SOIL MECHANICS

Hydrogeological engineering MSc.

2020/21 I. semester

COMMUNICATION FILE OF THE COURSE

University of Miskolc
Faculty of Earth Science and Engineering
Institute of Environmental Management

Contents

1. Course description, Responsible Instructor, Number of lectures and seminars, Credits
2. Topics of the subject (by hours)
3. Sample of a mid-term exam
4. Topics of the exam
5. Others

1. Course description, Responsible Instructor, Number of lectures and seminars, Credits

<table>
<tr><td>Course Title: Soil mechanics

Instructor: Dr. Tamás KÁNTOR assistant professor, Dr. Viktória MIKITA assistant professor</td><td>Code:MFKHT710008

Responsible department/institute: Deparment of Hydrogeology and Engineering Geology
Type of course:Compulsory</td></tr>
<tr><td>Position in curriculum (which semester): 1</td><td>Pre-requisites (if any): -</td></tr>
<tr><td>No. of contact hours per week (lecture + seminar): 2+1</td><td>Type of Assessment (examination/ practical mark / other): exam</td></tr>
<tr><td>Credits:4</td><td>Course: full time</td></tr>
<tr><td colspan="2">Course Description:
The students will be familiar with the basic concepts of soil mechanics. They will learn about the determination soil parameters, soil classification. After a short review the students will study the main topics of applied soil mechanics, in the interest of being able to manage interactions between buildings/objects and subsoil, to solve, handle or expertise occurring problems (construction, building, damages).
The short curriculum of the subject:
Bearing capacity of soils, foundations. Settlement and consolidation of foundations, solution to problems of stabilitay and settlement. Foundations and embankments over soft soil and peat. Determination of earth pressure, active and passive earth pressure. Stability analysis of natural and artificial slopes, factors in slope designe, reconstruction of landslides. Retaining walls, gravity walls, reinforced earth walls, embedded walls. Geotechnical aspects of deep foundations, excavations and hydraulic engineering. Geotechnical problems of open pit mining. Geosynthetics. Geotechnical objects of environmental protection. Engineering geological mapping.
Practical work: self-made solutions of simple case-study problems.</td></tr>
<tr><td colspan="2">Compatencies to evolve:
Knowledge:
T3 – Thorough understanding of the concepts and principles of engineering geology and civil engineering and their processes.
T4 – Have a working knowledge of computer-aided design and analysis
T7 – Have knowledge of a wide range of problem-solving techniques for research or academic work.
Ability:
K7 – Prepared to identify and solve geotechnical problems.
K12 – Ability to work in compliance with EU legislation, to cooperate with foreign partners to solve the tasks required by the EU Water Framework Directive
K13 – The ability to independently participate in and manage research, development and expertise in the field of hydrogeology
K15 – Ability to solve complex problems in a flexible way through creative problem solving, to work in a team, to think and cooperate effectively with representatives of other disciplines (e.g. environment, quality, consumer protection, human health, construction, etc.)
Attitude:
A2 – Open and sensitive to problems and sustainability issues related to the environment and its elements
A9 – In addition to his technical and engineering background, he also has an interest in science.
Autonomy and responsibility:
F1 – Act independently and proactively to solve professional problems.
F2 – Have a responsible attitude towards the environment.
F5 – Committed to sustainable natural resource management practices.
F6 – He/she is responsible claims in expert oppinions, professional judgements and for the work carried out under his/her supervision.</td></tr>
</table>

Assessment and grading:

Students will be assessed with using the following elements.

Attendance:	15 %
Midterm exam	35 %
Exam	50 %
Total	100%

Grading scale:

% value	Grade
90 -100%	5 (excellent)
80 – 89%	4 (good)
70 - 79%	3 (satisfactory)
60 - 69%	2 (pass)
0 - 59%	1 (failed)

Compulsory or recommended literature resources:

- J.A. Knappett, R.F. Craig: Craig's soil mechanics, Eight edition, Spon Press, London 2012.
- Atkinson, J.: The Mechanics of Soils and Foundations. Taylor and Francis, London, 2007.
- Jonathan Knappett, R.F. Craig: Craig's Soil Mechanics, Eighth Edition, 2012.
- Braja M. D.: Advanced soil mechanics, Spon Press, 2008
- Smith G. N., Smith I. Smith G. N.: Elements of soil mechanics, Wiley-Blackwell, 1998
- Mitchell, J. K., Soga, K.: Fundamentals of Soil Behaviour, John Wiley, 2005

2. Topics of the subject (by hours)

Soil mechanics.
Topics of the subject (Plan of the semester)
Autumn semester
Hydrogeological engineering MSc, 1. semester

Date	Topic of lecture and seminar
2020.09.07.	Introduction (requirements, thematic, time schedule, Soil mechanics)
2020.09.14.	Soil as a three phase system, Basic characteristics of soils, origin of soils, structure of soils
2020.09.21.	Site investigation methods
2020.09.28.	*Field practice*: sampling, sounding, penetrométer test, light drop weight tester
2020.10.05.	Classification of inorganic soils, Granular soils, Sieve test, Hydrometer test
2020.10.12.	Classification of inorganic soils, Cohesive soils, Consistency limits
2020.10.19.	*Laboratory practice*: Consistency limits, Hydrometer
2020.10.26.	Compaction of soils, Proctor test, field methods
2020.11.02.	**Rectorial break**
2020.11.09.	Shear strength of soils
2020.11.16.	*Laboratory practice*: Triaxial test, Uni-axial test, Direct shear test
2020.11.23.	Stresses in soils
2020.11.30.	Midterm exam 1st chance
2020.12.07.	Midterm exam 2nd chance

3) Sample of a mid-term exam

Soil mechanics
Mid-term exam
2018-12-03

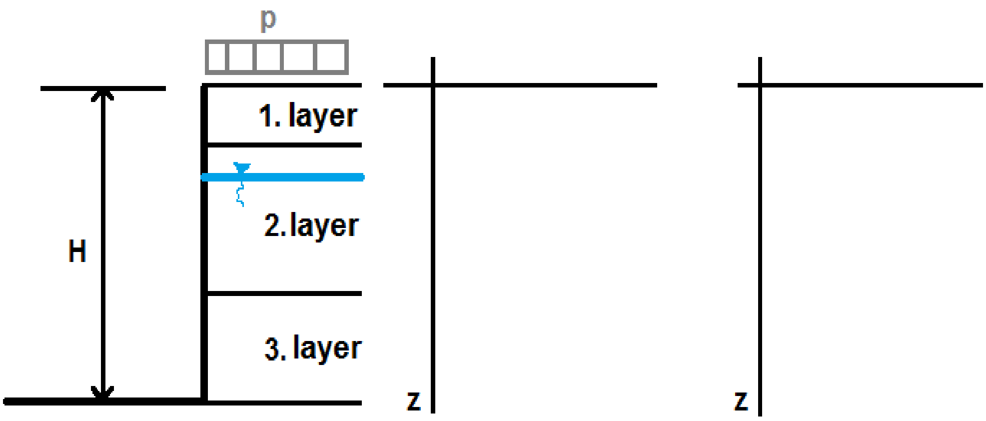
1. We had a cylindrical sample from clay (ρ_{solid} = 2,71 g/cm3) with the following parameters: the diameter is 8 cm, the height is 15 cm, wet mass is 1111 g. After drying (24h, 105 °C) the mass reduces to 1011 g. Calculate the value of void ration / porosity / wet, dry and saturated densities / saturation / ration of liquids, solids and air in the system.

2. There is a cylindrical soil sample with the following parameters D = 4,0 cm, h= 6,0 cm. During an uniaxial measurement we measured the axial displacement (Δh) and the changes of diameter (D).

   1. step: strains were linear with the stresses.
   F_1= 210 N, Δh_1 = 3,70 mm, D_1= 41,2 mm
   2. step: at the end of the step the sample was broken
   F_2= 470 N, D_1= 43,1 mm, α= 59°

   Determine the elastic properties (Young modulie, Poisson ration), and the shear parameters (Internal friction and cohesion) of the soil!

3. Describe the geostatic earth pressure in the following geological structure with given external stress (p)! Calculate the total, effective and neutral stresses and describe these on the graphs.



	soil	hi (m)	ρi (g/cm3)
1. layer	gravel	0,7	1,860
2. layer	dry sand	0,3	1,950
	wet sand	1,0	2,050
3. layer	silt	0,8	2,100
p =	30 kN/m2		

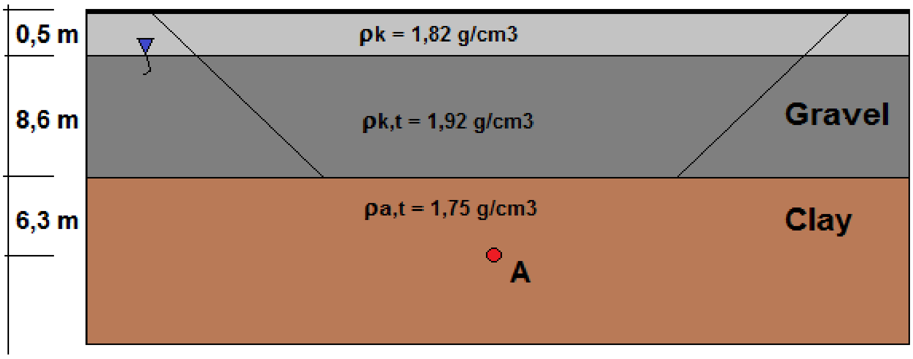
4. After a Proctor test we can describe the results with the following equation. Calculate the optimal water contant and the maximum dry density.

$$y = -0{,}0112\,x^2 + 0{,}1471\,x + 1{,}0010$$

5. Calculate the points of grain size distribution curve of mixture of A and B soil if the mixing ratio is 2/5!

d (mm)	S% Soils		
	A	B	Mixture
0032	100		
16	93		
8	79	100	
4	51	98	
2	33	91	
1	17	83	
0,5	11	74	
0,25	7	55	
0,125	3	36	
0,063	1	19	
0,05	0	11	
0,02		5	
0,01		1	
0,002		0	

6. Determine the stress (vertical and horizontal) situations in the A point before and after of mining out the gravel layer. (total, effective and neutral stresses). Internal friction on clay is 21°.



Key of mid-term exam

1.

void ration	**e =**	**1,021 -**
porosity	**n =**	**0,505 -**
wet density	**ρw =**	**1,474 g/cm3**
dry density	**ρd =**	**1,341 g/cm3**
saturated density	**ρsr =**	**1,846 g/cm3**
saturation	**Sr =**	**0,263 -**
ration of liquids	**l% =**	**0,133 -**
ration of solids	**s% =**	**0,495 -**
ration of air	**a% =**	**0,373 -**

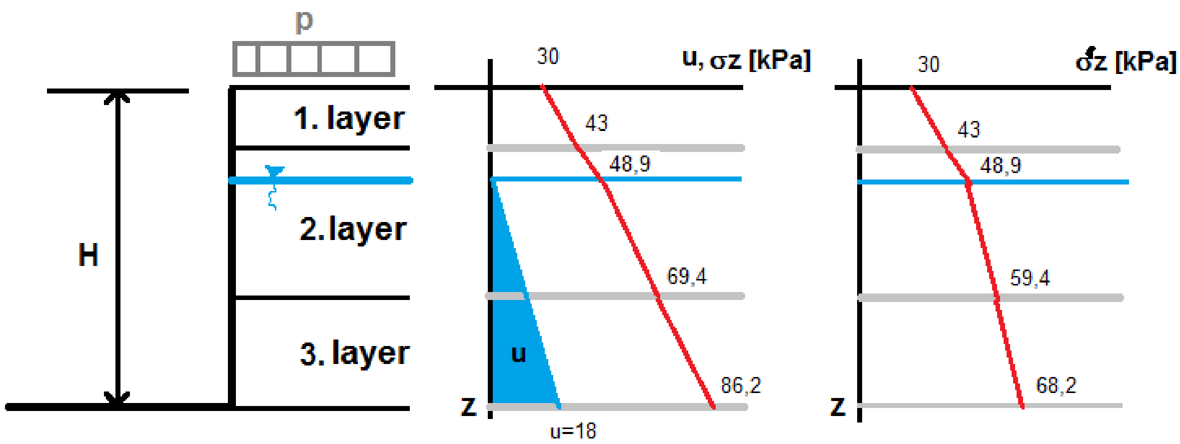
2.

σz1 = 157,5 kN/m2 **εz1 = 6,2 %**
σz2 = 322,1 kN/m2 **εx1 = -3,0 %**

internal friction **Φ = 28°**
cohesion **c = 96,8 kN/m2**

Young modulie **E = 2554,4 kN/m2**
Poisson number **μ = 0,486 -**

3.



4.

w opt = 6,57 %
ρ D max = 1,484 g/cm3

5.

d (mm)	S% Soils		
	A	B	Mixture
0032	100		**100**
16	93		**98**
8	79	100	**94**
4	51	98	**84,6**
2	33	91	**74,4**
1	17	83	**64,1**
0,5	11	74	**56**
0,25	7	55	**41,3**
0,125	3	36	**26,6**
0,063	1	19	**13,9**
0,05	0	11	**7,9**
0,02		5	**3,6**
0,01		1	**0,7**
0,002		0	**0**

6.

Before mining

$\sigma_{vert. A}$ **= 284,5 kPa**
u_A **= 149 kPa**
$\sigma'_{vert. A}$ **= 135,5 kPa**
$\sigma'_{horiz. A}$ **= 86,9 kPa**
$\sigma_{horiz. A}$ **= 235,9 kPa**

After mining

$\sigma_{vert. A}$ **= 196,3 kPa**
u_A **= 149 kPa**
$\sigma'_{vert. A}$ **= 47,3 kPa**
$\sigma'_{horiz. A}$ **= 51,3 kPa**
$\sigma_{horiz. A}$ **= 200,3 kPa**

4) Sample of an exam

MISKOLCI EGYETEM
Környezetgazdálkodási Intézet
Hidrogeológiai-Mérnökgeológiai
Intézeti Tanszék

UNIVERSITY OF MISKOLC
Institute of Environmental Management
Department of Hydrogeology and
Engineering Geology

SOIL MECHANICS
Exam
2018-01-09

5

Answer shortly (10-15 sentences) the following questions! If possible, draw a diagram, or a curve for demonstration!

1. *Describe the compaction of soils! What is the Proctor test? Show the parts of a Proctor curve! What is the use of the Proctor curve on the construction site?*

2. *How do you perform a triaxial test? What type of triaxial tests could we define? Which parameters are measured, which parameters are given? Draw the result of a triaxial test!*

3. *Describe the soil as a 3-phase system! What kind of parameters could we calculate from the ratios of phases? Define and describe minimum 6 of them!*

4. *How do you define the vertical stresses in soils? What are the total, effective and neutral stresses?*

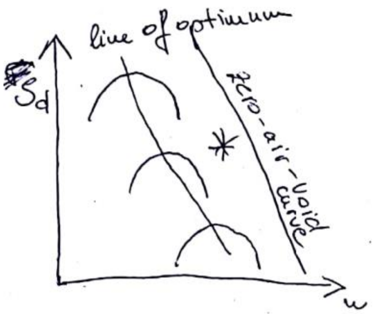
5. *What are the basics of classification of granular soils? Describe the measuring methods and results!*

5, Granular soil:
- there is no or minimal cohesion b/w. the particles
- the surface forces are dominant (loose sediment)
- until 0,063 mm grainsize diameter → sieve analysis
- or the silt content is > 10%.
- if the general grain size diameter is lower than 0,063, need to use hydrometration test.
- in course of sieve analysis, the nominal grainsize is the hole diameter of the sieve
- in case of hydrometration test, the falling/settling particles diameter is the diameter of a settling sphere (with same settling velocity), where Stoke's law is valid:

$$v = \frac{g \cdot (\rho_s - \rho_f) \cdot d^2}{18\eta} \quad (m/s)$$

d = diameter of grain (mm)
η = dyn. viscosity
g = grav. standard (9,81) (m/s²)
ρ_s = solid particles density (g/cc)
ρ_f = fluid density (g/cc)

Sieve analysis:
- sieve column/series with decreasing hole diameter
- shaking table
- falling through and remained % of the initial mass of sample



zero air-void curve: the pores are fullfilled with water (can't reach)

line of optimum: the connection ~~of~~ curve of the $\rho_{d,max}$ values, close to parallel with the zero-air-void curve

Proctor-test:

2 types of test
- $d_{max} < 5$ mm Proctor test no. of ~~layers~~ parts = 3
- $d_{max} > 5$ CBR-test no of ~~layers~~ parts = 5

Original proctor test (when the construction equipment were smaller)

$m_{hammer} = 2{,}45$ kg

drop height = 0,3 m

no. of blows: 25 or 55

no of layers: 3

Modified Proctor test (after the 2nd WW)

$m_{hammer} = 4{,}54$ kg   no of layers = 5

drop height = 0,4 m

no of blows = 25 / 55

In cource of Proctor test, need to ~~be~~ know:
- mass of hammer
- no. of layers
- drop height
- drop no.

Coeff of consolidation:

$$C_v = \frac{k \cdot E_{oed}}{\gamma_w} \quad (m^2/s)$$

Compressional index:

$$C_c = \frac{\Delta e}{\log\left(\frac{\sigma_1}{\sigma_0}\right)}$$

Swelling index:

$$C_s = \frac{-\Delta e}{\log\left(\frac{\sigma_1}{\sigma_0}\right)}$$

Relative compr.:

$$RC = \frac{\rho_d}{\rho_{d,max}}$$

Relative density:

$$I_d = \frac{e_{max} - e}{e_{max} - e_{min}}$$

Compaction at construction:
- permeability & porosity / void ratio decreasing
- increasing shear strength, increasing bearing capacity

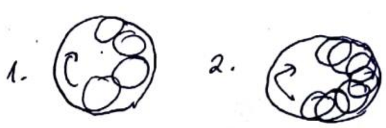
* 1-peak curve - med / high plast. clay
- w_L 30-70%

1,5-peak curve - low plast. clay
- $w_L < 30\%$ + gran.

2-peak curve - low / extr. high plast. clay
- $w_L < 30$ $w_L > 70\%$

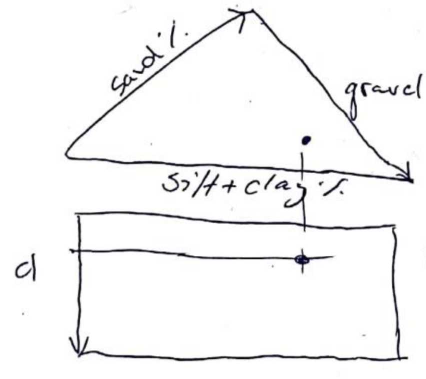
"No" curve (characteristic) - extr. high plast. $w_L > 70\%$

Proctor-test:



Hydrometration test:
- aerometer
- 50 g sample is mixed with water, where coagulant ~~a~~ is applied
- by the Stokes's law, the larger particles are settling down faster
- reading the ~~a~~ aerometer (density) at given time intervals

Results:
- the results are plotted in a grain-size distribution (GSD) plot
- X-axis: grain-size (log)
- Y-axis: % of remained weight percent
- curvature, inclination, are important in course of interpretation
- more parameters and the sample name can be given or calculated, like
- unpropotionality coeff. $= \frac{d_{60}}{d_{10}} = C_u$
- curvature coeff. $:= \frac{d_{30}^2}{d_{60} \cdot d_{10}} = C_c$
- Mean grainsize $= d_{50} = d_m$
- effective grainsize $= d_{10} = d_{eff}$
- naming by ternary diagram, and European Standards



→ related to sieve analysis

but in this case, we should use hydrometration

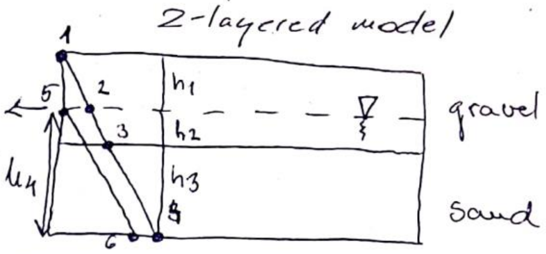
4./ $\rho \cdot g \cdot h = \sigma_{total}$
total stress for model

h = height of soil or model (m)
g = grav. standard (9,81 m/s²)
ρ = density of soil (g/cc)

$\rho \cdot g \cdot h = u$
neutral stress for water (fully water sat.)

$\sigma_{eff} = \sigma_{total} - u$

2-layered model



σ_t
- 1 = 0
- 2 = $\rho \cdot g \cdot h_1$
- 3 = $\rho \cdot g \cdot h_1 + \rho \cdot g \cdot h_2$
- 4 = $\rho \cdot g \cdot h_1 + \rho \cdot g \cdot h_2 + \rho \cdot g \cdot h_3$

u
- 5 = 0
- 6 = $\rho \cdot g \cdot h_4$ $(h_2 + h_3)$

they are affect to each other in reverse way

3./

air (gas)
water (fluid)
solid

$V_{air} + V_{water} + V_{solid} = 1$
in case of 3-phase system
↓
the pore-space is not full-saturated $S < 1$ or $< 100\%$

saturation: $\frac{V_{water}}{V_{pores}} = S$ (%) · 100%

porosity: $\frac{V_{void}}{V_{full}} = n$ (%) · 100%

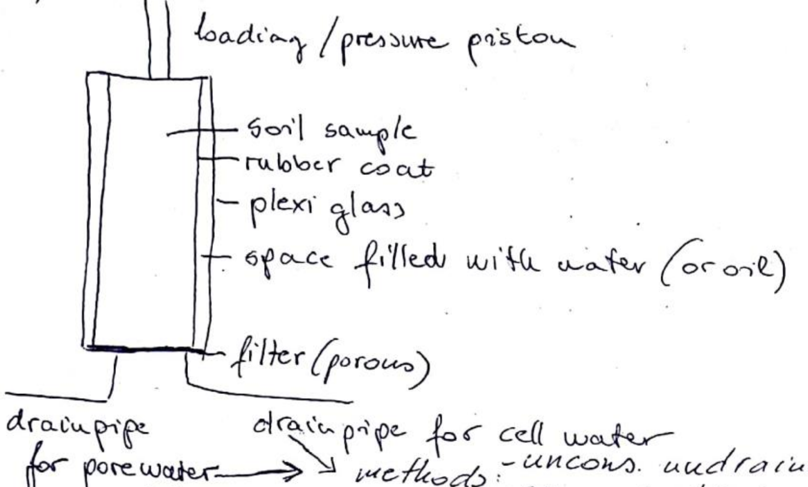
V = volume (L^3)
m = mass (g or kg)

Void ratio = $\frac{V_{void}}{V_{solid}} = e$ (-)

moisture content: $\frac{m_{water}}{m_{solid}} = w$ (-)

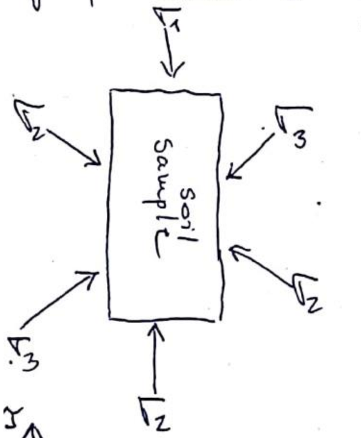
ratios of phases' volume $\frac{V_{air}}{V_{total}} + \frac{V_{water}}{V_{total}} + \frac{V_{solid}}{V_{total}} = 1$ (-)

2., Triaxial test

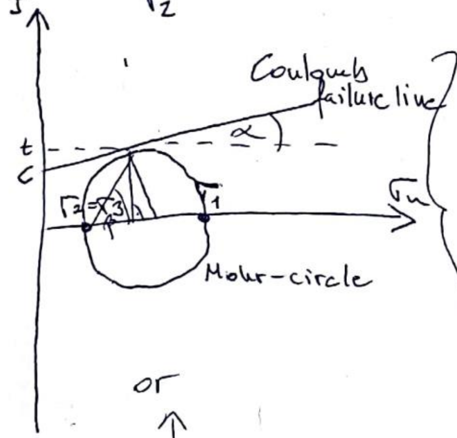


Structure of a triax. device

methods:
- uncons. undrained (quick) UU
- cons. undrained (quick) CU
- cons. drained (slow) CD



Stress field for triax. test where $\sigma_2 = \sigma_3$ and $\sigma_1 > \sigma_2 = \sigma_3$



plot for the measured results

σ_n = normal stress (kPa)

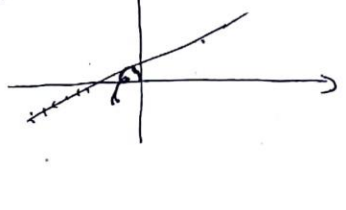
τ = shear stress (kPa)

c = cohesion (kPa)

ϕ α = internal friction angle (°) or φ

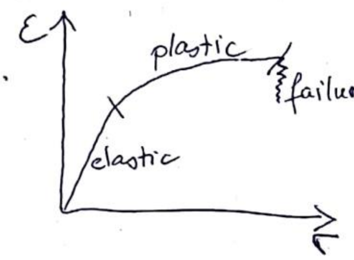
β = angle of failure plane (°) or θ

or



Steps of measurement:

- fill the sample into the sample holder in triax. device (dry, wet, compacted, uncomp.)
- close the system, apply one of them: UU, CU, CD
- give the expected F (N) values, which will be stresses after $\sigma = \frac{F}{A}$ where A is the surface of sample
- the sample will be pressed until a given σ values or ~~at~~ until failure
- the Coulumb failure curve is valid:



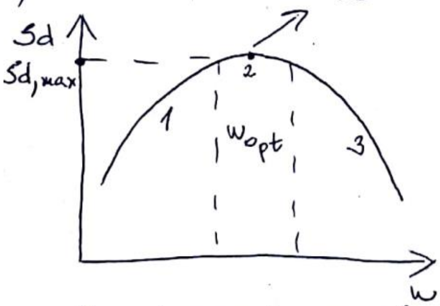
elastic: the sample can get back the initial shape, no remained deformation

plastic: the deformation is remained

- if we are in the elastic zone, the triax-measurement is repeated more times with different σ_1, $\sigma_{2=3}$ values because of the rubber coat which get back/help to receive the initial ~~volume~~ and shape

If the sample is failed

1., Proctor-test we are want to reach the $\rho_{d,max}$ and the related w_{opt} at construction site: max. compressibility of soil at a given moisture content



ρd = dry density
w = moisture content

1: the increasing moisture content can help by lubricating the particles ordering to a densest state

2: densest state, at a given moisture content

3: the increasing moisture content is decreasing the density by water replacing ~~at~~ solid particles (~ liquid phase)

Types of settlement

1. Immediate compression
   - no volume change
2. Primary compression / consolidation
   - squeezing of water
   - dissipation of pore water pressure
   - development of eff. stress
3. Secondary compression
   -
4. Failure

Terzaghi: - vertically compression and vertically volume change only
- fully saturated
- Darcy is valid
- incompressible the water and the solid
- homogeneous sample

5. Others

During the exams using of mobile phone, smart devices, notes or copies of books are not acceptable. Violation of the examination order entails the suspension and completion of the writing of the exam.