Stability Analysis of Reinforced Earth Retaining Walls - LEM

Slope Module Tutorial

Step 00

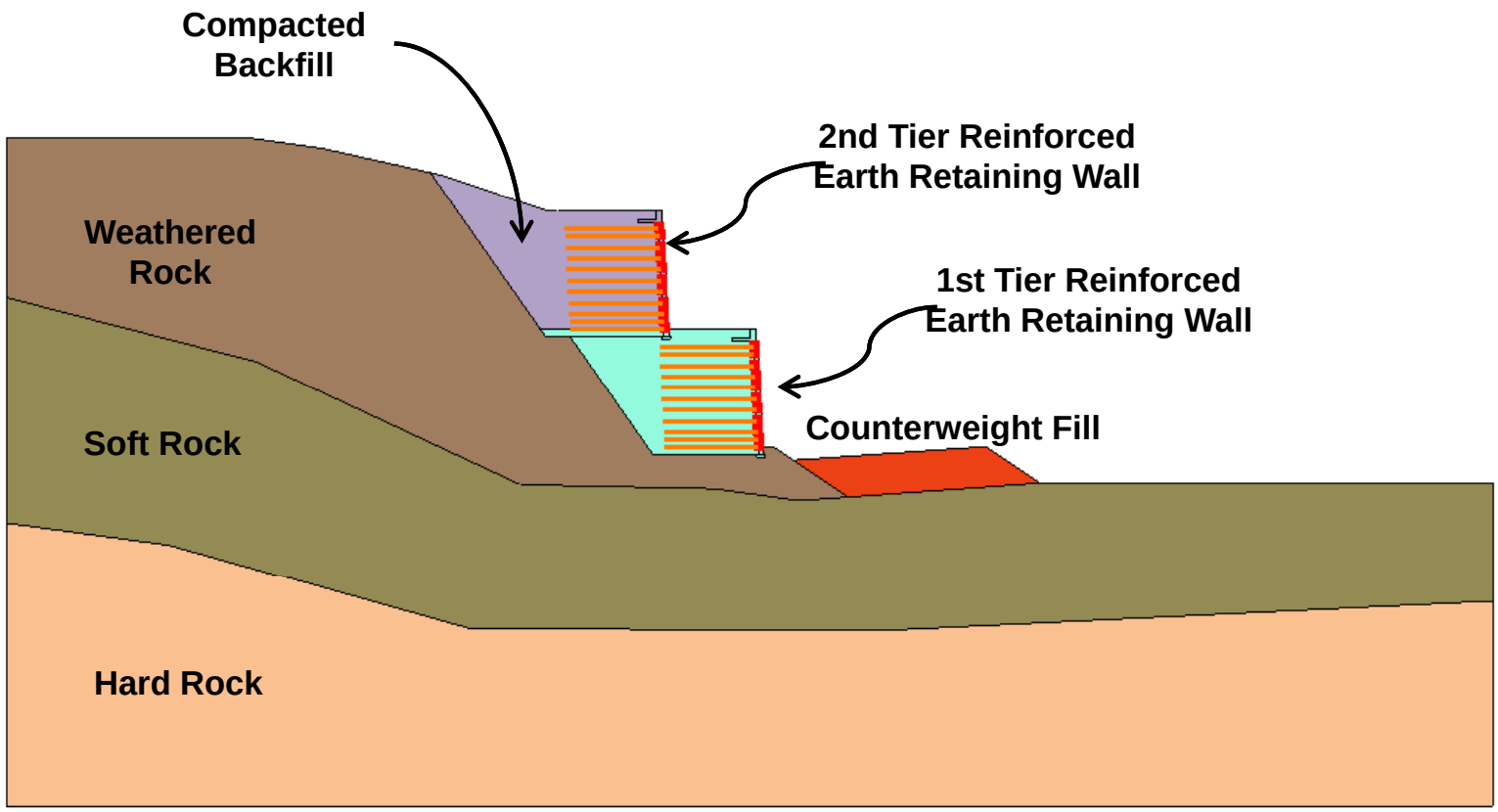
Stability Analysis of Reinforced Earth Retaining Walls - LEM

Overview

- Limit Equilibrium Method (LEM) is used to check the stability of the reinforced earth retaining walls. LEM assumes the ground as a unit soil mass within which equilibrium of forces and moments at a specific failure surface is considered. LEM is widely used for stability analysis of cohesive slopes.

- SoilWorks provides LEM by Fellenius, Bishop and Janbu. These methods present some discrepancies depending on the strength parameters and the accuracy in slope geometry.

- SoilWorks can perform LEM analysis with construction stages reflecting cutting and embankment.



Step 01

Material Properties

Ground Properties

No	Ground Type	Unit Weight [kN/m^3]	Saturated Unit Weight [kN/m^3]	Cohesion [kN/m^2]	Internal Friction Angle [deg]
1	Weathered rock	20	21	35	30
2	Soft rock	23	24	150	35
3	Hard Rock	24	25	200	37
4	Backfill	18.5	19.5	14	32
5	Counterweight Fill	18.6	19.6	15	25
6	Concrete Block	20	21	980	40

- **Ground and structural properties must be defined within the model of "(LEM)" .**
- **In case the limit earth pressure (pl) and the horizontal ground modulus of elasticity (KsB) are defined as the structural properties, 'Strip(LEM)', analysis results are not affected.**

Step 01

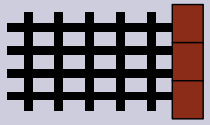
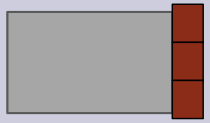
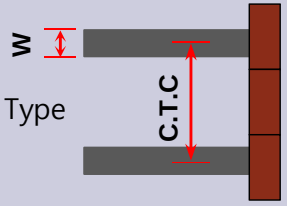
Material Properties

Structural Properties

No	Name /Member Type	Reinforcement Spacing [m]	Initial Diffusion Width [m]	Initial Diffusion Angle [deg]	Tensile Force [kN]	Width [m]	Backfill Unit Weight [kN/m3]	Friction Coefficient
1	Geogrid /Strip(LEM)	1	2	15	150	1	19.5	0.3

Points to consider in entering reinforcement property data

- **Reinforcement Spacing:** in the (transverse) direction of the section thickness
- **Initial Diffusion Width:** to account for the effective width of stress transfer Generally the width of bearing plate is used. In case of no bearing plate, the diameter of Strip may be specified. Even 0 may be specified.
- **Initial Diffusion Angle:** to account for the angle of stress distribution by Strip The angle is obtained from tests, or generally 10 to 15 degrees are used.
- **Tensile Force:** maximum tensile strength of Strip
- **Width:** width of Strip
- **Friction Coefficient:** between the backfill and Strip

Reinforcement Type	Spacing	Tensile Force	Width
Grid Type 	1m	Tensile Force/m	1m
Mat Type 	1m	Tensile Force/m	1m
Strip Type 	C.T.C	Tensile Force/m	W (m)

Step 02 Import > CAD File (*.dwg/*.dxf)

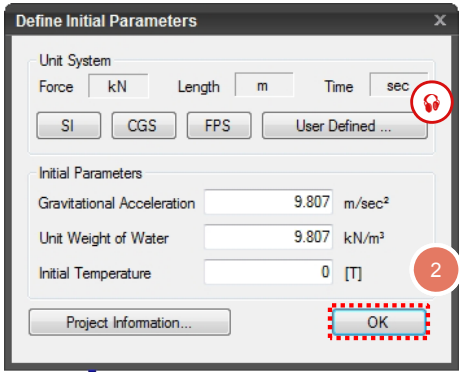
Procedure

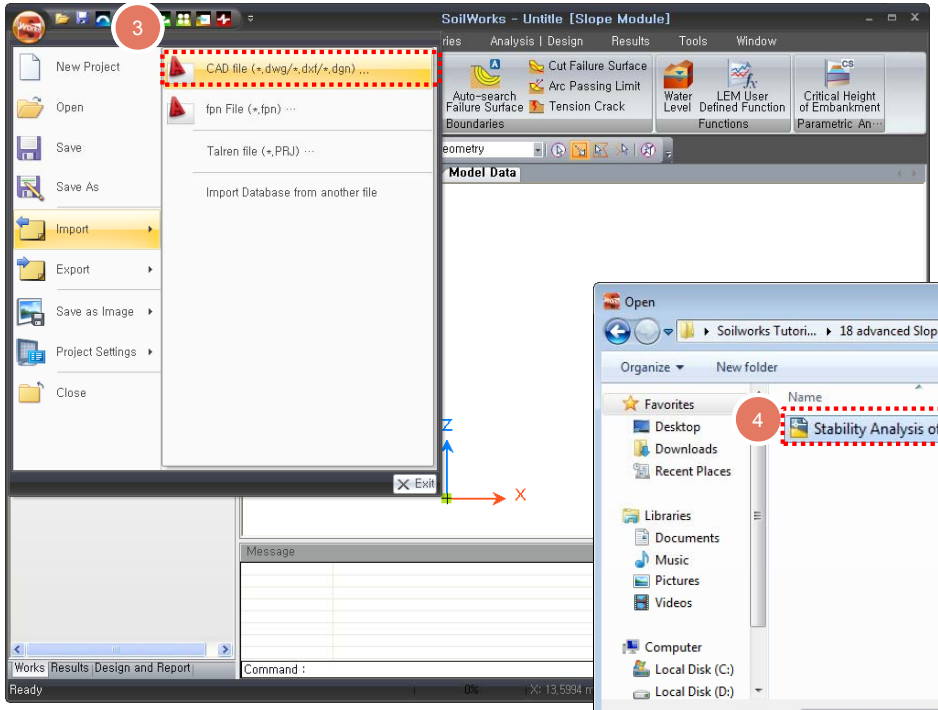
Select the SoilWorks execution icon from the Desktop.

1. Project Manager > click Slope.
2. Define Initial Parameters: click OK.
3. Main Icon > Import > select CAD File.
4. Select ‘Reinforced Earth Retaining Wall Section.dwg’ and click Open.

The user can change the default units for ‘Force’, ‘Length’ & ‘Time’, ‘kN’, ‘m’ & ‘sec’.

The user can also directly copy the object from the CAD program screen & paste it into SoilWorks.

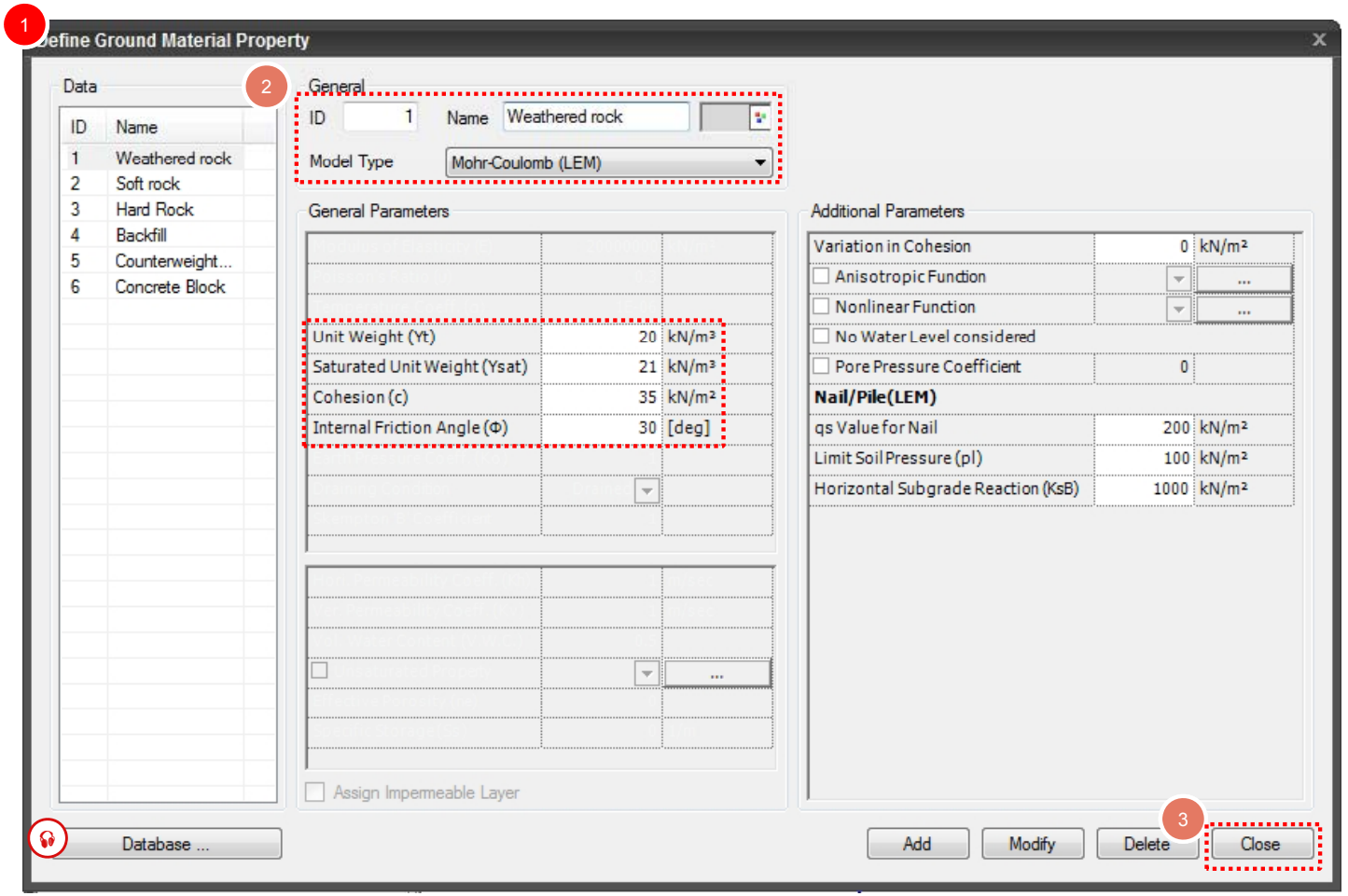




Procedure

1. **From the Main Menu**, select **Limit Equilibrium Method > Ground Material Property (command: gm)**
2. Refer to **Step 01**. to enter the ground material properties and click **Add.**
3. Click **Close.**

SoilWorks permits ground material properties used in projects to be compiled in a database. The database is created by editing the gdb file in SoilWorks/Dbase in the Install folder.



Procedure

1. From the **Main Menu**, select **Limit Equilibrium Method > Structural Property (command: sp)**

   Define Geogrid.

2. Refer to **Step 01**. to enter the structural properties and click **Add.**

3. Click **Close.**

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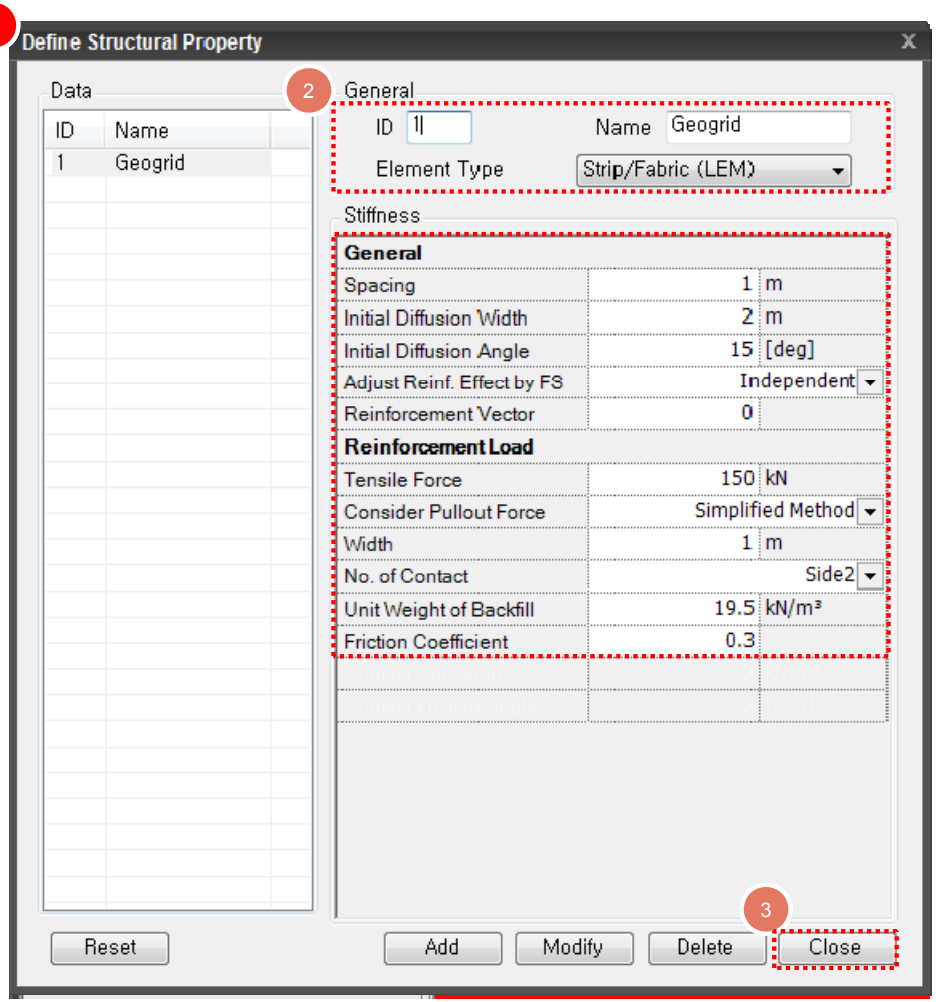


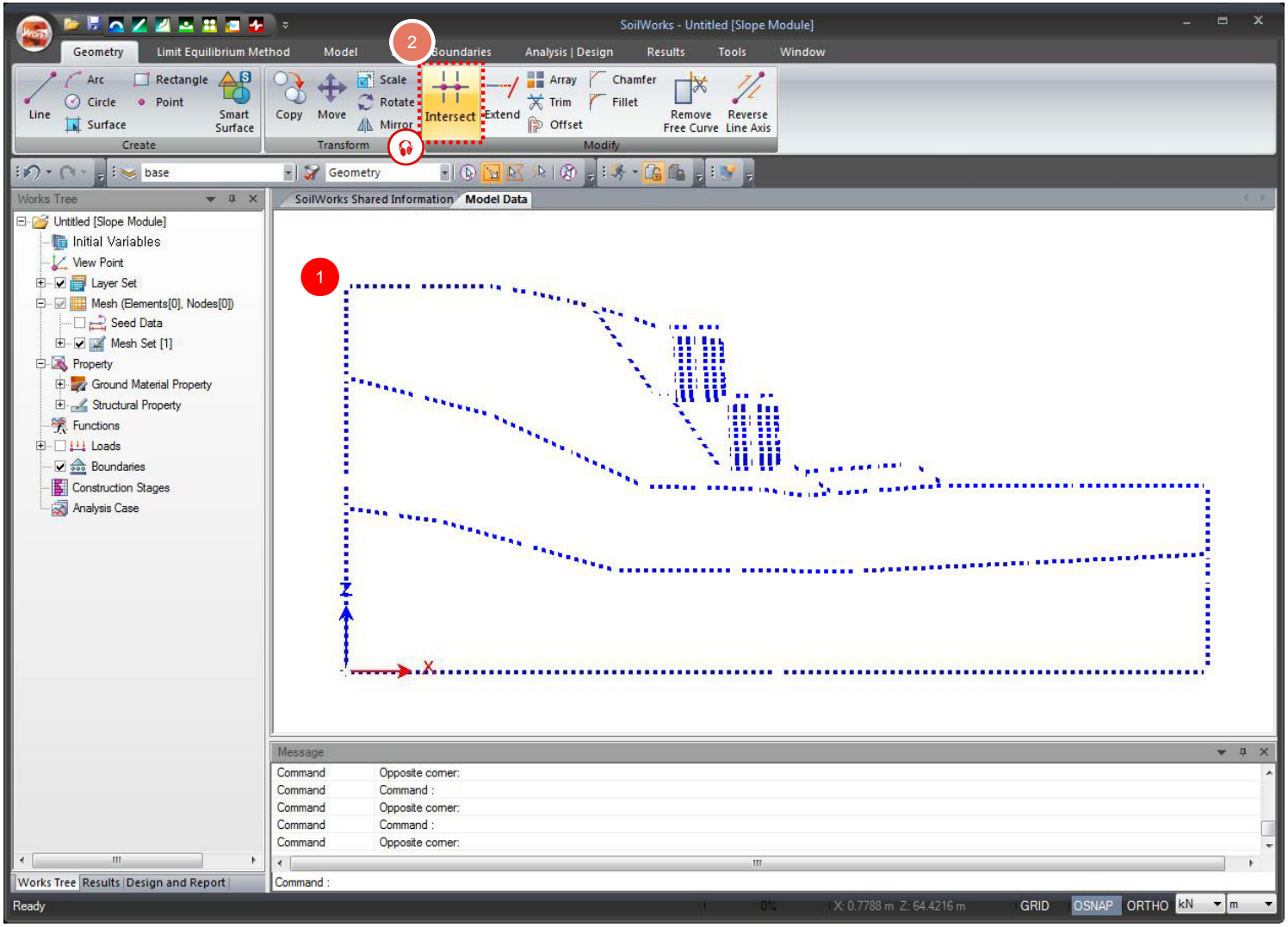
Geometric Shape > **Division at Intersection**

Procedure

Prior to creating surfaces for a complex section like reinforced earth retaining walls,

1. Select all the curves from **Model Data**.
2. From the **Main Menu**, select **Geometric Shape > Division at Intersection**.

In case the objects constituting the section in the CAD file are improperly composed (ie, overlapped curves, minute offsets, etc.), errors may occur in the process of auto-generating the surfaces. **Accordingly, intersections are divided in advance.**



Geometric Shape > **Auto-generate Surfaces**

Procedure

In order to create surfaces to which material properties will be assigned,

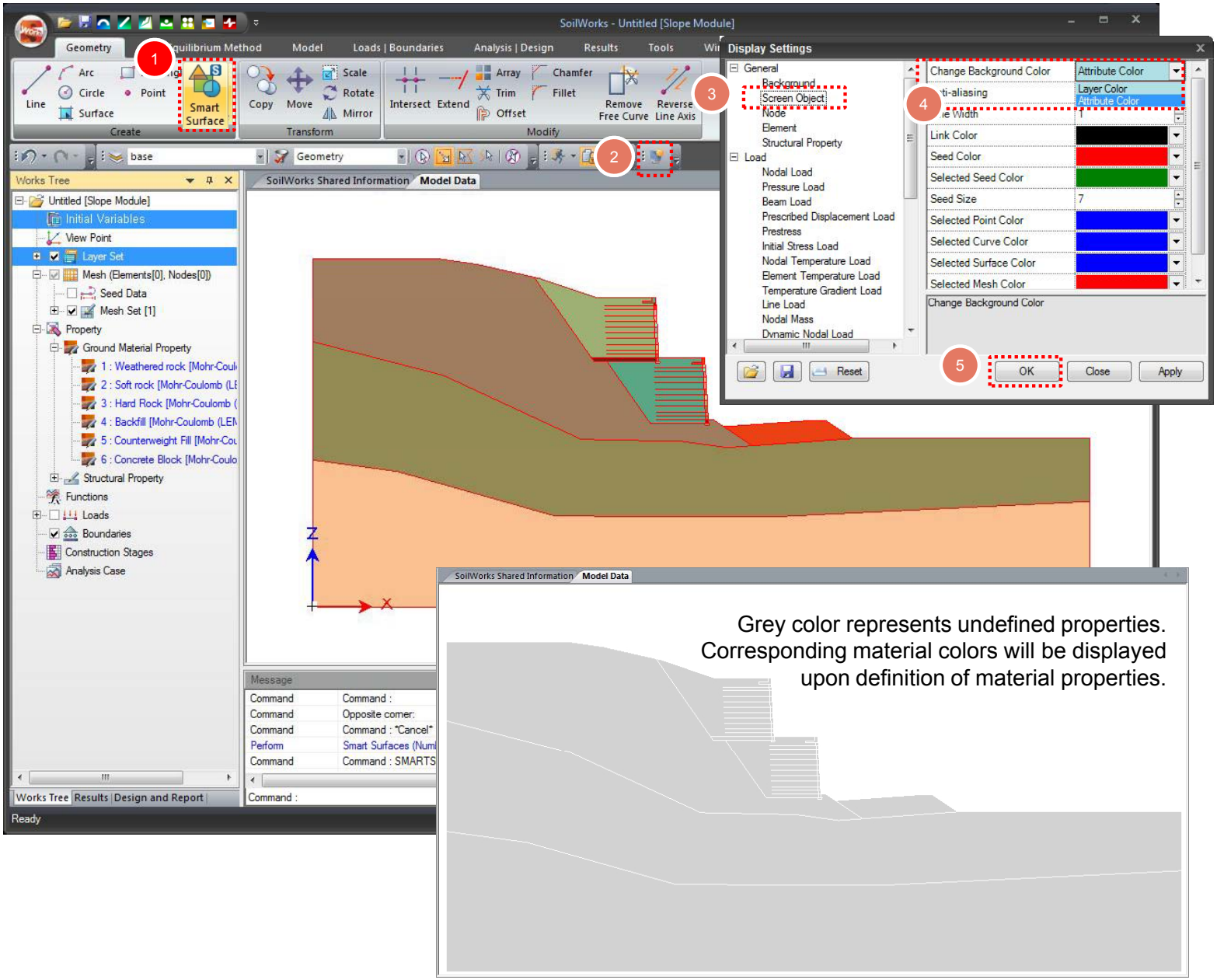
1. From the **Main Menu**, select **Geometric Shape > Auto-generate Surfaces (command: ss)**

2. In order top check proper input of material properties, select **Main Menu > Window > View Setting.** (or select the icon)

3. Select **Display Setting > Screen Object**.

4. Select **Change Background Color > Attribute Color**.

5. Click **OK**.



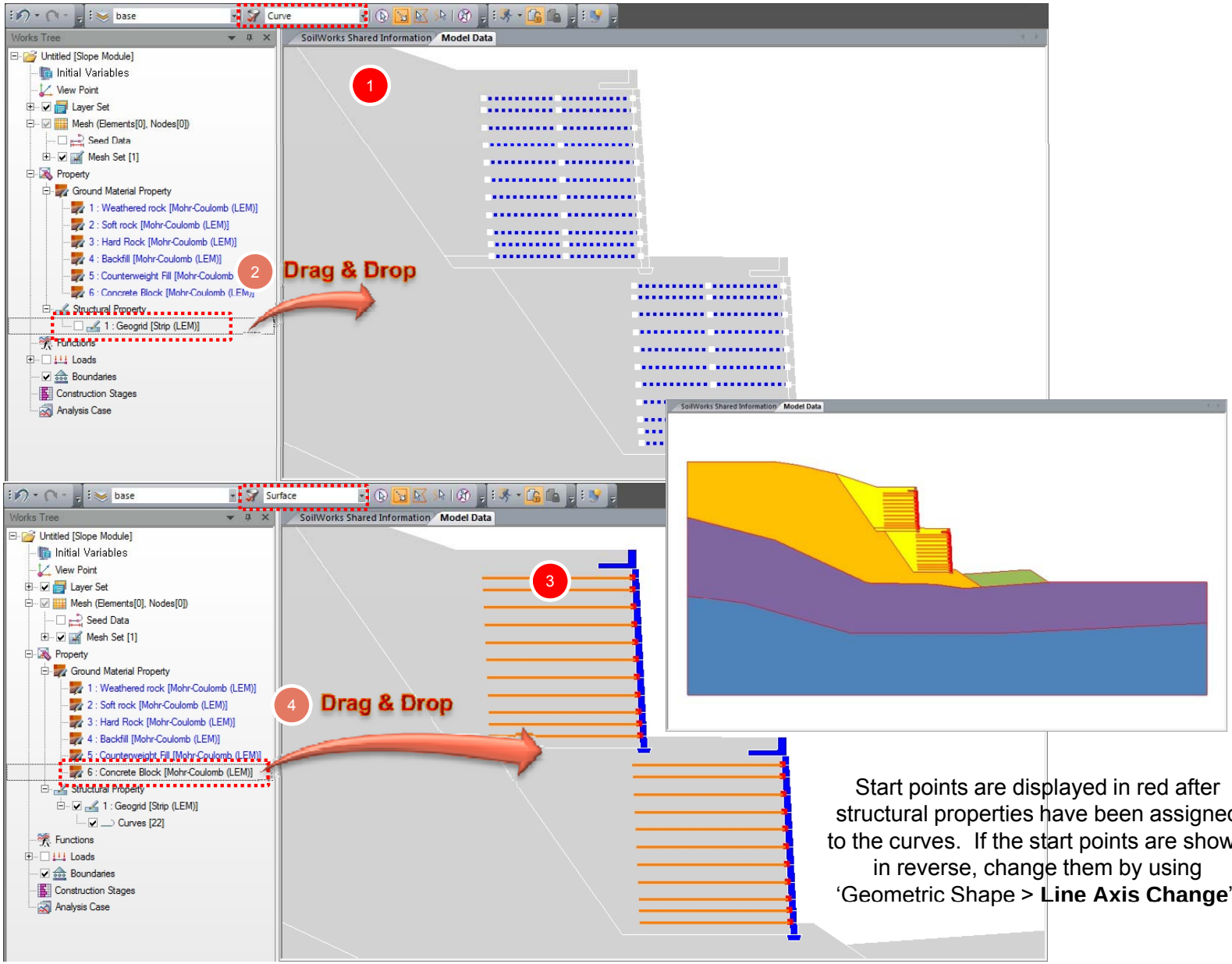
Step 07

Assign Material Properties

Procedure

First, the material properties of the reinforcement are assigned.

1. From the **Model Data**, select 22 curves corresponding to the reinforcement.
2. Select ‘Geogrid’ from the WorksTree and Drag & Drop.
3. From the **Model Data**, select the surfaces corresponding to block and structures.
4. Select ‘Concrete Structure’ under Ground Material Property from the WorksTree and Drag & Drop.
5. Similarly repeat the steps 3-4 sequentially for ‘Hard Rock’, ‘Soft Rock’, ’Weathered Rock’, ’Counterweight Fill’, ’Backfill’ and Drag & Drop.

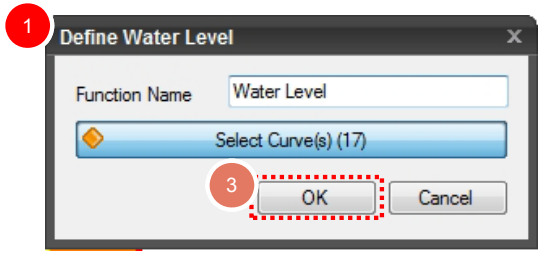


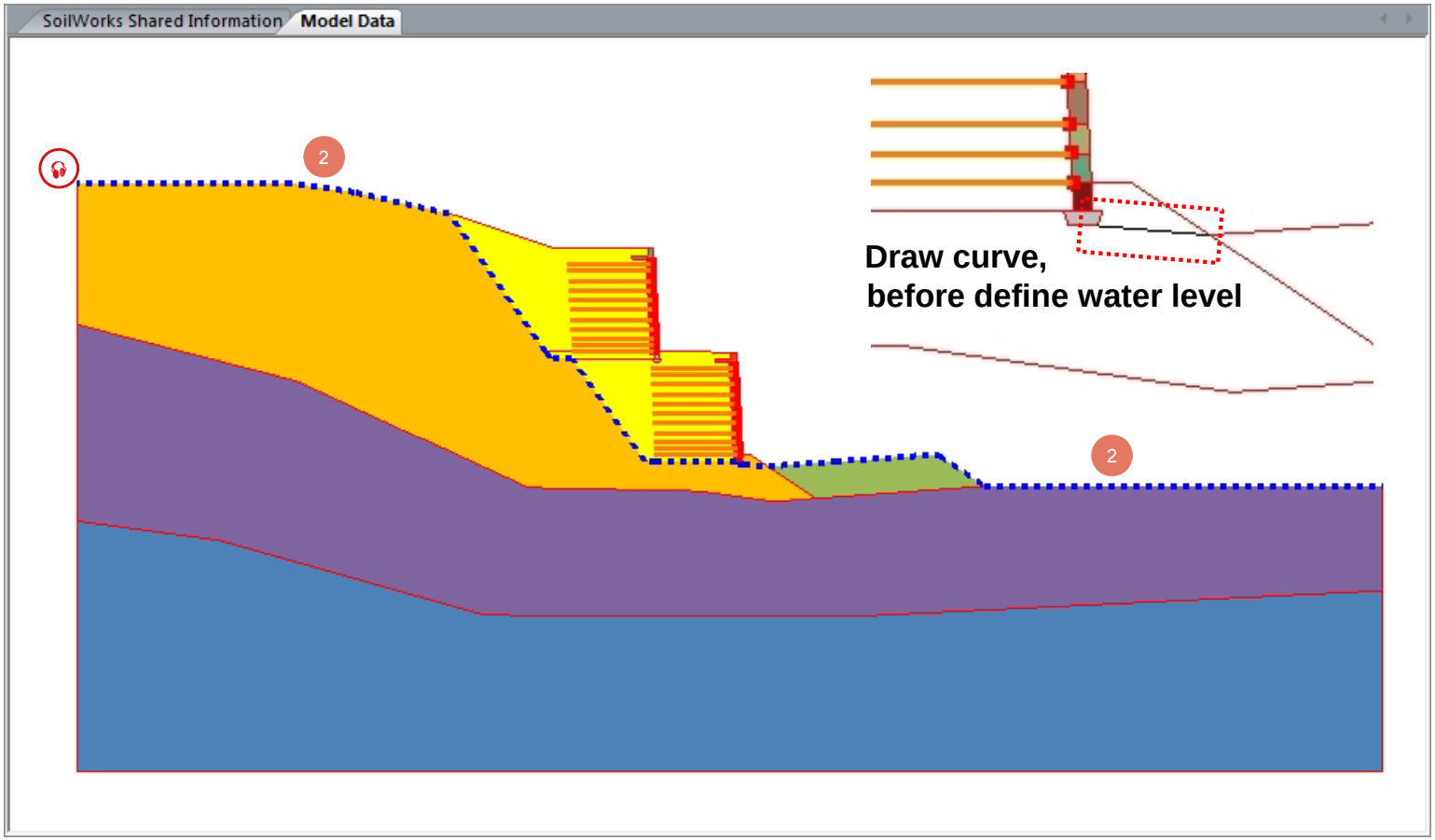
Start points are displayed in red after structural properties have been assigned to the curves. If the start points are shown in reverse, change them by using ‘Geometric Shape > **Line Axis Change**’.

Procedure

1. From the **Main Menu**, select **Limit Equilibrium Method > Water Level**.
2. From the **Model Data**, select the curves by which the water level will be defined (water level is set to the rainy season)
3. Click **OK**.

Saturated Unit Weight (γsat) of Ground Material Properties is used for the ground below the water level, and Wet Unit Weight (γt) is used for the ground above the water level.



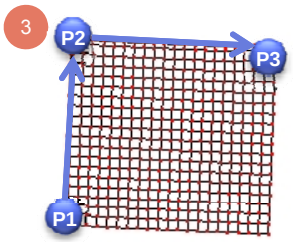


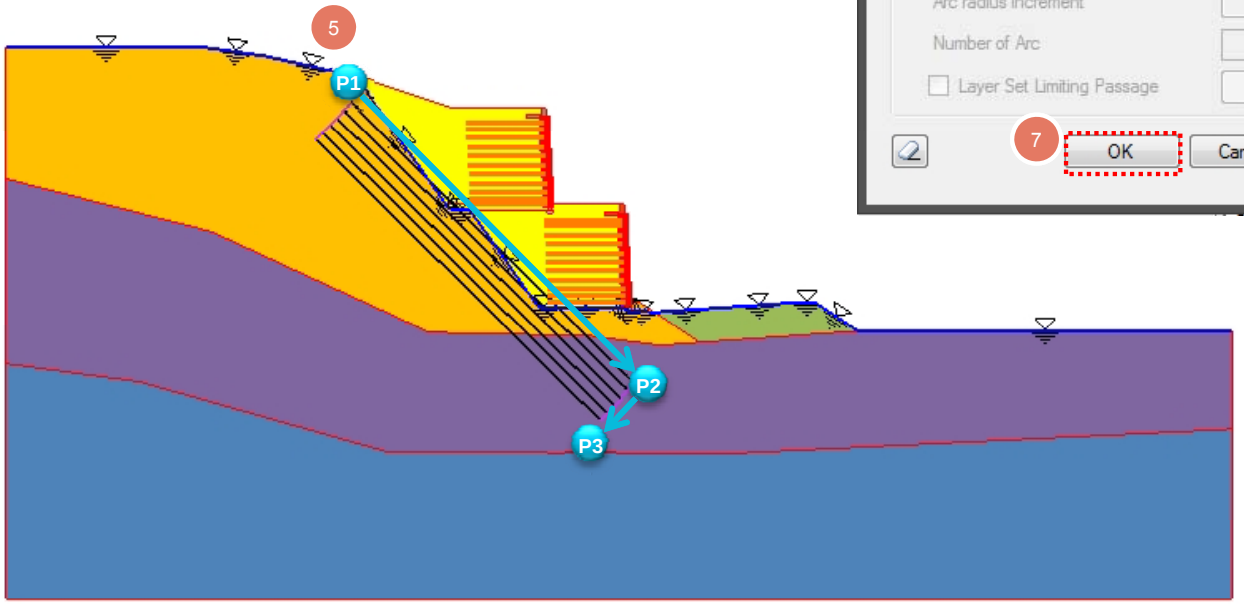
Limit Equilibrium Method > **Circular Failure Surface** (method of using circular tangents)

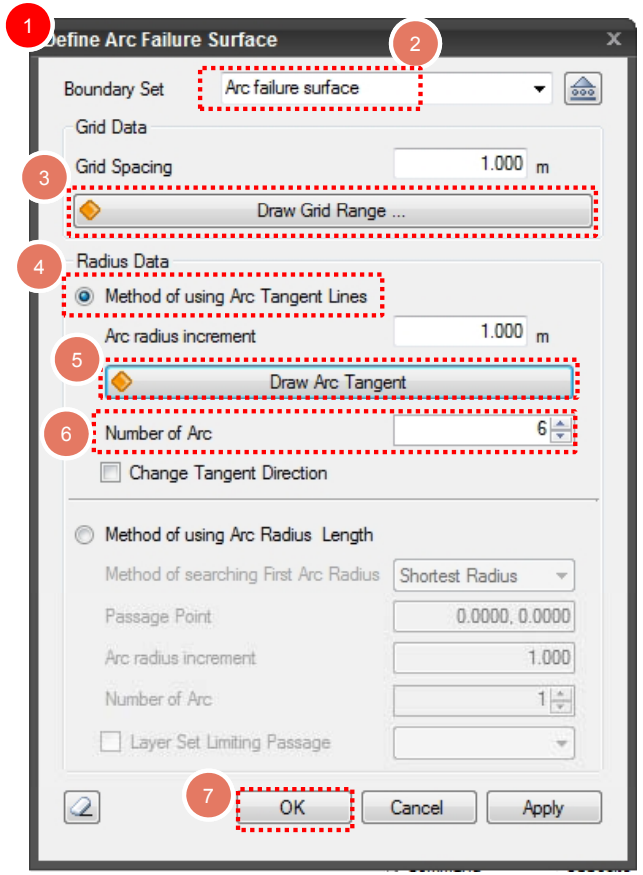
Procedure

1. From the **Main Menu**, select **Limit Equilibrium Method > Arc Failure Surface**.
2. **Boundary Set:** enter **'Arc failure surface'**.
3. Click **Draw Grid Range** and draw the range of grid on Model Data (in the order of P1→P2→P3)
4. Select **Method of using Arc Tangent Lines**.
5. Click **Draw Arc Tangent** and draw the range of tangent lines on Model Data.

   (in the order of P1→P2→P3)
6. **Number of Arc** : enter '**6**'.
7. Click **OK**.



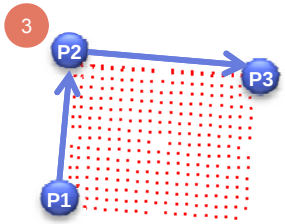


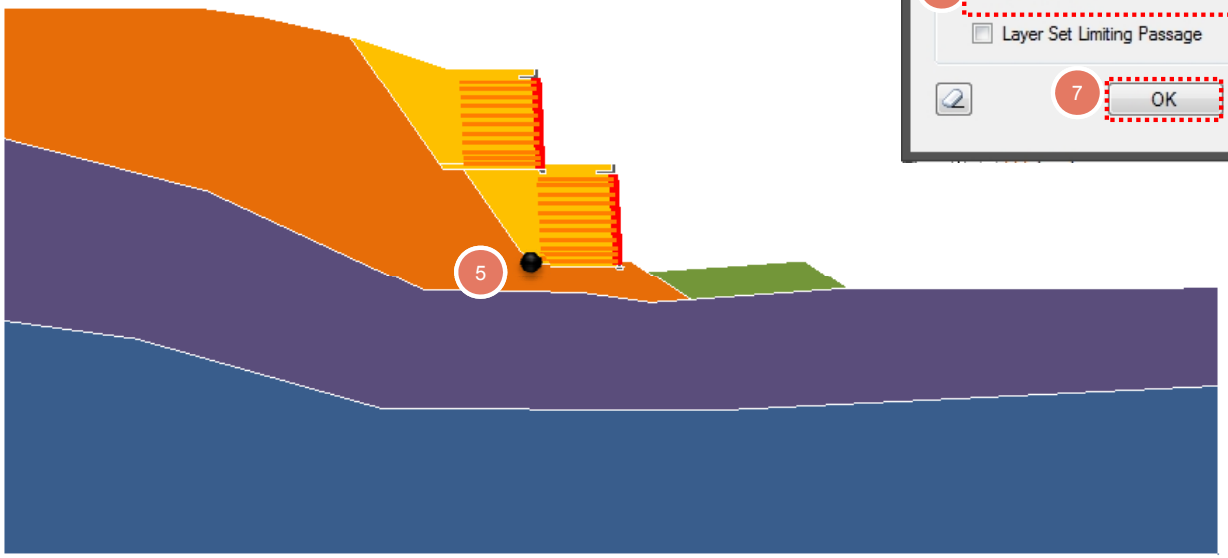


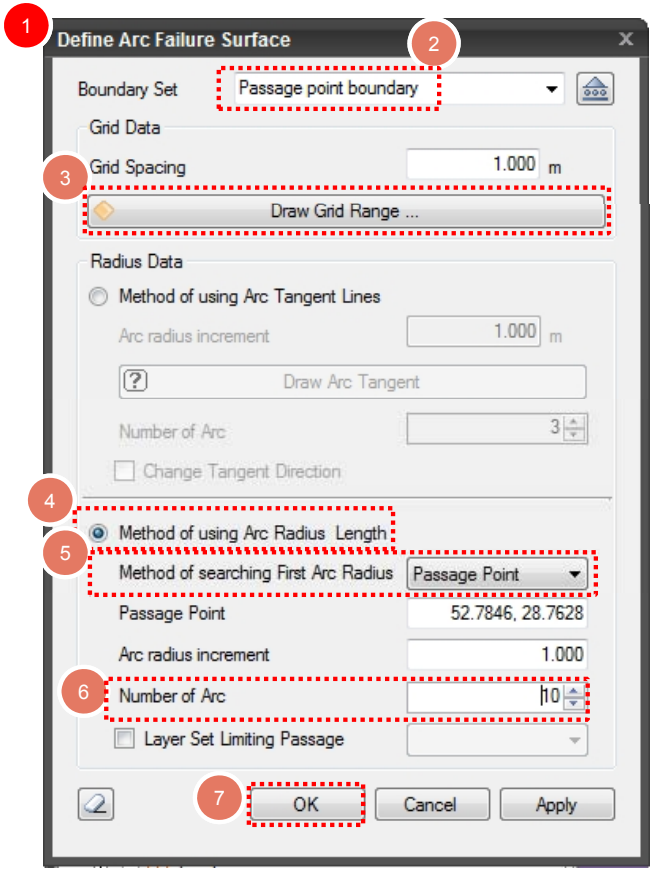
Limit Equilibrium Method > ***Circular Failure Surface*** **(Passing Point Boundary** method)

Procedure

1. From the **Main Menu**, select **Limit Equilibrium Method > Circular Failure Surface**.
2. **Boundary Set:** enter **'Passing point boundary'**.
3. Click **Drawing Grid Range** and draw the range of grid on Model Data (in the order of P1→P2→P3)
4. Select **Method of using Arc Radius Length**.
5. Select **Method of Searching First Arc Radius &** Define **Passing Point**, and enter **'52.7846, 28.7628'** in **Passing Point**. (or, click the **Passing Point** entry field and click the passing point on Model.)
6. **Number of Arc** : enter '**10**'.
7. Click **OK**.



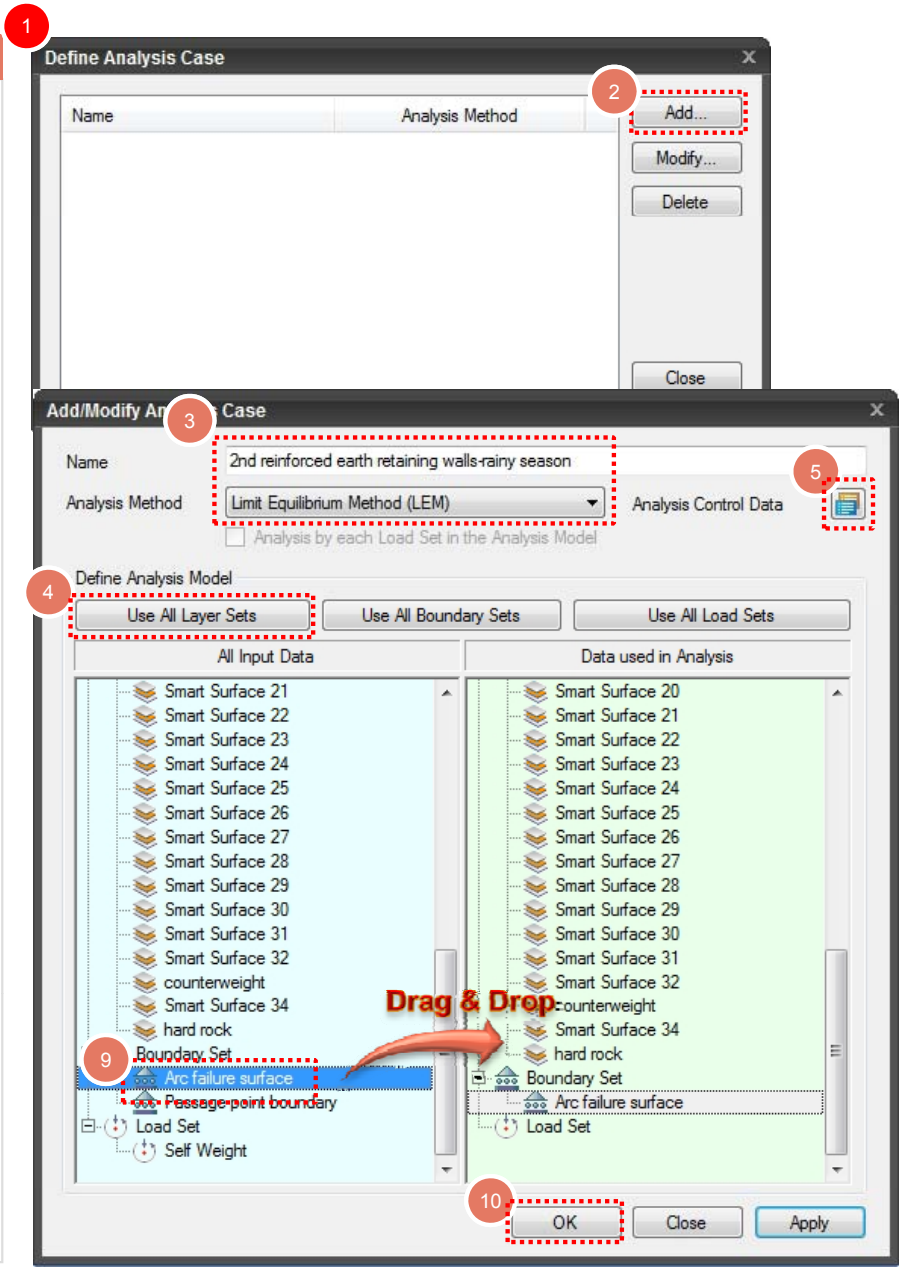


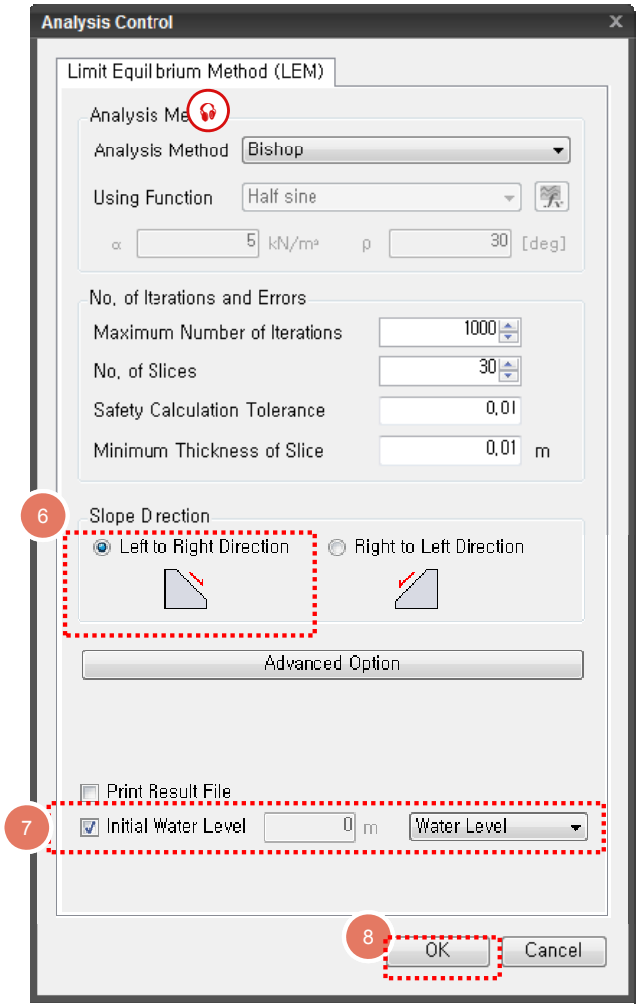


Procedure

1. From the **Main Menu**, select **Analysis/Design > Analysis Case**.
2. Click **Add**.
3. **Name**: enter **'2nd Tier Reinforced Earth-Rainy Season'**, and select **Analysis Method**: **Slope Stability (LEM) Analysis**.
4. Click **Use all Layer Sets** &
5. Click **Analysis Control Data**.
6. **Slope Direction**: select **'Left to Right'**.
7. Check on **Initial Water Level** and select **'Water Level'**.
8. Click **OK**.
9. Drag & Drop 'Arc failure surface' into Data used in Analysis
10. Click **OK**.

Analysis methods are 'Bishop', 'Fellenius' and 'Janbu'.

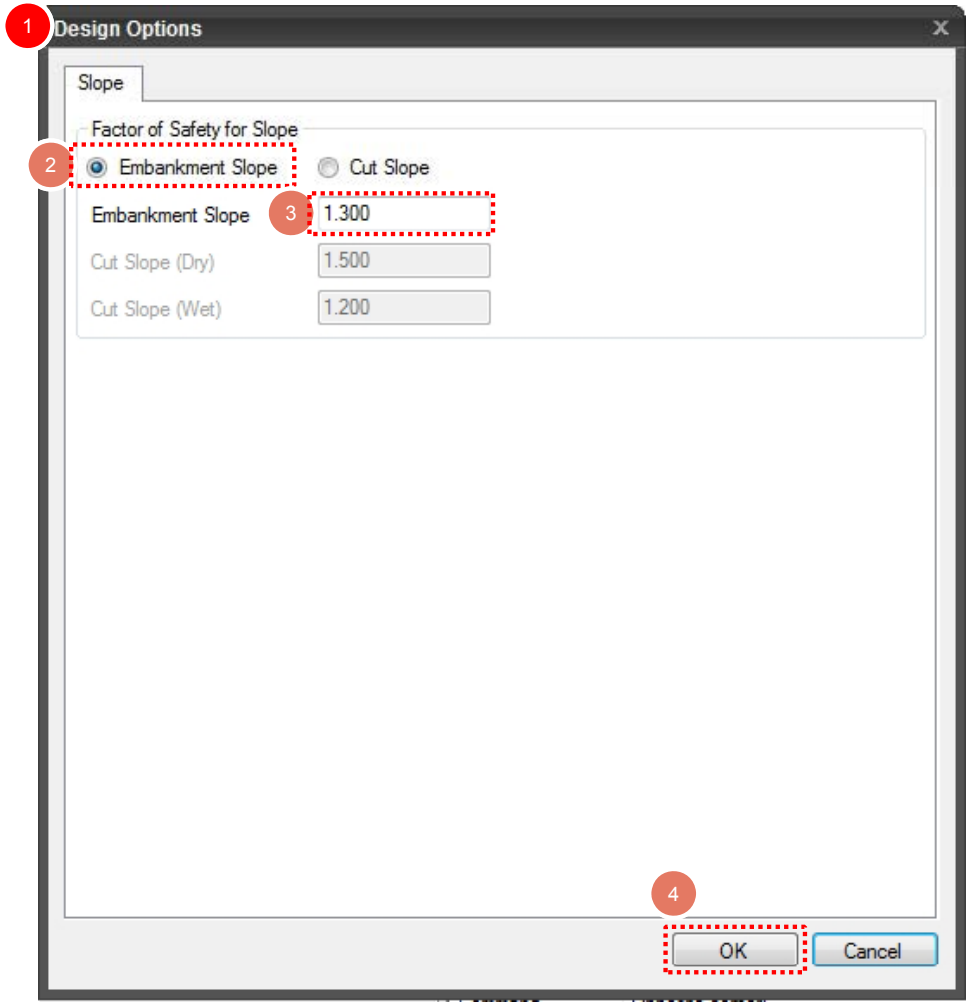




Analysis/Design > **Design Option**

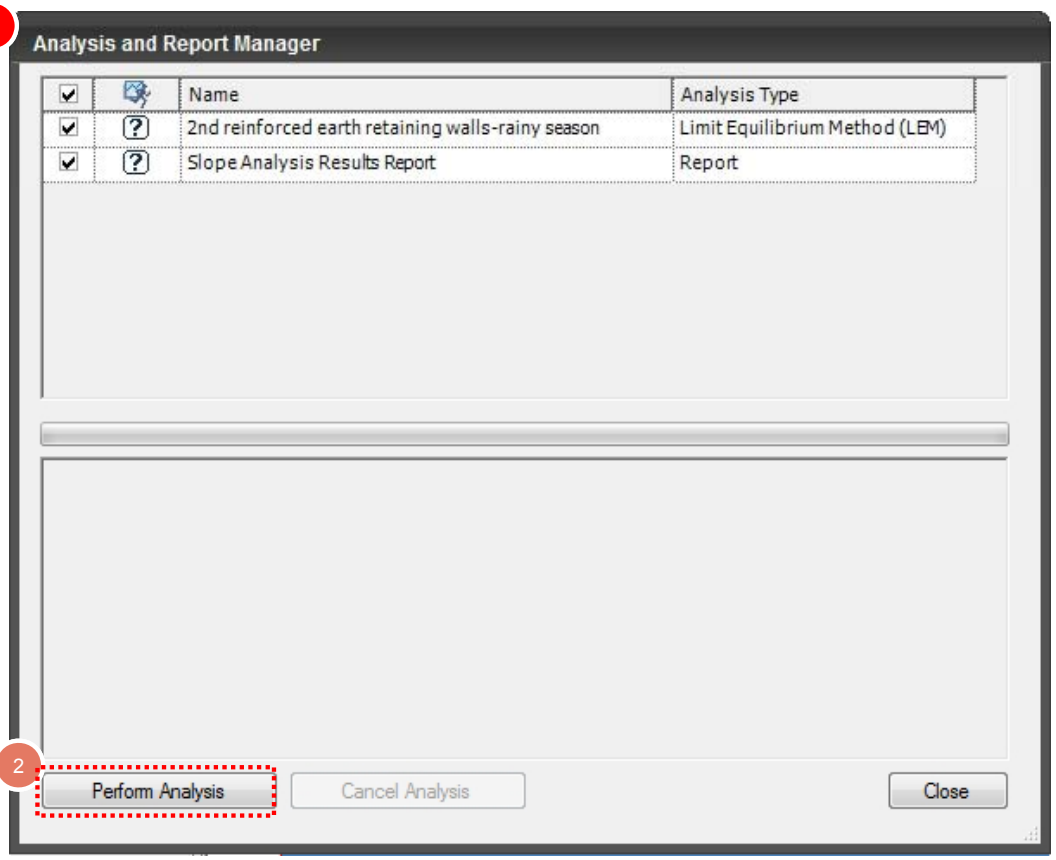
Procedure

1. From the **Main Menu**, select **Analysis/Design > Design Option**.
2. Select **Embankment Slope**.
3. Enter **'1.3'**
4. Click **OK**.



Procedure

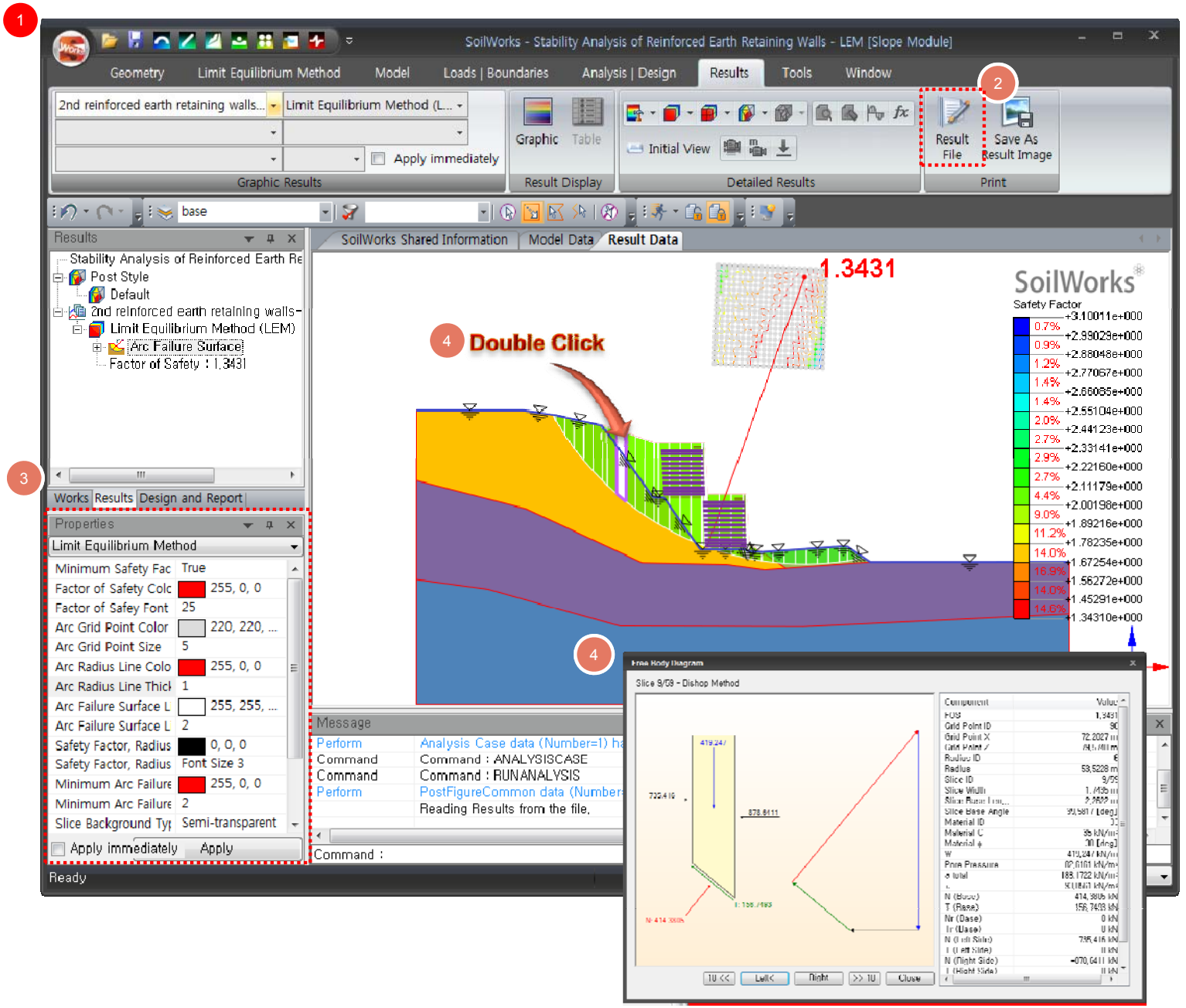
1. From the **Main Menu**, select **Analysis/Design > Analysis & Report**.
2. Click **Perform Analysis**.



Results > Result Analysis

Procedure

1. From the **Result WorksTree**, check **'Safety Factor'** of Slope Stability Analysis.
2. **Results > Result File** produces the results in a text file (*.txt).
3. **Property Window**: select **'Legend'**, **'Limit Equilibrium Method'** & **'Limit Equilibrium Method Contour'**, and maneuver the detail items.
4. Upon double-clicking a specific slice of the arc, detail data of the slice (Free Body Diagram) can be checked.
5. The result data background color **[Command: BK]** can be changed from **Main menu > Window > View Setting: Background Display**.

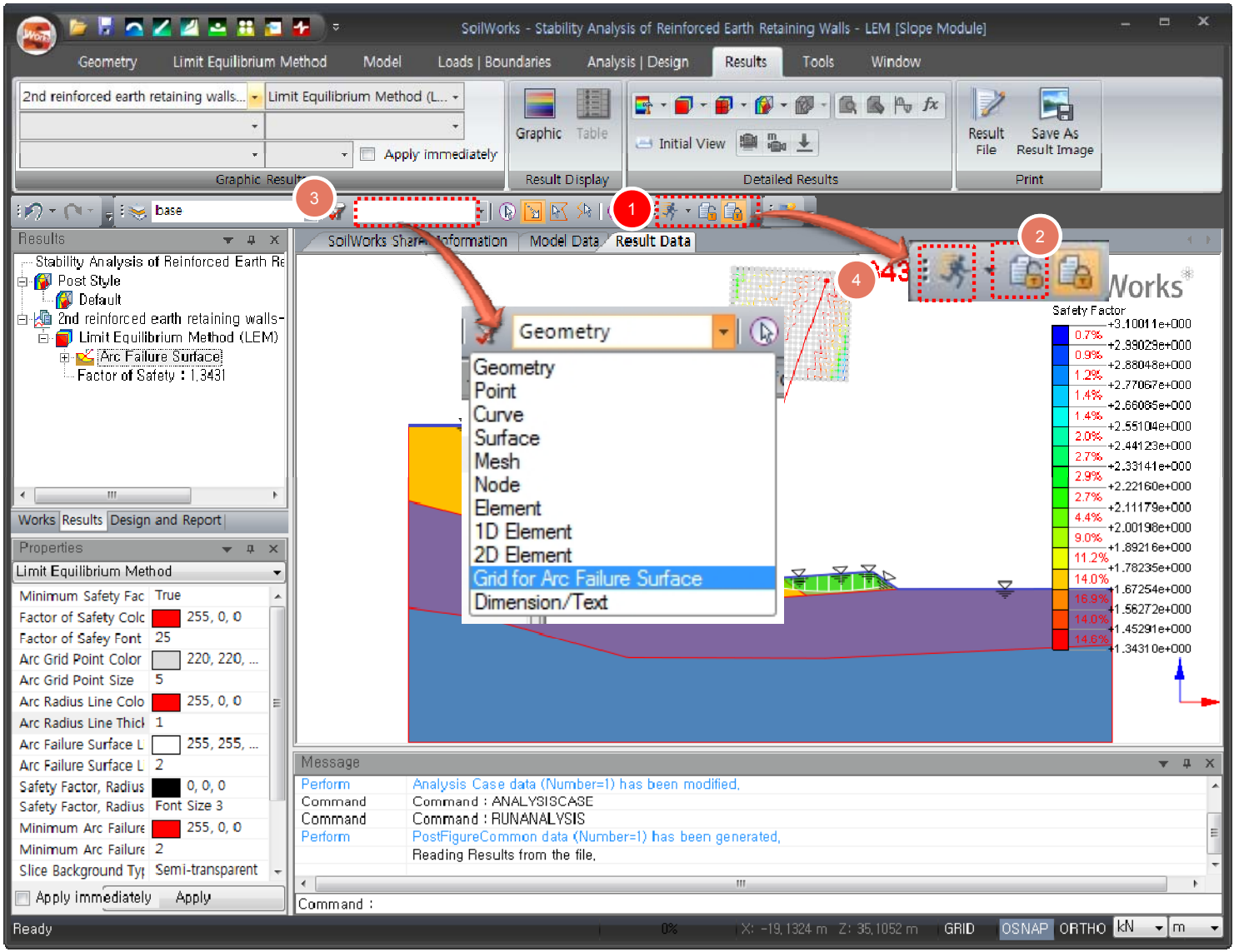


Step 14

Result Analysis & Re-Analysis

Procedure

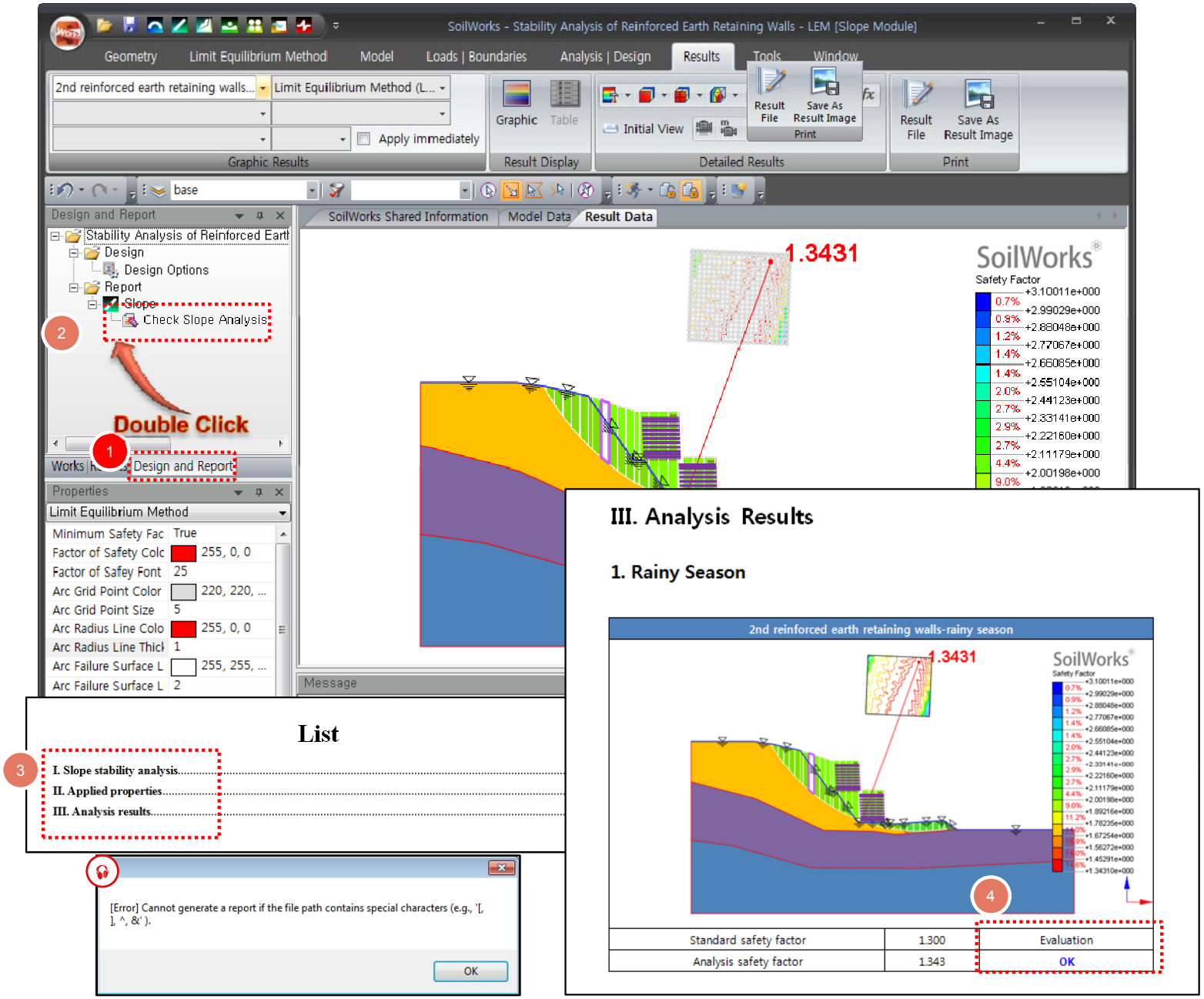
1. Upon execution of **Pre Mode/Post Mode** analysis, **Post Mode** automatically becomes active when results are produced.
2. If re-analysis is sought, any change in data such as the arc grid or arc tangents need to be revised after switching to the **Pre Mode**.
3. Select **Filter > Grid for Arc Failure Surface** to move or revise the **Failure Arc Center Grid**.
4. Once the model has been revised, repeat the ***STEP 12*** for re-analysis.



Procedure

1. Select **Design & Report** Workstree
2. Double click **'Slope Analysis Check'** to check the report Word file, which is created in the folder of the model file.
3. The contents of the Slope Report consist of **1. Slope Stability Analysis, 2. Applied Material Properties** and **3. Safety Factor Results**.
4. Evaluation against the safety factor reference defined in Design Option is reported in terms of **OK** *(acceptable)* **/NG** *(unacceptable)*.

When generating the report, the file path, file folder and file name must not include ' [,] , ^ , & ' .



Initial diffusion width and angle of reinforcement

When LEM is used to analyze slope stability in practice, it is not straightforward to account for the stiffness of the reinforcement. The safety factors are sensitive to the values of the diffusion width and the diffusion angle, the effects of which are often overlooked.

When reinforcement is inserted in a slope for LEM analysis, a certain increase in strength of a slice within the diffusion range needs to be reflected. The diffusion range is determined first by the diffusion width perpendicular to the reinforcement and the spread of the width by the diffusion angle, in contact with the failure arc as shown in hatch below. It is recommended that the initial diffusion width be 1.0m or 2.0m corresponding to the size of anchor plates, and the initial diffusion angle be 10 to 20 degrees.