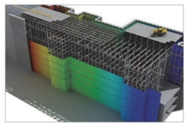
Release Note

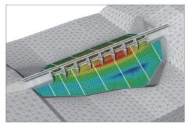
Release Date : June. 2014

Product Ver. : GTSNX 2014 (v2.1)

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

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Creep / Shrinkage Function Group

Integrated Solver Optimized for the next generation 64-bit platform

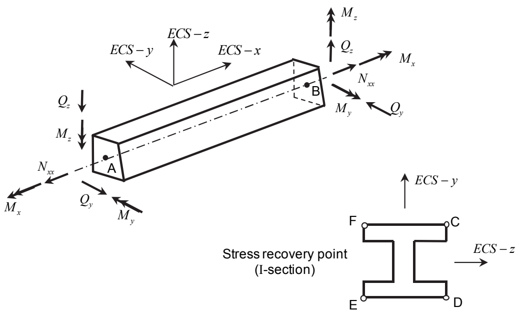
Finite Element Solutions for Geotechnical Engineering

MIDAS

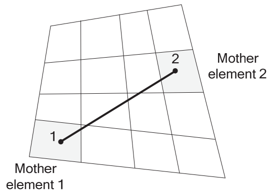
1. Pre Processing

1.1 Embedded Beam Element

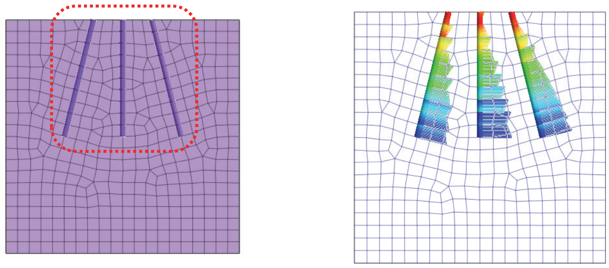
- Beam element must have a node connection with the surrounded element, otherwise embedded beam element can make a node connection with Mother element automatically.
- Beam and Embedded beam element have the same DOF(degree of freedom), so can be used for the same purpose, but even a node of Embedded element cannot protrude from Mother element.
- Embedded Beam Element are available in both 2D and 3D.
- In case of embedded structures like pile foundation or pipeline umbrella for tunnel, embedded beam element can be used to model those conveniently.



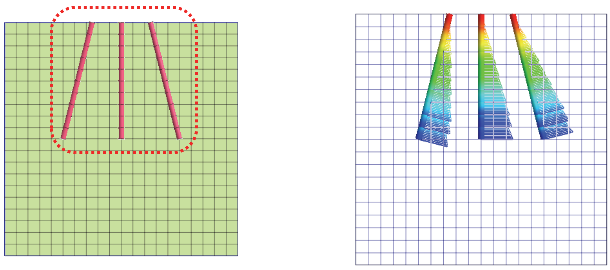
[Element Csys, DOF, and Output for Beam Element]



[Schematic view of Embedded Element]



[Beam Element with Nodal Connectivity]



[Embedded Beam Element without Nodal connectivity]

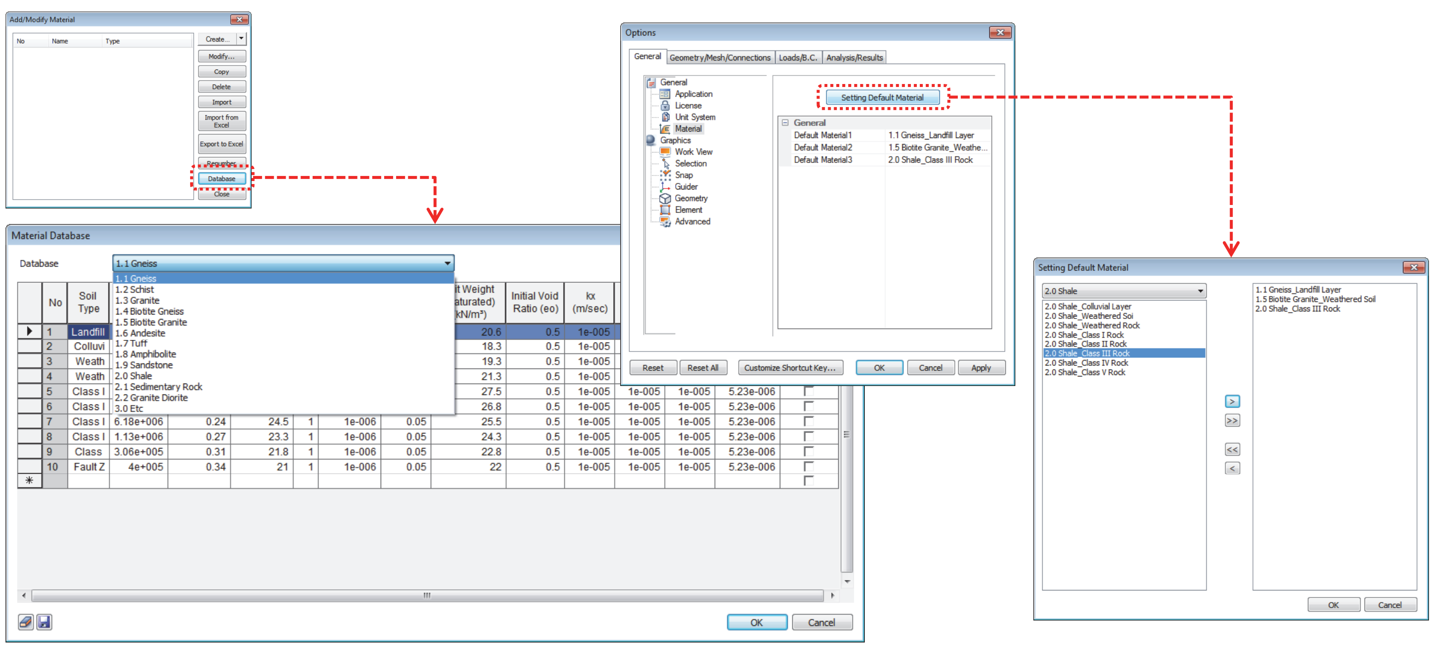
1. Pre Processing

1.2 Geological Parameters DB (Database)

- Provide database for general parameters of soil (***Mesh > Prop./Csys./Func. > Material > Database***)
- The user can customize database (***C:\Program Files\MIDAS\GTS NX\Dbase***)

(Users can add or change *.gdb files. Notepad (text editor) can be used to open this kind of file)

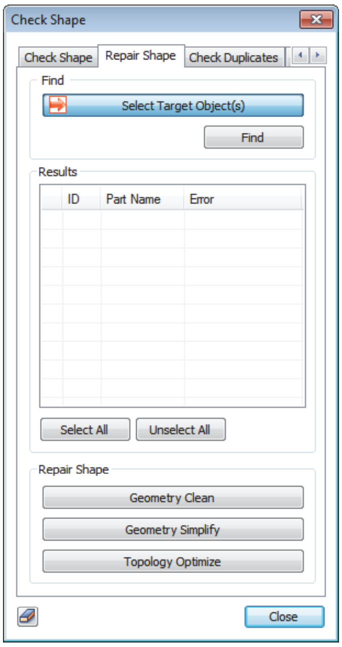
- The user can set default material for frequently used parameters. (***Tools > Options > General > Material***)



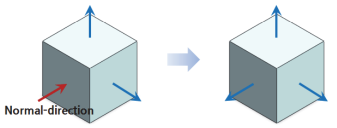
1. Pre Processing

1.3 Repair Shape (Automatic)

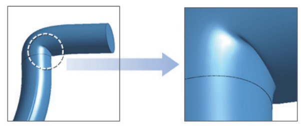
- ***Geometry > Tools > Check Shape > Repair Shape***
- Find and modify geometric errors automatically for atypical and inaccurate shape
- Recommend to perform "Geometry Clean → Geometry Simplify → Topology Optimize" continuously
- The user can perform this function when have failed to create mesh for selected geometry



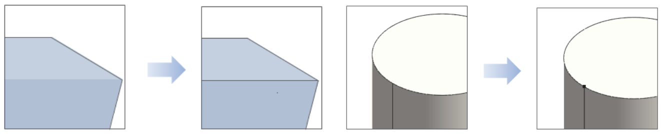
▪***Geometry Clean :*** modify invalid shape



[Abnormal topology]



[Tangled shape]



[Omission of Edge or vertex]

▪***Geometry Simplify :*** modify irregular shape

- ✓ B-Spline surface → plane, cylinder, sphere, cone and torus
- ✓ B-Spline curve → line, circle and ellipse
- ✓ Irregular shape → normalized and primitive shape

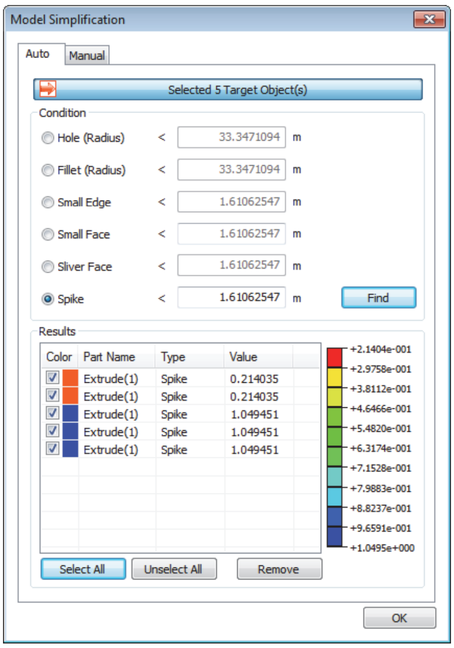
▪***Topology Optimize :*** performance improvement in creating mesh

- ✓ Simplify geometry and delete duplicated edge/surface automatically
- ✓ Delete unnecessary edge or vertex automatically

1. Pre Processing

1.4 Model Simplification (Auto)

- ***Geometry > Remove > Face / Edge***
- Find entities within the range of defined criteria and remove to simply geometry
- Recommend to remove small edge and face to create better quality of mesh
- The user can perform this function when have failed to create mesh with inputted size for selected geometry

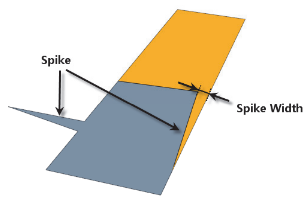


▪***Auto :*** find and remove selected entities automatically

- ✓ Hole (Radius) : Input radius of hole
- ✓ Fillet (Radius) : Input radius of fillet
- ✓ Small Edge : Input the length of edge
- ✓ Small face : Input the length for the longest edge of face
- ✓ Silver Face : Input the width of strip
- ✓ Spike : Input the width of spike

▪***Results:*** All entities which meet criteria are listed in the dialog.

- ✓ Selected entities will be highlighted in the model view
- ✓ Double click on the selected entity to fit zoom to window

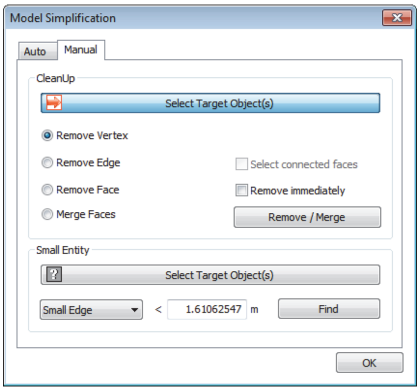


[Spike width]

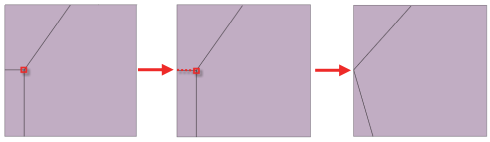
1. Pre Processing

1.4 Model Simplification (Manual)

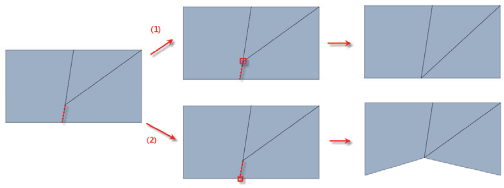
- ***Geometry > Remove > Remove Manual***
- Find and remove entities to simplify geometry
- Recommend to remove small edge and face to create better quality of mesh
- The user can perform this function when have failed to create mesh with inputted size for selected geometry



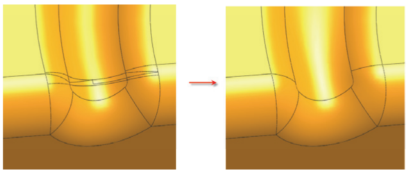
Remove Vertex : remove the shortest edge of ones which are connected to the selected vertex



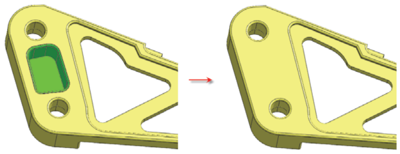
Remove Edge : remove selected edge and corresponding vertex at the same time



Merge Faces : merge faces with removing selected edge



Remove Face : remove selected face and merge

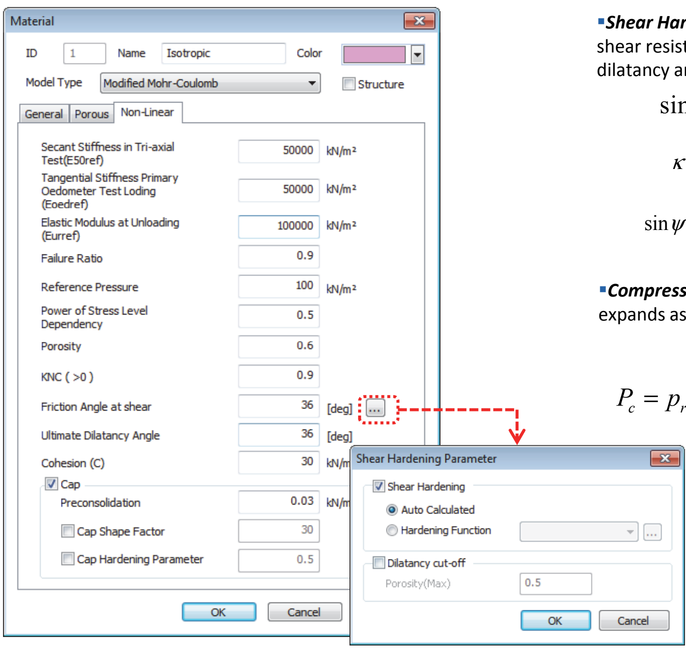


GTSNX 2014 Enhancement
GTSNX 2014 V2.1 Release Note

2. Analysis

2.1 Hardening Soil (MMC Hardening)

- Improvement in additional parameters to simulate **Shear and Compression hardening** simultaneously
- Three types of Elastic modulus can be defined
- Shear hardening parameter can be calculated automatically and Preconsolidation is used for compression hardening behavior
- Reasonable and applicable model especially for soils such as sand, silt and OC Clay.



Shear Hardening : can be defined by Equivalent plastic strain related to the mobilized shear resistance. When the soil is subject to shear hardening, solver recalculates dilatancy angle. Shear yield surface can expand up to the Mohr-Coulomb failure surface.

$$\sin\phi = \sin\phi(\kappa)$$

$$\kappa = \sqrt{\frac{2}{3}\gamma^p : \gamma^p}$$

$$\sin\psi = \frac{\sin\phi - \sin\phi_{cv}}{1 - \sin\phi \sin\phi_{cv}}$$

κ : Equivalent deviatoric plastic strain

γ_p : Deviatoric plastic strain

$\sin\phi_{cv}$: Critical state friction angle

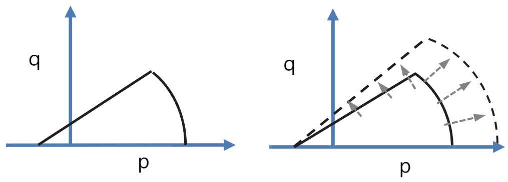
Compression Hardening : can be defined by pre-consolidation stress. Cap yield surface expands as a function of the pre-consolidation stress

$$P_c = p_{ref}\left(\left(\frac{P_{c0}}{p_{ref}}\right)^m + \frac{m}{\Gamma}\Delta\varepsilon_v^p\right)^{\frac{1}{m}}$$

P_c : Pre-consolidation stress

P_{c0} : Pre-overburden pressure (or OCR)

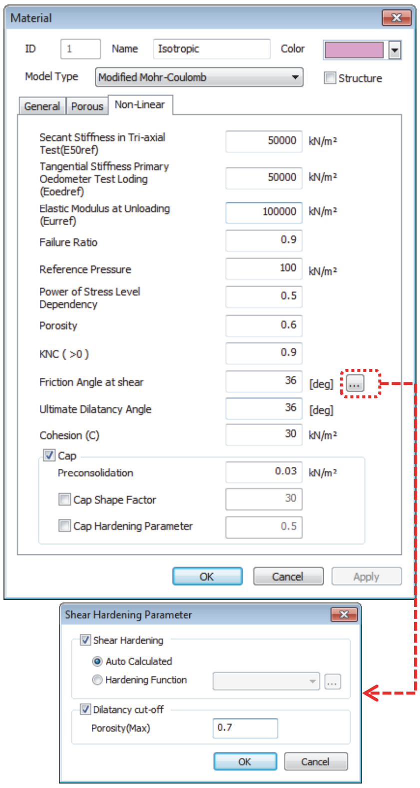
Γ : Cap hardening parameter



[Yield surface expansion, Hardening behavior]

2. Analysis

2.1 Hardening Soil (Review of model parameters)



Parameter	Description	Reference value (kN, m)
Soil stiffness and failure		
E50ref	Secant stiffness in standard drained triaxial test	Ei x (2 – Rf) /2 (Ei = Initial stiffness)
Eoedref	Tangent stiffness for primary oedometer loading	E50ref
Eurref	Unload / reloading stiffness	3 x E50ref
m	Power for stress-level dependency of stiffness	0.5 ≤ m ≤ 1 (**0.5** for hard soil, 1 for soft soil)
c	Effective cohesion	Failure parameter as in MC model
ϕ	Effective friction angle	Failure parameter as in MC model
ψ	Ultimate dilatancy angle	0 ≤ ψ ≤ ϕ
Advanced parameters (Recommend to use Reference value)		
Rf	Failure Ratio (qf / qa)	0.9 (< 1)
Pref	Reference pressure	100
KNC	Ko for normal consolidation	1-sinϕ (< 1)
Dilatancy cut-off		
Porosity	Initial void ratio	-
Porosity(Max)	Maximum void ratio	Porosity < Porosity(Max)
Cap yield surface		
Pc	Pre-overburden pressure (or from OCR)	-
α	Cap Shape Factor (scale factor of preconsolidation stress)	from KNC (Auto)
β	Cap Hardening Parameter	from Eoedref (Auto)

2. Analysis

2.1 Hardening Soil (Example : Validation of Hardening behavior)

Parameter	Input value (kN, m)
E	50,000
c	30
ϕ	36
ψ	5

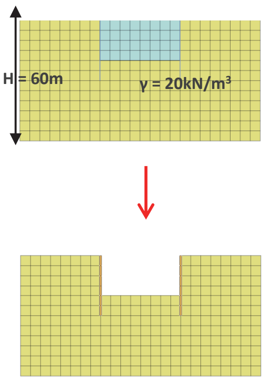
[MC model]

Parameter	Input value (kN, m)
E50ref	25,000
Eoedref	25,000
Eurref	75,000
m	0.5
c	30
ϕ	36
ψ	5
Rf	0.9
Pref	100
KNC	0.5

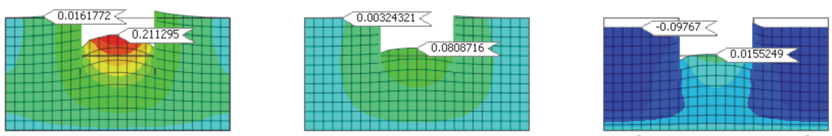
[MMC model]

Parameter	Input value (kN, m)
Auto (Shear Hardening)	
Pc	600 (OCR = 1)
α	Auto (uncheck)
β	Auto (uncheck)

[MMC with Hardening]

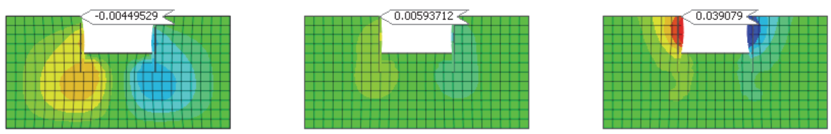


[1st Excavation]



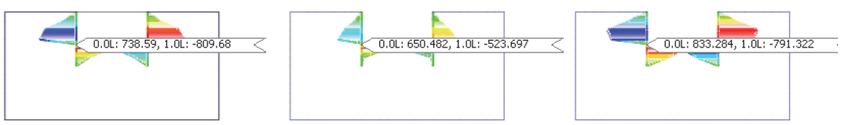
[MC model] [MMC model] [MMC with Hardening]

[Vertical Displacement]



[MC model] [MMC model] [MMC with Hardening]

[Horizontal Displacement]



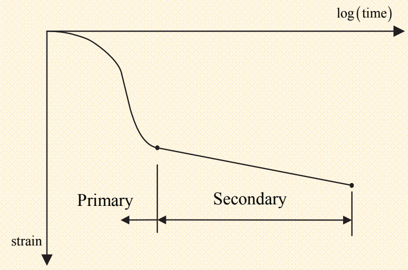
[MC model] [MMC model] [MMC with Hardening]

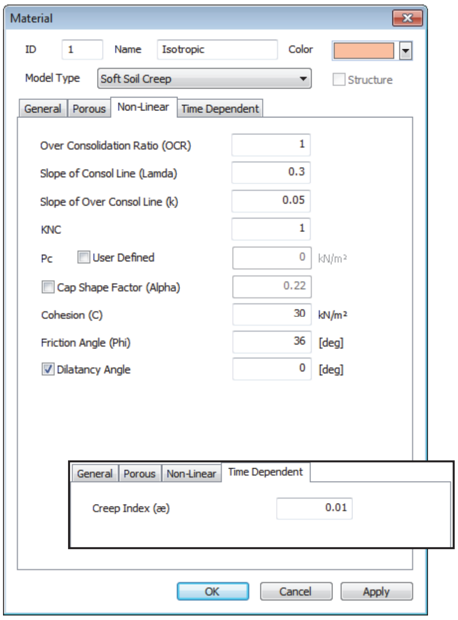
[Bending Moment of wall]

2. Analysis

2.2 Soft Soil Creep (Secondary Consolidation)

- Based on the 1D – creep theory, an extension was made to a 3D- model.
- Stress-dependent stiffness (Parameters can be estimated from Compression and Recompression index (Cc,Cs))
- Consider Secondary (time-dependent) consolidation and pre-consolidation stress
- Failure parameters as in Mohr-Coulomb model
- In case that time-dependent behavior is critical, this model is applicable to estimate the creep from FE analysis.





Parameter	Description	Reference value (kN, m)
Soil stiffness and failure		
λ	Swelling index	Cc / 2.303 / (1 + e)
κ	Compression index	Cs / 2.303 / (1 + e) (Cc / 5 for a rough estimation)
μ	Creep index	Cc / 20 for a rough estimation
c	Cohesion	Failure parameter as in MC model
ϕ	Friction angle	Failure parameter as in MC model
ψ	Dilatancy angle	0
Advanced parameters (Recommend to use Reference value)		
KNC	Ko for normal consolidation	1-sinϕ (< 1)
Cap yield surface		
OCR / Pc	Over Consolidation Ratio / Pre-overburden pressure	When entering both parameters, Pc has the priority of usage
α	Cap Shape Factor (scale factor of preconsolidation stress)	from KNC (Auto)

2. Analysis

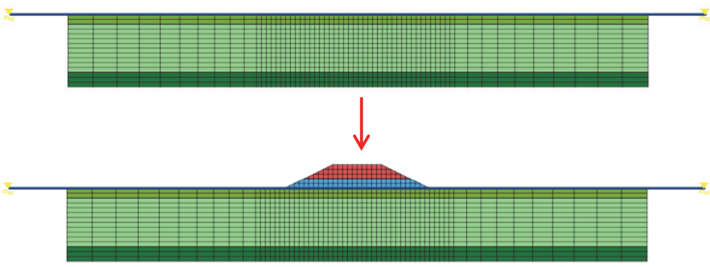
2.2 Soft Soil Creep (Example : Validation of Creep behavior)

Parameter	Reference value (kN, m)
λ	0.313
κ	0.063
M	1.113
OCR	2.05
α	Auto

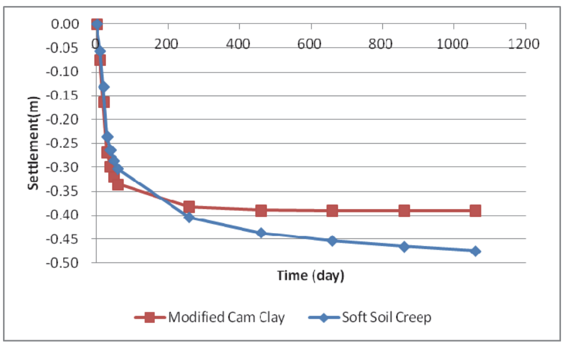
[MCC model]

Parameter	Reference value (kN, m)
λ	0.313
κ	0.063
μ	0.01
c	10
ϕ	28
ψ	0
KNC	0.5
OCR	2.05
α	Auto (uncheck)

[Soft Soil Creep model]



[Embankment with Time]

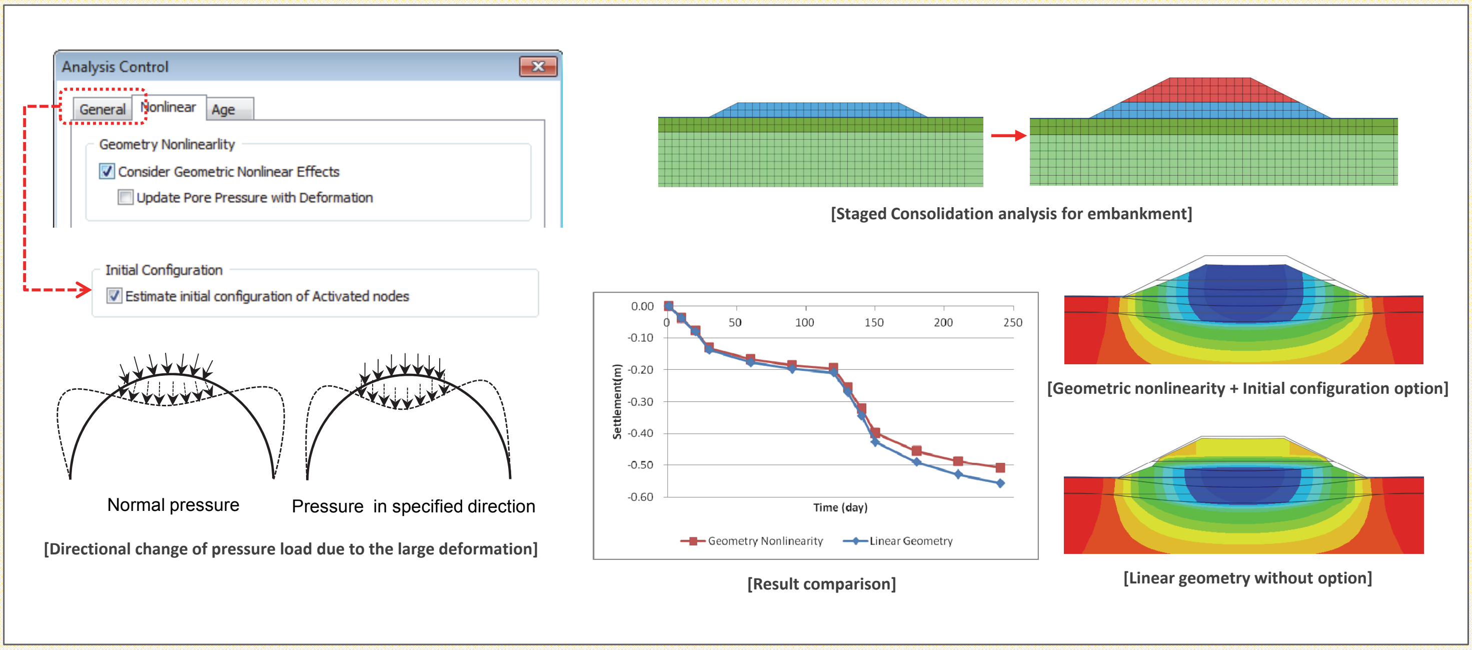


[Result comparison : Secondary consolidation]

2. Analysis

2.3 Geometric Nonlinear Effects (Estimate Initial configuration)

- ***Analysis > Analysis Case > General > Analysis Control***
- Consider geometric nonlinear effects in stress, fully coupled and slope stability analysis.
- Analysis can take into account load nonlinearity. Reflecting the effects of follower loads, where the load direction changes with the deformation.
- In case of large deformation analysis, the user can check more reasonable behavior.
- In case of embankment, "Initial Configuration" option in General tab is applicable to check more realistic behavior.



[Directional change of pressure load due to the large deformation]

[Staged Consolidation analysis for embankment]

[Result comparison]

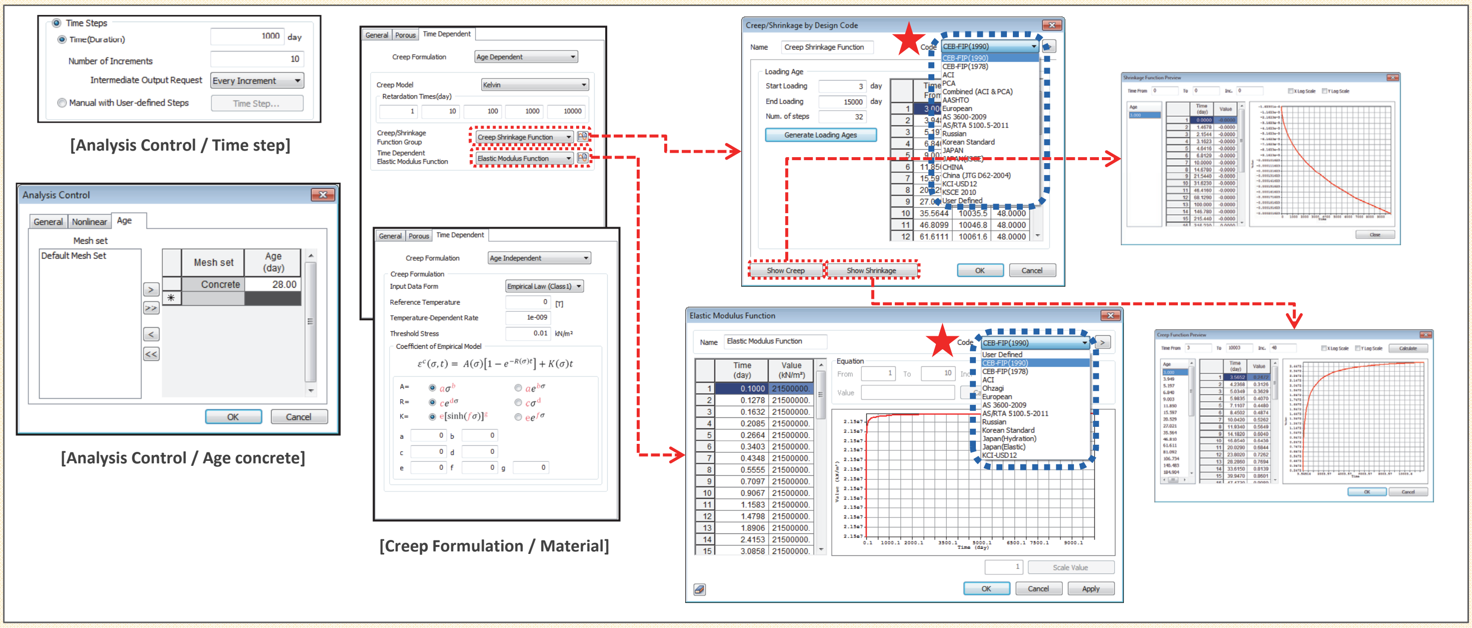
[Geometric nonlinearity + Initial configuration option]

[Linear geometry without option]

2. Analysis

2.4 Concrete Creep & Shrinkage (Time-dependent behavior) → *Refer to Appendix in detail...*

- ***Analysis > Analysis Case > General > Analysis Control*** → The user can define Time Steps to check the results with time elapse (Available in ***Nonlinear and Construction stage*** (Stress) analysis)
- ***Mesh > Prop./ Csys./ Func. > Material > Isotropic*** → The user can define Creep Formulation to simulate time-dependent behavior of concrete structures (Following constitutive models are available for concrete structures, ***Elastic, Tresca, von Mises, MC, Drucker Prager, and Hoek brown***)
- ***Mesh >Prop./ Csys./ Func. > Function > Creep / Shrinkage Function*** → The user can define Creep/Shrinkage Function based on the embedded **design codes(17ea)**
- ***Mesh>Prop./ Csys./ Func. >Function > Elastic Modulus Function*** → The user can define time dependent Elastic Modulus Function based on embedded **design codes(12ea)**



[Analysis Control / Time step]

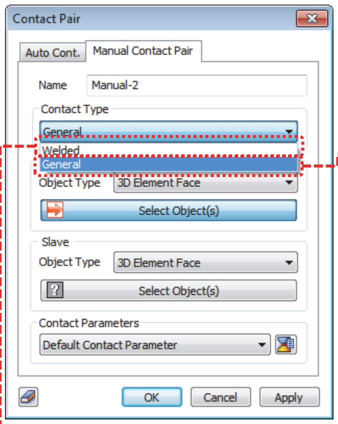
[Analysis Control / Age concrete]

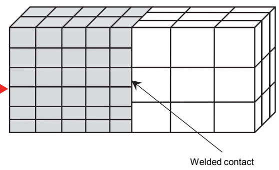
[Creep Formulation / Material]

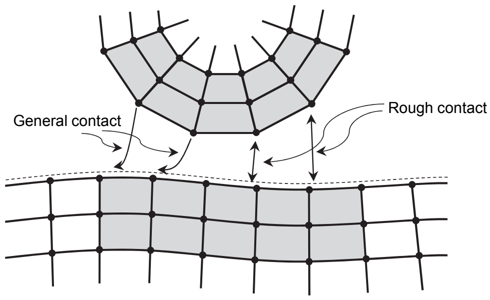
2. Analysis

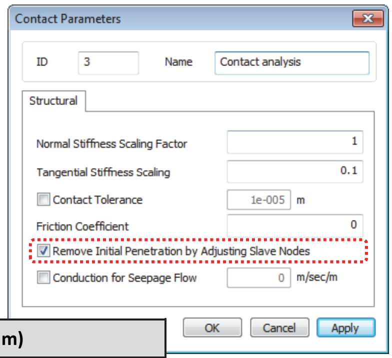
2.5 General Contact Element (Contact Analysis)

- ***Analysis Methods > Contact > Define Contact (Contact Type > General) → Only available in 3D model***
- **General contact** considers the impact and impact friction between two objects in analysis, otherwise two objects are bonded (like rigid link) each other by Welded contact
- General contact can be used in nonlinear (static, dynamic) and fully coupled analysis. With **Geometric Nonlinearity** option, solver will take into account all possible contact area automatically regardless of the distance (defined Contact tolerance) between two objects
- The user can consider Frictional behavior by Friction coefficient between two objects
- The penetration at initial stage can be ignored automatically







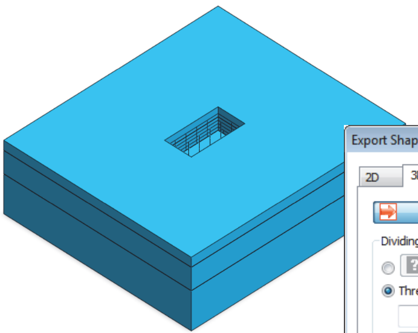


Parameter	Reference value (kN, m)
Contact stiffness (Recommend to use default setting)	
Normal stiffness scaling	1 (The smaller value, the larger penetration)
Tangential stiffness scaling	0.1 (Normal stiffness / 10)
Advanced options (parameters)	
Contact Tolerance	Auto (Uncheck)
Friction Coefficient (Optional)	0.3 ~ 0.6 (Depending on material types)
Conduction for Seepage Flow	Impermeable (Uncheck)

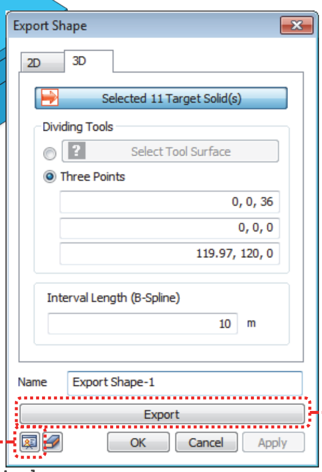
3. Post Processing

3.1 3D → 2D Section (Save & Export to SoilWorks)

- ***File > Export > SoilWorks Neutral Format File (.FPN)***
- The user can export any cross section of 3D model to SoilWorks
- The user can save more than two section profiles and check the shape in Model tree
- The user can use the exported shape as a geometry to generate 2D mesh in SoilWorks, in case of cross checking the results from 3D and 2D model

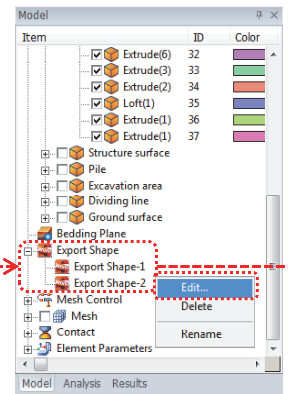


[3D model]

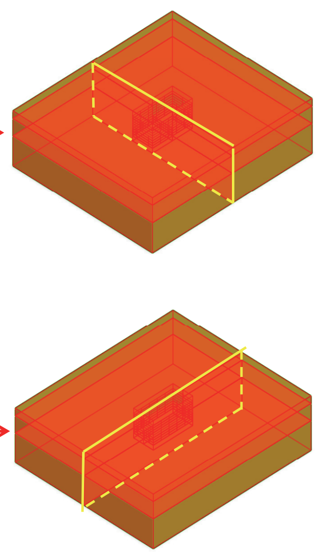


[Preview]

[Save / Export cross section]



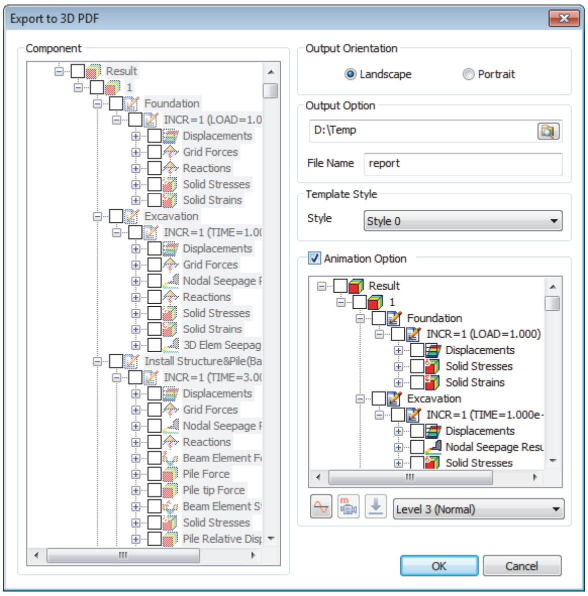
[Check cross section (Edit > Preview)]

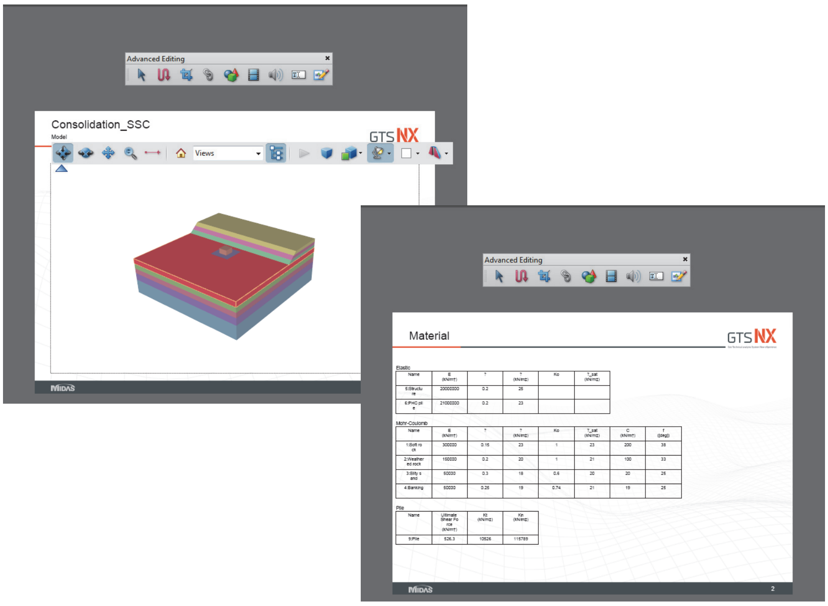


3. Post Processing

3.2 Improvement in 3D PDF Report (Material / Property table & Animation Option)

- ***Tools > Export 3D PDF > Export 3D PDF***
- The user can generate 3D PDF report automatically
- The report includes model information (material, geometry and mesh) and all types of results with animation like simulation of construction sequence
- Adobe reader is required to check the report



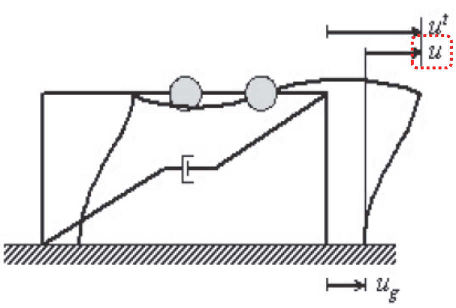


GTSNX 2014 Enhancement
GTSNX 2014 V2.1 Release Note

3. Post Processing

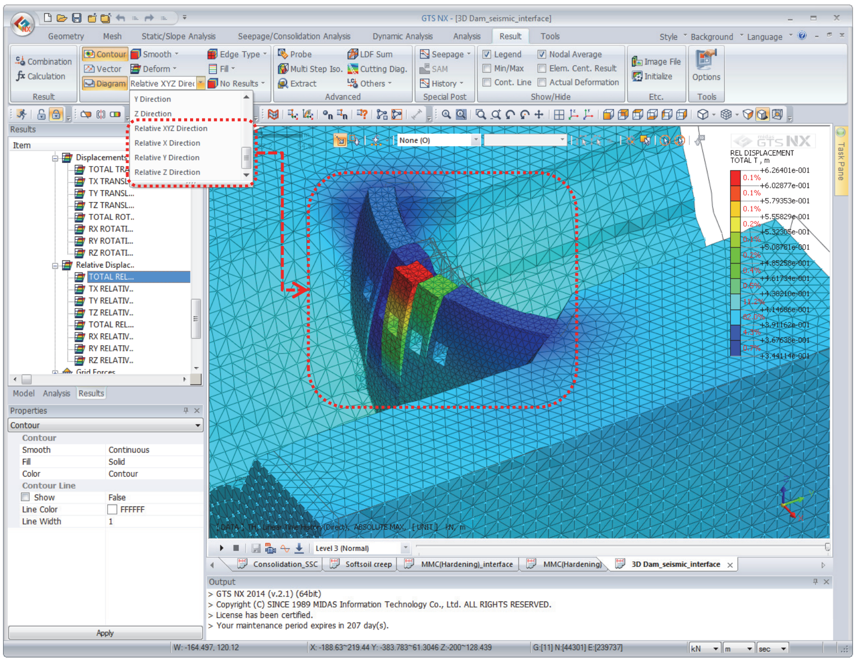
3.3 Relative deformed shape for Dynamic analysis results

- ***Result > General > Deformed shape (Direction)***
- In case of seismic analysis, the bottom of ground can be fixed by ground acceleration. The user could check only total(absolute) deformed shape in the previous version.
- The user can check the deformed shape based on the relative displacement



$$u^t(t) = u_g(t) + u(t)$$

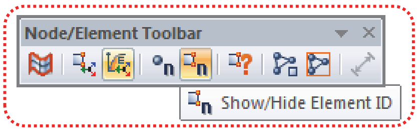
[Total displacement in Dynamic analysis]



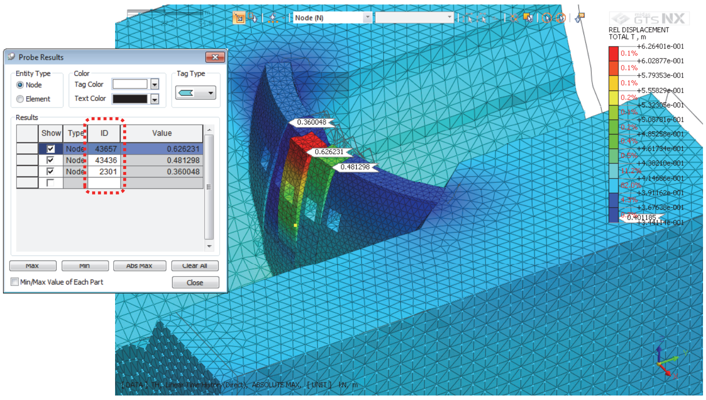
3. Post Processing

3.4 Improvement in Probe Result (3D PDF Report (Material / Property table & Animation Option)

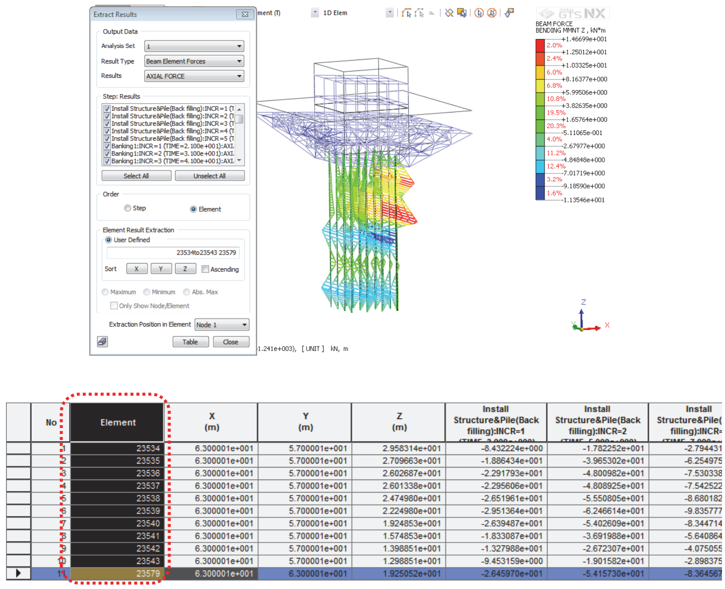
- ***Result > Advanced > Probe (Result Tag)***
- The user can check Node and Element ID in the table
- The user can check the result and its location in the model based on Node / Element ID



[Node / Element Toolbar]



[Probe Result]



[Extract Result]

Appendix

1. Time Steps / Creep Formulation
2. Creep / Shrinkage Function Group - **Design code**
3. Elastic Modulus Function - **Design code**

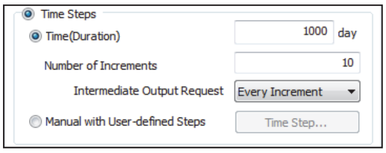
Integrated Solver Optimized for the next generation 64-bit platform

Finite Element Solutions for Geotechnical Engineering

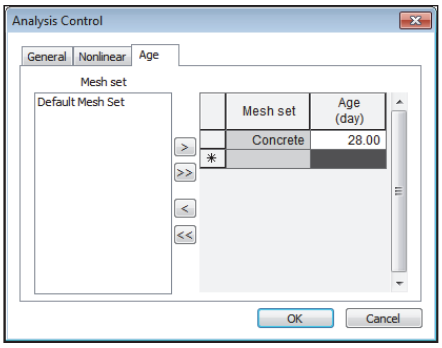
MIDAS

1. Time Steps / Creep Formulation

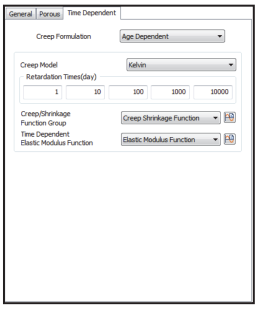
- The user can define Total elapsed time and the number of increments to output results for each time step. Uniform and non-uniform time steps can be defined
- In case of construction stage analysis, the user can take Age into account to consider creep/shrinkage effect generated in the previous stage. In general, the user can enter the curing period of concrete
- Two types of creep formulation are available to define Time-dependent behavior of material (**Age Dependent and Age Independent**)

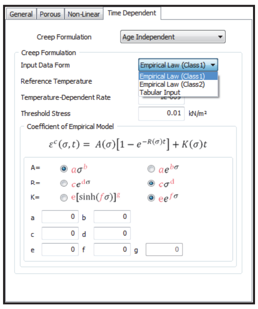


[Analysis Control / Time step]



[Analysis Control / Age concrete]



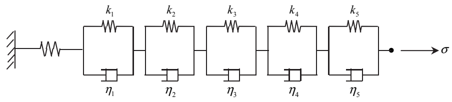


[Creep Formulation / Material]

[Age Dependent]

The stiffness of concrete changes with time, and the creep and shrinkage may cause unexpected deformation. And the creep strain of concrete depends on the time of stress occurrence even under the same applied load.

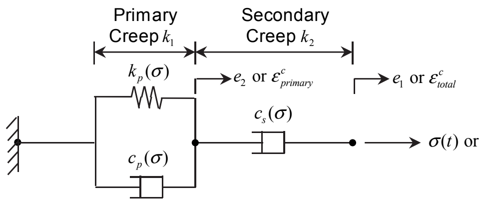
GTSNX supports aging-Kelvin model and aging-Viscous model excluding the spring from Kelvin model.



[Schematic view of aging-Kelvin creep model]

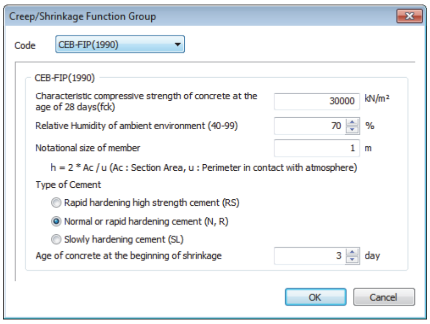
[Age Independent]

GTSNX can take into account the primary and secondary creep. The user can use two types of empirical law to define the creep behavior.



[Kelvin-Maxwell creep model]

2. Creep / Shrinkage Function – Design code



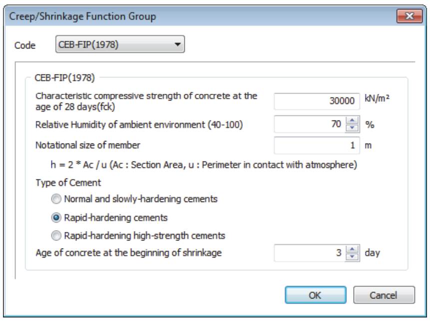
[CEB-FIP(1990)]

Notational size of member

-Conceptual (Equivalent) size of structure. Two times of equivalent area divided by perimeter of the member

Age of concrete at the beginning of shrinkage

-The number of days elapsed after pouring of concrete, when the shrinkage is assumed to start



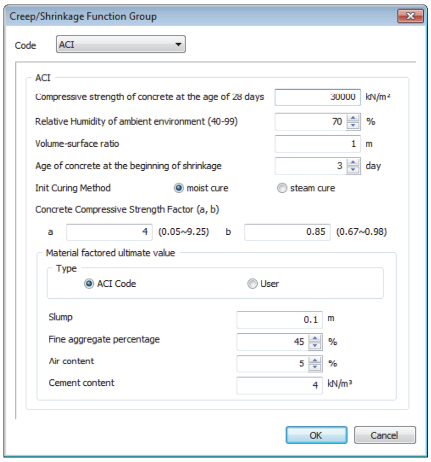
[CEB-FIP(1978)]

Notational size of member

-Conceptual (Equivalent) size of structure. Two times of equivalent area divided by perimeter of the member

Age of concrete at the beginning of shrinkage

-The number of days elapsed after pouring of concrete, when the shrinkage is assumed to start



[ACI]

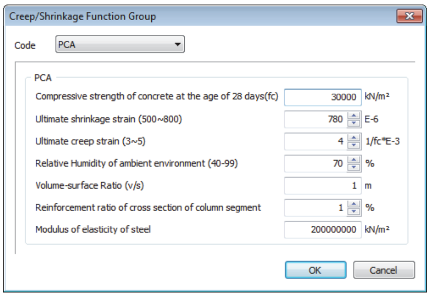
Age of concrete at the beginning of shrinkage

-The number of days elapsed after pouring of concrete, when the shrinkage is assumed to start

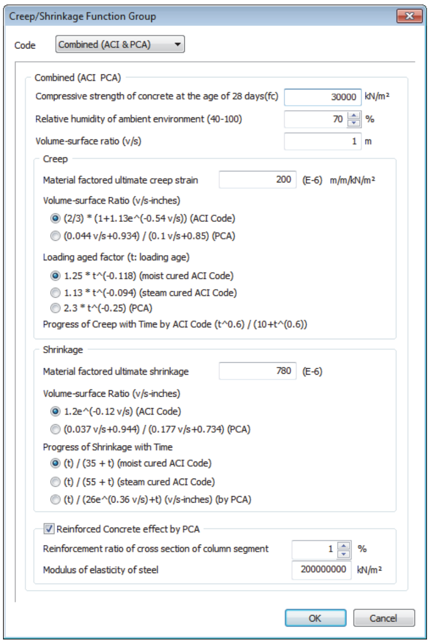
Material factored ultimate value

- The user may enter the ultimate values considering concrete properties by ACI code or User type.

2. Creep / Shrinkage Function – Design code



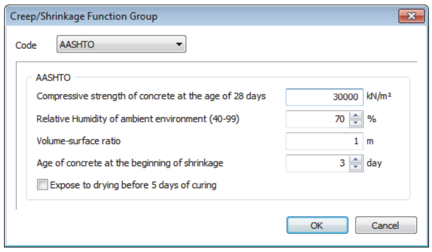
[PCA]



[Combined (ACI & PCA)]

Material factored ultimate creep strain / Shrinkage

- The user may enter the ultimate values considering concrete properties by User type.

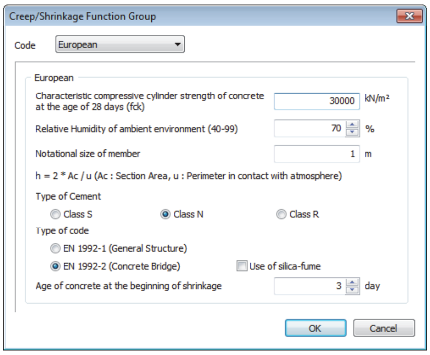


[AASHTO]

Expose to drying before 5 Days of curing

- If this option is checked on, the influence of Creep & Shrinkage is increased by 20% (ref. AASHTO 5.4.2.3)

2. Creep / Shrinkage Function – Design code



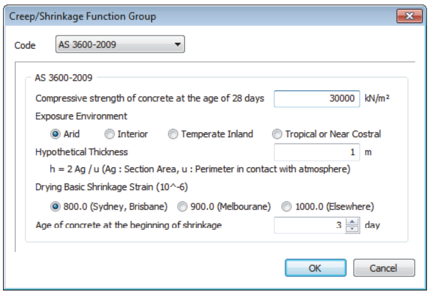
[European]

Notational size of member

-Conceptual (Equivalent) size of structure. Two times of equivalent area divided by perimeter of the member

Age of concrete at the beginning of shrinkage

-The number of days elapsed after pouring of concrete, when the shrinkage is assumed to start



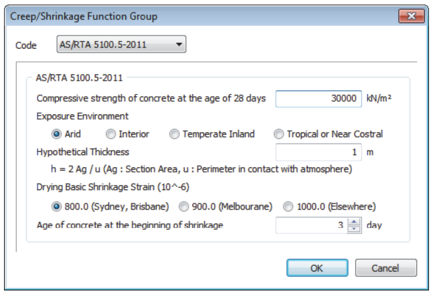
[AS 3600-2009]

Hypothetical Thickness

-Conceptual (Equivalent) size of structure. Two times of equivalent area divided by perimeter of the member

Age of concrete at the beginning of shrinkage

-The number of days elapsed after pouring of concrete, when the shrinkage is assumed to start



[AS/RTA 5100.5-2011]

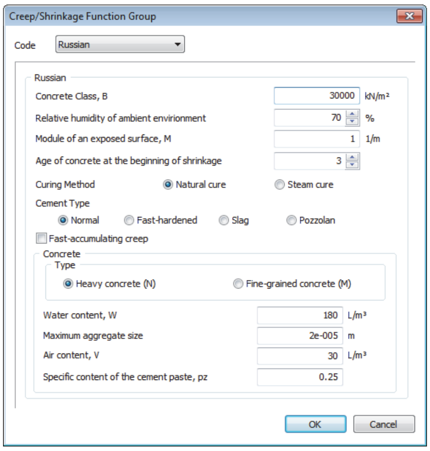
Hypothetical Thickness

-Conceptual (Equivalent) size of structure. Two times of equivalent area divided by perimeter of the member

Age of concrete at the beginning of shrinkage

-The number of days elapsed after pouring of concrete, when the shrinkage is assumed to start

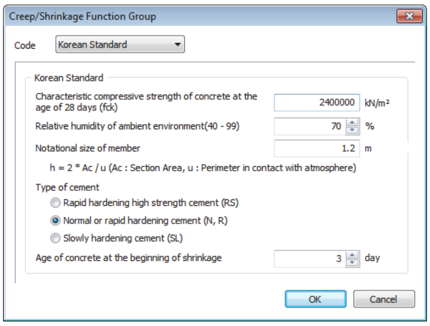
2. Creep / Shrinkage Function – Design code



[Russia]

<u>Age of concrete at the beginning of shrinkage</u>
-The number of days elapsed after pouring of concrete, when the shrinkage is assumed to start

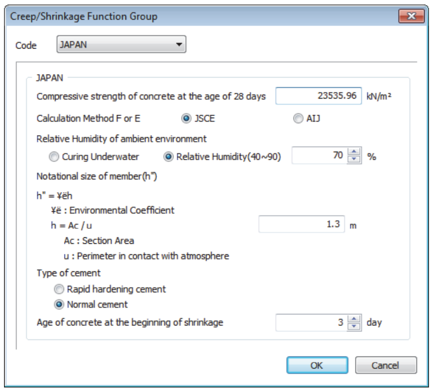
<u>Fast – accumulating creep</u>
- If this option is checked on, the influence of Creep & Shrinkage will be increased by % based on Russian code



[Korean Standard]

<u>Notational size of member</u>
-Conceptual (Equivalent) size of structure. Two times of equivalent area divided by perimeter of the member

<u>Age of concrete at the beginning of shrinkage</u>
-The number of days elapsed after pouring of concrete, when the shrinkage is assumed to start

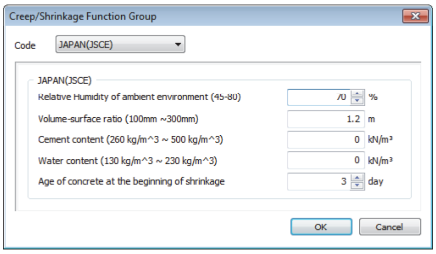


[Japan]

<u>Notational size of member</u>
-Conceptual (Equivalent) size of structure. Equivalent area divided by perimeter of the member considering Environmental Coefficient.

<u>Age of concrete at the beginning of shrinkage</u>
-The number of days elapsed after pouring of concrete, when the shrinkage is assumed to start

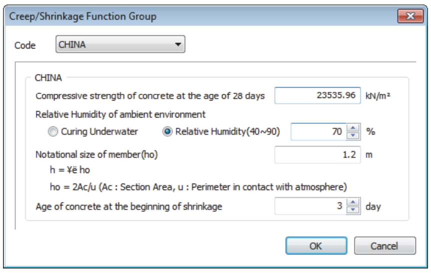
2. Creep / Shrinkage Function – Design code



[Japan (JSCE)]

<u>Cement content / Water content</u>
- Required to input each content per unit volume to generate Creep/Shrinkage Function automatically

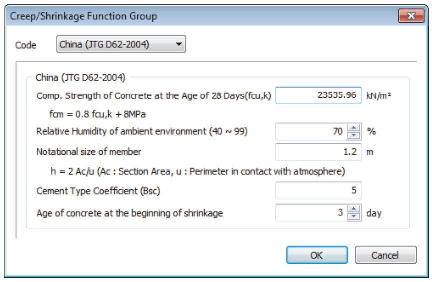
<u>Age of concrete at the beginning of shrinkage</u>
-The number of days elapsed after pouring of concrete, when the shrinkage is assumed to start



[CHINA]

<u>Notational size of member</u>
-Conceptual (Equivalent) size of structure. Two times of equivalent area divided by perimeter of the member considering Environmental coefficient

<u>Age of concrete at the beginning of shrinkage</u>
-The number of days elapsed after pouring of concrete, when the shrinkage is assumed to start

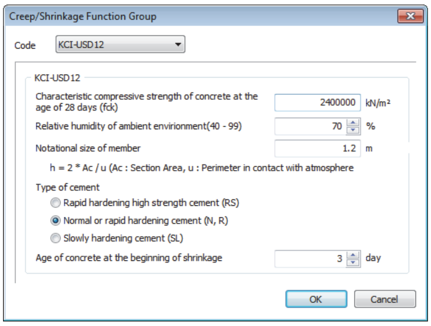


[China (JTG D62-2004)]

<u>Notational size of member</u>
-Conceptual (Equivalent) size of structure. Two times of equivalent area divided by perimeter of the member.

<u>Age of concrete at the beginning of shrinkage</u>
-The number of days elapsed after pouring of concrete, when the shrinkage is assumed to start

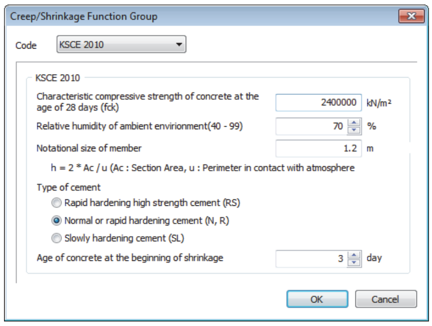
2. Creep / Shrinkage Function – Design code



[KCI-USD 12]

Notational size of member
-Conceptual (Equivalent) size of structure. Two times of equivalent area divided by perimeter of the member

Age of concrete at the beginning of shrinkage
-The number of days elapsed after pouring of concrete, when the shrinkage is assumed to start



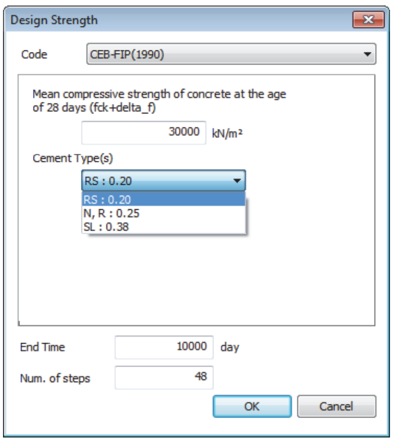
[KSCE 2010]

Notational size of member
-Conceptual (Equivalent) size of structure. Two times of equivalent area divided by perimeter of the member

Age of concrete at the beginning of shrinkage
-The number of days elapsed after pouring of concrete, when the shrinkage is assumed to start

3. Elastic Modulus Function – Design code

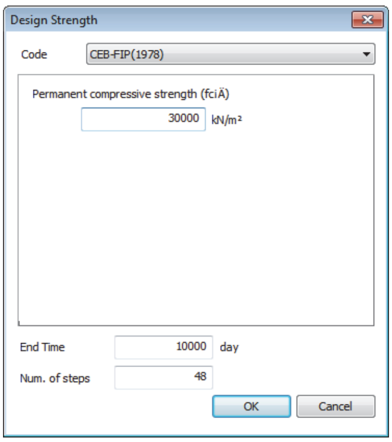
- The user can define Time-dependent Elastic modulus function based on selected design code]
- The user need to input End Time of function with the number of steps



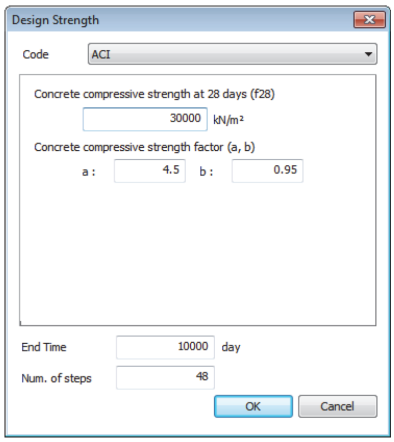
[CEB-FIP(1990)]

Specify the Concrete Compressive Strength at 28 Days and Cement Type

RS – Rapid hardening high strength cements
N,R – Normal or rapid hardening cements
SL – Slowly hardening cements



[CEB-FIP(1978)]



[ACI]

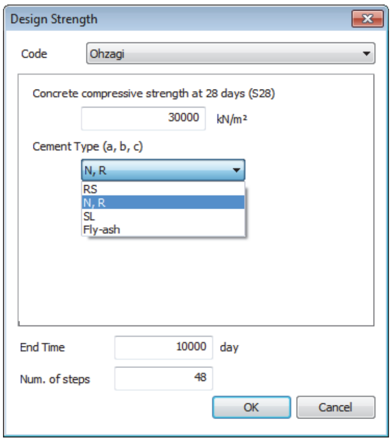
• Modulus of elasticity, which will be reflected in the analysis, is calculated using the compressive strength of concrete and weight density

$$E_c = w_c^{1.5} 0.043 \sqrt{f_c'} \text{ (in MPa)}$$

w_c : Density of concrete, kg/m3

f_c' : Compressive strength of concrete, MPa

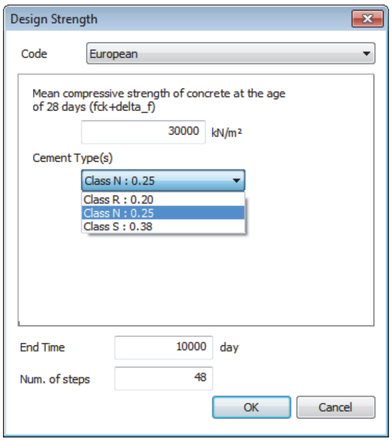
3. Elastic Modulus Function – Design code



[Ohzagi]

The equation proposed by Ohzagi is used to define the change of compressive strength of concrete. Specify the Concrete Compressive Strength at 28 Days and Cement Type

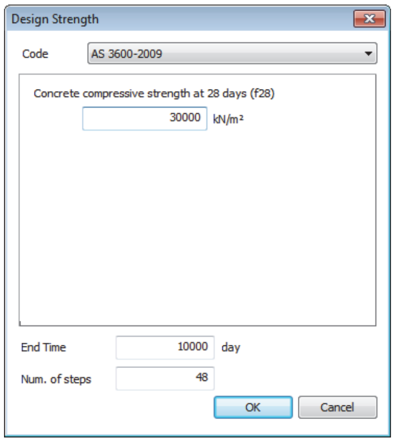
RS – Rapid hardening high strength cements
N,R – Normal or rapid hardening cements
SL – Slowly hardening cements
Fly ash – Fly ash cementing material



[European]

Specify the Concrete Compressive Strength at 28 Days and Cement Type

RS – Rapid hardening high strength cements
N,R – Normal or rapid hardening cements
SL – Slowly hardening cements



[AS 3600-2009]

• Mean modulus of elasticity of concrete at the appropriate age is calculated as follows.

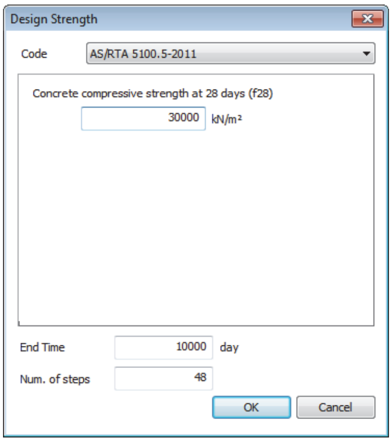
$f_{cmi} \le 40$ MPa, $E_{cj} = (\rho^{1.5}) \times (0.043\sqrt{f_{cmi}})$

$f_{cmi} > 40$ MPa, $E_{cj} = (\rho^{1.5}) \times (0.024\sqrt{f_{cmi}} + 0.12)$

• Since there is no equation for Compressive Strength at the appropriate age in Australian Standard, it is calculated based on the following equation specified in CEB-FIP 1978.

$$f(t) = \frac{1.451849874 \times t^{0.75} \times f_c'}{t^{0.75} + 5.5}$$

3. Elastic Modulus Function – Design code



[AS/RTA 5100.5-2011]

• Mean modulus of elasticity of concrete at the appropriate age is calculated as follows.

$f_{cmi} \le 40$ MPa, $E_{cj} = (\rho^{1.5}) \times (0.043\sqrt{f_{cmi}})$

$f_{cmi} > 40$ MPa, $E_{cj} = (\rho^{1.5}) \times (0.024\sqrt{f_{cmi}} + 0.12)$

• Since there is no equation for Compressive Strength at the appropriate age in Australian Standard, it is calculated based on the following equation specified in CEB-FIP 1978.

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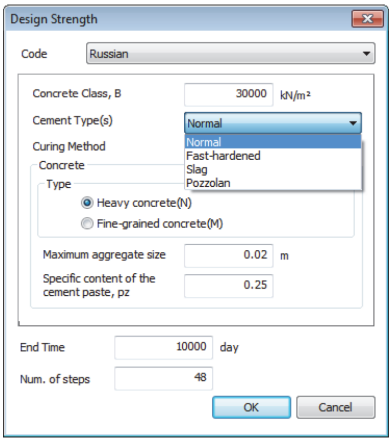
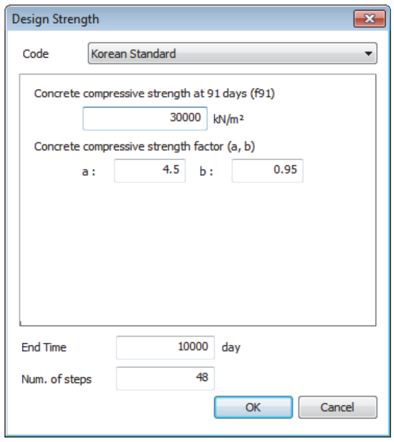


[Russian]

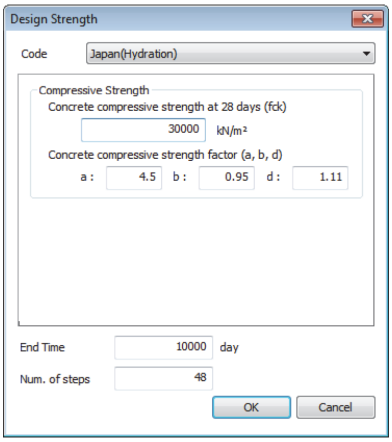


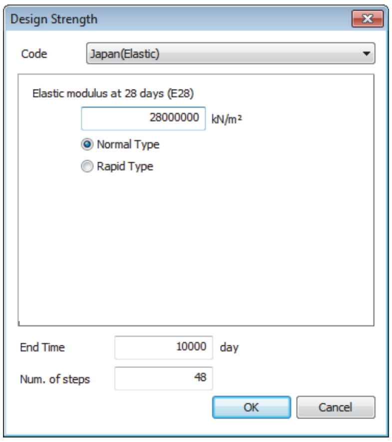
[Korean Standard]

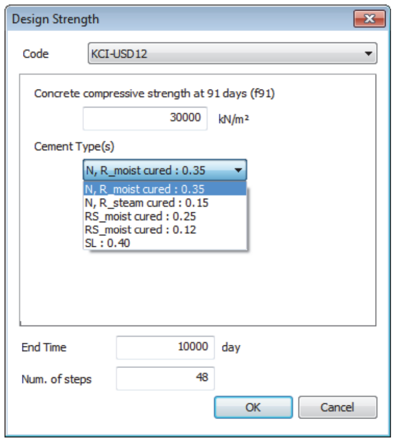
Specify the Concrete Compressive Strength at 91 Days and Strength Factor (a,b)

Cement Type	a	b
Rapid strength	2.9	0.97
Normal	4.5	0.95
Moderate heat	6.2	0.93

3. Elastic Modulus Function – Design code







[Japan (Hydration)]

Specify the Concrete Compressive Strength at 28 Days and Strength Factor (a,b,d)

Cement Type	a	b	d
Rapid strength	4.5	0.95	1.11
Normal	6.2	0.93	1.15
Moderate heat	2.9	0.97	1.07

[Japan (Elastic)]

[KCI-USD12]

Specify the Concrete Compressive Strength at 91 Days and Strength Factor (a,b)

N,R – Normal or rapid hardening cements
RS – Rapid hardening high strength cements
SL – Slowly hardening cements