53:139 Foundation Engineering
The University of Iowa

Slope Stability Analysis Using FEM

- What is the finite element method?
  - It is a computer-based method of solving engineering problems governed by partial differential equations (for example, Laplace's equation).
  - The spatial analysis domain is subdivided into a finite element mesh.
  - Approximate solutions are obtained for the stresses, displacements, flow rates, etc in the analysis domain.
  - As the refinement of the finite element mesh increases, the accuracy of the approximate solution increases.
- Uses of the FEM:
  - solid mechanics problems: such as structures, or soil mechanics problems
  - fluid mechanics problems: flow distributions in rivers, harbors, bays
  - heat conduction problems: heat transfer in buildings, auto engines, etc
  - electro magnetic problems:
- Essential Elements of the FEM:
  - Must know the underlying PDE's that govern the physics of the problem
  - Geometric modeling of the analysis domain –> FEM mesh
  - Constitutive models: i.e. the stress-strain relationships of the medium
  - Loading and boundary Conditions:

- Application of FEM to solve Slope Stability Problems
- Presently, the method can only be applied to slopes in which there is no flow (i.e. dry slopes, or soft clay slopes). Research is underway to also treat problems with flow and/or earthquake loadings.
- Basic idea: Gravity forces are the mechanism that cause slope failures.
  - In FEM slope analysis, we increase the gravity loading on slopes until they fail.
  - Note the unit weight of a soil is $\gamma_{\text{soil}} = \rho_{\text{soil}} \cdot g$ where:
    g is the gravitational acceleration
    ρ_{soil} is the mass density of the soil (assumed constant)
    γ_{soil} is the unit weight of the soil (varies with g)
  - For a given slope configuration, we gradually increase the gravity g on a FEM model until the slope fails. The gravity that causes slope failure is called g_{limit}.
  - The factor of safety for the slope against failure is then simply:

$$\text{FS} = \frac{g_{\text{limit}}}{g}$$

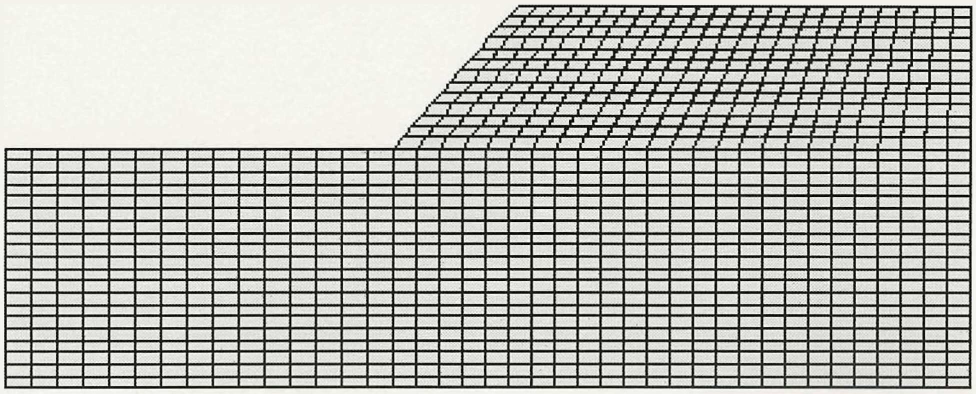
Potential advantages of FEM slope analysis:

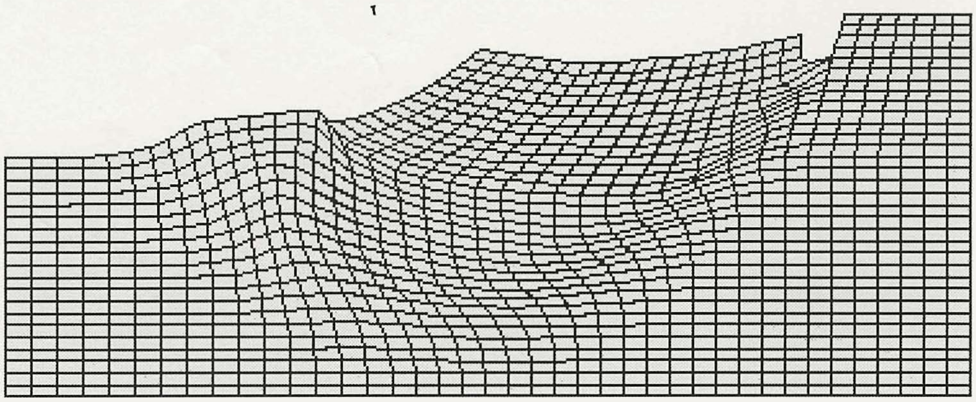
- Solution is more accurate, since the method doesn't need to make as many assumptions as the traditional slice and mass methods do.
- The method can easily deal with heterogeneous slopes – i.e. slopes with many different soil types.
- The method can also be extended to treat three-dimensional slope failures.
- Eventually, slope failures due to seepage will also be treated with the method.

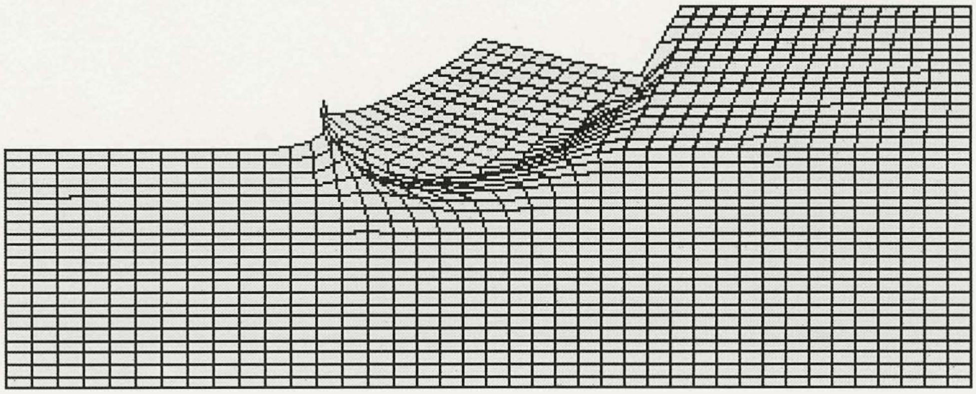
- Summary Statement

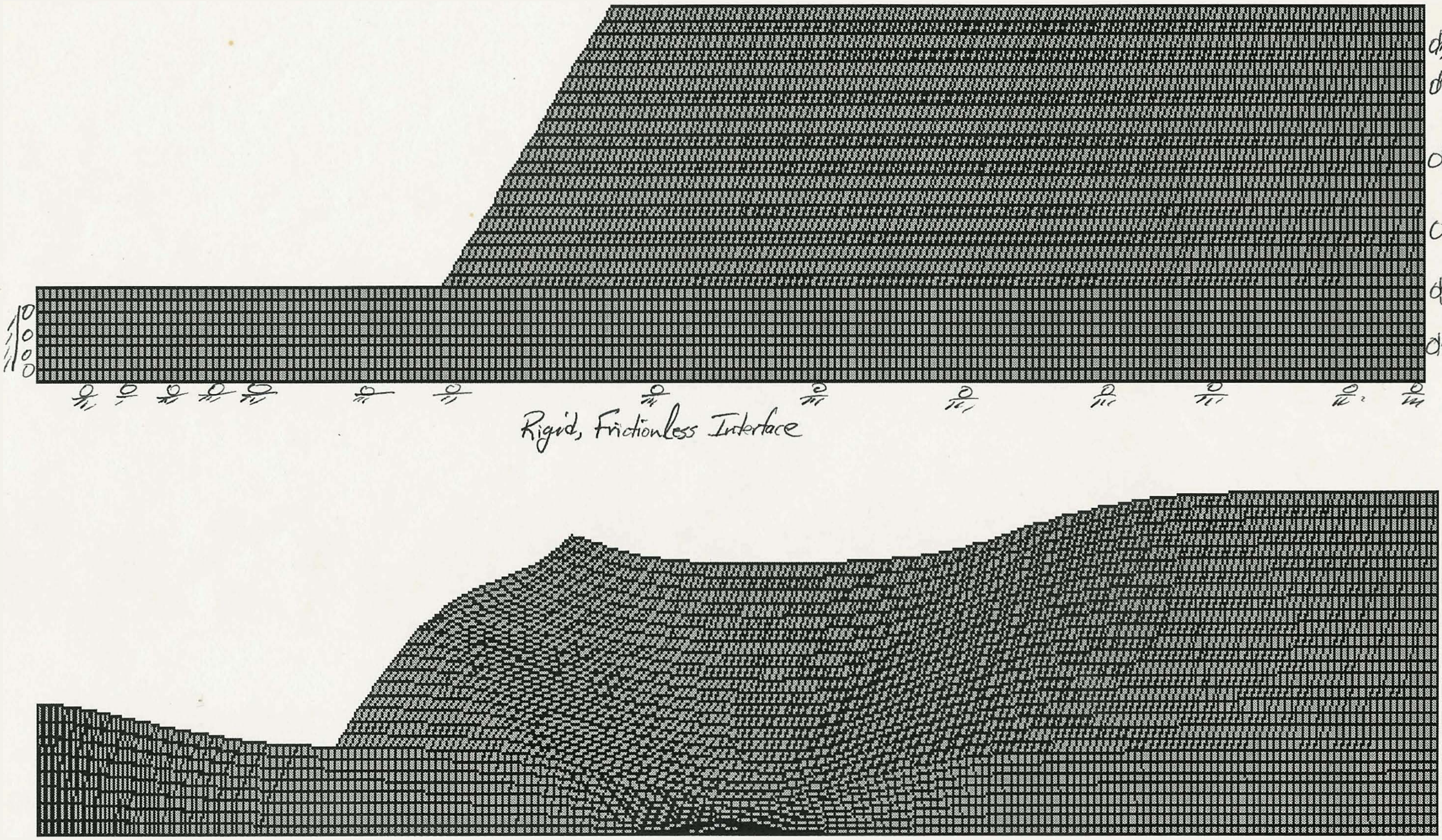
  Variations of the traditional slope stability analysis methods are most widely used in geotechnical engineering practice.

  As the FEM methods are perfected and more widely understood by practitioners, they will eventually be used in engineering practice as well.









Rigid, Frictionless Interface