Name: ***Date:***

SOIL MECHANICS I
LABORATORY CLASS 4: STRENGTH OF SAND, CAPILLARY COHESION

AIM

An easy method for determination of effective strength of sand is to measure its angle of repose. However, in geotechnical practice, the strength of materials is usually determined using loading tests. The most suitable one is the triaxial test, where a cylindrical specimen is loaded by the axial and radial stresses. A more simple form of the test is the unconfined compression test with zero total radial pressure, which is performed in this laboratory class. The experiments demonstrate some essential features of the strength and behaviour of granular (coarse grained) soils:

- Angle of repose and its relation to the critical state friction angle;
- Increase of strength caused by capillary suction; existence of capillary cohesion;
- Problems associated with unconfined compression test on soil: typically soils would be unsaturated during the test, and the effective stresses would not be known. In practice unconfined compression should be avoided with soils.

PROCEDURE

1 Angle of repose

Slowly pour dry sand onto a flat surface to make a cone of a convenient hight to measure the angle of repose of the slope. When pouring the sand watch the surface of the slope to make sure that the slope is continuously falling and that the critical state may be assumed.

2 Unconfined compression test

i. Thoroughly mix sand and water to prepare the sample of water content of approximately 10%.
ii. Build a sand castle and measure the average diameter and height.
iii. Using the balance and hand pressure carry out an unconfined compression test. On loading, watch the sample and the mass reading carefully to identify the reading at the failure of the soil.
iv. Immediately after the test take a sample to determine the water content and degree of saturation
v. Repeat the procedure until you receive three sets of data with a reasonable scatter in stress at failure (say 10%). Then consider average values of vertical stress, water content and degree of saturation.

PROCESSING DATA, REPORT

Compute vertical normal stress at failure and plot Mohr's circle for total stresses. Assuming a linear strength envelope determine the capillary cohesion caused by suction (use φ' determined from your angle of repose test and c'=0).
Determine the pore pressure within the sand castle at failure assuming that effective stress in unsaturated soil can be computed according $\sigma' = \sigma - (S u_w + (1-S) u_a)$, i.e. the pore pressure is $u = (S u_w + (1-S) u_a)$, where S is degree of saturation. Construct Mohr's circle for effective stresses at failure knowing its diameter and the failure envelope of the sand (φ'). From the effective stress compute the capillary suction $s=u_a-u_w$, which for continuous air ($u_a=0$) becomes $s=-u_w$.
Note: For unsaturated soils the formulation of the effective stress requires an additional information – the dependence of suction on water content (the water retention, or the so called soil-water characteristic curve). The use S in the above expression is a rather crude simplification of the unsaturated soils behaviour.

The report on the laboratory class should include:

1) Effective angle of friction of dry sand φ' determined from the angle of repose α. Explanation of the relationship between φ' a α (figure, equation).
2) Capillary cohesion determined graphically and by computation for your unsaturated sand specimen.
3) Mohr's circle of total and “effective” stresses at failure of unsaturated sand in unconfined compression. Graphically determined “pore pressure”.
4) Computation of the “pore pressure” (strictly valid only for saturated soil). From the geometry of Mohr's circle determine the general relationship between pore pressure and φ', vertical load at failure and geometry (diameter) of the specimen. From the equation compute the “pore pressure” and “suction” in your sand castle.
5) Your comment on the cohesion of the tested soil. Is dry sand cohesive or cohesionless soil? Is wet sand cohesive or cohesionless soil? Is the terminology “cohesive soil” and cohesionless soil” useful and based on sound physical concepts?

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DATA

Angle of repose

Test No	1	2	3			Average angle of friction φ' [°]
Angle of repose α [°]						
Angle of friction φ' [°]						

Strength of sand castle

Test	Height [m]	Dia [m]	Load at Failure (mass) [kg]	Force at Failure [N]	Cross Section Area [m^2]	Stress at Failure [Pa]	Water content				Void ratio e	Degree of Saturat. S
							No	Wet Mass [g]	Dry Mass [g]	w		
1												
2												
3												
Average	-------	-------	--------	--------	--------		--------	-------	-------			