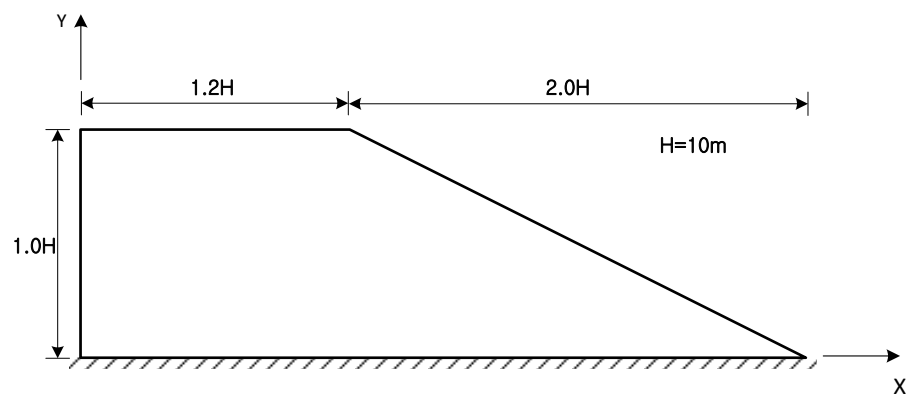


6.1 Homogeneous Slope on Rigid Foundation

| | |
|----------------|------------------------------|
| REFERENCE | Griffiths et al ¹ |
| ELEMENTS | Plane strain elements |
| MODEL FILENAME | SlopeStability01.fea |

Figure 6.1.1 shows the slope model with 21.57° inclination subjected to self-weight. The left side of the model is constrained in the horizontal direction and the bottom side is completely fixed. Slope stability analysis is carried out using strength reduction method (SRM) during which the strength reduction factor (SRF) is gradually increased until instability is reached. The resulting factor of safety is compared with the reference solution.

Figure 6.1.1
Slope model without
foundation



| | | |
|---------------|-----------------|----------------------------------|
| Material data | Young's modulus | $E = 2.0 \text{ MPa}$ |
| | Poisson's ratio | $\nu = 0.3$ |
| | Model type | <i>Mohr Coulomb</i> |
| | Cohesion | 10.0 kPa |
| | Friction angle | 20° |
| | Dilatancy angle | 20° |
| Load data | Self weight | $\gamma_t = 20.0 \text{ kN/m}^3$ |

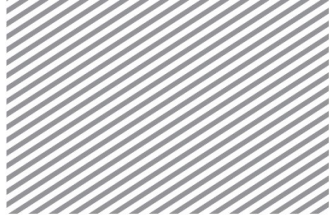


Figure 6.1.2
Safety reduction factor
vs. dimensionless
displacement

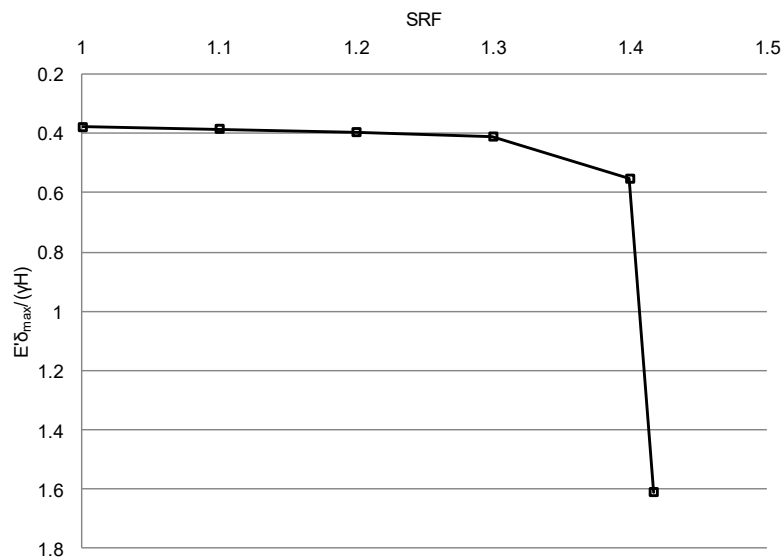
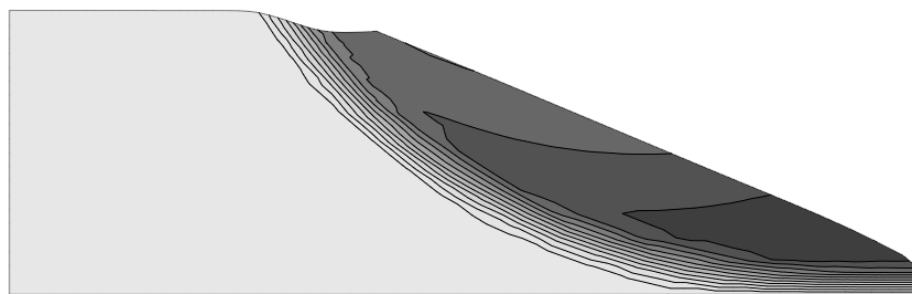


Table 6.1.1 Factor of safety at embankment

| | Factor of safety |
|-----------|------------------|
| Reference | 1.4 |
| Quad-8 | 1.4187 |

Figure 6.1.3
Deformed shape and
displacement contour at
failure



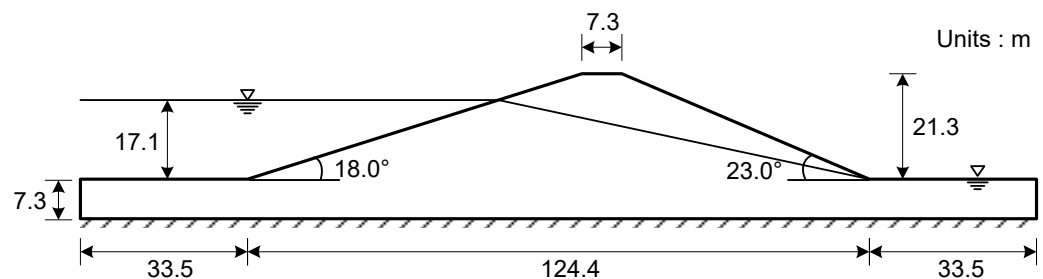
6.2 Two-sided Earth Embankment

| | |
|-----------------------|------------------------------|
| REFERENCE | Griffiths et al ¹ |
| ELEMENTS | Plane strain elements |
| MODEL FILENAME | SlopeStability02.fea |

Figure 6.2.1 shows a dam model with phreatic surface which varies from the reservoir level to the foundation level. Slope stability analyses are carried out by strength reduction method (SRM) for two cases; A) with water level and B) without water level.

For both cases, the displacements are constrained in the horizontal direction along the vertical edges and in all directions along the bottom edge. The dam model is subjected to self weight and external pressure due to the existence of reservoir water (case A only). The resulting factors of safety are compared with the reference solutions.

Figure 6.2.1
Two-sided earth
embankment



| | | |
|----------------------|-----------------|----------------------------------|
| Material data | Young's modulus | $E = 0.2 \text{ GPa}$ |
| | Poisson's ratio | $\nu = 0.3$ |
| | Model type | <i>Mohr Coulomb</i> |
| | Cohesion | 13.8 kPa |
| | Friction angle | 37° |
| | Dilatancy angle | 37° |
| Load data | Self weight | $\gamma_t = 18.2 \text{ kN/m}^3$ |

Table 6.2.1 Factor of safety at embankment

| | Case A) with water level | Case B) without water level |
|-----------|--------------------------|-----------------------------|
| Reference | 1.90 | 2.42 |
| Quad-8 | 1.9656 | 2.5094 |

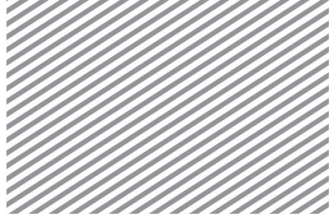


Figure 6.2.2

Safety reduction factor vs.
dimensionless
displacement

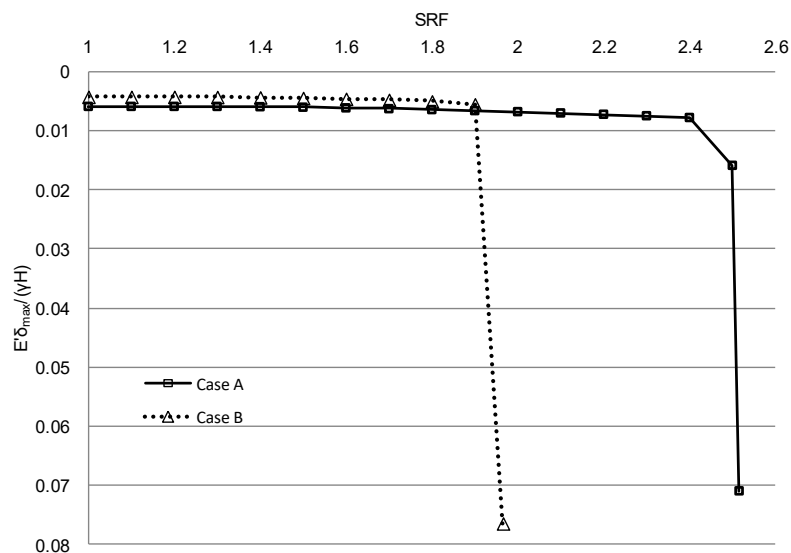
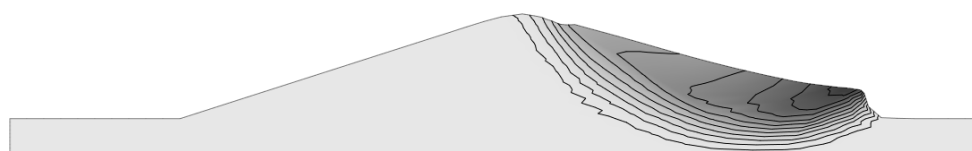
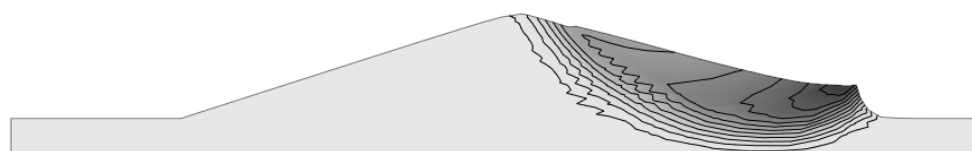


Figure 6.2.3 shows the deformed shape of the model in the vicinity of unstable equilibrium point for both with and without water level. For both cases, the instability occurs in the region where the slope is steeper. It is also noteworthy that if water is considered (case A), failure mechanism extends deeper into the foundation while, case B results in a toe failure. These results are in agreement with the limit equilibrium solutions included in the reference.

Figure 6.2.3
Deformed shape at
failure



(case A)



(case B)



6.3 Failure of Clay Slope with a Thin Weak Layer

| | |
|----------------|------------------------------|
| REFERENCE | Griffiths et al ¹ |
| ELEMENTS | Plane strain elements |
| MODEL FILENAME | SlopeStability03.fea |

Figure 6.3.1 shows a slope on a foundation layer with embedded layer of weaker material to simulate a slippery liner within a landfill system. Slope stability analysis based on strength reduction method (SRM) is conducted. The displacements are constrained in the horizontal direction along the vertical edges and in all directions along the bottom edge. The slope system is subjected to self-weight.

While maintaining the strength of the soil, slope stability was evaluated for several strength values of the weak layer; $C_{u2} / C_{u1} = 0.2, 0.4$ and 1.0 . Figure 6.3.2 shows the deformed shapes of the model in the vicinity of unstable equilibrium point for different strength values of the weak layer. The deformed shape matches the shape of the weak layer for $C_{u2} / C_{u1} = 0.2$ and turns to a circular shape as the model approaches homogeneous. Both failure mechanisms become active for $C_{u2} / C_{u1} = 0.6$.

These results illustrate the advantages of the finite element-based slope stability analysis which does not require a priori knowledge of the failure mechanism.

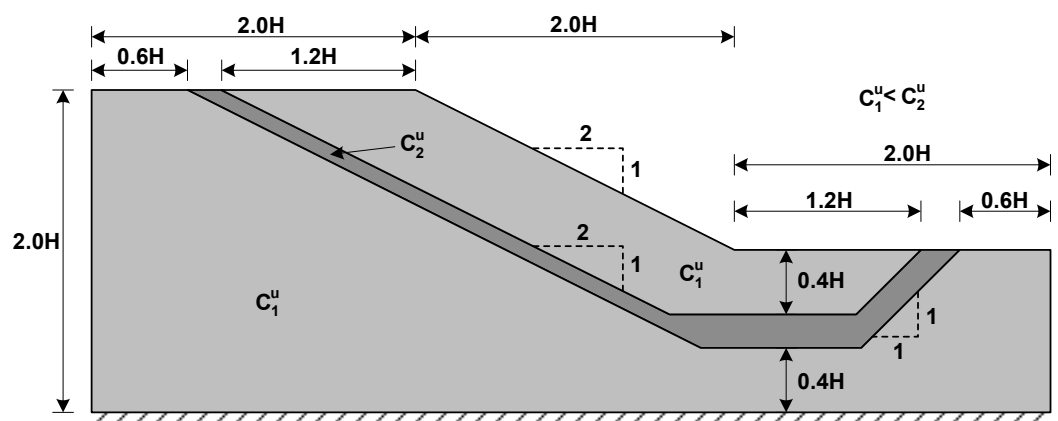


Figure 6.3.1
Clay slope with a thin
weak layer



| | | |
|----------------------|-----------------------|--|
| Material data | Young's modulus | $E = 0.8 \text{ GPa}$ |
| | Poisson's ratio | $\nu = 0.3$ |
| | Model type | <i>Mohr Coulomb</i> |
| | Cohesion (C_{u1}) | 50.0 kPa |
| | Cohesion (C_{u2}) | $20 \text{ kPa} \sim 50.0 \text{ kPa}$ |
| | Friction angle | 0° |
| | Dilatancy angle | 0° |
| Load data | Self weight | $\gamma_t = 20.0 \text{ kN/m}^3$ |

Table 6.3.1 Factor of safety at embankment for $C_{u2} / C_{u1} = 1.0$

| | Factor of safety |
|-----------|------------------|
| Reference | 1.47 |
| Quad-8 | 1.4617 |

Figure 6.3.2
Factor of safety for
different values of
 C_{u2}/C_{u1}

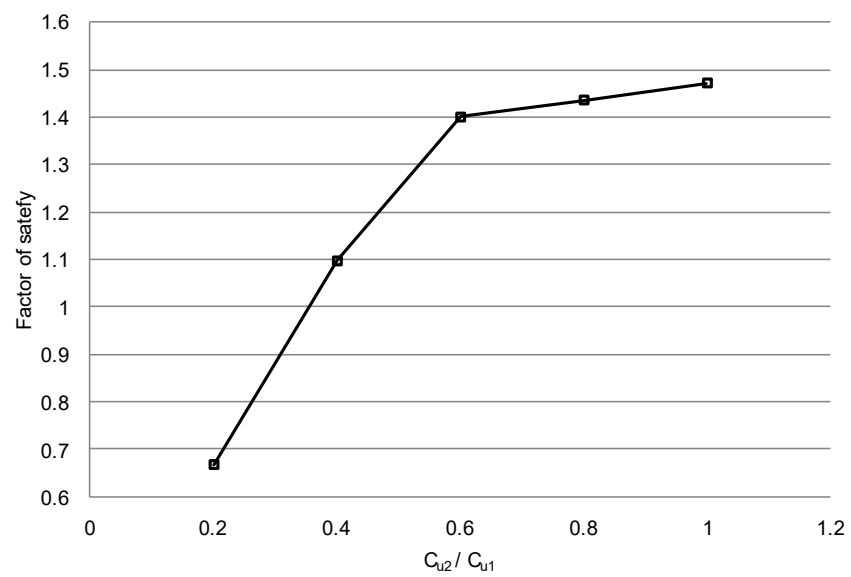
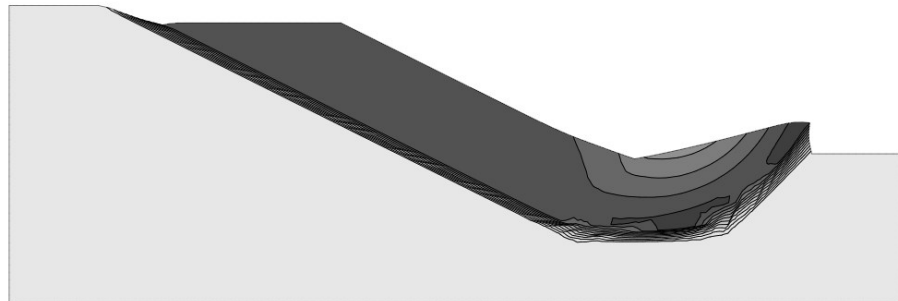
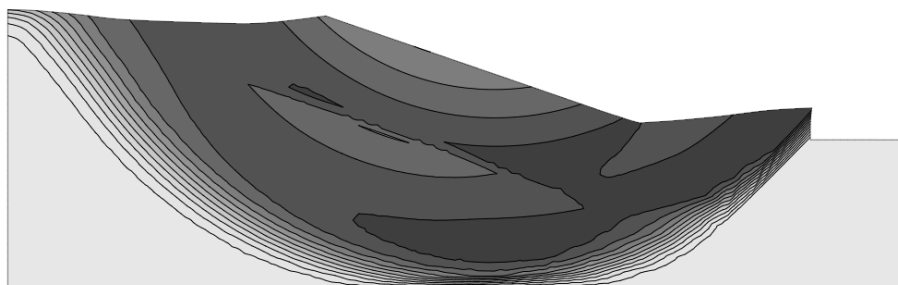




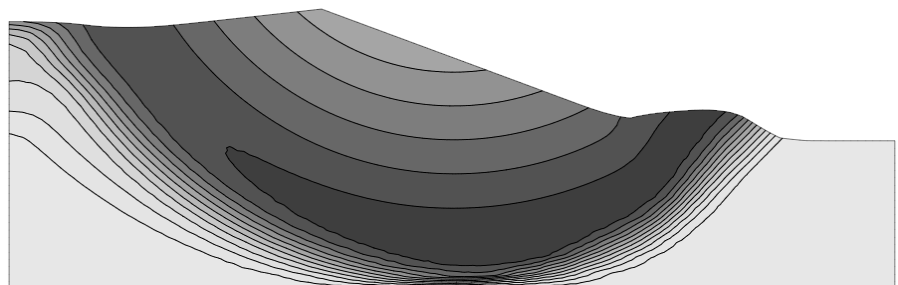
Figure 6.3.3
Deformed shape at
failure for (a) $C_{u2}/C_{u1} =$
0.2, (b) $C_{u2}/C_{u1} = 0.6$, (c)
 $C_{u2}/C_{u1} = 1.0$



(a) $C_{u2}/C_{u1} = 0.2$



(b) $C_{u2}/C_{u1} = 0.6$



(c) $C_{u2}/C_{u1} = 1.0$



References

- 1 Griffiths, D.V. and Lane, P.A., "Slope stability analysis by finite elements", in *Geotechnique*, Vol. 49, No.3, pp.387-403, 1999