

# Release Note

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Release Date : January 2021

Product Ver. : FEA NX 2021 (v1.1)



ADVANCED NONLINEAR AND DETAIL

New Paradigm in Advanced Structural Analysis

# Enhancements

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1. Concrete Damage Plasticity Model
2. Fatigue Analysis
3. Virtual Beam for Calculation of Resultant Forces of 2D/3D Mesh
4. Displacement-Control Method for Nonlinear Analysis
5. Modal Participation Factor
6. Improvement of Multi-Layered Grid (Composite Shell)
7. Improvement of Bond Slip Interface
8. Modified Menegotto-Pinto Material Model for Steel
9. General Hyperbolic Equation GHE-S Model
10. 3D Hill Plastic Model
11. Creep & Shrinkage Function and Expansive Additive for Concrete (JCI 2016/JSCE 2017)



## 1. Concrete Damaged Plasticity Model

- Concrete Damaged Plasticity Model is now available in midas FEA NX. It provides a general capability for modeling concrete and other quasi-brittle materials including masonry and is designed for applications in which concrete is subjected to dynamic loading due to earthquake under low confining pressures.

### Mesh > Material > Concrete Damaged Plasticity

**Material**

ID: 1 Name: Concrete Color: [Color]

Model Type: Concrete Damaged Plasticity  Structure

General Non-Linear Thermal

Parameters

Dilation Angle:  [deg]

Eccentricity:

fb0/fc0 ratio:

Kc:

Viscosity Parameter:

Tension Recovery:

Compression Recovery:

Concrete Damaged Plasticity Function

Compression Hardening Curve:

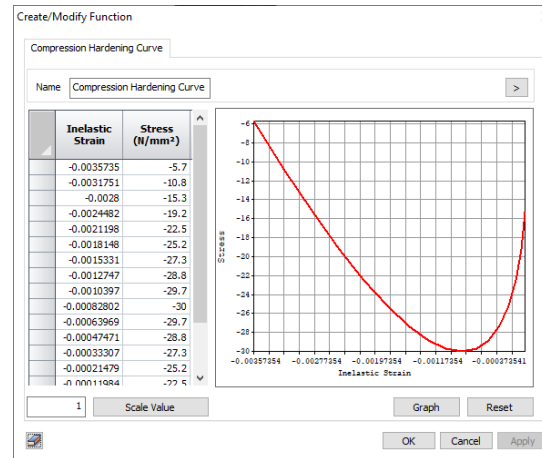
Compression Damage Curve:

Tension Softening Curve:

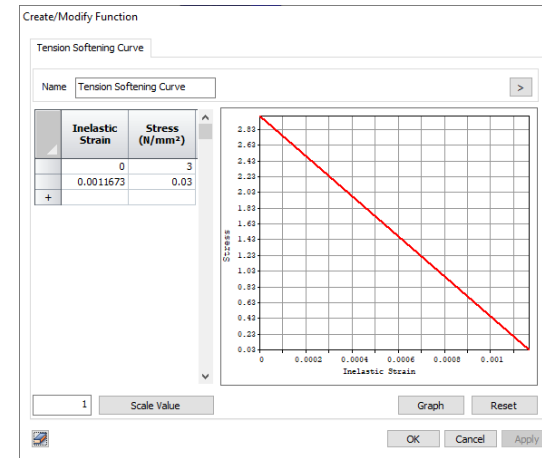
Tension Damage Curve:

OK Cancel Apply

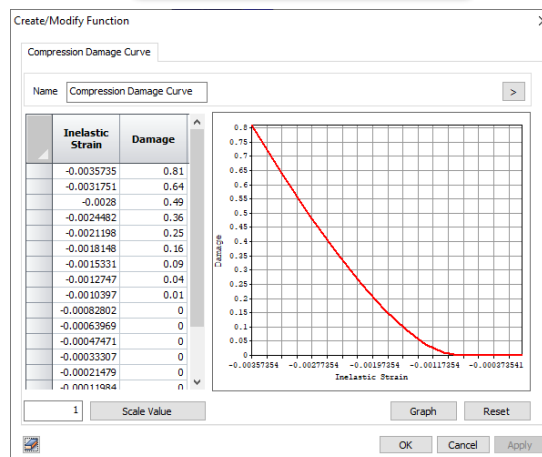
Concrete Damaged Plasticity Model



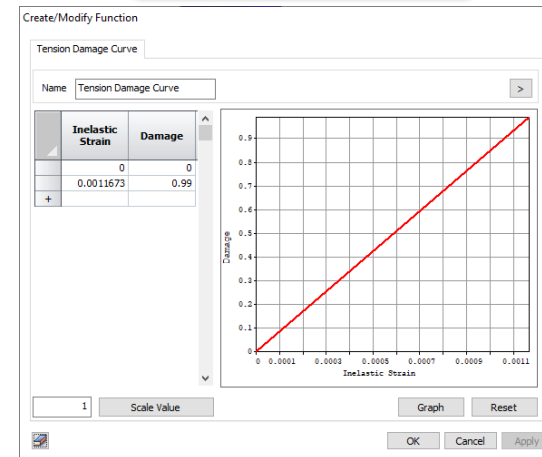
Compression Hardening Curve



Tension Softening Curve



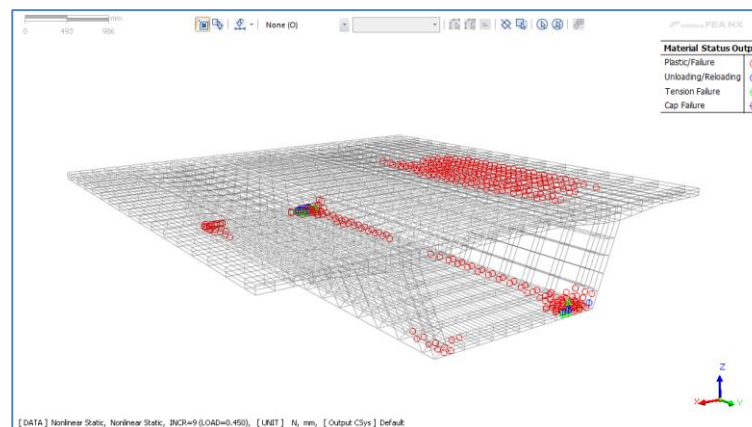
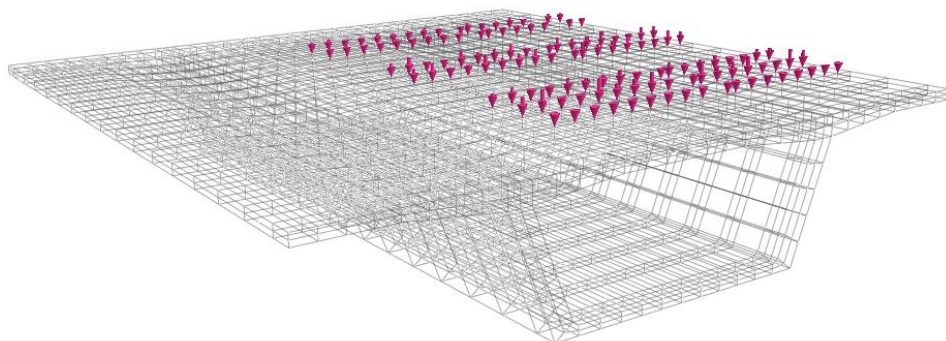
Compression Damage Curve



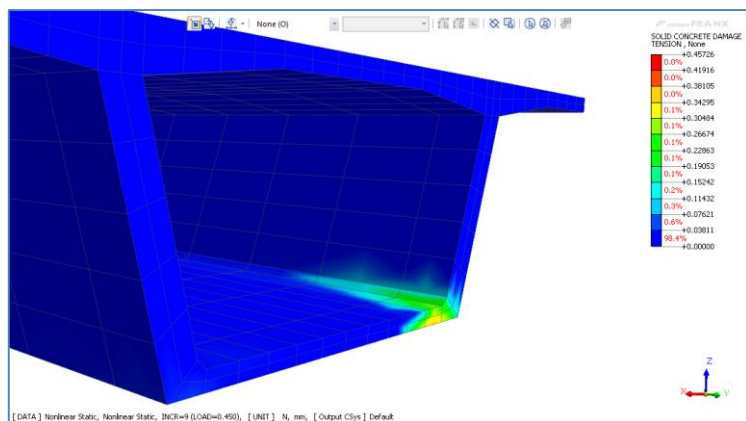
Tension Damage Curve

## 1. Concrete Damaged Plasticity Model

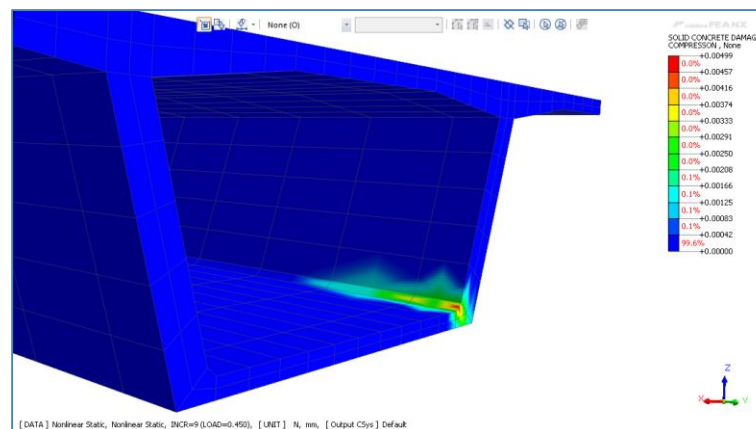
- Using this model, the following behaviors of concrete can be described. Different behaviors for tension and compression. Different reductions of the elastic stiffness when unloading for tension and compression. Stiffness recovery effects during cyclic load reversals.



Plastic Status



Tension Damage



Compression Damage

## 2. Fatigue Analysis

- Fatigue analysis can be performed on the basis of stress (stress-life method) and strain (strain-life method).
- Fatigue lifecycle and fatigue damage can be viewed for the various mean stress correction methods, i.e. Goodman, Gerber, etc.

### Results > Fatigue Analysis

**Fatigue Analysis** ✕

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**Analysis Data**

Name:

Description:

Method:

Analysis Set:

**Option**

Stress Type:

Strain Type:

Average     Max     Min

Quick Counting (Number of Stress Ranges)

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**Property**

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**Mean Stress Correction**

None     Goodman     Gerber

Soderberg     Morrow     SWT

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**Output Request**

Damage     Fatigue Life Cycle

Contribution of Fatigue

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**Fatigue Load**

Load/Stress History:

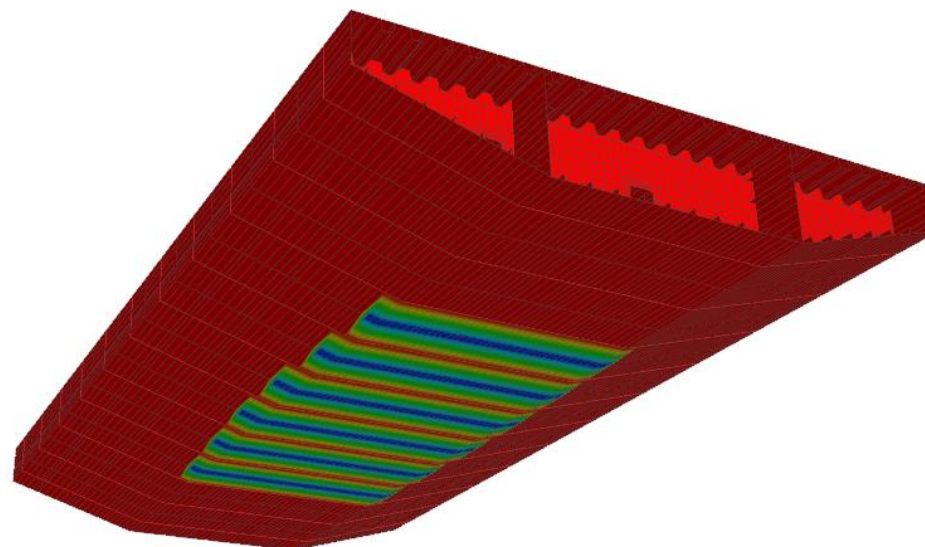
Number of Repetitions:

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Infinite Life:

0 731 1.46e+003 mm

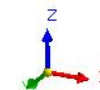
None (O)



FEA NX

FATIGUE LIFE CYCLE, None

98.1%	+1.00000e+009
0.0%	+9.16777e+008
0.0%	+8.33553e+008
0.0%	+7.50330e+008
0.0%	+6.67106e+008
0.0%	+5.83883e+008
0.0%	+5.00659e+008
0.0%	+4.17436e+008
0.0%	+3.34212e+008
0.0%	+2.50989e+008
0.0%	+1.67765e+008
1.9%	+8.45418e+007
	+1.31837e+006



[DATA] Linear\_Fatigue Results-2, Goodman, [UNIT] N, mm, [Output CSys] Default

Fatigue Lifecycle Contour

Fatigue Analysis

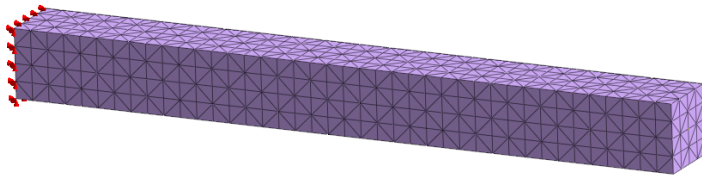


### 3. Virtual Beam for Calculation of Resultant Forces of 2D/3D Mesh

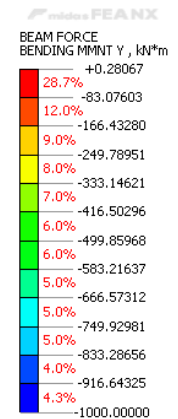
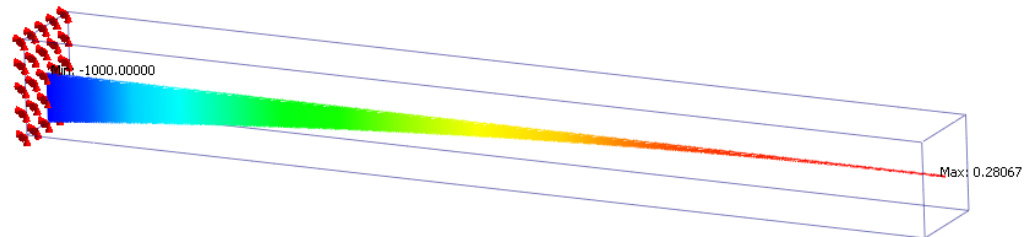
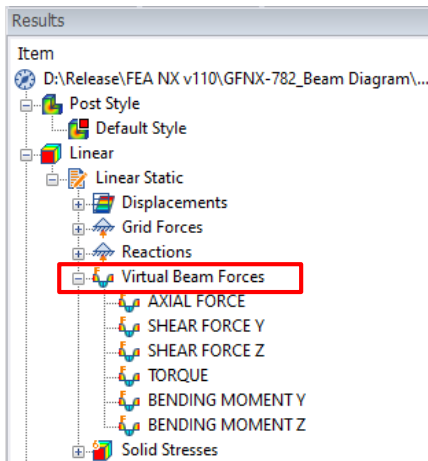
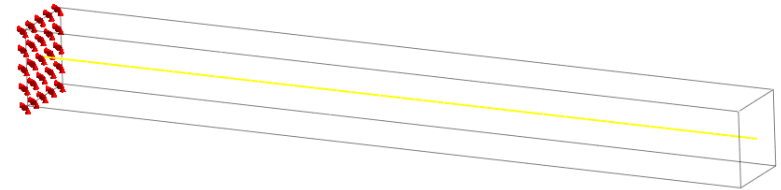
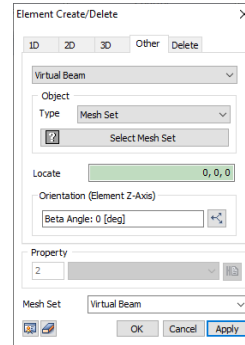
- Resultant forces of 2D/3D mesh can be calculated and viewed as force diagram.
- This is useful to check moment/shear force diagram for the pile modelled with solid elements.

▪ **Mesh > Element > Create > Other > Virtual Beam**

Step 1. Generate a 3D mesh.



Step 2. Generate a 1D mesh for virtual beam by clicking start point and end point of the virtual beam. 1D geometry is not necessary to generate virtual beam.



Bending Moment Diagram for Virtual Beam

## 4. Displacement-Control Method for Nonlinear Analysis

- For performing nonlinear analysis, the Displacement-Control method is added for the iteration method.
- Global displacement of a master node can be controlled, or relative displacement between two nodes can be controlled using the 'Relative Node' option.

### ▪ Analysis > Analysis Case > General > Nonlinear Static > Analysis Control > Nonlinear

Analysis Control

General Nonlinear

Geometry Nonlinearity

Consider Geometric Nonlinear Effects

Update Pore Pressure with Deformation

Basic Nonlinear Parameters

Load Steps

Number of Increments:

Intermediate Output Request: Last Increment

Manual with User-Defined Steps: Load Step...

Time Steps

Time(Duration):  sec

Number of Increments:

Intermediate Output Request: Last Increment

Manual with User-Defined Steps: Time Step...

Iterative Scheme

General  Enhanced Init Stress

Convergence Criteria / Error Tolerance

Displacement(U):

Load(P):

Work(W):

Use Iteration Method

Arc-Length Method  Displacement-Control Method

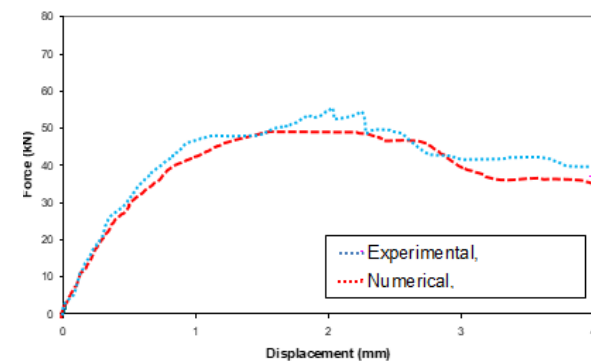
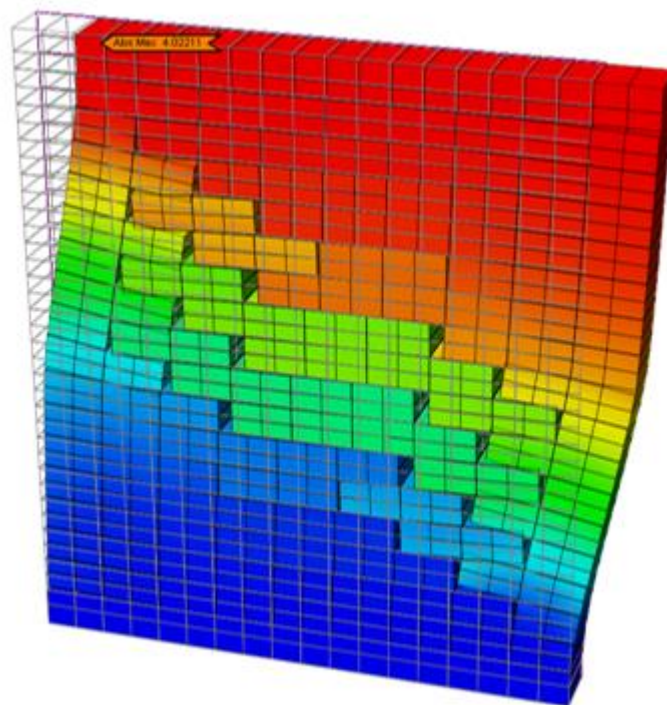
Master Node:

Maximum Disp.:  Direction: Dx

Relative Node:

Advanced Nonlinear Setting...

OK Cancel



Nonlinear Static Analysis of Masonry Wall

Analysis Control Dialog Box

## 5. Modal Participation Factor

- Modal participation factors are added on the Eigenvalue Analysis Result table.
- Modal participation factors measure the interaction between the modes and the directional excitation in a given reference frame. Larger values indicate a stronger contribution to the dynamic response.

### ▪ Analysis > Analysis Case > General > Eigenvalue

The screenshot displays the 'Eigenvalue Analysis Result Table' in the software interface. The table lists 20 modes with their respective frequencies and participation factors. A red box highlights the 'Eigenvalue Analysis Result Table' in the left-hand tree view. Another red box highlights the 'MODAL PARTICIPATION FACTOR' section of the table, which includes columns for T1, T2, T3, R1, R2, and R3.

MODE NUMBER	T1	T2	T3	R1	R2	R3
1	4.232951e-006	7.641526e+002	5.451806e-008	-2.386590e+003	4.623657e-006	9.782767e-008
2	8.686666e+002	-3.747556e-006	7.488364e-008	1.157561e-005	1.006357e+003	8.140729e-007
3	1.107821e-007	1.626399e-008	-2.120429e-008	9.181787e-009	4.448245e-007	-8.761479e+003
4	1.387459e+002	8.202906e-007	-4.643607e-007	-4.704561e-007	3.041575e+003	2.200145e-006
5	-2.036989e-007	4.512231e+002	-8.933741e-008	-2.571785e+002	-4.618771e-006	-2.009264e-007
6	1.348111e-007	8.343449e-008	2.577996e+002	-2.202076e-008	3.331761e-006	-2.618774e-007
7	4.325373e-009	-2.835867e-008	2.562032e-008	-6.652683e-008	5.210050e-007	-6.510971e+003
8	3.831609e+002	-9.225923e-007	1.584359e-006	-3.324123e-006	2.225873e+003	-3.502667e-009
9	1.062908e-006	3.129798e+002	-3.696034e-007	1.186511e+003	5.968742e-006	-2.192136e-007
10	-7.987340e-007	1.027265e-007	6.186671e+002	5.282248e-007	-4.215904e-006	1.058335e-007
11	-4.844969e-007	-5.861658e-008	3.207541e+002	1.309371e-007	-2.370148e-006	2.205706e-007
12	-1.348760e-007	-1.202912e+002	-1.739610e-007	-5.023965e-002	-7.097414e-006	9.110742e-006
13	3.620752e-008	-5.334179e-007	4.331499e-008	-2.224516e-006	2.551605e-006	-2.109102e+003
14	-8.219135e+000	-1.186601e-007	5.200613e-008	-5.166729e-007	7.196868e+003	8.417567e-007
15	-5.622794e-009	-3.898411e-009	1.774115e-009	-1.558507e-008	5.496881e-008	-1.281529e+003
16	-6.462378e+001	9.906624e-008	-4.053837e-008	6.069568e-007	6.547120e+002	6.040514e-007
17	-8.126314e-008	-4.295578e+001	-5.191696e-009	-2.583368e+002	8.038117e-007	3.793298e-007
18	-4.616023e-010	8.184668e-008	-1.502346e+002	2.518421e-007	3.570228e-007	2.924640e-007
19	1.506664e-008	6.466436e-008	4.677027e+002	1.919368e-007	2.245547e-008	3.888571e-007
20	8.483682e-008	9.408489e-009	-4.358896e-008	3.477454e-008	-9.055330e-007	2.591640e+003

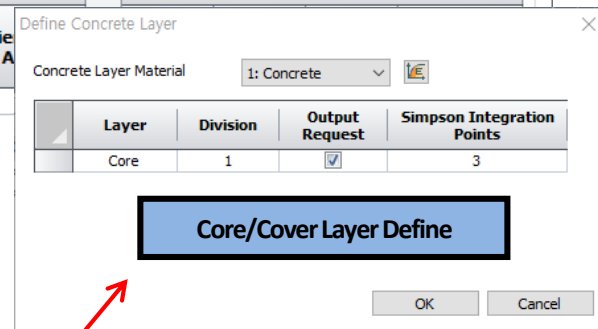
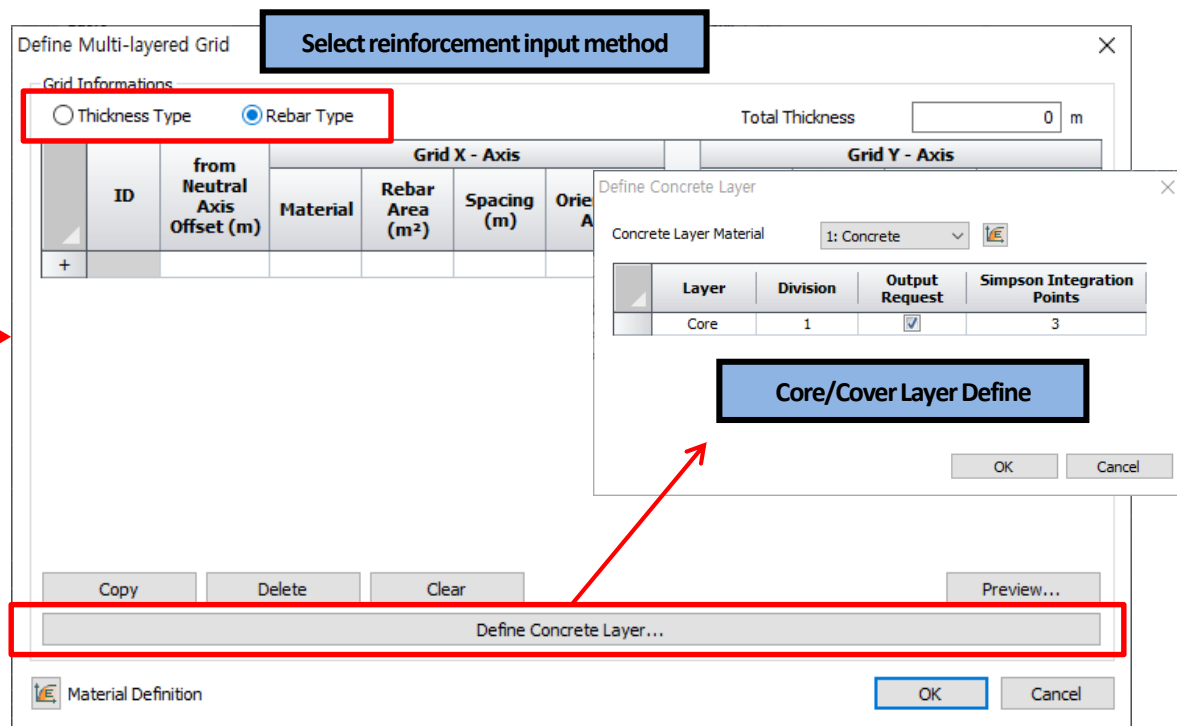
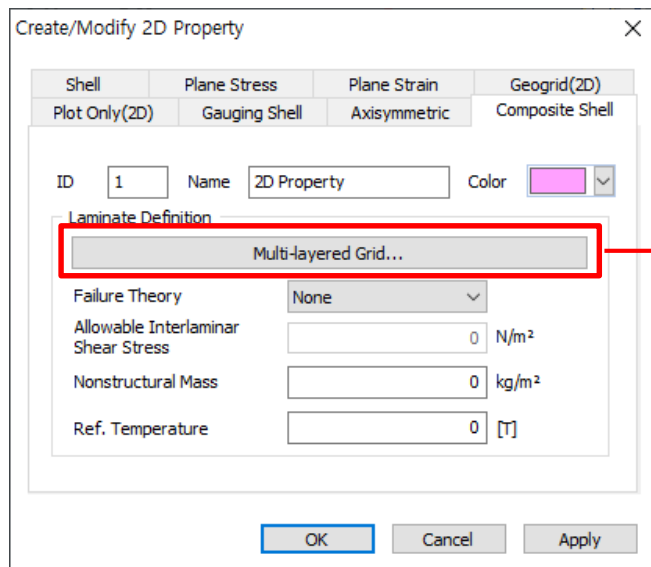
Modal Participation Factor Table



## 6. Improvement of Multi-Layered Grid (Composite Shell)

- Composite Shell Property for Multi-Layered Grid is added.
- In the existing Multi-Layered Grid, only the results for the reinforcing bar layer could be checked, but the improved Multi-Layered Grid defines the Core Layer and the Cover Layer, so that the results for this layer can be additionally checked.
- Reinforcement input method (Thickness Type, Rebar Type) is added.

▪ **Mesh > Prop./CSys./Func. > Property > Composite Shell**



Define Multi-layered Grid

## 7. Improvement of Bond Slip Interface

- For the bond slip interface, we define stiffness for normal and shear direction. The normal and shear direction represents the linear and nonlinear behavior of bond slip, respectively. Now, the behavior of the tangential direction of the interface can be defined by the user between linear and nonlinear behavior.

### Mesh > Material > Interface and Pile > Interface

Material

ID 1 Name Interface Color

Model Type Interface

General Seepage Thermal

Interface Nonlinearities Bond Slip

Structural Parameters

Normal Stiffness Modulus(Kn) 260000 N/mm<sup>2</sup>

Shear Stiffness Modulus(Ks) 26000 N/mm<sup>2</sup>

Polynomial Function

Constant (a) 0

Constant (b) 0

Constant (c) 0

Constant (d) 0

Shear Slip 0 mm

Shear Traction 0 N/mm<sup>2</sup>

Multilinear Hardening

Multilinear Hardening Function

**Coupling Tangential Stiffness Modulus(Kt)**

Normal Stiffness Modulus(Kn)

Shear Stiffness Modulus(Ks)

OK Cancel Apply

#### Coupling Tangential Stiffness Modulus(Kt)

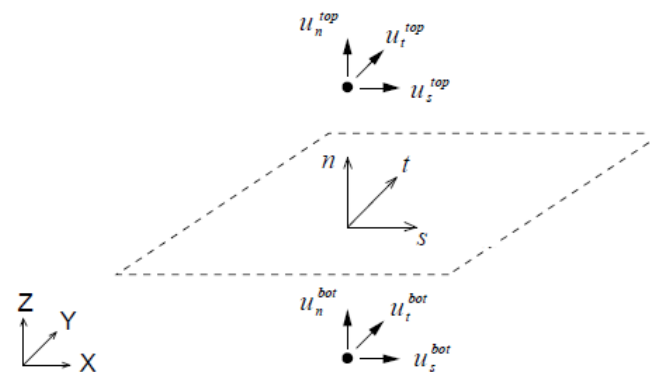
- Normal Stiffness Modulus(Kn)
- Shear Stiffness Modulus(Ks)

- Normal Stiffness Modulus(Kn)**

: Linear behavior in tangential direction

- Shear Stiffness Modulus(Ks)**

: Nonlinear behavior in tangential direction



## 8. Modified Menegotto-Pinto Material Model for Steel

- This is a model proposed by Menegotto & Pinto and modified by Filipoor et al.
- The model is widely used to simulate the dynamic response of steel structures and steel bars of reinforced concrete structures.

### ▪ Mesh > Material > Isotropic > Menegotto-Pinto

Material ×

ID  Name  Color   

Model Type Menegotto-Pinto Model  Structure

General Thermal Temperature Dependent

Elastic Modulus(E)  N/m<sup>2</sup> ...

Inc. of Elastic Modulus  N/m<sup>3</sup>

Inc. of Elastic Modulus Ref. Height  m

Poisson's Ratio( $\nu$ )

Unit Weight( $\gamma$ )  N/m<sup>3</sup>

Basic Properties  Direct Input  Using Code   

Initial Stress Parameters

Ko Determination

Automatic  Manual  Anisotropy   

Thermal Parameter

Thermal Coefficient  1/[T]

Molecular vapor diffusion coefficient  m<sup>2</sup>/sec

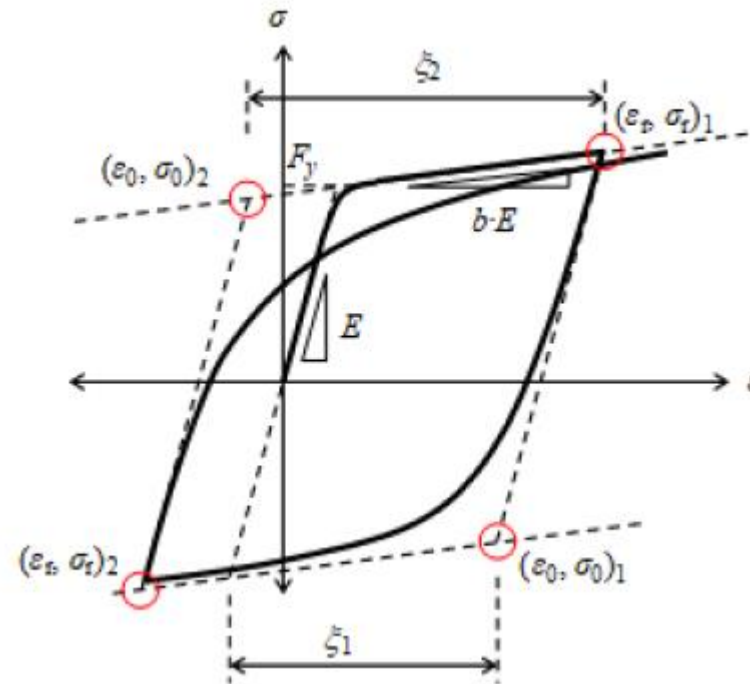
Thermal diffusion enhancement

Damping Ratio(For Dynamic)

Damping Ratio

Skeleton Curve

$f_y$	<input type="text" value="0"/> N/m <sup>2</sup>	$R_o$	<input type="text" value="20"/>
E	<input type="text" value="0"/> N/m <sup>2</sup>	a1	<input type="text" value="18.5"/>
b	<input type="text" value="0"/>	a2	<input type="text" value="0.15"/>



Hysteresis Rule

Menegotto – Pinto Model

## 9. General Hyperbolic Equation GHE-S Model

- Experimental data can be converted into general hyperbolic equation to define nonlinear material properties.

### Mesh > Material > Isotropic > GHE-S

Material X

ID  Name  Color ■

Model Type   Structure

General Non-Linear Temperature Dependent

**Non-Linear**

Initial Shear Modulus  kgf/m<sup>2</sup>

Reference Strain

C1(0)

C1(∞)

C2(0)

C2(∞)

alpha

beta

Consider Shear Only

Damping Function

Hmax

beta1

Large Strain

Minimum Strain

Maximum Strain

Unloading Stiffness

Gmin/Gref

Unloading Reference Strain

Pressure Dependent

n1

n2

Evaluate Experiment Data X

GHE-S Parameter

Type

G/Gmax~γ

Error Norm for Fit

Reference Strain

Damping Function

h~γ

Error Norm for Fit

Tolerance

— Curve Fitting • Test Data

— Curve Fitting • Test Data

C1(0)	<input type="text" value="1"/>
C1(∞)	<input type="text" value="0.705712358"/>
alpha	<input type="text" value="0.276218432"/>

C2(0)	<input type="text" value="0.320862631"/>
C2(∞)	<input type="text" value="1"/>
beta	<input type="text" value="16.5176246"/>

Hmax	<input type="text" value="0.0700739374"/>
beta1	<input type="text" value="-2.16652389"/>

Automatic Calculation

GHE-S Model

Generate GHE-S Material.

## 10. 3D Hill Plastic Model

- Orthotropic 3D Hill Plastic Model is added.
- It is possible to define nonlinear material properties of orthotropic, and it is easy to define materials for wood.

### ▪ *Mesh > Material > Orthotropic > 3D Hill Plastic*

Material

ID: 1 Name: Orthotropic Color:

Model Type: 3D Hill Plastic  Structure

Parameter 1 | Parameter 2 | Thermal | Porous

Elastic Modulus(E1)	2e+009	N/m <sup>2</sup>
Elastic Modulus(E2)	1e+009	N/m <sup>2</sup>
Elastic Modulus(E3)	1e+009	N/m <sup>2</sup>
Poisson's Ratio(v12)	0.4	
Poisson's Ratio(v23)	0.2	
Poisson's Ratio(v31)	0.4	
Shear Modulus(G12)	800000000	N/m <sup>2</sup>
Shear Modulus(G23)	400000000	N/m <sup>2</sup>
Shear Modulus(G31)	400000000	N/m <sup>2</sup>
Max Abs Stress xx	0	N/m <sup>2</sup>
Max Abs Stress yy	0	N/m <sup>2</sup>
Max Abs Stress zz	0	N/m <sup>2</sup>
Max Abs Stress xy	0	N/m <sup>2</sup>
Max Abs Stress yz	0	N/m <sup>2</sup>
Max Abs Stress zx	0	N/m <sup>2</sup>
Plastic Young's Modulus (Eup)	0	N/m <sup>2</sup>

OK Cancel Apply

3D Hill Plastic Model



## 11. Creep & Shrinkage Function and Expansive Additive for Concrete (JCI 2016/JSCE 2017)

- JCI 2016/ JSCE 2017 Japanese shrinkage standards have been added.
- An option to consider Expansive Additive for Concrete, and the user can also define the coefficient value for the Expansive Additive for Concrete.

▪ **Mesh > Prop./CSys./Func. > Creep/Shrinkage**

Creep/Shrinkage Function Group

Code: JAPAN(JSCE2012)

CEB-FIP(1990)  
 CEB-FIP(1978)  
 JAPAN(JSCE)  
 JAPAN(JSCE2007)  
 JAPAN(JSCE2012) **Selected**  
 JAPAN(JSCE2017)

Cement Content (260 kg/m<sup>3</sup> ~ 500 kg/m<sup>3</sup>): 3400 N/m<sup>3</sup>  
 Water Content (130 kg/m<sup>3</sup> ~ 230 kg/m<sup>3</sup>): 1500 N/m<sup>3</sup>  
 Cement Type: Normal portland cement  
 Maximum Temperature in Concrete (20 ~ 70): 50 [T]

ε<sub>ex,∞</sub>: 0.69    b<sub>ex</sub>: 1.11    t<sub>ex,0</sub>: 0.3

OK Cancel

Creep/Shrinkage Function Group

Code: JAPAN(JSCE2012)

JAPAN(JSCE2012)  
 Cement Content (260 kg/m<sup>3</sup> ~ 500 kg/m<sup>3</sup>): 3400 N/m<sup>3</sup>  
 Water Content (130 kg/m<sup>3</sup> ~ 230 kg/m<sup>3</sup>): 1500 N/m<sup>3</sup>  
 Cement Type: Normal portland cement  
 Maximum Temperature in Concrete (20 ~ 70): 50 [T]

Use Expansive Additive for Concrete  
 User define

ε<sub>ex,∞</sub>: 150    a<sub>ex</sub>: 0.69    b<sub>ex</sub>: 1.11    t<sub>ex,0</sub>: 0.3

OK Cancel

Expansive Additive for Concrete Option