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Geotechnical engineering

Origin and classification

Geotechnical engineering, also known as **geotechnics**, is the branch of civil engineering concerned with the engineering behavior of earth materials. It uses the principles and methods of soil mechanics and rock mechanics for the solution of engineering problems and the design of engineering works. It also relies on knowledge of geology, hydrology, geophysics, and other related sciences.

The application of the principles of mechanics to soils was documented as early as 1773 when Charles Coulomb (a physicist, engineer, and army Captain) developed improved methods to determine the earth pressures against military ramparts. Coulomb observed that, at failure, a distinct slip plane would form behind a sliding retaining wall and he suggested that the maximum shear stress on the slip plane, for design purposes, was the sum of the soil cohesion, and friction where is the normal stress on the slip plane and is the friction angle of the soil. By combining Coulomb's theory with Christian Otto Mohr's 2D stress state, the theory became known as Mohr-Coulomb theory. Although it is now recognized that precise determination of cohesion is impossible because is not a fundamental soil property,[5] the Mohr-Coulomb theory is still used in practice today.

In the 19th century Henry Darcy developed what is now known as Darcy's Law describing the flow of fluids in porous media. Joseph Boussinesq (a mathematician and physicist) developed theories of stress distribution in elastic solids that proved useful for estimating stresses at depth in the ground; William Rankine, an engineer and physicist, developed an alternative to Coulomb's earth pressure theory. Albert Atterberg developed the clay consistency indices that are still used today for soil classification. Osborne Reynolds recognized in 1885 that shearing causes volumetric dilation of dense and contraction of loose granular materials.

Modern geotechnical engineering is said to have begun in 1925 with the publication of Erdbaumechani*k* by Karl Terzaghi (a mechanical engineer and geologist). Considered by many to be the father of modern soil mechanics and geotechnical engineering, Terzaghi developed the principle of effective stress, and demonstrated that the shear strength of soil is controlled by effective stress. Terzaghi also developed the framework for theories of bearing capacity of foundations, and the theory for prediction of the rate of settlement of clay layers due to consolidation. In his 1948 book, Donald Taylor recognized that interlocking and dilation of densely packed particles contributed to the peak strength of a soil. The interrelationships between volume change behavior (dilation, contraction, and consolidation) and shearing behavior were all connected via the theory of plasticity using critical state soil mechanics by Roscoe, Schofield, and Wroth with the publication of "On the Yielding of Soils" in 1958. Critical state soil mechanics is the basis for many contemporary advanced constitutive models describing the behavior of soil.

<u>Preview of Geotechnical field problems in Civil Engineering;</u>

Geotechnical engineering involves many topics; however, this major topic in civil engineering is limited here to the analysis of soil that is the foundation of major highway elements, such as roadways and bridges, and elements that pass under roadways, such as culverts. In terms of it being an engineering material, soil has several characteristic attributes:-

1. It is a material that has been around for a long time. Not only has it been the foundation of many magnificent structures, it was the material used to make the structures themselves. Much of what we know today was learned by trial and error, and our knowledge of this ancient material is continually added to by modern science and technology.

2. It occurs naturally. It sounds almost trite to say that, but soil is not a material created by man, like steel or aluminum or even concrete. We must deal with what nature has provided, which highlights the art of geotechnical engineering. Its properties are so variable, even in the same area. And soil can act in unpredictable ways when used as a construction material.

3. Soil is used everywhere. No highway project can avoid making understanding the soil conditions a first priority. Roadways and bridges must obviously be supported properly; however, even the surface contours along roadways must be designed for proper drainage of storm water. If the soil structure associated with these elements is not right, or is not made right, serious consequences can and will result.

<u>Soil Formation:</u>

Soil is the thin layer of material covering the earth's surface and is formed from the weathering of rocks. It is made up mainly of mineral particles, organic materials, air, water and living organisms—all of which interact slowly yet constantly.

Most plants get their nutrients from the soil and they are the main source of food for humans, animals and birds. Therefore, most living things on land depend on soil for their existence.

Soil is a valuable resource that needs to be carefully managed as it is easily damaged, washed or blown away. If we understand soil and manage it properly, we will avoid destroying one of the essential building blocks of our environment and our food security.

The soil profile

As soils develop over time, layers (or horizons) form a soil profile.

Most soil profiles cover the earth as 2 main layers—topsoil and subsoil.

Soil horizons are the layers in the soil as you move down the soil profile. A soil profile may have soil horizons that are easy or difficult to distinguish.

Most soils exhibit 3 main horizons:

- **A horizon**—humus-rich topsoil where nutrient, organic matter and biological activity are highest (i.e. most plant roots, earthworms, insects and micro-organisms are active). The A horizon is usually darker than other horizons because of the organic materials.
- **B horizon**—clay-rich subsoil. This horizon is often less fertile than the topsoil but holds more moisture. It generally has a lighter colour and less biological activity than the A horizon. Texture may be heavier than the A horizon too.
- **C horizon**—underlying weathered rock (from which the A and B horizons form).
- Some soils also have an **O horizon** mainly consisting of plant litter which has accumulated on the soil surface.
- The properties of horizons are used to distinguish between soils and determine land-use potential.

Factors affecting soil formation

Soil forms continuously, but slowly, from the gradual breakdown of rocks through weathering. Weathering can be a physical, chemical or biological process:

- Physical weathering—breakdown of rocks from the result of a mechanical action. Temperature changes, abrasion (when rocks collide with each other) or frost can all cause rocks to break down.
- Chemical weathering—breakdown of rocks through a change in their chemical makeup. This can happen when the minerals within rocks react with water, air or other chemicals.
- biological weathering—the breakdown of rocks by living things. Burrowing animals help water and air get into rock, and plant roots can grow into cracks in the rock, making it split.

The accumulation of material through the action of water, wind and gravity also contributes to soil formation. These processes can be very slow, taking many tens of thousands of years. Five main interacting factors affect the formation of soil:

- parent material—minerals forming the basis of soil
- living organisms—influencing soil formation
- climate—affecting the rate of weathering and organic decomposition
- topography—grade of slope affecting drainage, erosion and deposition
- Time—influencing soil properties.

Interactions between these factors produce an infinite variety of soils across the earth’s surface.

Parent materials

Soil minerals form the basis of soil. They are produced from rocks (parent material) through the processes of weathering and natural erosion. Water, wind, temperature change, gravity, chemical interaction, living organisms and pressure differences all help break down parent material.

The types of parent materials and the conditions under which they break down will influence the properties of the soil formed. For example, soils formed from granite are often sandy and infertile whereas basalt under moist conditions breaks down to form fertile, clay soils.

Organisms

Soil formation is influenced by organisms (such as plants), micro-organisms (such as bacteria or fungi), burrowing insects, animals and humans.

As soil forms, plants begin to grow in it. The plants mature, die and new ones take their place. Their leaves and roots are added to the soil. Animals eat plants and their wastes and eventually their bodies are added to the soil.

This begins to change the soil. Bacteria, fungi, worms and other burrowers break down plant litter and animal wastes and remains, to eventually become organic matter. This may take the form of peat, humus or charcoal.

Climate

Temperature affects the rate of weathering and organic decomposition. With a colder and drier climate, these processes can be slow but, with heat and moisture, they are relatively rapid.

Rainfall dissolves some of the soil materials and holds others in suspension. The water carries or leaches these materials down through the soil. Over time this process can change the soil, making it less fertile.

Topography

The shape, length and grade of a slope affects drainage. The aspect of a slope determines the type of vegetation and indicates the amount of rainfall received. These factors change the way soils form.

Soil materials are progressively moved within the natural landscape by the action of water, gravity and wind (for example, heavy rains erode soils from the hills to lower areas, forming deep soils). The soils left on steep hills are usually shallower. Transported soils include:

- Alluvial (water transported)
- Colluvial (gravity transported)
- Aeolian (wind transported) soils.

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