Module 5: Induced stress

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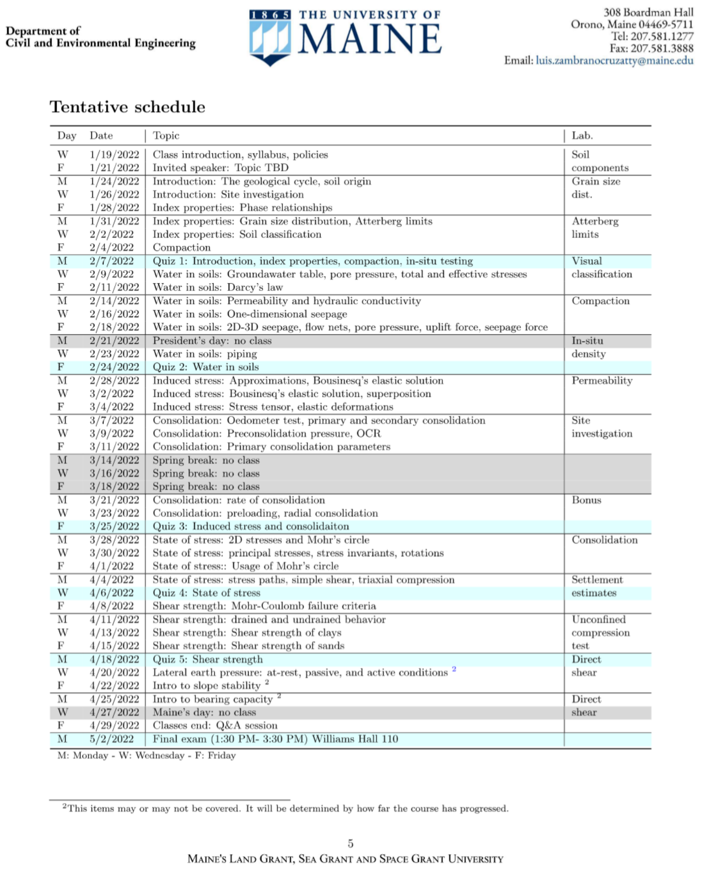
COURSE CONTENTS AND SCHEDULE



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Tentative schedule

Day	Date	Topic	Lab.
W	1/19/2022	Class introduction, syllabus, policies	Soil components
F	1/21/2022	Invited speaker: Topic TBD	
M	1/24/2022	Introduction: The geological cycle, soil origin	Grain size dist.
W	1/26/2022	Introduction: Site investigation	
F	1/28/2022	Index properties: Phase relationships	
M	1/31/2022	Index properties: Grain size distribution, Atterberg limits	Atterberg limits
W	2/2/2022	Index properties: Soil classification	
F	2/4/2022	Compaction	
M	2/7/2022	Quiz 1: Introduction, index properties, compaction, in-situ testing	Visual classification
W	2/9/2022	Water in soils: Groundawater table, pore pressure, total and effective stresses	
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 density
W	2/23/2022	Water in soils: piping	
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 investigation
W	3/9/2022	Consolidation: Preconsolidation pressure, OCR	
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 estimates
W	4/6/2022	Quiz 4: State of stress	
F	4/8/2022	Shear strength: Mohr-Coulomb failure criteria	
M	4/11/2022	Shear strength: drained and undrained behavior	Unconfined compression test
W	4/13/2022	Shear strength: Shear strength of clays	
F	4/15/2022	Shear strength: Shear strength of sands	
M	4/18/2022	Quiz 5: Shear strength	Direct shear
W	4/20/2022	Lateral earth pressure: at-rest, passive, and active conditions [2]	
F	4/22/2022	Intro to slope stability [2]	
M	4/25/2022	Intro to bearing capacity [2]	Direct shear
W	4/27/2022	Maine's day: no class	
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

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

RECAP

- We learned about flow nets and how to use them to calculate flow, total head, and pore pressure.
- We learned how to compute the factor of safety againts uplift.
- We learned how to calculate the critical hydraulic gradient and the maximum hydraulic gradient.
- We learned how to calculate the factor of safety againts piping.
- We learned what factor can be controlled to prevent piping.
- Today we will learn about induced stresses in soils (effects of external loading).

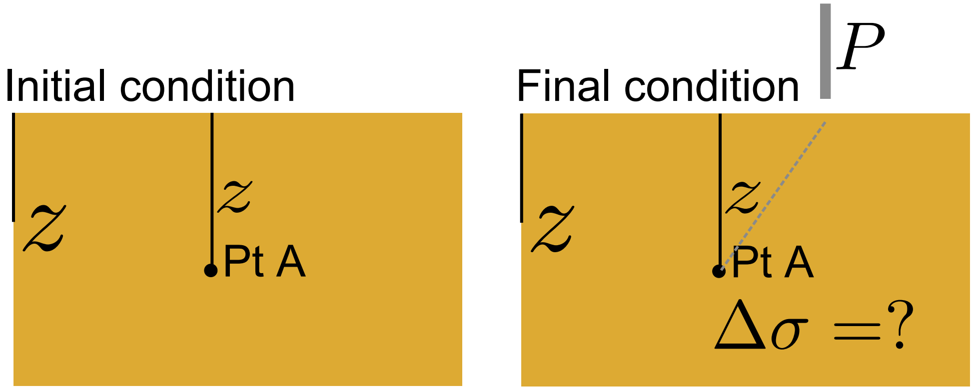
CONTENTS

- Increment of stress due to an infinitely loaded area.
- Increent of stress due to a point load (Bousinesq equation).
- Numerical approximation.
- Practical exmples.

More in chapter 7 of Budhu (2015) and CIE-460

INDUCED STRESSES

Induced stress is the increment of stress produced by an external action relative to a initial condition .



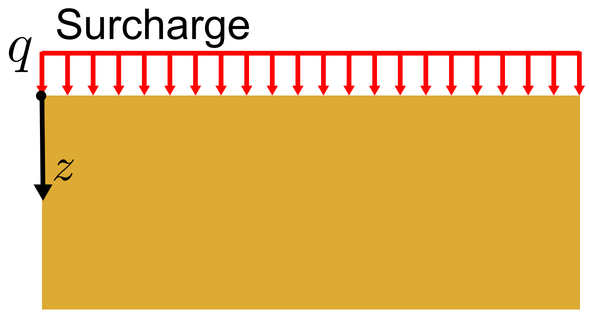
$$\sigma_f = \sigma_0 + \Delta\sigma$$

These stresses are absorbed either by the water as excess water pressure or by the soil skeleton as effective stresses . With enough time, the soil skeleton will finally carry the generated stress.

INFINITELY LOADED AREA

When the external load extends considerably in both directions at the surface, it can be modeled as an infinitely loaded area.

Idealization



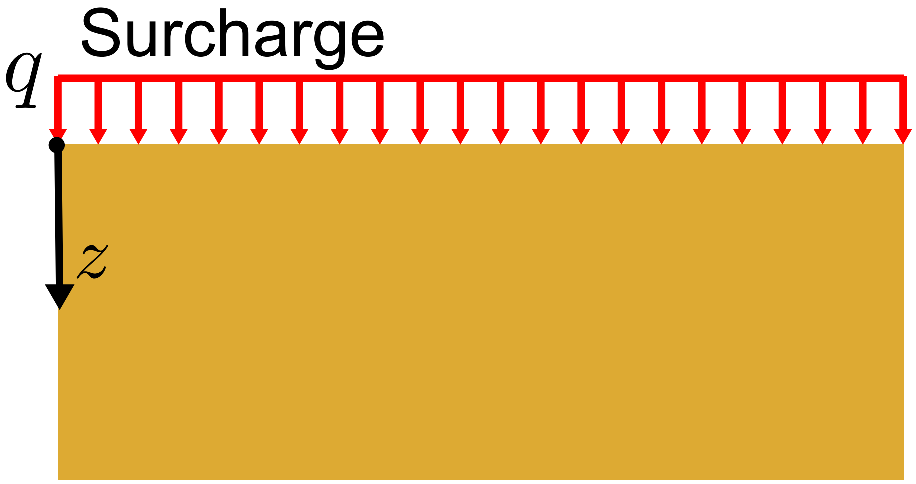
Example

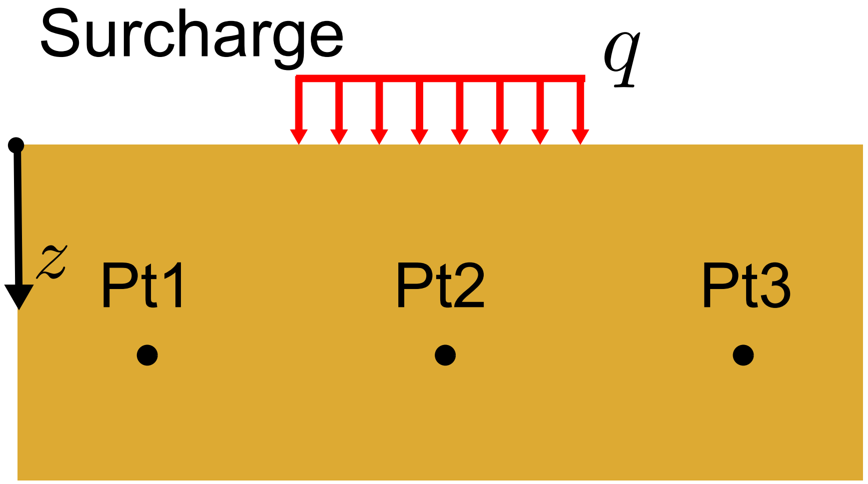
The increment of stress for the idealized model is independent of position and depth.

$$\Delta\sigma = q$$

INFINITELY LOADED AREA

In many cases, loads at the surface are not infinitely extended or uniformly distributed. Other models are needed.





What is the relationship between $\Delta\sigma_1$, $\Delta\sigma_2$, and $\Delta\sigma_3$

BOUSSINESQ EQUATION

- French mathematician and physicist who made contributions to the theory of hydrodynamics, vibration, light, and heat.
- He derived an equation to find the stress distribution in a semi-infinite elastic medium due to a point load acting on its surface.
- These equations are closed form solutions derived using continuum mechanics principles and its derivation is not straighforward.

Joseph Boussinesq (1842-1929)

STRESS DISTRIBUTION DUE TO A POINT LOAD

Boussinesq's equation for the stress distribution in a elastic semi-infinite medium is:

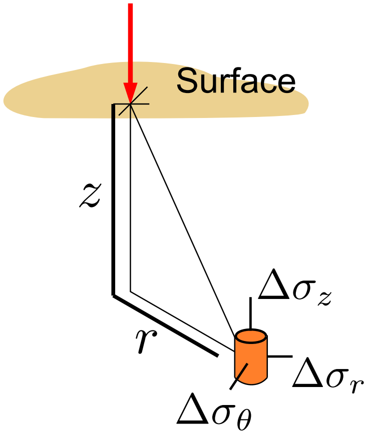
$$\Delta\sigma_z = \frac{3Q}{2\pi z^2\left[1+(r/z)^2\right]^{5/2}}$$

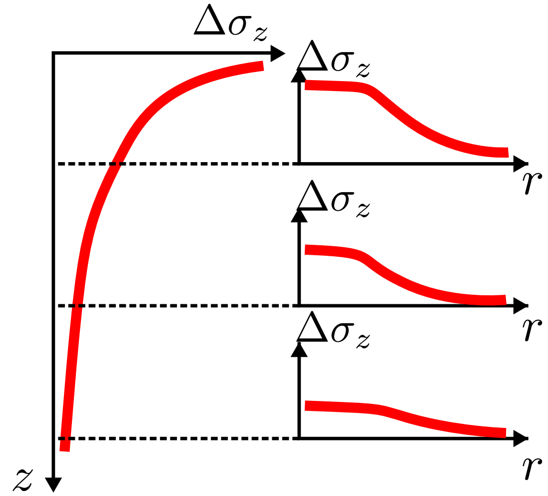
$$\Delta\sigma_z = QI$$

$$I = \text{influence factor}$$

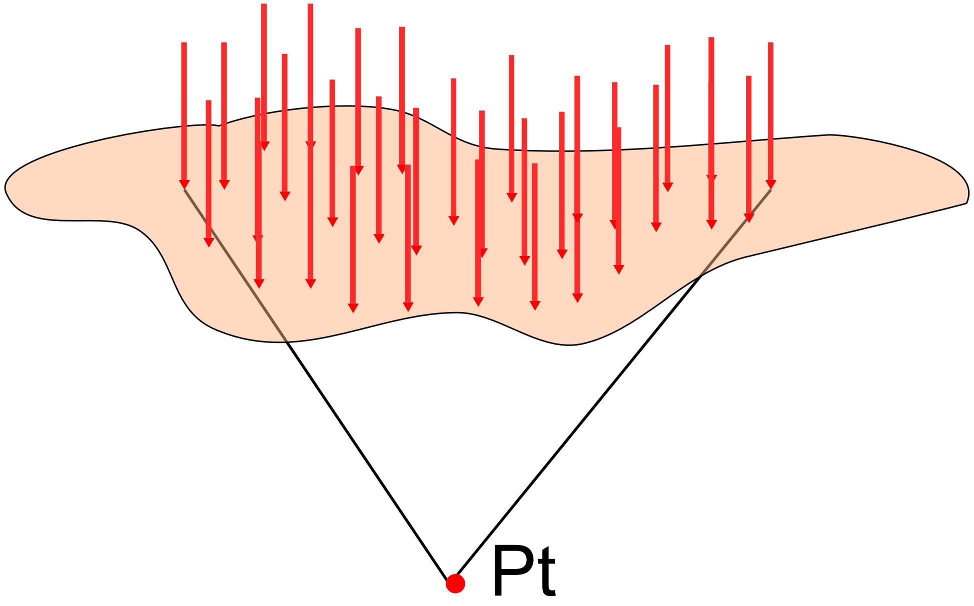
Assumptions:

- Continous material
- Isotropic
- Uniform
- Linear elastic





SUPERPOSITION AND NUMERICAL APPROXIMATION



- A_i = discretized area.

- The principle of superposition implies that the effect of multiple loads can be taken into account by simple addition.
- For complex load distributions and shapes use a numerical approximation:

$$\Delta\sigma_z = \sum_{i=1}^{n} q_i A_i I_i$$

ADVANCE NUMERICAL MODELS