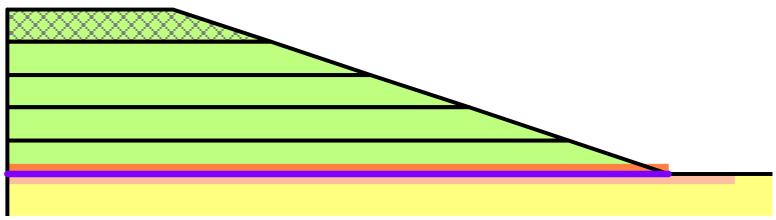
Embankment on Geofabric

1 Introduction

This example demonstrates how a geofabric can be included as reinforcement in the staged construction of an embankment on soft ground, and how the potential slip between the ground and the geofabric can be modeled with interface elements. The different colored layers at the bottom of the embankment show the geofabric and interface elements.



The primary purpose is to illustrate how to include a geofabric in an analysis like this and how to allow for some potential slip between the geofabric and the soil. The secondary purpose is to show that the geofabric itself and the slip friction forces do not enter into the stability analysis. The geofabric affects the ground stresses, which in turn affects the stability.

2 Problem configuration and setup

The complete problem configuration and setup is shown in Figure 1. The foundation is treated as a somewhat soft weak material. The embankment is deemed to be a sandy material.

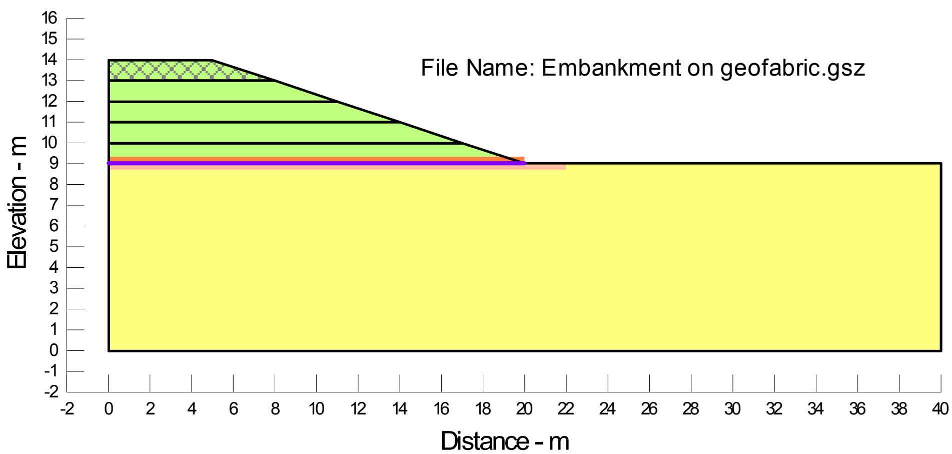


Figure 1 Problem configuration and setup

The embankment is constructed in five one-metre lifts.

Once the embankment has been constructed, the intention is to check the stability using the finite element stresses. The initial insitu stresses are consequently required, even though Linear Elastic material properties are used in the SIGMA/W analysis.

Figure 2 shows the sequential analysis procedure.

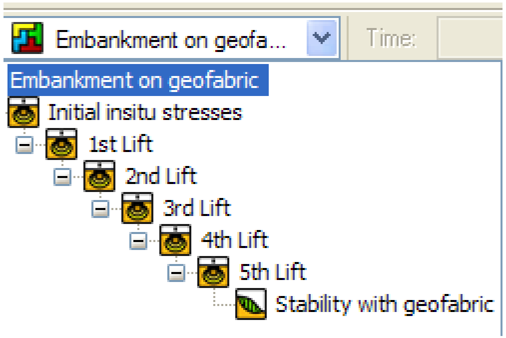


Figure 2 Sequential analysis steps and stages

Special attention has to be given to the interface elements and geofabric at the toe of the embankment. In order to completely isolate the geofabric from the embankment and from the foundation materials, it is necessary to have a short interface segment beyond the toe, as shown in Figure 3. Without this short interface segment, the geofabric will be connected to the foundation material, as shown in Figure 4. By the fact that the geofabric and the foundation soil have a common node (at Point 15) means the two materials are connected. Furthermore, the foundation soil region needs an extra point, like Point 16.

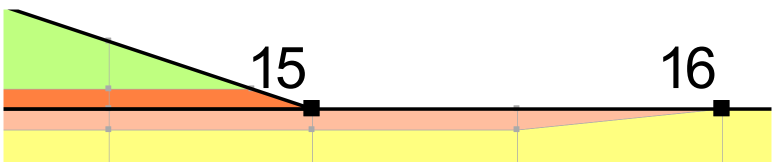


Figure 3 Interface elements beyond the toe

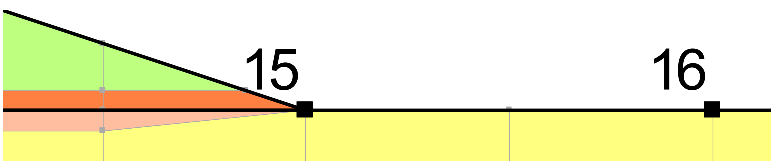


Figure 4 Interface elements up to the toe

3 Material properties

The material properties for this example are completely arbitrary. They were selected purely for the purpose of illustrating the analysis procedure and are not intended to represent any particular real field situation.

Of importance, from a SIGMA/W feature and capability point of view, is the fact that the frictional properties are different on the top from the properties on the bottom.

The geofabric is modeled as a beam with no flexural stiffness; that is, the moment of inertia *I* is specified as zero. The geofabric has stiffness (*E*) and a cross-sectional area. This being a 2D analysis, the thickness into the page is unity (1 m). The geofabric therefore is a strip 1 m wide. The thickness is consequently the area.

The frictional behavior is described as an elastic-plastic material. The frictional strength below the geofabric is specified as c = 0 and Ø = 18 degrees. Above the geofabric, the friction between the geofabric and the embankment material is specified with c = 0 and Ø = 20 degrees.

The geofabric has tensile capacity, but no compressive capacity. The option of "Allow Compression" is therefore unselected.

4 Response of reinforcement

Figure 5 shows the tension in the geofabric as each embankment lift is placed. What is rather interesting is that the maximum tension is more toward the embankment toe area for Lifts 2 and 3 (Figure 6). The reason for this is that the tendency for a slip is more towards the toe area than further back under the embankment. Ultimately, however, the maximum tension is under the center of the embankment. Also note that there are no compression (positive) forces in the geofabric.

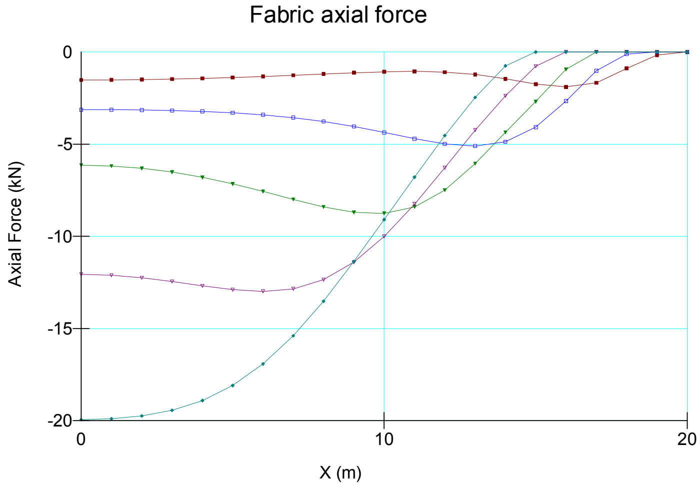


Figure 5 Tension in the geofabric

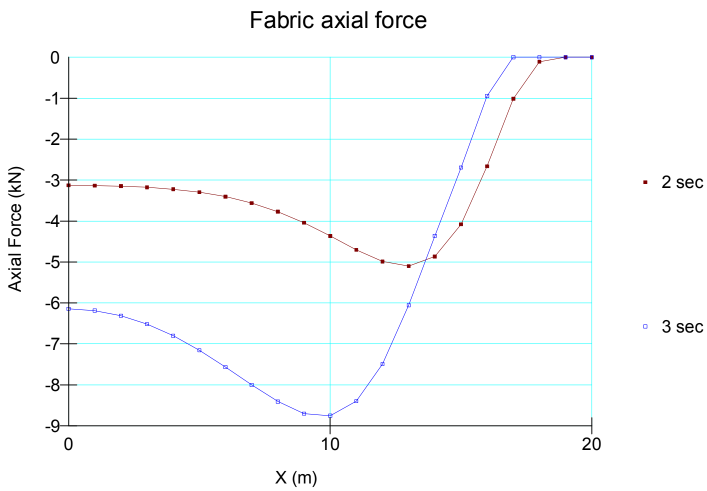


Figure 6 Tension in geofabric after placement of the 2nd and 3rd lifts

5 Stability

The resulting embankment and foundation stresses can be used in SLOPE/W to do a stability analysis, as illustrated in Figure 7. However, there are several issues that need to be recognized and appreciated.

The tension in the geofabric itself does not enter into the safety factor calculations. The geofabric alters the stresses, which in turn are used in the stability analysis, but the geofabric itself does not enter into the calculations. The geofabric forces come into play in a conventional Limit Equilibrium analysis, but not when the SIGMA/W computed stresses are used in the stability calculations.

In reality, the interface material is very thin and therefore does not affect the shear strength along the slip surface. The interface materials are therefore ignored in the stability calculations if the potential slip surface crosses the interface elements. Sliding along the geofabric is a different issue and has to be addressed separately.

The interface elements are also not considered in the slice discretization.

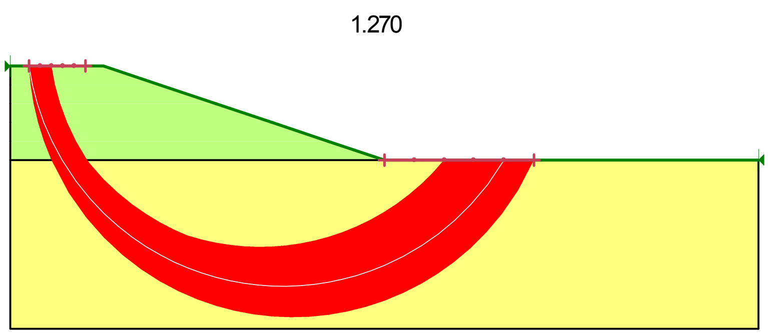


Figure 7 Stability analysis of reinforced embankment

The data file was saved with a new name, the geofabric and interface materials were removed, and then the analysis was repeated. Without the reinforcement, the factor of safety is 1.208, as shown in Figure 8.

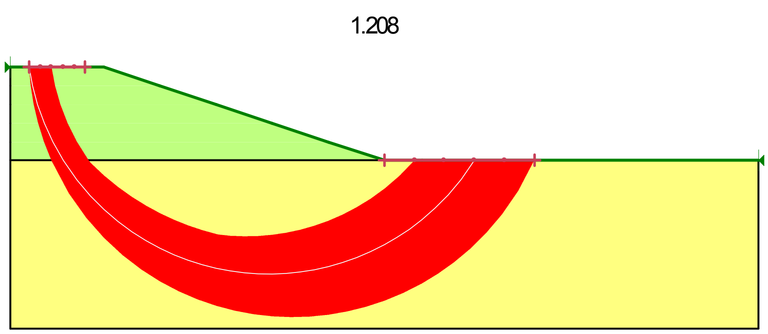


Figure 8 Stability with no reinforcement

The modified file is not included; this exercise is left up you, the reader.

The increase in the overall factory of safety is rather small in this case - increasing only from 1.208 to 1.270. This is not uncommon. The geofabric does not necessarily alter the overall factor of safety all that much but the geofabric provides other benefits such as controlling the shape and pattern of the deformations.

6 Concluding remarks

This example demonstrates how beam elements can be used to model the effects of geofabric reinforcement, and how the potential slip between the geofabric and the soil can be considered using an elastic-plastic material with a reduced friction angle. Also, demonstrated is how the frictional characteristics between the geofabric and the soil can be different above and below the material.

Stability is just one issue in the analysis, design and construction of reinforced embankments on soft ground. Other issues like long term settlement, for example, are beyond this illustrative example, but may be equally important.

The advantage of including the geofabric in a SIGMA/W analysis is that it is possible to study the tension in the reinforcement and to consider deformations. If the analyst is only interested in changes in factor of safety then doing a SLOPE/W limit equilibrium type of analysis is likely a better alternative.