The University of Iowa
Department of Civil & Environmental Engineering
Fall Semester, 2002

53:030 Soil Mechanics
Lab Experiment No. 10:
Consolidation Computations Using a FEM Code

A. Objective

In this laboratory assignment, a finite element program will be used to compute the two-dimensional pore pressure distribution and the two-dimensional elastic consolidation settlements that occur beneath a foundation loading on a soil. While this problem could be treated approximately using one-dimensional models, the objective of this lab assignment is to briefly demonstrate how these problems can also be solved using computer based methods. (In subsequent courses, especially 53:133, you'll have the opportunity to learn more about how these computer based methods actually work.) The specific problem to be addressed in this lab is shown in Figure 1 of this handout. For the geometry and loading conditions shown, the program solves for equilibrium of both the soil skeleton (1) and the pore fluid (2):

$$\nabla \cdot [\boldsymbol{\sigma}' - (1-n)p_w \mathbf{1}] - \boldsymbol{\xi} \cdot (\boldsymbol{v}^s - \boldsymbol{v}^w) = -\rho_{\text{dry}}\mathbf{g} \quad (1)$$

$$-\nabla(n^w p_w) + \boldsymbol{\xi} \cdot (\boldsymbol{v}^s - \boldsymbol{v}^w) = -n\rho_w \mathbf{g} \quad (2)$$

where: $\boldsymbol{v}^s$ is the velocity of the soil skeleton; $\boldsymbol{v}^w$ is the velocity of the pore fluid; $\boldsymbol{\xi}$ is the soil resistivity tensor (inverse of permeability); discharge velocity vector, ρ_{dry} is the dry density of the soil skeleton; ρ_w is the density of the pore fluid; n is the soil permeability; $\boldsymbol{\sigma}'$ are the soil effective stresses; p_w is the fluid pressure; and $\mathbf{g}$ is the gravity body force per unit mass acting on both the fluid and the solid phases. For simplicity in this problem, we will assume that the soil skeleton behavior is elastic, and thus

$$\boldsymbol{\sigma}' = \mathbf{C} \cdot \boldsymbol{\epsilon}. \quad (3)$$

where $\boldsymbol{\epsilon}$ are the strains in the soil skeleton.

B. Assignment

Your assignment in this lab assignment is to do the following:

1. Based on your processing of the lab 8 soil data, find reasonable estimates of the soil FI-10's dry density ρ_{dry} (in units of kilograms per cubic meter); bulk modulus K (in units of pascals); permeability k (in units of meters per day); and porosity n (dimensionless).
2. Enter these values in the consol.data file (which is the data file that sets up the problem shown in Figure 1).
3. Run the program FENDAC to solve the problem with your soil properties; and
4. Run the post-processing programs to find:
    a. the history of settlement beneath the center of the foundation and the edge of the foundation;

b. the pore pressure distribution in the soil deposit at a variety of time steps.

To execute the finite element program and to interpret its results, you will need to carefully step through the following process:

a. Log on to an ECSS HP work station.

b. Download the FEM data file typing: `cp /usr/ui/class/examples/cee5330/lab10/consol.data .`

c. Download a Matlab file by typing: `cp /usr/ui/class/examples/cee5330/lab10/consol.m .`

d. Download a shell script by typing: `cp /usr/ui/class/examples/cee5330/lab10/setup5330 .`

e. Execute this setup shell script by typing: `source setup5330` (Please note that you will need to re-execute this shell script each time you log in.)

f. You will need to edit the file consol.data to enter your values of ρ_{dry} K, k, and n.

g. Execute the finite element program (FENDAC) by typing: fhp-m <Enter>. The program will then prompt you for the name of the data file. In response, type: consol <Enter>. The finite element program (FENDAC) will execute in the background. Wait for the program to finish executing (This should take anywhere from 3 minutes to an hour, based on speed of the workstation you logged into.). Once the program has finished executing, you will have a number of files in your directory including consol.results, TAPE88.consol, and a number of PRESSt***** files.

h. You will first want to view the time histories of settlements beneath the foundation. To do this, execute the following command: nnthplt < TAPE88.consol. This program takes the file TAPE88.consol and generates nodal time histories of vertical displacements beneath the center of the foundation (node 1296) beneath the edge of the foundation (node 1291) and a distance 5m away from the edge of the foundation (node 1286). The actual plot is in a postscript file called graph1.ps. You can either view this file on your screen using ghostview, or send it to the printer to generate a hardcopy.

i. To view contours of the excess pore pressure distribution in the soil, execute the following command:
matlab <Enter >. This will allow Matlab to begin processing the results of the FEM computation. Once Matlab is started, it will with the >> sign wait for you to enter the necessary commands. Type: consol <Enter> and Matlab will prompt you for the name of a pressure distribution file. Enter an appropriate pressure distribution filename (PRESS_t***). Matlab will then display a color contour plot of the excess pore pressure distribution in the soil. To stop execution of Matlab, close the graphics window, and at the >> prompt type: quit <Enter>. Matlab will have created a postscript file of the excess pore pressure distribution in the soil called consol.ps. This can be sent to any laser printer and included in your report on Labs 8–9.

Using the nodal displacement histories and the pressure contour plots, you can observe that as pore pressures dissipate beneath the foundation, the soil settles. Using the time histories of settlement beneath the foundation, answer the following questions:

1. What is immediate settlement beneath the flexible foundation?
2. What is the ultimate settlement beneath the foundation?
3. What are t_{25}, t_{50}, t_{90}, t_{95}? Use the time history plots you generated to answer these questions.
4. How do the times t_{25}, t_{50}, t_{90}, t_{95} differ form those that would be predicted using one-dimensional consolidation?

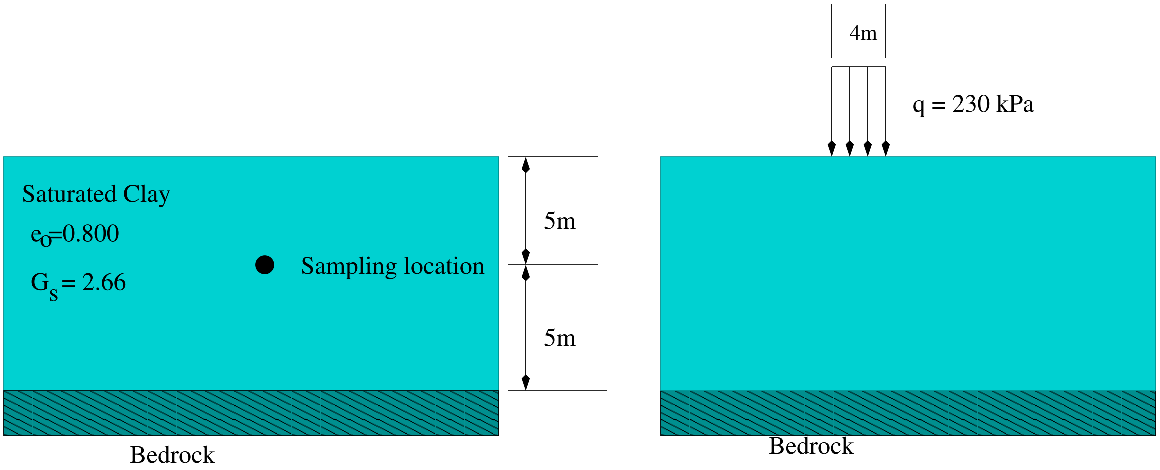

Figure 1. Geometry and loading conditions for the consolidation problem.