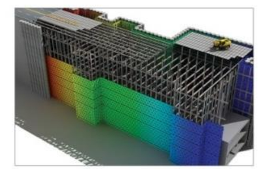
Release Notes

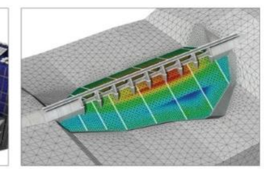
Release Date: September 2021

Product Version: GTSNX 2021(v1.1)

GTS NX

Geo-Technical analysis System New eXperience





Integrated Solver Optimized for the next generation 64-bit platform

Finite Element Solutions for Geotechnical Engineering

MIDAS

Enhancements

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1.2 GHE(General Hyperbolic Equation)-S Constitutive Model

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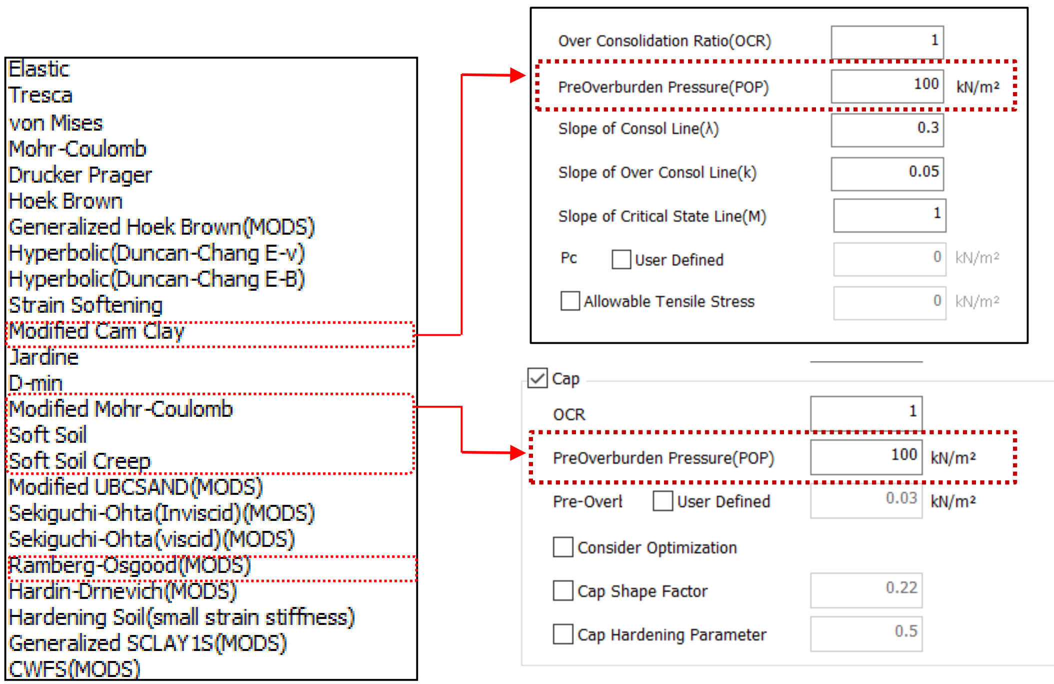
1. Analysis

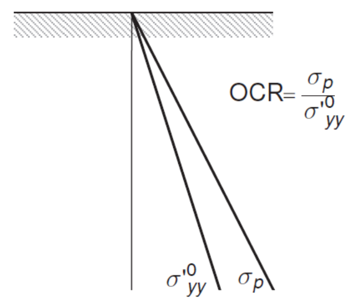
1.1 Pre-Overburden Pressure at Advanced Soil Model

- POP is applied on Modified Mohr-Coulomb, Hardening Soil, Soft Soil(Creep), Modified Cam Clay, User can define the initial stress state using Pre-Overburden Pressure(POP) instead of assigning Over-Consolidation Ratio(OCR).

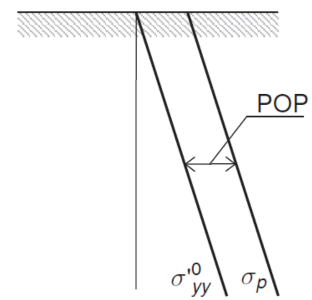
- **Mesh > Prop./Csys./Func. > Material > Create > Isotropic > MMC / HS / SS(C), MCC**



[Non-linear tab]



[OCR]



[POP]

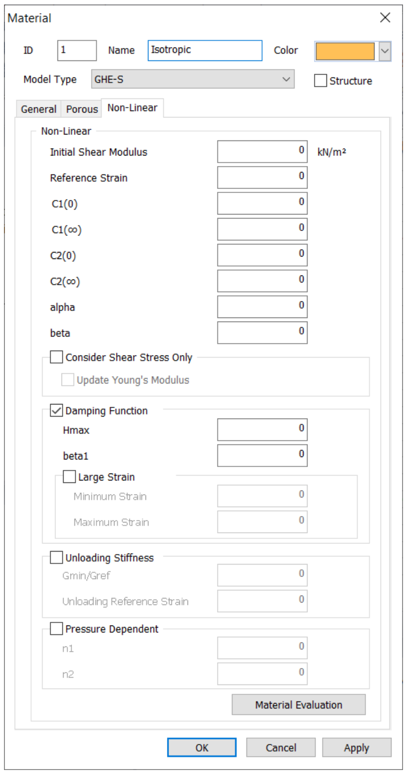
- User can define the initial stress state with OCR.
  And, Using POP instead of OCR is also possible
- Using vertical pre-consolidation(σ_p) is general,
  But, POP is used to define the initial place of the cap yield surface

1. Analysis

1.2 GHE(General Hyperbolic Equation)-S Constitutive Model

- This is for Japanese Railway Dynamic non-linear constitutive model. Unbounded curve is suggested from Tatsuoka and Shibuya[1)] using GHE(General Hyperbolic Equation) model. And, History law is a model which is satisfied with $G/G_0\sim\gamma$ relationship and $h\sim\gamma$ relationship after developing the Massing law.
- After inputting experiment data of $G/G_0\sim\gamma$ and $h\sim\gamma$ relationship, parameters for the defining material will be calculated automatically.

- **Mesh > Prop./Csys./Func. > Material > Create > Isotropic > GHE-S**



[GHE-S]

- **Unbounded Curve :** GHE(General Hyperbolic Equation) model has $C_1(0), C_2(0)$, $C_1(\infty)$, $C_2(\infty)$, α, β, these 6 material constant. However, if $x=0$, $dy/dx=1$ and if $x=\infty$, $dy/dx=0$, with these two formulas, $C_1(0)=1, C_2(\infty)=1$ is defined. Finally, there are 4 material constants left. And, these 4 constants are calculated from the repetitive loading test's $G/G_0\sim\gamma$ relationship.

$$y=\frac{x}{\dfrac{1}{C_1(x)}+\dfrac{x}{C_2(x)}}$$

$x : \gamma/\gamma_r$, γ_r : Reference Shear Modulus

$y : \tau/\tau_f$, τ_f: Shear Stiffness

$$C_1(x)=\frac{C_1(0)+C_1(\infty)}{2}+\frac{C_1(0)-C_1(\infty)}{2}\cos\left(\frac{\pi}{\alpha/x+1}\right)$$

$$C_2(x)=\frac{C_2(0)+C_2(\infty)}{2}+\frac{C_2(0)-C_2(\infty)}{2}\cos\left(\frac{\pi}{\beta/x+1}\right)$$

- **History Rules :** The Massing law states that at some point on an unbounded curve, the subsequent history is that the unbounded curve is magnified by a factor of . The GHE-S model uses a method of drawing a hysteresis curve of the S-shape using the constant function equation(6.11.3) from the point of contraction of the usual massing law to the point of symmetry.

$$\lambda(\gamma)=\left(\frac{2-\lambda_{\min}}{\gamma_a{}^2}\right)\gamma^2+\lambda_{\min}$$

γ_a : Shear Modulus when unloading

$\gamma_a<\gamma_{\min}$ $\quad h=h_{\max}\left(1-\dfrac{G}{G_r}\right)^{\beta}$

$\gamma_{\min}\le\gamma_a\le\gamma_{\max}$ $\quad h=h_{\max}\left(1-\dfrac{G}{G_r}\right)^{\beta}\left(1-\dfrac{\gamma_a'-\gamma_{\min}}{\gamma_{\max}-\gamma_{\min}}\right)$

$\gamma_a>\gamma_{\max}$ $\quad h=0$

[1)] 室野剛隆：強震時の非線形動的相互作用を考慮した杭基礎の耐震設計法に関する研究, 鉄道総研報告,1999

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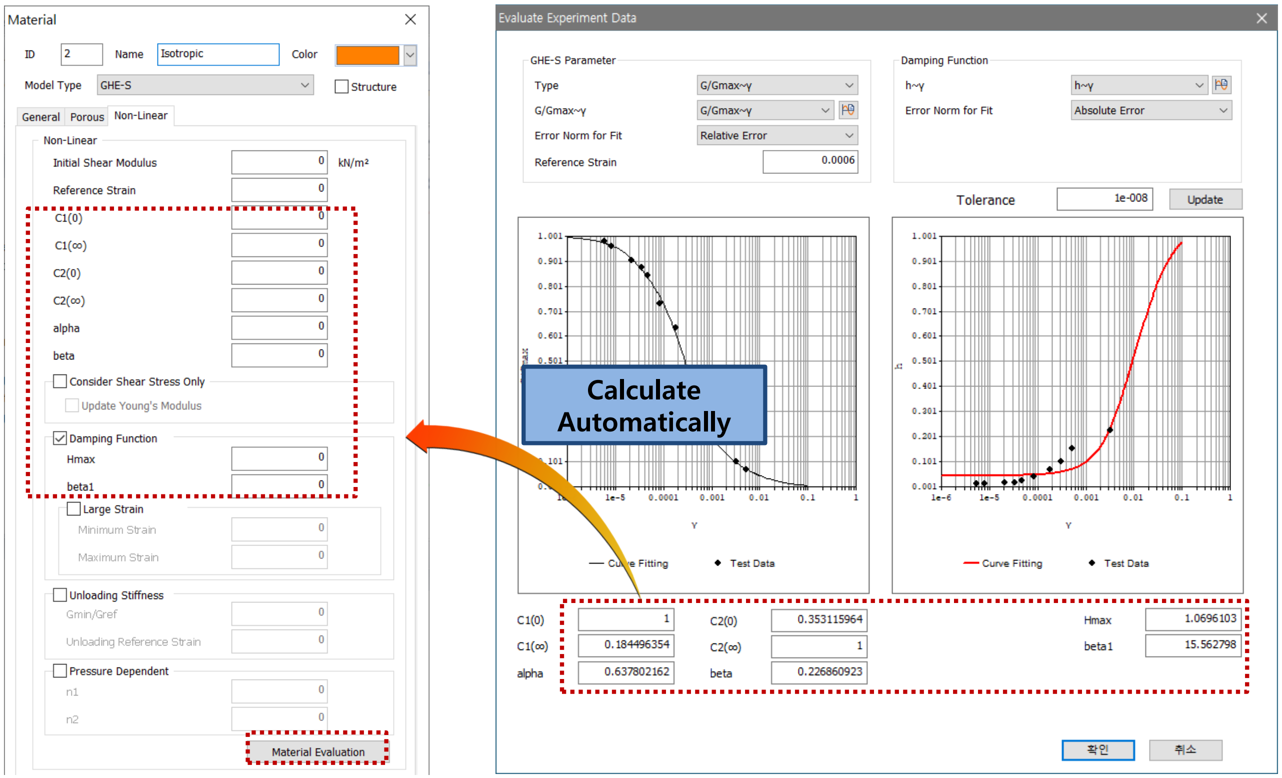
- After inputting experiment data of $G/G_0 \sim \gamma$ and $\mathrm{h} \sim \gamma$ relationship, parameters for the defining material will be calculated automatically.

- **Mesh > Prop./Csys./Func. > Material > Create > Isotropic > GHE-S**



[GHE-S]

- **Type :** Select the Type for evaluating the parameters between original data and normalized data from $G/G_{max} \sim \gamma$ test

- **Error Criteria for consistency :**
  Select the error criteria for estimating the data.
  - Relative Error :
    (True Value-Approximate Value)/True Value
  - Absolute Error : True Value-Approximate Value

※ $G/G_{\max} \sim \gamma$ and Normalization is recommended using Relative Error, $\mathrm{h} \sim \gamma$ is recommended using Absolute Error

1) 室野剛隆：強震時の非線形動的相互作用を考慮した杭基礎の耐震設計法に関する研究, 鉄道総研報告,1999

1. Analysis

1.3 NorSand Constitutive Model

- NorSand constitutive model is a critical state model was originated from the sand behavior in tailing dam previously. But, the model is widely applicable to t he ground from clay silt to sand.
- NorSand requires relatively few soil properties that can be collected from regular laboratory and in-situ tests so that users can get results easily.
- The consideration of a state parameter which is the difference between the current void ratio and the void ratio of its critical state is the prime advantage.

- **Mesh > Prop./Csys./Func. > Material > Create > Isotropic > NorSand**
  - **Non-linear Elasticity :** The Shear modulus of NorSand is non-linear elasticity like the below formula. And It is using power-low

$$G_t = G_{ref}\left(\frac{p}{p_{ref}}\right)^m$$

  - **Critical State :** state parameters(ψ) is defined with actual void ratio and critical void ratio, state parameters tend to be '0' when it is close to the critical state line(CSL)

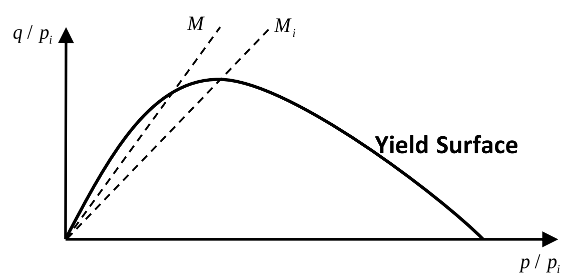
$$\psi = e - e_c$$

  - **Dilational Stress :** NorSand follows the associated flow rule, Dilational Stress is defined with the formula below

$$D_p = \frac{\dot{\varepsilon}_p^v}{\dot{\varepsilon}_p^q} = M_i - \eta$$

  - **Failure Envelope :** The Failure Envelope of NorSand is similar to Cam-Clay's bullet shape. And, the formula and the graph are like below

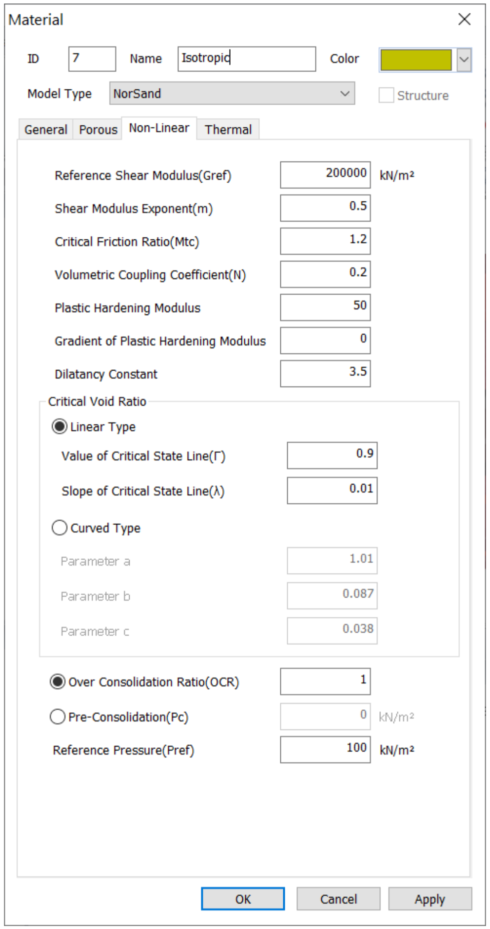
$$f = q - M_i p\left(1 - \ln(p) + \ln(p_i)\right)$$



1. Analysis

1.3 NorSand Constitutive Model

- **Mesh > Prop./Csys./Func. > Material > Create > Isotropic > NorSand**



[NorSand – Non-Linear Tab]

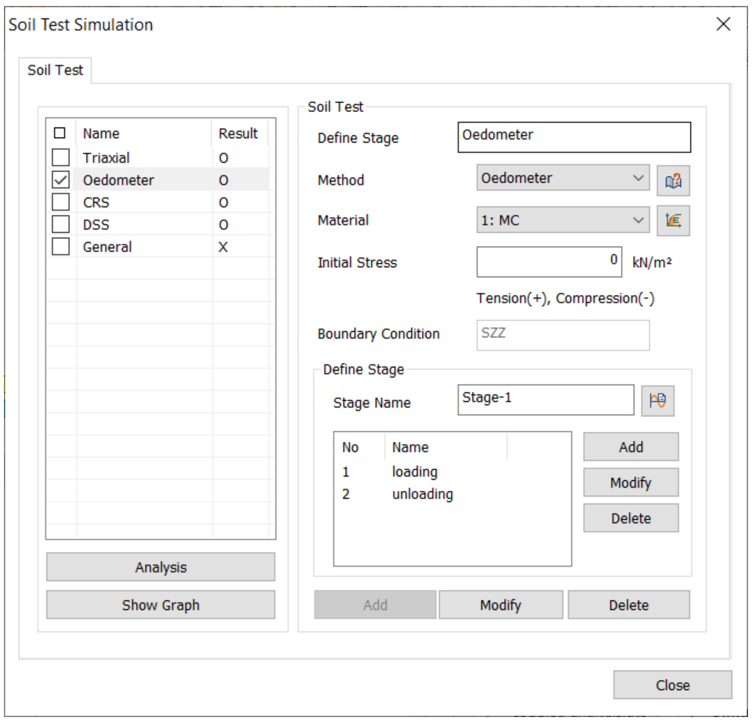
Parameter	Contents	Description
Gref	Reference Shear Modulus	$G_t = G_{ref}\left(\frac{p}{p_{ref}}\right)^m$
m	Shear Modulus Exponent(0≤m≤1)	
Mtc	Critical Friction Ratio	$M = M_{tc} - \frac{M_{tc}^2}{3+M_{tc}}\cos\left(\frac{3\theta}{2}+\frac{\pi}{4}\right)$
N	Volume linkage coefficient	
Plastic Hardening Modulus	Plastic Hardening Modulus	
Gradient of Plastic Hardening Modulus	Gradient of Plastic Hardening Modulus	
Dilatancy Constant	Dilatancy Constant	
Γ	Value of Critical State Line	$e_c = \Gamma - \lambda \ln\left(100p / p_{ref}\right)$
λ	Slope of Critical State Line	
a, b, c	Parameter a, b, c	$e_c = a - b\left(p / p_{ref}\right)^c$
OCR	Over Consolidation Ratio	$p_{i,init} = OCR \times p\exp\left(\frac{\eta}{M_i} - 1\right)$
Pc	Pre-Consolidation	
Pref	Reference Pressure	100kPa

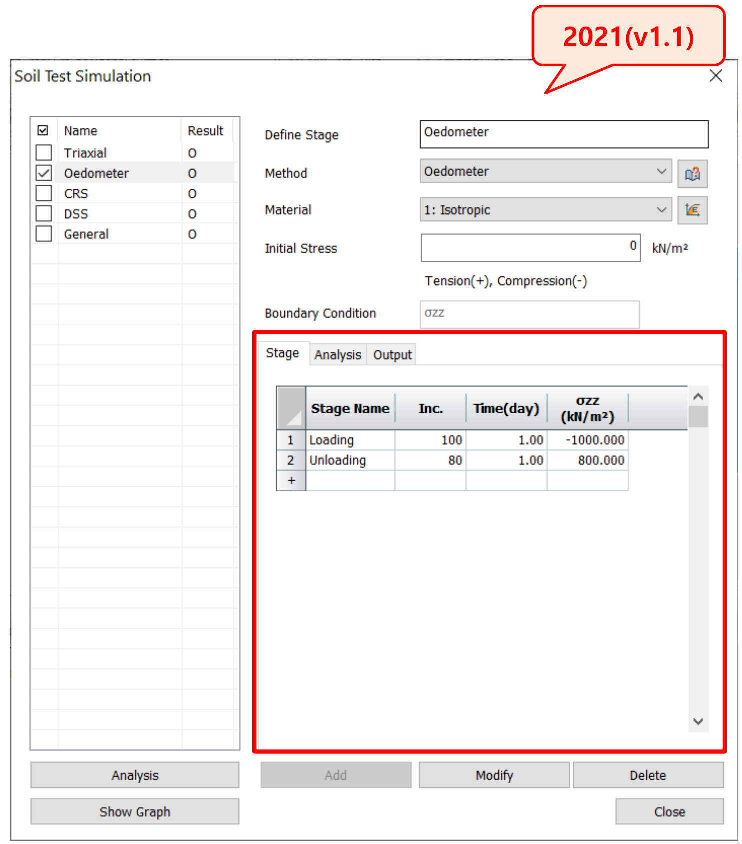
1. Analysis

1.4 Improvement of Soil Test

- For more convenience, User Interface is developed. One of them is preventing overlapped windows when the user conducts a soil test so that the user can add/edit/delete in one work tree.
- Additionally, Drawing Mohr-Circle is developed.

- **Static/Slope Analysis > Wizard > Soil Test**





[Development of Defining of Construction Stage]

1. Analysis

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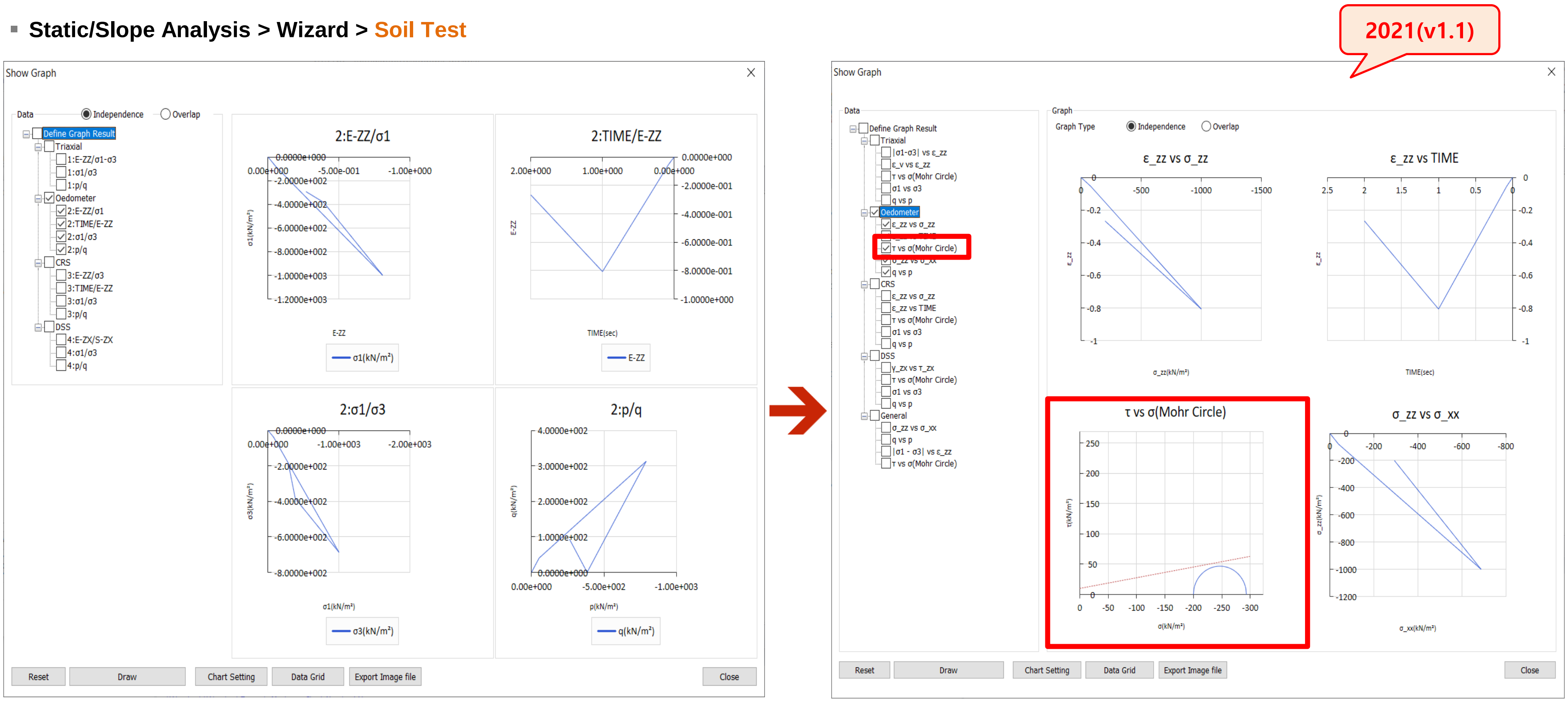


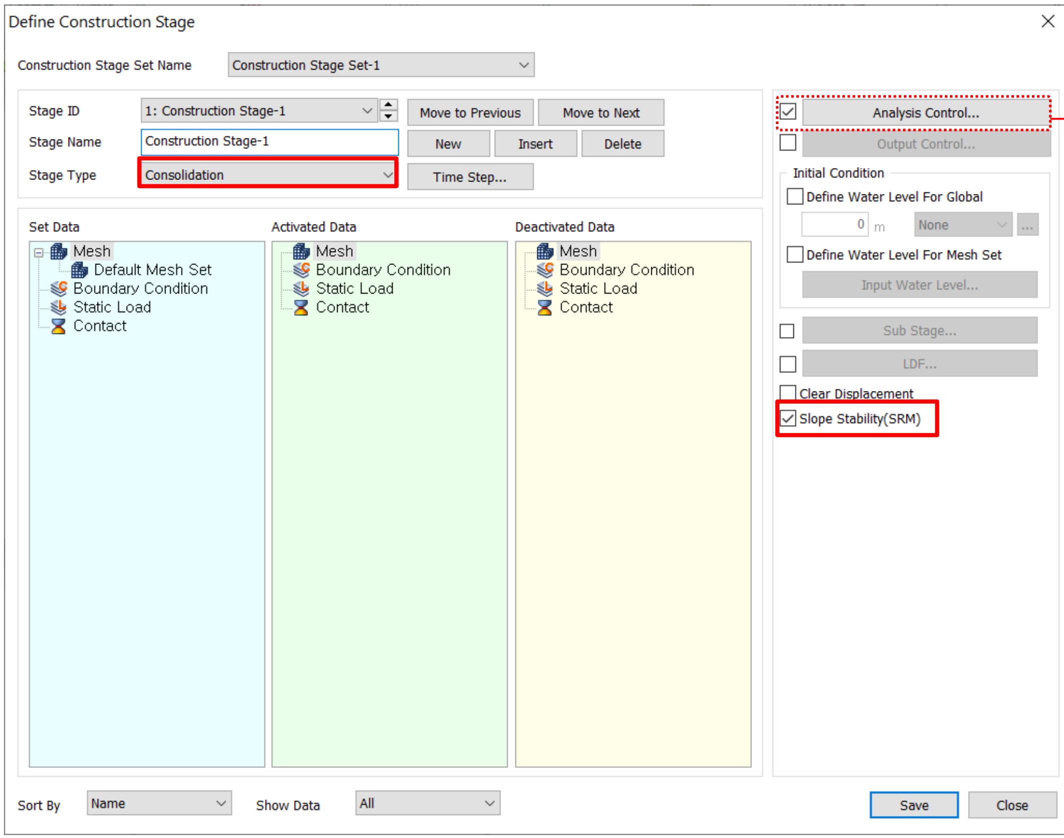
[Development of Drawing Graph and Mohr-Circle]

1. Analysis

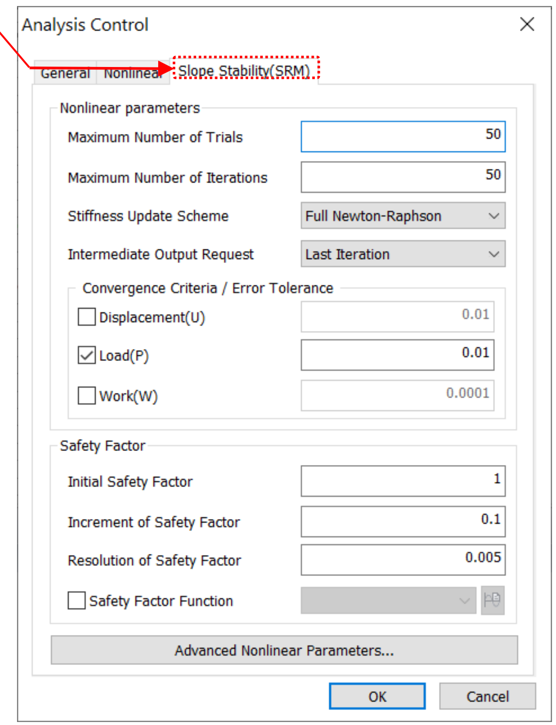
1.5 Slope Stability during Consolidation Analysis

- During Consolidation Analysis, the user can tick the Slope Stability Analysis(SRM) in Define Construction Stage.
- When the user ticks Slope Stability Analysis(SRM), Slope Stability Analysis is being conducted with the last time step's ground stress state and a separated result will be displayed.

- **Seepage/Consolidation Analysis > Stage Set > Consolidation > Define Construction Stage > Slope Stability(SRM)**



When the user ticks Slope Stability, Slope Stability is activated under the Analysis Control. Here, the user can control 'Convergence Criteria' or 'Safety Factor'.



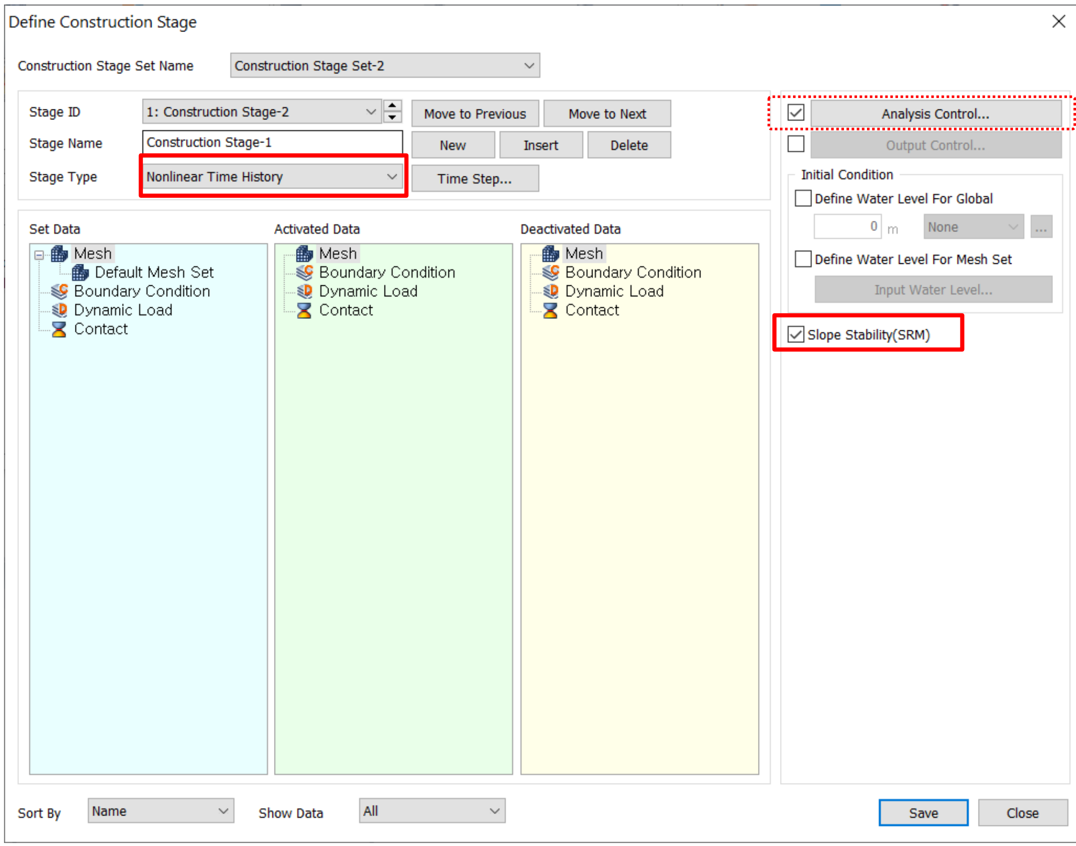
[Slope Stability(SRM) - Consolidation]

1. Analysis

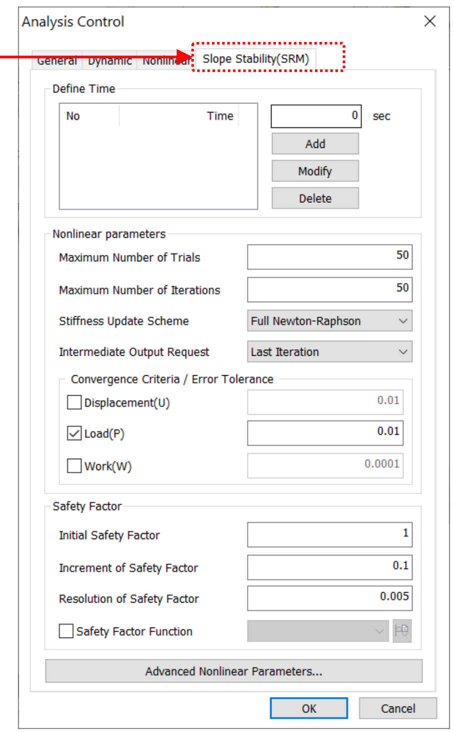
1.6 Slope Stability during Stress-Nonlinear Time History

- During Stress-Stress-Nonlinear Time History Analysis, the user can tick the Slope Stability Analysis(SRM) in Define Construction Stage.
- When the user ticks Slope Stability Analysis(SRM), Slope Stability Analysis will be conducted with the time step from 'Analysis Control' > 'Define Time' and a separated result will be displayed.

- **Static/Slope Analysis > Stage Set > Stress-Nonlinear Time History > Define Construction Stage > Nonlinear Time History > SlopeStability(SRM)**



When the user ticks Slope Stability, Slope Stability(SRM) is activated under the Analysis Control and the user can edit 'Define Time', 'Convergence Criteria' and 'Safety Factor'.



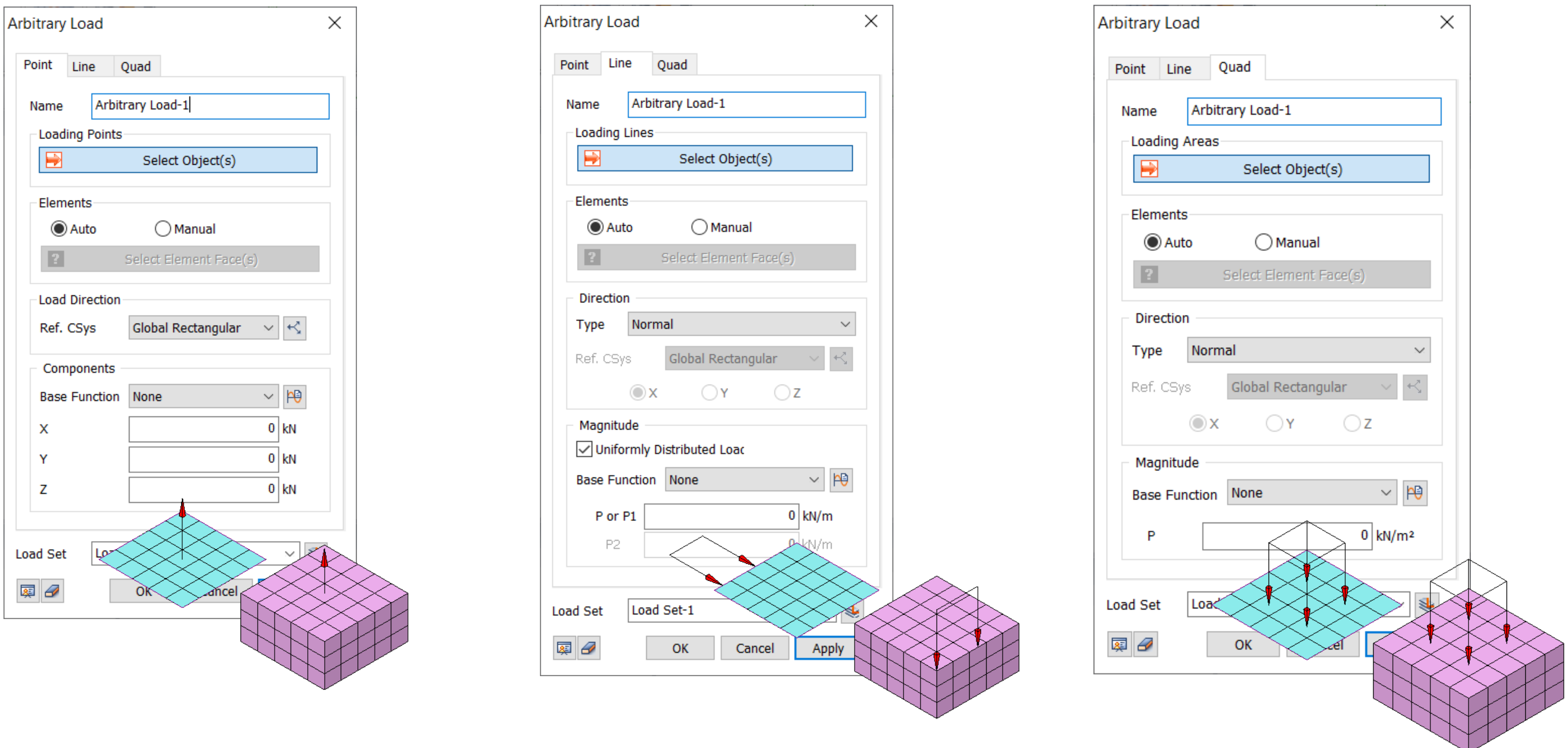
[Slope Stability(SRM) – Stress-Nonlinear Time History]

1. Analysis

1.7 Arbitrary Load

- GTS NX provides arbitrary loading function which can be applied to arbitrary locations/areas regardless of node and/or element connection.

- **Static/Slope Analysis > Load > Arbitrary Load**



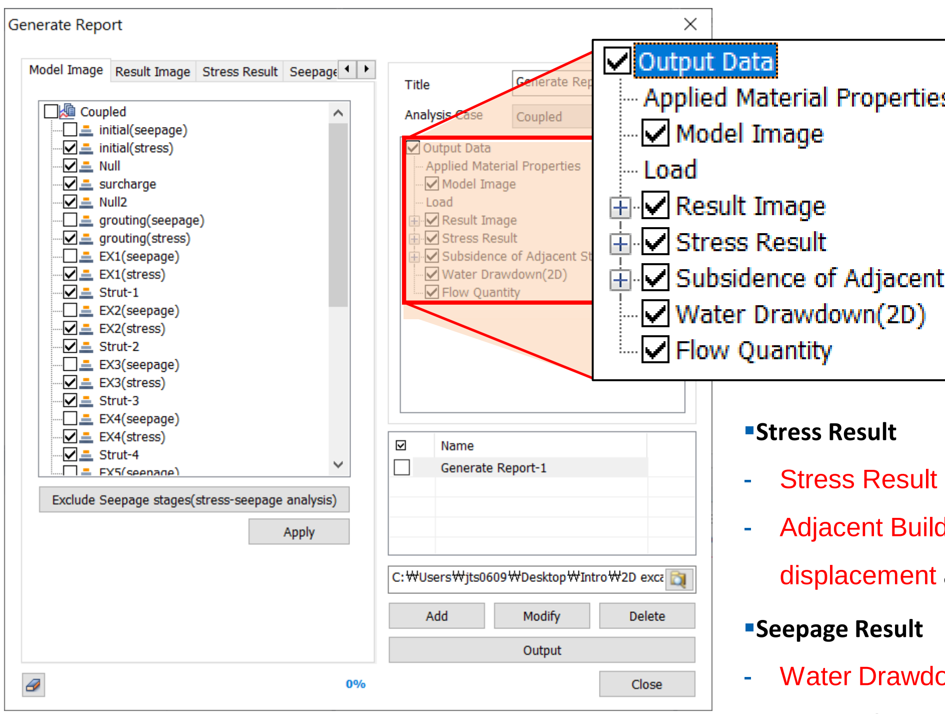
[Arbitrary Load – Point, Line, Quad]

2. Pre/Post Processing

2.1 Generate Report

- There are four groups : Model Image, Result Image and Stress/Seepage Result, with this, the user can organize the result from input data to results
- In addition to displacement or stress results by direction, the results of water drawdown that had a lot of work during the result organization are displayed in the form of a result table and graph through simple location definition. The evaluation of subsidence or water drawdown is automatically evaluated by input criteria.

- **Tools > Export > Generate Report**



[Generate Report option Window]

- **Applied Material Parameter/Load**

Material/Property/Unsaturated Property and Load(static load) which are used in the analysis control(construction stage) are displayed with tables and images

- **Model Image**

- Modelling Image : Construction Sequence table and image
- Construction Stage Image : Final Sequence Image is displayed from selected construction stages

- **Result Image**

Selected Construction Sequence and Results will be displayed with image files (Except for Plastic Status and Rotation result)

- **Stress Result**

- Stress Result : Generate result table and graph based on the nodes where user select
- Adjacent Building Assessment : the subsidence between two selected nodes and the angular displacement are displayed with table and image (Safety Assessment)

- **Seepage Result**

- Water Drawdown(2D) : Based on crossed phreatic lines, water levels are displayed with the result table and graph. (water drawdown(daily/accumulation) assessment)
- Flow Quantity : From selected nodes, flow quantity(daily/accumulation) result table and graph will be displayed

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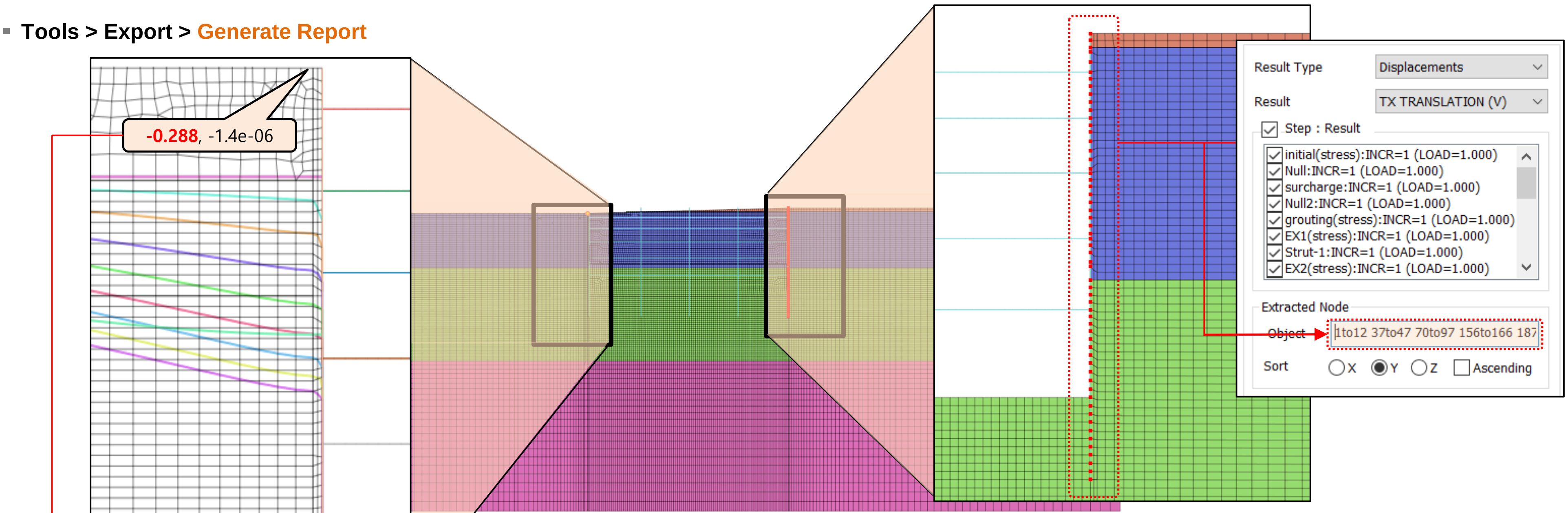
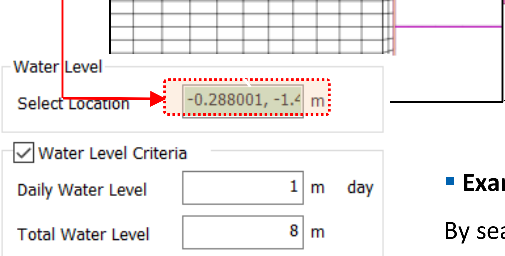




Example) Vertical displacement of Retaining Wall

the user can check displacement of retaining wall every stage

Select the result(TX Translation), Click the nodes for Retaining wall

- **Example) Water drawdown from Retaining wall's left side**

By searching phreatic lines automatically, the user can check the water drawdown by stages.

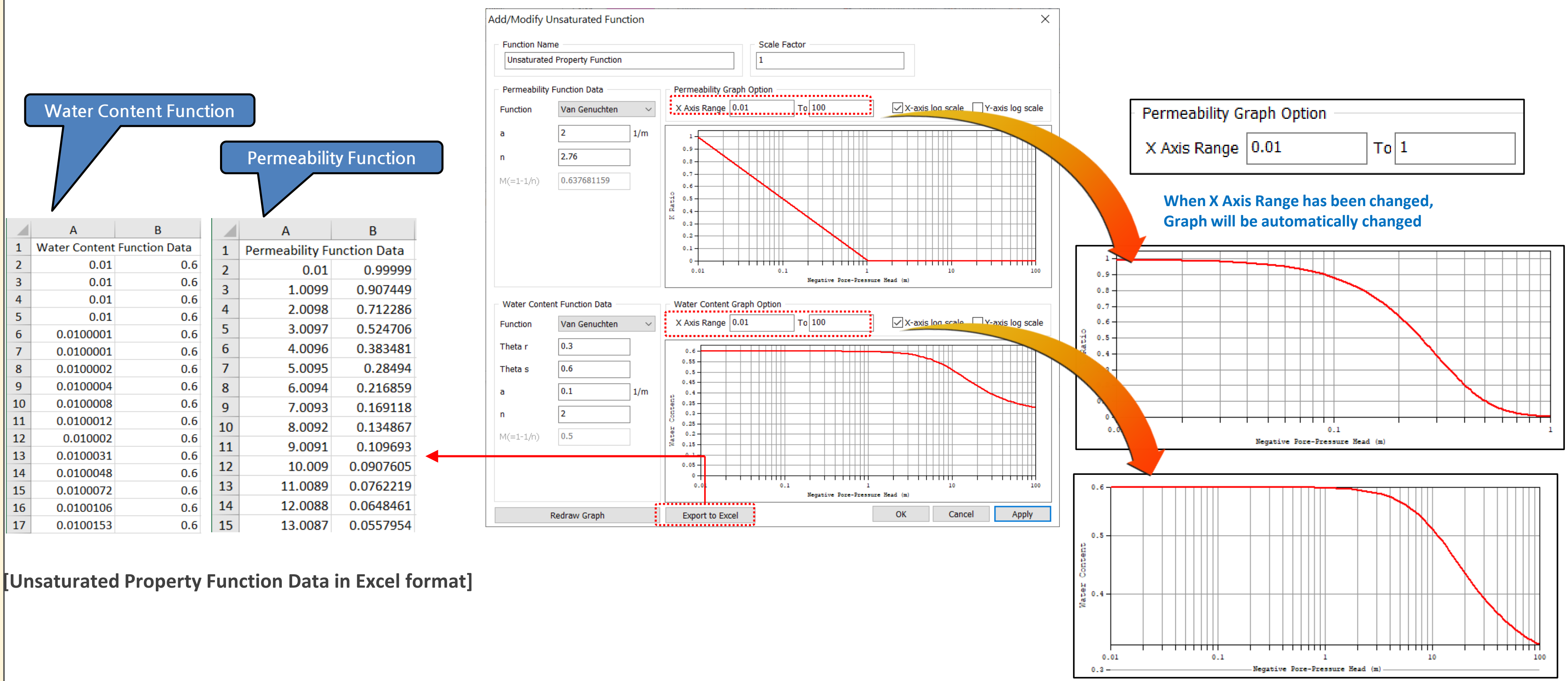
Based on two dimensions, the user selects the place of X-axis and then, input water level criteria.

2. Pre/Post Processing

2.2 Improvement of Unsaturated Property and Export to Excel

- Graphs(Water Content function/Permeability function) which is generated from parameter data can be modified by changing of X-axis range, The graph axis range automatically changes according to the specified range user input.
- 'Export to Excel' function has been developed so that the user can directly check the data of the graph.

- **Mesh > Prop./Csys./Func. > Function > Unsaturated Property**



	A	B
1	Water Content Function Data	
2	0.01	0.6
3	0.01	0.6
4	0.01	0.6
5	0.01	0.6
6	0.0100001	0.6
7	0.0100001	0.6
8	0.0100002	0.6
9	0.0100004	0.6
10	0.0100008	0.6
11	0.0100012	0.6
12	0.010002	0.6
13	0.0100031	0.6
14	0.0100048	0.6
15	0.0100072	0.6
16	0.0100106	0.6
17	0.0100153	0.6

	A	B
1	Permeability Function Data	
2	0.01	0.99999
3	1.0099	0.907449
4	2.0098	0.712286
5	3.0097	0.524706
6	4.0096	0.383481
7	5.0095	0.28494
8	6.0094	0.216859
9	7.0093	0.169118
10	8.0092	0.134867
11	9.0091	0.109693
12	10.009	0.0907605
13	11.0089	0.0762219
14	12.0088	0.0648461
15	13.0087	0.0557954

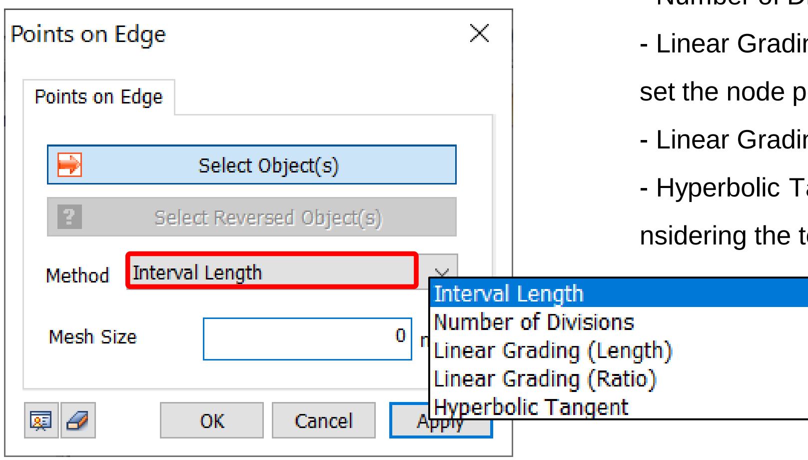
[Unsaturated Property Function Data in Excel format]

2. Pre/Post Processing

2.3 Points on Edge

- The user can make points based on the input intervals on edge.
- Generated Points can be used for getting the precise coordinate system or measuring the distance as a snap datum. That makes users helpful when making meshes or geometries.

- **Geometry > Point/Curve > Points on Edge( )**



- **Method**

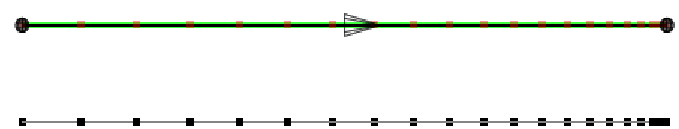
- Interval Length : Input the node spacing in the current length unit

- Number of Divisions : Divides the selected line into multiple divisions, specified by the input number.

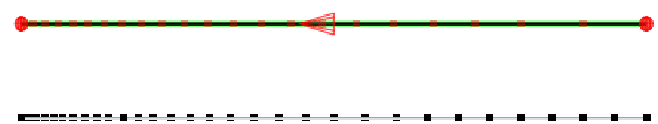
- Linear Grading(Length) : Input the spacing between the start and end points of a line to automatically set the node positions through linear interpolation

- Linear Grading(Ratio) : Input the spacing ratio (end/start) between the start and end points of a line.

- Hyperbolic Tangent : Input the start length and number of divisions to specify the nodes positions co nsidering the total length of the line and number of divisions.



[Generate points with Linear Grading(length)]



[Generate points with Linear Grading(ratio)]

※ Precautions

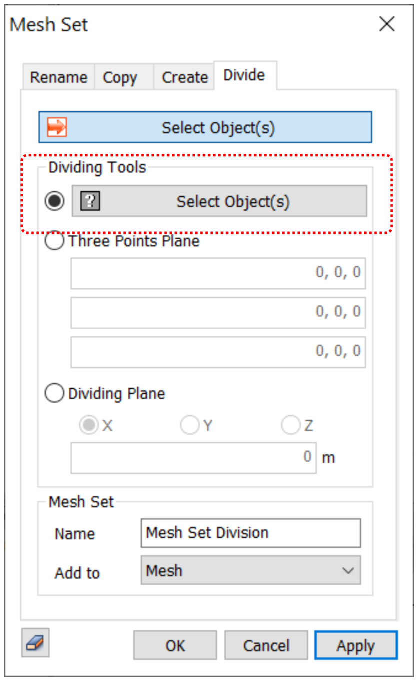
- Points on Edge function is generating points. That doesn't mean that the places(edge/face) where points generated are not automatically divided.
- It's totally the same way to give seed when making meshes.

2. Pre/Post Processing

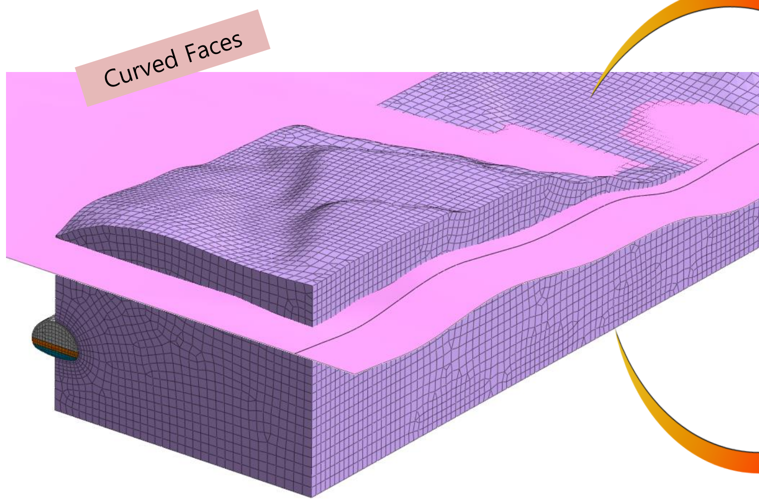
2.4 Cutting Mesh Set with Random Faces

- Cutting Mesh Set with Random Faces was developed in 2019ver. of GTS NX. And, The elements which are located middle of the faces will be automatically moved to the set which are more included.
- Previous version is only used with plane faces but in 2021ver. of GTS NX supports with curved faces too.

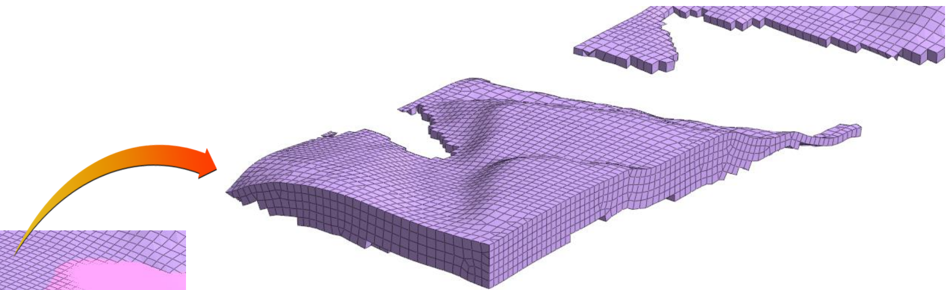
- **Mesh > Mesh Set > Divide**



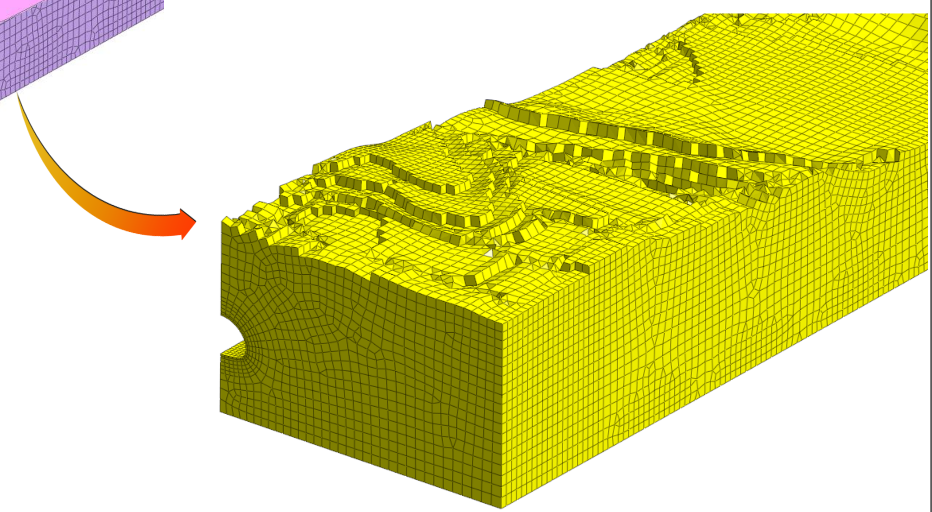
[Mesh Set Divide]



[Before Dividing Mesh Set]



[After Dividing Mesh Set]



2. Pre/Post Processing

2.5 Improvement of 3D PDF

- The Improvement of 3D PDF is focused on user convenience.
- Horizontal/Vertical tables have been crossed to make the user notice clearly. And, omitted parameters in non-linear tab are added.
- Some model is added(Other Property and so on).
- New Table is written by giving visibility into the section information assigned on property.

- **Tools > Export > Export 3D PDF**

Material

GTS NX

Geo-Technical analysis System New eXperience

Mohr-Coulomb

Name	E (kN/m²)	Inc. of Elastic (kN/m³)	Inc. of E Ref. Height (m)	ν	ɣ (kN/m³)	Ko	Thermal Coeff. (1/[T])	Molecular Vapor Diffusion Coeff. (m/sec²)	Thermal Diffusion Enhancement	Damping Ratio
	ɣ_sat (kN/m³)	e_o	kx (m/sec)	ky (m/sec)	kz (m/sec)	Ss (1/m)	C (kN/m²)	Inc. of Cohesion (kN/m³)	Inc. of C Ref. Height (m)	ϕ ([deg])
	Conductivity (W/(m·[T]))	Specific Heat (J/(ton·[T]))	Heat Gen. Factor							
2:soil1	10400	0	0	0.3	18	1	1e-006	0	0	0.05
	19	0.5	3.53e-005	3.53e-005	3.53e-005	5.23021333e-006	0	0	0	25
	0	0	1							
3:soil2	32000	0	0	0.35	19	0.498338273	1e-006	0	0	0.05
	20	0.5	4.53e-006	4.53e-006	4.53e-006	5.23021333e-006	18.2	0	0	30.11
	0	0	1							
4:soil3	115000	0	0	0.35	20	0.452144724	1e-006	0	0	0.05
	21	0.5	9.95e-007	9.95e-007	9.95e-007	5.23021333e-006	30.7	0	0	33.22
	0	0	1							
5:soil4	554000	0	0	0.3	23	0.370679609	1e-006	0	0	0.05

MIDAS 2

2021(v1.1)

Material

GTS NX

Geo-Technical analysis System New eXperience

Thermal Diffusion Enhancement		0	0	0	0
Damping Ratio		0.05	0.05	0.05	0.05
C	kN/m²	0	18.2	30.7	45
Inc. of C	kN/m³	0	0	0	0
Inc. of C Ref. Height	m	0	0	0	0
ϕ	[deg]	25	30.11	33.22	39
Creep Formulation		None	None	None	None
Conductivity	W/(m·[T])	0	0	0	0
Specific Heat	J/(ton·[T])	0	0	0	0
Heat Gen. Factor		1	1	1	1
ɣ_sat	kN/m³	19	20	21	24
e_o		0.5	0.5	0.5	0.5
kx	m/sec	3.53e-005	4.53e-006	9.95e-007	1.61e-007
ky	m/sec	3.53e-005	4.53e-006	9.95e-007	1.61e-007
kz	m/sec	3.53e-005	4.53e-006	9.95e-007	1.61e-007
Ss	1/m	5.23021333e-006	5.23021333e-006	5.23021333e-006	5.23021333e-006
Name		7:soil1G	8:soil2G	9:soil3G	10:soil4G
Structure		No	No	No	No
E	kN/m²	10400	32000	115000	554000
G	kN/m²	4000	11851.8519	42592.5926	213076.923
Inc. of Elastic	kN/m³	0	0	0	0
Inc. of E Ref. Height	m	0	0	0	0
ν		0.3	0.35	0.35	0.3
ɣ	kN/m³	18	19	20	23
Ko		1	0.498338273	0.452144724	0.370679609
Ko Method		Manual	Automatic	Automatic	Automatic
Anisotropy		No	No	No	No

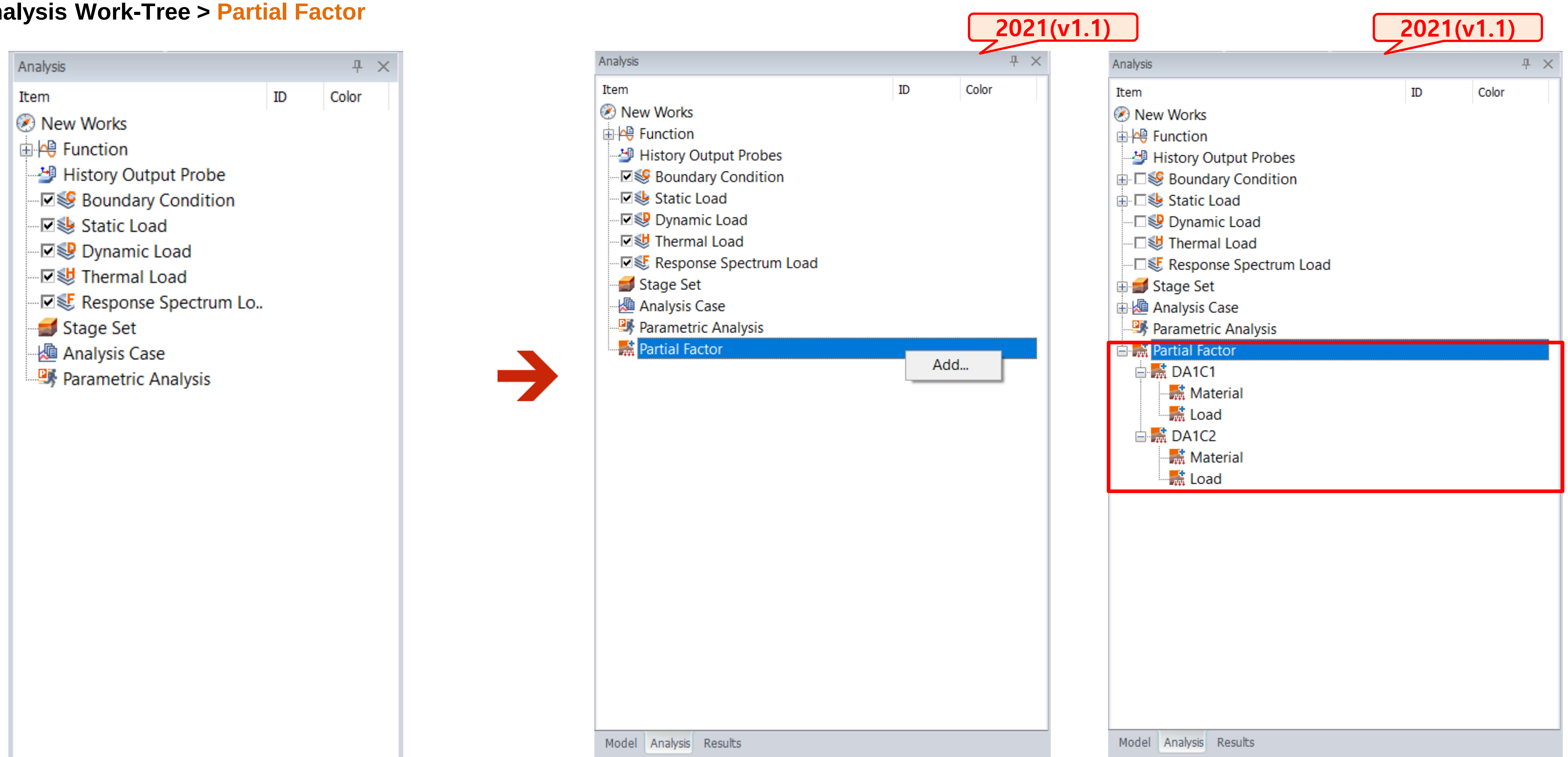
MIDAS 2

2. Pre/Post Processing

2.6 Partial Factor at Work-Tree

- Even though Partial Factor was not displayed under the work-tree in the previous version, In this version, the user can check/add/delete under the work-tree.
- User can see Partial Factor intuitively under the work-tree and edit/copy/delete/rename directly.

- **Analysis Work-Tree > Partial Factor**

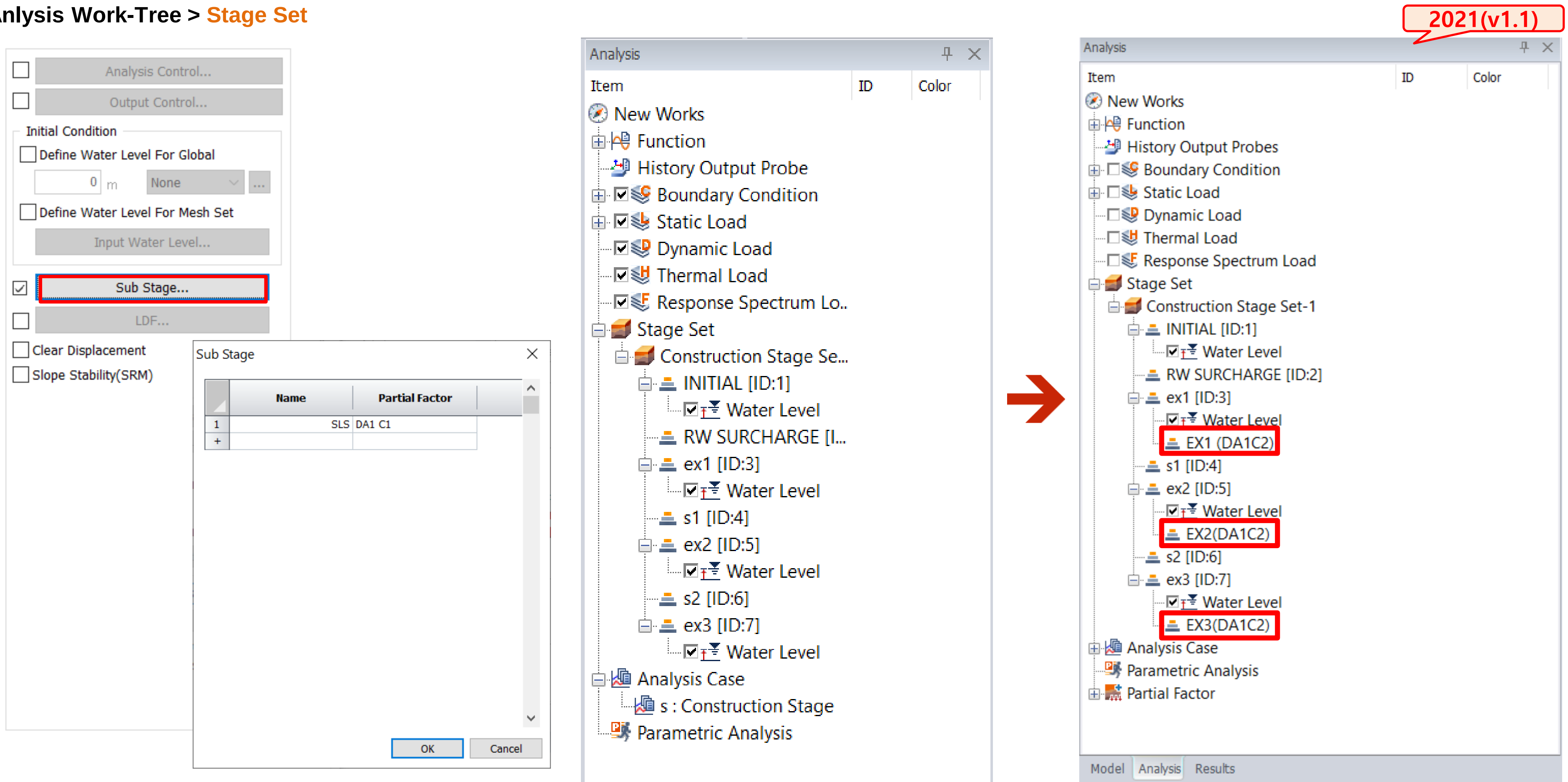


2. Pre/Post Processing

2.6 Partial Factor at Work-Tree

- Even though the Substage was not displayed under the work-tree in the previous version, the user can check substage under the work-tree in this version.
- When substage has been made, the user can see the state of partial factor intuitively under the work-tree.

- **Anlysis Work-Tree > Stage Set**

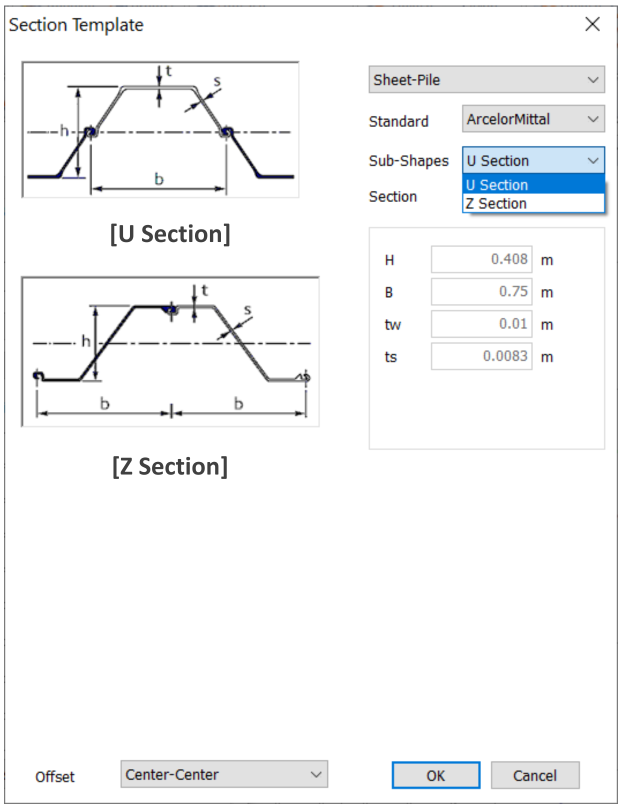


2. Pre/Post Processing

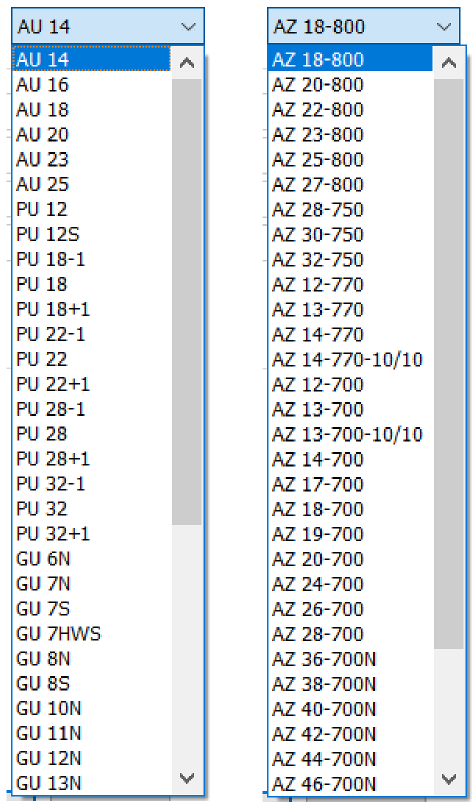
2.7 Sheet-Pile Property

- Sheet-Pile Property has been updated. User can select ArcelorMittal's Standard U and Z Shape and tons of Sections.
- When user selects section, Area and Area moment of Inertia(Iy) are automatically input into the property window.

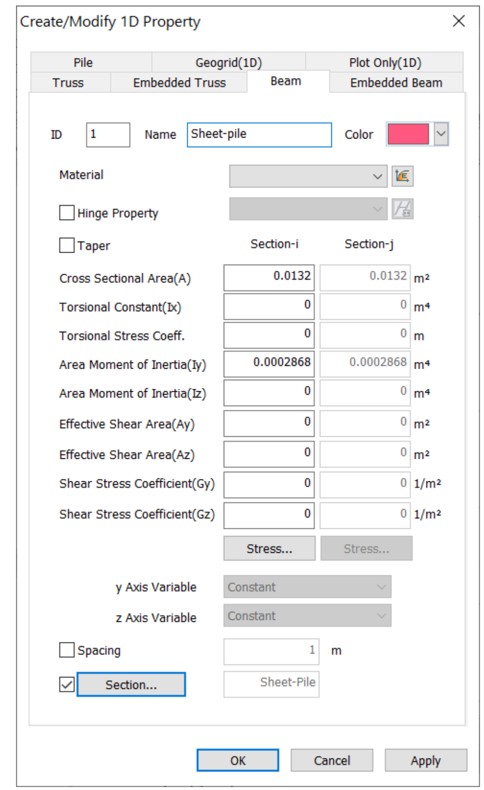
- **Mesh > Prop./Csys./Func. > Property > Create > 1D > Section**



[Sheet-Pile Section Window]



[Sheet-Pile Sections]



[Cross Sectional Area(A) & Area Moment of Inertia(Iy)]