Module 2: Index properties (Part 1)

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COURSE CONTENTS AND SCHEDULE

Department of
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Tentative schedule

Day	Date	Topic	Lab.
W	1/19/2022	Class introduction, syllabus, policies	Soil
F	1/21/2022	Invited speaker: Topic TBD	components
M	1/24/2022	Introduction: The geological cycle, soil origin	Grain size
W	1/26/2022	Introduction: Site investigation	dist.
F	1/28/2022	Index properties: Phase relationships	
M	1/31/2022	Index properties: Grain size distribution, Atterberg limits	Atterberg
W	2/2/2022	Index properties: Soil classification	limits
F	2/4/2022	Compaction	
M	2/7/2022	Quiz 1: Introduction, index properties, compaction, in-situ testing	Visual
W	2/9/2022	Water in soils: Groundawater table, pore pressure, total and effective stresses	classification
F	2/11/2022	Water in soils: Darcy's law	
M	2/14/2022	Water in soils: Permeability and hydraulic conductivity	Compaction
W	2/16/2022	Water in soils: One-dimensional seepage	
F	2/18/2022	Water in soils: 2D-3D seepage, flow nets, pore pressure, uplift force, seepage force	
M	2/21/2022	President's day: no class	In-situ
W	2/23/2022	Water in soils: piping	density
F	2/24/2022	Quiz 2: Water in soils	
M	2/28/2022	Induced stress: Approximations, Bousinesq's elastic solution	Permeability
W	3/2/2022	Induced stress: Bousinesq's elastic solution, superposition	
F	3/4/2022	Induced stress: Stress tensor, elastic deformations	
M	3/7/2022	Consolidation: Oedometer test, primary and secondary consolidation	Site
W	3/9/2022	Consolidation: Preconsolidation pressure, OCR	investigation
F	3/11/2022	Consolidation: Primary consolidation parameters	
M	3/14/2022	Spring break: no class	
W	3/16/2022	Spring break: no class	
F	3/18/2022	Spring break: no class	
M	3/21/2022	Consolidation: rate of consolidation	Bonus
W	3/23/2022	Consolidation: preloading, radial consolidation	
F	3/25/2022	Quiz 3: Induced stress and consolidaiton	
M	3/28/2022	State of stress: 2D stresses and Mohr's circle	Consolidation
W	3/30/2022	State of stress: principal stresses, stress invariants, rotations	
F	4/1/2022	State of stress:: Usage of Mohr's circle	
M	4/4/2022	State of stress: stress paths, simple shear, triaxial compression	Settlement
W	4/6/2022	Quiz 4: State of stress	estimates
F	4/8/2022	Shear strength: Mohr-Coulomb failure criteria	
M	4/11/2022	Shear strength: drained and undrained behavior	Unconfined
W	4/13/2022	Shear strength: Shear strength of clays	compression
F	4/15/2022	Shear strength: Shear strength of sands	test
M	4/18/2022	Quiz 5: Shear strength	Direct
W	4/20/2022	Lateral earth pressure: at-rest, passive, and active conditions [2]	shear
F	4/22/2022	Intro to slope stability [2]	
M	4/25/2022	Intro to bearing capacity [2]	Direct
W	4/27/2022	Maine's day: no class	shear
F	4/29/2022	Classes end: Q&A session	
M	5/2/2022	Final exam (1:30 PM- 3:30 PM) Williams Hall 110	

M: Monday - W: Wednesday - F: Friday

[2] This items may or may not be covered. It will be determined by how far the course has progressed.

RECAP

- Some aspects of site investigations were discussed.
- We learned about some site exploration techniques.
- We learned the difference between intact and disturbed samples.
- We learned how geotechnical/geological profiles are made.
- We will learn how to analyze the various soil phases today.

CONTENTS

- Soil phases
- Important definitions
- Phase diagram
- Volume and weight relations
- Practical examples

More in chapter 2 of Holtz et al. (2013)

UNIT SYSTEMS

Dimension	SI	Imperial	Conversion factor
Length	cm/m	in/ft	0.394/3.281
Mass	kg	slug	0.0685
Force	N	lb	0.225
Gravity	9.81 m/s^2	32.17 ft/s^2	-
Unit weight of water	9.81 kN/m^3	62.4 pcf	-

IMPORTANT UNIT WEIGHT RELATIONS

In general the density of a material is:.

$$\rho = m/V$$

And its unit weight is:

$$\gamma = W/V = mg/V = g\rho$$

The specific gravity of a solid is:

$$G_s = \rho_s/\rho_w = \gamma_s/\gamma_w$$

With:

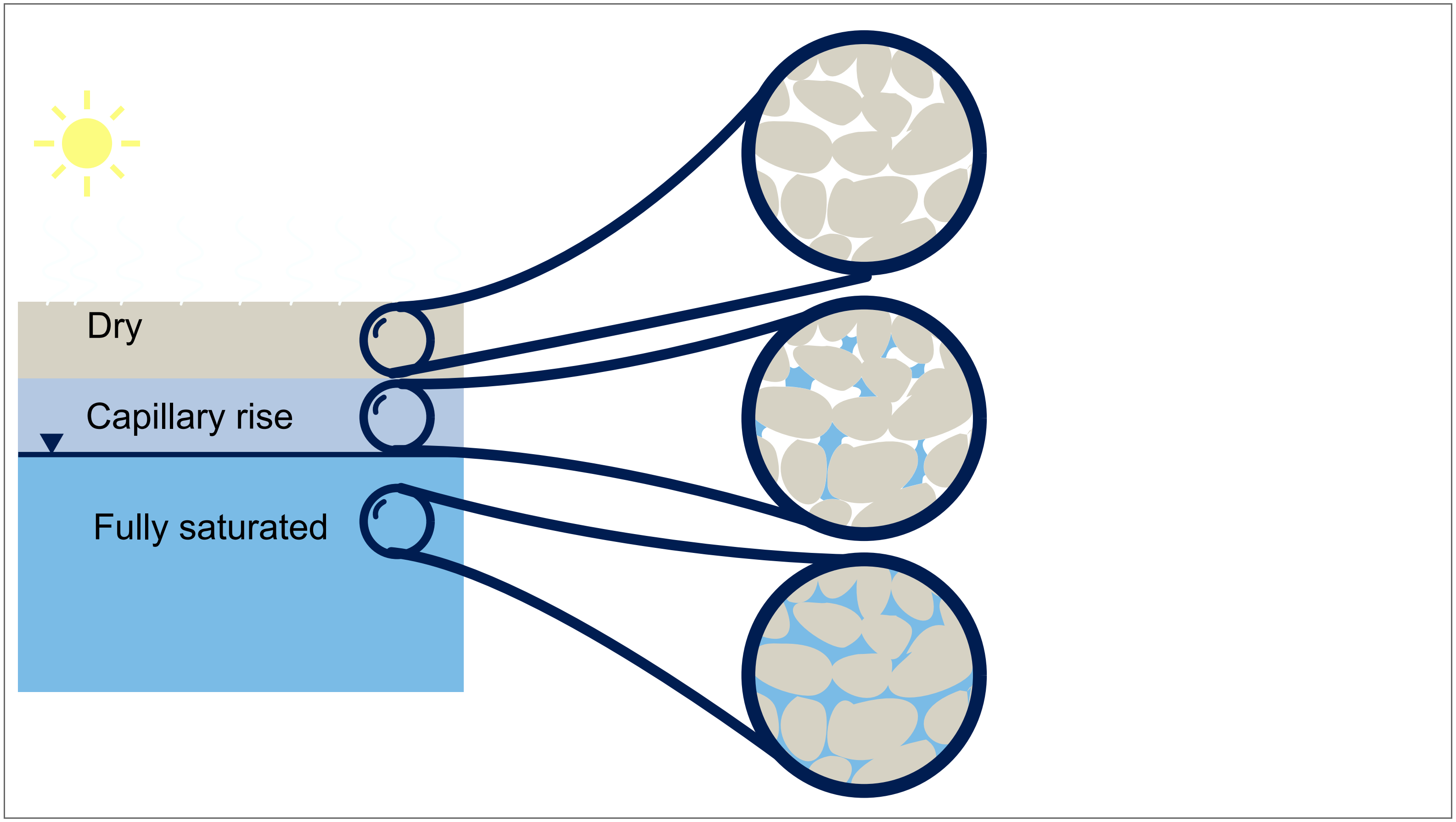
- m : Mass
- V : Volume
- W : weight
- g : Gravity
- $\rho_w = 1000 \text{ kg/m}^3$
- $\gamma_w = 9.81 \text{ kN/m}^3$

SPECIFIC GRAVITY OF COMMON MINERALS

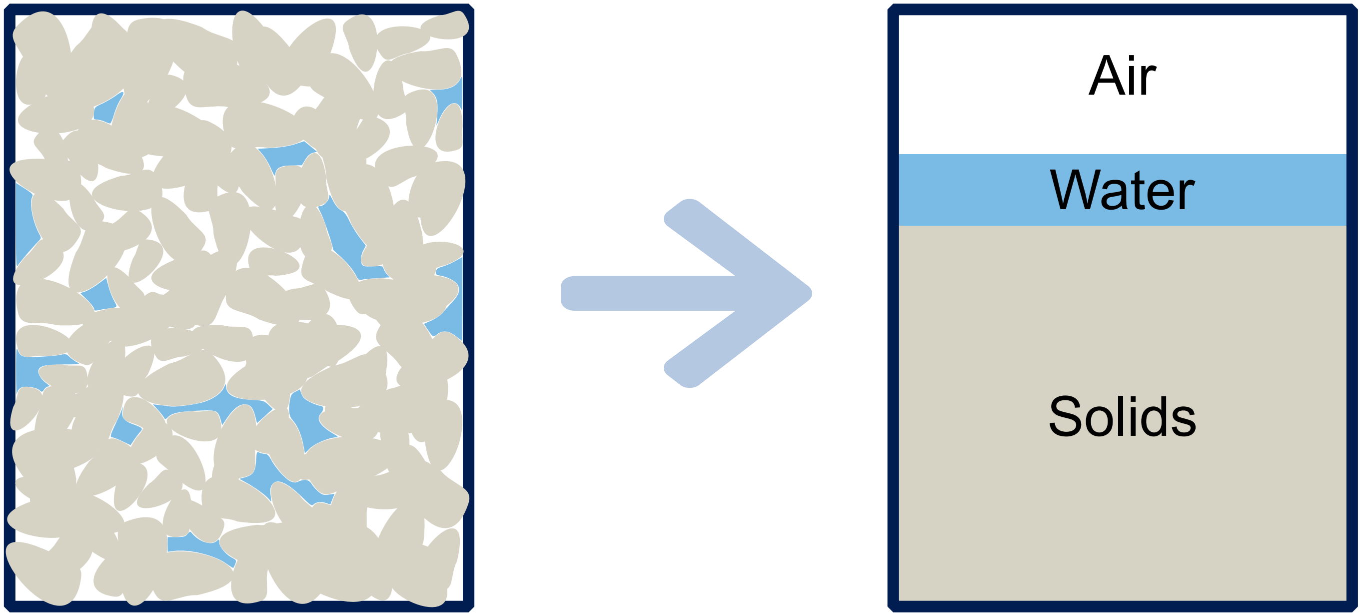
Mineral	Formula	G_s
Calcite	$CaCO_3$	2.71
Feldspar	-	2.6
Hematite	Fe_2O_3	5.2
Kaolinite	$Al_2Si_2O_5(OH)_4$	2.61-2.66
Mica	-	2.9
Quartz	SiO_2	2.65

a) CSP b) FSP

SOIL PHASES



PHASE DIAGRAM



VOID RATIO, POROSITY, AND SATURATION

- Void ratio is defined as:

$$e = V_v/V_s$$

- Porosity is defined as:

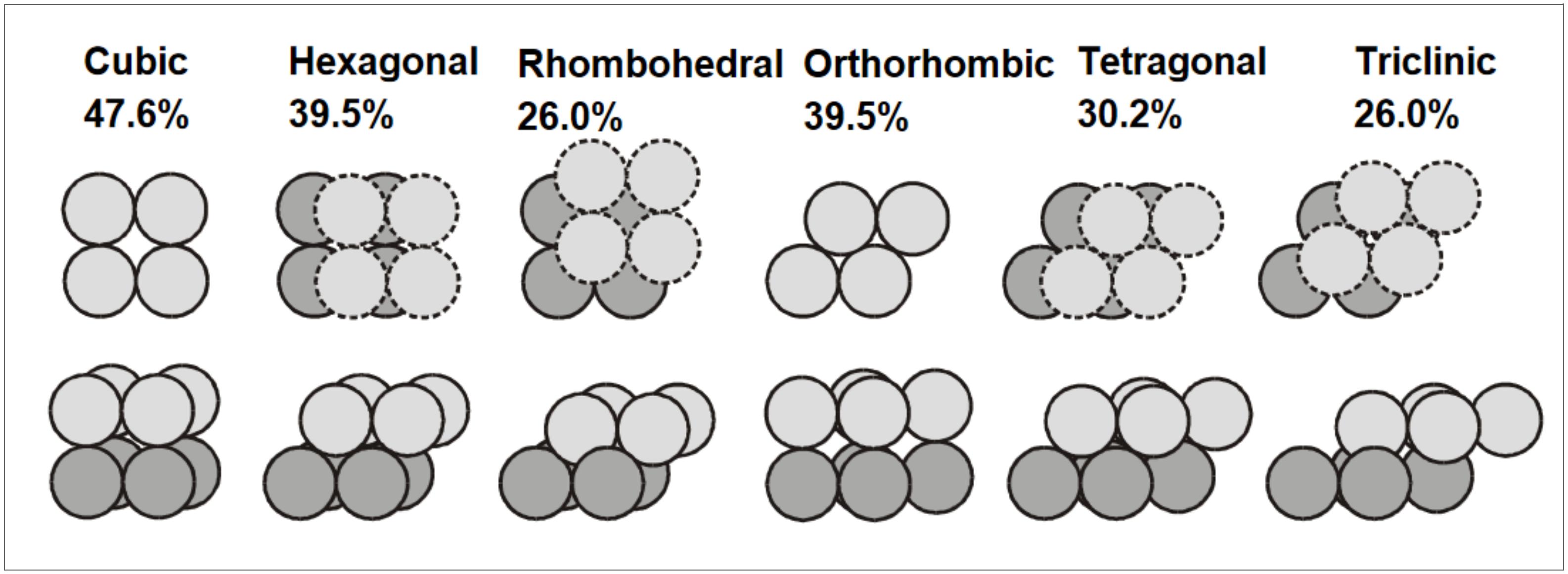
$$n = V_v/V_t$$

- And saturation:

$$S[\%] = \frac{V_w}{V_v} \times 100$$

- V_v = Volume of voids
- V_w = Volume of water
- V_s = Volume of solids

Porosity of uniform spherical particles.



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RELATIVE DENSITY

The relative density can be used to partially describe the arrangement of coarse soils:

$$D_r[\%] = \frac{e_{max} - e}{e_{max} - e_{min}} \times 100$$

- $e = e_{min} \longrightarrow$ Densest state
- $e = e_{max} \longrightarrow$ Loosest state

UNIT WEIGHT OF SOILS

- Total unit weight:

$$\gamma_t = W_t/V_t$$

- Dry unit weight $S = 0\%$

$$\gamma_d = W_s/V_t$$

- Saturated unit weight $S = 100\%$:

$$\gamma_{sat} = W_{sat}/V_t$$

- Buoyant unit weight:

$$\gamma' = \gamma_{sat} - \gamma_w$$

Typicall soil unit weight. Modified from Holtz et al. 2013

	γ_{sat}		γ_d		γ'	
S. type	kN/m^3	pcf	kN/m^3	pcf	kN/m^3	pcf
Sands and gravels	19-24	119-150	15-23	94-144	9-14	62-81
Silts and clay	14-21	87-131	6-18	37-112	4-11	25-69
Glacial tills	21-24	131-150	17-23	106-144	11-14	69-87
Crushed rock	19-22	119-137	15-20	94-125	9-12	56-75
Peats	10-11	60-69	1-3	6-19	0-1	0-6
Organincs silt and clay	13-18	81-112	5-15	31-94	3-8	19-50

WATER CONTENT

Gravimetric water content

$$w = \frac{W_w}{W_s} \times 100$$

We showed that:

$$\gamma_t = \gamma_d(1 + w/100)$$

Volumetric water content:

$$\Theta = \frac{V_w}{V_t}$$

If $S = 100\%$:

$$\Theta = n$$

OTHER USEFUL PHASE RELATIONS

For unit weight:

$$\gamma_t = \frac{\gamma_w(G_s + Se)}{1 + e}$$

$$\gamma_d = \frac{\gamma_w G_s}{1 + e}$$

$$\gamma_{sat} = \frac{\gamma_w(G_s + e)}{1 + e}$$

Relation between saturation, void ratio, specific gravity, and water content:

$$Se = wG_s$$

To remember: structural engineers are wacky guys 😂

EXAMPLE 2.1

A water content test was made on a sample of silty clay. The weight of the wet soil plus container was 17.53 g, and the weight of the dry soil plus container was 7.84 g. Calculate the water content of the sample.

EXAMPLE 2.2

A sample of fully saturated clay with $G_s = 2.66$ weighs 1350 g in its natural state and 975 g after drying. Solve:

1. The natural water content.
2. Void ratio and porosity.
3. Total or wet unit weight.
4. Dry unit weight.

EXAMPLE 2.3

A cylinder contains 500 cm^3 of loose dry sand which weighs 750 g, and under static load of 200 kPa the volume is reduced 1%, and then by vibration it is reduced 10% of the original volume. Assume the specific gravity of the sand is $G_s = 2.65$. Compute the void ratio, porosity, dry unit weight, and total unit weight corresponding to each of the following cases:

1. Loose sand.
2. Under static load.
3. Vibrated and loaded sand.