SEEQUENT

GeoStudio Example File
Tension Cracks

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Introduction

Finite element stress strain analyses of steep slopes demonstrate that a zone of tension can exist in the head scrap area. The tension zone can manifest itself as a tension crack. Moreover, the near surface soil profile is often stiff and desiccated. Tension cracks can form in this zone if there is some slope movement at depth.

In a Limit Equilibrium formulation, it is possible to compute a negative normal at the base of a slice at the head scrap if the inclination of the slice base becomes very steep. These are some reasons why it is desirable to sometimes simulate a tension crack in a stability analysis. SLOPE/W provides two options for simulating tension cracks. In addition, the hydrostatic force arising from standing water in a tension crack can be included.

Numerical Simulation

A simple homogeneous slope is used to illustrate the tension crack features in SLOPE/W (Figure 1). The 4:5 slope is assumed to be dry; that is, no pore-water pressure is considered. A Mohr-Coulomb material model is used with a unit weight of 20 kN /m^3, a cohesion 15 kPa, and a friction angle of 30°. The entry-exit method is used to search for the critical slip surface, with the exit zone modeled as a single point located at the toe of the slope.

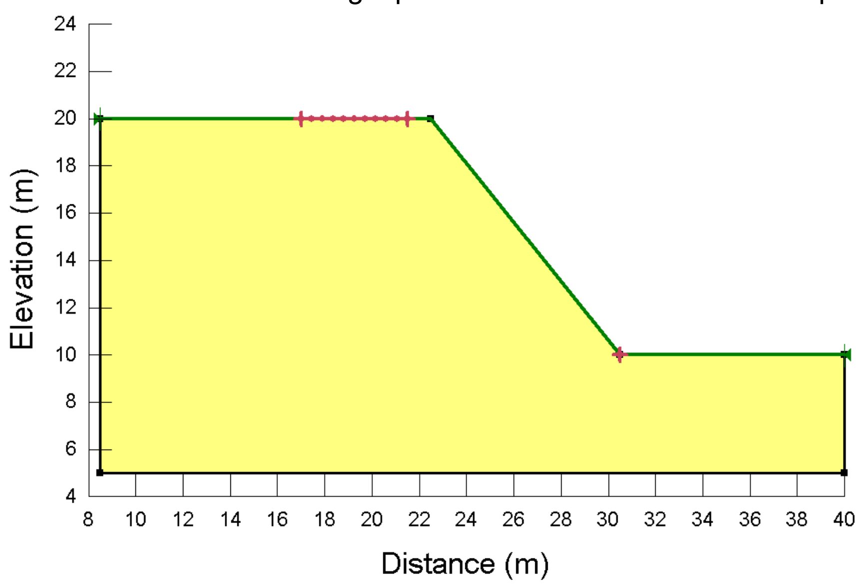

Figure 1. Problem configuration.

There are four analyses in the GeoStudio project (Figure 2). The first analysis considers the slope stability conditions without a tension cracks. The remaining analyses include the tension crack option (Figure 3). The second analysis assumes that a tension crack develops if the angle of slip surface exceeds 60° from horizontal (specified as 120° for a left-to-right analysis). The third analysis uses a tension crack line (Figure 4) drawn at a depth of 2 m below ground. In the final analysis, the "Water in Tension Crack" option is selected with the water unit weight set to 10 kN/m^3 and the 'filled with water' parameter set to 1.0.

Figure 2. Analysis Tree for the Project.

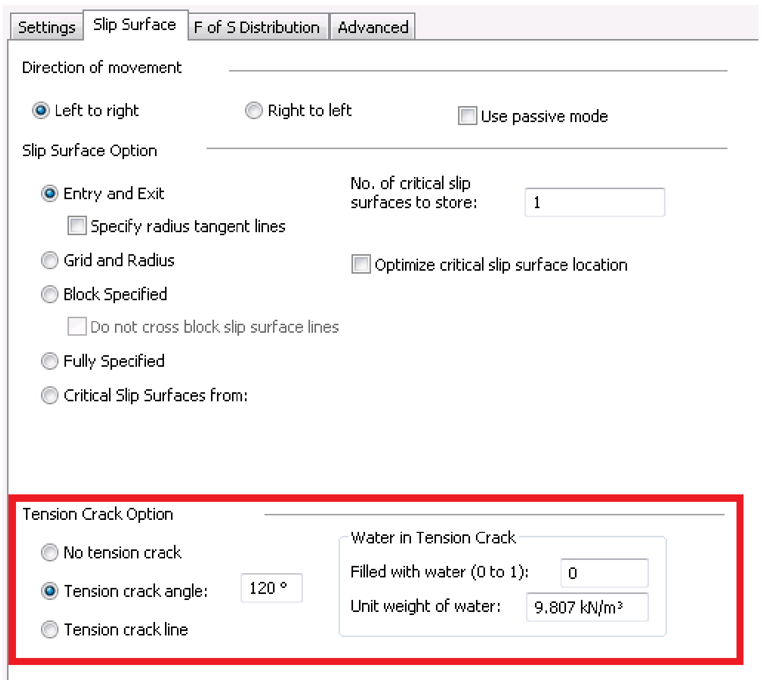

Figure 3. Tension crack options.

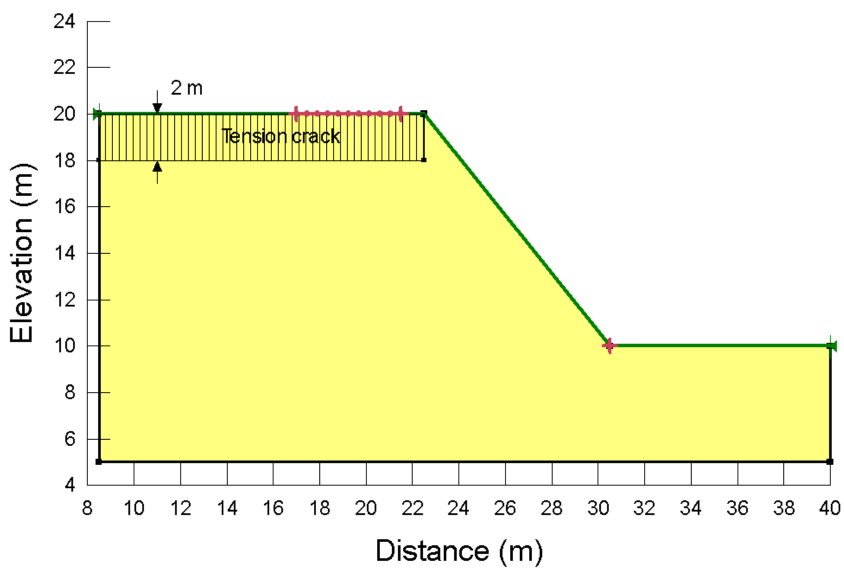

Figure 4. Location of tension crack line for Analyses 3 and 4.

Results and Discussion

The factor of safety and critical slip surface for case 1 is presented in Figure 5. Figure 6 presents the forces acting on slice #1 using the View Slice Information in Results View. The base normal force is pointing away (negative) from the base of the slice. This is an artifact of the LE formulation that comes about because the LE computed stresses do not necessarily represent the actual stresses in the ground.

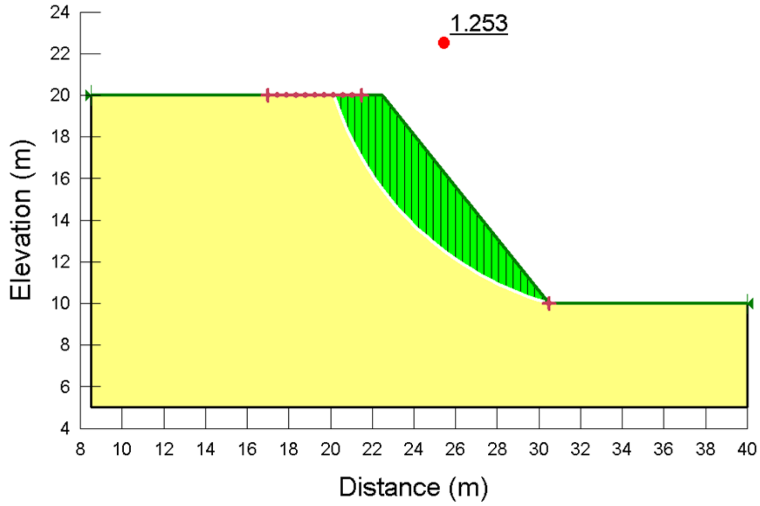

Figure 5. Critical slip surface and factor of safety with no tension crack (Analysis 1).

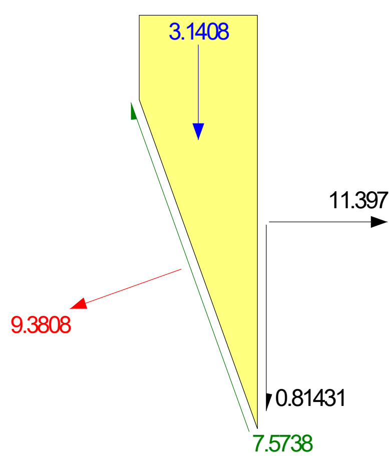

Figure 6. Free-body diagram for first slice at the head scrap.

Figure 7 shows the factor of safety and the critical slip surface when the embankment is analyzed with a tension crack angle of 120 degrees. The angle is measured counter-clockwise from the positive x-axis. The specified 120° means that when the slice base inclination exceeds 60° (180° – 120°), the slip surface is returned vertically to the ground surface.

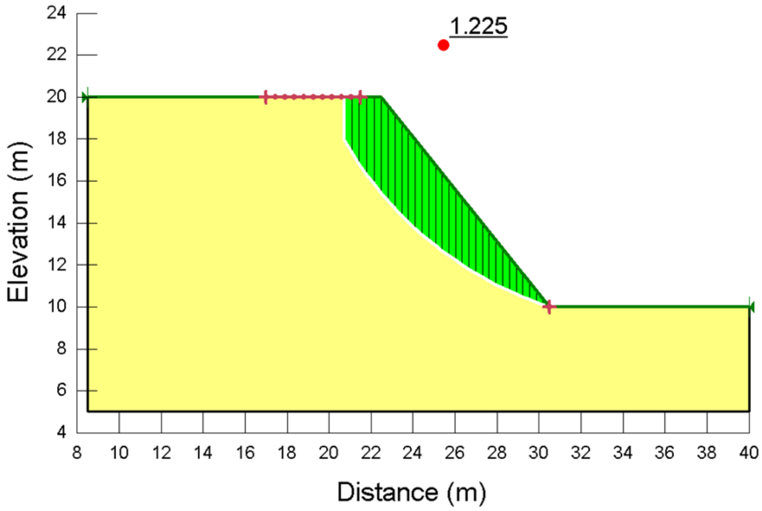

Figure 7. Critical slip surface and factor of safety with a tension crack angle (Analysis 2).

The base inclination for the first slice at the head scrap in Figure 7 is 58.9°. Other slices to the left would have had an inclination larger than 60°. Selection of an appropriate angle can be guided by considerations from earth pressure theory. If a crack were to open, it would be analogous to a vertical unsupported wall. The base inclination of an active wedge this case is given by:

$$\alpha = (45 + \frac{\phi}{2}) \quad \text{Equation 1}$$

For a friction angle of 30°, the active earth pressure angle, α, is 60°. Generally, there is a tendency for negative base normal forces to if the slice base inclination exceeds this value.

An alternative is to simply specify a line on the geometry indicating that any portion of a trial slip above this line is in a tension crack zone and the slip surface is, consequently, vertical in this zone. This might be a zone where there are active wetting and drying changes throughout the year.

The critical slip surface for this analysis is shown in Figure 8. The factor of safety is 1.181 when water is included in the tension crack (Figure 9).

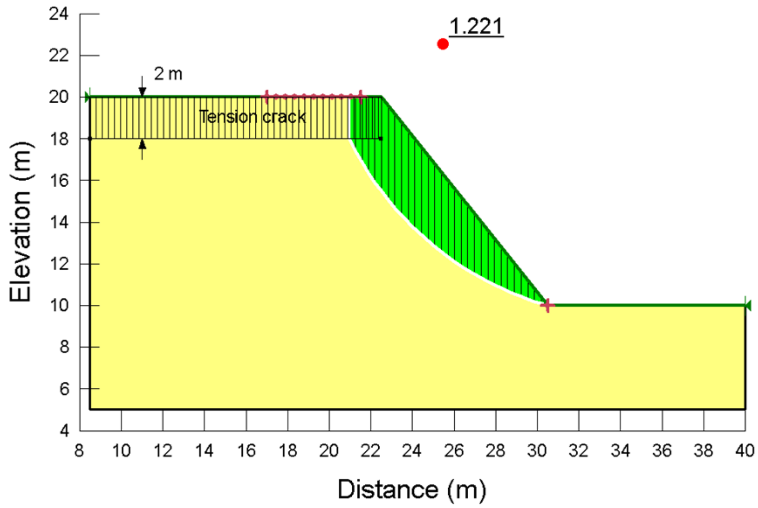

Figure 8. Result with tension crack defined by a line (Analysis 3).

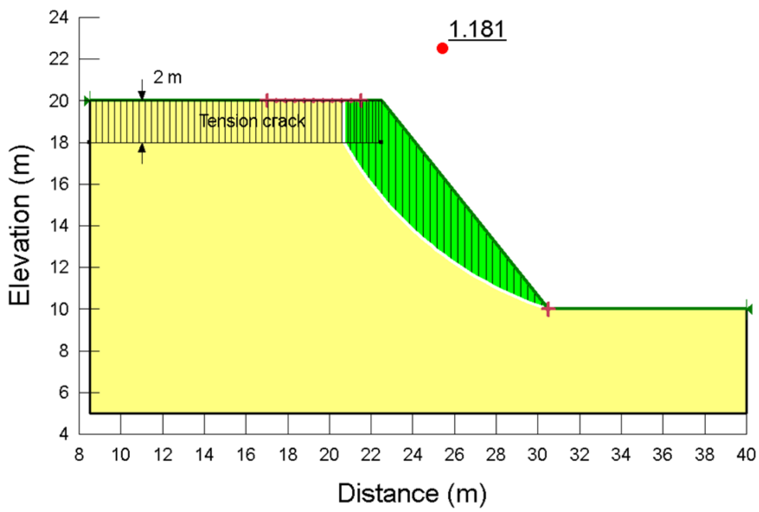

Figure 9. Factor of safety with tension crack full of water (Analysis 4).

The lateral hydrostatic force on the first slice should be:

$$\frac{\gamma H^2}{2} = \frac{10 \times 2^2}{2} = 20$$

Equation 2

This can be confirmed by looking at the slice free-body diagram in Figure 10. The 20 kN force acts on the left side of the slice. Note, the location of the hydrostatic force on the free-body diagram is only pictorial. It is not the location in space that the force is deemed to be acting for force equilibrium and moment equilibrium calculations. The force polygon closure indicates that the slice is in force equilibrium.

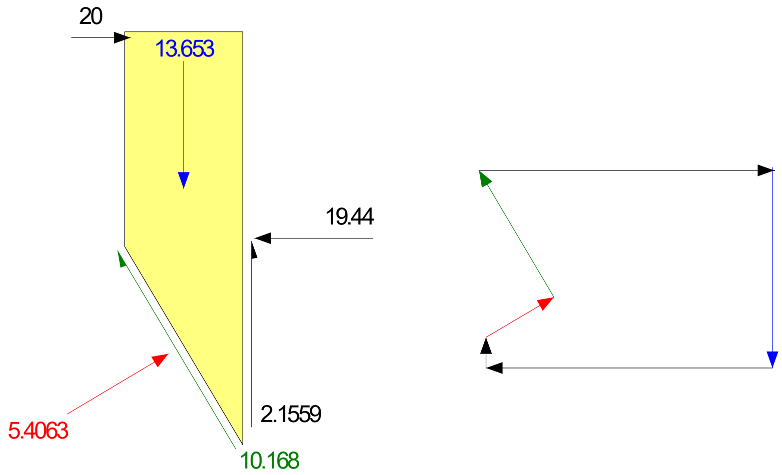

Figure 10. Slice free-body diagram and associated force polygon with water in tension crack (Analysis 4).

Summary and Conclusions

SLOPE/W includes two approaches for including tension cracks near the head scarp of a steep slope: a tension crack angle or a tension crack line. The first option is generally based on the principles of earth pressure theory. The second option is used to model an observed tension crack zone to some depth below ground. The presence of water in the tension crack can be included in option 2.