GeoStudio Example File

Pore-Water Pressures Defined using a Finite Element Analysis

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Introduction

Pore-water pressures impose one of the greatest controls on the stability of slopes. The pore-water pressure can be defined in a SLOPE/W analysis using a variety of approaches including a piezometric line, spatial pressure head function, or a finite element analysis. This example illustrates how to set-up and interpret the results of a SLOPE/W analysis that uses pore-water pressures defined using SEEP/W.

Numerical Simulation

Figure 1 presents the problem configuration. The analysis comprises a simple homogeneous dam with a toe under-drain. The GeoStudio Project includes a steady-state SEEP/W analysis and two slope stability analyses, both of which reference the seepage analysis as the Parent. The first stability analysis uses the pore-water pressures from the 'Parent' (Figure 2), while the second analysis uses a piezometric line. The reader should review the file for material inputs and boundary conditions. The search technique in the stability analyses is defined using entry-exit.

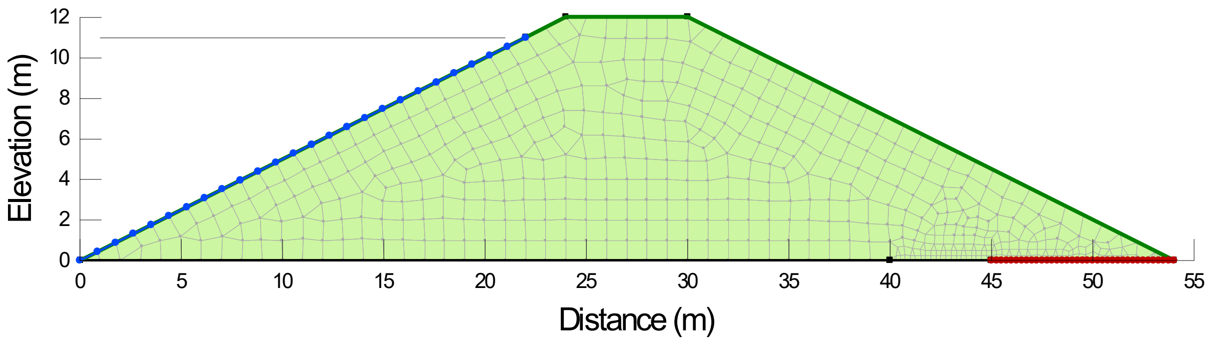

Figure 1. Problem configuration.

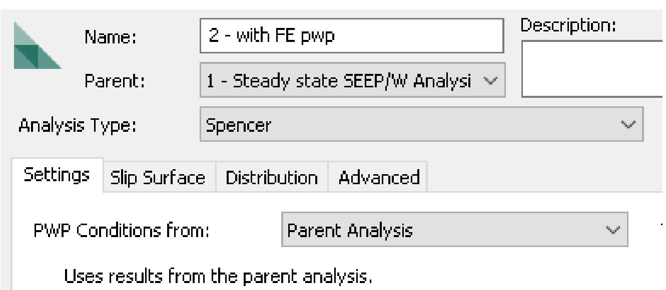

Figure 2. Selecting the parent as the source for the pore-water pressures.

Results and Discussion

The steady-state seepage results are shown in Figure 3, including the total head contours (equipotential lines), two flow paths and the zero-pressure contour representing the phreatic surface. The blue painting on the reservoir side is a visual indicator of positive pore-water pressure along the face of the dam.

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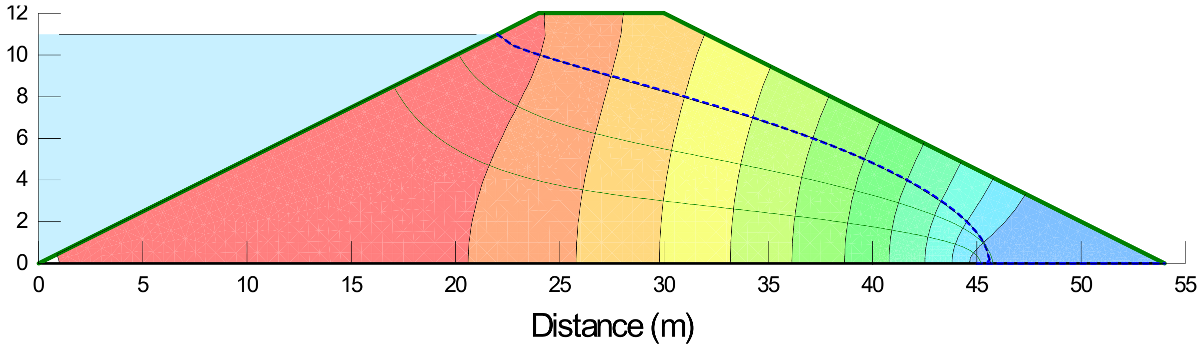

Figure 3. SEEP/W results.

Figure 4 presents the critical slip surface and factor of safety from the first stability analysis. The location of Slice #13 is shown in Figure 5 along with element numbers from the seepage analysis. This slice will be used to highlight the calculation procedure.

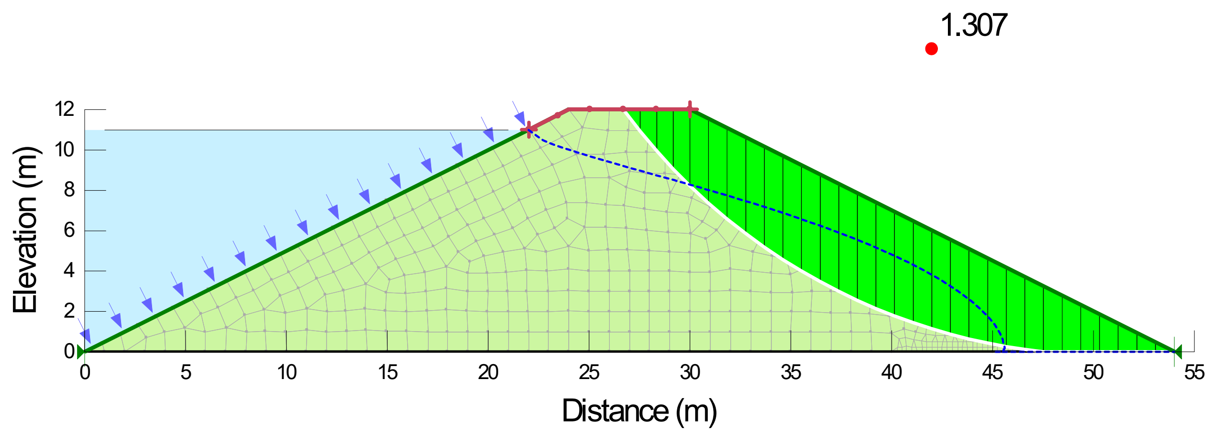

Figure 4. Stability analysis with SEEP/W pore-water pressures.

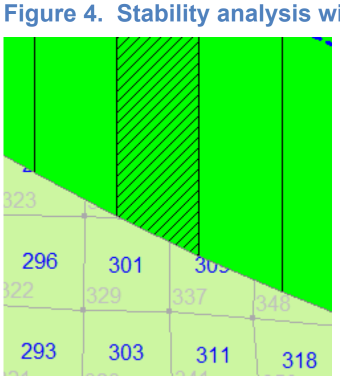

Figure 5. Slice 13 of the critical slip surface.

The base of Slice 13 is located in the upper-right corner Element 301. The local coordinates *r* and *s* can be found which represent the local position of the slice base inside the element. The finite element formulation is based on an equation that describes the pore-water pressure distribution inside the element in terms of nodal values. The equation is given by:

$$\tilde{u} = [N]\{U\} \quad \text{Equation 1}$$

where $\tilde{u}$ is the pore-water pressure at any point inside the element, [*N*] is a matrix of interpolating functions, and {*U*} is a vector of pore-water pressures at the nodes. The matrix [*N*] is a function of the local *r* and *s* coordinates. The pore-water pressures at the nodes {*U*} are known from SEEP/W. As such, the exact pore-water pressures can be computed at the slice base using the above interpolating equation.

The finite element pore-water pressure distribution along the slip surface is compared to the piezometric line result in Figure 6. The piezometric line yielded higher pore-water pressures, particularly when there was a greater downwards component to groundwater flow. The main reason for the discrepancy is that SLOPE/W takes the vertical distance from the slice base up to the piezometric line (left distance in Figure 7). In actual fact the pore-water pressure would rise up to the height of the piezometric line (right distance in Figure 7). As such, a piezometric line and finite element analysis will produce the same result in areas where the equipotential lines are vertical (i.e. horizontal flow) and will deviate as the equipotential lines are non-vertical.

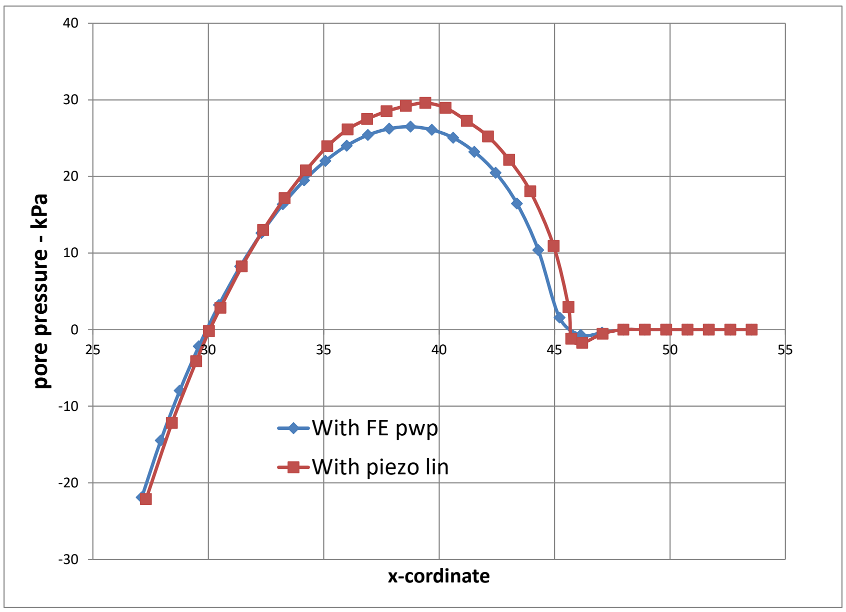

Figure 6 Comparison of pore pressure distributions

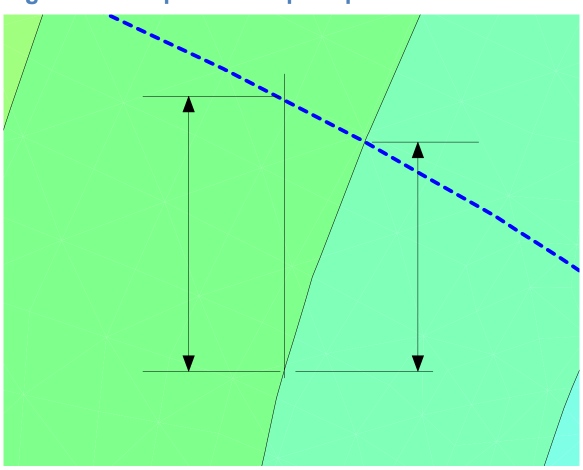

Figure 7. Pore-water pressures from an equipotential line.

Summary and Conclusions

This example compared the pore-water pressures in a SLOPE/w analysis defined using a piezometric line and a finite element SEEP/W analysis. The piezometric line approach assumes that the pore-water pressure at the base of a slice is based on the depth below the phreatic surface. This is assumption is incorrect if there is lateral flow. In this example, the piezometric line pore-water pressures were higher that the finite element pressures. Although it was not very dramatic in this case, there are examples where the difference is significant. There are also cases in which a piezometric line simply cannot be used to capture the spatial variability in pore-water pressure.