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

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LABORATORY ASSIGNMENT NUMBER 9

CONSOLIDATION TEST

Purpose: During this laboratory you will learn about:

(1) one dimensional consolidation equipment
(2) consolidation behavior of cohesive soils
(3) relationship between drainage path and consolidation time
(4) relationship between pore pressure and surface settlement
(5) difference between secondary compression and primary consolidation

Organization:

- Meeting A 90 minute *Group* exercise to conduct tests

Note: We will have a demonstration of Steel Quenching at the end of this lab

Reading:

- Read this handout carefully
- Skim ASTM D2435 on the consolidation test
- Lambe Chapter IX (a simple description of the test and interpretation)
- Lambe and Whitman Chapter 27 (presents the basic concept of consolidation theory)

Overview:

The consolidation test is the basic experiment to measure the settlement characteristics of a clay layer. The rate of consolidation is governed by a coupling between the hydraulic conductivity and the compressibility of the soil. For this laboratory you will measure the effect of the drainage height and the interaction between pore pressure and surface deformation. During this laboratory, you will be conducting an incremental consolidation test on a specimen trimmed from an undisturbed sample of soft clay. The oedometer has been modified to control drainage from the base of the specimen. The standard test configuration is to have both top and bottom (double) drainage. The modified test configuration has only top (single) drainage. This is achieved by closing the value at the base of the specimen. A pressure transducer measures the water pressure in a sealed chamber at the bottom of the specimen. This location is equivalent to the center plane of the specimen with double drainage.

It takes from several days to a few weeks to perform a complete consolidation test. The test duration depends on the number of consolidation increments and the soil type (actually the coefficient of consolidation). A typical commercial laboratory will invest as much as 20 hours of manpower to perform the test. This being the case, it is not possible for us to perform the complete experiment for class. The entire laboratory will be performed on one test specimen.

Each group will perform two increments on the same specimen but at different stress levels. We will setup the specimen, perform the rest of the increments, and give you the entire data set for analysis. You will be performing the more detailed calculations on the two increments that you apply but will need the entire data set to compute the compression curve.

This handout outlines the proper procedure for performing the entire consolidation test. This additional information is to help you understand what was done throughout the test and is for your reference. The last page has instructions for the 1.103 assignment.

Procedure:

Apparatus Calibration

1. Assemble the cell (stones, filter paper and top cap).
2. Align assembly in the loading frame.
3. Place a 1 lb seating load on the cell and obtain a zero reading on the displacement transducer.
4. Apply the same loads to the apparatus as will be used in testing the specimen.
5. At each load increment, record the displacement reading at 15 sec, 30 sec, 1 min, 2 min and 5 min.
6. The change in dial reading gives the machine deflection curve.

Apparatus preparation

1. Assemble the oedometer (stones, filter paper and top cap)
2. Measure the initial z_3 (height between top of cap and specimen ring). You can place a dummy specimen (block of known thickness) between the filter papers for added height.
3. Disassemble the oedometer.
4. Grease specimen ring and cutting shoe.
5. Determine the mass (M_r) of the empty specimen ring.
6. Measure the height (H_r) and diameter (D_r) of the ring.
7. Measure the thickness of one piece of filter paper (H_{fp}).
8. Cut two pieces of filter paper.
9. Boil or ultrasound the stones for 10 minutes to clean and remove air.
10. Cut 2 wax paper disks the diameter of the specimen.

Specimen preparation

1. Remove covering from sample.
2. Keep track of the sample orientation.
3. Place sample on wax paper disc and glass plate.
4. Rough cut the diameter with a wire saw to within 1/8" of final diameter.
5. Obtain water contents from trimmings.

6. Assemble sample in trimmer with extension disc supporting soil.
7. Trim sample with cutting shoe and spatula, obtain second water content.
8. Once sample is completely fitted into specimen ring, trim top and bottom with a wire saw. Make final cut on top surface with a sharp straight edge.
9. Obtain third and fourth water contents.
10. Use recess tool to create space at top of ring and trim excess soil from bottom with wire saw. Make final cut with the sharp straight edge.
11. Determine the mass of the specimen and ring (M_{s+r}).
12. Measure the recess from the top of ring to the soil surface (ΔH_i)

Apparatus assembly

1. Fill base with water.
2. Insert bottom stone into base and cover with filter paper.
3. Remove excess water with a paper towel.
4. Place specimen and ring on stone.
5. Cover rim with gasket.
6. Tighten with locking ring.
7. Cover specimen with filter paper and top stone, allow this stone to drain before placing on soil.
8. Place top cap on stone.
9. Measure z_3 with specimen.
10. Locate assembly in loading frame with dial gauge and balance arms (this is the true weight of the assembly which is the *tare* load).
11. Apply one pound seating load and zero displacement transducer.

Consolidation test

1. Consolidate the specimen using a load increment ratio ($\Delta P/P$) between 0.5 and 1.0 for loading and -0.25 and -0.50 for unloading. Note: I recommend the following schedule for class. S, 0.125, 0.25, 0.5, 1.0, 2, 4, 8,4, 1, S.
2. Fill the water bath at about 1/4 the overburden stress (0.25 ksc) or within 2 hours.
3. For each increment, record the displacement transducer reading versus time. Remember that the initial portion of the curve is very important to define the start of consolidation (ε_s).
4. During each increment plot both root time and log time curves.
5. Apply increments after the end of primary consolidation has been reached.
6. Allow one cycle of secondary compression to occur under the maximum load and before the unload-reload cycle.
7. At the end of the test unload the specimen to the seating load and allow time for swelling.

8. Remove the water from the bath and remove the specimen from the apparatus.
9. Remove any extruded soil and oven dry.
10. Dry the surface of the specimen and determine the mass of both soil and ring.
11. Extrude the soil and obtain water content.
12. Collect washings from filter paper and inside of ring and oven dry.

Calculations:

The following provides a summary description of the basic equations that are necessary to complete the test. The attached pages provide the actual equations. I hope this makes the test reduction process easier to follow.

- *Initial Specimen Height* = $H_r - \Delta H_i - H_{fp}$
- *Water Content* = (total mass - dry mass)/ dry mass

Note: compute the total mass during the test by subtracting (axial deformation X Area X unit weight of water) from initial wet mass. This assumes that only water comes out of the specimen during consolidation.

- *Void Ratio* = (total volume - volume of solids)/ volume of solids
- Volume of solids = mass of oven dried soil / specific gravity (use 2.7)
- *Degree of saturation* = specific gravity X water content / void ratio
- *Vertical effective stress* (σ'_v) (when the pore pressure is zero) = (Applied load - Tare load + top cap and stone)/ Area
- *Vertical strain* (ε_v) = (measured axial deformation - Apparatus compression)/ Initial specimen height

Note: The Apparatus compression curve is attached to this assignment

- *Compressibility* (a_v) = - change in void ratio / change in vertical stress

Note: change in void ratio is usually taken at the end of primary but for this laboratory assignment you can use end of increment values.

- *Coefficient of consolidation* (c_v).(root time) = 0.848 X (drainage height)^2 / time for 90% consolidation
- *Coefficient of consolidation* (c_v).(log time) = 0.197 X (drainage height)^2 / time for 50% consolidation

Note: Drainage height is computed at 50% consolidation for both cases.

- *Hydraulic conductivity* (k_v) = (coef. of consolidation X compressibility X unit weight of water) / (1 plus average void ratio)
- *Rate of secondary compression* (c_α) = change in strain per log cycle of time after primary is complete.

Report:

Your report should include the following information:

- All the hand recorded data sheets.
- A graph of vertical strain vs. root time and vs. log time for the two load increments performed by your group.
- Perform the construction for the coefficient of consolidation on each graph for these two increments (two log and two root time).
- A graph of the base excess pore pressure vs. root time and vs. log time for the one load increment of your group with the bottom drainage valve closed. On each of these graphs mark the time corresponding to the end of primary consolidation you obtained from the interpretation of the strain plots.
- For your two increments compute the following:
  - the void ratio at the point of 50% consolidation.
  - the compressibility (a_v).
  - the coefficient of consolidation (c_v).
  - the hydraulic conductivity (k_v).
  - rate of secondary compression for the increment with single drainage (c_α)
- A graph of vertical strain (ε_v) vs. log vertical stress (σ_v) indicating end of primary, •, and end of increment, **Δ.** Use the Log time method to determine the end of primary strain. You only need to provide the end of primary points for your two increments.
- Perform the construction for the preconsolidation pressure (σ_p) using the Casagrande construction.
- Additional information about the specimen, including
  - initial specimen water content
  - initial void ratio
  - initial degree of saturation.