Release Note

Release Date : December 2023

Product Ver. : FEA NX 2024 (v1.1)

Enhancements

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2. Bowl Model Element Simulation
3. HD/RO/GHE-S Function (Confining Pressure)
4. Initial Equilibrium Force and Initial Stress Table Functions
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8. Newmark-β Method
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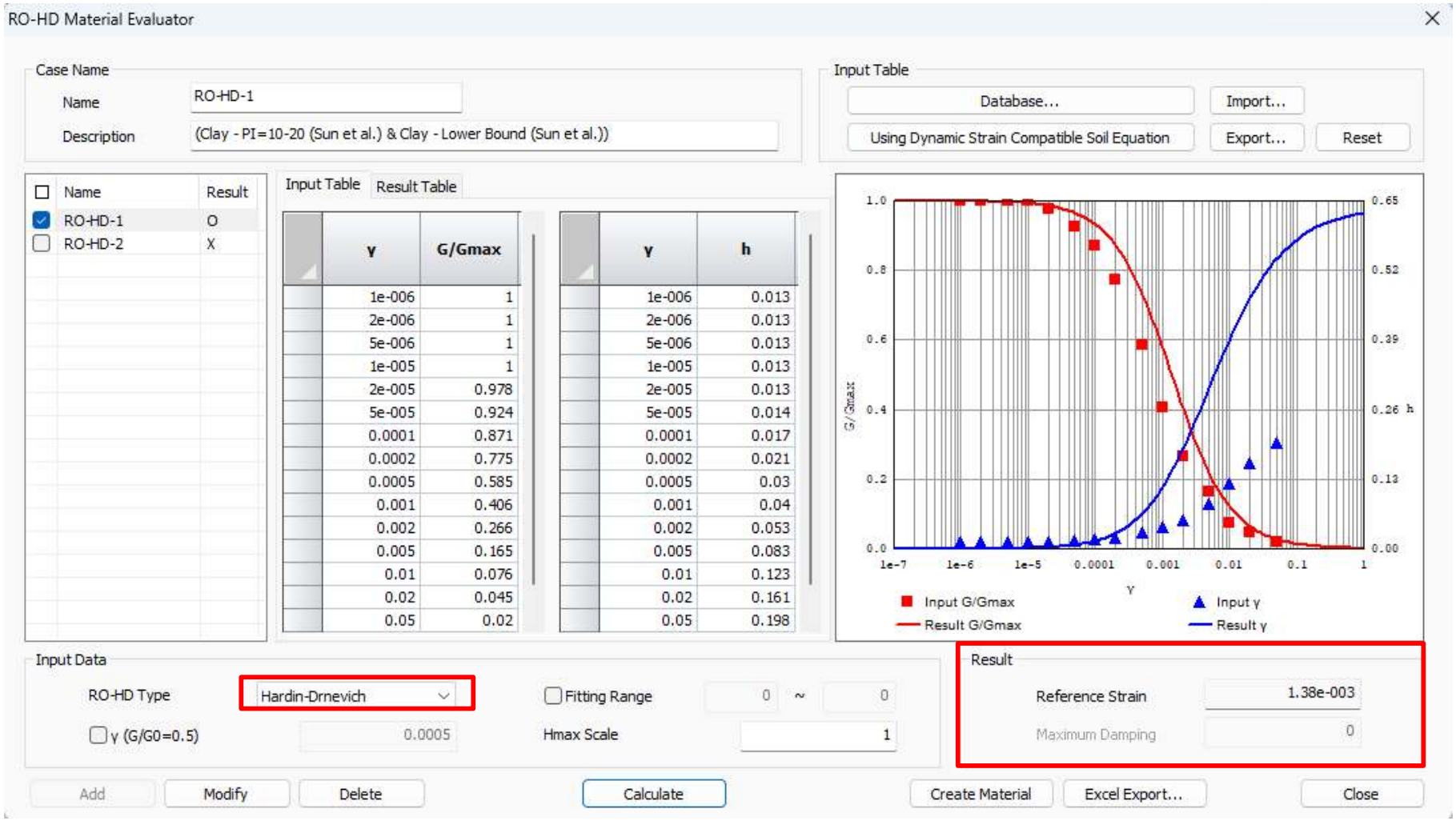
1. Variable Deformation Fitting Function

- During ground motion analysis, a tool is installed to obtain the standard strain rate and maximum damping coefficient from the material models R-O and H-D by fitting the dynamic properties with experimental results or proposed equations.

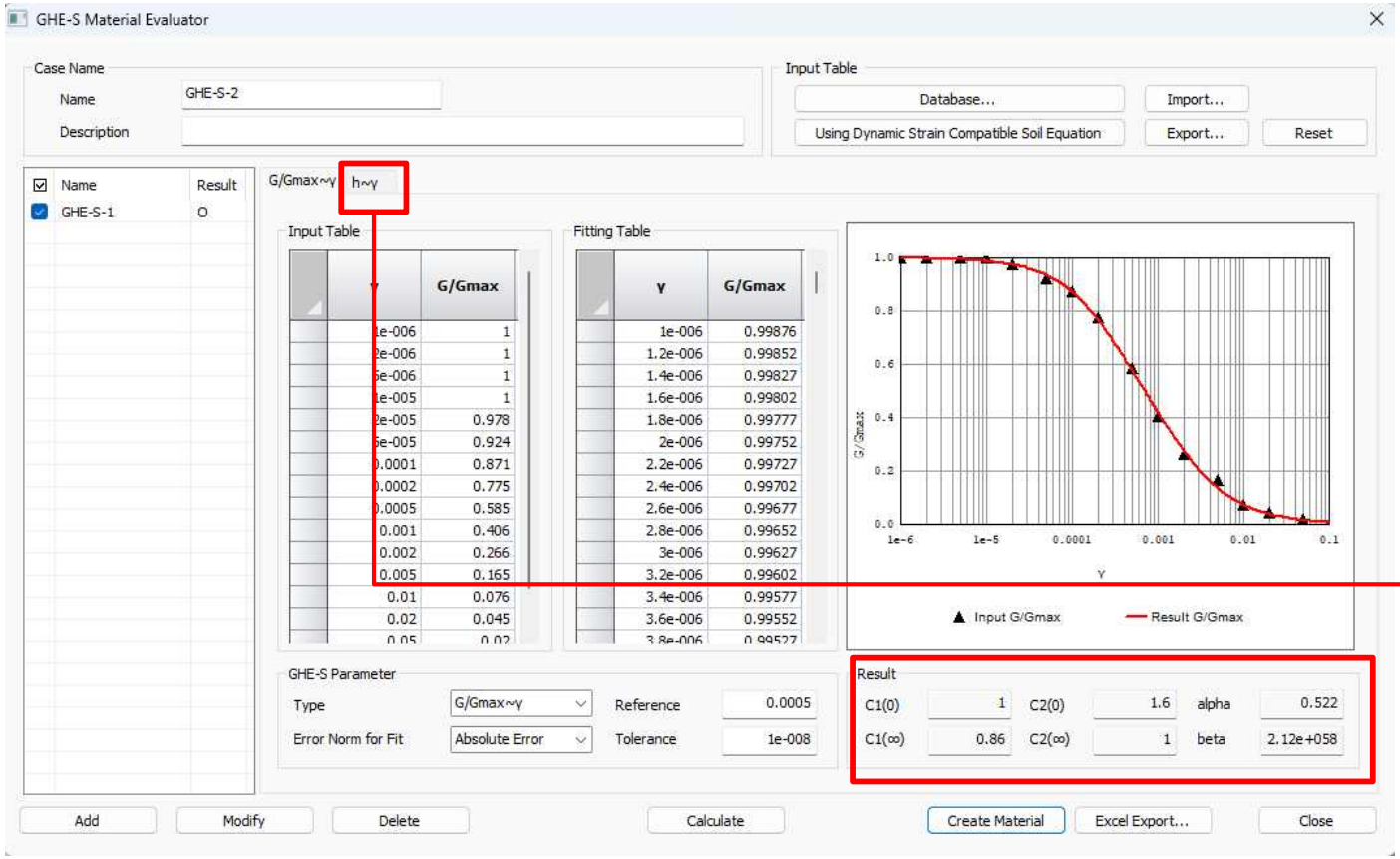
▪ **Dynamic Analysis > Tools > Material Evaluator > R-O/ H-D Model**

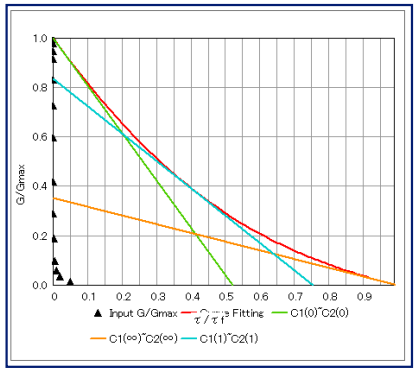


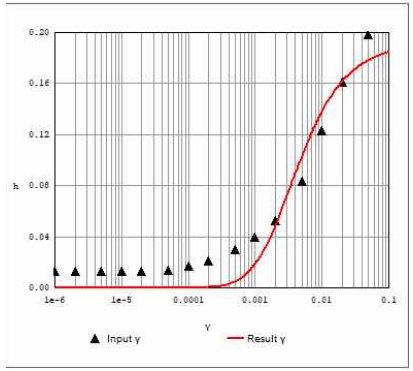
1. Variable Deformation Fitting Function

- During ground motion analysis, a tool is installed to obtain the standard strain rate, maximum damping coefficient, and parameters used during analysis in the material model GHES by fitting dynamic properties with experimental results or proposed equations.

▪ **Dynamic Analysis > Tools > Material Evaluator > GHE-S Model**





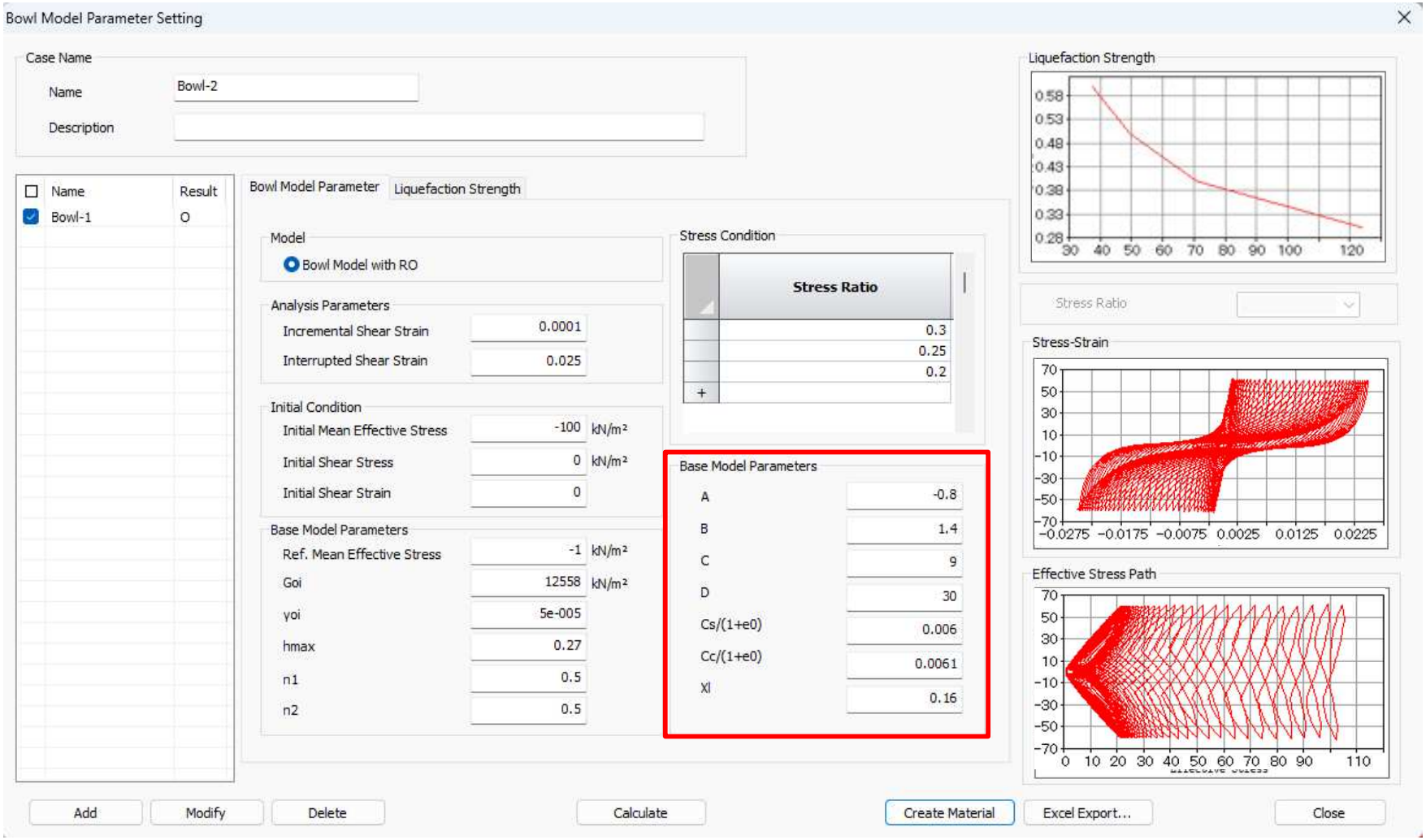


2. Bowl Model Element Simulation

- A tool for determining liquefaction parameters is installed. Liquefaction parameters can be set through single element analysis by fitting the relationship between liquefaction strength and loading recovery in repeated shear experiments.

▪ **Dynamic Analysis > Tools > Material Evaluator > Bowl Model**

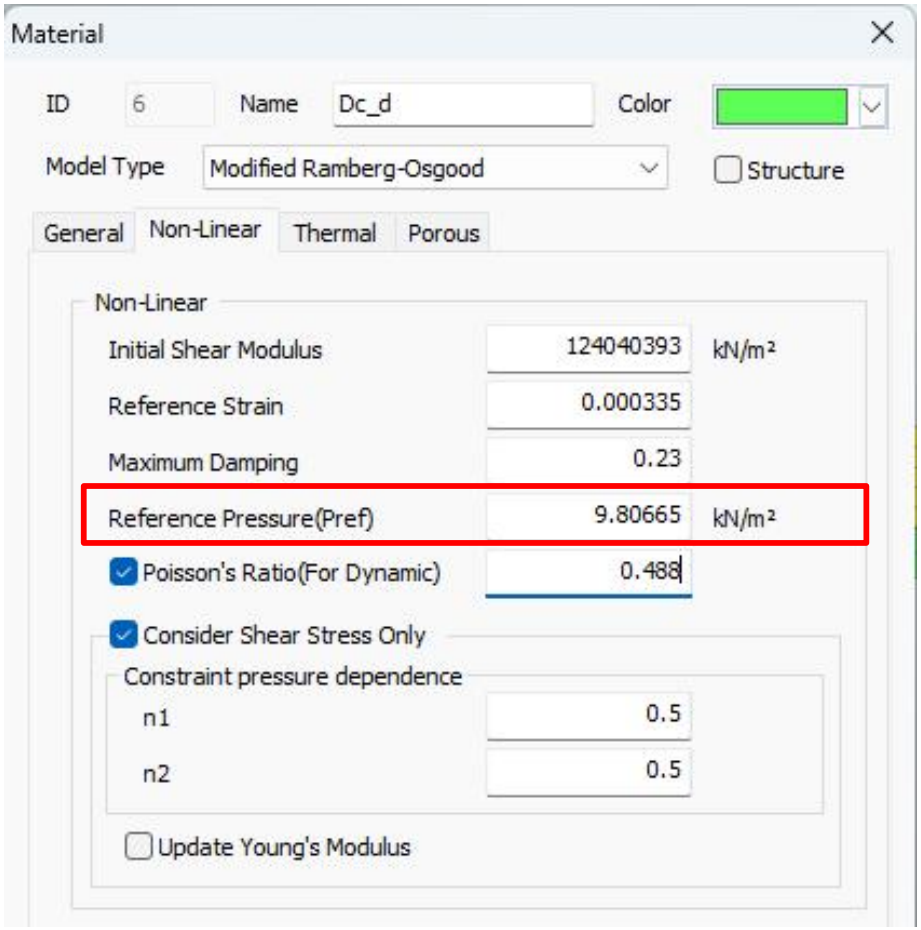
Density Sand



3. HD/ RO/ GHE-S Function (Confining Pressure)

- An input item has been added to allow input of the standard confining pressure. Under the standard confining pressure used in the 3-axis compression experiment
- You can directly enter shear stiffness and reference strain rate.

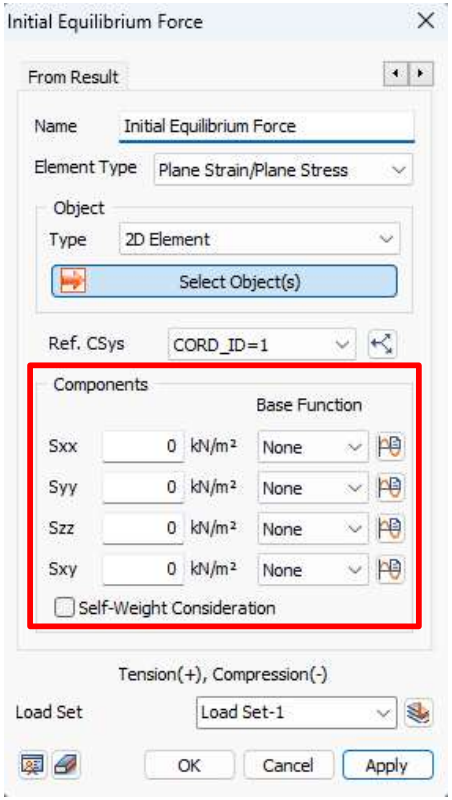
▪ **Mesh > Material > Isotropic > Modified Ramberg-Osgood > Nonlinear**

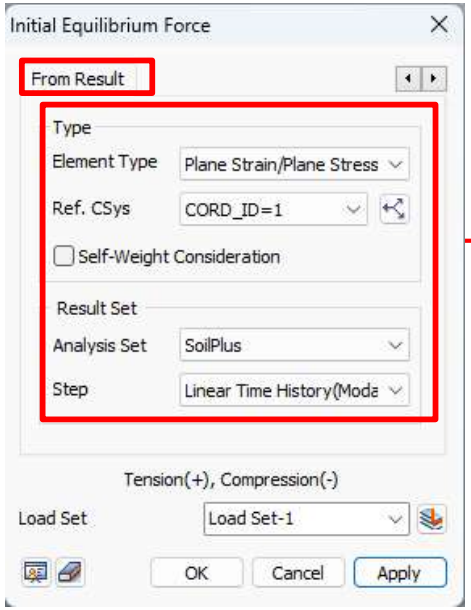


4. Initial Equilibrium Force and Initial Stress Table Functions

- Provides the ability to reflect Initial Force on various elements (Truss/Embedded Truss , Beam/Embedded Beam , Plane Strain/Plane Stress , Axisymmetric , Solid , Shell)
- These Initial Forces can be further used to obtained dynamic analysis results (Eigenvalue , Time History Analysis)

▪ ***Static Analysis > Static Load > Initial Equilibrium Force***

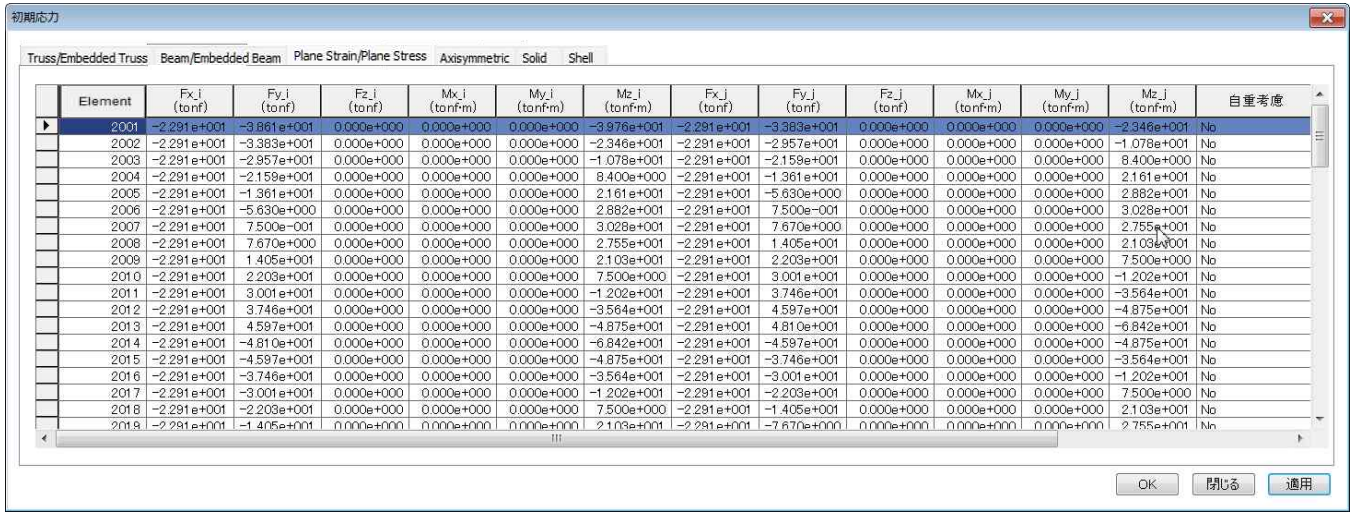




Transfer Initial Force

4. Initial Equilibrium Force and Initial Stress Table Functions

- ***Static Analysis > Static Load > Initial Equilibrium Force***



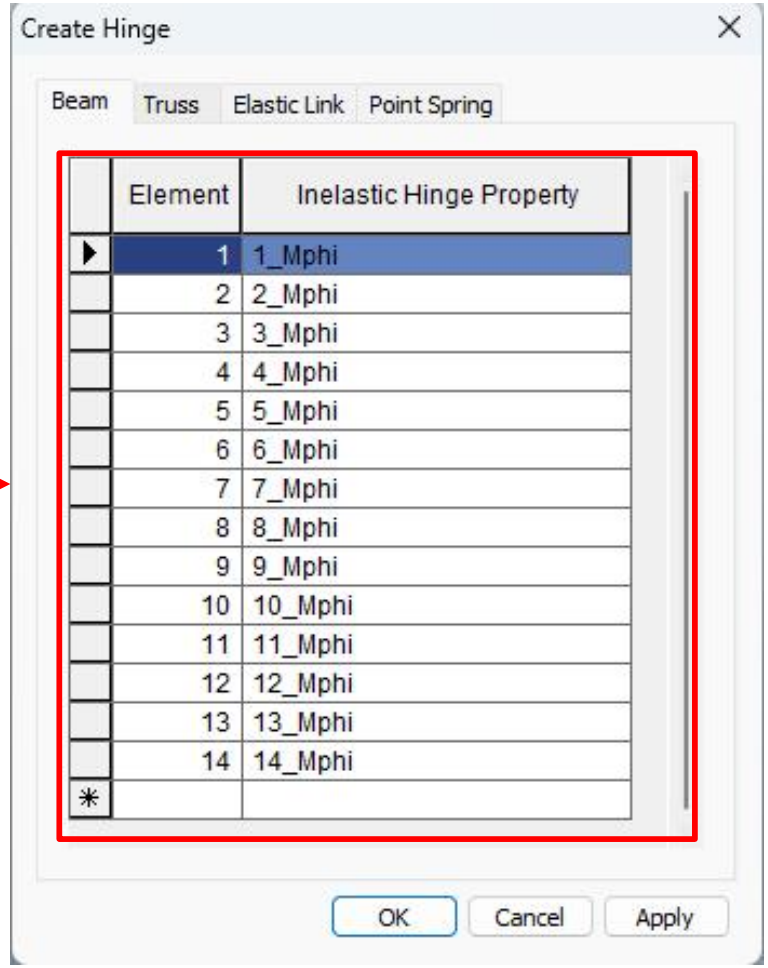
Initial Equilibrium Force of Beam Element

Initial Stress of Plane Strain/ Plane Stress Element

5. Hinge (M-Φ Data) Assign Table

- Provide a convenient function to define Hinge property as a Table.

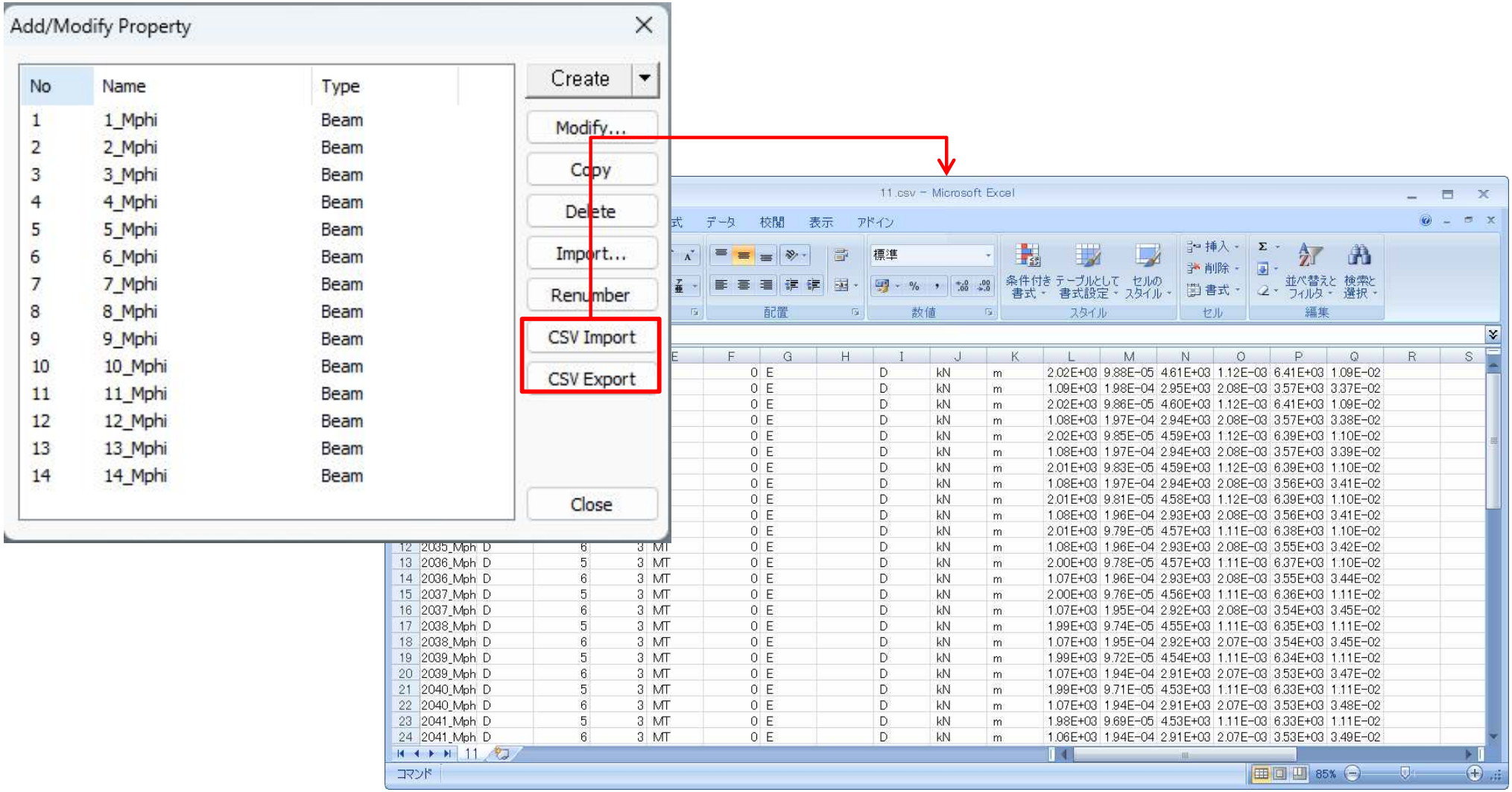
▪ ***Mesh > Element > Hinge Table***



6. Hinge (M-Φ Data) Import

- Provide a convenient function to export or import Hinge Property data in CSV file format.

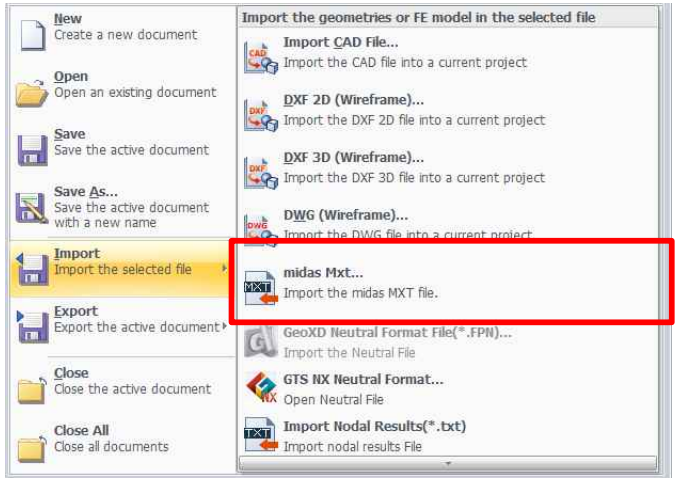
▪ ***Mesh > Prop./ Csys./ Func. > Hinge > CSV Import***

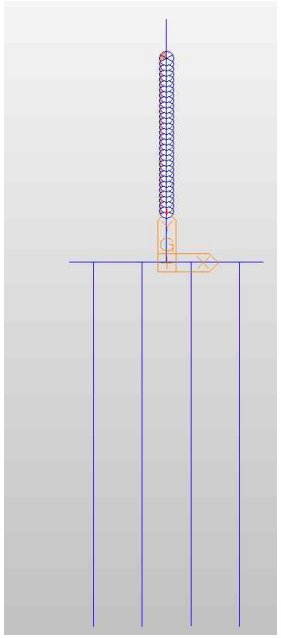


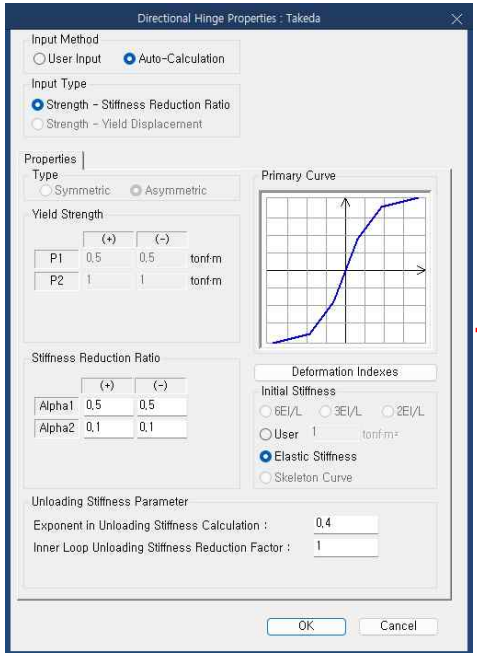
6. Hinge (M-Φ Data) Import

- Provide a convenient function to Import midas Civil mxt file format(Automatically calculated Hinge Property)

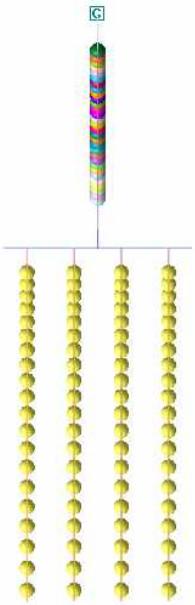
▪ ***File > Import > midas Mxt...***





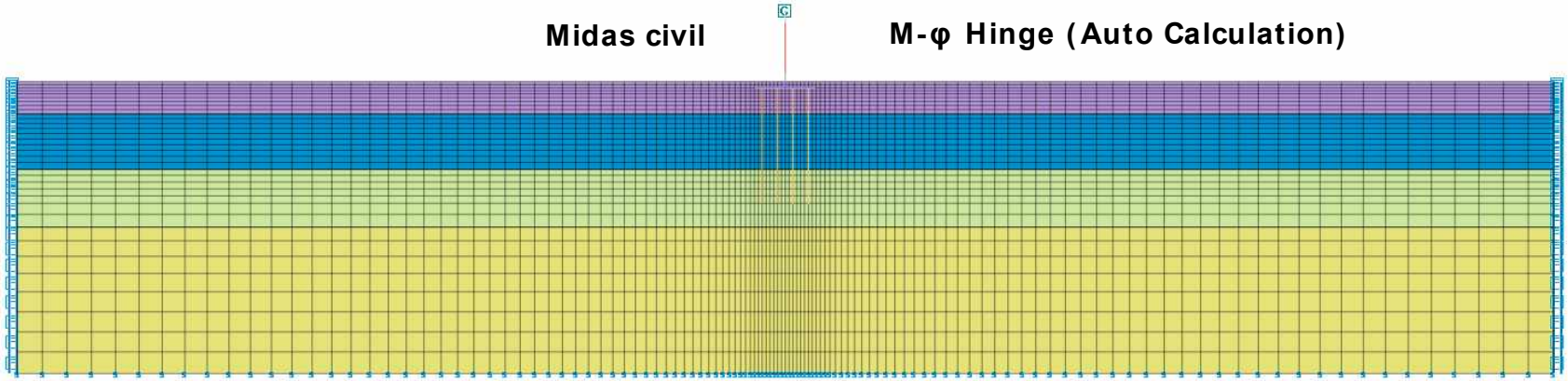


*.mxt



Midas civil

M-φ Hinge (Auto Calculation)

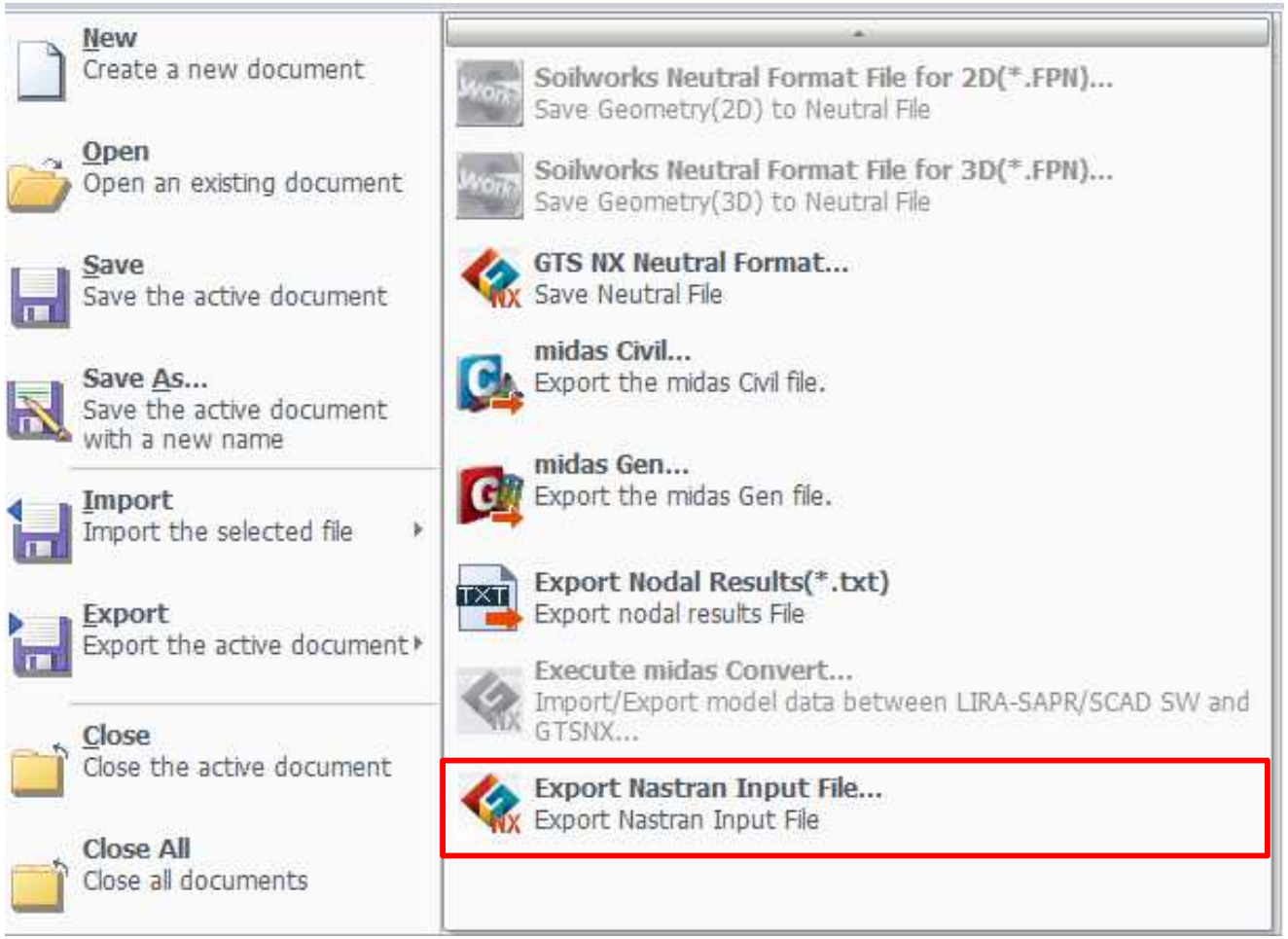


Structure + Ground Connection Analysis

7. Nastran file Export

- Provide a convenient function to export to a format that can be used as an Input file in Nastran.

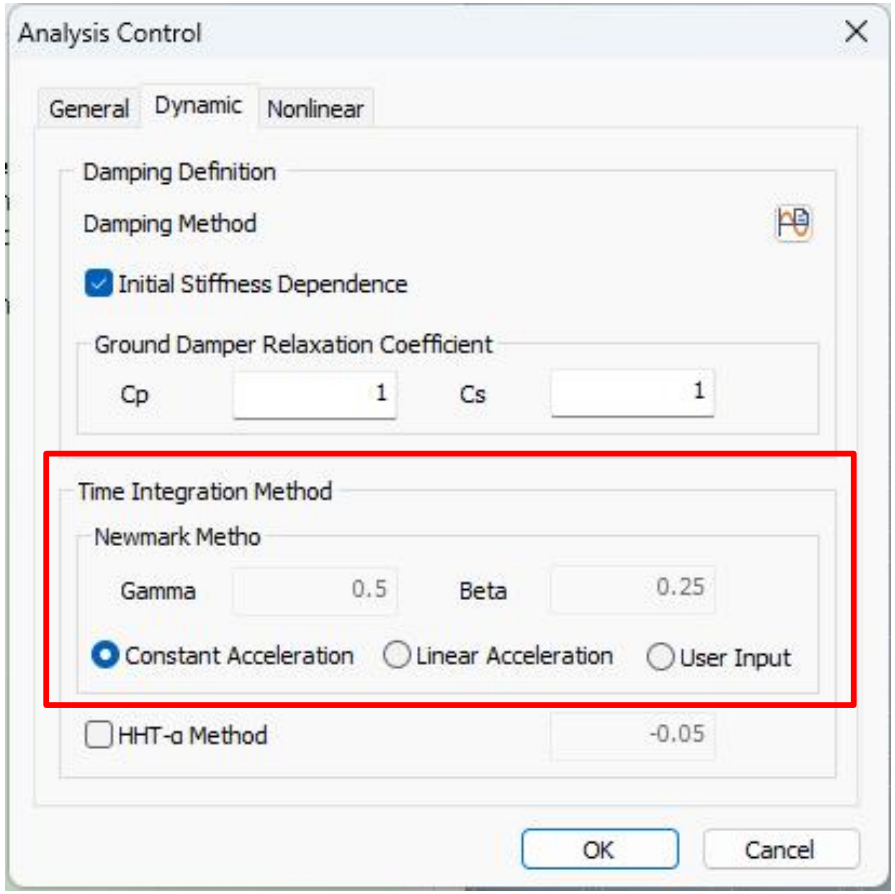
▪ ***File > Export > Nastran file export***



8. Newmark-β Method

- Provide the Newmark Method used in the Direct Integration Method of dynamic analysis.
- Three Input methods are provided, of which Constant Acceleration is recommended as it provides the most stable analysis.

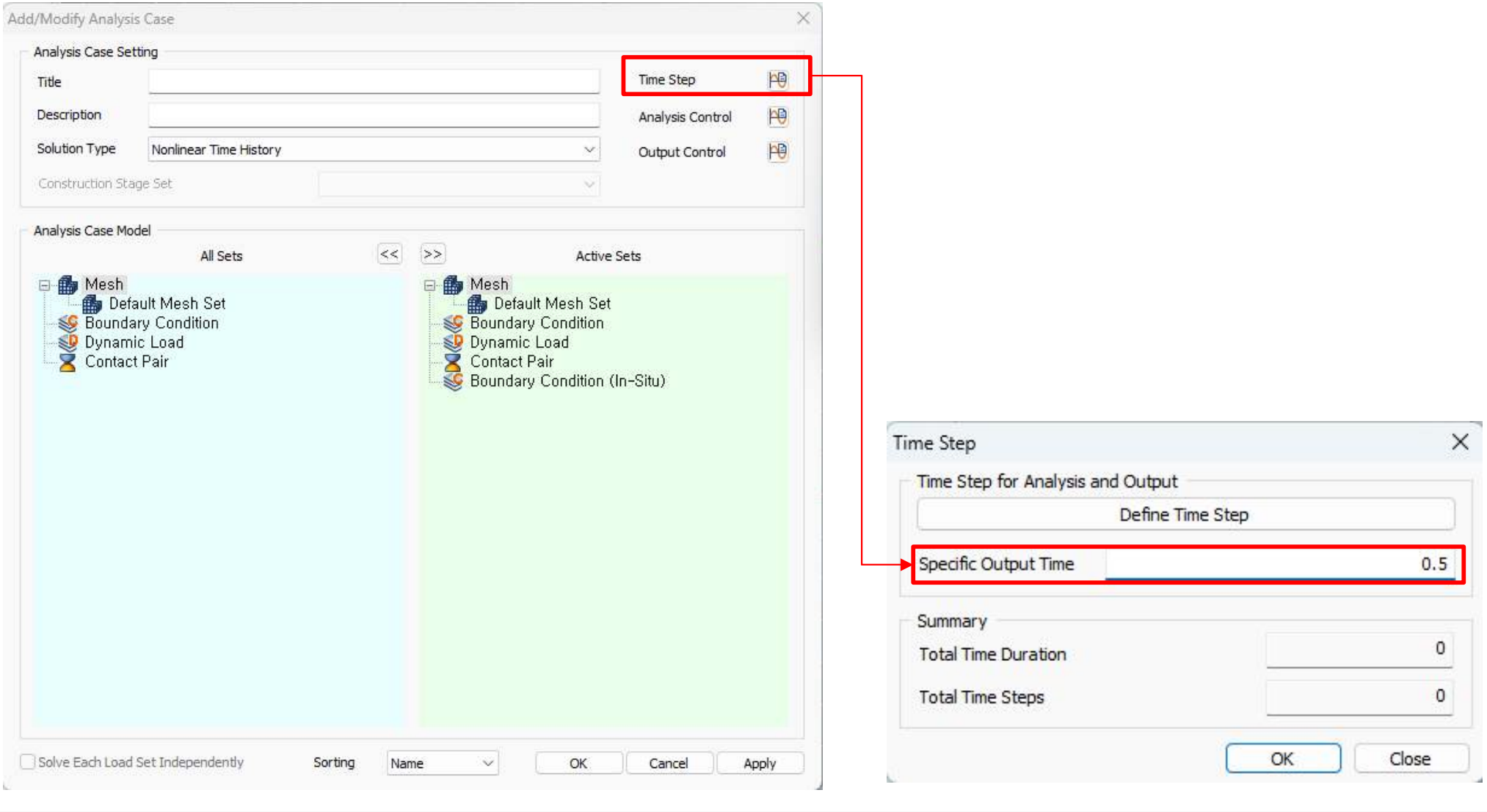
▪ ***Analysis Case > Analysis Control***



9. Random Setting of Dynamic Analysis Output Time

- The Output time interval for dynamic analysis can be set arbitrarily, facilitating result output only at required time steps.

▪ ***Analysis Case > Analysis Case Setting > Time Step***

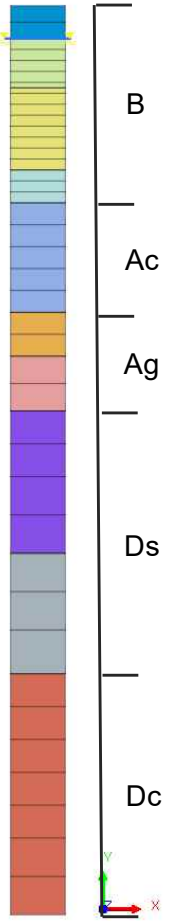


10. Bowl Model

- The Bowl Model, a material model capable of liquefaction analysis, has been added. Compared to other material models, it has fewer parameters, can be easily determined from experimental values and estimated values. The analysis time is also low, making it the ideal choice for liquefaction model that can be easily used in practice.

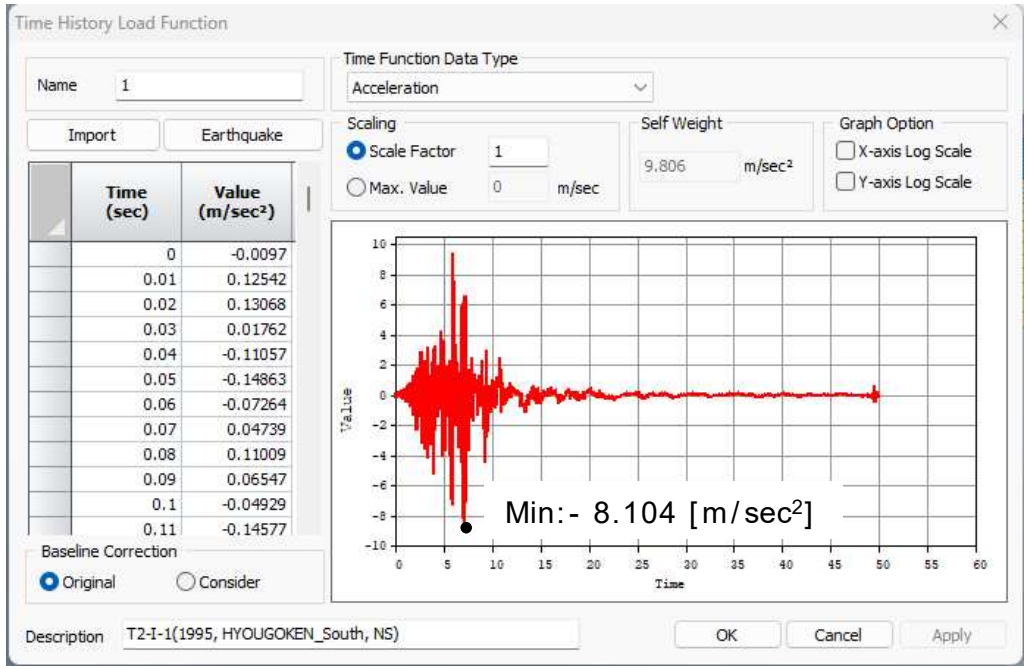
▪ ***Mesh > Prop./ Csys./ Func. > Material***

GL(m)	Soil Layer		Wave (m/s)	Unit vol. weight (kN/m3)
0	Back Fill	B	140	18.53
-3			170	21.28
-7.5			200	21.18
-15			220	21.57
-18	Clay	Ac	180	15.69
-28	Sand	Ag	245	17.65
-32			305	17.65
-37	Sand	Ds	305	18.14
-50			350	18.14
-61	Clay	Dc	303	17.65
-83				



Fixed End(E+F 입력)

B、Ag Layers → Modified Ramberg-Osgood+ Bowl Model
Ac、Ds、Dc Layers → Modified Ramberg-Osgood Model

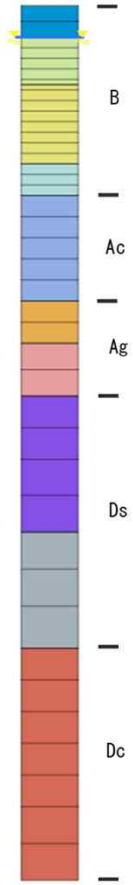


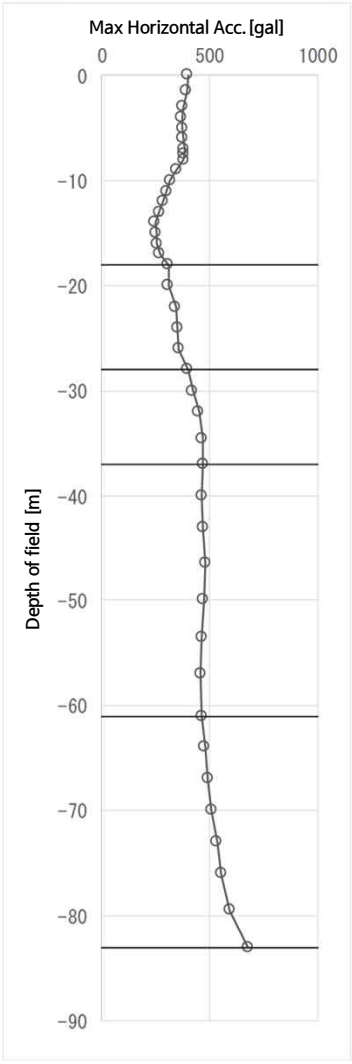
Ground Acceleration

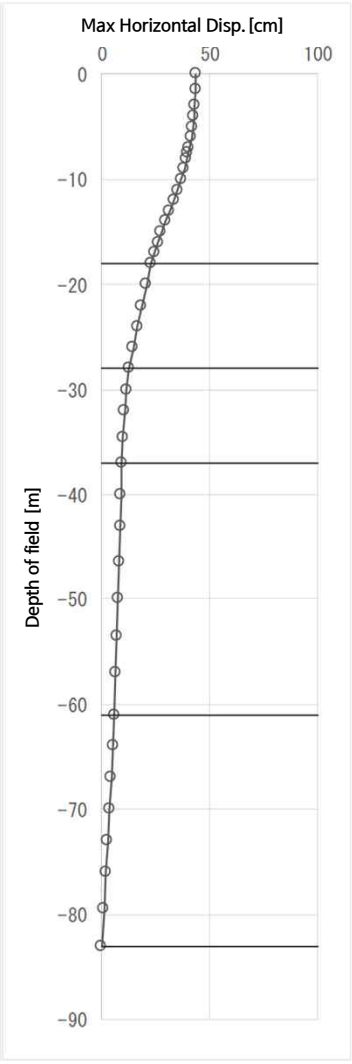
10. Bowl Model

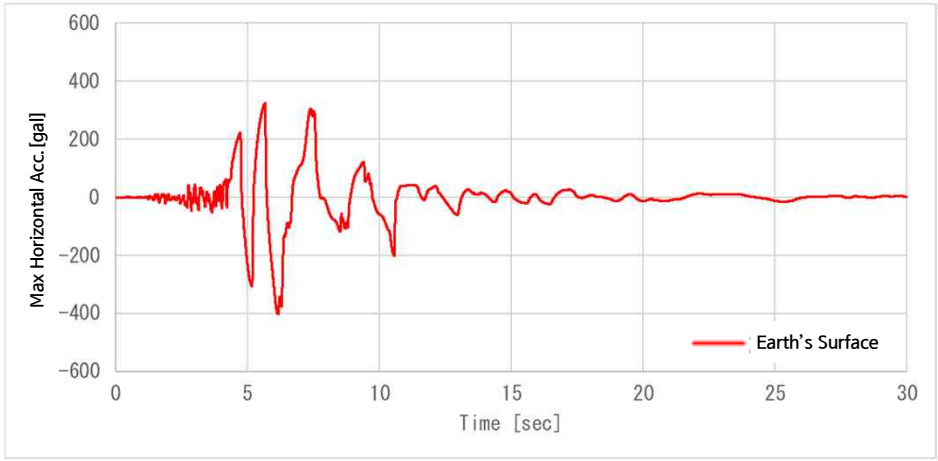
- During an earthquake in the depth direction, it can be confirmed that the acceleration is attenuated and the displacement increases through the response on the maximum acceleration and maximum displacement indicators.

▪ ***Mesh > Prop./ Csys./ Func. > Material***

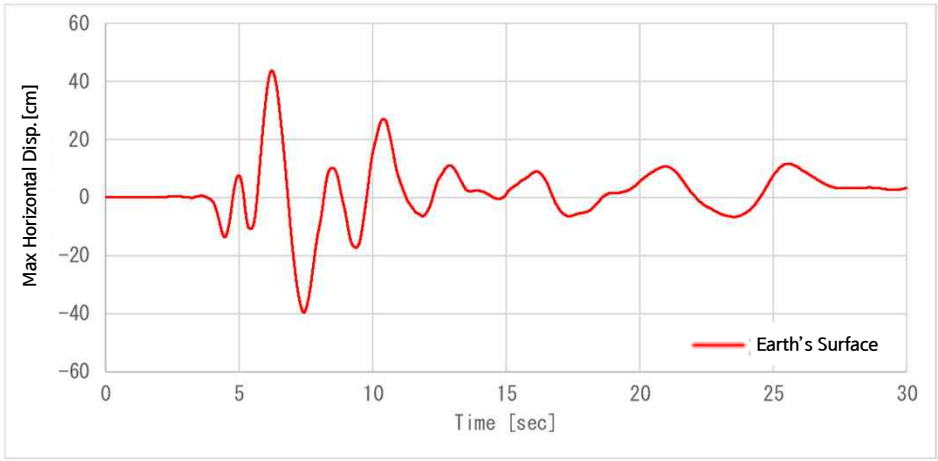








Surface Horizontal Acceleration – Time Graph

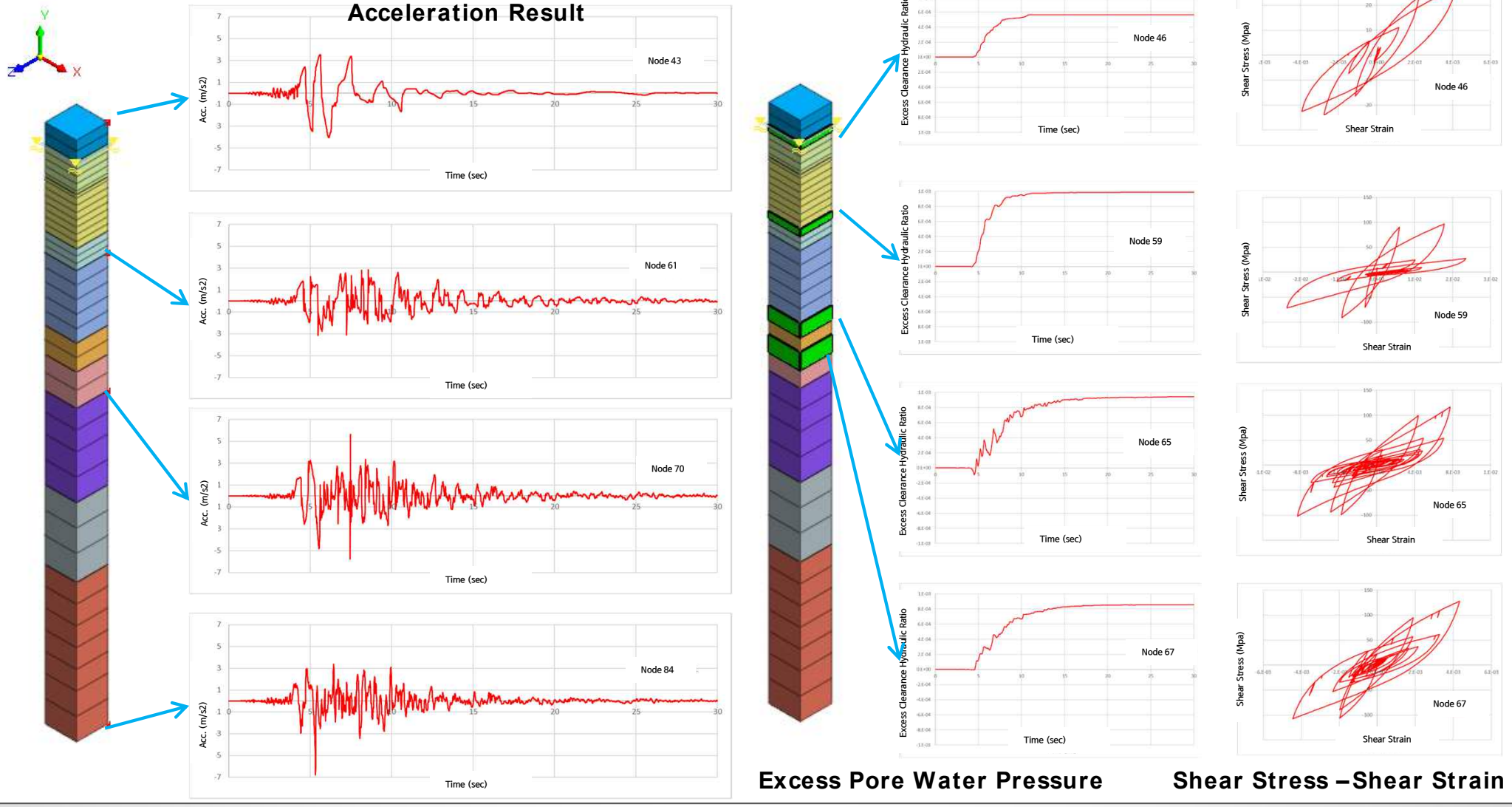


Surface Horizontal Displacement – Time Graph

10. Bowl Model

- As the acceleration of the focal point is transmitted to the surface, In the liquefaction layer, excess pore water pressure increases and shear stiffness decreases.
- This can be confirmed from the shear stress-shear strain relationship.

▪ ***Mesh > Prop./ Csys./ Func. > Material***

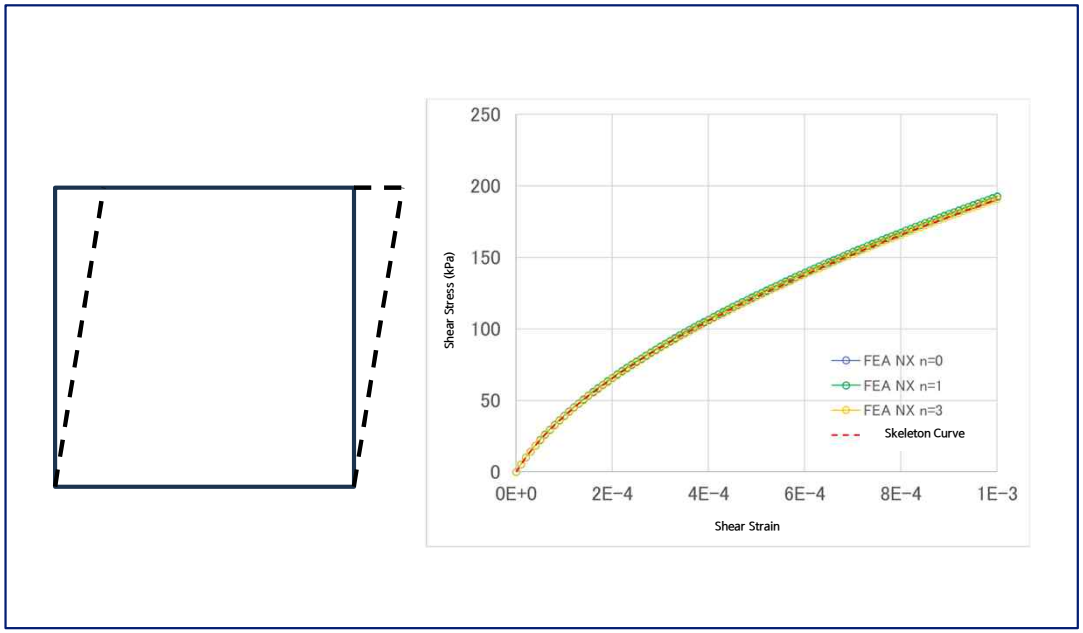


11. Multi-Spring(Multi Shear Spring)

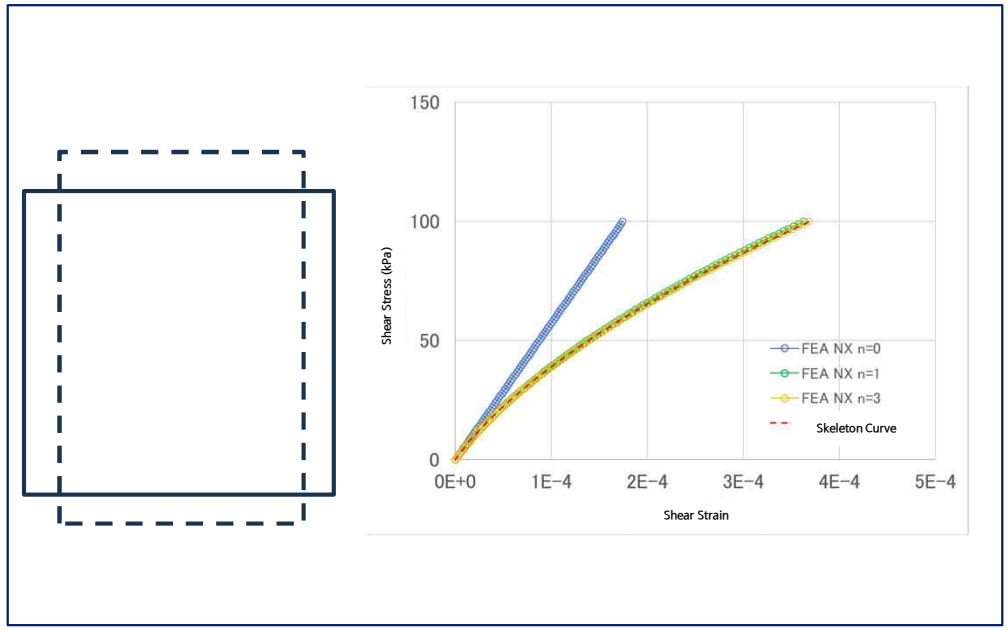
- The existing dynamic analysis material model was developed with focus on horizontal behavior for underground structures. By adding multi-spring elements, sequential shear was introduced. This is an expanded function that can predict displacement in the vertical direction during an earthquake.

▪ **Modified RO/HD、GHE-S Model、Multi Spring**

Multi-Spring(Multi Shear Spring) Can be considered when using Modified Ramberg-Osgood Model , Modified Hardin-Drnevich Model / GHE-S Model.



Simple Shear



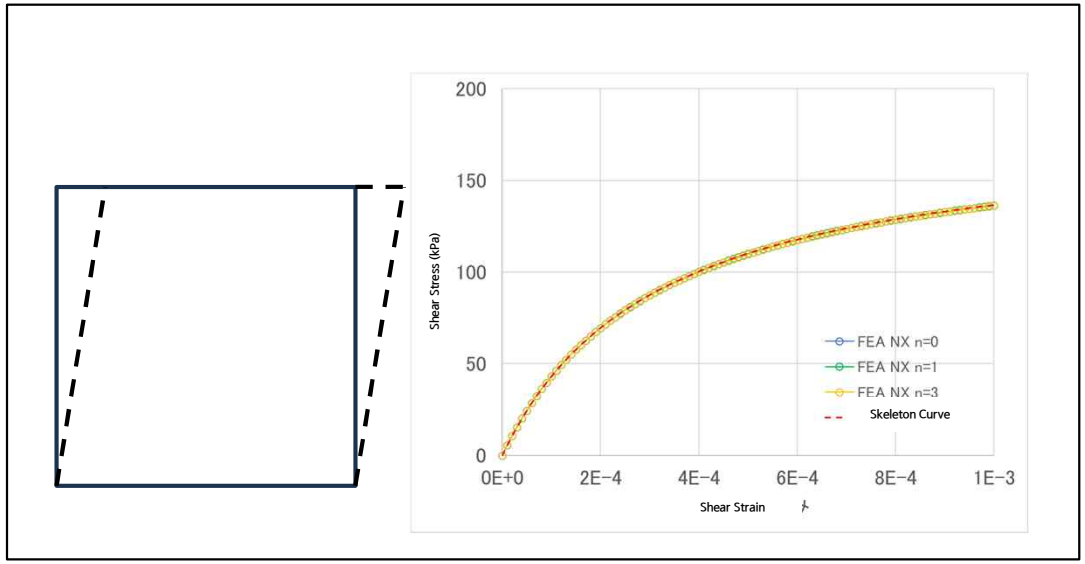
Sequential Shear

Modified Ramberg-Osgood Model

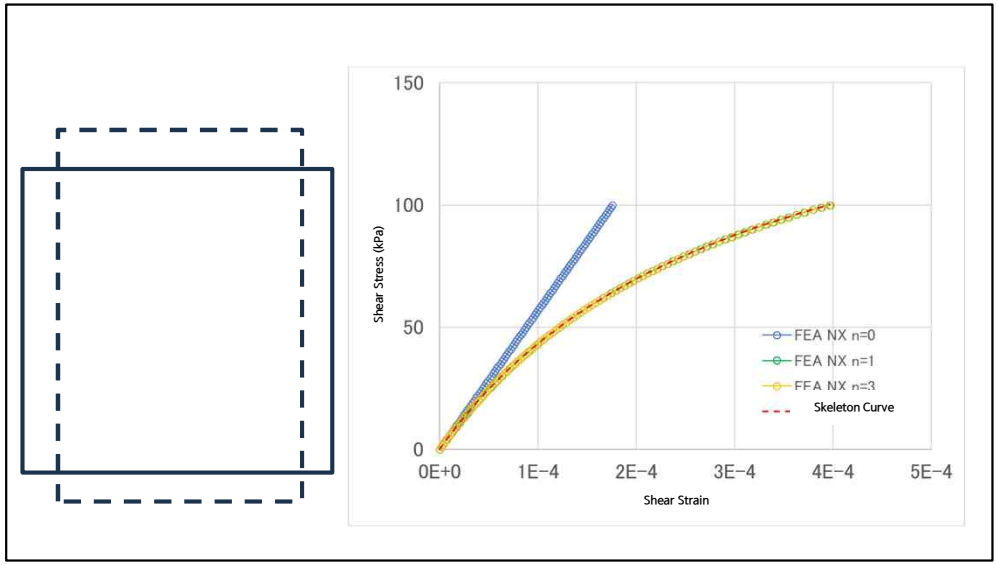
11. Multi-Spring(Multi Shear Spring)

Modified Hardin-Drnevich Model

Simple Shear

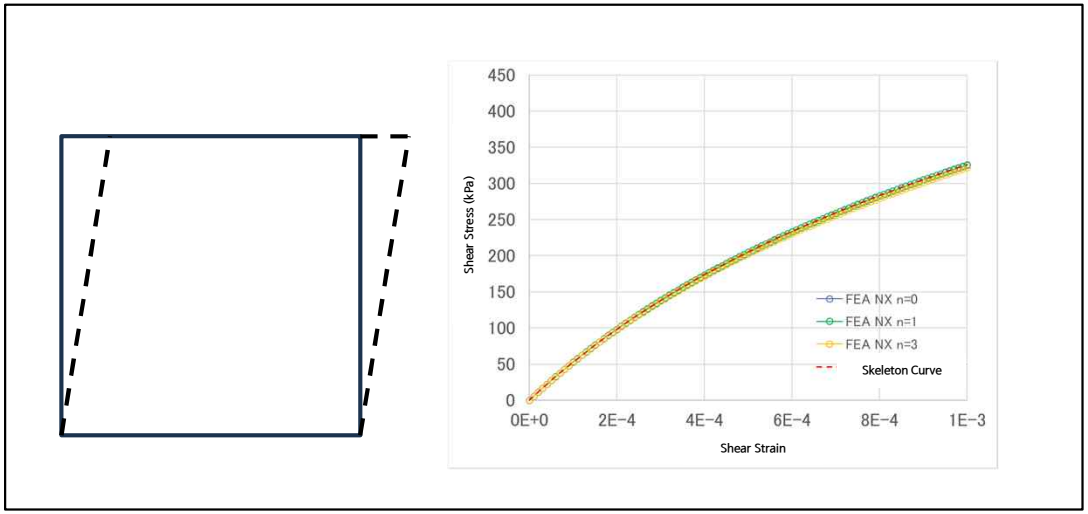


Sequential Shear

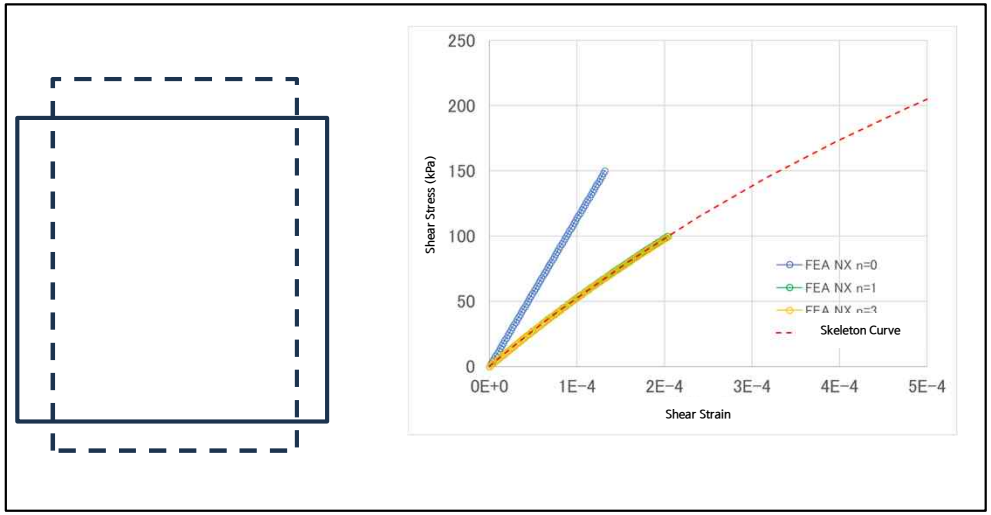


GHE-S Model

Simple Shear



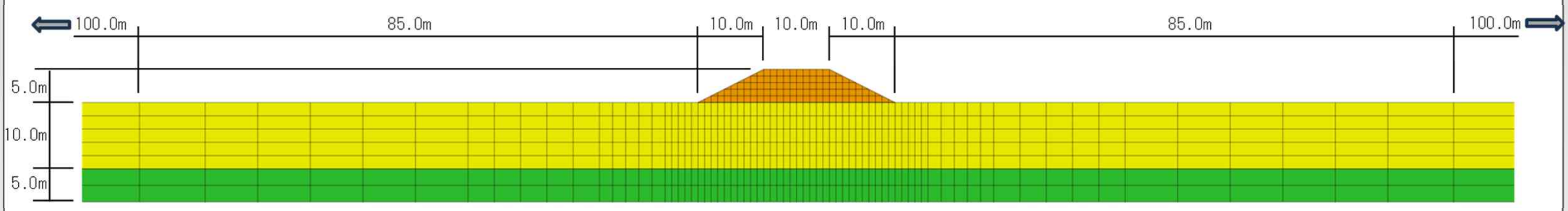
Sequential Shear



11. Multi-Spring(Multi Shear Spring)

- **Modified RO/HD、GHE-S Model、Multi Spring**

Analysis Model (2D)

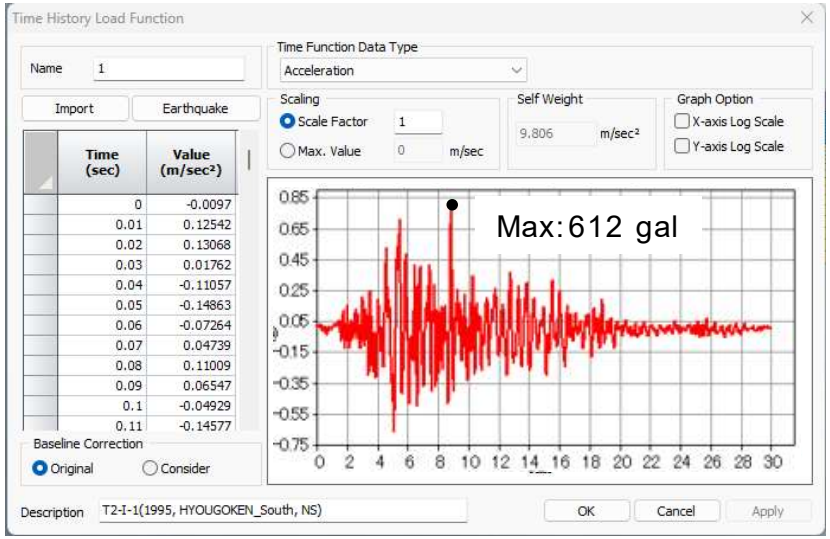


Side : Horizontal Roller

Fixed End(E+F Input)

Ground Material Properties

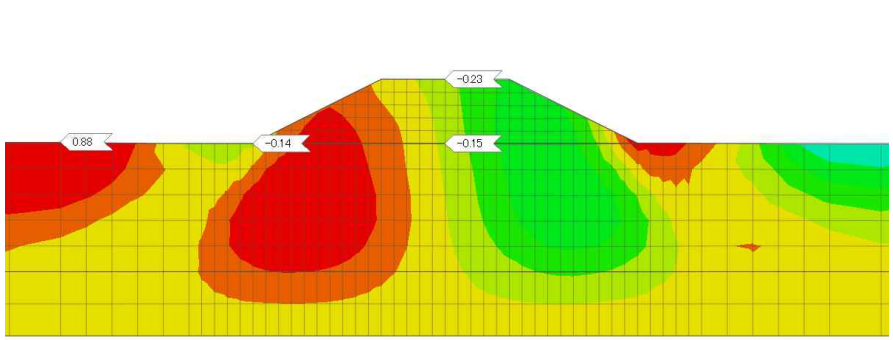
	Ground Model	Unit vol. weight [kN/m2]	Standard Confining Pressure [kN/m2]	Shear modulus of E [kN/m2]	Refer. Strain	Confining Pressure Dependence Coff.	Poisson's Ratio	Max. Damping Ratio
Fill Layer	Modified R-O	17.00	28.00	84000.00	4.29E-04	0.50	0.33	0.24
Sand Layer	Modified R-O	18.00	60.00	60000.00	1.27E-03	0.50	0.33	0.24
Clay Layer	Modified R-O	20.00	152.00	128000.00	1.51E-03	0.50	0.33	0.20

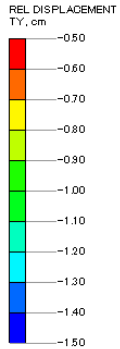


Ground Acceleration

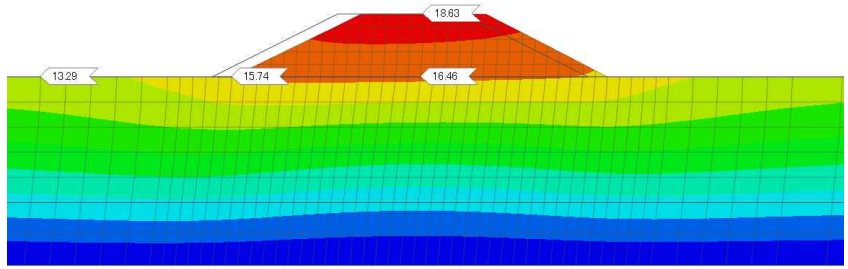
11. Multi-Spring(Multi Shear Spring)

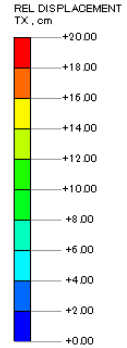
- **Modified RO/HD、GHE-S Model、Multi Spring**





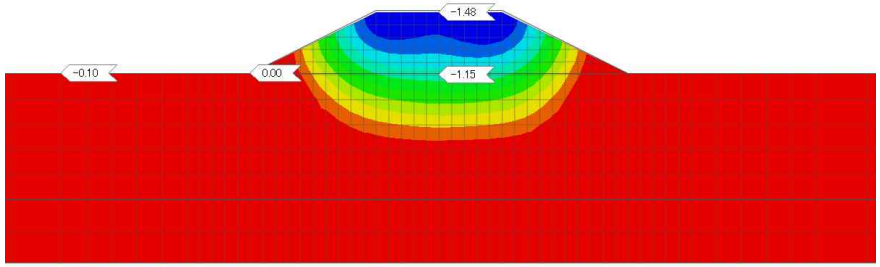
Residual Vertical Displacement

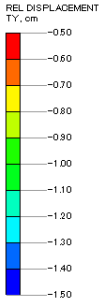




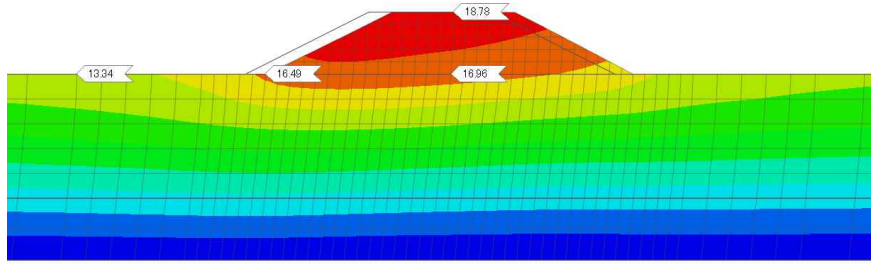
Maximum Horizontal Displacement

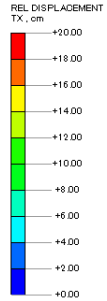
No Multi Spring





Residual Vertical Displacement



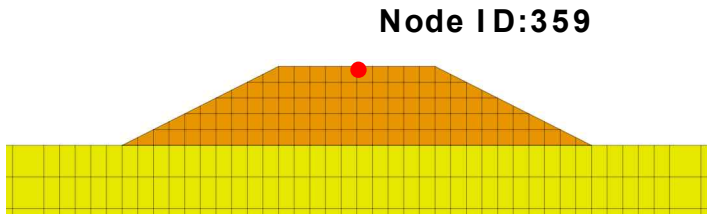


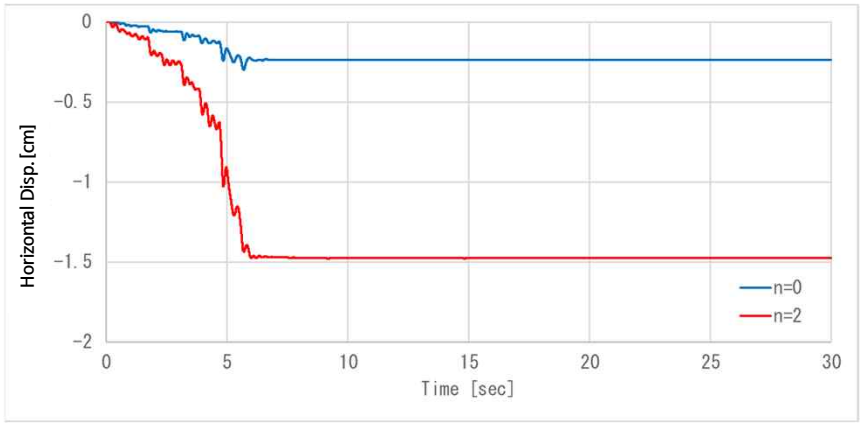
Maximum Horizontal Displacement

Multi Spring n= 2

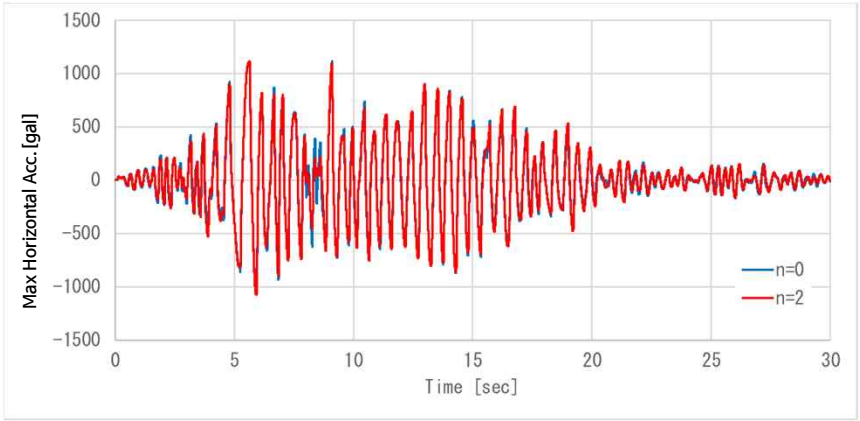
11. Multi-Spring(Multi Shear Spring)

- **Modified RO/HD、GHE-S Model、Multi Spring**

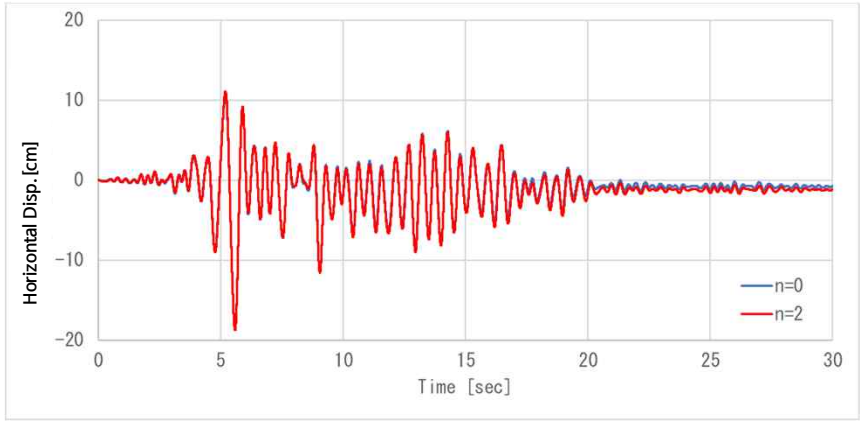




Vertical Displacement Time History



Horizontal Acceleration - Time



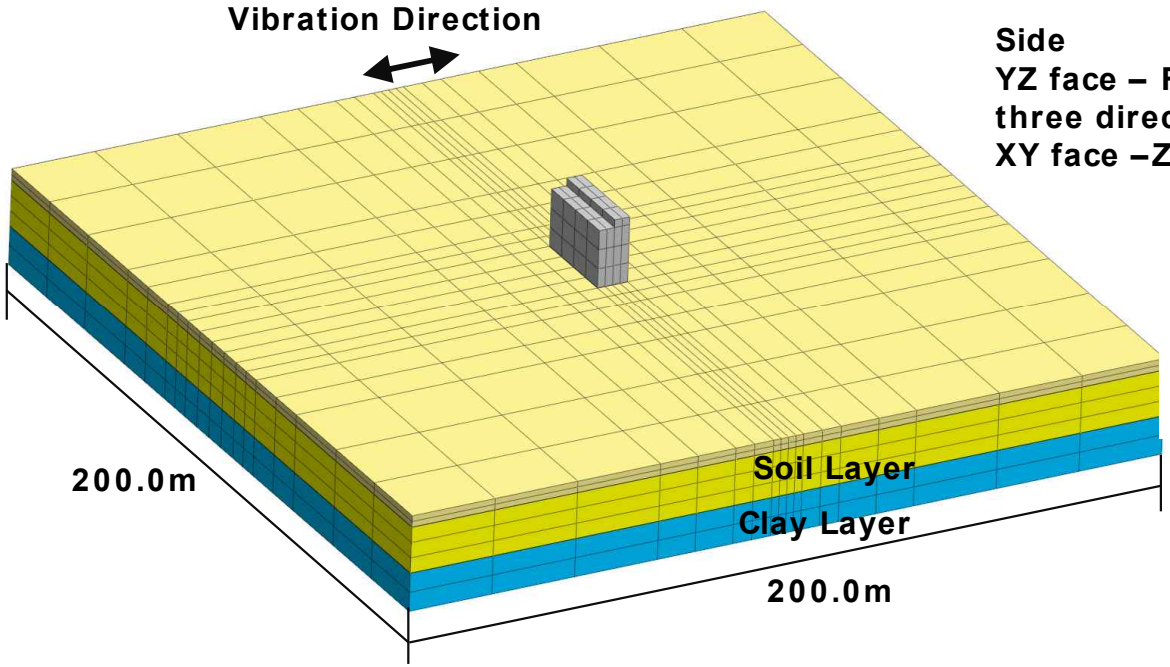
Horizontal Displacement – Time History

11. Multi-Spring(Multi Shear Spring)

- **Modified RO/HD、GHE-S Model、Multi Spring**

Analysis Case (3D)

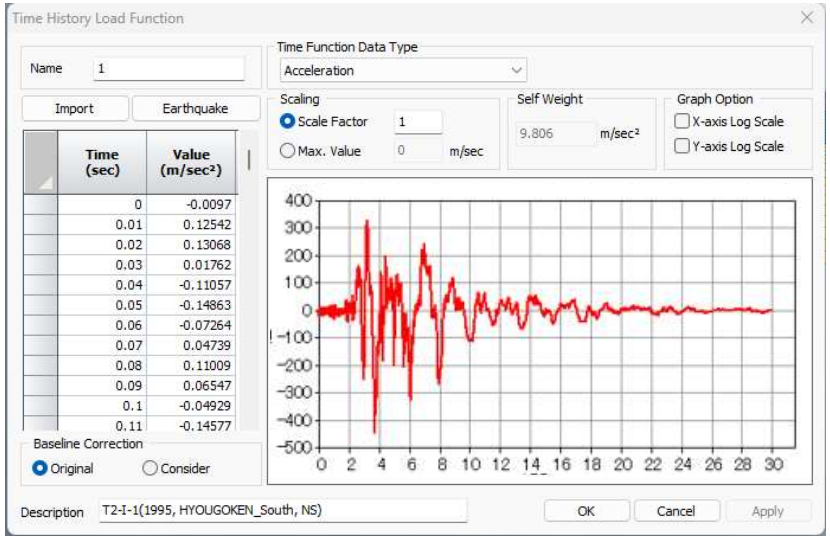
Bottom Viscous Boundary (2E Input)



Side
YZ face – Repeated BC (Equal Displacement constraint in all three directions for nodes at the same depth)
XY face –Z Direction Fixed

Ground Material Properties

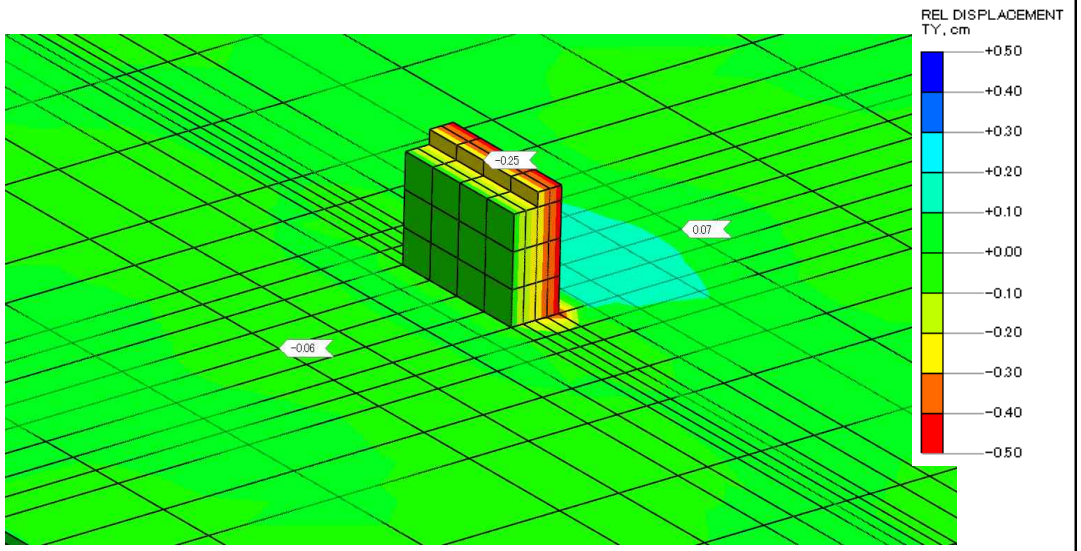
	Ground Model	Unit vol. weight [kN/m2]	Standard Confining Pressure [kN/m2]	Shear modulus of E [kN/m2]	Refer. Strain	Confining Pressure Dependence Coff.	Poisson's Ratio	Max. Damping Ratio
Fill Layer	Modified R-O	17.60	18.00	64980.00	3.39E-04	0.50	0.33	0.30
Sand Layer	Modified R-O	17.60	66.00	64980.00	1.29E-03	0.50	0.33	0.30
Clay Layer	Modified R-O	16.70	120.00	38250.00	3.97E-03	0.50	0.33	0.20



Ground Acceleration

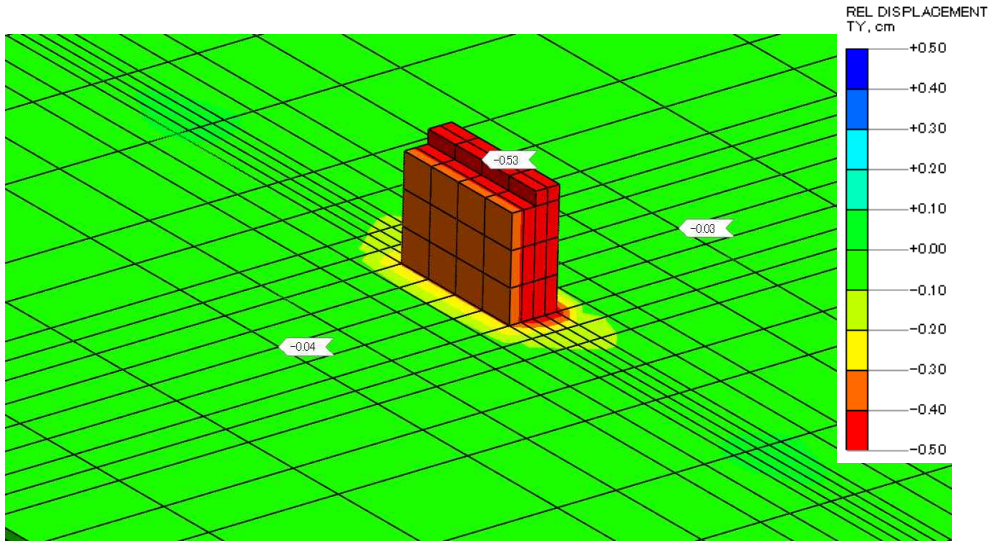
11. Multi-Spring(Multi Shear Spring)

- **Modified** RO/HD、GHE-S **Model**、**Multi Spring**



Residual Vertical Displacement

Multi Spring X

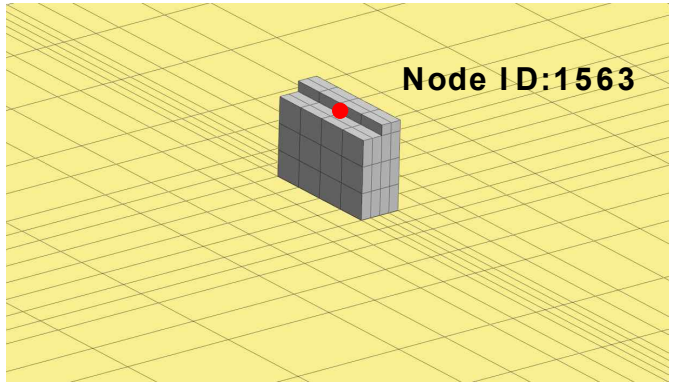


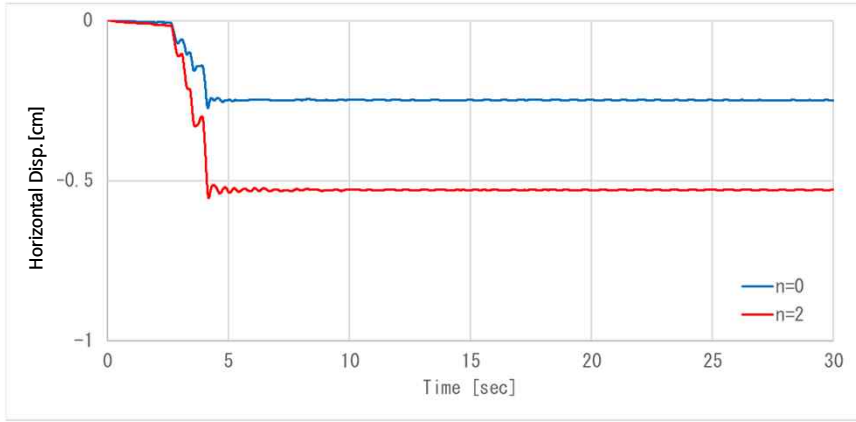
Residual Vertical Displacement

Multi Spring n= 2

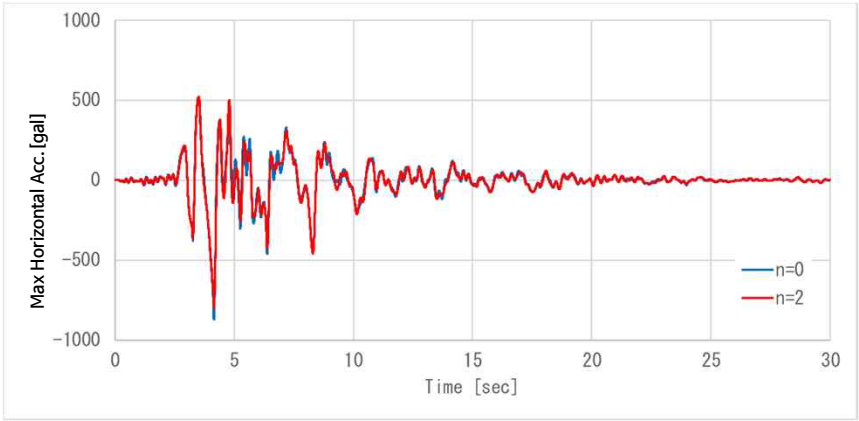
11. Multi-Spring(Multi Shear Spring)

- **Modified RO/HD、GHE-S Model、Multi Spring**

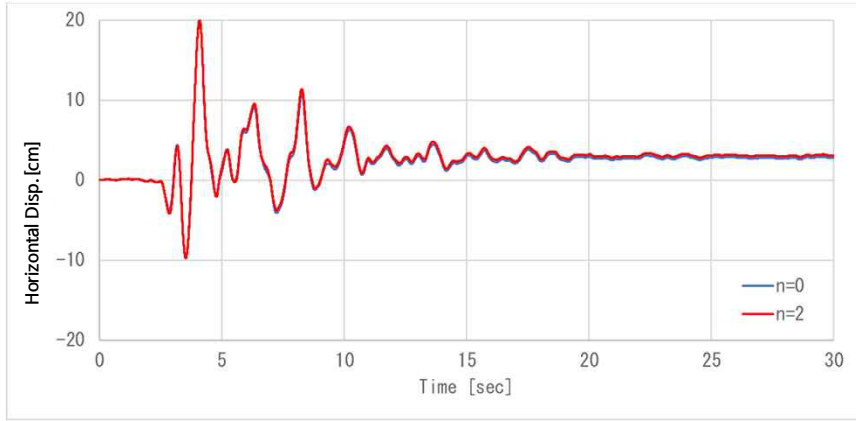




Vertical Displacement – Time Graph



Horizontal Acceleration – Time Graph



Horizontal Displacement – Time Graph

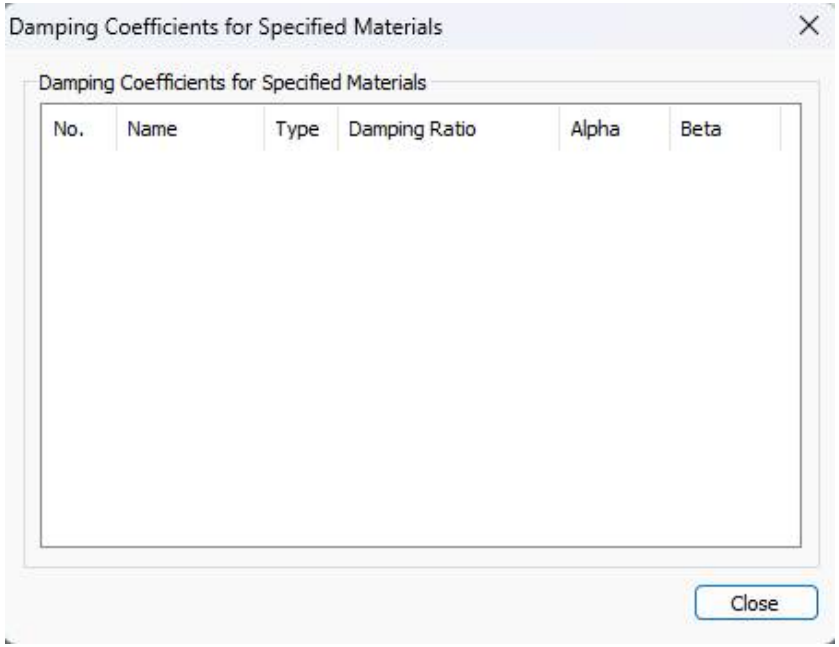
12. Rayleigh Damping by Element(Material)

- During seismic analysis, the superstructure, substructure, and ground all have different attenuation coefficients
- Therefore, in the analysis, a function is installed to calculate the attenuation coefficients α and β for each material.

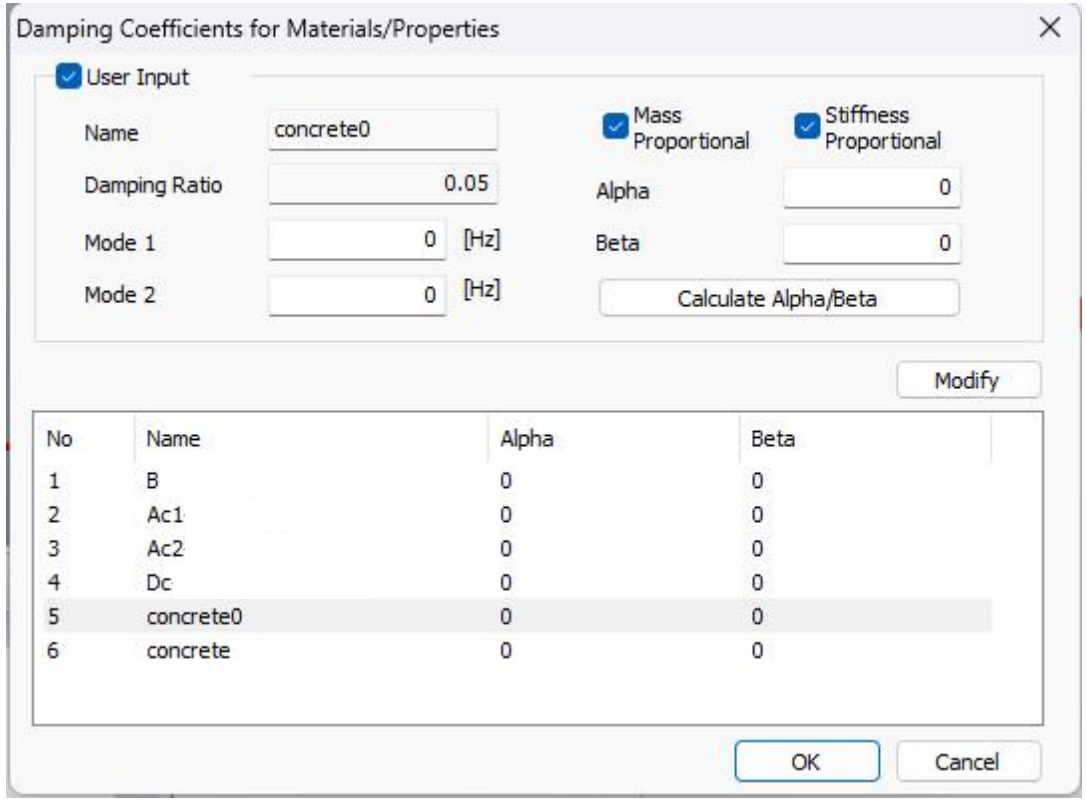
▪ ***Analysis > Analysis Control > Dynamic > Damping Method***

Previously, Only approximate Settings could be made by inputting the period and frequency and using internally calculated α and β.
Now it is possible to directly input α and β.

Previous Version

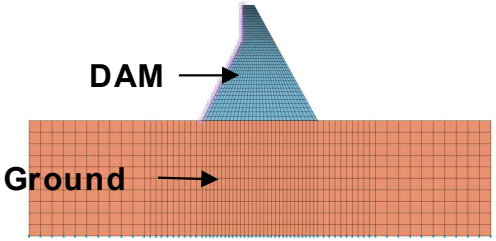


New Version

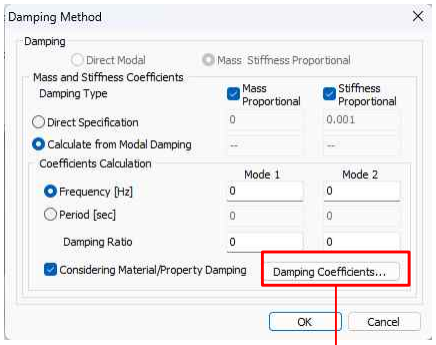


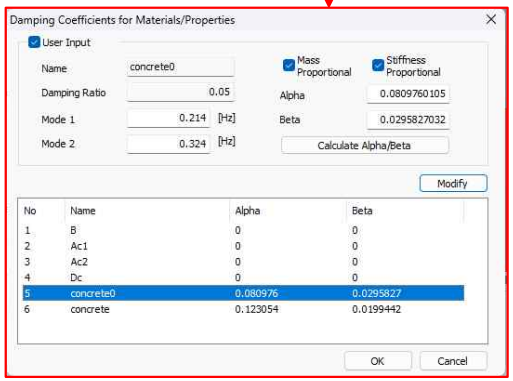
12. Rayleigh Damping by Element(Material)

▪ ***Analysis > Analysis Control > Dynamic > Damping Method***

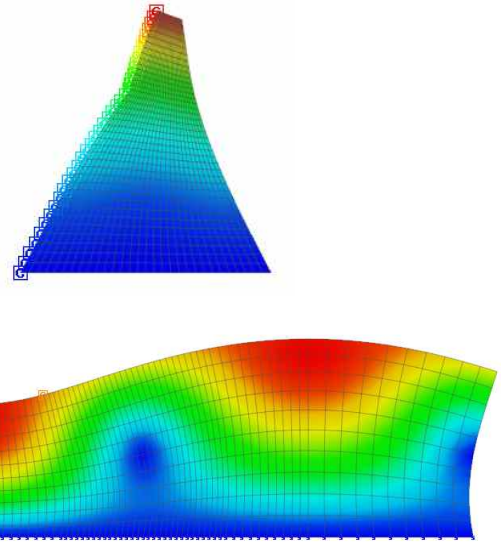


① Analysis Model

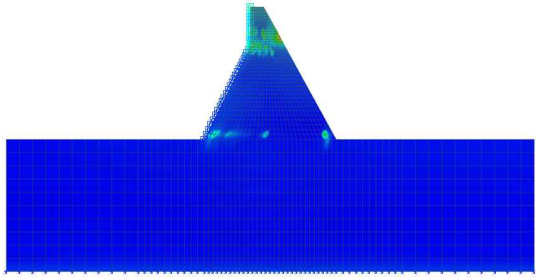




④ Damping Coefficients for Material

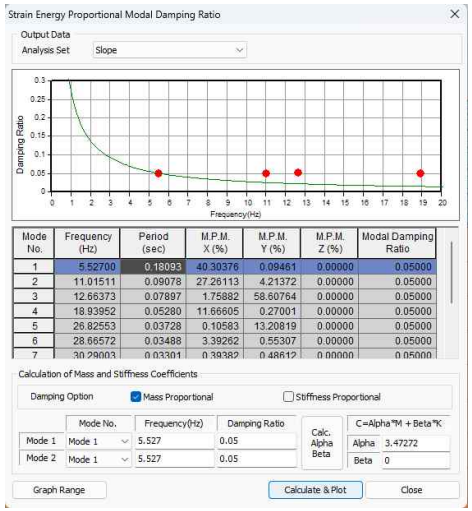


② Eigenvalue Analysis of Structures and Ground

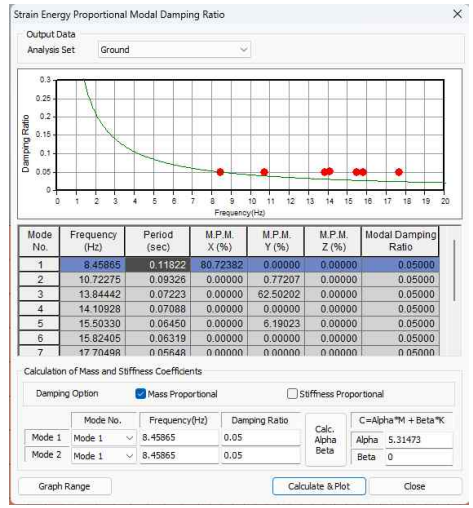


⑤ Perform Dynamic Analysis

Damping Constant of DAM



Damping Constant of the Ground

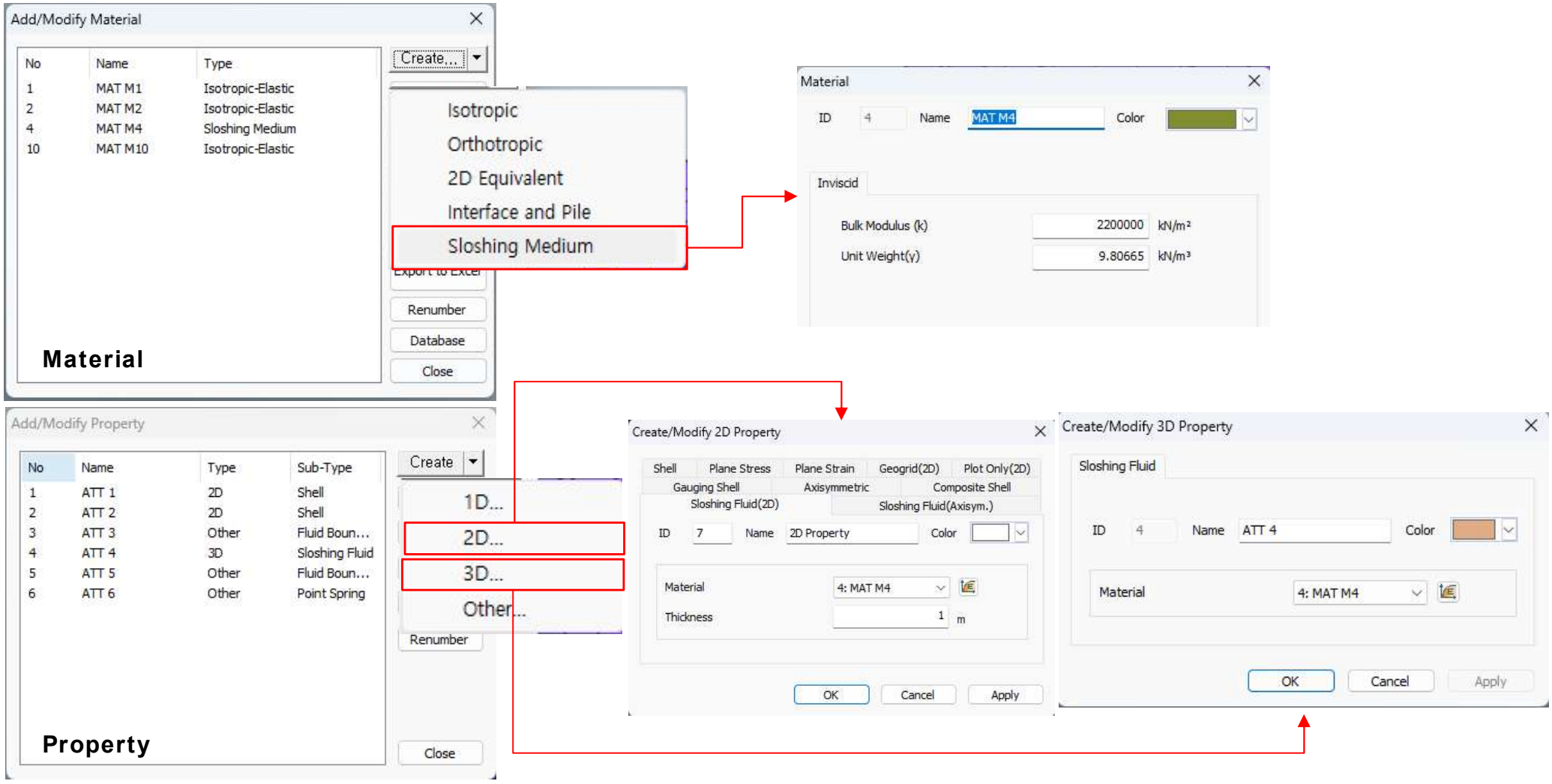


③ Damping Constant for each mode

13. Fluid Element (Sloshing)

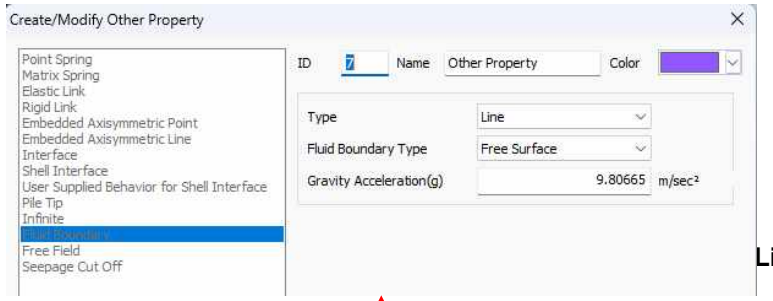
- A liquid element that can simulate the water in the structure and the liquid gas contained in LNG tank has been added. This is a function that calculates the wave height and pressure results during an earthquake and predicts through analysis how much pressure will be generated.

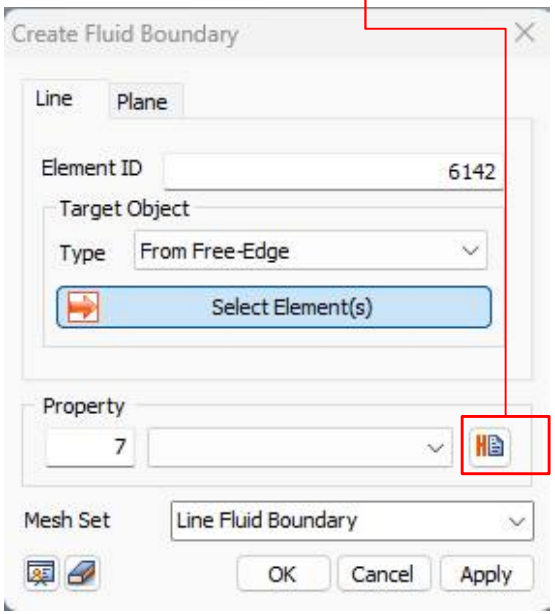
▪ ***Mesh > Prop./ CSys./ Func. > Material***

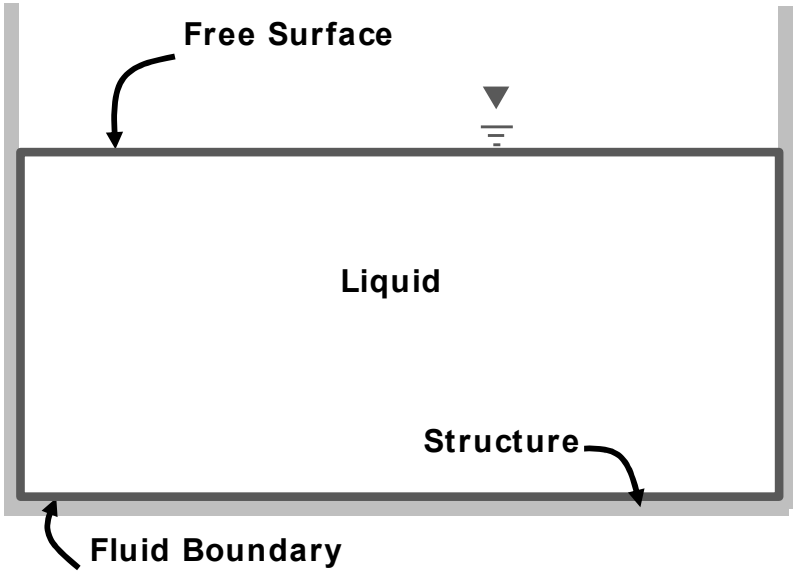


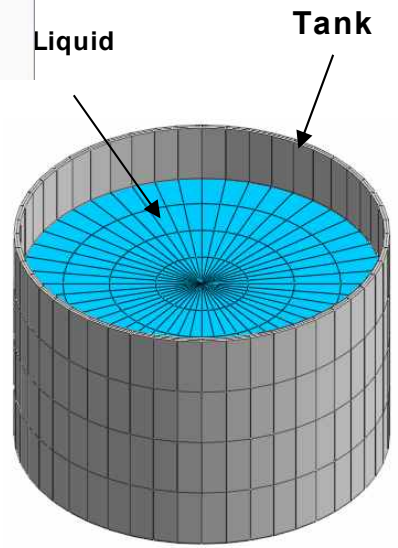
13. Fluid Element (Sloshing)

- ***Mesh > Element > Fluid Boundary***

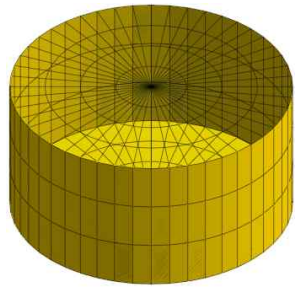


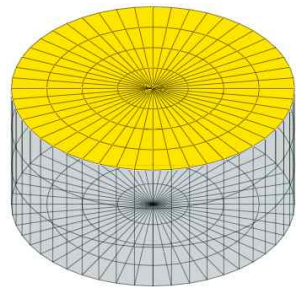




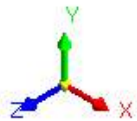


Analysis Model





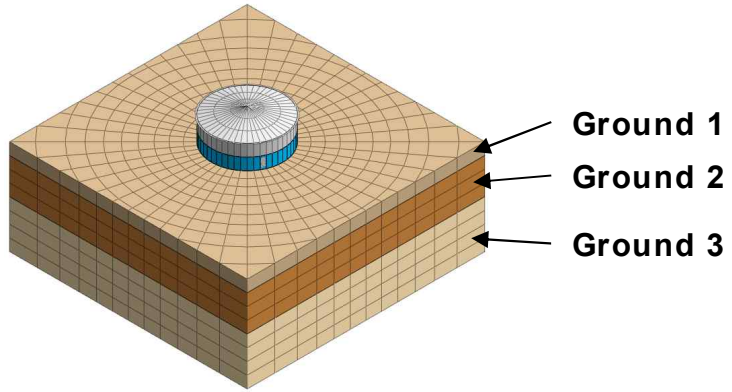
Fluid Boundary
(Interface between
Structure and liquid)

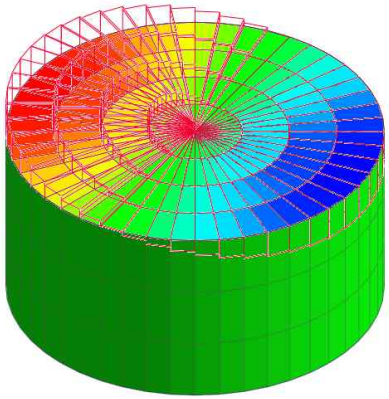


Set Boundary element on the part in contact with the object and on the top of the liquid

13. Fluid Element (Sloshing)

- ***Mesh > Prop./ CSys./ Func. > Material***

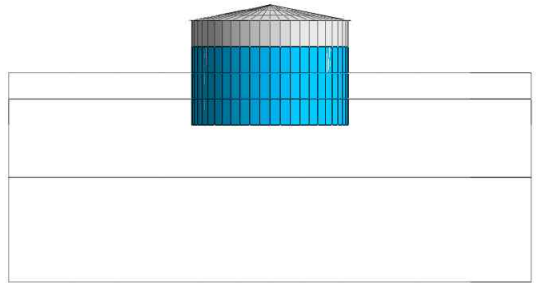




Velocity Potential Theory

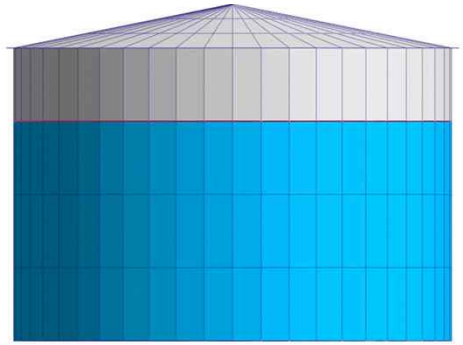
Natural Cycle $T_{si} = \frac{2\pi}{\omega_i} = 2\pi\sqrt{\frac{R}{\varepsilon_i g}\coth\left(\varepsilon_i \frac{H}{R}\right)}$

Natural Frequency $f(Hz) = \frac{1}{2\pi}\cdot\sqrt{\frac{(2n-1)\cdot\pi\cdot g}{L}\cdot\tanh\left(\frac{(2n-1)\cdot\pi\cdot H}{L}\right)}$



Perform an eigenvalue Analysis including liquid elements and compare the natural frequency and natural period as follows. εi is the i th root of dJ1(r)/ dr= 0 、and is calculate as ε1= 1.84118.

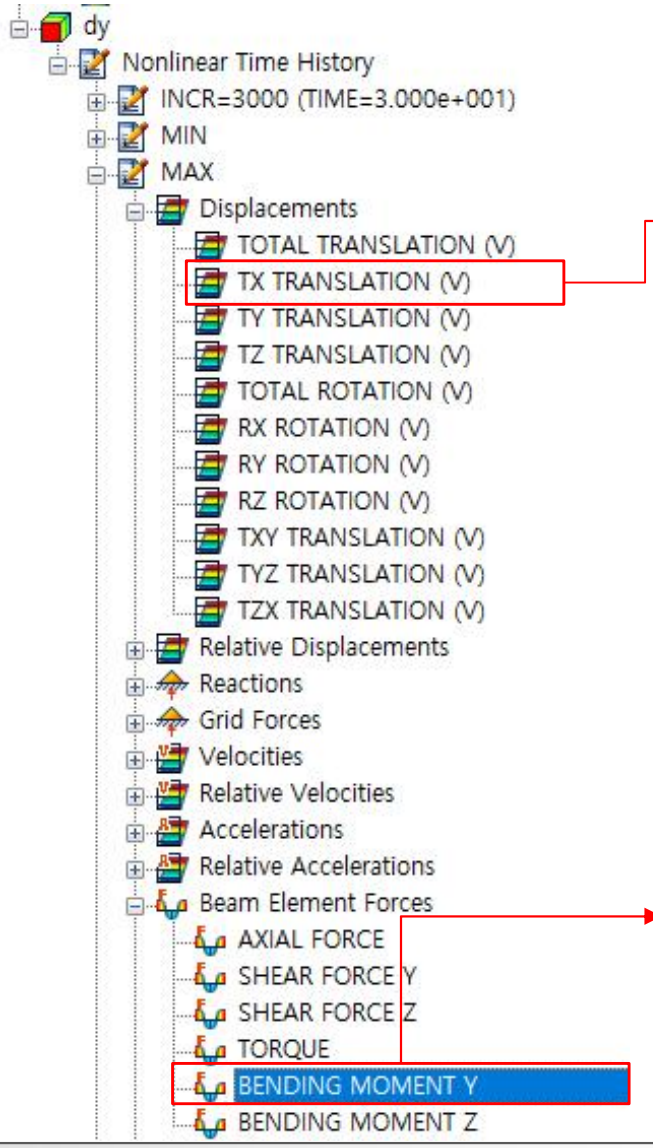
	Ts(s)	f(Hz)
Theoretical value	6.43	0.141
Analysis value	6.35	0.157



14. Dynamic Analysis Min/ Max value occurrence time output

- Occurrence time of the dynamic analysis min/max results can now be obtained in a tabular format.

▪ ***Results Tree*** **> MIN, MAX, ABSOLUTE MAX（Occurrence time output）**



Node	TX TRANSLATION (V) (m)	
	Value	Time (sec)
1	3.480e-001	5.510e+000
2	3.480e-001	5.510e+000
3	3.480e-001	5.510e+000
4	3.480e-001	5.520e+000
5	3.482e-001	5.520e+000
6	3.483e-001	5.520e+000
7	3.487e-001	5.530e+000
8	3.494e-001	5.540e+000
9	3.504e-001	5.550e+000
10	3.518e-001	5.560e+000
11	3.562e-001	5.580e+000
12	3.634e-001	5.620e+000
13	3.617e-001	5.650e+000
14	3.270e-001	5.690e+000
15	4.405e-001	2.105e+001
16	4.887e-001	2.104e+001
17	3.480e-001	5.510e+000

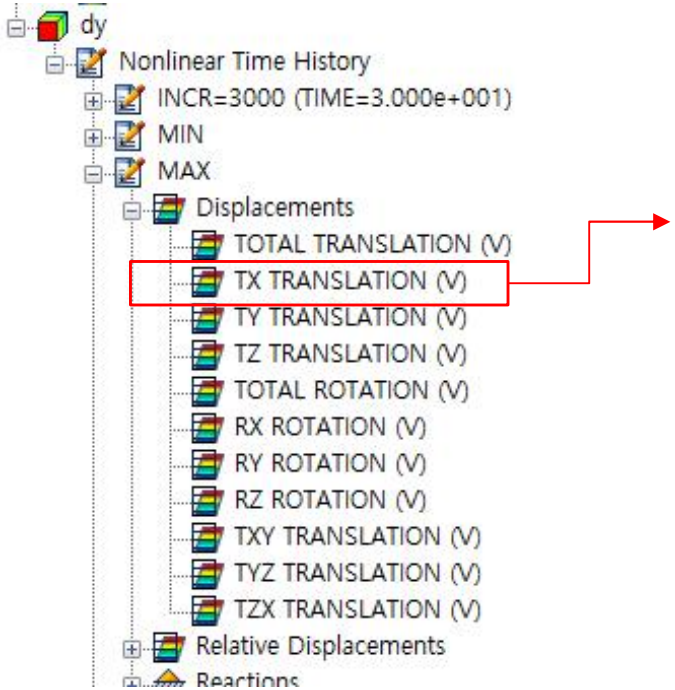
No.	BENDING MOMENT Y 0/4 (kN·m)		BENDING MOMENT Y 1/4 (kN·m)		BENDING MOMENT Y 1/4 (kN·m)		BENDING MOMENT Y 2/4 (kN·m)		BENDING MOMENT Y 2/4 (kN·m)		BENDING MOMENT Y 3/4 (kN·m)		BENDING MOMENT Y 3/4 (kN·m)		BENDING MOMENT Y 4/4 (kN·m)	
	Value	Time (sec)	Value	Time (sec)	Value	Time (sec)	Value	Time (sec)	Value	Time (sec)	Value	Time (sec)	Value	Time (sec)	Value	Time (sec)
1	4.561e+004	6.350e+000	4.510e+004	6.350e+000	4.510e+004	6.350e+000	4.459e+004	6.350e+000	4.459e+004	6.350e+000	4.409e+004	6.350e+000	4.409e+004	6.350e+000	4.358e+004	6.350e+000
2	4.351e+004	6.350e+000	4.299e+004	6.350e+000	4.299e+004	6.350e+000	4.247e+004	6.350e+000	4.247e+004	6.350e+000	4.194e+004	6.350e+000	4.194e+004	6.350e+000	4.145e+004	6.360e+000
3	4.138e+004	6.360e+000	4.087e+004	6.360e+000	4.087e+004	6.360e+000	4.036e+004	6.360e+000	4.036e+004	6.360e+000	3.986e+004	6.360e+000	3.986e+004	6.360e+000	3.935e+004	6.360e+000
4	3.927e+004	6.360e+000	3.875e+004	6.360e+000	3.875e+004	6.360e+000	3.822e+004	6.360e+000	3.822e+004	6.360e+000	3.770e+004	6.360e+000	3.770e+004	6.360e+000	3.717e+004	6.360e+000
5	3.711e+004	6.360e+000	3.657e+004	6.370e+000	3.657e+004	6.370e+000	3.607e+004	6.370e+000	3.607e+004	6.370e+000	3.556e+004	6.370e+000	3.556e+004	6.370e+000	3.505e+004	6.370e+000
6	3.495e+004	6.370e+000	3.388e+004	6.370e+000	3.388e+004	6.370e+000	3.281e+004	6.380e+000	3.281e+004	6.380e+000	3.182e+004	6.380e+000	3.182e+004	6.380e+000	3.083e+004	6.380e+000
7	3.067e+004	6.380e+000	2.965e+004	6.390e+000	2.965e+004	6.390e+000	2.868e+004	6.390e+000	2.868e+004	6.390e+000	2.776e+004	6.400e+000	2.776e+004	6.400e+000	2.689e+004	6.400e+000
8	2.662e+004	6.410e+000	2.576e+004	6.410e+000	2.576e+004	6.410e+000	2.494e+004	6.420e+000	2.494e+004	6.420e+000	2.418e+004	6.420e+000	2.418e+004	6.420e+000	2.342e+004	6.420e+000
9	2.316e+004	6.430e+000	2.242e+004	6.430e+000	2.242e+004	6.430e+000	2.177e+004	6.440e+000	2.177e+004	6.440e+000	2.121e+004	6.450e+000	2.121e+004	6.450e+000	2.072e+004	6.460e+000
10	2.040e+004	6.470e+000	1.956e+004	6.480e+000	1.956e+004	6.480e+000	1.921e+004	6.500e+000	1.921e+004	6.500e+000	1.915e+004	6.510e+000	1.915e+004	6.510e+000	1.936e+004	6.540e+000
11	1.896e+004	6.560e+000	2.031e+004	6.700e+000	2.031e+004	6.700e+000	2.273e+004	6.700e+000	2.273e+004	6.700e+000	2.516e+004	6.700e+000	2.516e+004	6.700e+000	2.758e+004	6.700e+000
12	2.758e+004	6.700e+000	2.861e+004	6.700e+000	2.861e+004	6.700e+000	2.965e+004	6.700e+000	2.965e+004	6.700e+000	3.074e+004	6.690e+000	3.074e+004	6.690e+000	3.183e+004	6.690e+000
13	3.189e+004	6.690e+000	3.020e+004	6.680e+000	3.020e+004	6.680e+000	2.858e+004	6.680e+000	2.858e+004	6.680e+000	2.706e+004	6.670e+000	2.706e+004	6.670e+000	2.566e+004	6.660e+000
14	2.575e+004	6.660e+000	2.068e+004	6.650e+000	2.068e+004	6.650e+000	1.571e+004	6.640e+000	1.571e+004	6.640e+000	1.110e+004	6.060e+000	1.110e+004	6.060e+000	6.601e+003	6.070e+000
15	6.680e+003	6.060e+000	5.010e+003	6.060e+000	5.010e+003	6.060e+000	3.340e+003	6.060e+000	3.340e+003	6.060e+000	1.670e+003	6.060e+000	1.670e+003	6.060e+000	1.140e-009	8.690e+000

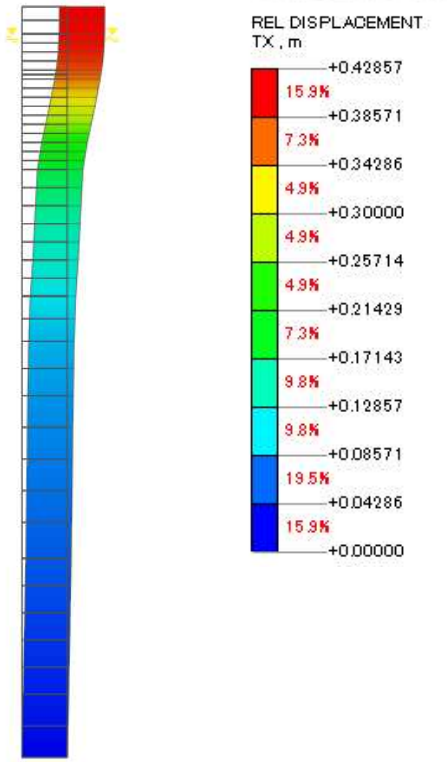
15. Improve Dynamic Analysis ABSOLUTE MAX(Absolute value output)

- For Dynamic Analysis, the results for max/min (+/-) can now be viewed in absolute value form.

▪ ***Results Tree*** > **ABSOLUTE MAX**

Positive/ Negative Result → Change Output format(ABS)





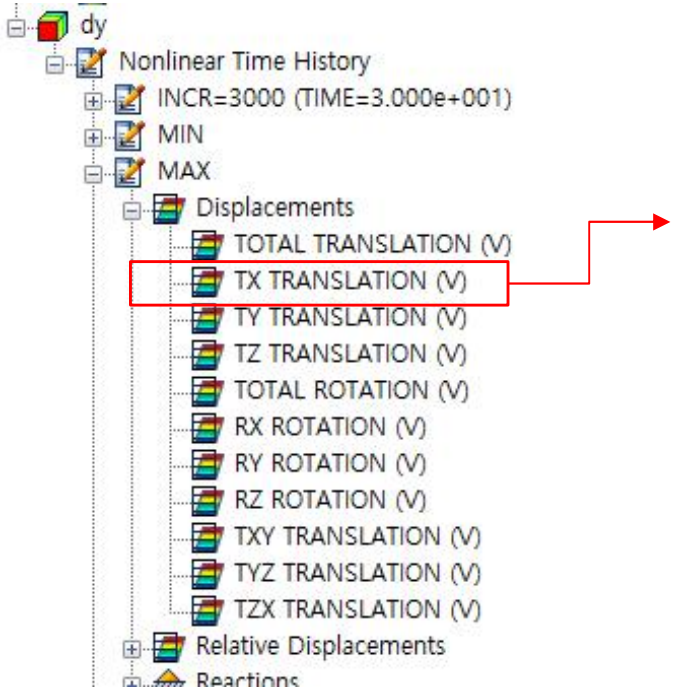
▶	1	4.286e-001	6.210e+000
	2	4.273e-001	6.210e+000
	3	4.244e-001	6.210e+000
	4	4.211e-001	6.210e+000
	5	4.151e-001	6.215e+000
	6	4.054e-001	6.215e+000
	7	3.915e-001	6.215e+000
	8	3.828e-001	6.210e+000
	9	3.739e-001	6.210e+000
	10	3.542e-001	6.210e+000
	11	3.356e-001	6.210e+000
	12	3.151e-001	6.210e+000
	13	2.937e-001	6.215e+000
	14	2.718e-001	6.220e+000
	15	2.497e-001	6.230e+000
	16	2.280e-001	6.230e+000
	17	2.105e-001	6.230e+000
	18	1.937e-001	6.230e+000
	19	1.779e-001	6.240e+000
	20	1.667e-001	6.240e+000
	21	1.559e-001	6.240e+000
	22	1.454e-001	6.245e+000
	23	1.352e-001	6.245e+000
	24	1.250e-001	6.240e+000
	25	1.102e-001	6.230e+000
	26	9.622e-002	6.215e+000
	27	8.688e-002	6.200e+000
	28	7.814e-002	6.190e+000
	29	7.277e-002	6.180e+000
	30	6.754e-002	6.180e+000
	31	6.316e-002	5.700e+000
	32	5.849e-002	5.690e+000
	33	5.447e-002	5.690e+000
	34	5.002e-002	5.680e+000
	35	4.441e-002	5.680e+000
	36	3.879e-002	5.680e+000
	37	3.296e-002	5.680e+000
	38	2.700e-002	5.680e+000
	39	2.099e-002	5.680e+000
	40	1.498e-002	5.680e+000
	41	7.626e-003	5.670e+000
	42	0.000e+000	1.000e-002
	43	4.286e-001	6.210e+000
	44	4.273e-001	6.210e+000
	45	4.244e-001	6.210e+000
	46	4.211e-001	6.210e+000

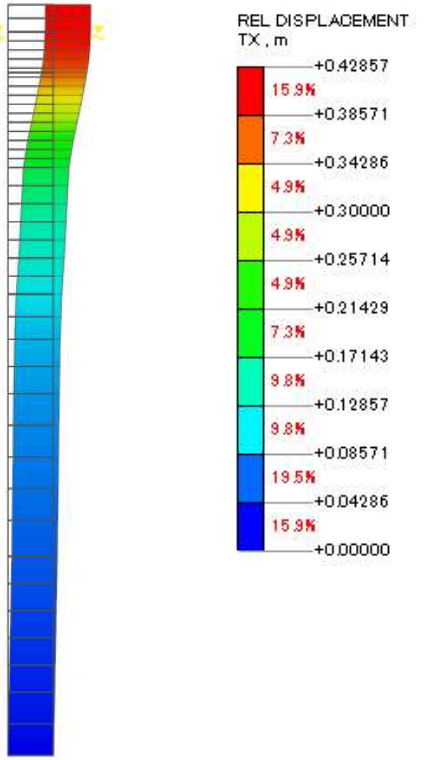
16. Customization of Results Display

- Set so that only the necessary parts of the output results are displayed in the result tree
- Output generation time can be reduced significantly in models with many large steps and stages, such as nonlinear time history analysis.

▪ ***Results Tree*** **> ABSOLUTE MAX**

Positive/ Negative Result → Change Output format(ABS)



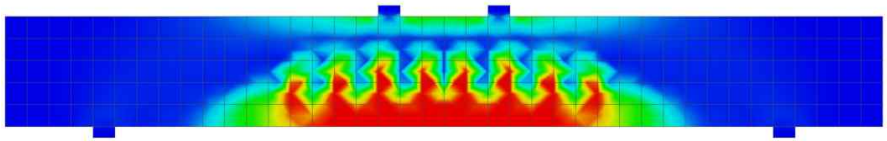


▶	1	4.286e-001	6.210e+000
	2	4.273e-001	6.210e+000
	3	4.244e-001	6.210e+000
	4	4.211e-001	6.210e+000
	5	4.151e-001	6.215e+000
	6	4.054e-001	6.215e+000
	7	3.915e-001	6.215e+000
	8	3.828e-001	6.210e+000
	9	3.739e-001	6.210e+000
	10	3.542e-001	6.210e+000
	11	3.356e-001	6.210e+000
	12	3.151e-001	6.210e+000
	13	2.937e-001	6.215e+000
	14	2.718e-001	6.220e+000
	15	2.497e-001	6.230e+000
	16	2.280e-001	6.230e+000
	17	2.105e-001	6.230e+000
	18	1.937e-001	6.230e+000
	19	1.779e-001	6.240e+000
	20	1.667e-001	6.240e+000
	21	1.559e-001	6.240e+000
	22	1.454e-001	6.245e+000
	23	1.352e-001	6.245e+000
	24	1.250e-001	6.240e+000
	25	1.102e-001	6.230e+000
	26	9.622e-002	6.215e+000
	27	8.688e-002	6.200e+000
	28	7.814e-002	6.190e+000
	29	7.277e-002	6.180e+000
	30	6.754e-002	6.180e+000
	31	6.316e-002	5.700e+000
	32	5.849e-002	5.690e+000
	33	5.447e-002	5.690e+000
	34	5.002e-002	5.680e+000
	35	4.441e-002	5.680e+000
	36	3.879e-002	5.680e+000
	37	3.296e-002	5.680e+000
	38	2.700e-002	5.680e+000
	39	2.099e-002	5.680e+000
	40	1.498e-002	5.680e+000
	41	7.626e-003	5.670e+000
	42	0.000e+000	1.000e-002
	43	4.286e-001	6.210e+000
	44	4.273e-001	6.210e+000
	45	4.244e-001	6.210e+000
	46	4.211e-001	6.210e+000

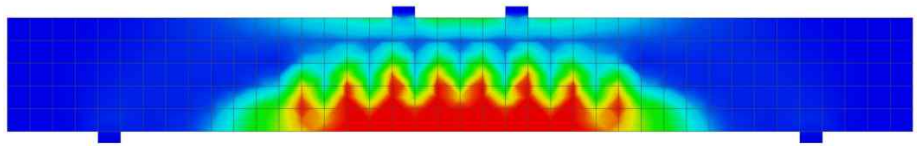
17. Concrete Result item

- Concrete damage evaluation items proposed in concrete standard specifications
- Deviation transformation second invariant, Formalized by transformation energy

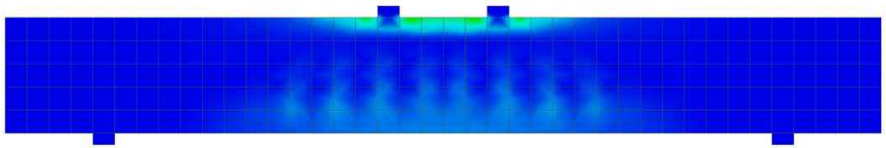
▪ ***Tools > Option > Analysis Result***



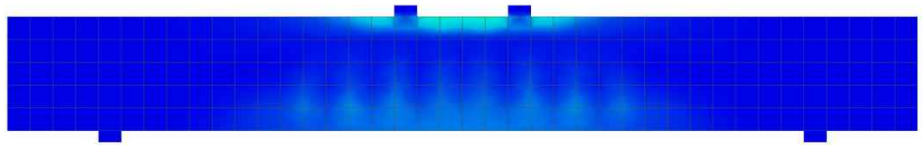
Deviation Transformation Second Invariant



Deviation Transformation Second Invariant (Average)



Formulated Cumulative Strain Energy



Formulated Cumulative Strain Energy (Average)

18. Convert to Load Sets using Load Combination Function

- By utilizing the load combination function, a new load set can be created considering the scale factor of each load set.

▪ *Convert to Load Sets*