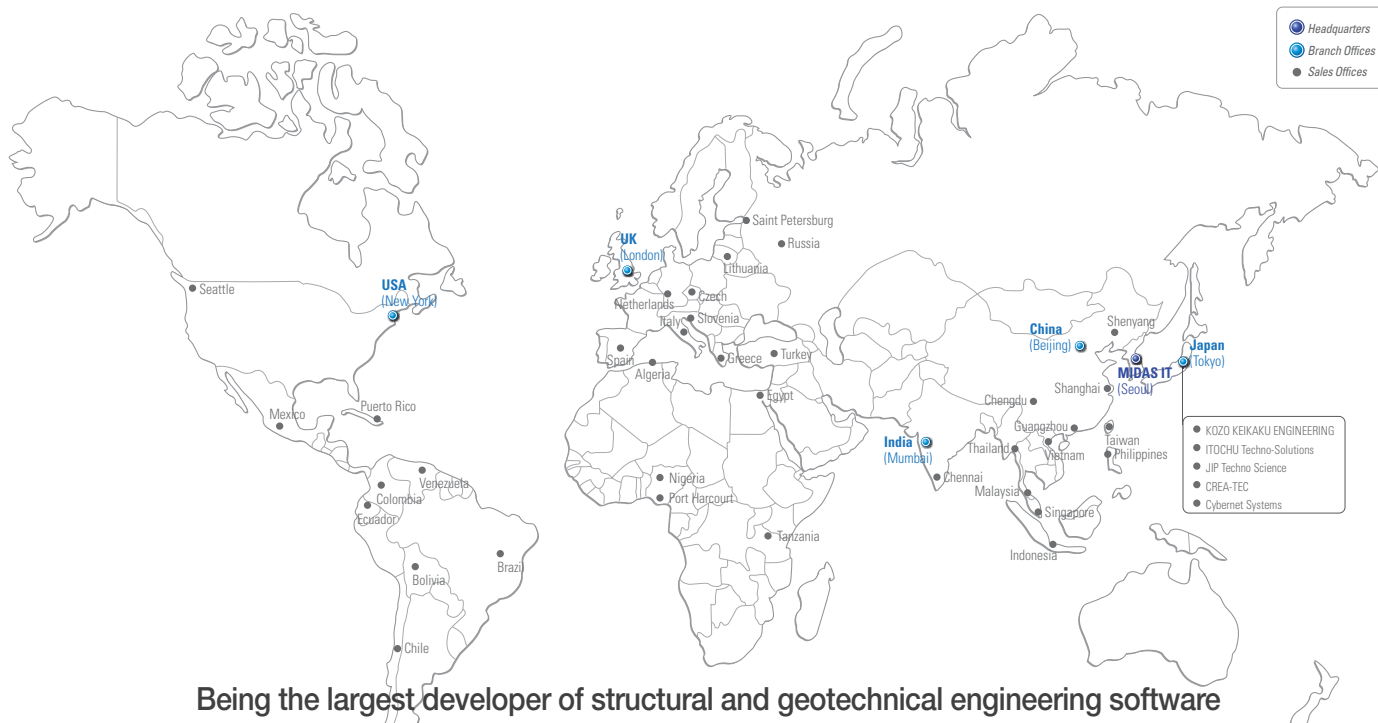


# SoilWorks

SLOPE PACKAGE

GEOTECHNICAL SOLUTION  
FOR PRACTICAL DESIGN

## A LEADING GLOBAL Engineering Solutions Provider



Being the largest developer of structural and geotechnical engineering software with extensive research in leading technologies in the world, MIDAS has garnered global recognition through its continuous passion and devotion towards the Advancement in Civil Engineering.

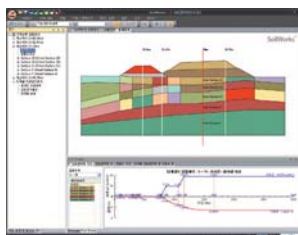
a total of over 30,000 MIDAS software licenses used worldwide in over **120** countries

a global network of engineering software distribution and technical support

over 450 engineers and professionals develop and distribute engineering software

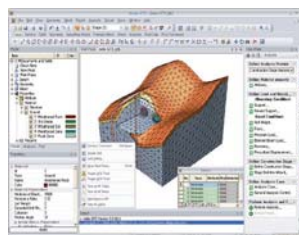
### ❖ Introducing geotechnical finite element programs

a New Paradigm for  
Geotechnical Engineering Solutions, all in one package



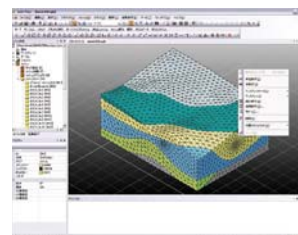
#### **SoilWorks**

2 Dimensional geotechnical analysis modules



#### **midas GTS**

3 Dimensional geotechnical analysis modules



#### **Soil+**

(CTC in Japan)

# Slope Package



## Applications

- 01 Slope Stability (LEM / SRM / SAM)
  - Stability with construction stage
  - Seepage – Slope coupled analysis
- 02 Lateral displacement of pier and abutment
- 03 Steady state / Transient seepage analysis
- 04 Design impermeable wall for embankment
- 05 Critical height of embankment considering increase in strength of softground
- 06 Stability of rock slope – stereographic analysis of discontinuities
- 07 Plane / Wedge failure of rock slope
- 08 Reinforcement / Improvement method check for slope and softground
- 09 Settlement of softground with parametric study (Drain spacing / Preloading)
- 10 Seepage-Softground-Slope coupled analysis

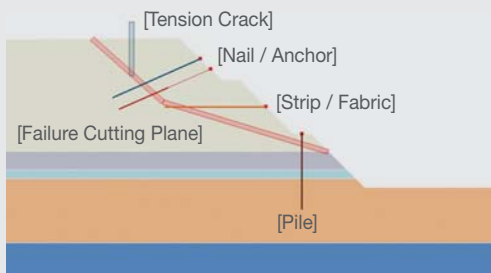


# SoilWorks Slope

## Slope Stability Analysis

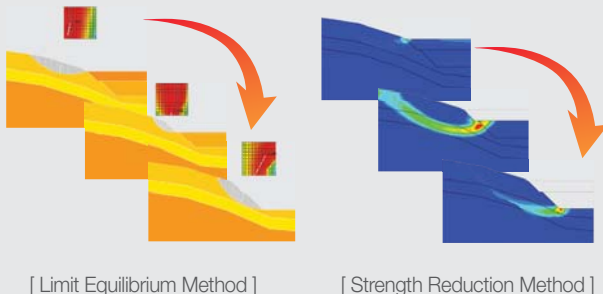
### Limit Equilibrium Method

- Define composite failure surfaces
- Reinforcing effect by reinforcement types and behavior
- Various analysis method for accurate result



### Staged Slope Stability Analysis

- Staged analysis for cut / fill slope
- Stress / strain distribution of ground
- Design reinforcement force



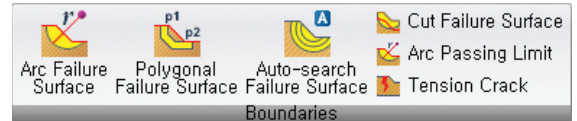
### Report Generation

- Result summary for all of analysis cases
- Provide result tables and images in single document

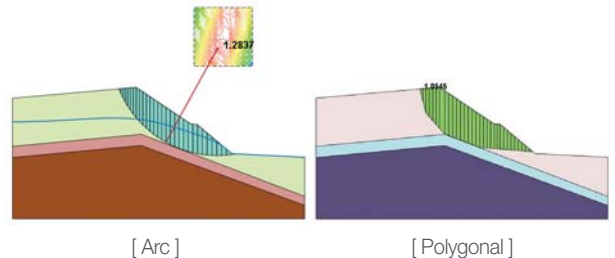


## 1. Define Failure Surfaces

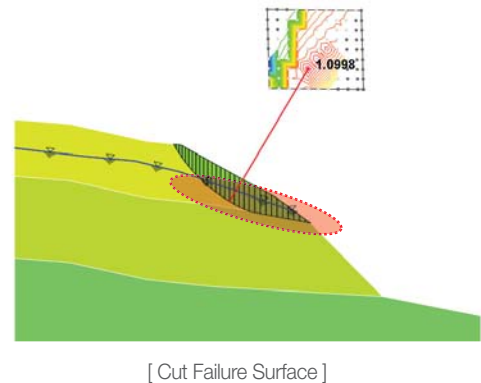
### | Composite Failure Surfaces



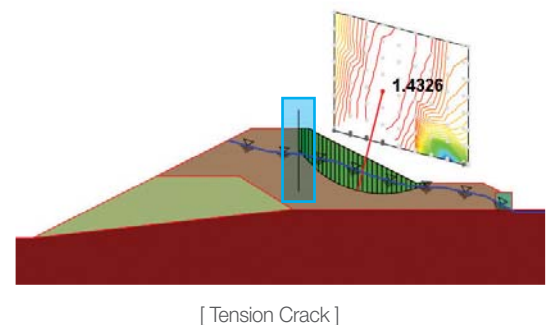
- Arc / Polygonal / Auto-search failure surface



- Cut failure surface / Arc passing limit



- Tension crack (Auto Search)
- Water pressure acting on tension crack



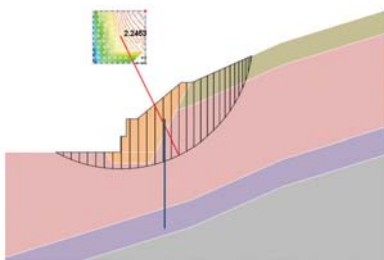




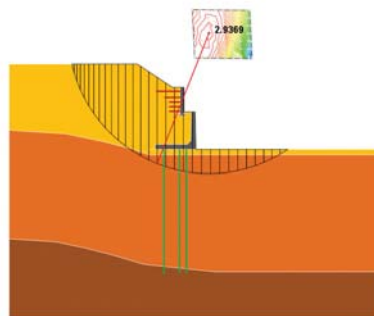
## 2. Reinforcement

### Define Reinforcing Effect with Reinforcement Types

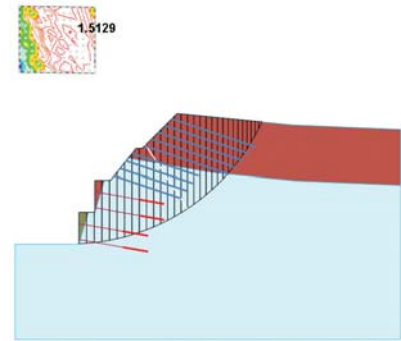
- Nail / Pile / Anchor / Fabric (Geogrid) / Strip / Strut
- Tensile force / Pullout force / Shear force / Frictional resistance / Compressive force
- Consider rigid or flexible behavior



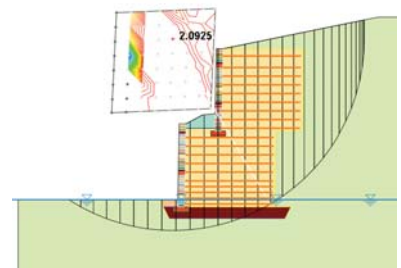
[ Pile ]



[ PHC Pile ]



[ Nail + Anchor ]



[ Geogrid ]

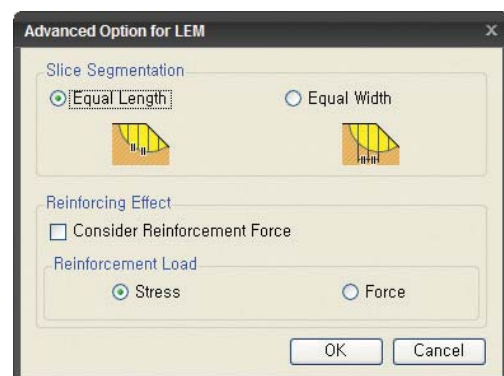
## 3. Analysis Methods / Options for LEM

### Advanced Analysis Methods

- Simplified methods : Bishop / Fellenius / Janbu
- Advanced methods : Spencer / Morgenstern – Price / Sarma
  - Satisfy force (Vertical / Horizontal) and moment equilibrium

### Advanced Analysis Options

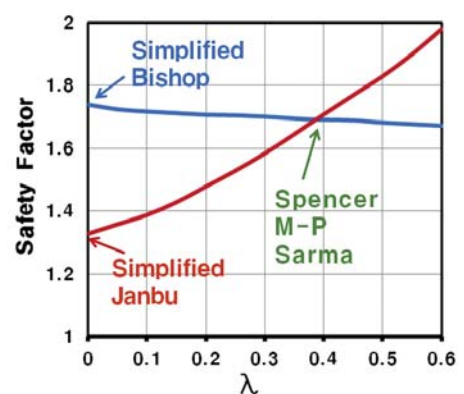
- Slice segmentation – Equal length / Equal width
- Reinforcement load – Stress / Force



[ Advanced Option for LEM ]

Analysis Method	Strength	Weakness
Simplified Bishop	<ul style="list-style-type: none"> <li>• Short analysis time</li> <li>• Applicable to arc / Polygonal</li> </ul>	<ul style="list-style-type: none"> <li>• Inaccurate result when horizontal force is acting (i.e., seismic load)</li> </ul>
Simplified Janbu	<ul style="list-style-type: none"> <li>• Short analysis time</li> <li>• Suitable for shallow slope</li> </ul>	<ul style="list-style-type: none"> <li>• More conservative result</li> </ul>
Spencer	<ul style="list-style-type: none"> <li>• Applicable to arc / Polygonal</li> <li>• More accurate safety factor</li> </ul>	<ul style="list-style-type: none"> <li>• Longer analysis time</li> <li>• More sensitive convergence</li> </ul>
Morgenstern-Price	<ul style="list-style-type: none"> <li>• Predictable internal normal force</li> <li>• More accurate safety factor</li> </ul>	<ul style="list-style-type: none"> <li>• Longer analysis time</li> <li>• More sensitive convergence</li> </ul>
Sarma (vertical)	<ul style="list-style-type: none"> <li>• Suitable for rock slope analysis</li> <li>• More accurate safety factor</li> </ul>	<ul style="list-style-type: none"> <li>• Longer analysis time</li> <li>• More sensitive convergence</li> <li>• Assumption needed for cohesive strength and friction angle</li> </ul>

[ Comparison of Analysis Methods ]



[ Variation of FS with the ratio of Ver. to Hori. Slice Force ]



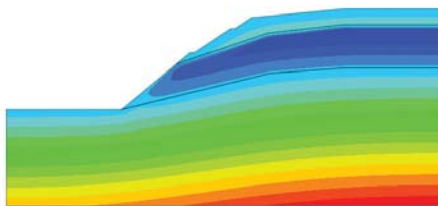
# SoilWorks Slope

## 4. Coupled Analysis for Slope Stability

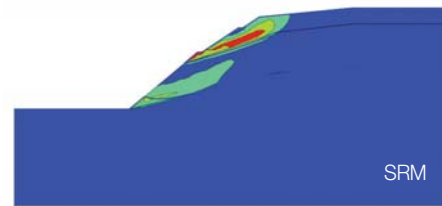
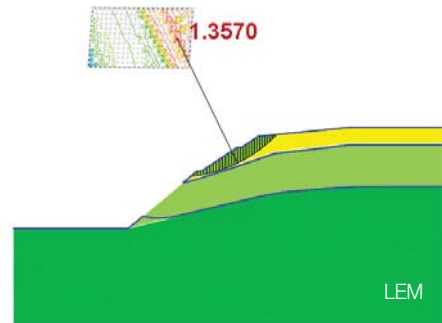
### | Seepage-Slope Coupled Analysis



- Effect of rainfall intensity and duration
- Limit Equilibrium Method : P.W.P from seepage analysis
  - Safety factor according to the failure surfaces
- Strength Reduction Method : P.W.P from seepage analysis
  - Maximum shear strain and stress with safety factor



[ Distribution of Pore Water Pressure ]

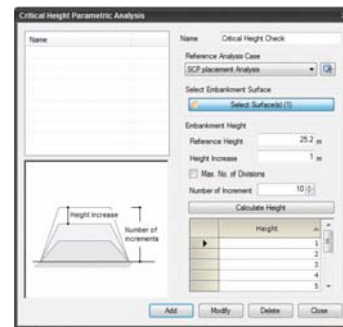


[ Slope Stability during and after Rainfall ]

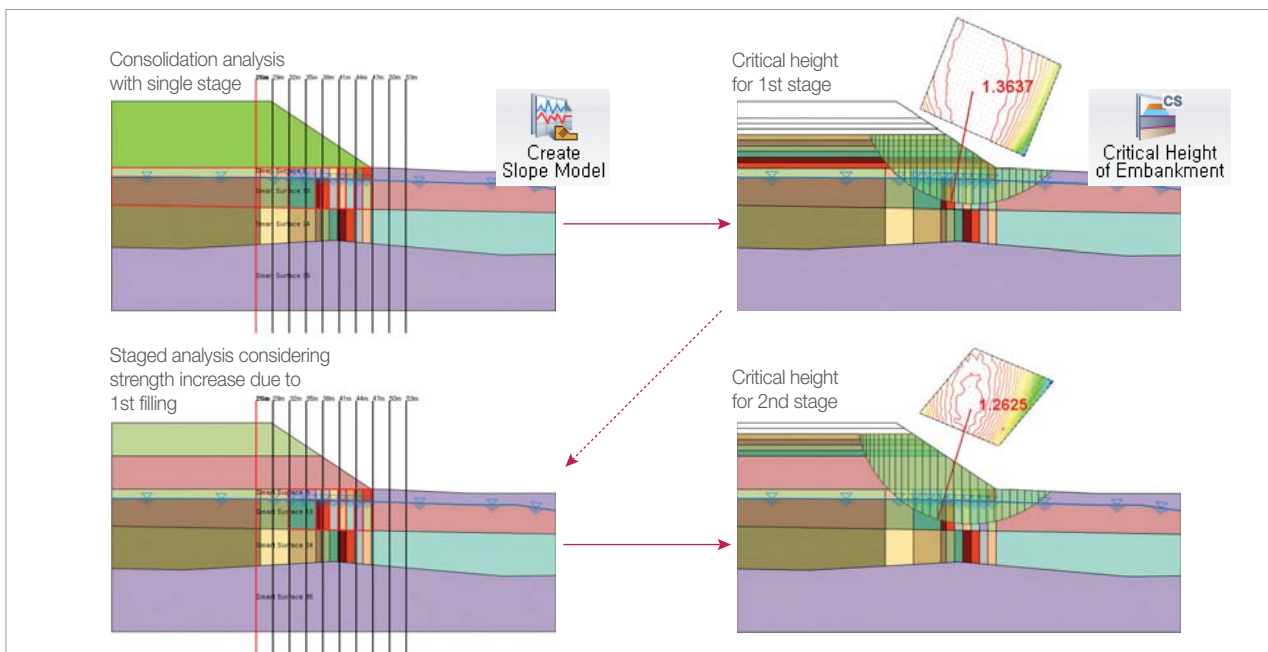
### | Softground-Slope Coupled Analysis



- Check critical height of embankment over softground
  - Divide surface and create analysis case for each increase of embankment automatically
  - Take account of strength increase of softground
  - Check critical height for each construction stage



[ Critical Height of Embankment ]



[ Check Critical Height for Each Construction Stage ]



# SoilWorks Seepage

## 1. Seepage Analysis

### | Effect of Rainfall with Infiltration Rate

- Define unit flux with seepage rate
- Seepage rate according to the slope inclination
  - Slope inclination vs Seepage rate (Unit flux reduction factor)

**Surface Flux**

Value:  m³/sec/m²

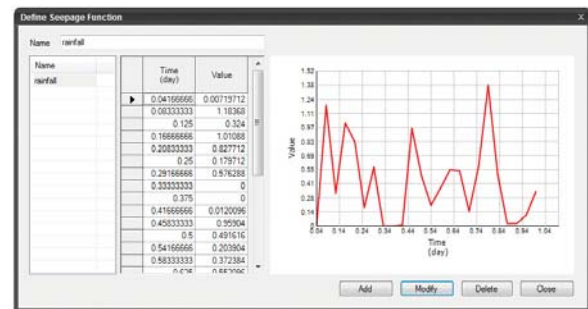
Function:

**Seepage Rate**

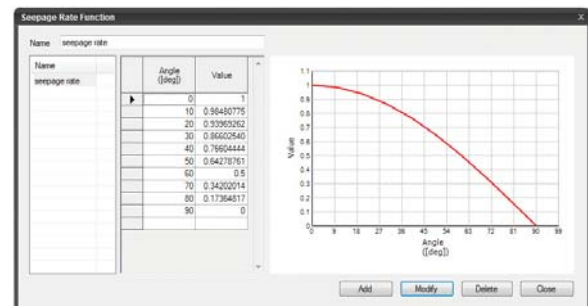
Value:

Function:

[ Unit Flux / Seepage Rate ]



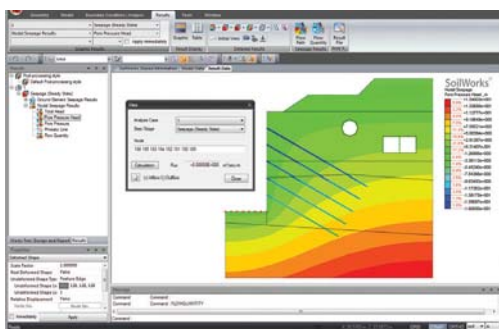
[ Seepage Function (value with time) ]



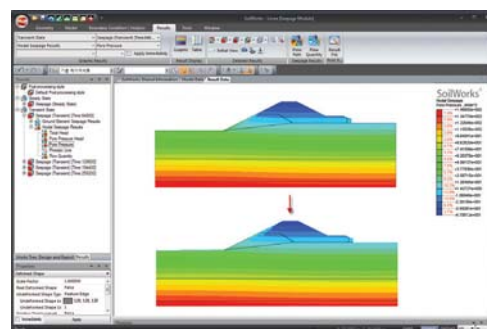
[ Seepage Rate Function (value with degree) ]

### | Application of Seepage Analysis

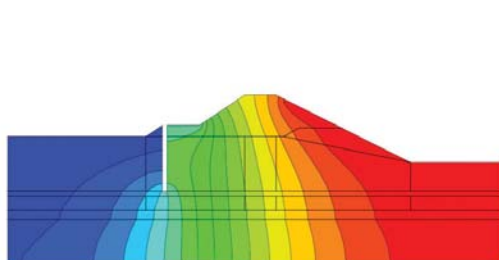
- Saturated / Unsaturated property of ground
- Variation of water level with time
- Seepage force effect
- Seepage-Slope coupled analysis
- Earth Dam / Embankment stability
- Design impermeable wall for embankment
- Design pump capacity during excavation



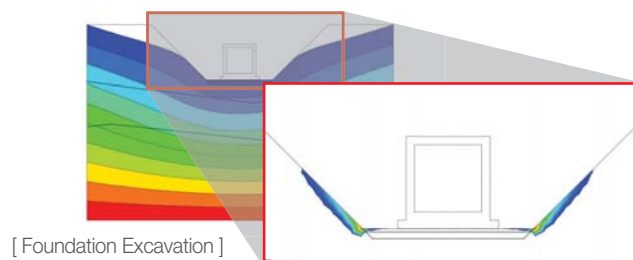
[ Retaining Wall ]



[ Transient Analysis ]



[ Impermeable Wall ]



[ Foundation Excavation ]

[ Outflow Discharge ]

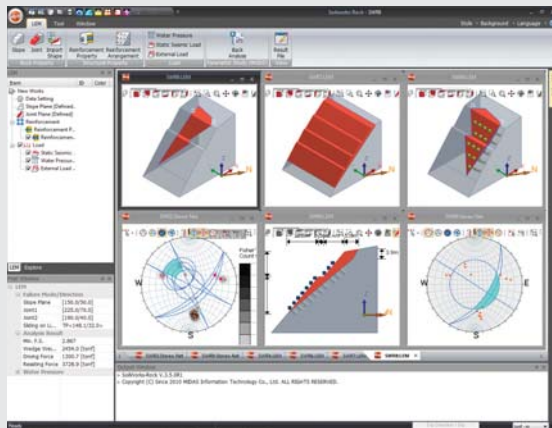


# SoilWorks Rock

## Rock Slope Stability Analysis

### Total Solution for Rock Slope

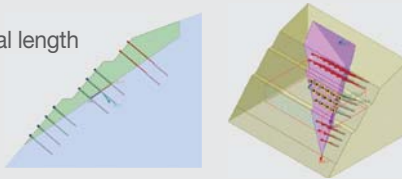
- Project file manager – multi document system
- Stereographic Analysis / Limit Equilibrium Analysis
- StereoNet – LEM coupled analysis



[ Framework Configuration ]

### Slope Modeling Wizard / Automatic Reinforcement Arrangement

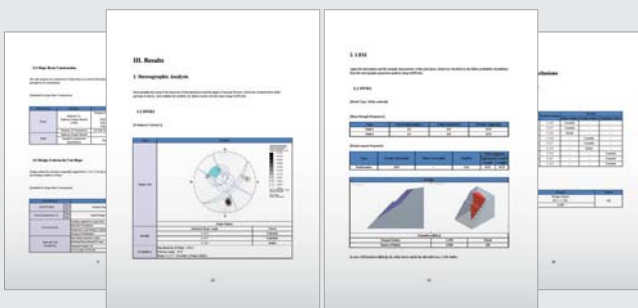
- Slope modeling wizard
- Reinforcement type (Rockbolt / Rockanchor)
- Automatic reinforcement arrangement
- Calculate the total length of reinforcement



[ Slope Modeling / Reinforcement ]

### Design Option / Report Generation

- Select design criteria – Minimum factor of safety
- Report generation - Set report format (style, font)



[ Report ]

## Stereographic Analysis

### 1. Stability of Discontinuities

#### | Possibility of Failure

- Weighting option to account for the sampling bias introduced by scanline

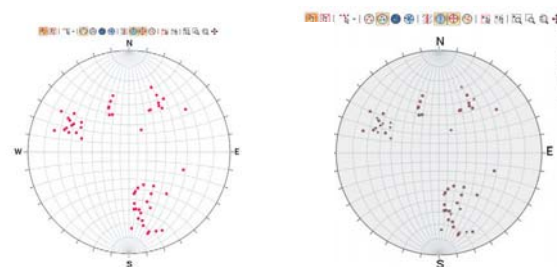
Discontinuity							
Global Orientation			Dip Direction / Dip		Declination		0.0 Deg
					Scanline		...
ID	Direction	Angle	Quantity	OxWeight	Type	Scanline	Set
1	352.0	67.0	1	1.165	Joint	1	4
2	110.0	58.0	1	1.513	Joint	1	1
3	349.0	69.0	1	1.197	Joint	1	4
4	115.0	64.0	1	1.573	Cleavage	1	1
5	164.0	60.0	1	3.864	Joint	1	2
6	349.0	63.0	1	1.127	Fault	1	4
7	349.0	73.0	1	1.257	Joint	1	4
8	340.0	55.0	1	1.064	Joint	1	4

[ Apply Weighting Option ]

- Data visualization with the various plot
  - Pole / Symbol / Contour / Rosette

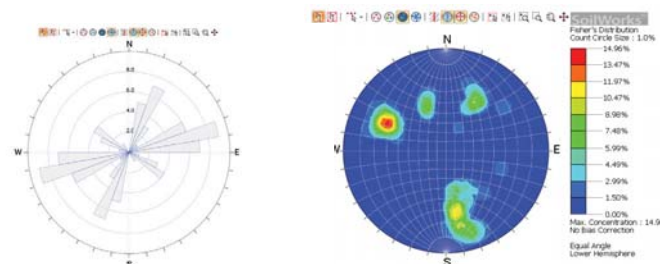


[ View Tool Bar ]



[ Pole Plot ]

[ Symbol Plot ]



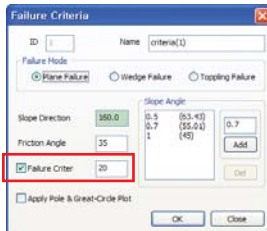
[ Rosette Plot ]

[ Contour Plot ]





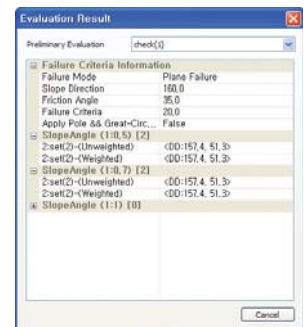
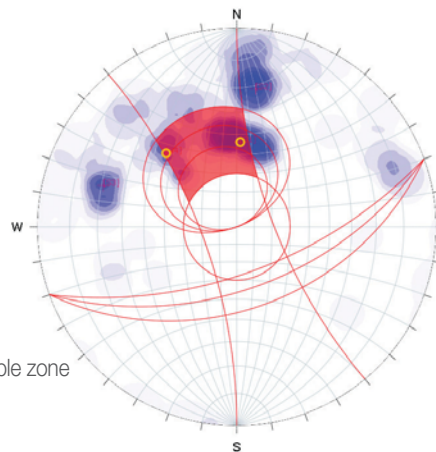
## 2. Preliminary Evaluation for Failure Modes | Auto-Search for Unstable Zone



- Select failure mode and input slope information
- Create line, plane, cone and daylight automatically
- Multi – Slope inclination



- Auto-search for unstable zone of each failure mode
- Auto-search for unstable discontinuities

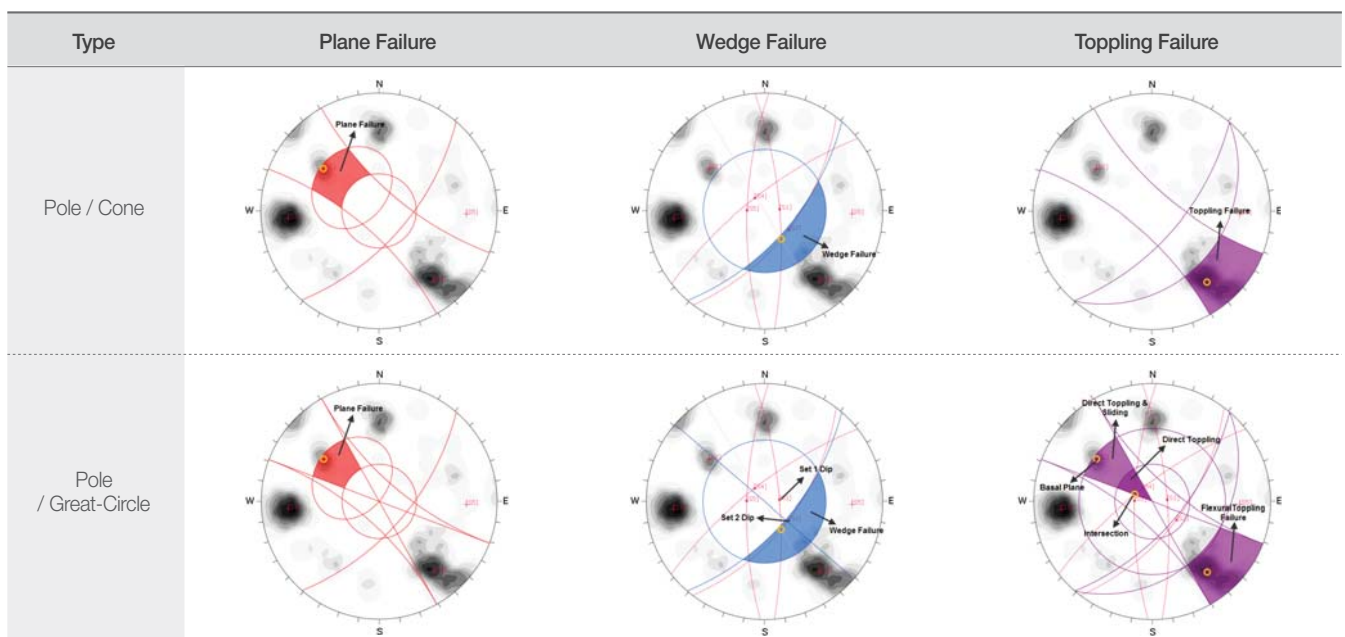


- Evaluation Result (Orientation of Discontinuities)

## 3. Advanced Option for Stereographic Analysis

### Pole & Great-Circle Plot

- Plane failure – Adjust over-estimated zone
- Wedge failure – Sliding on single plane / Sliding on intersection line
- Toppling failure – Direct toppling & sliding / Flexural toppling



## Limit Equilibrium Analysis

## 1. Modeling and Analysis

## Stability for Plane and Wedge Failure

- Slope modeling wizard
  - Stability of slopes with berms
- Five types of shear strength model
  - Mohr Coulomb / Barton-Bandis / Hoek-Brown / Generalized Hoek-Brown / Power Curve
- Roughness and filling materials between discontinuities

**Slope Plane**

Type

☐ Plane Failure ☒ Wedge Failure



Unit Weight  tonf/m³

Shape

Upper Slope(S)  deg

Slope Direction  deg

Input Method ☐ Width ☒ Angle

☒ Setup Bench   

	ID	Height (H)	Width (W)	Angle (alpha)	Length (L)
	0	15.0	12.6	50.0	0.0
	1	10.0	8.4	50.0	2.0
	2	10.0	8.4	50.0	2.0

OK Close Apply

[ Slope Geometry ]

**Joint Plane**

Shape | **Property1** | Property2

Joint Plane 1

Model Type: Mohr-coulomb (selected from dropdown: Mohr-coulomb, Barton-Bandis, Hoek-Brown, Generalized Hoek-Brown, Power Curve)

Cohesion: [ ]

Friction Angle: [ ] deg

☒ Filling

m: [1]

Cohesion: [1.5] tonf/m<sup>2</sup>

Friction Angle: [5] deg

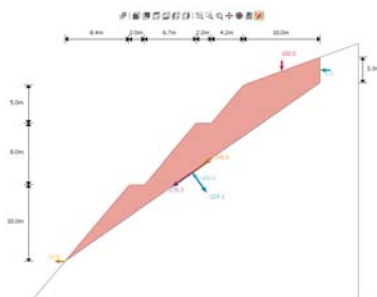
Filling Ratio: [50] %

☒ Roughness

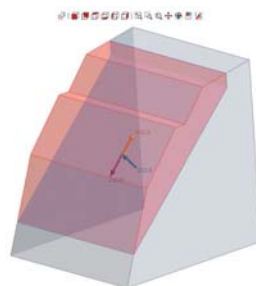
Angle: [5] deg

OK Close Apply

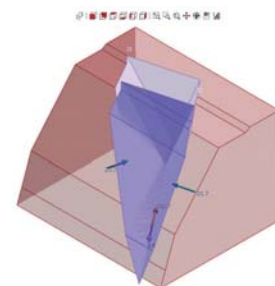
[ Joint Information ]



[ Dimension of Slope ]



[ Plane Failure ]

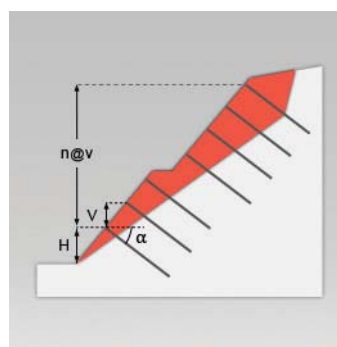


[ Wedge Failure ]

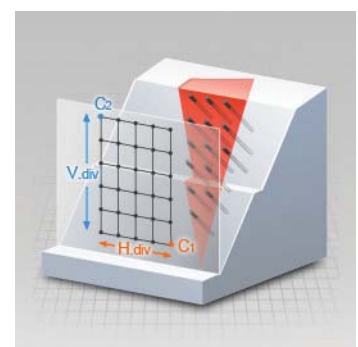
## 2. Design Reinforcement

## Reinforcement Type – Rockbolt / Rockanchor

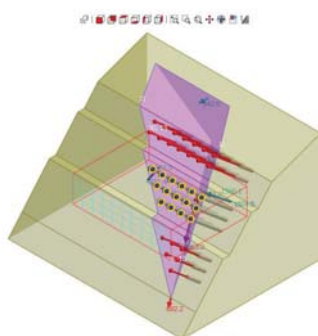
- Automatic arrangement by vertical and horizontal spacing
- Reinforcing forces including shear and pullout forces
- Text output for analysis results
- Total length of reinforcement



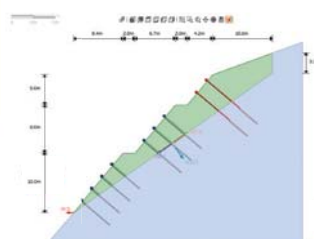
[ Plane Failure ]



[ Wedge Failure ]



[ Wedge Failure ]



[ Plane Failure ]

**Reinforcement Property**

General  
 ID 1 Name Reinforcement Property(1)

Structural Property  
☒ RockBolt ☐ RockAnchor

Tensile Force 20 tonf

☒ Pull-Out Force

Boring Diameter 0.05 m


Frictional Resistance 50 tonf/m<sup>2</sup>

☒ Shear Force

Value 10 tonf

Add OK Cancel

[ Reinforcing Forces ]



Microsoft Excel - [SWELL\_RESULTS.M.xls]

File Edit Format Tools Window Help

Summary

Slab Depth = 18.00 in  
 Slab Width = Slab Depth \* 2  
 Slab Length = 10.00 in  
 Slab Area = 180.00 in<sup>2</sup>  
 Slab Perimeter = 10.00 in  
 Slab Top Area = 180.00 in<sup>2</sup>  
 Slab Bottom Area = 180.00 in<sup>2</sup>  
 Slab Top Perimeter = 20.00 in  
 Slab Bottom Perimeter = 20.00 in  
 Line of Intersection Point = 10.00 in  
 Line of Intersection Length = 10.00 in  
 Slab Top Perimeter Length = 10.00 in  
 Slab Bottom Perimeter Length = 10.00 in  
 Slab Top Area Length = 10.00 in  
 Slab Bottom Area Length = 10.00 in  
 Slab Top Perimeter Length = 20.00 in  
 Slab Bottom Perimeter Length = 20.00 in  
 Slab Top Area Length = 10.00 in  
 Slab Bottom Area Length = 10.00 in

Design

Slab Depth = 18.00 in  
 Slab Width = 36.00 in  
 Slab Length = 10.00 in  
 Slab Area = 180.00 in<sup>2</sup>  
 Slab Perimeter = 10.00 in  
 Slab Top Area = 180.00 in<sup>2</sup>  
 Slab Bottom Area = 180.00 in<sup>2</sup>  
 Slab Top Perimeter = 20.00 in  
 Slab Bottom Perimeter = 20.00 in  
 Line of Intersection Point = 10.00 in  
 Line of Intersection Length = 10.00 in  
 Slab Top Perimeter Length = 10.00 in  
 Slab Bottom Perimeter Length = 10.00 in  
 Slab Top Area Length = 10.00 in  
 Slab Bottom Area Length = 10.00 in  
 Slab Top Perimeter Length = 20.00 in  
 Slab Bottom Perimeter Length = 20.00 in  
 Slab Top Area Length = 10.00 in  
 Slab Bottom Area Length = 10.00 in

Results

Slab Depth = 18.00 in  
 Slab Width = 36.00 in  
 Slab Length = 10.00 in  
 Slab Area = 180.00 in<sup>2</sup>  
 Slab Perimeter = 10.00 in  
 Slab Top Area = 180.00 in<sup>2</sup>  
 Slab Bottom Area = 180.00 in<sup>2</sup>  
 Slab Top Perimeter = 20.00 in  
 Slab Bottom Perimeter = 20.00 in  
 Line of Intersection Point = 10.00 in  
 Line of Intersection Length = 10.00 in  
 Slab Top Perimeter Length = 10.00 in  
 Slab Bottom Perimeter Length = 10.00 in  
 Slab Top Area Length = 10.00 in  
 Slab Bottom Area Length = 10.00 in  
 Slab Top Perimeter Length = 20.00 in  
 Slab Bottom Perimeter Length = 20.00 in  
 Slab Top Area Length = 10.00 in  
 Slab Bottom Area Length = 10.00 in

[ Text Output ]

### 3. Design Optimization

#### Minimum Anchored Length of Reinforcement

- Auto-calculate of minimum anchored length of reinforcement
- Auto or manual input of anchored length
- Quantity of required reinforcement

**Length**

Grouted Length  m

Ungouted Length  m

☐ Min. Anchored Length

**Length**

Grouted Length  m

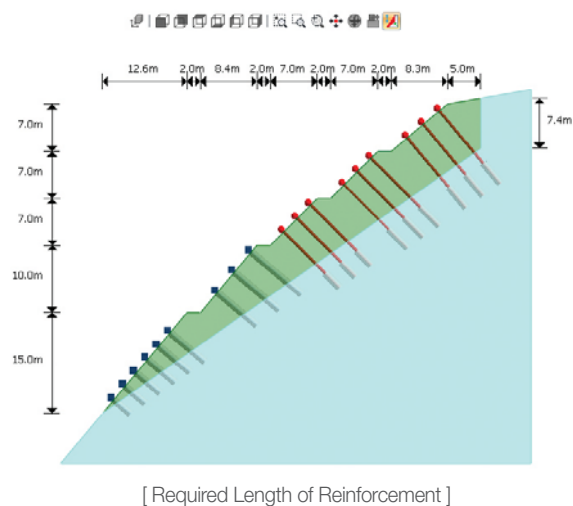
Ungouted Length  m

☒ Min. Anchored Length

Margin Length  m

☒ Auto ☐ Manual  m

[ Manual Input ]                      [ Auto ]

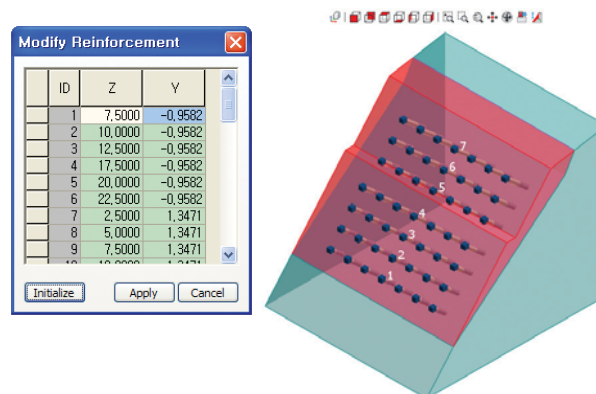
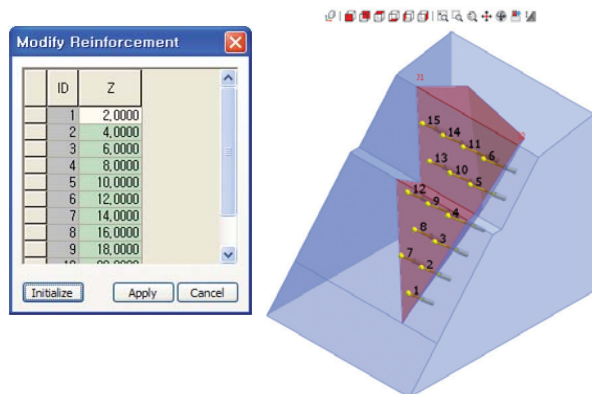


Type	Tensile Force(tonf)	Tensile Force(tonf)	Quantity	Total Length (m)	
				Ungouted Length	Grouted Length
Rockbolt (Plane Failure)	20.0	10.0	2.3 (/m)	–	11.1
Rockanchor (Wedge Failure)	20.0	–	29	89.9	73.8

[ Report – Reinforcement Table ]

#### Reinforcement Arrangement

- Edit coordinates of reinforcement
- Add / Delete reinforcement through table
- Check factor of safety in real time



# Limit Equilibrium Analysis

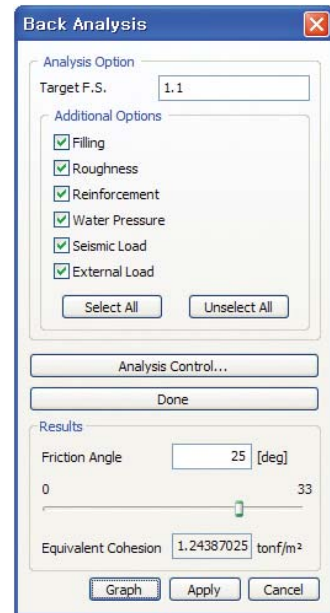
## 4. Back Analysis

### Estimate Shear Strength Parameters of Discontinuities

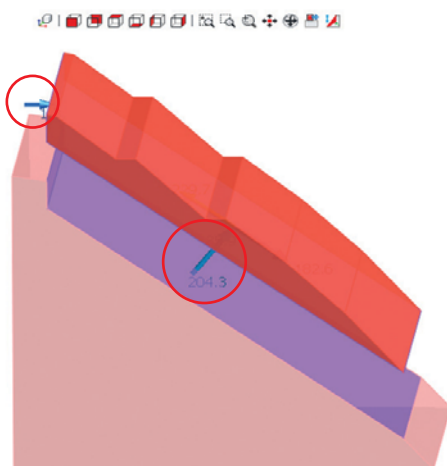
- Output equivalent cohesion and friction angle of joints
- All combinations of cohesion and friction angle by target factor of safety
- Graphic result and export to excel

### Additional Analysis Options

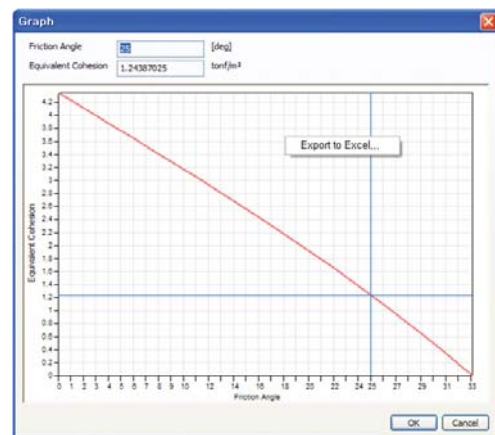
- Including or excluding site conditions
  - Filling materials and roughness of discontinuities
  - Water pressure / Seismic load / External load
  - Before and after reinforcement arrangement



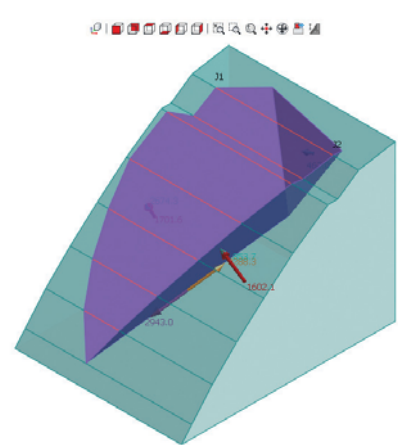
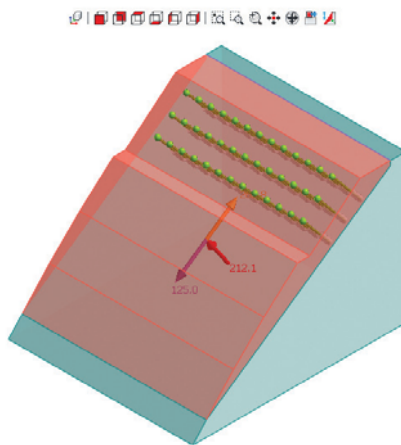
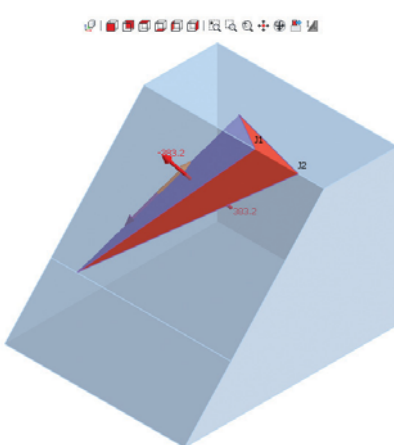
[ Back Analysis ]



[ Slope Modeling with Target F.S. ]



[ Analysis Result ]



[ Apply Back – Calculated Shear Strength Parameters ]

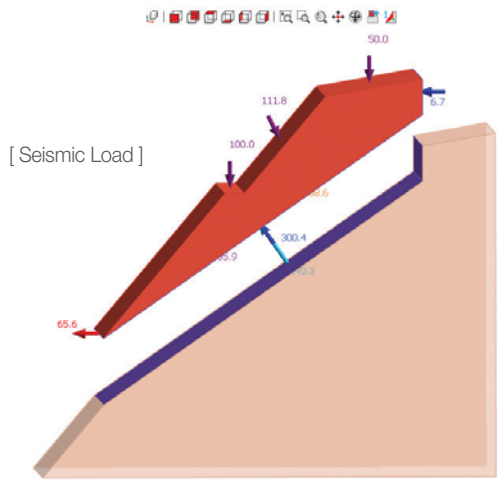
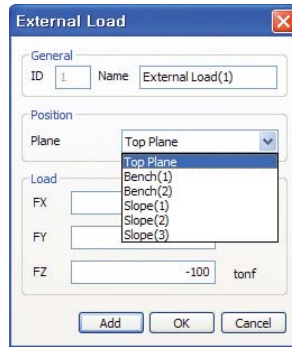
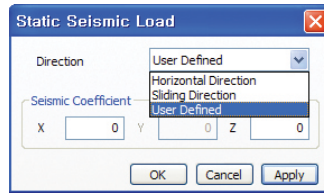




## 5. Loading Conditions

### Water Pressure / Static Seismic Load / External Load

- Define water level and distribution of water pressure
- Define seismic coefficient and direction
  - Horizontal / Sliding / User-defined
- External loads
  - Multiple loads with different position

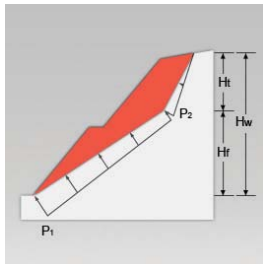


[ Seismic Load ]

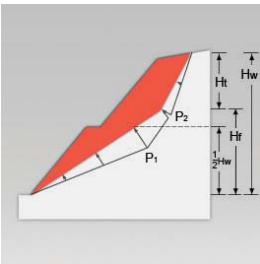
[ External Load ]

[ Define External Loads ]

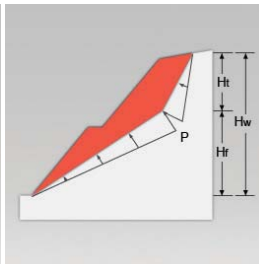
### Distribution of Water Pressure



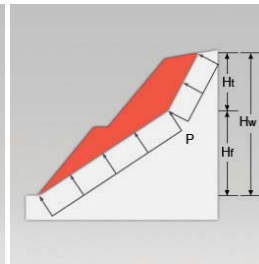
[ Linear ]



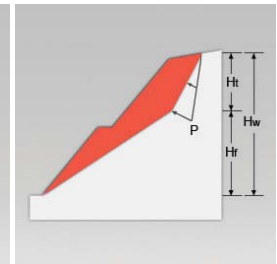
[ Triangle ]



[ Uniform ]



[ Tension Crack ]

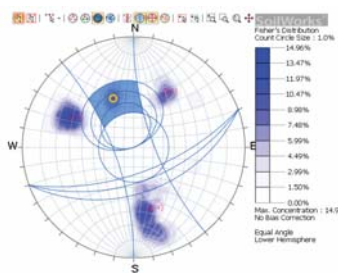


[ No Failure Plane Pressure ]

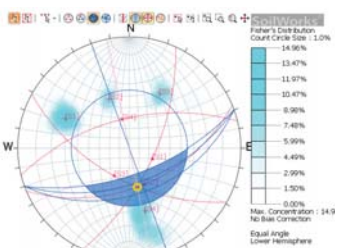
## 6. Import from StereoNet

### Auto-Generation of Slope Model

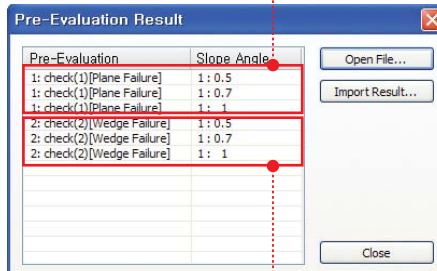
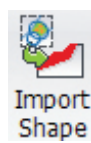
- Import joint information in unstable zone
- Automatic generation of slope and failure block



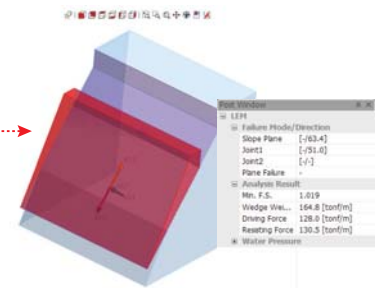
[ Plane Failure ]



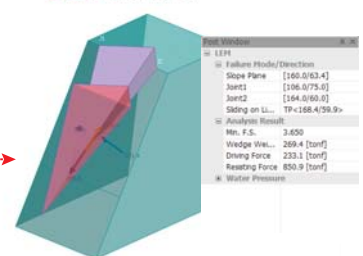
[ Wedge Failure ]



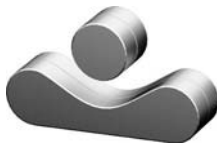
[ Import Shape ]



[ Plane Failure ]



[ Wedge Failure ]

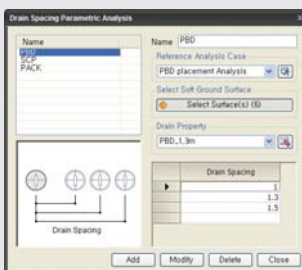


# SoilWorks Soft Ground

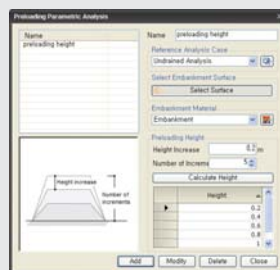
## Analysis & Design Soft Ground

### Parametric Analysis

- Preliminary Analysis
- Drain property and spacing check
- Minimum preloading height
- Softground – Slope coupled analysis
  - Auto-create slope model
  - / Critical height of embankment by limit equilibrium analysis



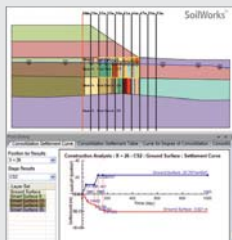
[ Drain Spacing ]



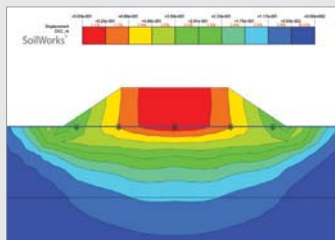
[ Preloading ]

### Analysis Methods (1D / 2D Consolidation)

- Consolidation analysis with construction stage
- 1D consolidation analysis
- 2D (FEM) consolidation analysis



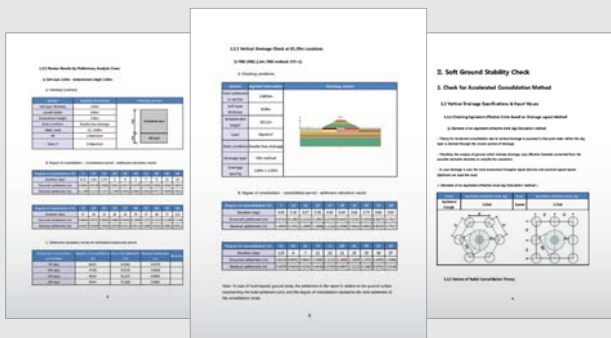
[ 1D Consolidation ]



[ FEM Consolidation ]

### Design Option / Report Generation

- Built-in design option for allowable settlement
- Report generation for parametric analysis



[ Report ]

## 1. Parametric Study



Preliminary Analysis

- Consolidation – Settlement curve with different site conditions
- Report generation



[ Preliminary Analysis ]



Drain Spacing

- Evaluate the maximum drain spacing
- Result analysis with different drain spacing / report generation

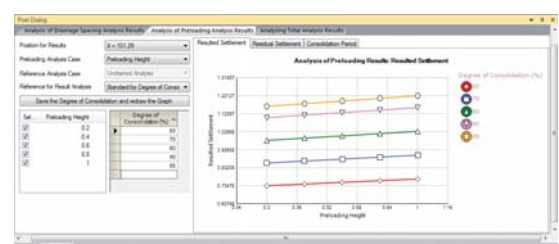


[ Drain Spacing ]



Preloading

- Evaluate the minimum preloading height
- Result analysis for each increment of embankment / report generation



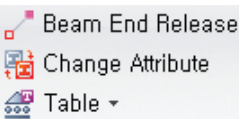
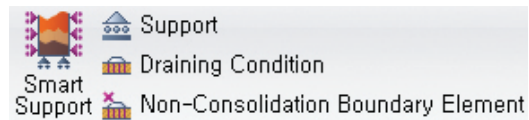
[ Preloading ]



## 2. Modeling & Analysis

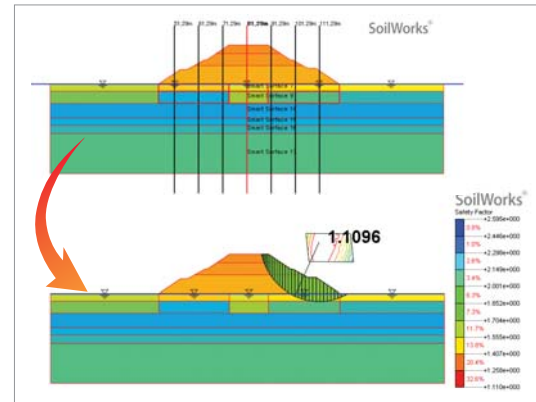
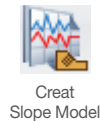
### | 1D Consolidation and FEM Consolidation

- Settlement by Terzaghi 1D-Consolidation theory
  - Primary and secondary consolidation
  - Initial settlement for sand
  - Multi-stage consolidation analysis
  - Auto-calculate of leave time for staged consolidation analysis
  - Improvement method (PBD, SCP, GCP, SD, Pack Drain, CD, Fiber)
  - Strength increase of softground for each construction stage
- FEM Consolidation
  - Modified Cam Clay model
  - Sekiguchi-Ohta model (Elasto-Plastic / Elasto-Visco Plastic)
  - Boundary condition (Drain / Non-consolidation boundary)

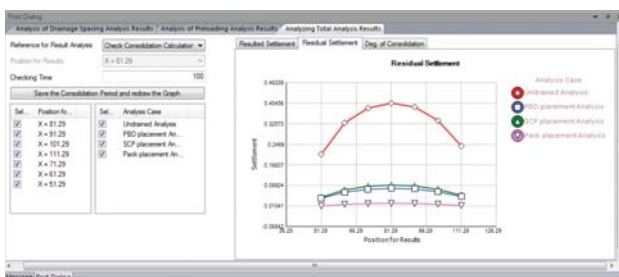


## 3. Result Analysis / Coupled Analysis

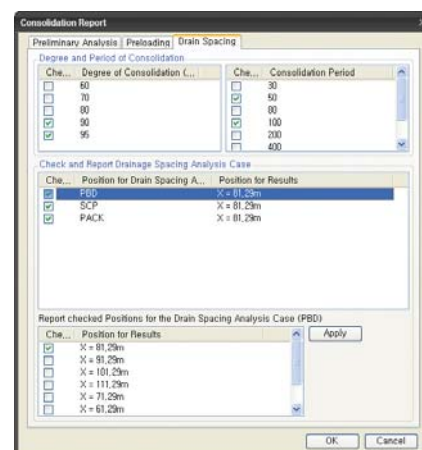
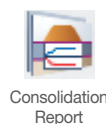
- Analyzing all result data for multi-analysis cases
- Settlement / Residual settlement / Degree of consolidation
- Stability of embankment with coupled analysis
- Check critical height of embankment for each construction stage



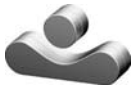
[ Create Slope Model ]



[ Analyzing Result Data ]

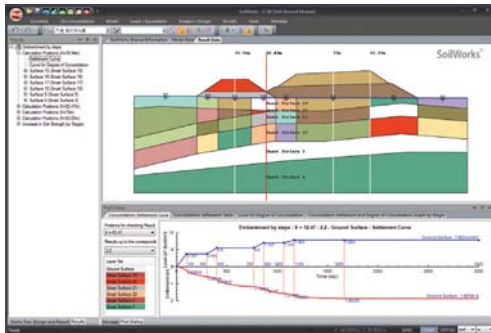


[ Consolidation Report ]

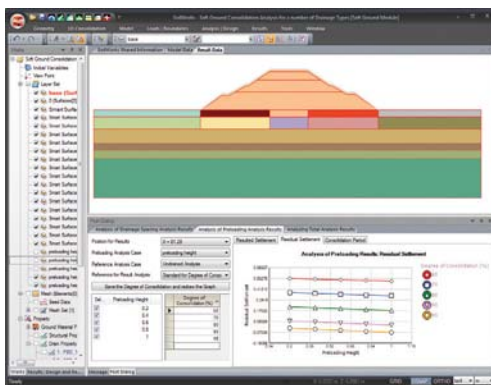


## 4. Applications

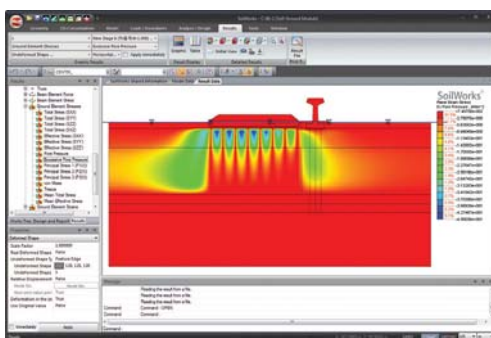
### | Design Approach



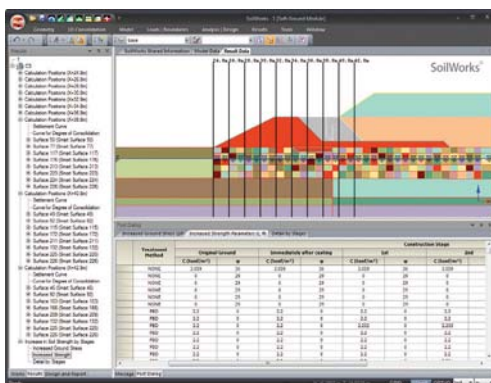
[ Staged Consolidation Analysis ]



[ Preloading Parametric Study ]



[ Dissipation of Excess P.W.P. ]



[ Increase in Strength of Soft ground ]

#### ■ Multi-stage 1D-Consolidation Analysis

- Settlement curve with time for each construction stage
- Settlement check with additional fill of embankment
- Selection of improvement method with different drainage

#### ■ Evaluate Minimum Preloading Height

- Residual settlement with increment of embankment
- Apply additional fill to compensate settlement

#### ■ FEM Consolidation

- Construction – Consolidation (Staged Consolidation) analysis
- Check reinforcement and member force
- Check dissipation of excess pore water pressure with time

#### ■ Increase in Shear Strength of Soft Ground

- Strength increase with depth of soft ground
- Softground-Slope coupled analysis
- Stability of embankment with limit equilibrium analysis



# a total satisfaction support system

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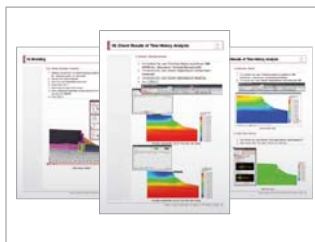
### Online Technical Support

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# SoilWorks

## SLOPE PACKAGE

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