transported Soils

Soils can be divided into two broad categories based on their origin. Residual soils are those that remain at the place of their formation as a result of the weathering of parent rocks. The depth of residual soils is primarily influenced by climatic conditions and the exposure time. In some areas, residual soils can be considerably deep. Residual soils retain many of the elements of the parent rock from which they were derived.

On the other hand, transported soils are those that are found far away from their place of formation and are transported by glaciers, wind, or water. The composition of these soils depends on the environment under which they were transported and is often different from the parent rock. The name of the transported soil is dependent on the mode of transportation. For instance, alluvial soils are those that have been transported by running water, while lacustrine soils are those deposited in quiet lakes. Much of our construction activity occurs in and on alluvial soils. It is worth noting that many transported soils are loose and soft, making it difficult to construct structures like foundations.

Organic vs Inorganic Soils

Soil can be further divided into organic and inorganic. In the context of engineering, organic soils are primarily composed of organic matter recently derived from plant remains whereas inorganic/mineral soils are primarily composed of inorganic matter. To be considered organic soil, the organic matter needs to be “fresh” and still in the process of decomposition. The identification of organic soils is very important because they are much weaker and more compressible than inorganic soils.

Commonly Used Soils

- **Bentonite:** Clay that forms from the decomposition of volcanic ash containing elevated amounts of montmorillonite. It swells (or shrinks) markedly with the addition (or removal) of water.
- **Varved Clays:** Made up of thin alternating layers of silt and fat clays that originate from glaciers. They have undesirable properties of both silt and clay. Freshwater lakes have constituents of varved clays transported by melted ice at the close of the ice age.
- **China Clay (Kaolin):** A very pure form of white clay that is often utilized in the ceramic industry. It is usually found in soil from hot and humid climates, like tropical rainforests.
- **Boulder Clay:** A mixed sedimentary deposit of glacial clay that contains unsorted rock fragments of all dimensions ranging from boulders, cobbles, and gravel to finely pulverized clay material. This is also referred to as glacial till.
- **Calcareous Soil:** Soil that contains calcium carbonate. When tested with weak hydrochloric acid, it effervesces.

- **Marl:** A combination of calcareous sands, clays, or loam.
- **Hardpan:** A soil layer that is relatively hard and densely cemented, like rock, which does not soften when wet. Boulder clays or glacial till are sometimes referred to as hardpan.
- **Caliche:** A mixture of clay, sand, and gravel that is cemented by calcium carbonate deposited from groundwater.
- **Peat:** A fibrous aggregate of finer fragments of decayed vegetable matter. It is very compressible, and one should be cautious when using it to support the foundations of structures.
- **Loam:** A combination of sand, silt, and clay.
- **Loess:** A fine-grained, air-borne deposit that is characterized by a very uniform grain size and high void ratio. The size of particles ranges between about 0.01 to 0.05 mm. The soil can stand deep vertical cuts because of slight cementation between particles. It is formed in dry continental regions, and its color is yellowish light brown.
- **Shale:** A material that is in a transitional state from clay to slate. Some consider shale a type of rock, but when it is exposed to air or water, it may rapidly decompose.

Size and Shape of Soil Particles

Soil particles can range in size from coarse gravel to the finest particles that can be observed only through an electron microscope, and the characteristics of the soil varies depending on the size of the particles. There are several systems used to classify soils based on size. Engineers should be familiar with the most common ones which are given in Table 1 below. The most widely accepted classification system for soil size is the Unified Soil Classification System, which is used by the US Bureau of Reclamation, the US Army Corps of Engineers and the American Society for Testing and Materials (ASTM). Soil classification systems aim to predict soil behavior based on simple tests, grouping soils with similar engineering characteristics. However, no system fully achieves this objective due to the complexity of soil behavior and the variety of soil problems. Progress has been made, but classification should be seen as a tool to understand soil behavior rather than an end goal.

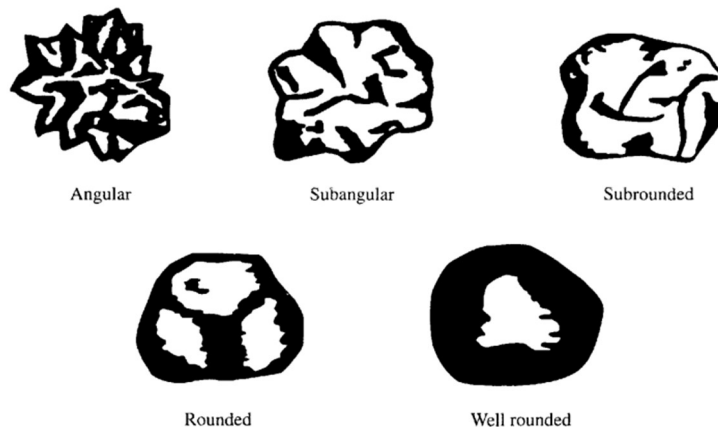
Table 1 Particle Size Classification by Various Systems

	Size of Clay	Size of Silt	Size of Sand	Size of Gravel
Unified Soil Classification System (USCS)	Fines (silts and clays) <0.075 mm		0.075 - 4.75 mm	4.75 - 76.2 mm
American Association of State Highway and Transportation Officials (AASHTO)	<0.002 mm	0.002 - 0.075 mm	0.075 - 2 mm	2 – 76.2 mm
Massachusetts Institute of Technology (MIT)	<0.002 mm	0.002 - 0.06 mm	0.06 - 2 mm	>2 mm
U.S. Department of Agriculture (USDA)	<0.002 mm	0.002 - 0.05 mm	0.05 - 2 mm	>2 mm

Gravel and sand make up the coarser fractions of soils, with gravel consisting of fragments of rock composed of one or more minerals, and sand grains mostly containing quartz. Gravel and

sand grains can have different shapes, including angular, subangular, sub-rounded, rounded, or well-rounded. Gravel can contain flat grains, while some sands have a high percentage of mica flakes that give them elasticity. Refer to Figure 1 for a visual on the shapes of coarser soils.

Figure 1 Shapes of Coarser Fractions of Soils



*Source- Geotechnical Engineering: Principles and Practices of Soil Mechanics and Foundation Engineering

The finer fractions of soils consist of silt and clay, with each grain generally consisting of only one mineral. These particles can have different shapes including angular, flake-shaped, or needle-like.

Specific Surface

The specific surface (or specific surface area) is an essential index of the relative importance of surface effects, and it is defined as the total surface area of the grains per unit mass (typically expressed in square centimeters per gram). The measure is important because many physical and chemical processes take place at the surface such as water retention and movement, ion exchange reactions, contaminant adsorption, microbial attachment, nutrient dynamics, soil aggregation, and irrigation management.

The specific surface area increases with decreasing particle size. The specific surface area is also increased if the particle has pores. The shape of clay particles is also a crucial property that affects the specific surface, as well as the amount of contact area per unit surface. The shape of the particles also influences the interparticle forces between their surfaces, which can significantly affect the mechanical properties of the soil mass.

The surface activity of particles depends not only on their specific surface but also on their chemical and mineralogical composition. Since clay particles have high specific surface and chemical constitution, they are the active portions of soil, and a discussion on the chemical composition and structure of clay minerals is essential.

It is important to note that even with the same material with identical weight and volume, the surface activity and adsorption volume are changed according to the specific surface area.

Composition of Clay Minerals

Clay is typically made up of tiny mineral particles that exhibit plasticity when mixed with specific amounts of water. Clay materials consist of small crystalline particles of one or more members of a group of minerals known as clay minerals. These minerals are hydrous aluminum silicates (magnesium or iron can replace the aluminum). Clay materials frequently contain organic material and water-soluble salts. Organic materials may exist as separate particles of wood, leaves, spores, etc., or as organic molecules adsorbed to the surface of clay mineral particles. Water-soluble salts in clay materials either are trapped in the clay during accumulation or arise later from groundwater movement, weathering, or alteration processes.

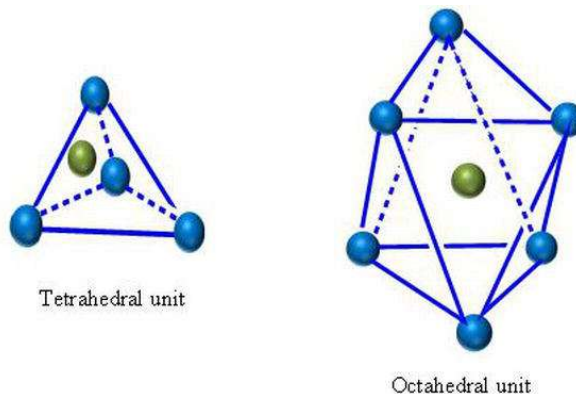
Clay minerals are typically crystalline, although some contain material that is non-crystalline (such as allophane). Clay minerals can be categorized into three main groups (kaolin, smectite, and illite, which will be explained later) based on their crystalline structure, with all clay minerals in the same group having comparable engineering properties. Examining the crystal structure of clay minerals can help in comprehending clay behavior under various loading conditions.

Clay minerals are formed by two basic building blocks: the tetrahedral unit and the octahedral unit (see Figure 2). The tetrahedral (four-surfaced shape) unit comprises four oxygen ions (or hydroxyls if needed to balance out the structure) arranged at the corners of a tetrahedron. The oxygen ions enclose a silicon atom. This structure forms a shell with all tips pointing in the same direction. Each of the oxygen ions have two negative charges. Silicon, on the other hand, has four positive charges. The three oxygen ions at the base share their charges with the adjacent tetrahedral unit, leaving three negative charges per unit at the base. These three negative charges, along with two negative charges at the apex, balances the four positive charges of the silicon ion, and leaves a net charge of -1 per unit.

The second building block is made up of an octahedral (eight-surfaced shape) unit containing six hydroxyl ions and an aluminum ion at the center. In some cases, iron or magnesium ions may replace the aluminum ion. These units are arranged in a sheet structure known as the gibbsite sheet, with each hydroxyl ion shared between three octahedral units. The aluminum ion has a charge of +3, while each hydroxyl ion shares its -1 charge with two neighboring units, resulting in a net charge of +1 per unit. If magnesium replaces the aluminum atoms, the sheet is called a

brucite sheet. Figure 2 illustrates the structure of a tetrahedral unit and an octahedral unit. On the tetrahedral unit, the green dot represents a silicon atom and the blue dots are oxygen ions. On the octahedral unit, the green dot represents a hydroxyl and the blue dots are either aluminum, magnesium, or iron ions.

Figure 2 Tetrahedral and Octahedral Units



*Source- "Basics of Clay Minerals and Their Characteristic Properties" by Kumari and Mohan

Clay Mineral Groups

Different clay minerals are formed based on the arrangement and conditions of two sheets of silica and gibbsite. During the formation of sheet silicate minerals, isomorphous substitution is a common phenomenon. Isomorphous substitution is when one type of atom is substituted for another, while maintaining the same form. The main clay mineral groups are discussed next.

Kaolin Group

Kaolin is the most basic group of clay minerals. It is typically a soft, powdery, white clay, but it may appear yellow or rusty in color after exposure to iron oxide. Its structure is composed of a silica tetrahedral (T) layer and an aluminum octahedral (O) layer, which forms a 1:1 layer silicate. It is often referred to as a T-O structure.

Minerals in the kaolin group typically have strong hydrogen bonds which prevent water molecules from entering the layers and give them a low shrink-swell capacity. Also, kaolin minerals are highly adsorbent, which is handy in the removal of undesirable substances. These properties make kaolin useful as an additive to concrete to make it less porous and strengthen the cementitious bonds. Kaolin soil also has little isomorphous substitution, which leads to a lower charge and cation-exchange capacity. However, kaolin clay has a low bearing capacity and thus, in order to hold up civil structures, soil improvement needs to be done to increase the bearing capacity.

The kaolin group includes kaolinite, halloysite, and allophane.

Smectite Group

Smectite is another mineral group. Smectite minerals are generally pale in color (white, cream, or light gray). This mineral group is composed of two silica tetrahedral (T) layers and an aluminum octahedral (O) layer. This combination of two tetrahedral layers and one octahedral layer forms a 2:1 layer silicate. It is often referred to as a T-O-T structure. The layers are separated by sheets of water molecules and exchangeable cations. In the smectite group, sodium, calcium, magnesium, and iron can be used as a substitute for aluminum.

Minerals in the smectite group typically have weaker bonds and high cleavage. As a result, water can enter between the layers, which leads to swelling and shrinkage. Also, smectite minerals can hold and release cations, which is beneficial for soil fertility. In addition, they can effectively adsorb and remove contaminants from soil and water. Lastly, they have a high specific surface area and are thermally stable. These properties make smectite minerals useful in drilling fluids, wastewater treatment, and catalysts in chemical reactions.

Montmorillonite is the most common mineral of the smectite group. Bentonite is also part of this group.

Illite Group

Illite is another mineral group. Minerals in this group are typically pale yellow, gray, green, or white. The illite group is like the smectite group in the sense that it is a T-O-T structure. However, some of the silicon atoms are replaced by aluminum atoms (which are balanced by potassium ions). The layers are held together by van der Waals forces. As a result, they slide past each other easily.

Minerals in this group have weaker bonds than the hydrogen bonds in the kaolin group, but they are stronger than the water bond in the smectite group. Thus, there is slight swelling in the presence of water, but less swelling than in smectite minerals. Also, minerals in the illite group remain stable up to temperatures of approximately 600°C, beyond which they begin to degrade. Overall, the properties of illite minerals make them valuable for various industrial and geological uses, including oil and gas drilling, agriculture, and geologic studies.

The illite mineral is the only common mineral found in the illite group.

Clay Particles and Water

The properties exhibited by a soil mass are determined by the properties of the individual particles that make up the mass, as well as the arrangement of these particles. Water is a critical factor. The behavior of the soil mass is significantly impacted by the inter-particle-water

relationships, the capacity of the soil particles to adsorb exchangeable cations, and the quantity of water present.

Adsorbed Water

Clay particles have a net negative charge on their surface due to isomorphous substitution and structural breaks at their edges. The intensity of the charge varies depending on the mineralogical character of the particle. This surface charge influences the surface activity of the mineral, which can be high or low. The surface activity not only depends on the specific surface but also on the chemical and mineralogical composition of the particle. For instance, sand does not have the same properties as clay, even when ground to a fine powder.

Water molecules behave like dipoles, the oxygen end has a slightly negative charge and the hydrogen end has a slightly positive charge. The negative charge on the surface of clay particles attracts the positive end (hydrogen) of the water molecules. The water molecules then arrange themselves in a specific pattern in the vicinity of the solid and water. Multiple water molecule layers stick on the surface with great force. The attractive force decreases as the water molecule gets farther away from the surface. The electrically attracted water surrounding the clay particle is known as the diffused double-layer of water, and the water that sticks to the soil particles is called the adsorbed film and is located within the zone of influence.

The properties of water in the zone of influence are different from those of free or normal water. More specifically, water behaves like a solid near the surface of the particle, it resembles a very viscous liquid in the middle of the layer, and it becomes more normal once beyond the zone of influence. The adsorbed water also affects the behavior of clay particles when faced with external stresses, as it comes between the particle surfaces. To remove the adsorbed water, the clay particle must be heated beyond 200°C, which shows that the bond between the water molecules and the surface is significantly stronger than the bond between normal water molecules.

The adsorbed film in coarse soils is thin compared to the size of the particles. However, in fine-grained soils, the adsorbed film can be much thicker than the particles themselves. The strength of the adsorbed film plays a vital role in determining the physical properties of fine-grained soils, but it has little effect on coarser soils.

Soils with a thick adsorbed film are different from soils with the same grain size but smaller adsorbed films. These cohesive soils can deform without cracking when mixed with water. This is because the grains move across each other, supported by the layers of the adsorbed film. Cohesive soils are easy to roll into threads and do not disintegrate under pressure. The cohesion in these soils is not due to molecular interaction between the soil particles but to the strength of the adsorbed layers that separate the grains.

Base Exchange

Electrolytes are substances that dissociate into positively charged cations and negatively charged anions upon dissolving in water. Acids, salts, bases, and water all exhibit this behavior in some fashion. Acids break up into cations of hydrogen and anions, salts and bases split into metallic cations and nonmetallic anions, and water dissociates itself into hydrogen ions H^+ and hydroxyl ions OH^- . These hydrogen ions form an adsorbed layer on negatively charged particles, which can be replaced by other cations like sodium, potassium or magnesium. Such cations then enter the adsorbed layers, thereby forming an adsorption complex. Note that when a specific element dominates the adsorption complex of a clay, it is often referred to as that element, such as hydrogen clay and calcium clay.

The process just described of exchanging cations of one kind with those of another in an adsorption complex is known as base exchange. In other words, base exchange is the ability of colloidal particles to alter the cations adsorbed on their surface. For instance, if a hydrogen clay is exposed continuously to water containing dissolved sodium salts, it can be modified into a sodium clay. This process is useful in reducing the permeability of soil. However, it is important to note that not all adsorbed cations are exchangeable.

Cation exchange capacity (CEC) refers to the amount of exchangeable cations in a soil. CEC is typically defined as the amount of cations that can be held on the surface of 100 grams of dry mineral and is expressed in milli-equivalents (meq) per 100 grams of dry soil. The larger this number, the more cations the soil can hold, and hence the more water it will hold. A clay soil will have a larger CEC than a sandy soil. The exchange capacities of kaolinites, illites, and smectites are 3.8, 40, and 80 meq per 100 grams, respectively. Smectites are known for their high CEC.

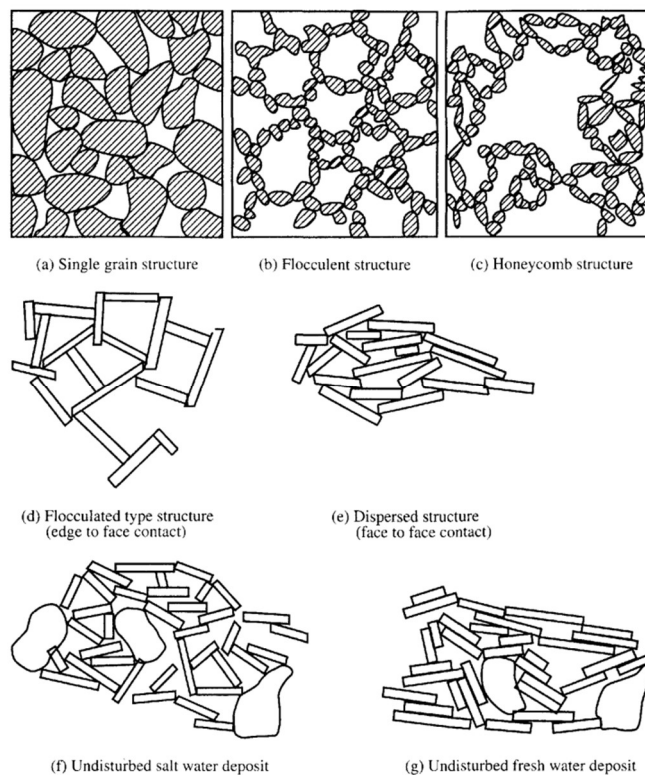
The thickness and physical attributes of the adsorbed film surrounding a particle depend significantly on the nature of the adsorption complex. For strongly water-adsorbent cations such as lithium and sodium cations, the films are relatively thick. On the other hand, for hydrogen cations, the films are very thin. As a result, soils that contain adsorbed lithium and sodium cations have greater plasticity at low water contents and possess lower shear strength due to the particles being separated by a thicker viscous film.

Sodium clays are naturally formed by either the deposition of clays in seawater or by the saturation of clays through saltwater flooding or capillary action. Calcium clays, on the other hand, are primarily formed by freshwater sediments. Hydrogen clays are the result of prolonged leaching of a clay by pure or acidic water, leading to the elimination of all other exchangeable bases.

Soil Mass Structure

The orientation of particles in a mass is influenced by various factors such as the size and shape of the grains and the minerals of which they are composed. The structure of soils can be changed by external forces. There are various types of soil structures. Examples include single grain structures, flocculent structures, honeycomb structures, flocculated type structures (edge to face contact), dispersed structures (face to face contact), undisturbed saltwater deposits, and undisturbed freshwater deposits. Each soil structure is formed differently. For instance, a single grained structure is formed by the settlement of coarse grained soils in water, while flocculent structures form from the deposition of fine soil in water. Figure 3 illustrates the soil structures mentioned above.

Figure 3 Soil Structures



*Source- Geotechnical Engineering: Principles and Practices of Soil Mechanics and Foundation Engineering

Summary

Understanding the properties of soil is crucial for building stable infrastructure. A good soil for construction needs to have balanced chemistry, low compressibility, stability through wetting

and drying cycles, strength under pressure, and the ability to prevent erosion. The strength and stability of soil are closely related to its physical properties. Soil with good structure is more stable. Clay textures are often more stable than sand textures due to their better structure; however, a mix of particle sizes and pore sizes is considered best for engineering purposes. When the natural soil properties are not ideal for construction, there are ways to alter the landscape and provide better building sites. For instance, drainage systems can be added, or land surfaces can be reshaped to direct water away from the site. It is crucial to assess the soil properties of a site to incorporate any necessary corrective measures into the design and prevent potential failures in the future.