General Introduction

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School of Civil Engineering

Course Outline

- 36 hours in total (32 hours in the classroom and 4 hours in the laboratory
- Theoretical part: physical properties of soil, flow of water through soil, stress in soil, compressibility of soils, strength of soils
- Laboratory part: physical indices of soil, direct shear test

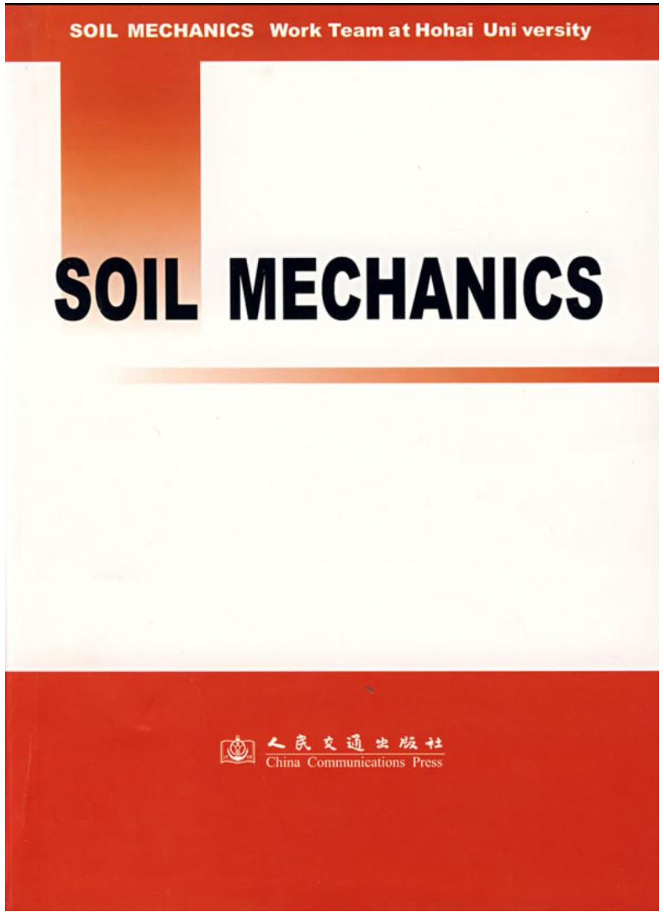
Activities

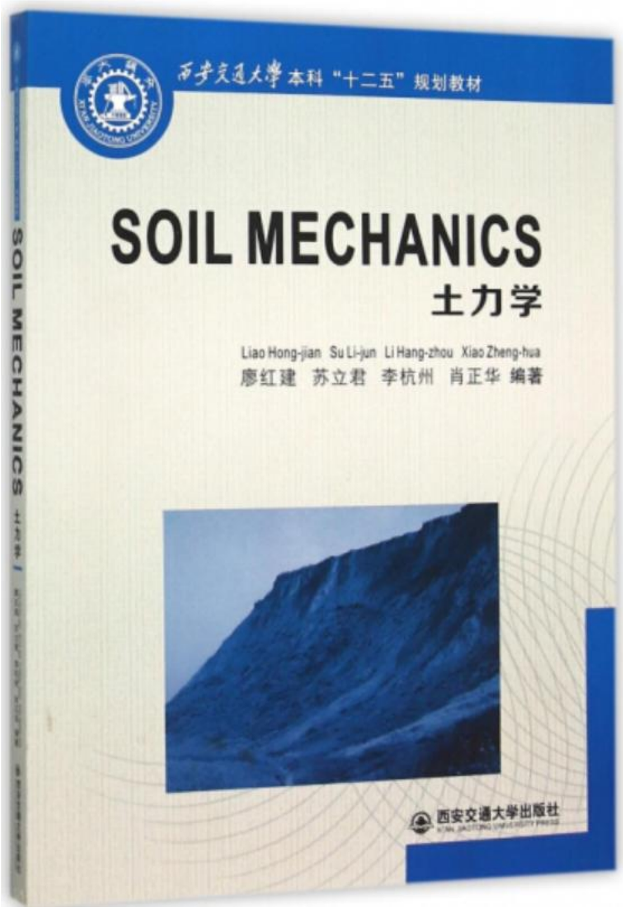
- Theoretical part
  - Theory and principles
  - Homework
  - Quizzes
- Laboratory part
  - 2 tests

Grading

Usual performance	10%
Homework and Quizzes	20%
Experiment	10%
Final examination	60%
	100%

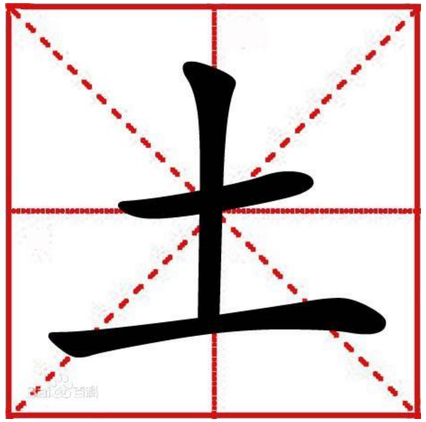
Reference books





Contents

General introduction of soils

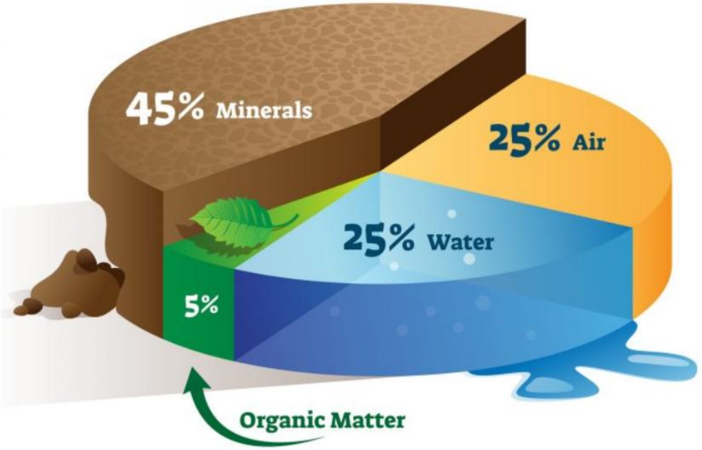


《Bible》, Chapter 2, Genesis, "**The LORD God formed man of the dust of the ground** and breathed into his nostrils the breath of life; and man became a living soul."

《**Greek Mythology**》, **Prometheus shaped man out of mud.**

General introduction of soils

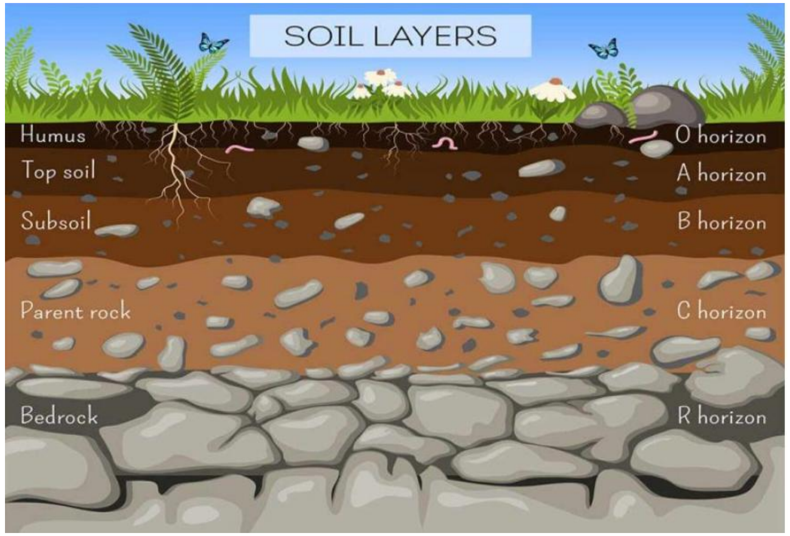
Soil is the mixture of mineral particles (grains), air, water, organic matters (derived from the decay of both plants and animals) and organisms.



Schematic diagram of soil formation

General introduction of soils

The superficial Soil is mainly arranged in distinct horizontal layers; these layers are called horizons. They range from organic matter（humus）to unweathered bed rock



Schematic diagram of soil layers

General introduction of soils

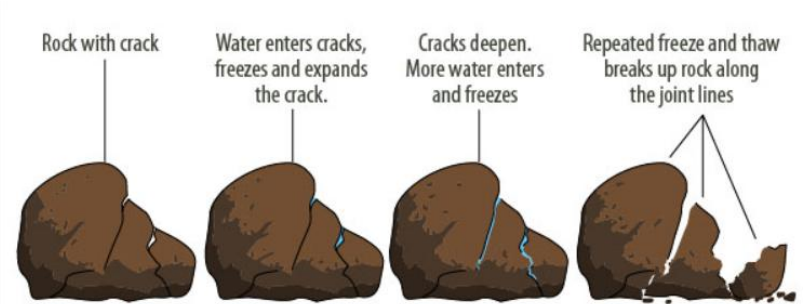
Weathering

Weathering

Physical (disintegration)

Chemical (Reaction)

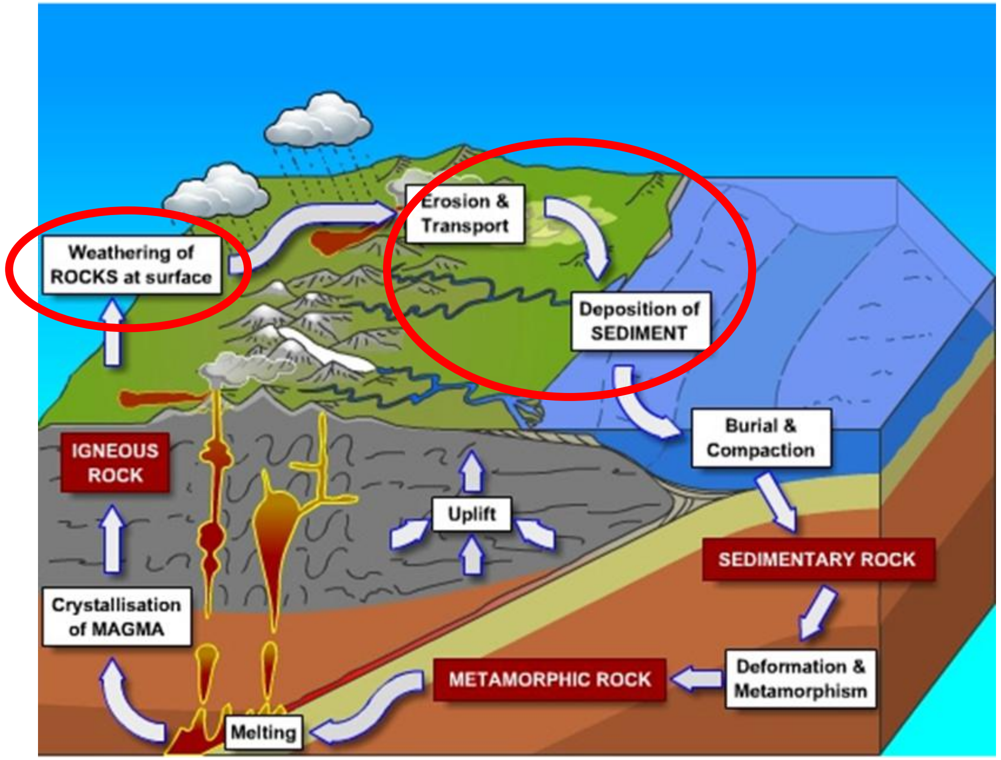
Biological weathering



General processes of physical weathering

Types of chemical weathering

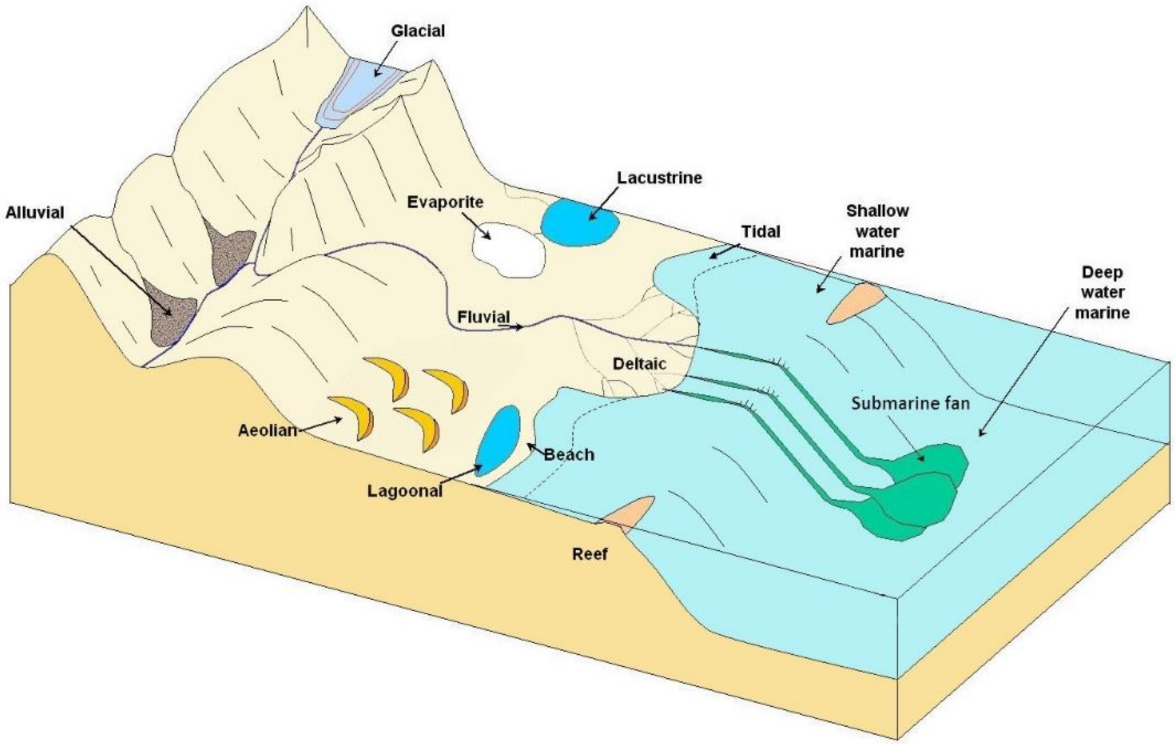
General introduction of soils



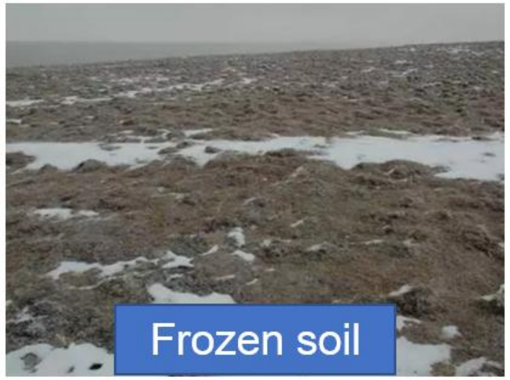
Rock cycle

When rocks are weathered, they break down into loose rock and mineral grains, which are then carried away by **erosion (**force of gravity**) and transport (**moving transport agent, e.g., wind, water and ice**)** processes.

General introduction of soils

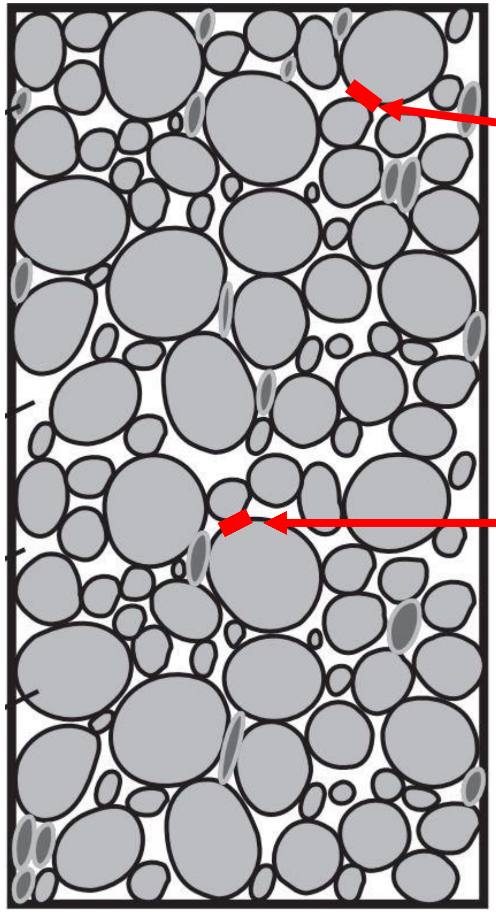


Various deposition environmental



Types of soil in different deposition environments

Typical characteristics of soil



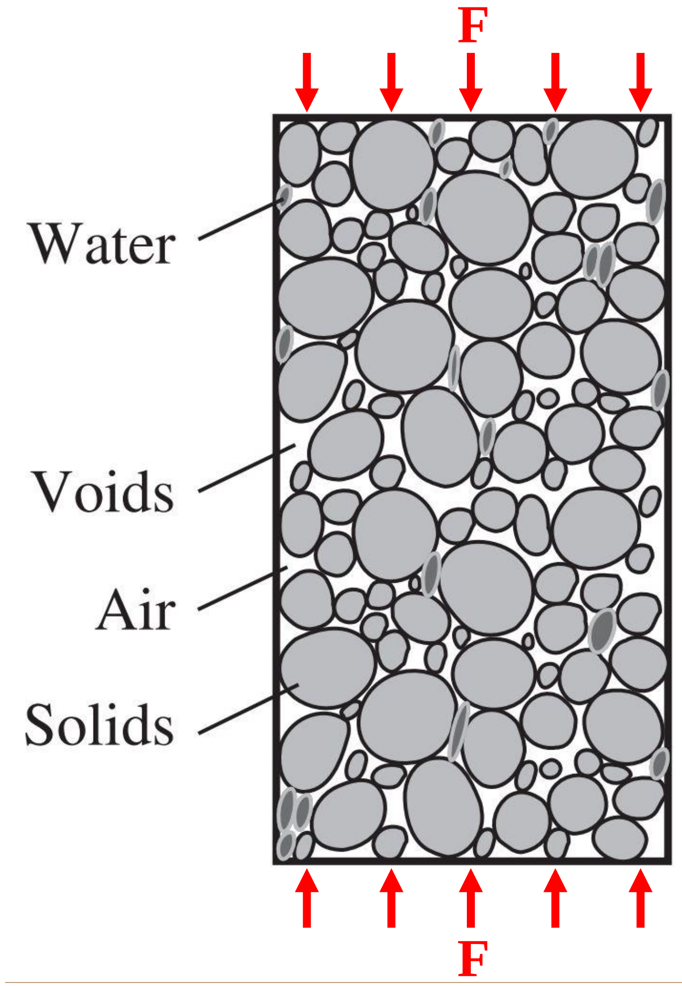
Attractive force
electrostatic force,
chemical bonds,
apparent force

Friction force
between particles

Soil is the **mixture** of mineral particles, air, water, organic and organisms

- Easy to deform
- Low strength

Typical characteristics of soil



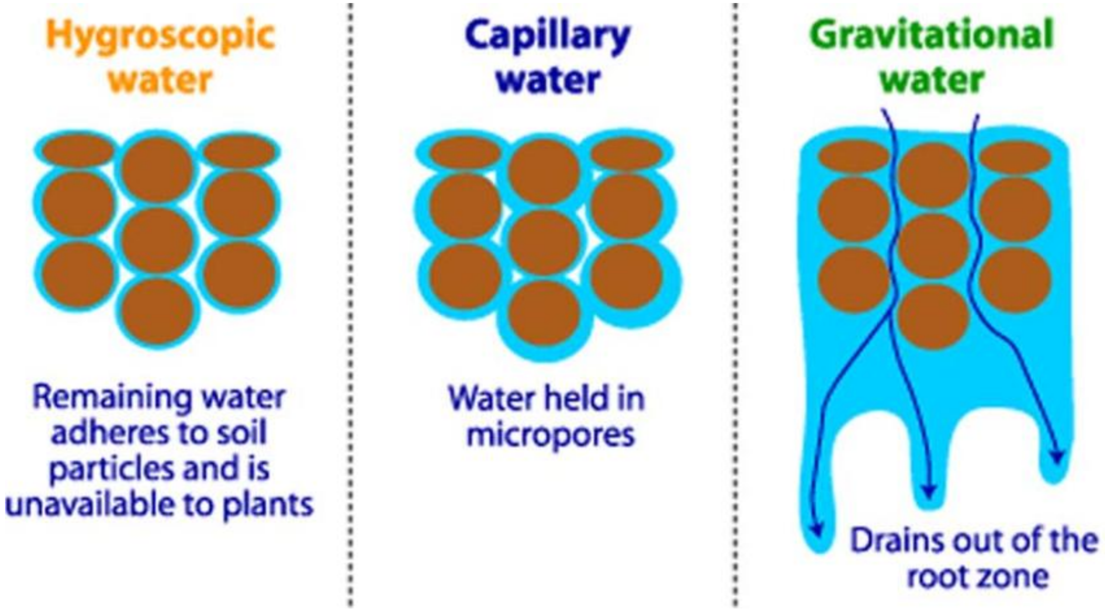
Three phases composite
- Solid phase
- Liquid phase
- Gaseous phase

Loads are shared by three phases (**Complex interaction**)

Typical characteristics of soil

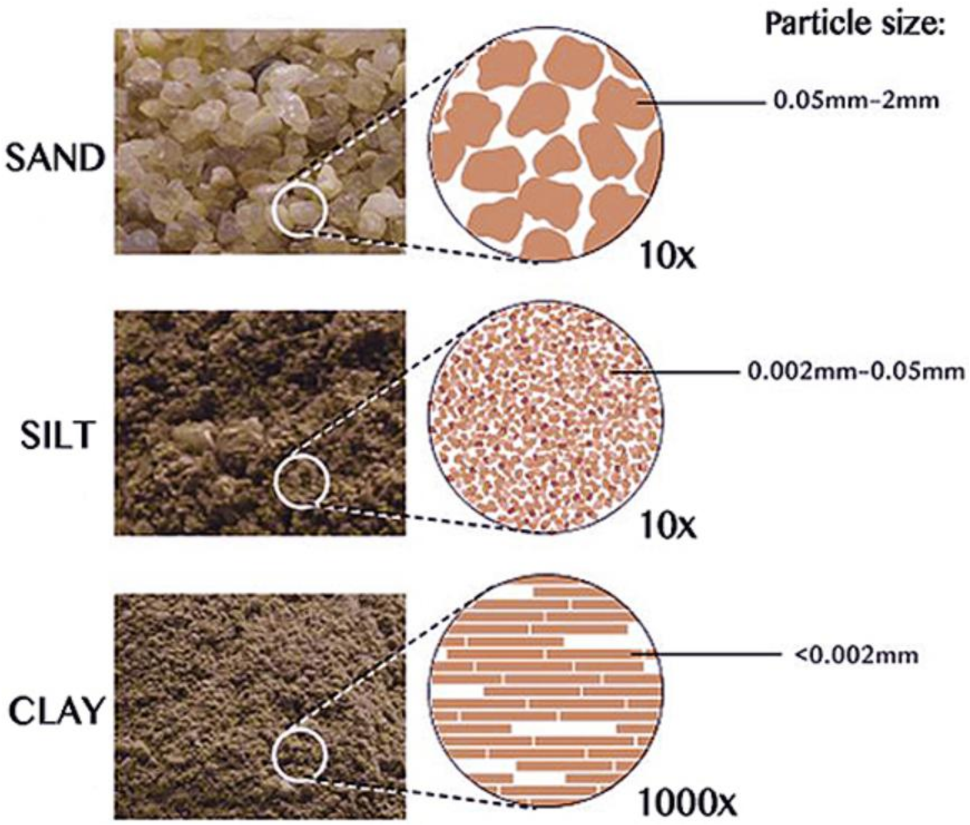
Comparing with other civil engineering materials (concrete, steel, wood).

Water is a distinctive phase (component) in soils, which has a great effect on their behavior



Three main types of water in soils

Typical characteristics of soil

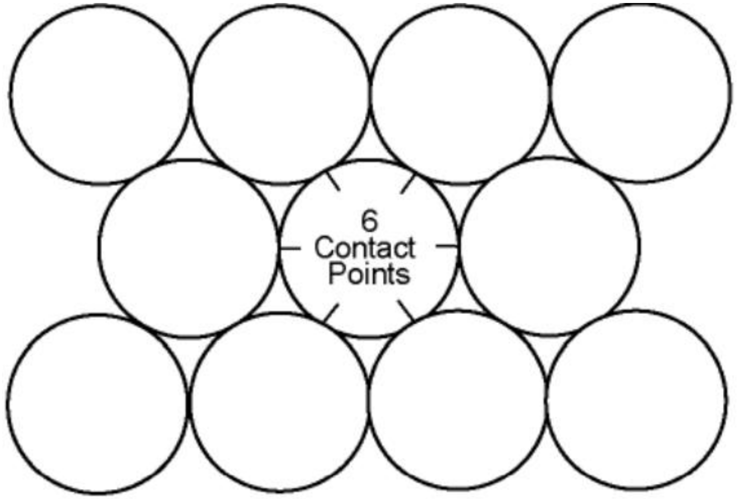


Microscopic view of soils

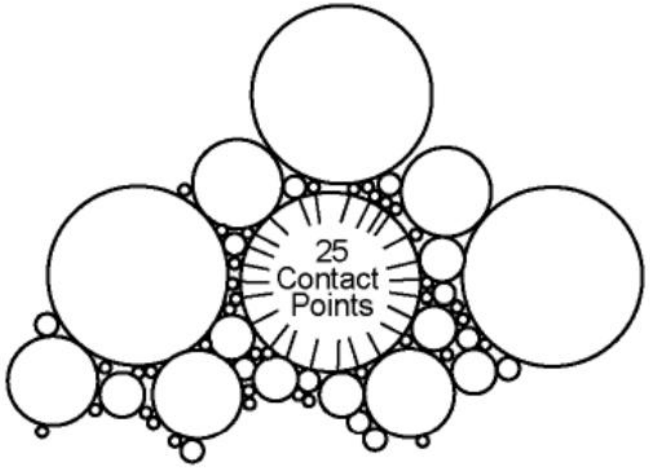
Soils are generally an anisotropic composite due to particles shapes and depositional direction under the action of gravity.

Typical characteristics of soil

Particle size distribution (gradation) have significant impact on the behavior of soils. Normally, well graded soils are easy to be compacted and accordingly, they have higher strength.

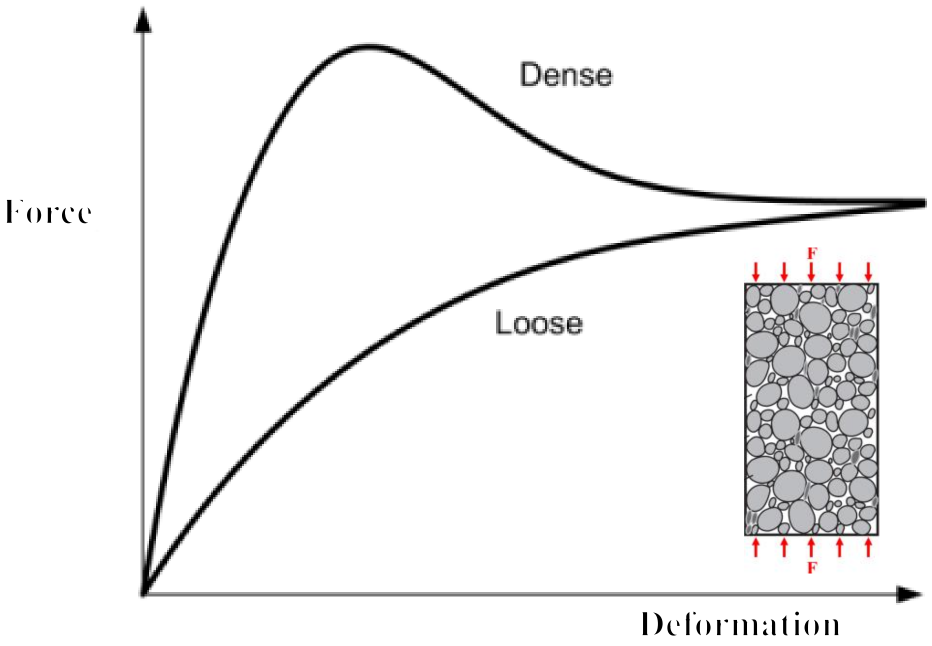


Uniformly or Poorly Graded Soil



Well Graded Soil

Typical characteristics of soil



Deformation-force relationship

Soils are not an idealistic elastic medium, which indicates **their behavior is non-linear after loading.** **Especially**, the deformation is time-dependent **(consolidation)**

For cohesionless soil, its behavior highly depends on the compactness

Why should we learn soil mechanics

Von Karl Terzaghi
Father of soil mechanics

Soil mechanics is the application of mechanics and hydraulics to engineering problems dealing with sediments and other unconsolidated accumulations of solid particles, which are produced by mechanical and chemical disintegration of rocks, regardless of whether or not they contain an admixture of organic constituents.

Why should we learn soil mechanics

- As the base of almost all the structures in civil engineering, it is necessary to master the deformation and strength laws of soils under the action of direct (structure loads) and indirect (thermal) loads
- It also helps civil engineers to know how and how much soil deforms, how soil resists deformation, and estimates their strength under different boundary conditions and different loading conditions.
- To make new researches in the relevant field
- To replace the old (unscientific) methods of construction with the new and advanced ones

Why should we learn soil mechanics

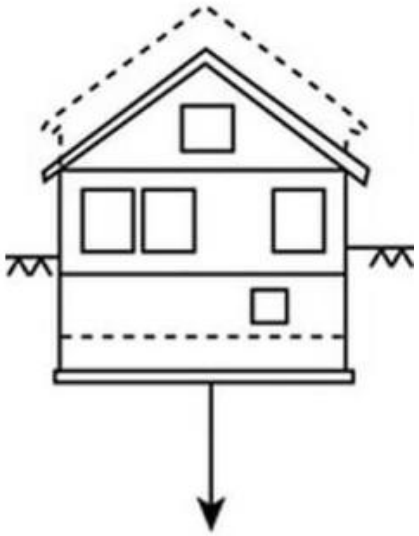
Three typical problems in soil mechanics

Deformation

seepage

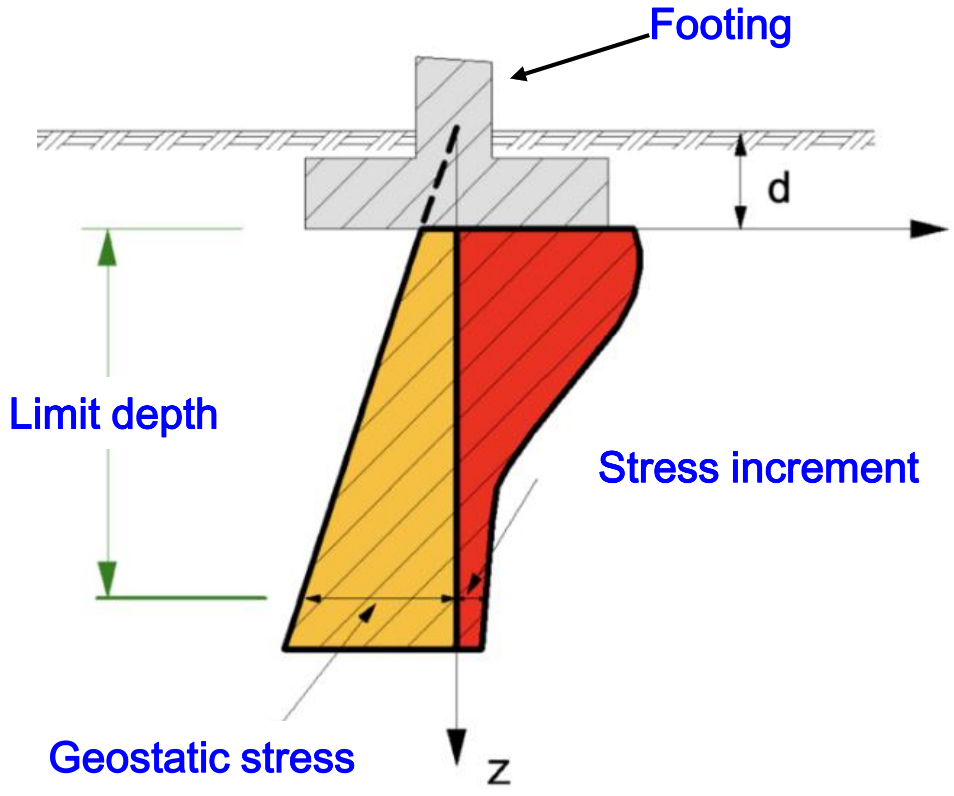
strength

Why should we learn soil mechanics



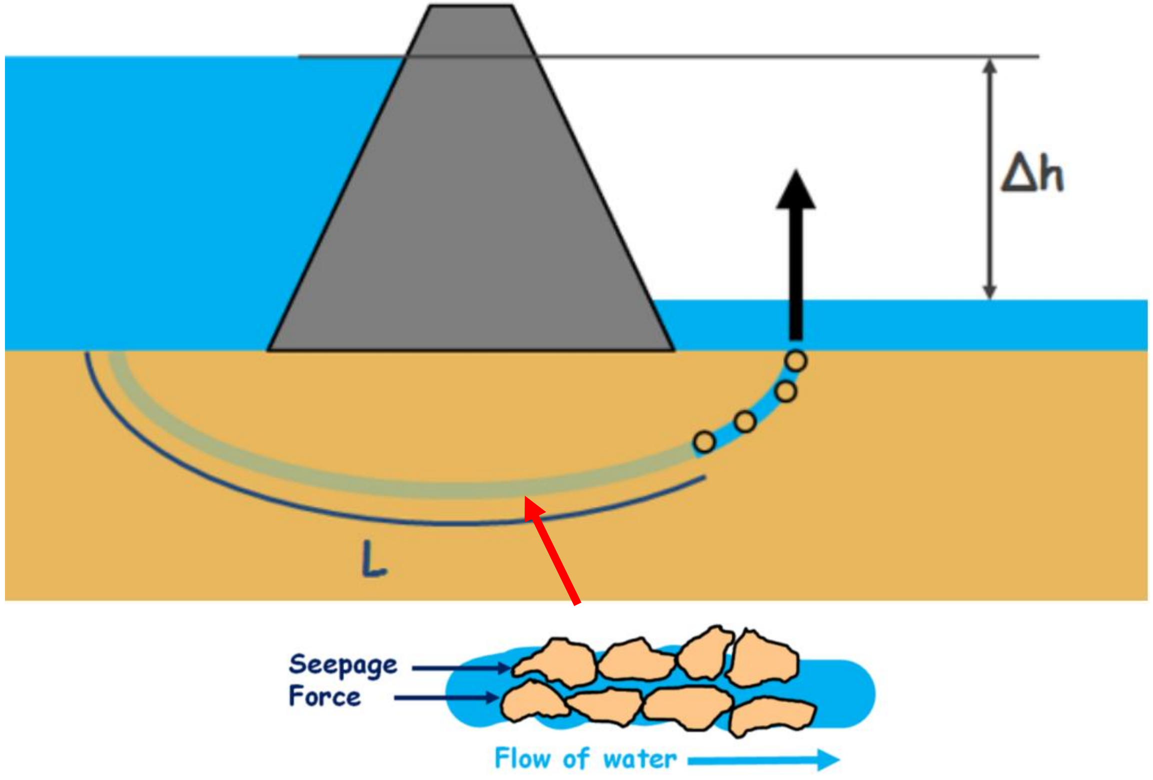
Uniform settlement
(Without crack)

Differential settlement
(With crack)



Schematic diagram for ground settlement calculation

Why should we learn soil mechanics

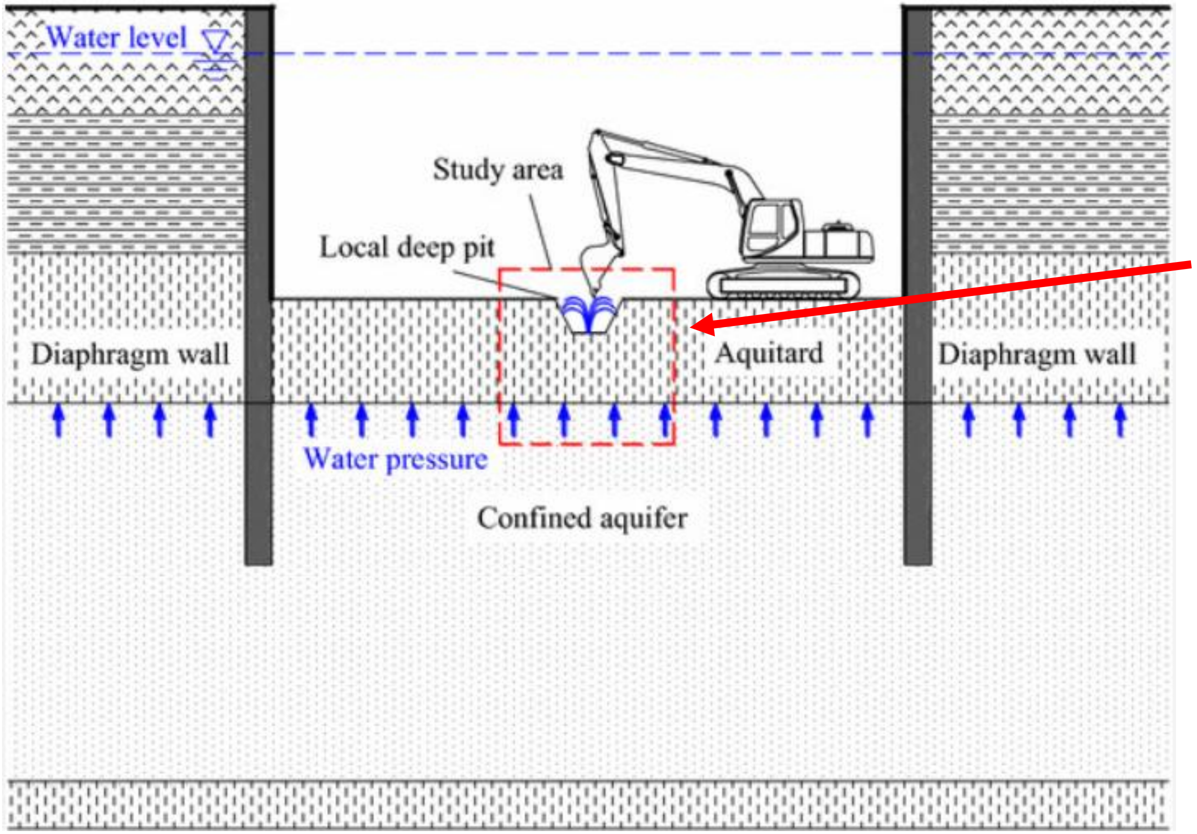


Schematic diagram for piping

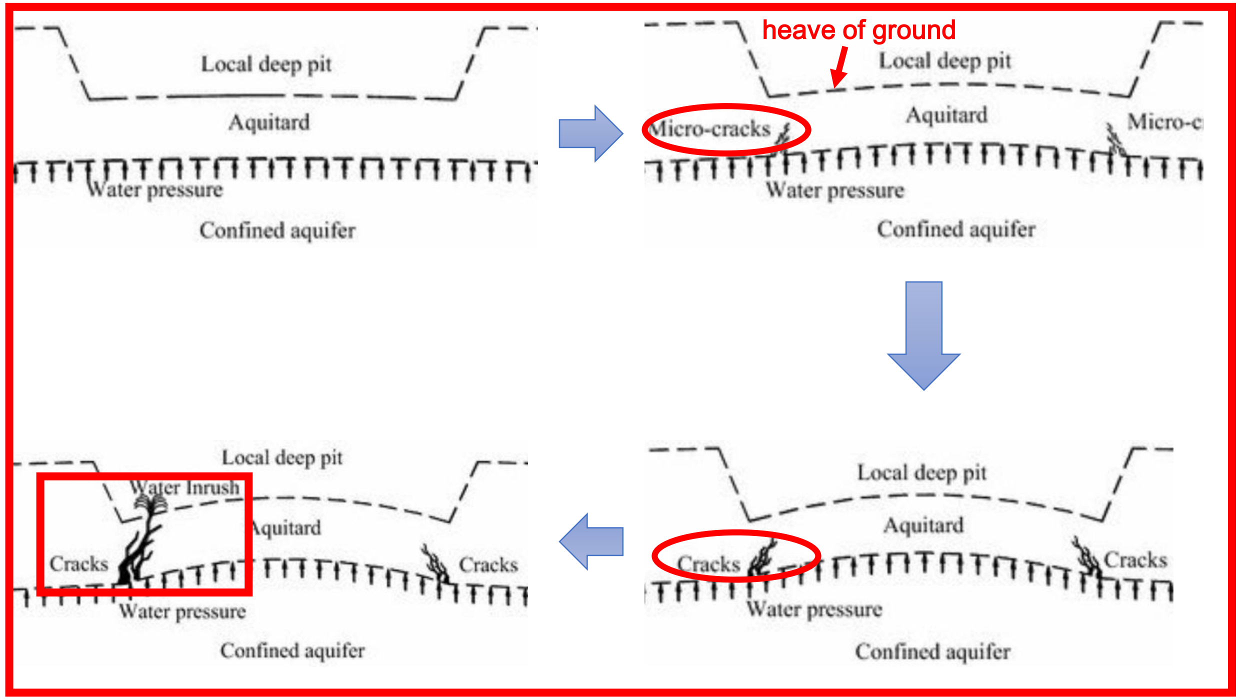
The seepage force of flowing water has the capability to displace the soil particles on its way. Generally, the higher of the velocity of water, the stronger of the seepage force.

With the particles being washed away, failure may occur due to progressively internal erosion. This phenomenon is called piping.

Why should we learn soil mechanics

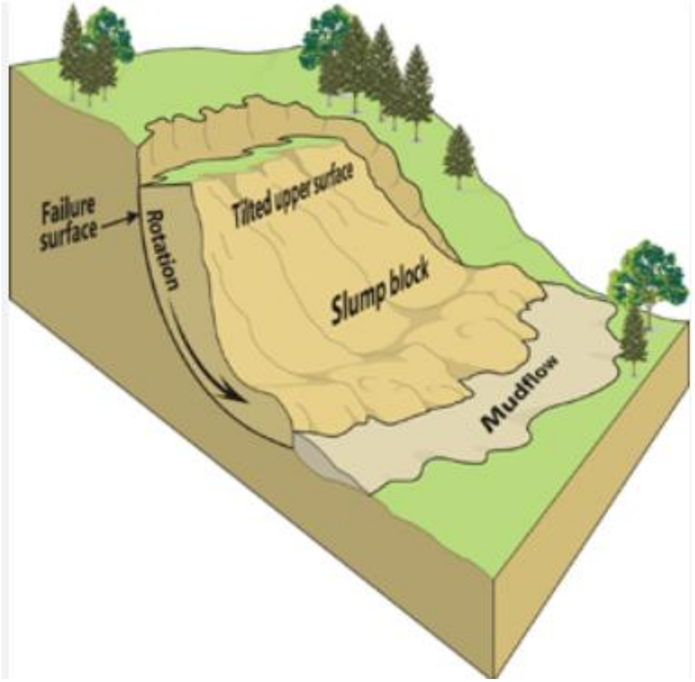


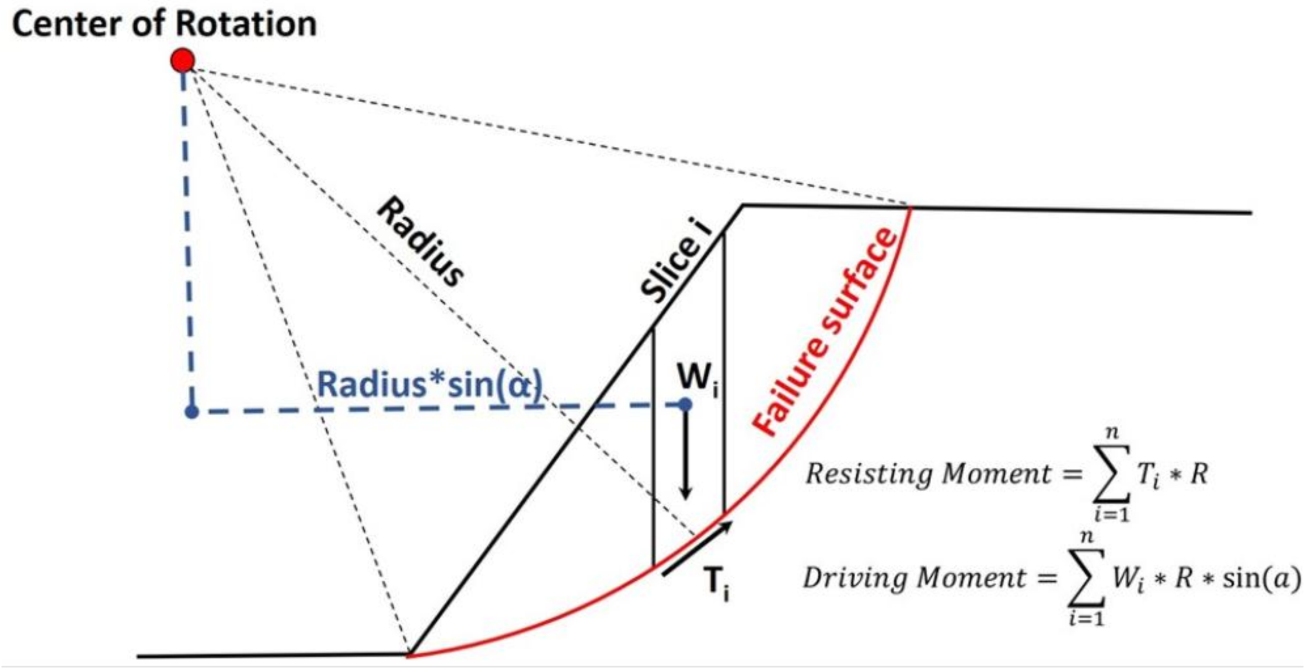
Conceptual model for heave of ground or water inrush



Progressive failure due to excavation

Why should we learn soil mechanics

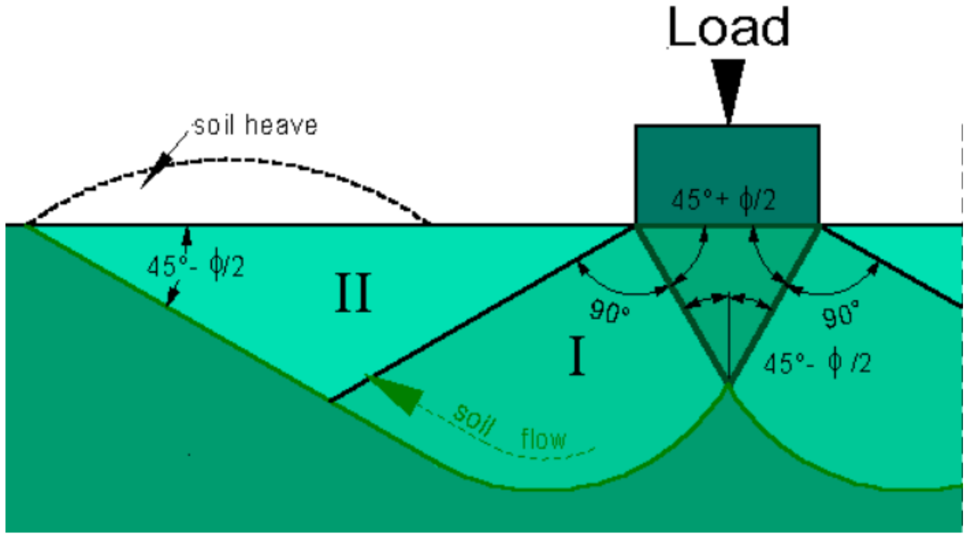




Slope stability analysis

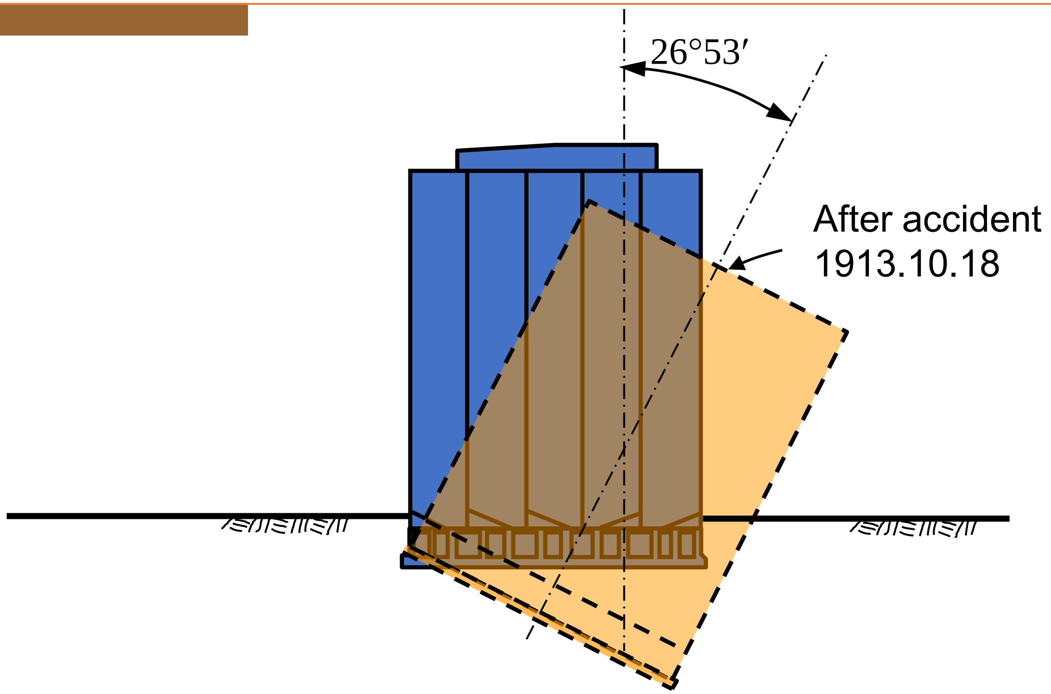
Why should we learn soil mechanics

Tilting of building due to bearing capacity failure



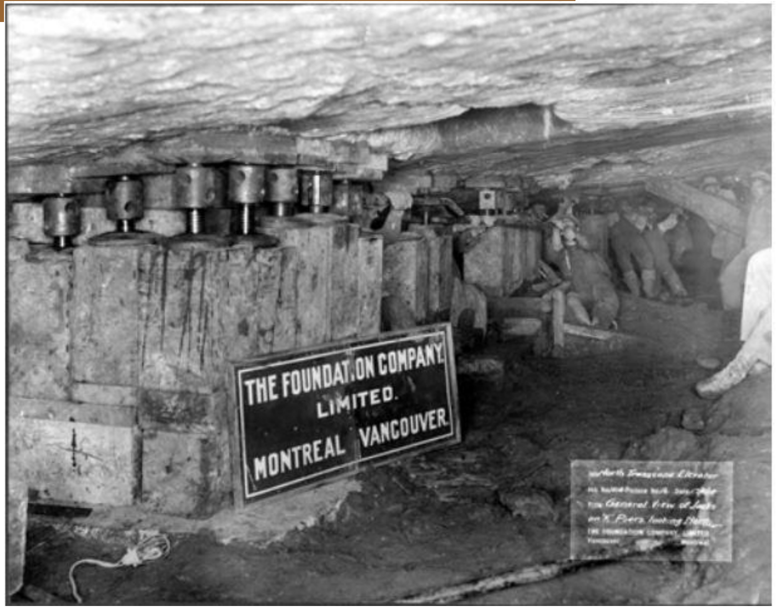
Conceptual model for bearing capacity calculation

Typical incidents related to soil



Transcona grain elevator, Canada. The self-weight of 65 bins is nearly 20000t. After storing 31822m^3 grain, it began to settle at the rate of 30.5cm/h and tilt toward the west. This process eventually came to rest after about 24 hours but was at an angle of 26º 53‘ to the vertical.

Typical incidents related to soil



Reasons: 1) No formal site investigation; 2) According to the borehole investigation, the thickness of soil layers under the foundation are not uniform. The load from the structure under the foundation also affected the softer layer, which has a much lower load-bearing capacity.

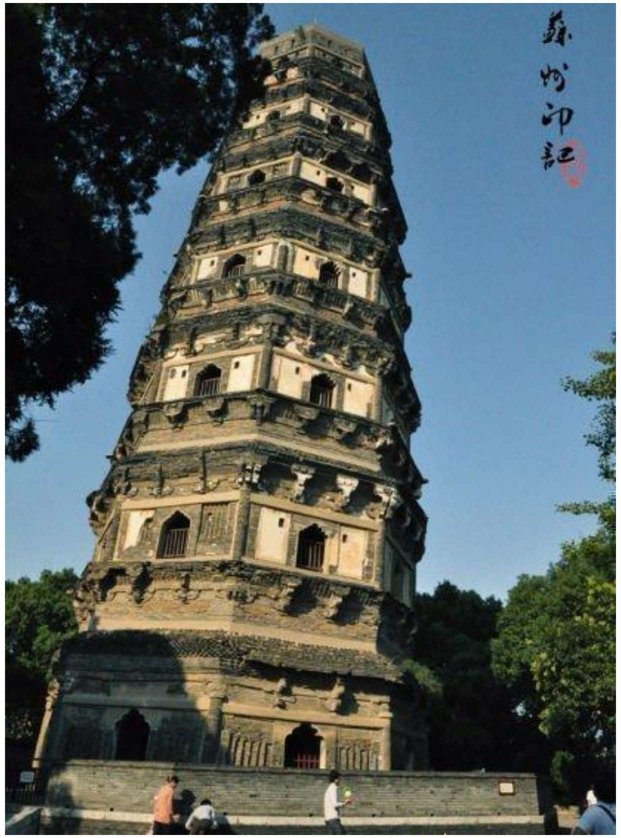
Typical incidents related to soil

Tower of Pisa

Tower of Pisa, Pisa, Italy. The height of the tower is 55.86m from the ground on the low side and 56.67m on the high side. The tower now leans at about 3.99º to the vertical, which means that the top of the tower is displaced horizontally 3.9m

Reasons: the bearing strata of the foundation are mainly silt and clay, which have poor drainage capacity. The time dependent process, consolidation, last long period of time.

Typical incidents related to soil



Tiger Hill Pagoda
Second leaning tower in the world

Tiger Hill Pagoda (Officially called Yunyan Pagoda), Suzhou, China. It is a masonry structure with an octagonal cross-section. It has 7 floors and the height is 47m. Due to the force of nature, the top and bottom of the tower vary by 2.32m

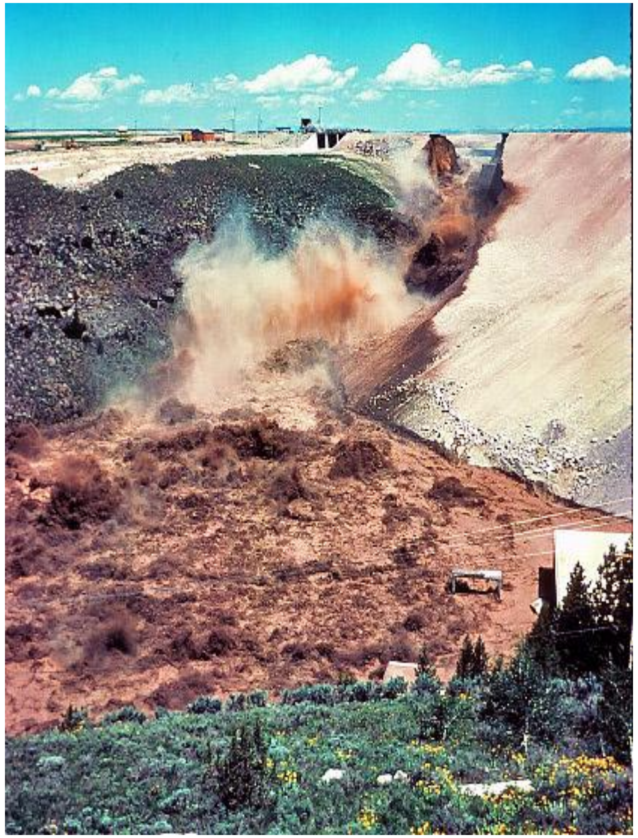
Reasons: 1) Damage of two internal brick column; 2) The soil layers beneath the Pagoda have different thickness; 3) No special treatment for water infiltration;

Typical incidents related to soil

Two major landslides occurred in Hong Kong in June 1972, killing 138 people

Reasons to the incident: 1) Erosion of slope surface, which reduce the strength of surficial soil and rock; 2) Granitic rock tends to be much more susceptible to Hong Kong's weather conditions. The weathering product of granitic rock is granite residual soil, which has poor strength; 3) Meteorological events.

Typical incidents related to soil



Teton earth fill dam

Teton earth fill dam, USA. 90m high and 1000m wide, finished in 1972-1975. The accident happened in June, 1976, which resulted in the deaths of 11 people and 13,000 cattle. The federal government paid over $300 million in claims related to its failure. Total damage estimates have ranged up to $2 billion. The dam has not been rebuilt

Reasons: 1) The flow of water under highly erodible and unprotected fill induce piping; 2) Hydraulic Fracturing cause by differential settlement

Typical incidents related to soil

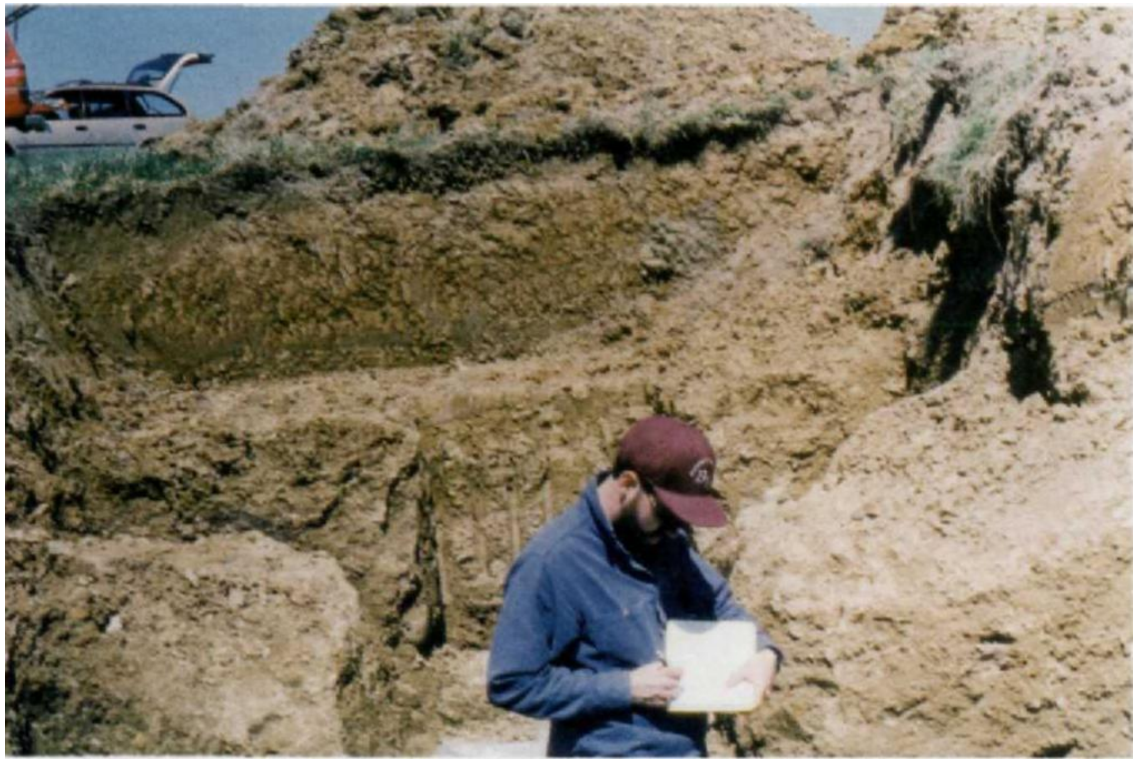
Building tilt and settlement due to liquefaction during the 1964 Niigata earthquake.

Reason: liquefaction of the soil. The shaking process rearrange and densify the particles, which squeezes the water between particles. The excessive pore pressure generates and effective stress reduces.

General approaches to study behavior of soil

Site investigation

General approaches to study behavior of soil

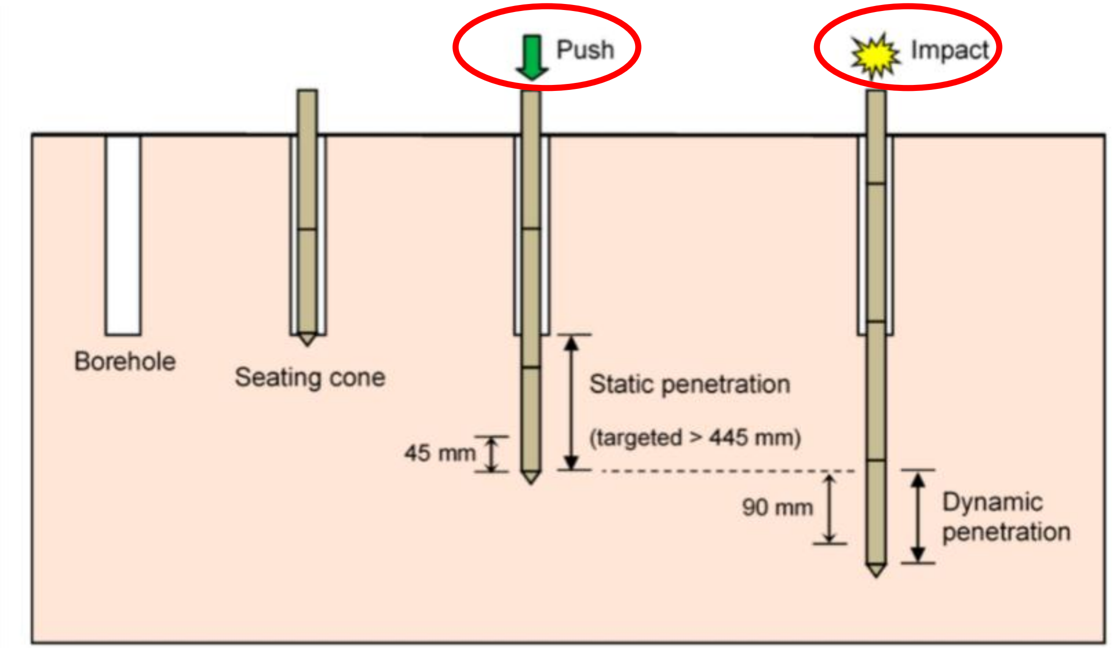


Pit test

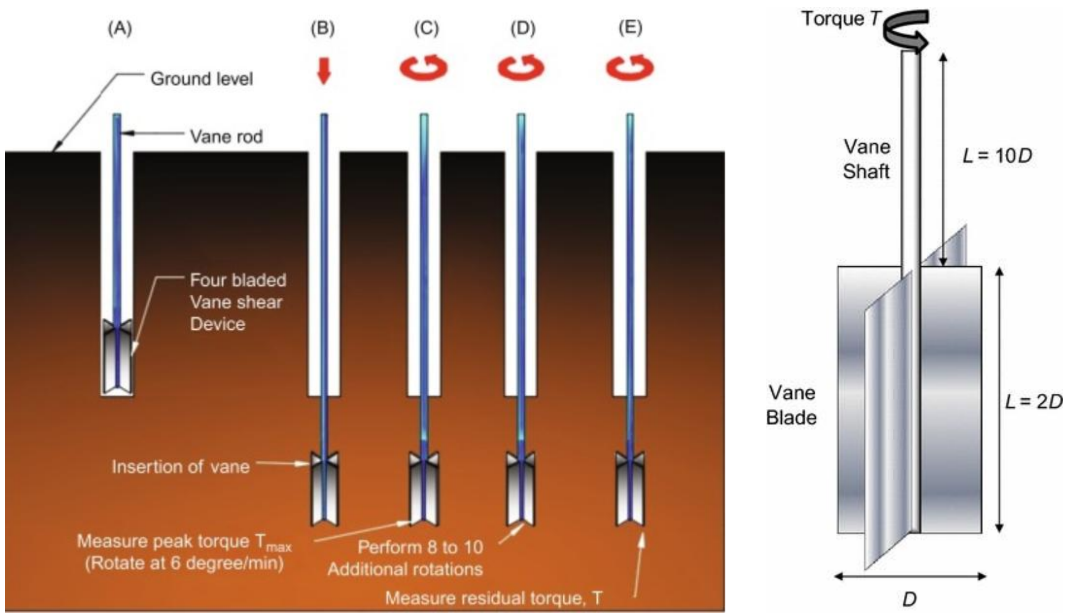
General approaches to study behavior of soil

Drill test

General approaches to study behavior of soil

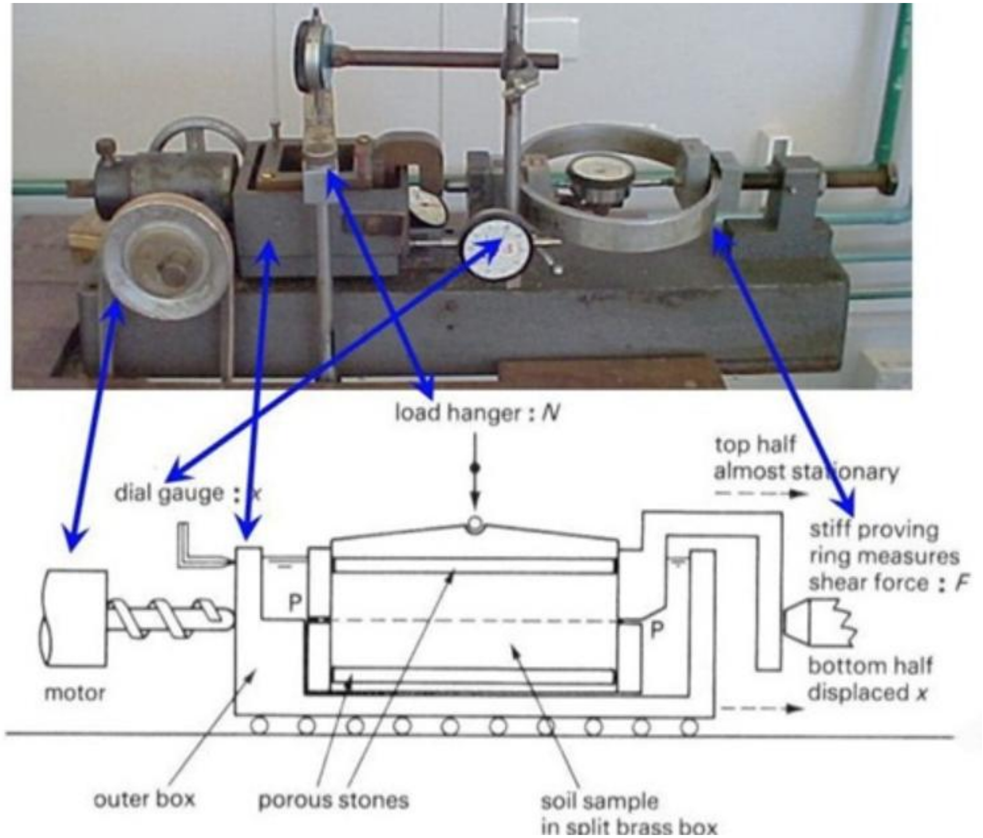


Cone penetration test (CPT)



Vane shear test

General approaches to study behavior of soil



Direct shear test

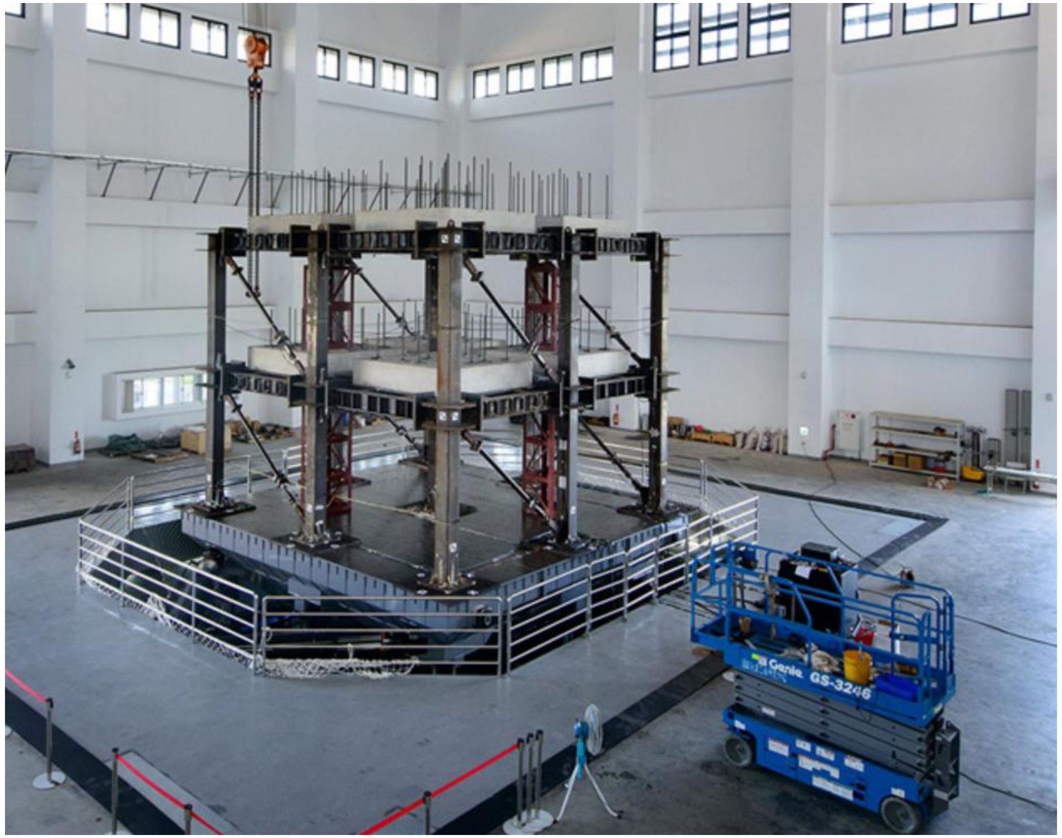
Triaxial compression test

General approaches to study behavior of soil

Scale model test

General approaches to study behavior of soil

Hypergravity centrifugal test



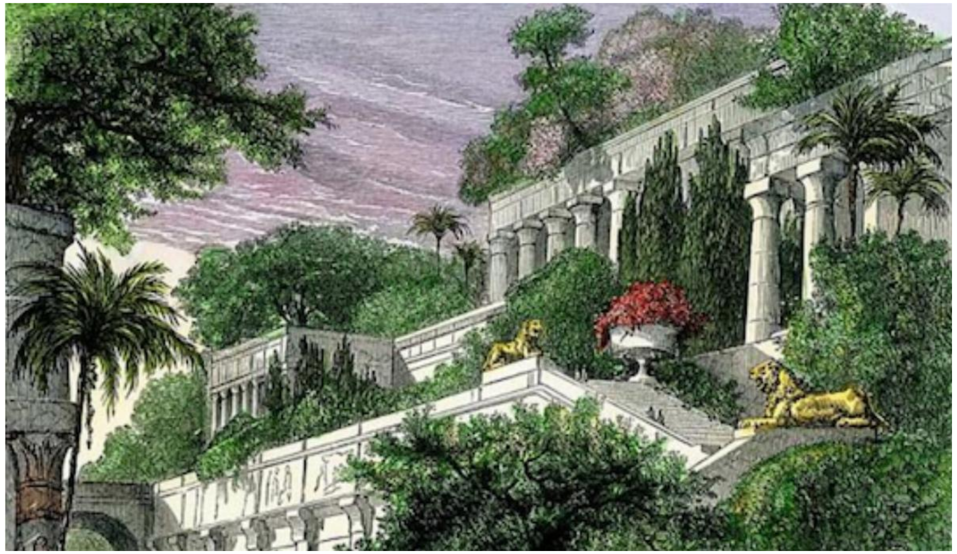
Vibration table test

Brief history of soil mechanics

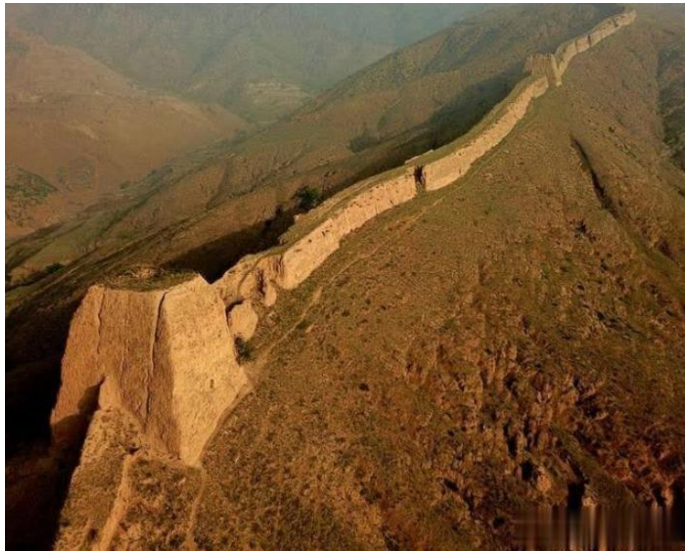
- Stage 1 (- 1773)
- Stage 2 (1773 - 1925)
- Stage 3 (1925 - 1963)
- Stage 4 (1963 -)

Brief history of soil mechanics

Stage 1 (-1773) During the long history of human development, although soil has been applied as main engineering material for various construction projects, there is no “soil engineering” prior to18 century. Ancient projects were mostly accomplished by accumulated experiences of ancient engineers.



Hanging Gardens of Babylon



The Great Wall

Brief history of soil mechanics

Charles-Augustin de Coulomb

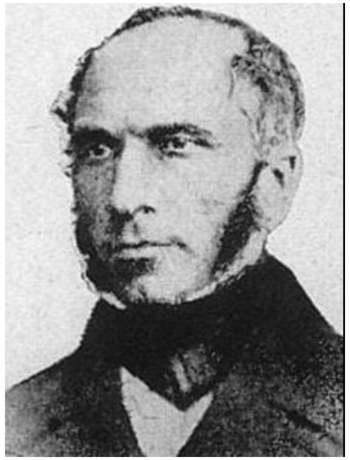
Stage 2 (1773-1925) Classical soil mechanics began in 1773, the French physicist Charles-Augustin de Coulomb published his paper concerning the theory of earth pressure laid the theoretical foundation for the soil failure. He also combined his theory with that of Otto Mohr and finally established the classical Mohr-Coulomb theory. In 1857, the Scottish engineer William Rankine also proposed his own theory of earth pressure, which combines Coulomb's work forms the primary tools to quantify lateral stresses on retaining walls.

Brief history of soil mechanics

Von Karl Terzaghi
Father of soil mechanics

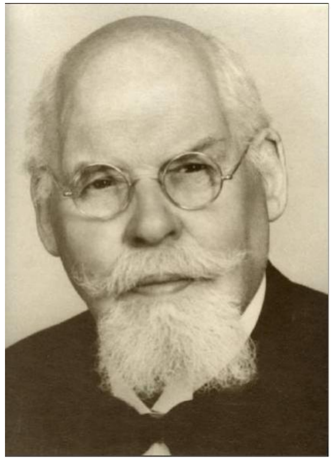
Stage 3 (1925-1963) This period was marked by a series of important studies and publications related soil mechanics. In 1925, Dr. Karl von Terzaghi published a book called "Erdbaumechanik". Especially, he proposed a completely new concept of “effective stress,” which deals with interaction with pore water, has revolutionized the mechanics of soils. Due to his great contribution, he is now regarded as the father of modern soil mechanics.

Brief history of soil mechanics

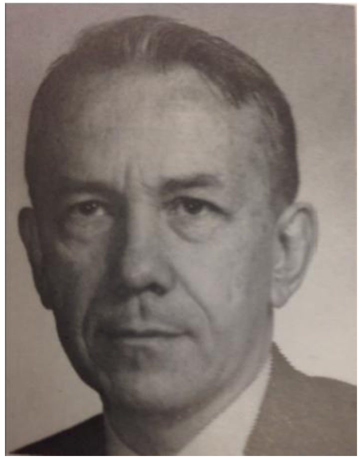


H. Darcy
established the seepage law, which deals with water flow in soil.

J. V. Boussinesq
developed the theory of stress distribution under the action of concentrated force



W. Fellenius
contributed to the conventional methods of slope stability



M. Biot
extended Terzaghi's 1D consolidation theory to 3D

A. M. Atterberg
explained the consistency of cohesive soil

Brief history of soil mechanics

Stage 4 (1963-) With the construction of numerous key projects, the practical problems involved have greatly promoted the development of soil mechanics. Moreover, with the revolution of computational capacity, more complex working can be taking into account. The modern soil mechanics in this stage has the following characteristics:

◆ Owing to the development of *in-situ* observation, more and more researches have been conducted from a microscopic point of view;

◆ More and more constitutive model taking into the corresponding deformation and damage mechanism are developed;

◆ Due to the heterogeneity of soil, several factors may affect the behavior of soil. To obtain more reliable evaluation, statically theory is introduced since 1970.

Brief history of soil mechanics

- Sophisticated field test devices with higher precision are developed and applied;
- The laboratory testing environment is more and more approaching the real working conditions, which could provide designer and engineer with more valuable information, e.g., scaled model combining with vibration table or hypergravity centrifuge test;
- The introduction of feedback analysis, which combines the advanced in-situ monitoring technique and design concepts, could help civil engineer better optimize the design;
- The introduction artificial intelligent, big data analysis has further revolutionized the modern soil mechanics theory.

Further reading

Biographies of some contributors to soil mechanics

- Von Karl Terzaghi https://en.wikipedia.org/wiki/Karl_von_Terzaghi
- Henry Darcy https://en.wikipedia.org/wiki/Henry_Darcy
- M. A. Biot https://en.wikipedia.org/wiki/Maurice_Anthony_Biot
- Charles-Augustin de Coulomb https://en.wikipedia.org/wiki/Charles-Augustin_de_Coulomb
- J. V. Boussinesq https://en.wikipedia.org/wiki/Joseph_Valentin_Boussinesq
- ……

The End