Dam Construction by Stages

GEO-SLOPE International Ltd. | www.geo-slope.com

1200, 700 - 6th Ave SW, Calgary, AB, Canada T2P 0T8
Main: +1 403 269 2002 | Fax: +1 888 463 2239

Introduction

This simple example demonstrates the simulation of staged embankment construction on soft ground. The primary objective of this example is to demonstrate the use of the hyperbolic model when:

- The undrained strength of the foundation varies with depth (elevation);
- The soil stiffness of the foundation varies with depth (elevation);
- The soil stiffness of the foundation material varies with the overburden stress (Y-stress); and
- A hyperbolic model is used for the fill material with a constant stiffness E.

Numerical Simulation

Figure 1 shows the Analysis Tree in the GeoStudio Project and Figure 2 shows the problem configuration. The fill is placed in eight successive 1 m lifts. Each lift is simulated using a single time step in each analysis. The foundation is fixed in the x- and y-direction on the bottom, left and right boundaries to prevent displacement on these boundaries using the Fixed X-Y boundary condition.

The initial (*in situ*) stresses are developed prior to the fill placement using a linear-elastic material model for the foundation soil. Prior to the fill placement, the water table is at the ground surface. Consequently, effective-drained parameters are required in the *in situ* analysis in order to get the correct *in situ* stress conditions. The effective drained parameters are required so that pore-water pressures will be taken into account in the *in situ* stress computations. If the pore-water pressures are ignored, the *in situ* stresses will not be correct.

Figure 1. Analysis Tree for the Project.

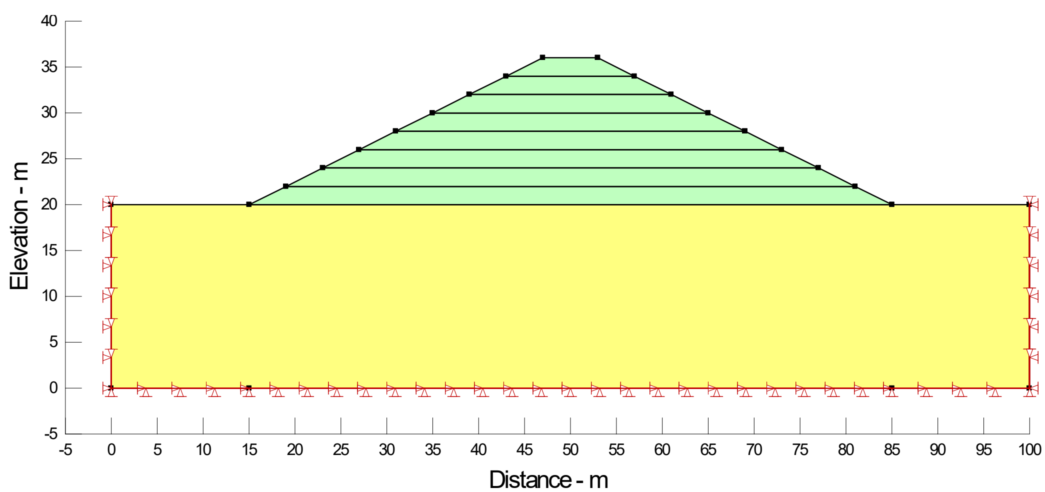

Figure 2. Problem configuration and setup.

A total stress undrained behavior is assumed for the foundation; that is, the strength is specified as C_u and the *E*-modulus is considered to be a total stress modulus. The embankment material is assumed to be a well compacted soil with a relatively high stiffness.

Figure 3 shows the undrained strength used for the foundation. The undrained strength varies from a minimum of 50 kPa at the surface to a maximum of 400 kPa at depth.

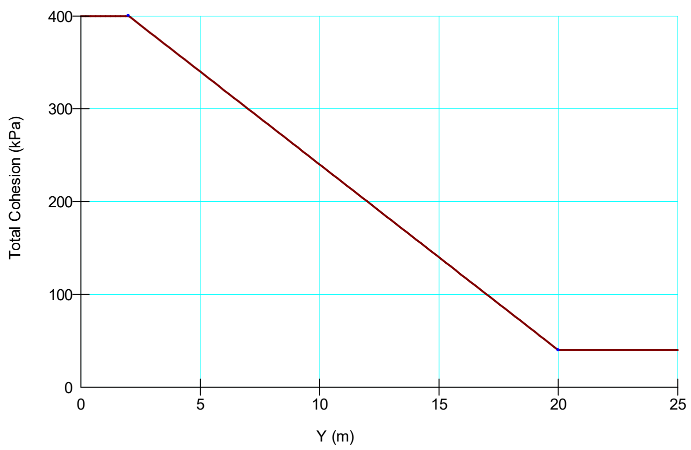

Figure 3. Undrained strength varying as a function of elevation.

The E modulus varies from a low value of 5000 kPa near the ground surface to about 12,000 kPa at depth (Figure 4).

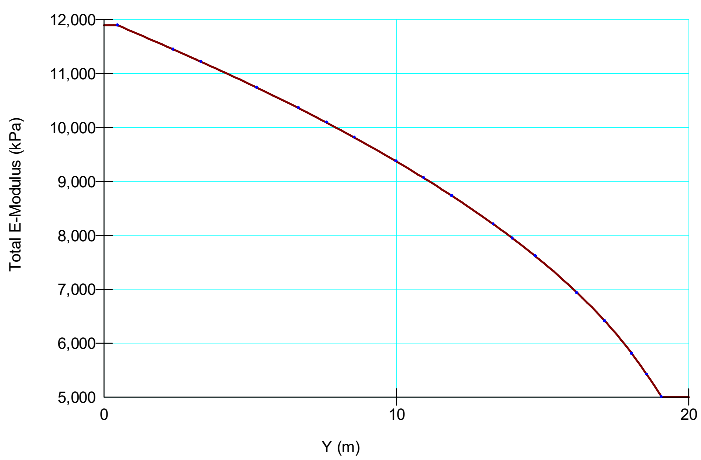

Figure 4. Foundation E-modulus varying as a function of elevation.

The fill material is assigned a constant undrained strength of 1000 kPa and the stiffness is assigned a constant E of 15,000 kPa.

Results and Discussion

Figure 5 shows the C_u profile for the foundation for all load steps. The legend has units of seconds (sec), which is equivalent to load step number in this particular case. Notice that the profile is the same for all load steps, as it is intended to simulate the undrained behavior. This is also the case for the initial modulus E_i as shown in Figure 6.

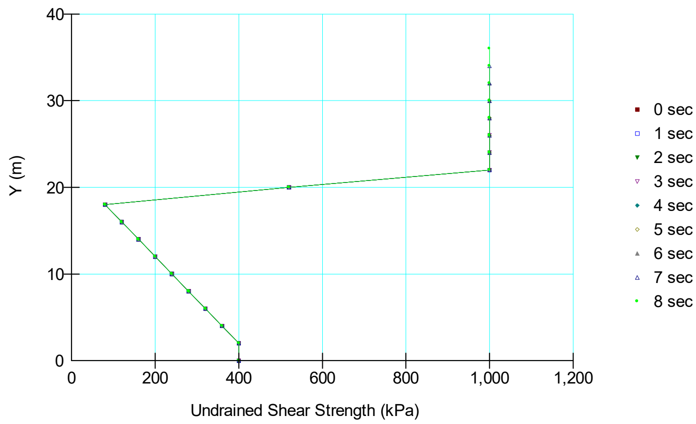

Figure 5. Undrained strength profile during loading.

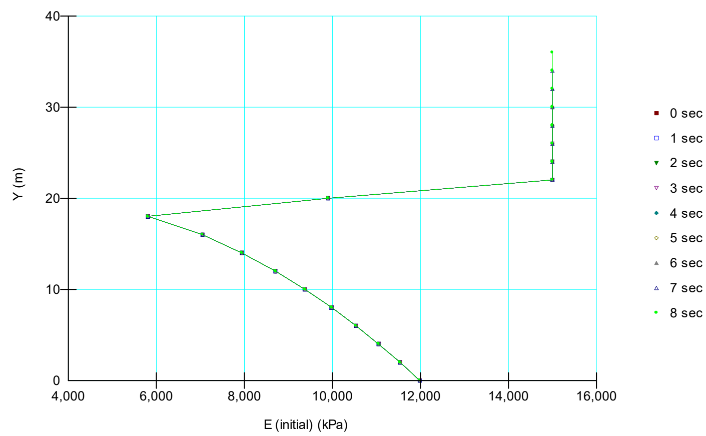

Figure 6. E_i profile during the embankment loading.

The vertical settlements along a profile at the centre-line of the embankment are shown in Figure 7. Of significance is that the largest settlement is not at the dam crest.

Displacement profiles along the original ground surface are presented in Figure 8. Naturally, settlement occurs under the central part of the embankment and heave occurs near the toe area and outside the foundation footprint.

The foundation soil is treated as being undrained, inferring that it cannot undergo any volume change (v = 0.49). Consequently, any settlement under the dam has to be reflected in heave beside the dam. This is also evident in the deformed mesh shown in Figure 9.

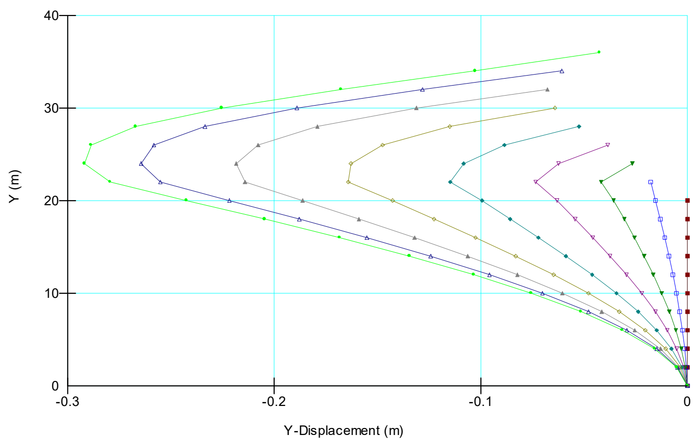

Figure 7. Vertical settlement profiles along center line of structure.

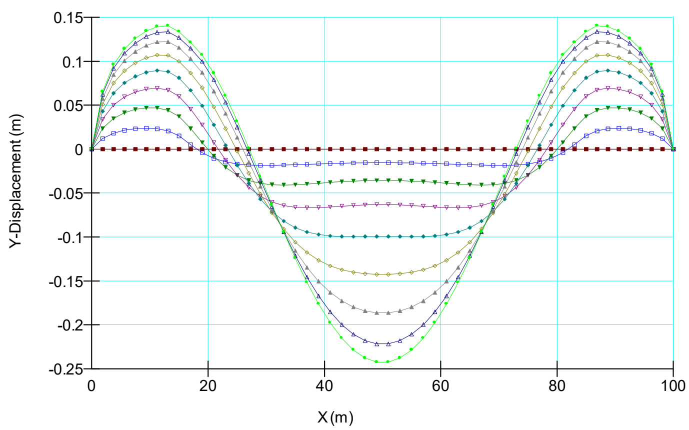

Figure 8. Settlement along original ground surface.

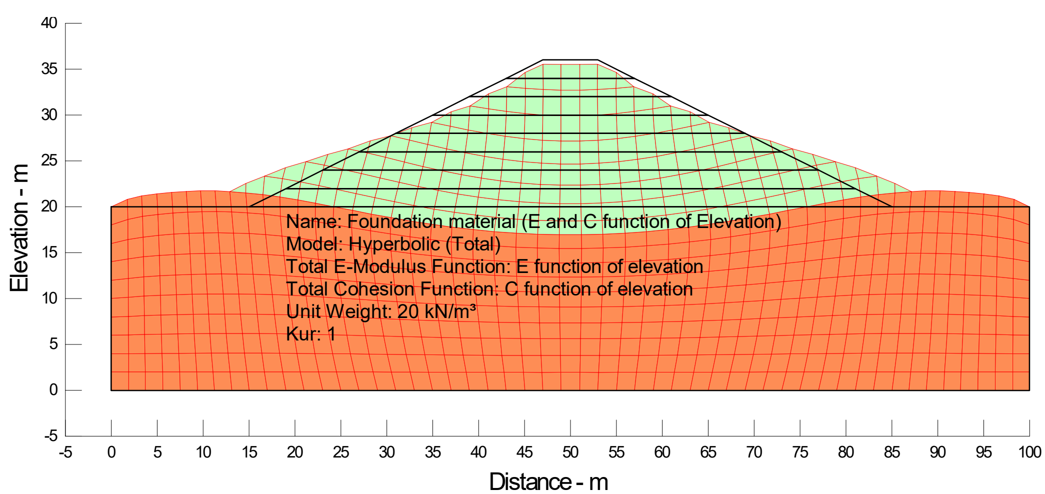

Figure 9. Deformed mesh.

The analysis was repeated with initial stiffness Ei varying as a function of in situ vertical effective stress. A plot of the initial modulus at all load steps reveals that it is unchanged during the simulation because the function only initializes the initial modulus (Figure 10). In contrast, the tangent modulus varies during loading and is commensurate with the Hyperbolic constitutive material model (Figure 11).

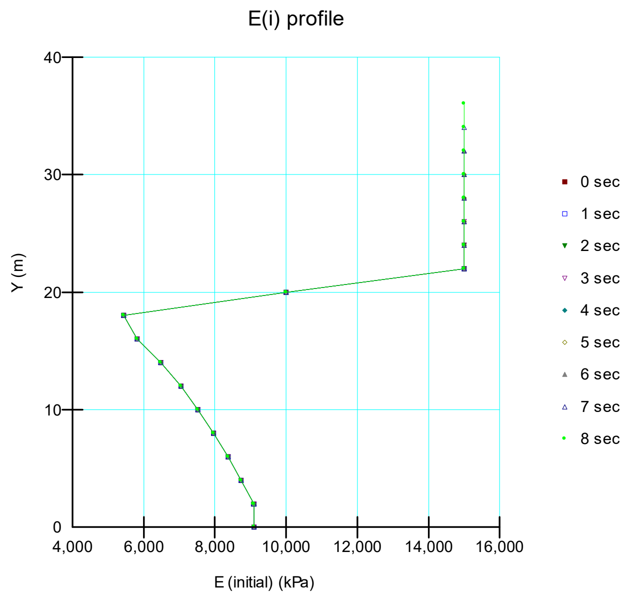

Figure 10. Variation of E when the stiffness is defined as a function of the overburden stress.

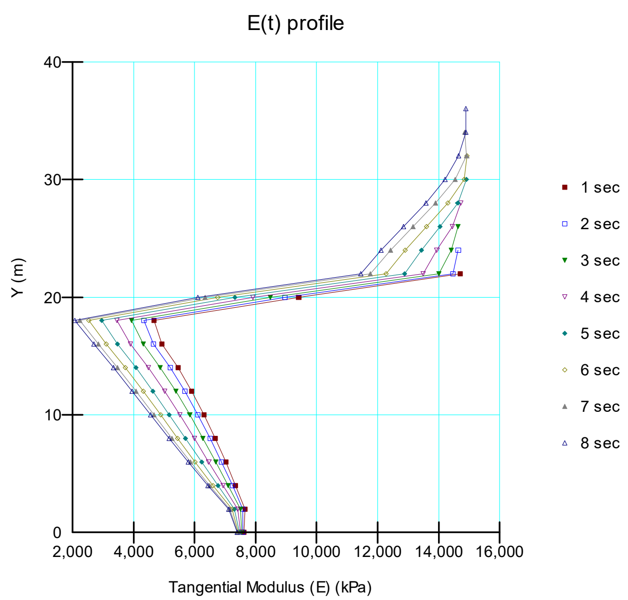

Figure 11. Variation in Tangent modulus during loading.

Summary and Conclusions

It is good modeling practice to treat the fill as having a constant E stiffness. The stresses in the fill are very low as each lift is placed, making it difficult to define an appropriate E as a function of the overburden stress. Also, as the elevation of the lifts keeps changing, an E versus elevation function is also hard to use. The best is to use a constant E.