

Sheet Pile Wall

1 Introduction

Deep excavation on a level ground usually results in a very low factor of safety, unless it is properly reinforced. The purpose of this example is to illustrate how the stability of a deep excavation with a sheet pile wall can be evaluated. Features of this simulation include:

- Analysis method: Morgenstern-Price
- Use of Entry and Exit slip surface option
- A dry slope with no pore-water pressure condition
- Use of anchors to reinforce the slope
- Use of a pile to model the sheet pile
- Use of a line load to model the sheet pile
- Hand calculation of the passive earth pressure

2 Configuration and setup

A dry homogeneous material is used in this example. A Mohr Coulomb soil model is used. The unit weight of the material is chosen to be 20 kN/m^3 , the material is assumed to have zero cohesion and a frictional angle of 30° . Since all surfaces are assumed to exit at the toe of the embankment, the exit zone is modeled with a single point. The depth of the vertical excavation is 10 m, and the sheet pile wall penetrates 3 m into the bottom of the excavation. The geometry and material properties are shown in Figure 1.

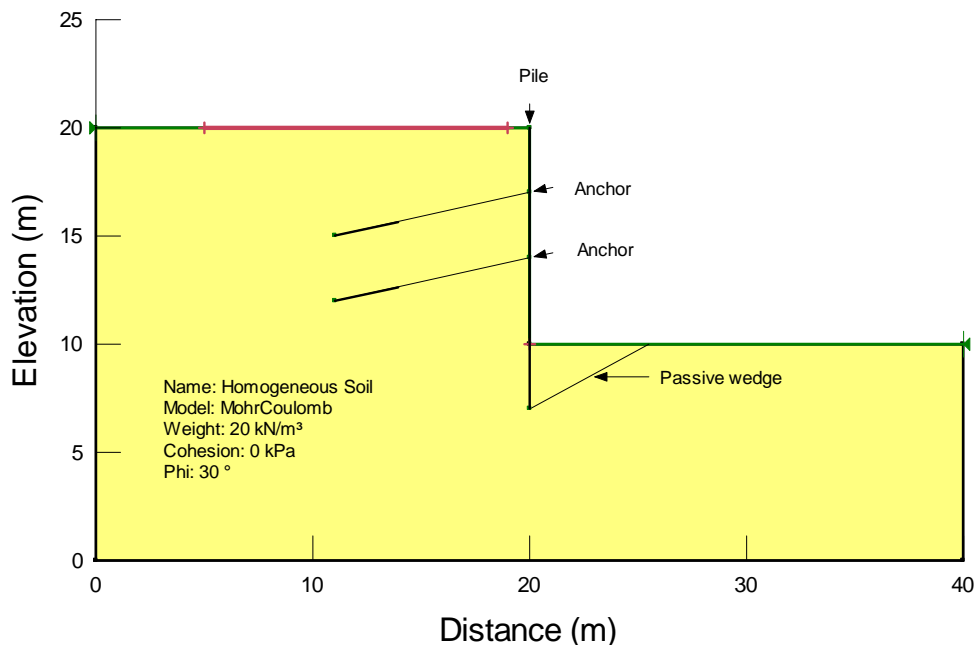


Figure 1 Geometry and soil properties of the sheet pile wall

The sheet pile wall is modeled with a pile. The sheet pile wall is reinforced with two anchors with a constant load of 100 kN each. Since the sheet pile wall is penetrated 3 m into the bottom of the excavation, it is reasonable to model an additional resistance force acting on the vertical cut, due to the passive wedge.

Using Rankine's passive pressure theory, the passive pressure force acting on the slope can be calculated as:

$$\text{Passive Force} = K_p \frac{\gamma H^2}{2} = \tan^2\left(45 + \frac{\phi^\circ}{2}\right) \frac{\gamma H^2}{2}$$

$$\text{Passive Force} = 3.0 \times \frac{20 \times 3 \times 3}{2} = 270 \text{ kN}$$

The Exit and Entry slip surface option is used. For the exit zone, note that a single point at the toe is used to model the situation that all slip surfaces must exit at the toe of the vertical cut.

3 Case 1 – No resistance from passive earth pressure

Figure 2 shows the critical slip surface and factor of safety of the case when the resistance of the passive wedge is not modeled. The factor of safety is 0.584, indicating that the vertical will fail even though the two anchors are used.

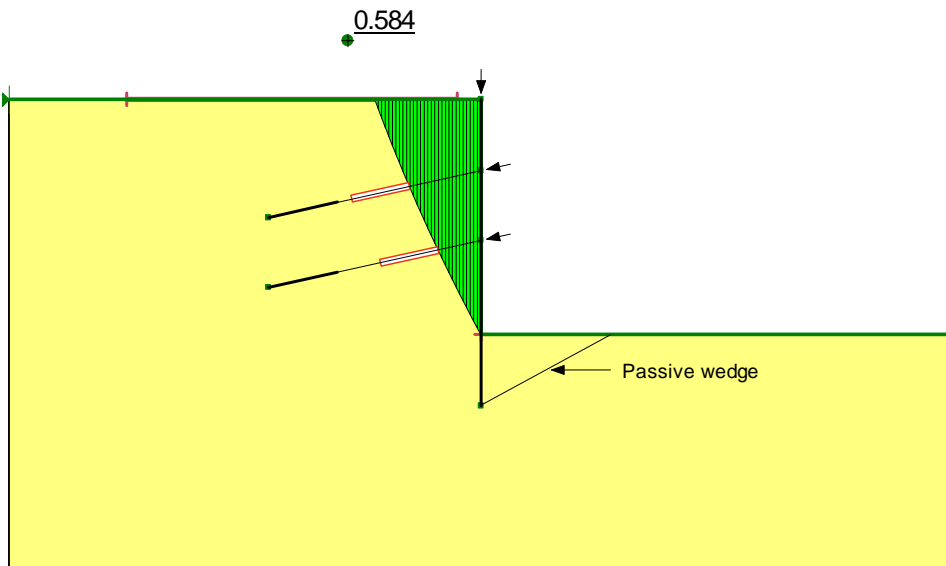


Figure 2 Critical slip surface and factor of safety

Figure 3 and Figure 4 show the free body diagram and force polygons of the slices that intersect the anchors. Note that the anchor loads of 100 kN are properly included in slices #10 and #18 in the factor of safety computation.

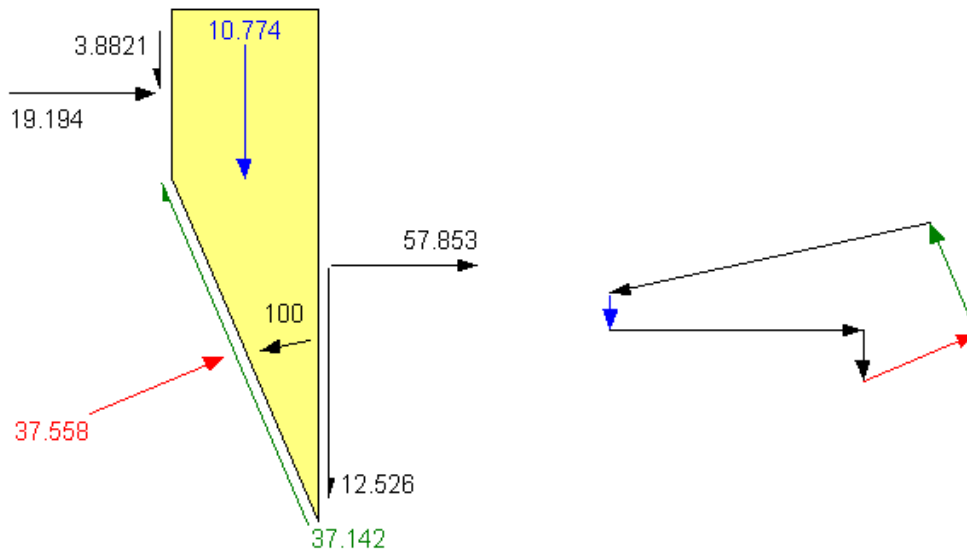


Figure 3 Free body diagram and force polygon of the slice # 10

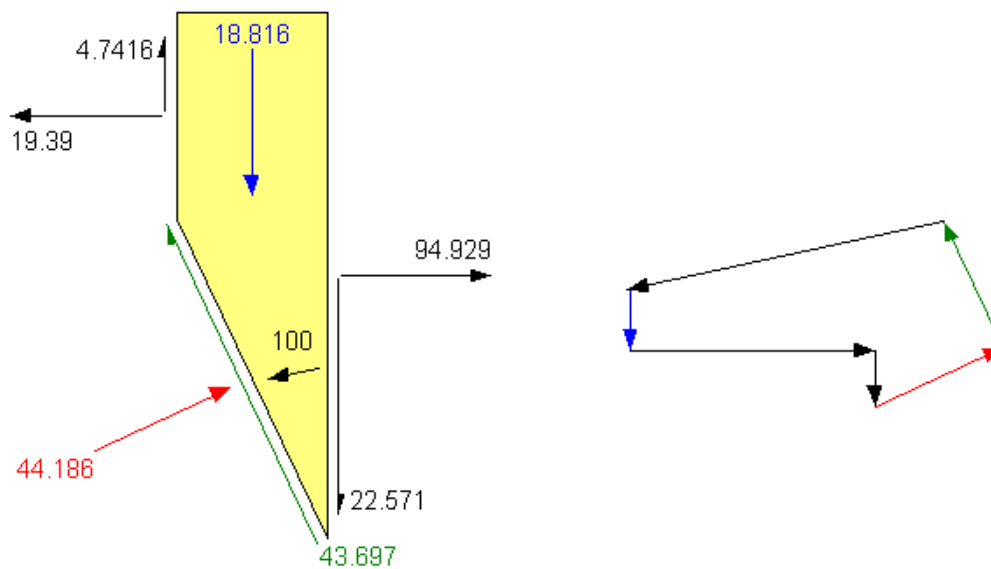


Figure 4 Free body diagram and force polygon of the slice # 18

4 Case 2 – passive earth pressure modeled with line load

Figure 5 shows the critical slip surface and factor of safety of the case when the resistance of the passive wedge is modeled with a line load of 270 kN acting at the toe of the slip surface. The factor of safety of the vertical cut improves to 1.525.

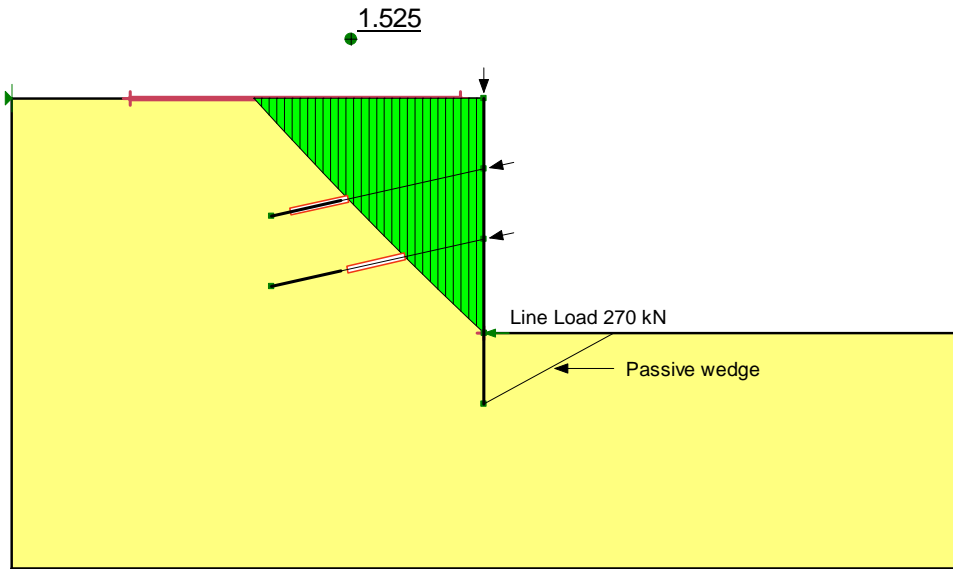


Figure 5 Critical slip surface and factor of safety

It is always a habit to use the view slice information feature in CONTOUR to examine the loading acting on the slope. Figure 6 shows the free body diagram and the force polygon of the last slice (slice # 30). The resistance force due to the passive wedge is shown correctly on the slice as a horizontal line load of 270 kN.

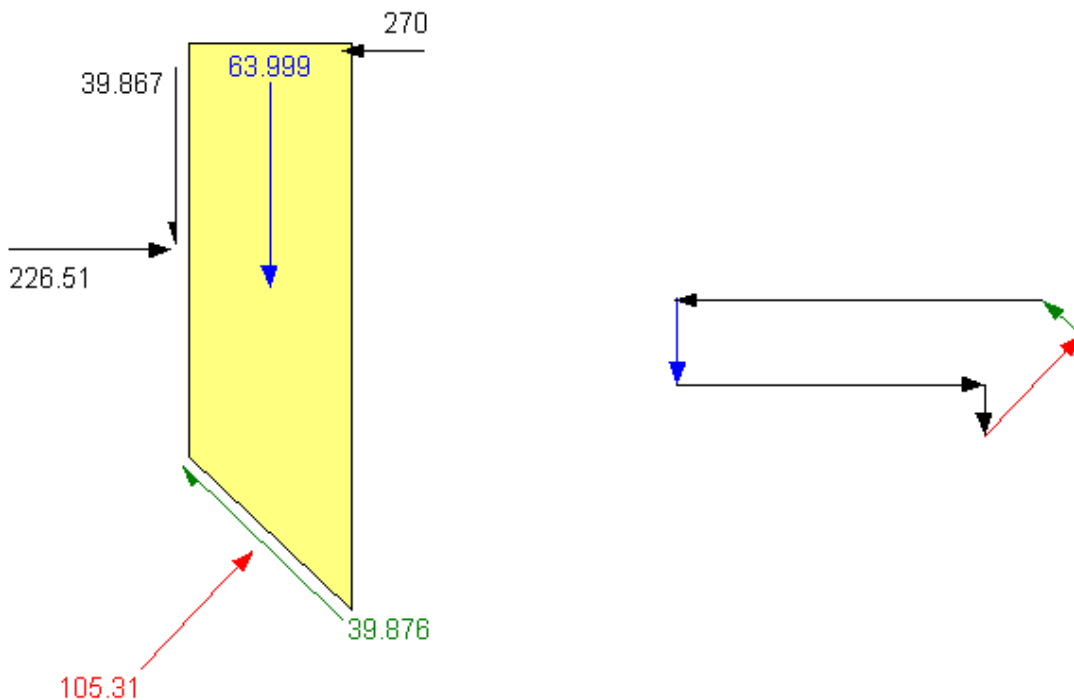


Figure 6 Free body diagram and force polygon of the last slice

5 Case 3 – passive earth pressure modeled with pile shear force

Alternatively, the resistance force of the passive wedge can be modeled as a shear force in the pile. Figure 7 shows the critical slip surface and factor of safety of the case when the shear force of the pile is set to be 270 kN. The factor of safety of the vertical cut is 1.525, which is the same as Case 1 when the resisting force is modeled with a line load.

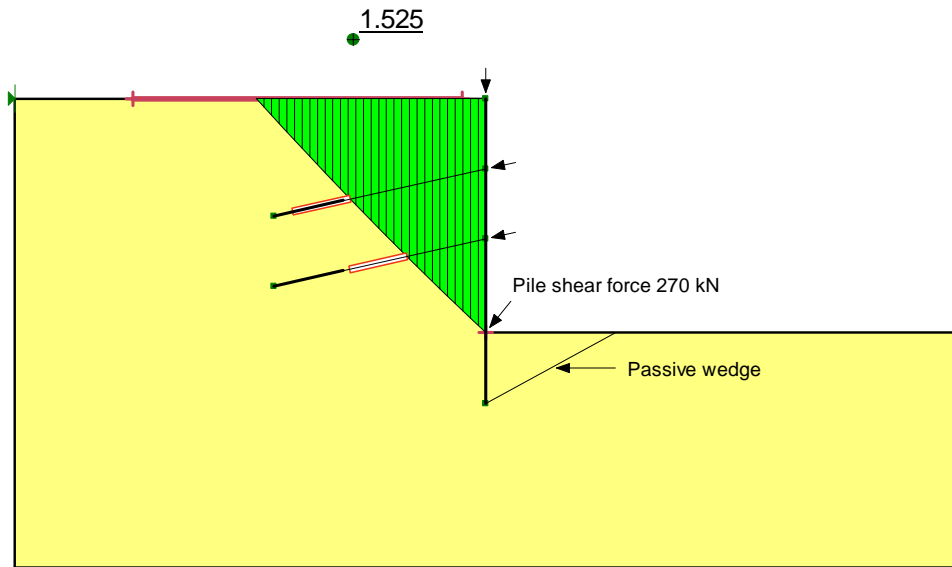


Figure 7 Critical slip surface and factor of safety

Figure 8 shows the free body diagram and the force polygon of the last slice (slice # 30). The resistance force due to the passive wedge is shown correctly on the slice as a shear force (270 kN) showing at the base of the slice.

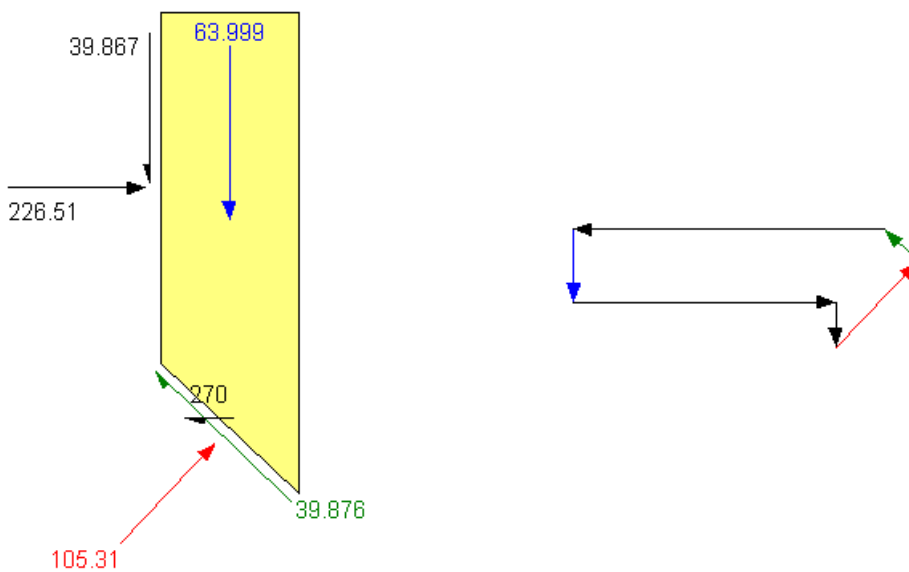


Figure 8 Free body diagram and force polygon of the last slice

6 Case 4 – Deep seated failure mode

Although it is likely that the critical failure mode will be at the toe of the vertical cut, it is a good practice to examine other possible modes of failure. One possible mode of failure in this example is a deep seated failure model in which the slip surface will pass below the sheet pile wall and the resistance force due to the passive wedge cannot be included in the factor of safety computation.

Figure 9 shows the critical slip surface and factor of safety of the deep seated failure model. The factor of safety is 1.954.

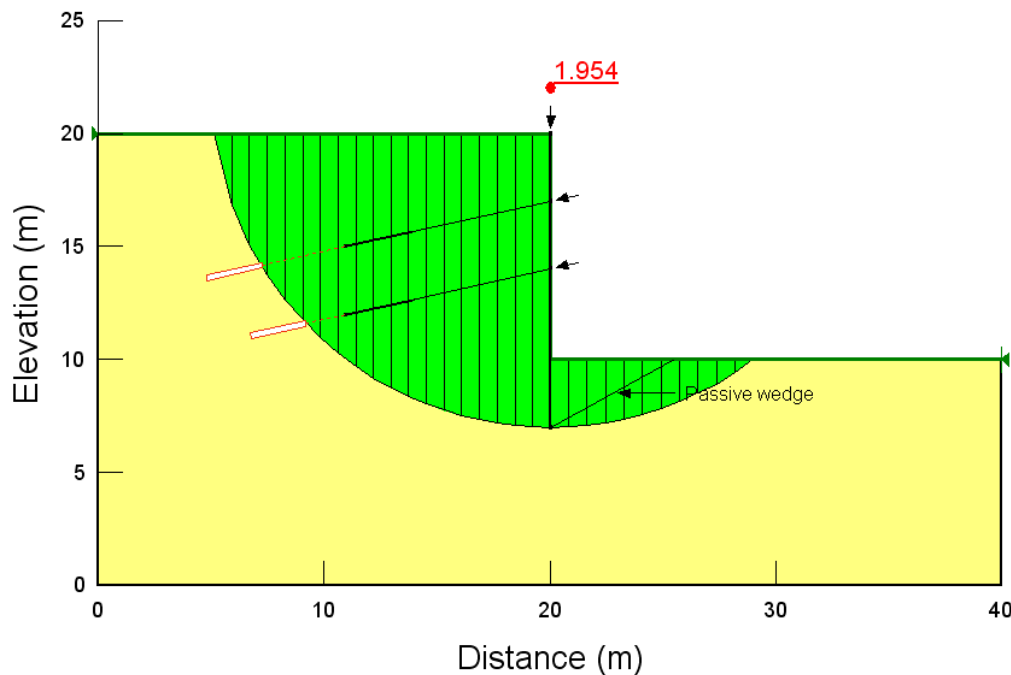


Figure 9 Critical slip surface and factor of safety

Since a constant load condition is specified for the two anchors, the anchor load (100 kN) is still being applied to slice #3 and #6. The red box and the extended length of the anchors indicated that the total length of the anchor need to be extended in order to have the anchor load being included in the factor of safety computation.