MIDAS GTS NX TRAINING ACADEMY 2025

ADVANCED NUMERICAL MODELLING AND ANALYSIS

MIDAS IT EUROPE

Pragati Saxena

SCHEDULE

Deep Excavation

February 04, 2025

February 18, 2025

Tunneling

Soil Structure Interaction

March 04, 2025

March 18, 2025

Ground Improvement

1. DEEP EXCAVATION
MODELLING AND ANALYSIS

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Session 1. DEEP EXCAVATION

1. GTS NX Introduction
2. Analysis Capabilities
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Engineering Applications (Infra)

Roads/Highways Engineering

- Slopes
- Pavement Design
- Ground Improvement
- Bridge Foundation Analysis
- MSE Walls
- Tunnels

Airports Engineering

- Runways/Taxiways
- Foundation Analysis

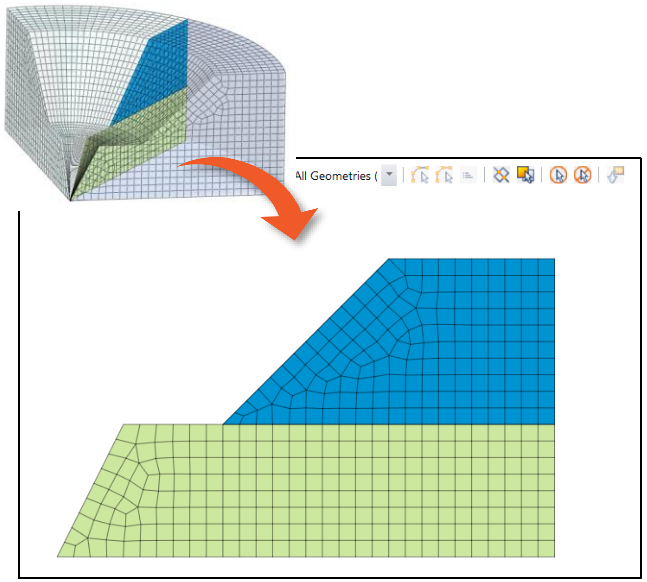
Railroads Engineering

- Subway Systems
- Tunnels
- Bridge Foundations
- Underground Stations

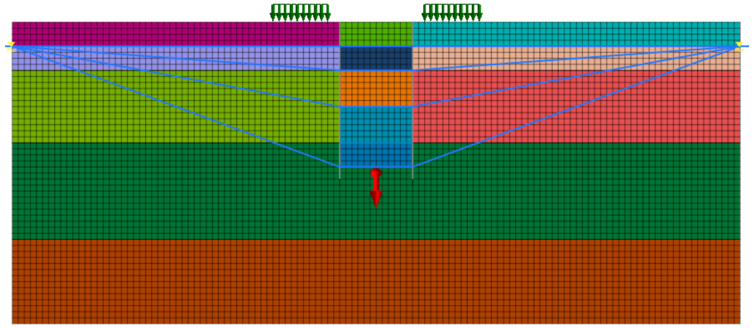
Waterways Engineering

- Docks
- Jetty/Quay Walls
- Land Reclamation
- Coastal Protection (Dykes)

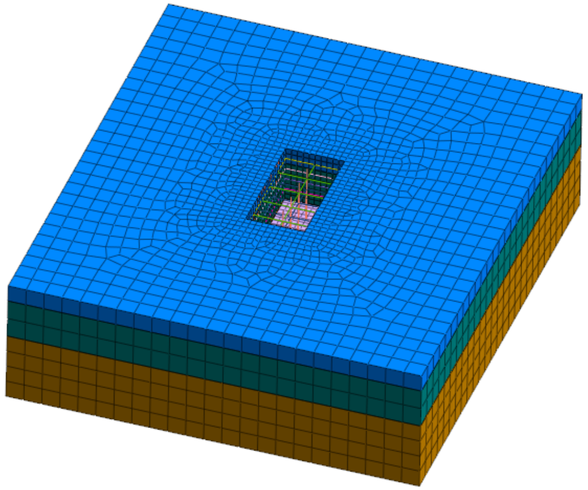
GTS NX: Finite Element Analysis based Platform catering Geotechnical Applications



Axisymmetric



2D Modeling



3D Modeling

Deep Excavation Fundamentals

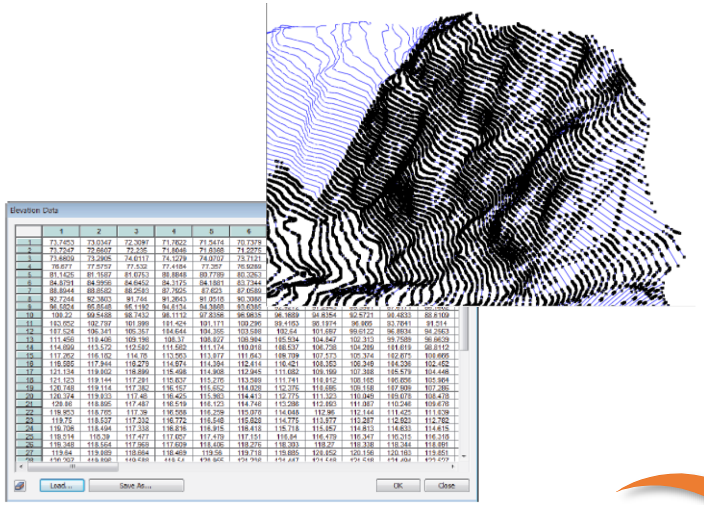
- Excavations where depth exceeds 4.5m.
- Support systems necessary unless it is entirely made in stable rock.
- Detailed design must be carried out by trained professionals.
- HSE determines the safety and guidelines for urban safety.
- Eurocode 7 gives guidelines for stability checks and calculations.

GTS NX ANALYSIS CAPABILITIES

Geometry Modelling

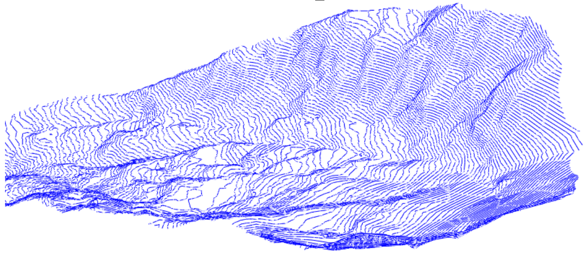
- Direct import of Survey Data Points and Elevation data from LIDAR Survey
- Complex 3D topography modelling using imported data points
- Complex 3D topography modelling using imported contour curves
- Supports .dxf, .dwg and other CAD format drawings import

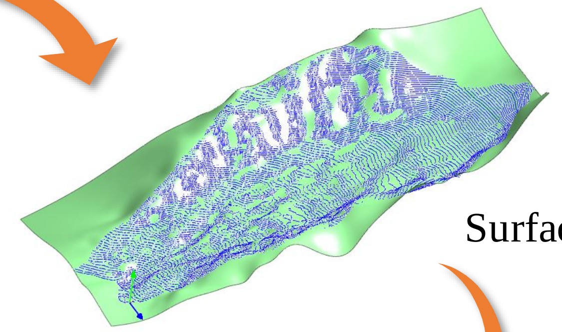
Data Points import



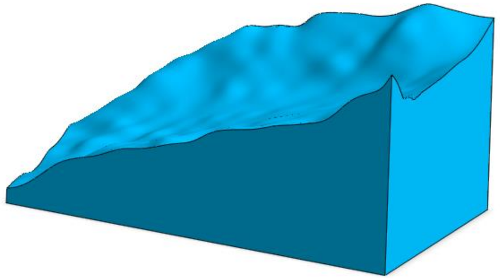
Elevation Data input

Contour curves import

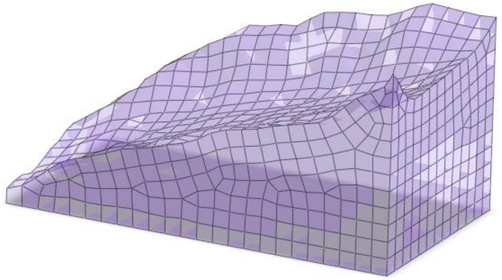




Surface Topography



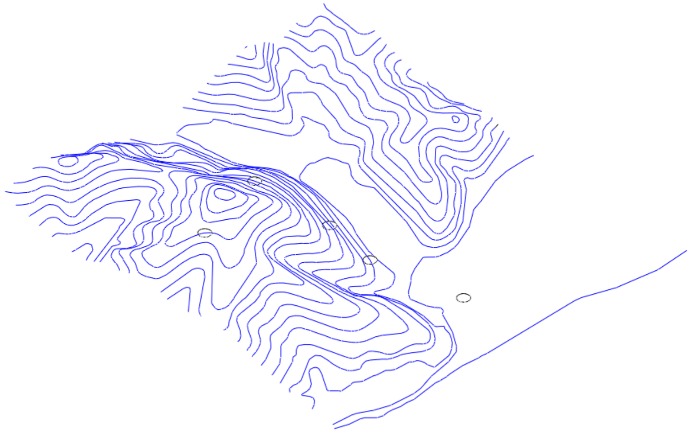
Geometry Modelling and Meshing

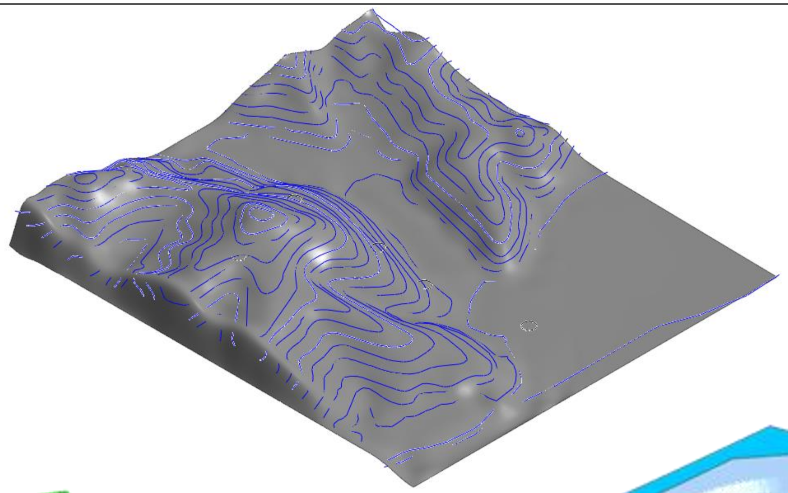


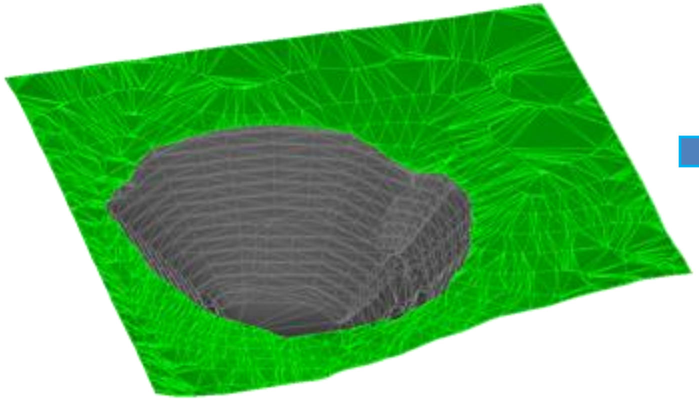
Parasolid (9 to 34) Files (*.x_t;*.xmt_txt;*.x_b;*.xmt_bin)
ACIS (R1 - 2022 1.0) Files (*.sat;*.sab;*.asat;*.asab)
STEP (AP203, AP214, AP242) Files (*.stp;*.step)
IGES (Up to 5.3) Files (*.igs;*.iges)
Pro-E (16 - Creo 8.0) Files (*.prt;*.prt.*;*.asm;*.asm.*)
CATIA V4 (CATIA 4.1.9 - 4.2.4) Files (*.model;*.exp;*.session)
CATIA V5 (V5 R8 - V5-6R2025) Files (*.CATPart;*.CATProduct)
SolidWorks (98 - 2022) Files (*.sldprt;*.sldasm)
Unigraphics (11 - NX2007) Files (*.prt)
Inventor Part (V6 - V2022) Files (*.ipt)
Inventor Assembly (V11 - V2022) Files (*.iam)

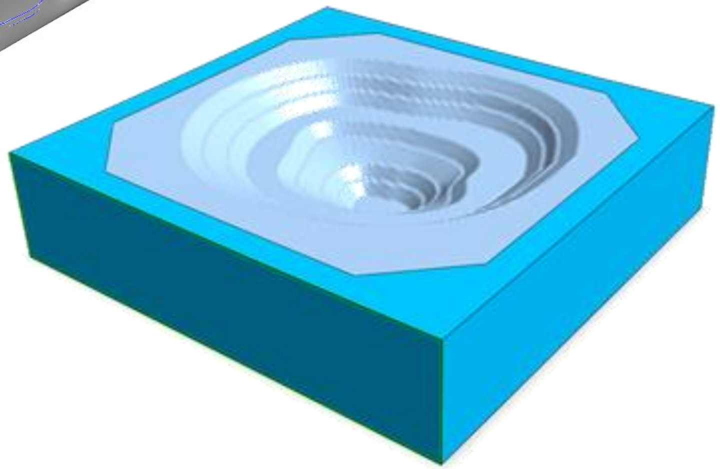
CAD Formats import

CAD Compatibility





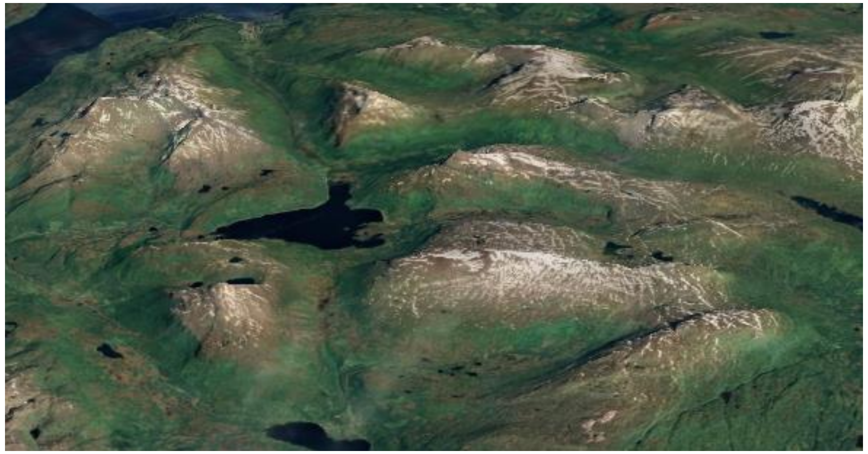


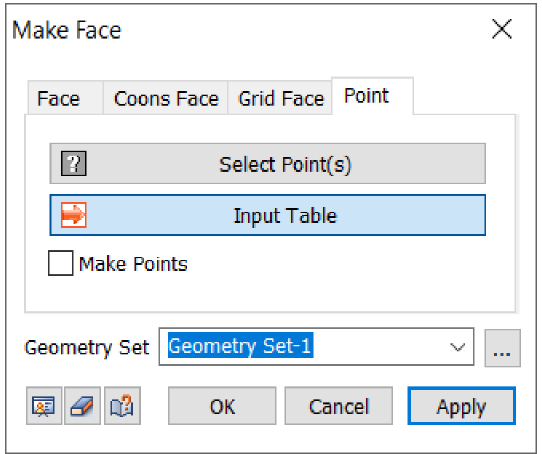


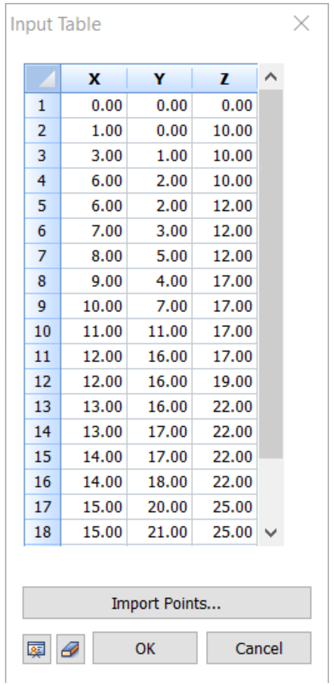
Import contour maps, soil stratigraphy data, borehole maps, on .dxf/.dwg/parasolid format (Leapfrog,MicroStation, AutoCAD, ArchGIS) in Terrain Geometry Maker to develop ground profile.

Data Points Face Generation

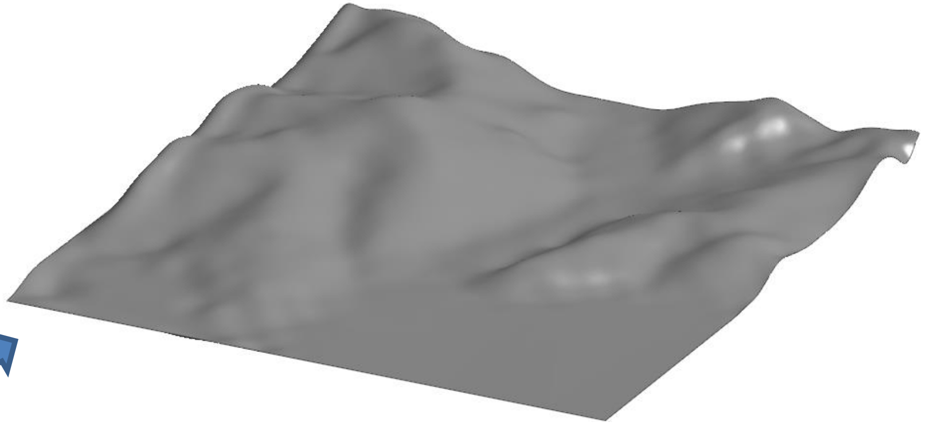
Directly import point coordinates for faster & accurate geometry development







	X	Y	Z
1	0.00	0.00	0.00
2	1.00	0.00	10.00
3	3.00	1.00	10.00
4	6.00	2.00	10.00
5	6.00	2.00	12.00
6	7.00	3.00	12.00
7	8.00	5.00	12.00
8	9.00	4.00	17.00
9	10.00	7.00	17.00
10	11.00	11.00	17.00
11	12.00	16.00	17.00
12	12.00	16.00	19.00
13	13.00	16.00	22.00
14	13.00	17.00	22.00
15	14.00	17.00	22.00
16	14.00	18.00	22.00
17	15.00	20.00	25.00
18	15.00	21.00	25.00

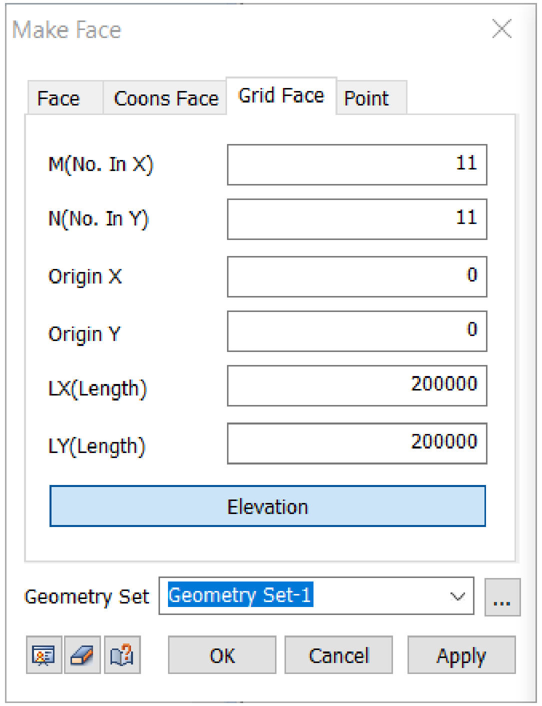


Import data points from Excel

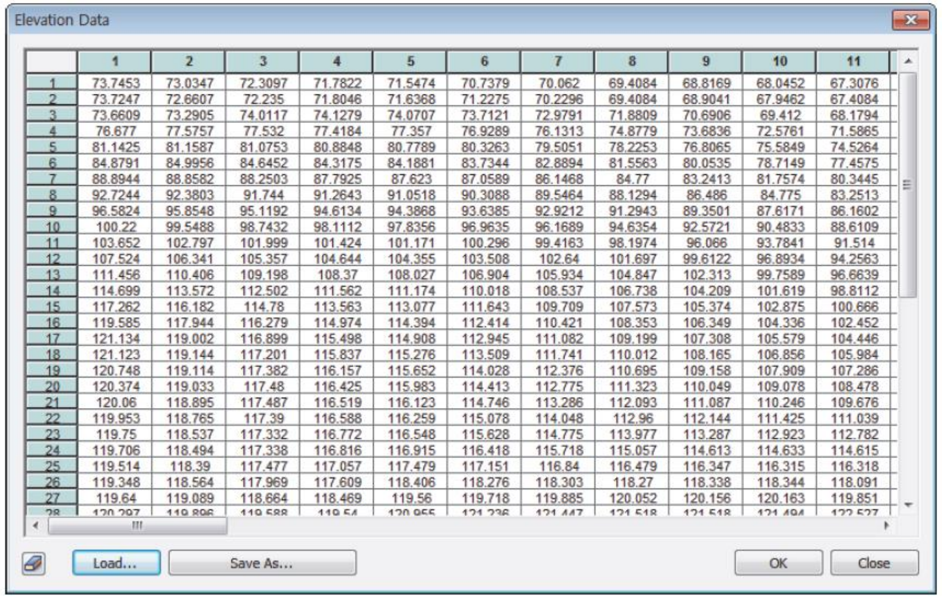
DEM (GIS) Data Interpretation

GTS NX has number of ways for creating complex geometries.

GTS NX geometric design features involve DEM data input, survey data points input to generate topographical surfaces.

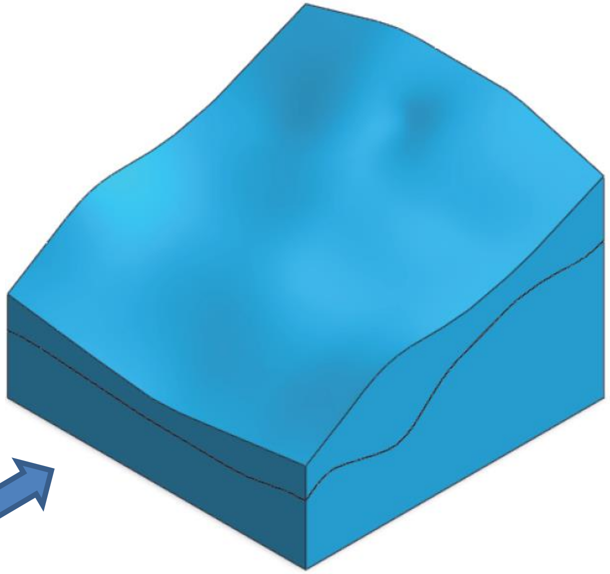


Insert DEM data directly into the table to create complex 2D face.

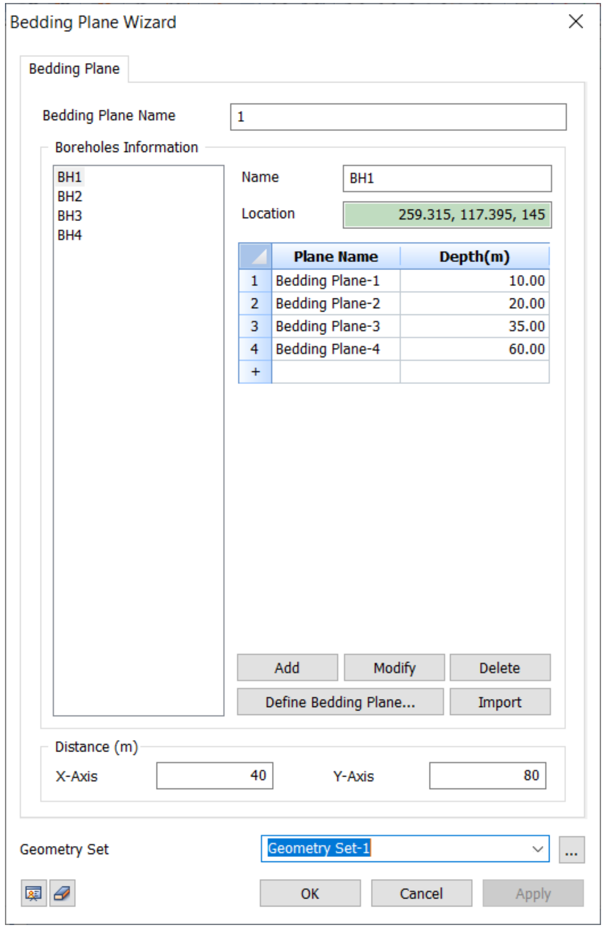

Elevation Data

	1	2	3	4	5	6	7	8	9	10	11
1	73.7453	73.0347	72.3097	71.7822	71.5474	70.7379	70.062	69.4084	68.8169	68.0452	67.3076
2	73.7247	72.6607	72.235	71.8046	71.6368	71.2275	70.2296	69.4084	68.9041	67.9462	67.4084
3	73.6609	73.2905	74.0117	74.1279	74.0707	73.7121	72.9791	71.8809	70.6906	69.412	68.1794
4	76.677	77.5757	77.532	77.4184	77.357	76.9289	76.1313	74.8779	73.6836	72.5761	71.5865
5	81.1425	81.1587	81.0753	80.8848	80.7789	80.3263	79.5051	78.2253	76.8065	75.5849	74.5264
6	84.8791	84.9956	84.6452	84.3175	84.1881	83.7344	82.8894	81.5563	80.0535	78.7149	77.4575
7	88.8944	88.8582	88.2503	87.7925	87.623	87.0589	86.1468	84.77	83.2413	81.7574	80.3445
8	92.7244	92.3803	91.744	91.2643	91.0518	90.3088	89.5464	88.1294	86.486	84.775	83.2513
9	96.5824	95.8548	95.1192	94.6134	94.3868	93.6385	92.9212	91.2943	89.3501	87.6171	86.1602
10	100.22	99.5488	98.7432	98.1112	97.8356	96.9635	96.1689	94.6354	92.5721	90.4833	88.6109
11	103.652	102.797	101.999	101.424	101.171	100.296	99.4163	98.1974	96.066	93.7841	91.514
12	107.524	106.341	105.357	104.644	104.355	103.508	102.64	101.697	99.6122	96.8934	94.2563
13	111.456	110.406	109.198	108.37	108.027	106.904	105.934	104.847	102.313	99.7589	96.6639
14	114.699	113.572	112.502	111.562	111.174	110.018	108.537	106.738	104.209	101.619	98.8112
15	117.262	116.182	114.78	113.563	113.077	111.643	109.709	107.573	105.374	102.875	100.666
16	119.585	117.944	116.279	114.974	114.394	112.414	110.421	108.353	106.349	104.336	102.452
17	121.134	119.002	116.899	115.498	114.908	112.945	111.082	109.199	107.308	105.579	104.446
18	121.123	119.144	117.201	115.837	115.276	113.509	111.741	110.012	108.165	106.856	105.984
19	120.748	119.114	117.382	116.157	115.652	114.028	112.376	110.695	109.158	107.909	107.286
20	120.374	119.033	117.48	116.425	115.983	114.413	112.775	111.323	110.049	109.078	108.478
21	120.06	118.895	117.487	116.519	116.123	114.746	113.286	112.093	111.087	110.246	109.676
22	119.953	118.765	117.39	116.588	116.259	115.078	114.048	112.96	112.144	111.425	111.039
23	119.75	118.537	117.332	116.772	116.548	115.628	114.775	113.977	113.287	112.923	112.782
24	119.706	118.494	117.338	116.816	116.915	116.418	115.718	115.057	114.613	114.633	114.615
25	119.514	118.39	117.477	117.057	117.479	117.151	116.84	116.479	116.347	116.315	116.318
26	119.348	118.564	117.969	117.609	118.406	118.276	118.303	118.27	118.338	118.344	118.091
27	119.64	119.089	118.664	118.469	119.56	119.718	119.885	120.052	120.156	120.163	119.851
28	120.297	119.896	119.588	119.54	120.955	121.236	121.447	121.518	121.518	121.494	122.527

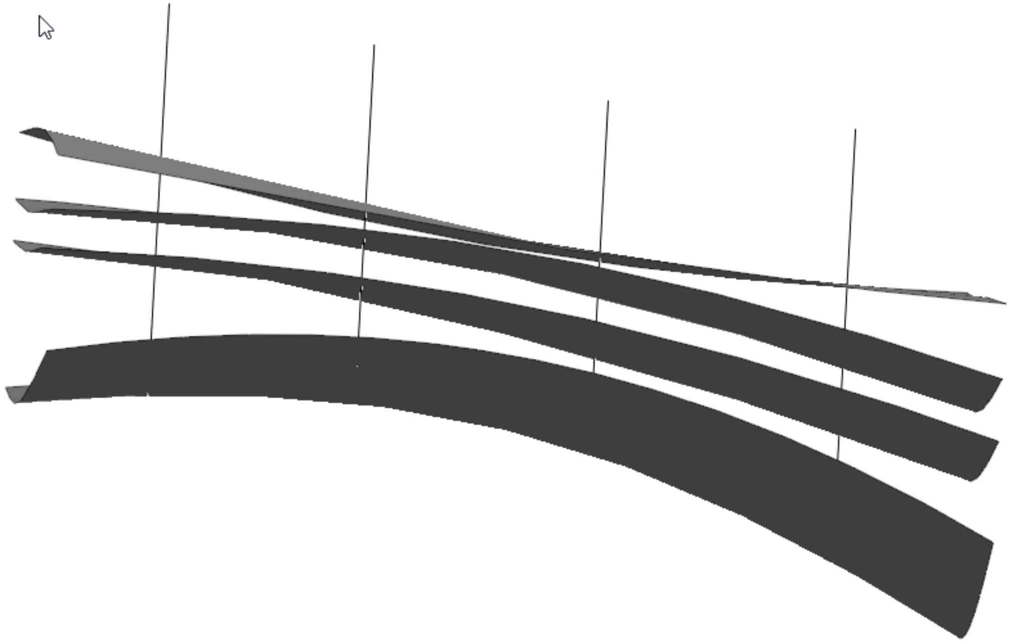
Load... Save As... OK Close



Bedding Plane Wizard



Directly import borehole log data to create stratified soil/rock layers.



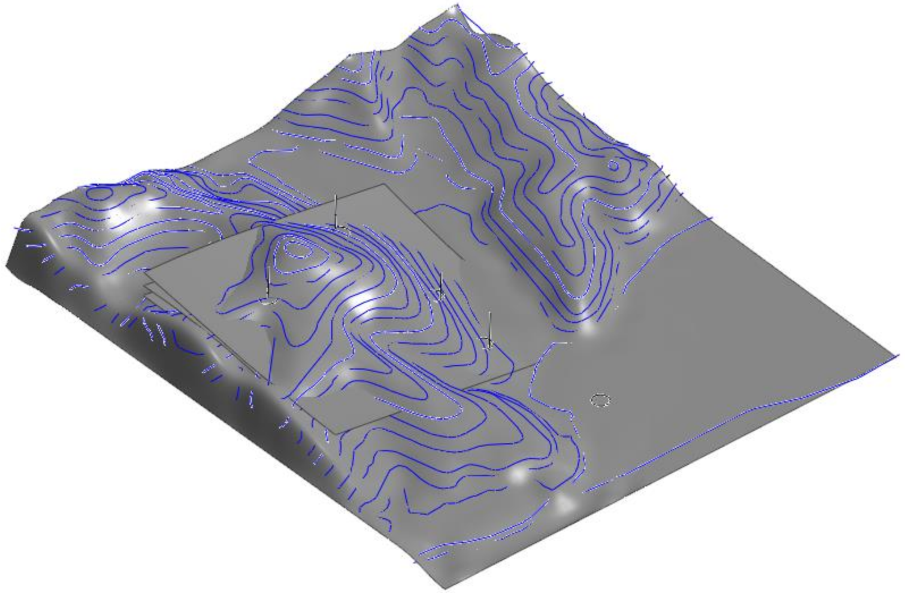
Soil Stratigraphy Layers (2D Surfaces)

Excel files can also be used for large data sets.

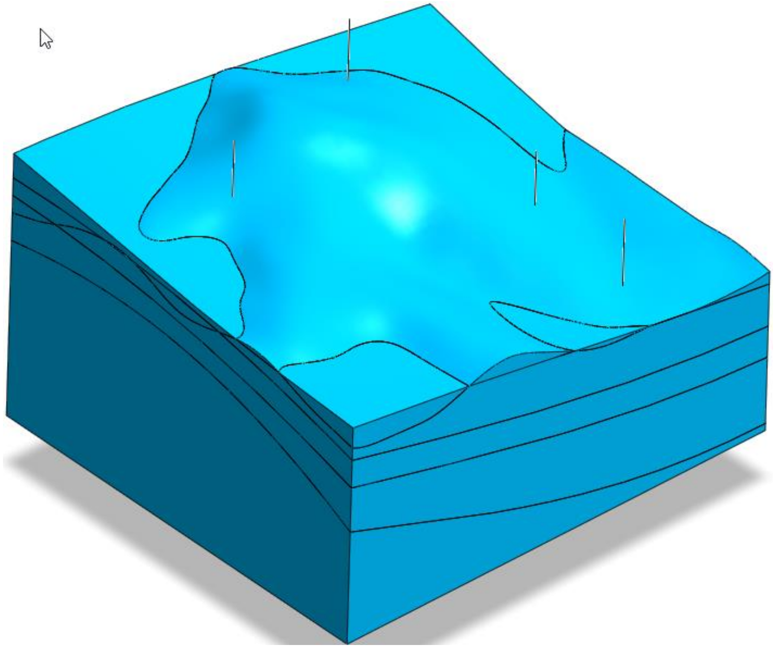
Concept To Reality

Using TGM & Bedding Plane Wizard To Generate 3D Models

Investigation Area

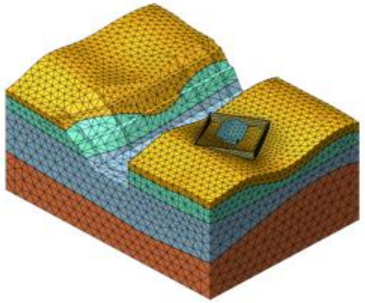


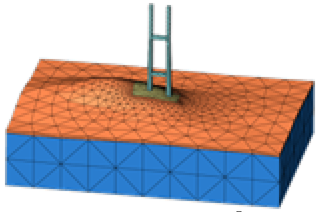
Ground Surface Profile (Borehole Data + Surface Topography)



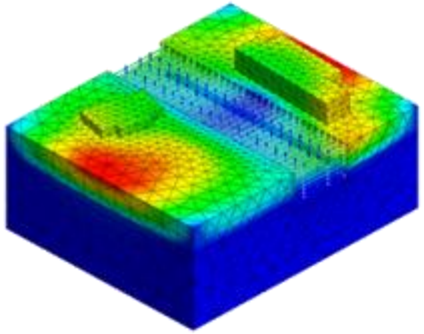
3D Model Ground Profile

All-in-One FEM based 3D Geotechnical Analysis Software

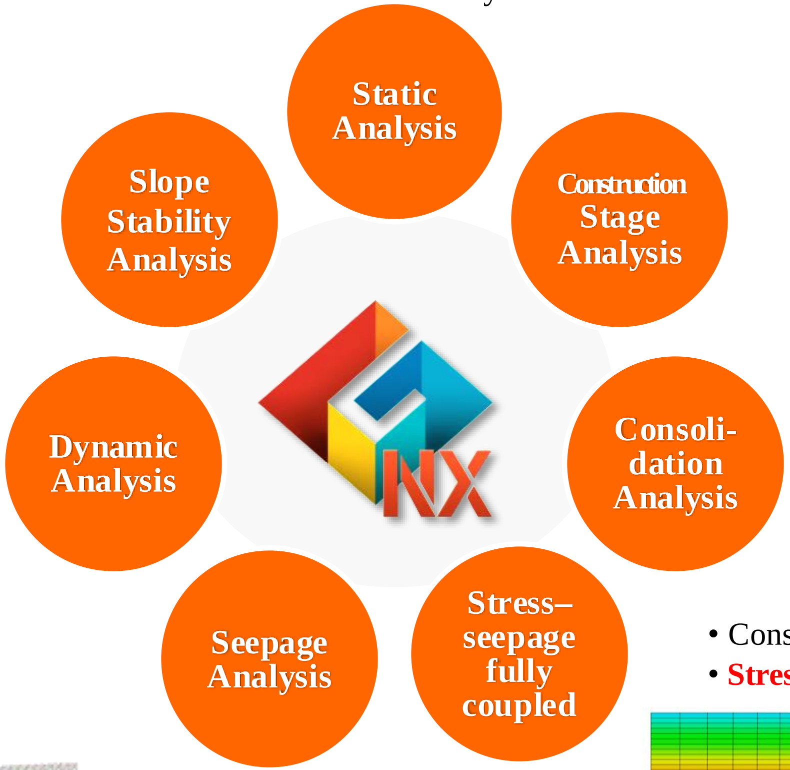




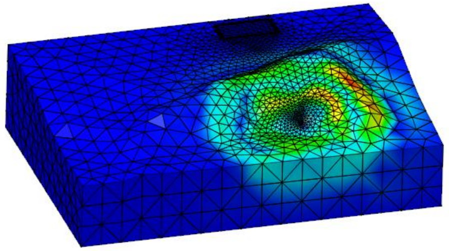
- Linear Static analysis
- Nonlinear Static analysis

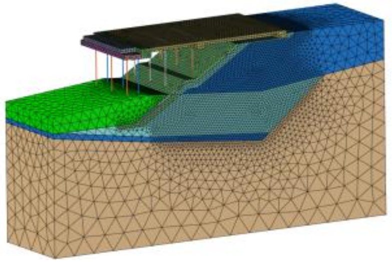


- Strength Reduction Method (SRM)
- Stress Analysis Method (SAM)
- Construction stages Slope stability (SRM/SAM)



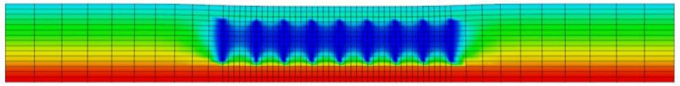
- Stress (drained/undrained) analysis
- Seepage analysis for each stage
- **Stress-seepage- slope coupled**
- Consolidation analysis for each stage
- **Fully coupled stress & seepage**
- **Thermal stress Analysis**

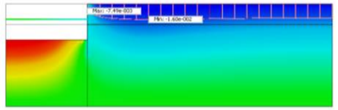


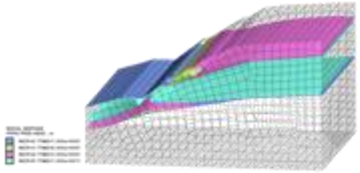


- Eigenvalue/Response Spectrum analysis
- Linear Time History (mode/direct methods)
- **Nonlinear Time History analysis**
- 1D/2D Equivalency Linear analysis
- **Nonlinear time history + SRM Coupled**

- Consolidation Analysis (coupled with SRM)
- **Stress–seepage fully coupled analysis**

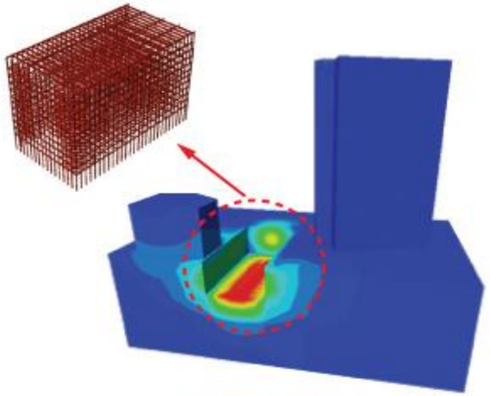




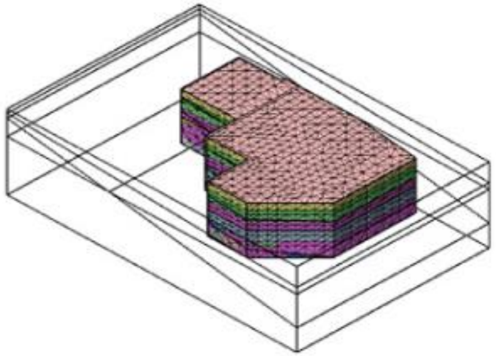


- Steady state seepage analysis
- Transient seepage analysis

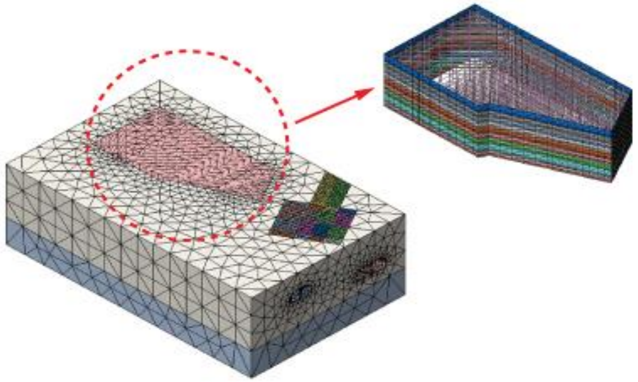
Excavation & Temporary Structures



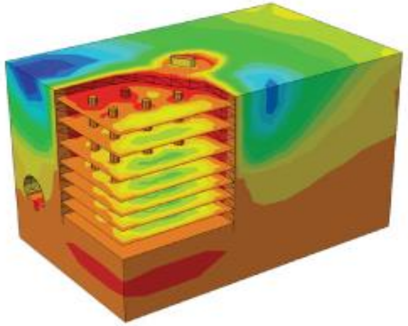
Subway station
(H-Pile+slurry wall)



Diaphragm Wall

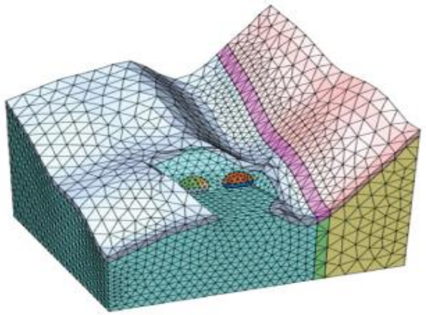


Temporary structure for foundation
of high-rise building



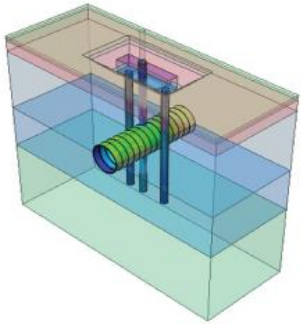
Stress distribution of subway line
and ventilation shaft by excavation

Tunnel

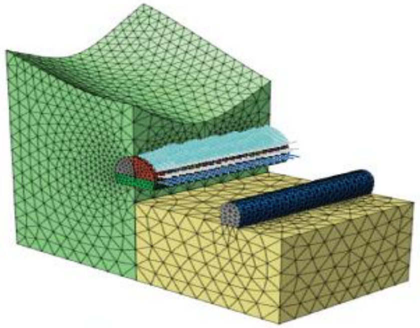


Portal with fault fractured Zone

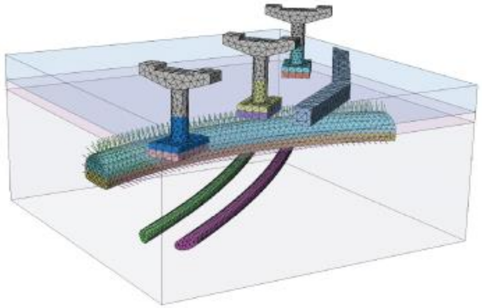
Ventilation Shaft
(vertical/horizontal)



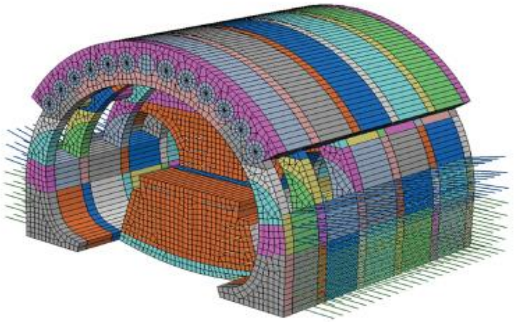
Shield TBM



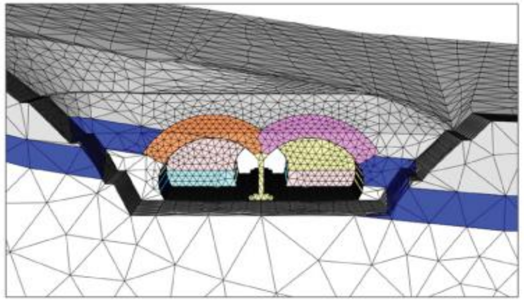
Steel Pipe Reinforced Step Grouting



Adjacent Structures

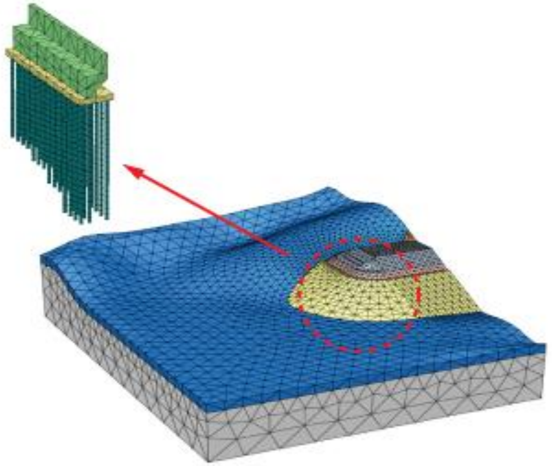


TRcM/CAM (Subway tunnel)

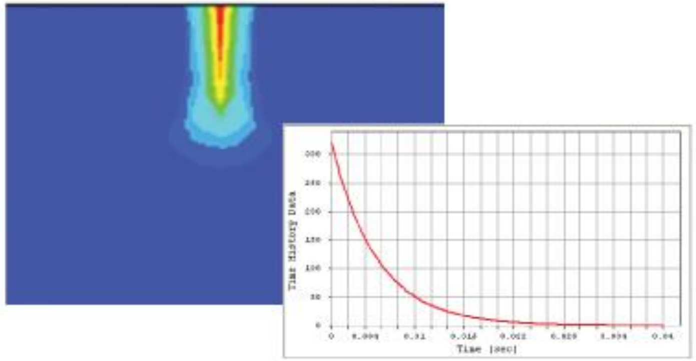


2-Arch Tunnel (NATM method)

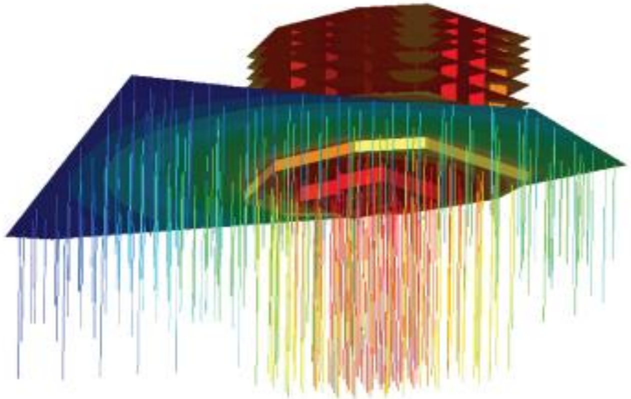
Foundations



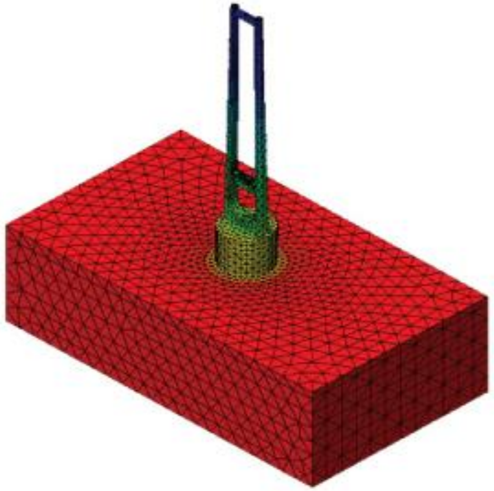
Foundation(Pier)



Driven Pile

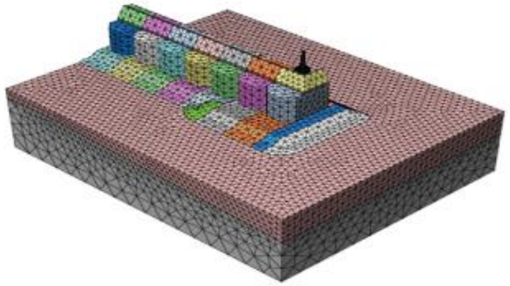


Raft Foundation

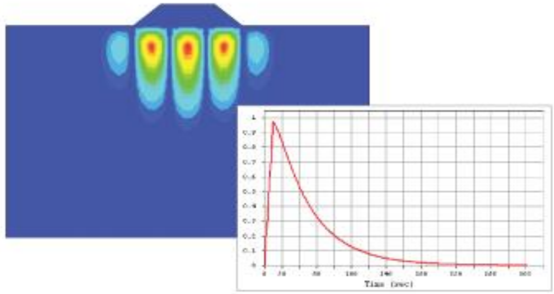


Well Foundation

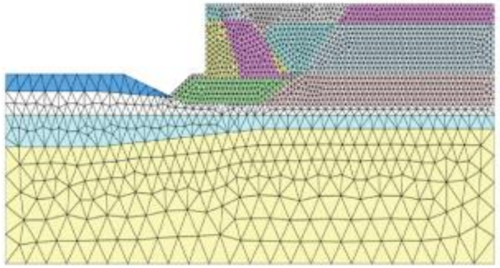
Ground Improvement



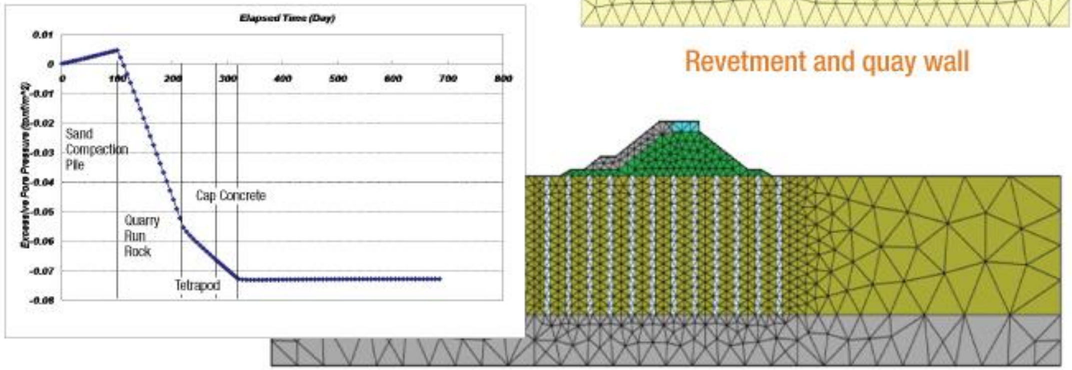
Breakwater



Vertical Drainage(PBD)

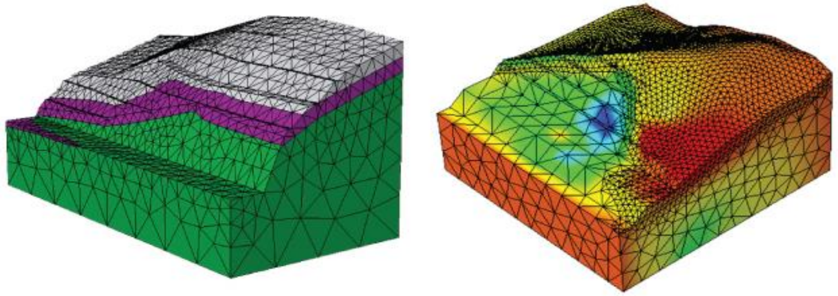


Revetment and quay wall

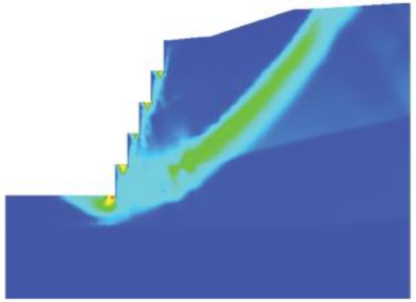


Consolidation analysis for
SCP drainage system in soft clay

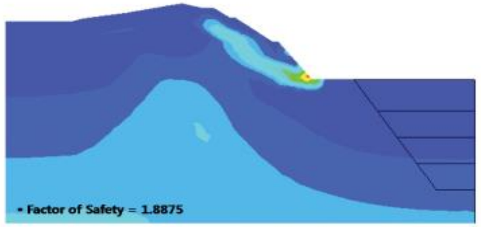
Slopes Stability Analysis



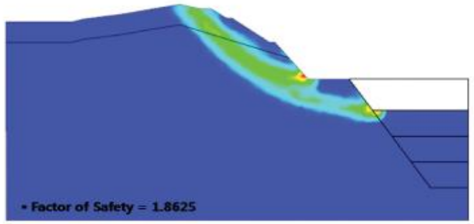
3D Slope Stability Analysis



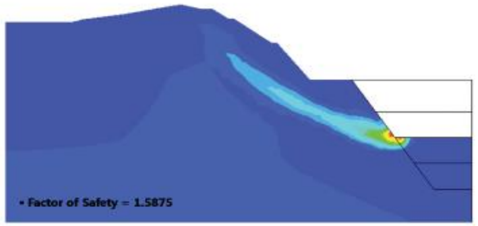
Slope stability considering earth retaining structures



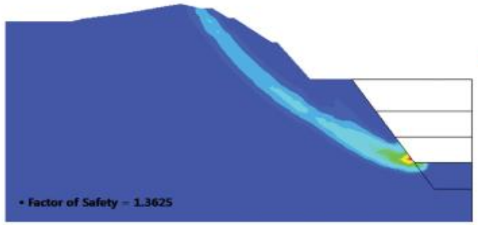
In-situ State



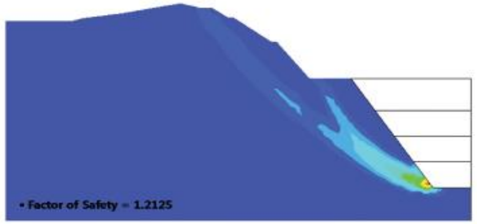
1st excavation



2nd excavation

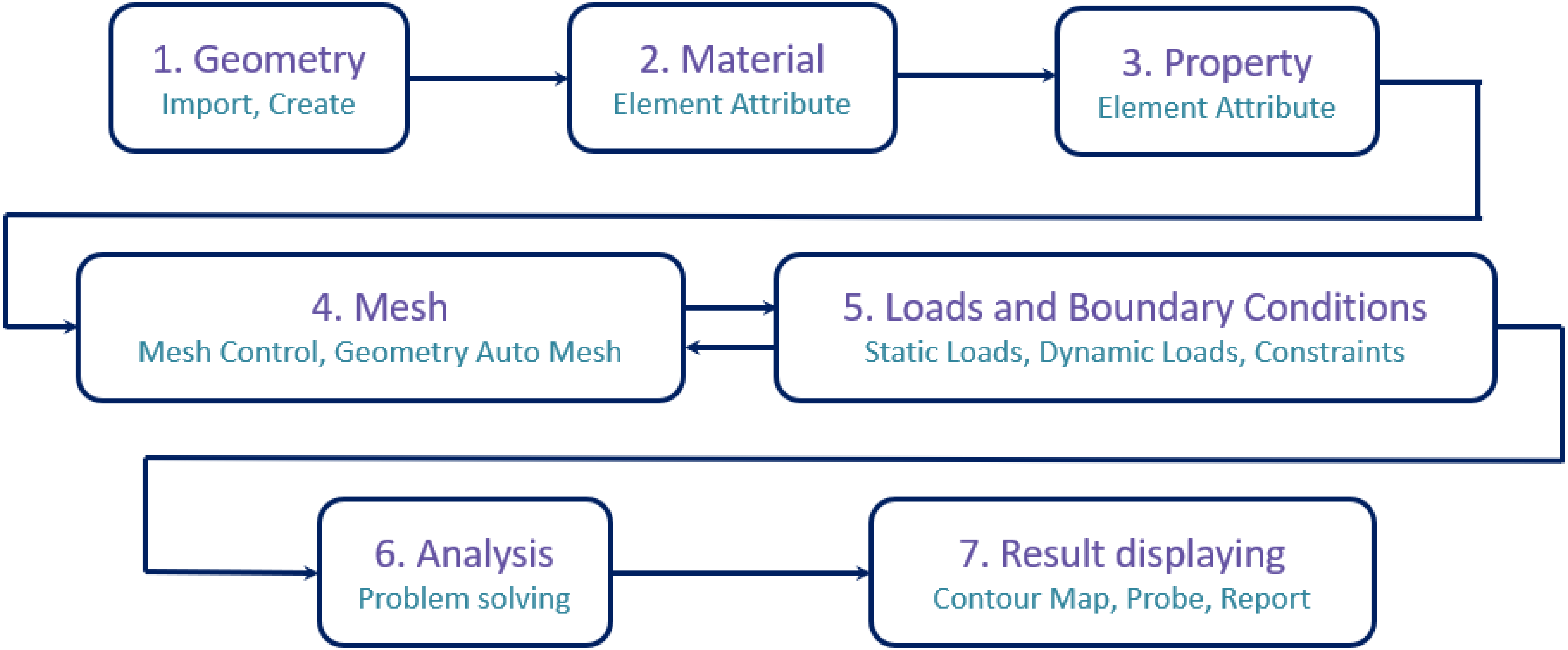


3rd excavation

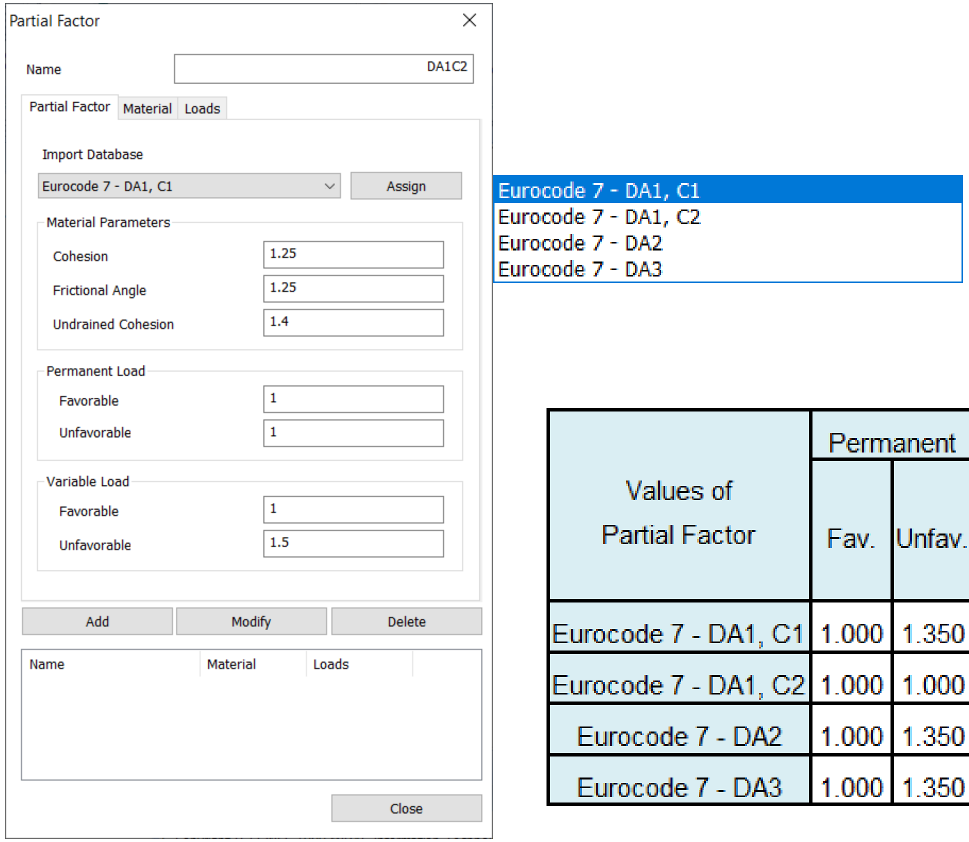


Last state

Modelling Methodology



Advanced Features: Partial factors



- **DA1, C1**: Partial factor will apply to load only.
- **DA1, C2**: Partial factor will apply to load and soil material.
- **DA2**: DA2 is similar with DA1, C1. But, the factors for pile and footing are different.
- **DA3**: DA3 is similar with DA1, C2. But, the factor for load (Unfavorable under Variable) is different

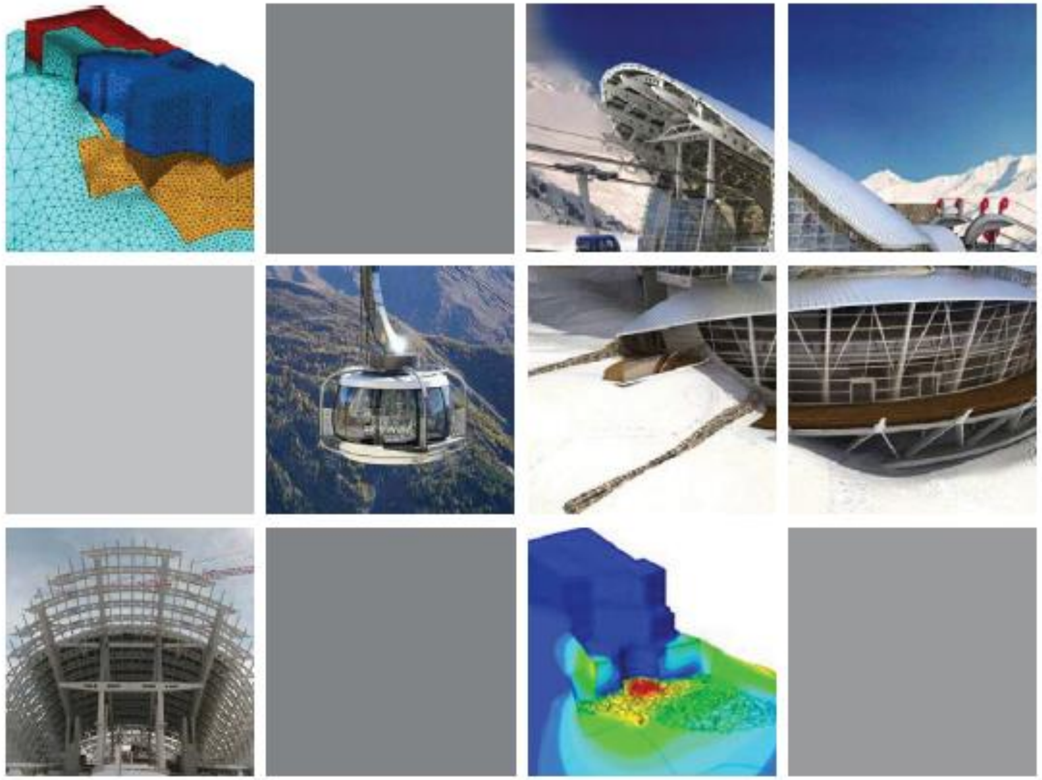
Values of Partial Factor	Permanent		Variable		Soil		
	Fav.	Unfav.	Fav.	Unfav.	Effective Cohesion (c)	tan Φ'	Undrained Strength (su)
Eurocode 7 - DA1, C1	1.000	1.350	1.000	1.500	1.000	1.000	1.000
Eurocode 7 - DA1, C2	1.000	1.000	1.000	1.300	1.250	1.250	1.400
Eurocode 7 - DA2	1.000	1.350	1.000	1.500	1.000	1.000	1.000
Eurocode 7 - DA3	1.000	1.350	1.000	1.500	1.250	1.250	1.400

PROJECT ACCOMPLISHMENTS

Skyway Monte Bianco
- Funivia del Monte Blanco

Courmayeur, Italy

Owner	Funivie Monte Bianco AG
General Contractor	Cogeis
Engineering Consultant	Holzner & Bertagnolli Engineering
Architecture	Studio Progetti
Design	Dimensione Ingenierie
Construction Period	2010 - 2015
Project Type	Aerial Lift
Main features in modelling	- Rock excavation stability on top of the mountain - Tensile variations of the existing tie rods cableway
Description on this project	The cable car in Aosta Valley, at the entrance to the Mont Blanc tunnel, leads from Courmayeur to 1,200m above sea level. The new cable car valley station is being built near an existing station, as well as a restaurant which must remain operational. A 3D FEM analysis was required to analyze the interaction of the new construction and current adjacent structures.

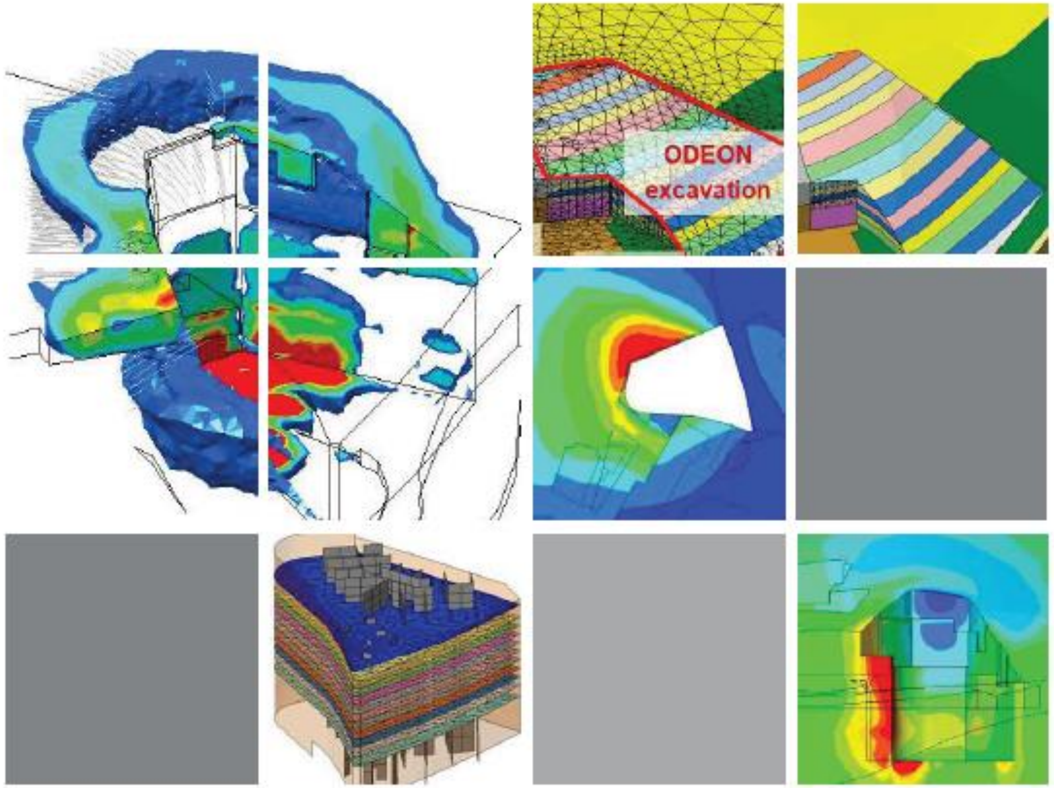


Odeon Tower

Mona

TRACTEBEL
ENGIE

Owner	Group Marzocco
General Contractor	Vinci Construction France
Engineering Consultant	Coyne et Bellier
Architecture	Alexandre Giraldi
Construction Period	2010 – 2015
Project Type	Office Building
Size of the Structure	170m Height (49-Story)
Main features in modelling	- Assessment of ground movements especially at adjacent building foundations - Deep excavation in a sloping site and retaining system (especially arching effects on the uphill side)
Description on this project	The Odeon Tower is a double – skyscraper in the Principality of Monaco. It was the first high-rise in the city to be built since the 1980s. But high-rise constructions had been abandoned due to aesthetic concerns and criticism of over-development. 3D model of excavation and construction sequence was necessary to ensure adjacent school buildings will not be affected.

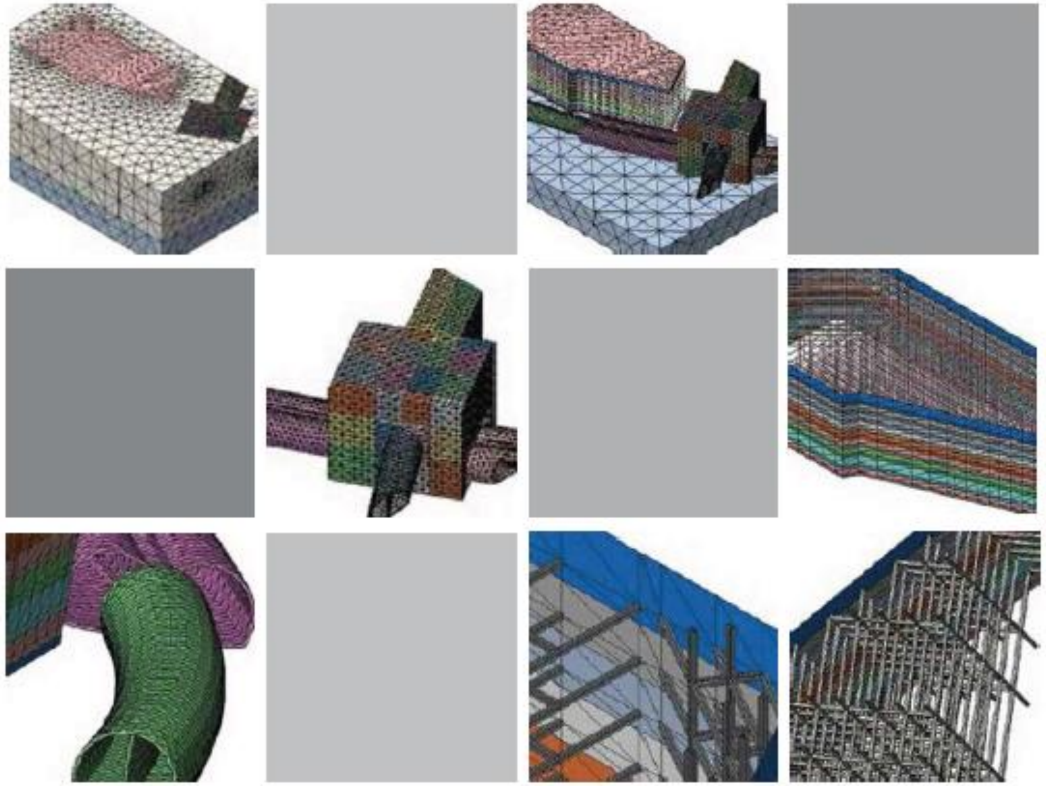


Subway Impact Assessment

- Minam Complex Construction

Busan, Korea

JIN YOUNG CONSULTANTS CO., LTD



Design for Construction

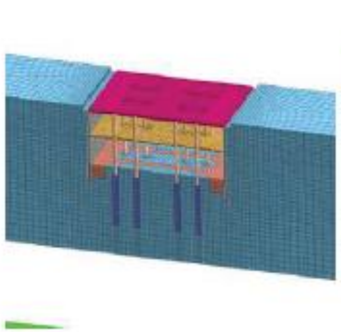
Investigation of existing subway structure subjected to excavation for new building construction.

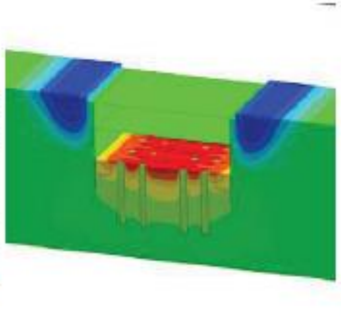
Overview

Safety investigation for 2-Arch tunnels and 1-Arch type tunnel where a large-scale excavation for a new building foundation takes place with temporary shoring within close proximity.

Deep Excavation
Pile Foundation

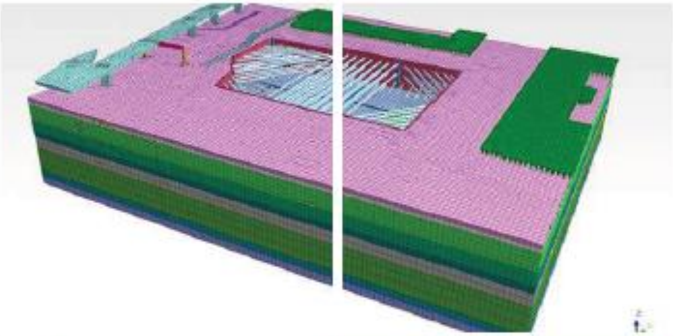
A construction stage analysis was used to design the complex foundation, which is a combination of piled raft and retaining walls with a thickness of 1m and depth of 36m. There is a three-story underground structure of rectangular shape with dimensions in the plan of 170.5m x 58m. Vertical bearing structures are steel columns, which are supported by piles with a diameter of 2m and a depth of 51m.

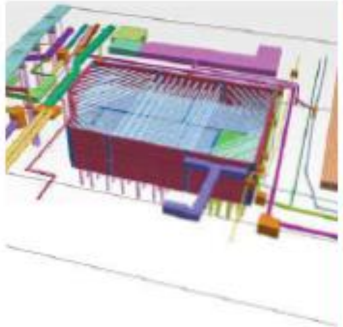


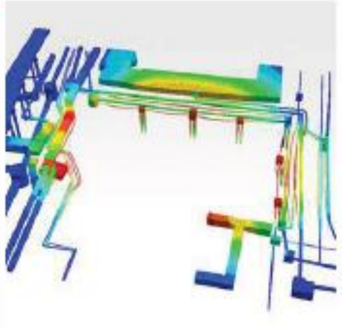


Deep Excavation
Effect of Adjacent Structure

A 3D FEM analysis was used to calculate the impact on surrounding buildings and a network of pipelines during the excavation and construction of multi-functional complex with deep pile foundation.







PROBLEM STATEMENT

Excavation Area 10mx20m
Excavation Depth 10m

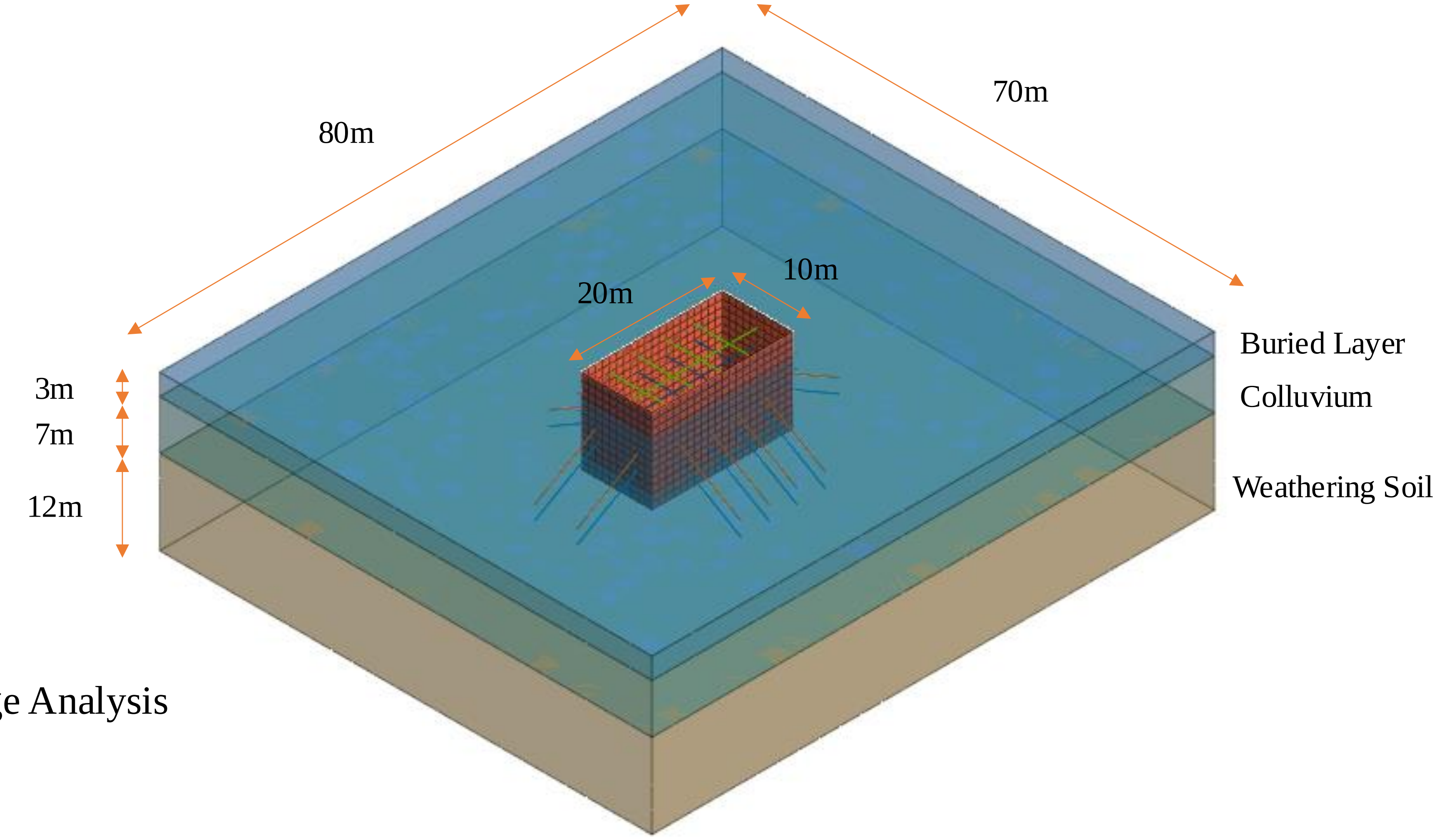
Supports Of Excavation:

Sheet Pile Wall Height 12m
Thickness 10cm

Strut H Section 300x300x10/15

Anchor Diameter 0.025m

Non-Linear Static Construction Stage Analysis



LET’S START MODELLING

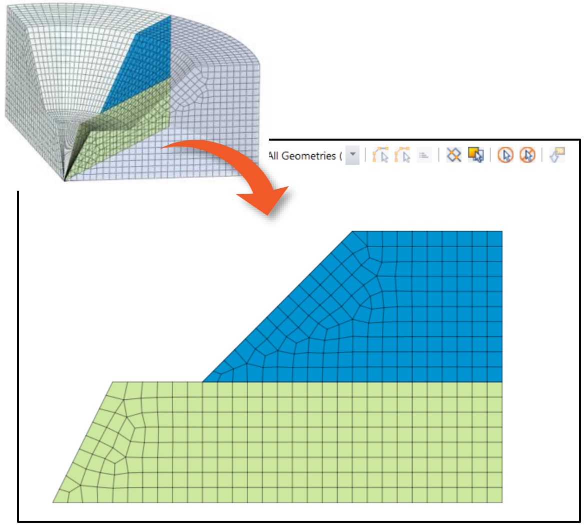
2. TUNELLING
MODELLING AND ANALYSIS

CONTENTS

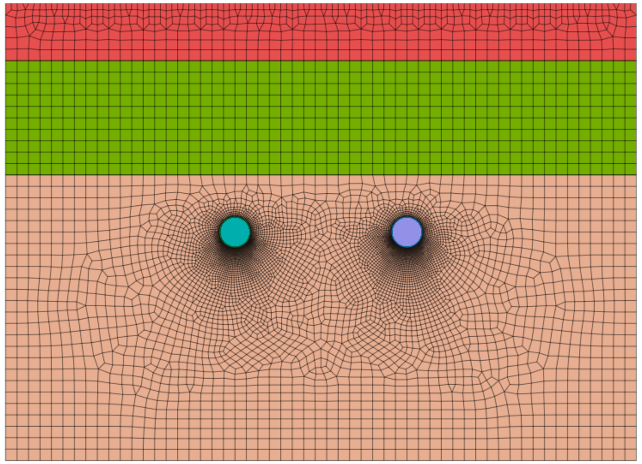
Session 2. TUNELLING

1. GTS NX Introduction
2. Analysis Capabilities
3. Project Accomplishments
4. Problem Statement

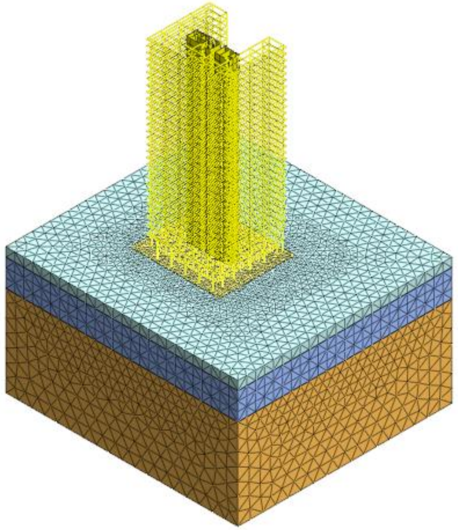
GTS NX is a Finite Element Analysis platform which can be used to deal with all types of Geotechnical Applications



Axisymmetric



2D Modeling

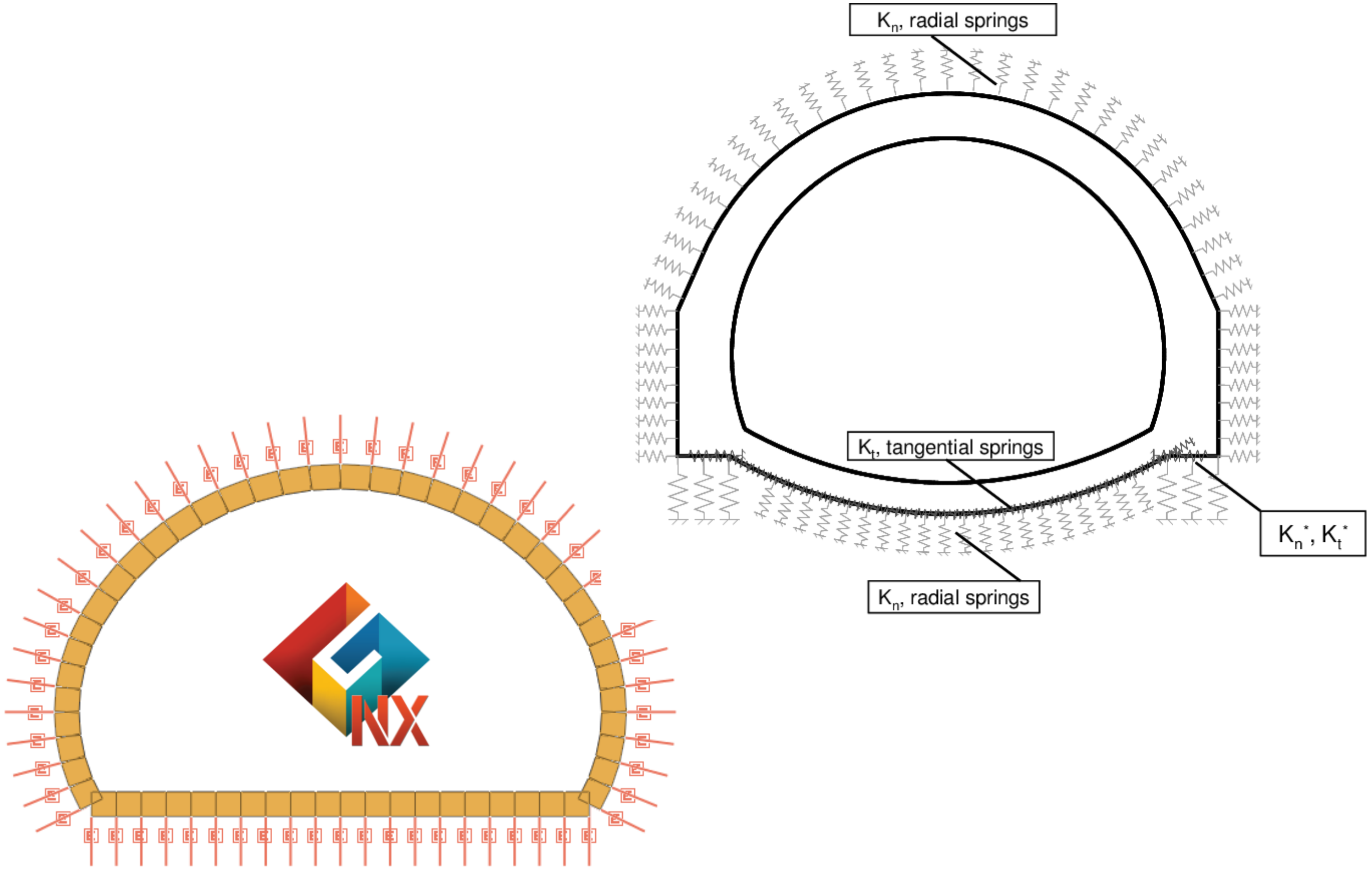


3D Modeling

GTS NX ANALYSIS CAPABILITIES

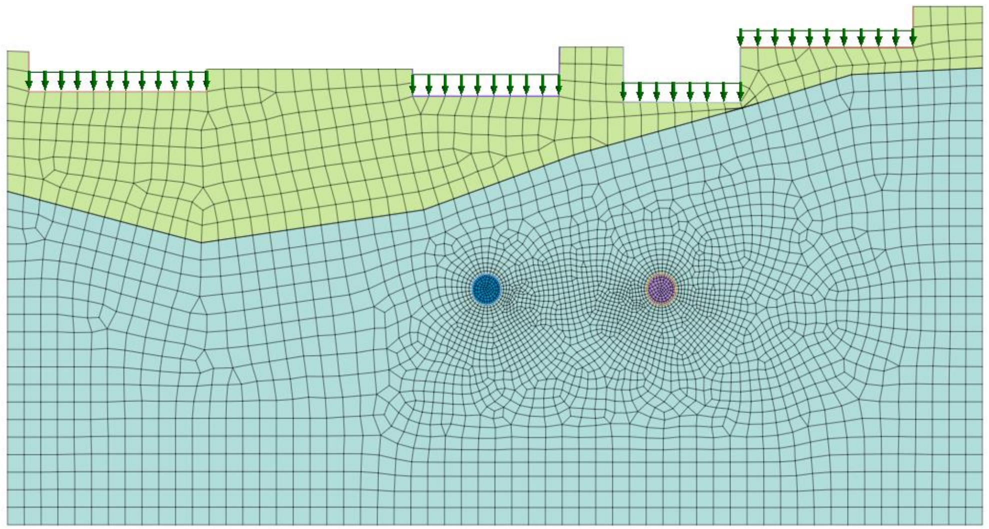
Tunnel Modelling Approaches

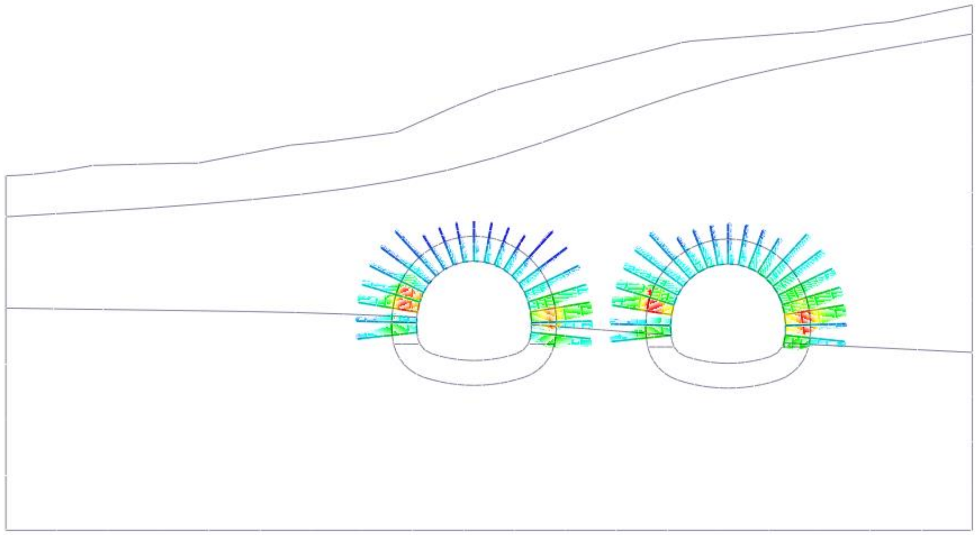
- Lining and Soil as Spring
- 2D Modelling
- 3D Modelling



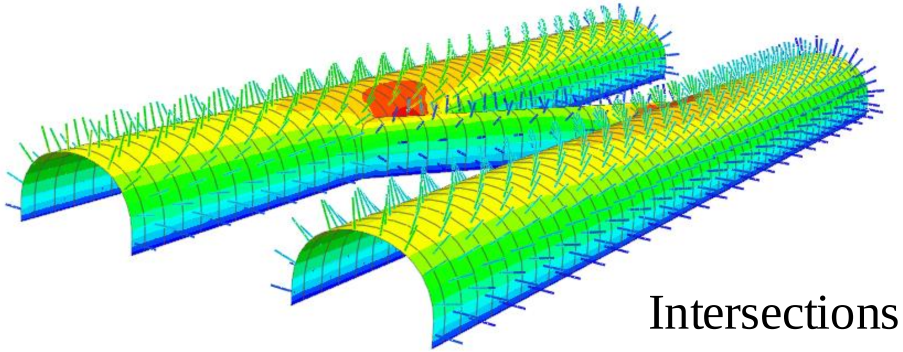
Lining and Soil as Spring Approach

2D Modelling-Plain Strain Condition

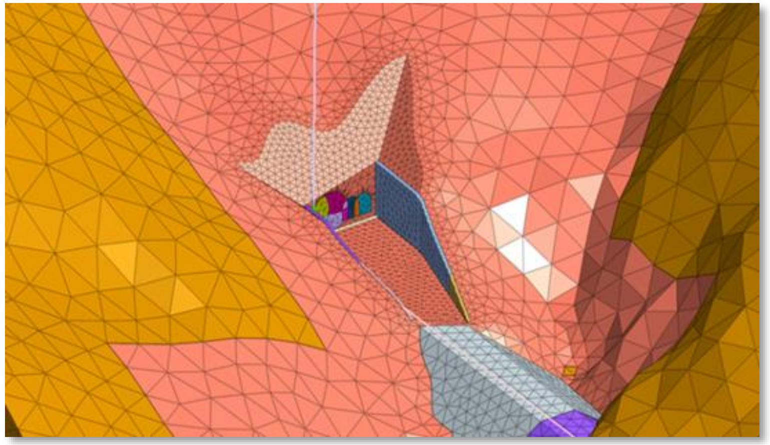




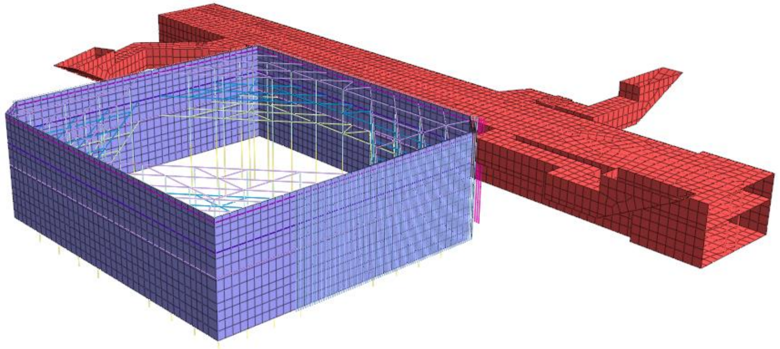
3D Modelling



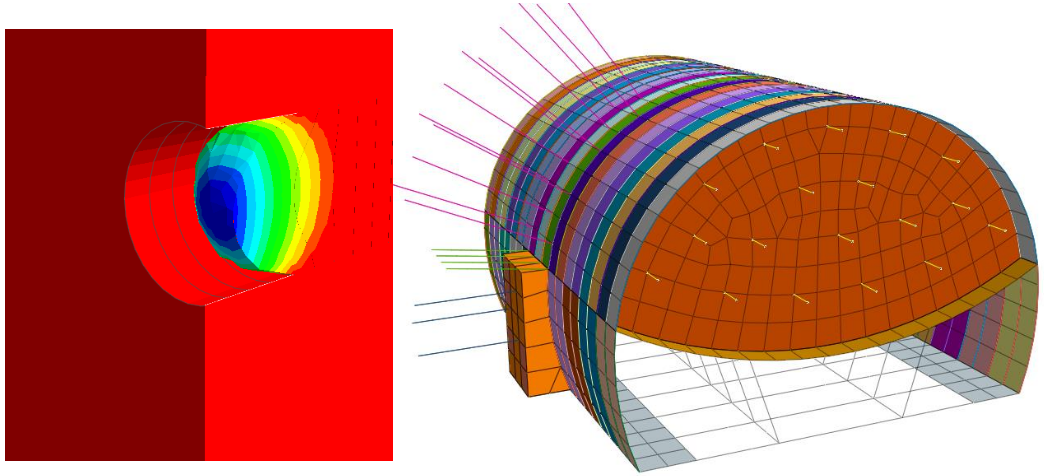
Intersections



Tunnel Portals

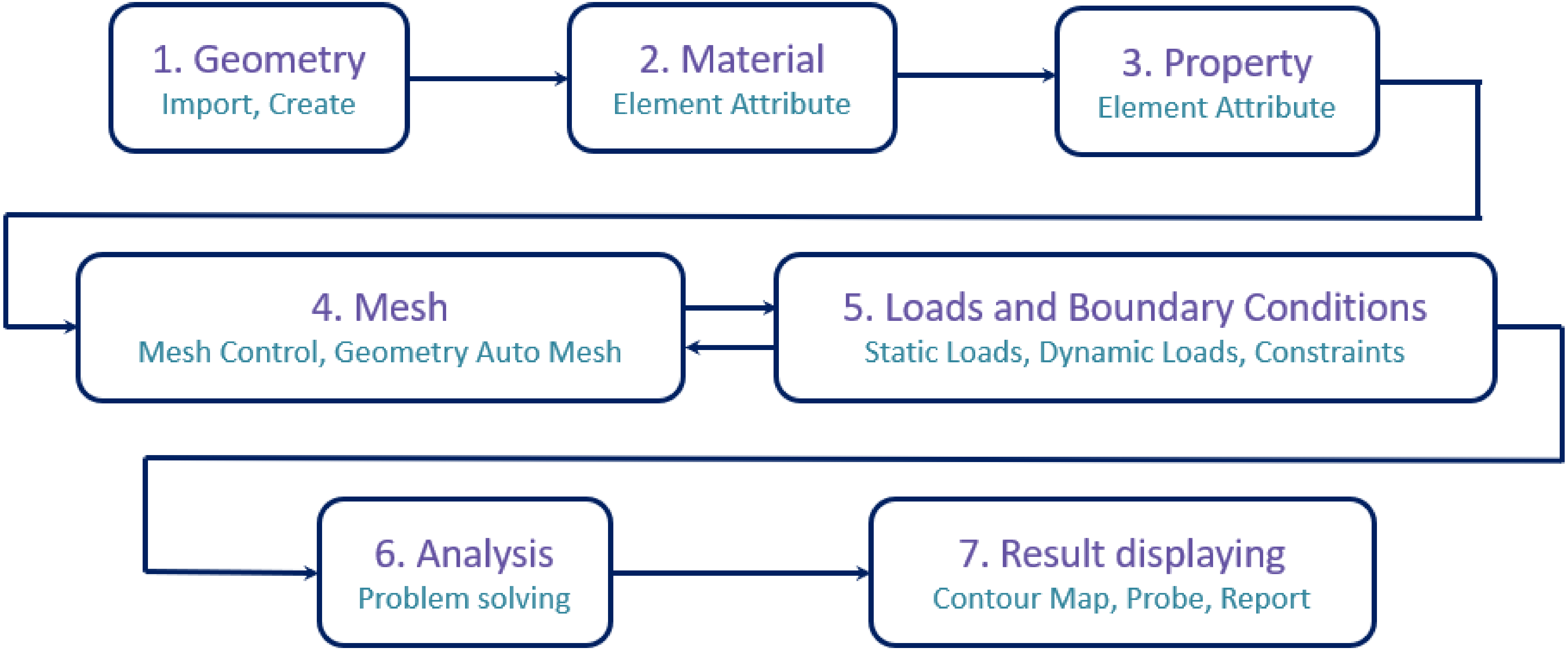


Metro Structures

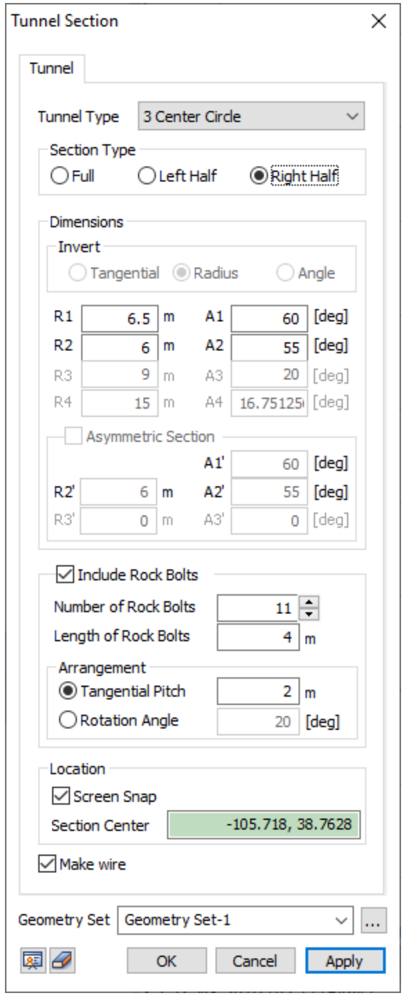


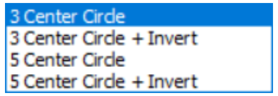
Tunnel Face Stabilization

Modelling Methodology

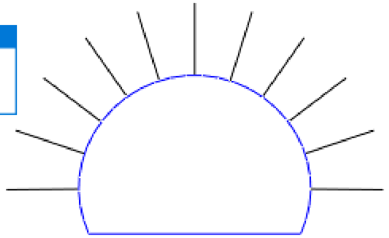


Tunnel Section Drawing

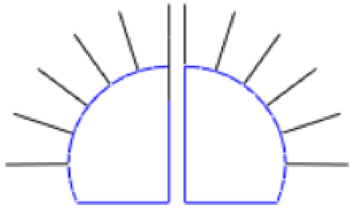




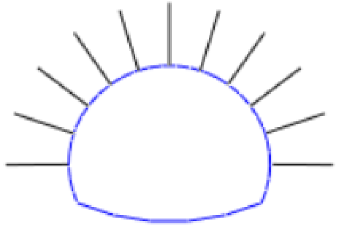
Easily create 2D Tunnel + Bolting pattern wireframes from scratch.



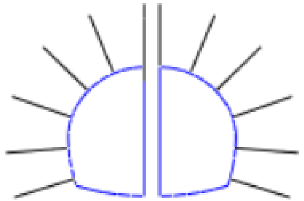
Tunnel + Bolts



Half Tunnel + Bolts



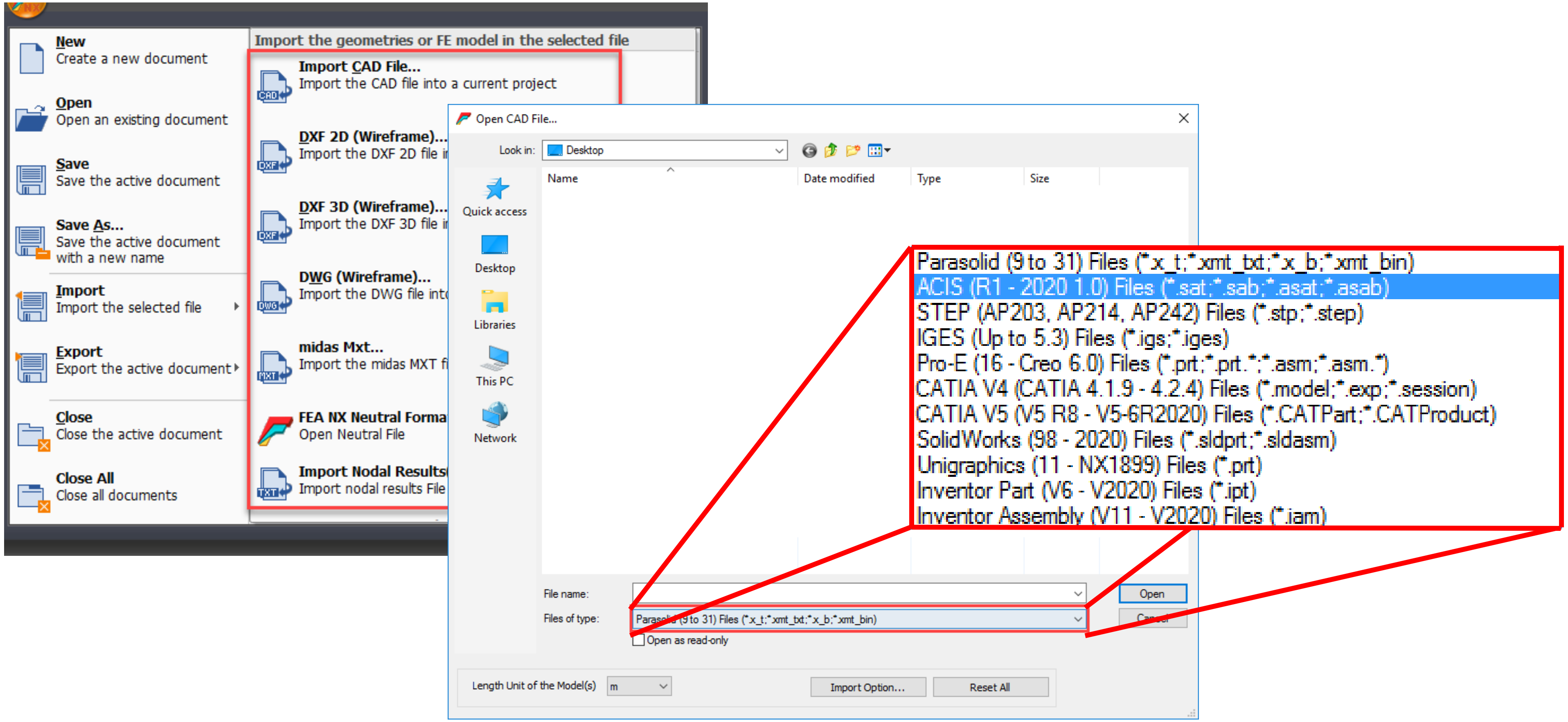
Tunnel + Invert + Bolts



Half Tunnel + Invert + Bolts

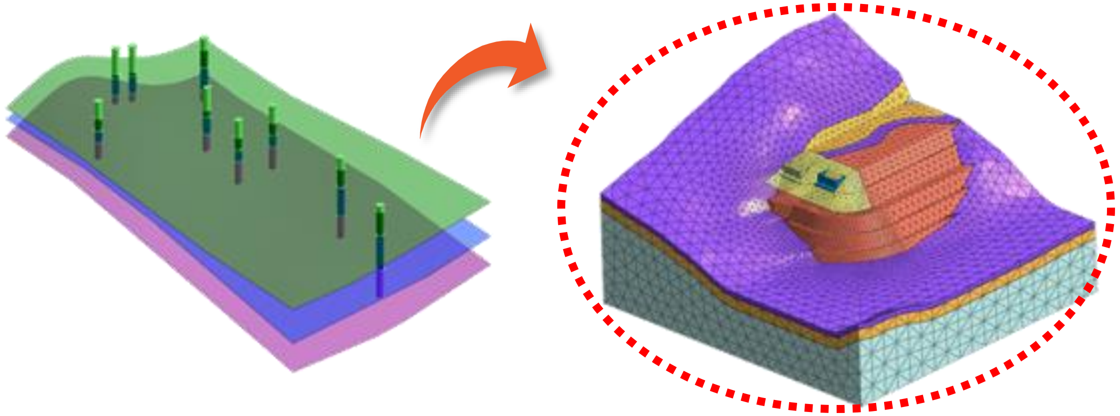
Also Define The Bolts Tangential Pitch And Orientation Directly

Supported CAD Formats

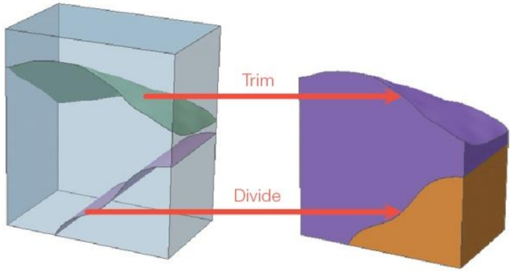


Interactive Geometry Modelling Tools

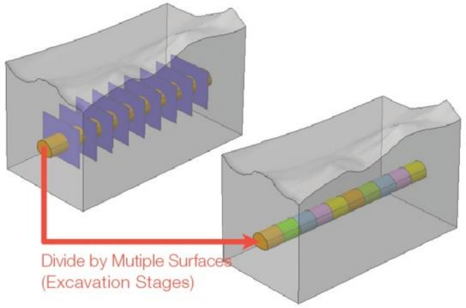
- **Borehole excel data import (Bedding plane wizard):** Automatically generate 3D geological stratum through actual field data.



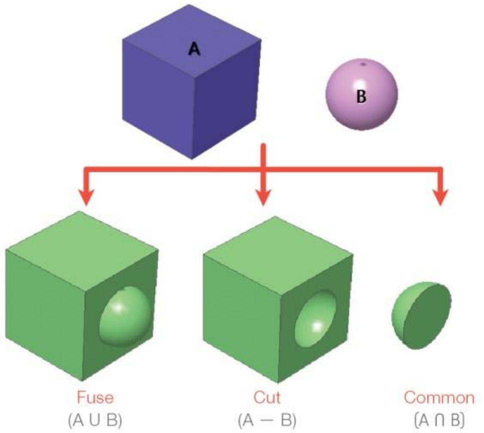
- **Other advanced modelling features:** Facilitate the creation of complex geometries.



Trim / Divide ▲



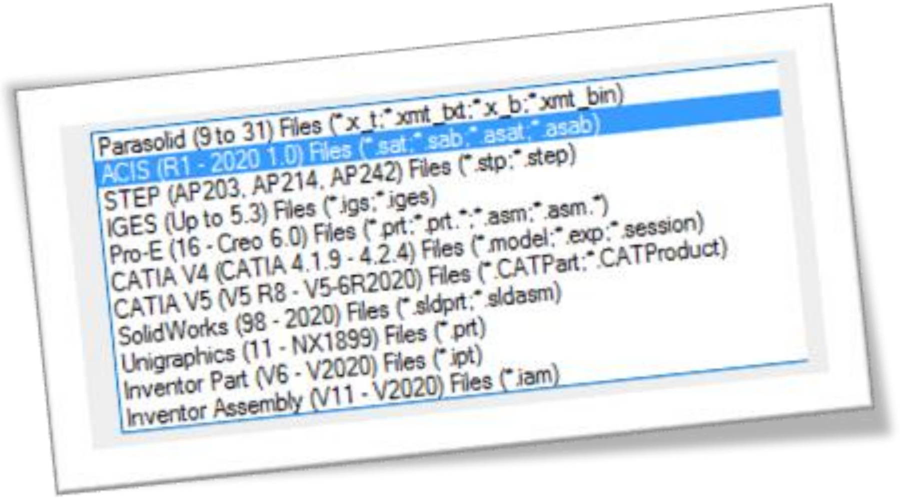
Divided (define excavation stages) ▲



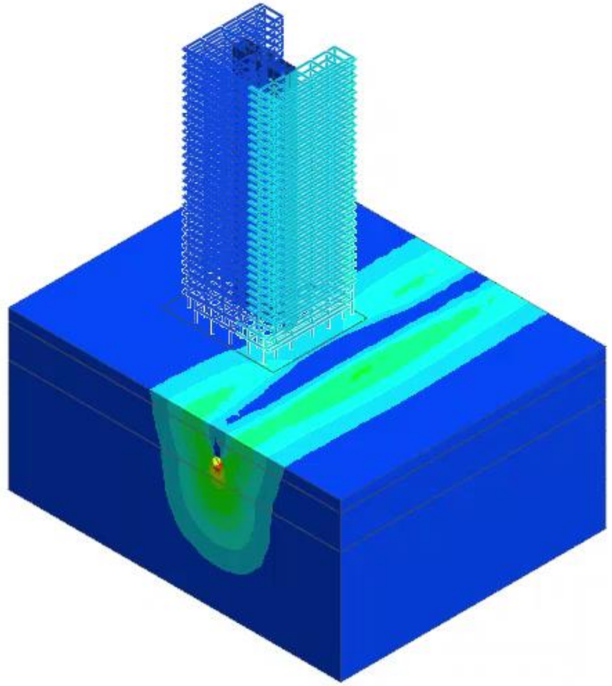
Boolean Operation ▲

Interoperability

CAD import: Import advanced geometry directly into GTS NX. Supports ".dwg" and ".dxf" files including other file formats.



Interoperability: Import superstructure data directly from Midas Civil and Midas Gen to perform SSI analysis.



Effect of Tunnelling on Surrounding Structures and Vice Versa

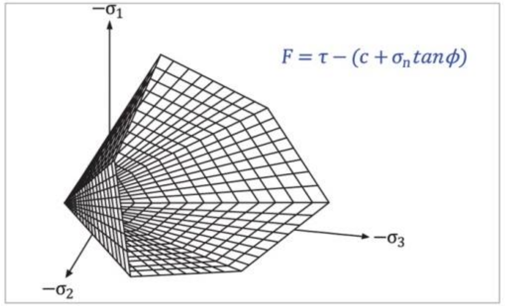
Material Models & Functions

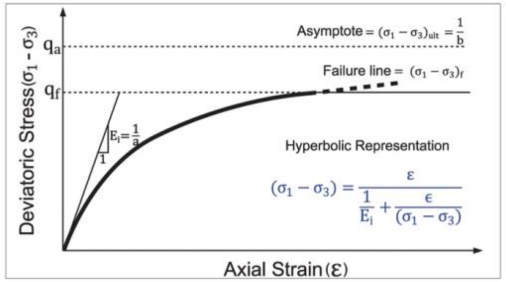
Elastic Materials

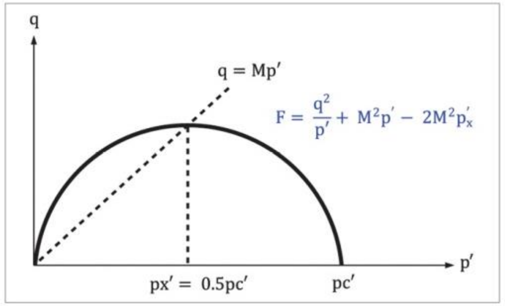
· Linear Elastic Isotropic
· Linear Elastic
· Transversely Isotropic
· Interface Elastic
· Nonlinear Elastic (1D)
· Jardine
· D-Min
· Hyperbolic (Duncan-Chang)

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

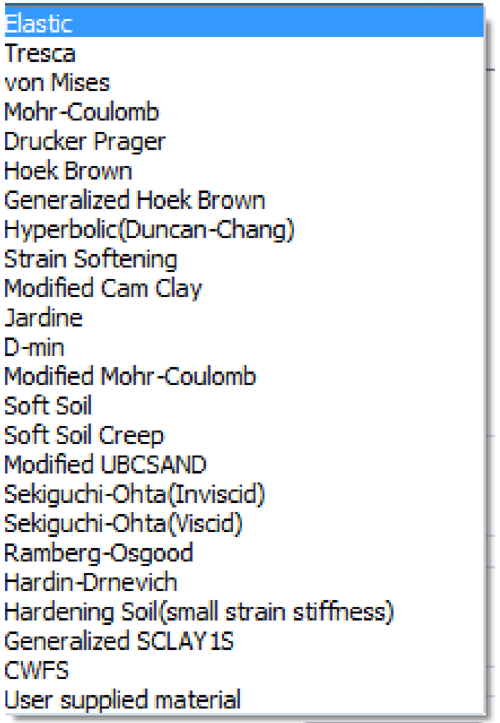
· Effective Stiffness / Effective Strength
· Effective Stiffness / Undrained Strength
· Undrained Stiffness / Undrained Strength

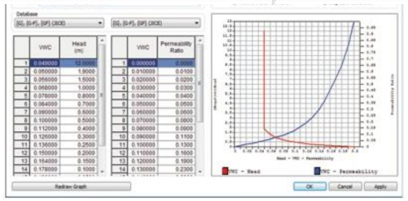
Functions

· 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)

Orthotropic

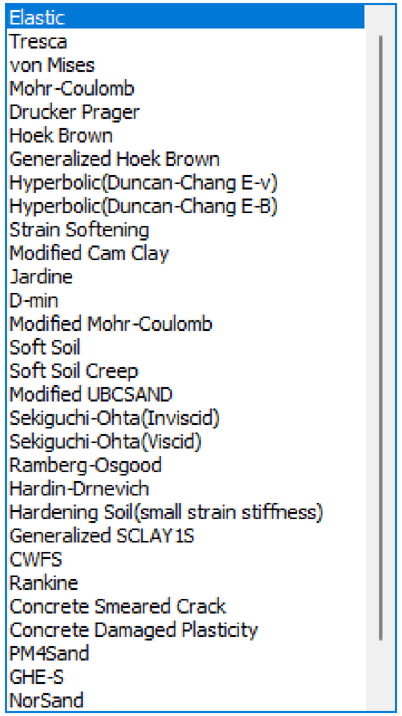
- Transversely Isotropic
- Jointed Rock Mass
- 2D Orthotropic
- Geogrid

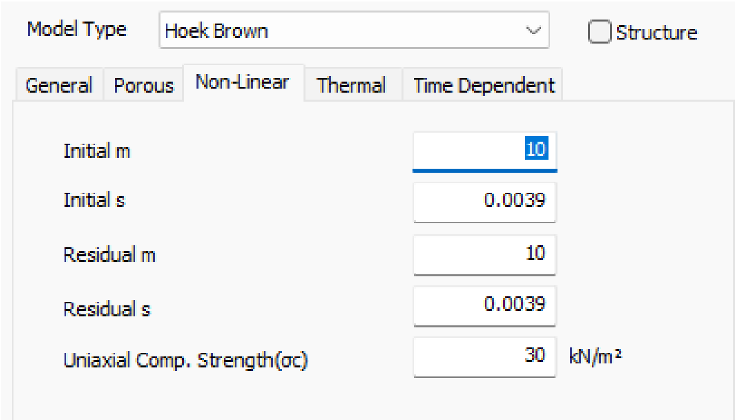


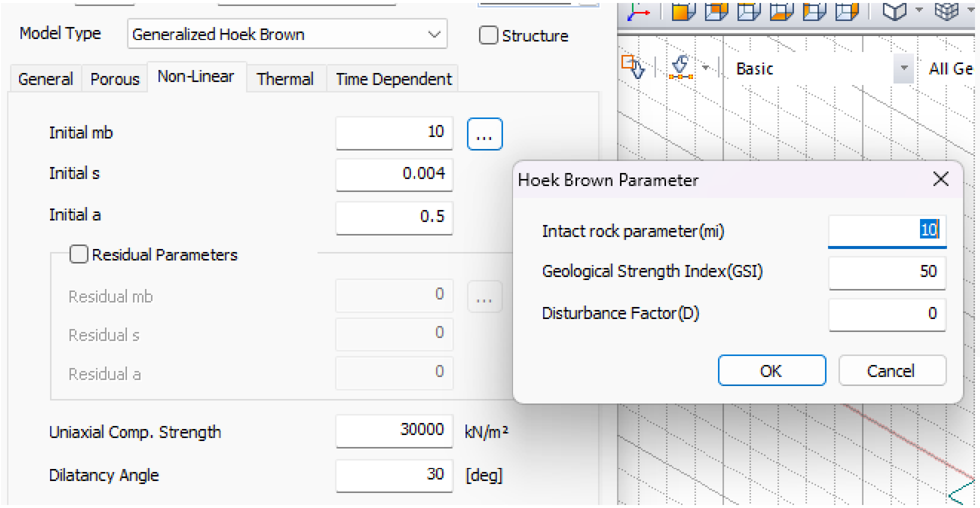


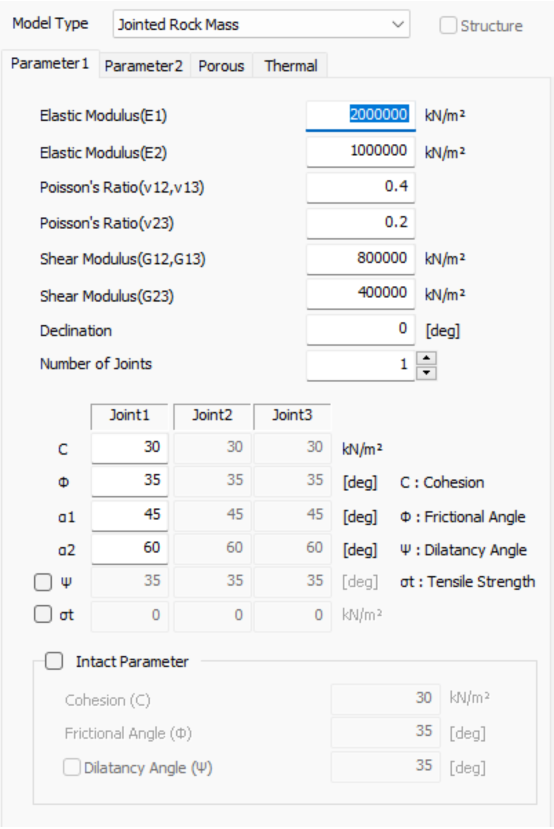
Unsaturated property (Relation) ▲

Material Models & Functions









Rocks Behaviour and Joints Modelling

Element Library

1D

Geogrid(1D)
Plot only(1D)
Truss
Embedded truss
Beam
Pile

2D

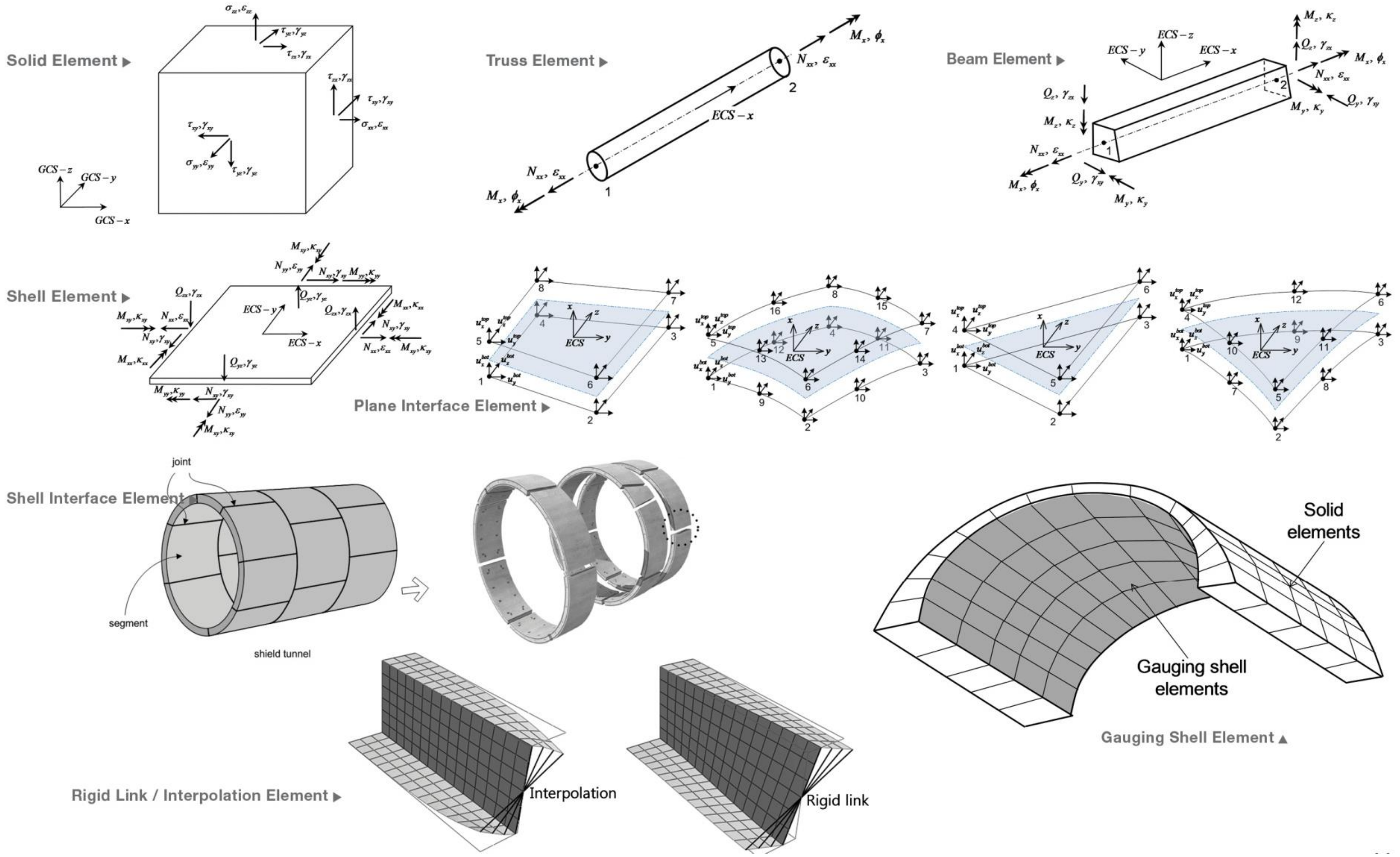
Geogrid(2D)
Plot only(2D)
Gauging shell
Axisymmetric
Shell
Plane stress
Plane strain

3D

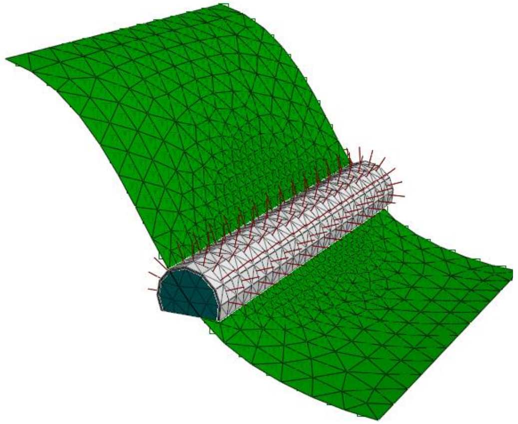
Solid

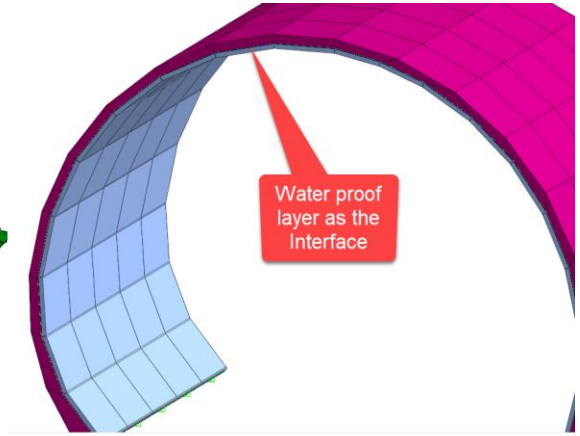
Applicable

Rigid link
Pile tip
User specified behavior for Shell interface
Point spring
Matrix spring
Interface
Shell interface
Elastic link



Interface Elements: Joints Modelling

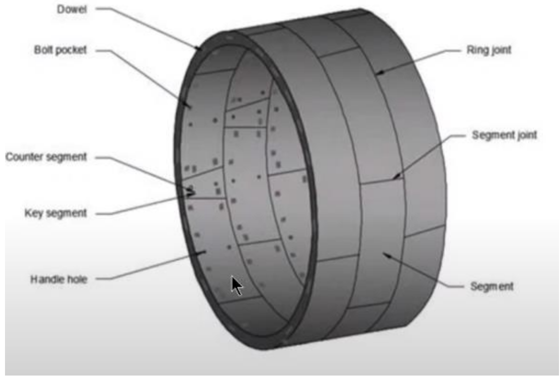


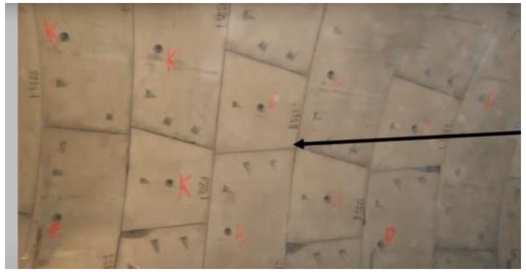


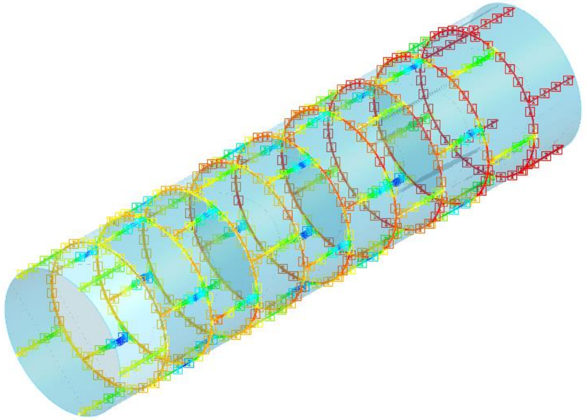
Interface can be used to simulate

- Joints
- Friction between primary and secondary Linings
- Crack propagation in segments

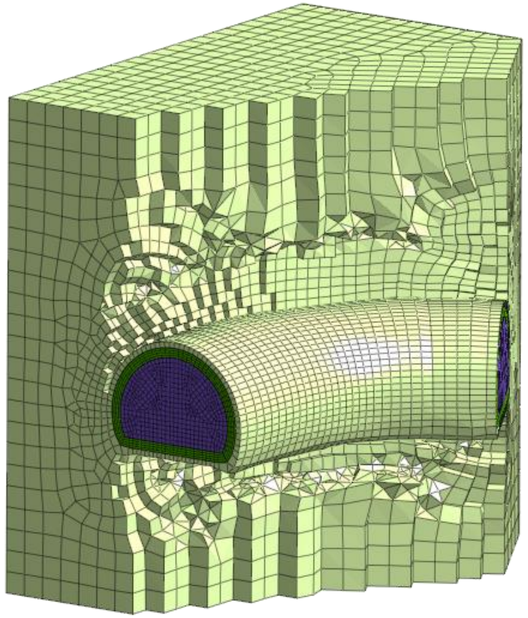
Etc.,





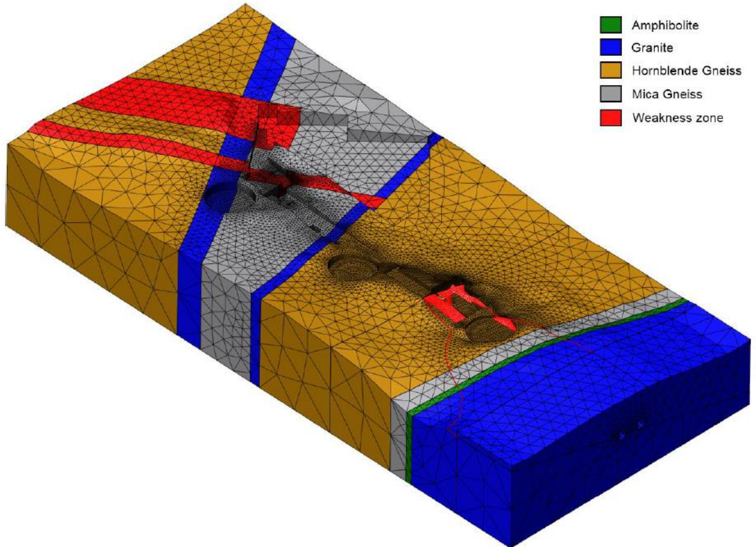


Hybrid Mesh with Hexahedral Elements



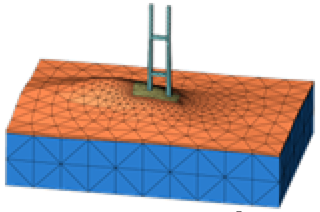
Supports Linear and Higher Order Elements

- Tetrahedron
- Pyramid
- Pentahedron
- Hexahedron
- Triangle
- Quadrilateral
- Hybrid

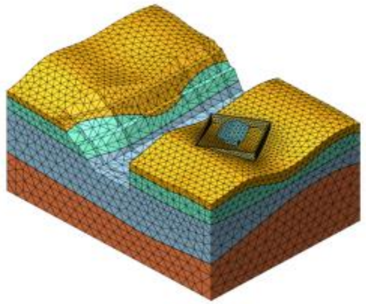


Hybrid Mesh and Higher Order Elements help in increasing Accuracy and Reducing Analysis Time

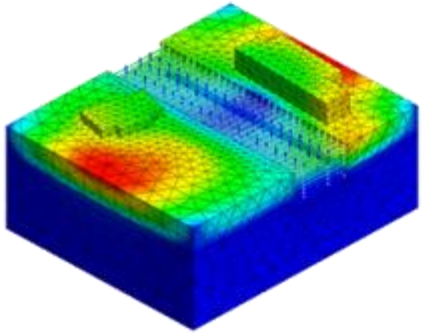
All-in-One FEM based 3D Geotechnical Analysis Software



- Linear Static analysis
- Nonlinear Static analysis



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



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

Static Analysis

Slope Stability Analysis

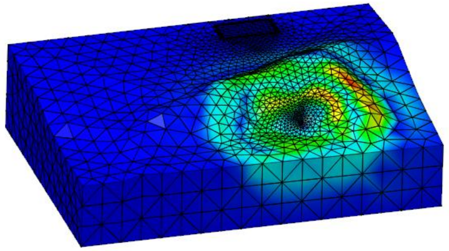
Construction Stage Analysis

Dynamic Analysis

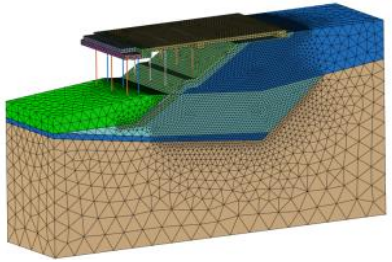
Consoli-dation Analysis

Seepage Analysis

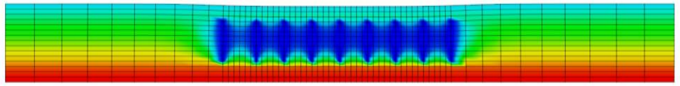
Stress–seepage fully coupled

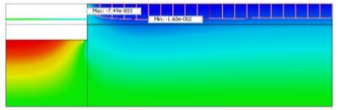


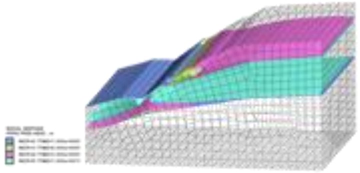
- Eigenvalue/Response Spectrum analysis
- Linear Time History (mode/direct methods)
- **Nonlinear Time History analysis**
- 1D/2D Equivalency Linear analysis
- **Nonlinear time history + SRM Coupled**



- Consolidation Analysis (coupled with SRM)
- **Stress–seepage fully coupled analysis**

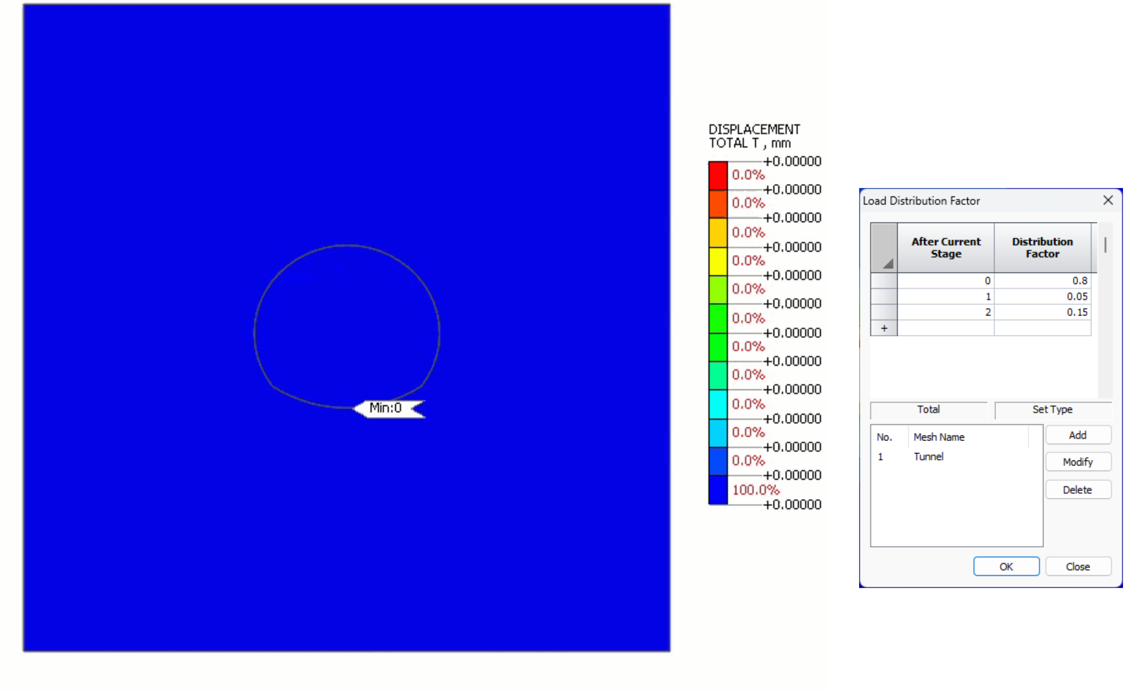




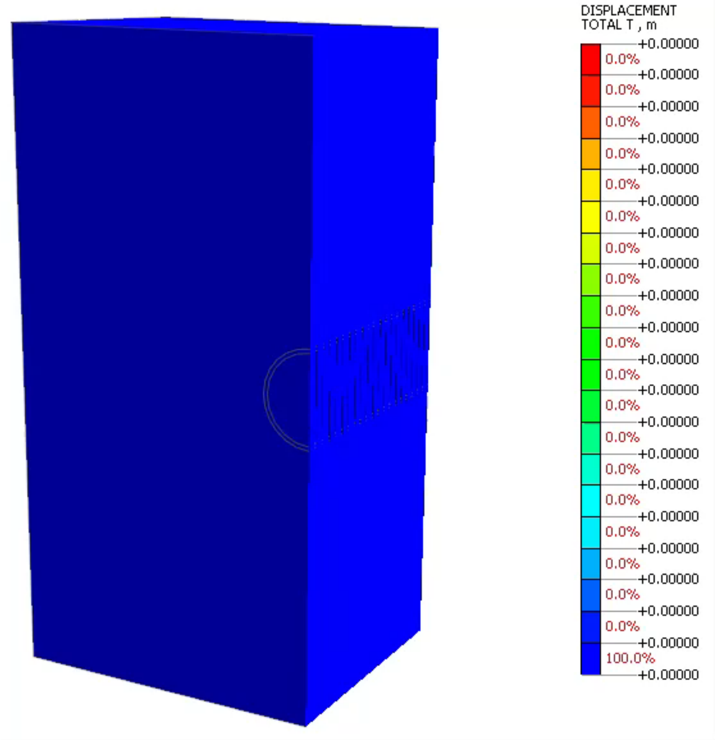


- Steady state seepage analysis
- Transient seepage analysis

Tunnel Construction Methods



NATM Tunnel – Relaxation Definition



Shield TBM and Contraction Definition

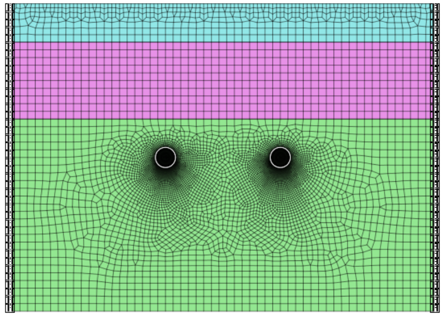
Dynamic Analysis

Dynamic Analysis Boundary Conditions:

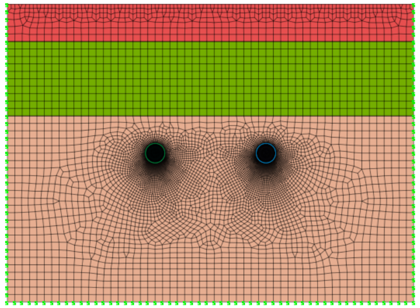
- Free-Field (Line/ Plane)
- Ground Surface Springs
- Absorbent/ Viscous Boundary

Dynamic Analysis Types:

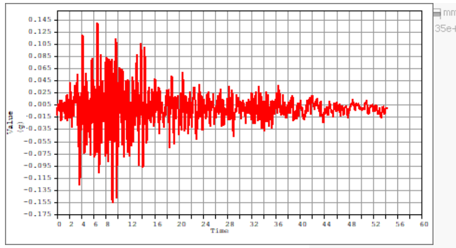
- Linear Time History
- Non- Linear Time History
- Response Spectrum
- Eigen value
- Stress- Non Linear Time History Coupled

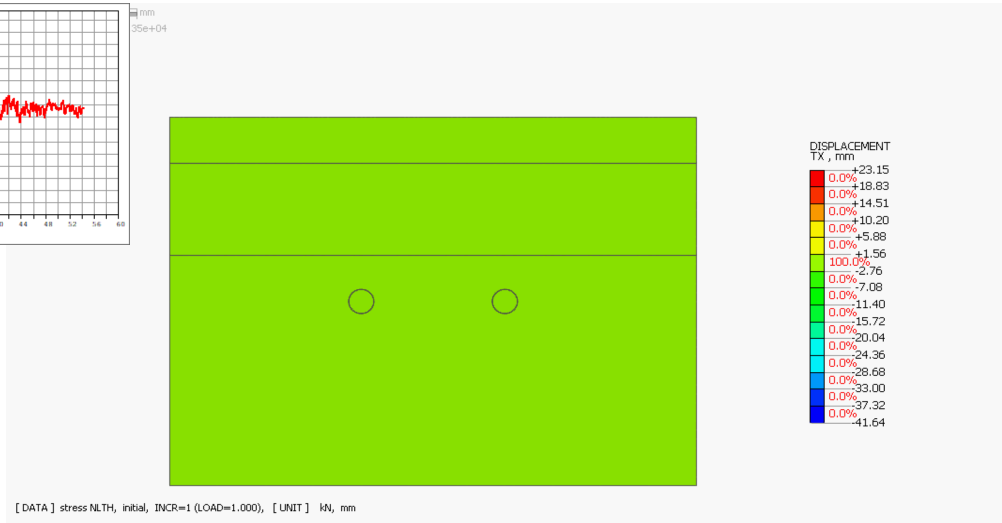


Free Field Dynamic Boundary

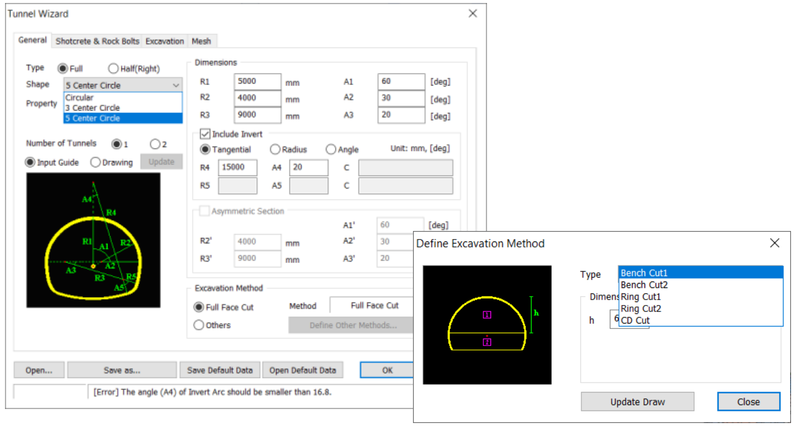


Absorbent/ Viscous Boundary

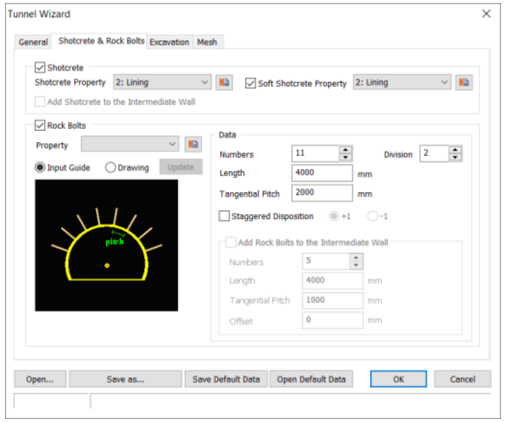




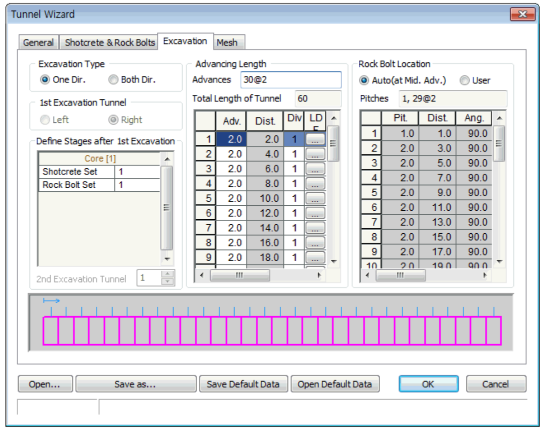
Tunnel Modelling Wizard



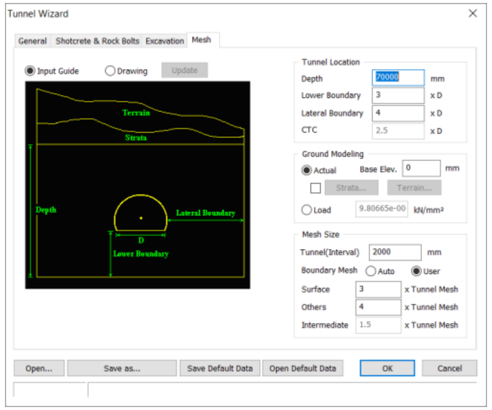
1.Input Tunnel Dimensions and Select Excavation Method

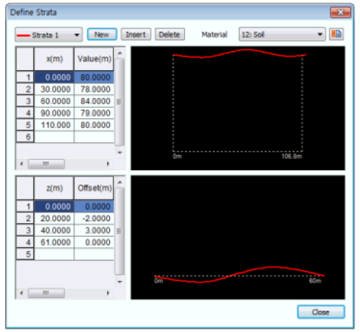


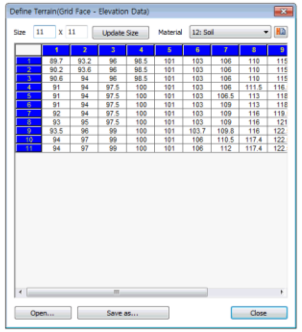
2. Input The Sequential Bolting Pattern & Shotcrete Properties



3. GTS NX Auto Calculates The Excavation Sequence and Reinforcement Placing Based On User Input

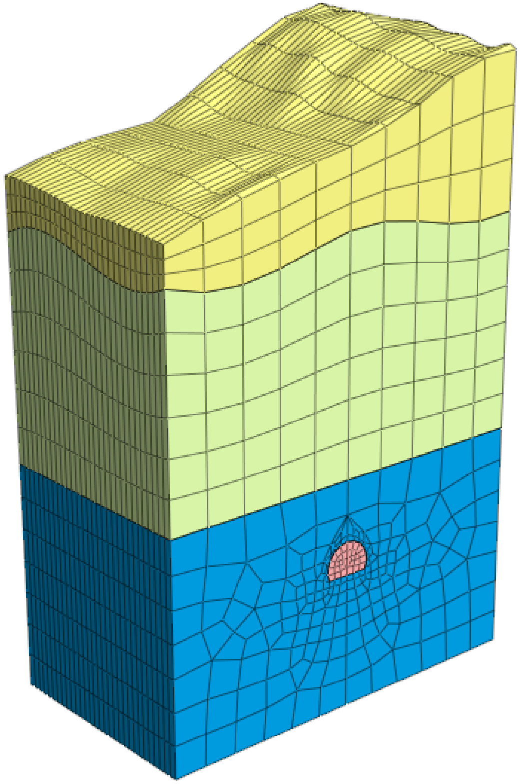






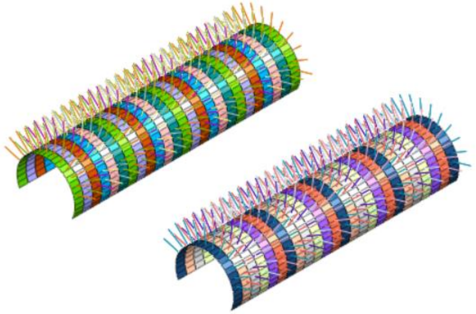
4. Terrain and Strata Modelling. Elevation Data from Lidar Survey

Tunnel Modelling Wizard



Model Created from
Tunnel Wizard

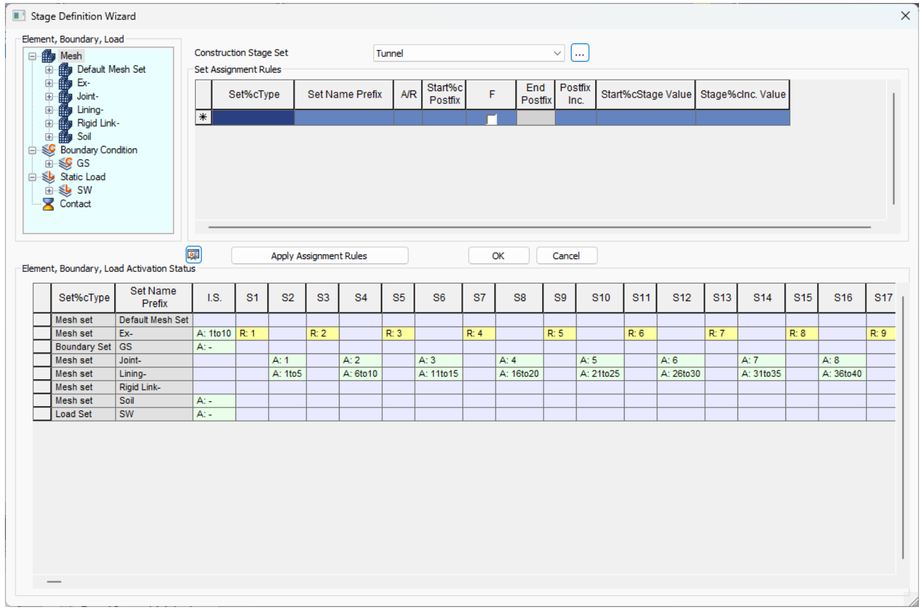
Tunnel Section

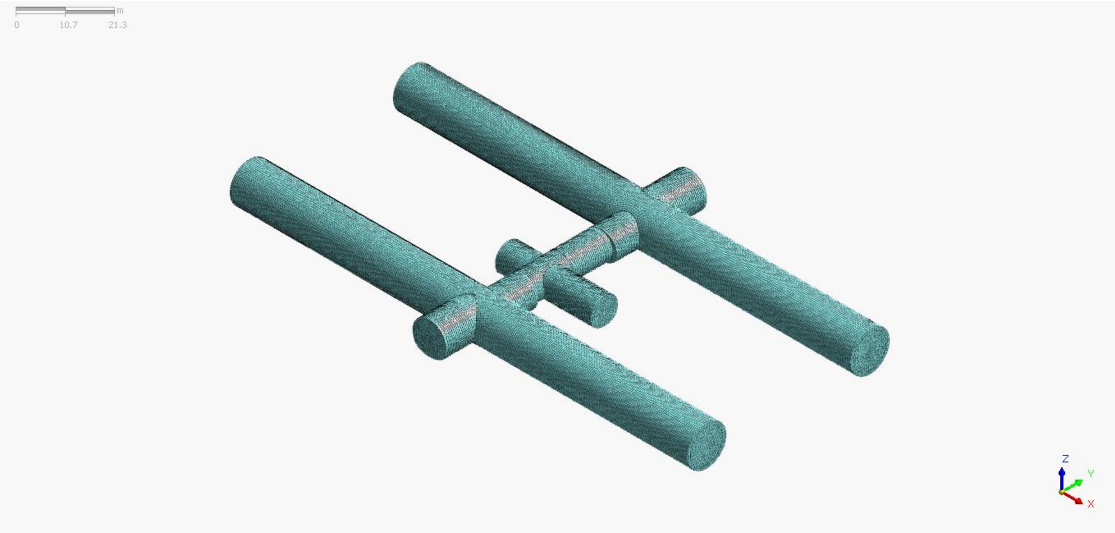


Shotcrete + Rock bolts

Constructions Stages

Stage Wizard: Construction Stages Simulation



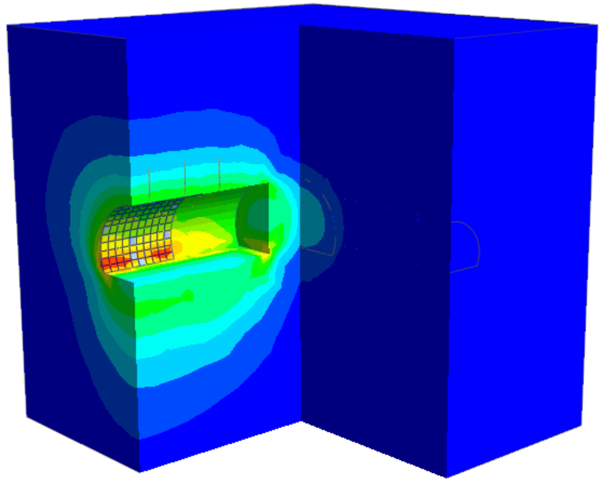


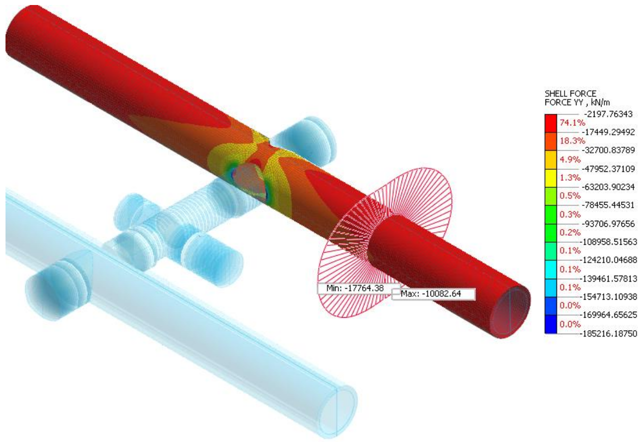
Stage Wizard to automatically assign Construction Stages when dealing with 100's of Mesh sets

Restart Analysis: You can Restart the analysis from a specific stage

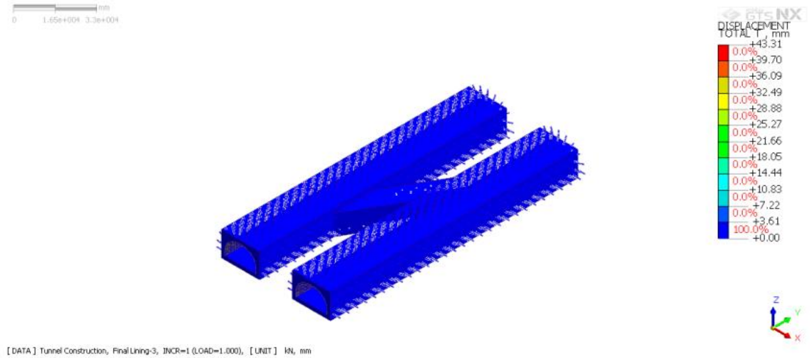
Post Processing Features

- Contours
- Graphs
- Animations
- Tables
- Cutting Plane
- Sections Diagrams
- Reports
- Result Tag/Probing

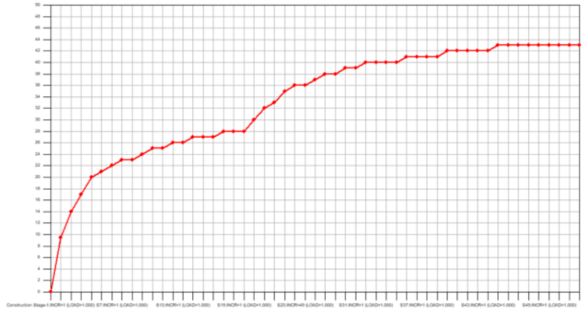


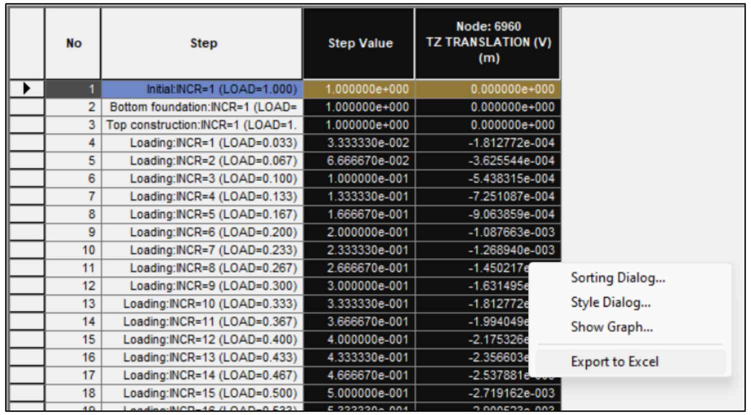


Sectional View: Clipping Line/Plane



Result Extraction as Image, Animation, Video Excel, pdf, Word formats

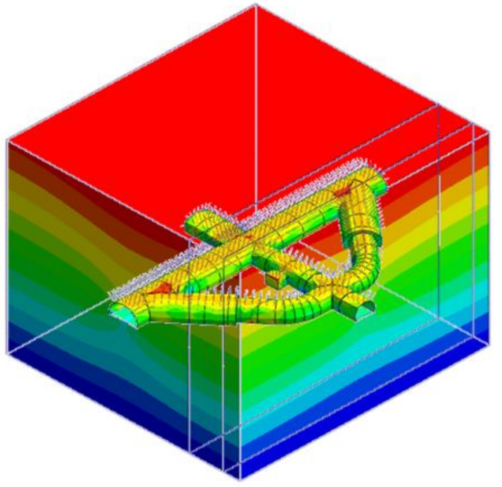


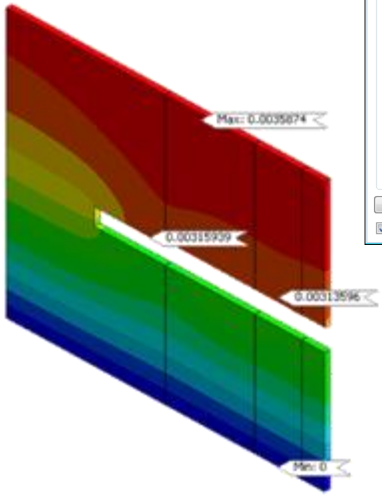


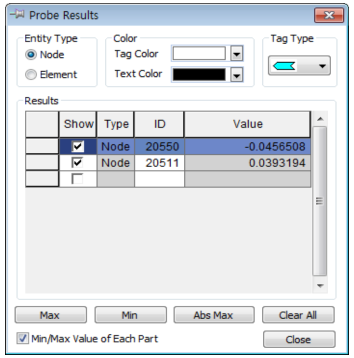
	No	Step	Step Value	Node: 6960 TZ TRANSLATION (V) (m)
▶	1	Initial:INCR=1 (LOAD=1.000)	1.000000e+000	0.000000e+000
	2	Bottom foundation:INCR=1 (LOAD=	1.000000e+000	0.000000e+000
	3	Top construction:INCR=1 (LOAD=1.	1.000000e+000	0.000000e+000
	4	Loading:INCR=1 (LOAD=0.033)	3.333330e-002	-1.812772e-004
	5	Loading:INCR=2 (LOAD=0.067)	6.666670e-002	-3.625544e-004
	6	Loading:INCR=3 (LOAD=0.100)	1.000000e-001	-5.438315e-004
	7	Loading:INCR=4 (LOAD=0.133)	1.333330e-001	-7.251087e-004
	8	Loading:INCR=5 (LOAD=0.167)	1.666670e-001	-9.063859e-004
	9	Loading:INCR=6 (LOAD=0.200)	2.000000e-001	-1.087663e-003
	10	Loading:INCR=7 (LOAD=0.233)	2.333330e-001	-1.268940e-003
	11	Loading:INCR=8 (LOAD=0.267)	2.666670e-001	-1.450217e
	12	Loading:INCR=9 (LOAD=0.300)	3.000000e-001	-1.631495e
	13	Loading:INCR=10 (LOAD=0.333)	3.333330e-001	-1.812772e
	14	Loading:INCR=11 (LOAD=0.367)	3.666670e-001	-1.994049e
	15	Loading:INCR=12 (LOAD=0.400)	4.000000e-001	-2.175326e
	16	Loading:INCR=13 (LOAD=0.433)	4.333330e-001	-2.356603e
	17	Loading:INCR=14 (LOAD=0.467)	4.666670e-001	-2.537881e
	18	Loading:INCR=15 (LOAD=0.500)	5.000000e-001	-2.719162e-003

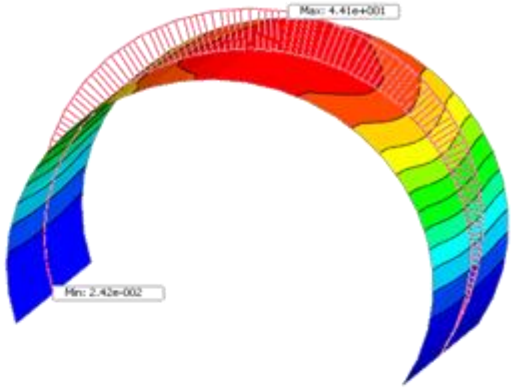
Results extracted as Tables and Graphs
Extracted results/graphs directly exported to excel

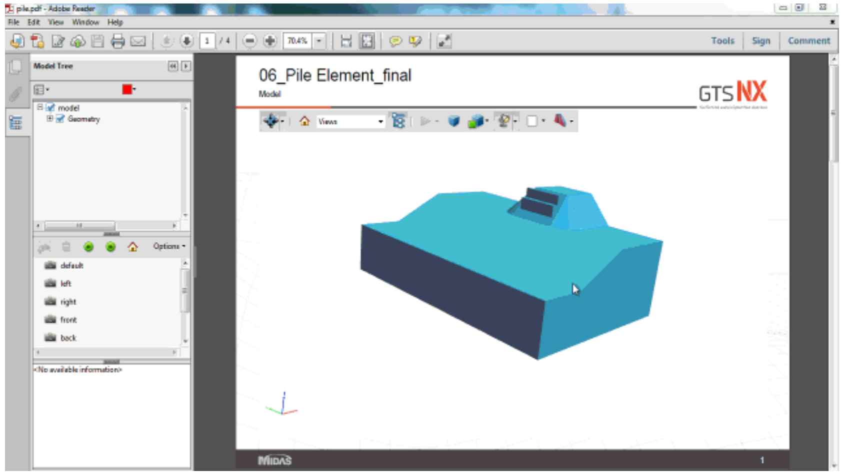
Post Processing Features



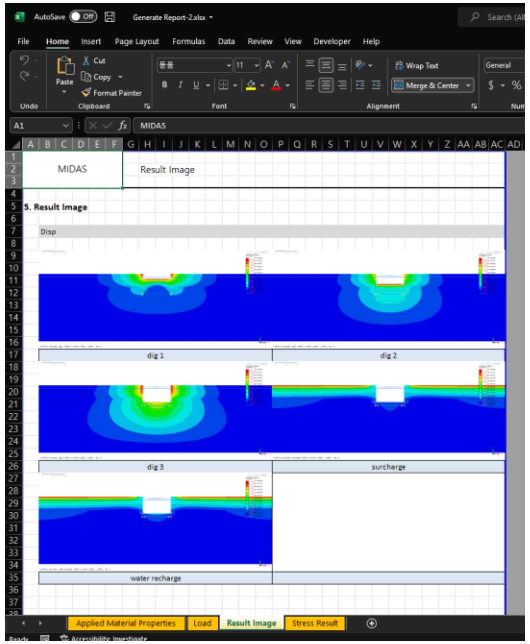








3D PDF Report



Excel report

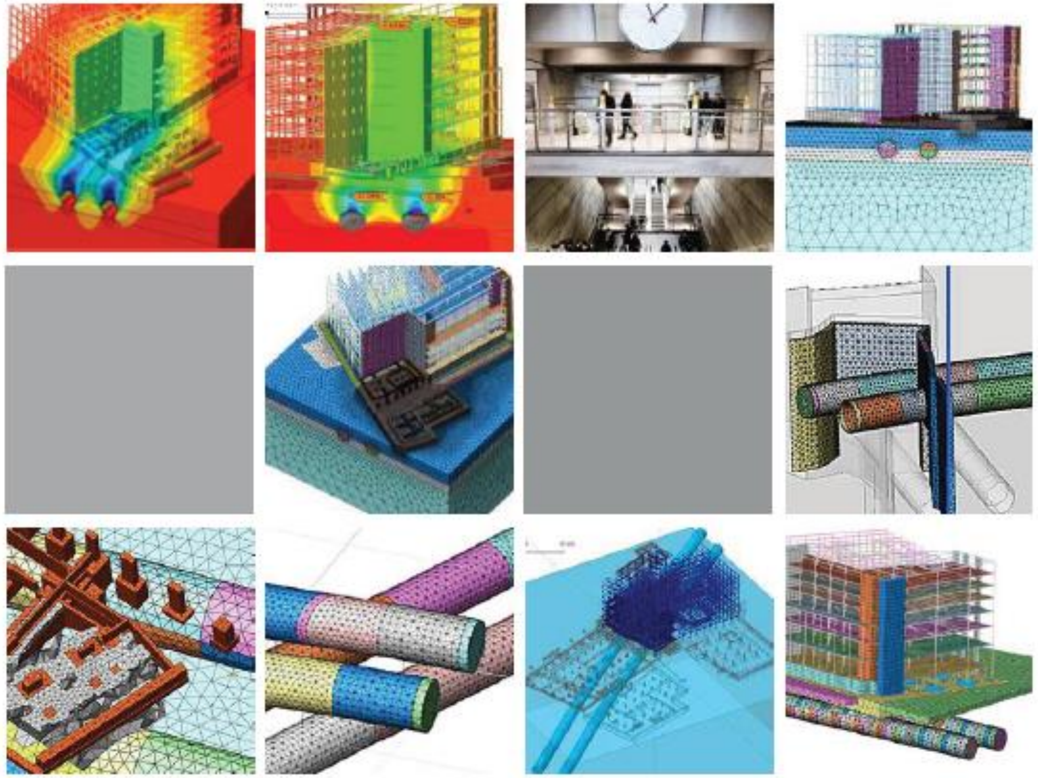
PROJECT ACCOMPLISHMENTS

Cityringen
Copenhagen Metro

Copenhagen, Denmark

Lombardi

Owner	Metroselskabet
Engineering Consultant	Lombardi
Construction Period	2011 - 2017
Project Type	Subway Station
Size of the Structure	15.5 km long twin single - track metro tunnels,
Main features in modelling	- Interaction between MIDAS family programs (Gen & GTS NX) - Construction stage analysis for TBM
Description on this project	The Cityringen is a city circle metro - line, approximately 15.5 km long and will serve major areas of the city of Copenhagen including the Danish Parliament, the Central Station, the City Hall, existing major S - train and metro stations and national monuments. The line will have driverless communication - based train control system, with stewards on board. A round trip is expected to take 23 minutes. The headway interval is expected to be 200 sec., with 28 trains of 3 carriages running at 90 km/h.

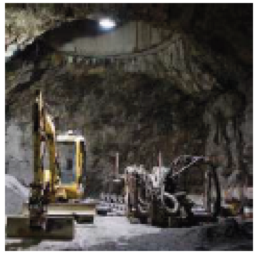
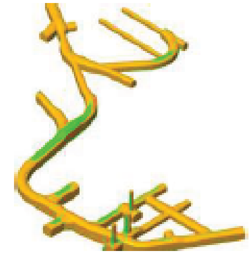
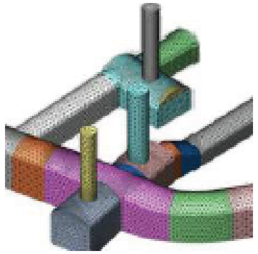
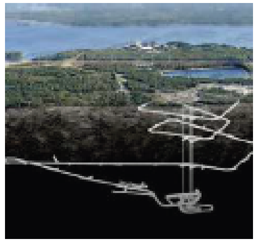


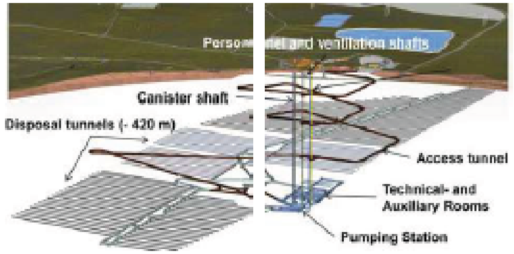
Posiva's ONKALO

Eurajoki, Finland

POSIVA

General Contractor	Kalliorakennus Oy, SK - Kaivin Oy and Destia Oy
Engineering Consultant	Posiva
Construction Period	2004 - Under Construction
Project Type	Nuclear Waste Disposal Facility
Size of Structure	455m Depth
Main features in modelling	- Stability of hard rock excavations in depth up to 500 m and to optimize rock support system - Impact of vibration due to blasting and groundwater level on underground cavern
Description on this project	The Onkalo Spent Nuclear Fuel Repository is a deep tunnel system for the final disposal of spent nuclear fuel. It is first of such repository in the world. It is currently under construction at the Olkiluoto Nuclear Power Plant in the municipality of Eurajoki, on the west coast of Finland, by the company Posiva. It is based on the KBS - 3 method of nuclear waste burial developed in Sweden by Svensk Karnbranslehantering AB (SKB).



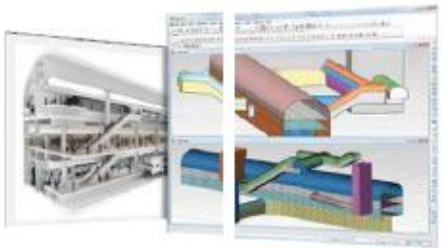
Trans - Hudson Express

New York, USA

ILF CONSULTING ENGINEERS

Owner	NJ Transit and Port Authority of New York and New Jersey
General Contractor	THE Partnership JV
Engineering Consultant	ILF Consulting Engineers
Construction Period	2009 - 2010
Project Type	Rail Tunnel
Size of Structure	- Palisades Tunnels (1.6km Length) - Hudson River Tunnels (2.3km Length) - Manhattan Tunnels (2km Length) - Station Cavern (29m Wide, 27m Height)
Main features in modelling	- Construction sequences of the subway complex - Stability of lining structures and rock bolts

Description on this project	- NYPSE Caverns and Ancillary Tunnels
	  - Evaluated geotechnical ground properties, geotechnical/geological models developed
	  - Defined excavation stages/sequences
	  - Designed initial ground support
	  - Predicted surface settlements
	- Provided Overbuild Criteria to specify magnitude, distribution and location of loading due to future overbuild along both sides of 34th Street

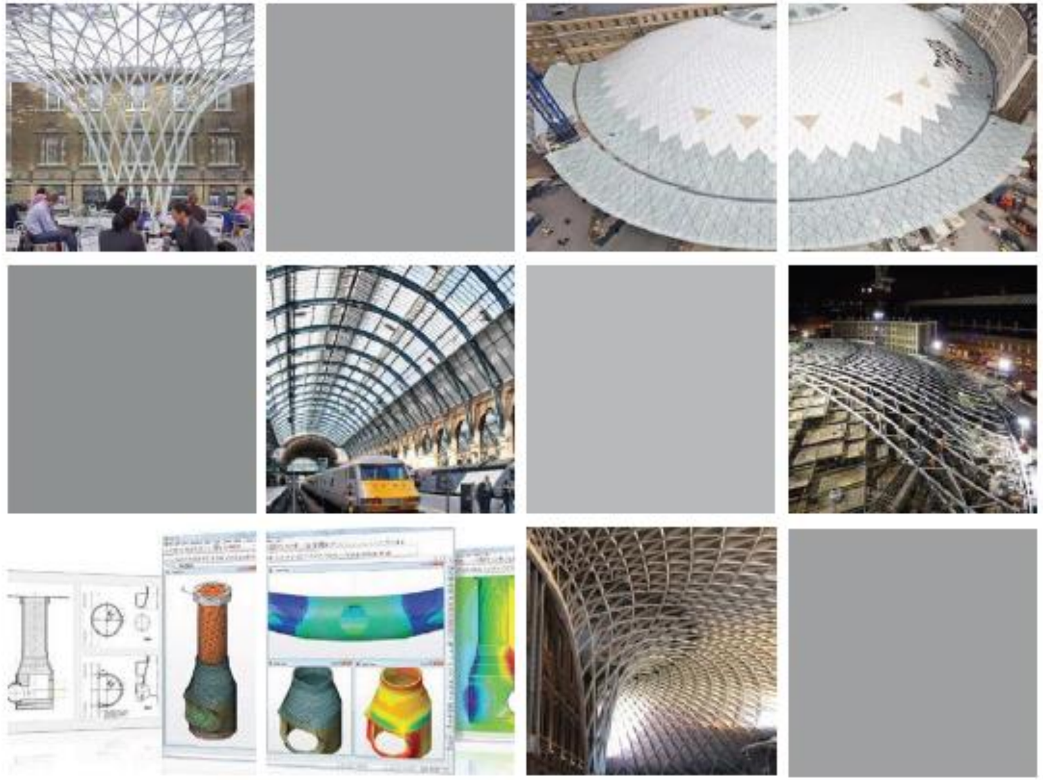


King's Cross Station

London, United Kingdom

ARUP

Owner	Network Rail
Architecture	John McAslan + Partners
Engineering Consultant	Arup/Morgan Sindall
Construction Period	2008 - 2013
Project Type	Railroad Station
Main features in modelling	- The section of the existing tunnel where the shaft intersects is strengthened with block work. - The cylindrical section of the shaft is built with segmental lining. - The tapered section of the shaft is built in 1 m deep stages and lined with sprayed concrete.
Description on this project	The redevelopment of King's Cross station in the city of London is turning a historic rail terminus into a dynamic transport hub. Arup's work as a lead consultant on King's Cross station embraced transport planning, multi-disciplinary engineering services, security, IT, lighting design, acoustics, visualization, and pedestrian modeling

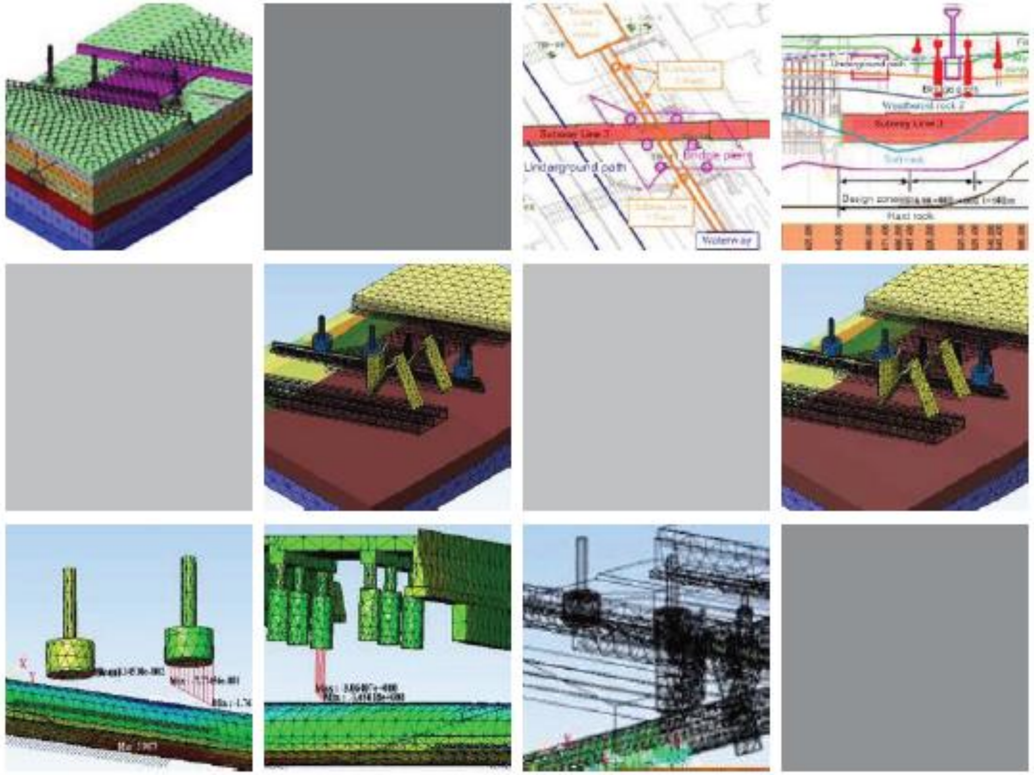


Busan Subway Line 3 Tunnel

- Zone 321

Busan, Korea

ORUM



Design for construction

Performing construction stage analysis to check the settlement while checking the initial support capacity for the fan plant structure.

Overview

Two types of analysis were performed based on different 3D model files. The full underground structure was modeled to monitor the initial support capacity including rock bolts and shotcrete, at structural level. A construction sequences analysis of the fan plant was ran to obtain the general stability and settlements of the soil layers, at geotechnical level.

PROBLEM STATEMENT

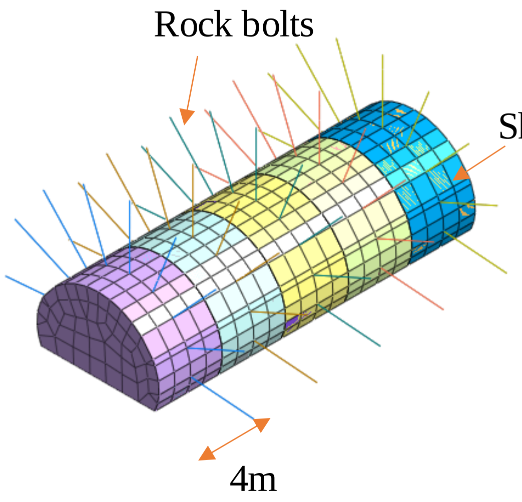
Tunnel Section:
Horseshoe Shape

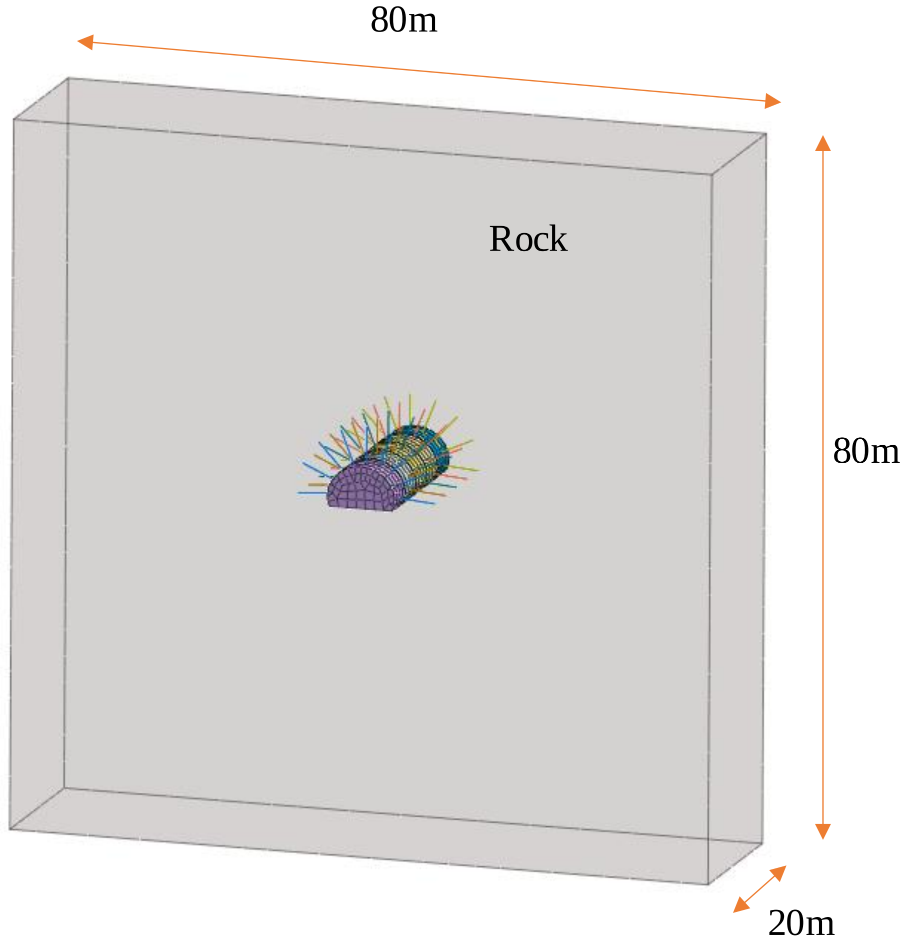
Shotcrete Thickness: 0.3m

Rock bolts Section:
Solid Round Diameter 0.025m
Length 4m

Excavation Length for each stage: 4m

Non-Linear static Construction Stage Analysis





LET’S START MODELLING

3. SOIL STRUCTURE INTERACTION MODELLING AND ANALYSIS

CONTENTS

Session 3. SOIL STRUCTURE INTERACTION

1. Soil Structure Interaction
2. SSI: Applications
3. GTS NX Analysis Capabilities: Pile Raft Foundation
4. Project accomplishments
5. Problem Statement

Soil Structure Interaction

- **What is SSI ?**
  - Interaction of Stiffness and Deformation between Structure and Soil
  - Necessary for Adequate Assessment of Stresses and Forces in the Supporting Structure

- **Why SSI ?**

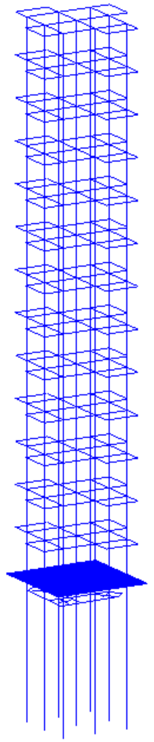
Supporting Soil,

- Generates Loading and
- Provides Resistance to Loading

Force on Deck and Pier depends on,

- Location of the foundation
- Flexibility of foundation
- Supporting Soil Behaviour

Soil Structure Interaction Methods



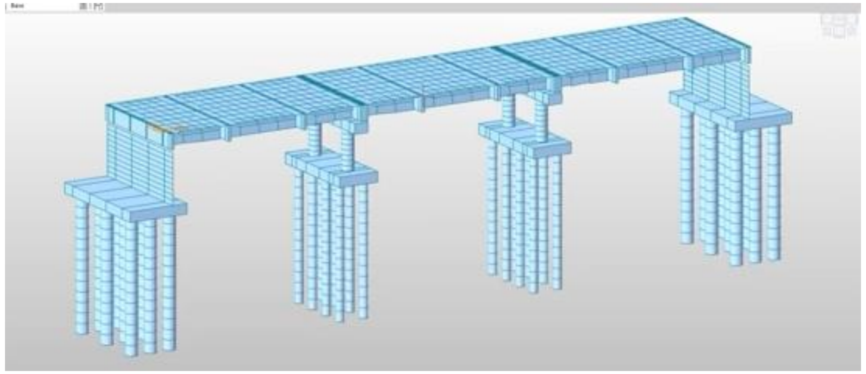
1. Substructure Method

Also known as Indirect or Superposition Method.

Soil and Structure Interaction is analyzed by separating them into two separate structural systems:

1) Free Field Analysis: The reaction / response of the soil is determined (mainly where the structure will be)

2) Structural Analysis: The soil can be modeled as spring damper system(impedance) with that response. The detailed structure is designed with the idealization of soil as independent damper spring



Example: Winkler Springs, Springs from Empirical Equations, etc

Soil Structure Interaction Methods

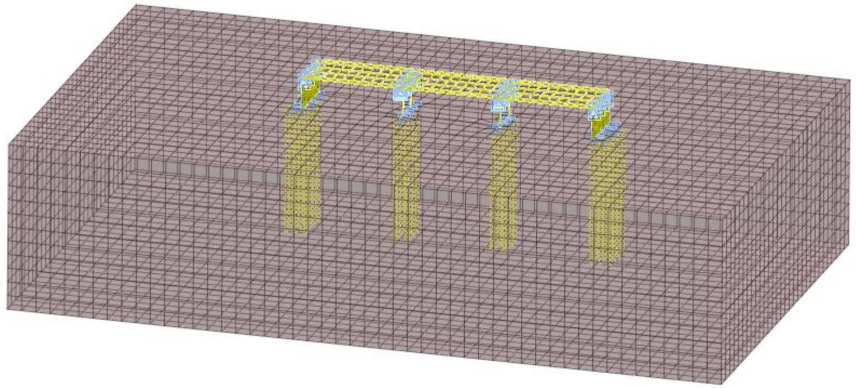
2. Direct Method

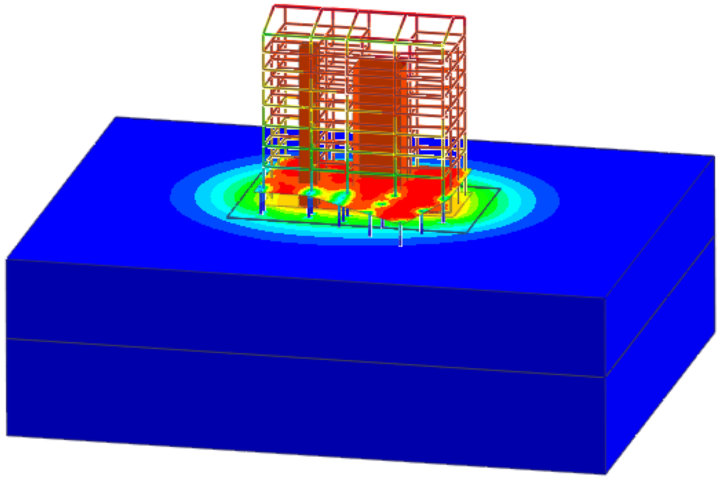
Soil and Structure- Single System

Seismic/ Other forces defined at the outer boundary of the single unified model

Responses of the soil and the structure- determined simultaneously

Numerical methods: Continuum Methods FEM, FDM



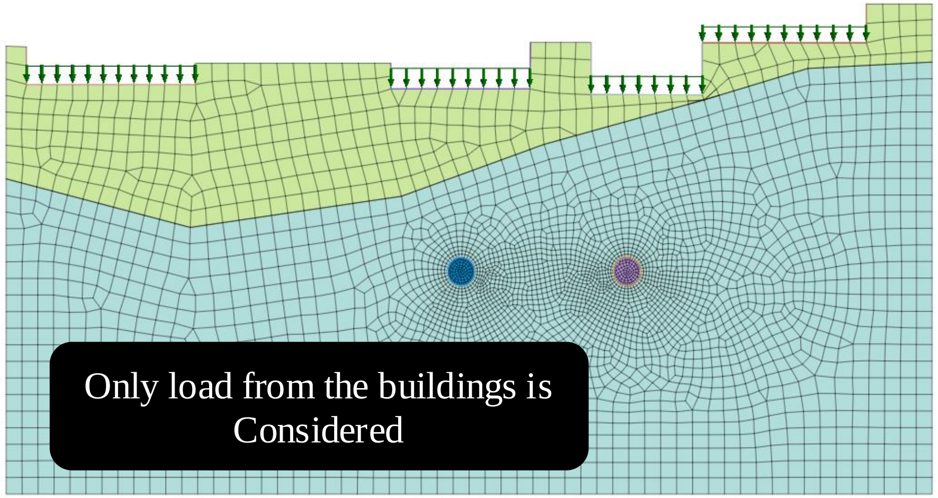


SSI: APPLICATIONS

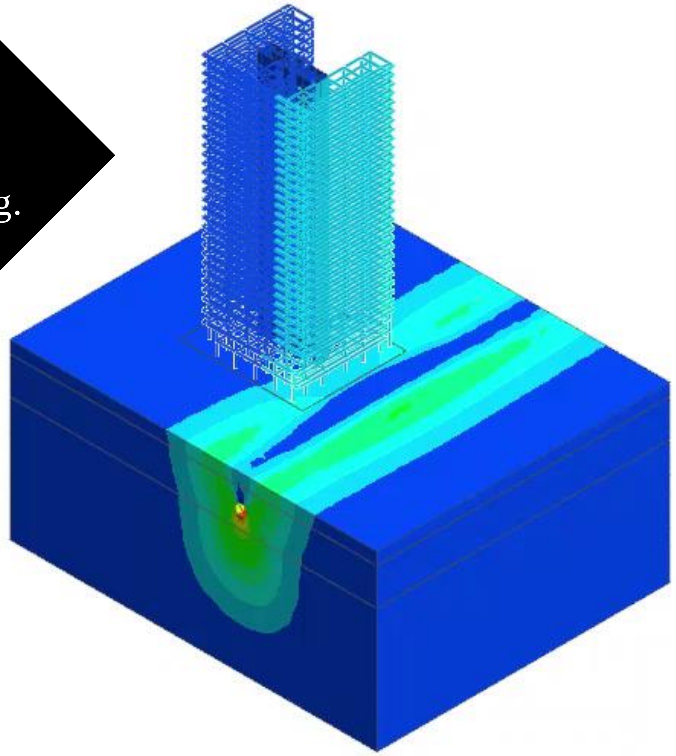
SSI: Applications

- Considering the WHOLE Super Structure in Continuum modelling

The building along with foundation is considered. Hence Differential Displacement can be easily estimated which in real results in cracks in the building.



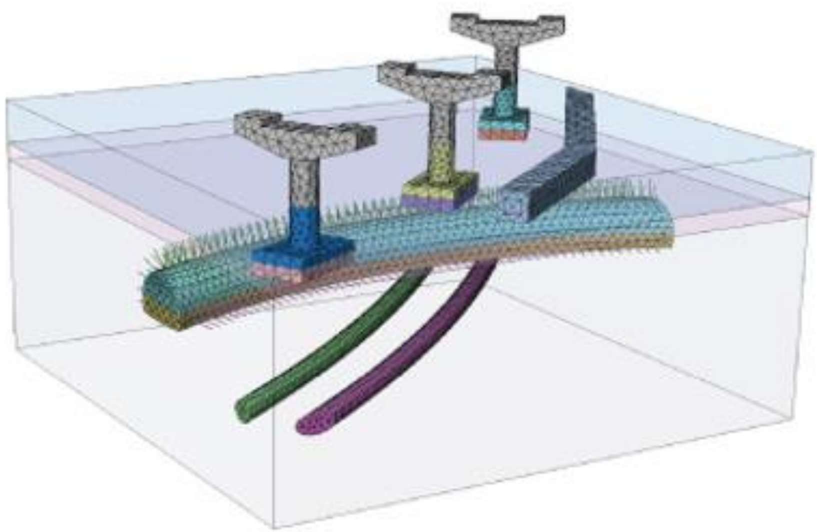
Regular Approach



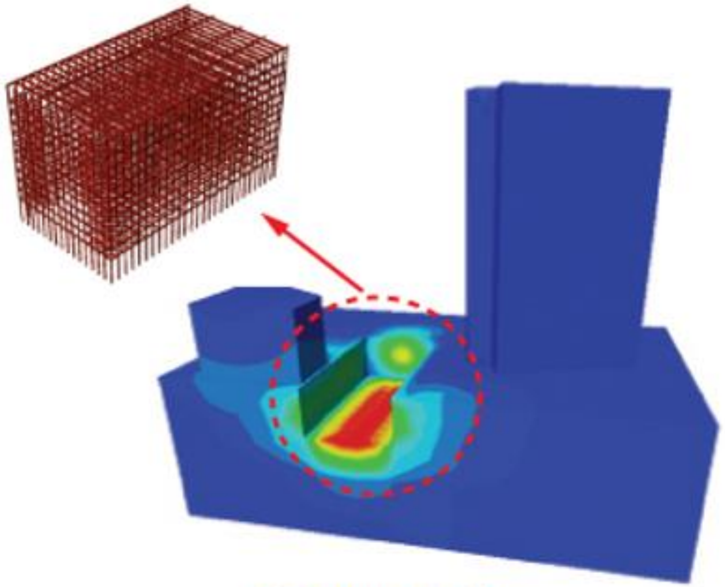
Best Approach

SSI: Applications

- Effect of Tunnelling on Adjacent Structures



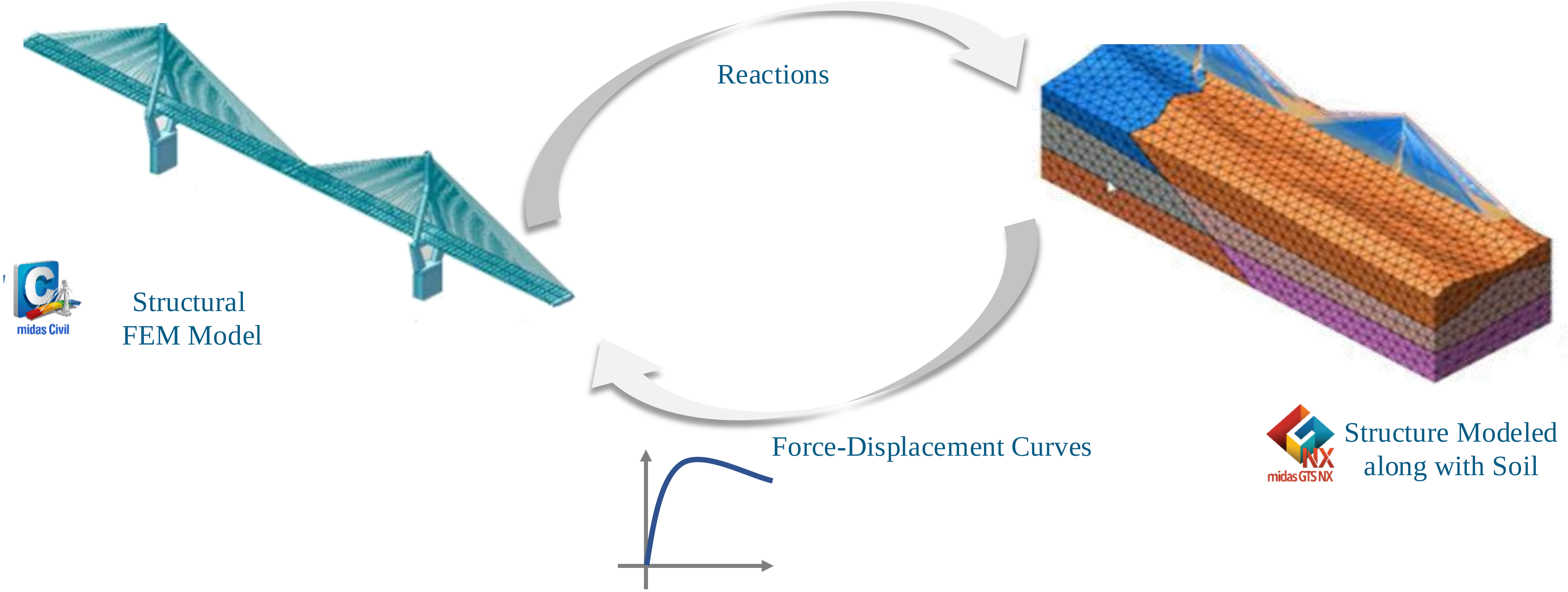
Adjacent Structures



Subway station
(H-Pile+slurry wall)

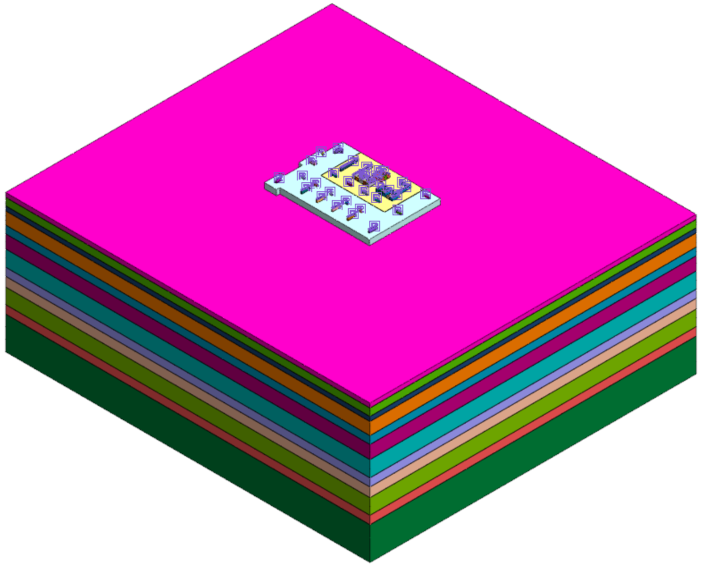
SSI: Applications

- Design Optimization Studies- using Interoperable Midas Programs

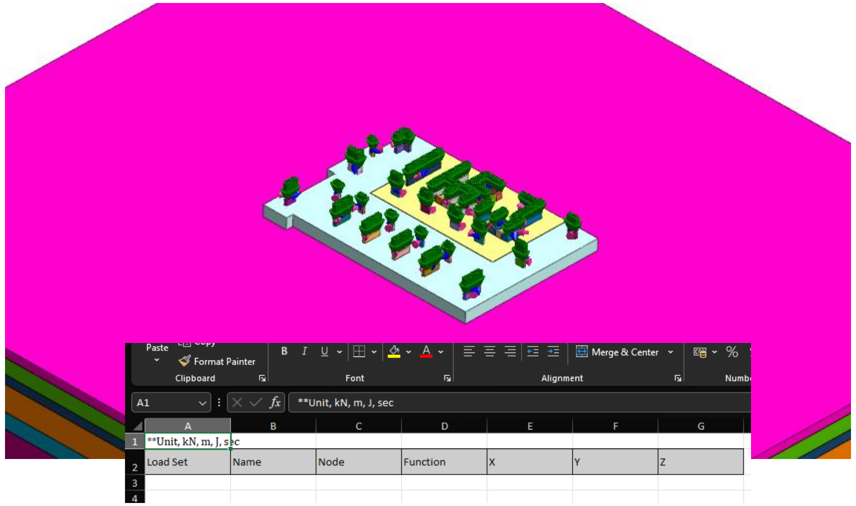


SSI: Applications

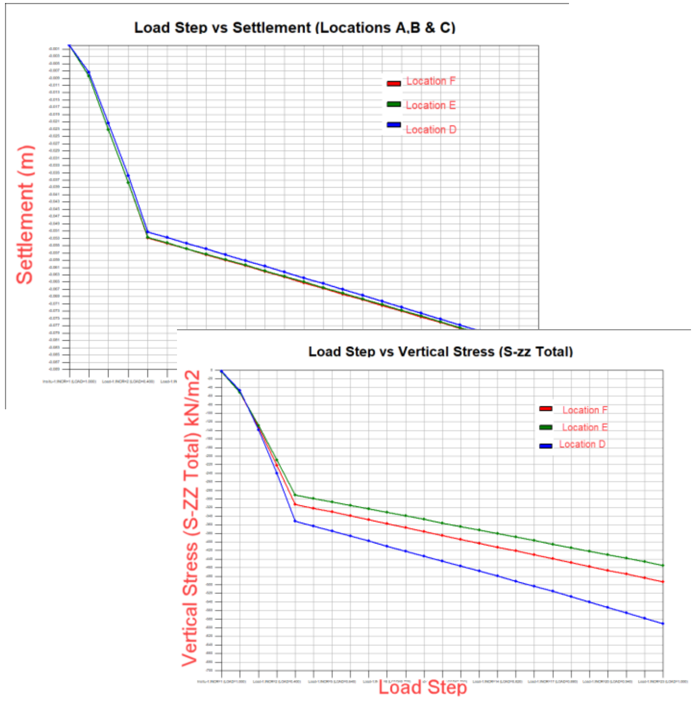
- Design Optimization- Manual



Step-1:
Foundation and Soil Modeling



Step-2:
Load Table Import/Export Option.
(Load imported into GTS NX via excel sheet from any Structural tool)

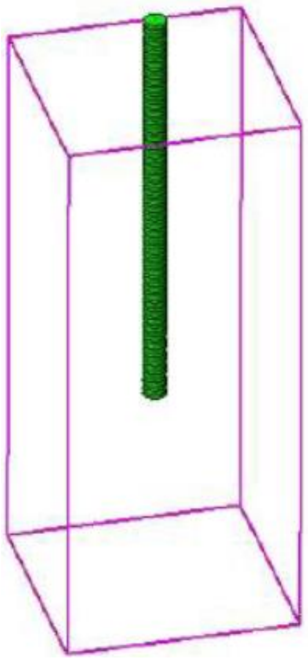


Step-3:
Export the Stiffnesses back to Structural tool

GTS NX ANALYSIS CAPABILITIES

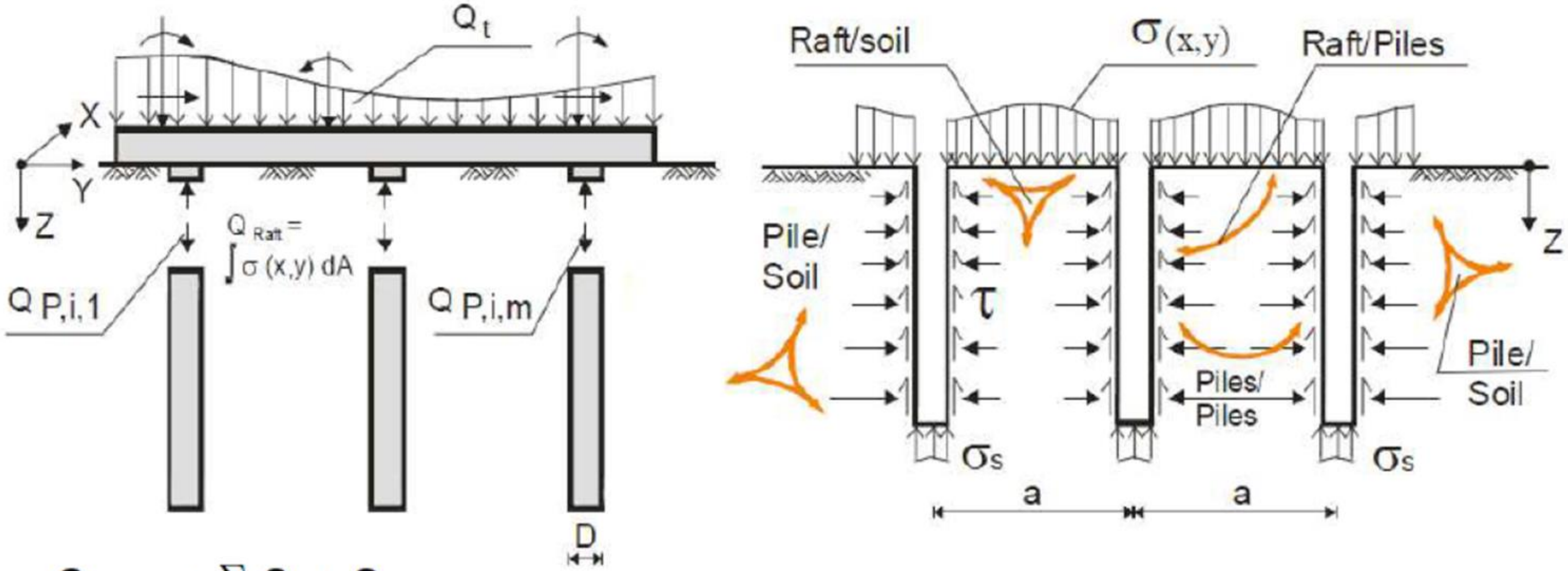
Pile Modelling Techniques

3D Solid + 3D Pile + Plane Interface



3D Solid + 1D Pile (Beam) + Pile Interface

Interactions



$$Q_{tot} = \Sigma\, Q_P + Q_R$$

$$Q_P = Q_b + Q_s$$

$$Q_R = \int \sigma(x,y)\, dA$$

$$Q_{tot} \geq \eta \cdot \Sigma\, S_{tot}$$

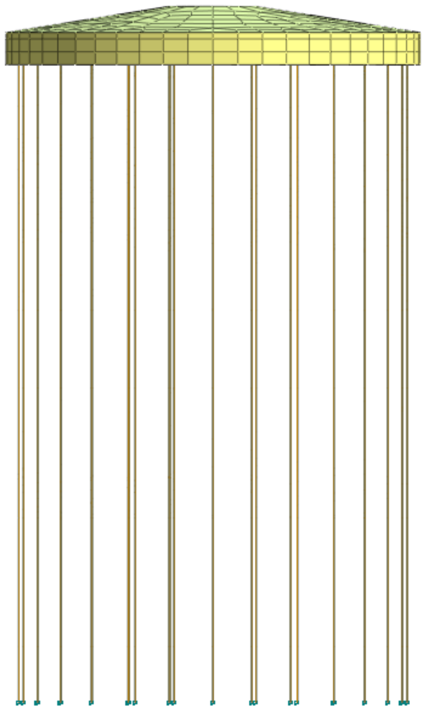
Interaction influences:

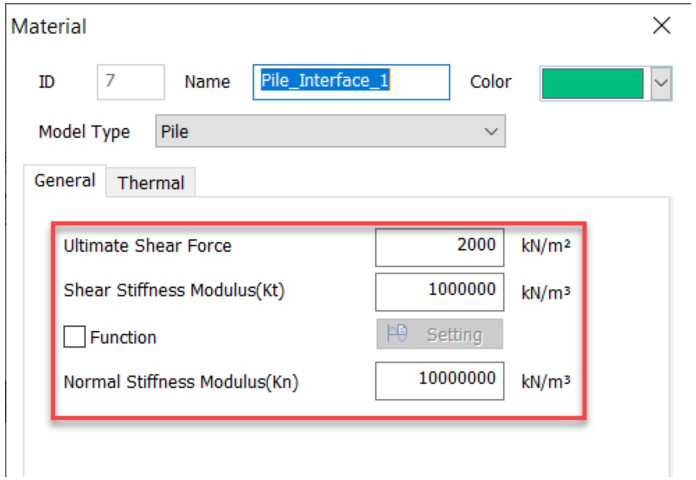
- Pile-Soil interaction
- Pile-Pile interaction
- Raft-Soil interaction
- Pile-Raft interaction

Pile Interface

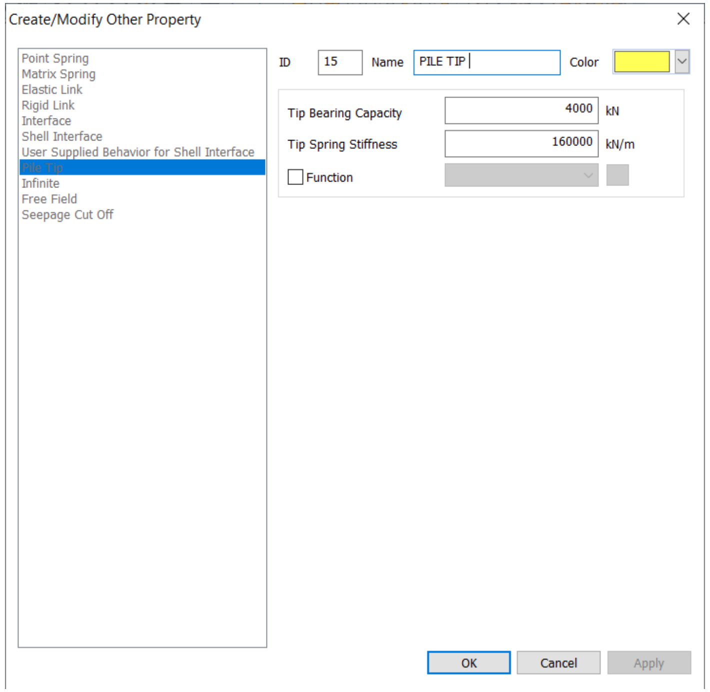
Important To Create a 3D model For These Foundations As Pile Group Effect is Ignored In 2D Models.

Easy Inputs For Modelling Pile Behaviour Based On Design Needs



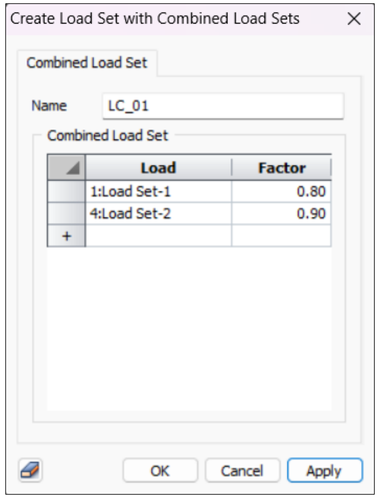


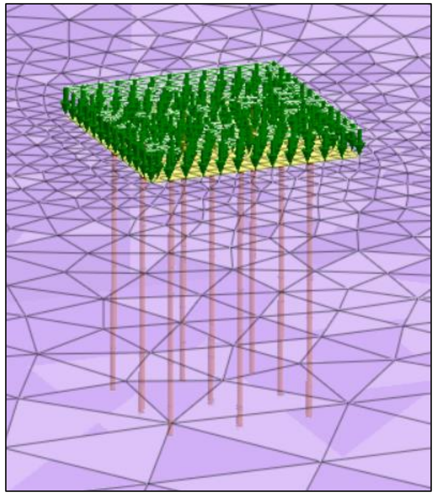
Friction Piles



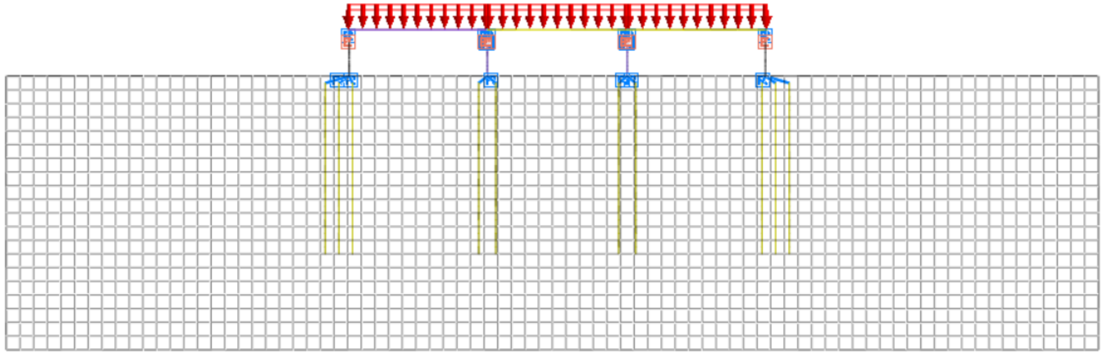
End Bearing Piles

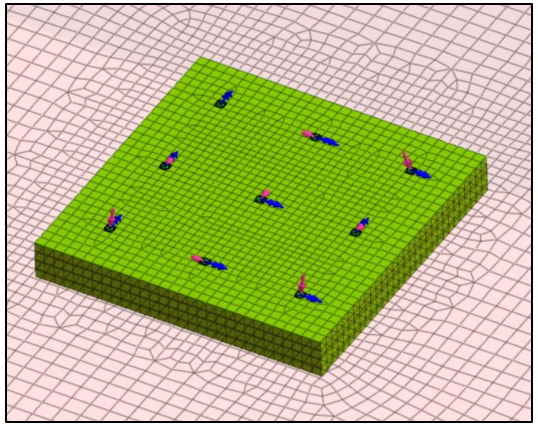
Advanced Loading Features





- Directly add point loads, moments, surface loads etc. to the model
- Create Load Combinations
- Import Load Data from Excel

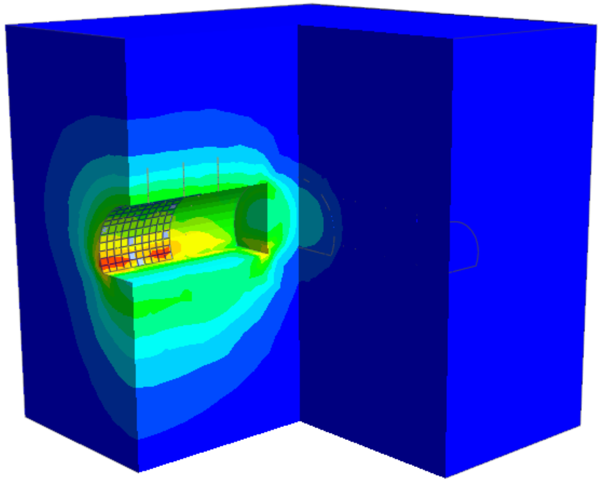


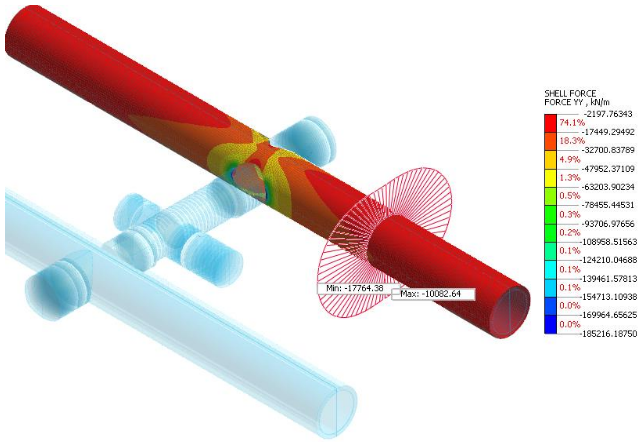


Loads acting at column locations on Raft

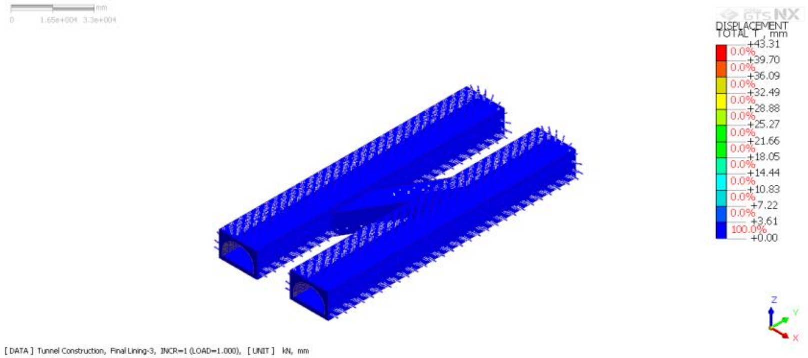
Post Processing Features

- Contours
- Graphs
- Animations
- Tables
- Cutting Plane
- Sections Diagrams
- Reports
- Result Tag/Probing

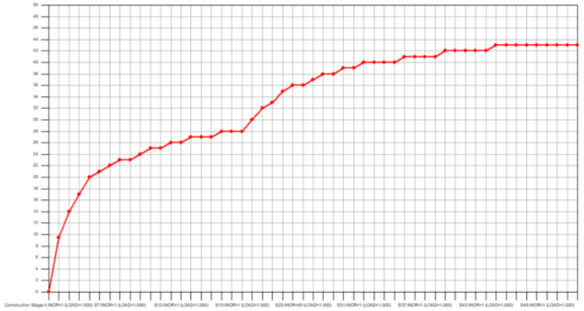




Sectional View: Clipping Line/Plane



Result Extraction as Image, Animation, Video Excel, pdf, Word formats

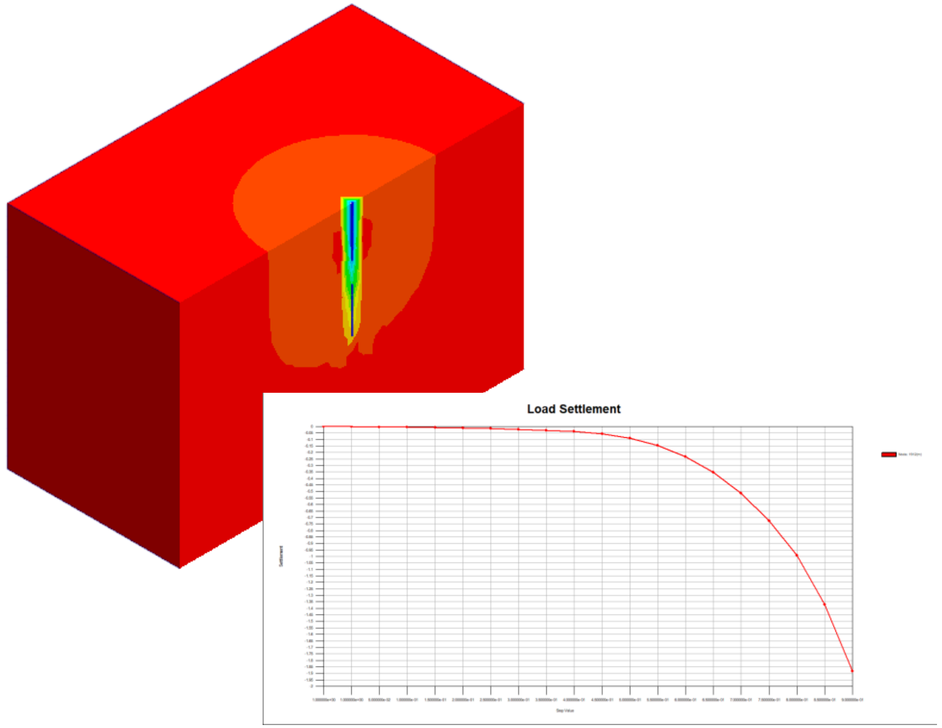


	No	Step	Step Value	Node: 6960 TZ TRANSLATION (V) (m)
▶	1	Initial:INCR=1 (LOAD=1.000)	1.000000e+000	0.000000e+000
	2	Bottom foundation:INCR=1 (LOAD=	1.000000e+000	0.000000e+000
	3	Top construction:INCR=1 (LOAD=1.	1.000000e+000	0.000000e+000
	4	Loading:INCR=1 (LOAD=0.033)	3.333330e-002	-1.812772e-004
	5	Loading:INCR=2 (LOAD=0.067)	6.666670e-002	-3.625544e-004
	6	Loading:INCR=3 (LOAD=0.100)	1.000000e-001	-5.438315e-004
	7	Loading:INCR=4 (LOAD=0.133)	1.333330e-001	-7.251087e-004
	8	Loading:INCR=5 (LOAD=0.167)	1.666670e-001	-9.063859e-004
	9	Loading:INCR=6 (LOAD=0.200)	2.000000e-001	-1.087663e-003
	10	Loading:INCR=7 (LOAD=0.233)	2.333330e-001	-1.268940e-003
	11	Loading:INCR=8 (LOAD=0.267)	2.666670e-001	-1.450217e
	12	Loading:INCR=9 (LOAD=0.300)	3.000000e-001	-1.631495e
	13	Loading:INCR=10 (LOAD=0.333)	3.333330e-001	-1.812772e
	14	Loading:INCR=11 (LOAD=0.367)	3.666670e-001	-1.994049e
	15	Loading:INCR=12 (LOAD=0.400)	4.000000e-001	-2.175326e
	16	Loading:INCR=13 (LOAD=0.433)	4.333330e-001	-2.356603e
	17	Loading:INCR=14 (LOAD=0.467)	4.666670e-001	-2.537881e
	18	Loading:INCR=15 (LOAD=0.500)	5.000000e-001	-2.719162e-003

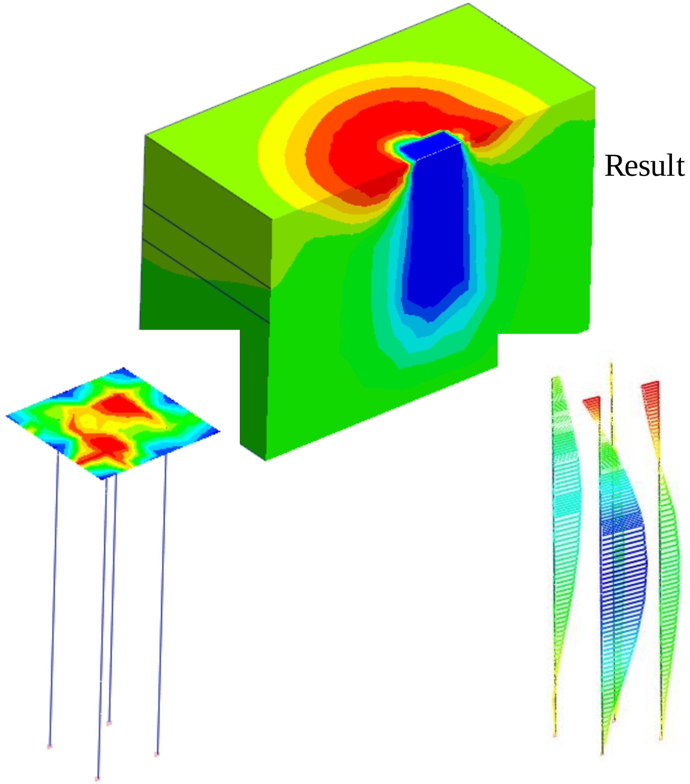
Sorting Dialog...
Style Dialog...
Show Graph...
Export to Excel

Results extracted as Tables and Graphs
Extracted results/graphs directly exported to excel

Post Processing Features



Load-Settlement Curves Extraction

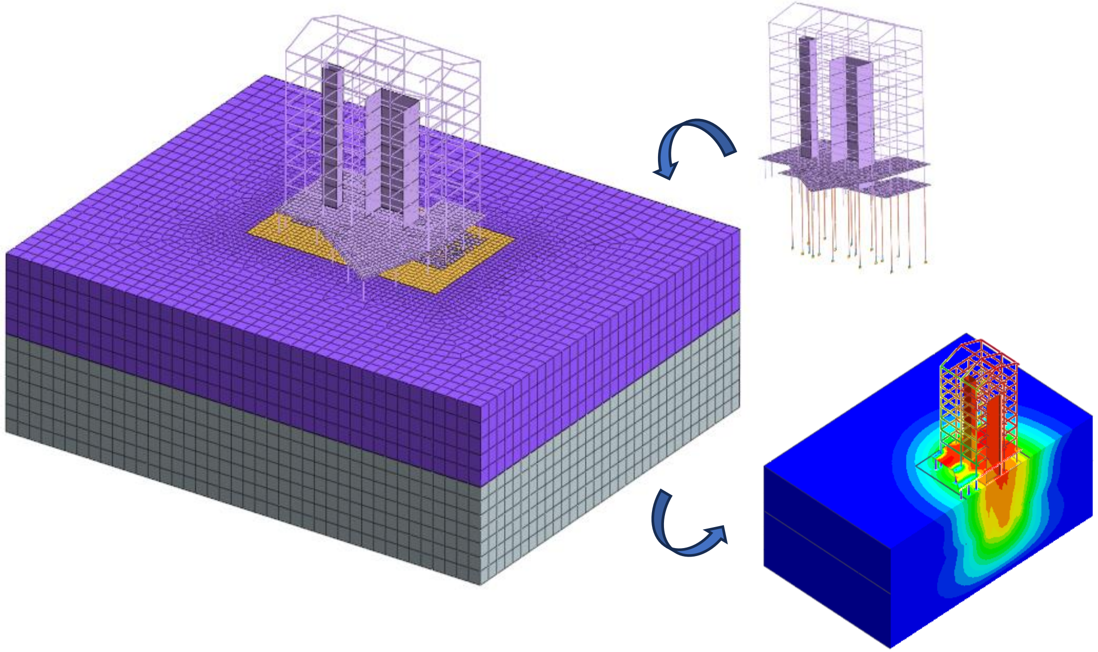


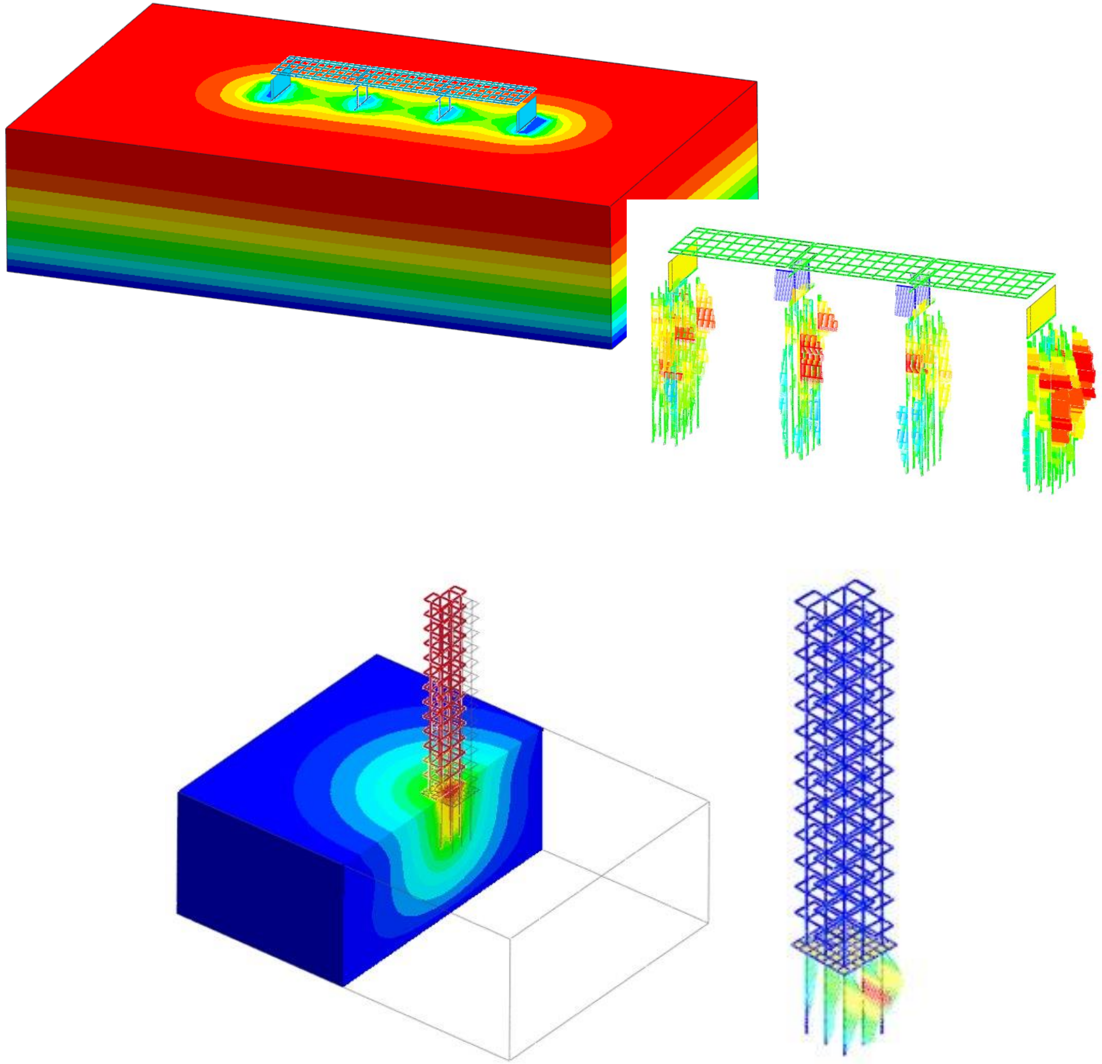
Result Contours in Sectional View

Pile: Axial Force, Shear Force and Bending Moment Results

Structural Forces Results for Piles and Raft

Post Processing Features





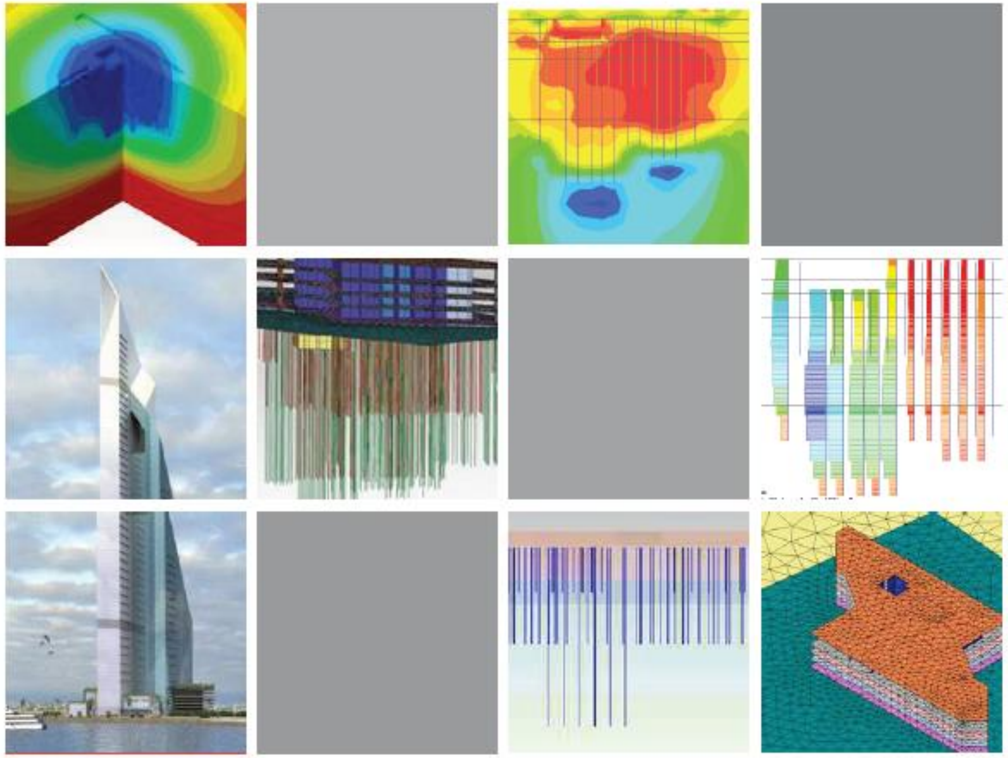
Pile Raft Foundation Modelling with imported Superstructure

PROJECT ACCOMPLISHMENTS

Dubai Tower in Qatar

Doha, Qatar

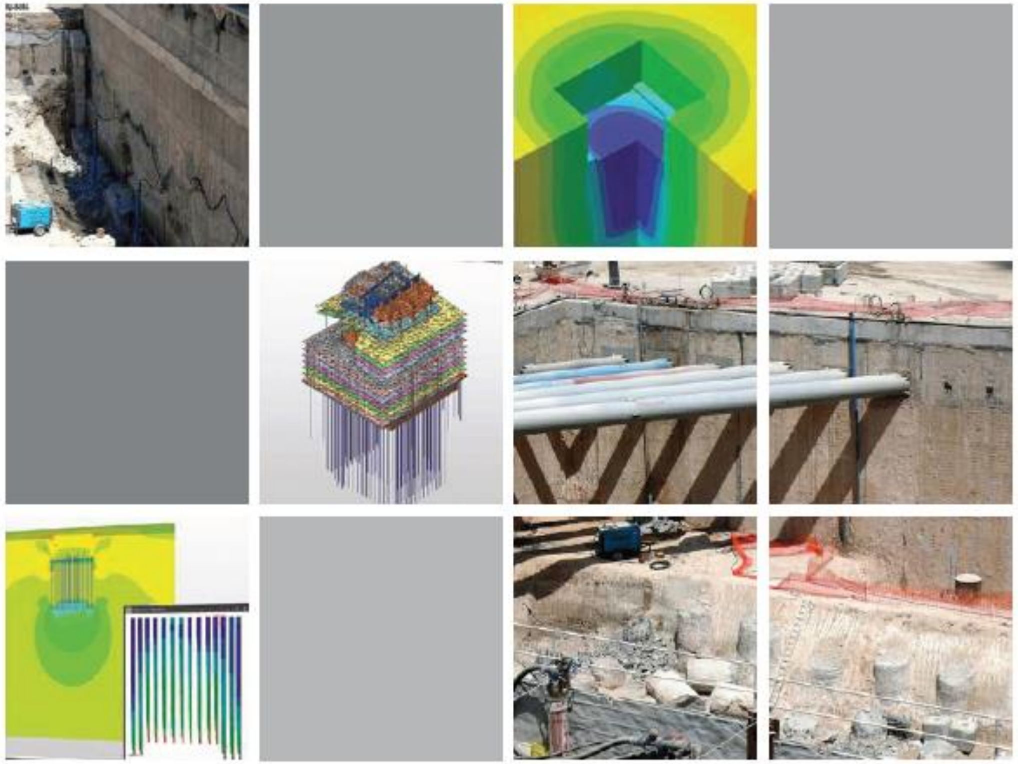
Owner	Sama Dubai (Dubai International Properties)
Engineering Consultant	Hyder Consulting
General Contractor	Al Habtoor - Al Jaber Joint Venture
Architecture	RMJM
Project Type	Mixed-Use Building
Size of the Structure	439m Height (88-Story)
Main features in modelling	- Piled - raft foundation for high - rise building - Analysis results for design (Settlements, Raft forces and bending moments, Pile forces and bending moments)
Description on this project	The proposed development for the Dubai Tower project comprises the construction of an approximately 80 floor high-rise tower with a mezzanine, ground floor and five basement levels. It will be the tallest structure in Qatar when it is complete. The tower was founded on soft sand and required the design of a piled raft in a 3D finite element model to fully understand the behavior.



Pentominium Residential Development in UAE

Dubai, United Arab Emirates

Owner	Trident International Holdings
General Contractor	Arabian Construction Company - Hitachi Plant Technologies
Engineering Consultant	Hyder Consulting
Construction Period	Under Construction
Project Type	Residential Building
Size of the Structure	516m Height (122-Story)
Main features in modelling	- Piled - raft foundation for high - rise building - Analysis results for design (Settlements, raft forces and bending moments, pile forces and bending moments)
Description on this project	The Pentominium Residential Development is located on the west side of the creek in Dubai. The development comprises the construction of an approximately 120 story high-rise tower inter-linked by low level podium structure housing up to 7 basement levels. The Pentominium Tower will be founded on a piled raft and required a 3D finite element model to fully understand the behavior of the foundation interaction with surrounding soil.

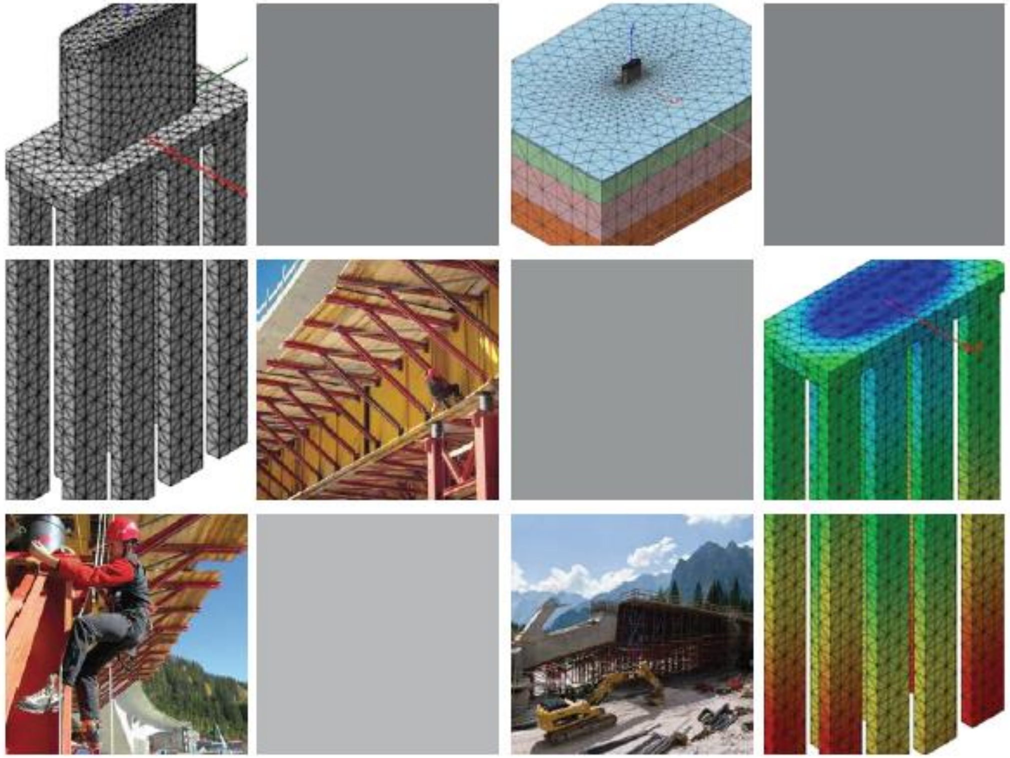


Bridge on the River Rudavoi
- CortIna d'Ampezzo

Belluno, Italy

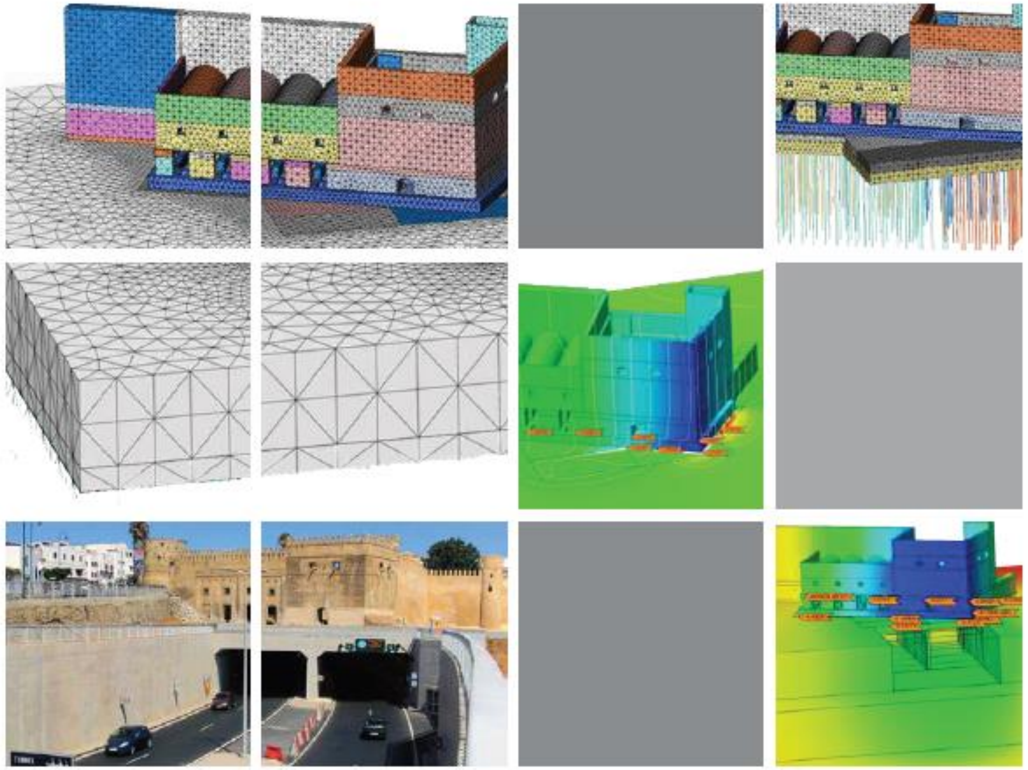
ULMA

Engineering Consultant	ULMA Construction
Size of the Structure	180m Total Length
Main features in modelling	- Construction stage analysis - Stability analysis for the pier foundation of bridge
Description on this project	After the pier construction, the bridge was completed in three stages. The 70m long stretch between the abutment and the pier was built with horizontal beam - based formwork and full shoring. After concrete hardening and falsework removal, the same material was used in a symmetrical manner between the abutment and the pier on the other side of the bridge. A high capacity shoring tower on a temporary footing supports the central part of the bridge (40m).



Oudayas Tunnel
- Royal Palace
Rabat, Morocco
Alpina

Owner	Royaume du Maroc - Agence pour l'Am nagement de la Vall e du Bouregreg
General Contractor	Pizzarotti
Engineering Consultant	Alpina
Construction Period	2007 - 2011
Project Type	Road Infrastructure
Main features in modelling	- Tunnel construction under the complex historical landmark - Modeling of micropiles, berlin wall and slab
Description on this project	The new roadway project is characterized by an extension of tunnel entrance that lies underneath the Des Oudayas monument complex. The complex consists of two historic buildings, the fortress, the library, the walls of the Kasbah, and an Andalusian garden. The design of the Des Oudayas Tunnel was necessary to ensure the stability, integrity, and safety throughout all the excavation and construction phases given the excavation's location under the historic structure. The design had to additionally consider the interaction between two parallel 300 m tunnels with on-going traffic.

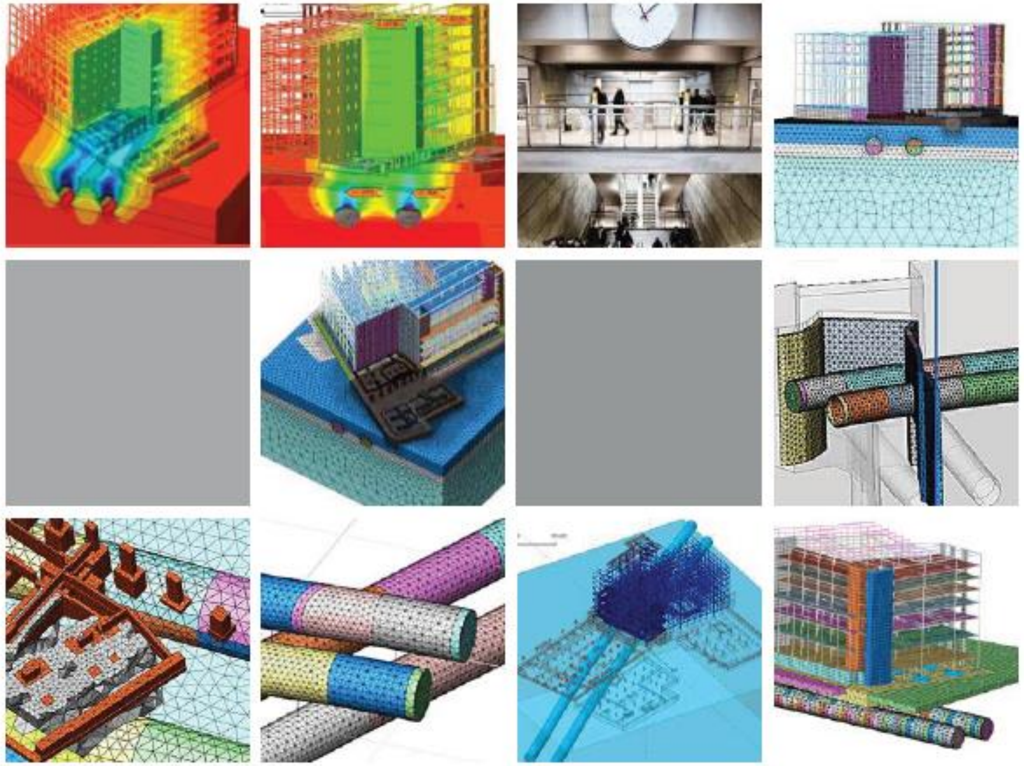


Cityringen
Copenhagen Metro

Copenhagen, Denmark

Lombardi

Owner	Metroselskabet
Engineering Consultant	Lombardi
Construction Period	2011 - 2017
Project Type	Subway Station
Size of the Structure	15.5 km long twin single - track metro tunnels.
Main features in modelling	- Interaction between MIDAS family programs (Gen & GTS NX) - Construction stage analysis for TBM
Description on this project	The Cityringen is a city circle metro - line, approximately 15.5 km long and will serve major areas of the city of Copenhagen including the Danish Parliament, the Central Station, the City Hall, existing major S - train and metro stations and national monuments. The line will have driverless communication - based train control system, with stewards on board. A round trip is expected to take 23 minutes. The headway interval is expected to be 200 sec., with 28 trains of 3 carriages running at 90 km/h.



PROBLEM STATEMENT

Pile Dimensions:

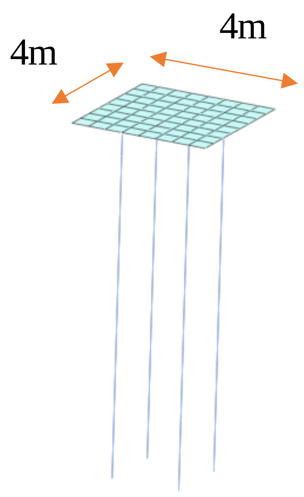
Diameter 0.5m
Length 10m
c/c Spacing 2m

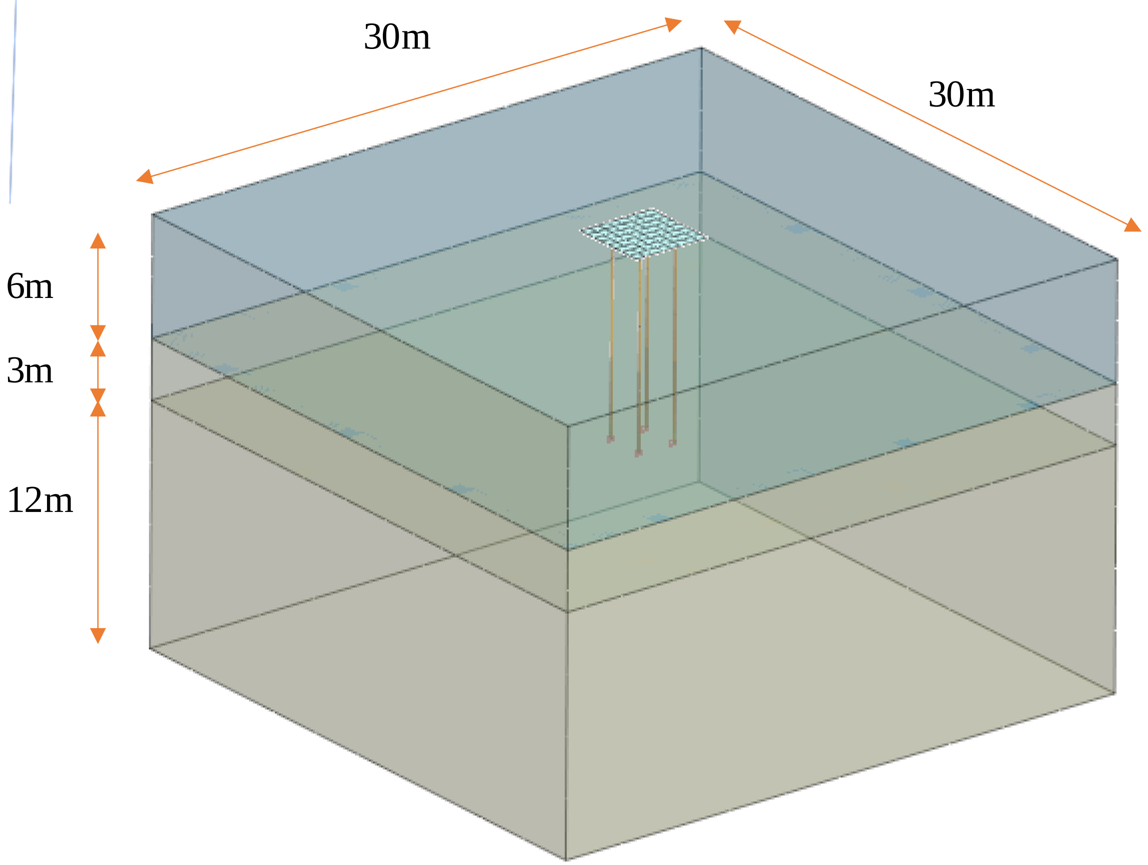
Raft Dimensions:

Section 4mx4m
Thickness 0.75m

Superstructure Loading on the Raft

Non-Linear Static Construction Stage Analysis





LET’S START MODELLING

4. GROUND IMPROVEMENT

MODELLING AND ANALYSIS

CONTENTS

Session 4. GROUND IMPROVEMENT

1. GTS NX Modelling Features
2. Analysis Capabilities
3. Problem Statement

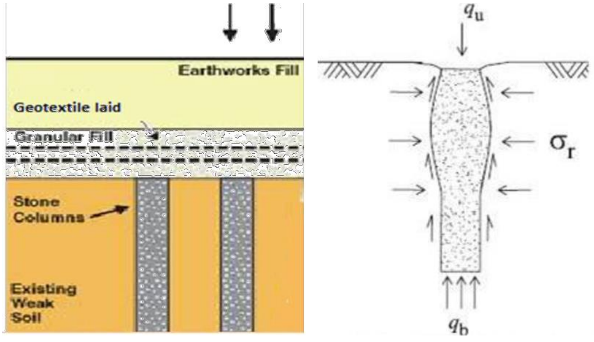
Ground Improvement

Modifying soil properties to enhance its performance

Addressed issues include poor bearing capacity, excessive settlements, etc

Examples for some Ground Improvement Methods:

Stone Columns
Soil Mixing
Jet Grouting
Prefabricated Vertical Drains
Vibration Techniques
Ground Freezing
Dynamic Compaction, etc

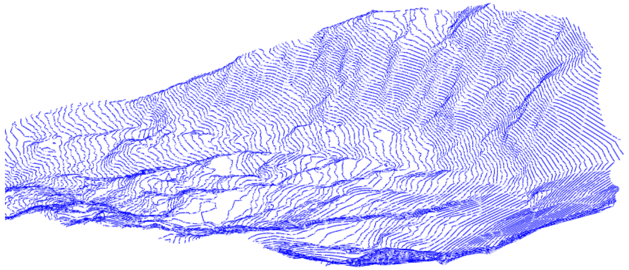


Geometry Modelling

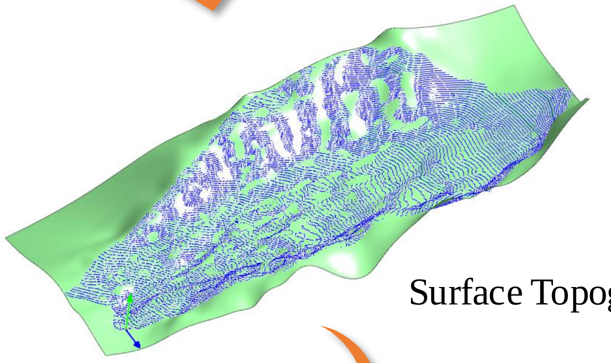
- Complex 3D topography modelling using imported contour curves
- Supports .dxf, .dwg and other CAD format drawings import

Parasolid (9 to 34) Files (*.x_t;*.xmt_txt;*.x_b;*.xmt_bin)
ACIS (R1 - 2022 1.0) Files (*.sat;*.sab;*.asat;*.asab)
STEP (AP203, AP214, AP242) Files (*.stp;*.step)
IGES (Up to 5.3) Files (*.igs;*.iges)
Pro-E (16 - Creo 8.0) Files (*.prt;*.prt.*;*.asm;*.asm.*)
CATIA V4 (CATIA 4.1.9 - 4.2.4) Files (*.model;*.exp;*.session)
CATIA V5 (V5 R8 - V5-6R2025) Files (*.CATPart;*.CATProduct)
SolidWorks (98 - 2022) Files (*.sldprt;*.sldasm)
Unigraphics (11 - NX2007) Files (*.prt)
Inventor Part (V6 - V2022) Files (*.ipt)
Inventor Assembly (V11 - V2022) Files (*.iam)

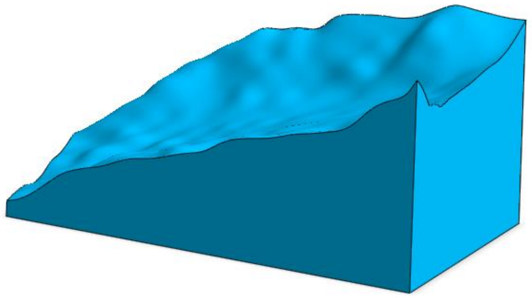
CAD Formats import

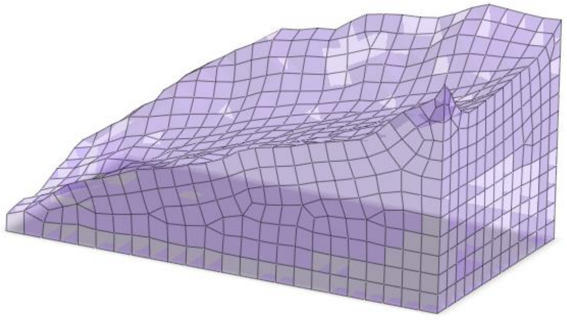


Contour curves import



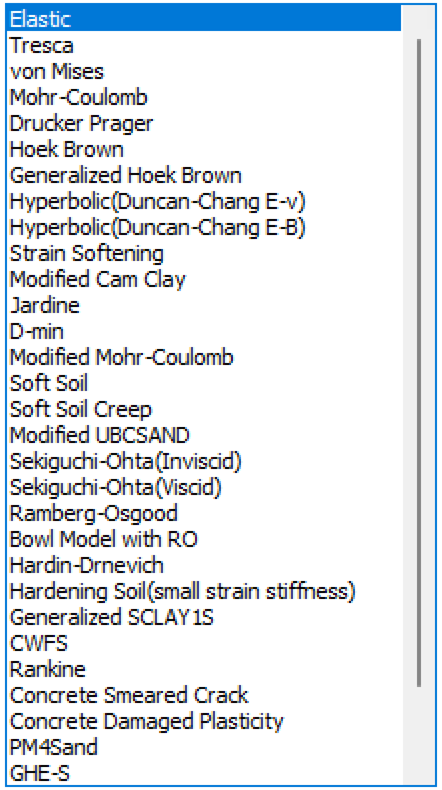
Surface Topography

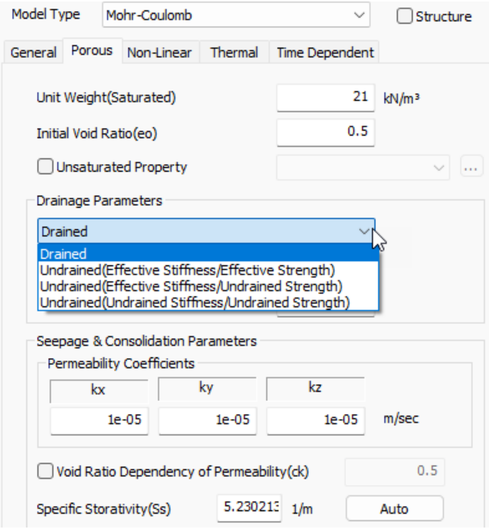


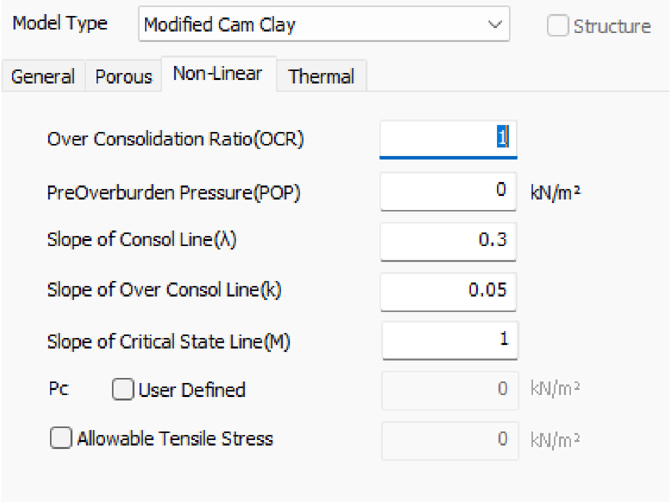


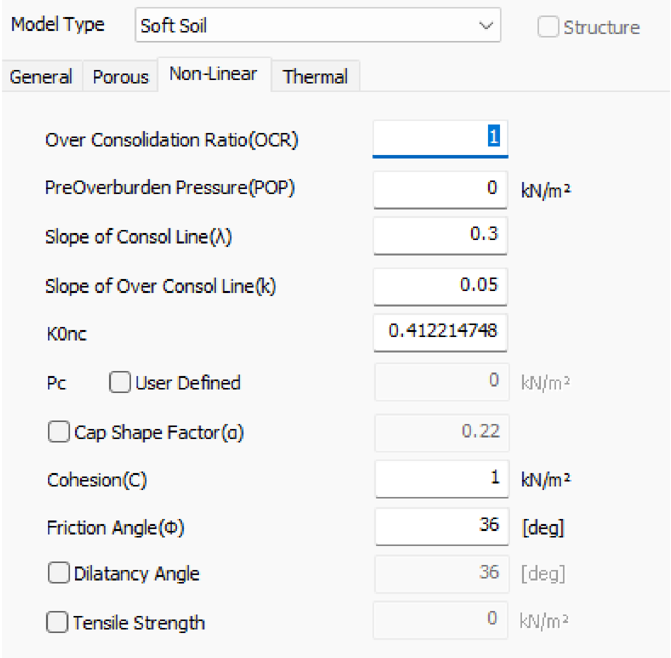
Geometry Modelling and Meshing

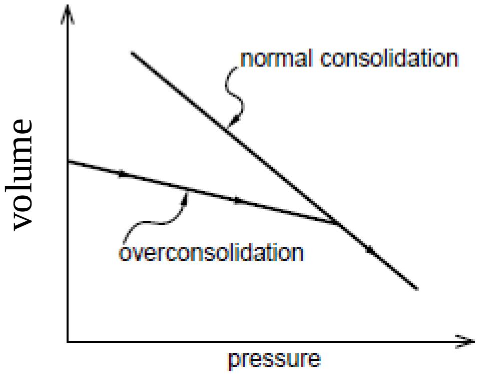
Material Models

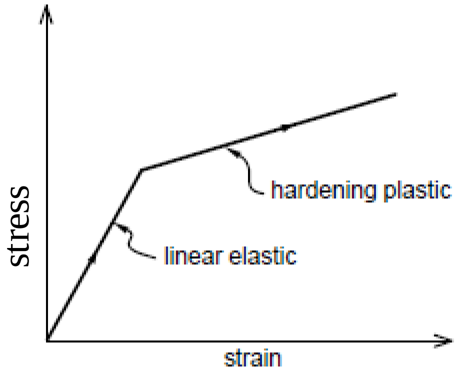








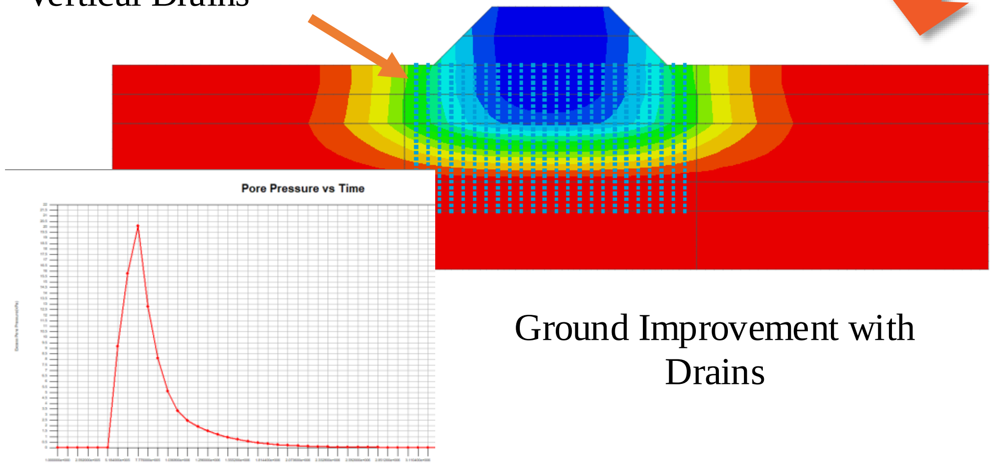




Ground Improvement- Drains Simulation

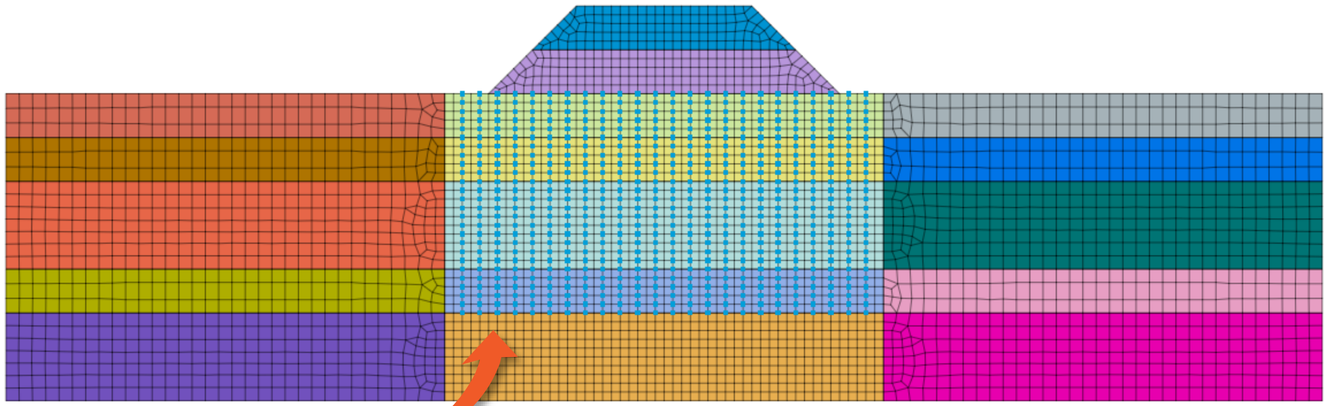
- **Draining condition**: Seepage Boundary used to simulate Drains(excess pore pressure is zero for this domain)
- **Non-Consolidation**: Used to model non-consolidation embankment layers

Vertical Drains



Ground Improvement with Drains

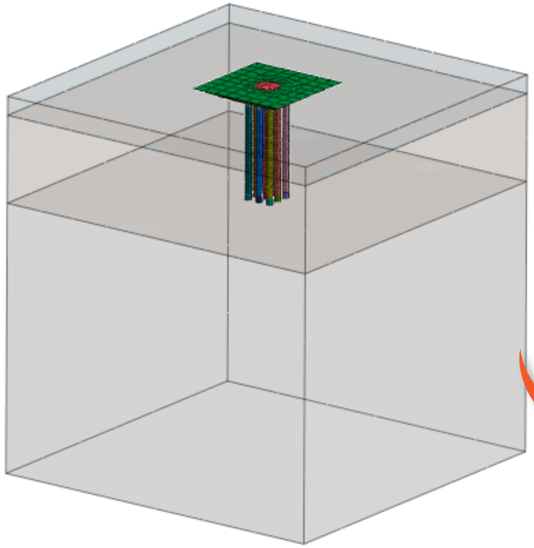
Non-Consolidation Layers Definition

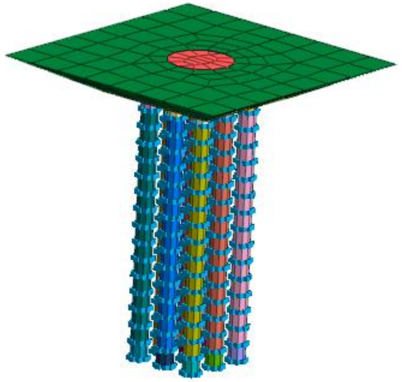


Drains simulation

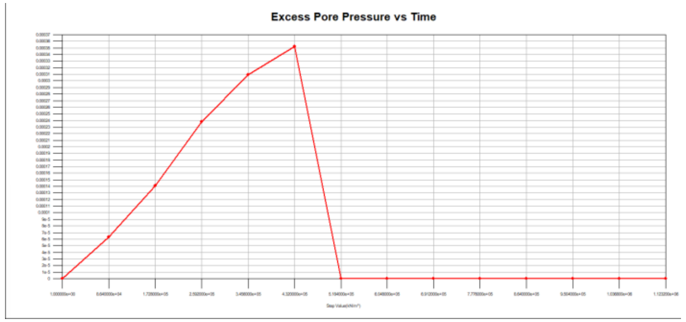
Ground Improvement- Stone Columns

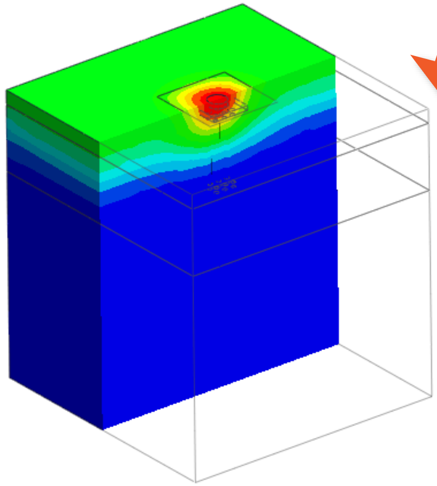
- **Draining condition**: Seepage Boundary used to simulate zero excess pore pressure condition
- **Non-Consolidation**: Used to model non-consolidation embankment layers





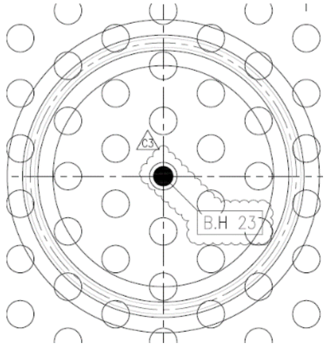
Stone Columns simulation

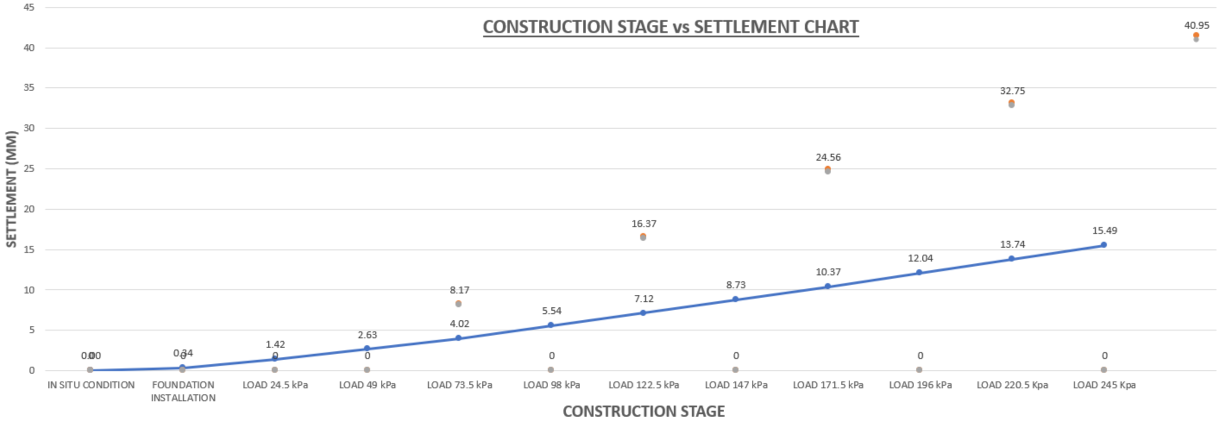




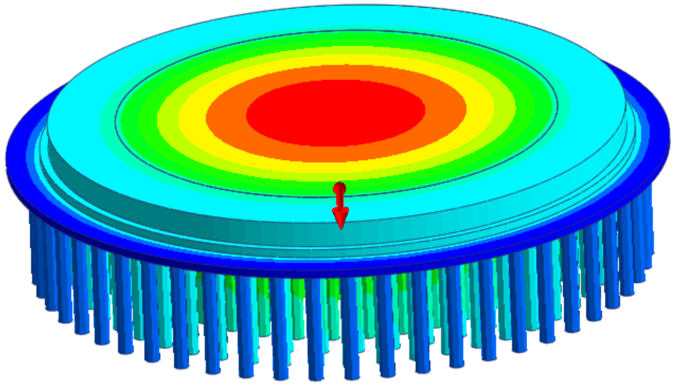
Ground Improvement with Stone Columns

Ground Improvement- Stone Columns





Hydrocarbon Tank Loading Stage Settlements

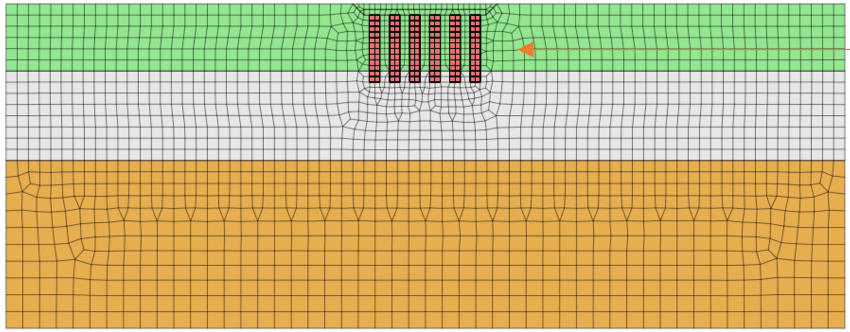


3D Model Results

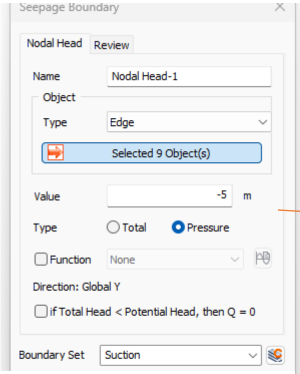
Ground Improvement- Suction Drains & Jet Grouting

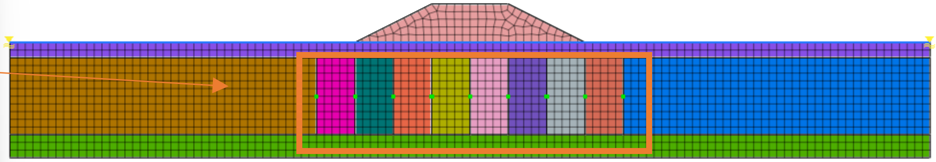
- **Change Property**: To define change in property of soil materials to grout, etc to simulate Jet Grouting Technique in Consolidation Construction Stage Analysis

- **Nodal Head**: To define water head value at specific nodes (Negative Water Head equivalent to Suction Pressure can be input to simulate Suction Drain Technique)

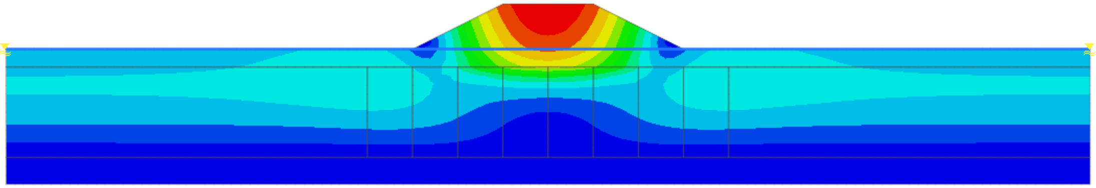


Property Change to Grout at specific locations



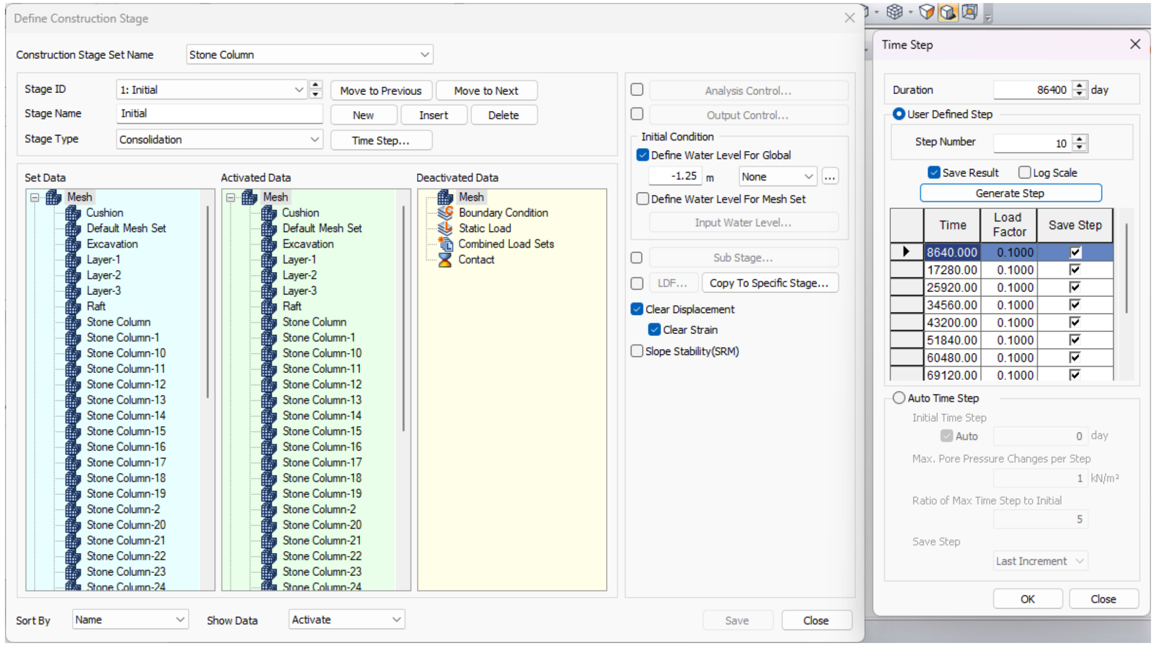


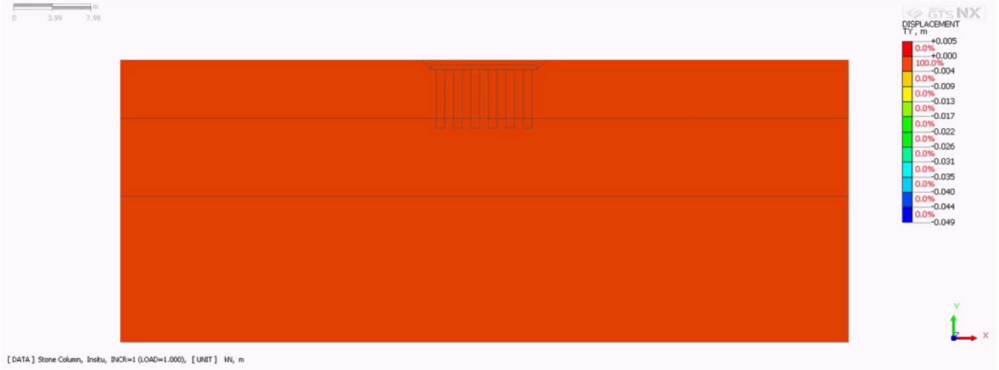
Suction Drain Simulation

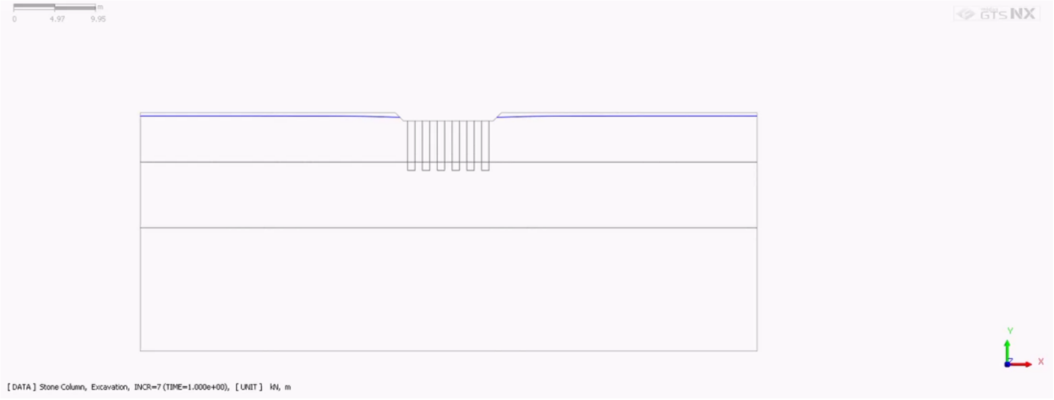


Consolidation Analysis

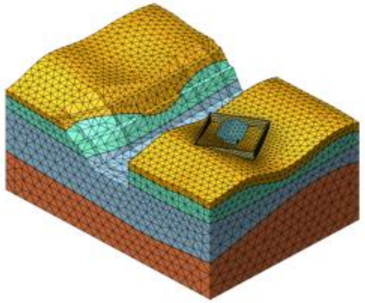
- Consolidation Analysis in Construction Stages
- User Defined or Auto Time Step input based on Max Pore Pressure Changes per step
- Consolidation Analysis coupled with SRM
- Total/ Pore Pressure Head results, Deformations, Stresses, Strains, etc- all the results available for each Time Step

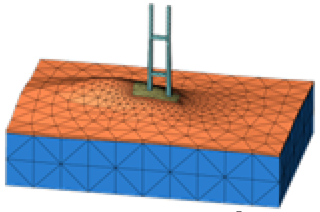




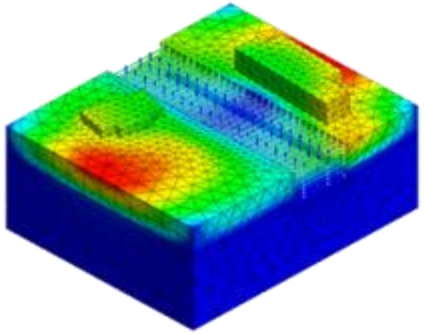


All-in-One FEM based 3D Geotechnical Analysis Software





- Linear Static analysis
- Nonlinear Static analysis



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

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

Static Analysis

Slope Stability Analysis

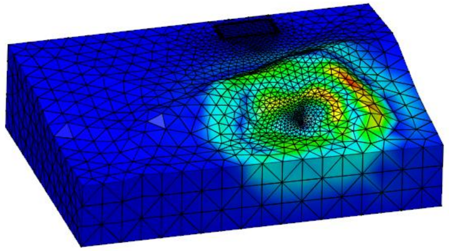
Construction Stage Analysis

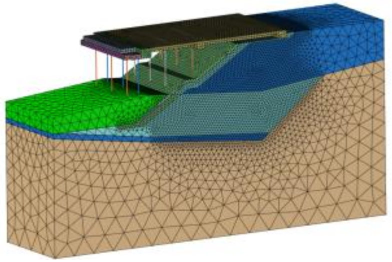
Dynamic Analysis

Consoli-dation Analysis

Seepage Analysis

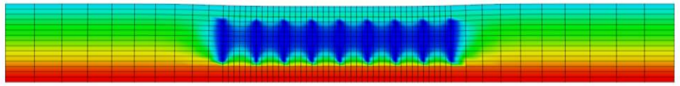
Stress–seepage fully coupled

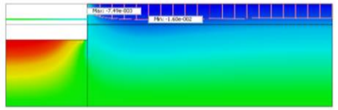




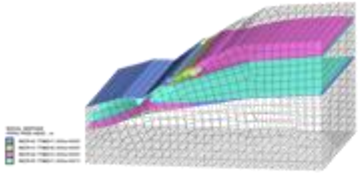
- Eigenvalue/Response Spectrum analysis
- Linear Time History (mode/direct methods)
- **Nonlinear Time History analysis**
- 1D/2D Equivalency Linear analysis
- **Nonlinear time history + SRM Coupled**

- Consolidation Analysis (coupled with SRM)
- **Stress–seepage fully coupled analysis**



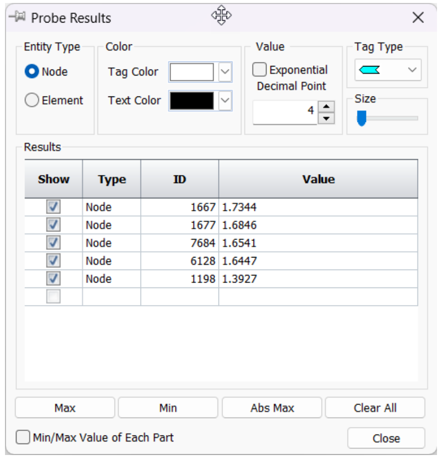


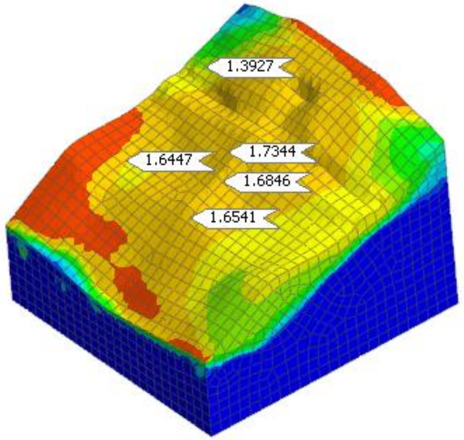
- Steady state seepage analysis
- Transient seepage analysis



Post Processing

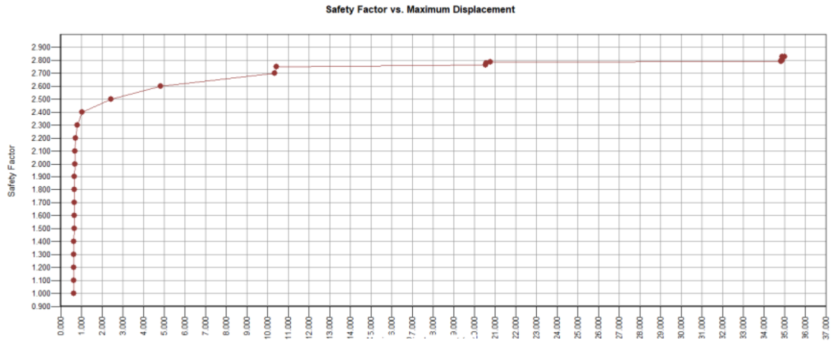
- Data Output at all nodes/elements
- Iteration vs Safety Factor Graph(SRM)
- Cutting Line/Plane Diagram with Tabular output

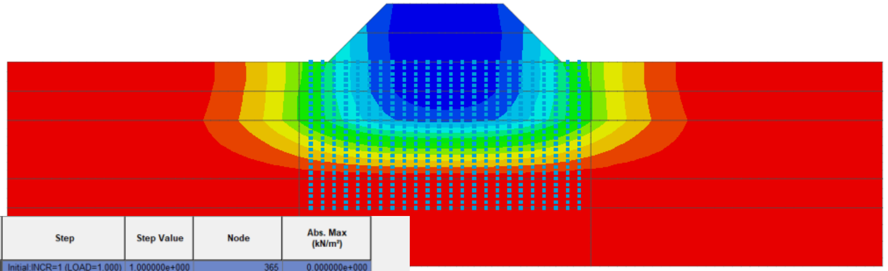




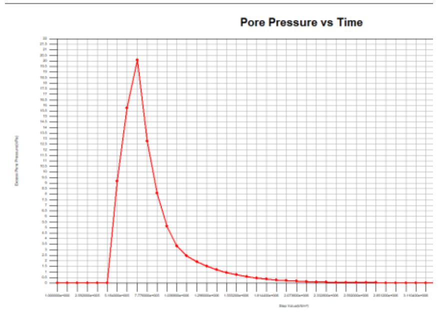
Probe: Check results at required nodes/elements

Safety Factor Graph plotted for each SRM iteration



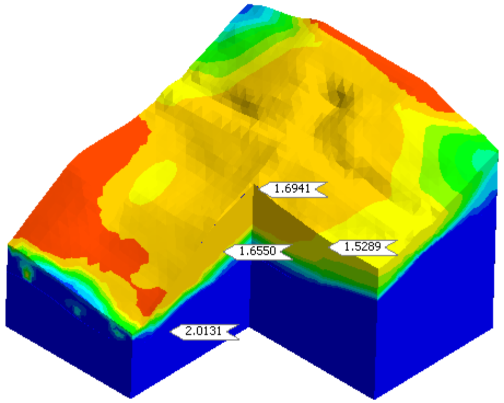


	No	Step	Step Value	Node	Abs. Max (kN/m³)
▶	1	Initial:INCR=1 (LOAD=1.000)	1.000000e+000	365	0.000000e+000
	2	Drains:INCR=1 (TIME=1.000e	8.640000e+004	3068	2.364377e-004
	3	Drains:INCR=2 (TIME=2.000e	1.728000e+005	3068	3.042831e-004
	4	Drains:INCR=3 (TIME=3.000e	2.592000e+005	3068	3.302812e-004
	5	Drains:INCR=4 (TIME=4.000e	3.456000e+005	3068	3.396794e-004
	6	Drains:INCR=5 (TIME=5.000e	4.320000e+005	3068	3.018639e-004
	7	Embankment 1:INCR=1 (TIM	5.184000e+005	3115	9.172249e+000
	8	Embankment 1:INCR=2 (TIM	6.048000e+005	3115	1.575894e+001
	9	Embankment 1:INCR=3 (TIM	6.912000e+005	3113	2.009952e+001
	10	Leave Period 1:INCR=1 (TIM	7.776000e+005	3219	1.279873e+001
	11	Leave Period 1:INCR=2 (TIM	8.640000e+005	3219	8.111315e+000
	12	Leave Period 1:INCR=3 (TIM	9.504000e+005	3219	5.128653e+000
	13	Leave Period 1:INCR=4 (TIM	1.036800e+006	3157	3.348599e+000
	14	Leave Period 1:INCR=5 (TIM	1.123200e+006	3187	2.459330e+000
	15	Leave Period 1:INCR=6 (TIM	1.209600e+006	3078	1.927799e+000
	16	Leave Period 1:INCR=7 (TIM	1.296000e+006	3076	1.517783e+000
	17	Leave Period 1:INCR=8 (TIM	1.382400e+006	3070	1.201794e+000
	18	Leave Period 1:INCR=9 (TIM	1.468800e+006	3068	9.491826e-001
	19	Leave Period 1:INCR=10 (TIM	1.555200e+006	3068	7.484057e-001
	20	Leave Period 1:INCR=11 (TIM	1.641600e+006	3066	5.878738e-001
	21	Leave Period 1:INCR=12 (TIM	1.728000e+006	3066	4.614347e-001
	22	Leave Period 1:INCR=13 (TIM	1.814400e+006	3064	3.613558e-001
	23	Leave Period 1:INCR=14 (TIM	1.900800e+006	3064	2.828163e-001
	24	Leave Period 1:INCR=15 (TIM	1.987200e+006	3054	2.215481e-001
	25	Leave Period 1:INCR=16 (TIM	2.073600e+006	3054	1.731974e-001
	26	Leave Period 1:INCR=17 (TIM	2.160000e+006	3054	1.352906e-001
	27	Leave Period 1:INCR=18 (TIM	2.246400e+006	3054	1.055939e-001
	28	Leave Period 1:INCR=19 (TIM	2.332800e+006	3054	8.233926e-002
	29	Leave Period 1:INCR=20 (TIM	2.419200e+006	3054	6.415379e-002



Results extracted as Tables and Graphs
Extracted results/graphs directly exported to excel

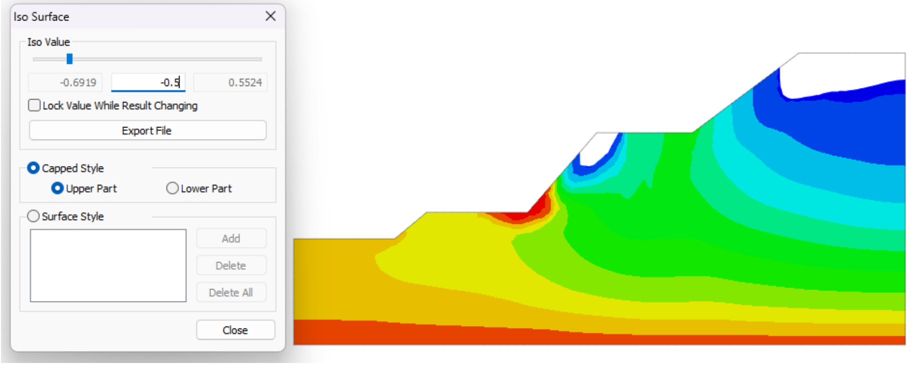
Result Extraction as Image, Animation, Excel, pdf, Word formats



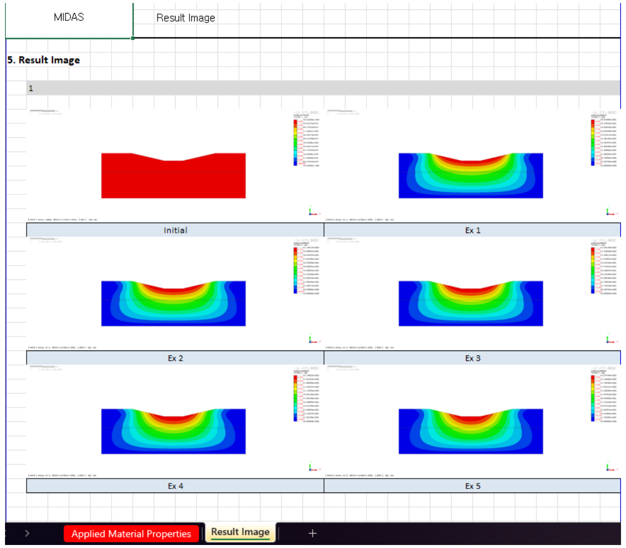
Sectional view: Clipping Line/Plane

Post Processing

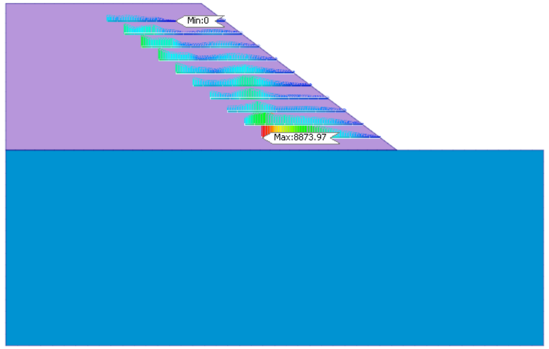
- Iso Value Surface: Displays domain inside/outside a preset specified value range
- Report Generation: Excel/PDF/Word
- Geogrid Element Results: Axial Force, Stress, Strain Results
- Stage Bar: Check the results directly without using workstree



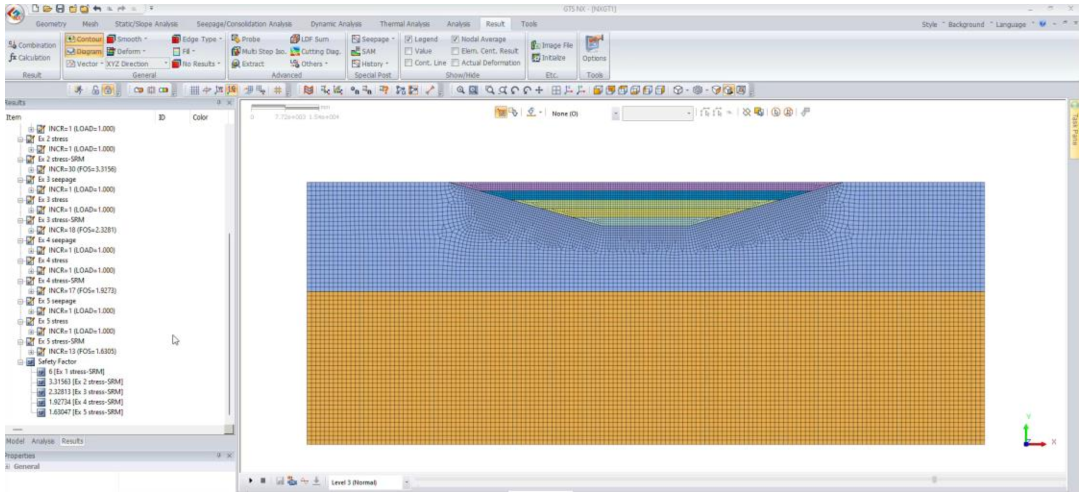
Iso Value Surface



Excel report Generation



Geogrid Element Results



Stage Bar

PROBLEM STATEMENT

Ground Improvement using PVDs

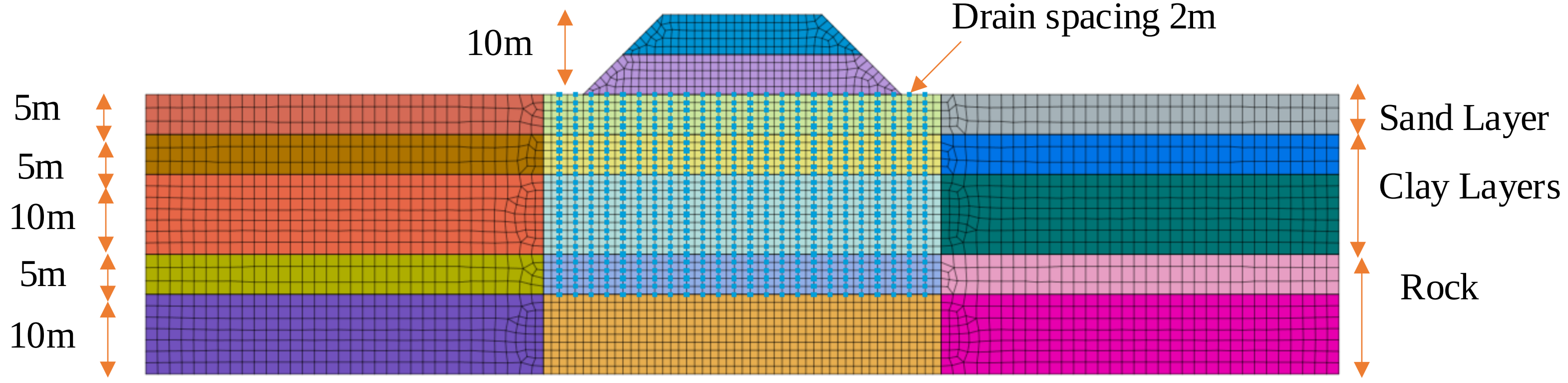
Drain spacing 2m

Embankment Height 10m

Modified Cam Clay (Undrained) used to model clay layers

Consolidation Analysis in Construction Stages

Total Consolidation Time considered: about 250 days



LET’S START MODELLING