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Search Techniques: Block Specified

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Introduction

The block specified search technique linearizes the slip surface into three sections. The search technique is best suited for critical modes of failure involving structural controls or, more generally, low strength layers that are spatially continuous and oriented at particular angle from the horizontal.

Numerical Simulation

Figure 1 shows the problem definition. An embankment is constructed on a clay foundation material. The clay foundation is characterized by undrained strength (S_u) increasing with depth. The embankment is assigned a conventional Mohr-Coulomb strength model with effective stress properties.

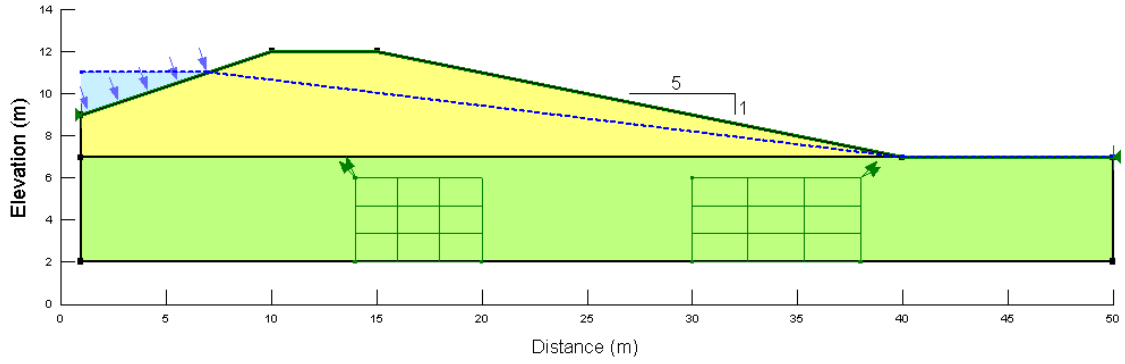

Figure 1. Illustrative example.

The left and right blocks have been drawn in the clay foundation soil. Each block comprises 16 points. The left and right blocks have 4 and 5 projections; respectively. The projections are constrained between a starting and ending angle measured counter-clockwise from the positive x direction. The Left Block has 4 projections between 115 and 135 degrees while the right block has 5 projections between 30 and 45 degrees (Define – Slip Surface). The total number of slip surfaces is equal to 16 x 16 x 4 x 5 = 5120. Maximum projection angles in the active and passive zones can generally be estimated from earth pressure theory.

Two cases are considered to illustrate the functionality of the Block Specified search technique. The first case demonstrates the basic application of the search technique. The critical slip surface is optimized in a separate analysis for demonstrative purposes.

The second case gives consideration to translation on a weak layer by means of two modifications to the analysis definition. Firstly, the analysis makes use of the optional control on the Block Specified Search technique: ‘do not cross block specified surface lines’ (Figure 2). The use of this option requires the same number of vertical increments in both blocks. Secondly, the clay foundation material model is assigned an anisotropic modifier function to reduce the undrained strength when the slice base angles are nearly horizontal (Figure 3). The modifier function assumes 70% of the strength definition when the inclination of the slips surface is within ± 1.0 degrees from the horizontal. The same technique could be used to simulate the presence of weak layers at an arbitrary angle from the horizontal axis as shown in Figure 4.

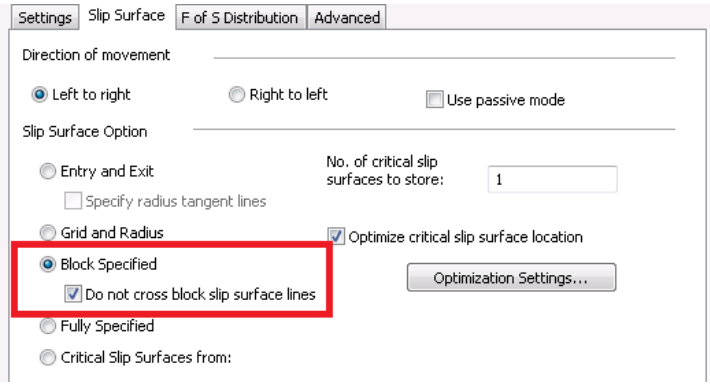

Figure 2. Choosing the modified block-specified method.

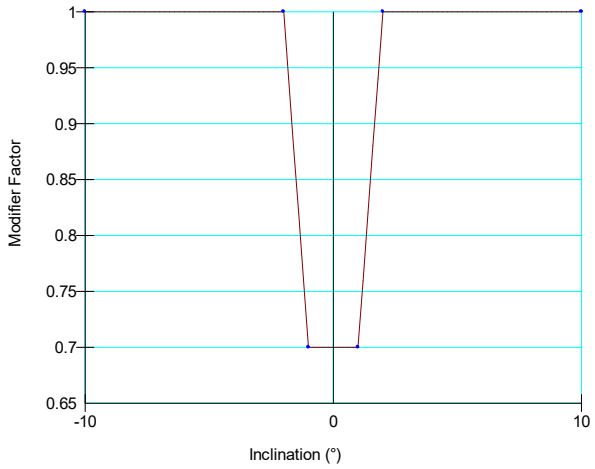

Figure 3. Anisotropic strength function.

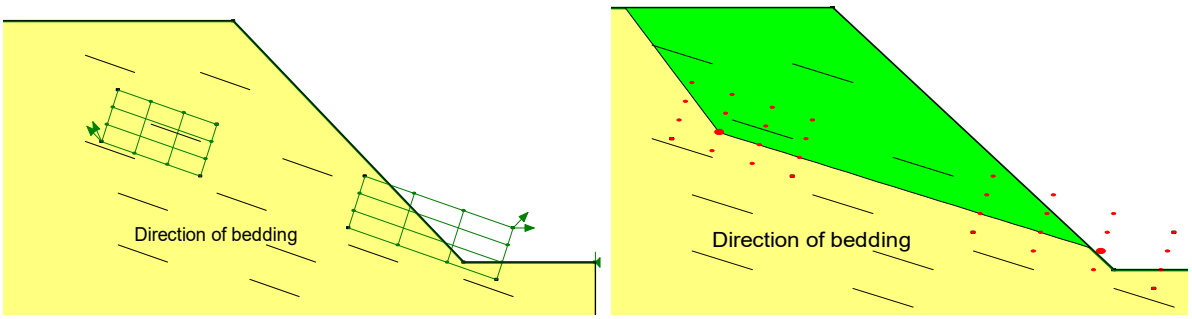

Figure 4. Grid blocks can be rotated in space and located outside of the domain.

Results and Discussion

Figure 5 shows the critical slip surface for Case 1. The slip surface comprises three linear sections. Intuitively a more critical slip surface should exist for this case given the strength definition in the clay foundation. Optimization produces the circular failure shown in Figure 6. A nearly identical result could have been obtained by means of a different search technique (e.g. entry-exit). The use of the block specified search technique is not reasonable in this case unless optimization is also used.

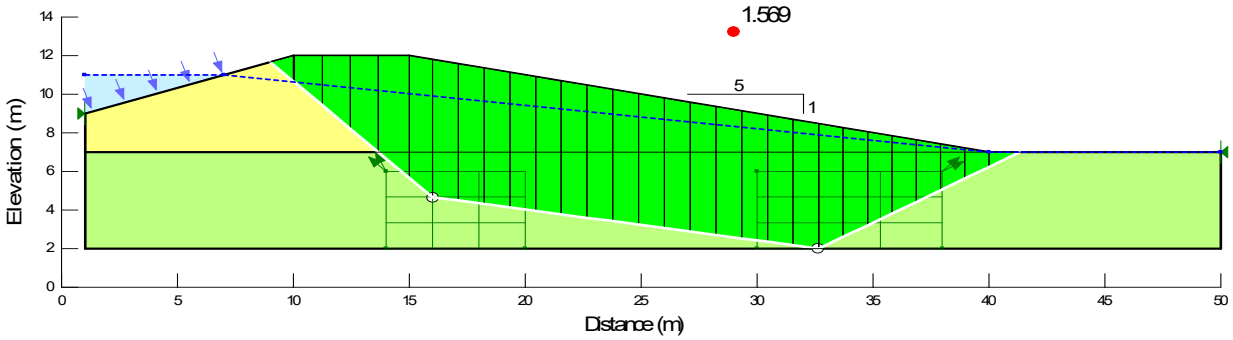

Figure 5. Critical slip surface for Case 1.

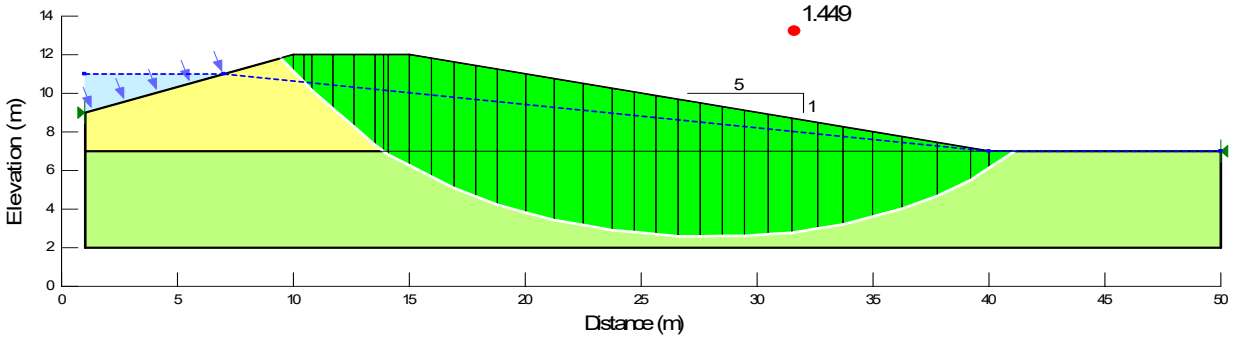

Figure 6. Optimized critical slip surface for Case 1.

Figure 7 shows the critical slip surface for Case 2. In this case, the block specified search technique was advantageous because the undrained strength is reduced in accordance with the anisotropic modifier function along near horizontal planes. The use of the 'do not cross option' ensured generation of a near horizontal translation component to the slip surface. Optimization shortened the near horizontal translational component of the slip surface and rounded the entry and exit projections, causing an overall reduction in the factor of safety (Figure 8). Figure 9 reveals the reduced strength along the horizontal portion of the optimized slip surface.

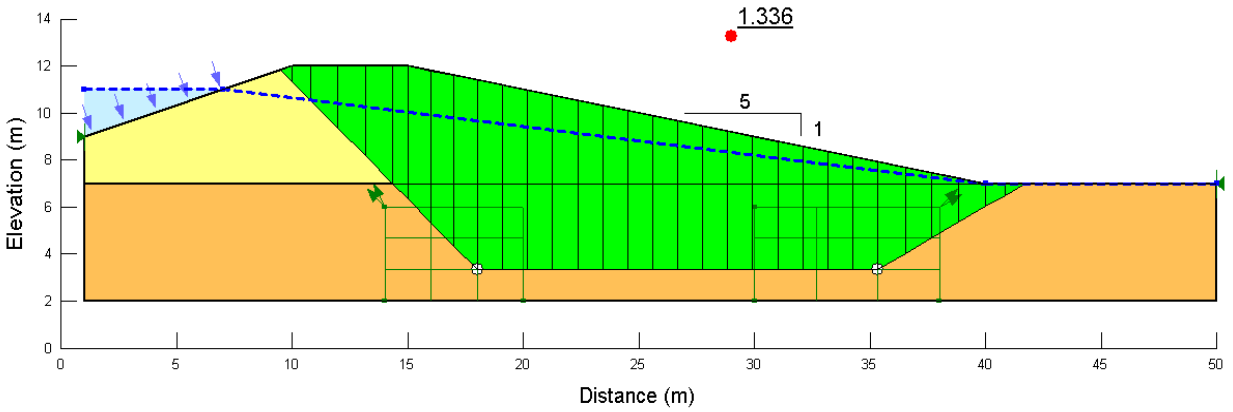

Figure 7. Critical slip surface for Case 2.

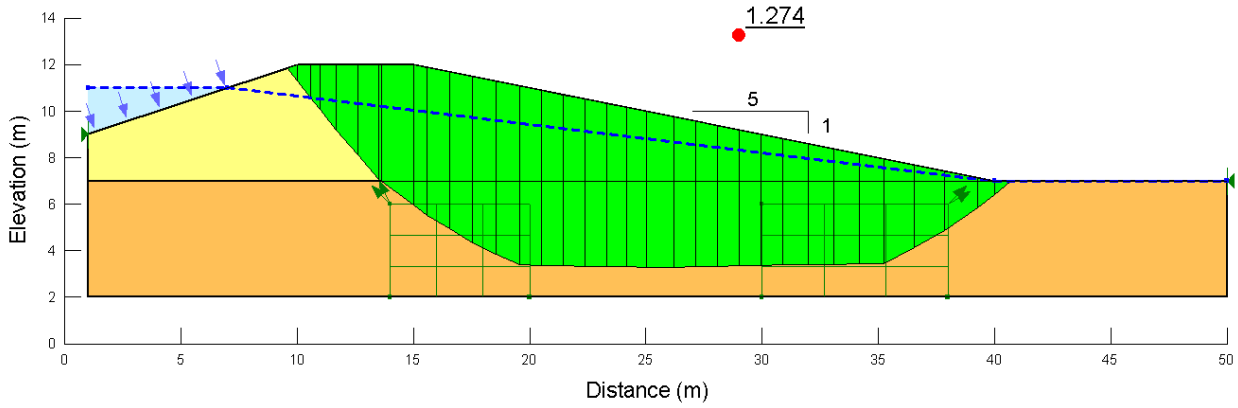

Figure 8. Optimized critical slip surface for Case 2.

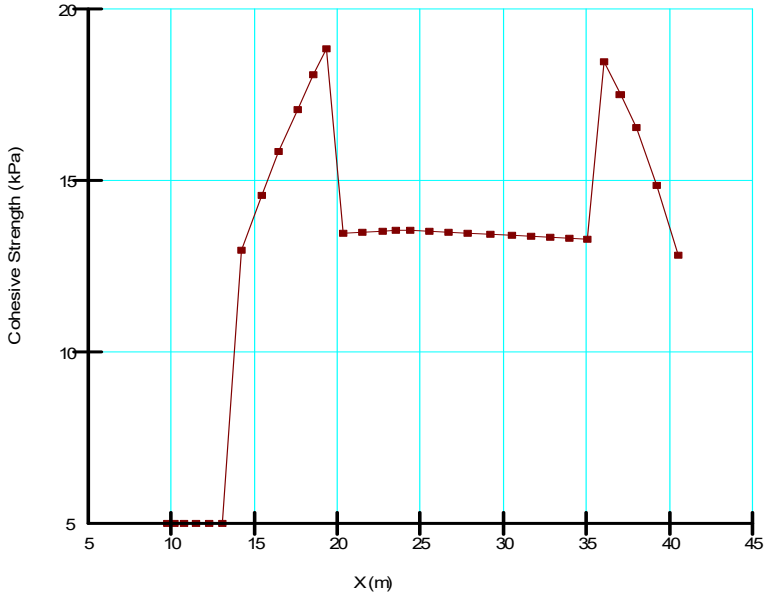

Figure 9. Strength along optimized critical slip surface in Case 2.

The Block Specified search method can produce numerous physically inadmissible trial slips surfaces such as trial slip surface 1,110 shown in Figure 10. Fortunately the solution did not converge in this case (i.e. E994) as is evidence by Factor of Safety versus Lambda plot (Figure 11). A more challenging situation arises if the solution convergences and the factor of safety is a minimum. In this case, one must rely on engineering judgement instead of non-convergence to deem the slip surface inadmissible. Krahn (2003) provides additional insights into non-convergence of a limit equilibrium slope stability analysis.

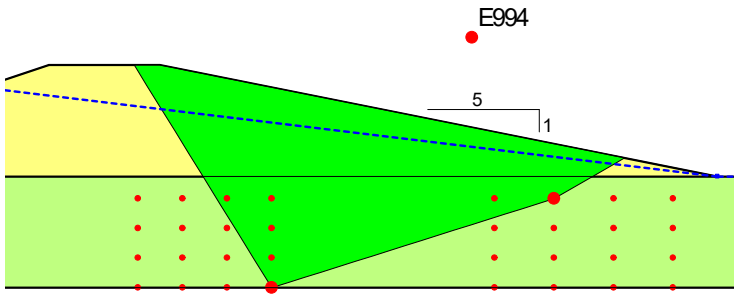

Figure 10. Illustration of a physically inadmissible trial slips surface.

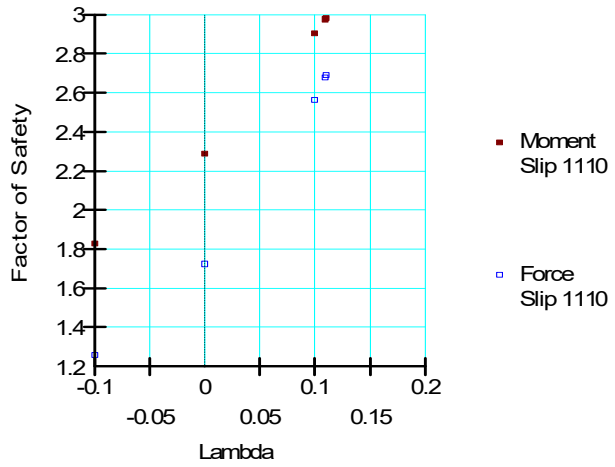

Figure 11. Factor of Safety versus Lambda plot for slip surface 1,110.

Summary and Conclusions

The Block Specified method of defining trial slips surfaces can be effective in some cases. The Block Specified method generally produces realistic slip surface geometries if the blocks are separated by a considerable distance. The search technique can be used if the blocks are closely located; however, the technique is then prone to produce slip surfaces with unrealistic geometries, which in-turn leads to poor convergence or converged solutions for kinematically inadmissible slip surfaces.

References

Krahn, John (2003). The 2001 R.M. Hardy Lecture: The Limits of Limit Equilibrium Analyses. Canadian Geotechnical Journal 40: p. 643-660.