The University of Iowa
Department of Civil & Environmental Engineering
53:030 Soil Mechanics, Fall Semester 2003
Laboratory Experiment Number 9:
1-Dimensional Consolidation of Fine-Grained Soil

A. Objective

In this laboratory experiment, one-dimensional consolidation of a fine-grained soil layer is measured. The results of the consolidation test are used to estimate the "e vs. log σ_v'" behavior of the soil as well as its coefficients of consolidation c_v and permeability k, both as functions of void ratio e.

B. Background

Consolidation is the process by which stresses applied to the soil are transferred to the soil skeleton (effective stresses) as excess pore pressures are dissipated. As fluid under pressure flows out of the stressed soil, the voids gradually collapse leading to a reduction in volume of the soil. For highly permeable soils such as coarse sands and gravels, consolidation tends to occur quite rapidly due to the soils' high permeabilities. Consolidation of fine-grained soils occurs very slowly, however, because of their very small permeabilities. The consolidation time can be minimized though by using thin clay layers with small drainage distances H_{dr}.

C. Experimental Procedure

The experimental setup and procedure for this test is relatively standard can be found in any of the following references available in the Engineering Library:

- Procedure for Testing Soils, 4^{th} edition, Sponsored by ASTM Committee D-18, 1964.
- C. Liu and J.B. Evett, "Soil Properties: Testing Measurement and Evaluation," Prentice-Hall, 1984.
- B. Das, "Soil Mechanics Laboratory Manual," Engineering Press, 1982.
- Bardet, J.-P., "Experimental Soil Mechanics," Prentice Hall, 1997.

The essential idea behind the test is to prepare a soil specimen as described in any of the preceding references and put it into an oedometer which then goes into the loading apparatus as shown in Figure 1. (Your instructor will demonstrate how this was done.) Once in the testing apparatus, loads increments are applied to the soil using the pneumatic loading apparatus in the laboratory. Each load increment is held constant on the soil sample for a period of up to 24 hours. During this time, the pressurized fluid in the soil sample gradually flows out into the oedometer chamber. As fluid leaves the soil sample, the void volume in the soil decreases, leading to a reduction in the soil sample's volume and height. To capture the gradual reduction in the soil's volume over a period of up to 24 hours, the vertical displacements of the top of the soil sample are measured electronically using an LVDT and the LabView program running on the Soils Lab PC. The sample is incrementally loaded in a geometric progression up to a vertical effective stress of 1600 kPa, following which it is unloaded back to 100 kPa.

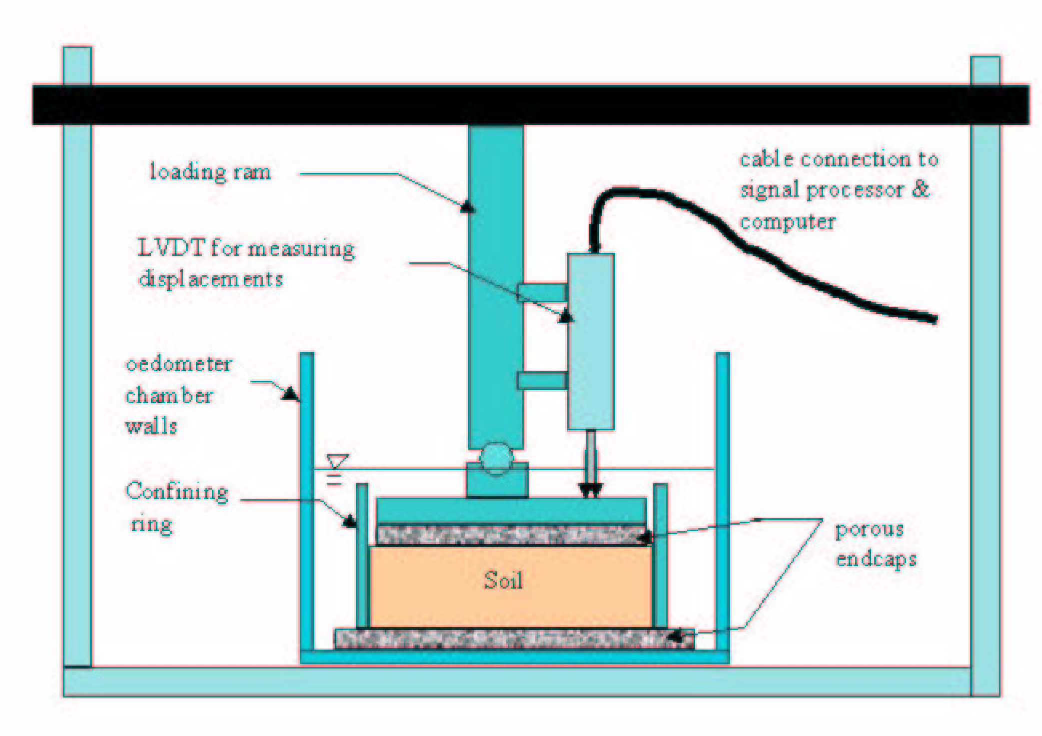

Figure 1. Schematic of the fine-grained soil sample loaded into the oedometer and the apparatus used to measure the change in height versus time.

D. Data Collection

Even with a very thin layer of fine-grained soil ($\approx$ 2cm), it takes approximately one week to perform a consolidation test. Hence this test will be performed and data collected during the week of 10/27–11/03/03. After the test is completed, you will be able to download all of the raw data collected during the experiment using the ECSS network as described below. Once you obtain the raw data, it must be reduced and processed to fill in Table 1.

When you obtain the data, it will be in the form of the nine separate files listed below. Each file contains a history of ΔH vs. t for a specific load increment or decrement. To obtain these data files:

a. Log on to any of ECSS's HPUX work stations.

b. Create a directory where you want to save the files, and move into that directory.

c. Copy the data files into your directory by typing: cp /usr/ui/class/examples/cee5330/lab9/* .

For all of the loading tests, use one-dimensional consolidation theory to complete the data in Table 1 of your Lab 8 handout. For the unloading tests, you need not compute t_{50} or c_v, *etc* but only the e vs. $\log(\sigma'_v)$ behavior of the soil.

03_50l	load from 25 kPa to 50 kPa;
03_100l	load from 50 kPa to 100 kPa;

03_200l	load from 100 kPa to 200 kPa;
03_400l	load from 200 kPa to 400 kPa;
03_800l	load from 400 kPa to 800 kPa;
03_1600l	load from 800 kPa to 1600 kPa;
03_400ul	unload from 1600 kPa to 400 kPa;
03_100ul	unload from 400 kPa to 100 kPa;
03_25ul	unload from 100 kPa to 25 kPa;

E. Computations and Plots

For each load increment you will obtain a separate file containing the settlement versus time data.

1. The raw data for each load increment i (ΔH vs. time) should be plotted as a separate displacement versus logarithm of time curve (you should have a total of nine such curves). Each of the loading plots is used to compute the t_{50_i} for the given load increment using the "logarithm of time method" described in the textbook.
2. For each load increment i:
   a. Compute the corresponding coefficient of consolidation c_{v_i} by
   $$c_{v_i} = \frac{T_{50}(H_{dr_i})^2}{t_{50_i}}.$$
   b. Compute the void ratio change Δe_i by
   $$\Delta e_i = \frac{\Delta H_i}{(H_o)_s} = \frac{(H_{i+1} - H_i)}{(H_o)_s}$$
   where:
   $$(H_o)_s = \frac{H_o}{1 + e_o}.$$
   c. Compute the "coefficient of compressibility" a_{v_i} as
   $$a_{v_i} = -\frac{\Delta e_i}{\Delta \sigma'_{v_i}}.$$
   d. Compute the permeability of the fine-grained soil k_i by
   $$k_i = \frac{c_{v_i} a_{v_i} \gamma_w}{1 + e_o}.$$
3. Plot a semi-logarithmic curve of vertical effective stress σ'_{v_i} versus final void ratios e_i. From this curve, compute the swelling index C_s, the compression index C_c, and the pre-consolidation stress σ'_{v_c}.
4. Plot the coefficient of consolidation c_{v_i} as a function of void ratio e_i.
5. Plot the permeability of the fine-grained soil k_i as a function of void ratio e_i.

Table 1. Data collection for coefficients of consolidation, compressibility, and permeability.

Load # i	σ'_{v_i} (kPa)	H_i (mm)	e_i	H_{dr_i} (mm)	t_{50_i} (sec)	c_{v_i} $(mm^2 s^{-1})$	Δe_i	$\Delta\sigma'_{v_i}$ (kPa)	a_{v_i} $(\text{kPa})^{-1}$	k_i (ms^{-1})
0	25									
1	50									
2	100									
3	200									
4	400									
5	800									
6	1600									
7	800									
8	400									
9	200									
10	100									

Notes:

- Since the soil layer drains only through the top, $H_{dr_i} = \frac{H_{i+1}+H_i}{2}$
- $c_{v_i} = \frac{T_{50} H^2_{dr_i}}{t_{50_i}}$
- $a_{v_i} = -\frac{\Delta e_i}{\Delta\sigma'_{v_i}}$
- $k_i = \frac{c_{v_i}\gamma_w a_{v_i}}{1+e_o}$