Global and Local Slope Stability: Strength Reduction Method for Factor of Safety Determination

Dr. Praveen Huded | Geotechnical Engineer, MIDAS IT

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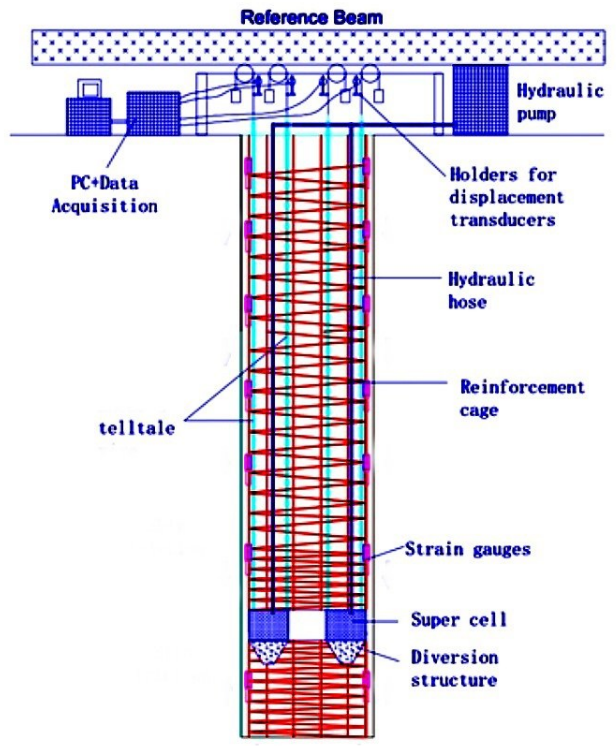
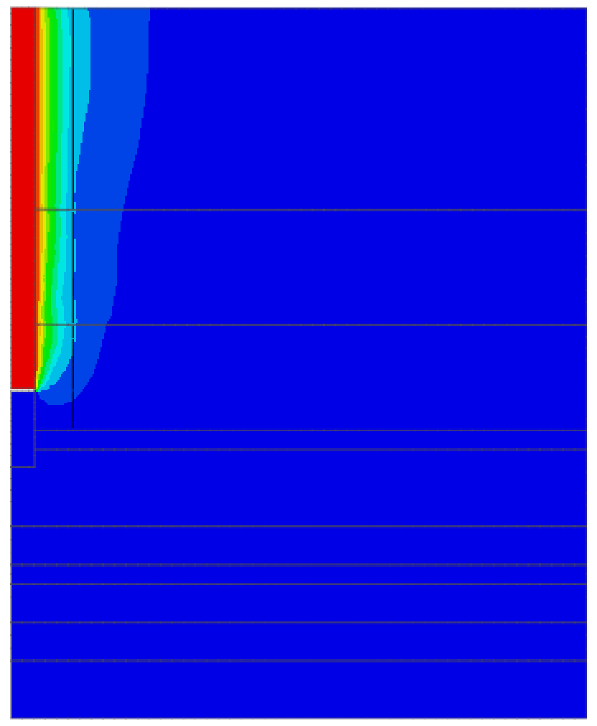
CONTENTS

GTS NX

Finite element analysis platform for geotechnical applications

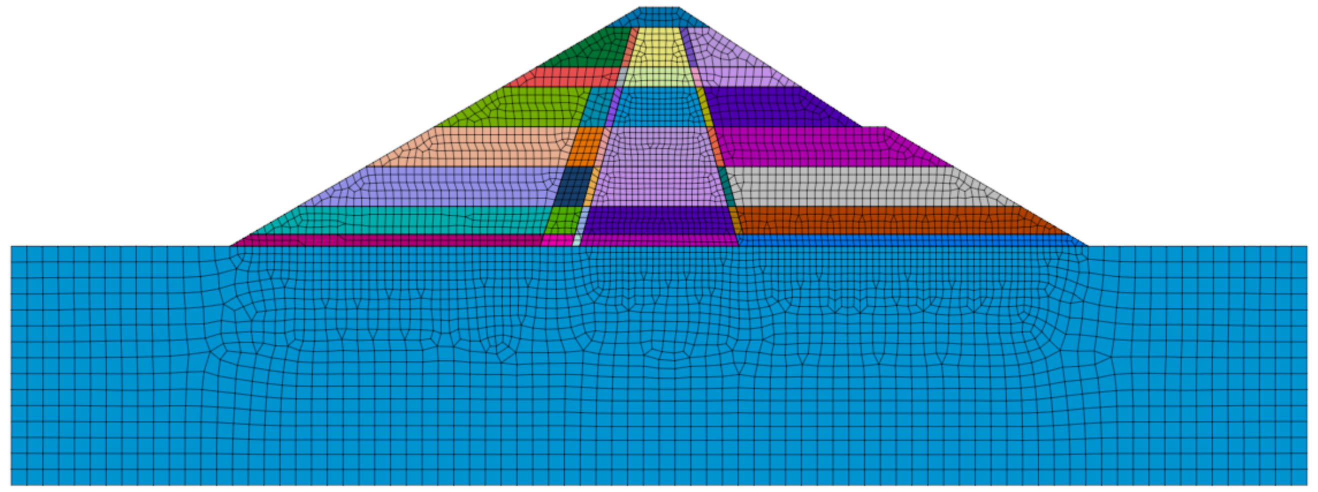


O-Cell Test

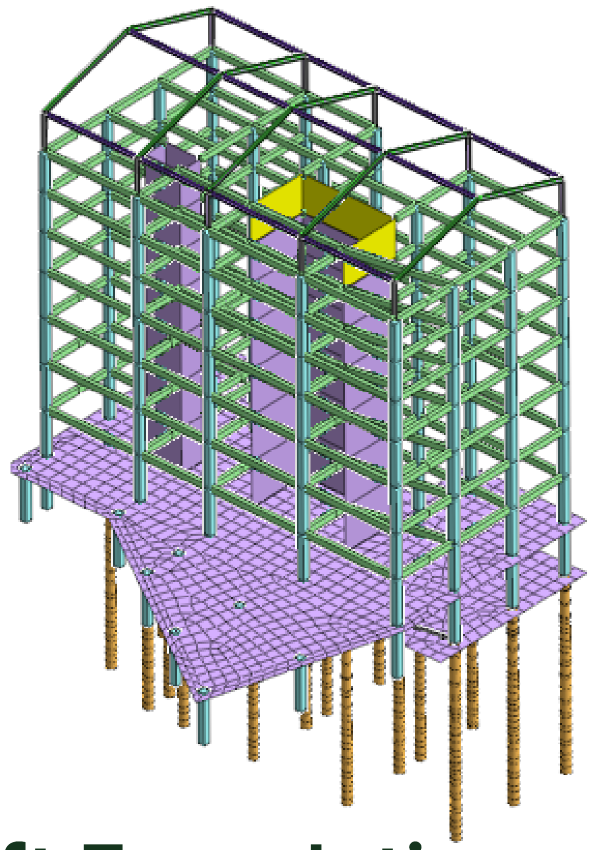


Axisymmetric

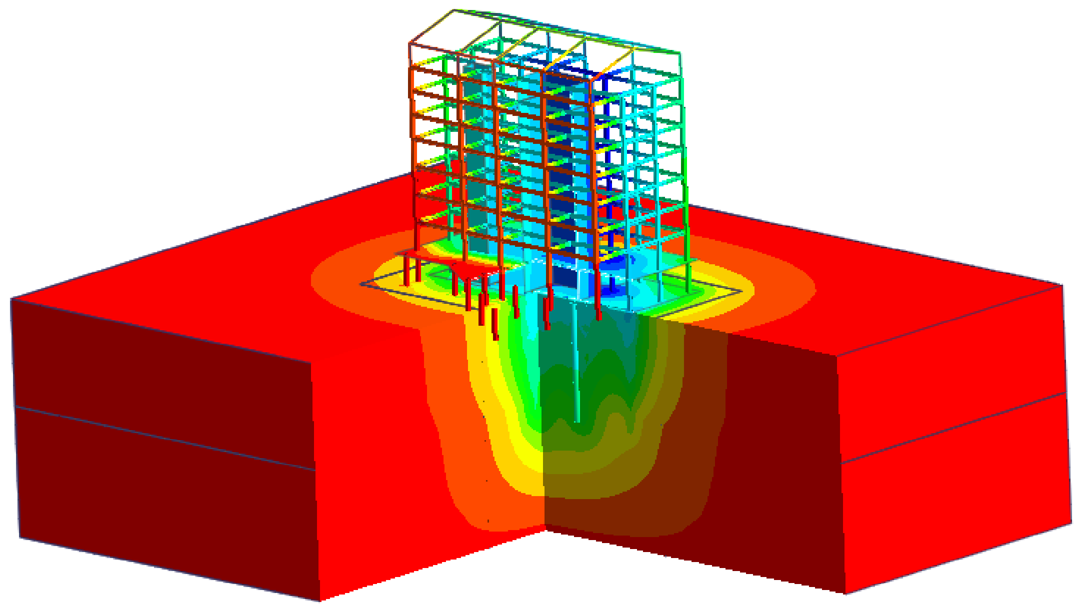
Earthen Dam/Embankment



Plane Strain Model

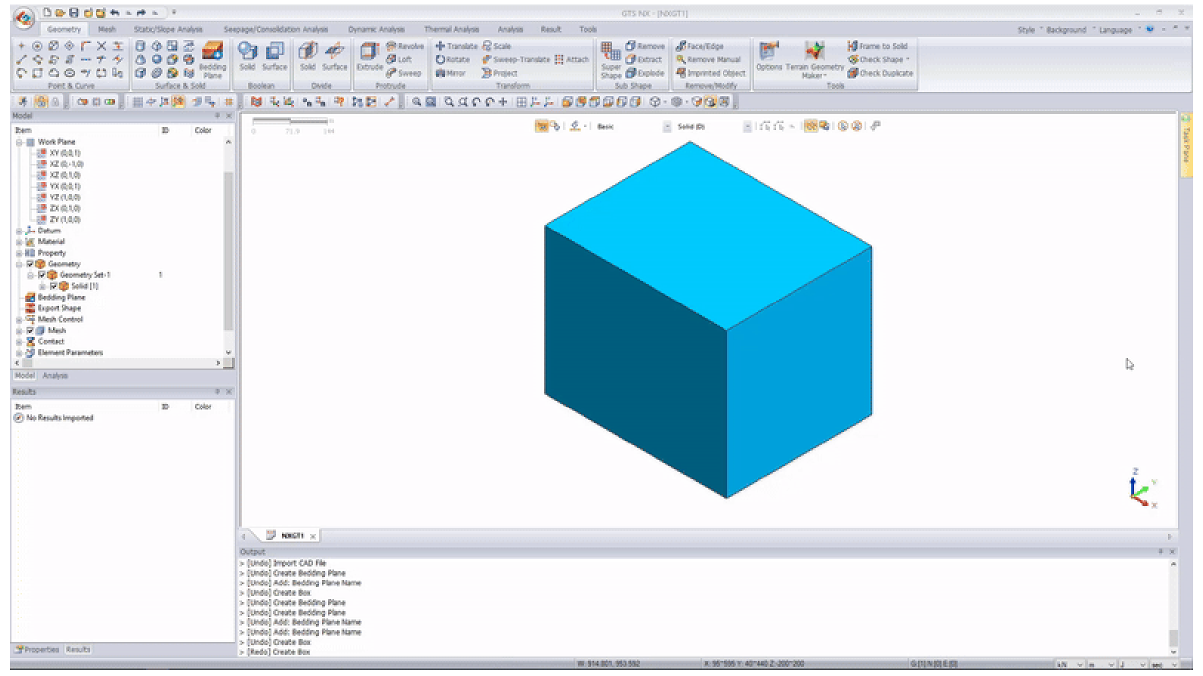


Pile Raft Foundation

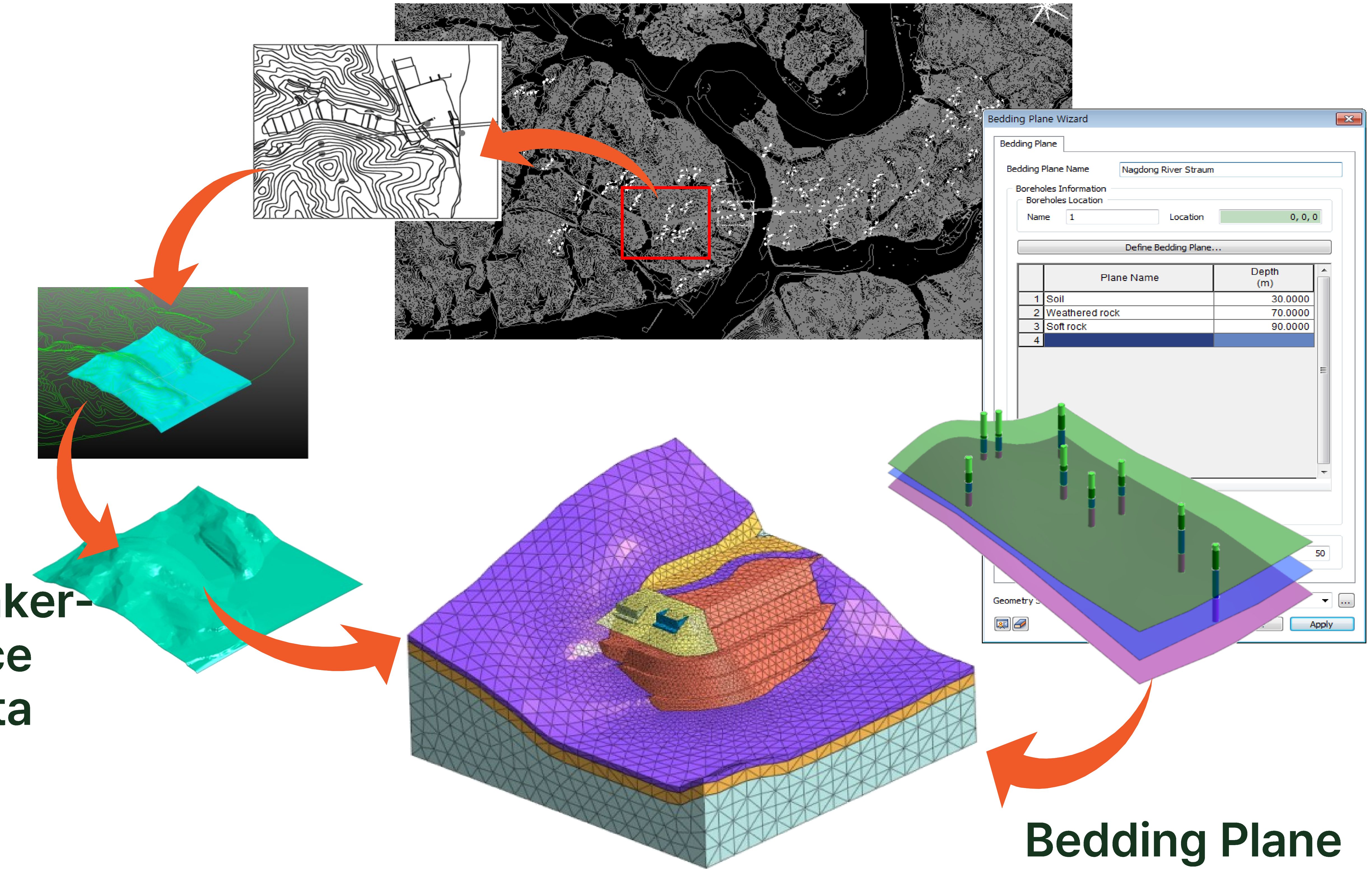


3D Model

Topography and Soil Stratum development



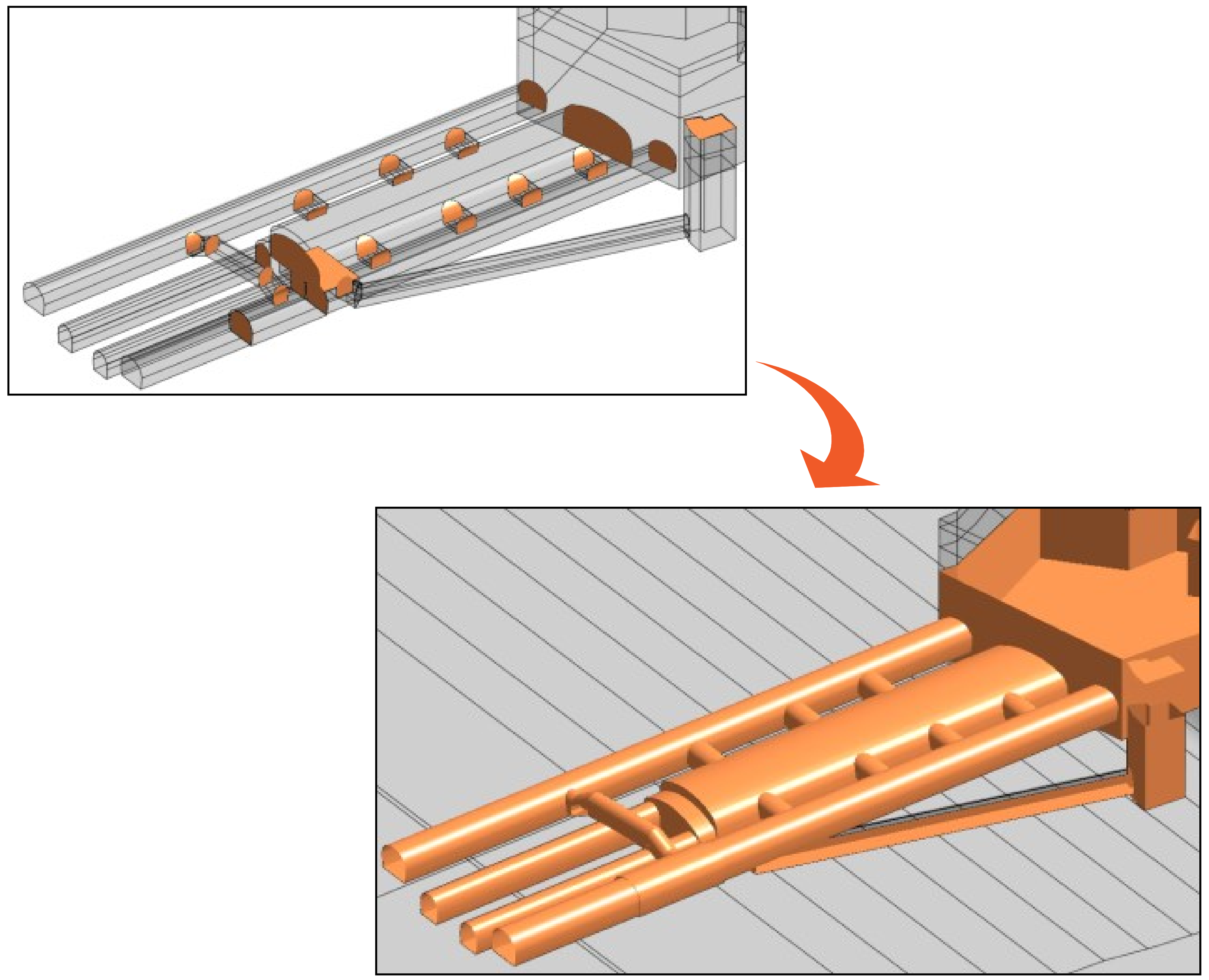
Bedding Plane Wizard

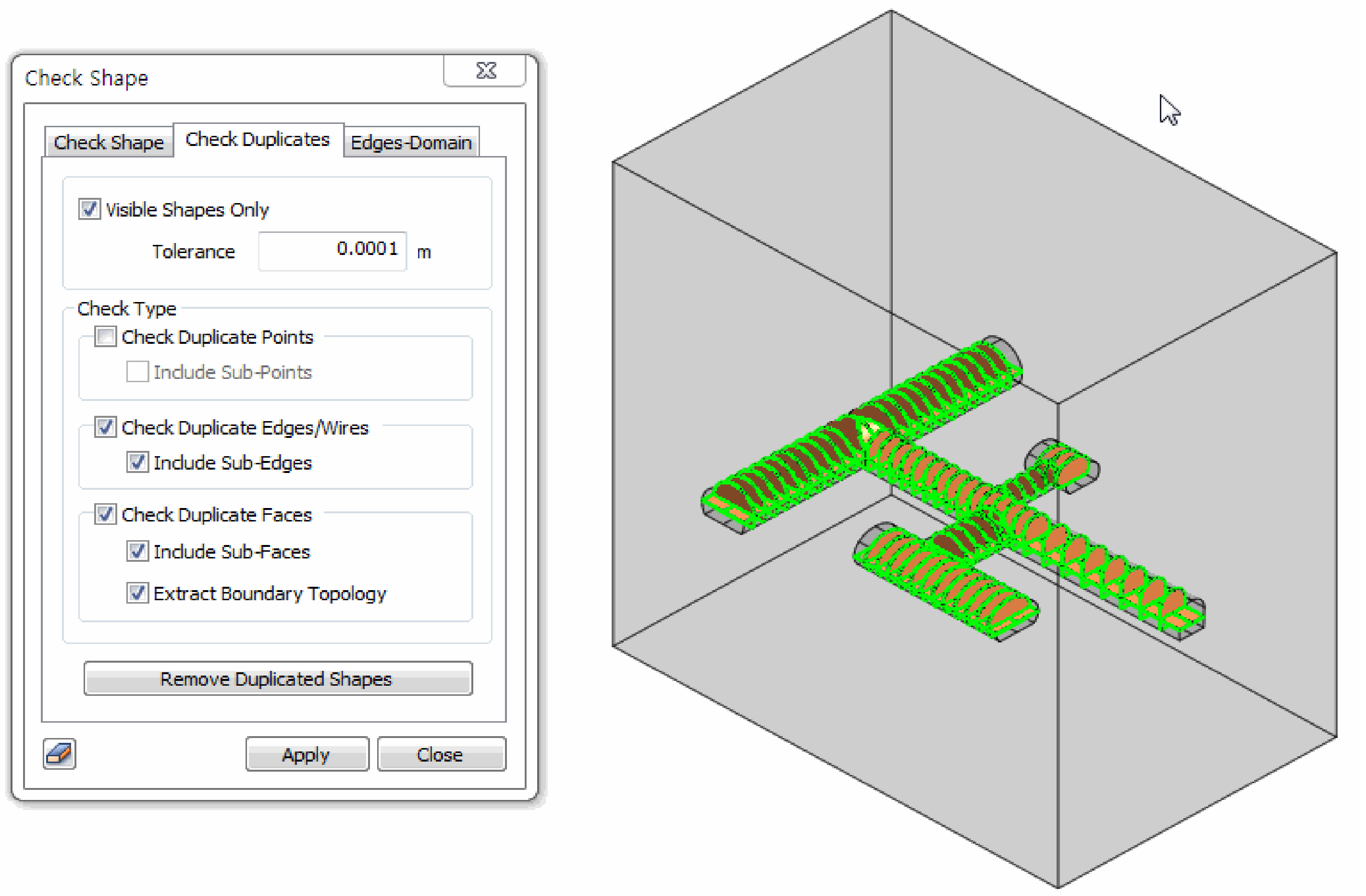


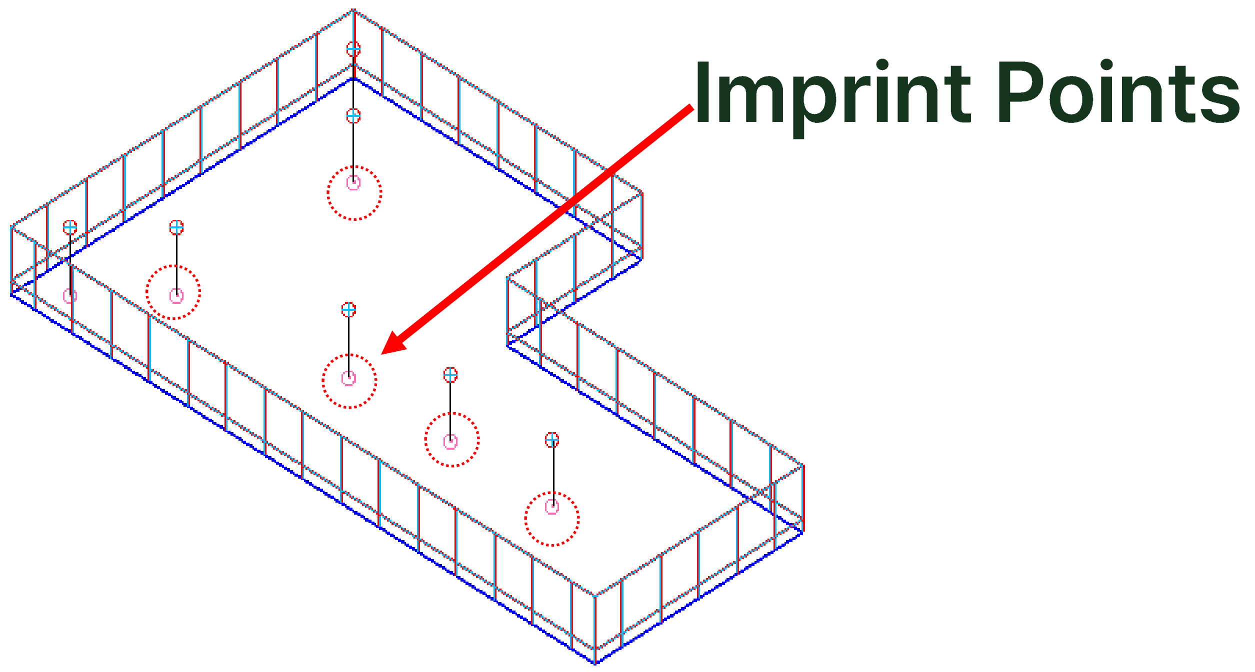
Terrain Geometry Maker-Create ground surface using topography data

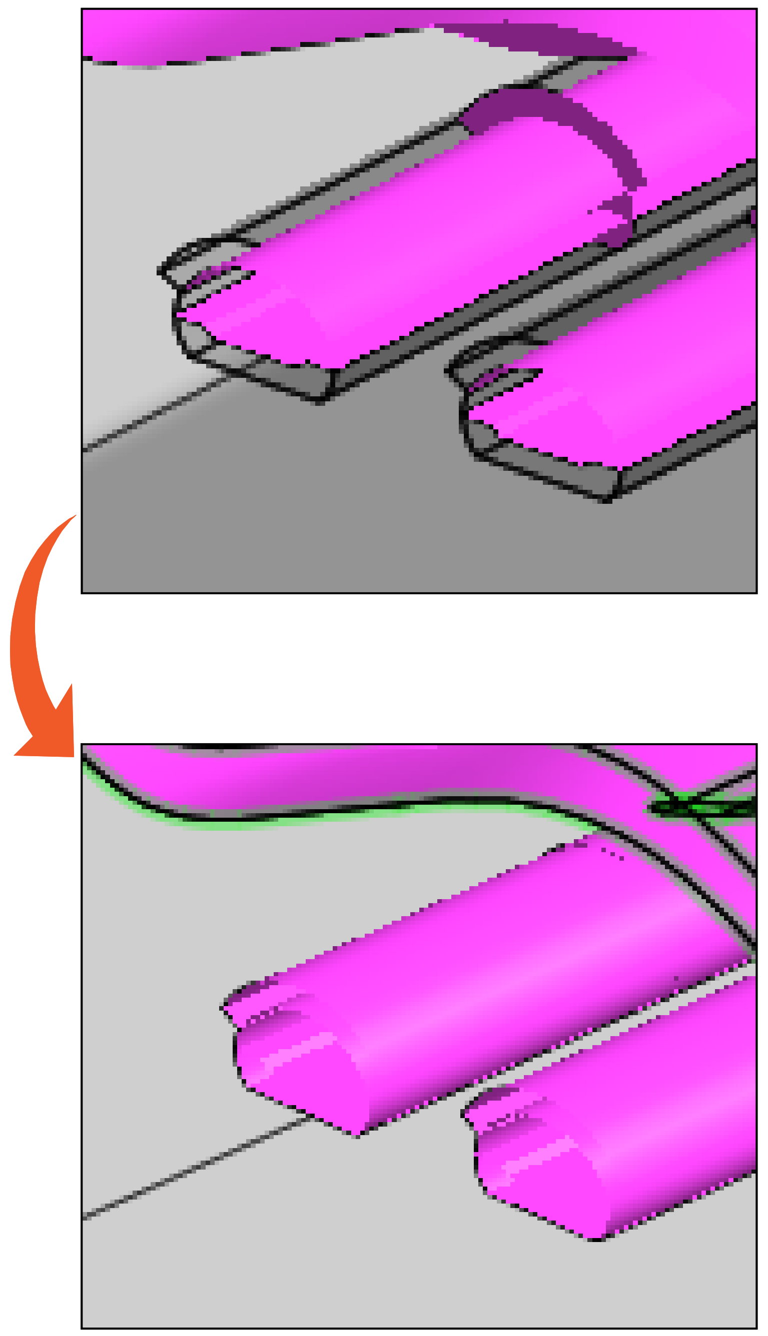
Bedding Plane Wizard-Generates soil strata using borehole data

Automated modeling function









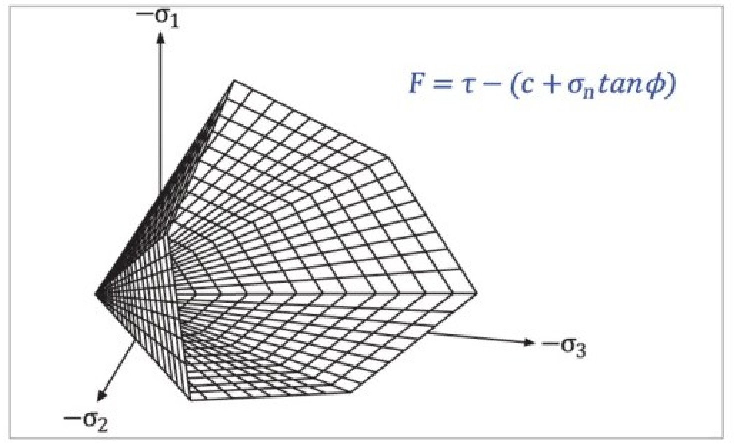
Material Models

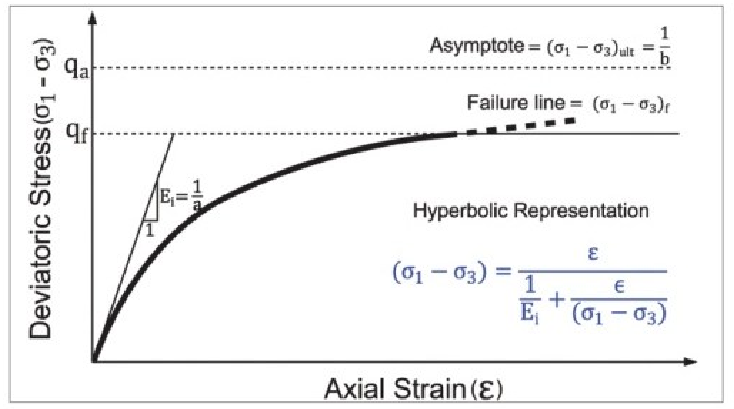
Elastic Materials

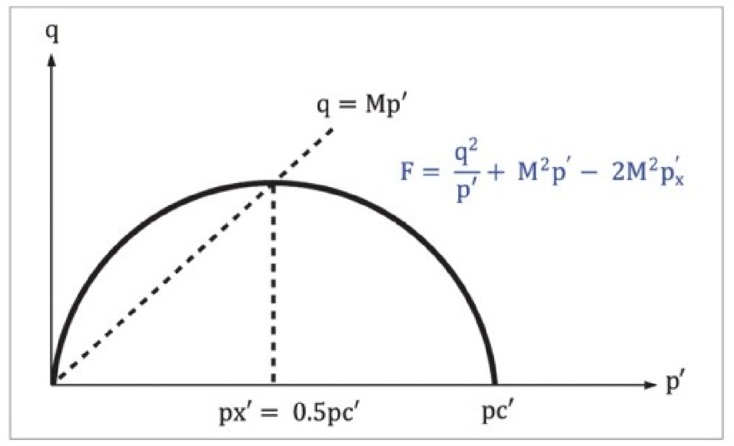
· Linear Elastic Isotropic
· Linear Elastic
· Transversely Isotropic
· Interface Elastic
· Nonlinear Elastic (1D)
· Jardine
· D-Min
· Hyperbolic (Duncan-Chang)

Plastic Materials

· von Mises
· Tresca
· Mohr-Coulomb
· Drucker-Prager
· Strain-Softening
· Modified Cam Clay
· Jointed Rock
· Modified Mohr Coulomb
· Hoek Brown
· Inverse Rankine
· Coulomb Friction (Interface)
· Janssen





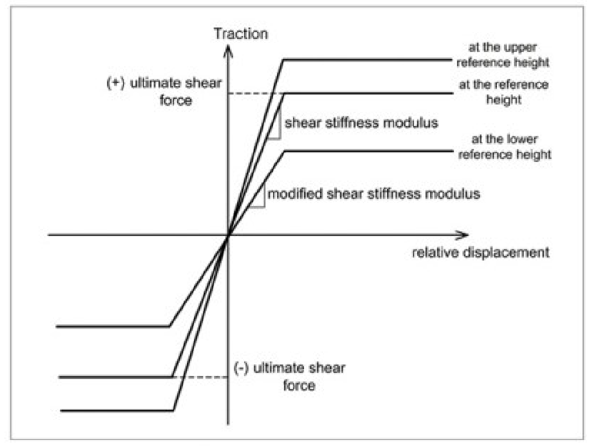


Undrained Materials

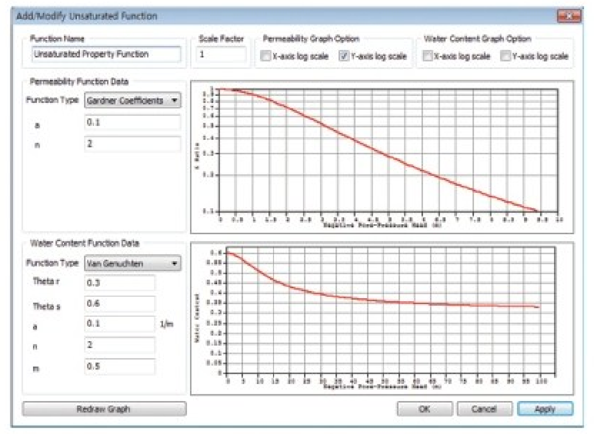
· Effective Stiffness / Effective Strength
· Effective Stiffness / Undrained Strength
· Undrained Stiffness / Undrained Strength

Functions

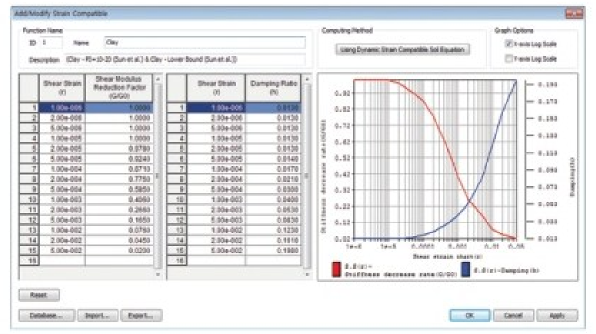
· General non-spatial functions
(pile / pile tip bearing nonlinear function)
· Nonlinear elastic functions
(truss / point spring / elastic link)
Unsaturated property functions
(Gardner, Frontal, Van Genuchten)
· Strain compatibility functions
(2D equivalent linear)



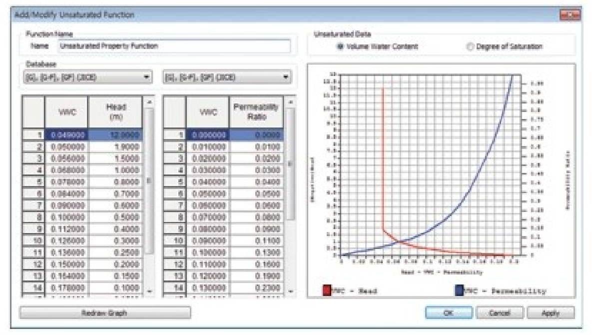
Pile bearing ▲



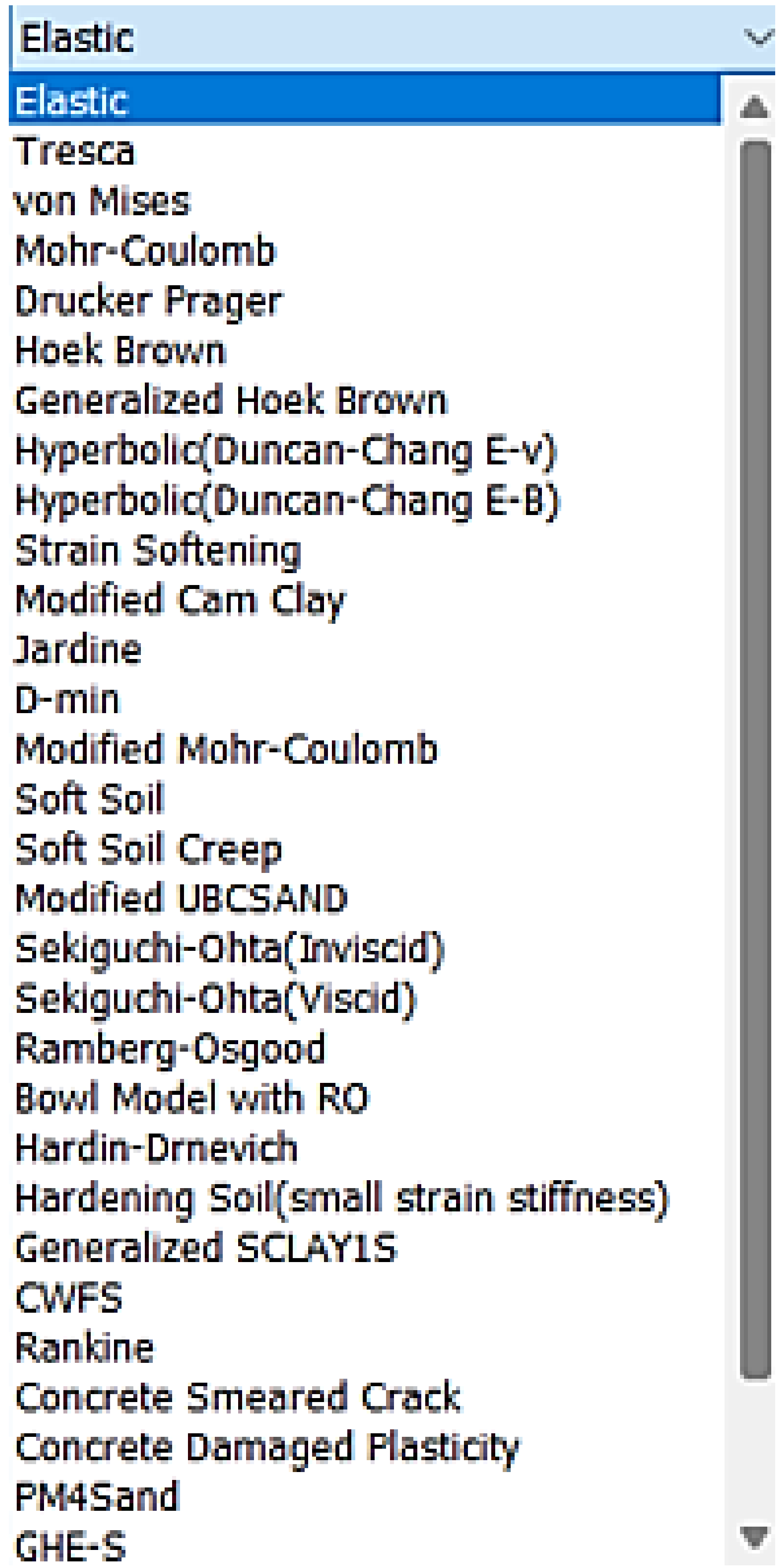
Unsaturated property (Individual) ▲



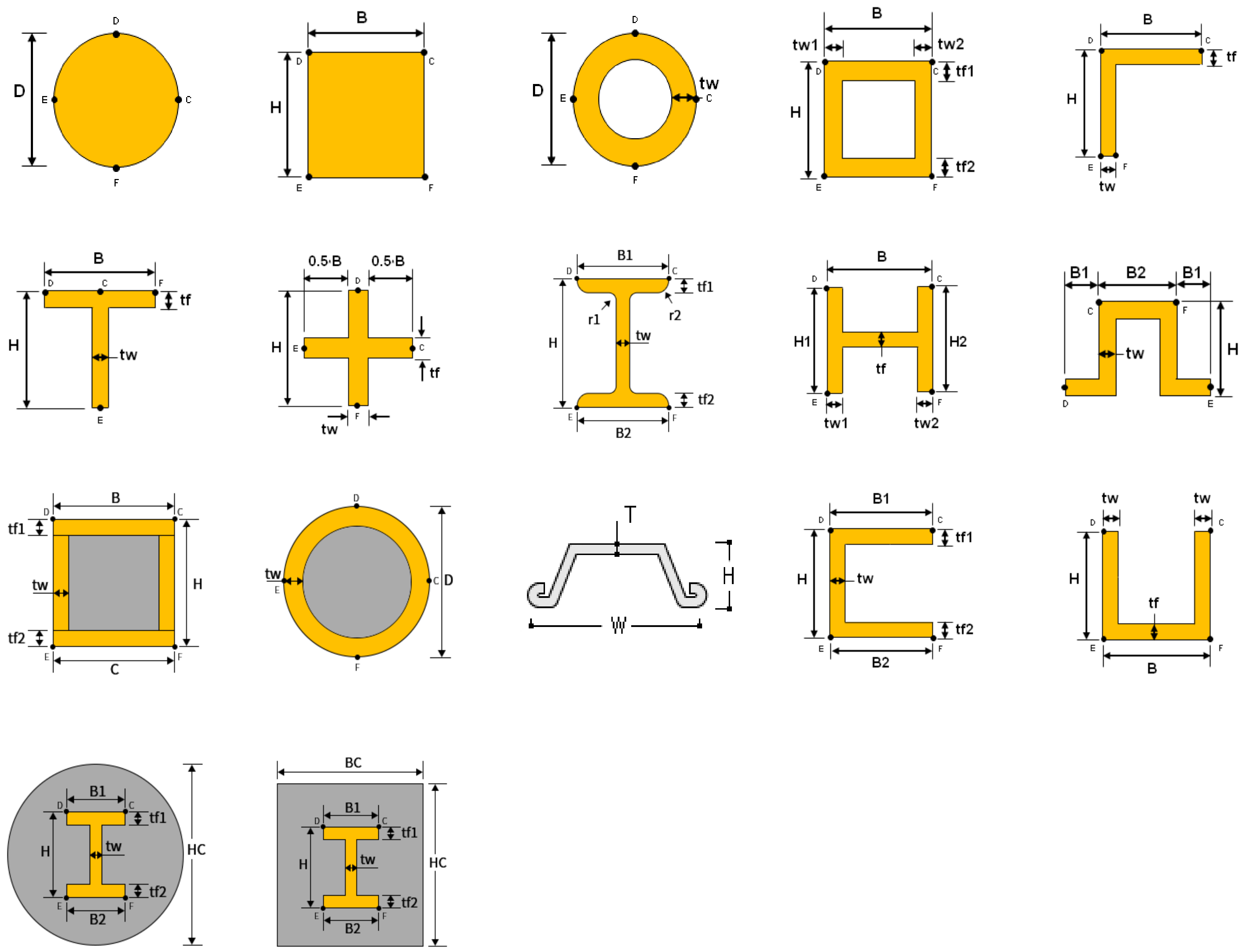
Strain compatibility ▲

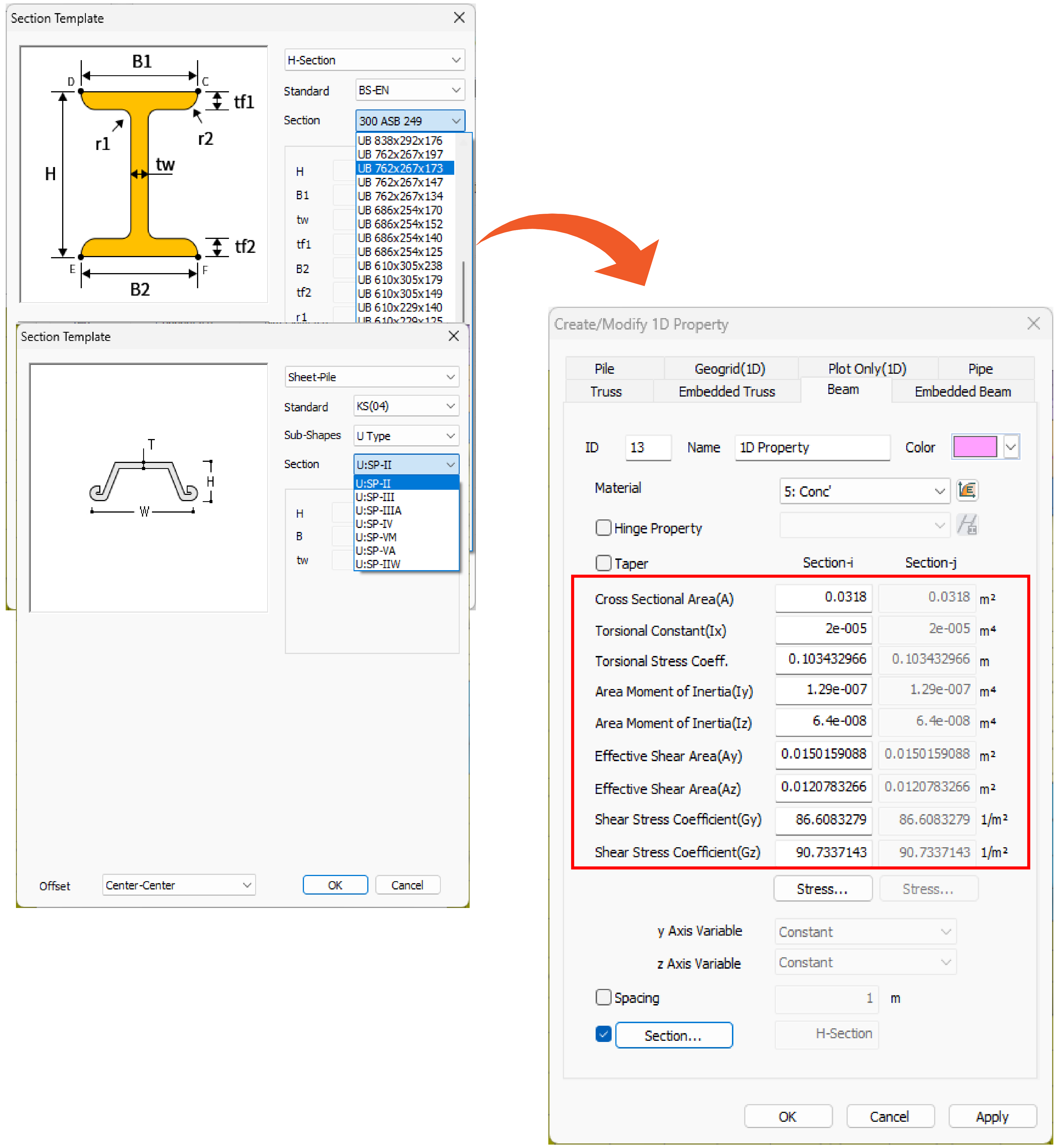


Unsaturated property (Relation) ▲



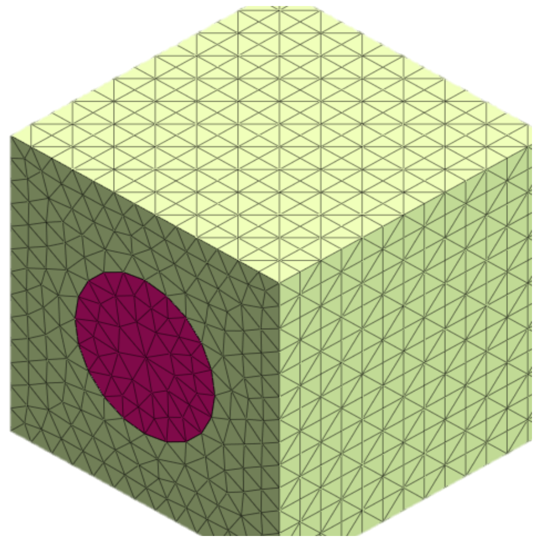
Section Property Database



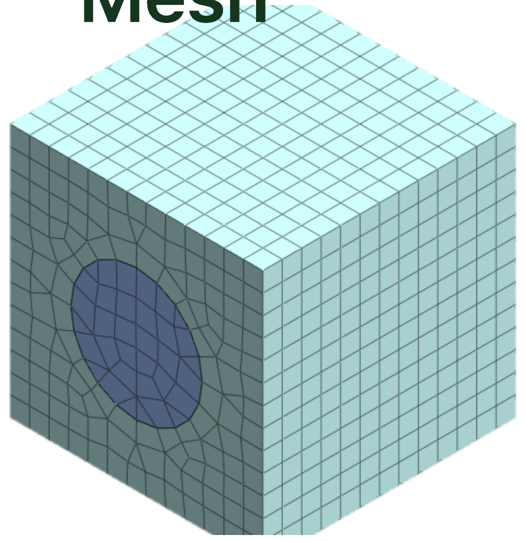


Automatically Calculate section parameters

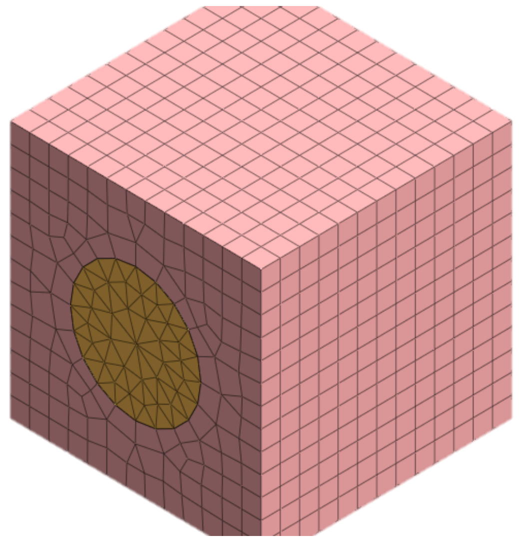
Mesh Generation



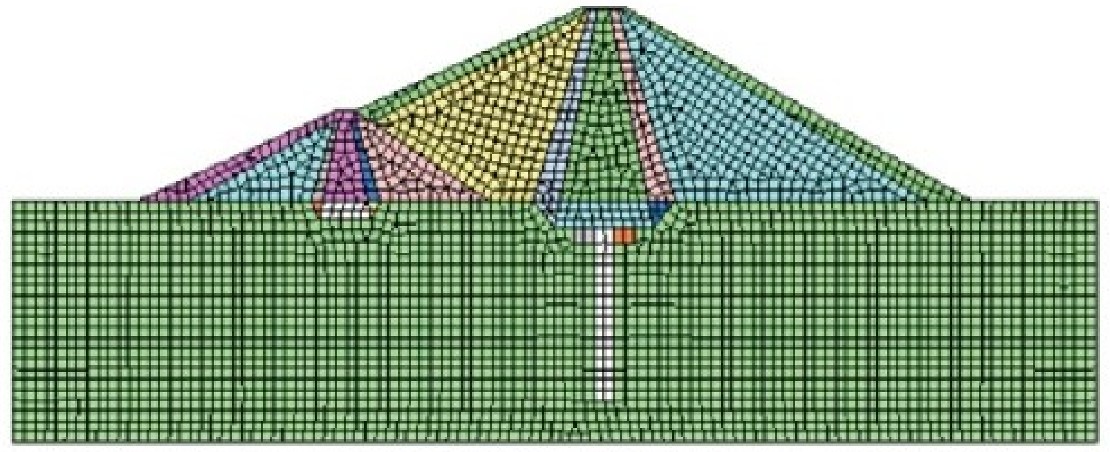
Tetrahedral Mesh



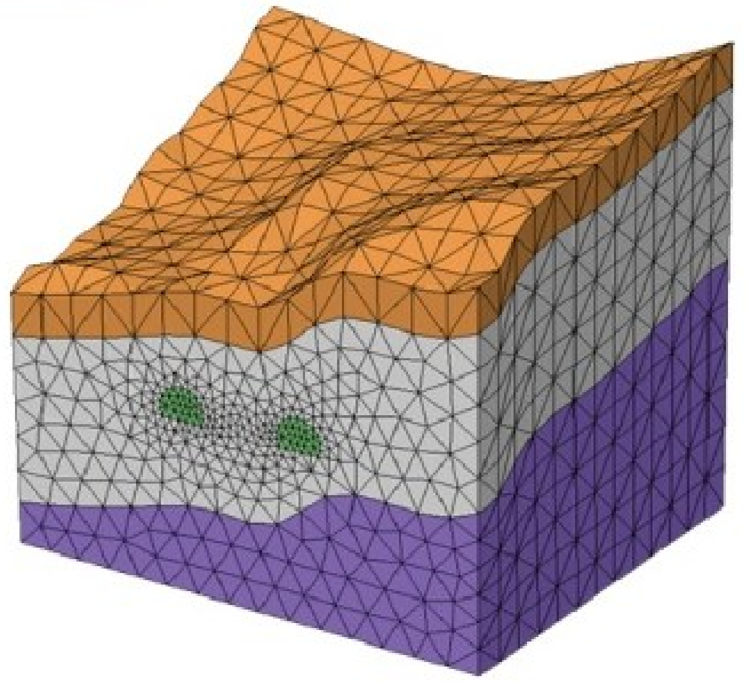
Hexahedral Mesh

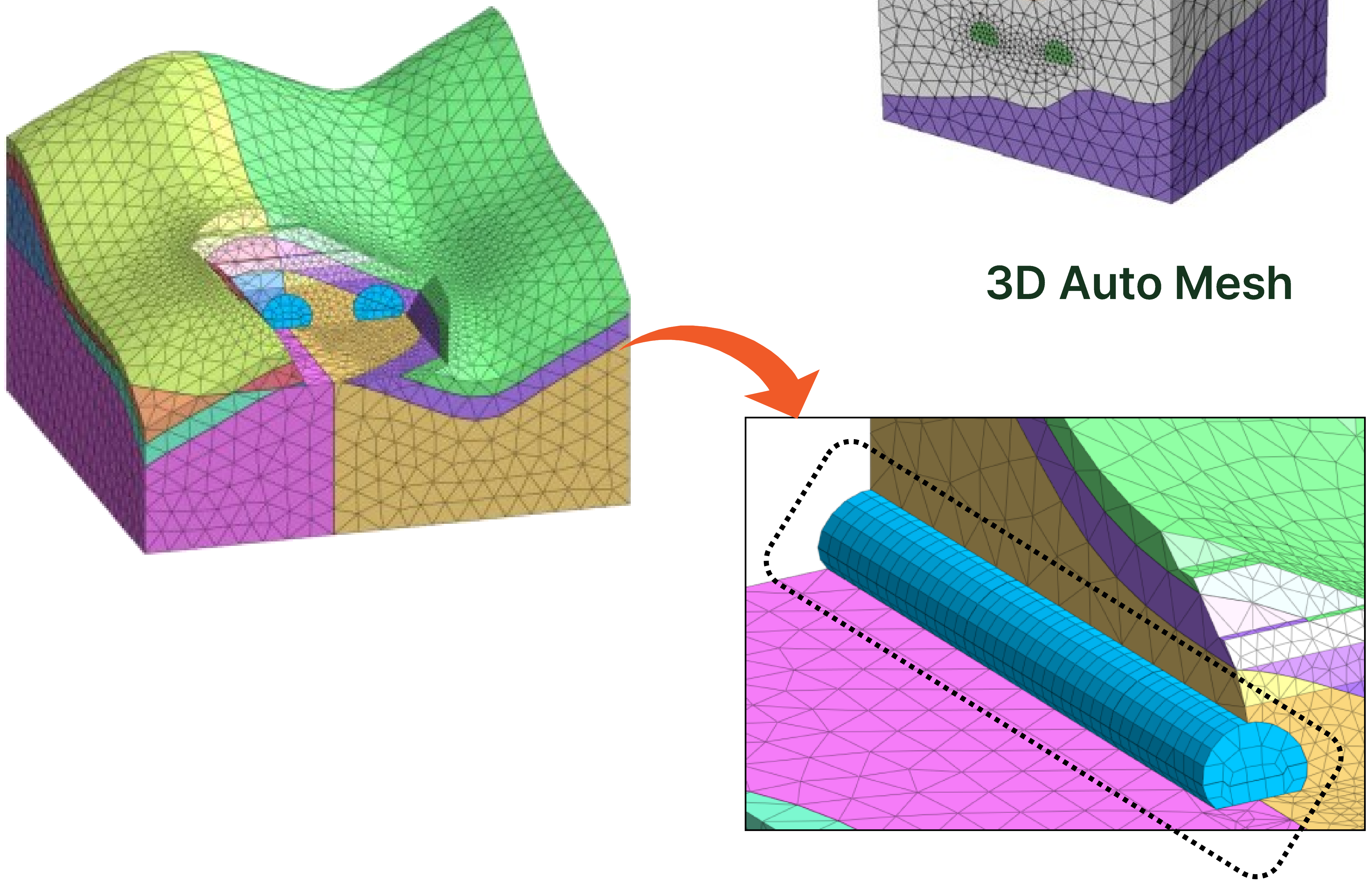


Hybrid Mesh (Tetra+ Hexa)

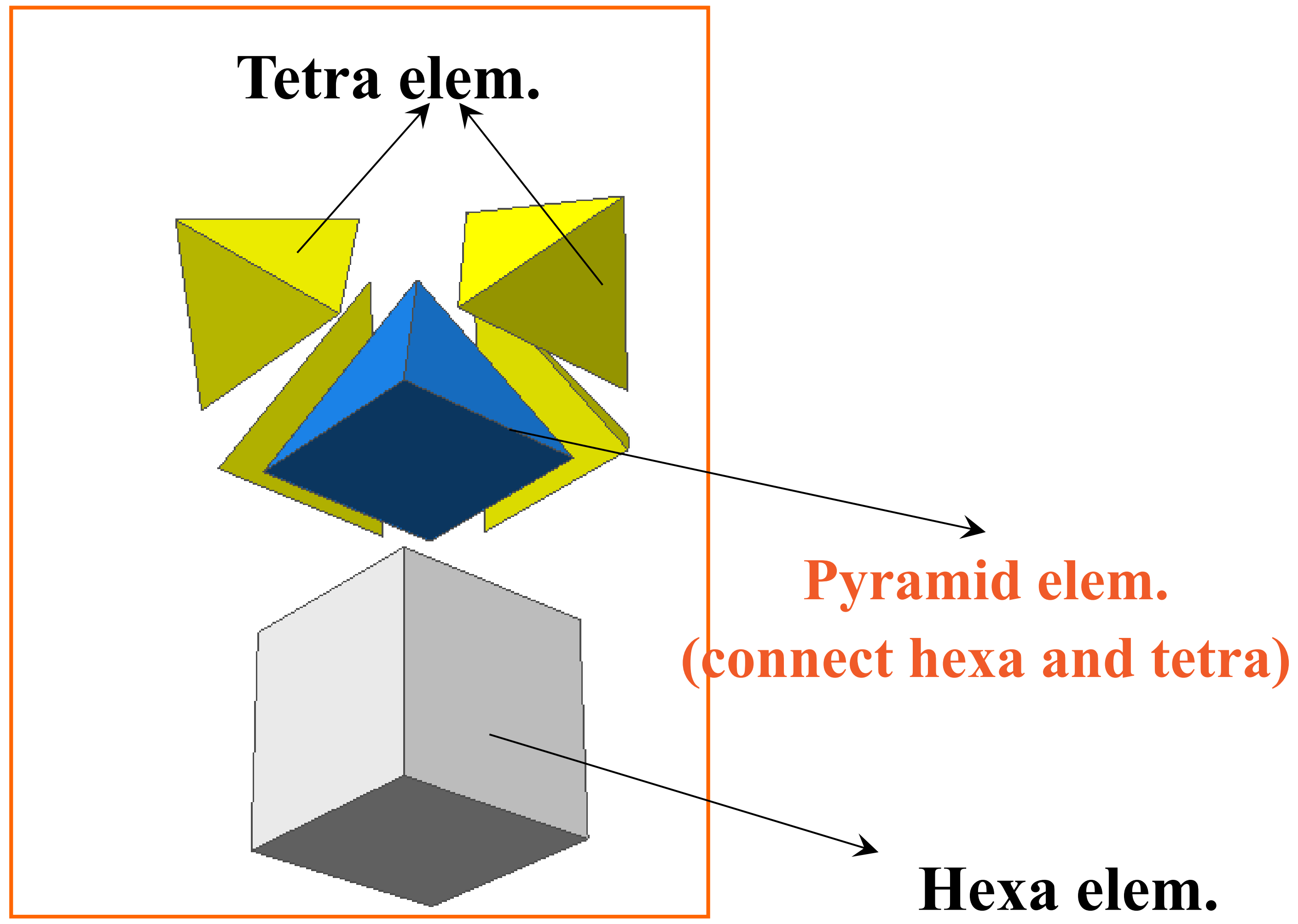


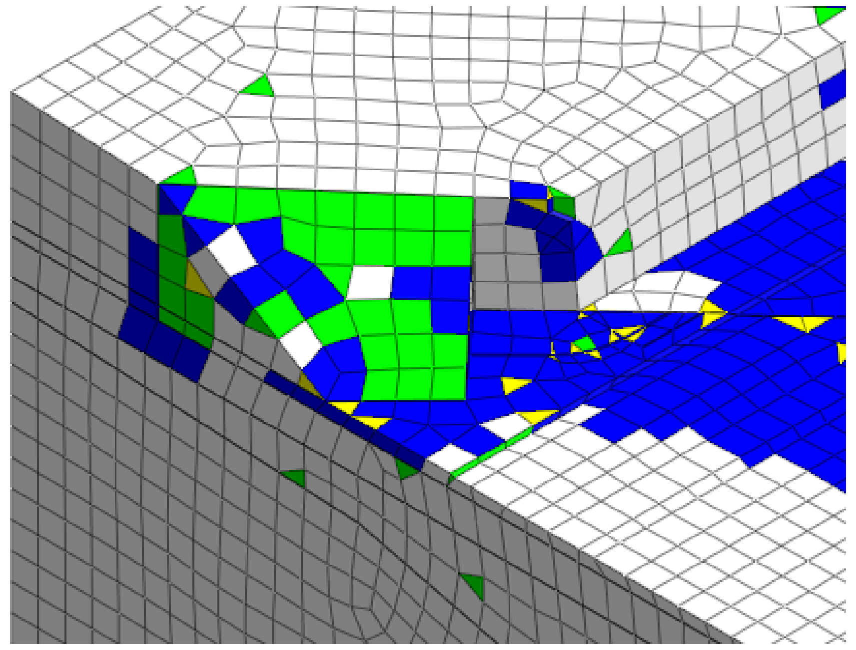
2D Auto Mesh

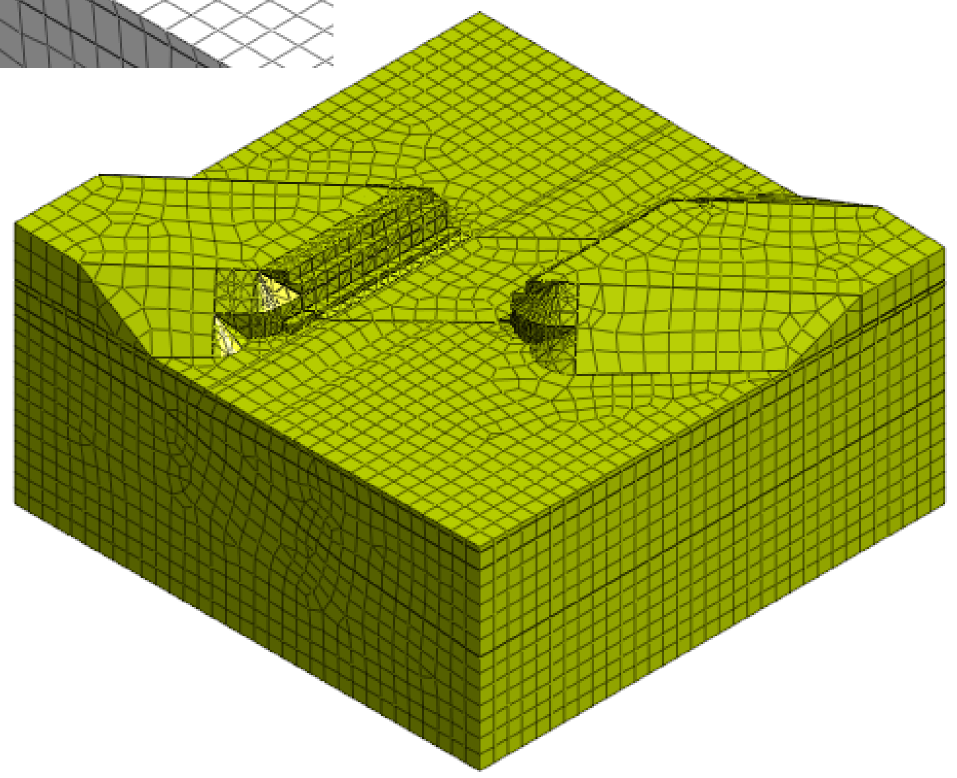




3D Auto Mesh



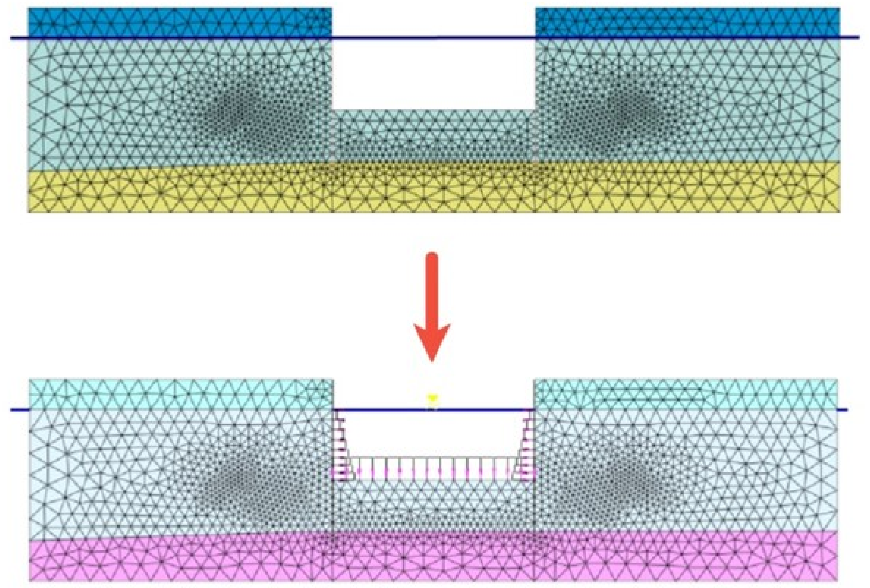




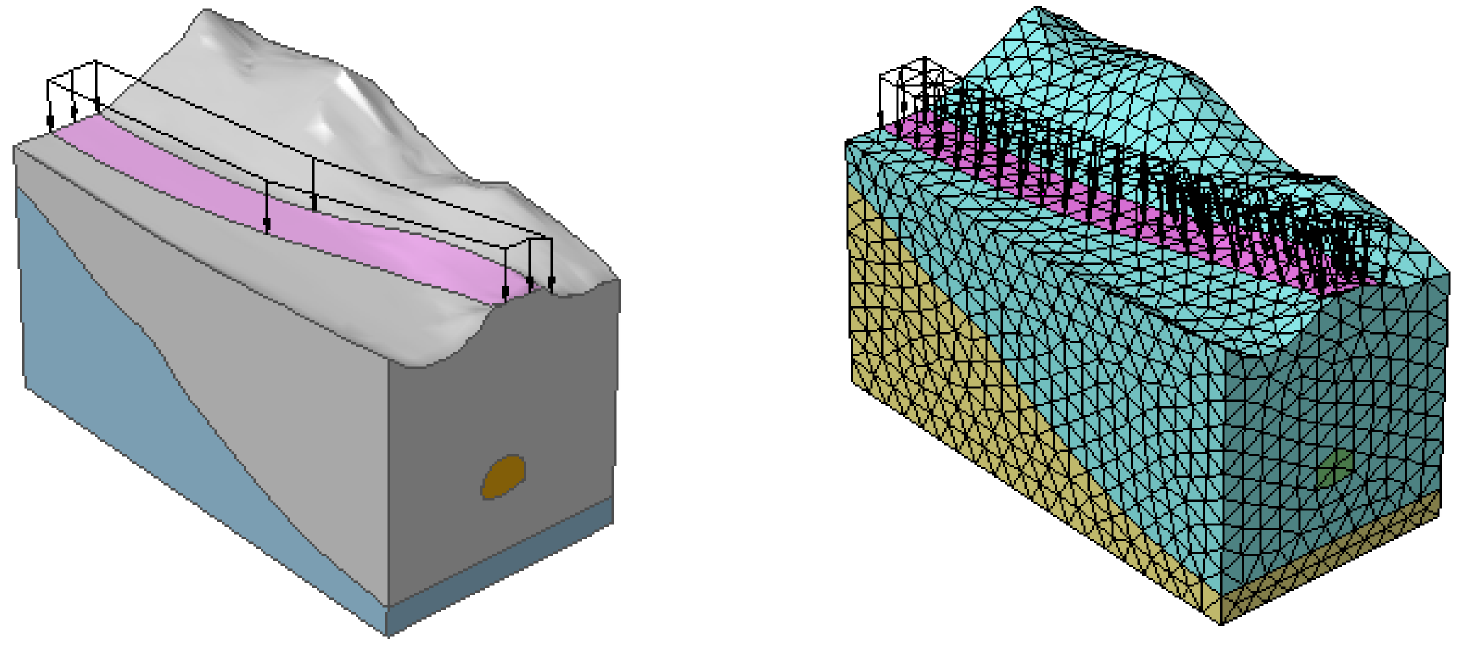
Load Assignment

Static Loads

- Self weight
- Force
- Moment
- Displacement
- Pressure
- Water pressure
- Line beam load
- Element beam load
- Temperature
- Prestress
- Initial equilibrium force
- Combined load



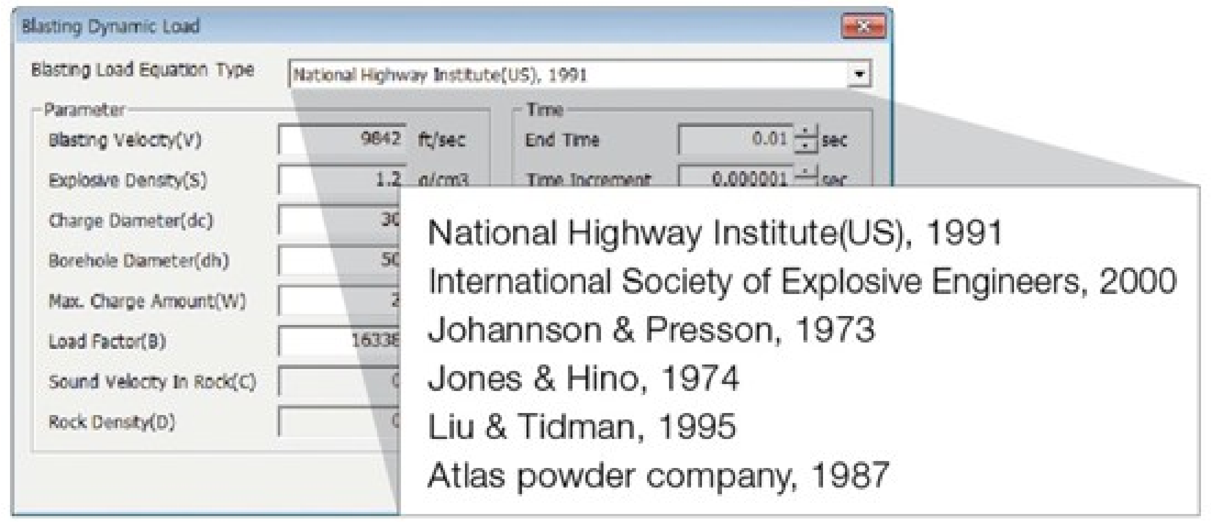
Water pressure automatic application
during underwater excavation ▲

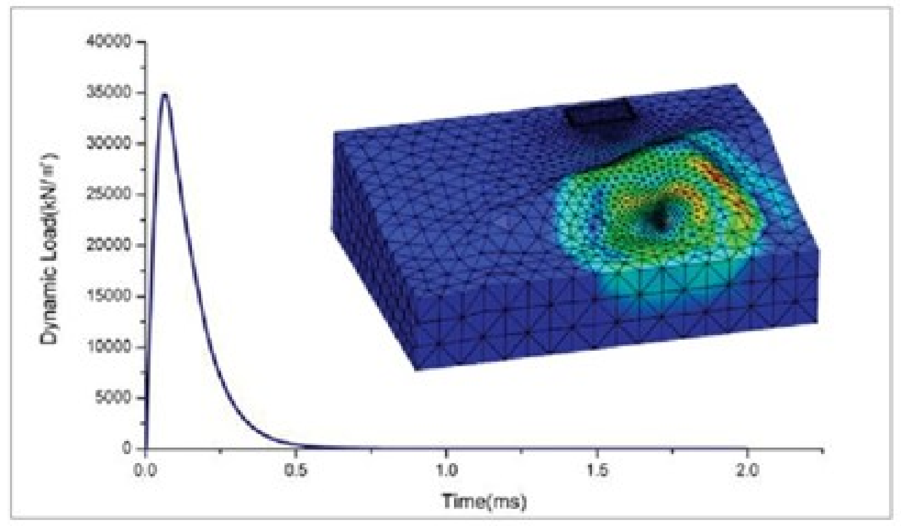


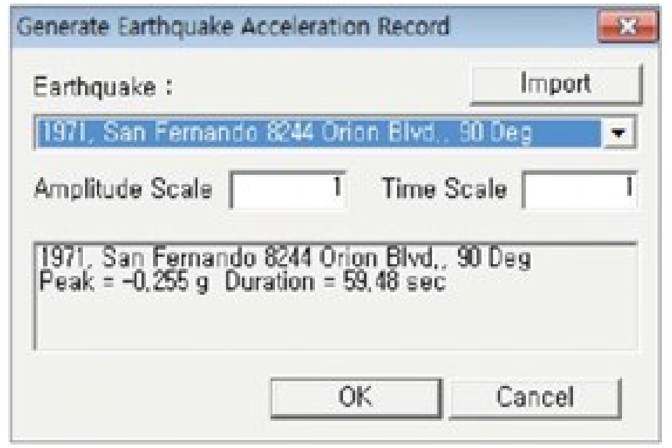
Automatic transfer to FE

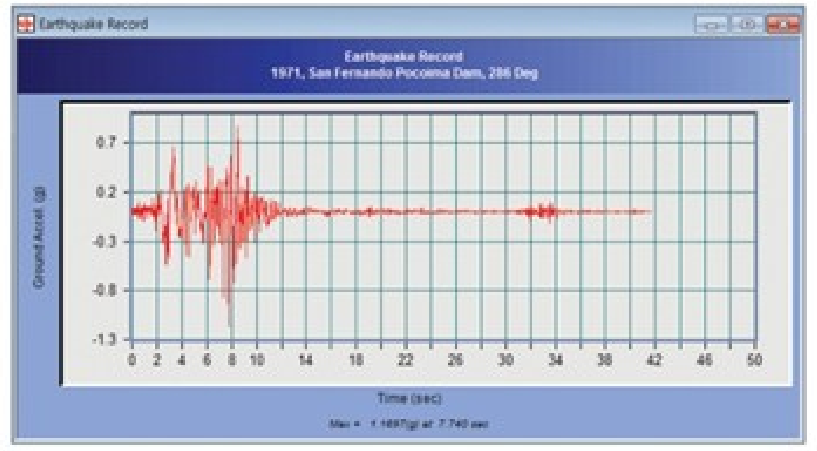
Dynamic Loads

- Response spectrum
- Ground acceleration
- Time varying static
- Dynamic nodal
- Dynamic surface
- Load to Mass
- Train Dynamic Load Table

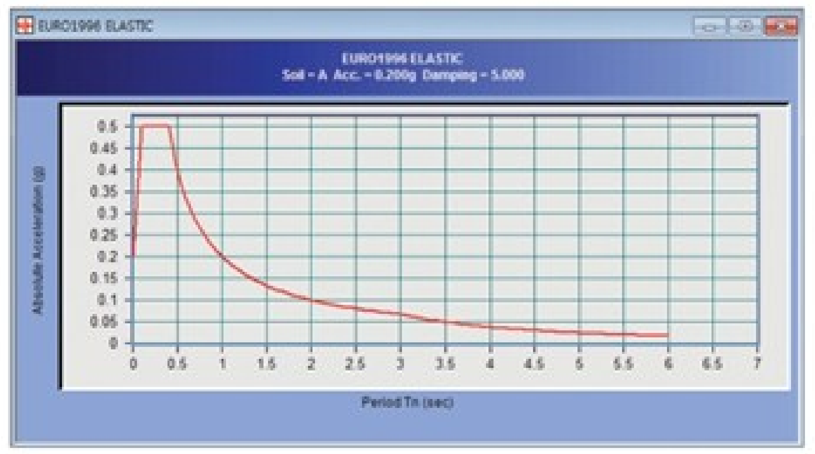






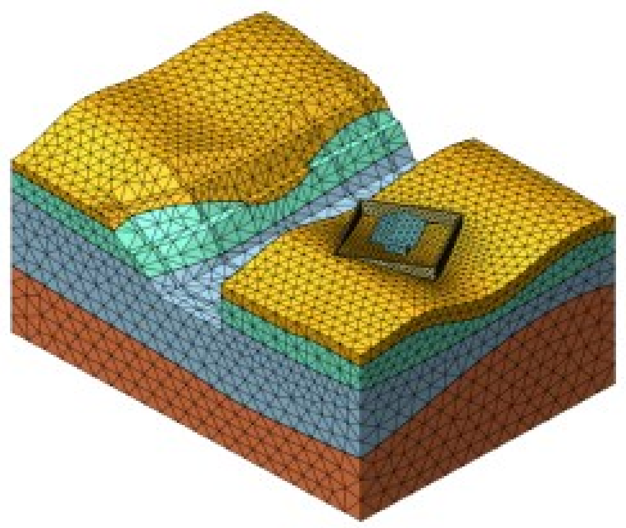


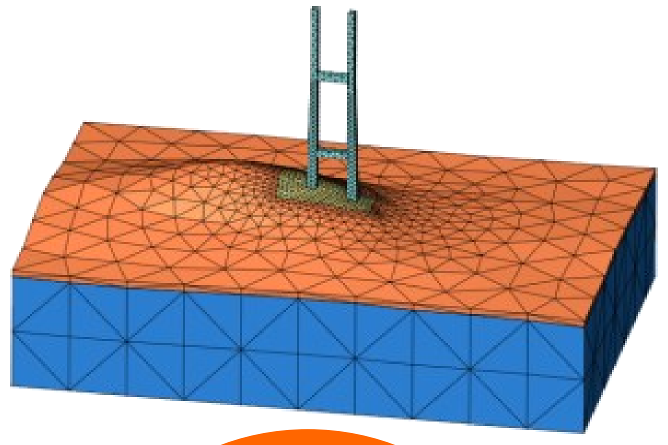
Earthquake record



Design response spectra

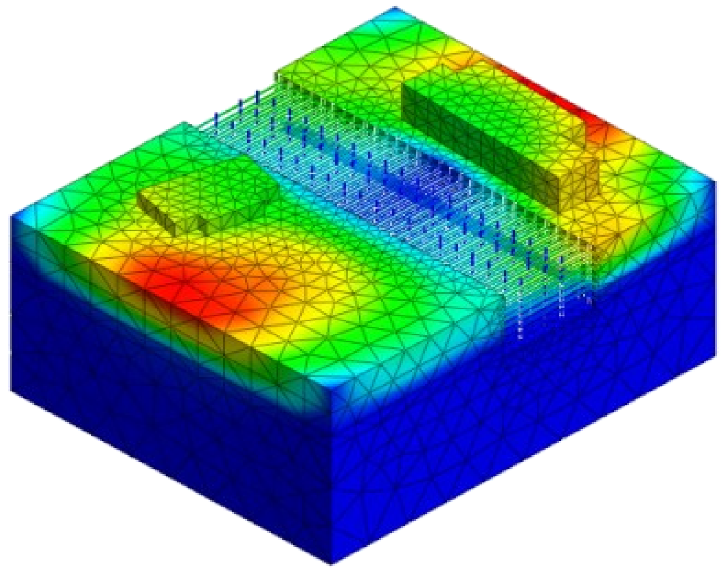
Analysis Capabilities





Static Analysis

- Linear static analysis
- Nonlinear static analysis

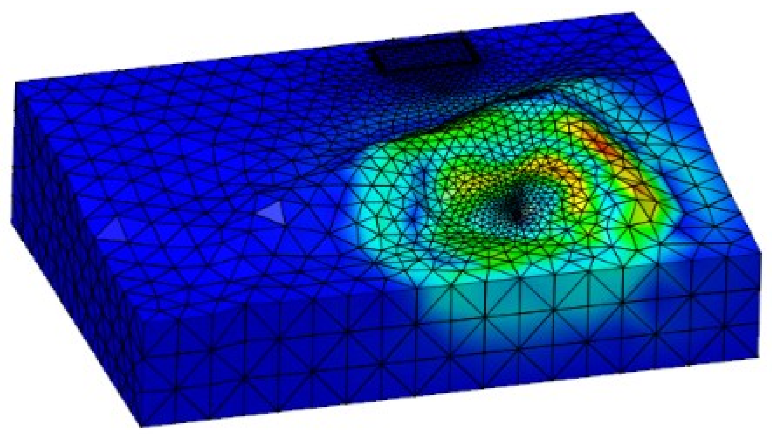


Slope Stability Analysis

- Strength Reduction Method (SRM)
- Strength Analysis Method (SAM)
- Construction stages Slope stability (SRM/SAM)

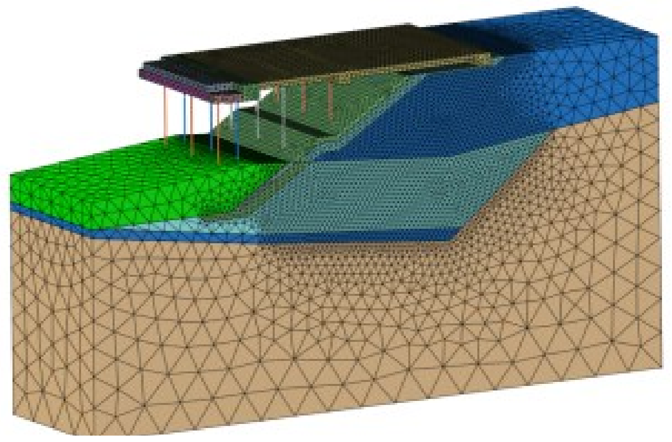
Constructio n Stage Analysis

- Stress (drained/undrained) analysis
- Seepage analysis for each stage
- **Stress-seepage- slope coupled**
- Consolidation analysis for each stage
- **Fully coupled stress & seepage**



Dynamic Analysis

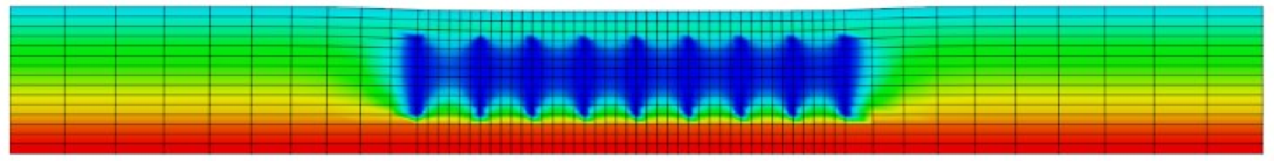
- Eigenvalue/Response Spectrum analysis
- Linear Time History (mode/direct methods)
- **Nonlinear Time History analysis**
- 1D/2D Equivalency Linear analysis
- **Nonlinear time history + SRM Coupled**



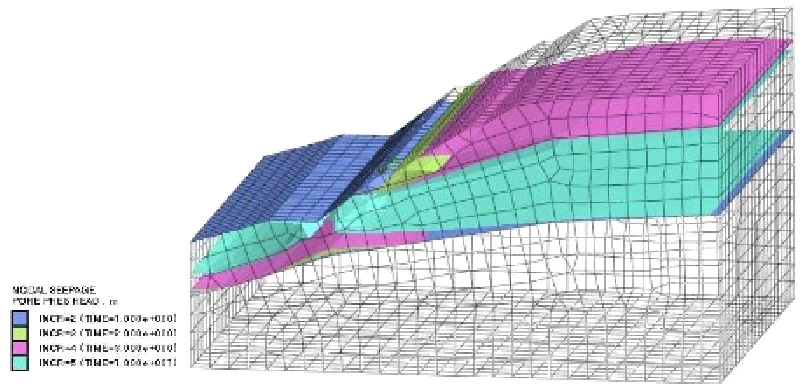
Consoli-dation Analysis

•Consolidation Analysis

•Stress seepage fully coupled analysis

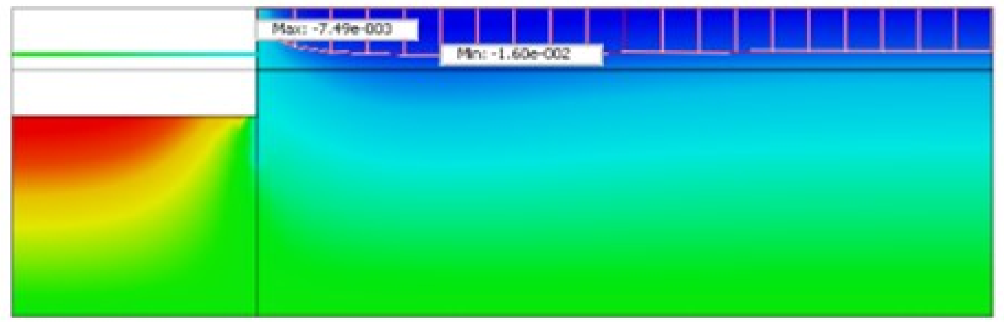


Seepage Analysis

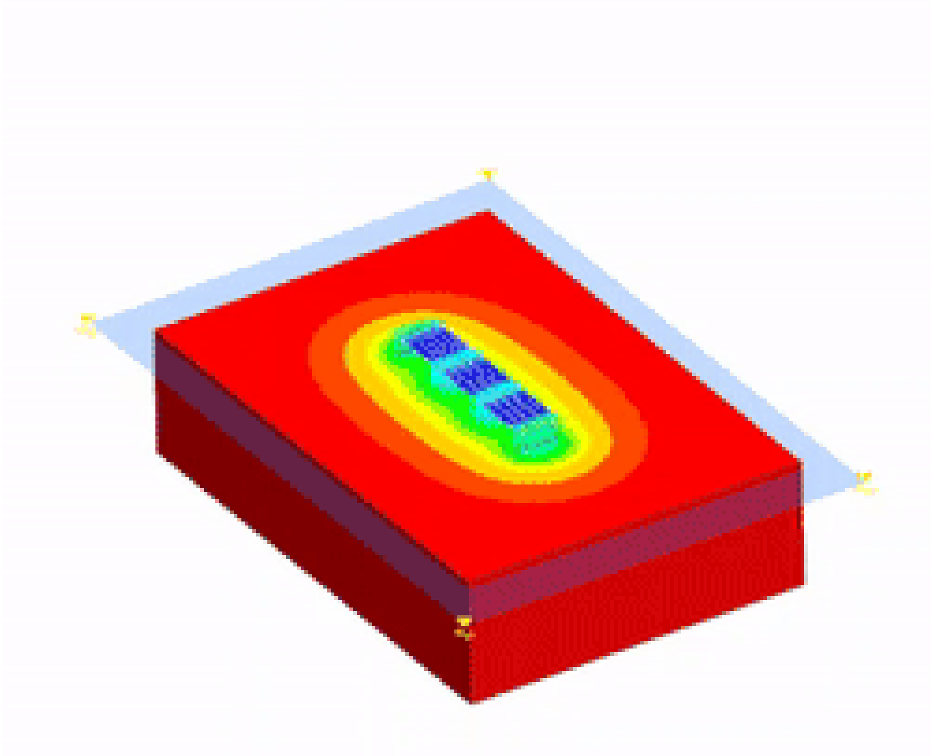


- Steady state seepage analysis
- Transient seepage analysis

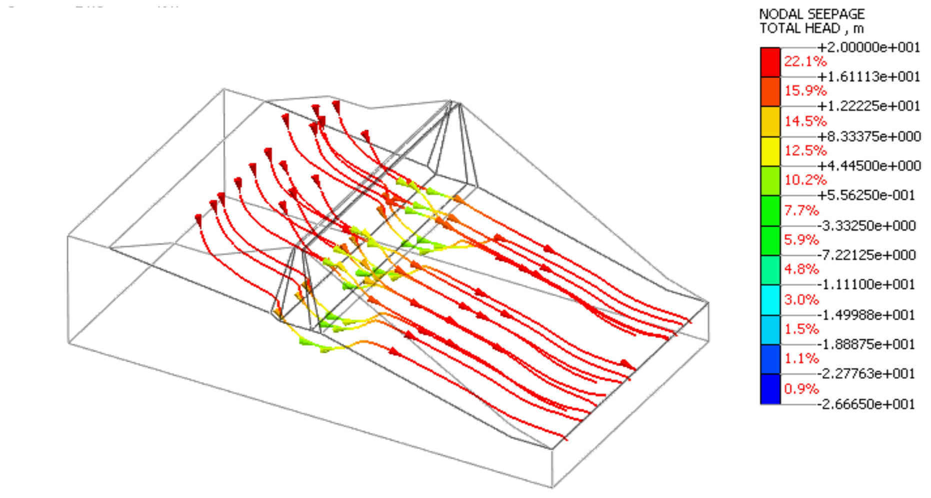
Stress–seepage fully coupled



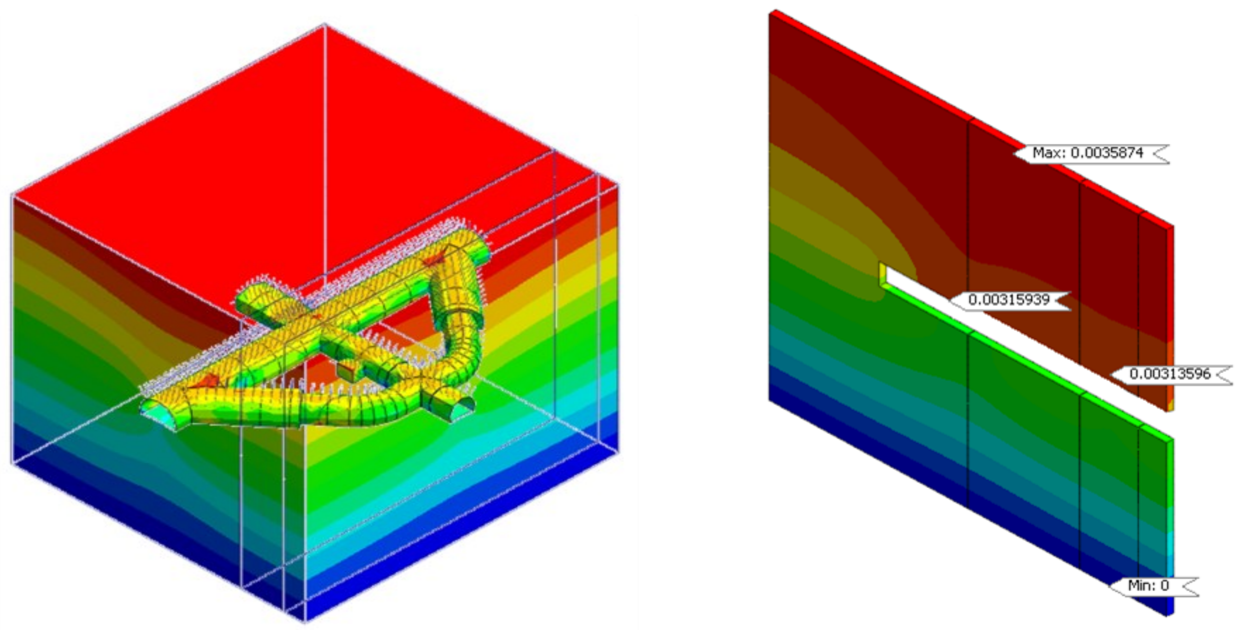
Result Extraction



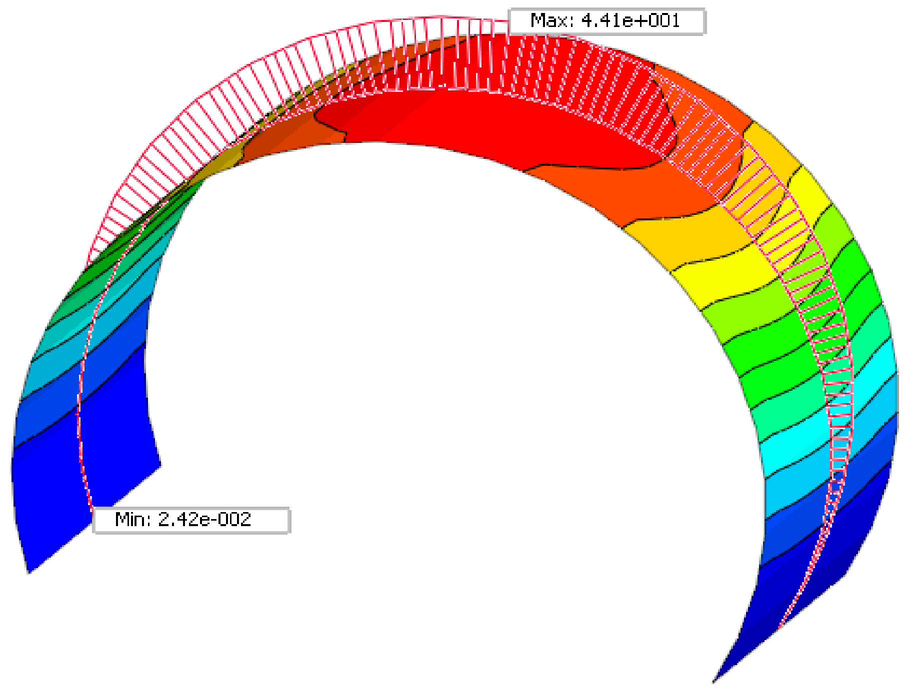
2D Auto Mesh



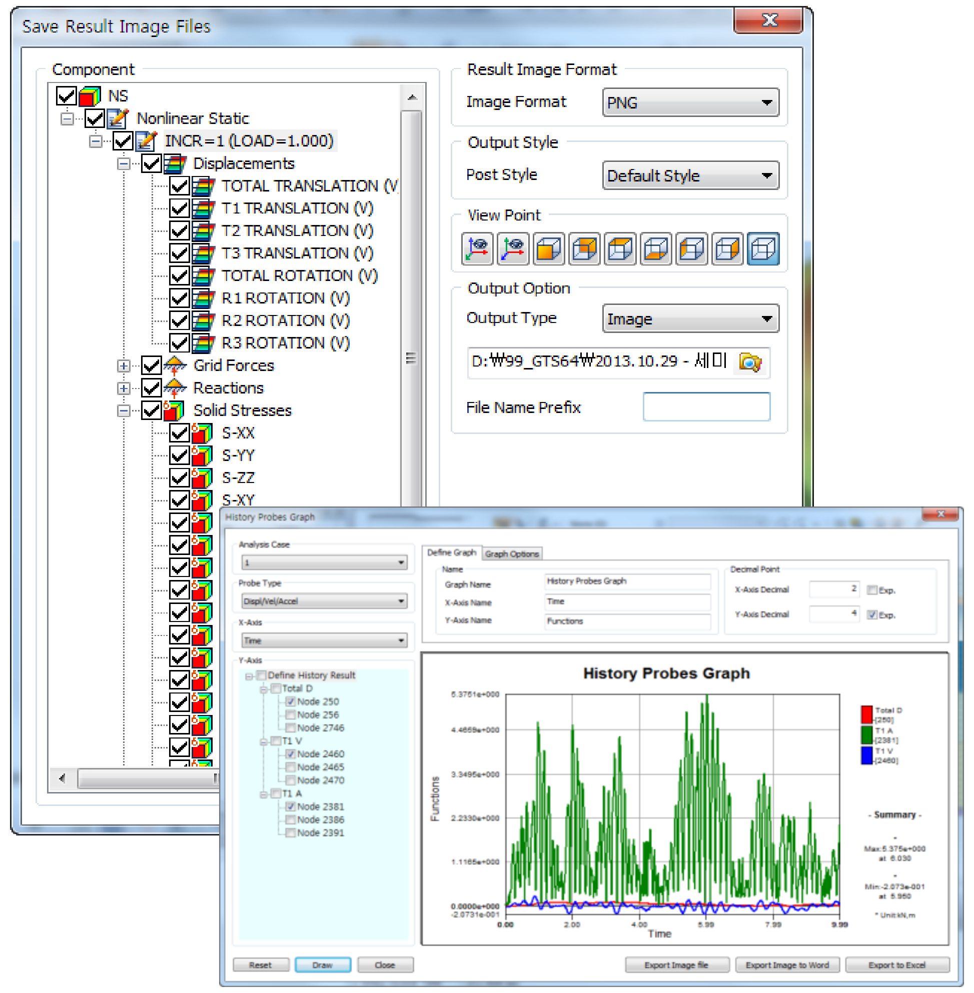
3D flow path result animation



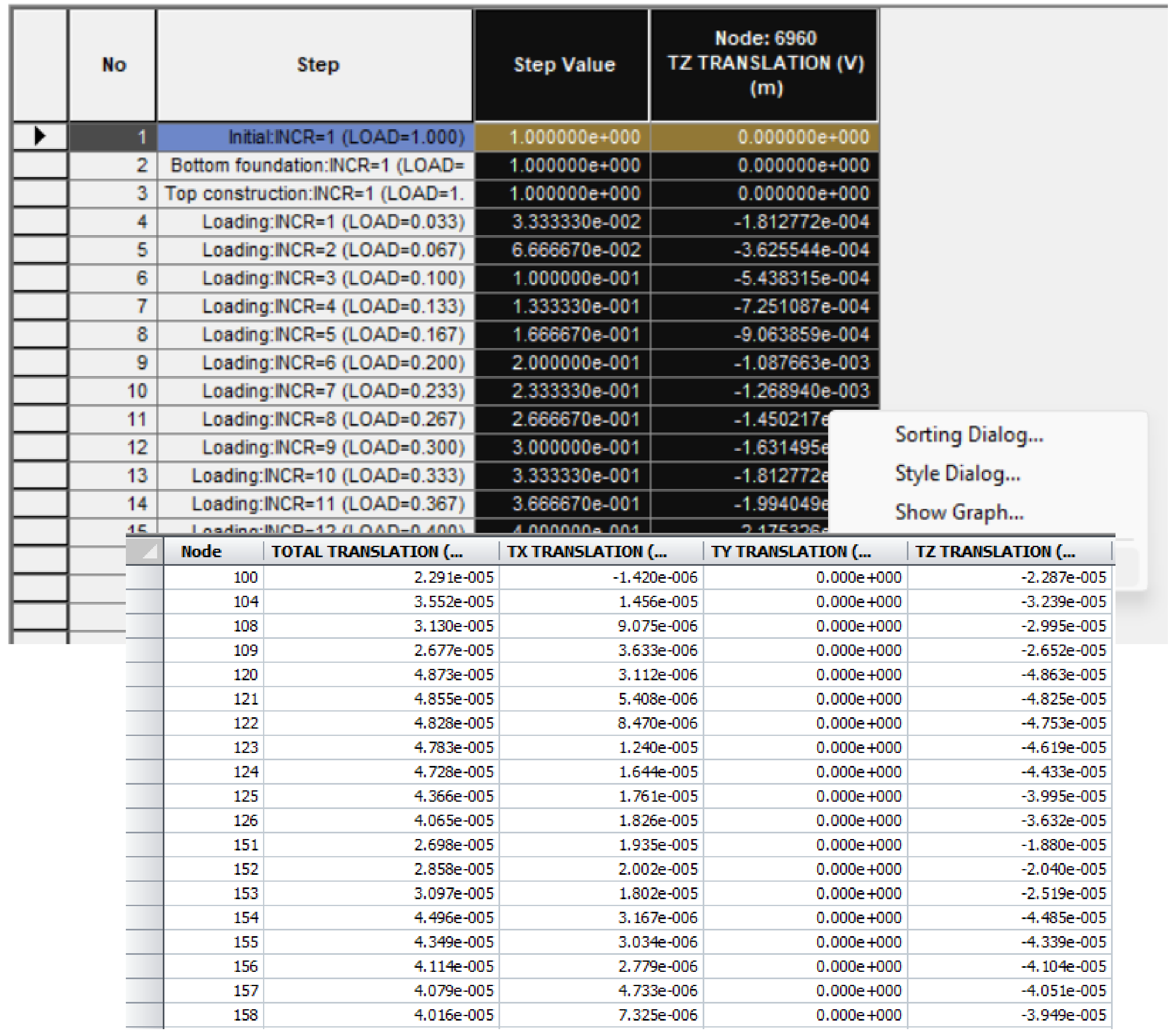
3D to 2D result wizard



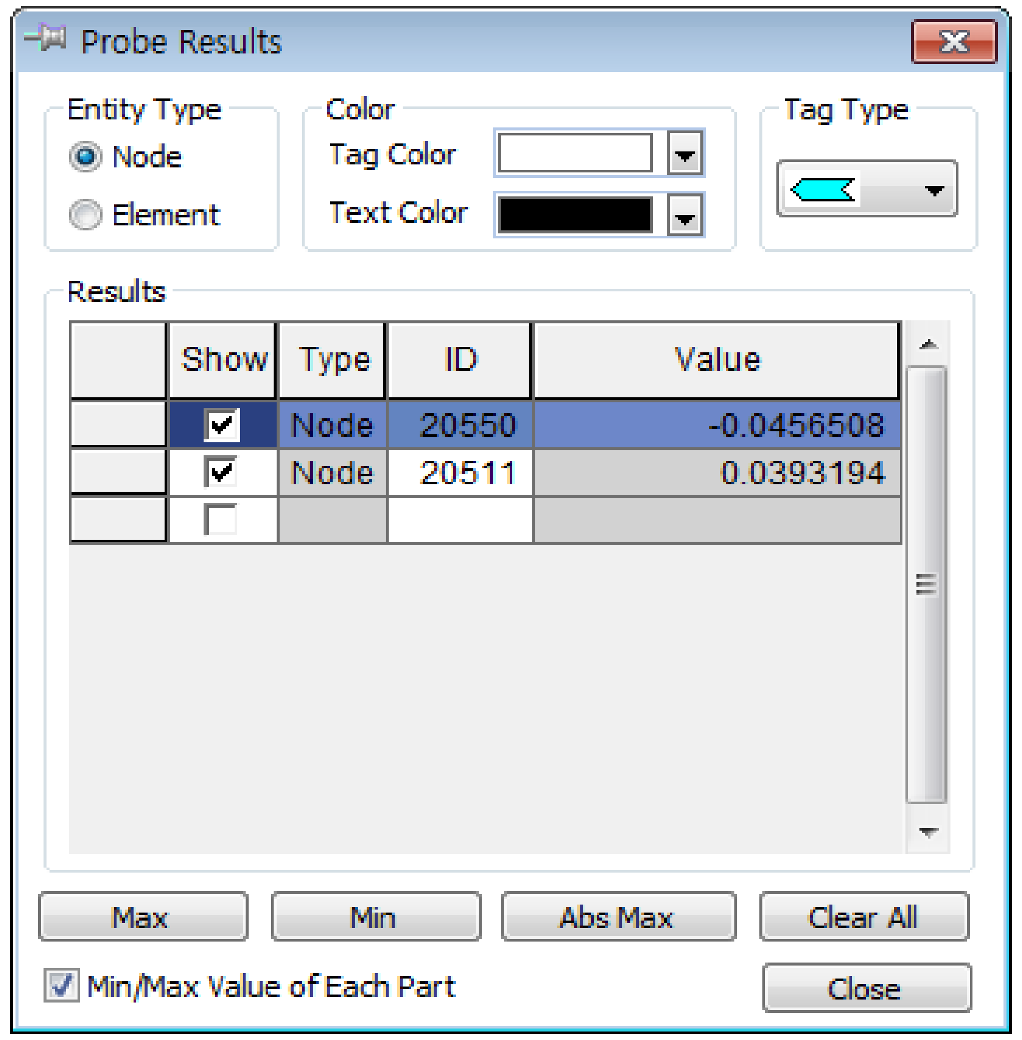
Section diaphragm (line/surface)



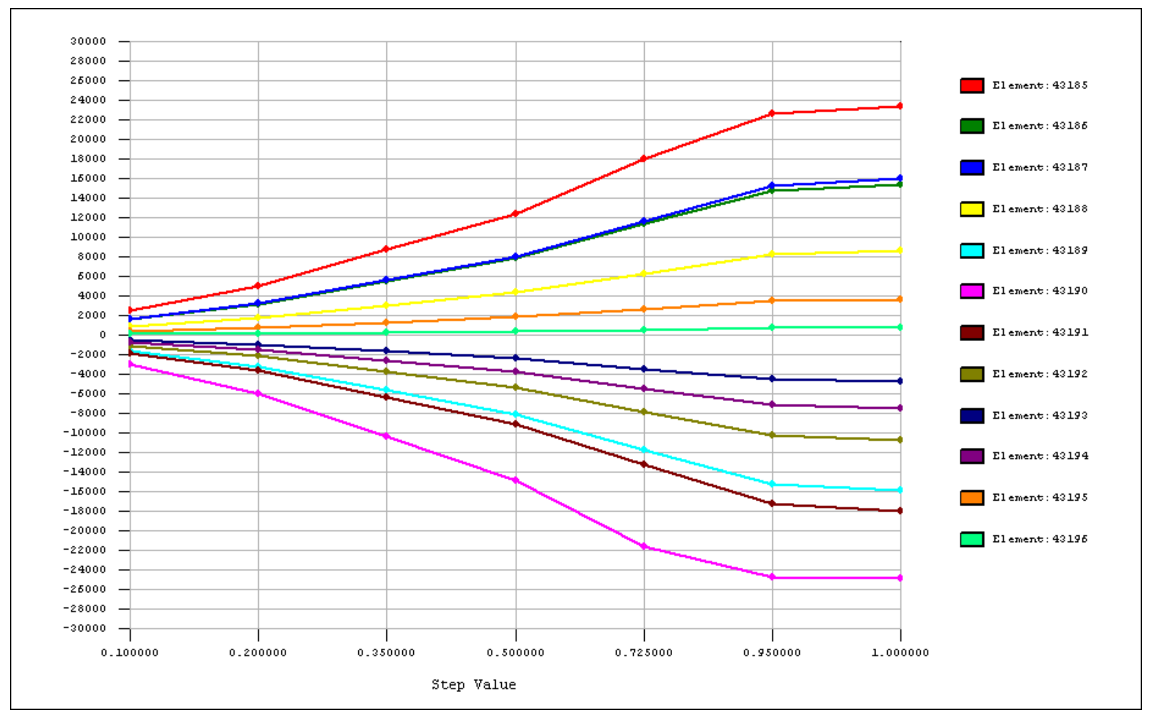
Printing result images/graphs



Excel compatible table



Probe Result



Graph Plots

Slope Stability Analysis

The slopes are formed by natural cause.

Slopes in Hilly areas.

The slopes are constructed for roads, railway lines, canals, earth dams etc.

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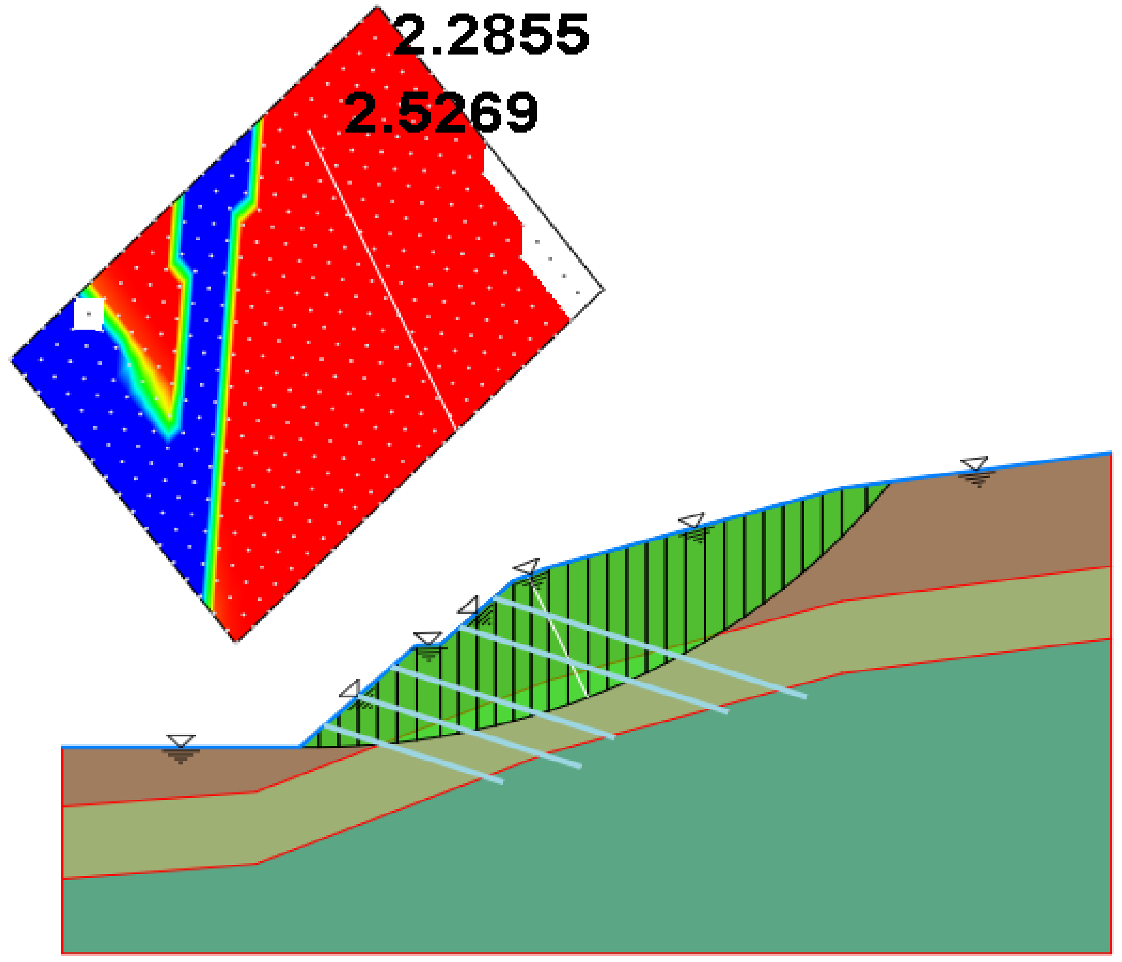
Limit Equilibrium Method (LEM)

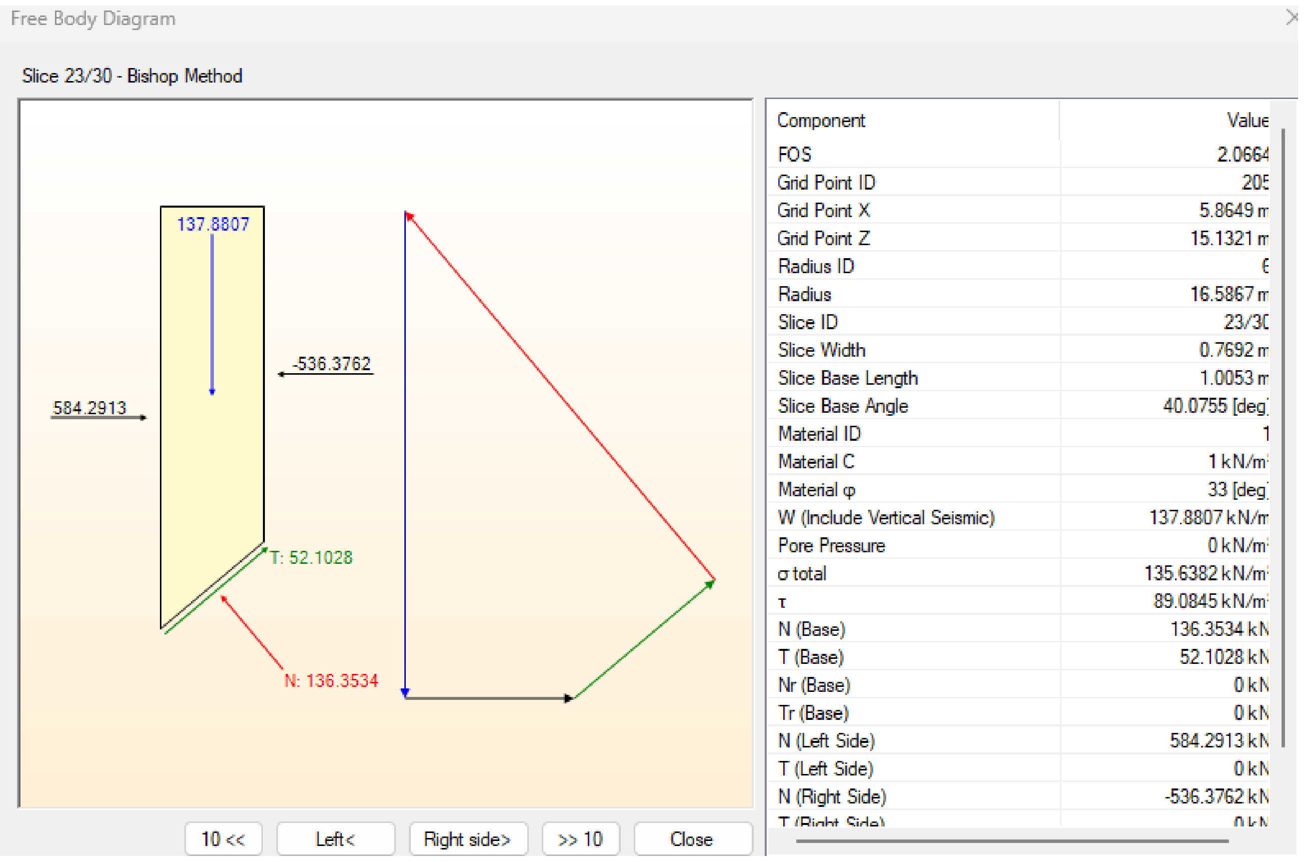
Limit Equilibrium Method

- The method discretizes the potential sliding mass into vertical slices and solved for static equilibrium to assess the Factor of Safety.



FOS of a Slip Circle

- The formulation is based on principles of limiting equilibrium.



Force/Moment Equilibrium

The factor of safety is defined as the factor by which the soil strength must be reduced so that the potential sliding mass is a point of limiting equilibrium

Methods

Method	Moment Equilibrium	Horizontal Force Equilibrium	Interslice normal Force (E)	Interslice shear Force (X)	Inclination of X/E resultant
Fellenius	Yes	No	No	No	No force
Bishop’s	Yes	No	Yes	No	Horizontal
Janbu	No	Yes	Yes	No	Horizontal
Spencer	Yes	Yes	Yes	Yes	Constant
Morgenstern-Price	Yes	Yes	Yes	Yes	Variable

LEM methods differ in the way the static equations are considered for equilibrium

Finite Element Analysis

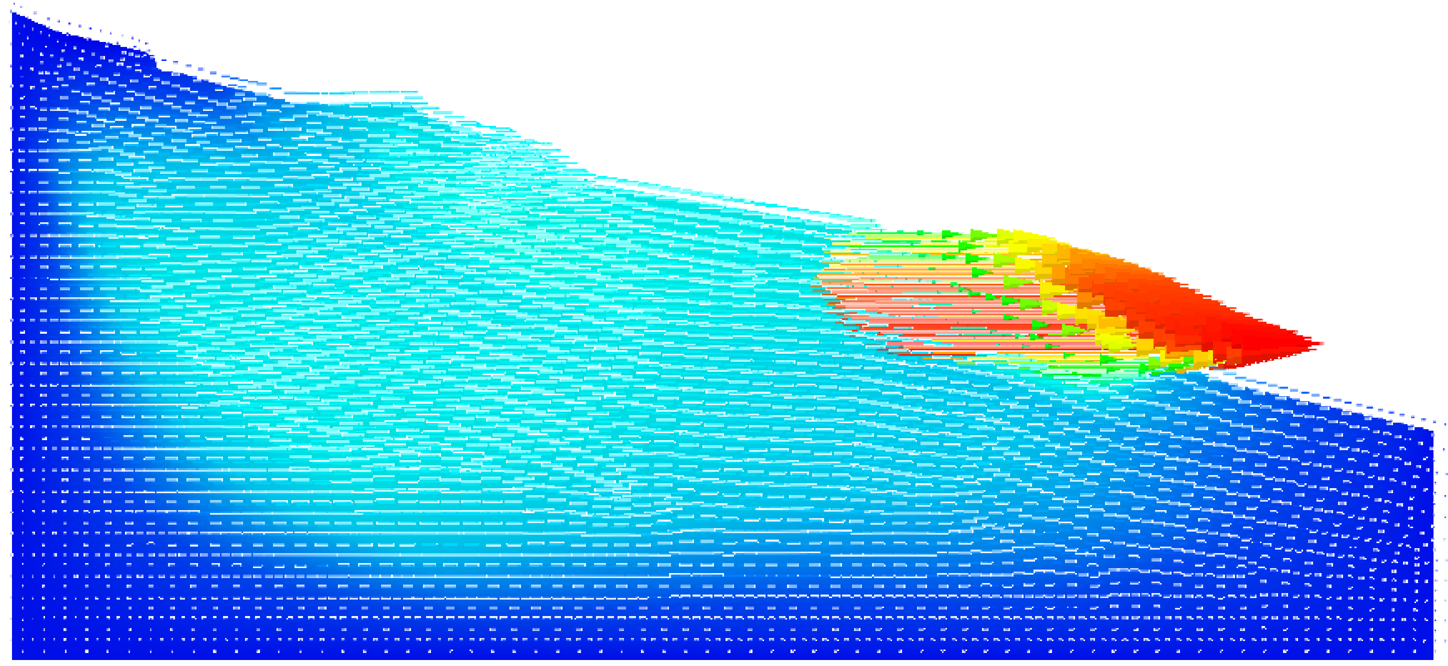
Strength Reduction Method

Strength Reduction Method (SRM)

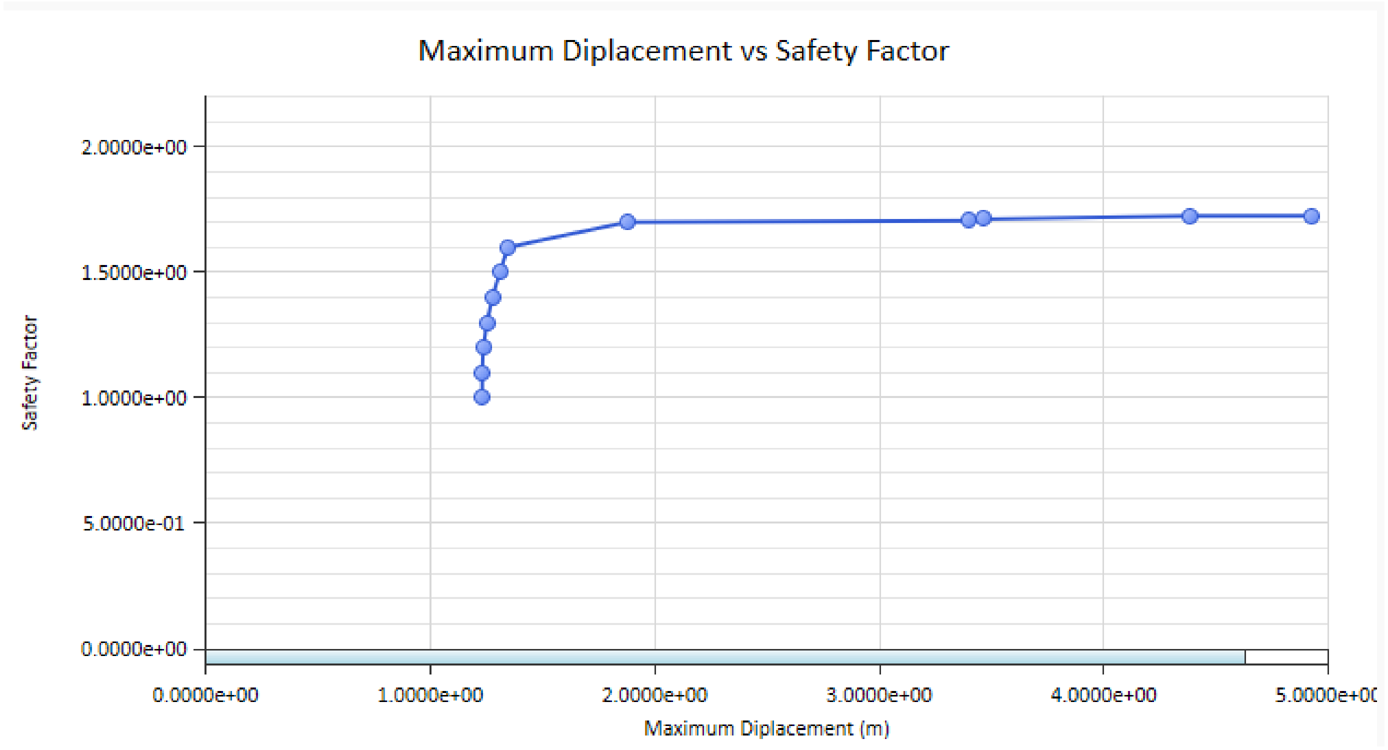
- ➢The soil strength parameters such as cohesion and internal friction angle are gradually reduced until the numerical divergence occur.

Advantages

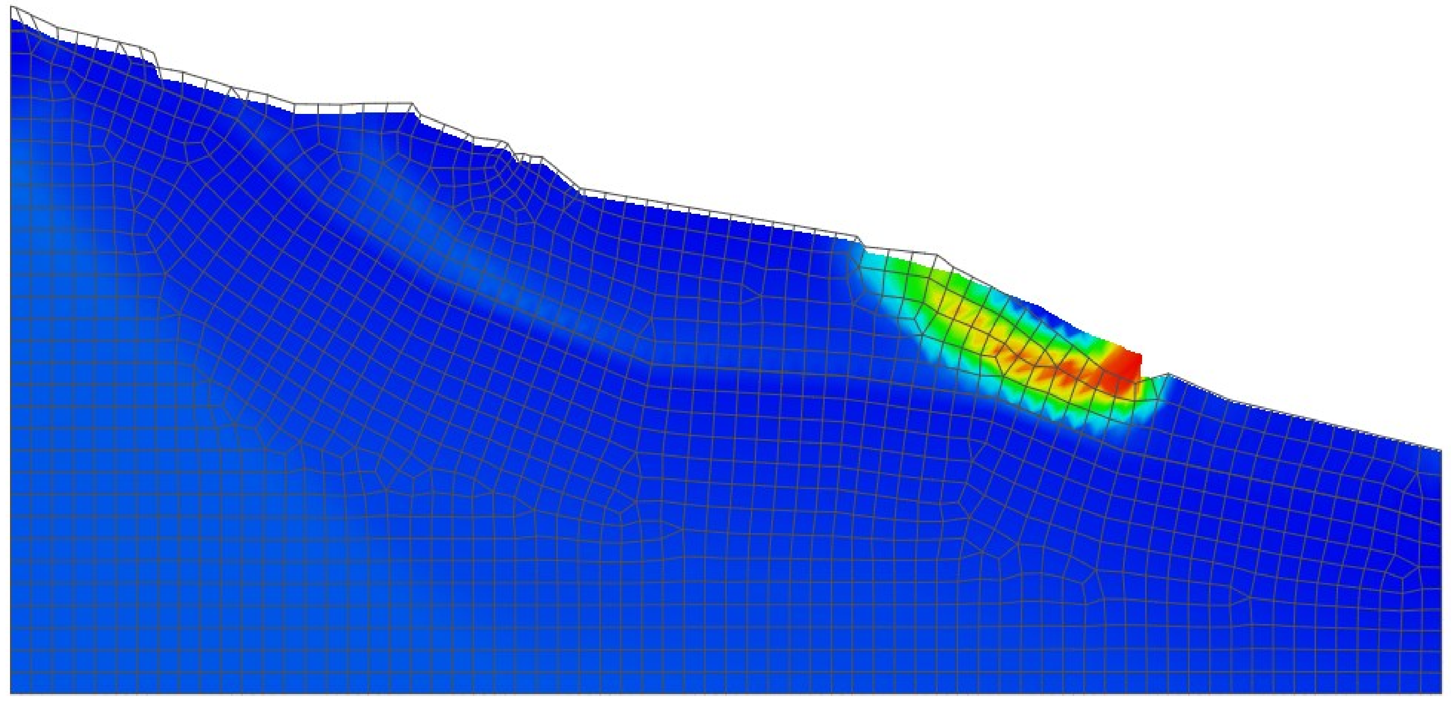
- ➢Failure surfaces and its shape is not assumed.
- ➢Possible to monitor the progressive failure.



Potential Direction of Soil Displacement



Factor of Safety Plot



Potential Slip Surface

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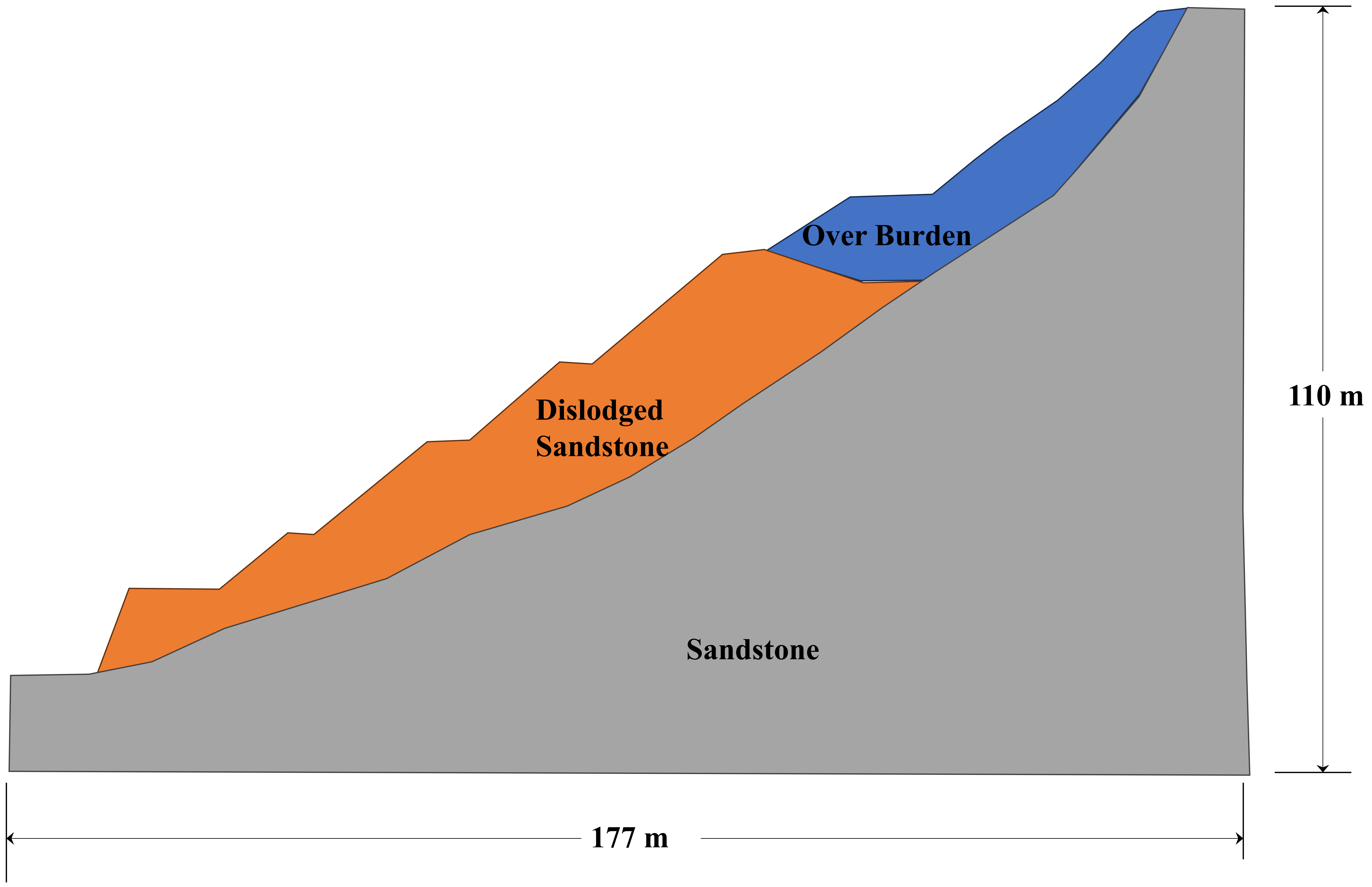
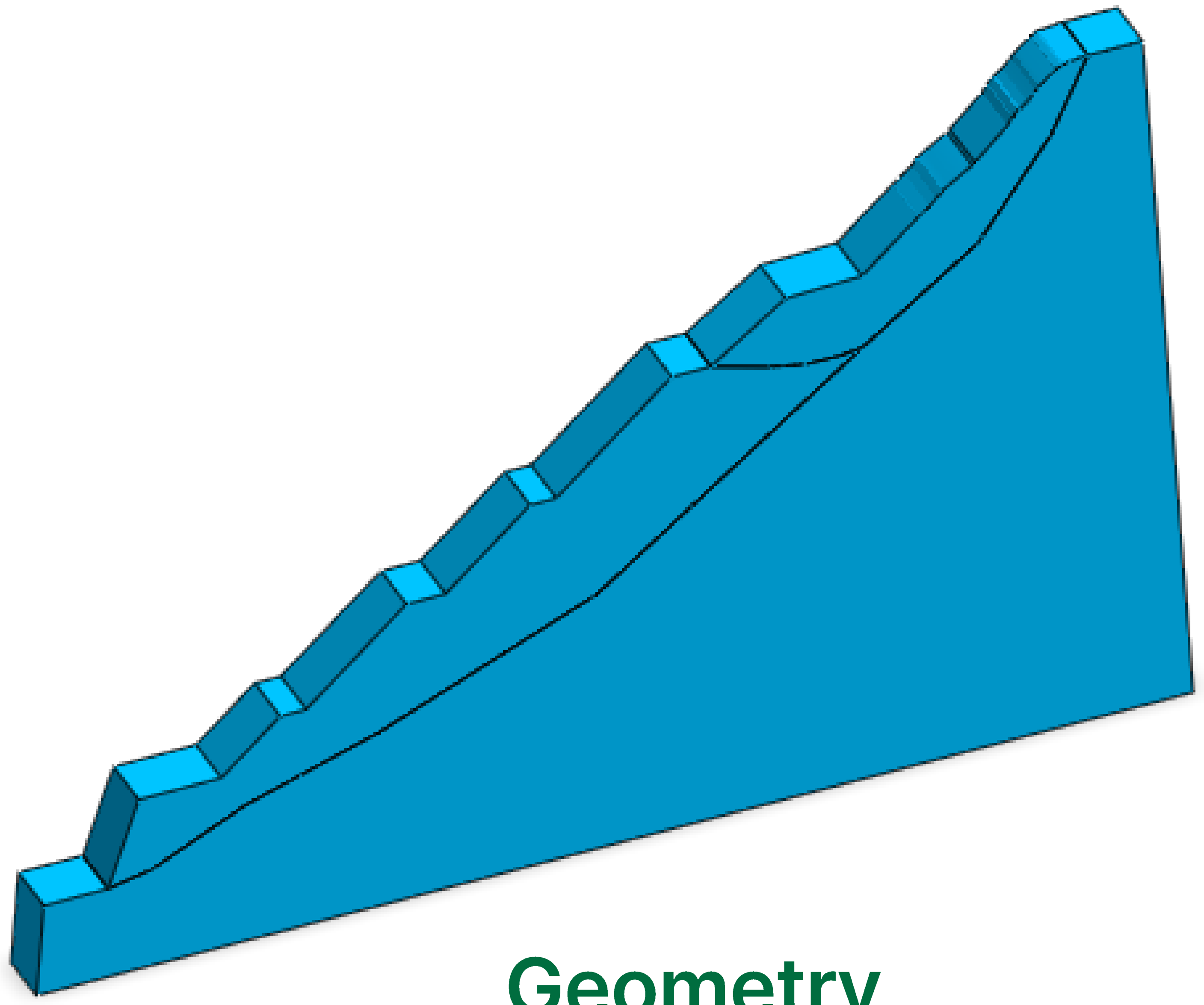
Problem Statement

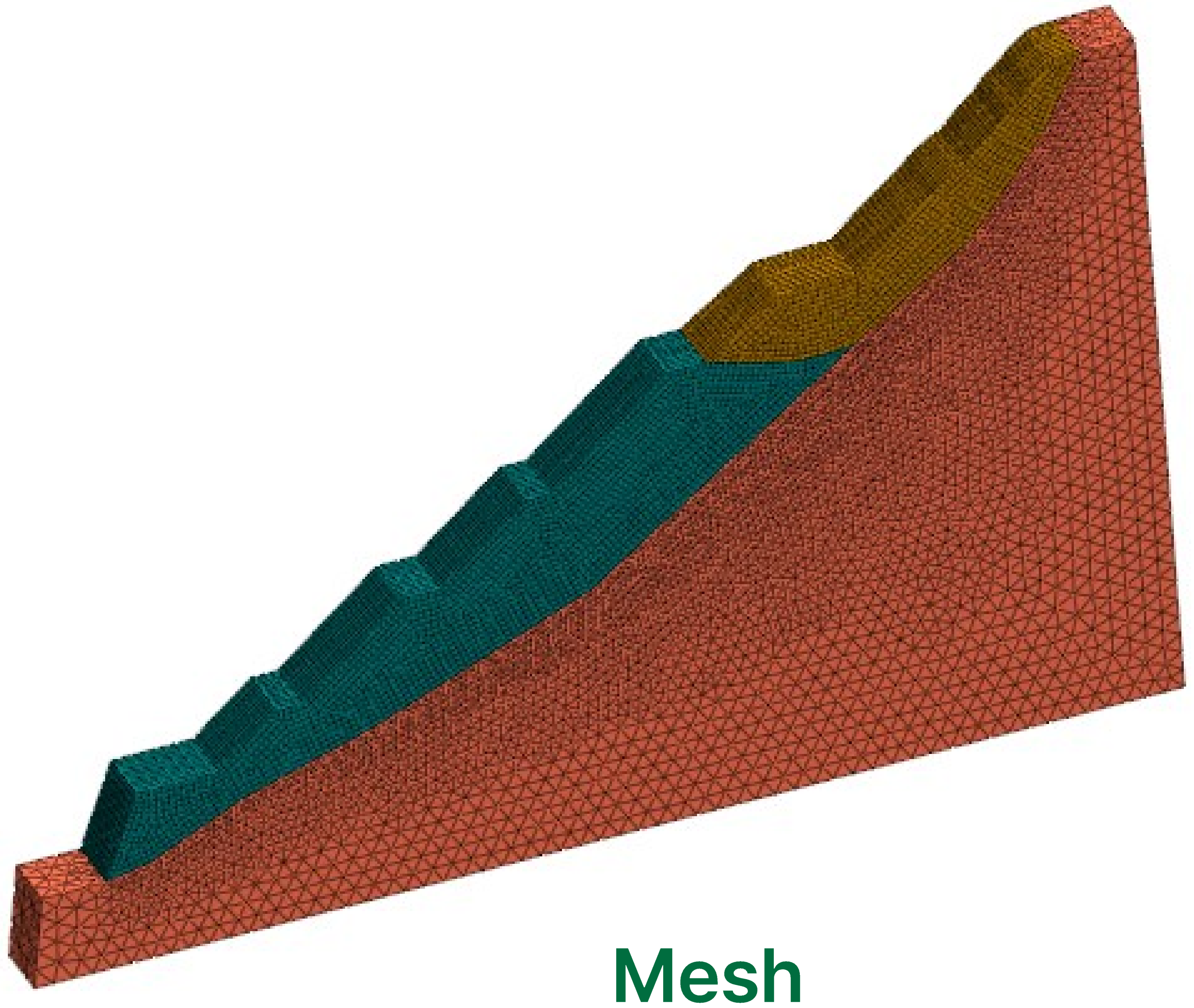


Analyze the Slope for Global and Local Slope Stability using Strength Reduction Method

Global Slope Stability



Geometry



Mesh

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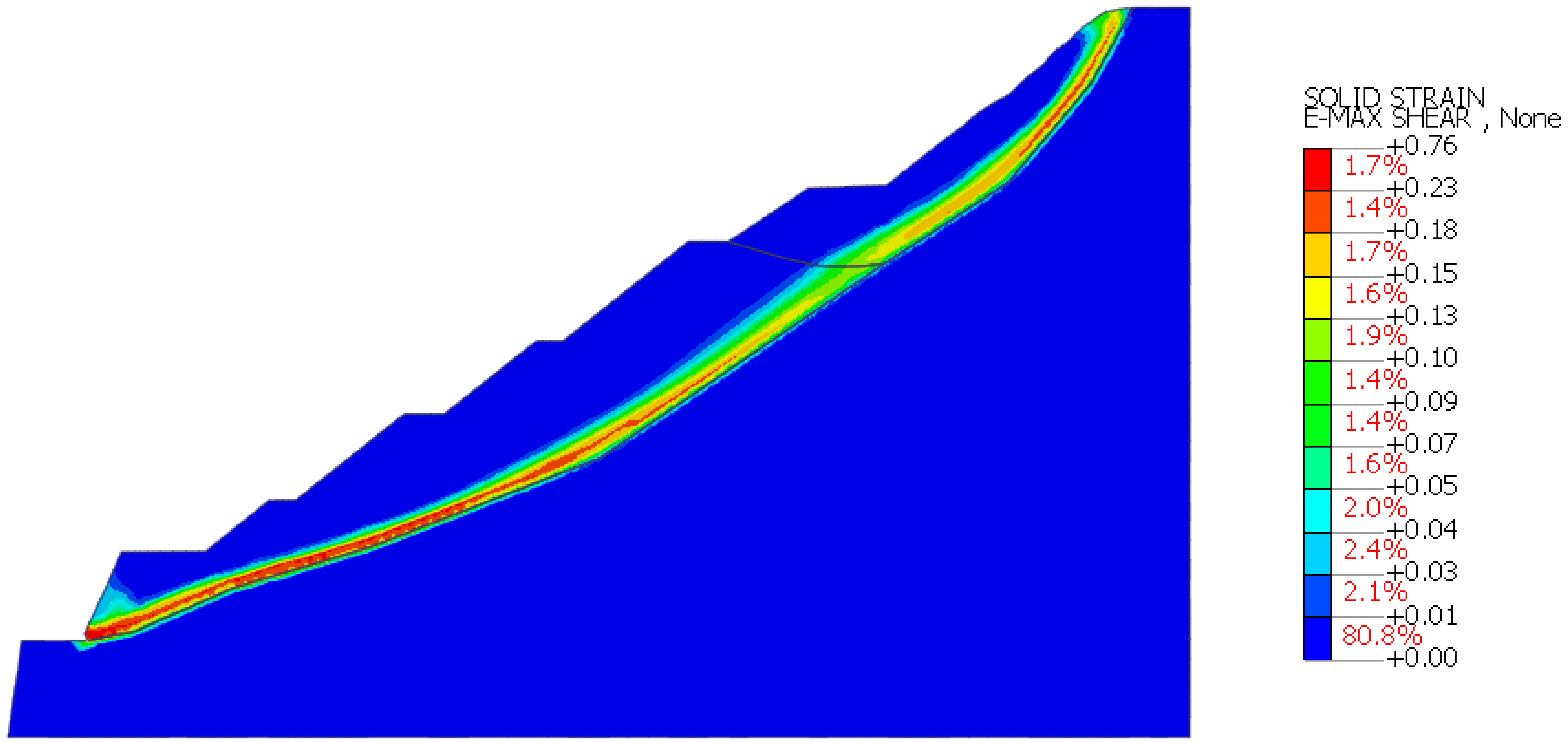
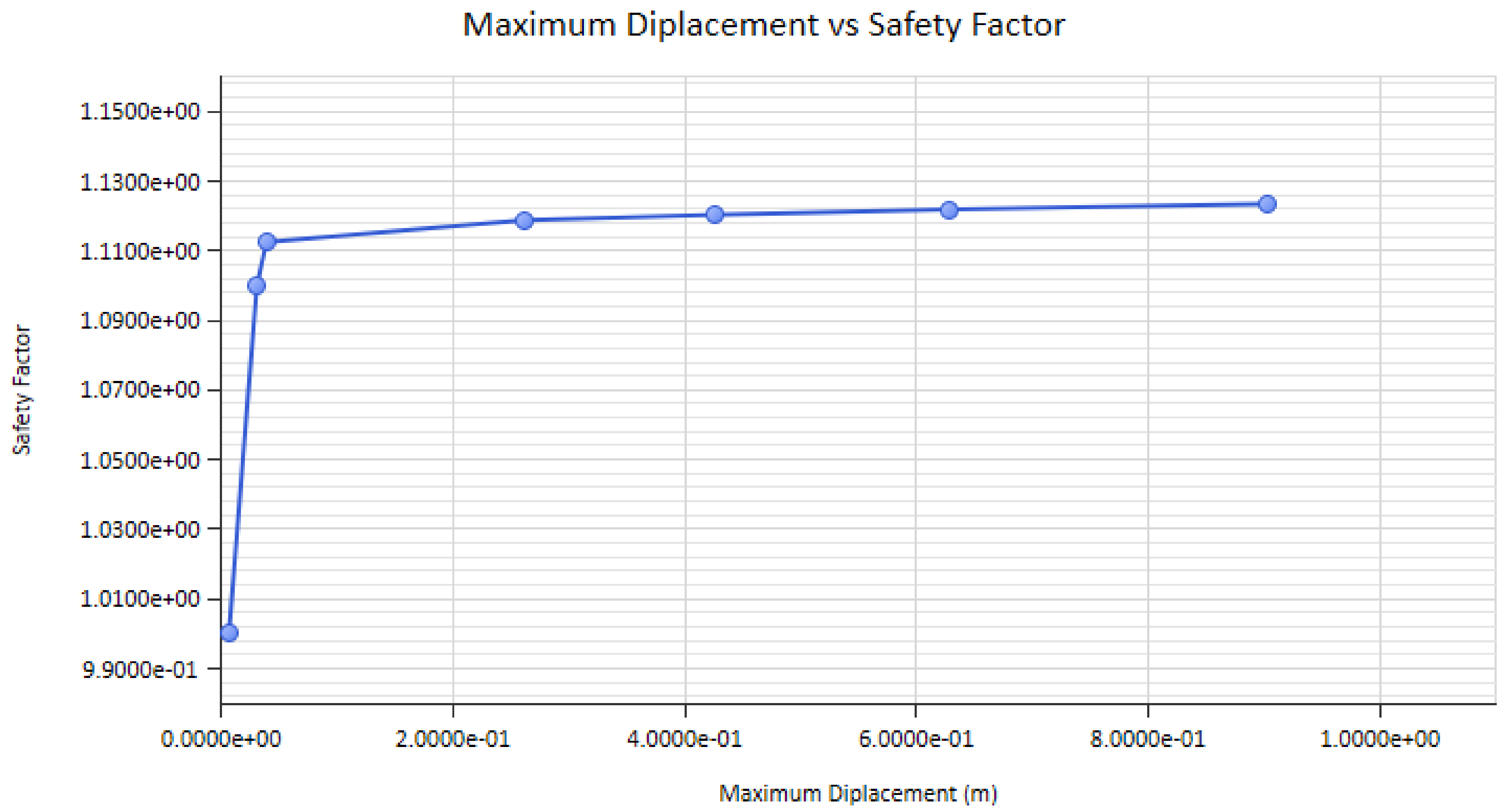
Global Slope Stability



Potential Slip Plane

FOS-1.12



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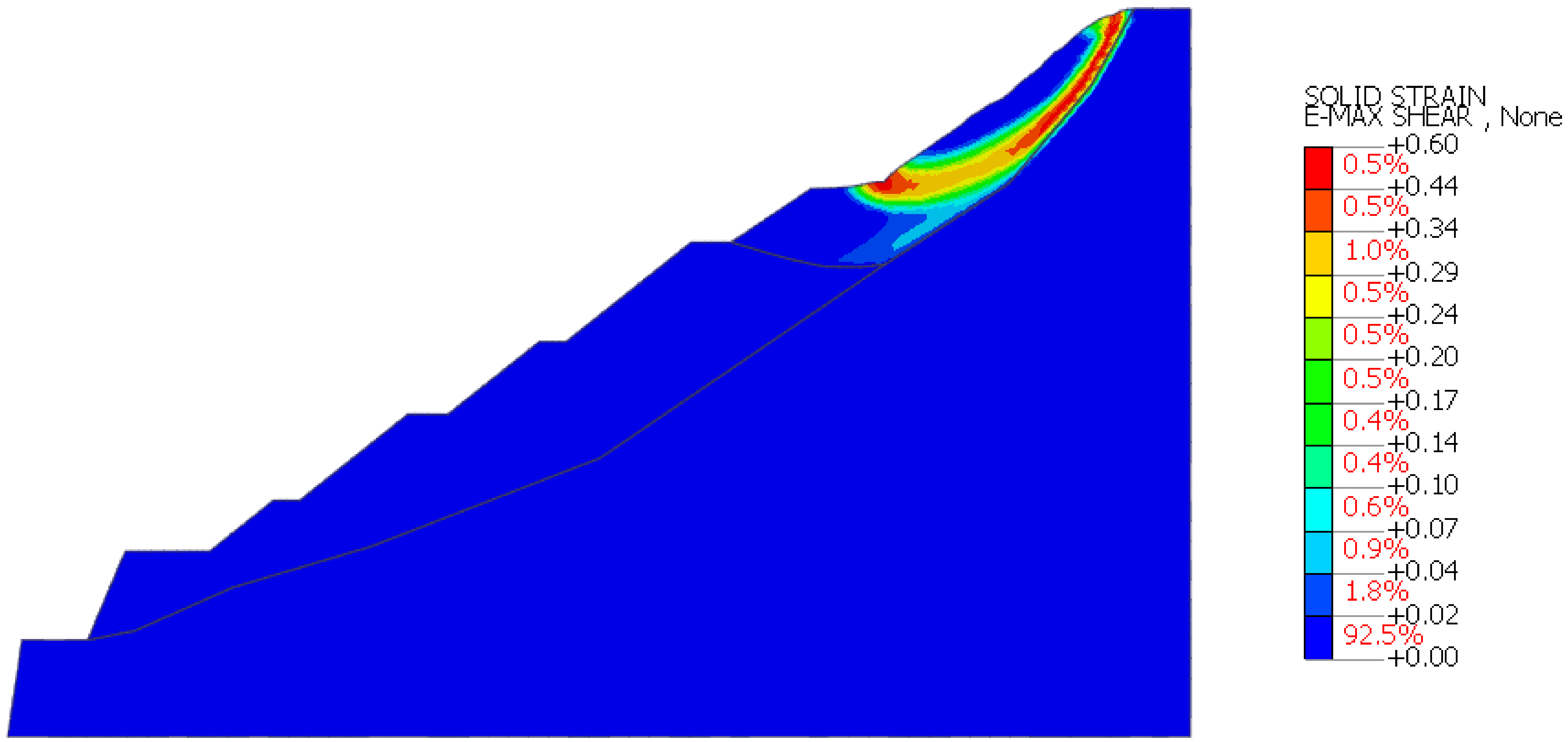
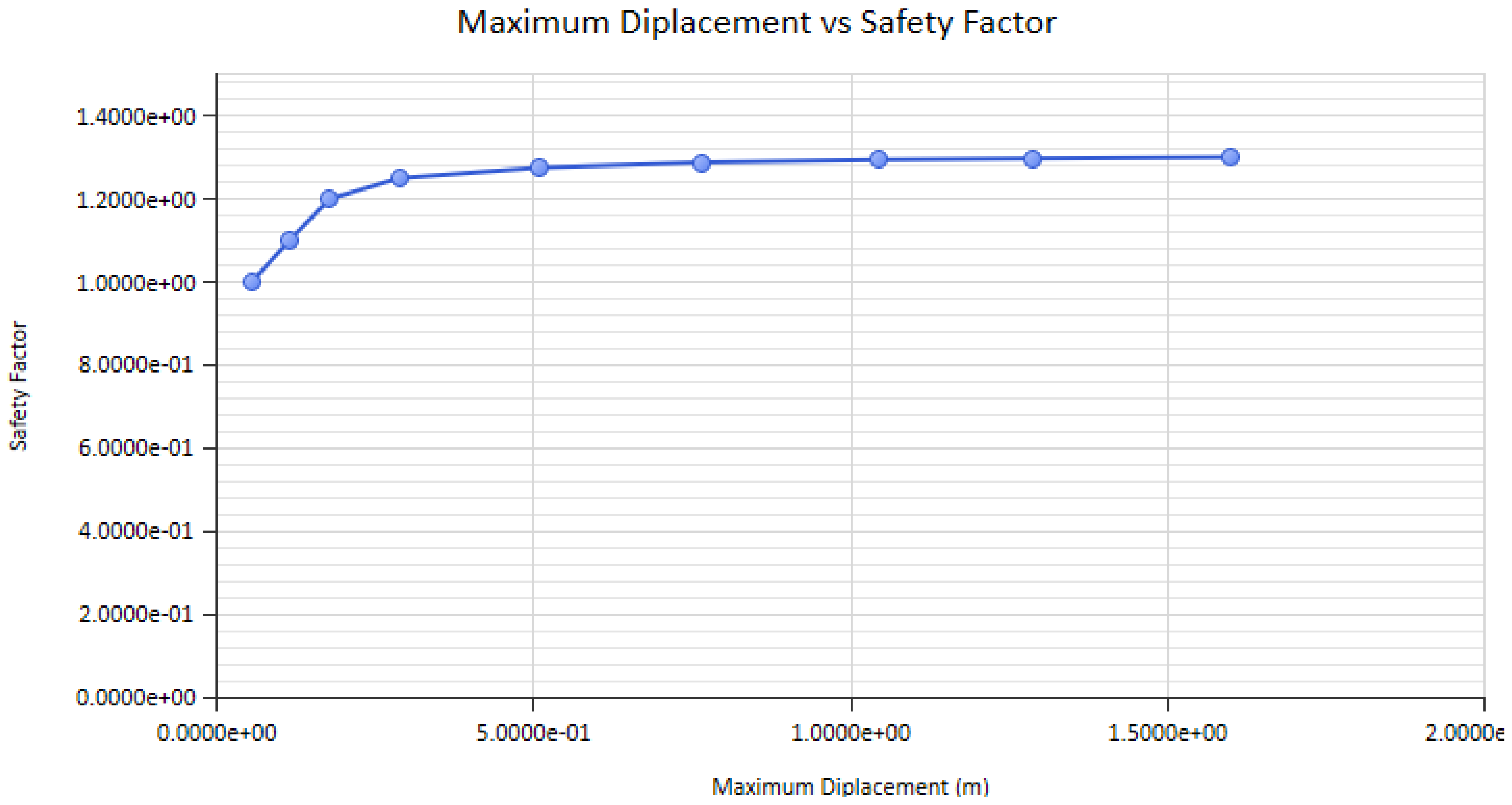
Local Slope Stability of Overburden Layer



Potential Slip Plane



FOS-1.30

MIDAS

Thank You