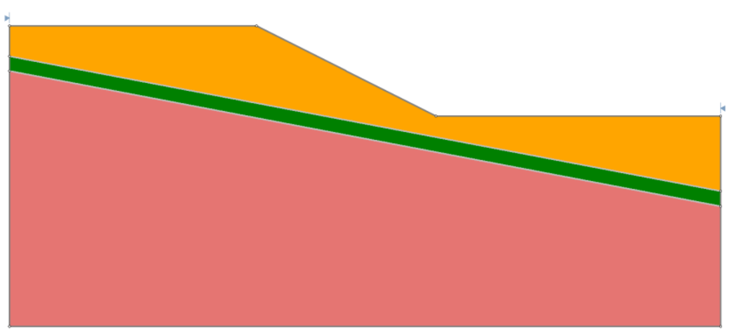
2D Swept Verification

Slide3, RS3, Slide, and RS2

Rocscience Inc.



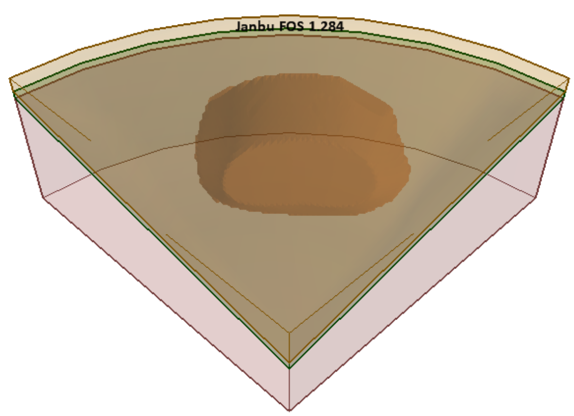


Table of Contents

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:

- 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 Swept 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 swept models, and has its own corresponding index. Both the verification and the index for 2D swept models are separate from the other two model types.

A 2D swept model is a given 2D cross section which has been swept along a polyline to create a 3D shape that is not a simple extrusion. These models are also not considered purely 3D models, since the 2D cross section is consistent throughout the model. Examples of 2D swept models include turning corners of various degrees, both sharp and circular, as well as other shapes, such as an L-shaped sweep. 2D swept models will have the 2D cross section, as well as multiple materials, water tables, and loading swept across the entire model. Elements such as micropile supports will be placed throughout the model, not swept to create a wall of support.

2D swept models often come in groups that sweep the same cross sections across a number of different corners or polylines. These groups will generally include a 2D extruded baseline slope, to compare the safety factor of the extrusion to other shapes. These ‘extruded baselines’ are shown in this verification and directly before a set of 2D swept models in the verification, instead of in the 2D extruded verification for the sake of clarity.

2D Swept Verification #1

2D swept baseline extruded, weak layer, ellipsoidal with SA

1.1 Introduction

This is a 2D cross section that has undergone a number of turning corners and circular turns. This problem is a straight extrusion of the model.

1.2 Problem Description

The model's cross section is shown in Figure 1, which will be extruded 95m in the Y direction. This model has a weak layer whose material properties are shown in Table 1.1, along with the material properties of the soil. The safety factor is required, and is found using a cuckoo search with surface optimization on Slide3.

1.3 Geometry and Properties

Table 1.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	28.5	20	19
Weak Layer	0	10	18.5
Infinite Strength	10000	65	19

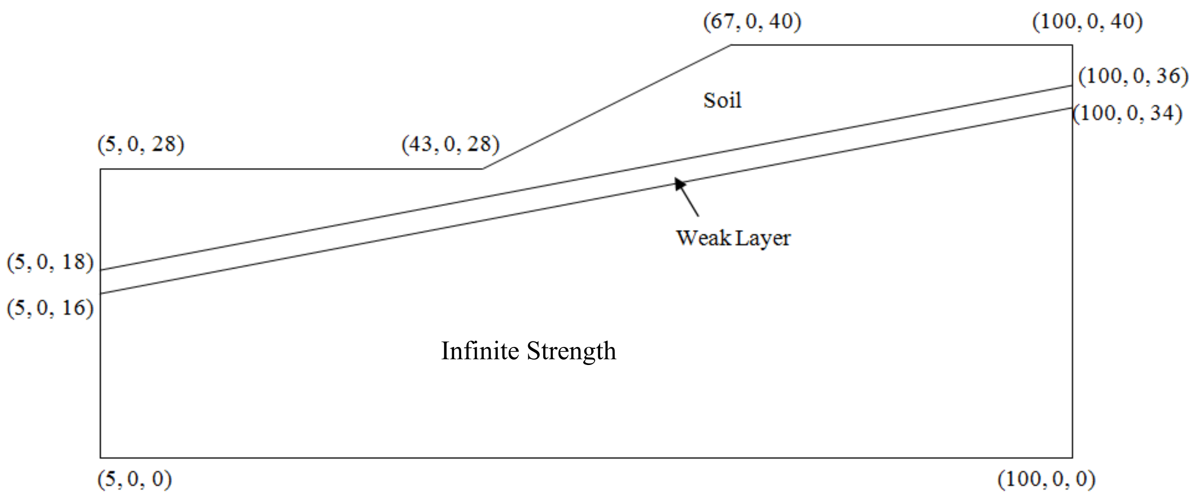


Figure 1

1.4 Results

Table 1.4.1: Safety Factors 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>1.875</td><td>1.725</td><td rowspan="4">2.17</td><td rowspan="4">1.94</td></tr>
<tr><td>GLE</td><td>1.98</td><td>1.826</td></tr>
<tr><td>Janbu</td><td>1.857</td><td>1.676</td></tr>
<tr><td>Spencer</td><td>2.016</td><td>1.845</td></tr>
</table>

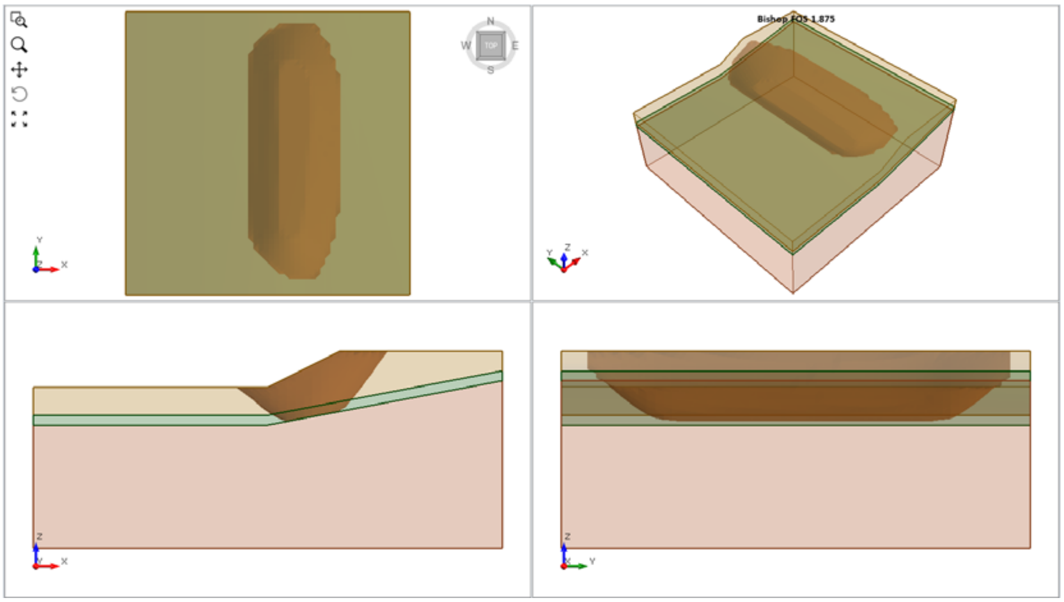


Figure 1.4.1 – Slide3 Solution Using the Bishop Method

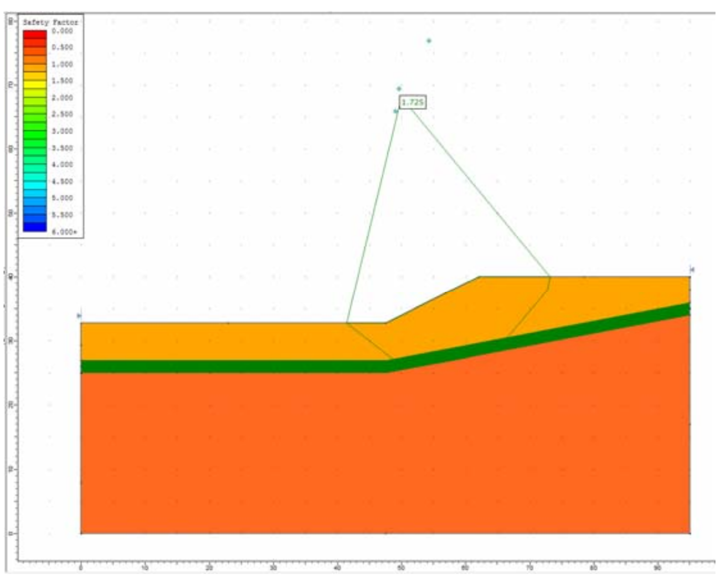


Figure 1.4.2 – Slide Solution Using the Bishop Method

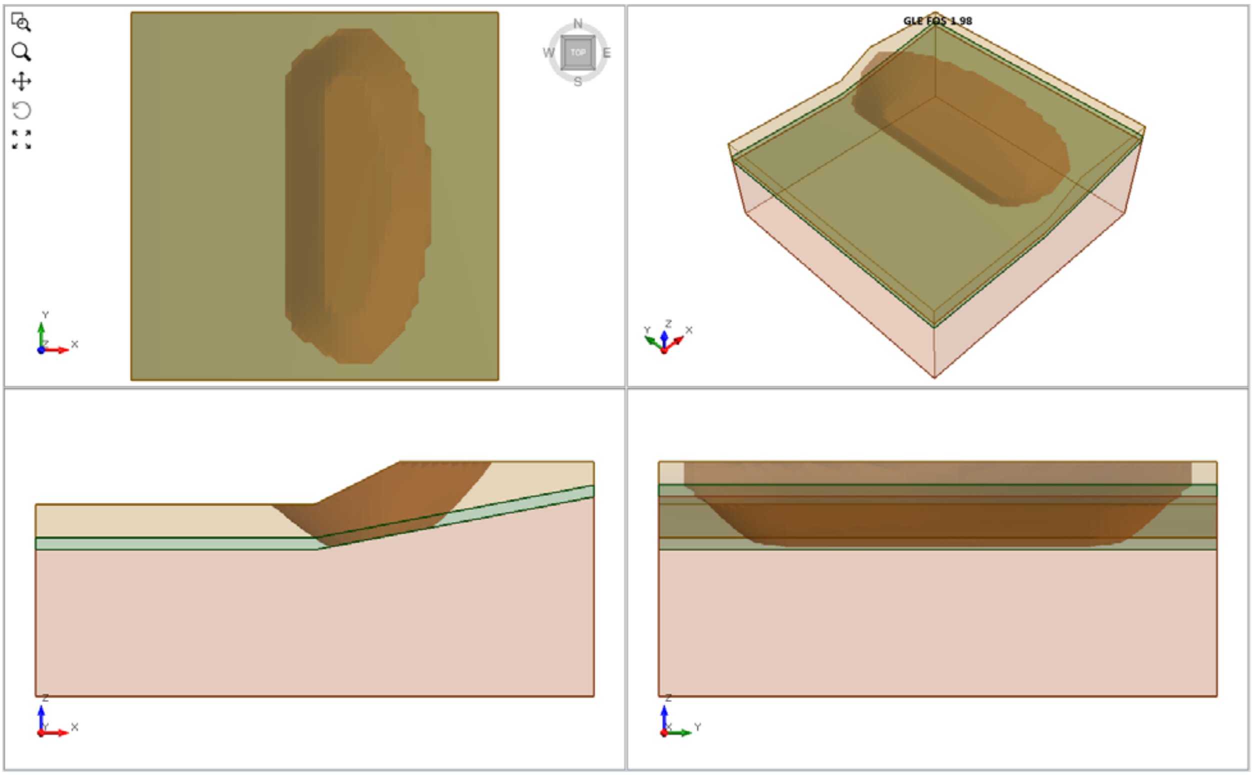


Figure 1.4.3 – Slide3 Solution Using the GLE Method

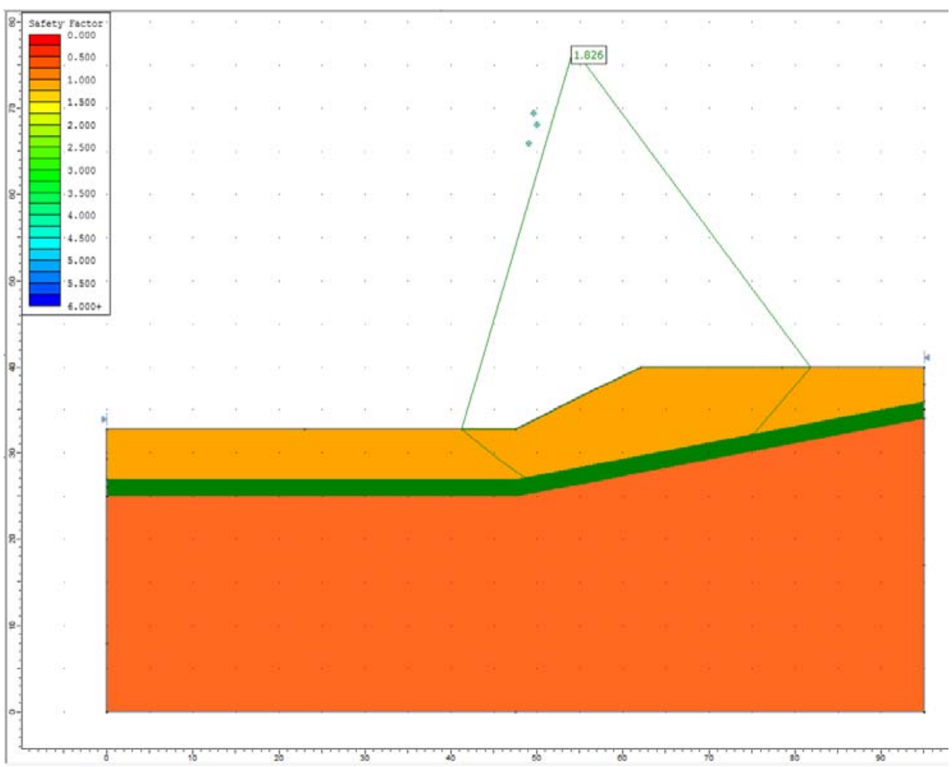


Figure 1.4.4 – Slide Solution Using the GLE Method

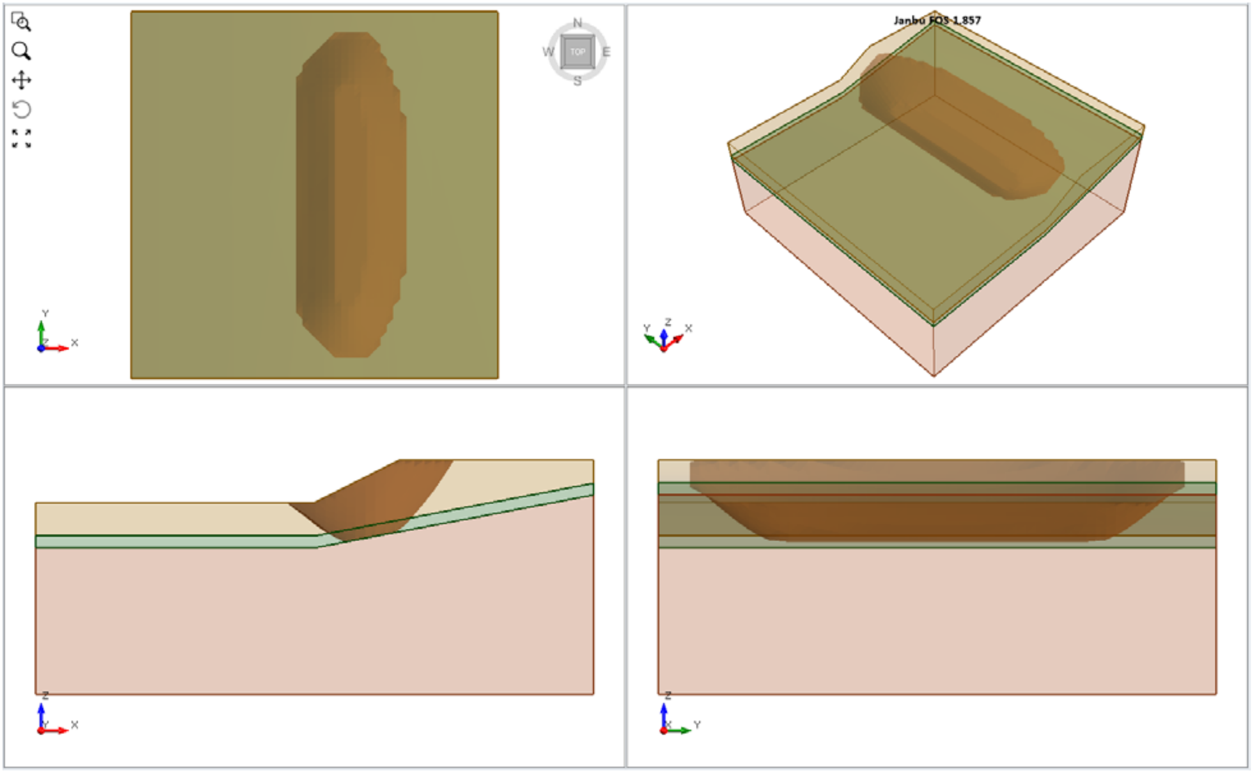


Figure 1.4.5 – Slide3 Solution Using the Janbu Method

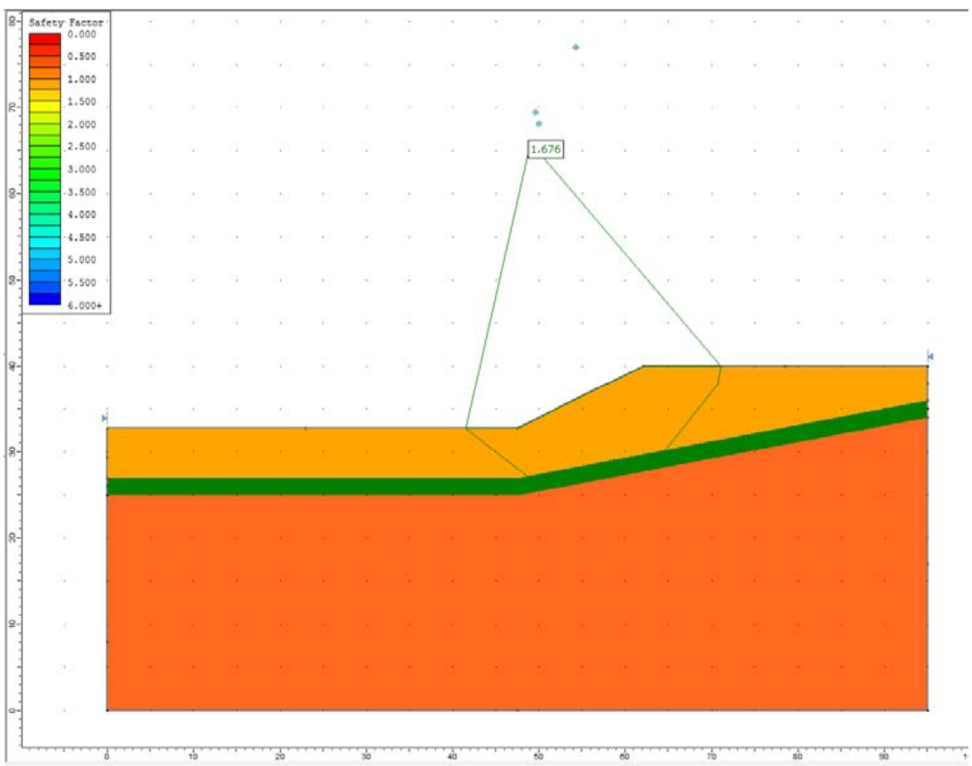


Figure 1.4.6 – Slide Solution Using the Janbu Method

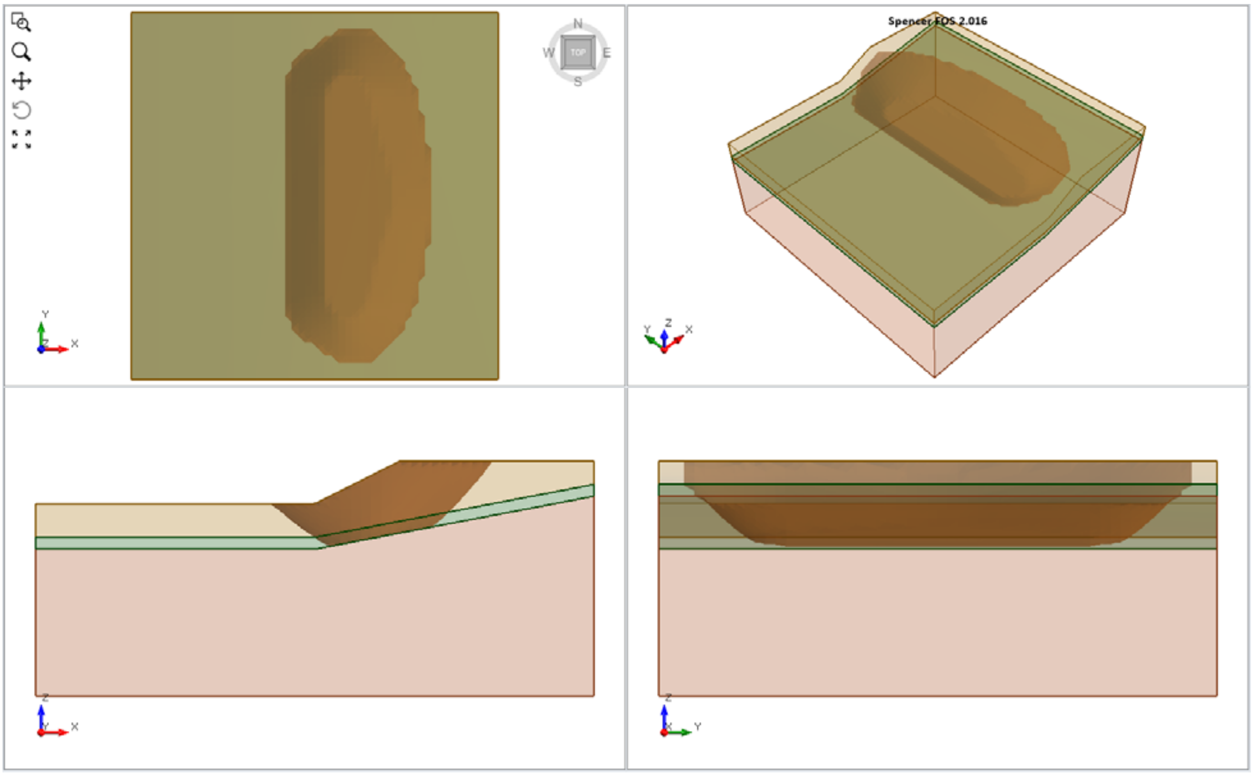


Figure 1.4.7 – Slide3 Solution Using the Spencer Method

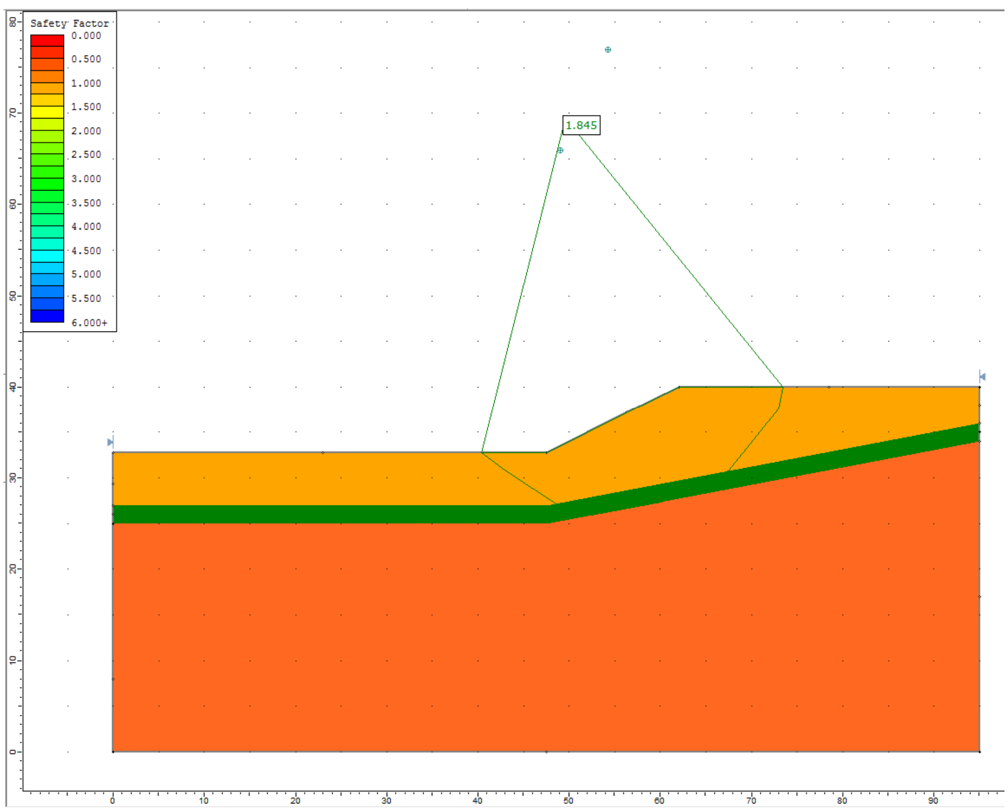


Figure 1.4.8 – Slide Solution Using the Spencer Method

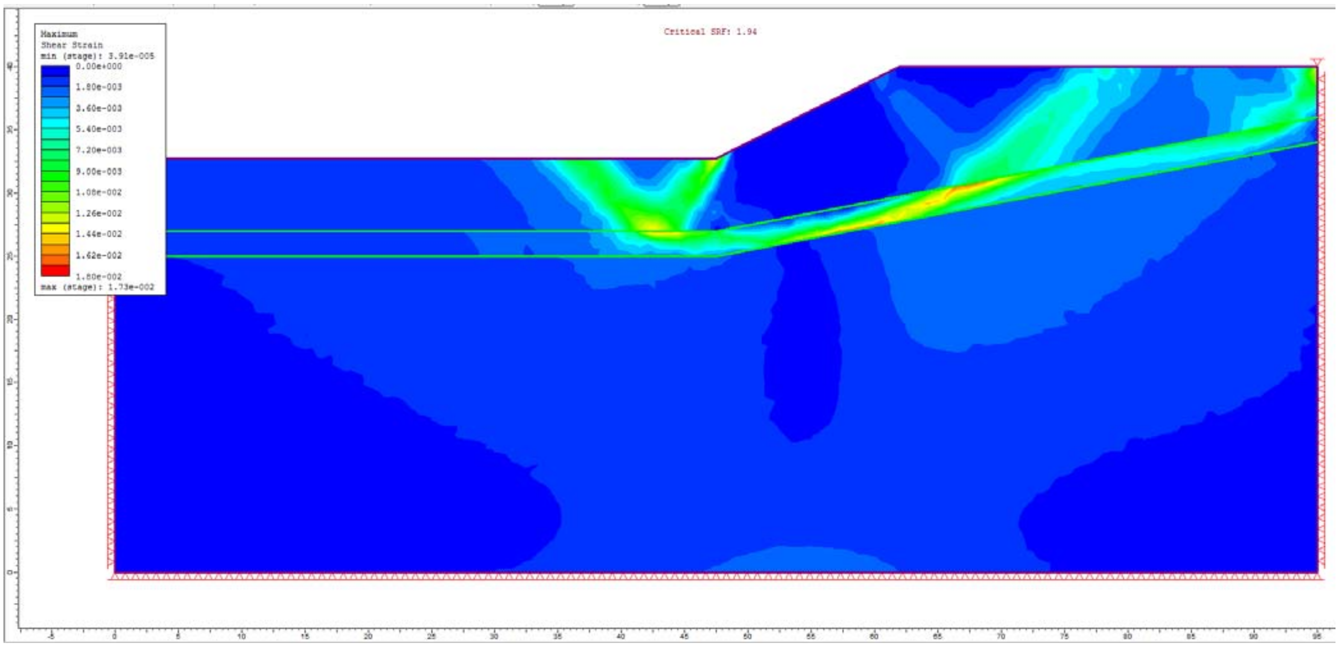


Figure 1.4.9 – RS2 Maximum Shear Strain

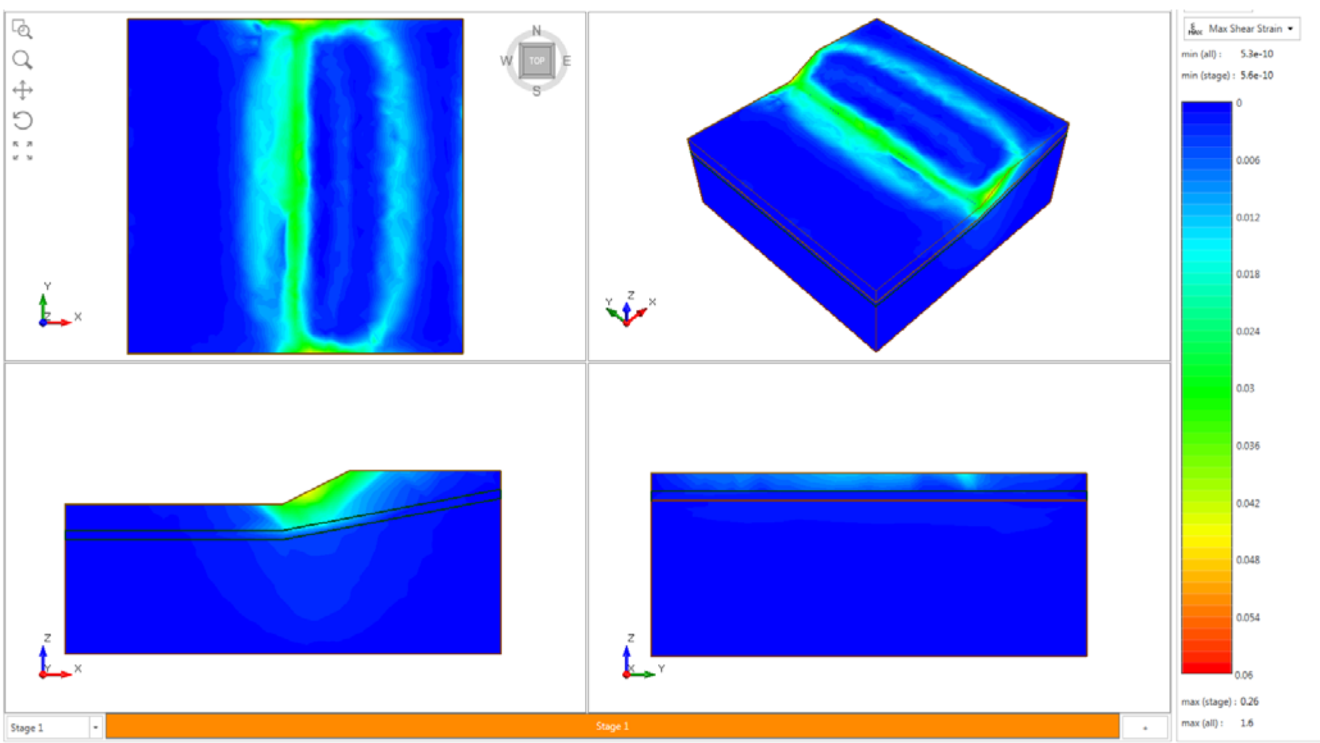


Figure 1.4.10 – RS3 Maximum Shear Strain

2D Swept Verification #2

2D swept, 90° turn, concave, weak layer, ellipsoidal with SA

2.1 Introduction

This is a 2D cross section that has undergone a number of turning corners and circular turns. This problem is the 90 degree turn of the model.

2.2 Problem Description

The model's cross section is shown in Figure 2(a) and the top view of the model is shown in Figure 2(b). This model has a weak layer whose material properties are shown in Table 2.1, along with the material properties of the soil. The safety factor is required, and is found using a cuckoo search with surface optimization on Slide3.

2.3 Geometry and Properties

Table 2.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	28.5	20	19
Weak Layer	0	10	18.5
Infinite Strength	10000	65	19

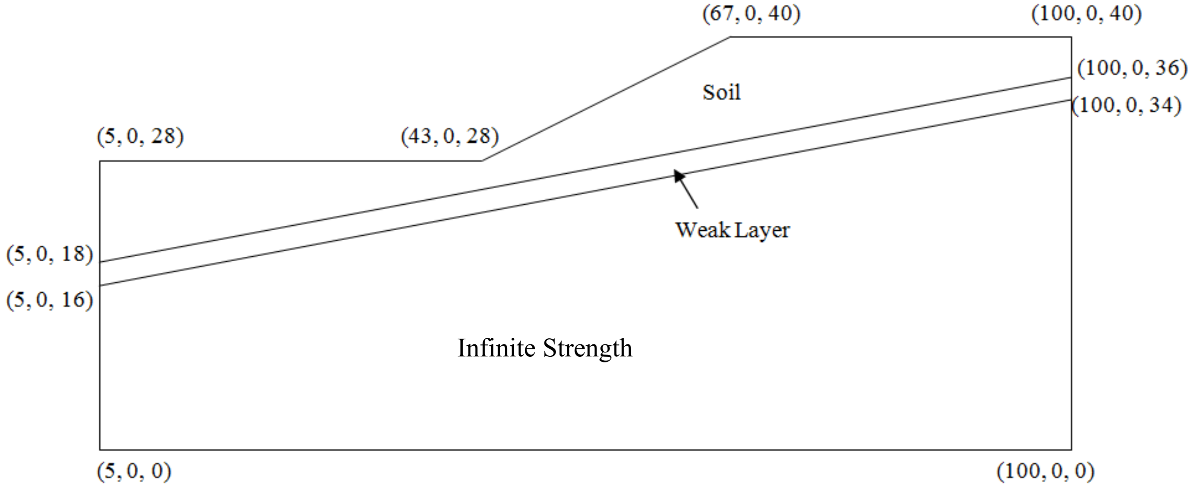


Figure 2(a)

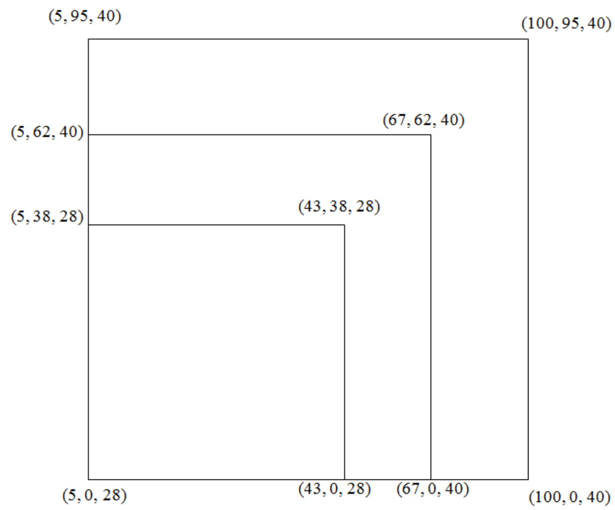


Figure 24(b)

2.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.236	1.046	1.48	1.15
GLE	1.29	1.064		
Janbu	1.218	1.030		
Spencer	1.306	1.078		

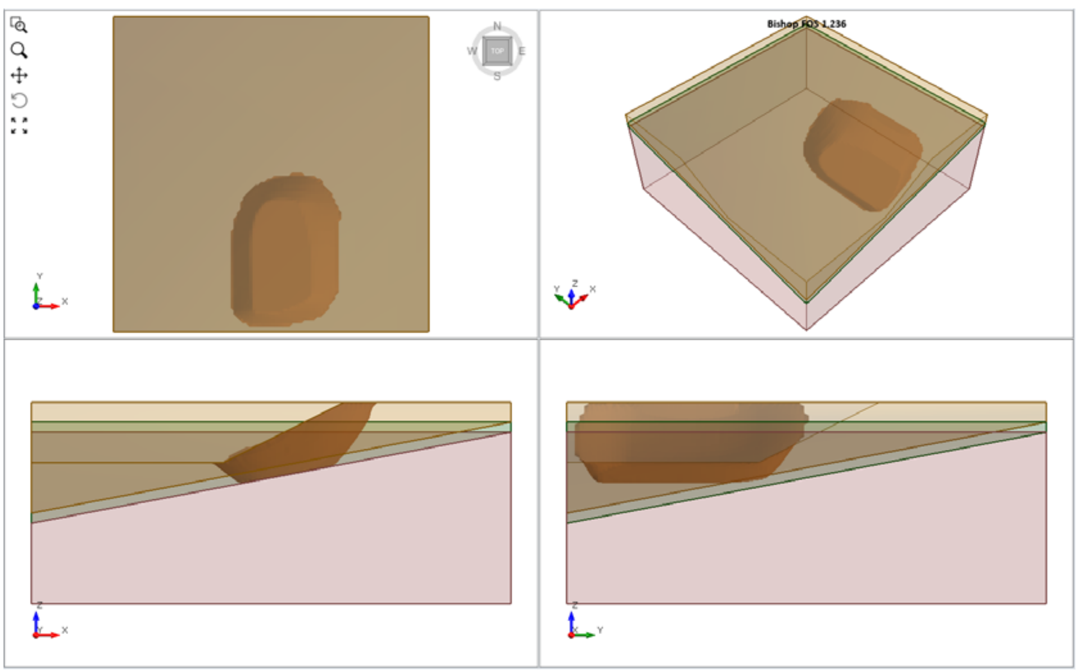


Figure 2.4.1 – Slide3 Solution Using the Bishop Method

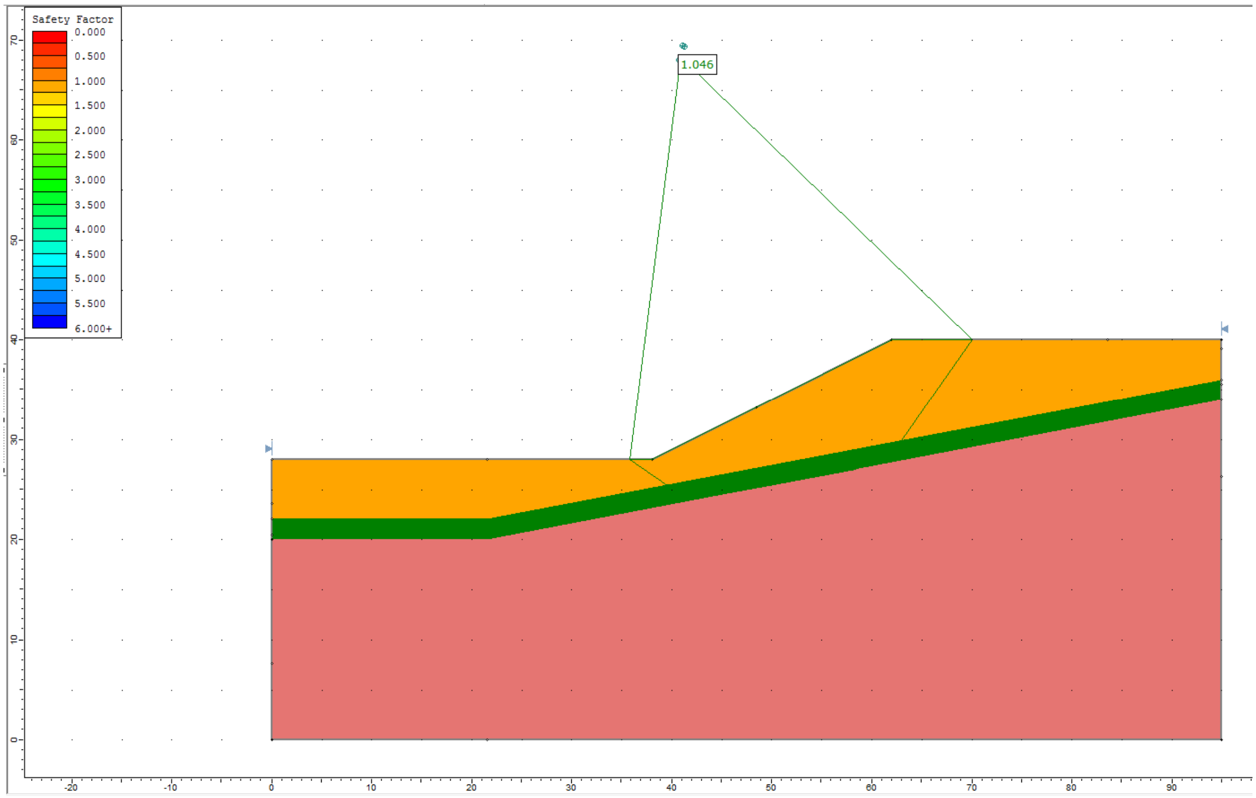


Figure 2.4.2 – Slide Solution Using the Bishop Method

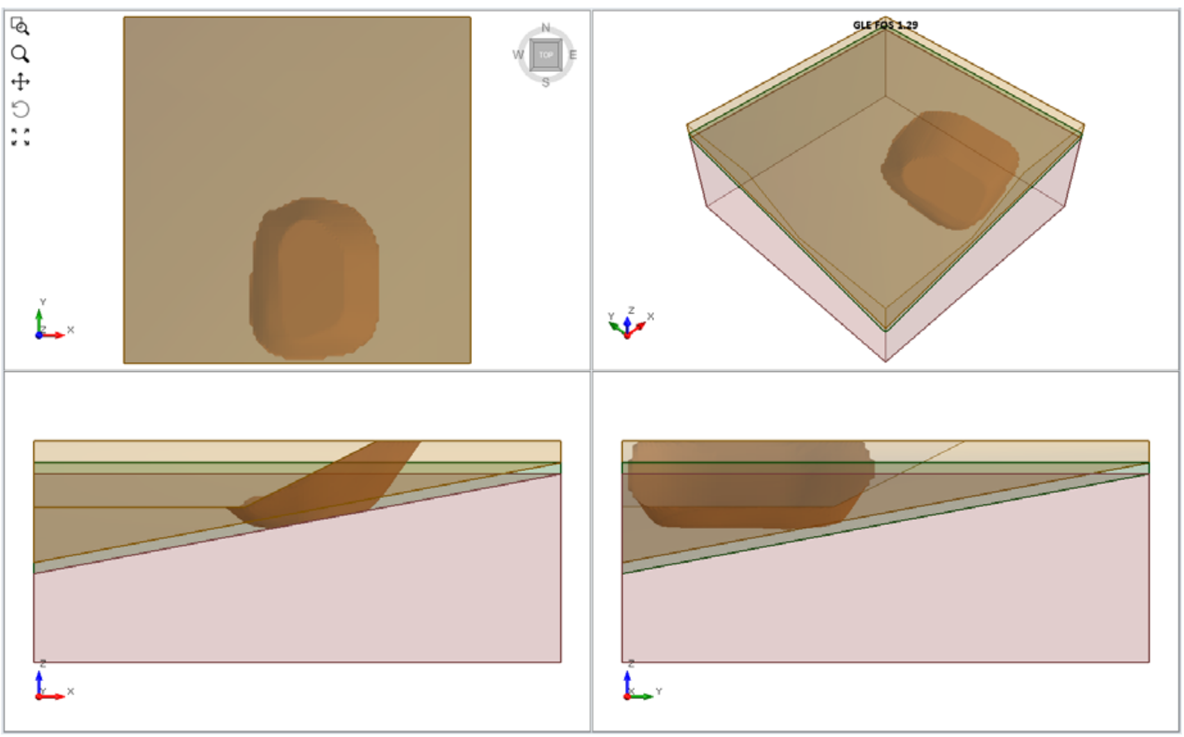


Figure 2.4.3 – Slide3 Solution Using the GLE Method

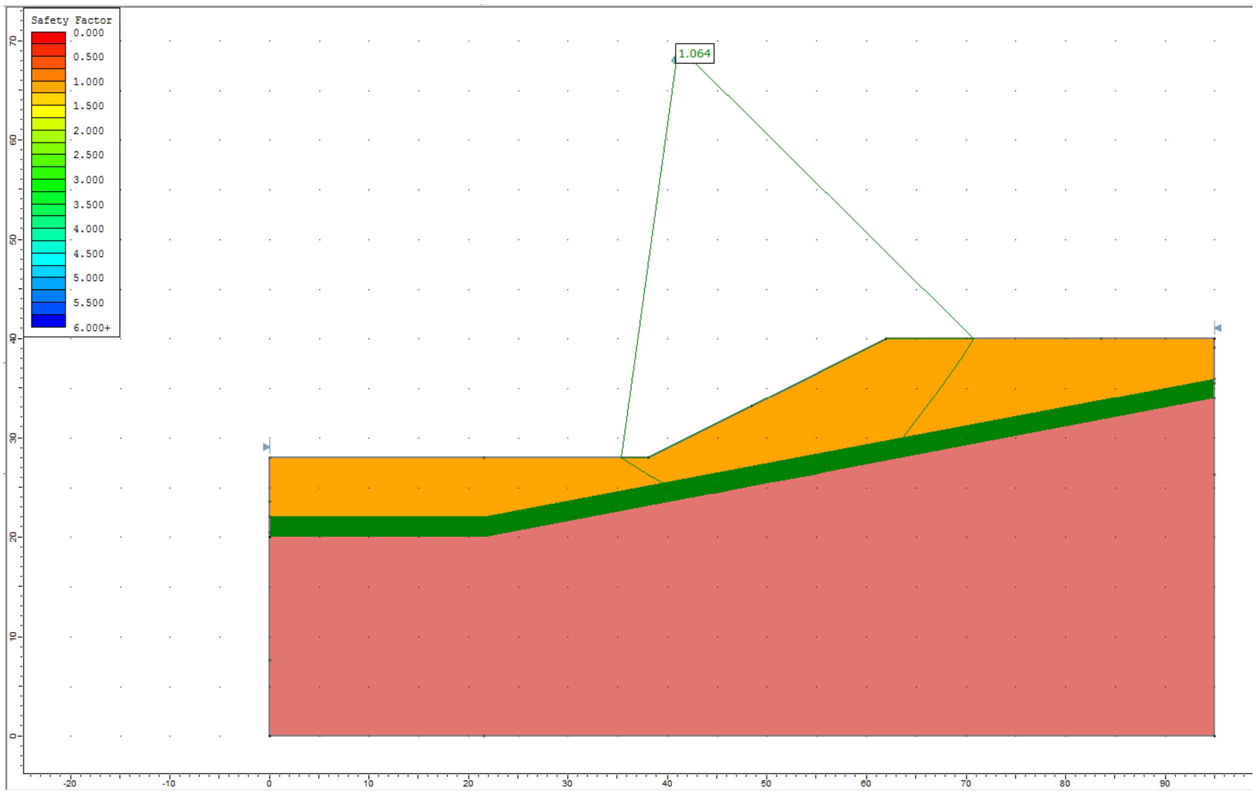


Figure 2.4.4 – Slide Solution Using the GLE Method

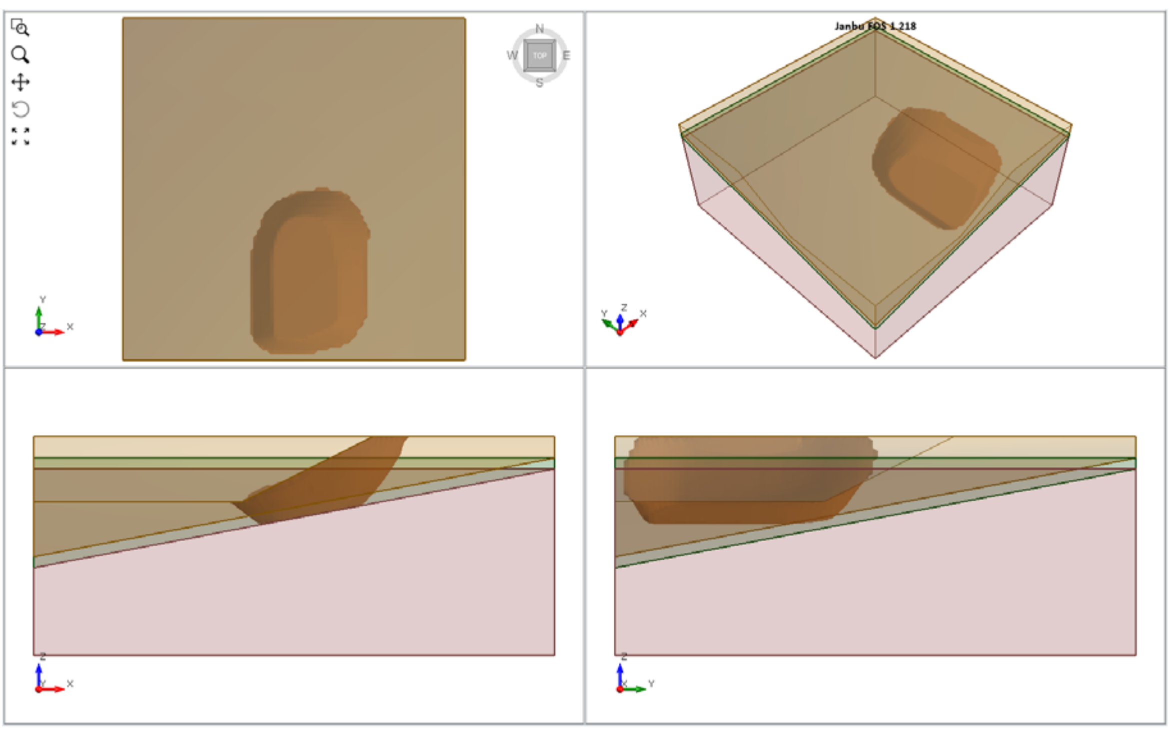


Figure 2.4.5 – Slide3 Solution Using the Janbu Method

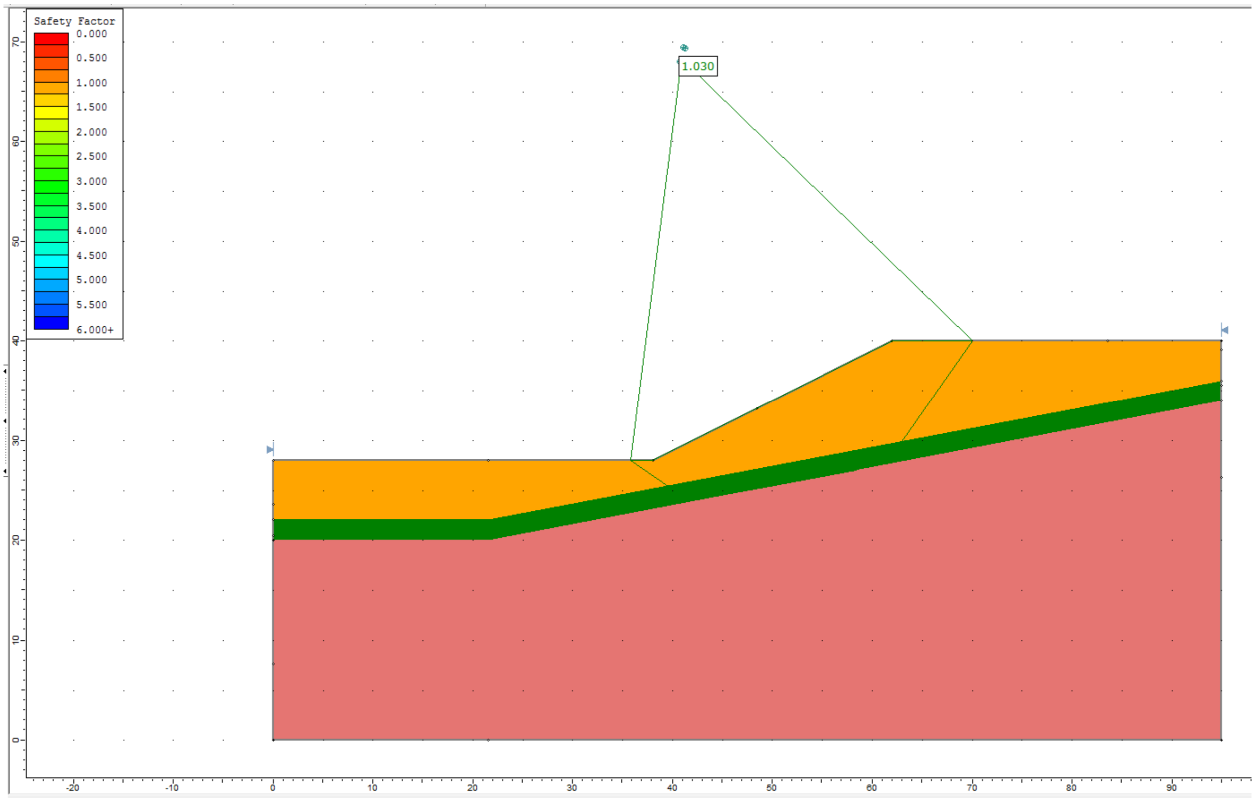


Figure 2.4.6 – Slide Solution Using the Janbu Method

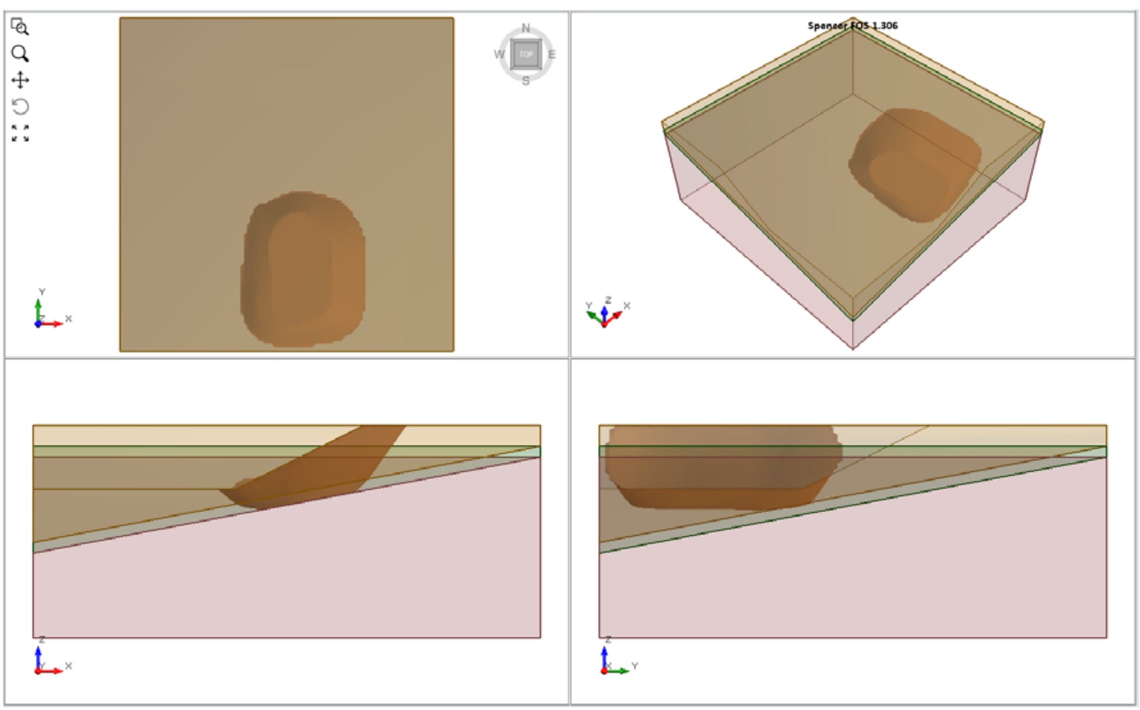


Figure 2.4.7 – Slide3 Solution Using the Spencer Method

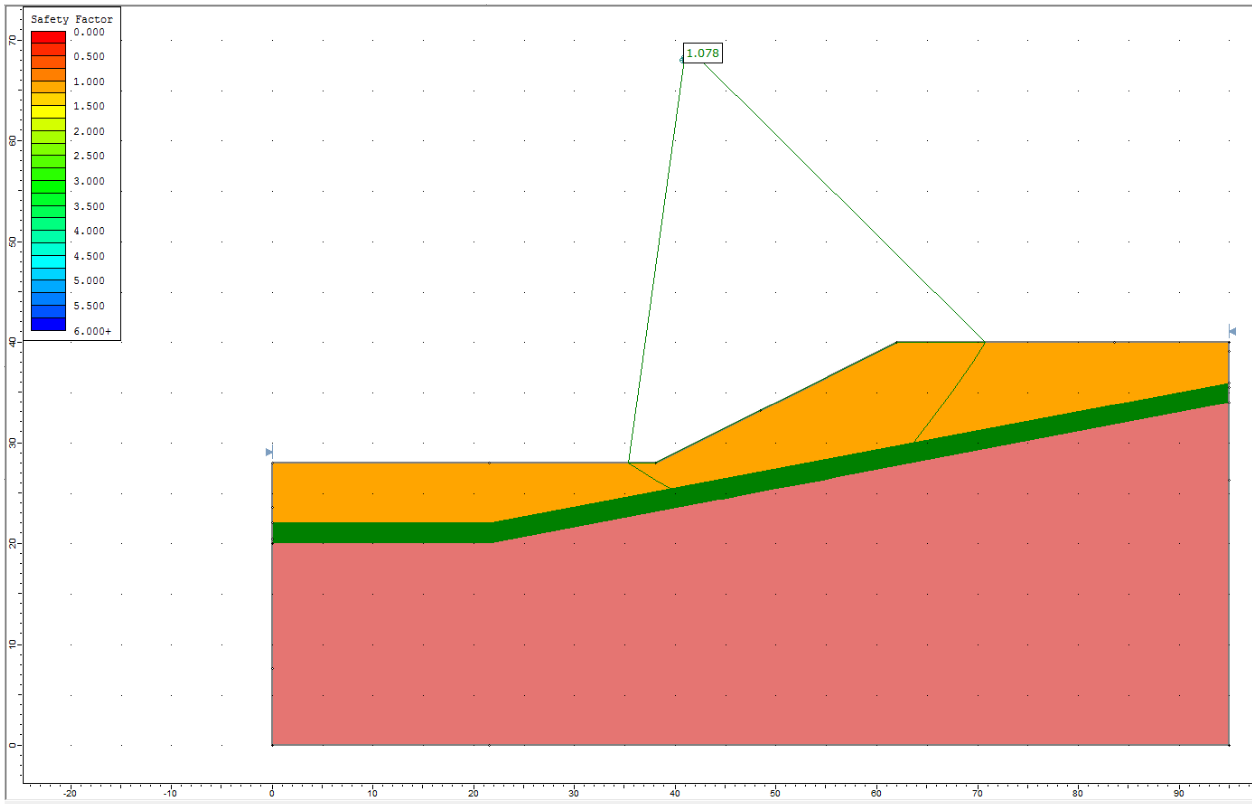


Figure 2.4.8 – Slide Solution Using the Spencer Method

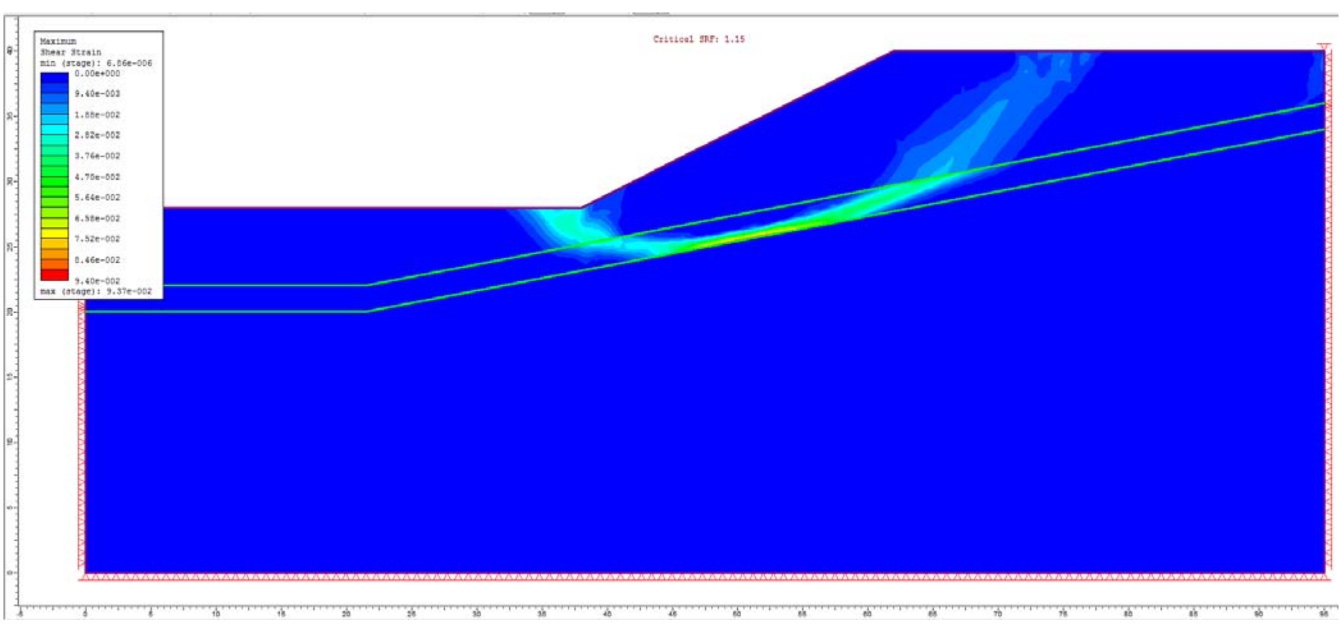


Figure 2.4.9 – RS2 Maximum Shear Strain

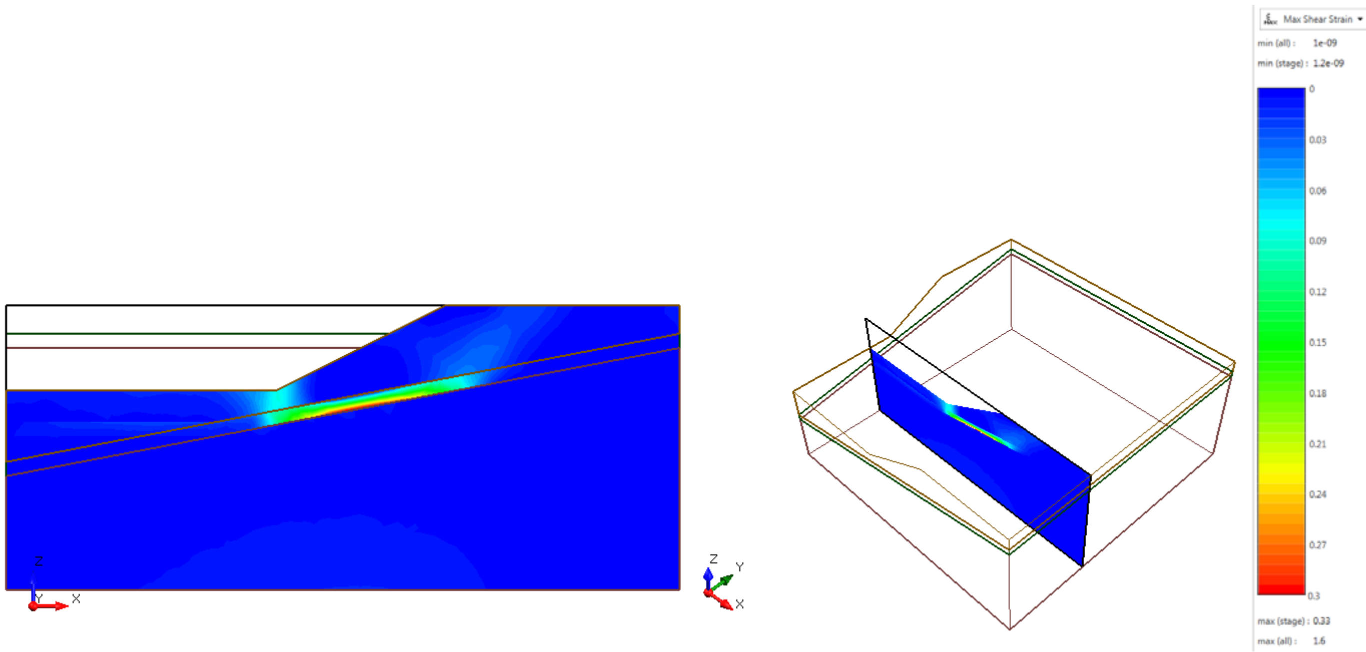


Figure 2.4.10 – RS3 Maximum Shear Strain

2D swept, 90° circular turn, concave, weak layer, ellipsoidal with SA

3.1 Introduction

This model is the same as problem #2, except the model is a 90 degree circular turn, which changes its 3D shape, but not the 2D cross section.

3.2 Problem Description

The model's cross section is shown in Figure 3(a) and the top view of the model is shown in Figure 3(b). This model has a weak layer whose material properties are shown in Table 3.1, along with the material properties of the soil. The safety factor is required, and is found using a cuckoo search with surface optimization on Slide3.

3.3 Geometry and Properties

Table 3.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	28.5	20	19
Weak Layer	0	10	18.5
Infinite Strength	10000	65	19

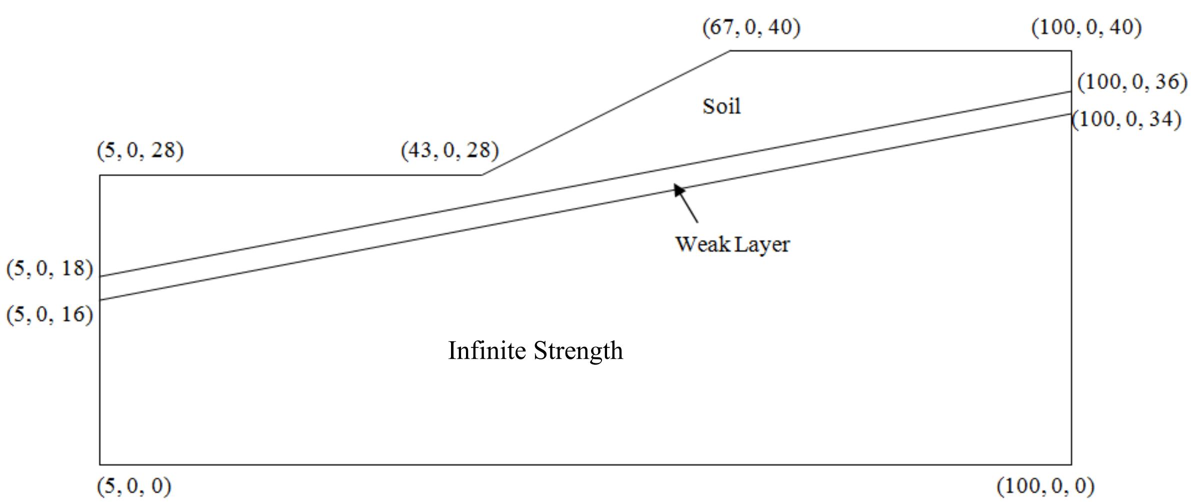


Figure 3(a)

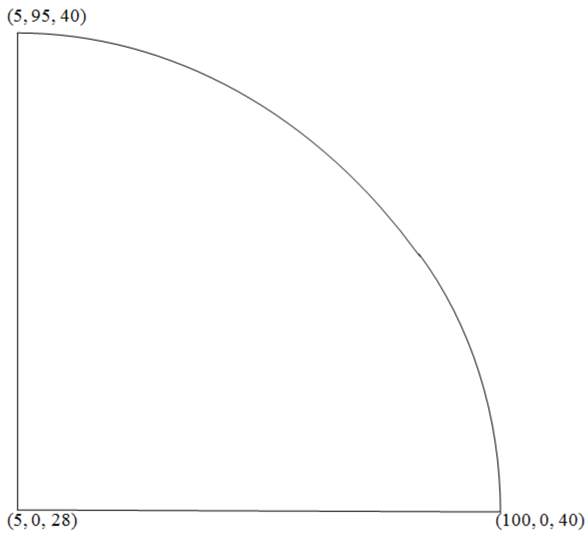


Figure 3(b)

3.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.283	1.046	1.47	1.19
GLE	1.326	1.065		
Janbu	1.265	1.030		
Spencer	1.344	1.082		

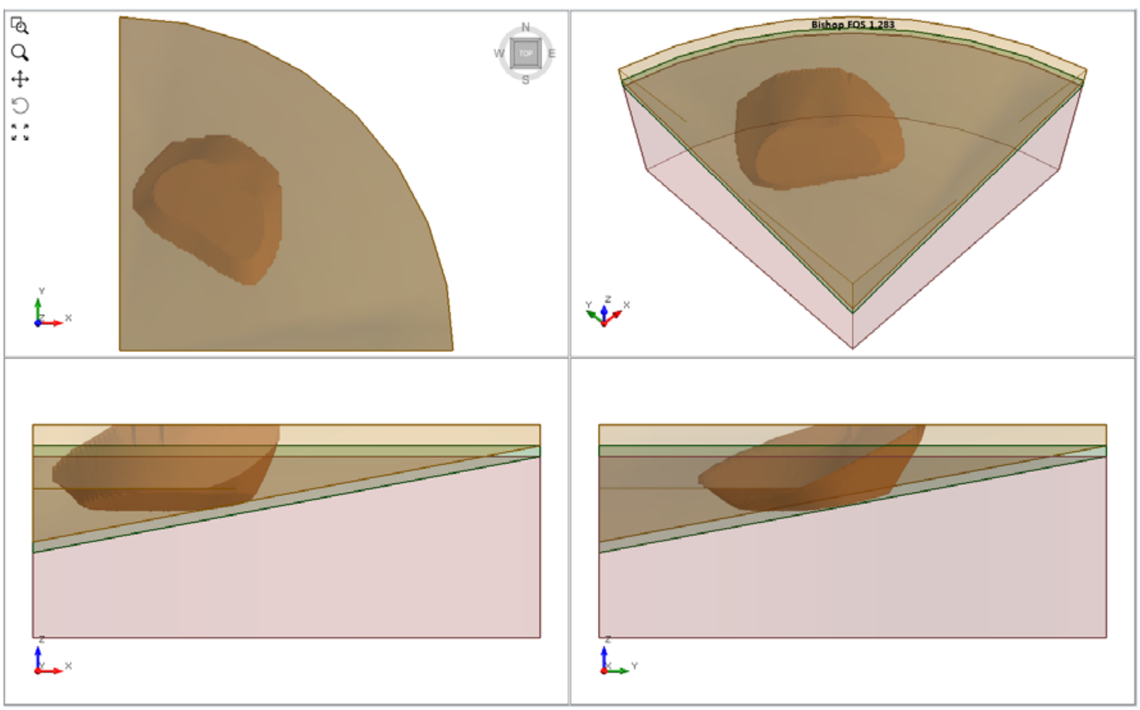


Figure 3.4.1 – Slide3 Solution Using the Bishop Method

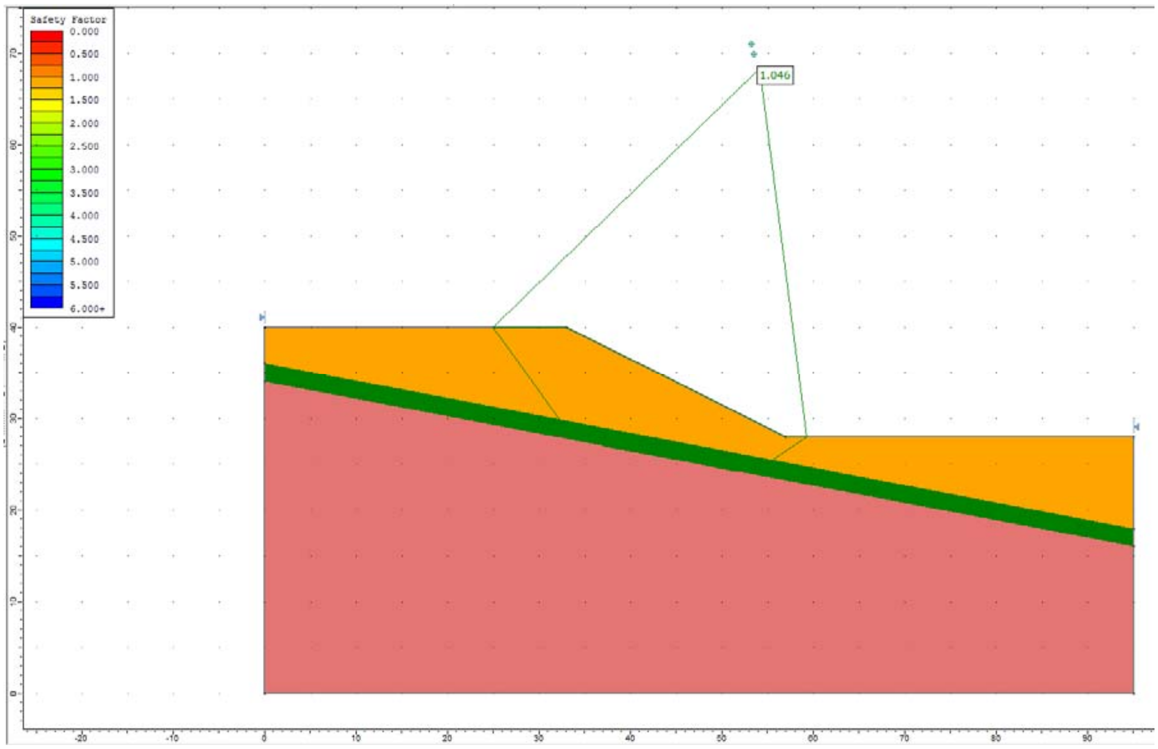


Figure 3.4.2 – Slide Solution Using the Bishop method

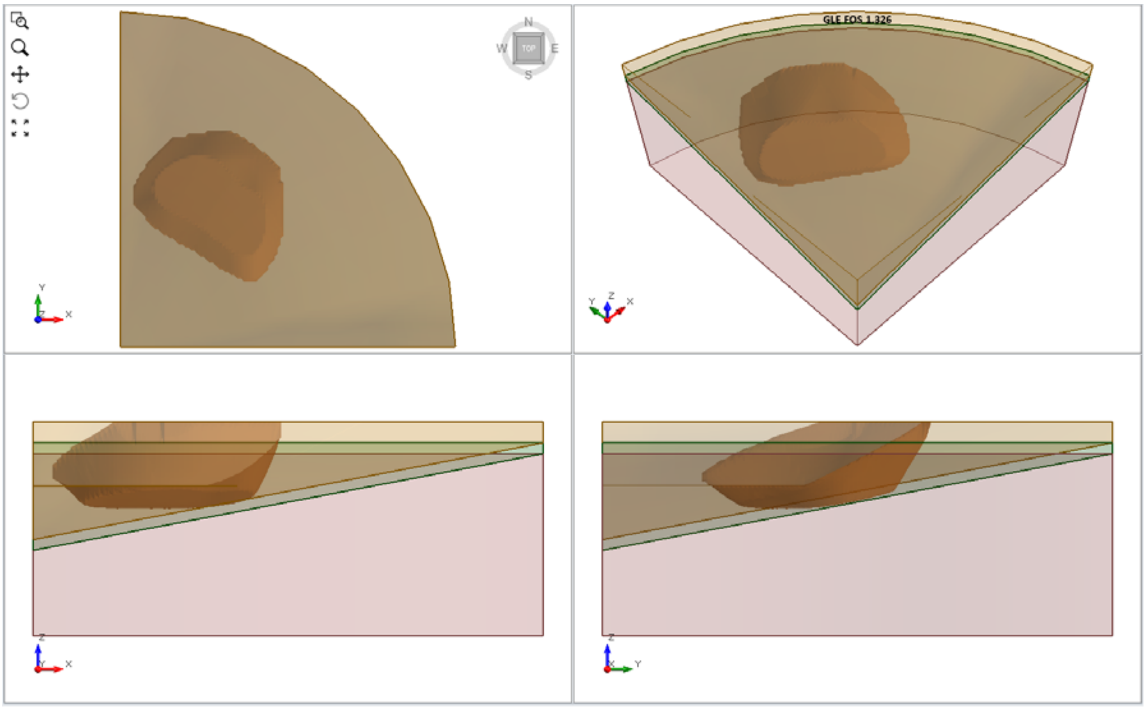


Figure 3.4.3 – Slide3 Solution Using the GLE Method

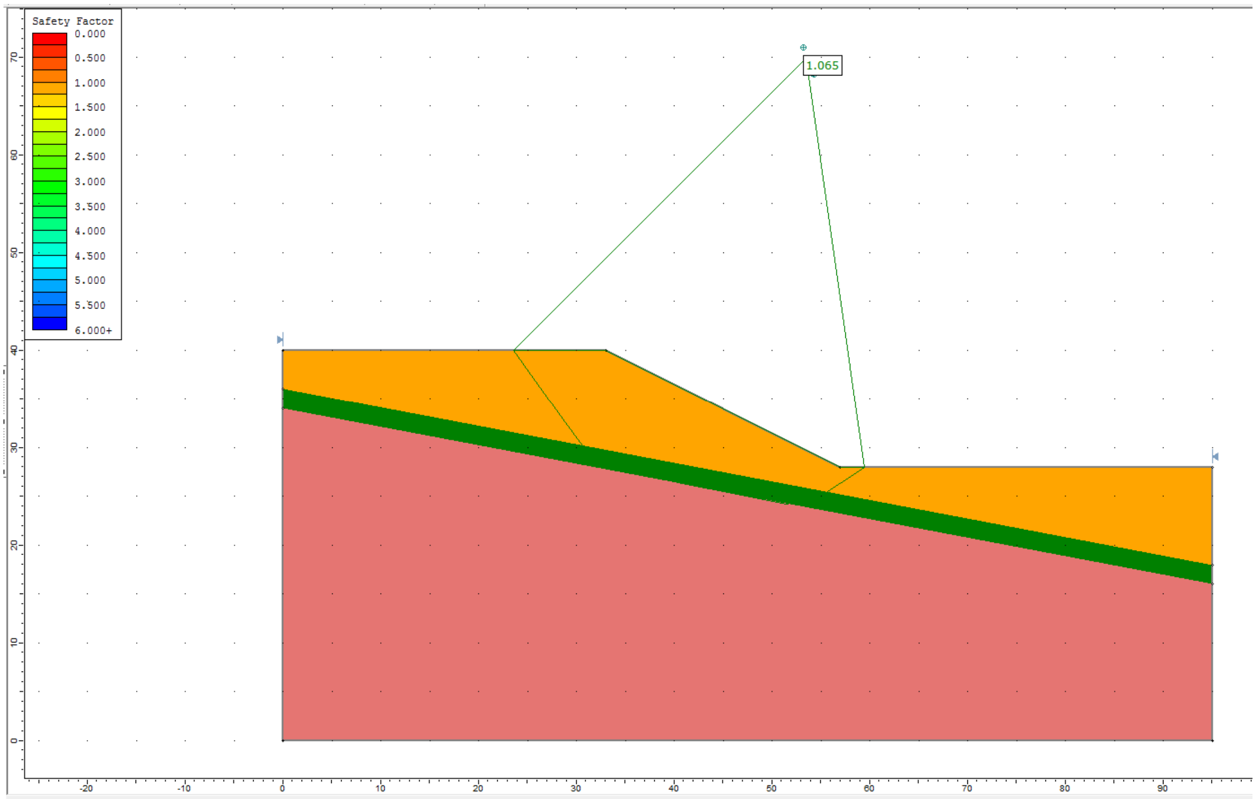


Figure 3.4.4 – Slide Solution Using the GLE Method

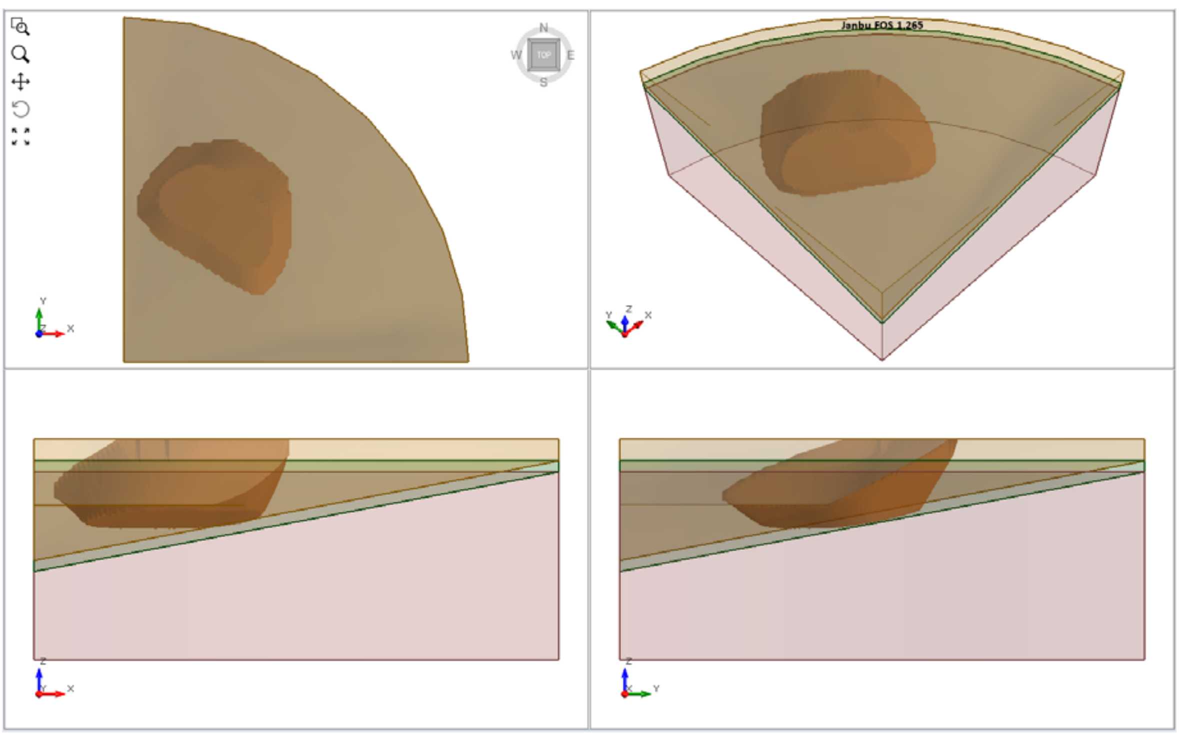


Figure 3.4.5 – Slide3 Solution Using the Janbu Method

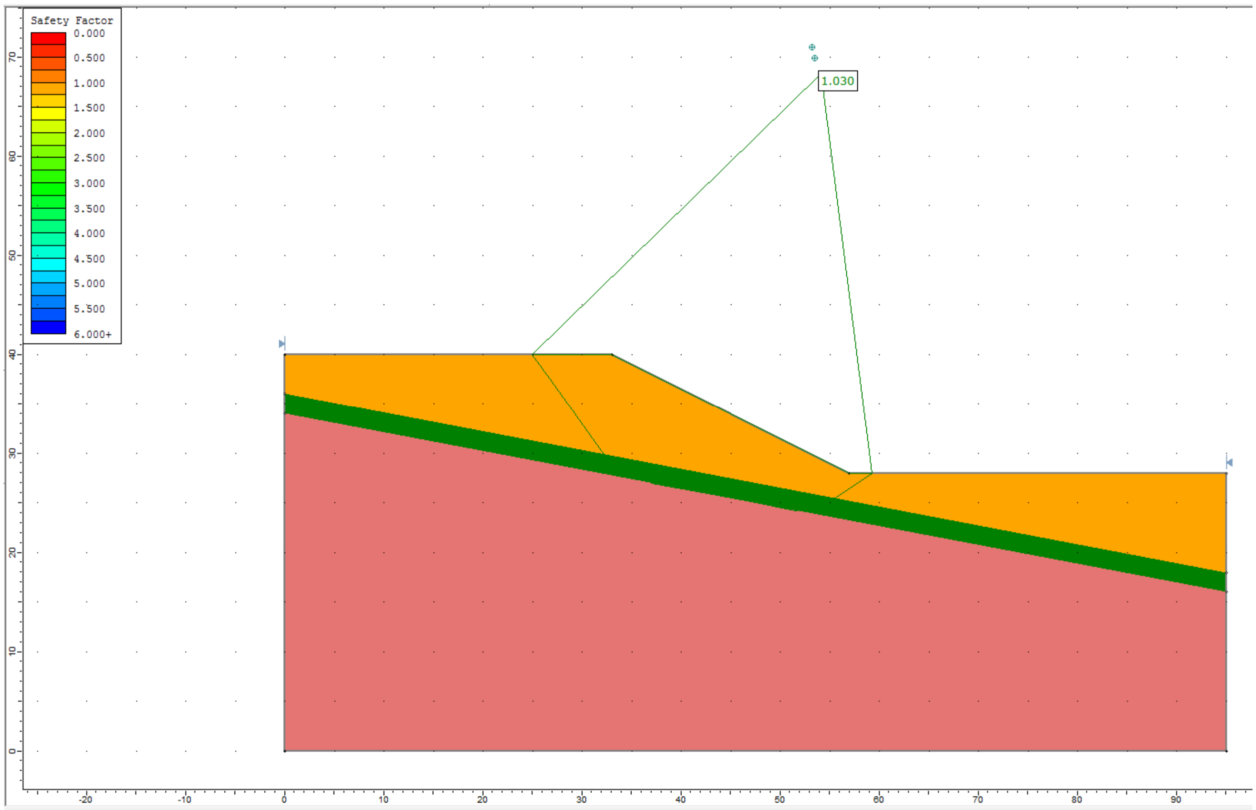


Figure 3.4.6 – Slide Solution Using the Janbu Method

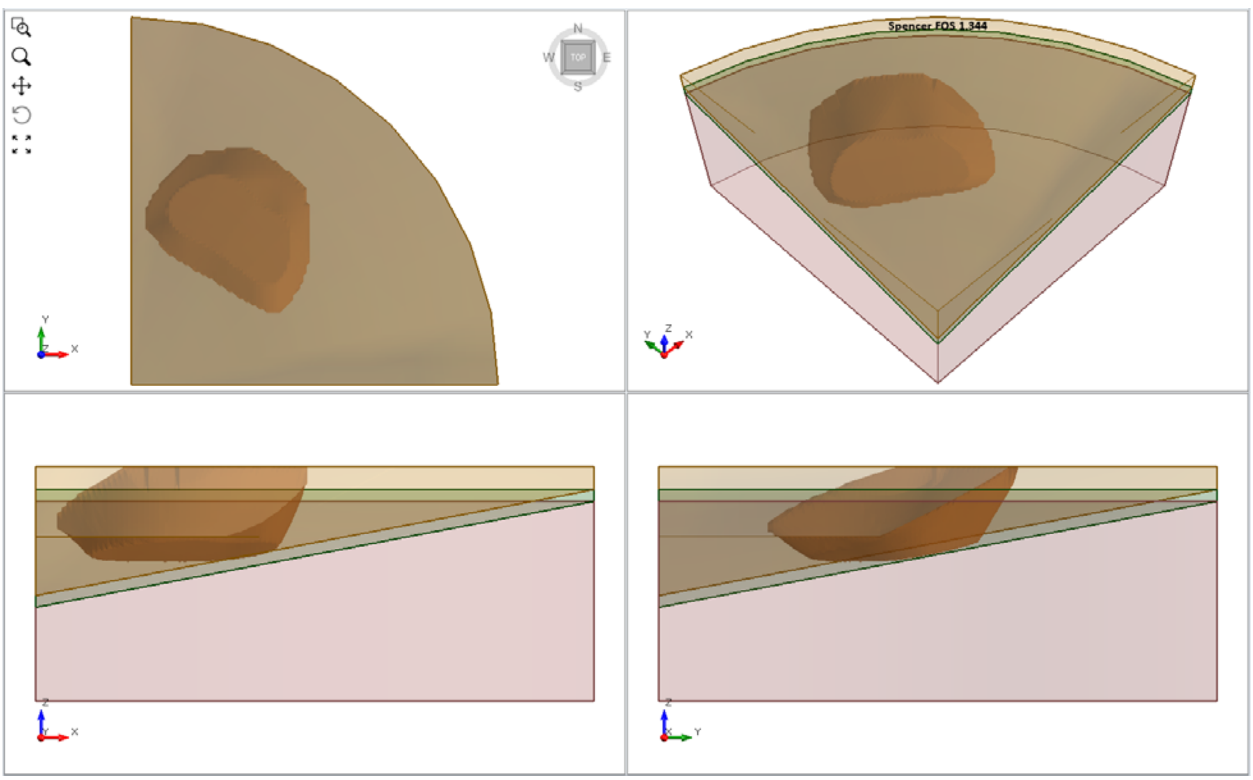


Figure 3.4.7 – Slide3 Solution Using the Spencer Method

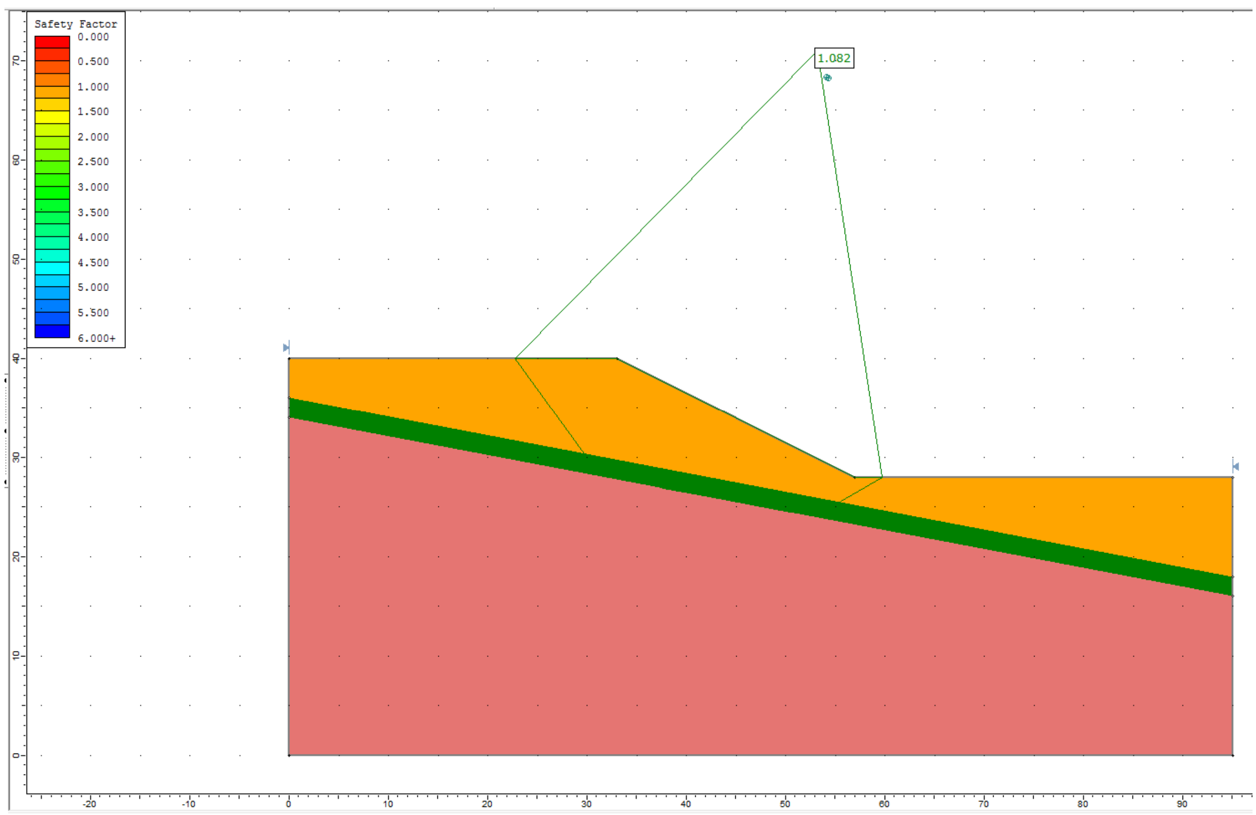


Figure 3.4.8 – Slide Solution Using the Spencer Method

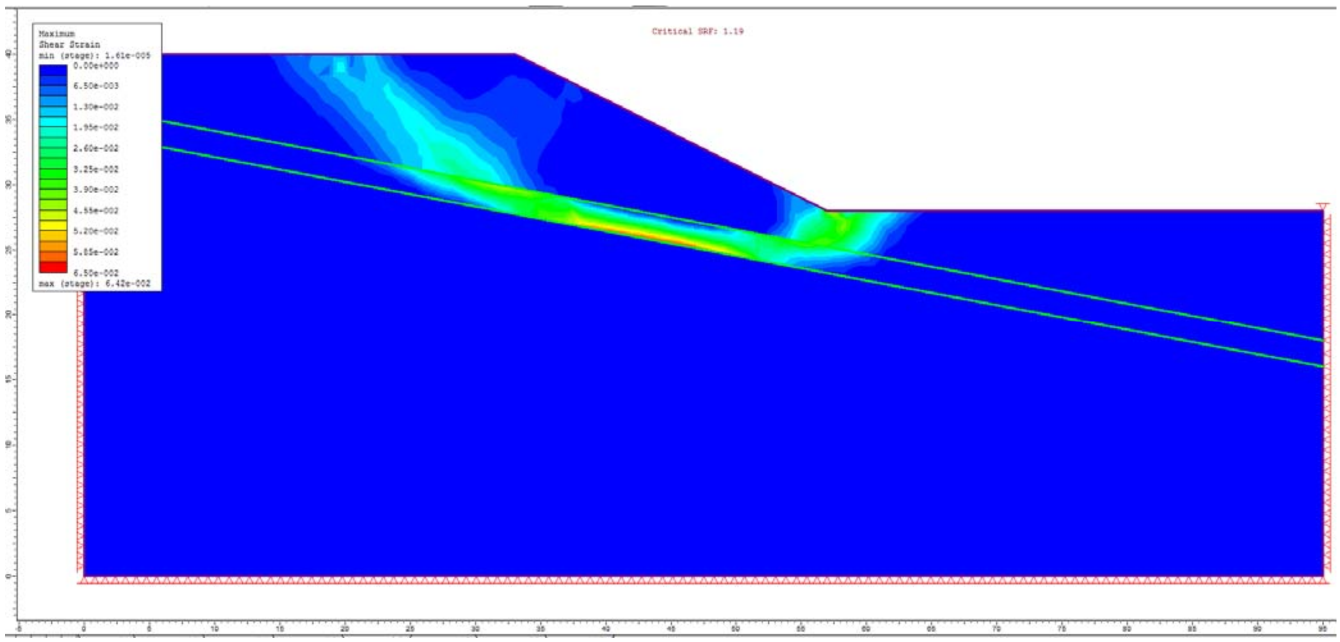


Figure 3.4.9 – RS2 Maximum Shear Strain

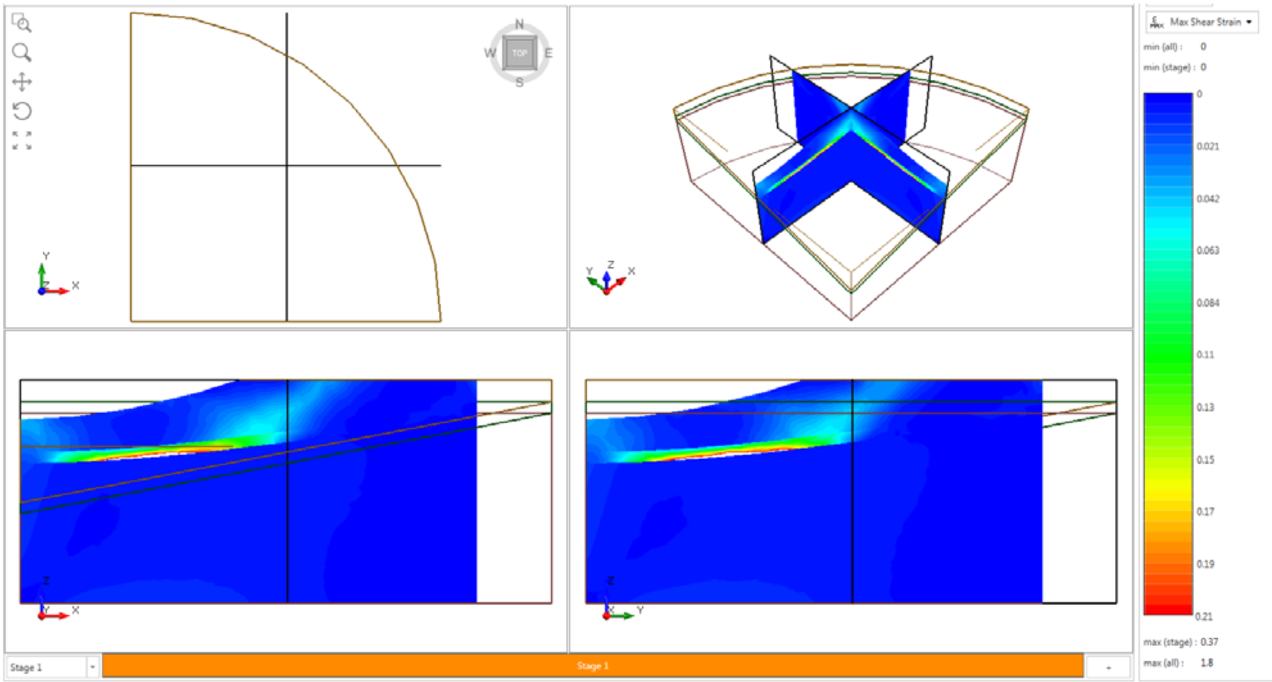


Figure 25.4.10 – RS3 Maximum Shear Strain

2D swept, 135° turn, concave, weak layer, ellipsoidal with SA

4.1 Introduction

2D Swept Verification #26 has the same cross section as the previous two problems, except it has undergone a 135 degree turn.

4.2 Problem Description

The model's cross section is shown in Figure 4(a) and the top view of the model is shown in Figure 4(b). This model has a weak layer whose material properties are shown in Table 4.1, along with the material properties of the soil. The ellipsoidal safety factor is required, and is found using a cuckoo search with surface optimization on Slide3.

4.3 Geometry and Properties

Table 4.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	28.5	20	19
Weak Layer	0	10	18.5
Infinite Strength	10000	65	19

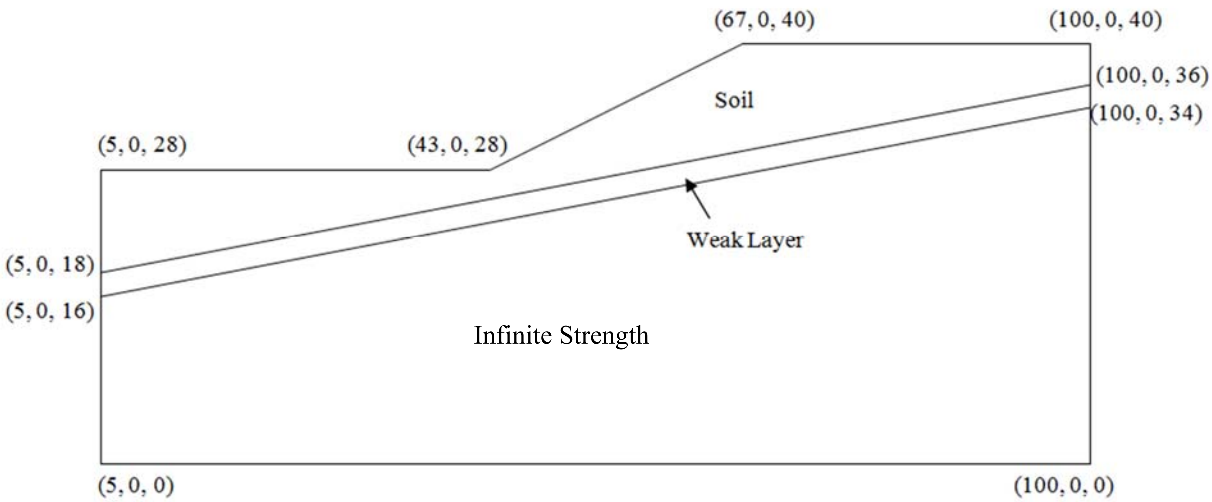


Figure 4(a)

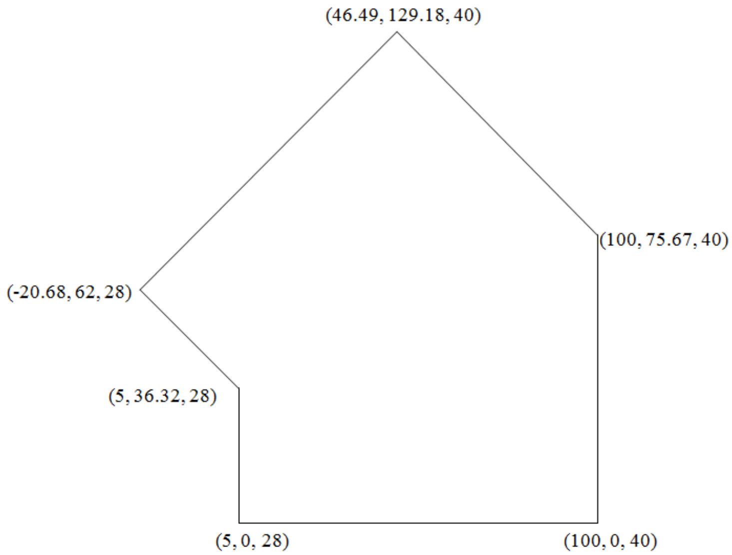


Figure 4(b)

4.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.252	1.046	1.38	1.16
GLE	1.286	1.066		
Janbu	1.146	1.030		
Spencer	1.315	1.082		

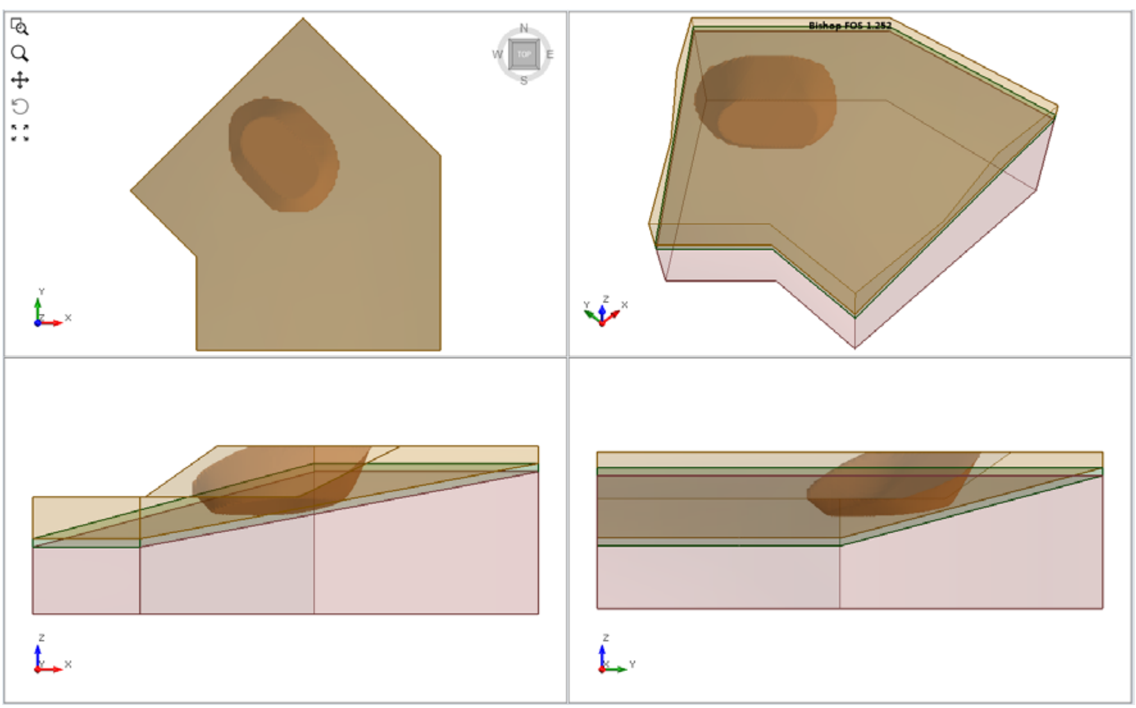


Figure 4.4.1 – Slide3 Solution Using the Bishop Method

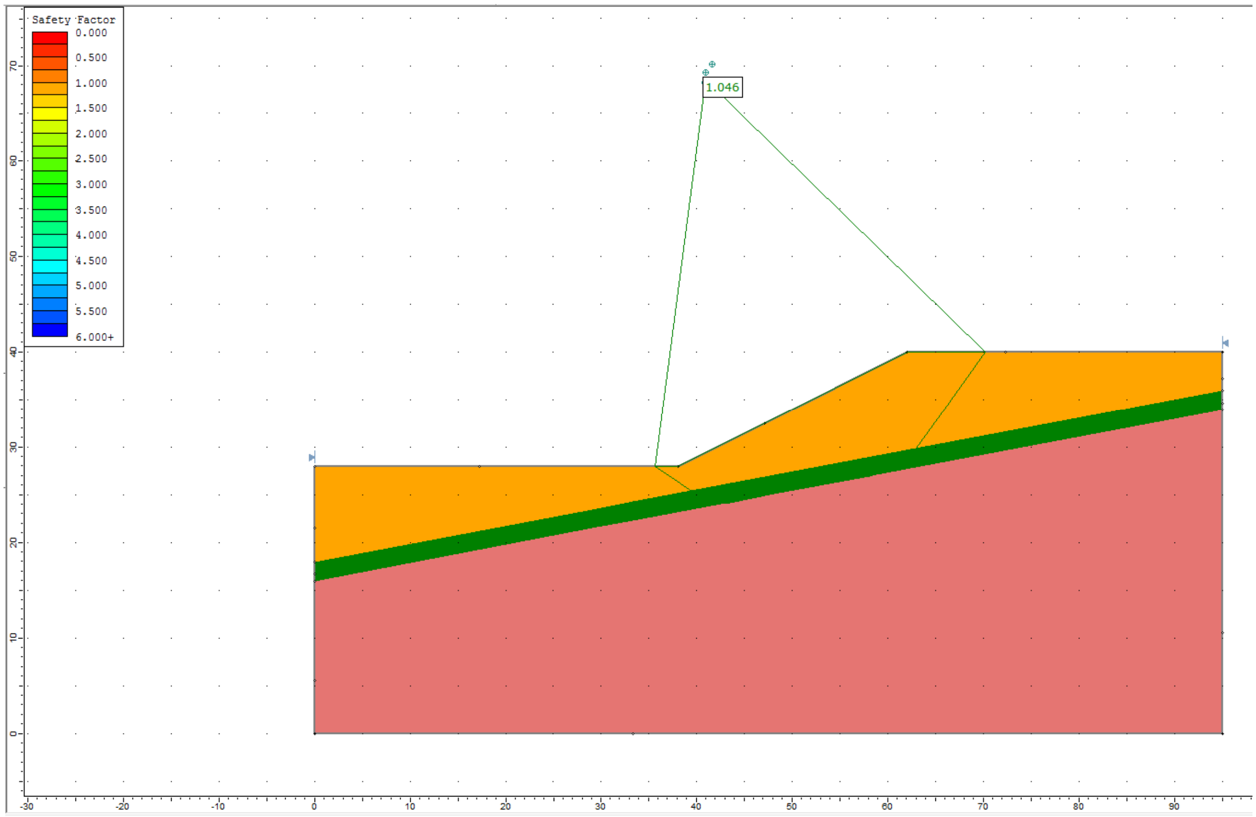


Figure 4.4.2 – Slide Solution Using the Bishop Method

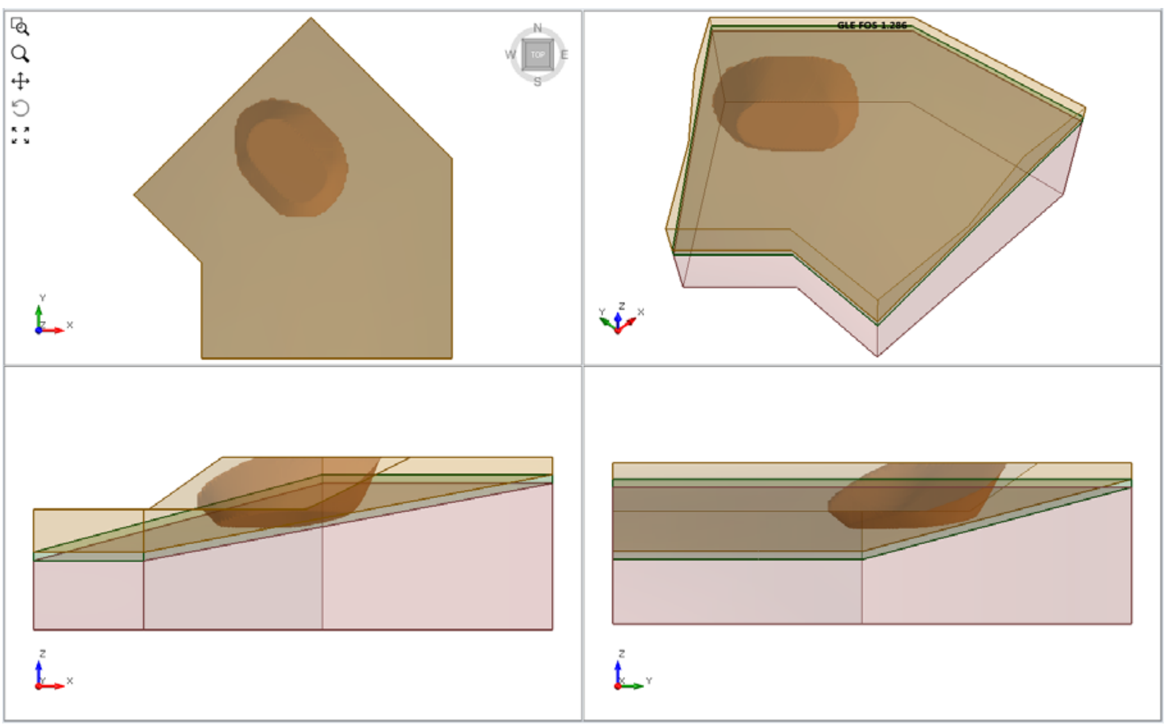


Figure 4.4.3 – Slide3 Solution Using the GLE Method

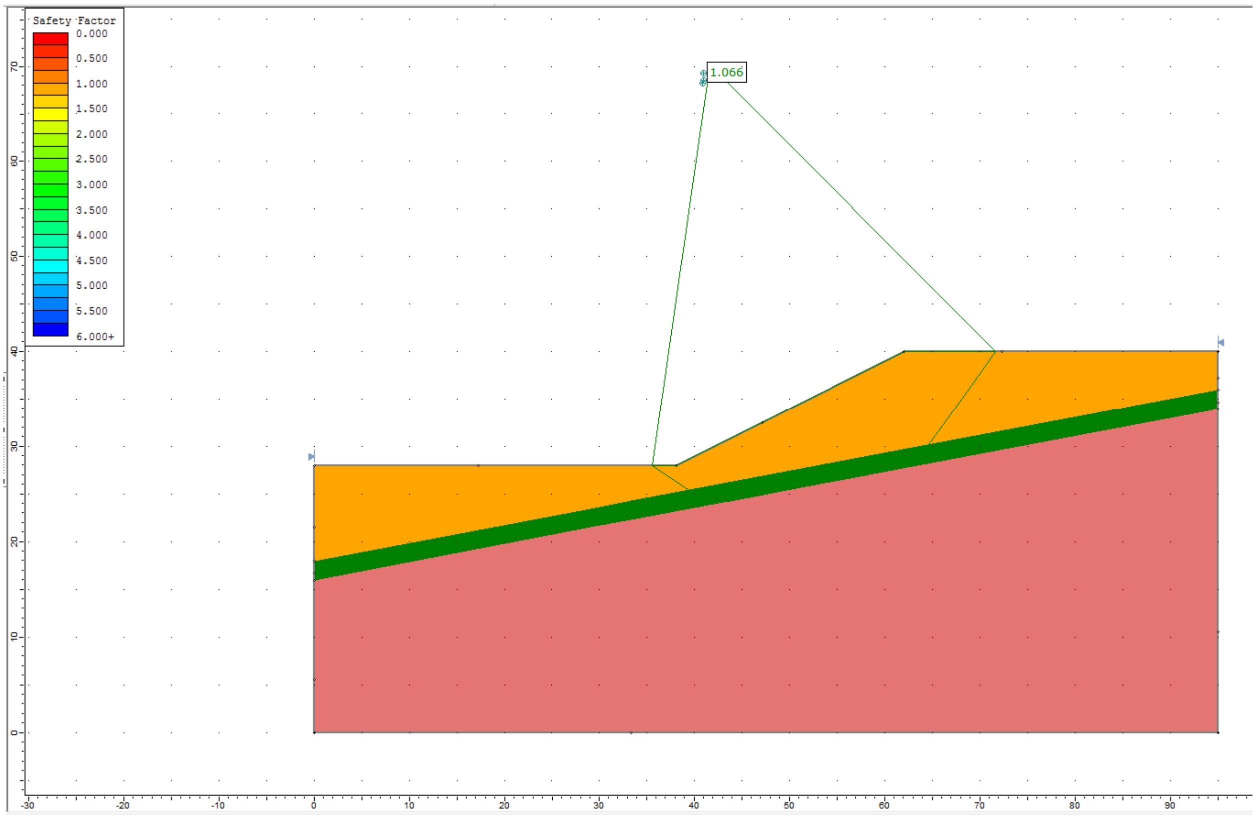


Figure 4.4.4 – Slide Solution Using the GLE Method

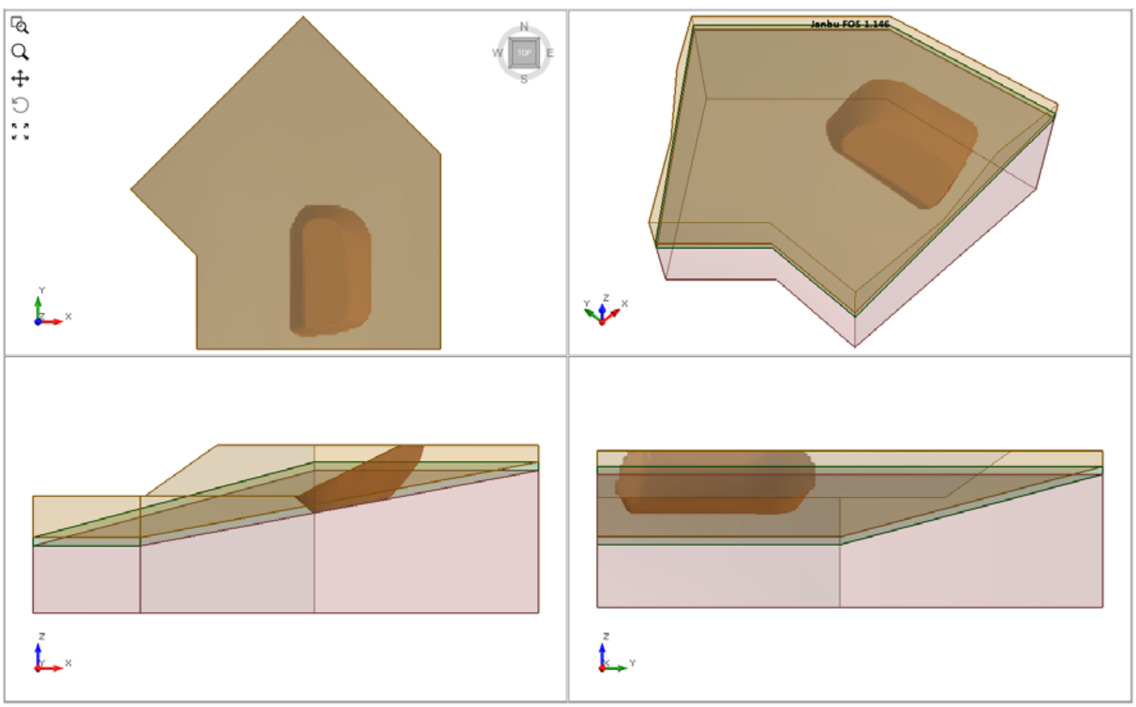


Figure 4.4.5 – Slide3 Solution Using the Janbu Method

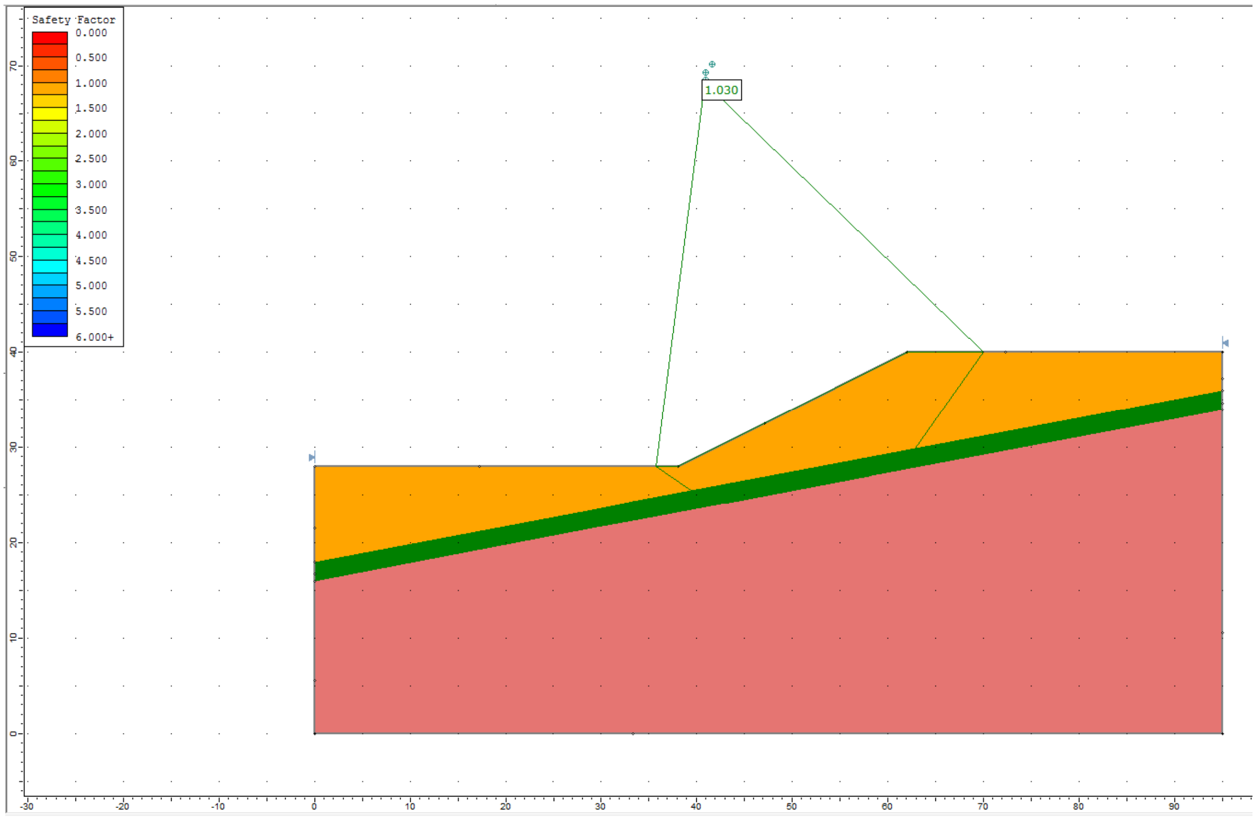


Figure 4.4.6 – Slide Solution Using the Janbu Method

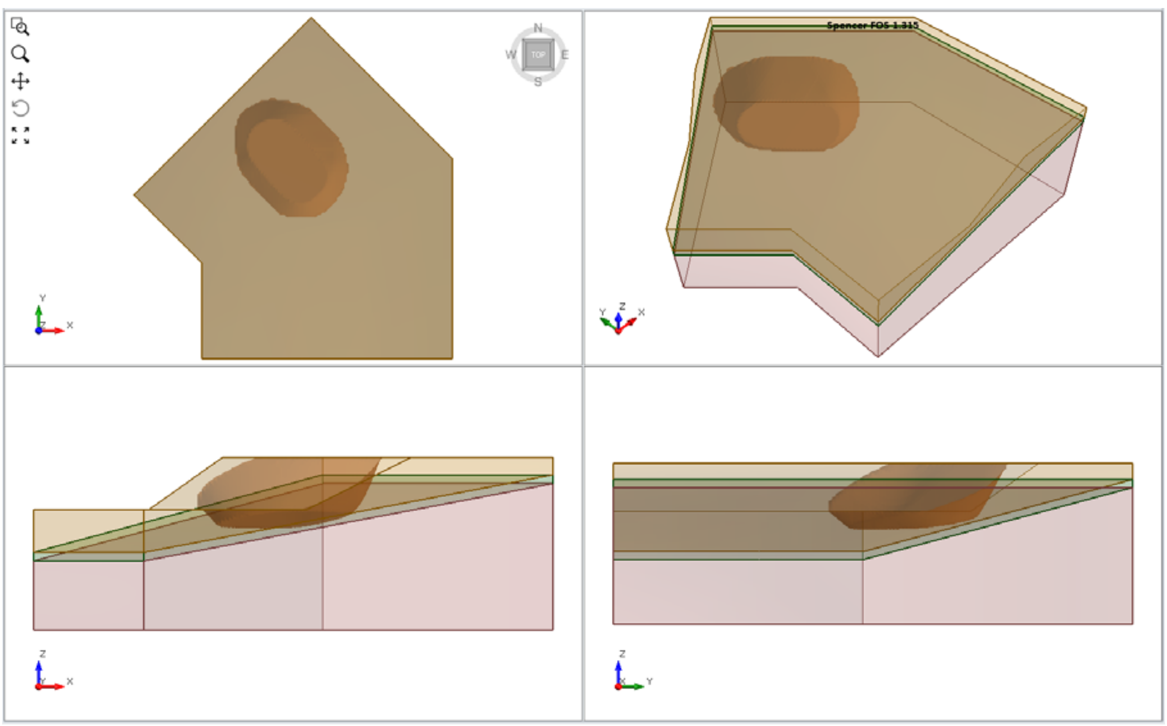


Figure 4.4.7 – Slide3 Solution Using the Spencer Method

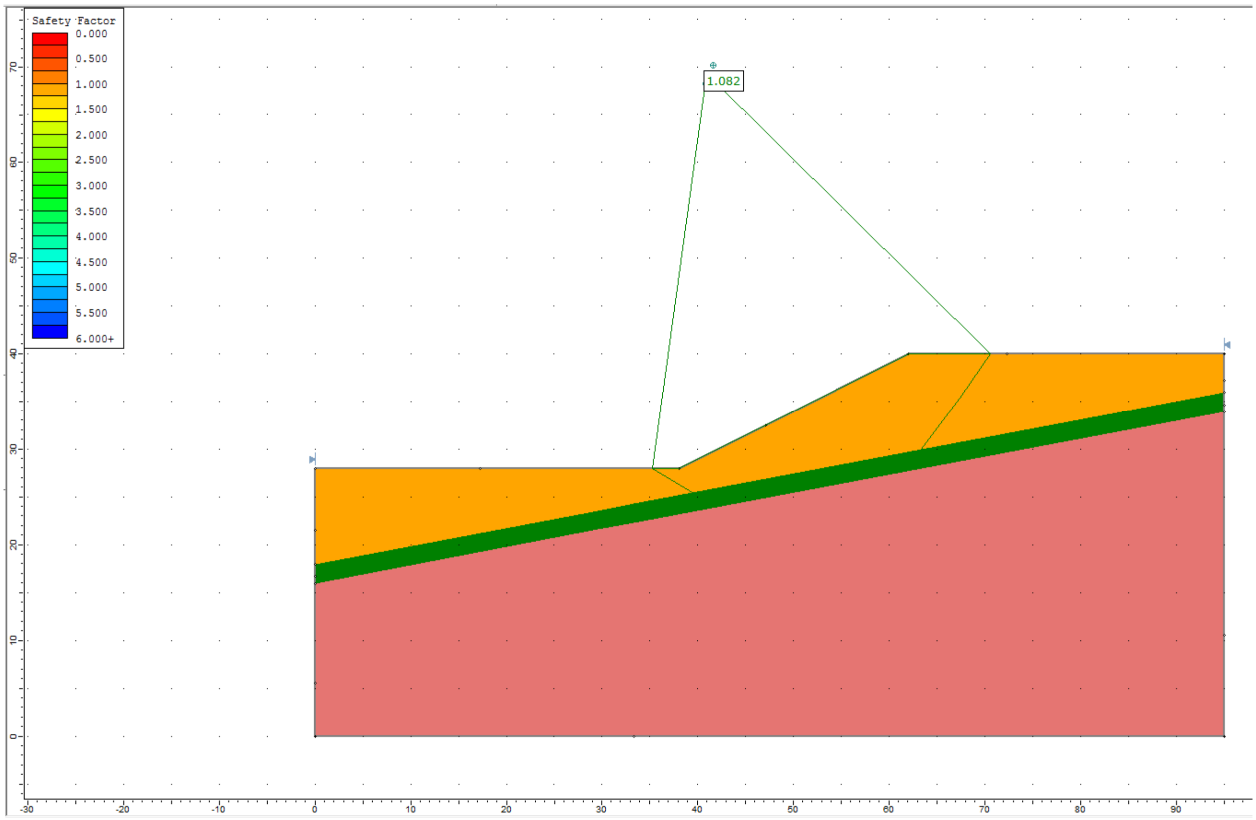


Figure 4.4.8 – Slide Solution Using the Spencer Method

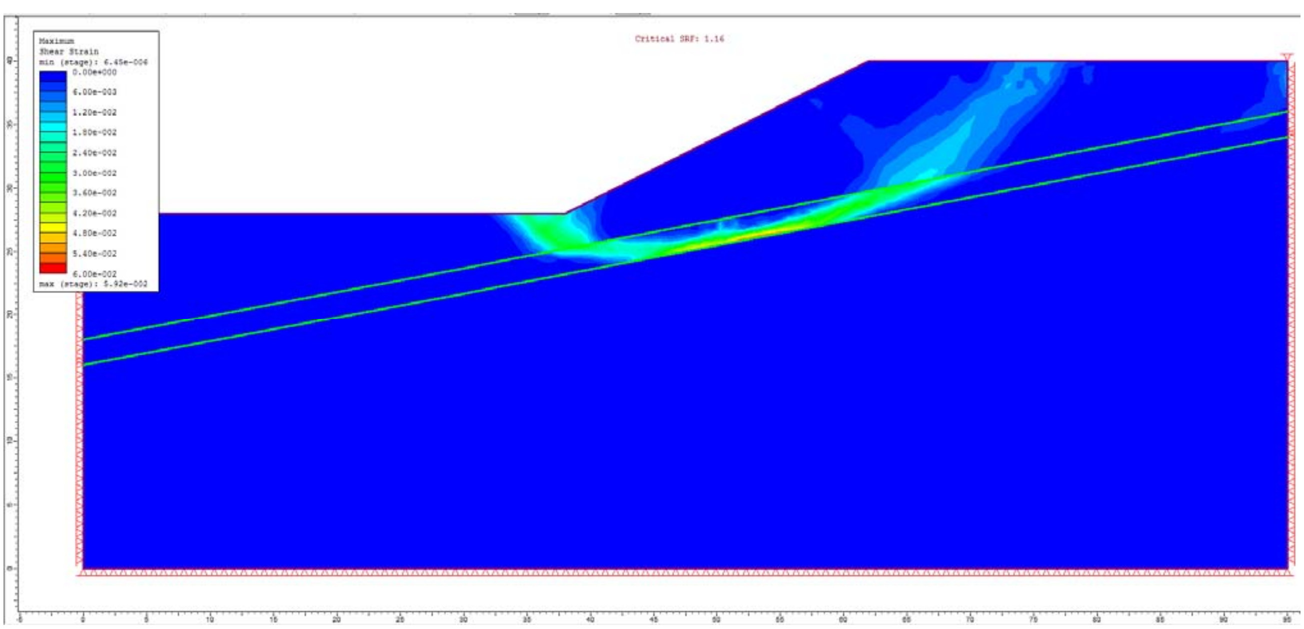


Figure 4.4.9 – RS2 Maximum Shear Strain

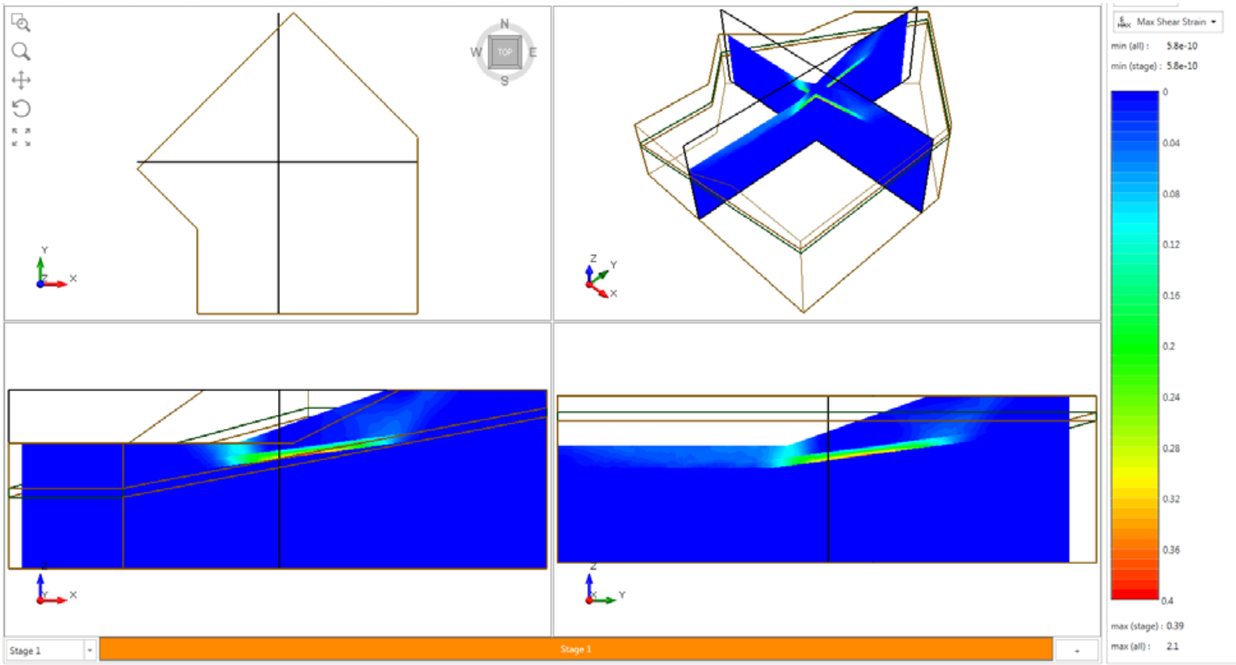


Figure 4.4.10 – RS3 Maximum Shear Strain

2D swept, 225° turn, convex, weak layer, ellipsoidal with SA

5.1 Introduction

2D Swept Verification #5 has the same cross section as the previous three problems, except it has undergone a 225 degree turn.

5.2 Problem Description

The model's cross section is shown in Figure 5(a) and the top view of the model is shown in Figure 5(b). This model has a weak layer whose material properties are shown in Table 5.1, along with the material properties of the soil. The safety factor is required, and is found using a cuckoo search with surface optimization on Slide3.

5.3 Problem Description

Table 5.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	28.5	20	19
Weak Layer	0	10	18.5
Infinite Strength	10000	65	19

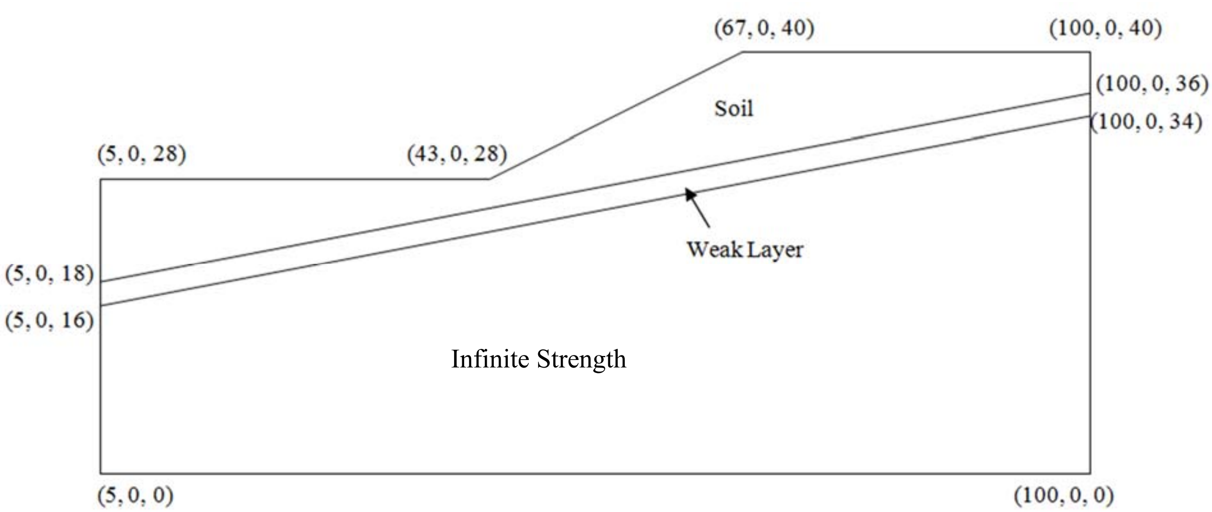


Figure 5(a)

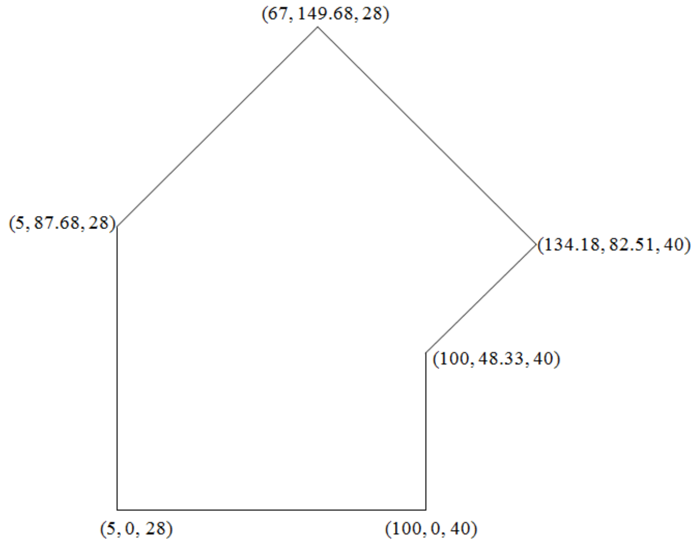


Figure 5(b)

5.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.113	1.046	1.27	1.15
GLE	1.158	1.066		
Janbu	1.102	1.030		
Spencer	1.18	1.083		

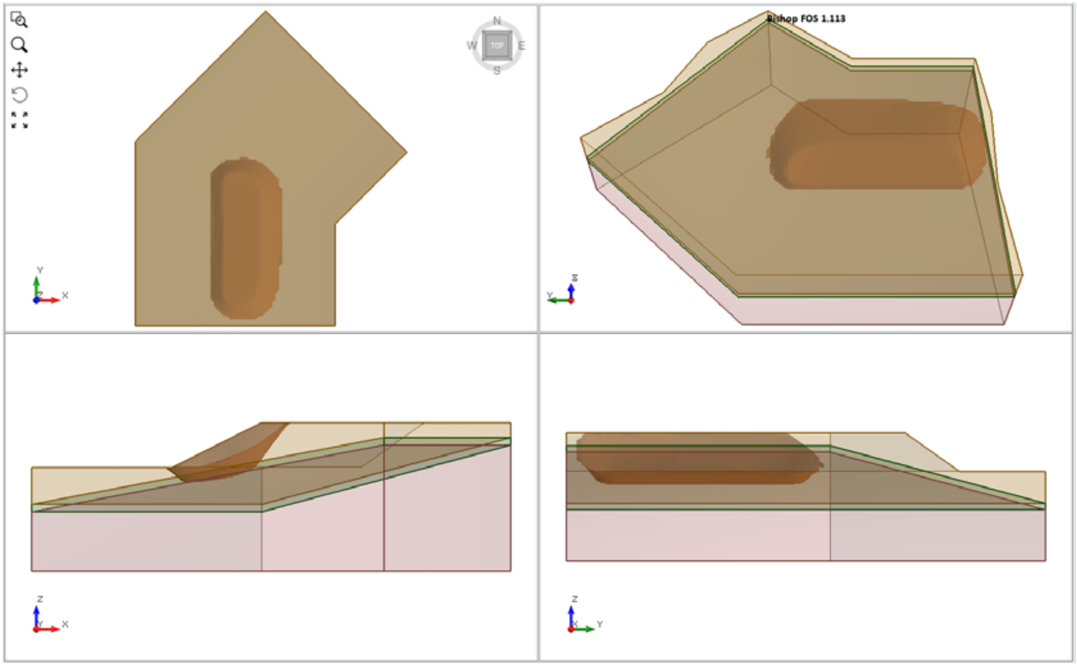


Figure 5.4.1 – Slide3 Solution Using the Bishop Method

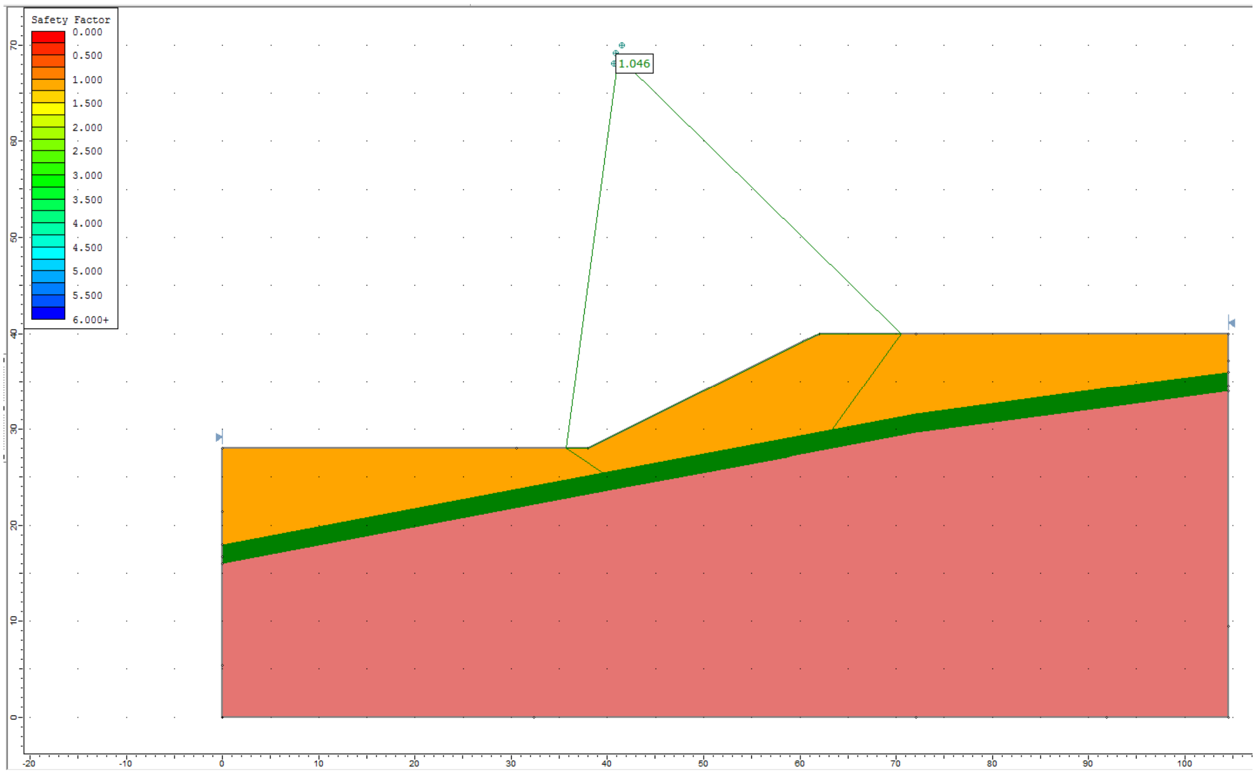


Figure 5.4.2 – Slide Solution Using the Bishop Method

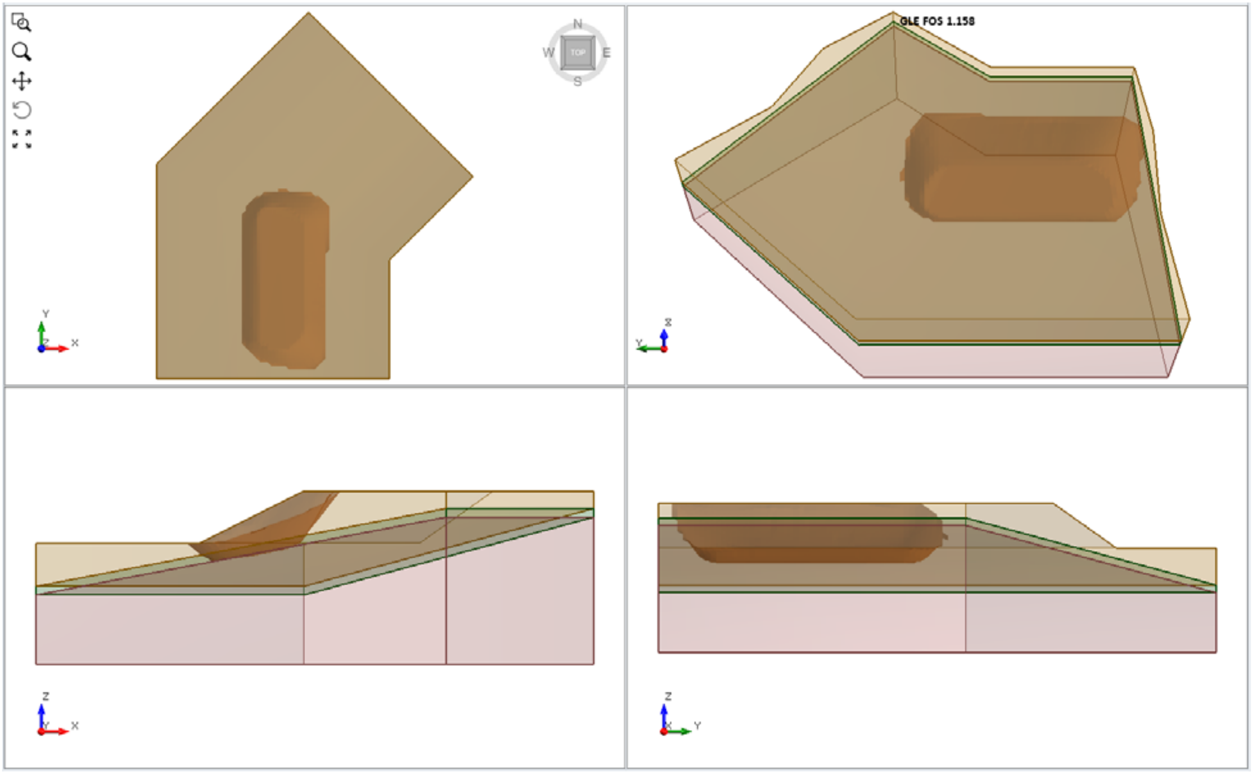


Figure 5.4.3 – Slide3 Solution Using the GLE Method

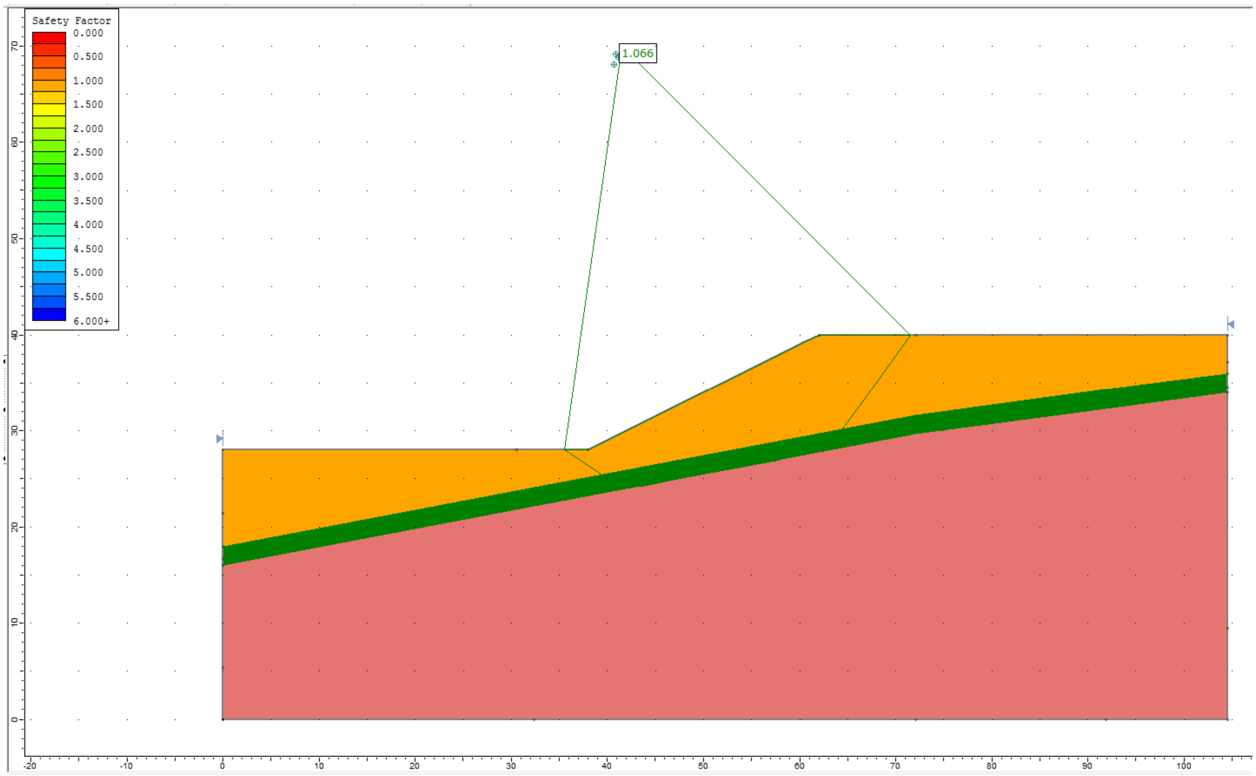


Figure 5.4.4 – Slide Solution Using the GLE Method

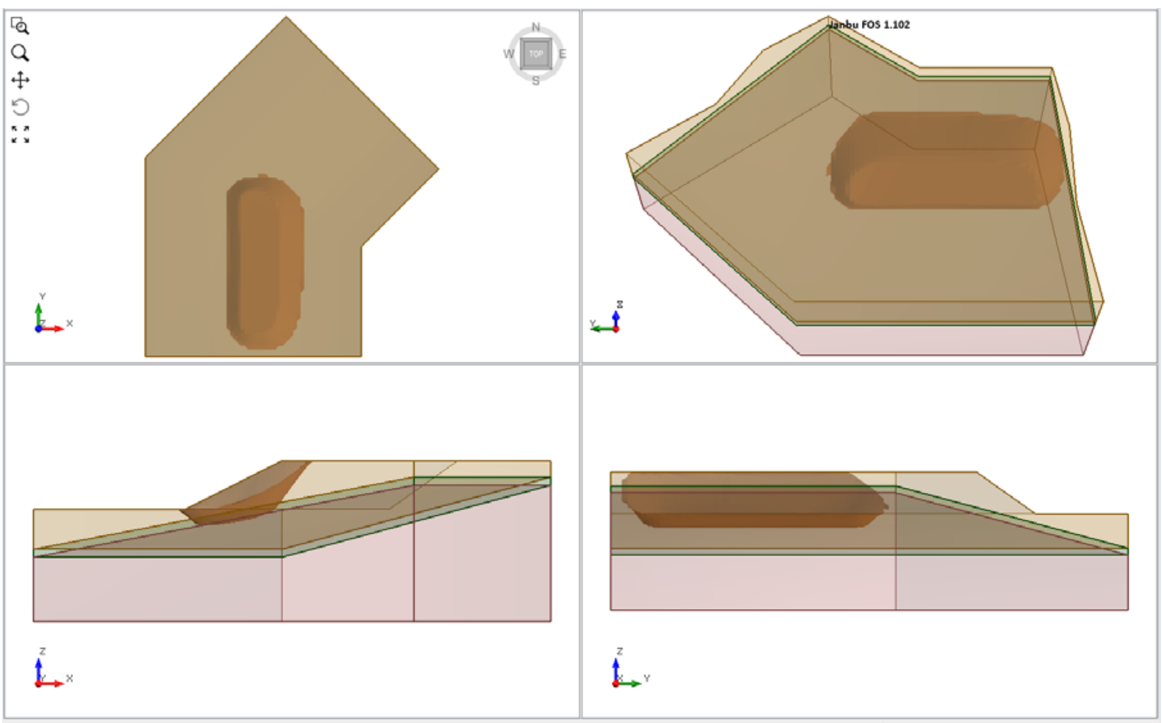


Figure 5.4.5 – Slide3 Solution Using the Janbu Method

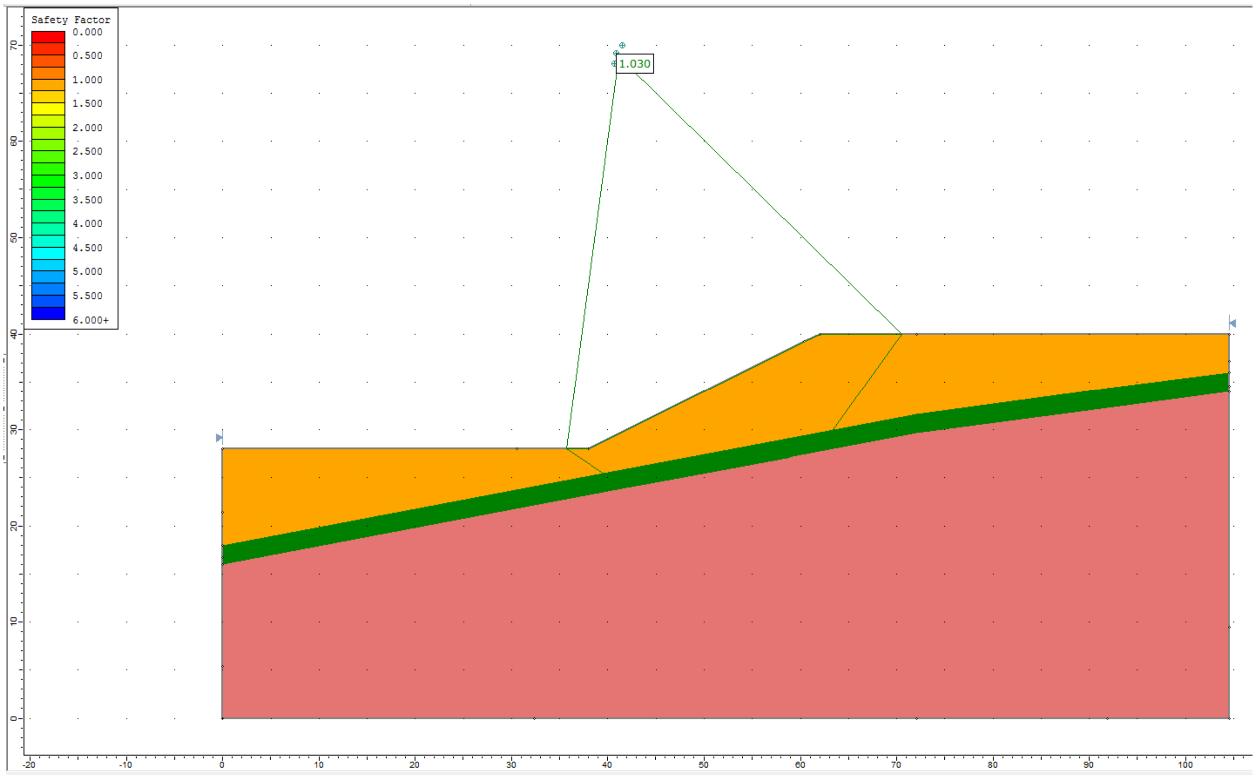


Figure 5.4.6 – Slide Solution Using the Janbu method

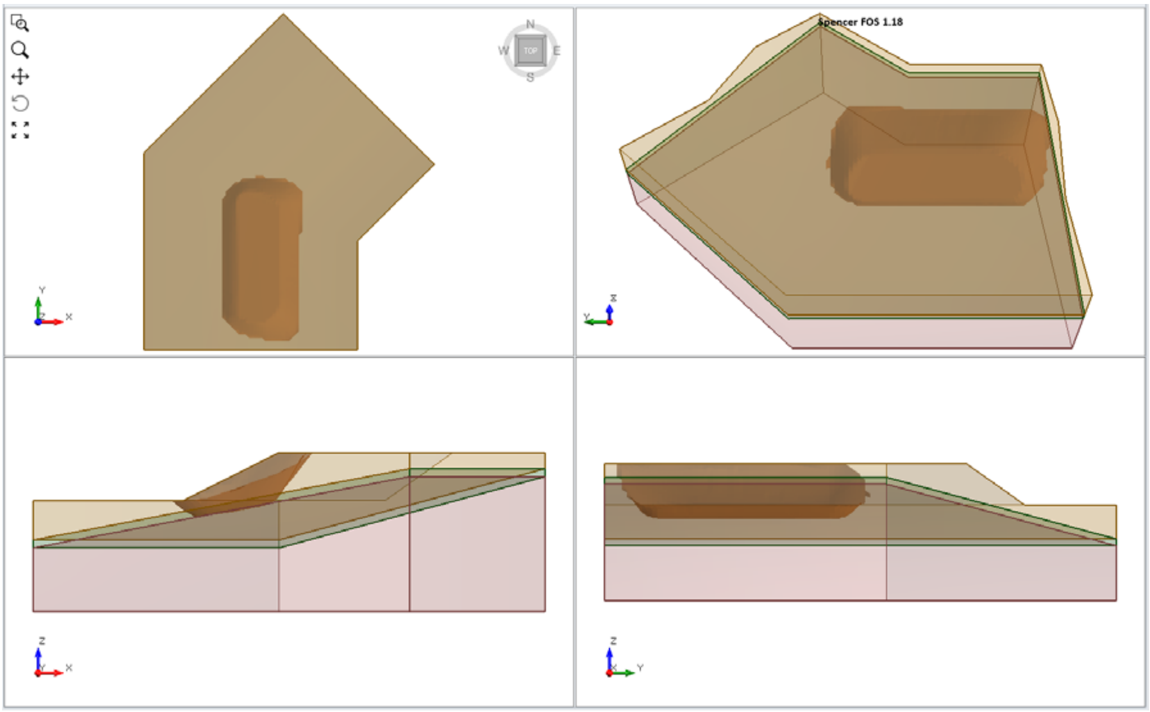


Figure 5.4.7 – Slide3 Solution Using the Spencer Method

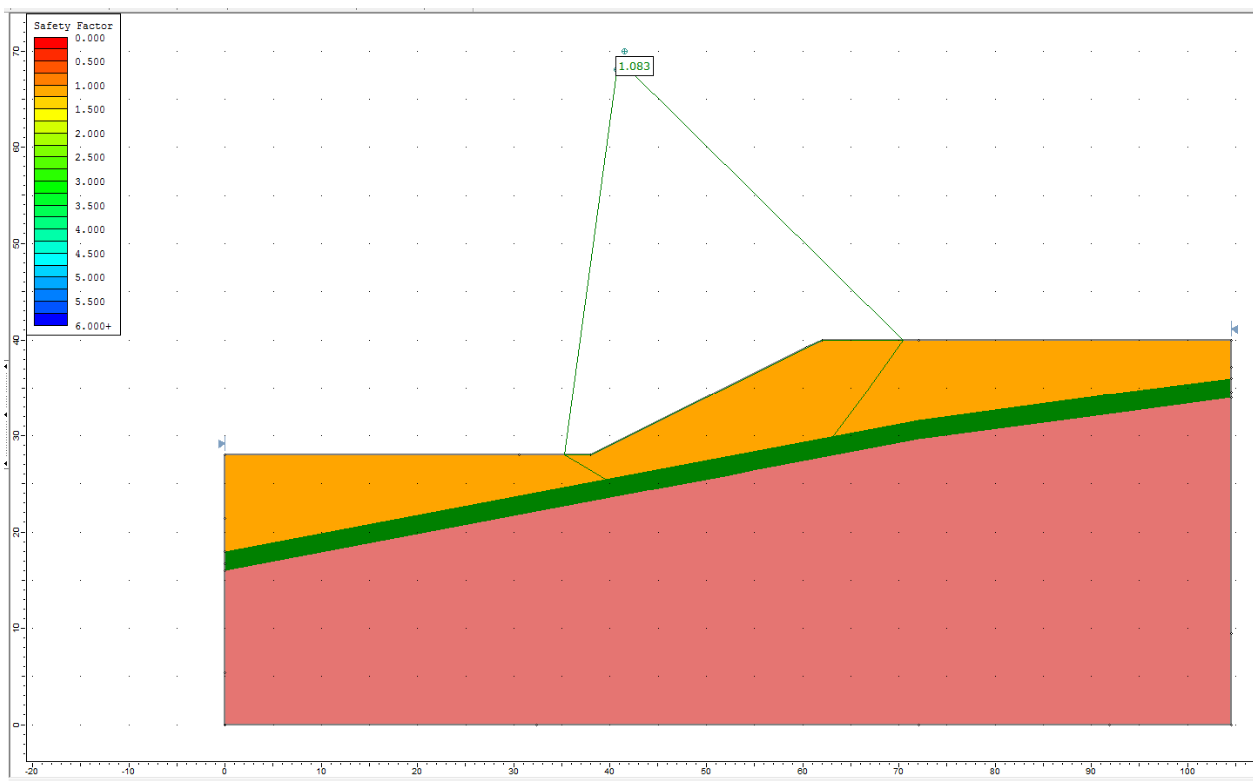


Figure 5.4.8 – Slide Solution Using the Spencer Method

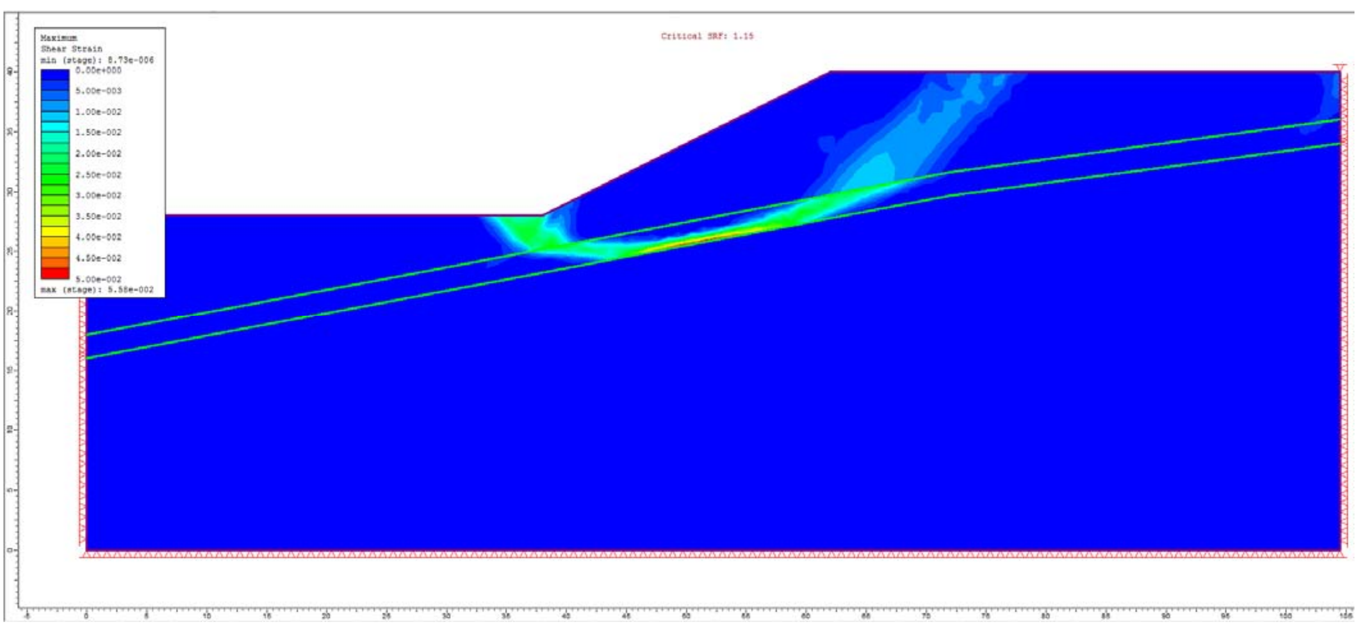


Figure 5.4.9 – RS2 Maximum Shear Strain

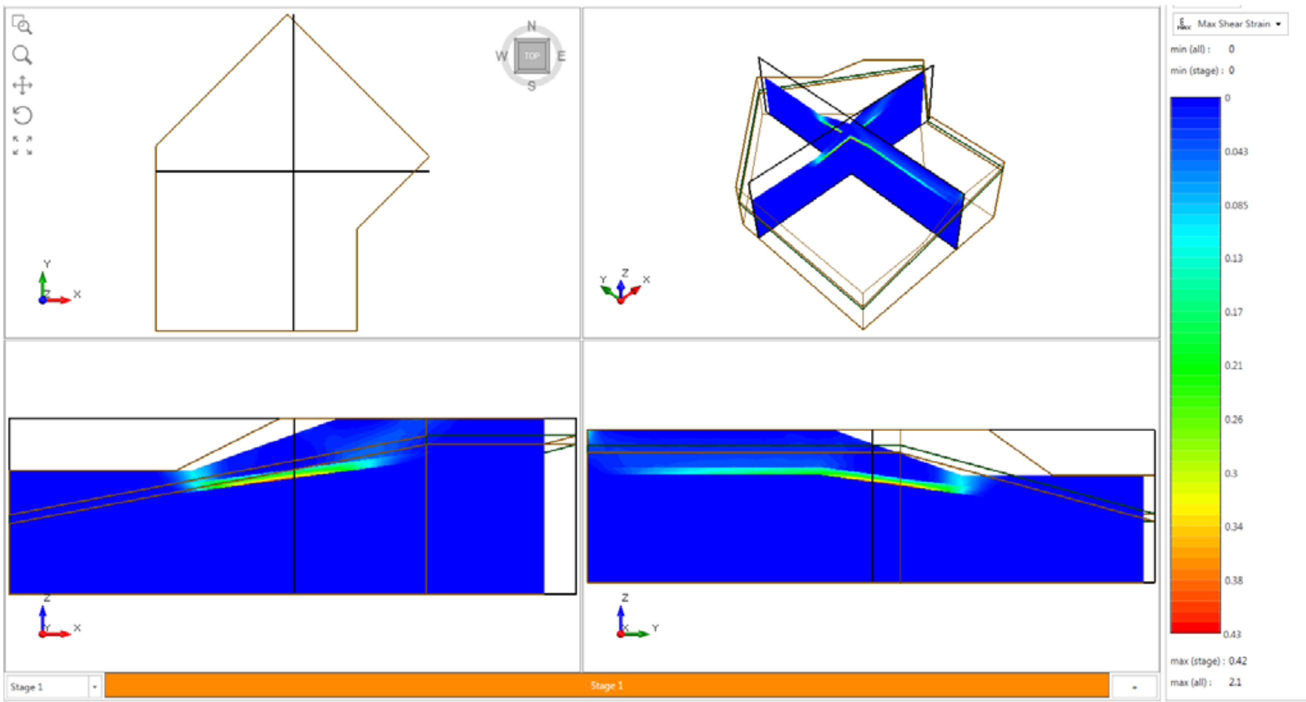


Figure 5.4.10 – RS3 Maximum Shear Strain

2D swept, 270° turn, convex, weak layer, ellipsoidal with SA

6.1 Introduction

2D Swept Verification #6 has the same cross section as the previous four problems, except it has undergone a 270 degree turn.

6.2 Problem Description

The model's cross section is shown in Figure 6(a) and the top view of the model is shown in Figure 6(b). This model has a weak layer whose material properties are shown in Table 6.1, along with the material properties of the soil. The safety factor is required, and is found using a cuckoo search with surface optimization on Slide3.

6.3 Problem Description

Table 6.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	28.5	20	19
Weak Layer	0	10	18.5
Infinite Strength	10000	65	19

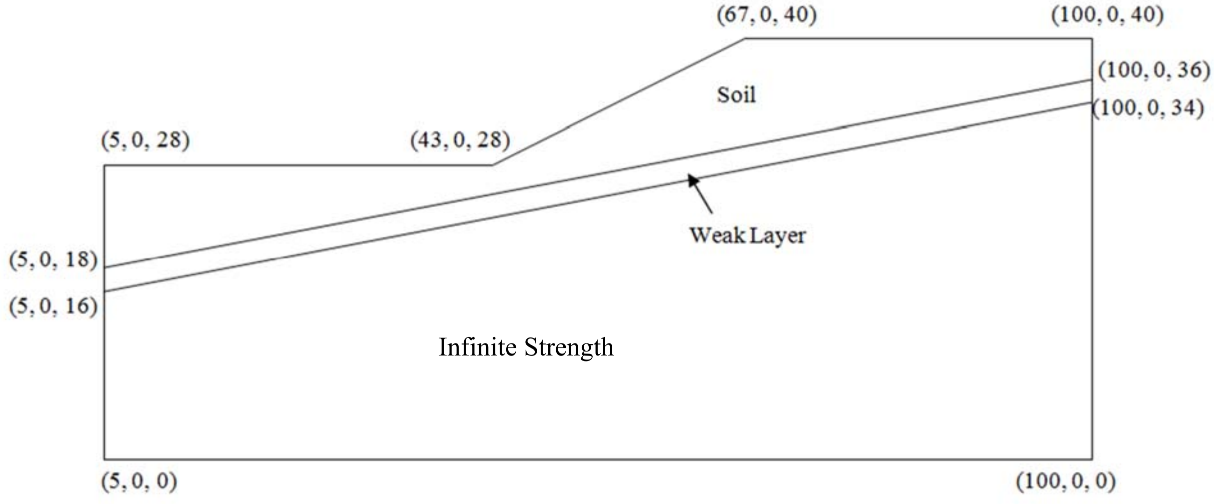


Figure 6(a)

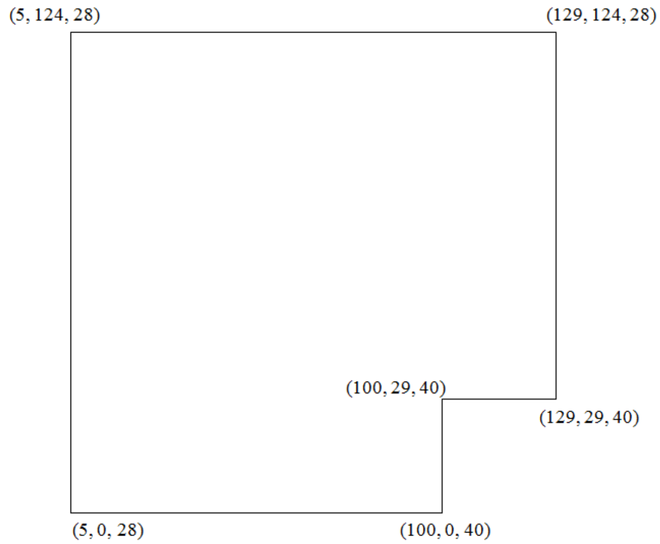


Figure 6(b)

6.4 Results

Table 6.4.1: Safety Factors 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>1.159</td><td>1.046</td><td rowspan="4">1.3</td><td rowspan="4">1.15</td></tr>
<tr><td>GLE</td><td>1.185</td><td>1.064</td></tr>
<tr><td>Janbu</td><td>1.149</td><td>1.030</td></tr>
<tr><td>Spencer</td><td>1.205</td><td>1.082</td></tr>
</table>

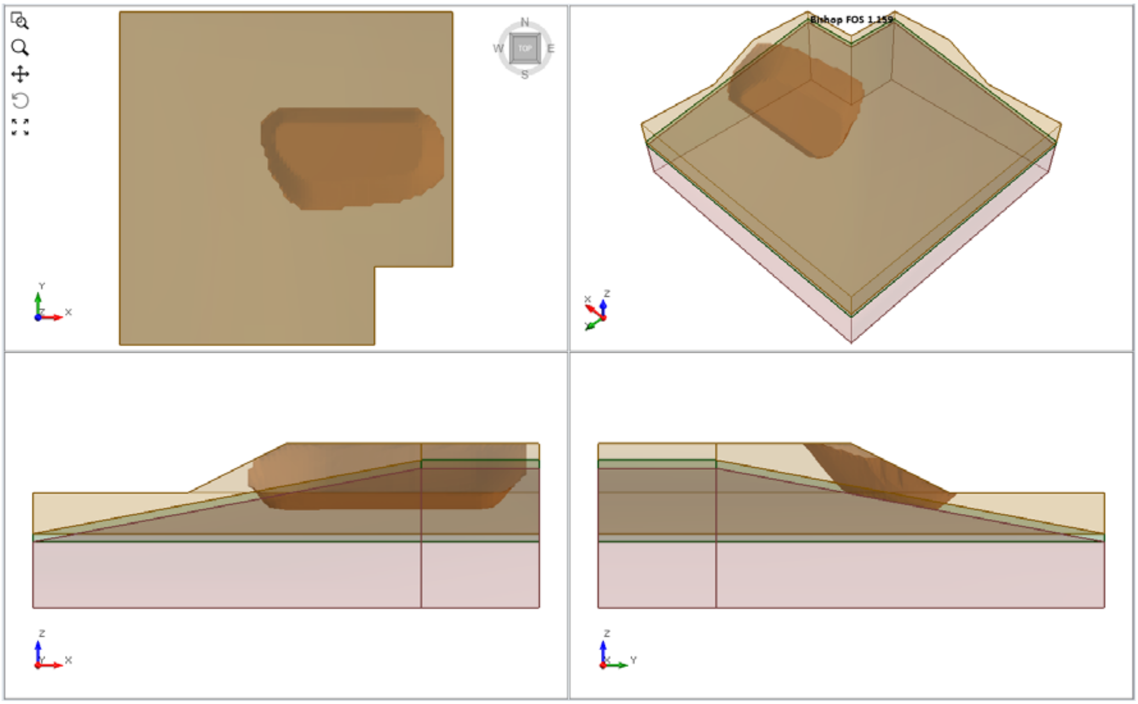


Figure 6.4.1 – Slide3 Solution Using the Bishop Method

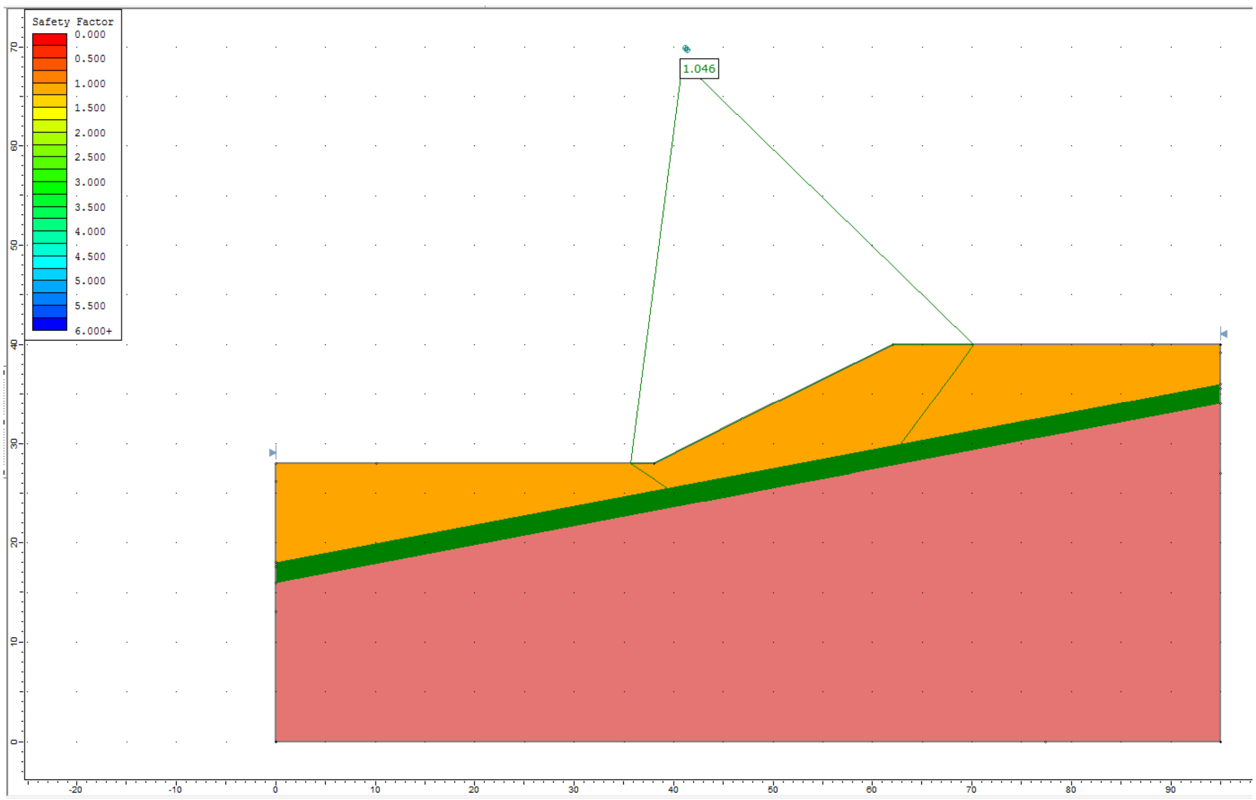


Figure 6.4.2 – Slide Solution Using the Bishop Method

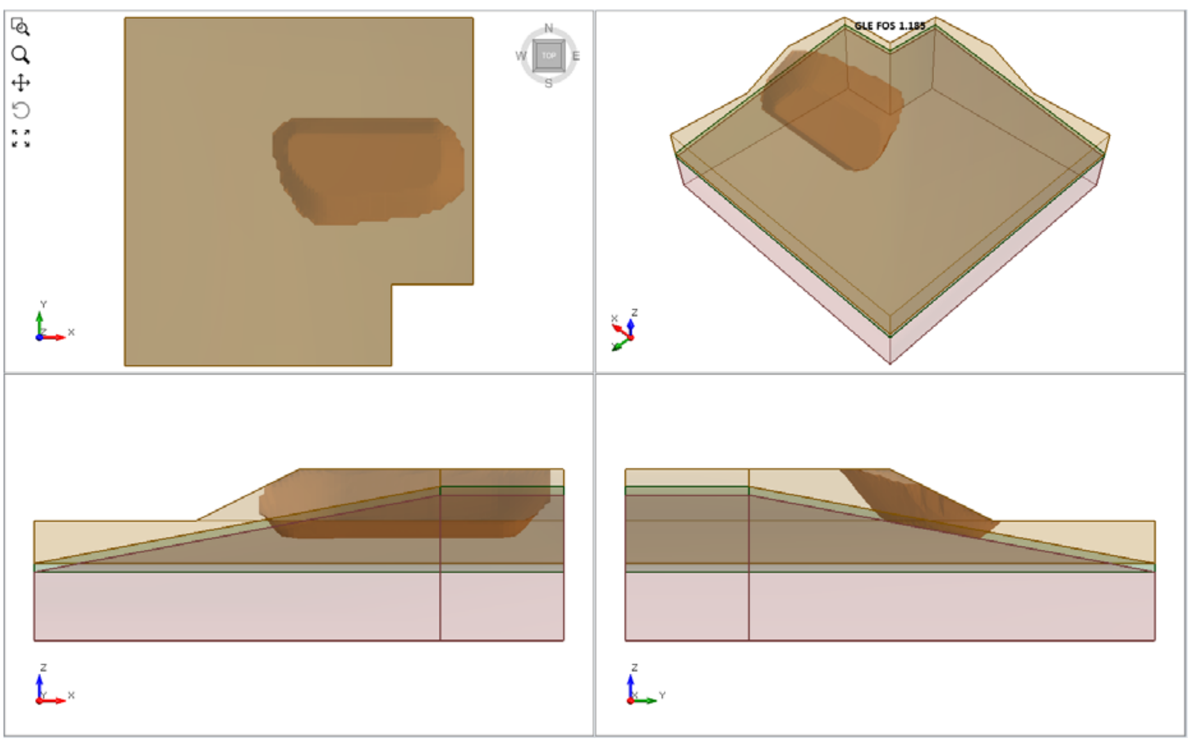


Figure 6.4.3 – Slide3 Solution Using the GLE Method

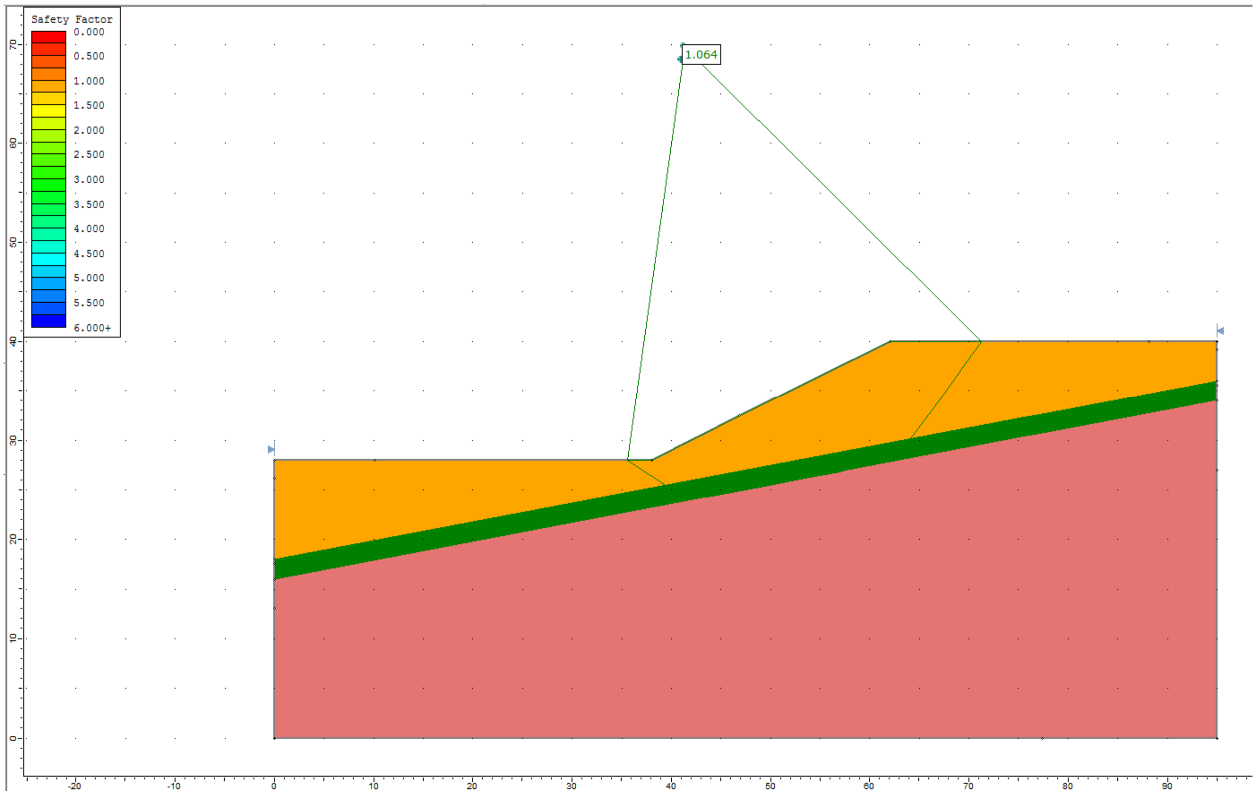


Figure 6.4.4 – Slide Solution Using the GLE Method

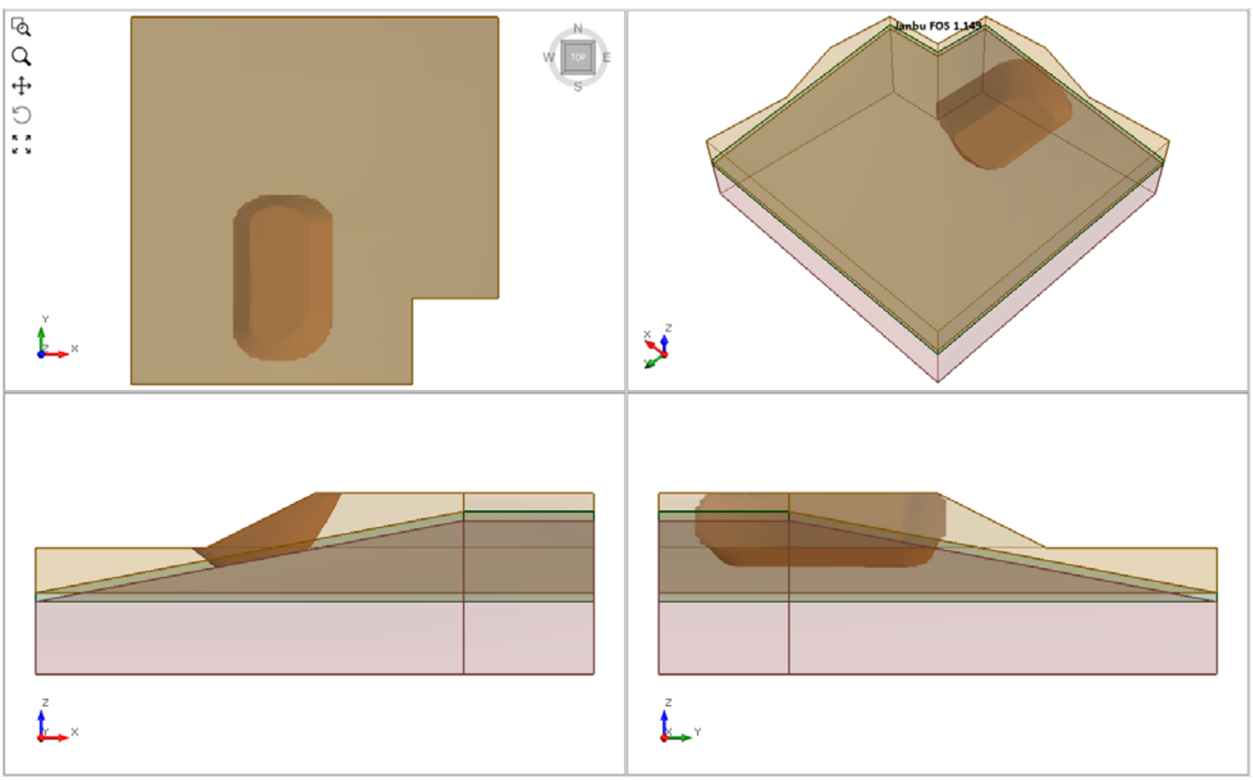


Figure 6.4.5 – Slide3 Solution Using the Janbu Method

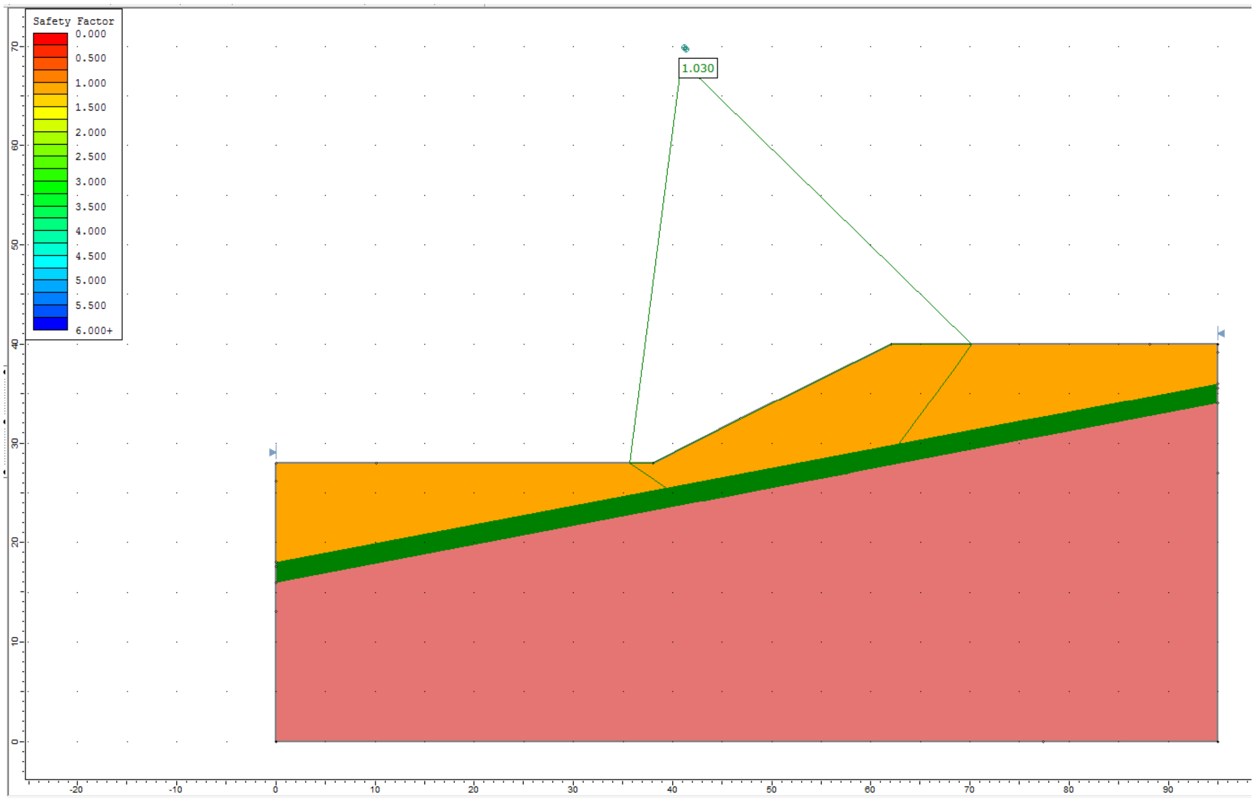


Figure 6.4.6 – Slide Solution Using the Janbu Method

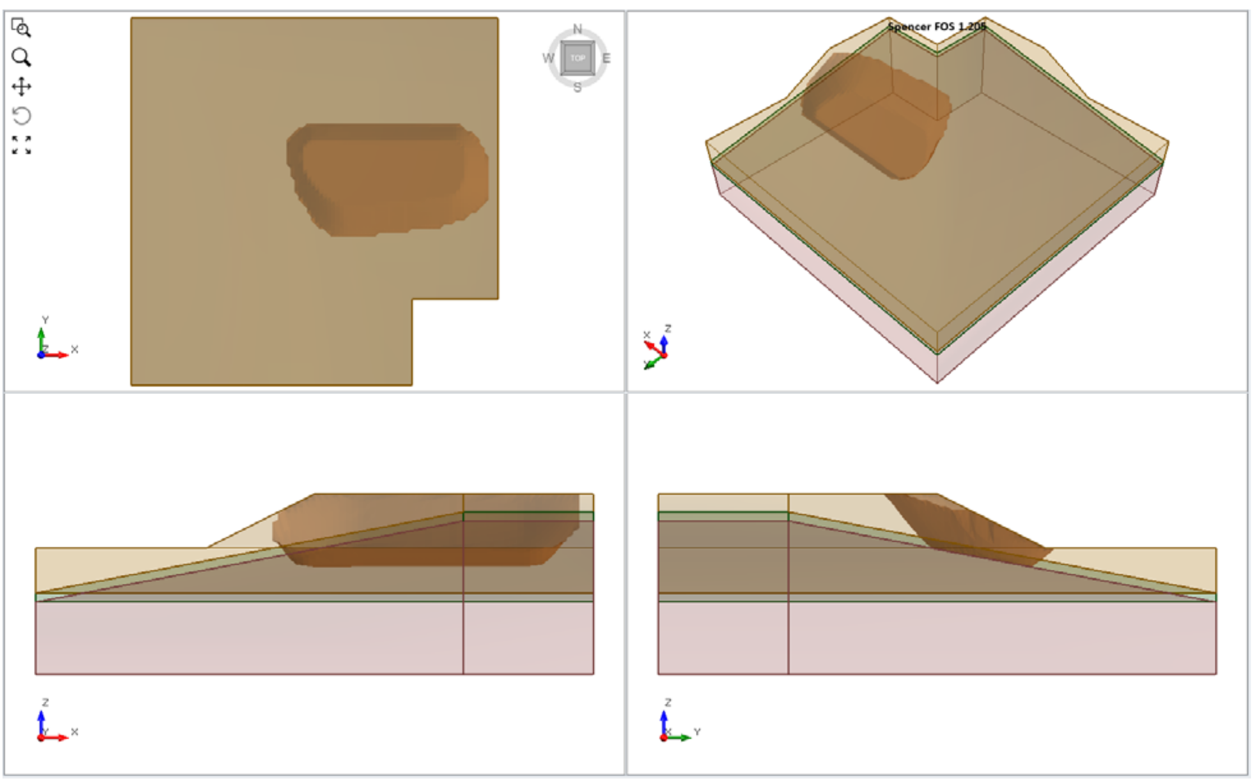


Figure 6.4.7 – Slide3 Solution Using the Spencer Method

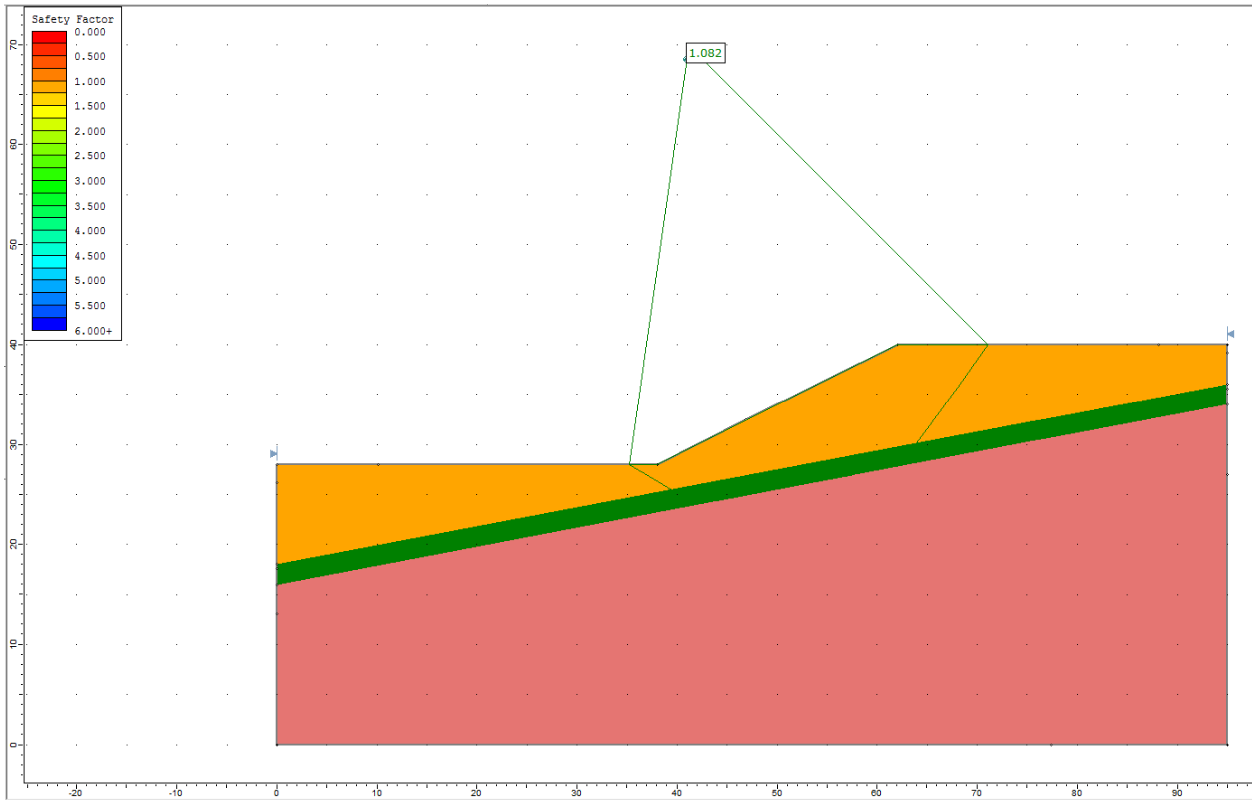


Figure 6.4.8 – Slide Solution Using the Spencer Method

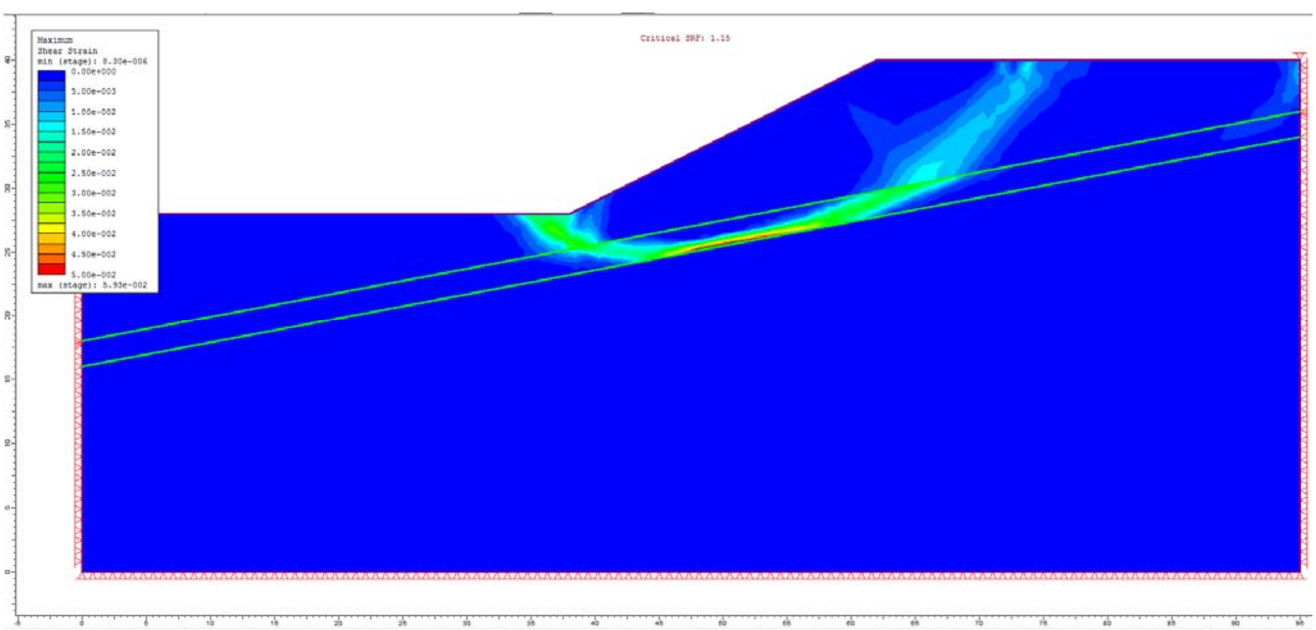


Figure 6.4.9 – RS2 Maximum Shear Strain

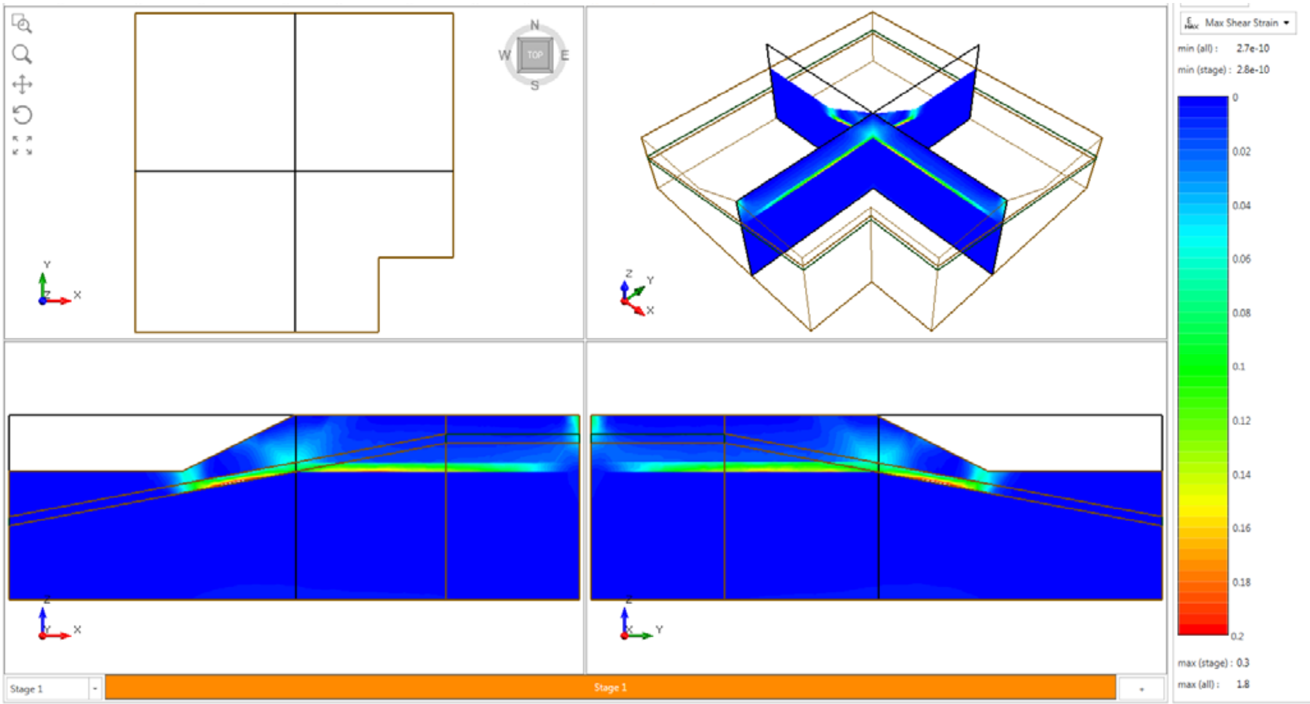


Figure 6.4.10 – RS3 Maximum Shear Strain

2D swept extruded baseline, homogeneous, ellipsoidal with SA

7.1 Introduction

This model comes from Nian et al. (2012). They used a simple homogeneous slope cross section and analyzed the effect of different turning corners in 3D on the safety factor. This is the 2D cross section extruded.

7.2 Problem Description

The cross section for this model in the XZ plane is shown in Figure 7. This cross section is then extruded 40m in the Y direction. The model consists of a homogeneous slope whose material properties are shown in Table 7.1. A cuckoo search with search optimization was used to find the ellipsoidal slip surface.

7.3 Geometry and Properties

Table 7.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	40	20	20

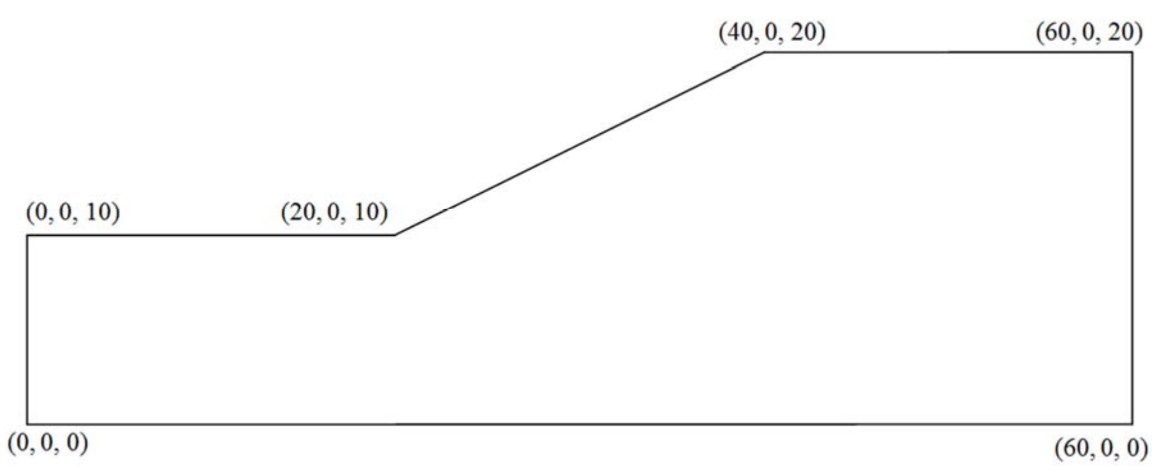


Figure 7

7.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	2.591	2.387	2.81	2.55
GLE	2.733	2.506		
Janbu	2.493	2.263		
Spencer	2.753	2.545		

Referee: 2.780 [Nian, 2012]

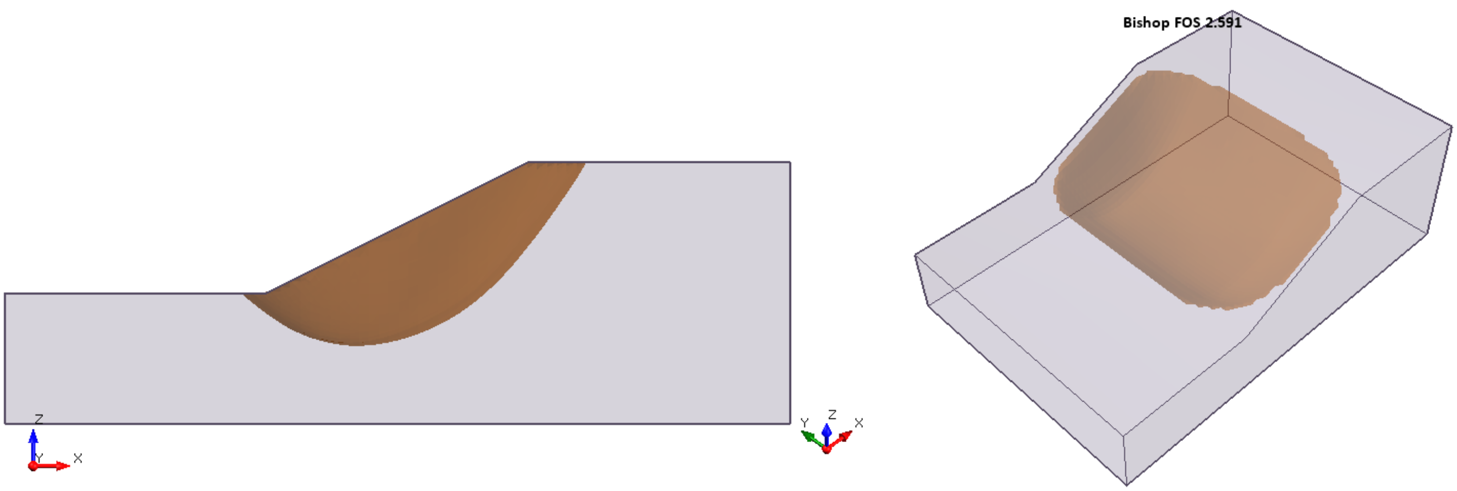


Figure 7.4.1 – Slide3 Solution Using the Bishop method

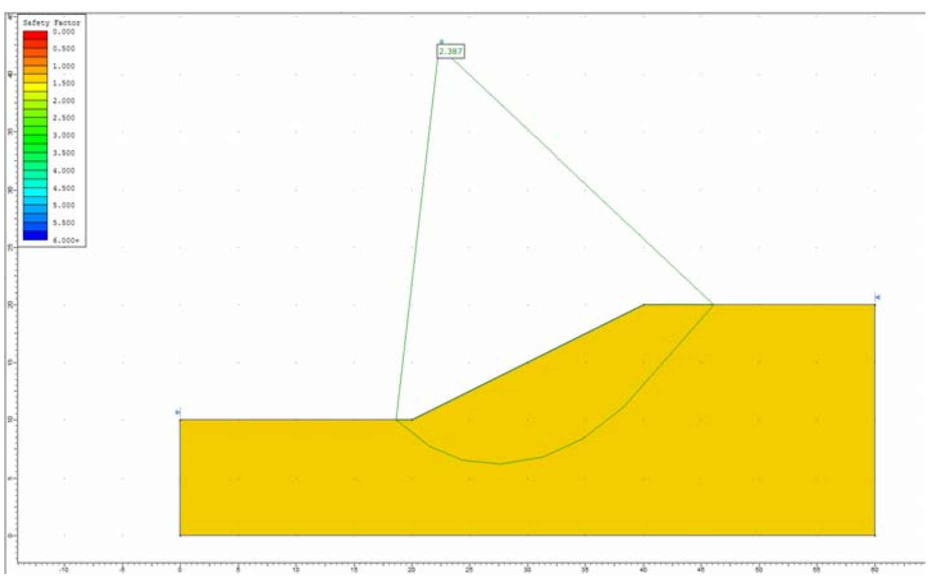


Figure 7.4.2 – Slide Solution Using the Bishop Method

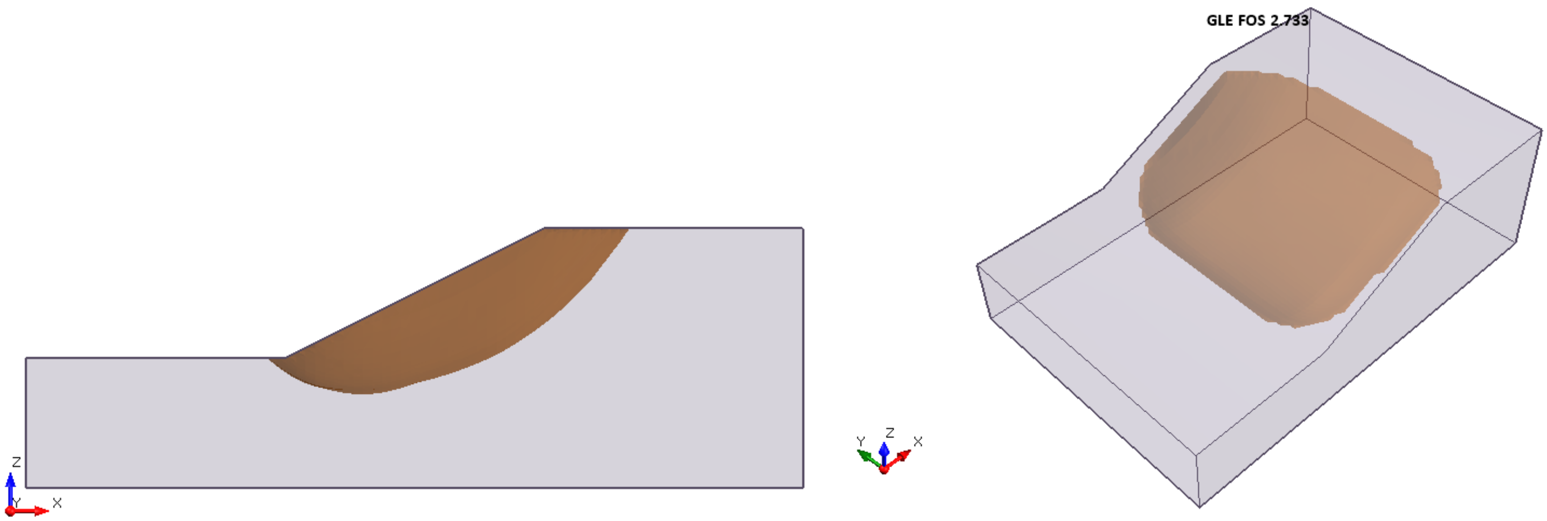


Figure 7.4.3 – Slide3 Solution Using the GLE Method

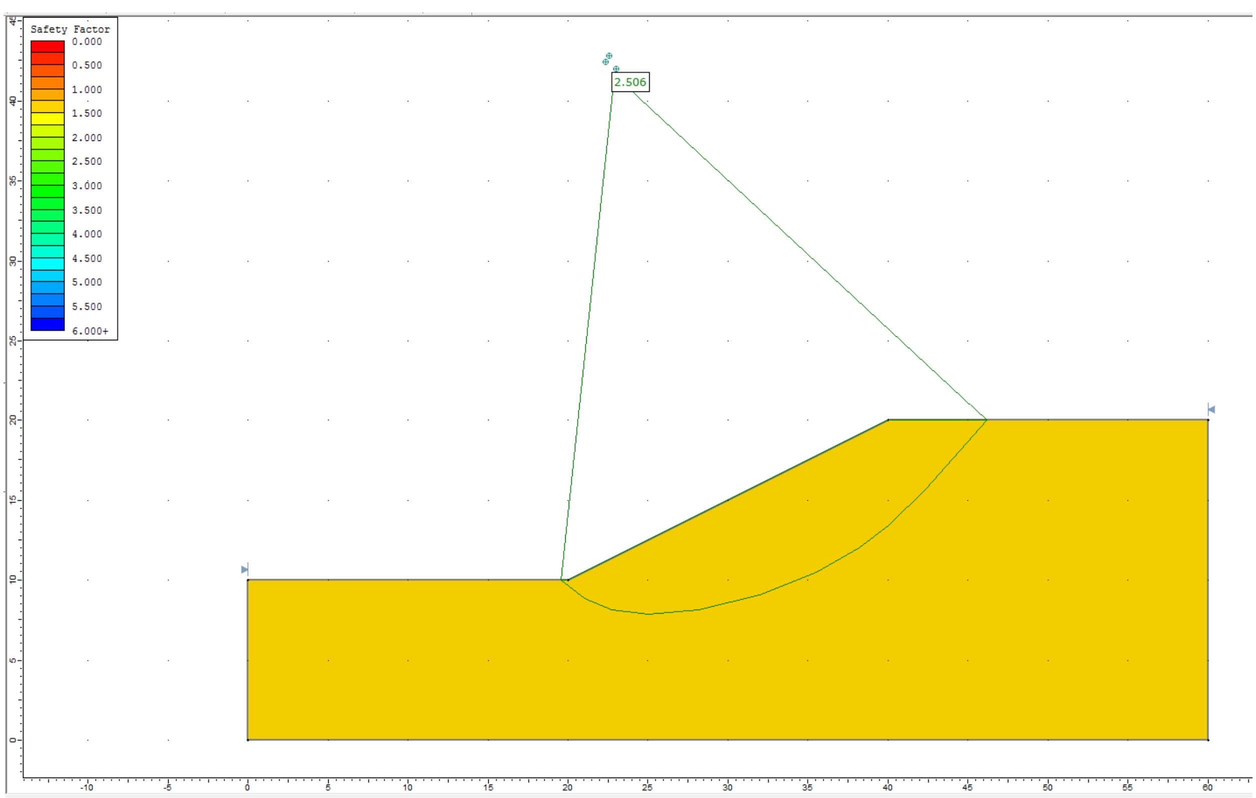


Figure 7.4.4 – Slide Solution Using the GLE Method

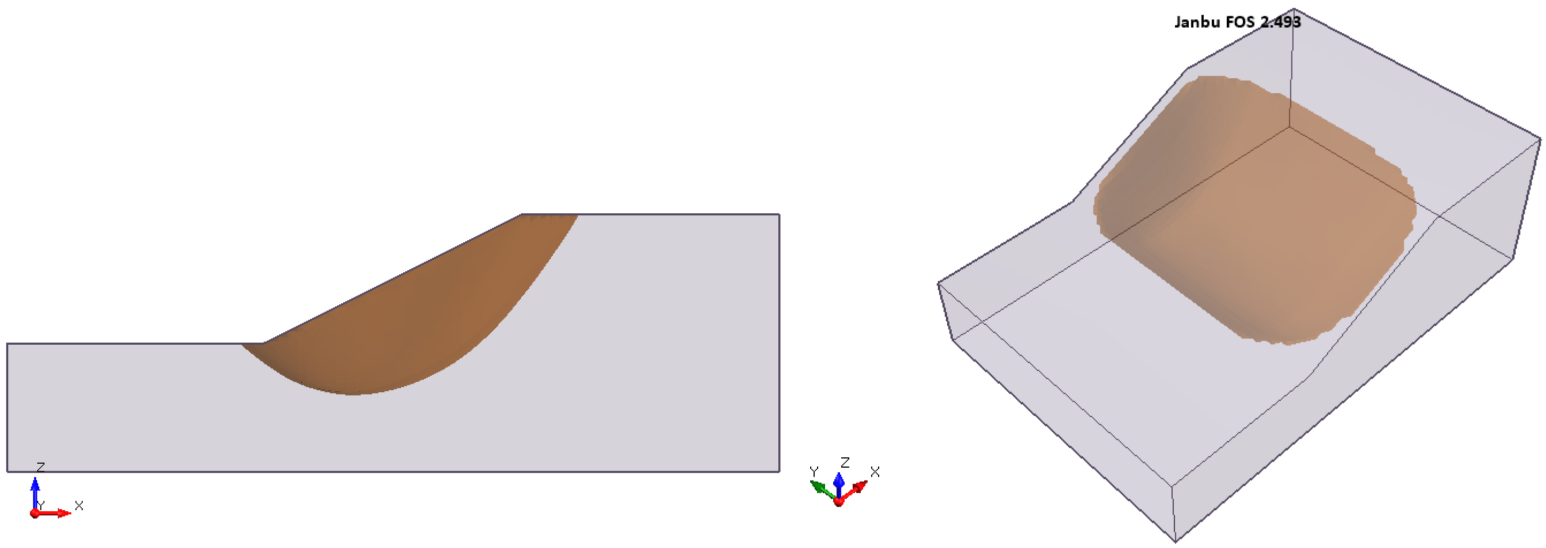


Figure 7.4.5 – Slide3 Solution Using the Janbu Method

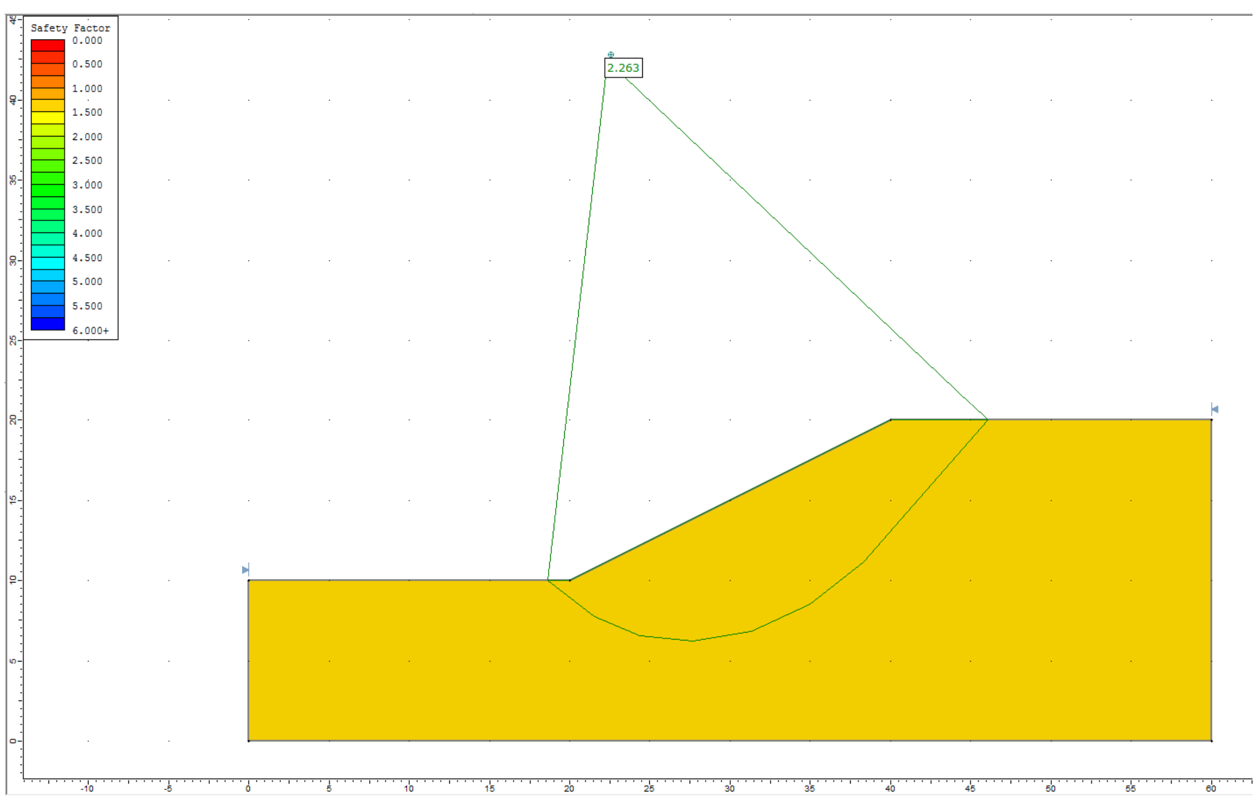


Figure 7.4.6 – Slide Solution Using the Janbu Method

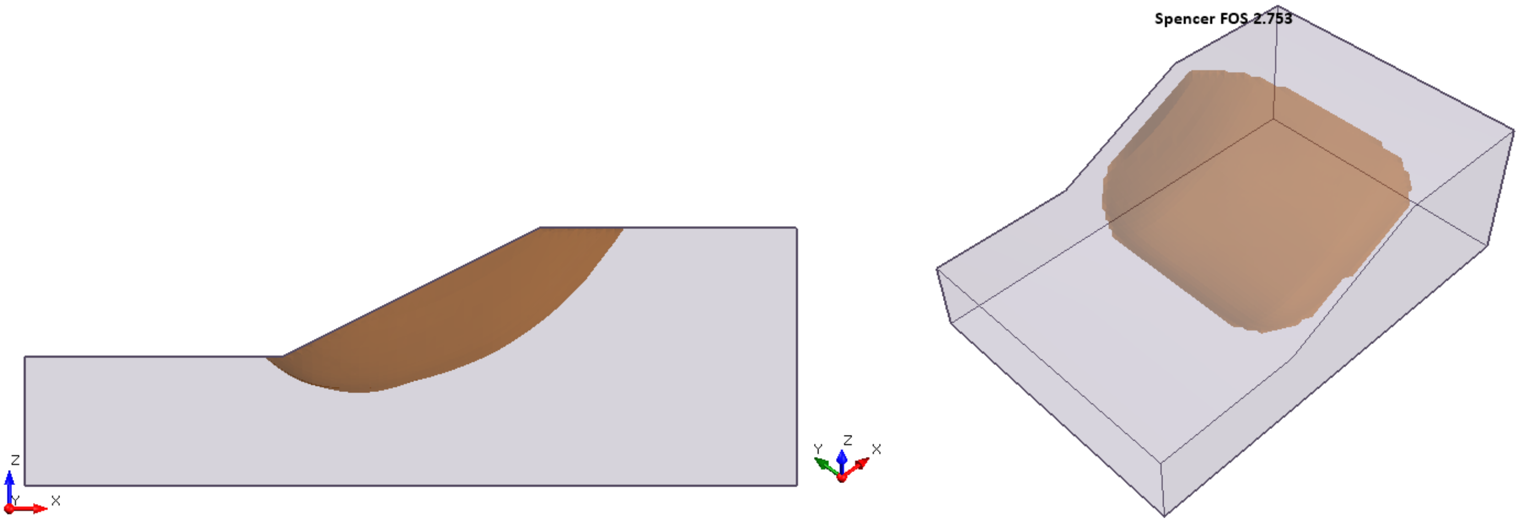


Figure 7.4.7 – Slide3 Solution Using the Spencer Method

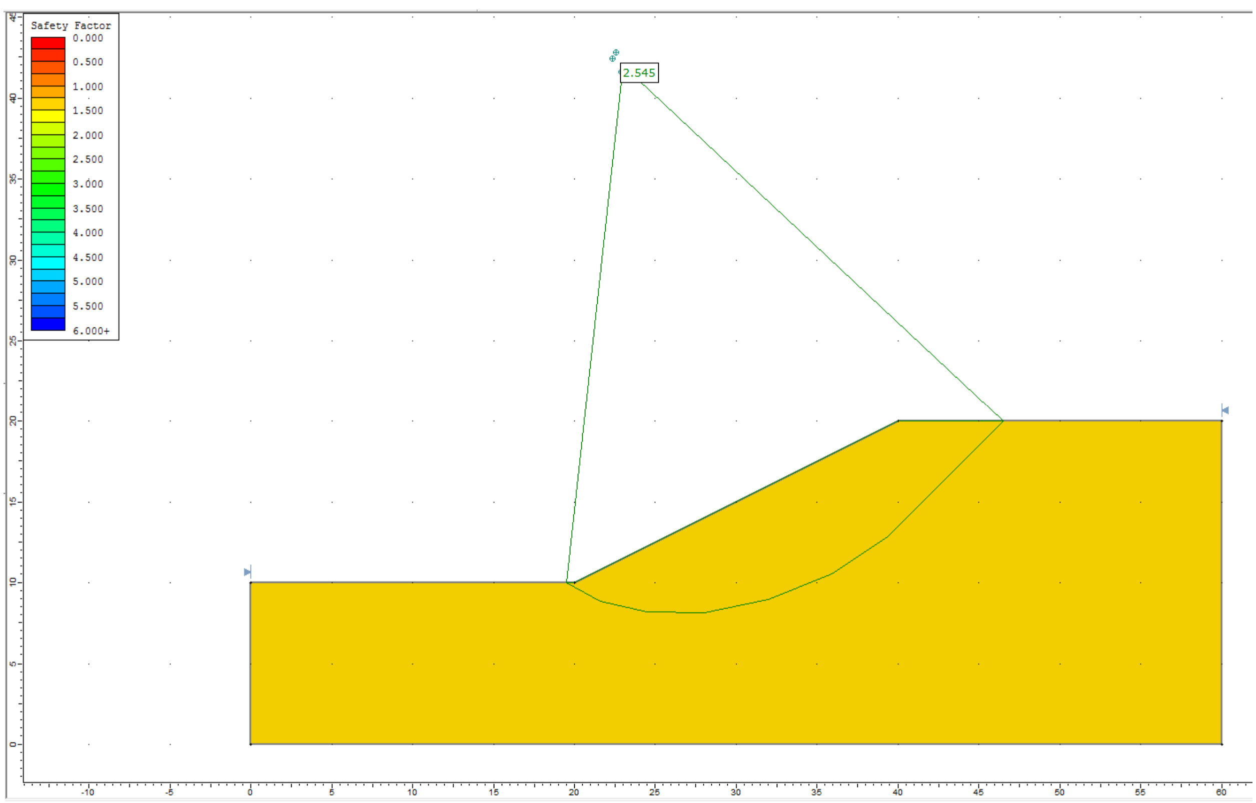


Figure 7.4.8 – Slide Solution Using the Spencer Method

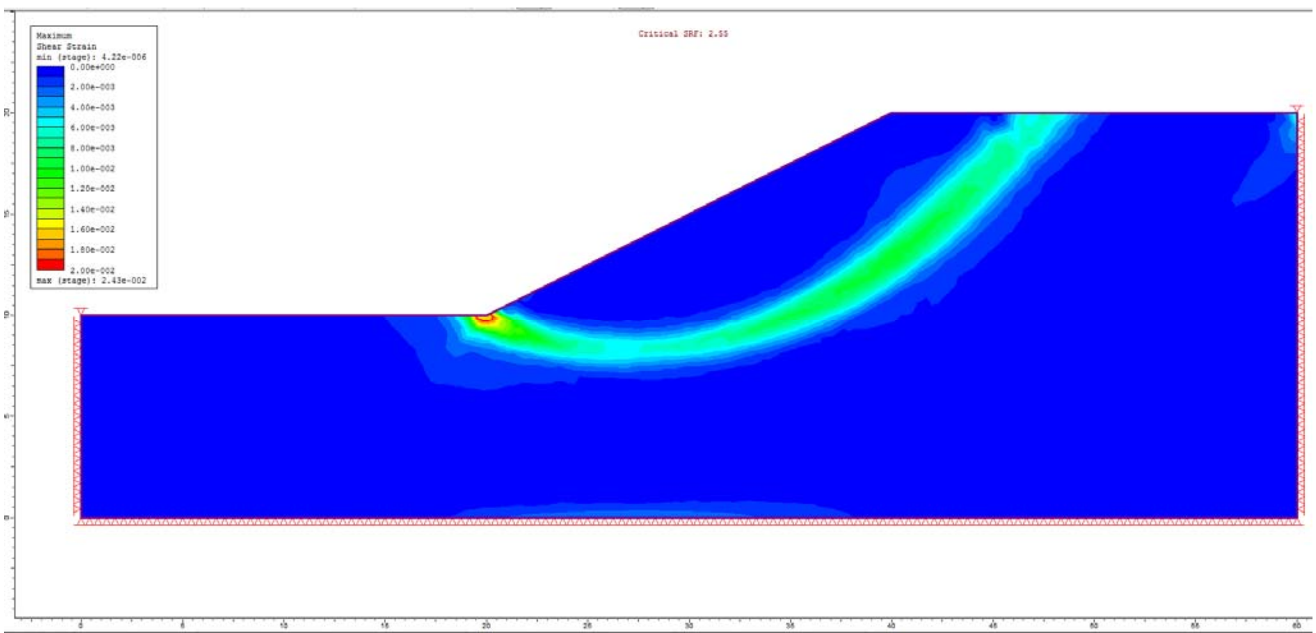


Figure 7.4.9 – RS2 Maximum Shear Strain

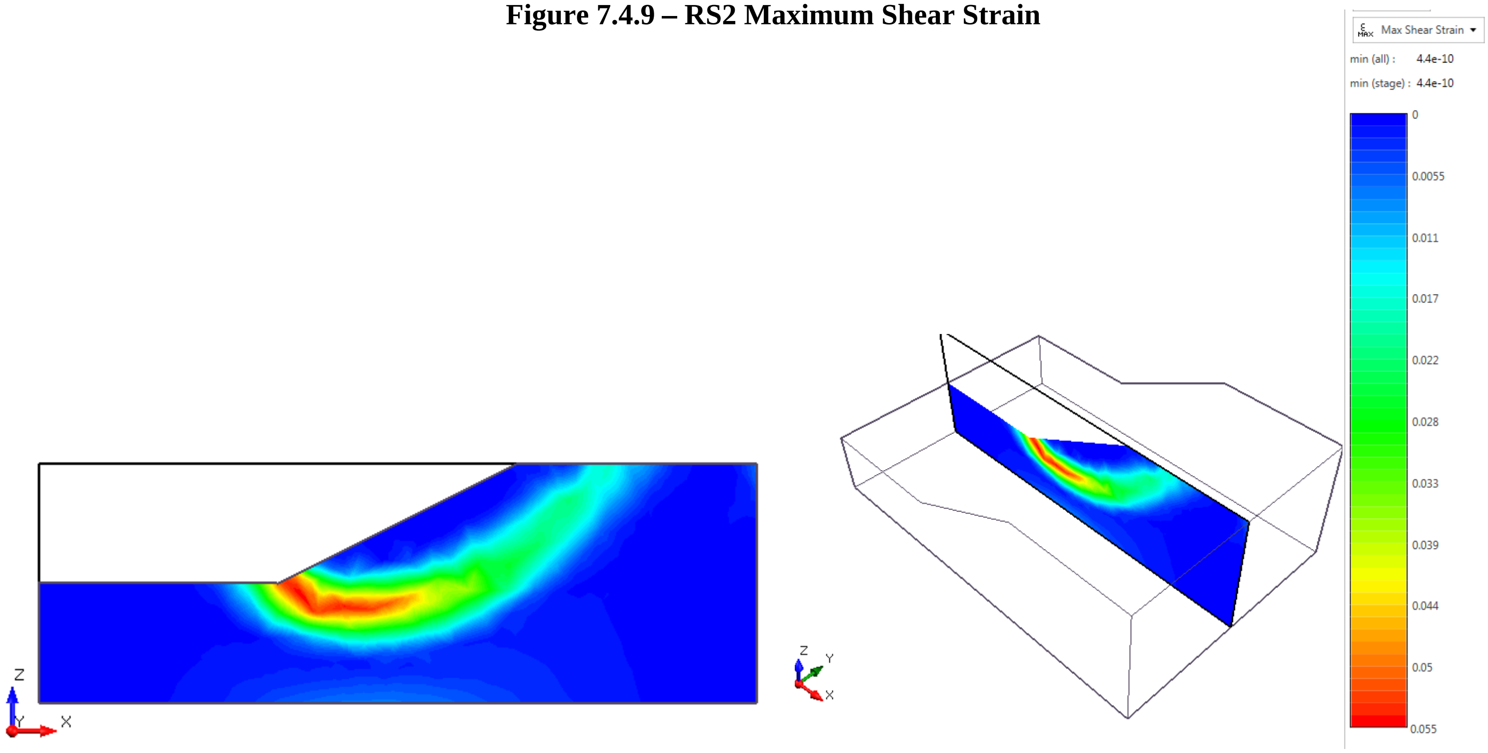


Figure 7.4.10 – RS3 Maximum Shear Strain

2D swept, 90° turn, convex, homogeneous, ellipsoidal with SA

8.1 Introduction

This model comes from Nian et al. (2012). They used a simple homogeneous slope cross section and analyzed the effect of different turning corners in 3D on the safety factor. This is the second case: a 90° corner.

8.2 Problem Description

The cross section for this model is shown in Figure 8(a) and the top view of the model is shown in Figure 8(b). The model was made by taking the cross section (which is in the XZ plane) and sweeping it across a 90° bend starting at (40, 0, 0), bending at (40, 20 0), and ending at (60, 20, 0), offset -10m. The model consists of a homogeneous slope whose material properties are shown in Table 8.1. A cuckoo search with search optimization was used to find the ellipsoidal slip surface.

8.3 Geometry and Properties

Table 8.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	40	20	20

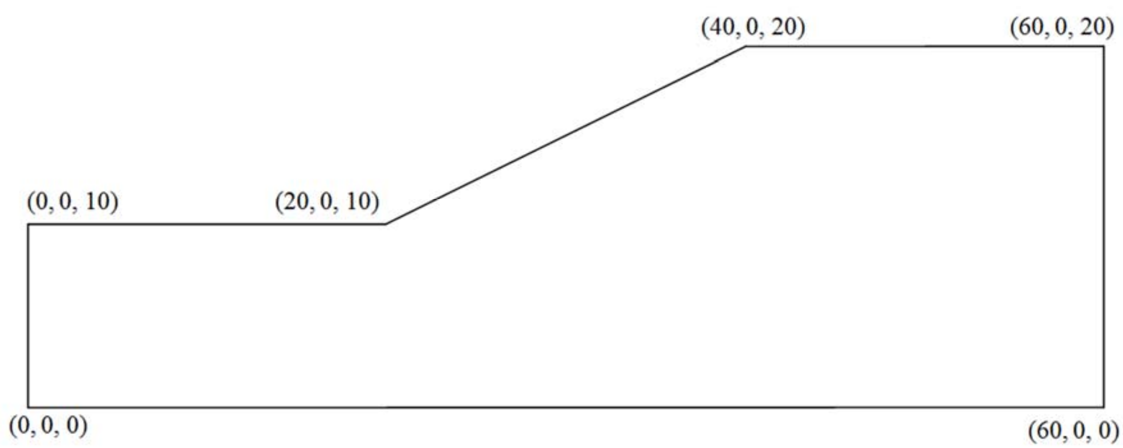


Figure 8(a)

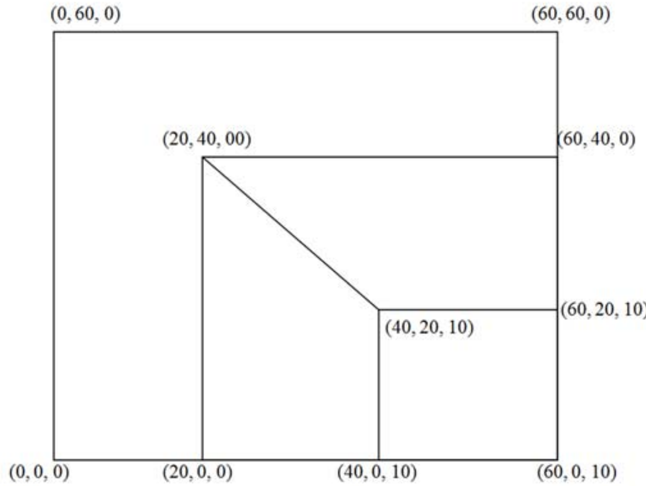


Figure 8(b)

8.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	2.726	2.387	2.91	2.55
GLE	2.871	2.506		
Janbu	2.602	2.263		
Spencer	2.876	2.545		

Referee: 2.860 [Nian et al., 2012]

Note: The 2D cross section for this example is the same as the previous example, therefore the RS2 and Slide 7.0 values have not changed and the Slide 7.0 slip surfaces and RS2 maximum shear strain will not be shown in this example.

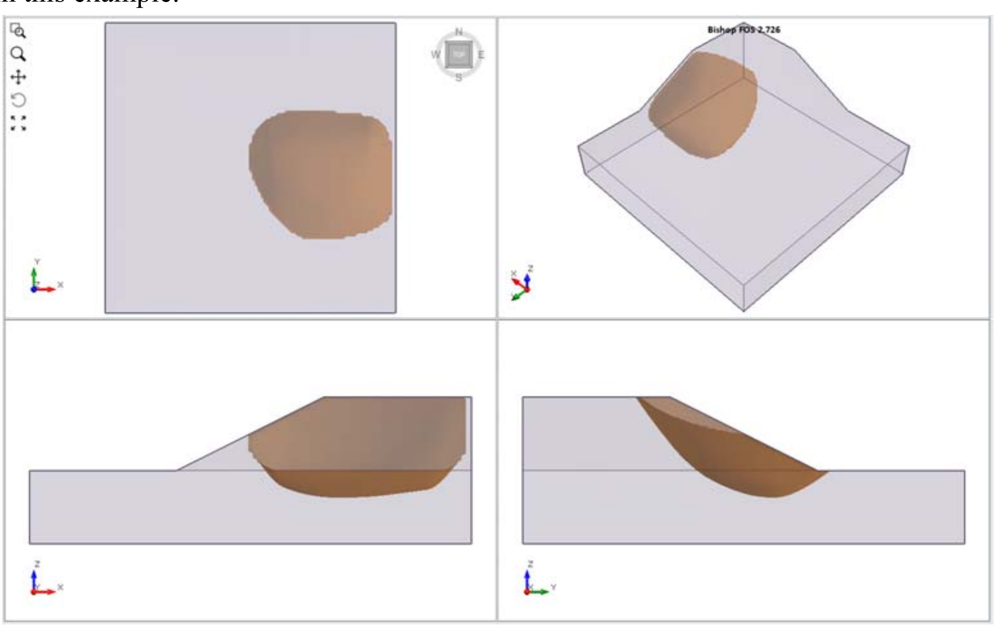


Figure 8.4.1 – Slide3 Solution Using the Bishop Method

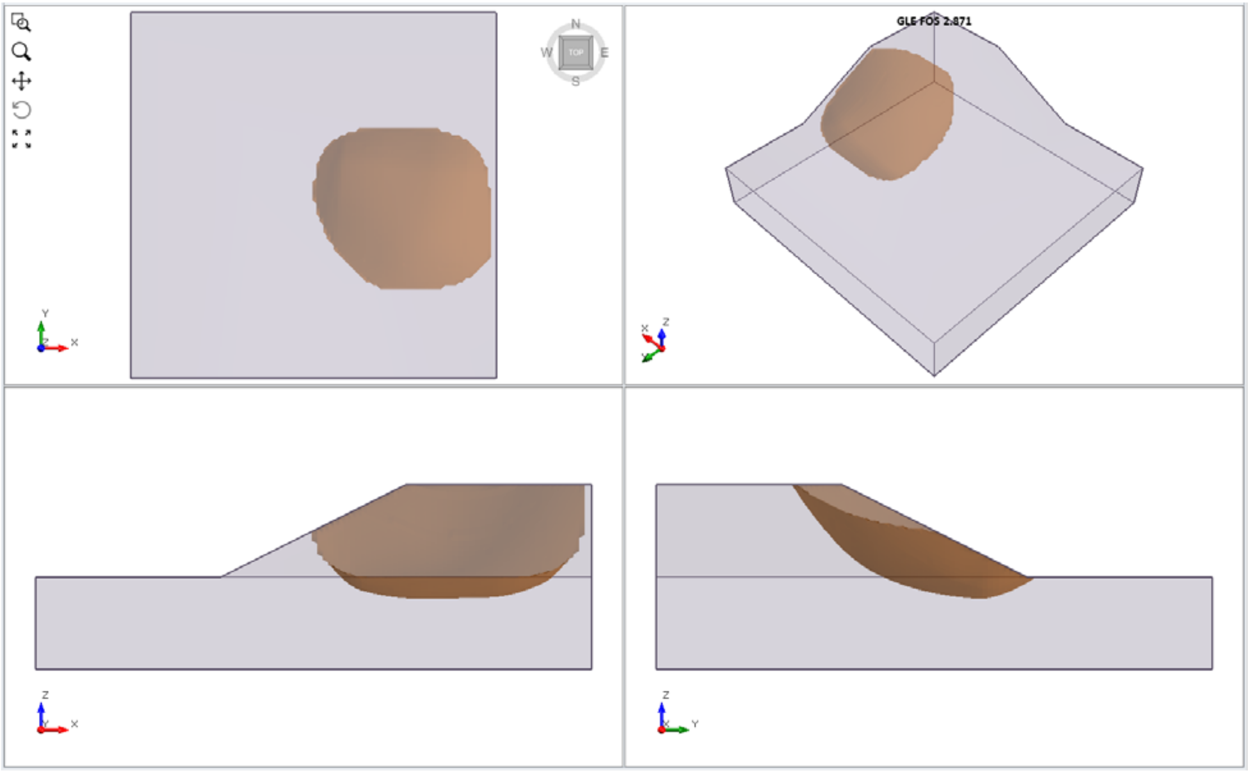


Figure 8.4.2 – Slide3 Solution Using the GLE Method

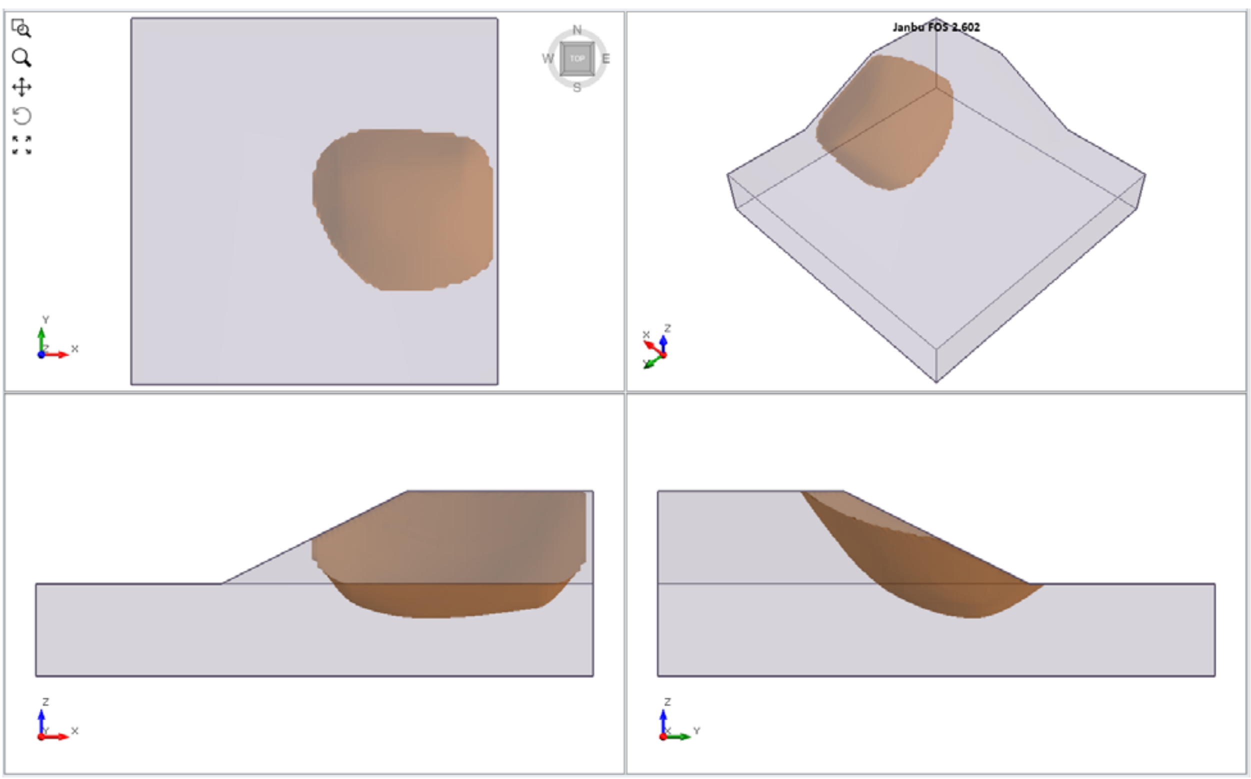


Figure 8.4.3 – Slide3 Solution Using the Janbu Method

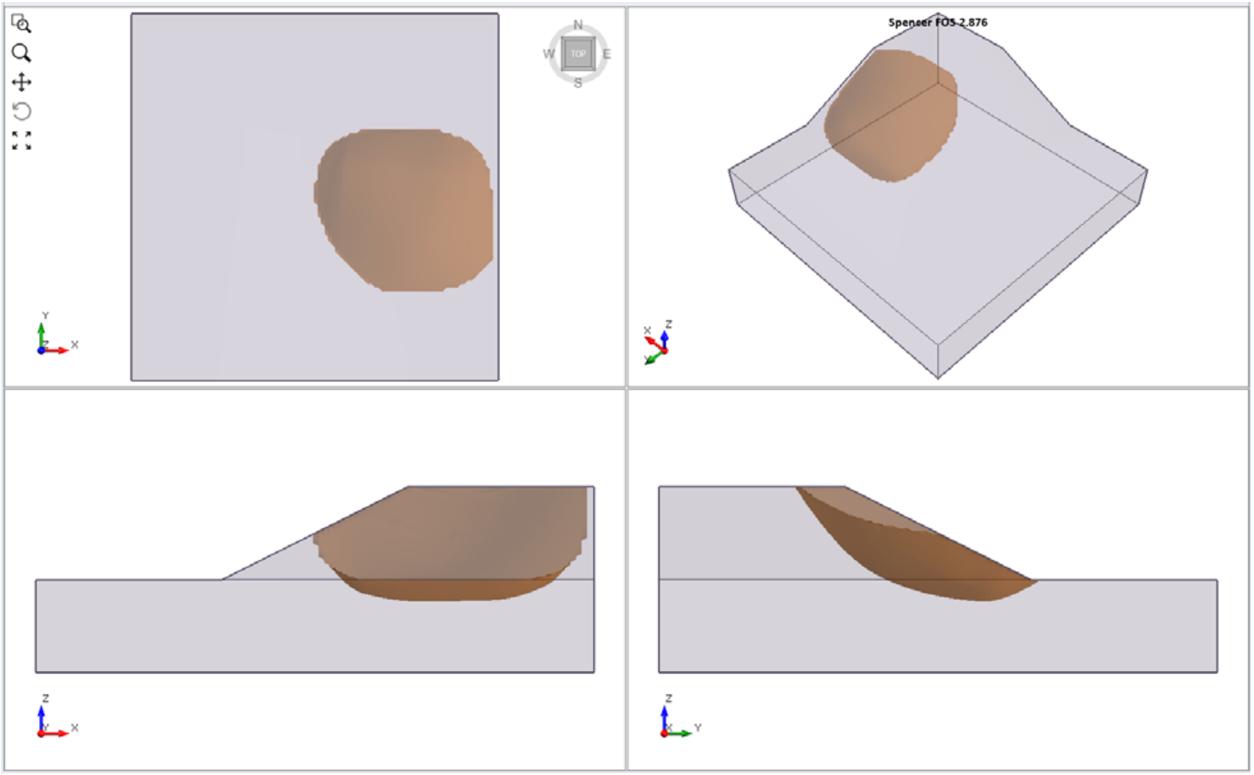


Figure 8.4.4 – Slide3 Solution Using the Spencer Method

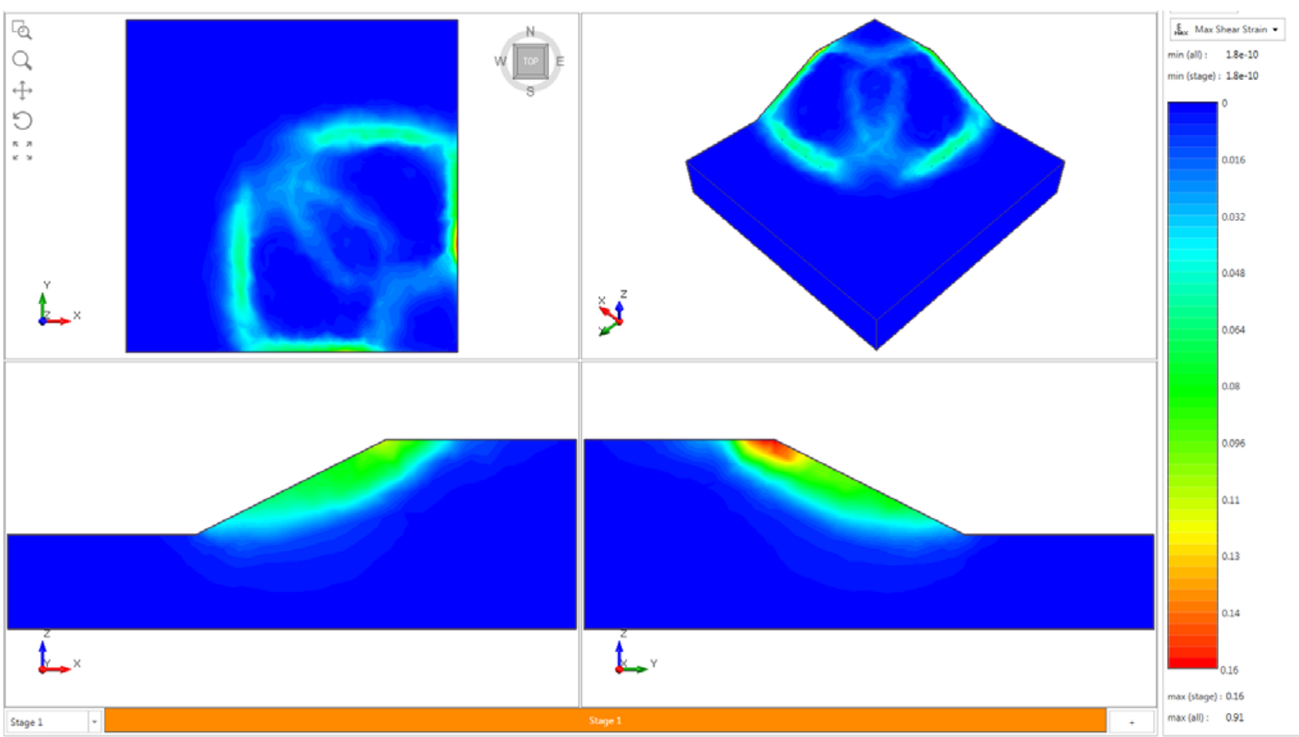


Figure 8.4.5 – RS3 Maximum Shear Strain

2D Swept, 135° turn, convex, homogeneous, ellipsoidal with SA

9.1 Introduction

This model comes from Nian et al. (2012). They used a simple homogeneous slope cross section and analyzed the effect of different turning corners in 3D on the safety factor. This is the third case: a 135° corner.

9.2 Problem Description

The cross section for this model is shown in Figure 9(a) and the top view of the model is shown in Figure 9(b). The model was made by taking the cross section (which is in the XZ plane) and sweeping it across a 135° bend starting at (40, 0, 0), bending at (40, 20 0), and ending at (54.14, 34.14, 0), offset -10m. The model consists of a homogeneous slope whose material properties are shown in Table 9.1. A cuckoo search with search optimization was used 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	40	20	20

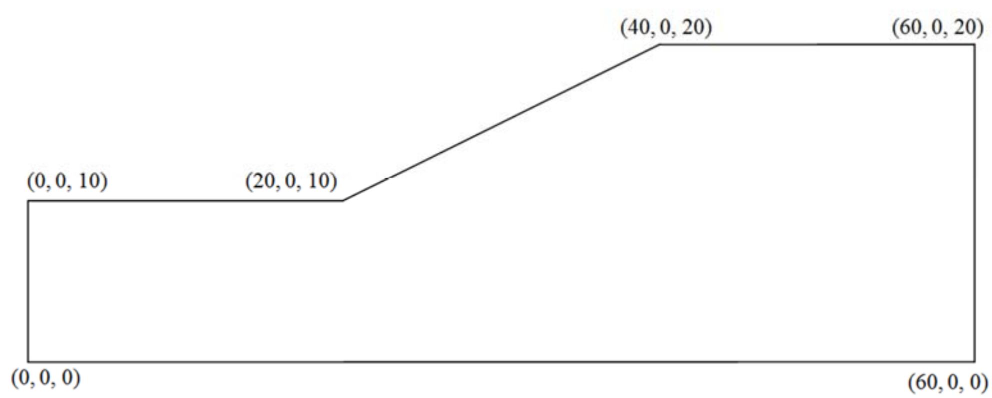


Figure 9(a)

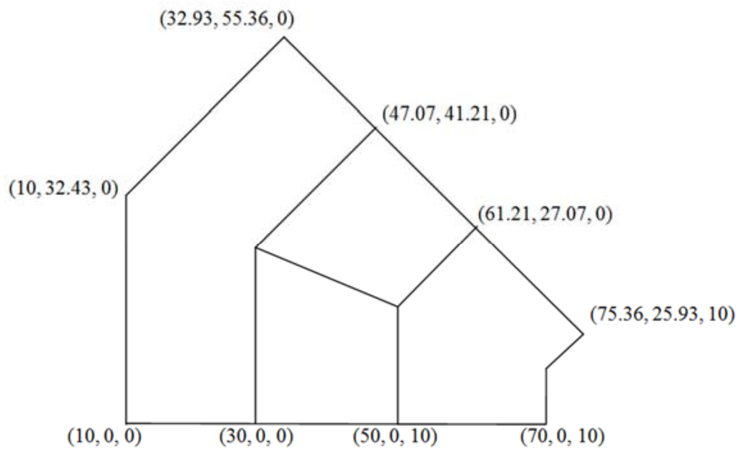


Figure 9(b)

9.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	2.671	2.387	2.87	2.55
GLE	2.841	2.506		
Janbu	2.552	2.263		
Spencer	2.9886	2.545		

Referee: 2.810 [Nian et al., 2012]

Note: The 2D cross section for this example is the same as the previous example, therefore the RS2 and Slide 7.0 values have not changed and the Slide 7.0 slip surfaces and RS2 maximum shear strain will not be shown is this example.

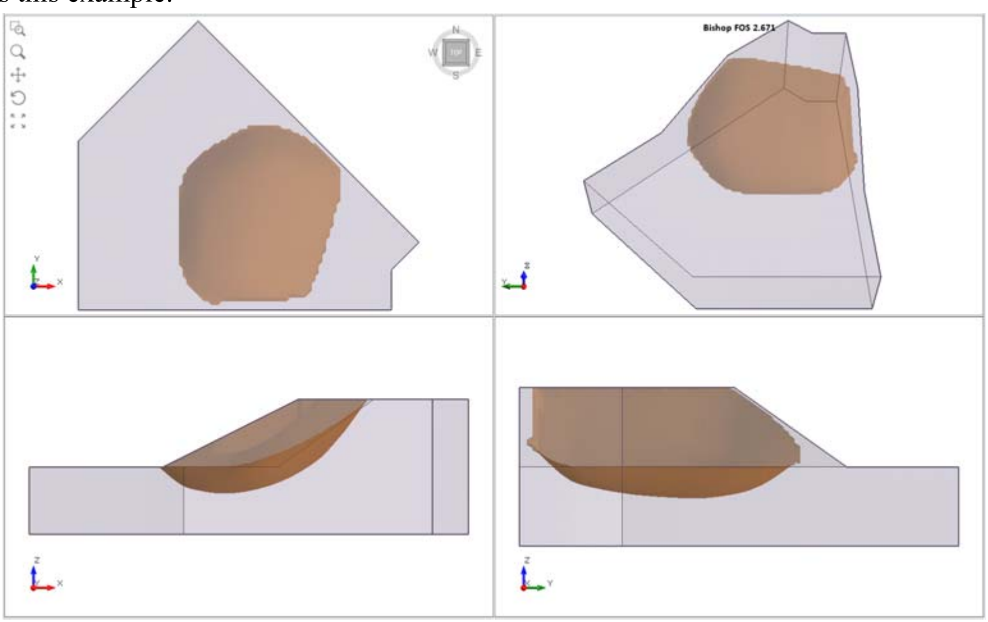


Figure 9.4.1 – Slide3 Solution Using the Bishop Method

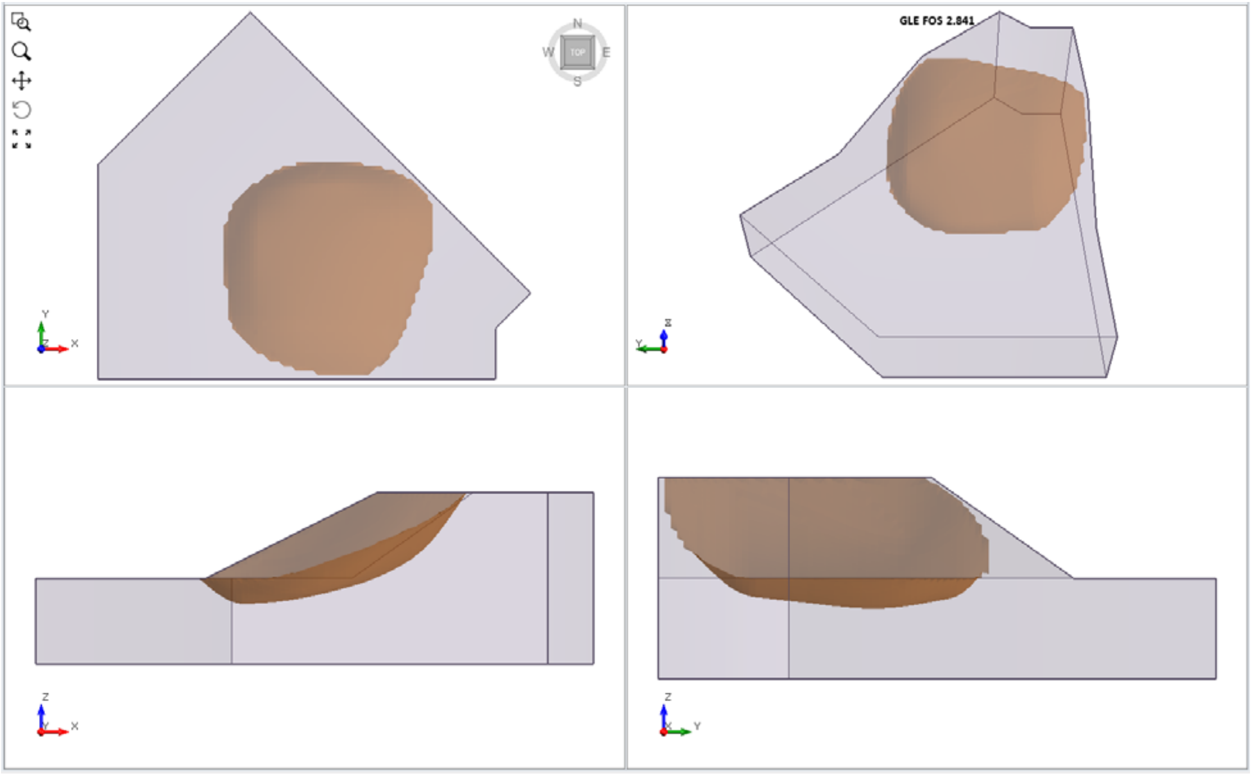


Figure 9.4.2 – Slide3 Solution Using the GLE Method

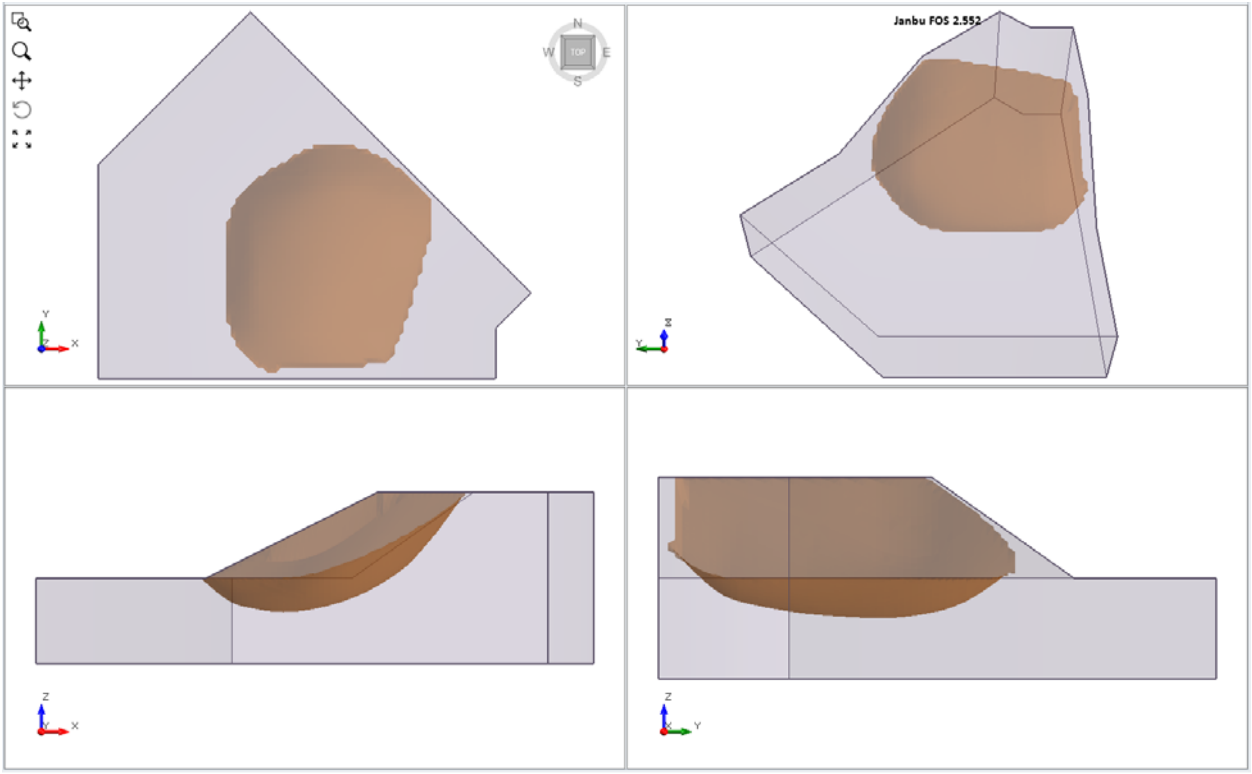


Figure 9.4.3 – Slide3 Solution Using the Janbu Method

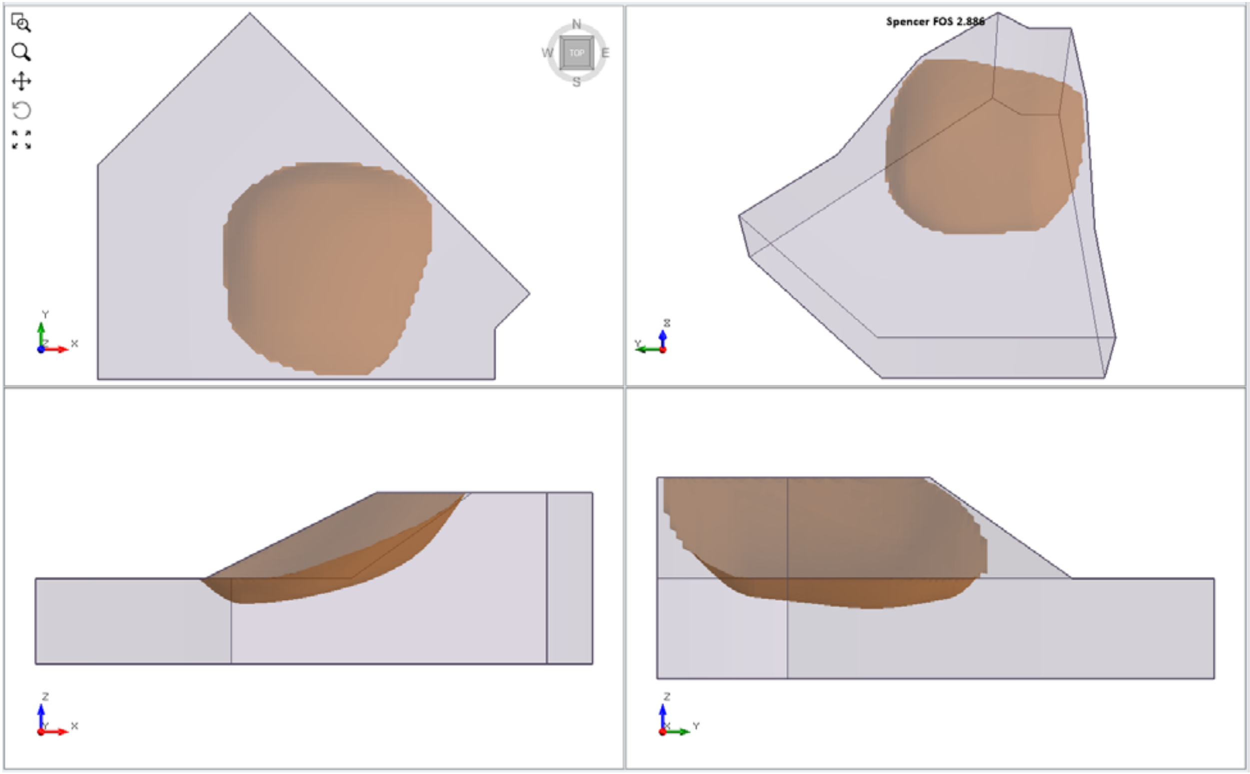


Figure 9.4.4 – Slide3 Solution Using the Spencer Method

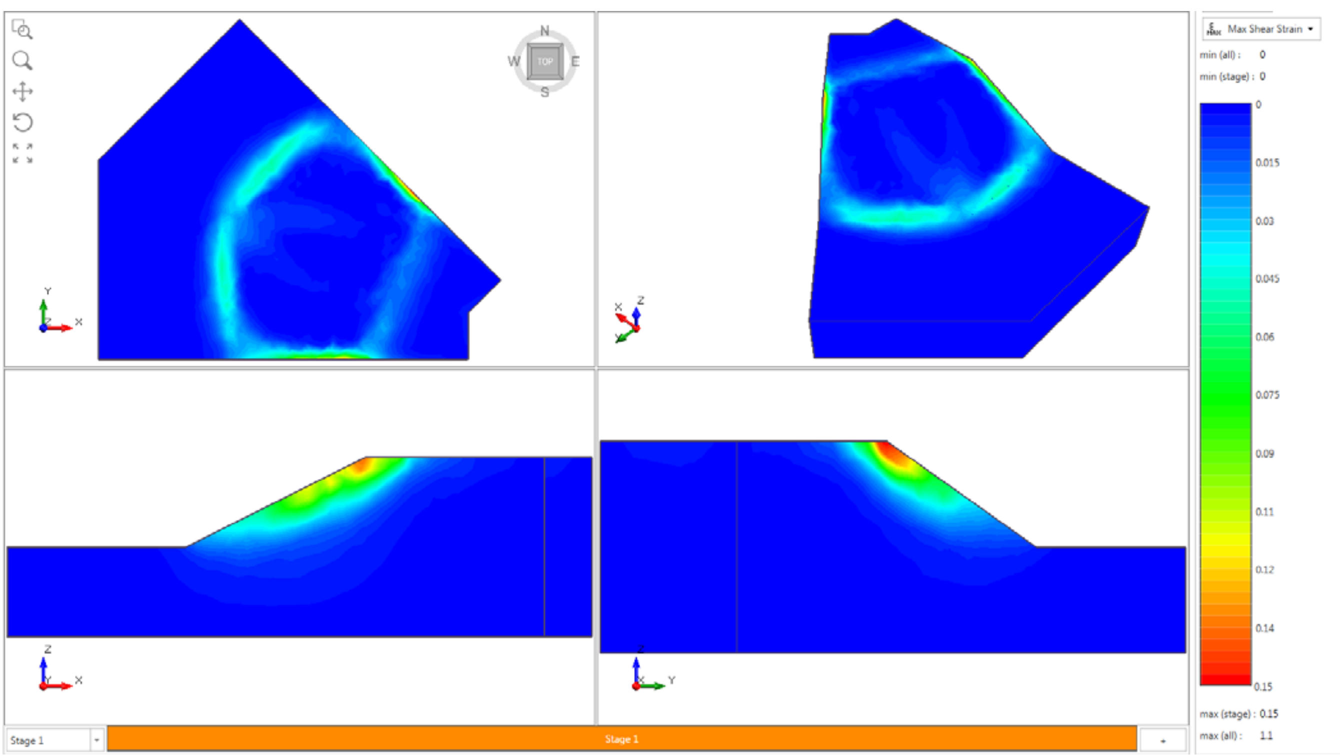


Figure 9.4.5 – RS3 Maximum Shear Strain

2D swept truncated cone, homogeneous, slope limits, spherical

10.1 Introduction

This example is taken from Huang et al. (2002). The model is a homogenous truncated cone on a stadium. The analysis was done using both simplified and rigorous methods.

10.2 Problem Description

The 2D cross section of this slope is Figure 10.1 and the top view of the cone is Figure 10.2. The cone is 6m tall with a 1m tall stadium extending from the bottom. The material properties of the homogeneous slope can be found in Table 10.1. The slip surface is assumed to be spherical and does not extend past the cone into the stadium; it is contained entirely within the cone. Slope limits are therefore put in place to accommodate this requirement. The slide cross section is the XZ plane taken at Y = 50.

10.3 Geometry and Properties

Table 10.1: Material Properties

c´ (kN/m^2)	φ´ (deg.)	γ (kN/m^3)
9.81	20	16.68

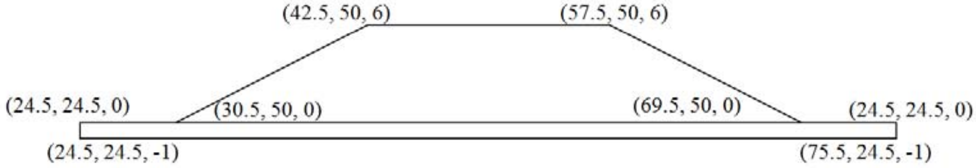


Figure 10.1

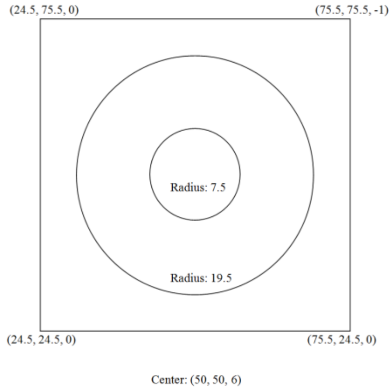


Figure 35.2

10.4 Results

Table 10.4.1: Safety Factors 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>2.099</td><td>1.784</td><td rowspan="4">1.95</td><td rowspan="4">1.77</td></tr>
<tr><td>GLE</td><td>2.095</td><td>1.776</td></tr>
<tr><td>Janbu</td><td>1.987</td><td>1.637</td></tr>
<tr><td>Spencer</td><td>2.12</td><td>1.781</td></tr>
</table>

Referee: 2.348 – 2.361 for simplified methods, 2.418 – 2.467 for rigorous methods [Huang et al., 2002]

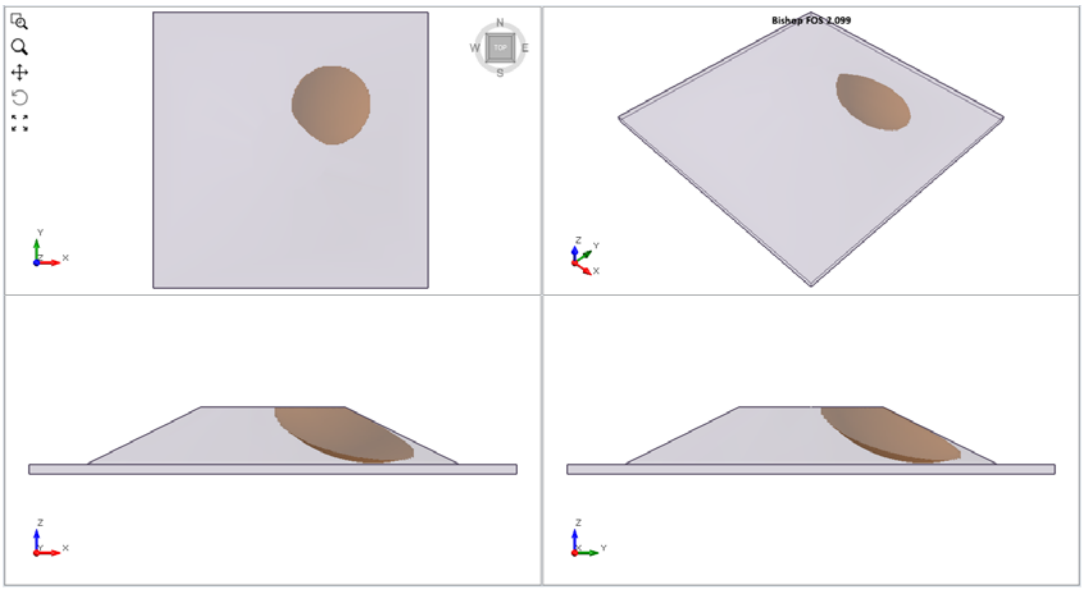


Figure 10.4.1 – Slide3 Solution Using the Bishop Method

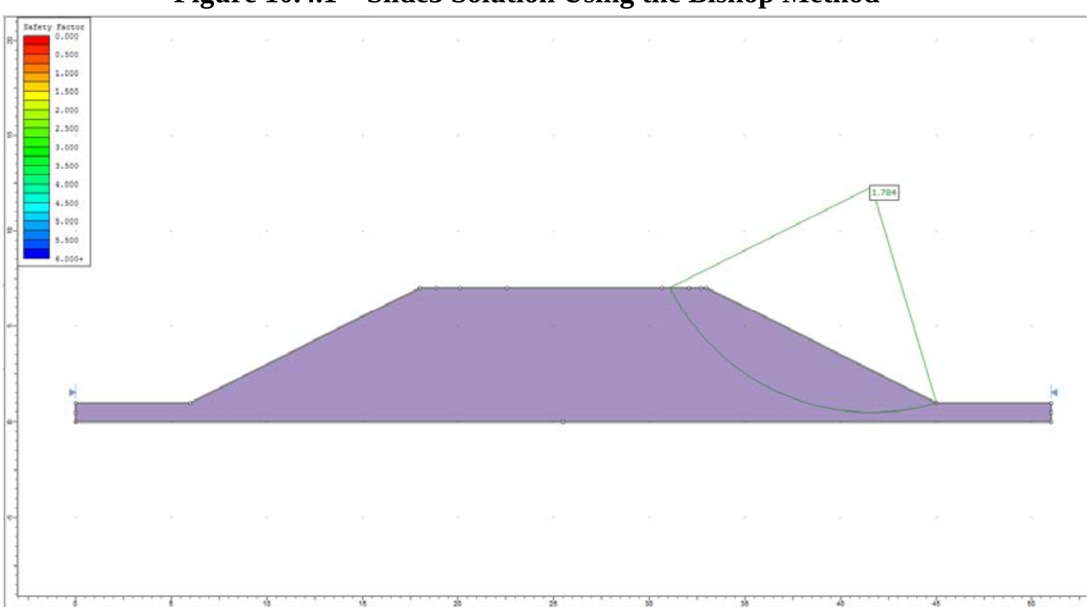


Figure 10.4.2 – Slide Solution Using the Bishop Method

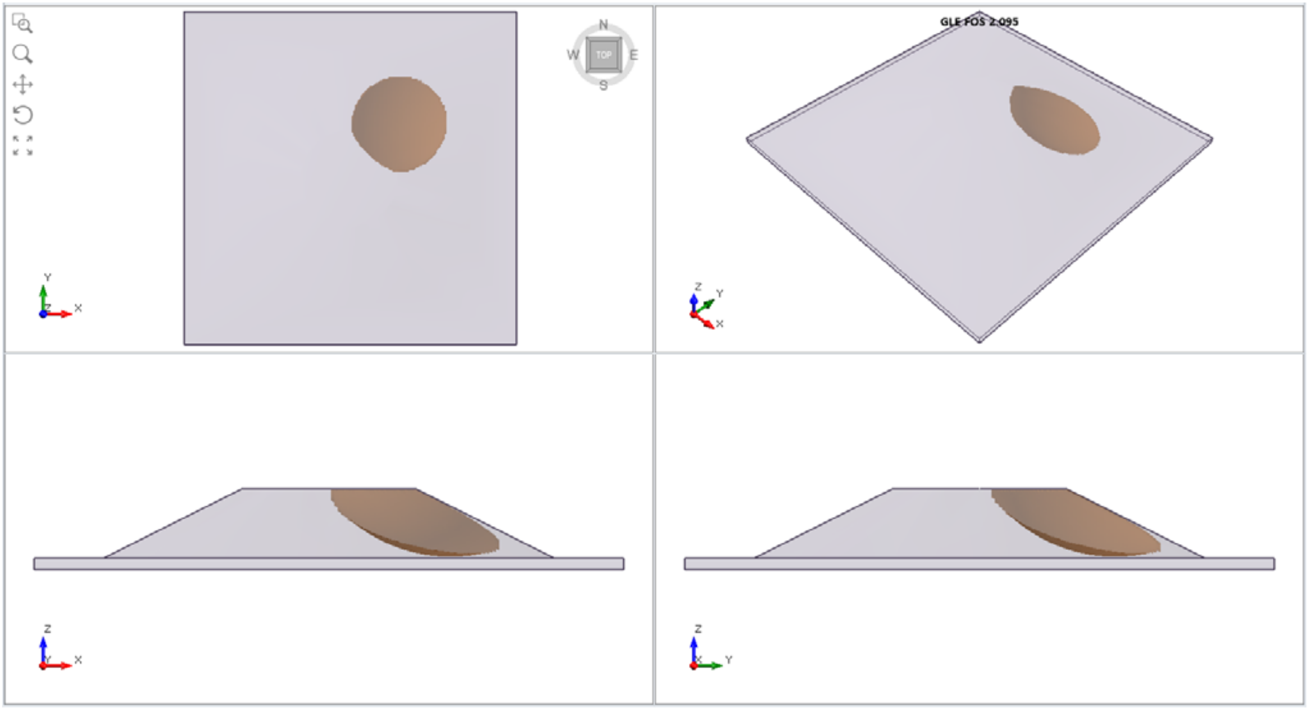


Figure 10.4.3 – Slide3 Solution Using the GLE Method

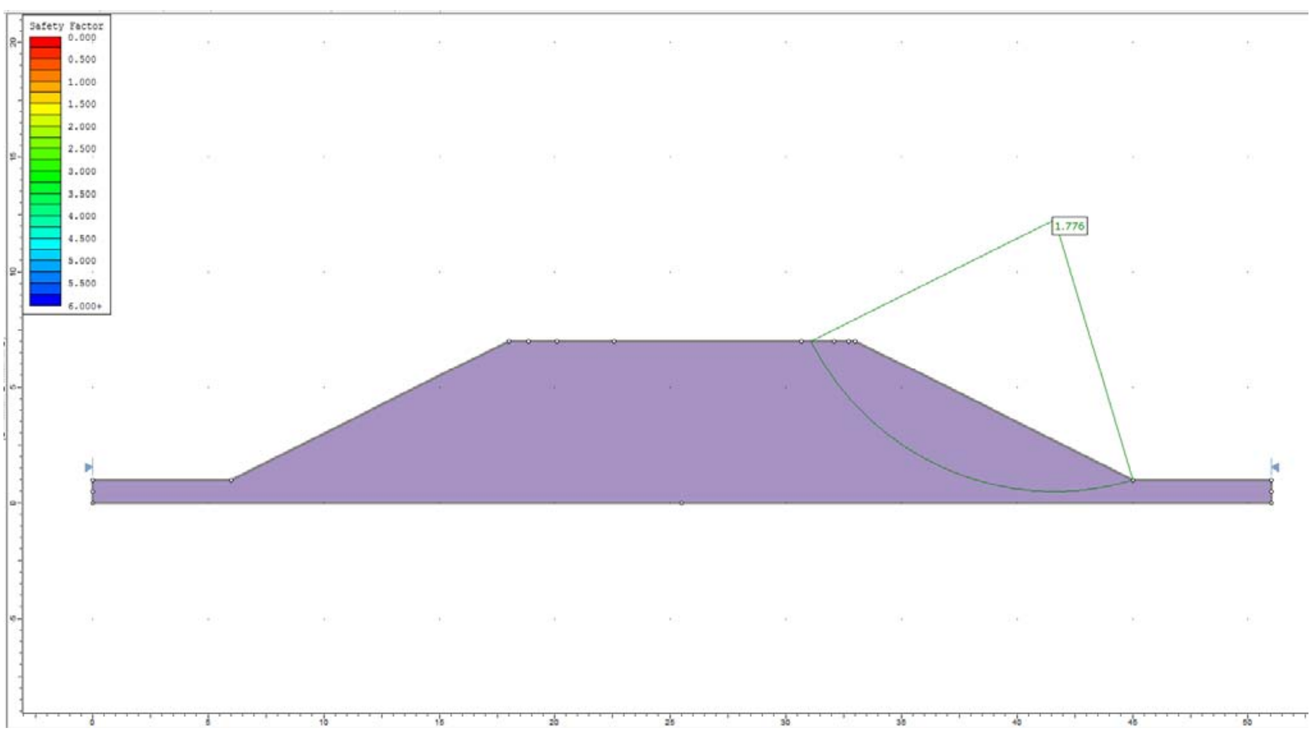


Figure 10.4.4 – Slide Solution Using the GLE Method

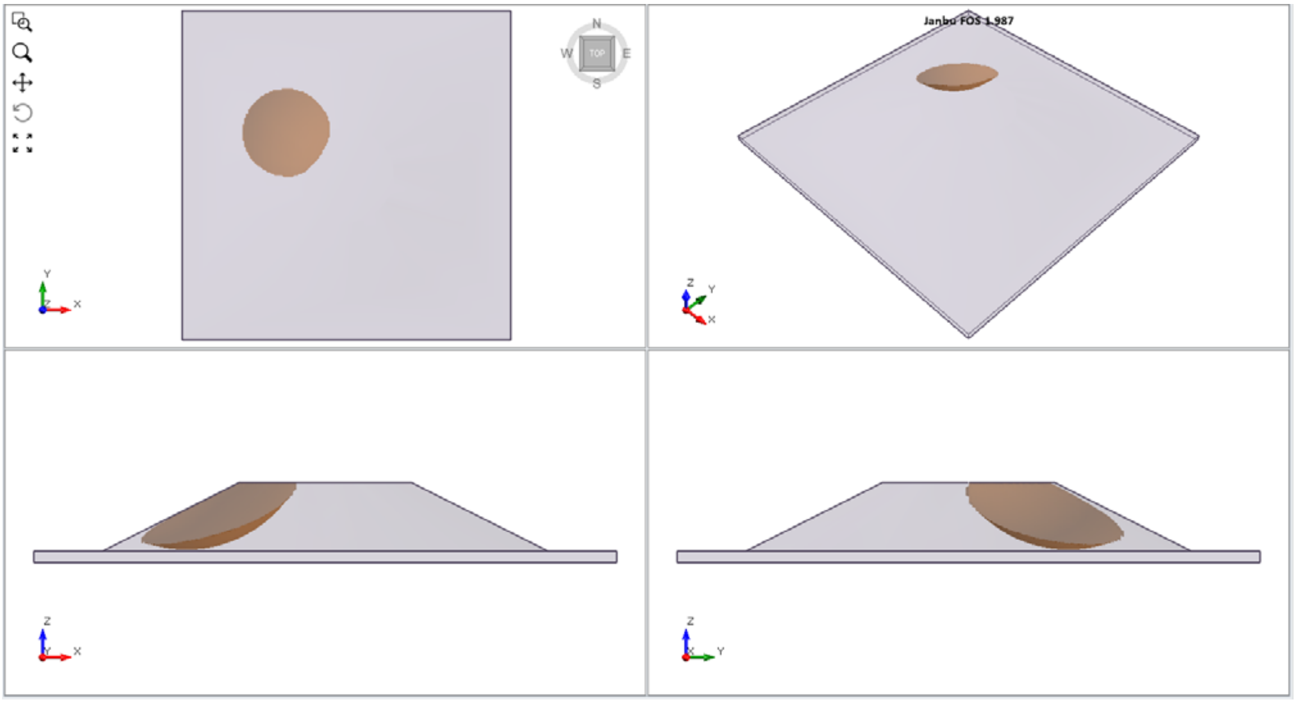


Figure 10.4.5 – Slide3 Solution Using the Janbu Method

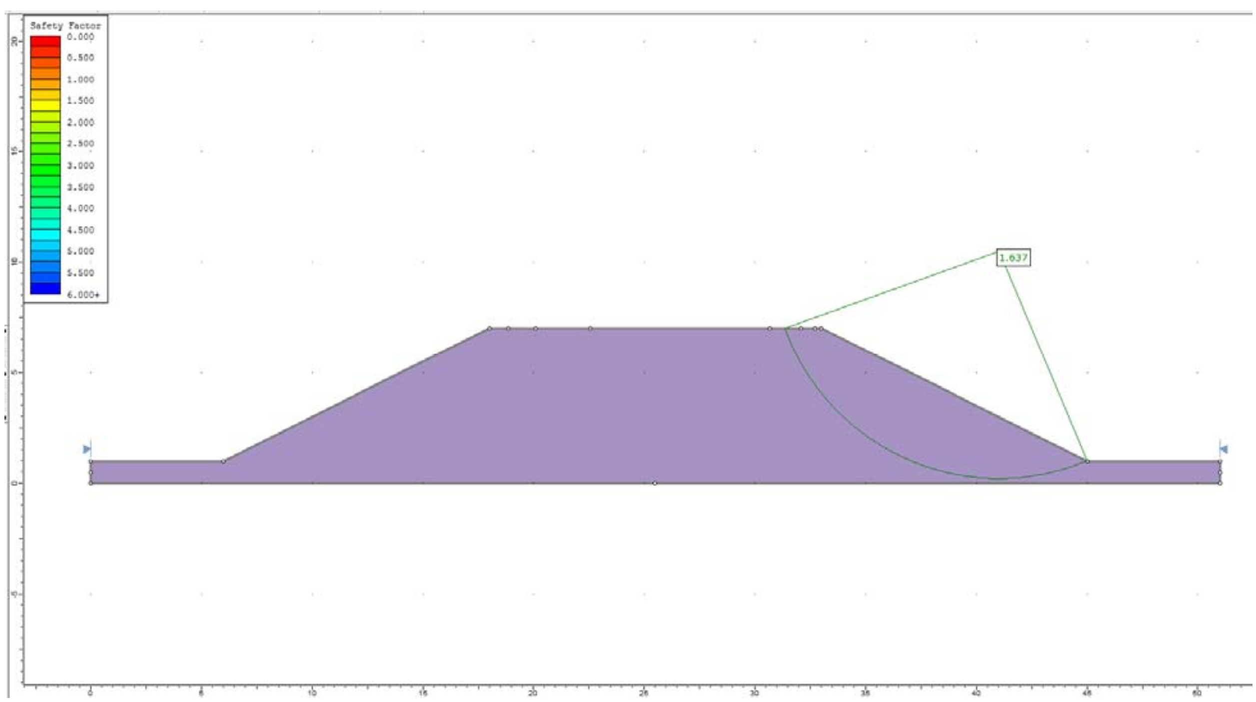


Figure 10.4.6 – Slide Solution Using the Janbu Method

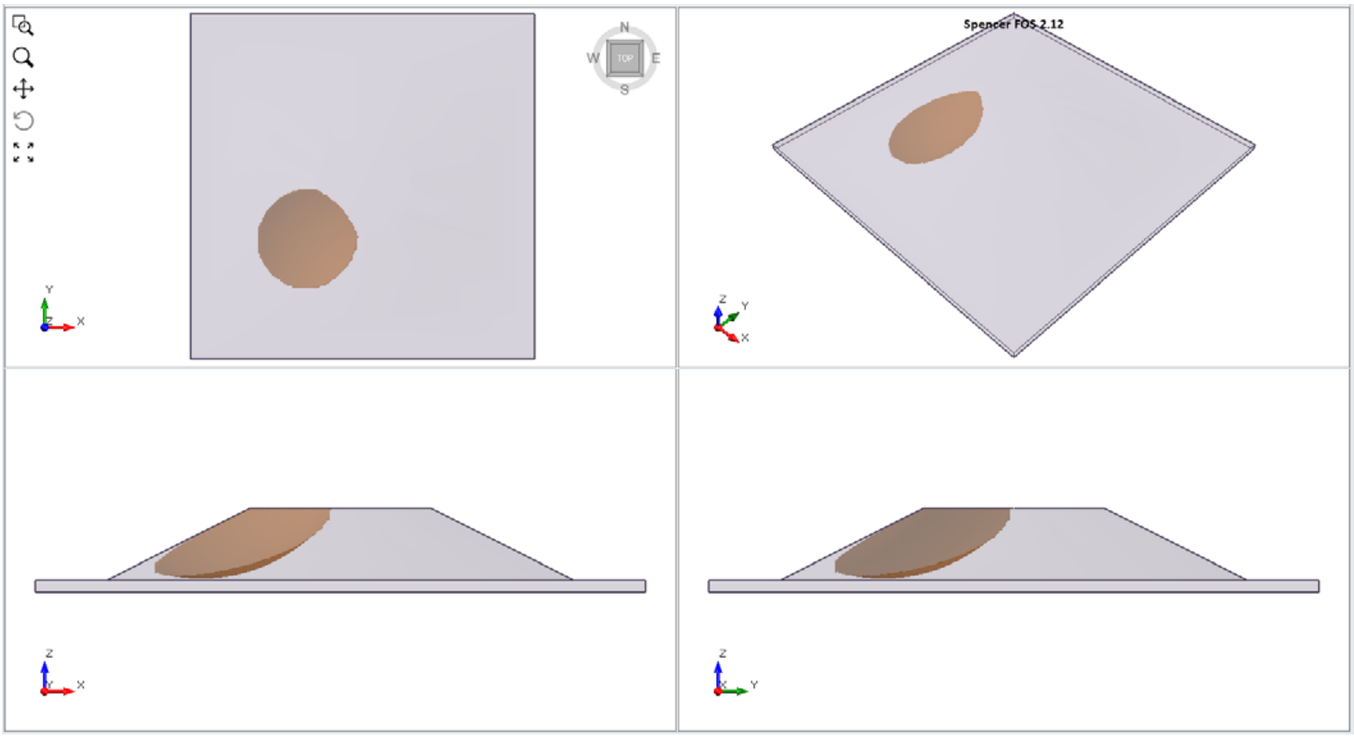


Figure 10.4.7 – Slide3 Solution Using the Spencer Method

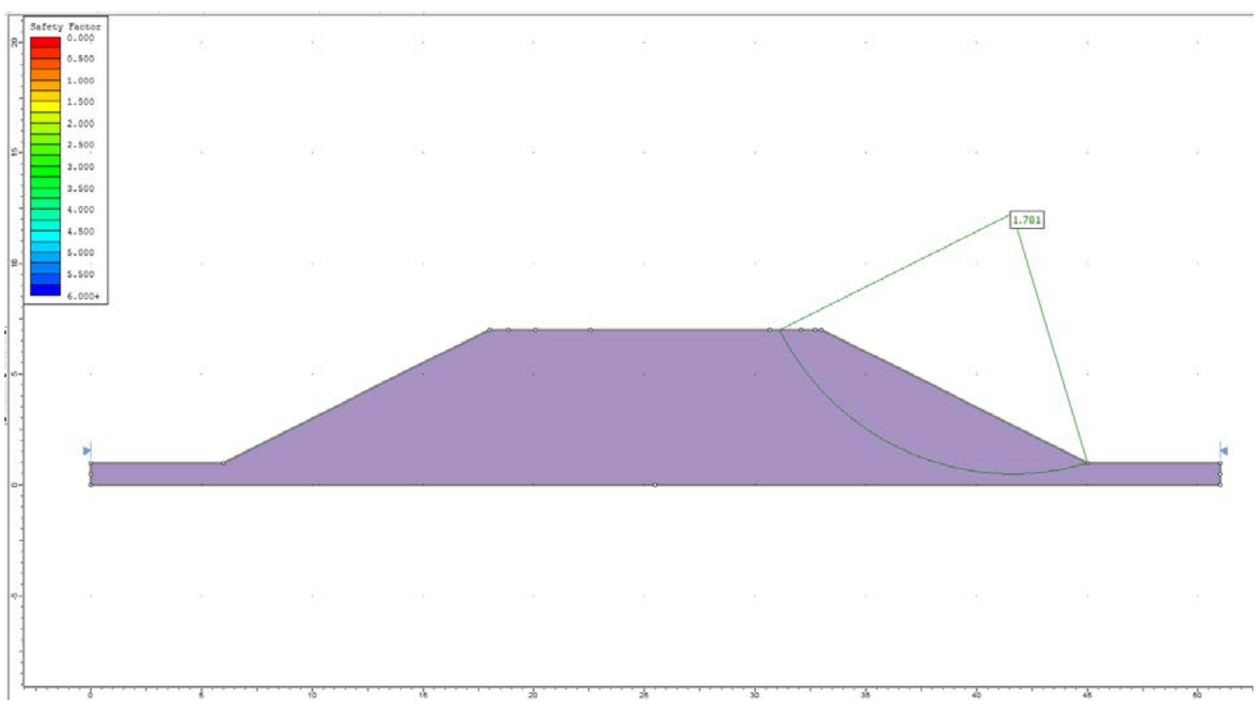


Figure 10.4.8 – Slide Solution Using the Spencer Method

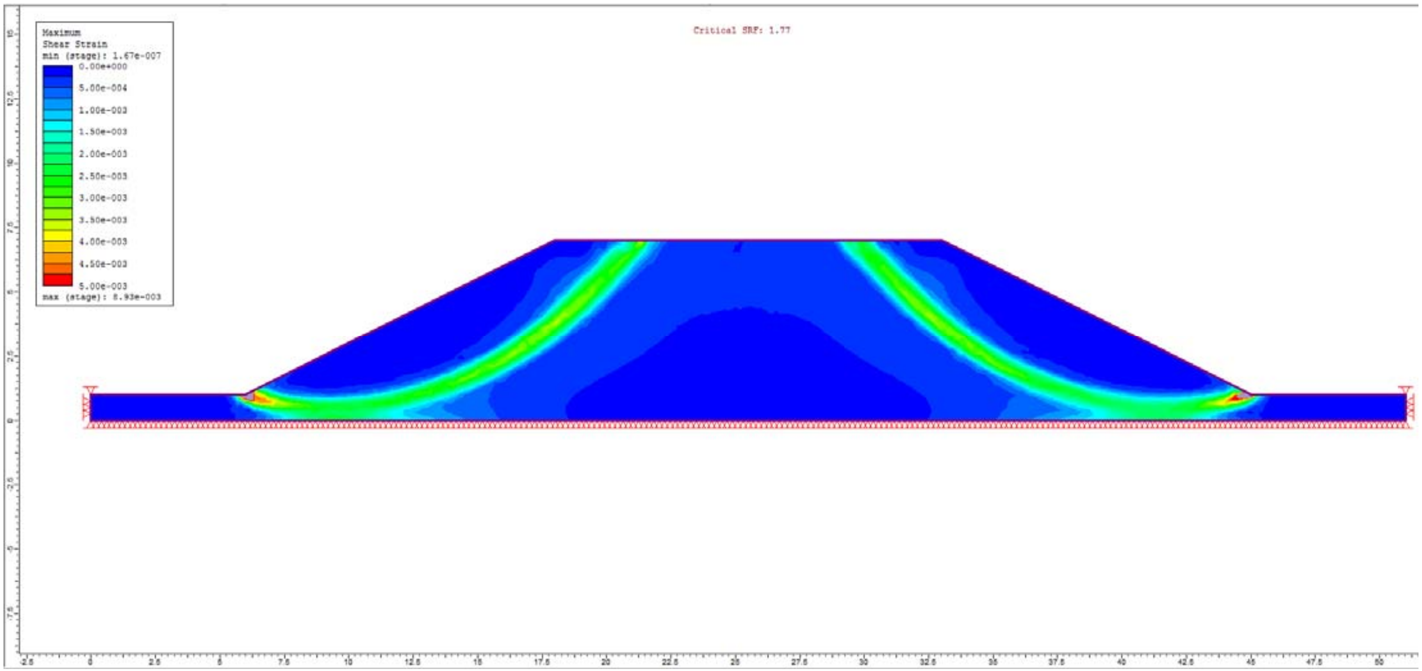


Figure 10.4.9 – RS2 Maximum Shear Strain

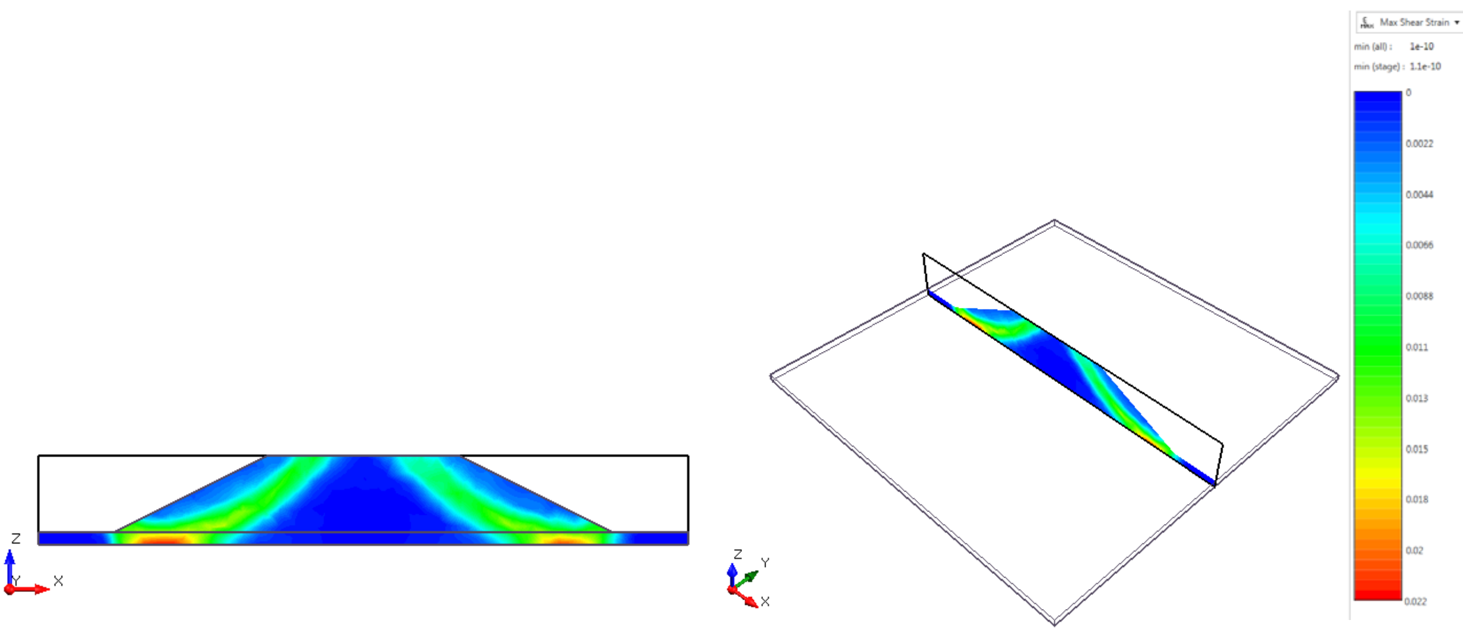


Figure 10.4.10 – RS3 Maximum Shear Strain

2D swept, 90° circular turn, convex, homogeneous, ellipsoidal with SA

11.1 Introduction

This model is taken from Kelesoglu (2016). Keleslоglu analyzed different slope geometries with rounded turning corners at various radii.

11.2 Problem Description

This example is a simple homogeneous slope with no groundwater. It is a convex slope turning at a 35 m radius from the slope crest. The model was made by sweeping a 2D cross section around a circle with the required radius and cutting the model, so that only one quadrant of the circle remains. The 2D cross section is Figure 11.1 and the top view is Figure 11.2. The material properties can be found in Table 11.1. The ellipsoidal slip surface and corresponding safety factor is required.

11.3 Geometry and Properties

Table 11.1: Material Properties

c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
15	24	18

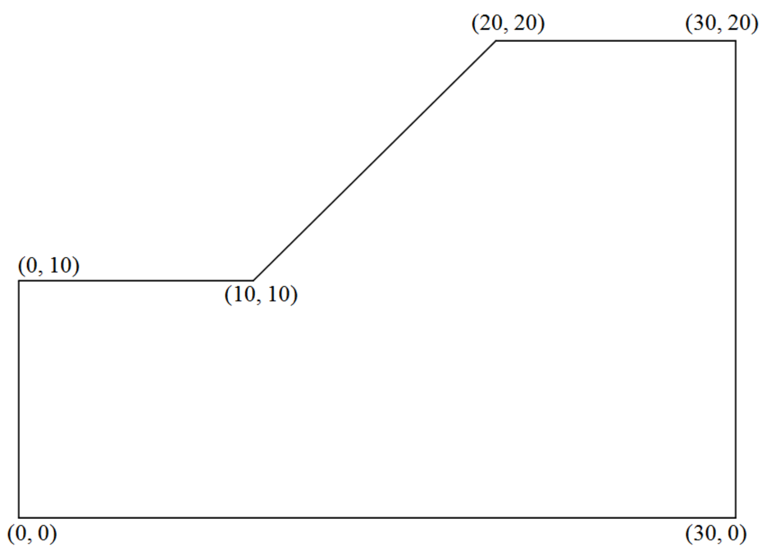


Figure 11.1

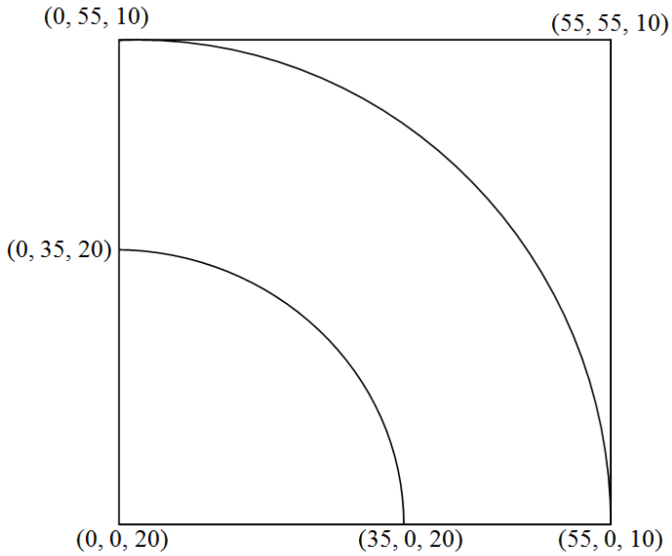


Figure 11.2

11.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.244	1.224	1.41	1.29
GLE	1.312	1.251		
Janbu	1.211	1.170		
Spencer	1.327	1.268		

Referee: 1.02 [Kelesoglu, 2016]

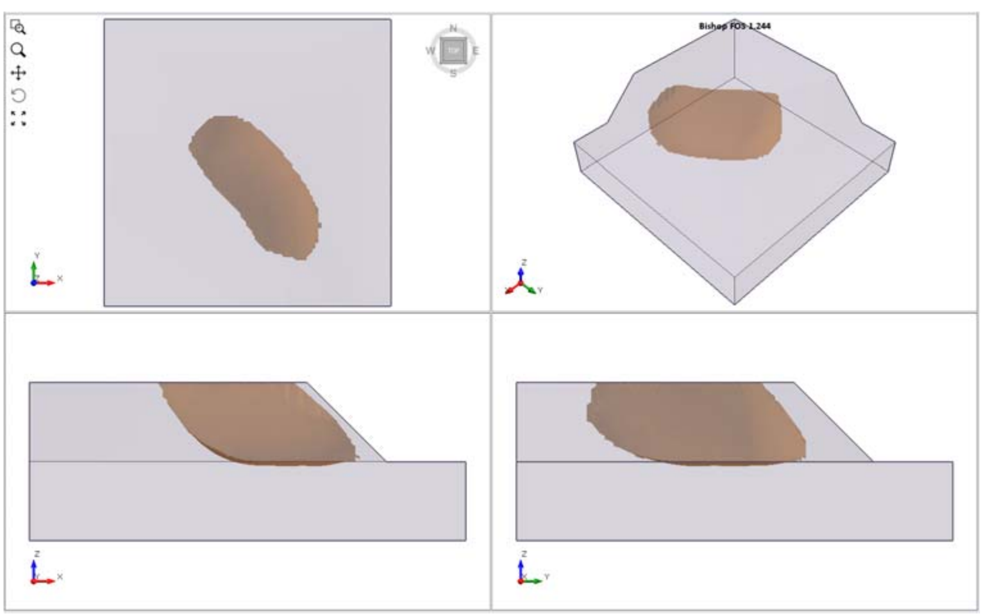


Figure 11.4.1 – Slide3 Solution Using the Bishop Method

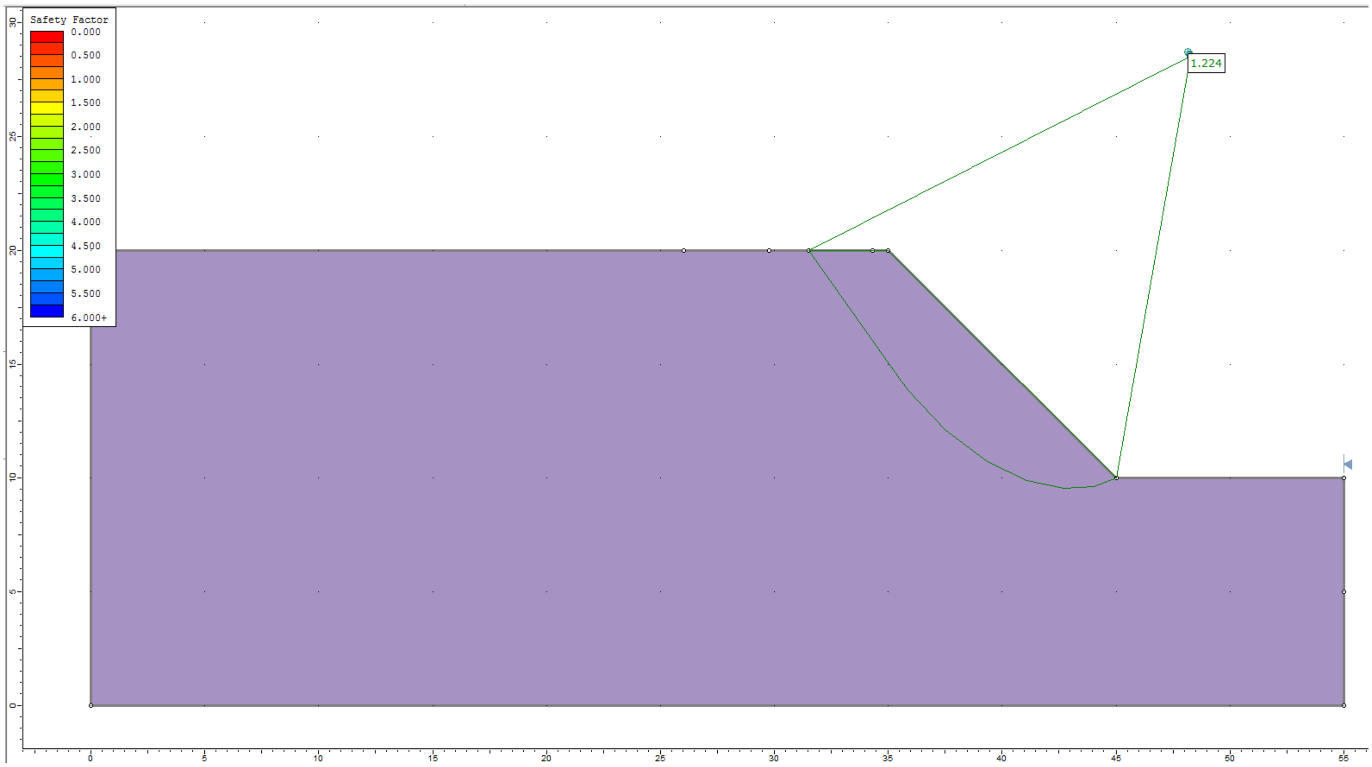


Figure 11.4.2 – Slide Solution Using the Bishop Method

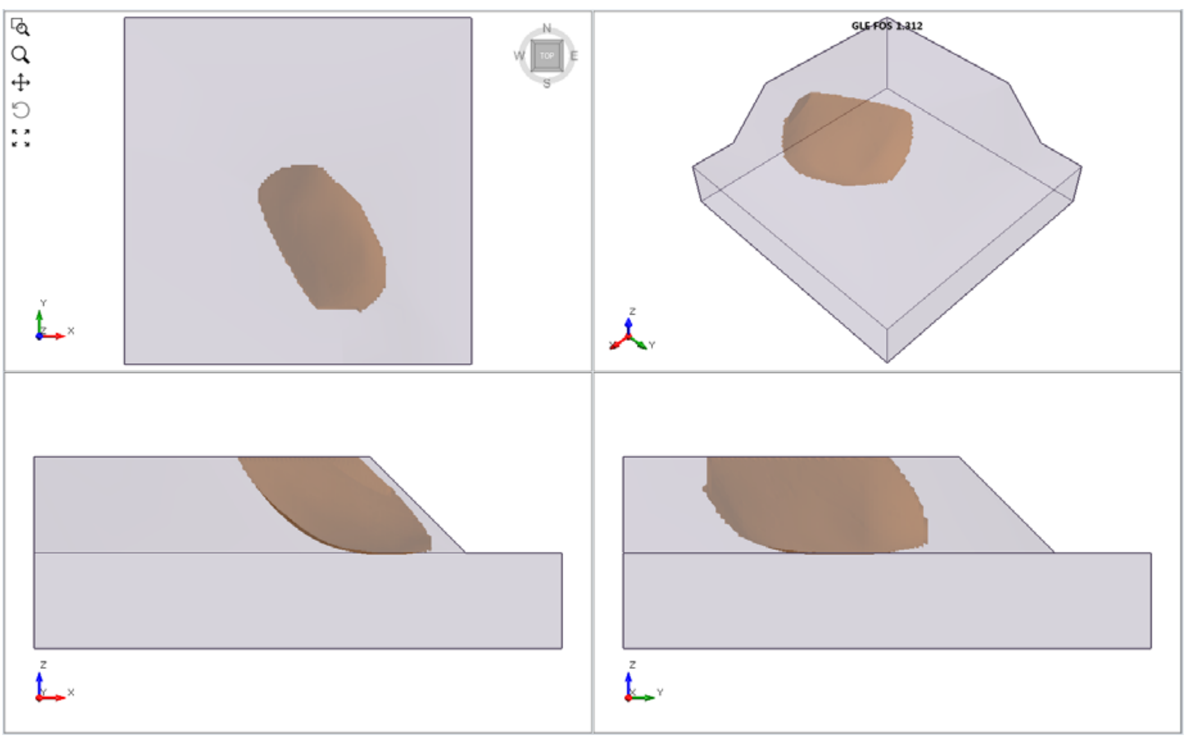


Figure 11.4.3 – Slide3 Solution Using the GLE Method

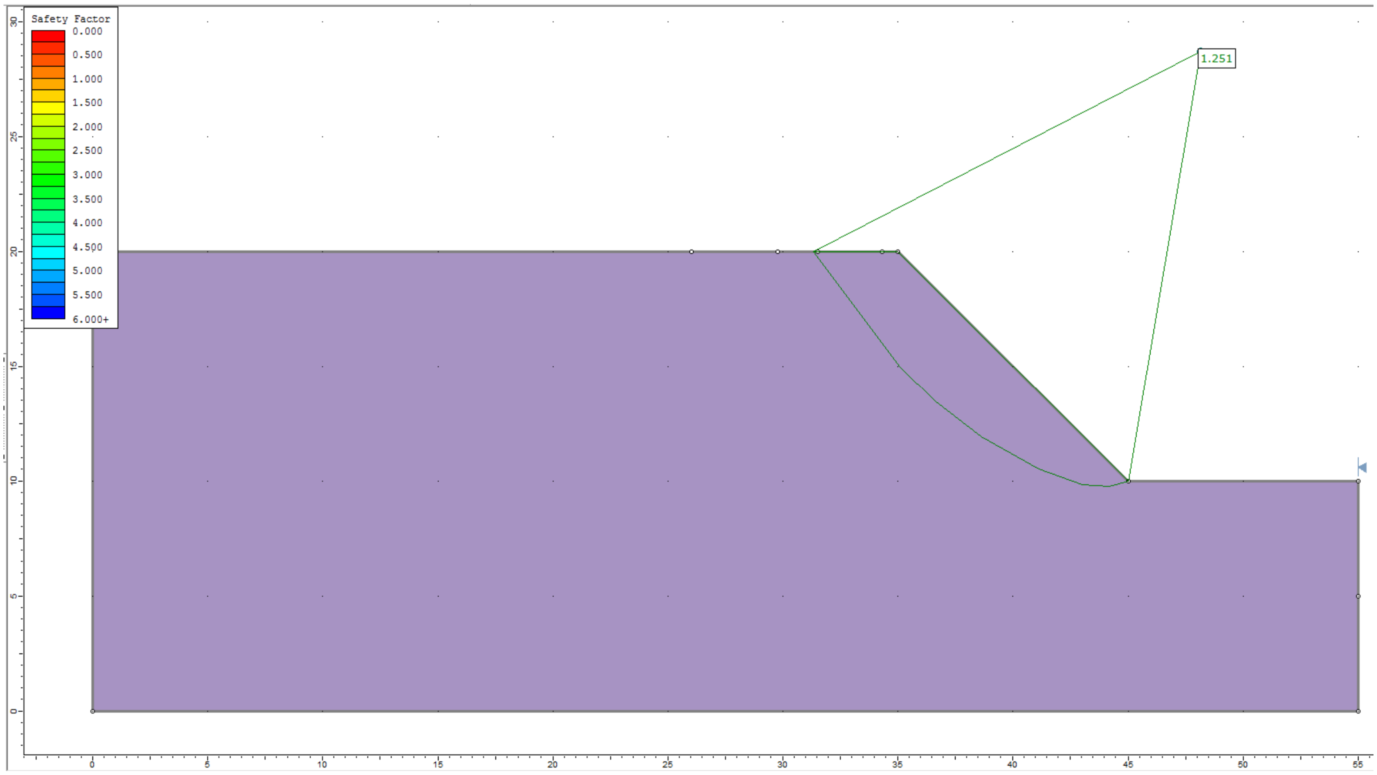


Figure 11.4.4 – Slide Solution Using the GLE Method

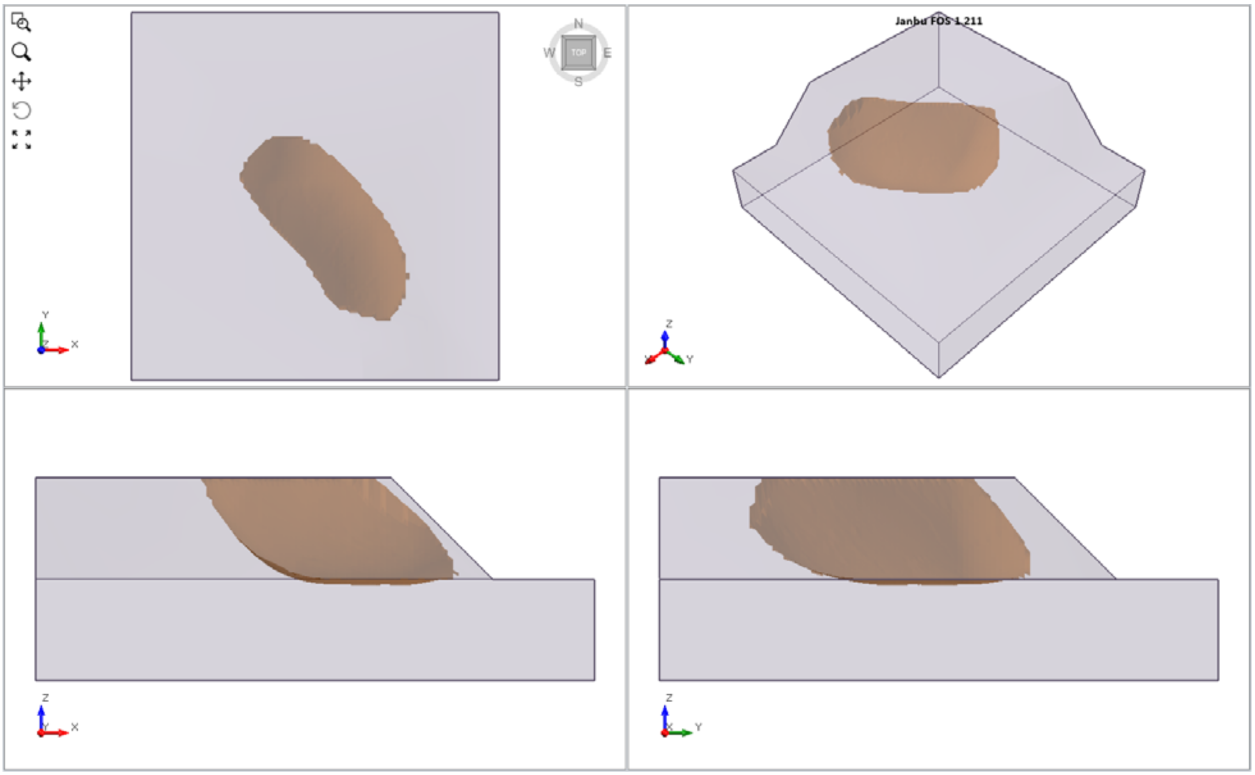


Figure 11.4.5 – Slide3 Solution Using the Janbu Method

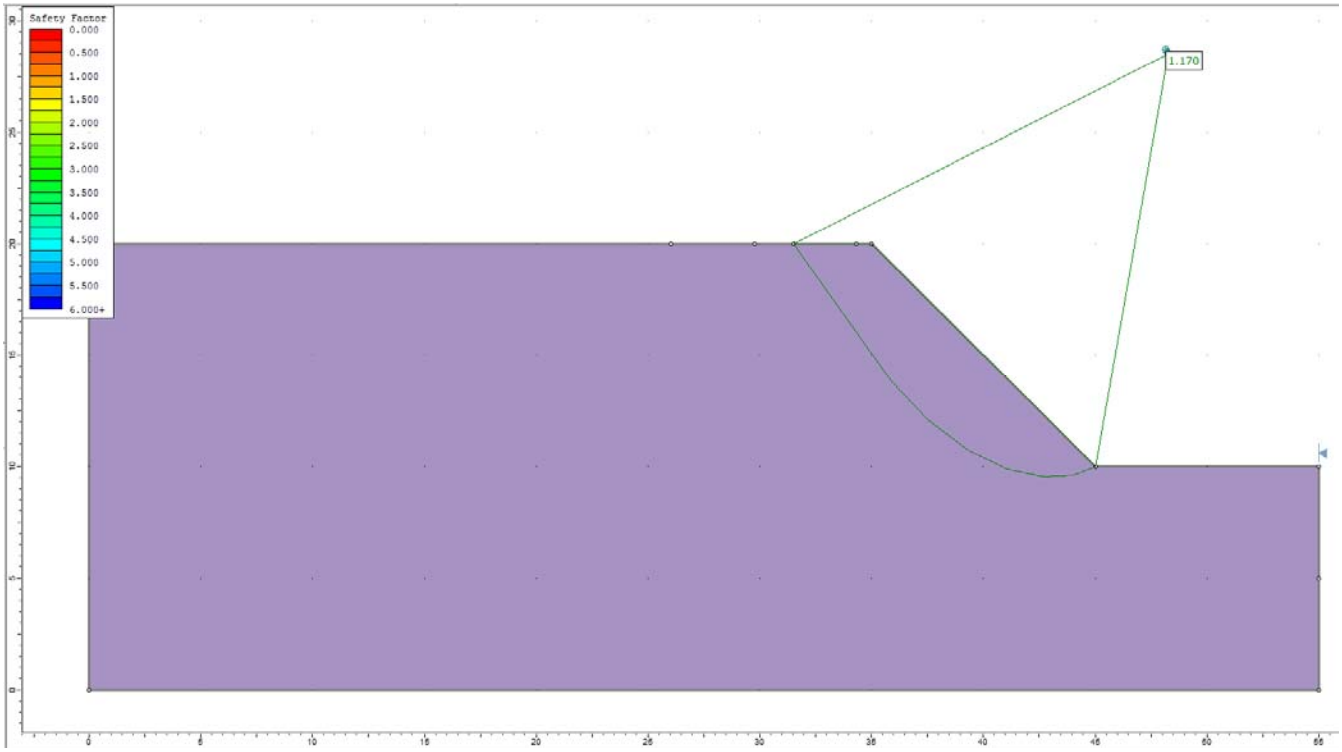


Figure 11.4.6 – Slide Solution Using the Janbu Method

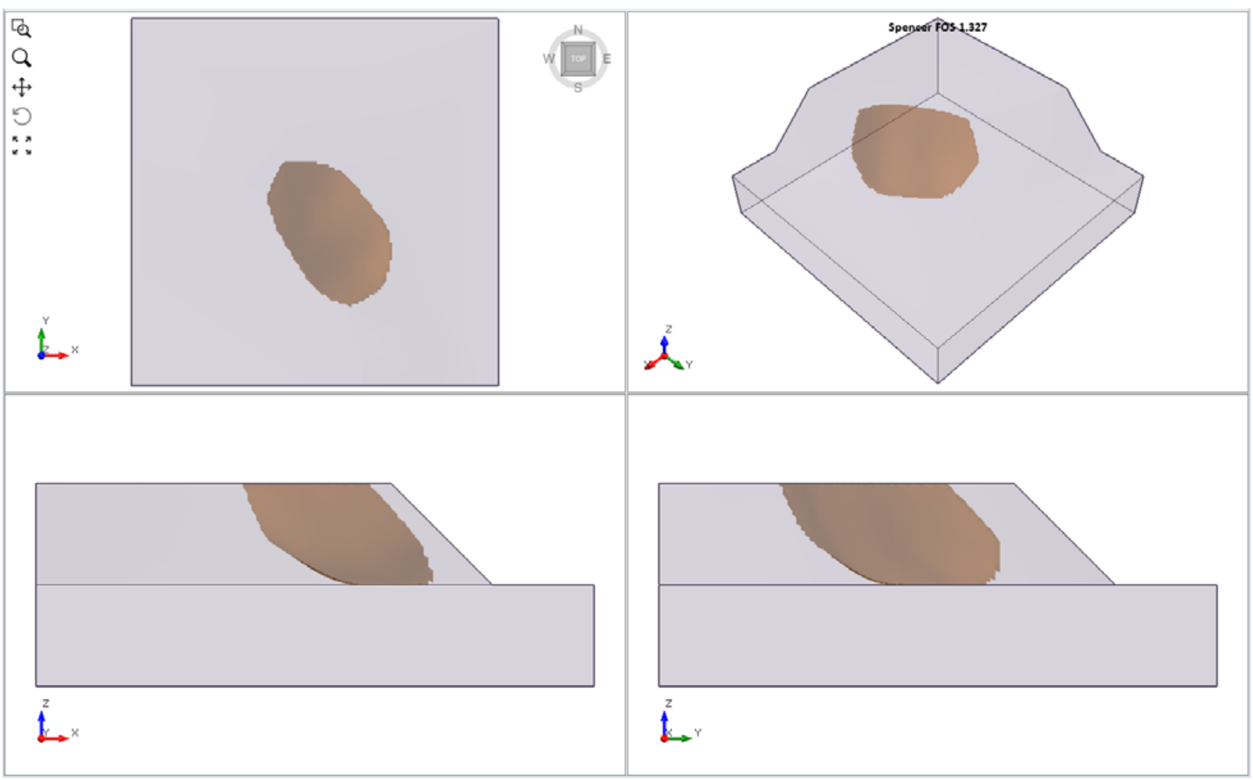


Figure 11.4.7 – Slide3 Solution Using the Spencer Method

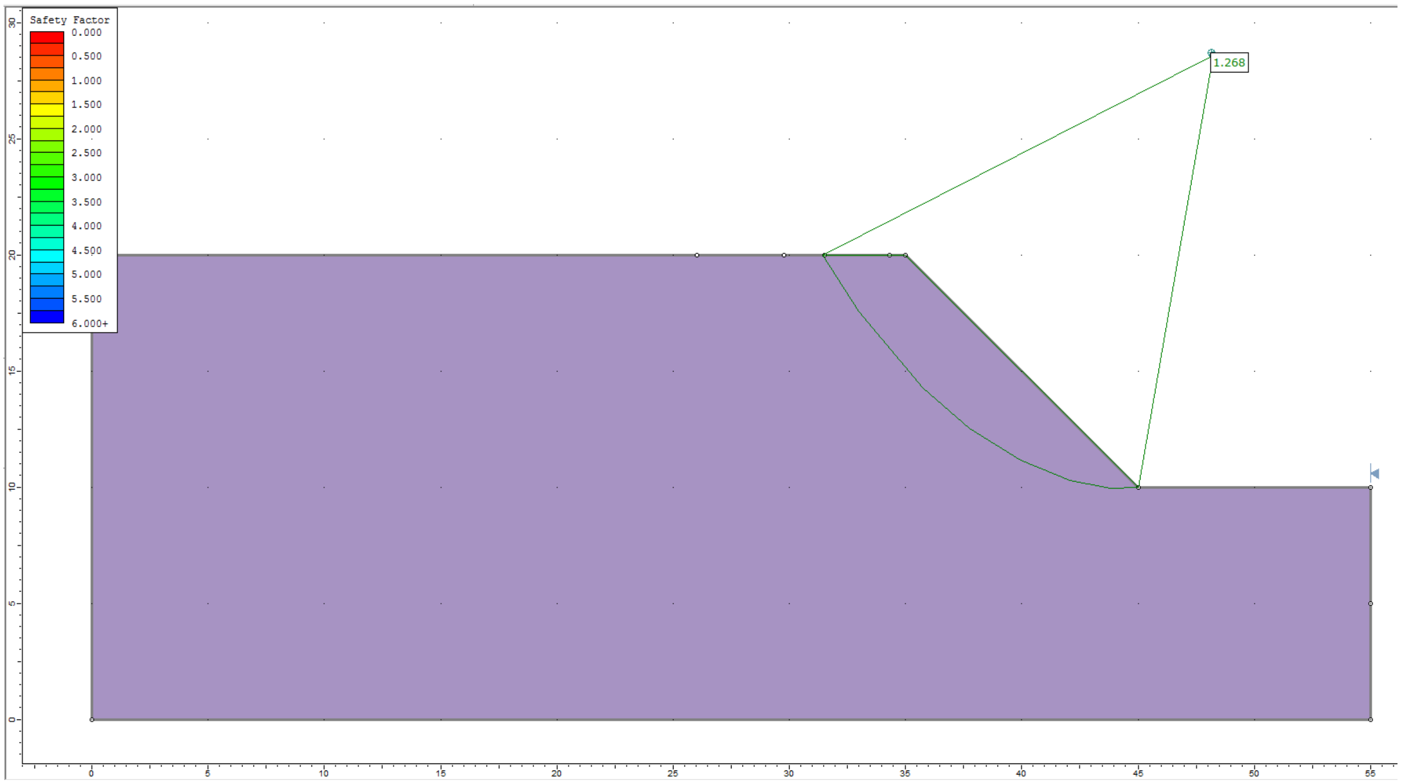


Figure 11.4.8 – Slide Solution Using the Spencer Method

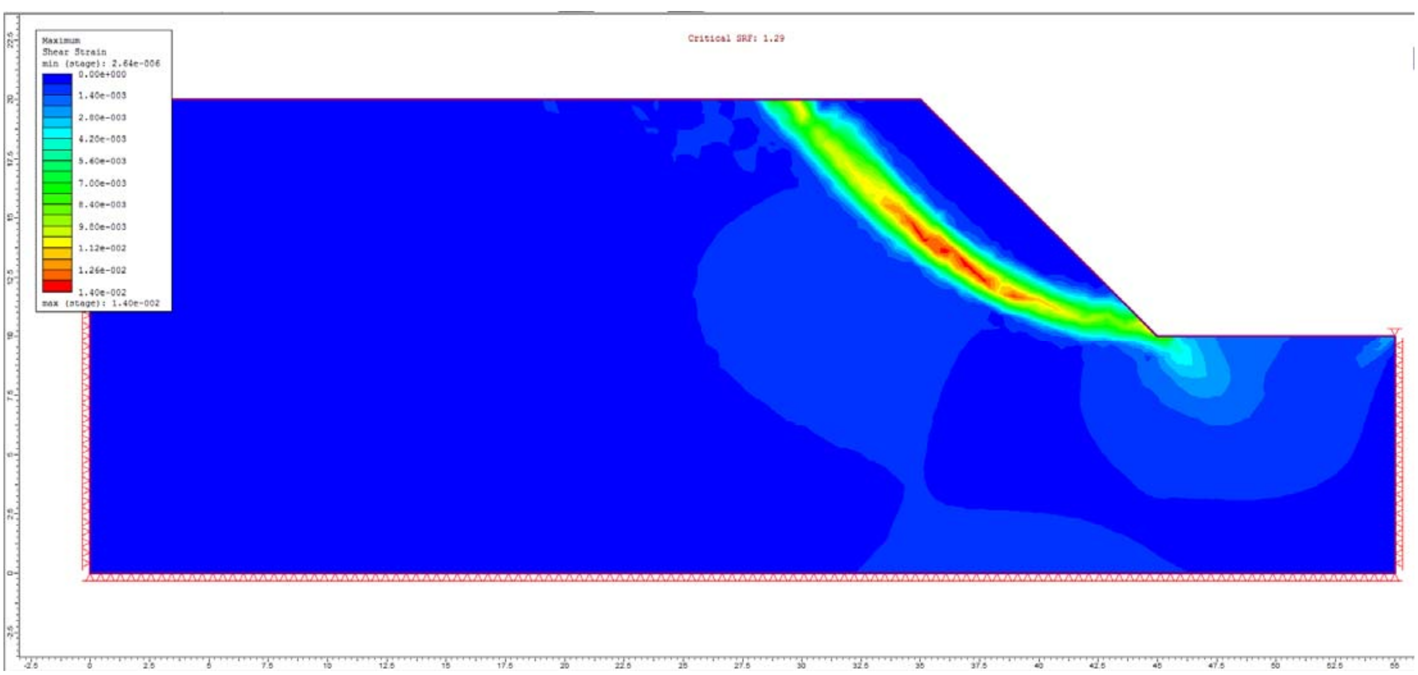


Figure 11.4.9 – RS2 Maximum Shear Strain

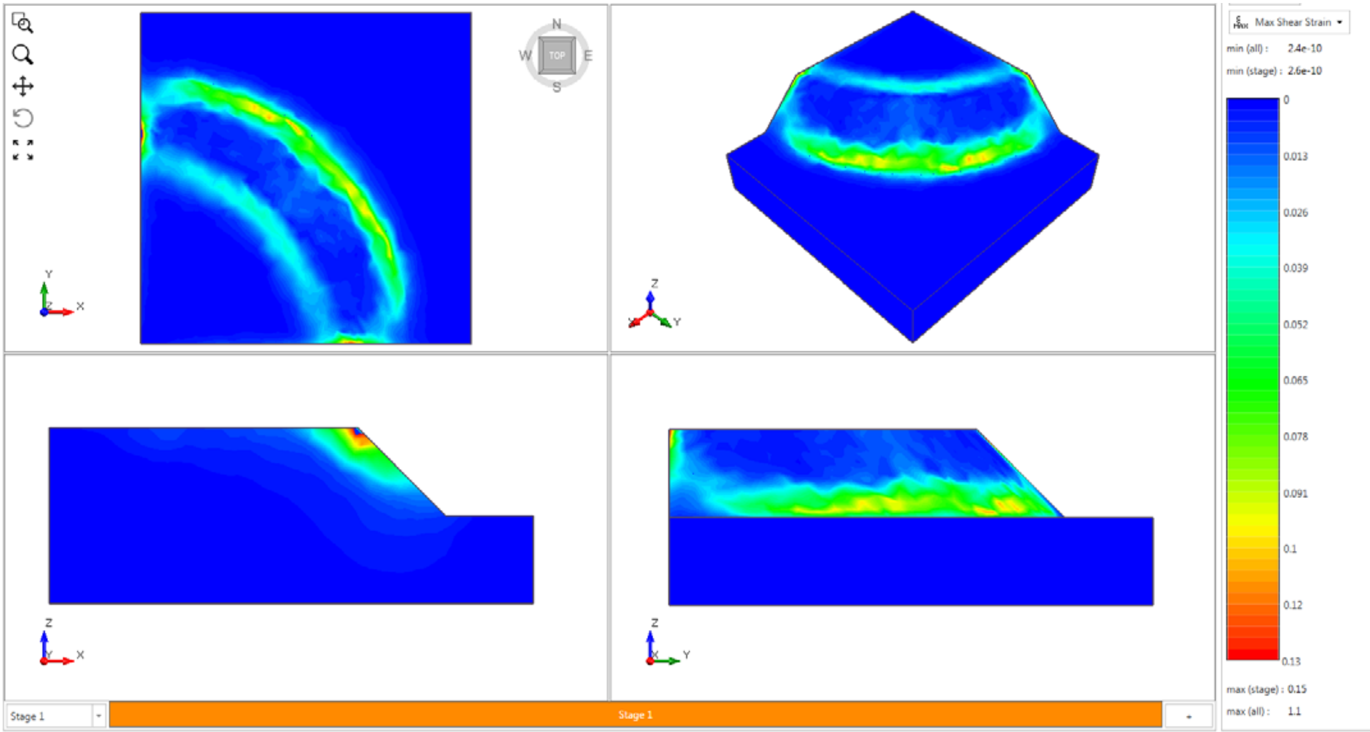


Figure 11.4.10 – RS3 Maximum Shear Strain

2D swept baseline extruded, weak layer, water table, ellipsoidal with SA

12.1 Introduction

This model is a simple extruded non-homogeneous slope with a water table. It was modeled in both RS3 and Slide3.

12.2 Problem Description

The slope geometry, including the location of the water table, for this problem is shown in Figure 12, as a 2D cross section in the XZ plane. This cross section is extruded 200 m in the Y direction. The material properties can be found in Table 12.1. The ellipsoidal slip surface is required and found using a cuckoo search with search optimization on Slide3.

12.3 Geometry and Properties

Table 12.1: Material Properties

	c´ (kN/m^2)	φ´ (deg.)	γ (kN/m^3)
Soil	48	20	19
Weak Layer	0	20	18.5
Infinite Strength	10000	65	19

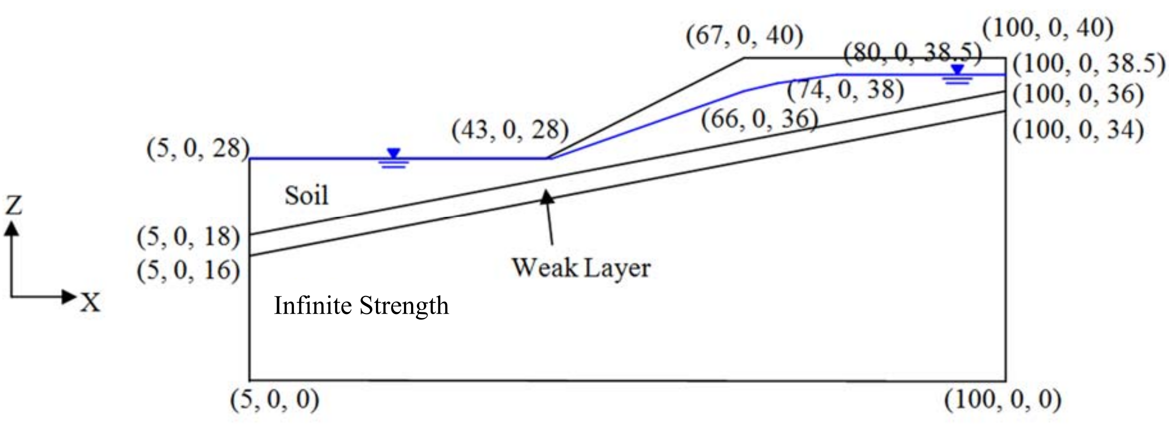


Figure 12

12.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
GLE	1.062	1.297	1.4	1.43
Spencer	1.267	1.312		

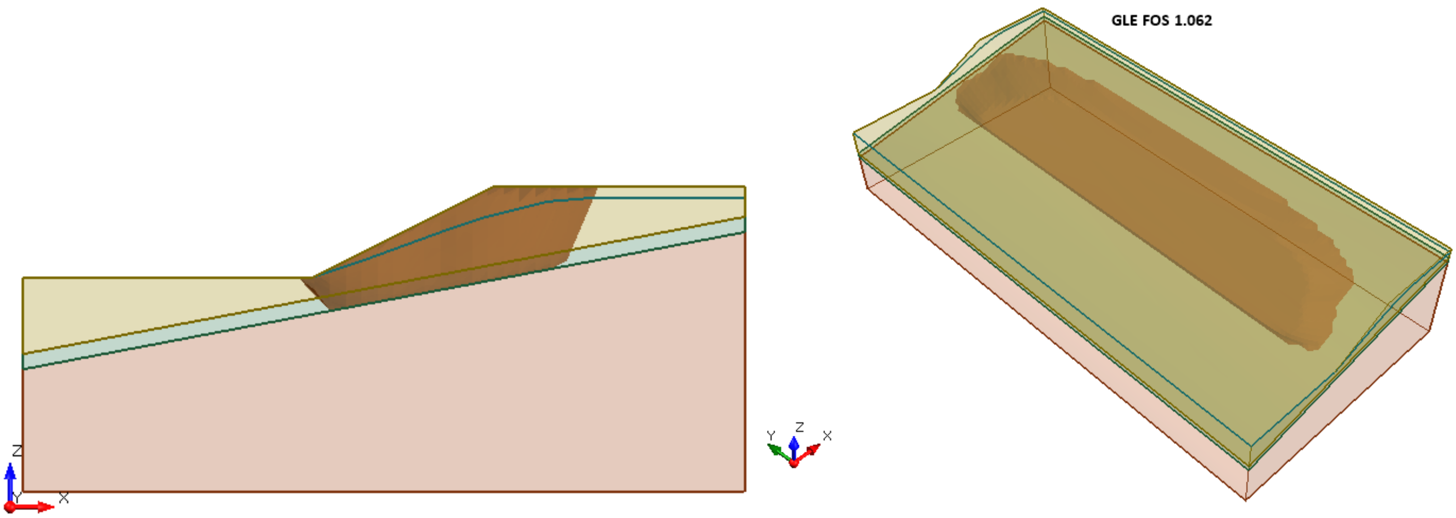


Figure 12.4.1 – Slide3 Solution Using the GLE Method

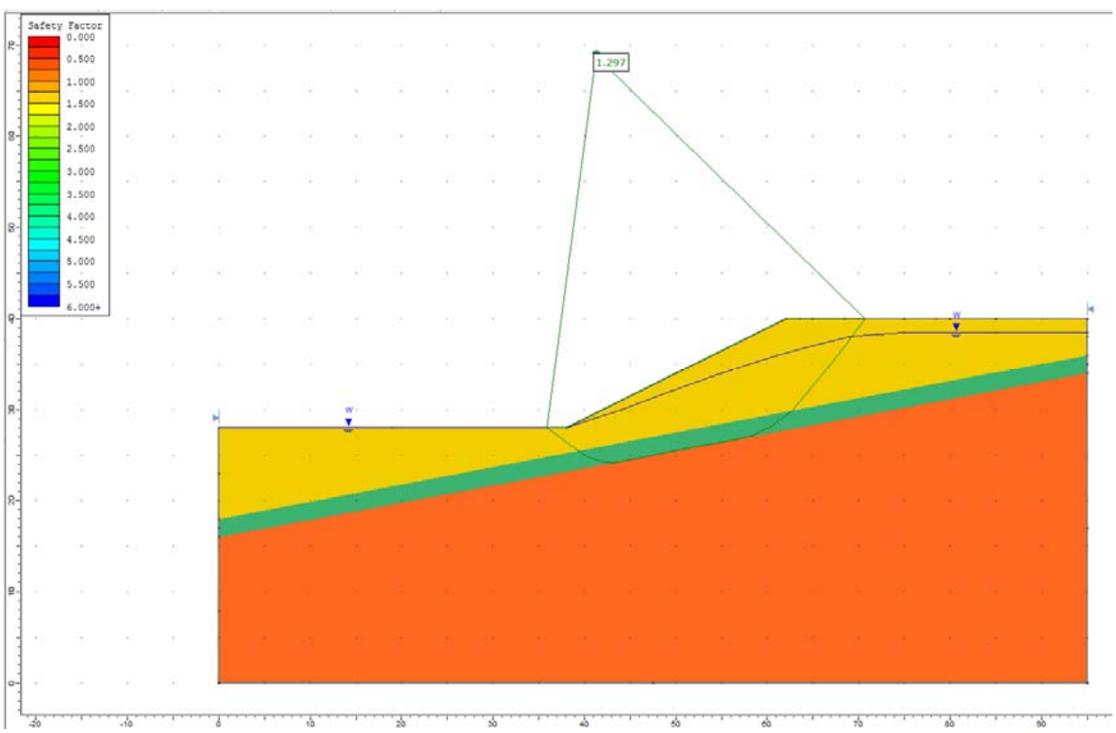


Figure 12.4.2 – Slide Solution Using the GLE Method

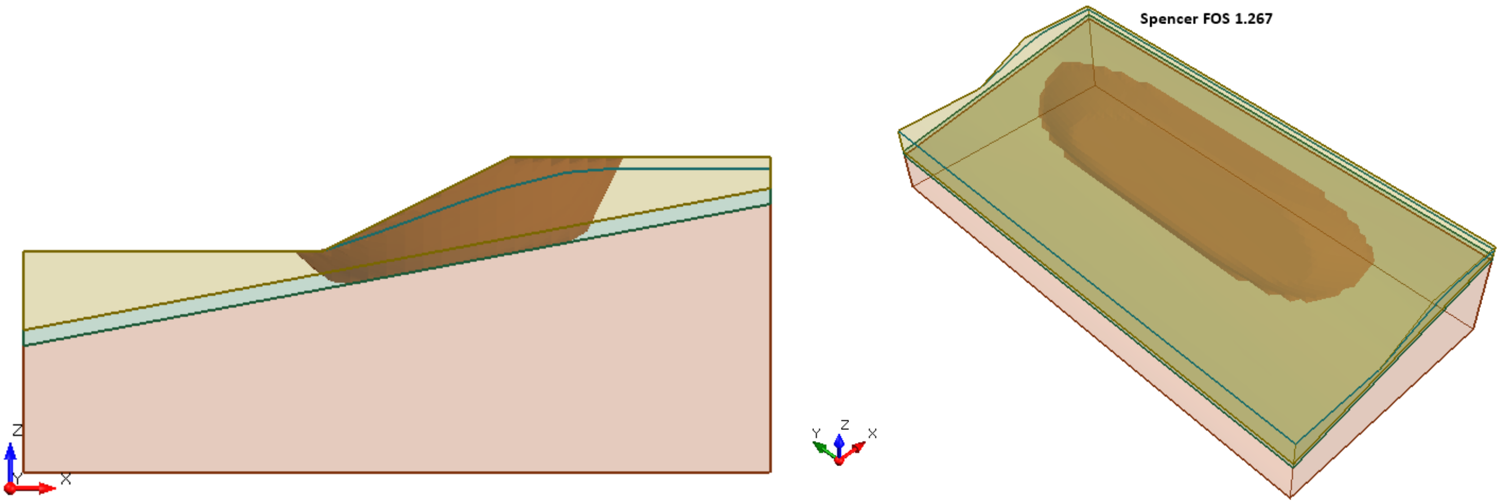


Figure 12.4.3 – Slide3 Solution Using the Spencer Method

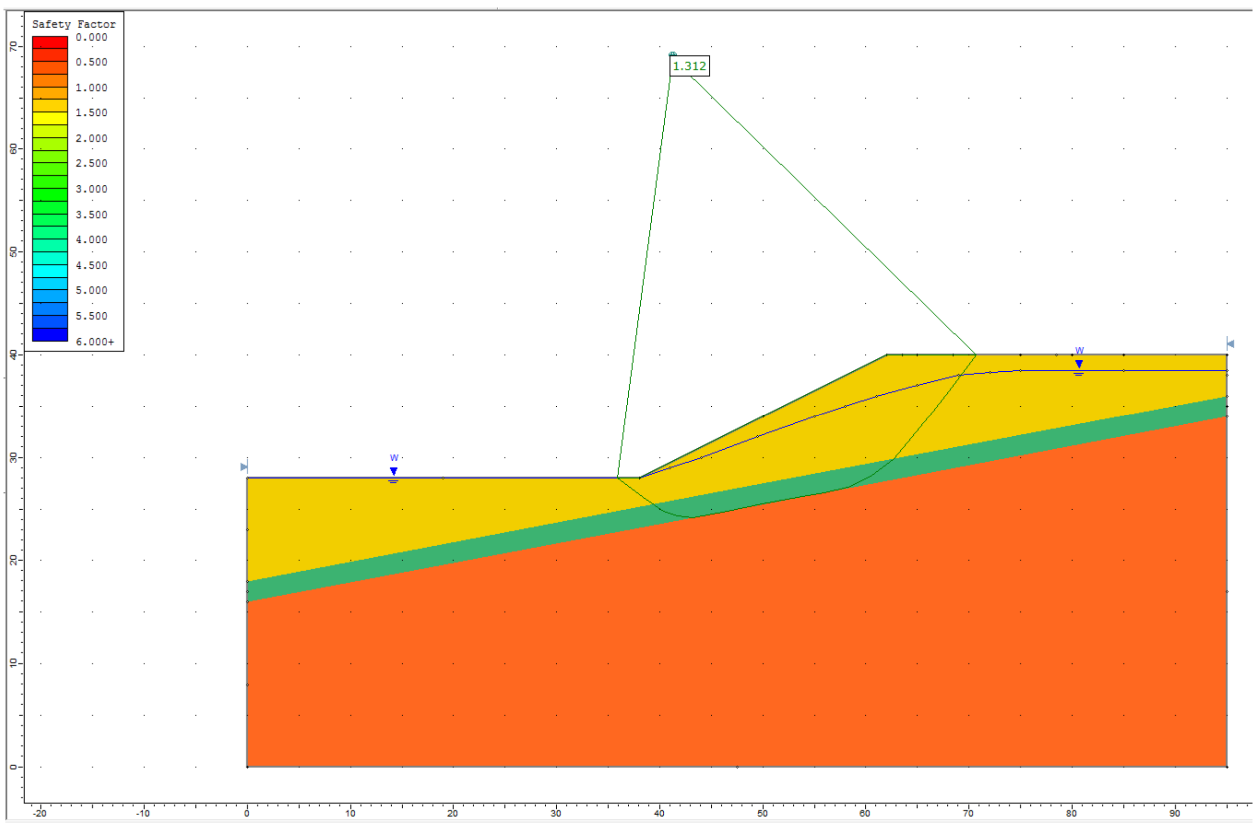


Figure 12.4.4 – Slide Solution Using the Spencer Method

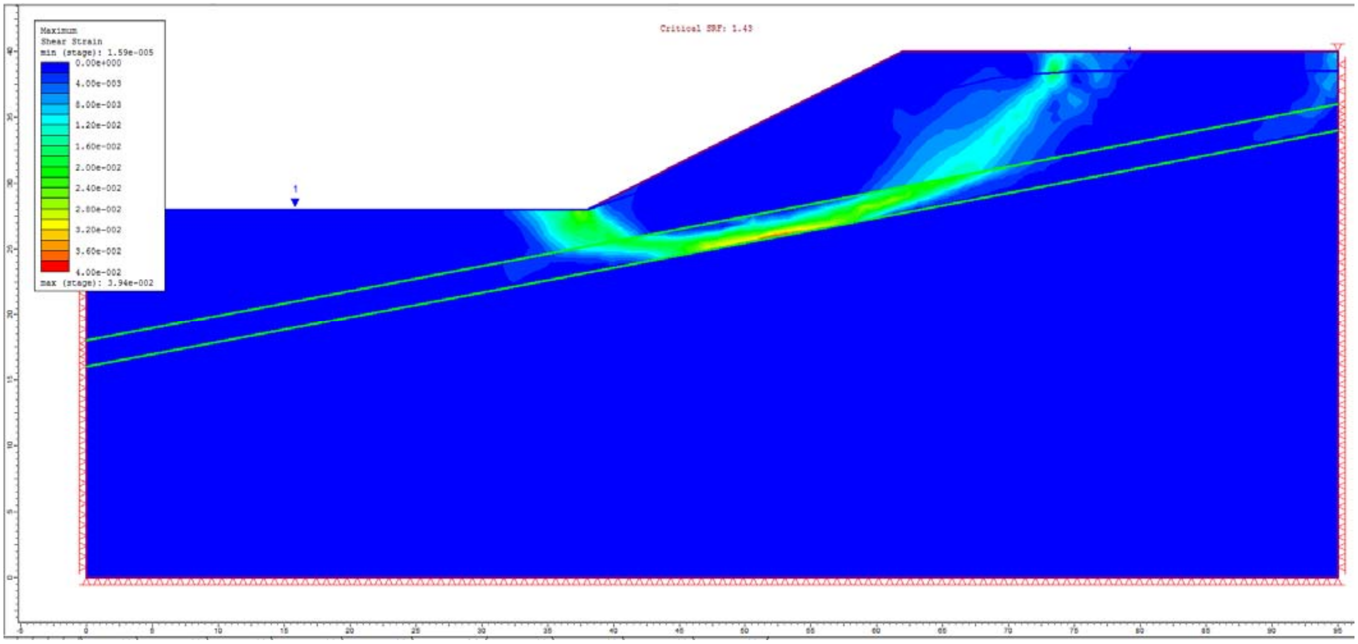


Figure 12.4.5 – RS2 Maximum Shear Strain

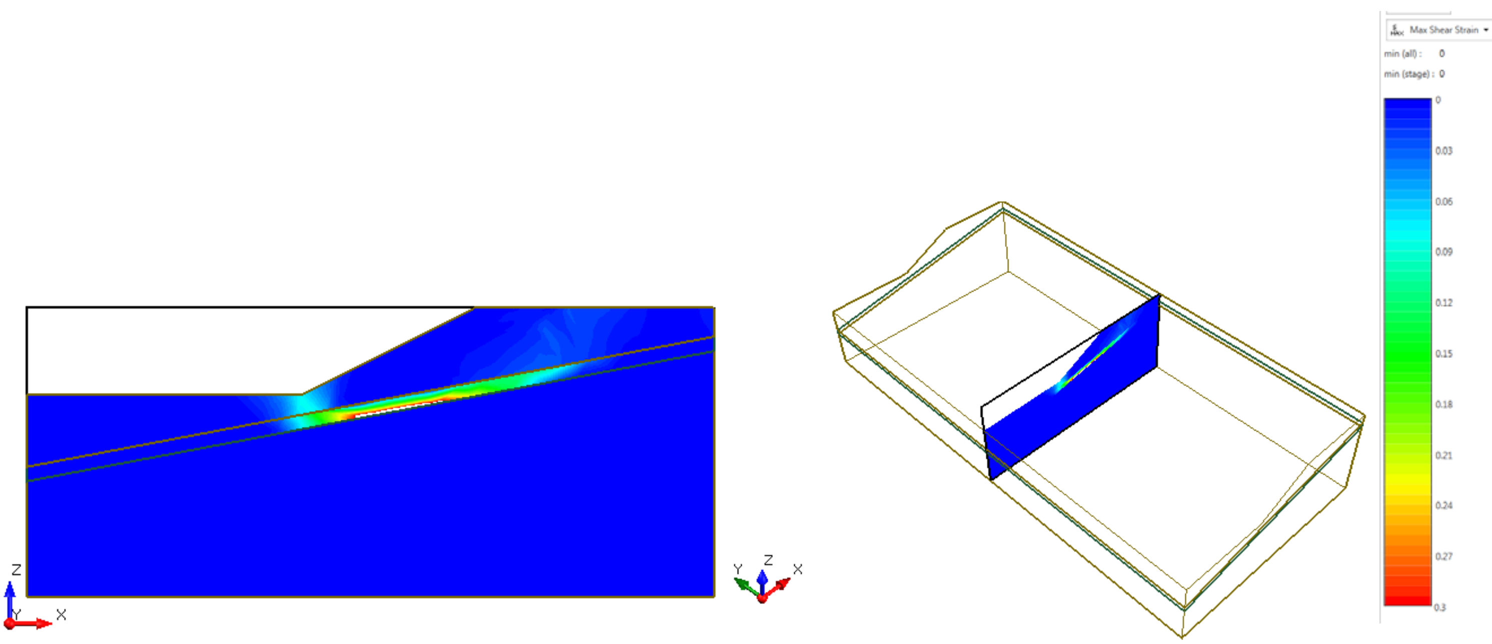


Figure 12.4.6 – RS3 Maximum Shear Strain

2D swept, L-shape, weak layer, water table, ellipsoidal with SA

13.1 Introduction

This model is a non-homogeneous slope with a water table swept along an L-shaped. It was modeled in both RS3 and Slide3.

13.2 Problem Description

The slope geometry, including the location of the water table, for this problem is shown in Figure 13(a), as a 2D cross section in the XZ plane. This cross section will be swept across an L-shape, which can be better seen in Figure 13(b), which is a top view of the model. The material properties can be found in Table 13.1. The ellipsoidal slip surface is required and found using a cuckoo search with search optimization on Slide3.

13.3 Geometry and Properties

Table 13.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	48	20	19
Weak Layer	0	20	18.5
Infinite Strength	10000	65	19

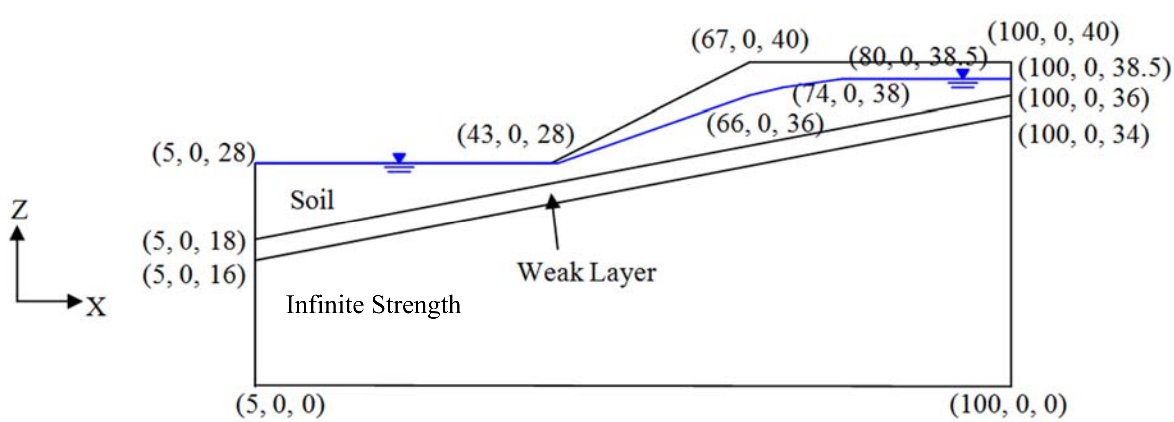


Figure 13(a)

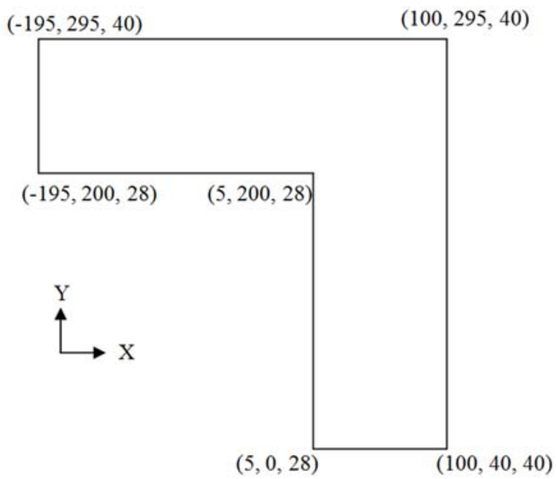


Figure 13(b)

13.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
GLE	1.137	1.285	1.4	1.42
Spencer	1.249	1.313		

Note: The 2D cross section for this example is the same as the previous example; therefore the Slide 7.0 and RS2 factors of safety as well as their slips surface and maximum shear strain diagrams have not changed.

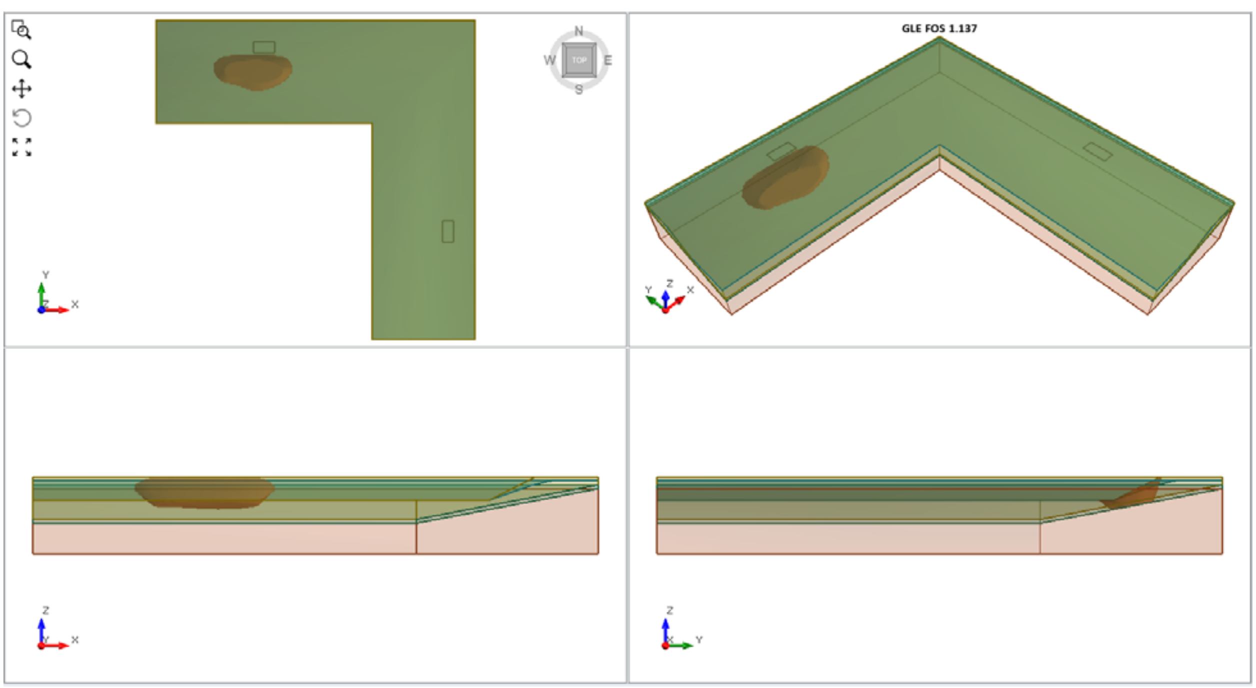


Figure 13.4.1 – Slide3 Solution Using the GLE Method

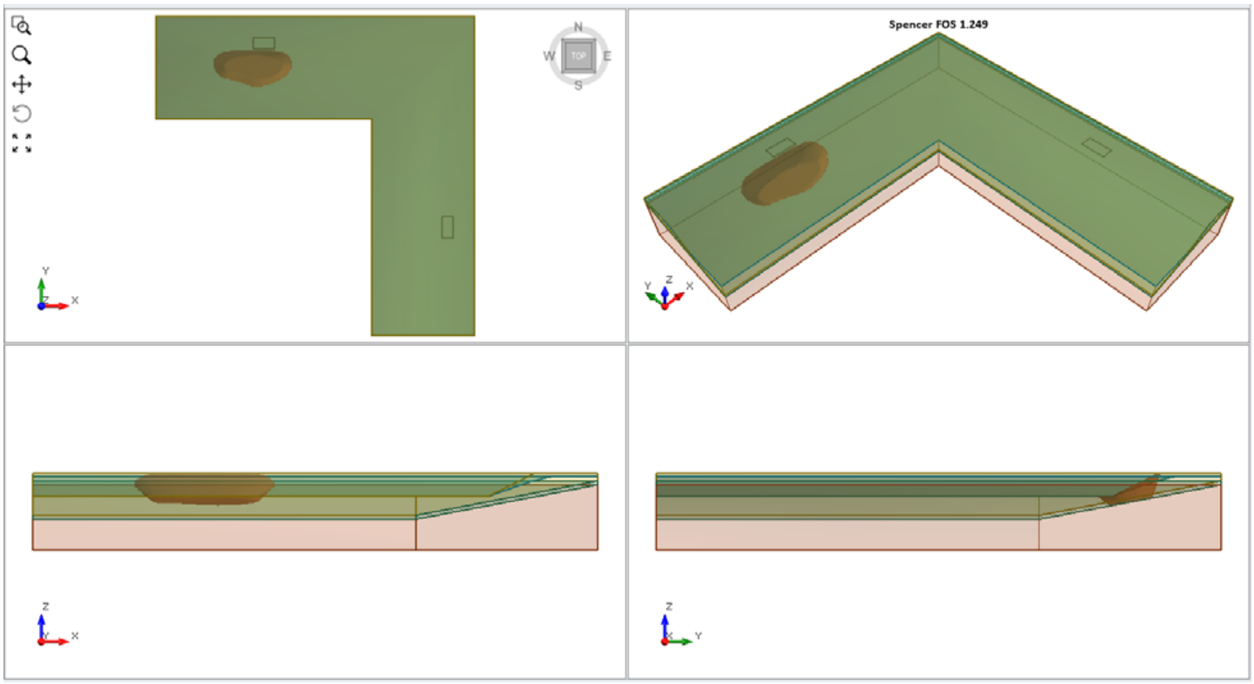


Figure 13.4.2 – Slide3 Solution Using the Spencer Method

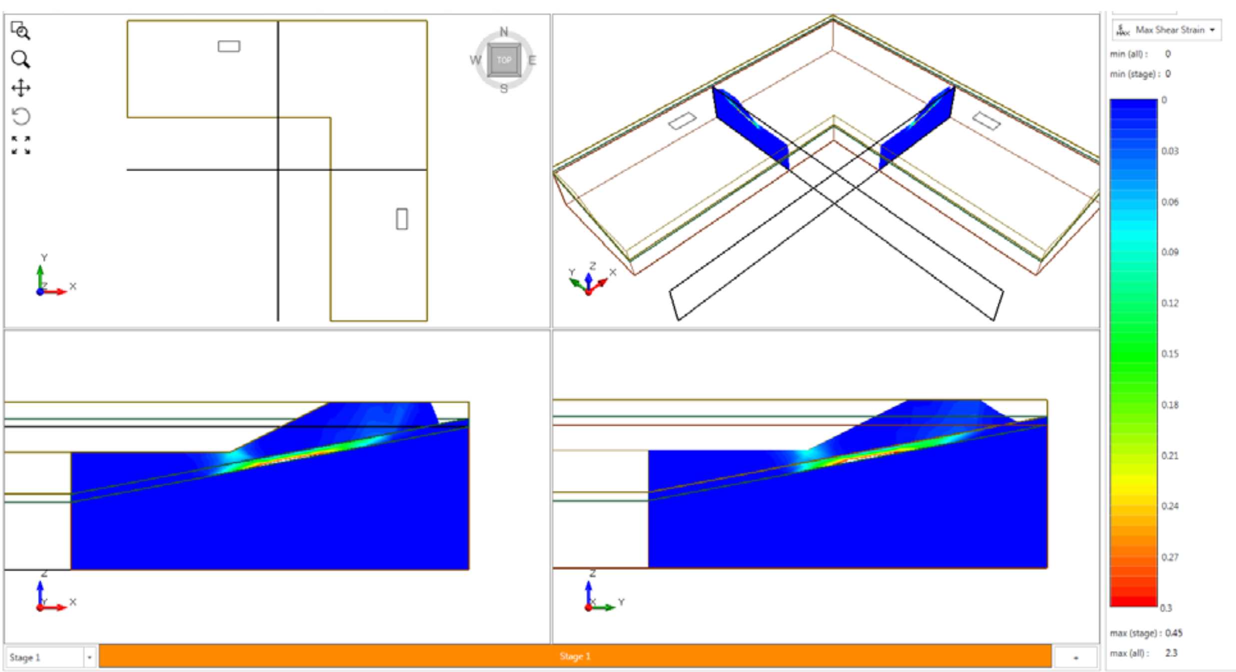


Figure 13.4.3 – RS3 Maximum Shear Strain

2D swept, 90° circular turn, concave, piles, water table, spherical

14.1 Introduction

This model was taken from Kelesoglu (2015), and is a concave slope with piles and a water table.

14.2 Problem Description

The cross section of the slope is shown in Figure 14(a), which includes the location of the water table. Figure 14(b) is the top view of the slope, which shows that the cross section was swept along a circle and cut to get the 90 degree angle. The piles are spread across the entire slope at height Z = 5.5, as shown in Figure 14(a). The piles are space 3.2m apart and are elastic, and therefore have very large shear strengths, as it is unlikely that they will fracture, the shear strength used in the model was $1*10^{10}$ kN. The material properties of the soil are shown in Table 14.1. The spherical slip surface and corresponding safety factor is required.

14.3 Geometry and Properties

Table 14.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	15	24	18

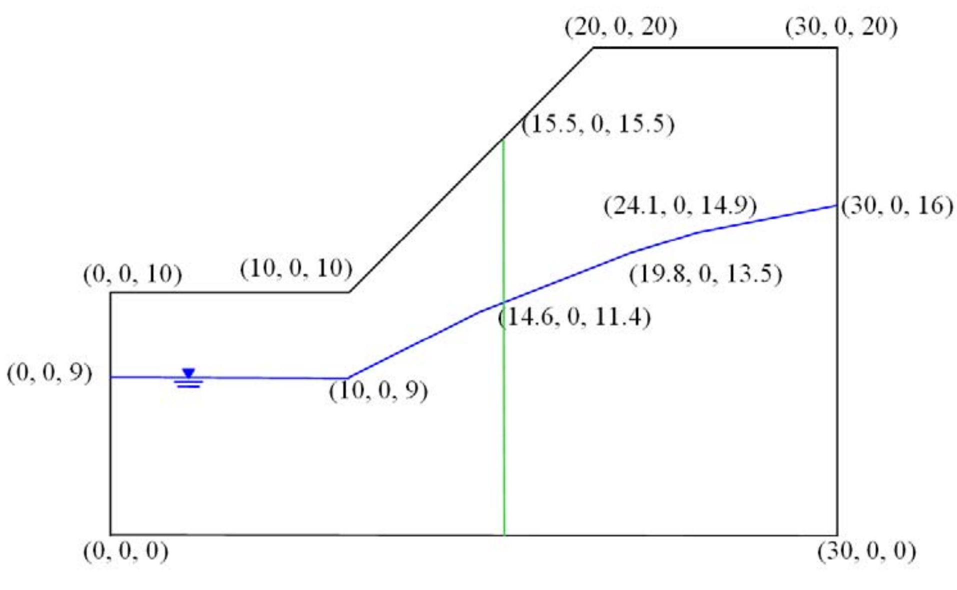


Figure 14(a)

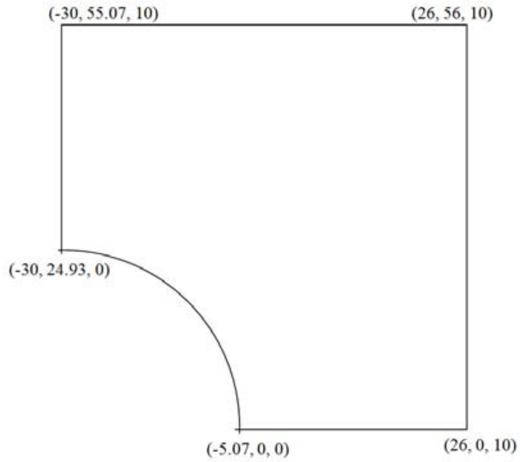


Figure 14(b)

14.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	2.144	1.993	1.49	1.25
GLE	2.152	1.991		
Janbu	2.03	1.947		
Spencer	2.187	1.991		

Referee: 2.02 [Kelesoglu, 2015]

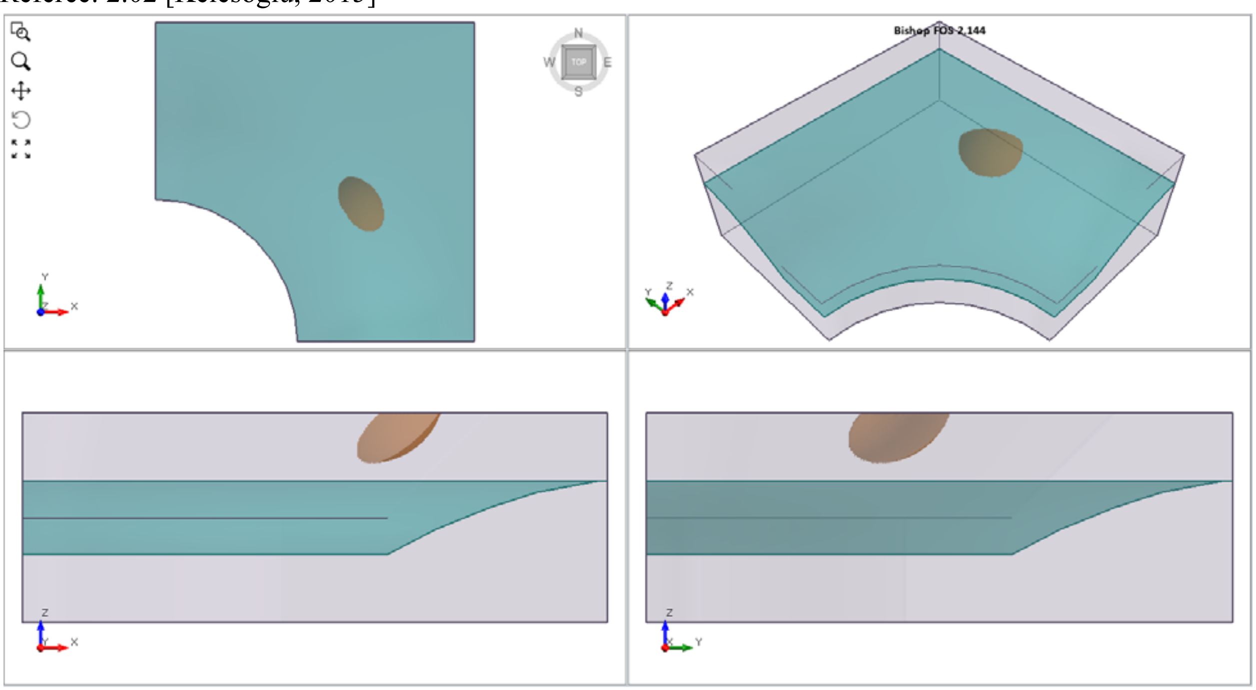


Figure 14.4.1 – Slide3 Solution Using the Bishop Method

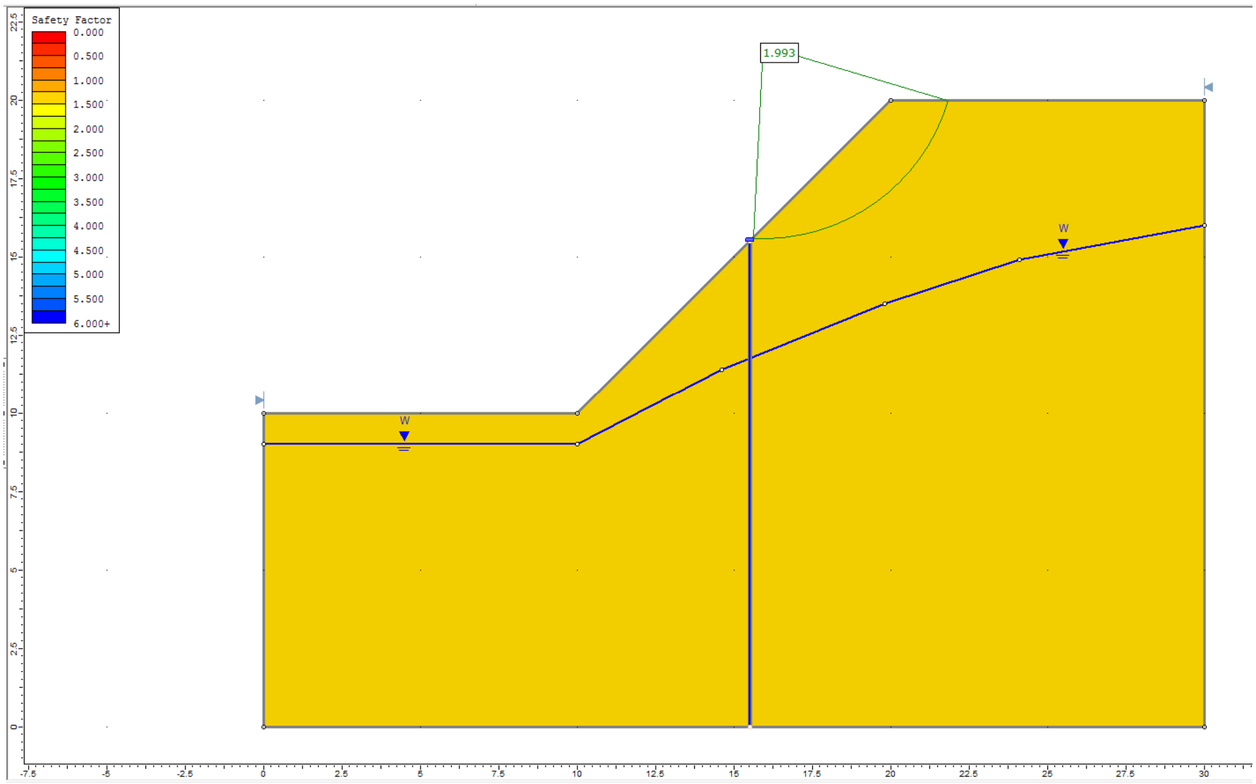


Figure 14.4.2 – Slide Solution Using the Bishop Method

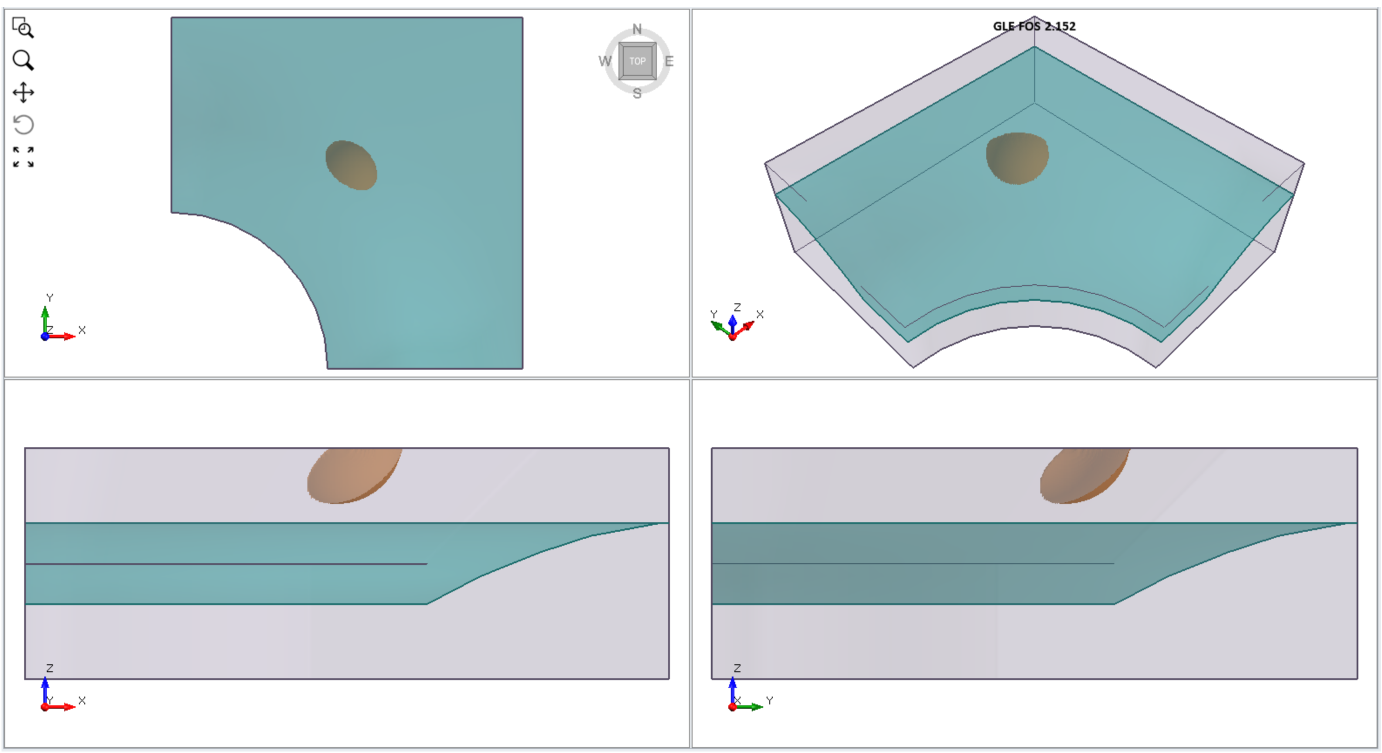


Figure 14.4.3 – Slide3 Solution Using the GLE Method

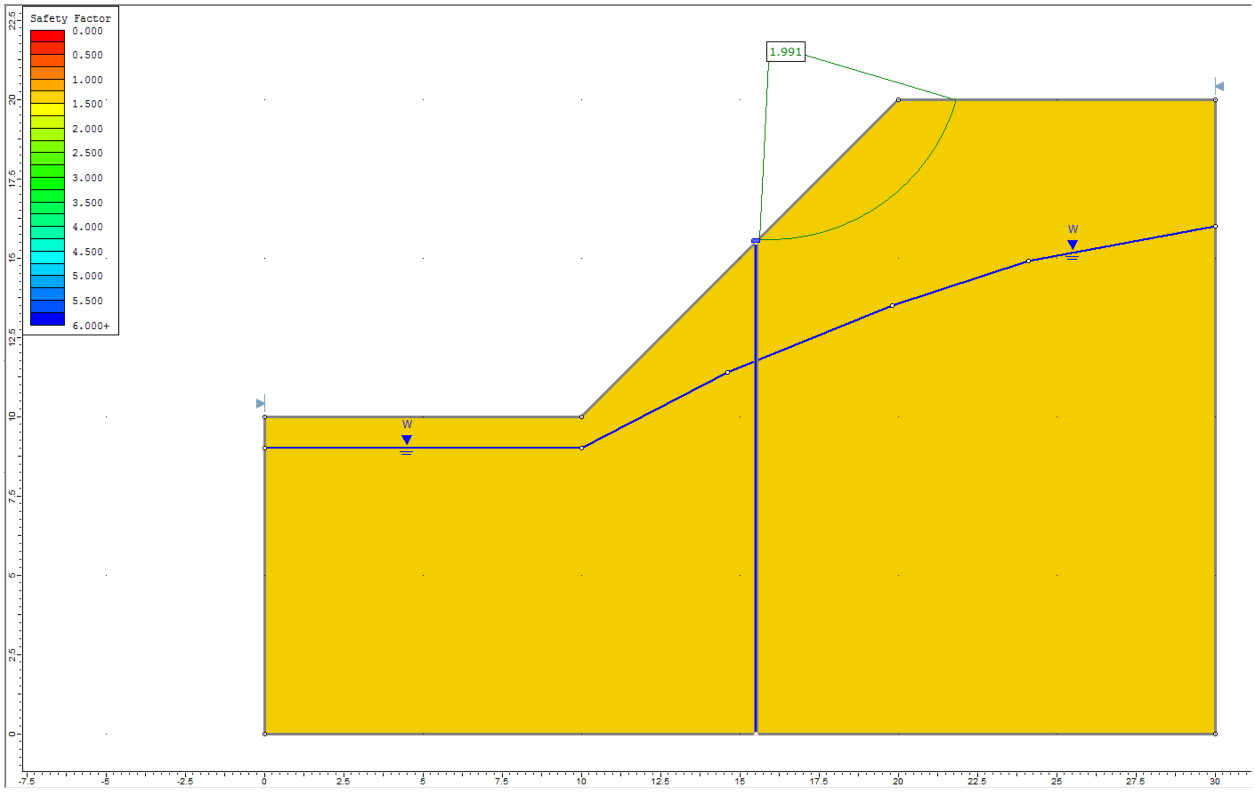


Figure 14.4.4 – Slide Solution Using the GLE Method

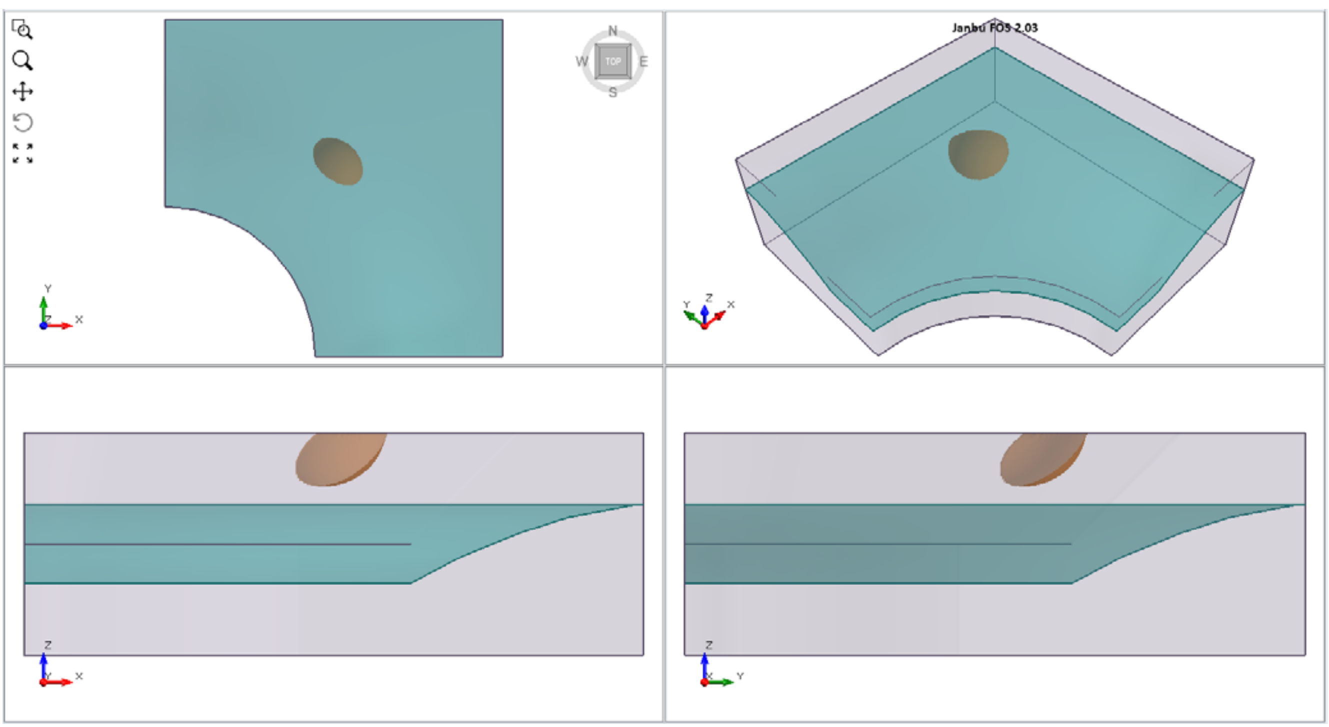


Figure 14.4.5 – Slide3 Solution Using the Janbu Method

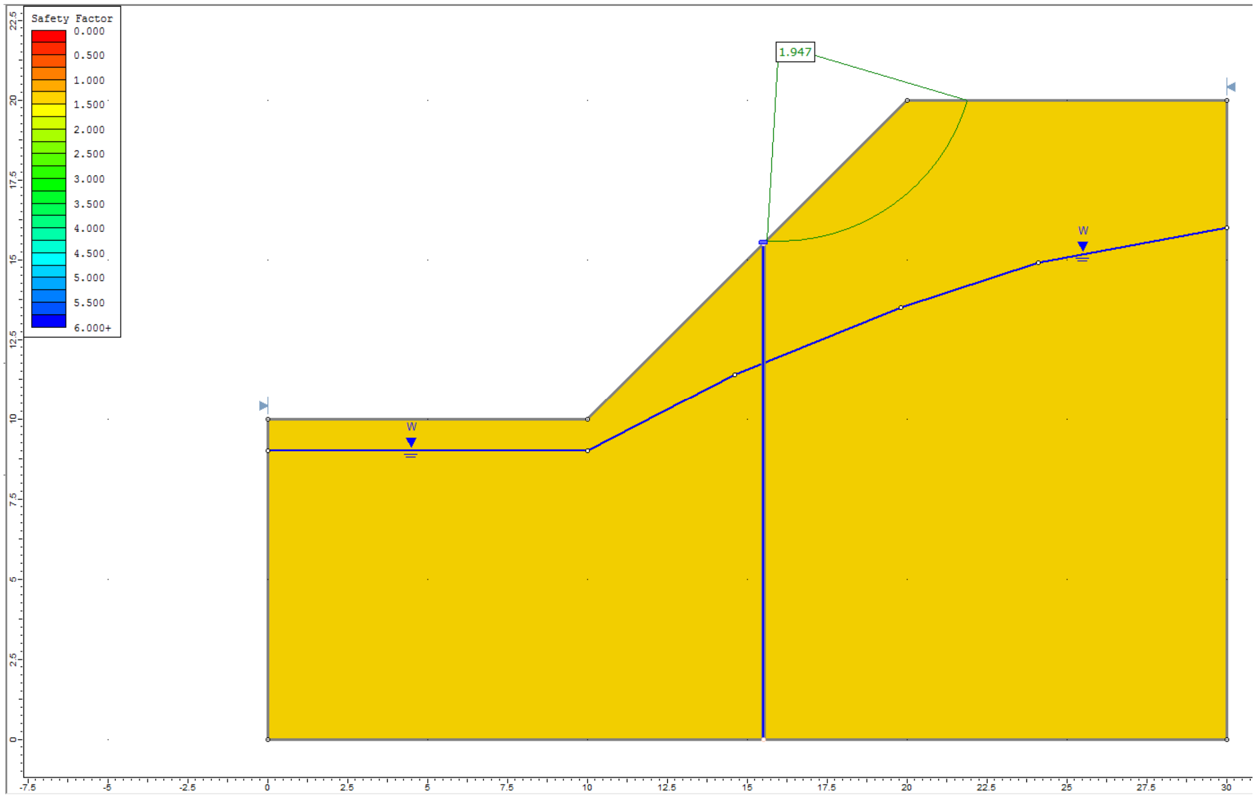


Figure 14.4.6 – Slide Solution Using the Janbu Method

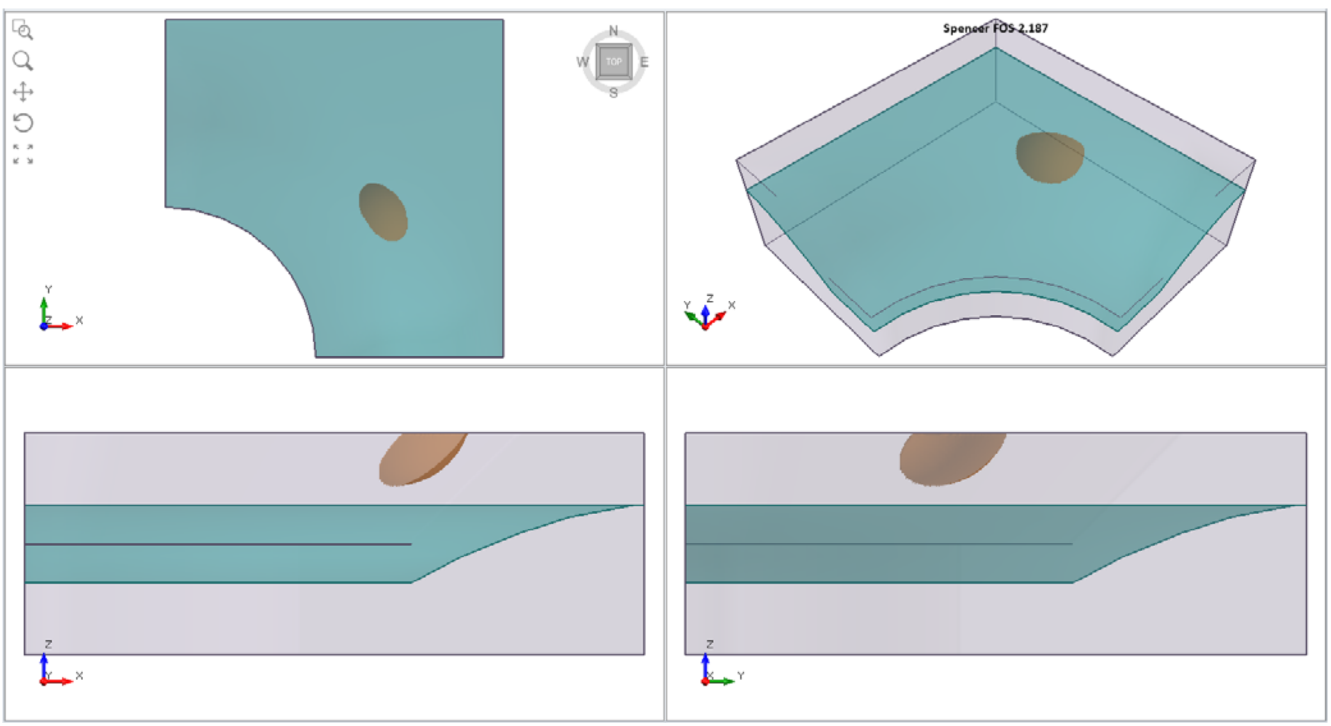


Figure 14.4.7 – Slide3 Solution Using the Spencer Method

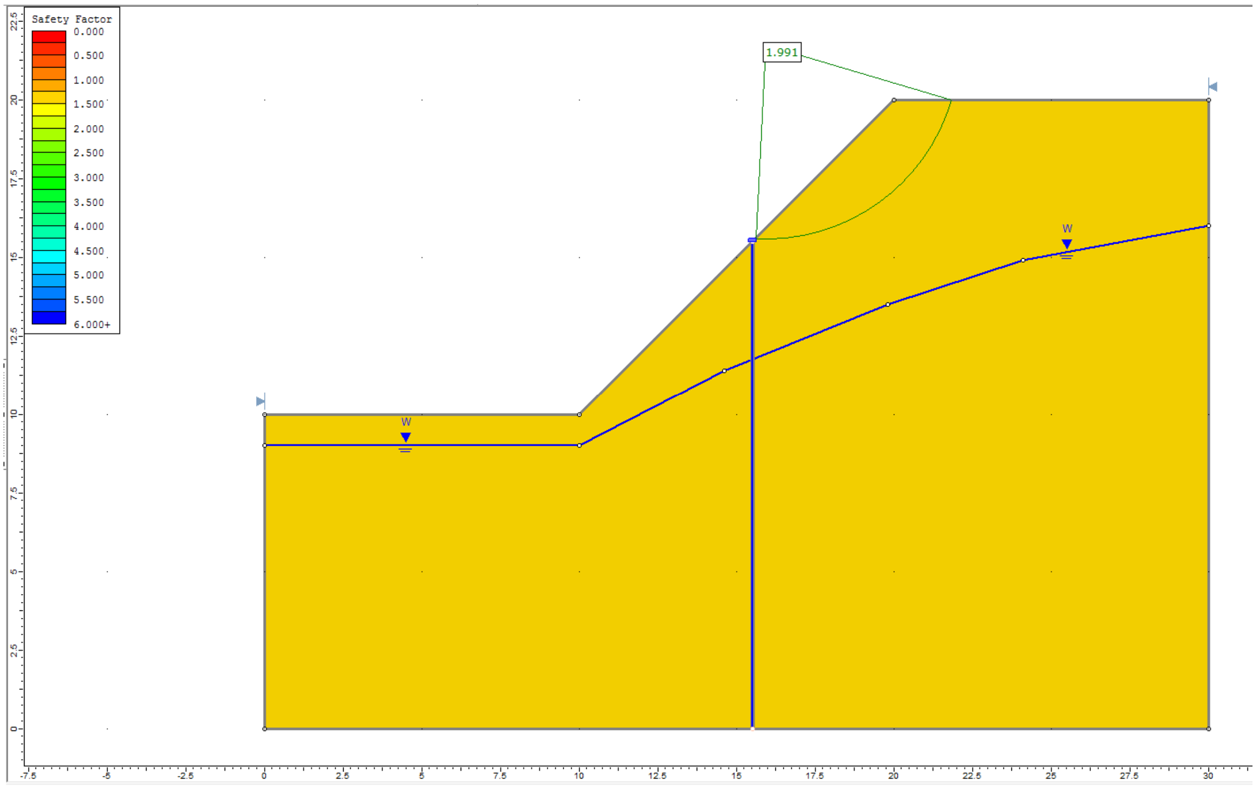


Figure 14.4.8 – Slide Solution Using the Spencer Method

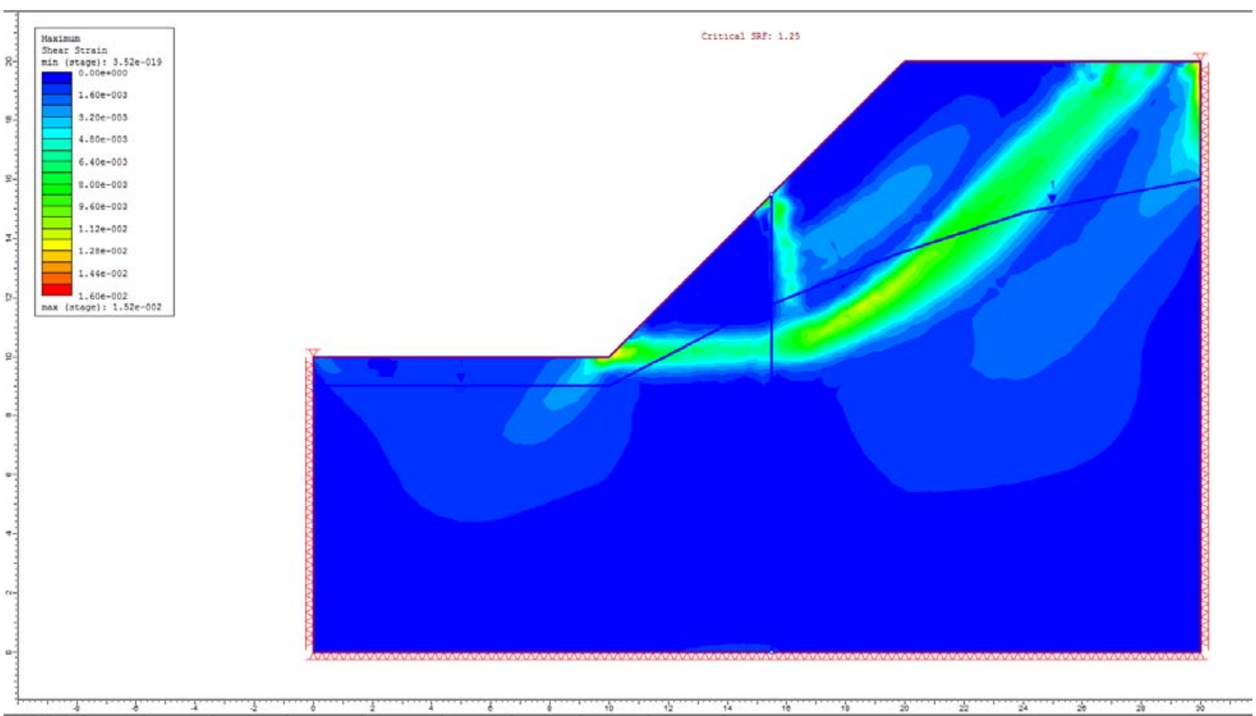


Figure 14.4.9 – RS2 Maximum Shear Strain

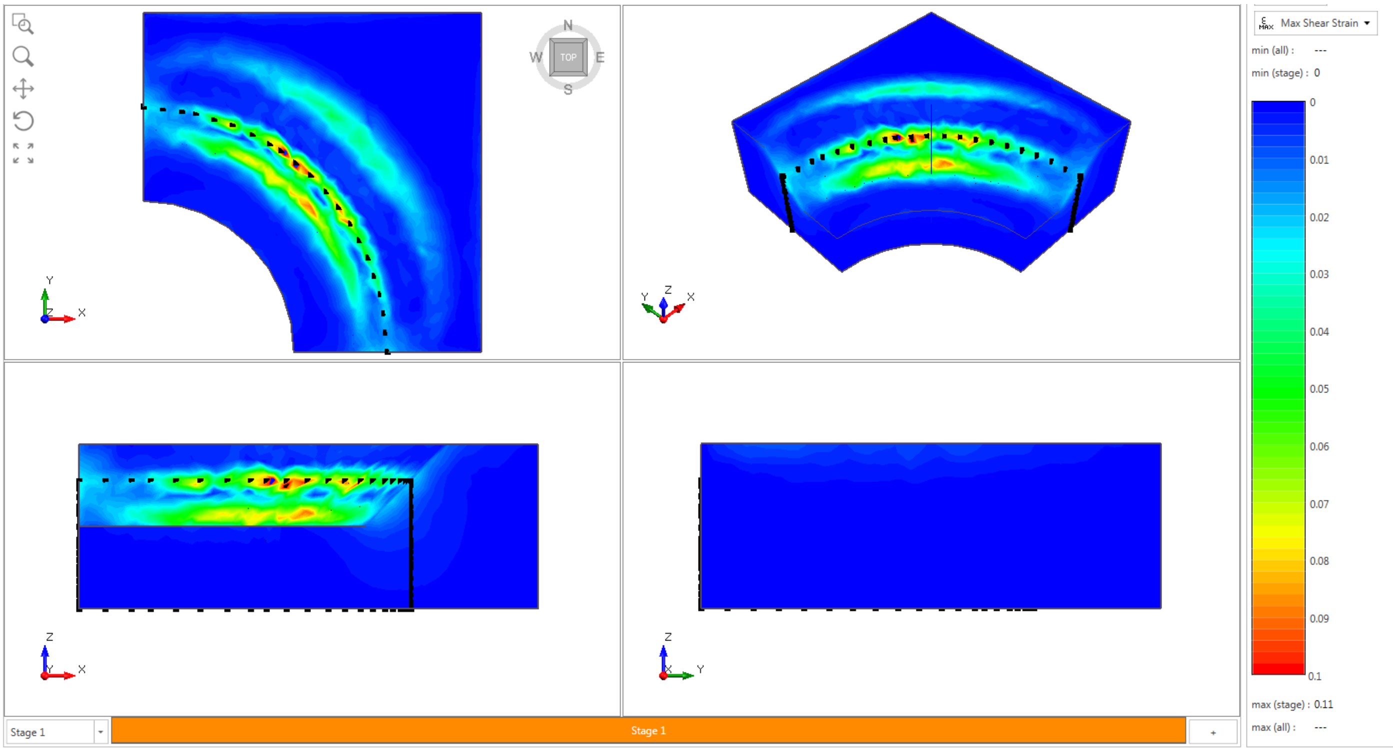


Figure 14.4.10 – RS3 Maximum Shear Strain

2D swept extruded baseline, vertical cut, homogeneous, ellipsoidal with SA

15.1 Introduction

This model comes from Nian et al. (2012). They used a simple homogeneous vertical cut cross section and analyzed the effect of different turning corners in 3D on the safety factor. This is the 2D cross section extruded.

15.2 Problem Description

The cross section for this model in the XZ plane is shown in Figure 15. This cross section is then extruded 60m in the Y direction. The model consists of a homogeneous slope whose material properties are shown in Table 15.1. A cuckoo search with search optimization was used to find the ellipsoidal slip surface.

15.3 Geometry and Properties

Table 15.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	40	20	20

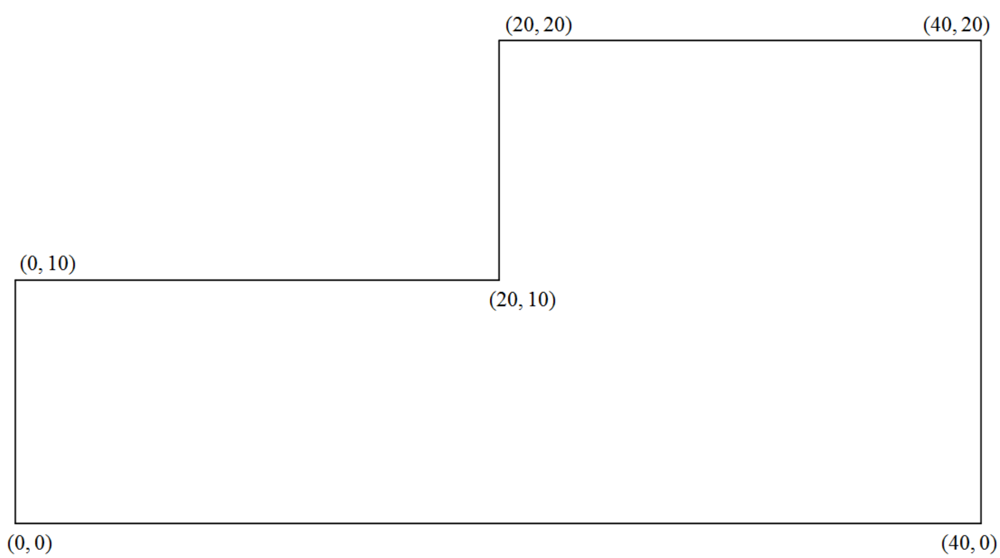


Figure 15

15.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.186	0.966	0.74	1.06
Janbu	1.225	1.106		

Referee: 1.273 [Nian, 2012]

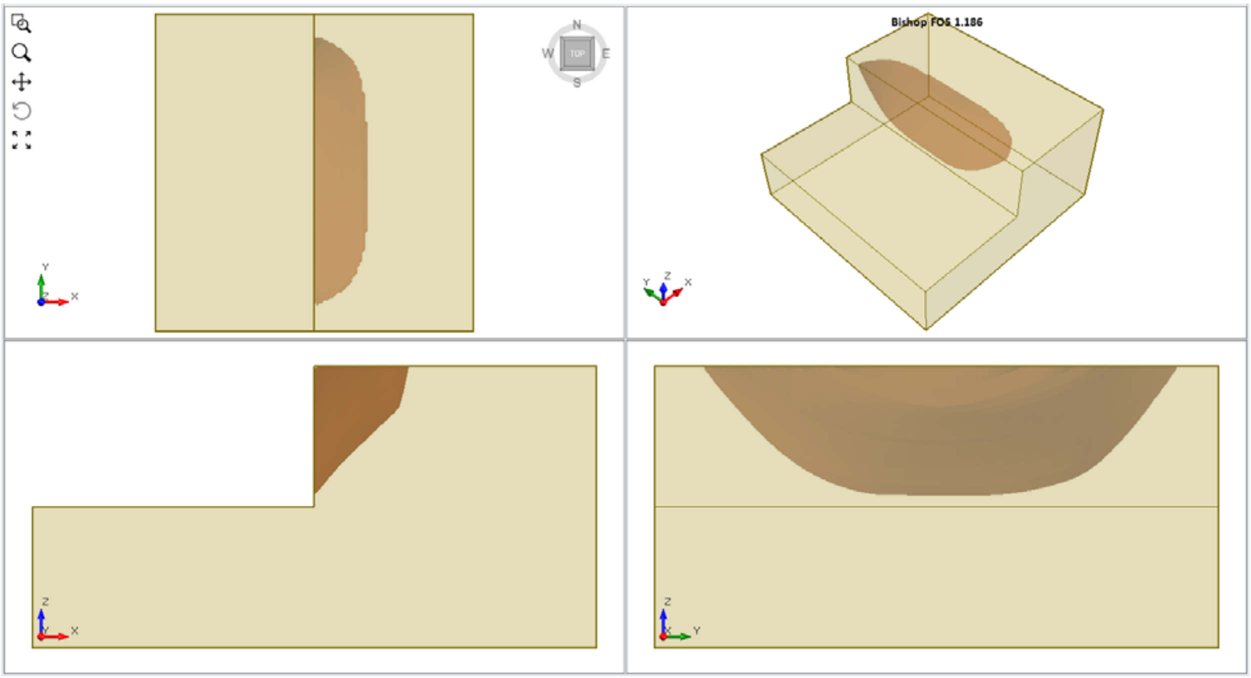


Figure 15.4.1 – Slide3 Solution Using the Bishop Method

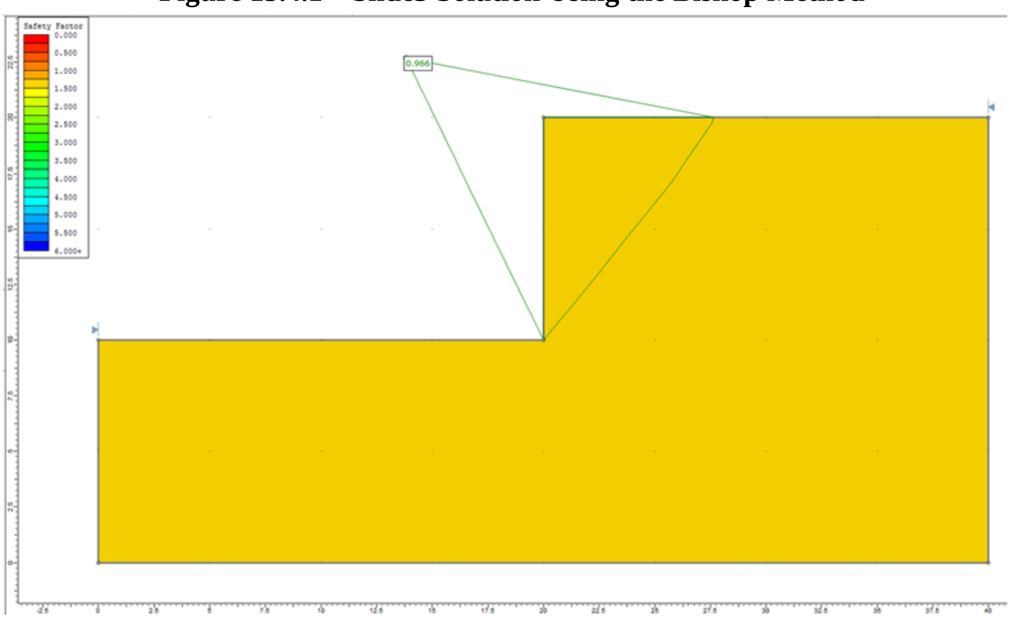


Figure 15.4.2 – Slide Solution Using the Bishop Method

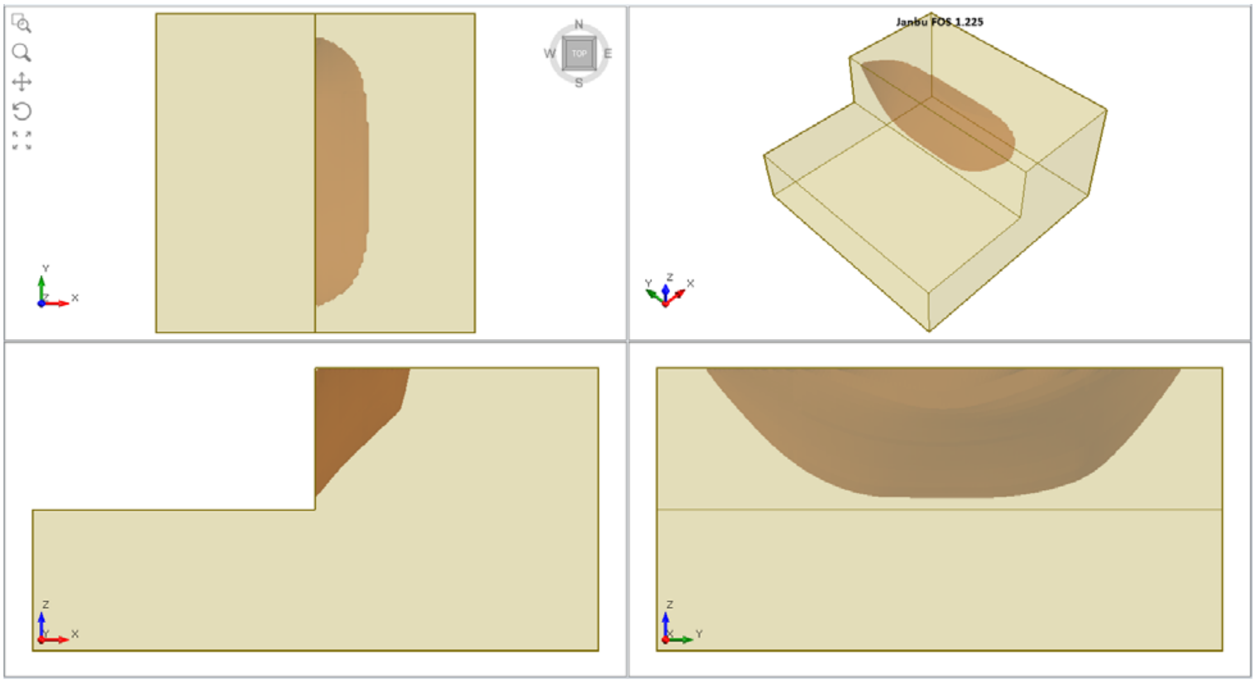


Figure 15.4.3 – Slide3 Solution Using the Janbu Method

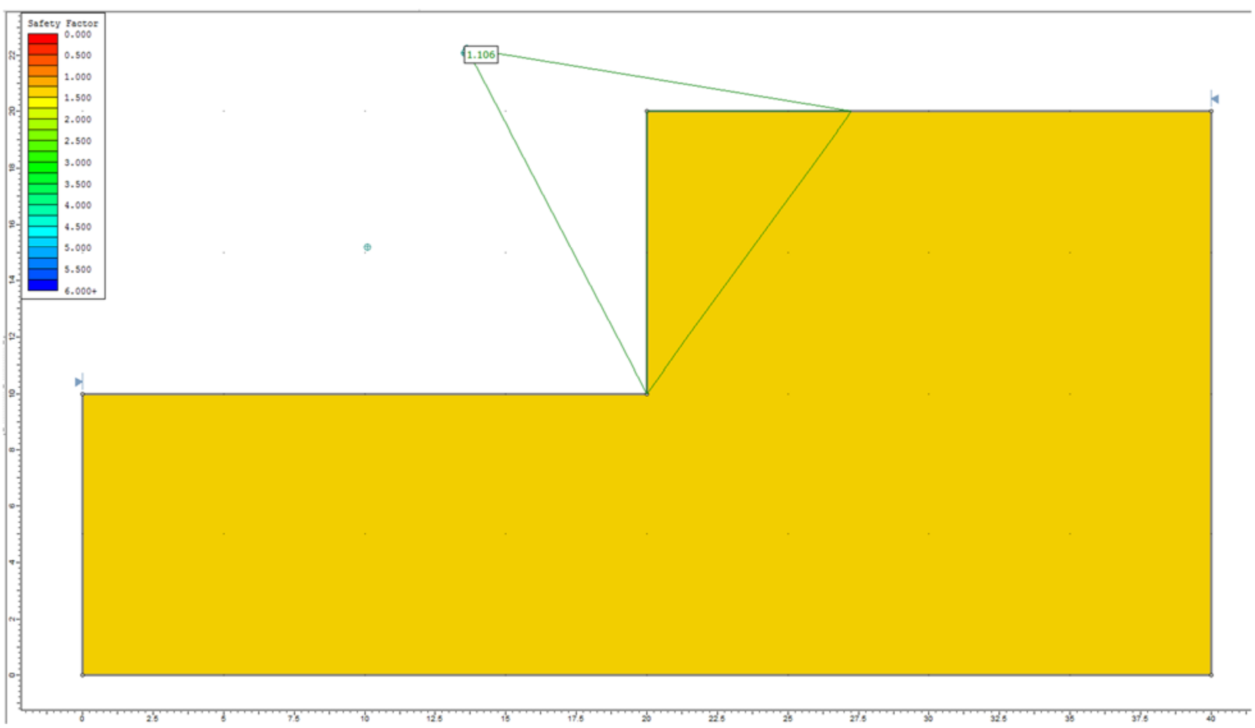


Figure 15.4.4 – Slide Solution Using the Janbu Method

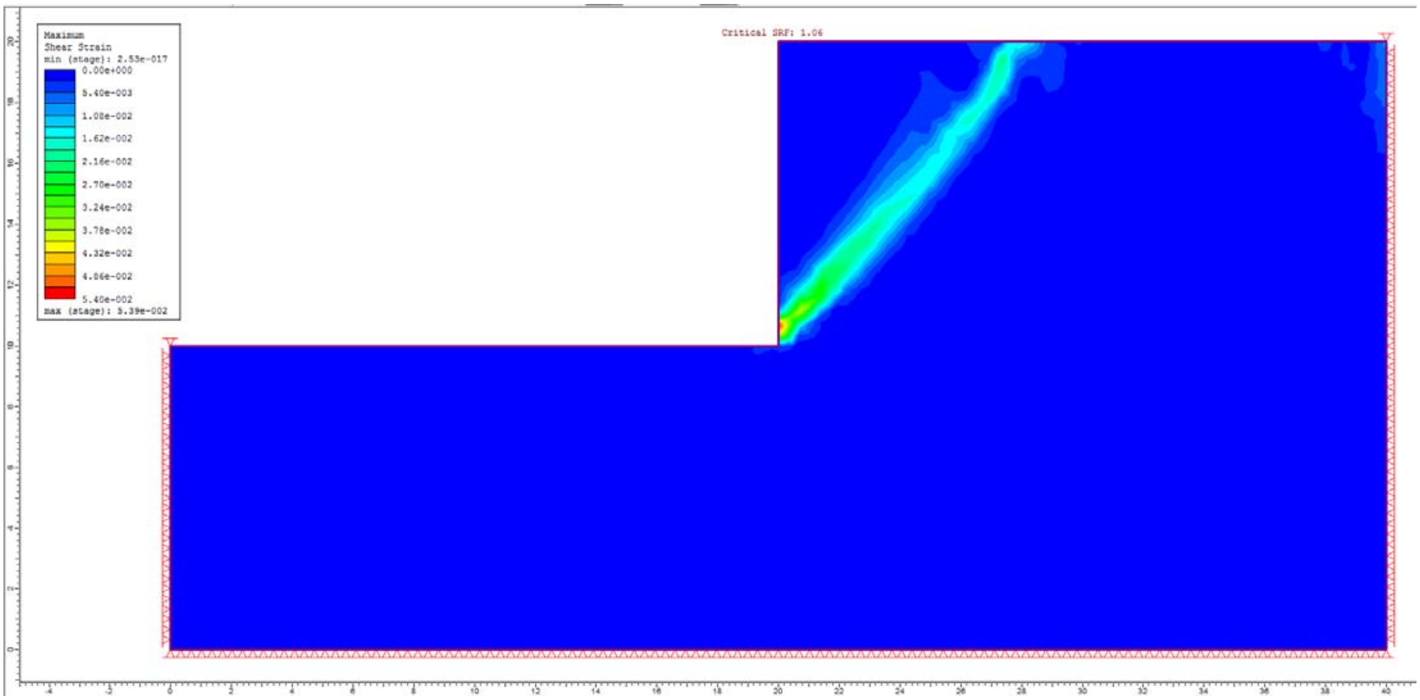


Figure 15.4.5 – RS2 Maximum Shear Strain

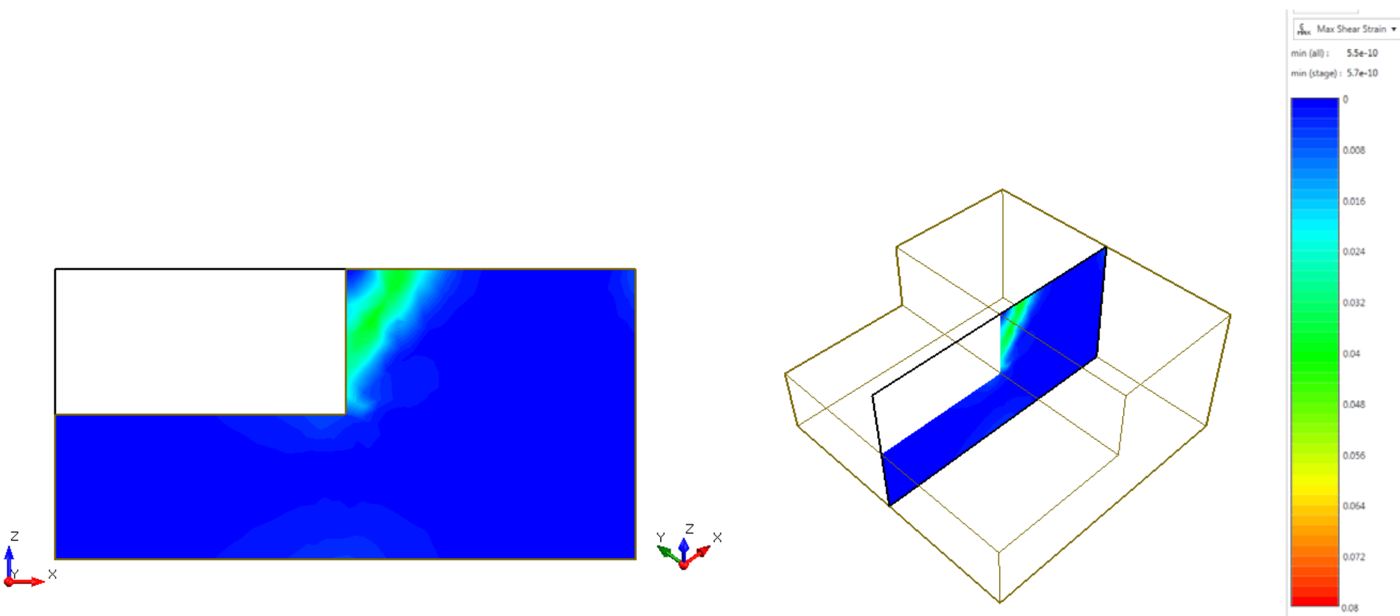


Figure 15.4.6 – RS3 Maximum Shear Strain

2D swept, 90° turn, convex, vertical cut, homogeneous, ellipsoidal with SA

16.1 Introduction

This model comes from Nian et al. (2012). They used a simple homogeneous vertical cut cross section and analyzed the effect of different turning corners in 3D on the safety factor. This is the second case: a 90 degree turn.

16.2 Problem Description

The cross section for this model is shown in Figure 16(a) and the top view of the model is shown in Figure 16(b). The model was made by taking the cross section (which is in the XZ plane) and sweeping it across a 90° bend starting at (20, 0, 0), bending at (20, 20 0), and ending at (40, 20, 0), offset -10m. The model consists of a homogeneous slope whose material properties are shown in Table 16.1. A cuckoo search with search optimization was used to find the ellipsoidal slip surface.

16.3 Geometry and Properties

Table 16.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	40	20	20

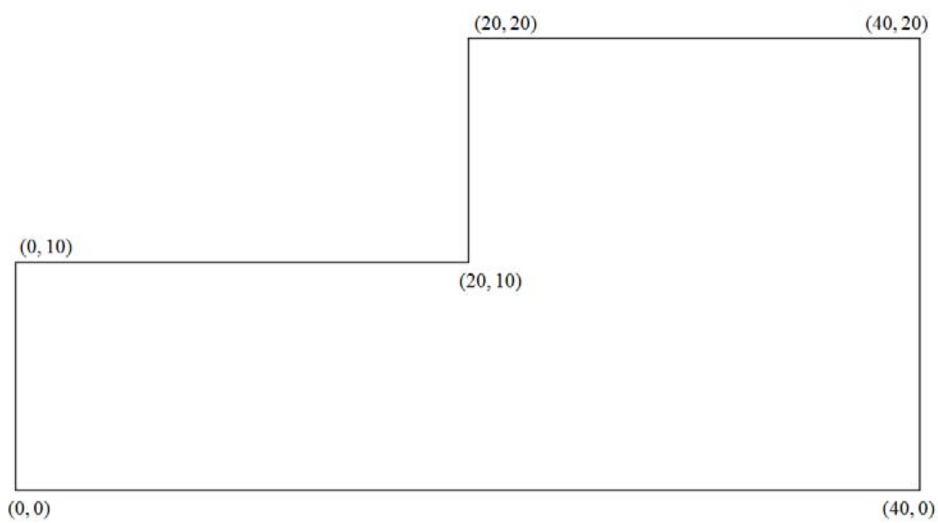


Figure 16(a)

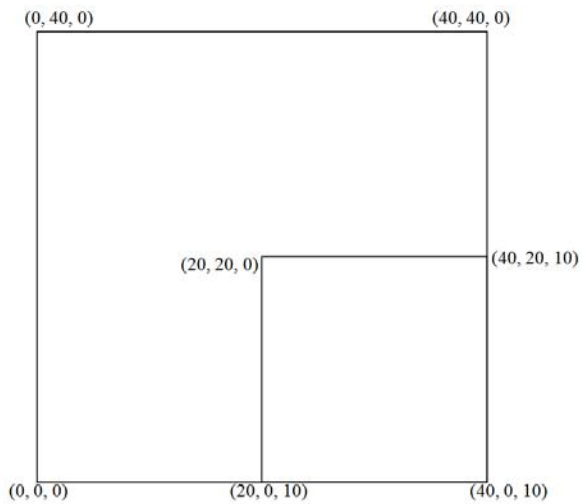


Figure 16(b)

16.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.233	0.966	0.64	1.06
Janbu	1.301	1.106		

Referee: 1.209 [Nian et al., 2012]

Note: The 2D cross section for this example is the same as the previous example, therefore the RS2 and Slide 7.0 values have not changed and the Slide 7.0 slip surfaces and RS2 maximum shear strain will not be shown in this example.

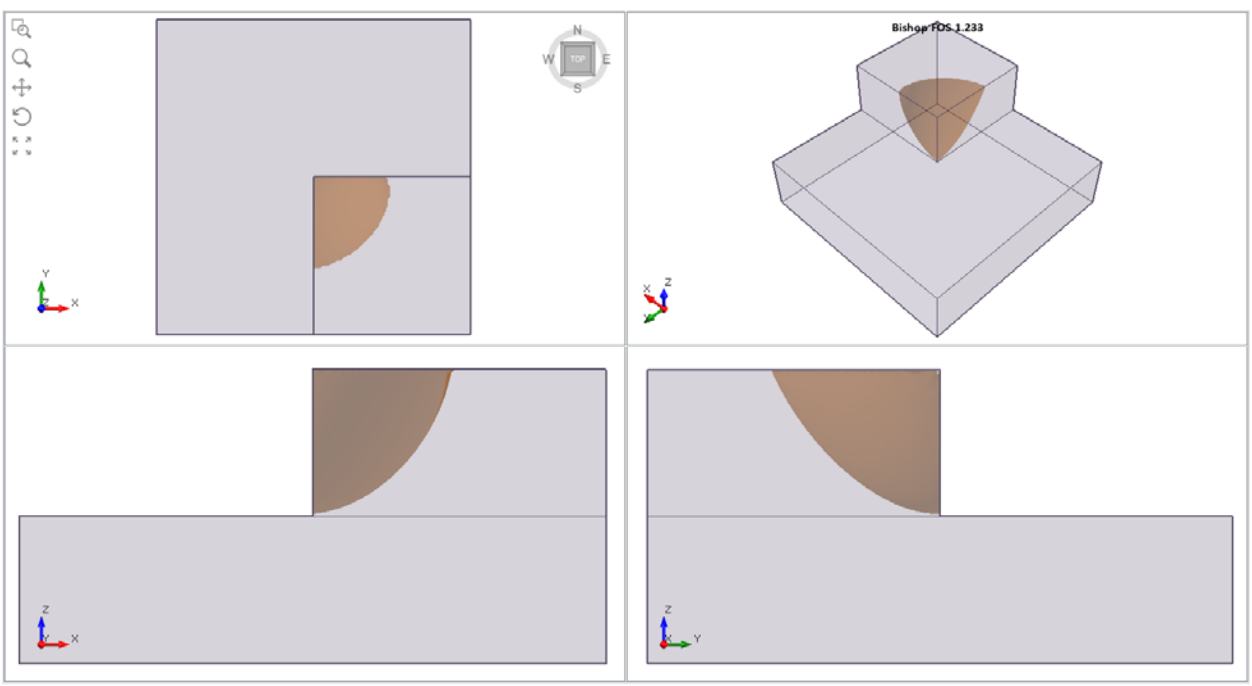


Figure 16.4.1 – Slide3 Solution Using the Bishop Method

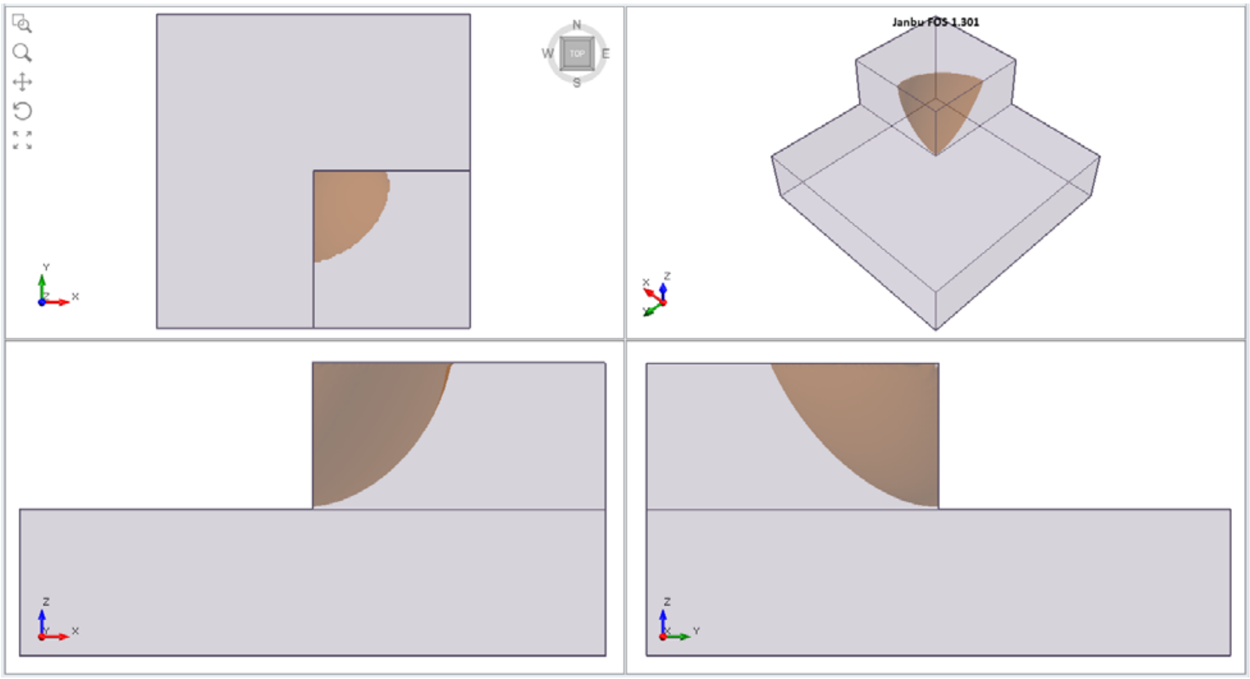


Figure 16.4.2 – Slide3 Solution Using the Janbu Method

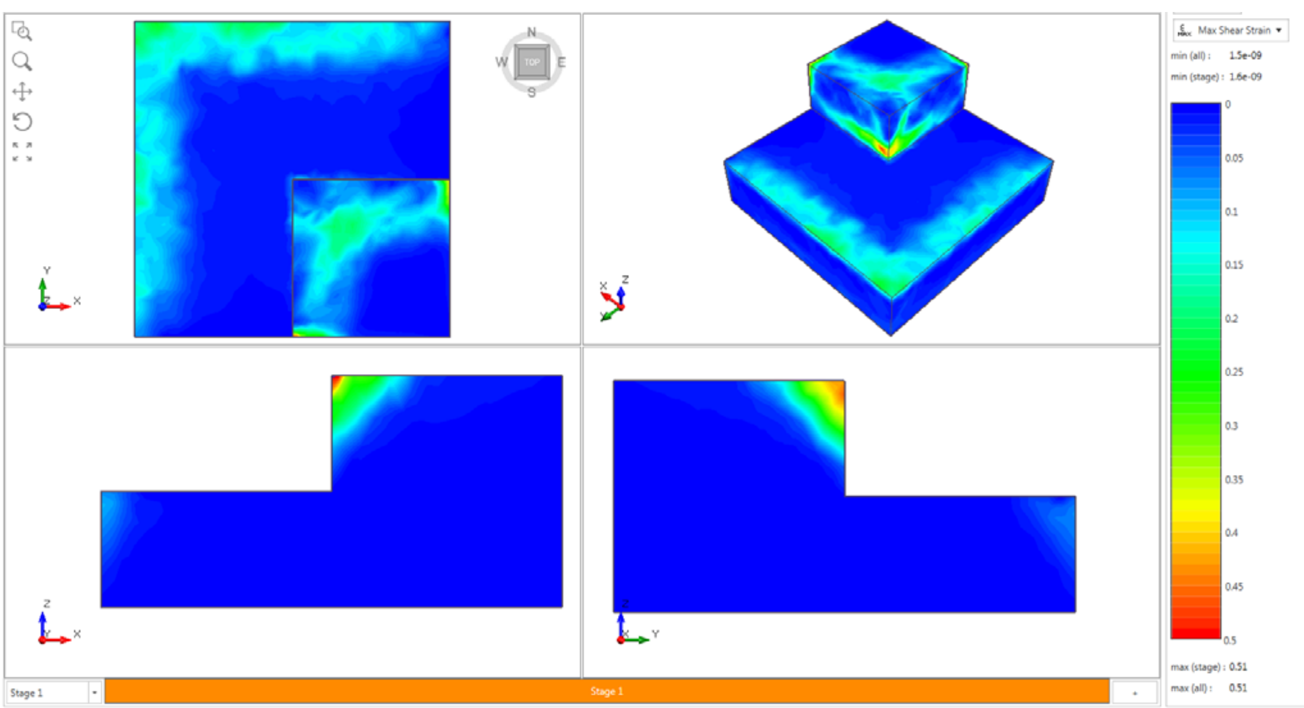


Figure 16.4.3 – RS3 Maximum Shear Strain

2D swept, 135° turn, convex, vertical cut, homogeneous, ellipsoidal with SA

17.1 Introduction

This model comes from Nian et al. (2012). They used a simple homogeneous vertical cut cross section and analyzed the effect of different turning corners in 3D on the safety factor. This is the third case: a 135° corner.

17.2 Problem Description

The cross section for this model is shown in Figure 17(a) and the top view of the model is shown in Figure 17(b). The model was made by taking the cross section (which is in the XZ plane) and sweeping it across a 135° bend starting at (40, 0, 0), bending at (40, 20 0), and ending at (54.14, 34.14, 0), offset -10m. The model consists of a homogeneous slope whose material properties are shown in Table 17.1. A cuckoo search with search optimization was used to find the ellipsoidal slip surface.

17.3 Geometry and Properties

Table 17.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	40	20	20

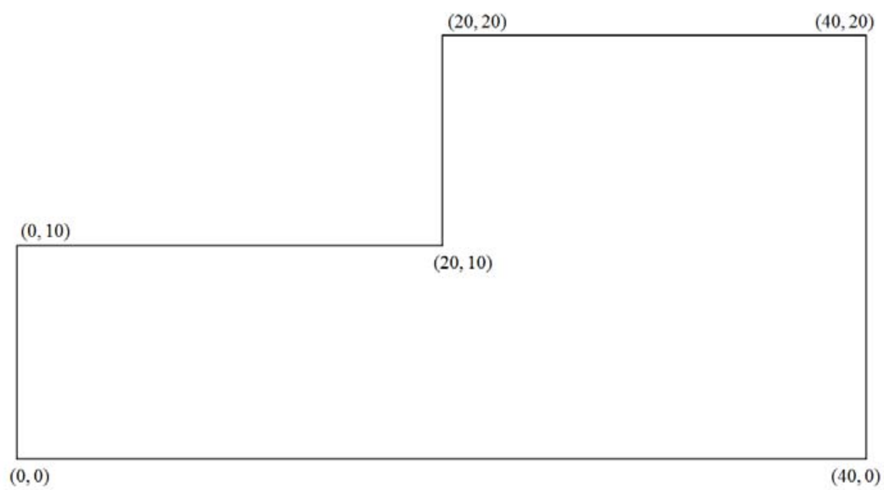


Figure 17(a)

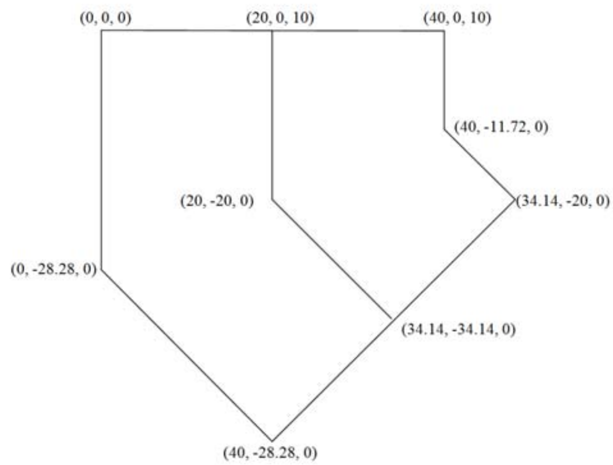


Figure 17(b)

17.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.109	0.966	0.56	1.06
Janbu	1.107	1.106		

Referee: 1.240 [Nian et al., 2012]

Note: The 2D cross section for this example is the same as the previous example; therefore the RS2 and Slide 7.0 values have not changed and the Slide 7.0 slip surfaces and RS2 maximum shear strain will not be shown is this example.

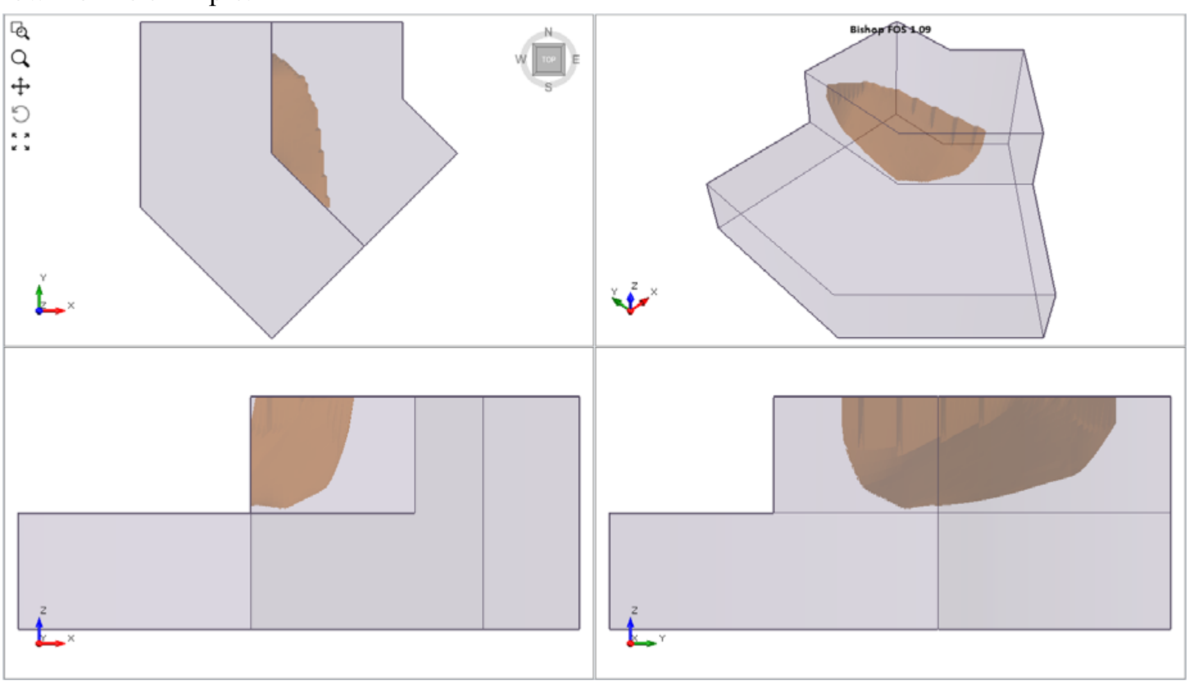


Figure 17.4.1 – Slide3 Solution Using the Bishop Method

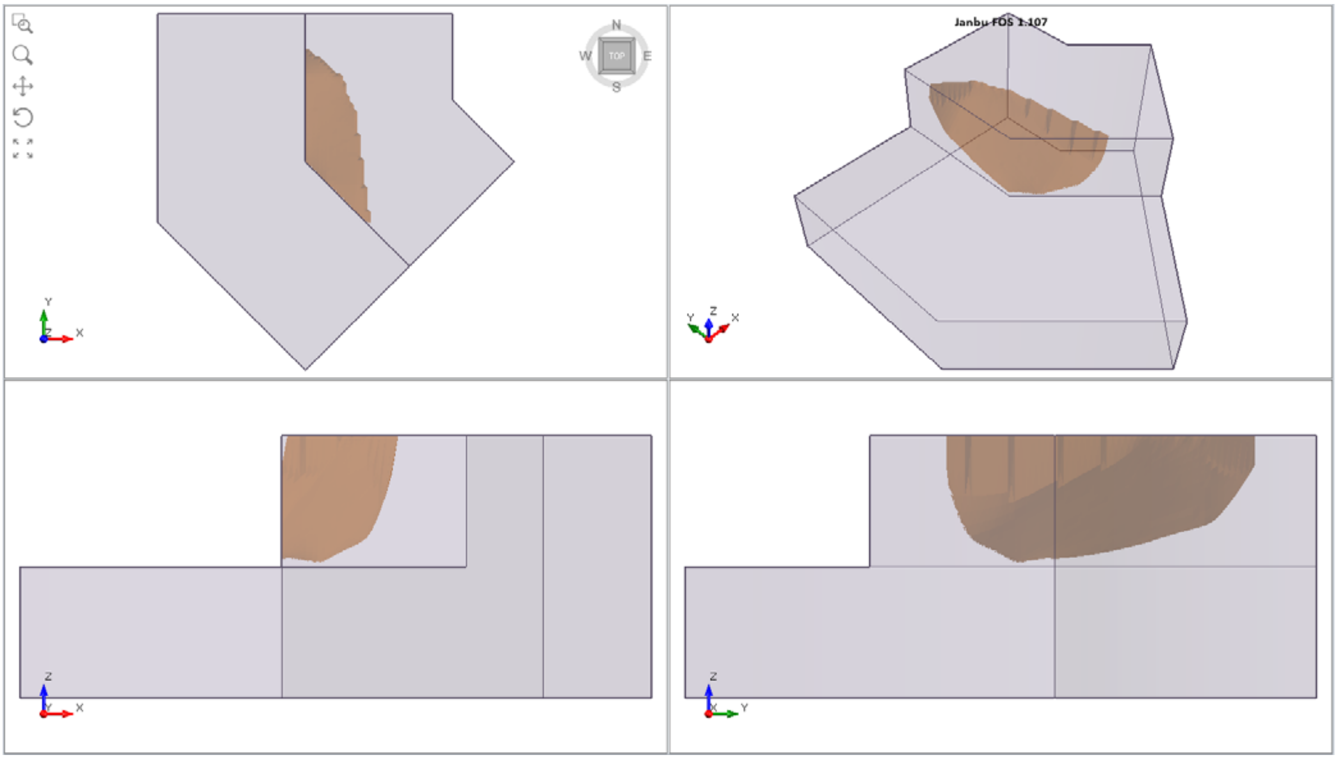


Figure 17.4.2 – Slide3 Solution Using the Janbu Method

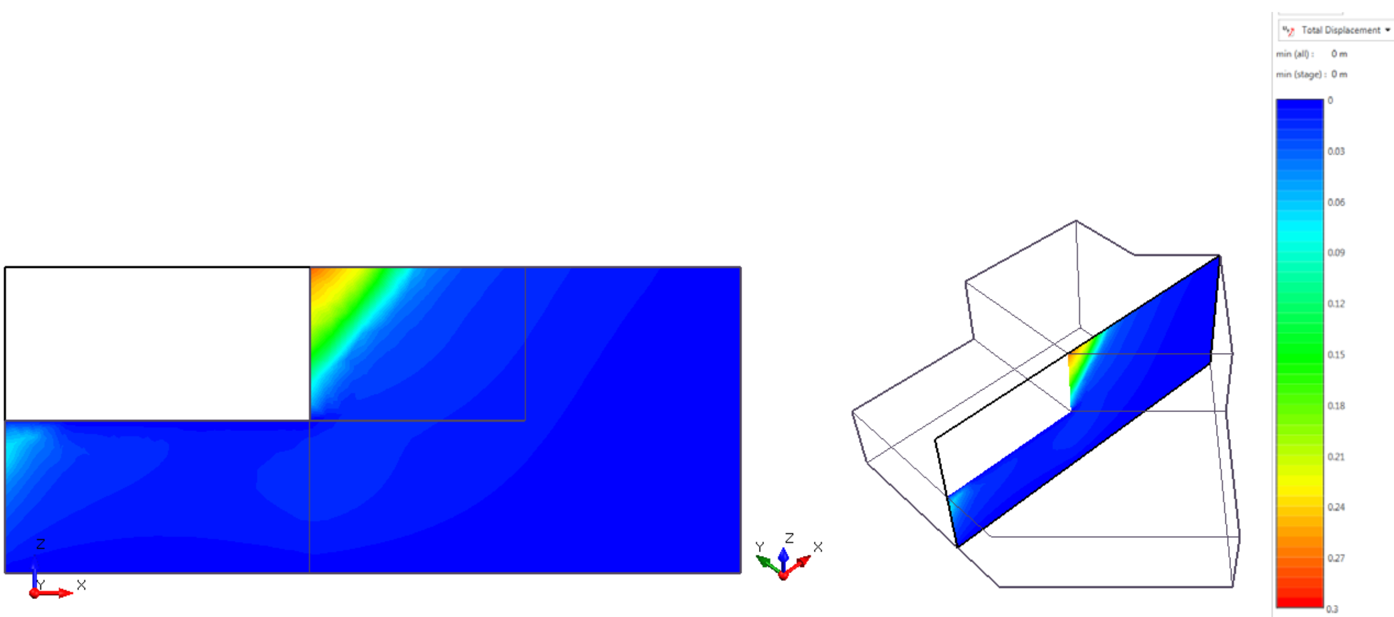


Figure 17.4.3 – RS3 Maximum Shear Strain

2D swept extruded baseline, vertical cut, homogeneous, ellipsoidal with SA

18.1 Introduction

This example is taken from Zhang et al. (2013). It is a vertical cut that has undergone two concave turns. This is the first example: the straight slope.

18.2 Problem Description

The 2D cross section of the vertical cut in the XZ plane is shown as Figure 18. This cross section is then extruded 20 m in the Y direction. The material properties for the homogeneous slope can be found in Table 18.1. The ellipsoidal slip surface and corresponding safety factor is required.

18.3 Geometry and Properties

Table 18.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	24.5	20	17.64

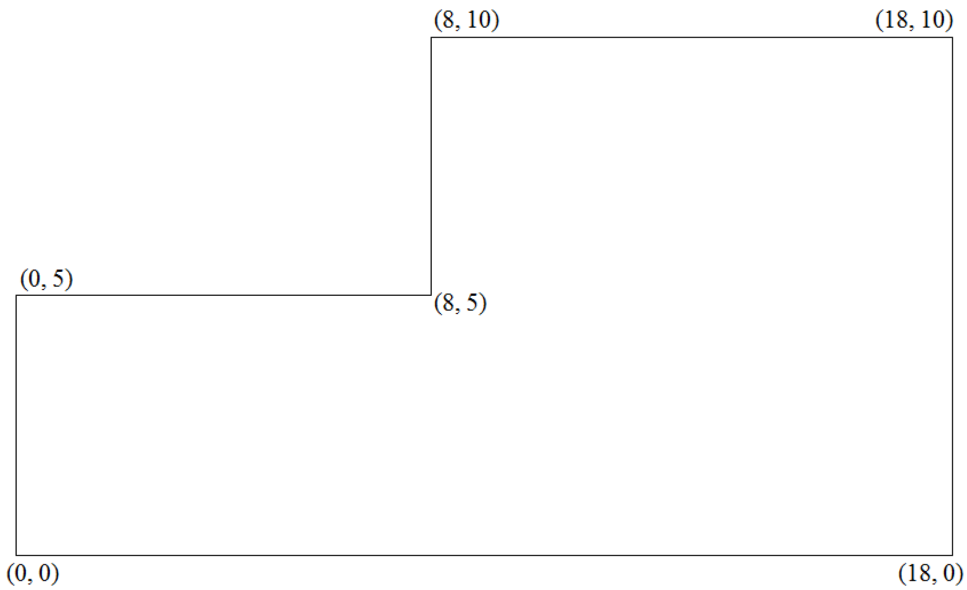


Figure 18

18.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.825	1.170	1.71	1.37
Janbu	1.913	1.430		

Referee: 1.66 [Zhang et al., 2013]

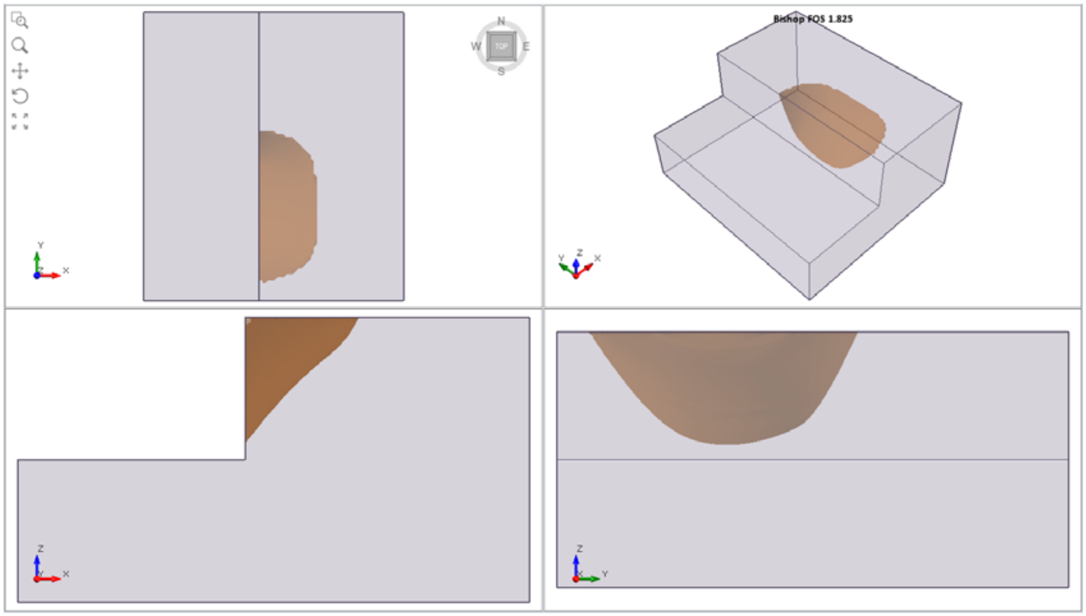


Figure 18.4.1 – Slide3 Solution Using the Bishop Method

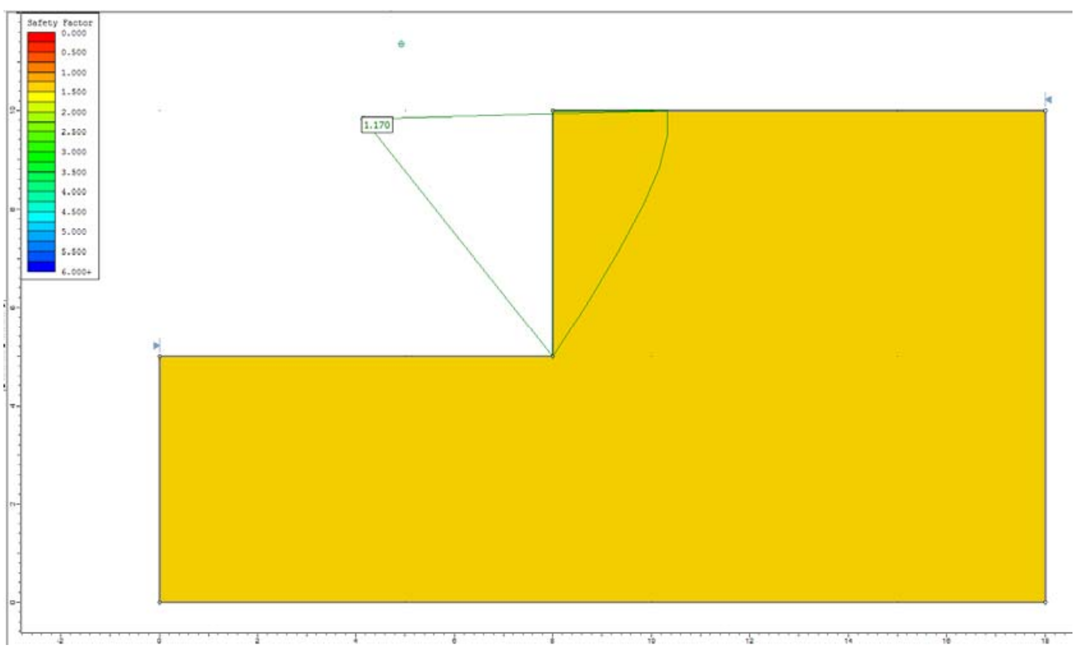


Figure 18.4.2 – Slide Solution Using the Bishop Method

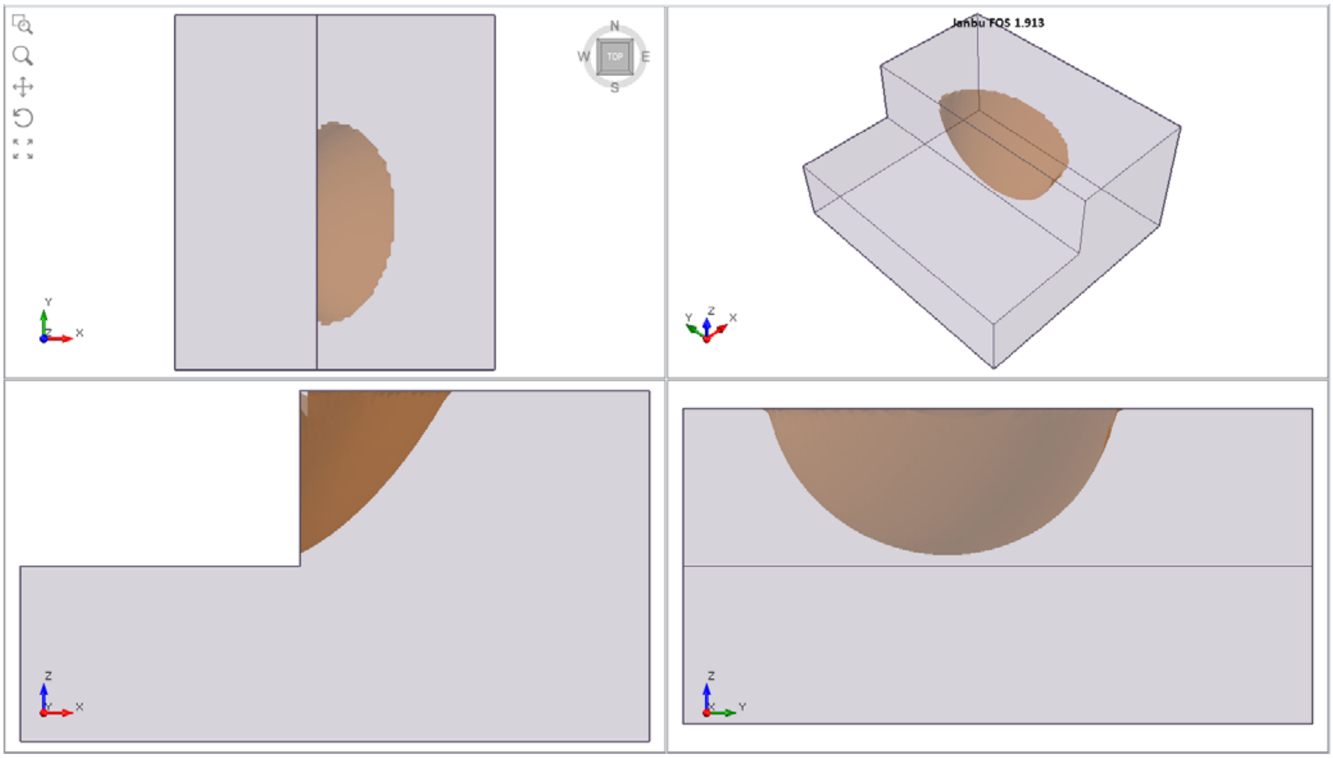


Figure 18.4.2 – Slide3 Solution Using the Janbu Method

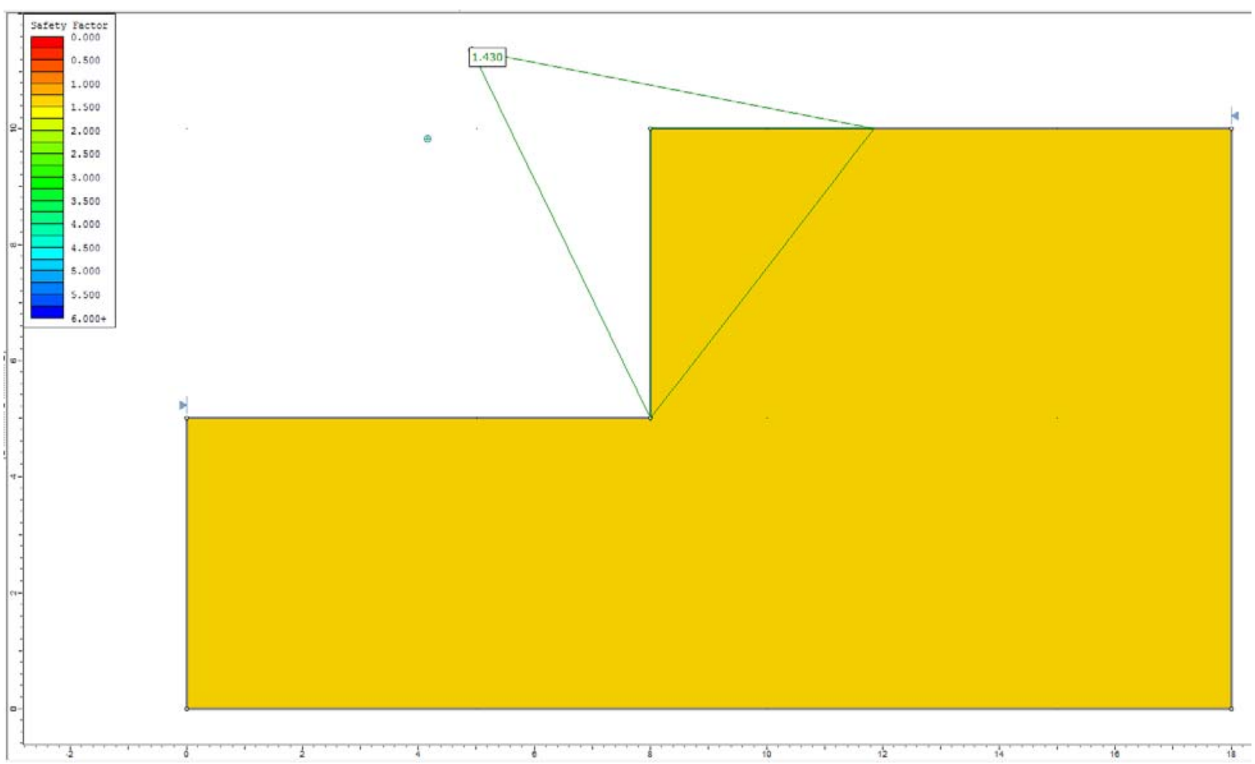


Figure 18.4.4 – Slide Solution Using the Janbu Method

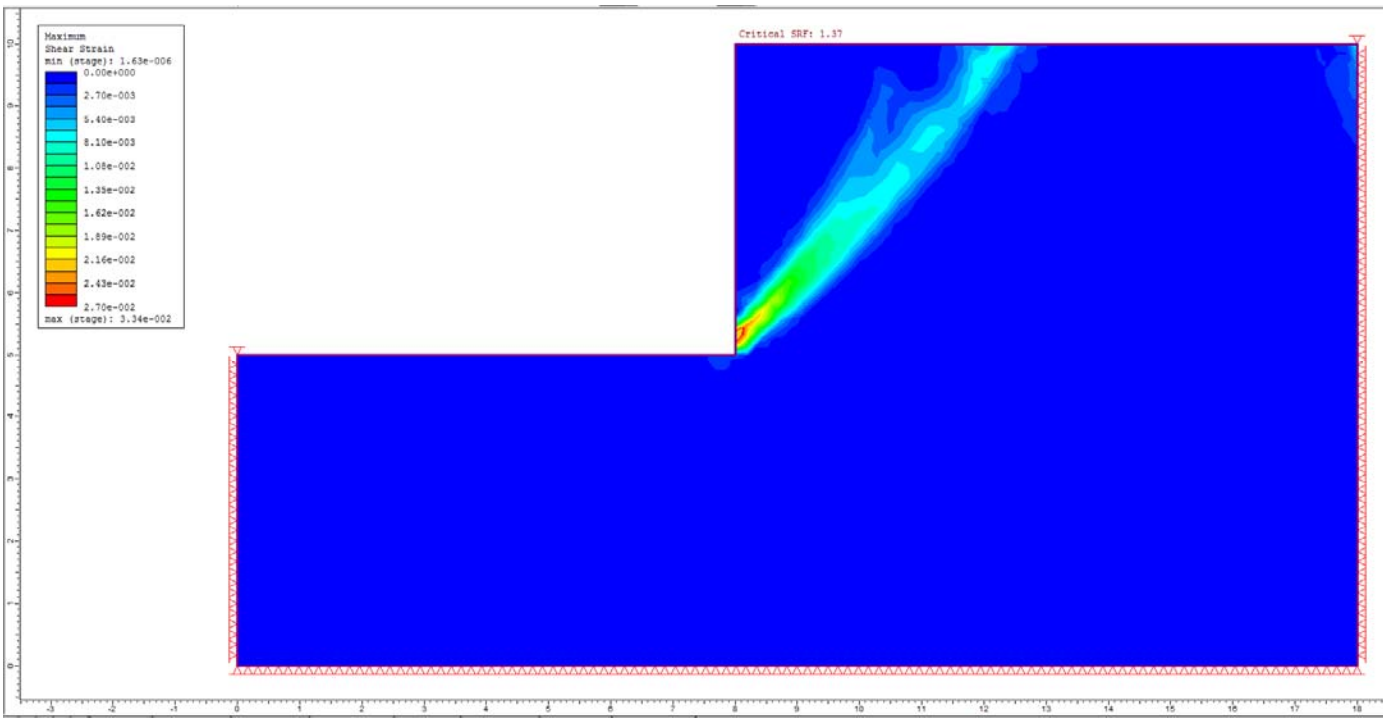


Figure 18.4.5 – RS2 Maximum Shear Strain

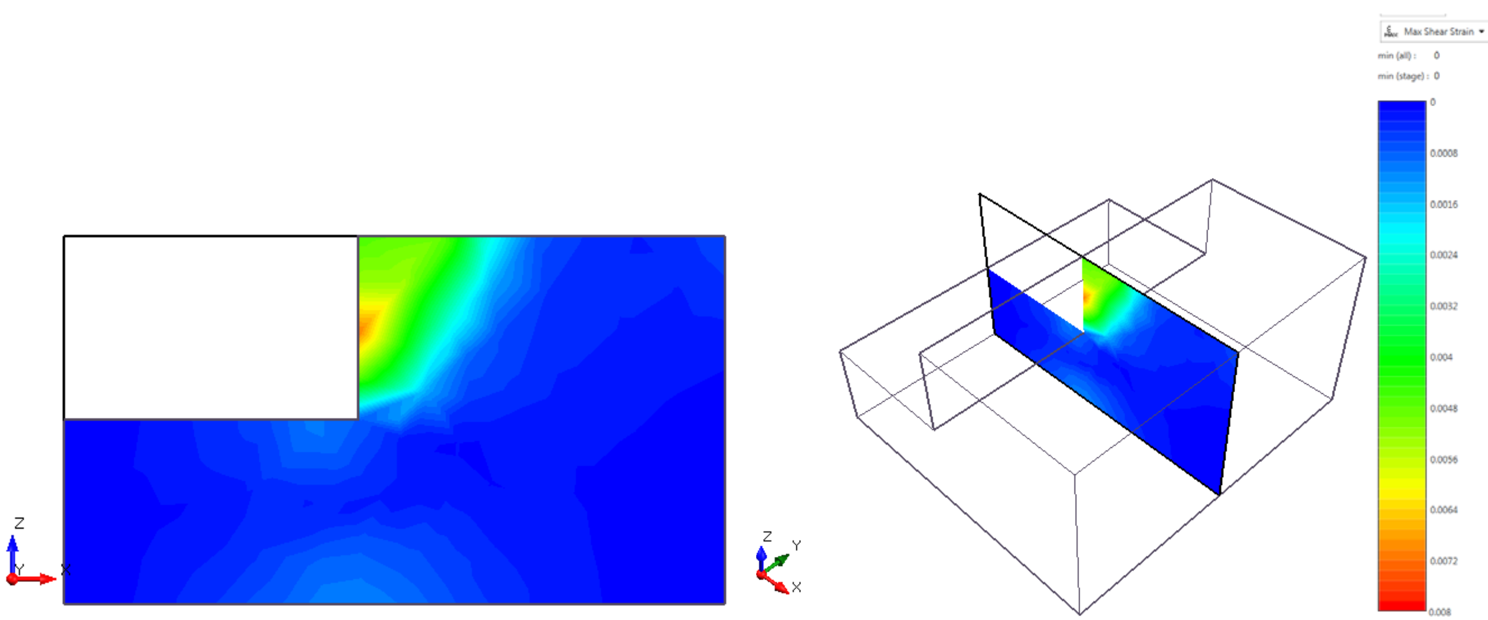


Figure 18.4.6 – RS3 Maximum Shear Strain

2D swept, 90° turn, concave, vertical cut, homogeneous, ellipsoidal with SA

19.1 Introduction

This example is taken from Zhang et al. (2013). It is a vertical cut that has undergone two concave turns. This is the 90 degree turn.

19.2 Problem Description

The 2D cross section of the vertical cut in the XZ plane is shown as Figure 19(a). The top view of the turn can be seen in Figure 19(b). The material properties for the homogeneous slope can be found in Table 19.1. The ellipsoidal slip surface and corresponding safety factor is required.

19.3 Geometry and Properties

Table 19.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	24.5	20	17.64

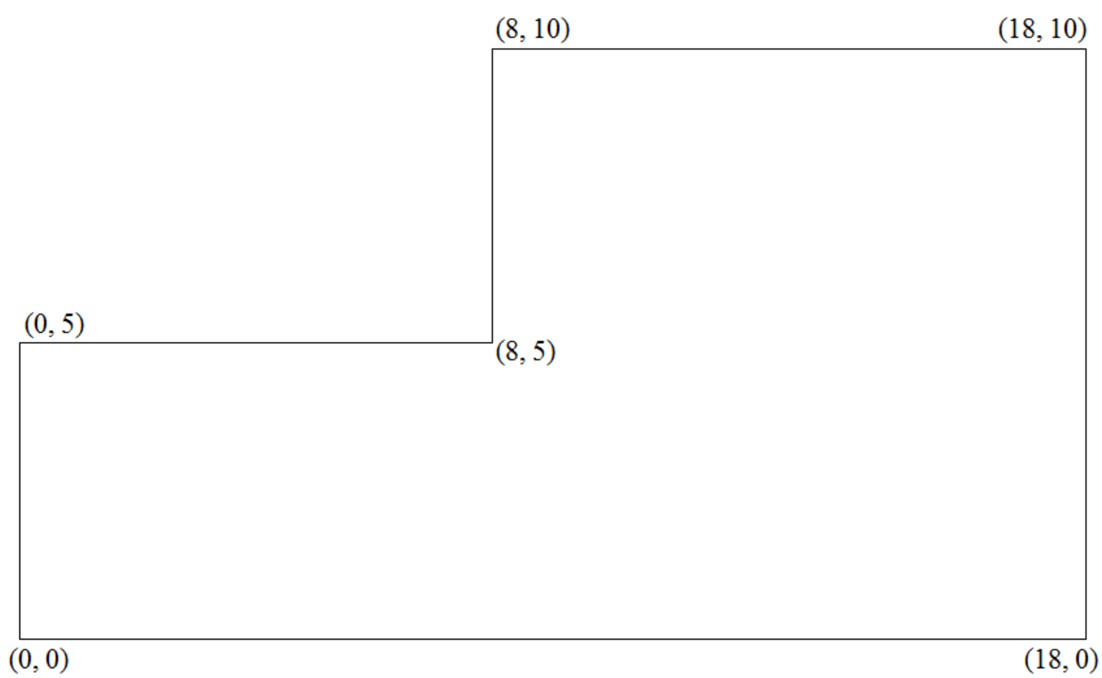


Figure 19(a)

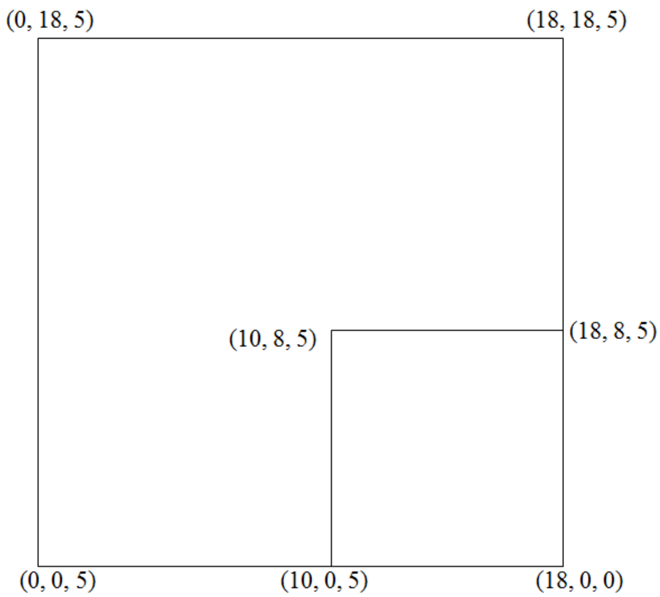


Figure 19(b)

19.4 Results

Table 19.4.1: Safety Factors 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>1.784</td><td>1.170</td><td rowspan="2">1.55</td><td rowspan="2">1.37</td></tr>
<tr><td>Janbu</td><td>1.955</td><td>1.430</td></tr>
</table>

Referee: 1.82 [Zhang et al., 2013]

Note: The 2D cross section for this example is the same as the previous example; therefore the RS2 and Slide 7.0 values have not changed and the Slide 7.0 slip surfaces and RS2 maximum shear strain will not be shown is this example.

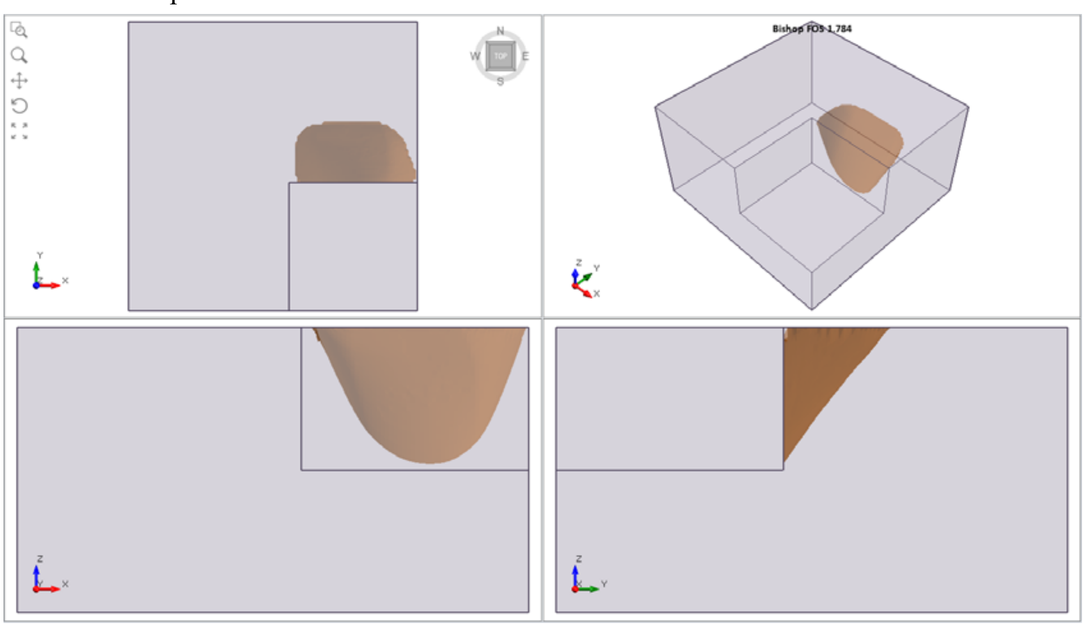


Figure 19.4.1 – Slide3 Solution Using the Bishop Method

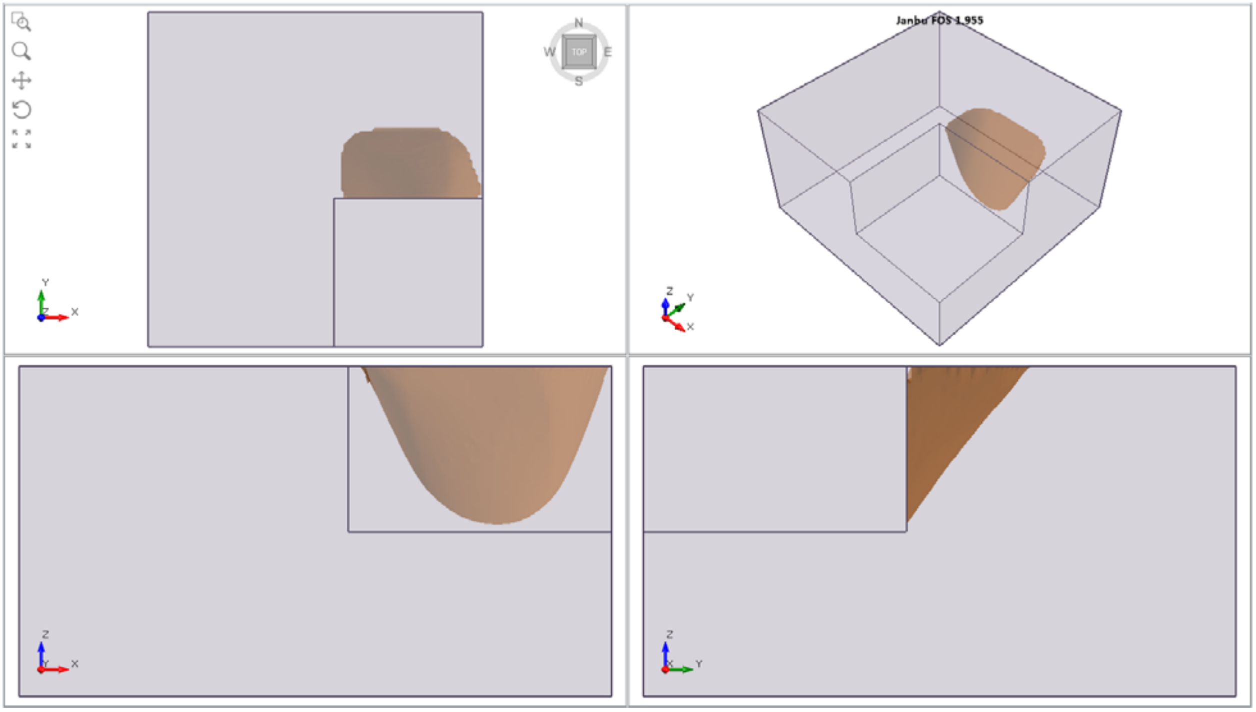


Figure 19.4.2 – Slide3 Solution Using the Janbu method

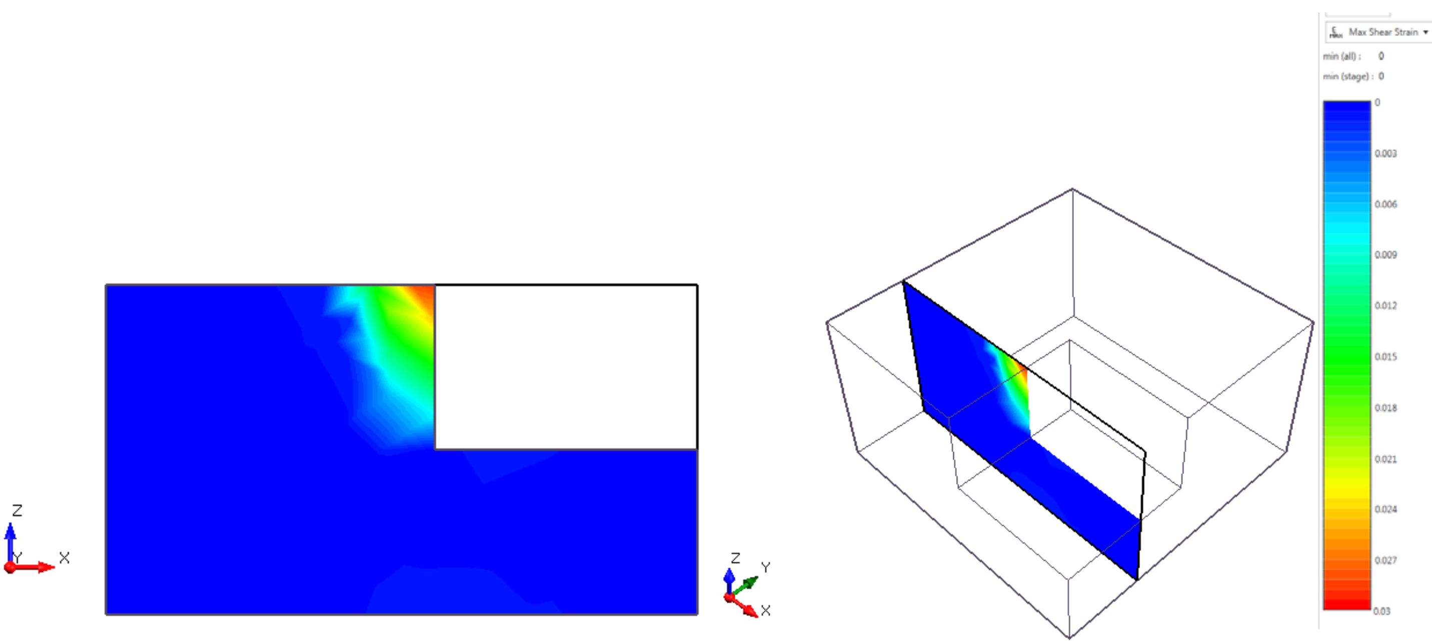


Figure 19.4.4 – RS3 Maximum Shear Strain

2D swept, 135° turn, concave, vertical cut, homogeneous, ellipsoidal with SA

20.1 Introduction

This example is taken from Zhang et al. (2013). It is a vertical cut that has undergone two concave turns. This is the 135 degree turn.

20.2 Problem Description

The 2D cross section of the vertical cut in the XZ plane is shown as Figure 20(a). The top view of the turn can be seen in Figure 20(b). The material properties for the homogeneous slope can be found in Table 20.1. The ellipsoidal slip surface and corresponding safety factor is required.

20.3 Geometry and Properties

Table 20.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	24.5	20	17.64

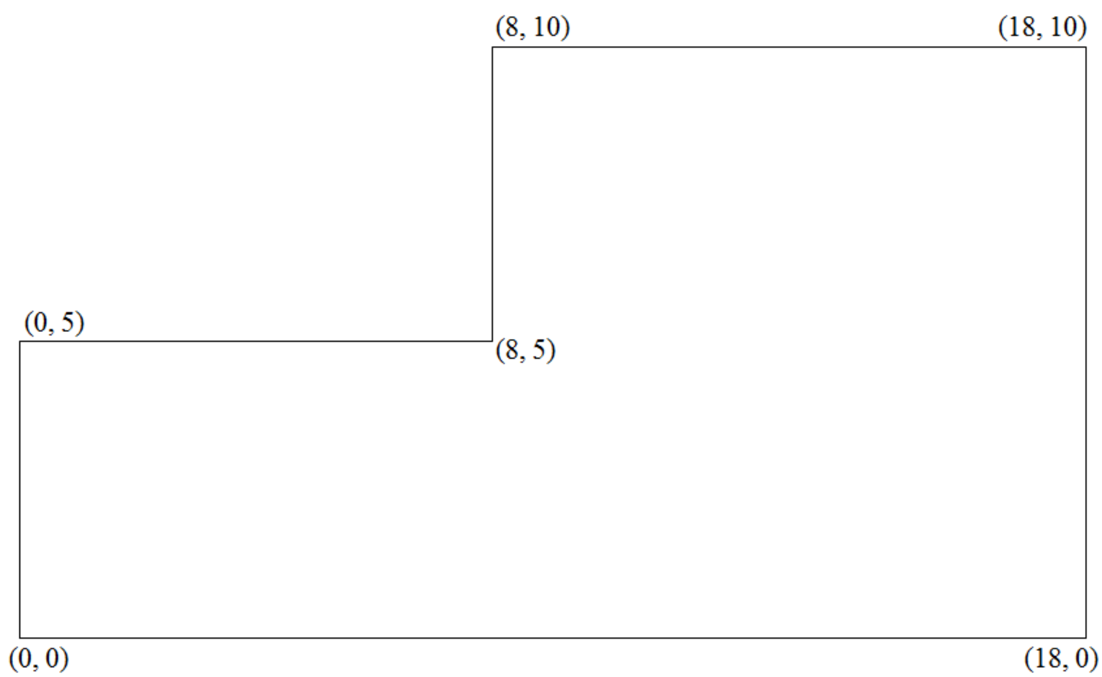


Figure 20(a)

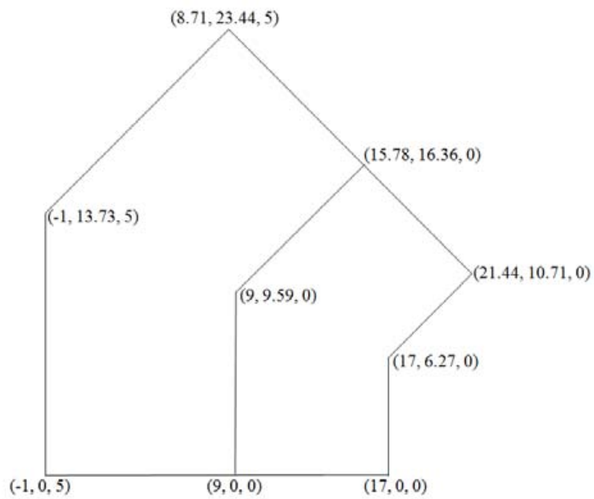


Figure 20(b)

20.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.939	1.170	1.86	1.37
Janbu	2.09	1.430		

Referee: 1.78 [Zhang et al., 2013]

Note: The 2D cross section for this example is the same as the previous example; therefore the RS2 and Slide 7.0 values have not changed and the Slide 7.0 slip surfaces and RS2 maximum shear strain will not be shown is this example.

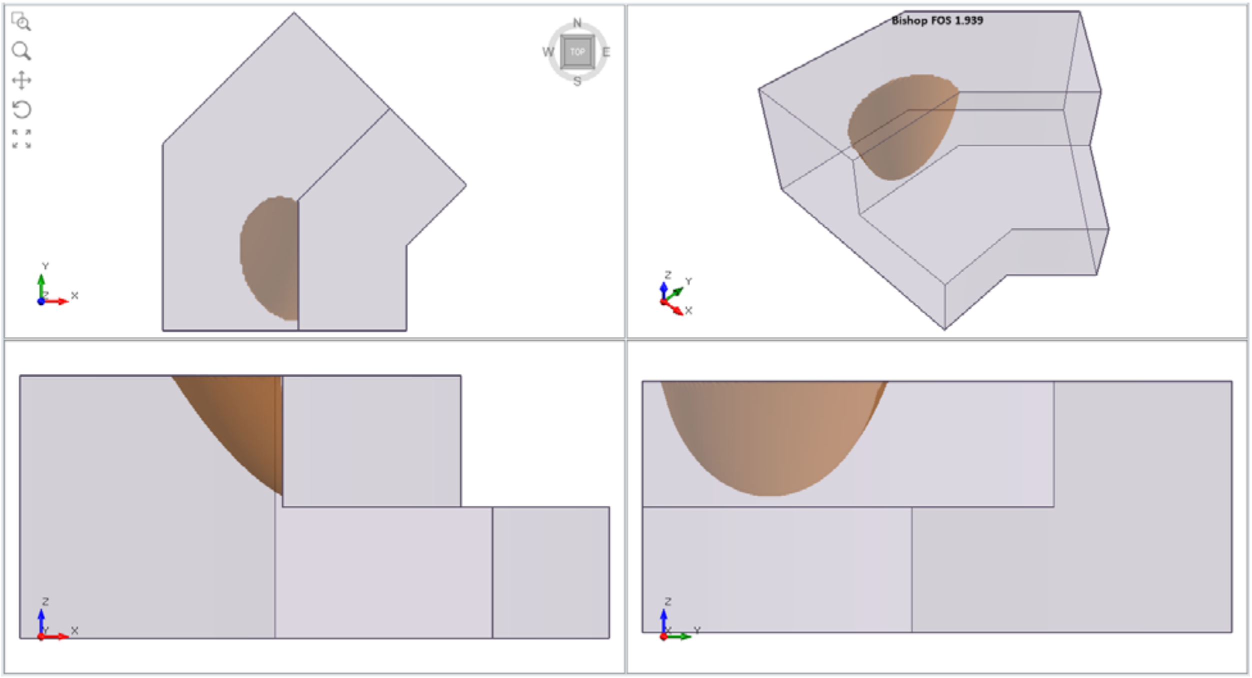


Figure 20.4.1 – Slide3 Solution Using the Bishop Method

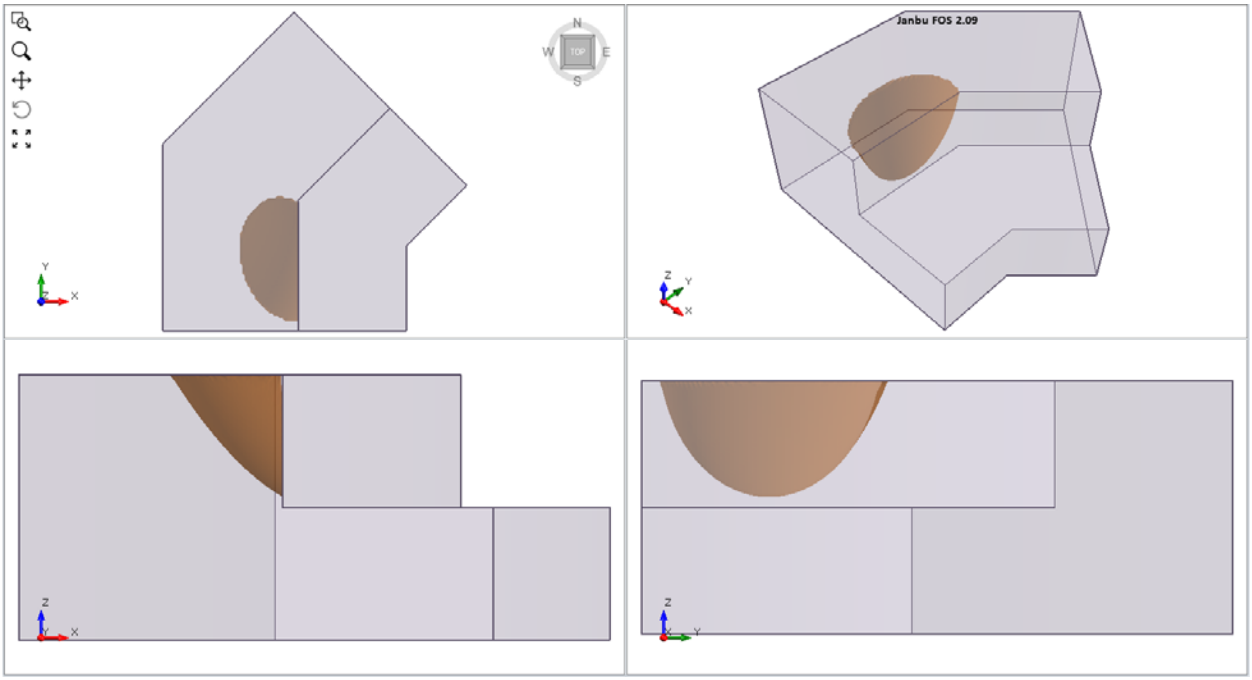


Figure 20.4.2 – Slide3 Solution Using the Janbu method

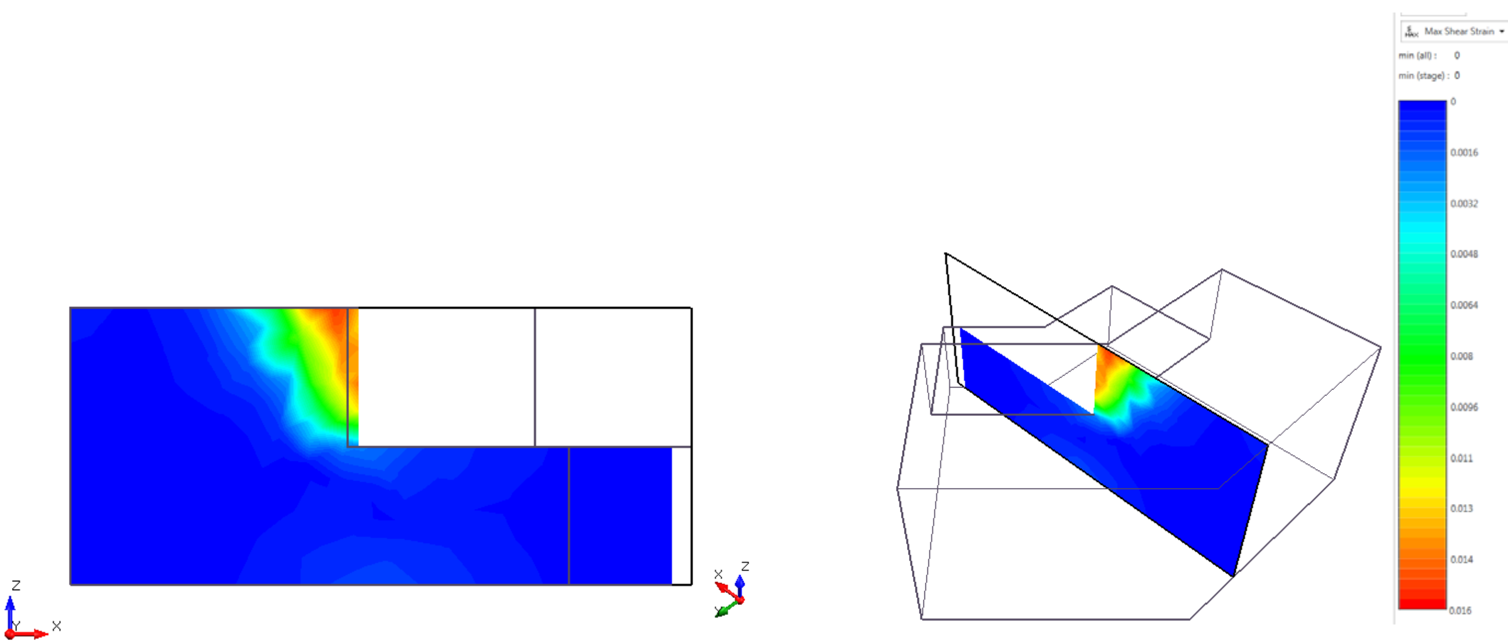


Figure 20.4.4 – RS3 Maximum Shear Strain

2D swept, 90° turn, convex, seismic, ellipsoidal with SA

21.1 Introduction

This example is taken from Nian et al. (2011). It is a vertical cut slope with a 90 degree turn that is subjected to seismic loading.

21.2 Problem Description

The 2D cross section of the slope geometry in the XZ plane can be seen as Figure 21(a). Figure 21(b) is the top view of the slope. The material properties of the homogeneous slope can be found in Table 21. There is a seismic load of magnitude 0.173205 in the direction (1, 1, -1). The ellipsoidal slip surface and corresponding safety factor is required.

21.3 Geometry and Properties

Table 21.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)	Tensile Strength (kPa)
Soil	24.5	20	17.6	0

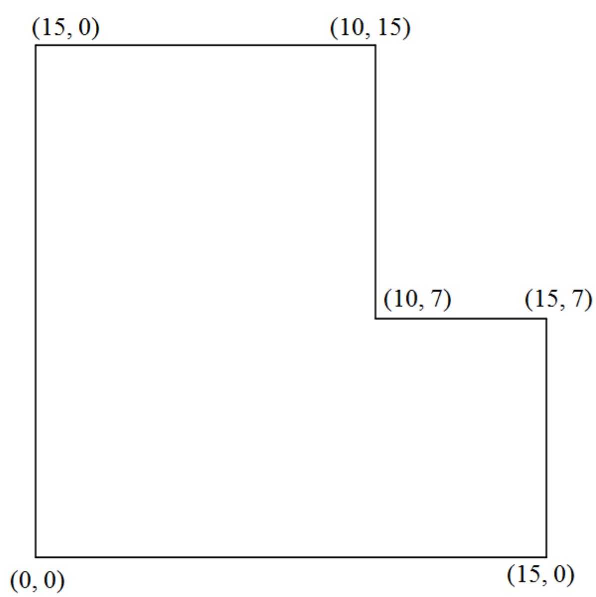


Figure 57(a)

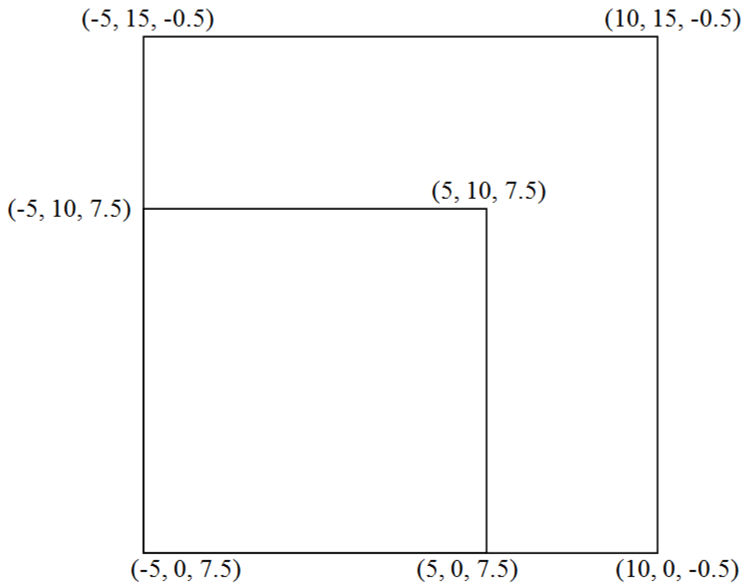


Figure 21(b)

21.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.481	0.584	1.11	0.714
Janbu	1.551	0.442		

Referee: 1.304 [Nian et al., 2011]

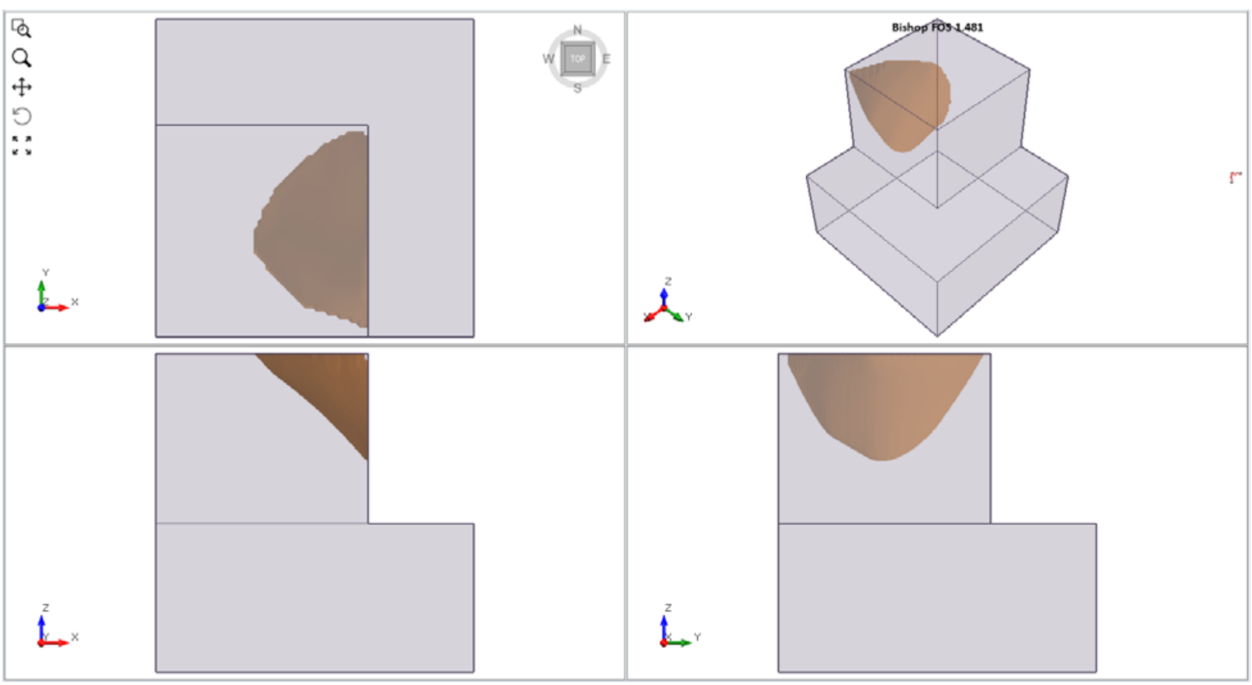


Figure 21.4.1 – Slide3 Solution Using the Bishop Method

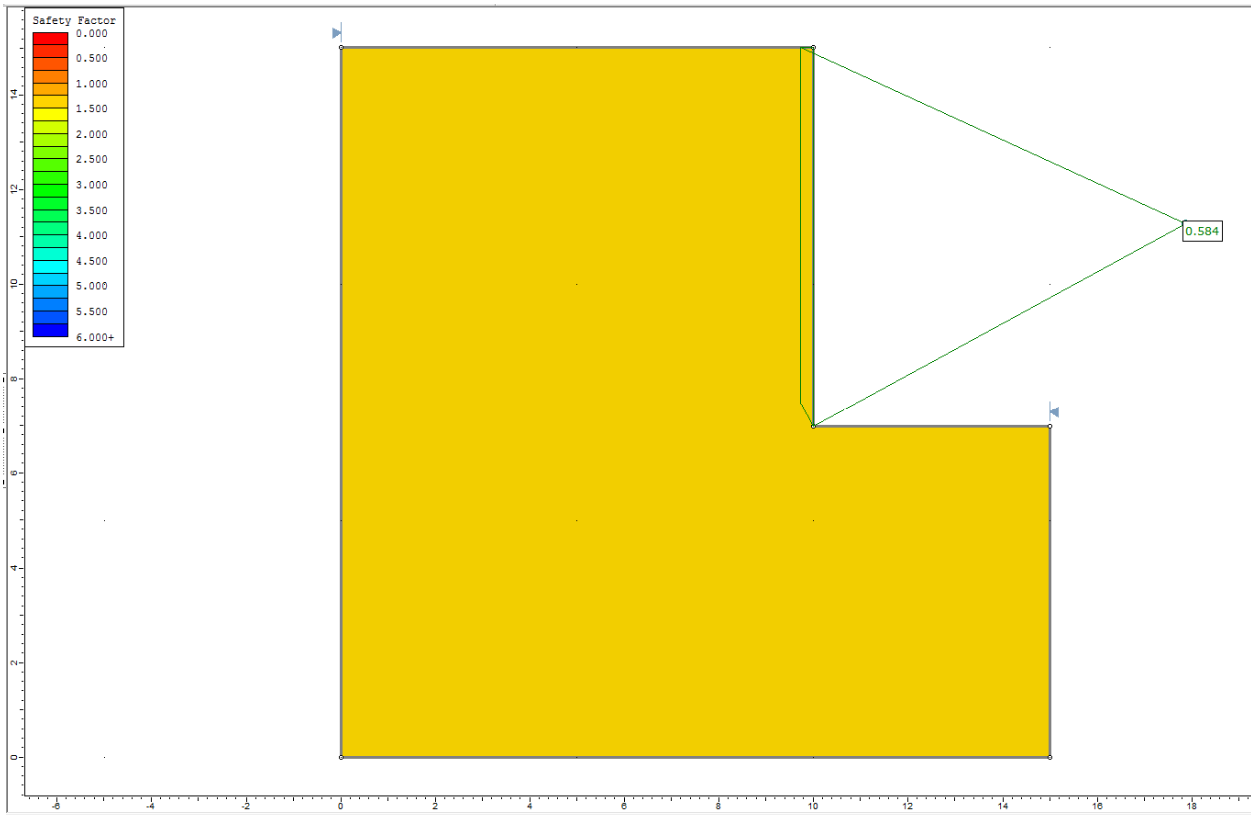


Figure 21.4.2 – Slide Solution Using the Bishop Method

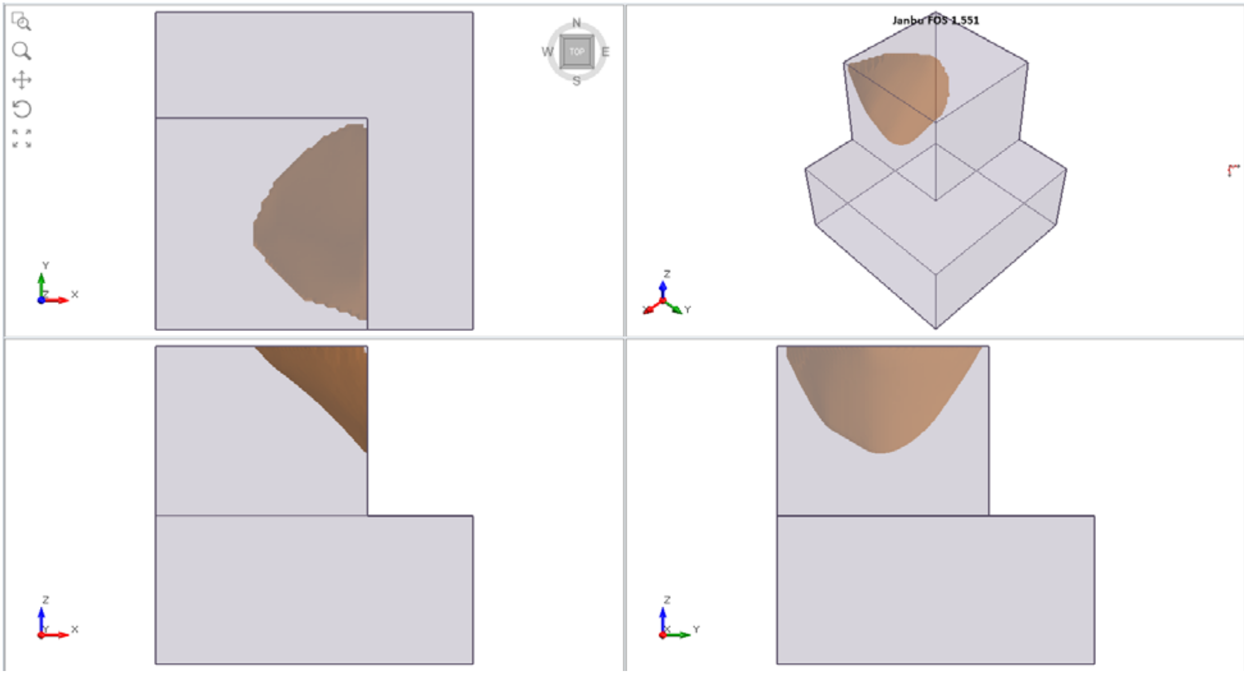


Figure 21.4.3 – Slide3 Solution Using the Janbu Method

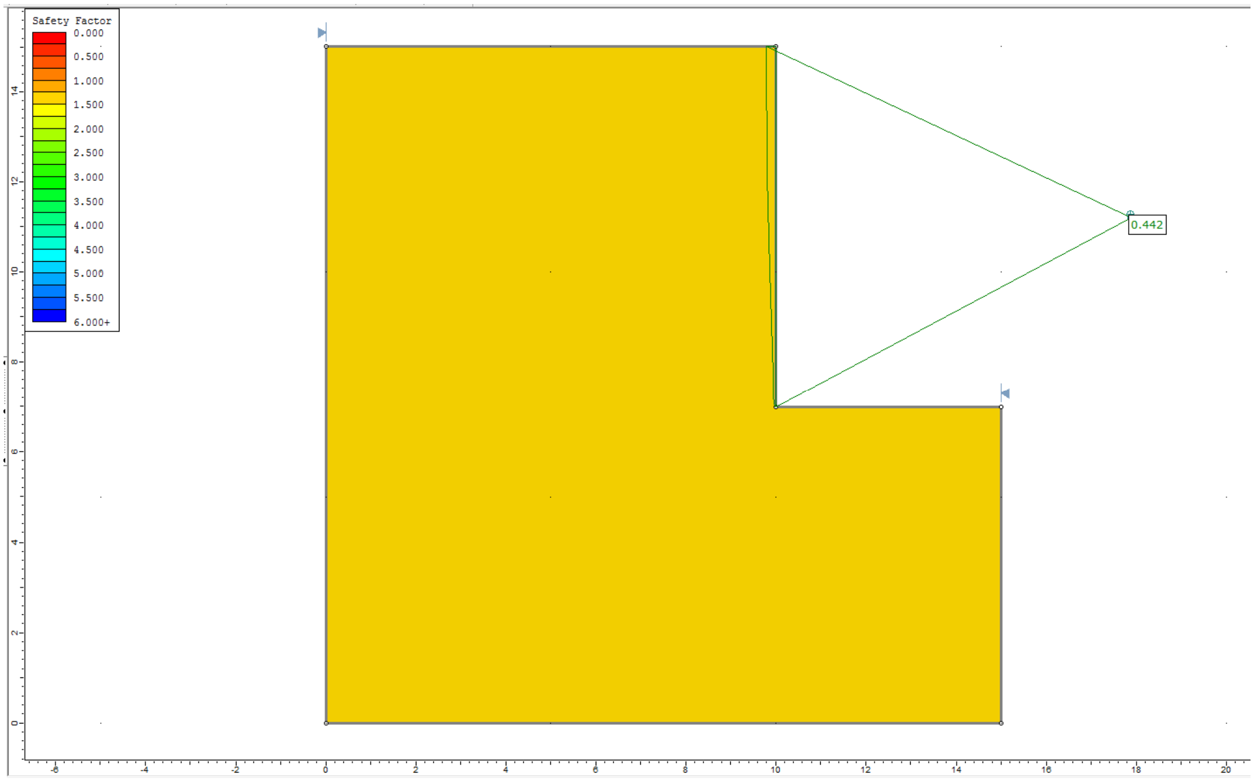


Figure 21.4.4 – Slide Solution Using the Janbu Method

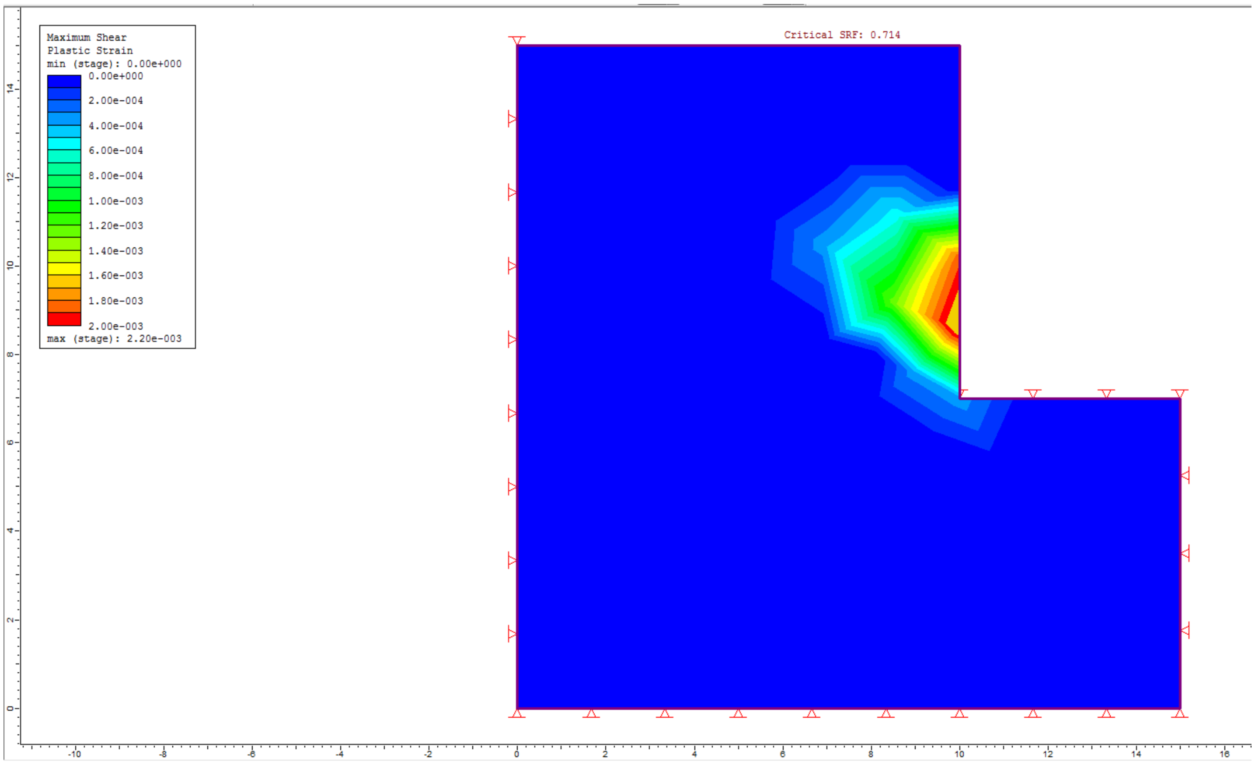


Figure 21.4.5 – RS2 Maximum Shear Strain

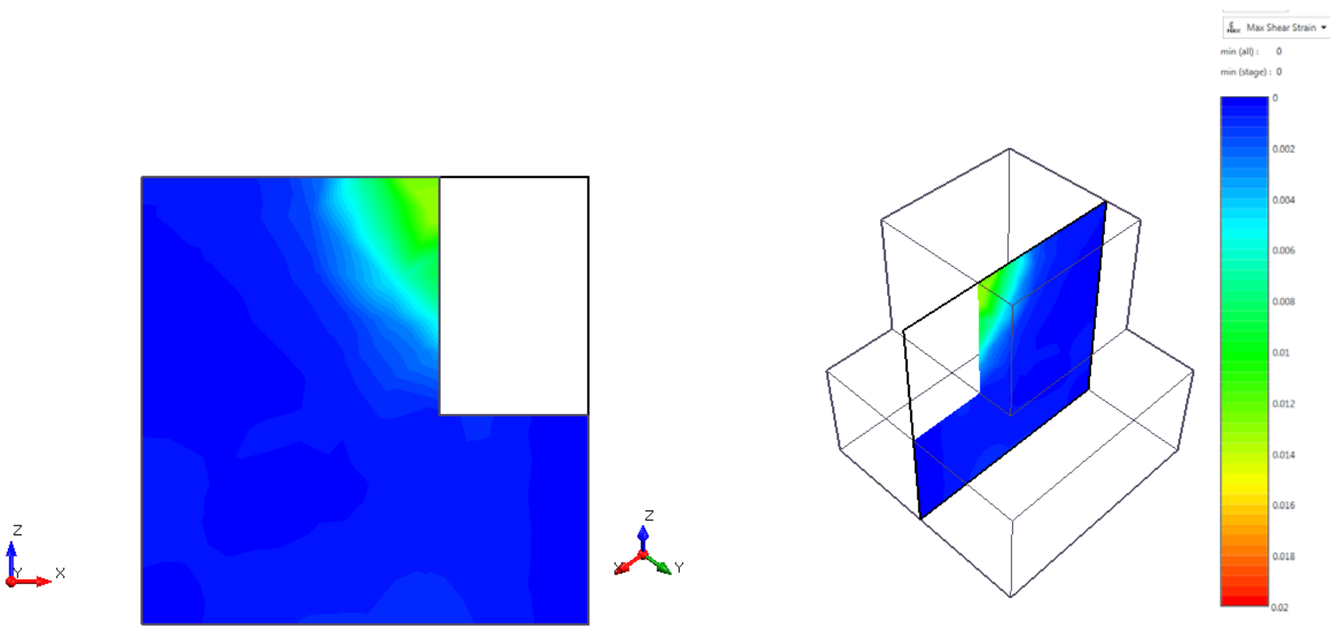


Figure 21.4.6 – RS3 Maximum Shear Strain

2D swept, 90° turn with circular corner, vertical cut, homogeneous, ellipsoidal with SA

22.1 Introduction

This model is taken from Stauffer (2015). It is a homogeneous vertical cut, which has undergone a 90 degree turning corner, with a rounded corner on the slope. Stauffer did this problem first with no reinforcement and then with soil nails. This is the vertical cut with no reinforcement.

22.2 Problem Description

The 2D cross section of this problem is shown as Figure 22(a). The cross section is turned 90 degrees, before the top corner is rounded to an arc with radius 5m, this can be seen in the top view, Figure 22(b). The material properties are shown in Table 22.1. There is no groundwater or pore pressure. A cuckoo search with optimization is used.

22.3 Geometry and Properties

Table 22.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	10	18	15

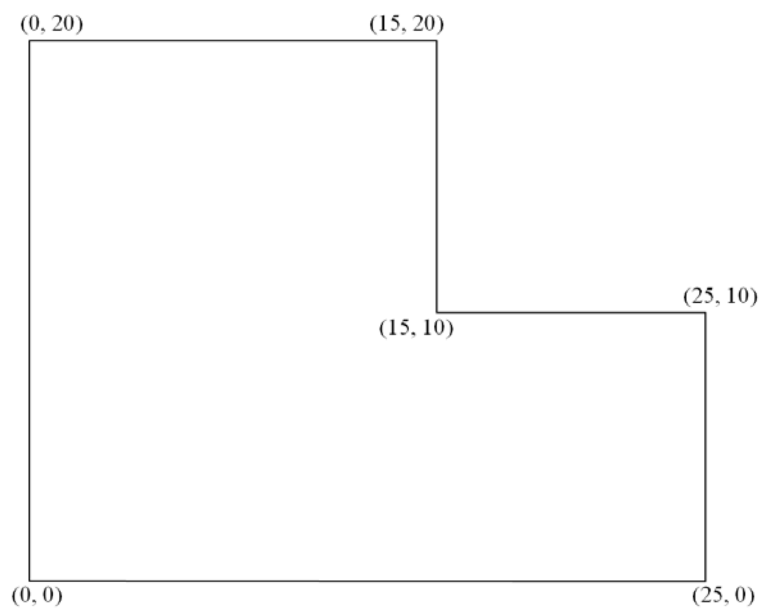


Figure 22(a)

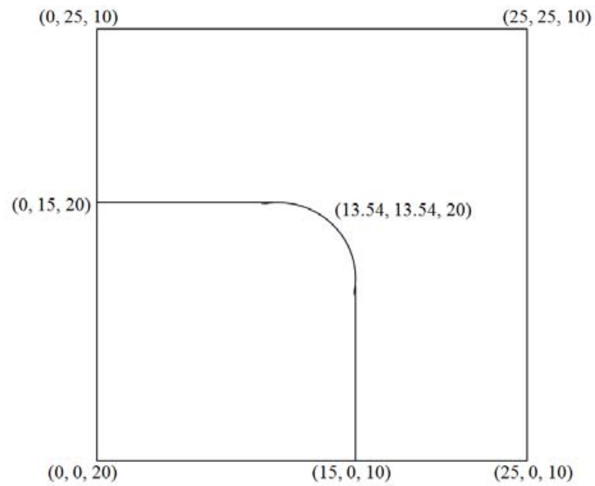


Figure 22(b)

22.4 Results

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

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	0.542	0.378	0.24	0.47
Janbu	0.527	0.495		

Referee: 0.52 [Stauffer, 2015]

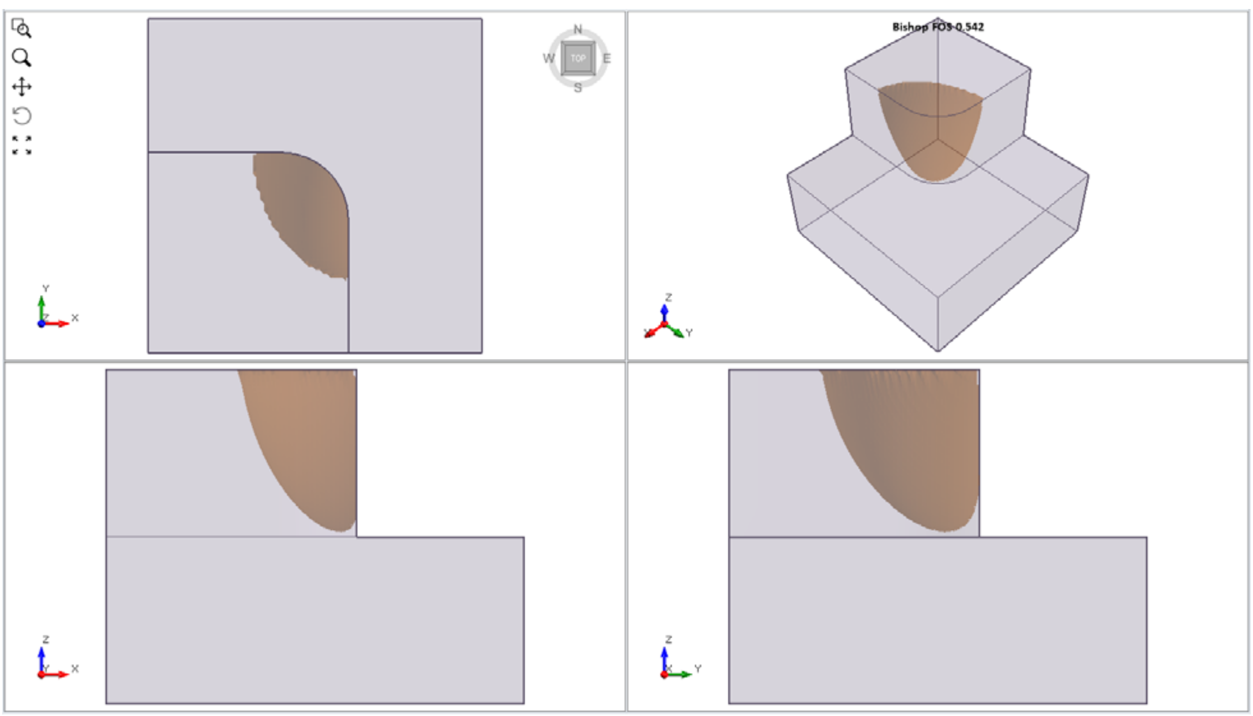


Figure 22.4.1 – Slide3 Solution Using the Bishop Method

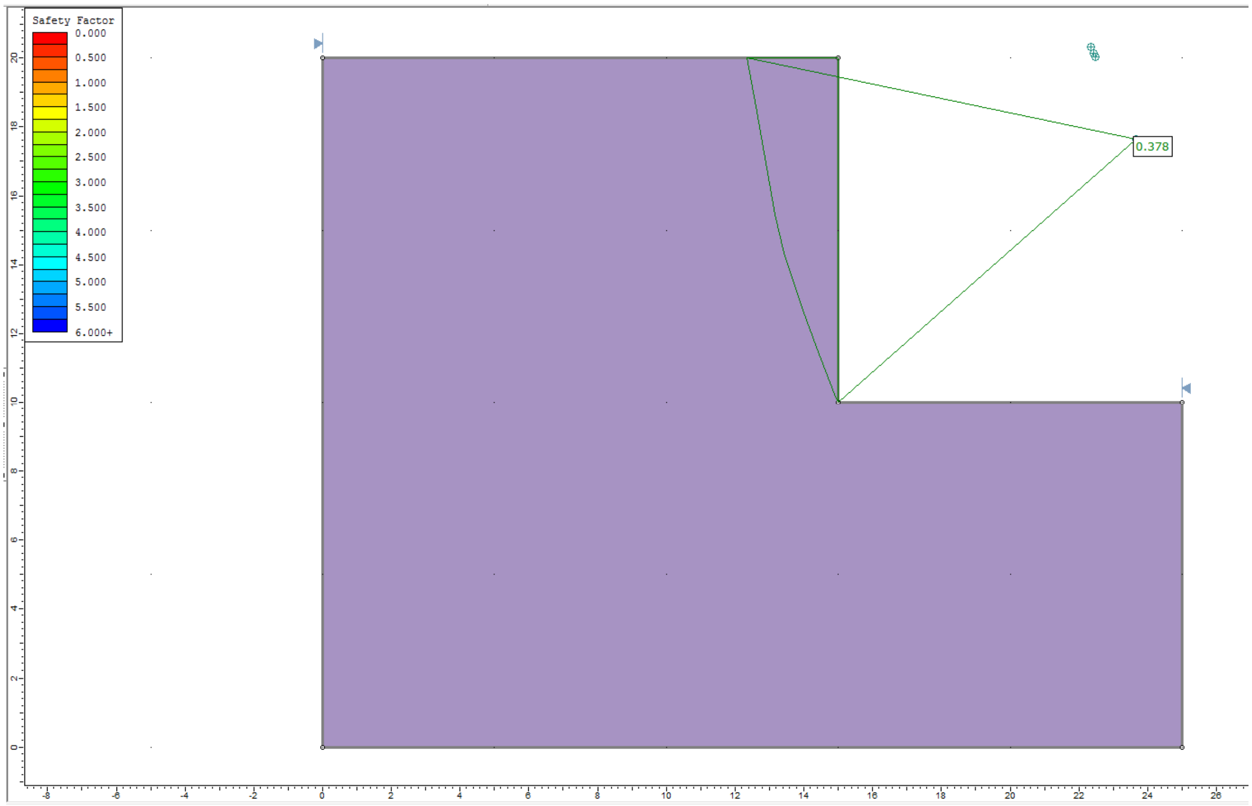


Figure 22.4.2 – Slide Solution Using the Bishop Method

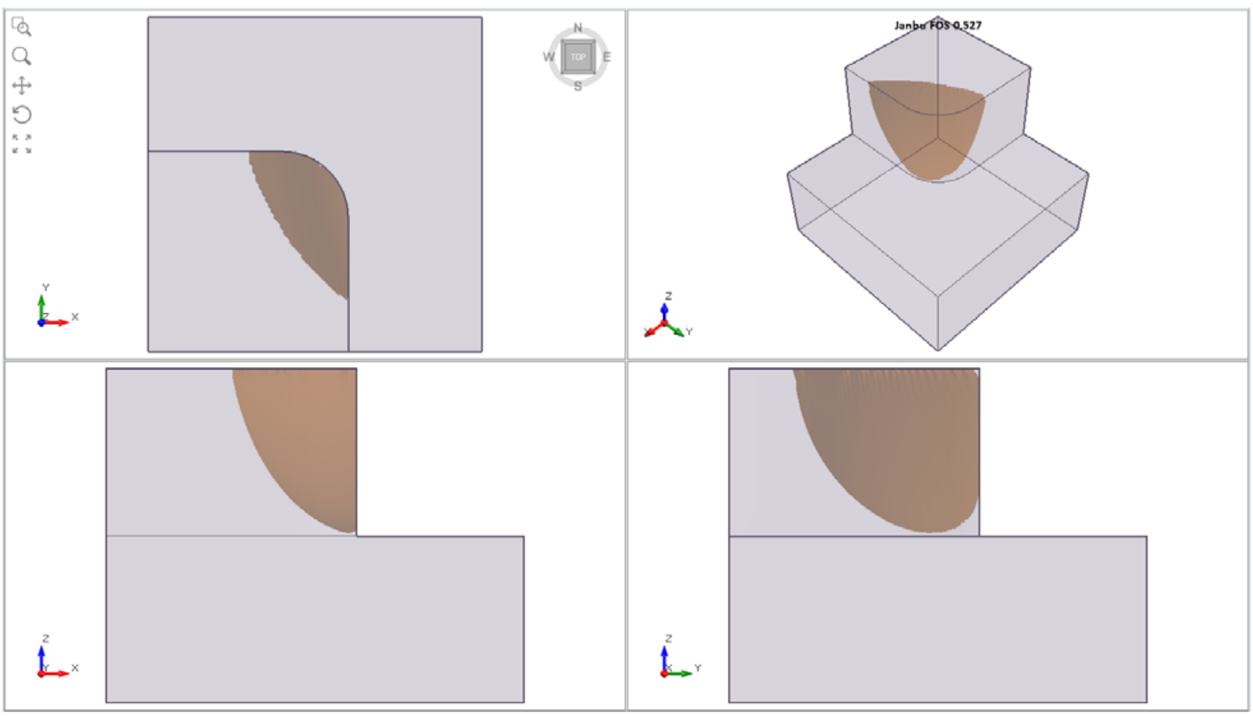


Figure 22.4.5 – Slide3 Solution Using the Janbu Method

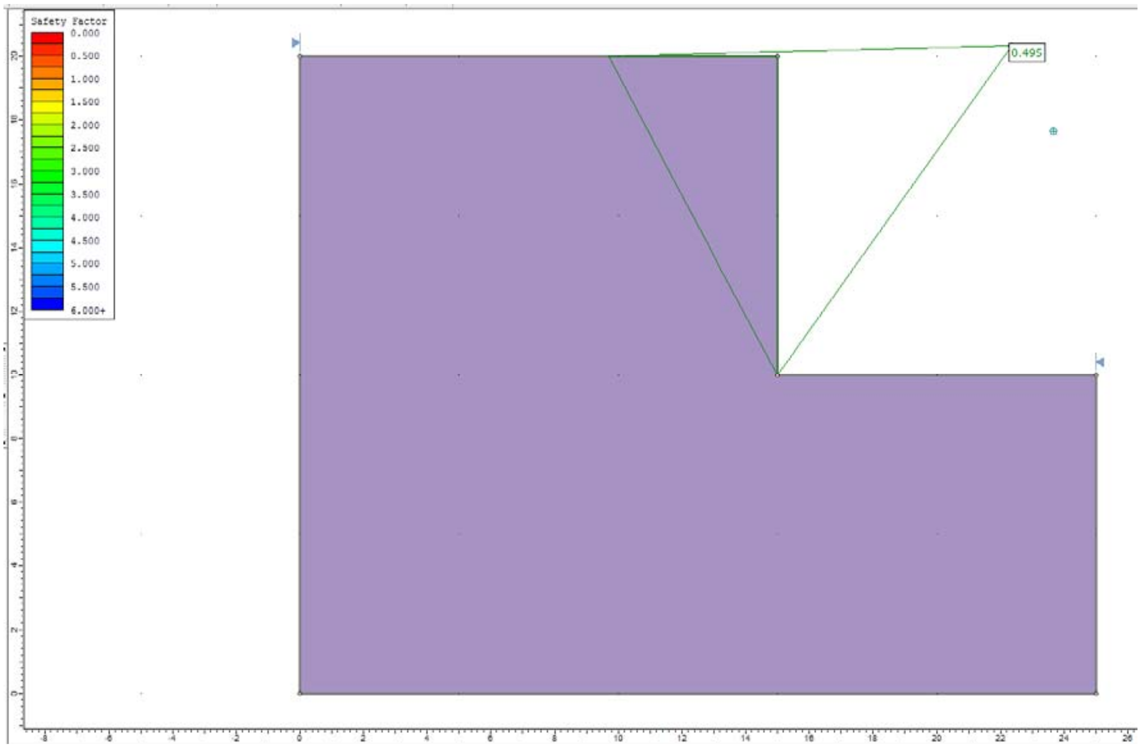


Figure 22.4.6 – Slide Solution Using the Janbu Method

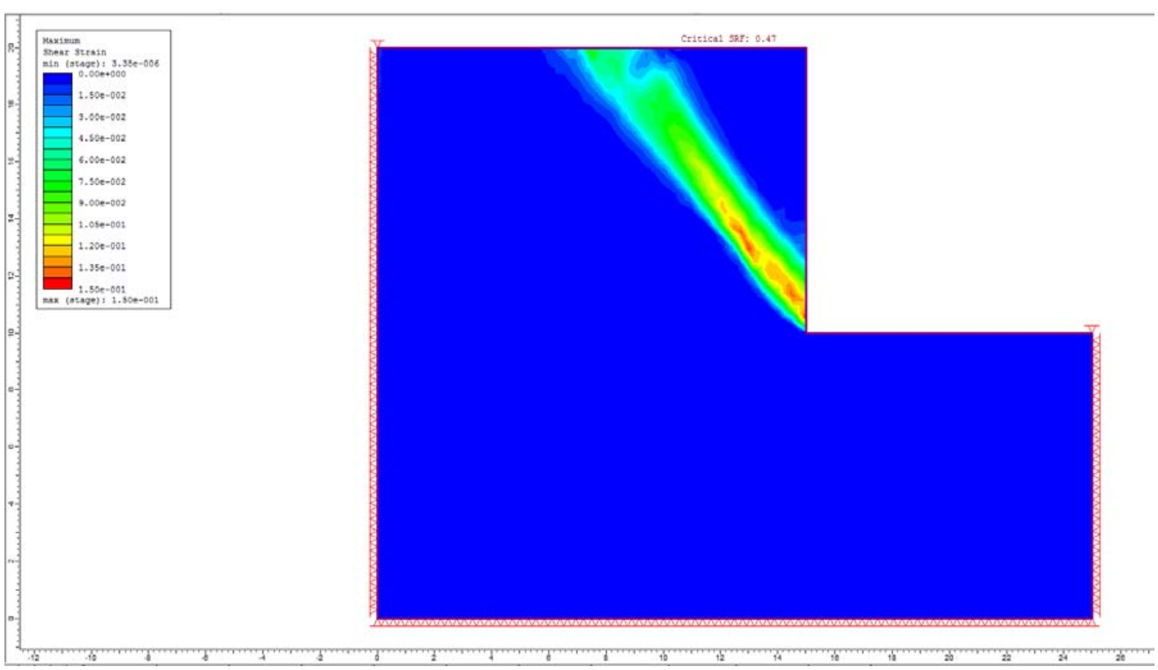


Figure 22.4.9 – RS2 Maximum Shear Strain

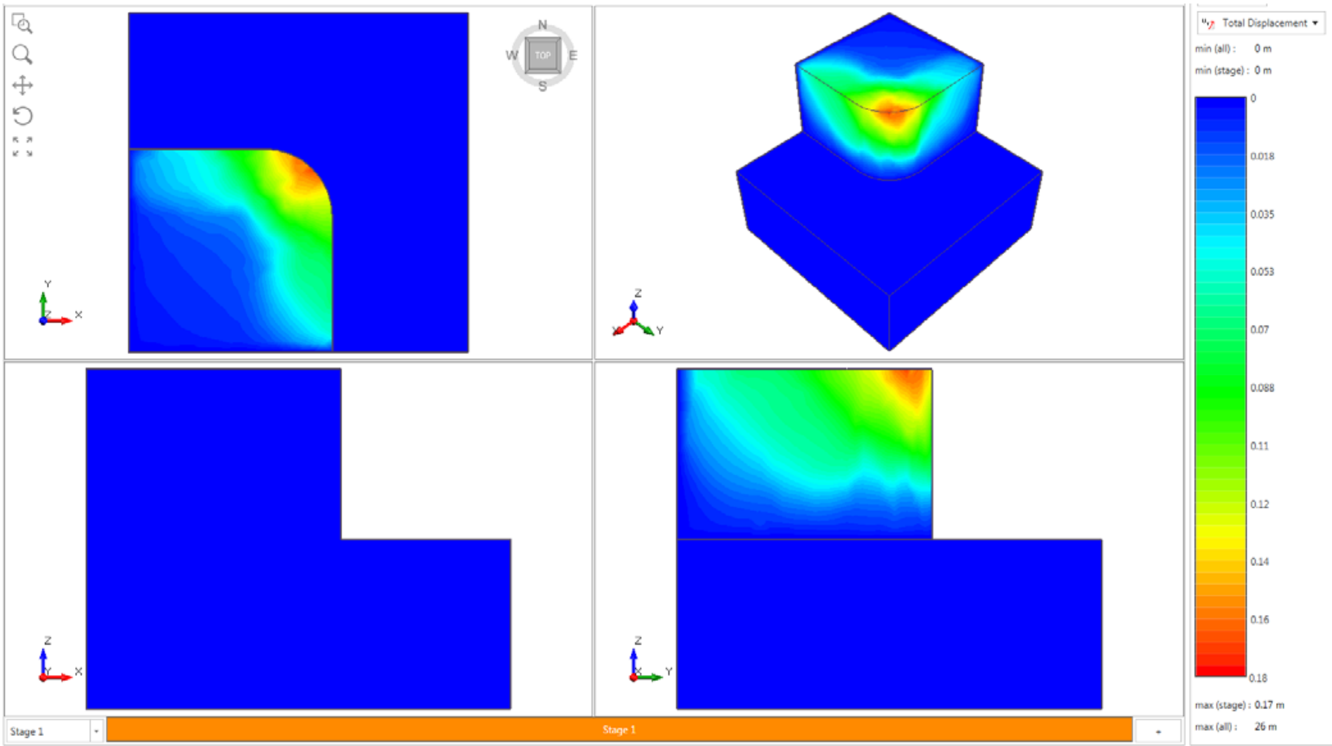


Figure 22.4.10 – RS3 Total Displacement

2D swept, 90° turn with circular corner, vertical cut, homogeneous, soil nails ellipsoidal with SA

23.1 Introduction

This model is taken from Stauffer (2015.) It is a homogeneous vertical cut, which has undergone a 90 degree turning corner, with a rounded corner on the slope. Stauffer did this problem first with no reinforcement and then with soil nails. This is the vertical cut with reinforcement.

23.2 Problem Description

The 2D cross section of this problem is shown as Figure 23(a). The cross section is turned 90 degrees, before the top corner is rounded to an arc with radius 5m, this can be seen in the top view, Figure 23(b). The material properties are shown in Table 23.1. The properties of the soil nails are the default settings. The nails are 10m long and are rotated 5° below the horizontal. The nail pattern is on the vertical face of the embankment, and starts 0.5 m inwards from the edge, with a horizontal spacing of 1.5mand a vertical spacing of 2 m, starting 1 m above the stadium. The ellipsoidal slip surface and corresponding safety factor is required.

23.3 Geometry and Properties

Table 23.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
Soil	10	18	15

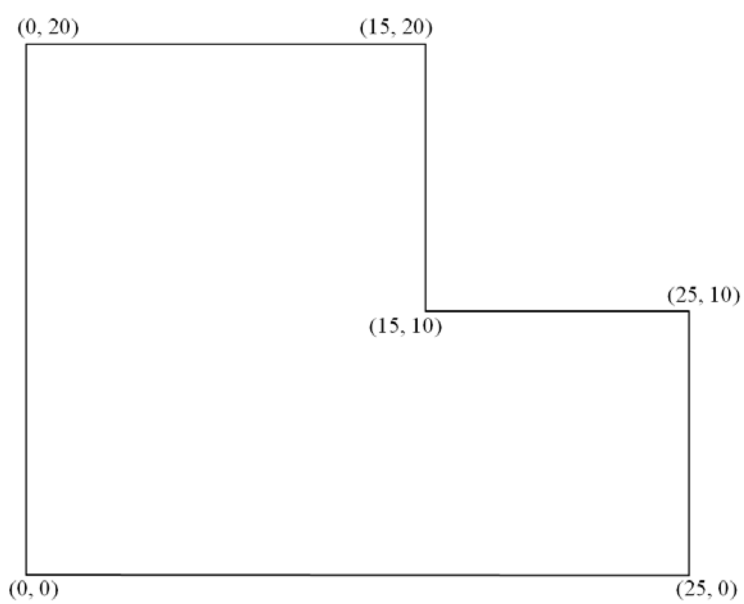


Figure 23(a)

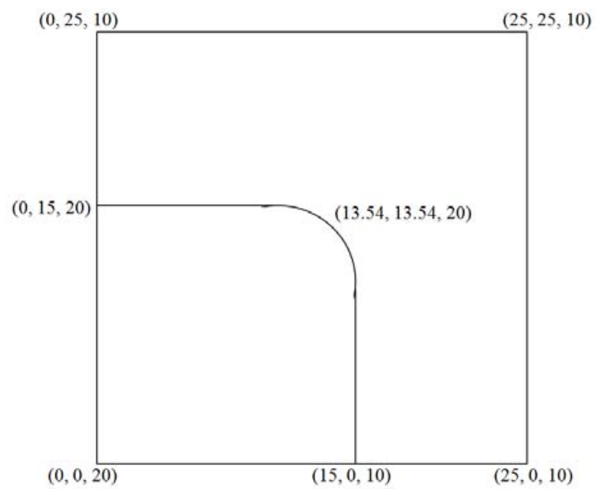


Figure 23(b)

23.4 Results

Table 23.4.1: Safety Factors Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.137	1.042	0.96	1.05
Janbu	1.262	1.010		

Referee: 1.06 [Stauffer, 2015]

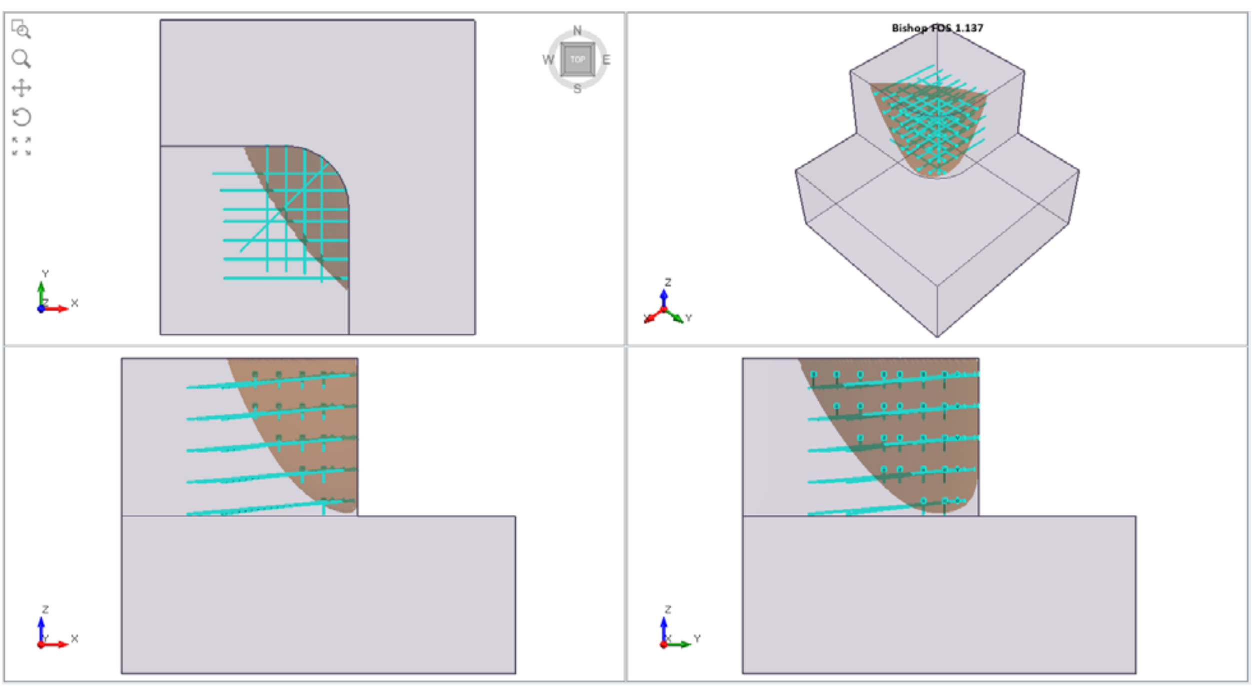


Figure 23.4.1 – Slide3 Solution Using the Bishop Method

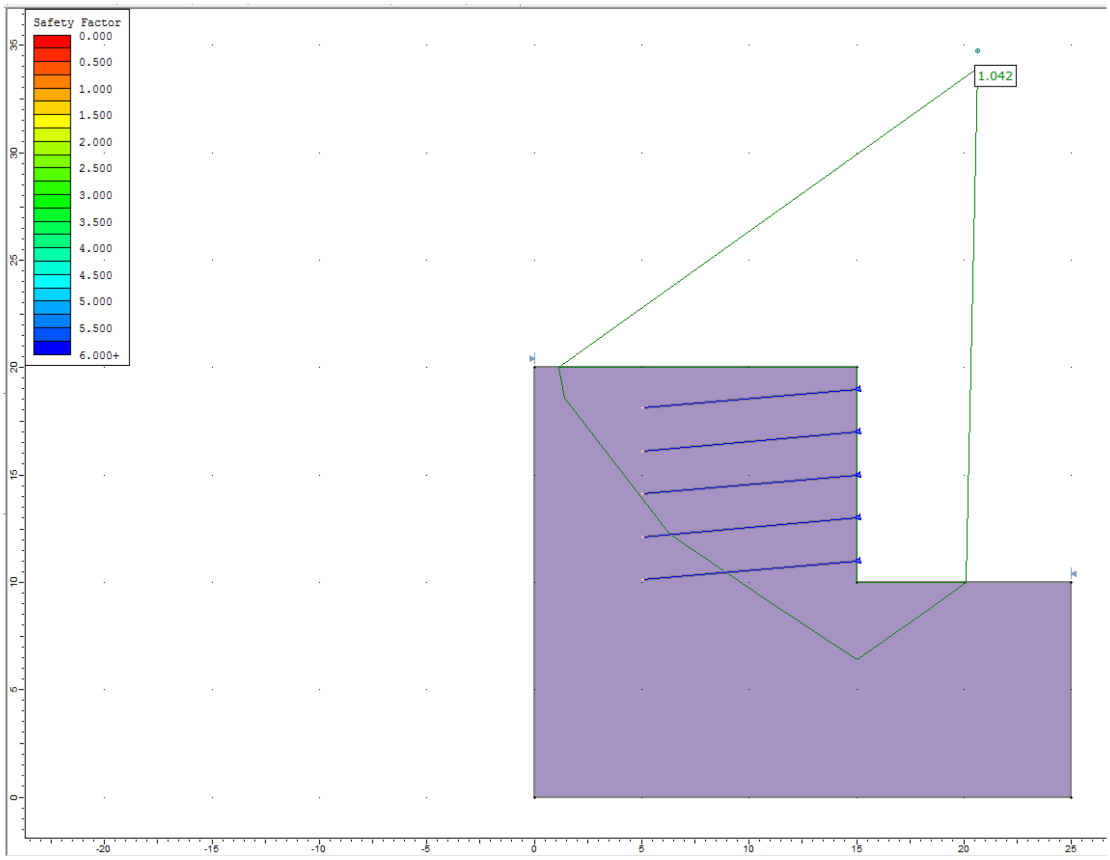


Figure 23.4.2 – Slide Solution Using the Bishop Method

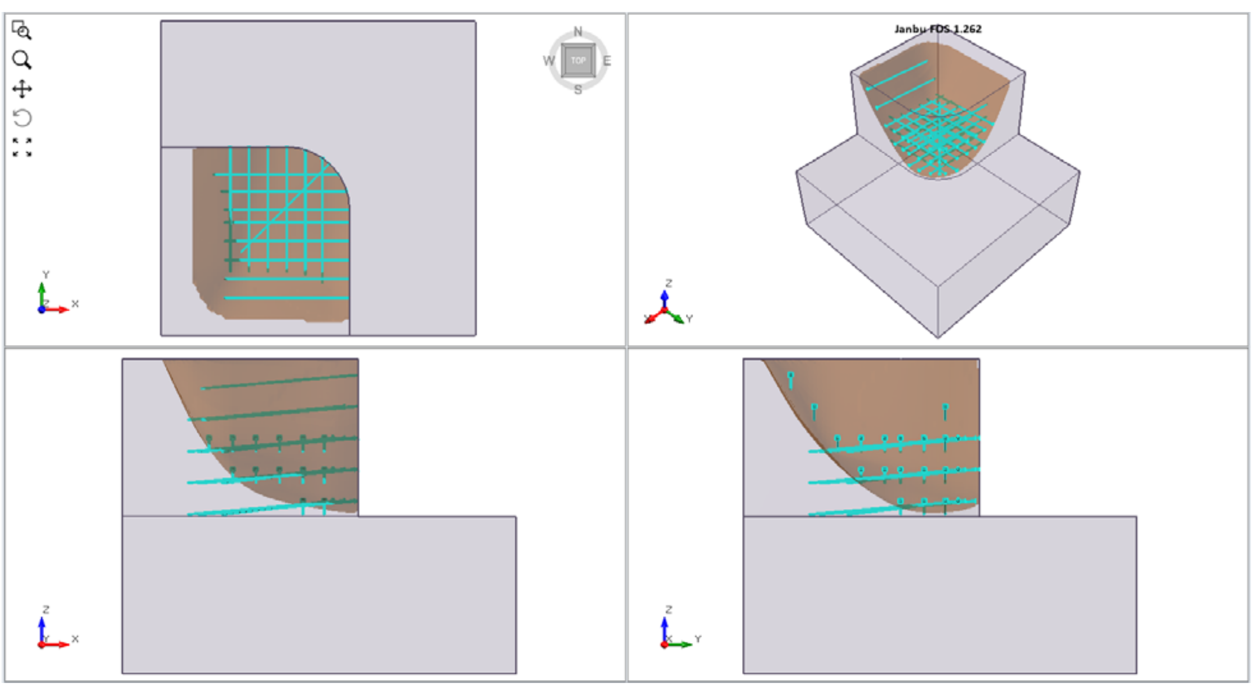


Figure 23.4.5 – Slide3 Solution Using the Janbu Method

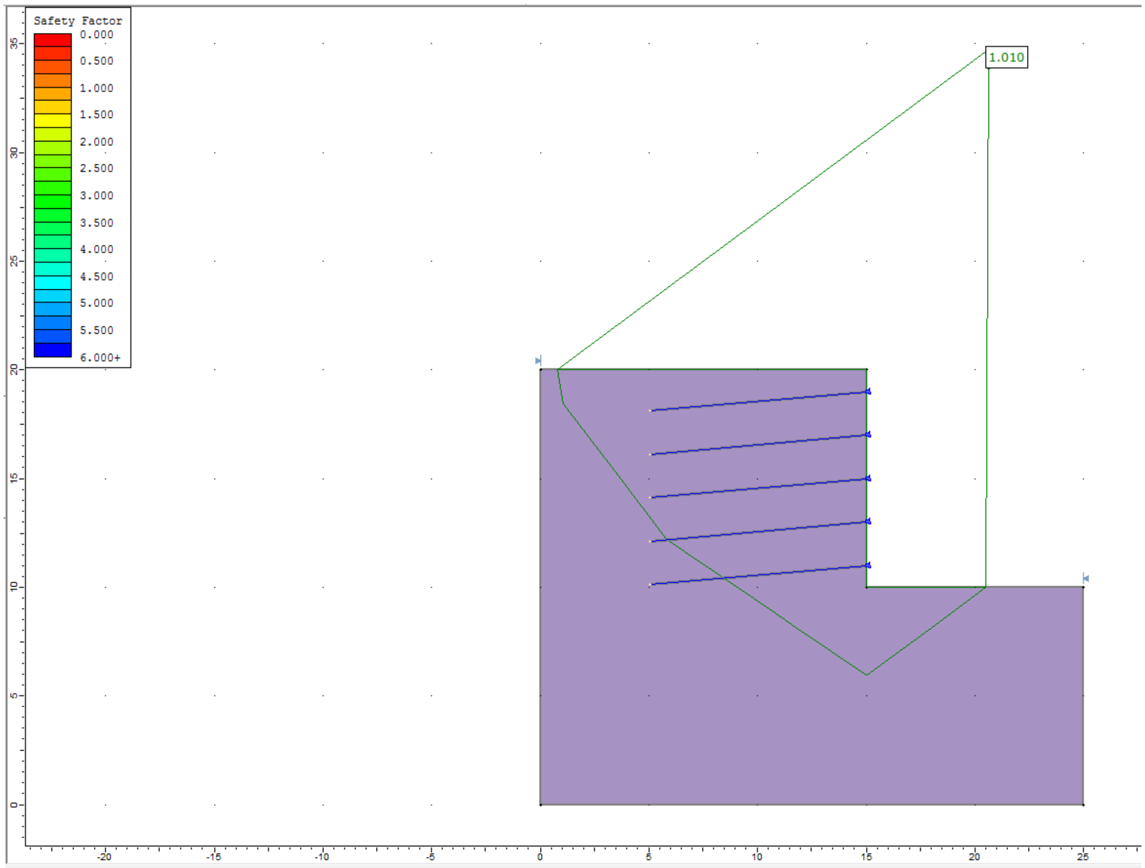


Figure 23.4.6 – Slide Solution Using the Janbu Method

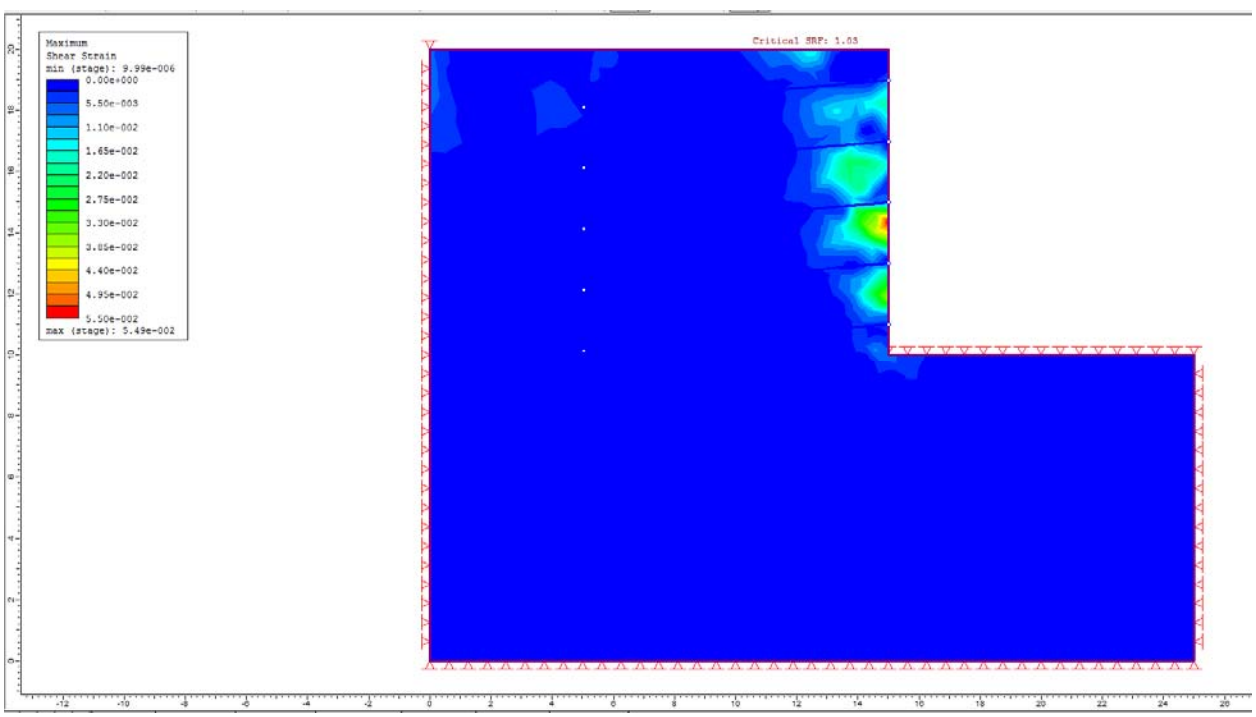


Figure 23.4.9 – RS2 Maximum Shear Strain

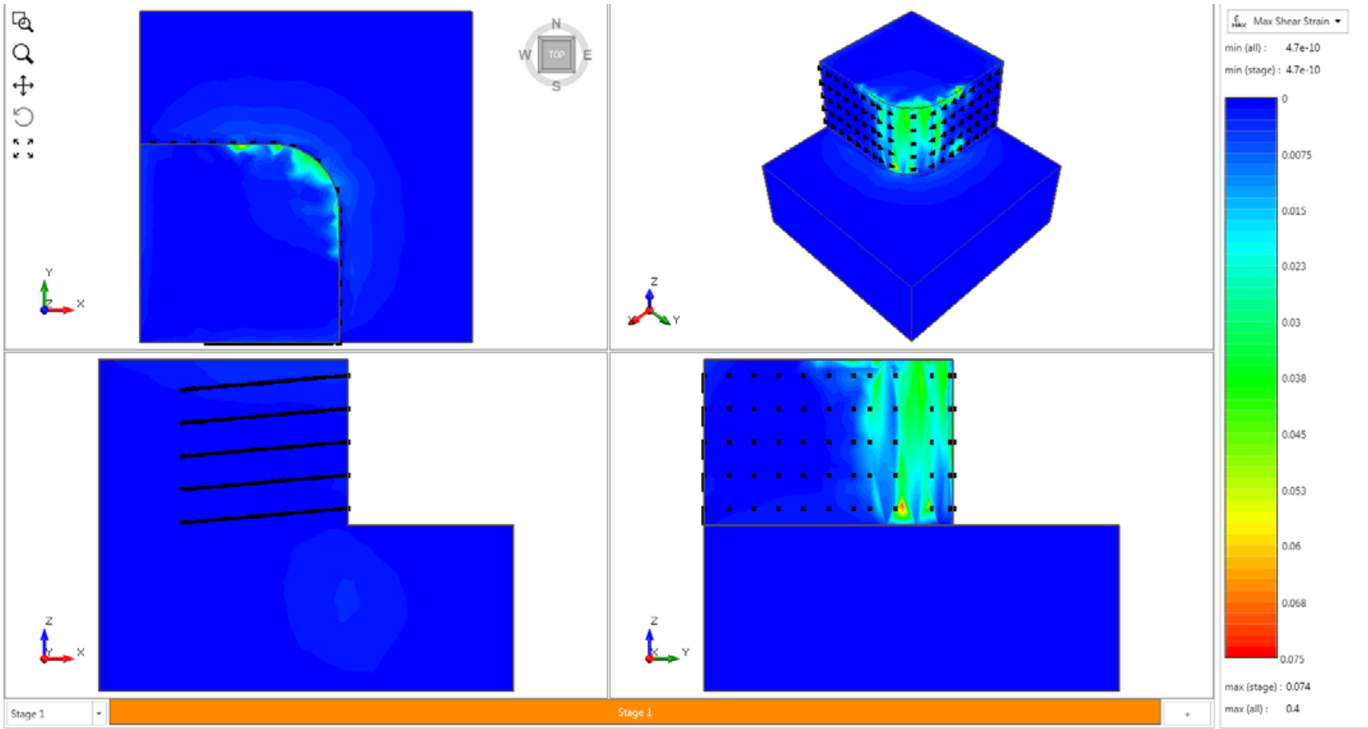


Figure 23.4.10 – RS3 Maximum Shear Strain

2D swept, 90° circular turn, convex, homogeneous, ellipsoidal with SA

24.1 Introduction

This model is taken from Stauffer (2015.) It is a homogeneous vertical cut, which has undergone a 90 degree turning corner, with a fully rounded slope. Stauffer did this problem first with no reinforcement and then with soil nails. This is the vertical cut turning corner with no reinforcement.

24.2 Problem Description

The 2D cross section of this problem is shown as Figure 24(a). The cross section is turned 90 degrees, before the top corner is rounded to an arc with radius 5m, this can be seen in the top view, Figure 24(b). The material properties are shown in Table 24.1. There is no groundwater or pore pressure. A cuckoo search with optimization is used.

24.3 Geometry and Properties

Table 24.1: Material Properties

	c´ (kN/m^2)	φ´ (deg.)	γ (kN/m^3)
Soil	10	18	15

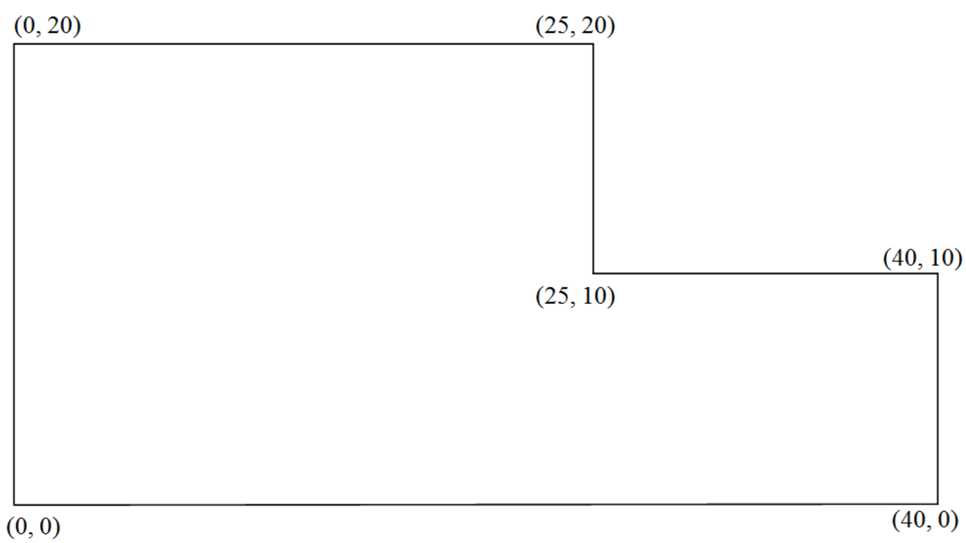


Figure 24(a)

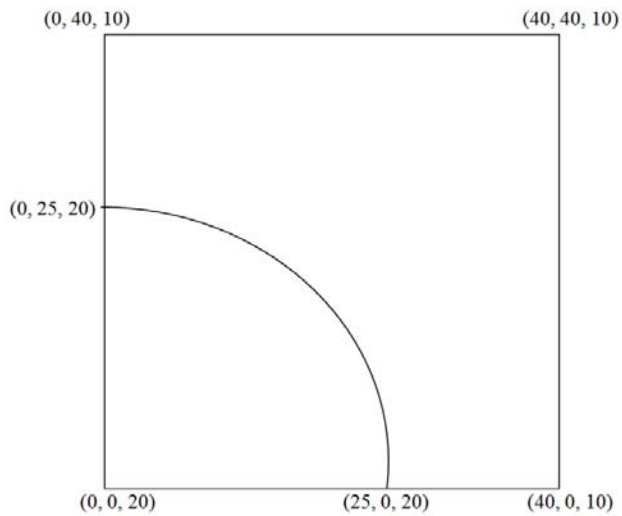


Figure 24(b)

24.4 Results

Table 24.4.1: Safety Factors Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	0.545	0.378	0.31	0.47
Janbu	0.564	0.495		

Referee: 0.51 [Stauffer, 2015]

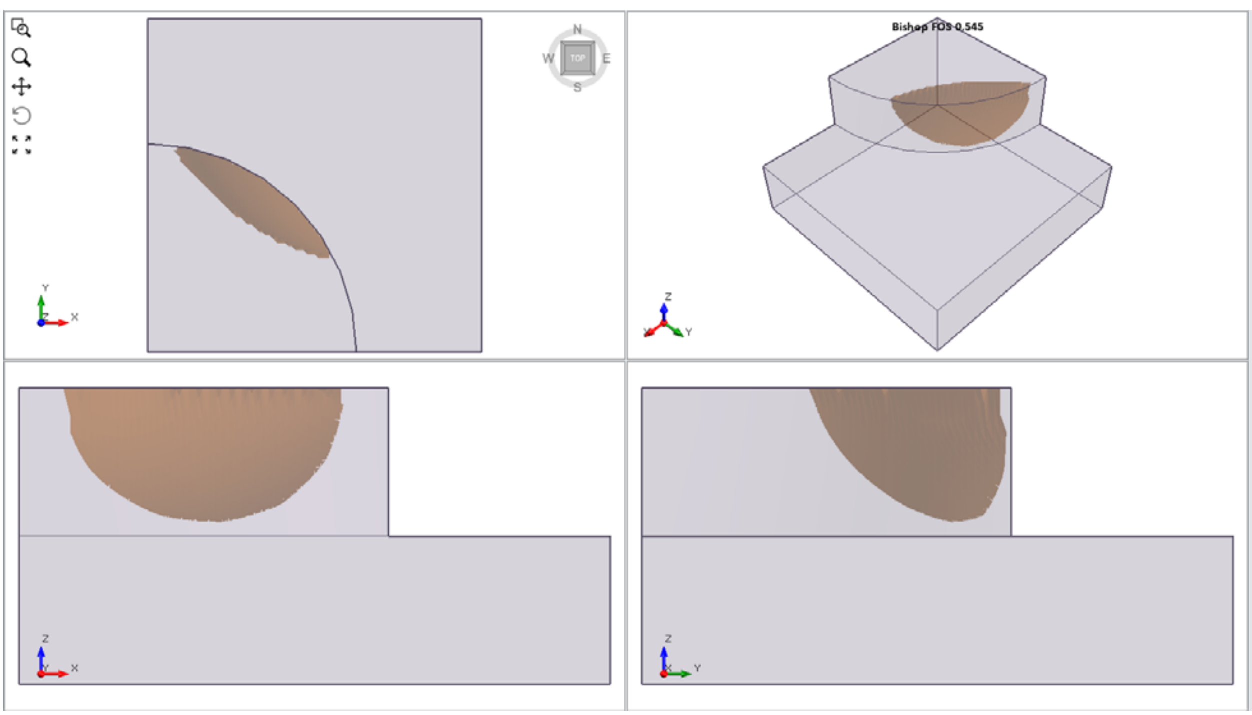


Figure 24.4.1 – Slide3 Solution Using the Bishop Method

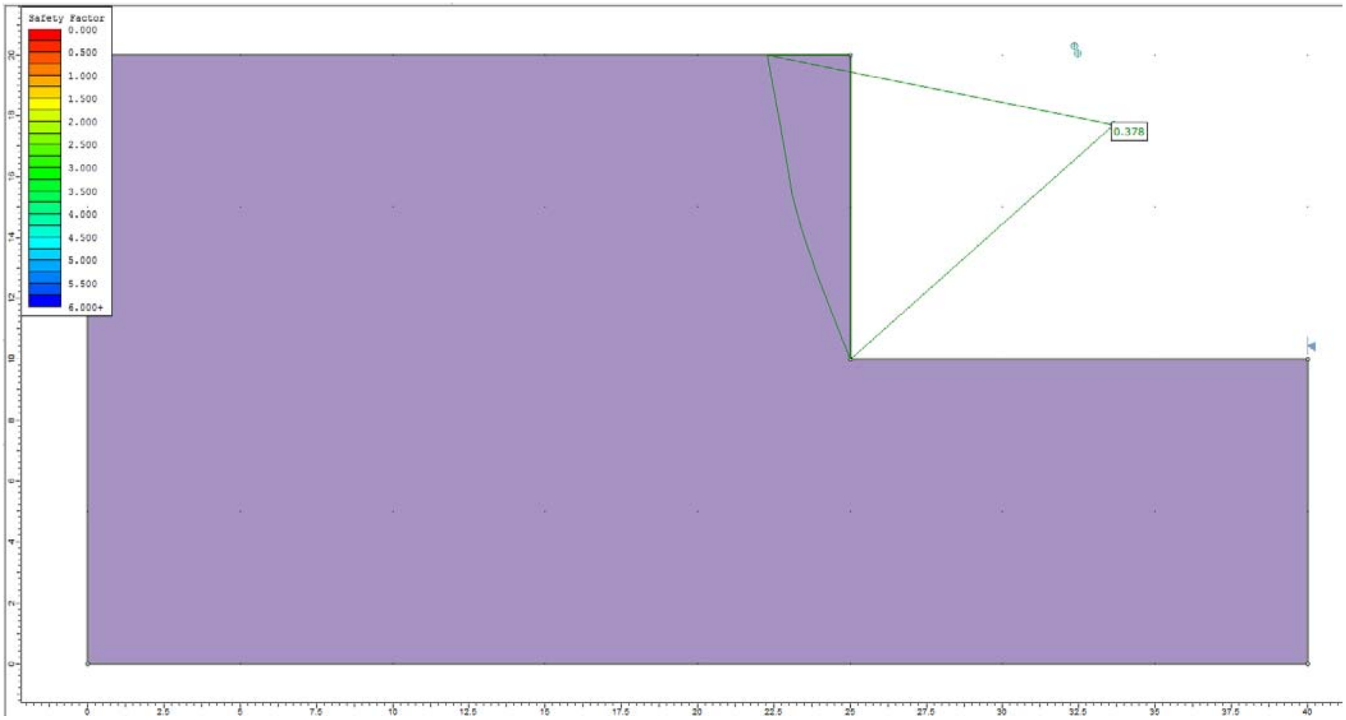


Figure 24.4.2 – Slide Solution Using the Bishop Method

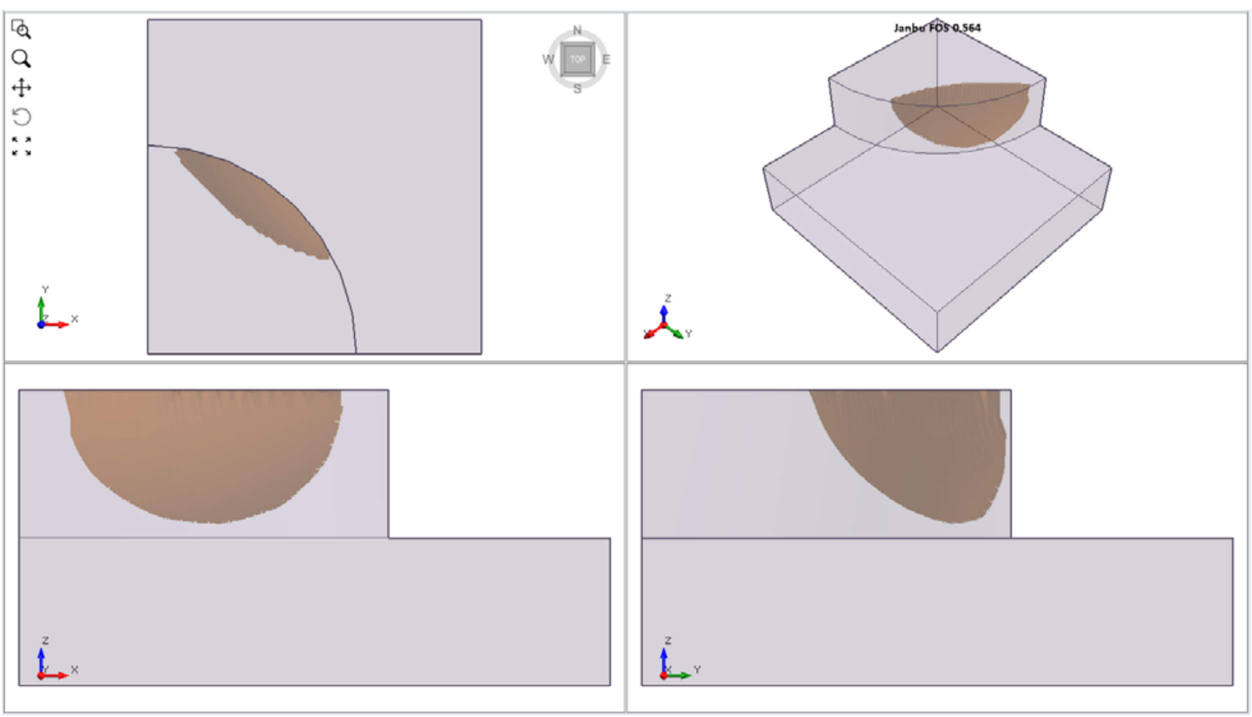


Figure 24.4.5 – Slide3 Solution Using the Janbu Method

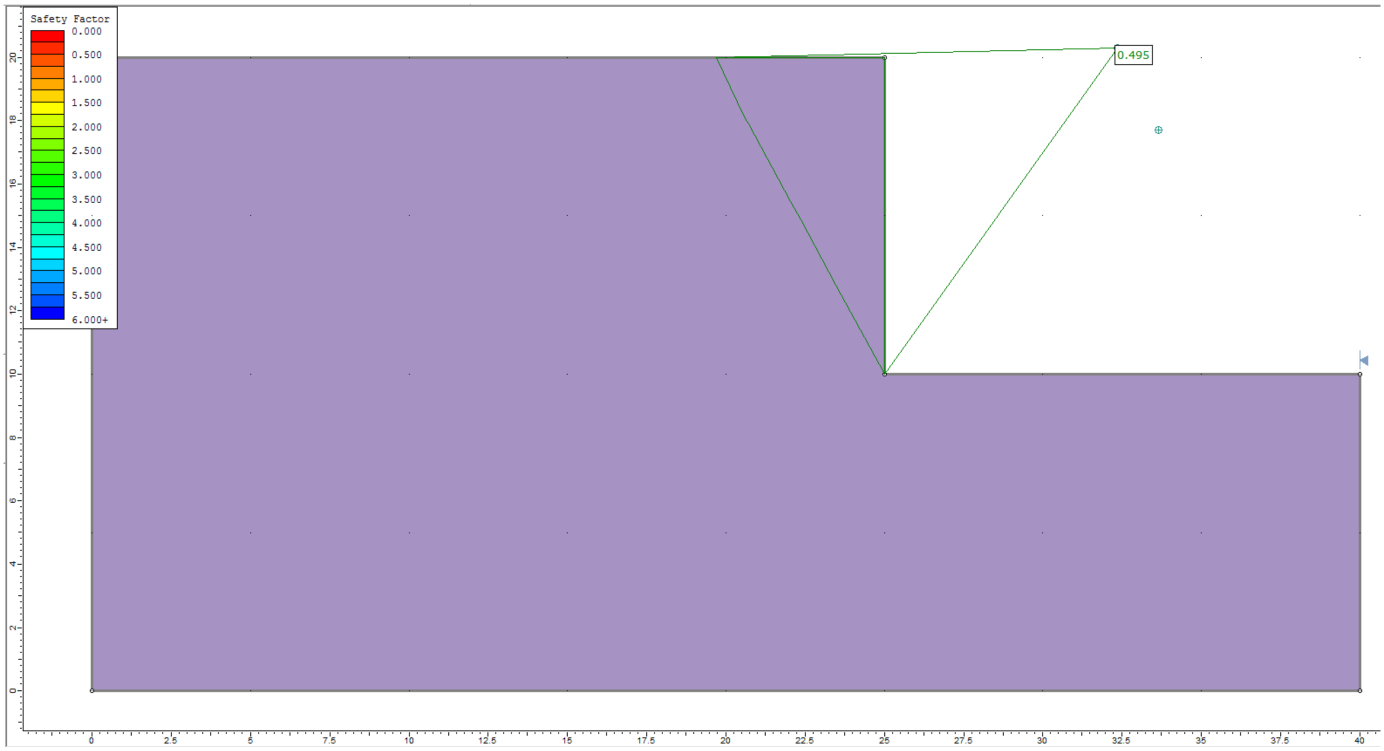


Figure 24.4.6 – Slide Solution Using the Janbu Method

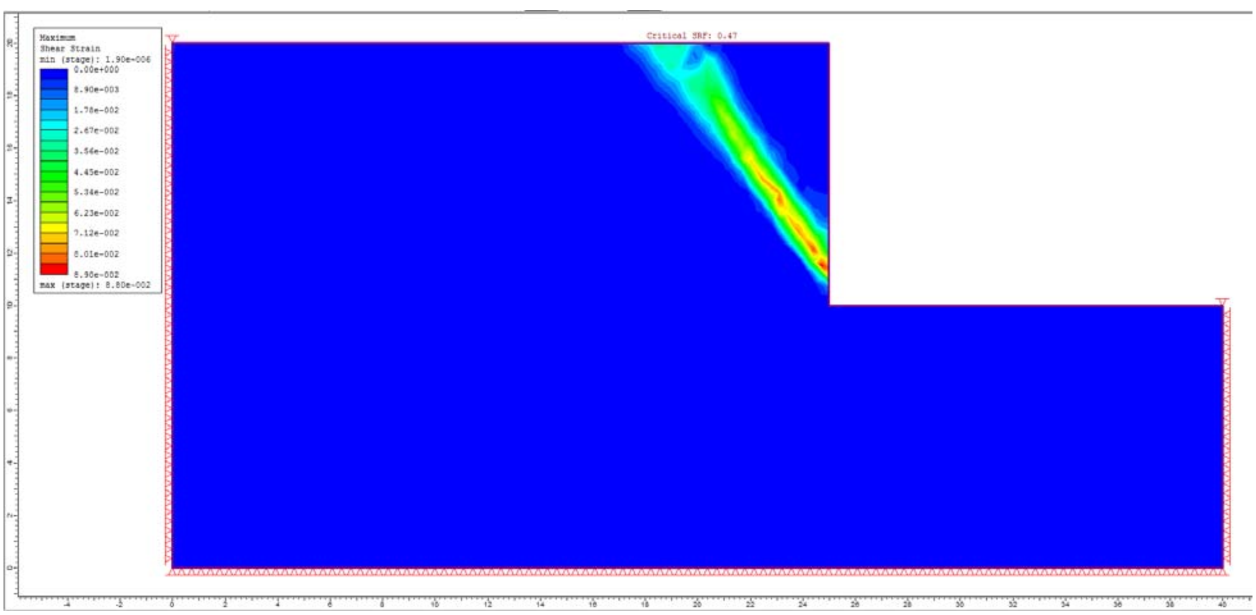


Figure 24.4.9 – RS2 Maximum Shear Strain

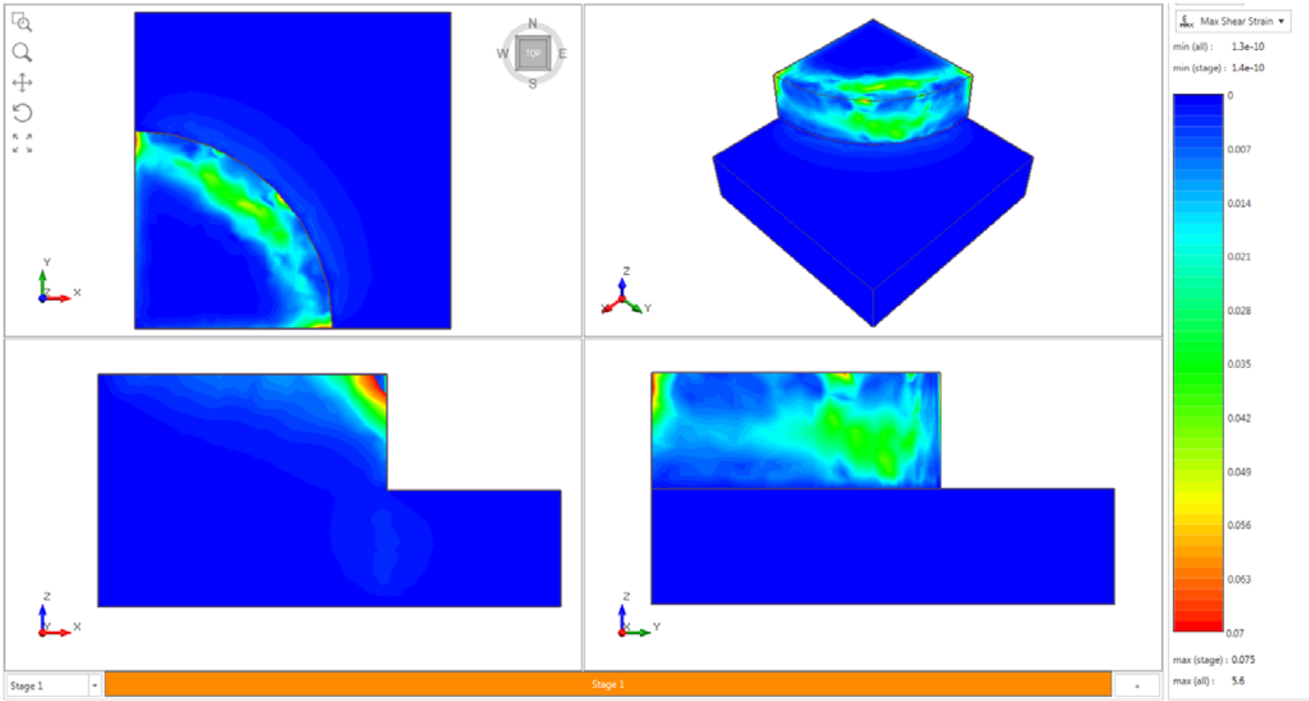


Figure 24.4.10 – RS3 Maximum Shear Strain

2D swept, 90° circular turn, convex, homogeneous, soil nails, ellipsoidal with SA

25.1 Introduction

This model is taken from Stauffer (2015.) It is a homogeneous vertical cut, which has undergone a 90 degree turning corner, with a fully rounded slope. Stauffer did this problem first with no reinforcement and then with soil nails. This is the vertical cut turning corner with reinforcement.

25.2 Problem Description

The 2D cross section of this problem is shown as Figure 25(a). The cross section is turned 90 degrees, before the top corner is rounded to an arc with radius 5m, this can be seen in the top view, Figure 25(b). The material properties are shown in Table 25.1. The properties of the soil nails are the default settings. The nails are 10m long and are rotated 5° below the horizontal. The nail pattern is on the vertical face of the embankment, and starts 0.5 m inwards from the edge, with a horizontal spacing of 1.5m and a vertical spacing of 2 m, starting 1 m above the stadium. The ellipsoidal slip surface and corresponding safety factor is required.

25.3 Geometry and Properties

Table 25.1: Material Properties

	c' (kN/m^2)	φ' (deg.)	γ (kN/m^3)
Soil	10	18	15

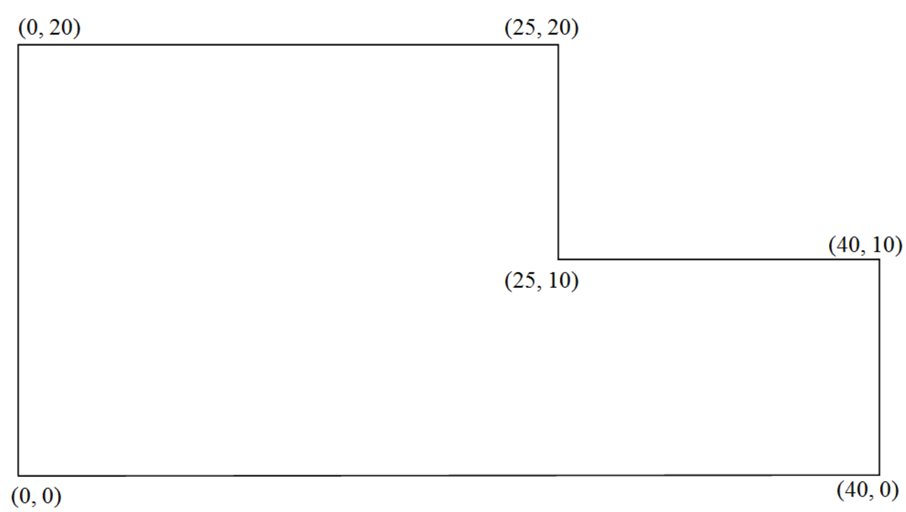


Figure 25(a)

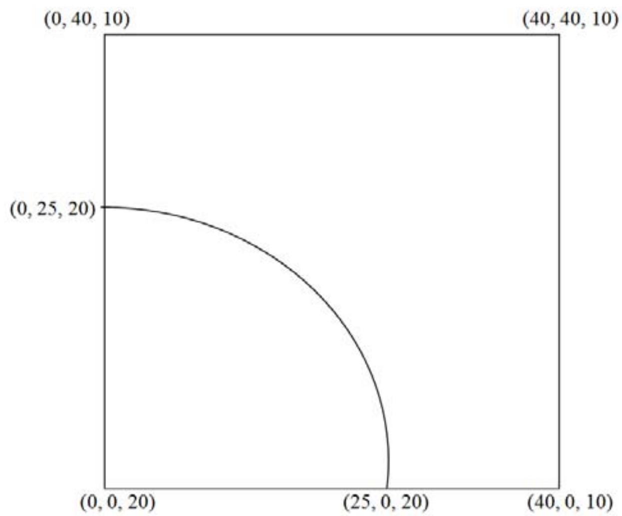


Figure 25(b)

25.4 Results

Table 25.4.1: Safety Factors Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	1.339	1.005	0.93	1.06
Janbu	1.371	1.014		

Referee: 1.04 [Stauffer, 2015]

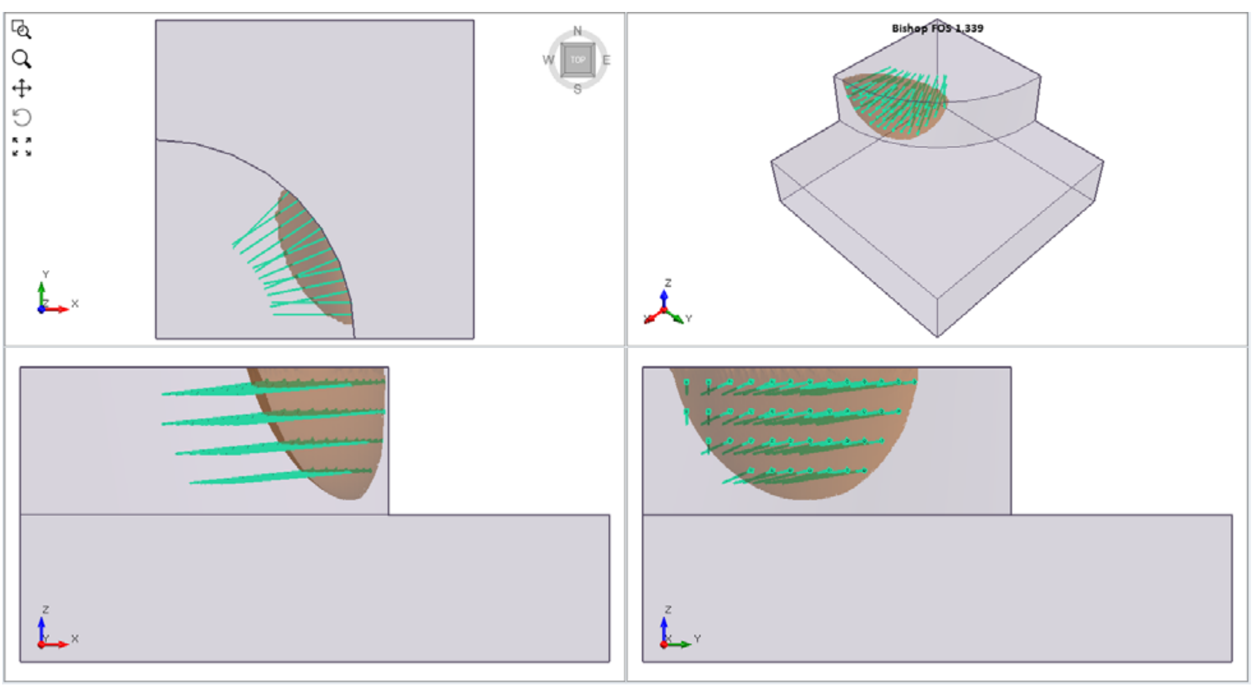


Figure 25.4.1 – Slide3 Solution Using the Bishop Method

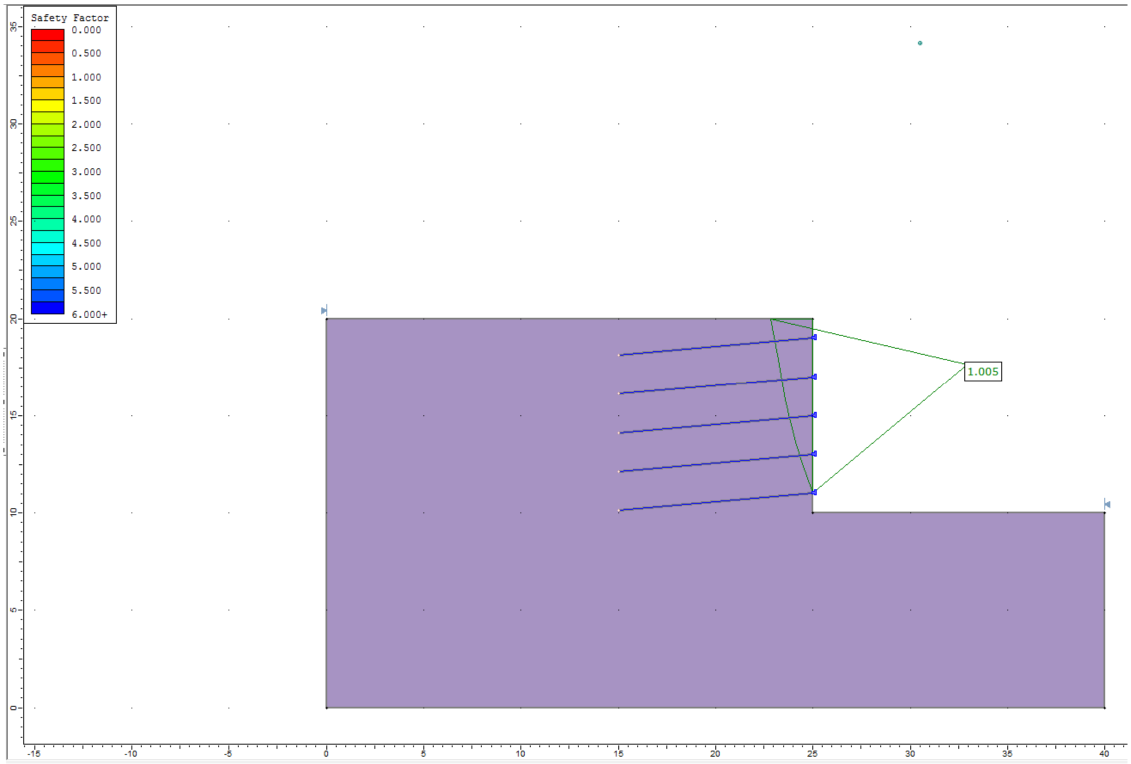


Figure 25.4.2 – Slide Solution Using the Bishop Method

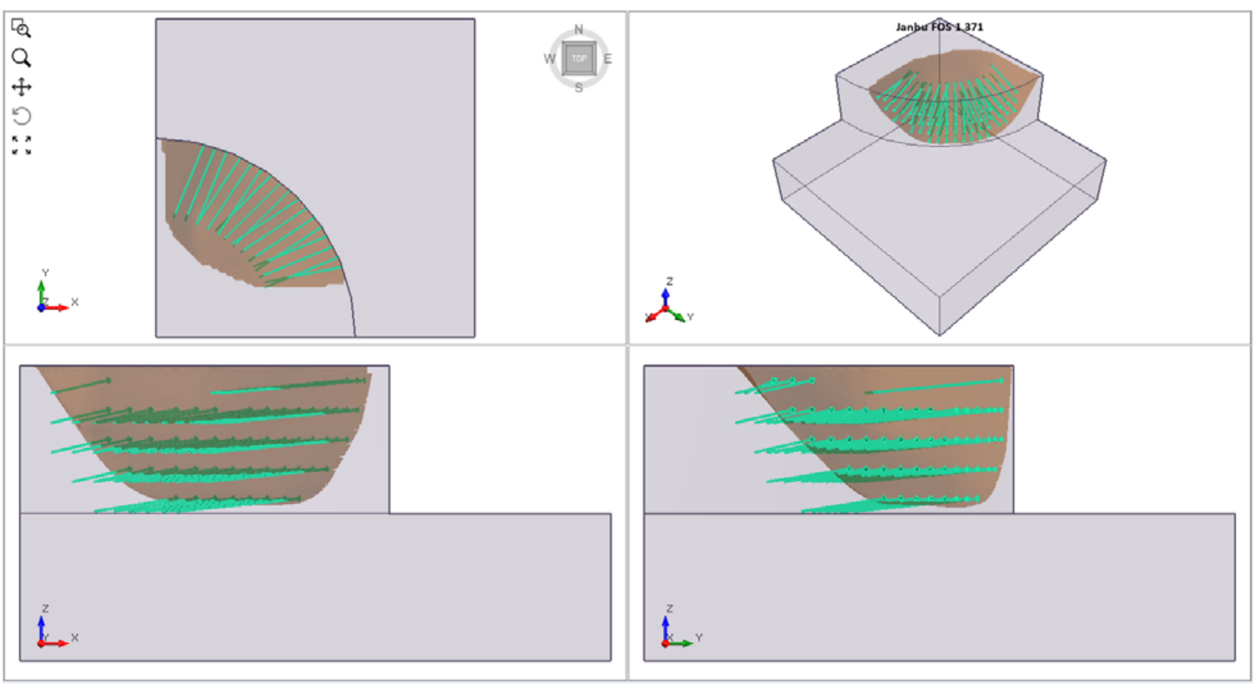


Figure 25.4.5 – Slide3 Solution Using the Janbu Method

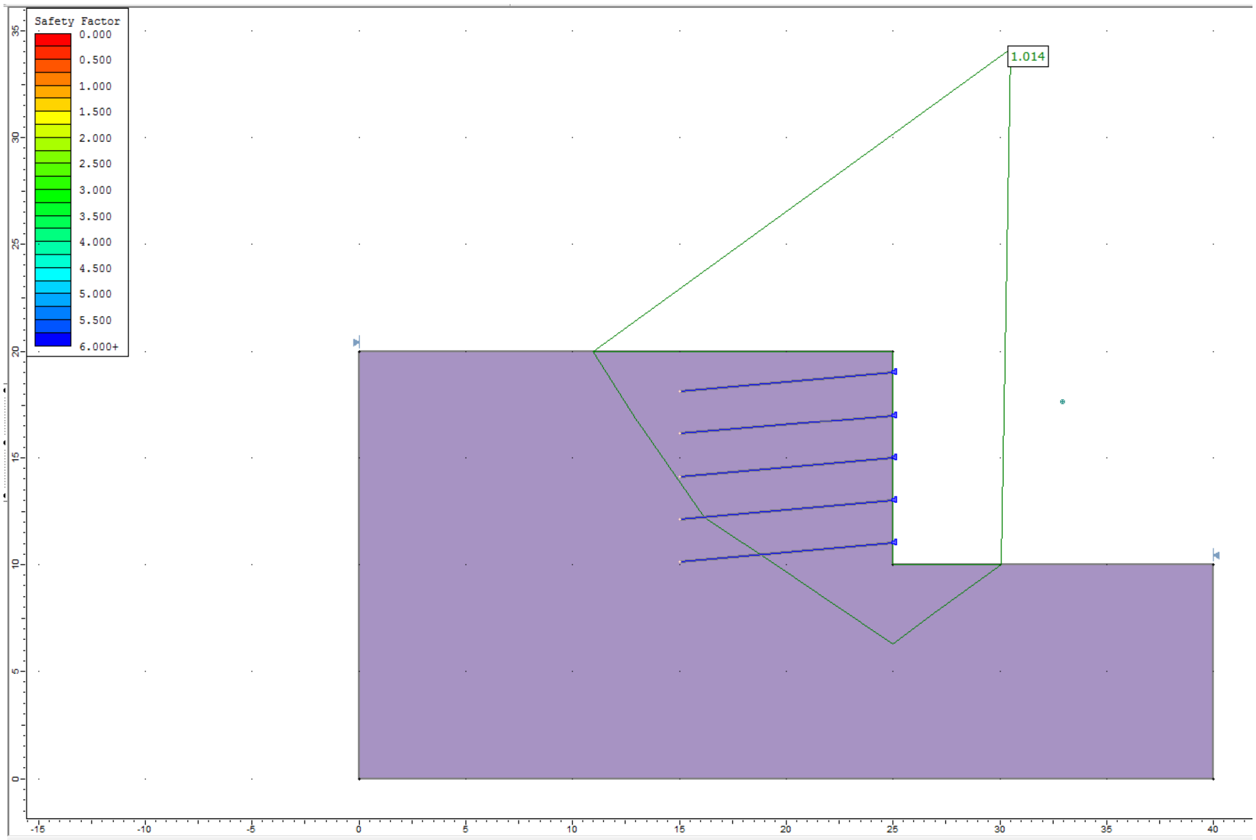


Figure 25.4.6 – Slide Solution Using the Janbu Method

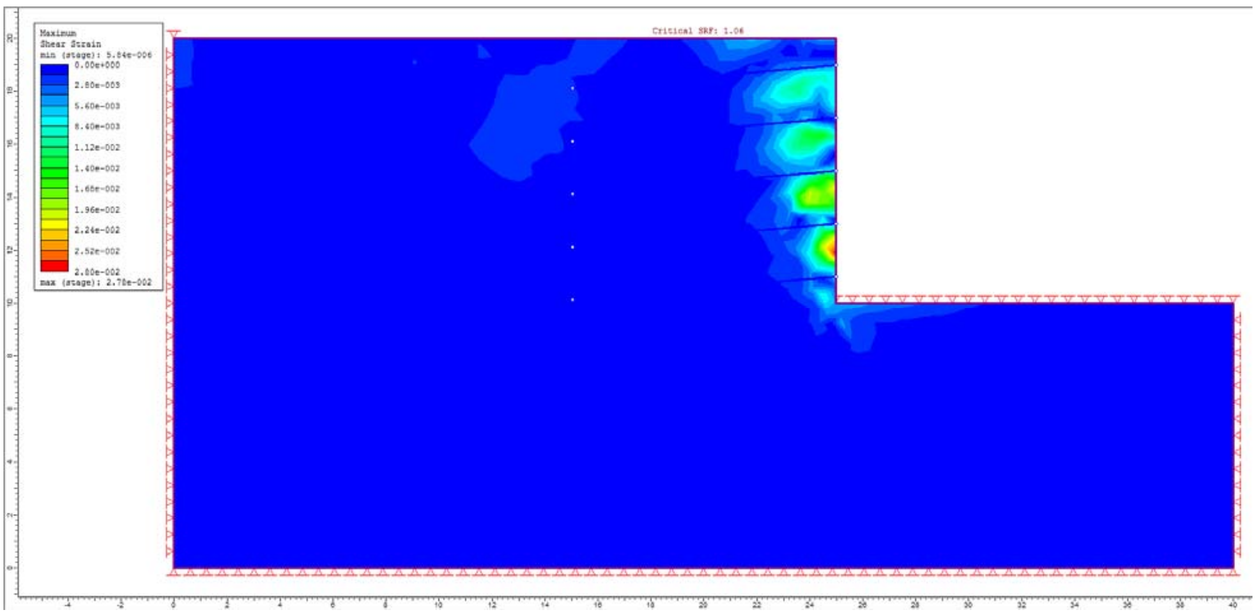


Figure 25.4.9 – RS2 Maximum Shear Strain

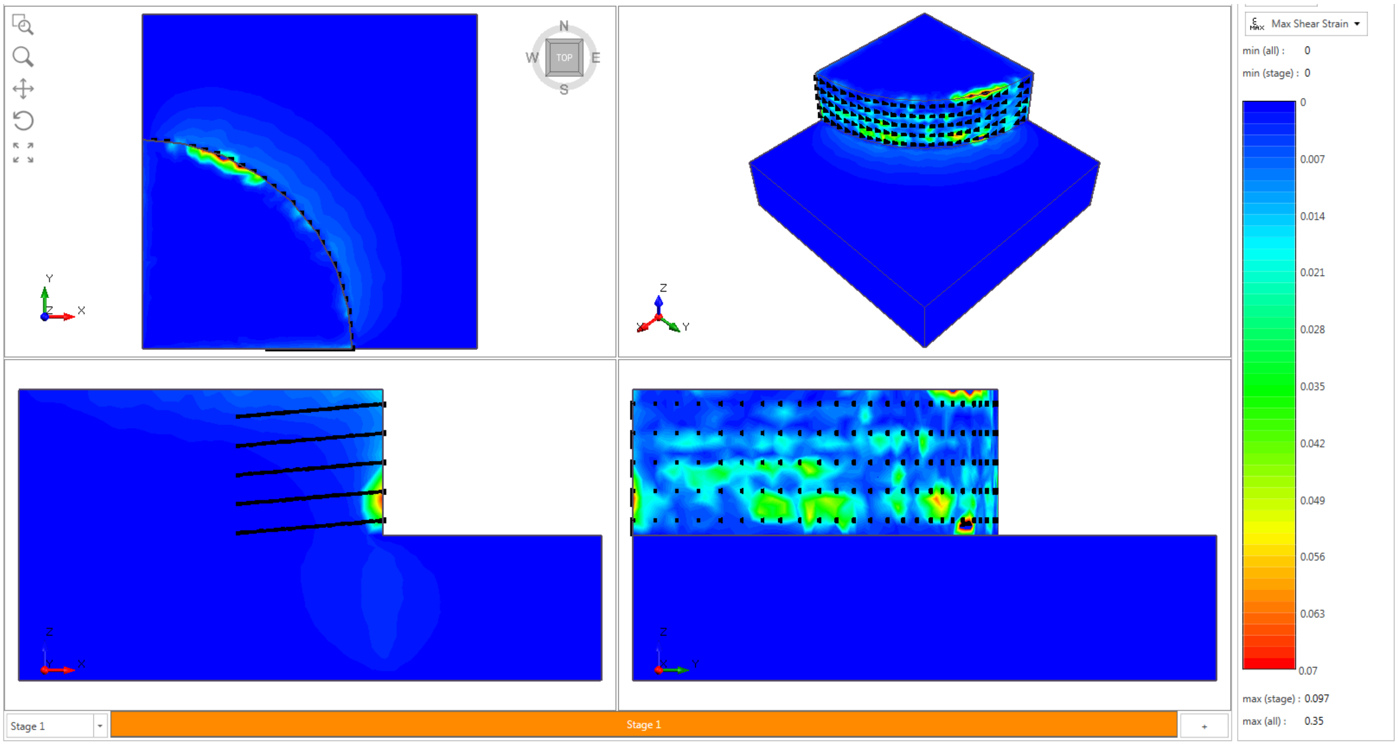


Figure 25.4.10 – RS3 Maximum Shear Strain

2D swept, 90° circular turn with foundation, (3) materials + weak layer, water table, ellipsoidal no SA

26.1 Introduction

This example is taken from Yamagami and Jiang (1997). This example was done both as a homogenous slope and as a non-homogeneous slope. 2D Swept Verification #26 will focus only on the non-homogenous example.

26.2 Problem Description

This example is a non-homogenous 2D cross section with a water table that was circularly swept 90°. The foundation of the slope is a box that starts at the origin and extends 46m in the X direction and 26m in the Y direction so that it is uneven across the sweep. Figure 26.1 shows the slope in the YZ plane, and Figure 26.2 shows the slope in the XZ plane, the cross sections are different because of the uneven foundation. The material properties can be found in Table 26.1.

26.3 Geometry and Properties

Table 26.1: Material Properties

	c′ (kN/m^2)	φ′ (deg.)	γ (kN/m^3)
1	29.3	20	19.2
2	17.5	10	18
Weak Layer	0	10	19.2
Infinite Strength	10000	65	19.2

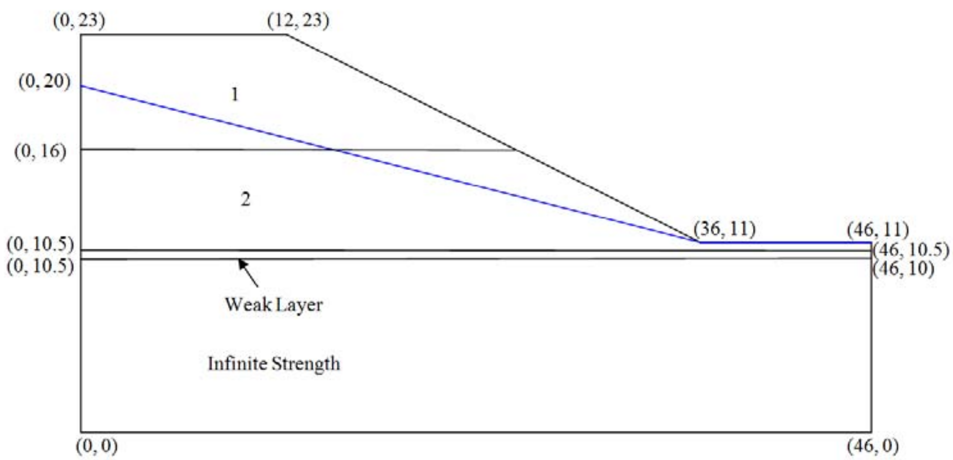


Figure 26.1

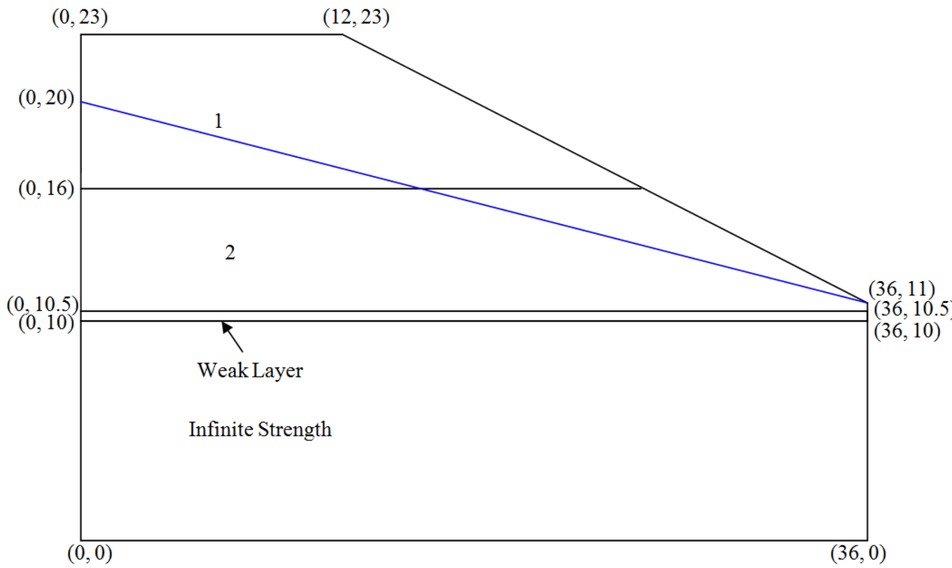


Figure 26.2

26.4 Results

Table 26.4.1: Safety Factors Safety Factors Using Slide3, Slide 7.0, RS3, and RS2

Method	Slide3	Slide 7.0	RS3	RS2
Bishop	0.834	0.747	0.78	0.79
GLE	0.846	0.742		
Janbu	0.828	0.753		
Spencer	0.863	0.739		

Referee: 1.08 [Yamagami and Jiang, 1997]

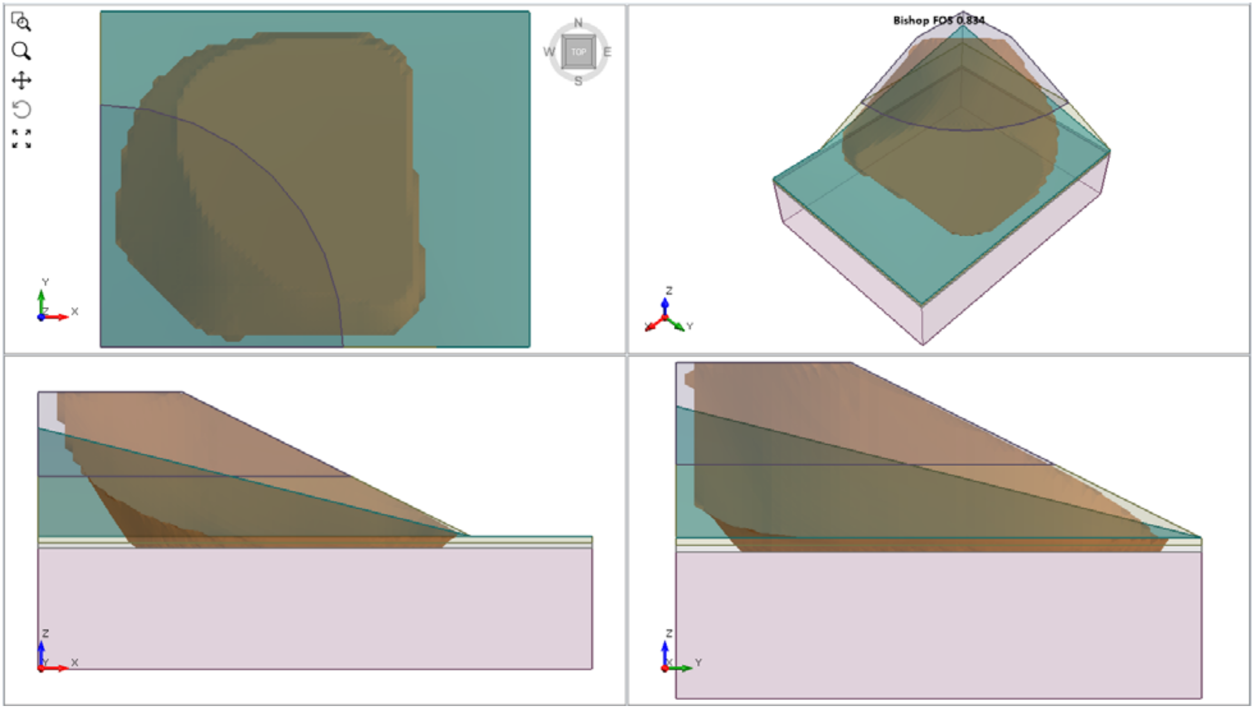


Figure 26.4.1 – Slide3 Solution Using the Bishop Method

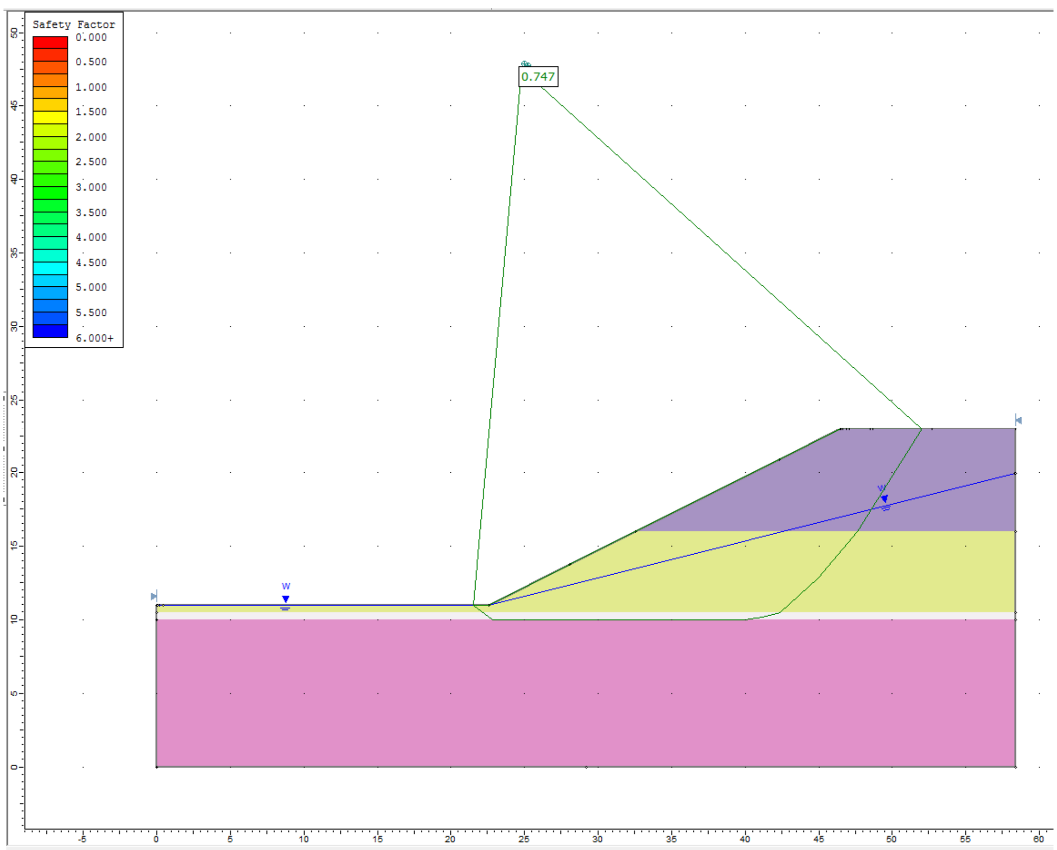


Figure 26.4.2 – Slide Solution Using the Bishop Method

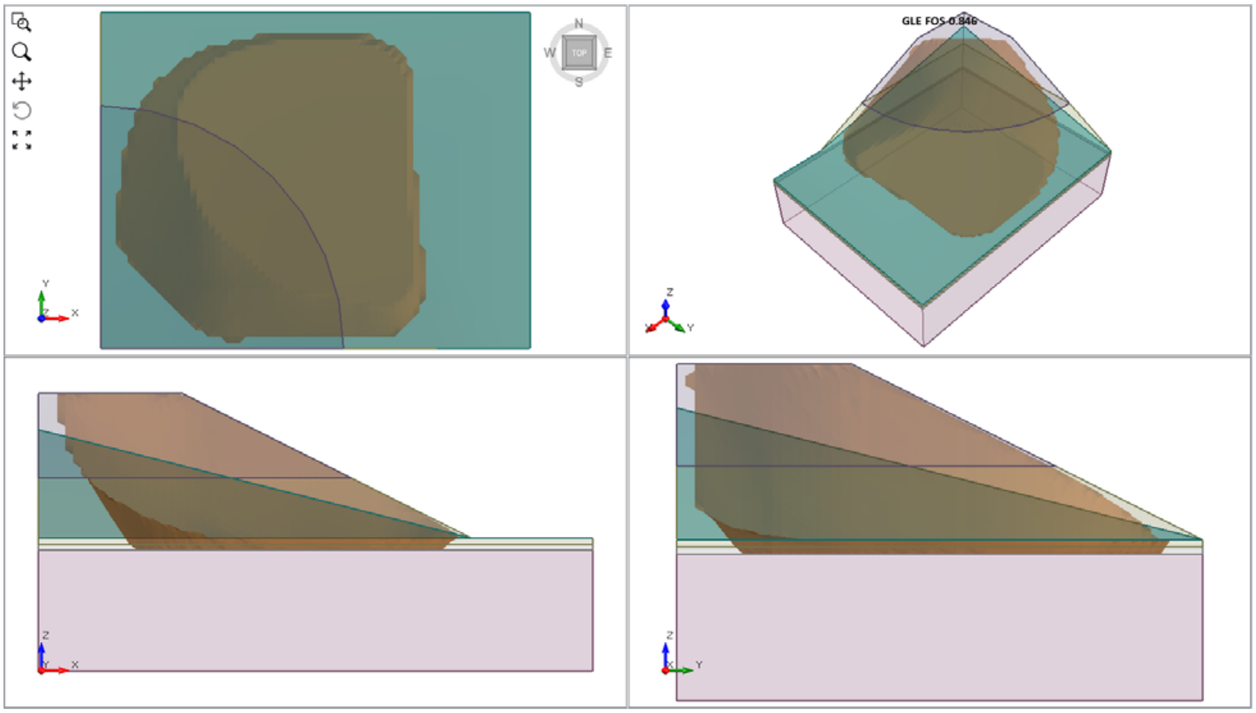


Figure 26.4.3 – Slide3 Solution Using the GLE Method

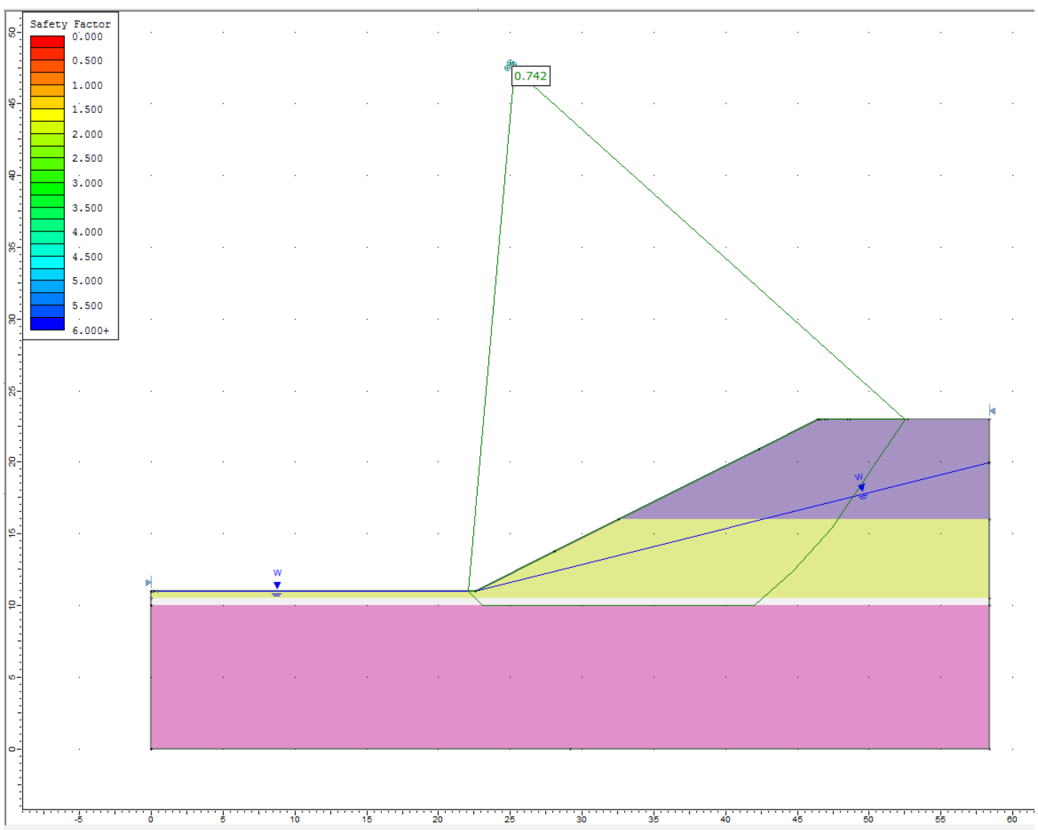


Figure 26.4.4 – Slide Solution Using the GLE Method

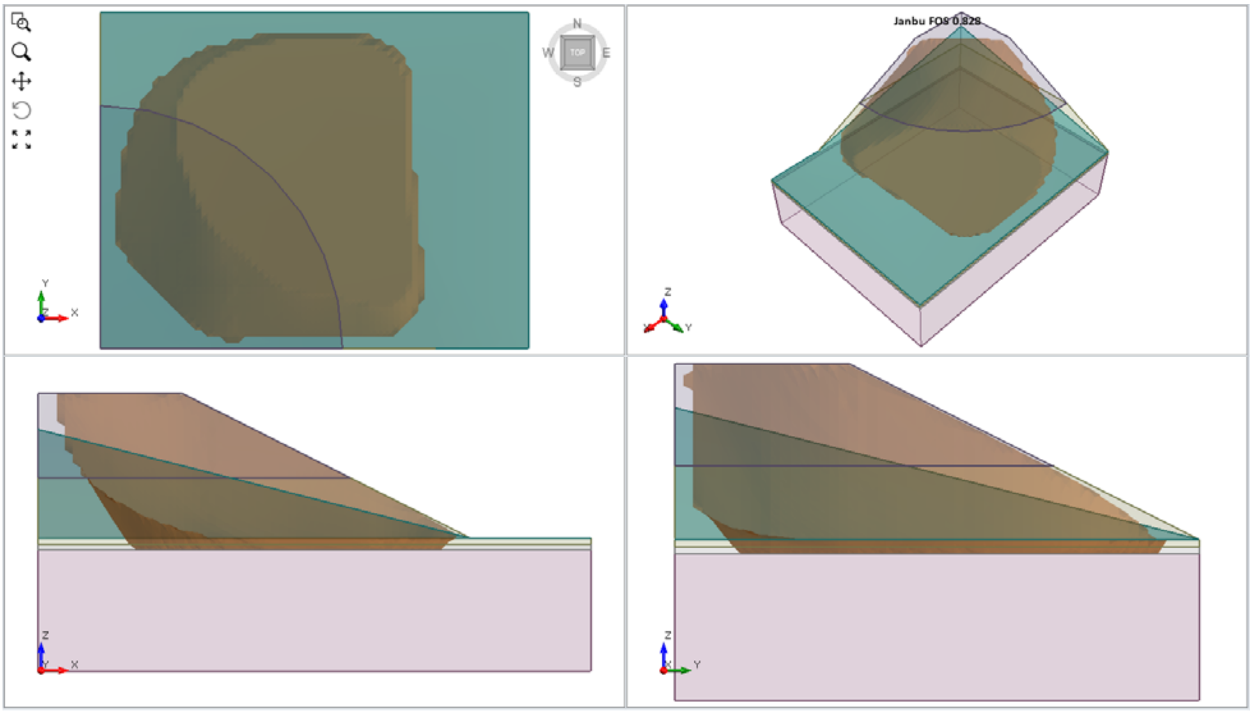


Figure 26.4.5 – Slide3 Solution Using the Janbu Method

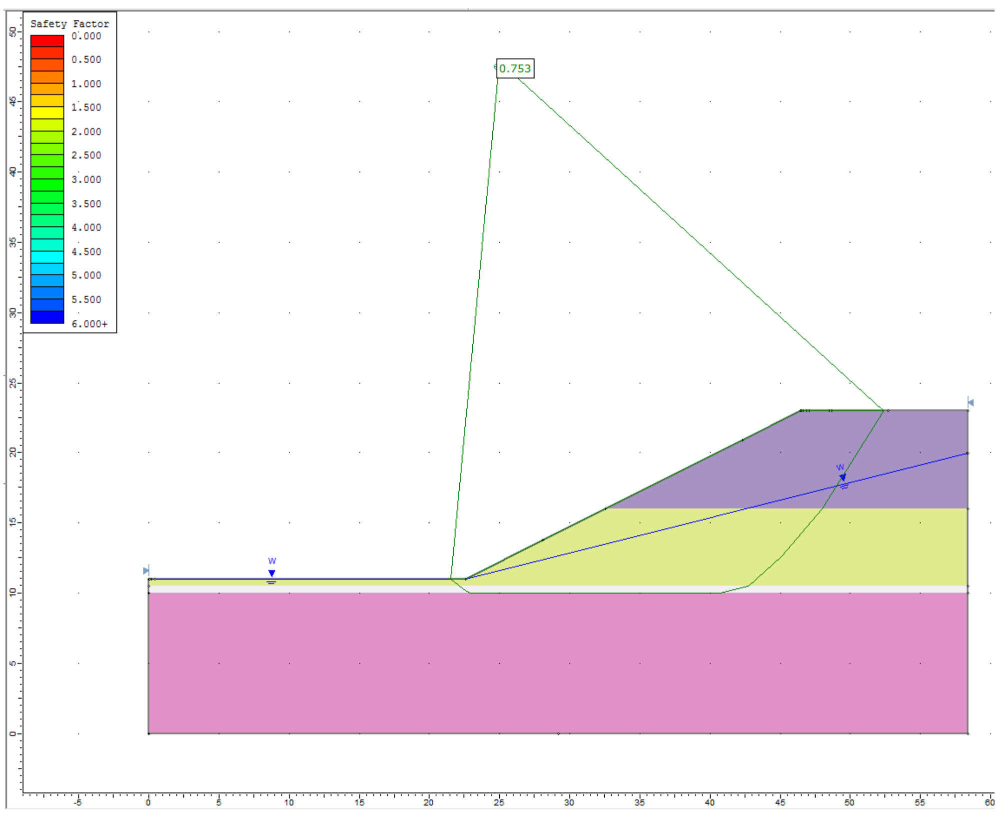


Figure 26.4.6 – Slide Solution Using the Janbu Method

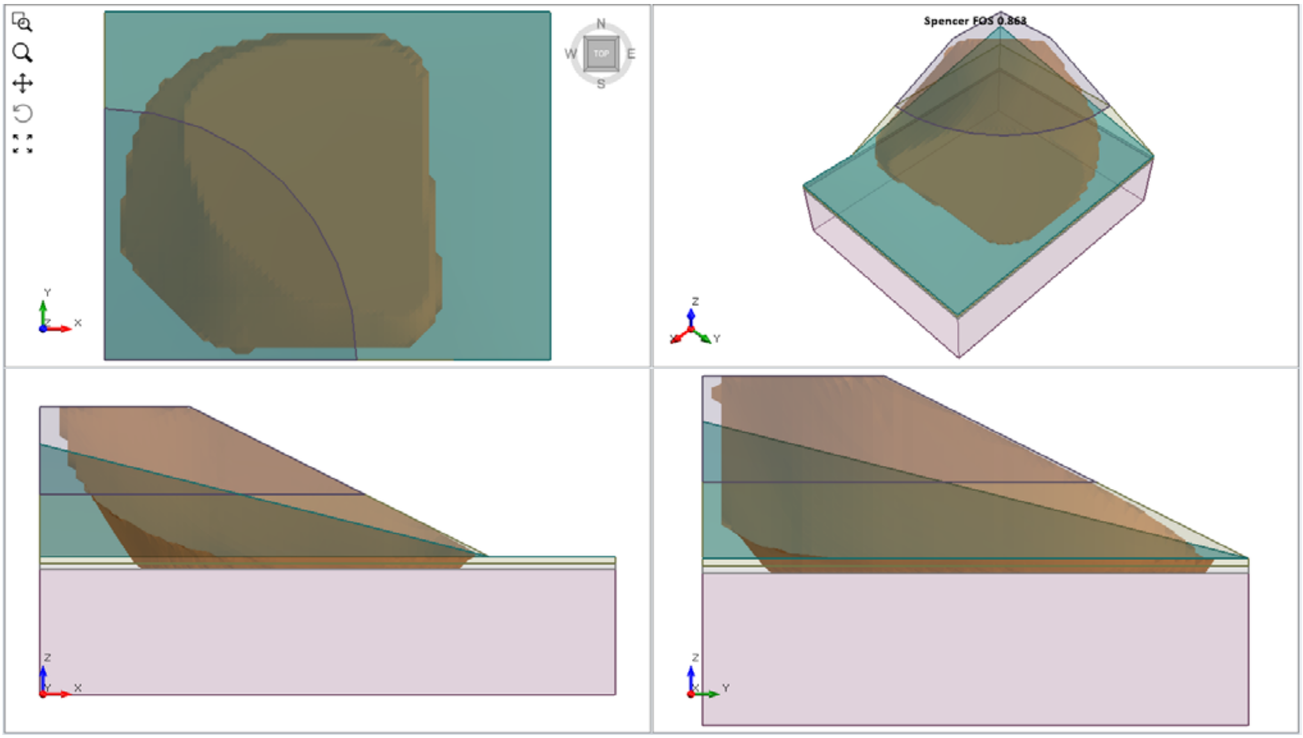


Figure 26.4.7 – Slide3 Solution Using the Spencer Method

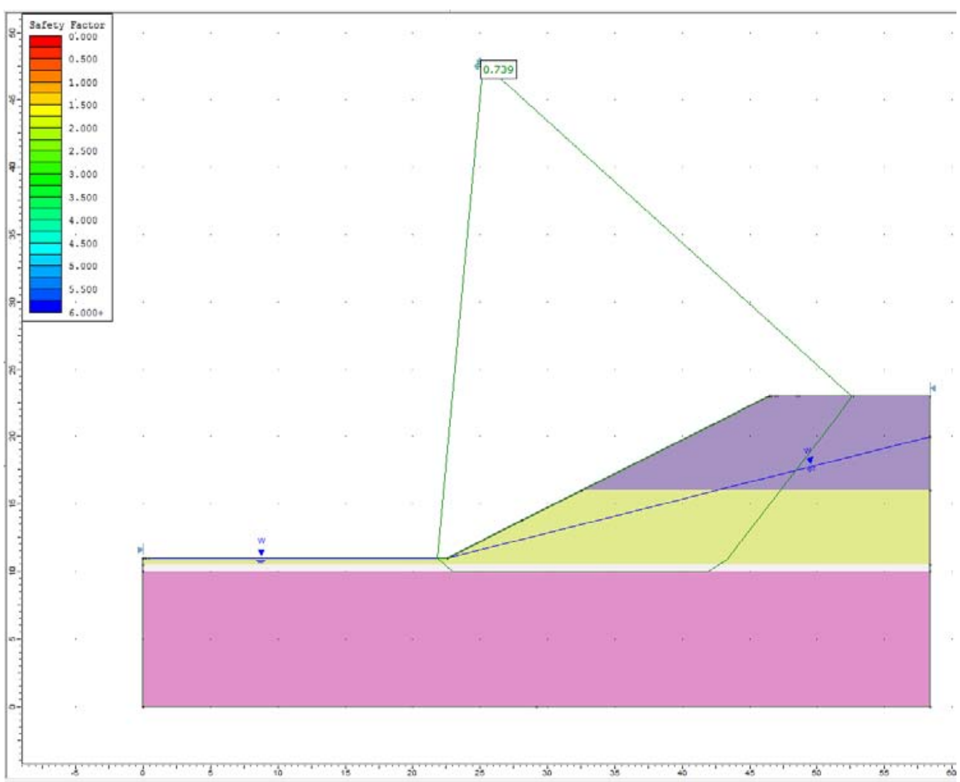


Figure 26.4.8 – Slide Solution Using the Spencer Method

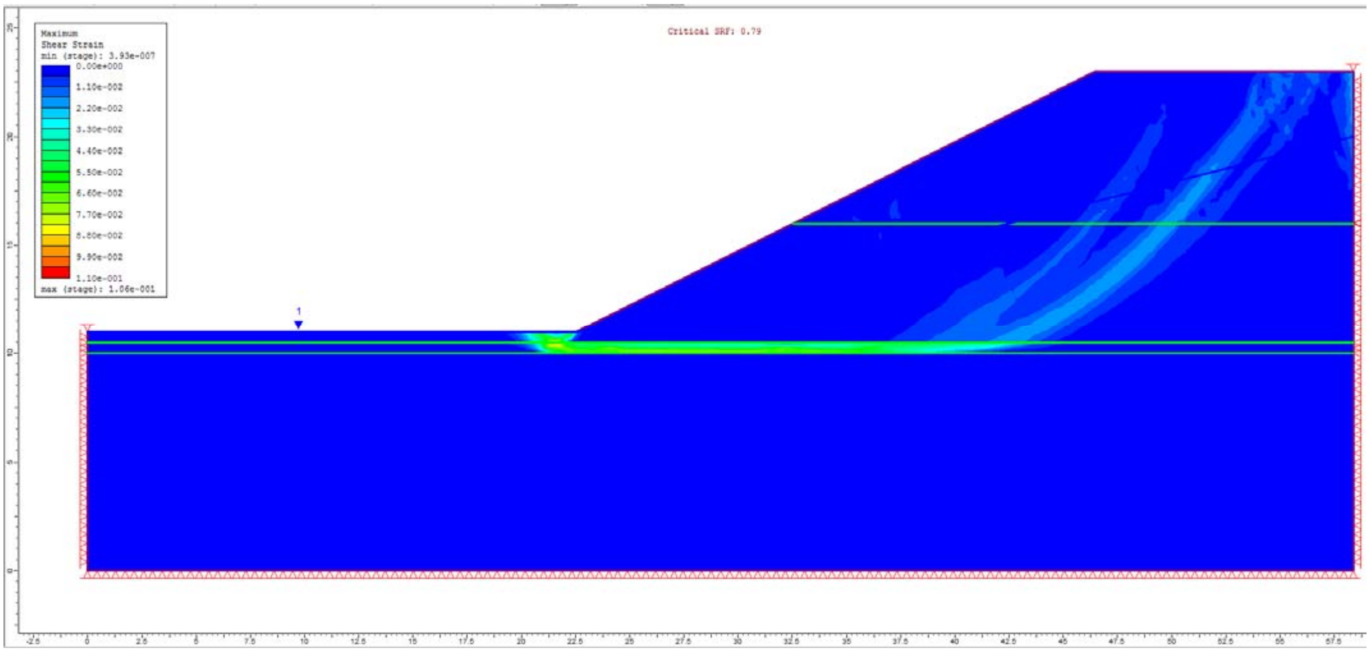


Figure 26.4.9 – RS2 Maximum Shear Strain

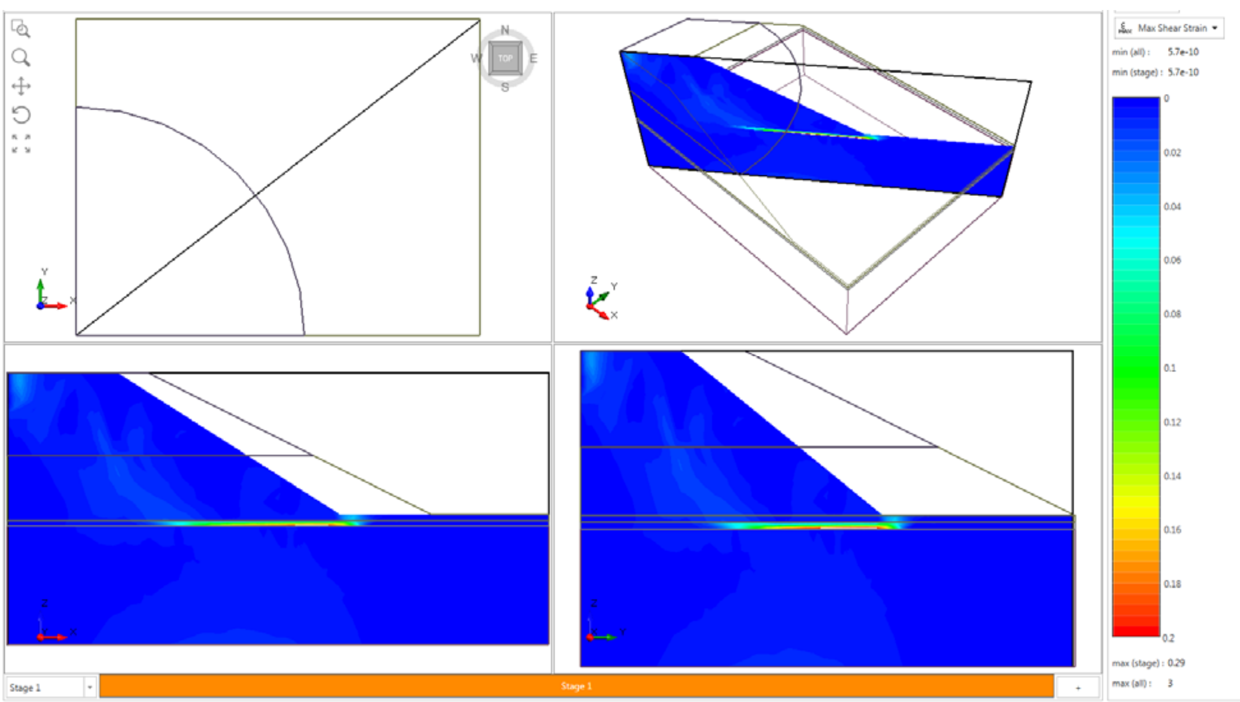


Figure 26.4.10 – RS3 Maximum Shear Strain

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