53:030 Soil Mechanics   Lab Experiment No. 6:
                        Seepage Computations Using a FEM Code

A. Objective

In this laboratory assignment, a finite element program will be used to compute the pressure head distribution and the rate of flow under a dam for a case that would be very difficult to analyze using flow-nets. One objective of this lab assignment is to demonstrate the relative ease and rapidity with which seepage problems can be solved using computer based methods. (In subsequent courses, you'll have the opportunity to learn more about how these computer-based methods actually work.) In this lab, your goal will be to use a finite element program to solve the groundwater flow problem described in Figure 1 of this handout. For the geometry and permeabilities shown, the program solves the following system of equations:

The continuity equation:

$$\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z} = 0$$

Generalized Darcy's law:

$$\begin{Bmatrix} v_x \\ v_y \\ v_z \end{Bmatrix} = - \begin{bmatrix} k_{11} & k_{12} & k_{13} \\ k_{21} & k_{22} & k_{23} \\ k_{31} & k_{32} & k_{33} \end{bmatrix} \begin{Bmatrix} \partial h / \partial x \\ \partial h / \partial y \\ \partial h / \partial z \end{Bmatrix}$$

where **v** is the discharge velocity vector, h is the piezometric head of the groundwater, and **k** is the permeability tensor of each soil.

B. Background

Because of their conceptual simplicity, flow nets have been emphasized as a method of solving steady-state groundwater flow problems in two-dimensional geometries. In practice, however, there are many applications where flow nets cannot be applied: For example, it is very difficult to apply flow nets to problems having multiple deposits of different soils, and to problems having three-dimensional geometries. For complicated problems like these, engineers usually resort to computer based methods. The finite element method (FEM) is among the most potent of the computer-based methods. In the lab lecture, the instructor will briefly describe to you how the finite element method is used to solve groundwater flow problems. In the lab assignment, you will then use the results of a FEM computation to answer questions pertaining to a complex flow problem.

C. Execution Procedures

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

1. Log on to any ECSS Itanium unix workstation, specifically, any of l-ecn000 through l-ecn019. (Sorry, a PC version of this software is not yet available.)
2. To make sure you're running in a C-shell type: `csh [Enter]`
3. Download the FEM data file typing:
   `cp –p /usr/ui/class/examples/cee5330/53_030/lab6/lab6.data lab6.data`
4. Download a shell script by typing:
   `cp -p /usr/ui/class/examples/cee5330/lab6/setup5330 setup5330`
5. Execute this setup shell script by typing: `source setup5330`. This will give you access to a number of executables in the cee5330/53_030/lab6 directory.   (Please note that you will need to re-execute this shell script each time you log in.)
6. Execute the finite element program (FENDAC) by typing: `fhp-m [Enter]`. The program will then prompt you for either "0" to quit or "1" to execute. To respond type: `1 [Enter]`. The program will then prompt you for the name of the data file you'd like to have it run. In response, type: `lab6 [Enter]`. The finite element program (FENDAC) will execute in the background. Wait for the program to finish executing (This should take about 10 seconds). After executing the program, you will have a file called lab6.results in your directory in addition to a number of TAPE**.lab6 files which contain information for the post-processing software. This lab6.results file is quite large, so do not print it out. You will need to go into this file with an editor to read it so that you can answer the questions posed below.
7. To view the solved piezometric head distribution and the discharge velocity distribution in the soil, execute the following command: `rpost6 lab6 [Enter]`. This creates a Matlab file called `lab6.m` that you can use to see graphical results.
8. To view your results, start up Matlab 7.0 from an XP system that has access to the files you've just created. In the "Current Directory" window, click to the directory where your `lab6.m` file resides. In the "Command Window" type `lab6 [Enter]` at the `>>` prompt.   Matlab will then display three plots from this computation:
     - The mesh geometry and material regions;
     - A color contour plot of the head distribution in the flow domain; and
     - A discharge velocity vector plot.
   You can save each of these plots in whatever graphical form you choose (*.eps, *.jpg, *.gif, etc.) using the "print" and/or "export" utilities for each window.
9. To stop execution of Matlab and close the graphics window, enter `quit` at the `>>` prompt.

D. Questions

Using the output from the FEM program (in file lab6.results), answer the following questions regarding the problem shown in Figure 1:

1. What is the flow rate (per unit width) under the dam? (Use the element flux rates to compute the flow rate).
2. Compute and show (plot) the distribution of pore pressure along the base of the dam. (The program provides you with head values at all nodes, and so you can compute pressures from these.)

Assume that there is approximately 50% uncertainty in the conductivity of the soil directly beneath the dam. That is, for that soil the actual conductivity could lie between .005 m/hr and .015 m/hr . Insert these respective values into the data file lab6.data and re-execute the program. For each computation, use the results in the data file to calculate the flow-rate of water beneath the dam. In the write-up for labs 5-7, you will be requested to discuss the results of these computations.
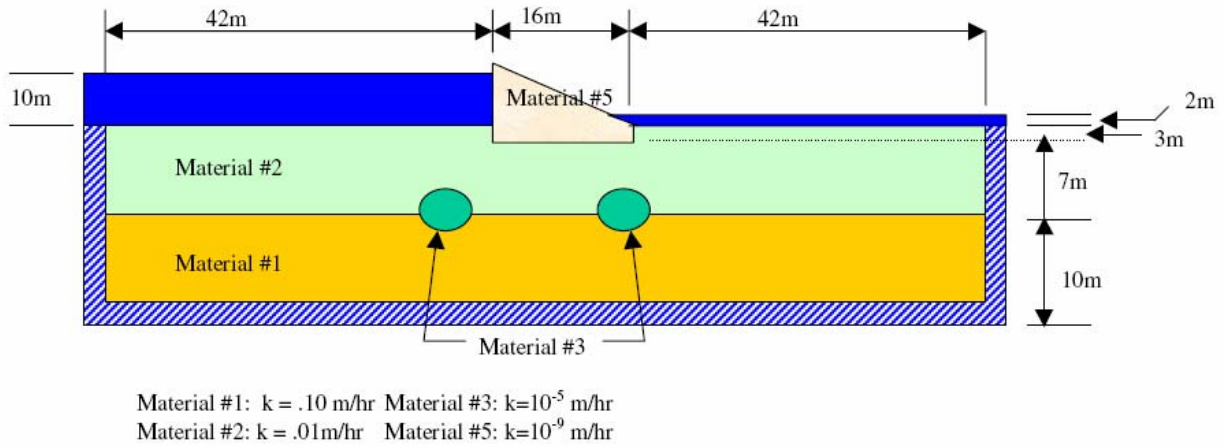
Material #1: $k = .10$ m/hr   Material #3: $k=10^{-5}$ m/hr
Material #2: $k = .01$ m/hr   Material #5: $k=10^{-9}$ m/hr

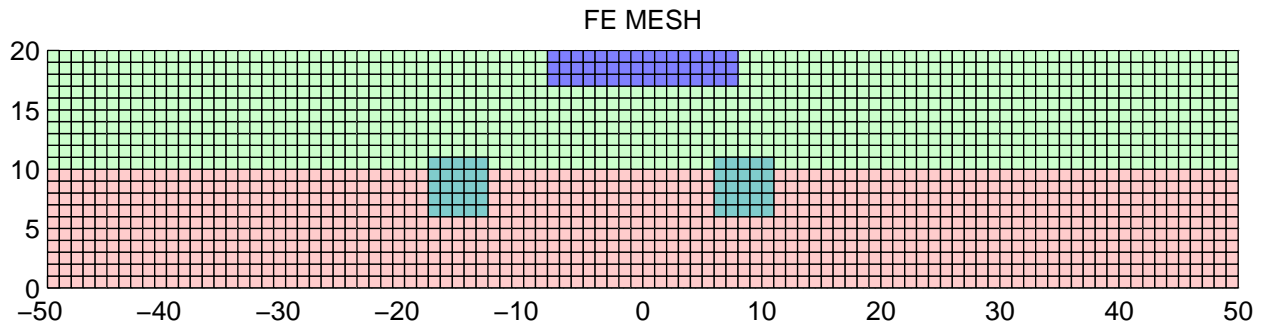Figure 1. Geometry and conductivities for the seepage problem.

FE MESH

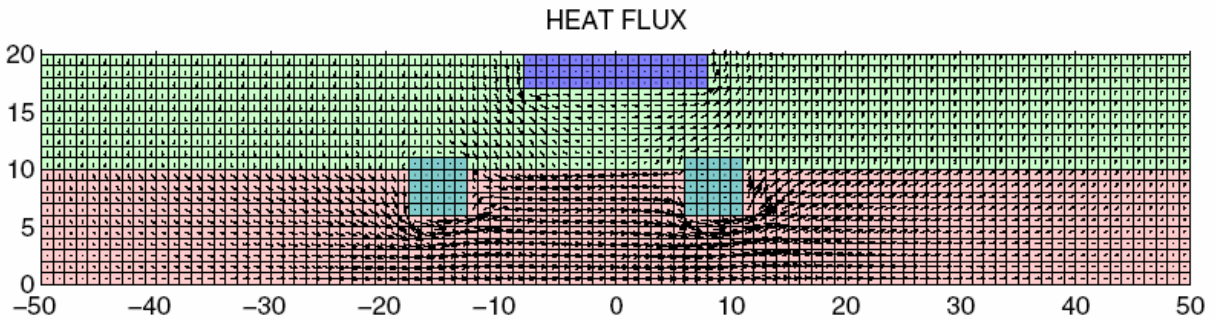Figure 2. FEM mesh used in the computations.
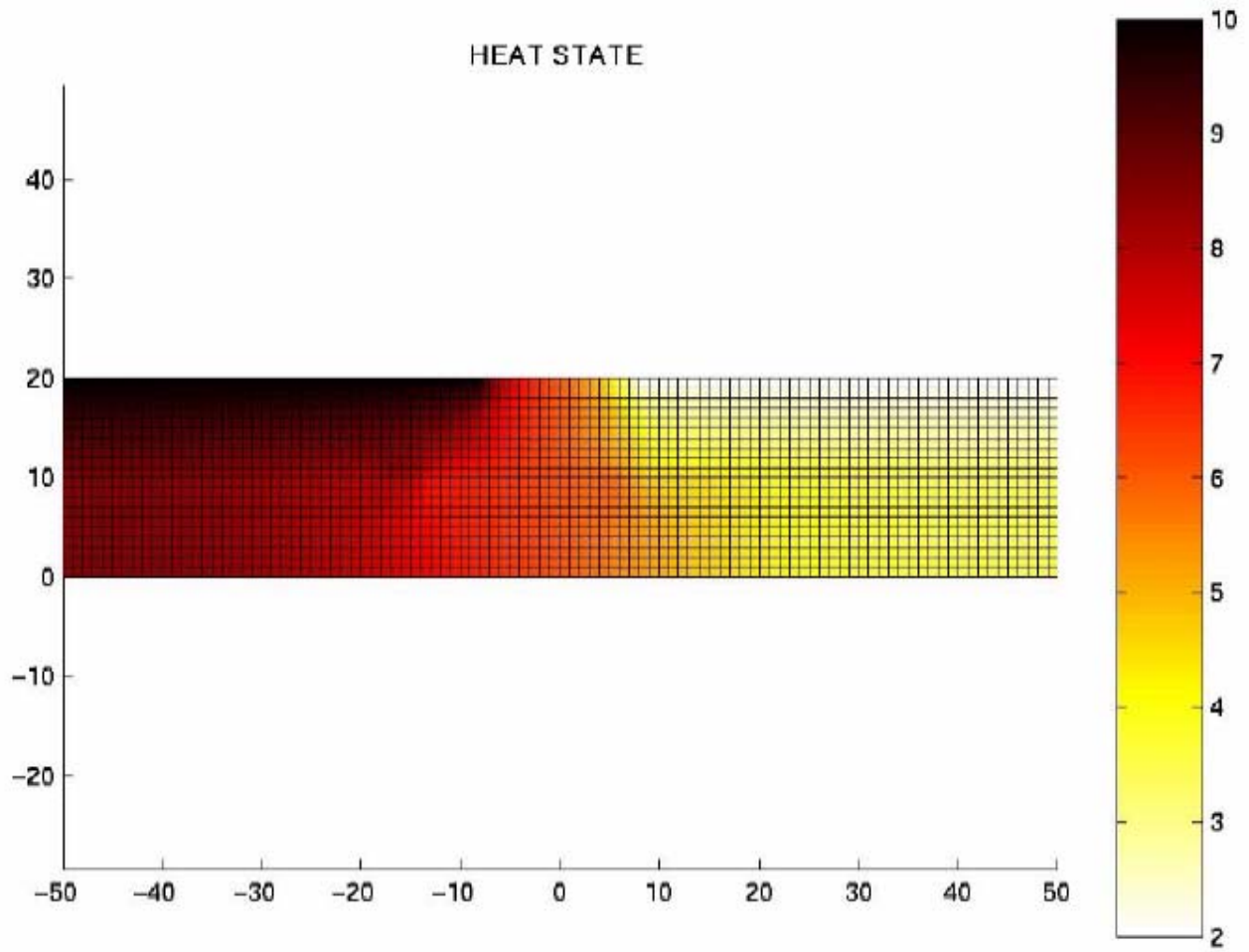
HEAT FLUX

Figure 3. Discharge velocity distribution in the flow domain.

Figure 4. Piezometric head distribution in the flow domain.