GeoStudio Example File
Active and Passive Earth Pressures

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Introduction

Reinforcement is used in many geotechnical applications to limit the amount of deformation that occurs during loading or excavation. Although the analysis of reinforcement is ultimately a soil-structure interaction problem, it is useful to think of the mechanisms in the context of lateral earth pressure theory. This example reviews earth pressure theory and demonstrates how the active and passive failure conditions can be modeled in SLOPE/W.

Background

Lateral earth pressure theory provides a method to calculate the force required to prevent failure along a pre-defined slip surface. This theory is often used in the design of gravity retaining walls or sheet pile walls. The removal of soil in an excavation causes a reduction in the lateral stress within the retained earth. Conversely, the application of a lateral load to the excavation face can increase the lateral stress within the soil. After sufficient unloading or loading, the stress state in the soil will move on to the Mohr-Coulomb failure state.

From earth pressure theory, the equivalent active earth pressure force (F_a) is given as:

$$F_a = \frac{\gamma H^2}{2} K_a$$ **Equation 1**

where K_a is the active earth pressure coefficient. Theoretically K_a is calculated as:

$$K_a = \tan^2\left(45 - \frac{\phi}{2}\right)$$ **Equation 2**

The slip surface inclination is calculated as:

$$\alpha = 45 + \frac{\phi}{2}$$ **Equation 3**

The equivalent passive earth pressure force is:

$$F_p = \frac{\gamma H^2}{2} K_p$$ **Equation 4**

The slip surface inclination for the passive condition is given by:

$$\alpha = 45 - \frac{\phi}{2}$$ **Equation 5**

Numerical Simulation

The problem domain comprises a 10 m excavation as shown in Figure 1. The upper material has a unit weight equal to 20 kN/m^3 and a friction angle equal to 30°. The material properties of the lower layer are irrelevant because the critical slip surface exits at the toe of the excavation.

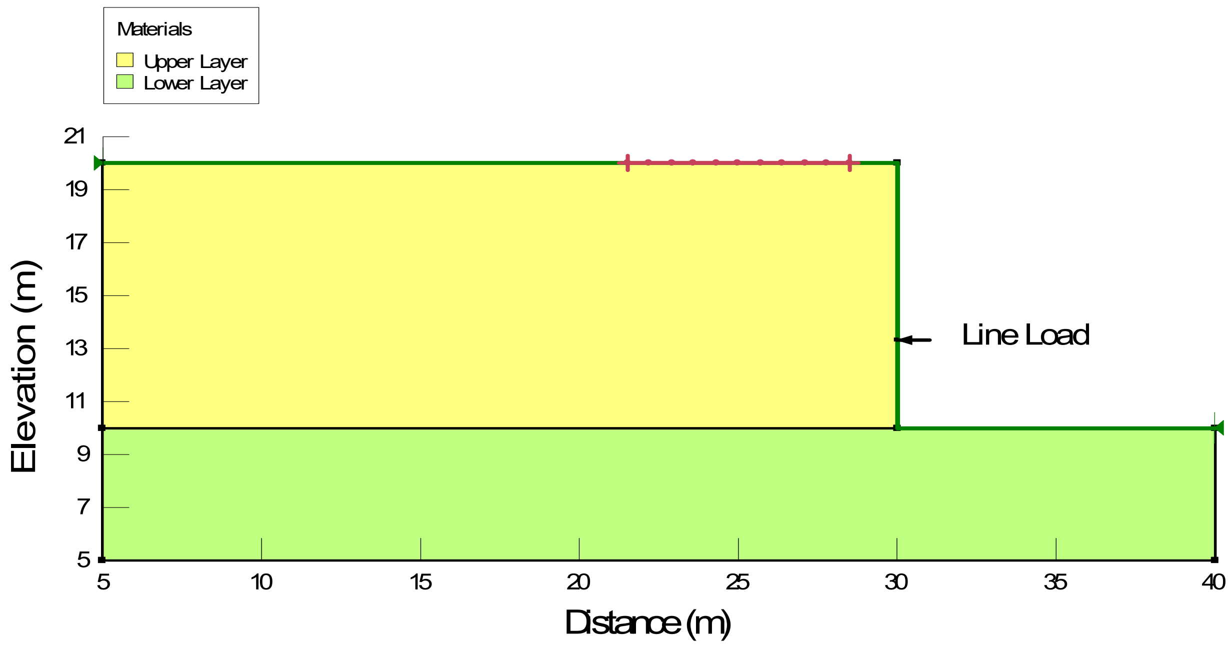

Figure 1. Example configuration.

There are two analyses in the GeoStudio Project: one for the active failure condition and one for the passive condition. The former condition is analyzed with the slip surface direction of movement set as ‘left to right’. In contrast, the passive condition is simulated with ‘right to left’ movement and the ‘Use Passive Mode’ toggle selected (Figure 2). This toggle is required because the elevation at which the slip surface enters the soil is lower than the exit. SLOPE/W will not analyze slip surfaces with this condition unless the toggle is activated.

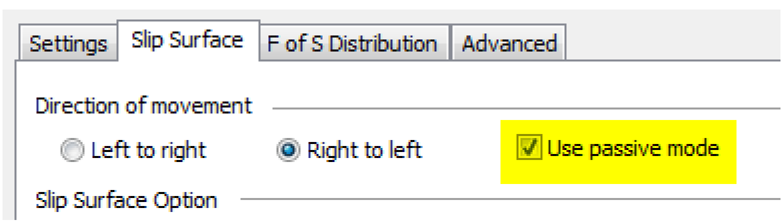

Figure 2. Activation of the passive mode.

The active and passive earth pressure force required for equilibrium is modeled using a point load. According to the equations above, the active and passive forces are 334 kN and 3000 kN, respectively. These forces are applied at 1/3 the height from the base of the excavation height.

Results and Discussion

Figure 3 and Figure 4 present the factor of safety and critical slip surface for the active and passive condition, respectively. As expected, the factor of safety of the critical slip surface is 1.0 in both cases. The computed slice base inclinations for the active condition vary from 64° at the crest to 56° at the toe. The average of all slices is 60°, which is equal to the theoretical value calculated using Equation 3. Similarly, the computed slice base inclinations vary from 32° at the crest to 26° at the toe for the passive condition. The average is right around the theoretical 30°.

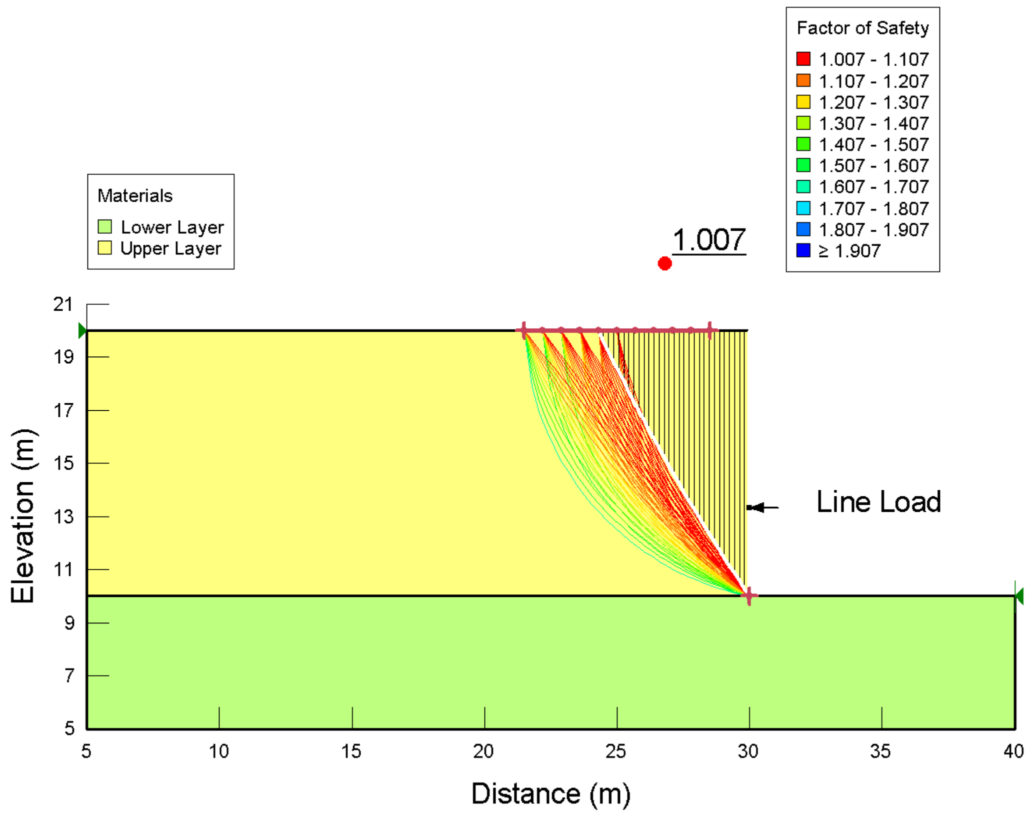

Figure 3. Factor of safety for the active condition.

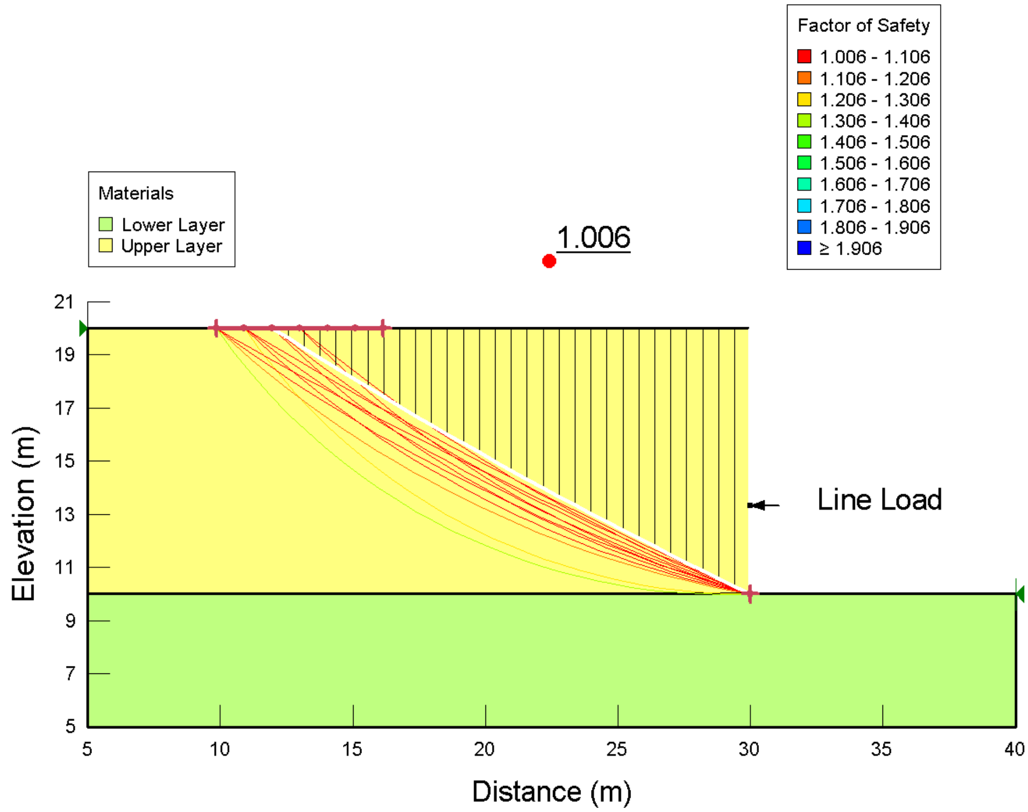

Figure 4. Factor of safety for the passive condition.

Assuming that grouted anchors were installed horizontally to retain this 10 m excavation, the total mobilized pull-out resistance from all anchors would have to be about 330 kN to stabilize the excavation. This is only an approximation because in a physical system the reinforcement would be installed at different depths and likely at an inclination. Regardless, the earth pressure concept allows the engineer to conceptualize the problem and gain an understanding of the stresses/forces required for equilibrium. Similarly, the second case demonstrates that applying a lateral load via pre-tensioning, for example, could cause the passive mode of failure to develop.

Summary and Conclusions

The active and passive earth pressure condition can be analysed in SLOPE/W. This straightforward analysis provides a context for interpreting the results of reinforced slopes or walls. For example, if all the reinforcement in a particular analysis gives a factor of safety of unity, then the reinforcement collectively is providing a stabilizing force equivalent to the active earth pressure. Furthermore, the reinforcement has the capacity to hold back more than the active pressure if the factor of safety is greater than 1.0.

Computing the active and passive earth pressures is rather straightforward for uniform conditions with no positive pore-water pressures. It gets more complicated where several different types of soil are present and if there is a water table present behind the wall. In such cases, a SLOPE/W analysis can be useful to establish the required lateral earth pressure.