

GTS NX

Slope Reinforcement by Nailing

Lesson 03

Midas Taiwan

Reference: Midas GTX NX Tutorials



OUTLINE

Part 1: General introduction

Part 2: Strength Reduction Method

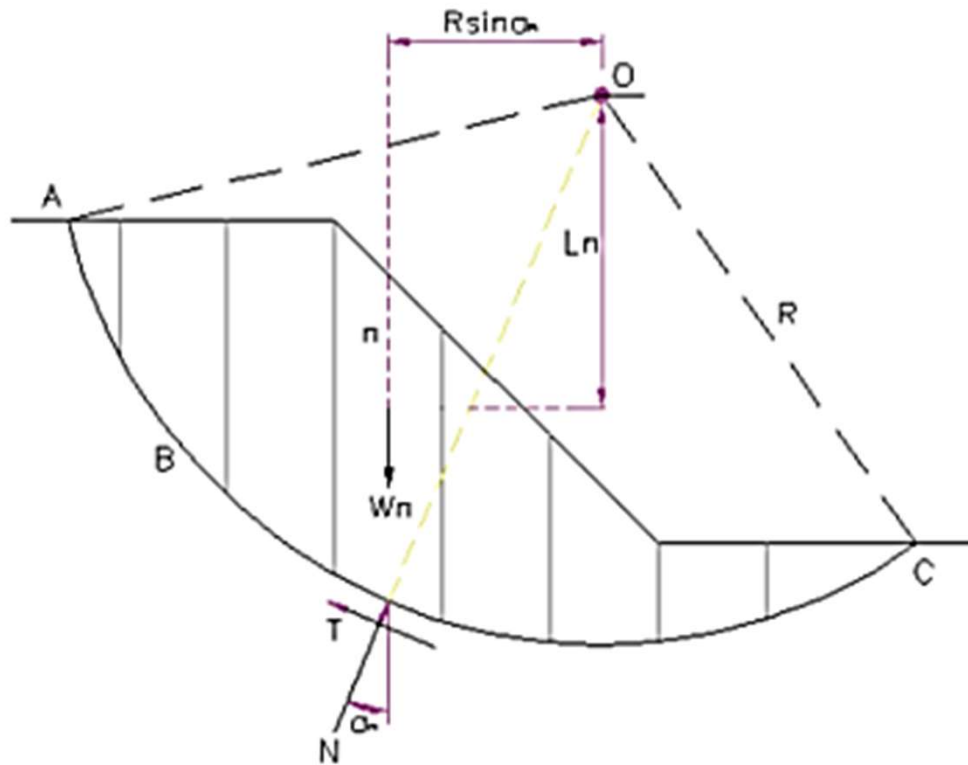
Part 3: Limit Equilibrium Method

Part 4: Results and discussion



Part 1: General introduction

Overview



Fig, Limit Equilibrium Method

$$F_s = \frac{\sum_{n=1}^{n=p} (cb_n + W_n \tan \phi + \Delta T \tan \phi) \frac{1}{m} \alpha(n)}{\sum_{n=1}^{n=p} (\sin \alpha_n)}$$

where $m \alpha(n) = \cos \alpha_n + \frac{\tan \phi \cdot \sin \alpha_n}{F_s}$

W : Total weight of soil slices (tf/m³)

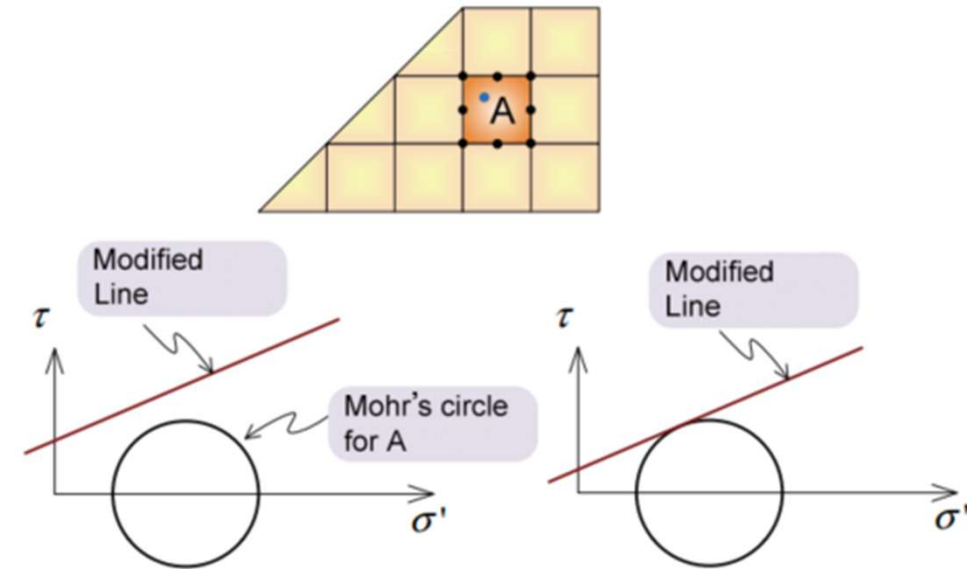
α : Angle of slope (degree)

C : Cohesion of soil (tf/m²)

b : Slice width (m)

ϕ : Internal angle of friction (degree)

ΔT : $T_n - T_{n+1}$



Fig, Strength Reduction Method

In **SAM**, based on the stress analysis results, safety factors for various sliding surfaces used in LEM are calculated.

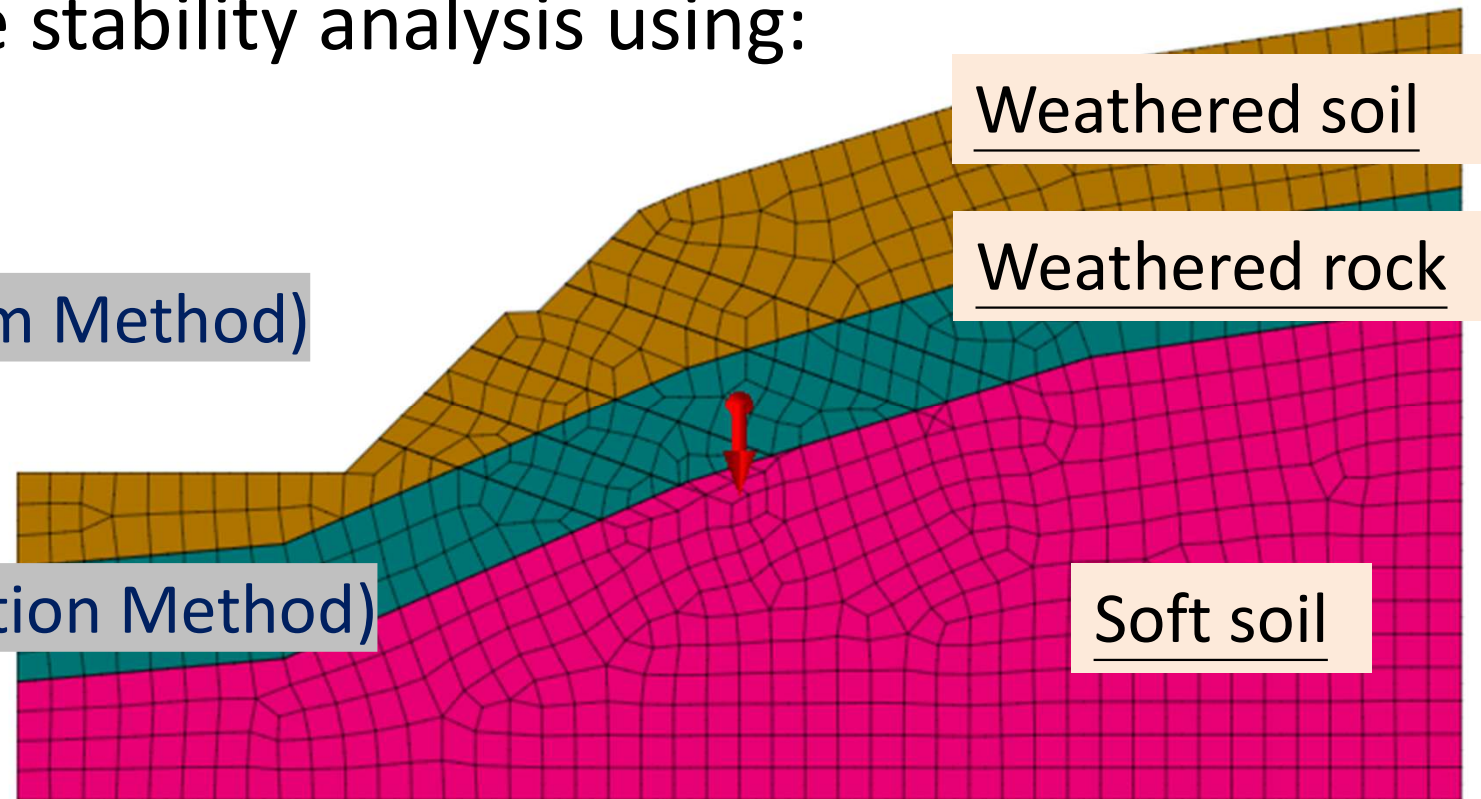
Overview

- Expose to slope stability analysis using:

✓ LEM
(Limit Equilibrium Method)

✓ SRM
(Strength Reduction Method)

✓ SAM
(Stress Analysis Method)



Fig, Soil distribution

- Nailing can be assigned as 'Embedded truss'
- Then, No need the same node **between soil & truss**

Learning Objective

► Ground properties

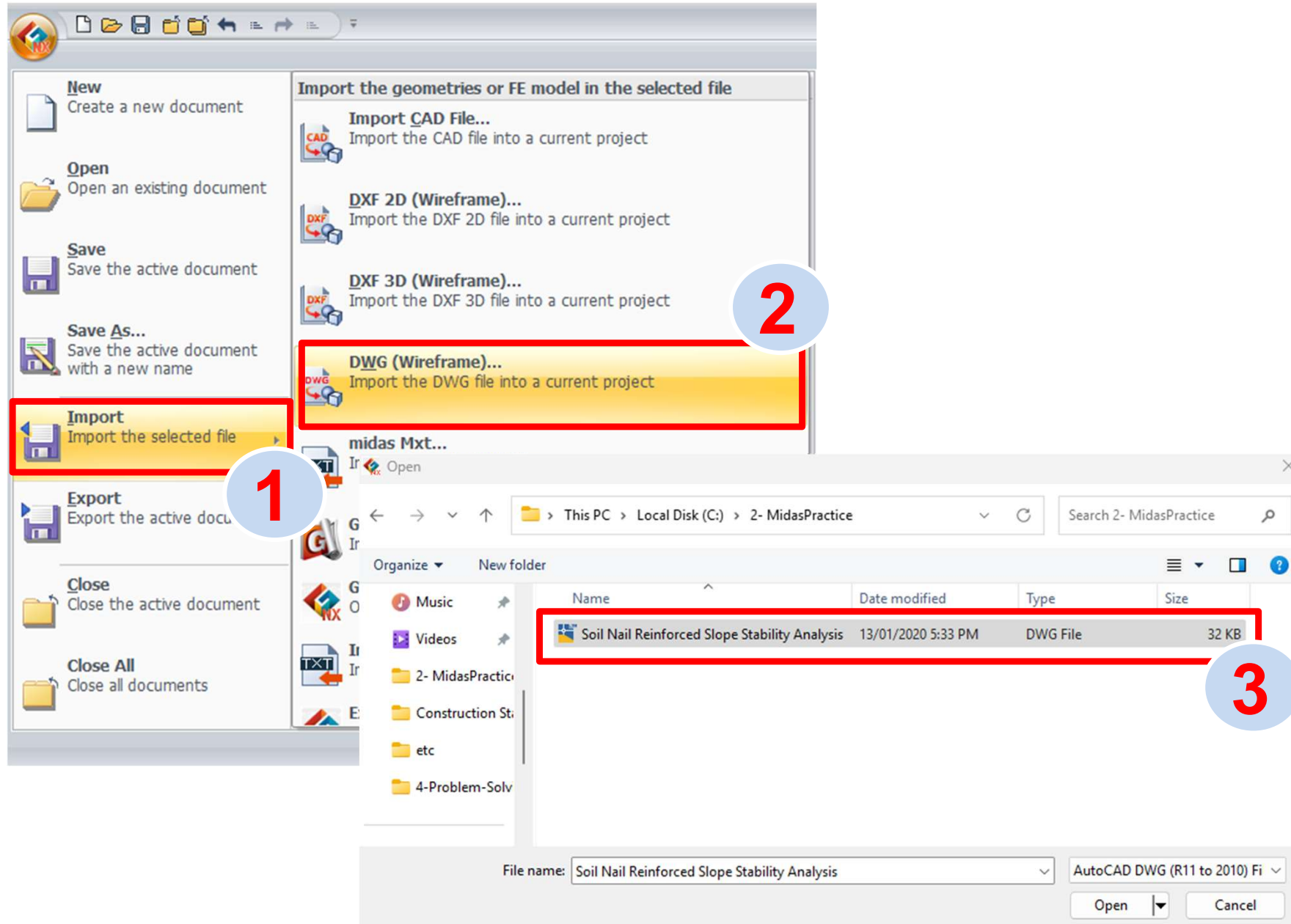
No	Ground Type	Model Type	Modulus of Elasticity (kN/m ²)	Unit Weight (kN/m ³)	Saturated Unit Weight (kN/m ³)	Poisson's Ratio	Cohesion (kN/m ²)	Internal Friction Angle (degree)
1	Weathered soil	Mohr Coulomb	36,500	18.5	19.5	0.33	17.5	31
2	Weathered rock	Mohr Coulomb	150,000	21	22	0.30	50	33
3	Soft rock	Mohr Coulomb	1,850,000	24	25	0.28	180	35.5
4	Weathered soil	Mohr Coulomb (LEM)	-	18.5	-	-	17.5	31
5	Weathered rock	Mohr Coulomb (LEM)	-	21	-	-	50	33
6	Soft rock	Mohr Coulomb (LEM)	-	24	-	-	180	35.5

► Structural properties

No	Structure Type	Model Type	Reinforcement Spacing (m)	Initial Diffusion Width (m)	Initial Diffusion Angle (deg)	Tensile Strength (kN)	Equivalent Radius (m)
1	Nail (LEM)	Nail (LEM)	2.0	1.0	10	115	0.05

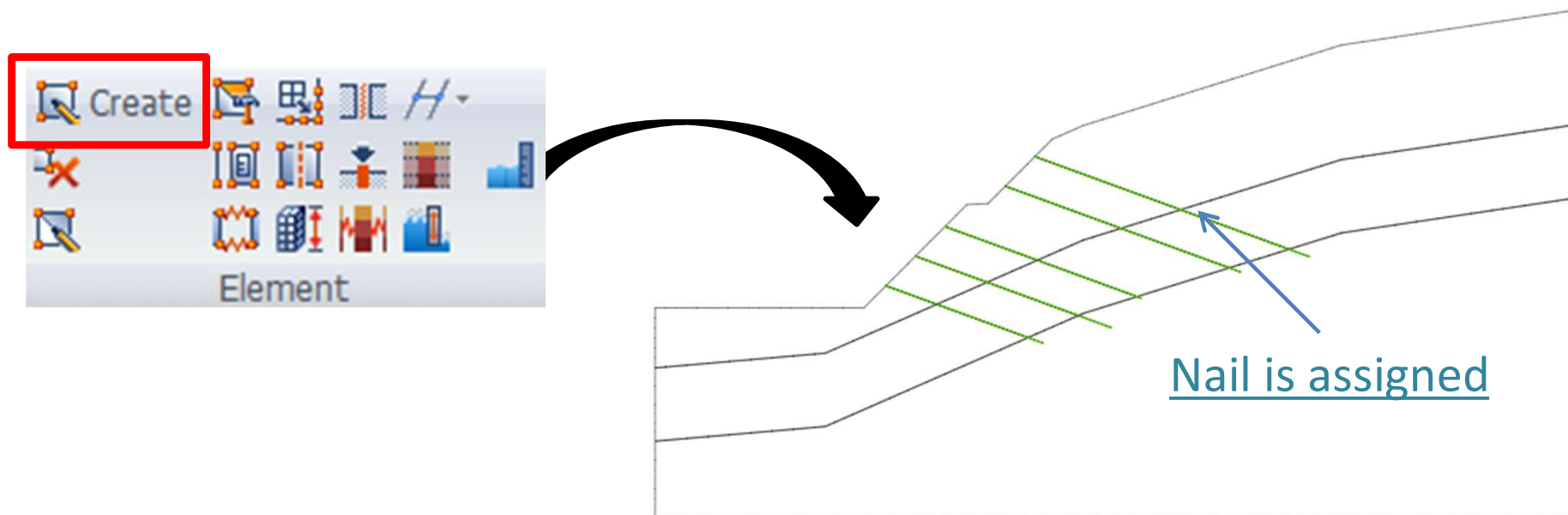
No	Structure Type	Model Type	Horizontal Spacing (m)	Rebar Section Area (m ²)	Modulus of Elasticity (kN/m ²)	Poisson's Ratio	Unit Weight (kN/m ³)	Yield Strength (kN/m ²)
1	Nail	Embedded Truss	2.0	10	115	0.05	25	350,000

Import File

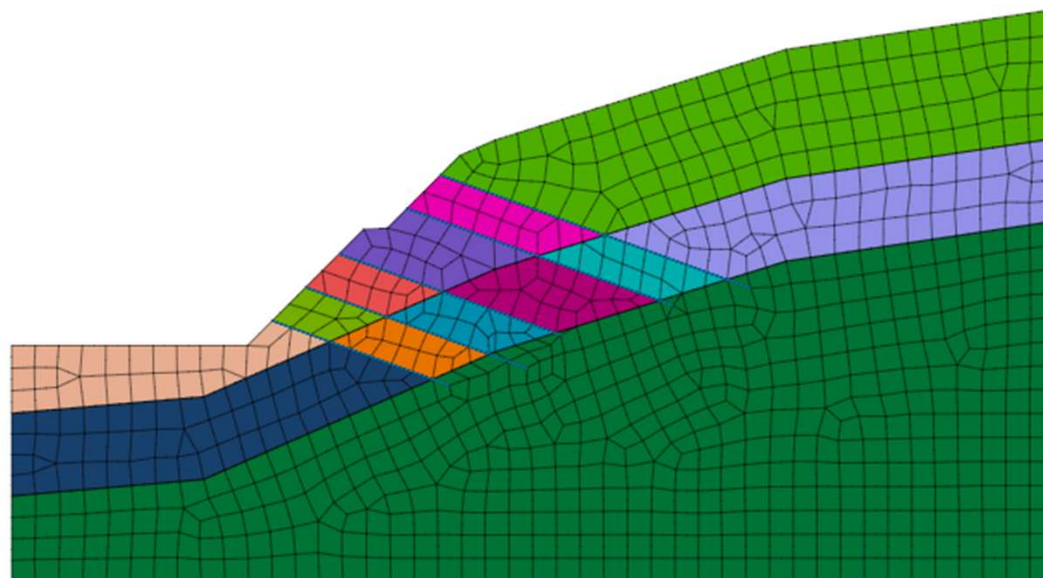


Part 2: Strength Reduction Method (SRM)

Embedded truss

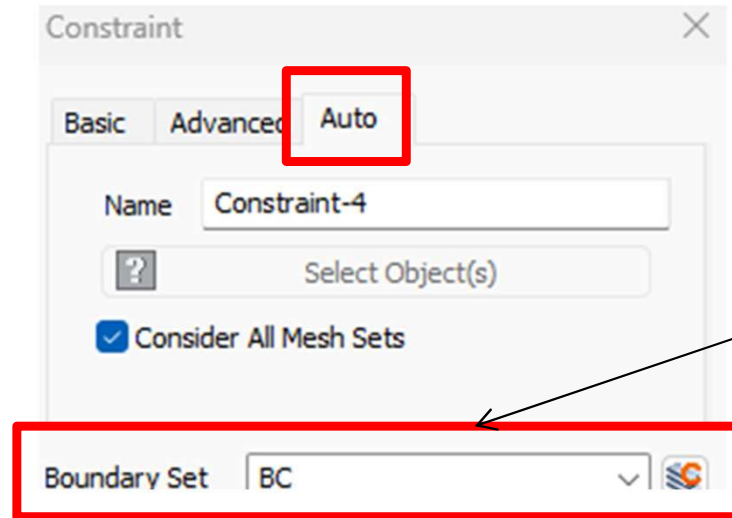
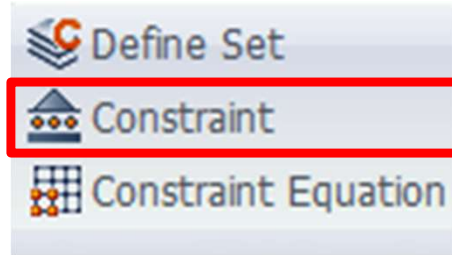


Fig, Assigning 'Embedded truss'



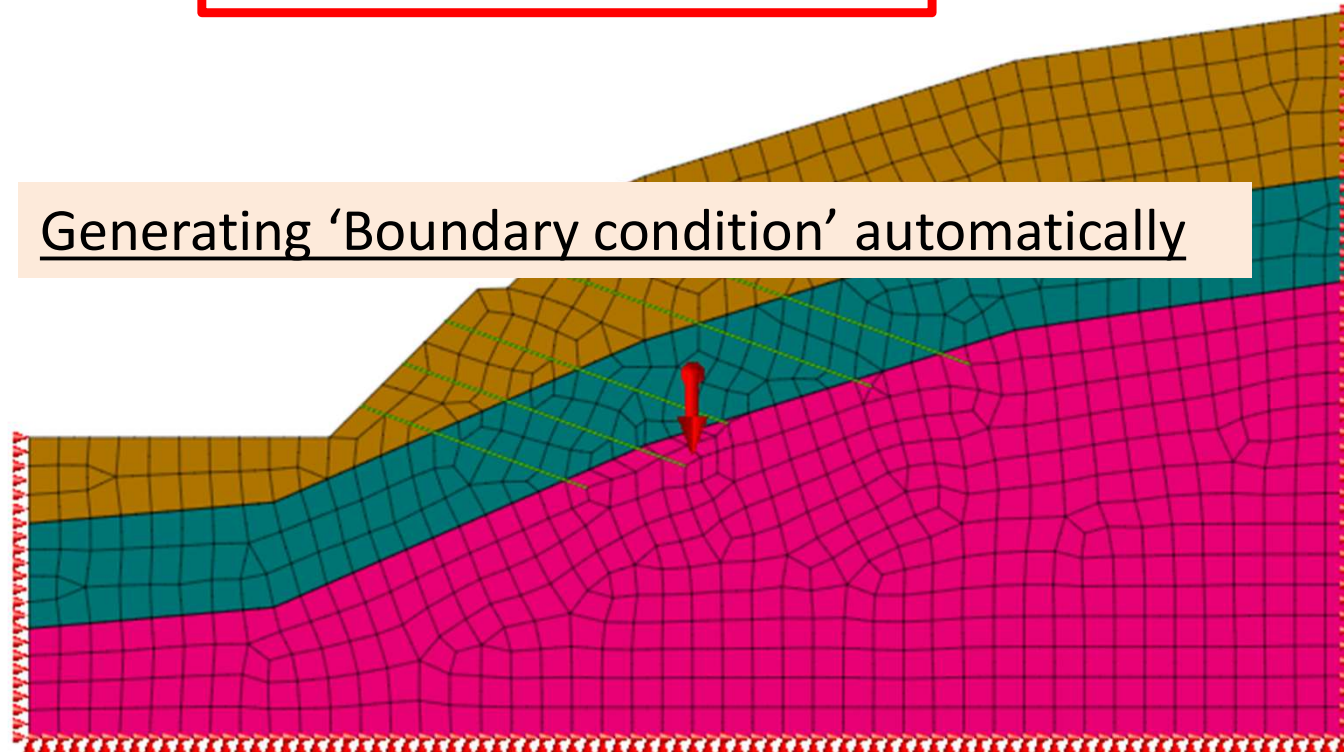
Fig, Mesh generation

Boundary

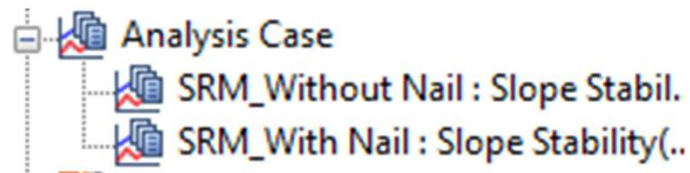


Naming for boundary set

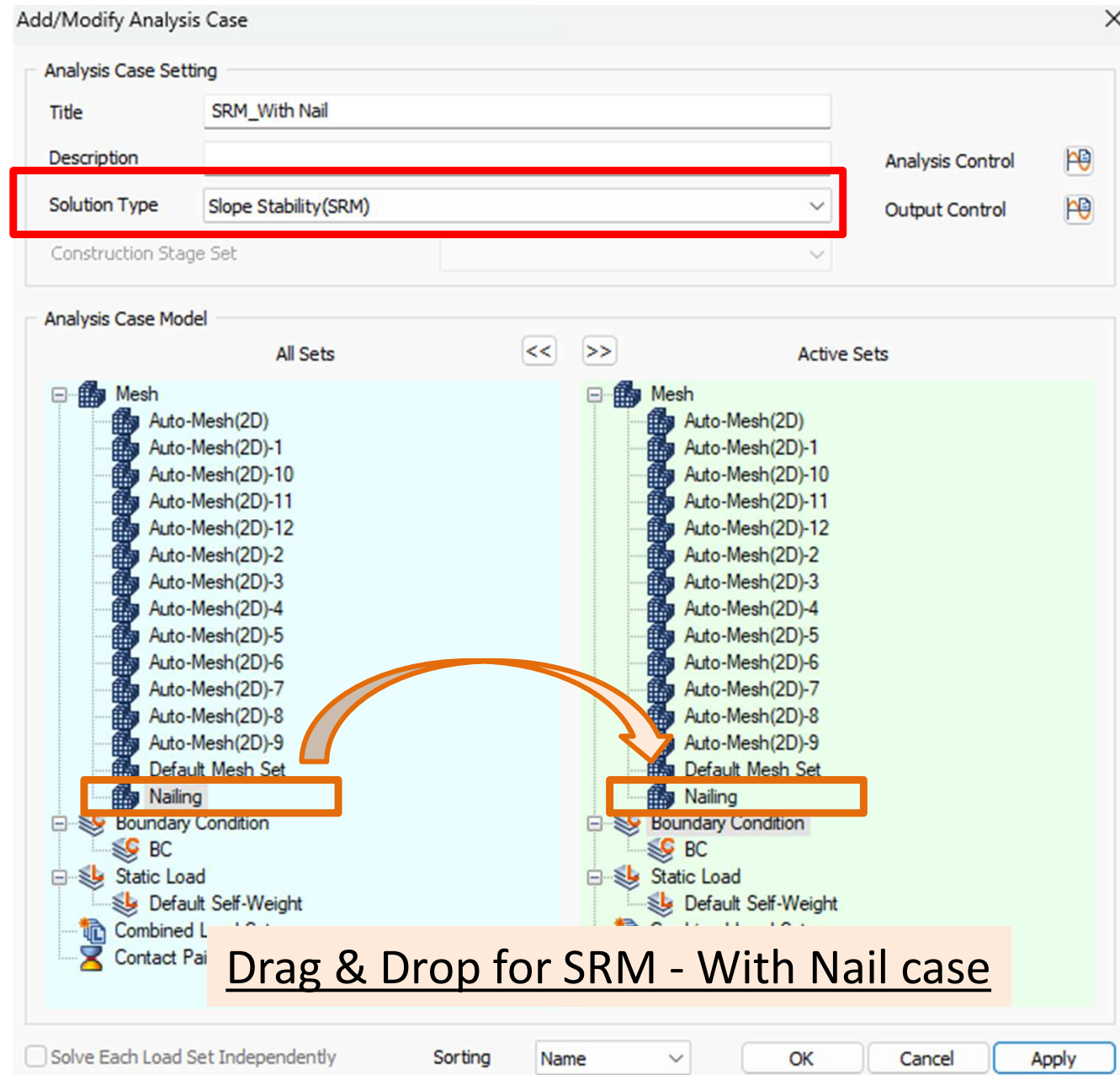
Generating 'Boundary condition' automatically



Analysis Setting

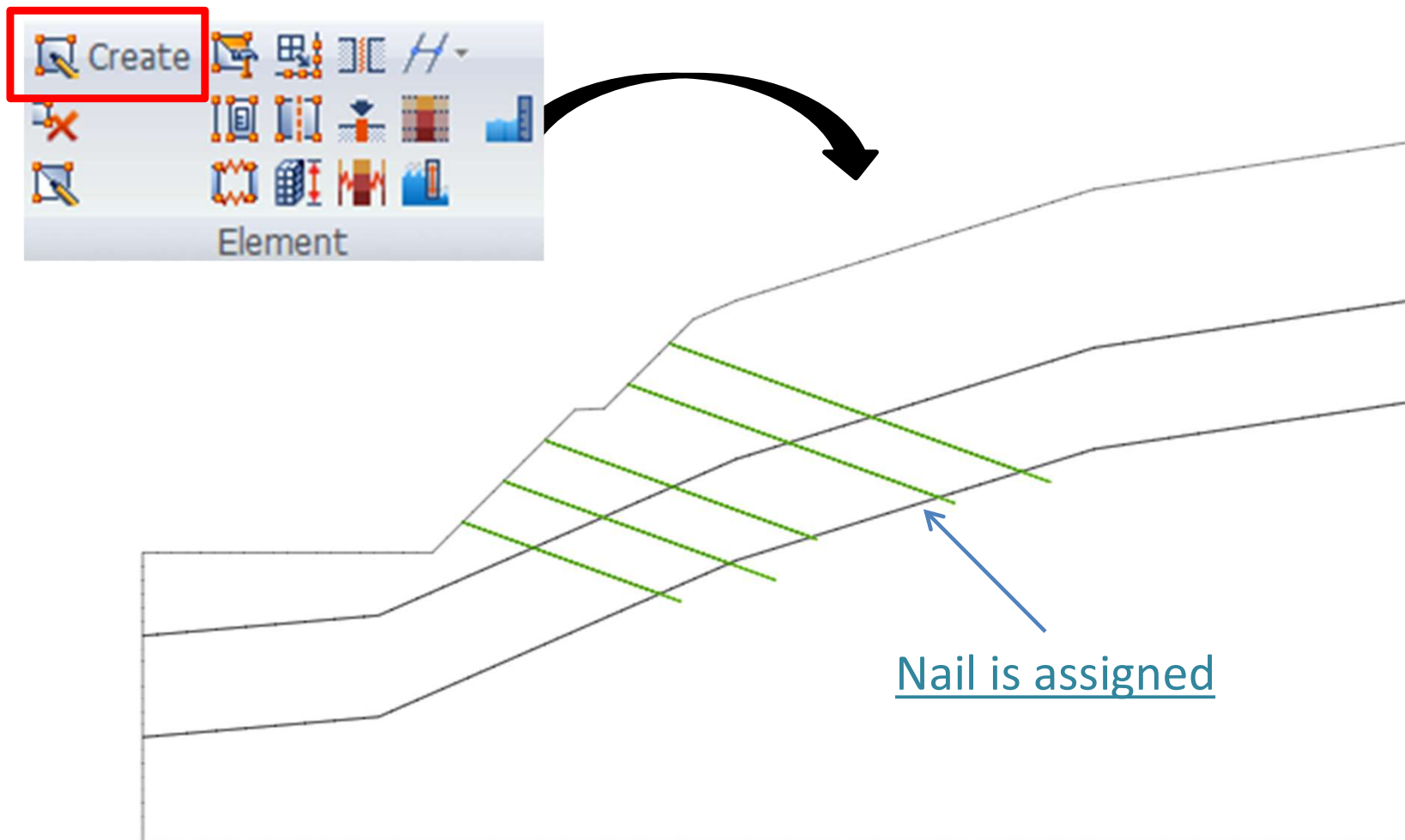


RUN analysis →

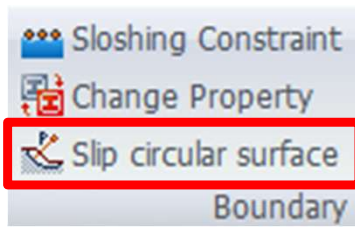


Part 3: Limit Equilibrium Method (LEM)

Embedded truss



Fig, Assigning 'Embedded truss'



Arc boundary

Slip Surface

Slip Circular Surface | Slip Polygonal Surface

Name: Slip Circular Surface-1 Unit: m

Grid Range

☒ Grid Points Defined

Reference Point X1: -2.77901 Reference Point Y1: 29.39513

Reference Point X2: 8.852429 Reference Point Y2: 36.35411

Reference Point X3: 15.71199 Reference Point Y3: 29.59396

Num. of Centers(X): 10 Num. of Centers(Y): 10

Radius Range

☒ Method using Tangent Line of Circle

☒ Radius Tangent line Defined

	Left		Right	
Up	x: 11.6178	y: 4.67285	x: 33.3837	y: 15.4845
Down	x: 9.19647	y: 7.73221	x: 27.9205	y: 19.9733

Number of Radius Increment: 4

☐ Switch Tangent Direction

☐ Method using Length and Range of Radius

Length of Initial Circular Radius: 0

Increment for Circle Radius: 0

Number of Increments for Circle Radius: 3

Boundary Set: Arc BC

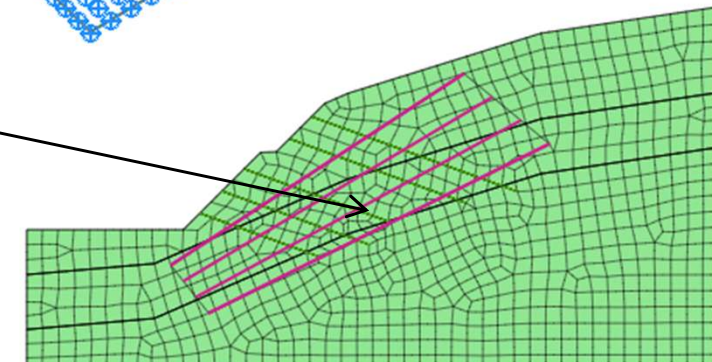
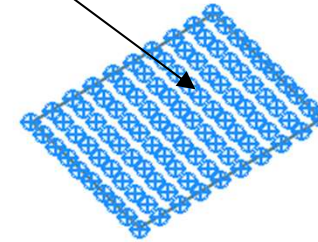
OK Cancel Apply

Grid point

No. of grid point

Radius

No. of radius



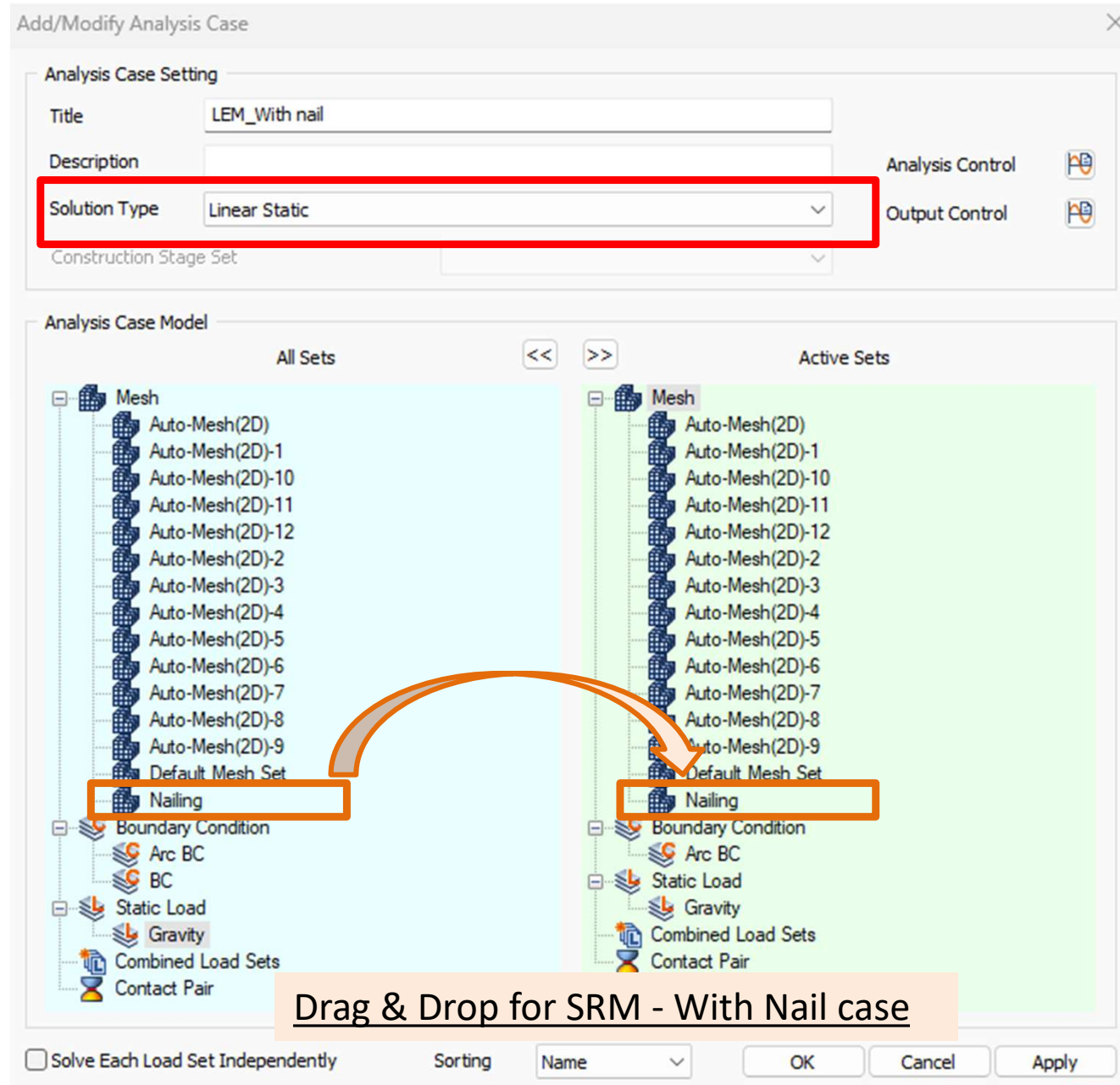
Defining 'Arc failure boundary condition'



Analysis Setting

LEM_Without nail : Slope Stability(S..
LEM_With nail : Slope Stability(SAM.

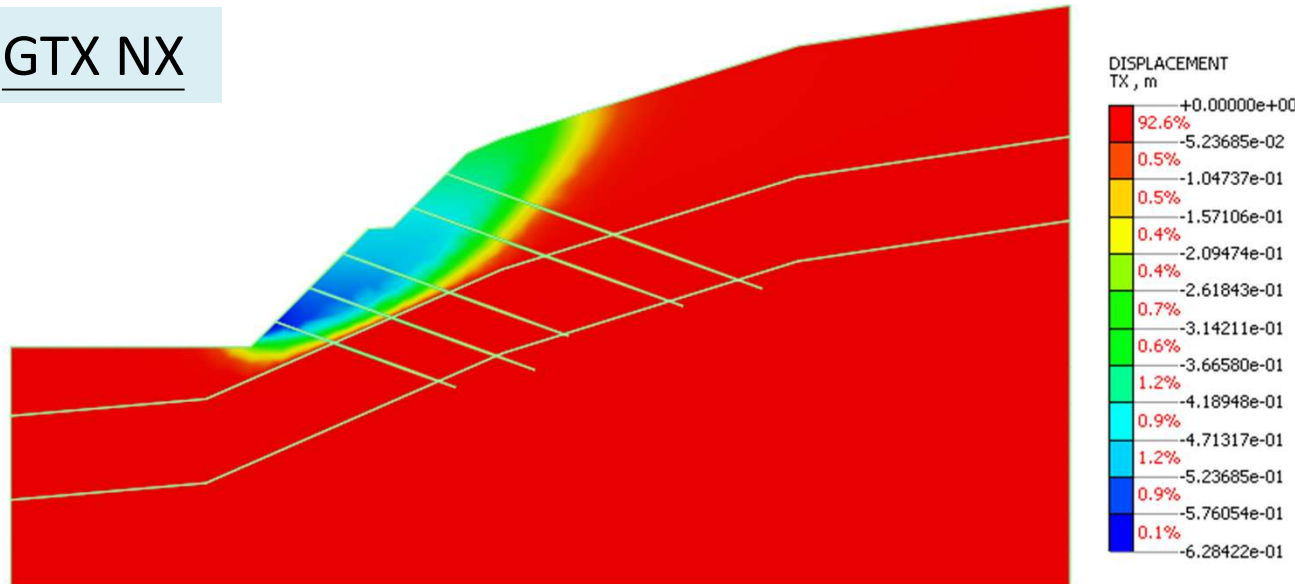
RUN analysis →



Part 4: Results and discussion

Results – Horizontal Displacements (SRM)

GTX NX



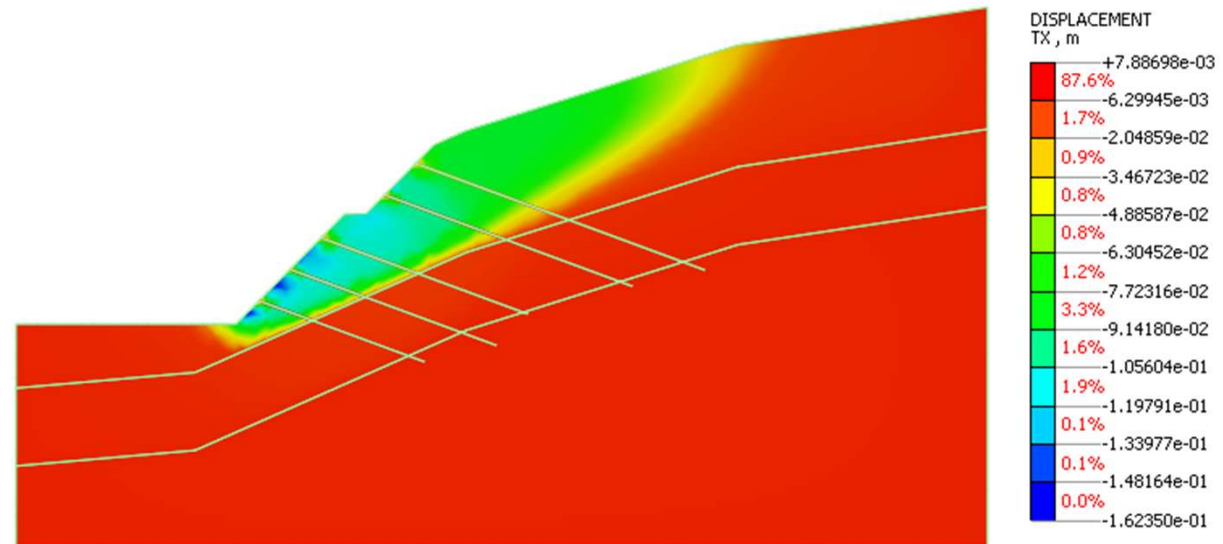
Horizontal displacement

SRM_Without nail
Slope Stability(SRM)
INCR=15 (FOS=1.8859)

Without Nail
FOS = 1.8375

Horizontal displacement

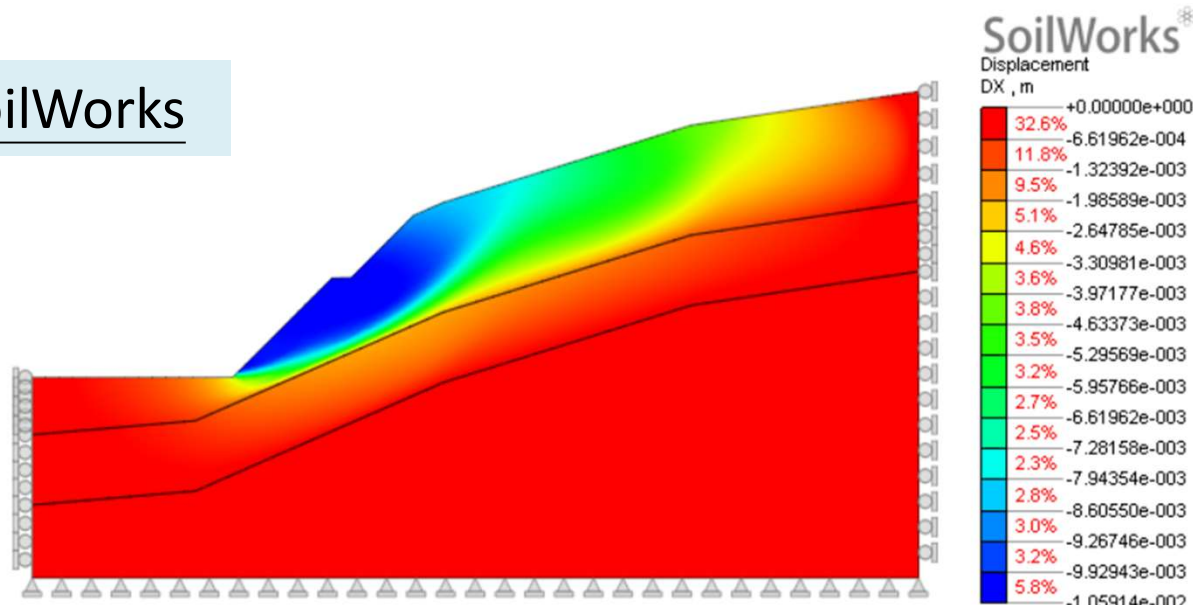
SRM_With nail
Slope Stability(SRM)
INCR=22 (FOS=2.6527)
Safety Factor
2.65273 [Slope Stability(SR...)]



With Nail
FOS = 2.65273

Results – Horizontal Displacements (SRM)

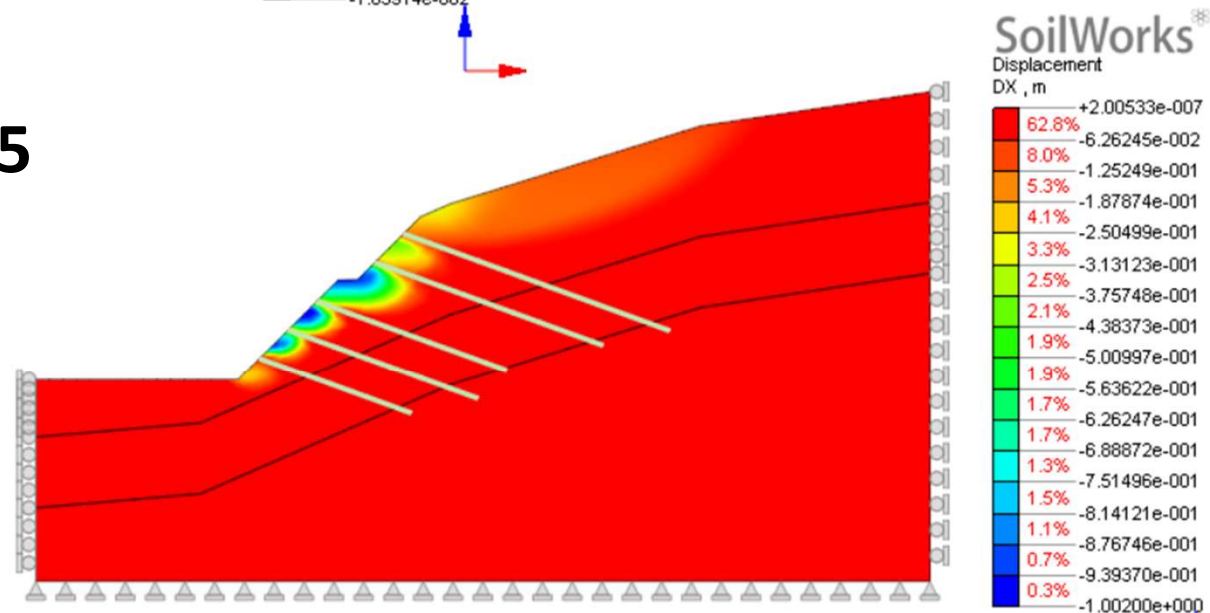
SoilWorks



Horizontal displacement

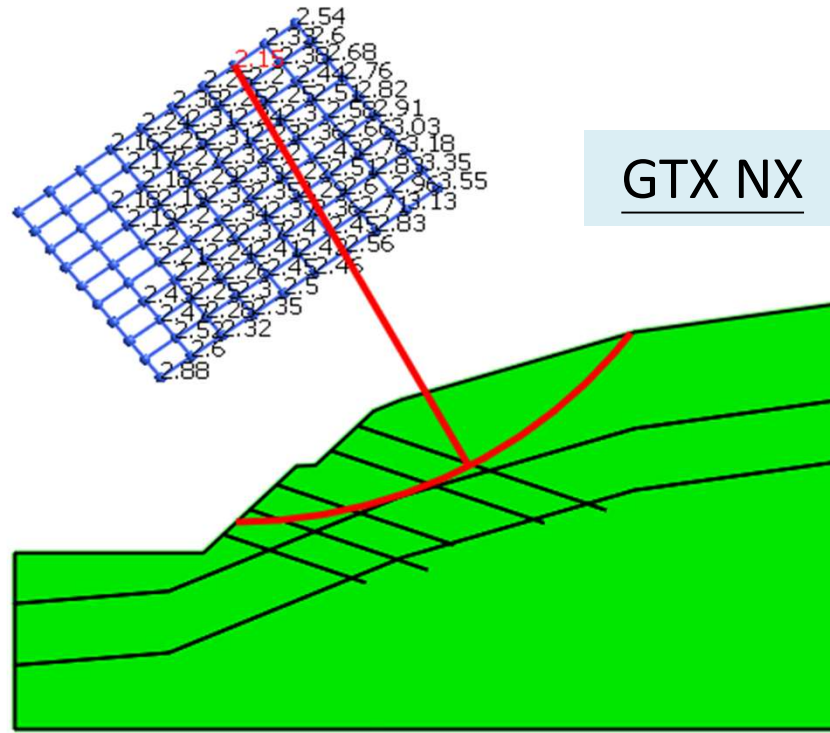
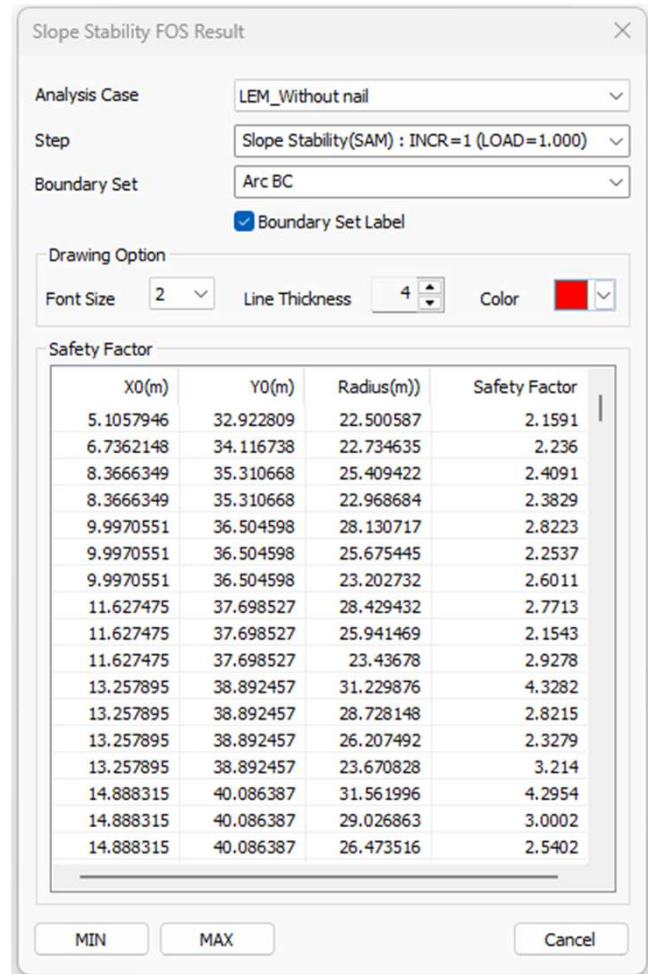
Without Nail
(Same as GTX NX) **FOS = 1.8375**

Horizontal displacement

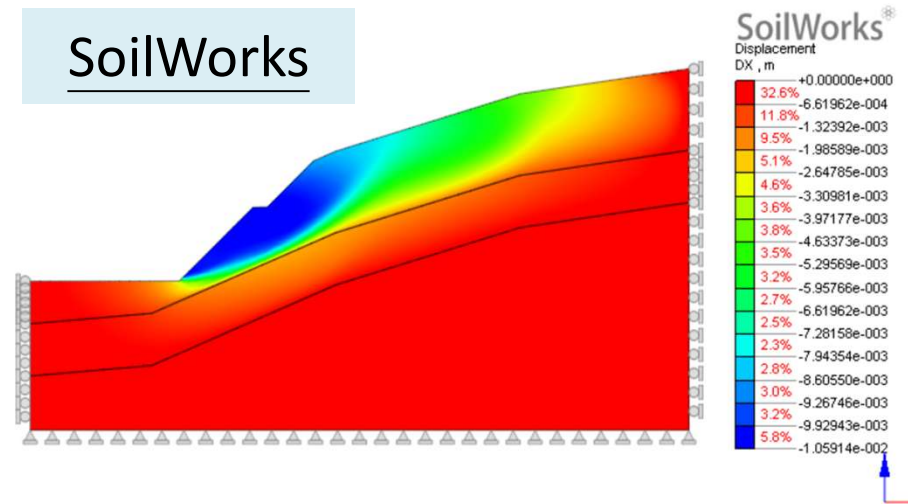


With Nail
FOS = 3.5875 (> 26% of GTX NX)

Results – Factor of safety (LEM)



Without Nail
FOS = 2.15



Without Nail
FOS = 1.8375

- LEM_Without nail
- Slope Stability(SAM)
- INCR=1 (LOAD=1.000)
- Safety Factor
- 2.15434 [Slope Stability(SA...]

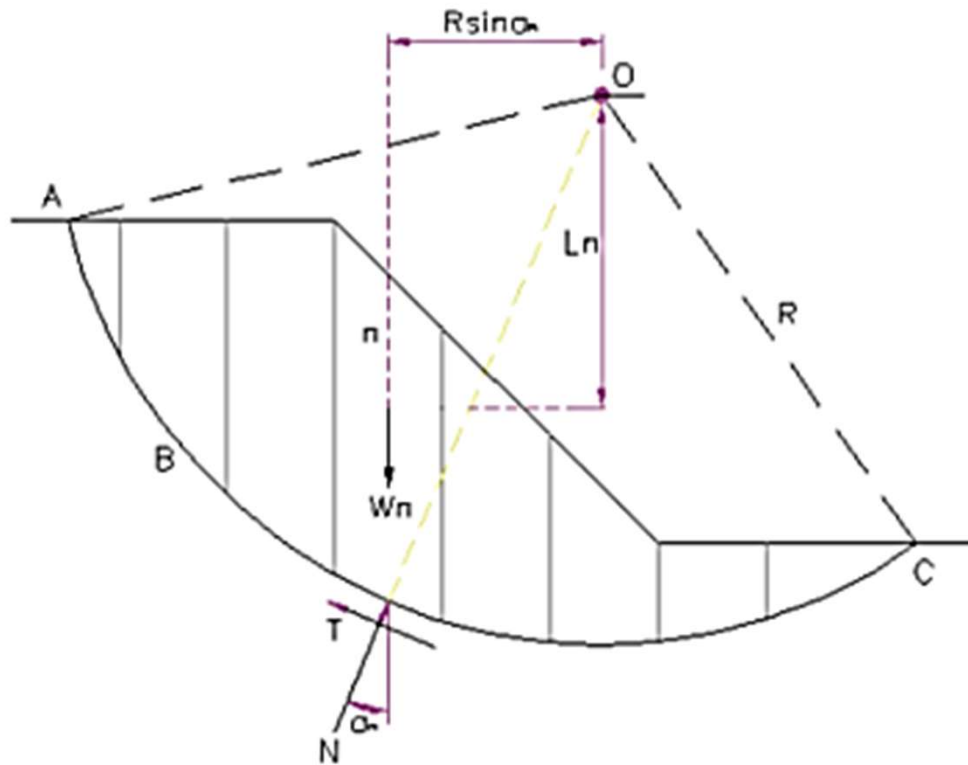
Thank you! ♥

GTS NX 3D Slope Simulation

Midas Taiwan

Reference: Midas GTX NX Tutorials

Overview



Fig, Limit Equilibrium Method

$$F_s = \frac{\sum_{n=1}^{n=p} (cb_n + W_n \tan \phi + \Delta T \tan \phi) \frac{1}{m} \alpha(n)}{\sum_{n=1}^{n=p} (\sin \alpha_n)}$$

where $m \alpha(n) = \cos \alpha_n + \frac{\tan \phi \cdot \sin \alpha_n}{F_s}$

W : Total weight of soil slices (tf/m³)

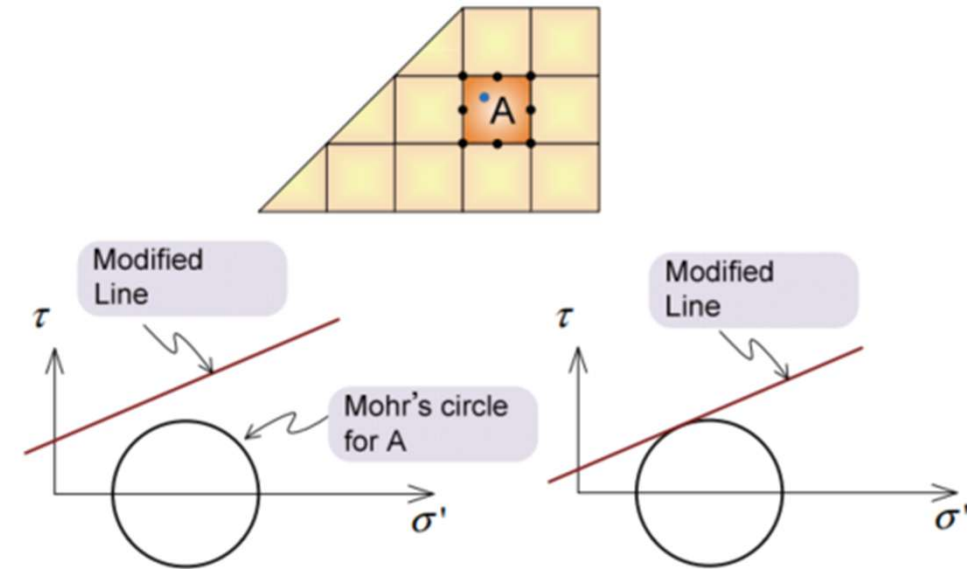
α : Angle of slope (degree)

C : Cohesion of soil (tf/m²)

b : Slice width (m)

ϕ : Internal angle of friction (degree)

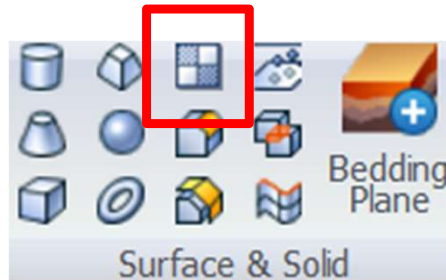
ΔT : $T_n - T_{n+1}$



Fig, Strength Reduction Method

In **SAM**, based on the stress analysis results, safety factors for various sliding surfaces used in LEM are calculated.

Irregular face – Make face



Make Face

Face Coons Face **Grid Face** Point

M(No. In X) 50

N(No. In Y) 50

Origin X -10

Origin Y -10

LX(Length) 260

LY(Length) 260

Elevation

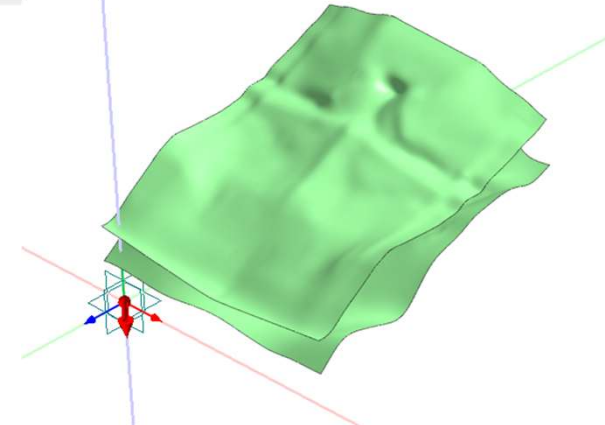
Geometry Set Geometry Set-1

OK Cancel Apply

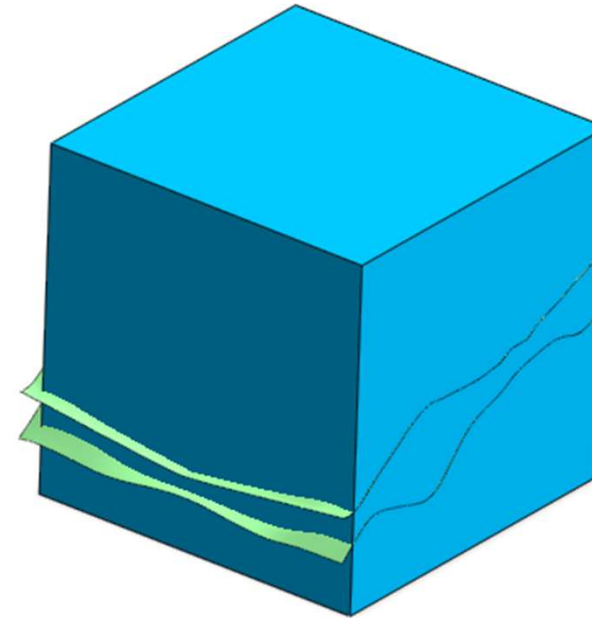
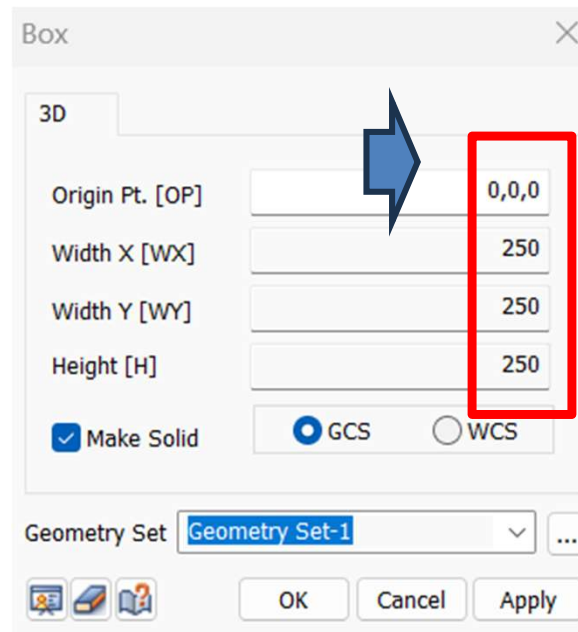
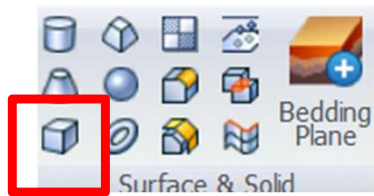
Elevation Data

	1	2	3	4	5	6	7	8	9	10	11
1	41.7729	41.4015	41.5076	41.1182	40.8738	40.7864	40.5953	40.3339	39.9225	39.2286	38.3808
2	41.7729	46.3879	45.9678	46.1847	45.7086	45.5197	45.4133	45.3389	45.2119	44.7773	43.707
3	45.9678	46.3879	51.6664	51.0488	51.4	50.6848	50.4246	50.278	50.237	50.1589	49.7259
4	51.4	51.0488	51.6664	57.2501	56.2878	56.8105	55.6805	55.2363	54.9825	54.9181	54.7049
5	55.6805	56.8105	56.2878	57.2501	62.7779	61.3427	62.2045	60.3638	59.6523	59.2404	59.0736
6	59.6523	60.3638	62.2045	61.3427	62.7779	68.0349	65.8724	67.3225	64.4677	63.4682	62.85
7	62.85	63.4682	64.4677	67.3225	65.8724	68.0349	68.235	68.235	68.235	67.6258	65.9883
8	64.2498	65.0904	65.9883	67.6258	68.235	68.235	68.235	68.235	68.235	68.235	68.235
9	64.2852	65.5386	66.5929	67.8853	68.235	68.235	68.235	68.235	68.235	68.235	68.235
10	64.5303	64.5303	65.867	67.2014	68.235	68.235	68.235	68.235	68.235	67.6082	68.235
11	63.2295	64.5271	64.5271	65.8181	67.0816	68.235	68.235	68.235	68.235	67.6082	62.6419
12	61.4692	62.8682	64.1306	64.1306	65.2992	66.3424	66.9704	67.2694	65.2188	66.4988	62.6419
13	60.213	61.3138	62.4147	63.4637	63.4637	64.421	65.0942	65.2673	65.2018	62.3835	64.1187
14	58.5894	59.6902	60.7911	61.6604	62.4256	62.4256	63.2067	63.5494	63.555	63.1337	60.4538
15	58.235	58.235	59.1675	60.2361	60.6978	61.0412	61.0412	61.4369	61.6413	61.5587	61.07
16	56.3383	57.5274	58.235	58.6447	59.1064	59.2468	59.4437	59.4437	59.6121	59.6526	59.5231
17	55.2313	56.6223	58.0133	58.235	58.235	58.235	58.235	58.235	58.235	58.235	58.235
18	54.4659	55.7249	57.1159	58.235	58.235	58.235	58.235	58.235	58.235	58.235	58.235
19	54.3749	55.7157	56.3867	57.6094	58.235	58.235	58.235	58.235	58.235	58.235	58.235
20	56.6691	57.0236	57.2403	57.7039	58.103	58.235	58.235	58.235	58.235	58.235	58.235
21	59.6506	59.4617	60.2849	59.5024	59.7166	59.728	59.2773	58.2526	58.235	58.235	58.235
22	64.8947	63.1375	62.5764	63.9117	62.205	61.9326	61.5537	60.8518	59.804	58.4708	58.235
23	70.0248	68.816	66.7951	65.9967	67.7397	65.2347	64.3951	63.3156	62.4466	61.346	59.9874
24	75.5039	74.1033	72.8031	70.563	69.5277	71.6397	68.3736	67.2611	65.9685	64.5526	62.9527
25	81.0085	79.5482	78.1721	76.8617	74.4285	73.1945	75.5841	71.9313	70.4277	68.6163	66.9812
26	86.3809	84.924	83.5129	82.0948	80.787	78.317	77.0676	79.5361	75.6019	73.8274	71.8554
27	91.8221	90.1748	88.688	87.2081	85.8253	84.5726	82.2359	80.9375	83.428	79.3839	77.5346
28	95.2082	95.2082	93.6706	92.1154	90.6809	89.3509	88.1324	85.7178	84.5486	86.8872	83.1562

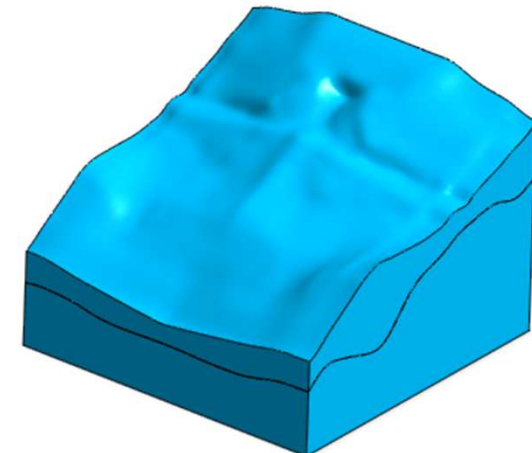
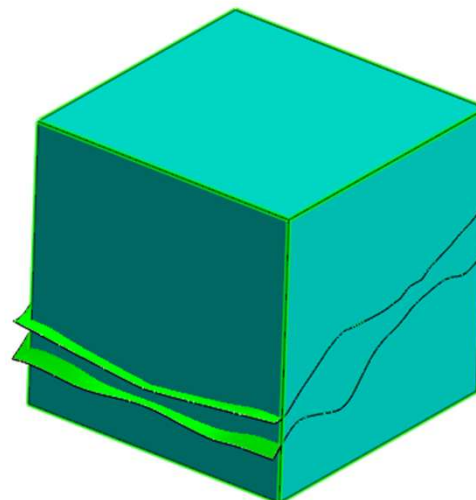
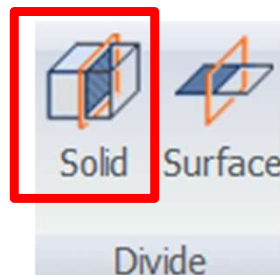
Load... Save As... OK Close



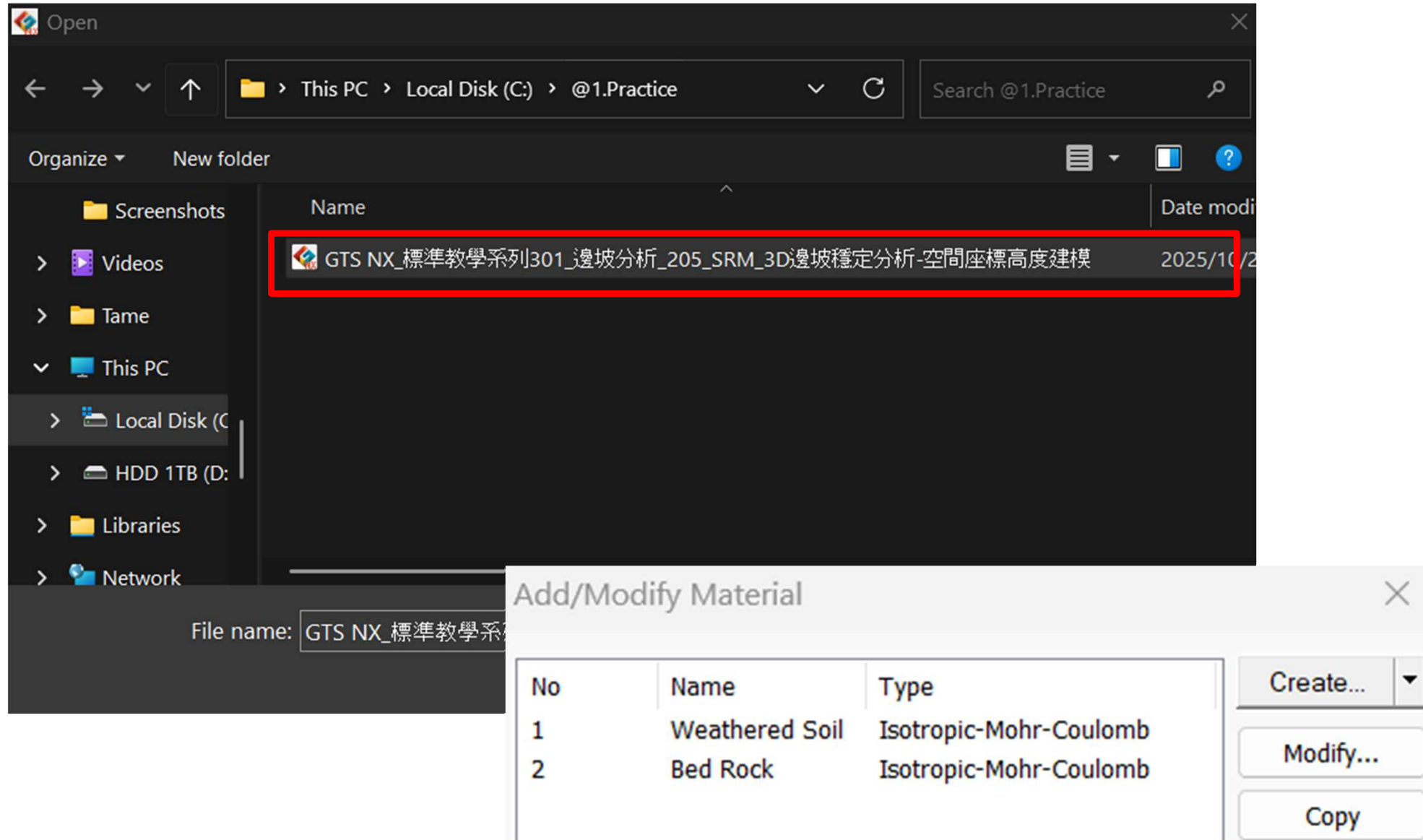
Geometry - Ground



Irregular ground surface

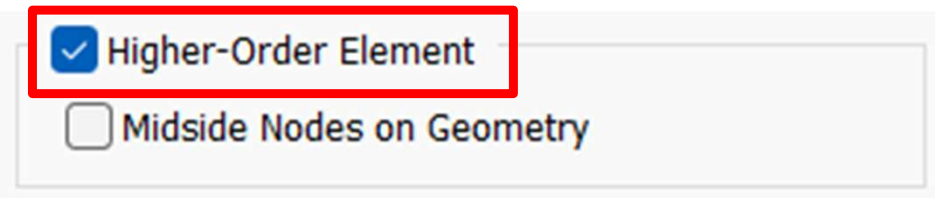
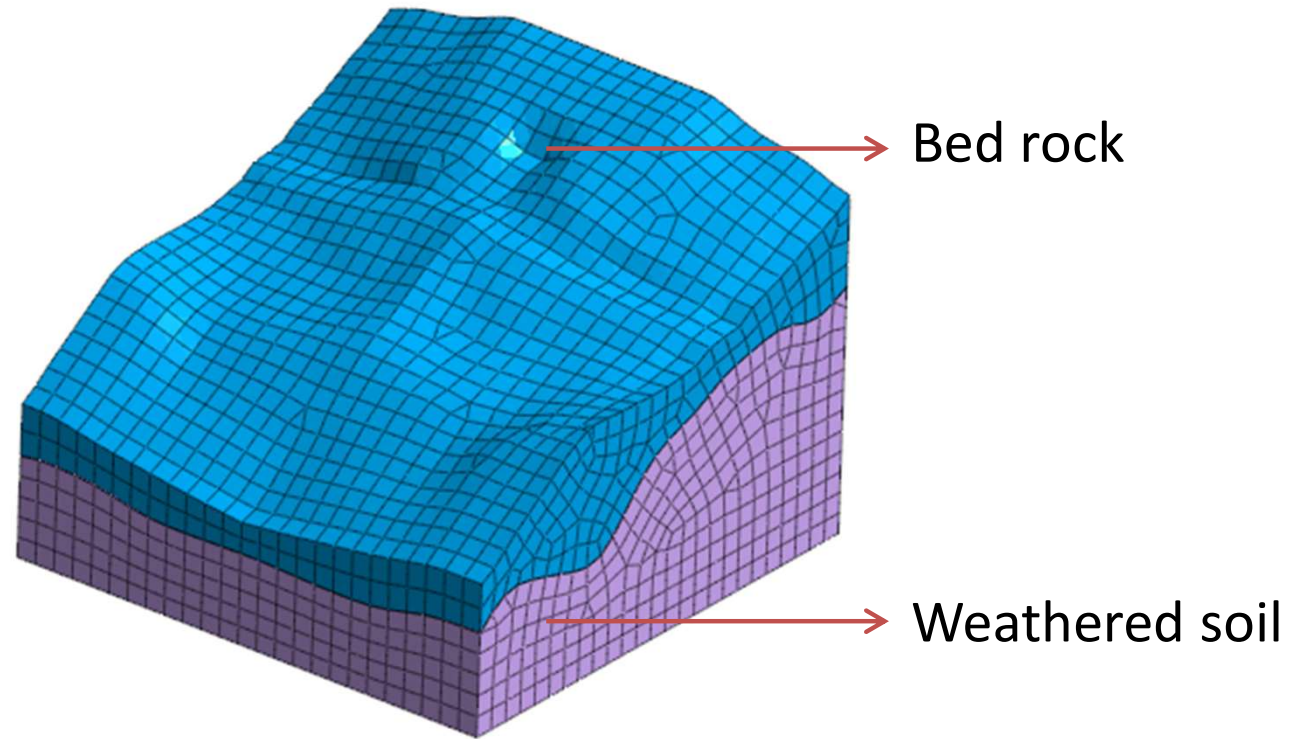
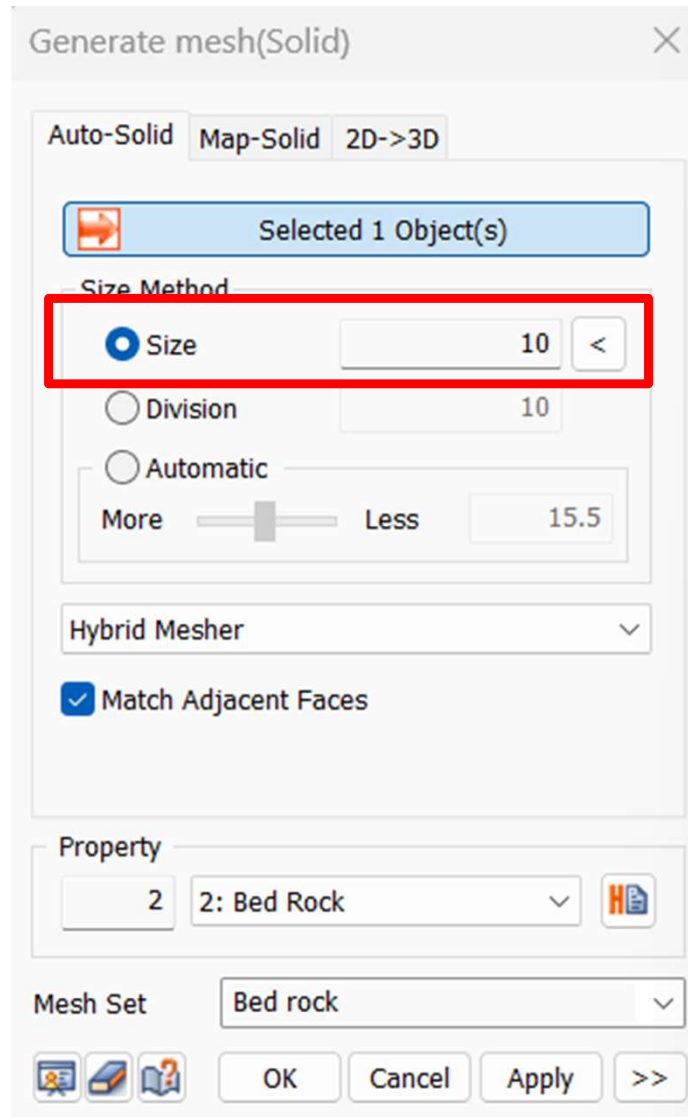


Import Property

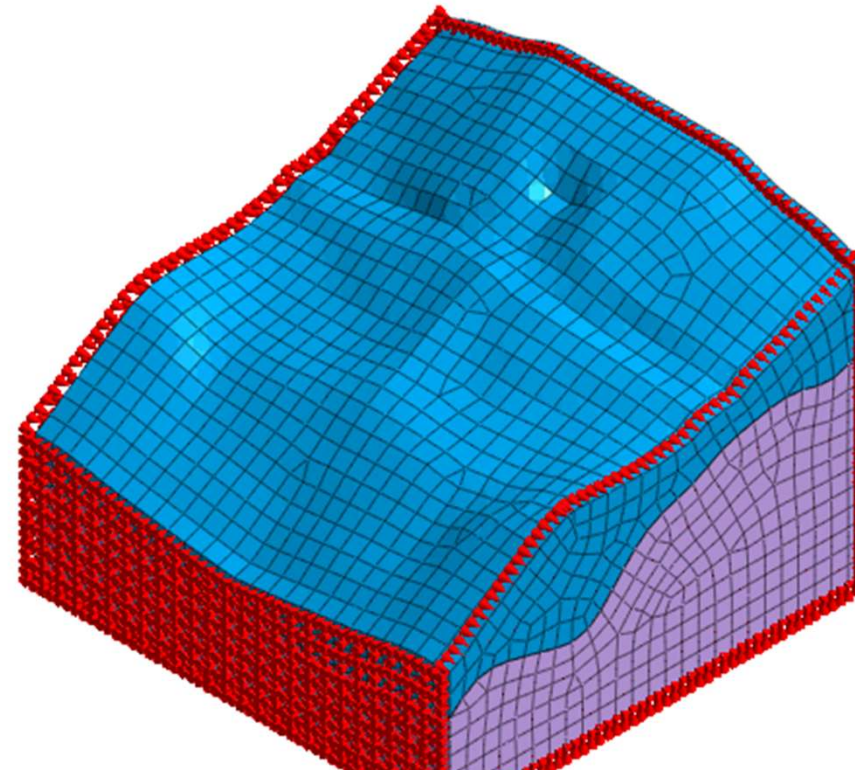
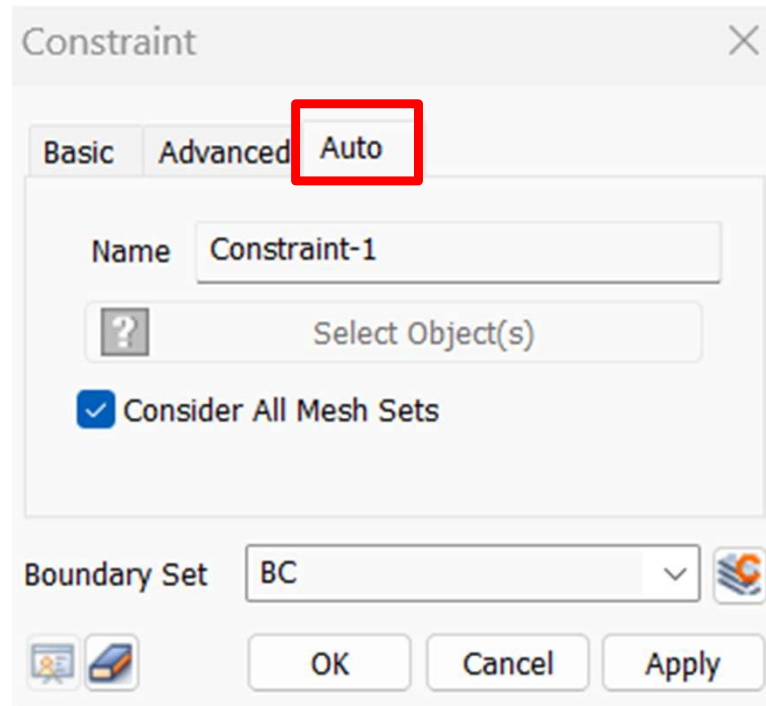


Soil Material & Property are imported

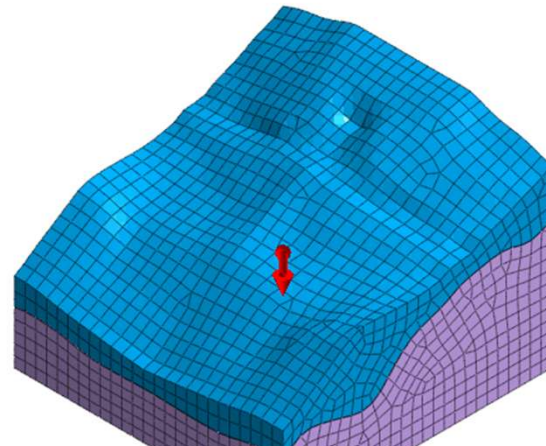
Mesh



Boundary Condition

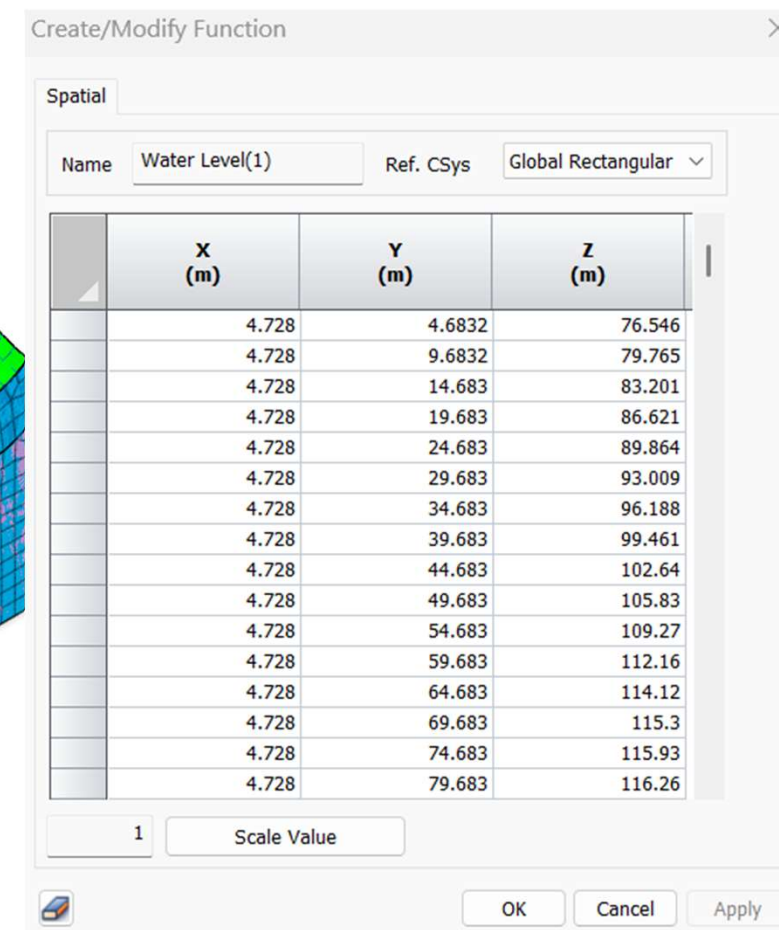
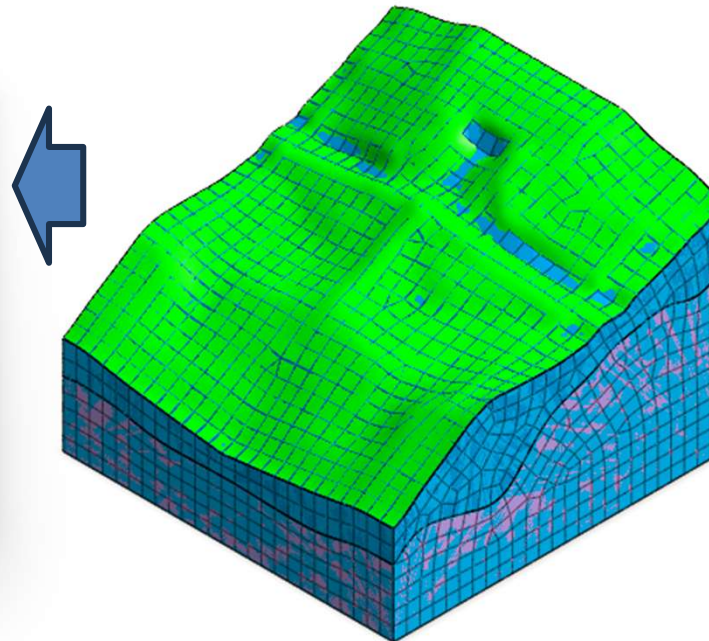
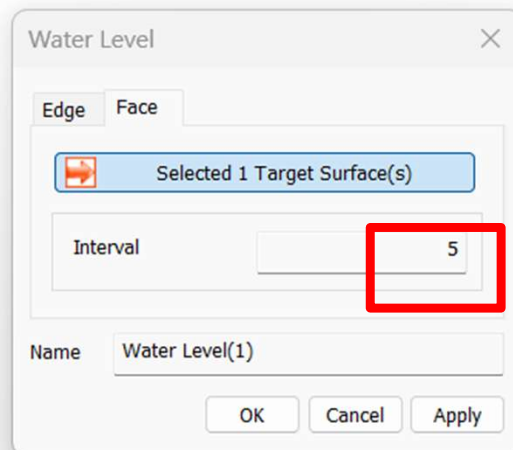
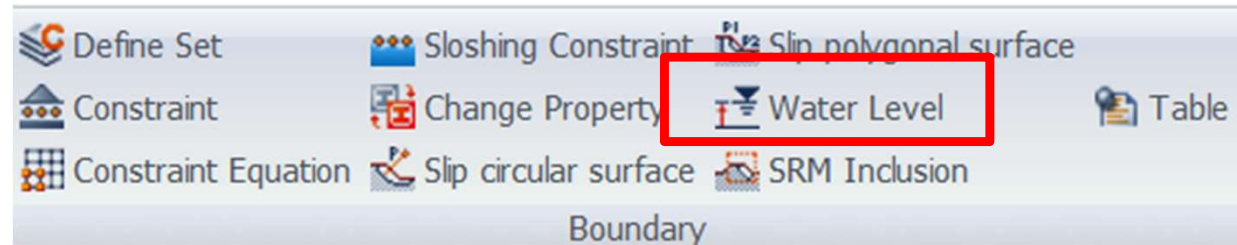


Boundary condition is assigned



Gravity assignment

Water Level



Analysis - SRM

Add/Modify Analysis Case

Analysis Case Setting

Title: 3D SRM

Description:

Solution Type: **Slope Stability(SRM)**

Construction Stage Set:

Analysis Case Model

All Sets << >> Active Sets

Mesh

- Bed rock
- Default Mesh Set
- Weathered soil

Boundary Condition

- BC

Static Load

- Default Self-Weight
- Combined Load Sets
- Contact Pair

Analysis Control

General Slope Stability(SRM)

Geometry Nonlinearity

☐ Consider Geometric Nonlinear Effects

Nonlinear parameters

Maximum Number of Trials: 50

Maximum Number of Iterations: 50

Stiffness Update Scheme: Full Newton-Raphson

Intermediate Output Request: **Every Iteration**

Convergence Criteria / Error Tolerance

☐ Displacement(U): 0.01

☒ Load(P): 0.01

☐ Work(W): 0.0001

Safety Factor

Initial Safety Factor: 1

Increment of Safety Factor: 0.1

Resolution of Safety Factor: 0.01

☐ Safety Factor Function

Advanced Nonlinear Parameters...

OK Cancel

Element Results

☒ Force Mesh Set...

☒ Stress Mesh Set...

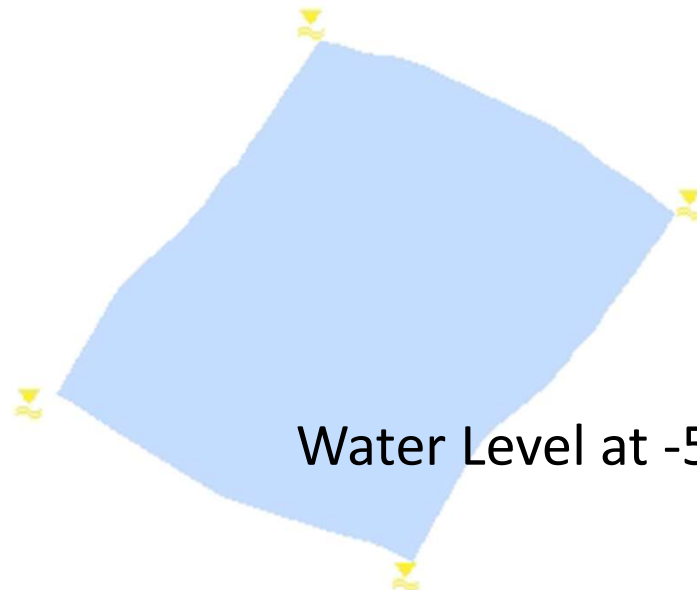
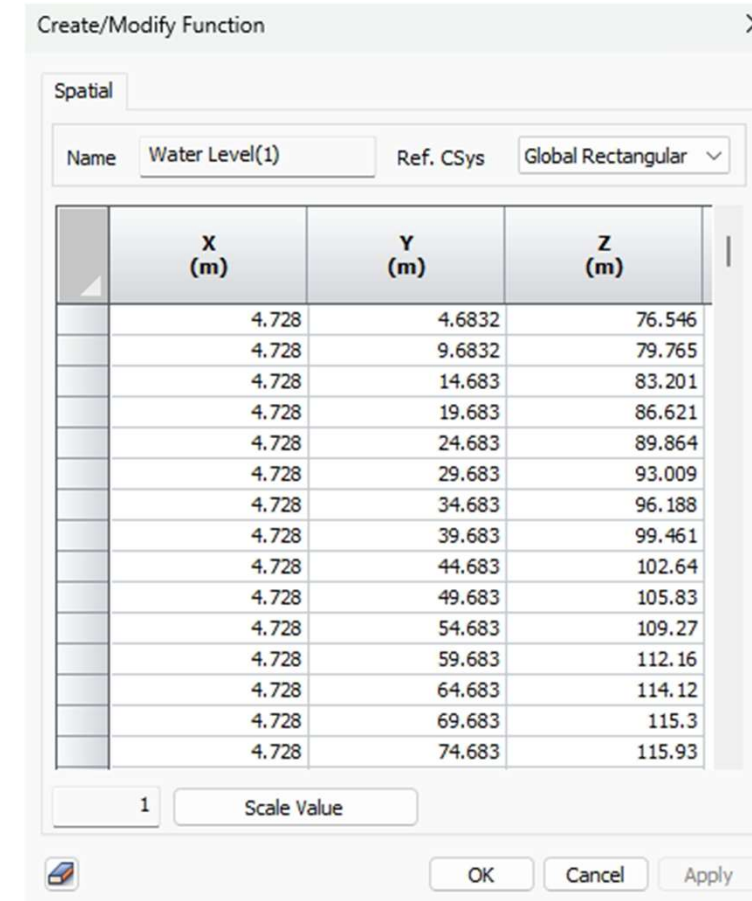
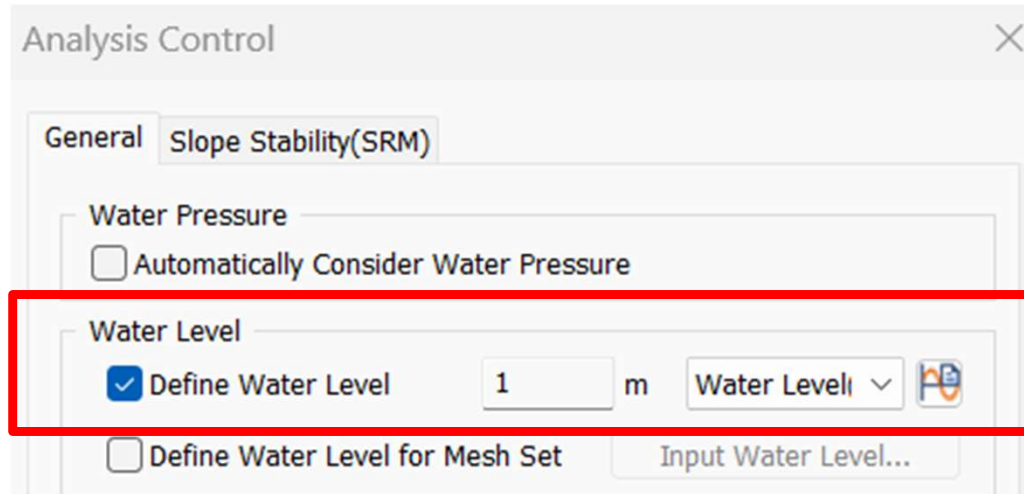
☒ Strain Mesh Set...

☒ Status Mesh Set...

☐ Damaged Index Mesh Set...

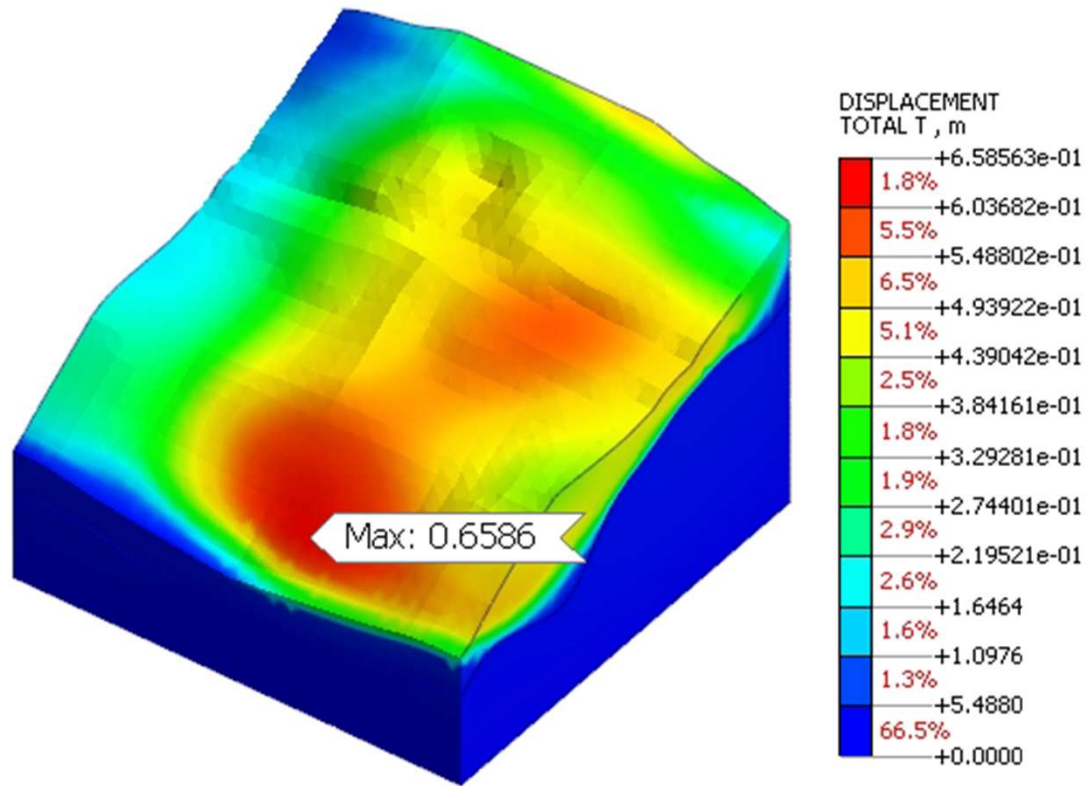
☐ Ductility Mesh Set...

Analysis – WL define

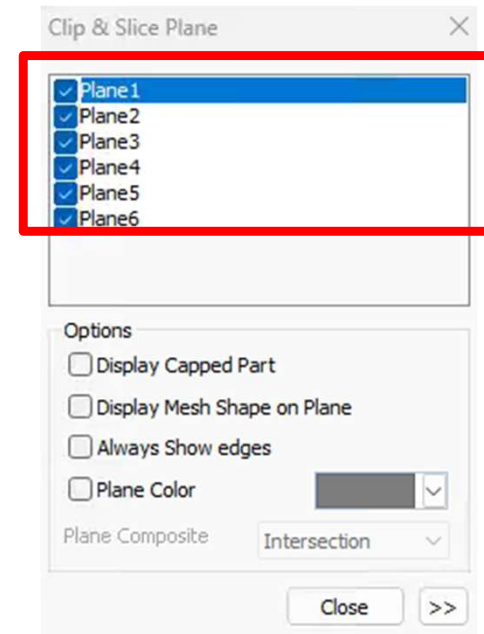


Water Level at -5 m

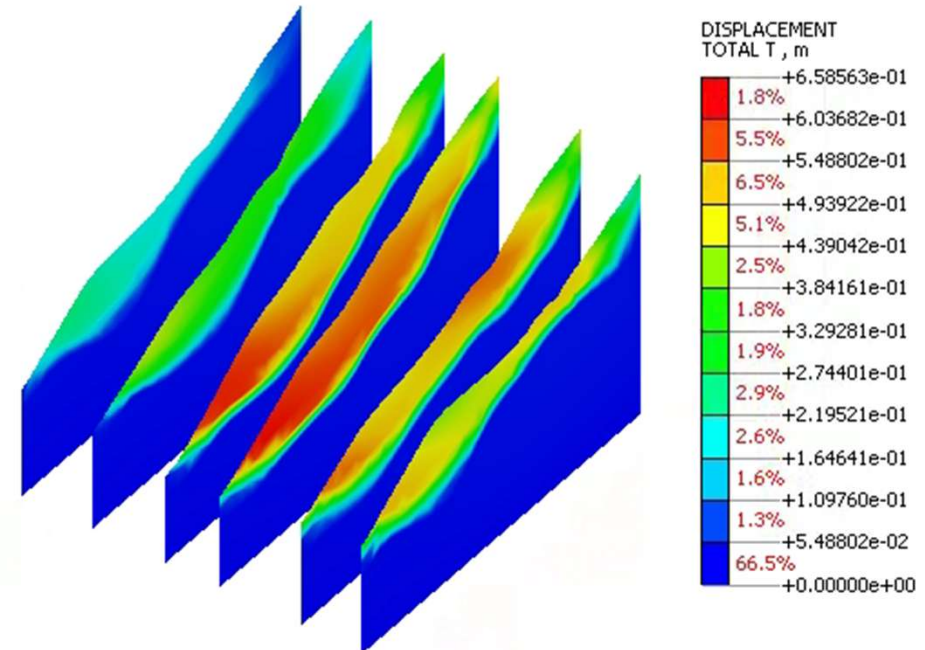
Results



Maximum Total Translation 0.66 m



Section View



Thank you! ♥