

Chapter One: Introduction

1. Definition:

The term soil mechanics was coined by Dr. Karl Terzaghi and is the application of laws of mechanics and hydraulics to engineering problems dealing with sediments and other unconsolidated accumulations of soil particles produced by the mechanical and chemical disintegration of rocks regardless whether or not they contain an admixture of organic constituents; and therefore soil mechanics is a branch of mechanics which deals with the action of forces on soil and with flow of water in soil.

Soil engineering is not an exact science because of the nature and the variability of soils; sweeping assumptions are in the derivation of equations.

1.1 Coulomb's Contribution in soil mechanics

Coulomb (1773) is credited as the first person to use mechanics to solve soil problems. He was a member of the French Royal engineers, who were interested in protecting old fortresses that fell easily from cannon fire. To protect the fortresses from artillery attack, sloping masses of soil were placed in front of them (Fig. 1.1). The enemy had to tunnel below the soil mass and the fortress to attack. Of course, the enemy then became an easy target.

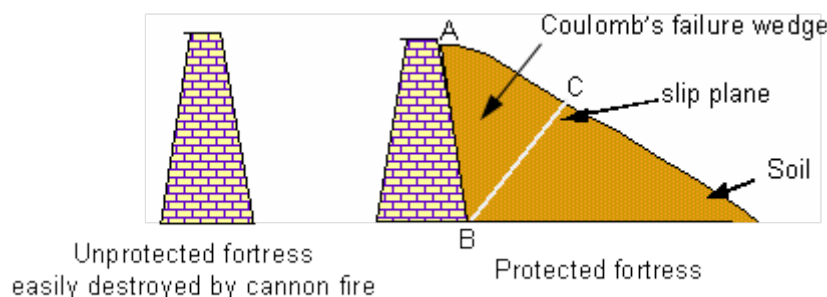


Figure 1.1: Unprotected and protected fortress.

The soil mass applies a lateral force to the fortress that could cause it to topple over or slide away from the soil mass. Coulomb attempted to determine the lateral force so that he could evaluate the stability of the fortress. He postulated that a wedge of soil ABC (Fig. 1.1) would fail along a slip plane BC and this wedge would push the wall out or overtopple it as it moves down the slip plane. Movement of the wedge along the slip plane would occur only if the soil resistance along the wedge were overcome. Coulomb assumed that the soil resistance is provided by friction between the soil particles and the problem now becomes one of a wedge sliding on a rough (frictional) plane, which you may have analyzed in your Physics or Mechanics course. Coulomb has tacitly defined a

failure criterion for soils. Today, Coulomb's failure criterion and method of analysis still prevail.

1.2 Birth of Soil Mechanics

From the early 20th century, the rapid growth of cities, industry and commerce required numerous building systems. For example, skyscrapers, large public buildings, dams for electric power generation and reservoirs for water supply and irrigation, tunnels, roads and railroads, port and harbor facilities, bridges, airports and runways, mining activities, hospitals, sanitation systems, drainage systems, towers for communication systems, etc. These building systems require stable and economic foundations and new questions about soils were asked. For example, *what is the state of stress in a soil mass, how to design safe and economic foundations, how much would a building settle and what is the stability of structures founded on or within soil?* We continue to ask these questions and to try to find answers as new issues has confronted us. Some of these new issues include removing toxic compounds from soil and water, designing foundations and earth structures to mitigate damage from earthquakes and other natural hazards, and designing systems to protect the environment.

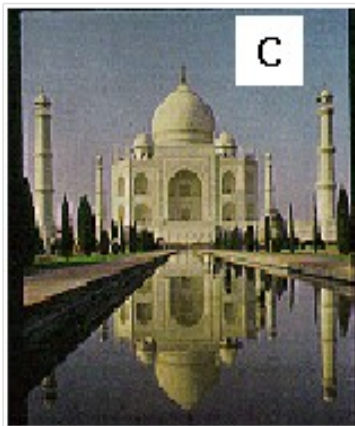
To answer these questions, we need the help of some rational method and, consequently, soil mechanics was born. **Karl Terzaghi (1883-1963)** is the undisputed father of soil mechanics. The publication of his book "Erdbaumechanik" in 1925 laid the foundation for soil mechanics and brought recognition to the importance of soils in engineering activities.

1.3 Soil Mechanics and its application to foundations

Soil mechanics also called geotechnique or geotechnics or geomechanics, is the application of engineering mechanics to the solution of problems dealing with soils as a foundation and a construction material. Engineering mechanics is used to understand and interpret the properties, behavior, and performance of soils. Soil mechanics is a subset of geotechnical engineering, which involves the application of soil mechanics, geology and hydraulics to the analysis and design of geotechnical systems such as dams, embankments, tunnels, canals and waterways, foundations for bridges, roads, buildings, etc. Every application of soil mechanics involves uncertainty because of the variability of soils and their compositions. Thus, engineering mechanics can provide only partial solutions to soil problems. Experience and approximate calculations are essential for the successful application of soil mechanics to practical problems. Many of the calculations that you will learn in this course are approximations

1.4 Geotechnical lessons from past failures

All structures that are founded on earth rely on our ability to design safe and economic foundations. Structural failures do occur due to different reasons. Some failures have been catastrophic and caused severe damage to lives and properties. Failures occur because of inadequate site and soil investigations; unforeseen soil and water conditions; natural hazards; poor engineering analysis, design, construction, and quality control; post-construction activities; and usage outside the design conditions. When failures are investigated thoroughly, we obtain lessons and information that will guide us to prevent similar types of failures in the future.



1.4 NATURE, ORIGIN AND FORMATION OF SOILS

To the civil engineer, Soil is any uncemented or weakly cemented accumulation of mineral particles formed by the weathering of rocks, the void space between the particles containing water and/or air. Weak cementation can be due to carbonates or oxides precipitated between the particles or due to organic matter. If the products of weathering remain at their original location they constitute a residual soil. If the products are transported and deposited in a different location they constitute a transported soil, the agents of transportation being gravity, wind, water and glaciers. During transportation the size and shape of particles can undergo change and the particles can be sorted into size ranges.

The destructive process in the formation of soil from rock may be either physical or chemical. The physical process may be erosion by the action of wind, water or glaciers, or disintegration caused by alternate freezing and thawing in cracks in the rock. The actions of frost, temperature, gravity, wind, rain and chemical weathering are continually forming rock particles that eventually become soils. There are three types of soil when considering modes of formation.

i) Transported soil (gravels, sands, silts and clays)

Most soils have been transported by water. As a stream or river loses its velocity it tends to deposit some of the particles that it is carrying, dropping the larger, heavier particles first. Hence, on the higher reaches of a river, gravel and sand are found whilst on the lower or older parts, silts and clays predominate, especially where the river enters the sea or a lake and loses its velocity. Ice has been another important transportation agent, and large deposits of boulder clay and moraine are often encountered.

ii) Residual soil (topsoil, laterites)

These soils are formed in-situ by chemical weathering and may be found on level rock surfaces where the action of elements has produced a soil with little tendency to move. Residual soils can also occur whenever the rate of break up of the rock exceeds the rate of removal. Laterites are formed by chemical weathering under warm, humid tropical conditions when the rain water leaches out the soluble rock material leaving behind the insoluble hydroxide of Iron and Aluminum giving them their characteristic red-brown color.

iii) Organic soil

These soils contain large amounts of deposited animal and vegetation material. They are usually dark in color and give off a distinctive odor. Deposits of organic silts and clays have usually been created from river or lake sediments. Peat is a special form of organic soil and is a dark brown spongy material which almost entirely consists of lightly to fully decomposed vegetable material.

The resultant soil particles retain the same composition as that of the parent rock. Particles of this type are described as being of 'bulky' form and their shape can be indicated by terms such as angular, rounded, flat and elongated. The particles occur in a wide range of Sizes, from boulders down to the fine rock flour formed by the grinding action of glaciers. The structural arrangement of bulky particles is described as *single grain*, each particle being in direct contact with adjoining particles without there being any bond between them. The state of the particles can be described as dense, medium dense or loose, depending on how they are packed together.

The chemical process results in changes in the mineral form of the parent rock due to the action of water (especially if it contains traces of acid or alkali), oxygen and carbon dioxide. Chemical weathering results in the formation of groups of crystalline particles of colloidal size (<0.002 mm) known as clay minerals. The clay mineral Kaolinite, for example, is formed by the breakdown of feldspar by the action of water and carbon dioxide. Most clay mineral particles are of 'plate-like' form having a high specific surface (i.e. a high surface area to mass ratio) with the result that their structure is influenced significantly by surface forces. Long 'needle-shaped' particles can also occur but are comparatively rare.

Common soil types

- ✓ **Expansive soil:** high shrinkage and swelling characteristics (attributes to the mineral)
- ✓ **Marine soil:** very soft and may contain organic matter
- ✓ **Laterite soil:** red in colour due to Iron oxide (laterization-leaching of Silica due to intense chemical weathering)
- ✓ **Alluvial soil:** Alternate layers of sand, silt and clay
- ✓ **Desert soil:** wind- blown, uniformly graded
- ✓ **Glacial soil:** boulder clay (all ranges of particle sizes)