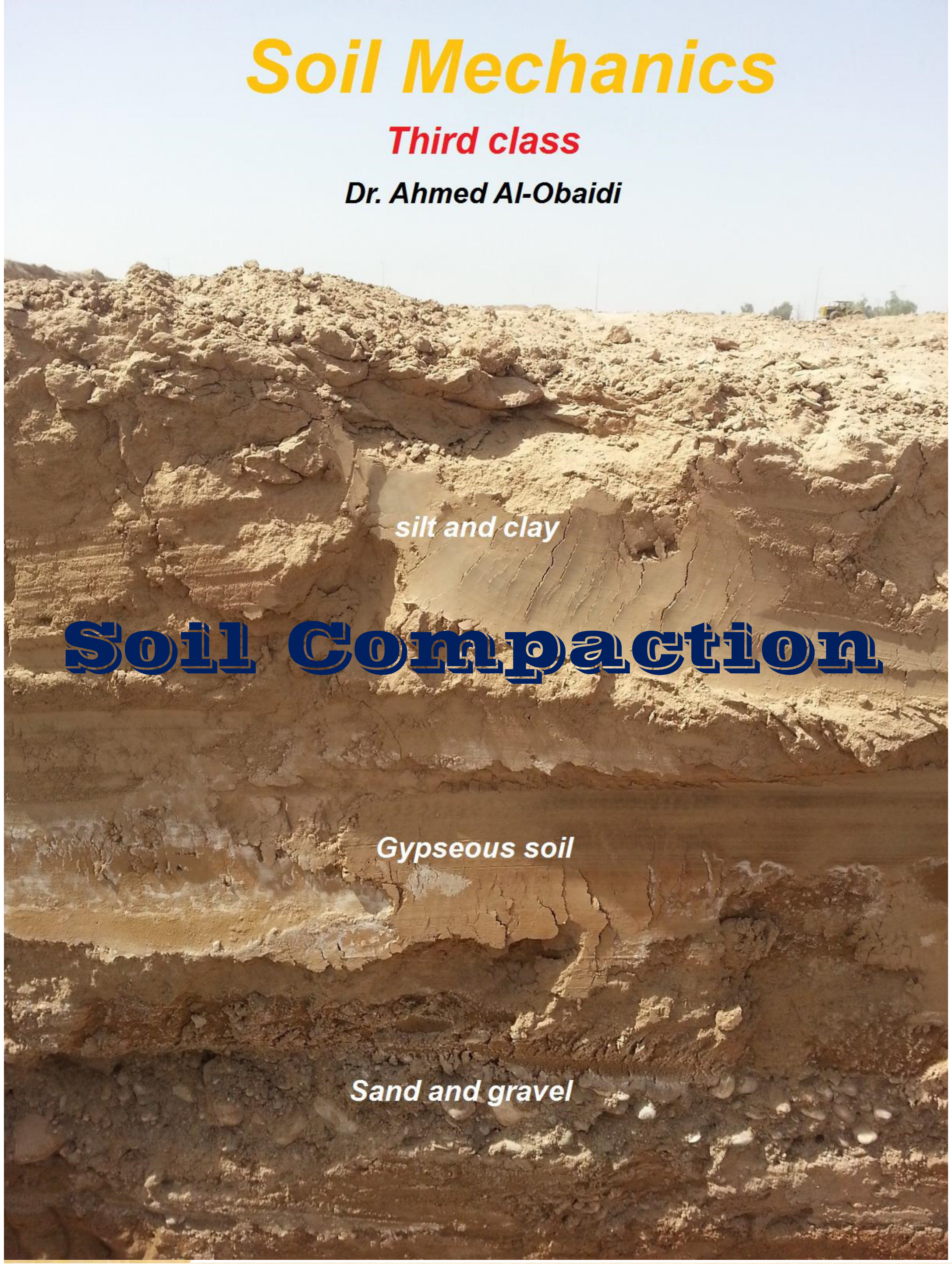


Tikrit University

College of Engineering
Civil engineering Department

Soil Mechanics

3rd Class

Lecture notes

Soil Compaction

Compaction is the application of mechanical energy to a soil so as to rearrange its particles and reduce the void ratio. It is applied to improve the properties of an existing soil or in the process of placing fill such as in the construction of embankments, road bases, runways, earth dams, and reinforced earth walls. Compaction is also used to prepare a level surface during construction of buildings. There is usually no change in the water content and in the size of the individual soil particles.

Soil Compaction

The objectives of compaction are:

- To increase soil shear strength and therefore its bearing capacity.
- To reduce subsequent settlement under working loads.
- To reduce soil permeability making it more difficult for water to flow through.

Soil Compaction

Laboratory Compaction The variation in compaction with water content and compactive effort is first determined in the laboratory. There are several tests with standard procedures such as:

- Standard Proctor Test

Soil is compacted into a 1000 cm3 mould in 3 equal layers, each layer receiving 25 blows of a 2.6 kg rammer dropped from a height of 310 mm above the soil. The compaction is repeated at various moisture contents.

Soil Compaction

Modified Proctor Test

It was found that the Light Compaction Test (Standard Test) could not reproduce the densities measured in the field under heavier loading conditions, and this led to the development of the Heavy Compaction Test (Modified Test). The equipment and procedure are essentially the same as that used for the Standard Test except that the soil is compacted in 5 layers, each layer also receiving 25 blows. The same mould is also used. To provide the increased compactive effort, a heavier rammer of 4.9 kg and a greater drop height of 450 mm are used.

Soil Compaction

In the construction of highway embankments, earth dams, and many other engineering projects, loose soils must be compacted to increase their unit weight.

** Compaction improves characteristics of soils:*

1- Increases Strength

2- Decreases permeability

3- Reduces settlement of foundation

4- Increases slope stability of embankments

Soil Compaction

Soil Compaction can be achieved either by static or dynamic loading:

1- Smooth-wheel rollers

2- Sheepfoot rollers

3- Rubber-tired rollers

4- Vibratory Rollers

5- Vibroflotation

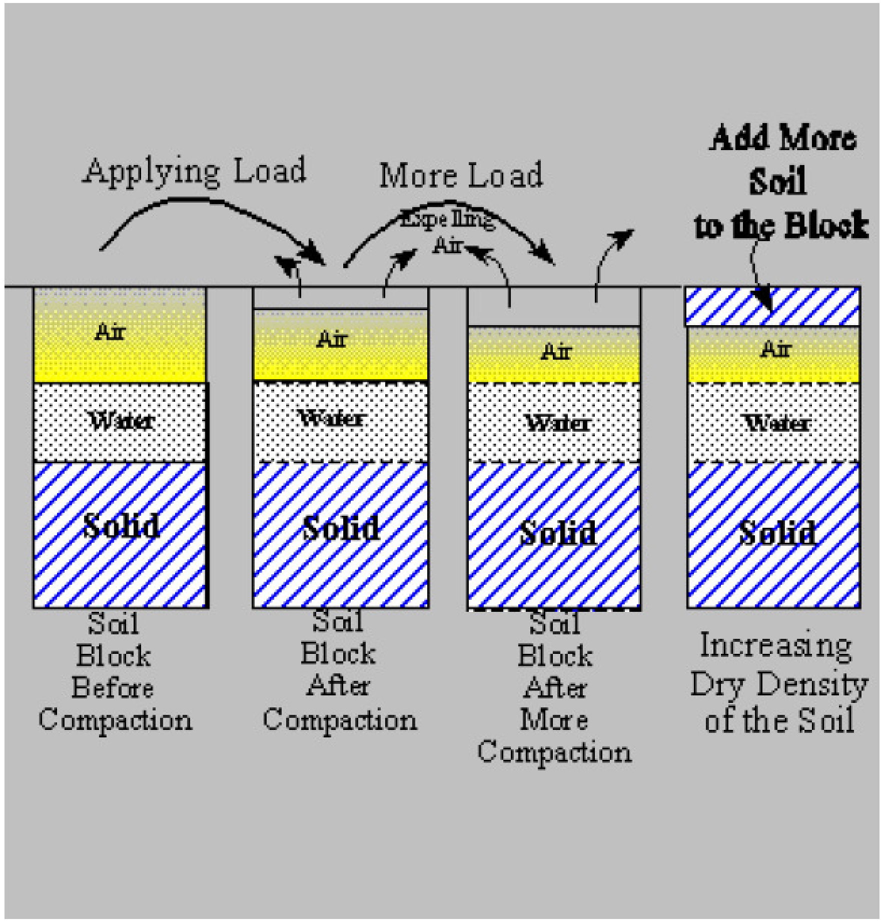
Soil Compaction

General Principles:

- ***The degree of compaction of soil is measured by its unit weight, ----- and optimum moisture content, wc.***
- ***The process of soil compaction is simply expelling the air from the voids. or reducing air voids***
- ***Reducing the water from the voids means consolidation.***

Soil Compaction

Mechanism of Soil Compaction:

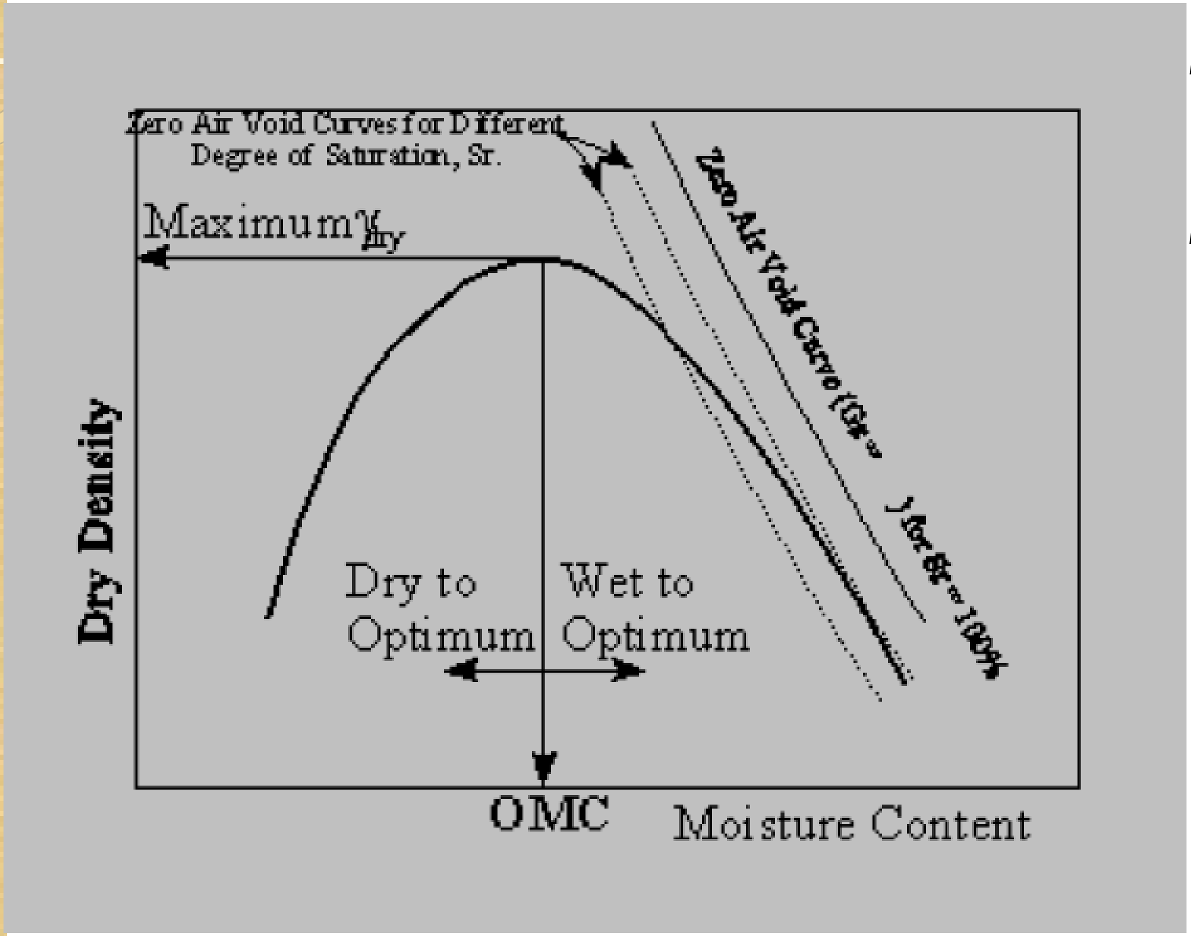


Soil Compaction

- ***By reducing the air voids, more soil can be added to the block. When moisture is added to the block (water content, wc, is increasing) the soil particles will slip more on each other causing more reduction in the total volume, which will result in adding more soil and, hence, the dry density -----will increase, accordingly.***
- ***Increasing Wc will increase-----***

Up to a certain limit (Optimum moister Content, OMC)After this limit

Soil Compaction



Increasing Wc will decrease ----

Density-Moisture Relationship

Soil Compaction

Knowing the wet unit weight and the moisture content, the dry unit weight can be determined from:

$$\gamma_{dry} = \frac{\gamma_{wet}}{1 + \frac{w_c(\%)}{100}}$$

The theoretical maximum dry unit weight assuming zero air voids is:

$$\gamma_{zav} = \frac{G_s \gamma_w}{1 + \frac{w_c G_s}{S_r}} = \frac{\gamma_w}{\frac{w_c}{S_r} + \frac{1}{G_s}}$$

Soil Compaction

I- Laboratory Compaction:

- ***Two Tests are usually performed in the laboratory to determine the maximum dry unit weight and the OMC.***

1- Standard Proctor Test

2- Modified Proctor Test

In both tests the compaction energy is:

$$E = \frac{\text{Number of blows per layer} \times \text{Number of layers} \times \text{Weight of hammer} \times \text{Height of drop of hammer}}{\text{volume of mold}}$$

Soil Compaction

1- Standard Proctor Test

Factors Affecting Compaction:

1- Effect of Soil Type

2- Effect of Energy on Compaction

3- Effect of Compaction on Soil Structure

4- Effect of Compaction on Cohesive Soil Properties

Field Compaction Equipment

There is a wide range of compaction equipment. The compaction achieved will depend on the thickness of lift (or layer), the type of roller, the no. of passes of the roller, and the intensity of pressure on the soil. The selection of equipment depends on the soil type as indicated.

Soil Compaction

Equipment	Most suitable soils	Least suitable soils
Smooth steel drum rollers (static or vibratory)	Well-graded sand-gravel, crushed rock, asphalt	Uniform sands, silty sands, soft clays
Pneumatic tyred rollers	Most coarse and fine soils	Very soft clays
Sheepsfoot rollers	Fine grained soils, sands and gravels with > 20% fines	Uniform gravels, very coarse soils
Grid rollers	Weathered rock, well-graded coarse soils	Uniform materials, silty clays, clays
Vibrating plates	Coarse soils with 4 to 8% fines	
Tampers and rammers	All soil types	

Soil Compaction

II- Field Compaction- ***Control and Specifications***

Control Parameter

Dry density and water content correlate well with the engineering properties, and thus they are convenient construction control parametersSince the objective of compaction is to stabilize soils and improve their engineering behavior, it is important to keep in mind the desired engineering properties of the fill, not just its dry density and water content. This point is often lost in the earthwork construction control.

Soil Compaction

Design-Construct Procedures

- **Laboratory tests are conducted on samples of the proposed borrow materials to define the properties required for design.**
- **After the earth structure is designed, the compaction specifications are written. Field compaction *control tests are specified, and the results of these become the standard for controlling the project.***

Soil Compaction

Specifications

(1) End-product specifications

This specification is used for most highways and building foundation, as long as the contractor is able to obtain the specified *relative compaction* , *how he obtains it doesn't matter, nor does the equipment he uses.*

(2) Method specifications **The type and weight of roller, the number of passes of that roller, as well as the lift thickness are specified. A maximum allowable size of material may also be specified. *It is typically used for large compaction project***

Soil Compaction

Relative Compaction (R.C.)

Determine the Relative Compaction in the Field Where and When

- **First, the test site is selected. It should be representative or typical of the compacted lift and borrow material. Typical specifications call for a new field test for every 1000 to 3000 m2 or so, or when the borrow material changes significantly. It is also advisable to make the field test at least one or maybe two compacted lifts below the already compacted ground surface, especially when sheepsfoot rollers are used or in granular soils.**

Soil Compaction

Method

- **Field control tests, measuring the dry density and water content in the field can either be *destructive or nondestructive.***

Destructive Methods

(a) **Sand cone**

(b) **(b) Balloon**

(c) **(c) Oil (or water) method**

Calculations

- **Know Ms and Vt**
- **Get ρd field and w (water content)**
- **Compare ρd field with ρd max-lab and calculate relative compaction R.C.**

Soil Compaction

Destructive Methods

Sometimes, the laboratory maximum density may not be known exactly. It is not uncommon, especially in highway construction, for a series of laboratory compaction tests to be conducted on "representative" samples of the borrow materials for the highway. If the soils at the site are highly varied, there will be no laboratory results to be compared with. It is time consuming and expensive to conduct a new compaction curve. The alternative is to implement a *field check point, or 1 point Proctor test.*

Soil Compaction

Check Point Method

- **1 point Proctor test**
- **Known compaction curves A, B, C**
- **Field check point X (it should be on the dry side of optimum)**
- **The measuring error is mainly from the determination of the volume of the excavated material.**

Soil Compaction

- For example,
- **For the sand cone method, the vibration from nearby working equipment will increase the density of the sand in the hole, which will gives a larger hole volume and a lower field density.**
- **If the compacted fill is gravel or contains large gravel particles. Any kind of unevenness in the walls of the hole causes a significant error in the balloon method.**
- **If the soil is coarse sand or gravel, none of the liquid methods works well, unless the hole is very large and a polyethylene sheet is used to contain the water or oil.**

Soil Compaction

Nuclear density meter

(a) Direct transmission

(b) Backscatter

(c) Air gap

Principles

Density

The Gamma radiation is scattered by the soil particles and the amount of scatter is proportional to the total density of the material. The Gamma radiation is typically provided by the radium or a radioactive isotope of cesium.

Soil Compaction

Water content

The water content can be determined based on the neutron scatter by hydrogen atoms. Typical neutron sources are americium-beryllium isotopes.

Calibration

Calibration against compacted materials of known density is necessary, and for instruments operating on the surface the presence of an uncontrolled air gap can significantly affect the measurements.

Examples