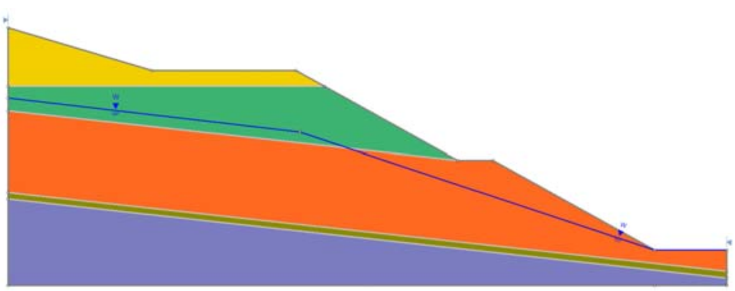
2D Extruded Verification

Slide3, RS3, Slide, and RS2

Rocscience Inc.



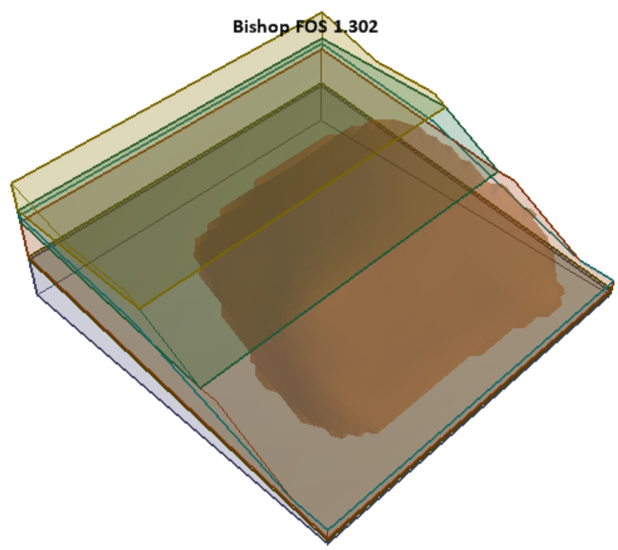


Table of Contents

Introduction

This document contains a series of verification slope stability problems that have been analyzed using Slide^3, RS^3, Slide, and RS^2. The verification tests come from:

- A set of 5 basic slope stability problems, together with 5 variants, was distributed in the Australian Geomechanics profession and overseas as part of a survey sponsored by ACADS (Association for Computer Aided Design), in 1988. Verification problems #1 to #7 are based on these ACADS example problems (Giam & Donald (1989)).

- The Slide 7.0 Verification document, where the 2D slopes have been extruded to create 3D models. All referee values are for the 2D slope.

- Published examples found in reference material such as journal and conference proceedings.

- Other examples verified by comparing results from each program.

For all examples, a short statement of the problem is given first, followed by a presentation of the analysis results, using various limit equilibrium analysis methods for Slide 7.0 and Slide^3. Full references cited in the verification tests are found at the end of this document. The Bishop and Janbu methods are both simplified for all examples.

Each example is numbered, which is shown in the title, and will remain consistent across all verification documents relating to that model. As well, the folder that contains the models in each program will be titled 2D Extruded Verification [number of the model]. Each model also has a description under its title in the Table of Contents and in the body of the verification. The first part of its description will define its type as either 2D extruded, 2D swept, or 3D. This verification document contains only 2D extruded models, and has its own corresponding index. Both the verification and the index for 2D extruded models are separate from the other two model types.

A 2D extruded model is a 2D cross section that has been extruded a given distance in the 3D programs, without altering the shape of the cross section at all throughout the model. These examples may have features such as multiple materials, water tables, and loading, which will all be extruded across the entire model. Examples with weak plane defined slip surfaces may also be included in this verification, as long as the slope itself is a 2D extruded model. Elements such as micropile supports will be placed throughout the model, not extruded to create a wall of support.

2D extruded, homogeneous, spherical

1.1 Introduction

In 1988 a set of 5 basic slope stability problems, together with 5 variants, was distributed both in the Australian Geomechanics profession and overseas as part of a survey sponsored by ACADS (Giam & Donald (1989)). This is a 3D extrusion of the ACADS 1(a) problem.

1.2 Problem Description

This problem is a total stress analysis without considering water pore pressures. Figure 1 is the geometry of the slope in the XZ plane. This geometry is then extruded 50m in the Y direction. It represents a homogenous slope with soil properties given in Table 1.1. The factor of safety and its corresponding critical spherical failure surface is required.

A slip center search grid of 20 x 20 intervals was used, with 11 circles per gridpoint. Grid is located at (22.8, 25, 62.6), (22.8, 25, 42.3), (43.7, 25, 62.6), (43.7, 25, 42.3). Tolerance is 0.0001.

1.3 Geometry and Properties

Table 1.1 Material Properties

c´ (kN/m^2)	φ´ (deg.)	γ (kN/m^3)
3.0	19.6	20.0

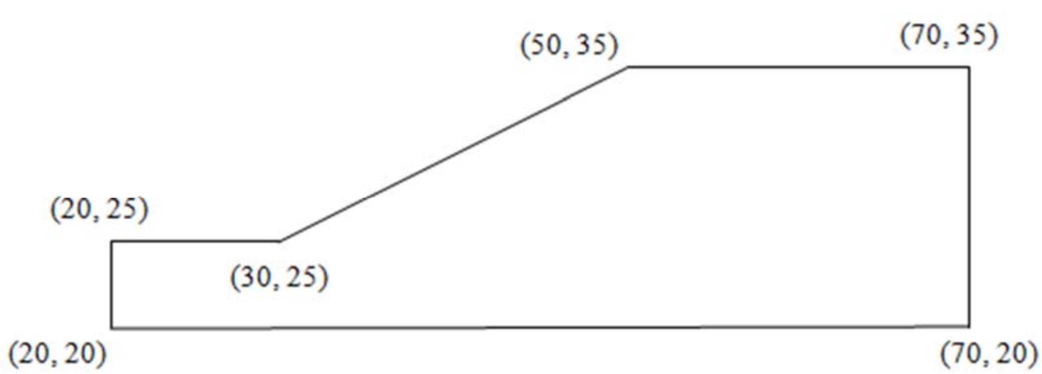


Figure 1

1.4 Results

Table 1.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.045	0.987		
Spencer	1.037	0.986	1.06	0.98
GLE	1.043	0.986		

Note: Referee Factor of Safety = 1.00 [Giam]

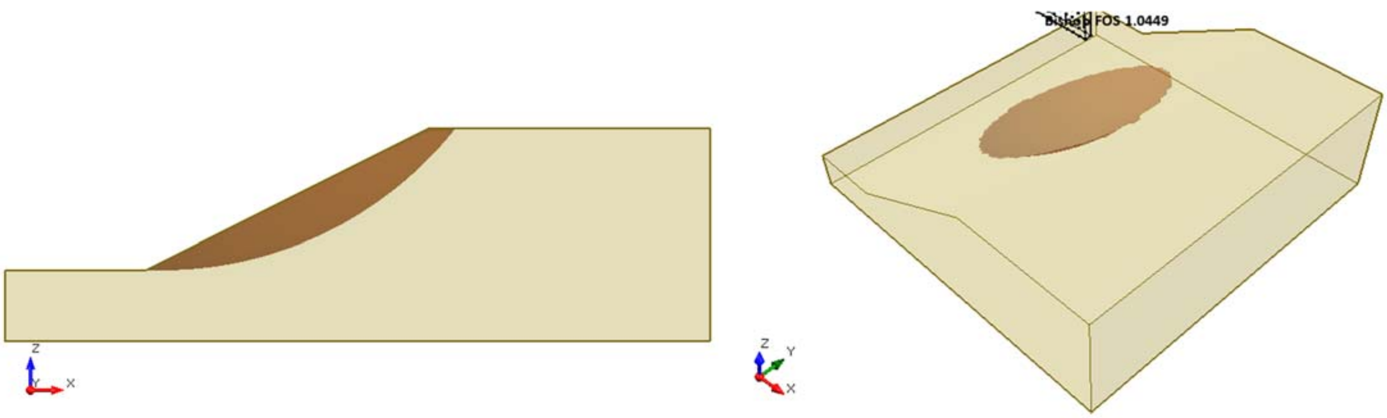


Figure 1.4.1 – Slide3 Solution Using the Bishop Method

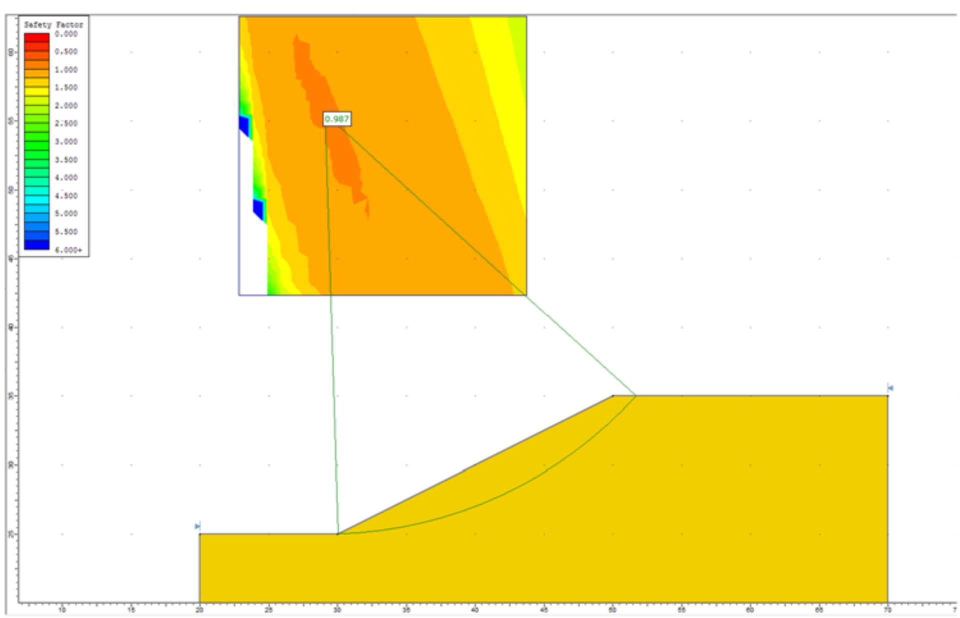


Figure 1.4.2 – Slide Solution Using the Bishop Method

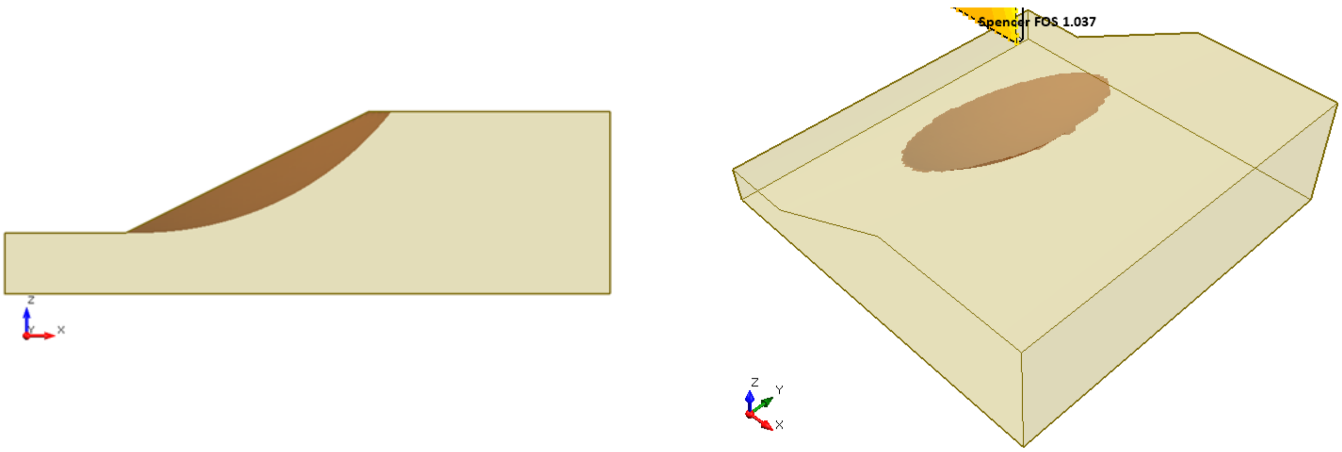


Figure 1.4.3 – Slide3 Solution Using the Spencer Method

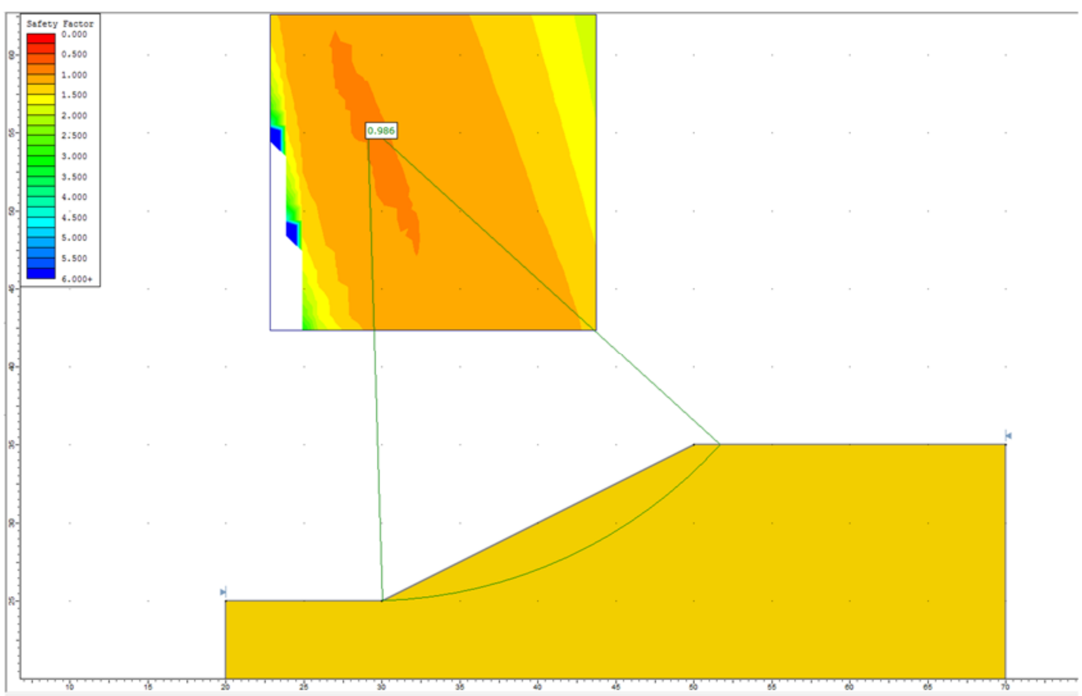


Figure 1.4.4 – Slide Solution Using the Spencer Method

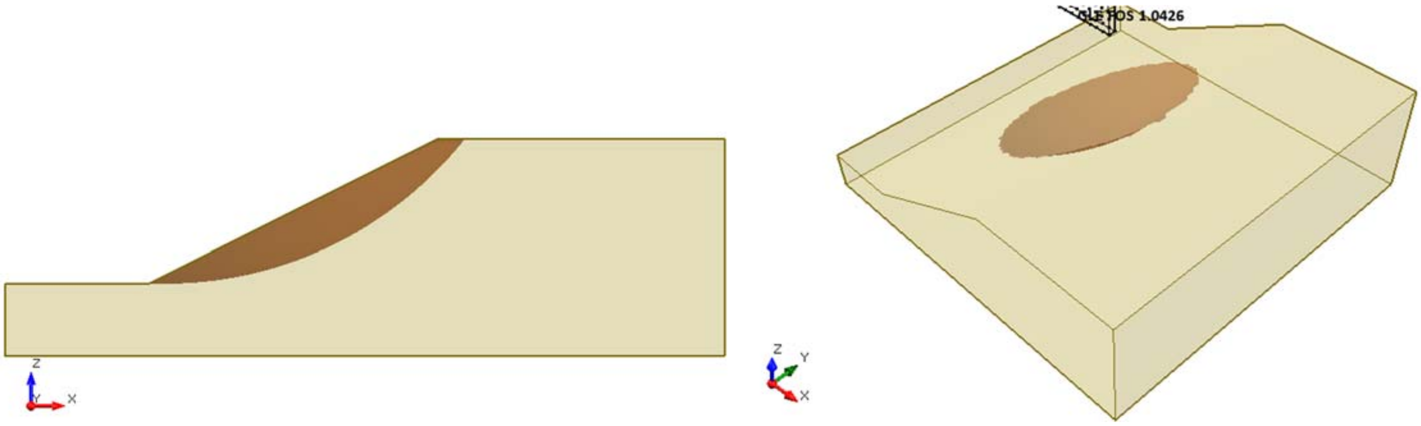


Figure 1.4.5 – Slide3 Solution Using the GLE Method

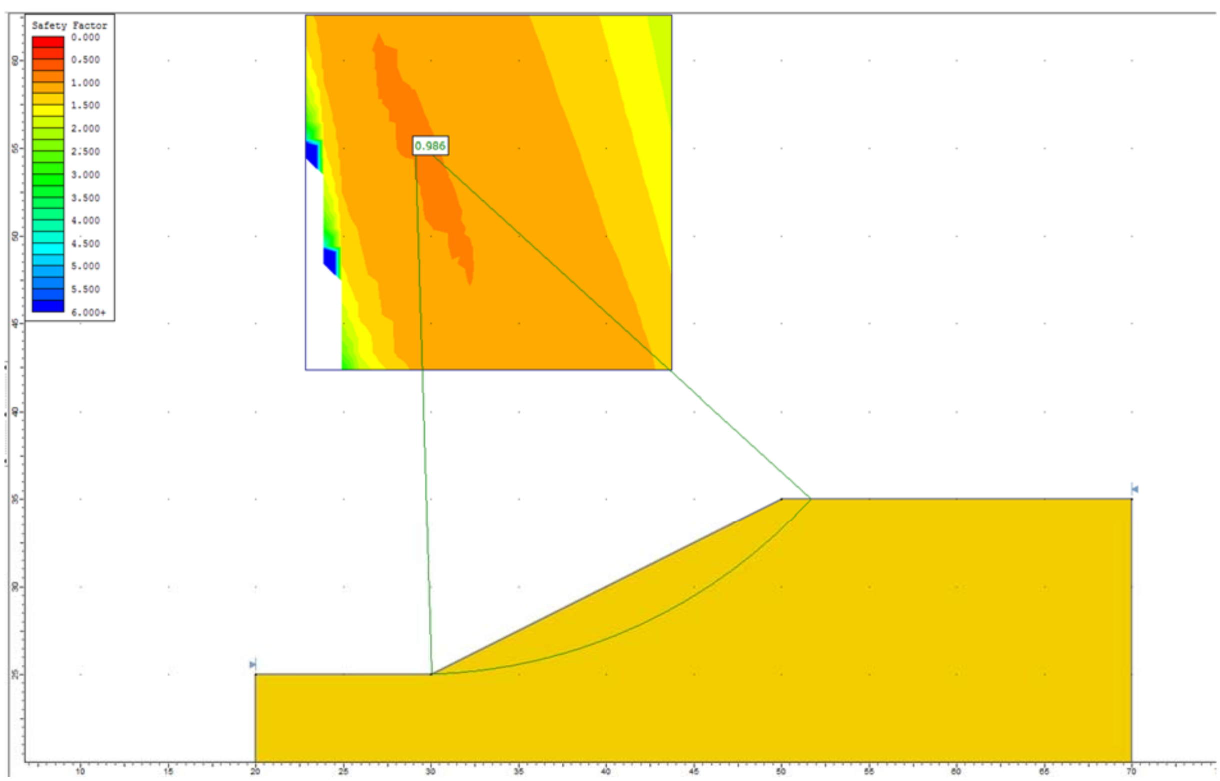


Figure 1.2.6 – Slide Solution Using the GLE Method

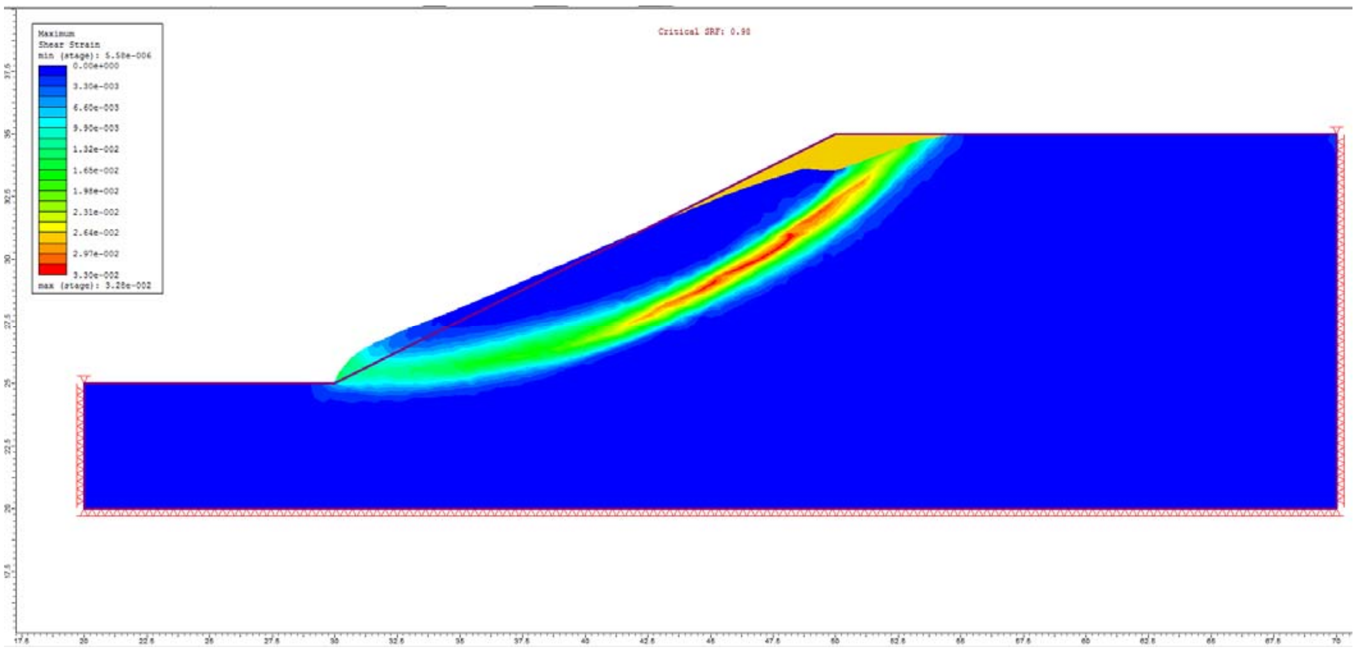


Figure 1.4.7 – RS2 Maximum Shear Strain with Deformation Contours

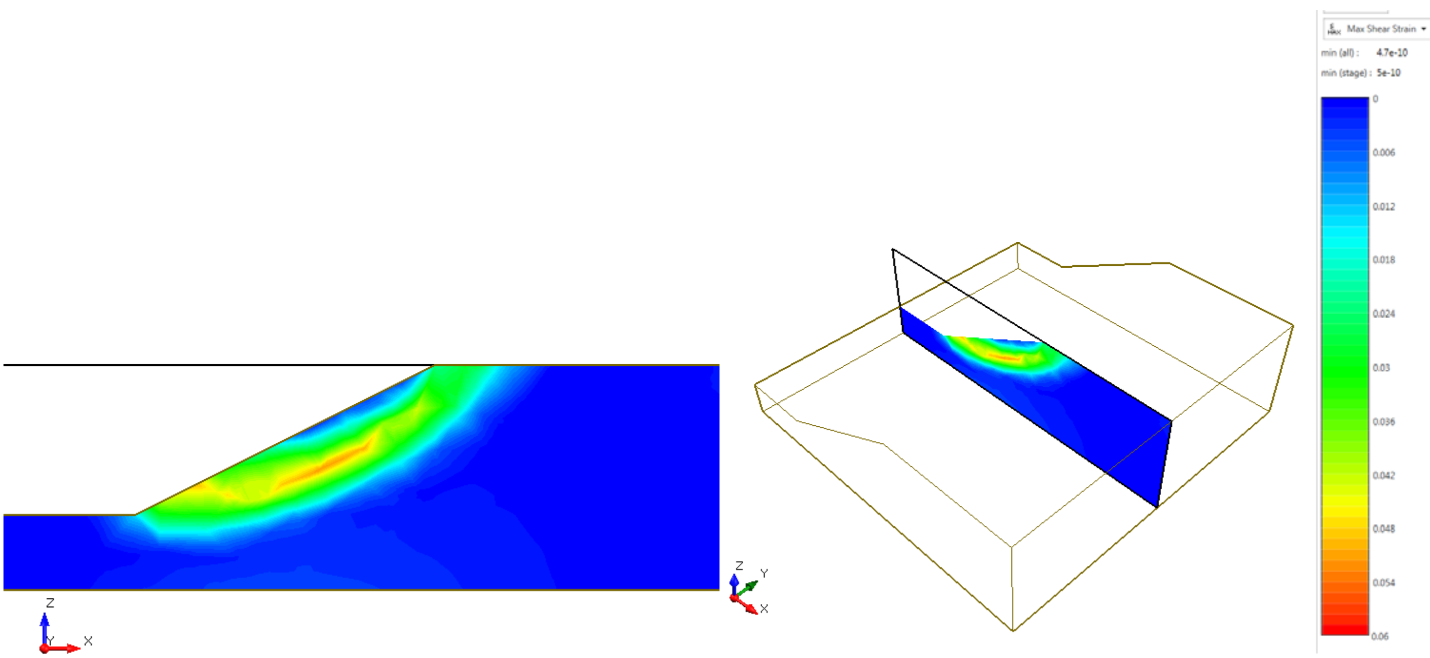


Figure 1.4.8 – RS3 Maximum Shear Strain

2D extruded, homogeneous, ellipsoidal with SA

2.1 Introduction

This is the same problem as 2D Extruded Verification #1; however the ellipsoidal slip surface is required, instead of the spherical slip surface.

2.2 Problem Description

The slope geometry and soil properties of this problem are the same as problem #1, but problem #2 calculates the ellipsoidal slip surface using a cuckoo search with SA, instead of the spherical slip surface calculated using a grid search. The soil properties are provided again in Table 2.1 and Figure 2 is the slope geometry in the XZ plane, which will be extruded 50m in the Y direction.

2.3 Geometry and Properties

Table 2.1 Material Properties

c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
3.0	19.6	20.0

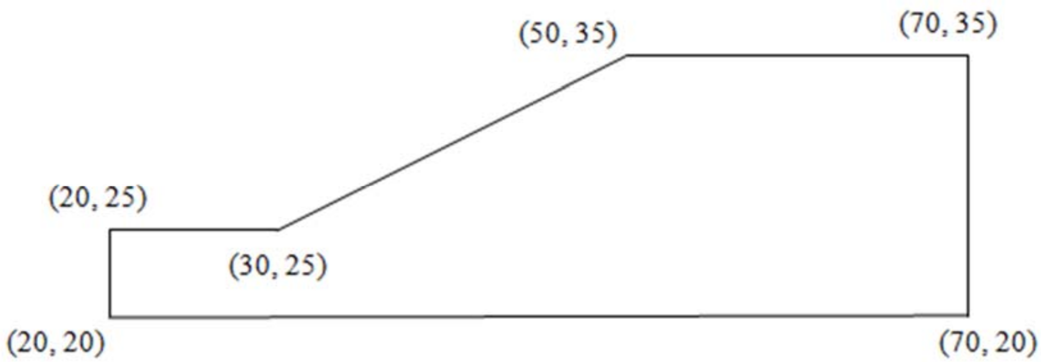


Figure 2

2.4 Results

Table 2.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Janbu	0.961	0.933		
Spencer	1.006	0.983	1.06	0.98
GLE	0.993	0.974		

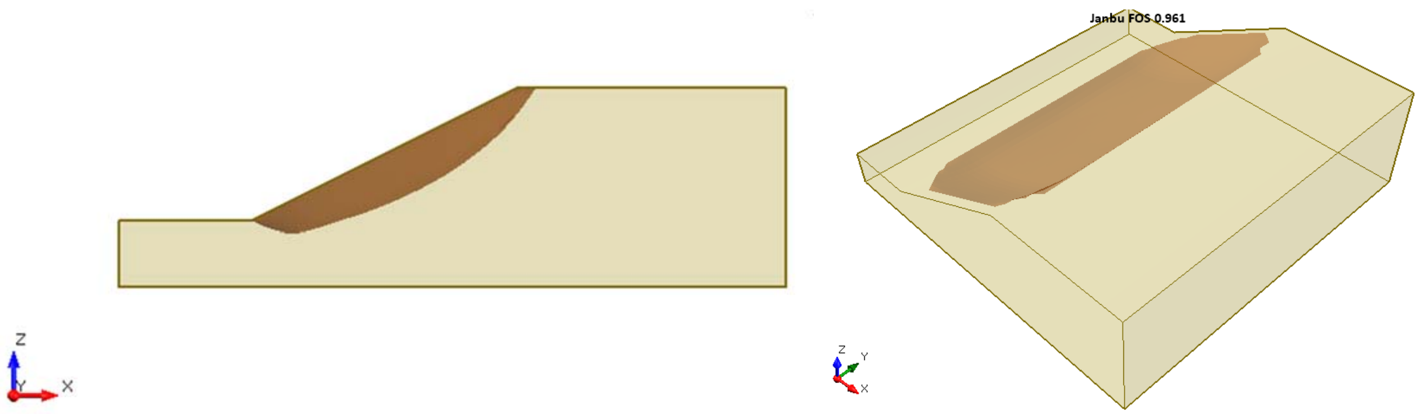


Figure 2.4.1 – Slide3 Solution Using the Janbu Method

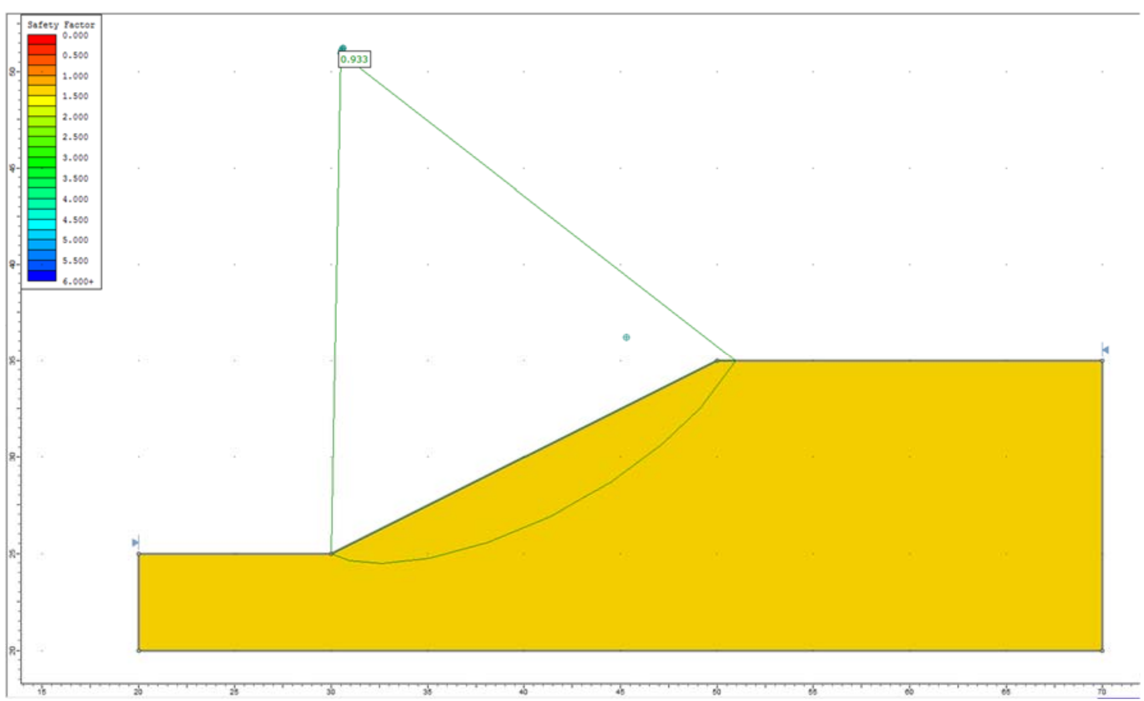


Figure 2.4.2 – Slide Solution Using the Janbu Method

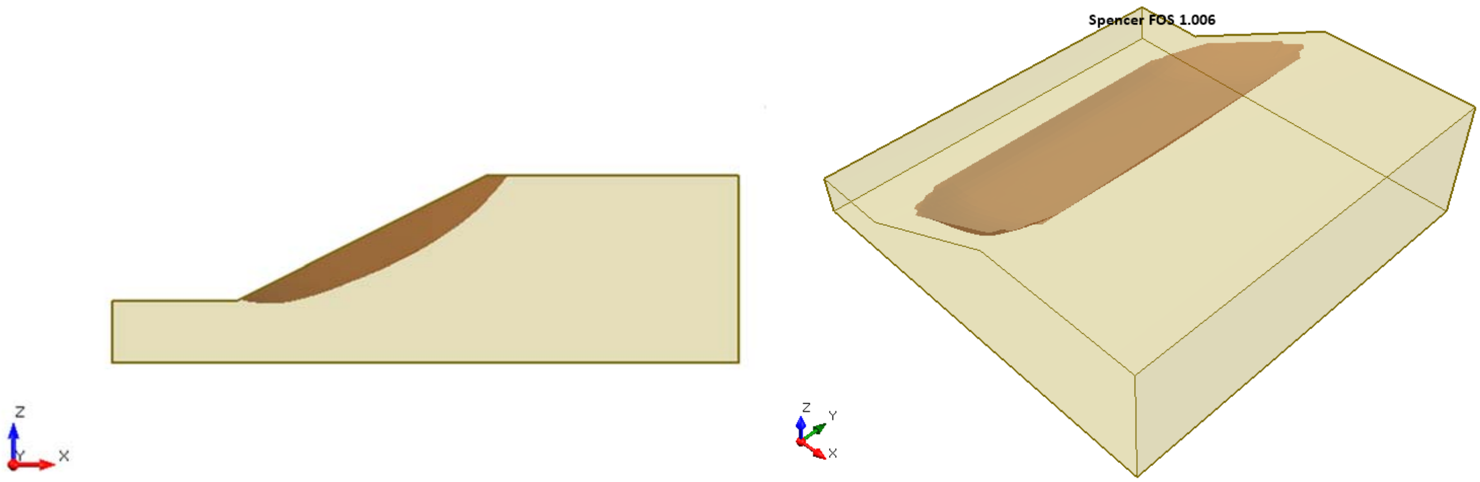


Figure 2.4.3 – Slide3 Solution Using the Spencer Method

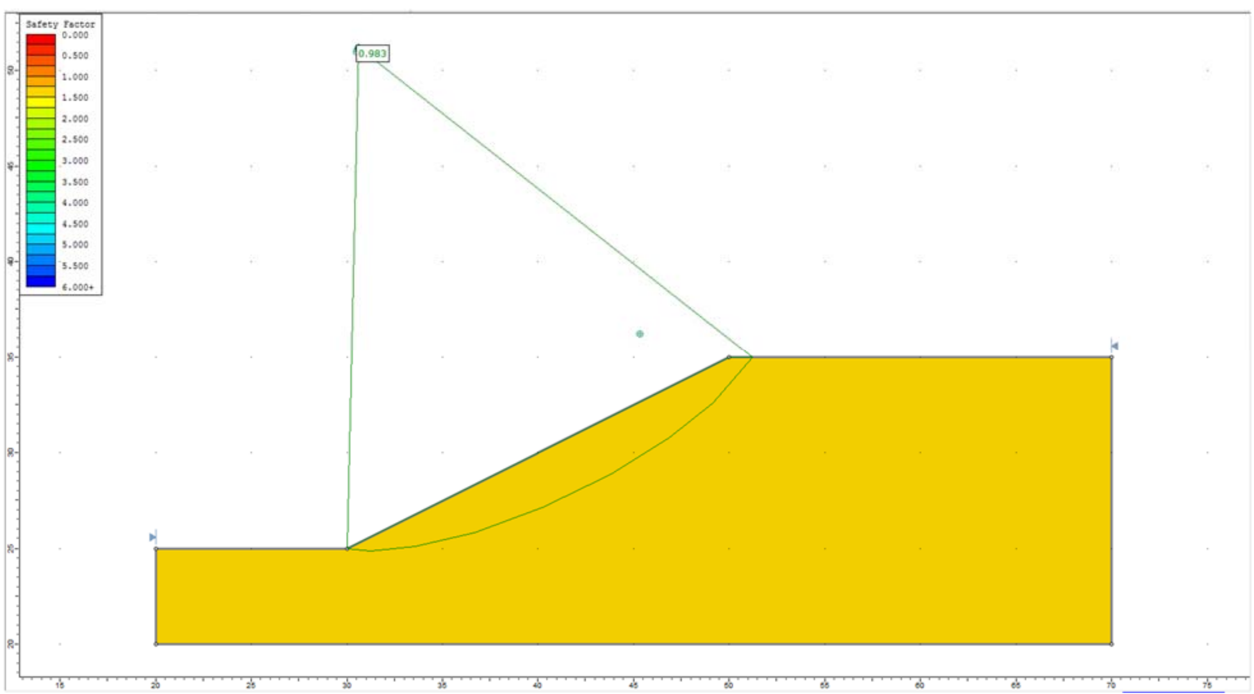


Figure 2.4.4 – Slide Solution Using the Spencer Method

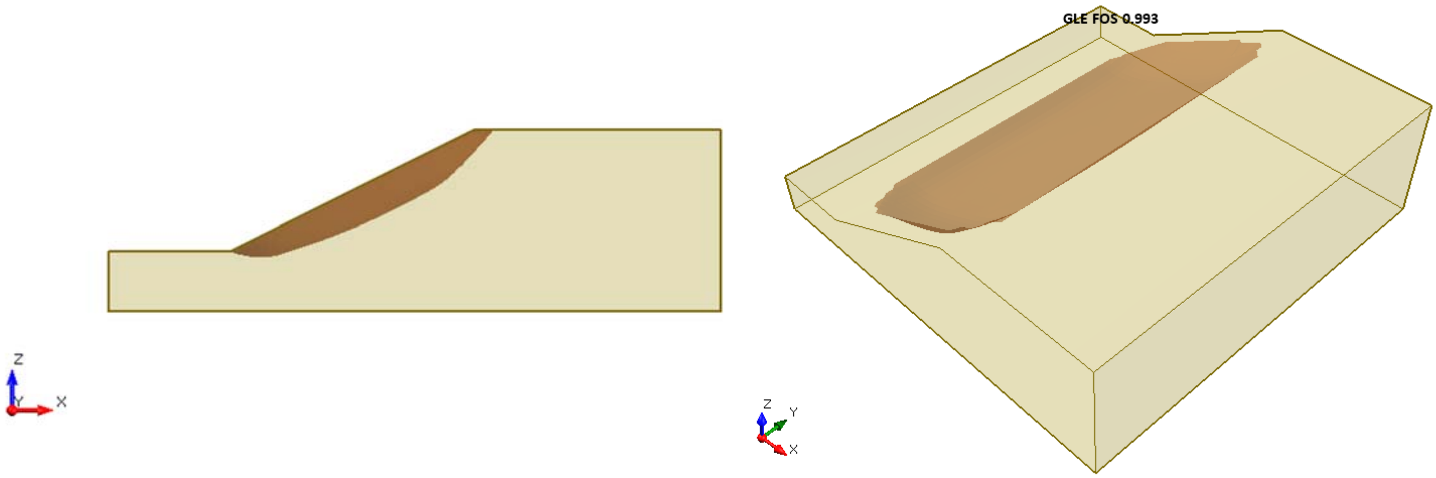


Figure 2.4.5 – Slide3 Solution Using the GLE Method

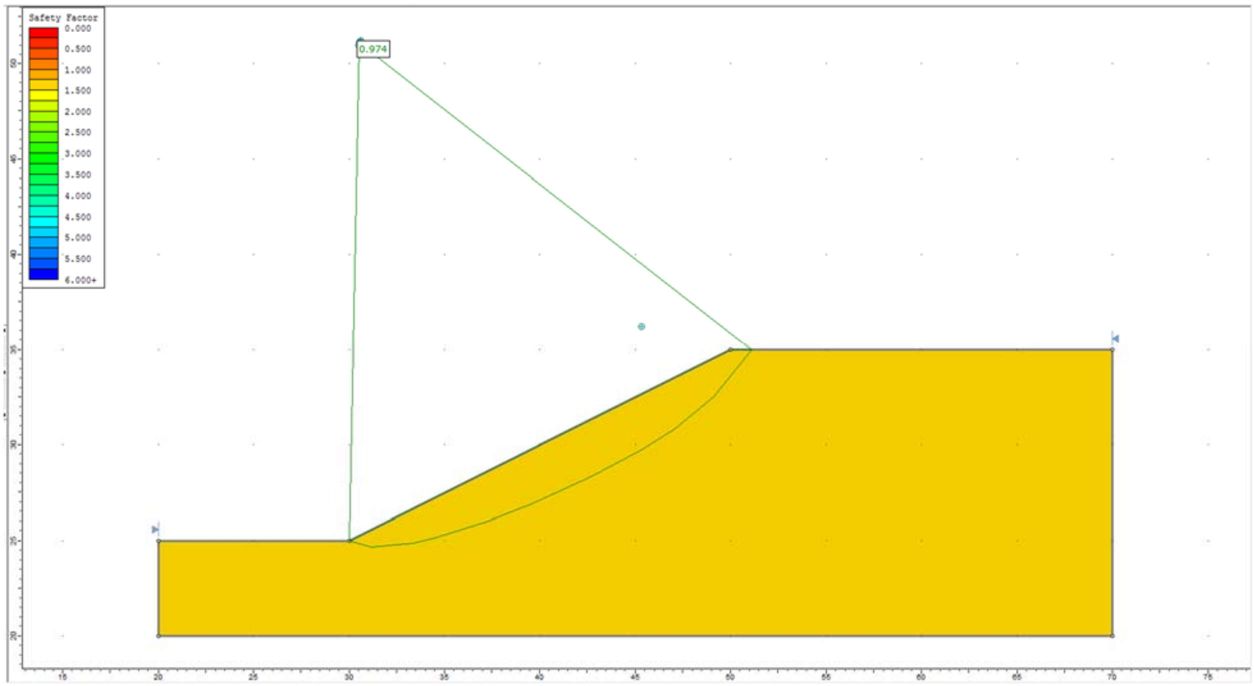


Figure 2.4.6 – Slide Solution Using the GLE Method

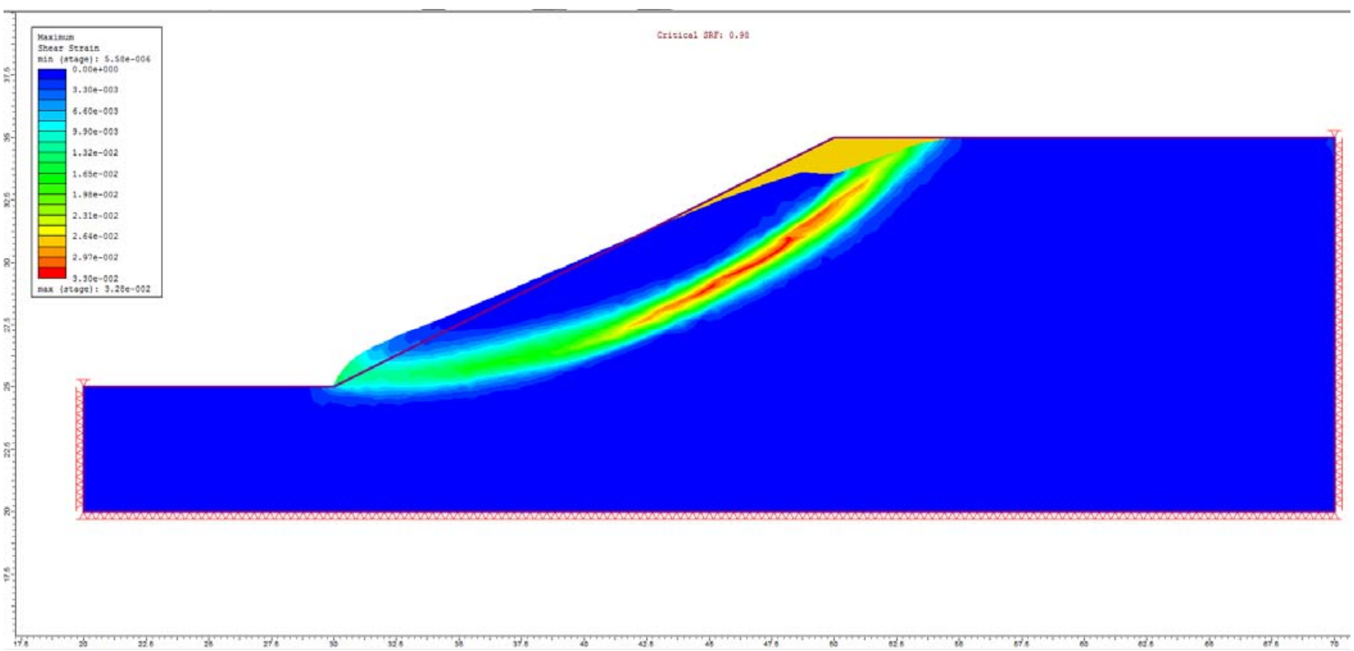


Figure 2.4.7 – RS2 Maximum Shear Strain with Deformation Contours

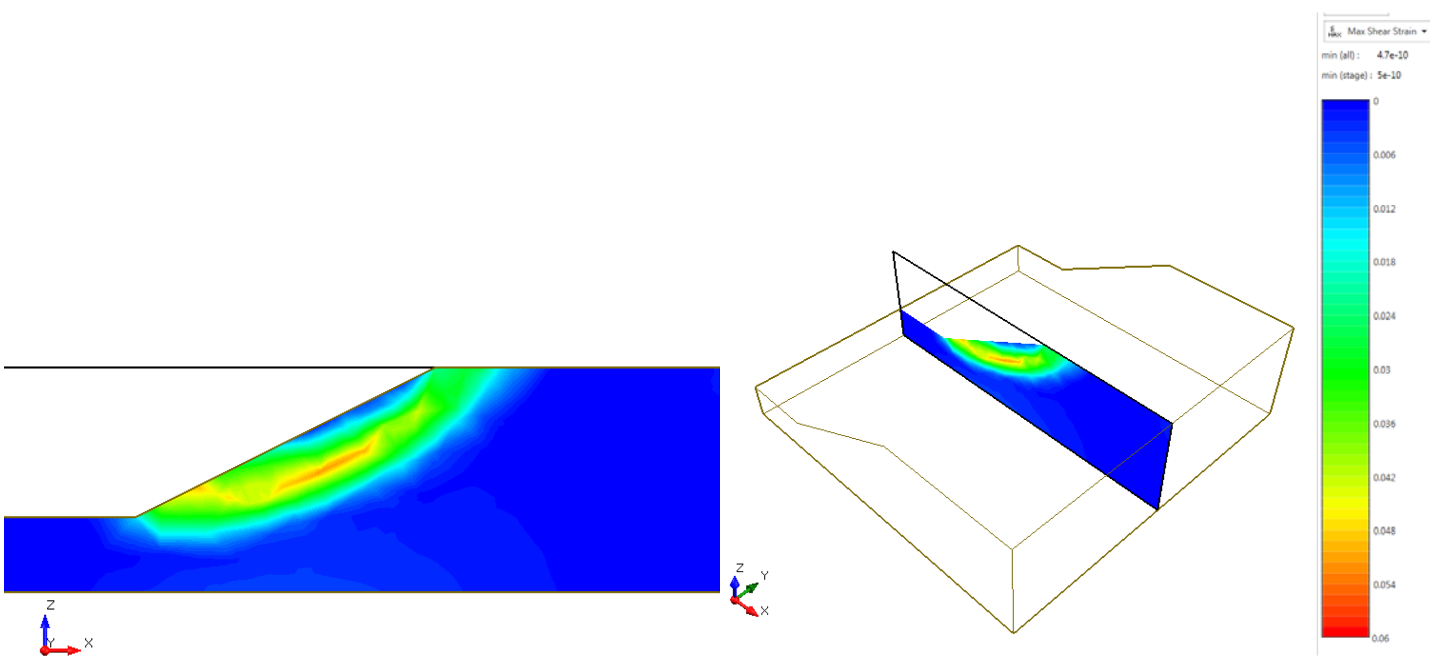


Figure 2.4.8 – RS3 Maximum Shear Strain

2D extruded, (3) materials, spherical

3.1 Introduction

In 1988 a set of 5 basic slope stability problems, together with 5 variants, was distributed both in the Australian Geomechanics profession and overseas as part of a survey sponsored by ACADS (Giam & Donald (1989)). This is a 3D extrusion of the ACADS 1(c) problem.

3.2 Problem Description

Problem #3 is a three layer slope with material properties given in Table 3.1. Figure 3 is the slope geometry in the XZ plane, which is extruded 50m in the Y direction. The factor of safety and its corresponding critical spherical failure surface is required.

3.3 Geometry and Properties

Table 3.1 Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil #1	0.0	38.0	19.5
Soil #2	5.3	23.0	19.5
Soil#3	7.2	20.0	19.5

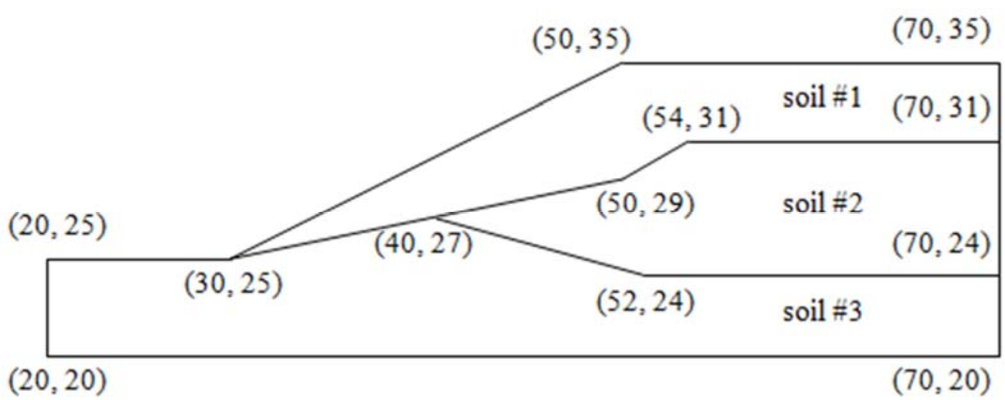


Figure 3

3.4 Results

Table 3.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.519	1.405		
Spencer	1.498	1.375	1.44	1.35
GLE	1.495	1.374		

Referee: 1.39 [Giam]

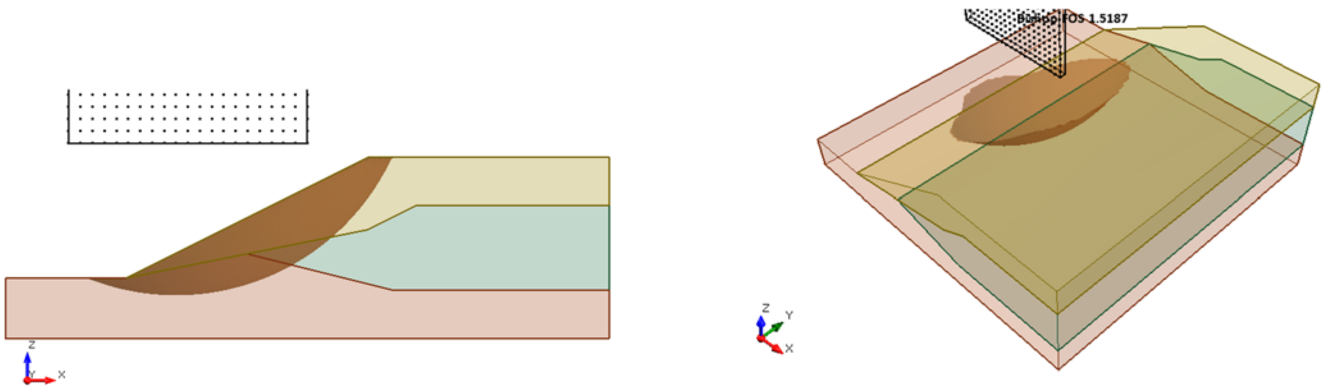


Figure 3.4.1 – Slide3 Solution Using the Bishop Method

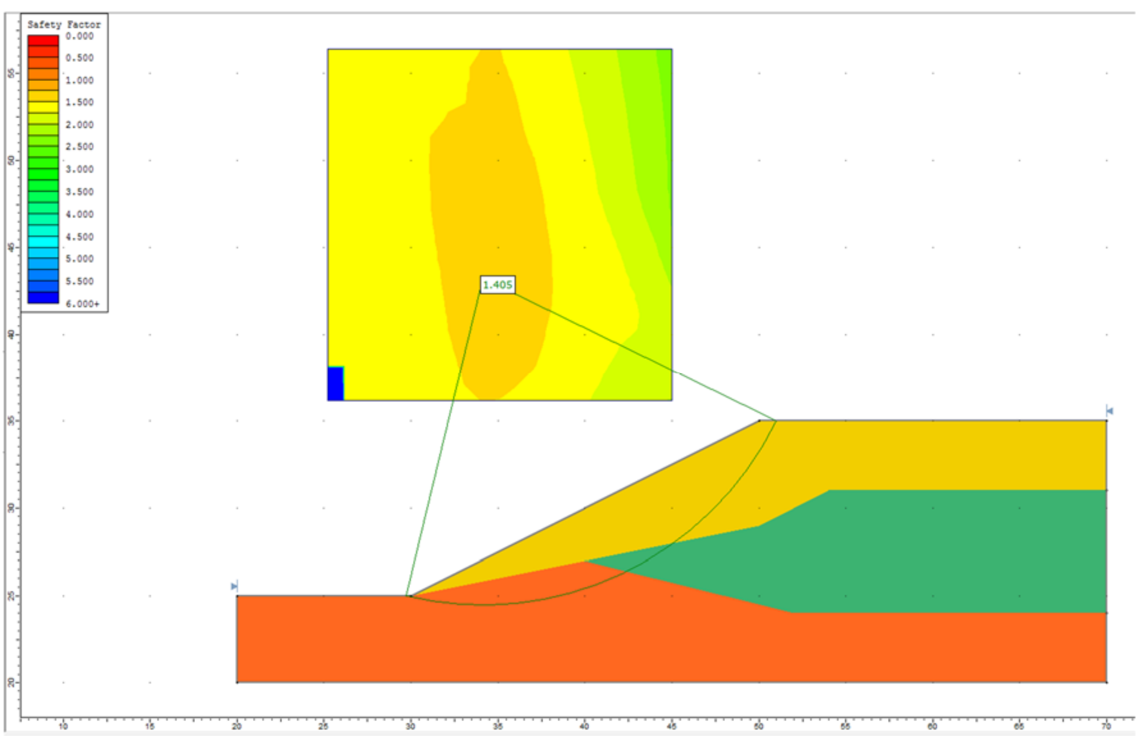


Figure 3.4.2 – Slide Solution Using the Bishop Method

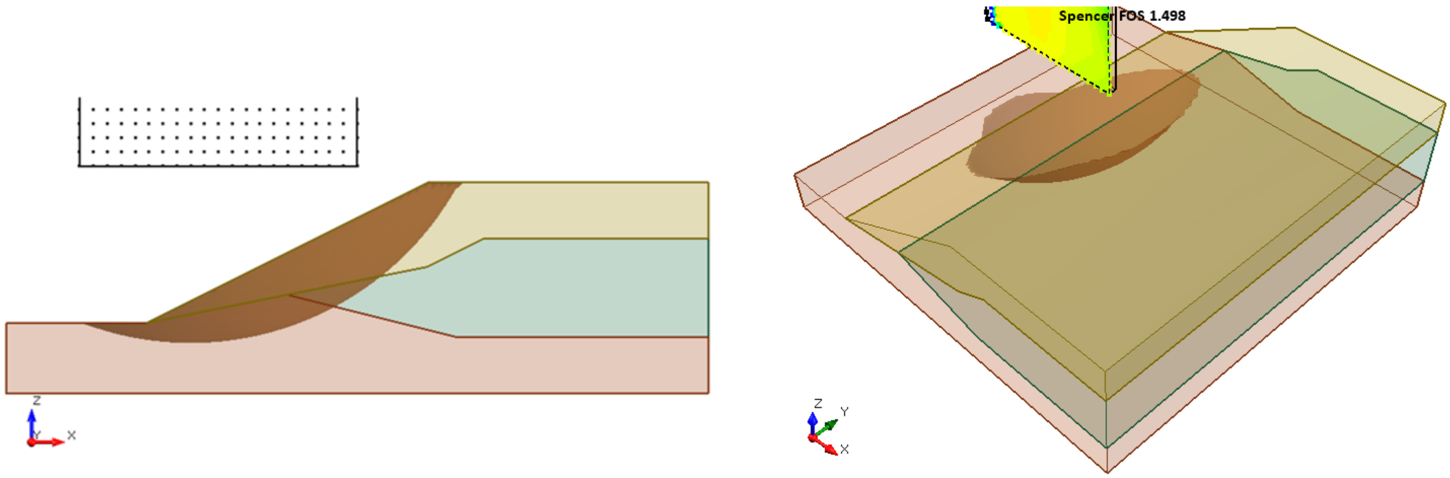


Figure 3.4.3 – Slide3 Solution Using the Spencer Method

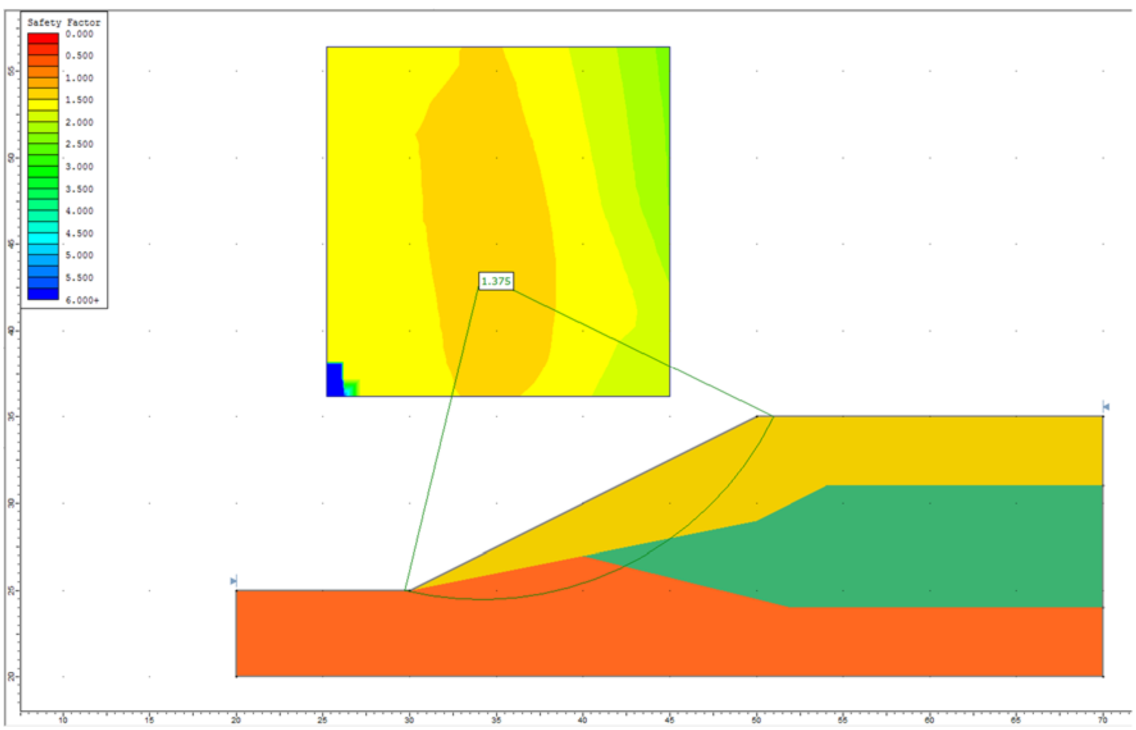


Figure 3.4.4 – Slide Solution Using the Spencer Method

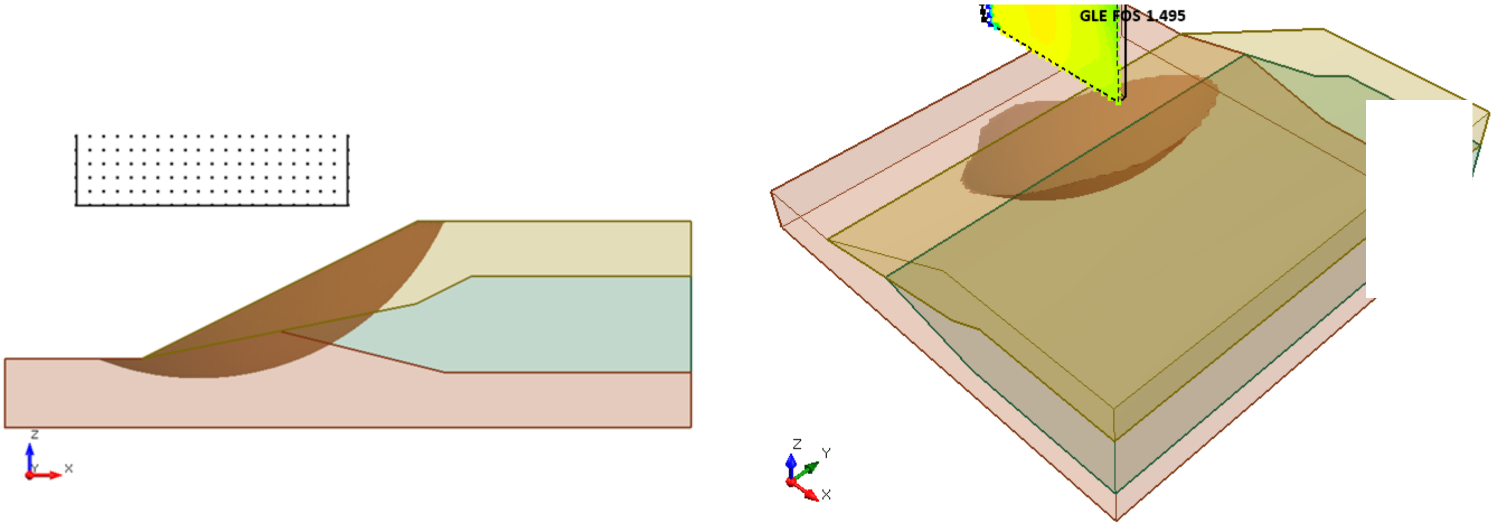


Figure 3.4.5 – Slide3 Solution Using the GLE Method

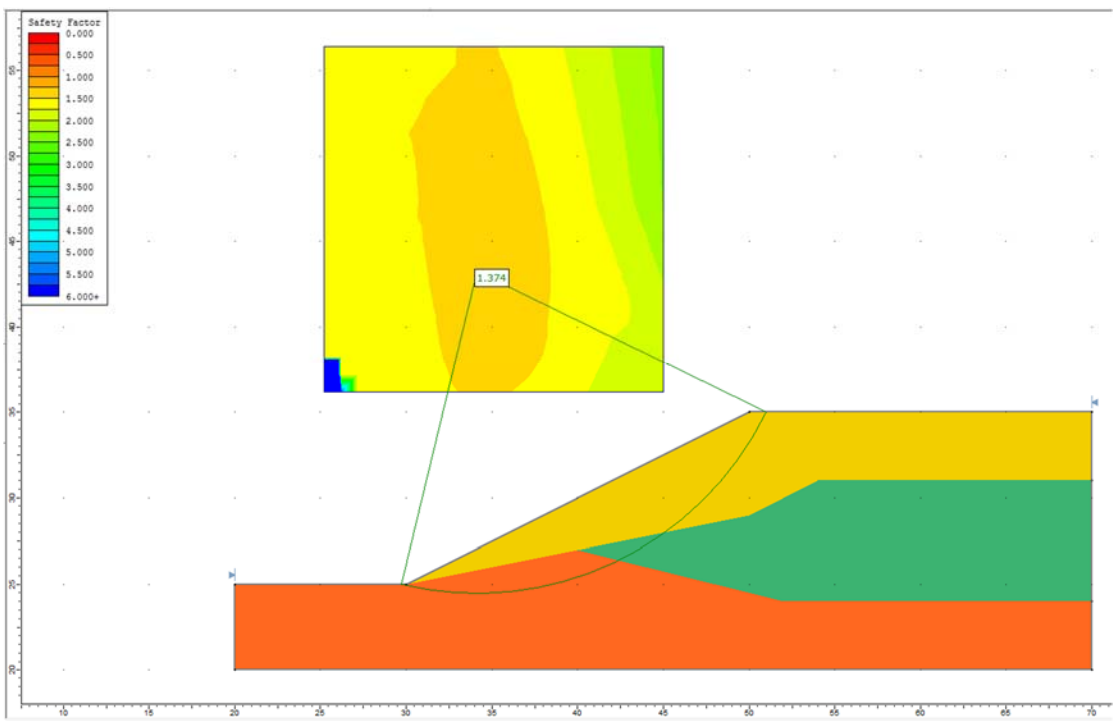


Figure 3.4.6 – Slide Solution Using the GLE Method

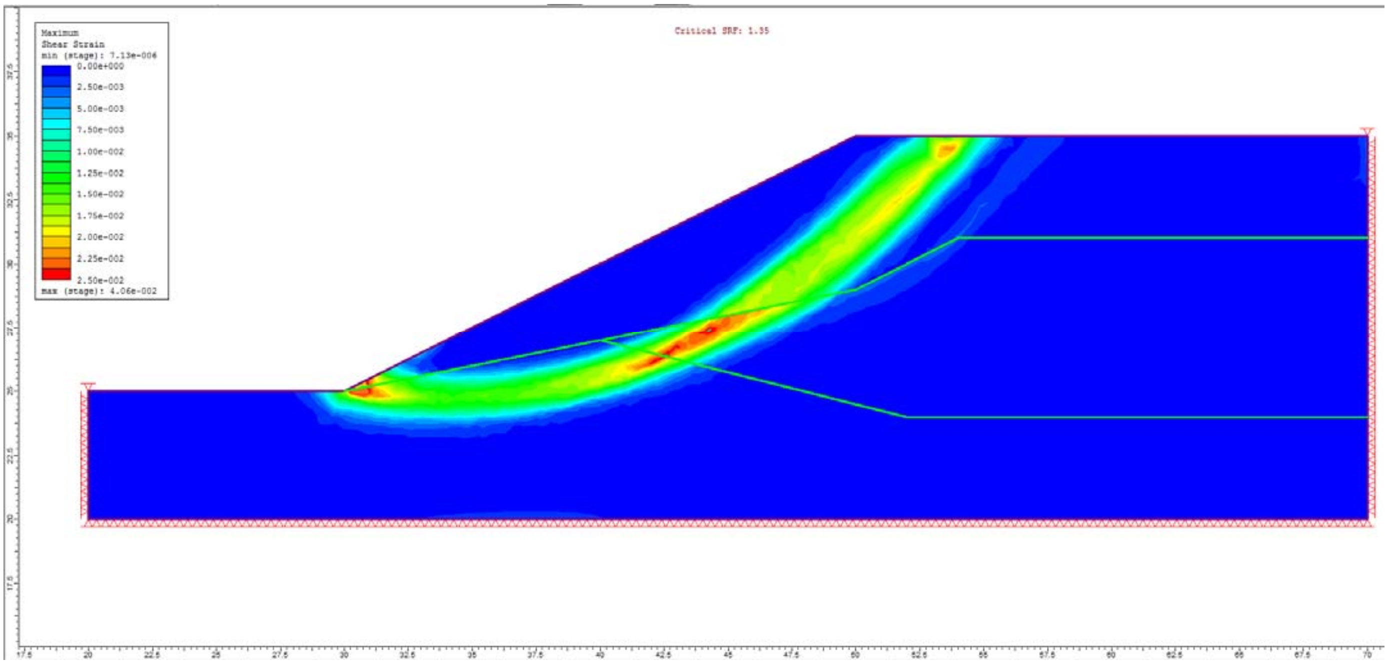


Figure 3.4.7 – RS2 Maximum Shear Strain

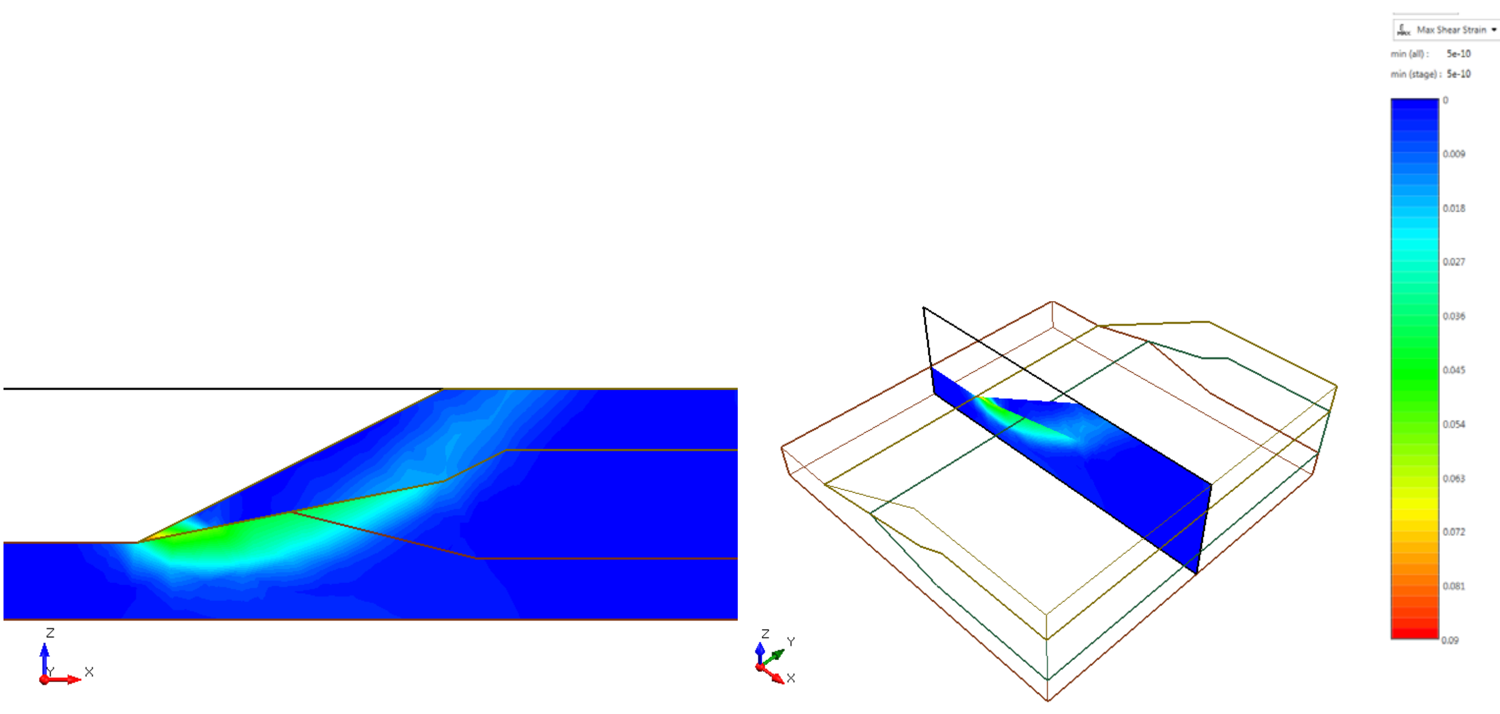


Figure 3.4.8 – RS3 Maximum Shear Strain

2D extruded, (3) materials, ellipsoidal with SA

4.1 Introduction

This is the same problem as 2D Extruded Verification #3; however the ellipsoidal slip surface is required, instead of the spherical surface, which was verified in problem #3.

4.2 Problem Description

The slope geometry and soil properties of this problem are the same as problem #3, but problem #4 calculates the ellipsoidal slip surface using a cuckoo search with SA, instead of the spherical slip surface calculated using a grid search. The soil properties are provided again in Table 4.1 and Figure 4 is the slope geometry in the XZ plane, which is extruded 50m in the Y direction.

4.3 Geometry and Properties

Table 4.1 Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil #1	0.0	38.0	19.5
Soil #2	5.3	23.0	19.5
Soil #3	7.2	20.0	19.5

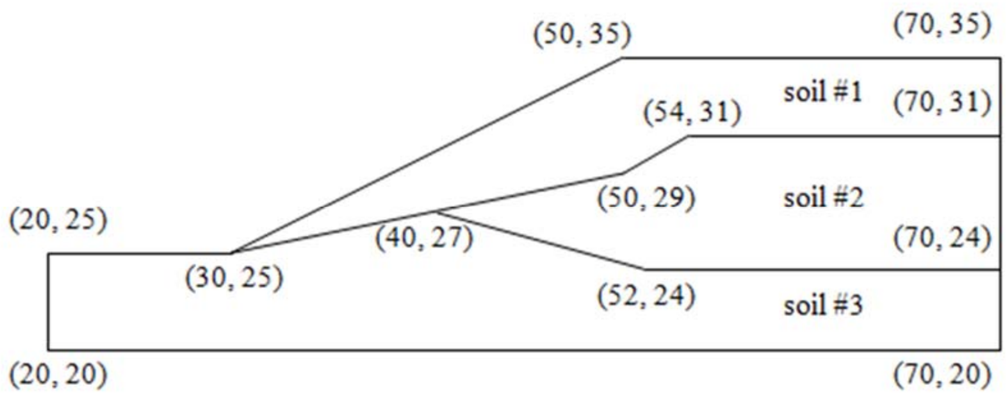
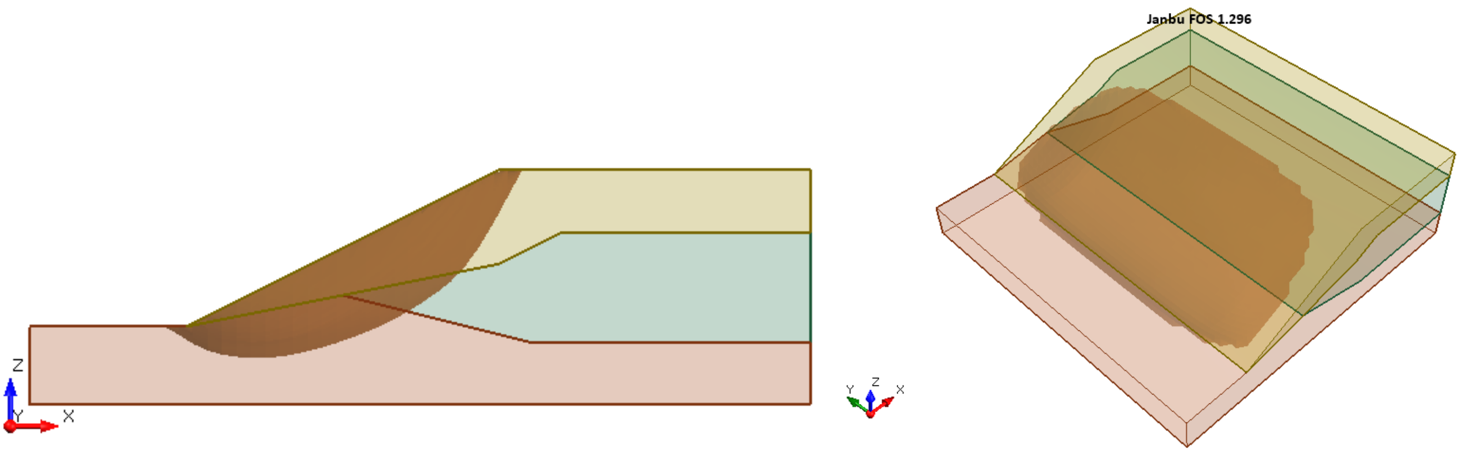


Figure 4

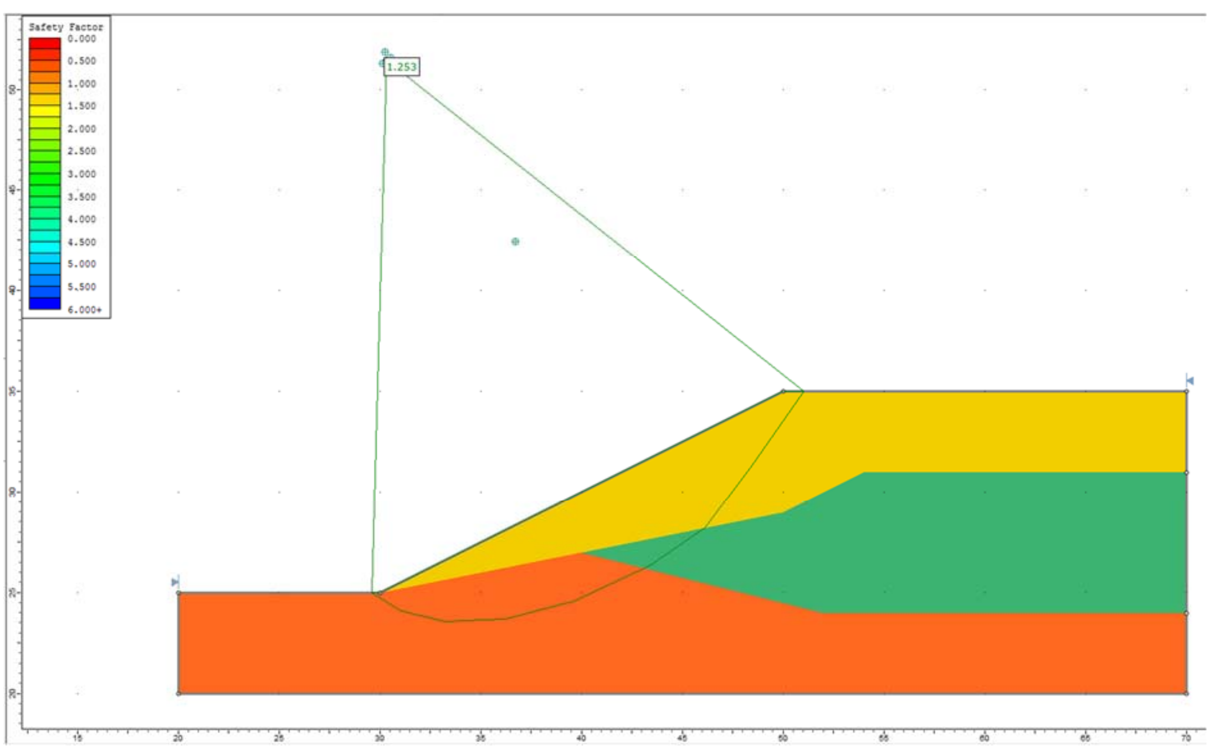
4.4 Results

Table 4.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

<table>
<tr><th>Method</th><th>Slide3</th><th>Slide 7.0</th><th>RS3</th><th>RS2</th></tr>
<tr><td>Janbu</td><td>1.296</td><td>1.253</td><td rowspan="3">1.35</td><td rowspan="3">1.44</td></tr>
<tr><td>Spencer</td><td>1.405</td><td>1.361</td></tr>
<tr><td>GLE</td><td>1.378</td><td>1.346</td></tr>
</table>



4.4.1 – Slide3 Solution Using the Janbu Method



4.4.2 – Slide Solution Using the Janbu Method

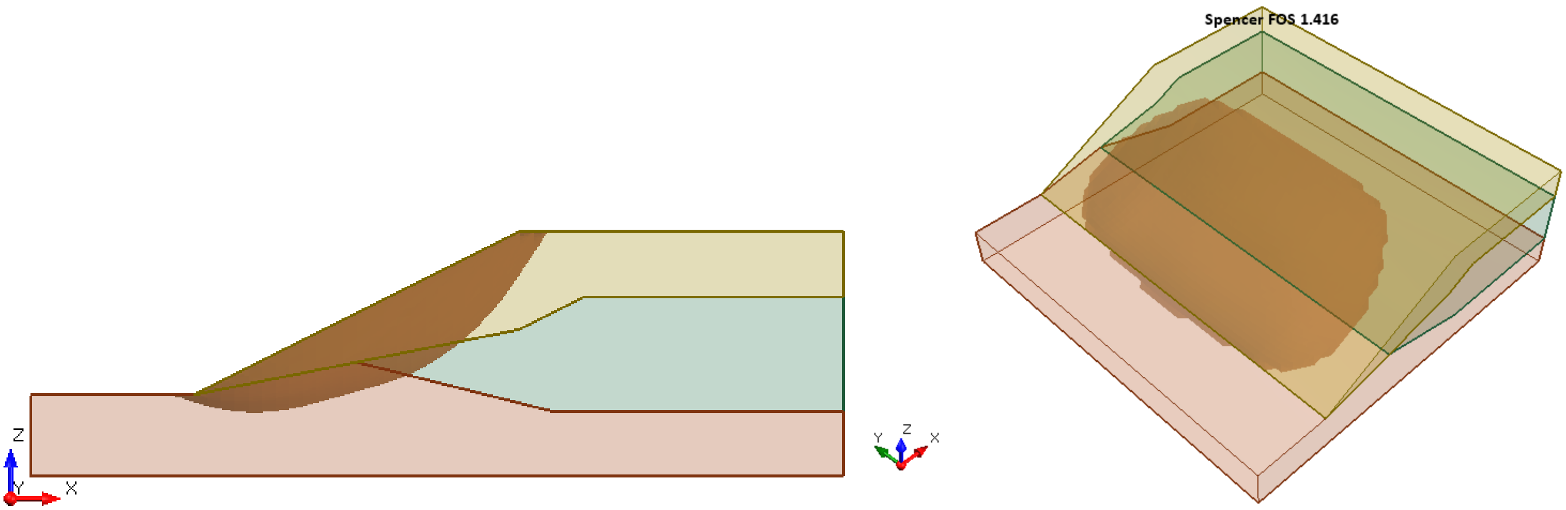


Figure 4.4.3 – Slide3 Solution Using the Spencer Method

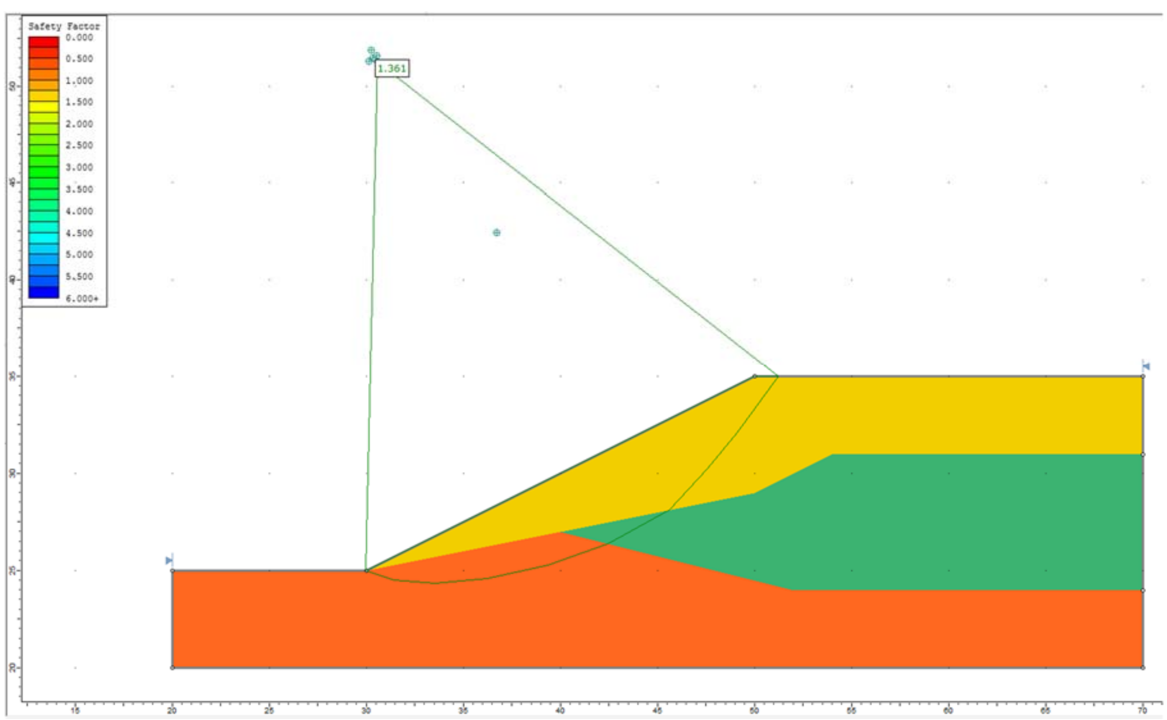


Figure 4.4.4 – Slide Solution Using the Spencer Method

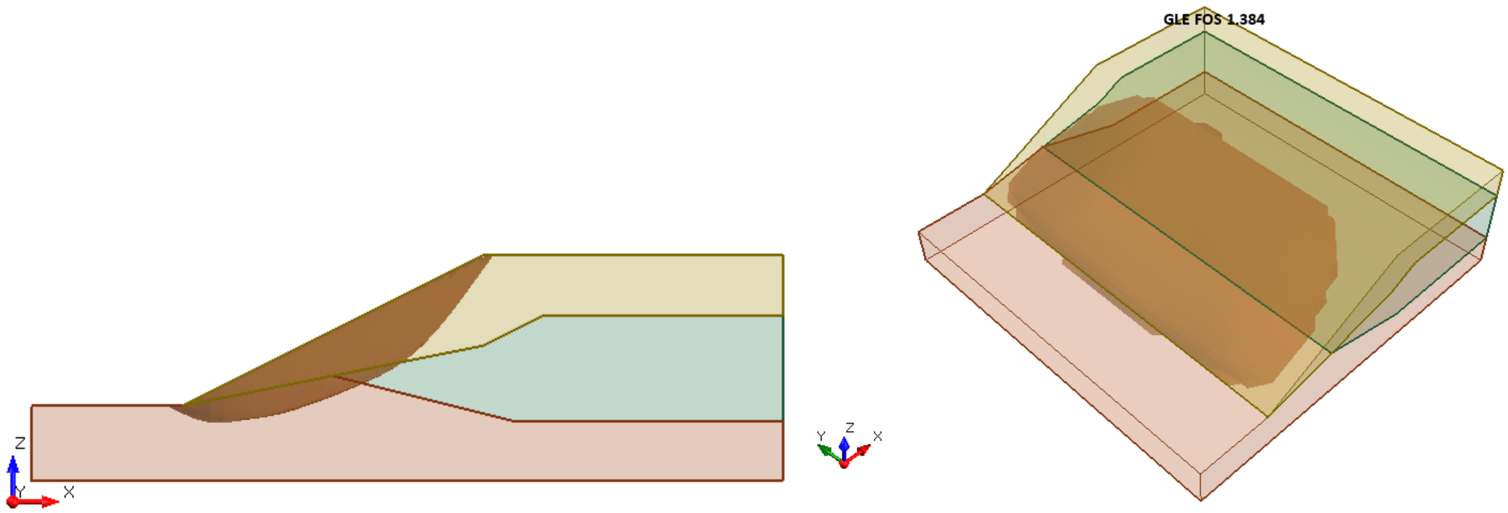


Figure 4.4.5 – Slide3 Solution Using the GLE Method

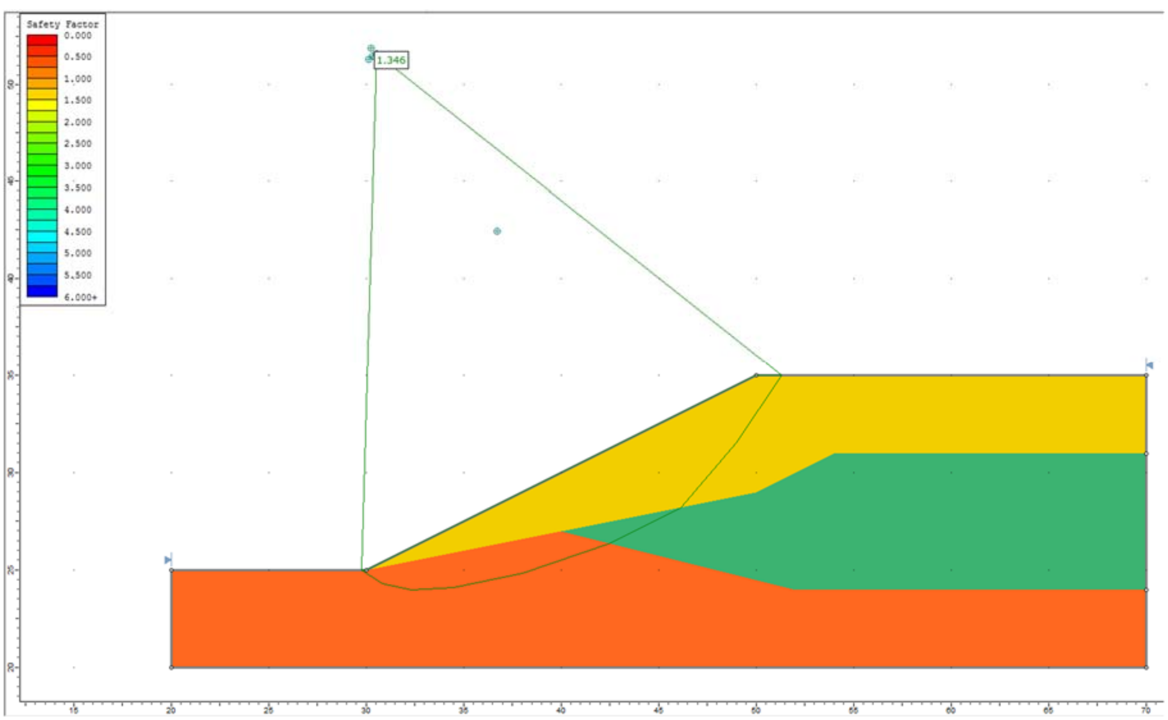


Figure 4.4.6 – Slide Solution Using the GLE Method

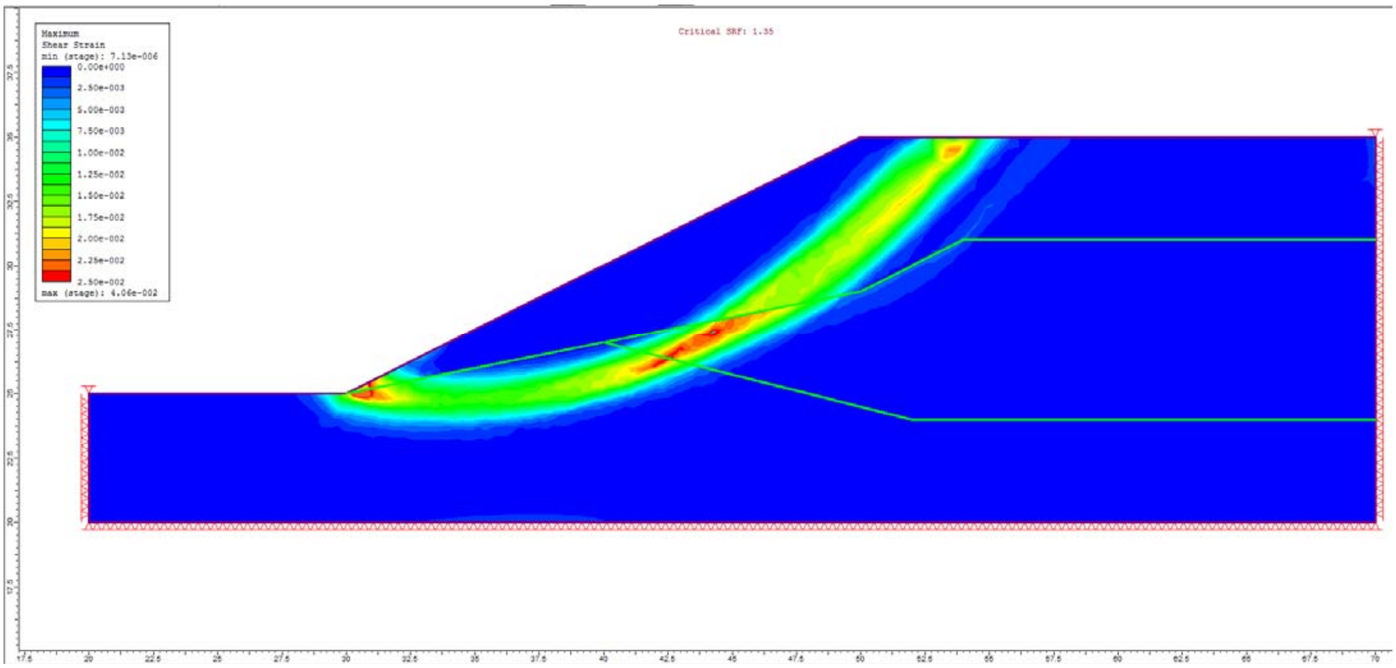


Figure 4.4.7 – RS2 Maximum Shear Strain

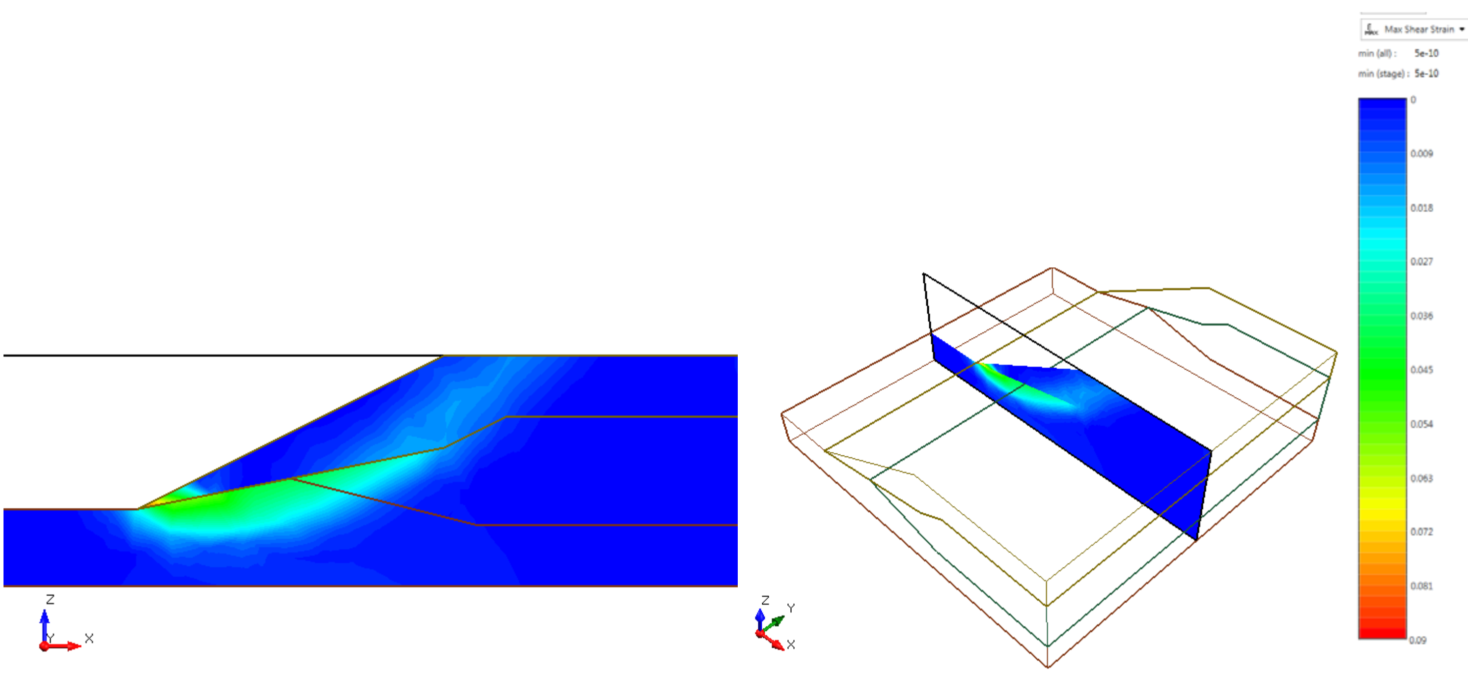


Figure 4.4.8 – RS3 Maximum Shear Strain

2D extruded, (3) materials, seismic, spherical

5.1 Introduction

In 1988 a set of 5 basic slope stability problems, together with 5 variants, was distributed both in the Australian Geomechanics profession and overseas as part of a survey sponsored by ACADS (Giam & Donald (1989)). This is a 3D extrusion of the ACADS 1(d) problem.

5.2 Problem Description

Problem #5 is a three layer slope with material properties given in Table 5.1 and geometry as shown in Figure 5. This problem is identical to #3, but with a horizontal seismically induced acceleration of 0.15g included in the analysis. The factor of safety and its corresponding critical spherical failure surface is required.

5.3 Geometry and Properties

Table 5.1 Material Properties

	c´ (kN/m^2)	φ´ (deg.)	γ (kN/m^3)
Soil #1	0.0	38.0	19.5
Soil #2	5.3	23.0	19.5
Soil#3	7.2	20.0	19.5

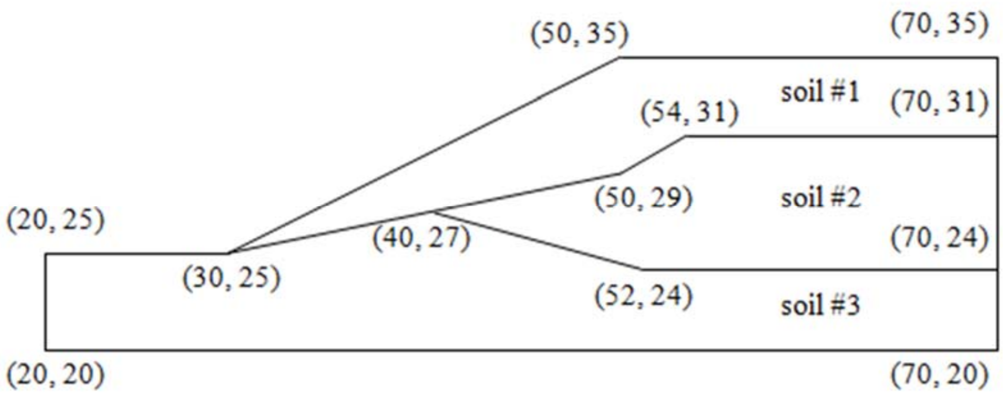


Figure 5

5.4 Results

Table 5.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.093	1.016	1.01	0.96
Spencer	1.084	0.991		
GLE	1.076	0.989		

Referee: 1.00 [Giam]

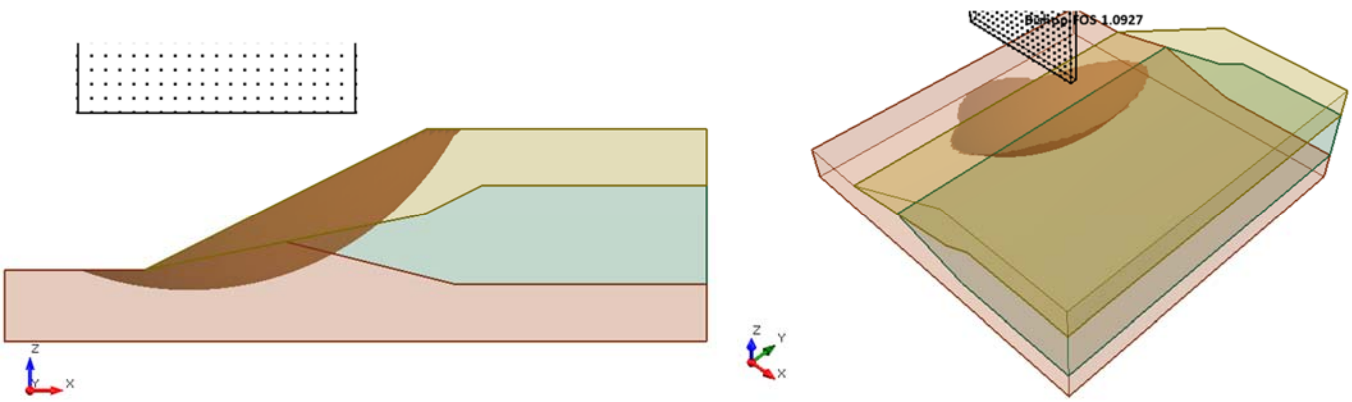


Figure 5.4.1 – Slide3 Solution Using the Bishop Method

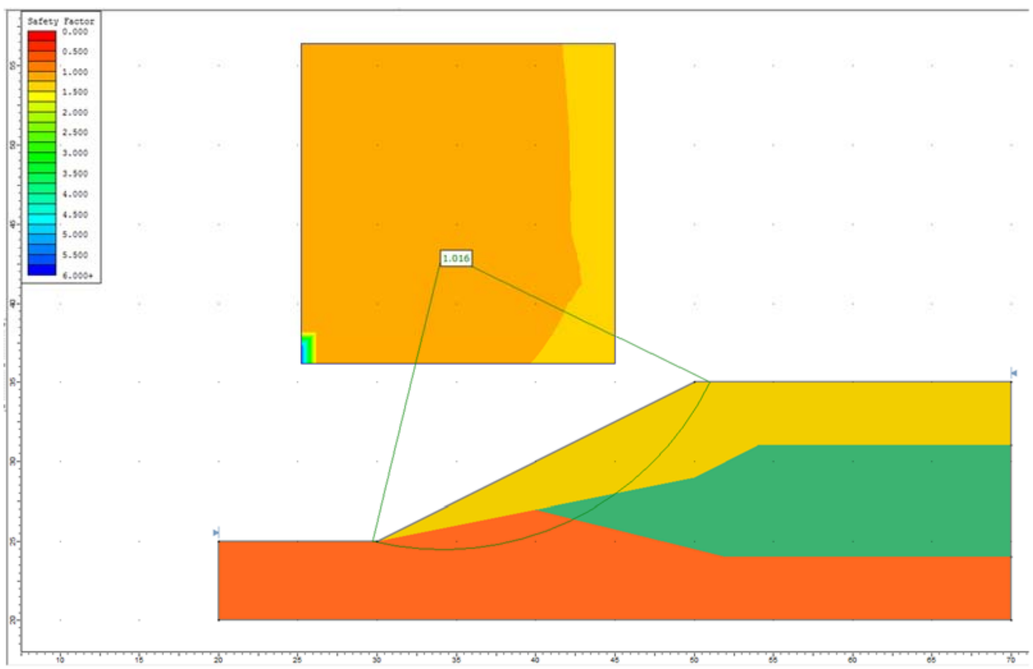


Figure 5.4.2 – Slide Solution Using the Bishop Method

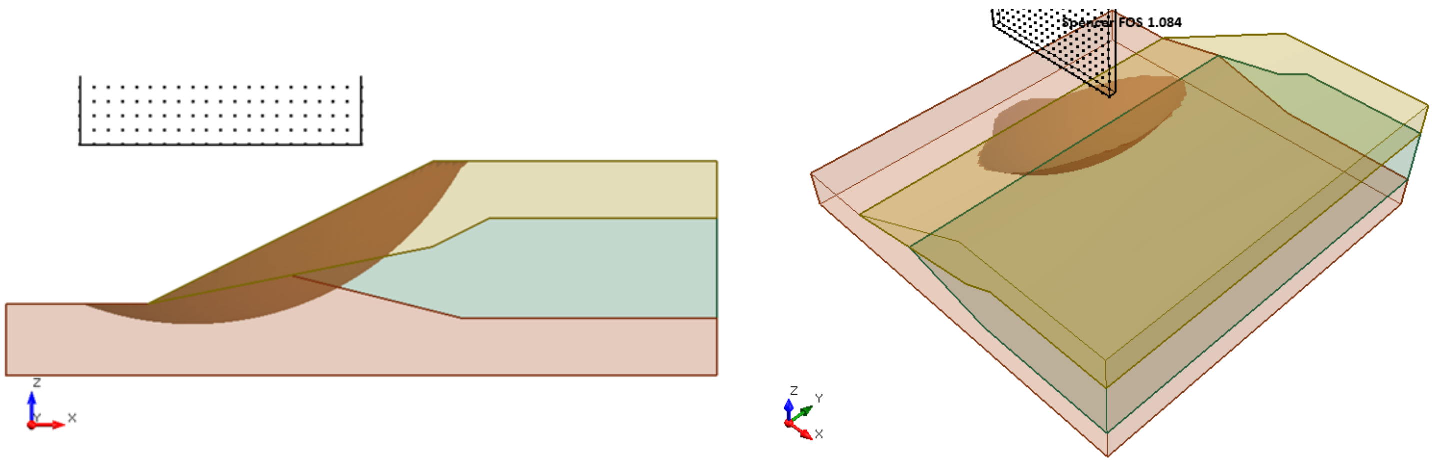


Figure 5.4.3 – Slide3 Solution Using the Spencer Method

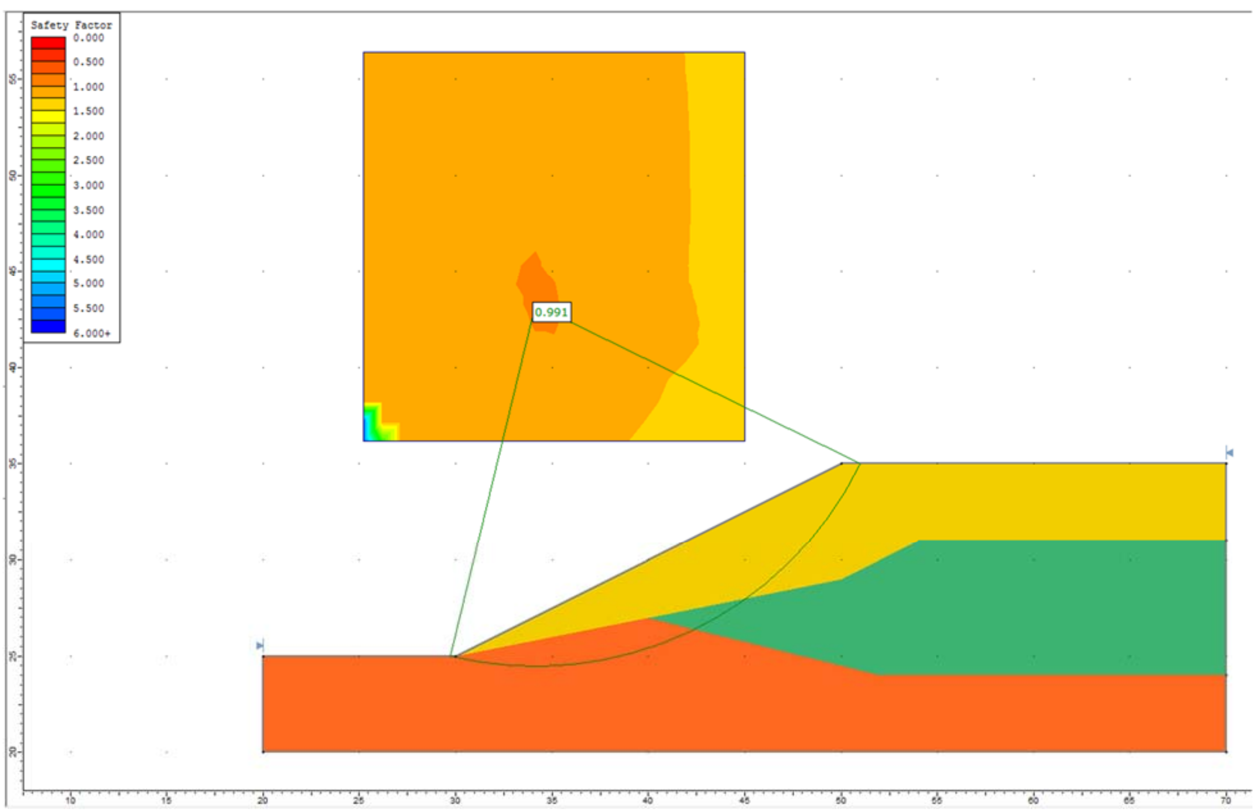


Figure 5.4.4 – Slide Solution Using the Spencer Method

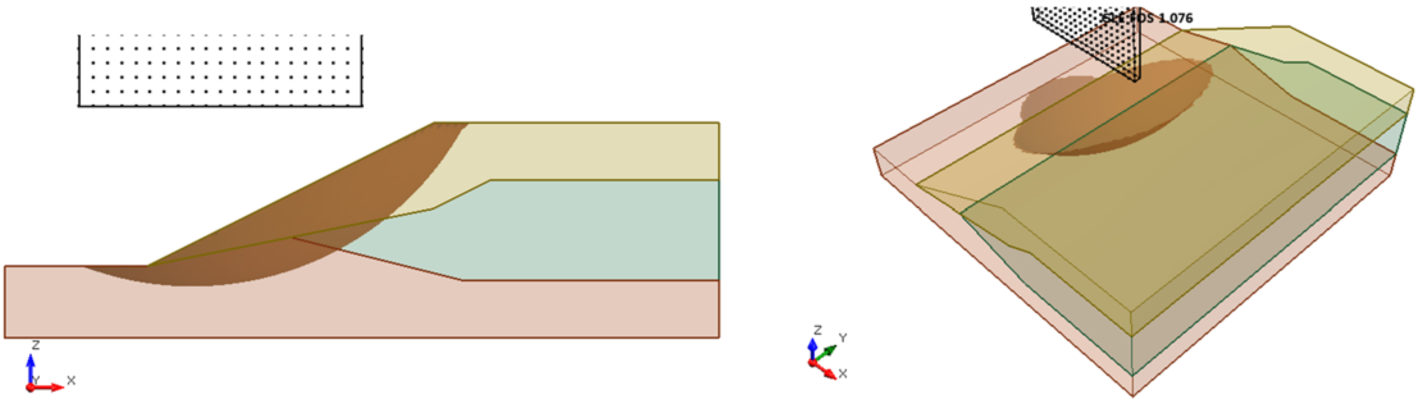


Figure 5.4.5 – Slide3 Solution Using the GLE Method

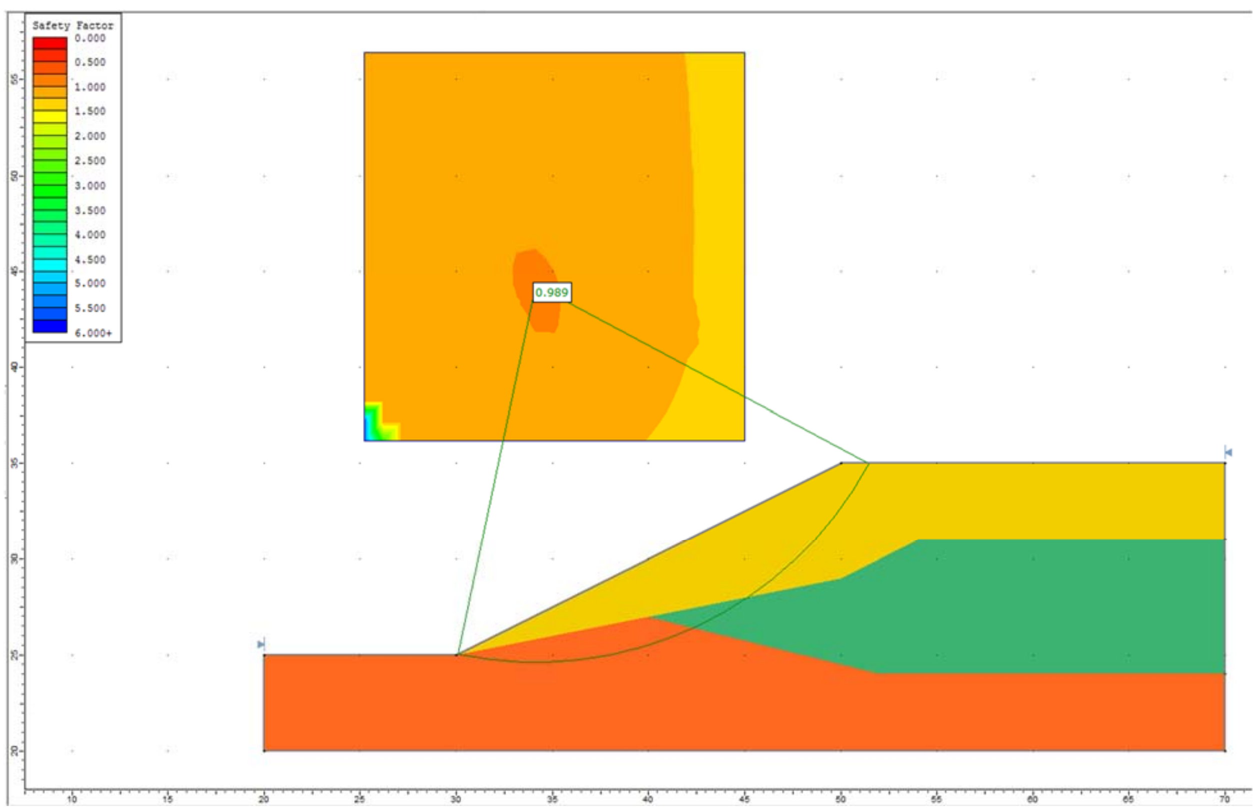


Figure 5.4.6 – Slide Solution Using the GLE Method

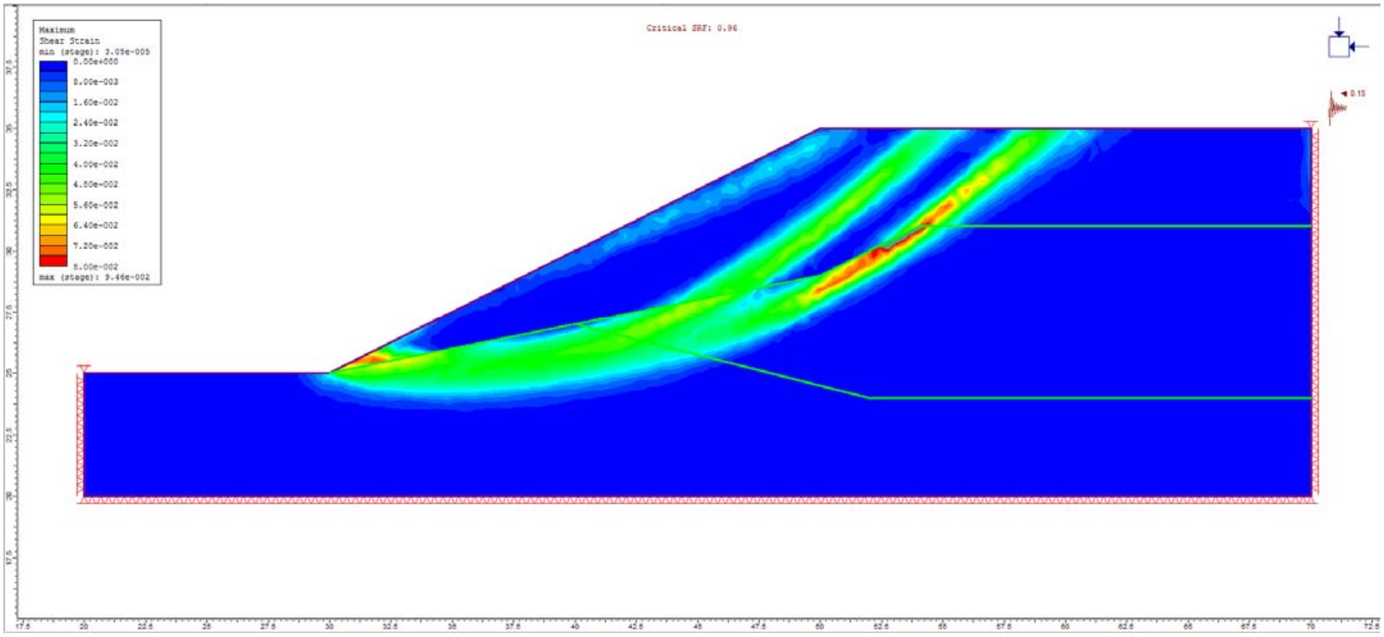


Figure 5.4.7 – RS2 Maximum Shear Strain

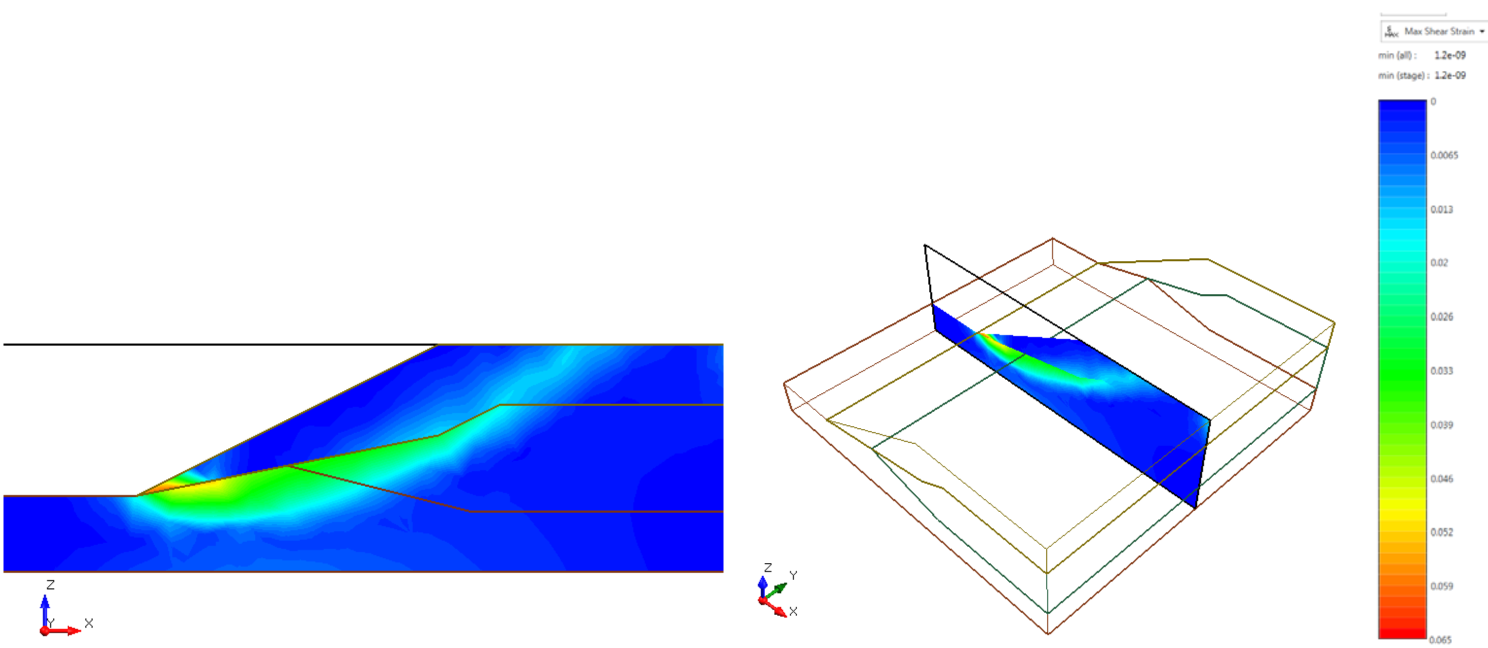


Figure 5.4.8 – RS3 Maximum Shear Strain Contour in the XZ Plane

2D extruded, (3) materials, seismic, ellipsoidal with SA

6.1 Introduction

In 1988 a set of 5 basic slope stability problems, together with 5 variants, was distributed both in the Australian Geomechanics profession and overseas as part of a survey sponsored by ACADS (Giam & Donald (1989)). This is a 3D extrusion of the ACADS 1(d) problem.

6.2 Problem Description

Problem #6 is a non-homogeneous, three layer slope with material properties given in Table 6.1 and geometry as shown in Figure 6. This problem is identical to #5, but the ellipsoidal slip surface is required. A horizontal seismically induced acceleration of 0.15g included in the analysis.

6.3 Geometry and Properties

Table 6.1 Material Properties

	c´ (kN/m^2)	φ´ (deg.)	γ (kN/m^3)
Soil #1	0.0	38.0	19.5
Soil #2	5.3	23.0	19.5
Soil#3	7.2	20.0	19.5

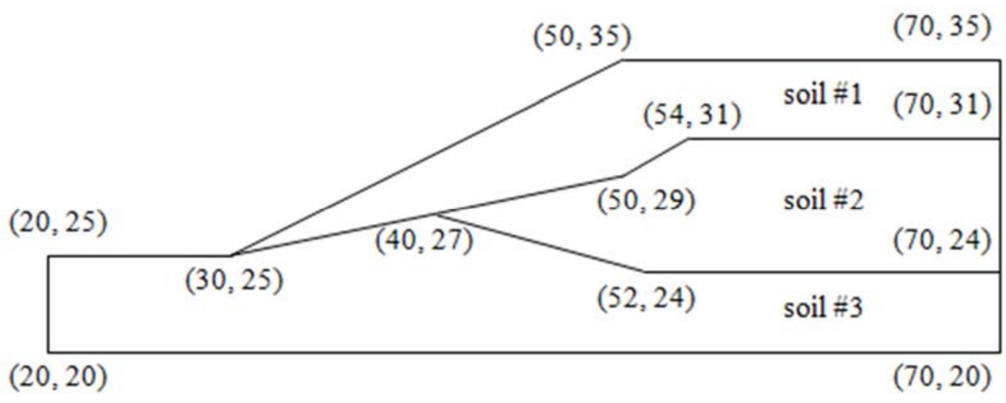


Figure 6

6.4 Results

Table 6.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Janbu	0.922	0.893		
Spencer	1.001	0.980	1.01	0.96
GLE	0.998	0.965		

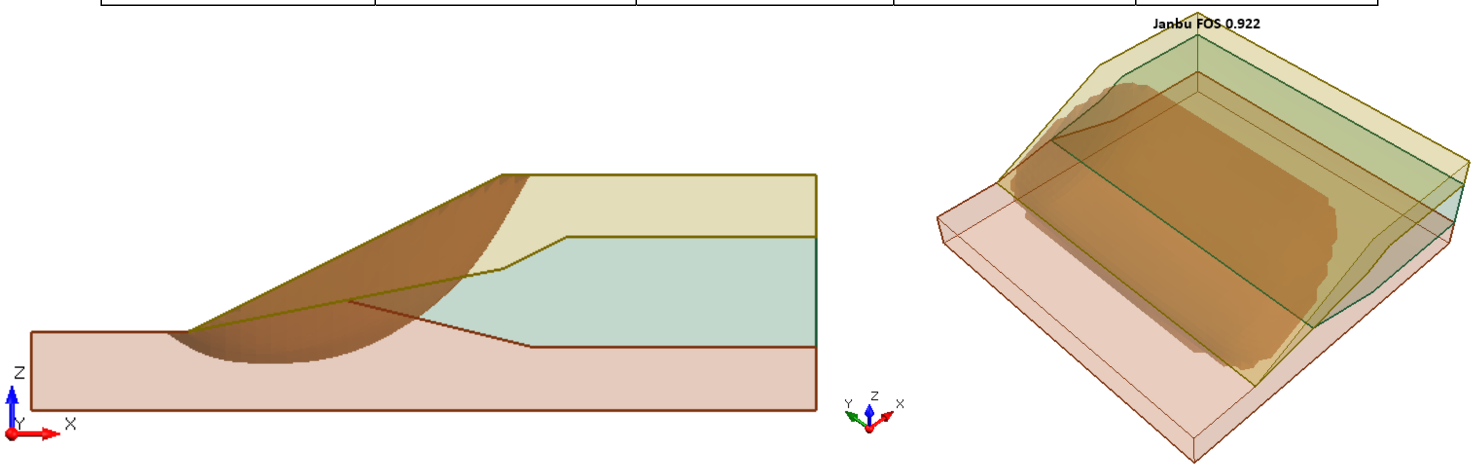


Figure 6.4.1 – Slide3 Solution Using the Janbu Method

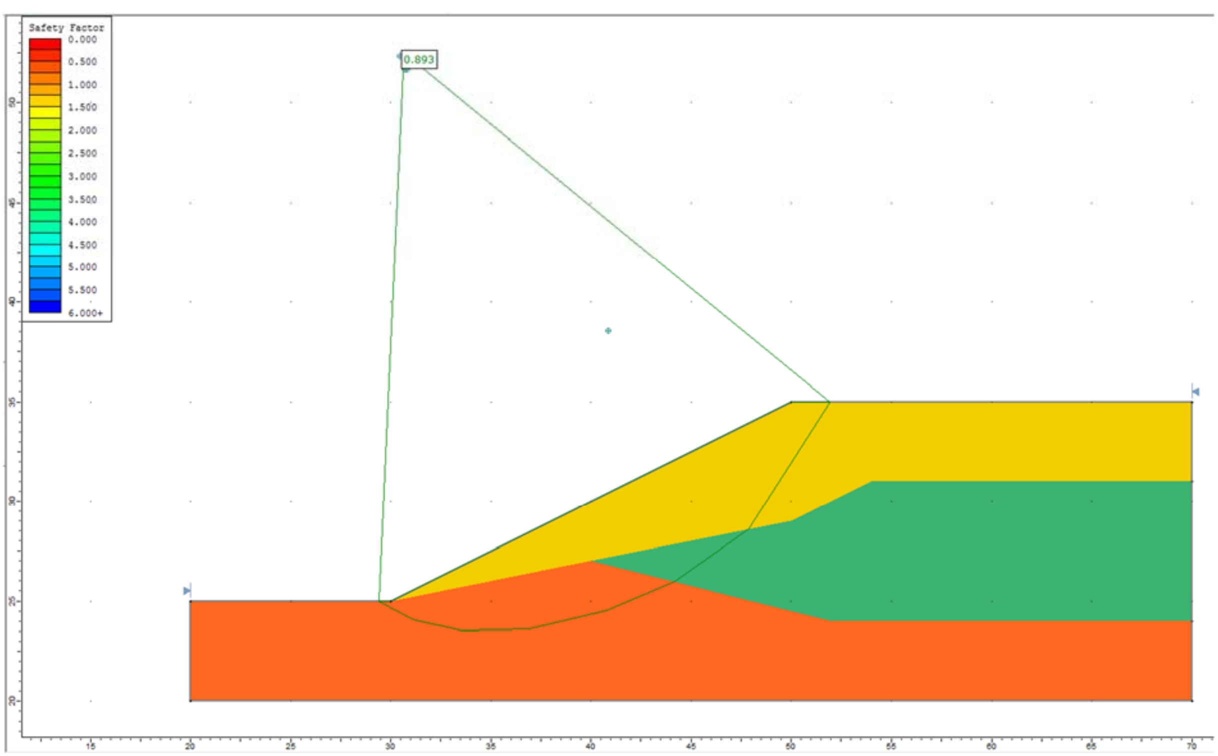


Figure 6.4.2 – Slide Solution Using the Janbu Method

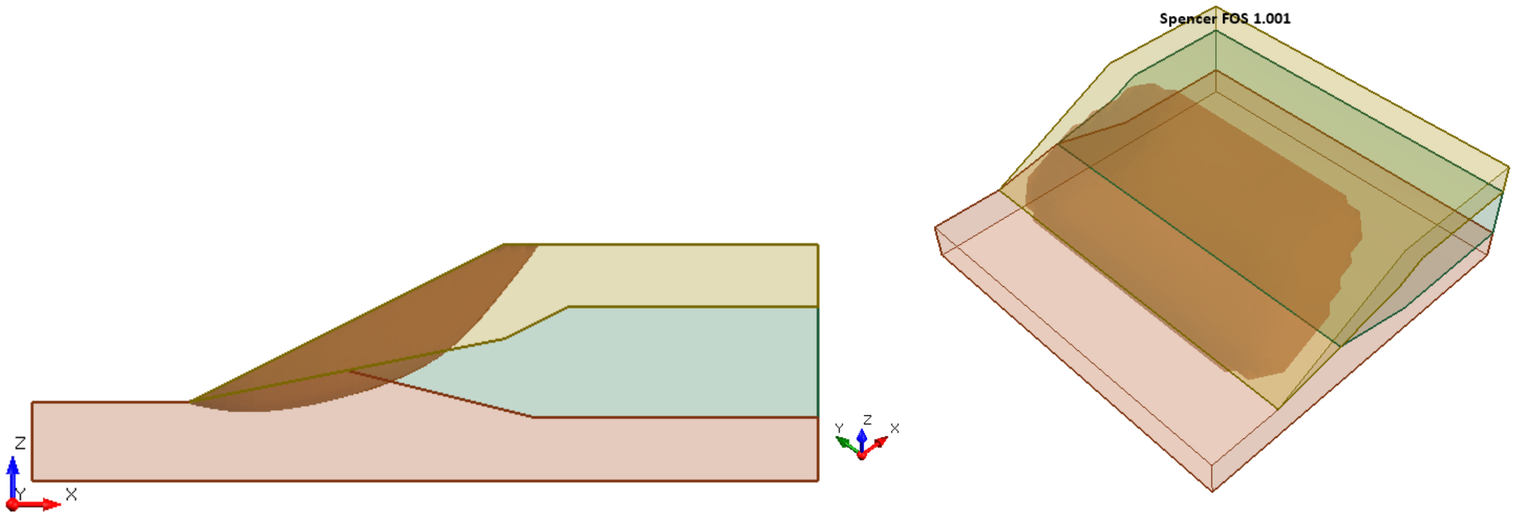


Figure 6.4.3 – Slide3 Solution Using the Spencer Method

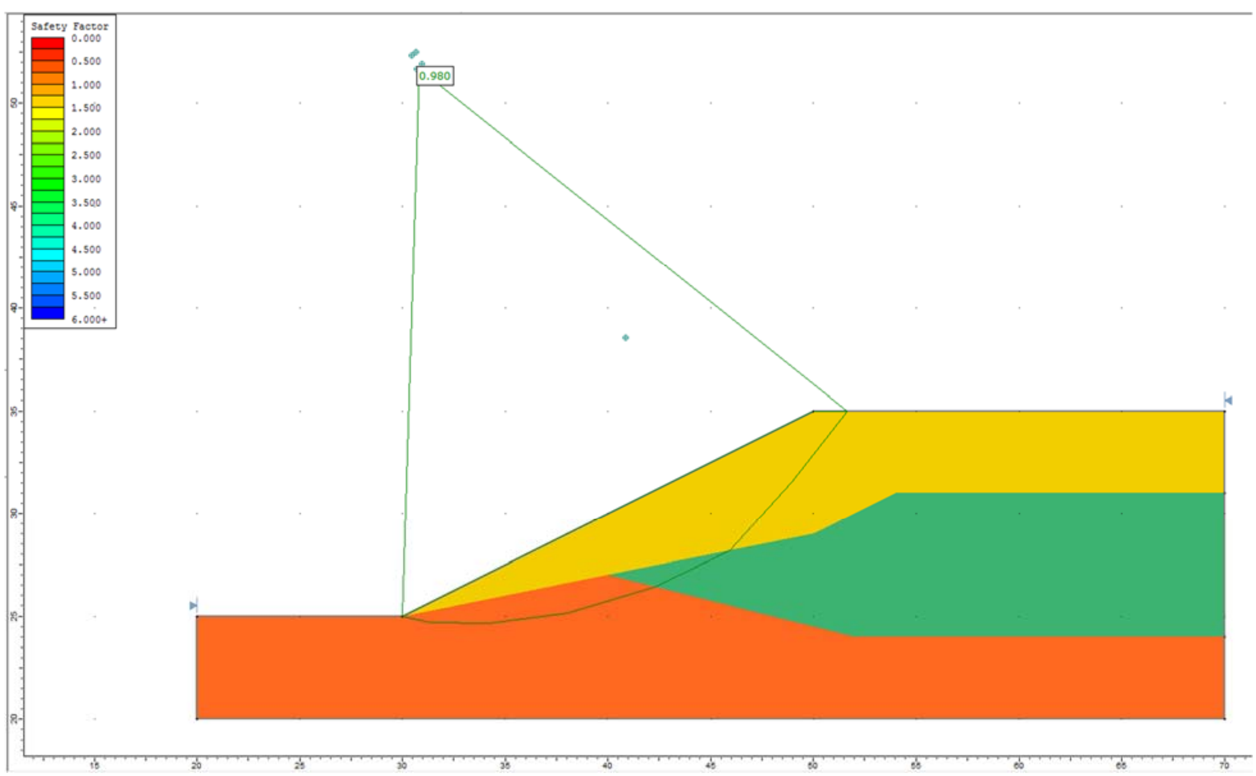


Figure 6.4.4 – Slide Solution Using the Spencer Method

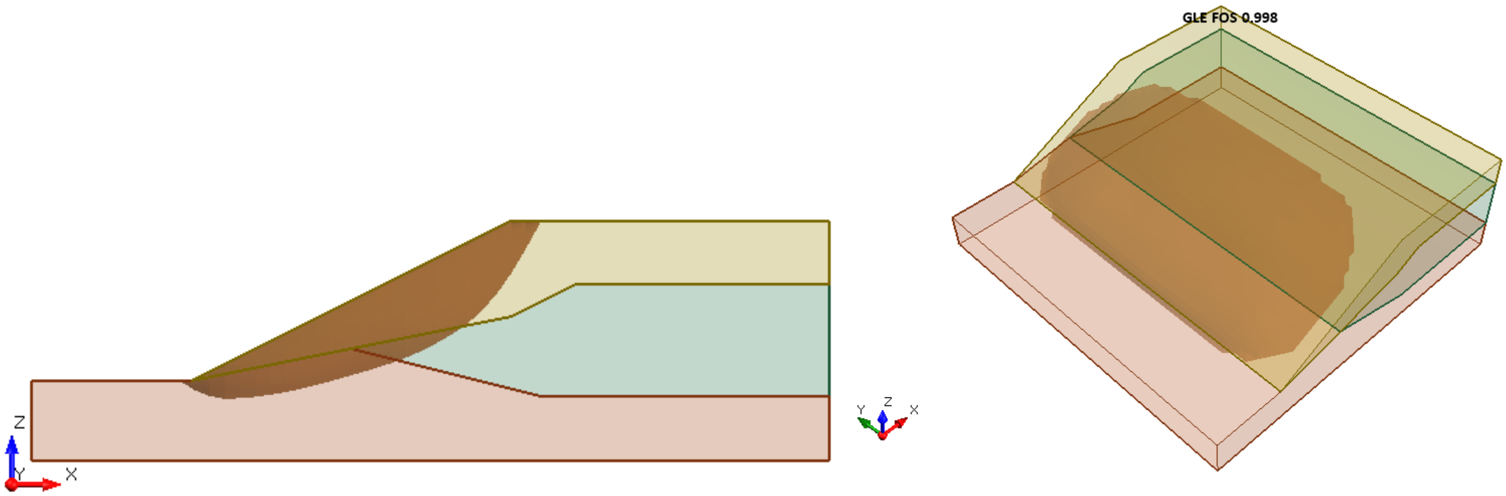


Figure 6.4.5 – Slide3 Solution Using the GLE Method

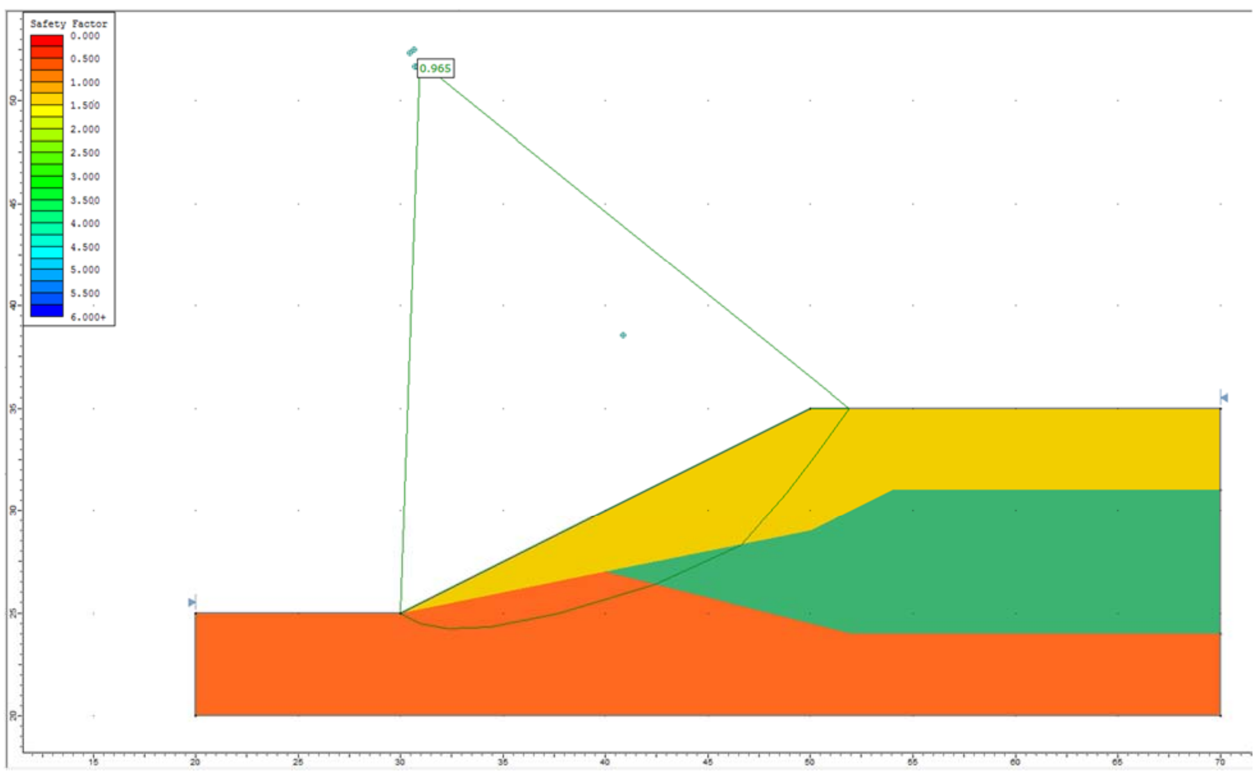


Figure 6.4.6 – Slide Solution Using the GLE Method

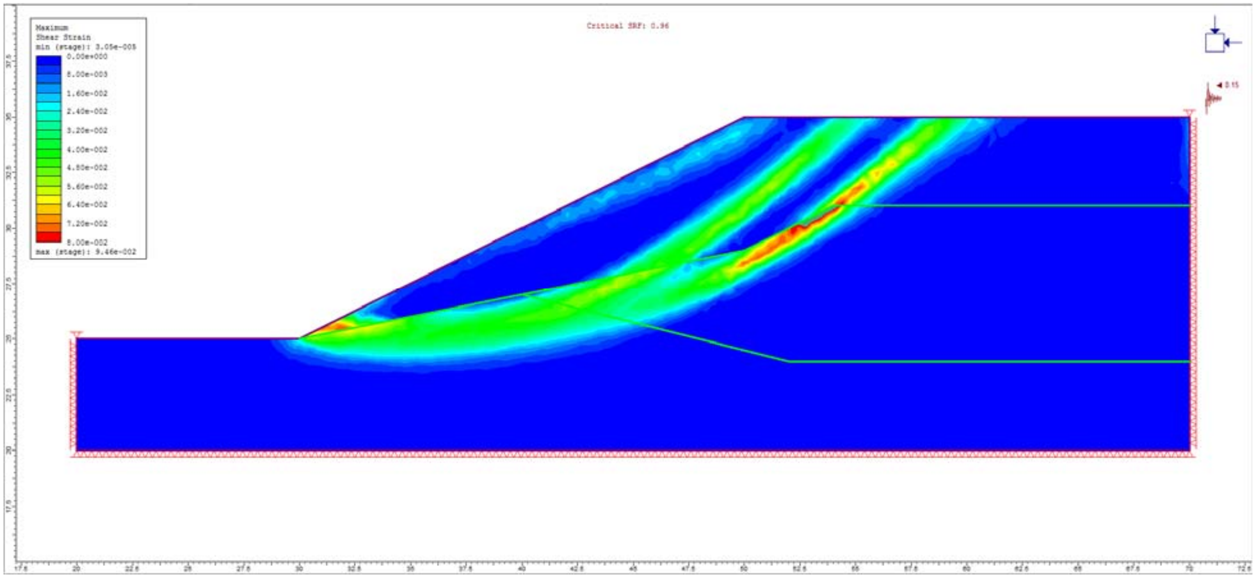


Figure 6.4.7 – RS2 Maximum Shear Strain Contour with Displacement Contour

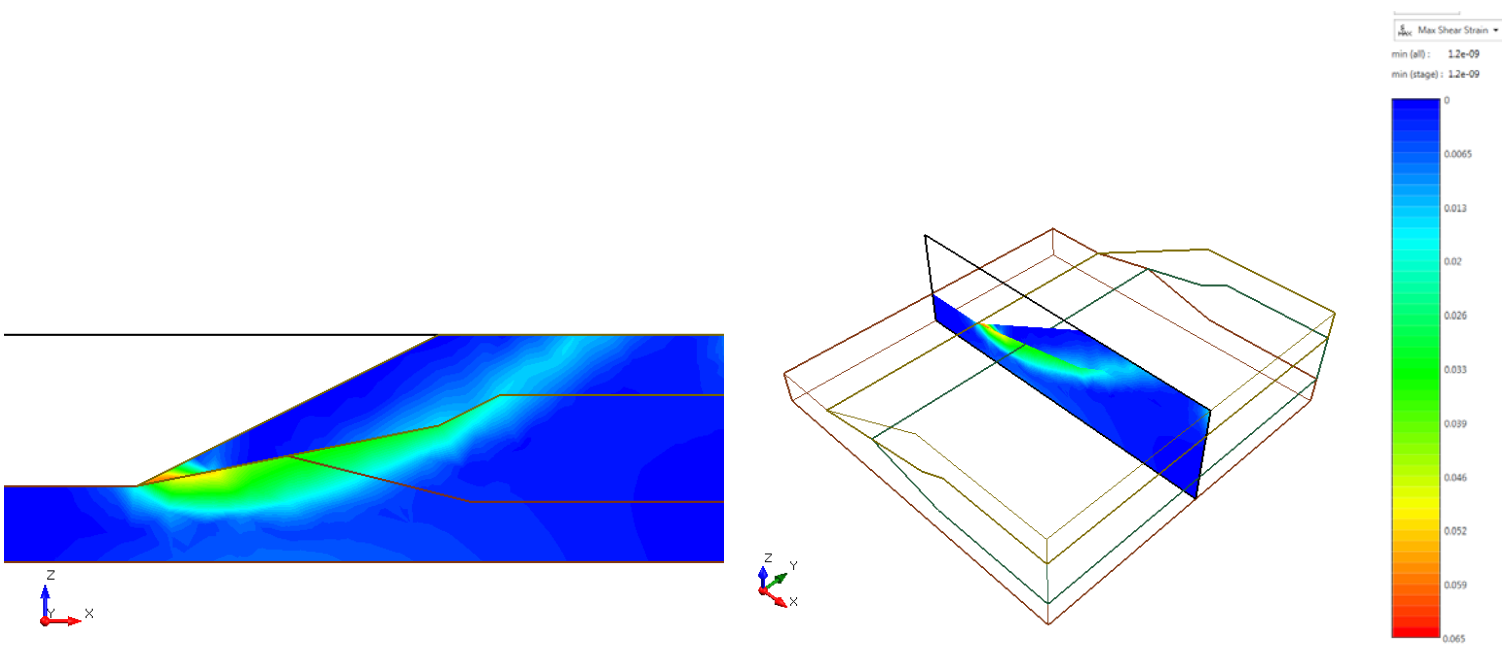


Figure 6.4.8 – RS3 Maximum Shear Strain Contour in the XZ Plane

2D extruded, weak layer, infinite strength base, ellipsoidal with SA

7.1 Introduction

In 1988 a set of 5 basic slope stability problems, together with 5 variants, was distributed both in the Australian Geomechanics profession and overseas as part of a survey sponsored by ACADS (Giam & Donald (1989)). This is a 3D extrusion of the ACADS 3(a) problem.

7.2 Problem Description

This problem has material properties given in Table 7.1. The slope geometry in the XZ plane is given in Figure 7, and is extruded 64m in the Y direction. The water table is assumed to coincide with the base of the weak layer. The effect of negative pore water pressure above the water table is to be ignored (i.e. u=0 above water table). The effect of the tension crack is also to be ignored in this problem. The factor of safety and its corresponding critical ellipsoidal failure surface is required.

7.3 Geometry and Properties

Table 7.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil #1	28.5	20.0	18.84
Soil #2	0	10.0	18.84
Infinite Strength (for RS2 and RS3 only)	10000	65	18.84

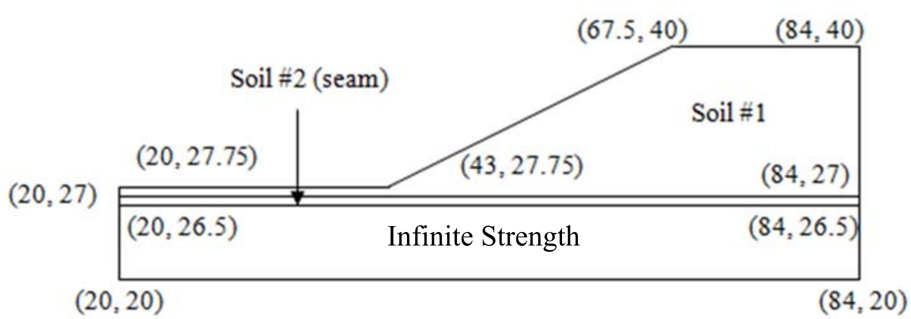


Figure 7

7.4 Results

Table 7.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Janbu	1.317	1.180		
Spencer	1.37	1.258	1.4	1.24
GLE	1.354	1.246		

Note: Referee Factor of Safety = 1.24 – 1.27 [Giam]

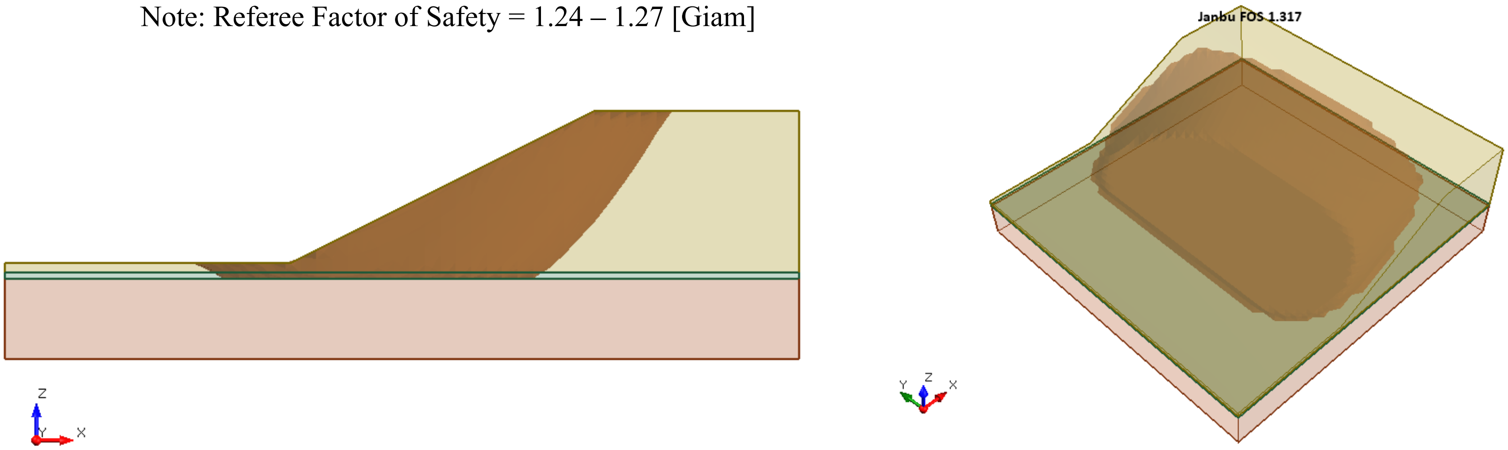


Figure 7.4.1 – Solution Using the Janbu Simplified Method

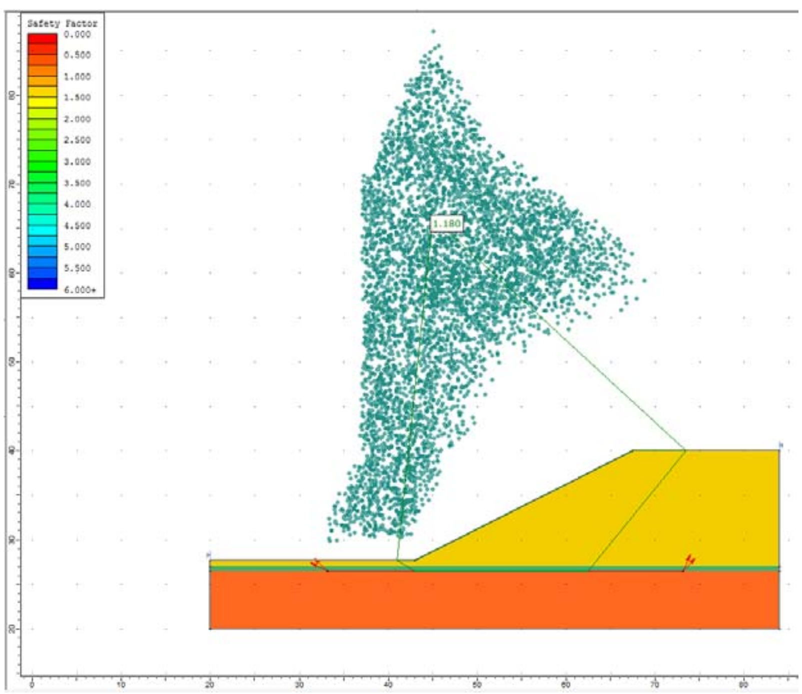


Figure 7.4.2 – Slide Solution Using the Janbu Method

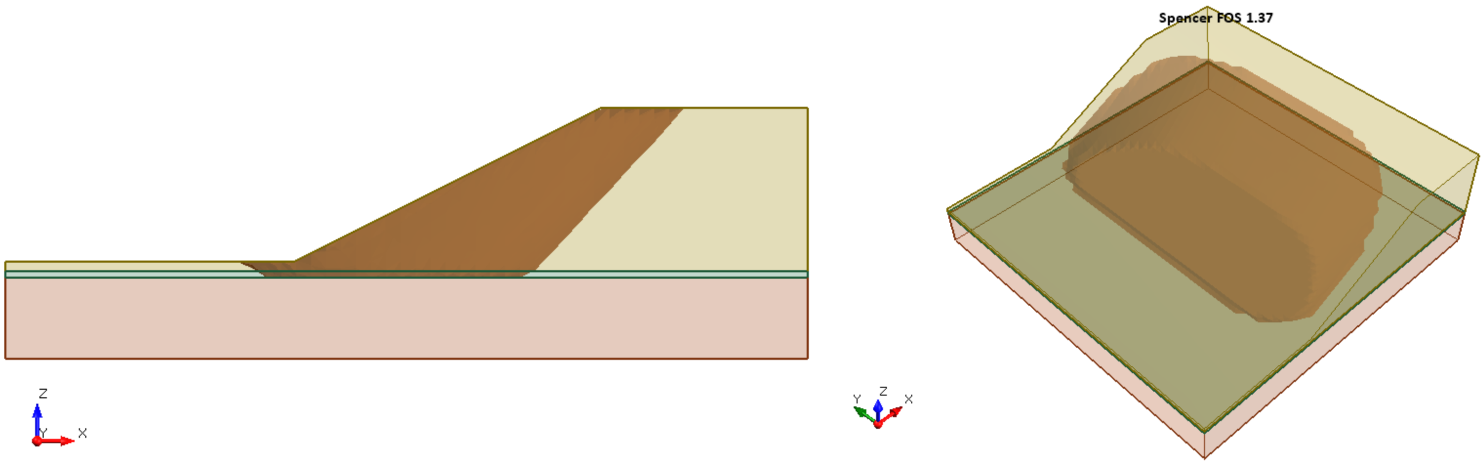


Figure 7.4.3 – Solution Using the Spencer Method

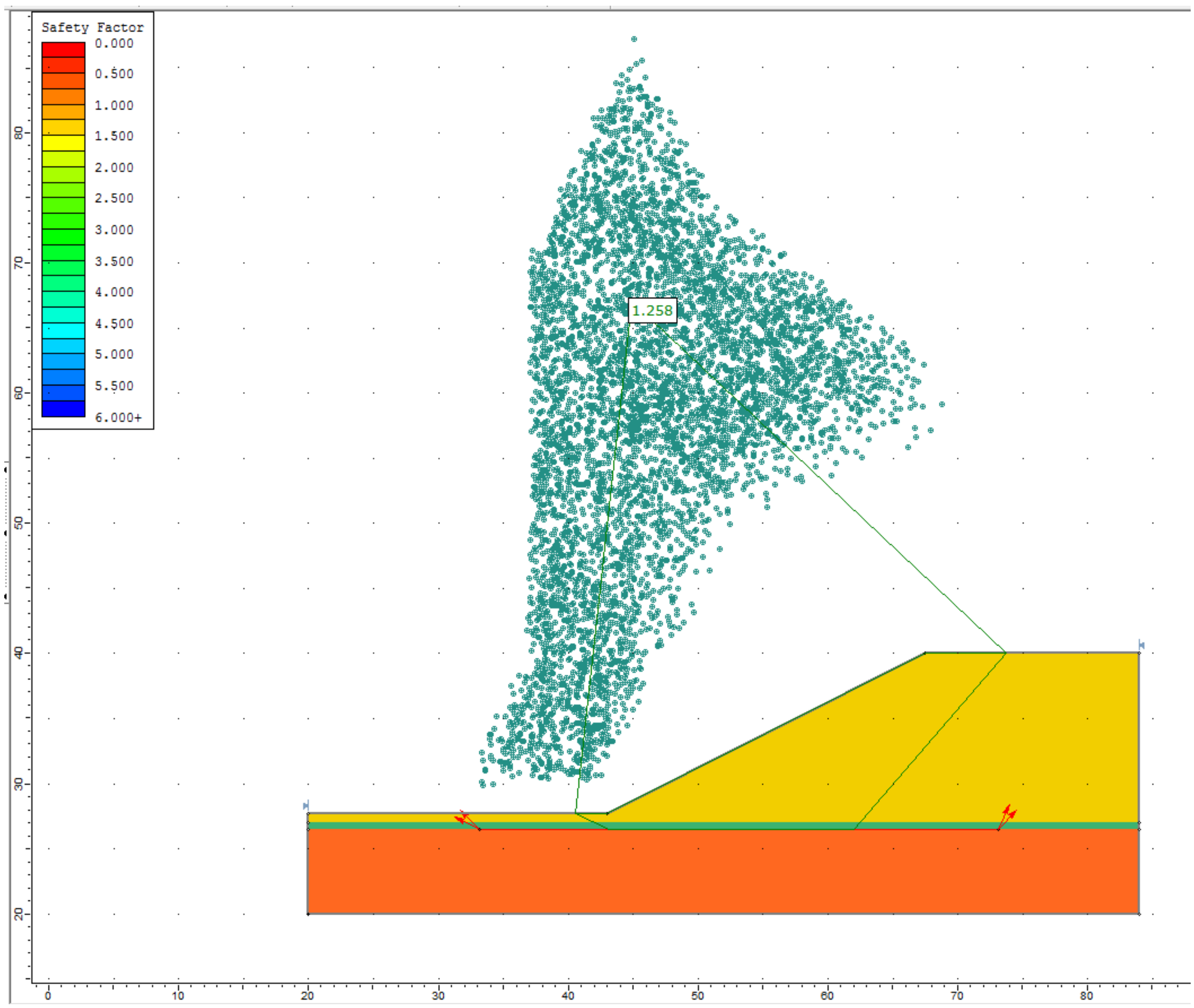


Figure 7.4.4 – Slide Solution Using the Spencer Method

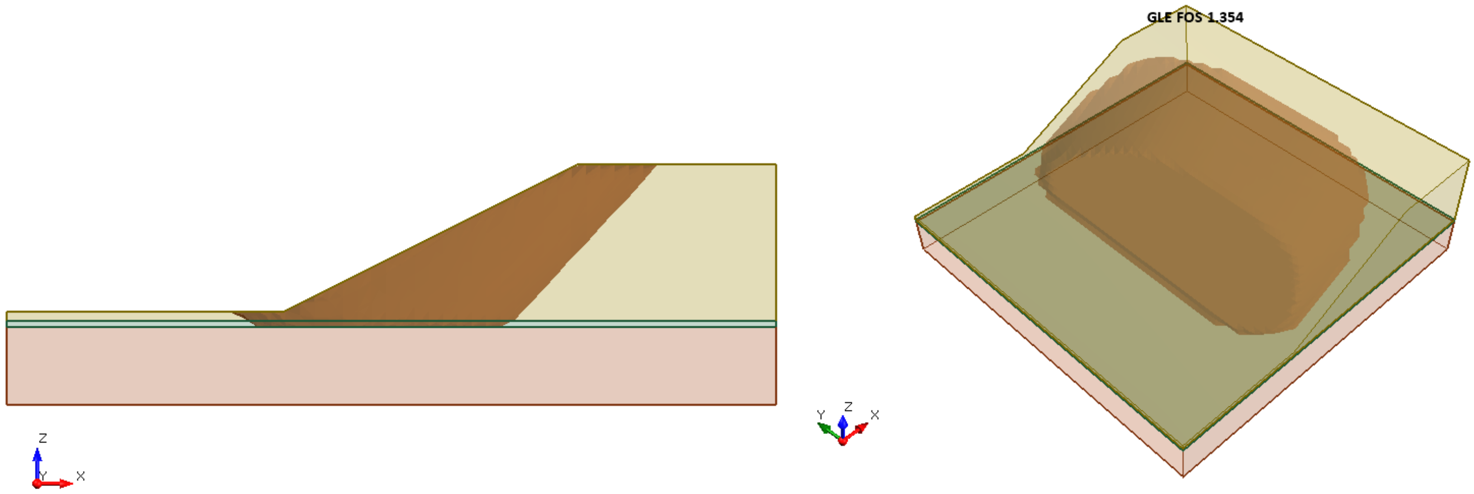


Figure 7.4.5 – Solution Using the GLE Method

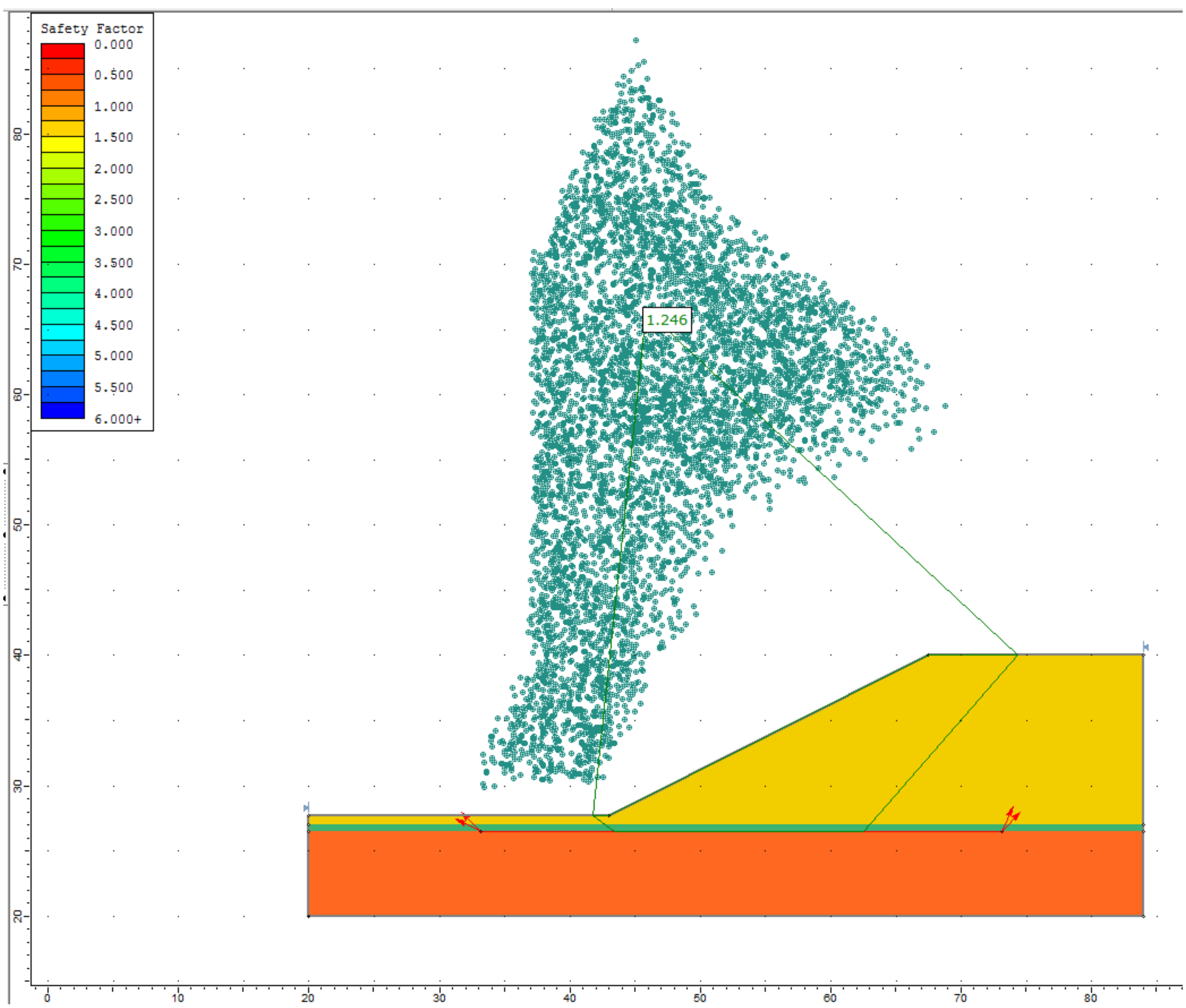


Figure 7.4.6 – Slide Solution Using the GLE Method

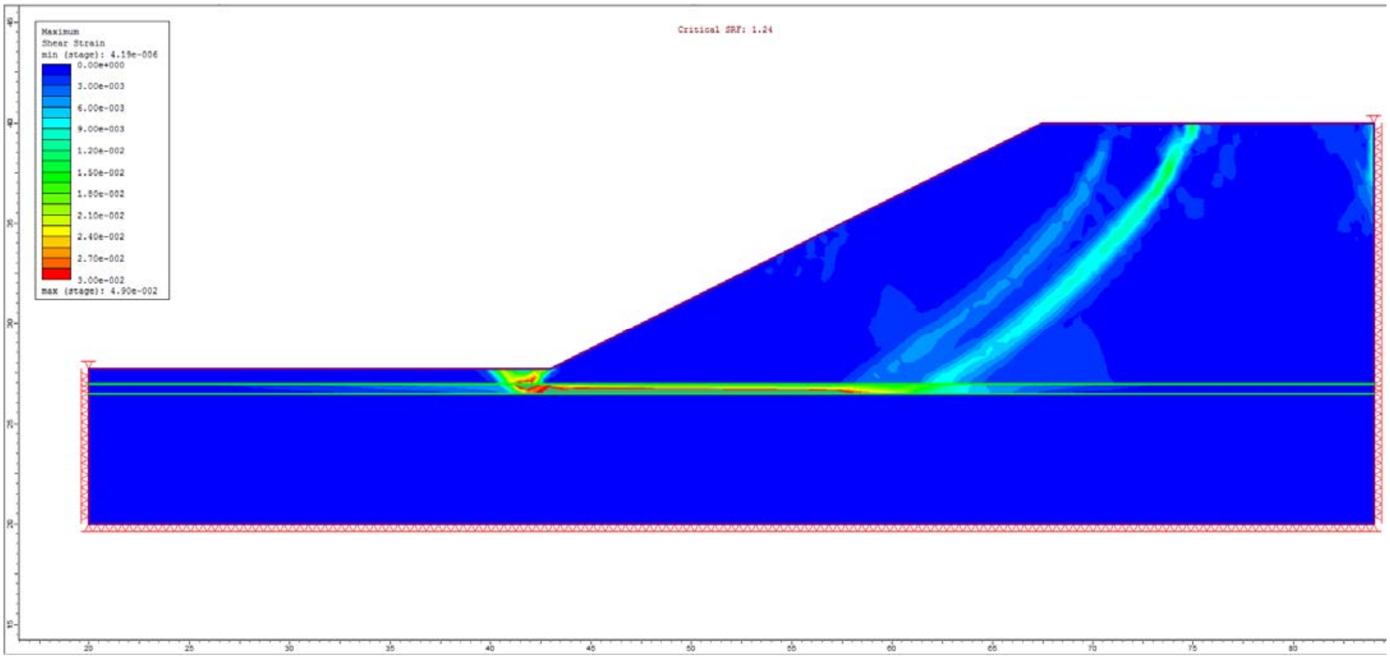


Figure 7.4.7 – RS2 Maximum Shear Strain

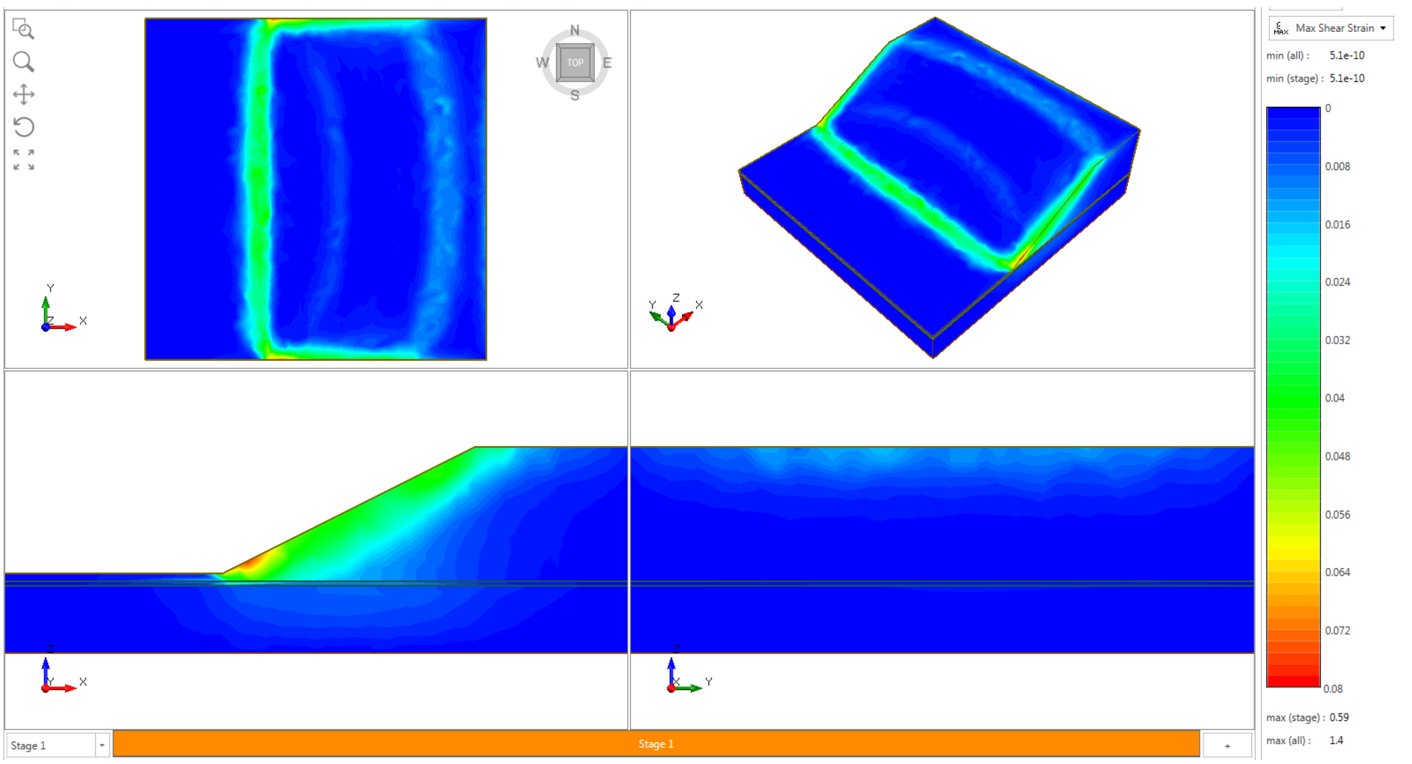


Figure 7.4.8 – RS3 Maximum Shear Strain

2D extruded, homogeneous, spherical

8.1 Introduction

This model is a 3D extrusion of the model taken from Arai and Tagyo (1985) example#1 and consists of a simple slope of homogeneous soil with zero pore pressure.

8.2 Problem Description

The slope geometry in the XZ plane of 2D Extruded Verification #8 is shown in Figure 8.1. This geometry will be extruded 66m in the Y direction. The material properties are given in Table 8.1. The position of the critical slip surface and the corresponding factor of safety are calculated for a spherical slip surface. There are no pore pressures in this problem.

This problem uses the auto refine search to find the spherical slip surface.

8.3 Geometry and Properties

Table 8.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
soil	41.65	15	18.82

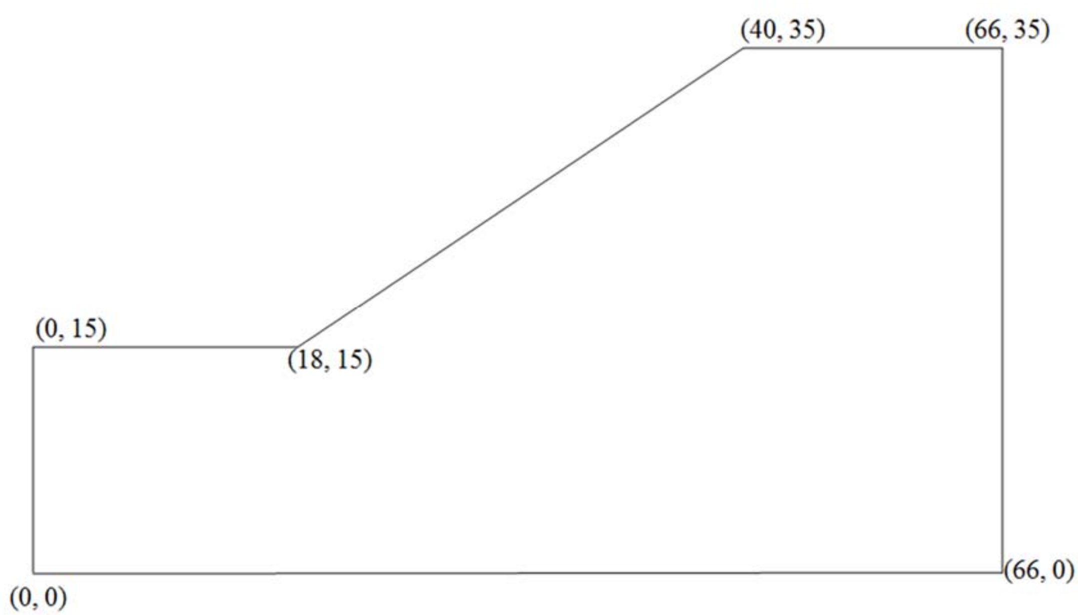


Figure 8

8.4 Results

Table 8.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.589	1.409	1.53	1.4
Spencer	1.575	1.407		
GLE	1.589	1.406		

Referee: 1.451 [Arai and Tagyo, 1985]

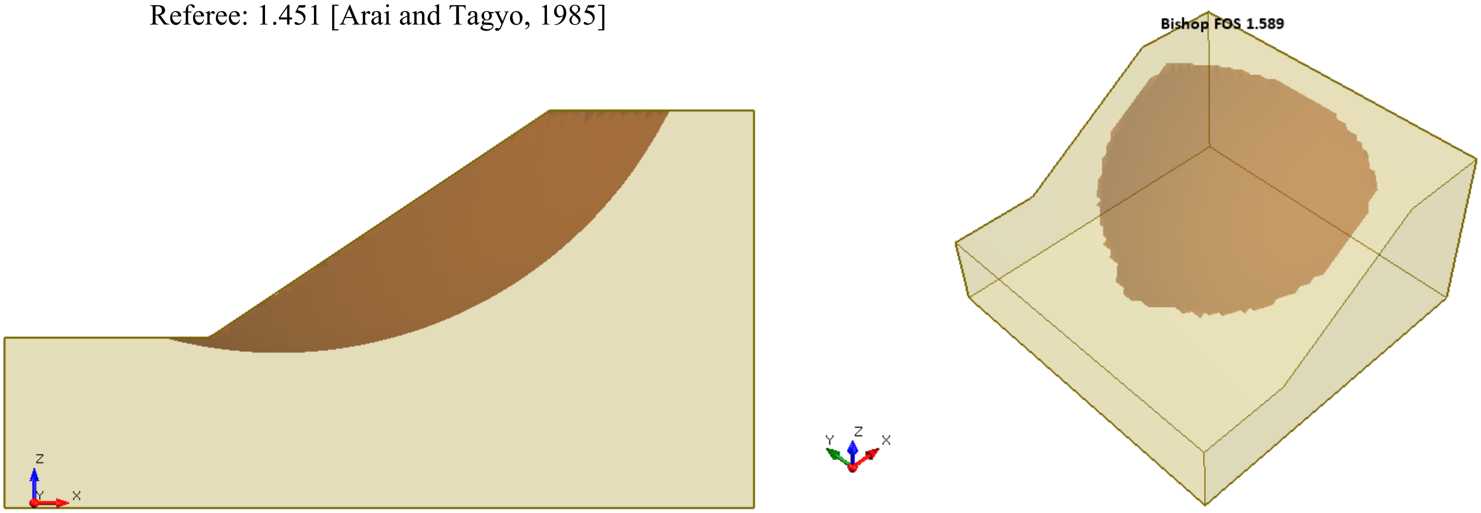


Figure 8.4.1 – Slide3 Solution Using the Bishop Method

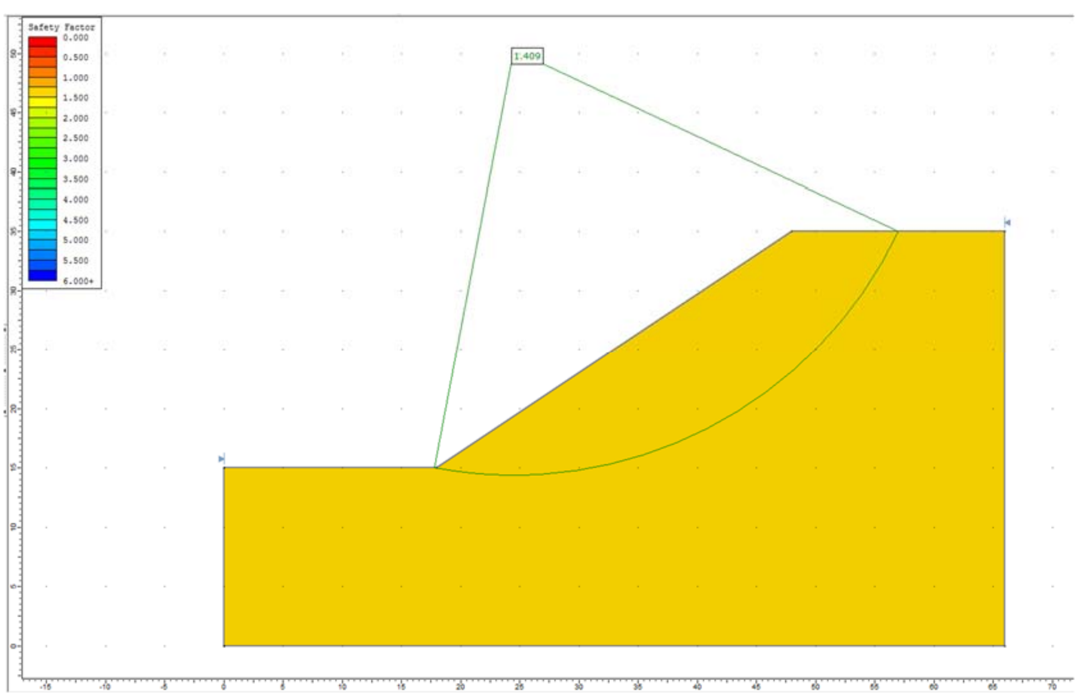


Figure 8.4.2 – Slide Solution Using the Bishop Method

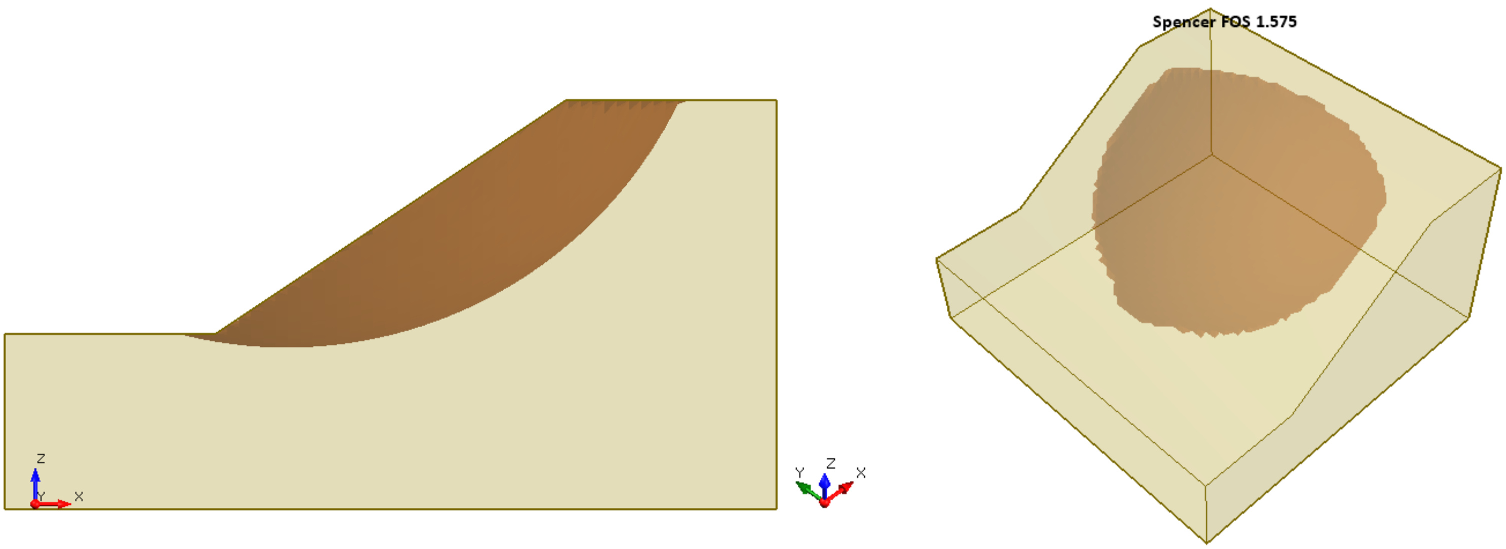


Figure 8.4.3 – Slide3 Solution Using the Spencer Method

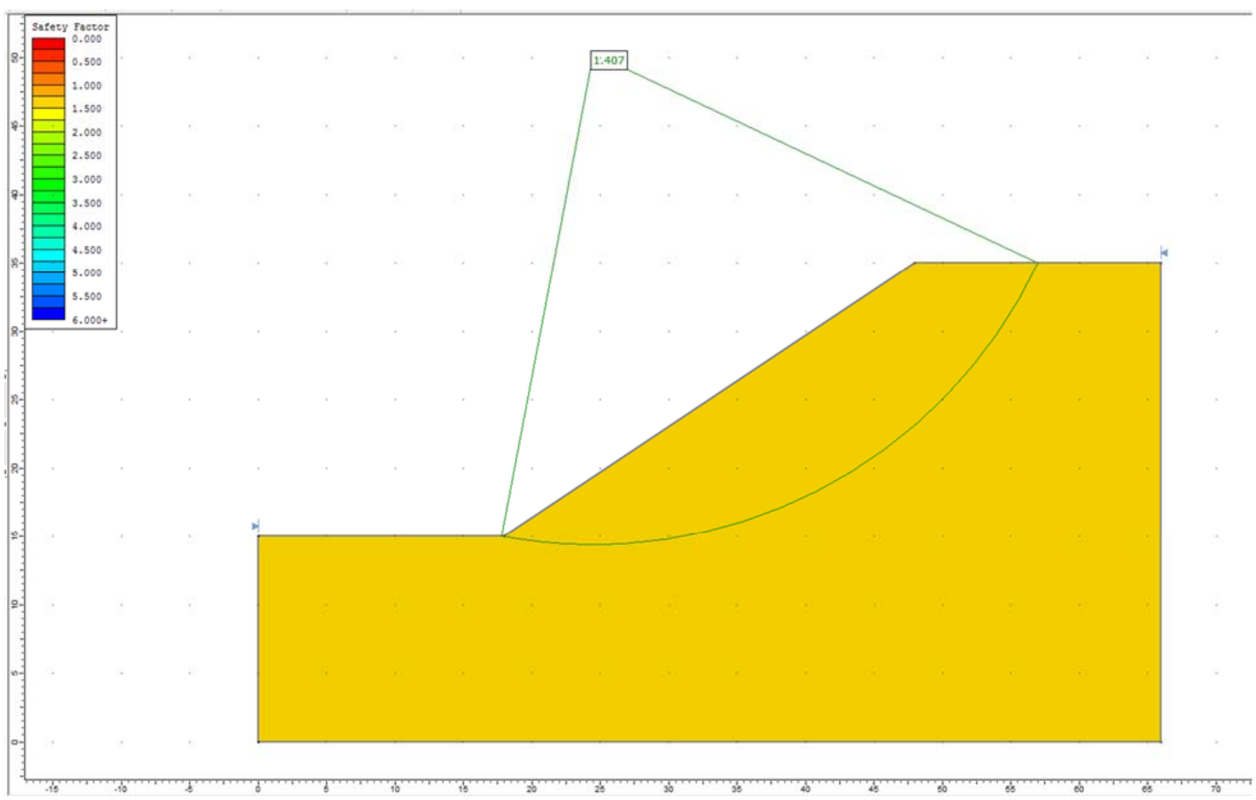


Figure 8.4.4 – Slide Solution Using the Spencer Method

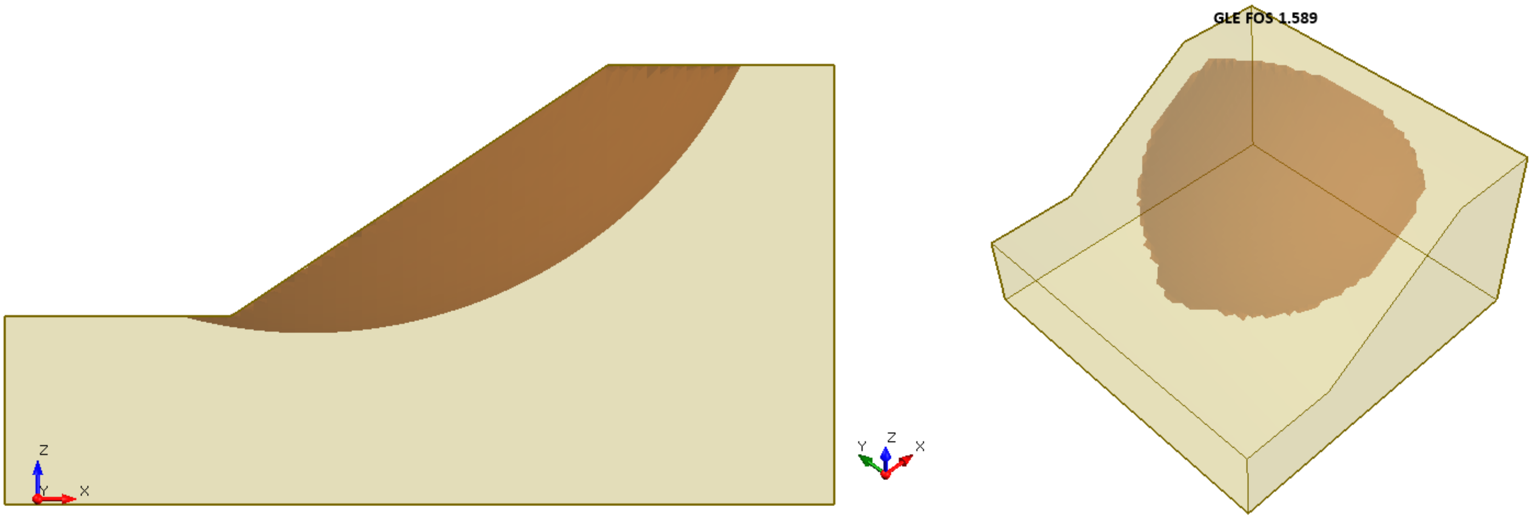


Figure 8.4.5 – Slide3 Solution Using the GLE Method

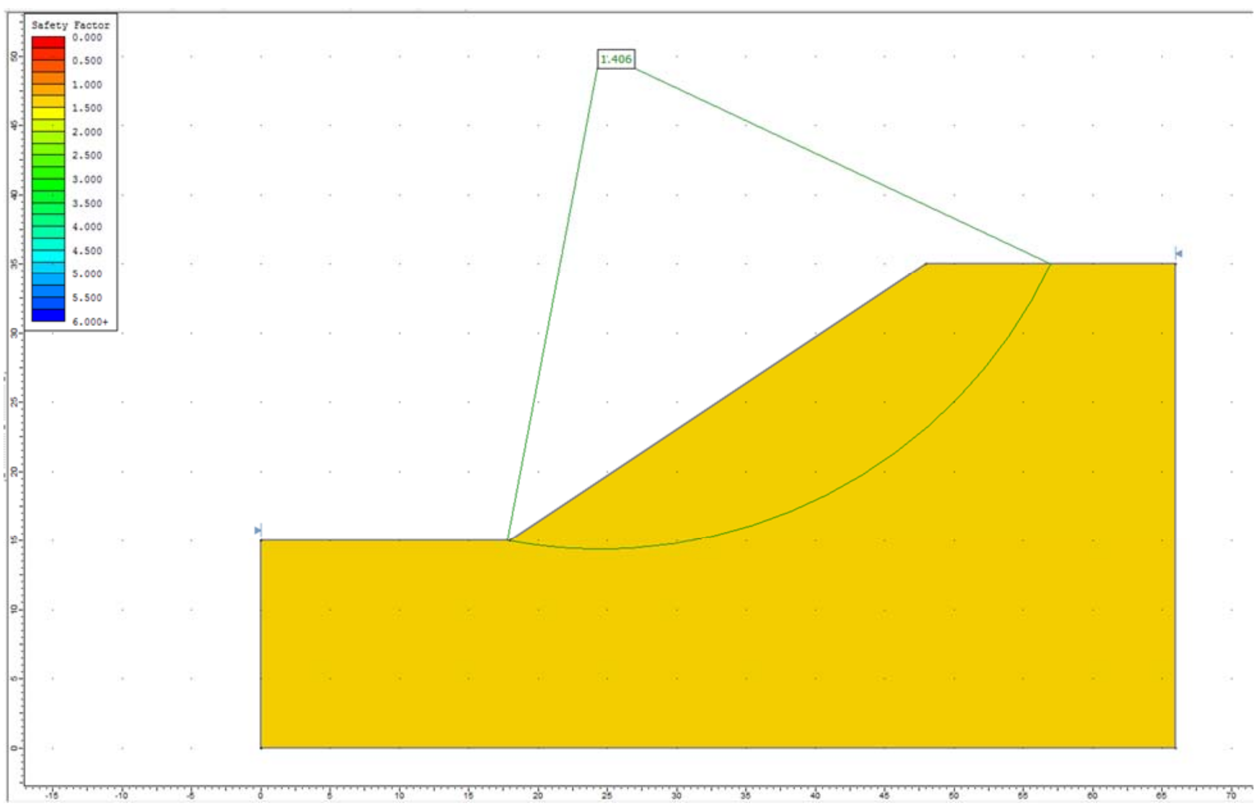


Figure 8.4.6 – Slide Solution Using the GLE Method

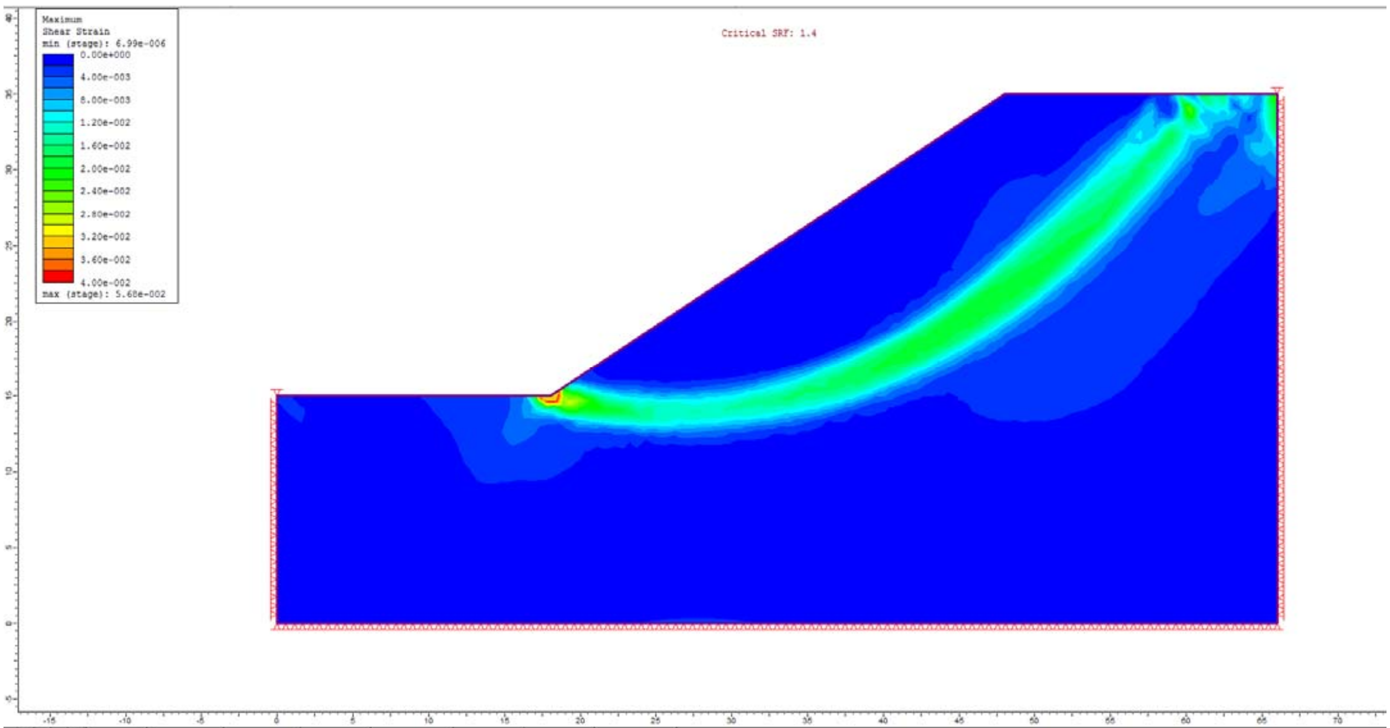


Figure 8.4.7 – RS2 Maximum Shear Strain

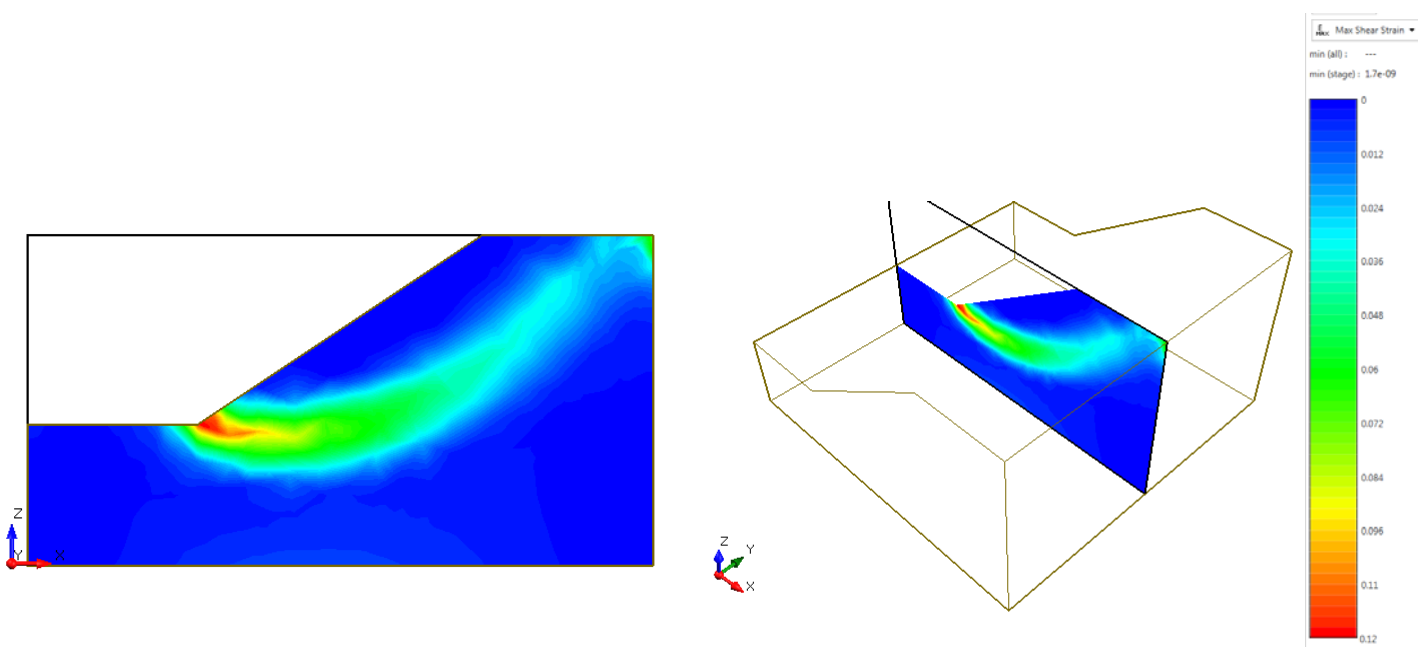


Figure 8.4.8 – RS3 Maximum Shear Strain

2D extruded, homogeneous, ellipsoidal with SA

9.1 Introduction

This model is a 3D extrusion of the model taken from Arai and Tagyo (1985) example#1 and consists of a simple slope of homogeneous soil with zero pore pressure.

9.2 Problem Description

The slope geometry in the XZ plane of 2D Extruded Verification #9 is shown in Figure 9.1. This geometry will be extruded 66m in the Y direction. The material properties are given in Table 9.1. The position of the critical slip surface and the corresponding factor of safety are calculated for an ellipsoidal slip surface. There are no pore pressures in this problem.

The slide models use Path search with Optimization, and the Slide3 models use a cuckoo search with Surface Optimization to find the ellipsoidal slip surface.

9.3 Geometry and Properties

Table 9.1: Material Properties

	c´ (kN/m^2)	φ´ (deg.)	γ (kN/m^3)
soil	41.65	15	18.82

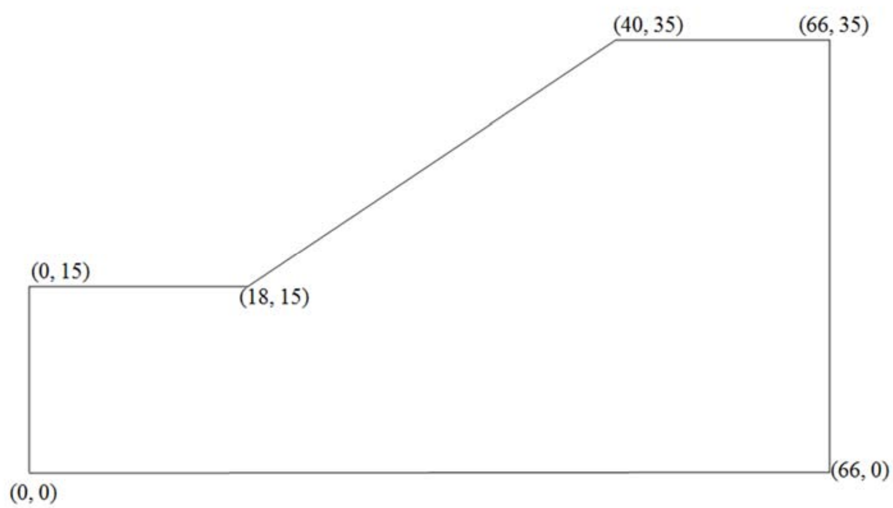


Figure 9

9.4 Results

Table 9.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Janbu	1.346	1.253		
Spencer	1.488	1.386	1.53	1.4
GLE	1.495	1.372		

Referee: 1.265, 1.37 [Arai and Tagyo, 1985]

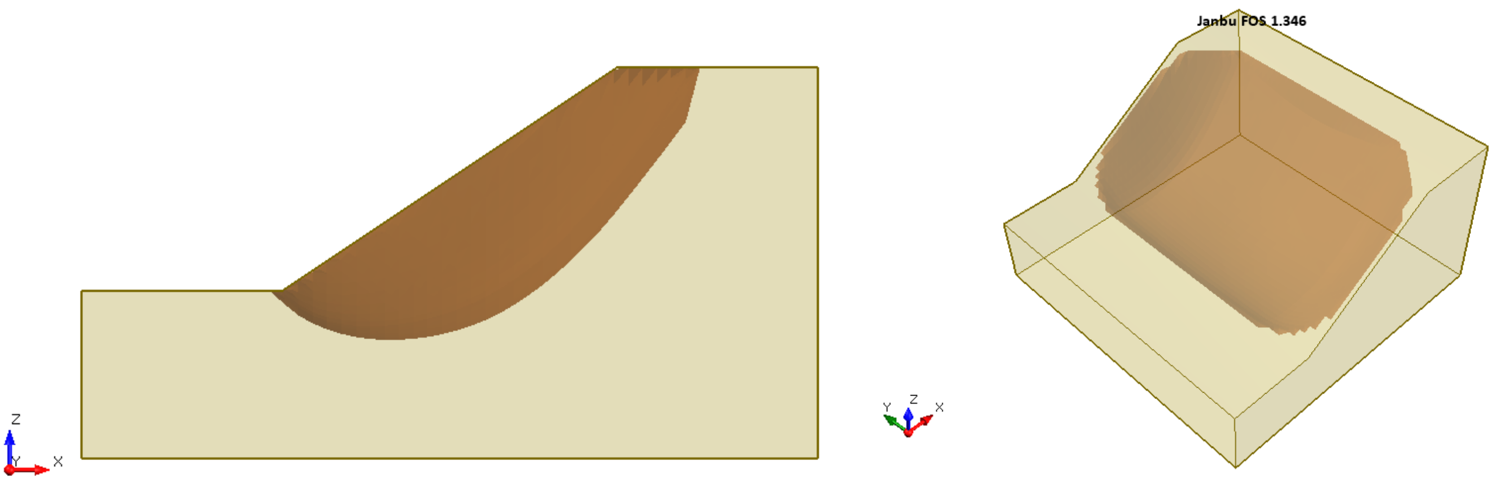


Figure 9.4.1 – Slide3 Solution Using the Janbu Method

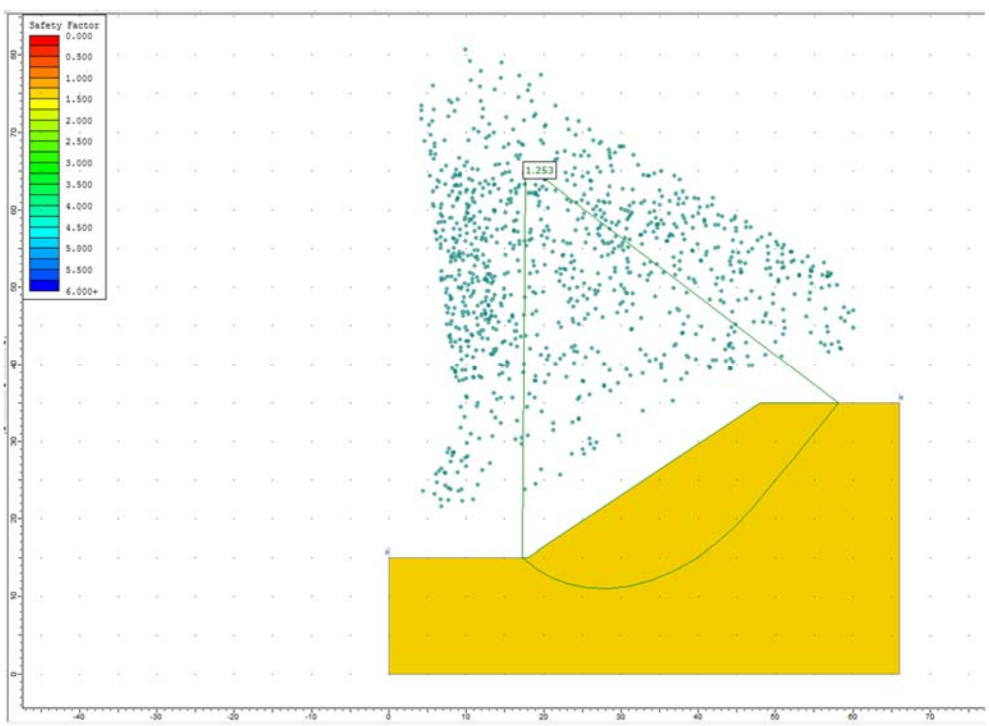


Figure 9.4.2 – Slide Solution Using the Janbu Method

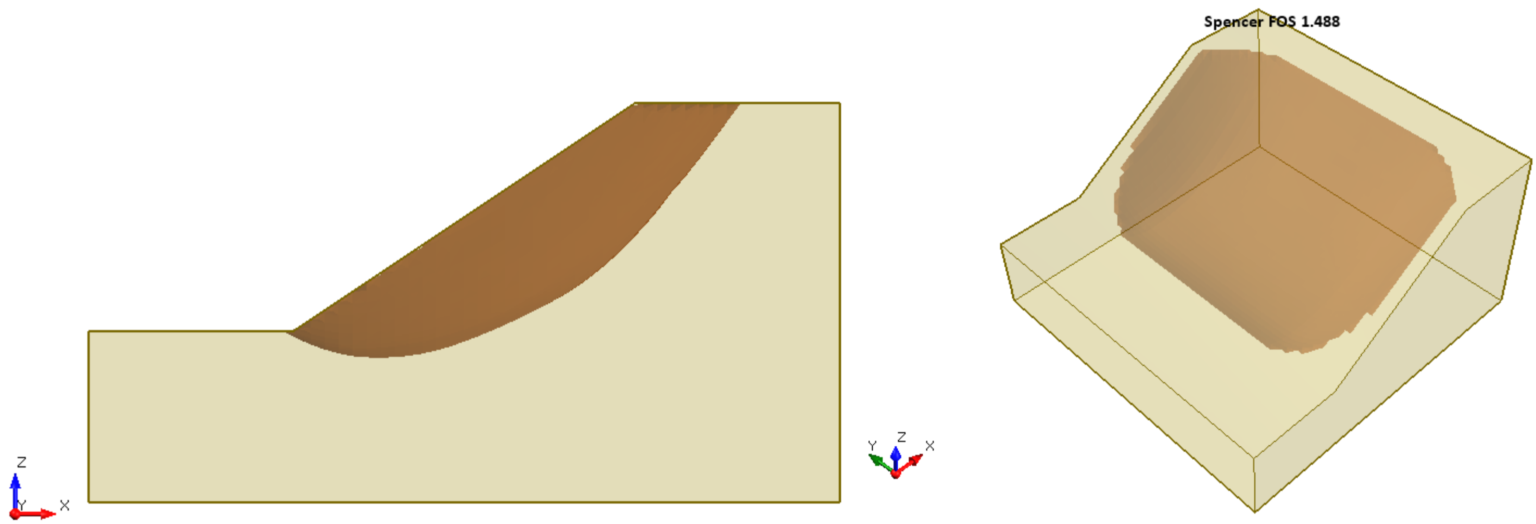


Figure 9.4.3 – Slide3 Solution Using the Spencer Method

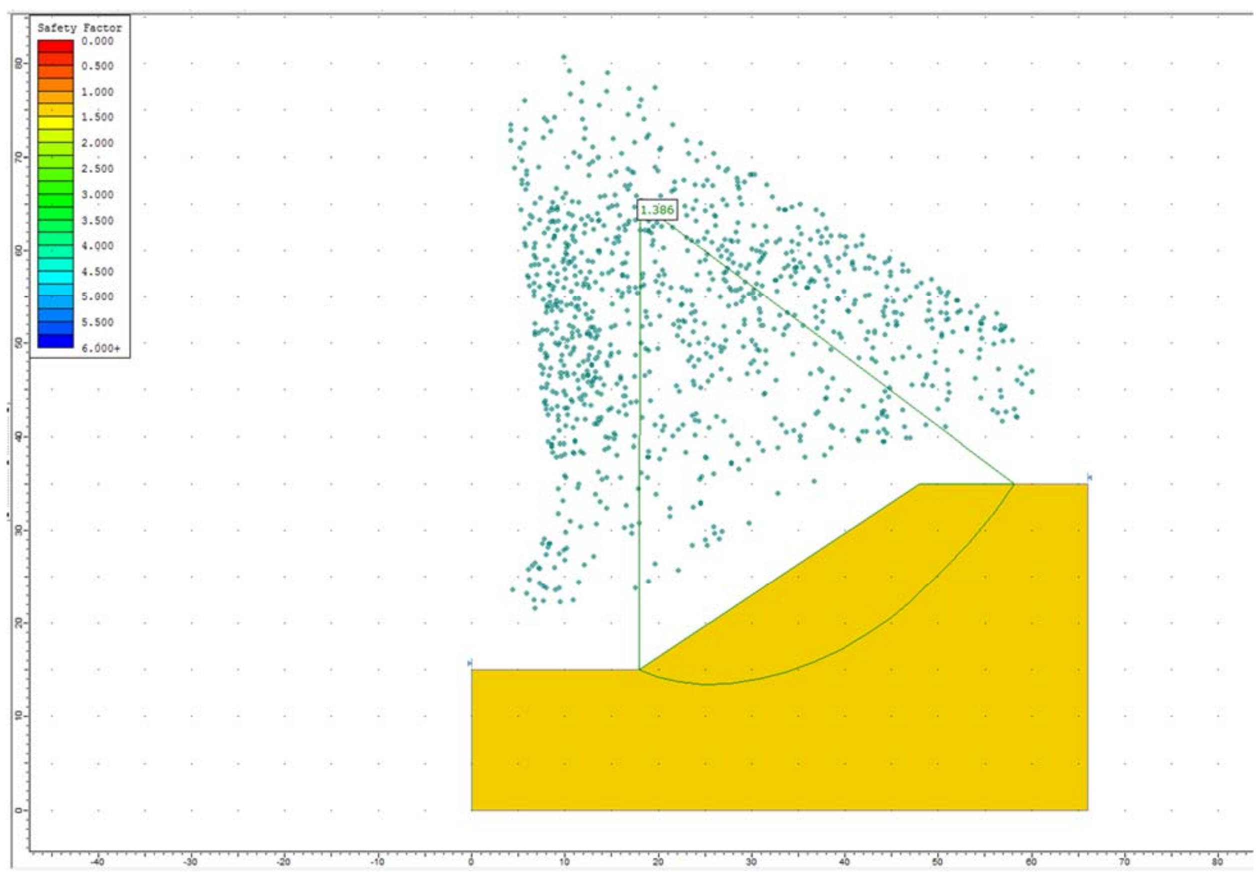


Figure 9.4.4 – Slide Solution Using the Spencer Method

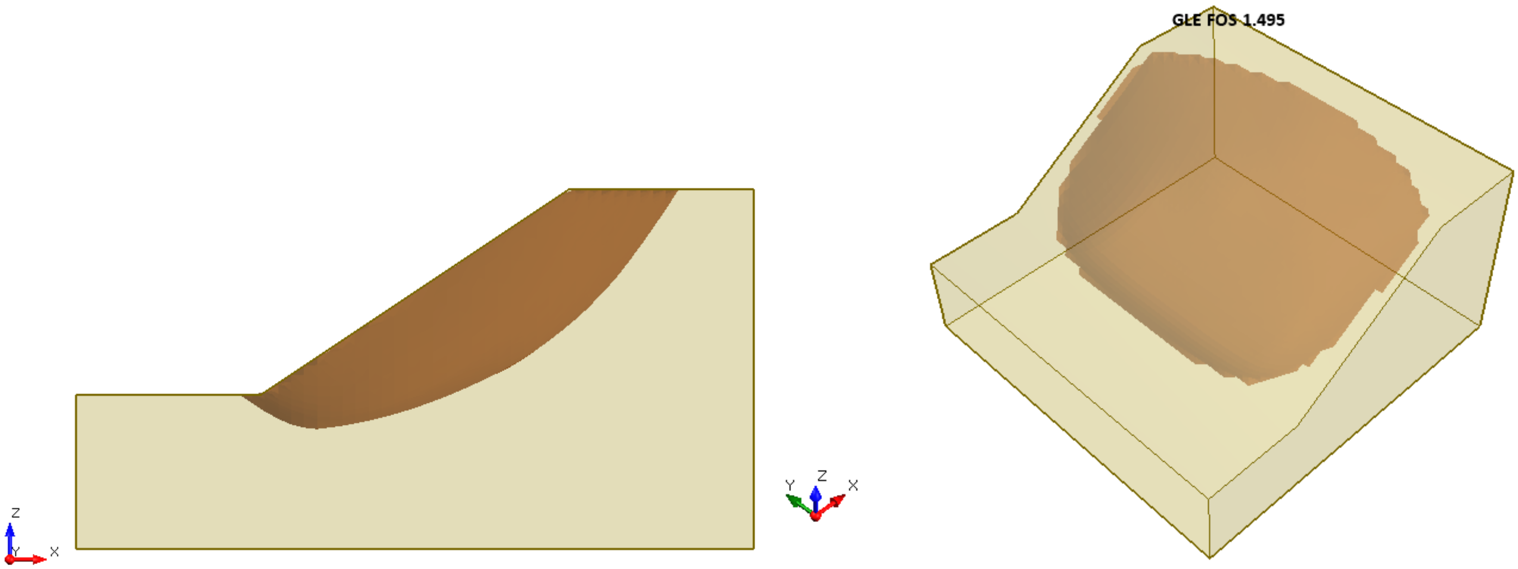


Figure 9.4.5 – Slide3 Solution Using the GLE Method

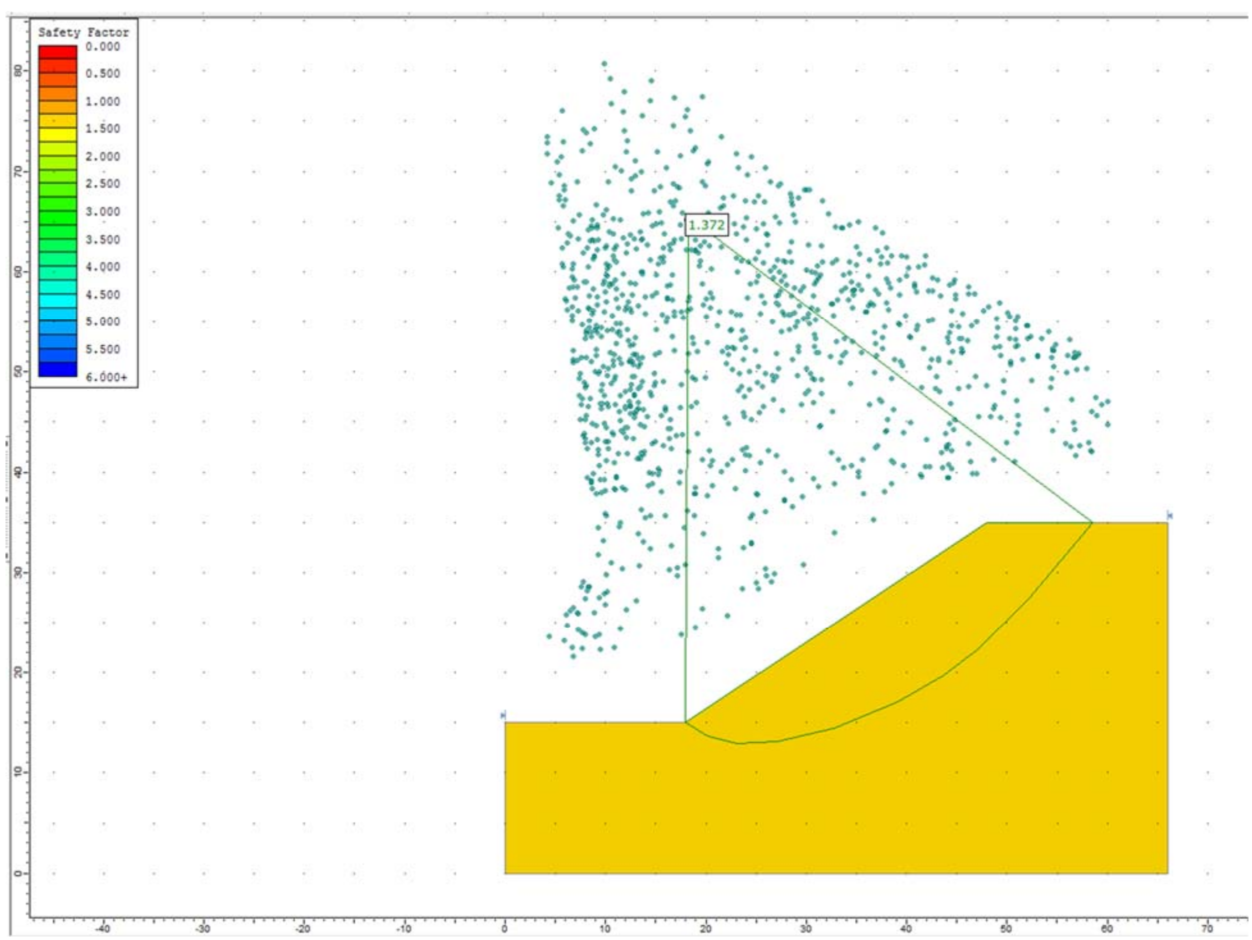


Figure 9.4.6 – Slide Solution Using the GLE Method

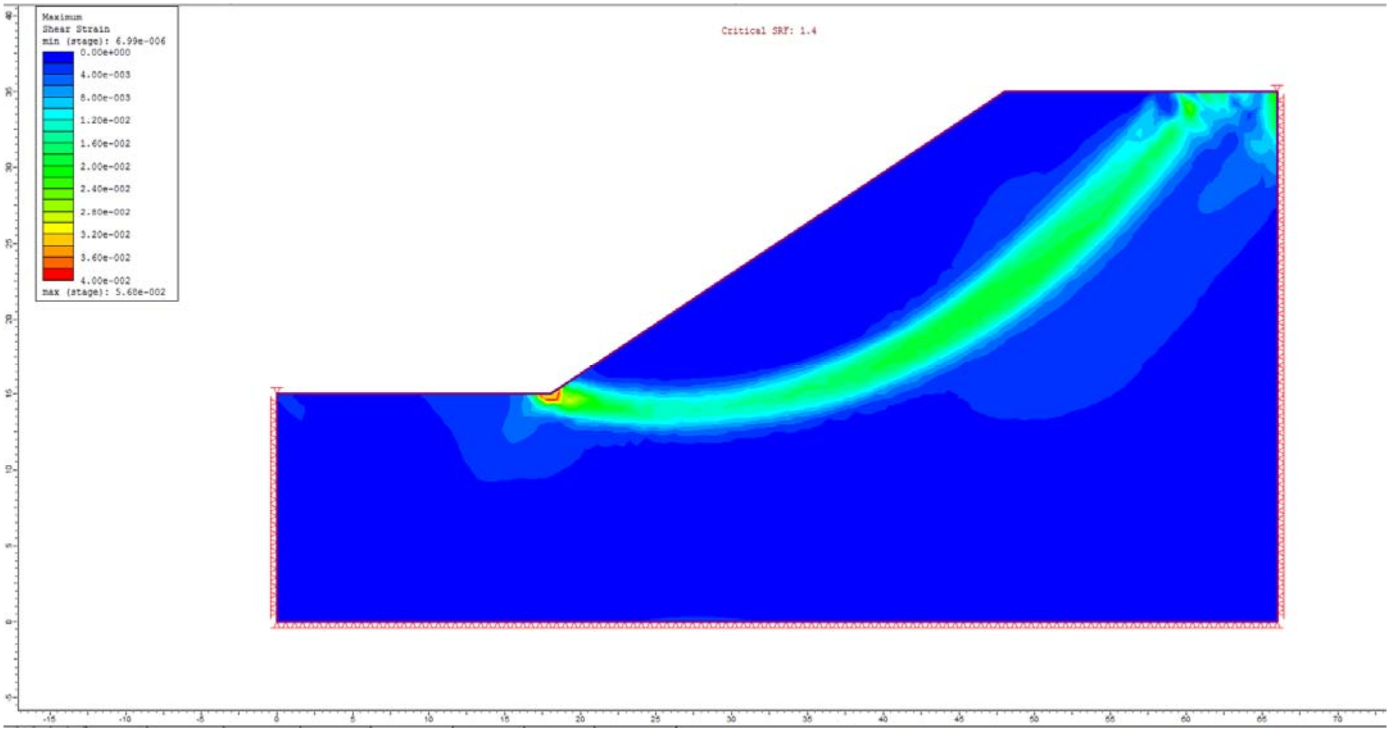


Figure 9.4.7 – RS2 Maximum Shear Strain

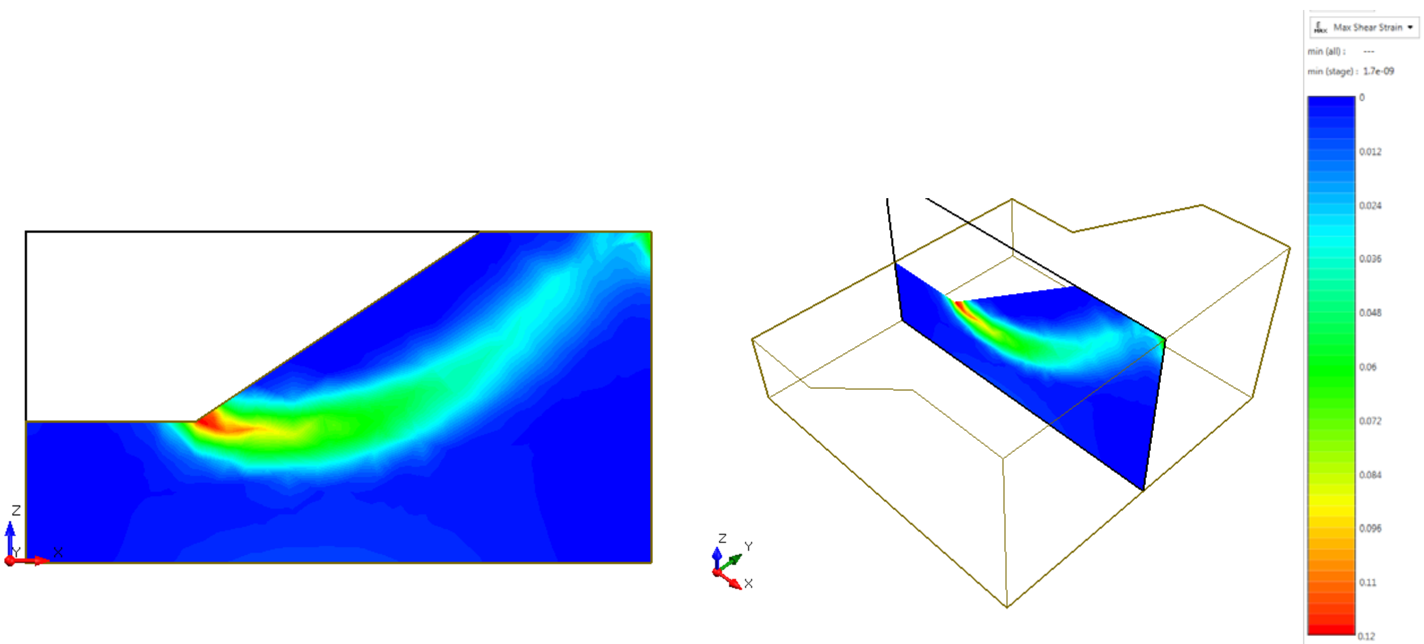


Figure 9.4.8 – RS3 Maximum Shear Strain

2D extruded, (3) materials, spherical

10.1 Introduction

This model a 3D extrusion of the model taken from Arai and Tagyo (1985) example #2 and consists of a layered slope where a layer of low resistance is interposed between two layers of higher strength. A number of other authors have also analyzed this problem, notably Kim et al. (2002), Malkawi et al. (2001), and Greco (1996).

10.2 Problem Description

The 2D slope geometry in the XZ plane of 2D Extruded Verification #10 is shown in Figure 10.1. This 2D model with be extruded 96m in the Y direction. The material properties are given in Table 10.1. The position of the critical slip surface and the corresponding factor of safety are calculated for a spherical slip surface. There are no pore pressures in this problem.

This problem uses the auto refine search to find the spherical slip surface.

10.3 Geometry and Properties

Table 10.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Upper Layer	29.4	12	18.82
Middle Layer	9.8	5	18.82
Lower Layer (infinite strength for Slide 7.0 and Slide3)	10000	65	18.82

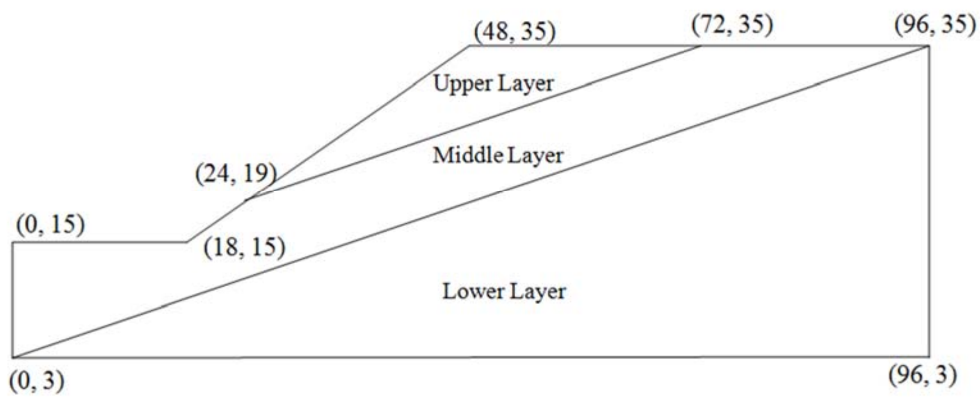


Figure 10

10.4 Results

Table 10.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

<table>
<tr><th>Method</th><th>Slide3</th><th>Slide 7.0</th><th>RS3</th><th>RS2</th></tr>
<tr><td>Bishop</td><td>0.501</td><td>0.420</td><td rowspan="3">0.44</td><td rowspan="3">0.41</td></tr>
<tr><td>Spencer</td><td>0.508</td><td>0.423</td></tr>
<tr><td>GLE</td><td>0.495</td><td>0.420</td></tr>
</table>

Referee: 0.417 [Arai and Taygo, 1985], 0.43 [Kim et al., 2002]

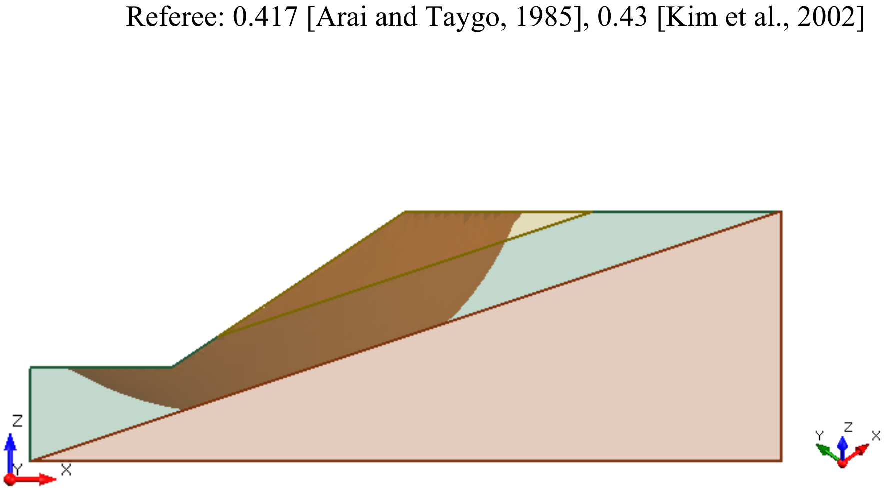


Figure 10.4.1 – Slide3 Solution Using the Bishop Method

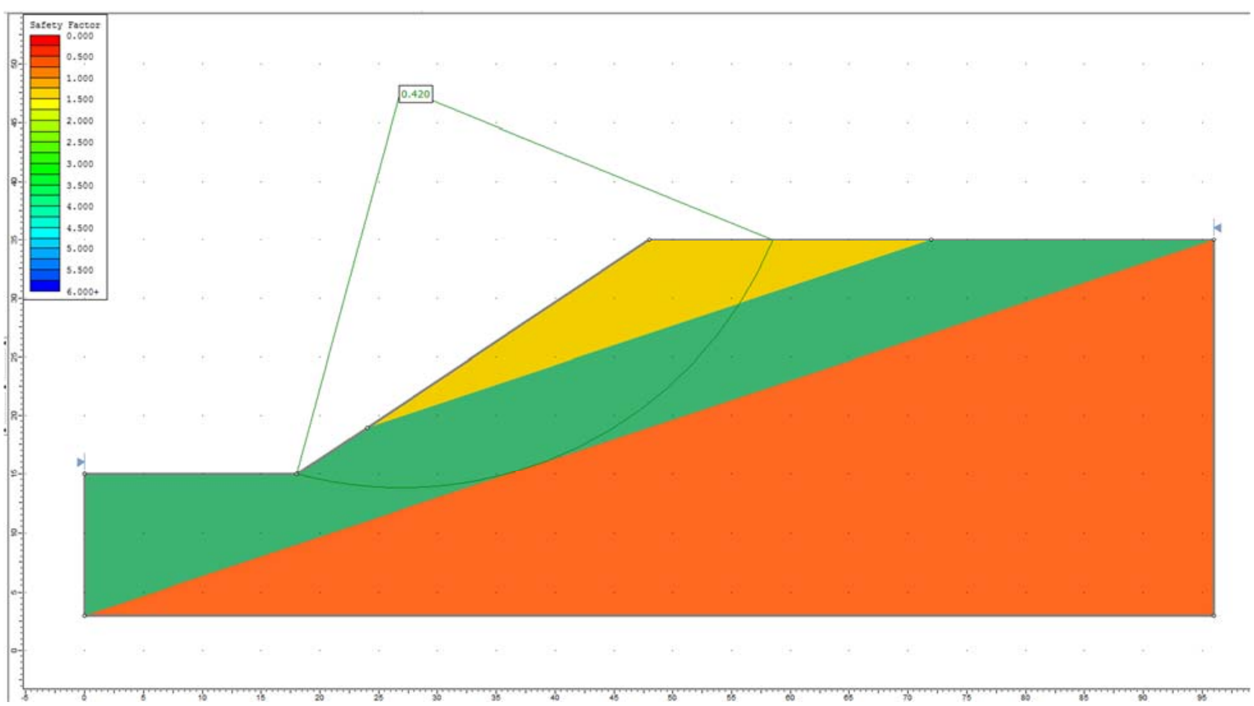


Figure 10.4.2 – Slide Solution Using the Bishop Method

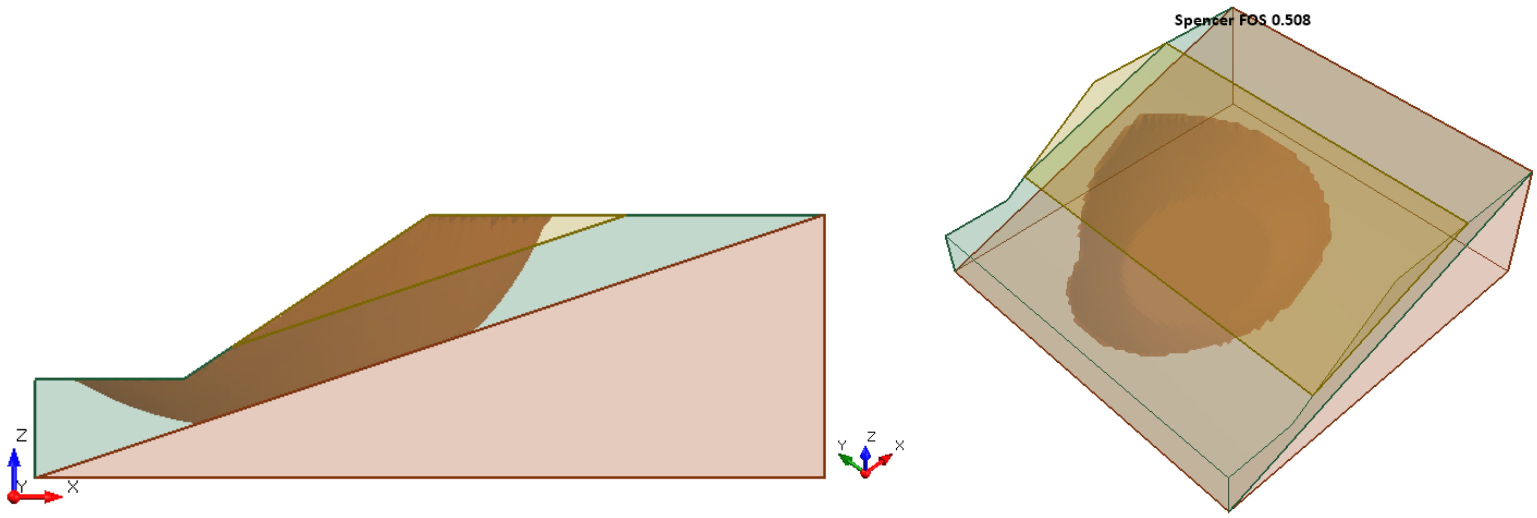


Figure 10.4.3 – Slide3 Solution Using the Spencer Method

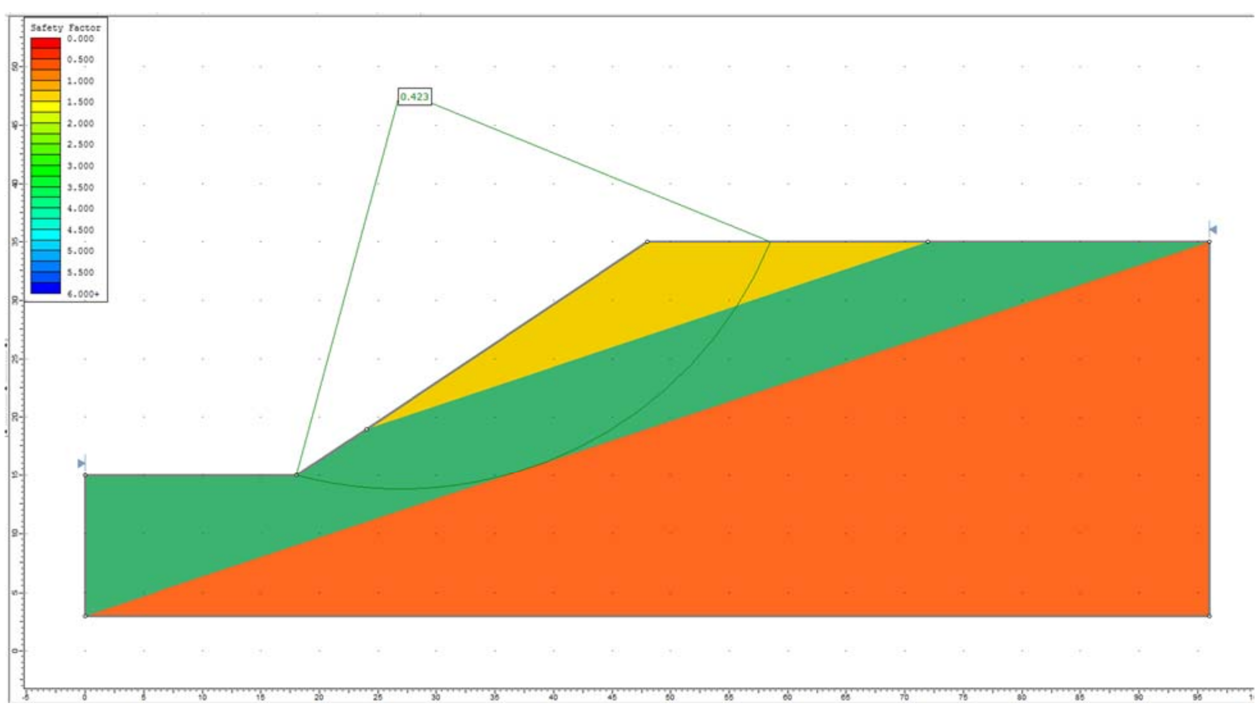


Figure 10.4.4 – Slide Solution Using the Spencer Method

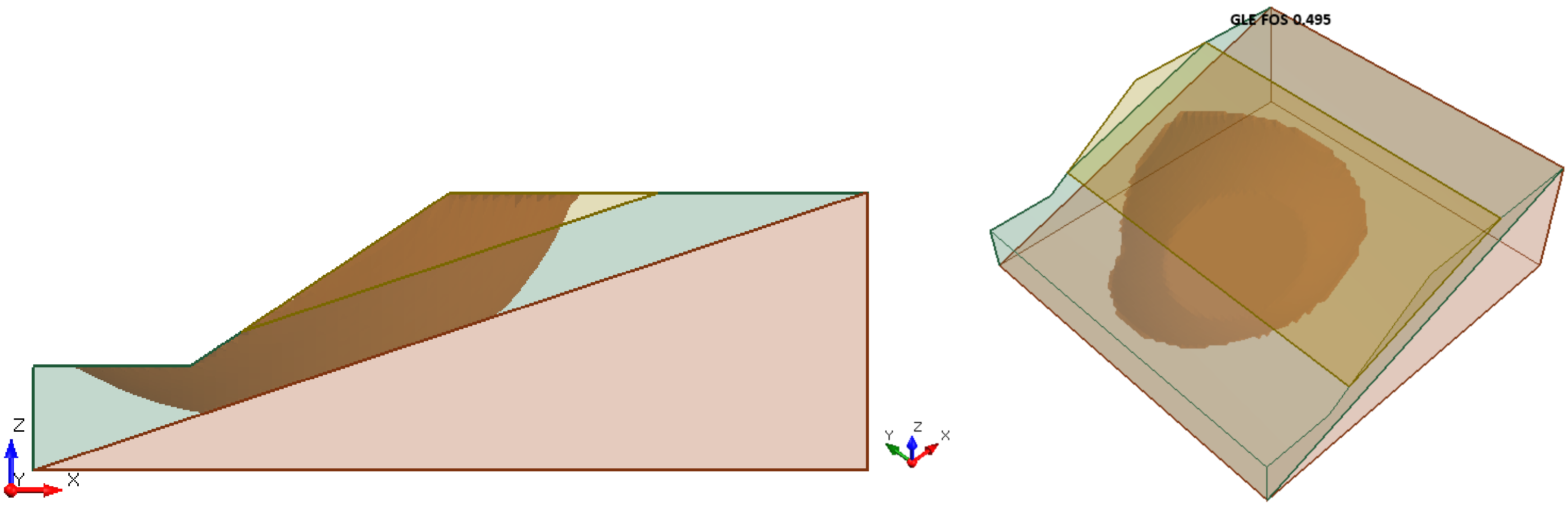


Figure 10.4.5 – Slide3 Solution Using the GLE Method

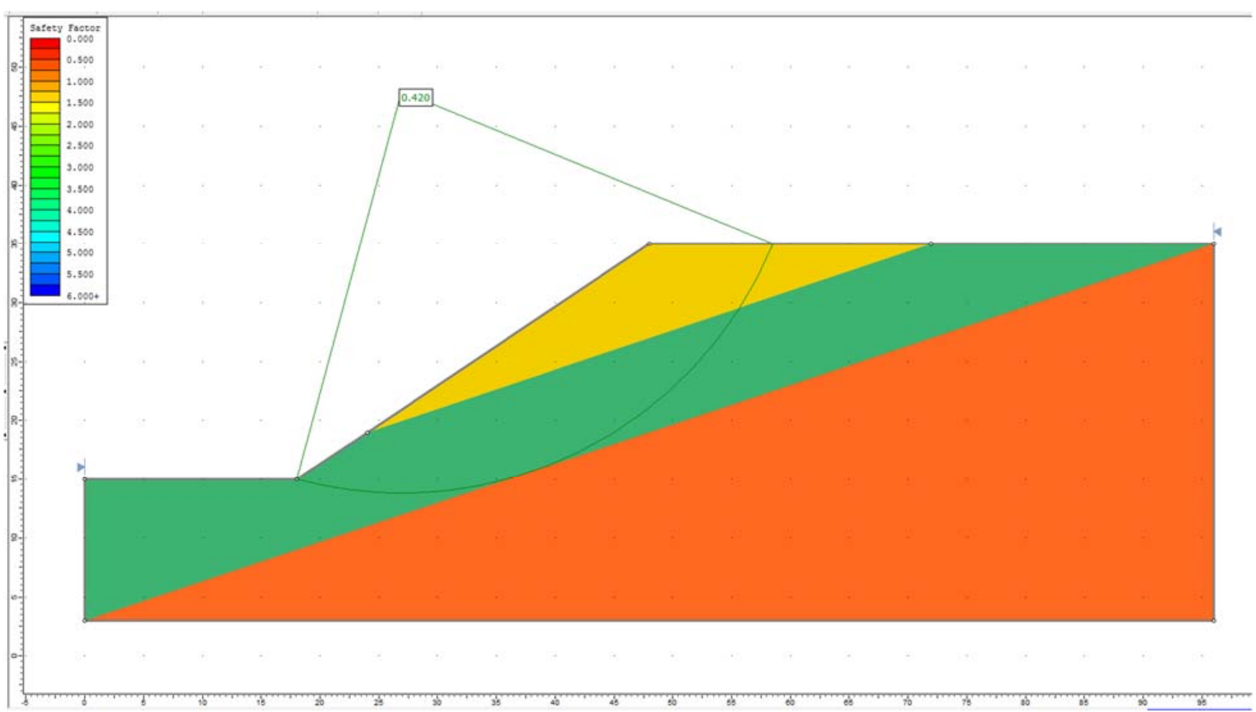


Figure 10.4.6 – Slide Solution Using the GLE Method

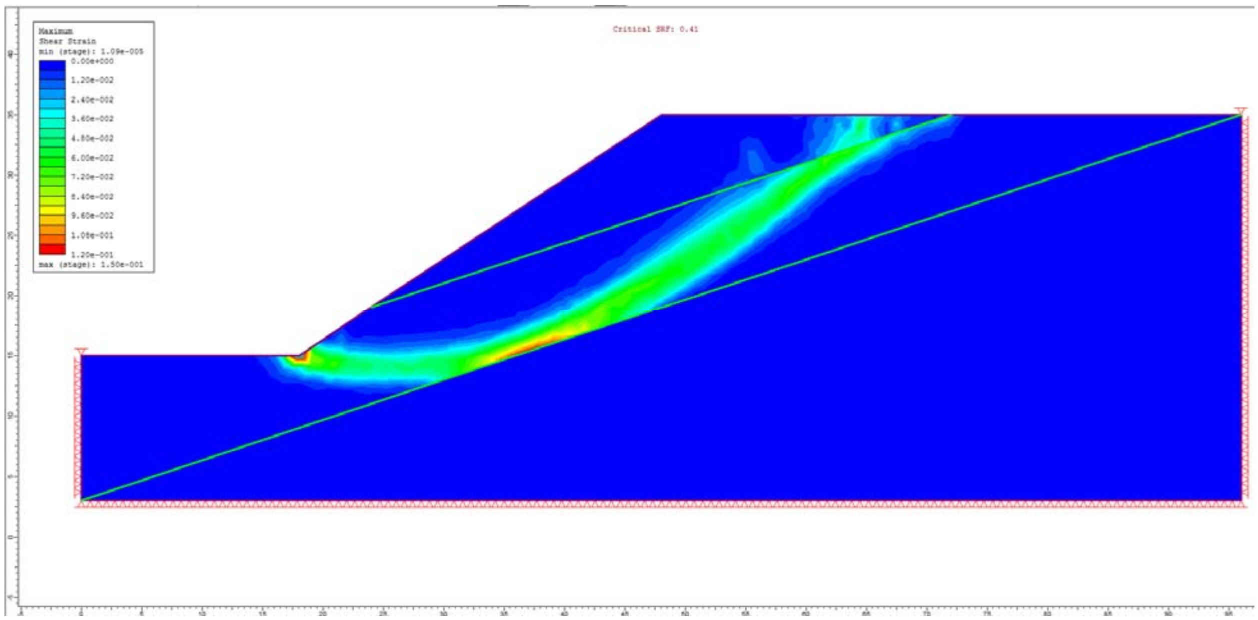


Figure 10.7 – RS2 Maximum Shear Strain

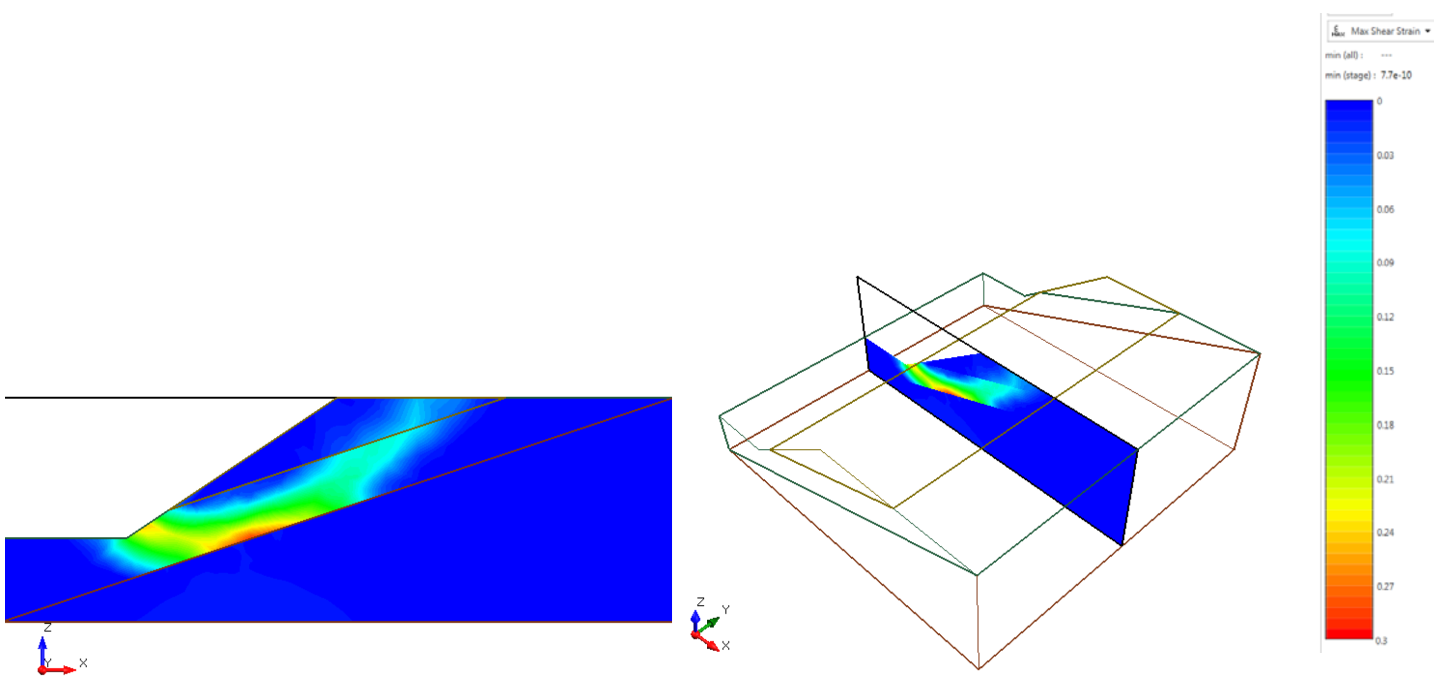


Figure 10.4.8 – RS3 Maximum Shear Strain

2D extruded, (3) materials, ellipsoidal with SA

11.1 Introduction

This model a 3D extrusion of the model taken from Arai and Tagyo (1985) example#2 and consists of a layered slope where a layer of low resistance is interposed between two layers of higher strength. A number of other authors have also analyzed this problem, notably Kim et al. (2002), Malkawi et al. (2001), and Greco (1996).

11.2 Problem Description

The 2D slope geometry in the XZ plane of 2D Extruded Verification #11 is shown in Figure 11.1. This 2D model with be extruded 96m in the Y direction. The material properties are given in Table 11.1. The position of the critical slip surface and the corresponding factor of safety are calculated for an ellipsoidal slip surface. There are no pore pressures in this problem.

The slide models use Random search (1000 surfaces) with Optimization, and the Slide3 models use a cuckoo search with Surface Optimization to find the ellipsoidal slip surface.

11.3 Geometry and Properties

Table 11.1: Material Properties

	c´ (kN/m^2)	φ´ (deg.)	γ (kN/m^3)
Upper Layer	29.4	12	18.82
Middle Layer	9.8	5	18.82
Lower Layer (infinite strength for Slide 7.0 and Slide3)	10000	65	18.82

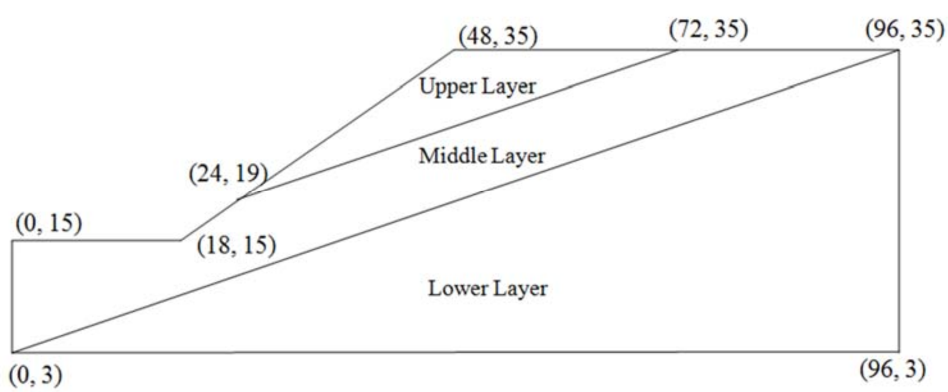


Figure 11

11.4 Results

Table 11.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Janbu	0.341	0.395		
Spencer	0.42	0.412	0.44	0.41
GLE	0.42	0.408		

Referee: 0.39 [Greco, 1996], 0.44, 0.39 [Kim et al., 2002], 0.405, 0.430 [Arai and Taygo, 1985]

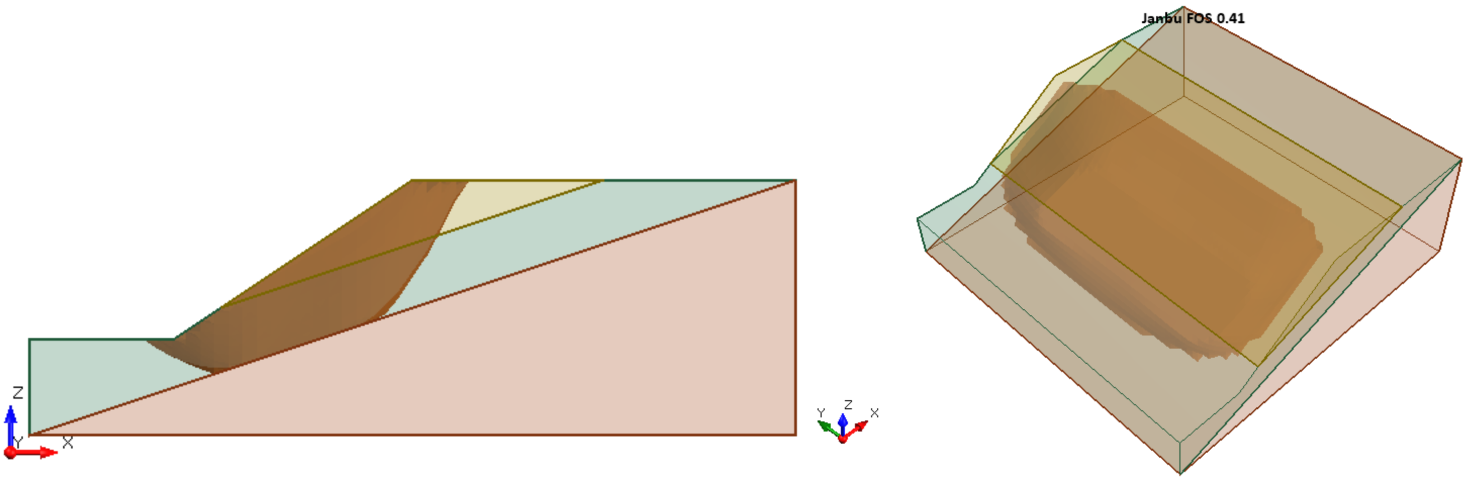


Figure 11.4.1 – Slide3 Solution Using the Janbu Method

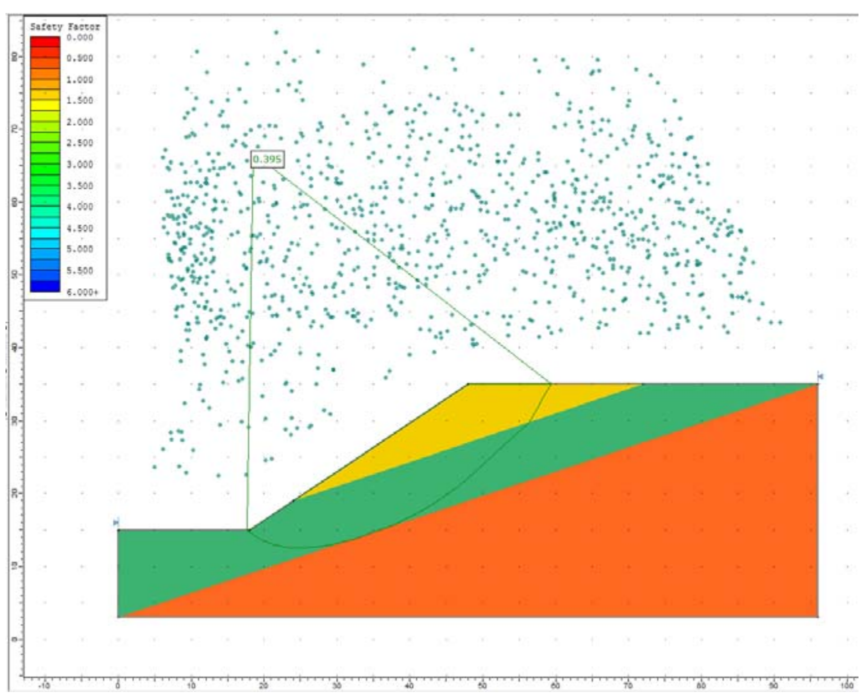


Figure 11.4.2 – Slide Solution Using the Janbu Method

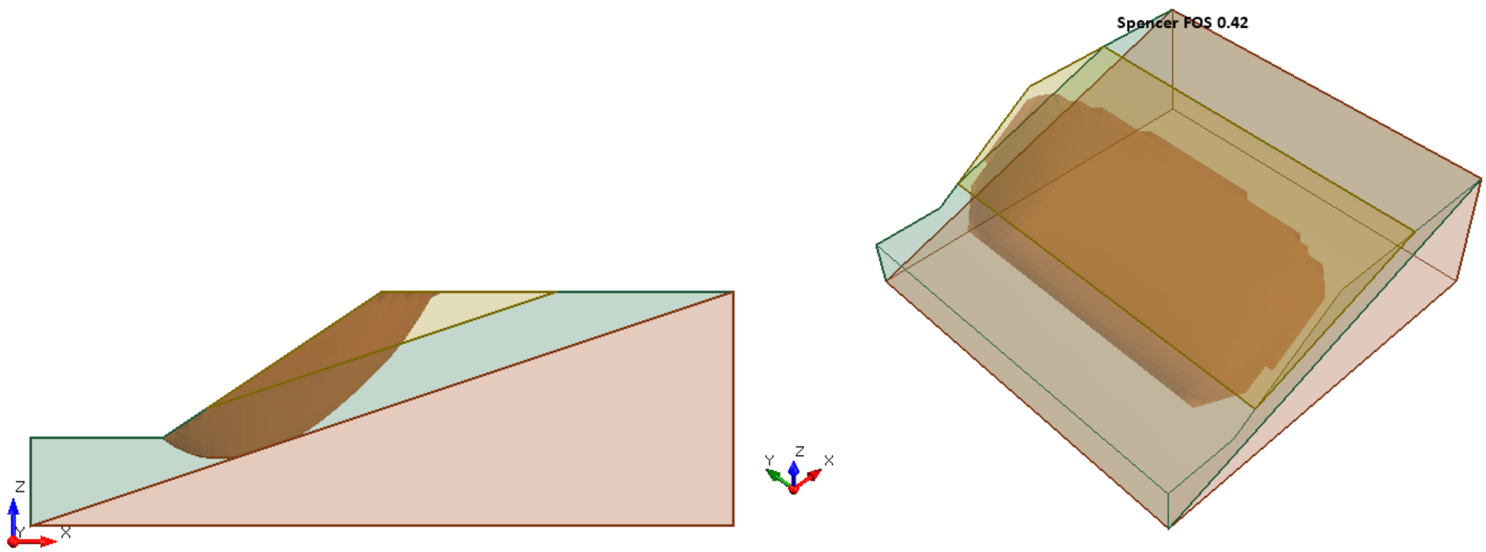


Figure 11.4.3 – Slide3 Solution Using the Spencer Method

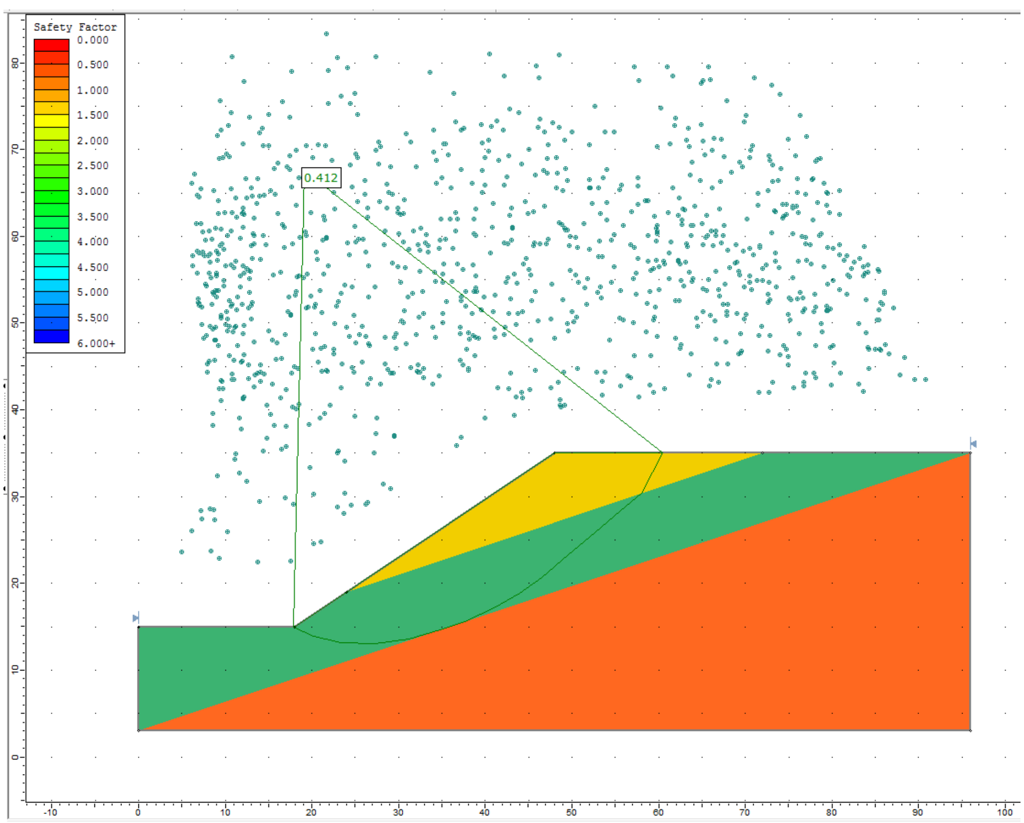


Figure 11.4.4 – Slide Solution Using the Spencer Method

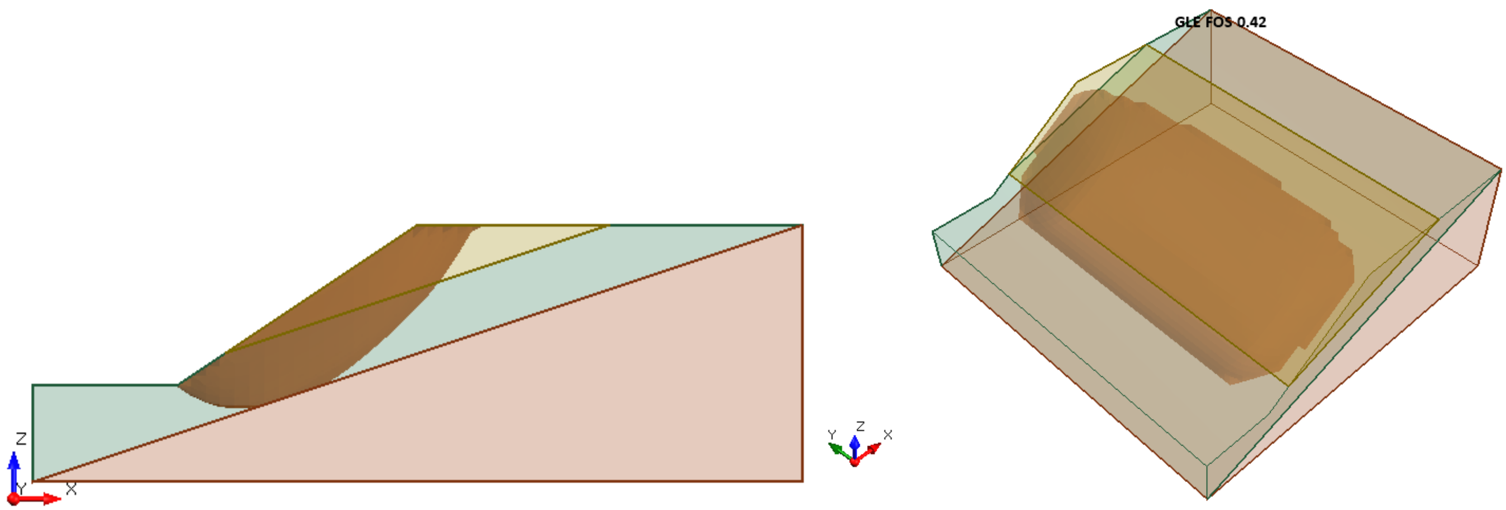


Figure 11.4.5 – Slide3 Solution Using the GLE Method

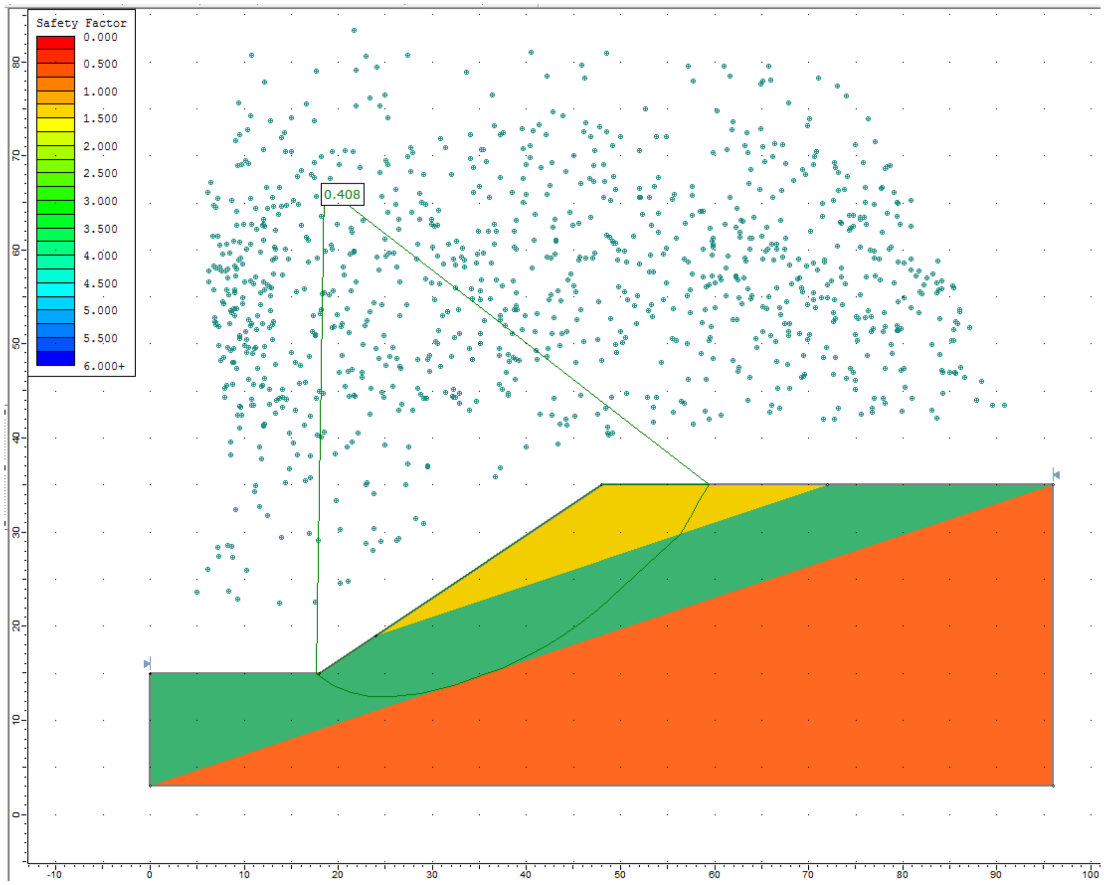


Figure 11.4.6 – Slide Solution Using the GLE Method

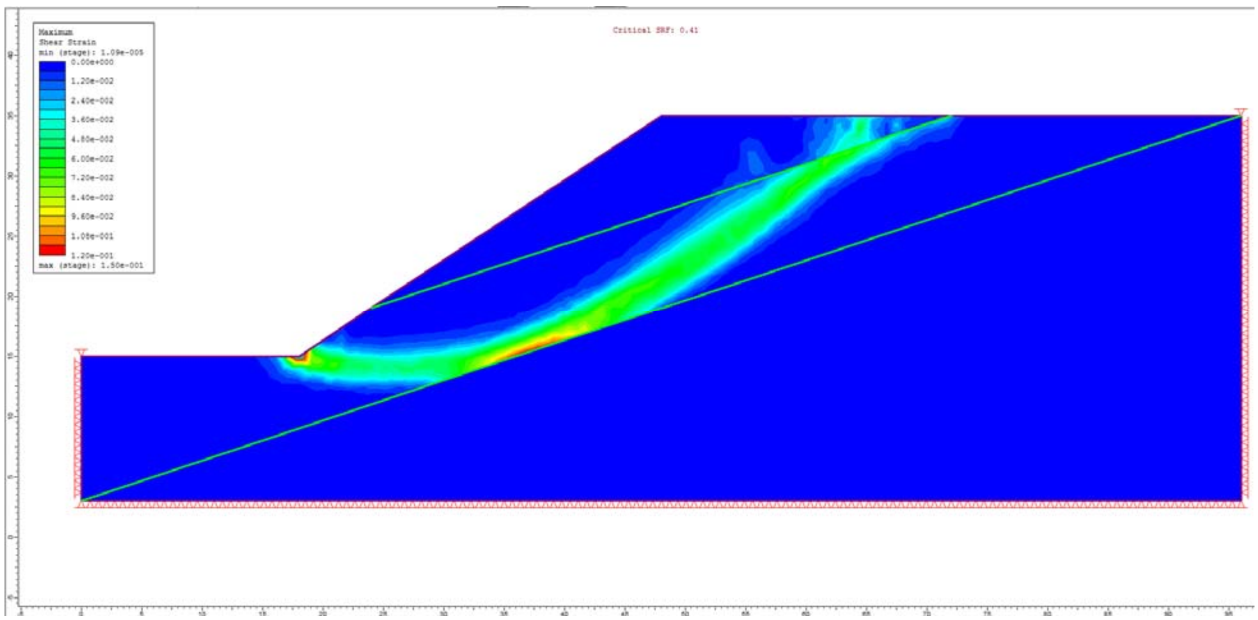


Figure 11.7 – RS2 Maximum Shear Strain

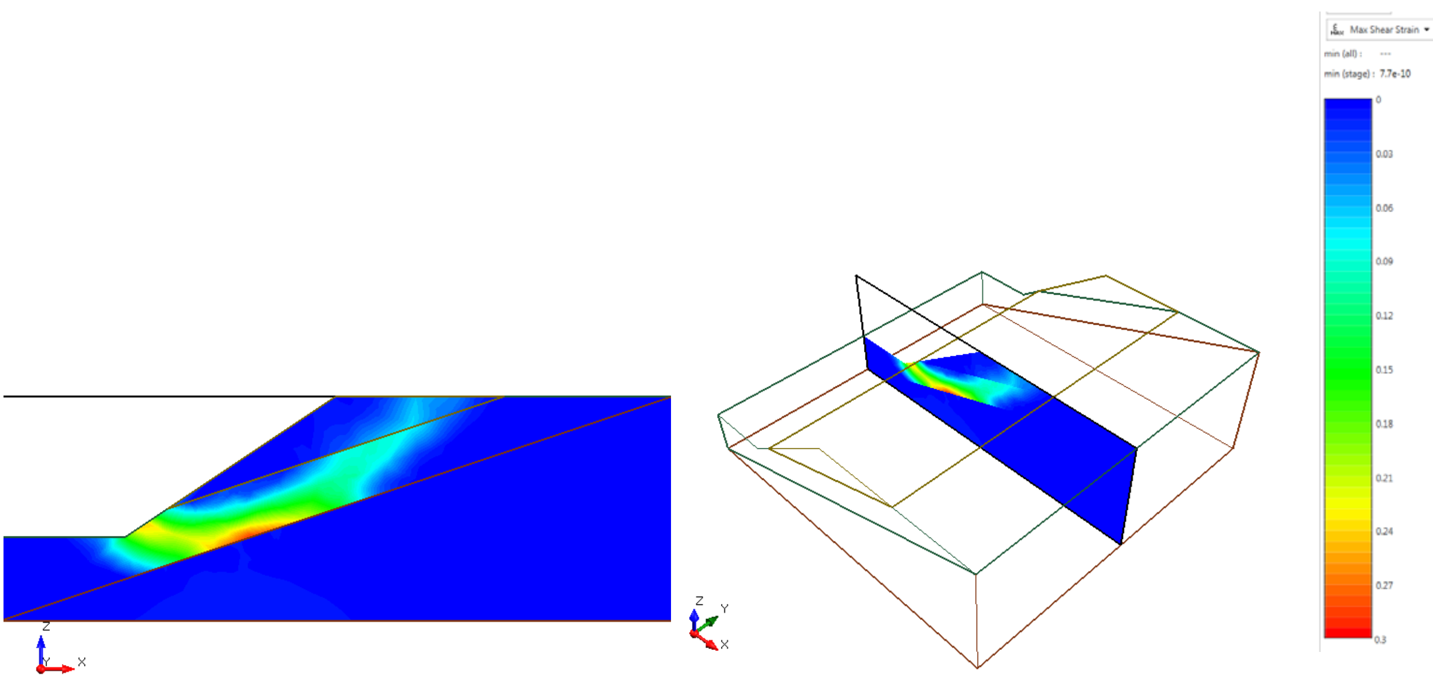


Figure 11.4.8 – RS3 Maximum Shear Strain

2D extruded embankment, homogeneous, empty reservoir, ellipsoidal

12.1 Introduction

This model is taken from Gharti et al. (2011). It is an analysis of a 3D Embankment and reservoir by Gharti et al. using a spectral-element method, but originally analyzed in 2D by Griffiths and Lane (1999).

12.2 Problem Description

This is a 3D embankment whose 2D geometry in the XZ plane is shown in Figure 12. This geometry will be extruded 200m in the Y direction. Material properties are shown in Table 12.1. The embankment is analyzed in two ways: with an empty reservoir and a full reservoir. This example is the empty reservoir. When the reservoir is empty the pore water pressure is 0. The ellipsoidal slip surface and corresponding safety factor is required.

12.3 Geometry and Properties

Table 12.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Embankment	13.8	37	18.2

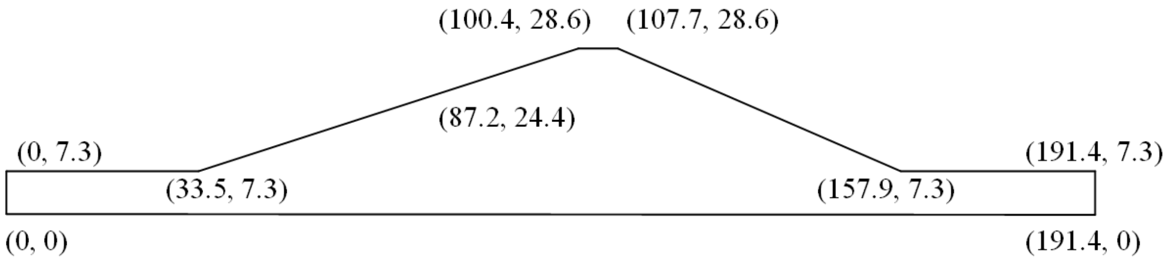


Figure 12

12.4 Results

Table 12.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	2.389	2.418	2.71	2.43
GLE	2.458	2.405		
Janbu	2.345	2.300		
Spencer	2.469	2.424		

Referee: 2.54 [Gharti et al., 2011]

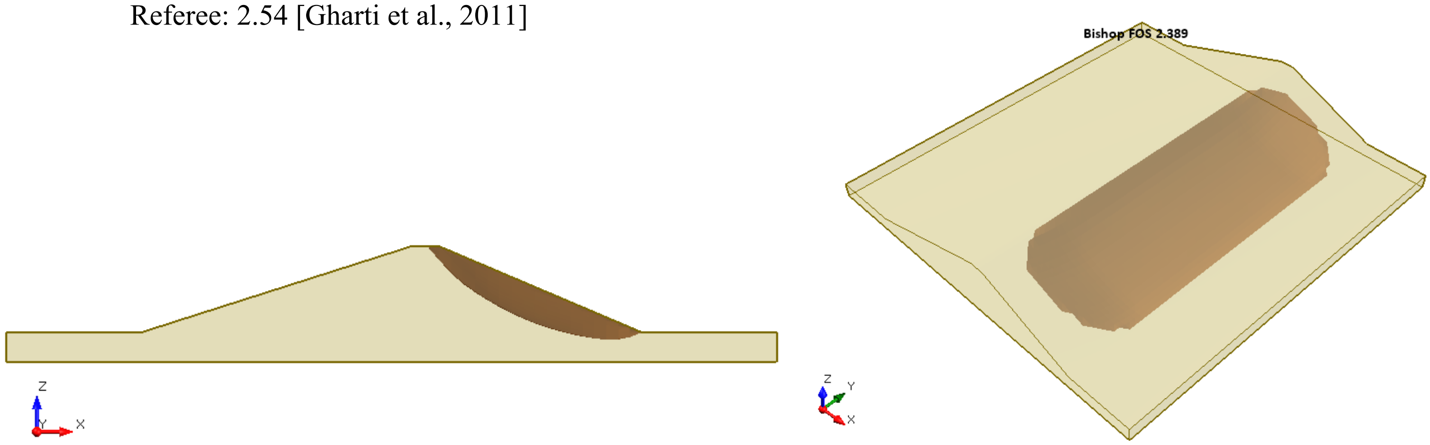


Figure 12.4.1 – Slide3 Solution Using the Bishop Method

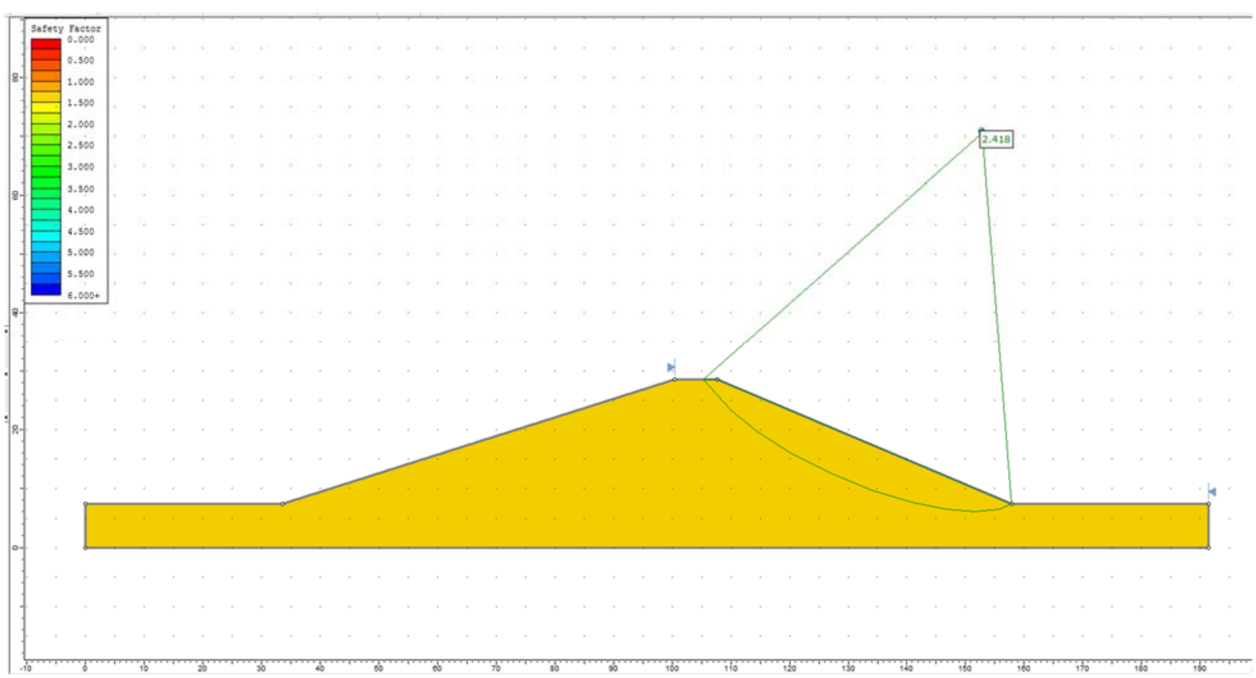


Figure 12.4.2 – Slide Solution Using the Bishop Method

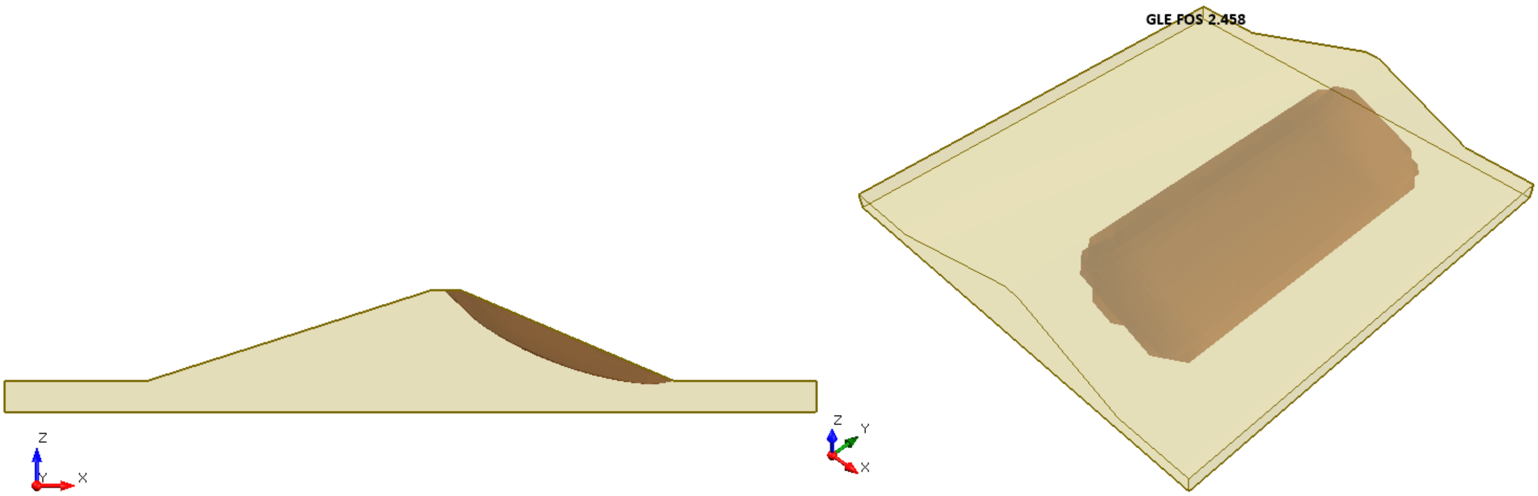


Figure 12.4.3 – Slide3 Solution Using the GLE Method

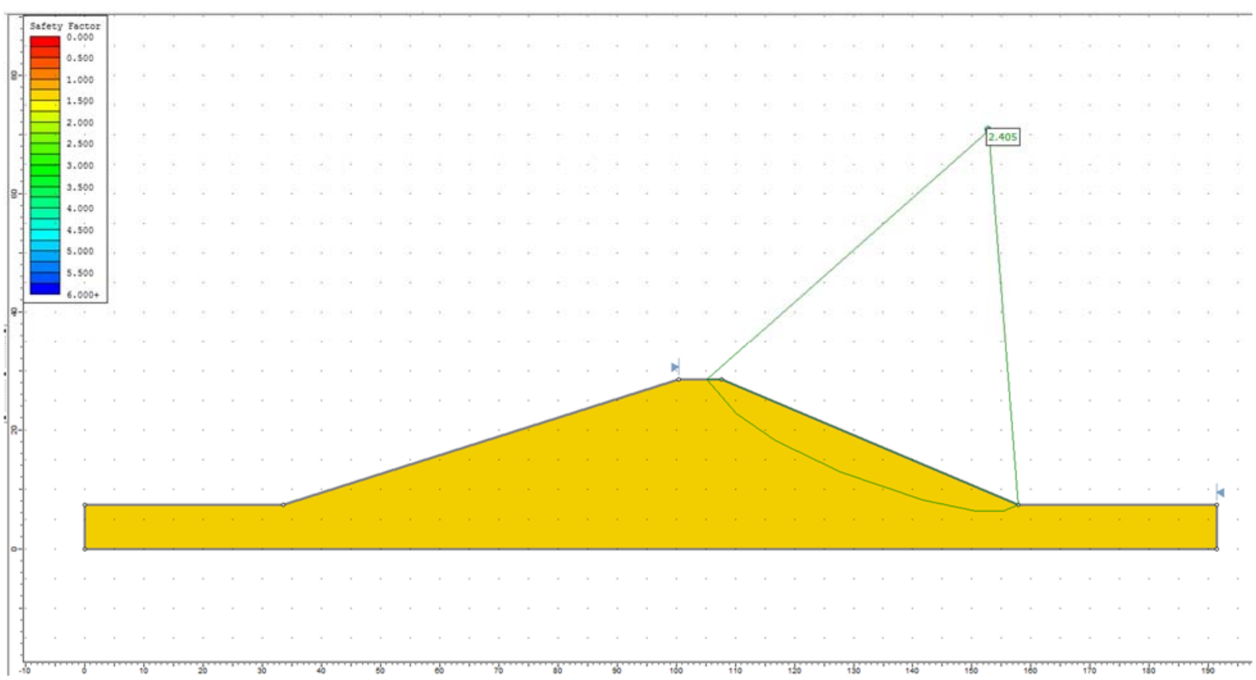


Figure 12.4.4 – Slide Solution Using the GLE Method

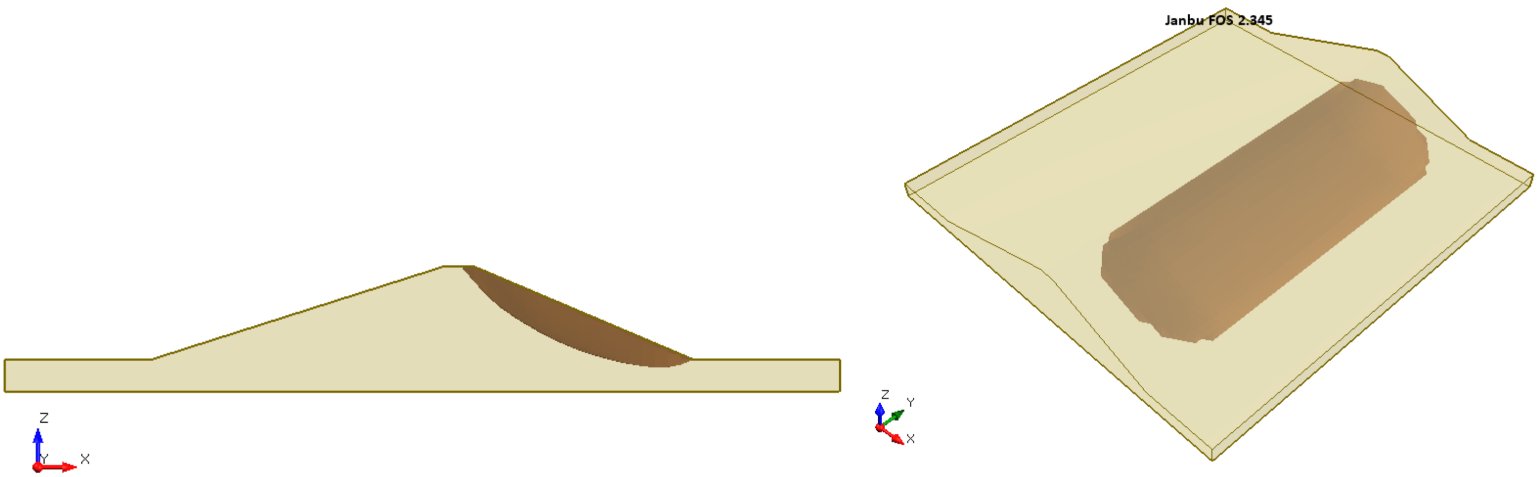


Figure 12.4.5 – Slide3 Solution Using the Janbu Method

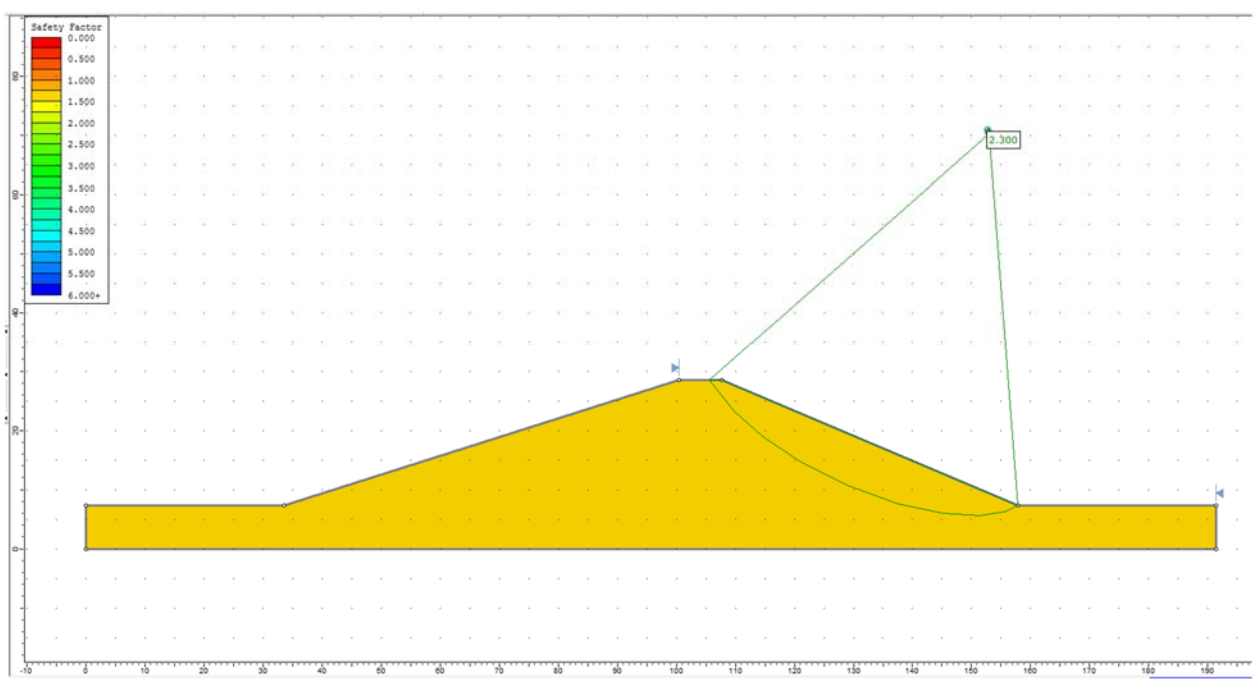


Figure 12.4.6 – Slide Solution Using the Janbu Method

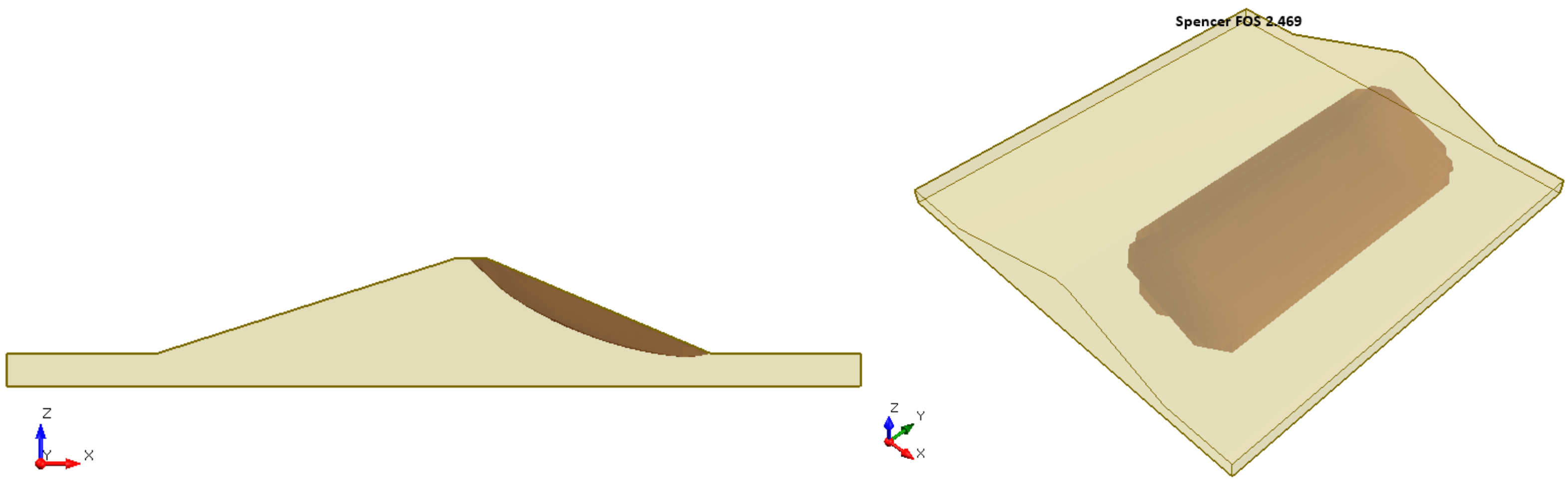


Figure 12.4.7 – Slide3 Solution Using the Spencer Method

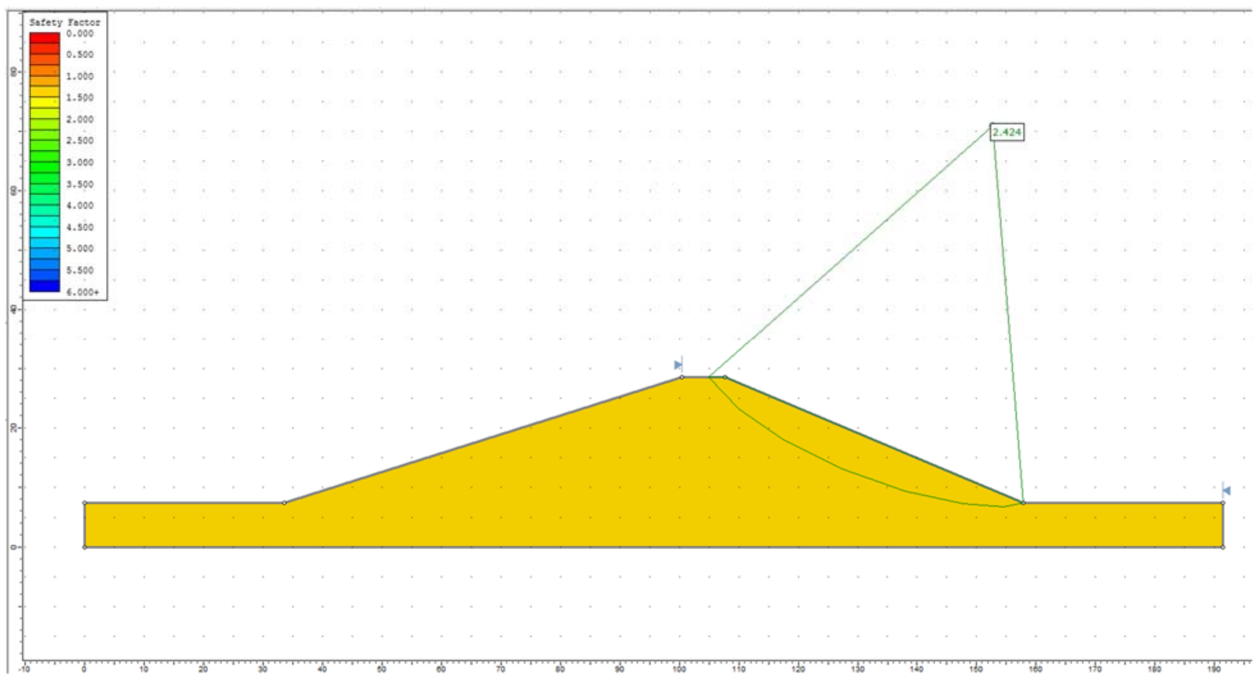


Figure 12.4.8 – Slide Solution Using the Spencer Method

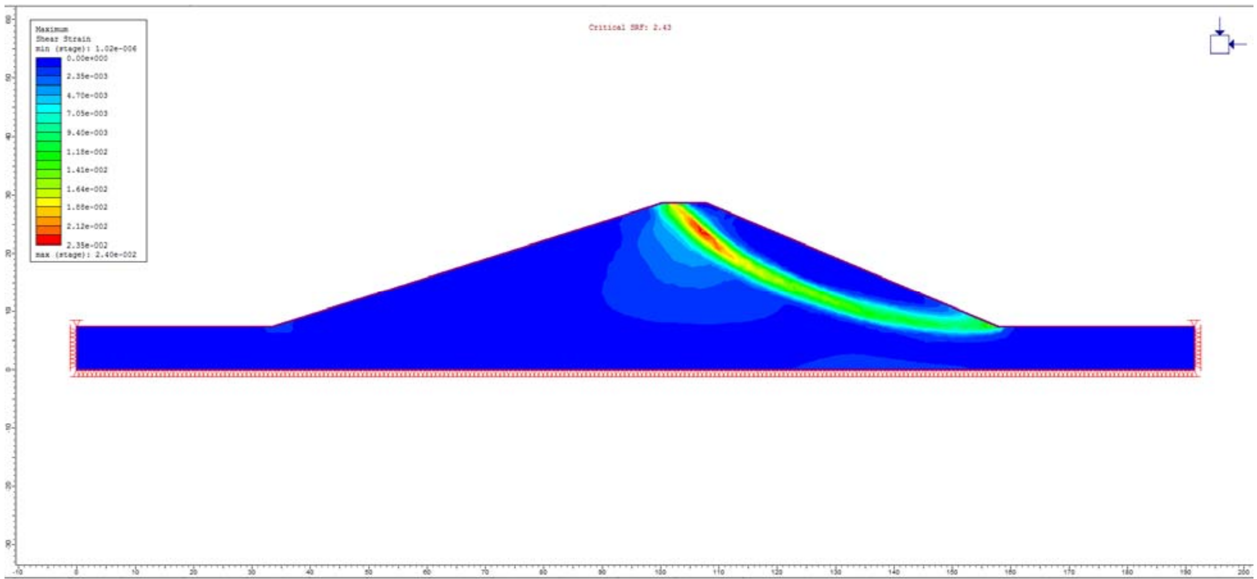


Figure 12.4.9 – RS2 Maximum Shear Strain

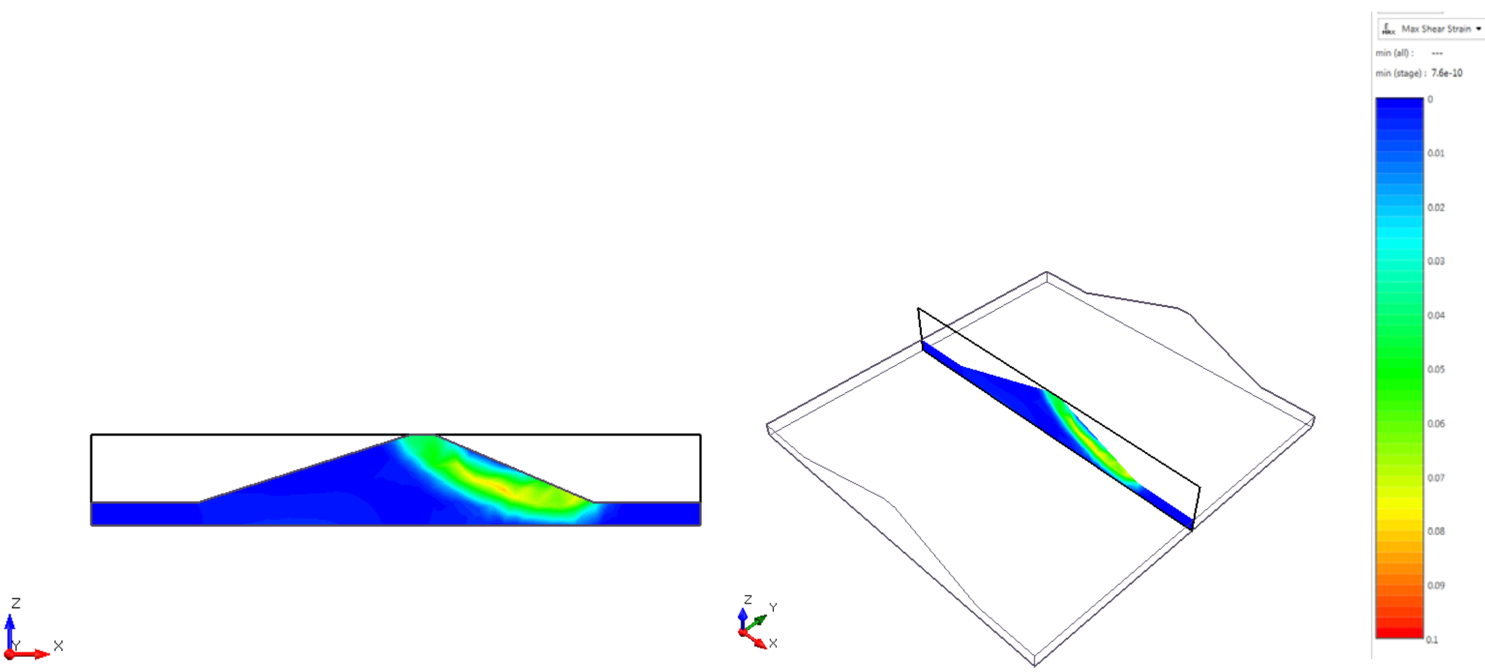


Figure 12.4.10 – RS3 Maximum Shear Strain

2D extruded embankment, homogeneous, full reservoir, ellipsoidal with SA

13.1 Introduction

This model is taken from Gharti et al. (2011). It is an analysis of a 3D Embankment and reservoir by Gharti et al. using a spectral-element method, but originally analyzed in 2D by Griffiths and Lane (1999).

13.2 Problem Description

This is a 3D embankment whose 2D geometry in the XZ plane is shown in Figure 13. This geometry will be extruded 200m in the Y direction. Material properties are shown in Table 13.1. The embankment is analyzed in two ways: with an empty reservoir and a full reservoir. This example is the full reservoir. When the reservoir is full a water table is in place to account for the water pressure; the water table is shown on Figure 13.

13.3 Geometry and Properties

Table 13.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Embankment	13.8	37	18.2

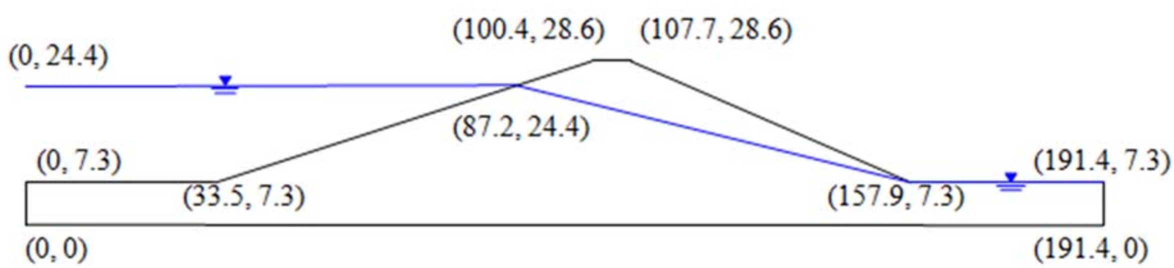


Figure 13

13.4 Results

Table 13.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.774	1.795	1.96	1.87
GLE	1.97	1.889		
Janbu	1.732	1.689		
Spencer	1.974	1.901		

Referee: 1.91 [Gharti et al., 2011]

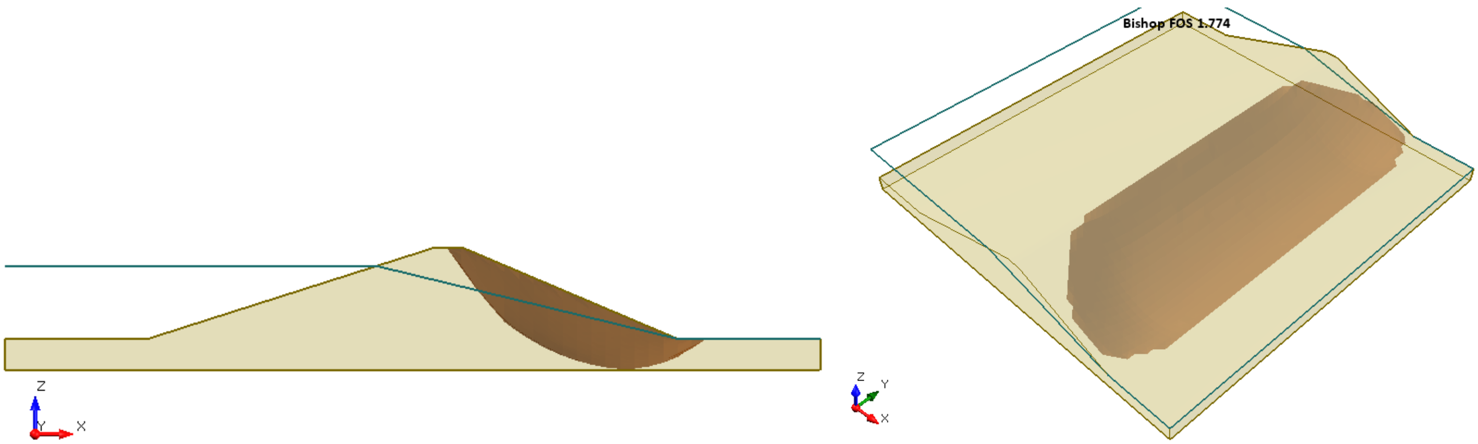


Figure 13.4.1 – Slide3 Solution Using the Bishop Method

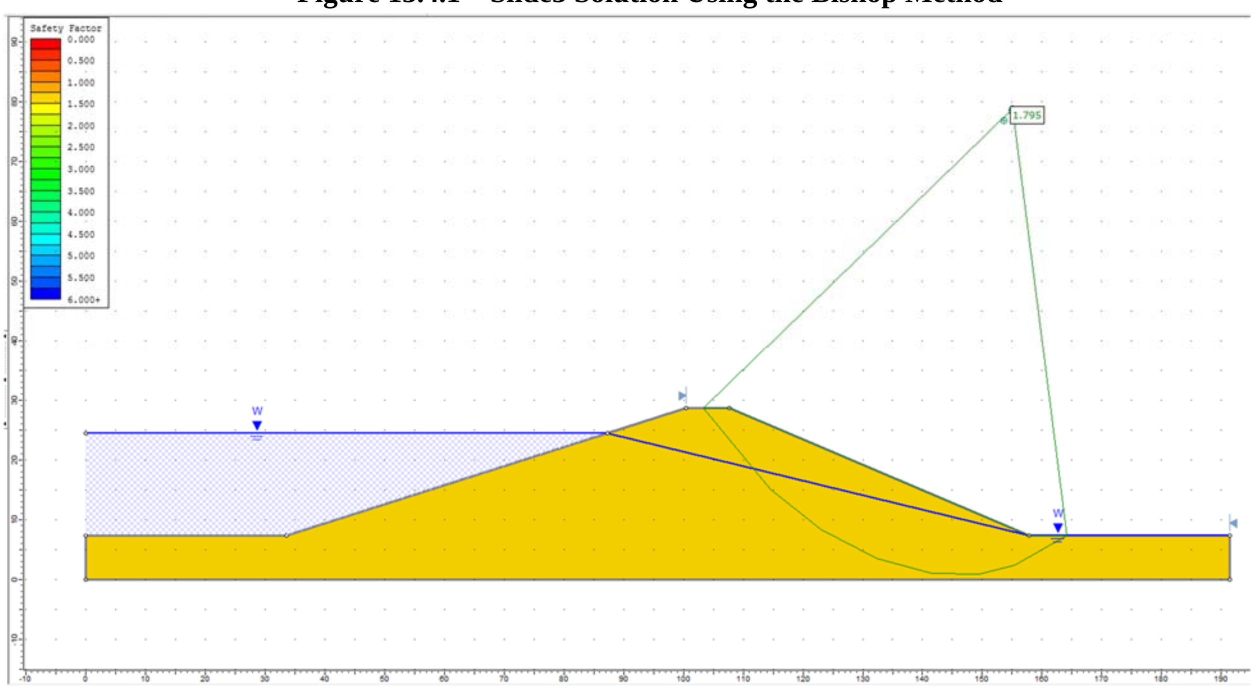


Figure 13.4.2 – Slide Solution Using the Bishop method

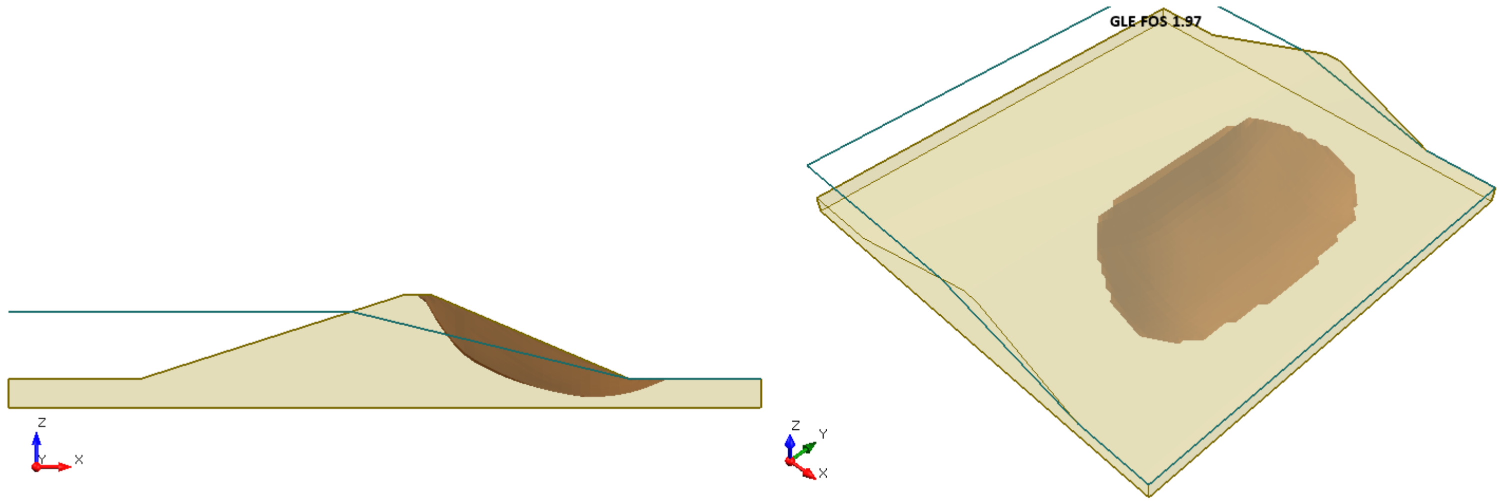


Figure 13.4.3 – Slide3 Solution Using the GLE Method

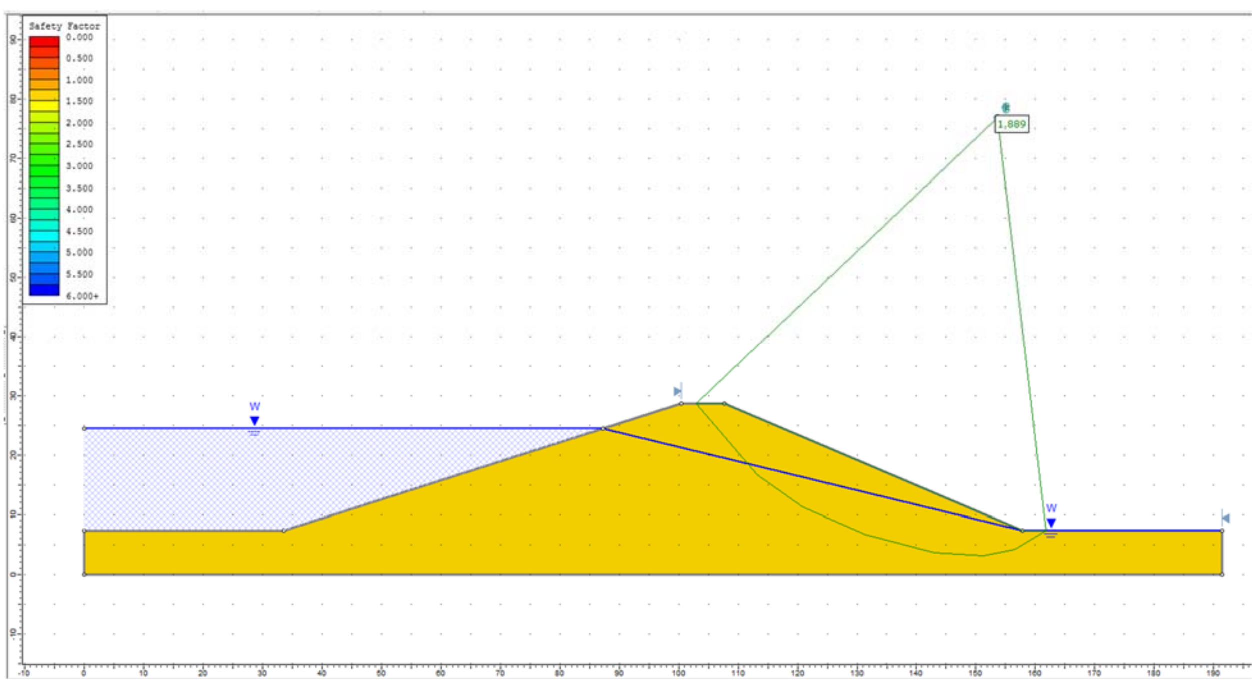


Figure 13.4.4 – Slide Solution Using the GLE Method

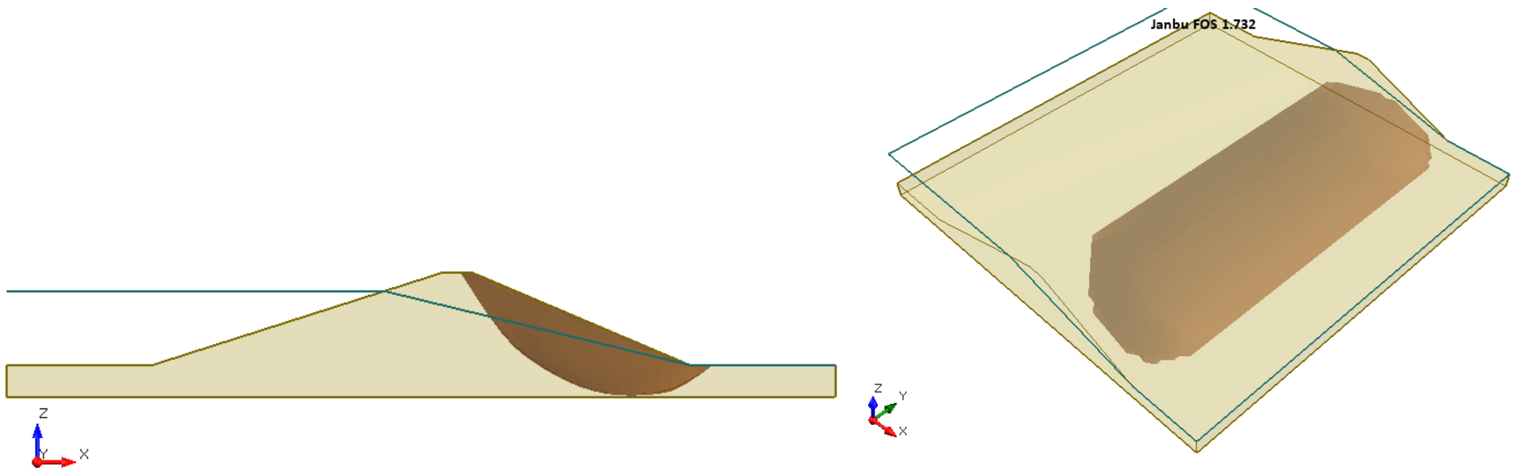


Figure 13.4.5 – Slide3 Solution Using the Janbu Method

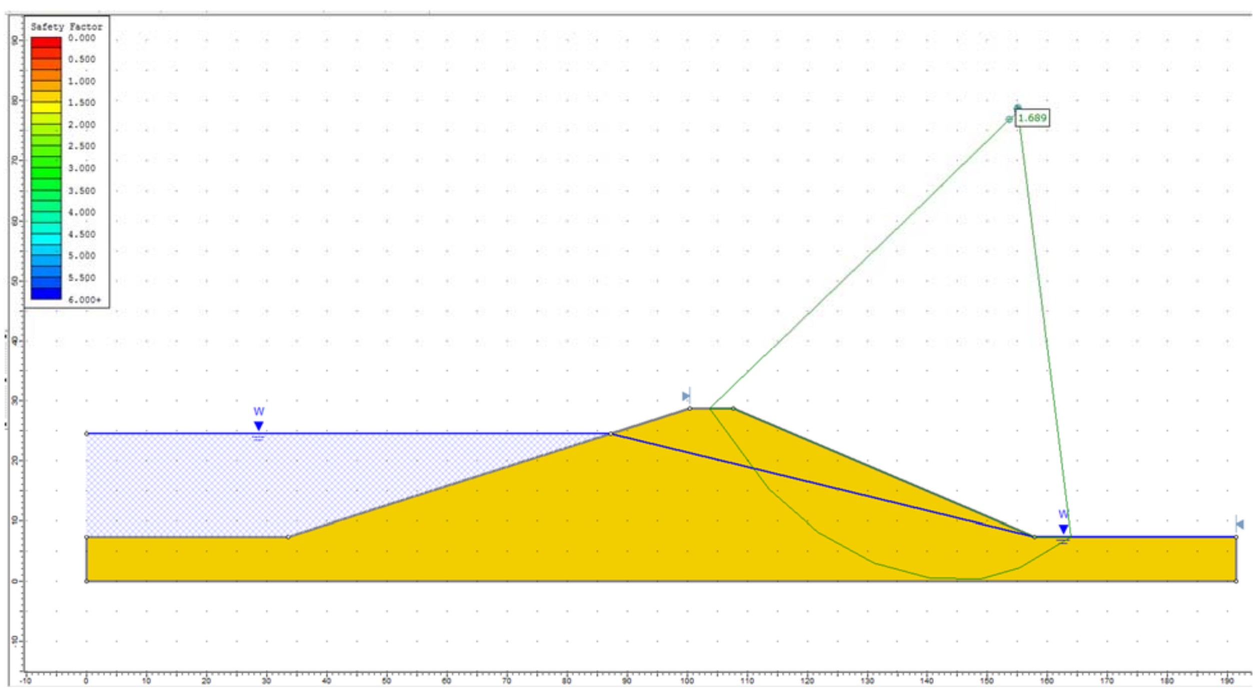


Figure 13.4.6 – Slide Solution Using the Janbu Method

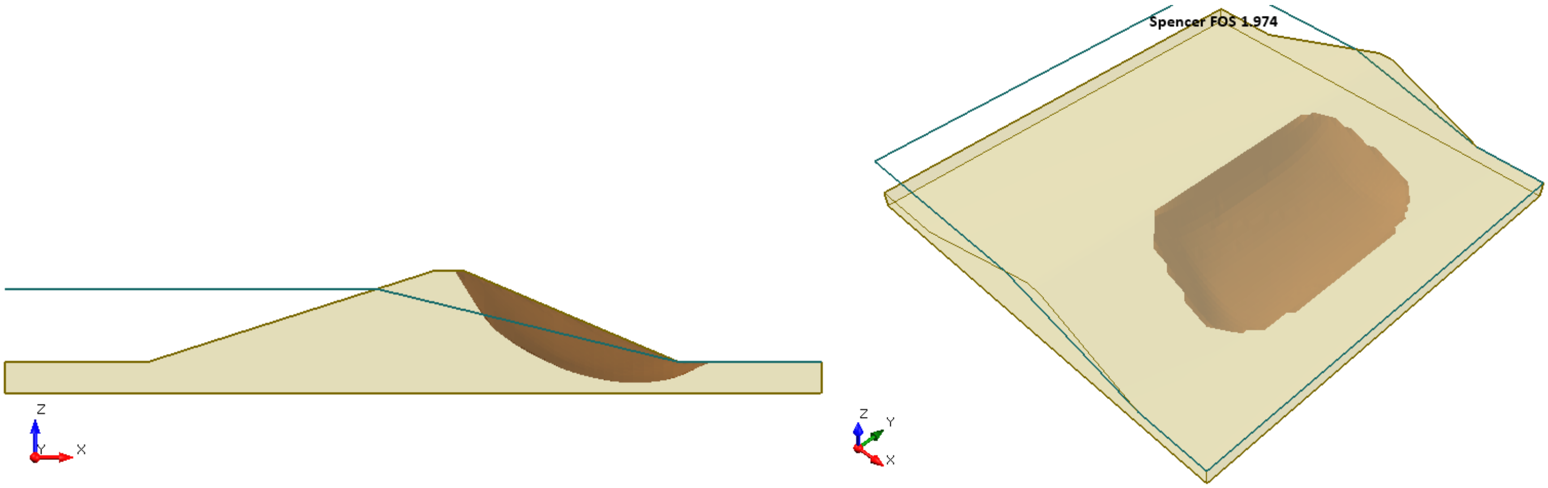


Figure 13.4.7 – Slide3 Solution Using the Spencer Method

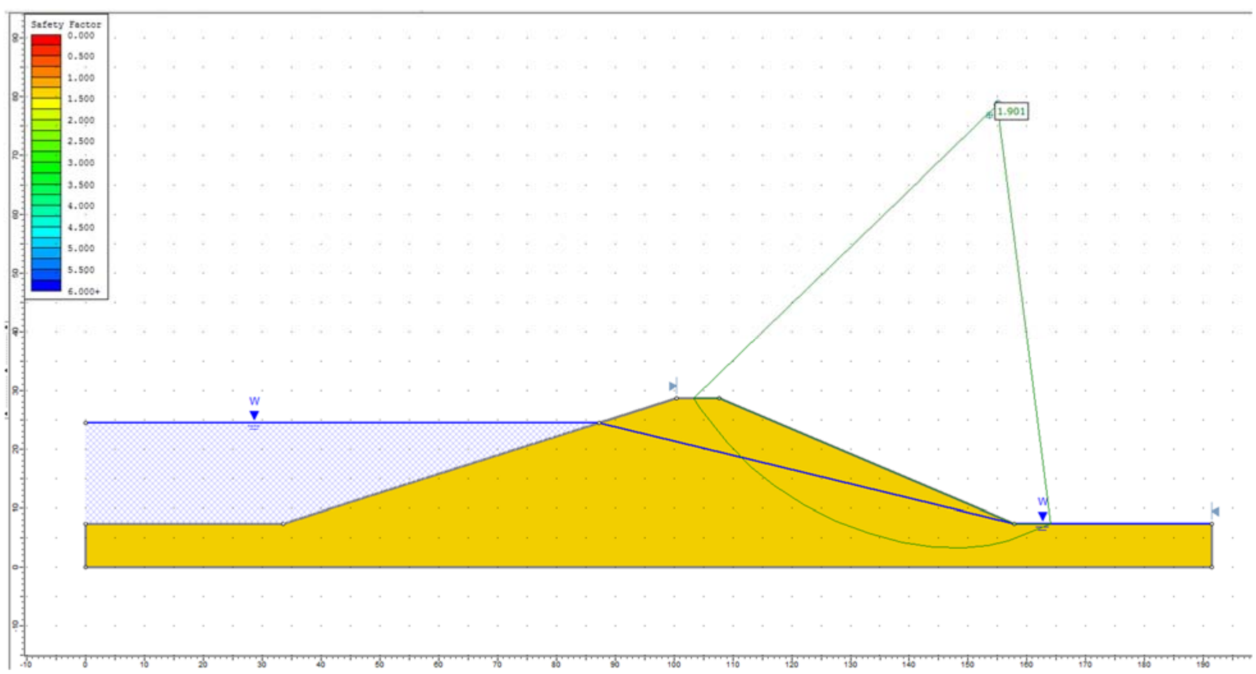


Figure 13.4.8 – Slide Solution Using the Spencer Method

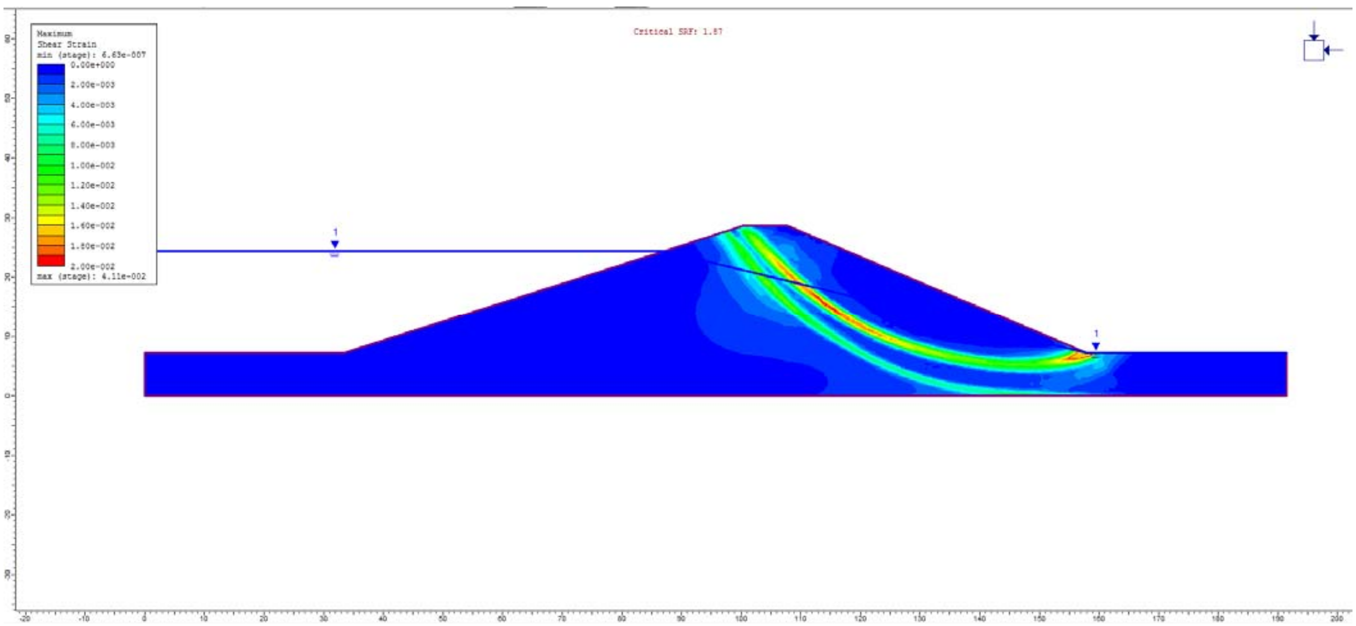


Figure 13.4.9 – RS2 Maximum Shear Strain

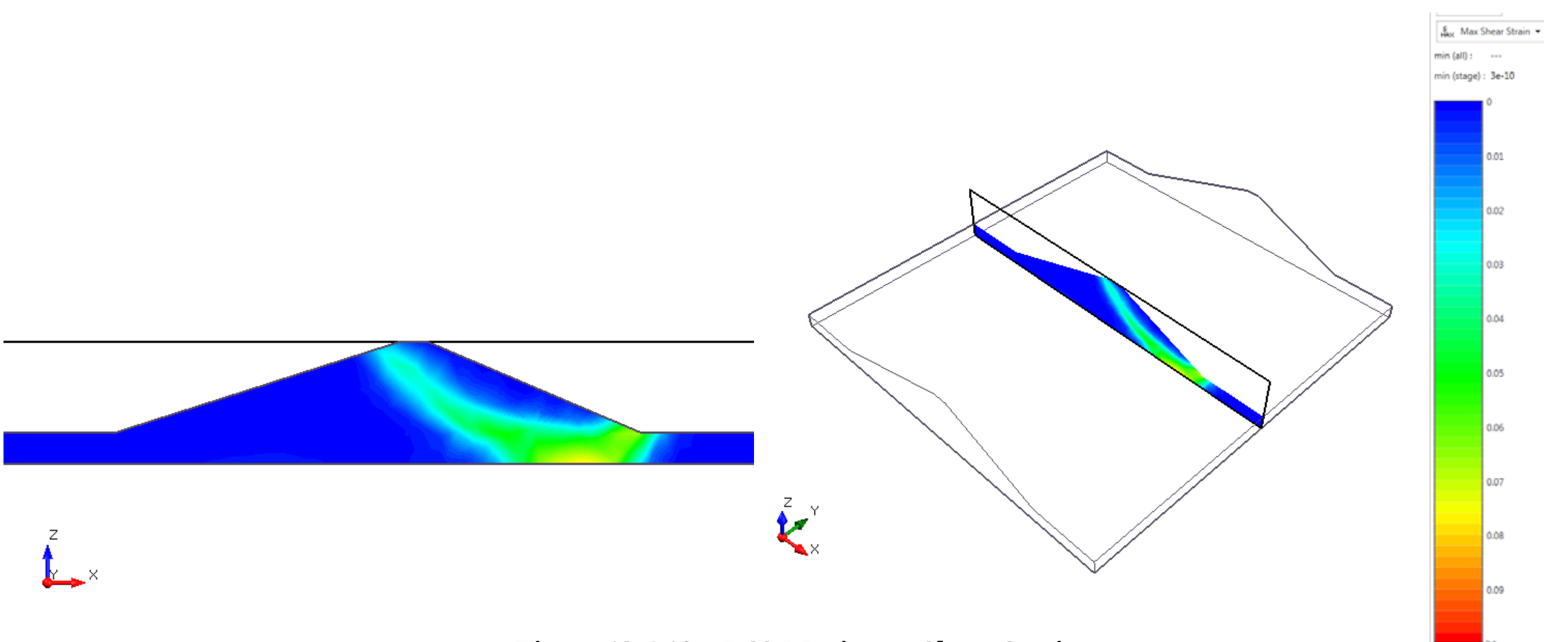


Figure 13.4.10 – RS3 Maximum Shear Strain

2D extruded, homogeneous, ellipsoidal with SA

14.1 Introduction

Gharti et al. did a spectral-element analysis of a slope under four different conditions, changing the soil type, groundwater, and seismic loading (2011). Other authors also analyzed this model, most notably Xing (1988), Lam and Fredlund (1993), and Chen et al. (2003). This is Case 1.

14.2 Problem Description

This is a 3D slope model whose 2D slope geometry in the XZ plane is shown in Figure 14. This geometry will be extruded 40m in the Y direction. Table 14.1 contains the material properties for the homogeneous slope. Pore pressures are not considered in this problem.

14.3 Geometry and Properties

Table 14.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	29	20	18.8

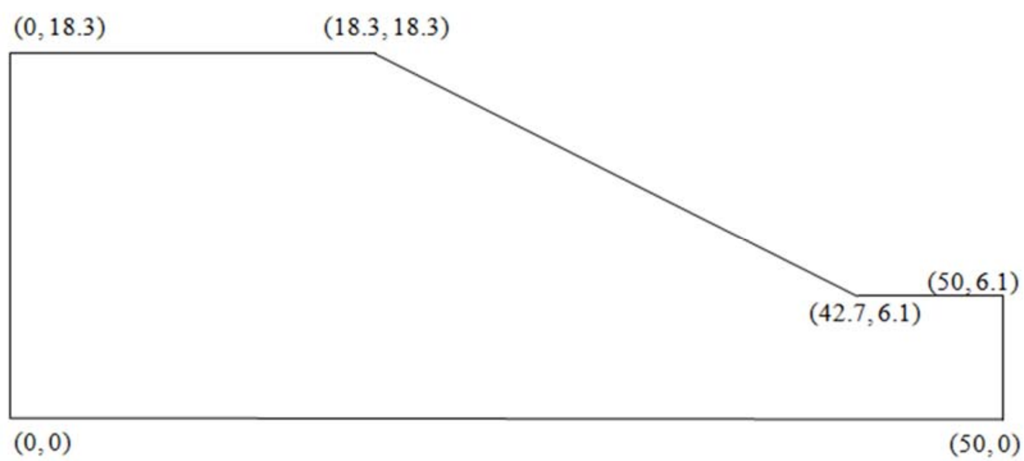


Figure 14

14.4 Results

Table 14.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	2.074	1.901	2.39	2.00
GLE	2.161	1.978		
Janbu	1.992	1.801		
Spencer	2.164	2.002		

Referee: 2.122 [Xing, 1988], 2.187 [Chen et al., 2003], 2.18 [Gharti et al., 2011]

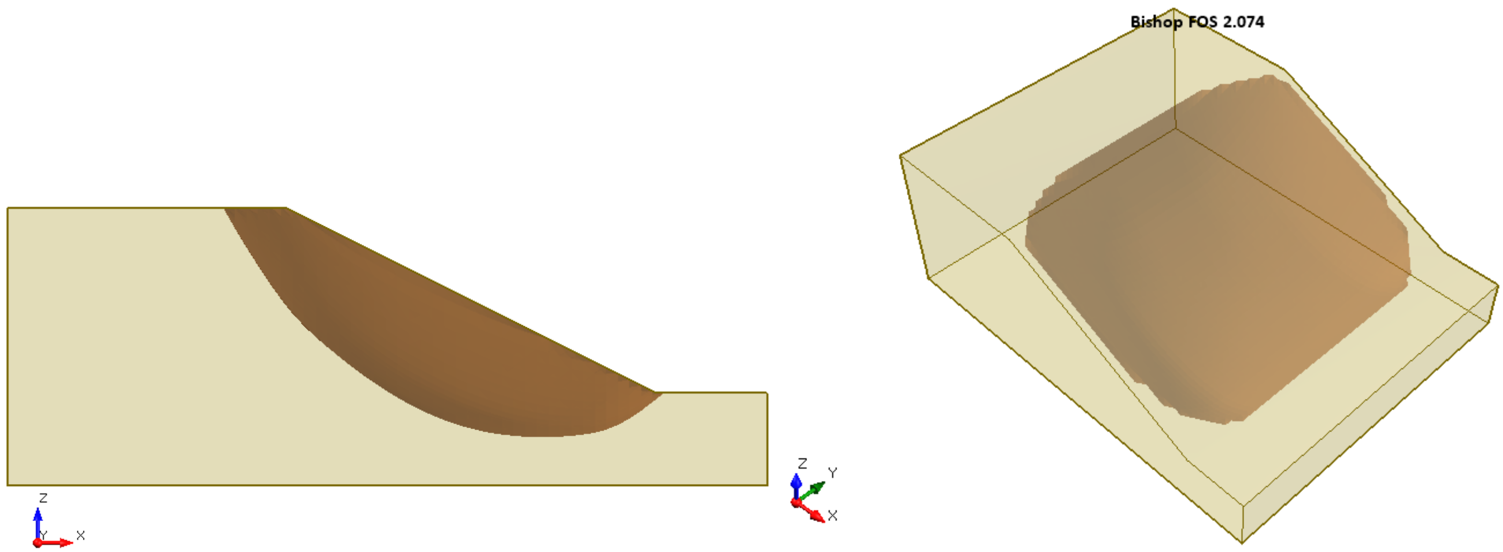


Figure 14.4.1 – Slide3 Solution Using the Bishop Method

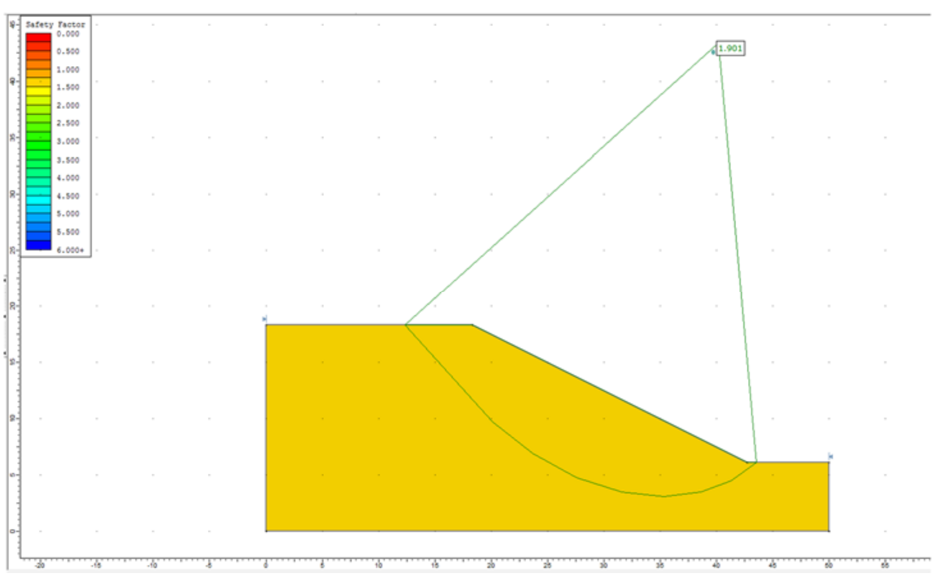


Figure 14.4.2 – Slide Solution Using the Bishop Method

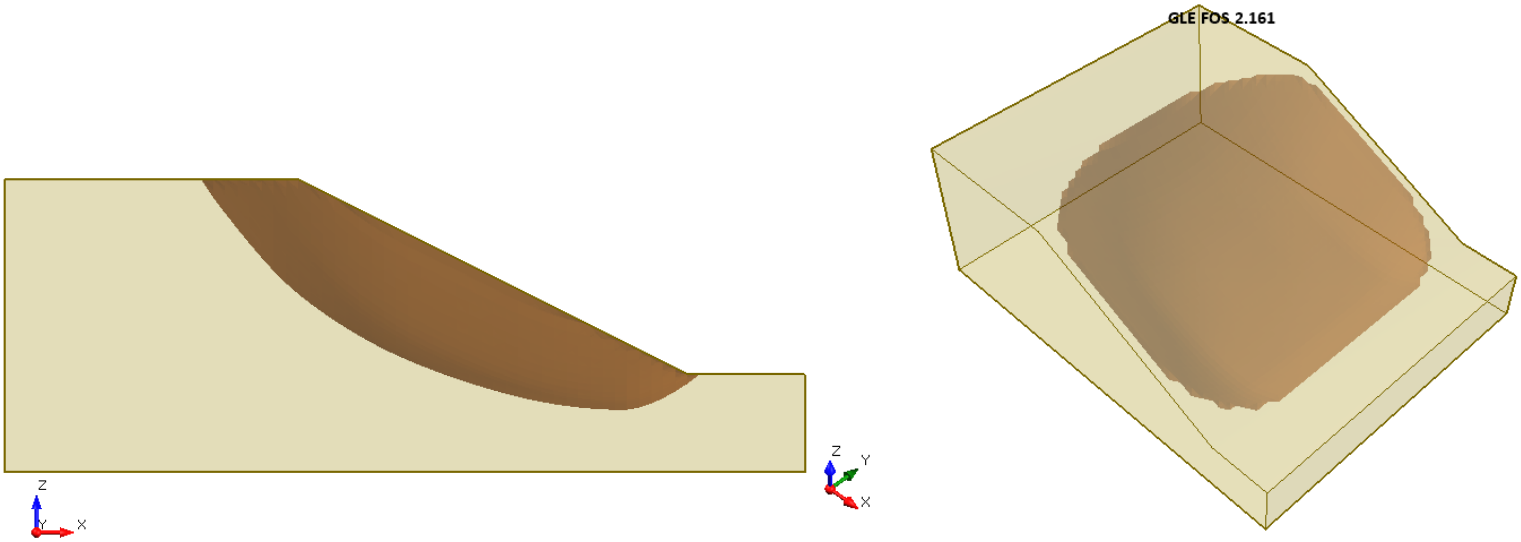


Figure 14.4.3 – Slide3 Solution Using the GLE Method

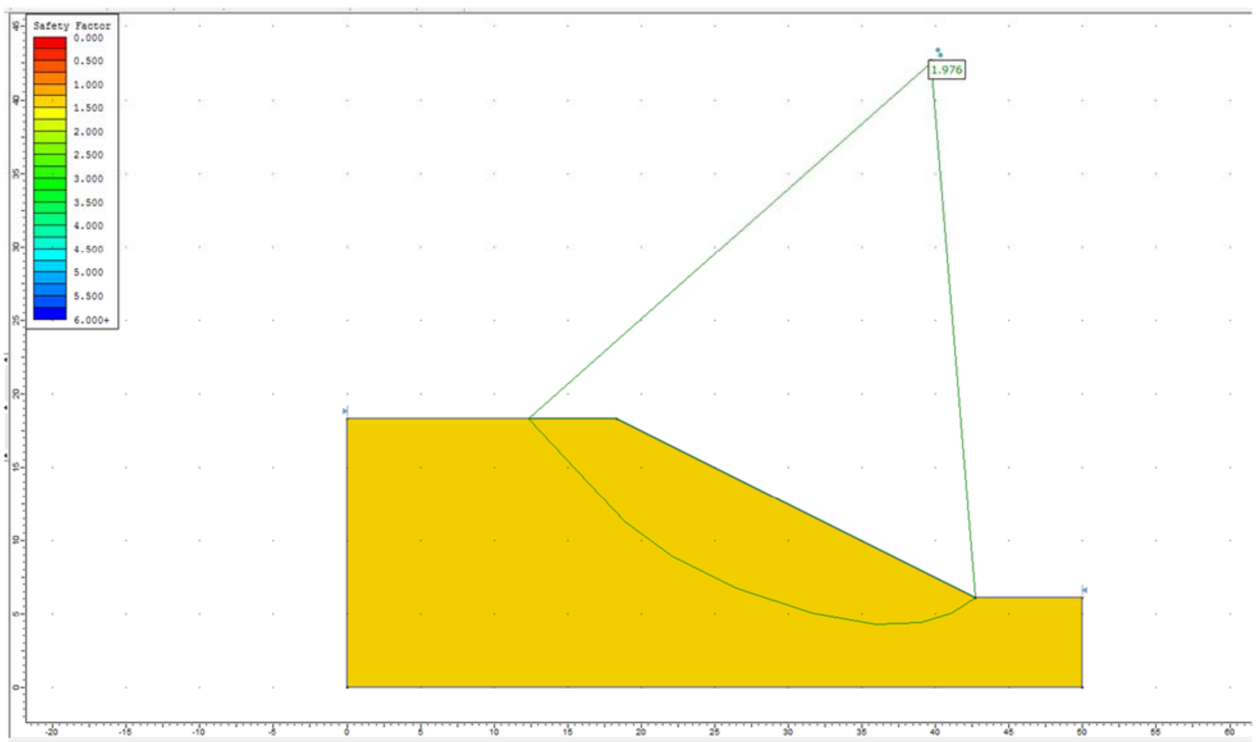


Figure 14.4.4 – Slide Solution Using the GLE Method

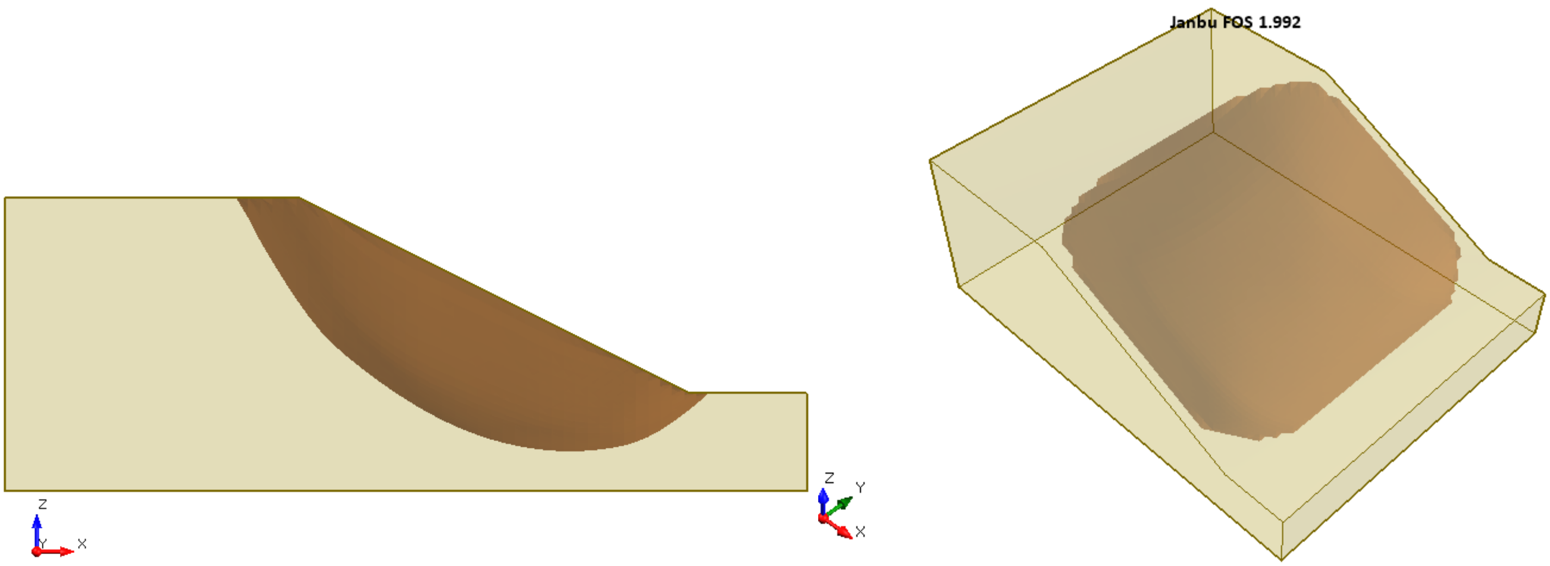


Figure 14.4.5 – Slide3 Solution Using the Janbu Method

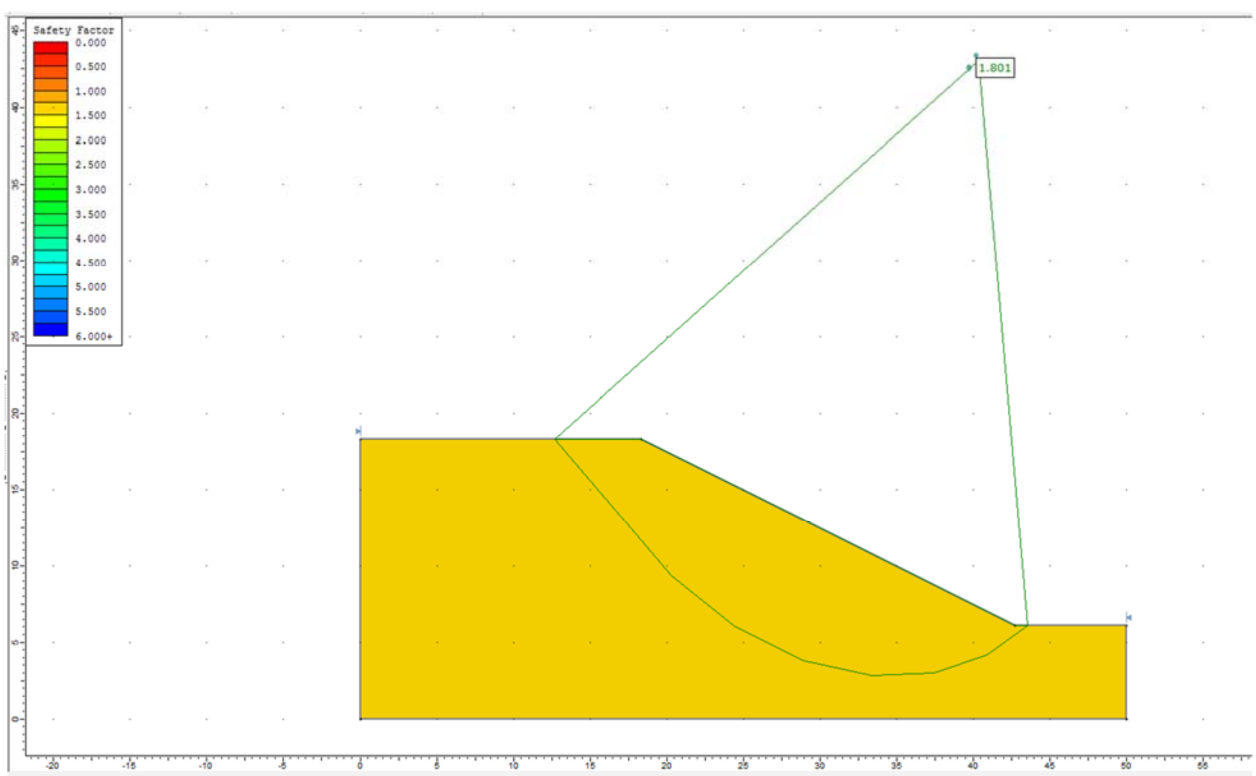


Figure 14.4.6 – Slide Solution Using the Janbu Method

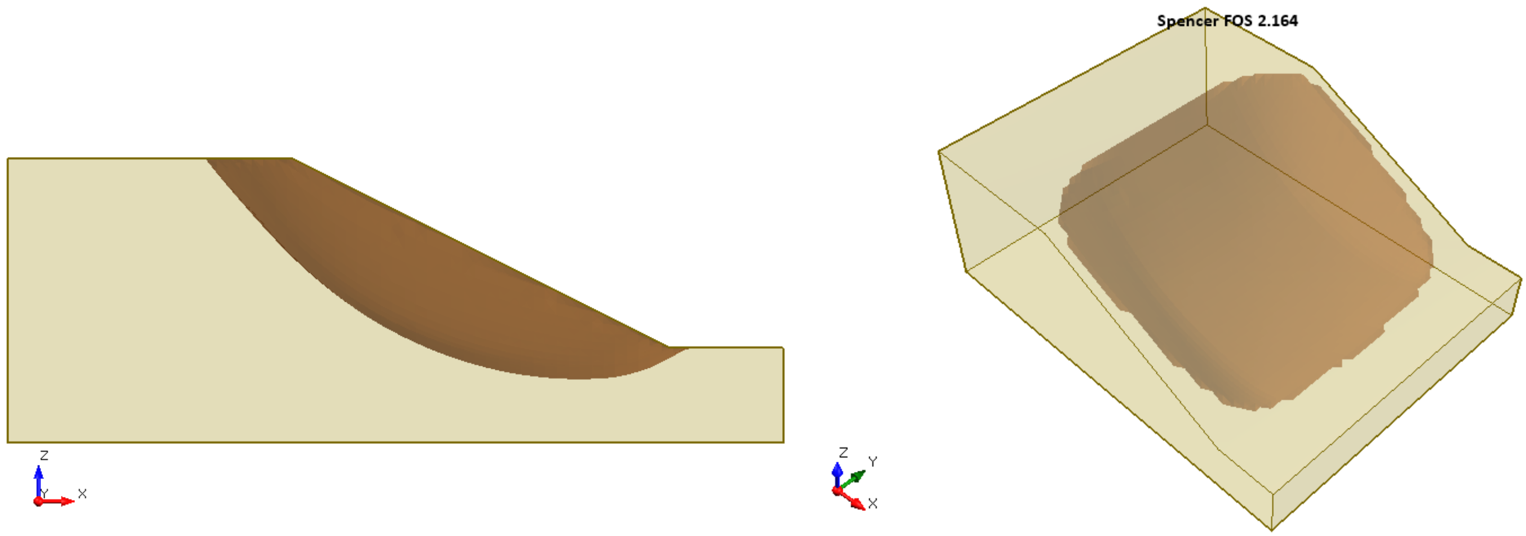


Figure 14.4.7 – Slide3 Solution Using the Spencer Method

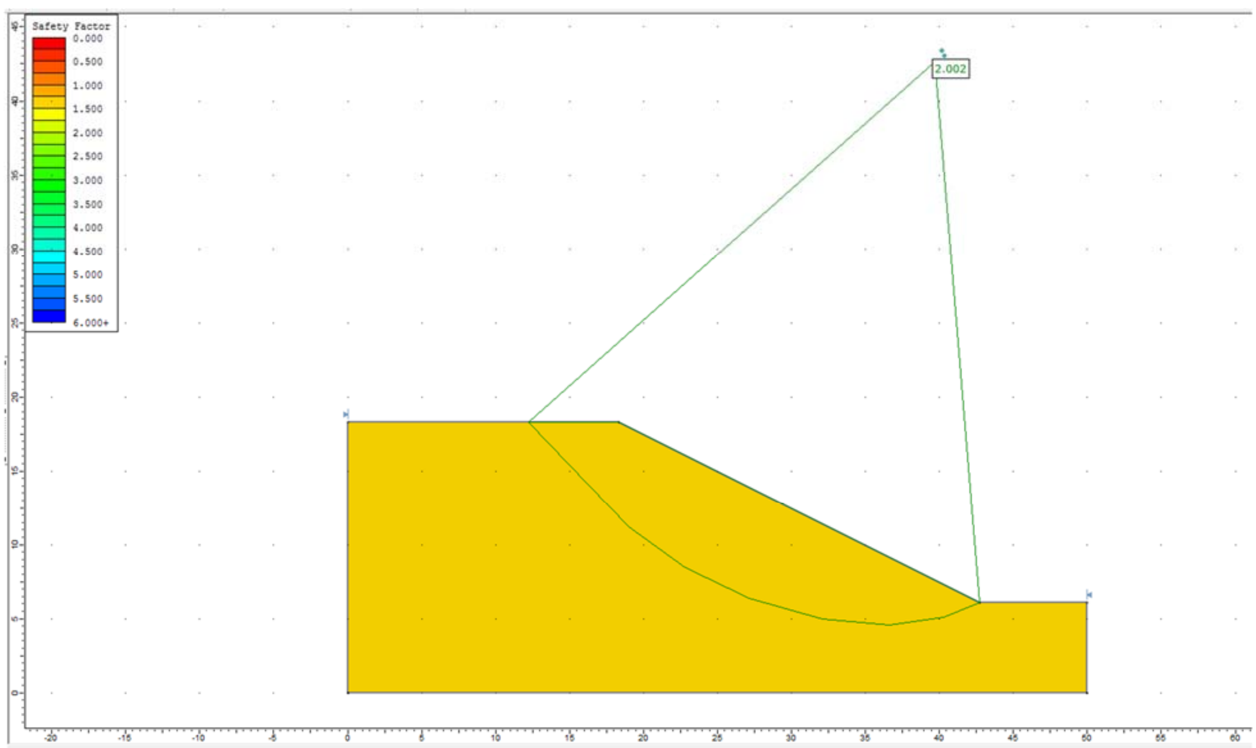


Figure 14.4.8 – Slide Solution Using the Spencer Method

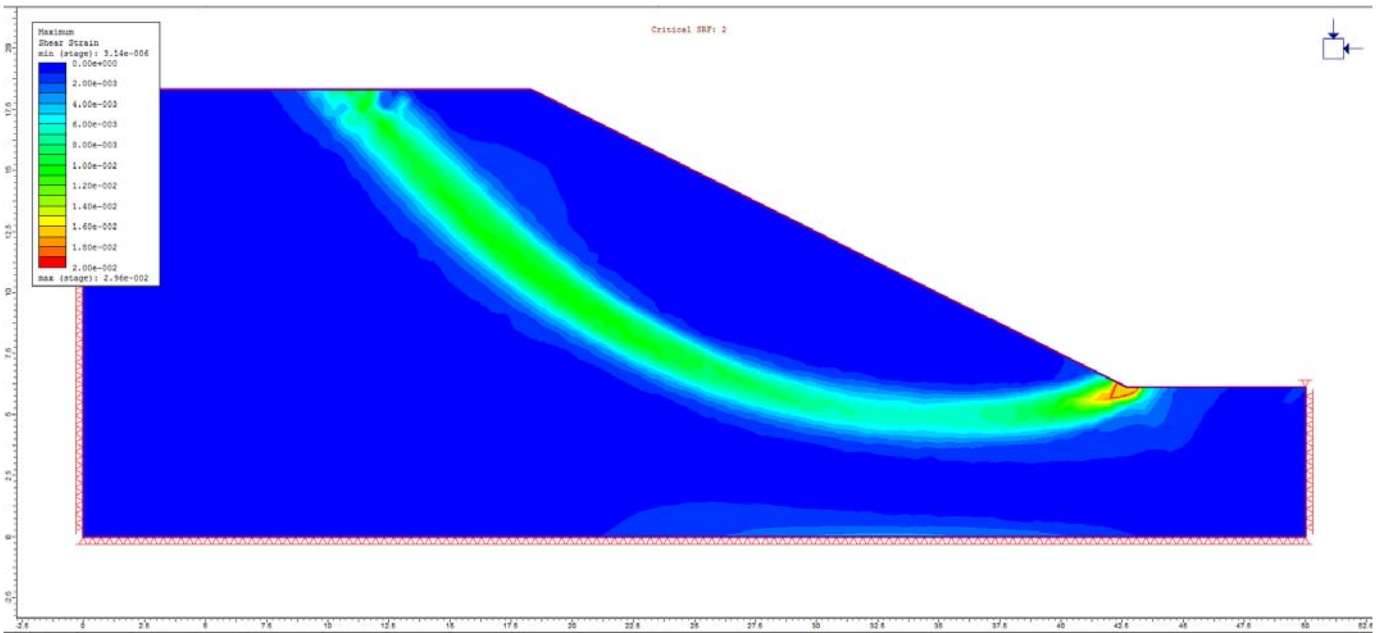


Figure 14.4.9 – RS2 Maximum Shear Strain

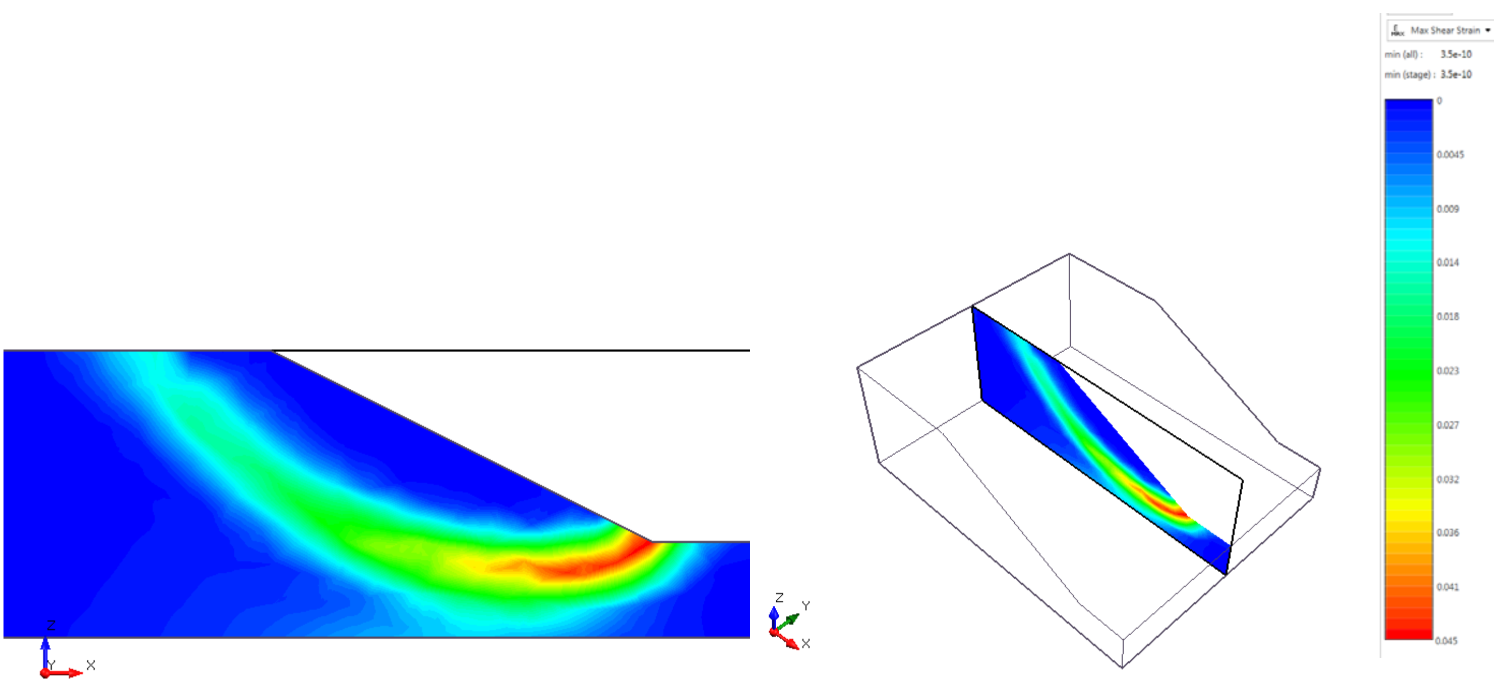


Figure 14.4.10 – RS3 Maximum Shear Strain

2D extruded, weak seam, ellipsoidal with SA

15.1 Introduction

Gharti et al. did a spectral-element analysis of a slope under four different conditions, changing the soil type, groundwater, and seismic loading (2011). Other authors also analyzed this model, most notably Xing (1988), Lam and Fredlund (1993), and Chen et al. (2003). This is Case 2.

15.2 Problem Description

This is a 3D slope model whose 2D slope geometry in the XZ plane is shown in Figure 15. This geometry will be extruded 40m in the Y direction. Table 15.1 contains the material properties for both the soil and the weak layer. Pore pressures are not considered in this problem.

This example uses a Cuckoo search to find the ellipsoidal slip surface on the downstream side of the embankment. The settings for the Cuckoo search are Maximum Number of Iterations: 40, Number of Nests: 20. Surface Altering Optimization should be on with settings as Conversion Resolution: Medium, Iteration Tolerance: 0.0001, Max Iterations: 20, Max Concavity Angle = 5.

15.3 Geometry and Properties

Table 15.1: Material Properties

	c´ (kN/m^2)	φ´ (deg.)	γ (kN/m^3)
Soil	29	20	18.8
Weak Layer	10	0	18.8
Infinite Strength	10000	65	18.8

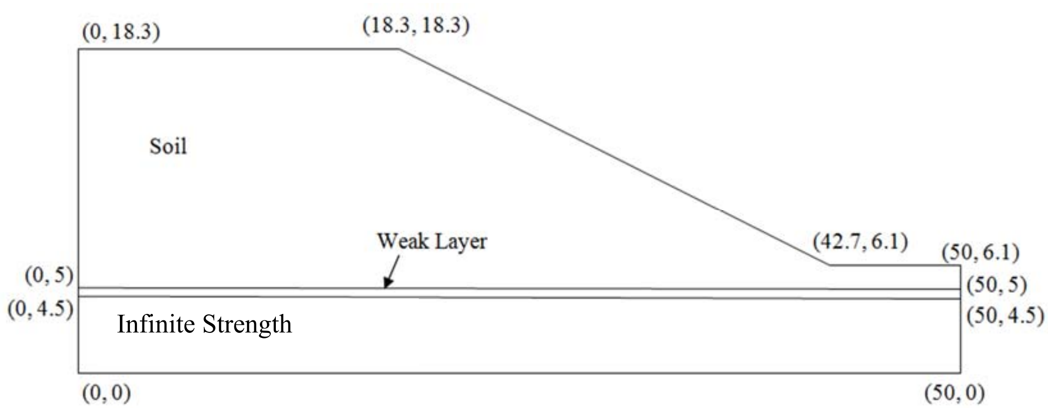


Figure 15

15.4 Results

Table 15.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.186	0.979	1.33	1.08
GLE	1.198	0.979		
Janbu	1.181	0.980		
Spencer	1.228	0.977		

Referee: 1.553 [Xing, 1988], 1.607, 1.558, 1.62, 1.603 [Lam and Fredlund, 1993], 1.603 [Chen et al. 2003], 1.57 [Gharti et al., 2011]

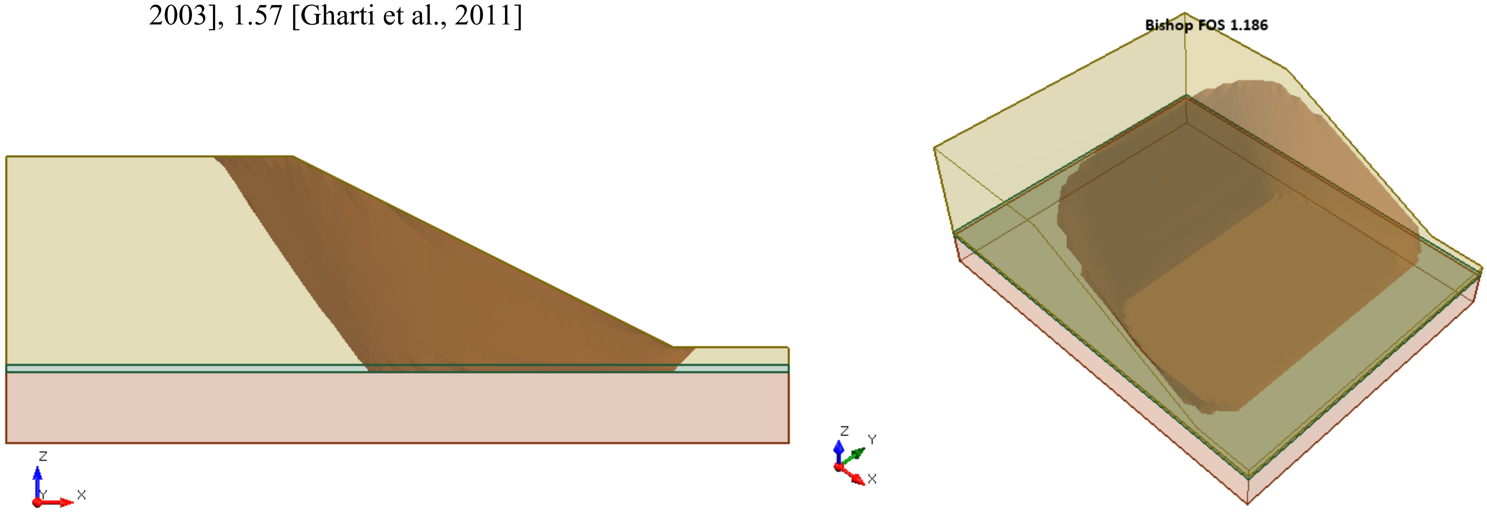


Figure 15.4.1 – Slide3 Solution Using the Bishop Method

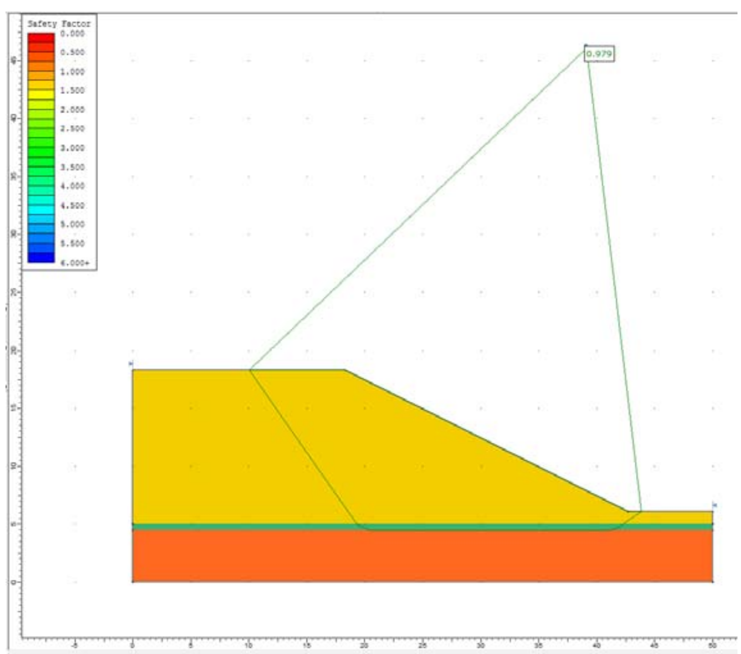


Figure 15.4.2 – Slide Solution Using the Bishop Method

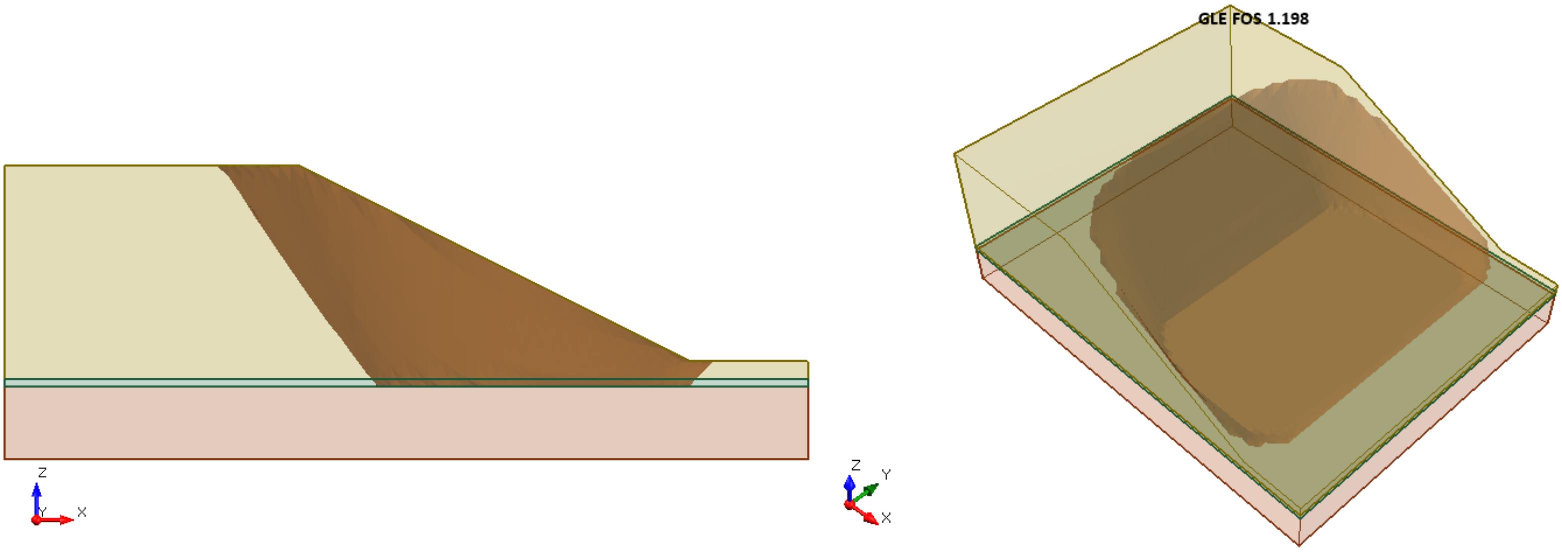


Figure 15.4.3 – Slide3 Solution Using the GLE Method

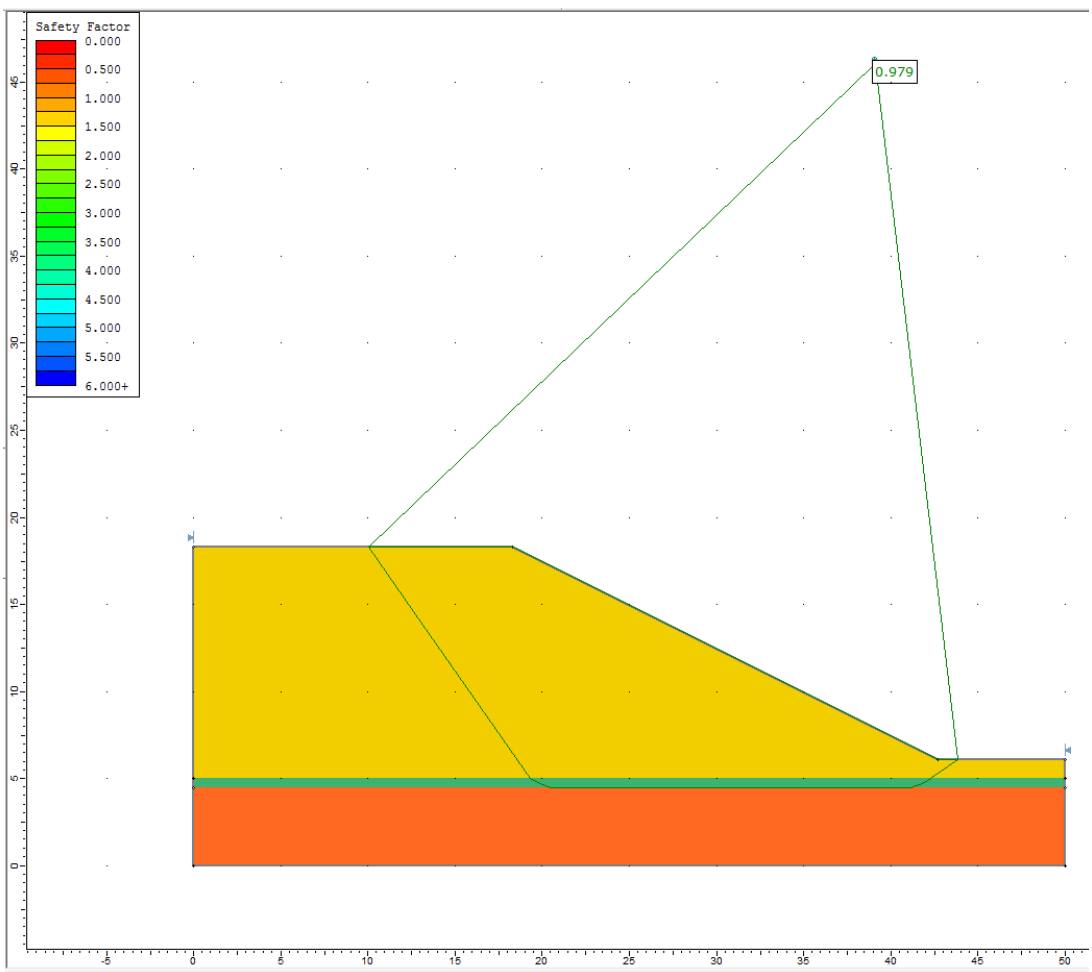


Figure 15.4.4 – Slide Solution Using the GLE Method

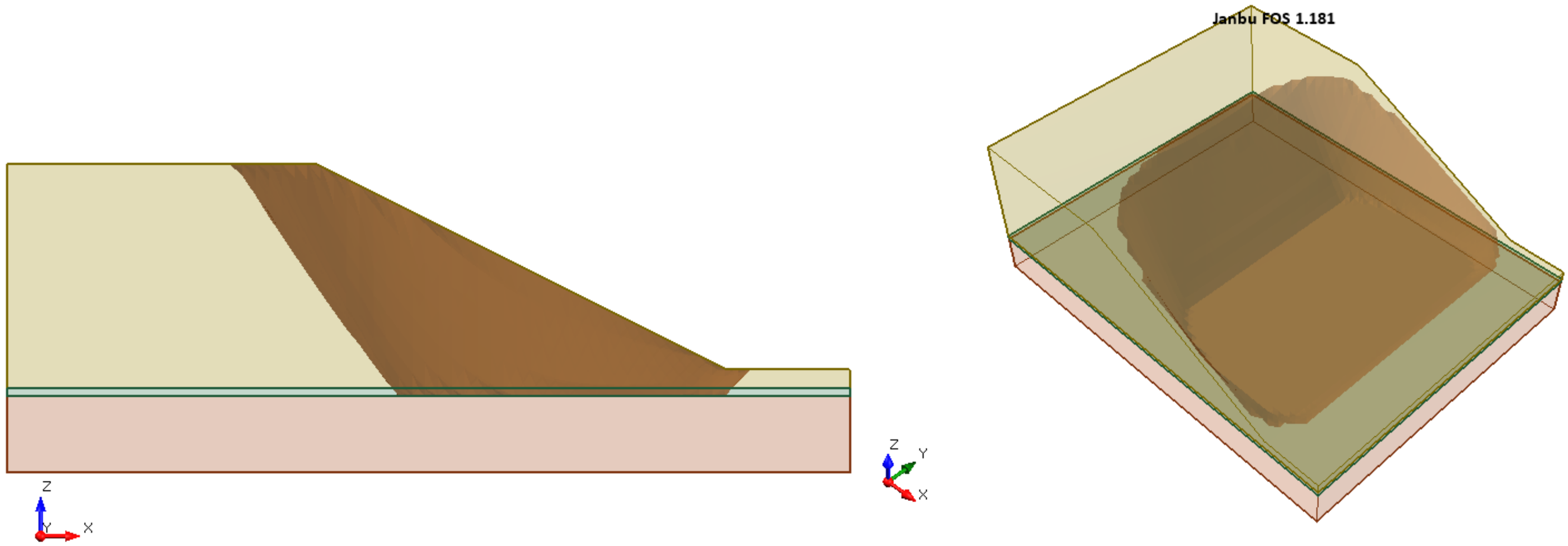


Figure 15.4.5 – Slide3 Solution Using the Janbu Method

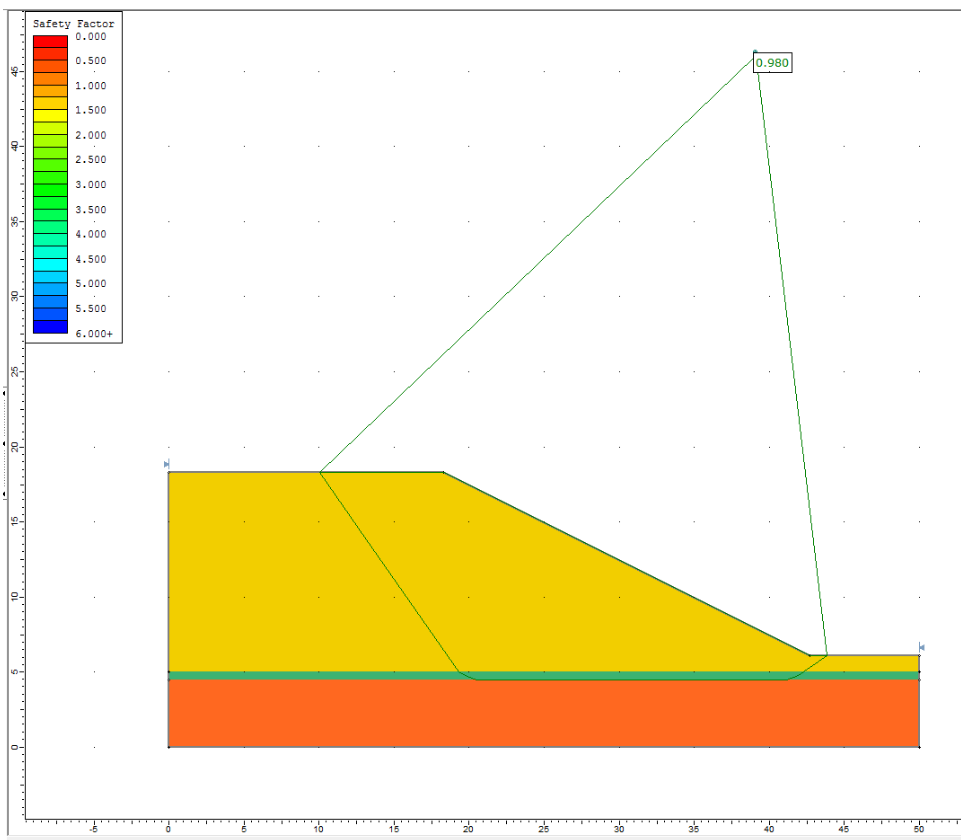


Figure 15.4.6 – Slide Solution Using the Janbu Method

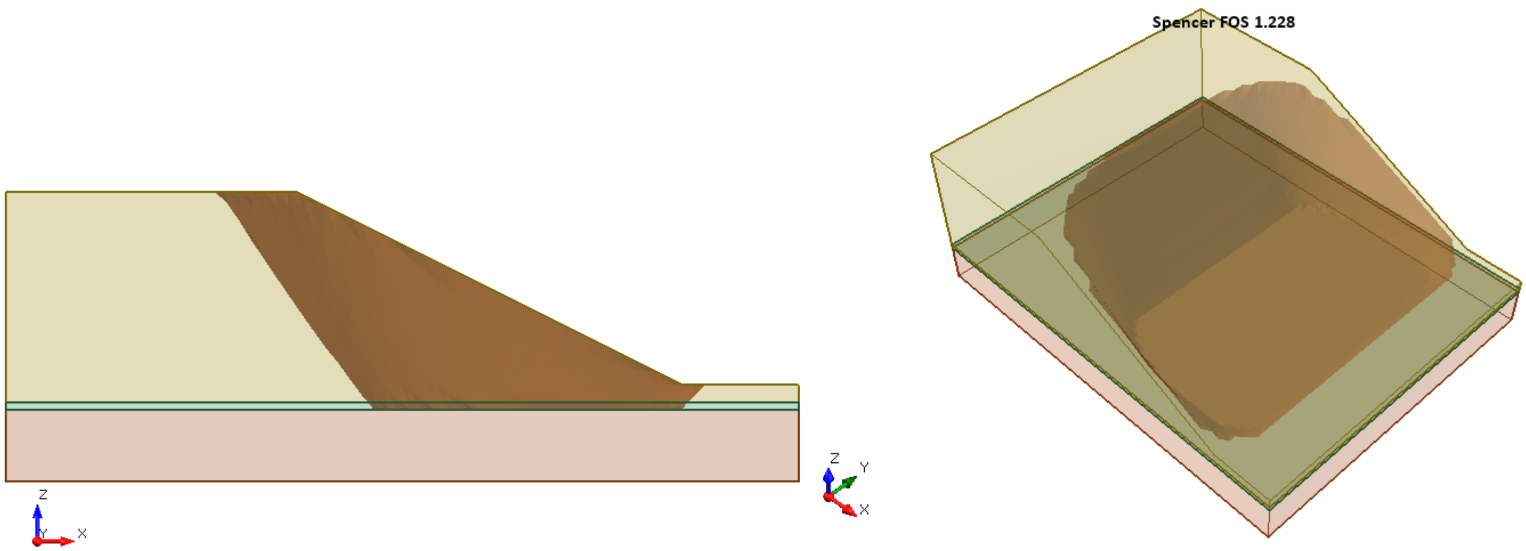


Figure 15.4.7 – Slide 3 Solution Using the Spencer Method

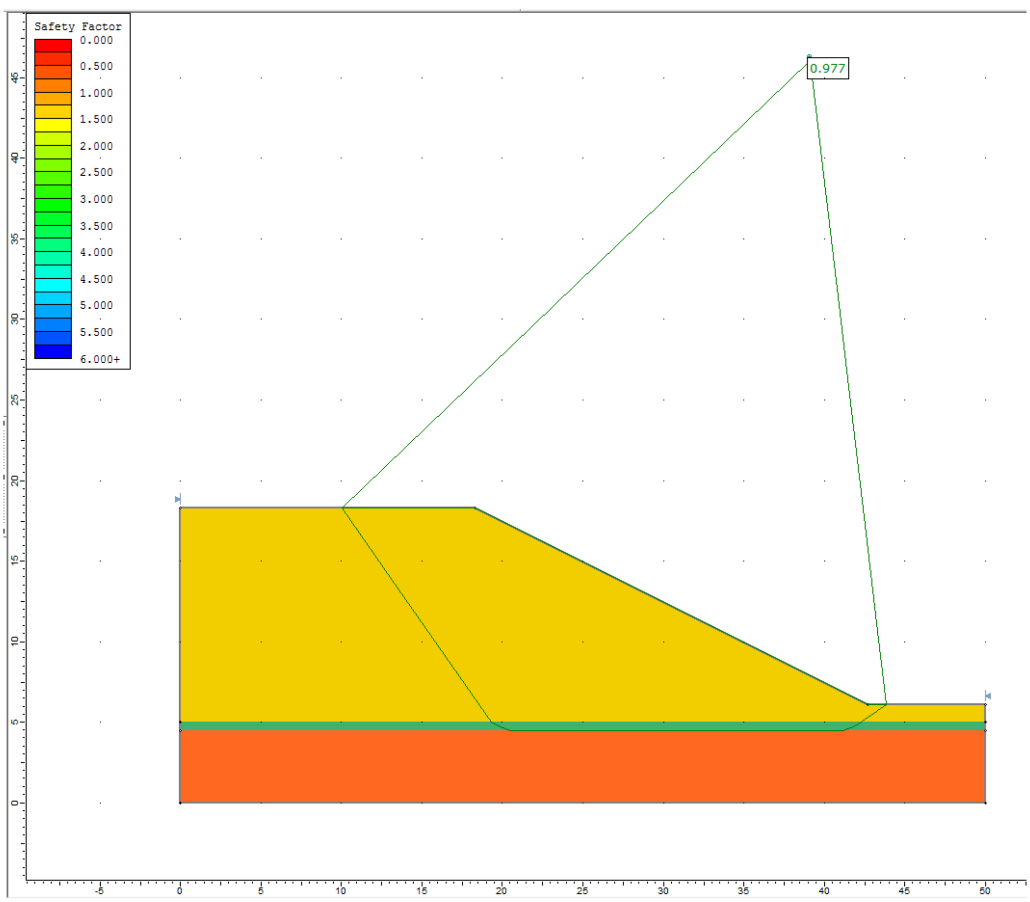


Figure 15.4.8 – Slide Solution Using the Spencer Method

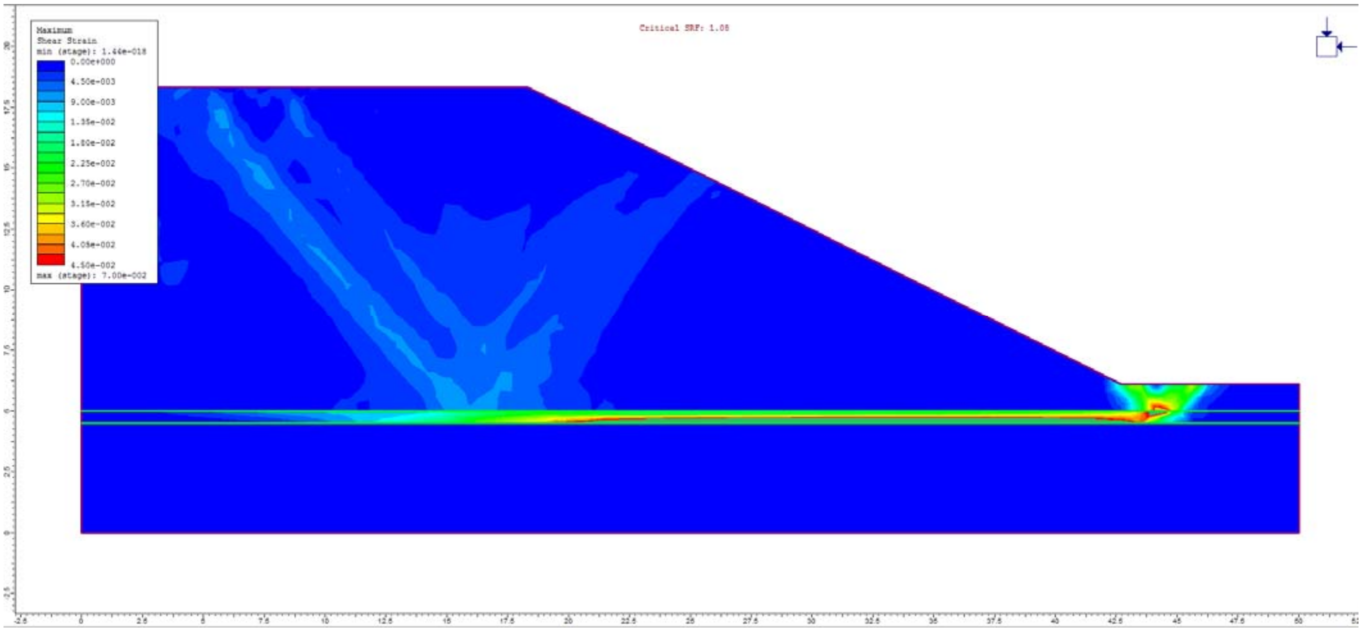


Figure 15.4.9 – RS2 Maximum Shear Strain

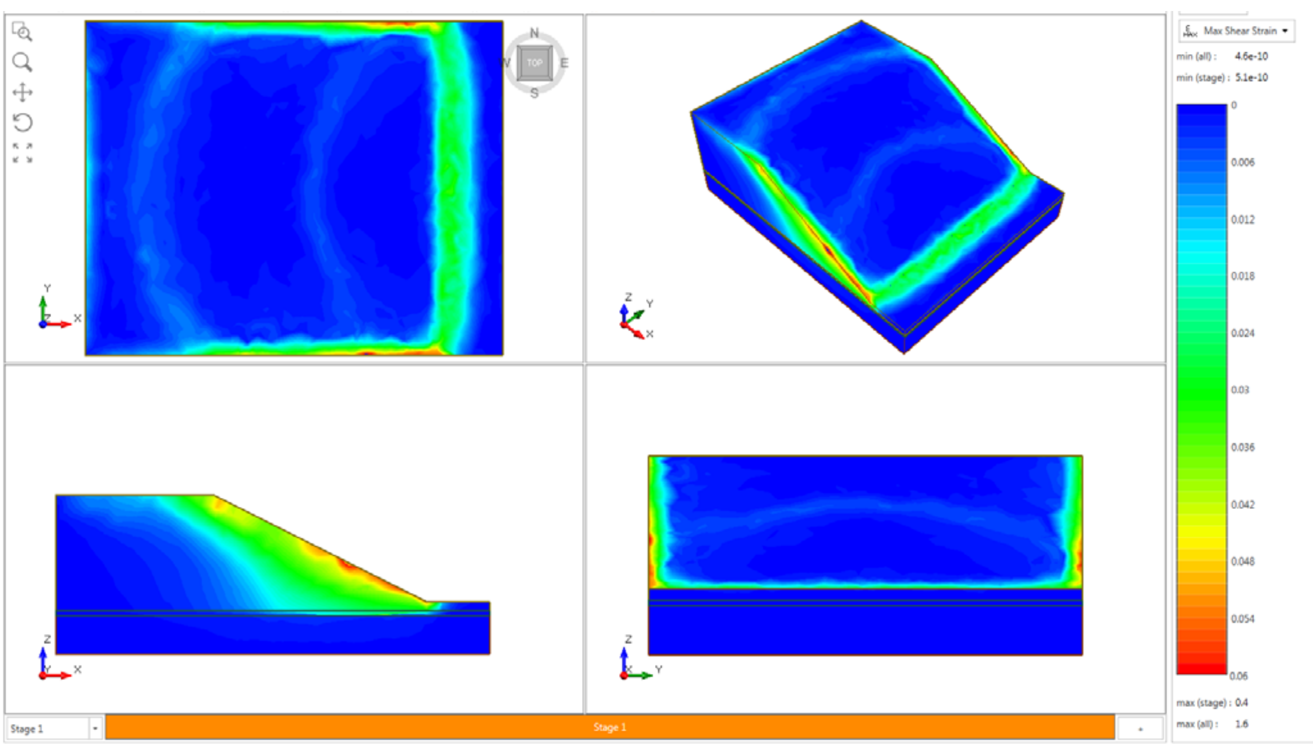


Figure 15.4.10 – RS3 Maximum Shear Strain

2D extruded, weak seam, water table, ellipsoidal with SA

16.1 Introduction

Gharti et al. did a spectral-element analysis of a slope under four different conditions, changing the soil type, groundwater, and seismic loading (2011). Other authors also analyzed this model, most notably Xing (1988), Lam and Fredlund (1993), and Chen et al. (2003). This is Case 3.

16.2 Problem Description

This is a 3D slope model whose 2D slope geometry in the XZ plane is shown in Figure 16. This geometry will be extruded 40m in the Y direction. Table 16.1 contains the material properties for both the soil and the weak layer. A water table is shown in Figure 16, which causes pore pressure. The ellipsoidal slip surface is required.

16.3 Geometry and Properties

Table 16.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	29	20	18.8
Weak Layer	10	0	18.8
Infinite Strength	10000	65	18.8

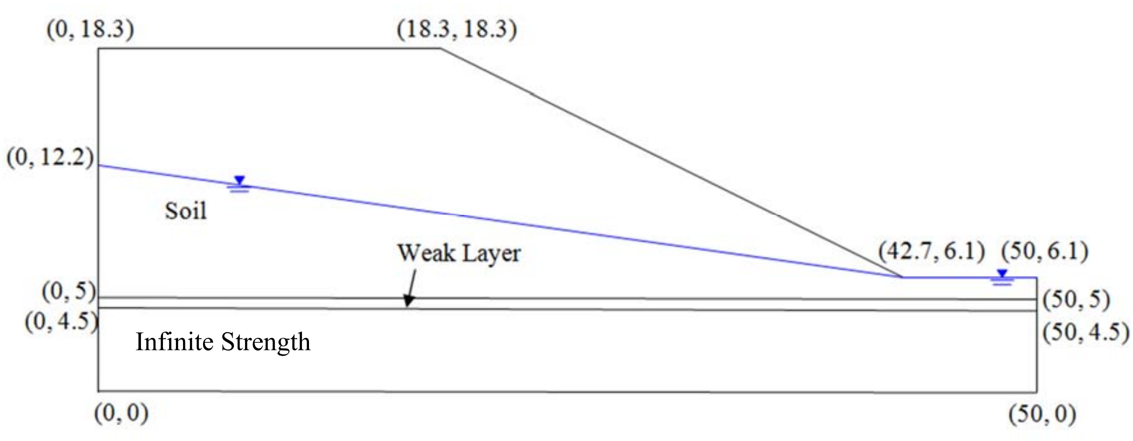


Figure 16

16.4 Results

Table 16.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.146	0.929	1.27	1.02
GLE	1.143	0.927		
Janbu	1.141	0.933		
Spencer	1.143	0.917		

Referee: 1.441 [Xing, 1988], 1.511, 1.481, 1.54, 1.508 [Lam and Fredlund 1993], 1.49 [Gharti et al., 2011]

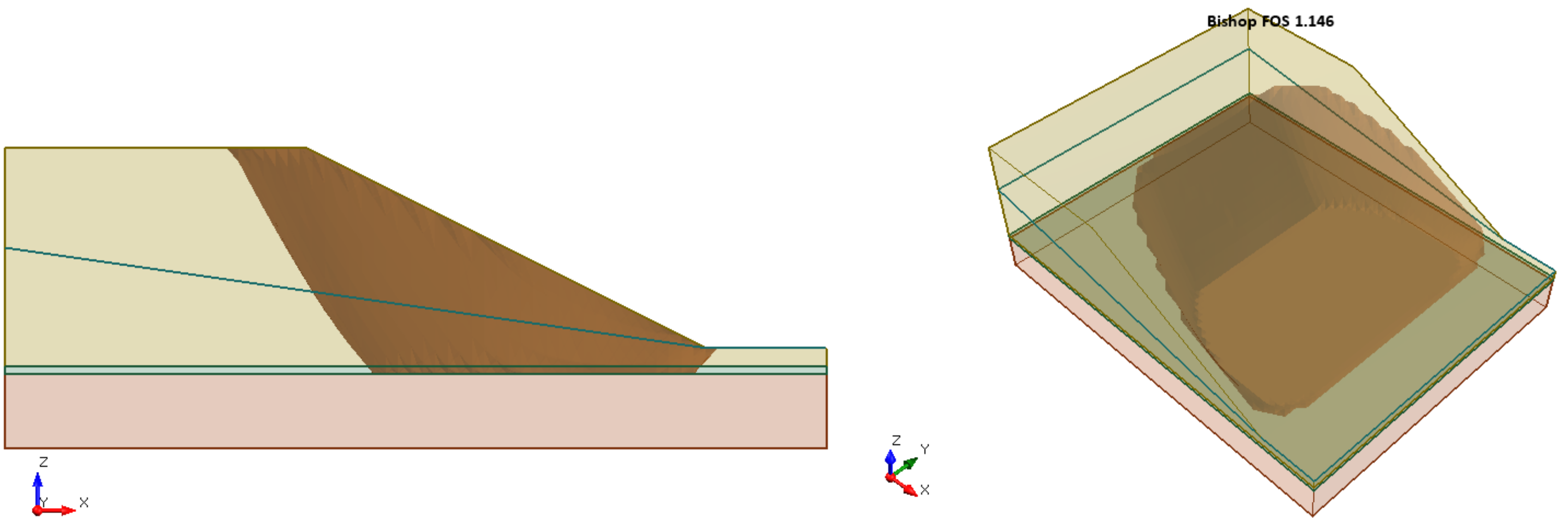


Figure 16.4.1 – Slide3 Solution Using the Bishop Method

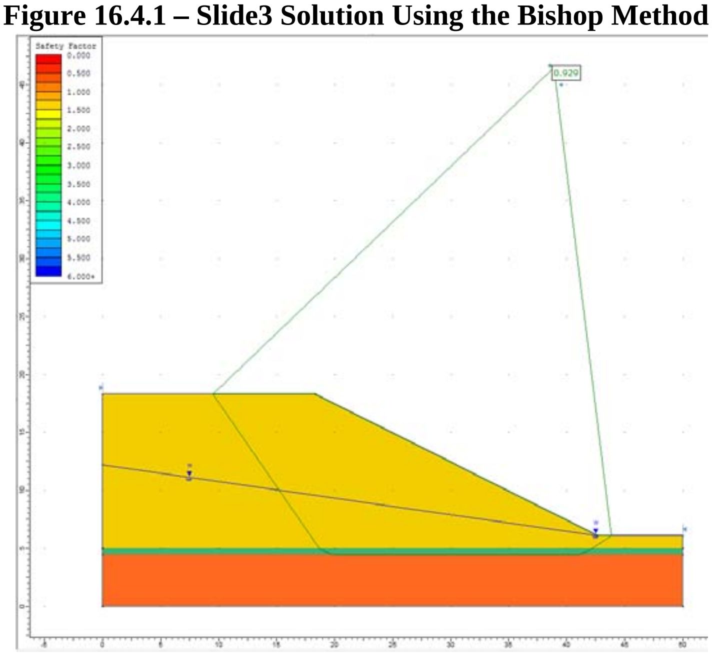


Figure 16.4.2 – Slide Solution Using the Bishop Method

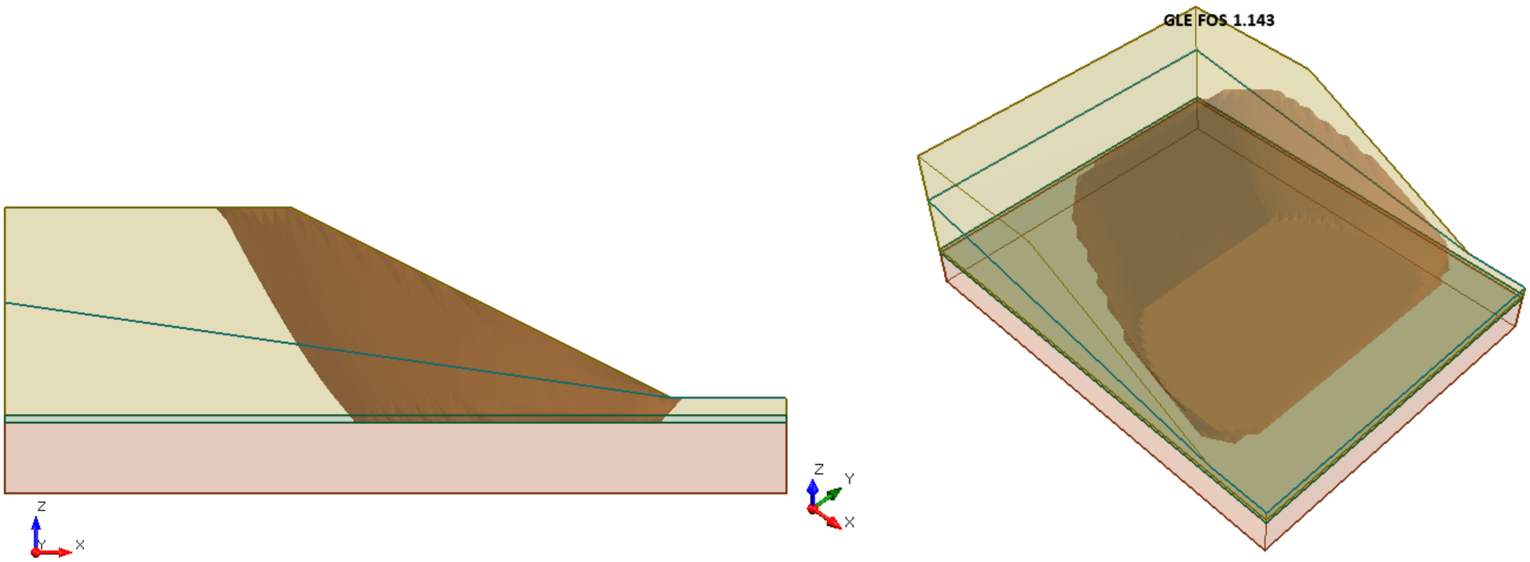


Figure 16.4.3 – Slide3 Solution Using the GLE Method

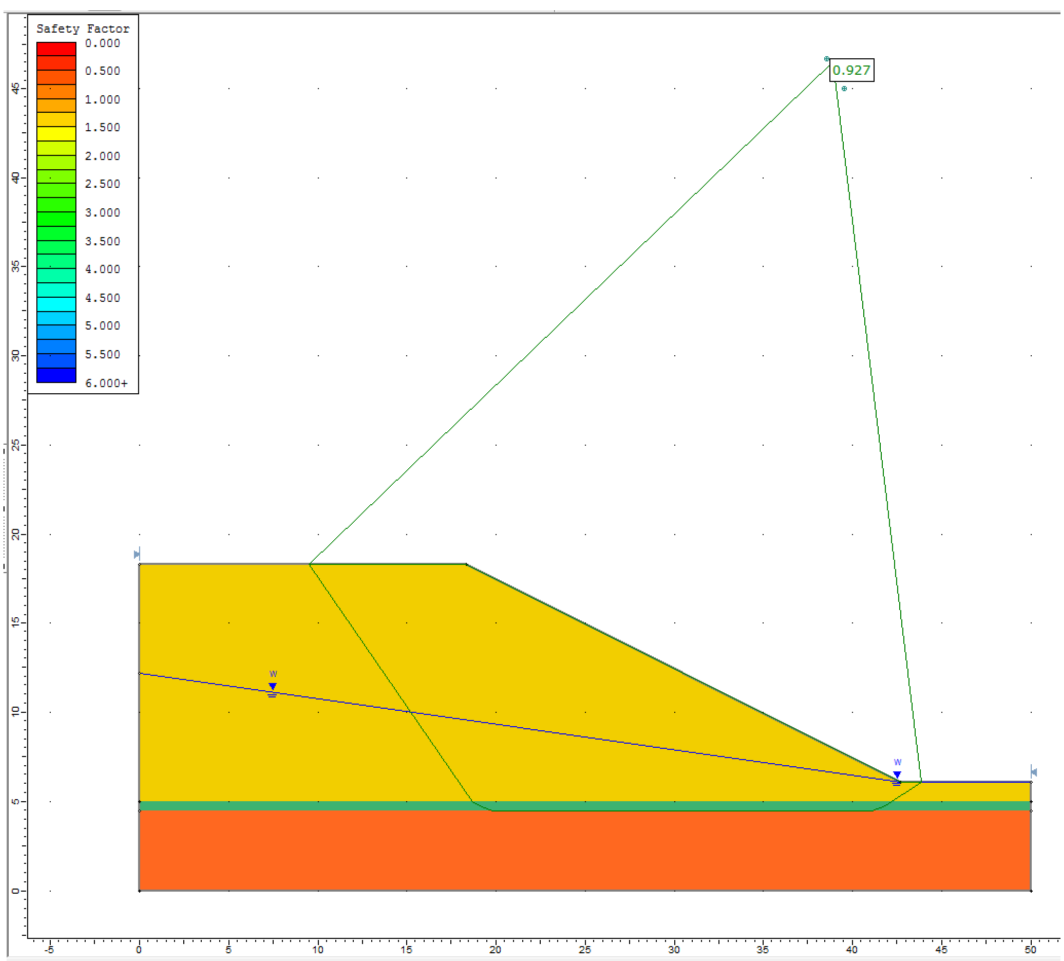


Figure 16.4.4 – Slide Solution Using the GLE Method

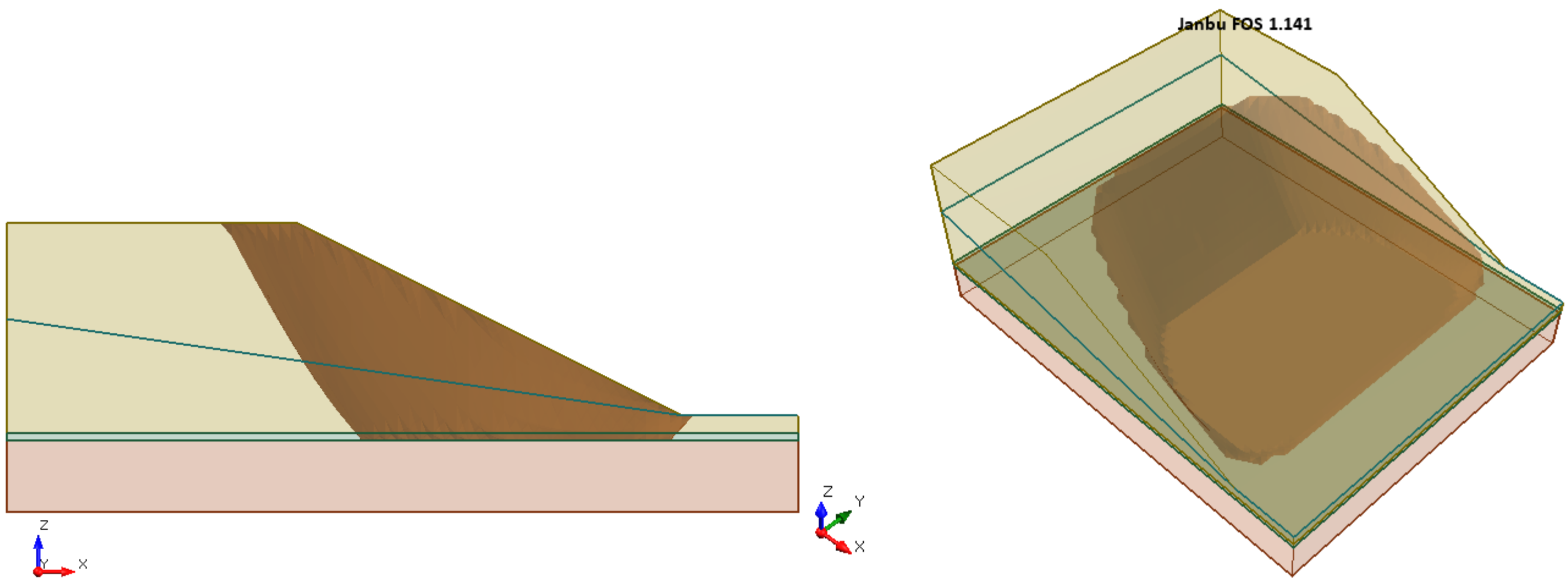


Figure 16.4.5 – Slide3 Solution Using the Janbu Method

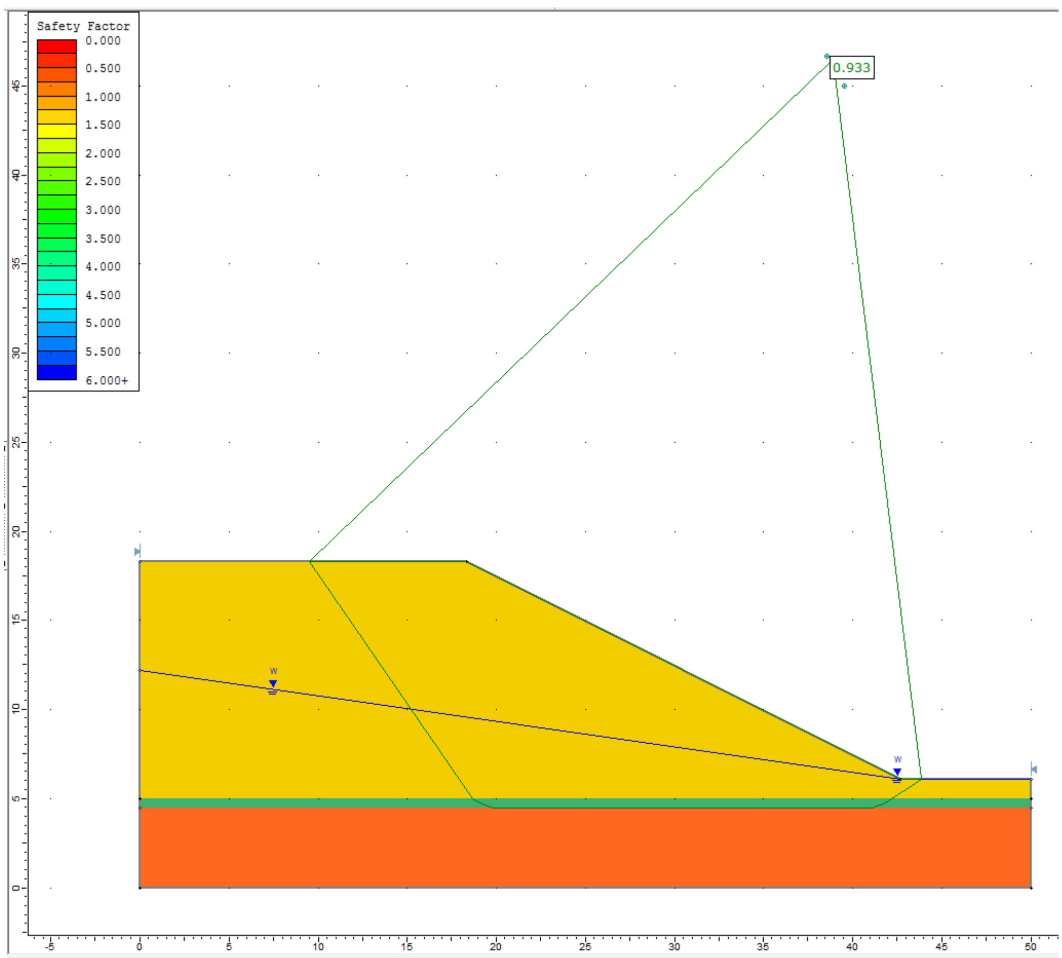


Figure 16.4.6 – Slide Solution Using the Janbu Method

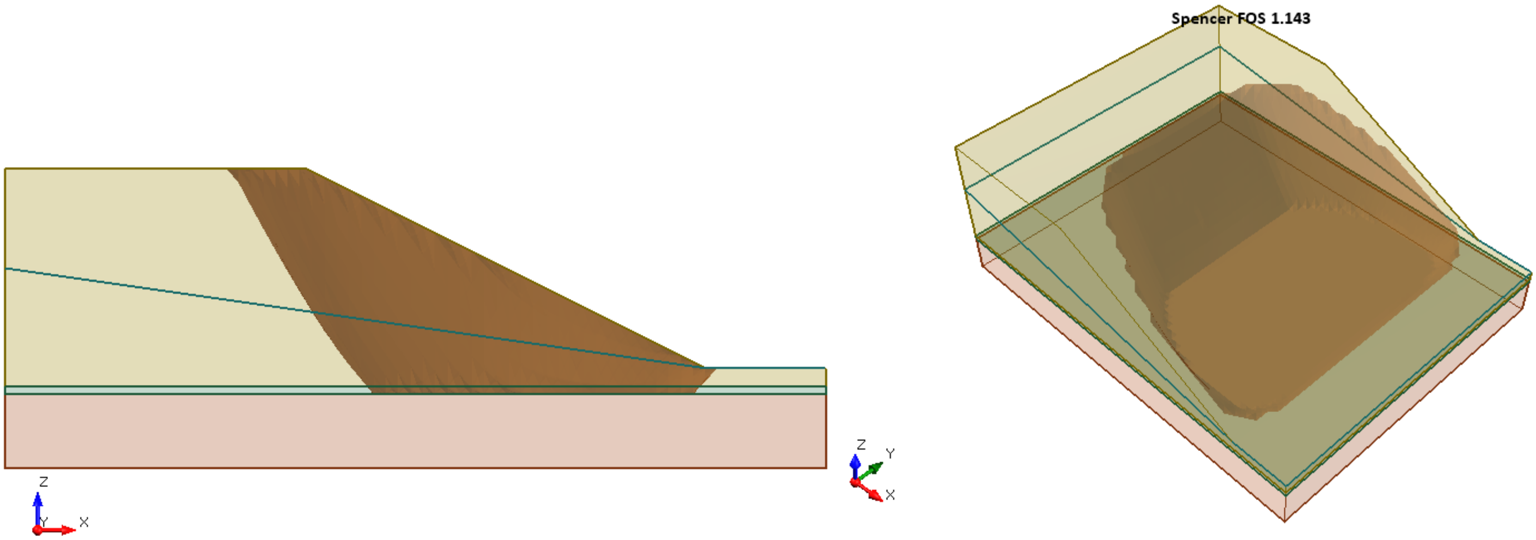


Figure 16.4.7 – Slide3 Solution Using the Spencer Method

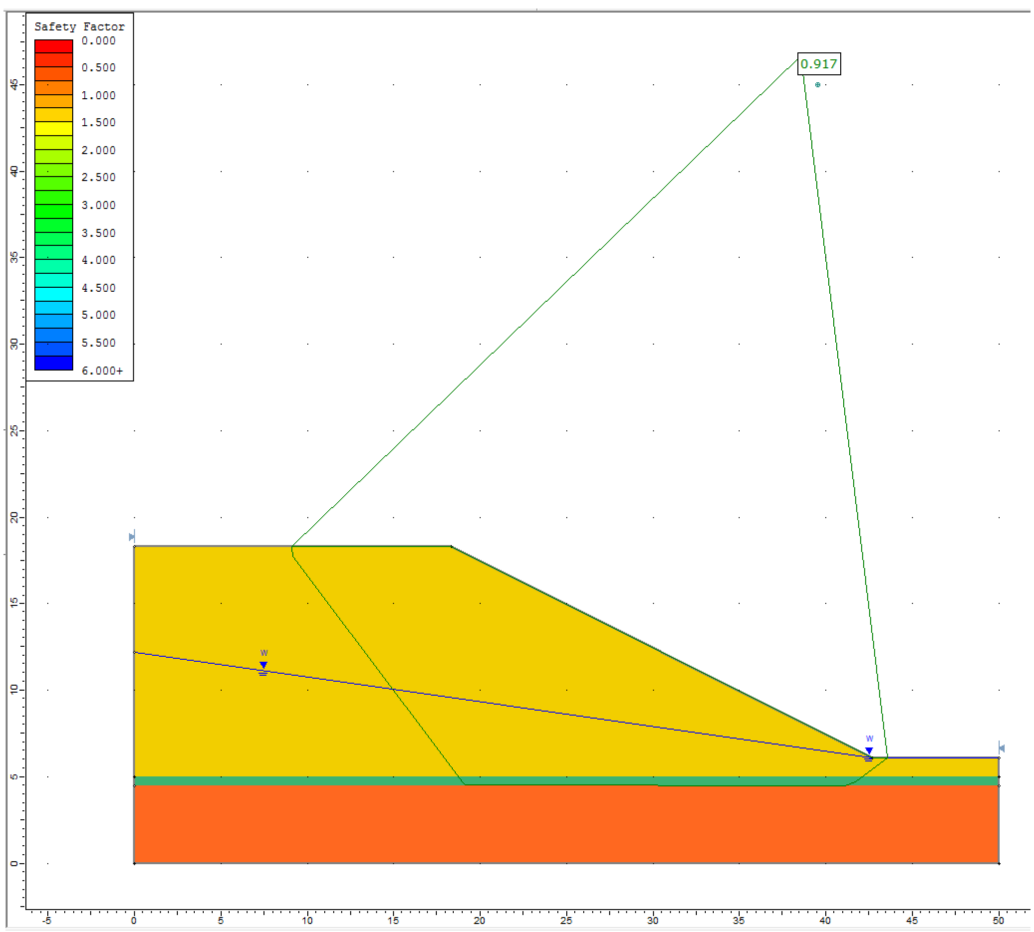


Figure 16.4.8 – Slide Solution Using the Spencer Method

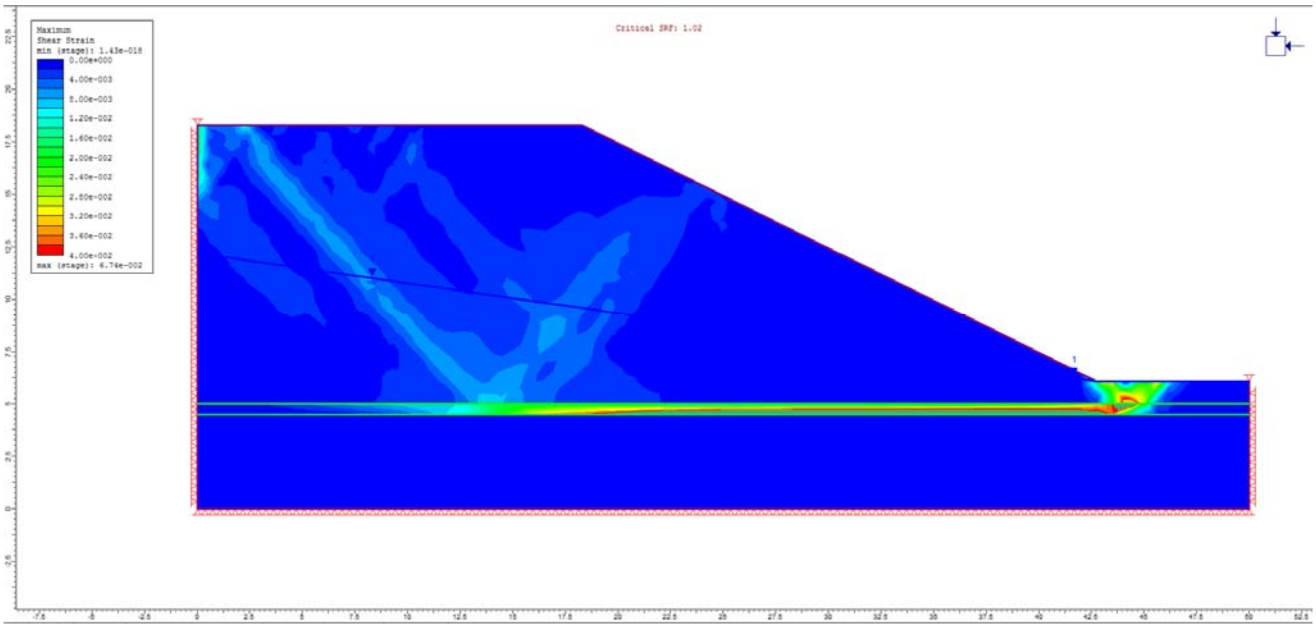


Figure 16.4.9 – RS2 Maximum Shear Strain

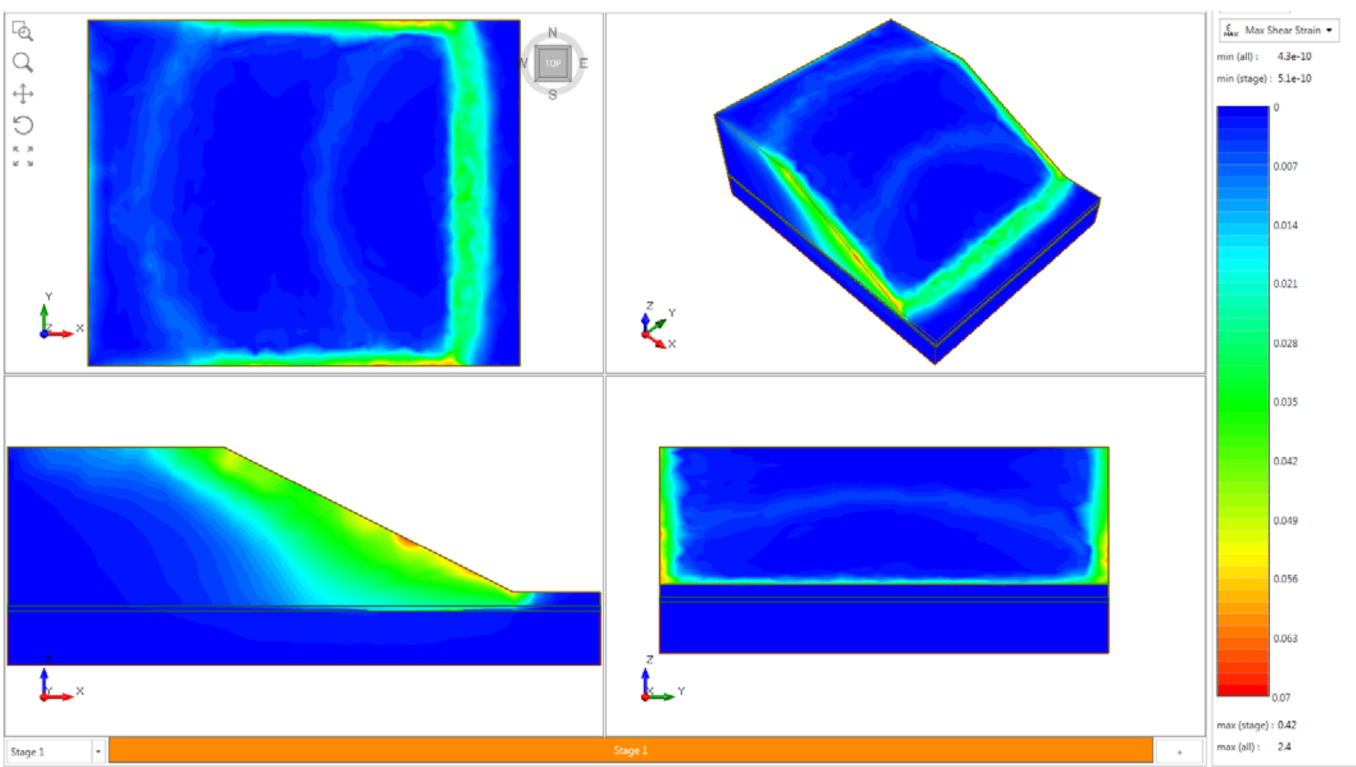


Figure 16.4.10 – RS3 Maximum Shear Strain

2D extruded, (2) materials, ellipsoidal with SA

17.1 Introduction

This model is taken from Carrión et al. and is a non-homogeneous slope analyzed using Numerical Limit Analysis and Elasto-plastic Analysis (2017).

17.2 Problem Description

The non-homogeneous slope geometry in the XZ plane is shown as Figure 17. This slope geometry will be extruded 40m in the Y direction. The material properties of both the top and bottom layers are shown in Table 17.1. This problem has no pore pressure.

17.3 Geometry and Properties

Table 17.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Lower Layer	20	30	18
Upper Layer	15	25	17

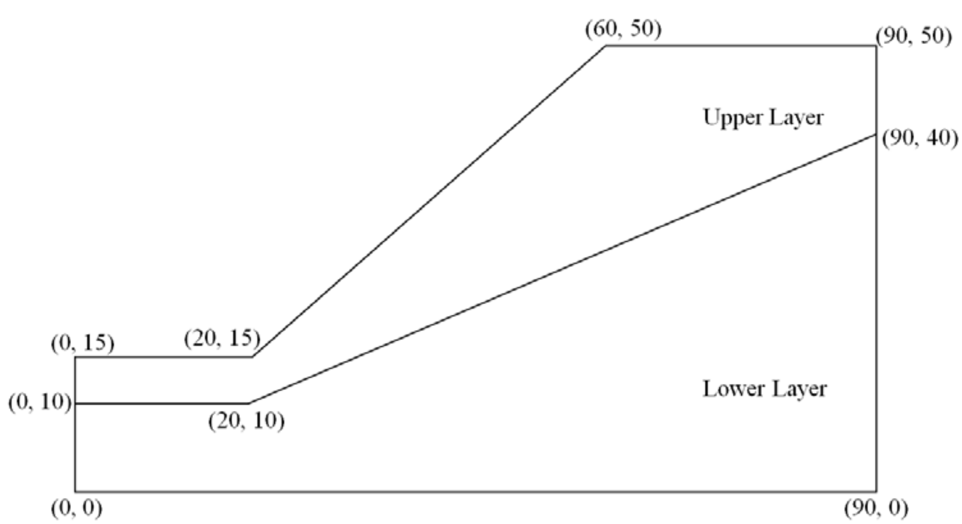


Figure 17

17.4 Results

Table 17.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	0.988	0.900	1.04	0.9
GLE	0.985	0.849		
Janbu	0.941	0.907		
Spencer	0.986	0.895		

Referee: 0.98, 1.11 [Carrión et al., 2017]

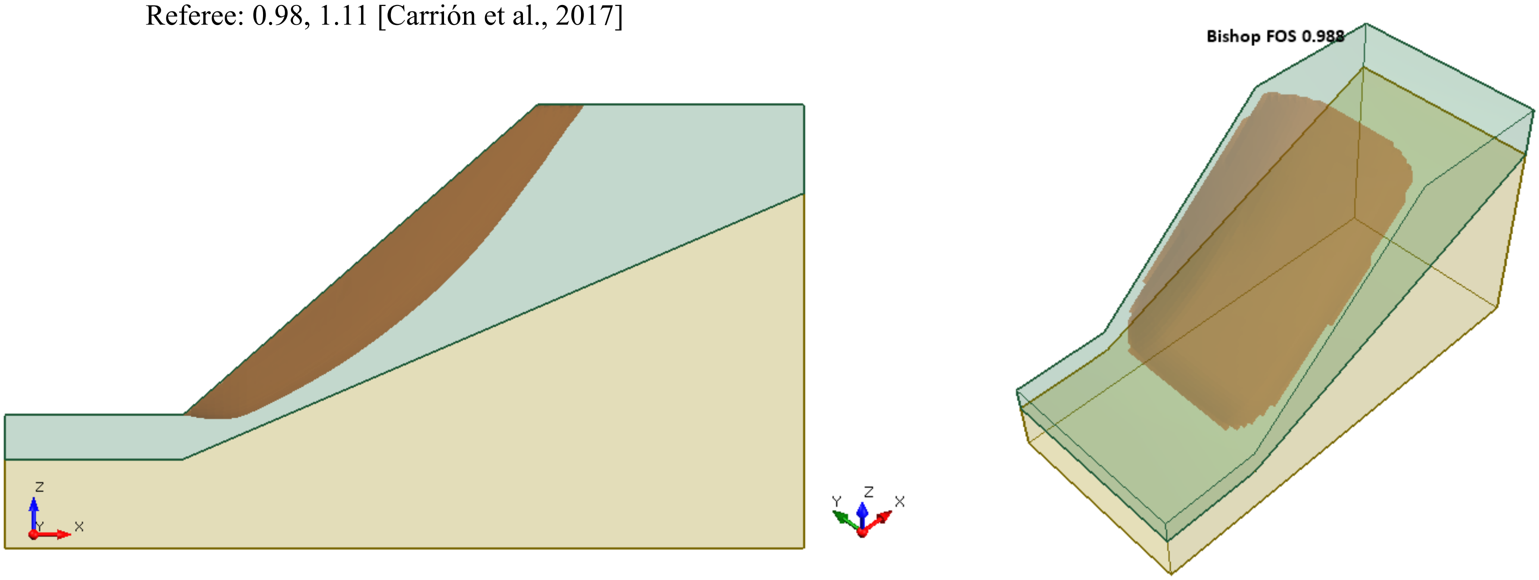


Figure 17.4.1 – Slide3 Solution Using the Bishop Method

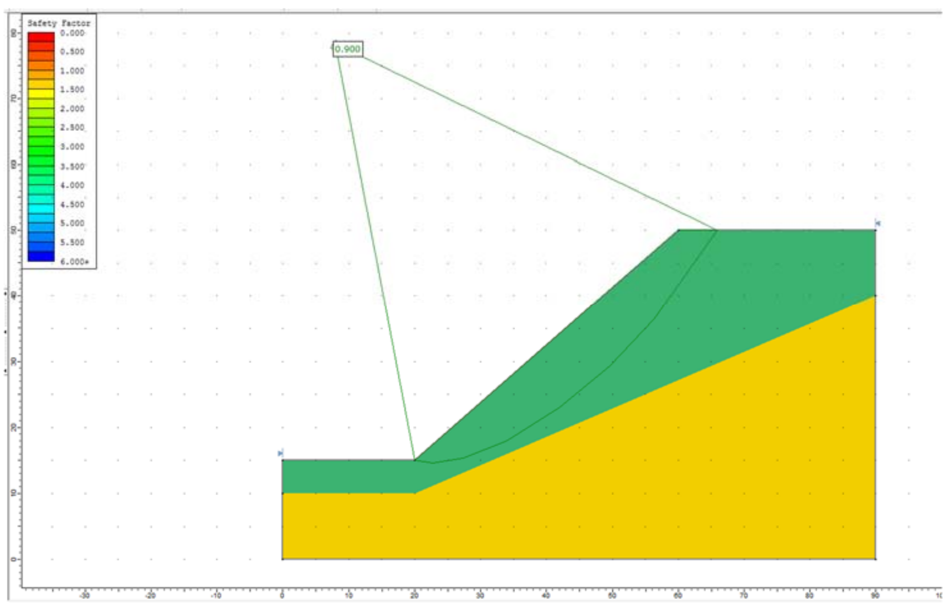


Figure 17.4.2 – Slide Solution Using the Bishop Method

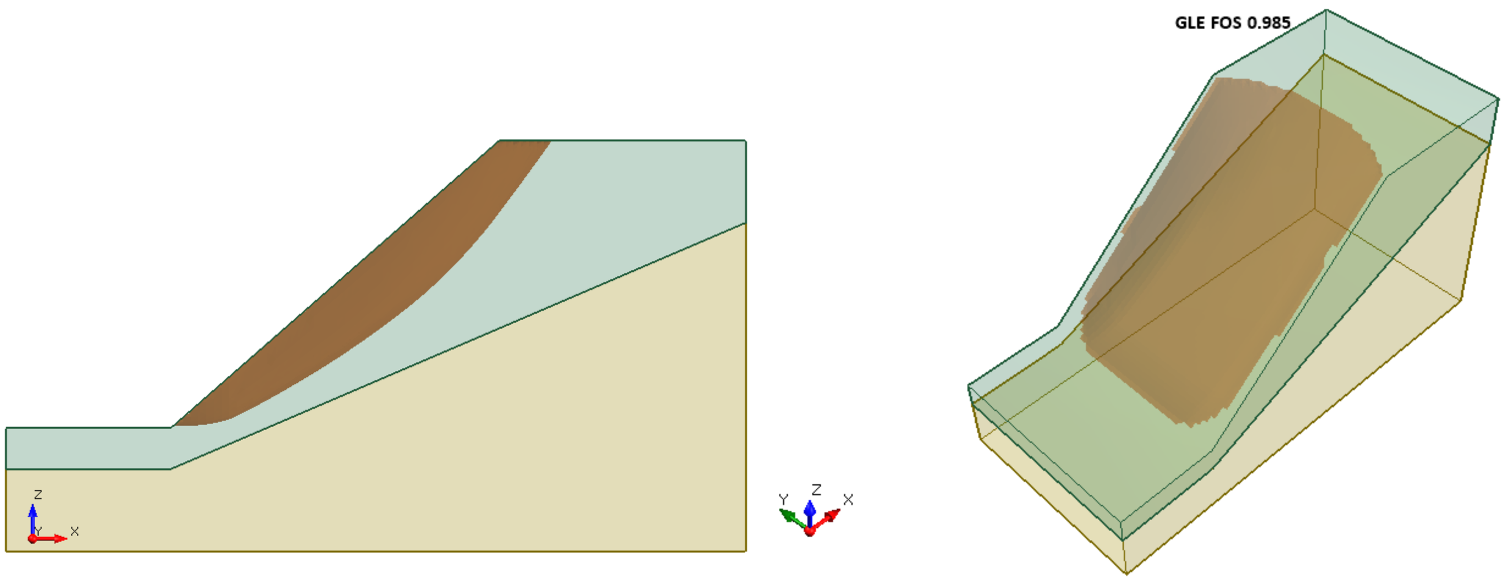


Figure 17.4.3 – Slide3 Solution Using the GLE Method

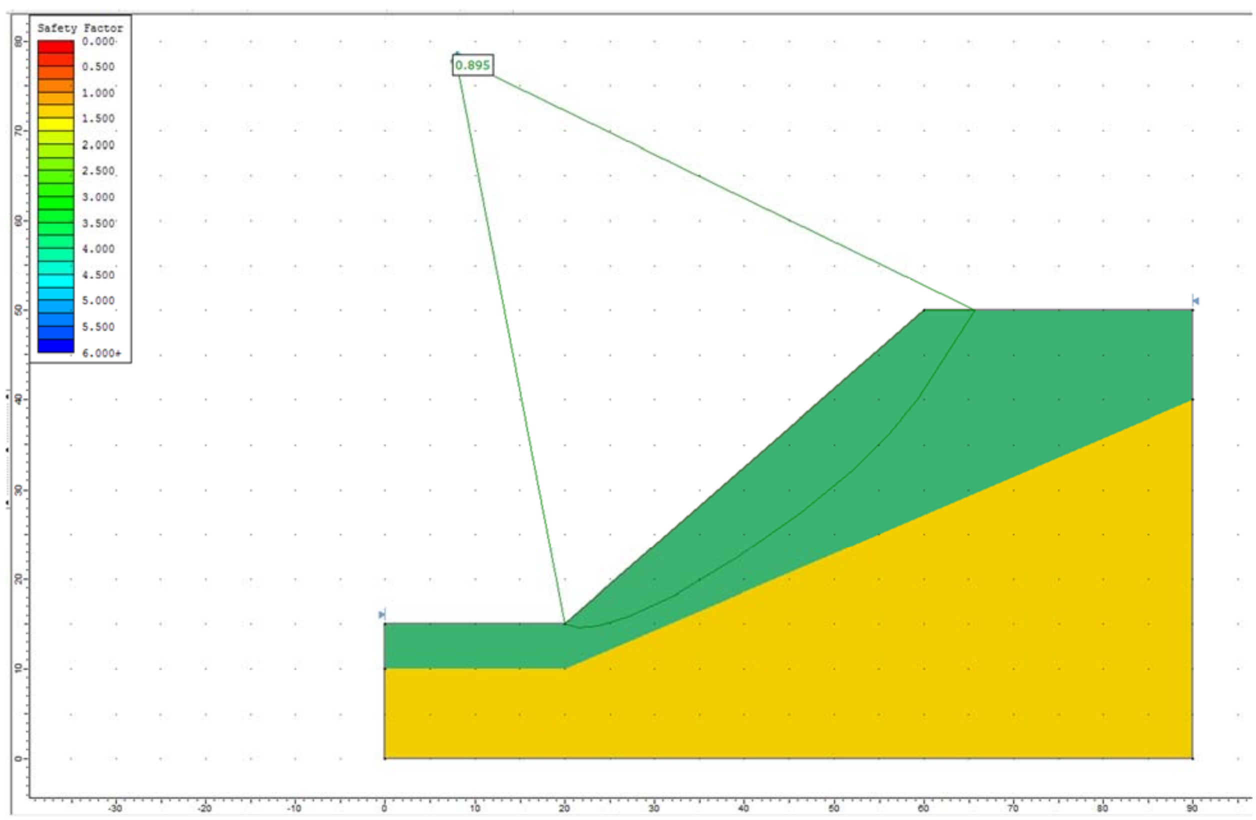


Figure 17.4.4 – Slide Solution Using the GLE Method

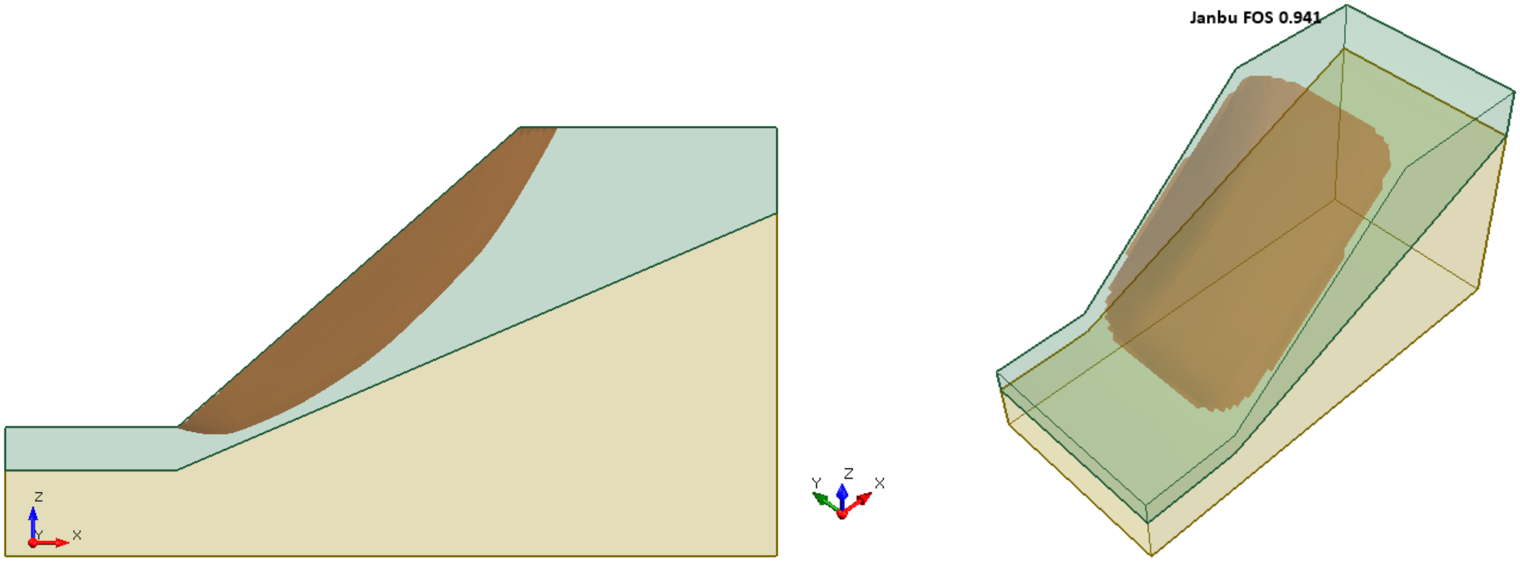


Figure 17.4.5 – Slide3 Solution Using the Janbu Method

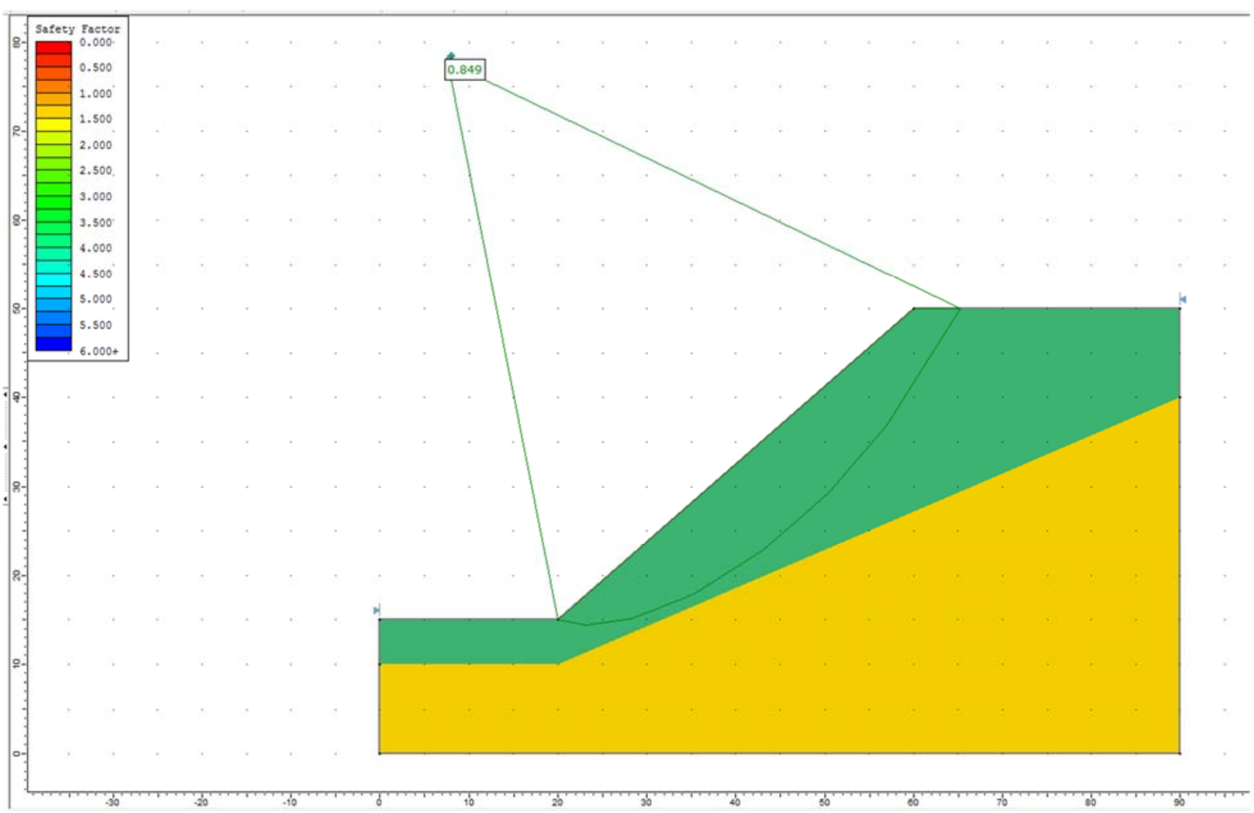


Figure 17.4.6 – Slide Solution Using the Janbu Method

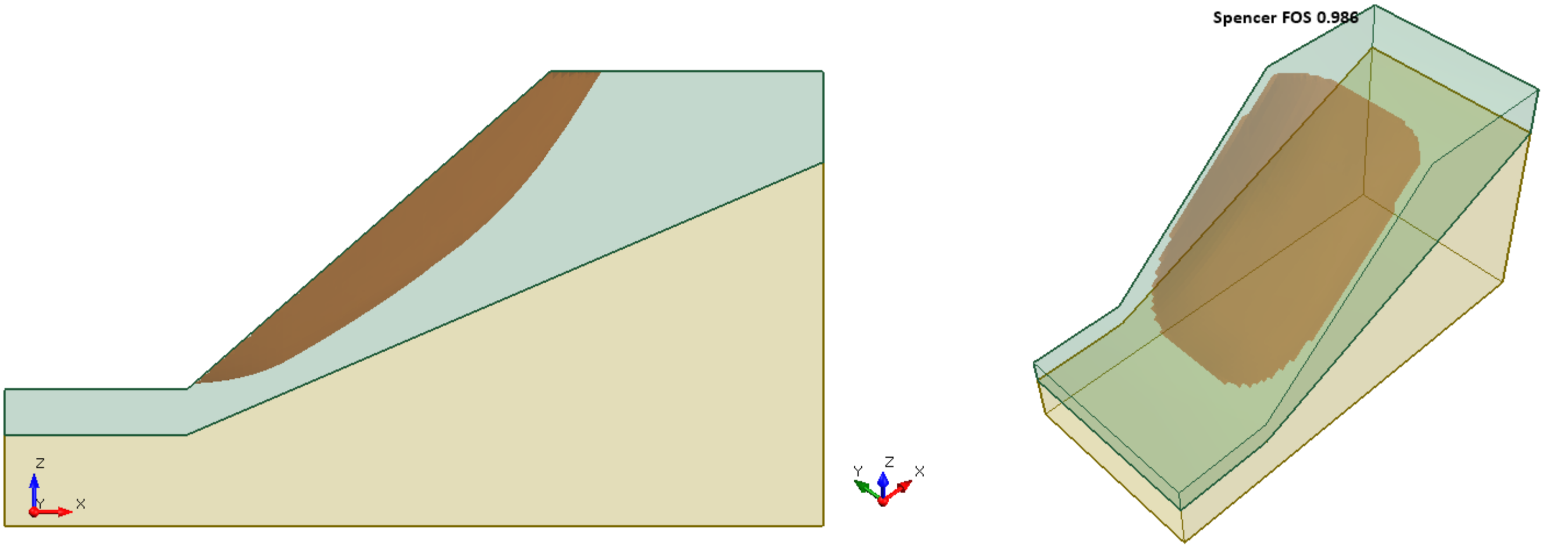


Figure 17.4.7 – Slide3 Solution Using the Spencer Method

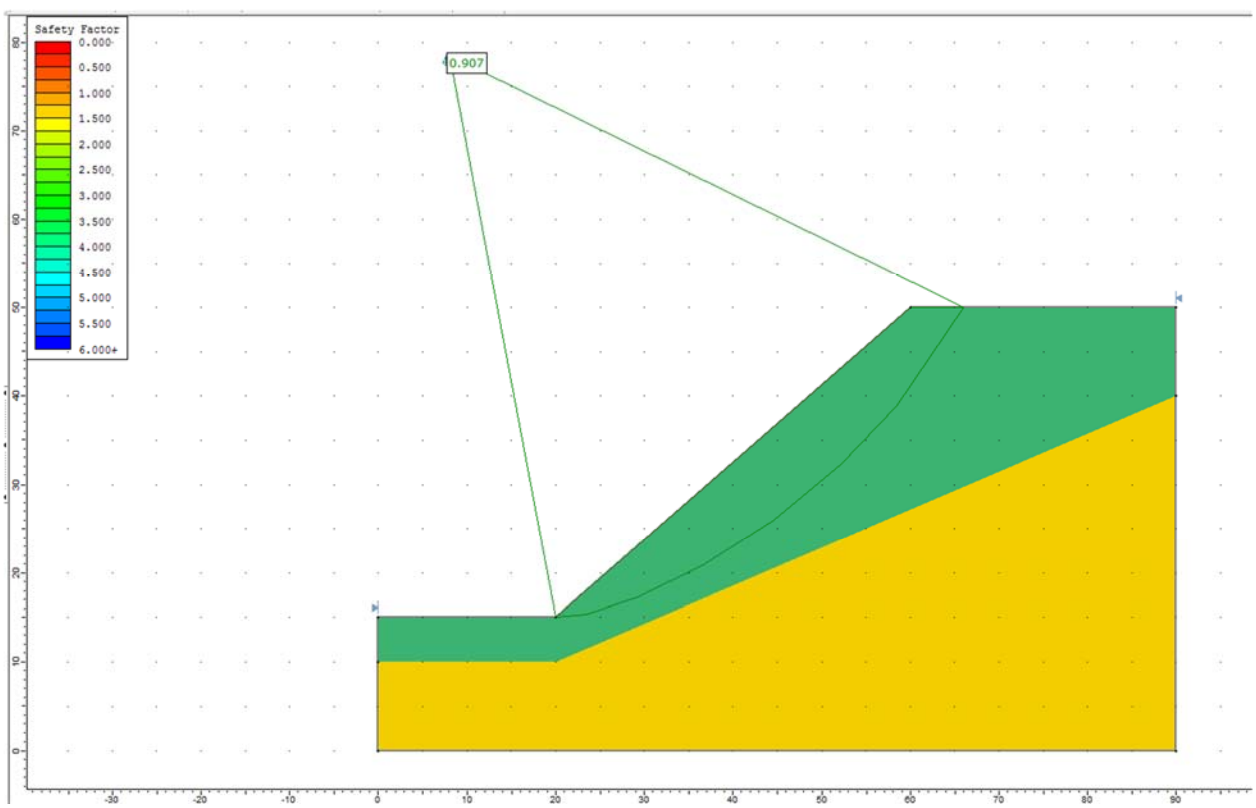


Figure 17.4.8 – Slide Solution Using the Spencer Method

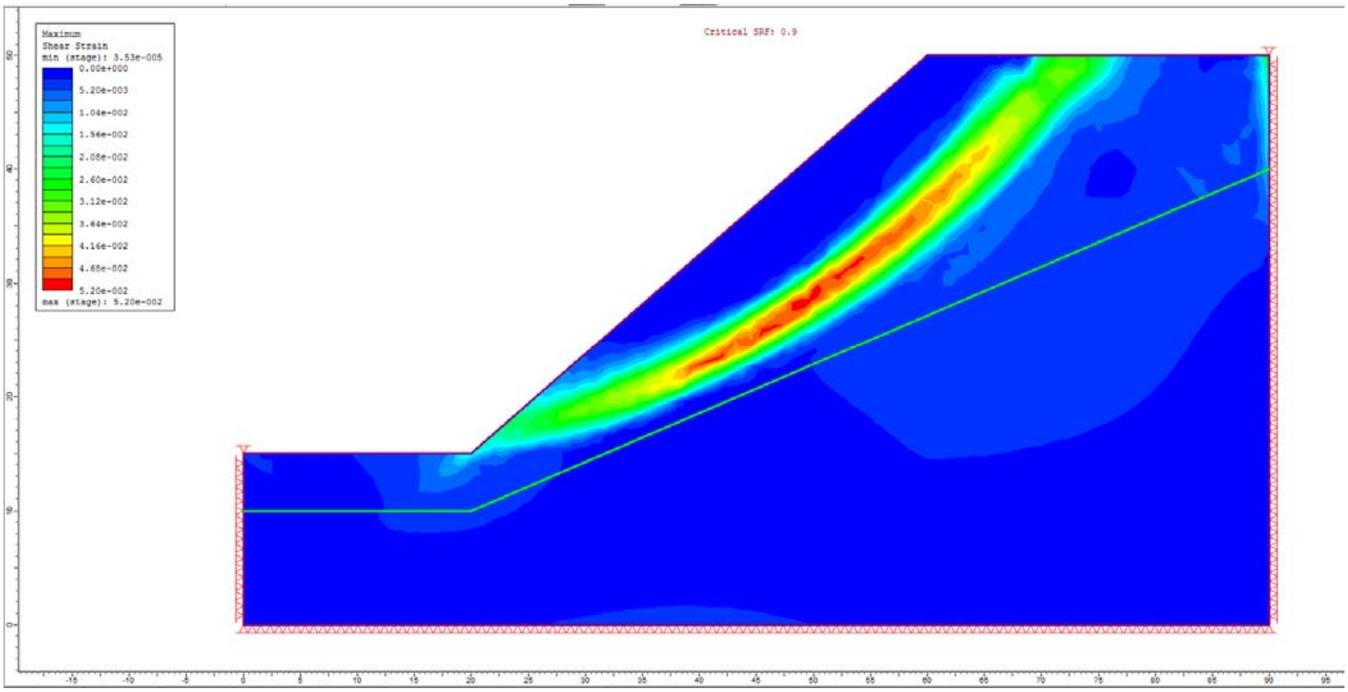


Figure 17.4.9 – RS2 Maximum Shear Strain

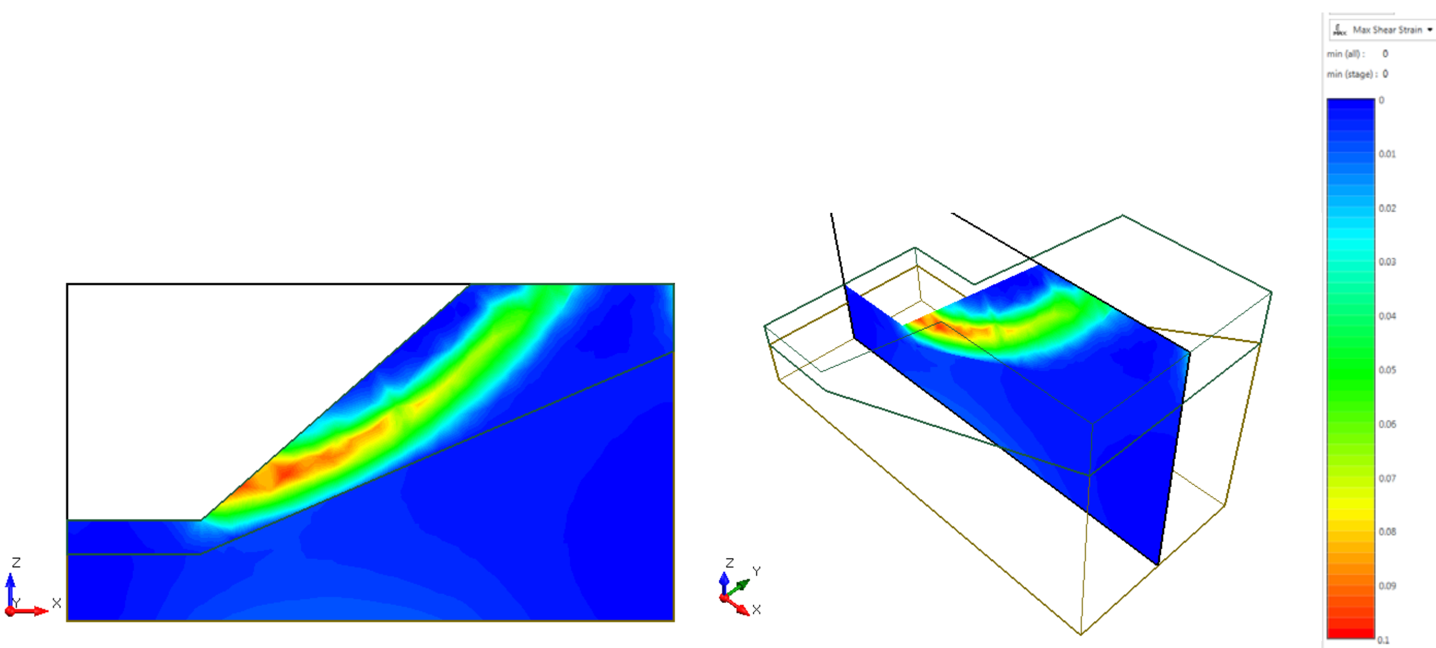


Figure 17.4.10 – RS3 Maximum Shear Strain

2D extruded, homogeneous, ellipsoidal with SA

18.1 Introduction

This model is taken from Carrión et al. and is a homogeneous slope analyzed using Numerical Limit Analysis and Elasto-plastic Analysis (2017).

18.2 Problem Description

The simple homogeneous slope geometry in the XZ plane is shown as Figure 18. This slope geometry will be extruded 10m in the Y direction. The material properties of both the top and bottom layers are shown in Table 18.1. This problem has no pore pressure. A slope limit is defined by surface as the top face and the slope face.

18.3 Geometry and Properties

Table 18.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	10	25	18

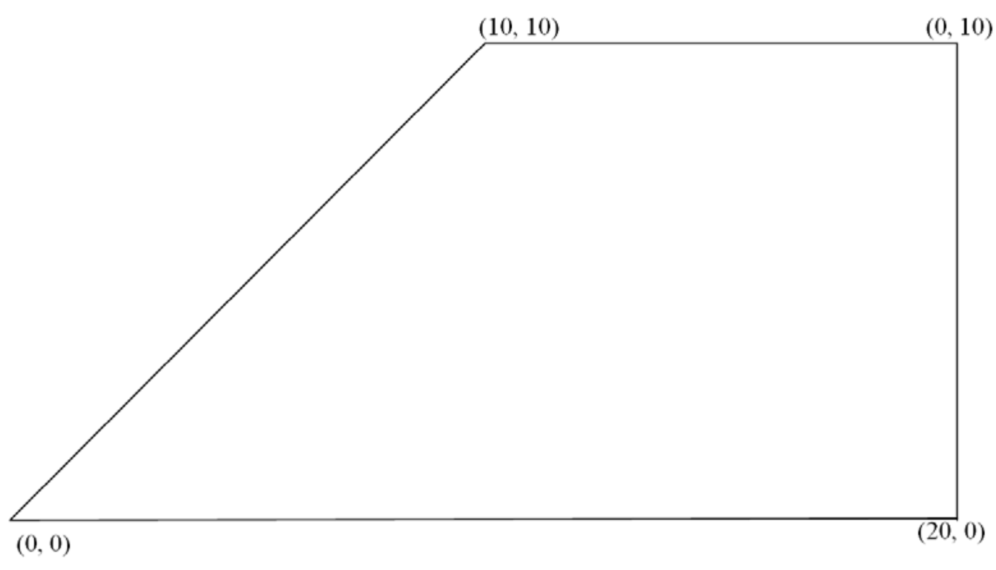


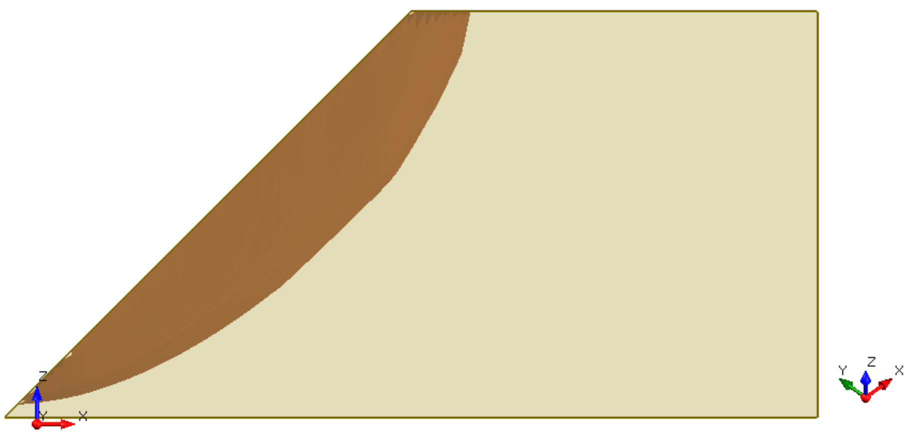
Figure 18

18.4 Results

Table 18.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.225	1.068	1.4	1.07
GLE	1.226	1.081		
Janbu	1.177	1.016		
Spencer	1.211	1.089		

Referee: 1.35, 1.46 [Carrión et al., 2017]



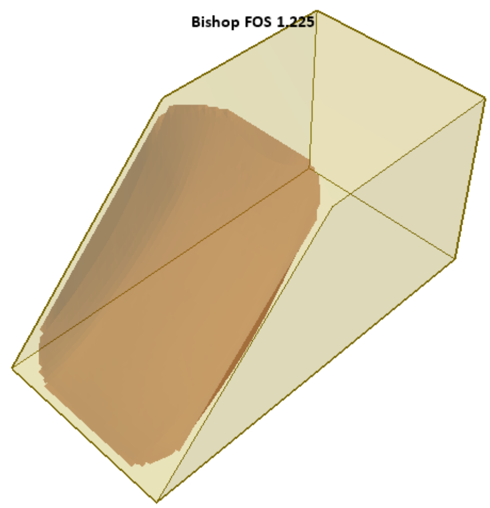


Figure 18.4.1 – Slide3 Solution Using the Bishop Method

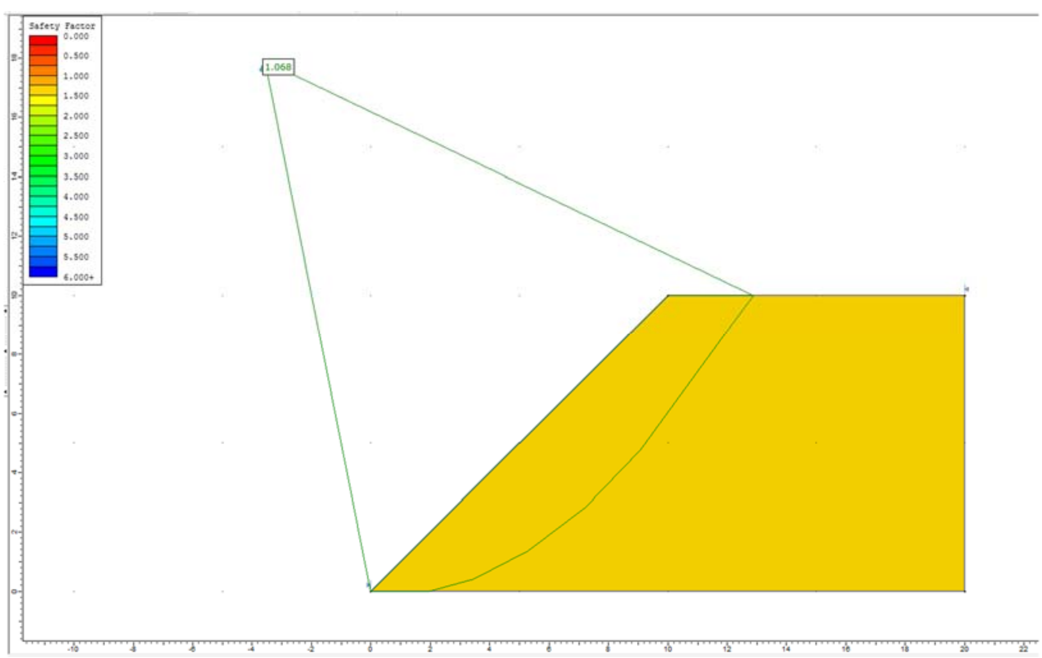


Figure 18.4.2 – Slide Solution Using the Bishop Method

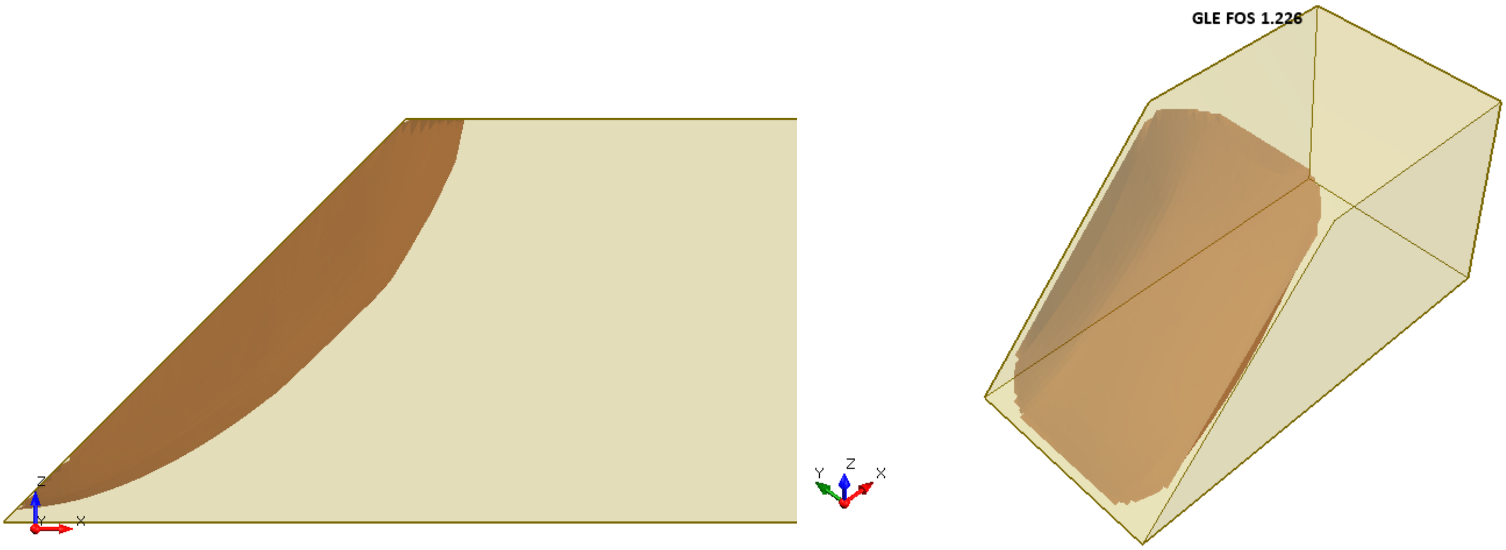


Figure 18.4.3 – Slide3 Solution Using the GLE Method

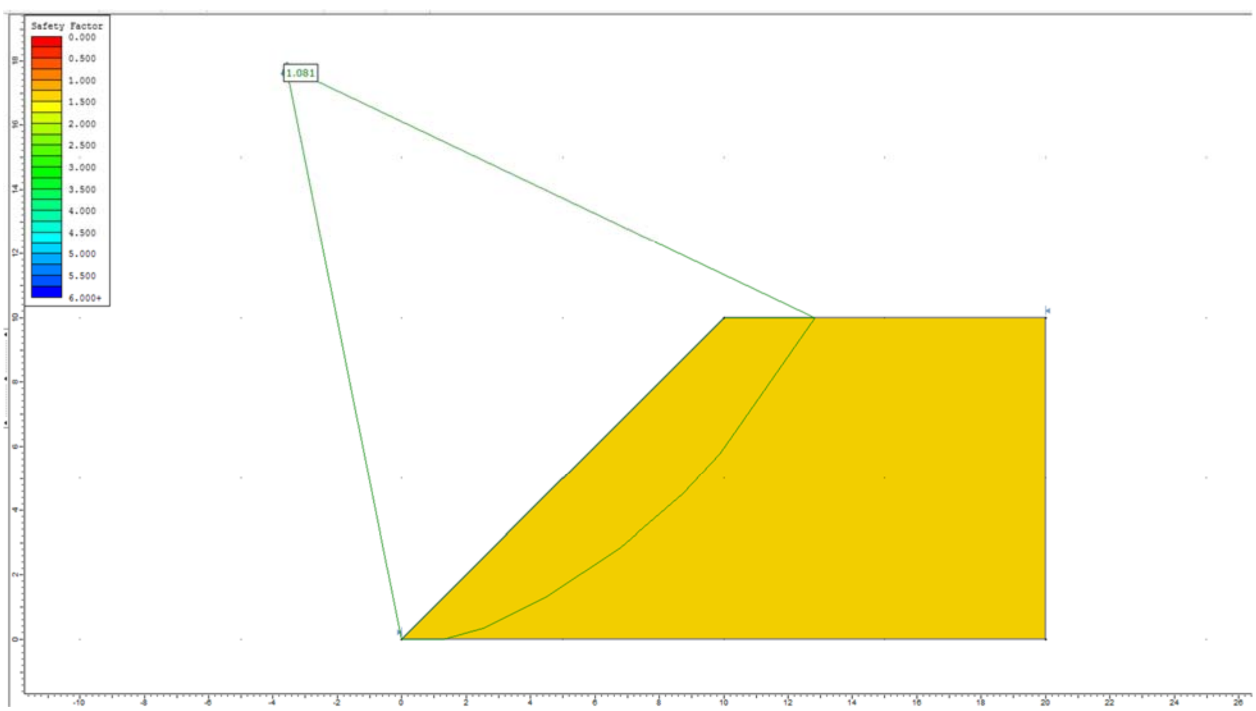


Figure 18.4.4 – Slide Solution Using the GLE Method

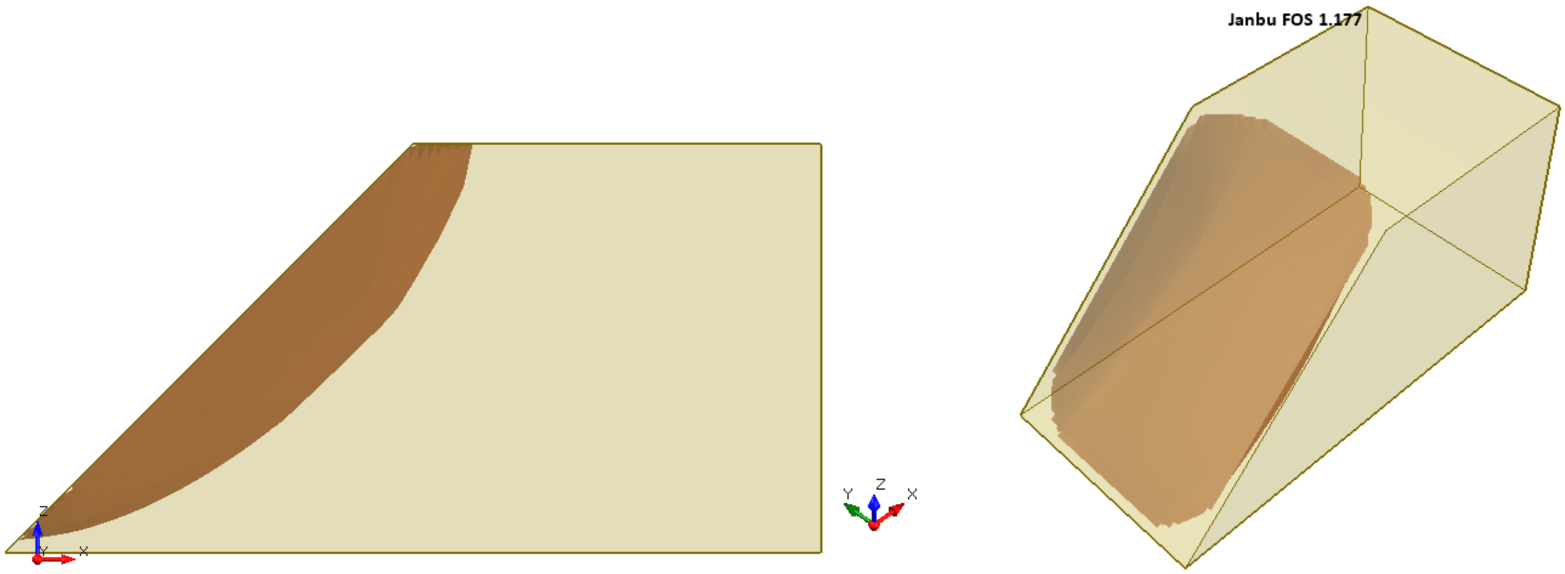


Figure 18.4.5 – Slide3 Solution Using the Janbu Method

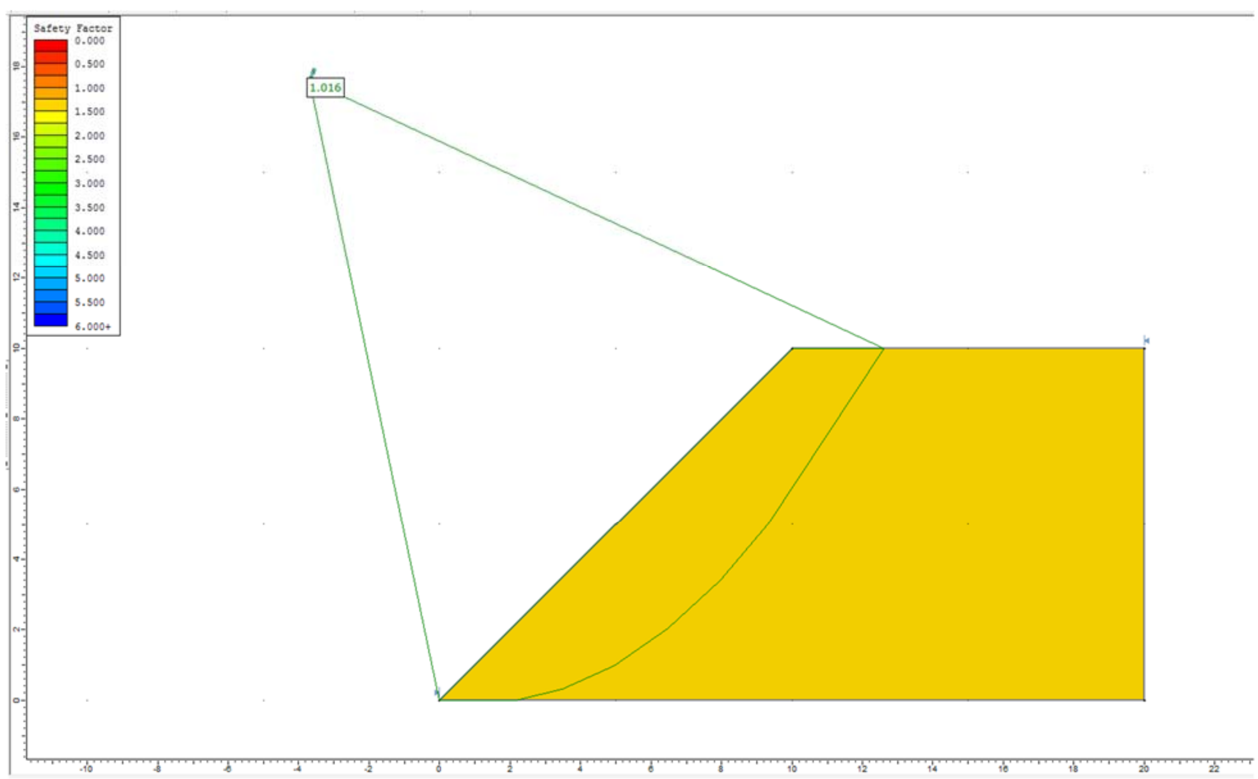


Figure 18.4.6 – Slide Solution Using the Janbu Method

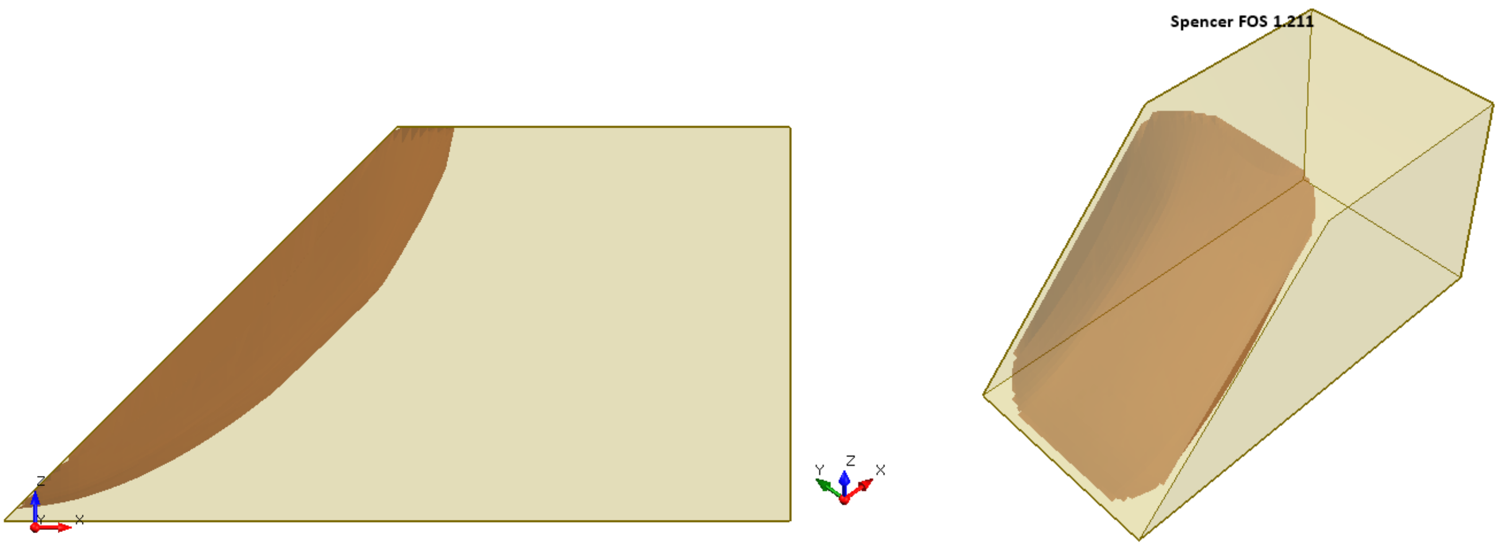


Figure 18.4.4 – Slide3 Solution Using the Spencer Method

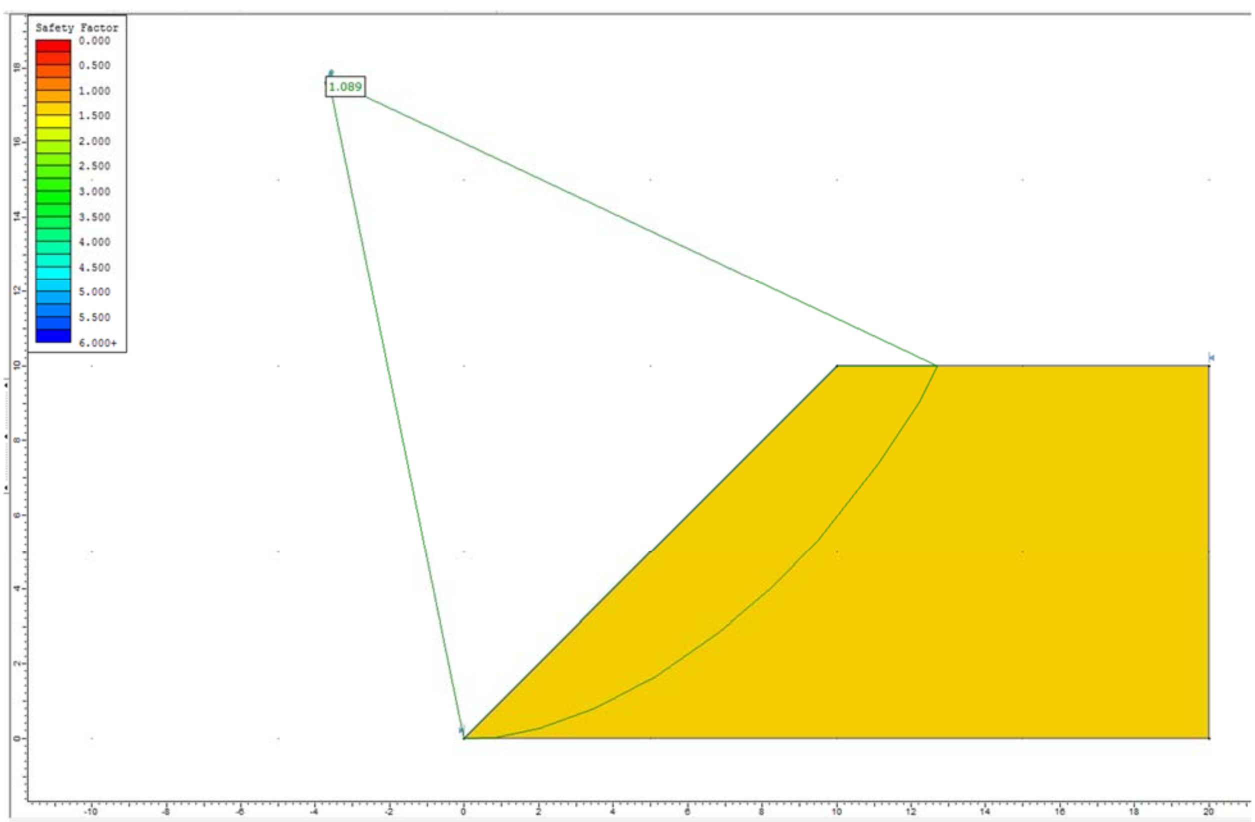


Figure 18.4.8 – Slide Solution Using the Spencer Method

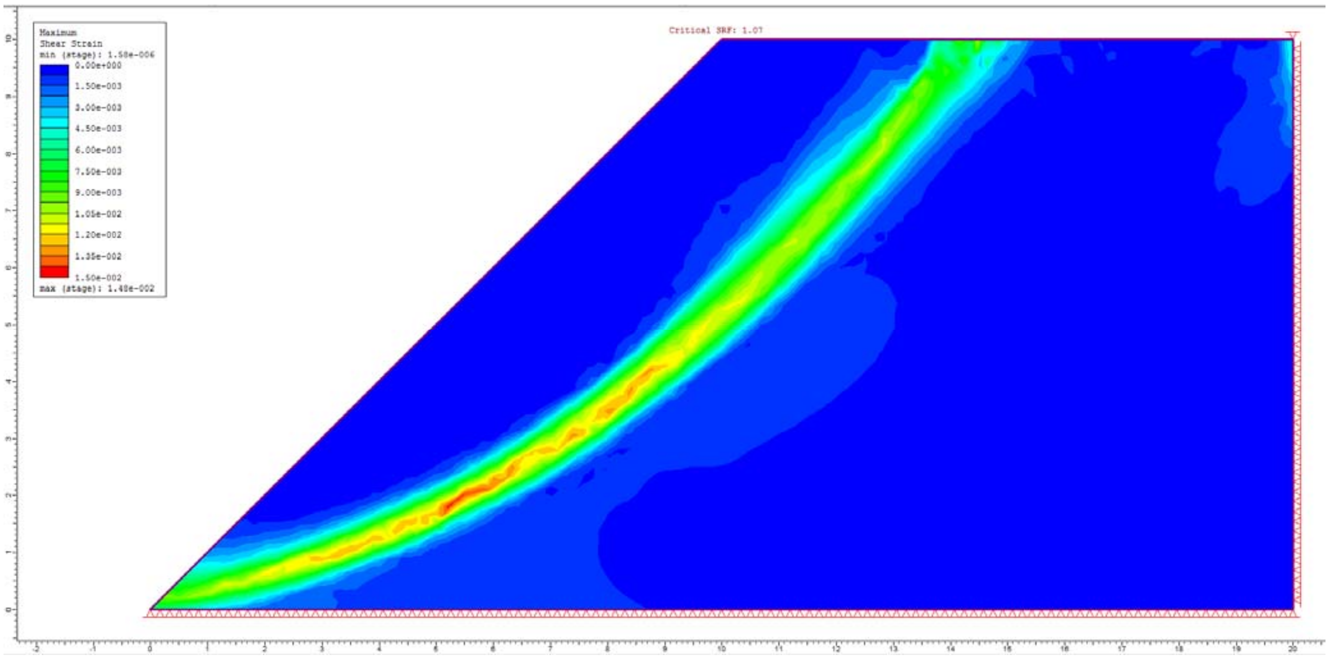


Figure 18.4.9 – RS2 Maximum Shear Strain

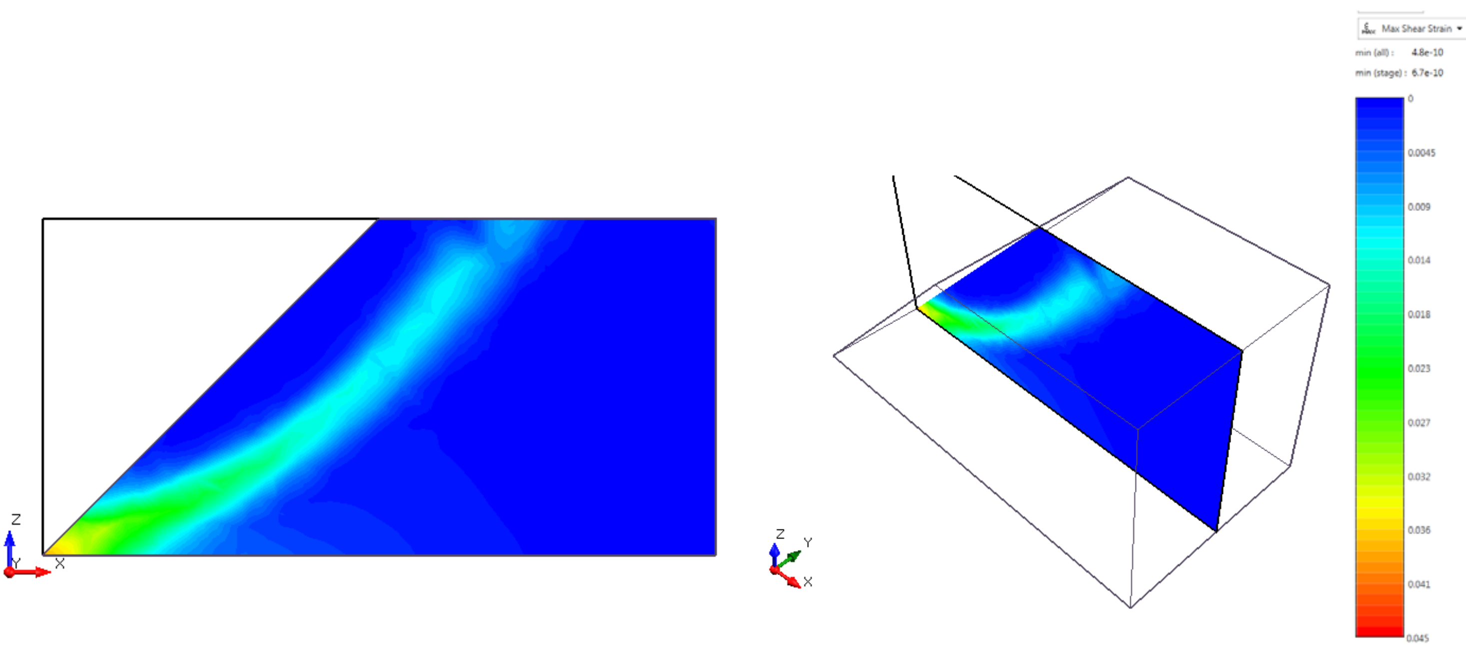


Figure 18.4.10 – RS3 Maximum Shear Strain

2D extruded, homogeneous, ellipsoidal with SA

19.1 Introduction

This model is the first example analyzed by Kalatehjari et al. (2014). Particle Swarm Optimization and LEM were used to find the critical slip surface.

19.2 Problem Description

This problem is a simple homogeneous slope whose slope geometry in the XZ plane can be found as Figure 19. This geometry will be extruded 100m in the Y direction. The properties of the soil are shown in Table 19.1. This example uses a cuckoo search. Pore pressures are not considered.

19.3 Geometry and Properties

Table 19.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	15	20	17

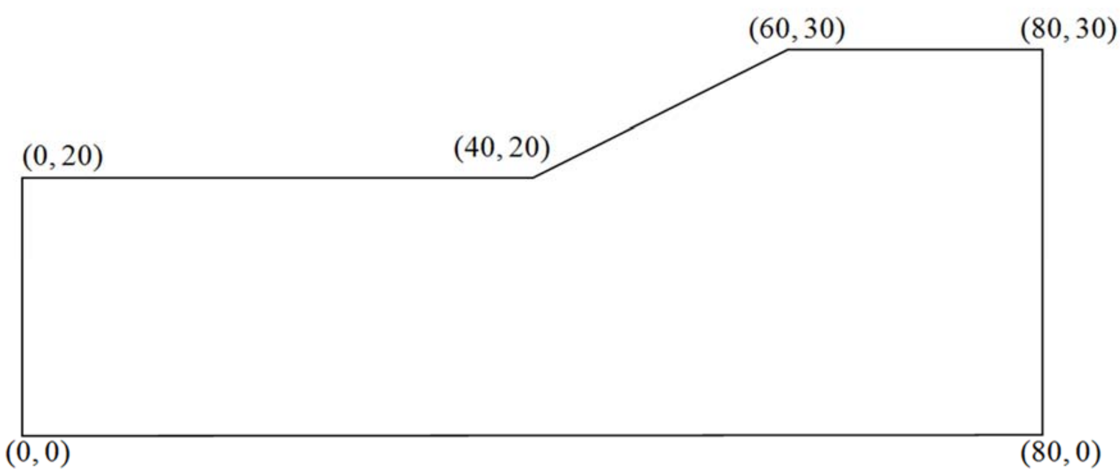


Figure 19

19.4 Results

Table 19.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

<table>
<tr><th>Method</th><th>Slide3</th><th>Slide 7.0</th><th>RS3</th><th>RS2</th></tr>
<tr><td>Bishop</td><td>1.622</td><td>1.636</td><td rowspan="4">2.03</td><td rowspan="4">1.71</td></tr>
<tr><td>GLE</td><td>1.721</td><td>1.674</td></tr>
<tr><td>Janbu</td><td>1.588</td><td>1.543</td></tr>
<tr><td>Spencer</td><td>1.749</td><td>1.692</td></tr>
</table>

Referee: 1.78 [Kalatehjari et al., 2014]

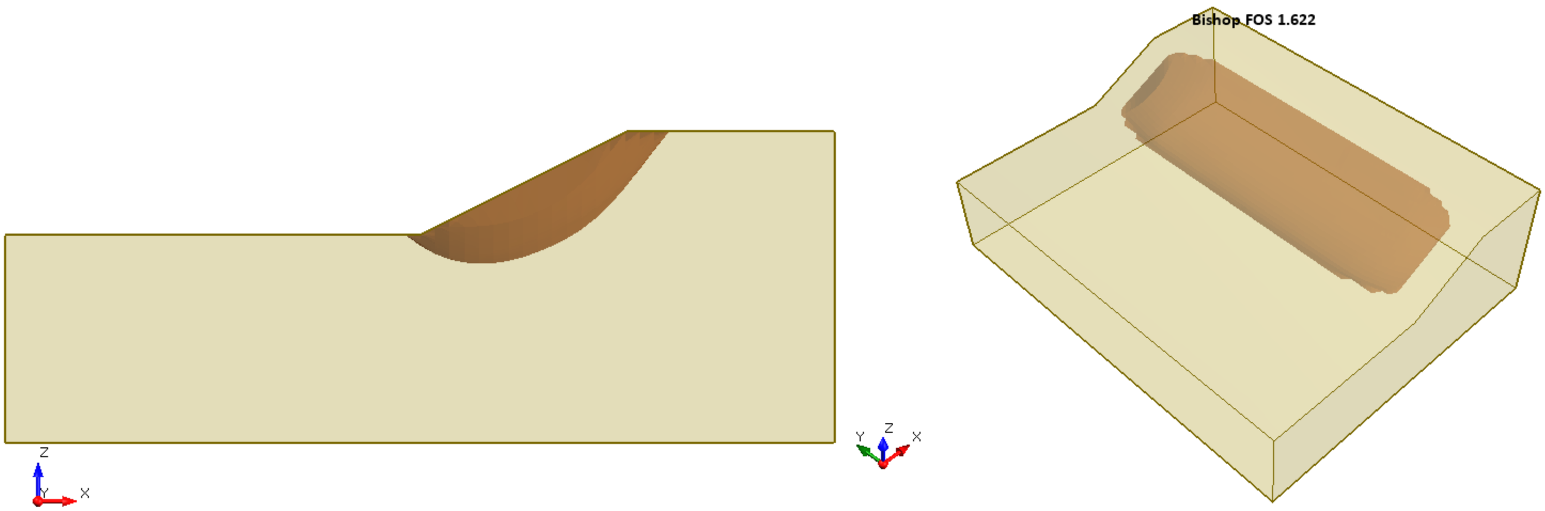


Figure 19.4.1 – Slide3 Solution Using the Bishop Method

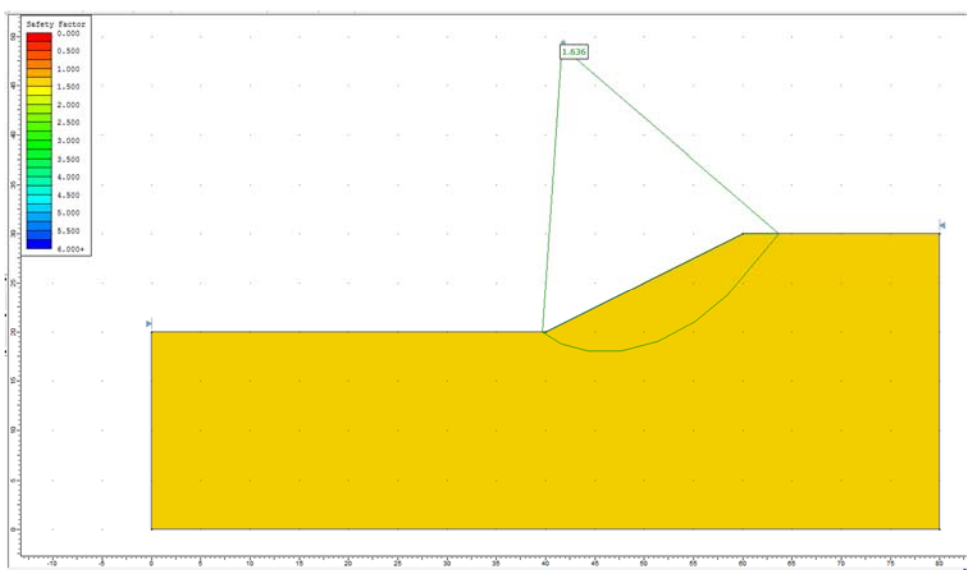


Figure 19.4.2 – Slide Solution Using the Bishop Method

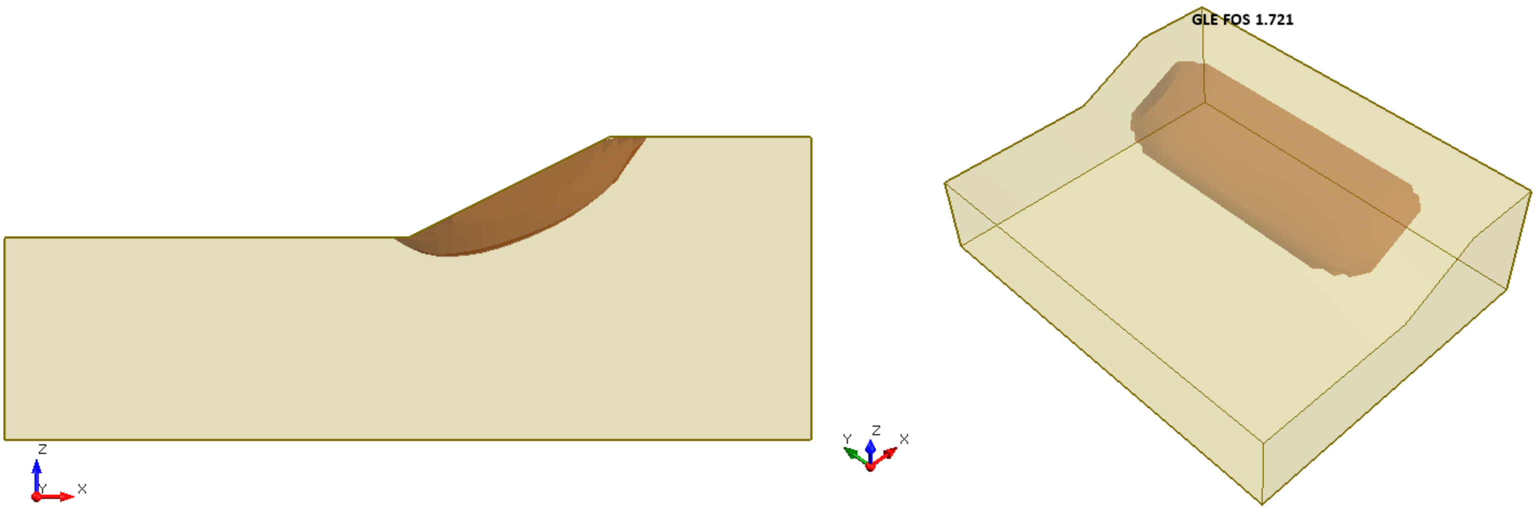


Figure 19.4.3 – Slide3 Solution Using the GLE Method

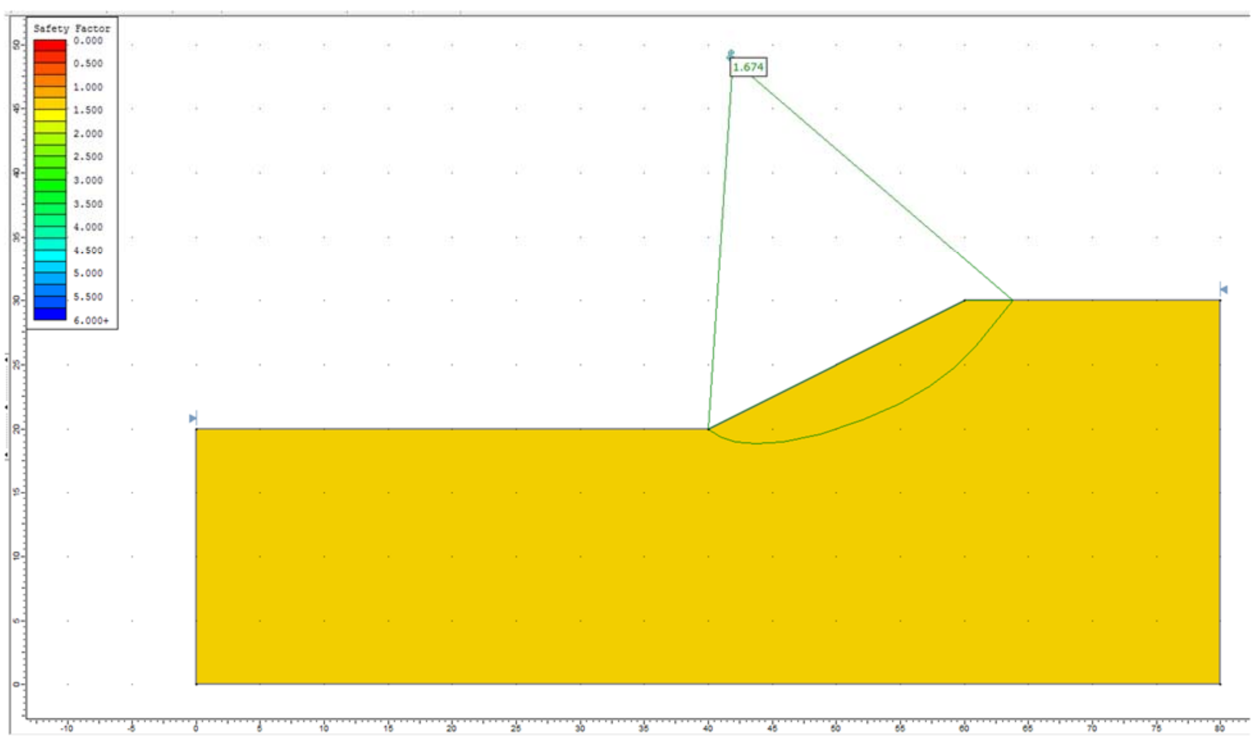


Figure 19.4.4 – Slide Solution Using the GLE Method

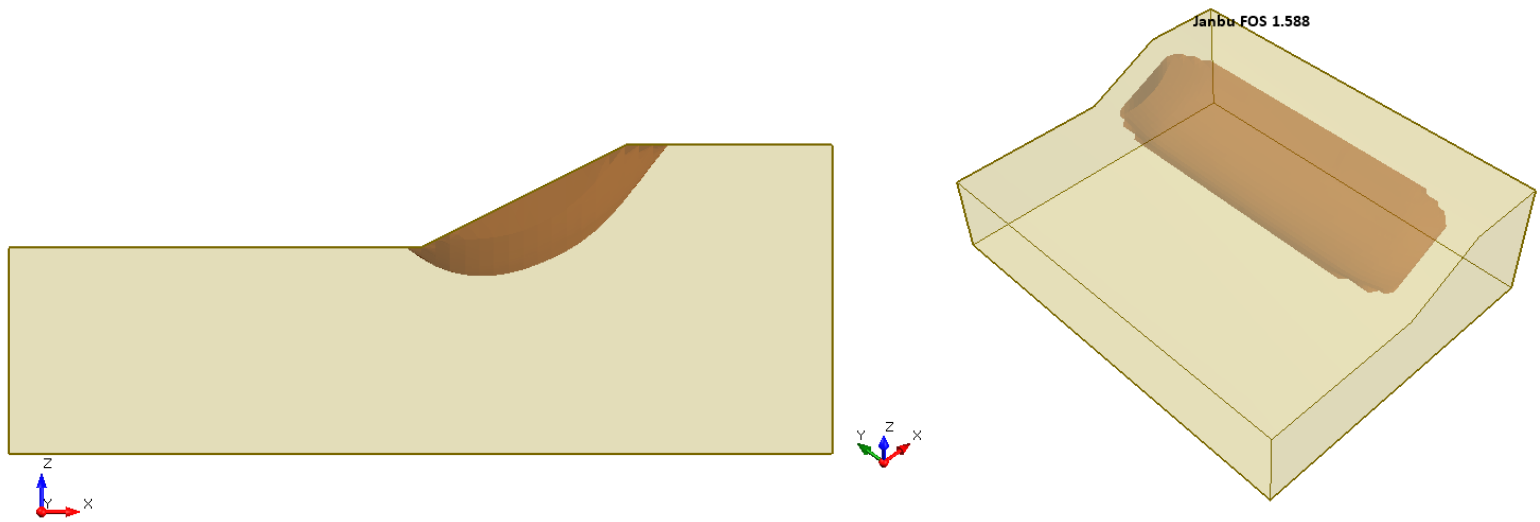


Figure 19.4.5 – Slide3 Solution Using the Janbu Method

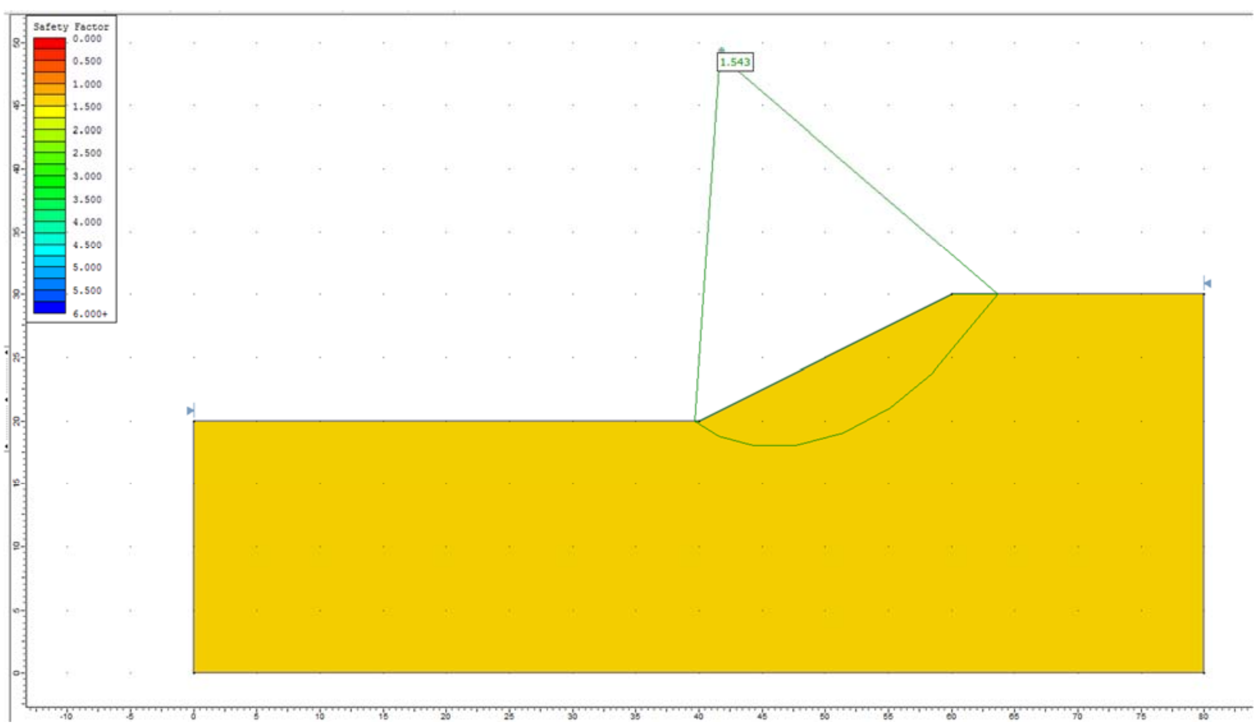


Figure 19.4.6 – Slide Solution Using the Janbu Method

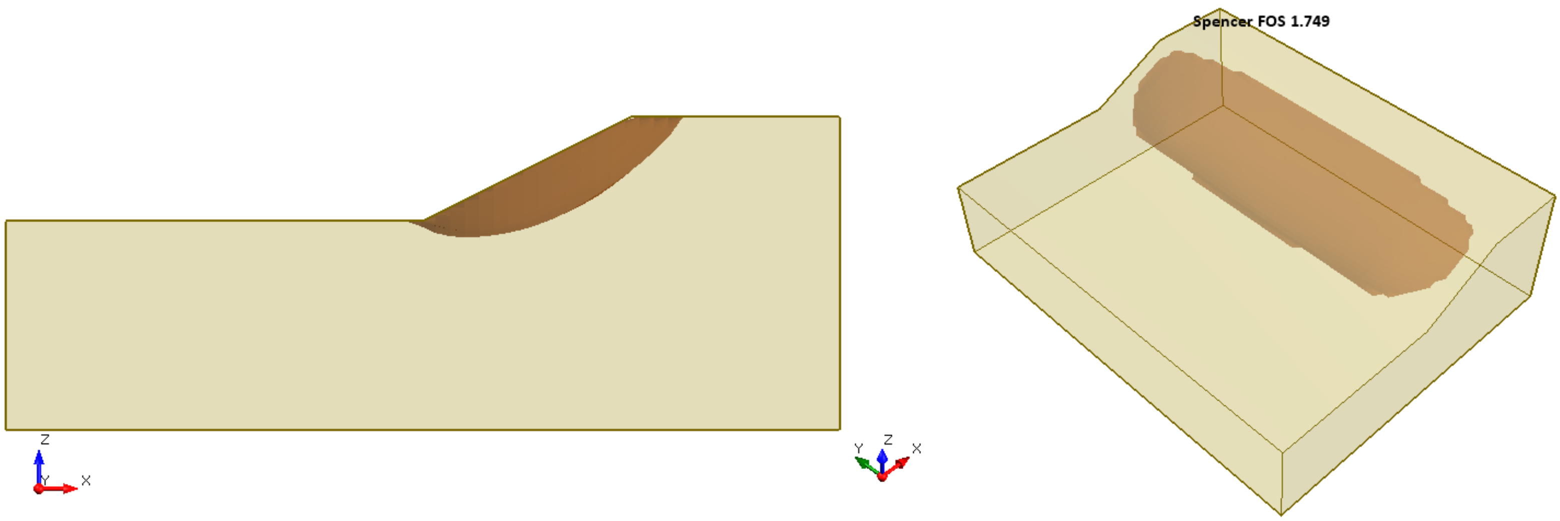


Figure 19.4.7 – Slide3 Solution Using the Spencer Method

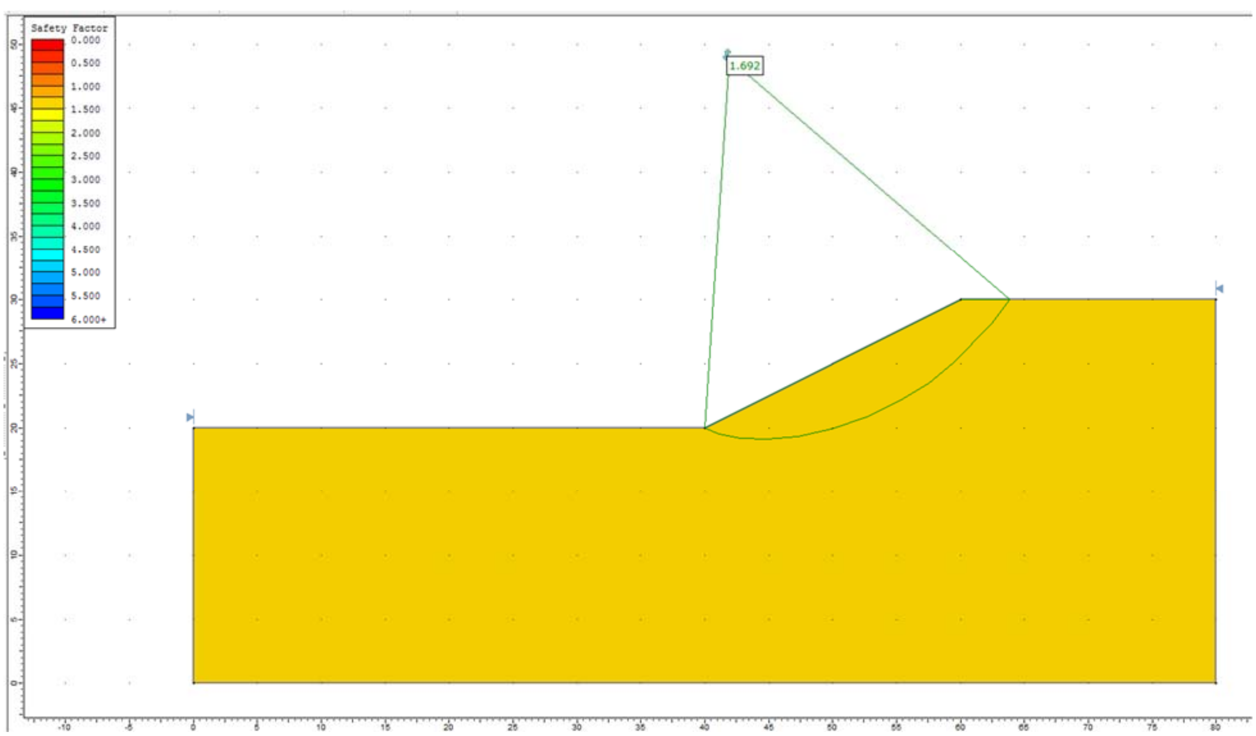


Figure 19.4.8 – Slide Solution Using the Spencer Method

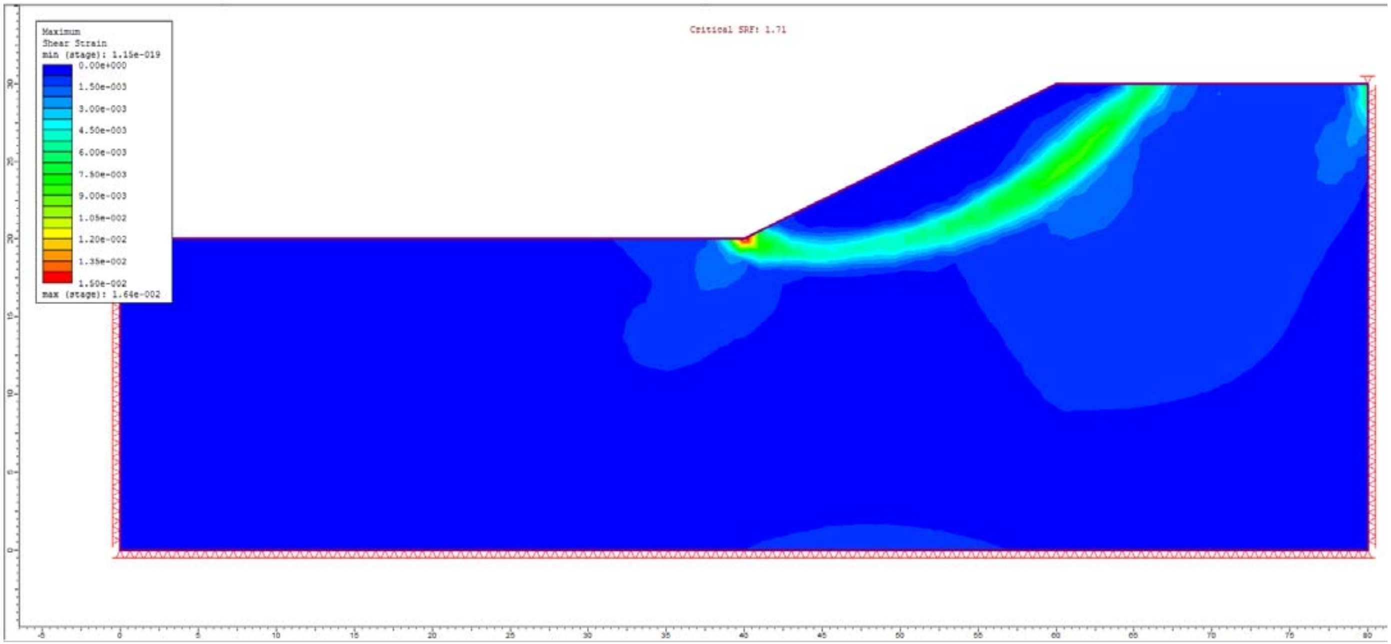


Figure 19.4.9 – RS2 Maximum Shear Strain

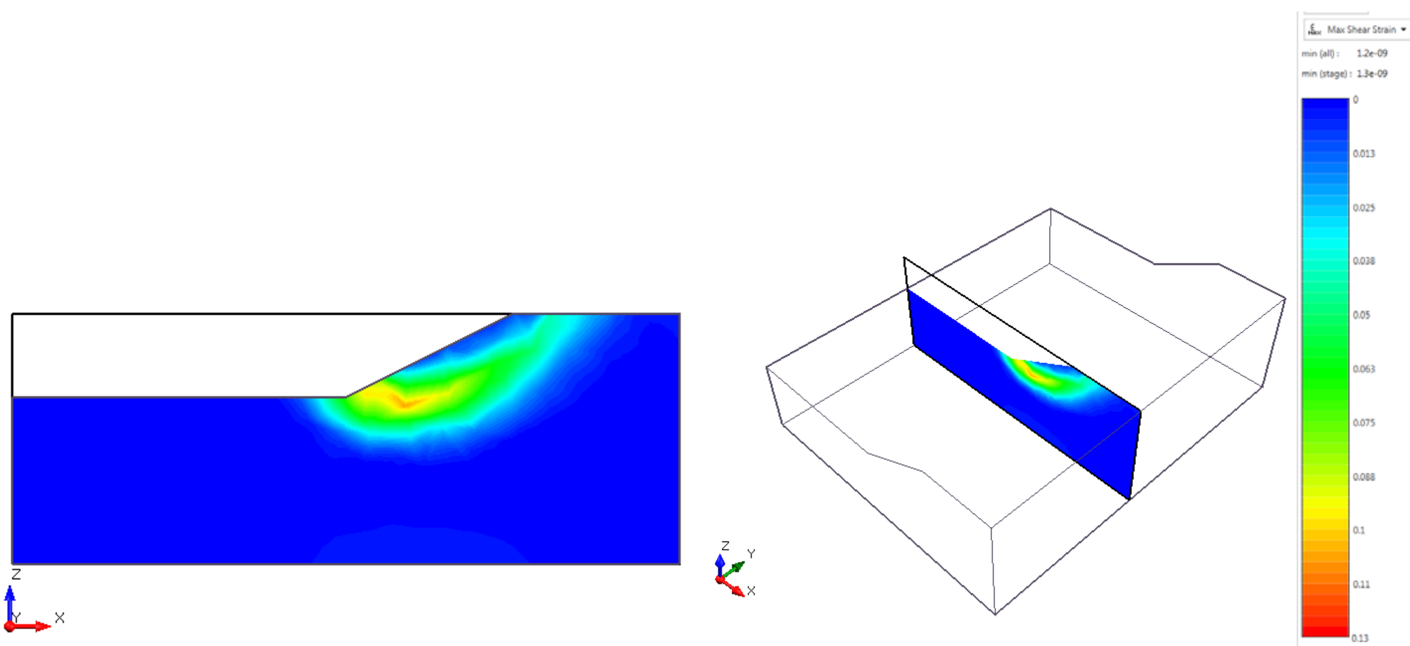


Figure 19.4.10 – RS3 Maximum Shear Strain

2D extruded, (4) materials + weak layer, water table, ellipsoidal with SA

20.1 Introduction

This problem is taken from Wang et al. (2015). It is a non-homogeneous extruded slope with a water table and a thin weak layer.

20.2 Problem Description

The 2D slope stability for this problem is shown as Figure 20. This 2D model is then extruded 200m in the Y direction. The material properties for all four soil layers, as well as the weak layer, can be found in Table 20.1.

20.3 Geometry and Properties

Table 20.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil 1	9.8	30	22
Soil 2	58.8	25	24
Soil 3	49.8	30	26
Soil 4 (Infinite Strength)	10000	65	27
Weak Layer	9.8	20	20

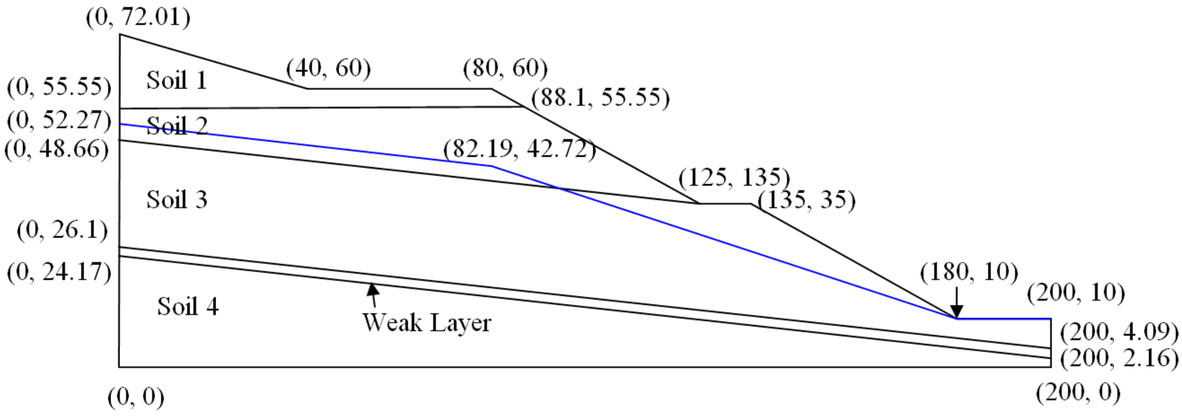


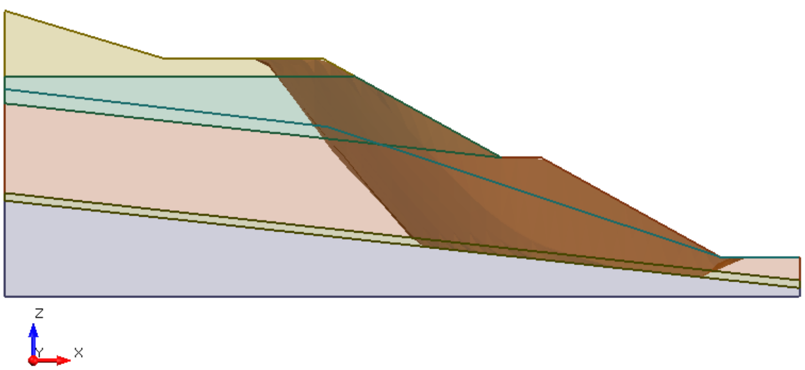
Figure 20

20.4 Results

Table 20.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide7.0	RS3	RS2
Bishop	1.129	1.075	1.2	1.13
GLE	1.192	1.105		
Janbu	1.101	1.027		
Spencer	1.224	1.128		

Referee: 1.45 [Wang et al., 2015]



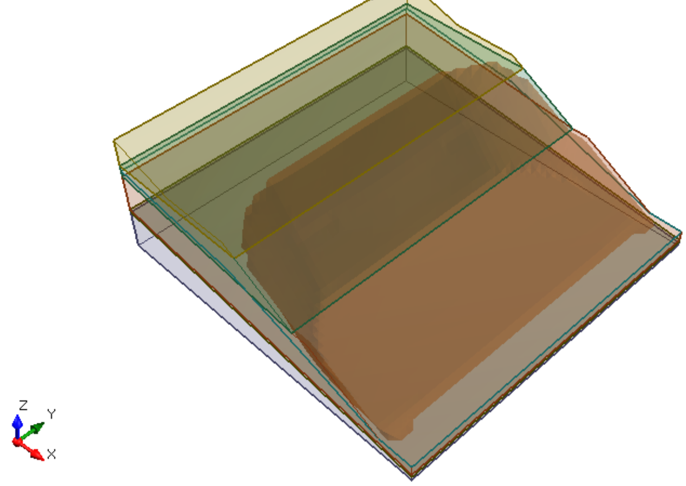


Figure 20.2.1 – Slide3 Solution Using the Bishop Method

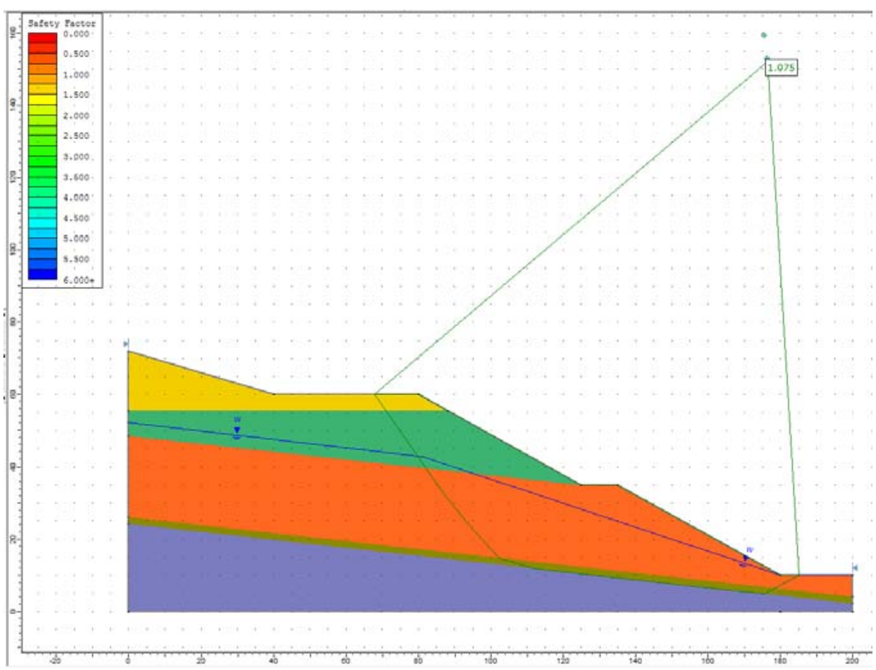


Figure 20.4.2 – Slide Solution Using the Bishop Method

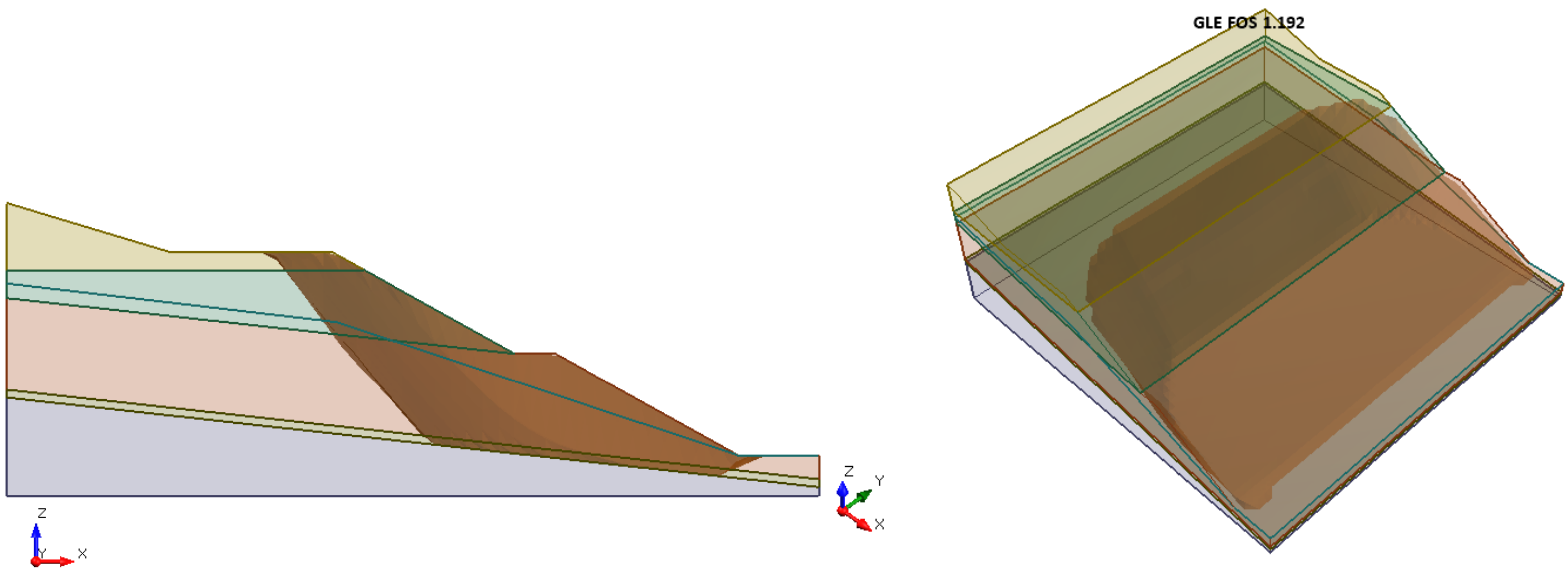


Figure 20.4.3 – Slide3 Solution Using the GLE Method

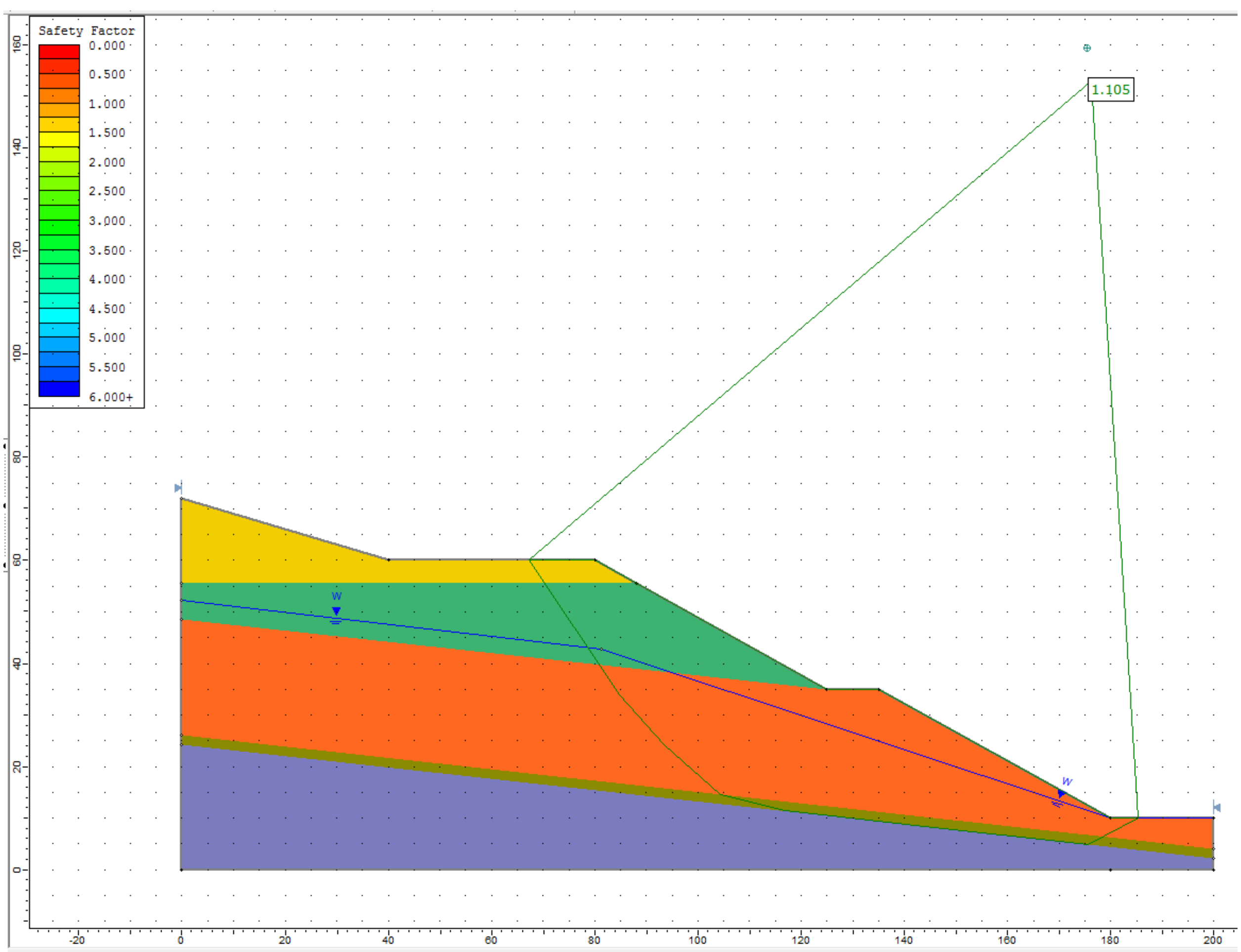


Figure 20.4.4 – Slide Solution Using the GLE Method

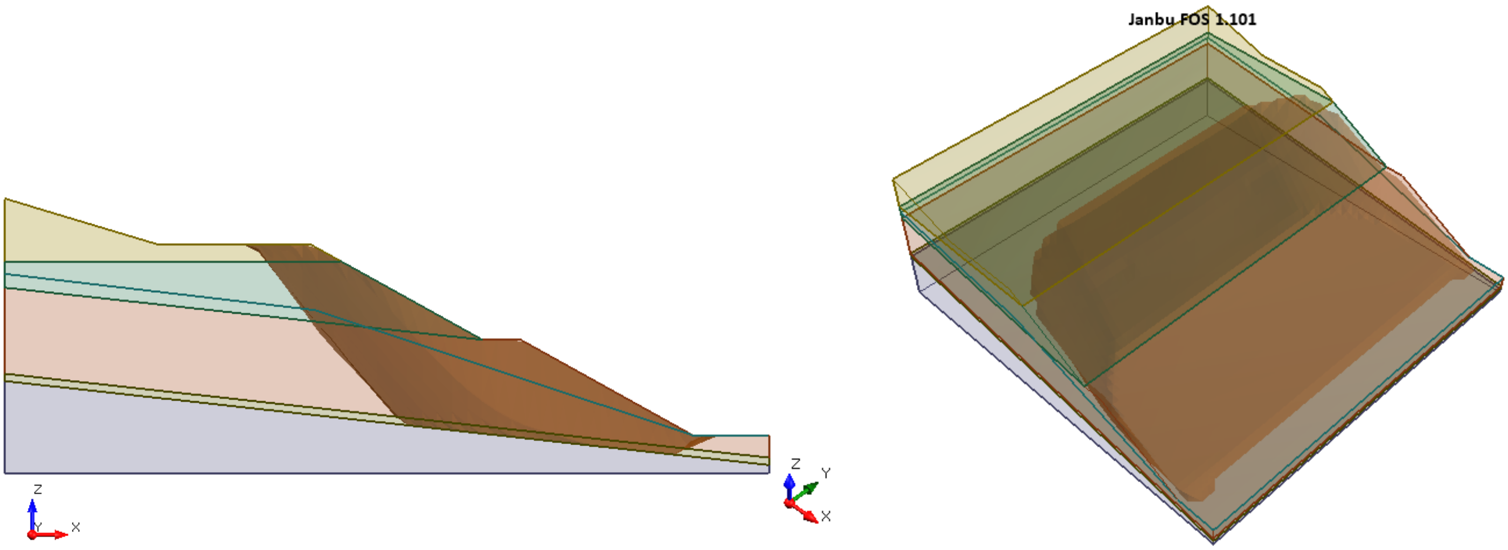


Figure 20.4.5 – Slide3 Solution Using the Janbu Method

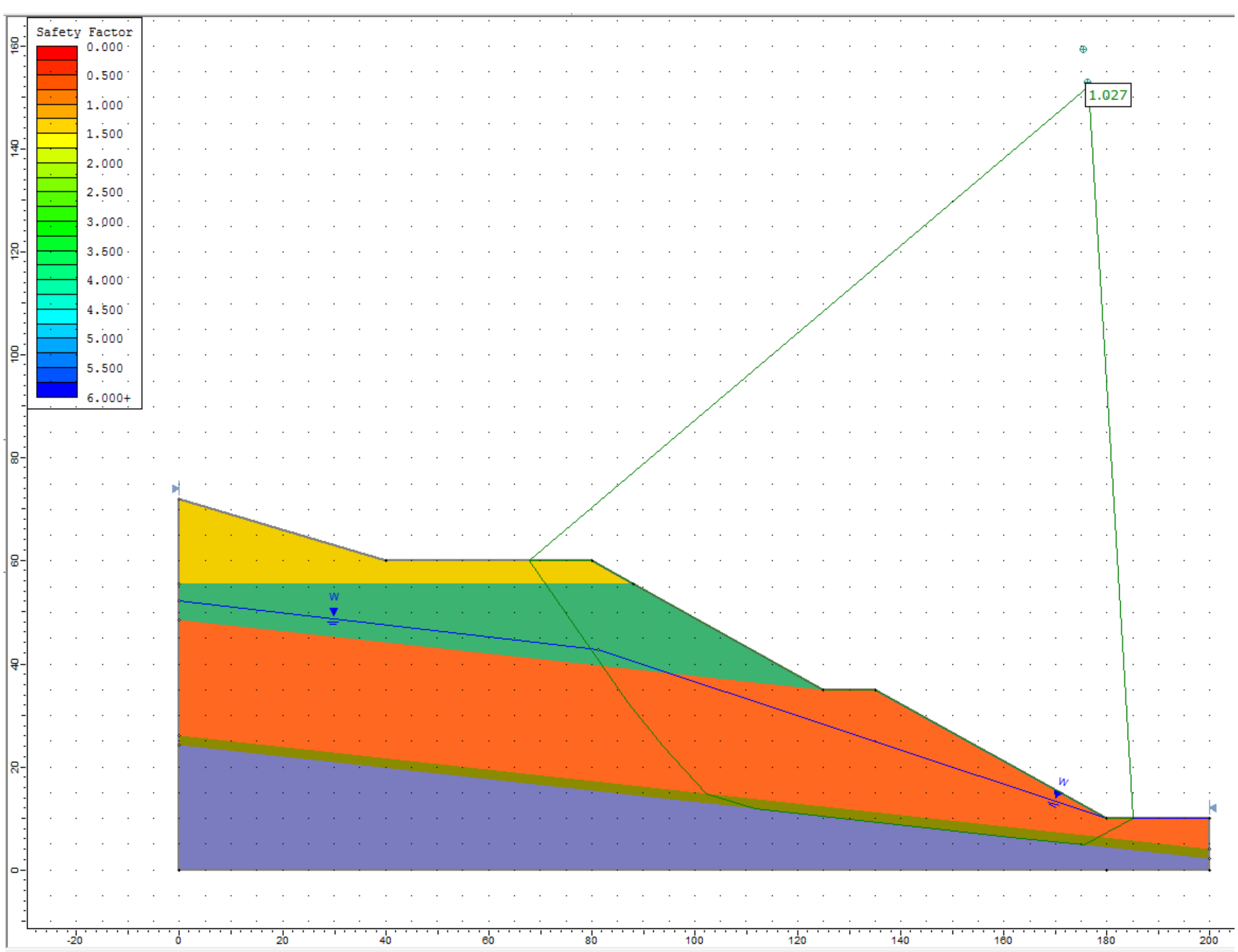


Figure 20.4.6 – Slide Solution Using the Janbu Method

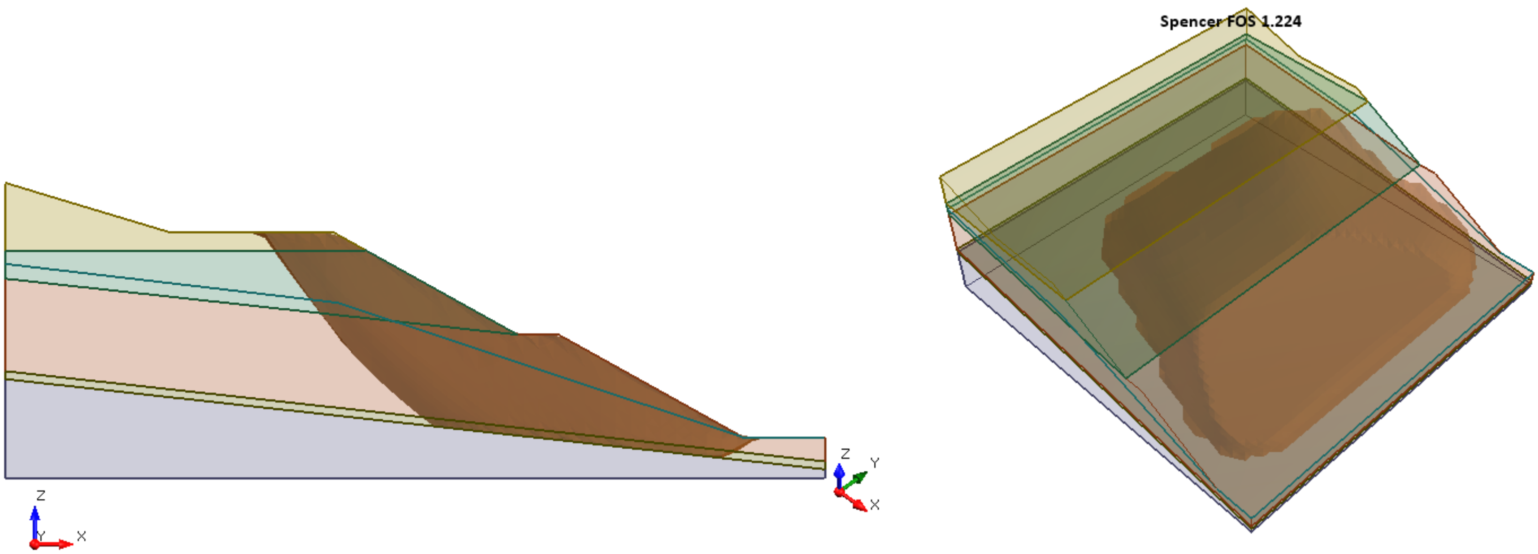


Figure 20.4.7 – Slide3 Solution Using the Spencer Method

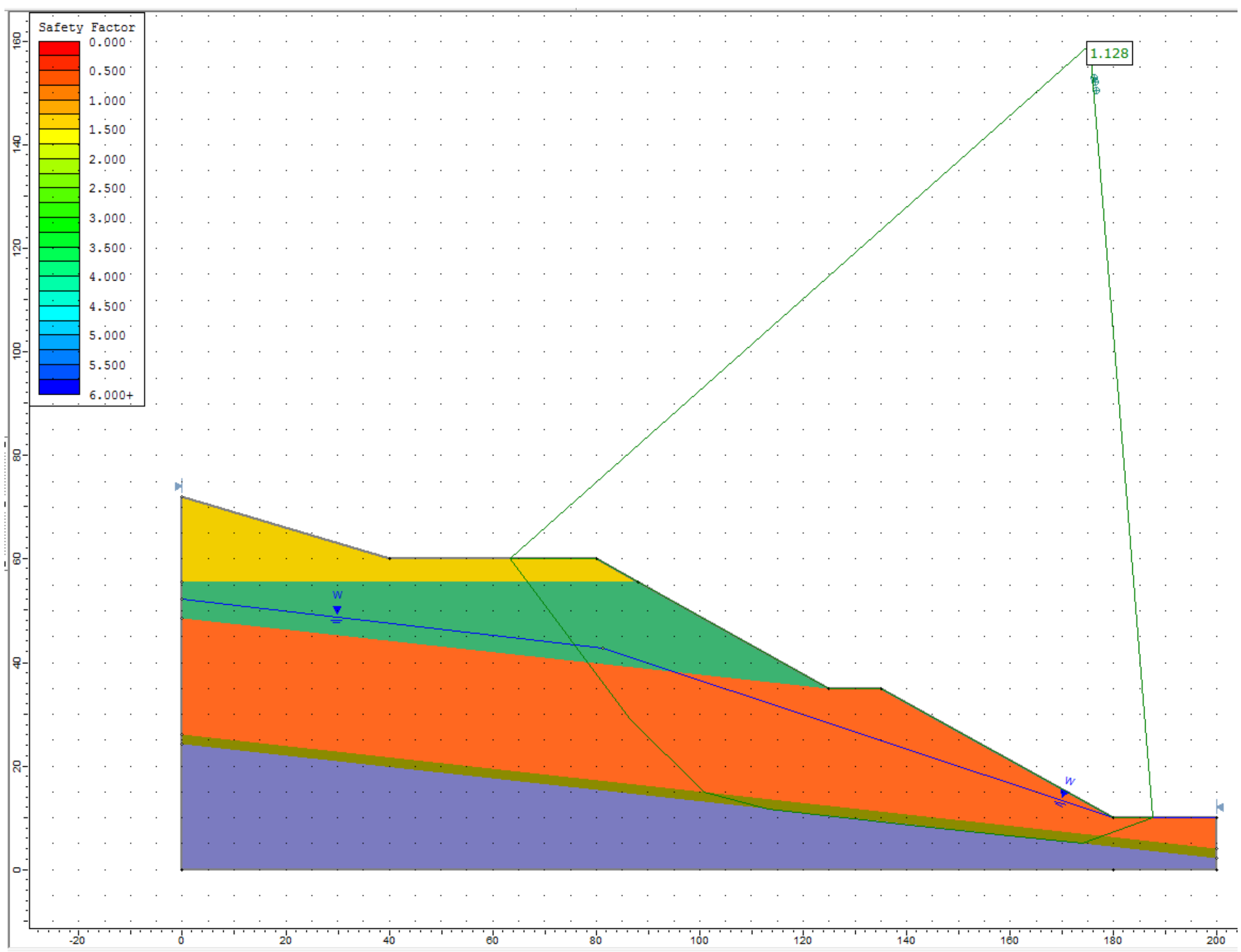


Figure 20.4.8 – Slide Solution Using the Spencer Method

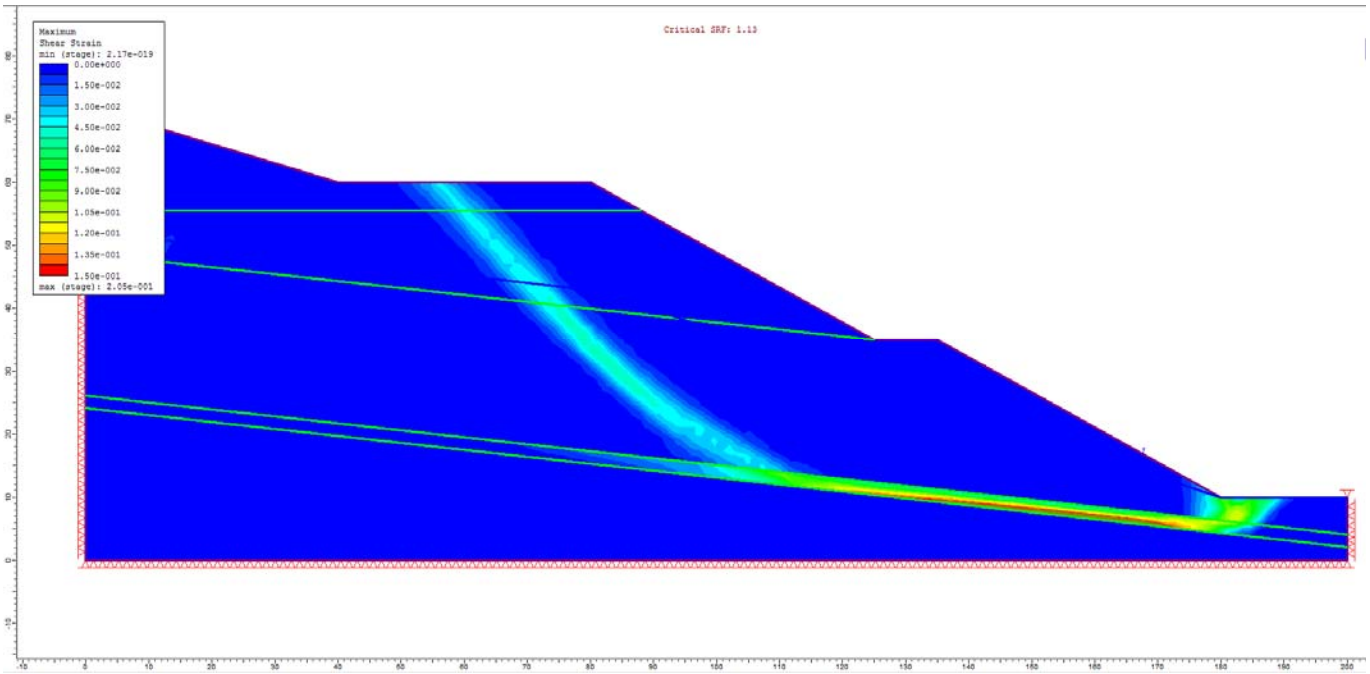


Figure 20.4.9 – RS2 Maximum Shear Strain

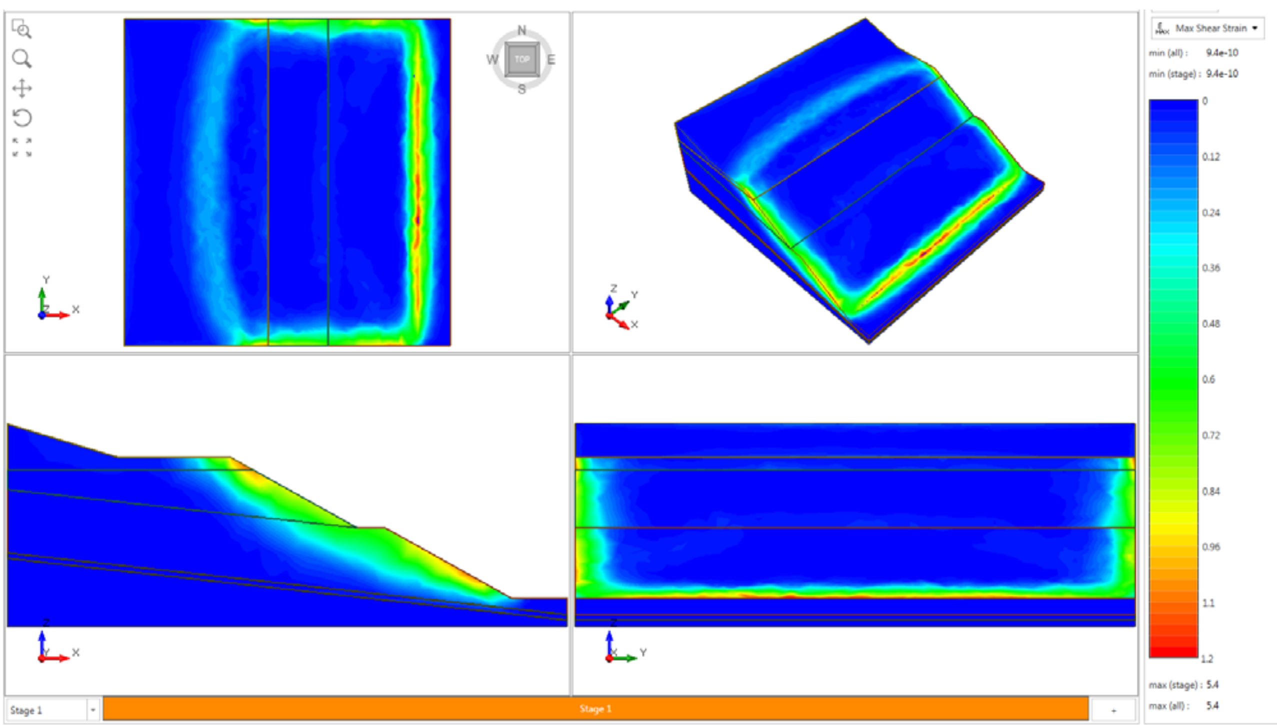


Figure 20.4.10 – RS3 Maximum Shear Strain

2D extruded, homogeneous, uniform loading, ellipsoidal with SA

21.1 Introduction

Liu and Liu did an analysis of 3D slopes with varying distributed loads using FEM (2012). This model is the first case, where the load is distributed across the entire length of the slope.

21.2 Problem Description

This is a simple homogeneous slope with a distributed load, q, of magnitude 40 kN/m^2. The 3D diagram for this problem, which includes the slope geometry and load placement, is shown in Figure 21. The material properties are shown in Table 21.1.

21.3 Geometry and Properties

Table 21.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	14	25	18.5

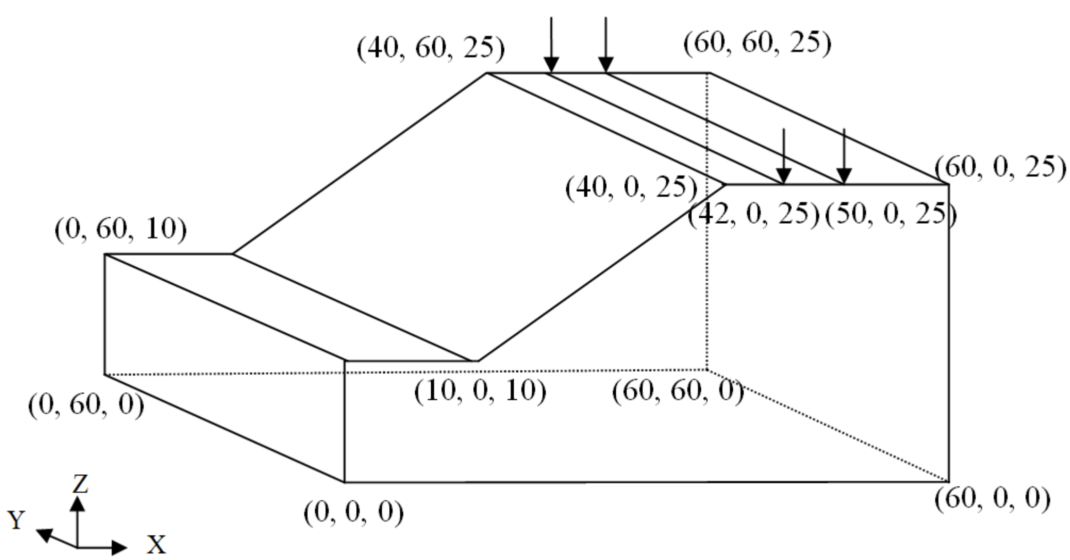


Figure 21

21.4 Results

Table 21.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.593	1.531	1.68	1.55
GLE	1.622	1.531		
Janbu	1.531	1.436		
Spencer	1.629	1.546		

Referee: 1.57 [Liu and Liu, 2012]

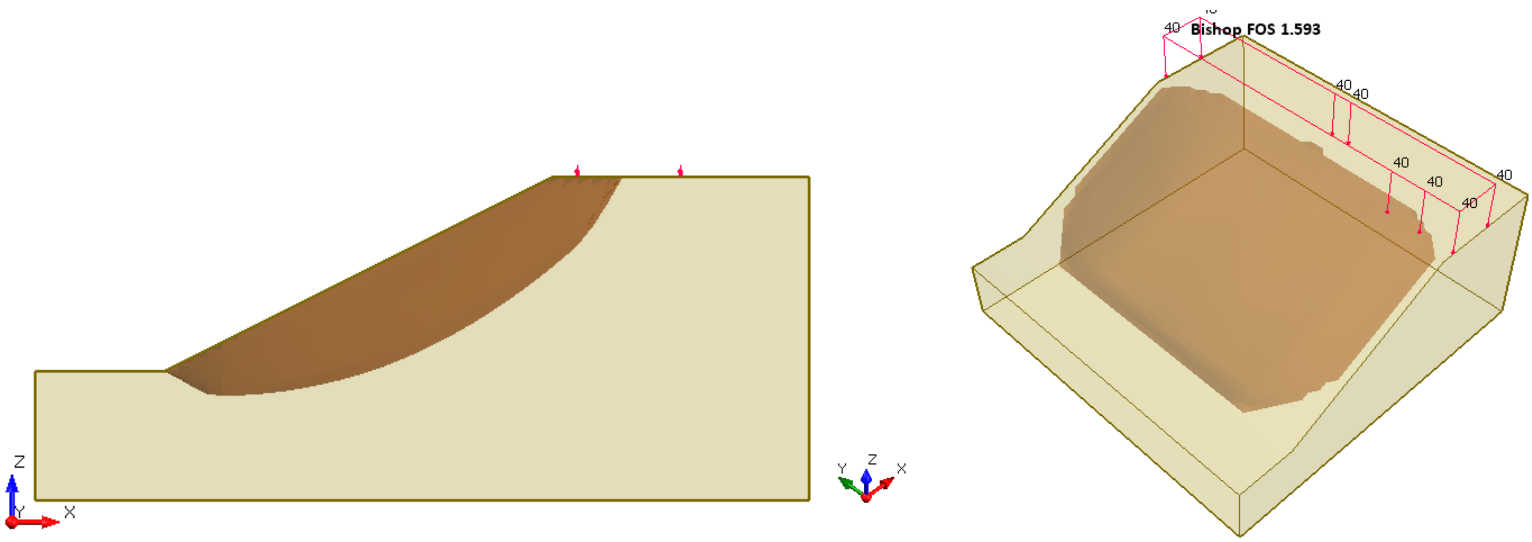


Figure 21.4.1 – Slide3 Solution Using the Bishop Method

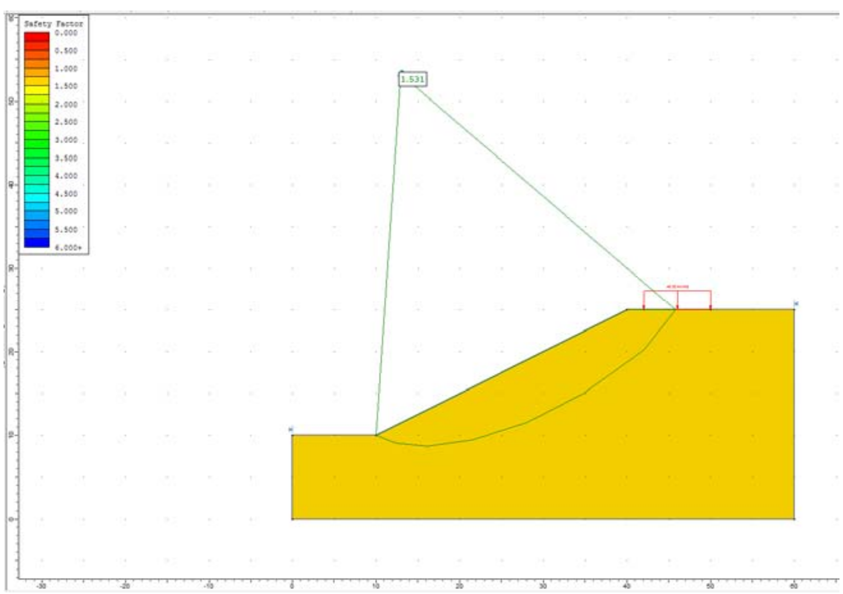


Figure 21.4.2 – Slide Solution Using the Bishop Method

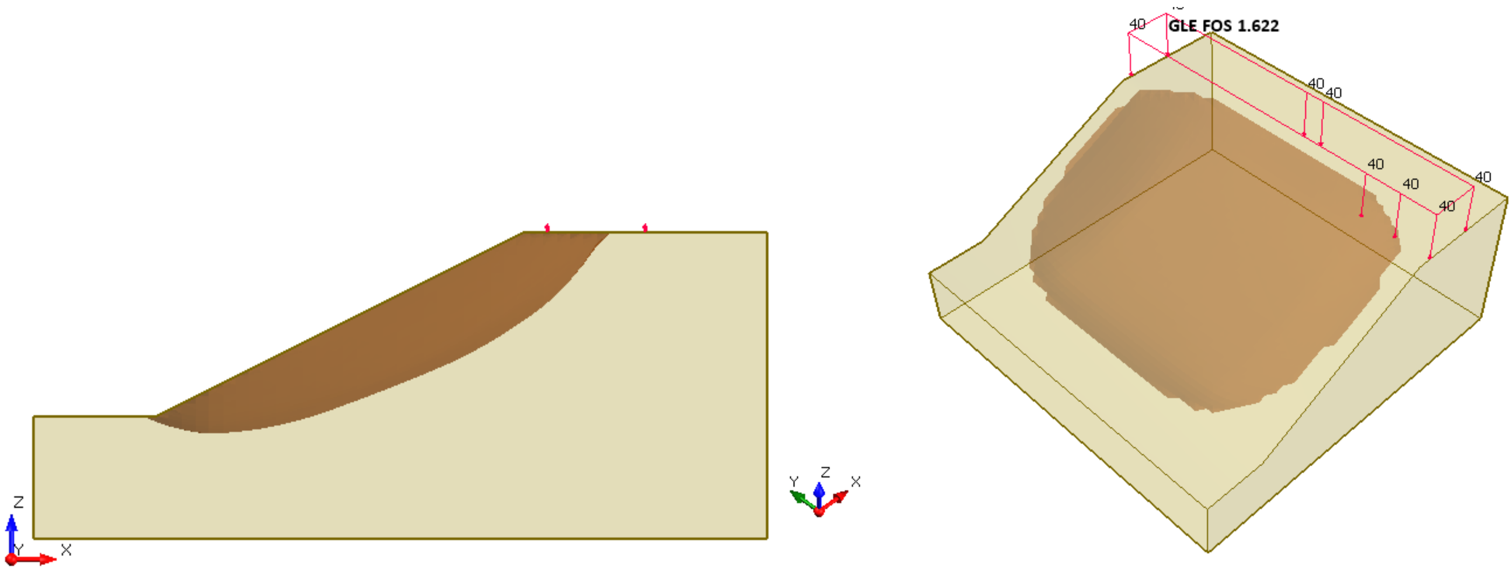


Figure 21.4.3 – Slide3 Solution Using the GLE Method

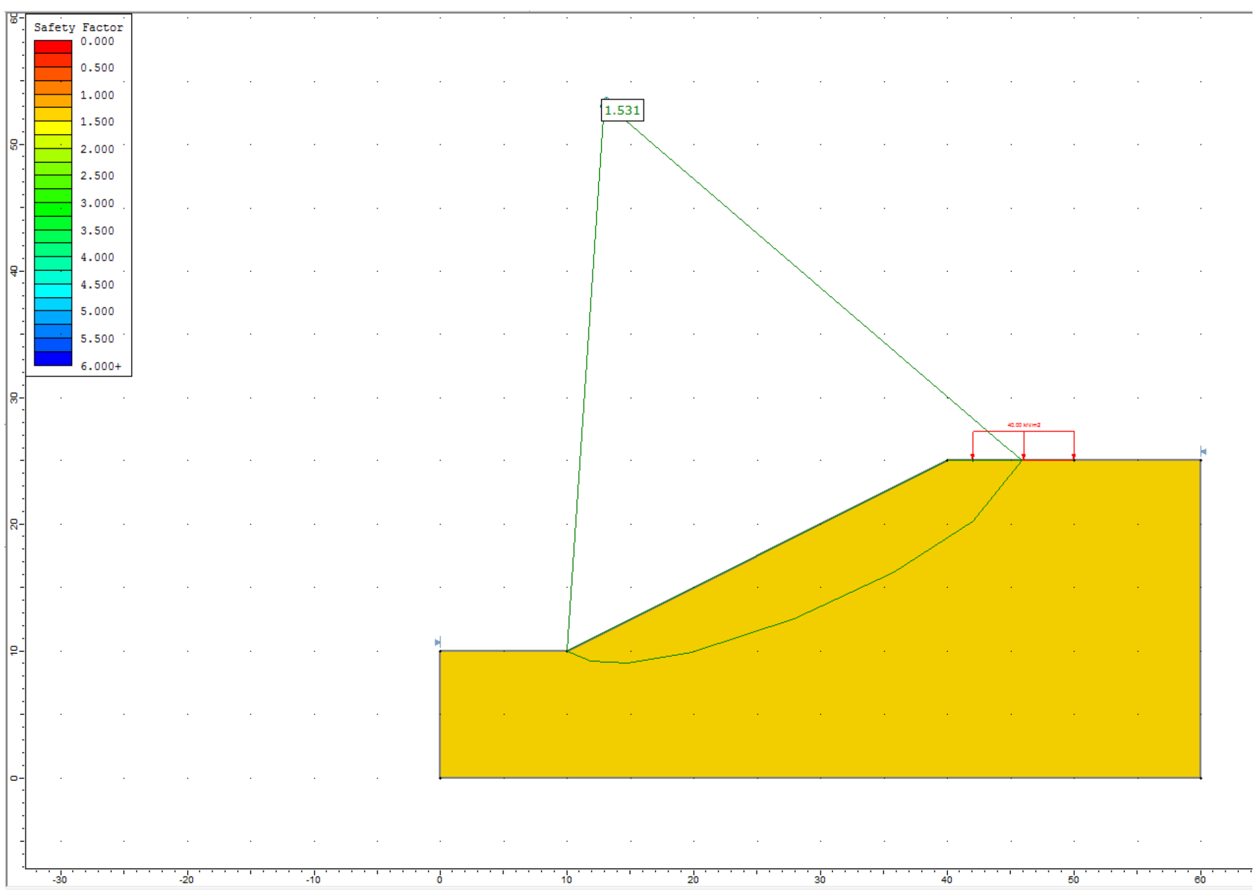


Figure 21.4.4 – Slide Solution Using the GLE Method

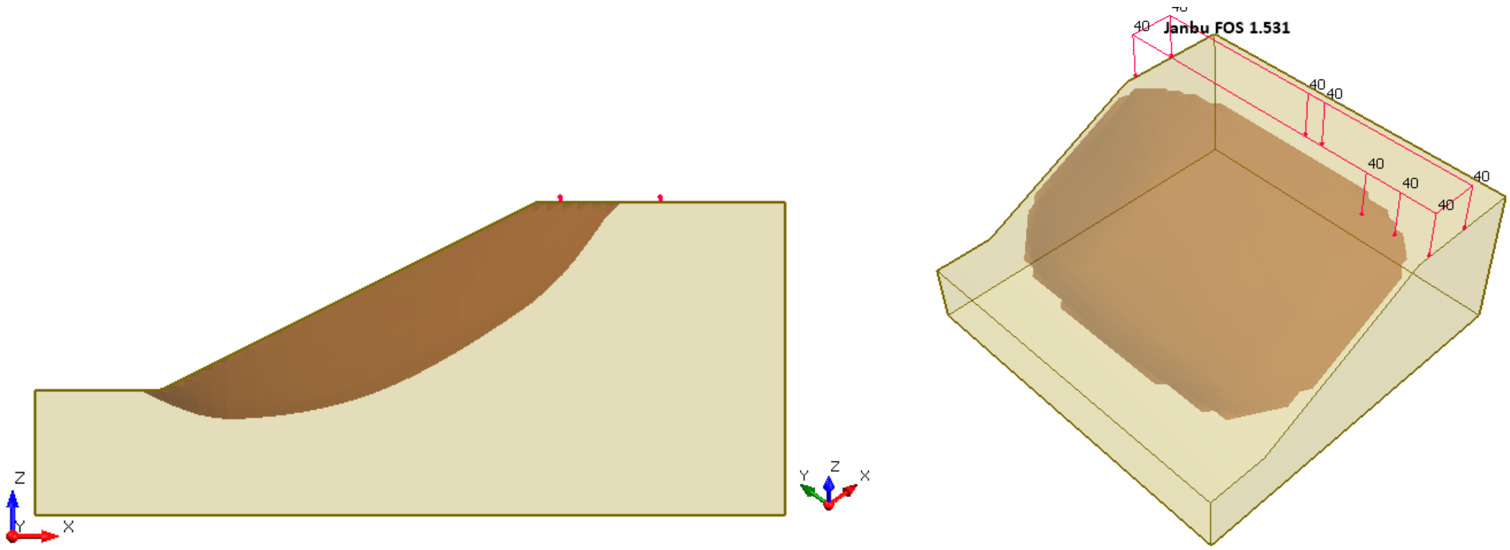


Figure 21.4.5 – Slide3 Solution Using the Janbu Method

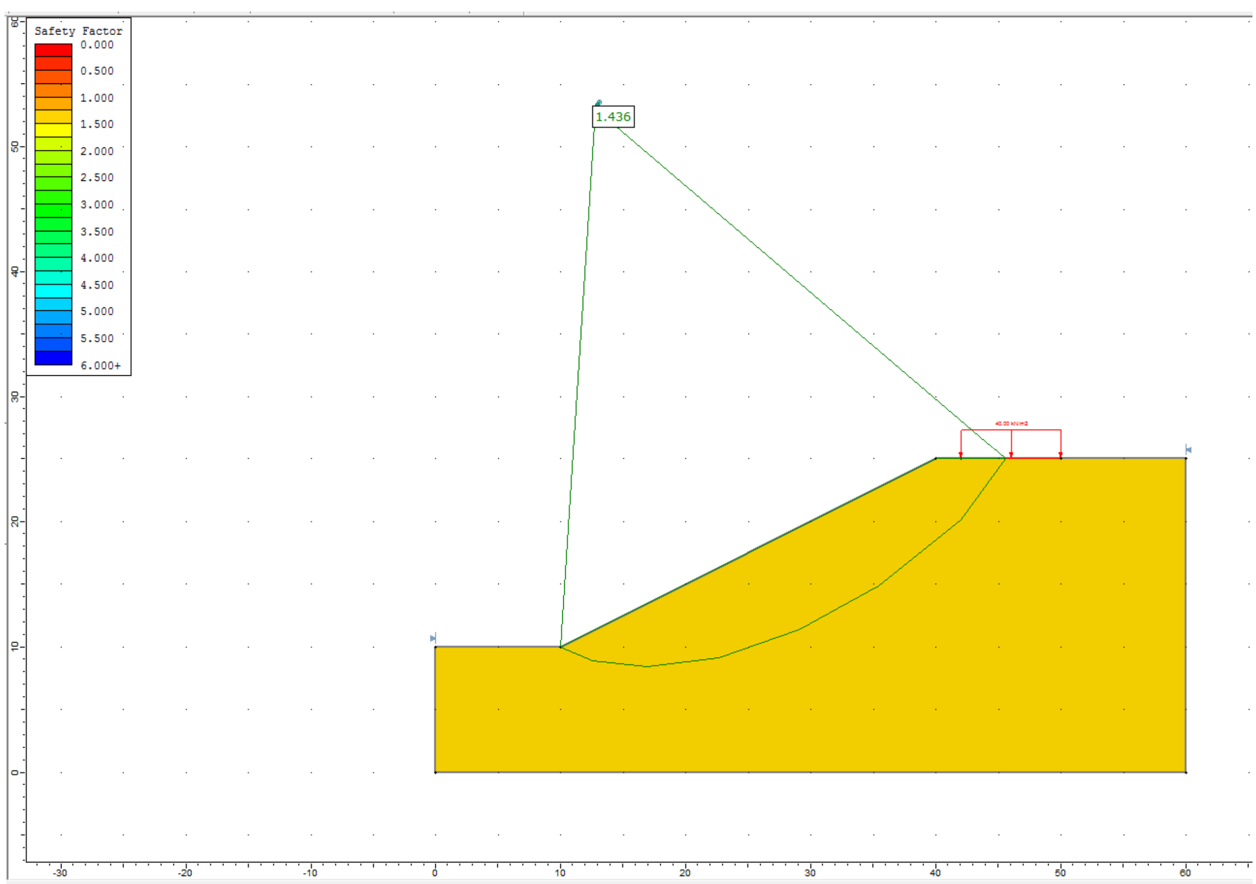


Figure 21.4.6 – Slide Solution Using the Janbu Method

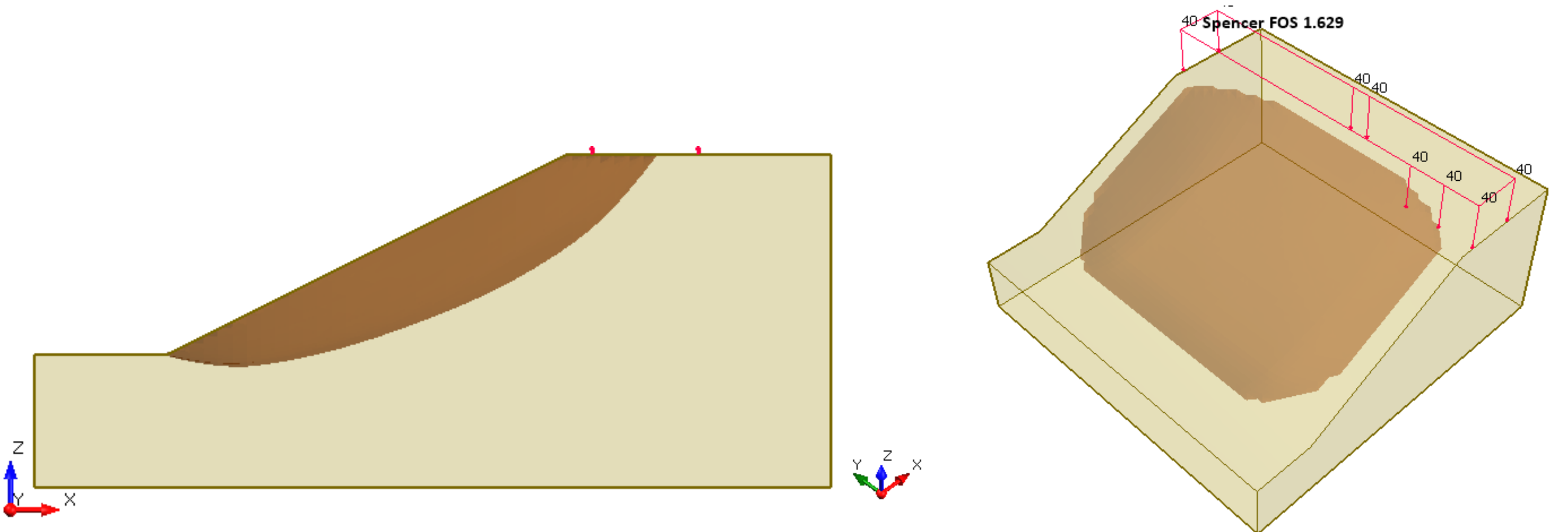


Figure 21.4.7 –Slide3 Solution Using the Spencer Method

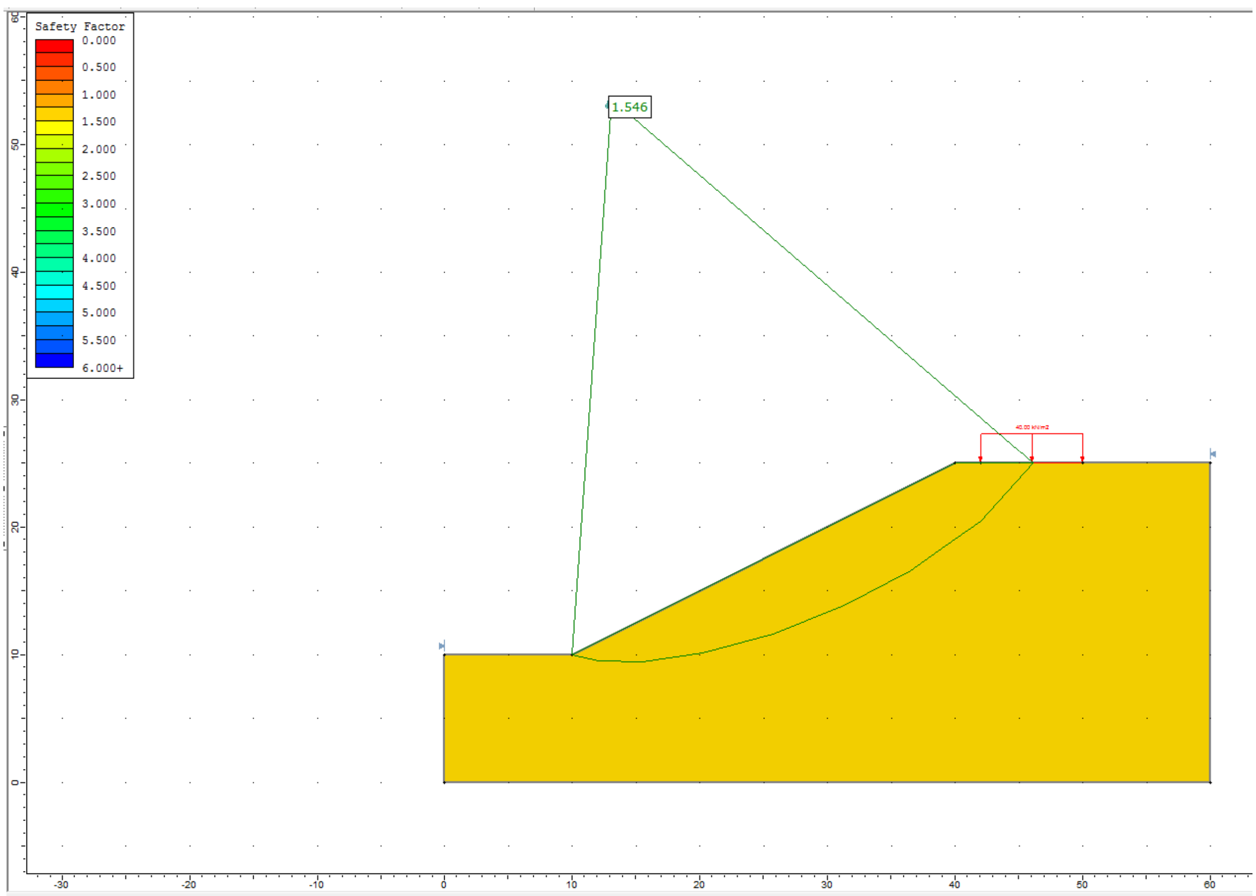


Figure 21.4.8 – Slide Solution Using the Spencer Method

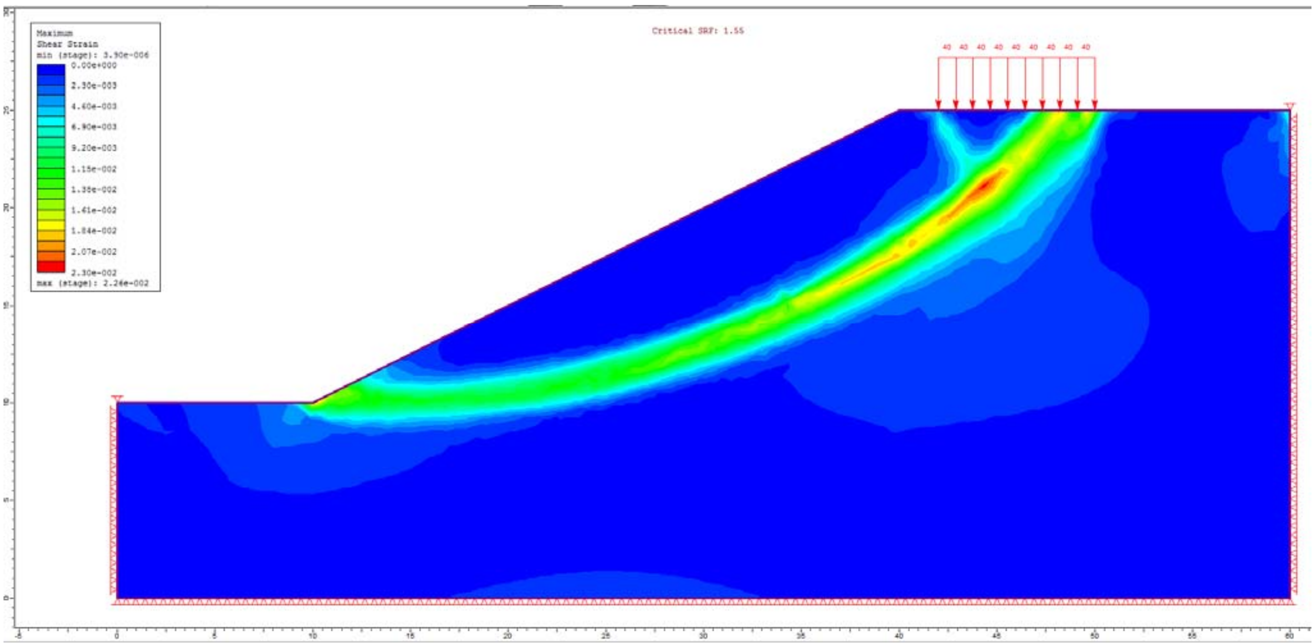


Figure 21.4.9 – RS2 Maximum Shear Strain

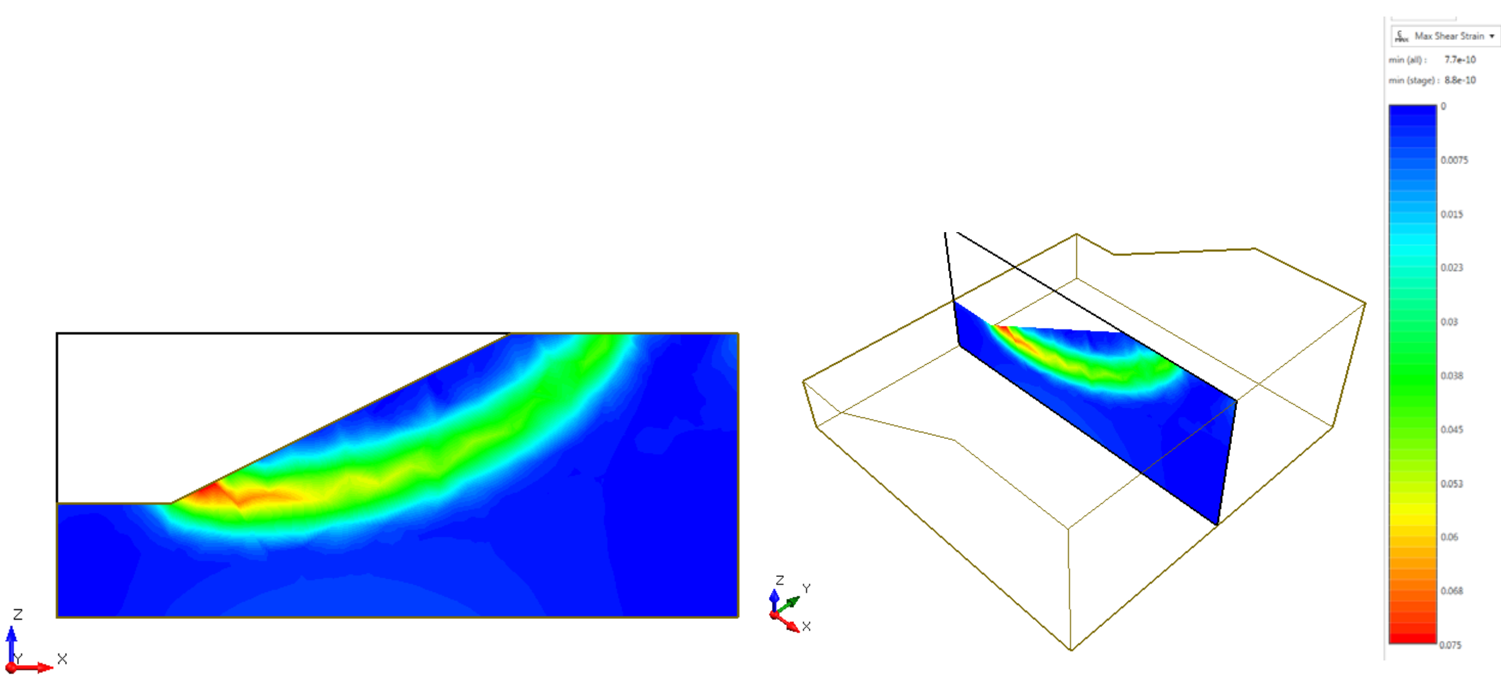


Figure 21.4.10 – RS3 Maximum Shear Strain

2D extruded, homogeneous, micropiles, ellipsoidal with SA

22.1 Introduction

This example is taken from Abdelaziz et al. (2015). Abdelaziz et al. did a number of calculations regarding various pile parameters, such as length and placement along the slope.

22.2 Problem Description

The slope is a homogeneous extruded slope reinforced with one row of piles. The 2D cross section of this model in the XZ plane is shown as Figure 22. This cross section will be extruded 50 m in the Y direction to produce the 3D model. The material properties for the slope can be found in Table 22.1. The piles are active, with a Pile Shear Strength of 20 kN and a length of 5 m. The piles are located at Z = 39.375 m, perpendicular to the slope's surface, as shown in Figure 22. The piles are space 12.5 m apart with a 6.25 m offset. The ellipsoidal slip surface and corresponding safety factor is required.

22.3 Geometry and Properties

Table 22.1: Material Properties

c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
3.4	33	18

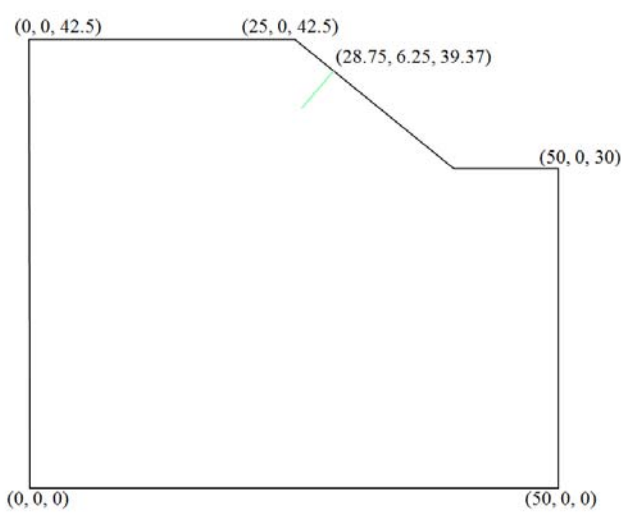


Figure 22

22.4 Results

Table 22.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.078	1.088	1.25	1.09
GLE	1.094	1.072		
Janbu	1.053	1.028		
Spencer	1.096	1.081		

Referee: 1.08 [Abdelaziz et al., 2015]

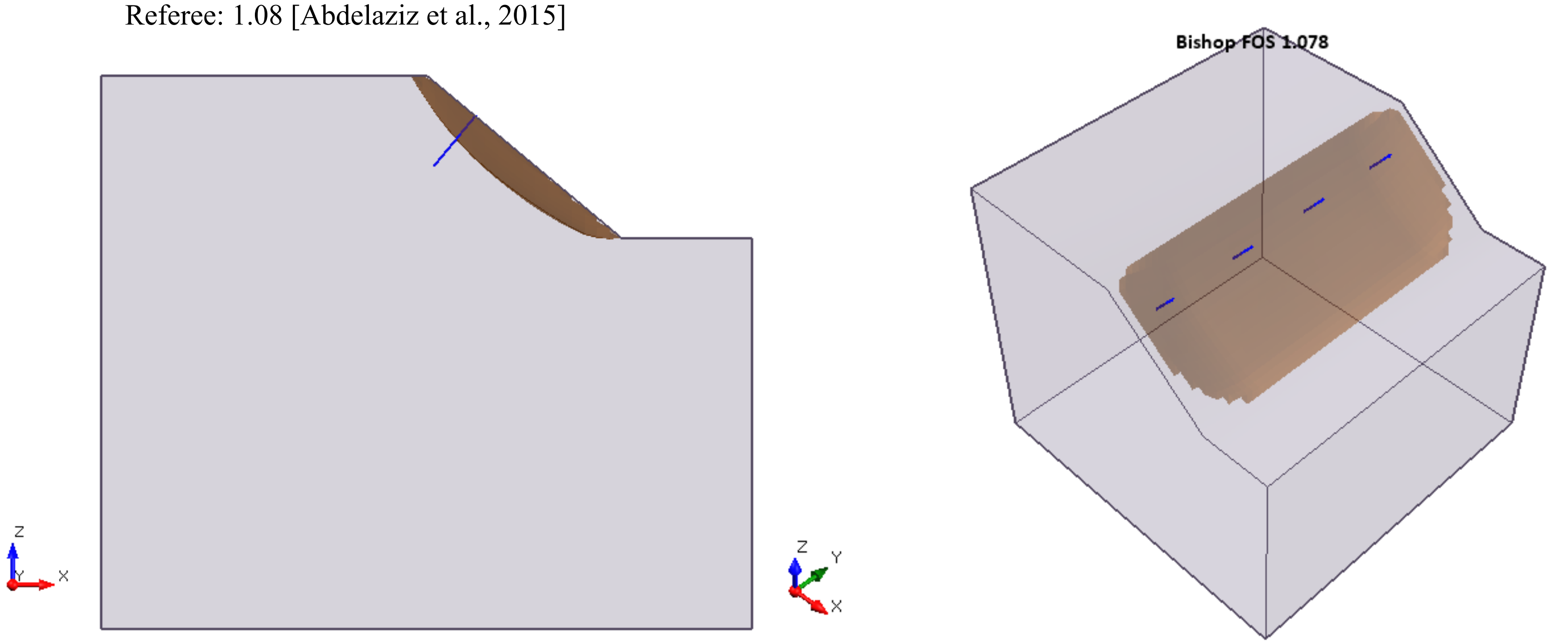


Figure 22.4.1 – Slide3 Solution Using the Bishop Method

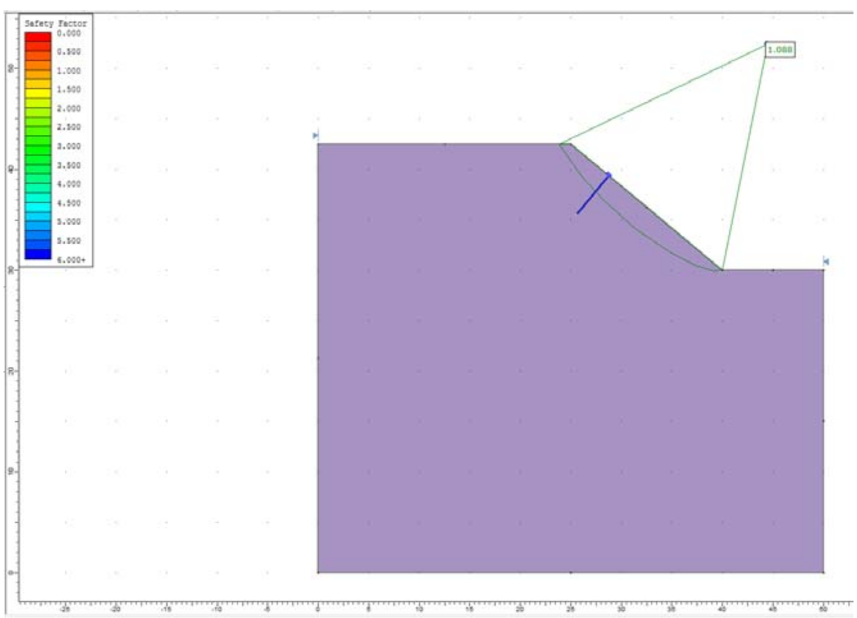


Figure 22.4.2 – Slide Solution Using the Bishop Method

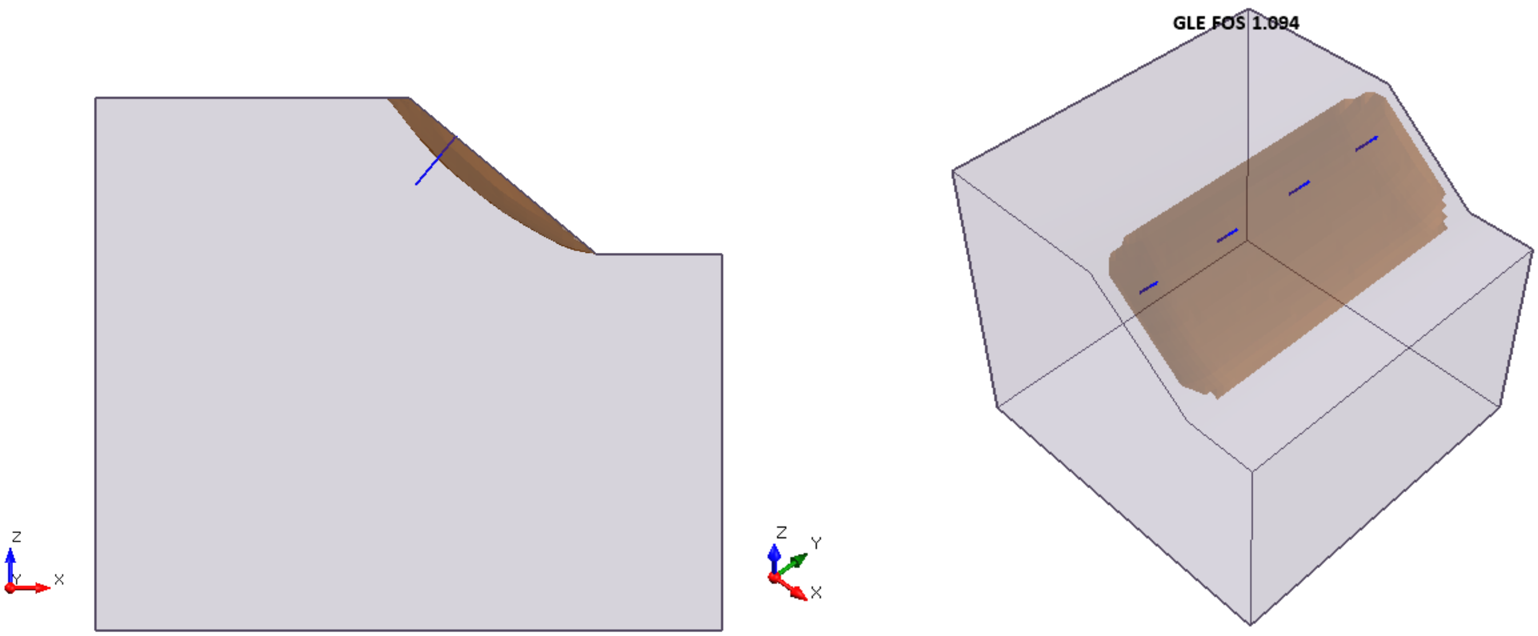


Figure 22.4.3 – Slide3 Solution Using the GLE Method

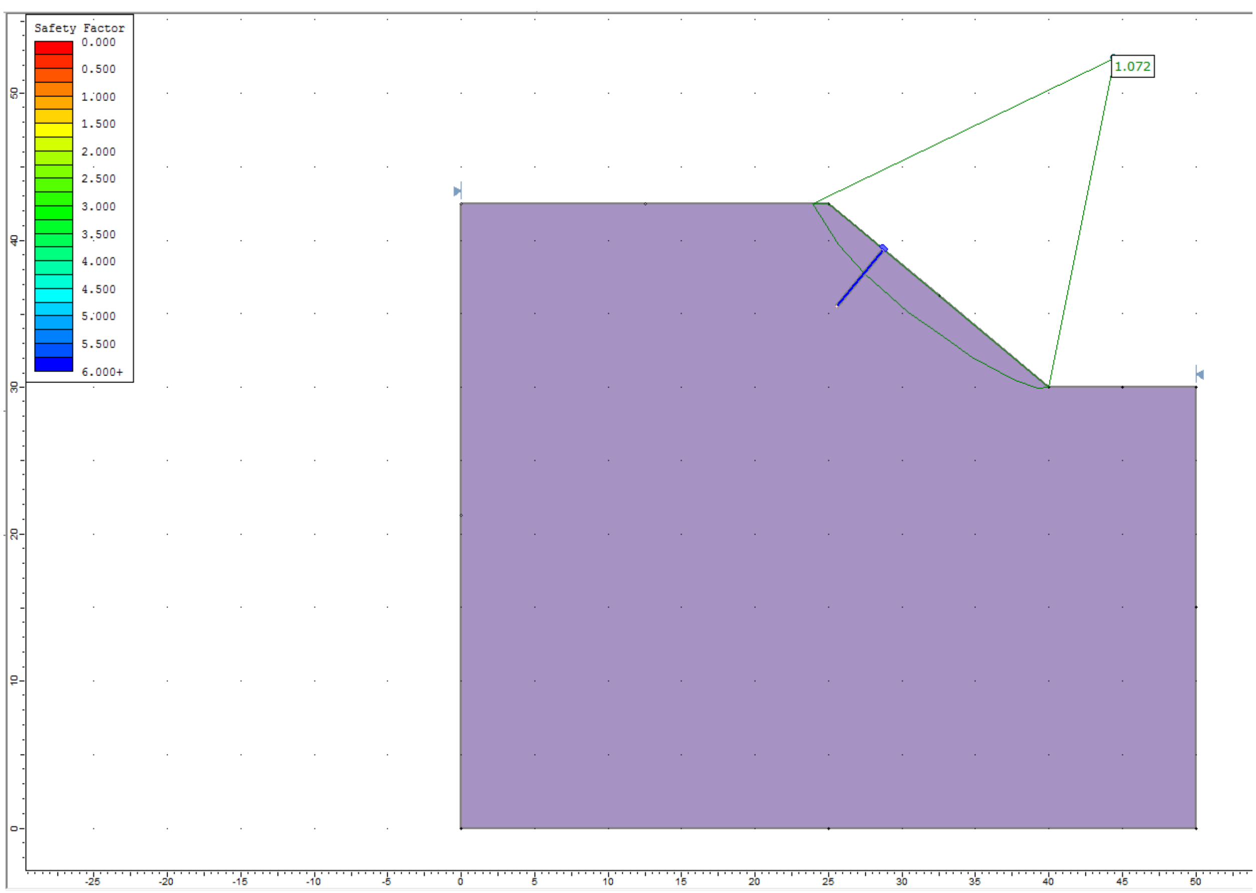


Figure 22.4.4 – Slide Solution Using the GLE Method

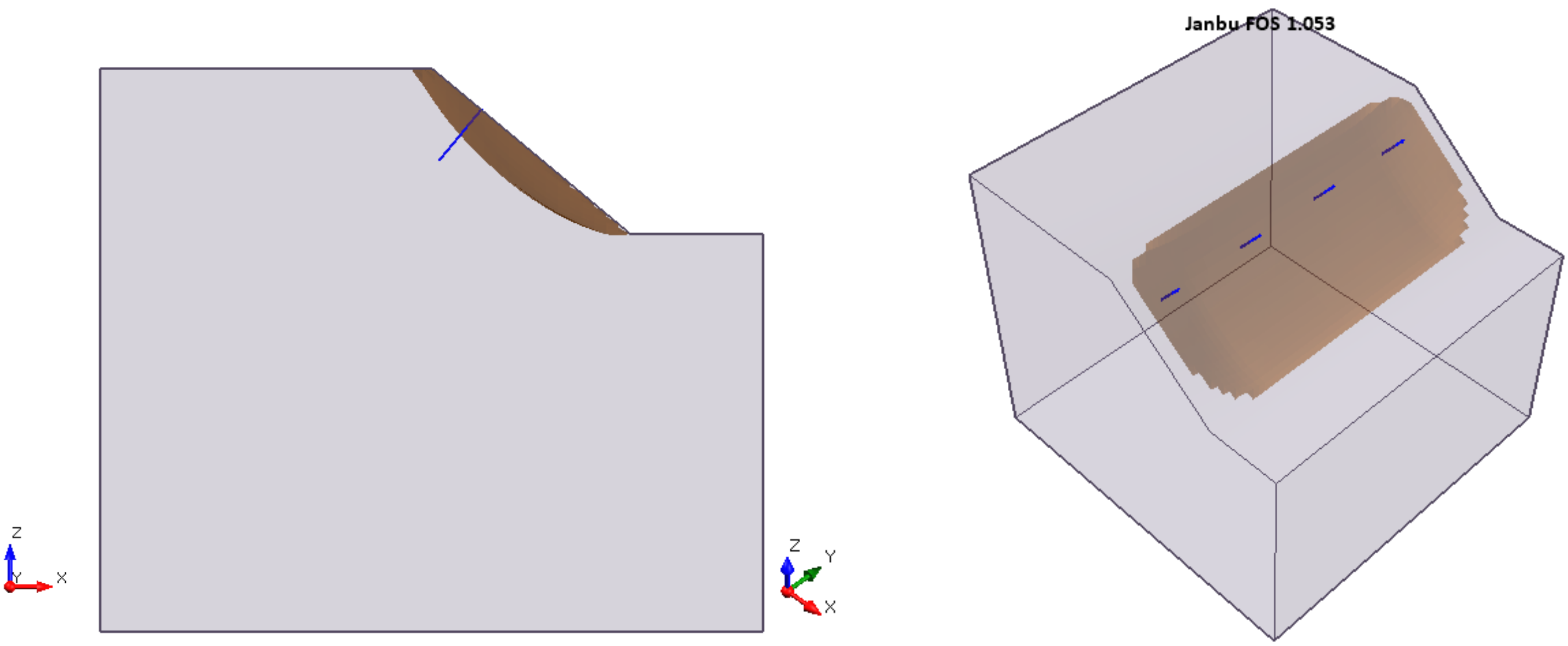


Figure 22.4.5 – Slide3 Solution Using the Janbu Method

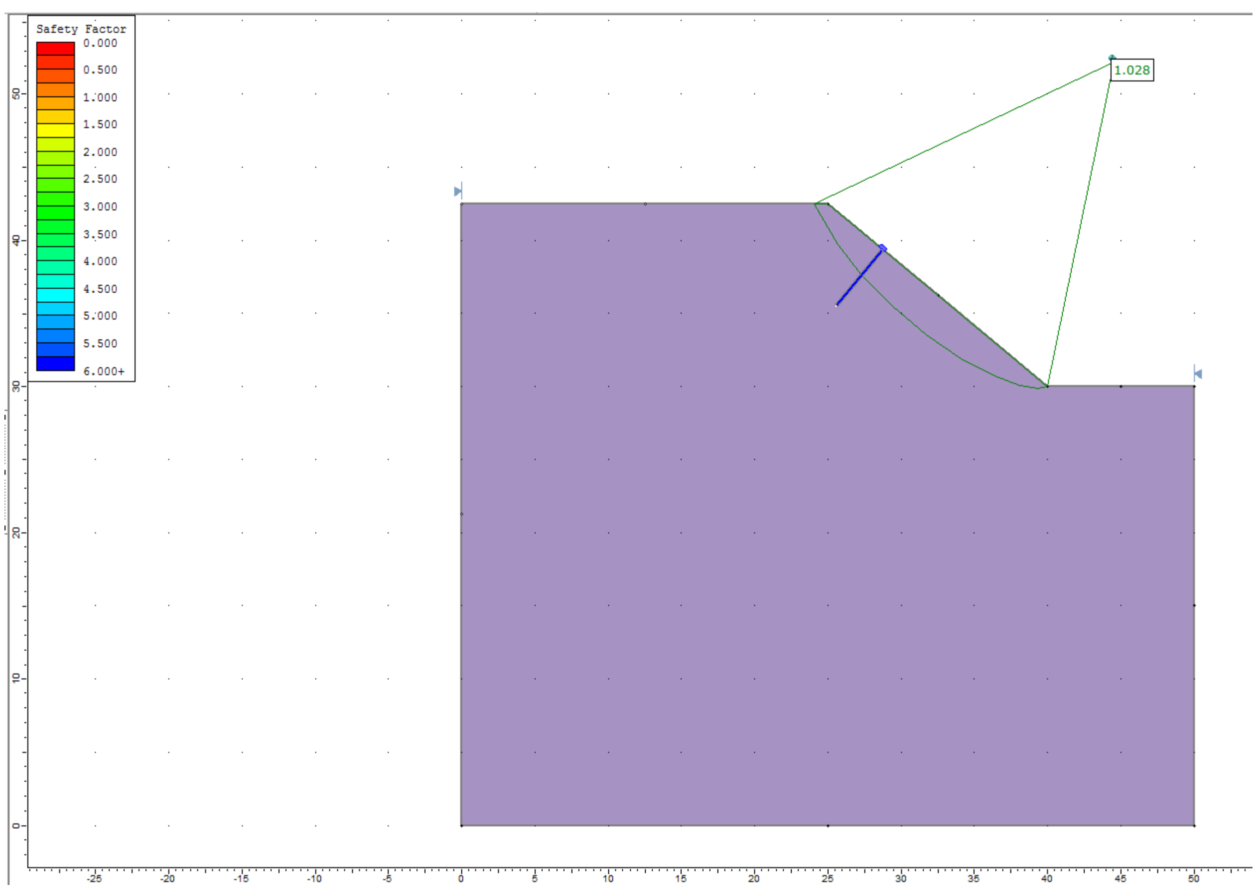


Figure 22.4.6 – Slide Solution Using the Janbu Method

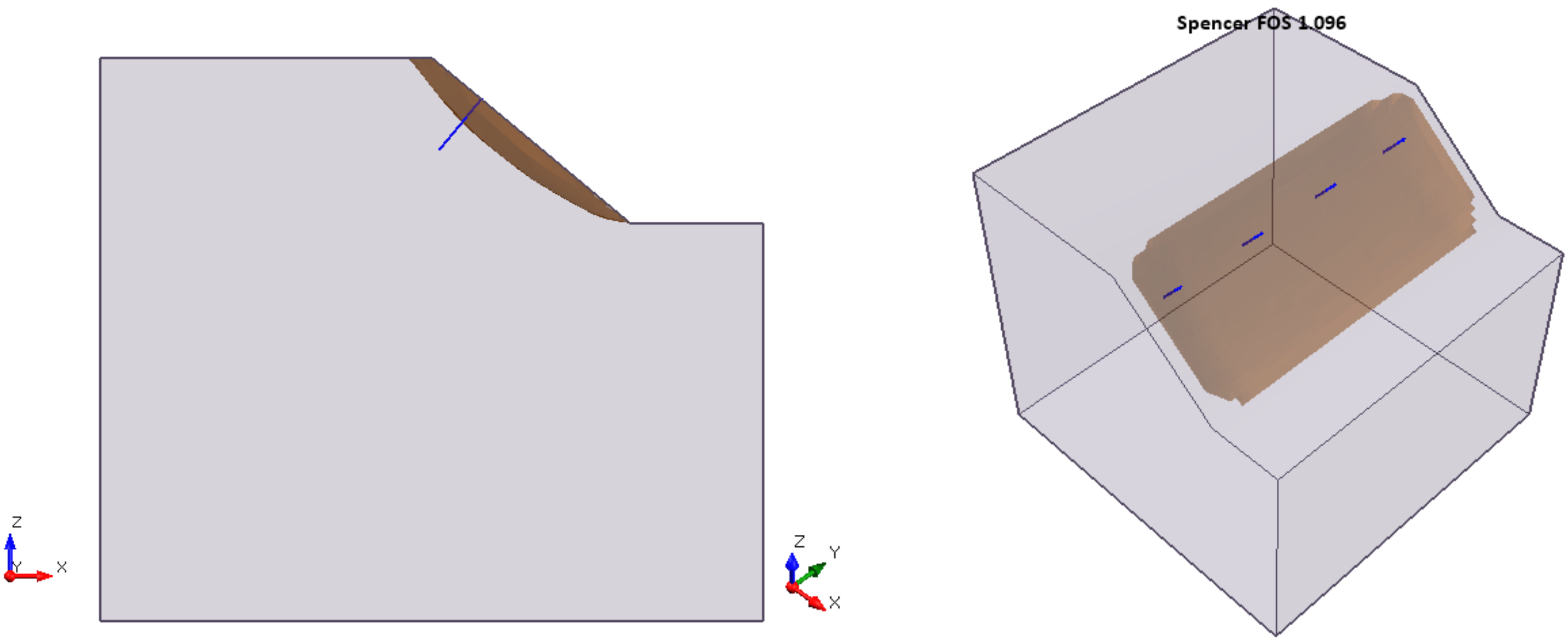


Figure 22.4.7 – Slide3 Solution Using the Spencer Method

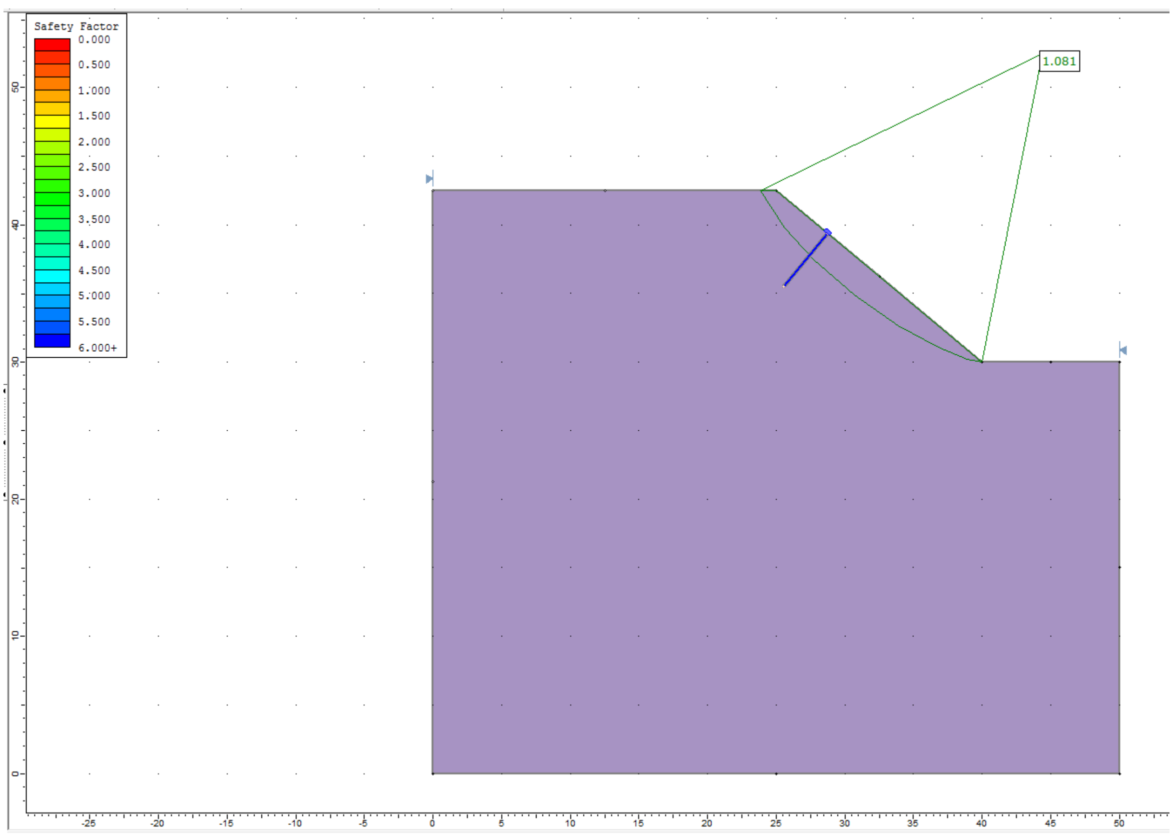


Figure 22.4.8 – Slide Solution Using the Spencer Method

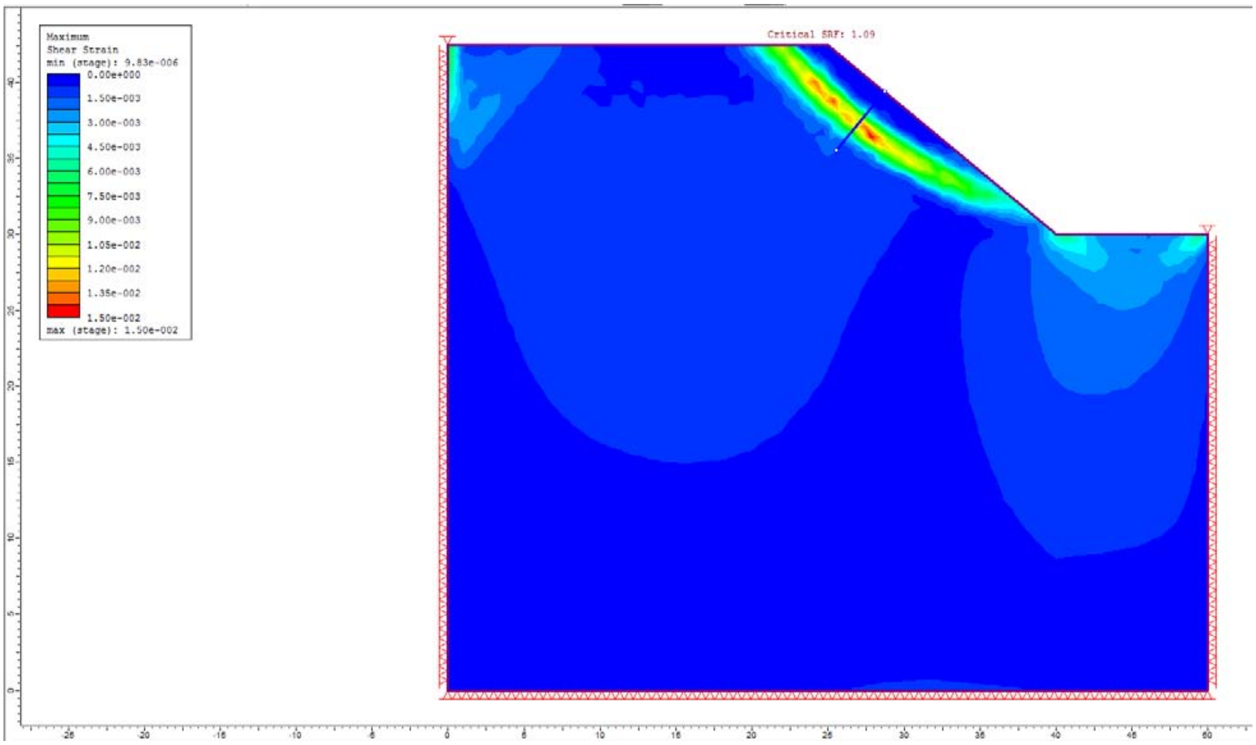


Figure 22.4.9 – RS2 Maximum Shear Strain

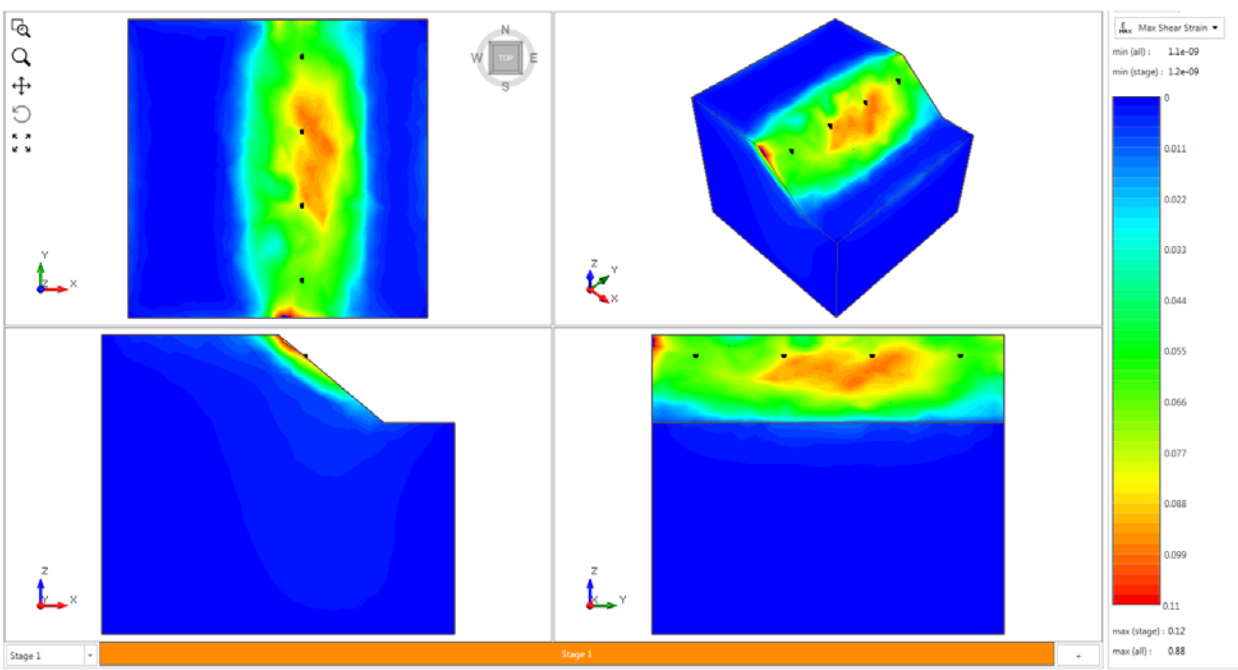


Figure 22.4.10 – RS3 Maximum Shear Strain

2D extruded, water table, weak layer defined slip surface

23.1 Introduction

Huang, Fan and Wang analyzed a slope with a weak layer and a water table, where they observed the effect of changing the height of the water table on the safety factor of the slope. This is case 1, where the water table is at the toe of the slope.

23.2 Problem Description

Figure 23 shows the 2D slope geometry in the XZ plane, which will be extruded 80m in the Y direction, including the weak layer and water table. Table 23.1 shows the material properties of the slope and the weak layer. The slip surface is defined by the weak layer, whose properties can be found in Table 23.1, and a number of other weak planes which have the same properties as the soil. One of the planes is a flat XY plane at the toe of the slope. There are two planes at either side of the slope create the slip surface's length, which is defined as 70m by Huang, Fan and Wang, therefore one plane has a center located at (17.5, 5, 12) with a normal of (0, -1, -0.001) and the other has a center located at (17.5, 74, 12) and has a normal of (0, -1, 0.001). The final plane intersects the weak plane, has a center located at (17.5, 40 12) and a normal of (-1, 0, 0.798636), to make an angle of 53° with the horizontal, as prescribed by Huang, Fan and Wang.

23.3 Geometry and Properties

Table 23.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	20	15	20
Weak Layer	10	10	20

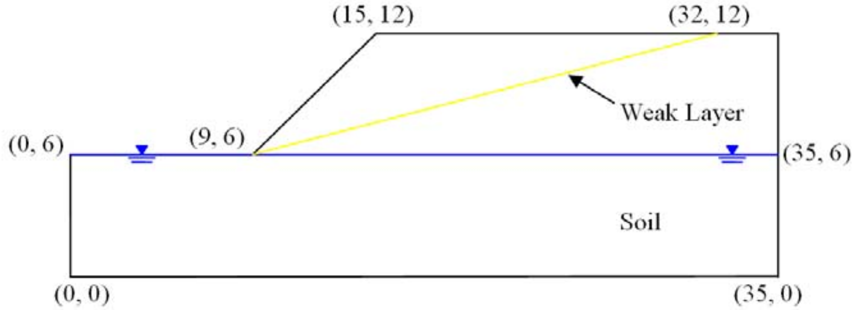


Figure 26

23.4 Results

Table 23.4.1: Safety Factors Using Slide3

Method	Safety Factor
Bishop	1.26
GLE	1.261
Janbu	1.262
Spencer	1.261

Referee: 1.37 [Huang et al., 2016]

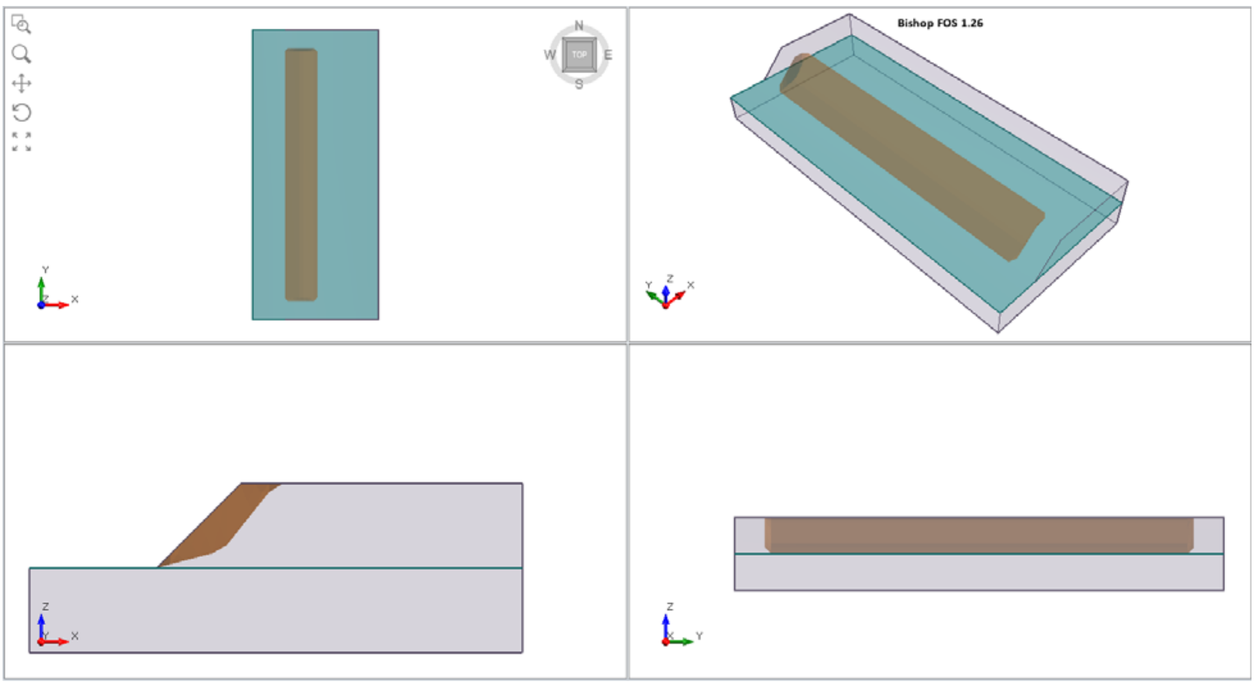


Figure 23.4.1 – Slide3 User Defined Slip Surface Using Weak Planes

2D extruded, water table, weak layer defined slip surface

24.1 Introduction

Huang, Fan and Wang analyzed a slope with a weak layer and a water table, where they observed the effect of changing the height of the water table on the safety factor of the slope. This is case 2, where the water table is 1.2 m above the toe of the slope.

24.2 Problem Description

Figure 24 shows the 2D slope geometry in the XZ plane, which will be extruded 80m in the Y direction, including the weak layer and water table. Table 24.1 shows the material properties of the slope and the weak layer. The slip surface is defined by the weak layer, whose properties can be found in Table 24.1, and a number of other weak planes which have the same properties as the soil. One of the planes is a flat XY plane at the toe of the slope. There are two planes at either side of the slope create the slip surface's length, which is defined as 70m by Huang, Fan and Wang, therefore one plane has a center located at (17.5, 5, 12) with a normal of (0, -1, -0.001) and the other has a center located at (17.5, 74, 12) and has a normal of (0, -1, 0.001). The final plane intersects the weak plane, has a center located at (17.5, 40 12) and a normal of (-1, 0, 0.798636), to make an angle of 53° with the horizontal, as prescribed by Huang, Fan and Wang.

24.3 Geometry and Properties

Table 24.1: Material Properties

	c´ (kN/m^2)	φ´ (deg.)	γ (kN/m^3)
Soil	20	15	20
Weak Layer	10	10	20

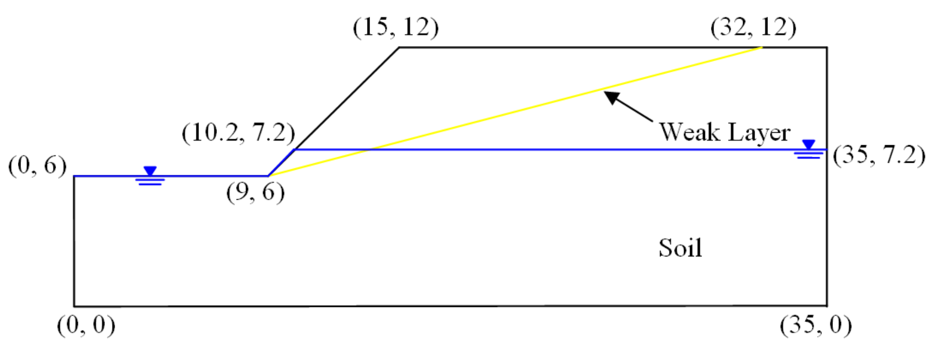


Figure 24

24.4 Results

Table 24.4.1: Safety Factors Using Slide3

Method	Safety Factor
Bishop	1.241
GLE	1.242
Janbu	1.244
Spencer	1.242

Referee: 1.35 [Huang et al., 2016]

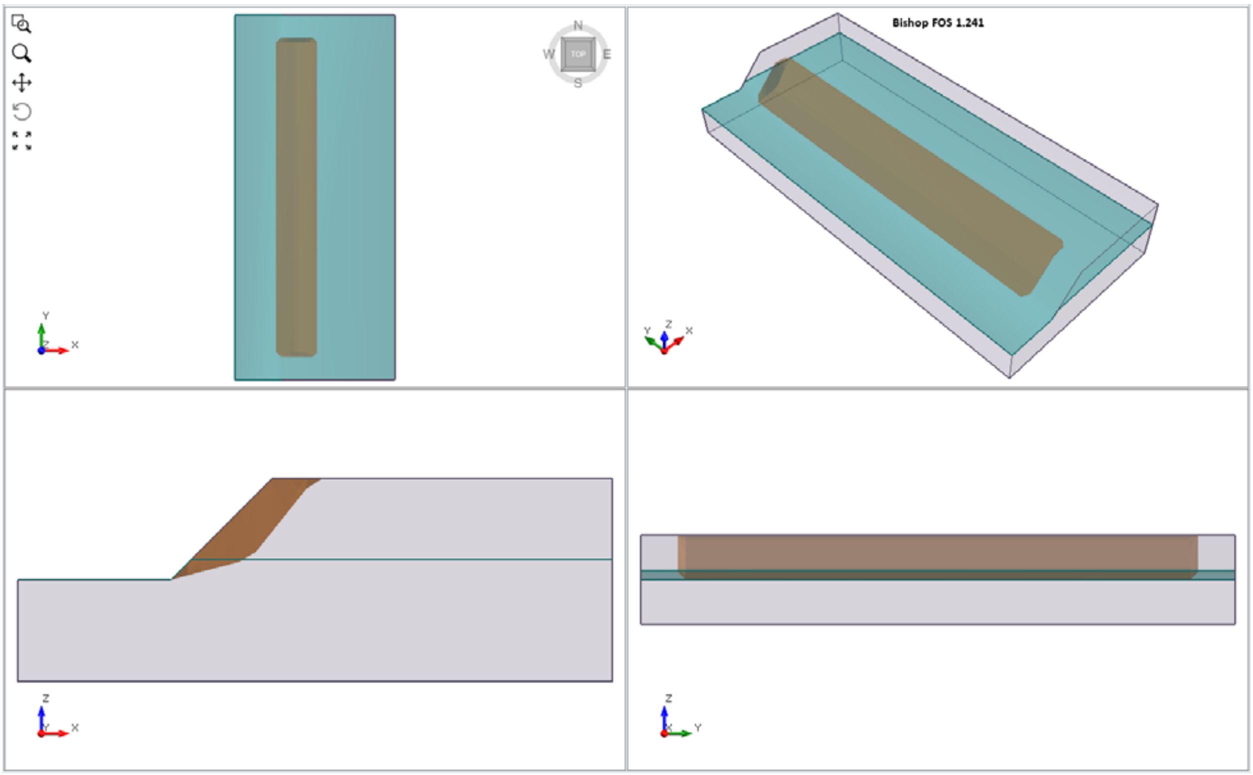


Figure 24.4.1 – Slide3 User Defined Slip Surface Using Weak Planes

2D extruded, water table, weak layer defined slip surface

25.1 Introduction

Huang, Fan and Wang analyzed a slope with a weak layer and a water table, where they observed the effect of changing the height of the water table on the safety factor of the slope. This is case 3, where the water table is 2.4 m above the toe of the slope.

25.2 Problem Description

Figure 25 shows the 2D slope geometry in the XZ plane, which will be extruded 80m in the Y direction, including the weak layer and water table. Table 25.1 shows the material properties of the slope and the weak layer. The slip surface is defined by the weak layer, whose properties can be found in Table 25.1, and a number of other weak planes which have the same properties as the soil. One of the planes is a flat XY plane at the toe of the slope. There are two planes at either side of the slope create the slip surface's length, which is defined as 70m by Huang, Fan and Wang, therefore one plane has a center located at (17.5, 5, 12) with a normal of (0, -1, -0.001) and the other has a center located at (17.5, 74, 12) and has a normal of (0, -1, 0.001). The final plane intersects the weak plane, has a center located at (17.5, 40 12) and a normal of (-1, 0, 0.798636), to make an angle of 53° with the horizontal, as prescribed by Huang, Fan and Wang.

25.3 Geometry and Properties

Table 25.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	20	15	20
Weak Layer	10	10	20

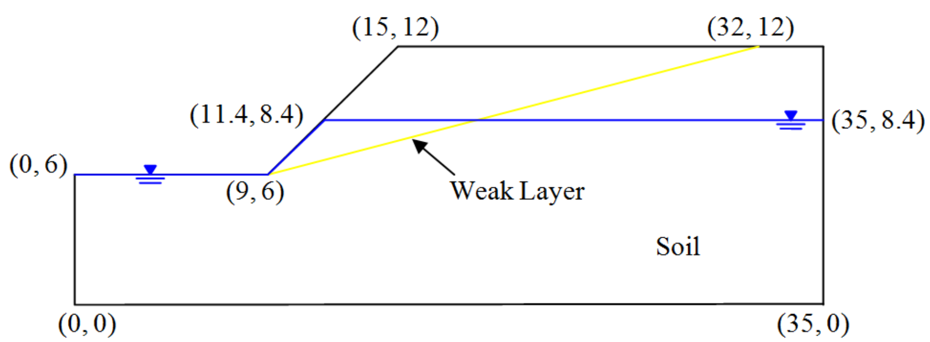


Figure 25

25.4 Results

Table 25.4.1: Safety Factors Using Slide3

Method	Safety Factor
Bishop	1.195
GLE	1.196
Janbu	1.198
Spencer	1.196

Referee: 1.30 [Huang et al., 2016]

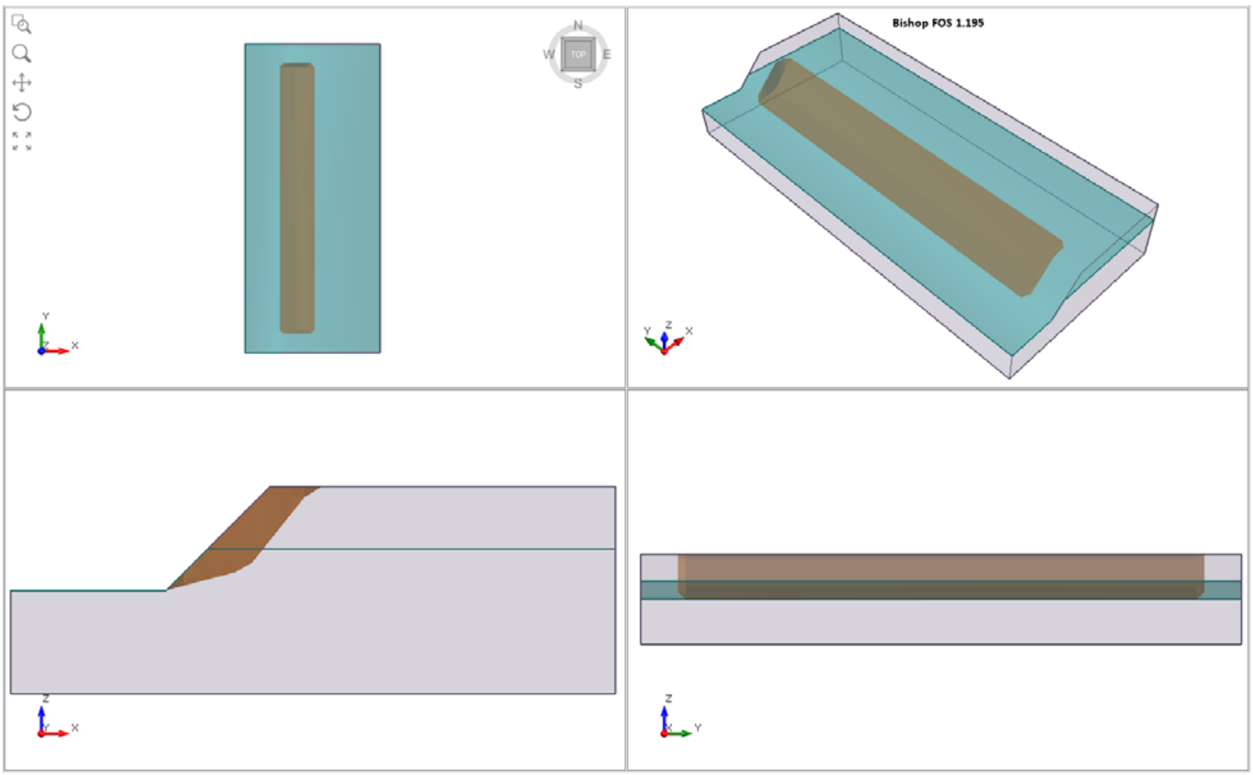


Figure 25.4.1 – Slide3 User Defined Slip Surface Using Weak Planes

2D extruded, water table, weak layer defined slip surface

26.1 Introduction

Huang, Fan and Wang analyzed a slope with a weak layer and a water table, where they observed the effect of changing the height of the water table on the safety factor of the slope. This is case 4, where the water table is 3.6 m above the toe of the slope.

26.2 Problem Description

Figure 26 shows the 2D slope geometry in the XZ plane, which will be extruded 80m in the Y direction, including the weak layer and water table. Table 26.1 shows the material properties of the slope and the weak layer. The slip surface is defined by the weak layer, whose properties can be found in Table 26.1, and a number of other weak planes which have the same properties as the soil. One of the planes is a flat XY plane at the toe of the slope. There are two planes at either side of the slope create the slip surface's length, which is defined as 70m by Huang, Fan and Wang, therefore one plane has a center located at (17.5, 5, 12) with a normal of (0, -1, -0.001) and the other has a center located at (17.5, 74, 12) and has a normal of (0, -1, 0.001). The final plane intersects the weak plane, has a center located at (17.5, 40 12) and a normal of (-1, 0, 0.798636), to make an angle of 53° with the horizontal, as prescribed by Huang, Fan and Wang.

26.3 Geometry and Properties

Table 26.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	20	15	20
Weak Layer	10	10	20

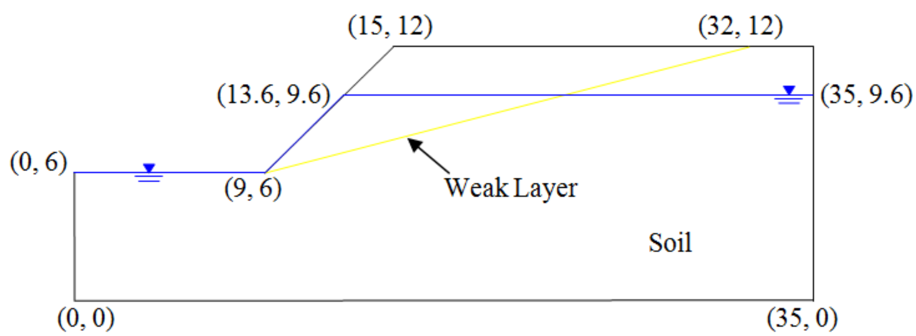


Figure 26

26.4 Results

Table 26.4.1: Safety Factors Using Slide3

Method	Safety Factor Slide3
Bishop	1.13
GLE	1.131
Janbu	1.132
Spencer	1.131

Referee: 1.25 [Huang et al., 2016]

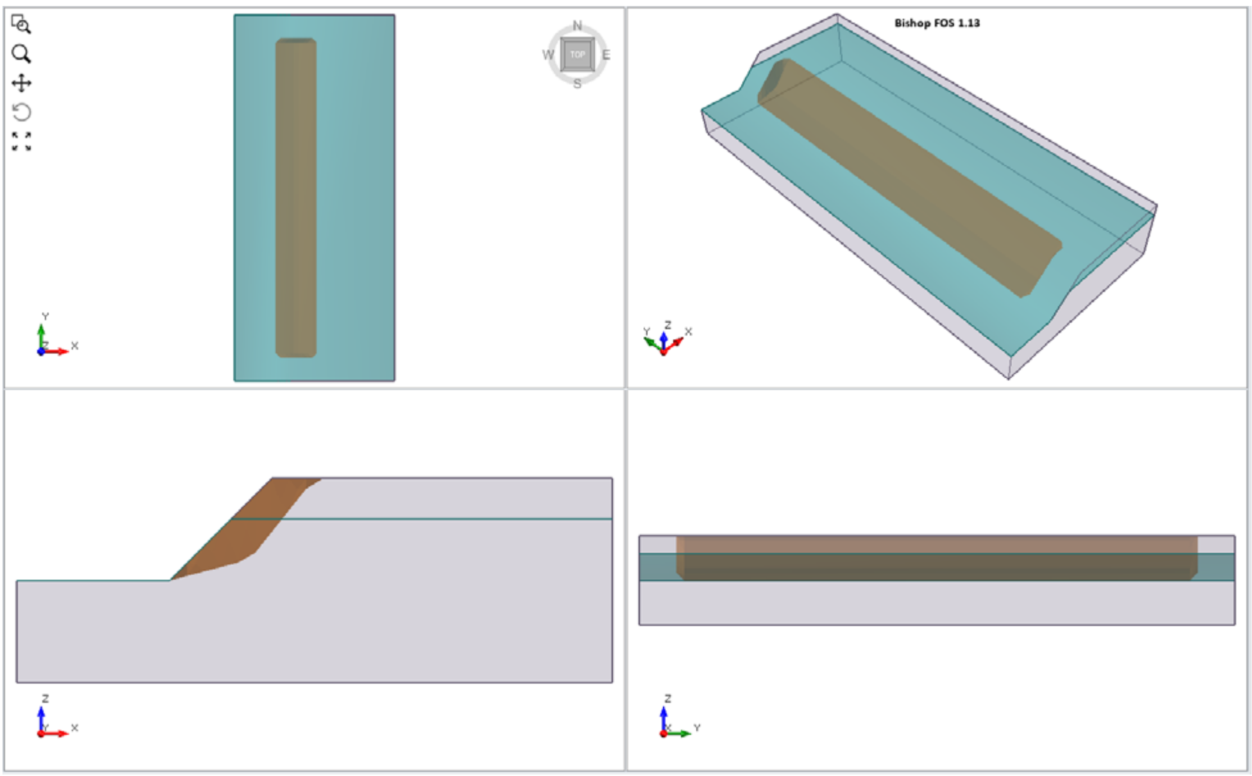


Figure 26.4.1 – Slide3 User Defined Slip Surface Using Weak Planes

2D extruded, homogeneous, submerged slope, spherical

27.1 Introduction

This problem is taken from Figure 6.27 on page 88 of Duncan and Wright (2005).

27.2 Problem Description

This problem is a slope submerged under a water table located 30 ft above the crest. Figure 27 shows the slope geometry in the XZ plane as well as the location of the water table. Figure 27 gets extruded 140 ft in the Y direction. Material properties can be found in Table 27.1. The spherical slip surface and corresponding safety factor is required.

27.3 Geometry and Properties

Table 27.1: Material Properties

	c′ (psf)	φ′ (deg.)	γ (pcf)
Soil	100	20	128

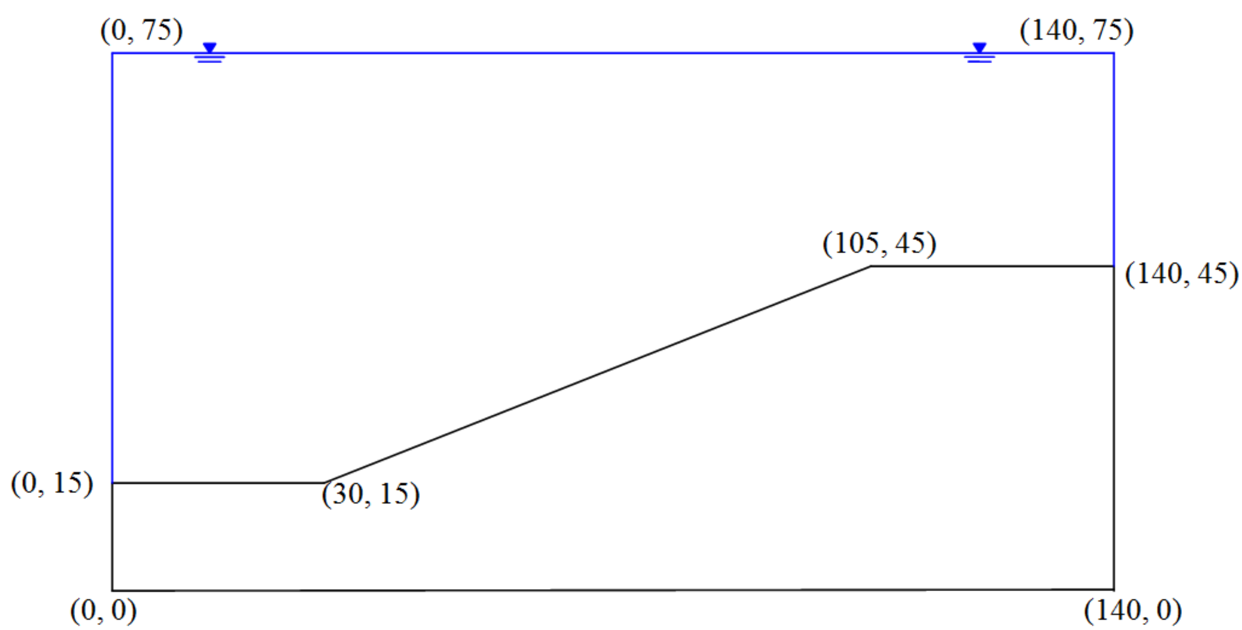


Figure 27

27.4 Results

Table 27.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.796	1.603		
GLE	1.791	1.599	1.43	1.59
Spencer	1.791	1.599		

Referee: 1.60 [Duncan and Wright, 2005]

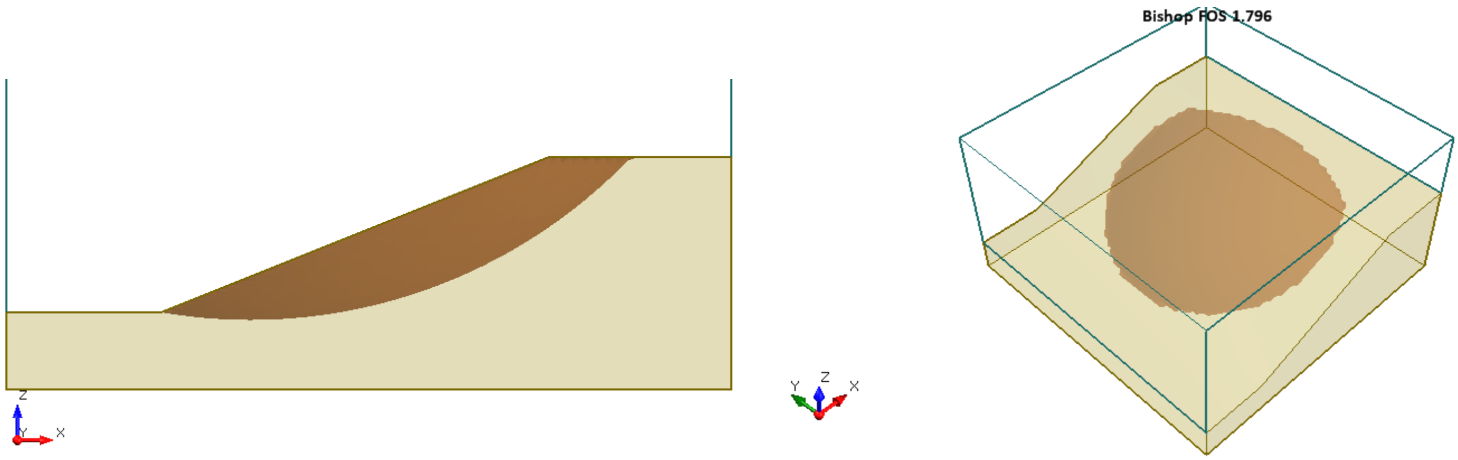


Figure 27.4.1 – Slide3 Solution Using the Bishop Method

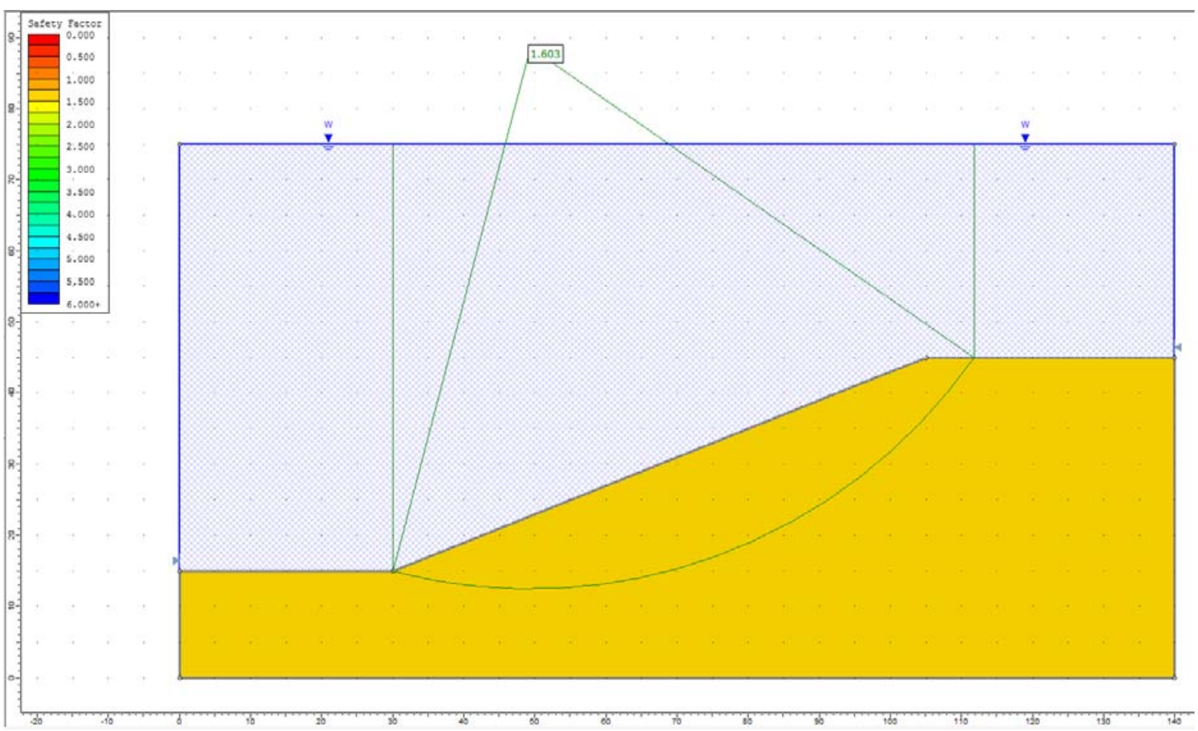


Figure 27.4.2 – Slide Solution Using the Bishop Method

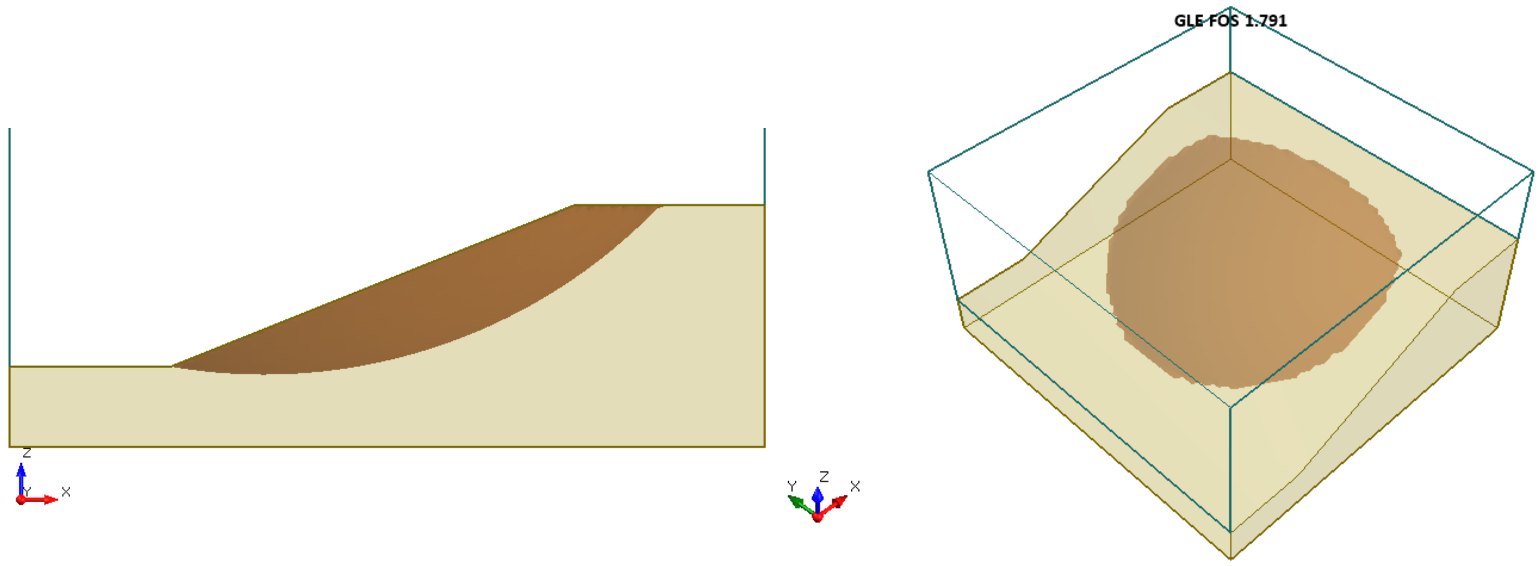


Figure 27.4.3 – Slide3 Solution Using the GLE Method

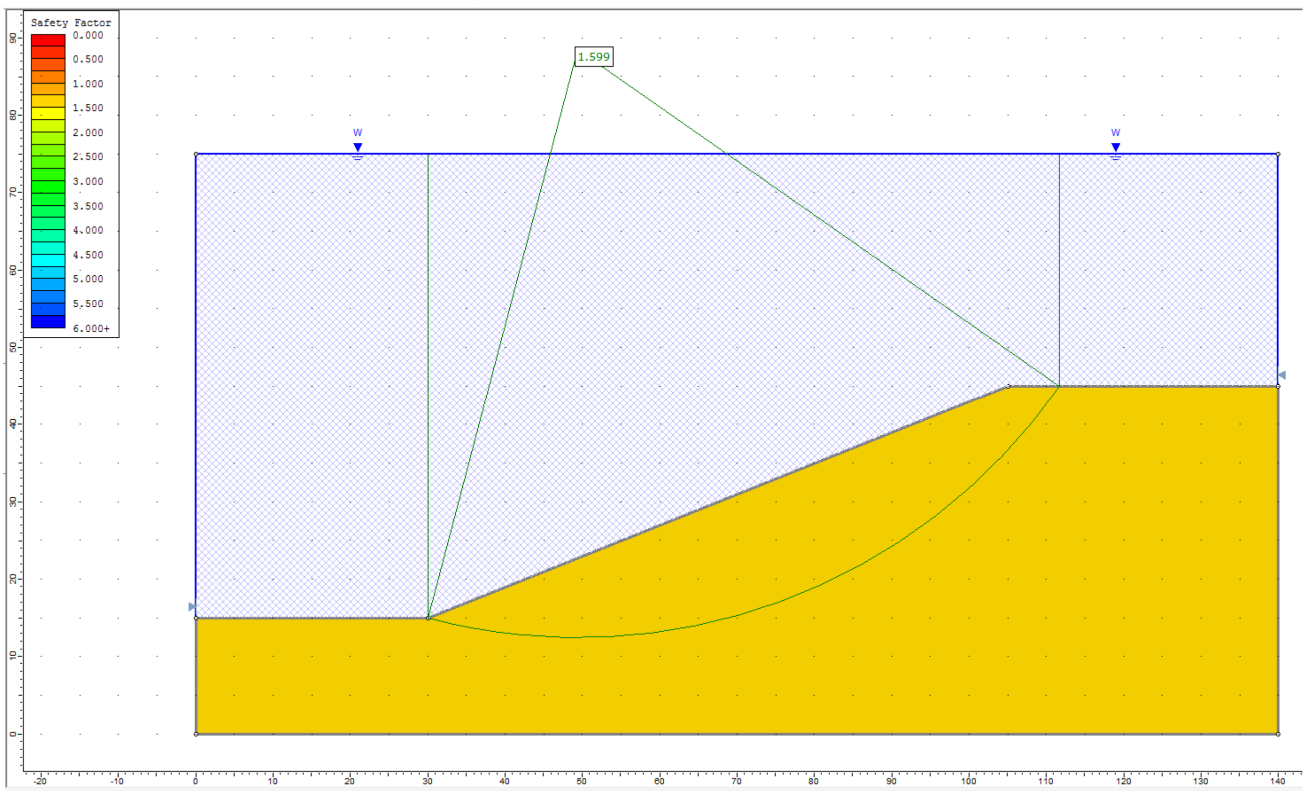


Figure 27.4.4 – Slide Solution Using the GLE Method

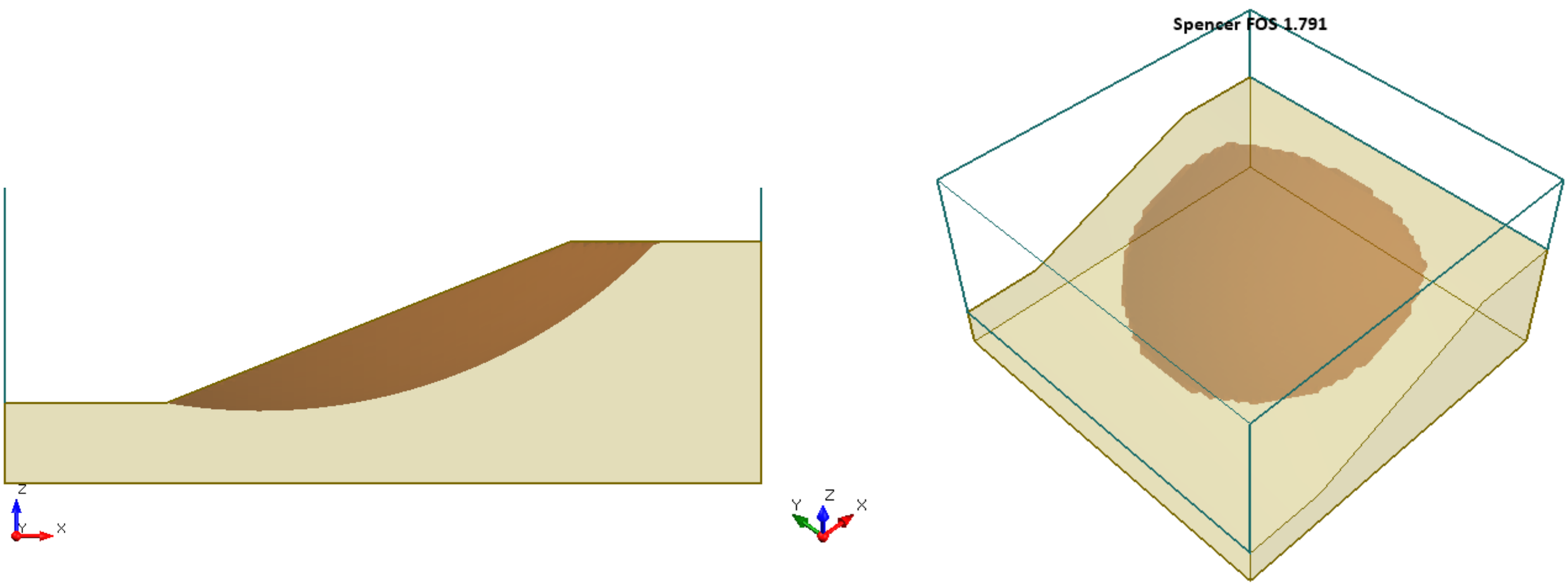


Figure 27.4.5 – Slide3 Solution Using the Spencer Method

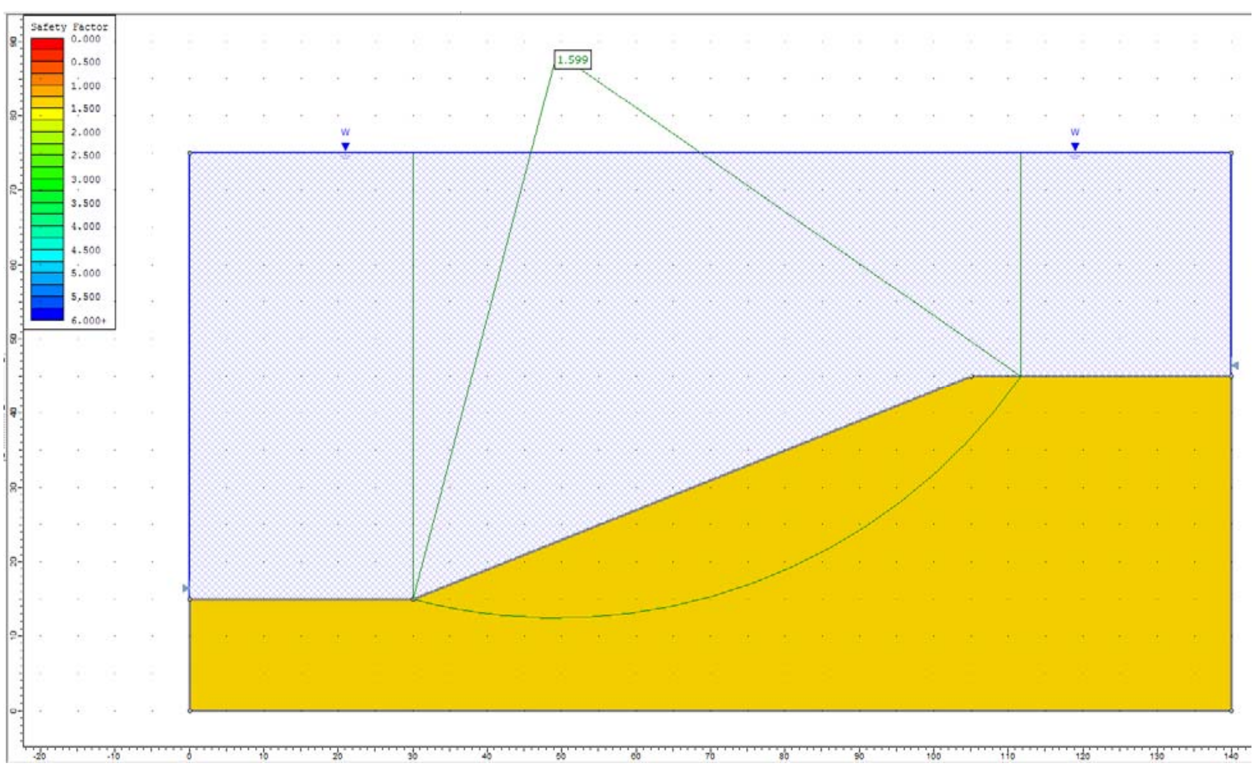


Figure 27.4.6 – Slide Solution Using the Spencer Method

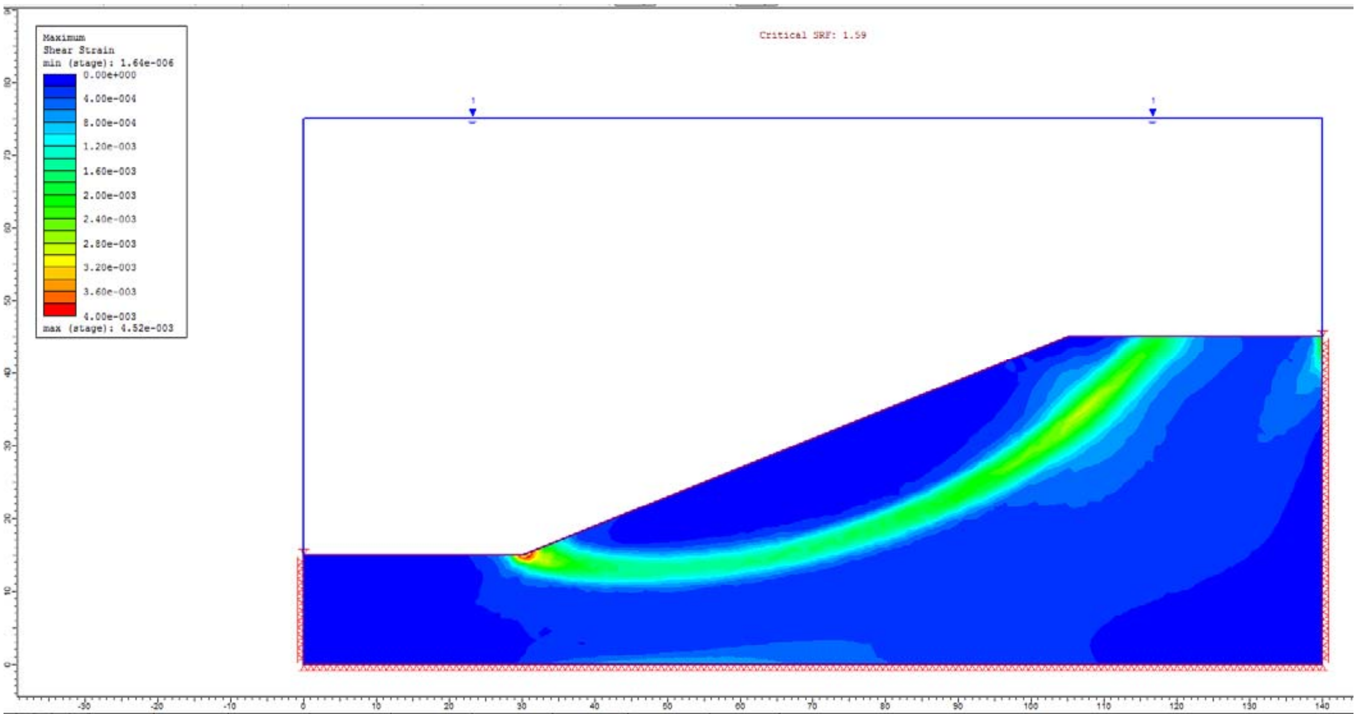


Figure 27.4.7 – RS2 Maximum Shear Strain

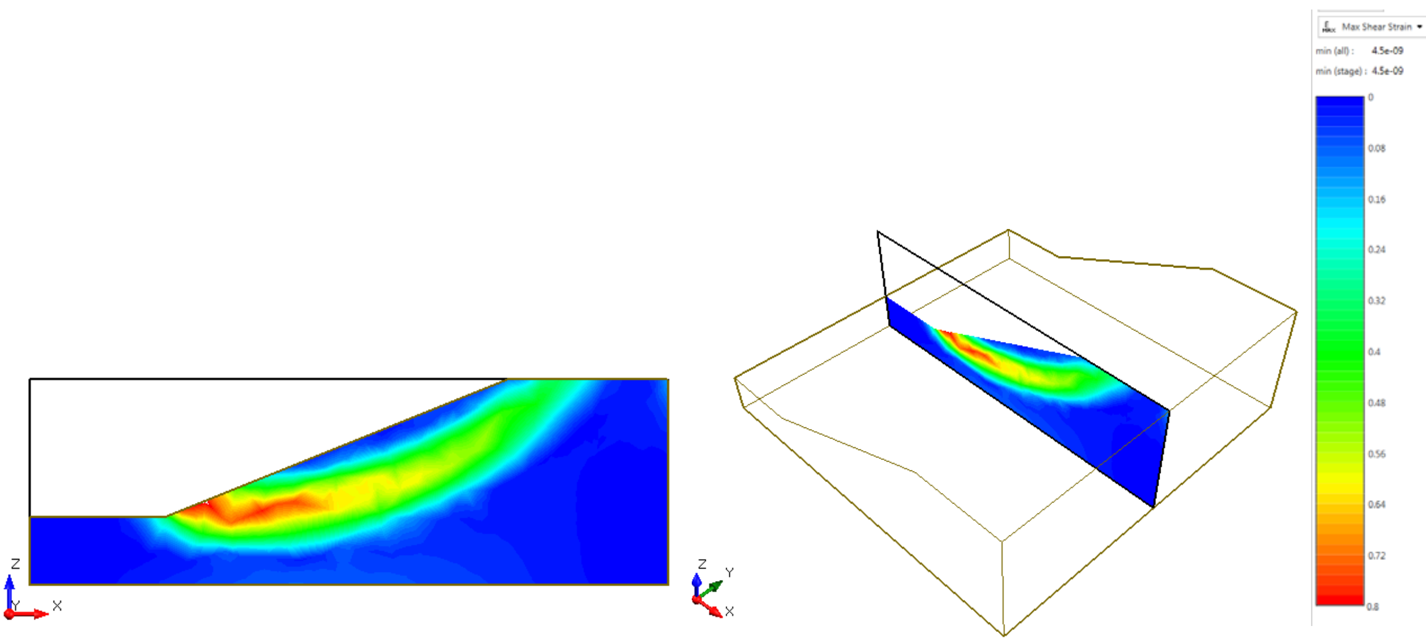


Figure 27.4.8 – RS3 Maximum Shear Strain

2D extruded, homogeneous, submerged slope, ellipsoidal with SA

28.1 Introduction

This problem is taken from Figure 6.27 on page 88 of Duncan and Wright (2005).

28.2 Problem Description

This problem is a slope submerged under a water table located 60 ft above the crest. Figure 28 shows the slope geometry in the XZ plane as well as the location of the water table. Figure 28 gets extruded 140 ft in the Y direction. Material properties can be found in Table 28.1. The ellipsoidal slip surface and corresponding safety factor is required.

28.3 Geometry and Properties

Table 28.1: Material Properties

	c′ (psf)	φ′ (deg.)	γ (pcf)
Soil	100	20	128

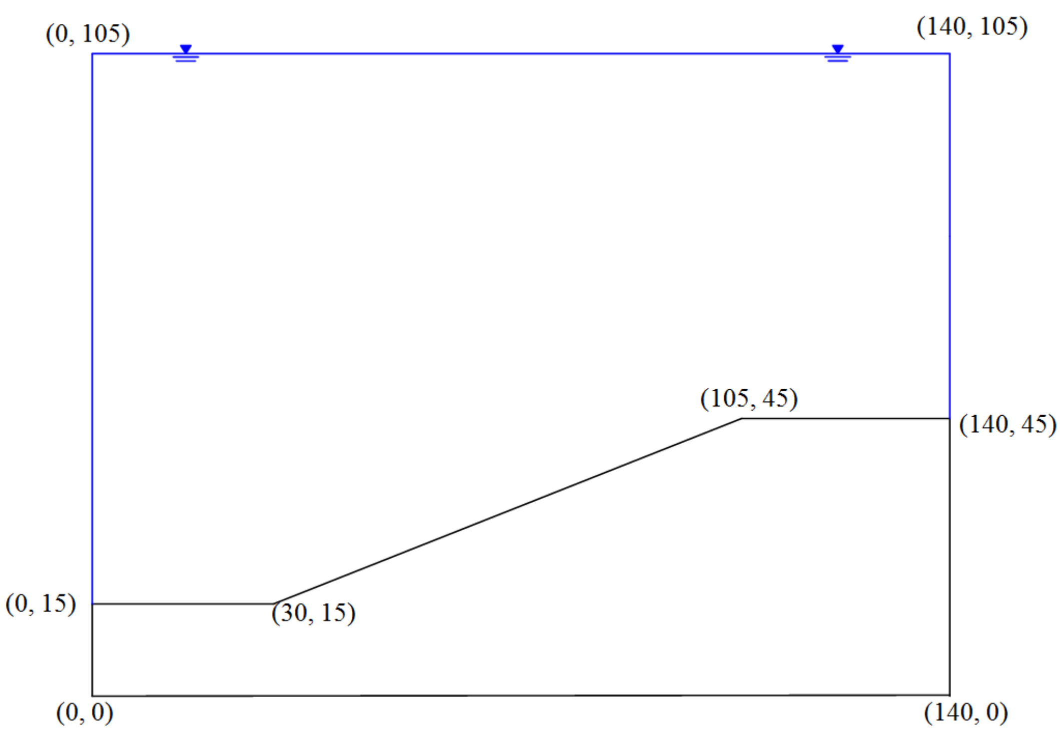


Figure 28

28.4 Results

Table 28.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.624	1.560	1.43	1.59
GLE	1.669	1.579		
Spencer	1.674	1.590		

Referee: 1.60 [Duncan and Wright, 2005]

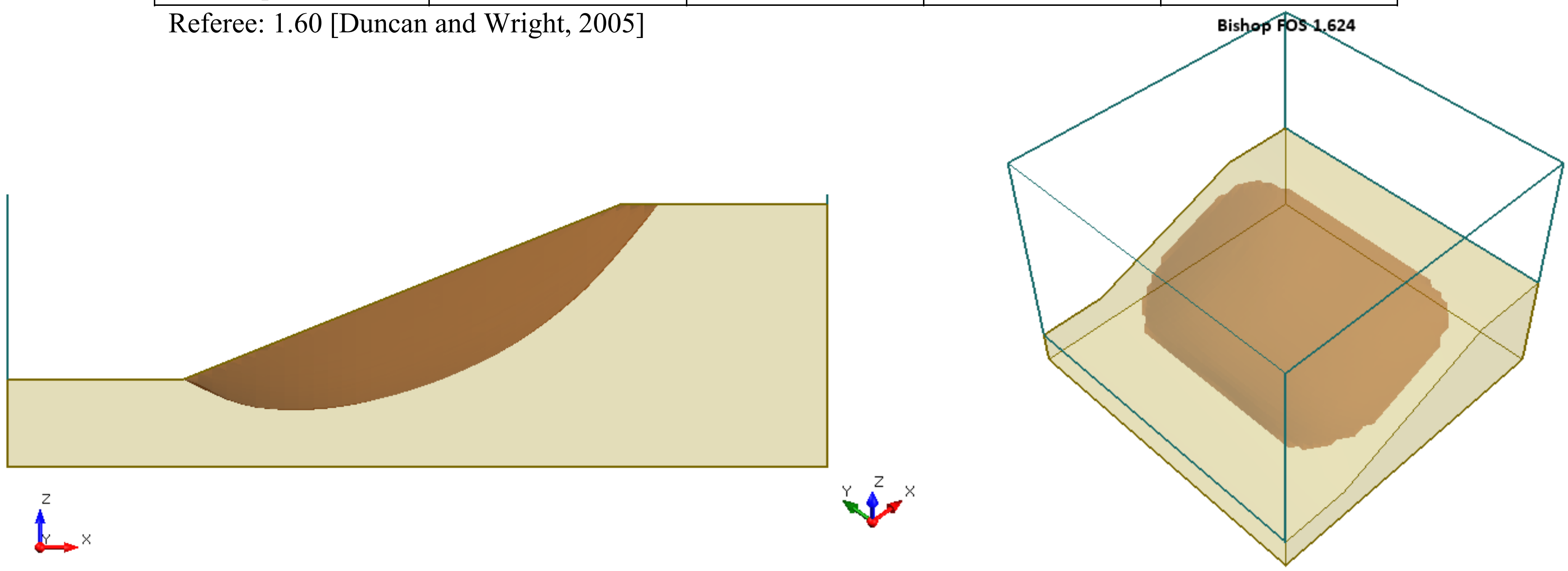


Figure 28.4.1 – Slide3 Solution Using the Bishop Method

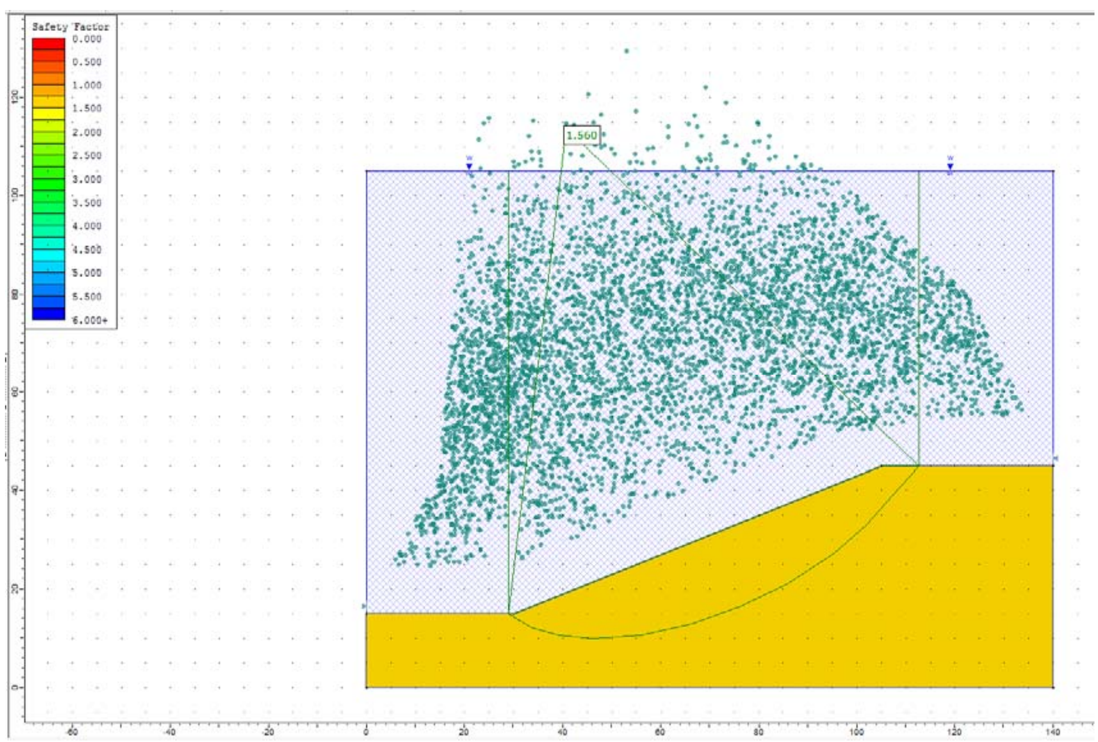


Figure 28.4.2 – Slide Solution Using the Bishop Method

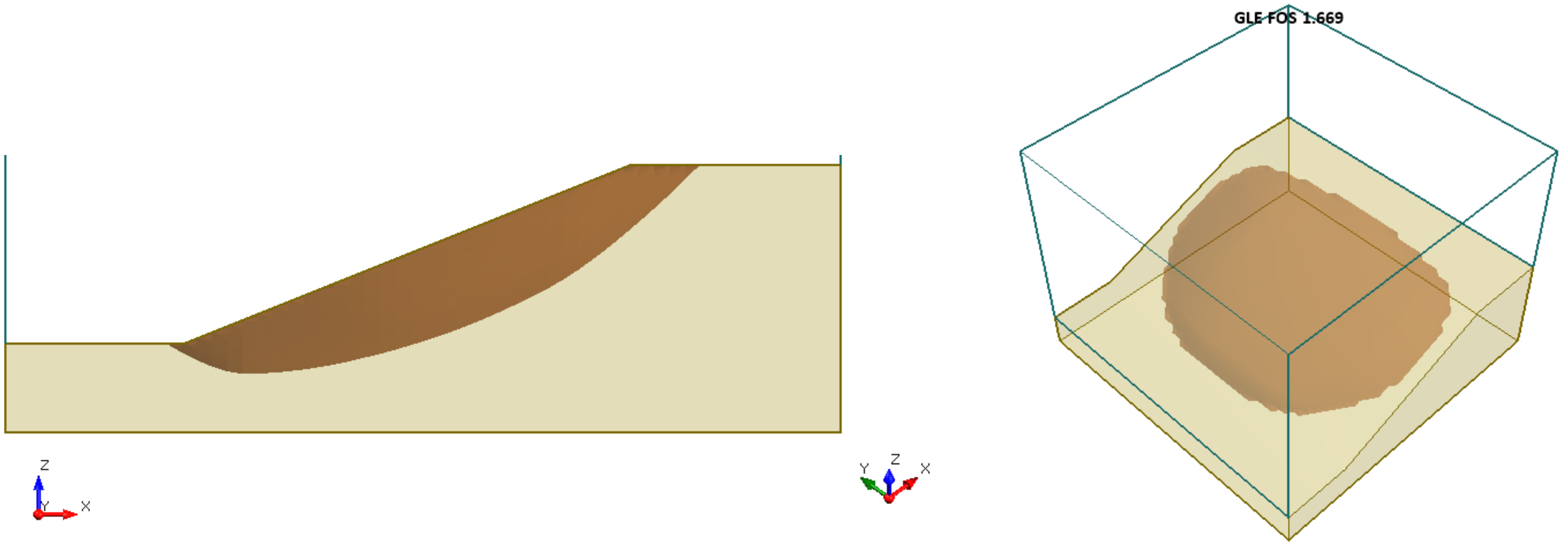


Figure 28.4.3 – Slide3 Solution Using the GLE Method

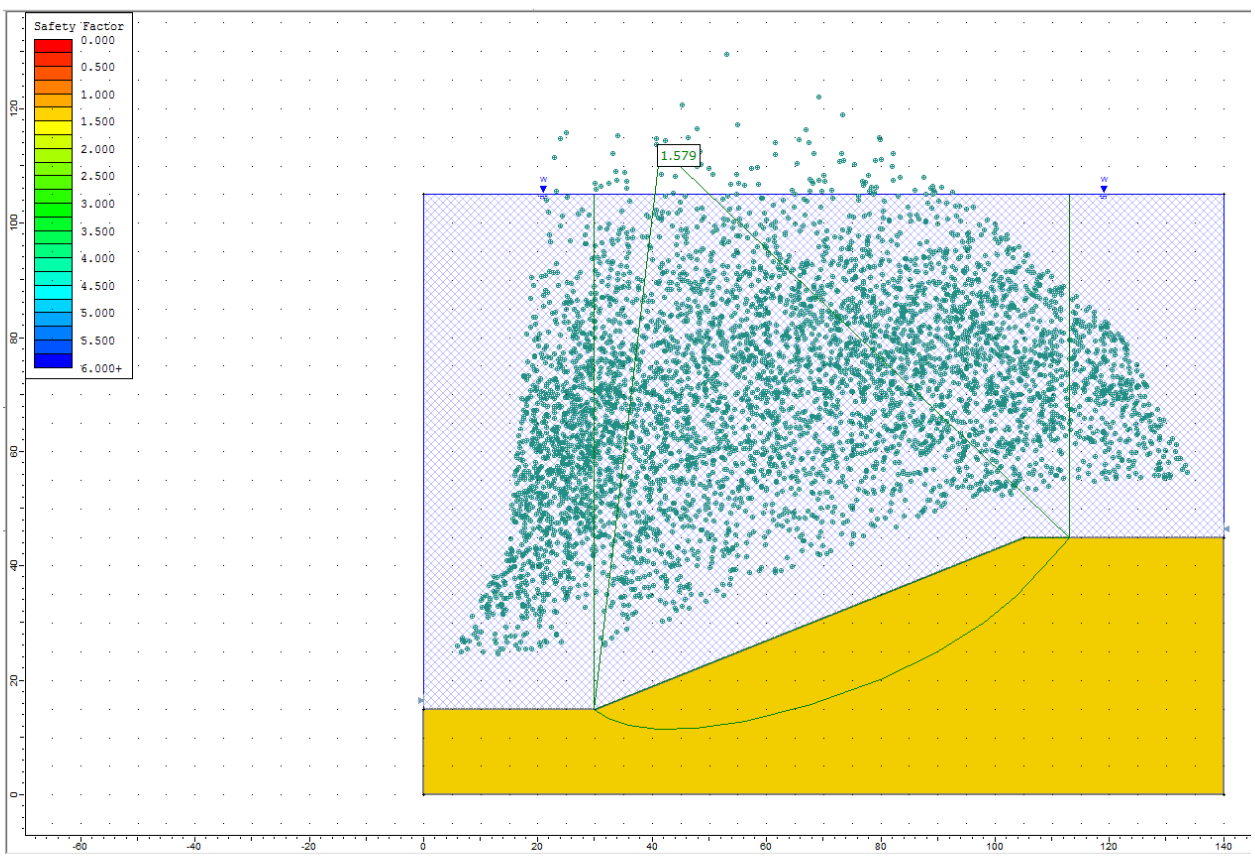


Figure 28.4.4 – Slide Solution Using the GLE Method

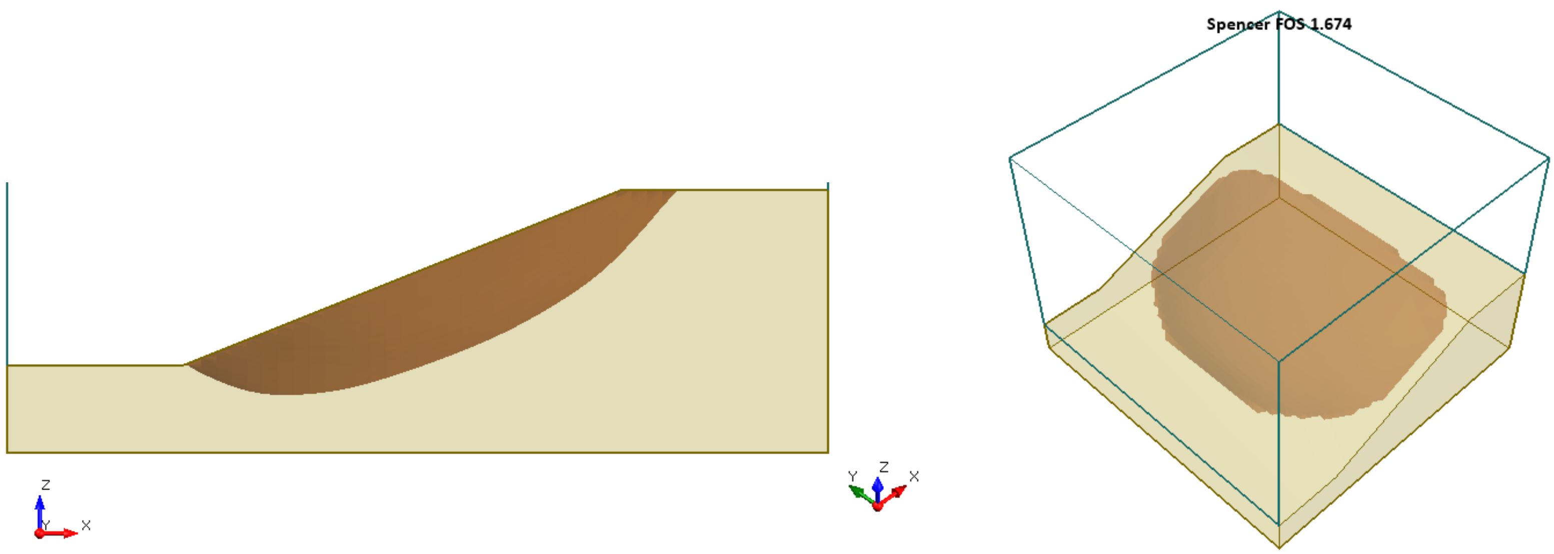


Figure 28.4.5 – Slide3 Solution Using the Spencer Method

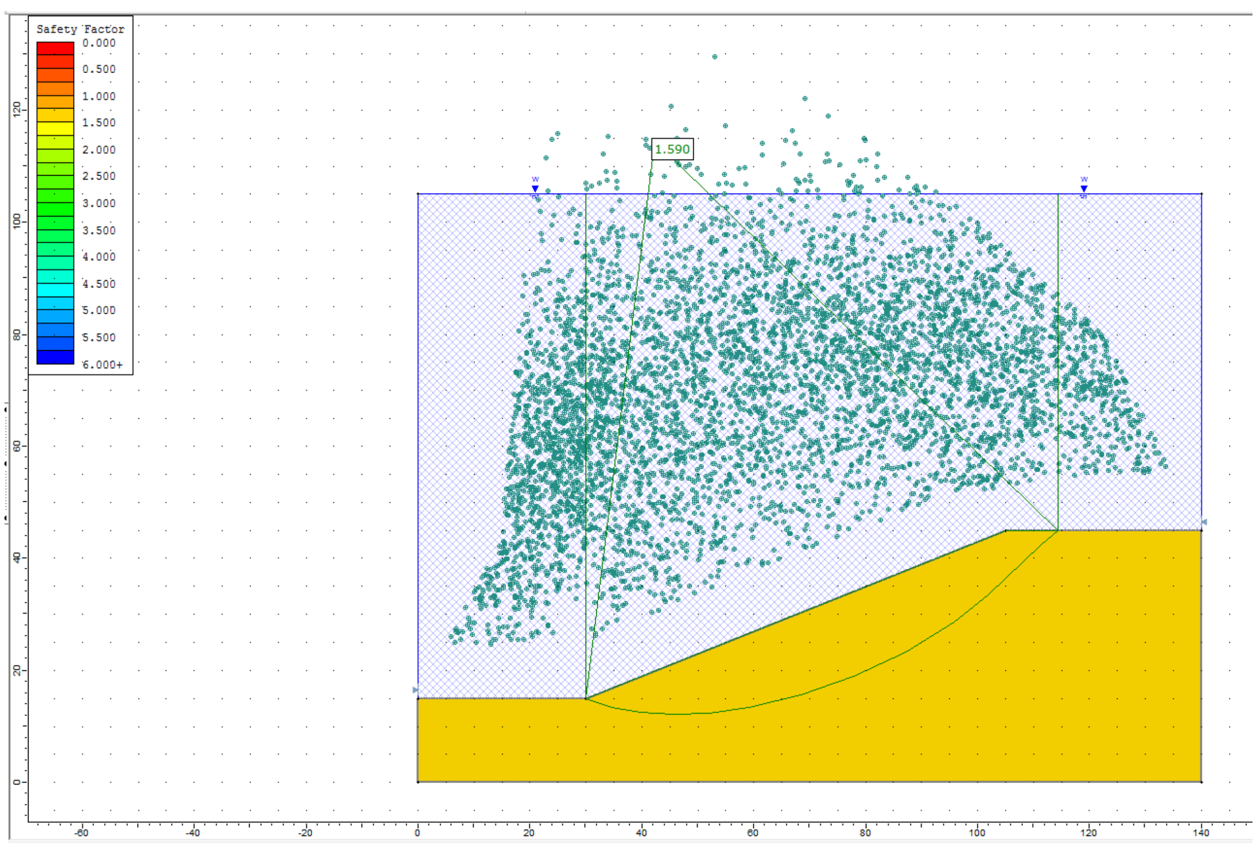


Figure 28.4.6 – Slide Solution Using the Spencer Method

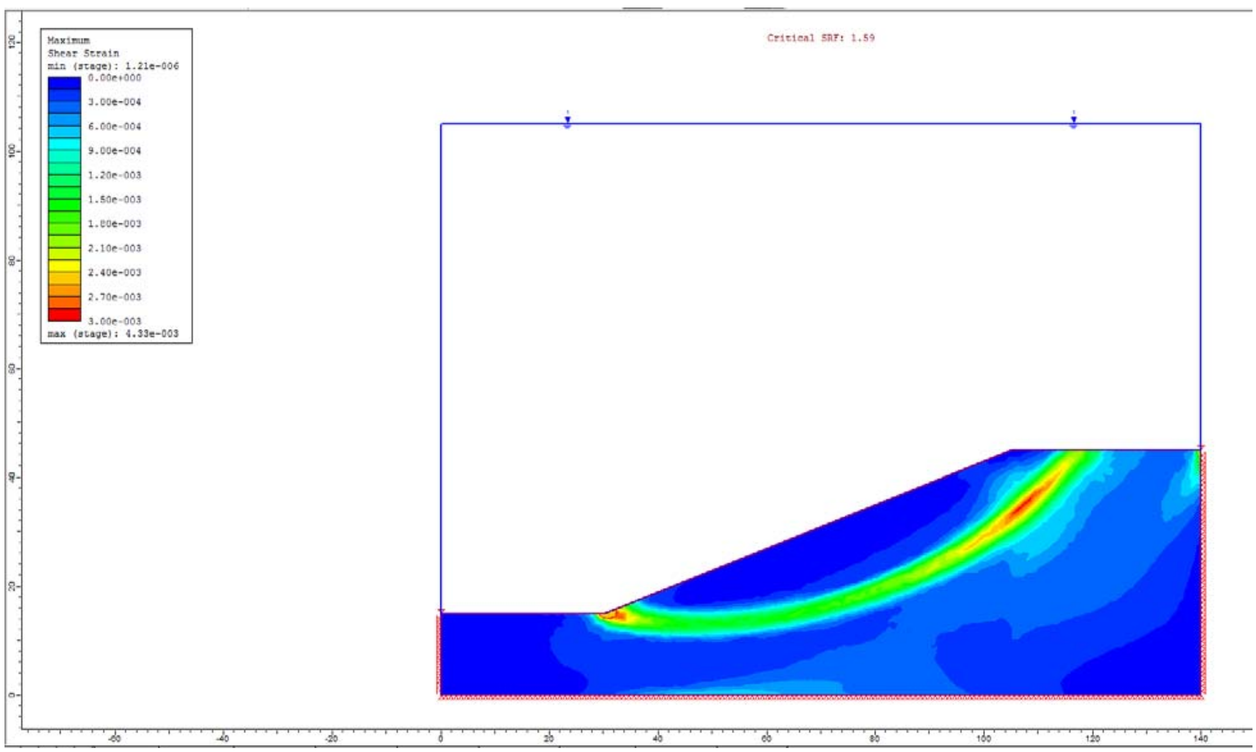


Figure 28.4.7 – RS2 Maximum Shear Strain

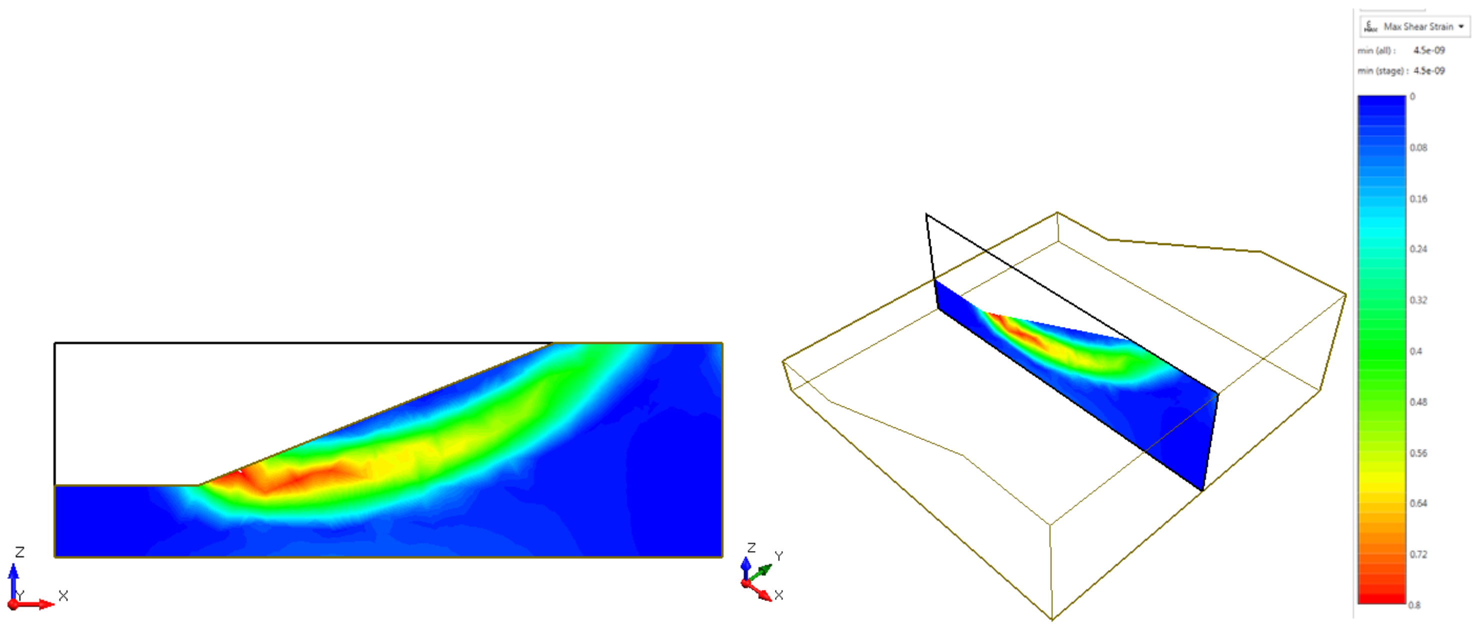


Figure 28.4.8 – RS3 Maximum Shear Strain

2D extruded embankment, (2) materials, spherical

29.1 Introduction

This problem is taken from Figure 7.12 on page 120 of Duncan and Wright (2005).

29.2 Problem Description

Figure 29 shows an embankment constructed of cohesionless material resting on saturated clay foundation in the XZ plane. This geometry will be extruded 700 ft in the Y direction. The critical slip surface is assumed to be spherical and located using auto refine search.

29.3 Geometry and Properties

Table 29.1: Material Properties

	c′ (psf)	φ′ (deg.)	γ (pcf)
Embankment (Sand)	0	40	140
Foundation (Saturated Clay)	2500	0	140

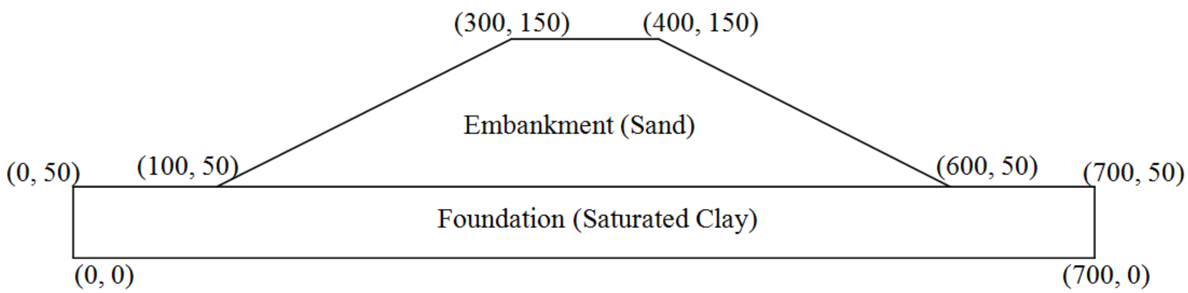


Figure 29

29.4 Results

Table 29.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2	Referee [Duncan and Wright, 2005]
Bishop	1.658	1.228	1.37	1.19	1.22
Janbu	1.489	1.079			1.07
Spencer	1.605	1.201			1.19

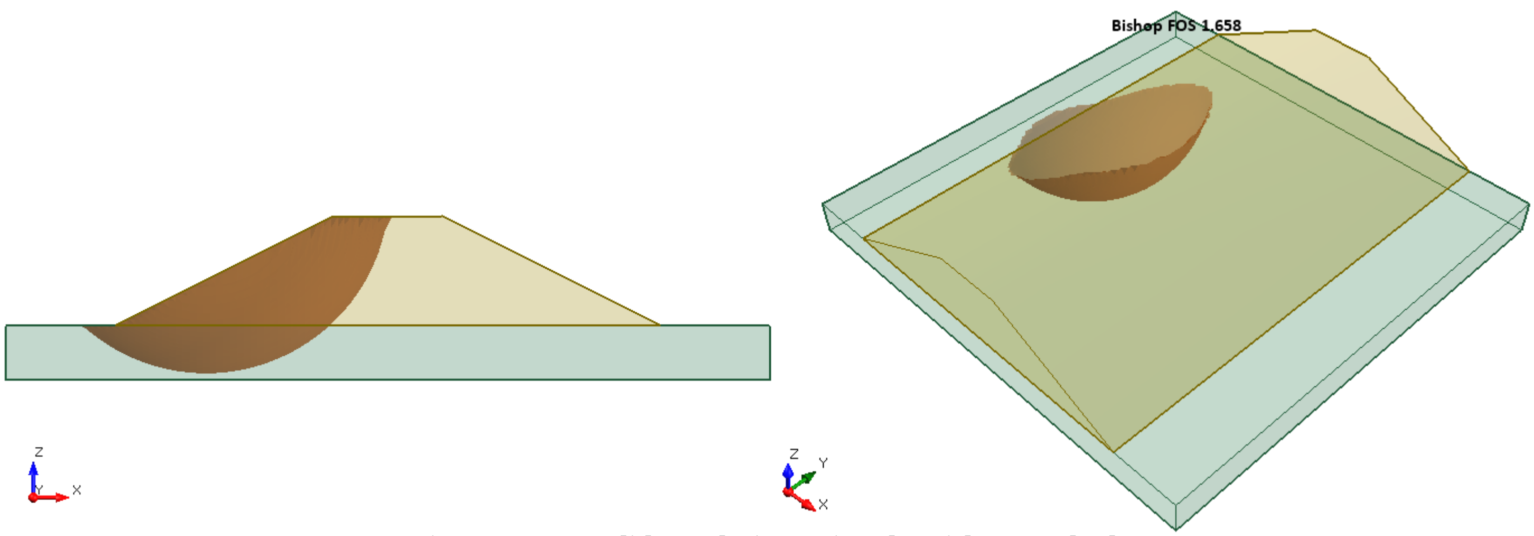


Figure 29.4.1 – Slide3 Solution Using the Bishop Method

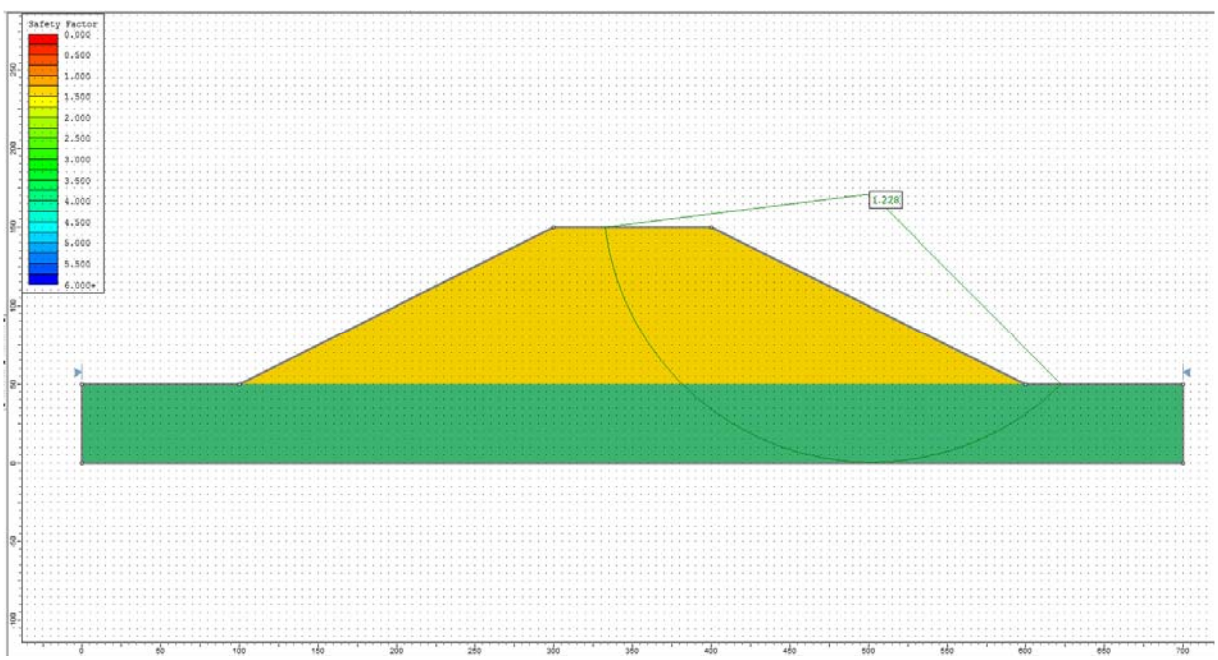


Figure 29.4.2 – Slide Solution Using the Bishop Method

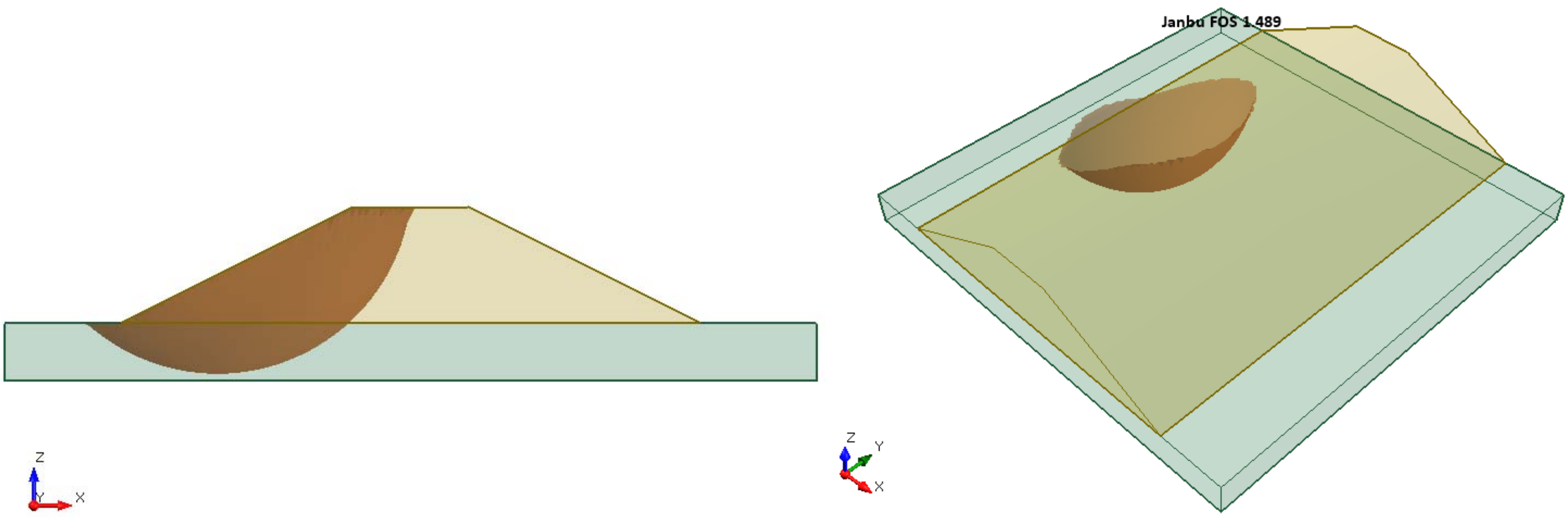


Figure 29.4.3 – Slide3 Solution Using the Janbu Method

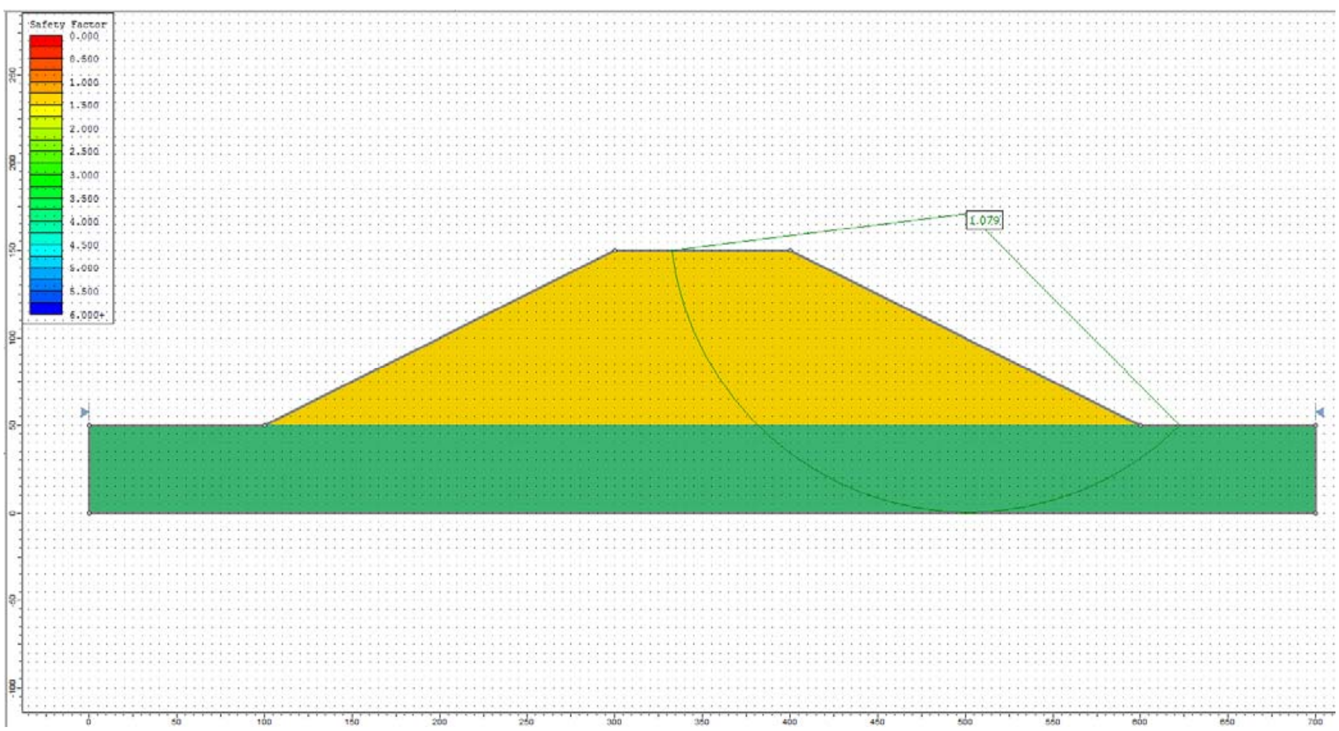


Figure 29.4.4 – Slide Solution Using the Janbu Method

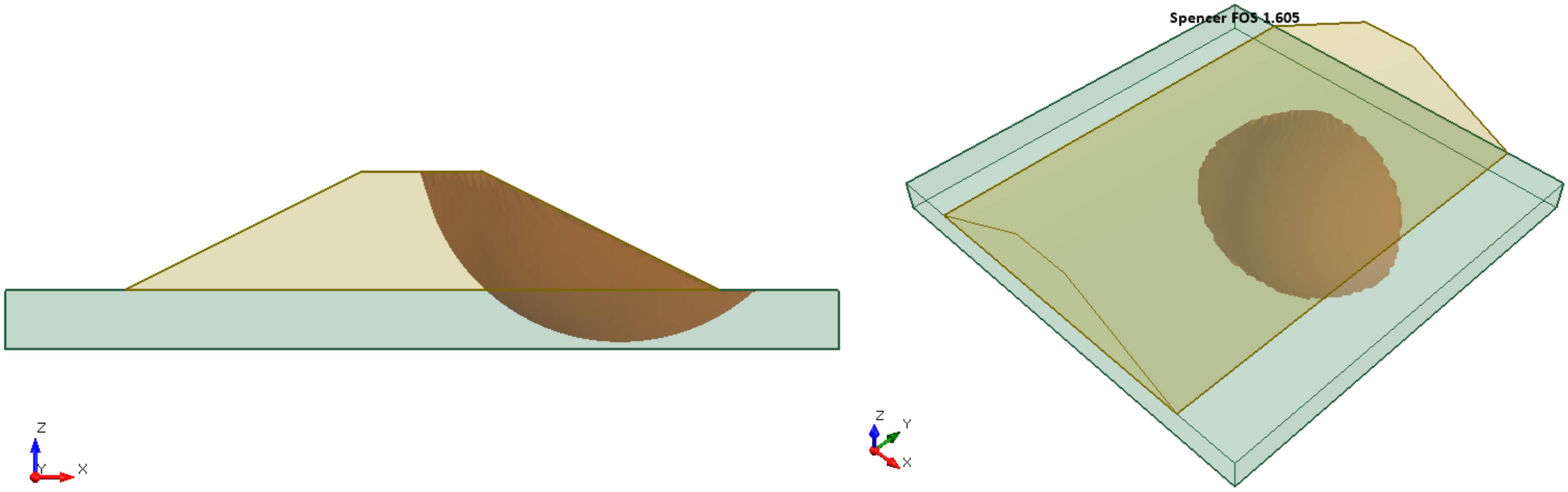


Figure 29.4.5 – Slide3 Solution Using the Spencer Method

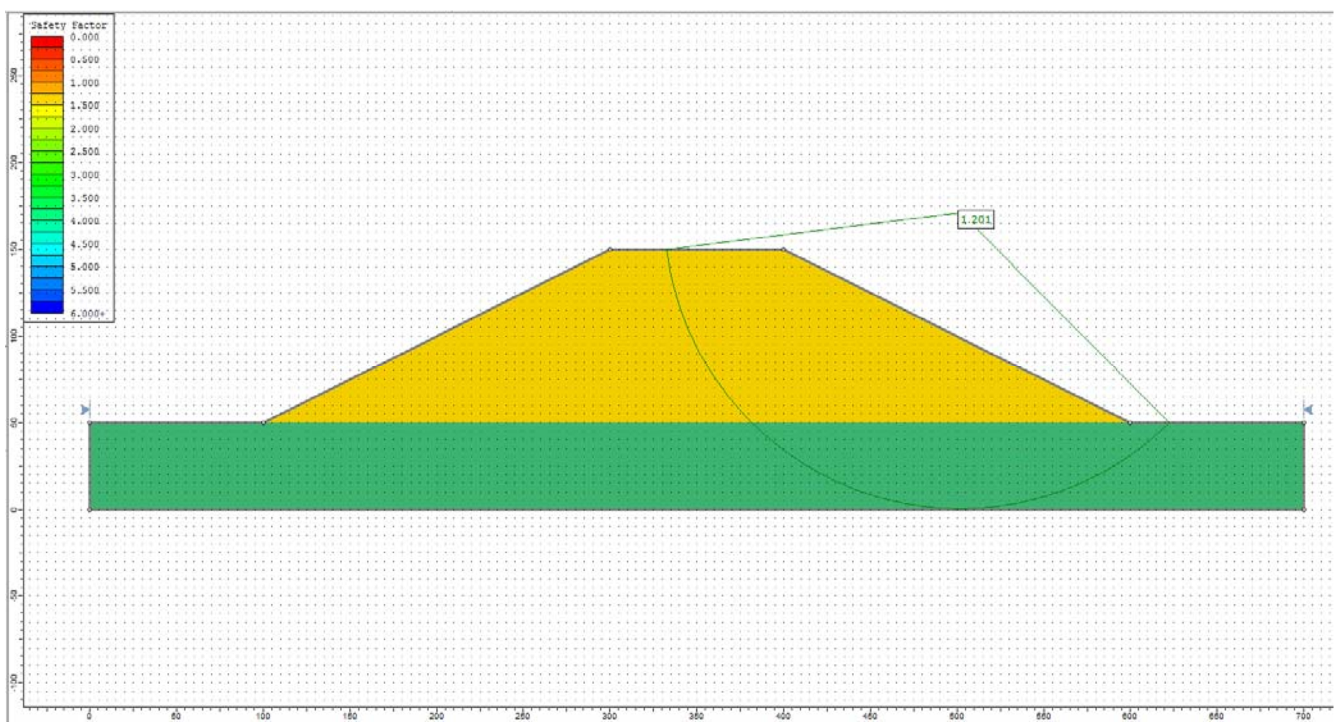


Figure 29.4.6 – Slide Solution Using the Spencer Method

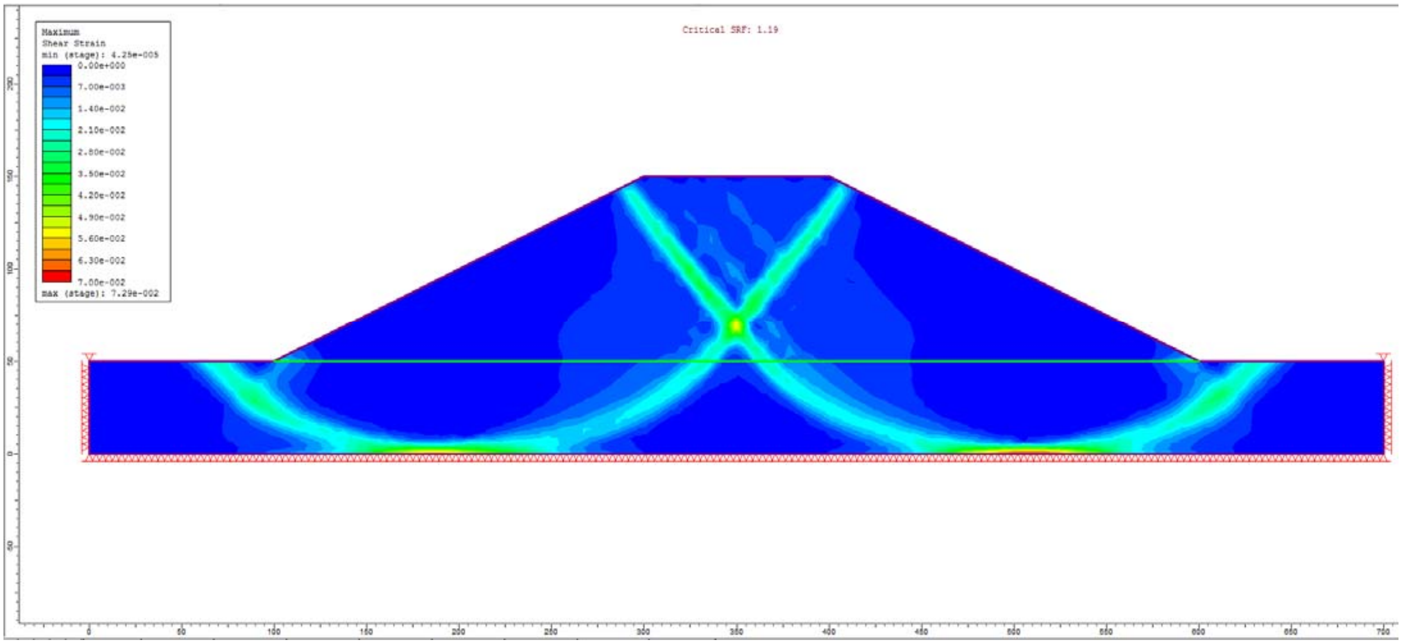


Figure 29.4.7 – RS2 Maximum Shear Strain

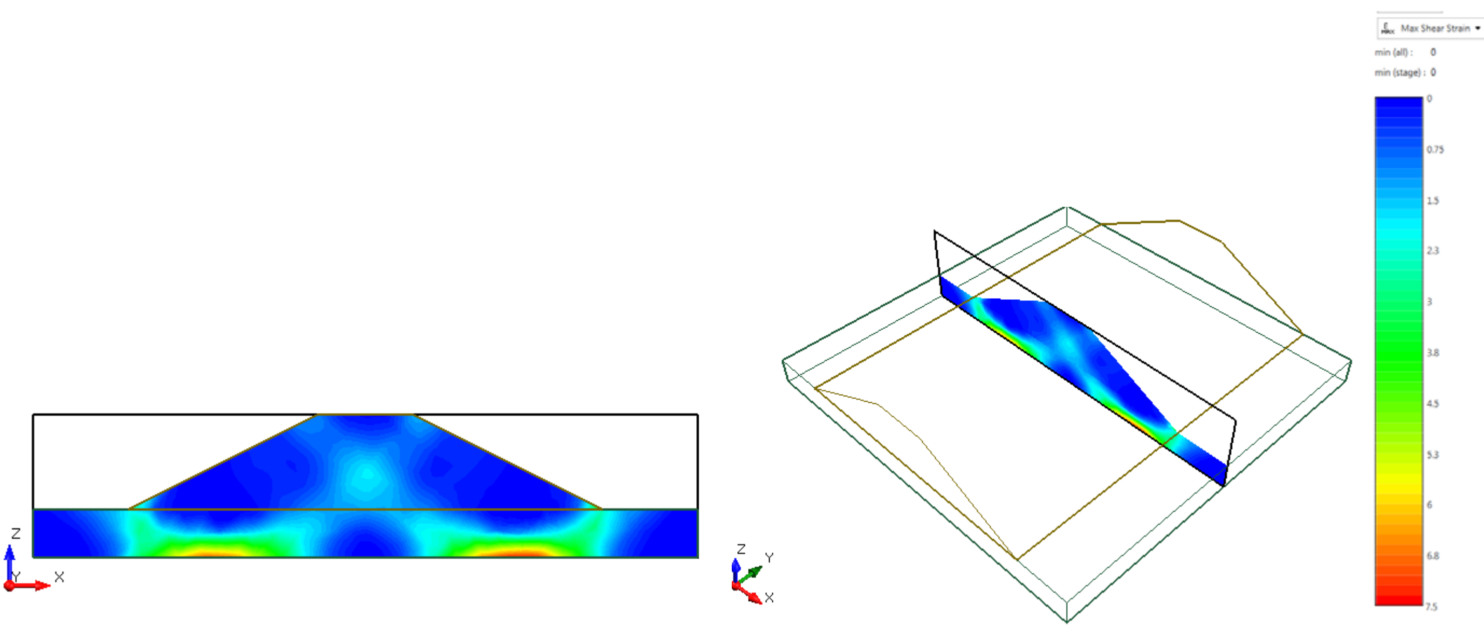


Figure 29.4.8 – RS3 Maximum Shear Strain

2D extruded embankment, homogeneous, water table with ponded water, spherical

30.1 Introduction

This problem is taken from Figure 7.19 on page 128 of Duncan and Wright (2005).

30.2 Problem Description

A symmetric homogeneous earth embankment resting on an impermeable foundation with a ponded water of elevation 40 feet on its left side is shown in Figure 30. Figure 30 is the slope geometry in the XZ plane and will be extruded 255 ft to obtain the 3D model. The pore water pressure is piezometric line approximation. The critical slip surface is assumed to be spherical and located using auto refine search.

30.3 Geometry and Properties

Table 30.1: Material Properties

	c´ (psf)	φ´ (deg.)	γ (pcf)
Embankment	100	30	100

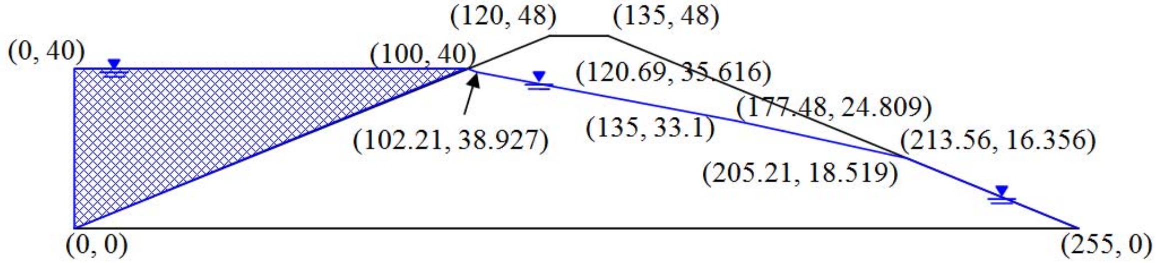


Figure 30

30.4 Results

Table 30.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.249	1.090	1.08	0.99
GLE	1.252	1.094		
Spencer	1.309	1.100		

Referee: 1.16 [Duncan and Wright, 2005]

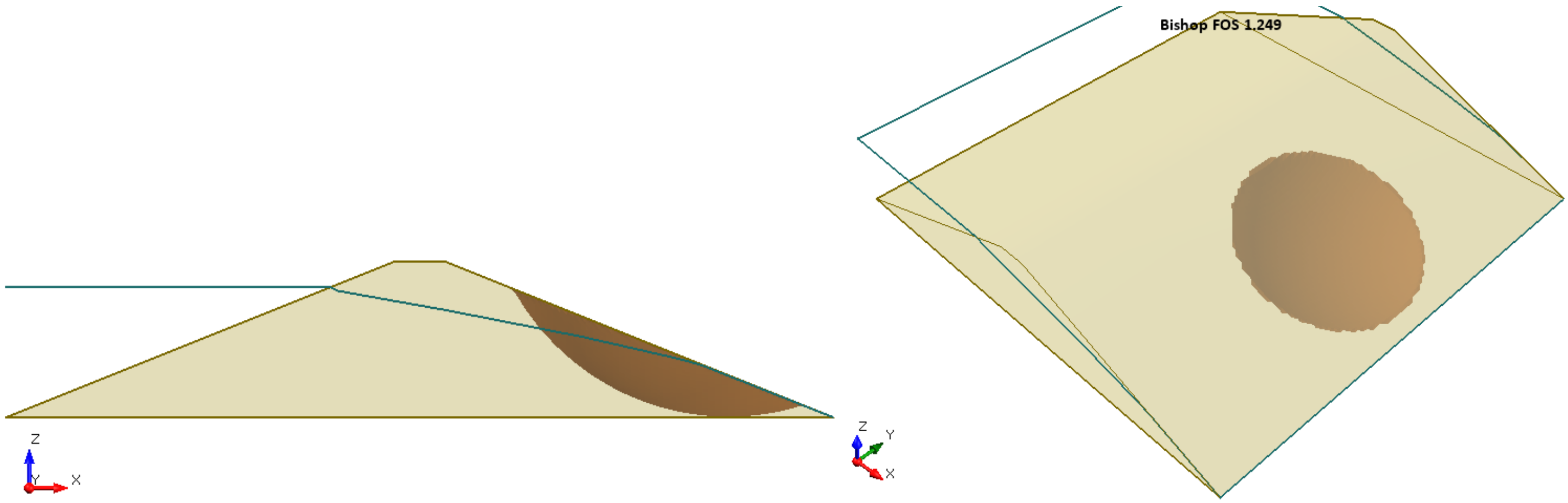


Figure 30.4.1 – Slide3 Solution Using the Bishop Method

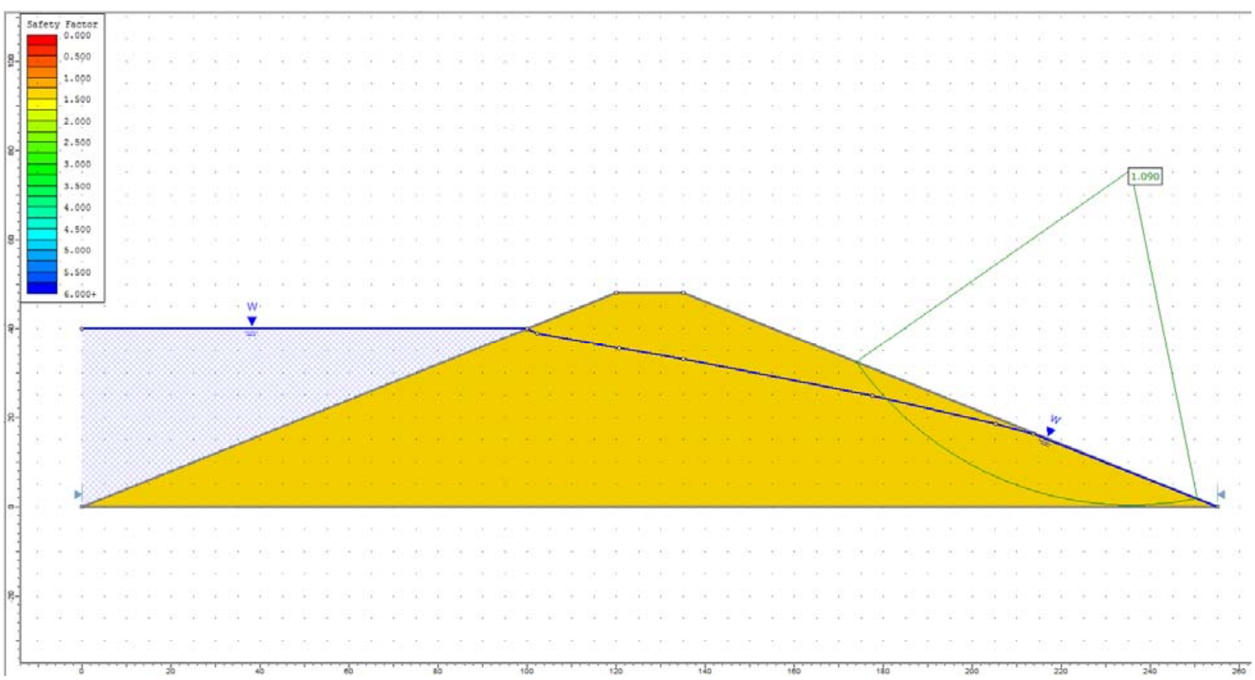


Figure 30.4.2 – Slide Solution Using the Bishop Method

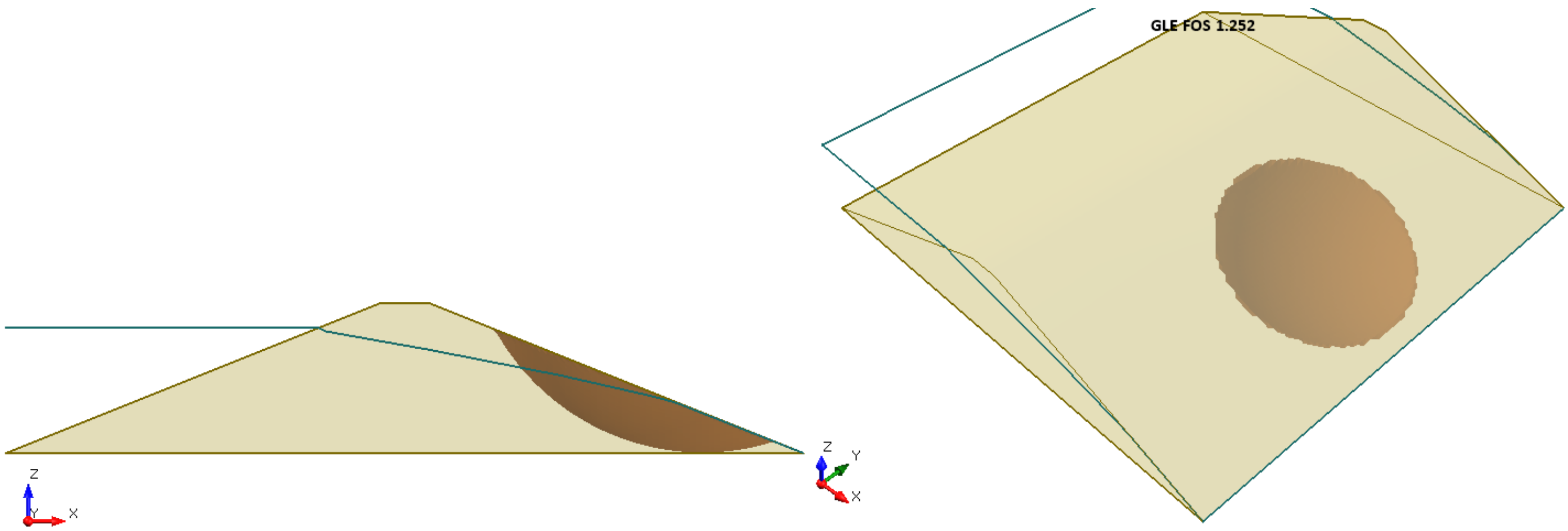


Figure 30.4.3 – Slide3 Solution Using the GLE Method

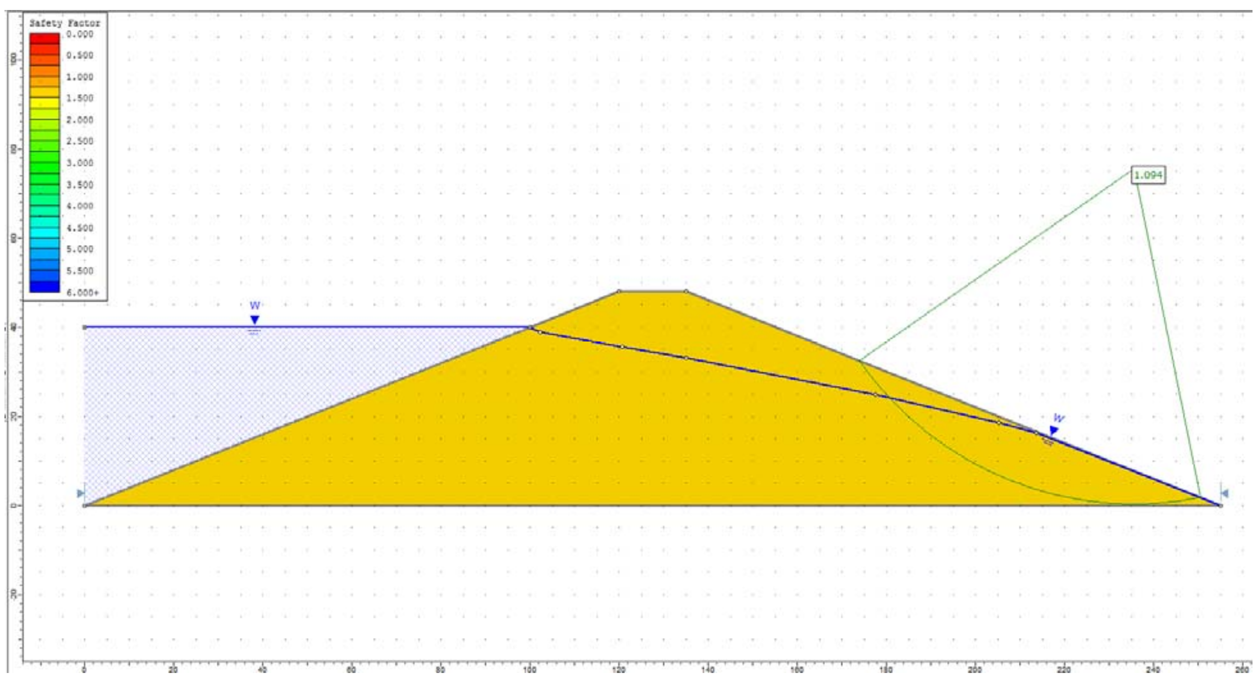


Figure 30.4.4 – Slide Solution Using the GLE Method

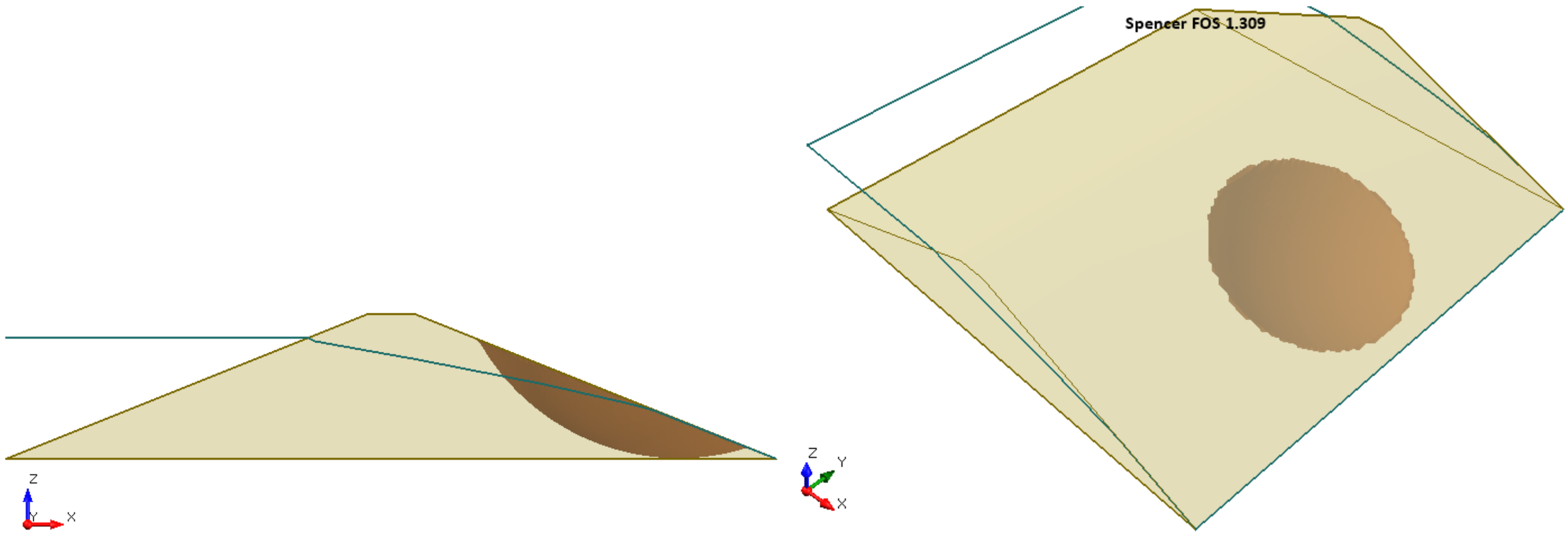


Figure 30.4.5 – Slide3 Solution Using the Spencer Method

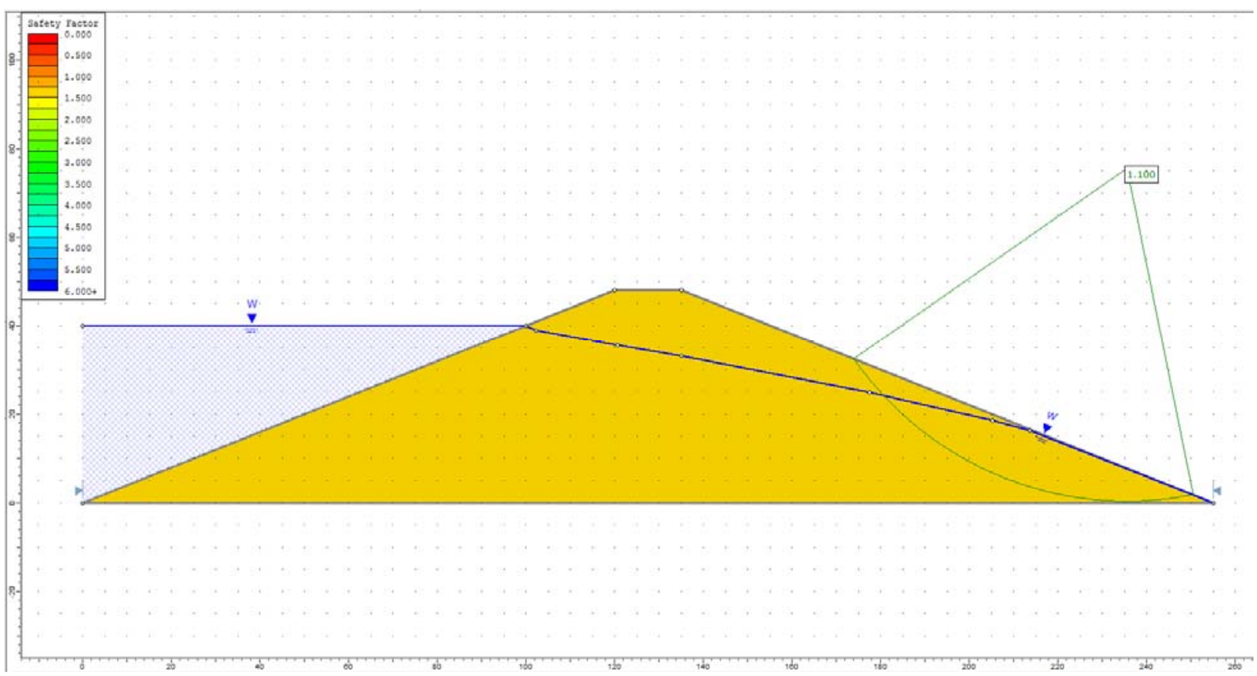


Figure 30.4.6 – Slide Solution Using the Spencer Method

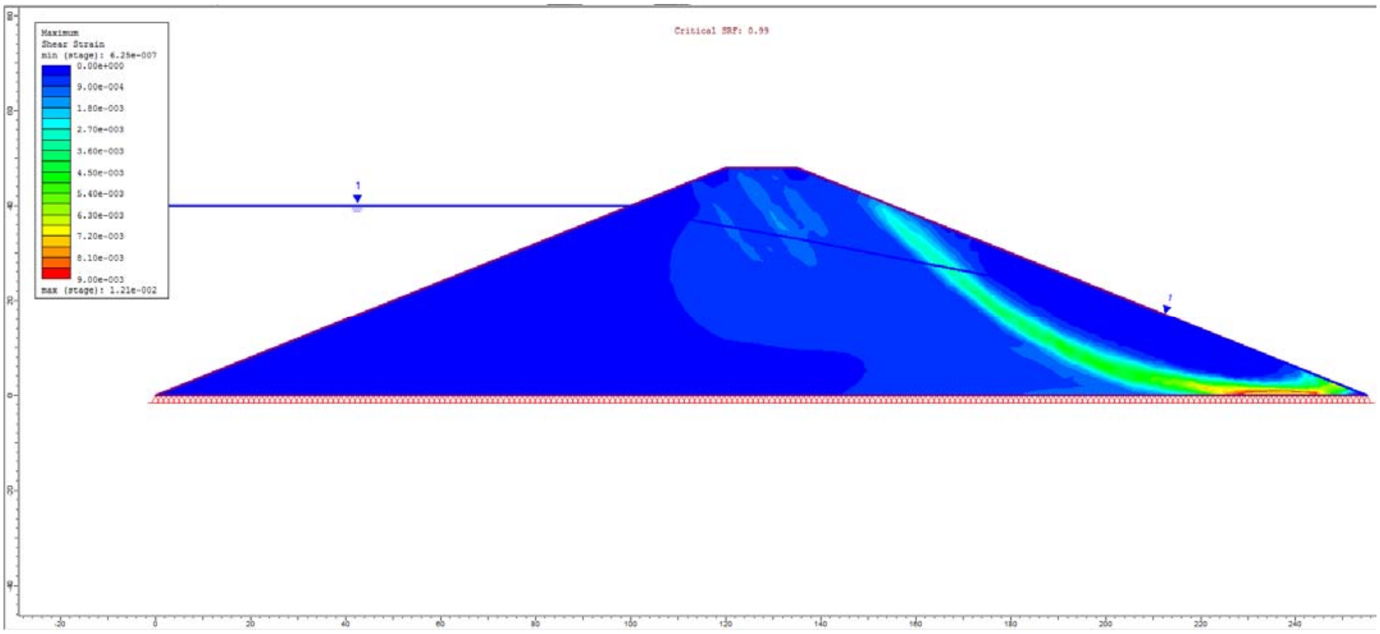


Figure 30.4.7 – RS2 Maximum Shear Strain

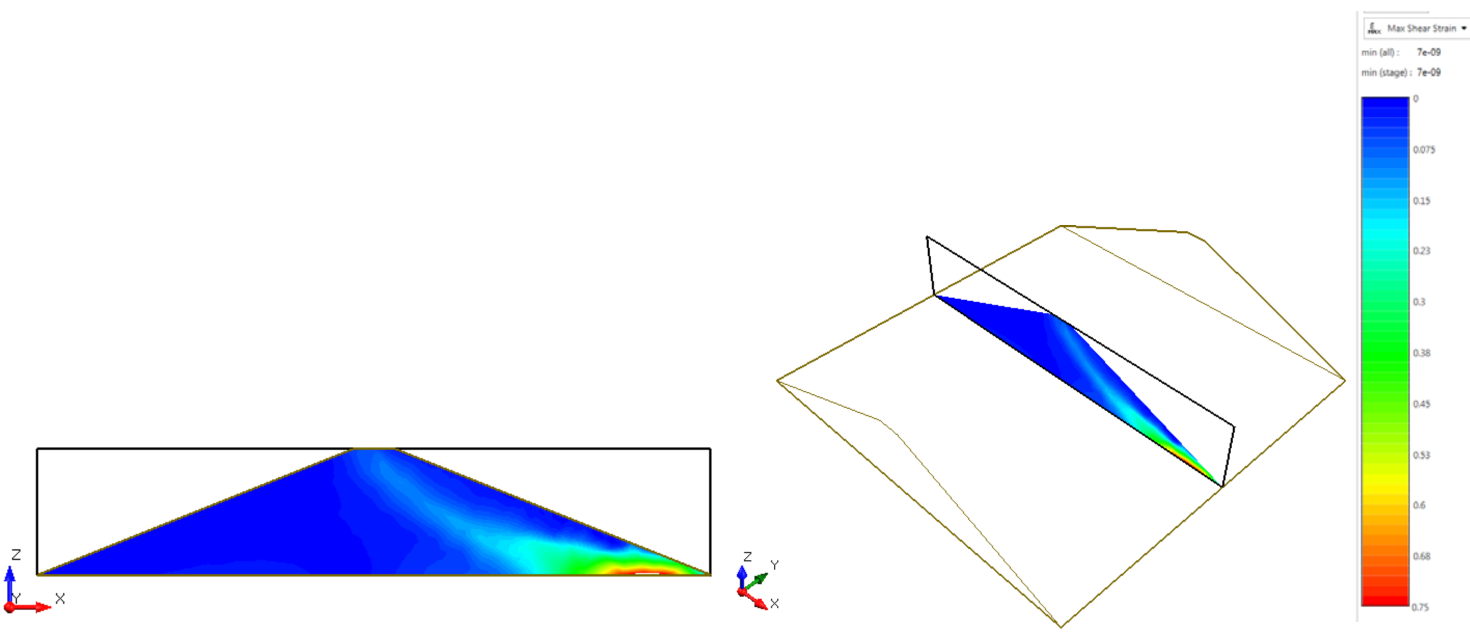


Figure 30.4.8 – RS3 Maximum Shear Strain

2D extruded embankment, homogeneous, water table with ponded water, ellipsoidal with SA

31.1 Introduction

This problem is taken from Figure 7.19 on page 128 of Duncan and Wright (2005).

31.2 Problem Description

A symmetric homogeneous earth embankment resting on an impermeable foundation with a ponded water of elevation 40 feet on its left side is shown in Figure 31. Figure 31 is the slope geometry in the XZ plane and will be extruded 255 ft to obtain the 3D model. The pore water pressure is modeled using a piezometric line approximation. The ellipsoidal slip surface and corresponding safety factor is required.

31.3 Geometry and Properties

Table 31.1: Material Properties

	c′ (psf)	φ′ (deg.)	γ (pcf)
Embankment	100	30	100

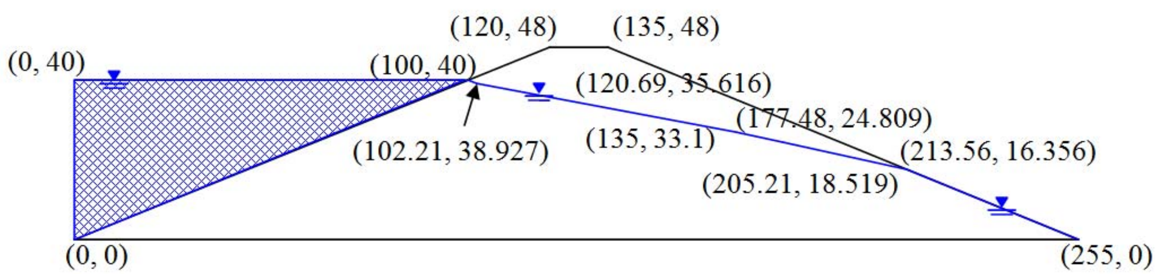


Figure 31

31.4 Results

Table 31.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.06	1.045		
GLE	1.112	1.069	1.08	0.99
Spencer	1.11	1.066		

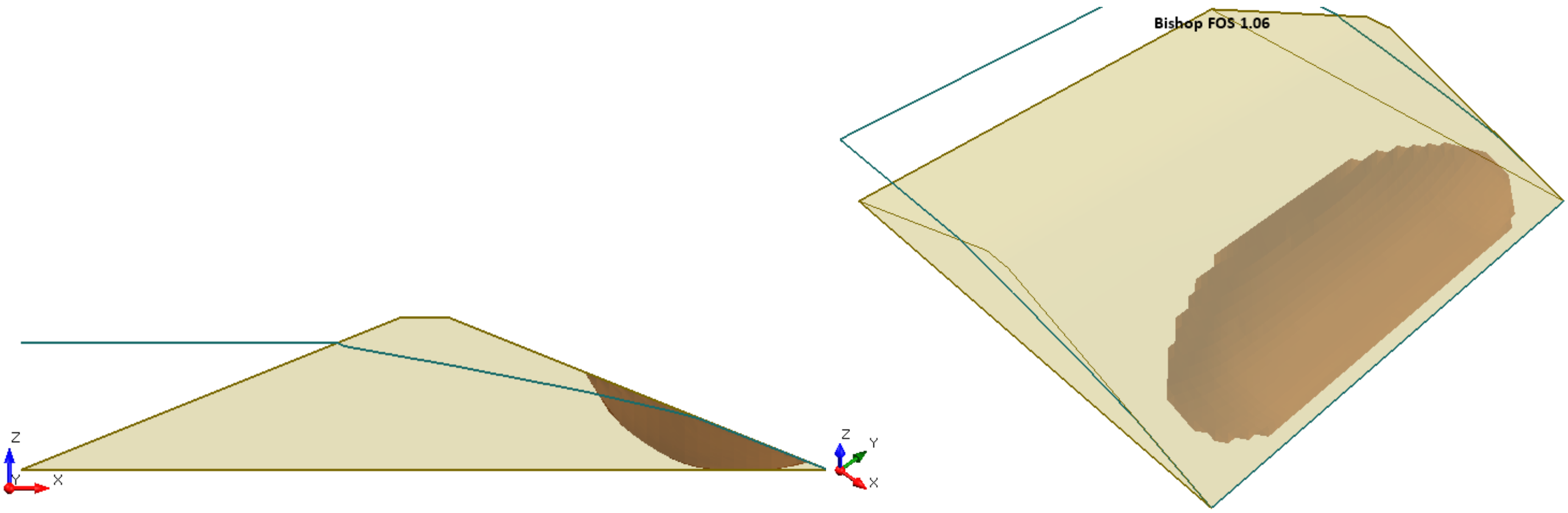


Figure 31.4.1 – Slide3 Solution Using the Bishop Method

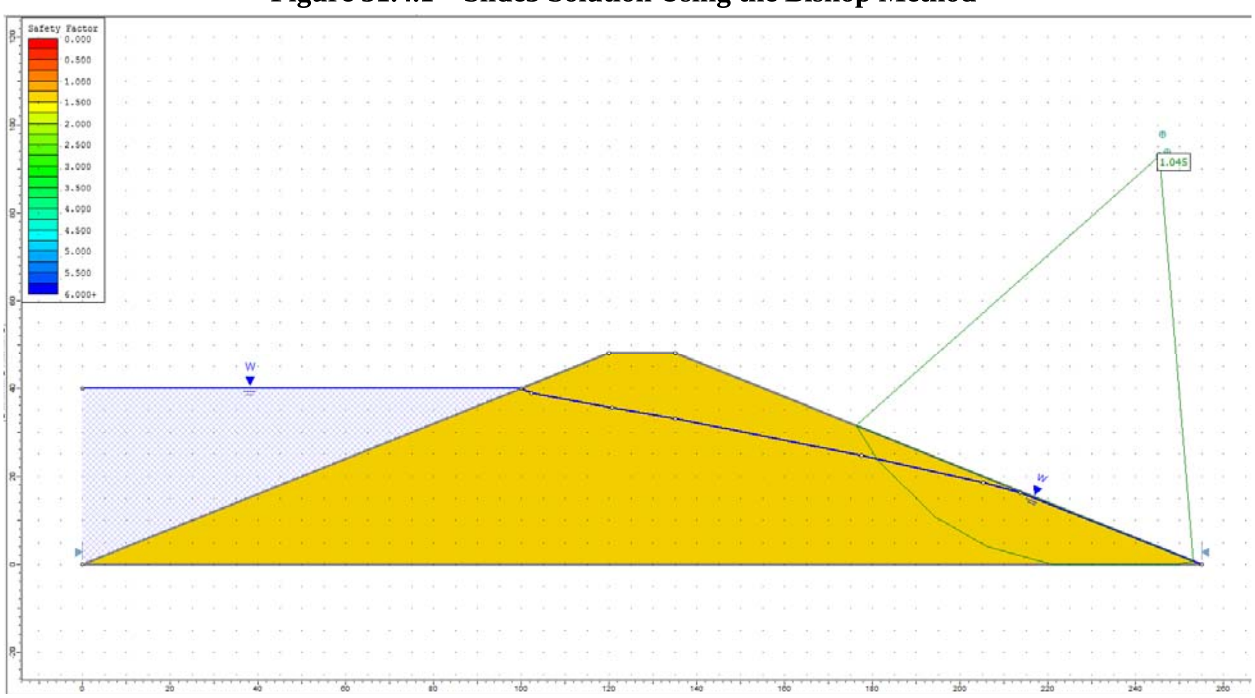


Figure 31.4.2 – Slide Solution Using the Bishop Method

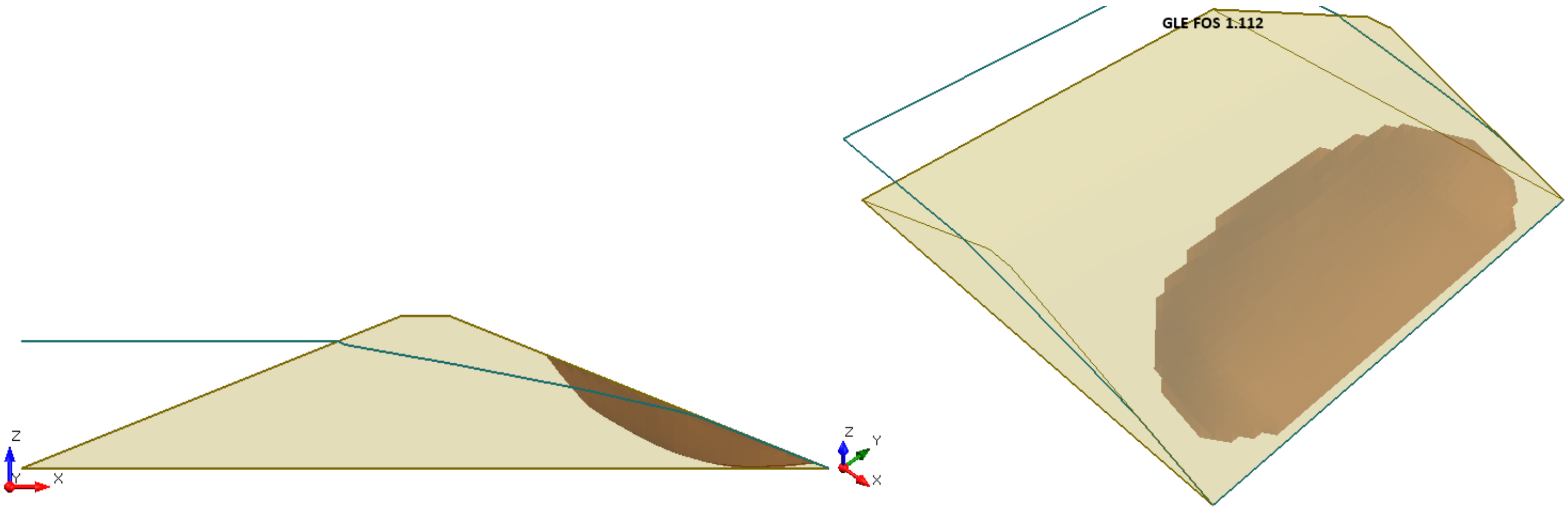


Figure 31.4.3 – Slide3 Solution Using the GLE Method

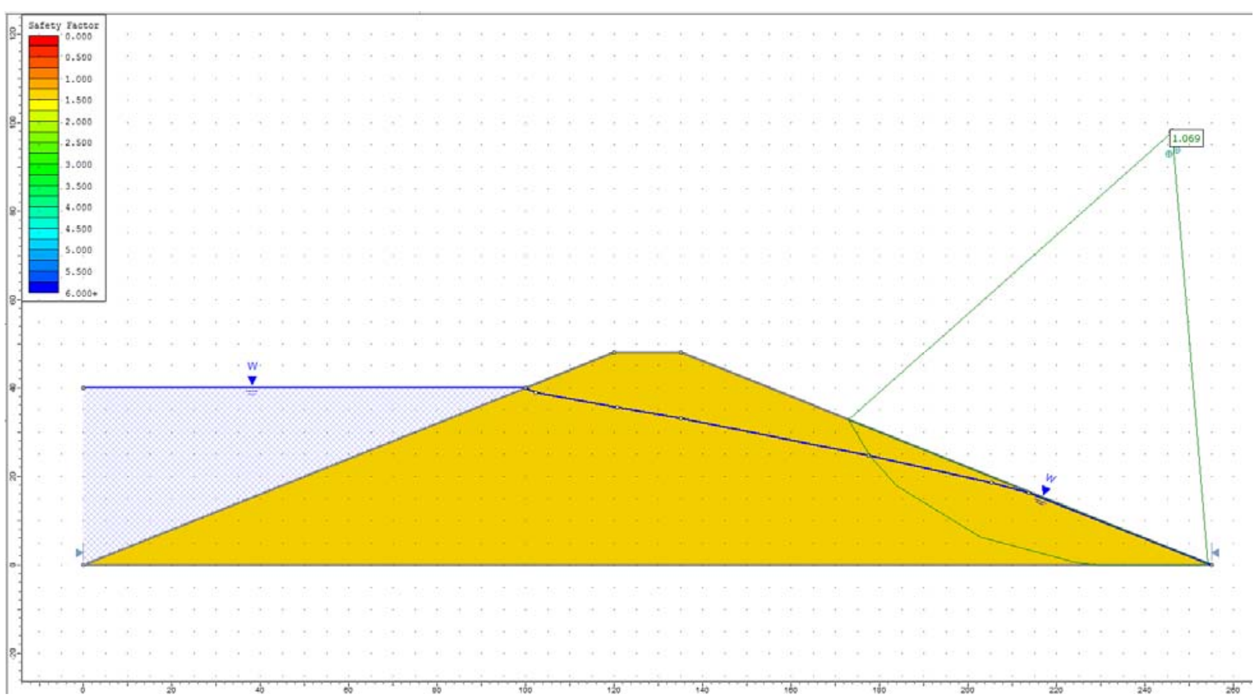


Figure 31.4.4 – Slide Solution Using the GLE Method

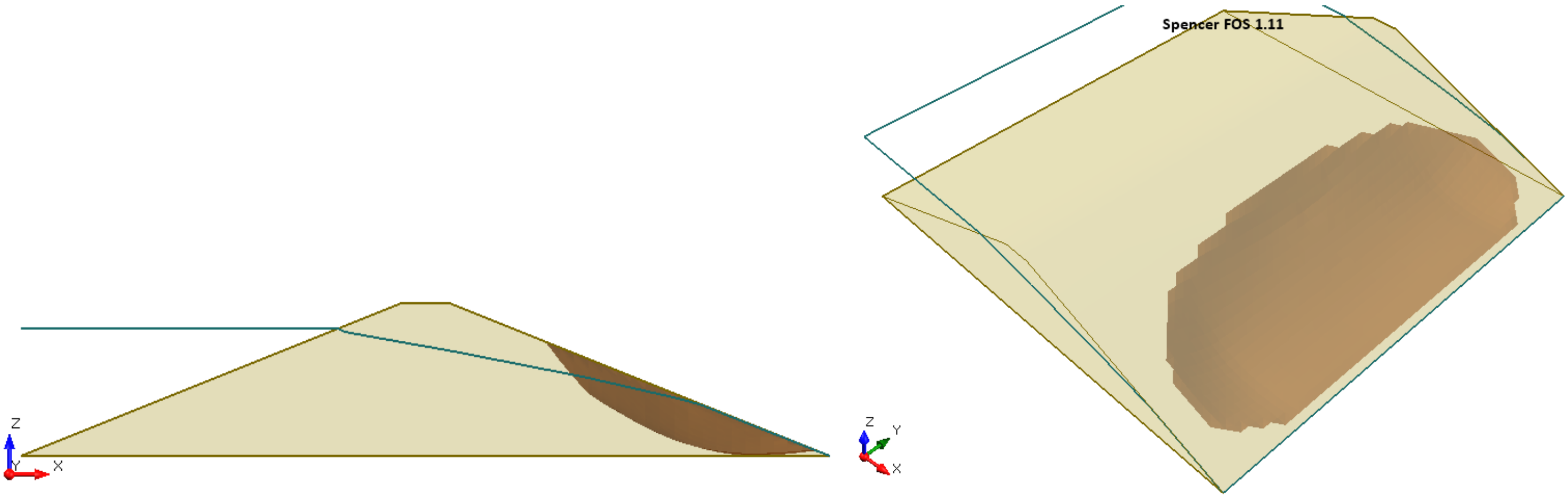


Figure 31.4.5 – Slide3 Solution Using the Spencer Method

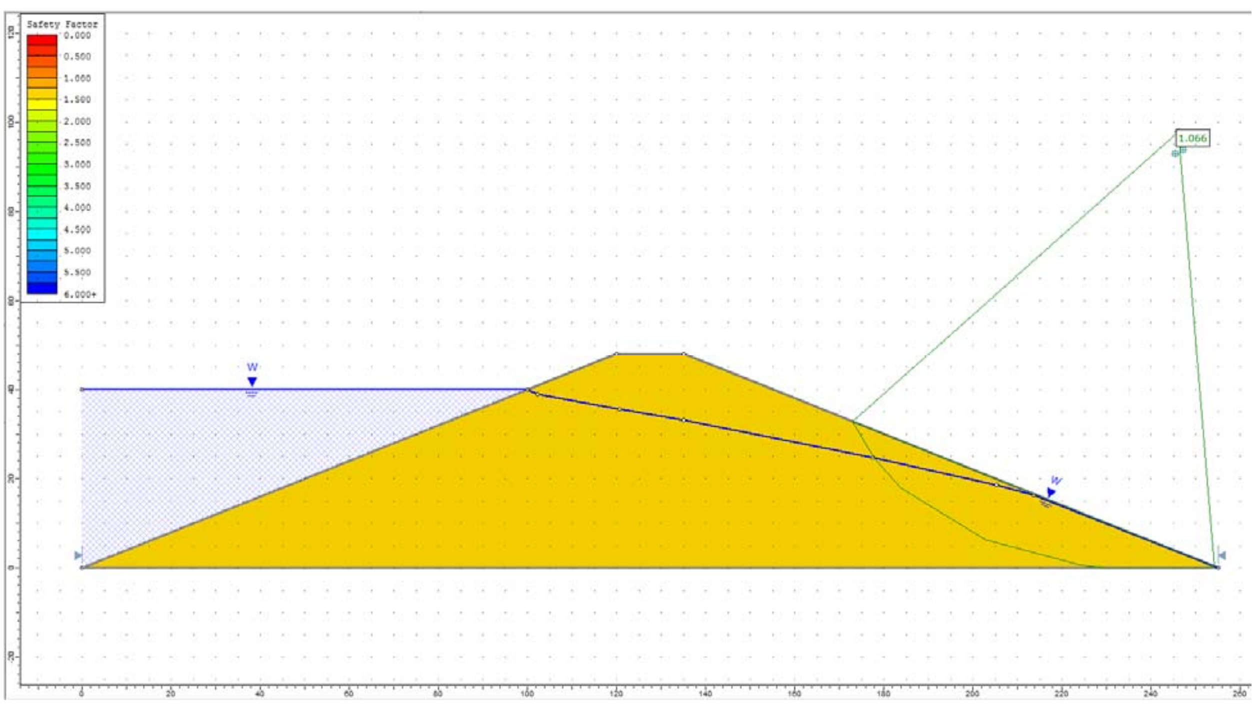


Figure 31.4.6 – Slide Solution Using the Spencer Method

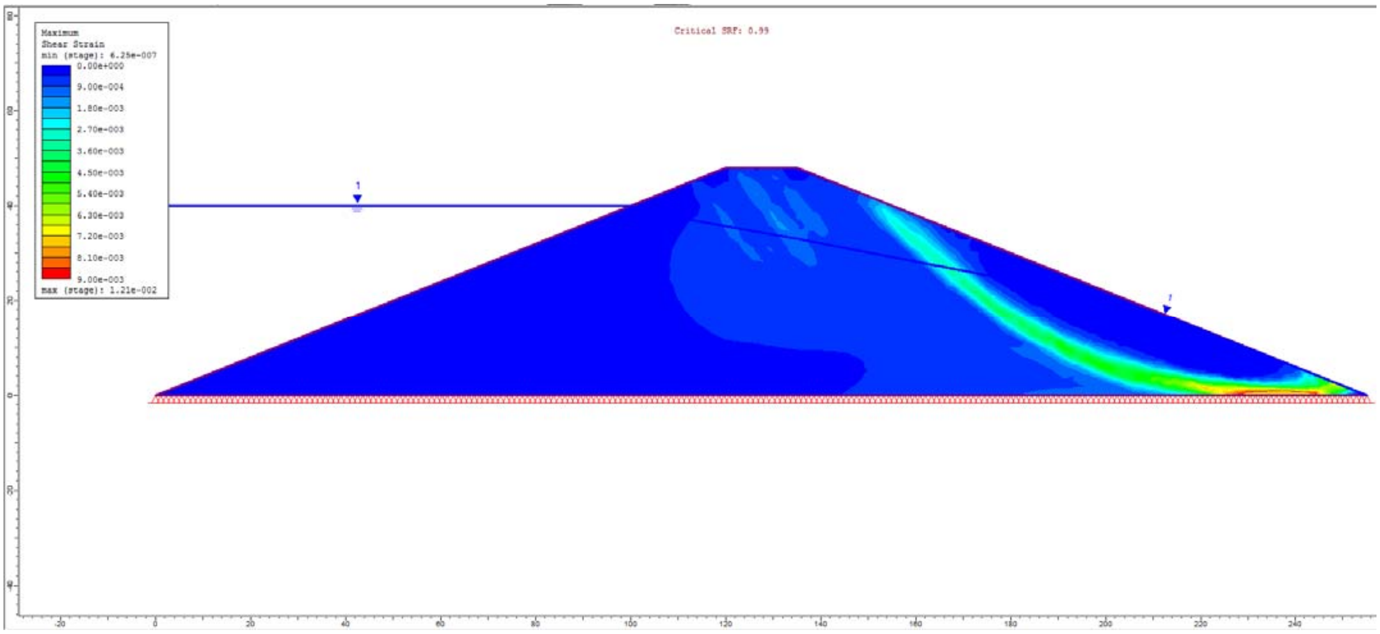


Figure 31.4.7 – RS2 Maximum Shear Strain

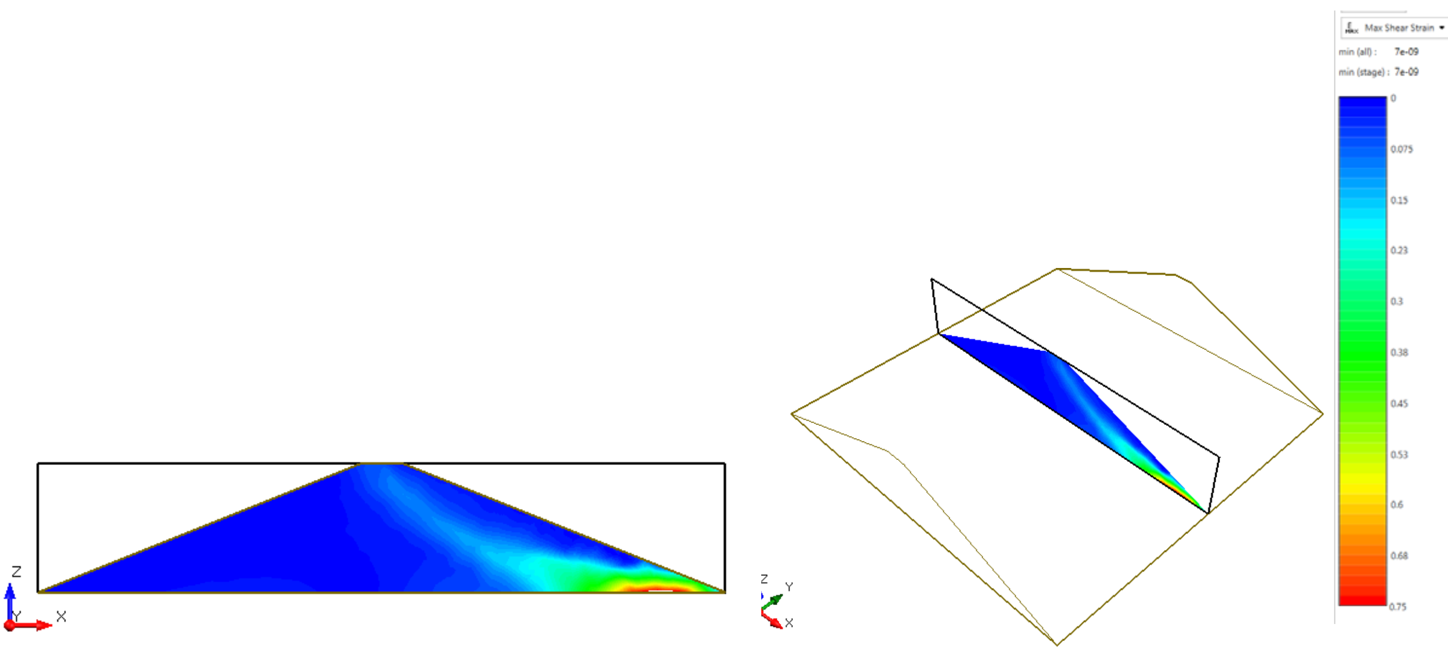


Figure 31.4.8 – RS3 Maximum Shear Strain

2D extruded embankment, (2) materials, water table with ponded water, spherical

32.1 Introduction

This problem is taken from Figure 7.24 on page 131 of Duncan and Wright (2005).

32.2 Problem Description

A symmetric earth dam with thick core and with ponded water of elevation 315 on its left side resting on an impervious foundation is shown in Figure 32 in the XZ plane. This geometry will be extruded 1241 m in the Y direction. The pore water pressure is modeled using piezometric line approximation. The coordinates of the pieziometric line are shown in Table 32.2 and the material properties are shown in Table 32.1. The global critical slip surface occurs at shallow circles at the toe. However, in this Verification, it is the deeper slip surface that is of interest. The deep critical slip surface is assumed to be spherical and tangent to the boundary between the dam and its foundation.

32.3 Geometry and Properties

Table 32.1: Material Properties

	c′ (psf)	φ′ (deg.)	γ (pcf)
Core	0	20	120
Shell	0	38	140

Table 32.2: Pieziometric Surface Points

X	Z	X	Z
0	315	884.57	162.86
517	315	897.25	160
571.94	312.46	1153.3	151.36
583.84	303.96	1179.5	149.17
833.82	184.81	1240.5	127

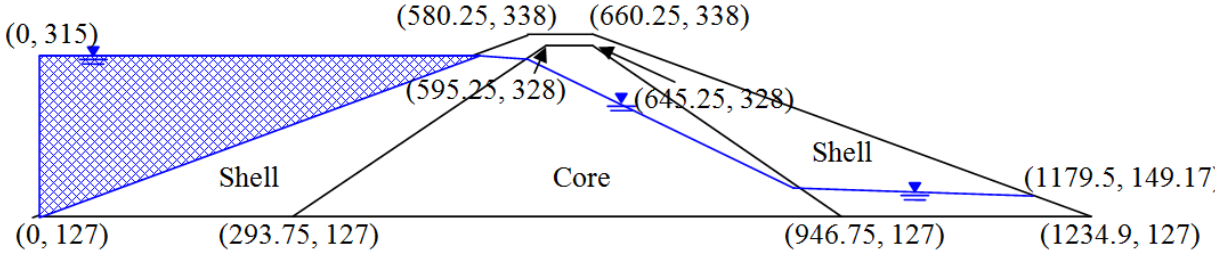


Figure 32

32.4 Results

Table 32.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.766	1.584		
GLE	1.822	1.656	1.49	1.46
Spencer	1.815	1.648		

Referee: 1.67 [Duncan and Wright, 2005]

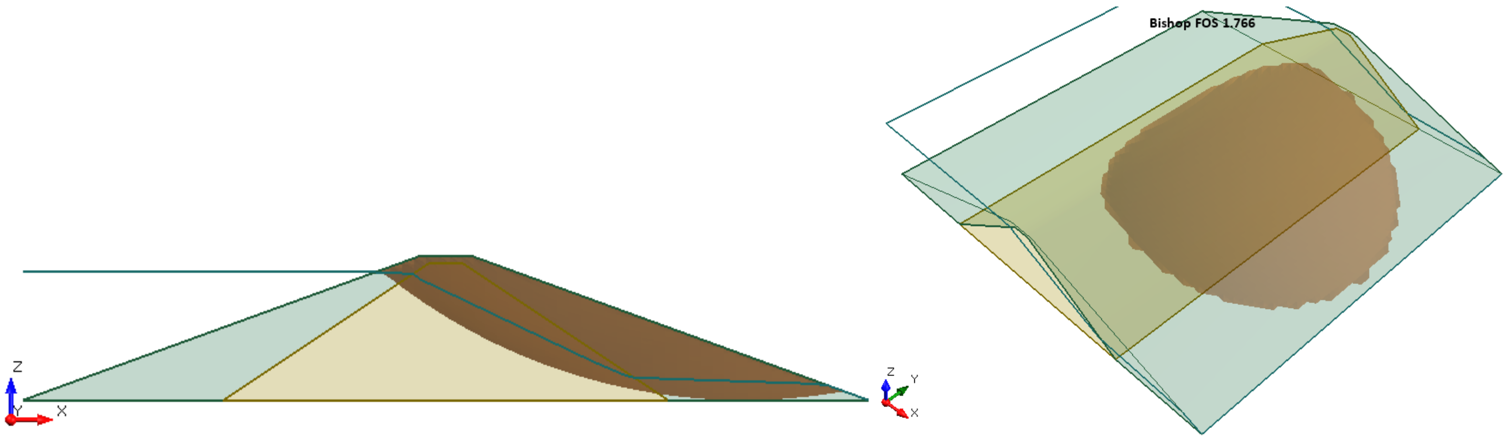


Figure 32.4.1 – Slide3 Solution Using the Bishop Method

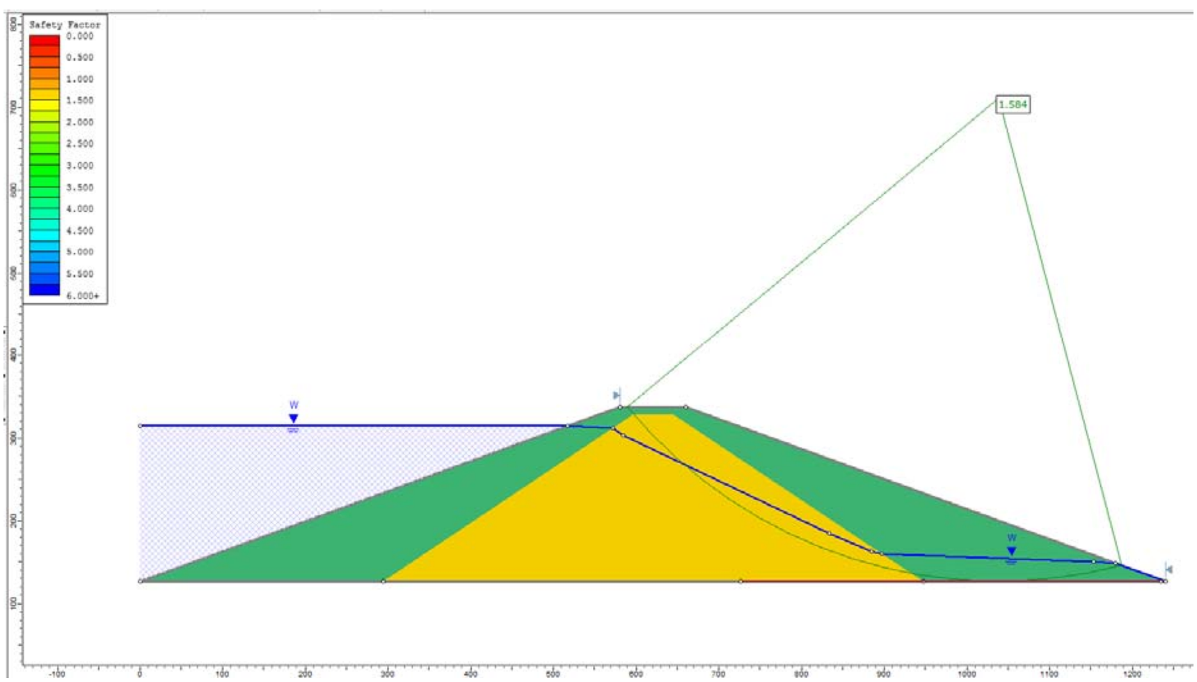


Figure 32.4.2 – Slide Solution Using the Bishop Method

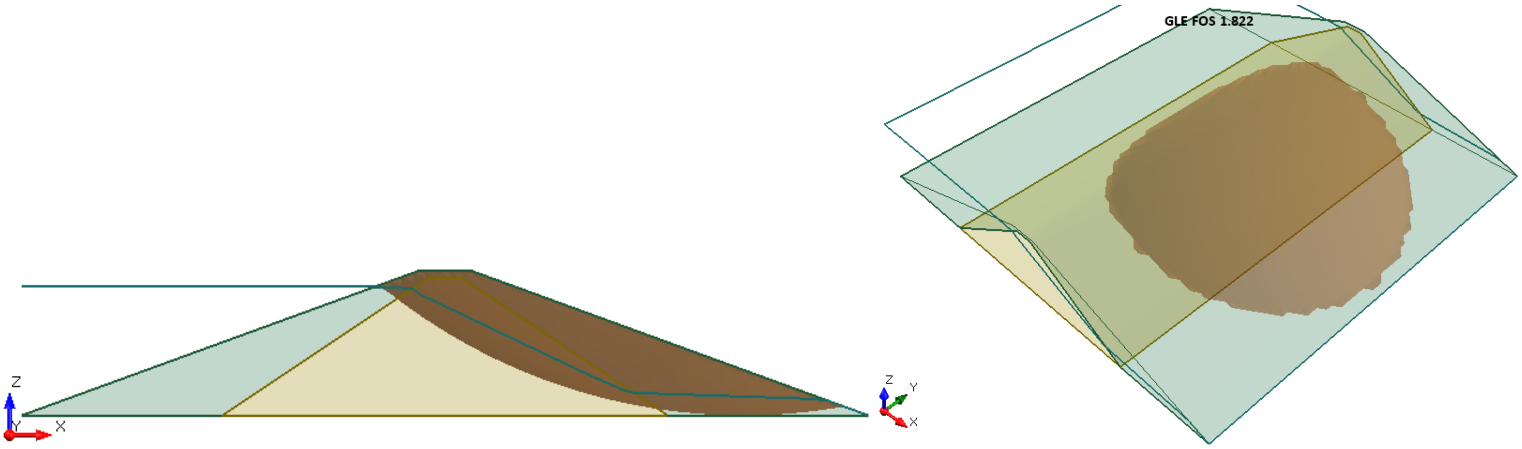


Figure 32.4.3 – Slide3 Solution Using the GLE Method

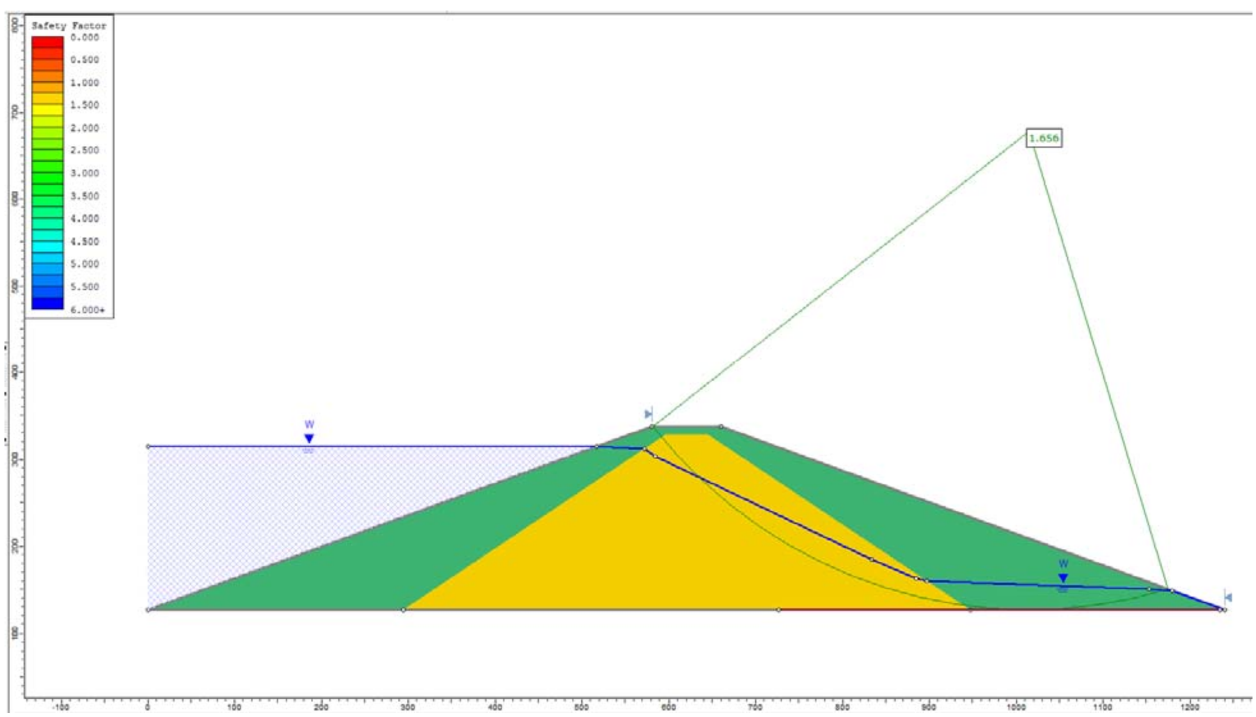


Figure 32.4.4 – Slide Solution Using the GLE Method

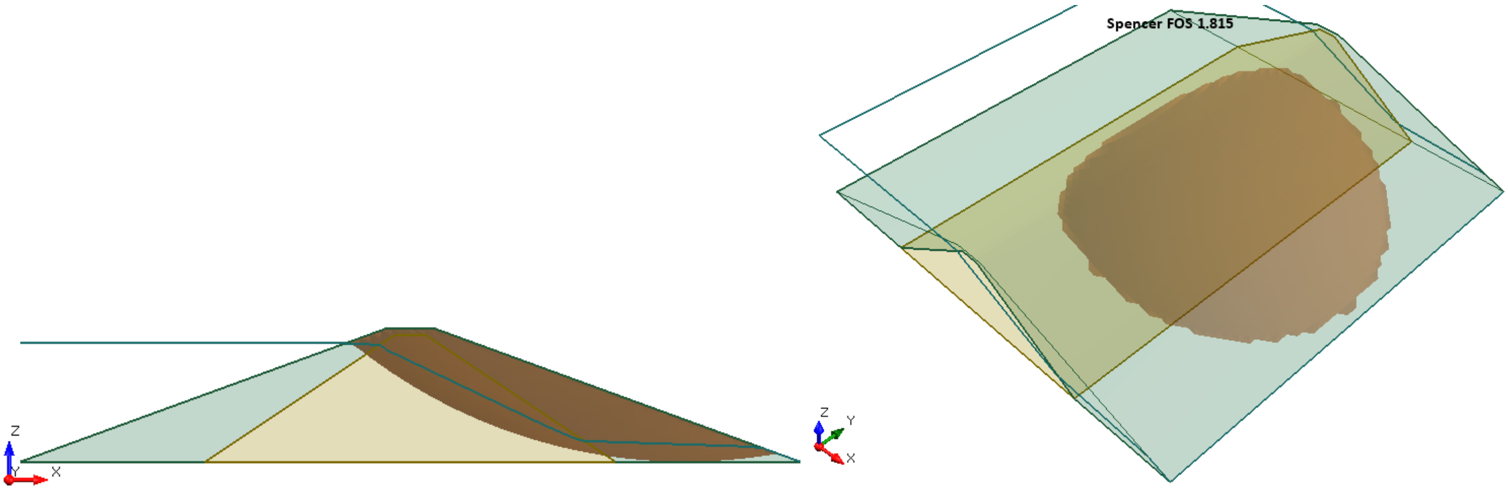


Figure 32.4.5 – Slide3 Solution Using the Spencer Method

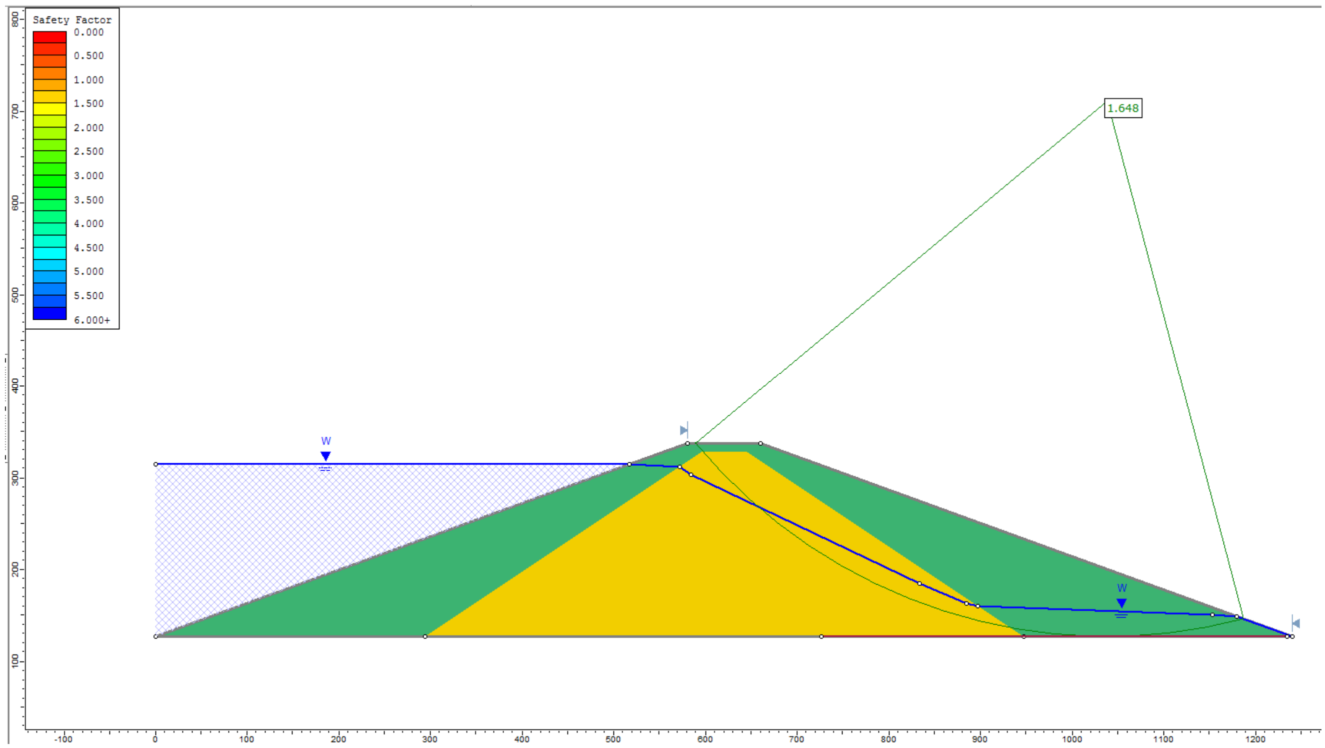


Figure 32.4.6 – Slide Solution Using the Spencer Method

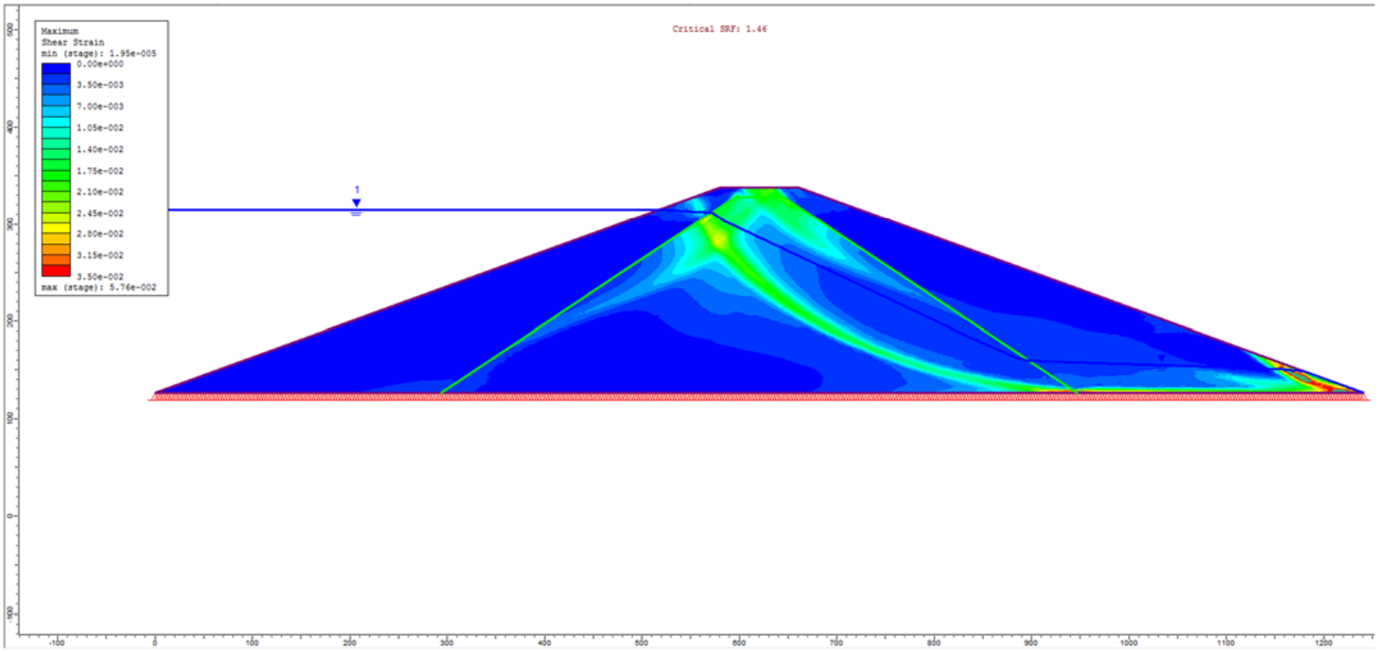


Figure 32.4.7 – RS2 Maximum Shear Strain

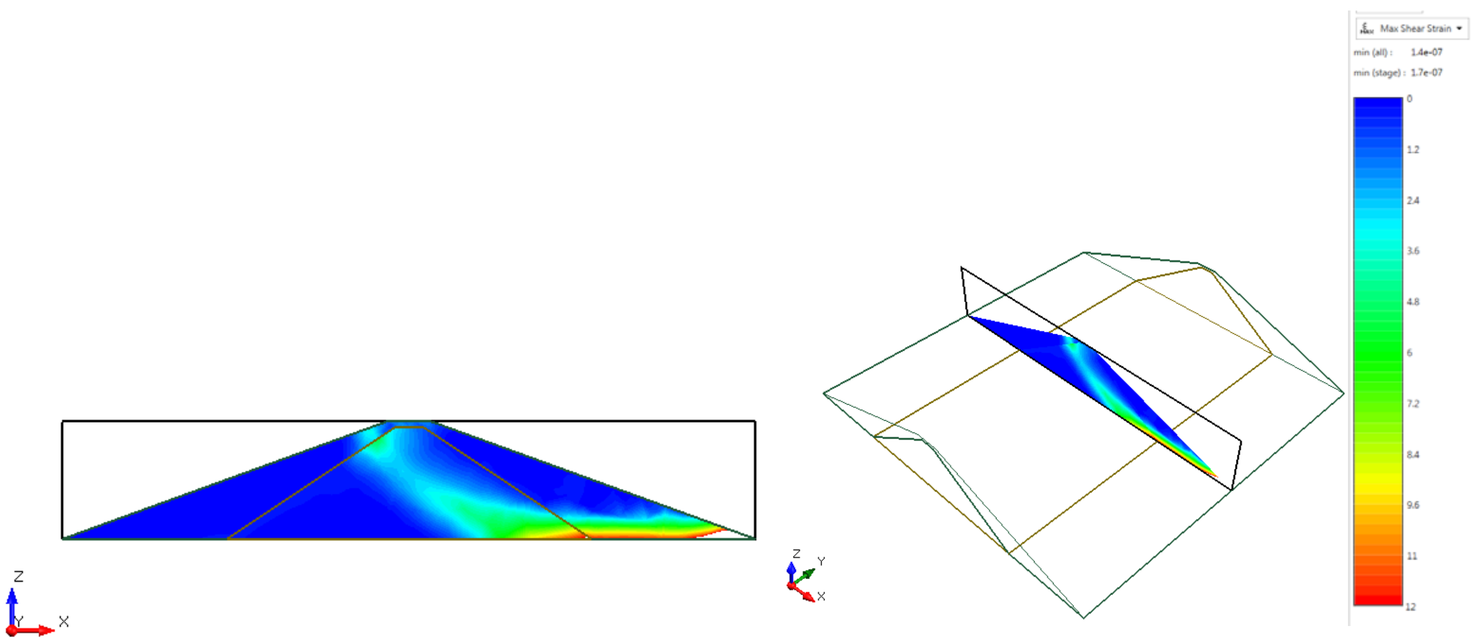


Figure 32.4.8 – RS3 Maximum Shear Strain

2D extruded embankment, (2) materials, water table with ponded water, ellipsoidal with SA

33.1 Introduction

This problem is taken from Figure 7.24 on page 131 of Duncan and Wright (2005).

33.2 Problem Description

A symmetric earth dam with thick core and with ponded water of elevation 315 on its left side resting on an impervious foundation is shown in Figure 33 in the XZ plane. This geometry will be extruded 1241 m in the Y direction. The pore water pressure is modeled using piezometric line approximation. The coordinates of the pieziometric line are shown in Table 33.2 and the material properties are shown in Table 33.1. The global critical slip surface occurs at shallow circles at the toe. However, in this Verification, it is the deeper slip surface that is of interest. The ellipsoidal slip surface is required.

33.3 Geometry and Properties

Table 33.1: Material Properties

	c′ (psf)	φ′ (deg.)	γ (pcf)
Core	0	20	120
Shell	0	38	140

Table 33.2: Pieziometric Surface Points

X	Z	X	Z
0	315	884.57	162.86
517	315	897.25	160
571.94	312.46	1153.3	151.36
583.84	303.96	1179.5	149.17
833.82	184.81	1240.5	127

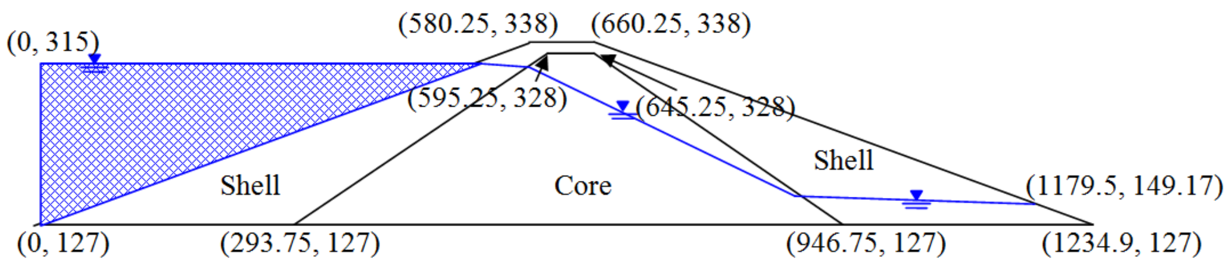


Figure 33

33.4 Results

Table 33.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.555	1.478	1.49	1.46
GLE	1.71	1.571		
Spencer	1.702	1.570		

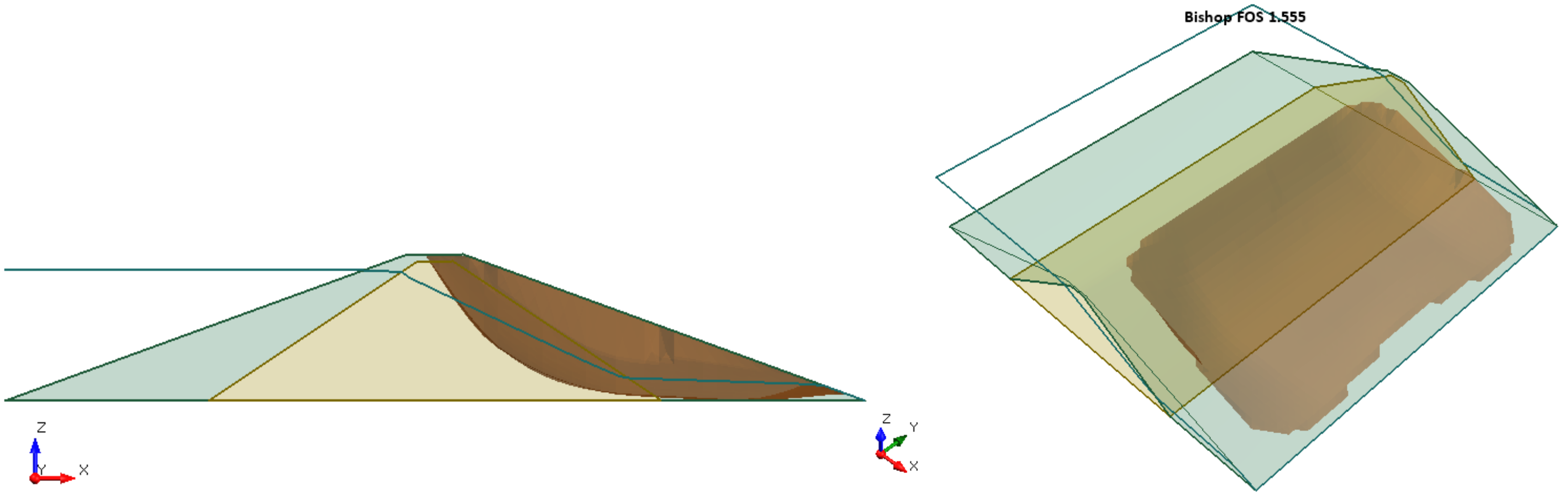


Figure 33.4.1 – Slide3 Solution Using the Bishop Method

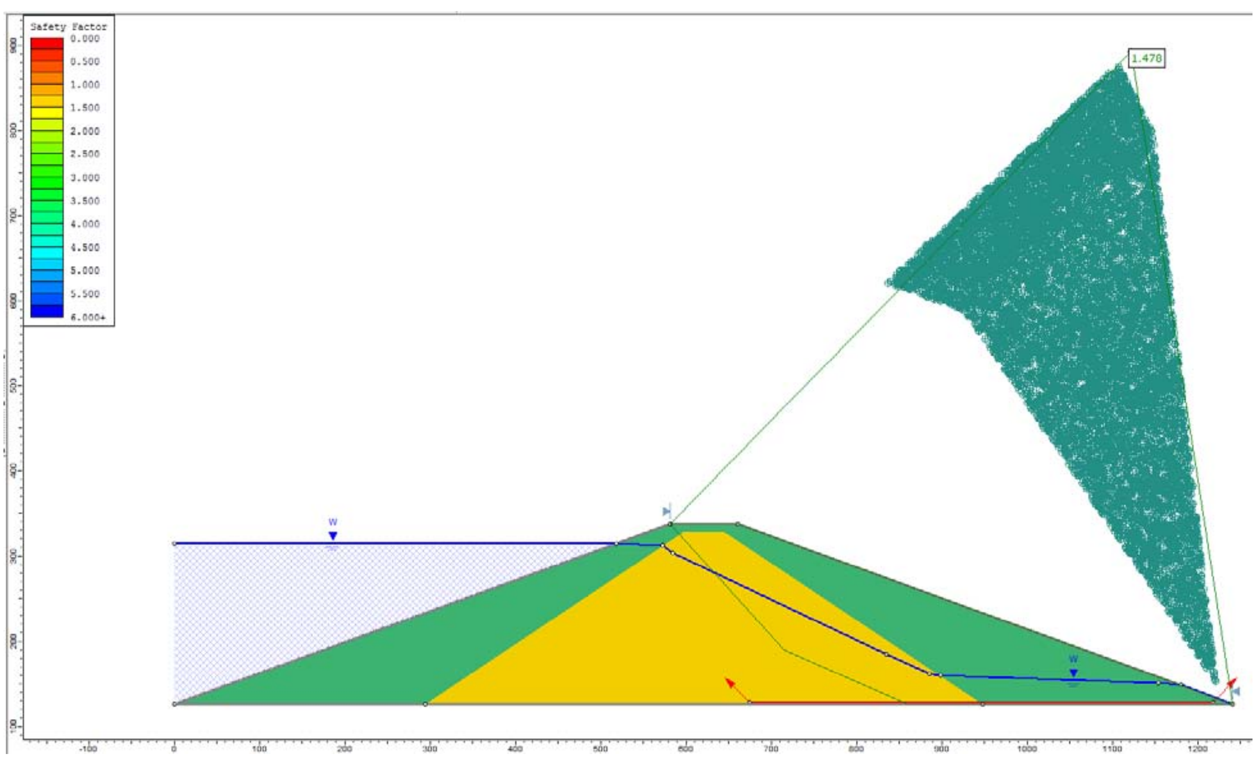


Figure 33.4.2 – Slide Solution Using the Bishop Method

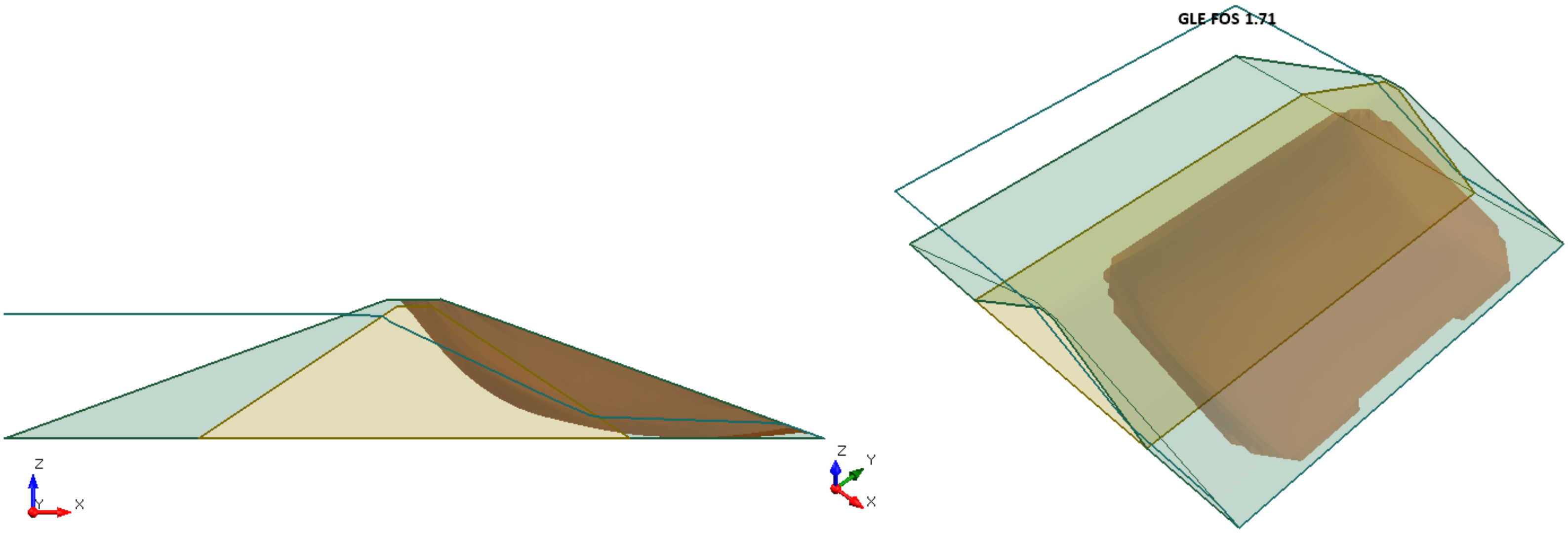


Figure 33.4.3 – Slide3 Solution Using the GLE Method

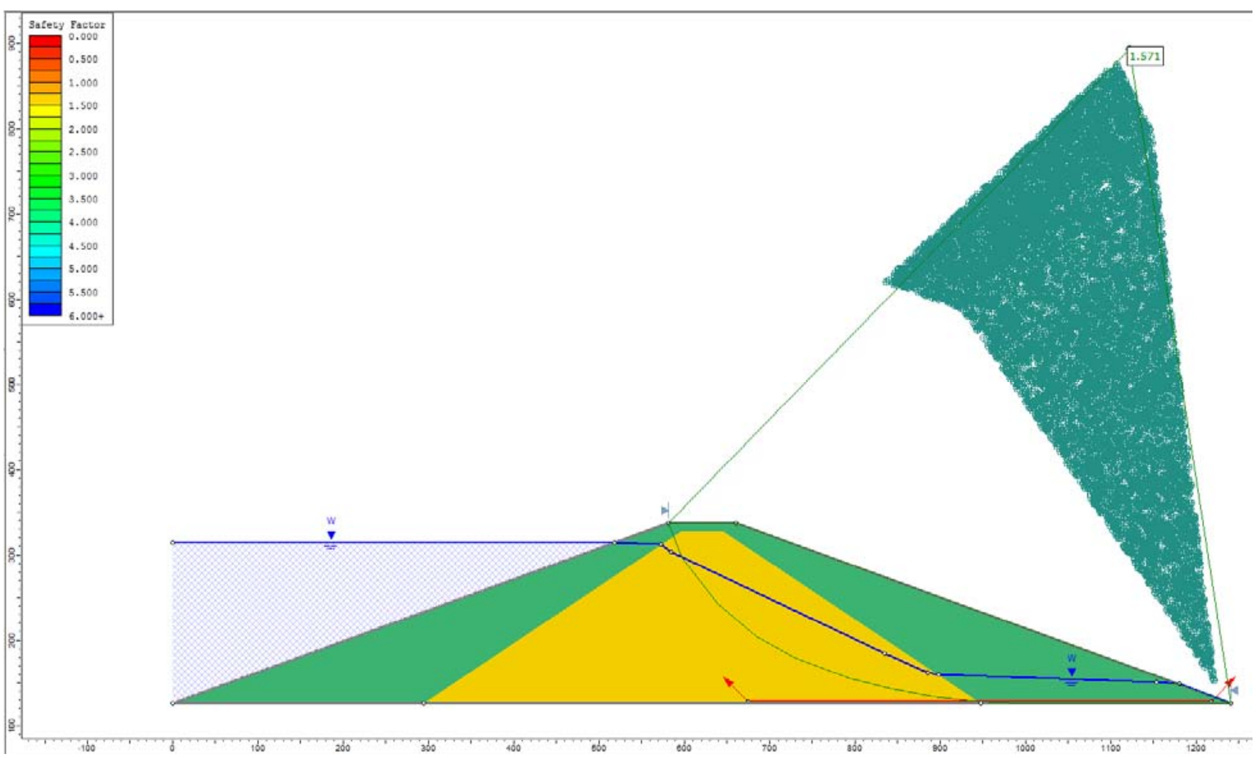


Figure 33.4.4 – Slide Solution Using the GLE Method

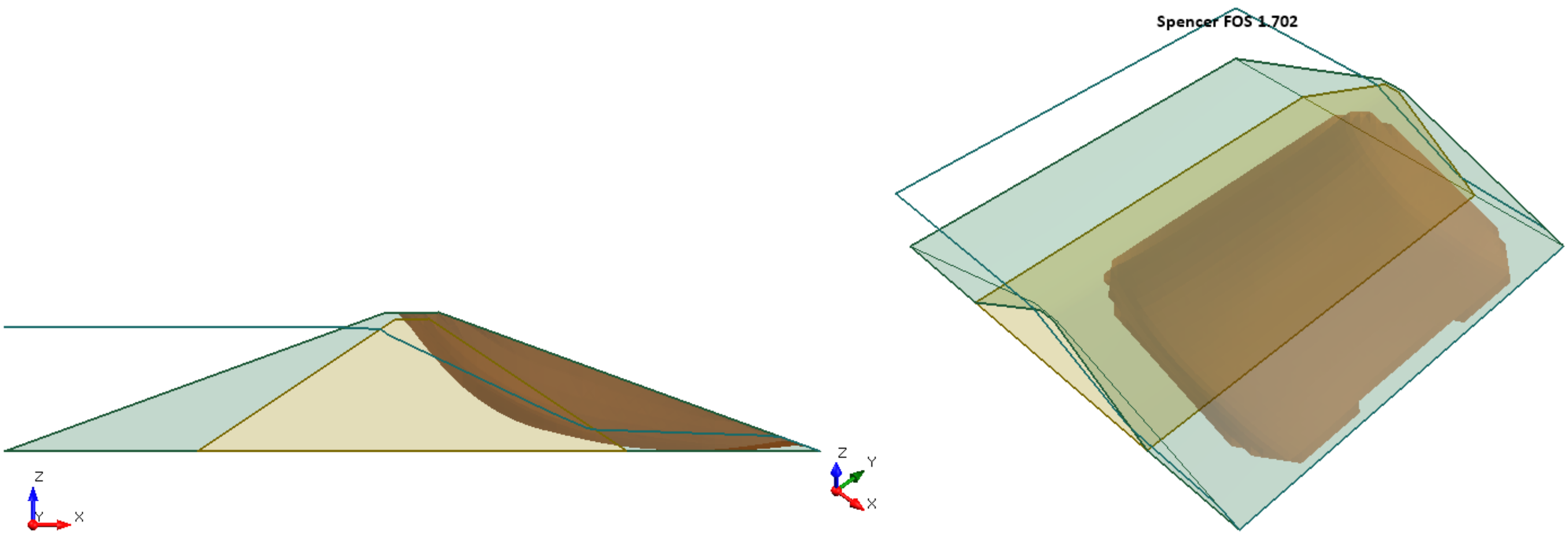


Figure 33.4.5 – Slide3 Solution Using the Spencer Method

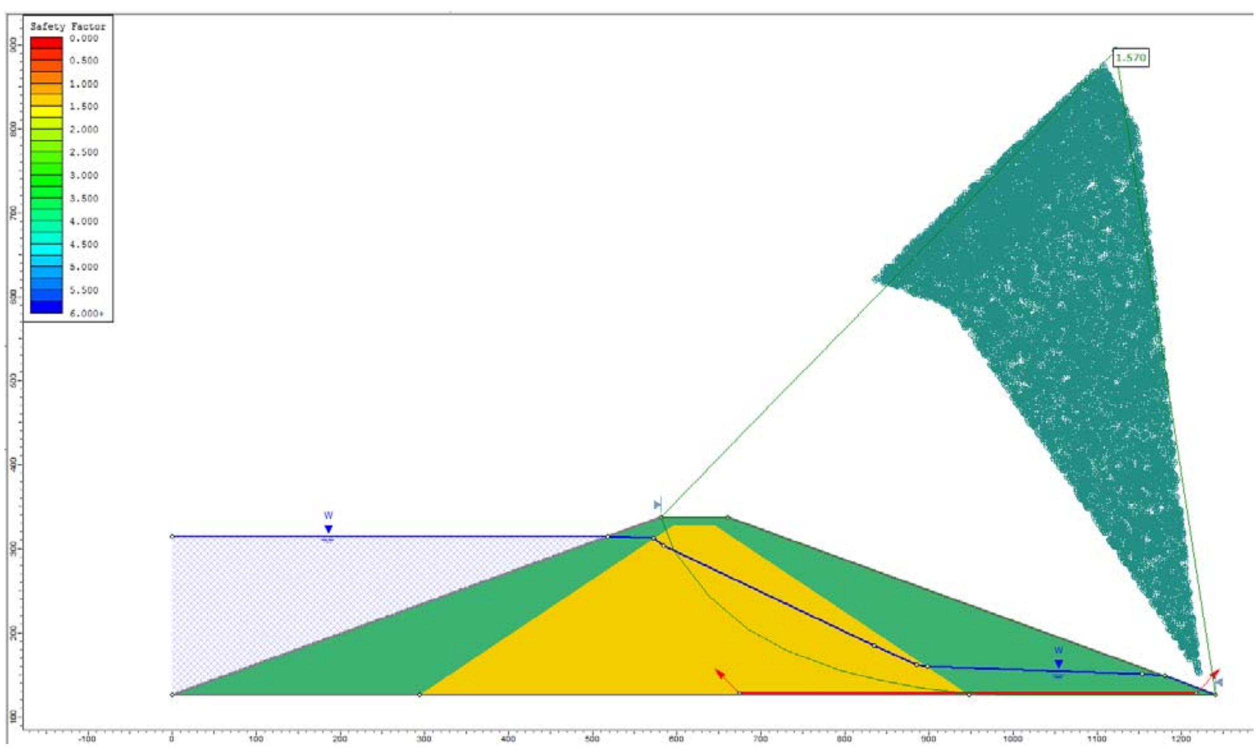


Figure 33.4.6 – Slide Solution Using the Spencer Method

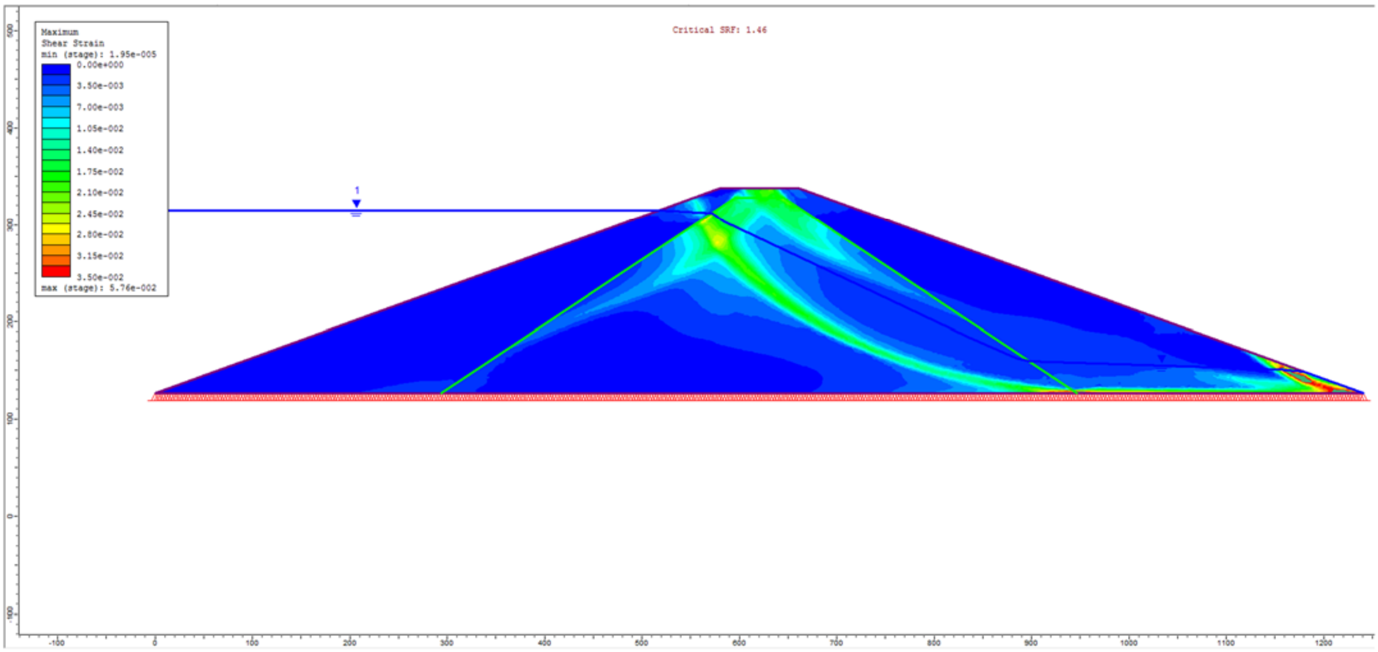


Figure 33.4.7 – RS2 Maximum Shear Strain

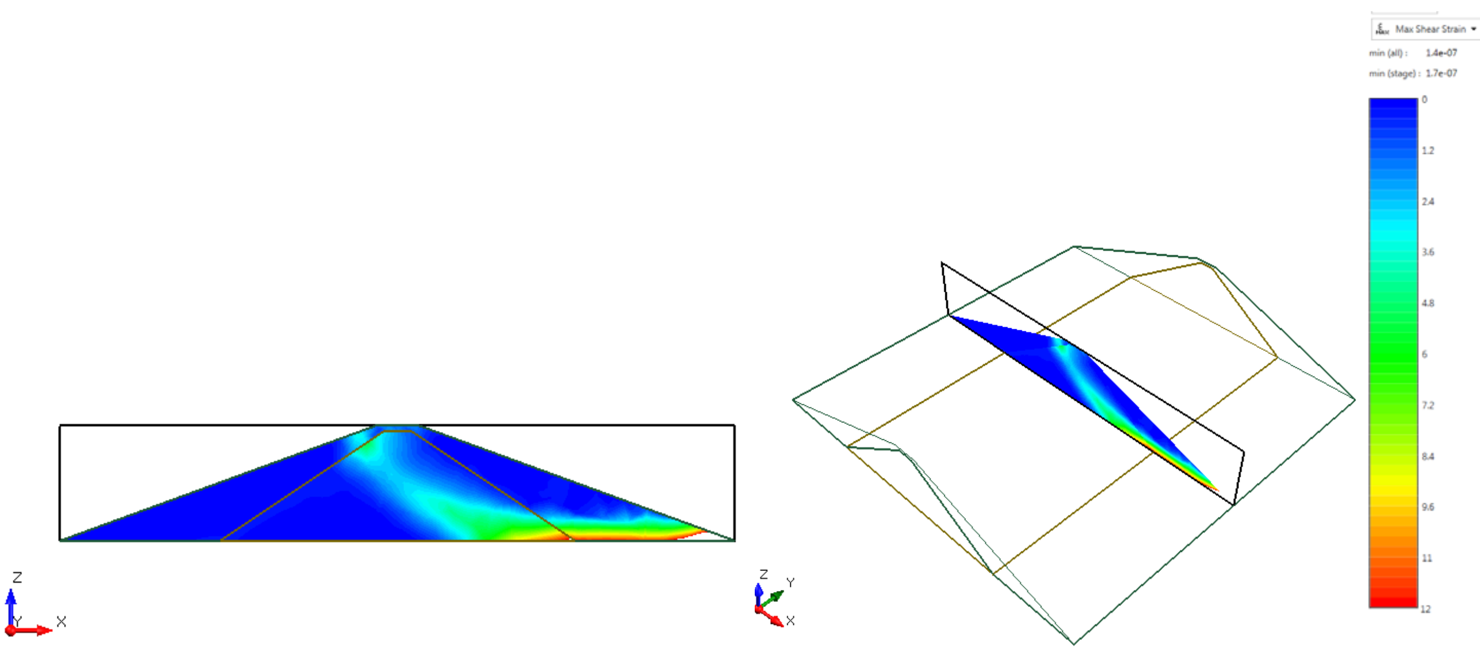


Figure 33.4.8 – RS3 Maximum Shear Strain

2D extruded, homogeneous, minimum depth, spherical

34.1 Introduction

This problem is taken from Figure 14.3 on page 216 of Duncan and Wright (2005). Three different foundation thicknesses (30 feet-thick, 46.5 feet-thick and 60 feet-thick) are tested. This problem has a 30 feet-thick foundation.

34.2 Problem Description

A simple, pure cohesive slope is shown in Figure 34 in the XZ plane. It will then be extruded 240 m in the Y direction to obtain the 3D slope geometry. The first slip surface passes through the toe and the second slip surface is tangent to the bottom of the foundation. The material properties for this problem can be found in Table 34.1. The slip surface of interest is tangent to the bottom of the foundation. The slip surfaces are assumed to be spherical.

34.3 Geometry and Properties

Table 34.1: Material Properties

	c′ (psf)	φ′ (deg.)	γ (pcf)
Soil	1000	0	100

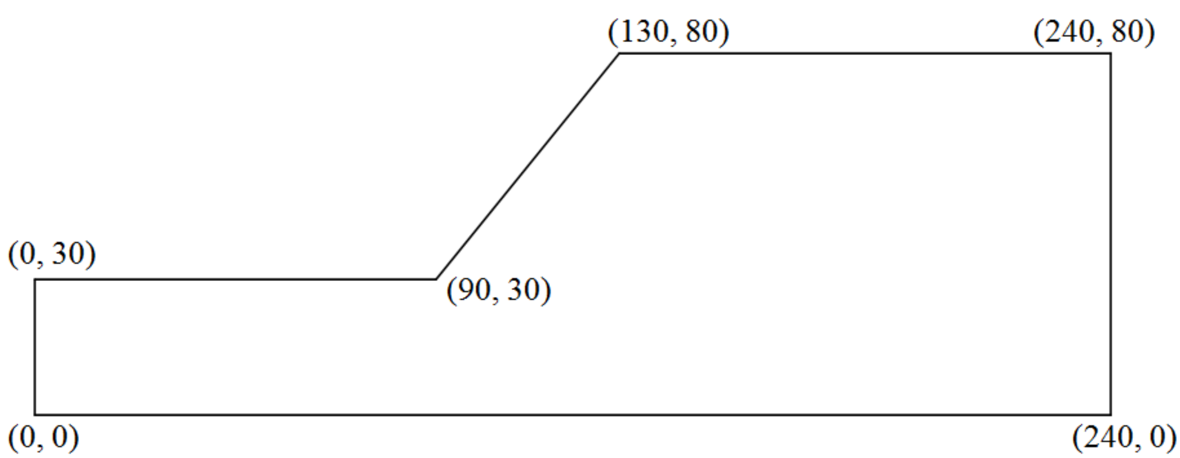


Figure 34

34.4 Results

Table 34.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.245	1.141		
GLE	1.249	1.139	1.18	1.05
Spencer	1.253	1.139		

Referee: 1.135 [Duncan and Wright, 2005]

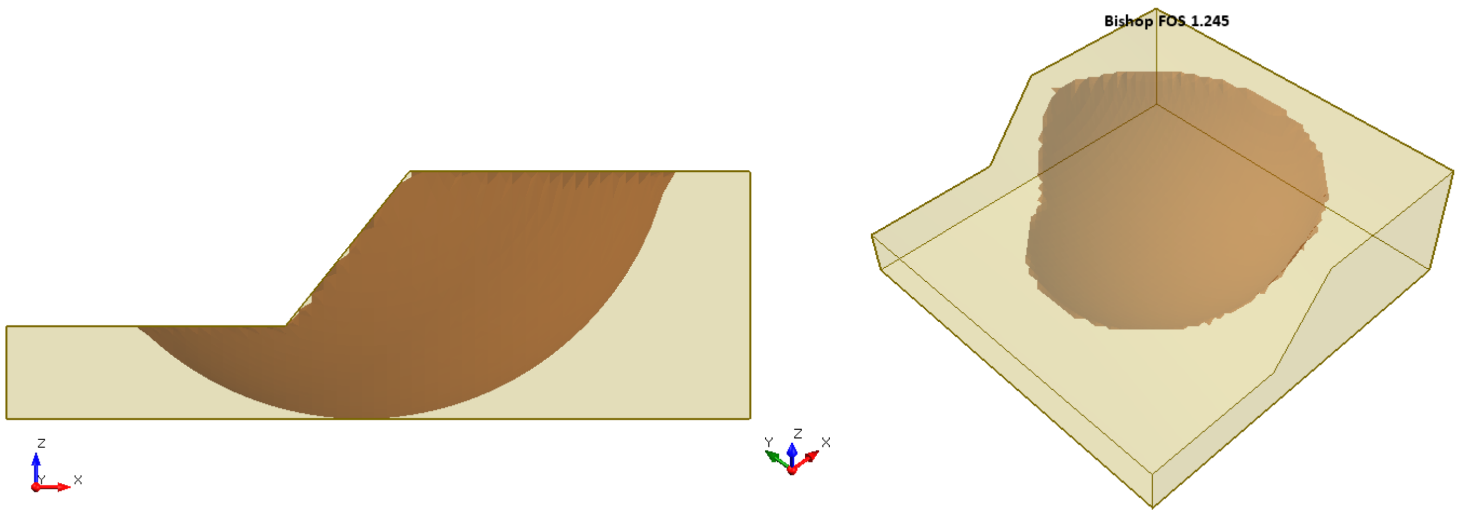


Figure 34.4.1 – Slide3 Solution Using the Bishop Method

Figure 34.4.2 – Slide Solution Using the Bishop Method

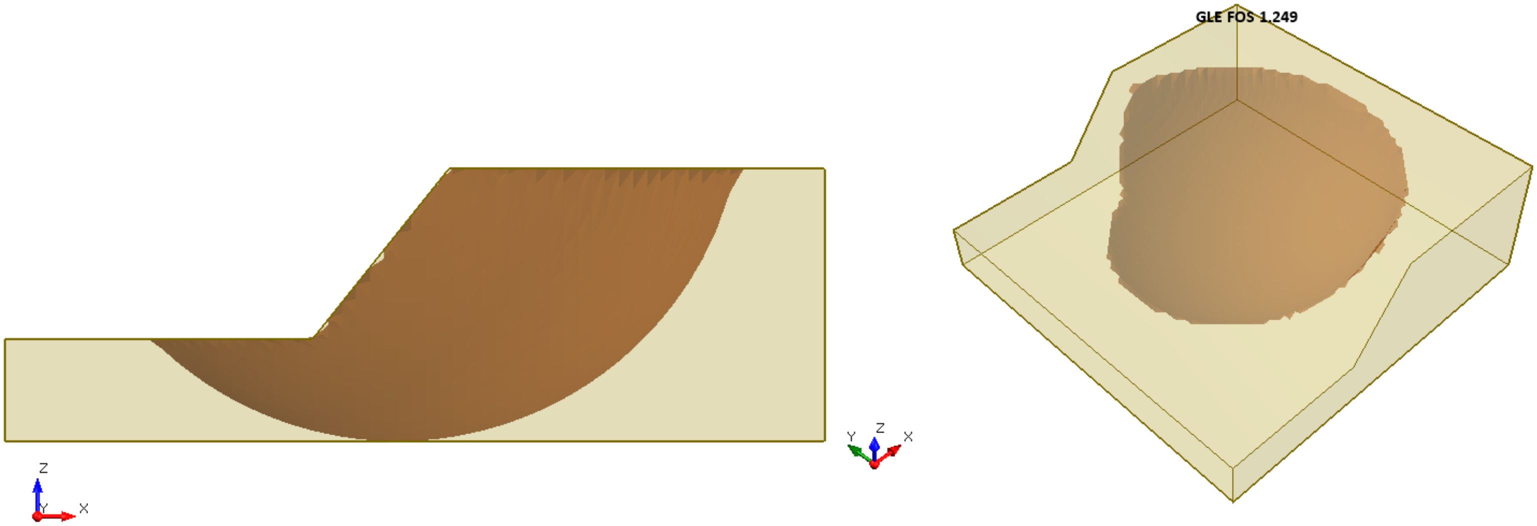


Figure 34.4.3 – Slide3 Solution Using the GLE Method

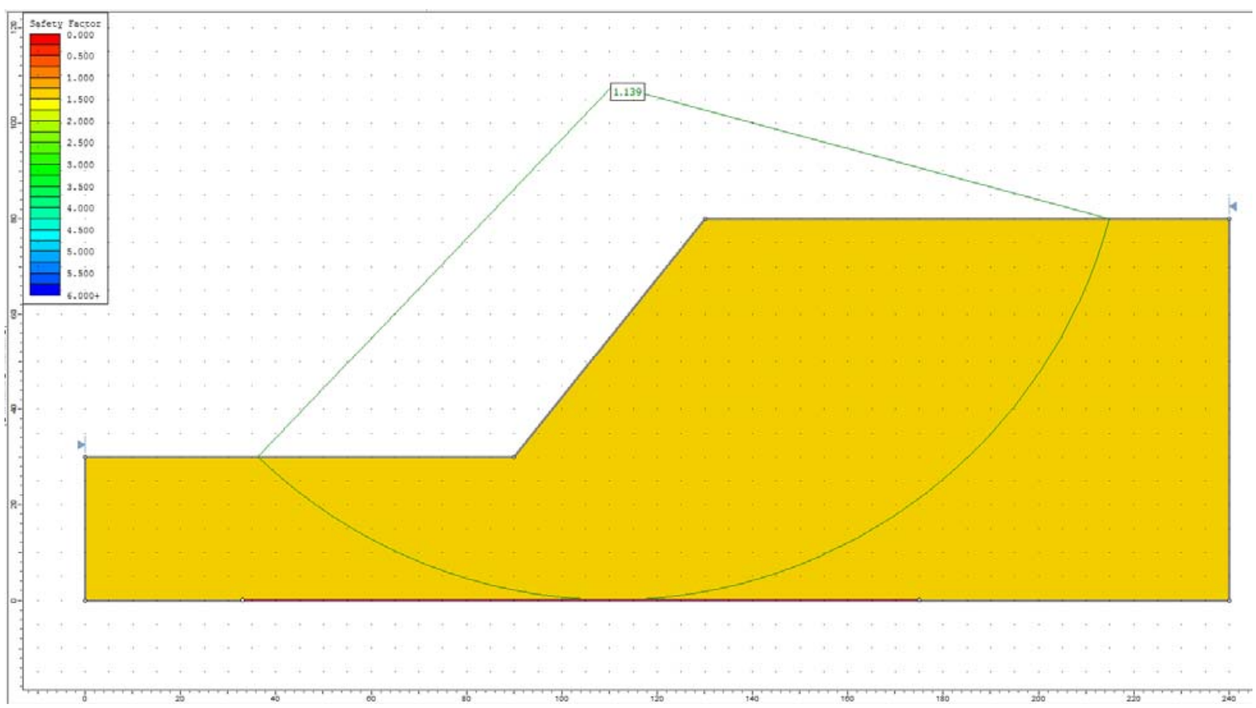


Figure 34.4.4 – Slide Solution Using the GLE Method

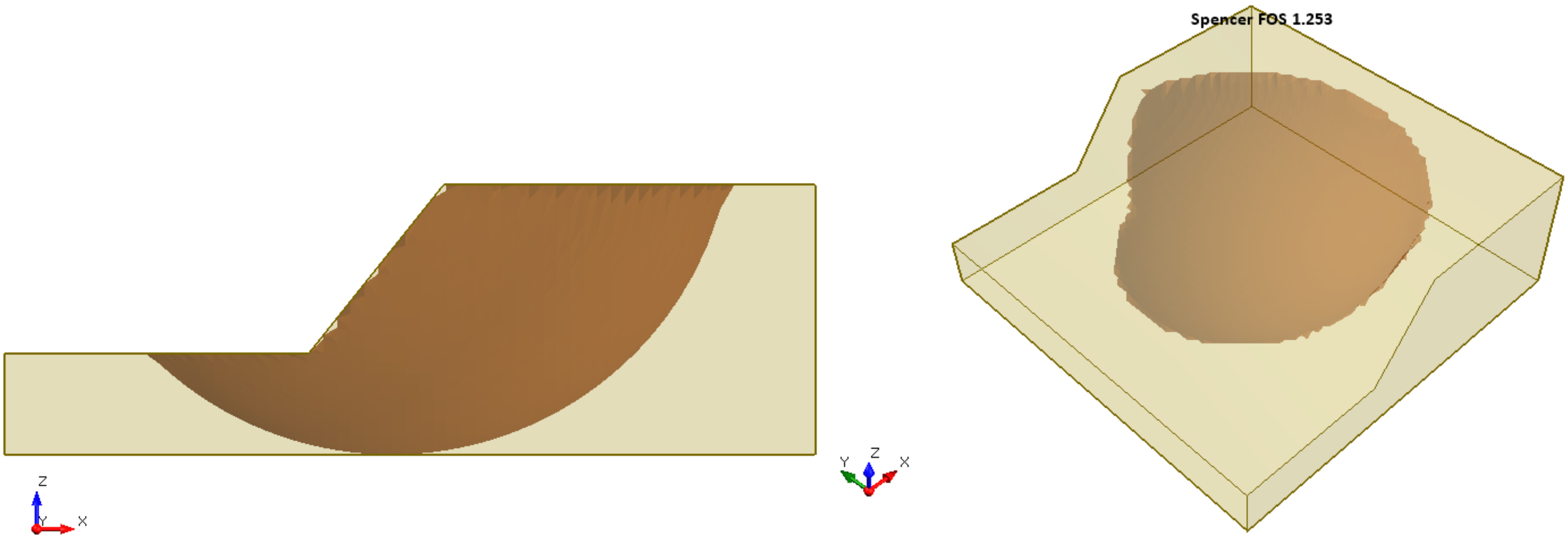


Figure 34.4.5 – Slide3 Solution Using the Spencer Method

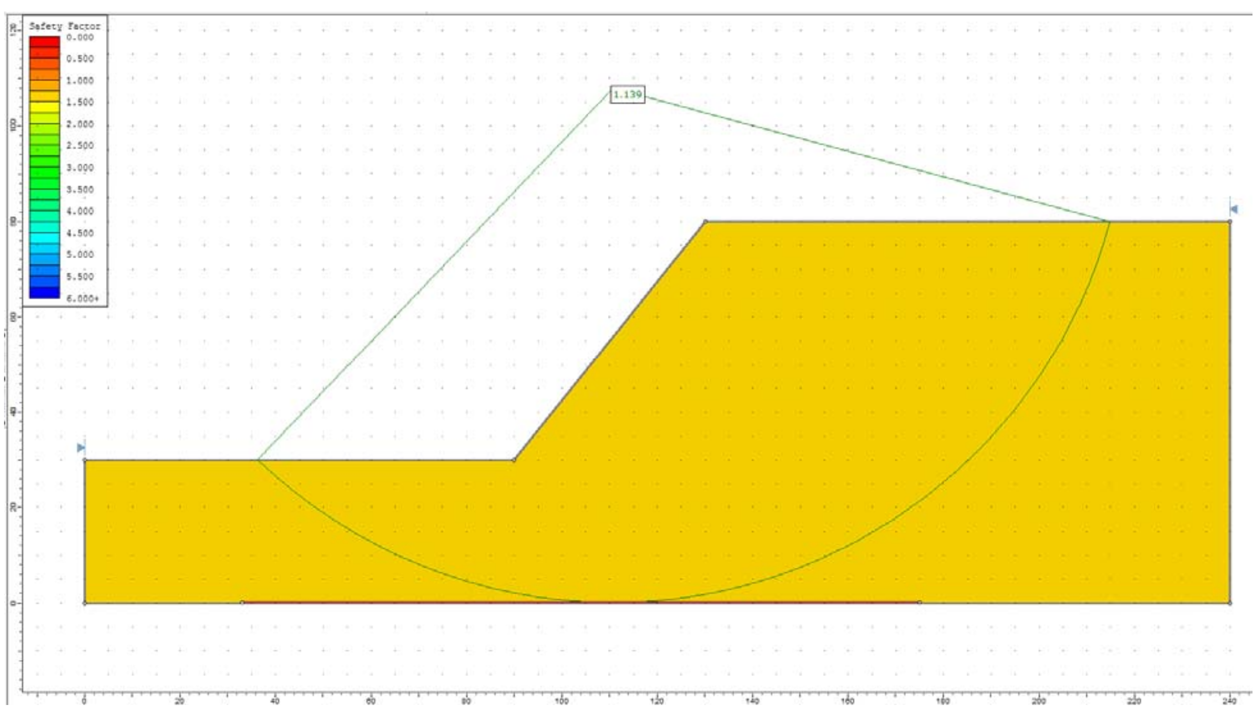


Figure 34.4.6 – Slide Solution Using the Spencer Method

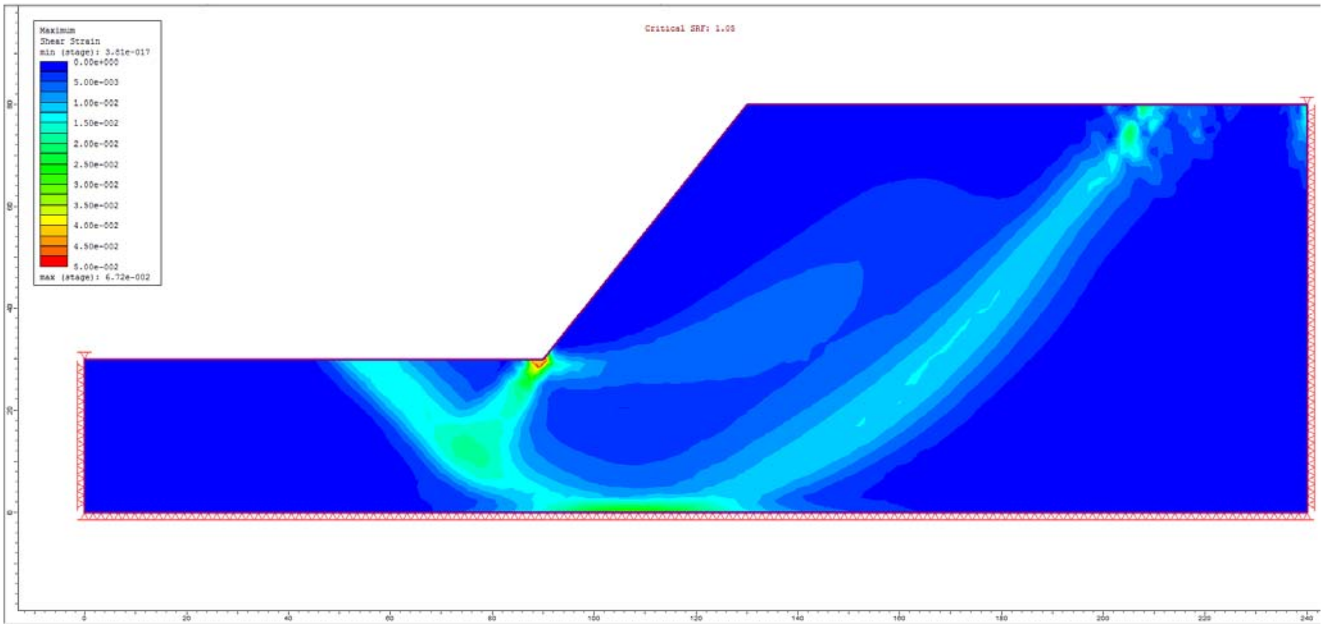


Figure 34.4.7 – RS2 Maximum Shear Strain

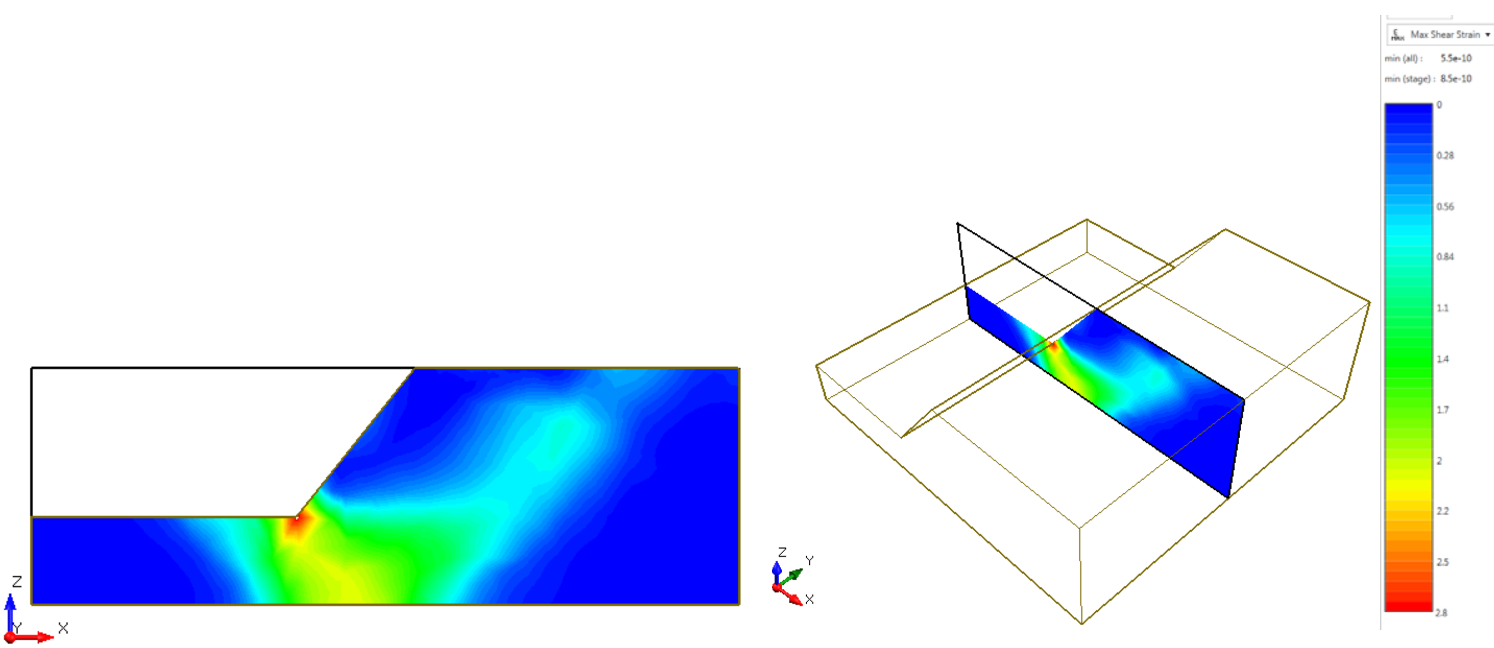


Figure 34.4.8 – RS3 Maximum Shear Strain

2D extruded, homogeneous, ellipsoidal with SA

35.1 Introduction

This problem is taken from Figure 14.3 on page 216 of Duncan and Wright (2005). Three different foundation thicknesses (30 feet-thick, 46.5 feet-thick and 60 feet-thick) are tested. This problem has a 30 feet-thick foundation.

35.2 Problem Description

A simple, pure cohesive slope is shown in Figure 35 in the XZ plane. It will then be extruded 240 m in the Y direction to obtain the 3D slope geometry. The material properties for this problem can be found in Table 35.1. The ellipsoidal slip surface is required.

35.3 Geometry and Properties

Table 35.1: Material Properties

	c´ (psf)	φ´ (deg.)	γ (pcf)
Soil	1000	0	100

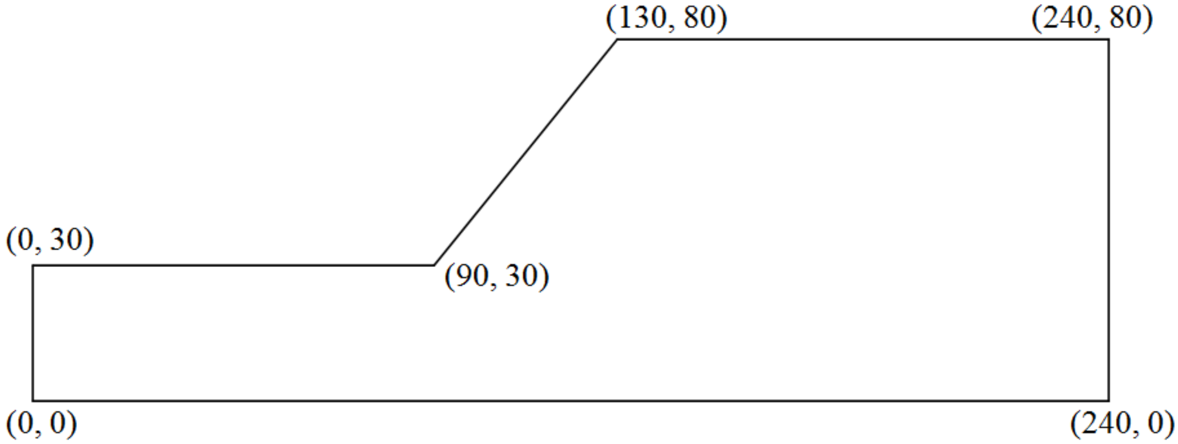


Figure 35

35.4 Results

Table 35.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	0.961	0.905		
GLE	0.978	0.870	1.18	1.05
Spencer	0.978	1.005		

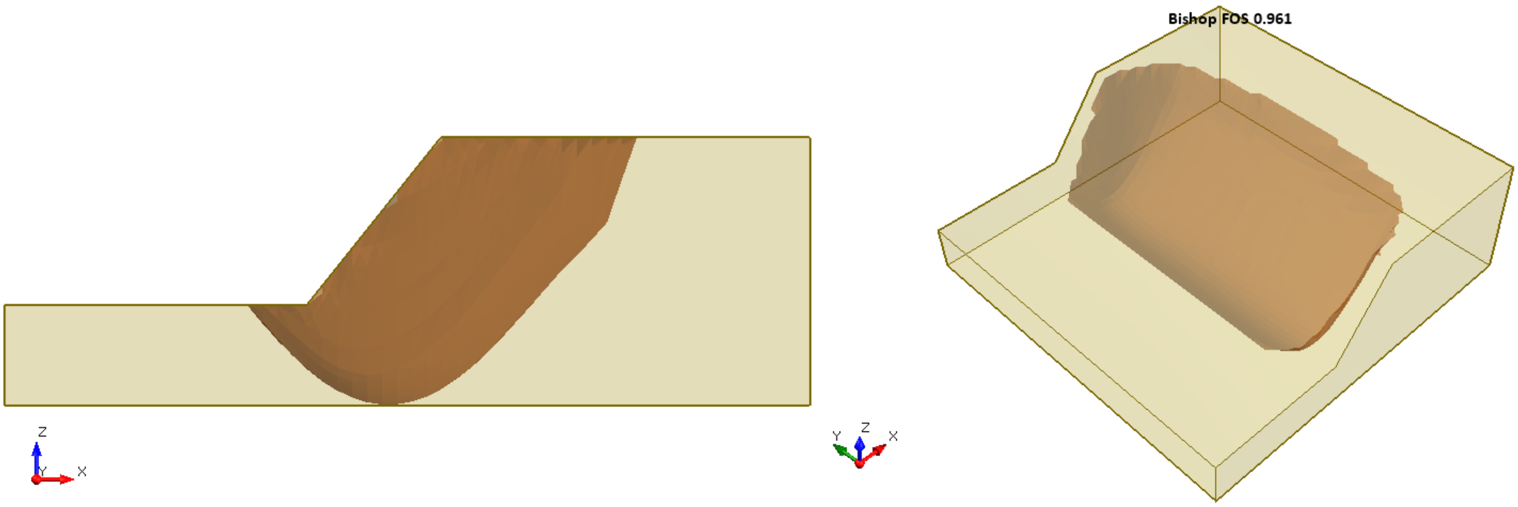


Figure 35.4.1 – Slide3 Solution Using the Bishop Method

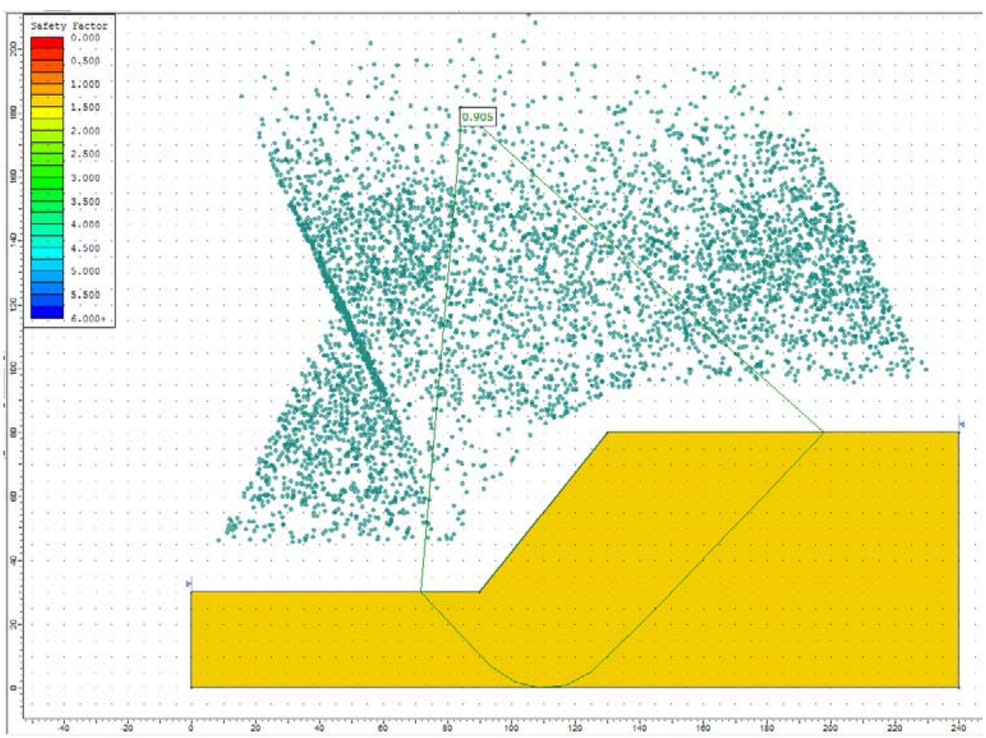


Figure 35.4.2 – Slide Solution Using the Bishop Method

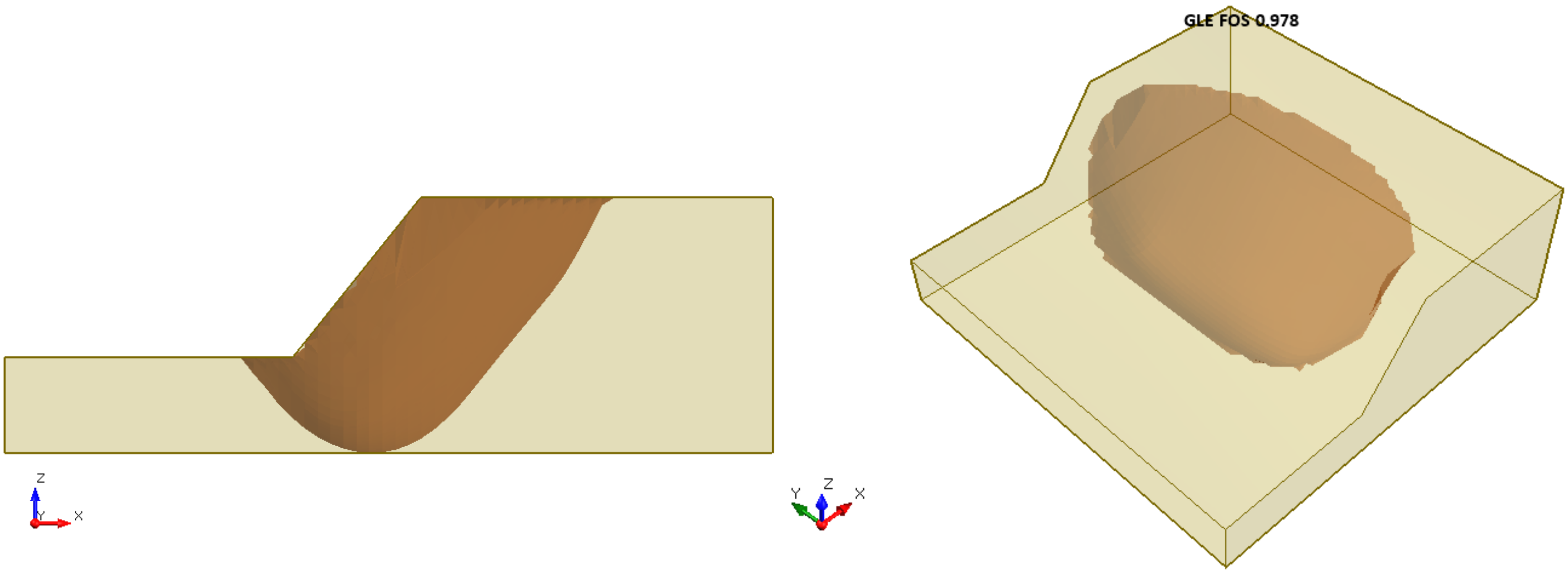


Figure 35.4.3 – Slide3 Solution Using the GLE Method

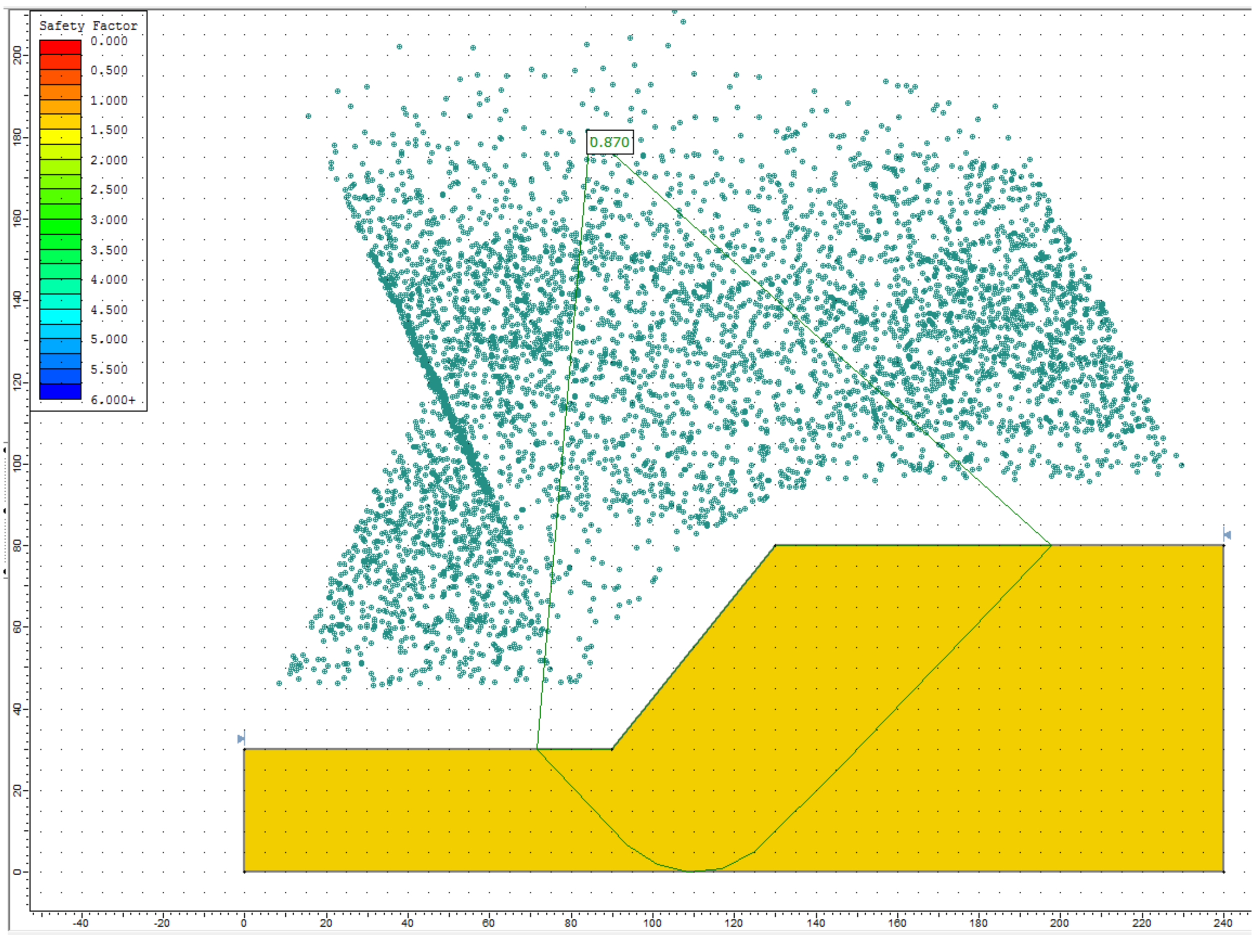


Figure 35.4.4 – Slide Solution Using the GLE Method

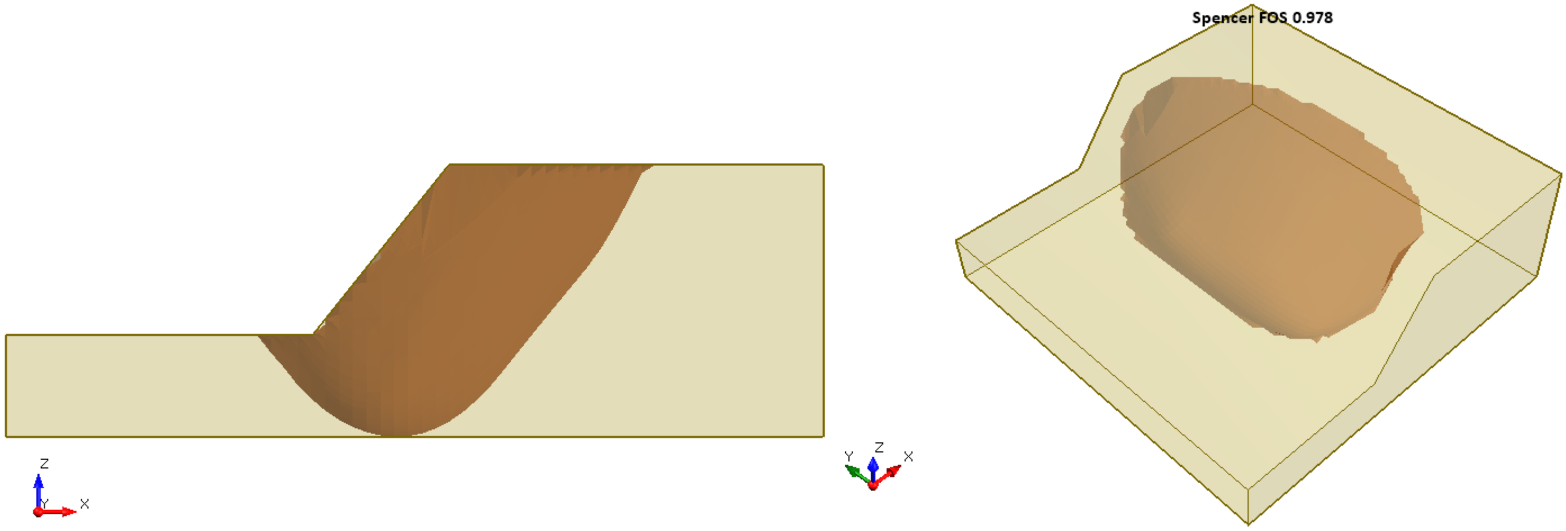


Figure 35.4.5 – Slide3 Solution Using the Spencer Method

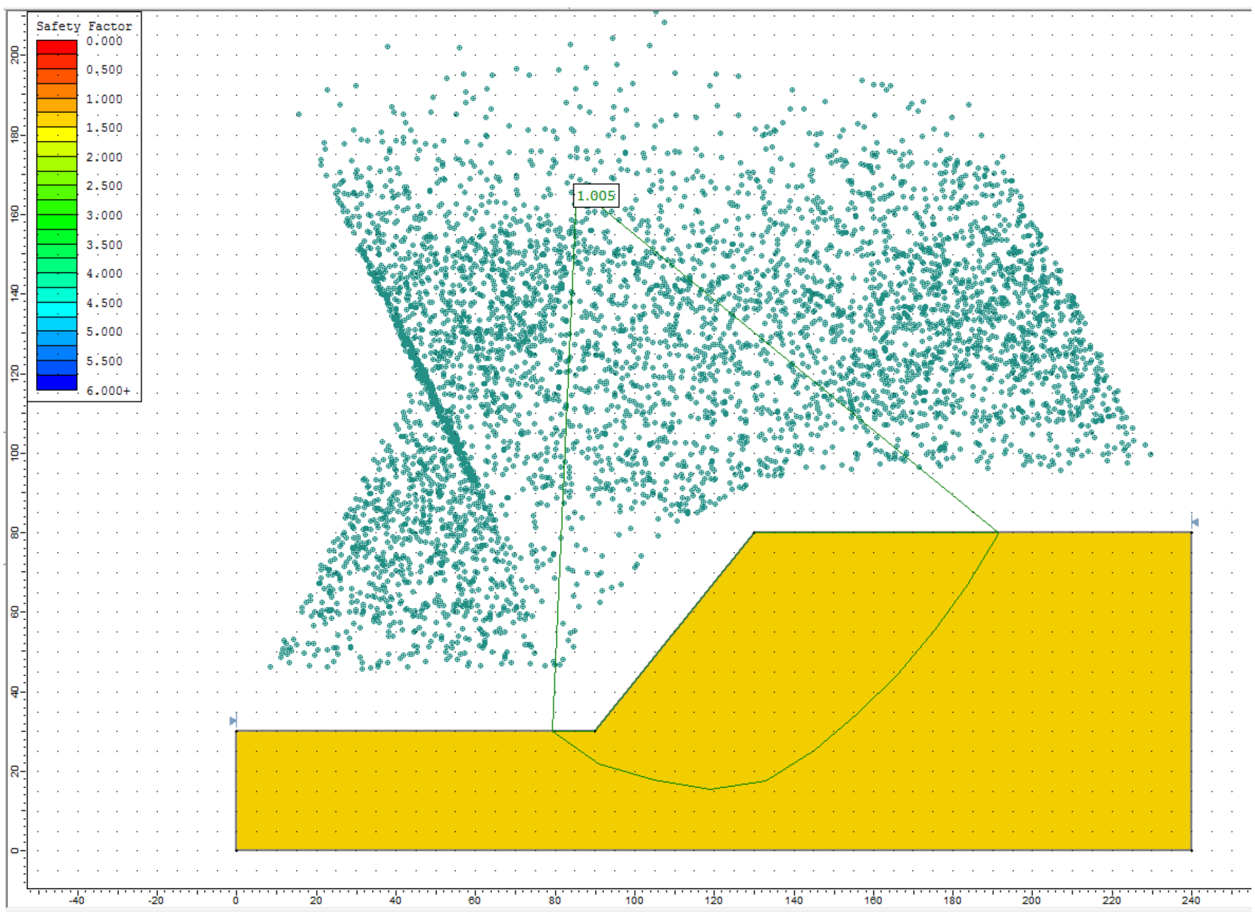


Figure 35.4.6 – Slide Solution Using the Spencer Method

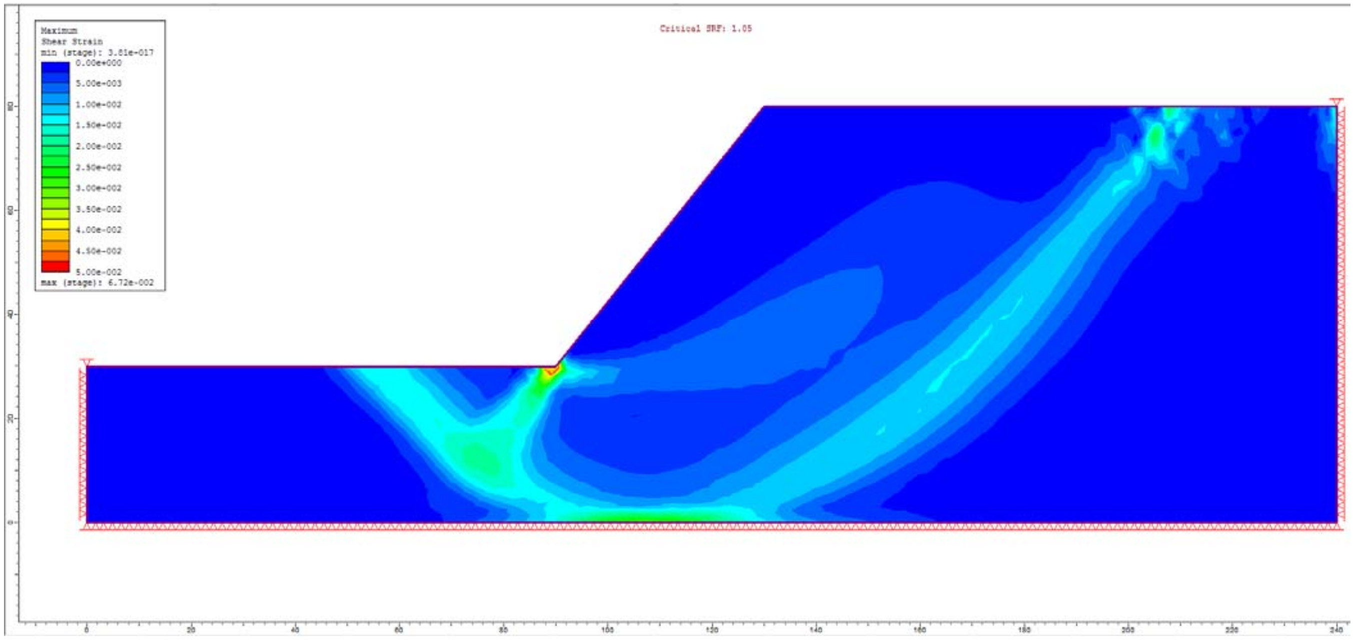


Figure 35.4.7 – RS2 Maximum Shear Strain

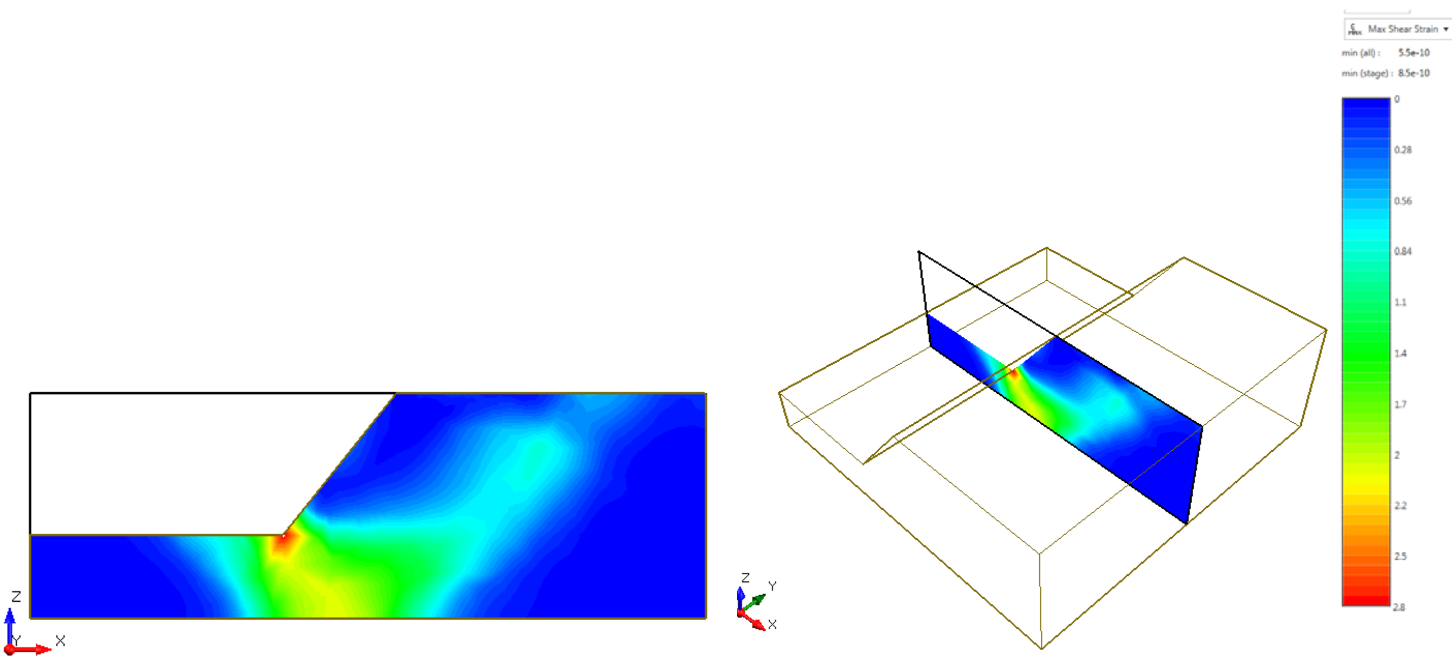


Figure 35.4.8 – RS3 Maximum Shear Strain

2D extruded, homogeneous, minimum depth, spherical

36.1 Introduction

This problem is taken from Figure 14.3 on page 216 of Duncan and Wright (2005). Three different foundation thicknesses (30 feet-thick, 46.5 feet-thick and 60 feet-thick) are tested. This problem has a 46.5 feet-thick foundation.

36.2 Problem Description

A simple, pure cohesive slope is shown in Figure 36 in the XZ plane. It will then be extruded 280 m in the Y direction to obtain the 3D slope geometry. The first slip surface passes through the toe and the second slip surface is tangent to the bottom of the foundation. The material properties for this problem can be found in Table 36.1. The slip surface of interest is tangent to the bottom of the foundation. The slip surfaces are assumed to be spherical.

36.3 Geometry and Properties

Table 36.1: Material Properties

	c′ (psf)	φ′ (deg.)	γ (pcf)
Soil	1000	0	100

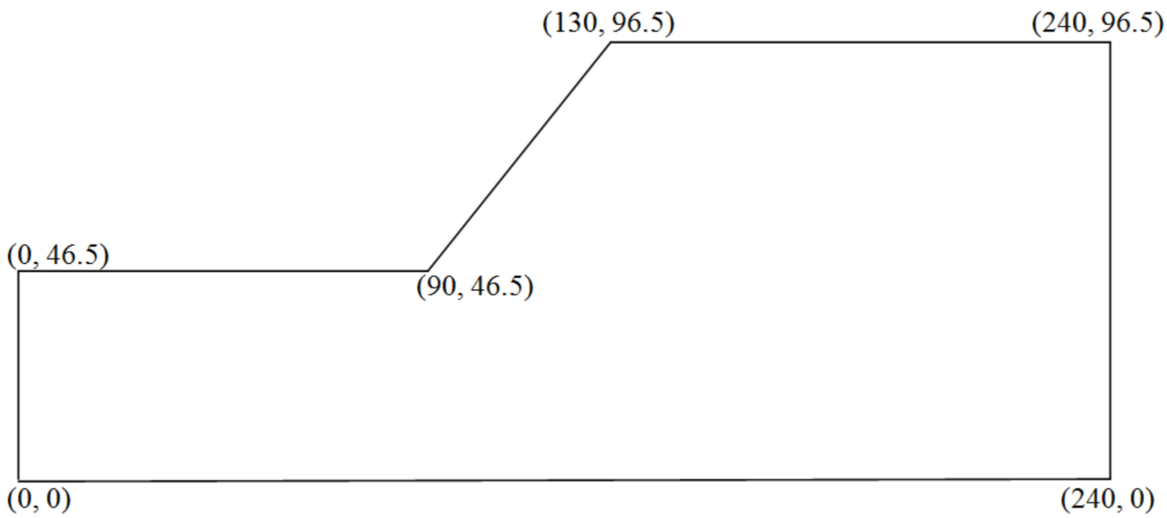


Figure 36

36.4 Results

Table 36.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.274	1.130	1.16	1.04
GLE	1.277	1.129		
Spencer	1.279	1.129		

Referee: 1.124 [Duncan and Wright, 2005]

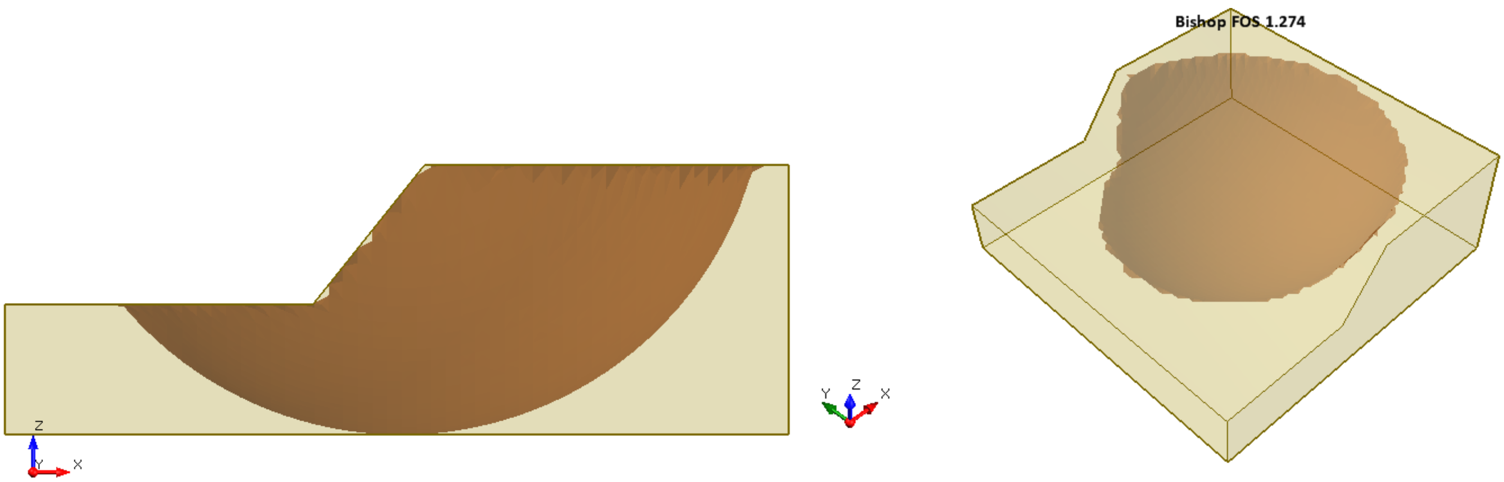


Figure 36.4.1 – Slide3 Solution Using the Bishop Method

Figure 36.4.2 – Slide Solution Using the Bishop Method

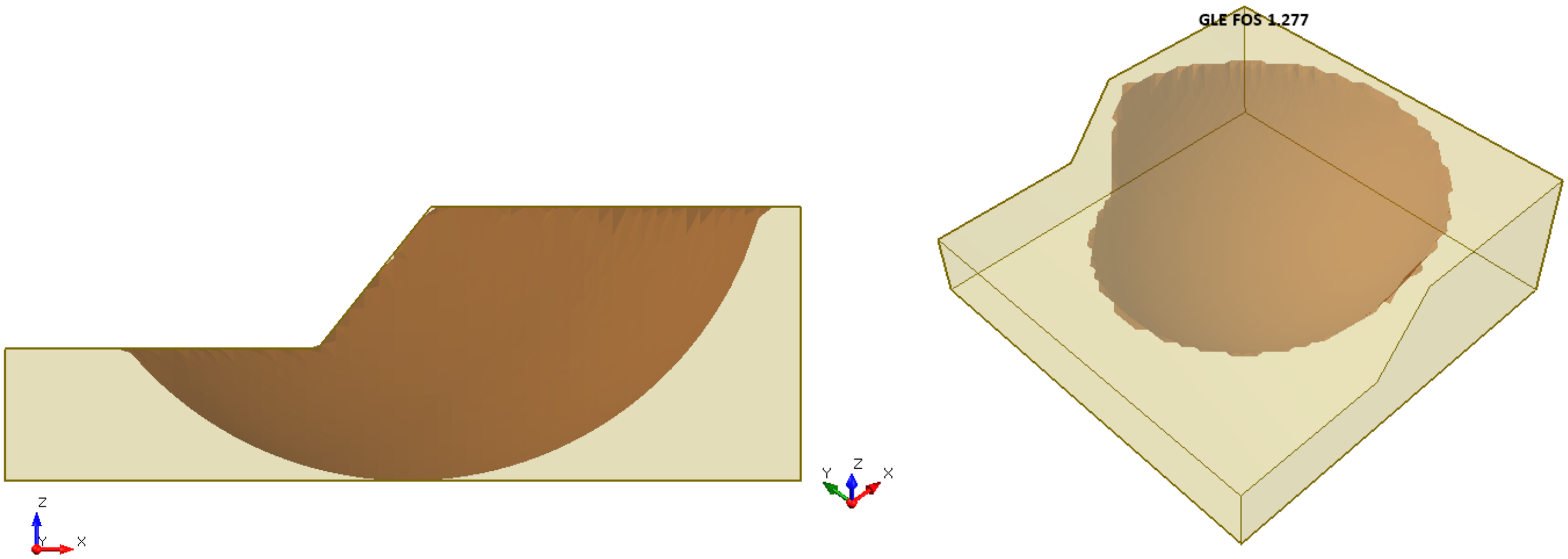


Figure 36.4.3 – Slide3 Solution Using the GLE Method

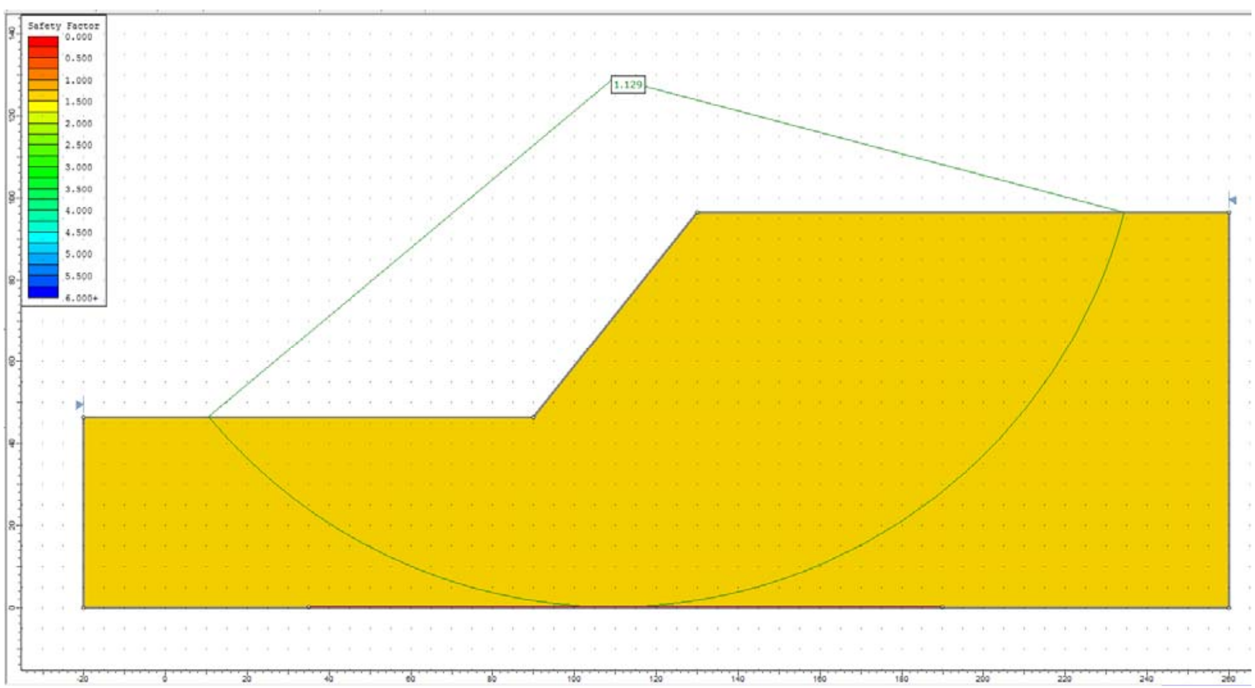


Figure 36.4.4 – Slide Solution Using the GLE Method

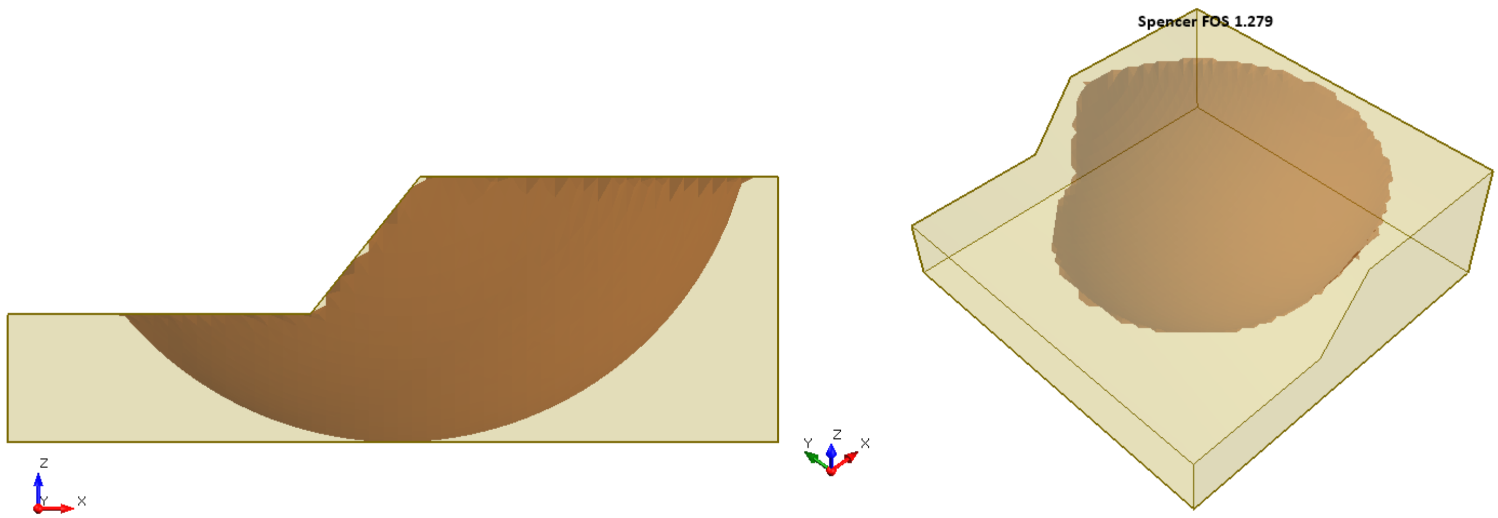


Figure 36.4.5 – Slide3 Solution Using the Spencer Method

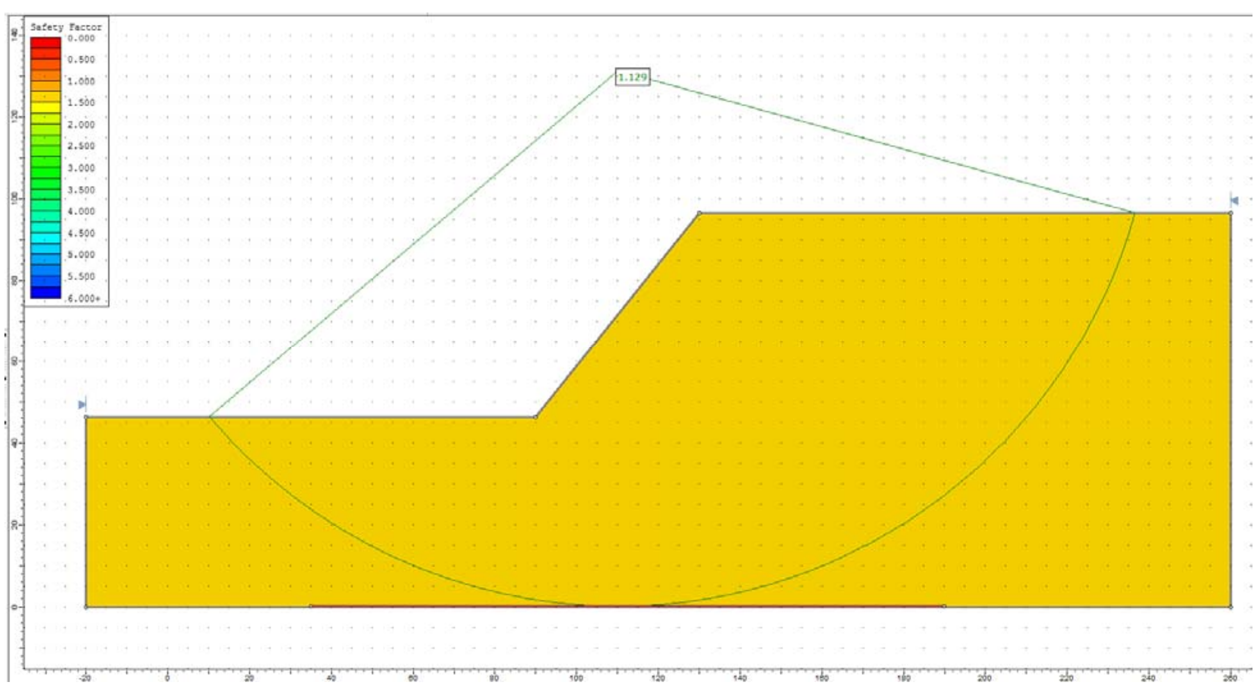


Figure 36.4.6 – Slide Solution Using the Spencer Method

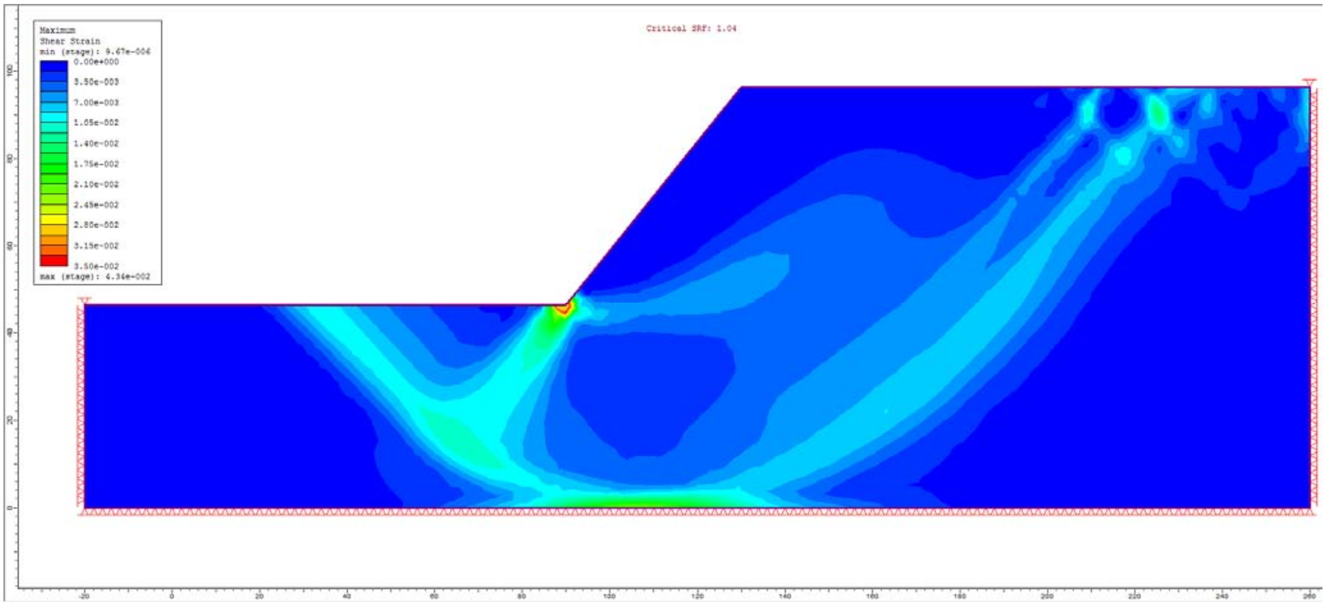


Figure 36.4.7 – RS2 Maximum Shear Strain

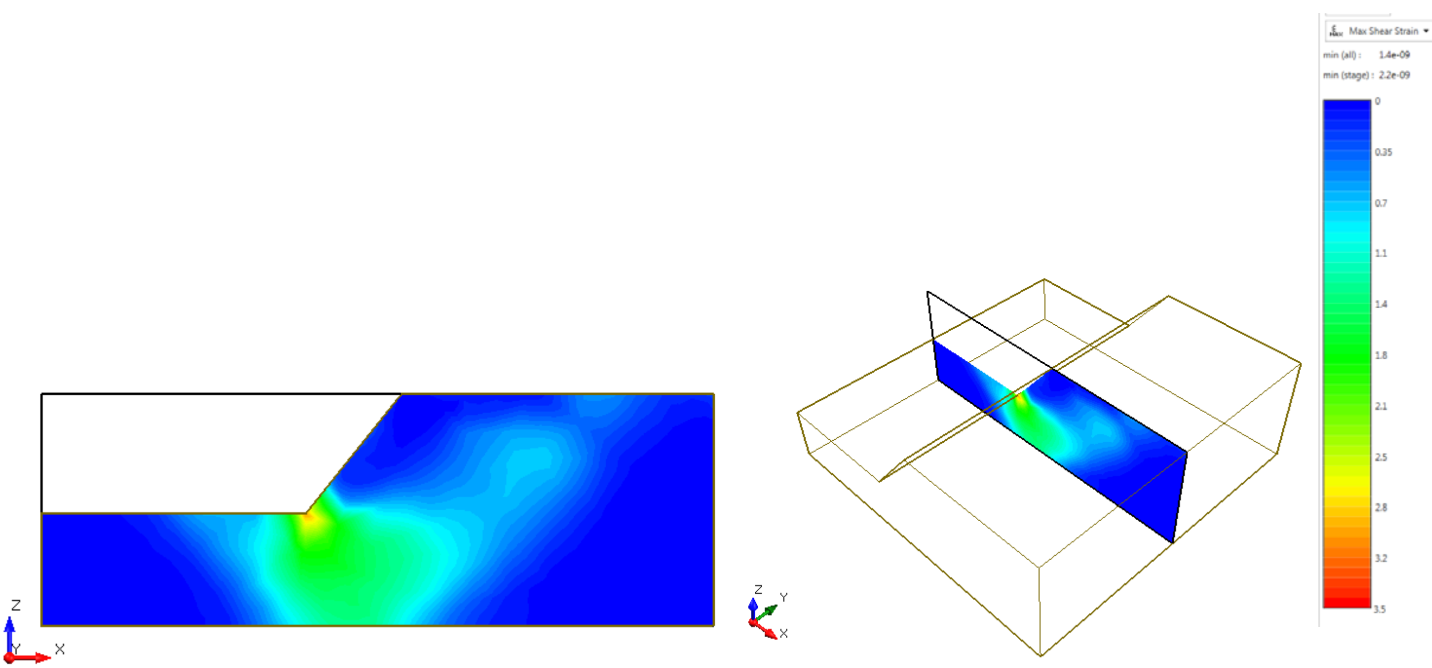


Figure 36.4.8 – RS3 Maximum Shear Strain

2D extruded, homogeneous, ellipsoidal with SA

37.1 Introduction

This problem is taken from Figure 14.3 on page 216 of Duncan and Wright (2005). Three different foundation thicknesses (30 feet-thick, 46.5 feet-thick and 60 feet-thick) are tested. This problem has a 46.5 feet-thick foundation.

37.2 Problem Description

A simple, pure cohesive slope is shown in Figure 37 in the XZ plane. It will then be extruded 280m in the Y direction to obtain the 3D slope geometry. The first slip surface passes through the toe and the second slip surface is tangent to the bottom of the foundation. The material properties for this problem can be found in Table 37.1. The slip surfaces are assumed to be ellipsoidal.

37.3 Geometry and Properties

Table 37.1: Material Properties

	c´ (psf)	φ´ (deg.)	γ (pcf)
Soil	1000	0	100

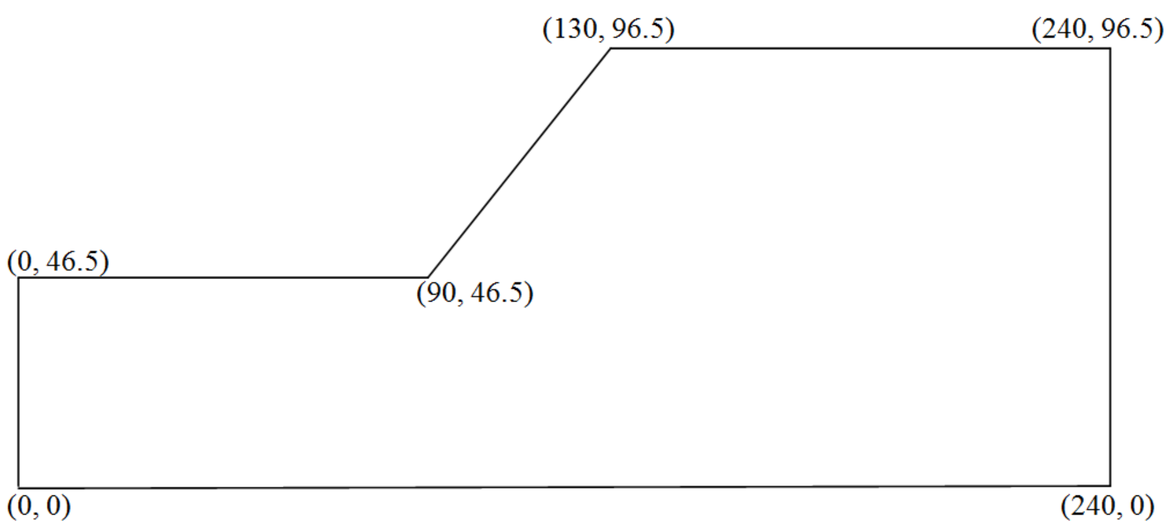


Figure 37

37.4 Results

Table 37.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	0.965	0.882	1.16	1.04
GLE	0.963	0.918		
Spencer	0.963	0.912		

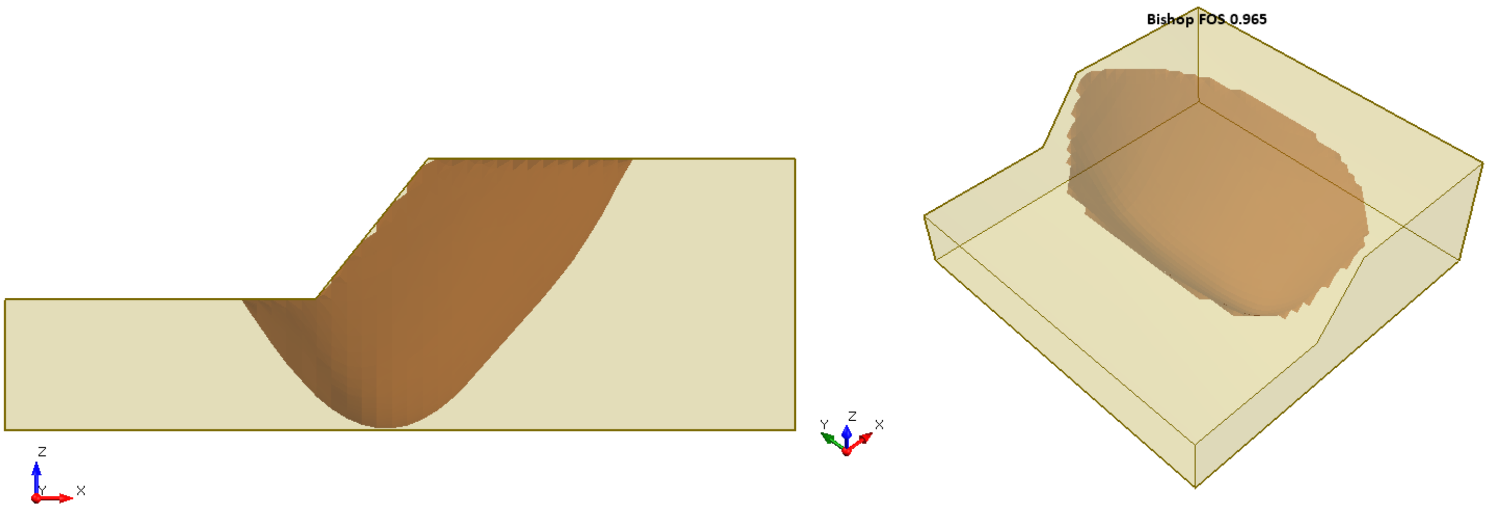


Figure 37.4.1 – Slide3 Solution Using the Bishop Method

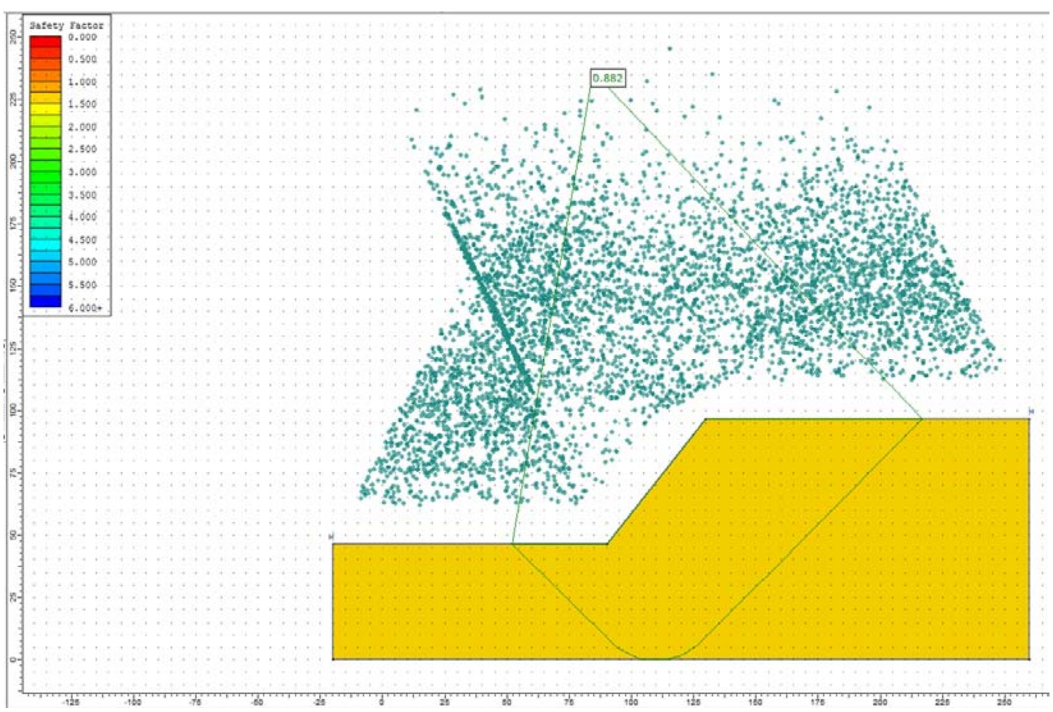


Figure 37.4.2 – Slide Solution Using the Bishop Method

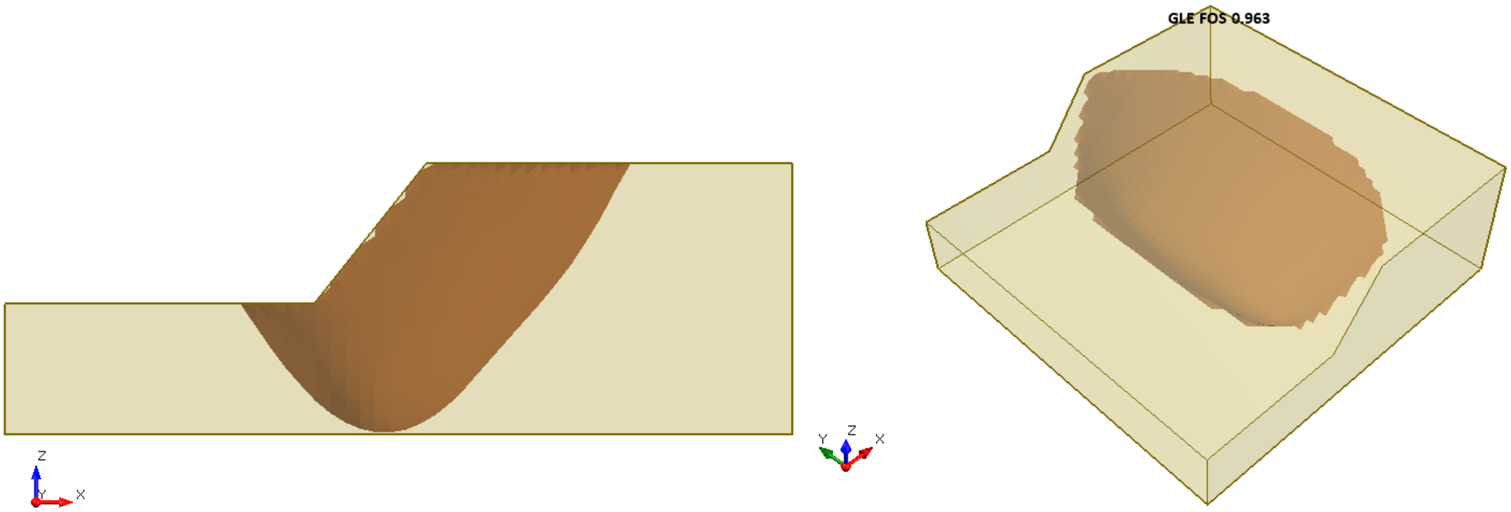


Figure 37.4.3 – Slide3 Solution Using the GLE Method

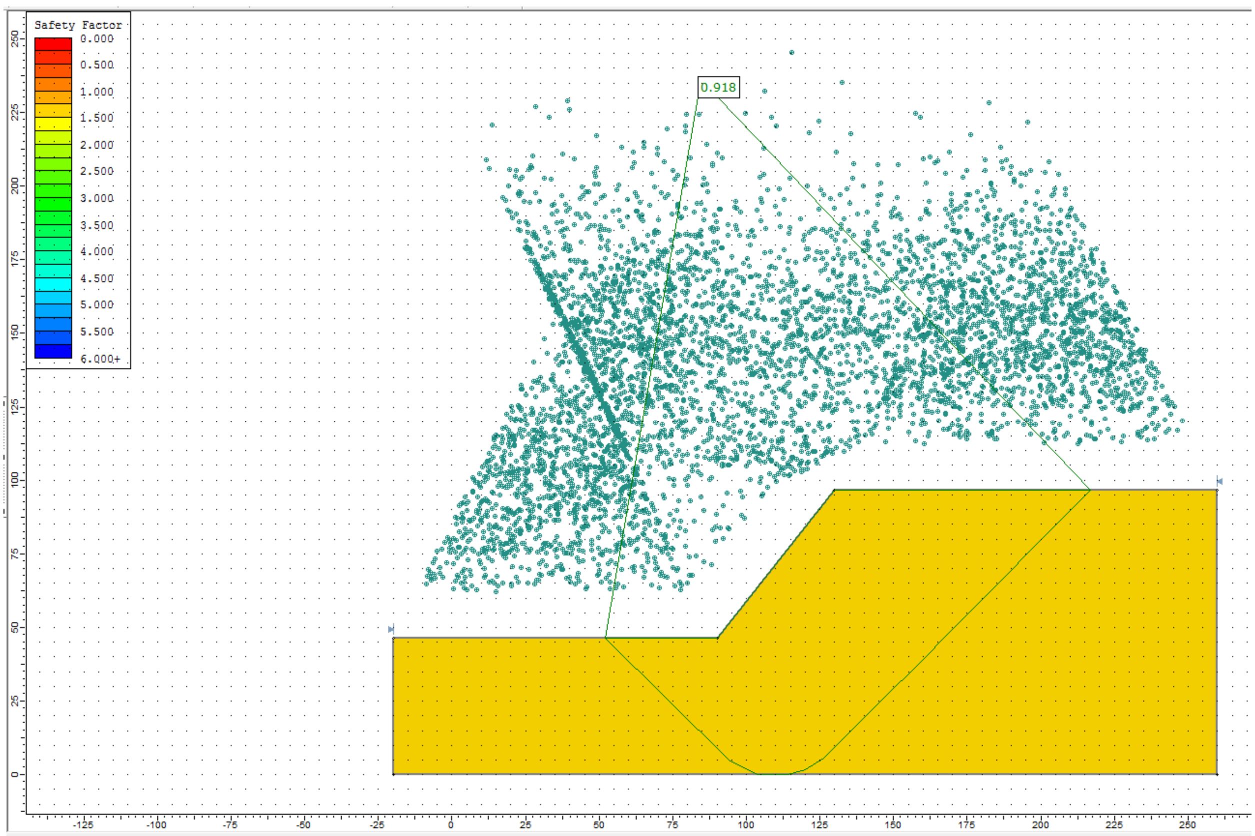


Figure 37.4.4 – Slide Solution Using the GLE Method

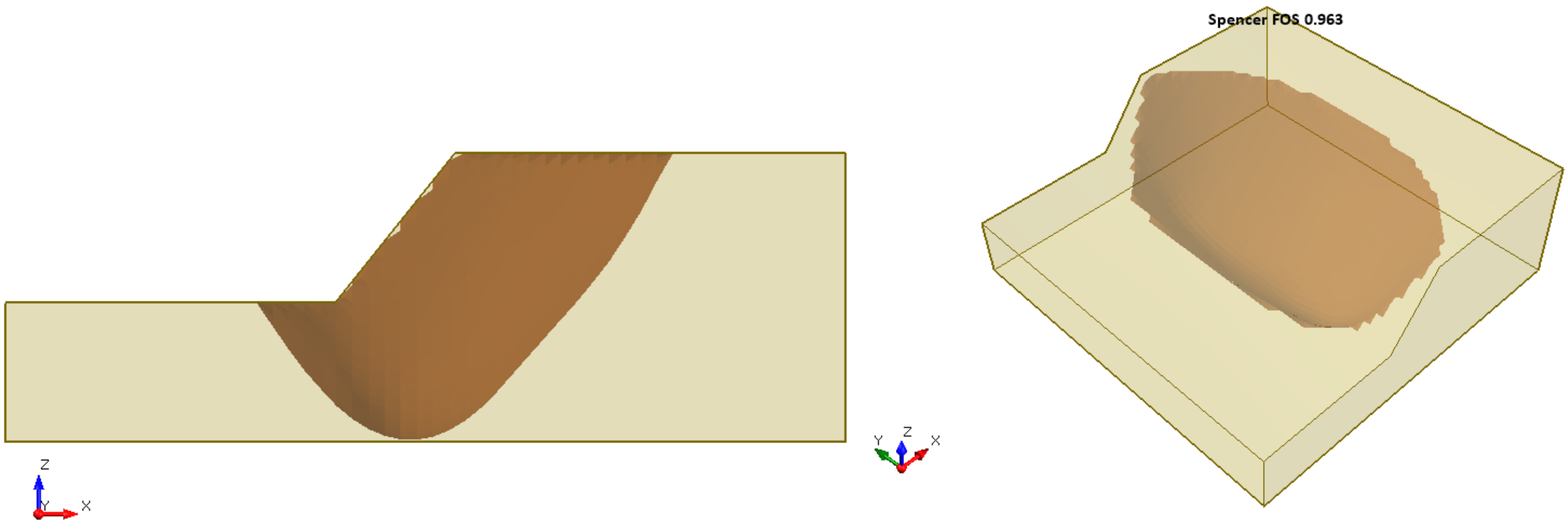


Figure 37.4.5 – Slide3 Solution Using the Spencer Method

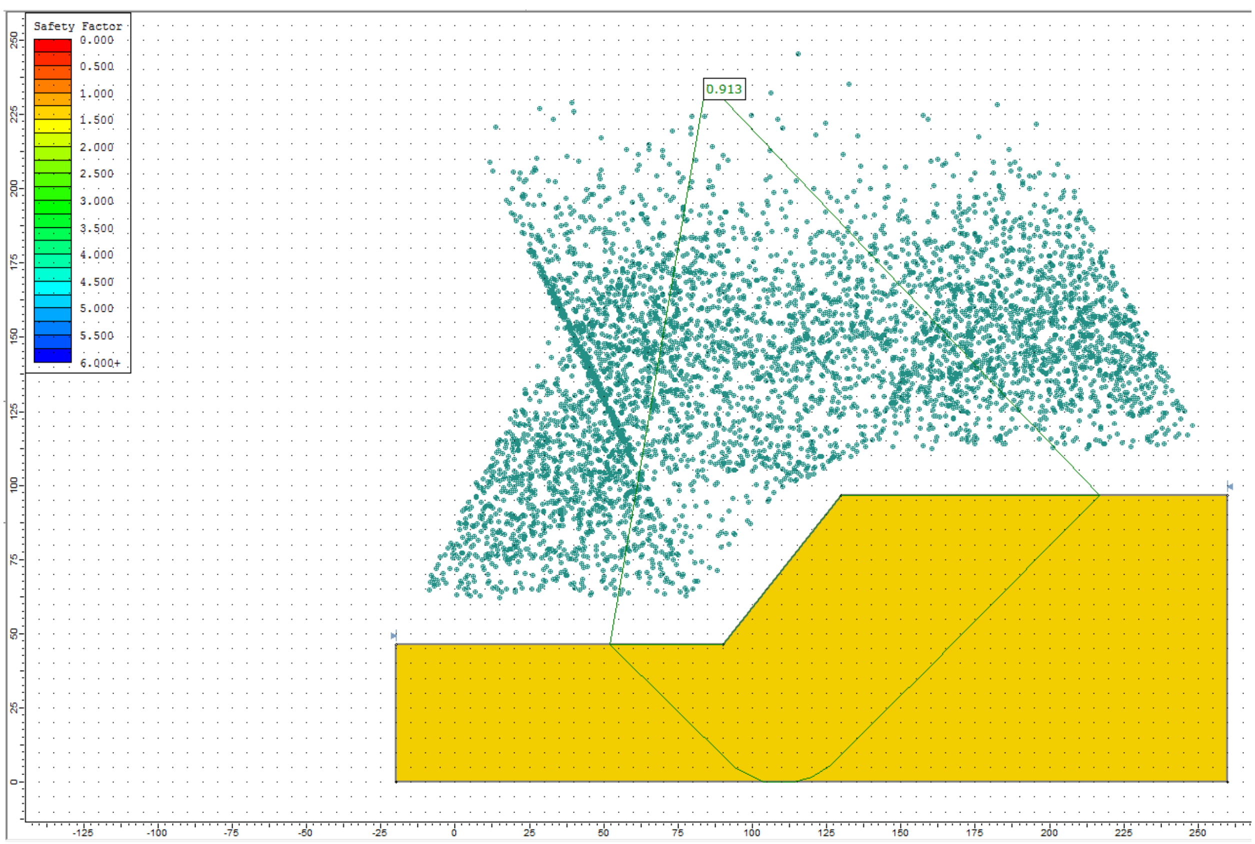


Figure 37.4.6 – Slide Solution Using the Spencer Method

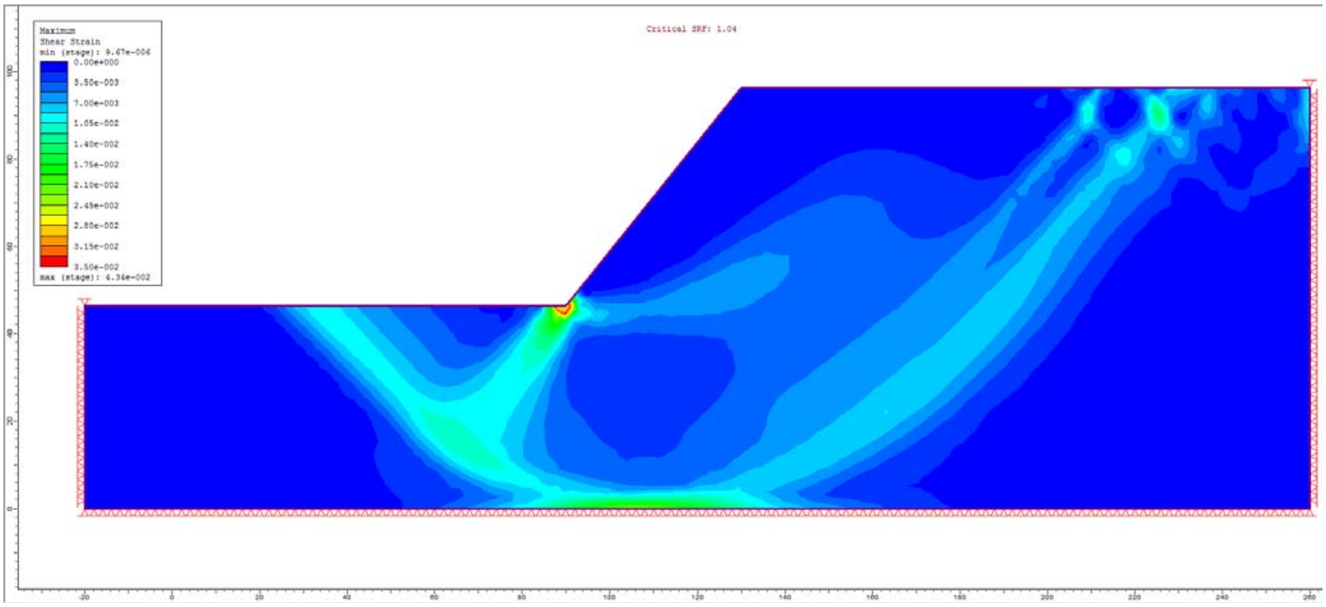


Figure 37.4.7 – RS2 Maximum Shear Strain

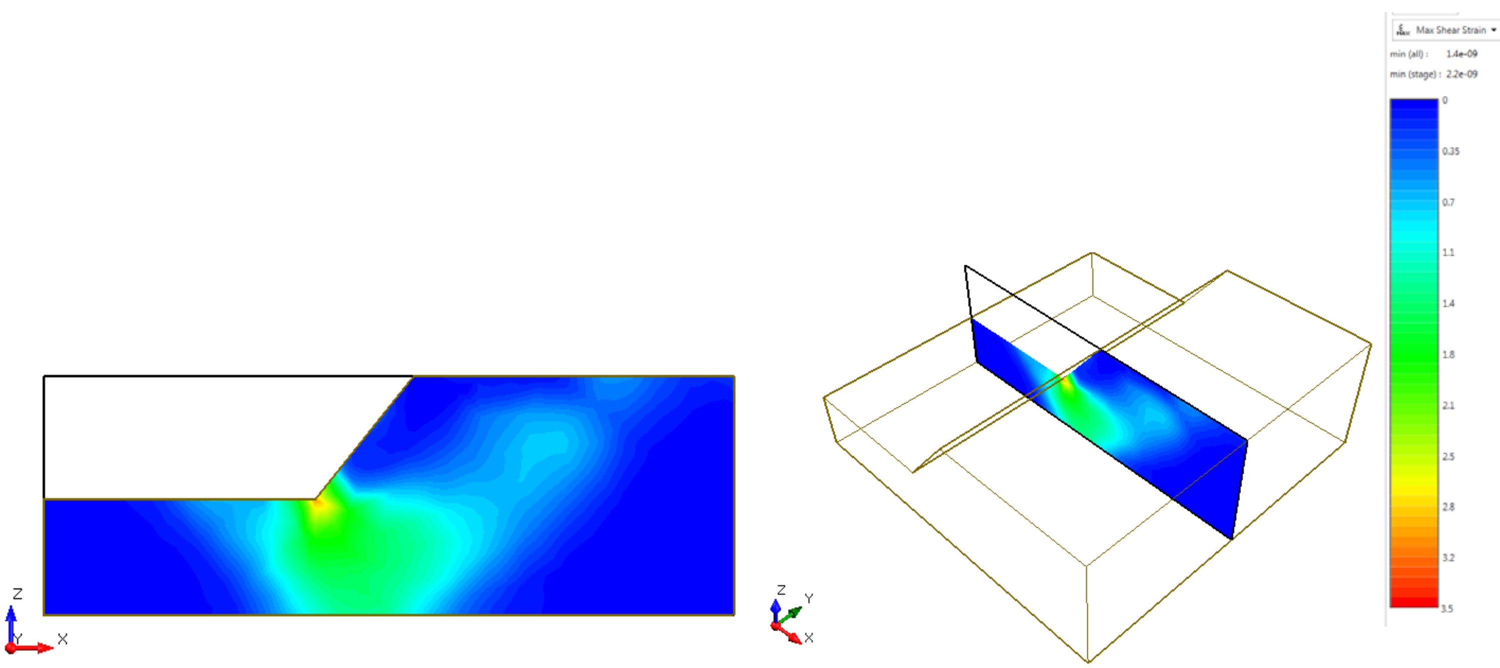


Figure 37.4.8 – RS3 Maximum Shear Strain

2D extruded, vertical cut, weak layer defined slip surface

38.1 Introduction

This model is taken from Cheng and Yip (2007). It is a vertical cut slope whose slip surface is defined by a weak layer.

38.2 Problem Description

The slope geometry for this example can be found as Figure 38. The weak layer, which defines the slip surface can also be found in Figure 38 in orange, and is made of the same material as the slope. The slope is homogeneous and its material properties can be found in Table 38.1.

38.3 Geometry and Properties

Table 38.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	0	32	20

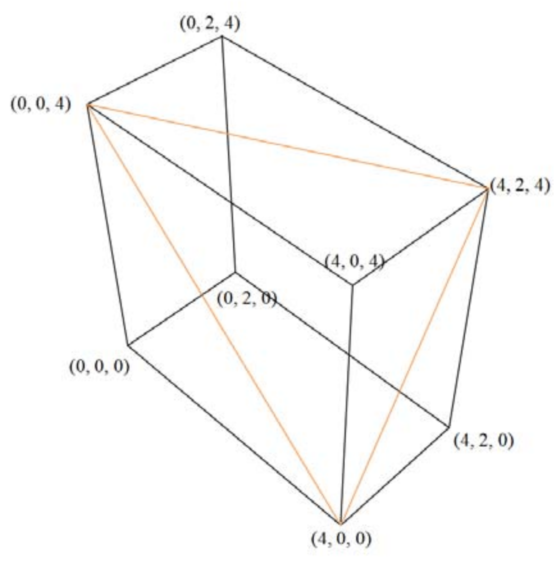


Figure 38

38.4 Results

Table 38.4.1: Safety Factors Using Slide3

Method	Slide3
Bishop	0.288
Janbu	0.288

Referee: 0.280 [Cheng and Yip, 2007]

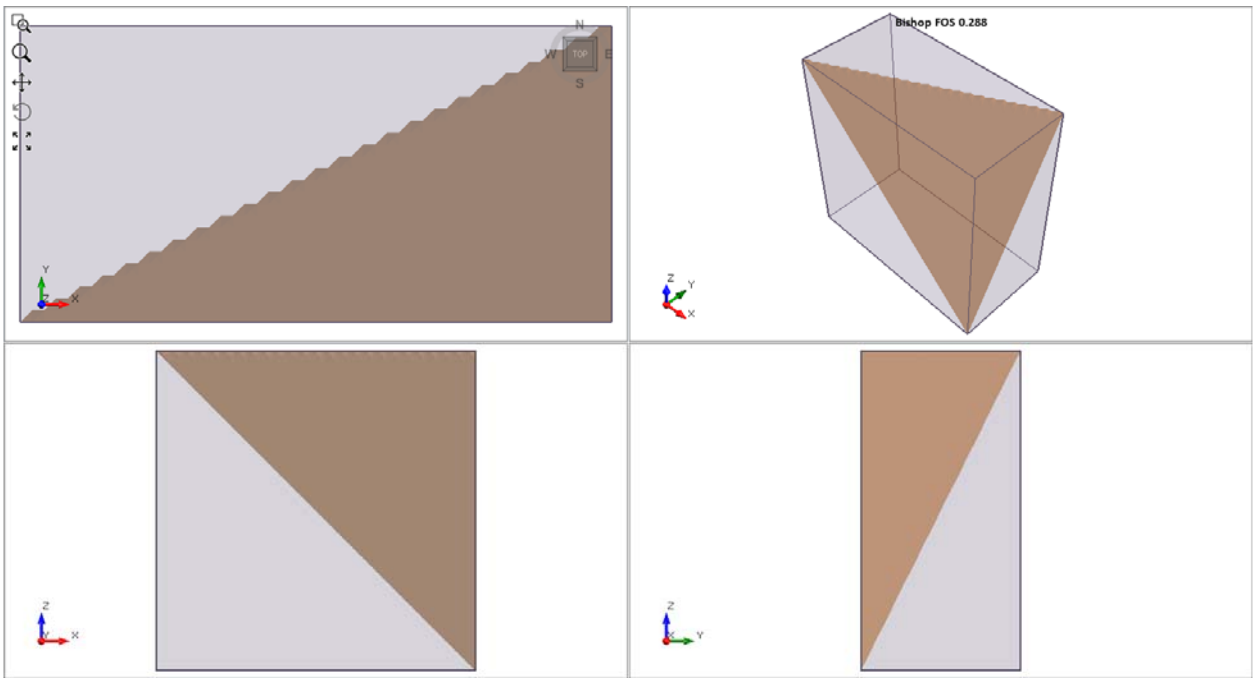


Figure 38.4.1 – Slide3 Solution Using a Weak Plane Slip Surface

2D extruded, (6) materials, water table, ellipsoidal with SA

39.1 Introduction

This example is a model of a slope excavated through previously spoiled material access coal under a dump.

39.2 Problem Description

This example is a 2D slope in the XZ plane that has been extruded 300m in the Y direction. The properties for all 6 materials can be found in Table 39.1. Pore pressure is created by the water table. The ellipsoidal slip surface and corresponding safety factor is required.

39.3 Properties

Table 39.1: Material Properties

Material	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
BMA Cat 1U	20	25	18
Weathered Tert det.	35	17	20
DAW Fresh CMR	568	36.1	24
Coal	35	30	15
Immediate Floor (BA)	0	10	24
Weathered Coal	0	30	15

39.4 Results

Table 39.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.131	1.071	1.32	1.12
GLE	1.13	1.066		
Janbu	1.12	1.052		
Spencer	1.152	1.081		

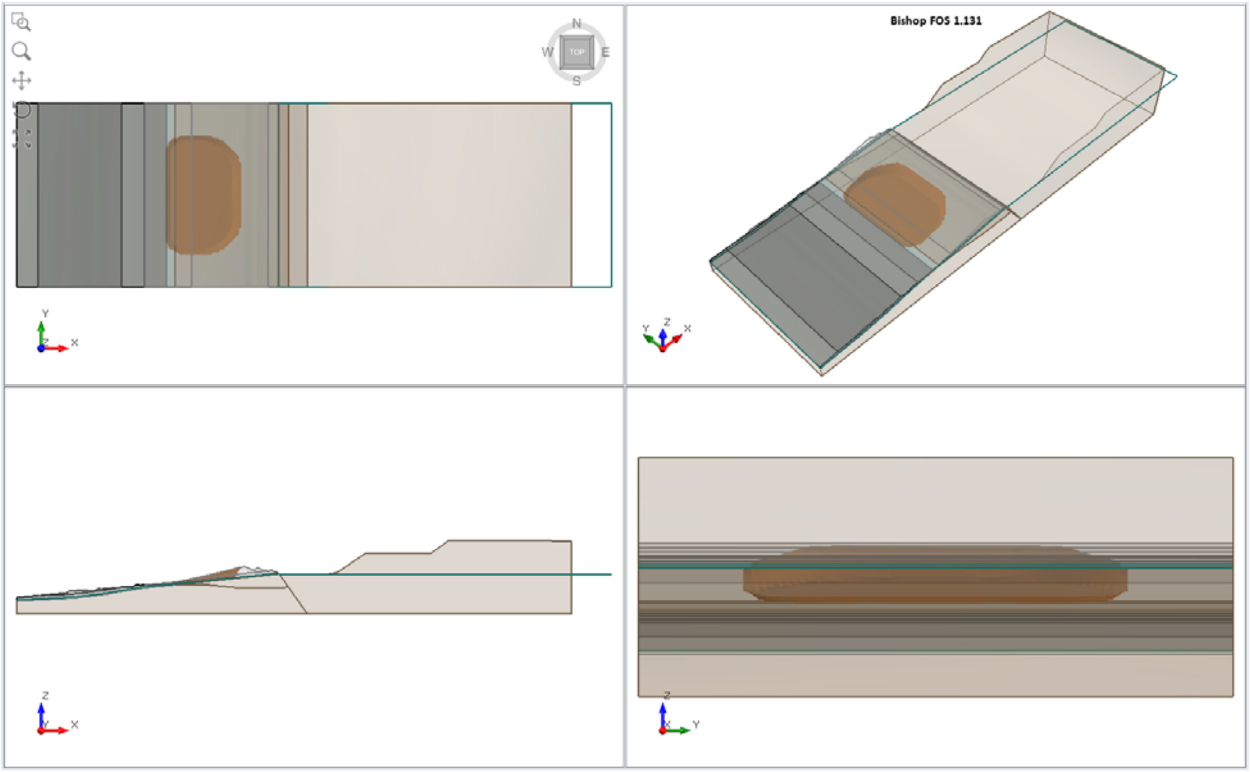


Figure 39.4.1 – Slide3 Solution Using the Bishop Method

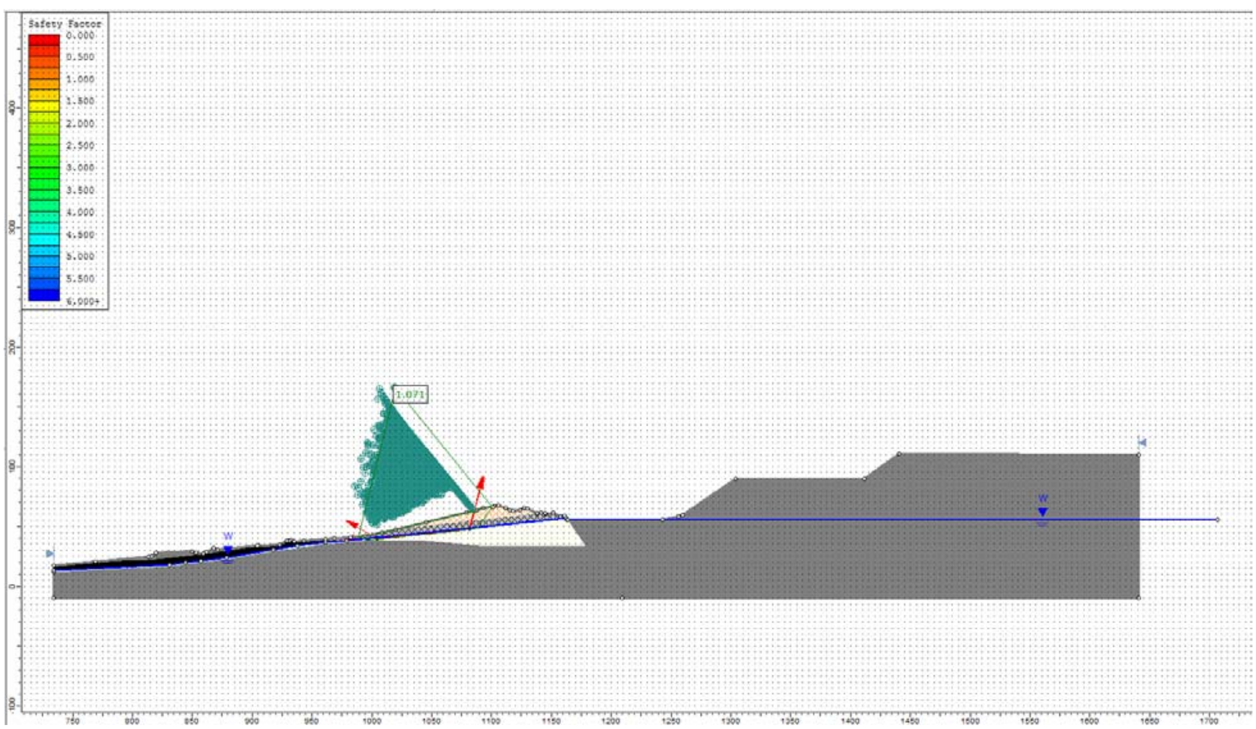


Figure 39.4.2 – Slide Solution Using the Bishop Method

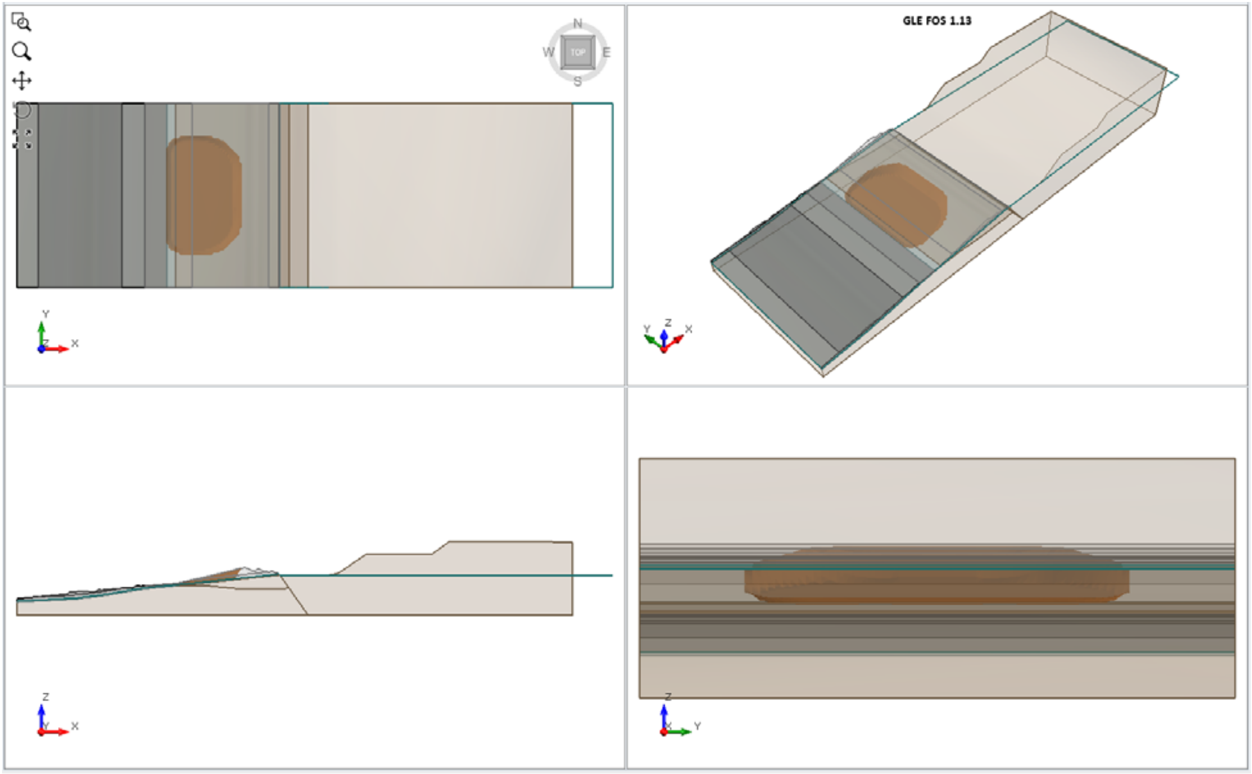


Figure 39.4.3 – Slide3 Solution Using the GLE Method

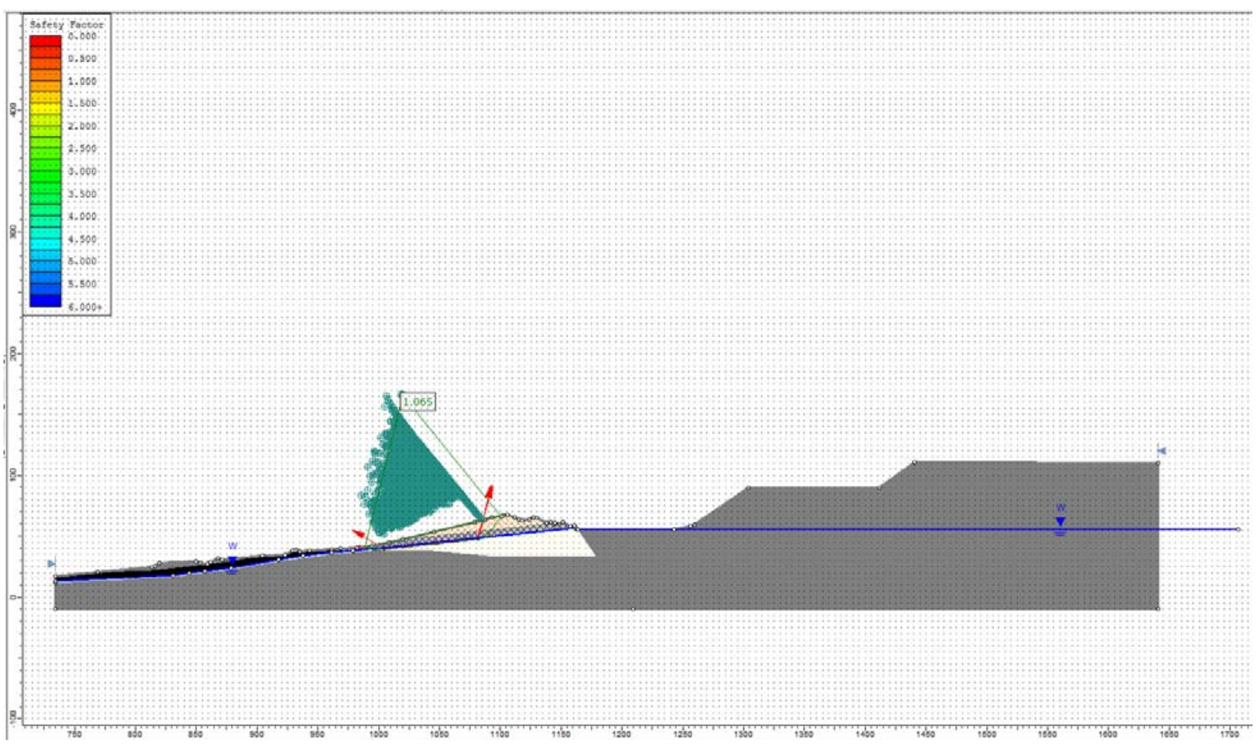


Figure 39.4.4 – Slide Solution Using the GLE Method

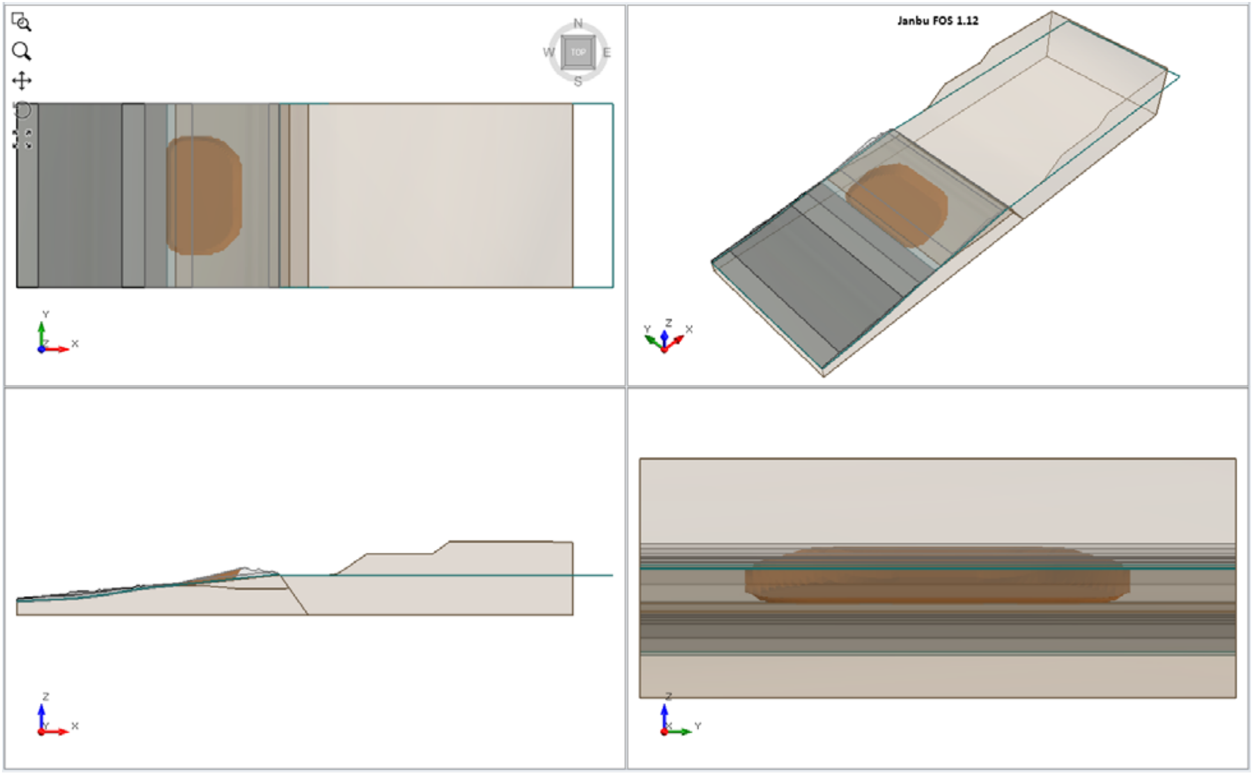


Figure 39.4.5 – Slide3 Solution Using the Janbu Method

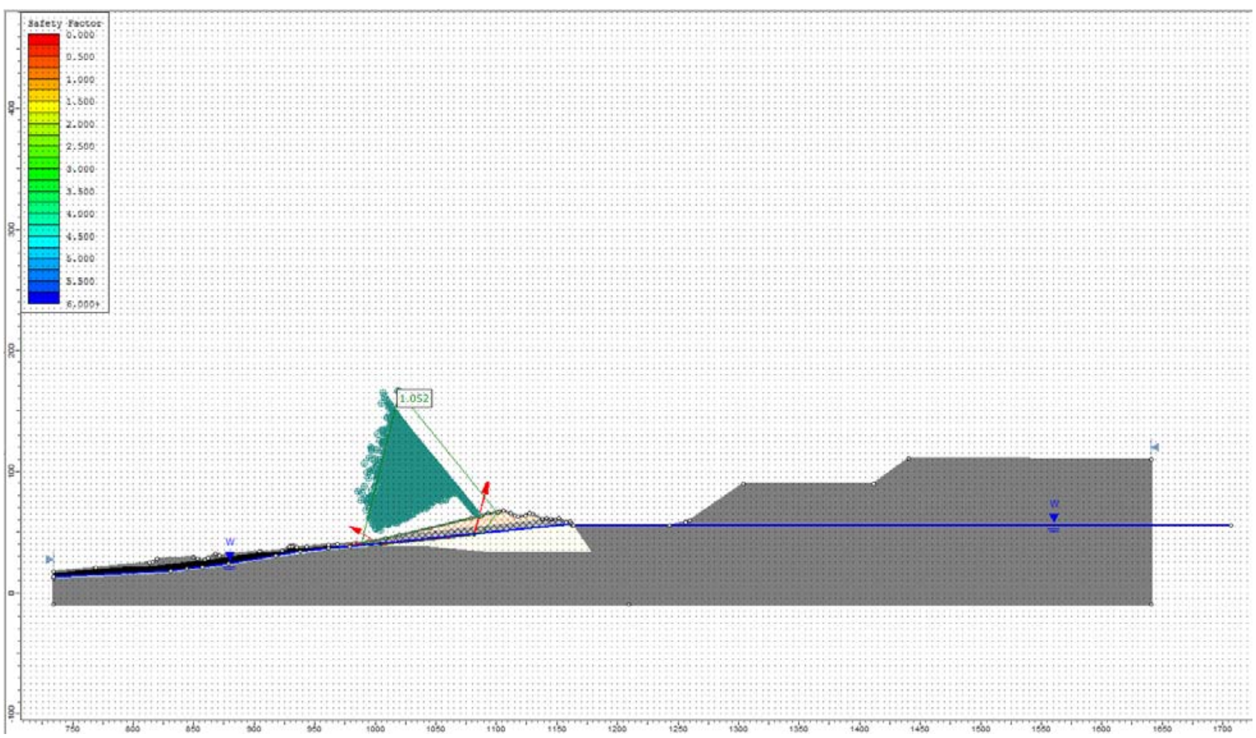


Figure 39.4.6 – Slide3 Solution Using the Janbu Method

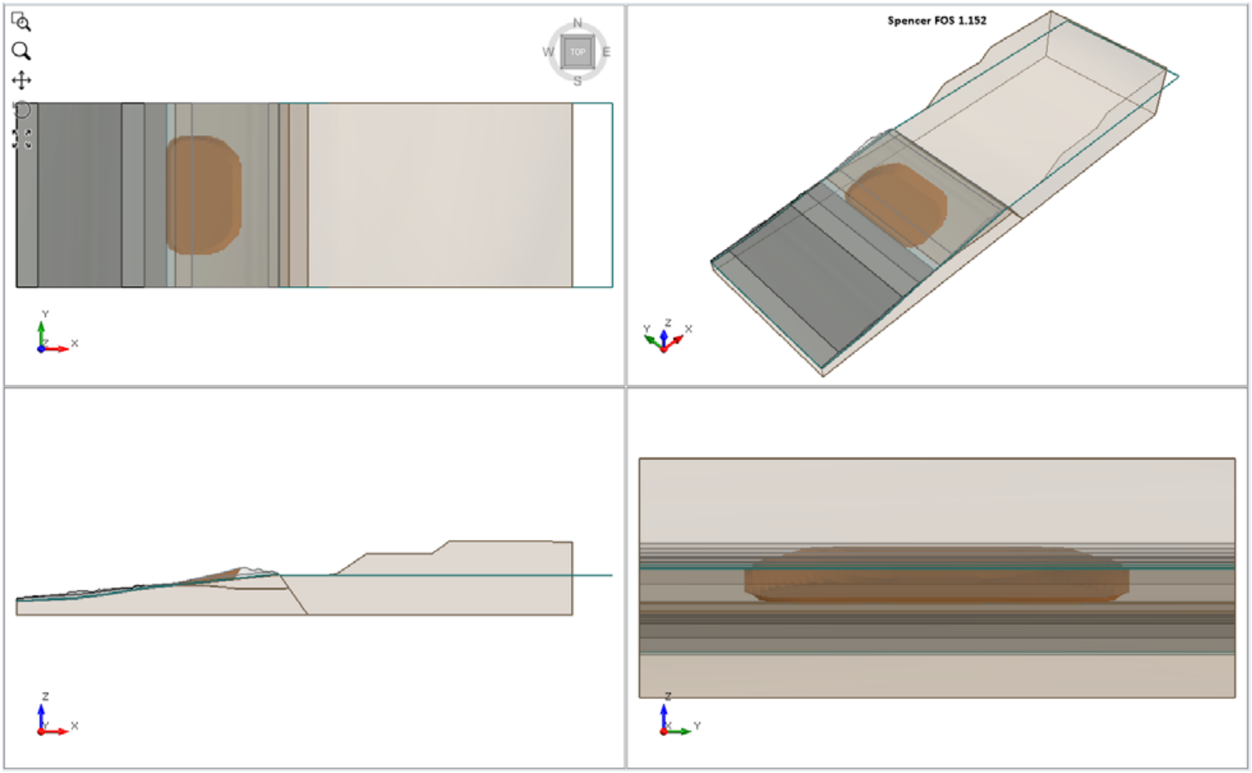


Figure 39.4.7 – Slide3 Solution Using the Spencer Method

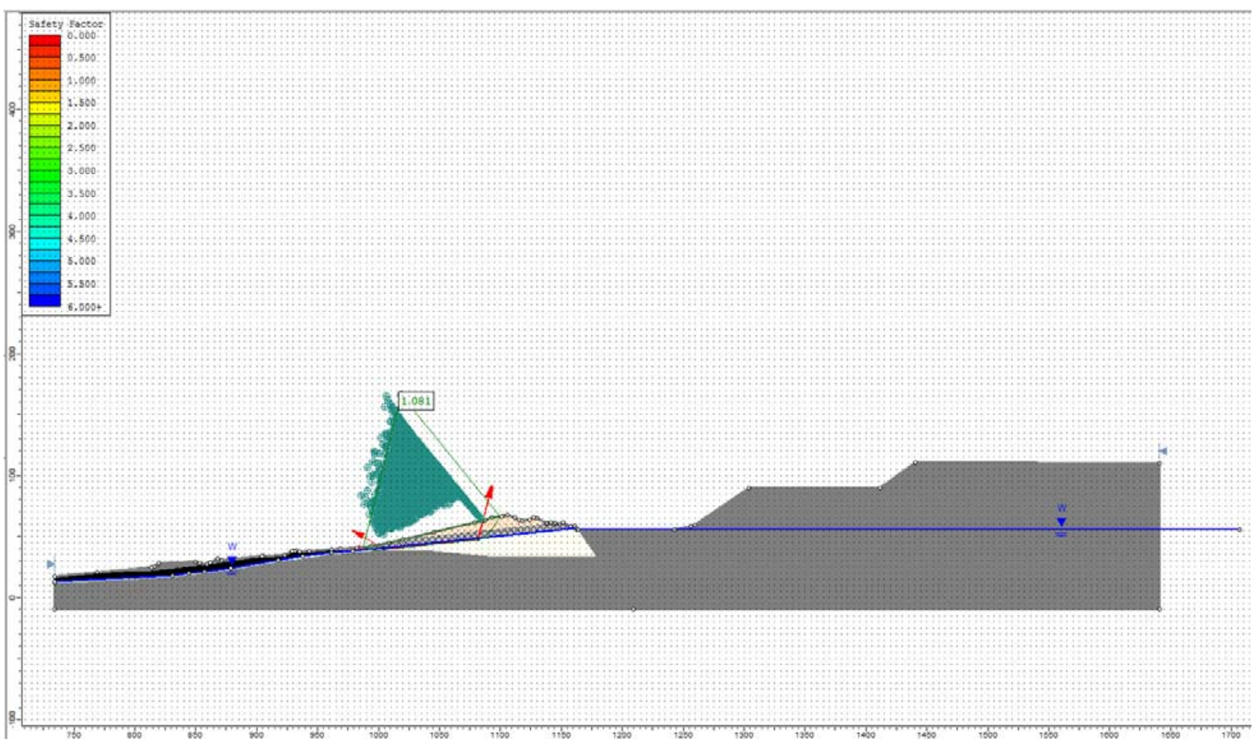


Figure 39.4.8 – Slide3 Solution Using the Spencer Method

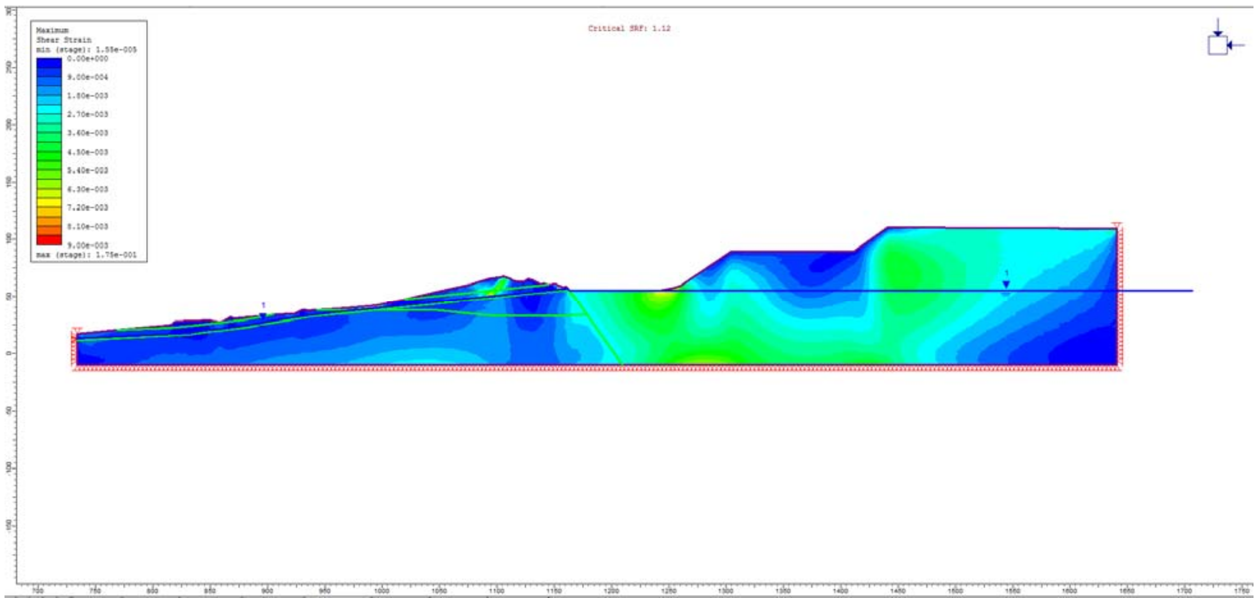


Figure 39.4.9 – RS2 Maximum Shear Strain

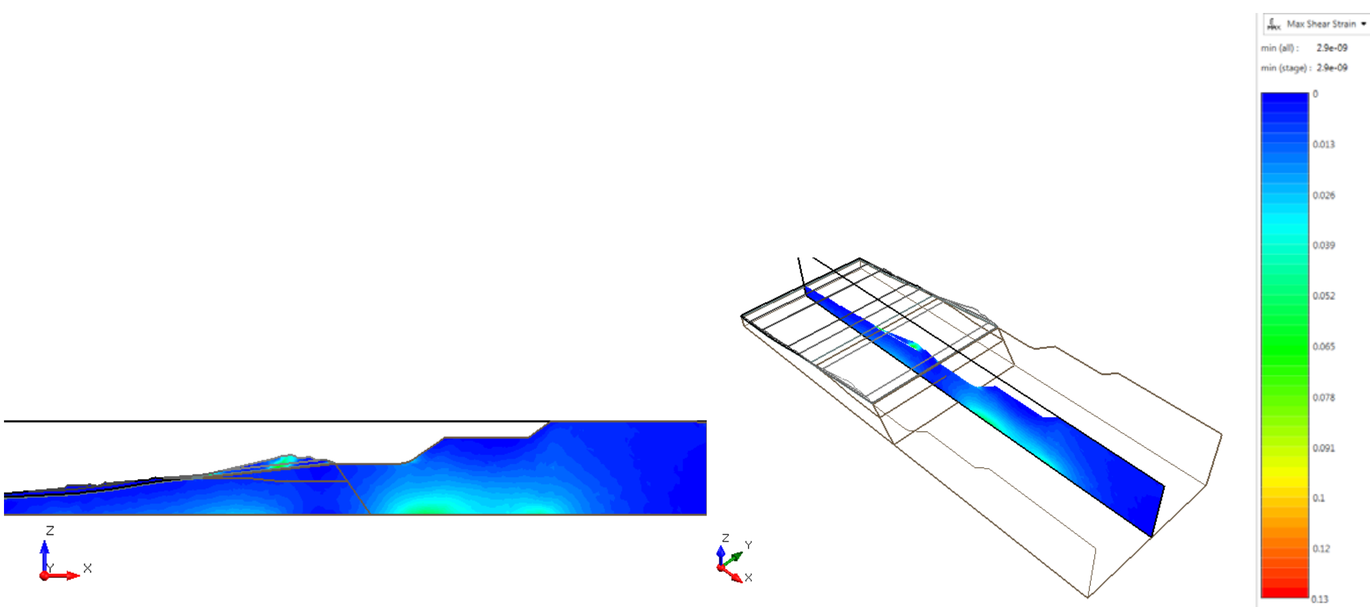


Figure 39.4.10 – RS3 Maximum Shear Strain

2D extruded embankment, (5) materials, ellipsoidal SA

40.1 Introduction

This example is taken from Sachpazis (2013). The model is a 2D embankment that is extruded in the Y direction to obtain the slope in Slide3 and RS3. The model was first analyzed dry, then with a full reservoir, and finally with an empty reservoir. The last case was intended to model rapid drawdown conditions, as a rapid drawdown analysis was also done in Slide3, and is compared to the model of the rapid drawdown conditions proposed by Sachpazis. A transient analysis of the slope was also done in RS3, and will be compared to the rapid drawdown conditions in Slide3 and proposed by Sachpazis. This is the dry model.

40.2 Problem Description

The 2D geometry in the XZ plane can be found as Figure 40. The XZ profile will then be extruded 400m in the Y direction. The material properties can be found in Table 40.1. These are the properties that apply to a completely dry slope, as soon as water is introduced to the embankment the material properties change. The ellipsoidal slip surface and corresponding safety factor is required.

40.3 Geometry and Properties

Table 40.1: Material Properties

	c´ (psf)	φ´ (deg.)	γ (pcf)
Embankment Fill	40	25	18
Clay Core	125	0	19
Firm Silty Clay	50	0	17
Stiff Sandy Clay	80	15	20
Impervious Bedrock	200	35	24

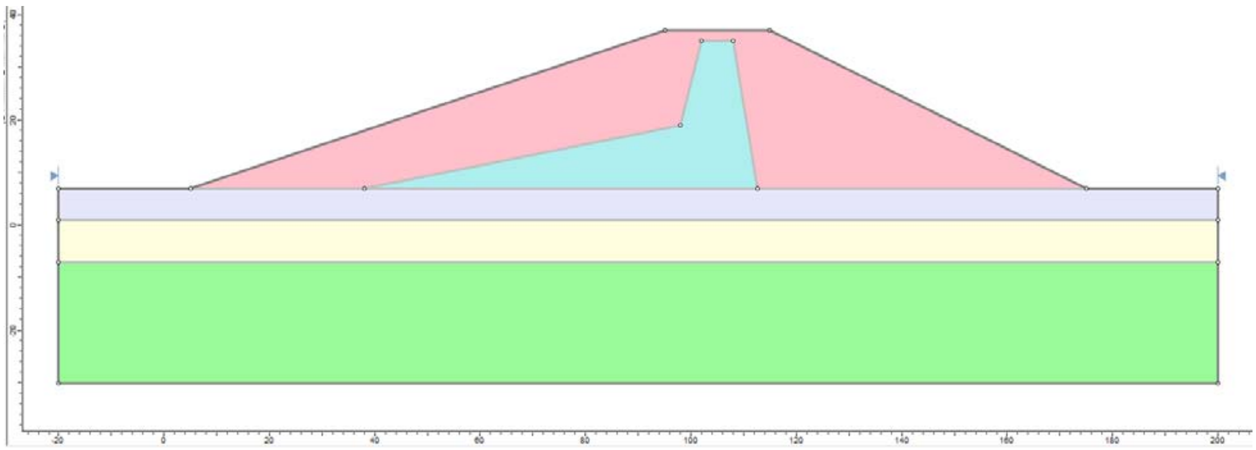


Figure 40

40.4 Results

Table 40.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

<table>
<tr><td>Method</td><td>Slide3</td><td>Slide 7.0</td><td>RS3</td><td>RS2</td></tr>
<tr><td>Bishop</td><td>0.952</td><td>0.817</td><td rowspan="4">1.01</td><td rowspan="4">0.91</td></tr>
<tr><td>GLE</td><td>0.99</td><td>0.836</td></tr>
<tr><td>Janbu</td><td>0.947</td><td>0.802</td></tr>
<tr><td>Spencer</td><td>0.984</td><td>0.839</td></tr>
</table>

Referee: 0.96 – 2D [Sachpazis, 2013]

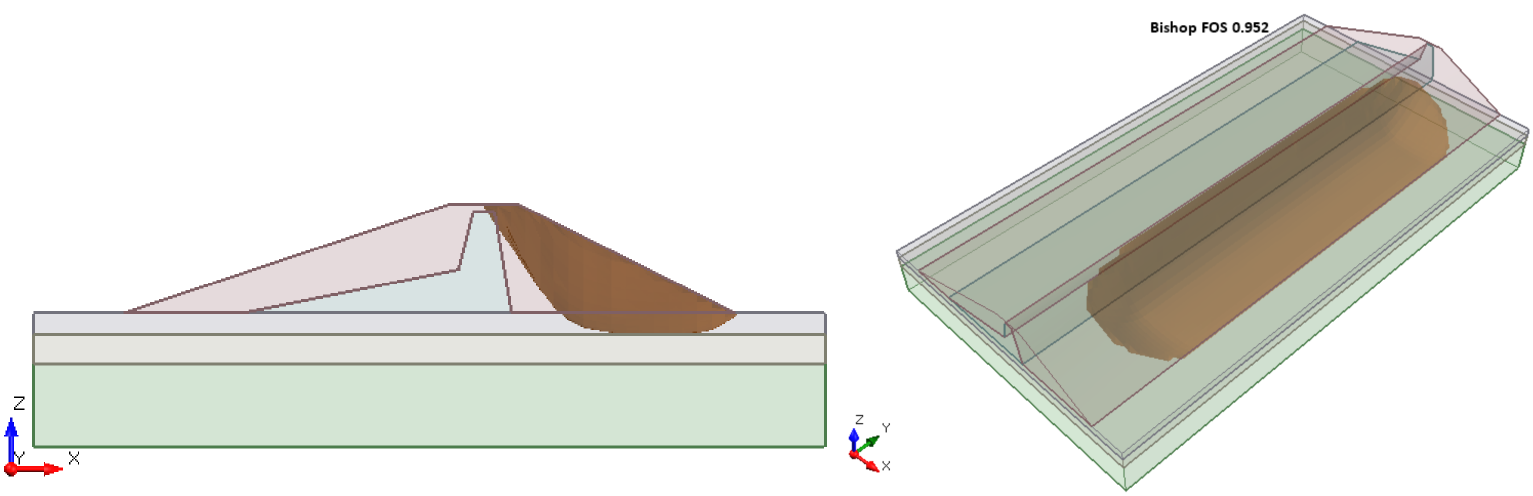


Figure 40.4.1 – Slide3 Solution Using the Bishop Method

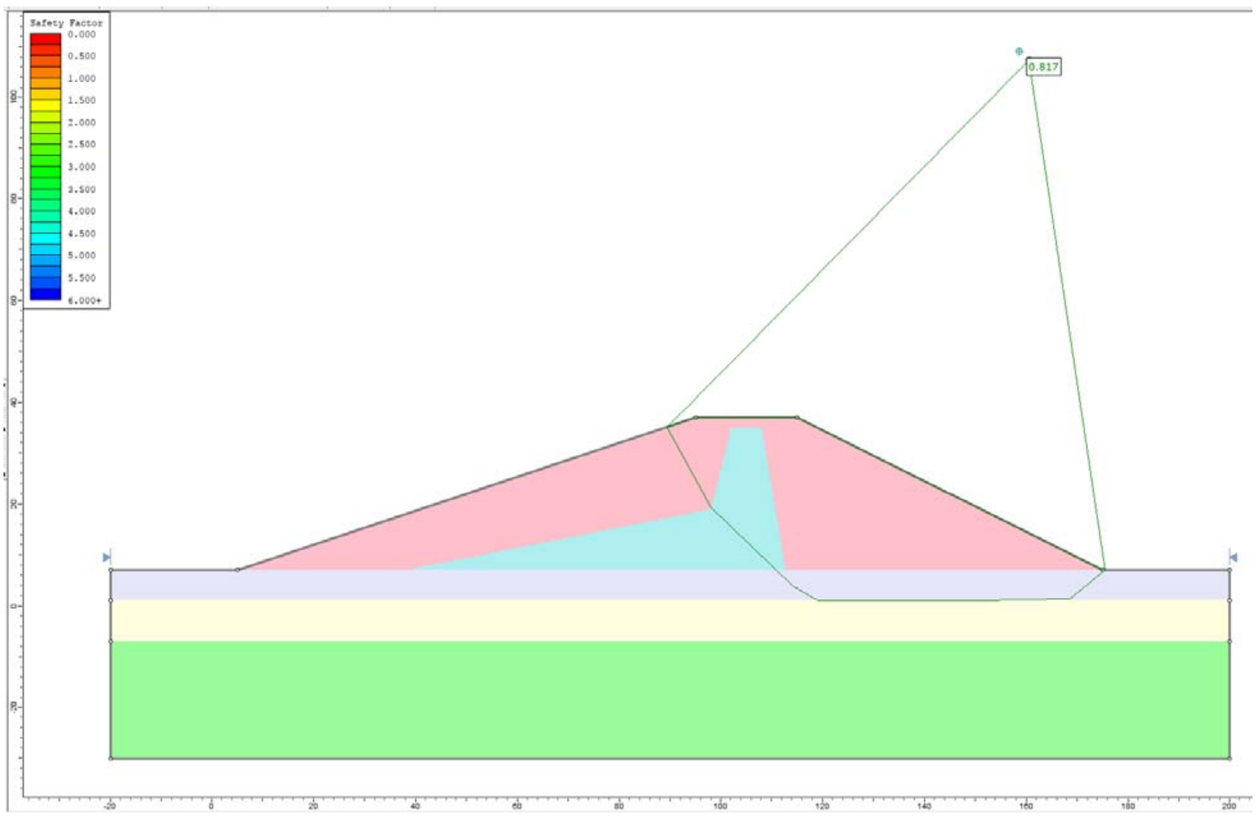


Figure 40.4.2 – Slide Solution Using the Bishop Method

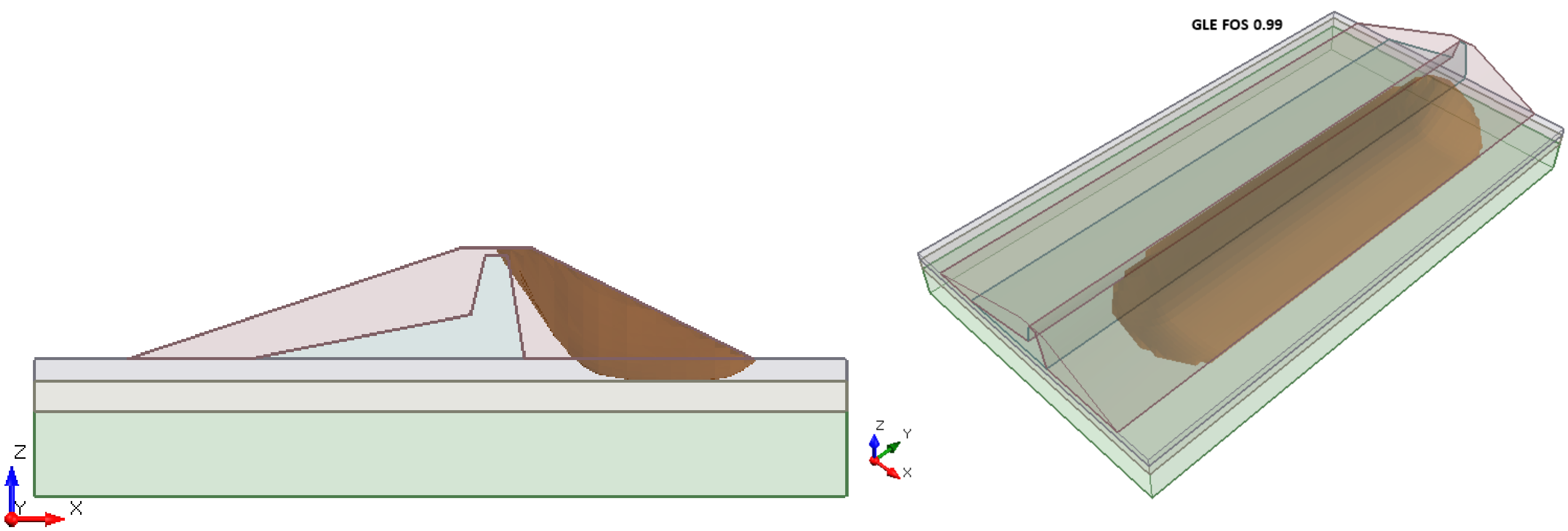


Figure 40.4.3 – Slide3 Solution using the GLE Method

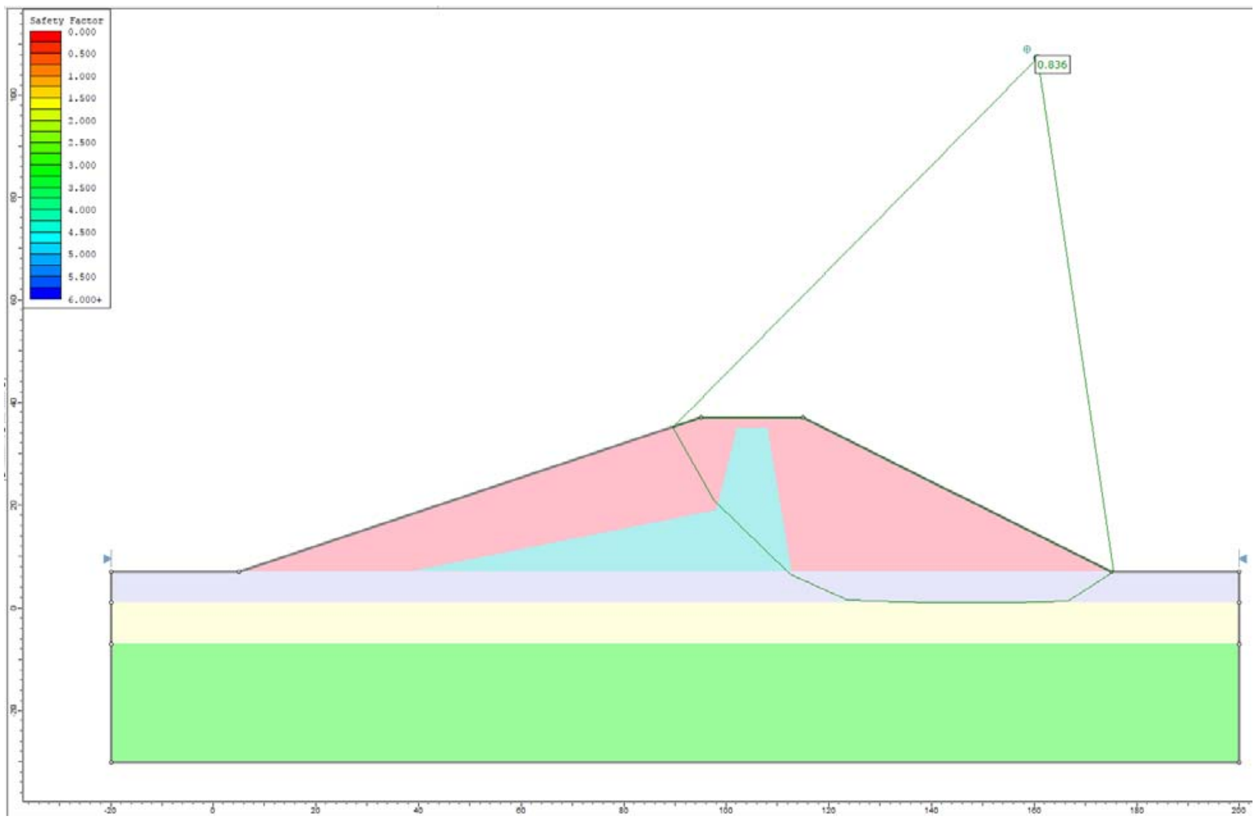


Figure 40.4.4 – Slide Solution Using the GLE Method

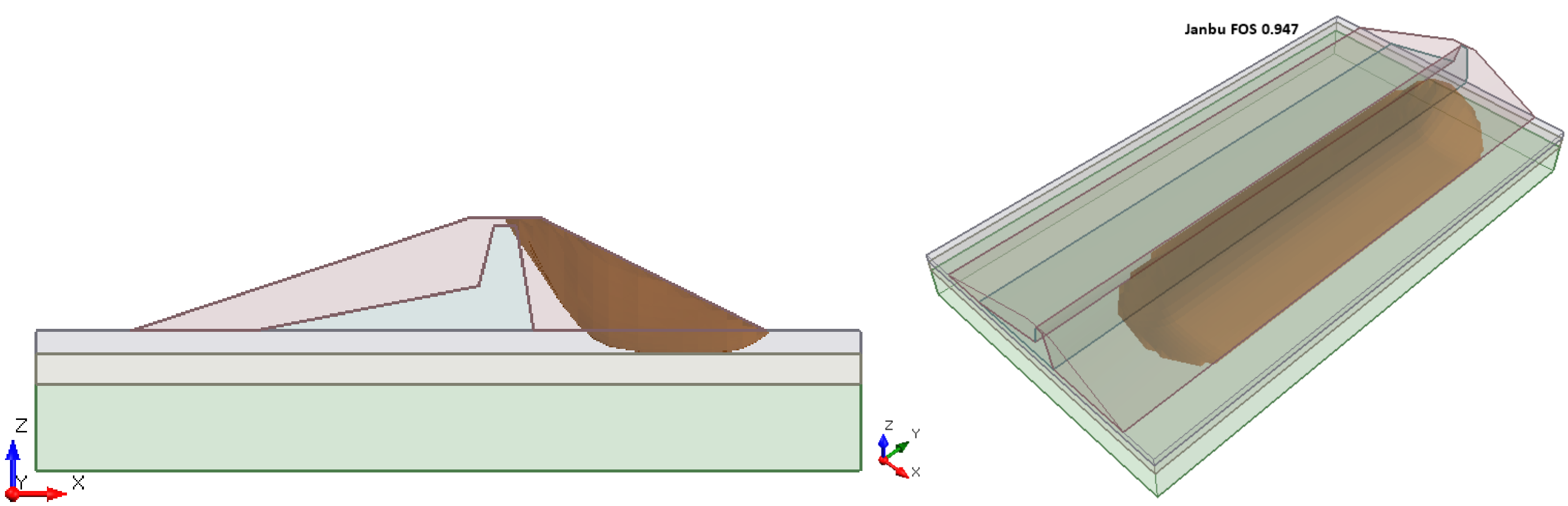


Figure 40.4.5 – Slide3 Solution Using the Janbu Method

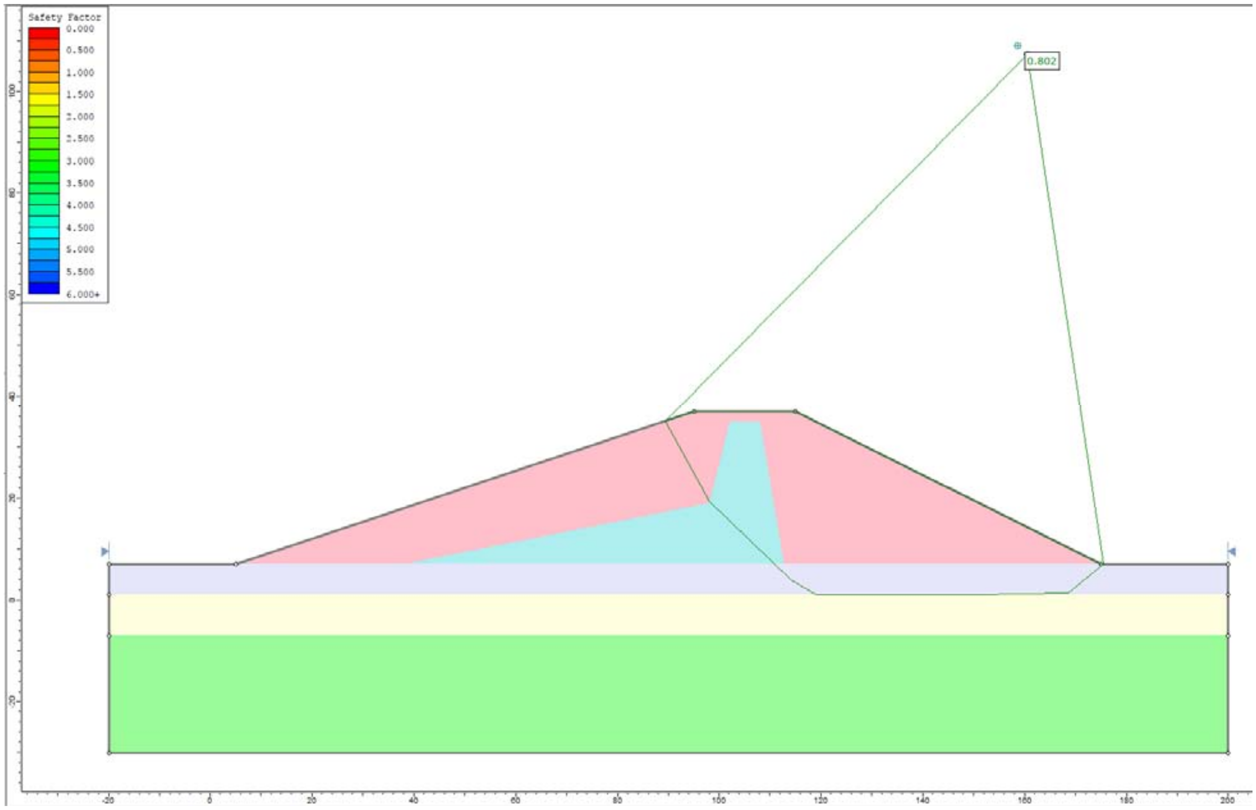


Figure 40.4.6 – Slide Solution using the Janbu Method

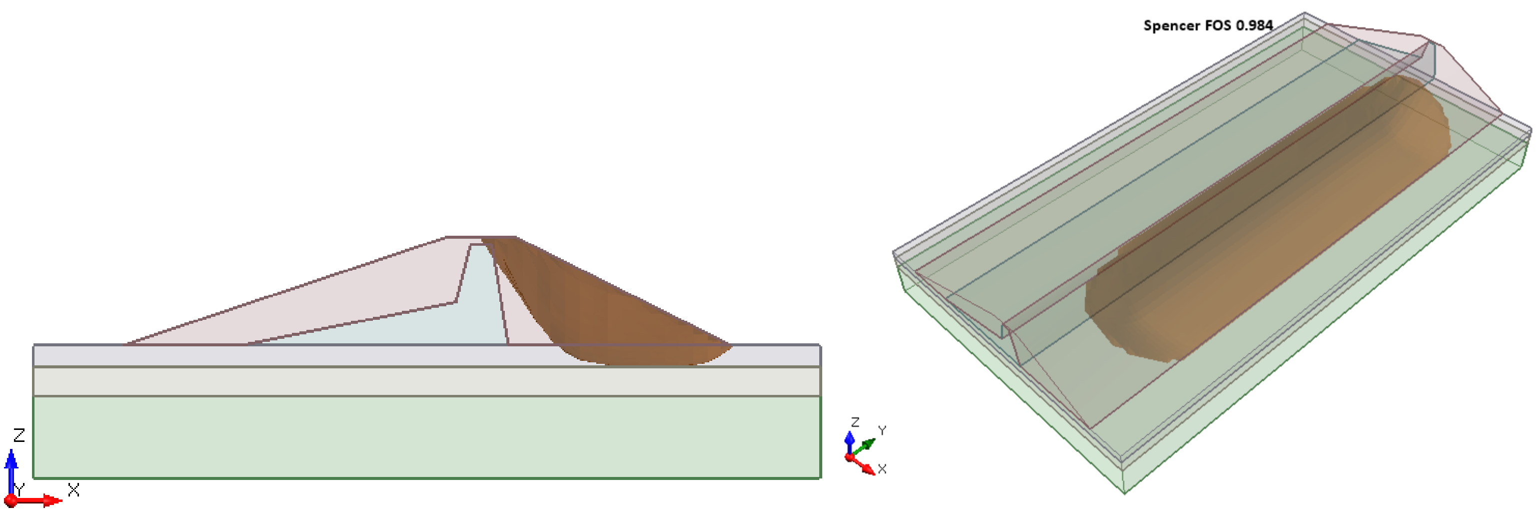


Figure 40.4.7 – Slide3 Solution using the Spencer Method

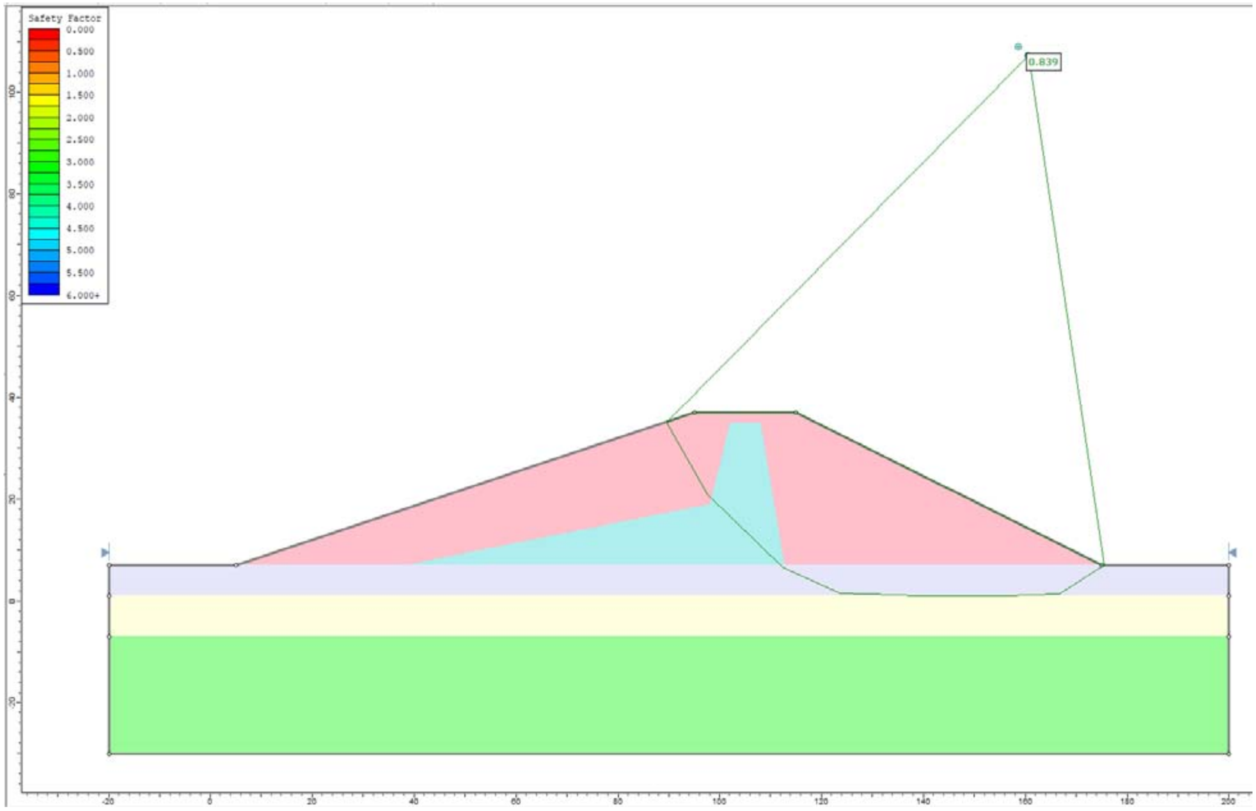


Figure 40.4.8 – Slide Solution Using the Spencer Method

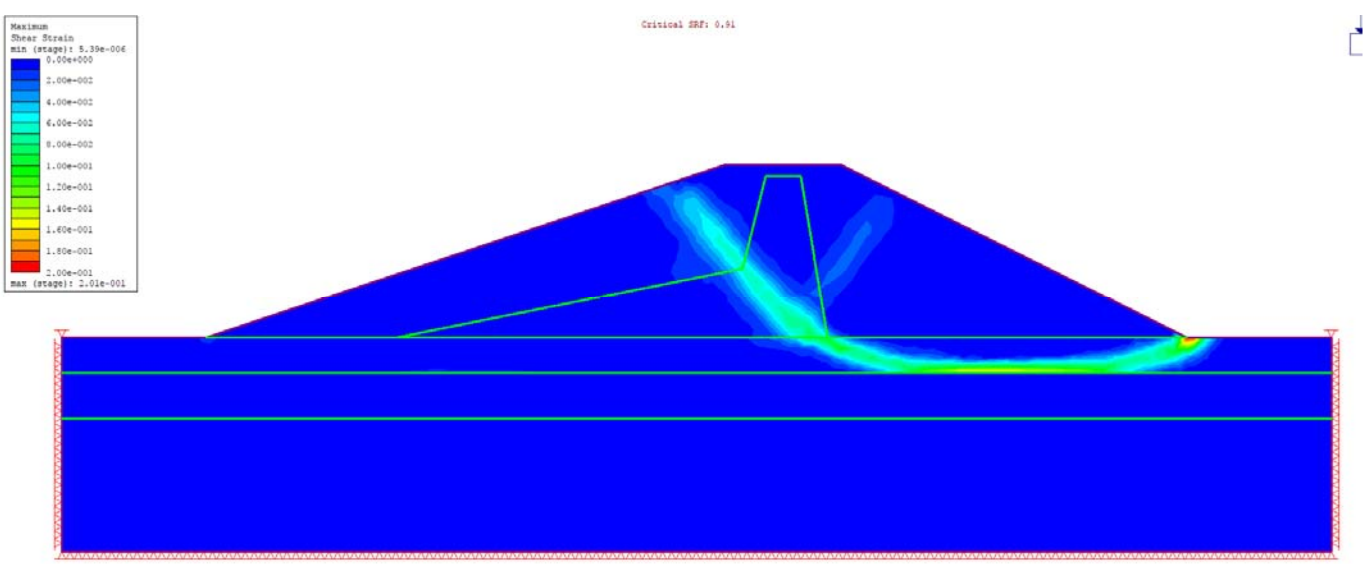


Figure 40.4.9 – RS2 Maximum Shear Strain

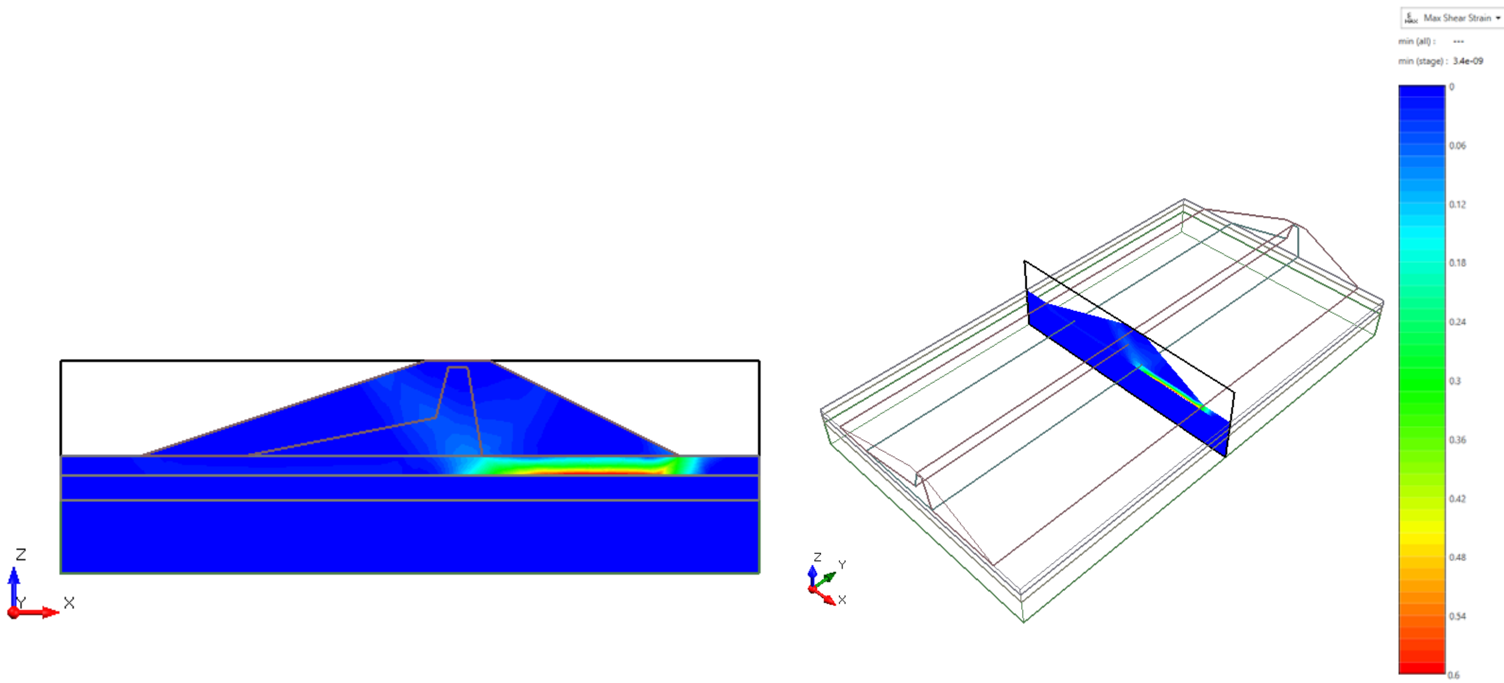


Figure 40.4.10 – RS3 Maximum Shear Strain

2D extruded embankment, (5) materials, full reservoir, ellipsoidal SA

41.1 Introduction

This example is taken from Sachpazis (2013). The model is a 2D embankment that is extruded in the Y direction to obtain the slope in Slide3 and RS3. The model was first analyzed dry, then with a full reservoir, and finally with an empty reservoir. The last case was intended to model rapid drawdown conditions, as a rapid drawdown analysis was also done in Slide3, and is compared to the model of the rapid drawdown conditions proposed by Sachpazis. A transient analysis of the slope was also done in RS3, and will be compared to the rapid drawdown conditions in Slide3 and proposed by Sachpazis. This is the model with a full reservoir.

41.2 Problem Description

The 2D geometry in the XZ plane can be found as Figure 41. The XZ profile will then be extruded 400m in the Y direction. The material properties can be found in Table 41.1. These are the properties that apply to a completely dry slope, as soon as water is introduced to the embankment the material properties change. The ellipsoidal slip surface and corresponding safety factor is required.

41.3 Geometry and Properties

Table 41.1: Material Properties

	c′ (psf)	φ′ (deg.)	γ (pcf)
Embankment Fill	20	24	18
Clay Core	15	4	19
Firm Silty Clay	35	10	17
Stiff Sandy Clay	60	30	20
Impervious Bedrock	200	35	24

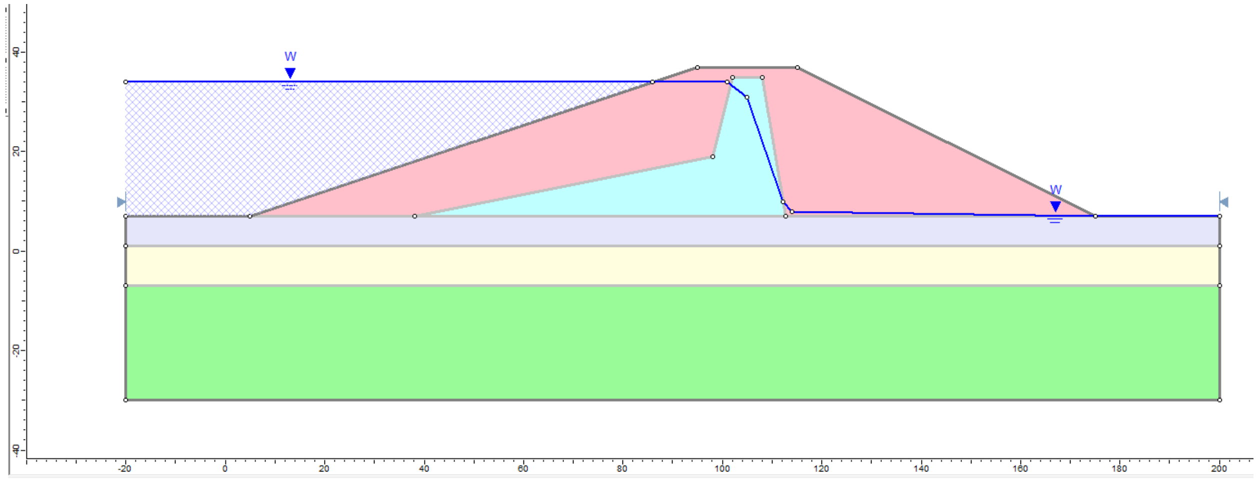


Figure 41

41.4 Results

Table 41.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

<table>
<tr><th>Method</th><th>Slide3</th><th>Slide 7.0</th><th>RS3</th><th>RS2</th></tr>
<tr><td>Bishop</td><td>0.798</td><td>0.752</td><td rowspan="4">0.92</td><td rowspan="4">0.85</td></tr>
<tr><td>GLE</td><td>0.904</td><td>0.824</td></tr>
<tr><td>Janbu</td><td>0.773</td><td>0.692</td></tr>
<tr><td>Spencer</td><td>0.921</td><td>0.831</td></tr>
</table>

Referee: 0.81 – 2D [Sachpazis, 2013]

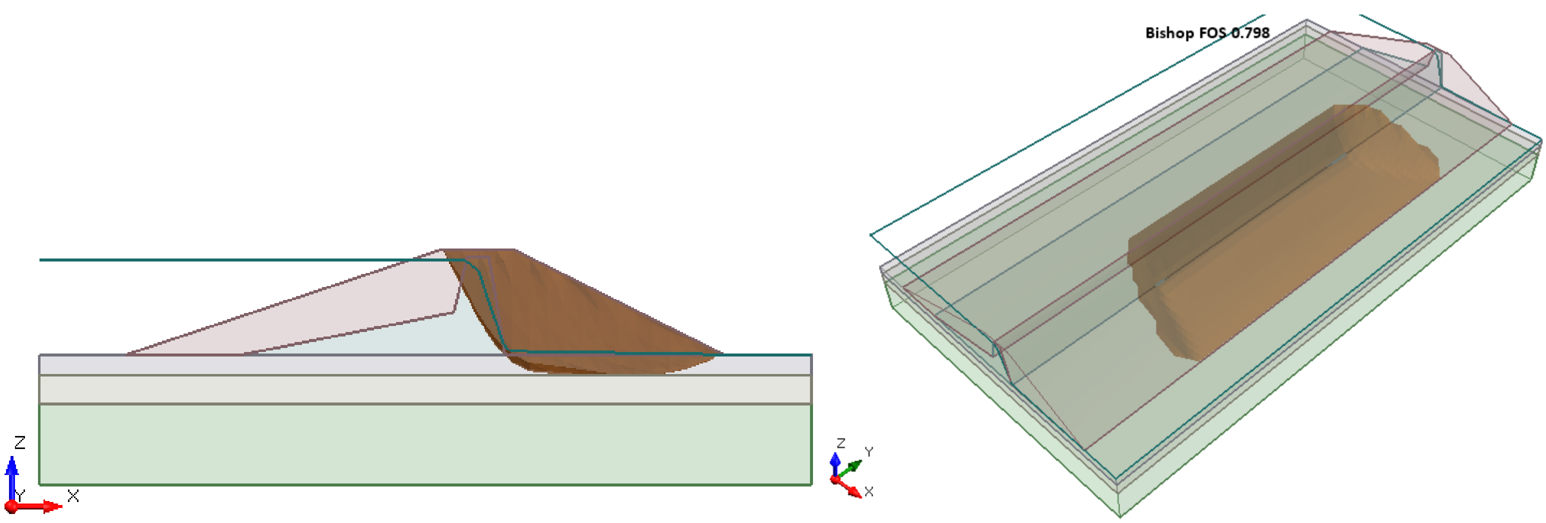


Figure 41.4.1 – Slide3 Solution Using the Bishop Method

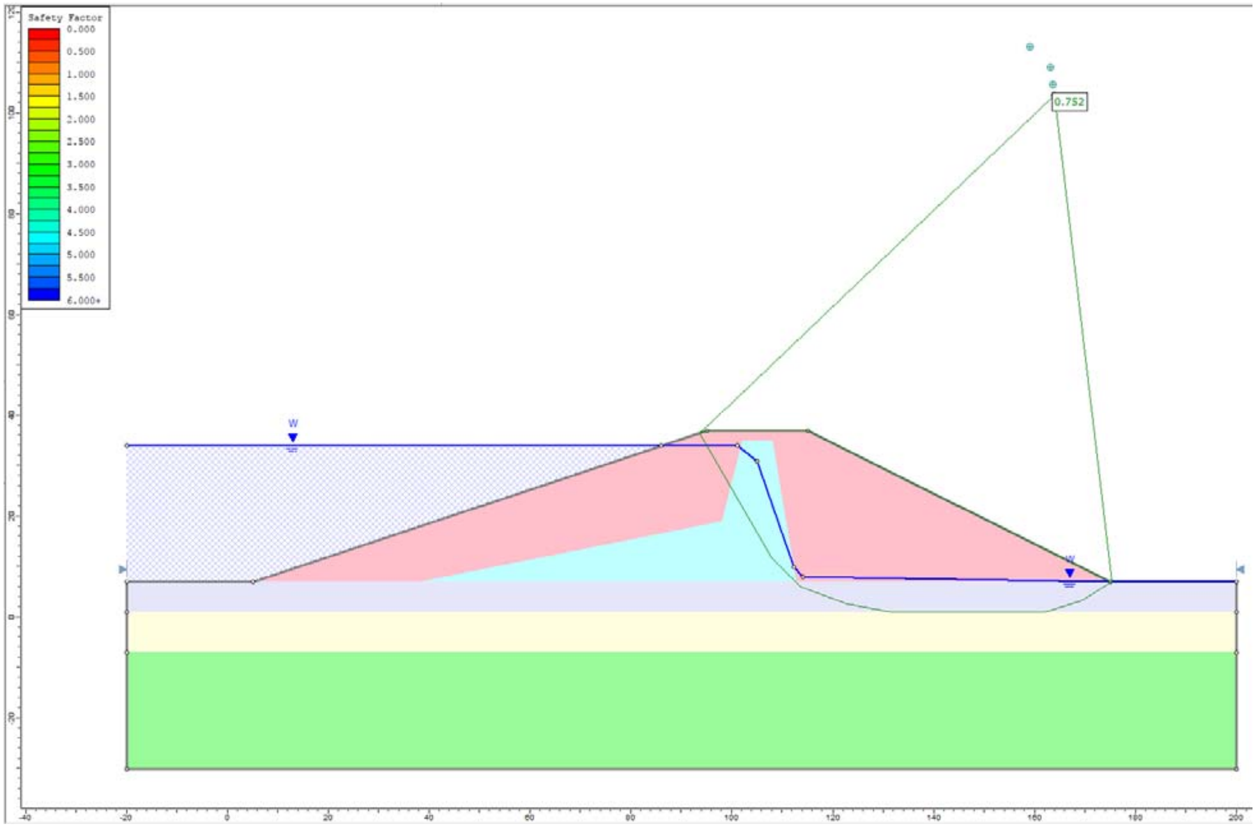


Figure 41.4.2 – Slide Solution Using the Bishop Method

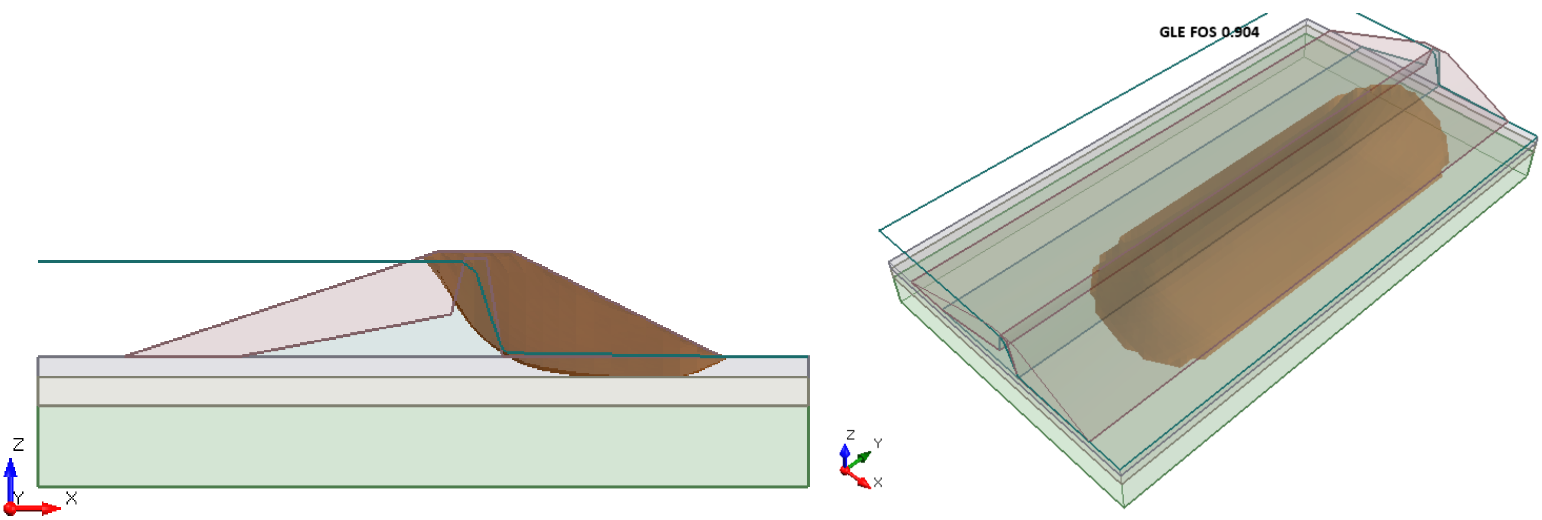


Figure 41.4.3 – Slide3 Solution using the GLE Method

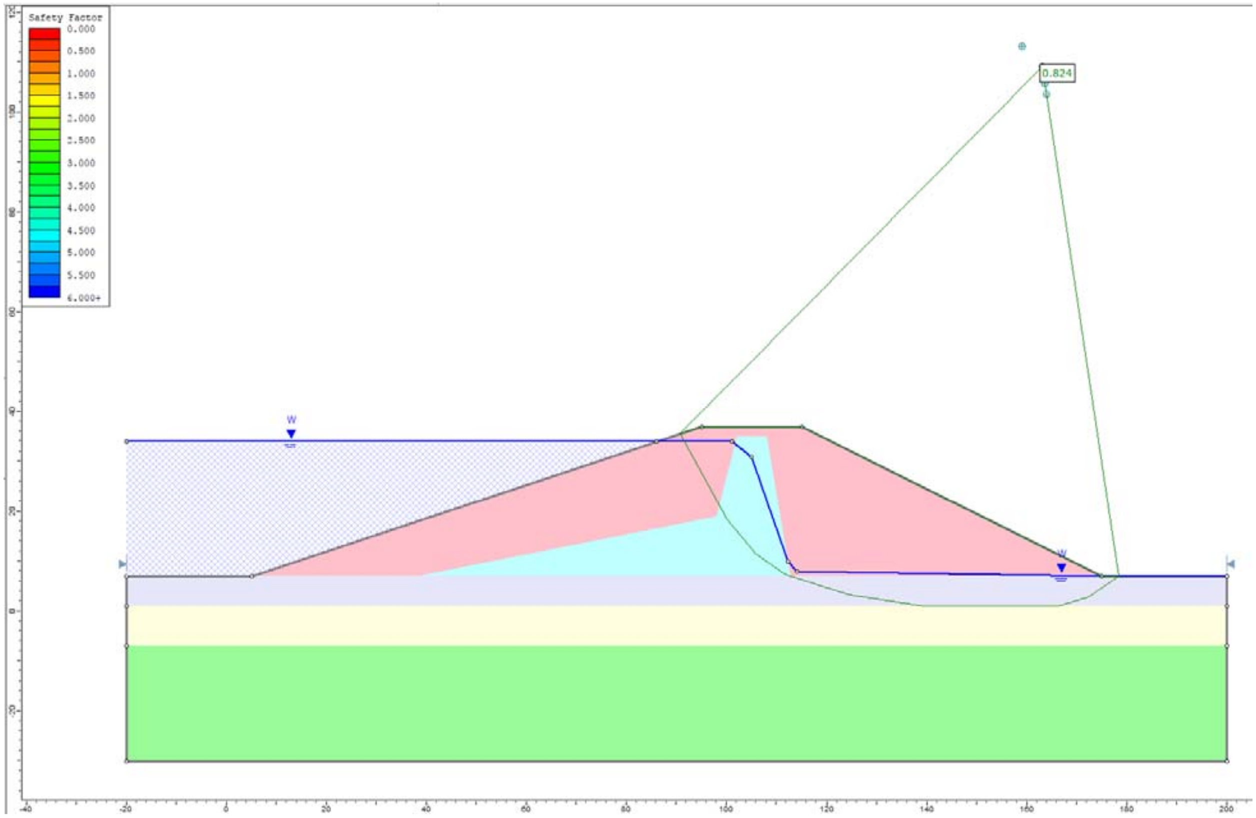


Figure 41.4.4 – Slide Solution Using the GLE Method

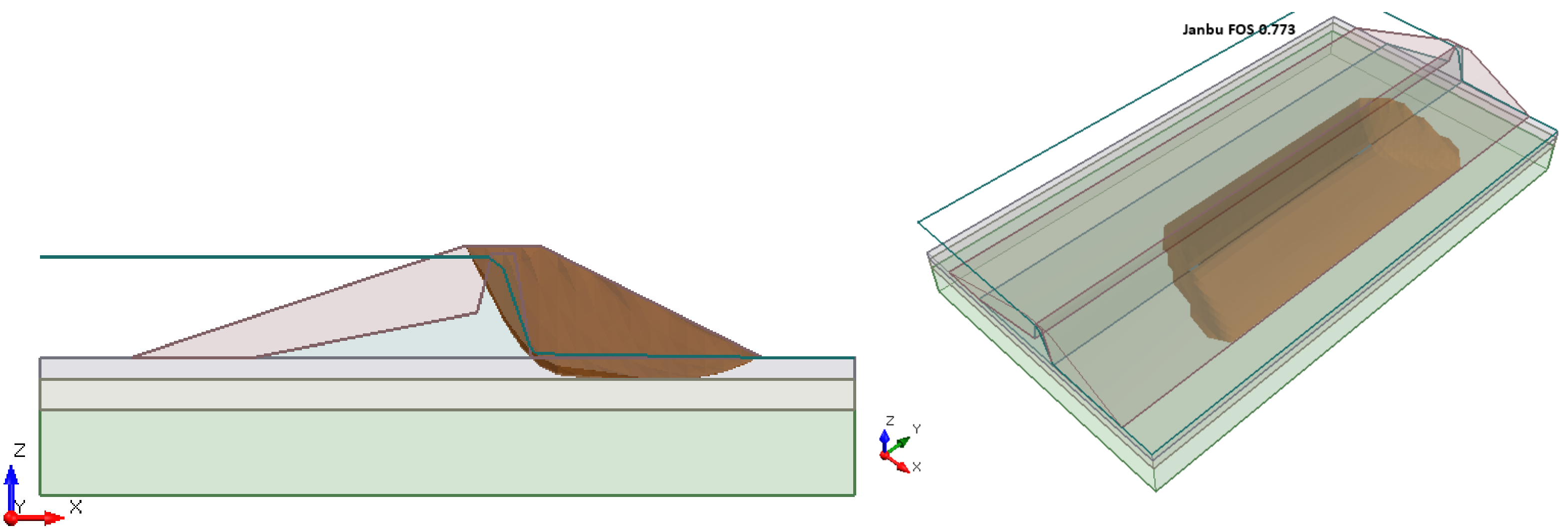


Figure 41.4.5 – Slide3 Solution Using the Janbu Method

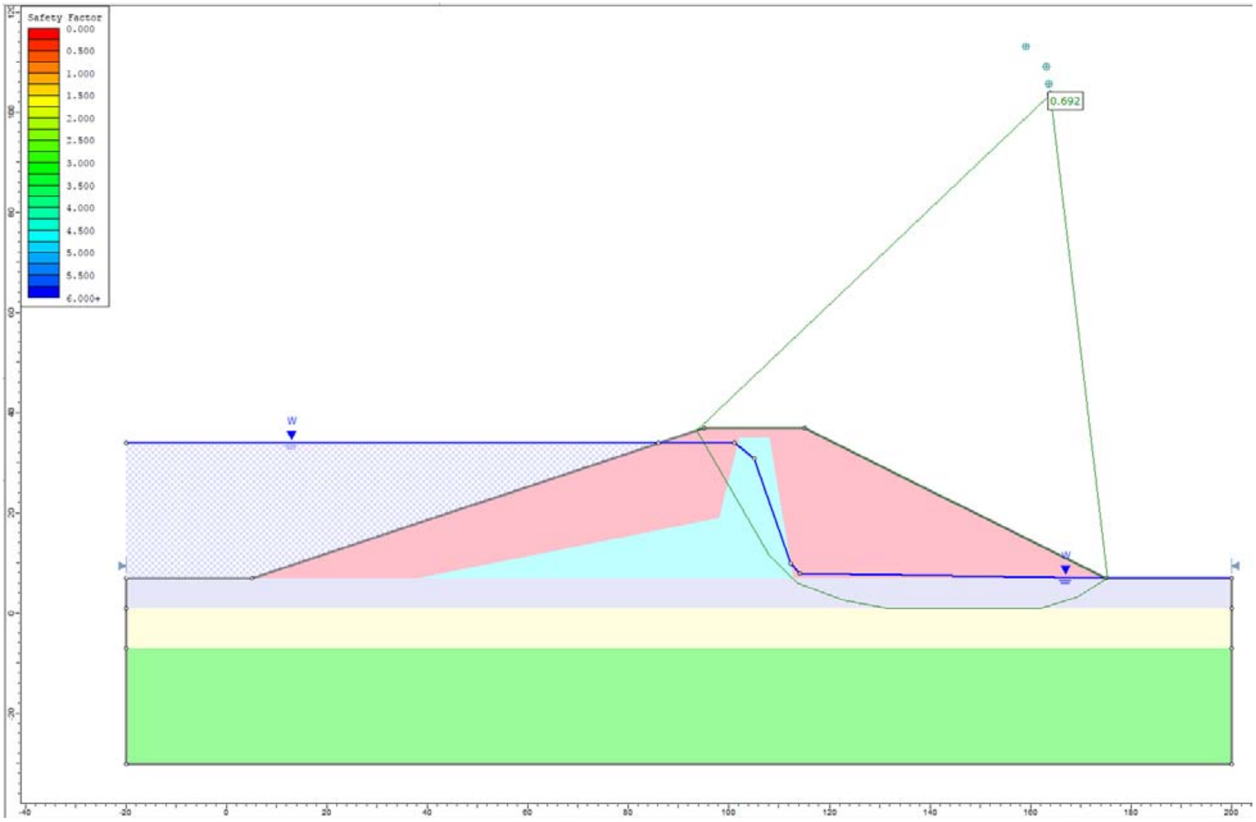


Figure 41.4.6 – Slide Solution using the Janbu Method

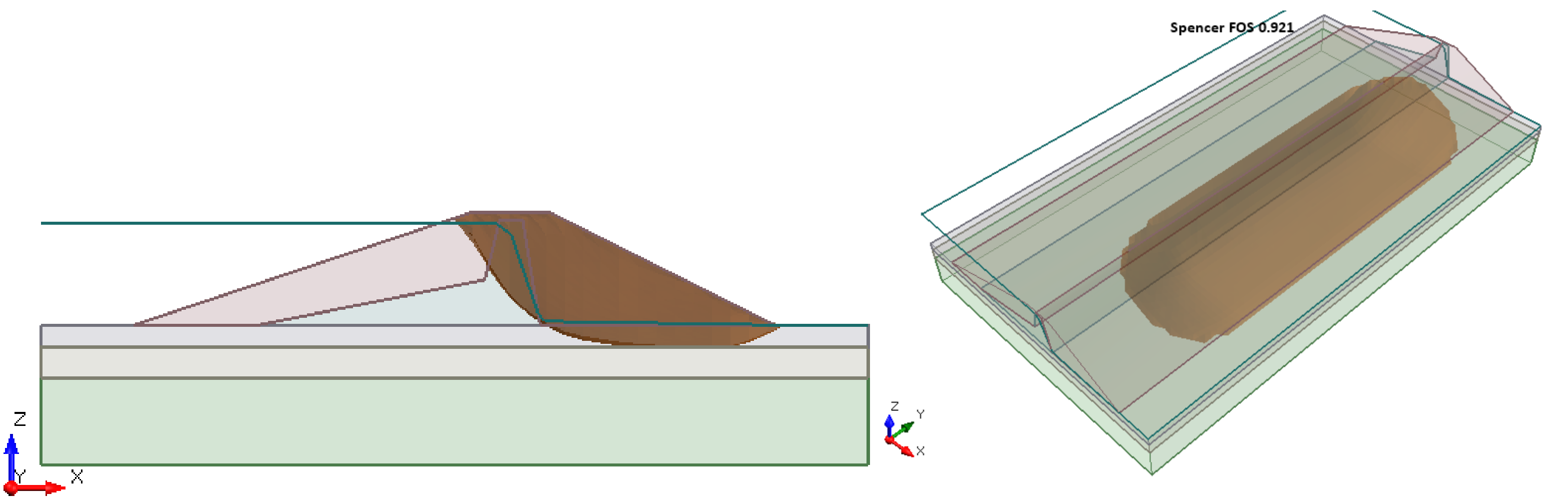


Figure 41.4.7 – Slide3 Solution using the Spencer Method

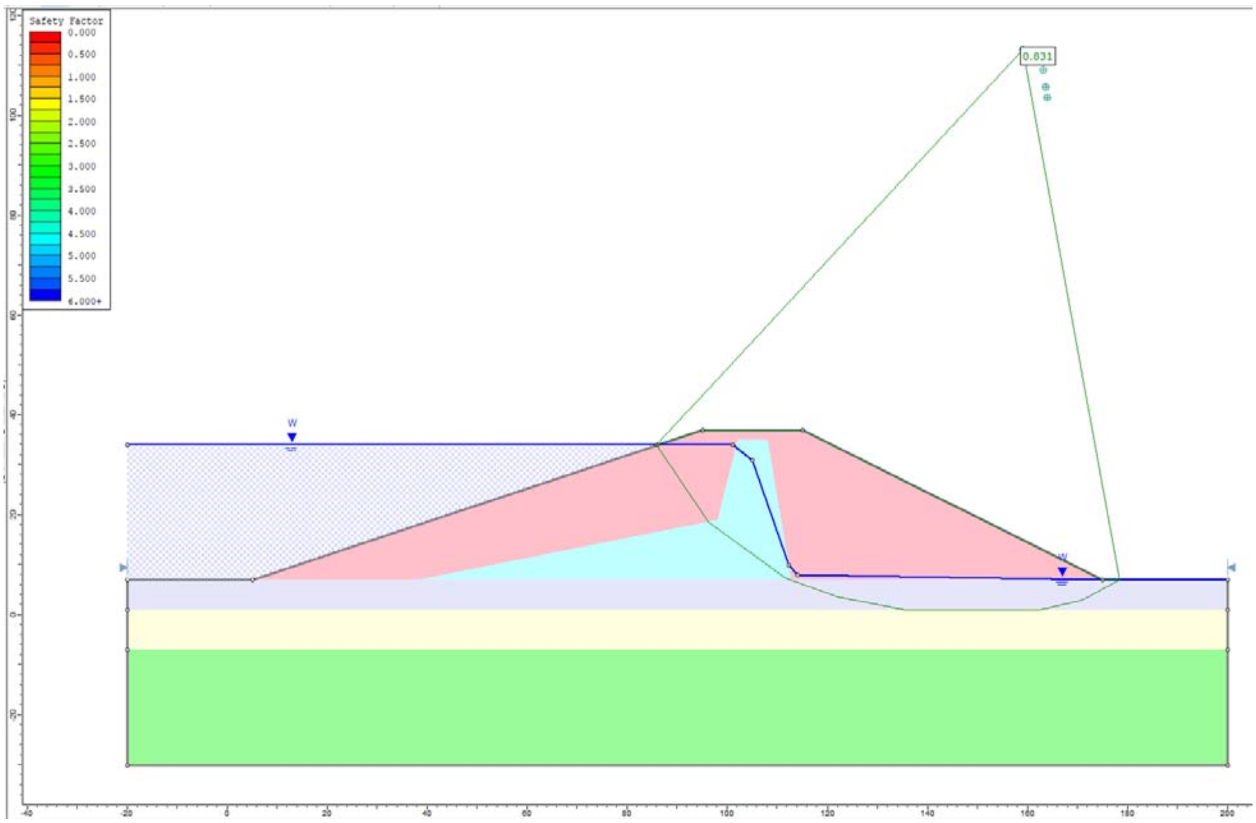


Figure 41.4.8 – Slide Solution Using the Spencer Method

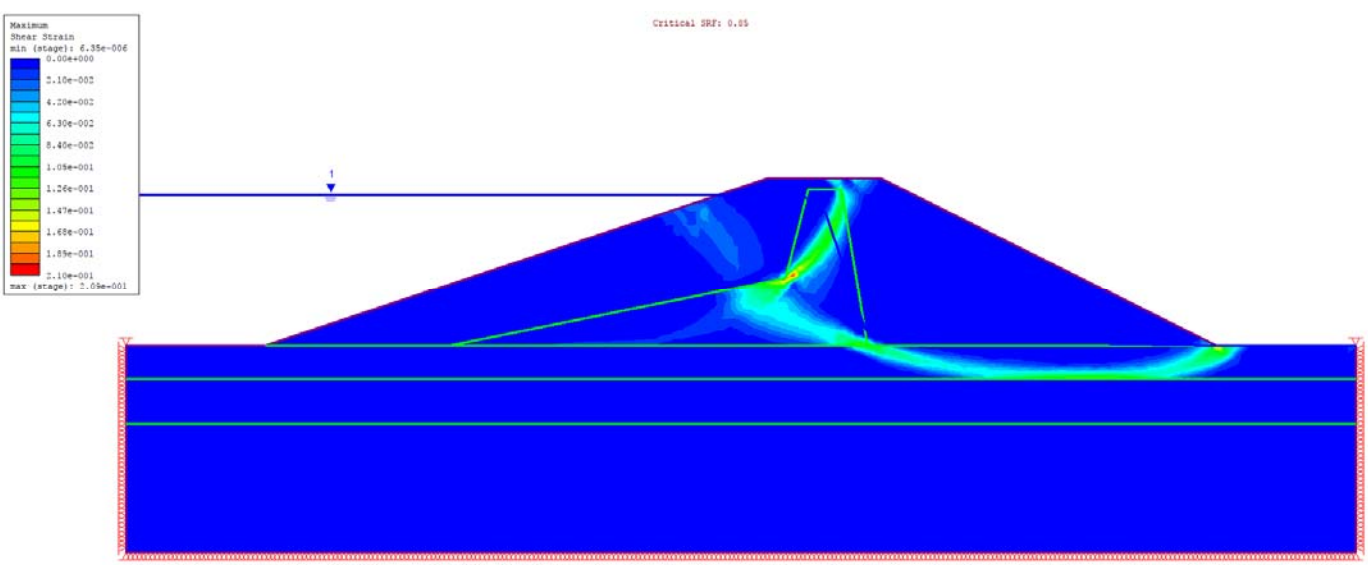


Figure 41.4.9 – RS2 Maximum Shear Strain

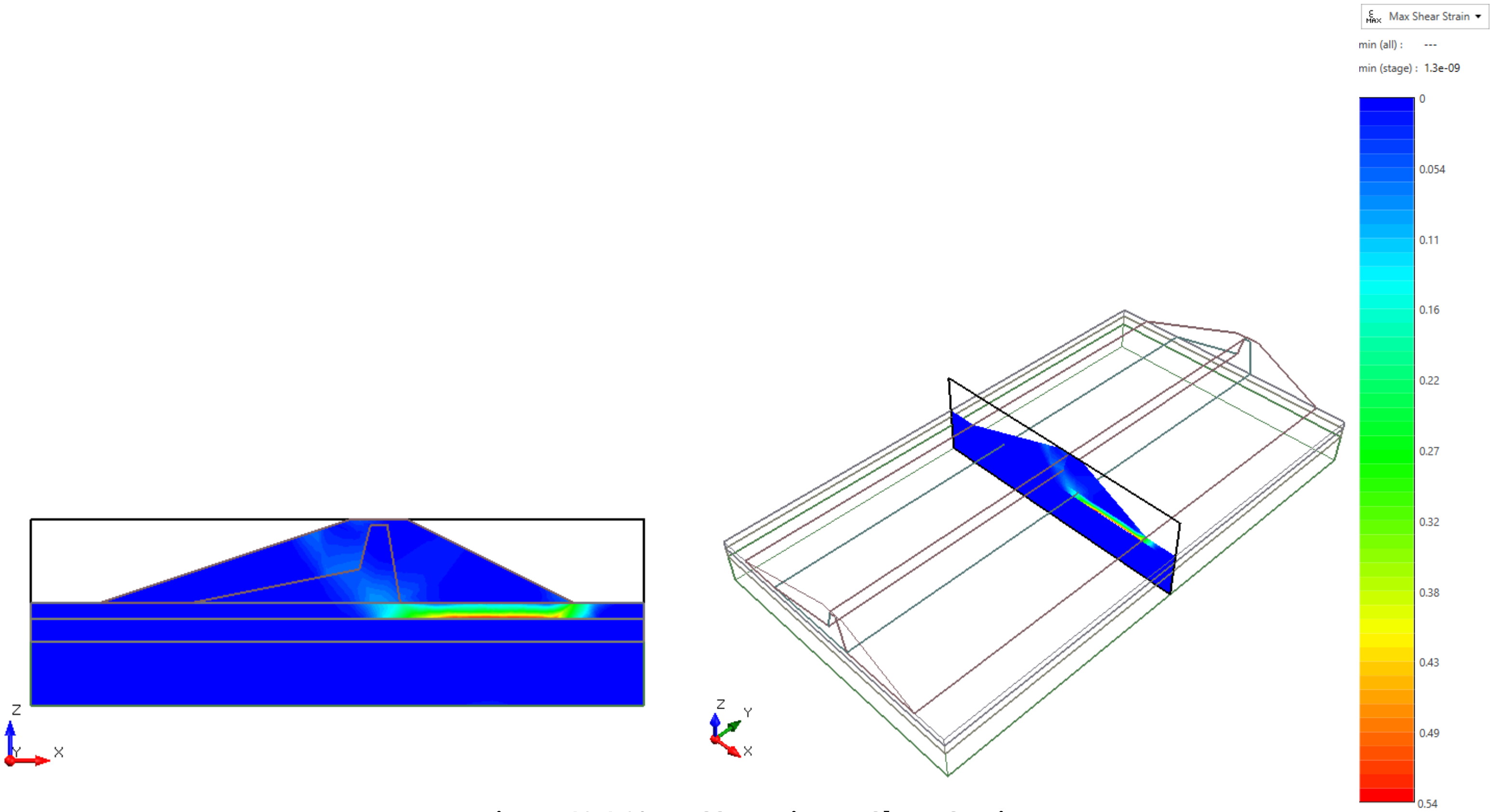


Figure 41.4.10 – RS3 Maximum Shear Strain

2D extruded embankment, (5) materials, empty reservoir, rapid drawdown, transient, ellipsoidal SA

42.1 Introduction

This example is taken from Sachpazis (2013). The model is a 2D embankment that is extruded in the Y direction to obtain the slope in Slide3 and RS3. The model was first analyzed dry, then with a full reservoir, and finally with an empty reservoir. The last case was intended to model rapid drawdown conditions, as a rapid drawdown analysis was also done in Slide3, and is compared to the model of the rapid drawdown conditions proposed by Sachpazis. A transient analysis of the slope was also done in RS3, and will be compared to the rapid drawdown conditions in Slide3 and proposed by Sachpazis. This is the model with an empty reservoir. This example was meant to measure rapid drawdown, so the Slide3 rapid drawdown model and the RS3 transient analysis will also be included in this example.

42.2 Problem Description

The 2D geometry in the XZ plane can be found as Figure 42. The XZ profile will then be extruded 400m in the Y direction. The material properties can be found in Table 42.1. These are the properties that apply to a completely dry slope, as soon as water is introduced to the embankment the material properties change. The ellipsoidal slip surface and corresponding safety factor is required.

42.3 Geometry and Properties

Table 42.1: Material Properties

	c′ (psf)	φ′ (deg.)	γ (pcf)
Embankment Fill	20	24	18
Clay Core	15	4	19
Firm Silty Clay	35	10	17
Stiff Sandy Clay	60	30	20
Impervious Bedrock	200	35	24

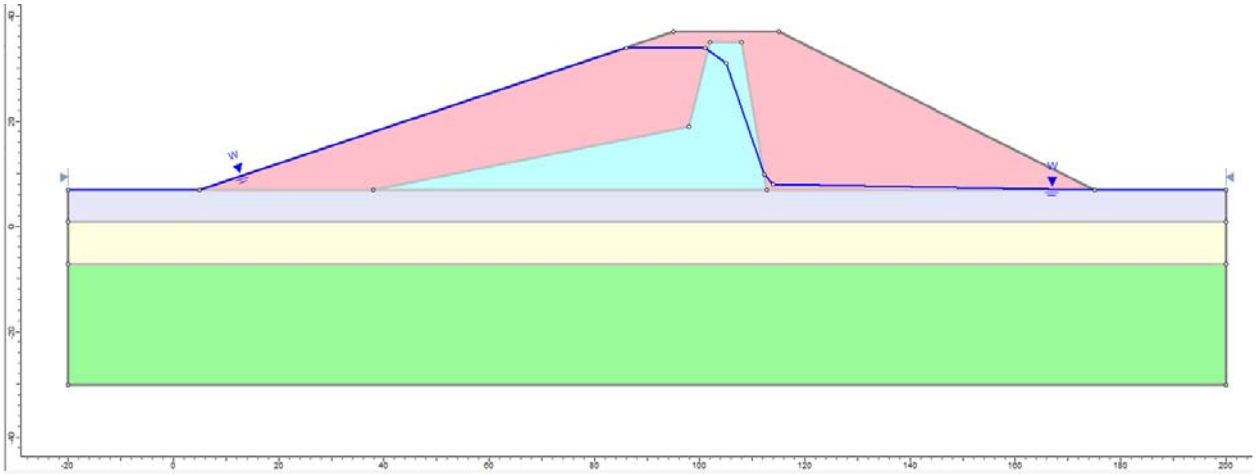


Figure 42

42.4 Results

Table 42.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	0.524	0.493	0.65	0.55
GLE	0.544	0.514		
Janbu	0.516	0.468		
Spencer	0.591	0.528		

Referee: 0.50 – 2D [Sachpazis, 2013]

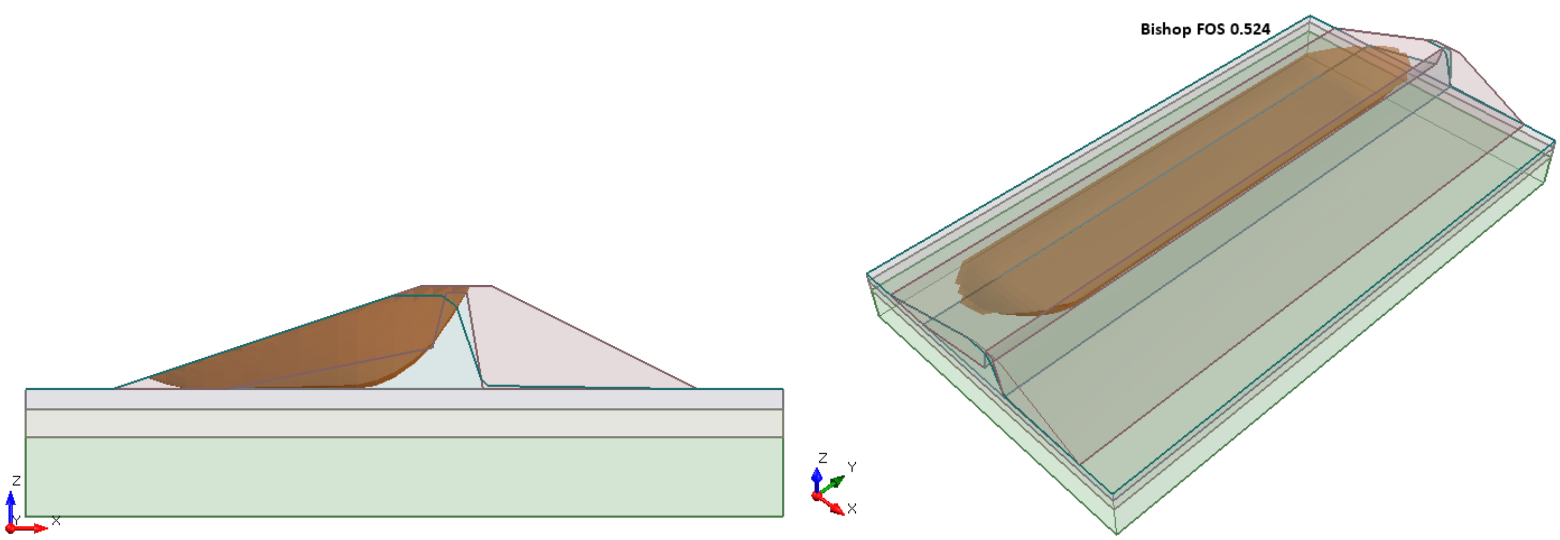


Figure 42.4.1 – Slide3 Solution Using the Bishop Method

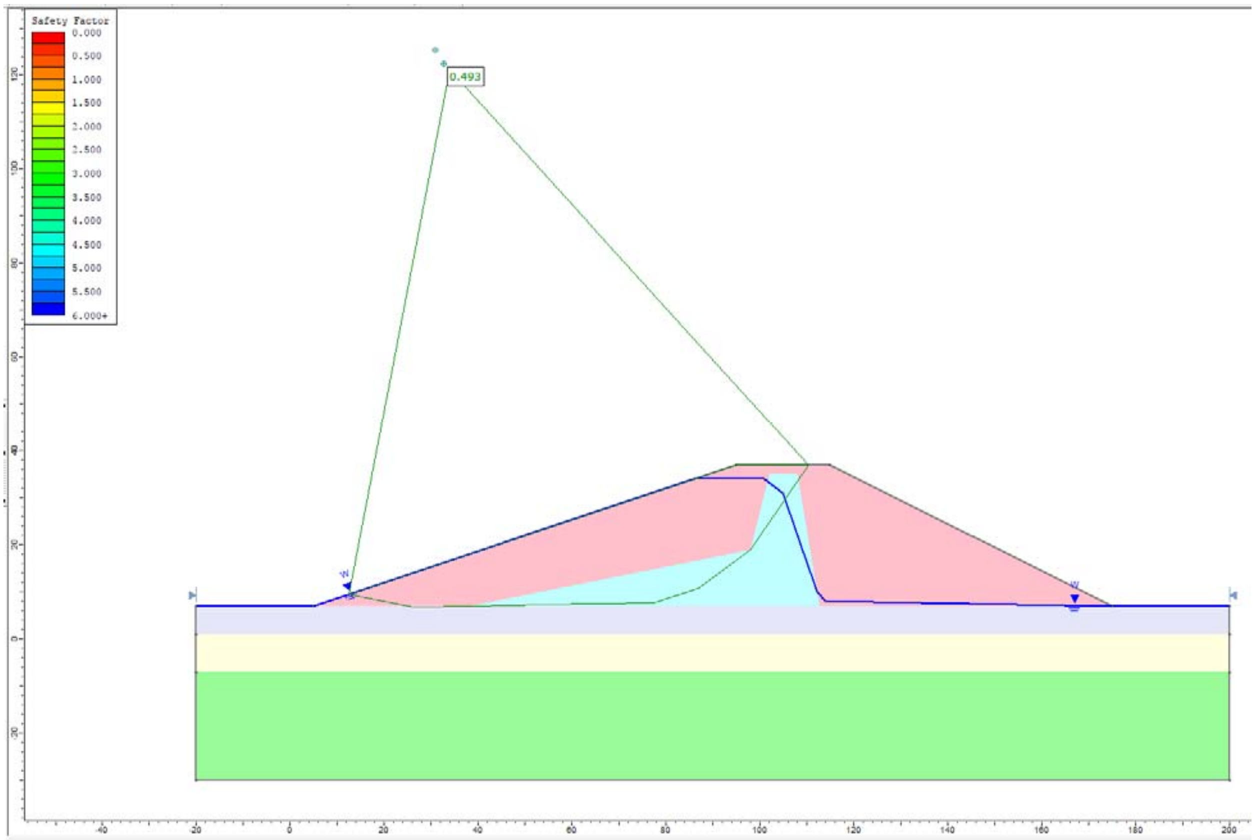


Figure 42.4.2 – Slide Solution Using the Bishop Method

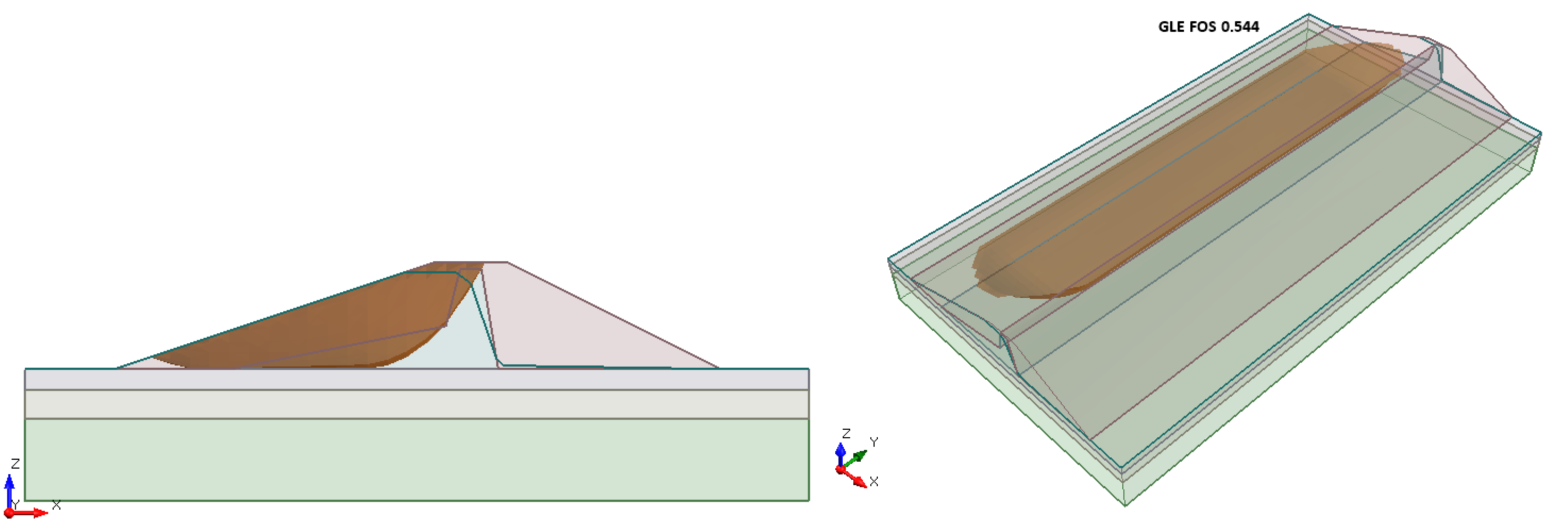


Figure 42.4.3 – Slide3 Solution using the GLE Method

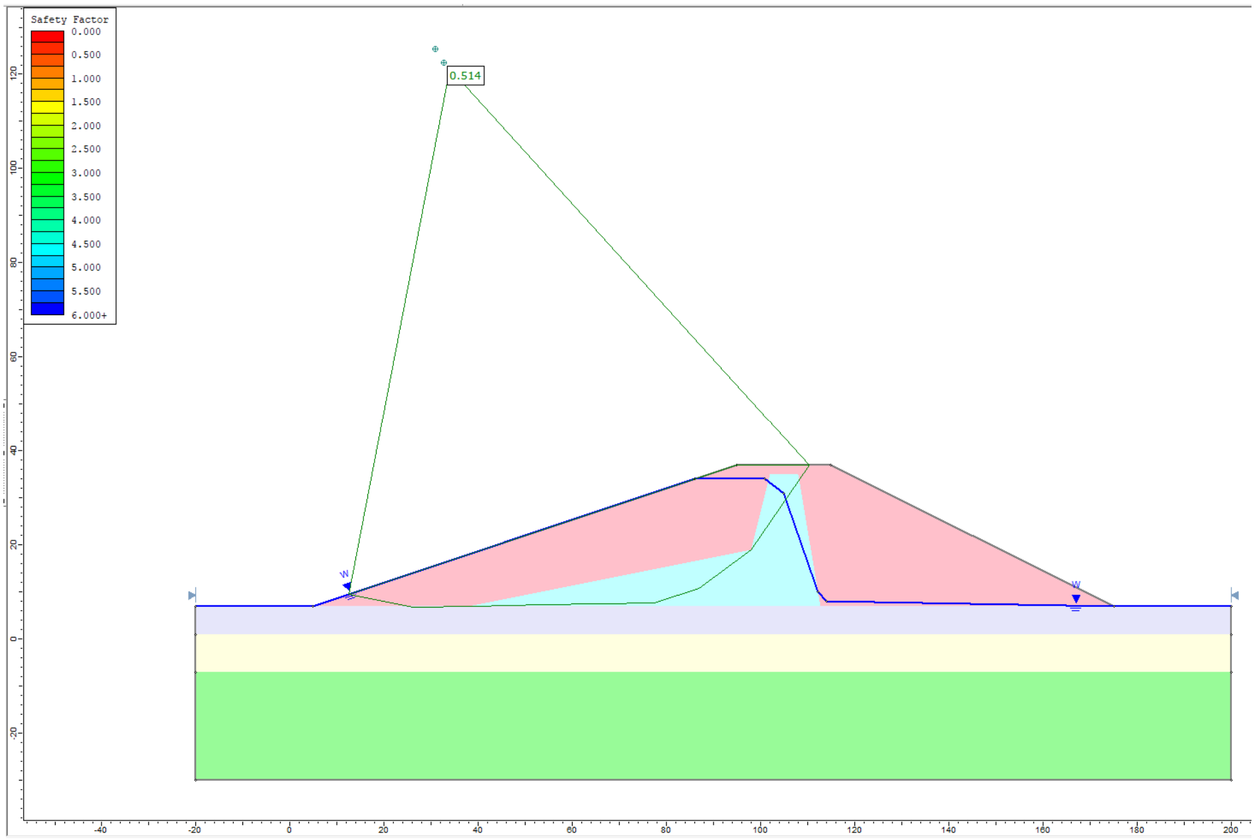


Figure 42.4.4 – Slide Solution Using the GLE Method

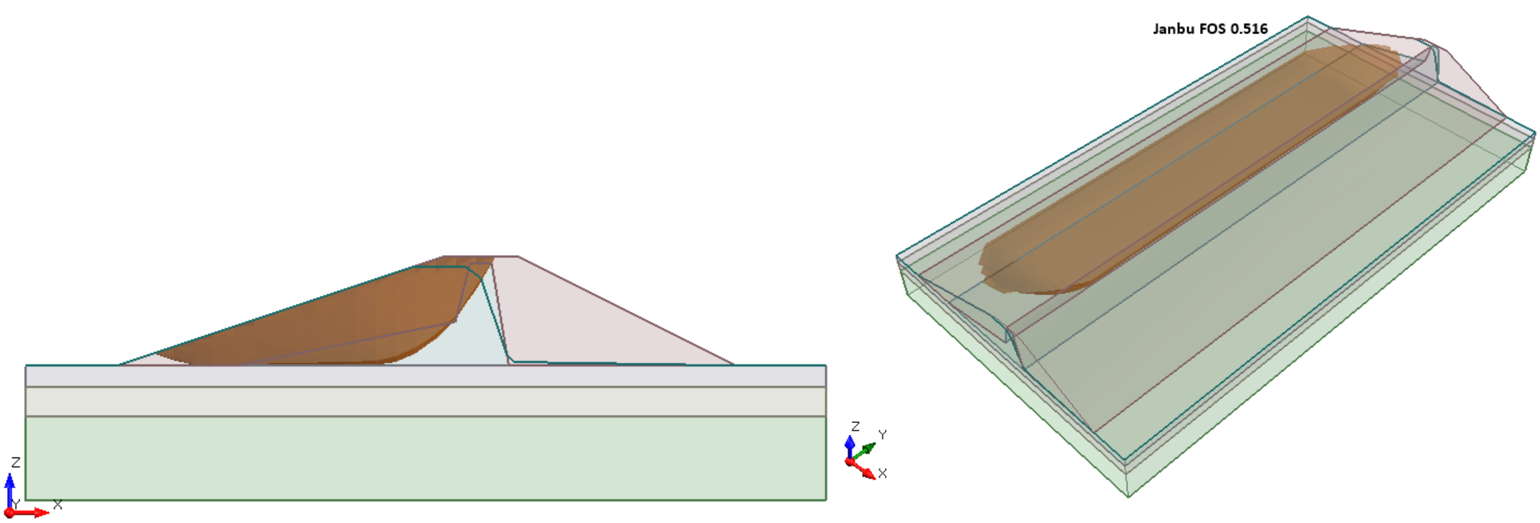


Figure 42.4.5 – Slide3 Solution Using the Janbu Method

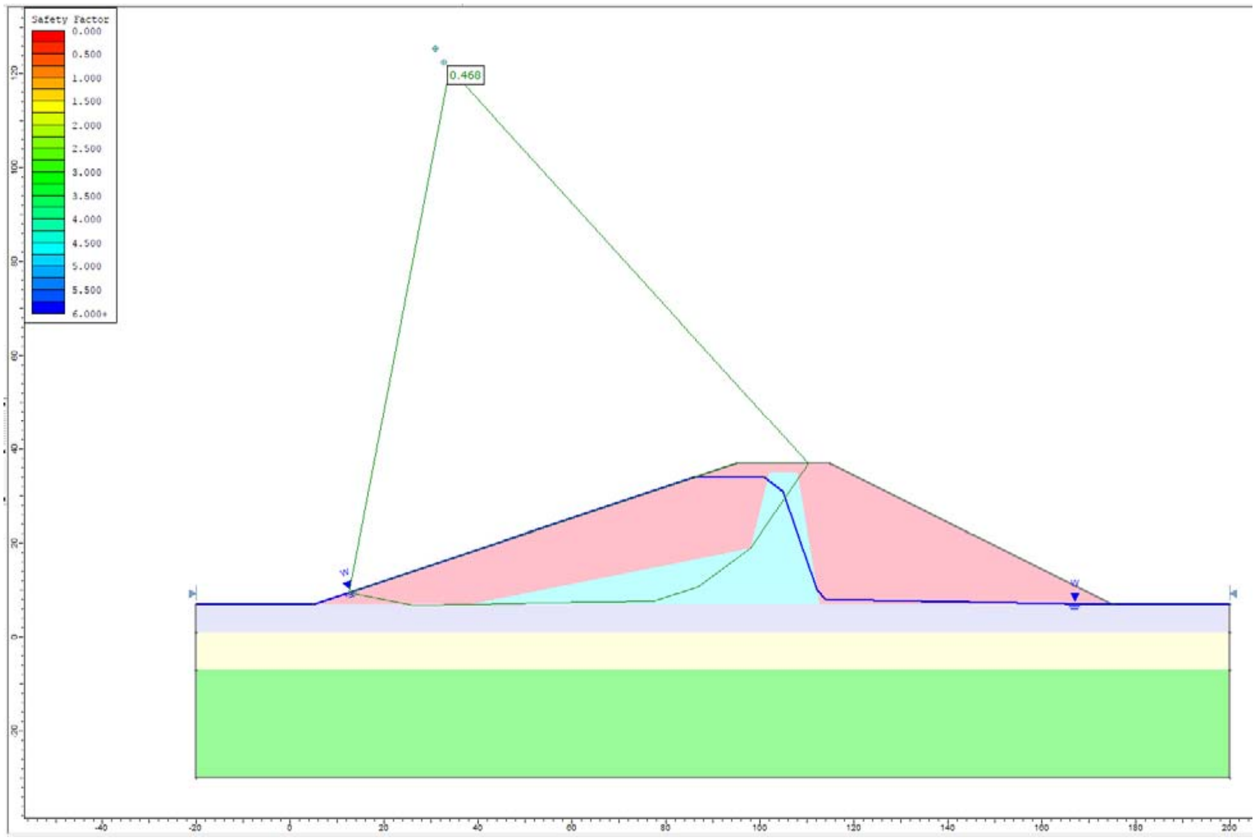


Figure 42.4.6 – Slide Solution using the Janbu Method

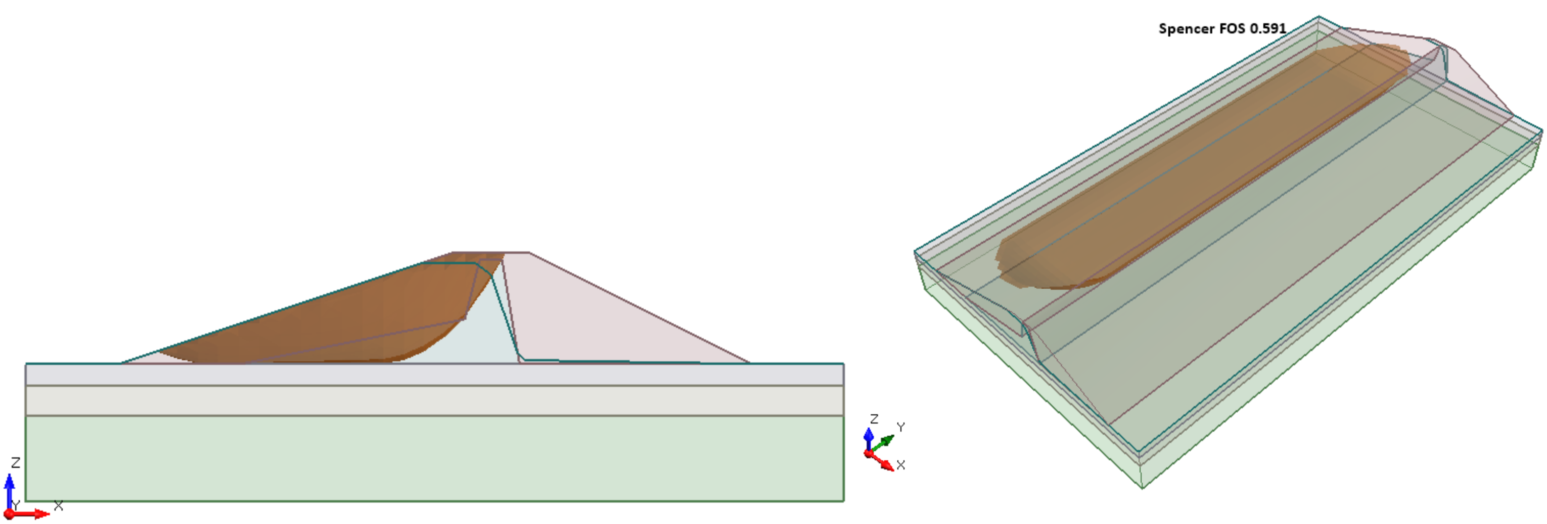


Figure 42.4.7 – Slide3 Solution using the Spencer Method

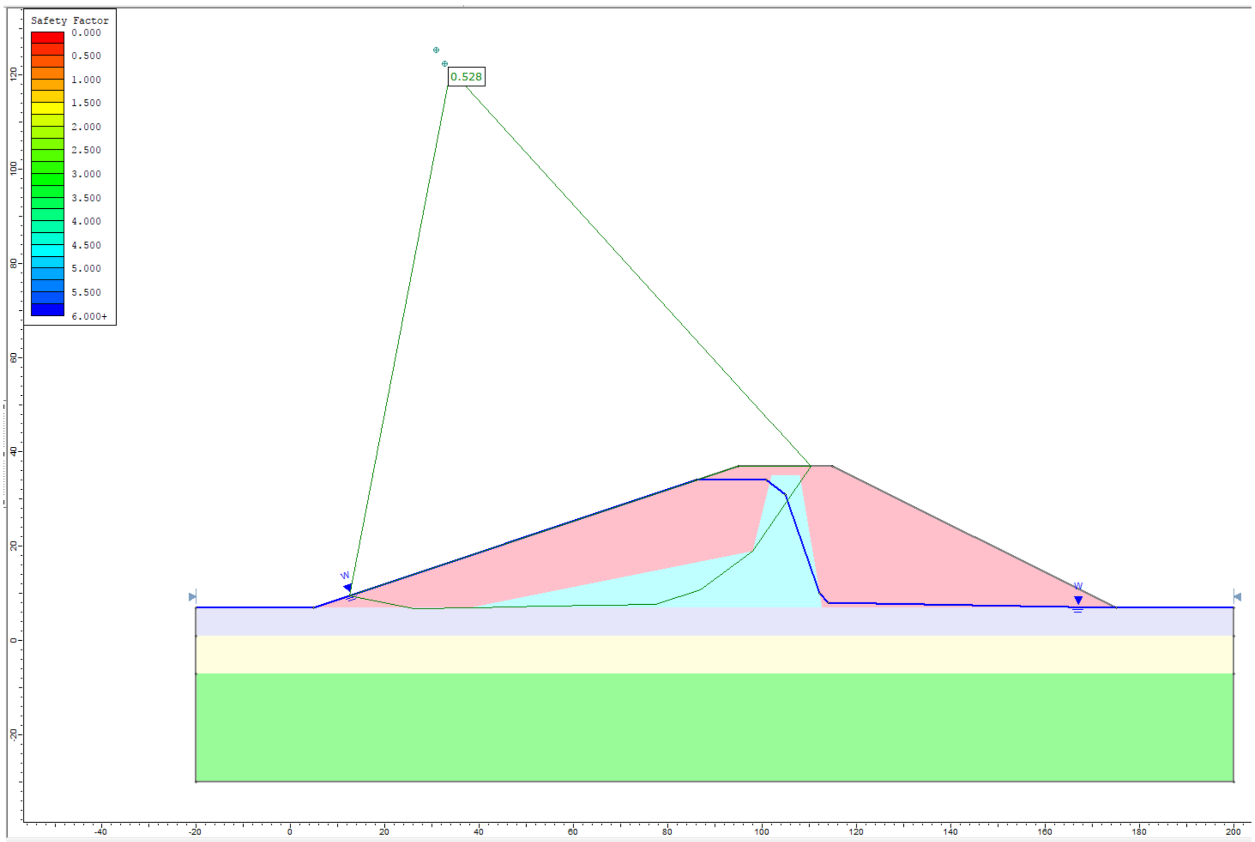


Figure 42.4.8 – Slide Solution Using the Spencer Method

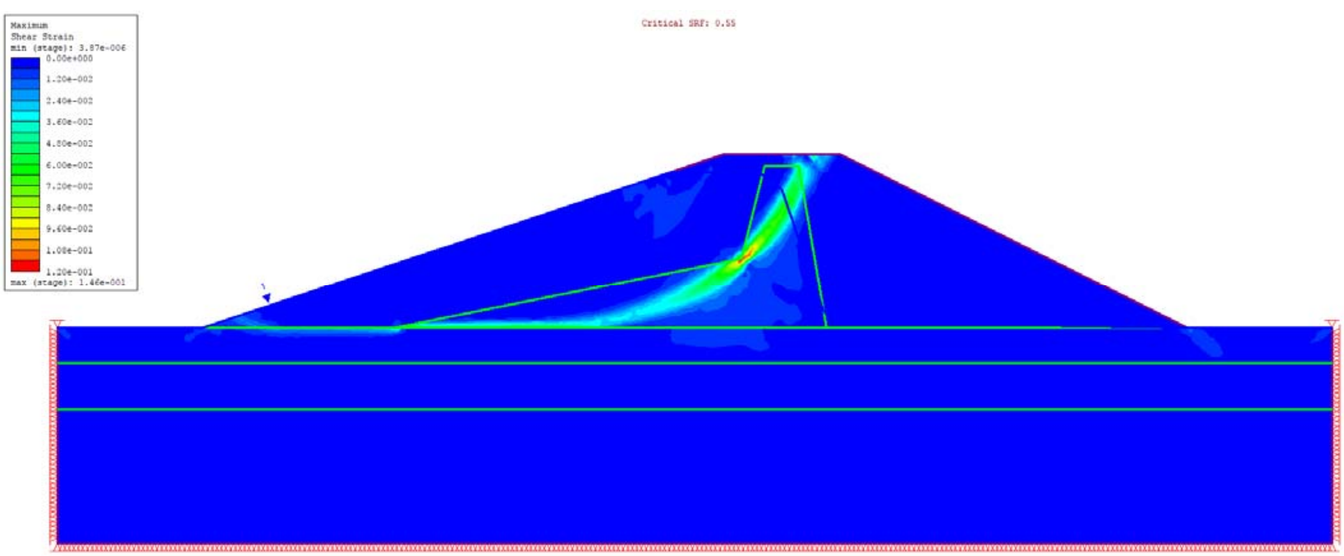


Figure 42.4.9 – RS2 Maximum Shear Strain

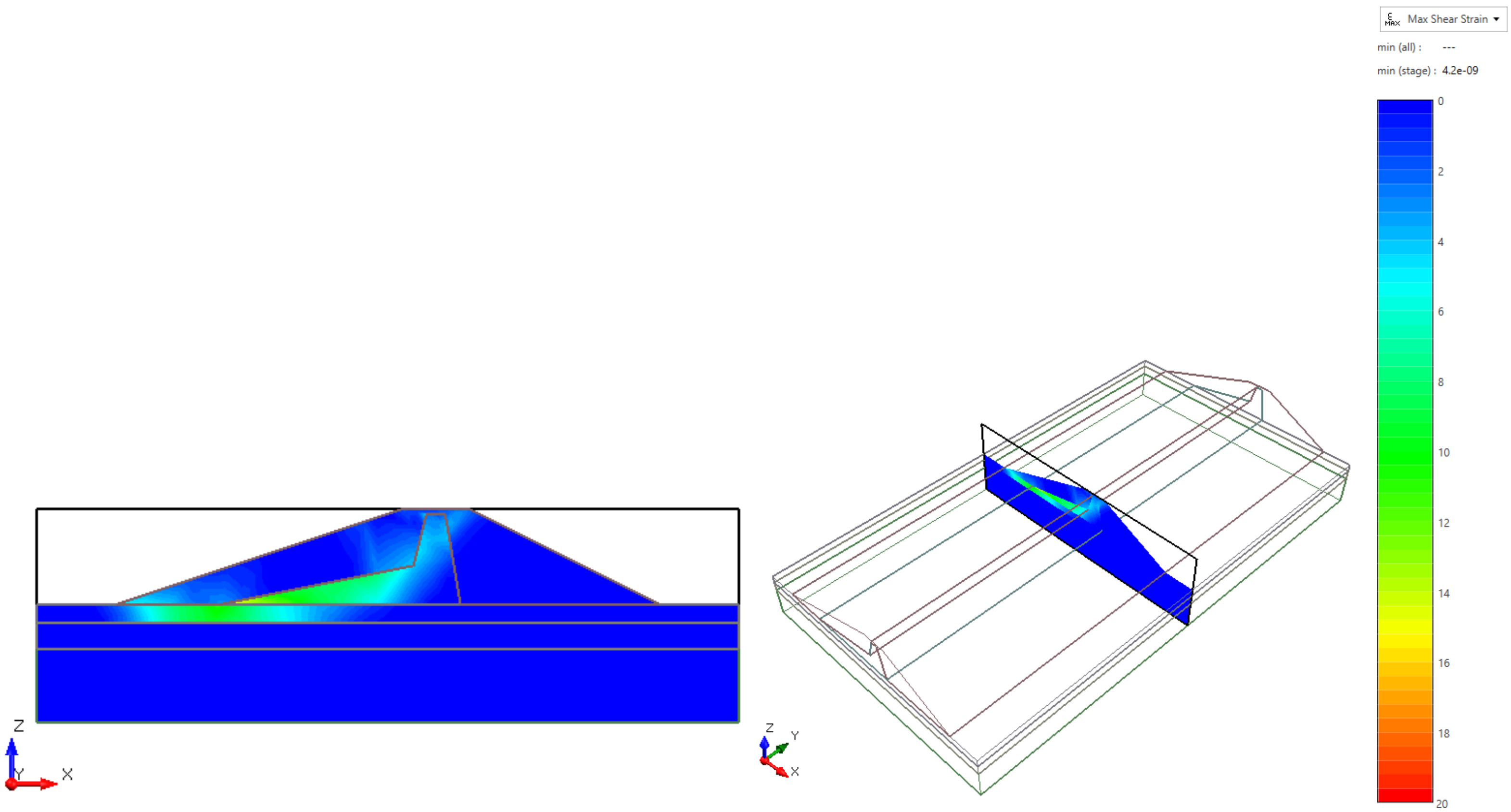


Figure 42.4.10 – RS3 Maximum Shear Strain

42.5 Results of Rapid Drawdown

Table 42.5.1: Safety Factors of Slide3 Rapid Drawdown to Empty Reservoir Model

Method	Slide3 Rapid Drawdown	Slide3 Empty Reservoir
Bishop	0.526	0.537
GLE	0.565	0.559
Janbu	0.51	0.527
Spencer	0.606	0.608

Note: Sachpazis' Model of a rapid drawdown is the empty reservoir model and the results are summarized in section 43.4, so only the Slide3 results will be shown in this table. The slip surfaces are shown above and will not be repeated, the slip surfaces shown are for the rapid drawdown.

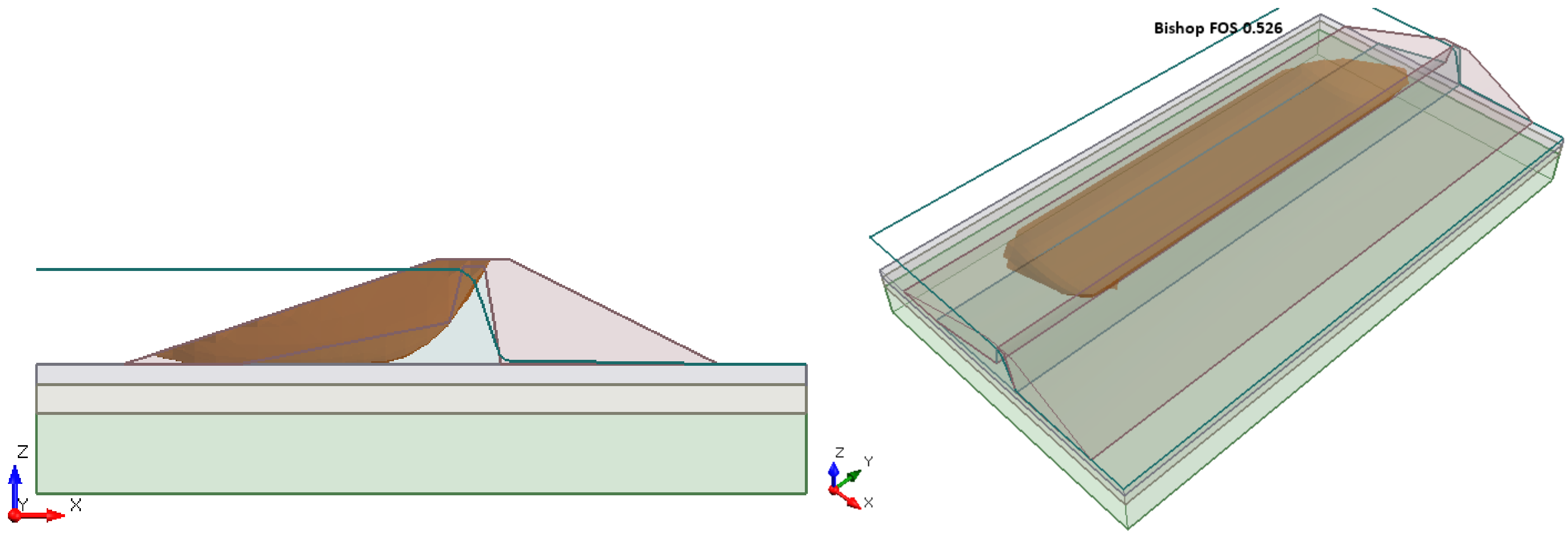


Figure 42.5.1 – Slide3 Rapid Drawdown Using the Bishop Method

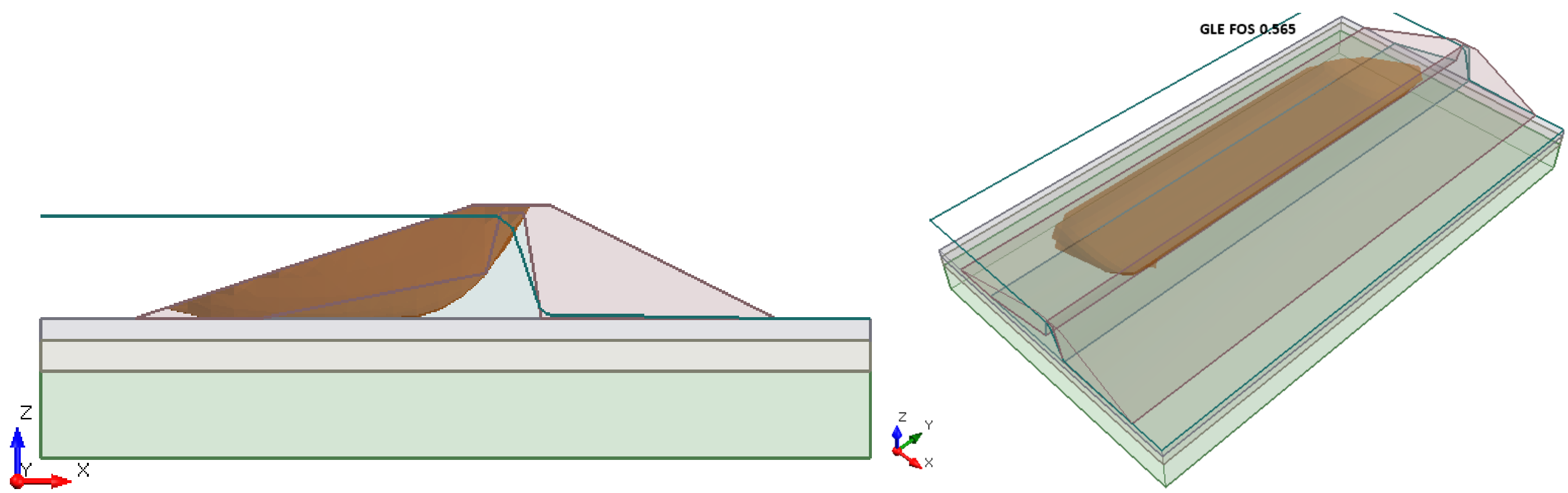


Figure 42.5.2 – Slide3 Rapid Drawdown Using the GLE Method

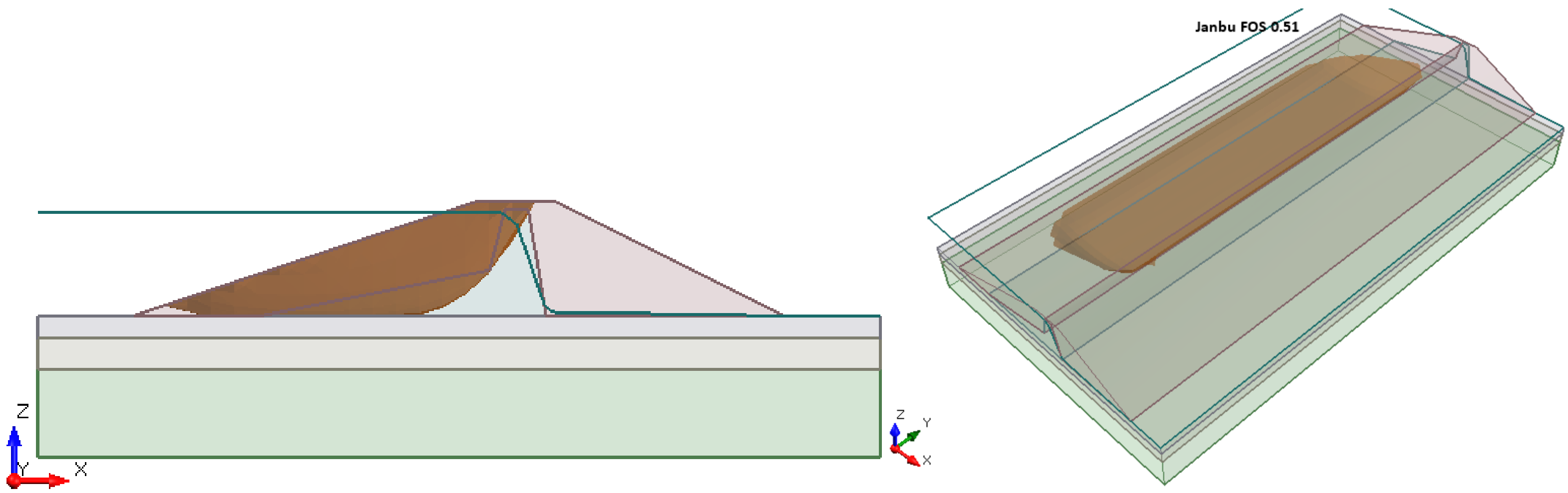


Figure 42.5.3 – Slide3 Rapid Drawdown Using the Janbu Method

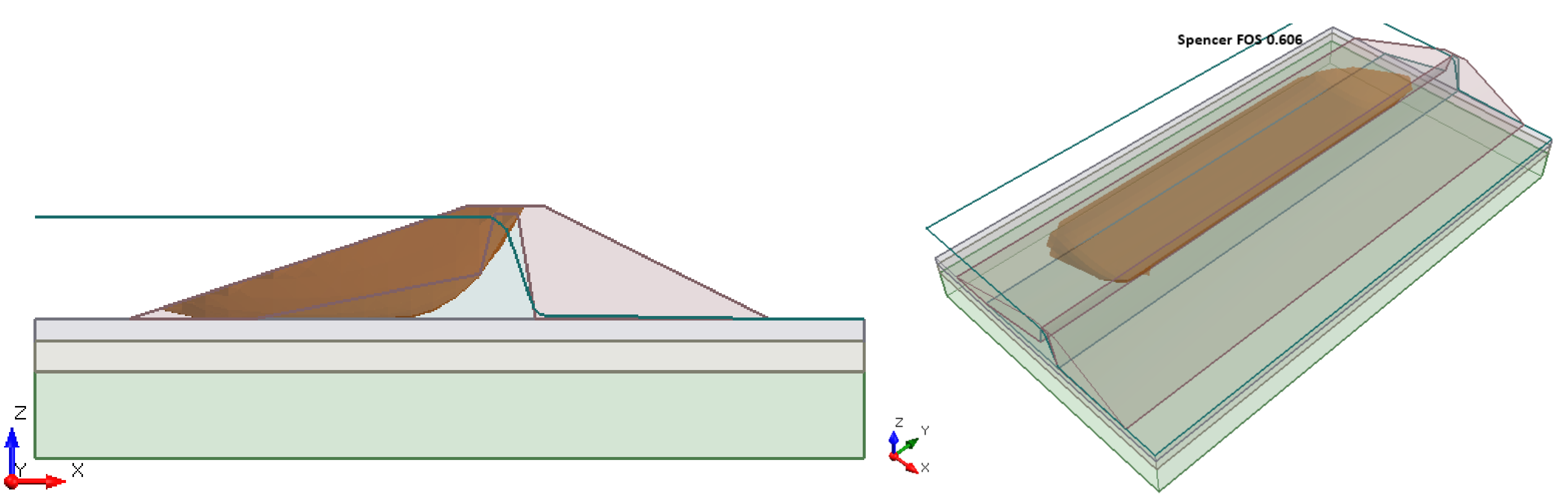


Figure 42.5.4 – Slide3 Rapid Drawdown Using the Spencer Method

42.6 Results of Transient Analysis

Table 42.6.1 Transient Analysis Model and Results

Stage	Day	Total Head on Surface (m)	SRF
1	1	34	0.92
2	2	17	Not calculated
3	3	0	1.1
4	5	0	Not calculated
5	10	0	Not calculated
6	20	0	1.23

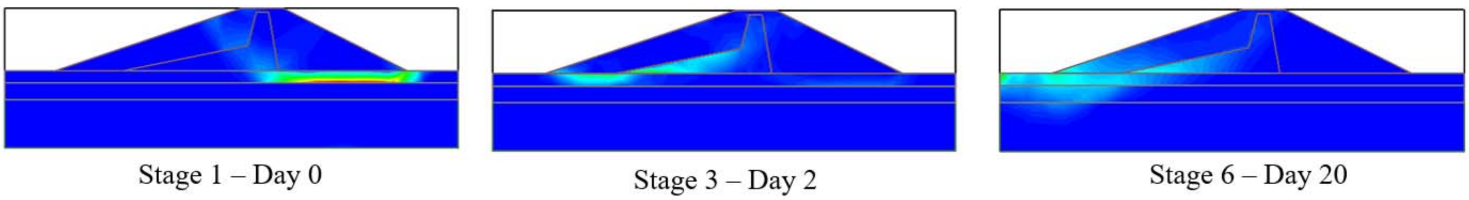


Figure 42.6.1 – RS3 Maximum Shear Strain by Stage

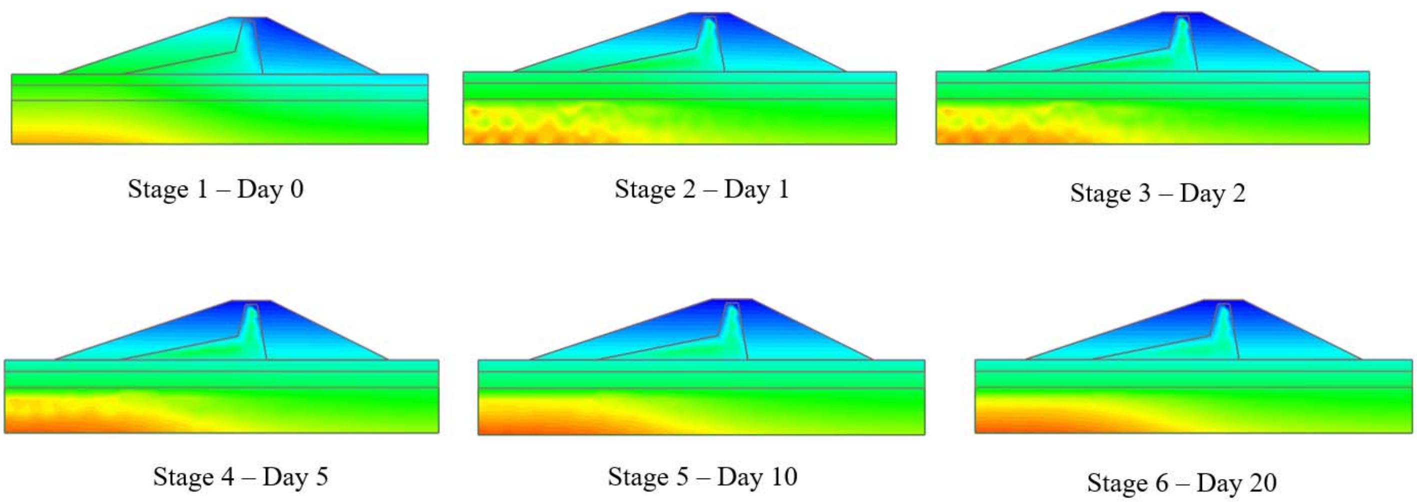


Figure 42.6.2 – RS3 Pore Pressure by Stage

2D extruded levee, (10) materials, water table, ellipsoidal with SA

43.1 Introduction

This example is a typical levee cross section in St. Bernard Parish in Louisiana taken from Koutnik et al. (2008). The cross section has been extruded in the Y direction to create the model used in Slide3 and RS3. The referee value, however, has been calculated for the 2D cross section.

43.2 Problem Description

The geometry of the 2D cross section for this model can be found as Figure 43. This XZ cross section will then be extruded 105 m in the Y direction. The material properties for all 10 materials can be found in Table 43.1. The ellipsoidal slip surface and corresponding safety factor is required.

43.3 Geometry and Properties

Table 43.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
CH1	28.7	0	18.1
CH2	19.2	0	17.3
CH3	7.2	0	12.6
CH4	12.6	0	14.9
CH5	15	0	15.5
ML	9.6	15	18.1
CH7	37.1	0	16.5
CH8	41.9	0	16.5
CH9	46.7	0	16.5
CH10	47.9	0	16.5

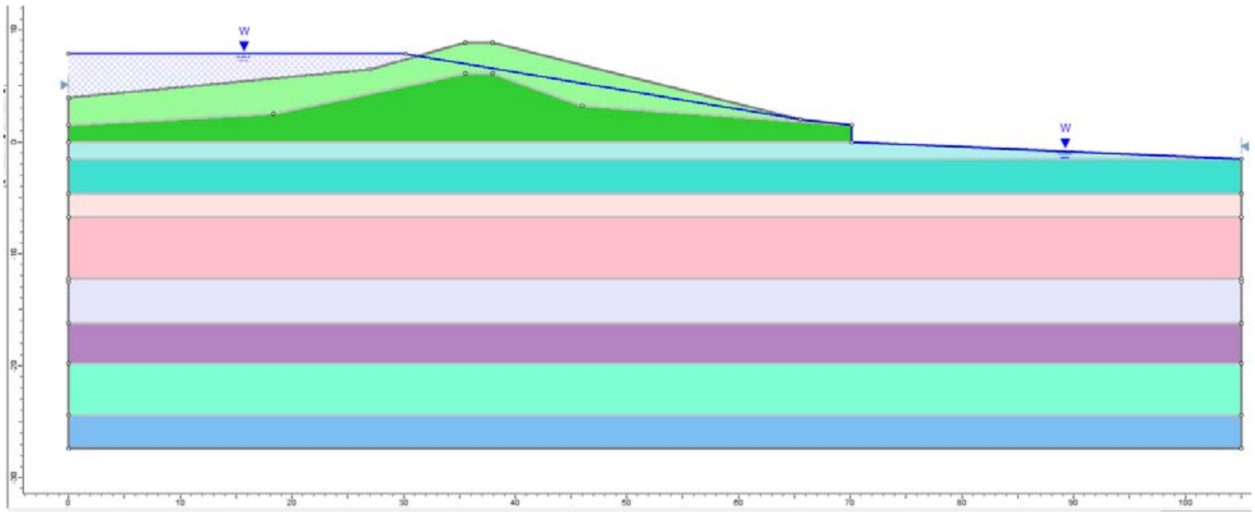


Figure 43

43.4 Results

Table 43.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

<table>
<tr><th>Method</th><th>Slide3</th><th>Slide 7.0</th><th>RS3</th><th>RS2</th></tr>
<tr><td>Bishop</td><td>0.66</td><td>0.653</td><td rowspan="4">0.79</td><td rowspan="4">0.66</td></tr>
<tr><td>GLE</td><td>0.71</td><td>0.674</td></tr>
<tr><td>Janbu</td><td>0.648</td><td>0.636</td></tr>
<tr><td>Spencer</td><td>0.72</td><td>0.680</td></tr>
</table>

Referee: Bishop - 0.74, Janbu – 0.68, Spencer – 0.74 (2D Analysis) [Koutnik et al., 2008]

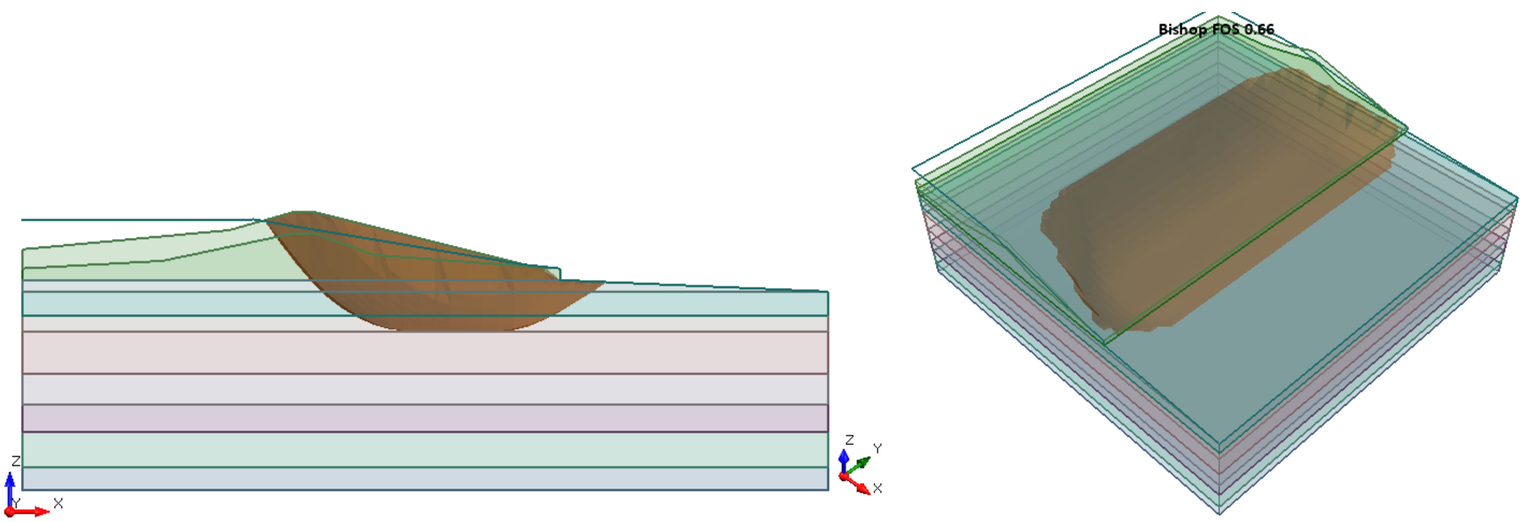


Figure 43.4.1 – Slide3 Solution Using the Bishop Method

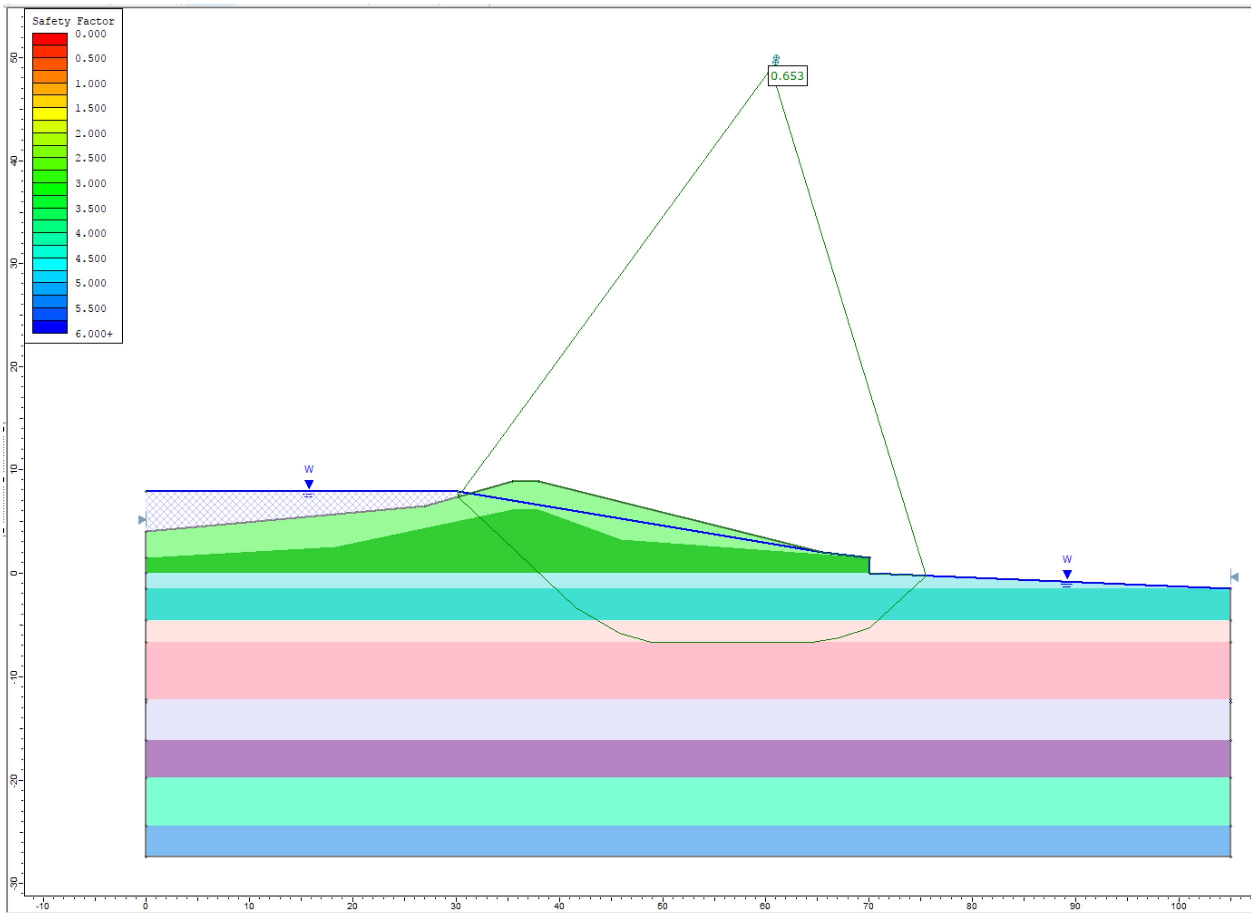


Figure 43.4.2 – Slide Solution Using the Bishop Method

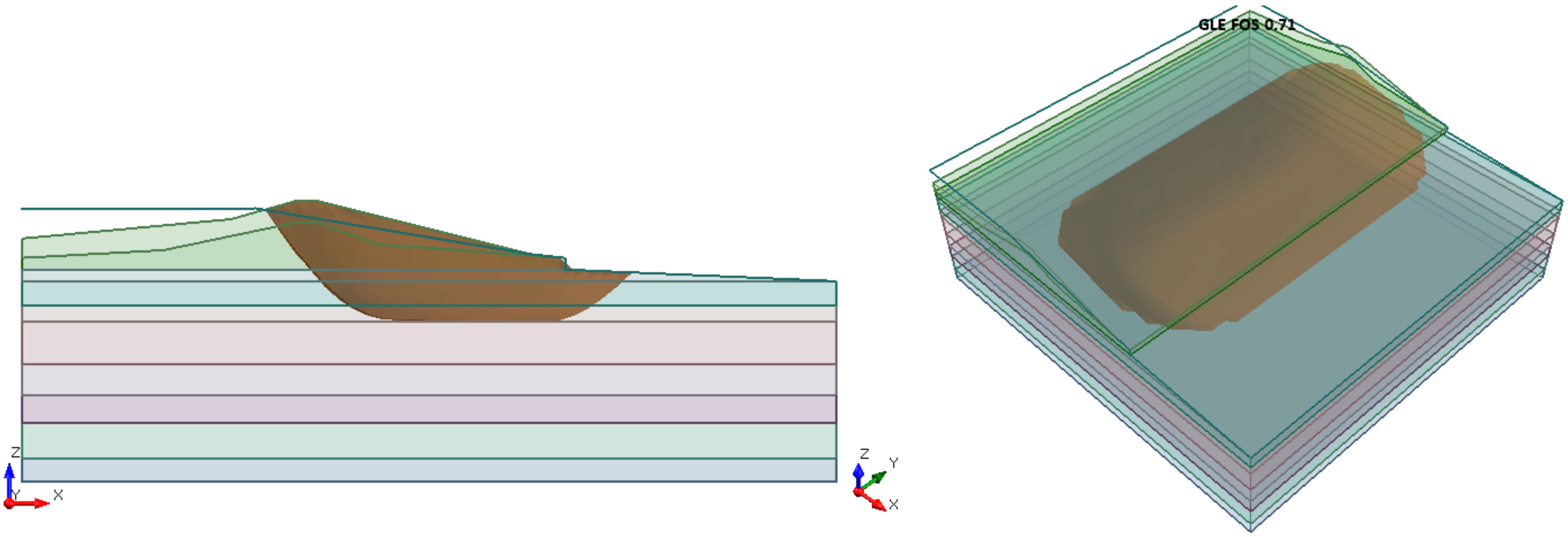


Figure 43.4.3 – Slide3 Solution Using the GLE Method

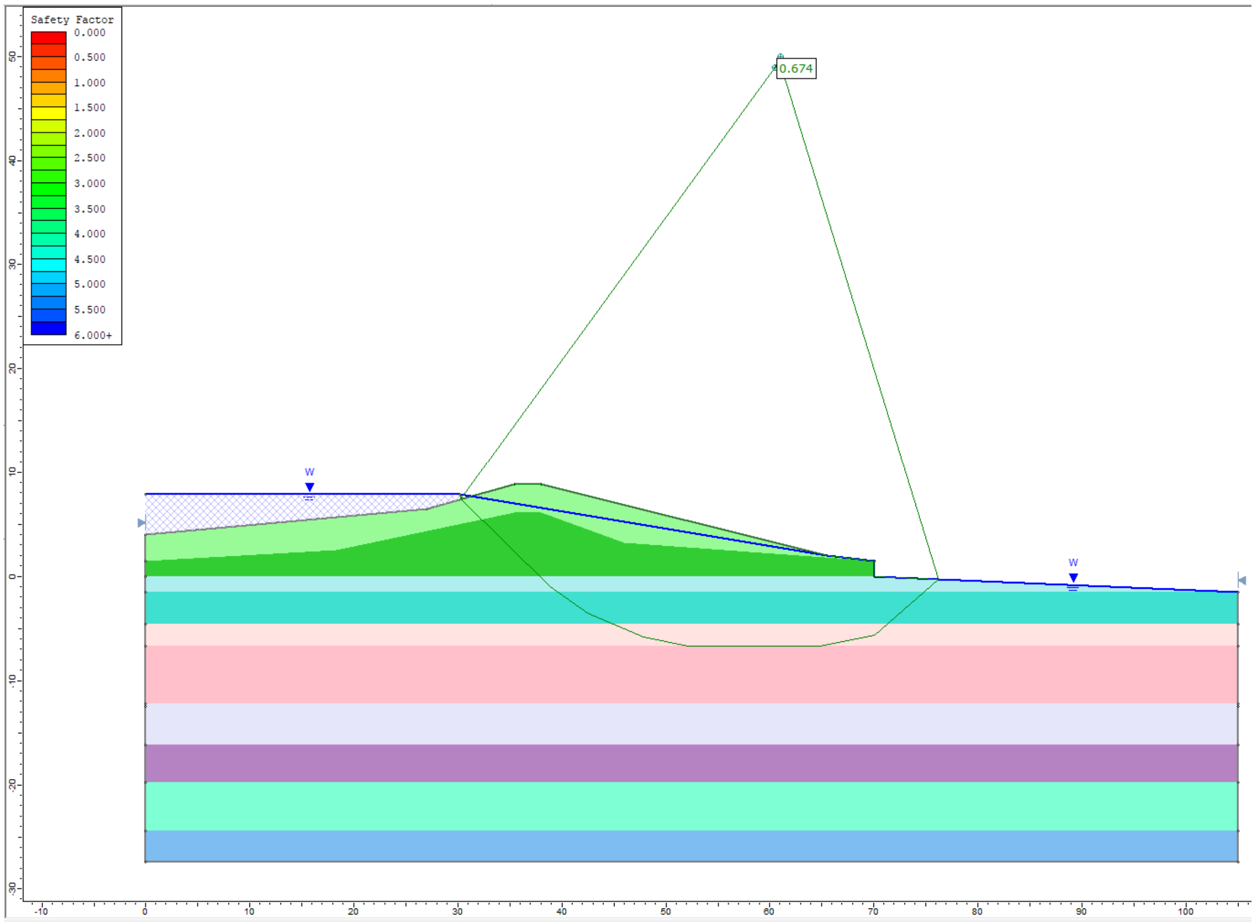


Figure 43.4.4 – Slide Solution Using the GLE Method

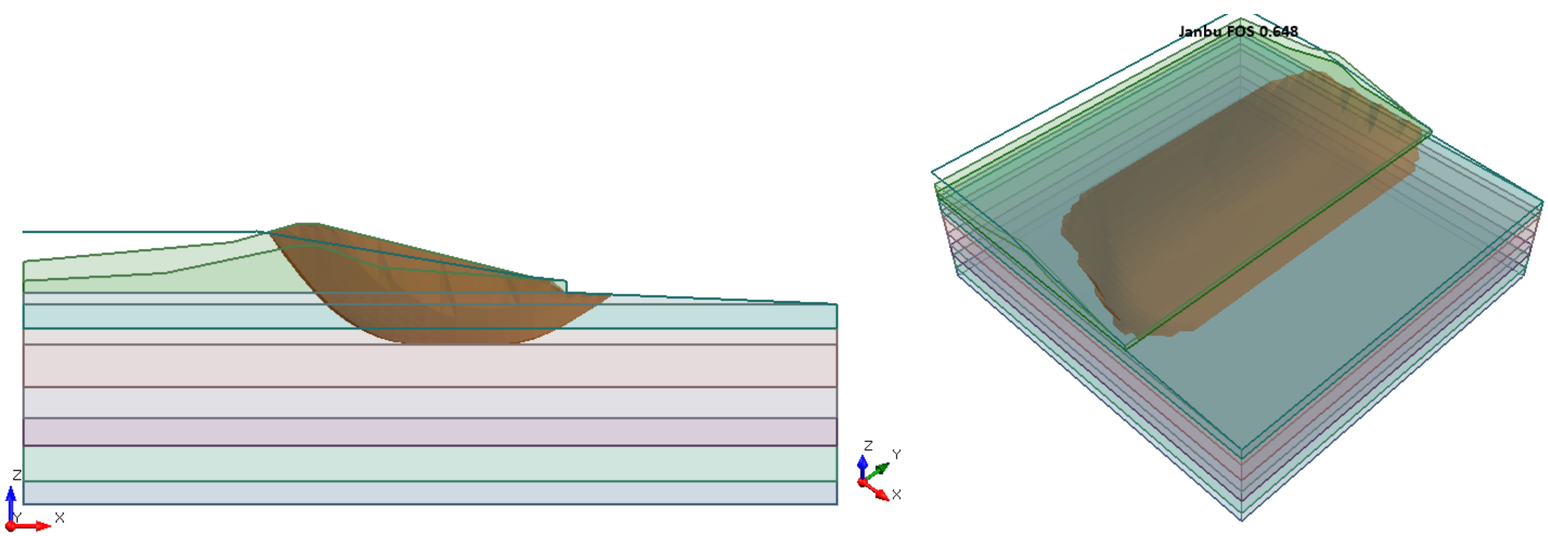


Figure 43.4.5 – Slide3 Solution Using the Janbu Method

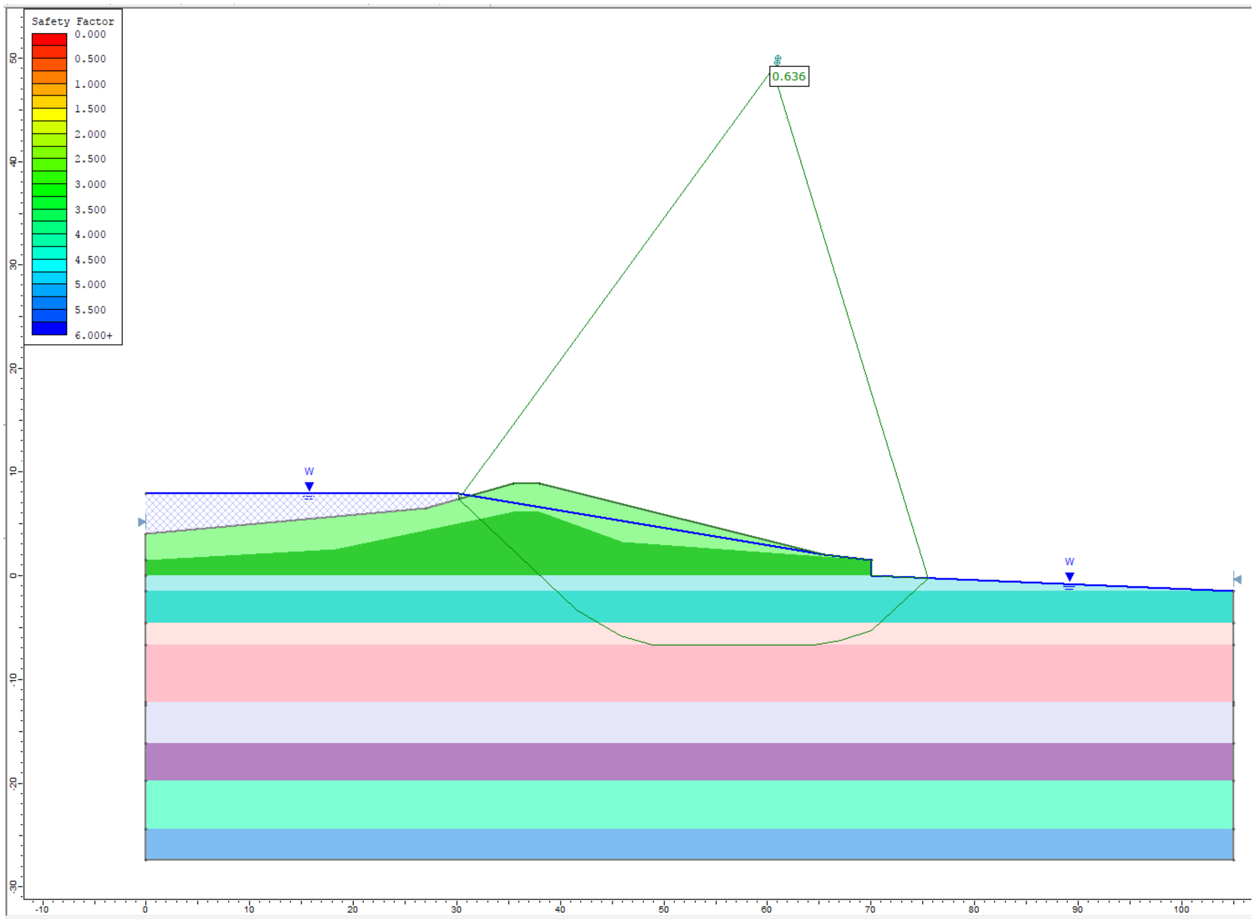


Figure 43.4.6 – Slide Solution Using the Janbu Method

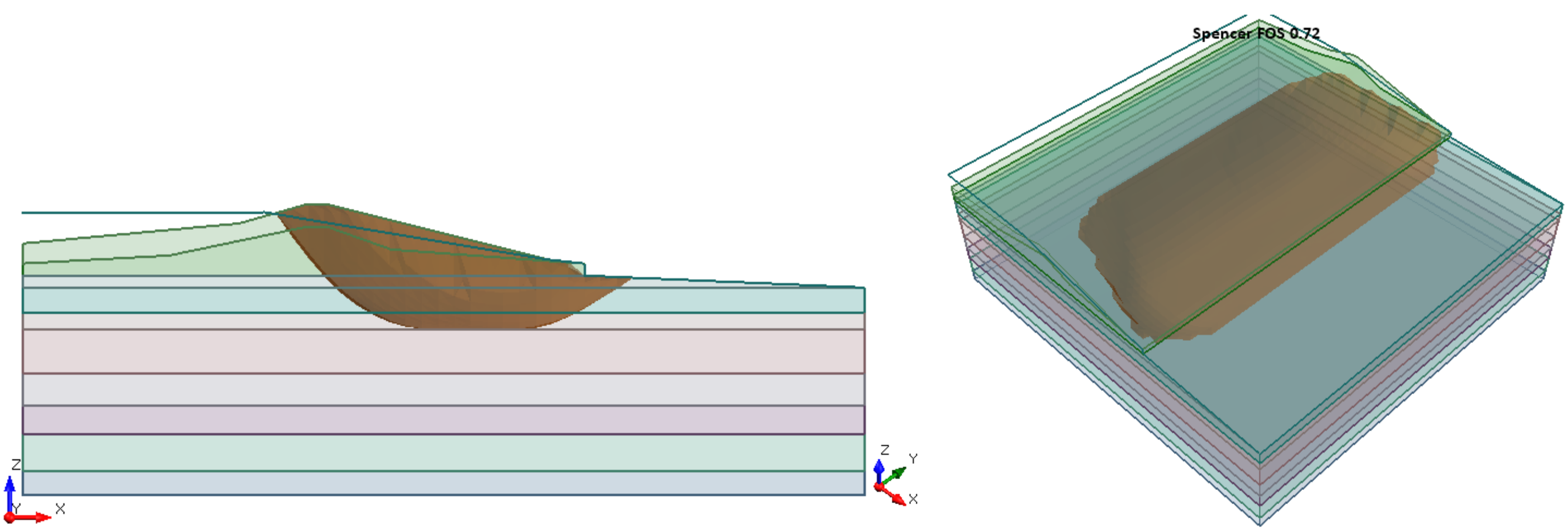


Figure 43.4.7 – Slide3 Solution Using the Spencer Method

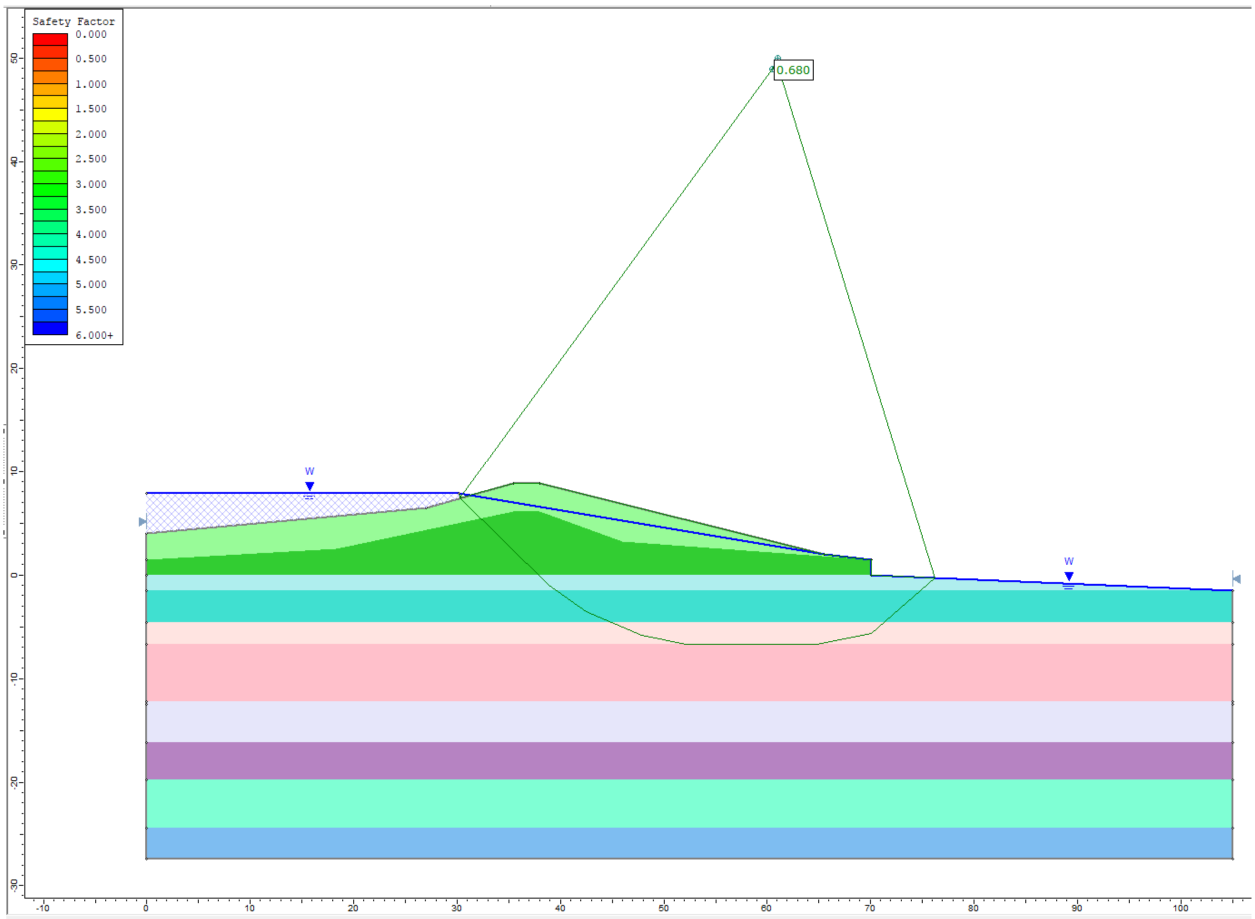


Figure 43.4.8 – Slide Solution Using the Spencer Method

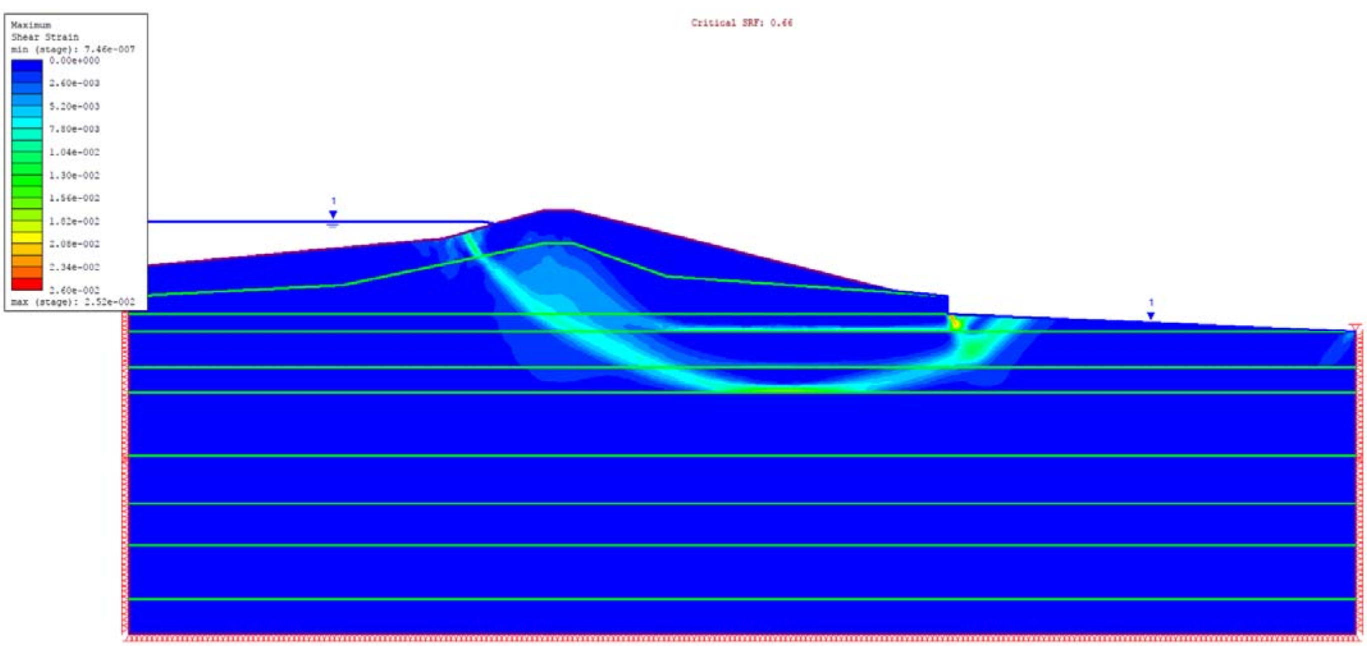


Figure 43.4.9 – RS2 Maximum Shear Strain

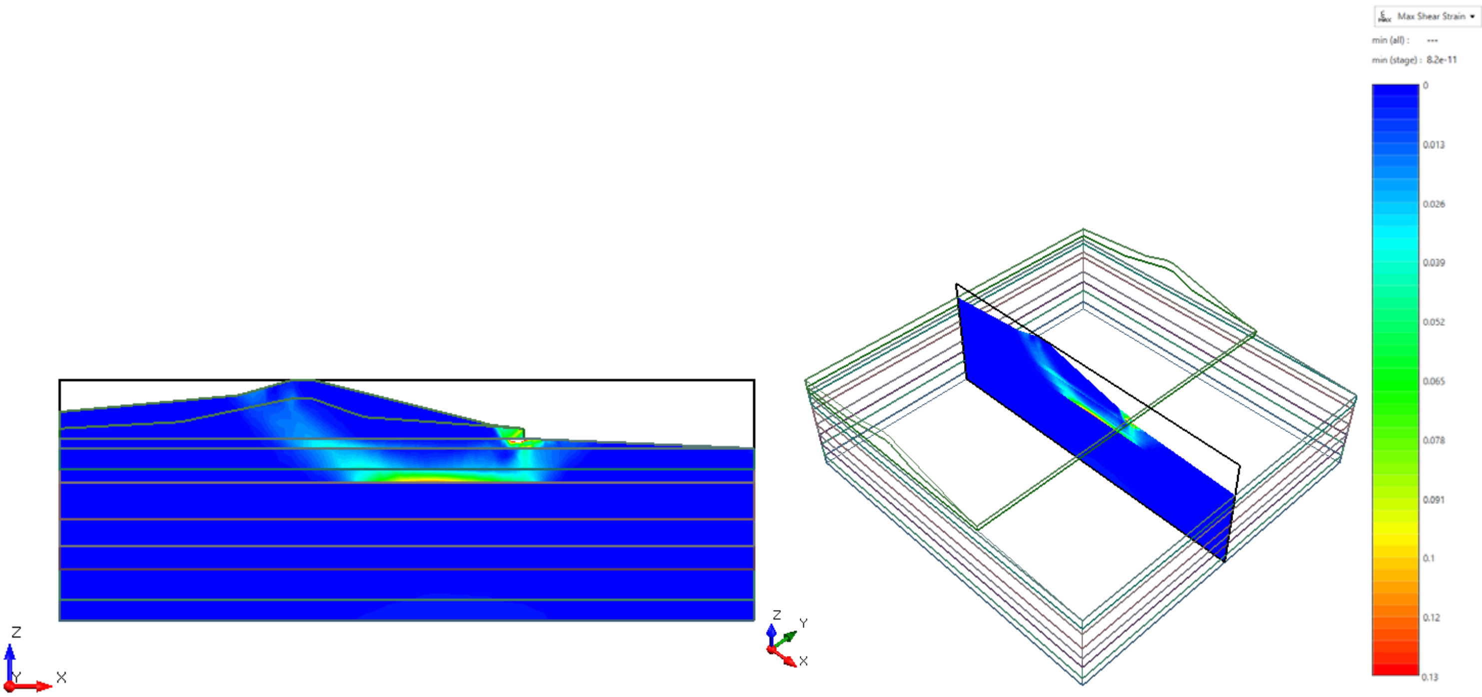


Figure 43.4.10 – RS3 Maximum Shear Strain

2D extruded slope, (6) materials, ellipsoidal with SA

44.1 Introduction

This example is a 2D non-homogeneous extruded slope.

44.2 Problem Description

The 2D cross section in the XZ plane is shown in Figure 44. It will then be extruded 100 m in the Y direction. The material properties for all six materials can be found in Table 44.1. There is no groundwater in this problem. The ellipsoidal slip surface and corresponding safety factor is required.

44.3 Geometry and Properties

Table 44.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil 1	7	13	20
Soil 2	13	10	18.9
Soil 3	6	34	17.5
Soil 4	36	25	21.3
Soil 5	19	35	21
Soil 6	51	24	23.5

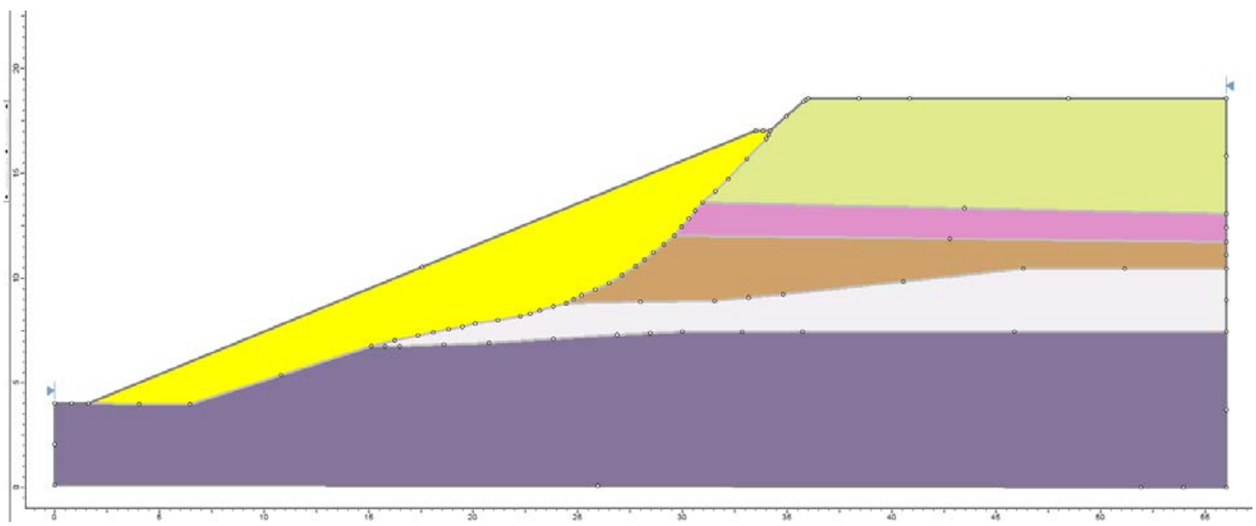


Figure 44

44.4 Results

Table 44.4.1: Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.073	1.041	1.1	1.05
GLE	1.096	1.036		
Janbu	1.058	0.998		
Spencer	1.096	1.044		

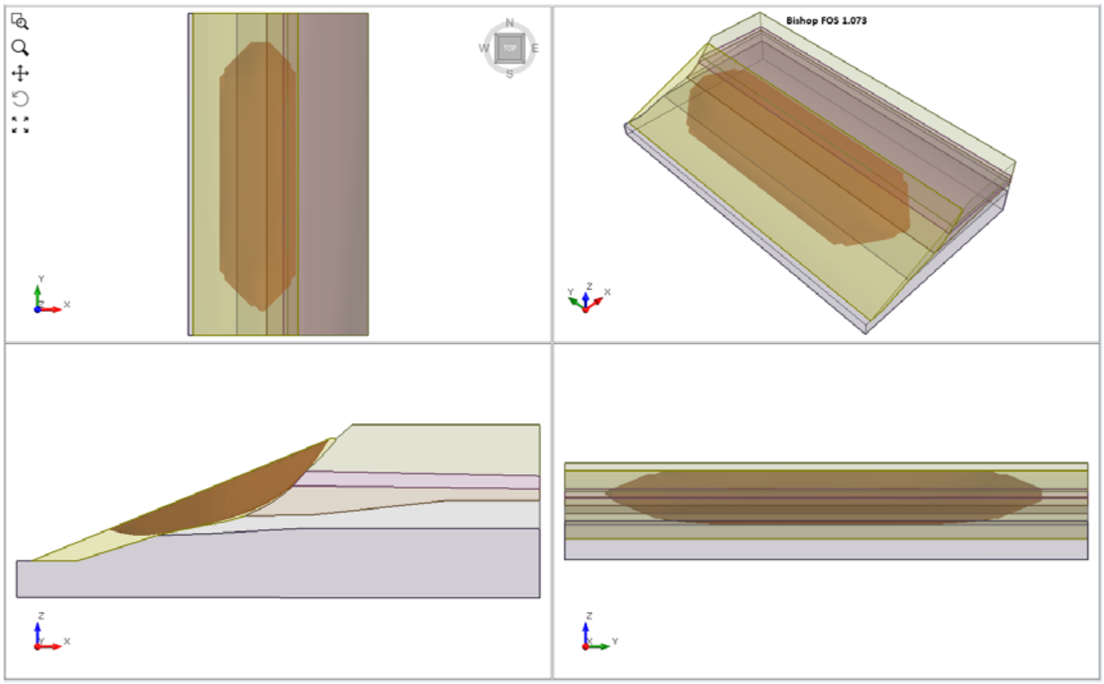


Figure 44.4.1 – Slide3 Solution Using the Bishop Method

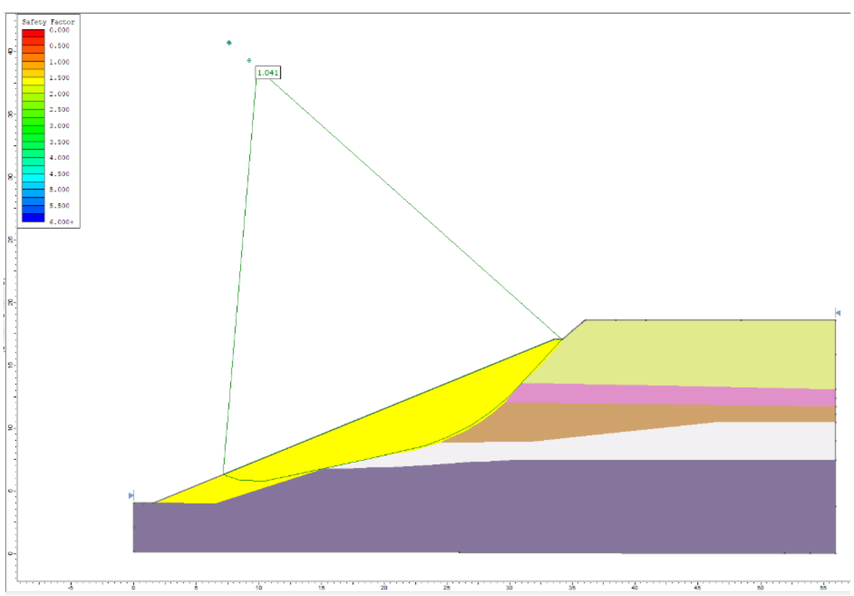


Figure 44.4.2 – Slide Solution Using the Bishop Method

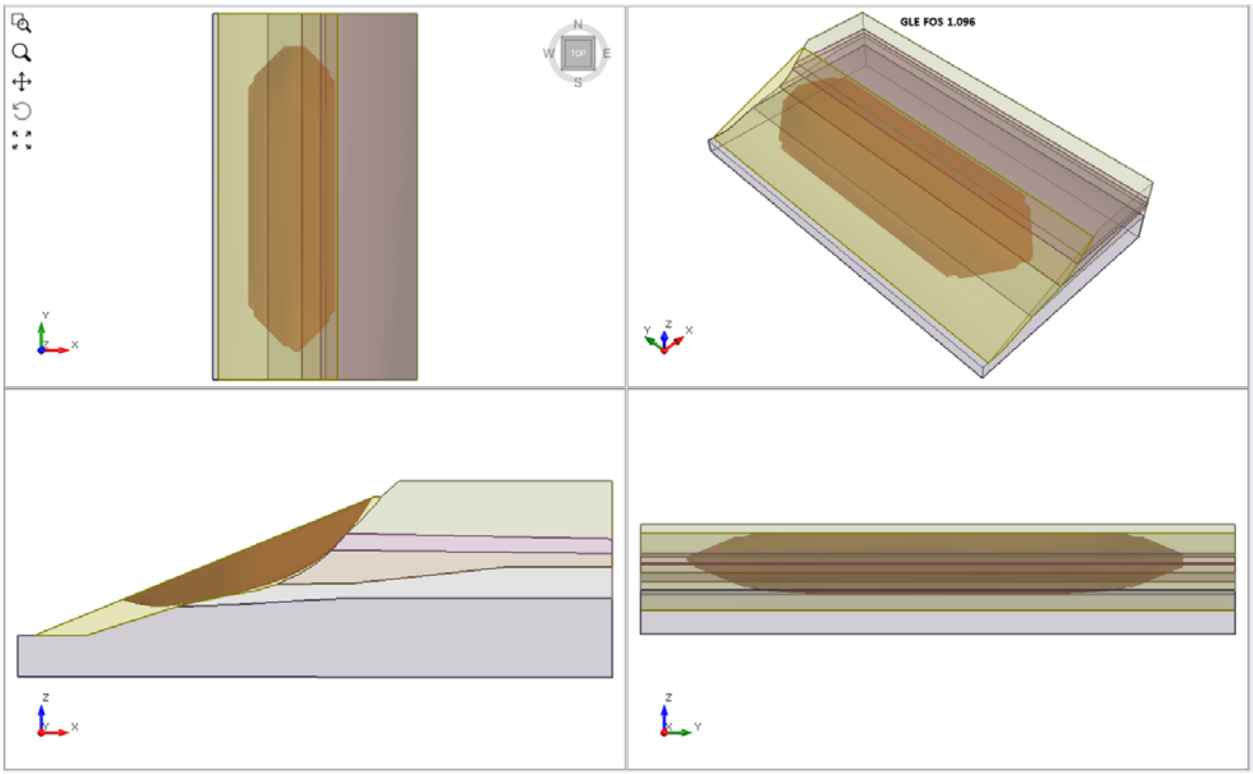


Figure 44.4.3 – Slide3 Solution Using the GLE Method

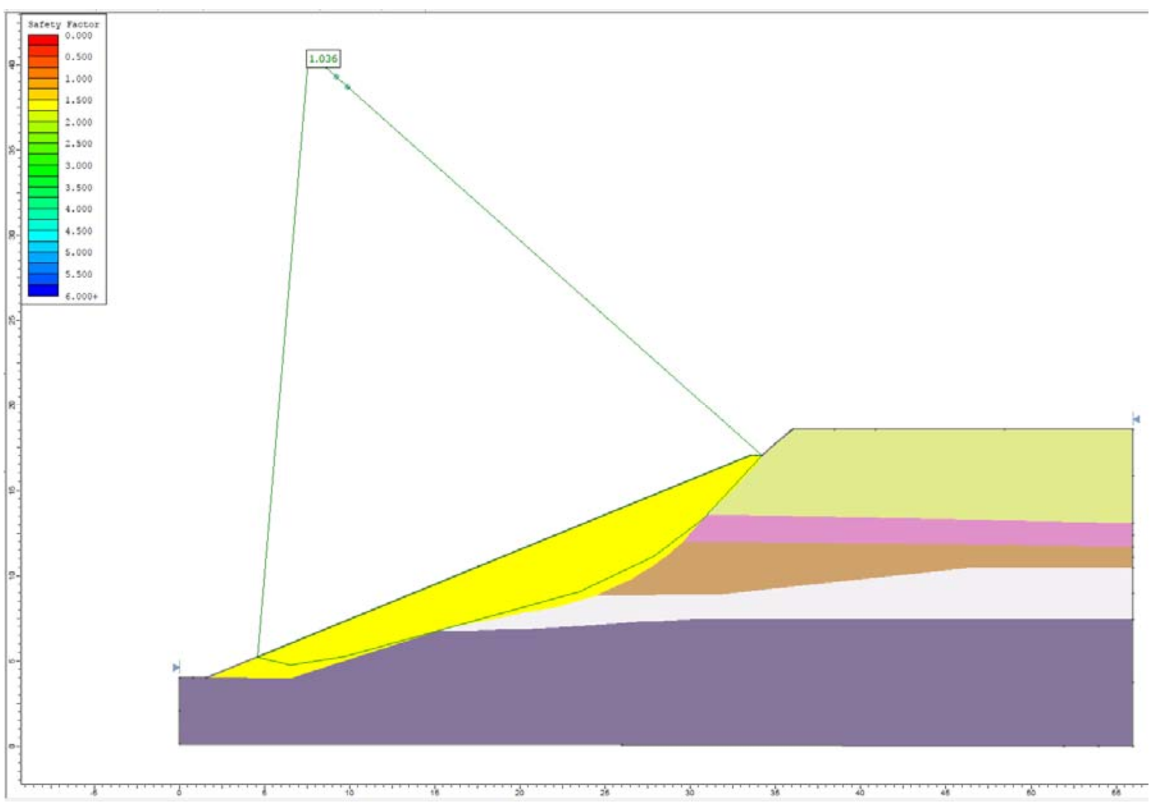


Figure 44.4.4 – Slide Solution Using the GLE Method

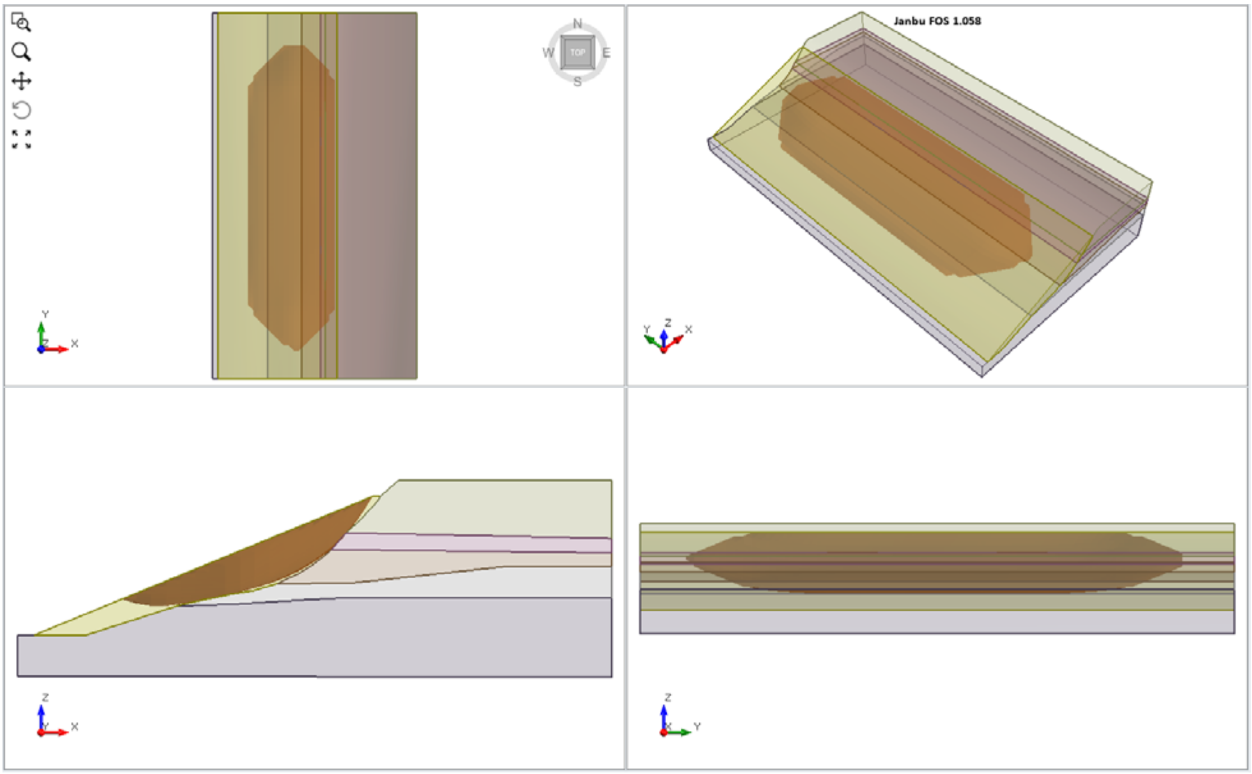


Figure 44.4.5 – Slide3 Solution Using the Janbu Method

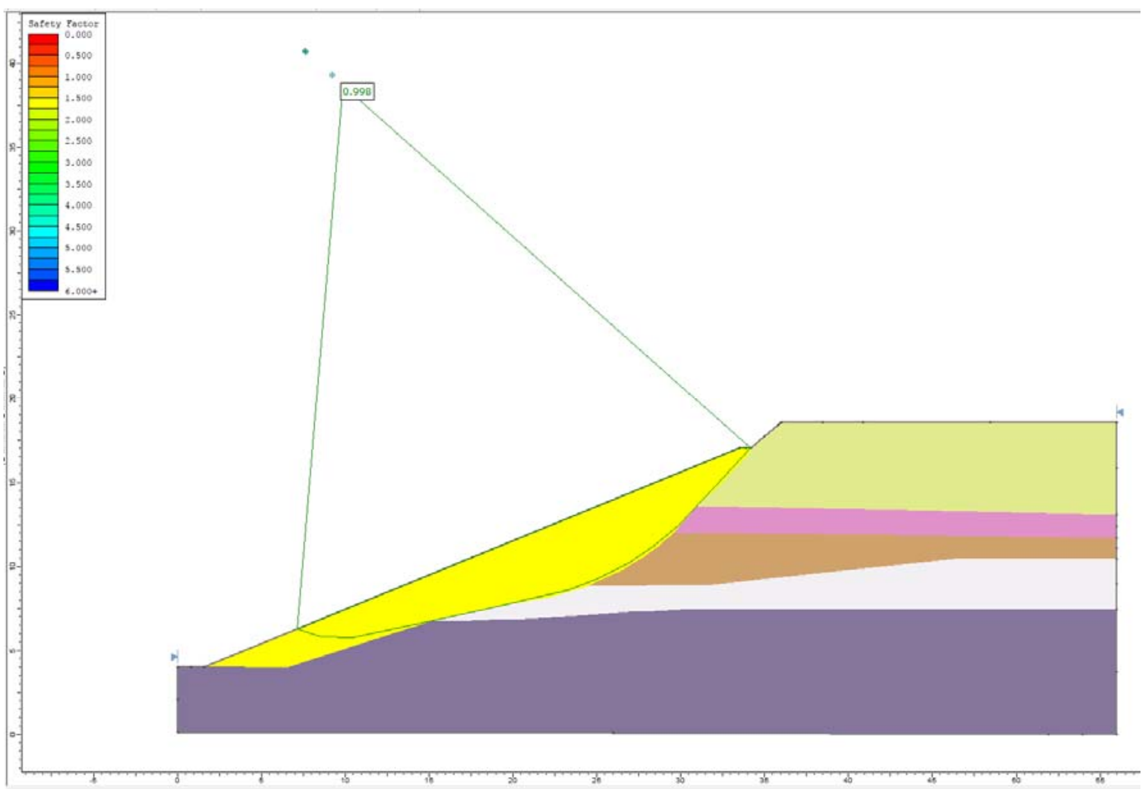


Figure 44.4.6 – Slide Solution Using the Janbu Method

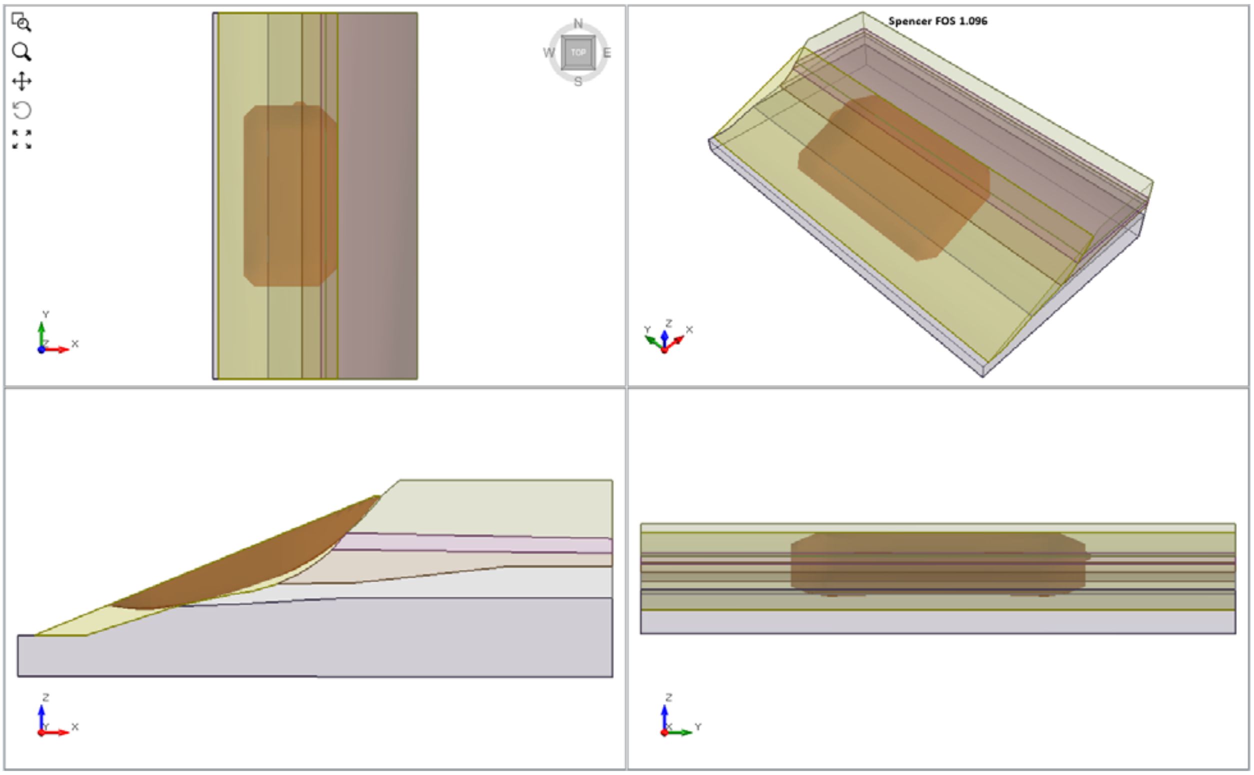


Figure 44.4.7 – Slide3 Solution Using the Spencer Method

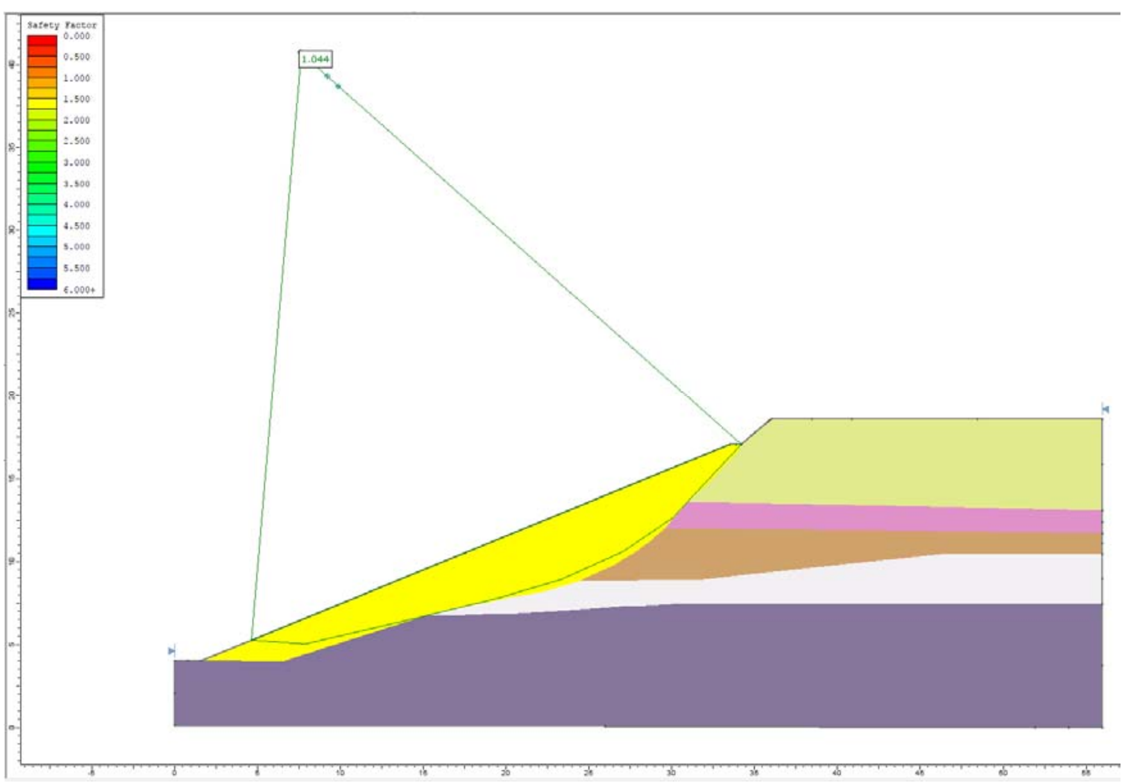


Figure 44.4.8 – Slide Solution Using the Spencer Method

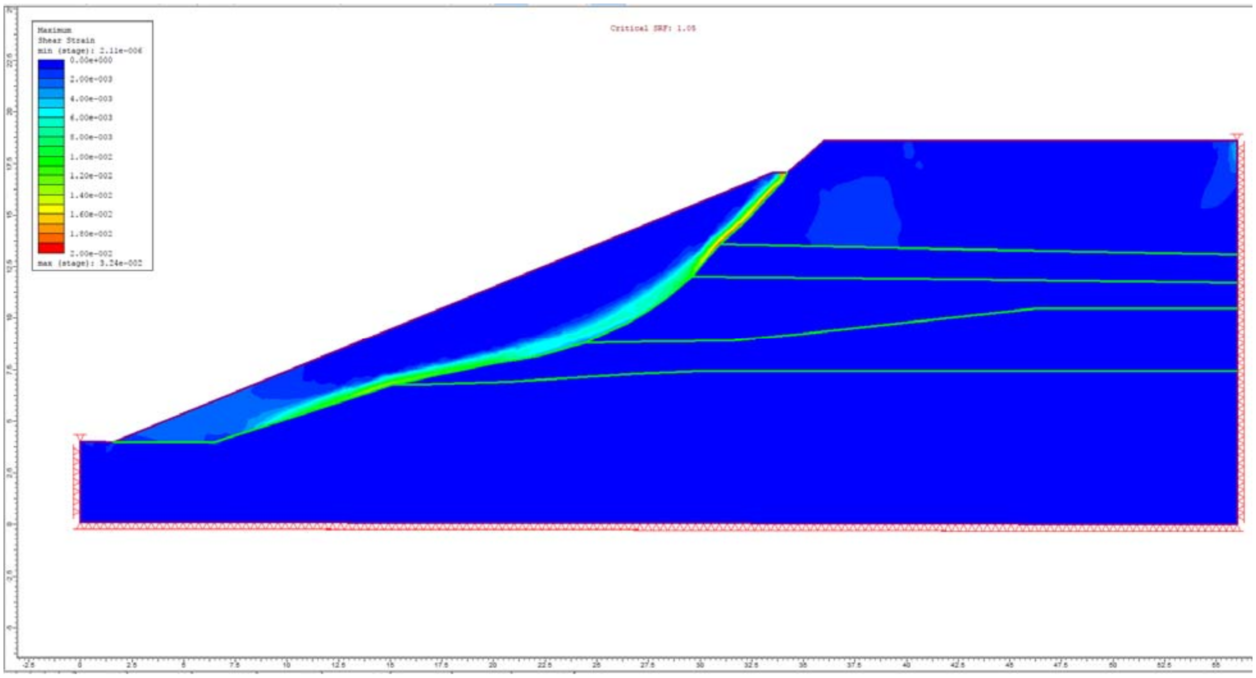


Figure 44.4.9 – RS2 Maximum Shear Strain

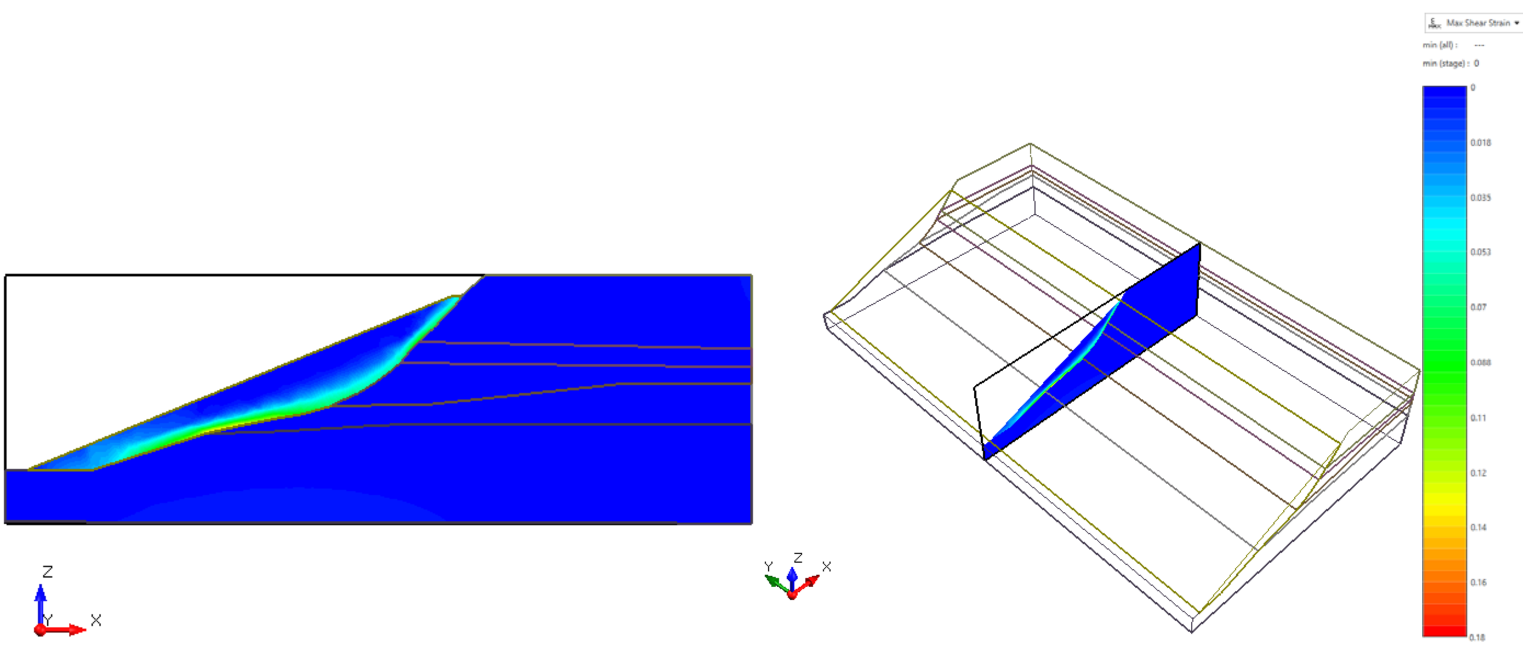


Figure 44.4.10 – RS3 Maximum Shear Strain

2D extruded slope, (9) materials, (1) SHANSEP material, water table, seismic, ellipsoidal with SA

45.1 Introduction

This example is a 2D non-homogeneous extruded slope with a water table and seismic loading.

45.2 Problem Description

The geometry in the XZ plane is shown in Figure 45. This cross section will be extruded 264 m in the Y direction to create the 3D slope. The material properties for all 9 materials can be found in Table 45.1. The seismic load has a coefficient of k = 0.1015g is the positive X direction. The ellipsoidal slip surface and corresponding safety factor is required.

45.3 Geometry and Properties

Table 45.1: Material Properties

Material	Strength Type	γ (kN/m^3)	c′ (kN/m^2)	φ′ (deg.)	A	S	m
Med dense sand	Mohr-Coulomb	21.2	0	31	X	X	X
Till	Mohr-Coulomb	21.2	0	38	X	X	X
Dense-v dense sand	Mohr-Coulomb	21.2	0	36	X	X	X
Granite Bedrock	Infinite Strength	22.8	X	X	X	X	X
Dredged material fill	Mohr-Coulomb	20	0	28	X	X	X
Silt/Clay	SHANSEP	17.3	X	X	0	0.15	0.8
Berm EQ	Mohr-Coulomb	21.2	0	34	X	X	X
Riprap EQ	Mohr-Coulomb	22.7	0	42	X	X	X
Filter Layer EQ	Mohr-Coulomb	22.7	0	40	X	X	X

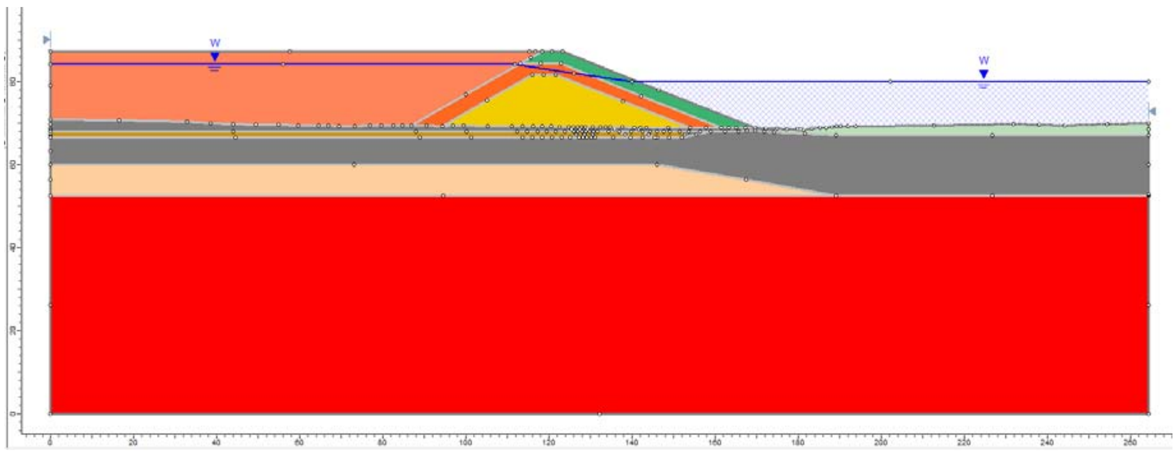


Figure 45

45.4 Results

Table 45.4.1: Safety Factors Using Slide3 and Slide 7.0

Method	Slide3	Slide 7.0
Bishop	0.722	0.686
GLE	0.795	0.734
Janbu	0.704	0.632
Spencer	0.804	0.743

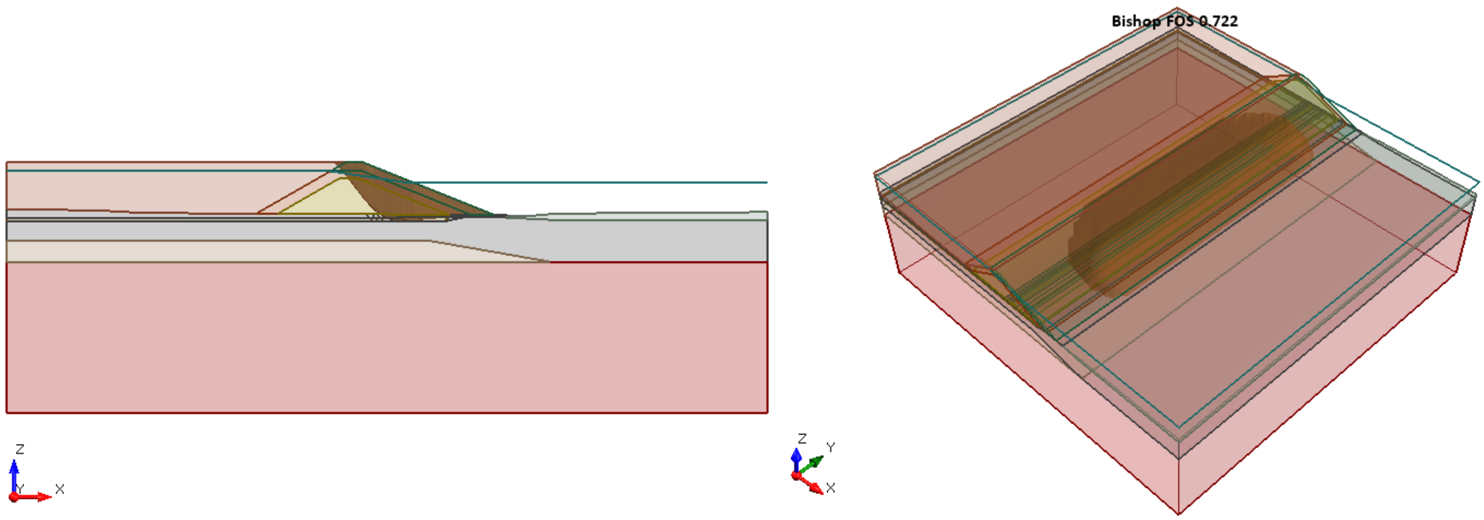


Figure 45.4.1 – Slide3 Solution Using the Bishop Method

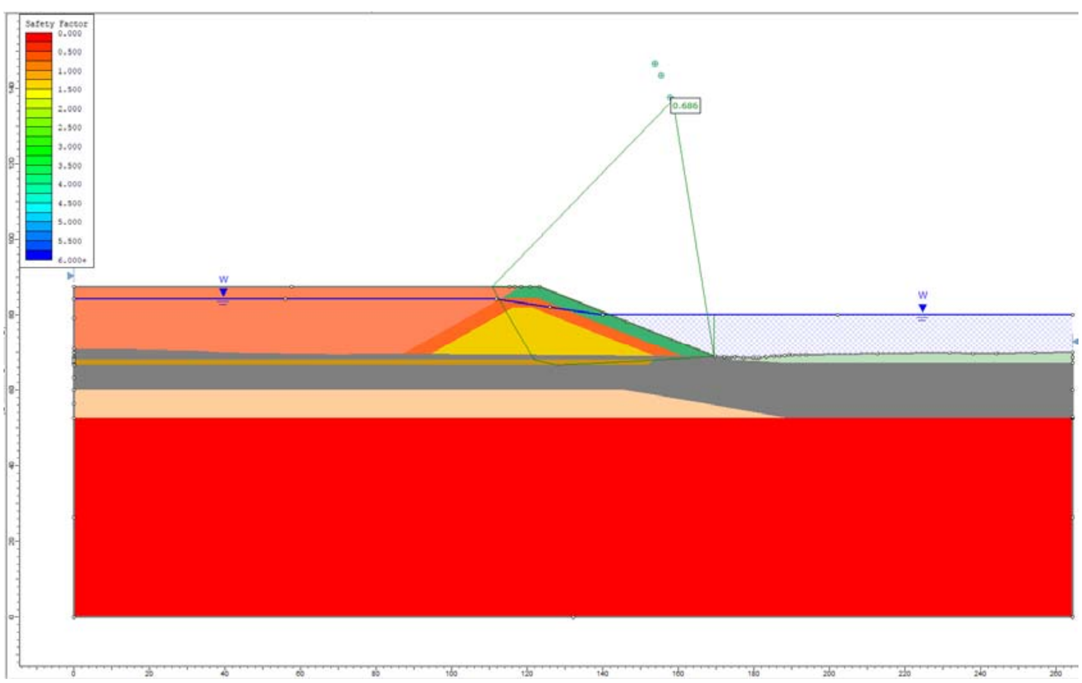


Figure 45.4.2 – Slide Solution Using the Bishop Method

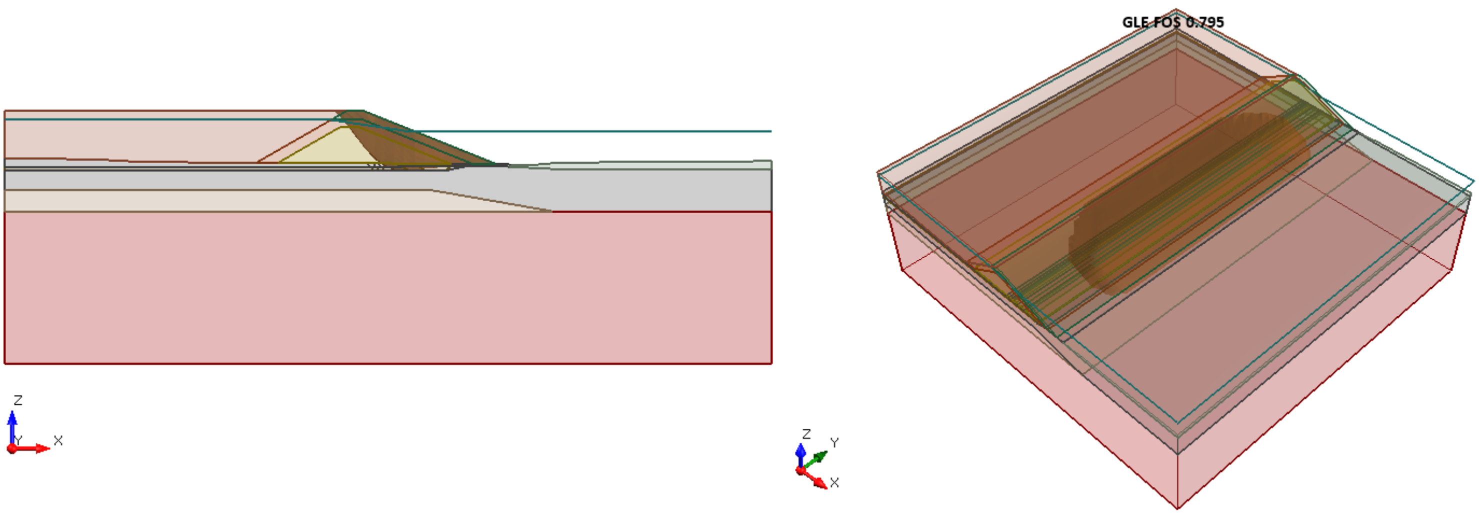


Figure 45.4.3 – Slide3 Solution Using the GLE Method

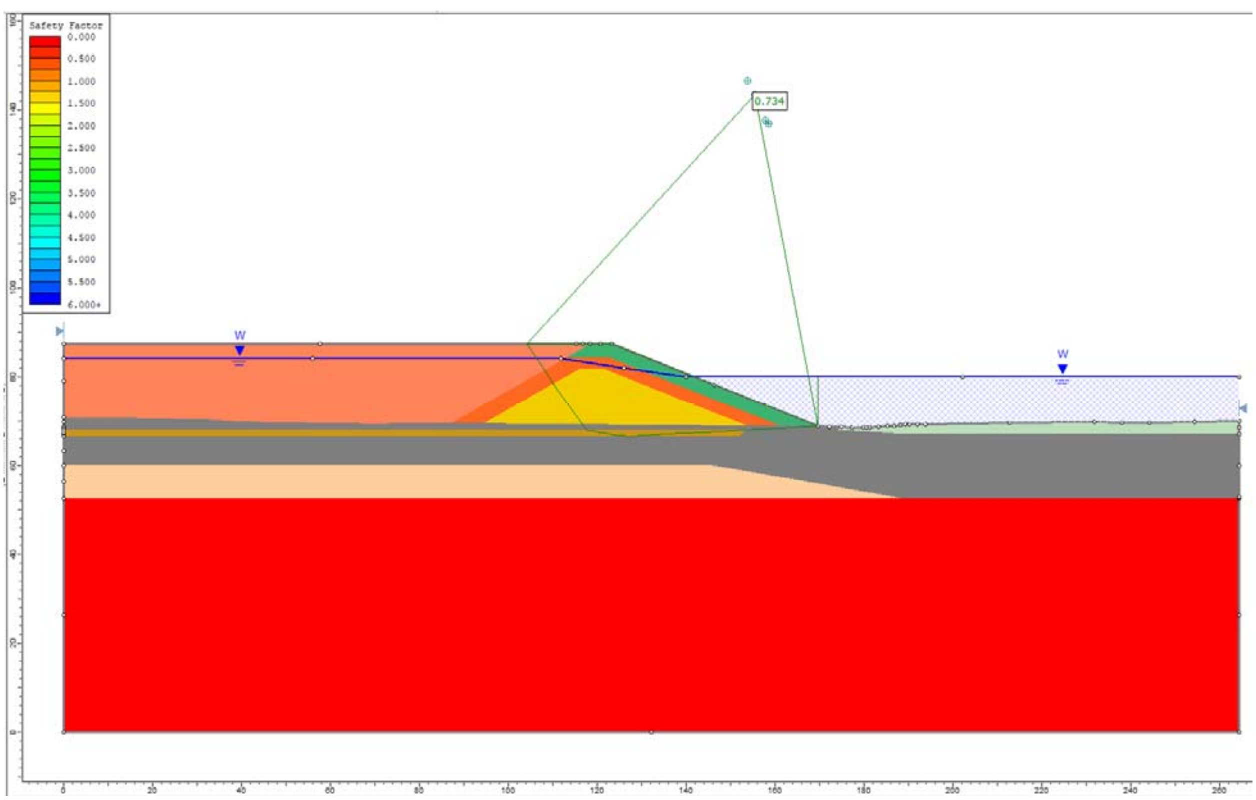


Figure 45.4.4 – Slide Solution Using the GLE Method

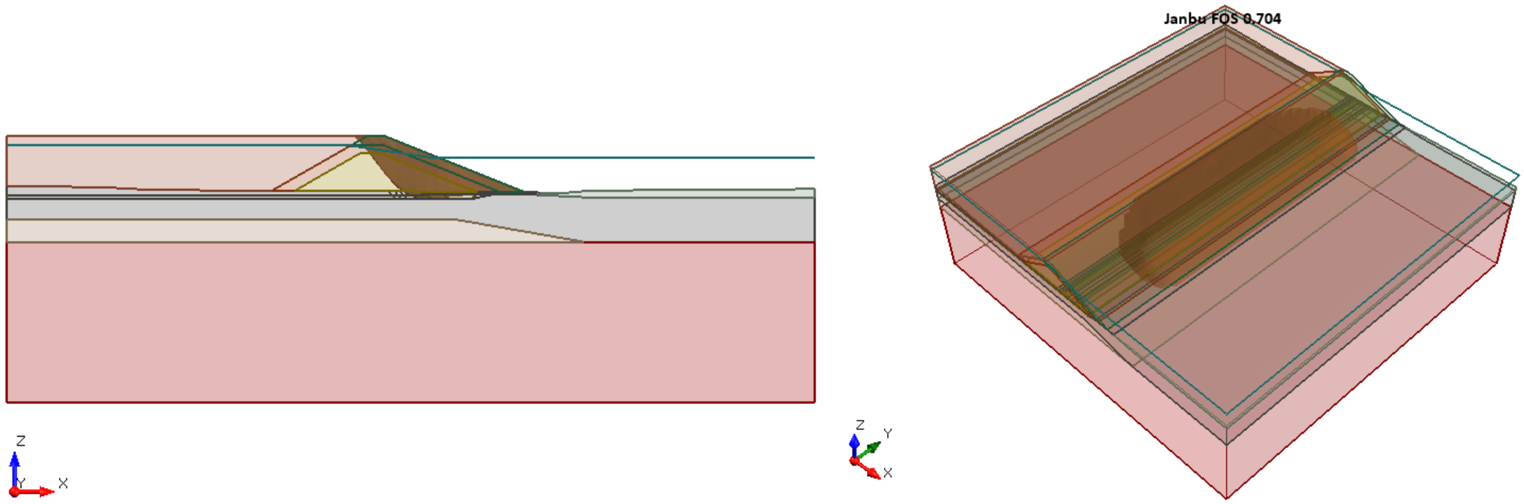


Figure 45.4.5 – Slide3 Solution Using the Janbu Method

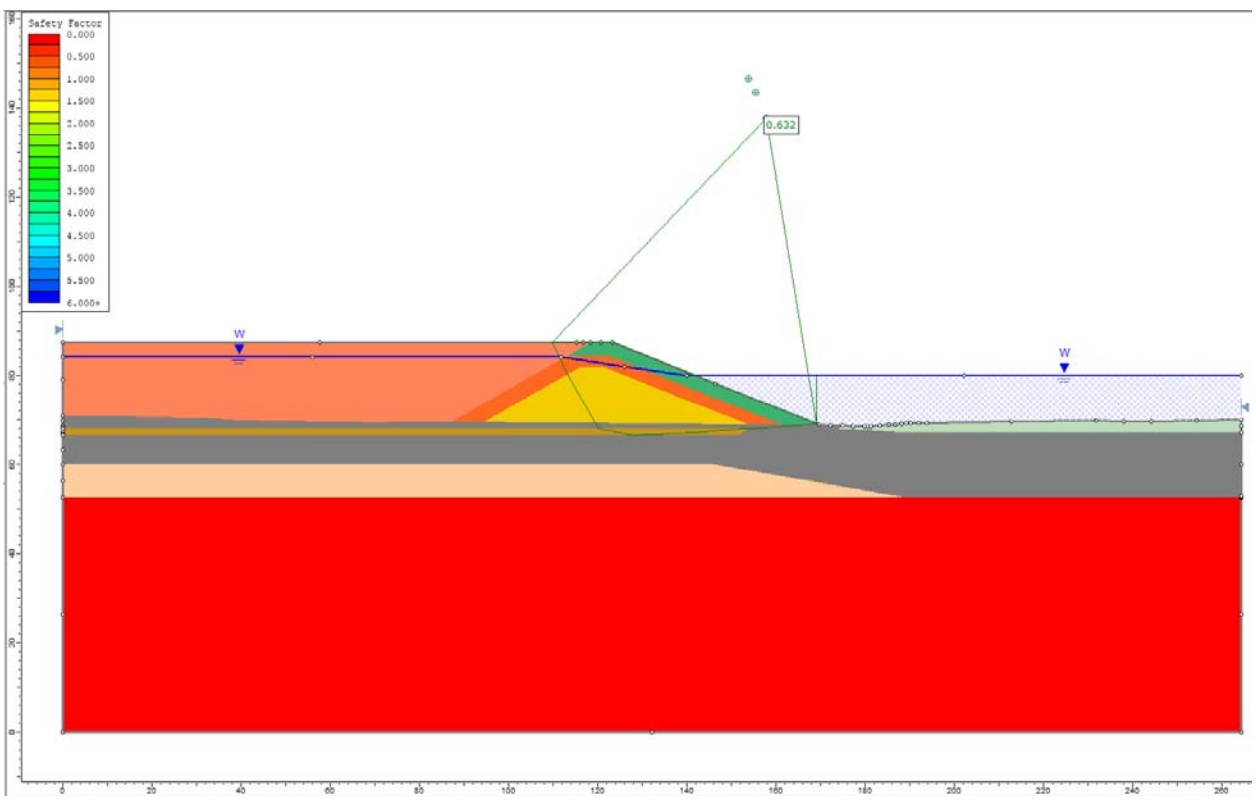


Figure 45.4.6 – Slide Solution Using the Janbu Method

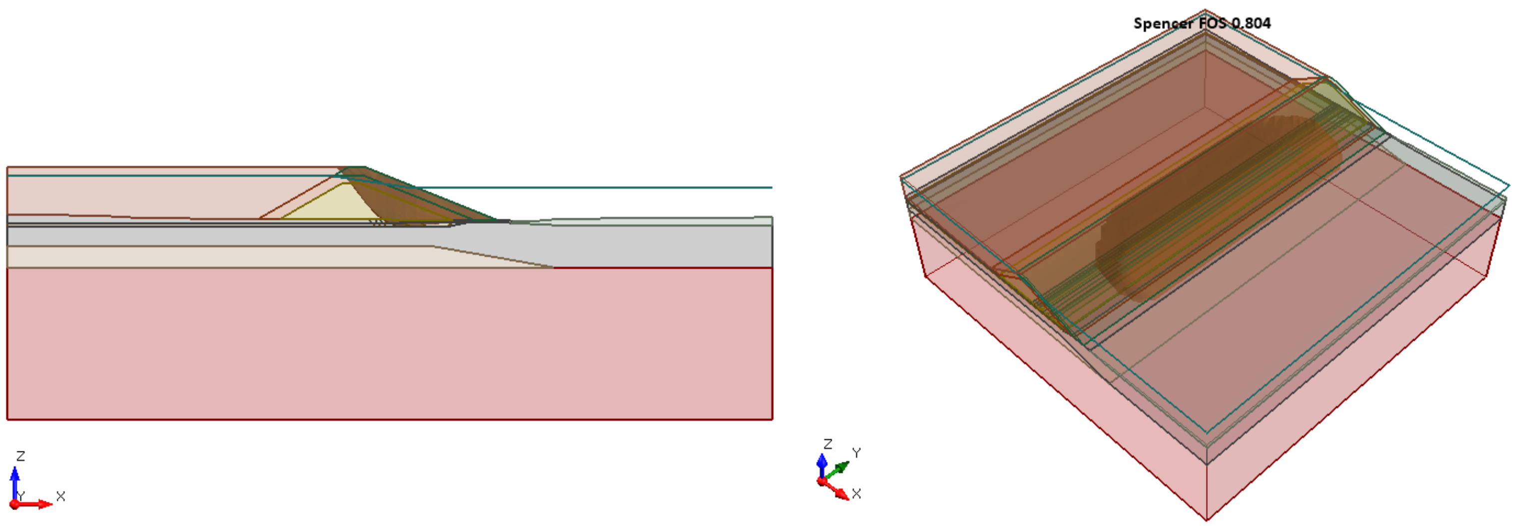


Figure 45.4.7 – Slide3 Solution Using the Spencer Method

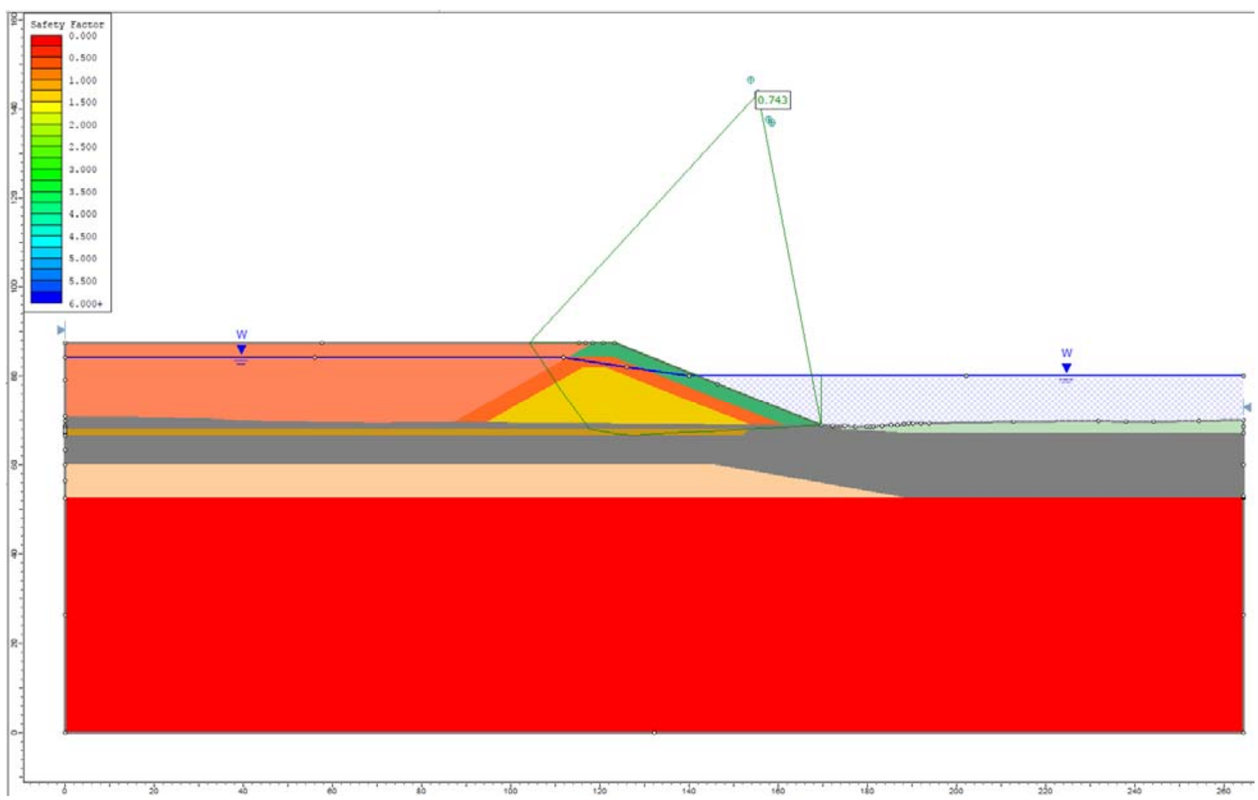


Figure 45.4.8 – Slide Solution Using the Spencer Method

2D extruded slope, (5) materials, (1) Shear/Normal Function Material, ellipsoidal with SA

46.1 Introduction

This example is a 2D non-homogeneous extruded slope.

46.2 Problem Description

The geometry in the XZ plane is shown in Figure 46, which will be extruded 200 m in the Y direction to create the 3D slope. The material properties for the Mohr-Coulomb materials and the Shear/Normal Function material can be found in Tables 46.1 and 46.2 respectively.

46.3 Geometry and Properties

Table 46.1: Material Properties for Mohr-Coulomb Materials

Material	γ (kN/m^3)	c´ (kN/m^2)	φ´ (deg.)
Core	20.5	0	35
Tailings	18	0	30
Hard Glaciolacustrine	20	0	28
Basal Till	21	0	33

Table 46.2: Material Properties for Rock – the Shear/Normal Material

Normal (kPa)	Shear (kPa)	Normal (kPa)	Shear (kPa)
0	0	482.6	445
3.4	5.4	689.5	612.8
24.1	30.3	1103	933.8
41.4	49.1	4826	3494.9
82.7	91.4	6894.8	4802.8
275.8	269.3		

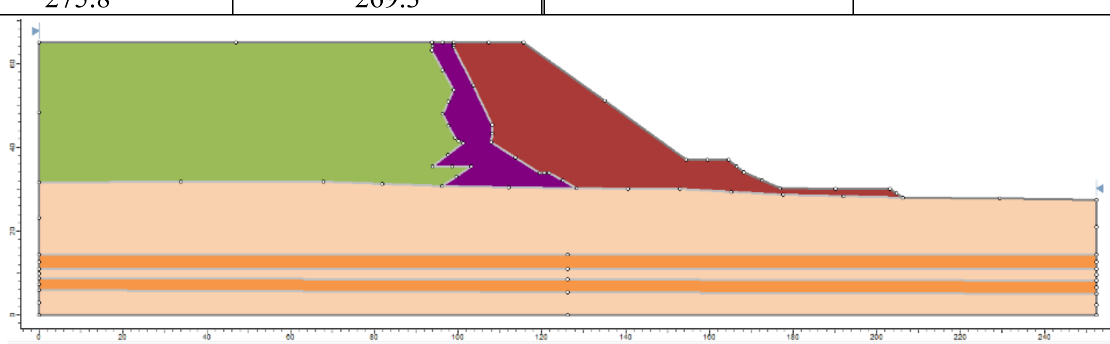


Figure 46

46.4 Results

Table 46.4.1: Safety Factors Using Slide3 and Slide 7.0

Method	Slide3	Slide 7.0
Bishop	1.68	1.723
GLE	1.718	1.689
Janbu	1.654	1.639
Spencer	1.725	1.697

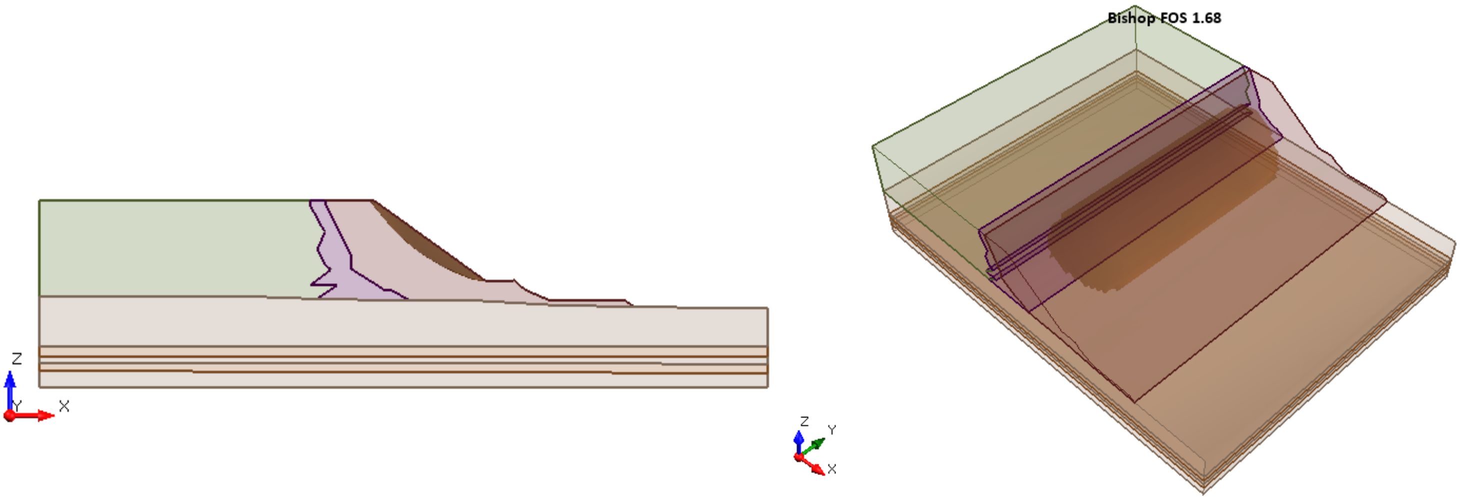


Figure 46.4.1 – Slide3 Solution Using the Bishop Method

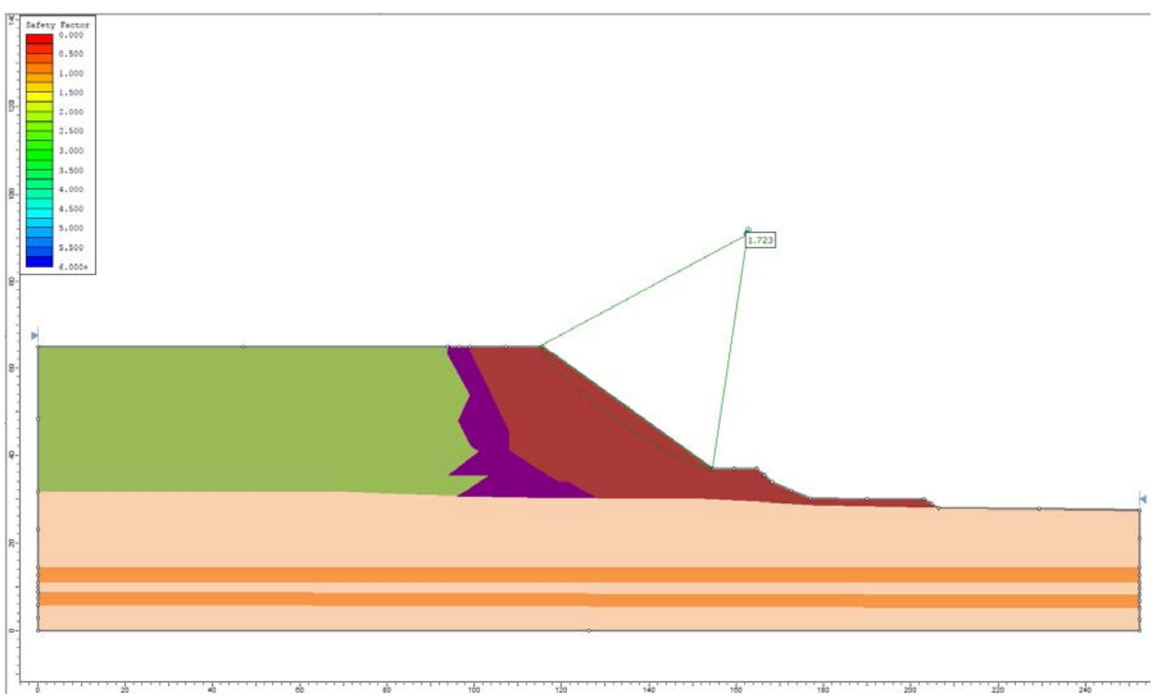


Figure 46.4.2 – Slide Solution Using the Bishop Method

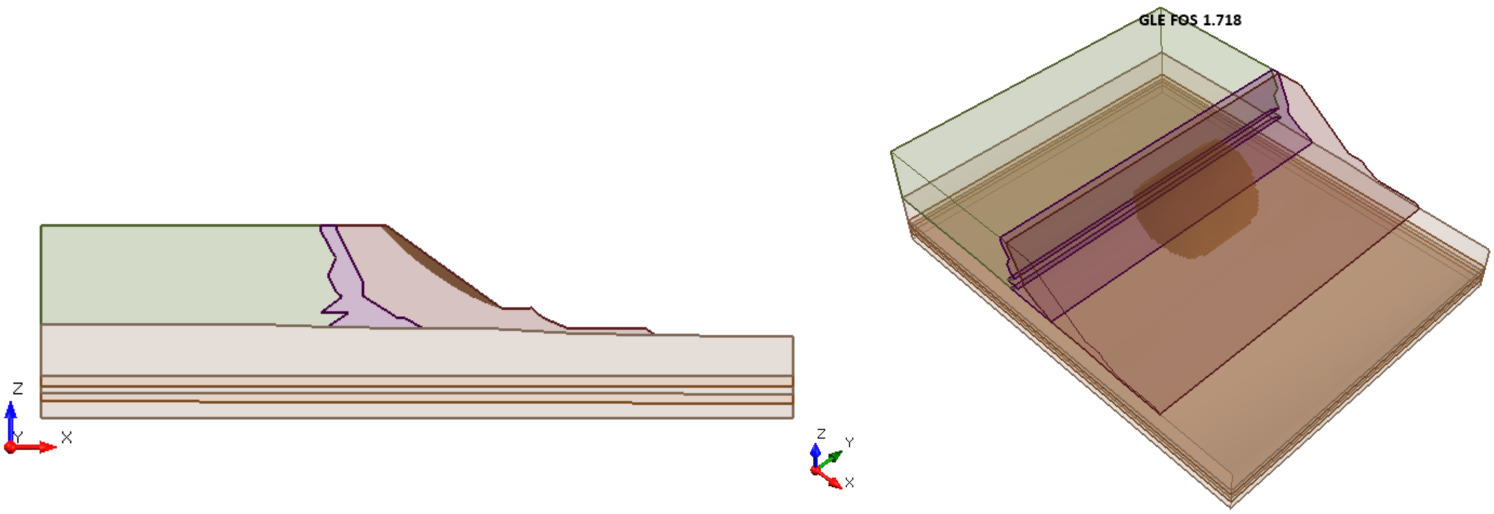


Figure 46.4.3 – Slide3 Solution Using the GLE Method

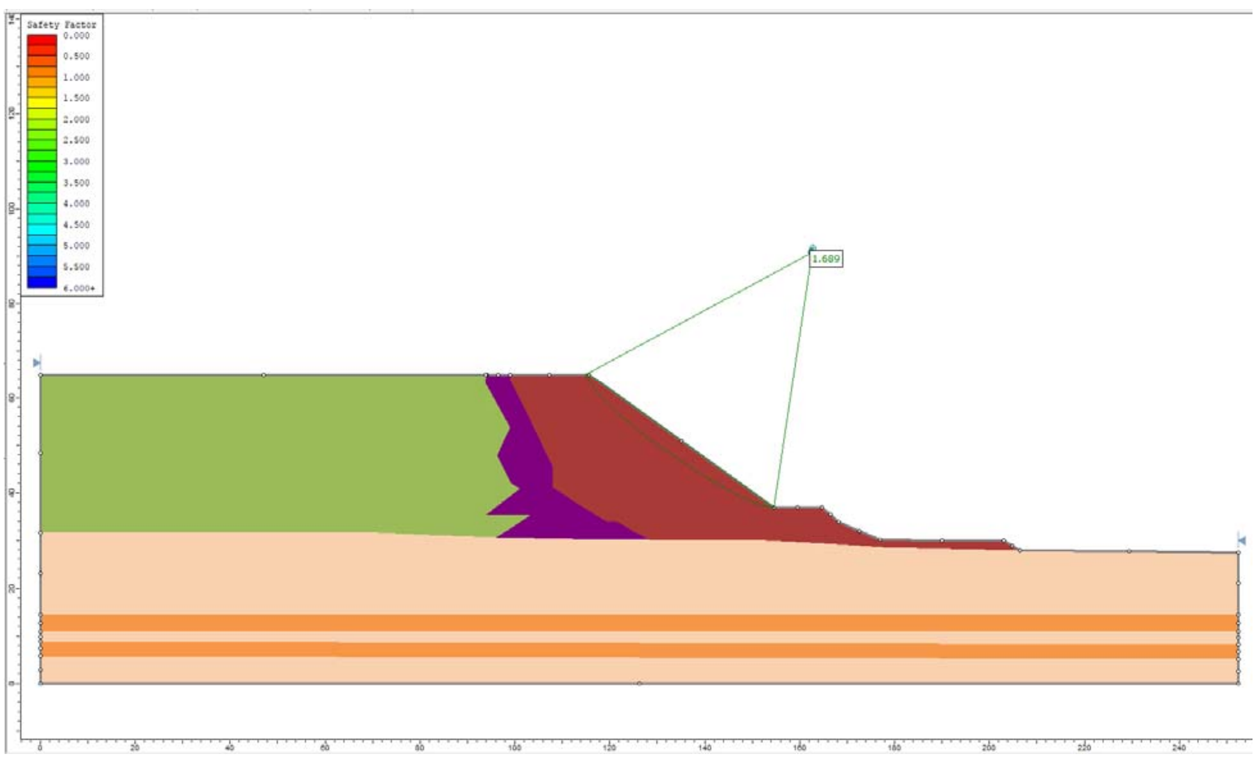


Figure 46.4.4 – Slide Solution Using the GLE Method

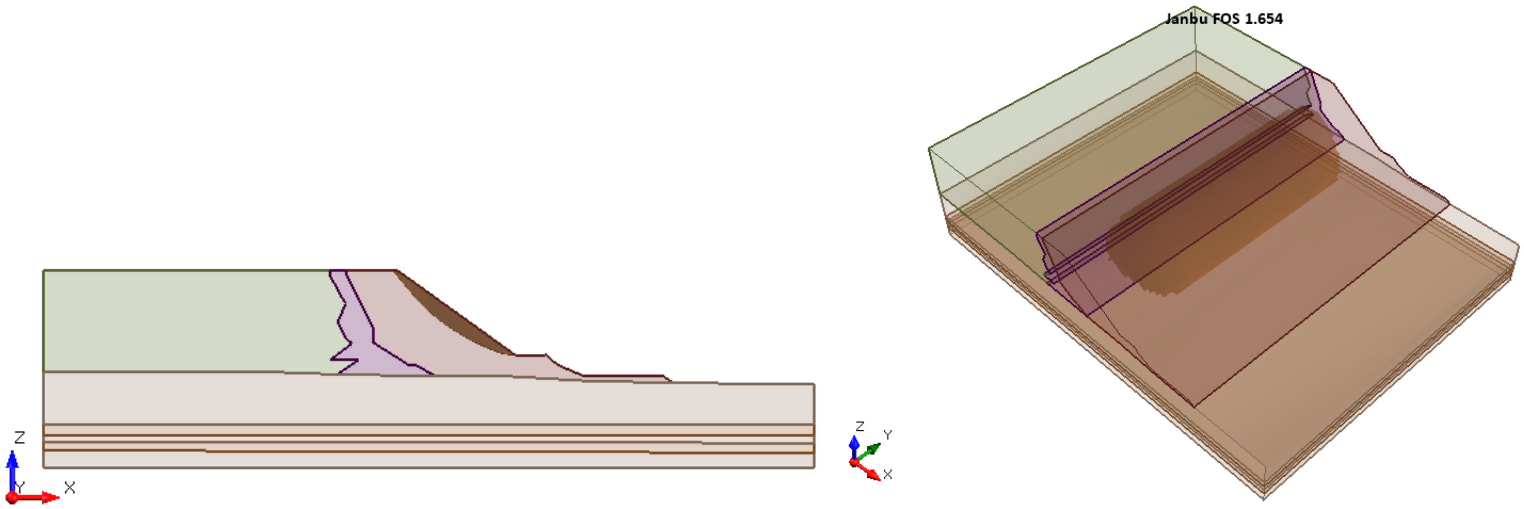


Figure 46.4.5 – Slide3 Solution Using the Janbu Method

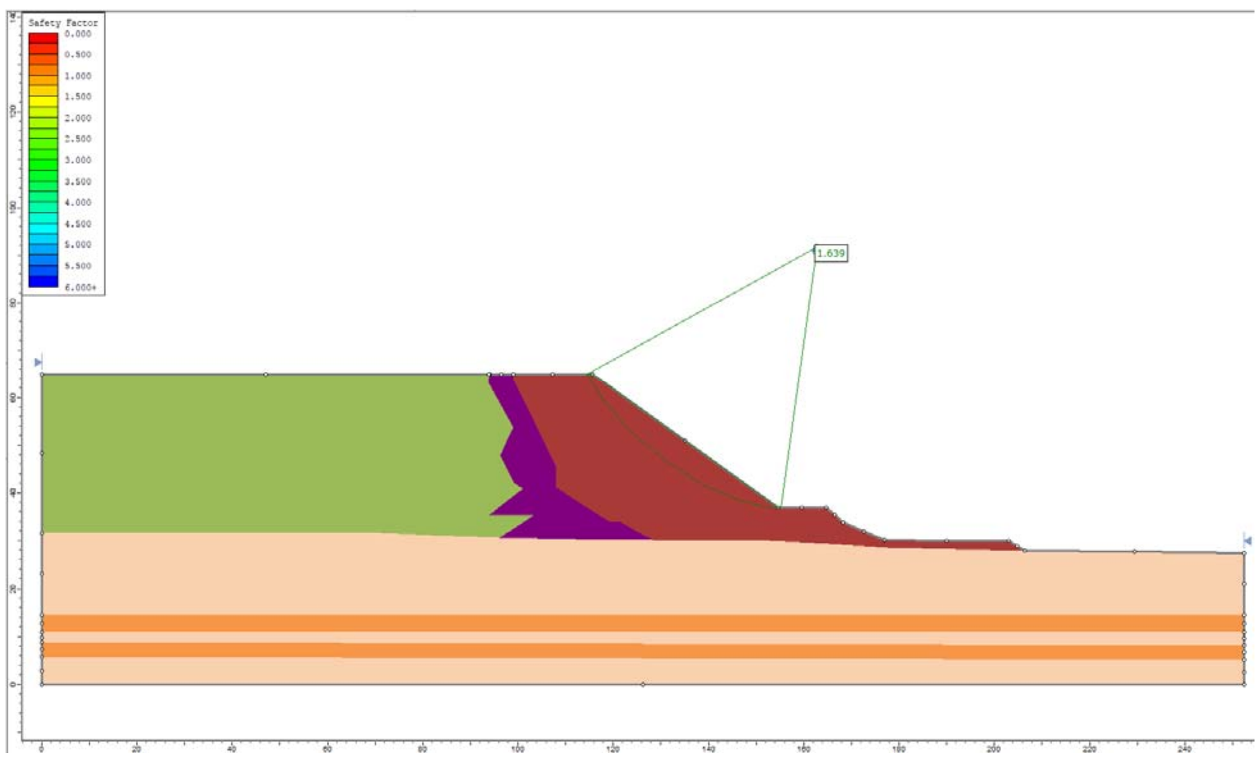


Figure 46.4.6 – Slide Solution Using the Janbu Method

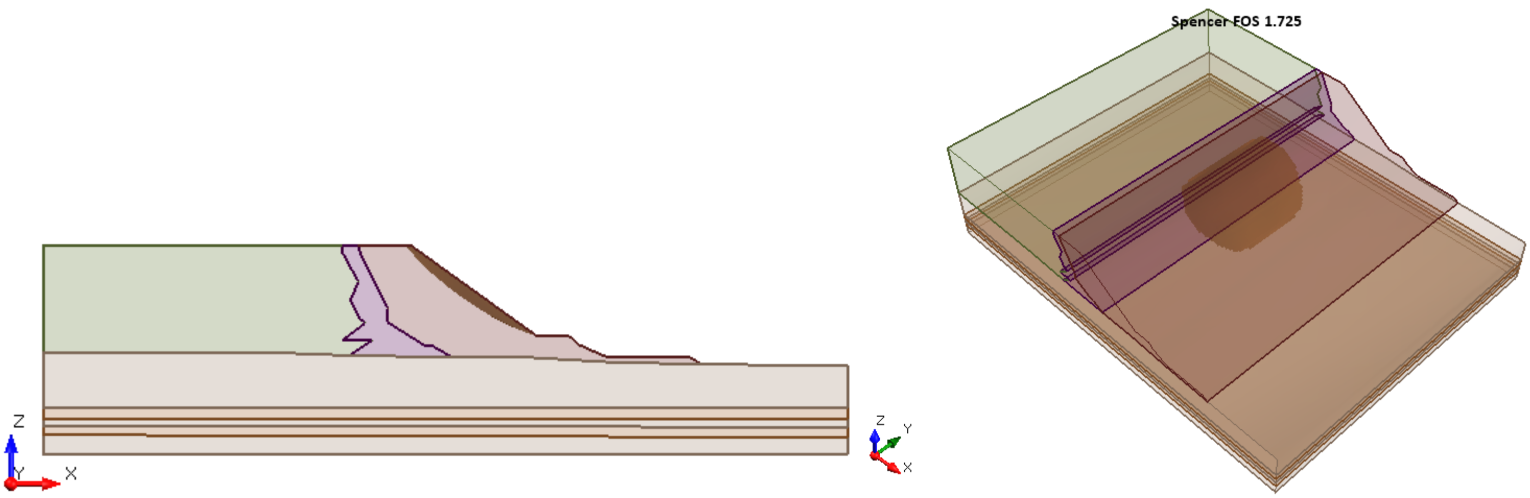


Figure 46.4.7 – Slide3 Solution Using the Spencer Method

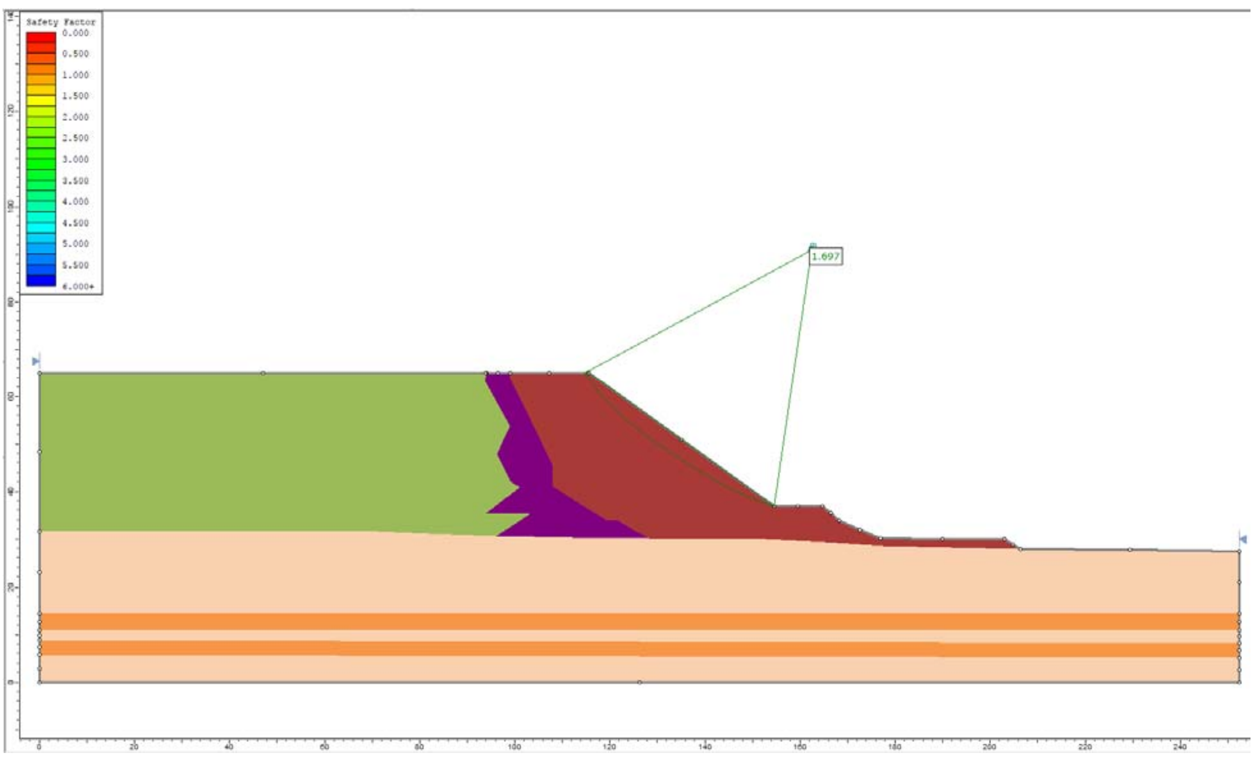


Figure 46.4.8 – Slide Solution Using the Spencer Method

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