Soil Mechanics
Unit 4 - Compaction

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May 21^{st}, 2025

Programme

Day	08:00-09:30	09:45-11:15	13:00-14:30	14:45-16:15
19/05/25	Introduction	Programming	Phase Rel.	Tutorial
20/05/25	Classification	Tutorial	LAB	LAB
21/05/25	Compaction	Tutorial		
22/05/25	Groundwater	Tutorial	LAB	LAB
23/05/25	Groundwater	Tutorial		
26/05/25	Effective Str.	Tutorial	Stress Incr.	Tutorial
27/05/25	Compressib.	Tutorial	LAB	LAB
28/05/25	Consolidation	Tutorial		
29/05/25	Shear Str.	Tutorial	Shear.Str.	Tutorial
30/05/25	Shear Str.	Review		

Overview

Why is this lecture important?

Compaction is one of the most common procedures required for any construction project. It needs to be done properly!

Why is this lecture important?

It is not just dumping soil... This is only the beginning!

Some problems caused by (not so good) compaction

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Compaction and its objectives

- To decrease compressibility and reduce the likelihood of later settlement.
- To increase shear strength and improve stability and/or bearing capacity.
- To decrease permeability (by reducing the void ratio).
- To reduce swelling/shrinkage potential.

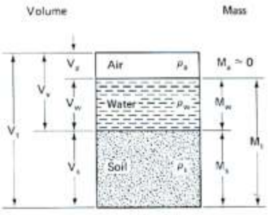
Compaction and water content

Think of the highway embankment under construction above... The water content of such a fill will depend on various factors including:

- **Clay content.** Sandy soils allow for easier water drainage.
- **Weather.** High temperatures contribute to evaporation.
- **Time of exposition**. There is chance of rainfall or prolonged drying.

What is compaction?

Remember your phase diagrams?



It is unlikely that the water content will change quickly (for fills with some fines content).

The mass of solids will not change during compaction, therefore compaction occurs at constant moisture content

Compaction is then the reduction of soil density due to the reduction of air voids volume only.

What materials can you compact?

Fine-grained soils? They have low permeabilities, difficult to expel water. Tend to be in the form of clumps or clods. These clumps are difficult to re-mould. Consider swelling/shrinking potential

Coarse-grained soils? Expensive if not available

Laboratory compaction

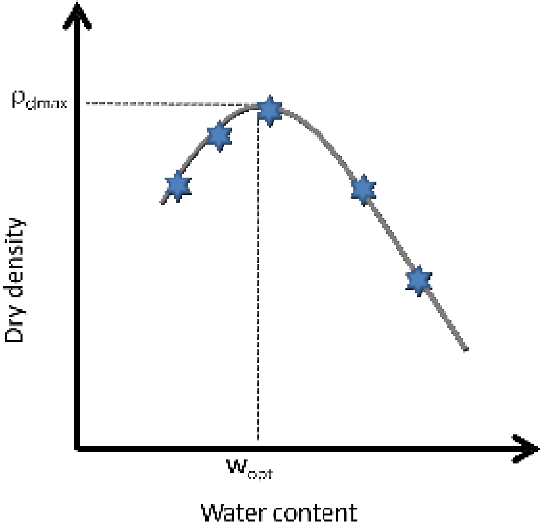
LIGHT COMPACTION:
Rammer = 2.5 kg
Falling height = 300 mm
Number of blows = 27
Number of layers = 3

HEAVY COMPACTION:
Rammer = 4.5 kg
Falling height = 450 mm
Number of blows = 27
Number of layers = 5

Procedure

1. Fill the mould using the appropriate number of soil layers and blows.
2. Extract the compacted soil out of the mould
3. Determine moisture content (w) and bulk density (ρ) .
4. Calculate the dry density (ρ_{dry})
5. Repeat five times using different amounts of water for the soil samples
6. Plot the results

Results and reporting



Calculation example

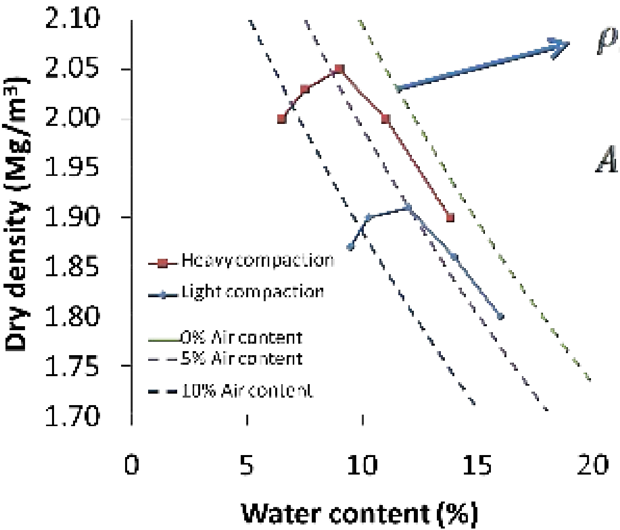
Calculate the optimum water content and the maximum dry density for the experimental data below:

Diameter of mould (cm) = 10.07
Height of mould (cm) = 11.54
Mass of mould (g) = 4258.00

Mass of soil and mould (g)	Mass of tin + wet soil (g)	Mass of tin + dry soil (g)	Mass of tin (g)
6070.00	98.03	94.65	46.67
6274.00	79.00	76.08	45.61
6218.00	77.32	73.73	45.67
6248.00	62.68	60.63	45.61
6232.00	86.33	80.34	45.61

We solve this using MS Excel... and the solution should be provided to you by your tutors. This is real data!

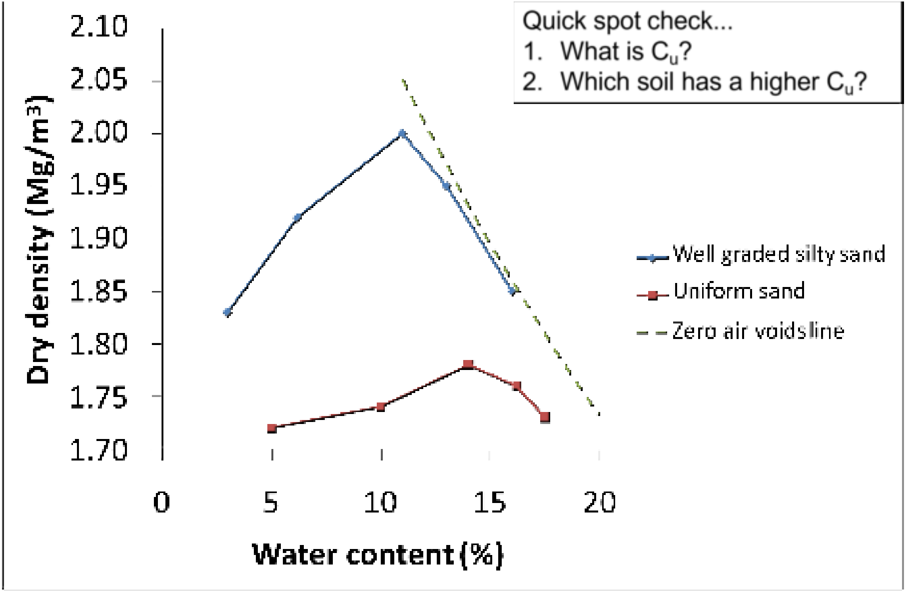
Compactive effort effects



$$\rho_{dry} = \frac{G_s(1-A)}{1+wG_s}$$

$A = \%$ Air content

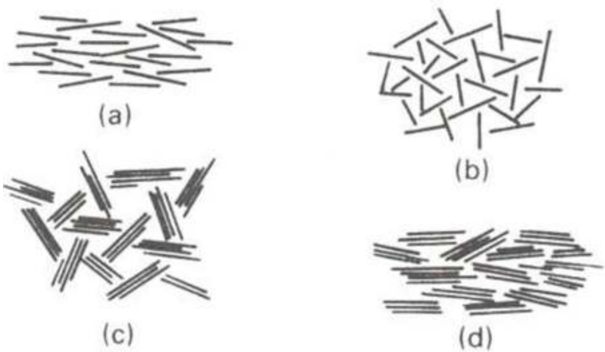
PSD effects



Quick spot check...

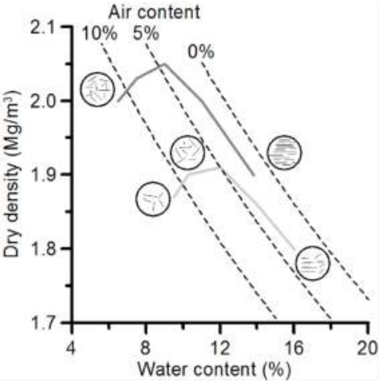
1. What is C_u?
2. Which soil has a higher C_u?

Mineralogy effects



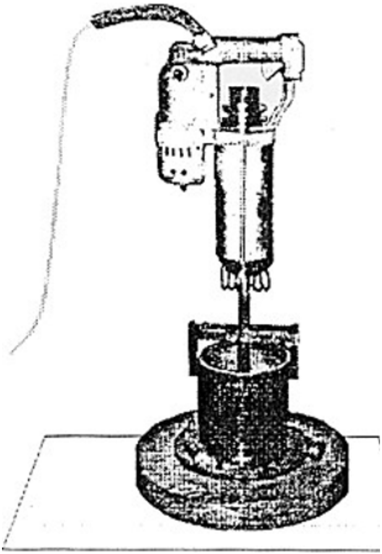
Different clay structures can be formed due to the different attractive/repulsive forces between clay minerals, and also due to the compactive state.

Mineralogy effects



- Flocculated structures form when soil is compacted at the dry side of the optimum
- Dispersed structures form when soil is compacted at the wet side of the optimum
- Both clay structure types are affected by the compactive effort
- Flocculated structures are stronger but they can swell much more
- Dispersed structures are more prone to shrinkage
- High pressures can reverse this tendency

Vibrating compaction test - Another possibility



Suitable for fine-grained soils

- Number of layers = 3
- Mould = 150 mm diameter
- Hammer = 750 W
- Load duration per layer = 60 s

Compaction the field

Practical considerations

- Compact as close to w_{opt} as possible.
- If $w < w_{opt}$ soils could be stiff and difficult to compact. Also for these values of S and ρ_{dry} diminish rapidly. Compaction curve is steeper on the dry side.
- If w increases soils become more workable. Do not go too far after $w > w_{opt}$.
- Saturation might be reached only at very high values of w.

Moisture content control

Moisture content control

Practical considerations

- A required number of passes is required to achieve a desired value of maximum dry density (usually 3-12)
- Number of passes depends on machinery and thickness of soil layer
- Do not over do it. After a certain number of passes there is no significant increase in dry density. Be aware of over-compaction effects.
- The thicker the soil layer the heavier the equipment required for compaction.

Specification of compaction

You as the geotechnical designer often need to request that the compaction is done in such a way that a good outcome is guaranteed. You can do this in two ways:

METHOD COMPACTION: Specifies type and mass of equipment as well as layer depth and number of passes. Normally used for earthworks. (For example, the contractor must be told that he/she must compact the soil using a roller compactor in layer of 35 cm and doing 3 passes of the roller for each layer)

END-PRODUCT COMPACTION: Specifies the required dry density. For example, the works must achieve a maximum dry density within a minimum of 90% of w_{opt}. Frequently used for specific fills (i.e. fuel ashes). (In this case you do not mind how the contractor does the compaction, but you will need confirmation that a certain dry density was indeed achieved)

Compaction equipment

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Compaction equipment

Recap

- What is compaction? What are its objectives?
- Describe a few consequences of ineffective compaction.
- What type of soils can you use for the compaction of fills? ‘
- Describe the process to perform a laboratory compaction test
- What is the objective (i.e. outcome) of a laboratory compaction test?
- What is the maximum dry density? How do you determine it?
- What is the optimum water content?
- You need to be able to calculate both the maximum dry density and optimum water content from experimental data
- What determines the compactive effort? How does it affect the results?
- What is the effect of the particle size distribution on compaction results?
- What is the difference between a dispersed and a flocculated clay structure? Which one is more prone to shrinkage? Why?
- What is the difference between method compaction and end-product compaction?

Before the break...

Are there any questions?