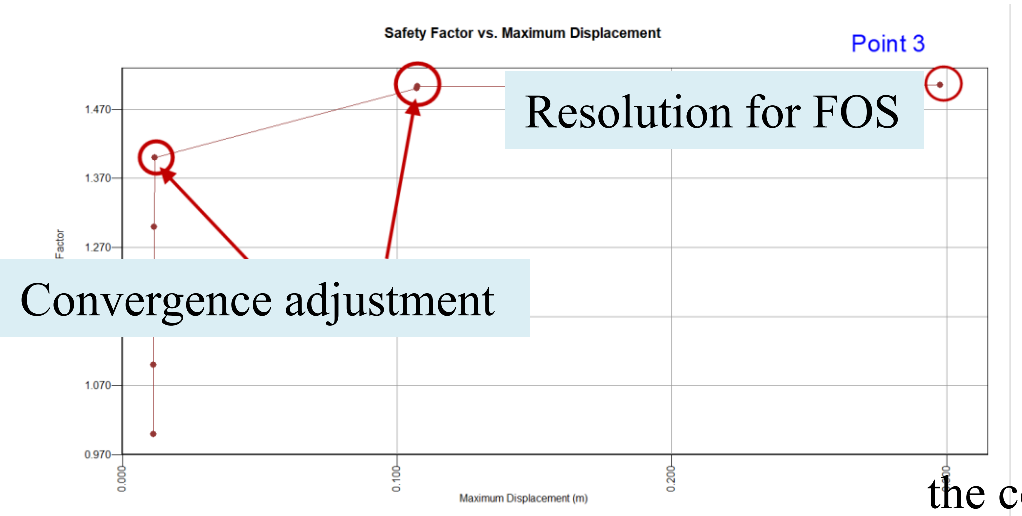
MIDAS TAIWAN
GTS NX

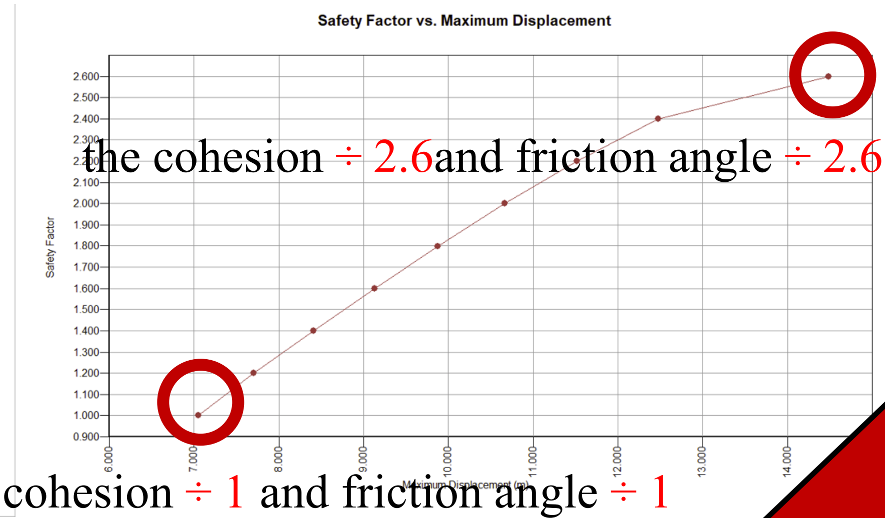
# DIFFERENT HAZARD CONDITIONS IN SLOPE STABILITY

# 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.




**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:

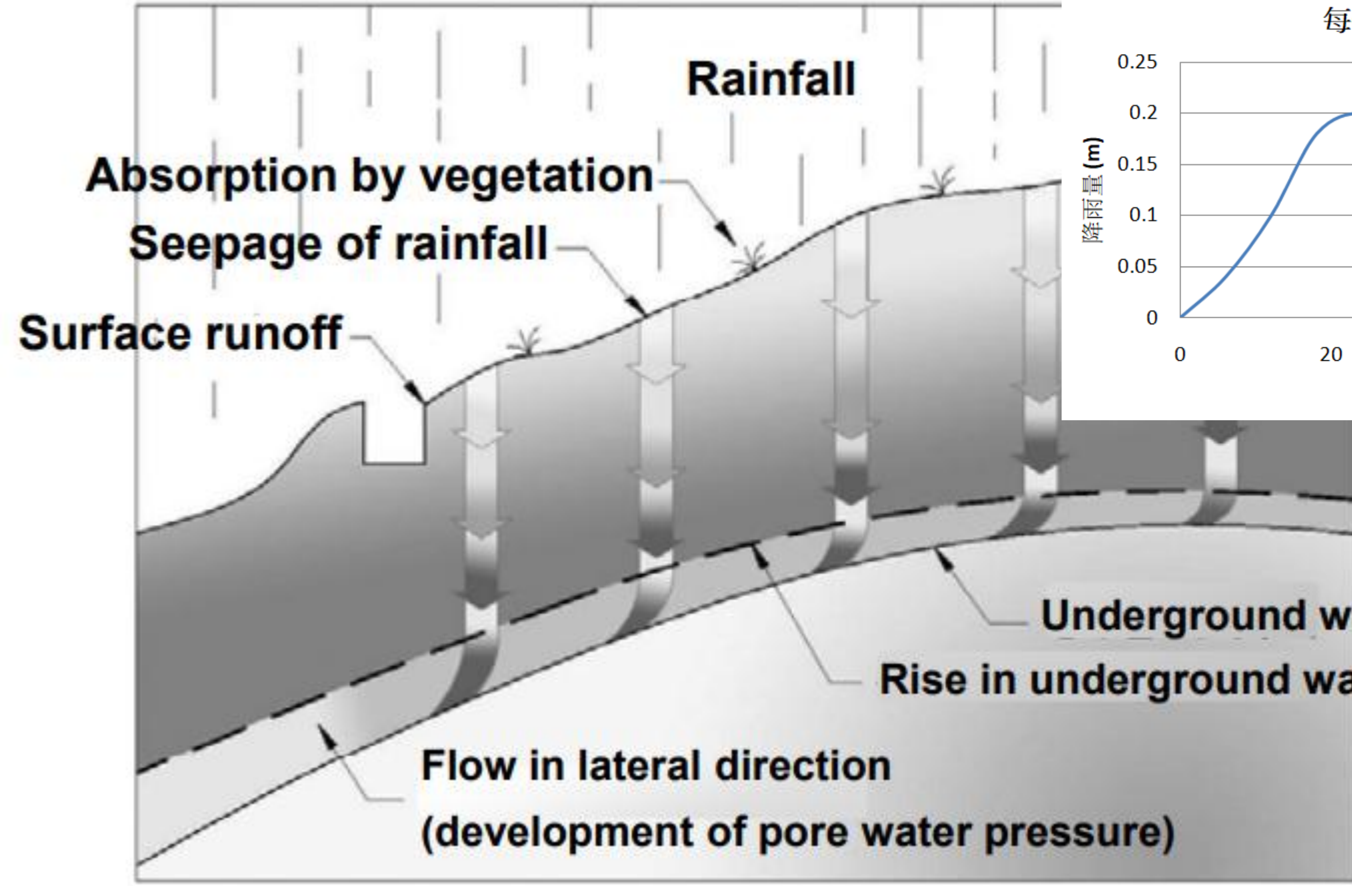
- $k_h$ = horizontal seismic coefficient
- $k_v$ = vertical seismic coefficient

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

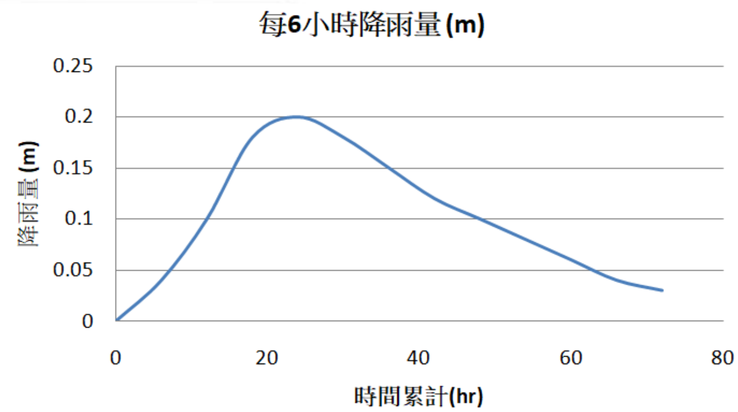
**Reference**
GTS NX/FEA NX/Soilworks Manual

# SEEPAGE THROUGH UNSATURATED SLOPE

SEEPAGE INDUCED BY RAINFALL

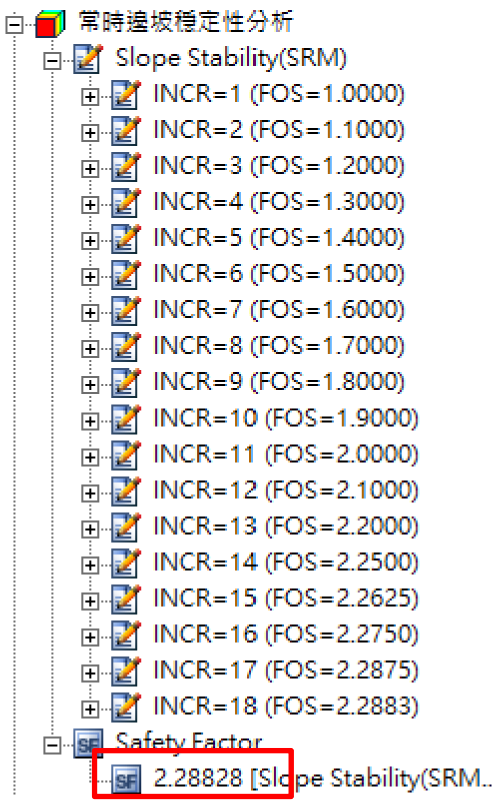



SURFACE RAINFALL OVER 72 HOURS



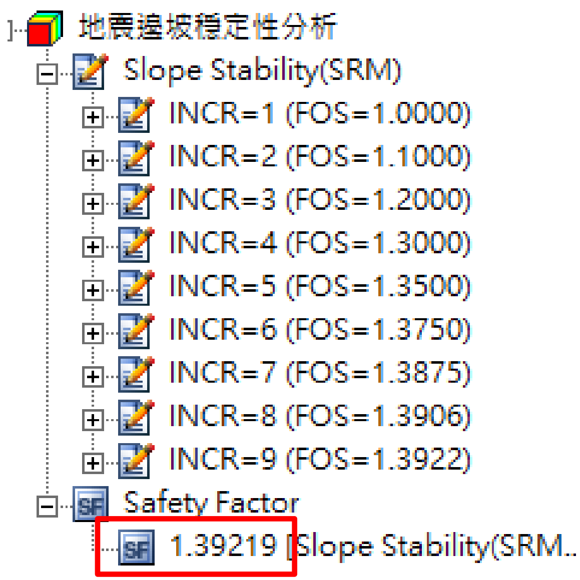
# COMPARISON FOR DIFFERENT CASES

## Normal case



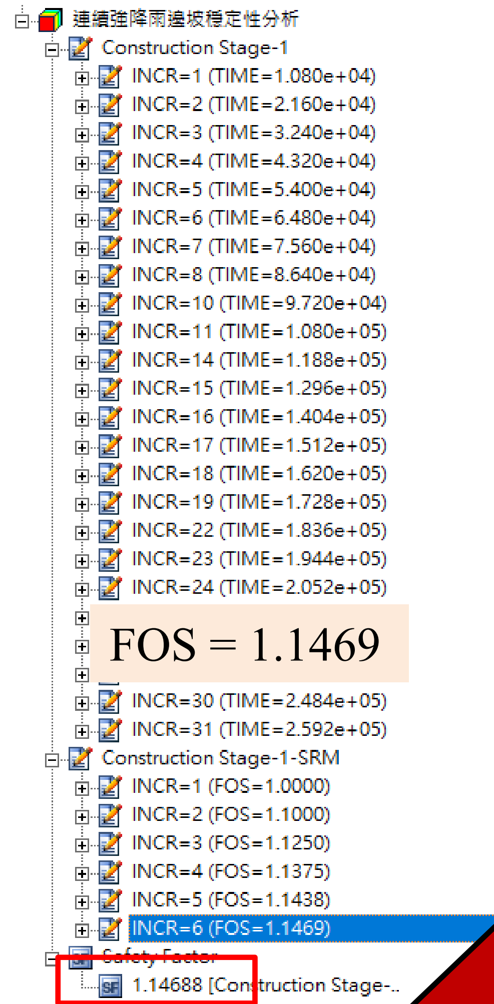

FOS = 2.2883

## Pseudo-static seismic




FOS = 1.3922

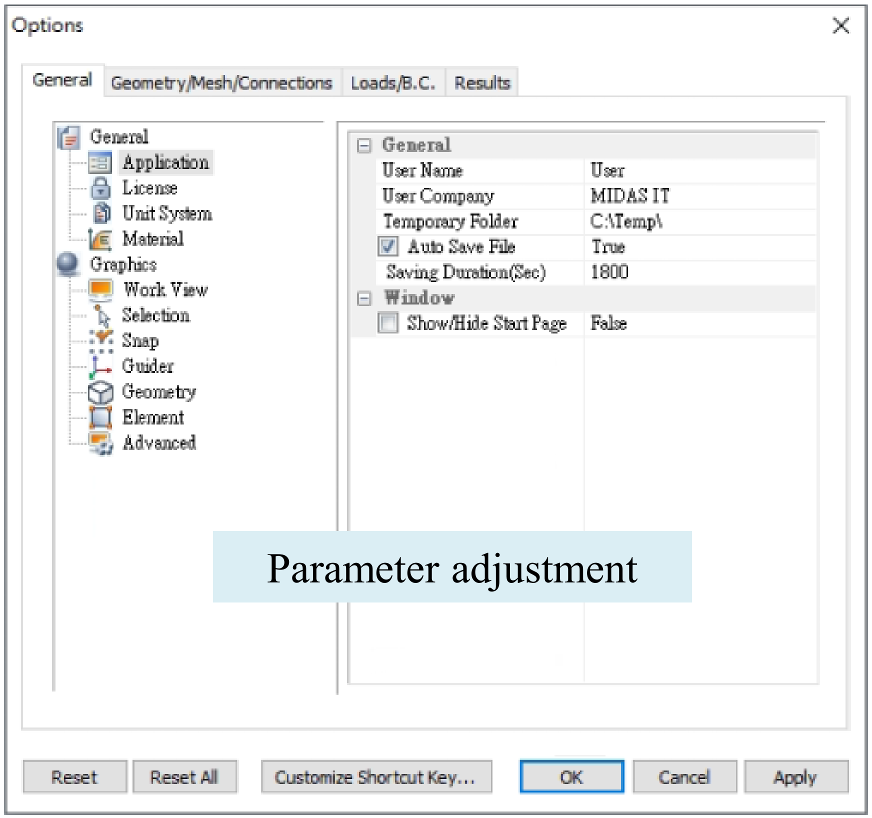
## Heavy rainfall case




FOS = 1.1469

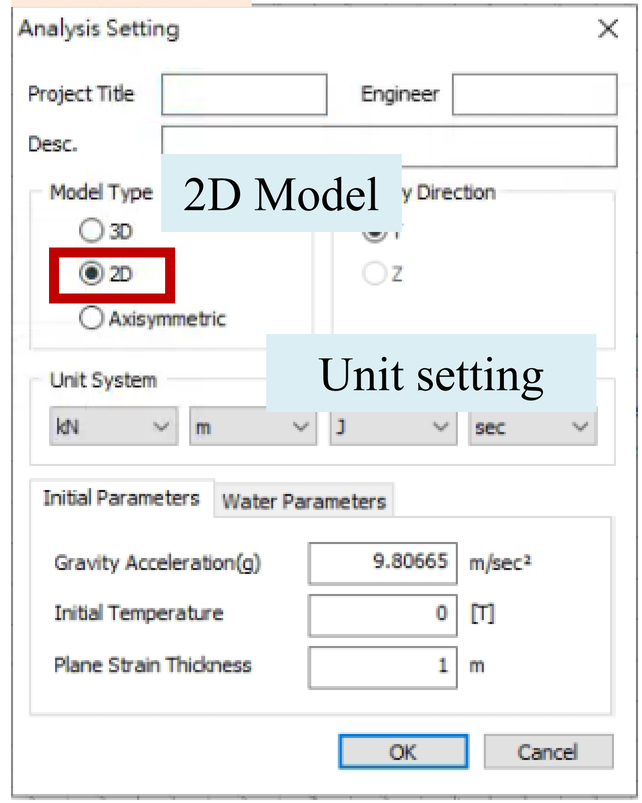
# Part 1
# NORMAL CONDITION

# IMPORT

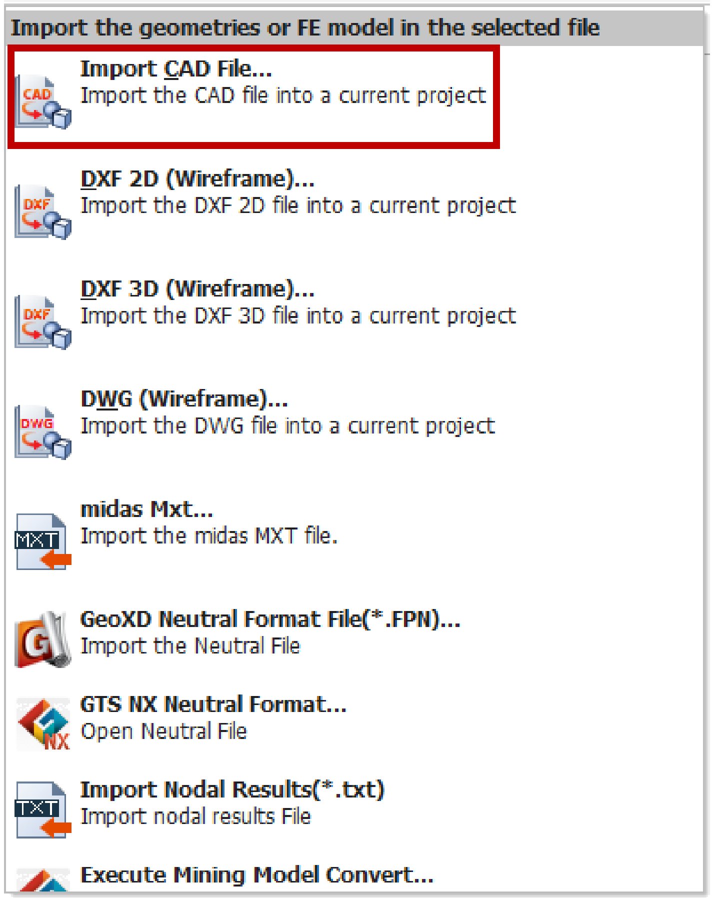


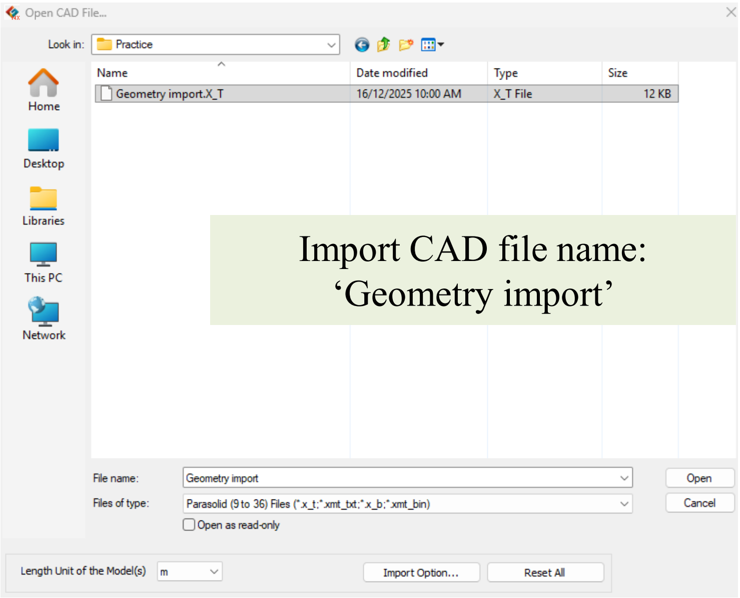
New file



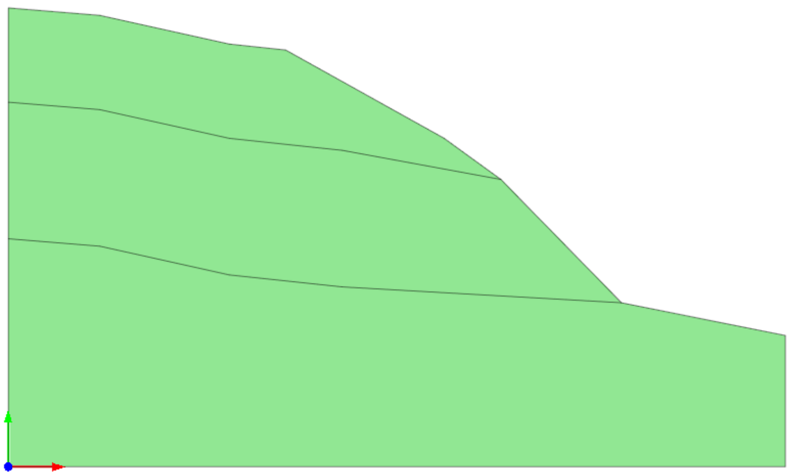

Unit setting: KN/m/J/sec

# 2D MODEL IMPORT

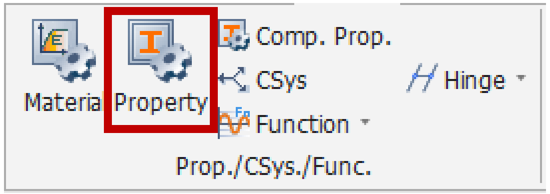


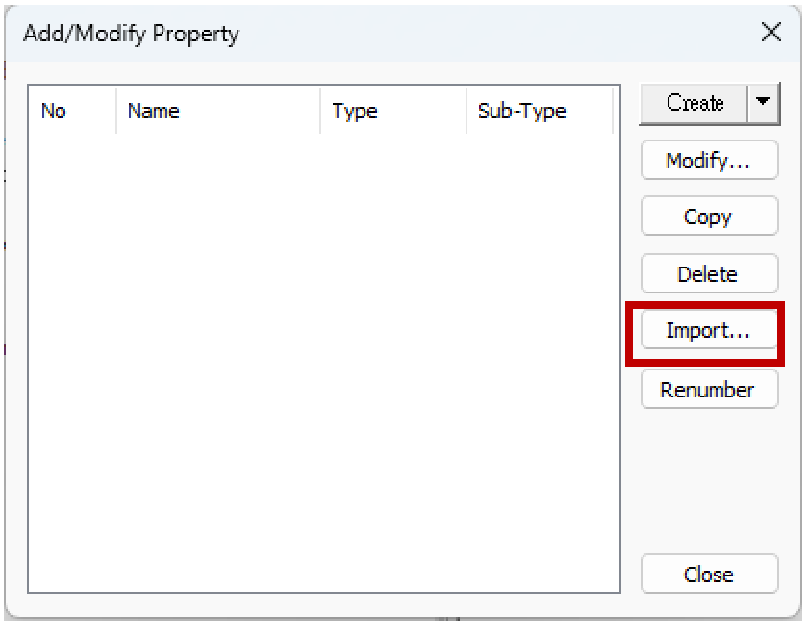



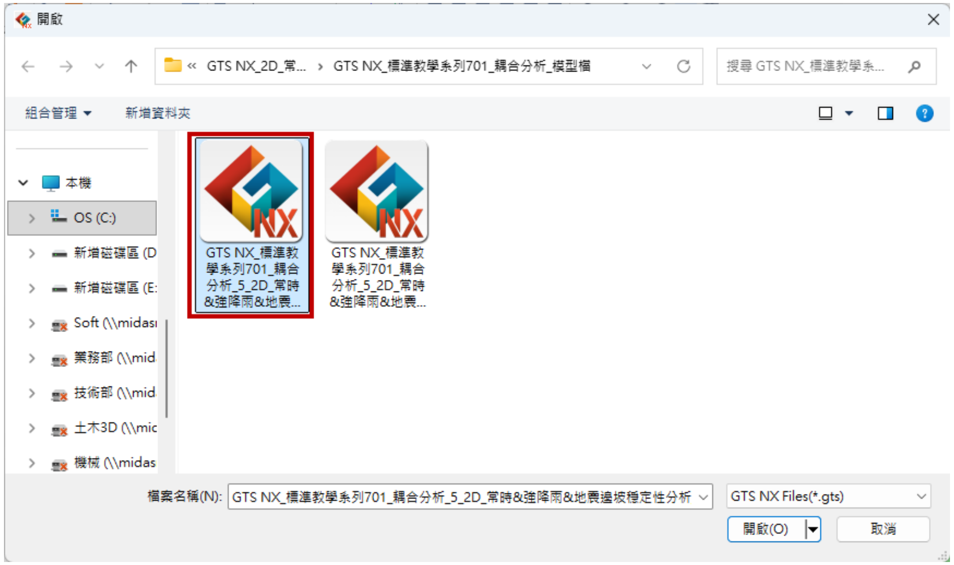

Import CAD file name:
'Geometry import'

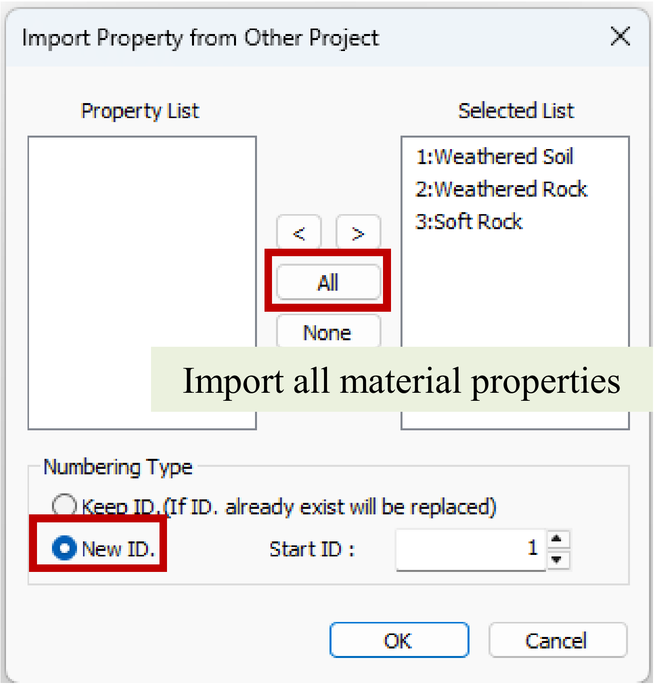


# MATERIAL & PROPERTY



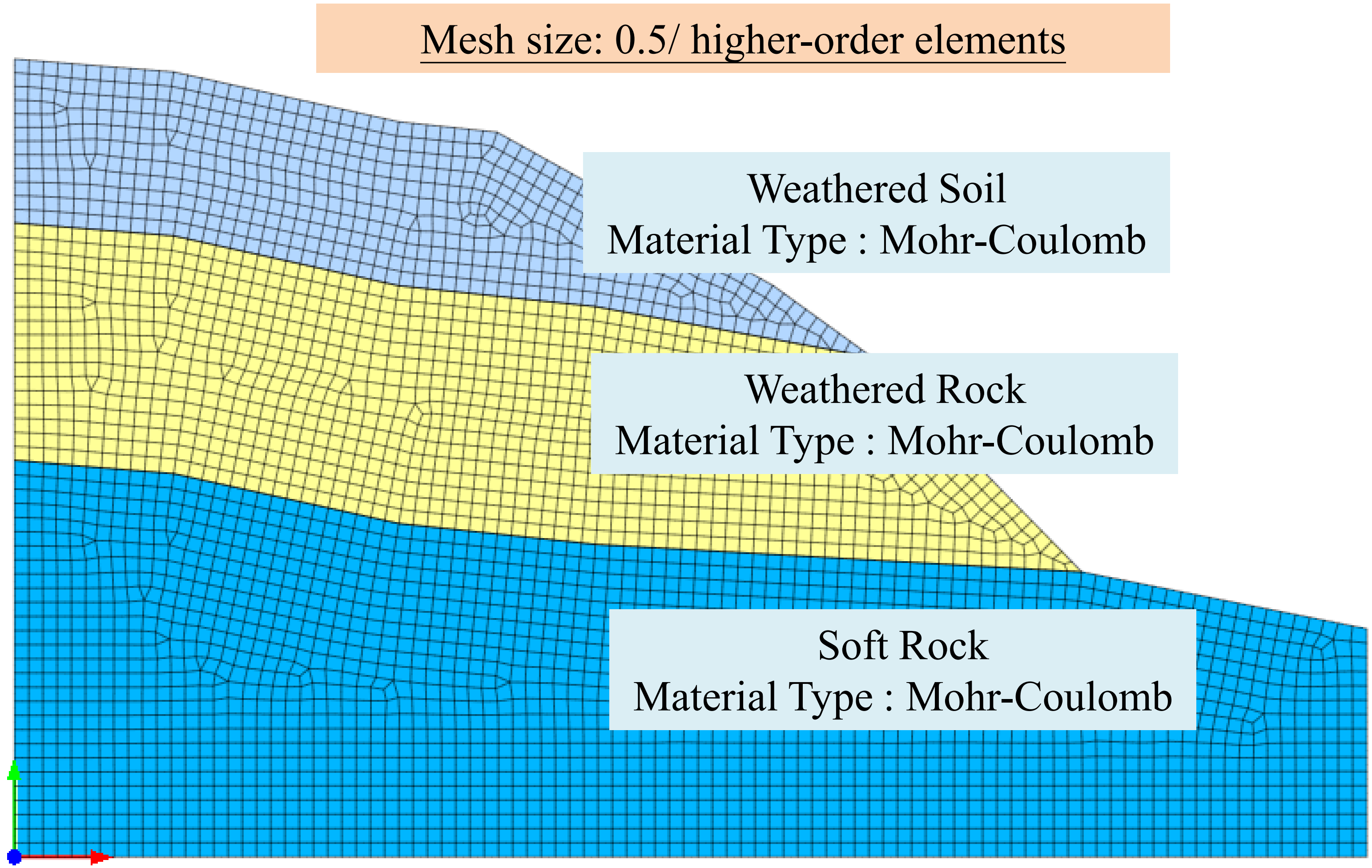



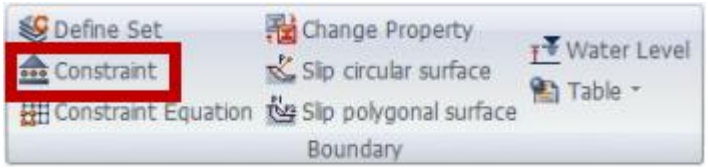

Import all material properties

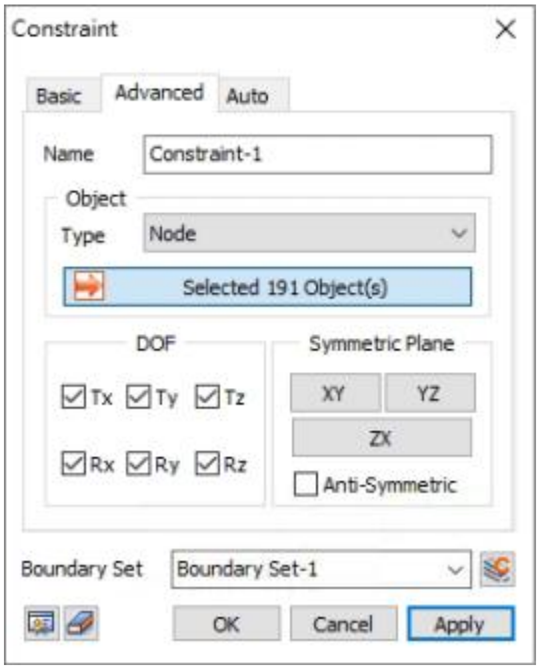
# 2D MESH GENERATION

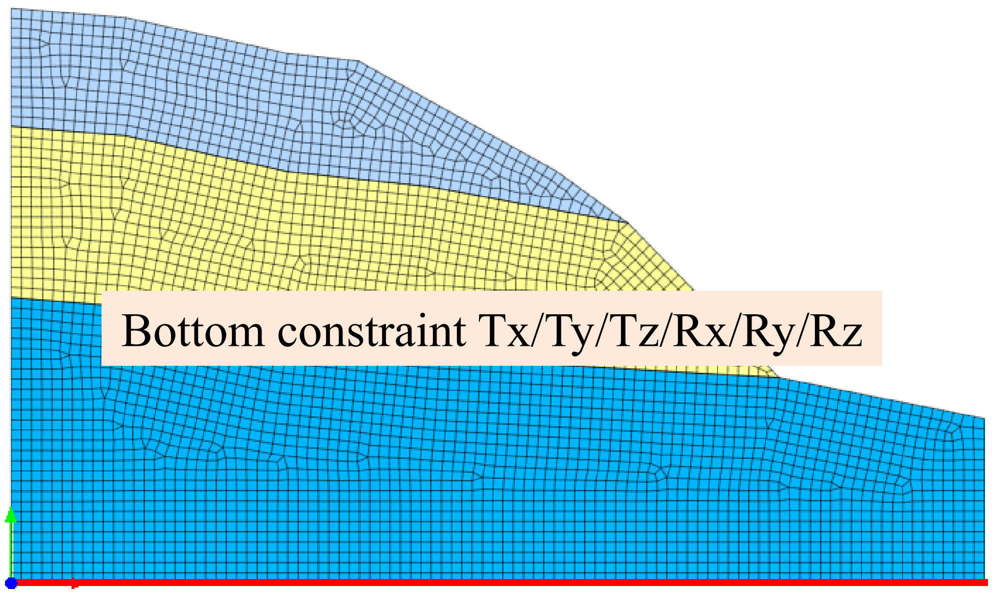



Note: Using higher-order elements and smaller grid sizes for slope analysis

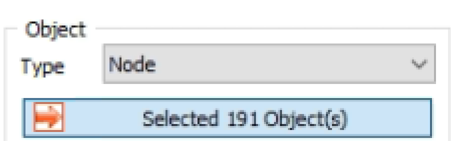
# BOTTOM BOUNDARY

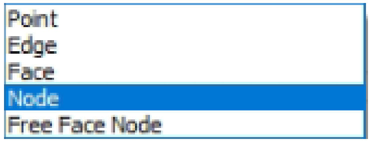


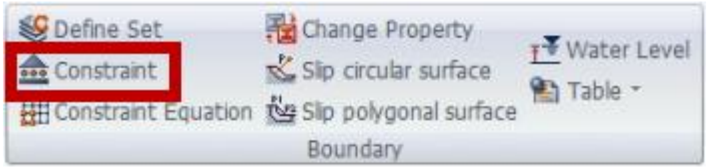



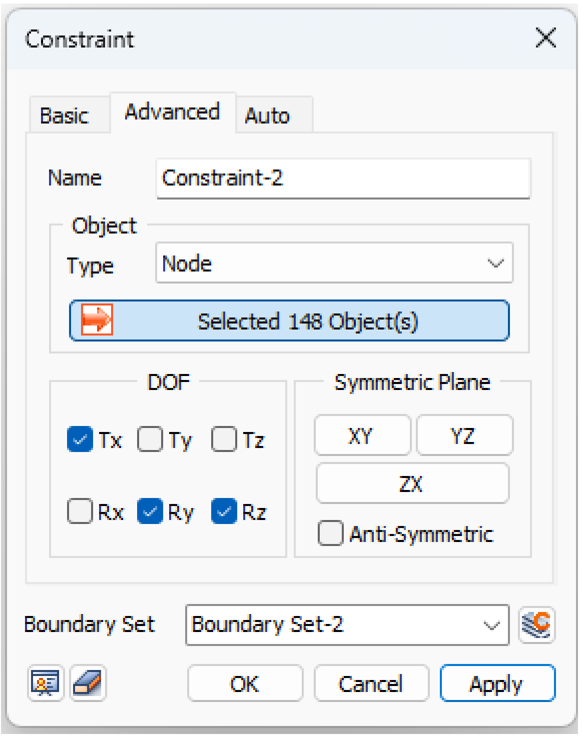

The geometric features or nodes can be applied to the boundary

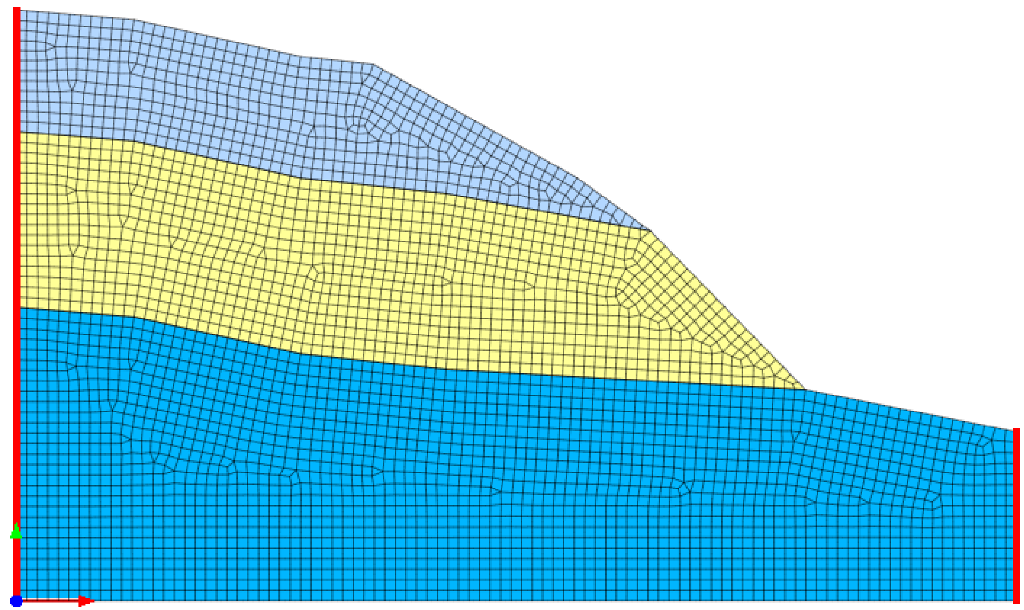


# 2-SIDED BOUNDARY



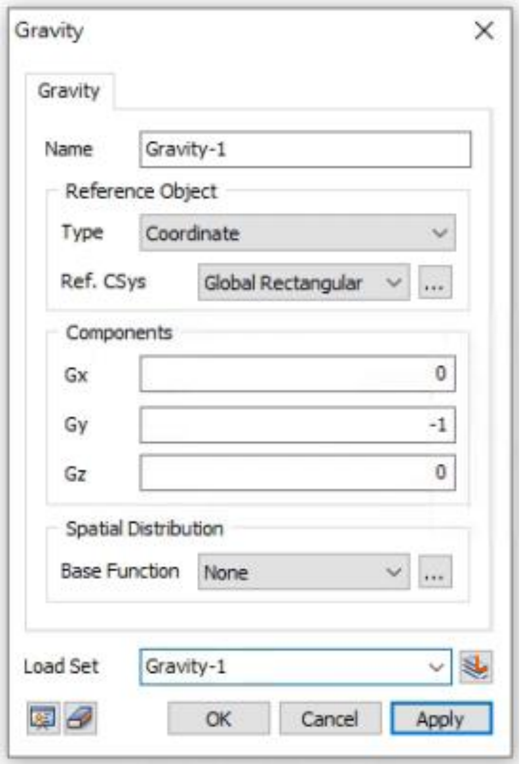



2-sided constraint Tx/Ry/Rz

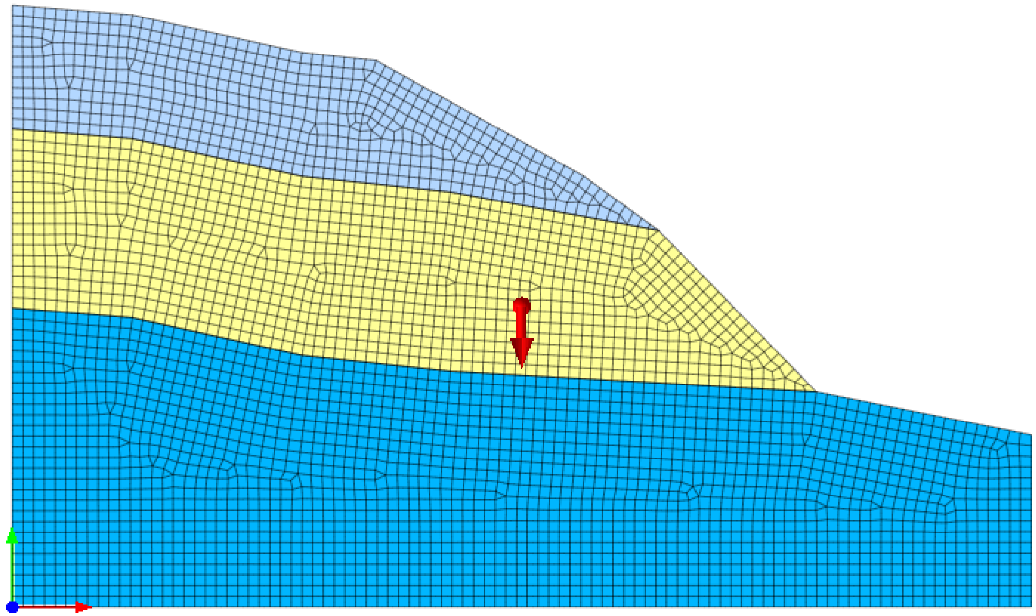
It is recommended to set boundary sets for different location

# SELF-WEIGHT

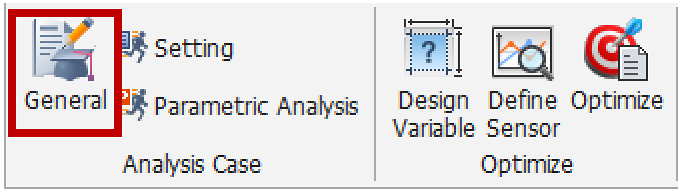
Self Weight
Load

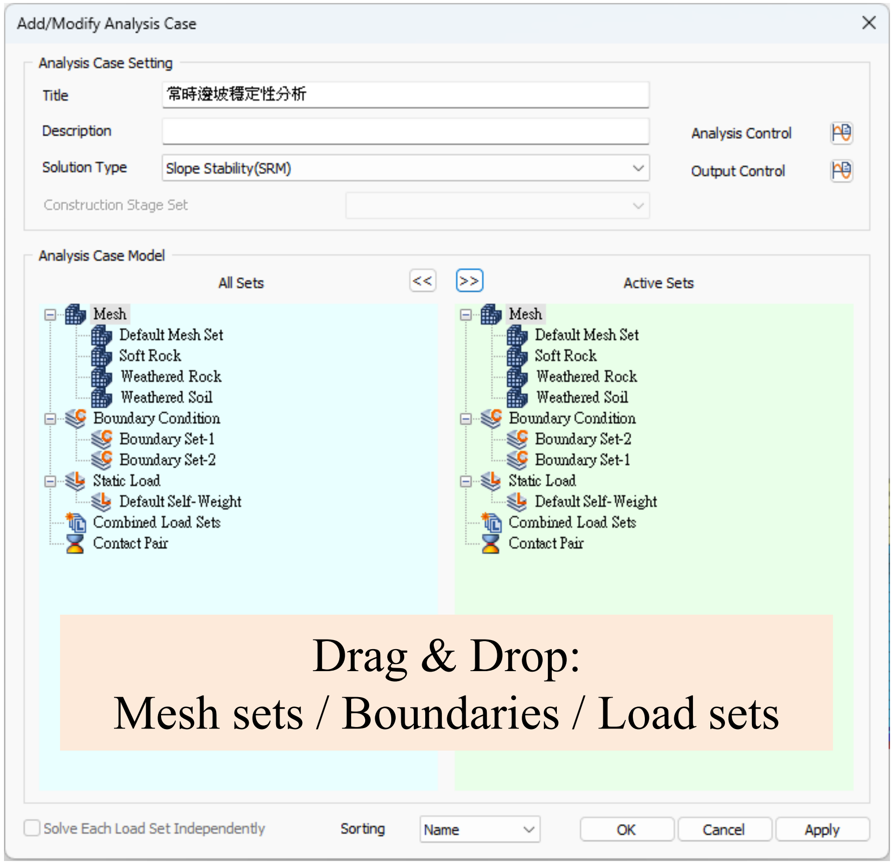
Gravity
Gravity
Name
Gravity-1
Reference Object
Type
Coordinate
Ref. CSys
Global Rectangular
...
Components
Gx
0
Gy
-1
Gz
0
Spatial Distribution
Base Function
None
...
Load Set
Gravity-1
OK
Cancel
Apply

# ANALYSIS 1 |SLOPE STABILITY (SRM) – NORMAL CASE)



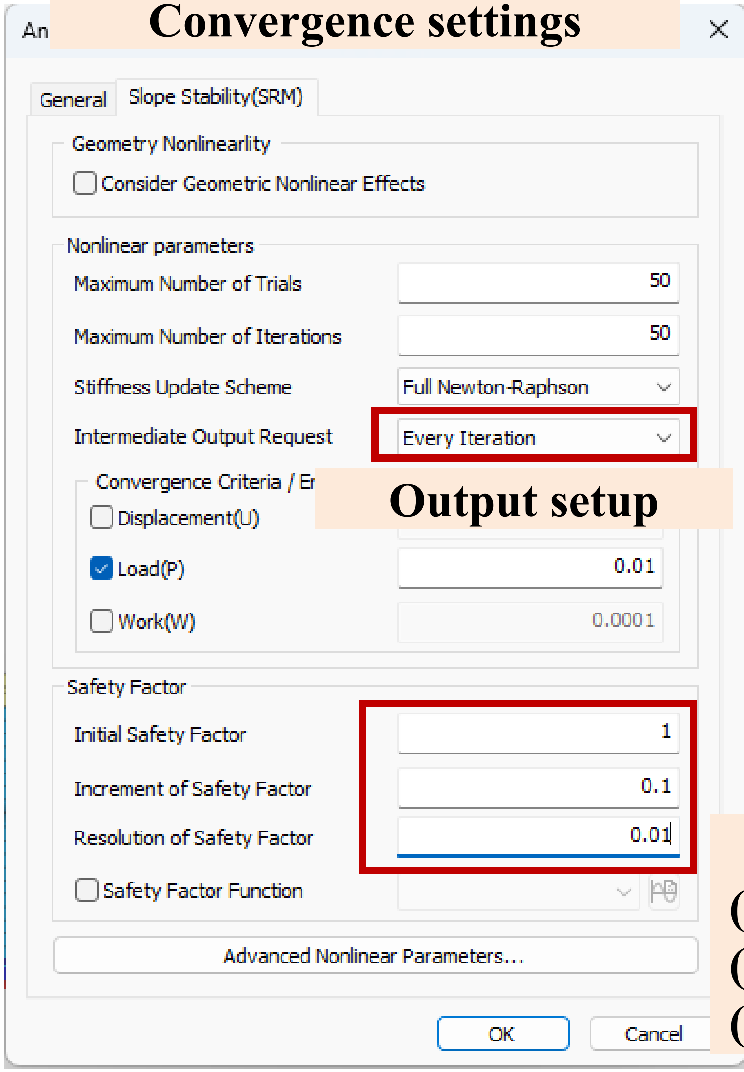

Simulation type: Slope Stability(SRM)




Drag & Drop:
Mesh sets / Boundaries / Load sets

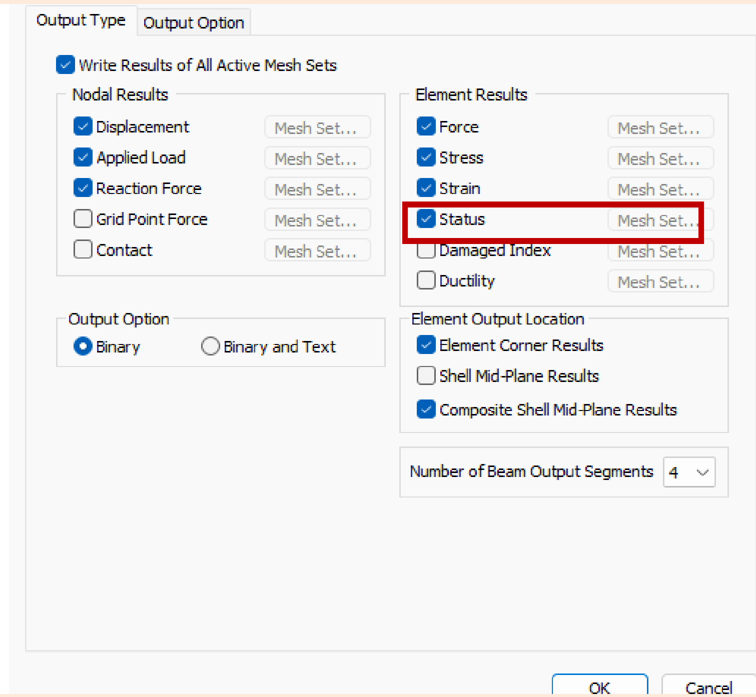
# ANALYSIS 2 |SLOPE STABILITY (SRM) – NORMAL CASE)

## Convergence settings




## Output setup

## Output=>Strain
## Shear strain indicates the failure arc



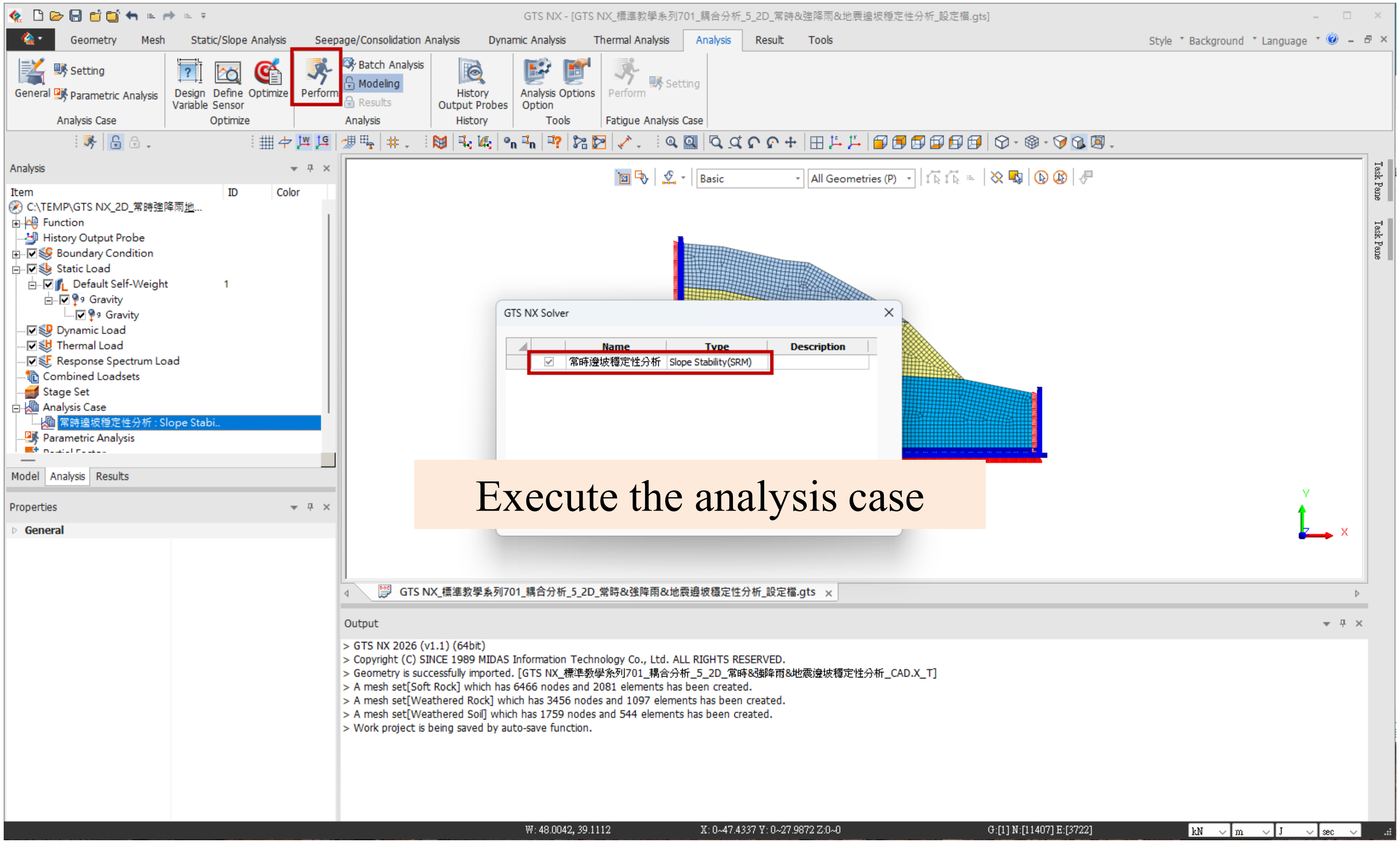

## <u>SRM convergence adjustment</u>

**(1) Initial safety factor 1**

**(2) FOS increment by 0.1 each time**

**(3) Residual < 0.01, minimum FOS reached**

# CALCULATION

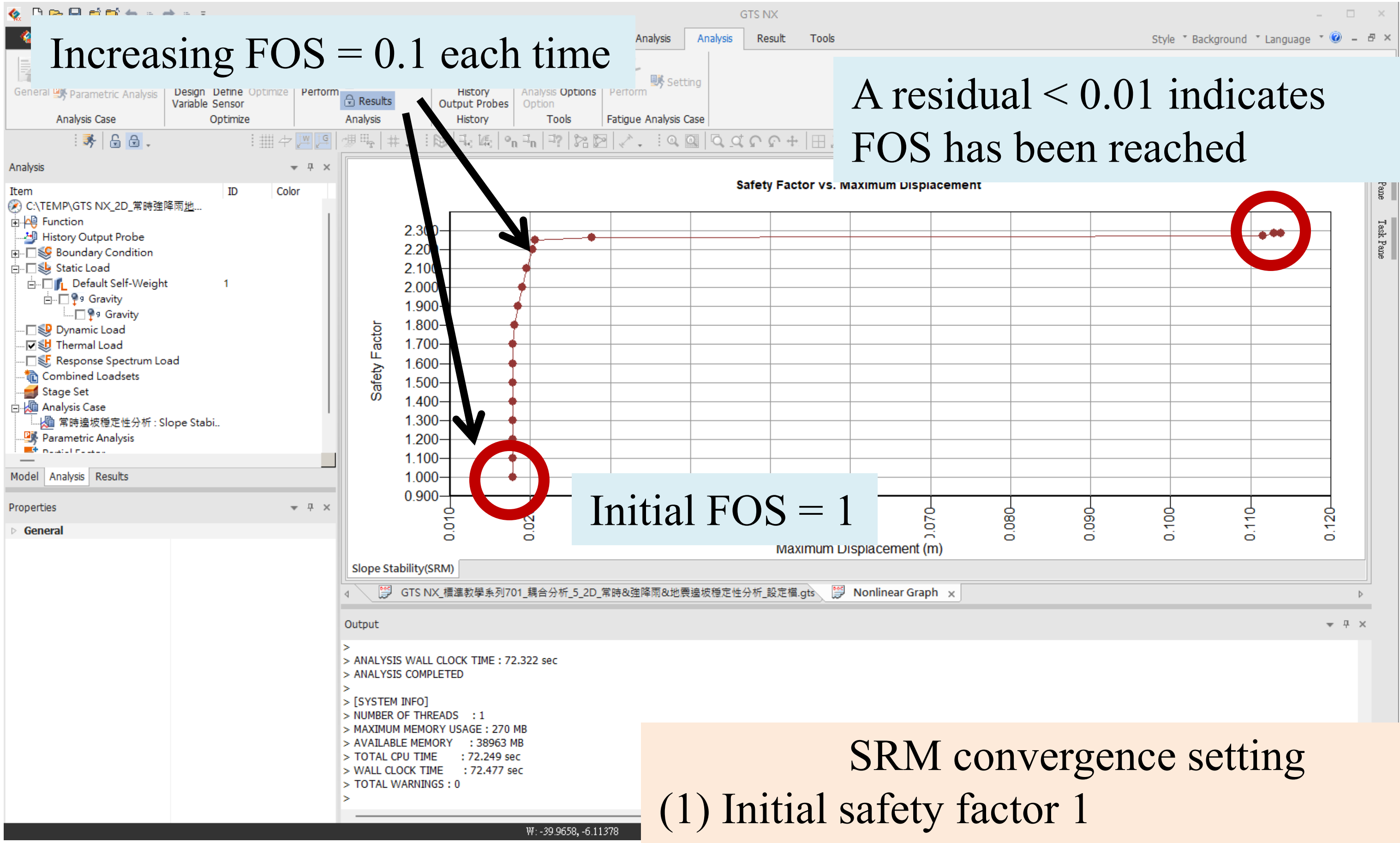



Execute the analysis case

# SAFETY FACTOR INDICATION | CONVERGENCE CRITERIA

Increasing FOS = 0.1 each time

A residual < 0.01 indicates FOS has been reached




Initial FOS = 1

SRM convergence setting

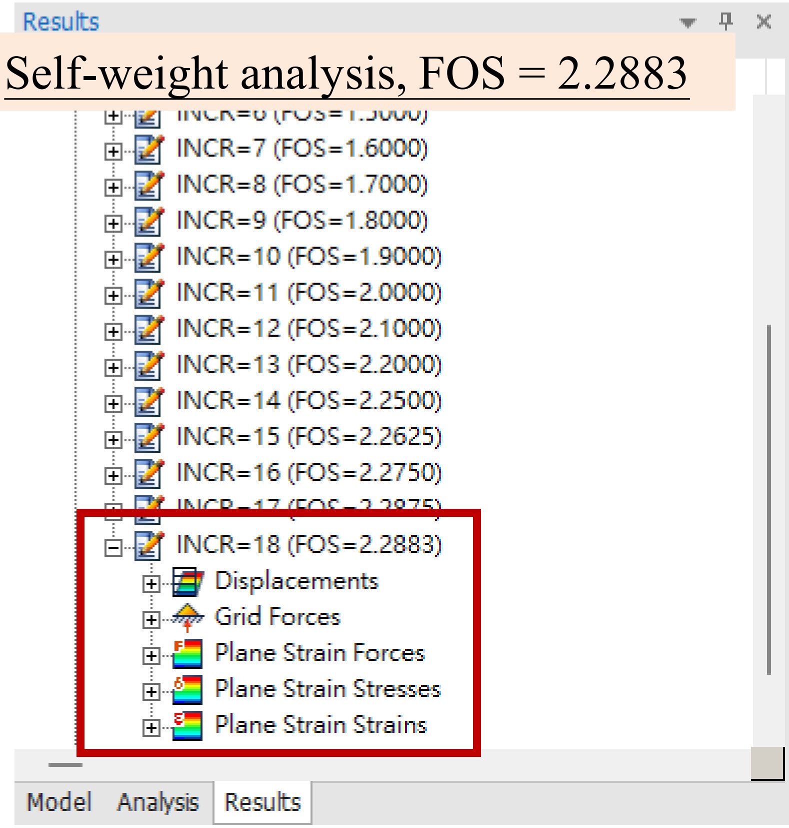
(1) Initial safety factor 1

(2) FOS increment by 0.1 each time

(3) Residual < 0.01, minimum FOS reached

# RESULTS | NORMAL CASE

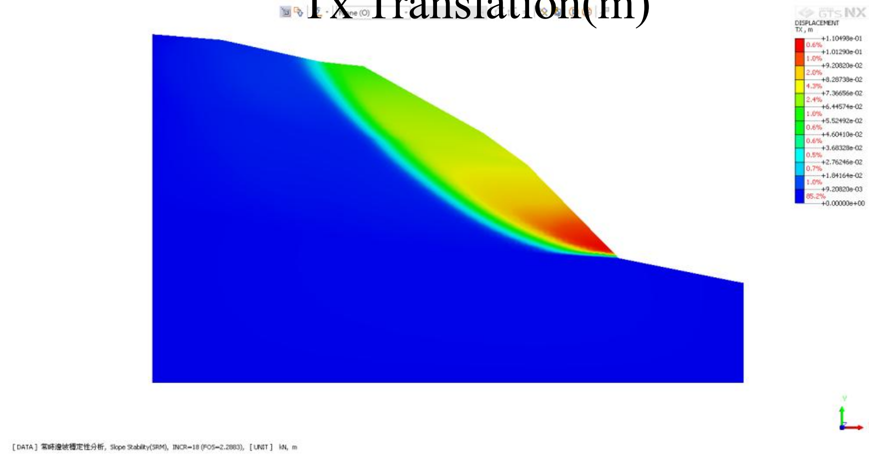
Self-weight analysis, FOS = 2.2883



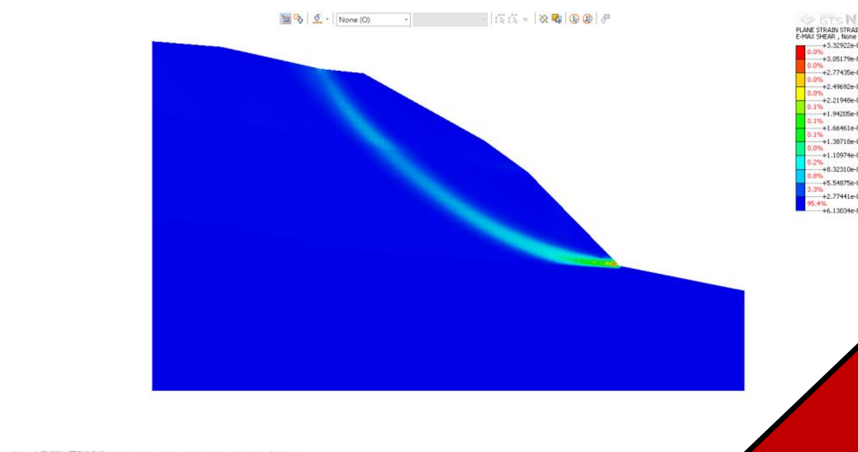

SRM for safety factor calculation

Failure surface indicated by horizontal displacement & maximum shear strain

Tx Translation(m)

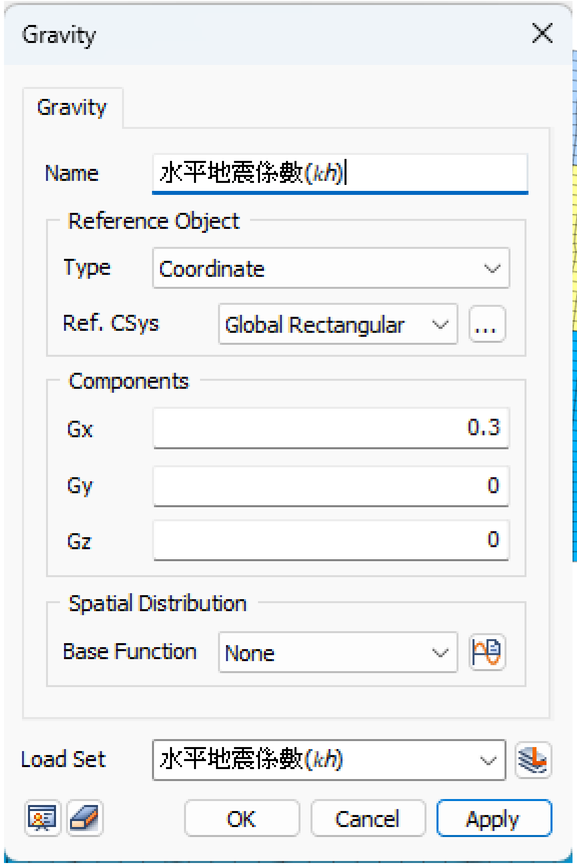


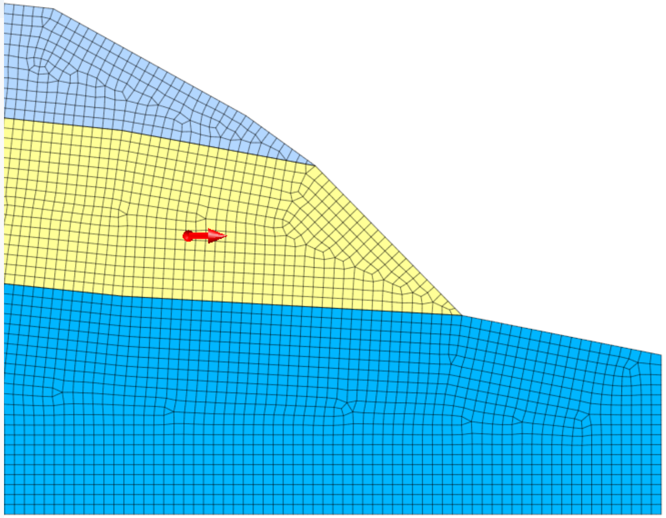
Maximum Shear Strain



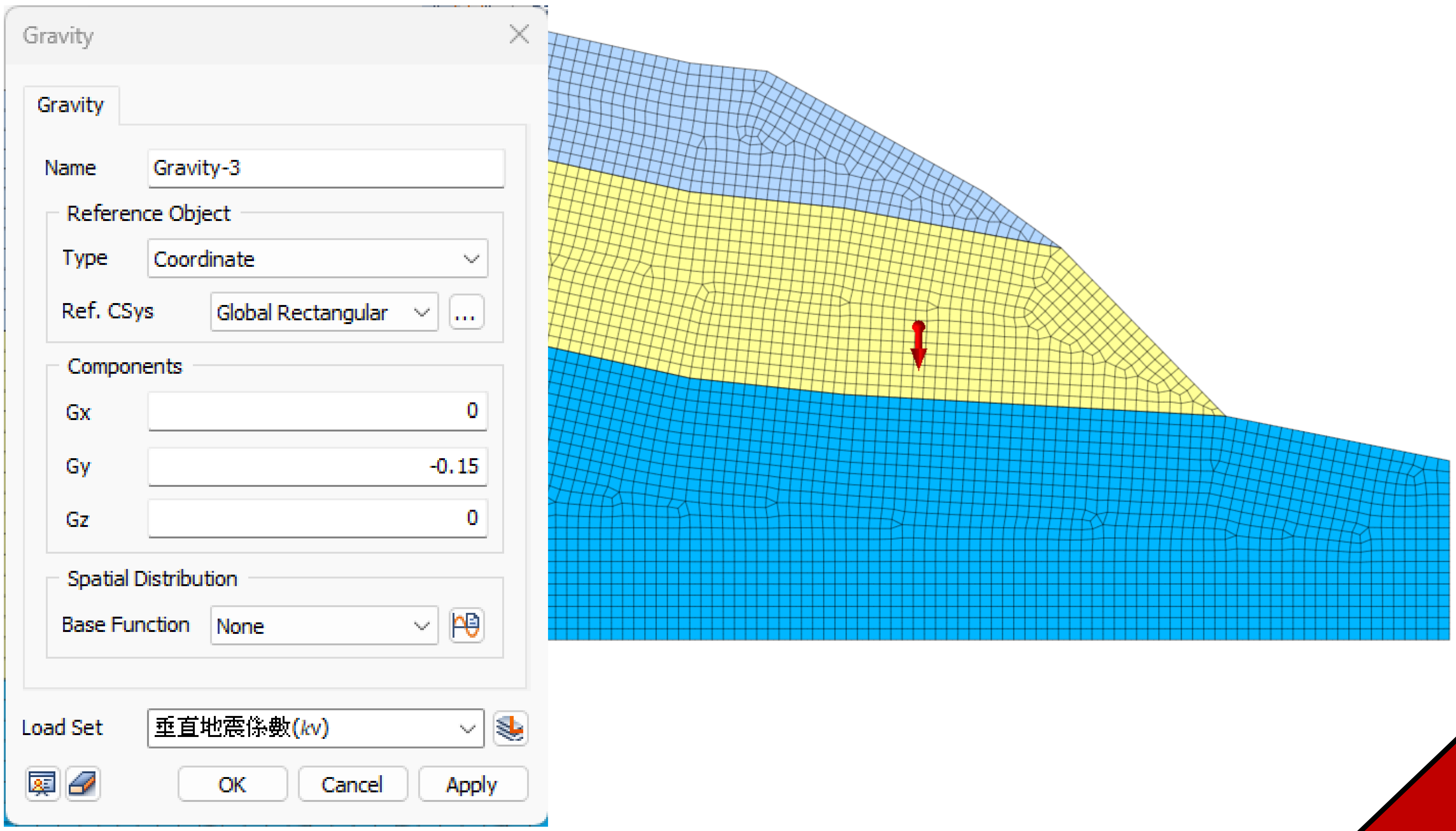
# Part 2
# PSEUDO-STATIC SEISMIC CASE

# HORIZONTAL SEISMIC COEFFICIENT ($K_H$)

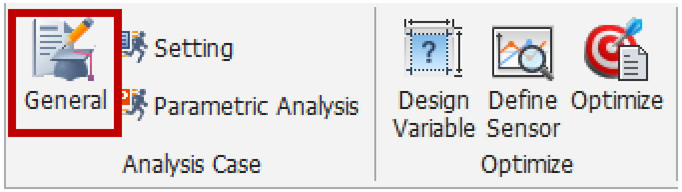



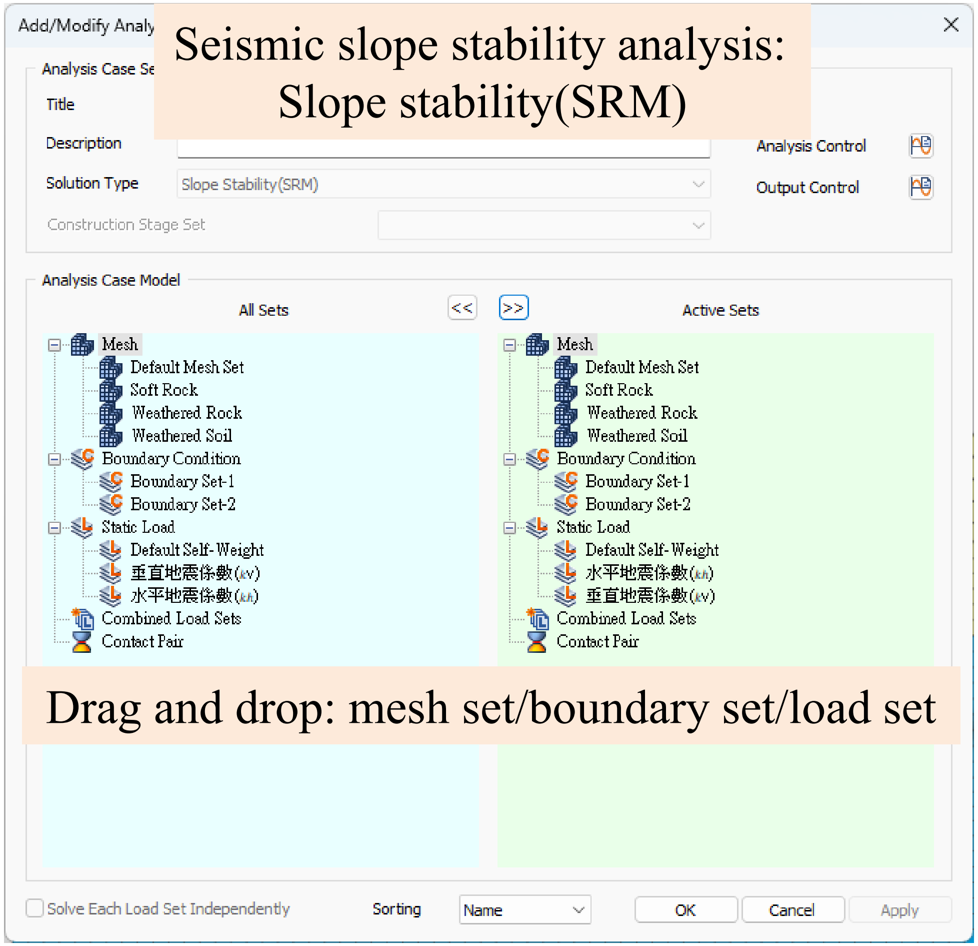
# VERTICAL SEISMIC COEFFICIENT ($K_V$)

# ANALYSIS 1 | PSEUDO-STATIC SEISMIC CASE



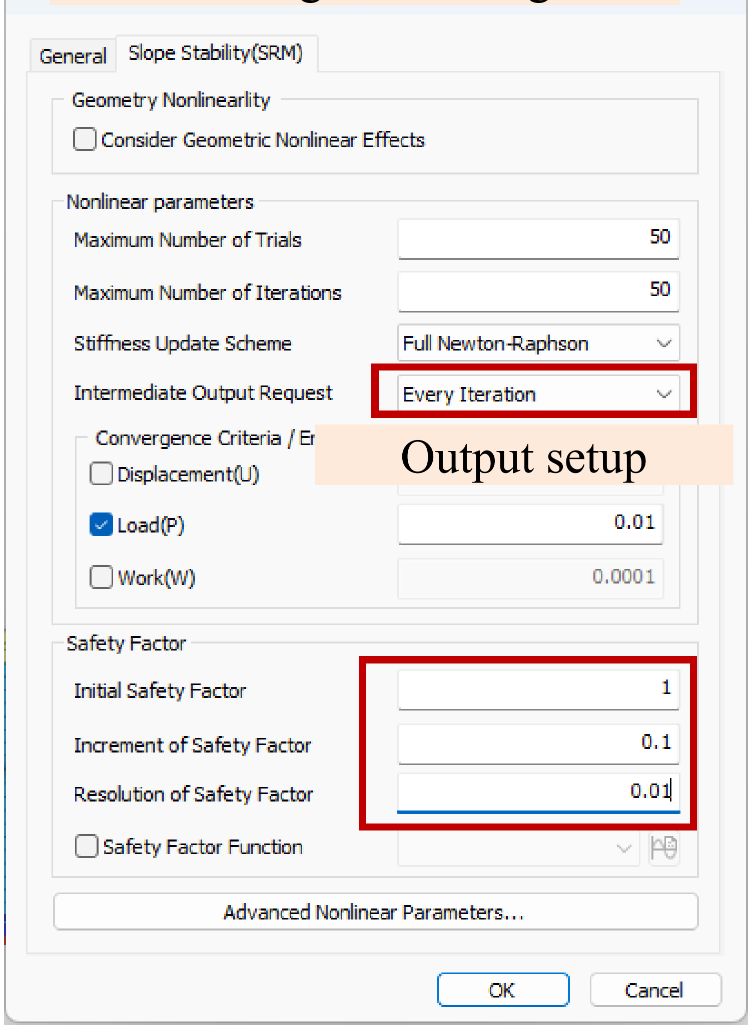

Seismic slope stability analysis:
Slope stability(SRM)




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

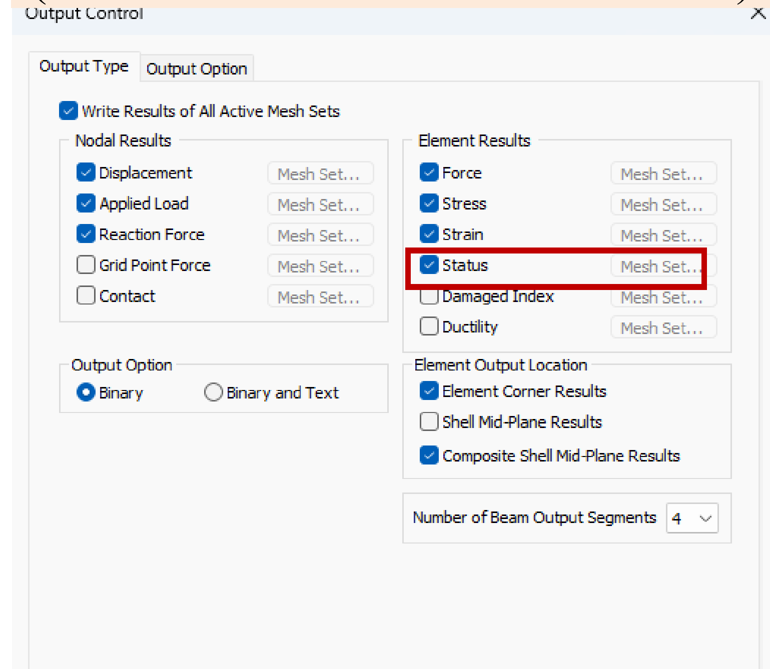
# ANALYSIS 2 | PSEUDO-STATIC SEISMIC CASE

Convergence settings




Output setup

Output: Strain
(Shear strain indicates the failure arc)



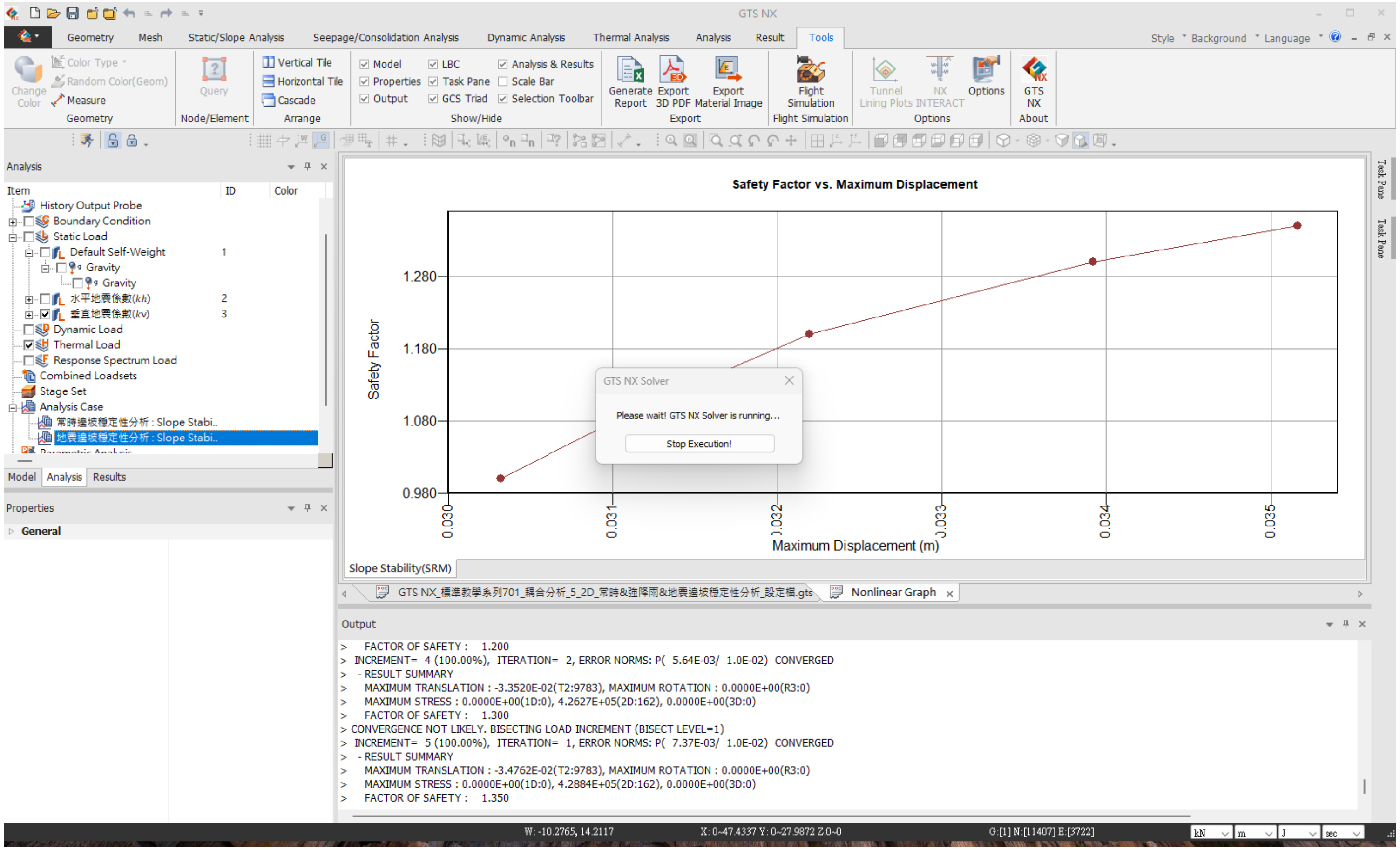

**SRM convergence adjustment**

(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

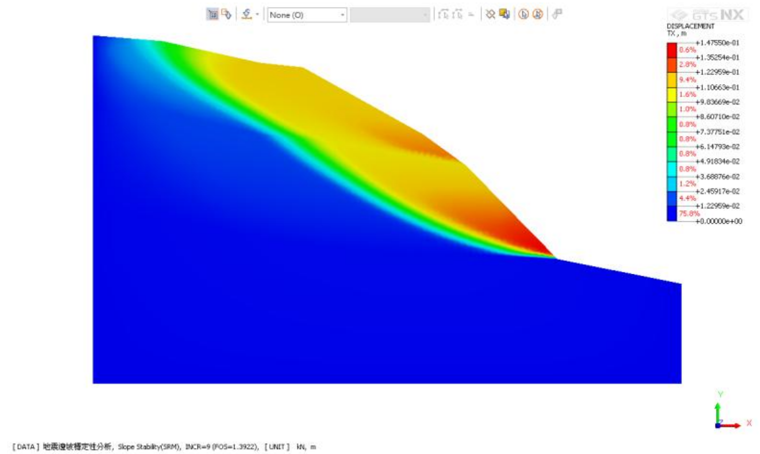
Pseudo-static seismic by $k_h$ & $k_v$,
FOS = 1.3922

- 地震邊坡穩定性分析
  - Slope Stability(SRM)
    - INCR=1 (FOS=1.0000)
    - INCR=2 (FOS=1.1000)
    - INCR=3 (FOS=1.2000)
    - INCR=4 (FOS=1.3000)
    - INCR=5 (FOS=1.3500)
    - INCR=6 (FOS=1.3750)
    - INCR=7 (FOS=1.3875)
    - INCR=8 (FOS=1.3906)
    - INCR=9 (FOS=1.3922)
  - Safety Factor
    - 1.39219 [Slope Stability(SRM..

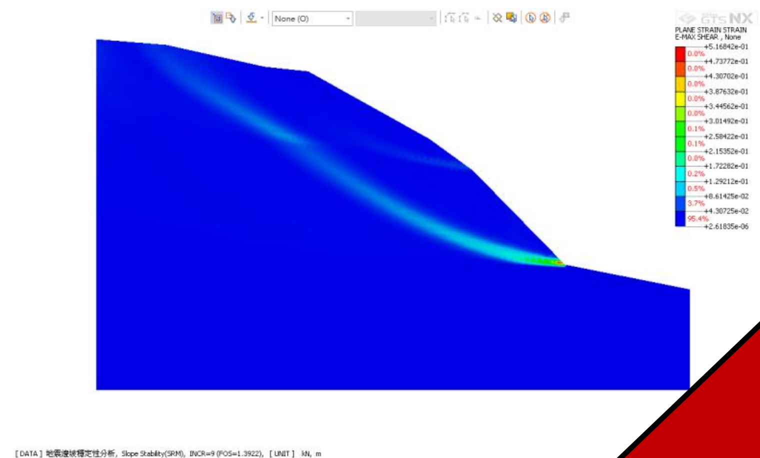
SRM for safety factor calculation

Failure surface indicated by horizontal displacement and maximum shear strain

Tx Translation(m)



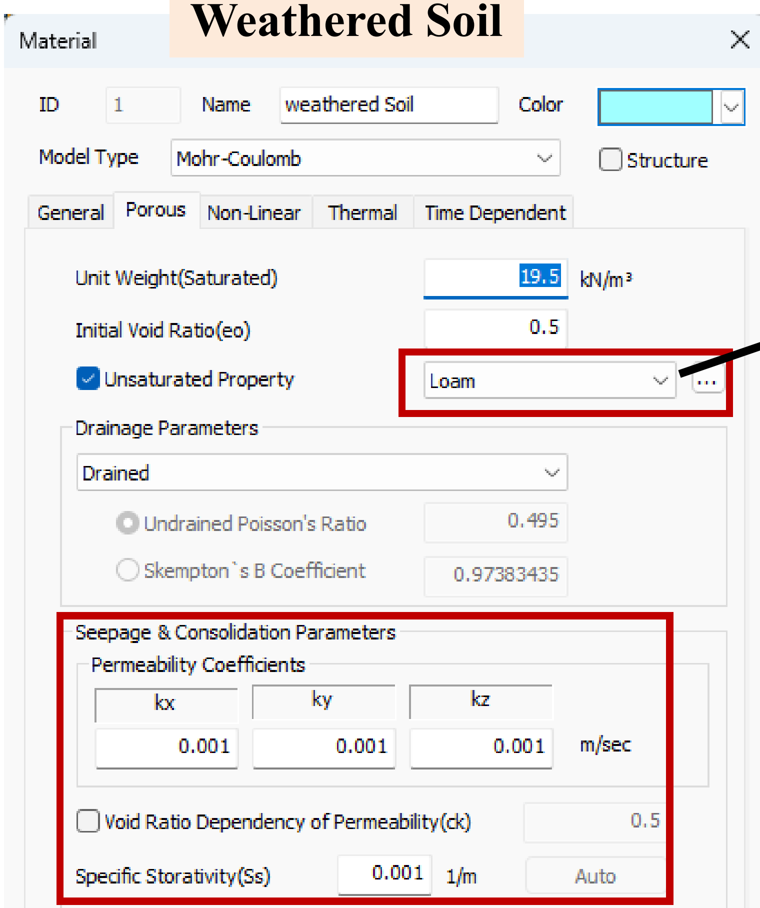

Maximum Shear Strain

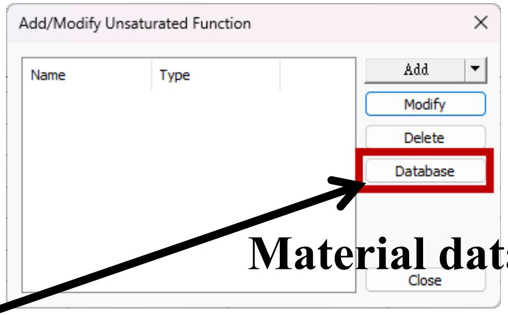


# Part 3
# HEAVY RAINFALL CASE

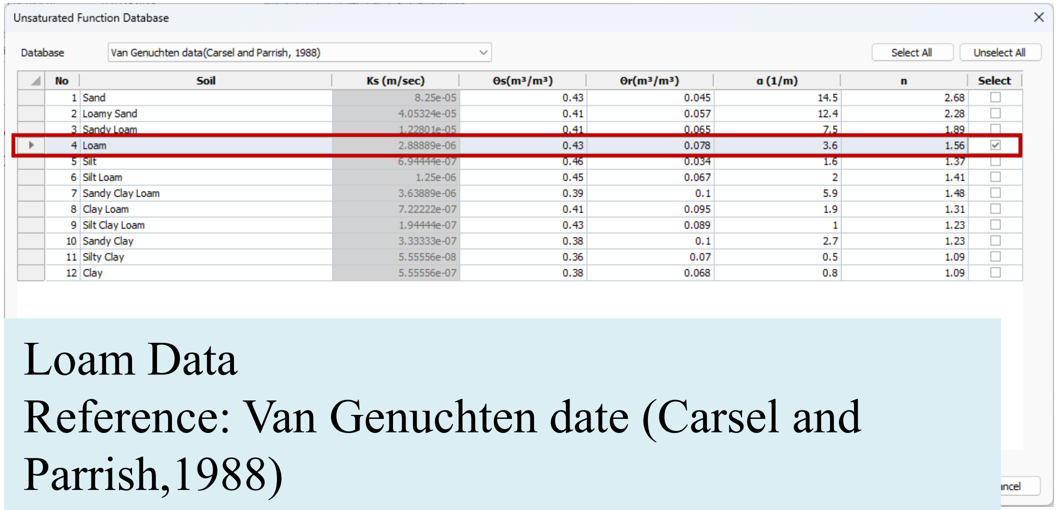
# POROUS MATERIAL 1 | WEATHERED SOIL

## Weathered Soil




**Material database in GTS NX**



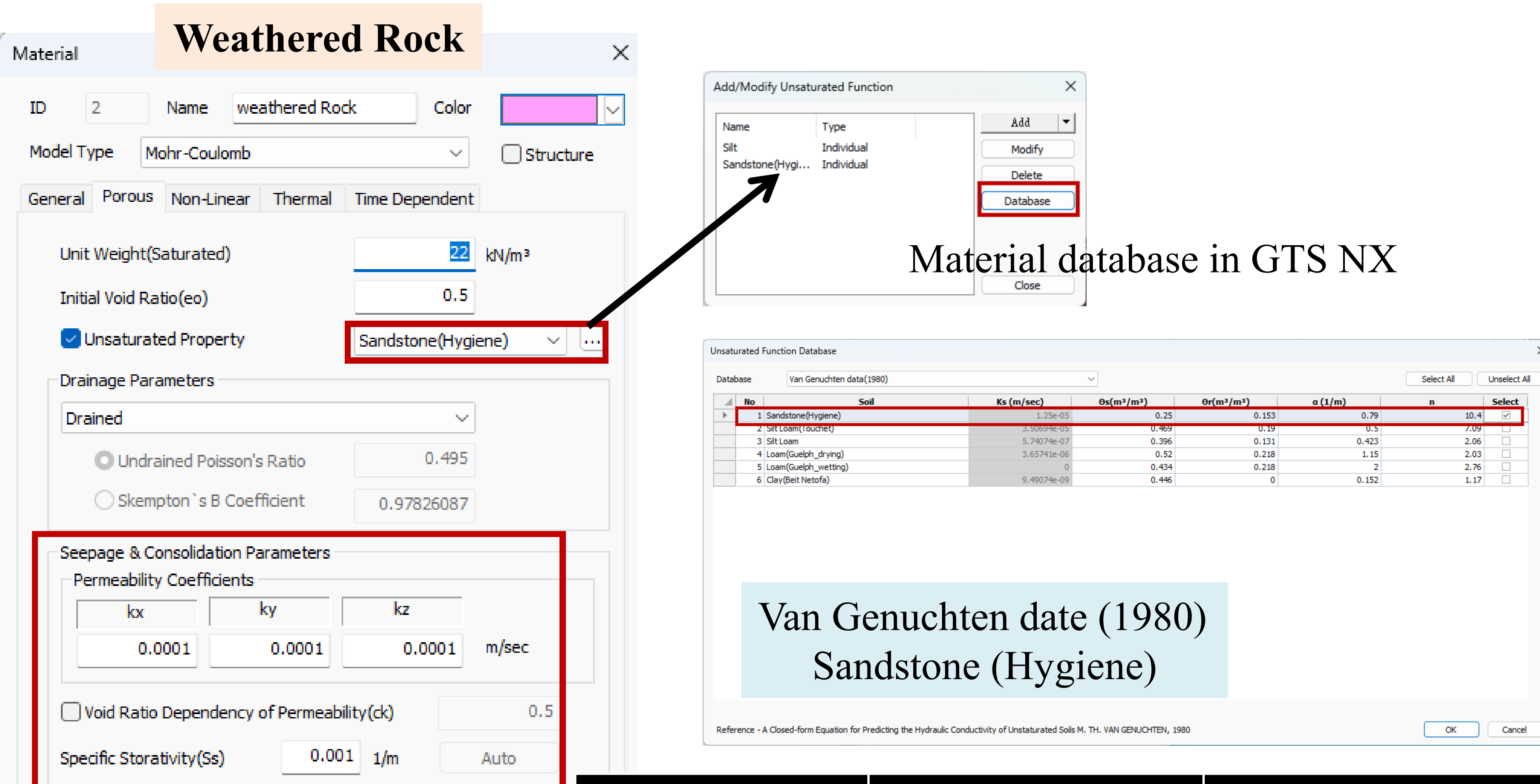

| No | Soil | Ks (m/sec) | θs(m³/m³) | θr(m³/m³) | α (1/m) | n | Select |
|---|---|---|---|---|---|---|---|
| 1 | Sand | 8.25e-05 | 0.43 | 0.045 | 14.5 | 2.68 | |
| 2 | Loamy Sand | 4.05324e-05 | 0.41 | 0.057 | 12.4 | 2.28 | |
| 3 | Sandy Loam | 1.22801e-05 | 0.41 | 0.065 | 7.5 | 1.89 | |
| 4 | Loam | 2.88889e-06 | 0.43 | 0.078 | 3.6 | 1.56 | ✓ |
| 5 | Silt | 6.94444e-07 | 0.46 | 0.034 | 1.6 | 1.37 | |
| 6 | Silt Loam | 1.25e-06 | 0.45 | 0.067 | 2 | 1.41 | |
| 7 | Sandy Clay Loam | 3.63889e-06 | 0.39 | 0.1 | 5.9 | 1.48 | |
| 8 | Clay Loam | 7.22222e-07 | 0.41 | 0.095 | 1.9 | 1.31 | |
| 9 | Silt Clay Loam | 1.94444e-07 | 0.43 | 0.089 | 1 | 1.23 | |
| 10 | Sandy Clay | 3.33333e-07 | 0.38 | 0.1 | 2.7 | 1.23 | |
| 11 | Silty Clay | 5.55556e-08 | 0.36 | 0.07 | 0.5 | 1.09 | |
| 12 | Clay | 5.55556e-07 | 0.38 | 0.068 | 0.8 | 1.09 | |

Loam Data
Reference: Van Genuchten date (Carsel and Parrish,1988)

| | 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

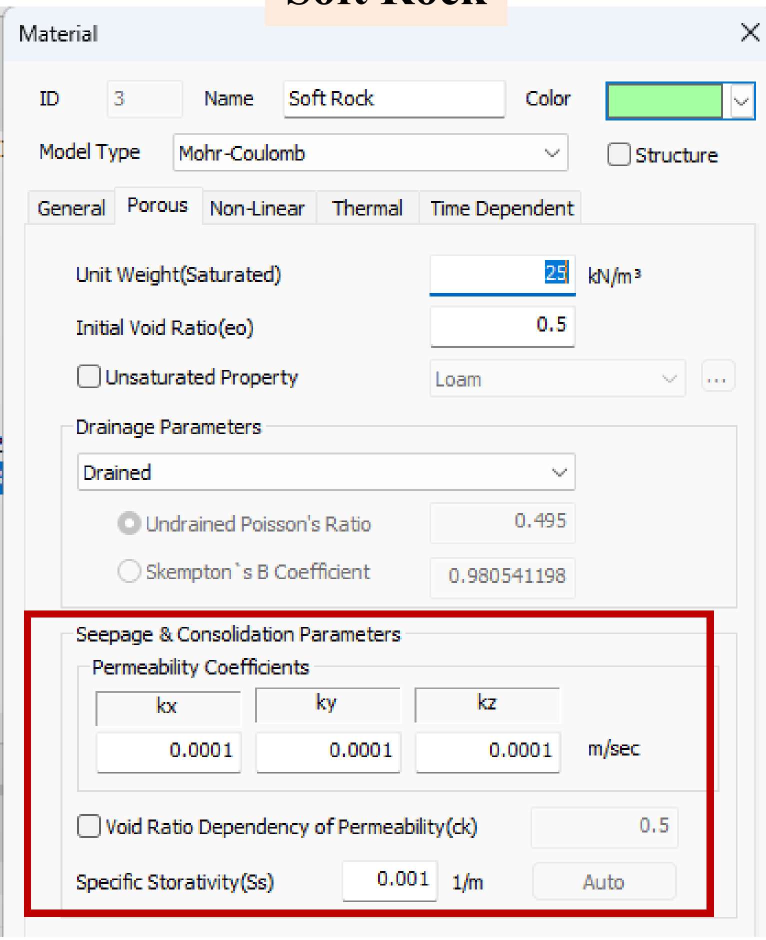



| | Coefficient of permeability(K) (m/sec) | Specific Storativity(Ss) (1/m) |
|---|---|---|
| Weathered Rock | $10^{-6}$~$10^{-4}$ | $10^{-6}$~$10^{-3}$ |

**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 2 | SOFT ROCK

**Soft Rock**

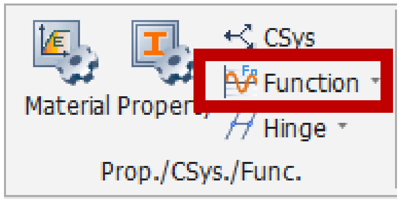



Flow of rainfall case does not calculate as saturated

| | 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)

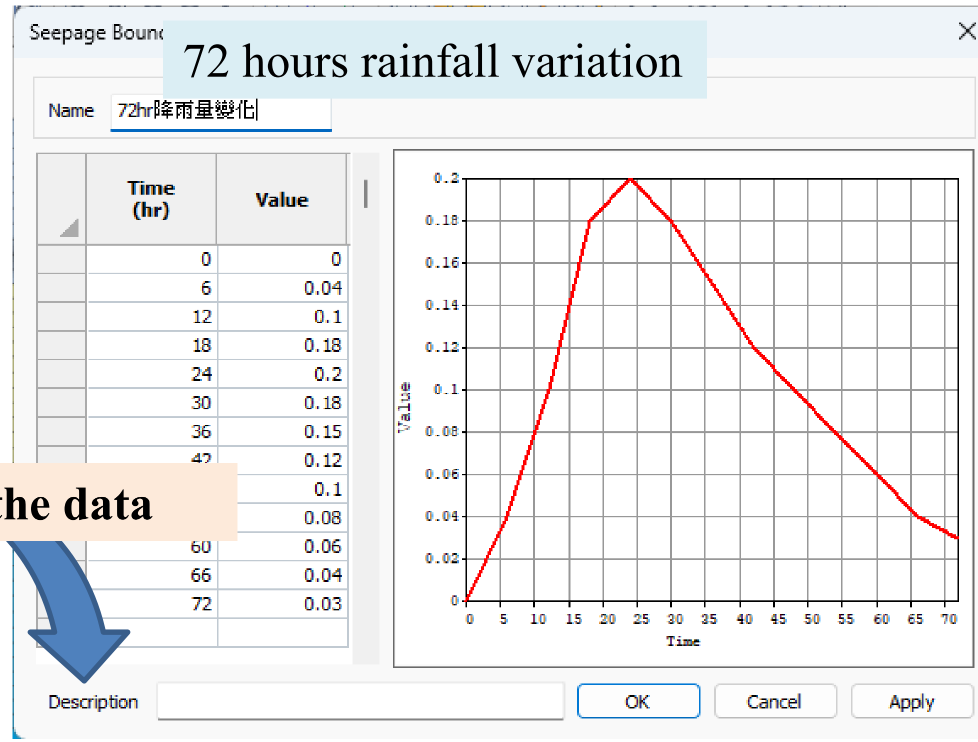
## Seepage Boundary


## Excel data


| 時間累計(hr) | 每6小時降雨量 (m) |
|---|---|
| 0 | [illegible] |
| 6 | [illegible] |
| 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

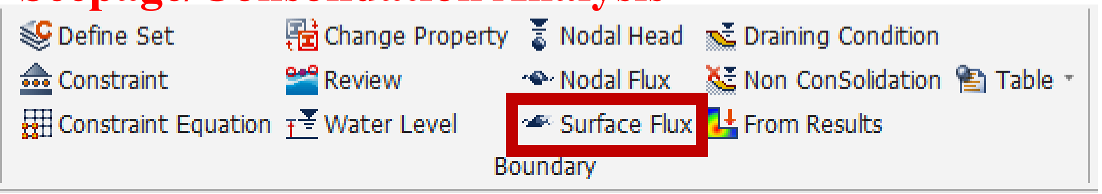


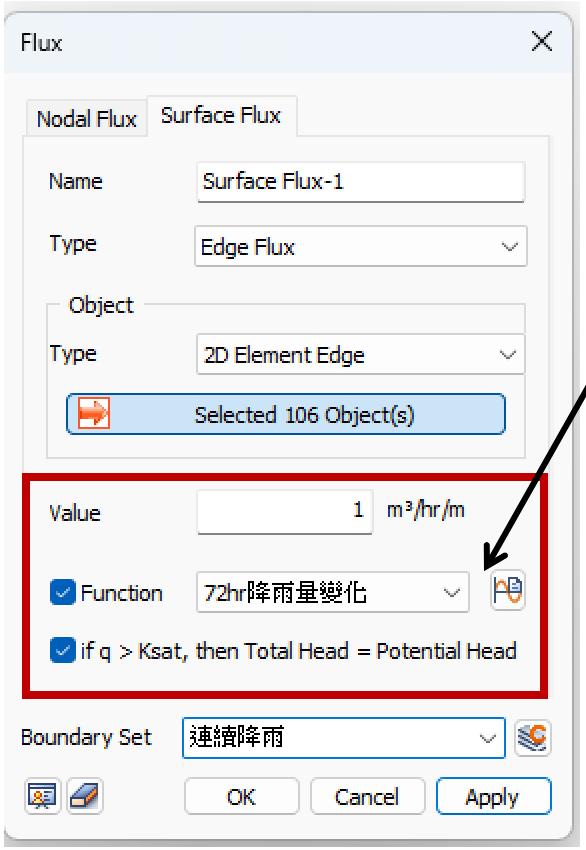

註:GTS NX不支援Y軸單位切換。

# SURFACE FLUX

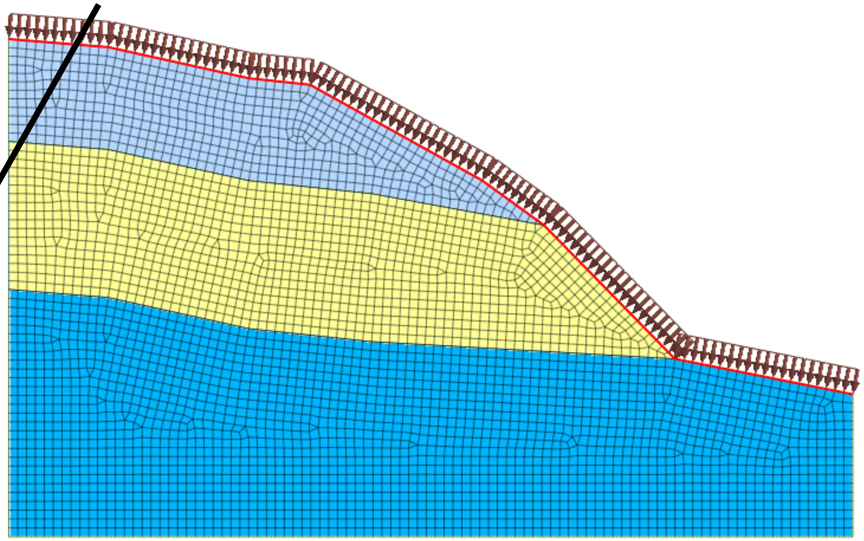
## Unit (KN/m/J/hr)


## Seepage/Consolidation Analysis




**Flux = Value × Function**



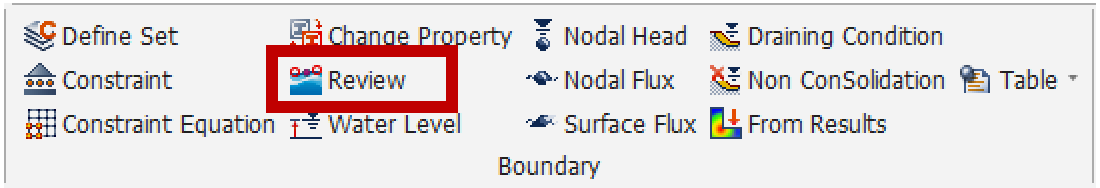
**Setting:**

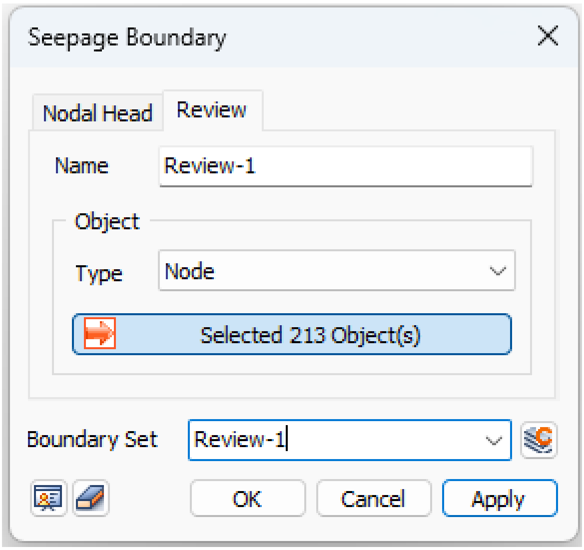
if surface flux > coefficient of permeability

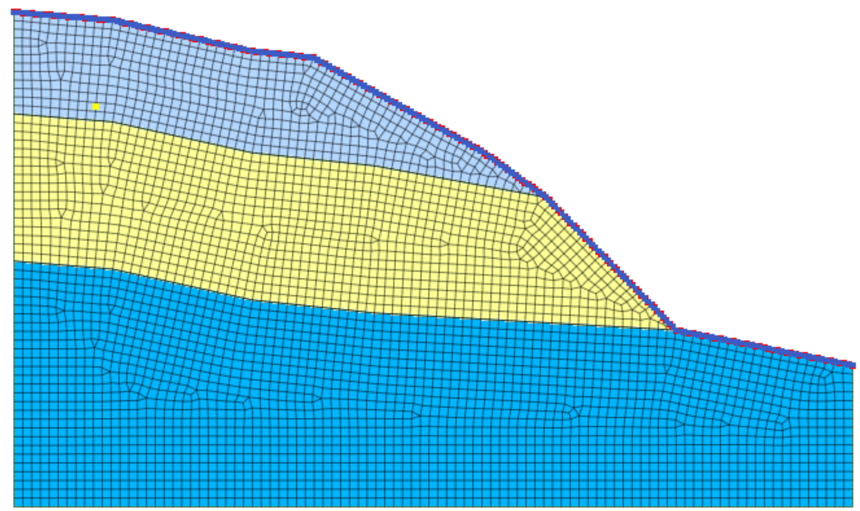
total head = potential head

# REVIEW / SEEPAGE

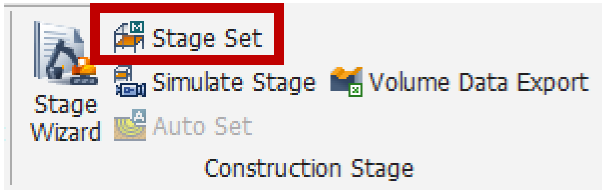
## Seepage/Consolidation Analysis



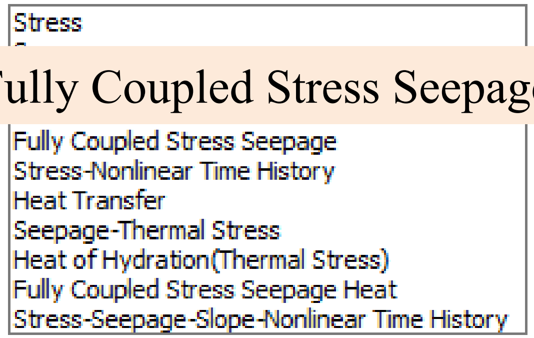



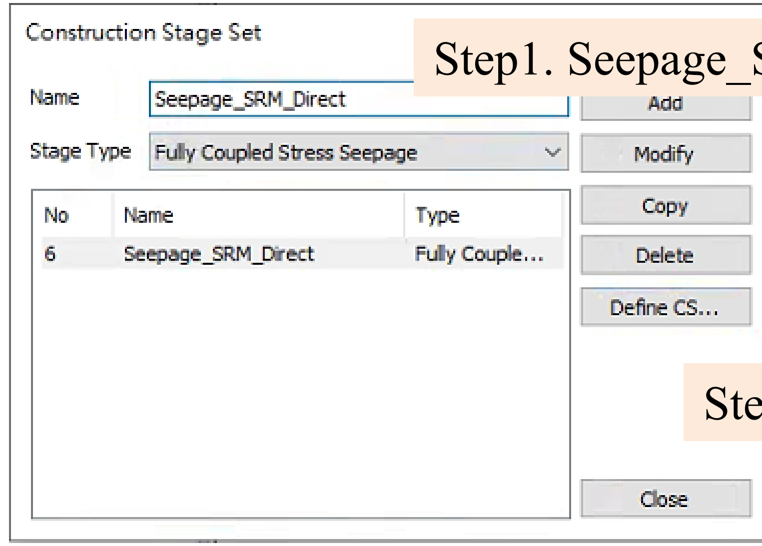
# CONSTRUCTION STAGE 1 | PSEUDO-STATIC SEISMIC CASE




Construction phase types in GTS NX

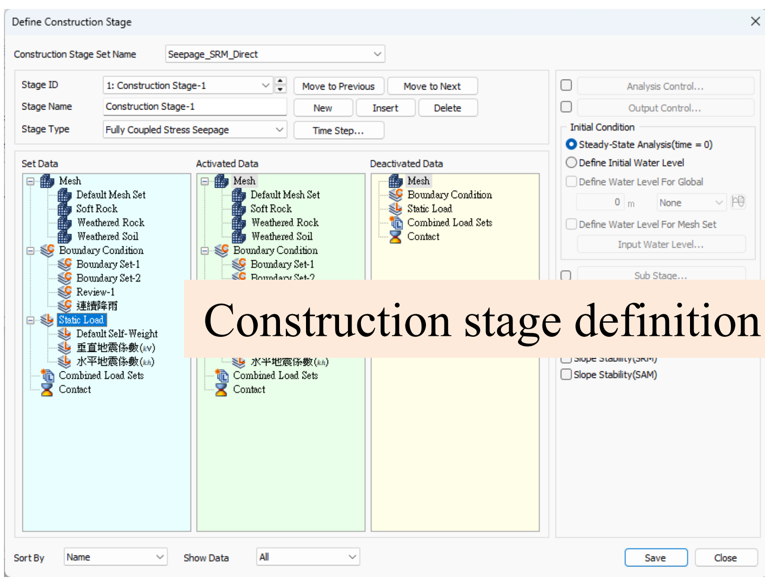



Fully Coupled Stress Seepage



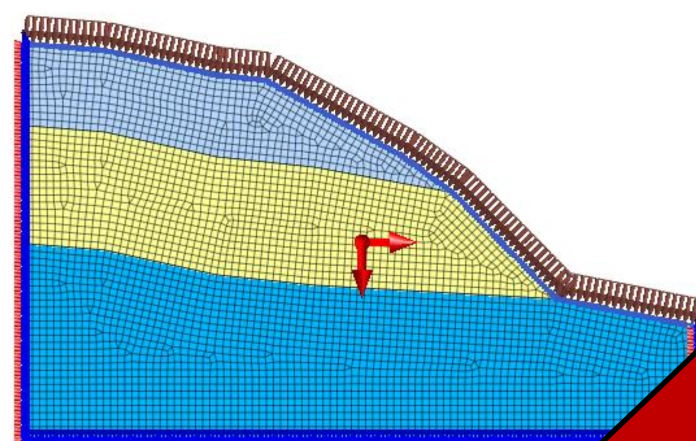

Step1. Seepage_SRM_Direct

Step2.Define CS

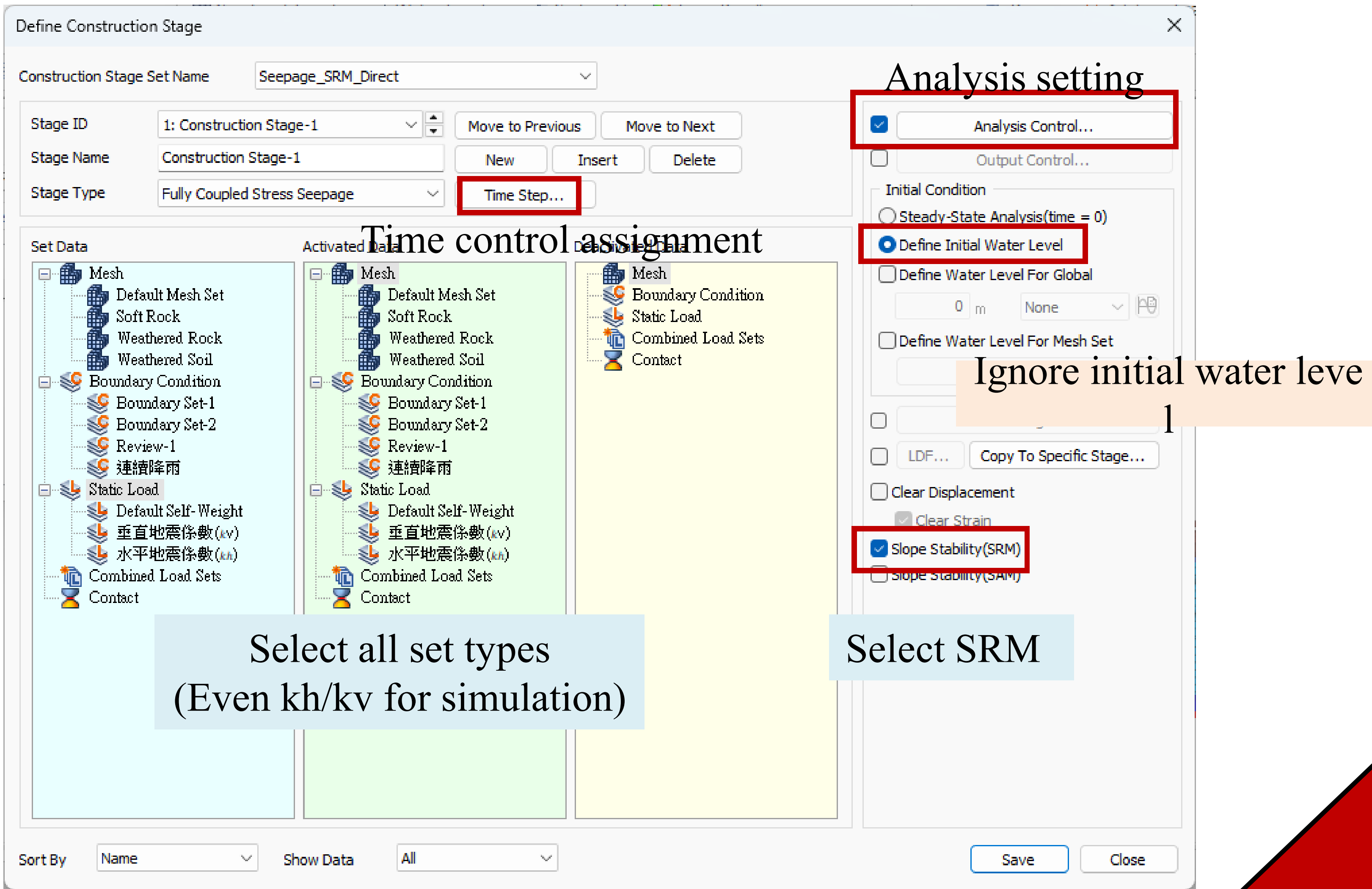



Construction stage definition

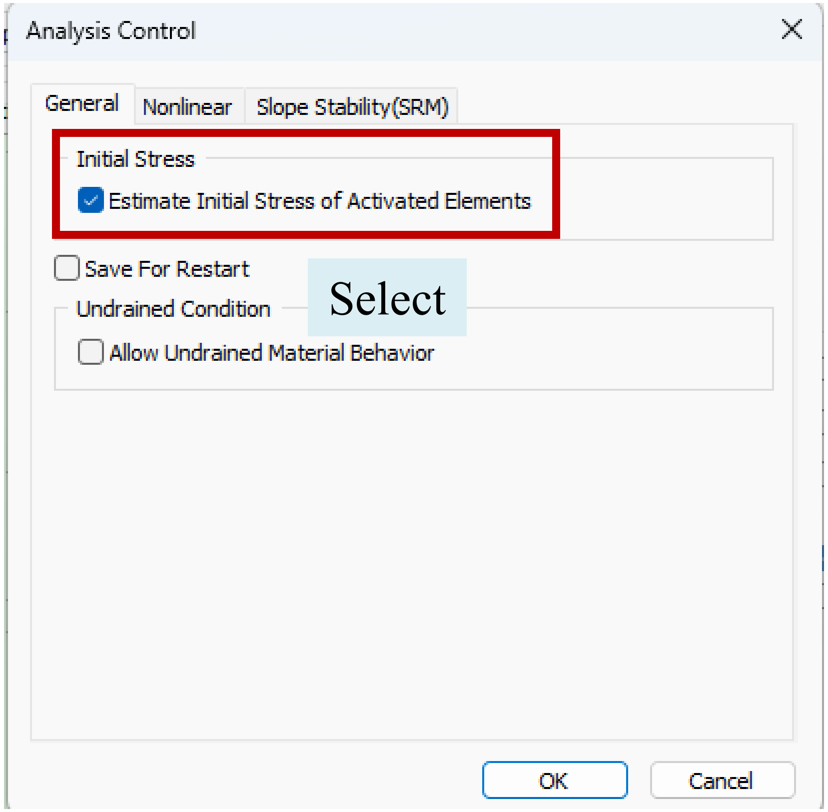
Activate all mesh sets/boundary sets

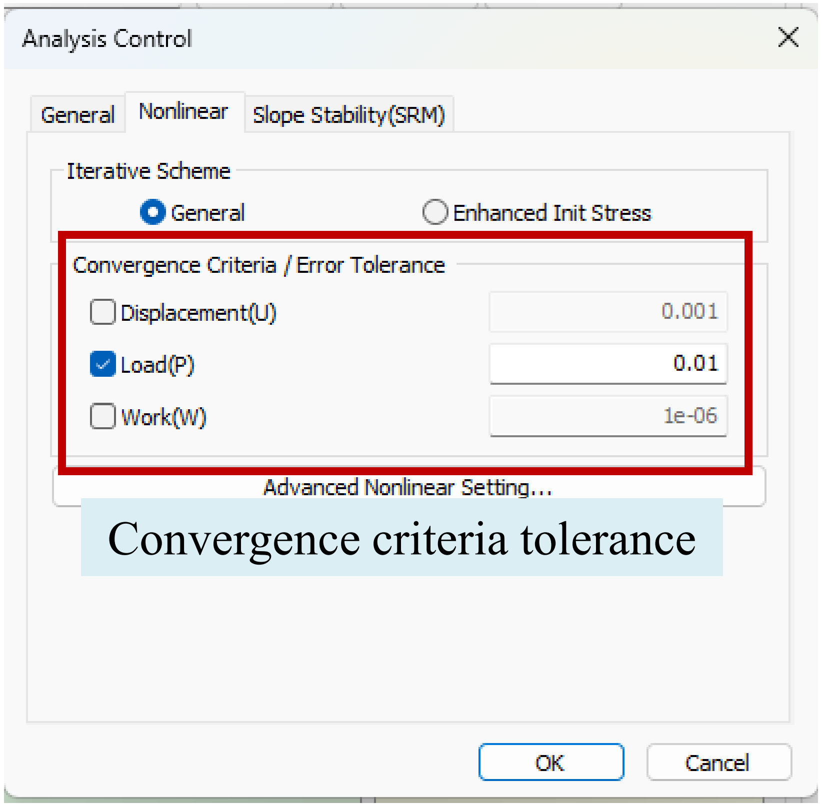


# CONSTRUCTION STAGE 2 | FULLY COUPLED STRESS SEEPAGE

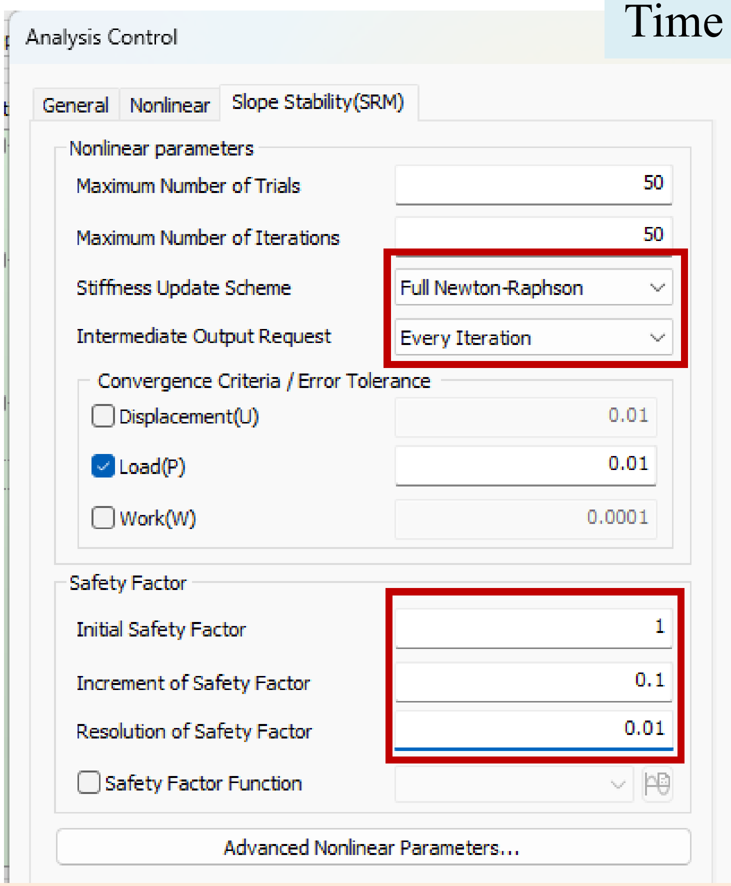


# CONSTRUCTION STAGE 3 | ANALYSIS & CONTROL

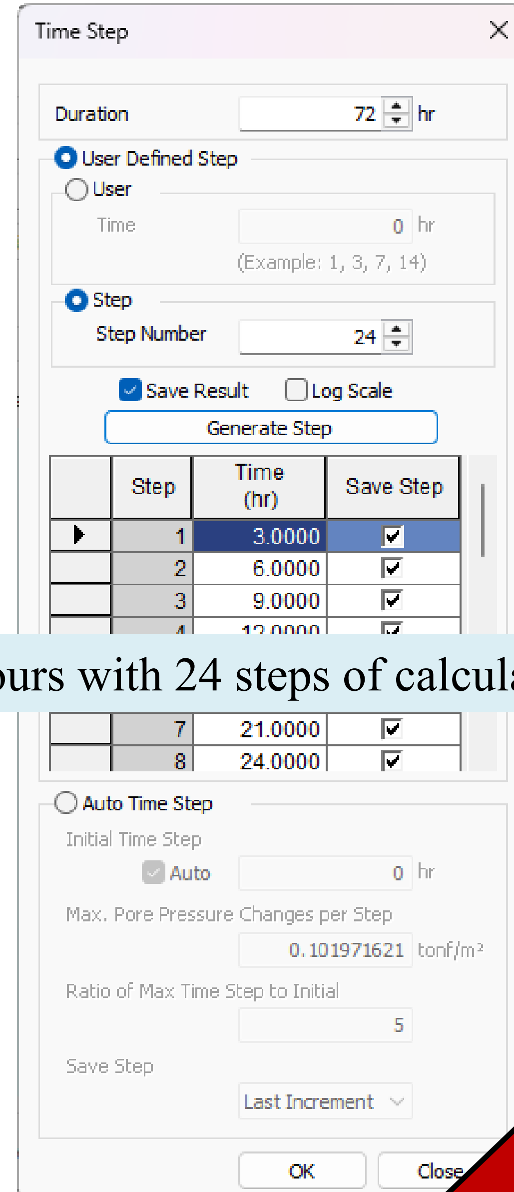


# CONSTRUCTION STAGE 4 | ANALYSIS CONTROL/ TIME CONTROL




Time Step




72 hours with 24 steps of calculation

SRM convergence adjustment

(1) Initial safety factor 1

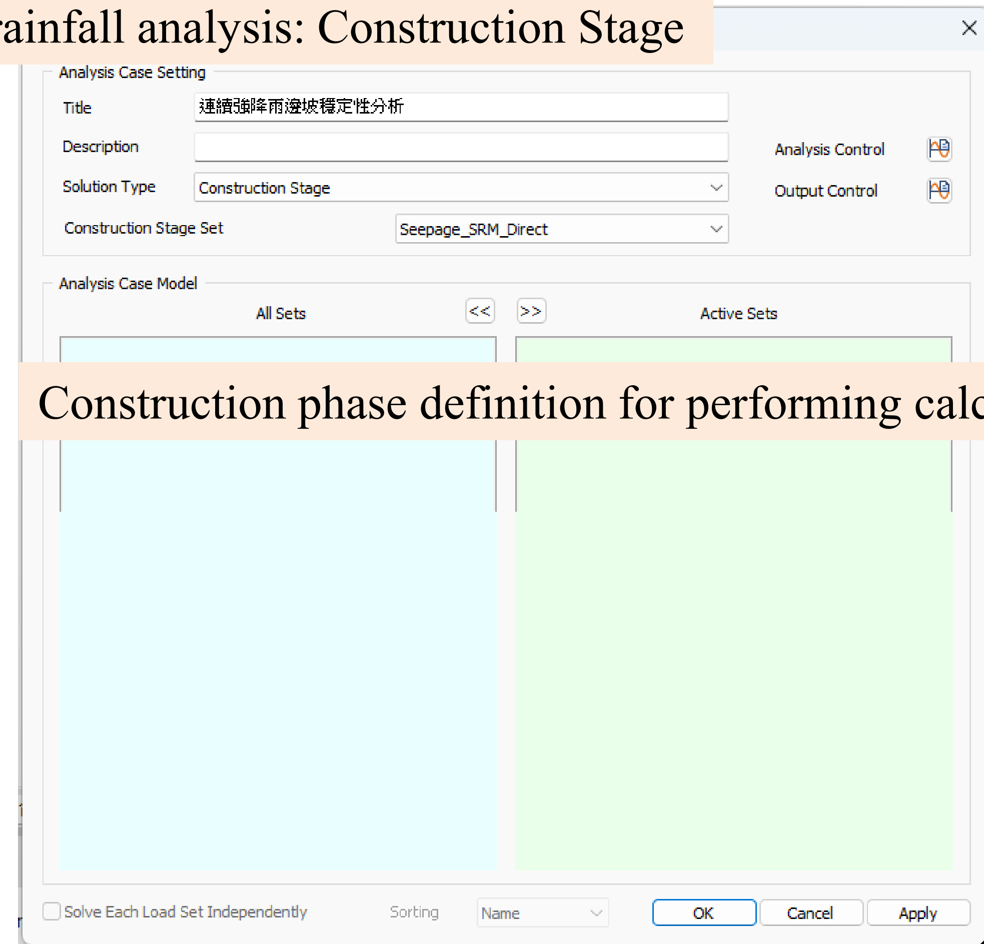
(2) FOS increment by 0.1 each time

(3) Residual < 0.01, minimum FOS reached

# ANALYSIS | HEAVY RAINFALL CASE

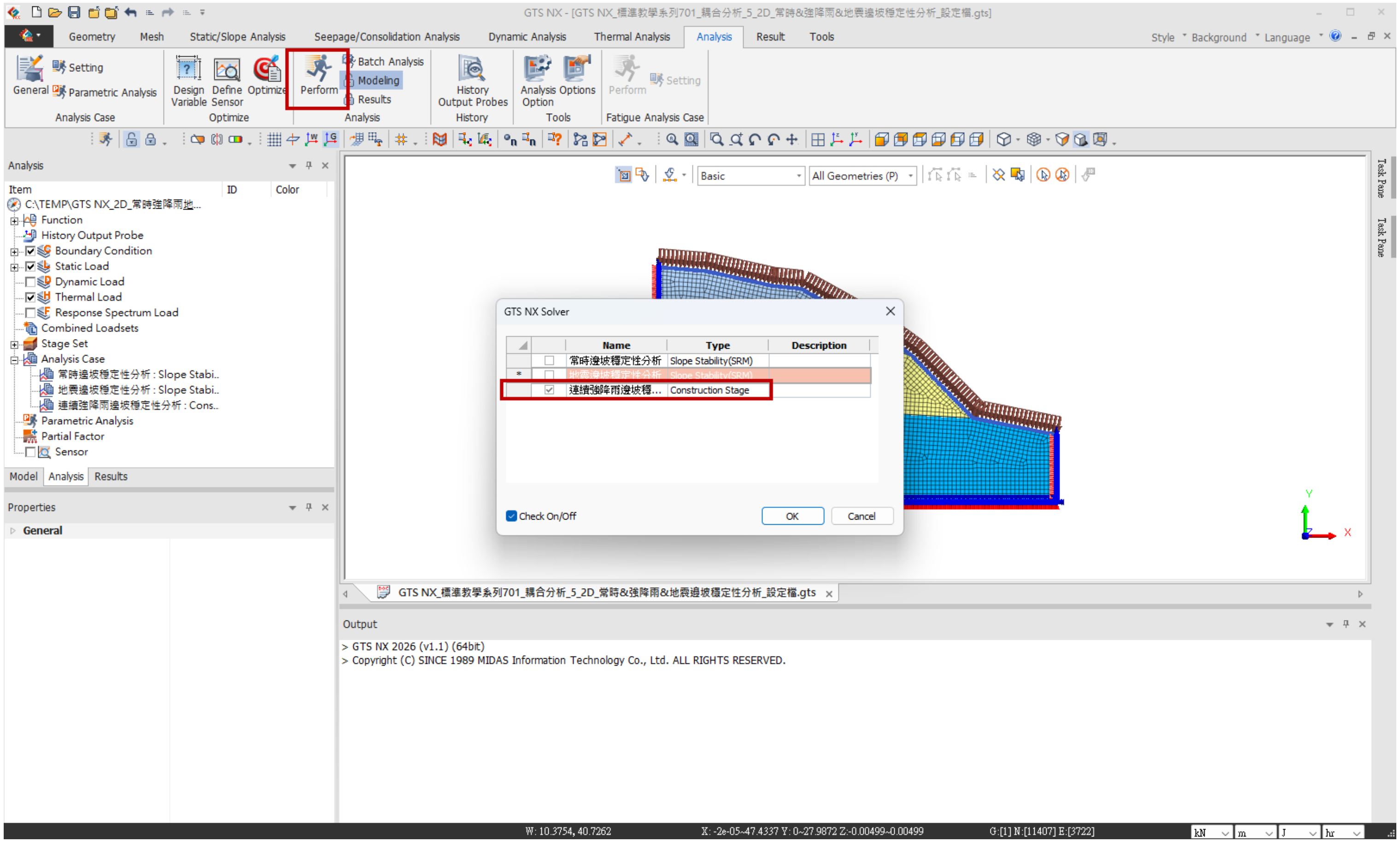

72hr of heavy rainfall analysis: Construction Stage

Construction Stage

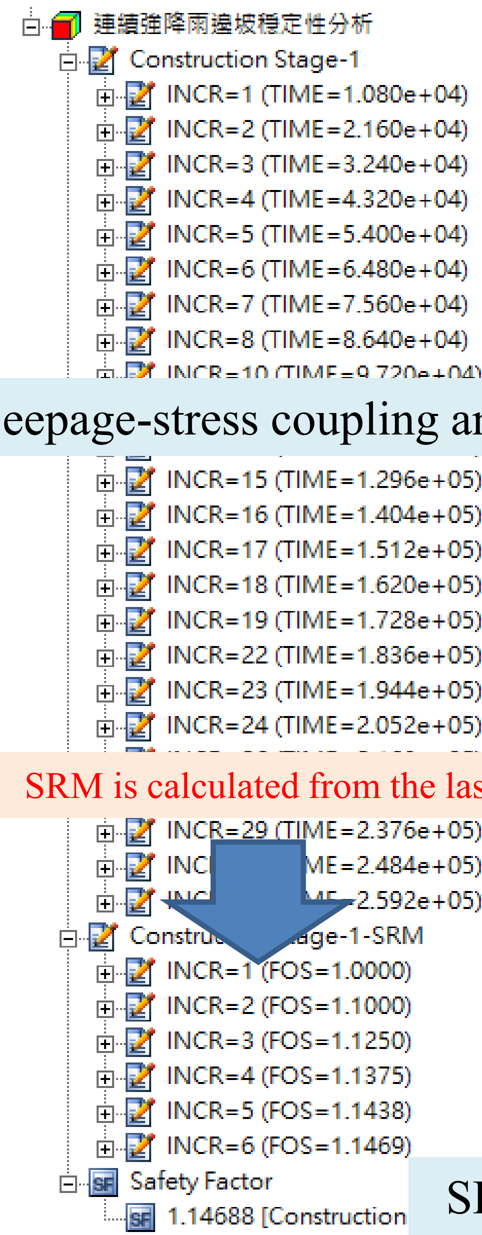




Construction phase definition for performing calculations

# CALCULATION



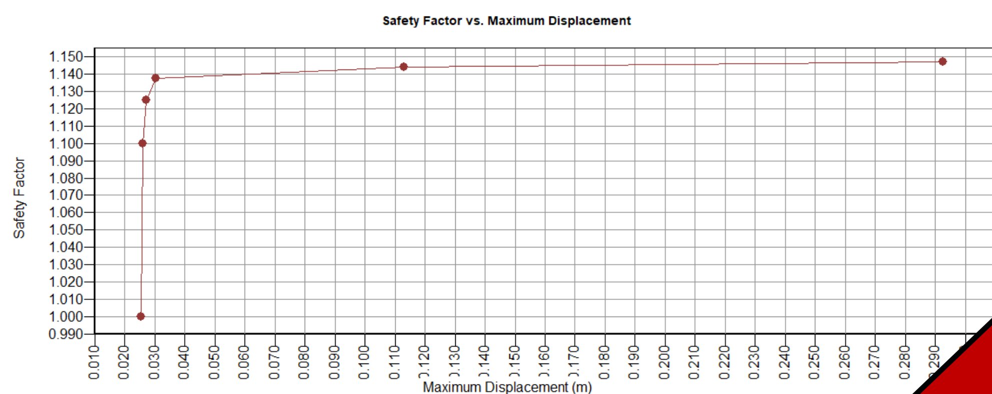
# DIRECT METHOD ANALYSIS RESULTS




Seepage-stress coupling analysis

SRM is calculated from the last step

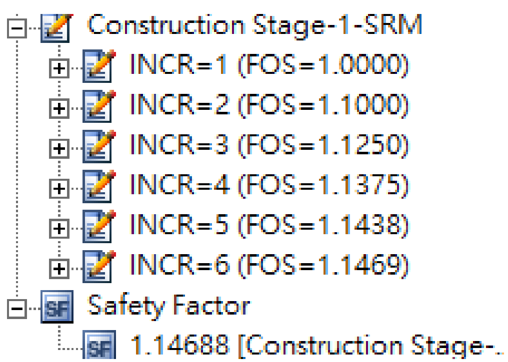
Each time step of calculation


SRM analysis results

# ANALYSIS RESULTS | HEAVY RAINFALL CASE

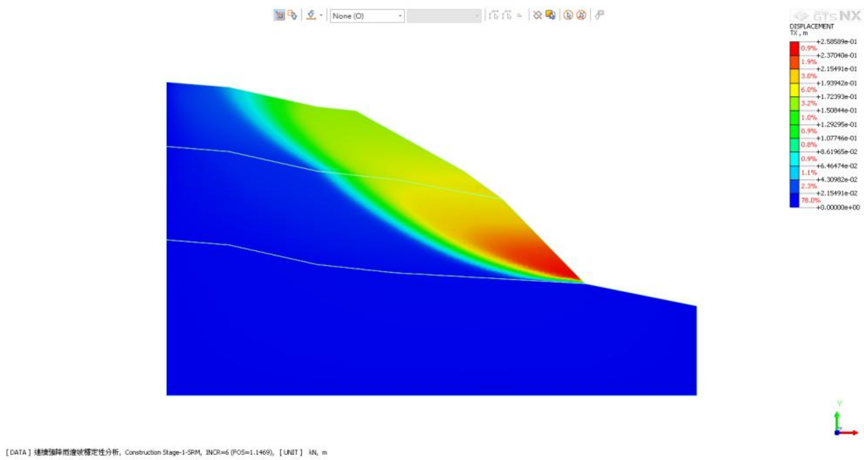
Heavy rainfall simulation, FOS = 1.1469




SRM for safety factor calculation

Failure surface indicated by horizontal displacement & maximum shear strain

Tx Translation(m)



Maximum Shear Strain