GTS NX

Different hazard conditions in slope stability

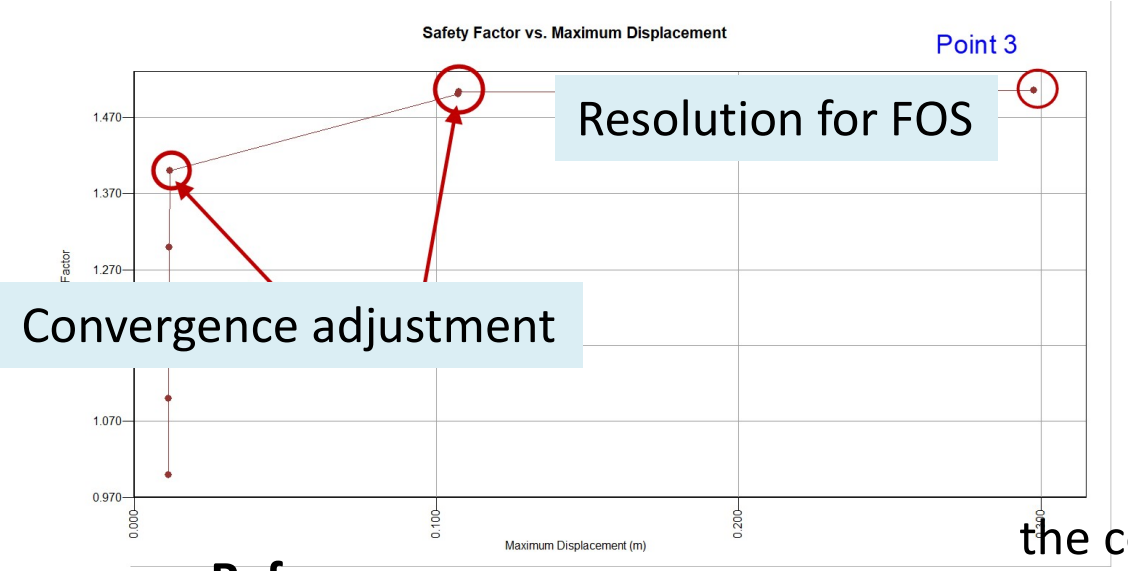
MIDAS Taiwan

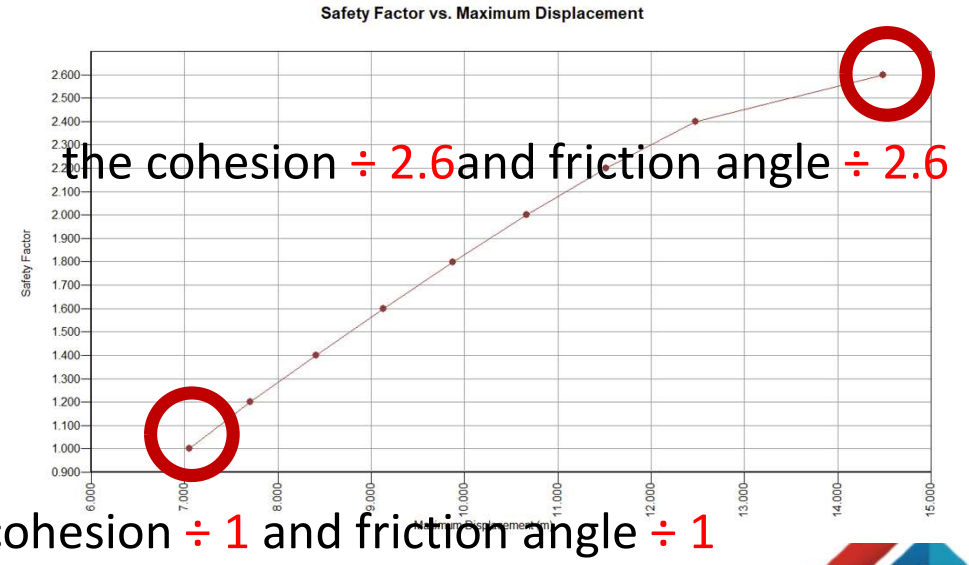
Note: The parameters in the example use assumed conditions.

Strength Reduction Method (SRM)

In GTS NX, slope stability assessment uses the Strength Reduction Method (SRM), which determines the failure point by progressively reducing the soil's shear strength parameters. In this method, the soil's cohesion (c) and internal friction angle (ϕ) are systematically reduced using a reduction factor F; this reduction factor value is the safety factor (FoS).

The slope stability calculation depends on the soil strength, which in turn depends on the soil's cohesion and internal friction angle, as well as instability factors such as soil weight, water pressure, and external loads. Users can adjust the convergence criteria (load/displacement/work) in the analysis definition according to their preferences.





the cohesion ÷ 1 and friction angle ÷ 1

Reference

The intensity reduction method proposed by Griffith et al. (1999) and Matsui (1990)

Pseudo-static seismic

Pseudo-static seismic method is a simplified way to represent earthquake effects by replacing dynamic ground shaking with constant equivalent static forces

→ Applying inertial body forces proportional to gravity instead of time-varying acceleration

$$F_h = k_h W, \qquad F_v = k_v W$$

Where:

- k_h = horizontal seismic coefficient
- k_v = vertical seismic coefficient

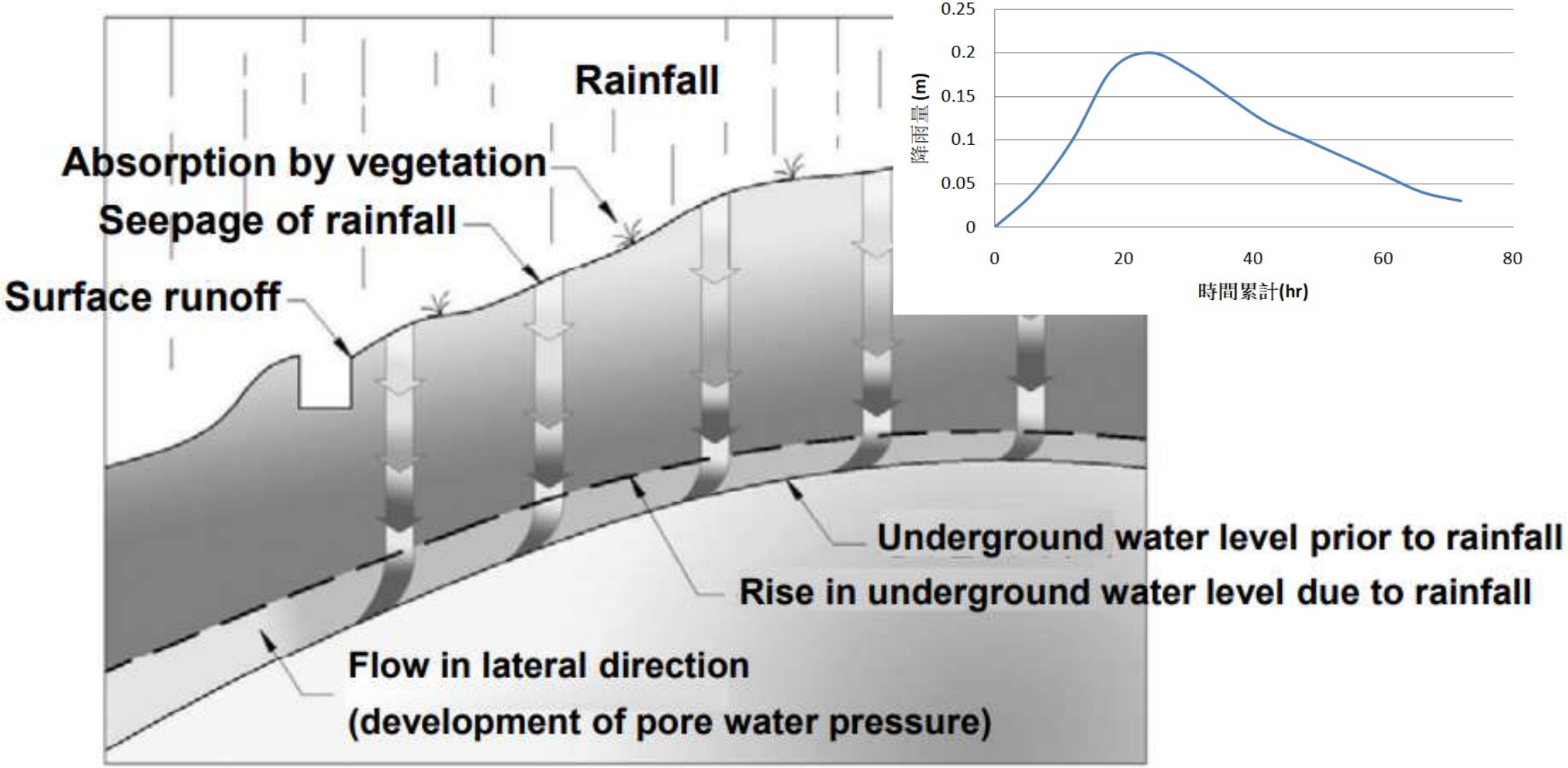
These forces are applied **uniformly to the entire soil mass.**

Reference

GTS NX/FEA NX/Soilworks Manual

Seepage through Unsaturated Slope

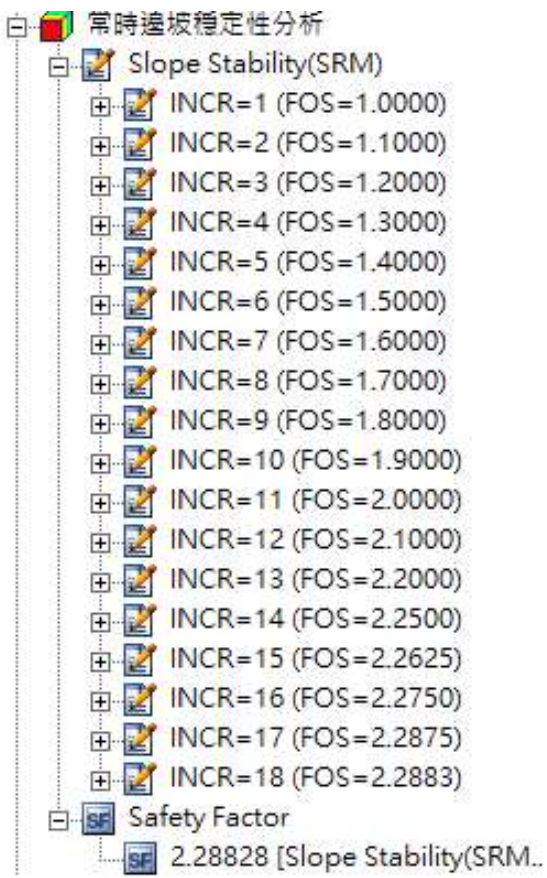
Seepage induced by rainfall



Surface rainfall over 72 hours

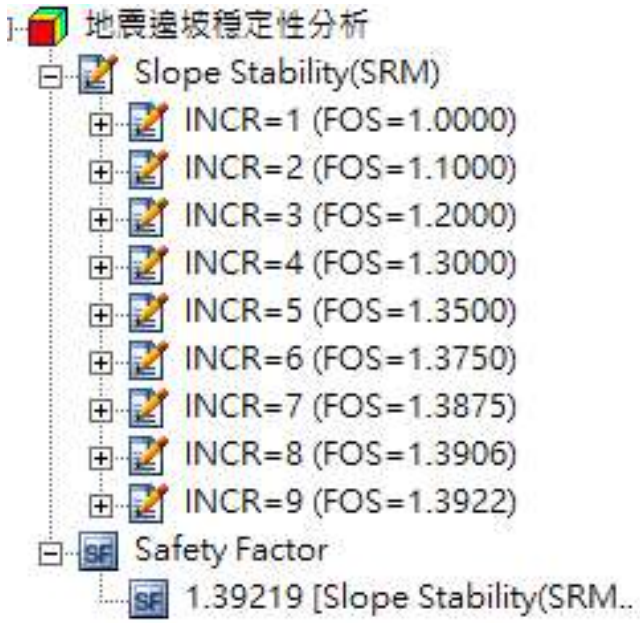
Comparison for different cases

Normal case



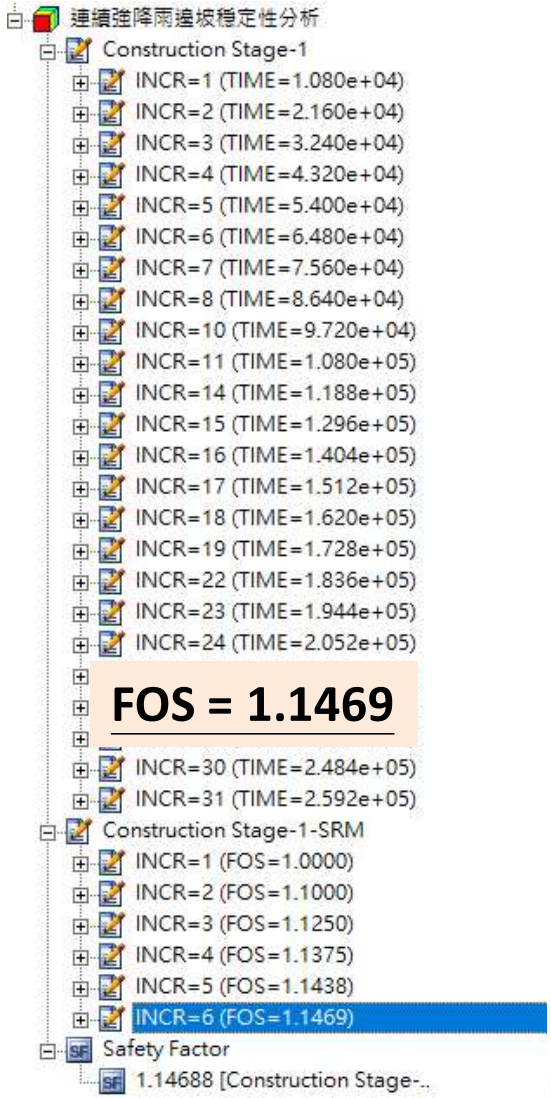
FOS = 2.2883

Pseudo-static seismic



FOS = 1.3922

Heavy rainfall case

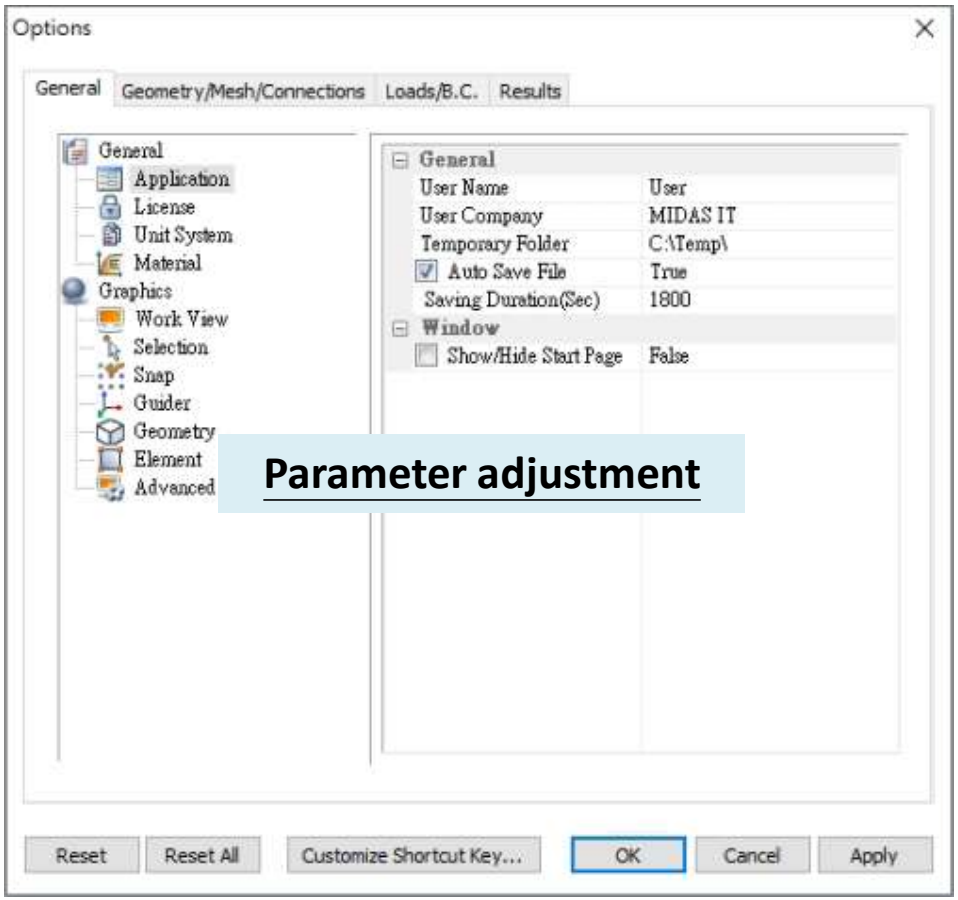


FOS = 1.1469

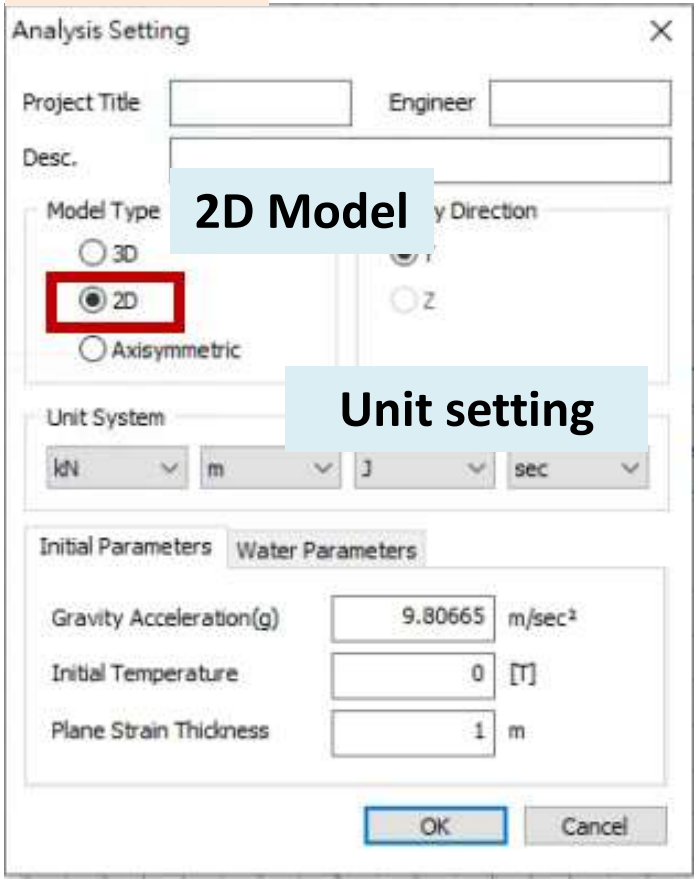
Part1. Normal condition

Import

New file



Parameter adjustment

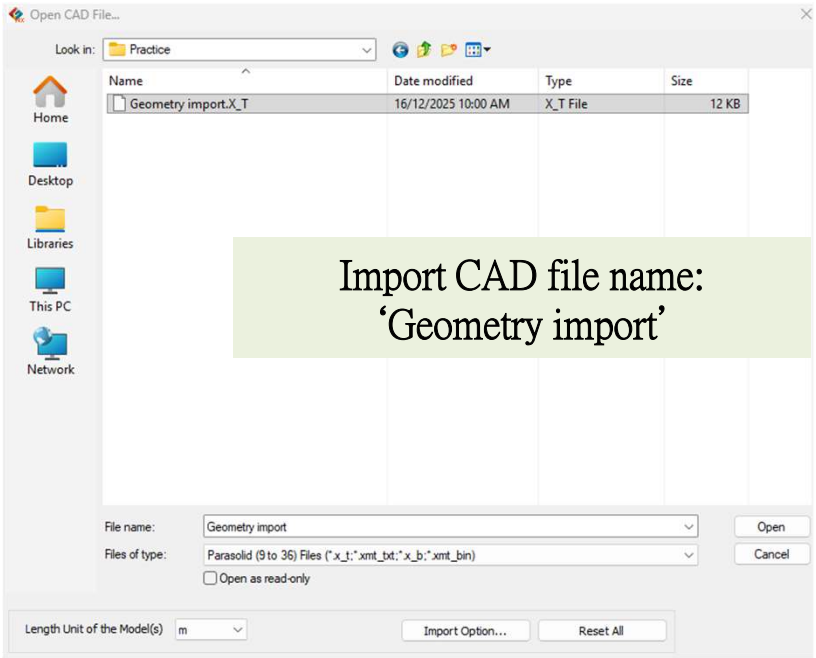


2D Model

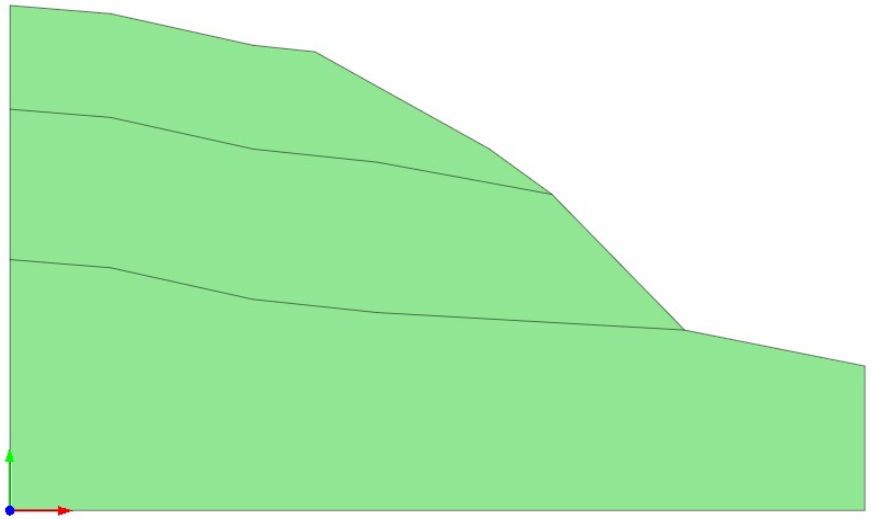
Unit setting

Unit setting as:
KN/m/J/sec

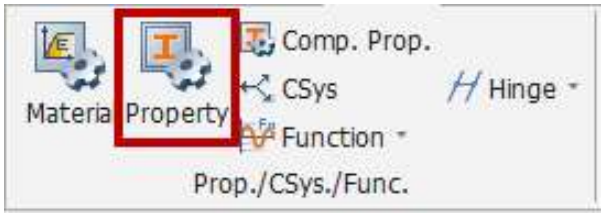
2D Model Import

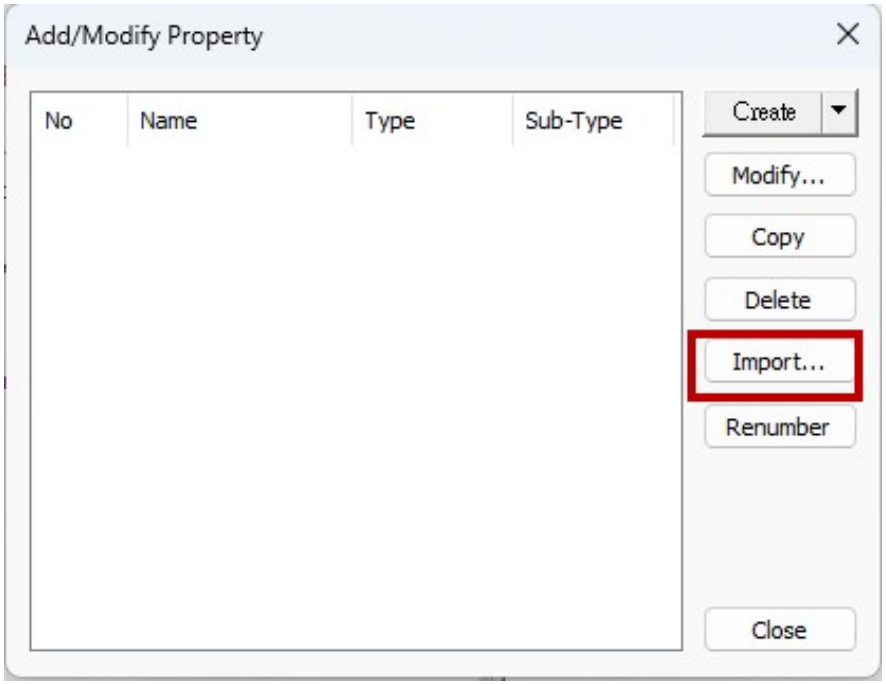


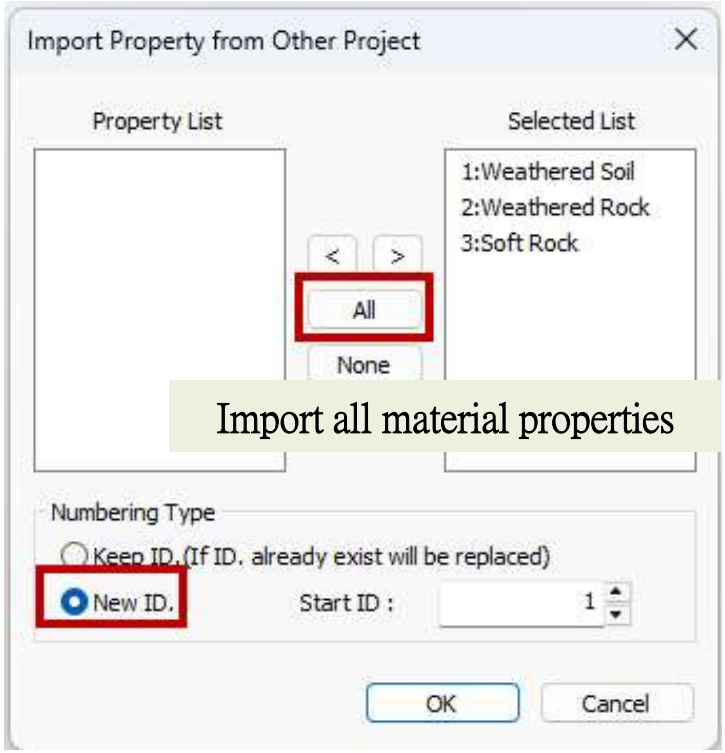
Import CAD file name:
'Geometry import'



Material & Property



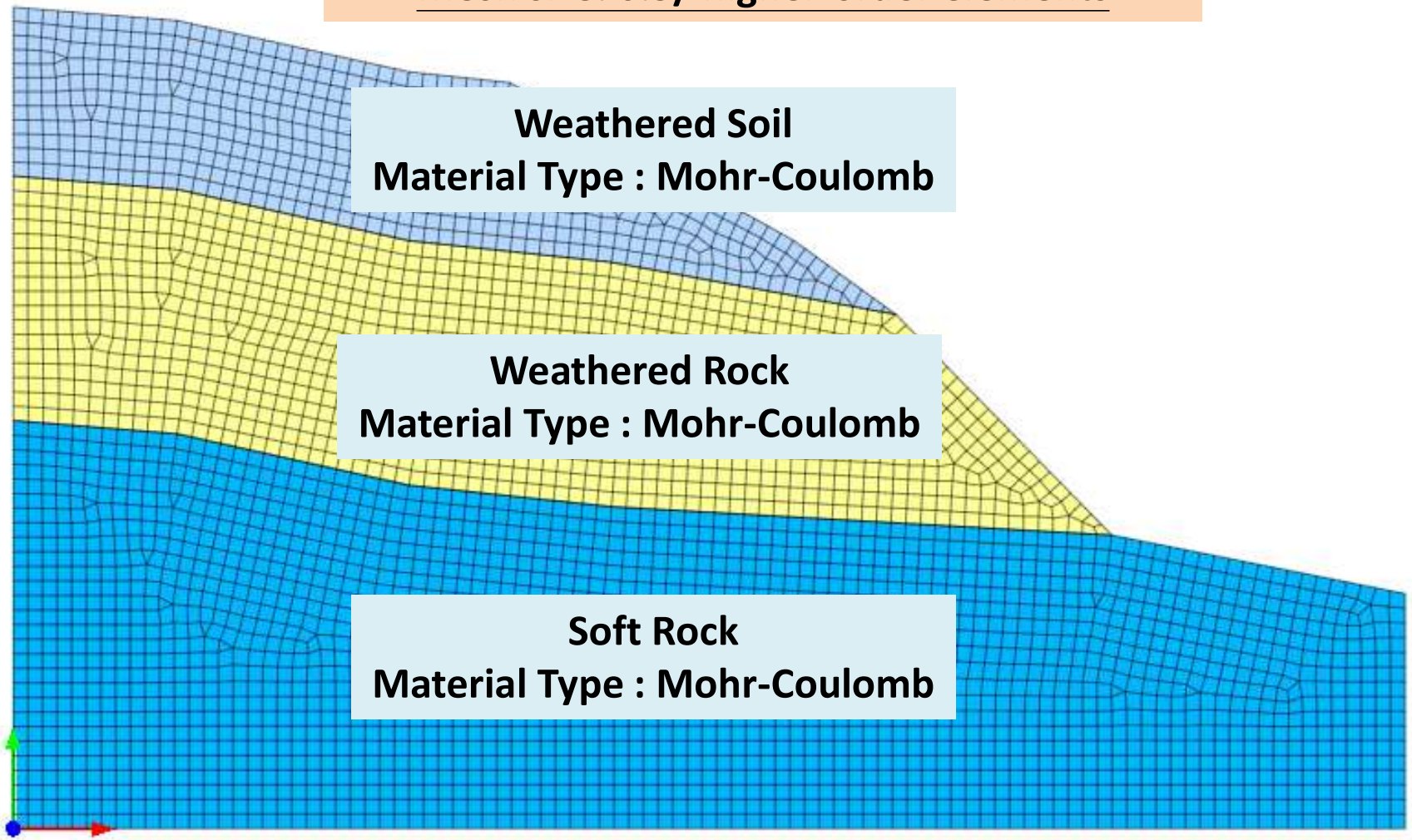




Import all material properties

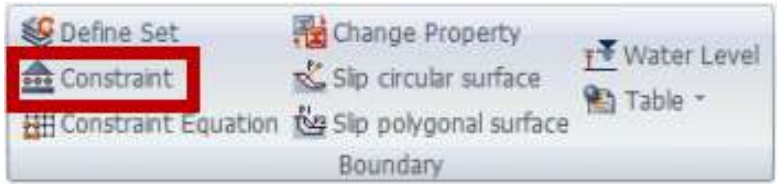
2D Mesh Generation

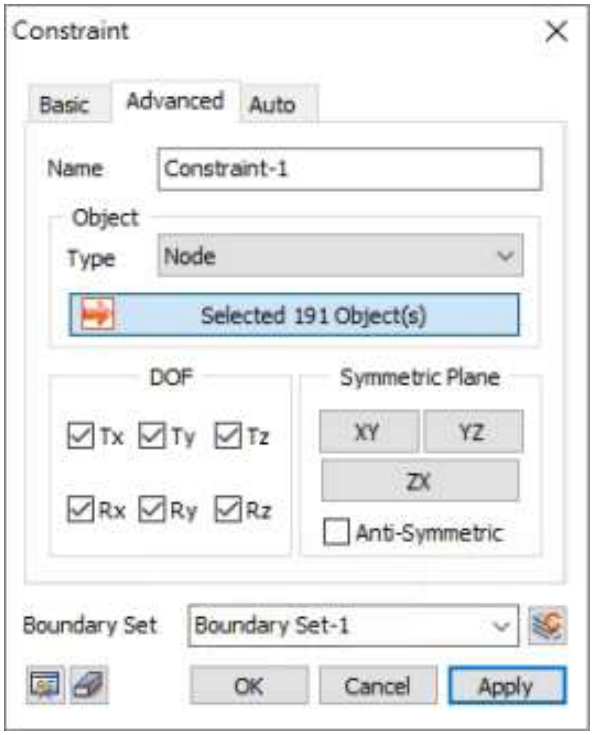
Mesh size: 0.5/ higher-order elements

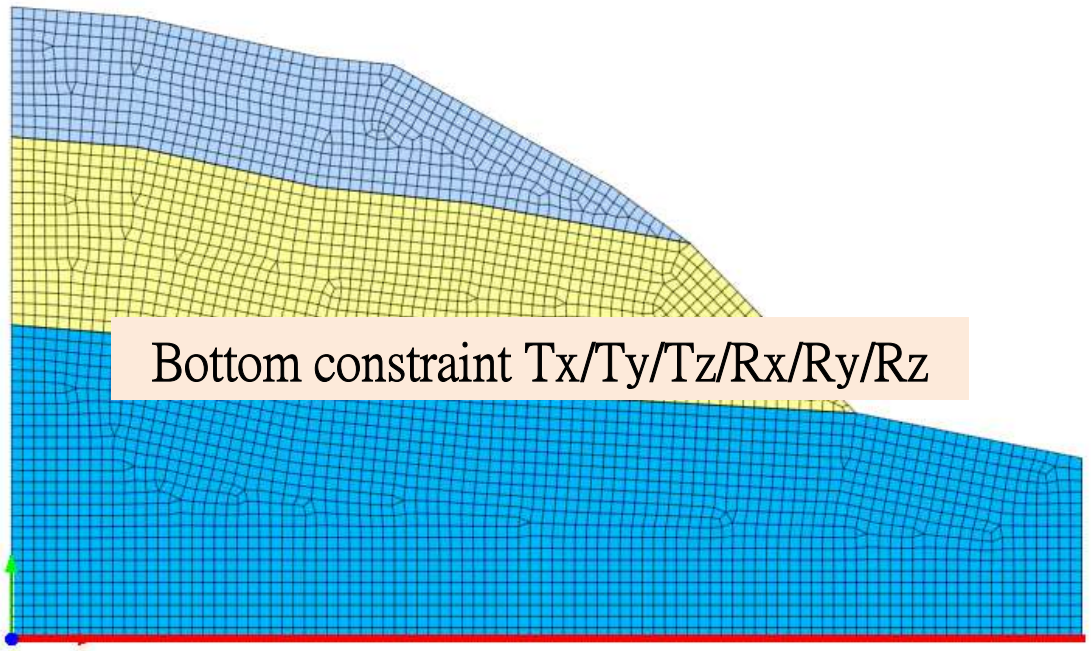


Note: Using higher-order elements and smaller grid sizes for slope analysis

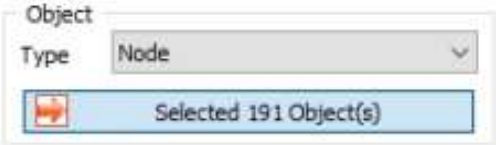
Bottom Boundary

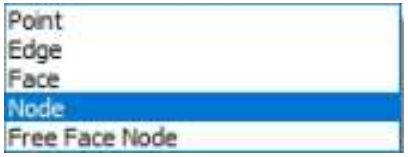




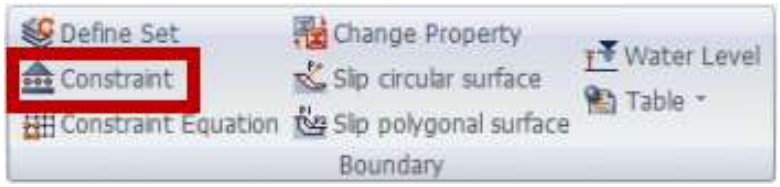


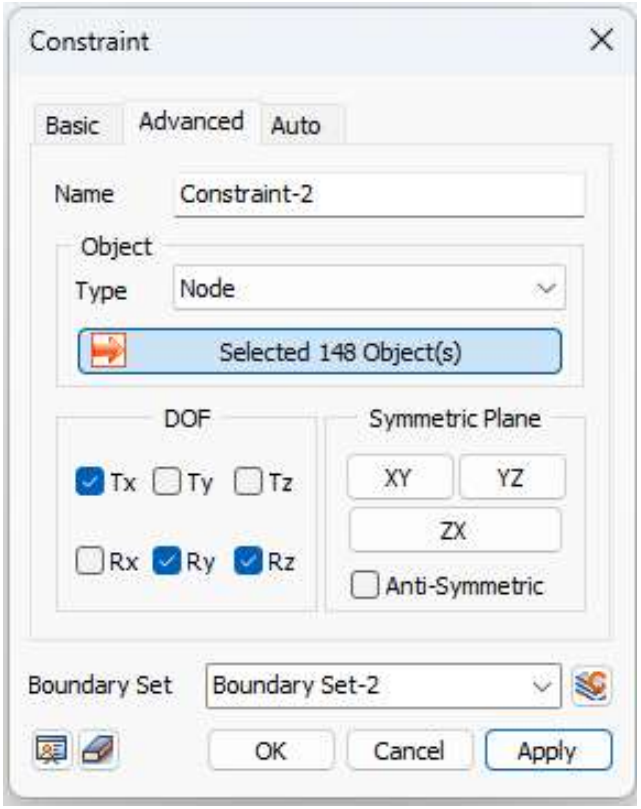
The geometric features or nodes can be applied to the boundary

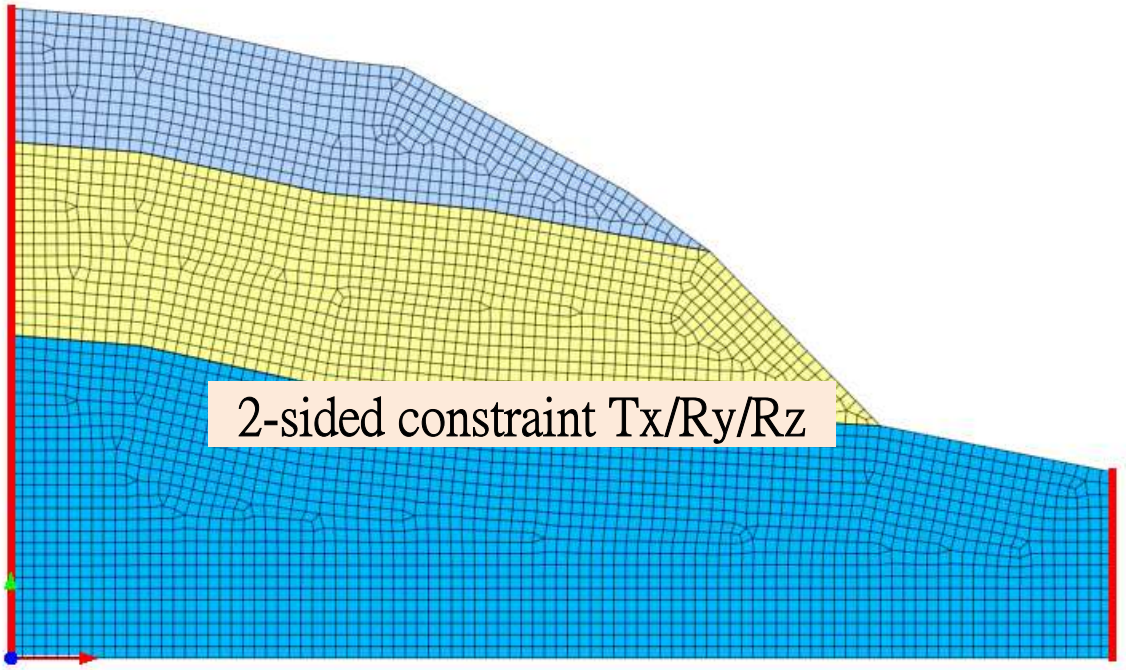




2-Sided Boundary



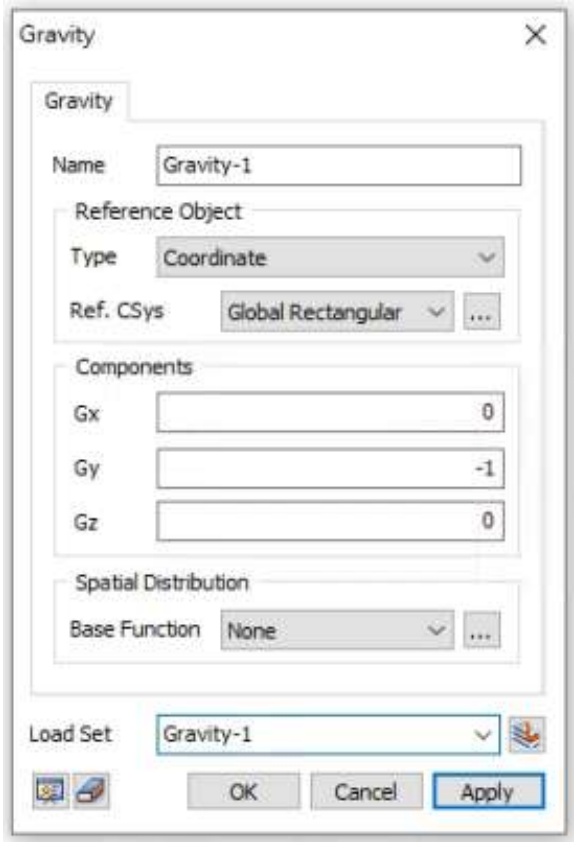


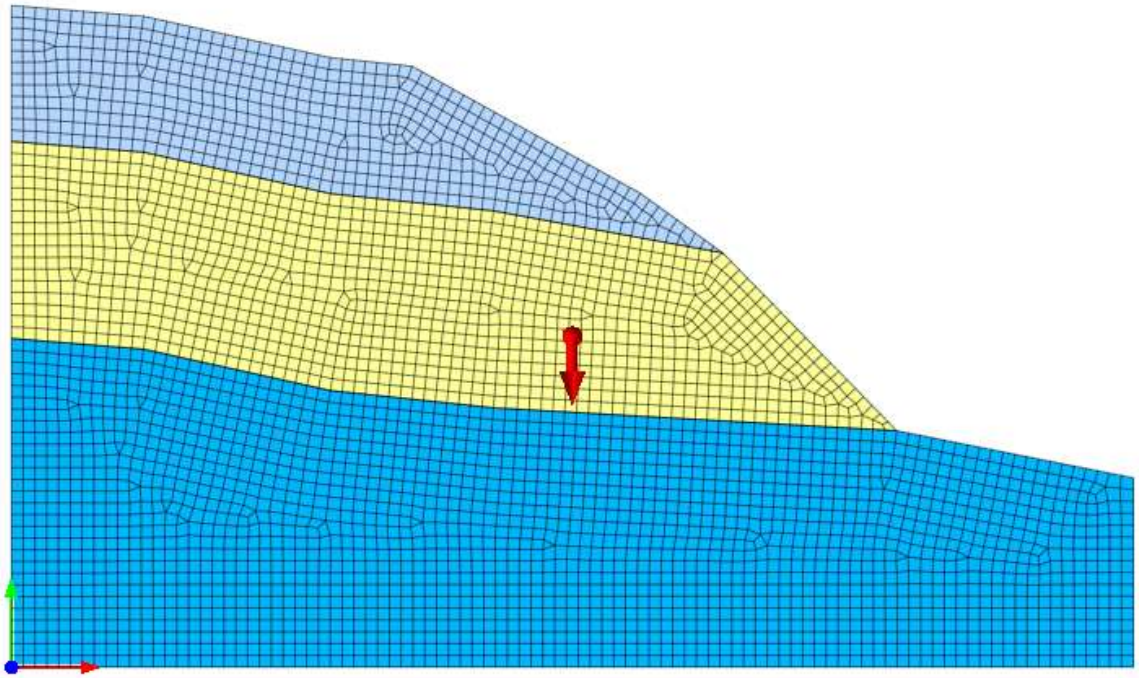


It is recommended to set boundary sets for different location

Self-Weight

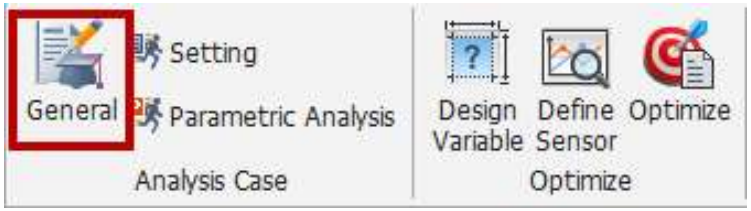

Self
Weight
Load


Gravity
Gravity
Name
Gravity-1
Reference Object
Type
Coordinate
Ref. CSys
Global Rectangular
Components
Gx
0
Gy
-1
Gz
0
Spatial Distribution
Base Function
None
Load Set
Gravity-1
OK
Cancel
Apply

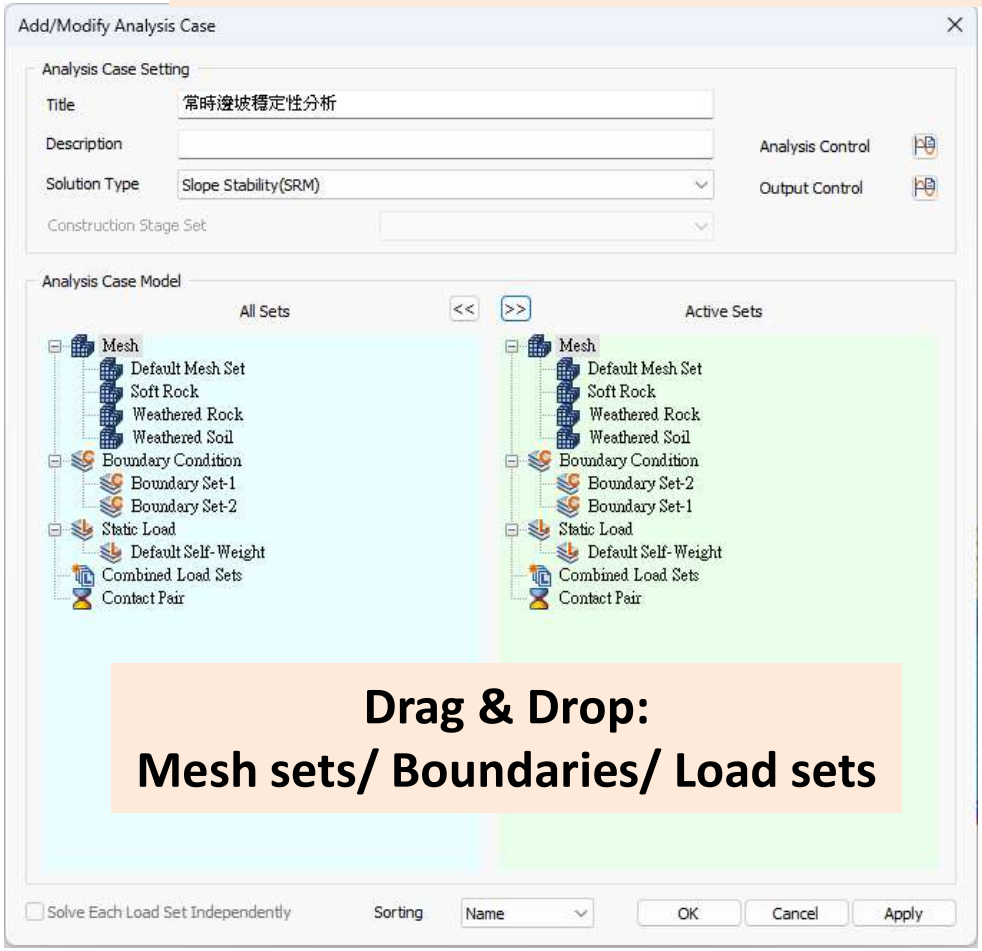


Analysis-1

(Slope stability (SRM) – Normal case)



Simulation type: Slope Stability(SRM)

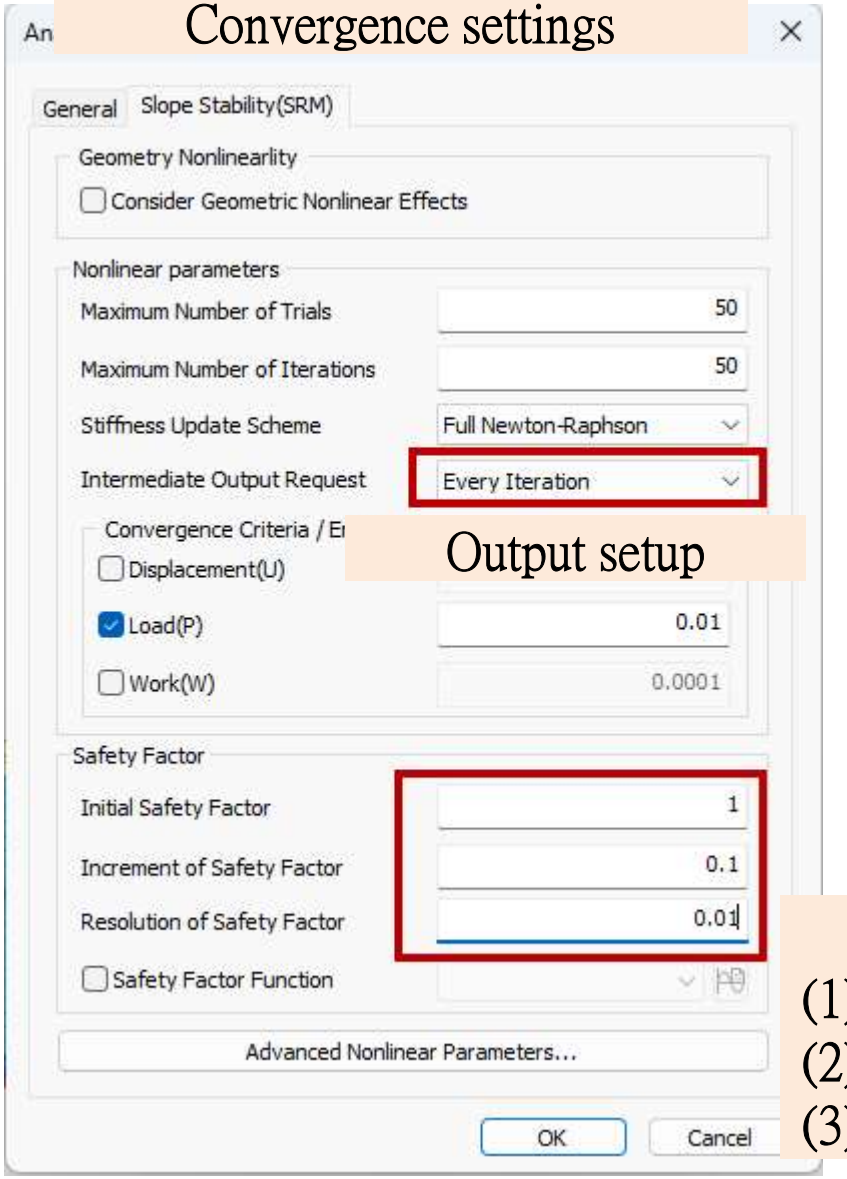


Drag & Drop:
Mesh sets/ Boundaries/ Load sets

Analysis-2

(Slope stability (SRM) – Normal case)

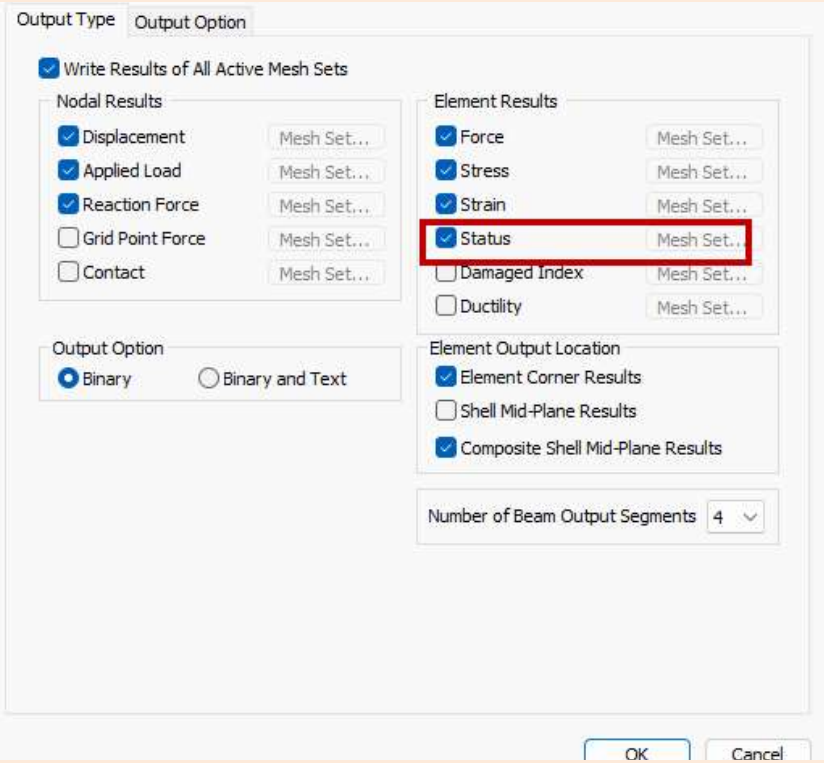
Convergence settings



Output setup

Output=>Strain

Shear strain indicates the failure arc



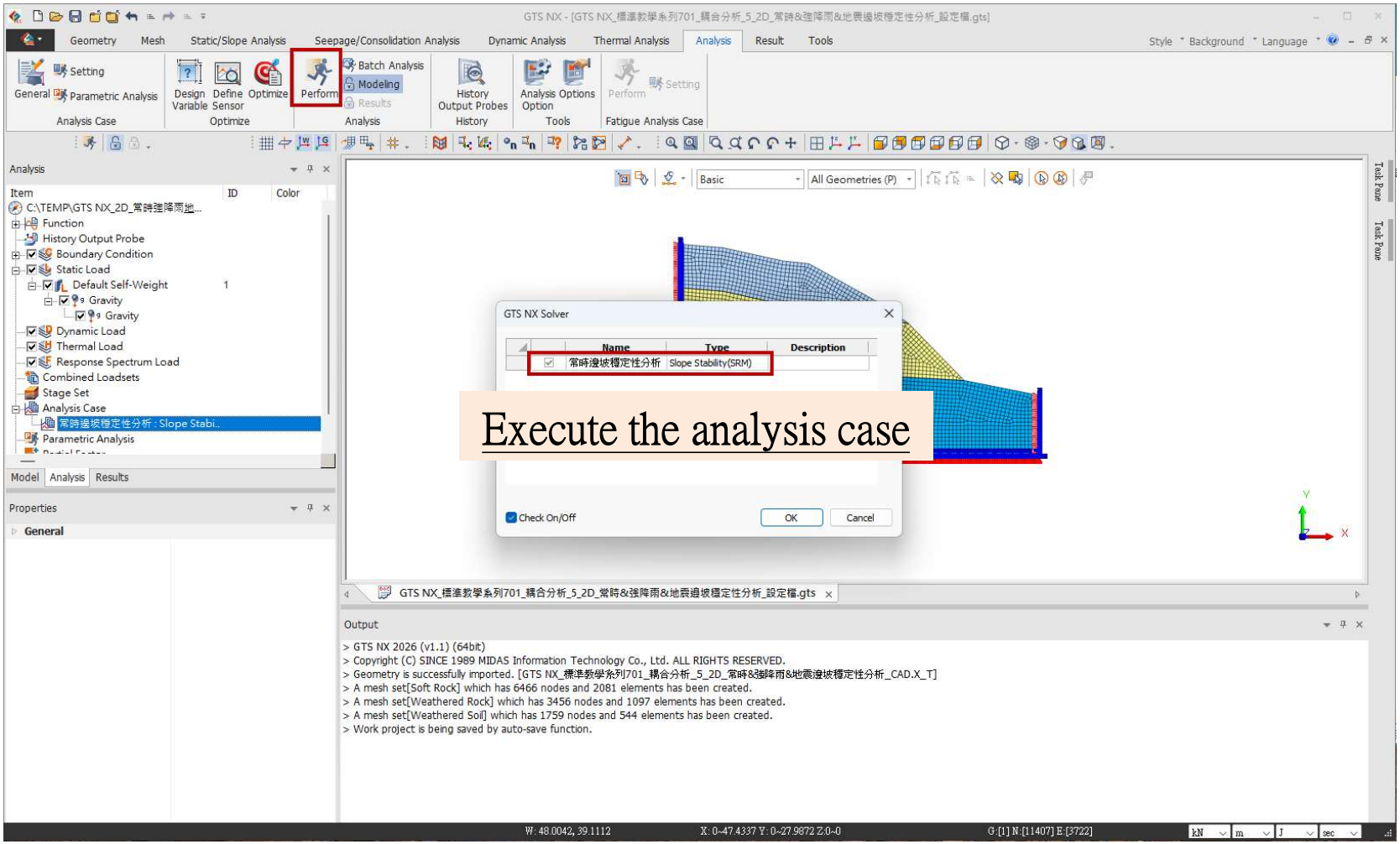
SRM convergence adjustment

(1) Initial safety factor 1

(2) FOS increment by 0.1 each time

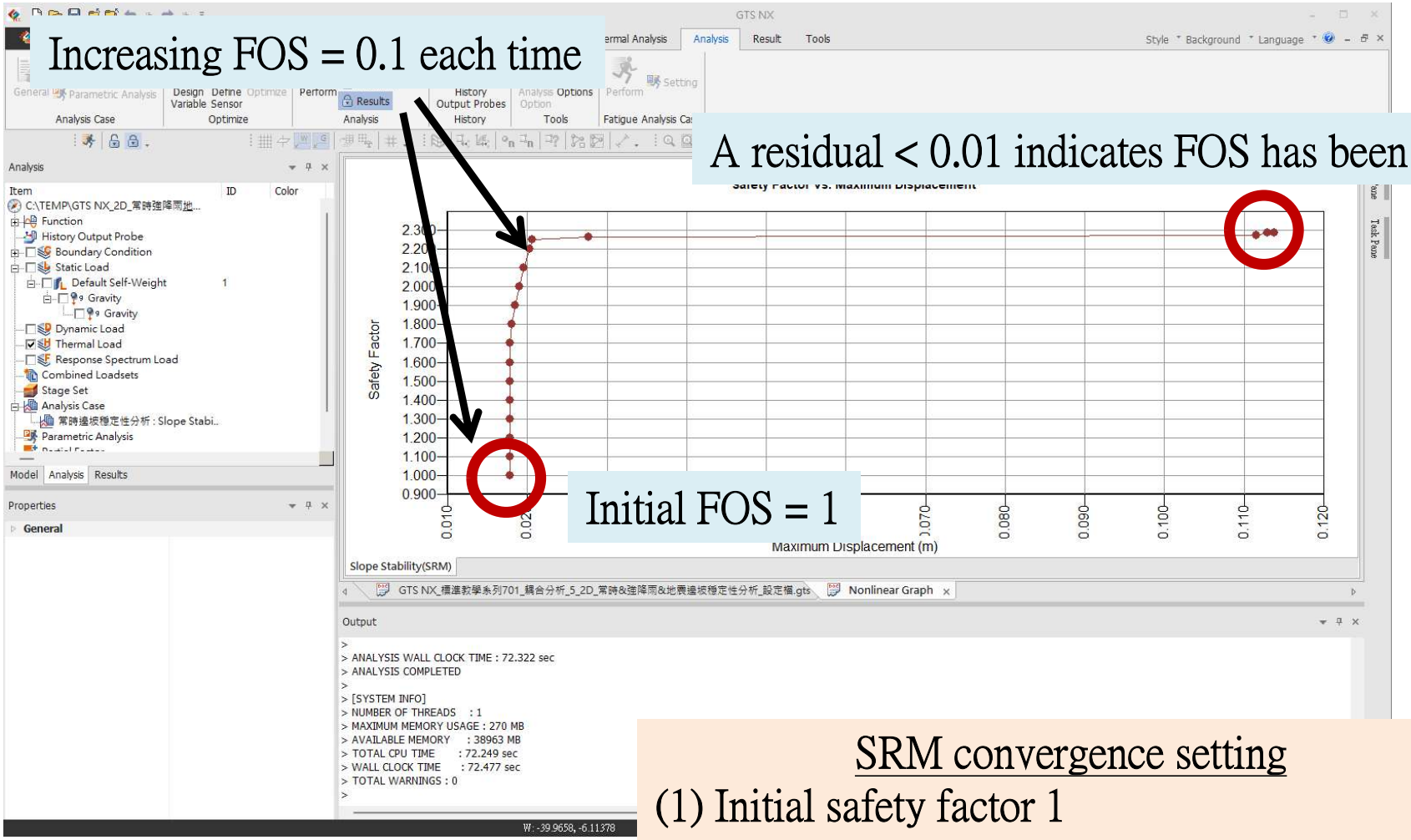
(3) Residual < 0.01, minimum FOS reached

Calculation



Safety factor indication

(Convergence criteria)



SRM convergence setting

(1) Initial safety factor 1

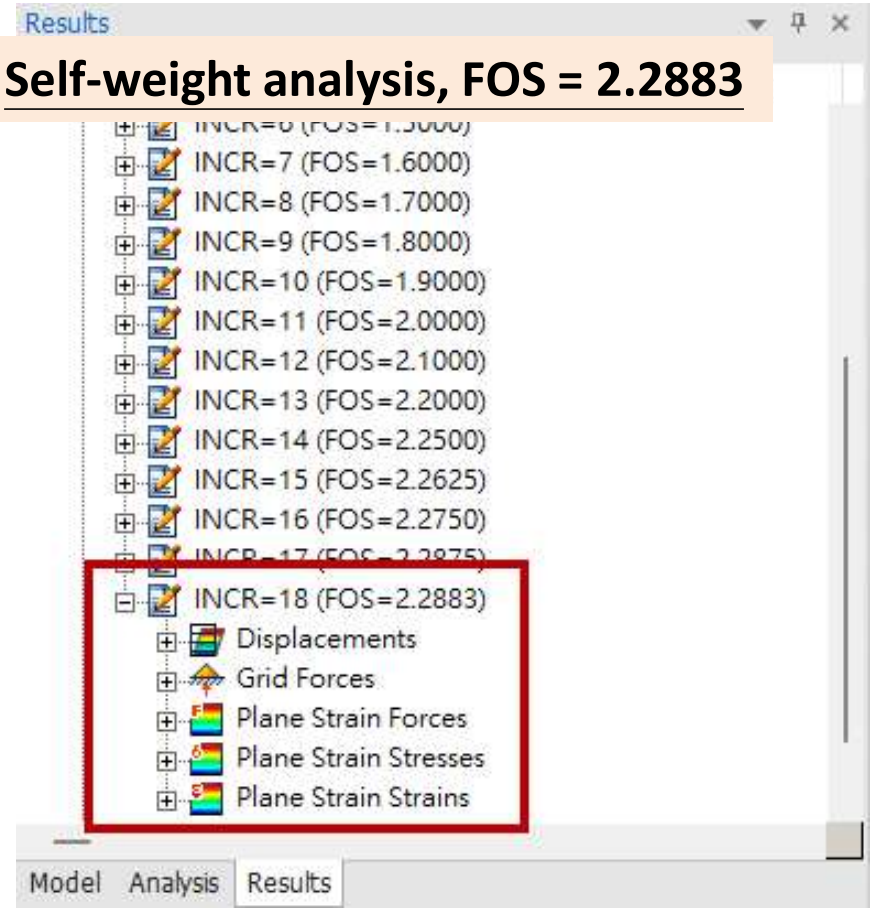
(2) FOS increment by 0.1 each time

(3) Residual < 0.01, minimum FOS reached

Results

(Normal case)

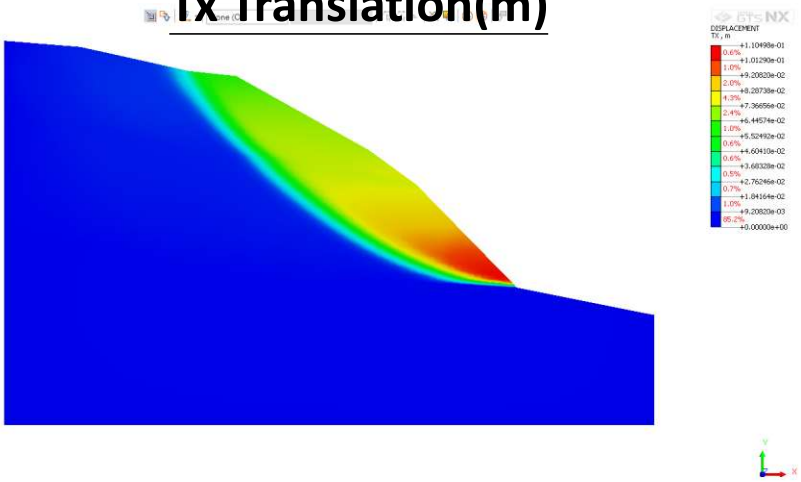
Self-weight analysis, FOS = 2.2883



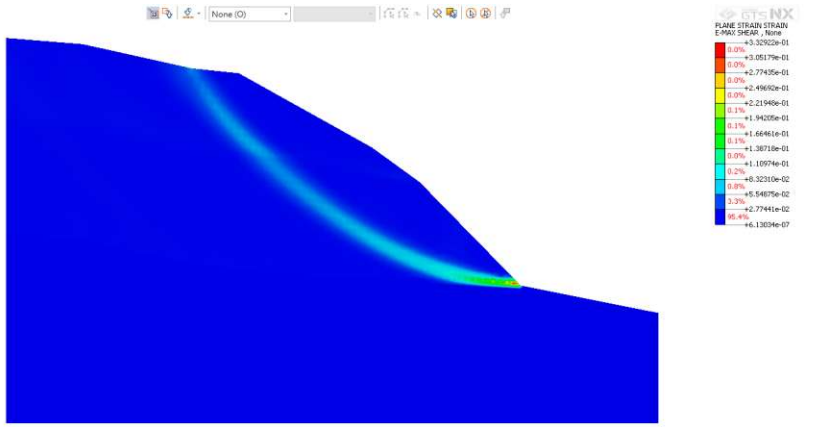
SRM for safety factor calculation

Failure surface indicated by horizontal displacement & maximum shear strain

Tx Translation(m)

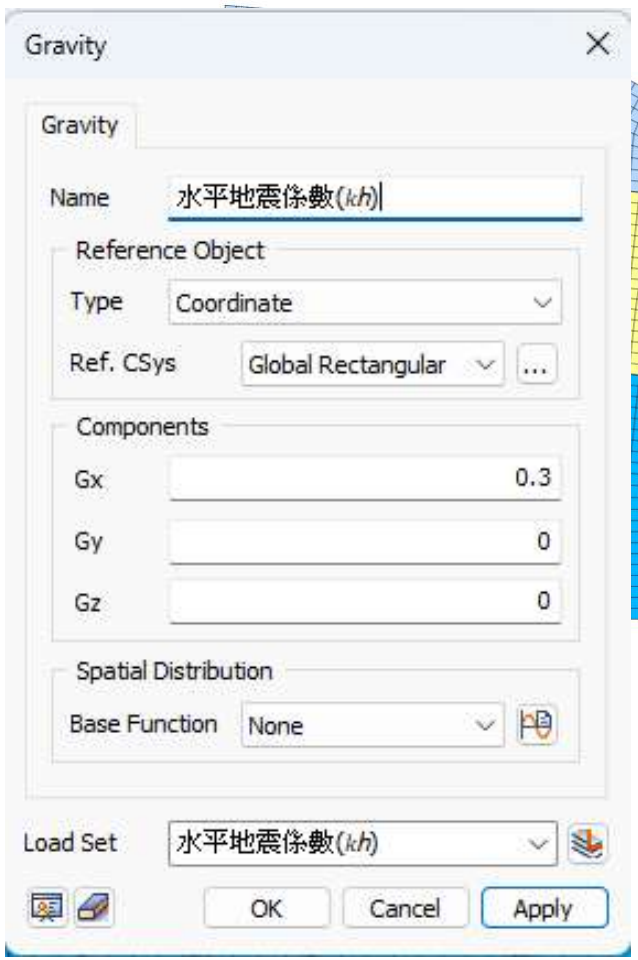


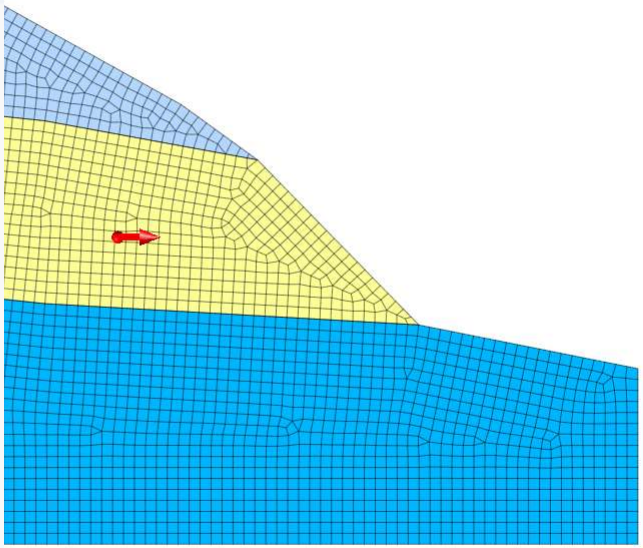
Maximum Shear Strain



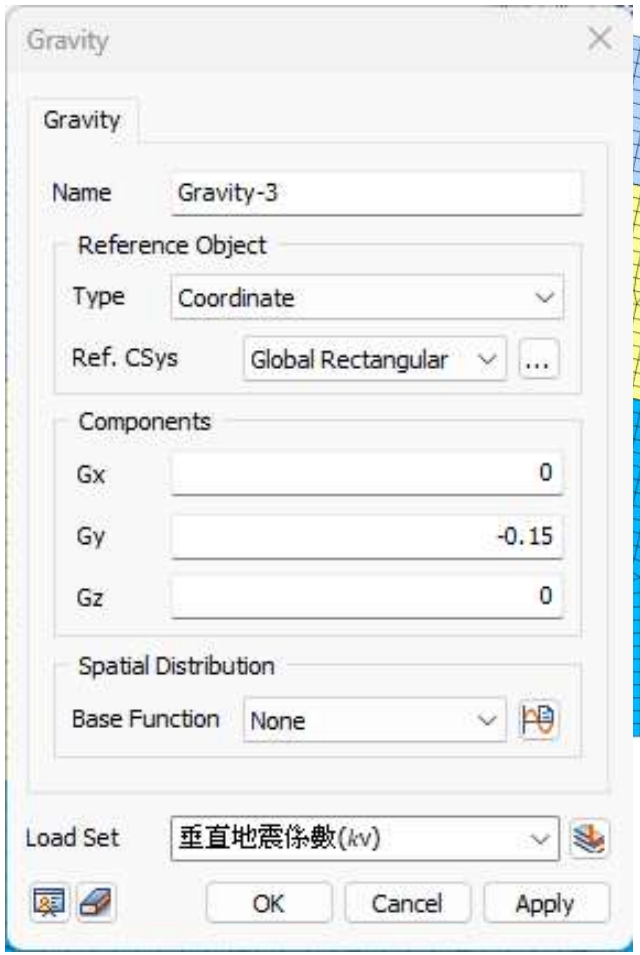
Part2. Pseudo-static seismic case

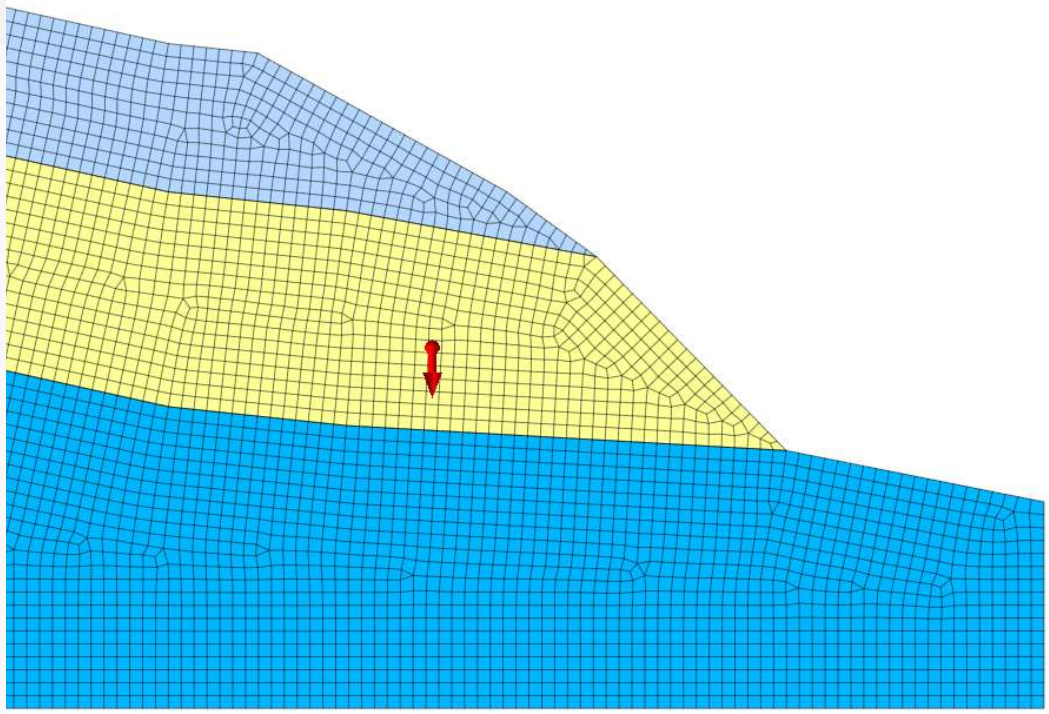
Horizontal seismic coefficient (k_h)





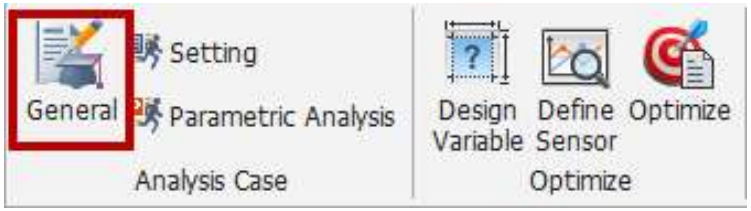
Vertical seismic coefficient (k_v)



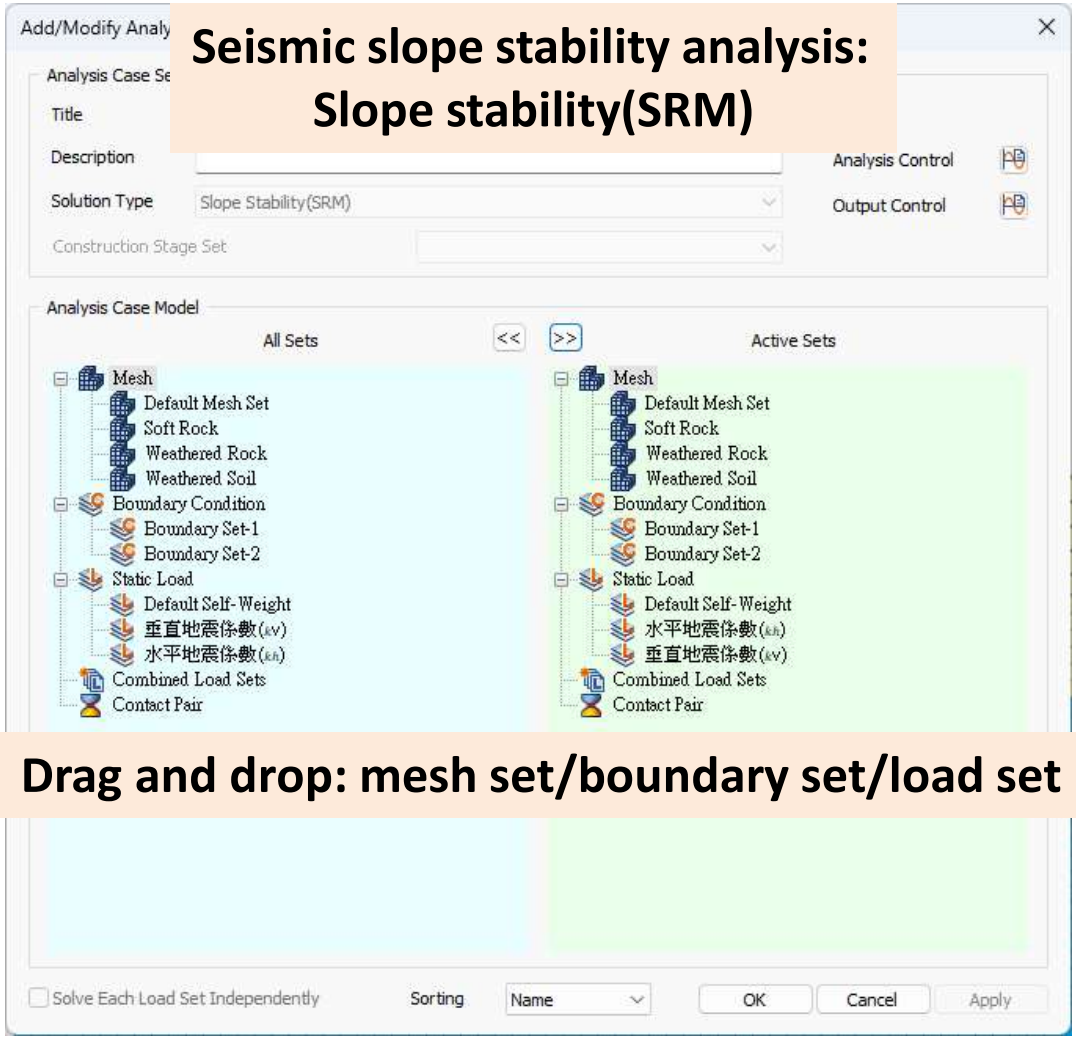


Analysis-1

(Pseudo-static seismic case)



Seismic slope stability analysis: Slope stability(SRM)

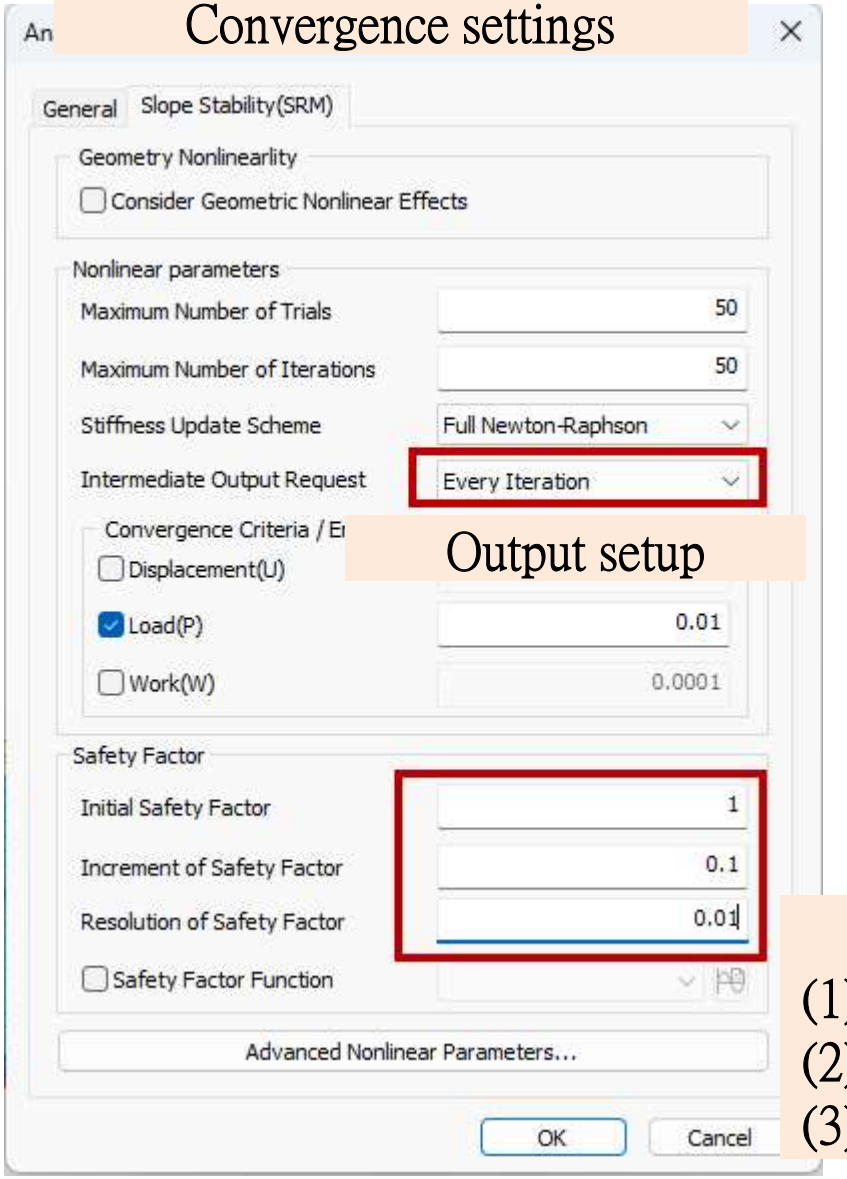


Drag and drop: mesh set/boundary set/load set

Analysis-2

(Pseudo-static seismic case)

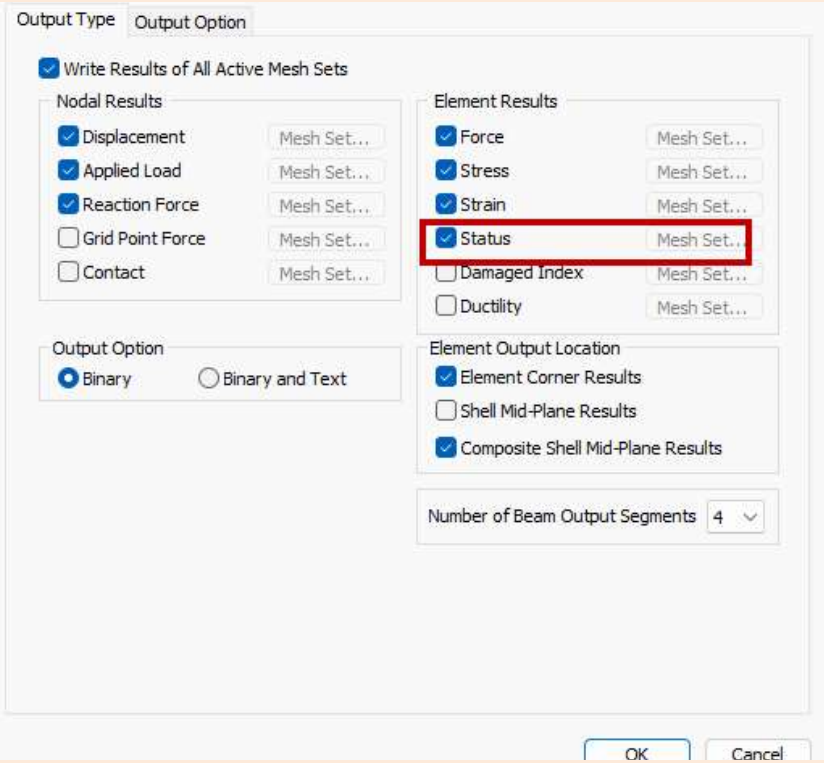
Convergence settings



Output setup

Output=>Strain

Shear strain indicates the failure arc



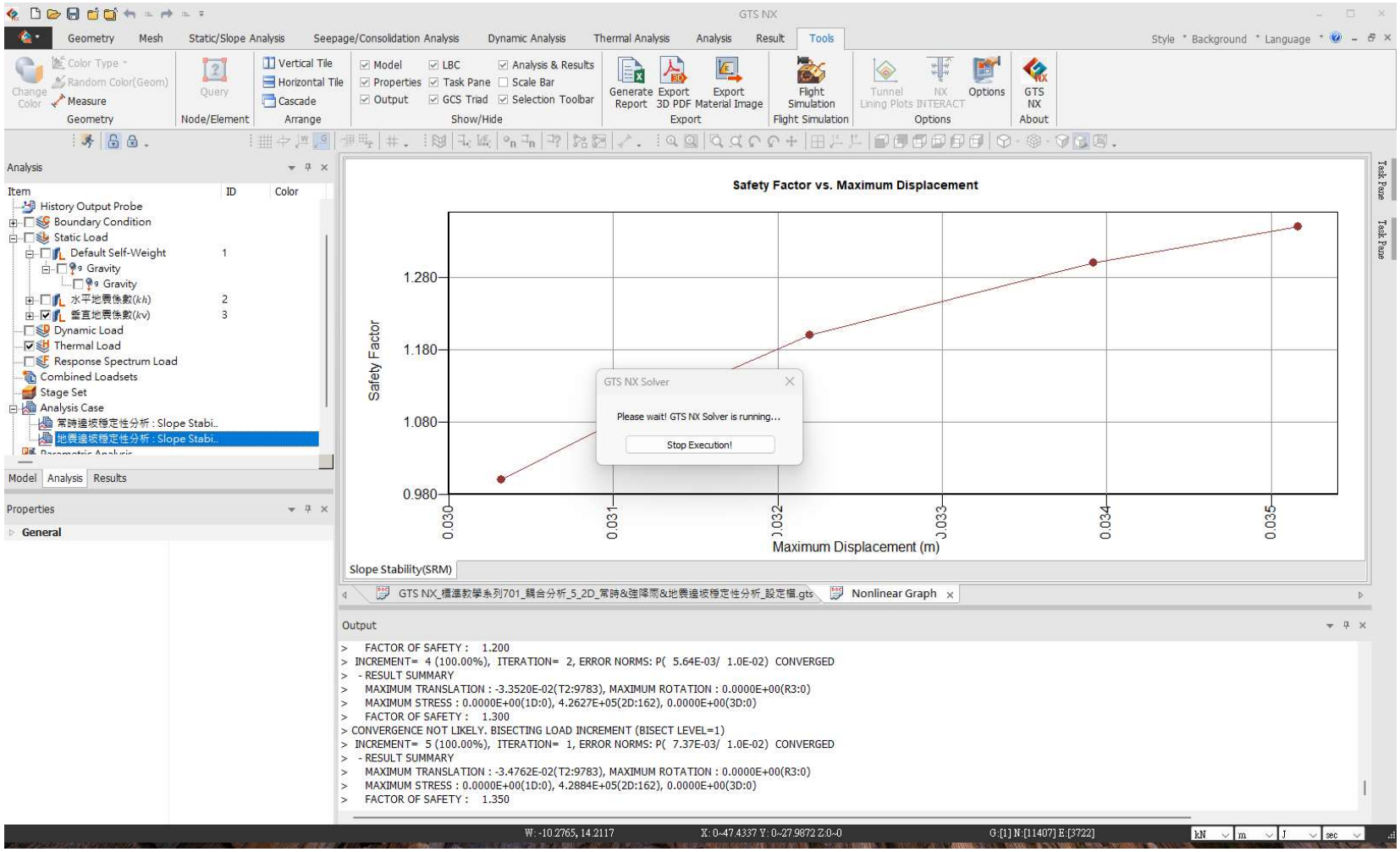
SRM convergence adjustment

(1) Initial safety factor 1

(2) FOS increment by 0.1 each time

(3) Residual < 0.01, minimum FOS reached

Calculation

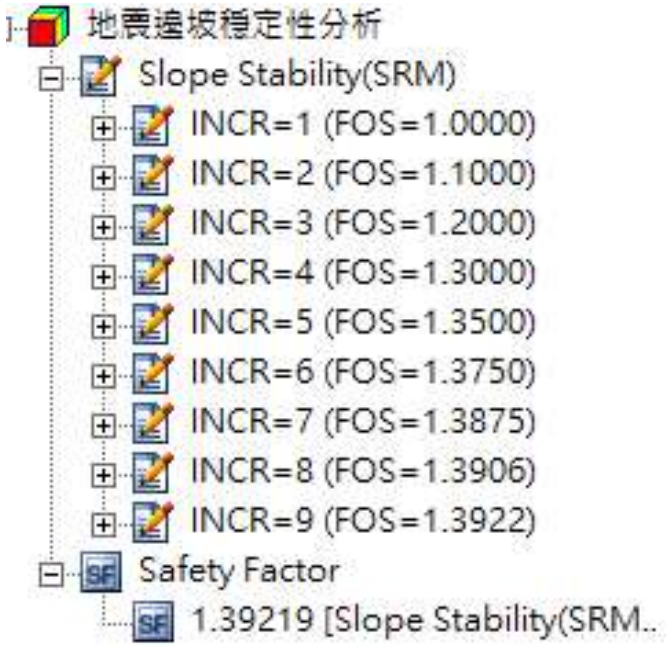


Results

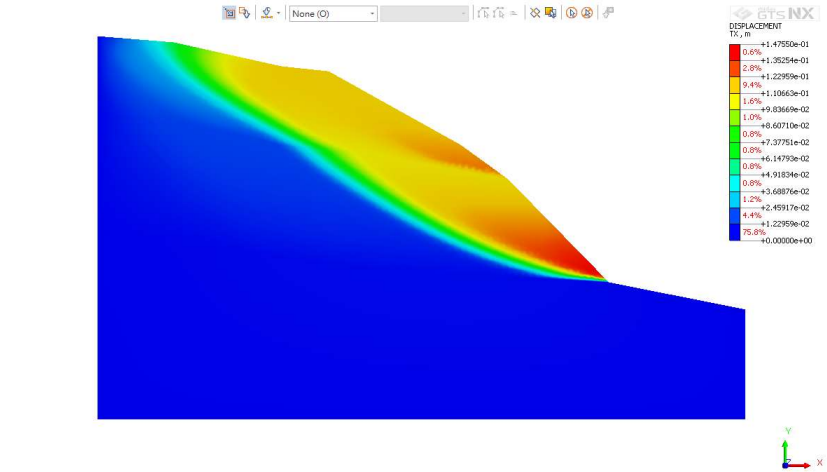
(Pseudo-static seismic case)

Failure surface indicated by horizontal displacement & maximum shear strain

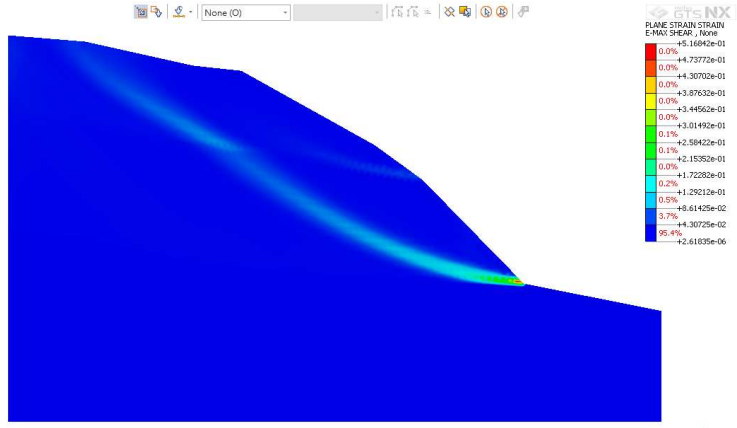
Pseudo-static seismic by k_h & k_v, FOS = 1.3922



Tx Translation(m)



Maximum Shear Strain

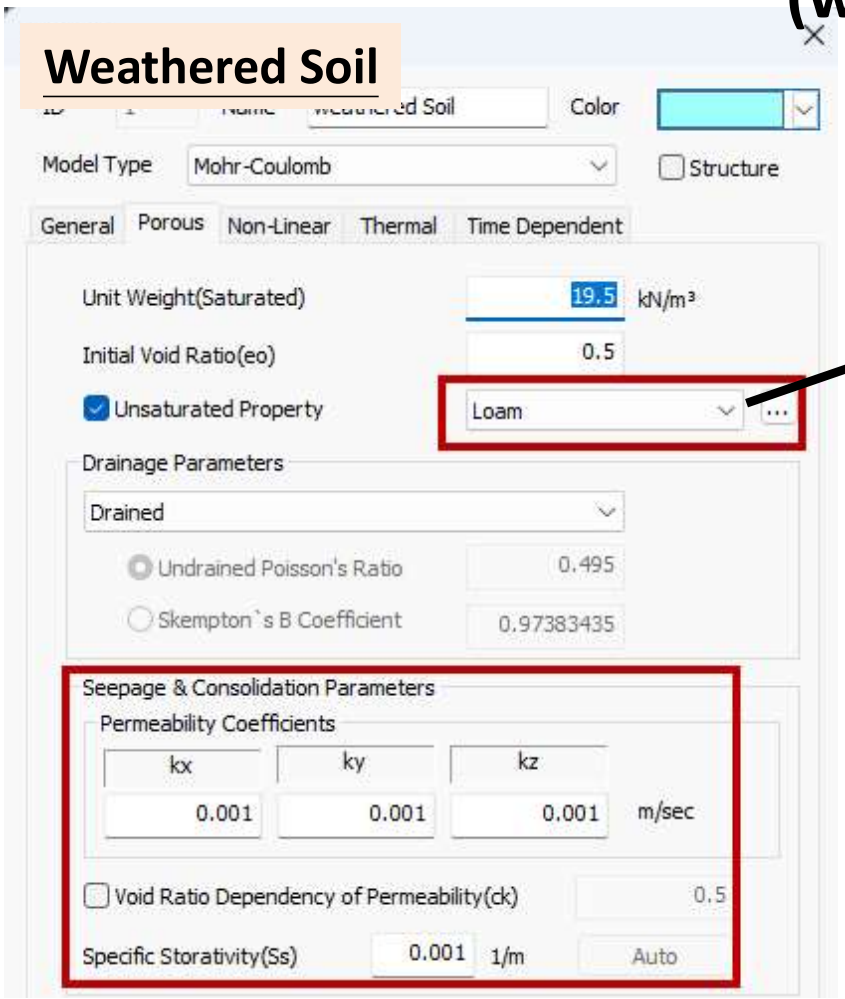


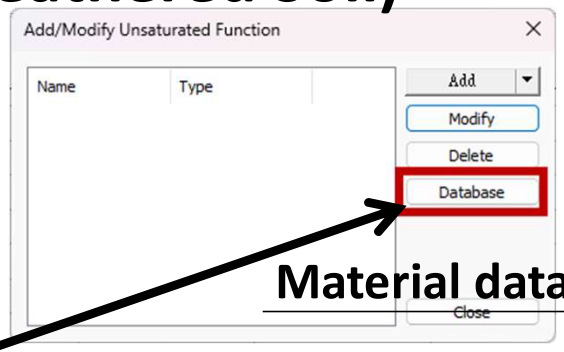
SRM for safety factor calculation

Part3. Heavy rainfall case

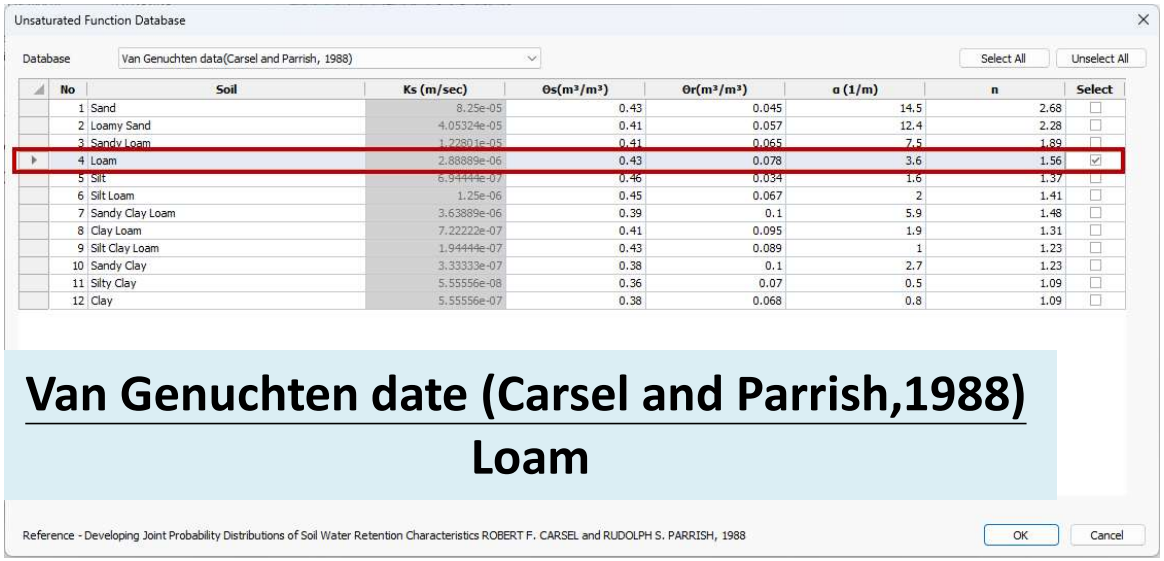
Porous Material-1

(weathered Soil)





Material database in GTS NX



Van Genuchten date (Carsel and Parrish,1988)
Loam

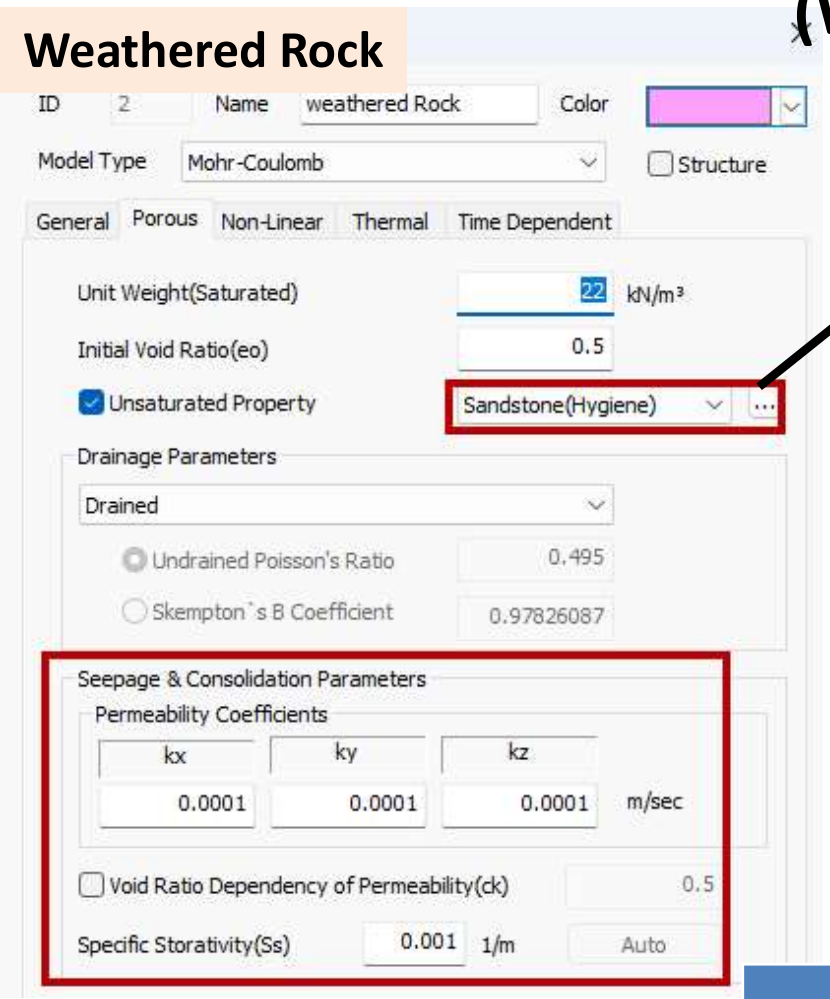
	Coefficient of permeability(K) (m/sec)	Specific Storativity(Ss) (1/m)
Weathered Soil	10^{-5}~10^{-3}	10^{-6} ~10^{-3}

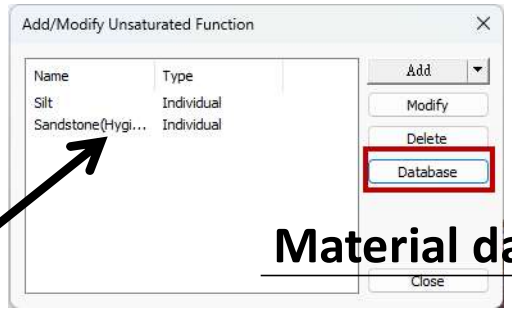
Note 1: The relevant parameters use assumed conditions.
Note 2: Unsaturated parameters are not defined in the seepage calculation process; the soil is treated as saturated.

Porous Material-2

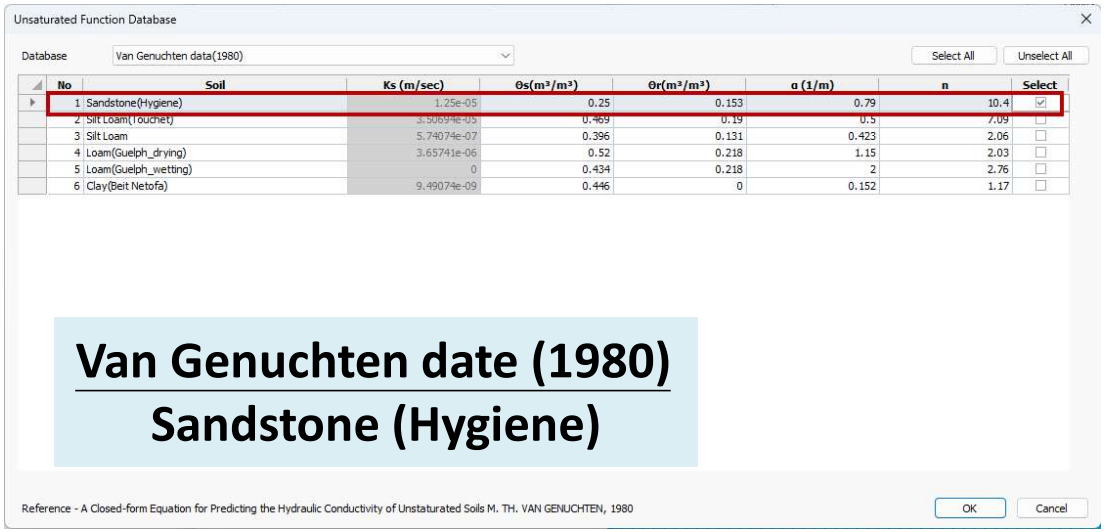
(Weathered Rock)

Weathered Rock





Material database in GTS NX



Van Genuchten date (1980)
Sandstone (Hygiene)

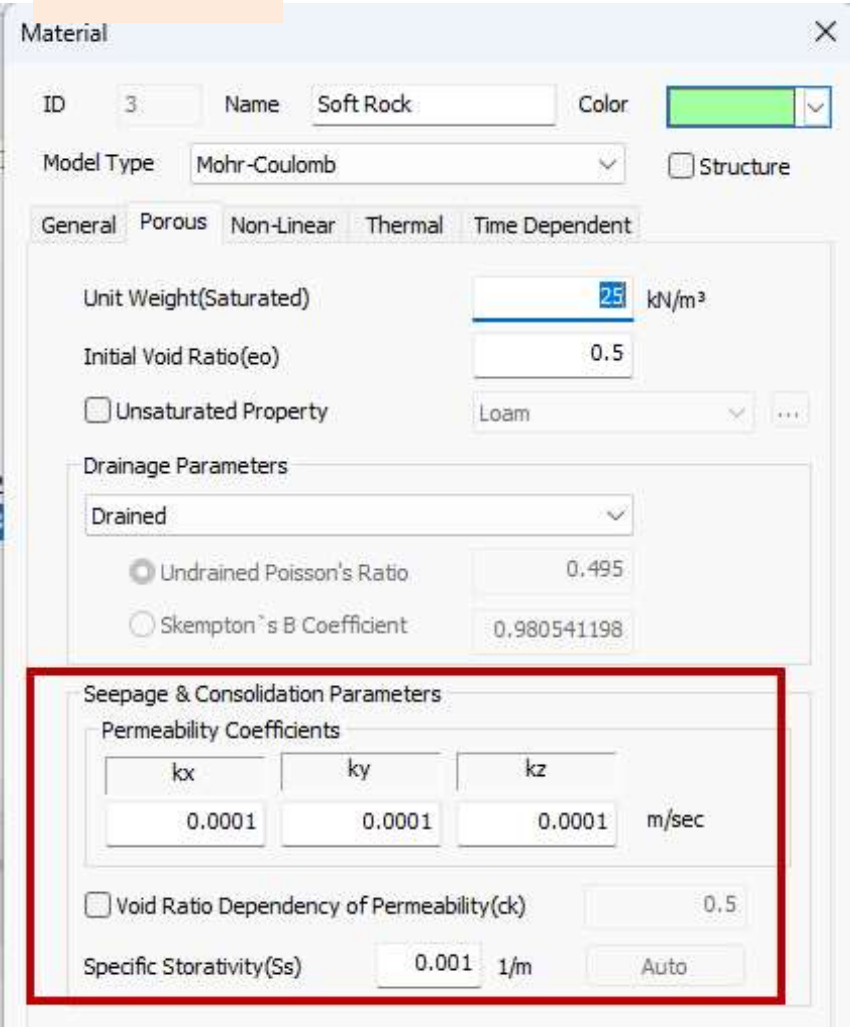
	Coefficient of permeability(K) (m/sec)	Specific Storativity(Ss) (1/m)
Weathered Rock	10^{-6}~10^{-4}	10^{-6} ~10^{-3}

Note 1: The relevant parameters use assumed conditions.
Note 2: Unsaturated parameters are not defined in the seepage calculation process; the soil is treated as saturated.

Porous Material-3

(Soft Rock)

Soft Rock



Flow of rainfall case does not calculate as saturated

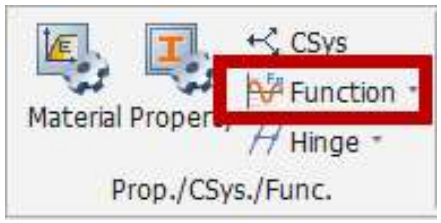
	Coefficient of permeability(K) (m/sec)	Specific Storativity(Ss) (1/m)
Soft Rock	**10^{-6}~10^{-4}**	**10^{-6} ~10^{-3}**

Note 1: The relevant parameters use assumed conditions.
Note 2: Unsaturated parameters are not defined in the seepage calculation process; the soil is treated as saturated.

In-situ Recorded Rainfall

(Hourly rainfall)

Unit (kn/m/J/hr)



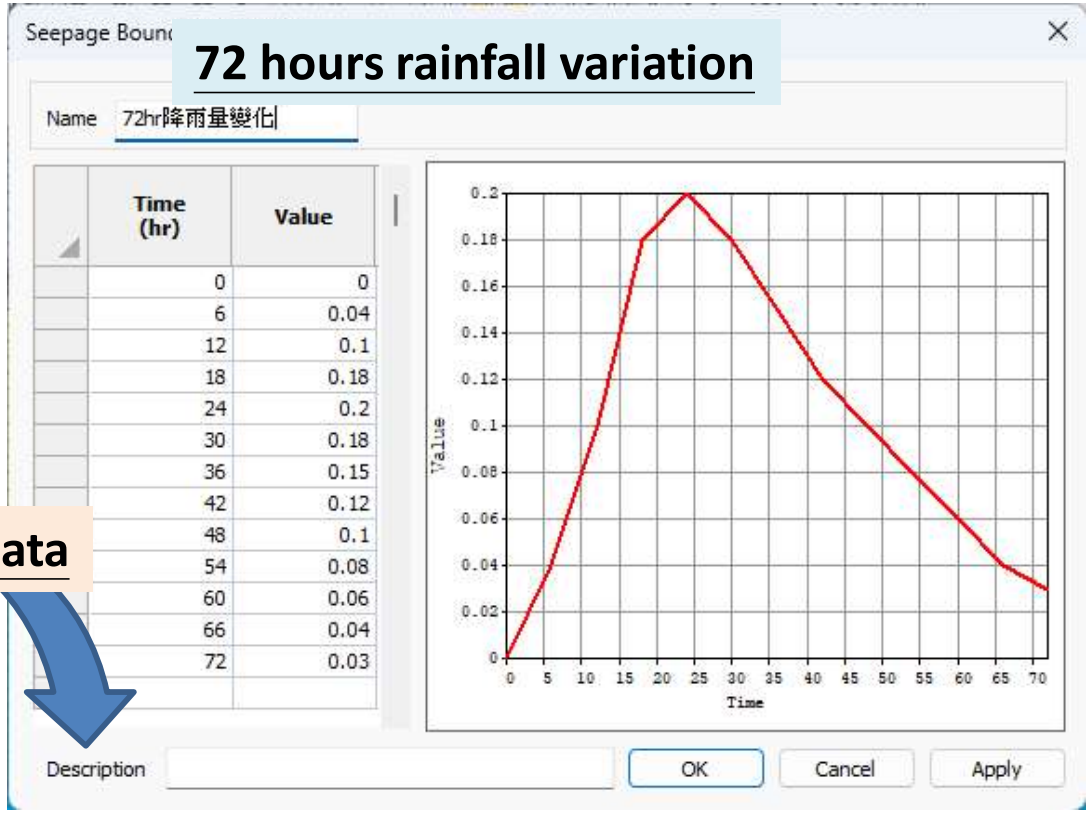
Seepage Boundary

Excel data

時間累計(hr)	每6小時降雨量 (m)
0	
6	
12	0.1
18	0.18
24	0.2
30	0.18
36	0.15
42	0.12
48	0.1
54	0.08
60	0.06
66	0.04
72	0.03

Copy & paste the data

72 hours rainfall variation



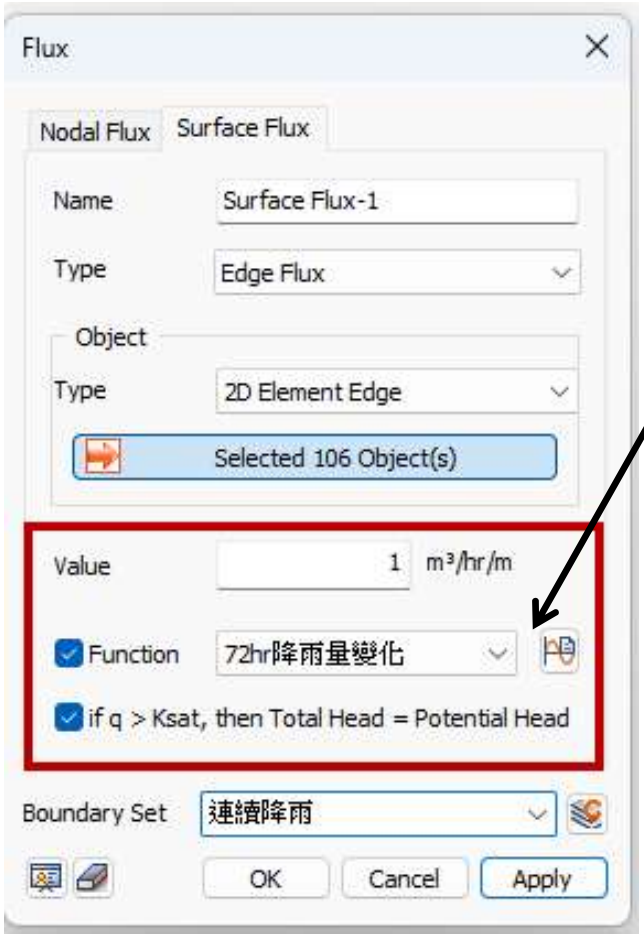
註:GTS NX不支援Y軸單位切換。

Surface Flux

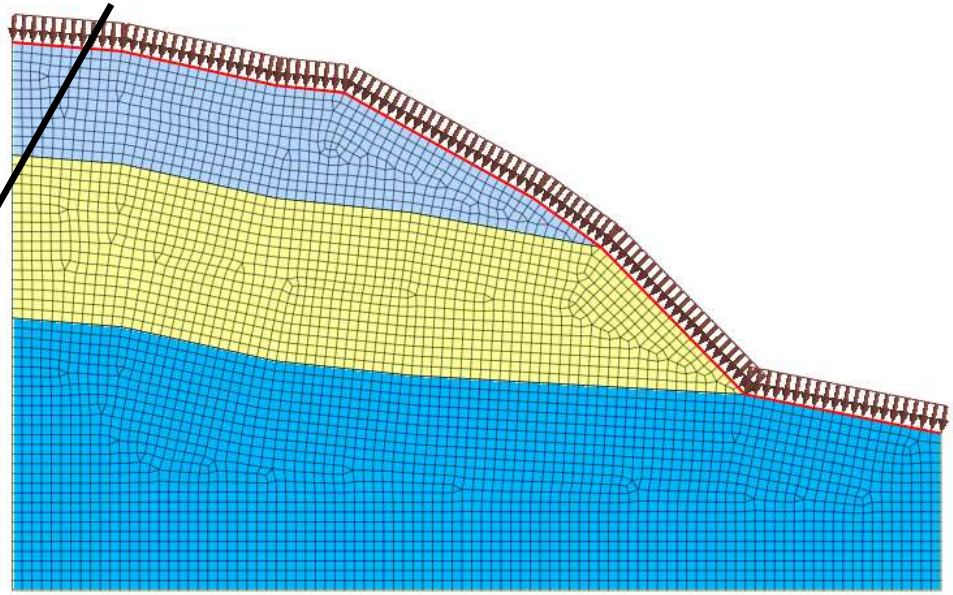
Unit (KN/m/J/hr)

kN | m | J | hr

Seepage/Consolidation Analysis



Flux = Value × Function



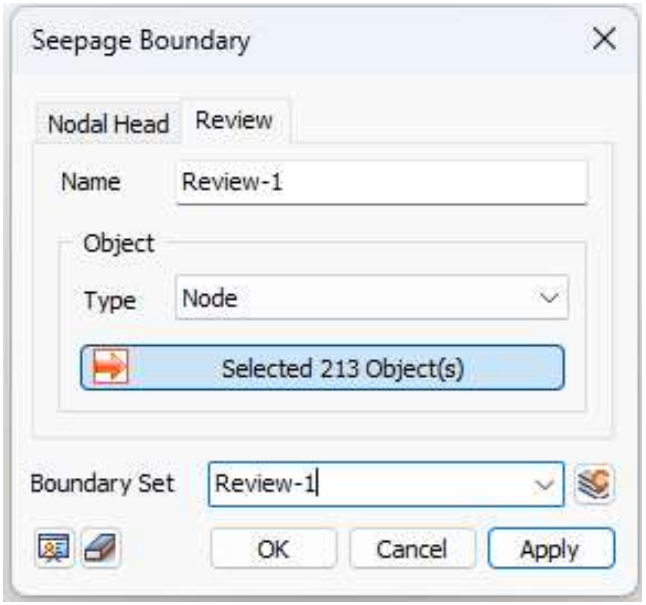
Setting:

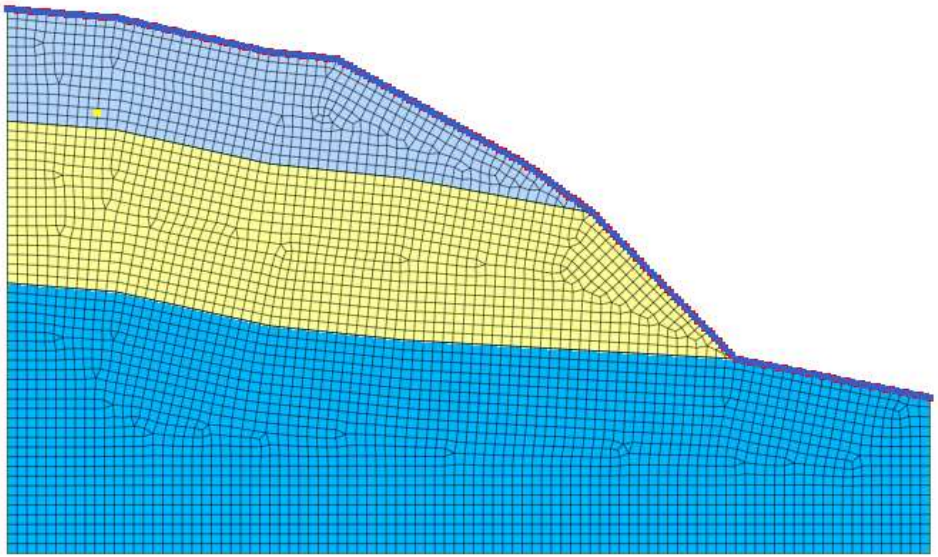
if surface flux > coefficient of permeability

total head = potential head

Review/ Seepage

Seepage/Consolidation Analysis





Construction Stage-1

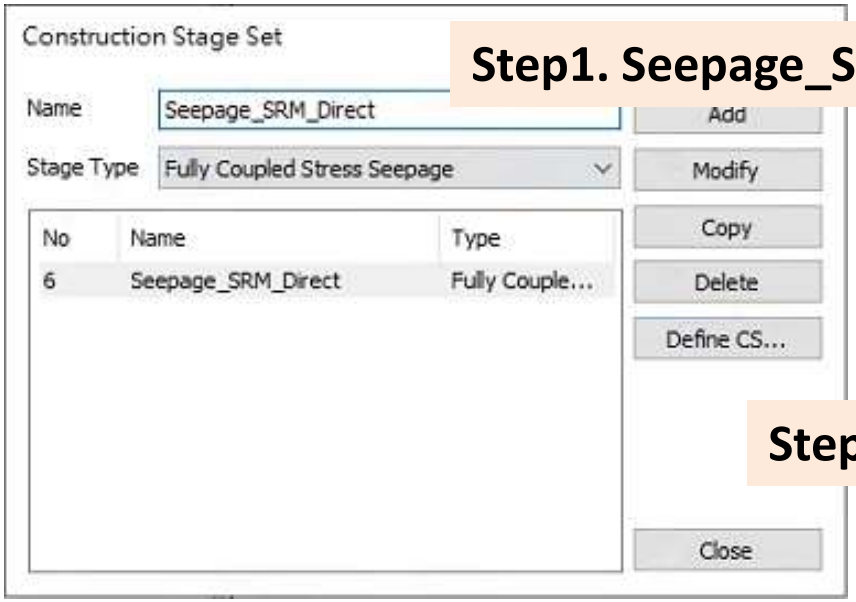
(Pseudo-static seismic case)

Construction phase types in GTS NX

Stress

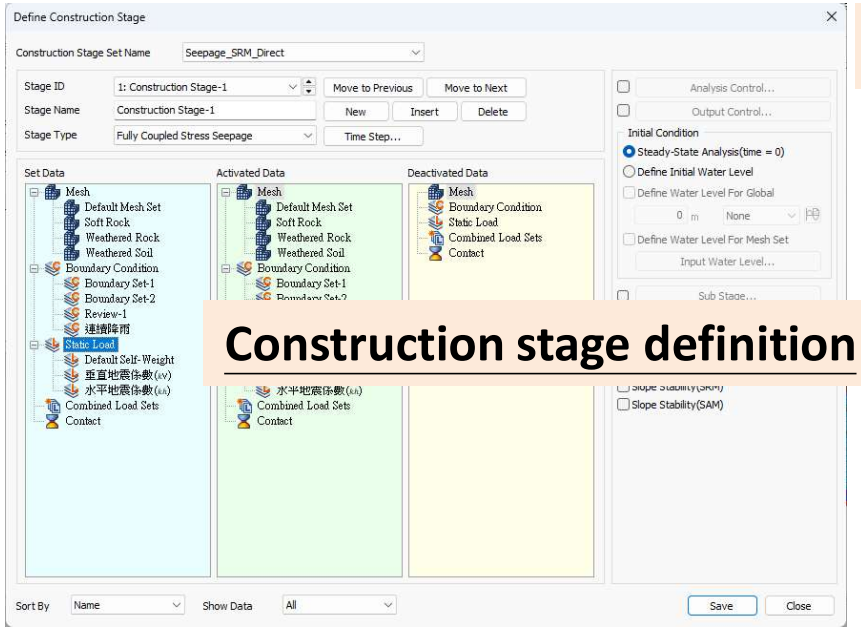
Fully Coupled Stress Seepage

Fully Coupled Stress Seepage
Stress-Nonlinear Time History
Heat Transfer
Seepage-Thermal Stress
Heat of Hydration(Thermal Stress)
Fully Coupled Stress Seepage Heat
Stress-Seepage-Slope-Nonlinear Time History



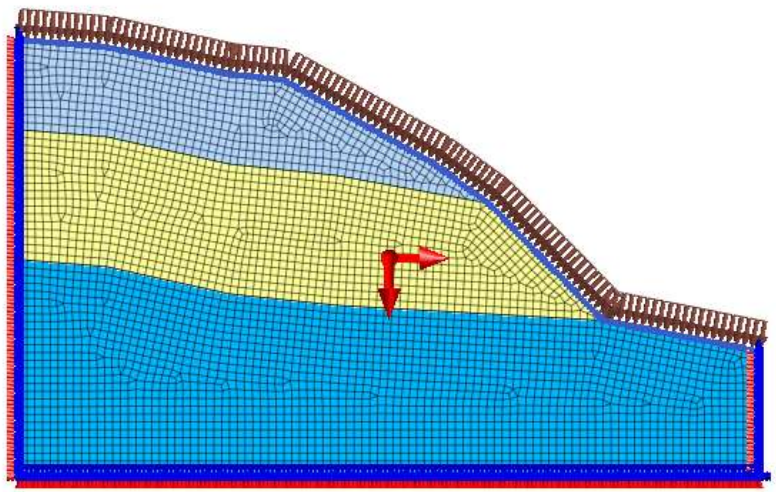
Step1. Seepage_SRM_Direct

Step2.Define CS

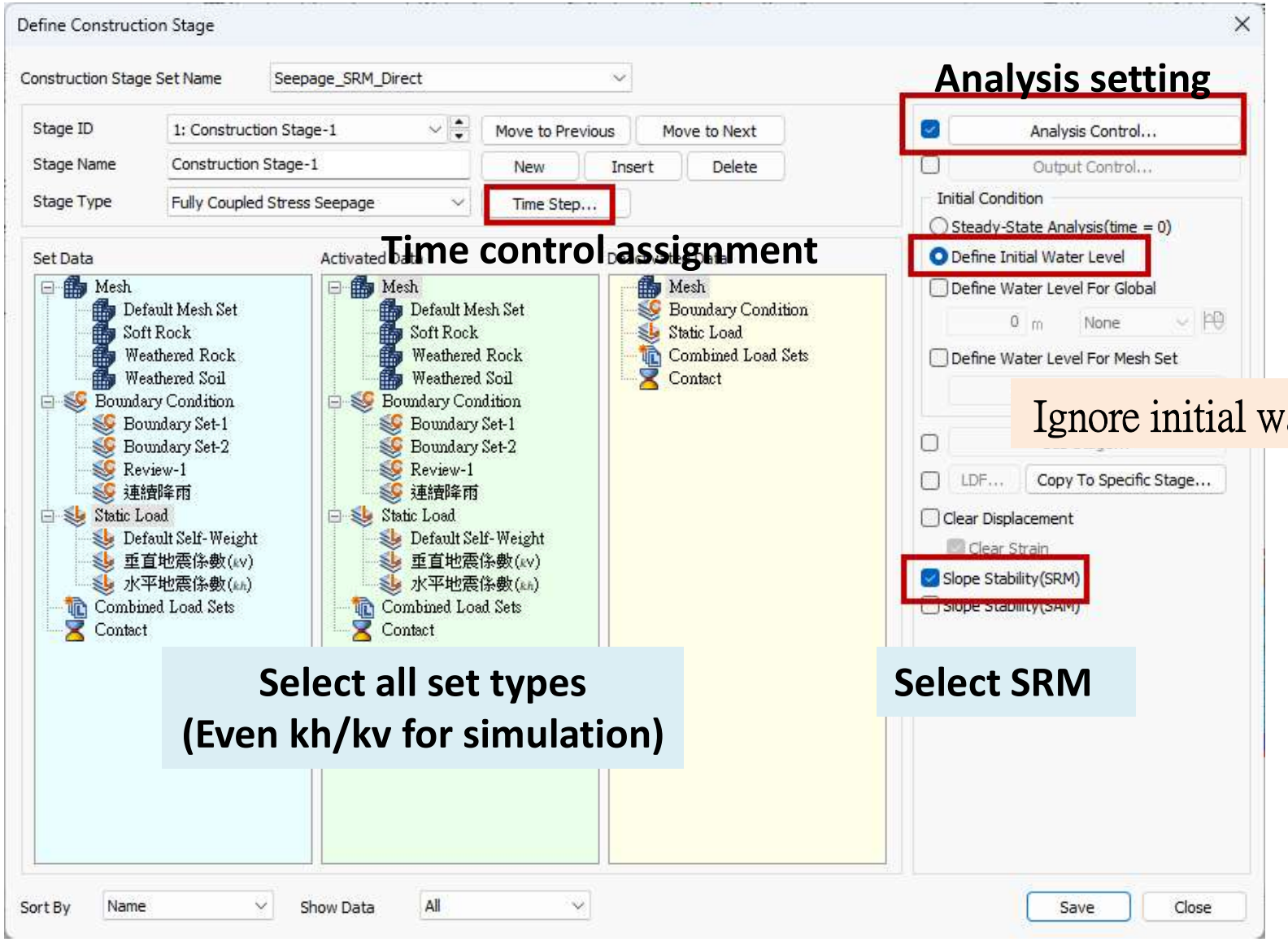


Construction stage definition

Activate all mesh sets/boundary sets

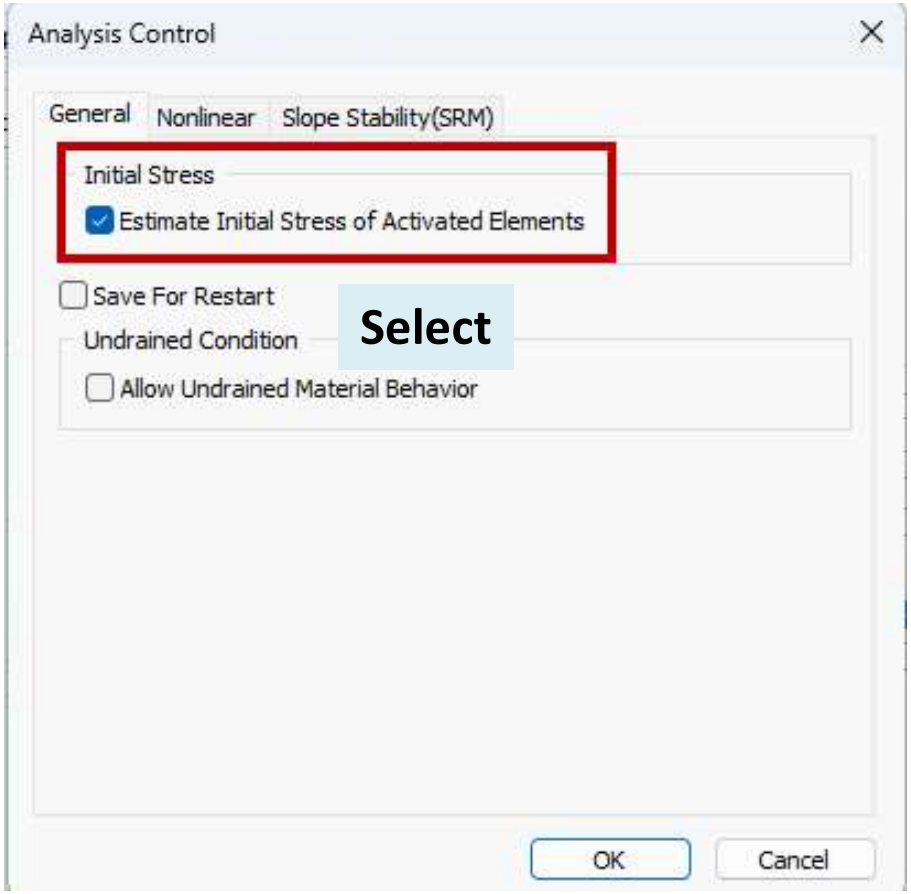


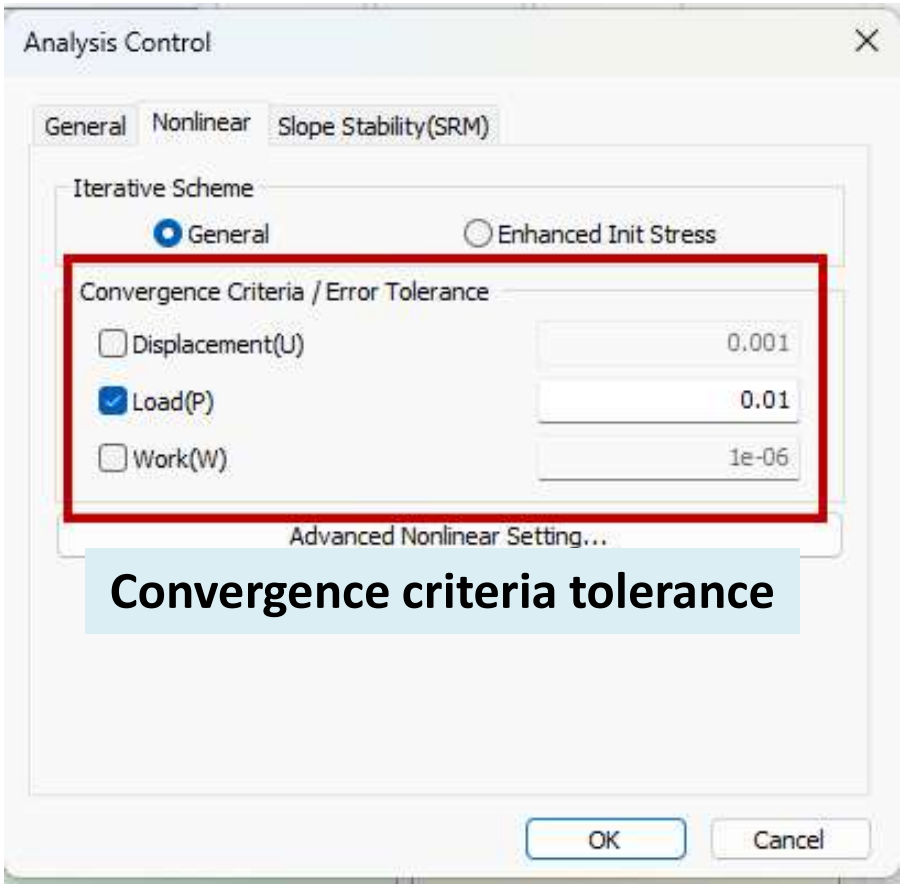
Construction Stage-2
(Fully Coupled Stress Seepage)



Construction Stage-3

(Analysis & Control)

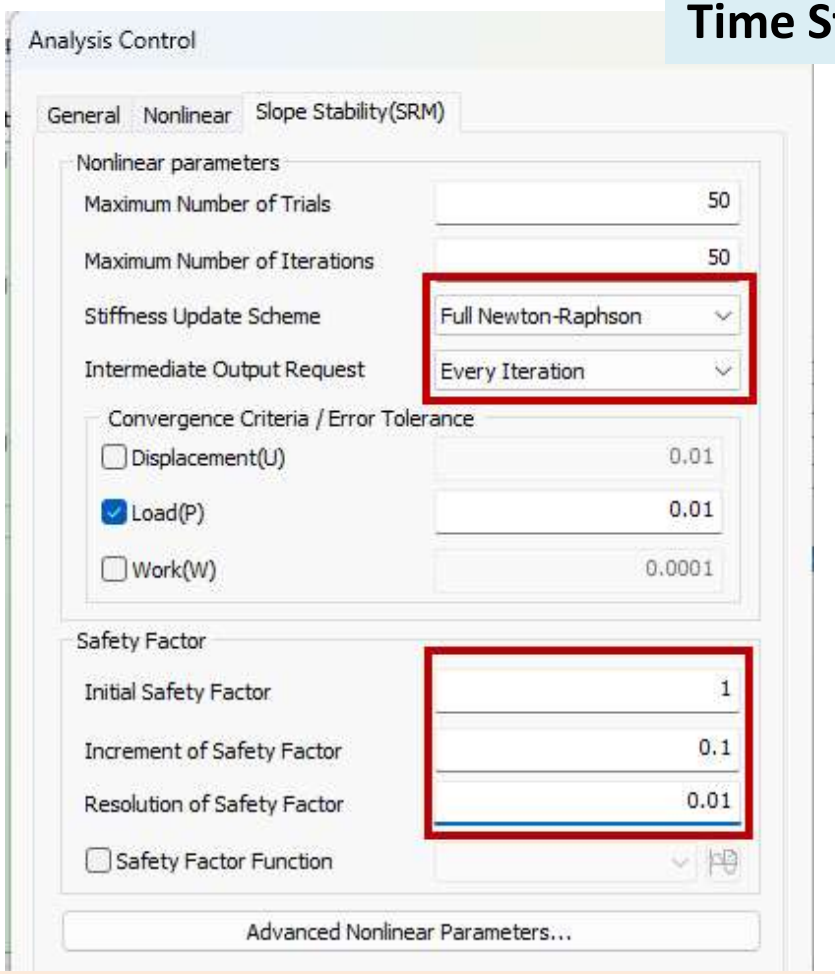


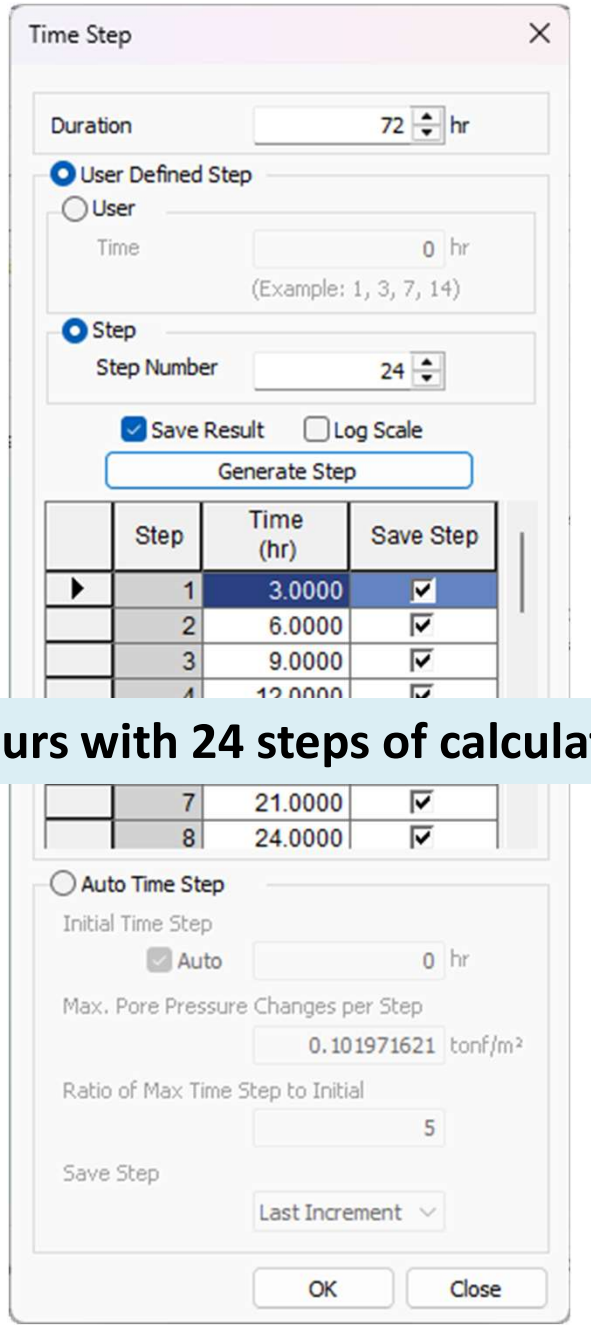


Construction Stage-4

(Analysis Control/ Time Control)

Time Step





72 hours with 24 steps of calculation

SRM convergence adjustment

(1) Initial safety factor 1

(2) FOS increment by 0.1 each time

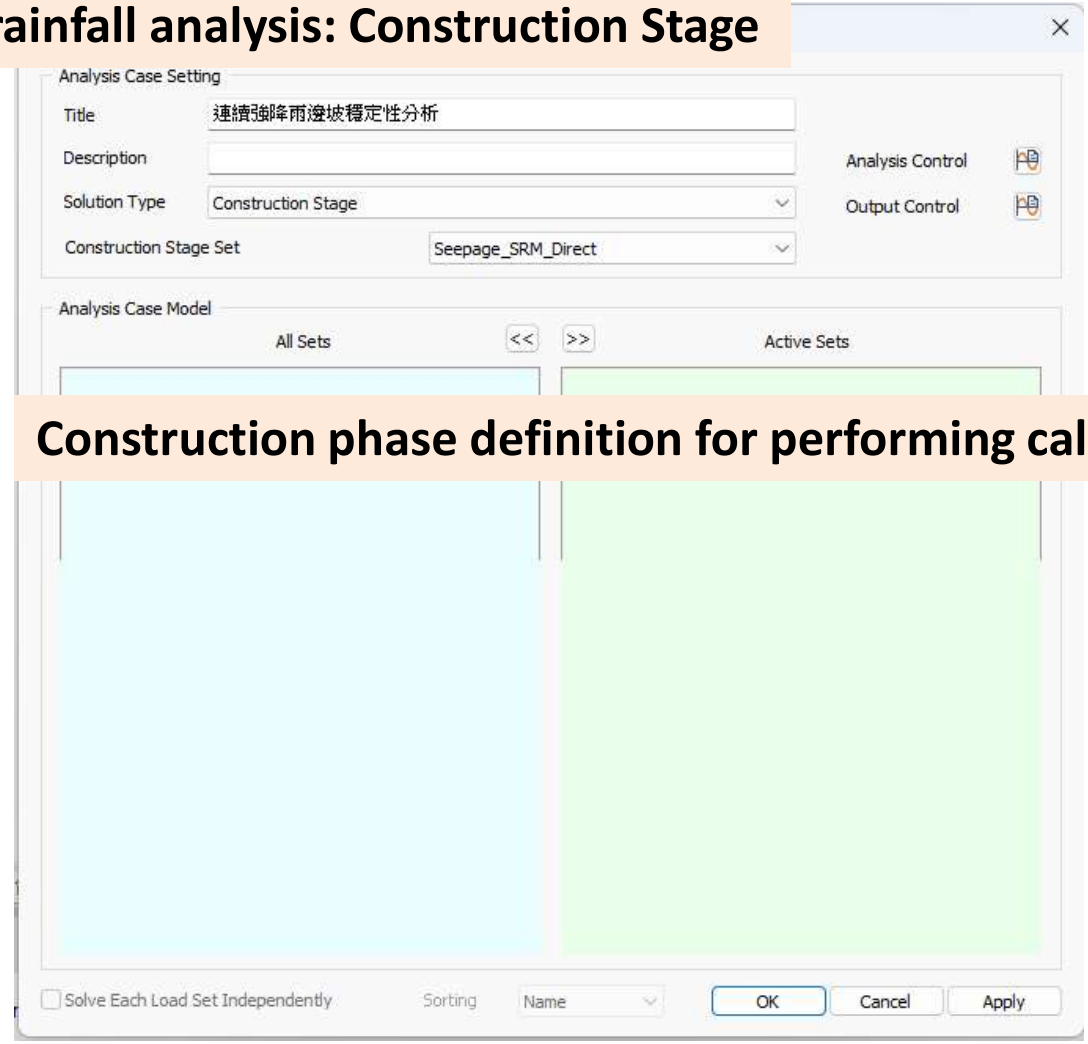
(3) Residual < 0.01, minimum FOS reached

Analysis
(Heavy Rainfall Case)

72hr of heavy rainfall analysis: Construction Stage

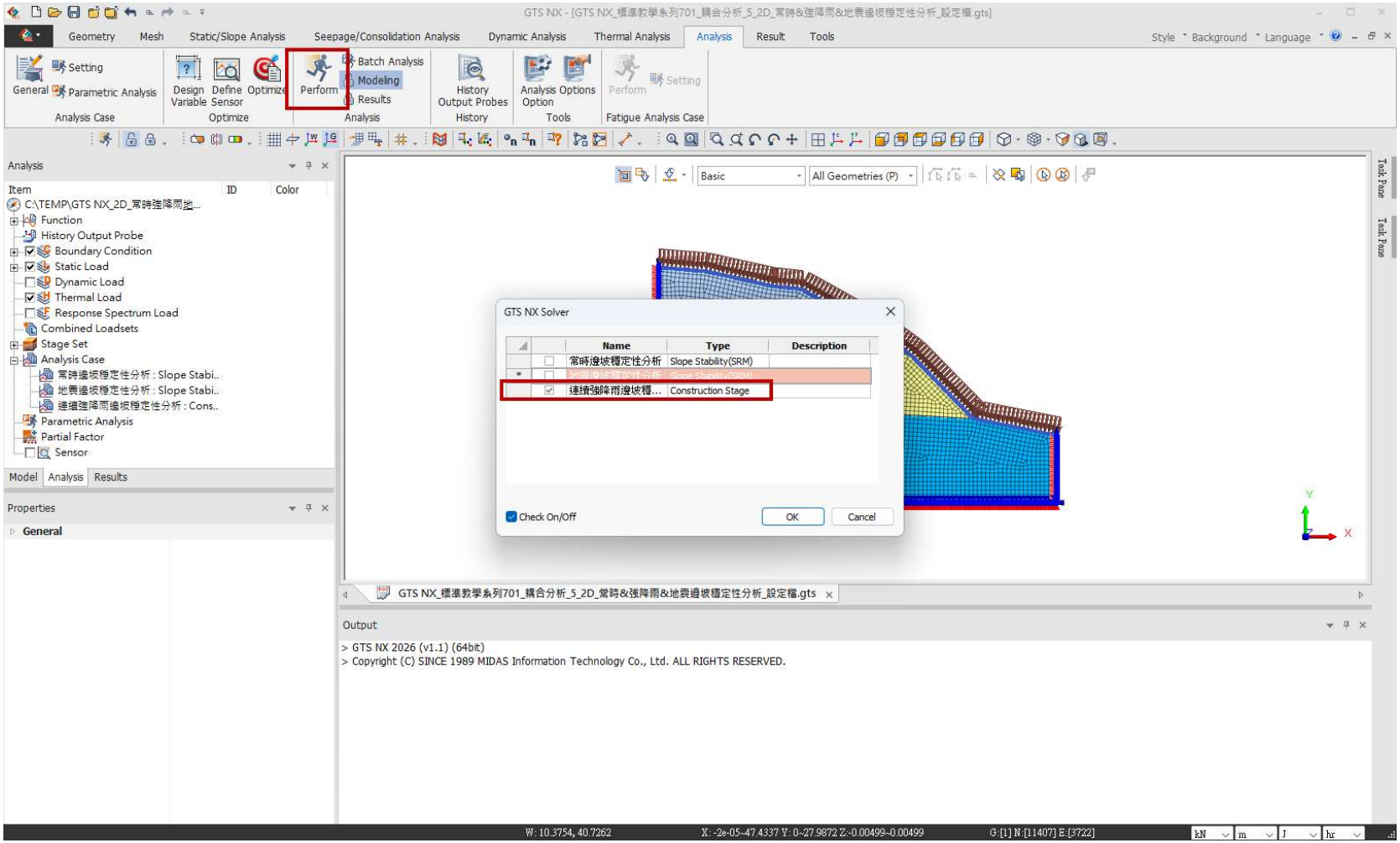
Construction Stage

- Linear Static
- Nonlinear Static
- Construction Stage
- Eigenvalue
- Response Spectrum
- Linear Time History(Modal)
- Linear Time History(Direct)
- Nonlinear Time History
- Nonlinear Time History + SRM
- 2D Equivalent Linear
- Consolidation
- Fully Coupled Stress Seepage
- Seepage(Steady-state)
- Seepage(Transient)
- Slope Stability(SRM)
- Slope Stability(SAM)

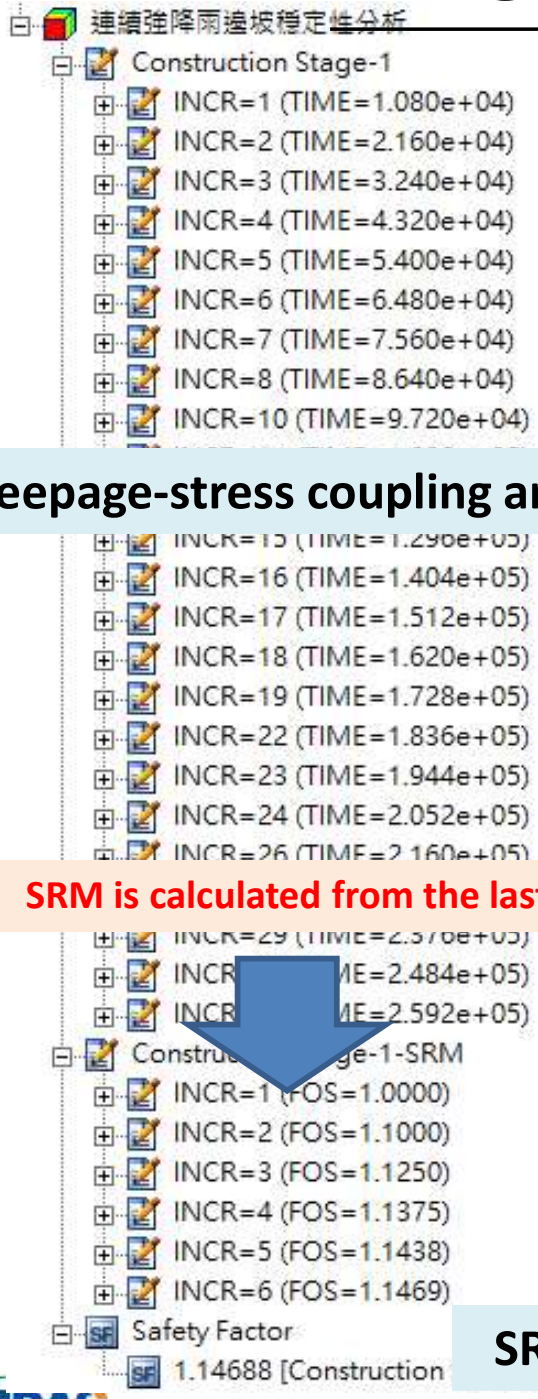


Construction phase definition for performing calculations

Calculation



Direct Method Analysis Results



Seepage-stress coupling analysis

Each time step of calculation

SRM is calculated from the last step

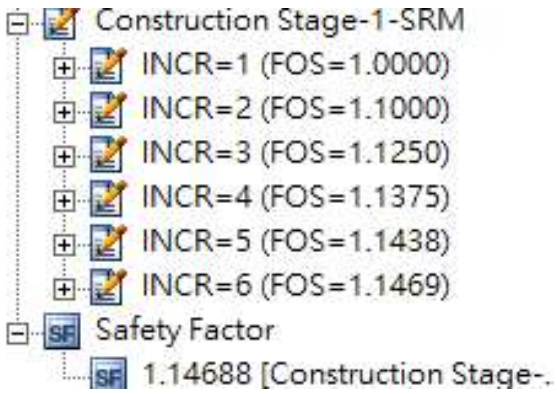
SRM analysis results

Analysis Results

(Heavy Rainfall Case)

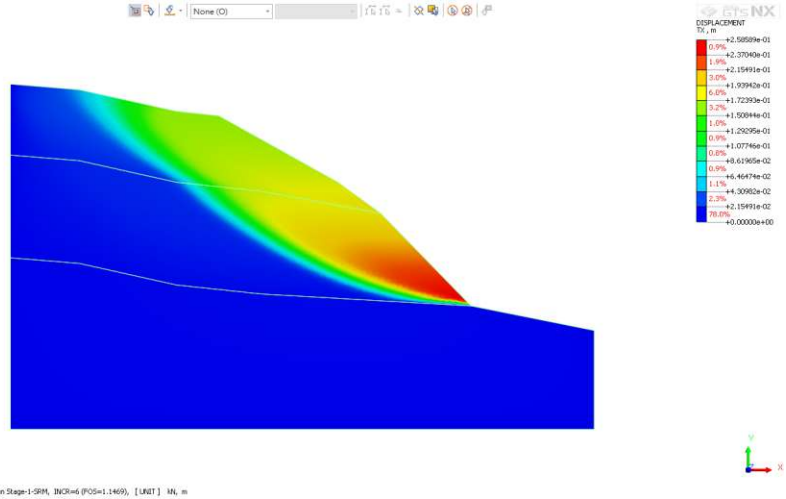
Failure surface indicated by horizontal displacement & maximum shear strain

Heavy rainfall simulation, FOS = 1.1469



SRM for safety factor calculation

Tx Translation(m)



Maximum Shear Strain