1.103 CIVIL ENGINEERING MATERIALS LABORATORY (1-2-3)

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LABORATORY ASSIGNMENT NUMBER 4

DIRECT SHEAR TESTING AND FRICTIONAL PROPERTIES

Purpose: You will learn about:
(1) Measurement techniques for testing non-cohesive soil
(2) Shearing and frictional properties of dry sand
(3) Effects of particle packing and different components of frictional resistance
(4) Techniques for the preparation of test specimens

Organization:
- Meeting A   30 min. *Group* organization
- Meeting B   90 min. *Subgroup* testing
- Data   Will be posted after lab

Reading:

Read this handout carefully
Read ASTM test method D3080
Review Lambe Chapter X

Overview:

The Direct Shear test is commonly used to measure the frictional characteristics of soils and many other granular materials including everything from corn flakes to coal. While the test has many shortcomings (nonuniform and rotating state of stress, nonuniform state of strain, stress concentrations at edges of box, etc.) it is simple, inexpensive and provides useful results for engineering practice and for illustrating the basic drained behavior of cohesionless materials. This assignment will develop experience with the device, the data acquisition system, and the mechanical characteristics of cohesionless soil.

Each group is to perform six individual direct shear tests. Remember that the characteristics of the stress strain curve and peak resistance depend on the density of the sand and the applied normal (consolidation) stress. We will be performing tests on quartz sand at three different consolidation stresses and two densities. The dense sand will be dry and tamped into place to achieve as dense a state as possible. The loose sand will be deposited with a funnel to allow the particles to settle at the angle of repose. Ideally you should try to prepare each loose specimen and each dense specimen at the same density. You will also perform tests on glass plates at three different normal stress levels. Glass is basically quartz and hence has the same interparticle friction characteristics as the sand. These tests will approximate the sliding component of friction. Tests will be performed at normal loads

corresponding to about 17.5, 27.5 and 47.5 kg of mass acting on the specimen. Remember to account for the mass of the apparatus (upper half of box and top cap) when computing the normal force applied to the specimen.

In an effort to reduce laboratory time and still provide sufficient information to perform the analysis, I have divided the testing between the groups according to the following table:

Applied Mass (kg)	17.5	27.5	47.5
Material	Group		
Glass	All	All	All
Dense Sand	GP A1	GP A2,B1	GP B2
Loose Sand	GP B1	GP A1,B2	GP A2

Procedure:
  Apparatus preparation

1. Locate all the transducers and record the calibration factors and data acquisition channel numbers.
2. Check the electronics including the input voltage, stability of signals and direction of the output signals.
3. Measure the mass of the top plate, top cap and upper half of the specimen box.
4. Determine the area of the specimen box.
5. Determine the depth of the specimen box.
6. Estimate the volume of the vanes in the end plates (you need this to compute the specimen volume and density).

  Shear test on glass plate

1. Place the 3/4 inch brass spacer in the dry water bath.
2. Place the rubber pad on the spacer.
3. Place the large glass plate on the rubber and against the loading stop.
4. Put the bath in the load frame.
5. Place the upper half of the shear box in place on the glass plate.
6. Put the small glass plate in the box and cover it with the rubber pad.
7. Put the top cap on the pad and locate the load hanger.
8. Set the vertical Displacement Transducer (V-LVDT) and add the first normal load.
9. Set the shear rate using the gears and lever position to the fastest rate.
10. Start the data acquisition system. Use an integration time of 300 msec and 22 bit precision. Take readings every second. Set up the system to plot shear load on the vertical axis and shear displacement on the horizontal axis.
11. Turn on the motor and engage the clutch.
12. Shear until constant shear is obtained, reverse the motor and unload to zero shear force.

13. Repeat the shear to obtain three cycles.
14. At the end of the third unload phase, stop the motor and increase the load to the next value.
15. Again perform three shear cycles.
16. Increase the load to the final normal force value and measure the final three shear cycles.

Measure the minimum density

1. Measure the mass of the density cup.
2. Place the extension collar on the cup.
3. Using the funnel and extension tube to fill the density cup with sand. Be sure to keep the tube full of sand during the deposition process. Allow the sand to slide out the end to the tube and deposit in a spiral motion.
4. Fill the cup to the top of the extension collar.
5. Remove the collar and scrape the sand level with the rim of the cup.
6. Measure the mass of the cup and the dry sand.
7. Tap the side of the cup and notice how much the sand densifies.
8. Repeat this several times to determine a consistent number.
9. Finally measure the volume of the cup by filling it with distilled water and measuring the mass f the cup and water.
10. Use these data to compute the minimum sand density (or maximum void ratio).

Specimen preparation for Sand

1. Fill the box with sand to a level just below the drainage hole.
    1.1. Use the funnel method to prepare a loose specimen. Remember the loose specimens are very delicate and slight vibrations will cause the sand to densify. Remember to correct the final dry mass for this water.
    1.2. For the dense specimen, scoop the sand into the box and densify by tapping the side of the box and the surface of the sand to create a medium dense specimen.
2. Level the sand surface and cover with the grated plate.
3. Tamp the surface with the wooden block to densify the sand and check that it remains level.
4. Assemble the shear box in the frame and obtain zeros for the horizontal force and two displacement transducers (horizontal and vertical deformation of specimen).
5. Measure the distance from the top of the box to the plate. This is used to compute the specimen height and the initial volume.
6. Turn the hand crank until the box is in contact with the shear piston.

Apply normal stress to the specimen

1. Compute the required normal force. Remember to account for the mass of the top cap, top plate, and top half of specimen box.

2. Apply the required weights to the hanger in increments.
3. Record, using the voltmeter, the vertical deformation after the weights have been applied to the specimen.

Shear the specimen

1. Remove the screws which hold the two halves of the box together.
2. Simultaneously turn the two spacer screws to separate the box along the shear plane. Use one half turn and remember to return the screws to the original position before shearing.
3. Set the shear rate using the gears and lever position to the fastest rate.
4. Start the data acquisition system. Use an integration time of 300 msec and 22 bit precision. Take readings every second.
5. Turn on the motor and engage the clutch.
6. For at least two of the tests perform an unload reload loop after the peak shear force has been achieved. Be sure to unload to zero shear force.
7. Shear the specimen for the full stroke of the load frame (about 1/2 inch).
8. At the end of the test pour the sand into a bowl and determine the final dry soil mass. (assume the wet sand is till at 2% water content)

Calculations:

Compute the normal consolidation force as:

N = (mass of various components plus added masses) x gravity

Compute the applied shear force as:

S = (load cell reading - load cell zero) / Input voltage x Calibration factor

Horizontal (shear) displacement:

δ_h = (LVDT reading - LVDT zero) / Input voltage x Calibration factor

Vertical displacement:

δ_V = (LVDT reading - LVDT zero) / Input voltage x Calibration factor

Dilation rate (this is the rate that the sand expands or contracts):

$\mu = \Delta (\delta_V) / \Delta (\delta_h) = [\delta_{V(i)} - \delta_{V(i-1)}] / [\delta_{h(i)} - \delta_{h(i-1)}]$

Void Ratio (this is the volume of the voids divided by the volume of the solids):

$e = (H - H_s) / H_s$

Where:

H = current specimen height $= H_i - \delta_V$
H_s = height of the solids (= Mass dry solids / specific gravity / area)
Specific gravity = 2.65

Friction Angle

$\phi = \arctan (S / N)$

Report:
All the data will be posted by the end of the week. Each person is responsible for doing calculations for the nine tests specified in the table (three glass, three loose sand and three dense sand). You should use data from your tests plus the sand data from two other groups.

- Plot of shear force vs. horizontal displacement for each test. Show all the glass plate data on one graph.

- Plot of vertical displacement vs. horizontal displacement for each sand test.

- Plot of shear force vs. normal force with friction angle for peak and residual conditions for the glass, the dense sand and the loose sand.

- Make a graph of the friction angle versus the void ratio. Set the range for the void ratio scale from about the maximum void ratio to the minimum void ratio. Indicate the maximum void ratio and the initial void ratio on the x-axis. Add a horizontal line indicating the glass friction angle. Plot the peak friction angles (maximum value for a given test) and the residual friction angles (value at the end of shearing) at the current void ratios.

- A summary table of the initial, peak, and final void ratio, the peak and residual friction angle, and the maximum rate of dilation for each test.

- One set of calculations for the void ratio.

- One set of example calculations from the data acquisition (one measurement point).

- The data sheets.

- One page of computer calculations and raw data.

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DIRECT SHEAR TESTING AND FRICTIONAL PROPERTIES

DATA SHEET (1 of 2)

DATE _____   All dimensions in _____ Group No. _____   Date _____

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Measurement Device   Shear Force   Vertical Disp.   Shear Disp.

Calibration. Factor _____   _____   _____

DAQ Channel _____   _____   _____

Input Voltage _____   _____   _____

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Shear Box Measurements

Mass of Top Half of Box _____   Mass of Top Cap _____

Mass of Top Plate _____   Mass of Load Hanger _____

Height of Empty Box (with plates) _____ , _____ , _____ , _____

Plan Dimensions of Box _____ , _____ By _____ , _____

Volume of Plate vanes: Number _____; Height _____; Width _____

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Minimum Density Measurements

Mass of Empty Cup _____ Mass of Cup with Distilled Water

_____

Mass of Cup and Sand _____ , _____ , _____ , _____

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Test Description _____   File Name   _____

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Test Description _____   File Name   _____

Height of Full Box (with plates) _____ , _____ , _____ , _____

Zero V-LVDT _____ Applied Load _____ Preshear V LVDT _____

Mass of Bowl _____   Mass of Bowl and Sand _____

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Test Description _____   File Name   _____

Height of Full Box (with plates) _____ , _____ , _____ , _____

Zero V-LVDT _____ Applied Load _____ Preshear V LVDT _____

Mass of Bowl _____   Mass of Bowl and Sand _____

==

Test Description _____   File Name   _____

Height of Full Box (with plates) _____ , _____ , _____ , _____

Zero V-LVDT _____   Applied Load _____ Preshear V LVDT _____

Mass of Bowl   _____   Mass of Bowl and Sand   _____

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DATA SHEET (1 of 2)

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Test Description _____   File Name   _____
Height of Full Box (with plates) _____ , _____ , _____ , _____
Zero V-LVDT _____ Applied Load _____Preshear V LVDT _____
Mass of Bowl   _____   Mass of Bowl and Sand   _____
==
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Test Description _____   File Name   _____
Height of Full Box (with plates) _____ , _____ , _____ , _____
Zero V-LVDT _____ Applied Load _____Preshear V LVDT _____
Mass of Bowl   _____   Mass of Bowl and Sand   _____
==
=

Test Description _____   File Name   _____
Height of Full Box (with plates) _____ , _____ , _____ , _____
Zero V-LVDT _____ Applied Load _____Preshear V LVDT _____
Mass of Bowl   _____   Mass of Bowl and Sand   _____
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