

Introduction: RS³ Tutorial 5 Weak Layer Slope

Welcome to RS³. This tutorial demonstrates how to model a weak layer inside a sloped terrain. The analysis uses a Shear Strength Reduction (SSR) method to determine the factor of safety.

The finished product of this tutorial can be found in the **Tutorial 05 Weak Layer Slope.rs3dmodel** file. All tutorial files installed with RS³ can be accessed by selecting File \rightarrow Recent \rightarrow Tutorials folder from the RS³ main menu.

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Tutorial Key Concepts Importing .dxf files Shear Strength Reduction (SSR) method Weak layer slope

Note

The SSR method involves iterative solving of the model with different guesses of the SRF for each solution, meaning the model is repeatedly solved. The created model is also made of complex geometry. These two factors makes the compute engine work for longer.



Step 1: Starting the Model

CREATING A BLANK DOCUMENT



Start RS³ by selecting Programs \rightarrow Rocscience \rightarrow RS3 2.0 \rightarrow RS3 from the Windows start menu. RS³ opens to a blank screen, which allows you to create a new model by pressing the [New Project] button. If the RS³ application window is not already maximized, maximize it now so the full screen space is available for use.



First, save as **Tutorial 05 Weak Layer Slope.rs3dmodel**: File \rightarrow Save.

Step 2: Editing the Project Settings

CONFIGURING THE SSR METHOD



The Project Settings dialog is used to configure the main analysis parameters for your RS³ model. Open the dialog through File \rightarrow Project Settings. This will open the dialog, change to tab [Shear Strength Reduction] and check Determine Strength Reduction Factor = Active, Initial Estimate of SRF = <u>1.76</u>. Keep all other settings as their defaults.

Note

The SSR method involves iterative solving of the model with different guesses of the SRF for each solution. This means the model is repeatedly solved until the set of solutions has reached failure (giving the critical SRF aka SF) within the defined tolerance. Then generally, the closer the initial guess, the less guesses the solver has to make – meaning it should run faster than with a farther guess.

Drainat	🗊 Project Settings			?	\times
Project Settings: Shear Strength Reduction	Units Units Units Units Units Units Units Units Stages Solver Options Units Units Units Units Solver Options Units	Determine Strength Reduction Factor Initial Estimate of SRF: Step Size Automatic Custom Step Size Step Size Final SRF: Accelerate SRF	1.76 0.01 0.2 2		



OTHER OPTIONS

Define Materials Next, select the [Groundwater] tab.

Project	😚 Project Settings		"	?	×
Settings: Ground water	Units 	Method: Pore Fluid Unit Weight (kN/m3):	None	9.81	

Enter Method = <u>None</u>, then select [Project Summary] and enter <u>Weak Layer Slope</u> as the Project Title. Do not change any other settings. Select [OK] to close the dialog.

Step 3: Defining the Materials

Geology)

DEFINING MATERIAL PROPERTIES

Under the same tab (<u>Geology</u> or <u>Excavations</u>) you can assign the materials and properties of our model through Materials \rightarrow Define Materials.

Enter the following properties for "Material 1" in the [Strength] & [Stiffness] tabs.

Material 1	😚 Material Properties				?	×
Properties:	Soil Material 2	Name Soil				1 -
Strength	Material 3 Material 4	Initial Element Loading	Field Stress & Body Force	e 👻 Unit Weight (kN/m3):		19
	Material 5	Material Behavior:	Drained	*		
		Strength Stiffness Staging	Datum Dependency	Hydraulics		
		Failure Criterion: Mohr Coulomb	•	Material Type: Plastic	•	
		Tensile Strength (peak) (kPa):	400	Tensile Strength (resid) (kPa):	400	
		Friction Angle (peak) (degree):	30	Friction Angle (resid) (deg.):	30	
		Cohesion (peak) (kPa):	400	Cohesion (resid) (kPa):	400	
		Jointed Material Joint Opti	ons	Dilation Angle (deg.):	0	
		Unsaturated Shear Strength				
		Phi b:	0			
		Air Entry (kPa):	0			
		Apply SSR (Shear Strength Red	duction)			

Enter Name = <u>Soil</u>, Initial Element Loading = <u>Field Stress & Body Force</u>, Unit Weight = <u>19</u> kN/m³, Tensile Strength = <u>400</u> kPa, Friction Angle = <u>30</u>, deg, Cohesion = <u>400</u> kPa.

Material Type = <u>Plastic</u>, Tensile Strength (resid) = $\frac{400}{kPa}$, Friction Angle (resid) = $\frac{30}{degrees}$, Cohesion (resid) = $\frac{400}{kPa}$, Dilation Angle = $\frac{0}{degrees}$, Apply SSR = <u>Active</u>, then [Stiffness].



Material 1	1 Material Properties	I.	? ×
Properties: Stiffness	Soil Soil Aterial 2 Aterial 3 Aterial 3 Aterial 4 Material 5	Name Soil Initial Element Loading Field Stress & Body Force Unit Weight (kN/m3): Material Behavior: Drained • Strength Stiffness Staging Datum Dependency Hydraulics Type: Linear Isotropic • Use Unloading Condition Loading Young's Modulus (kPa): 50000 Poisson's Ratio: 0.3 Young's Modulus (kPa): 0 0 0	19

Enter Young's Modulus = 50000 kPa, then [Material 2].

Enter the following properties for "Material 2" in the [Strength] & [Stiffness] tabs.

Soil Name Weak Layer Name Material 3 Initial I Material 5 Materi	Weak Layer Element Loading	Field Stress & Body Force	 Unit Weight (kN/m3); 		-
Material 3 Material 4 Material 5 Materi	Element Loading	Field Stress & Body Force	 Unit Weight (kN/m3); 		
Material 5 Materi			onie rreigne (any noy)		19
Stren Failu Tens Frict Coh	al Behavior: gth Stiffness Staging re Criterion: Mohr Coulomb sile Strength (peak) (kPa): tion Angle (peak) (kPa): lointed Material Joint Optio aturated Shear Strength b: Entry (kPa):	Datum Dependency Hy 50 25 50 ns 0	Additional and the second	- 50 25 50 0	
	Failu Ten: Coh Uns Phi Air	Failure Criterion: Mohr Coulomb Tensile Strength (peak) (kPa): Friction Angle (peak) (degree): Cohesion (peak) (kPa): Jointed Material Joint Optio Unsaturated Shear Strength Phi b: Air Entry (kPa):	Failure Criterion: Mohr Coulomb + Tensile Strength (peak) (kPa): 50 Friction Angle (peak) (kPa): 25 Cohesion (peak) (kPa): 50 Jointed Material Joint Options Unsaturated Shear Strength Phi b: Phi b: 0 Air Entry (kPa): 0	Failure Criterion: Mohr Coulomb - Material Type: Plastic Tensile Strength (peak) (kPa): 50 Tensile Strength (resid) (kPa): Friction Angle (resid) (kPa): Friction Angle (peak) (kPa): 25 Friction Angle (resid) (kPa): Cohesion (resid) (kPa): Cohesion (peak) (kPa): 50 Cohesion (resid) (kPa): Dilation Angle (deg.): Unsaturated Shear Strength Phi b: 0 Air Entry (kPa): 0 0	Failure Criterion: Mohr Coulomb • Material Type: Plastic • Tensile Strength (peak) (kPa): 50 Tensile Strength (resid) (kPa): 50 Friction Angle (peak) (kPa): 25 Friction Angle (resid) (deg.): 25 Cohesion (peak) (kPa): 50 Cohesion (resid) (kPa): 50 Jointed Material Joint Options Dilation Angle (deg.): 0 Unsaturated Shear Strength 0 0 Phi b: 0 0 Air Entry (kPa): 0 0

Enter Name = <u>Weak Layer</u>, Initial Element Loading = <u>Field Stress & Body Force</u>, Unit Weight = <u>19</u> kN/m³, Tensile Strength = <u>50</u> kPa, Friction Angle = <u>25</u> degrees, Cohesion = <u>50</u> kPa.

Material Type = <u>Plastic</u>, Tensile Strength (resid) = $\frac{50}{20}$ kPa, Friction Angle (resid) = $\frac{25}{20}$ degrees, Cohesion (resid) = $\frac{50}{20}$ kPa, Dilation Angle = $\frac{0}{2}$ degrees, Apply SSR = <u>Active</u>, then [Stiffness].

Material 2 Properties: Stiffness	Material Properties ■		?	×
	Soil Weak Layer Material 3 Material 4 Material 5	Name Weak Layer Initial Element Loading Field Stress & Body Force Unit Weight (kN/m3): Material Behavior: Drained 		•
		Strength Staging Datum Dependency Hydraulics Type: Linear Isotropic Use Unloading Condition Loading Young's Modulus (kPa): 10000 Poisson's Ratio: 0.3 Young's Modulus (kPa): 0 Young's Modulus (kPa): 0 0 10000 Young's Modulus (kPa): 0 10000 10000 10000 10000 Young's Modulus (kPa): 0 10000 10		

Enter Young's Modulus = <u>10000</u> kPa, [OK].

Geology

Step 4: Creating Geometry

CREATING THE EXTERNAL BOX



Ensure the <u>Geology</u> tab is selected from the workflow at the top of the screen.

Select: Geometry \rightarrow 3D Primitive Geometry \rightarrow Box. A Create External dialog will open, enter First Corner (x, y, z) = (-375, -310, -500), Second Corner (x, y, z) = (200, 275, 200), then press [OK].

Create Box



IMPORTING THE SLOPED TERRAIN



Select: Geometry \rightarrow Import.

Import Geometry

Open the provided **Terrain.dxf** file, then an Import Geometry dialog will open, you can select Layer 1 to take a better look at it, then press [OK].





FINALIZING THE EXTERNAL BOUNDARY

Select both the box and the imported terrain in the visibility pane.



Geometry \rightarrow 3D Boolean \rightarrow Intersect. An Intersection dialog will open, make sure Box and Entity are in the dropdowns, [OK].

Import
Geometry

🖅 Intersection		?	\times
Box			-
Entity 0			-
	OK	Car	ncel

Select new body "Intersection_1" in visibility pane, then Geometry \rightarrow Set as External. Then select "Intersection_1" again in the visibility pane and make sure in properties pane, the Role = <u>Geology</u>.

IMPORTING AND MODIFYING THE WEAK LAYER TERRAIN

Open the provided **Terrain.dxf** file, then press [OK].



Select: Geometry \rightarrow Import.

Import Geometry

Select either of the "Entity 0" objects in the visibility pape. Geometry \rightarrow Tran



Select either of the "Entity 0" objects in the visibility pane, Geometry \rightarrow Transform \rightarrow Translate, From (x, y, z) = (0, 0, 0), To (x, y, z) = (0, 0, -40), [OK].

Translate	
Goomotry	
Geometry	

🎓 Ti	ranslate Geomet	Ŋ		? ×		
	x	У	z			
From	0.000	0.000	0.000	Start Point		
То	0.000	0.000	-40.000	End Point		
Geometry 1 Entity 0						
Add Geometry Delete Selected Geometry						
Preview OK Cancel						



Select "Entity 0_prime" in the visibility pane, Geometry \rightarrow Transform \rightarrow Rotate, Fix (x, y, z) = (-405, 285, -186), Axis (x, y, z) = (16, 49, 6), Angle = 5, [OK].



	😚 Rotat	e Geometry		? ×
Rotate Geometry	Fix: Axis: Angle: Geo 1 Entit	x -405 16 metry ty 0_prime	у 285 49 5	z -186 Degrees *
		Add Geometry	Delete Sel	ected Geometry
	• Pre	view	ОК	Cancel



Select "Entity 0_prime_prime" in the visibility pane (can do so by double-clicking on the desired body in the viewport), Geometry \rightarrow Copy Geometry, in the Copy Entity dialog, enter Copies = <u>1</u>, Spacing = <u>-50</u>, Define By = <u>Z-Axis</u>, [OK].

Copy Entity

😚 Copy Entity	? ×
Copy Mode	
1D-Array Copy	2D-Array Copy
First Axis	
Copies: 1	Spacing: -50
Define by: Z-Axis	*
X: 0 _ Y:	Ĵ Z: 1 Ĵ
Total Copies:	OK Cancel

FINALIZING THE GEOMETRY



Now we can cut into the external box with the weak layer terrains: Geometry \rightarrow 3D Boolean \rightarrow Divide All Geometry.

Select the middle thin layer in the visibility pane, and in the properties pane change their Applied Property = <u>Weak Layer</u>. Your model should now look like the following.



Current State of Model

Step 5: Adding Stress Loading



APPLYING FIELD STRESS TO THE MODEL

Field Stress

Next we go to the <u>Loads</u> tab. This tab allows you to edit the loading conditions. Select: Loading \rightarrow Field Stress.

	쑺 Field Stress	? x
Field Stress	Field Stress Type: Gravity -	ОК
	Use actual ground surface Ground Surface Elevation: 0 m	Cancel
	Unit Weight of Overburden: 0.027 MN/m3	
	✓ Use effective stress ratio	
	Use variable stress ratio	
	Horizontal Stress 1 Horizontal Stress 2	
	K1: 1 K2: 2	
	Locked In: 0 MPa Locked In: 0 MPa	

Enter Field Stress Type = <u>Gravity</u>, the rest should be default (check screenshot), [OK].

Step 6: Setting Boundary Conditions



ADDING MODEL RESTRAINTS

Move to the <u>Restraints</u> tab to assign restraints to the external boundary of the model.



RS³ has a built in "Auto Restrain" tool for use on underground models. Select: Restraints \rightarrow Auto Restrain (Surface).

Restrain (*Surface*) This completes the construction of the model (in terms of geometry).



Step 7: Meshing



CONFIGURING AND CALCULATING MESH



Next we move to the <u>Mesh</u> tab. Customize mesh: Mesh \rightarrow Mesh Settings.

The Mesh Settings dialog appears. This dialog allows you to customize parameters of your mesh. We want to use a graded, 10-noded element mesh.



🗲 Mesh Settings			8 ×
Element Type:	10-Noded Tetrahedra		-
Mesh Gradation:	Graded		
# Elements: ~No clue at the moment		ОК	Cancel

Enter Element Type = <u>10-Noded Tetrahedra</u>, Mesh Gradation = <u>Graded</u>, [OK]



Then mesh the model: Mesh \rightarrow Mesh. The model with the generated mesh should look like the one below.

Model with completed mesh



Step 8: Computing Results

Compute

COMPUTE



Next we move to the <u>Compute</u> tab. From this tab we can compute the results of our model. First, save: File \rightarrow Save.

Use the Save As dialog to save the file, and next you need to save the compute file: File \rightarrow Save Compute File. You are now ready to compute the results.



Note

The SSR method involves iterative solving of the model with different guesses of the SRF for each solution, meaning the model is repeatedly solved. The created model is also made of complex geometry. These two factors makes the compute engine work for longer.

-	-	-	-
u	-	-	-
H	-	-	-

Select: Compute \rightarrow Compute.

Compute	- 🚚 RS3 2.0 64-bit			_		×
Compute Engine	File Queue:	Input File: Writing File:	Tut 5.rs3compute	2		
	2	Elements:	83401	DOF:	322284	
			10% (stag	e 1 of 1)	
1	Processed Files:		66% (load s	step 4 <mark>o</mark> f	6)	
		Iteration	8	Max:	500	
	System Statistics: Free Disk = 713 GB Total Memory = 63.9 GB Free Memory = 54.0 GB	Solid Tolera	0.0378541	Max:	0.001	
		Fluid Tolera	Fluid Tolerance			
	Execution Priority: Normal	\sim	1.10333e-007	Max:	1e-006	
	Information:					
	Read solid restraintsDone Filling initial stress Solid elements Bolt elements Beam and strut elements Done					^
	Time to read file: 2.86918					*
	😰 Open 🔪 🗙 Delete		Pause		Abort	
	Computing, Please Wait				00:00	:37

Step 9: Interpreting Results

Results

DISPLAYING THE RESULTS



Next we move to the <u>Results</u> tab. From this tab we can analyze the results of our model. First, refresh the results: Interpret \rightarrow Refresh Results.

On the top right corner of the Results tab, you should see two drop down menus:



We will analyze a number of different "Data Type" results. Let's turn on the exterior contours so we can see some results: Interpret \rightarrow Show Exterior Contour.





We also want to define a plane that goes through the peak. First we must define a plane, Interpret \rightarrow XZ Plane. In the Create Plane dialog, enter: Plane Center (x, y, z) = (-87.5, 87, -246.191), Plane Normal (x, y, z) = (0, 1, 0), then press [OK].

Create	🎲 Create Plane		?	\times
Plane	x	у	z	
	Center: -87.5	87	-246.19	91:
	Plane Orientation			
	Defined by:	Normal	Vector	-
	X: 0 Y:	1 Z:	0	
	Normalized: [0, 1, 0]			
		ОК	Canc	el

TOTAL DISPLACEMENT

In the top right corner of the Results tab, ensure Element = <u>Solids</u>, and change data type = <u>Total Displacement</u>, and select SRF = <u>1.76</u>:

) Solids 🔻					
Total Displacement 🔻	1	Criti	Critical SRF:	Critical SRF: 1.71	Critical SRF: 1.71 1.72

Solids Total The Total Displacement results are shown below. Displ



As expected, the displacement sharply decreases at the boundary where the weak layer ends (indicated on right image in dashed box).

Other results are available to view as well. Thank you, this concludes the tutorial.