# Release Note

Release Date : July 2018

Product Ver. : Civil 2019 (v1.1)

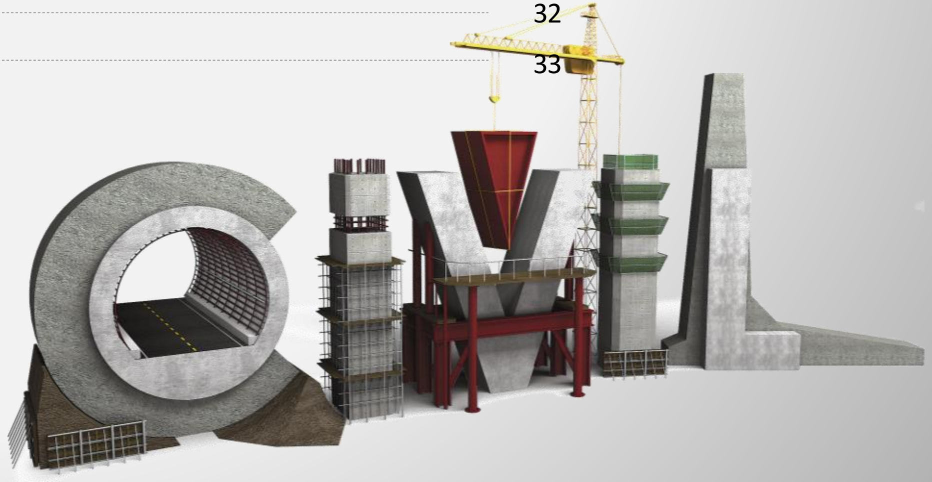
DESIGN OF CIVIL STRUCTURES

Integrated Solution System for Bridge and Civil Engineering

# Enhancements

## ▪ Analysis & Design

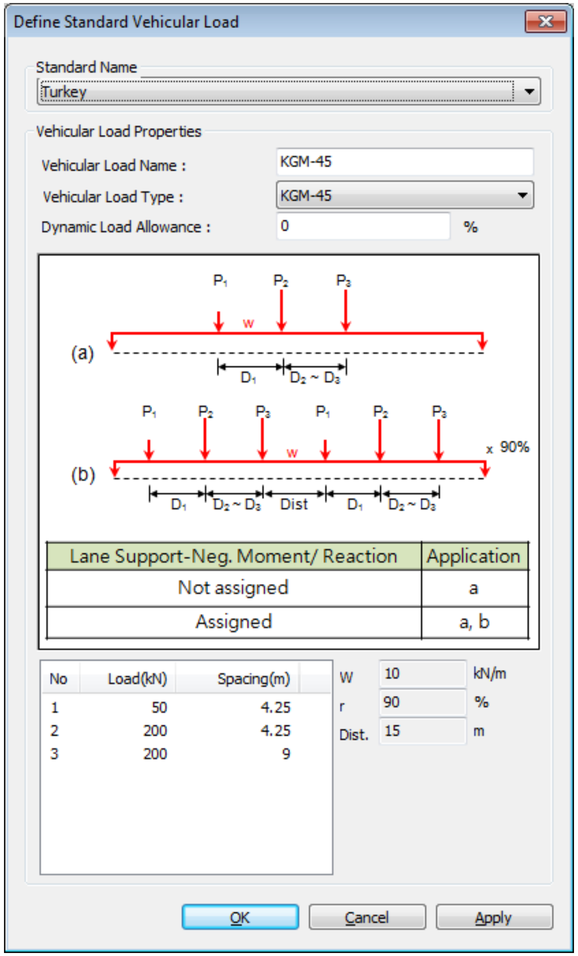
## ▪ Pre & Post-Processing



# 1. Traffic Load Models for Turkey

- Five Turkish live load models are implemented in midas Civil. KGM-45, H30-S24, H30-S24L, H20-S16, H20-S16L
- These vehicles can be found from the AASHTO LRFD / AASHTO Standard code.

- ***Load/Moving Load Analysis Data > Vehicles***



Define Standard Vehicular Load

Standard Name: Turkey

Vehicular Load Properties

Vehicular Load Name : KGM-45

Vehicular Load Type : KGM-45

Dynamic Load Allowance : 0 %

| Lane Support-Neg. Moment/ Reaction | Application |
|---|---|
| Not assigned | a |
| Assigned | a, b |

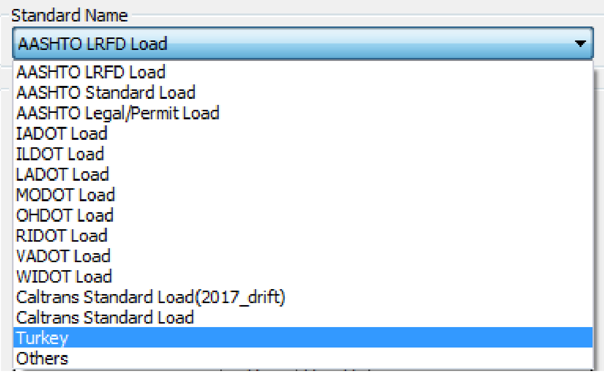
| No | Load(kN) | Spacing(m) |
|---|---|---|
| 1 | 50 | 4.25 |
| 2 | 200 | 4.25 |
| 3 | 200 | 9 |

W: 10 kN/m

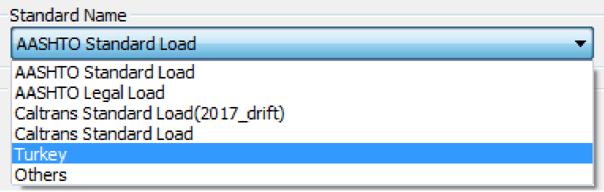
r: 90 %

Dist.: 15 m

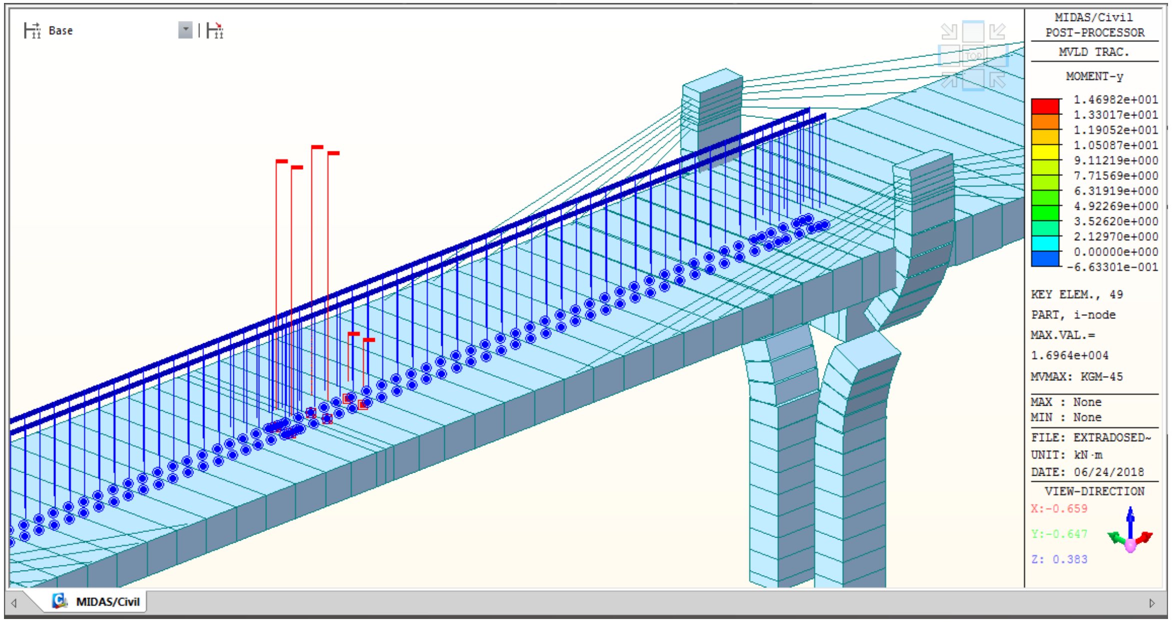
Standard Vehicular Load, KGM-45



Standard Name: AASHTO LRFD Load



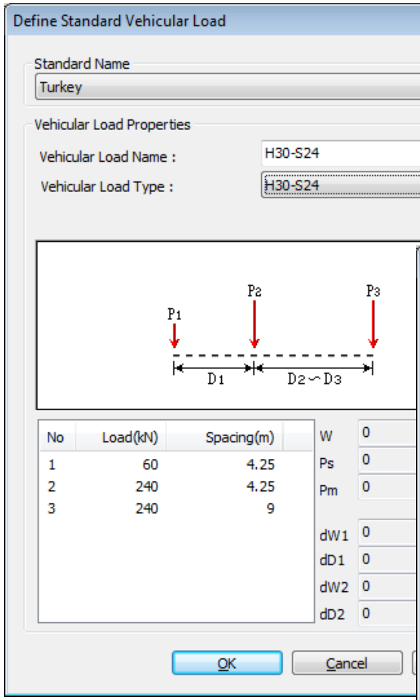
Standard Name: AASHTO Standard Load



Moving Load Tracer, KGM-45

# 1. Traffic Load Models for Turkey

- ***Load/Moving Load Analysis Data > Vehicles***



Standard Name: Turkey

Vehicular Load Properties

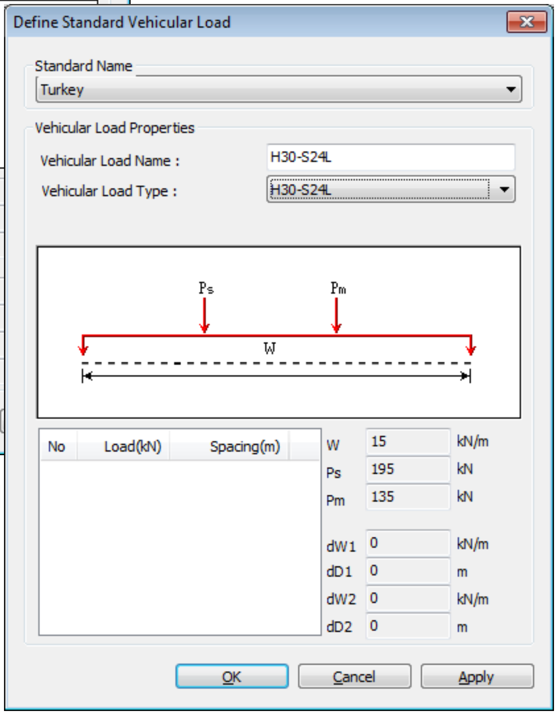
Vehicular Load Name : H30-S24

Vehicular Load Type : H30-S24

| No | Load(kN) | Spacing(m) |
|---|---|---|
| 1 | 60 | 4.25 |
| 2 | 240 | 4.25 |
| 3 | 240 | 9 |

W 0
Ps 0
Pm 0
dW1 0
dD1 0
dW2 0
dD2 0

Standard Vehicular Load, H30-S24



Standard Name: Turkey

Vehicular Load Properties

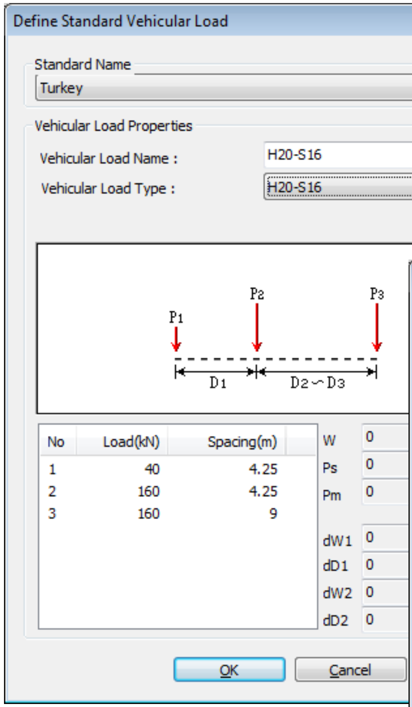
Vehicular Load Name : H30-S24L

Vehicular Load Type : H30-S24L

| No | Load(kN) | Spacing(m) |
|---|---|---|

W 15 kN/m
Ps 195 kN
Pm 135 kN
dW1 0 kN/m
dD1 0 m
dW2 0 kN/m
dD2 0 m

Standard Vehicular Load, H30-S24L



Standard Name: Turkey

Vehicular Load Properties

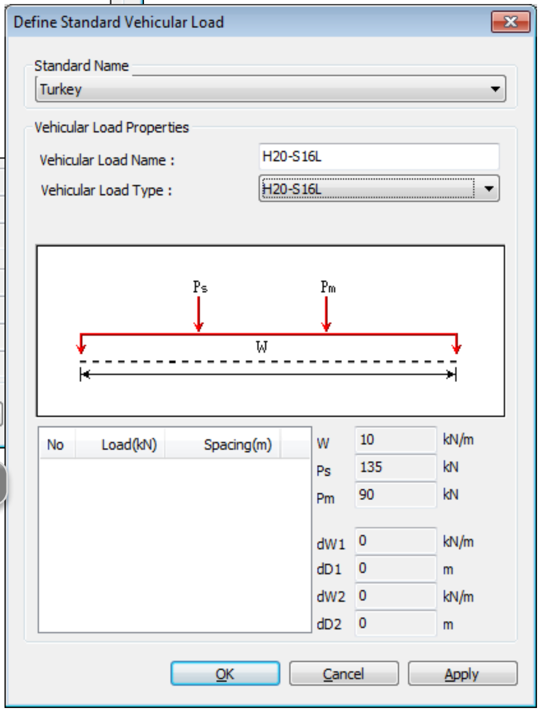
Vehicular Load Name : H20-S16

Vehicular Load Type : H20-S16

| No | Load(kN) | Spacing(m) |
|---|---|---|
| 1 | 40 | 4.25 |
| 2 | 160 | 4.25 |
| 3 | 160 | 9 |

W 0
Ps 0
Pm 0
dW1 0
dD1 0
dW2 0
dD2 0

Standard Vehicular Load, H20-S16



Standard Name: Turkey

Vehicular Load Properties

Vehicular Load Name : H20-S16L

Vehicular Load Type : H20-S16L

| No | Load(kN) | Spacing(m) |
|---|---|---|

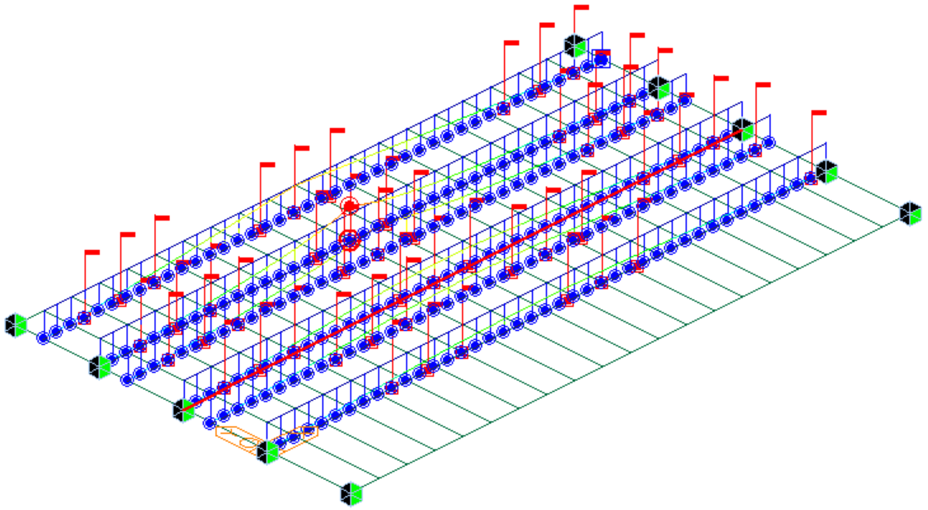
W 10 kN/m
Ps 135 kN
Pm 90 kN
dW1 0 kN/m
dD1 0 m
dW2 0 kN/m
dD2 0 m

Standard Vehicular Load, H20-S16L

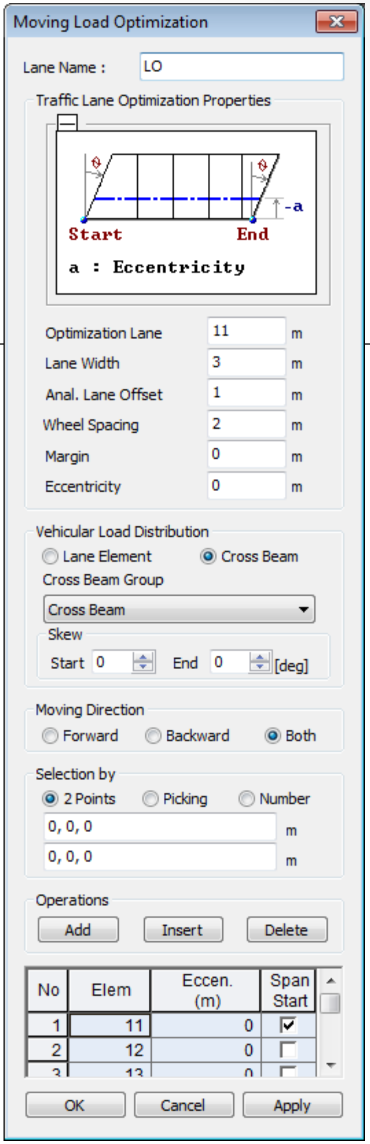
## 2. Moving Load Optimization for Australia

- Now, the moving load optimization function can be applied with the Australia code as well.
- Moving Load Optimization extends the capabilities of moving load analysis and helps to significantly simplify the evaluation of critical vehicle locations. The critical locations of vehicles can be identified in the transverse direction as well as longitudinal direction according to the code provision.

- ***Load > Moving Load > Traffic Line/Surface Lane > Moving Load Optimization***
- ***Load > Moving Load > Moving Load Cases***



Optimized Results for Exterior Girder by S1600



Lane Name : LO

Traffic Lane Optimization Properties

Optimization Lane: 11 m

Lane Width: 3 m

Anal. Lane Offset: 1 m

Wheel Spacing: 2 m

Margin: 0 m

Eccentricity: 0 m

Vehicular Load Distribution: ○ Lane Element ● Cross Beam

Cross Beam Group: Cross Beam

Skew: Start 0 End 0 [deg]

Moving Direction: ○ Forward ○ Backward ● Both

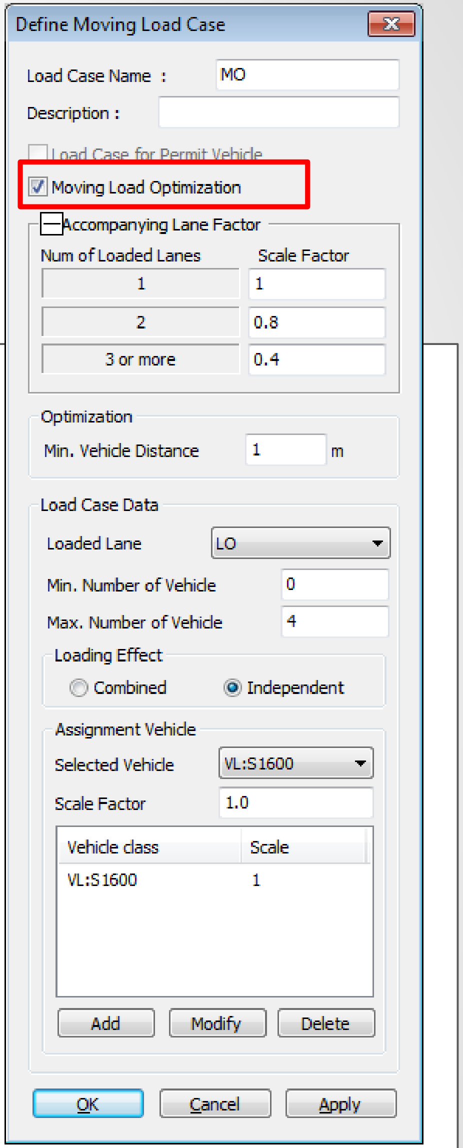
Selection by: ● 2 Points ○ Picking ○ Number

0, 0, 0 m

0, 0, 0 m

| No | Elem | Eccen. (m) | Span Start |
|---|---|---|---|
| 1 | 11 | 0 | ☑ |
| 2 | 12 | 0 | ☐ |
| 3 | 13 | 0 | ☐ |

Traffic Line Lane Optimization



Load Case Name : MO

Description :

☐ Load Case for Permit Vehicle

☑ Moving Load Optimization

Accompanying Lane Factor

| Num of Loaded Lanes | Scale Factor |
|---|---|
| 1 | 1 |
| 2 | 0.8 |
| 3 or more | 0.4 |

Optimization

Min. Vehicle Distance: 1 m

Load Case Data

Loaded Lane: LO

Min. Number of Vehicle: 0

Max. Number of Vehicle: 4

Loading Effect: ○ Combined ● Independent

Assignment Vehicle

Selected Vehicle: VL:S1600

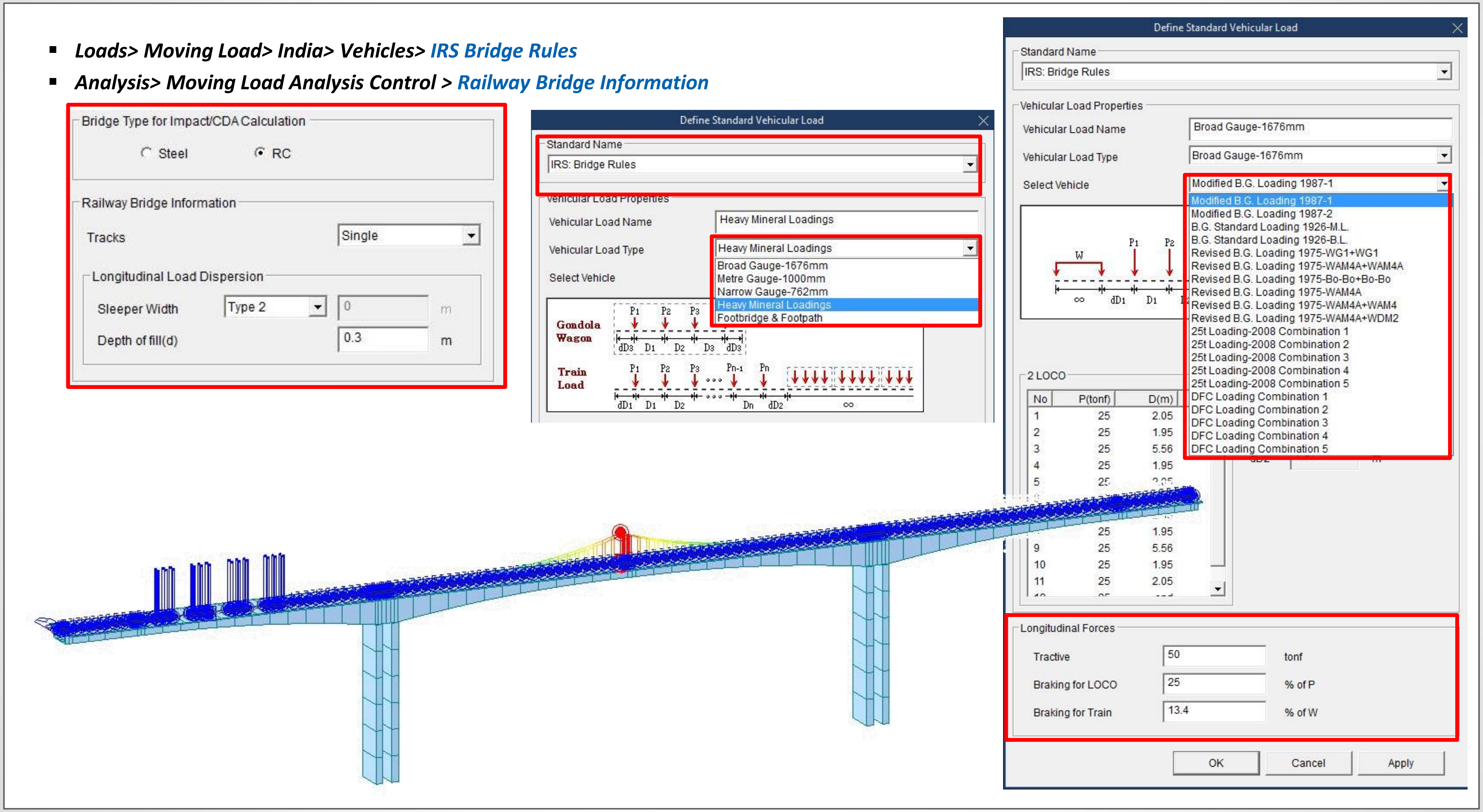
Scale Factor: 1.0

| Vehicle class | Scale |
|---|---|
| VL:S1600 | 1 |

Moving Load Case

# 3. India IRS Bridge Rules: Railway Loads

- All the applicable railway loads could now directly be applied to any structure.  The tractive and braking load of locomotive as well as wagon would be automatically considered.



- ***Loads> Moving Load> India> Vehicles> IRS Bridge Rules***
- ***Analysis> Moving Load Analysis Control > Railway Bridge Information***

Bridge Type for Impact/CDA Calculation

○ Steel ● RC

Railway Bridge Information

Tracks: Single

Longitudinal Load Dispersion

Sleeper Width: Type 2, 0 m

Depth of fill(d): 0.3 m

Define Standard Vehicular Load

Standard Name: IRS: Bridge Rules

Vehicular Load Properties

Vehicular Load Name: Heavy Mineral Loadings

Vehicular Load Type: Heavy Mineral Loadings

Broad Gauge-1676mm
Metre Gauge-1000mm
Narrow Gauge-762mm
Heavy Mineral Loadings
Footbridge & Footpath

Select Vehicle

Define Standard Vehicular Load

Standard Name: IRS: Bridge Rules

Vehicular Load Properties

Vehicular Load Name: Broad Gauge-1676mm

Vehicular Load Type: Broad Gauge-1676mm

Select Vehicle: Modified B.G. Loading 1987-1

Modified B.G. Loading 1987-1
Modified B.G. Loading 1987-2
B.G. Standard Loading 1926-M.L.
B.G. Standard Loading 1926-B.L.
Revised B.G. Loading 1975-WG1+WG1
Revised B.G. Loading 1975-WAM4A+WAM4A
Revised B.G. Loading 1975-Bo-Bo+Bo-Bo
Revised B.G. Loading 1975-WAM4A
Revised B.G. Loading 1975-WAM4A+WAM4
Revised B.G. Loading 1975-WAM4A+WDM2
25t Loading-2008 Combination 1
25t Loading-2008 Combination 2
25t Loading-2008 Combination 3
25t Loading-2008 Combination 4
25t Loading-2008 Combination 5
DFC Loading Combination 1
DFC Loading Combination 2
DFC Loading Combination 3
DFC Loading Combination 4
DFC Loading Combination 5

2 LOCO

| No | P(tonf) | D(m) |
|---|---|---|
| 1 | 25 | 2.05 |
| 2 | 25 | 1.95 |
| 3 | 25 | 5.56 |
| 4 | 25 | 1.95 |
| 5 | 25 | 2.05 |
|  | 25 | 1.95 |
| 9 | 25 | 5.56 |
| 10 | 25 | 1.95 |
| 11 | 25 | 2.05 |

Longitudinal Forces

Tractive: 50 tonf

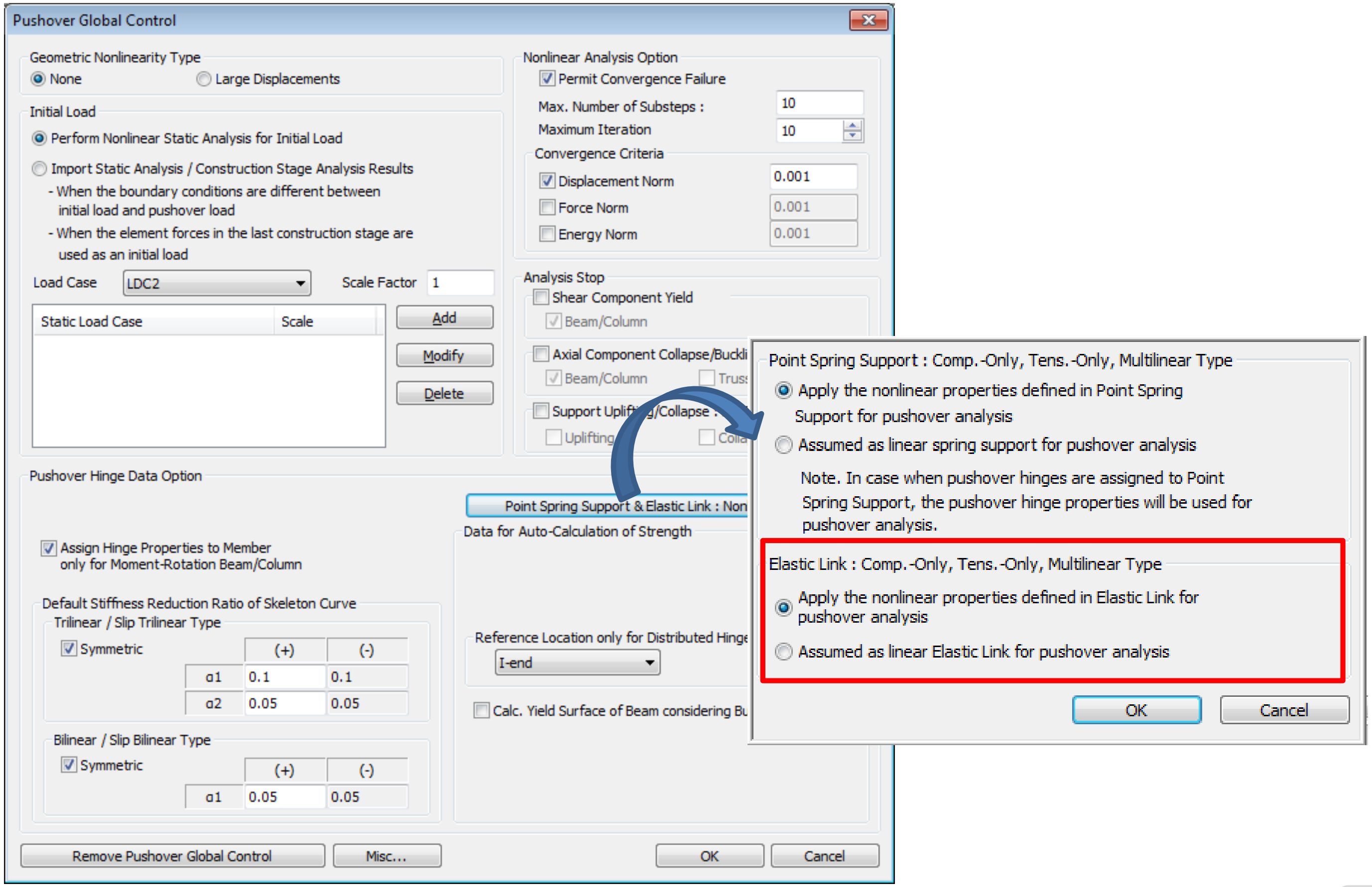
Braking for LOCO: 25 % of P

Braking for Train: 13.4 % of W

# 4. Nonlinear Elastic Links for Pushover Analysis

- Nonlinear behavior of the elastic links, i.e. comp.-only, tens.-only, multi-linear can be taken into account in the pushover analysis.
- Link forces imported from static analysis or construction stage analysis cannot be specified as initial loads for pushover analysis.

- ***Pushover > Control > Global Control***



Pushover Global Control

Geometric Nonlinearity Type
● None ○ Large Displacements

Initial Load
● Perform Nonlinear Static Analysis for Initial Load
○ Import Static Analysis / Construction Stage Analysis Results
- When the boundary conditions are different between initial load and pushover load
- When the element forces in the last construction stage are used as an initial load

Load Case: LDC2 Scale Factor: 1

| Static Load Case | Scale |
|---|---|

Nonlinear Analysis Option
☑ Permit Convergence Failure
Max. Number of Substeps : 10
Maximum Iteration: 10

Convergence Criteria
☑ Displacement Norm: 0.001
☐ Force Norm: 0.001
☐ Energy Norm: 0.001

Analysis Stop
☐ Shear Component Yield
☑ Beam/Column
☐ Axial Component Collapse/Buckli
☑ Beam/Column ☐ Truss
☐ Support Uplifting/Collapse
☐ Uplifting ☐ Colla

Pushover Hinge Data Option
☑ Assign Hinge Properties to Member only for Moment-Rotation Beam/Column

Default Stiffness Reduction Ratio of Skeleton Curve

Trilinear / Slip Trilinear Type
☑ Symmetric

| | (+) | (-) |
|---|---|---|
| α1 | 0.1 | 0.1 |
| α2 | 0.05 | 0.05 |

Bilinear / Slip Bilinear Type
☑ Symmetric

| | (+) | (-) |
|---|---|---|
| α1 | 0.05 | 0.05 |

Data for Auto-Calculation of Strength

Reference Location only for Distributed Hinge: I-end

☐ Calc. Yield Surface of Beam considering Bu

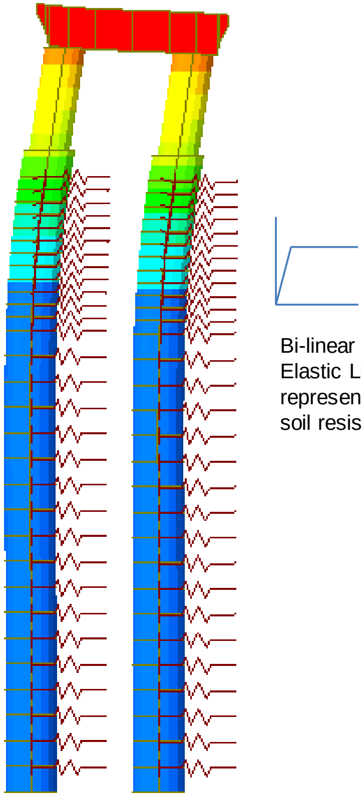
Point Spring Support & Elastic Link : Non

Point Spring Support : Comp.-Only, Tens.-Only, Multilinear Type
● Apply the nonlinear properties defined in Point Spring Support for pushover analysis
○ Assumed as linear spring support for pushover analysis

Note. In case when pushover hinges are assigned to Point Spring Support, the pushover hinge properties will be used for pushover analysis.

Elastic Link : Comp.-Only, Tens.-Only, Multilinear Type
● Apply the nonlinear properties defined in Elastic Link for pushover analysis
○ Assumed as linear Elastic Link for pushover analysis

Pushover Global Control



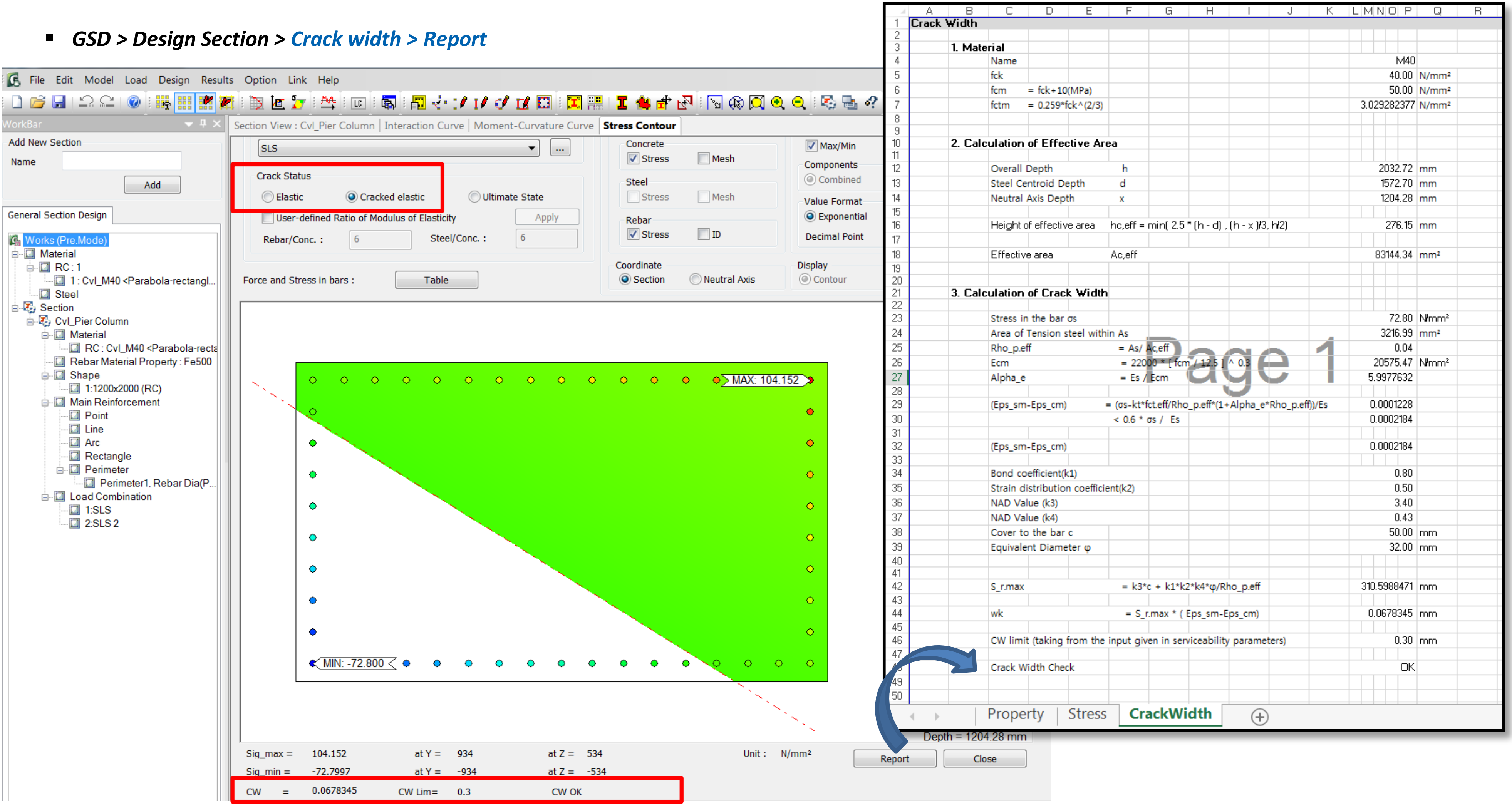
Bi-linear Elastic Links representing soil resistance

Pushover Analysis for the Pier and Shaft

# 5. GSD - Crack Width Calculation as per IRC 112: 2011

- For any irregular section, both elastic and cracked-elastic crack width can be computed as per IRC 112: 2011 code.
- Excel report of the stress and crack width calculation can be obtained.

- ***GSD > Design Section > Crack width > Report***



SLS

Crack Status: ○ Elastic ● Cracked elastic ○ Ultimate State

☐ User-defined Ratio of Modulus of Elasticity

Rebar/Conc. : 6 Steel/Conc. : 6

Concrete: ☑ Stress ☐ Mesh

Steel: ☐ Stress ☐ Mesh

Rebar: ☑ Stress ☐ ID

☑ Max/Min

Components: ● Combined

Value Format: ● Exponential

Coordinate: ● Section ○ Neutral Axis

Display: ● Contour

Sig_max = 104.152 at Y = 934 at Z = 534 Unit : N/mm²

Sig_min = -72.7997 at Y = -934 at Z = -534

CW = 0.0678345 CW Lim= 0.3 CW OK

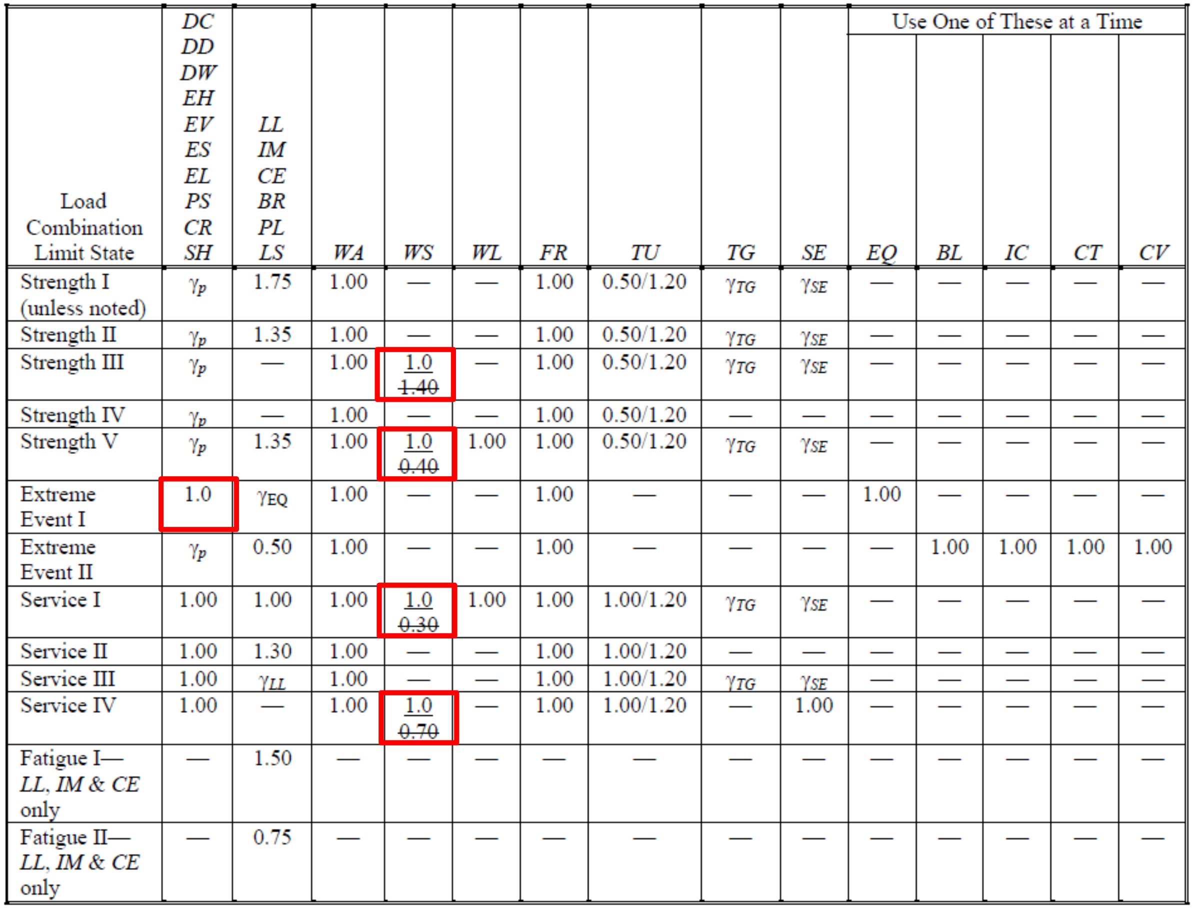
**Crack Width**

| | | | |
|---|---|---|---|
| **1. Material** | | | |
| Name | | M40 | |
| fck | | 40.00 | N/mm² |
| fcm | = fck+10(MPa) | 50.00 | N/mm² |
| fctm | = 0.259*fck^(2/3) | 3.029282377 | N/mm² |
| **2. Calculation of Effective Area** | | | |
| Overall Depth | h | 2032.72 | mm |
| Steel Centroid Depth | d | 1572.70 | mm |
| Neutral Axis Depth | x | 1204.28 | mm |
| Height of effective area | hc,eff = min( 2.5 * (h - d) , (h - x )/3, h/2) | 276.15 | mm |
| Effective area | Ac,eff | 83144.34 | mm² |
| **3. Calculation of Crack Width** | | | |
| Stress in the bar σs | | 72.80 | N/mm² |
| Area of Tension steel within As | | 3216.99 | mm² |
| Rho_p.eff | = As/ Ac,eff | 0.04 | |
| Ecm | = 22000 * [ fcm / 12.5 ] ^ 0.3 | 20575.47 | N/mm² |
| Alpha_e | = Es / Ecm | 5.9977632 | |
| (Eps_sm-Eps_cm) | = (σs-kt*fct.eff/Rho_p.eff*(1+Alpha_e*Rho_p.eff))/Es | 0.0001228 | |
| | < 0.6 * σs / Es | 0.0002184 | |
| (Eps_sm-Eps_cm) | | 0.0002184 | |
| Bond coefficient(k1) | | 0.80 | |
| Strain distribution coefficient(k2) | | 0.50 | |
| NAD Value (k3) | | 3.40 | |
| NAD Value (k4) | | 0.43 | |
| Cover to the bar c | | 50.00 | mm |
| Equivalent Diameter φ | | 32.00 | mm |
| S_r.max | = k3*c + k1*k2*k4*φ/Rho_p.eff | 310.5988471 | mm |
| wk | = S_r.max * ( Eps_sm-Eps_cm) | 0.0678345 | mm |
| CW limit (taking from the input given in serviceability parameters) | | 0.30 | mm |
| Crack Width Check | | OK | |

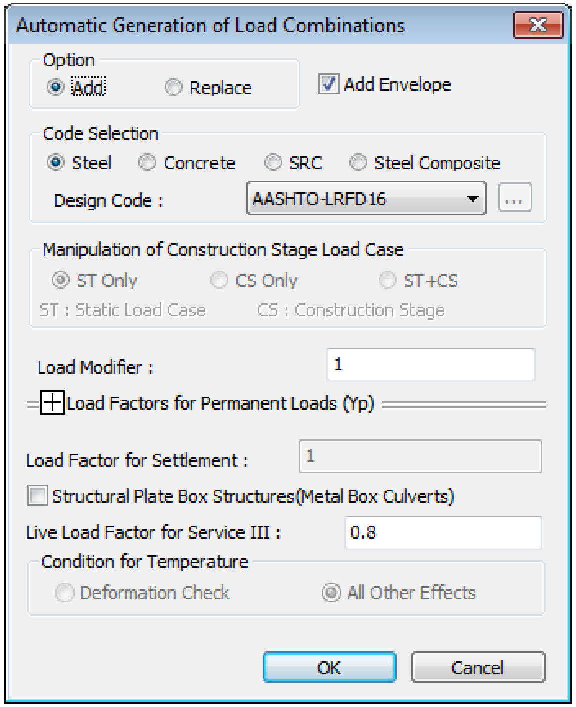
Page 1

## 6. AASHTO LRFD 2016 update

- ***Load Combination***



| Load Combination Limit State | DC DD DW EH EV ES EL PS CR SH | LL IM CE BR PL LS | WA | WS | WL | FR | TU | TG | SE | Use One of These at a Time | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *WA* | *WS* | *WL* | *FR* | *TU* | *TG* | *SE* | *EQ* | *BL* | *IC* | *CT* | *CV* |
| Strength I (unless noted) | $\gamma_p$ | 1.75 | 1.00 | — | — | 1.00 | 0.50/1.20 | $\gamma_{TG}$ | $\gamma_{SE}$ | — | — | — | — | — |
| Strength II | $\gamma_p$ | 1.35 | 1.00 | — | — | 1.00 | 0.50/1.20 | $\gamma_{TG}$ | $\gamma_{SE}$ | — | — | — | — | — |
| Strength III | $\gamma_p$ | — | 1.00 | 1.0<br>~~1.40~~ | — | 1.00 | 0.50/1.20 | $\gamma_{TG}$ | $\gamma_{SE}$ | — | — | — | — | — |
| Strength IV | $\gamma_p$ | — | 1.00 | — | — | 1.00 | 0.50/1.20 | — | — | — | — | — | — | — |
| Strength V | $\gamma_p$ | 1.35 | 1.00 | 1.0<br>~~0.40~~ | 1.00 | 1.00 | 0.50/1.20 | $\gamma_{TG}$ | $\gamma_{SE}$ | — | — | — | — | — |
| Extreme Event I | 1.0 | $\gamma_{EQ}$ | 1.00 | — | — | 1.00 | — | — | — | 1.00 | — | — | — | — |
| Extreme Event II | $\gamma_p$ | 0.50 | 1.00 | — | — | 1.00 | — | — | — | — | 1.00 | 1.00 | 1.00 | 1.00 |
| Service I | 1.00 | 1.00 | 1.00 | 1.0<br>~~0.30~~ | 1.00 | 1.00 | 1.00/1.20 | $\gamma_{TG}$ | $\gamma_{SE}$ | — | — | — | — | — |
| Service II | 1.00 | 1.30 | 1.00 | — | — | 1.00 | 1.00/1.20 | — | — | — | — | — | — | — |
| Service III | 1.00 | $\gamma_{LL}$ | 1.00 | — | — | 1.00 | 1.00/1.20 | $\gamma_{TG}$ | $\gamma_{SE}$ | — | — | — | — | — |
| Service IV | 1.00 | — | 1.00 | 1.0<br>~~0.70~~ | — | 1.00 | 1.00/1.20 | — | 1.00 | — | — | — | — | — |
| Fatigue I— *LL, IM & CE* only | — | 1.50 | — | — | — | — | — | — | — | — | — | — | — | — |
| Fatigue II— *LL, IM & CE* only | — | 0.75 | — | — | — | — | — | — | — | — | — | — | — | — |



Automatic Generation of Load Combinations

Option

● Add ○ Replace ☑ Add Envelope

Code Selection

● Steel ○ Concrete ○ SRC ○ Steel Composite

Design Code : AASHTO-LRFD16

Manipulation of Construction Stage Load Case

● ST Only ○ CS Only ○ ST+CS

ST : Static Load Case CS : Construction Stage

Load Modifier : 1

Load Factors for Permanent Loads (Yp)

Load Factor for Settlement : 1

☐ Structural Plate Box Structures(Metal Box Culverts)

Live Load Factor for Service III : 0.8

Condition for Temperature

○ Deformation Check ● All Other Effects

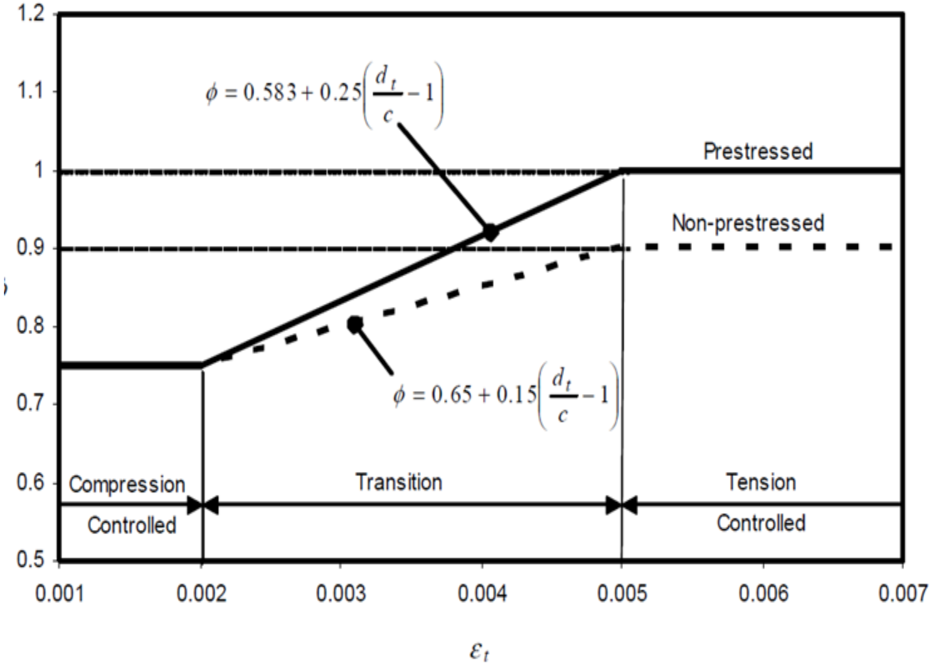
Load Combinations Dialog

- Load factors of WS for Strength III, Strength V, Service I, Service IV are changed from 1.4 to 1.0, 0.4 to 1.0, 0.3 to 1.0, 0.7 to 1.0, respectively.
- Load factor of permanent effects for Extreme Event I is changed from $\gamma_p$ to 1.0. AASHTO-LRFD 2012 used a value for $\gamma_p$ greater than 1.0.

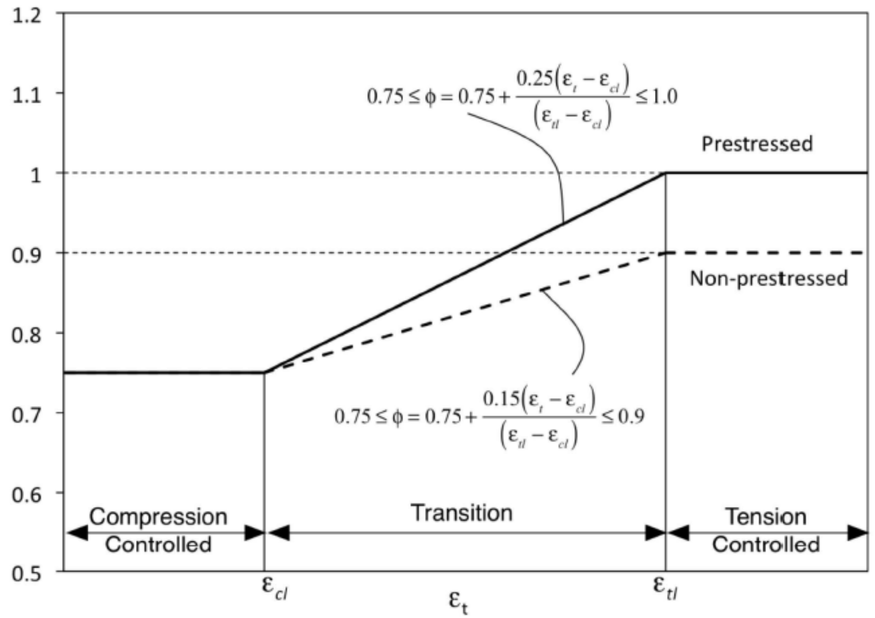
# 6. AASHTO LRFD 2016 update

- ***Resistance Factor***

AASHTO 2012



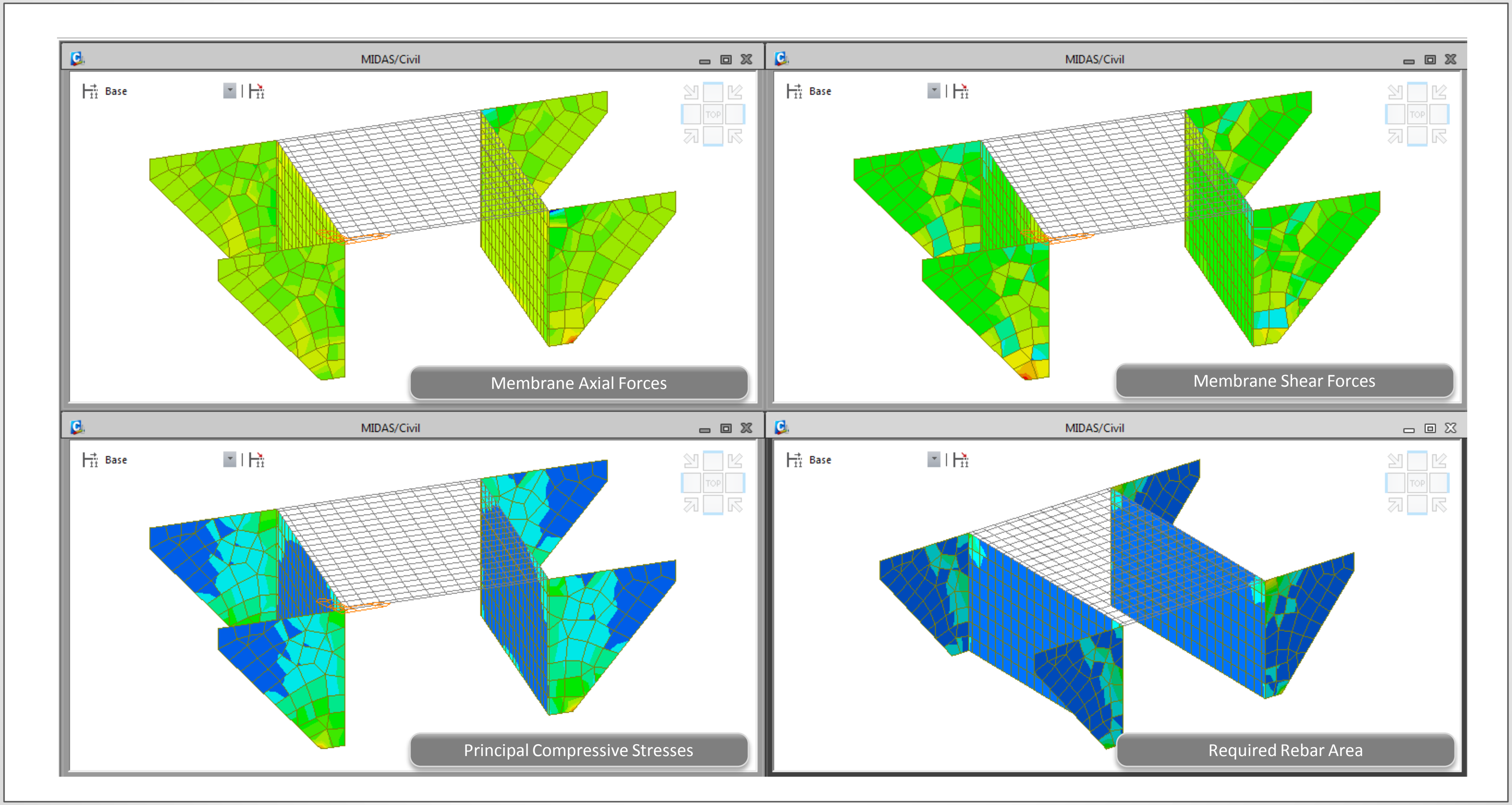
AASHTO 2016



- $\varepsilon_{cl}$ : compression-controlled strain limit in the extreme tension steel
- $\varepsilon_{tl}$ : tension-controlled strain limit in the extreme tension steel

## 7. Shell Design

- The design of reinforcement concrete shells as per Annex LL of EN 1992-2 is implemented.
- Shell design considers three membrane forces, two flexural moments, twisting moment and two transverse shear forces.
- This design feature can be applied to concrete shell structure, abutment walls / wing walls, under ground structures.



Membrane Axial Forces

Membrane Shear Forces

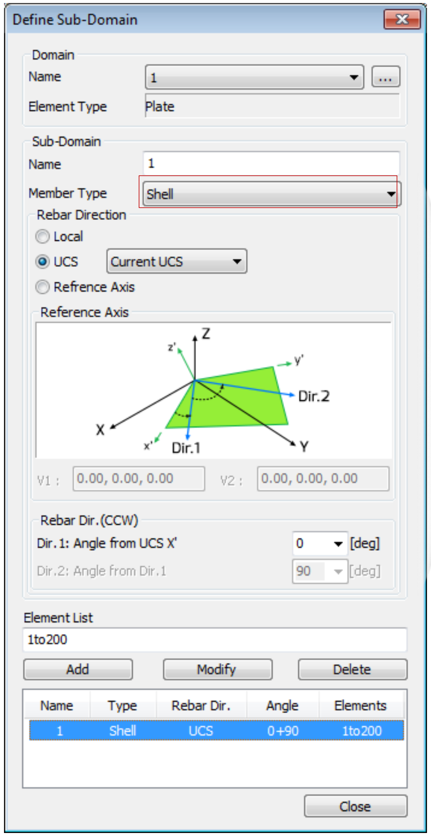
Principal Compressive Stresses

Required Rebar Area

# 7. Shell Design

## *Shell Design*

### *Step 1. Define as a shell member*



Domain
Name: 1
Element Type: Plate

Sub-Domain
Name: 1
Member Type: Shell

Rebar Direction
○ Local
● UCS Current UCS
○ Refrence Axis

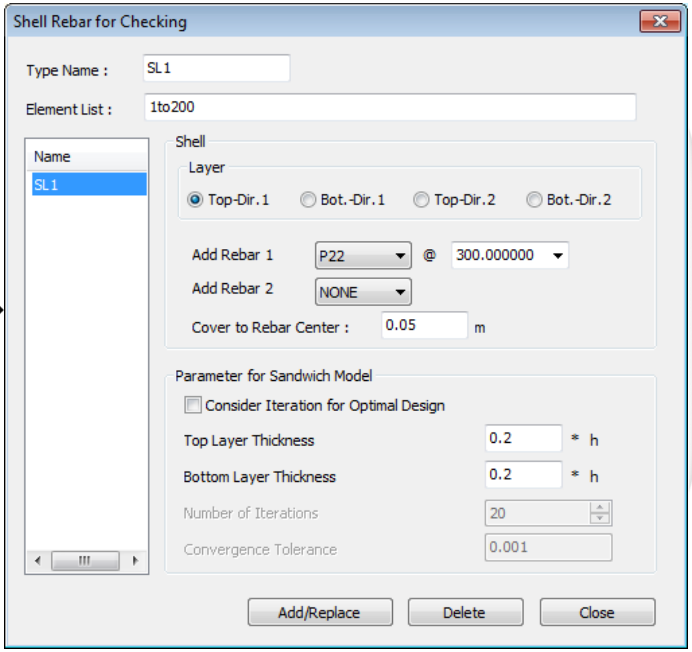
Reference Axis
V1 : 0.00, 0.00, 0.00
V2 : 0.00, 0.00, 0.00

Rebar Dir.(CCW)
Dir.1: Angle from UCS X' 0 [deg]
Dir.2: Angle from Dir.1 90 [deg]

Element List: 1to200

| Name | Type | Rebar Dir. | Angle | Elements |
|---|---|---|---|---|
| 1 | Shell | UCS | 0+90 | 1to200 |

### *Step 2. Define Rebar Data and Layer Thickness*



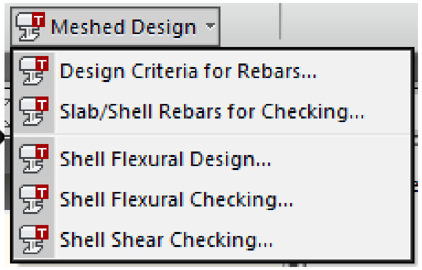
Type Name : SL1
Element List : 1to200

Name
SL1

Shell
Layer
● Top-Dir.1 ○ Bot.-Dir.1 ○ Top-Dir.2 ○ Bot.-Dir.2
Add Rebar 1: P22 @ 300.000000
Add Rebar 2: NONE
Cover to Rebar Center : 0.05 m

Parameter for Sandwich Model
☐ Consider Iteration for Optimal Design
Top Layer Thickness: 0.2 * h
Bottom Layer Thickness: 0.2 * h
Number of Iterations: 20
Convergence Tolerance: 0.001

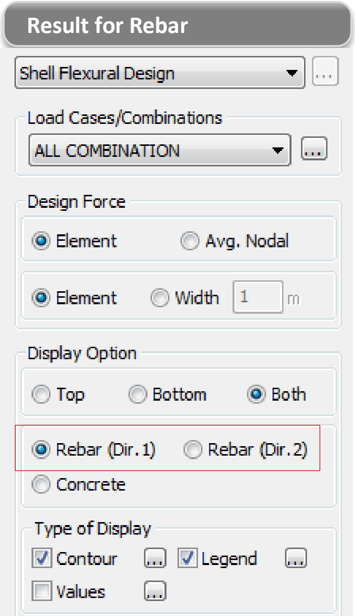
### *Step 3. Run Shell Design and Checking*



# 7. Shell Design

## *Shell Flexural Design/Checking*

**Result for Rebar**



Shell Flexural Design

Load Cases/Combinations: ALL COMBINATION

Design Force: ● Element ○ Avg. Nodal

● Element ○ Width 1 m

Display Option: ○ Top ○ Bottom ● Both

● Rebar (Dir. 1) ○ Rebar (Dir. 2)

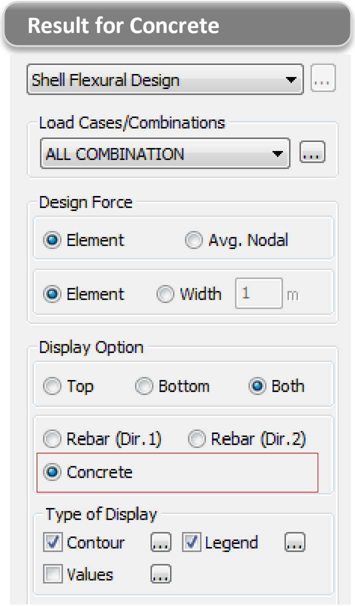
○ Concrete

Type of Display: ☑ Contour ☑ Legend ☐ Values

The followings can be displayed.

1. Membrane Axial Force
2. Membrane Shear Force
3. Rebar Stress
4. As_req<br>(Required reinforcement area)
5. Rho_req<br>(Required reinforcement ratio)
6. Rebar Arrangement

**Result for Concrete**



Shell Flexural Design

Load Cases/Combinations: ALL COMBINATION

Design Force: ● Element ○ Avg. Nodal

● Element ○ Width 1 m

Display Option: ○ Top ○ Bottom ● Both

○ Rebar (Dir. 1) ○ Rebar (Dir. 2)

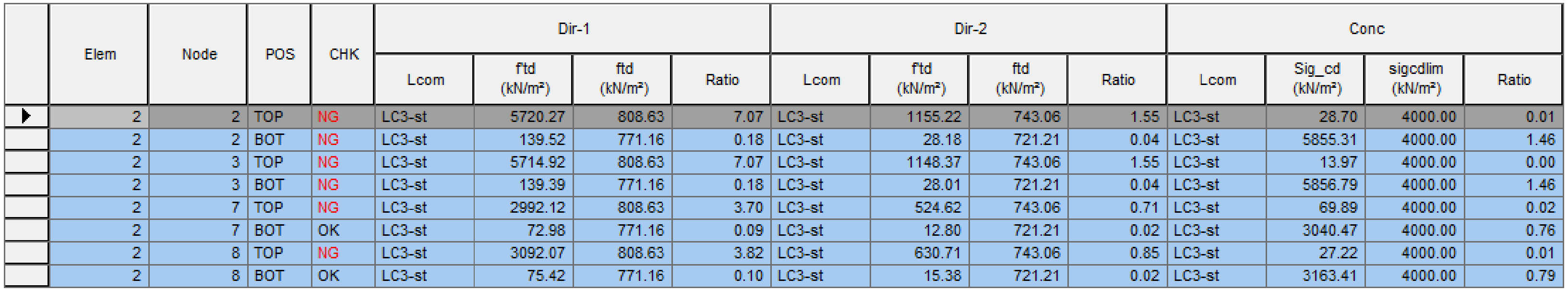
● Concrete

Type of Display: ☑ Contour ☑ Legend ☐ Values

The followings can be displayed.

1. Membrane Axial Force
2. Membrane Shear Force
3. Principal Compressive Stress of Concrete

**Results Table**

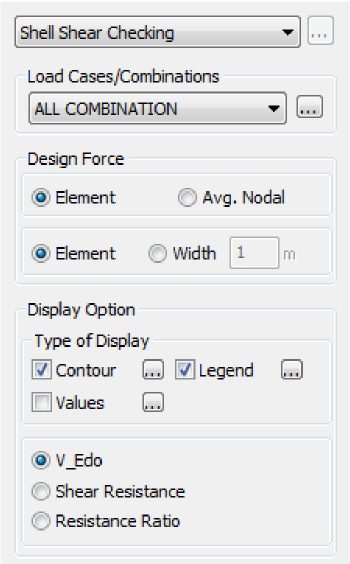


| | Elem | Node | POS | CHK | Dir-1 | | | | Dir-2 | | | | Conc | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Lcom | f'td (kN/m²) | ftd (kN/m²) | Ratio | Lcom | f'td (kN/m²) | ftd (kN/m²) | Ratio | Lcom | Sig_cd (kN/m²) | sigcdlim (kN/m²) | Ratio |
| ▶ | 2 | 2 | TOP | NG | LC3-st | 5720.27 | 808.63 | 7.07 | LC3-st | 1155.22 | 743.06 | 1.55 | LC3-st | 28.70 | 4000.00 | 0.01 |
| | 2 | 2 | BOT | NG | LC3-st | 139.52 | 771.16 | 0.18 | LC3-st | 28.18 | 721.21 | 0.04 | LC3-st | 5855.31 | 4000.00 | 1.46 |
| | 2 | 3 | TOP | NG | LC3-st | 5714.92 | 808.63 | 7.07 | LC3-st | 1148.37 | 743.06 | 1.55 | LC3-st | 13.97 | 4000.00 | 0.00 |
| | 2 | 3 | BOT | NG | LC3-st | 139.39 | 771.16 | 0.18 | LC3-st | 28.01 | 721.21 | 0.04 | LC3-st | 5856.79 | 4000.00 | 1.46 |
| | 2 | 7 | TOP | NG | LC3-st | 2992.12 | 808.63 | 3.70 | LC3-st | 524.62 | 743.06 | 0.71 | LC3-st | 69.89 | 4000.00 | 0.02 |
| | 2 | 7 | BOT | OK | LC3-st | 72.98 | 771.16 | 0.09 | LC3-st | 12.80 | 721.21 | 0.02 | LC3-st | 3040.47 | 4000.00 | 0.76 |
| | 2 | 8 | TOP | NG | LC3-st | 3092.07 | 808.63 | 3.82 | LC3-st | 630.71 | 743.06 | 0.85 | LC3-st | 27.22 | 4000.00 | 0.01 |
| | 2 | 8 | BOT | OK | LC3-st | 75.42 | 771.16 | 0.10 | LC3-st | 15.38 | 721.21 | 0.02 | LC3-st | 3163.41 | 4000.00 | 0.79 |

# 7. Shell Design

## *Shell Shear Checking*

**Result for Shear**



Shell Shear Checking

Load Cases/Combinations: ALL COMBINATION

Design Force: ● Element ○ Avg. Nodal

● Element ○ Width 1 m

Display Option

Type of Display: ☑ Contour ☑ Legend ☐ Values

● V_Edo

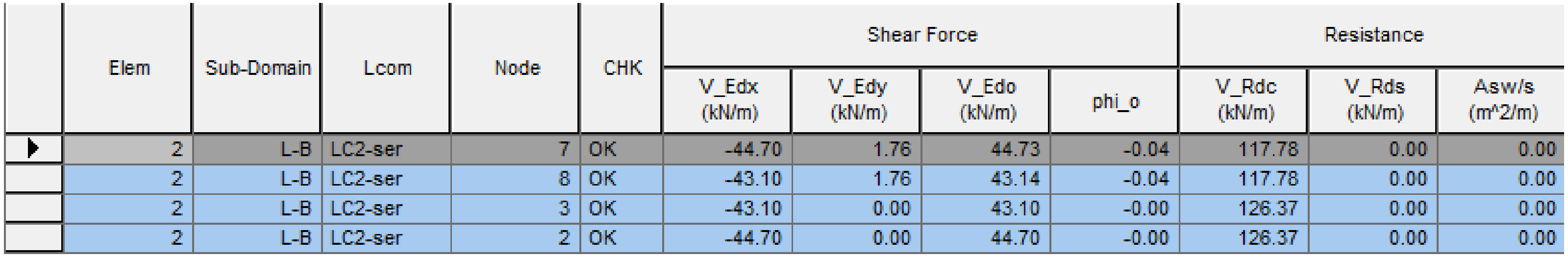
○ Shear Resistance

○ Resistance Ratio

The followings can be displayed.

1. V_Edo
2. Shear Resistance for Concrete
3. Resistance Ratio

**Results Table**



| | Elem | Sub-Domain | Lcom | Node | CHK | Shear Force | | | | Resistance | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | V_Edx (kN/m) | V_Edy (kN/m) | V_Edo (kN/m) | phi_o | V_Rdc (kN/m) | V_Rds (kN/m) | Asw/s (m^2/m) |
| ▶ | 2 | L-B | LC2-ser | 7 | OK | -44.70 | 1.76 | 44.73 | -0.04 | 117.78 | 0.00 | 0.00 |
| | 2 | L-B | LC2-ser | 8 | OK | -43.10 | 1.76 | 43.14 | -0.04 | 117.78 | 0.00 | 0.00 |
| | 2 | L-B | LC2-ser | 3 | OK | -43.10 | 0.00 | 43.10 | -0.00 | 126.37 | 0.00 | 0.00 |
| | 2 | L-B | LC2-ser | 2 | OK | -44.70 | 0.00 | 44.70 | -0.00 | 126.37 | 0.00 | 0.00 |

# 7. Shell Design

## *Design Concept of Shell Design*

- Shell or plate element subjected to membrane forces Nx,Ny,Nxy + flexural forces Mx,My,Mxy
- Resisted by resultant tensile forces of reinforcement + resultant compressive forces of concrete

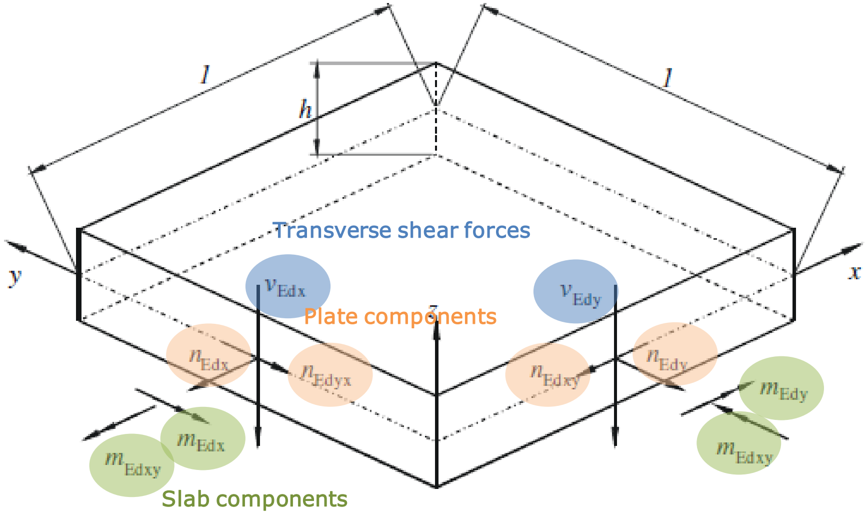
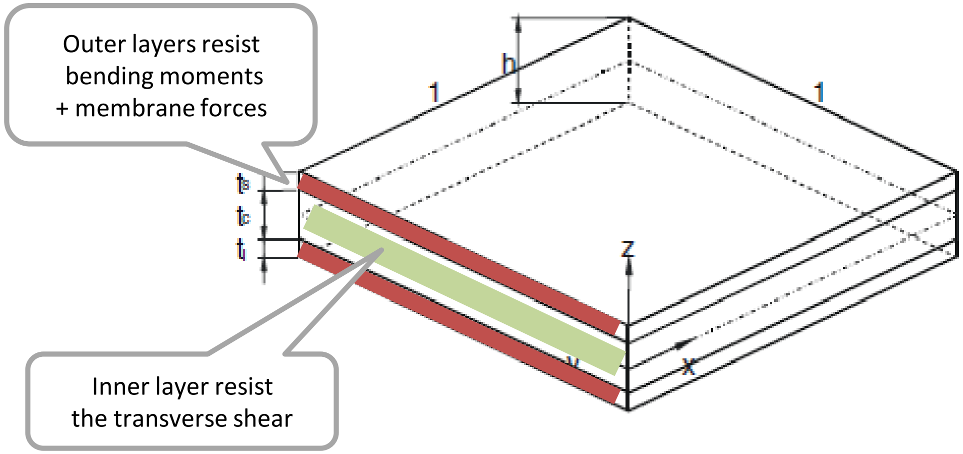


**Figure LL.1 — Shell element**



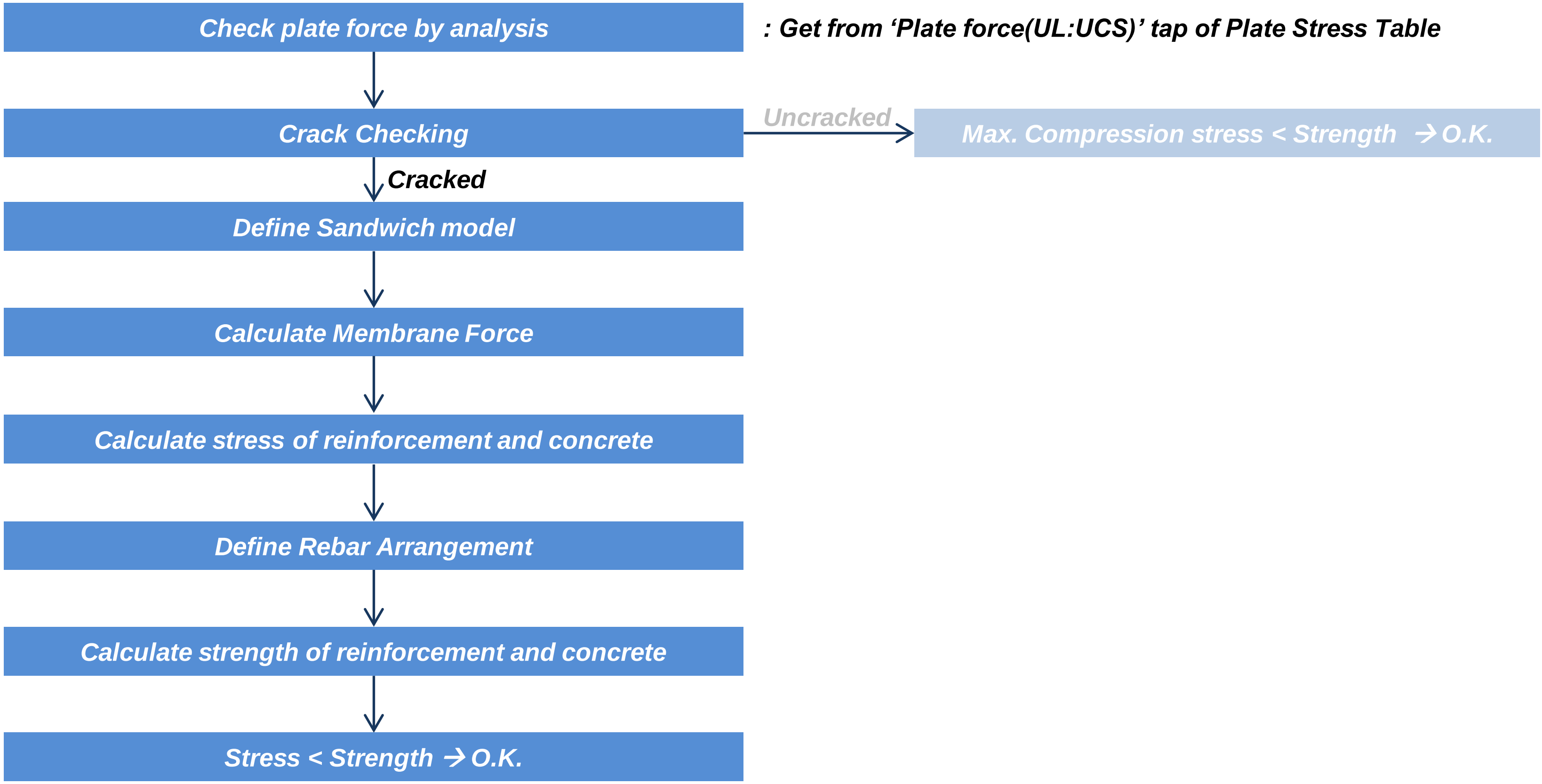
Outer layers resist bending moments + membrane forces

Inner layer resist the transverse shear

**Figure LL.2 — The sandwich model**

## 7. Shell Design

### *Procedure of Shell Design*



*Check plate force by analysis*

*: Get from 'Plate force(UL:UCS)' tap of Plate Stress Table*

*Crack Checking*

*Uncracked*

*Max. Compression stress < Strength → O.K.*

*Cracked*

*Define Sandwich model*

*Calculate Membrane Force*

*Calculate stress of reinforcement and concrete*

*Define Rebar Arrangement*

*Calculate strength of reinforcement and concrete*

*Stress < Strength → O.K.*

# 7. Shell Design

## *Procedure of Shell Design*

### *Crack Checking*

$$\Phi = \alpha \frac{J_2}{f_{\mathrm{cm}}{}^2} + \lambda \frac{\sqrt{J_2}}{f_{\mathrm{cm}}} + \beta \frac{I_1}{f_{\mathrm{cm}}} - 1 \leq 0$$

*→ Uncracked,* *If Φ>0.0, Cracked*

where:

$$J_2 = \frac{1}{6}[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]$$

$$J_3 = (\sigma_1 - \sigma_{\mathrm{m}})\,(\sigma_2 - \sigma_{\mathrm{m}})\,(\sigma_3 - \sigma_{\mathrm{m}})$$

$$I_1 = \sigma_1 + \sigma_2 + \sigma_3$$

$$\sigma_{\mathrm{m}} = (\sigma_1 + \sigma_2 + \sigma_3)/3$$

$$\alpha = \frac{1}{9k^{1,4}}$$

*σ1 = Max. [σx, σy] = Max. [Fxx, Fyy]*

*σ2 = Min. [σx, σy] = Min. [Fxx, Fyy]*

*σ3 = 0*

$$\lambda = c_1 \cos\left[\frac{1}{3}\mathrm{ar}\cos(C_2 \cos 3\theta)\right] \quad \text{for} \quad \cos 3\theta \geq 0$$

$$\lambda = c_1 \cos\left[\frac{\pi}{3} - \frac{1}{3}\mathrm{ar}\cos(-C_2 \cos 3\theta)\right] \quad \text{for} \quad \cos 3\theta < 0$$

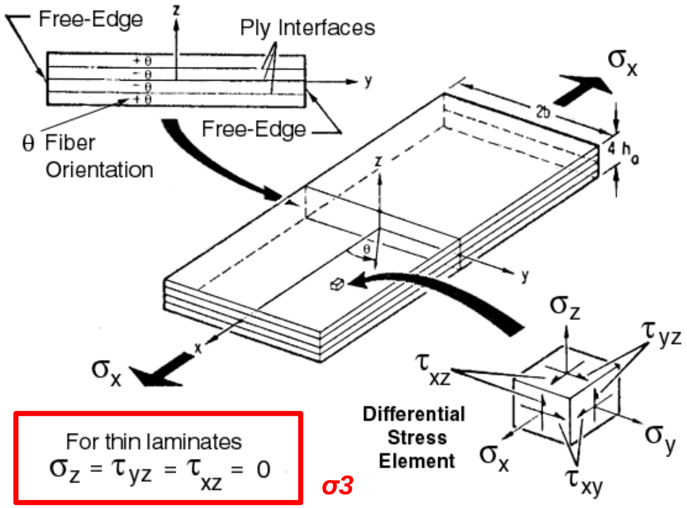
$$\beta = \frac{1}{3{,}7k^{1,1}}$$

$$\cos 3\theta = \frac{3\sqrt{3}}{2}\frac{J_3}{J_2^{3/2}}$$

$$c_1 = \frac{1}{0{,}7k^{0,9}}$$

$$c_2 = 1 - 6{,}8\,(k - 0{,}07)^2$$

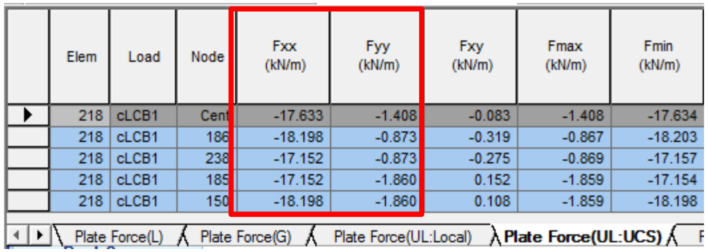
$$k = \frac{f_{\mathrm{ctm}}}{f_{\mathrm{cm}}}$$



For thin laminates
$\sigma_z = \tau_{yz} = \tau_{xz} = 0$

σ3

### *Plate Stress (UL : UCS) Table*



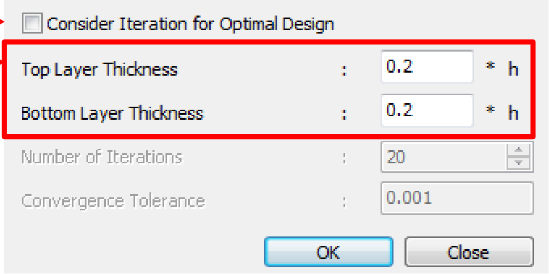
| | Elem | Load | Node | Fxx (kN/m) | Fyy (kN/m) | Fxy (kN/m) | Fmax (kN/m) | Fmin (kN/m) |
|---|---|---|---|---|---|---|---|---|
| ▶ | 218 | cLCB1 | Cent | -17.633 | -1.408 | -0.083 | -1.408 | -17.634 |
| | 218 | cLCB1 | 186 | -18.198 | -0.873 | -0.319 | -0.867 | -18.203 |
| | 218 | cLCB1 | 238 | -17.152 | -0.873 | -0.275 | -0.869 | -17.157 |
| | 218 | cLCB1 | 185 | -17.152 | -1.860 | 0.152 | -1.859 | -17.154 |
| | 218 | cLCB1 | 150 | -18.198 | -1.860 | 0.108 | -1.859 | -18.198 |

# 7. Shell Design

## *Procedure of Shell Design*

### *Define Sandwich model*

- Use ‘ 0.2*h’ as default value.
- If check on “ Consider Iteration for optimal design”, layer thickness will be calculated automatically.



☐ Consider Iteration for Optimal Design

Top Layer Thickness : 0.2 * h

Bottom Layer Thickness : 0.2 * h

Number of Iterations : 20

Convergence Tolerance : 0.001

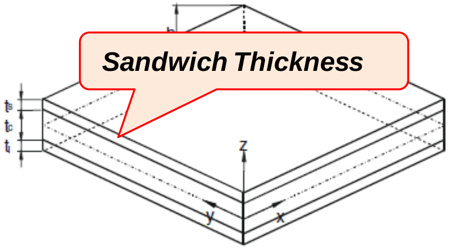


Figure LL.2 — The sandwich model

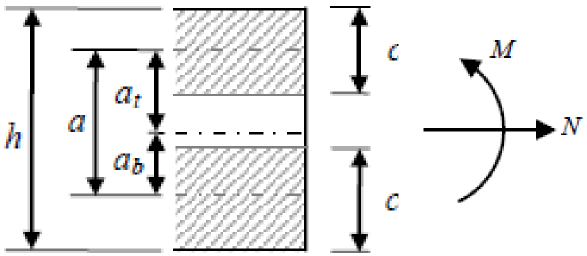
### *Calculate Membrane Force*

- The geometry of sandwich element has to be known to compute the membrane forces (Nxk, Nyk, Nxyk).

$$N_{xt} = N_x \frac{a_b}{a} - \frac{M_x}{a} \qquad N_{xb} = N_x \frac{a_t}{a} + \frac{M_x}{a}$$

$$N_{yt} = N_y \frac{a_b}{a} - \frac{M_y}{a} \qquad N_{yb} = N_y \frac{a_t}{a} + \frac{M_y}{a}$$

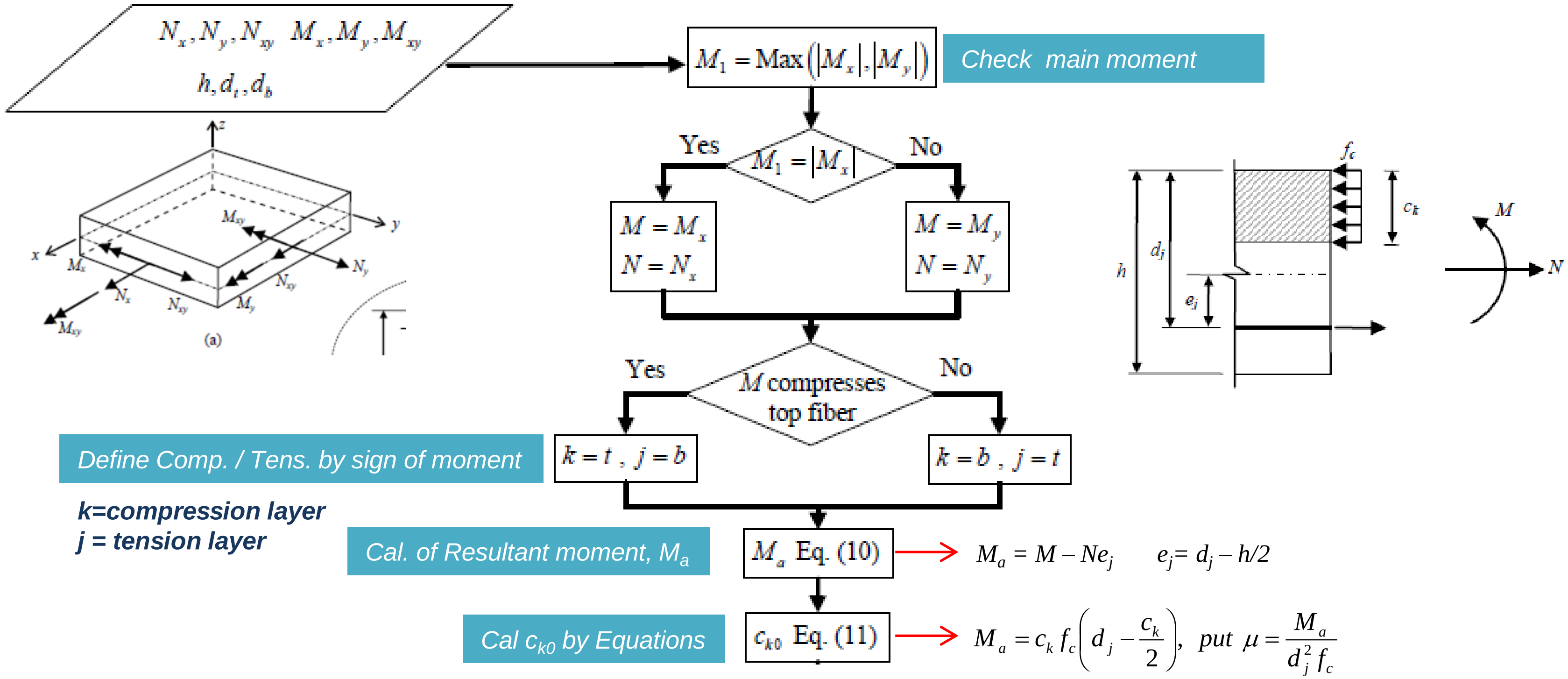
$$N_{xyt} = N_{xy} \frac{a_b}{a} - \frac{M_{xy}}{a} \qquad N_{xyb} = N_{xy} \frac{a_t}{a} + \frac{M_{xy}}{a}$$



# 7. Shell Design

## *Procedure of Shell Design*

### *Calculation of Sandwich Thickness for Optimal Design - 1*



*Check main moment*

*Define Comp. / Tens. by sign of moment*

***k=compression layer***
***j = tension layer***

*Cal. of Resultant moment, $M_a$*

*Cal $c_{k0}$ by Equations*

$$M_a = M - Ne_j \qquad e_j = d_j - h/2$$

$$M_a = c_k f_c\left(d_j - \frac{c_k}{2}\right),\quad put\ \ \mu = \frac{M_a}{d_j^2 f_c}$$

$$c_k = d_j\left(1 - \sqrt{\max[1.0 - 2\mu,\ 0]}\right)$$

***ck0 : 1st estimation of ck***
***ck : the depth of the compression block***

# 7. Shell Design

## *Procedure of Shell Design*

### *Calculation of Sandwich Thickness for Optimal Design - 2*

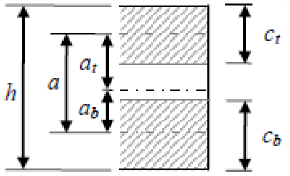
*Membrane force in compression layer.*

$a = d_j - \frac{c_k}{2}$, $a_k = \frac{h - c_k}{2}$, $a_j = a - a_k$

$N_{xk} = N_x \frac{a_j}{a} - \frac{M_x}{a}$

$N_{yk} = N_y \frac{a_j}{a} - \frac{M_y}{a}$

$N_{xyk} = N_{xy} \frac{a_j}{a} - \frac{M_{xy}}{a}$



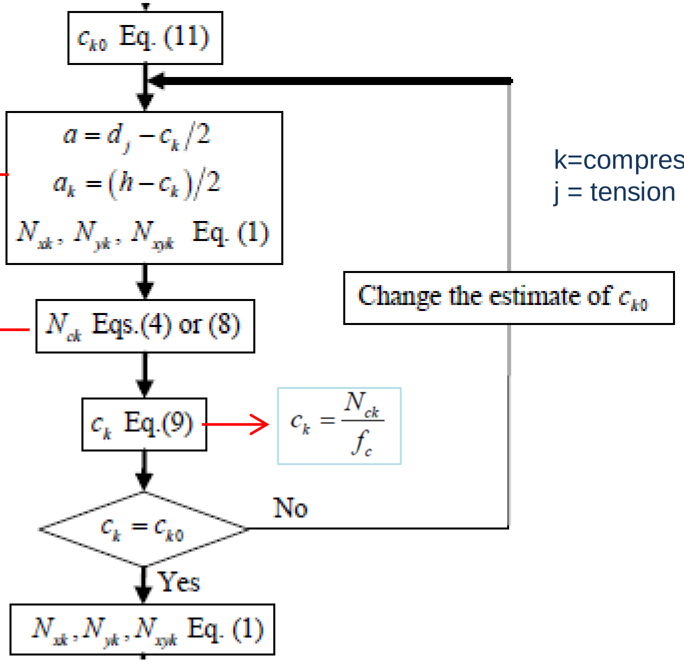
*Compression Force of Concrete .*

***When*** $N_{xk} < -|N_{xyk}|,\ N_{yk} < -|N_{xyk}|$

$$N_{ck} = \frac{1}{2}(N_{xk} + N_{yk}) - \frac{1}{2}\sqrt{(N_{xk} - N_{yk})^2 + 4N_{xyk}}$$

***When excluding*** $N_{xk} < -|N_{xyk}|,\ N_{yk} < -|N_{xyk}|$

$$N_{ck} = |N_{xyk}|(\tan\alpha_k + \cot\alpha_k)$$



$c_{k0}$ Eq. (11)

$a = d_j - c_k/2$

$a_k = (h - c_k)/2$

$N_{xk}, N_{yk}, N_{xyk}$ Eq. (1)

$N_{ck}$ Eqs.(4) or (8)

$c_k$ Eq.(9)

$c_k = \frac{N_{ck}}{f_c}$

$c_k = c_{k0}$

No

Change the estimate of $c_{k0}$

Yes

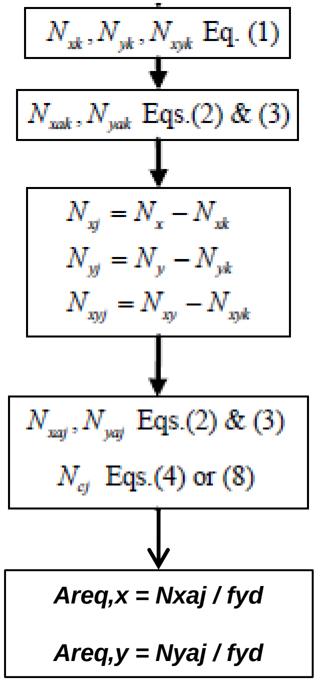
$N_{xk}, N_{yk}, N_{xyk}$ Eq. (1)

k=compression layer
j = tension layer

## 7. Shell Design

### *Procedure of Shell Design*

### *Calculation of Membrane Force in tension layer and Required Rebar Area*



$N_{xk}, N_{yk}, N_{xyk}$ Eq. (1)

$N_{xak}, N_{yak}$ Eqs.(2) & (3)

$$N_{xak} = N_{xk} + |N_{xyk}| \cot \alpha_k$$

$$N_{yak} = N_{yk} + |N_{xyk}| \tan \alpha_k$$

*Calculate Comp. forces in reinforcement in compressed layer.*
*In Gen, Ignore Comp. forces in reinforcement (Required rebar Area by comp. is 0)*

$$N_{xj} = N_x - N_{xk}$$
$$N_{yj} = N_y - N_{yk}$$
$$N_{xyj} = N_{xy} - N_{xyk}$$

*Calculate membrane force in tensioned layer.*

$N_{xaj}, N_{yaj}$ Eqs.(2) & (3)

$N_{cj}$ Eqs.(4) or (8)

*Calculate tension forces in reinforcement in tension layer.*

***Areq,x = Nxaj / fyd***

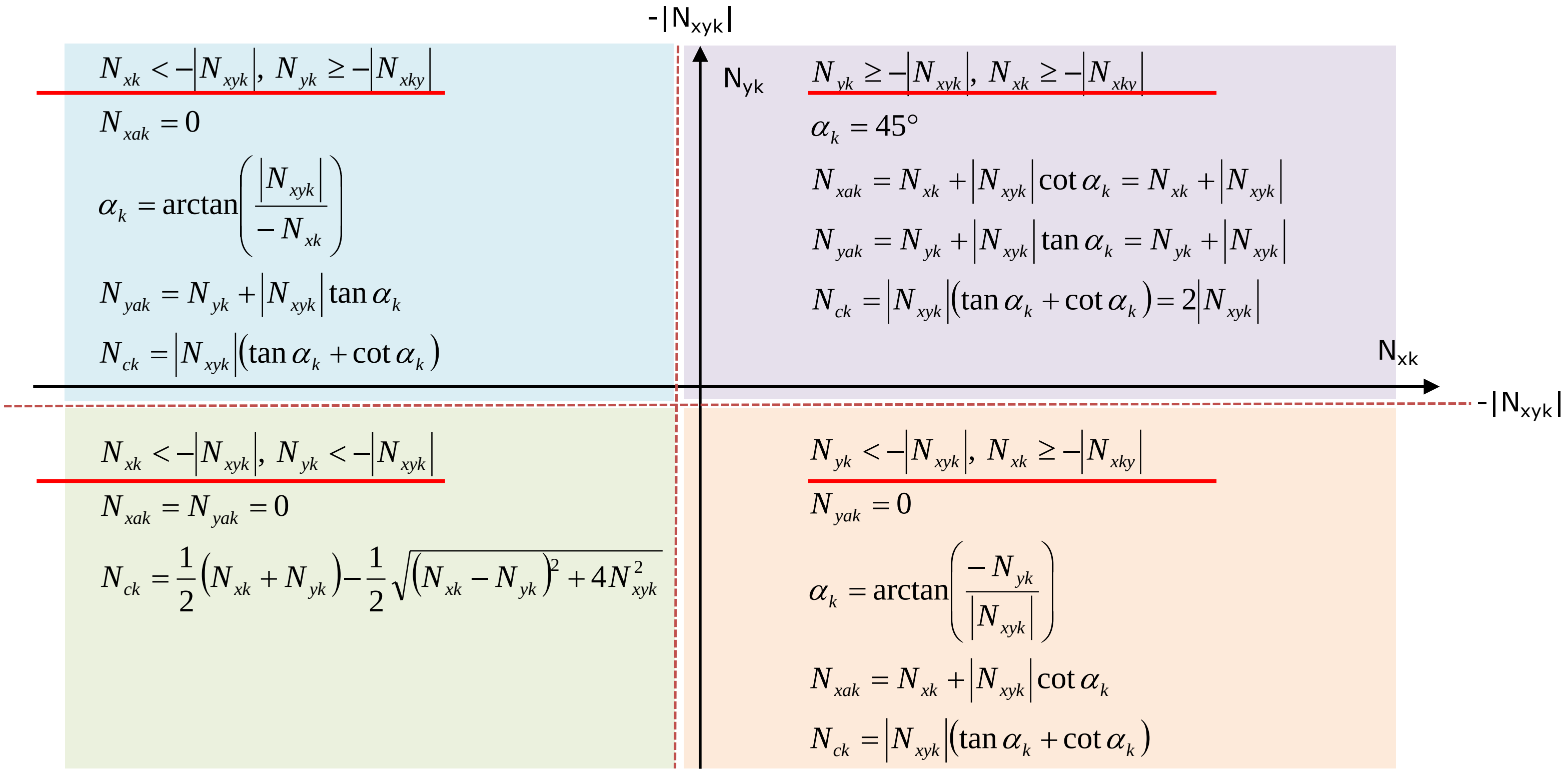
***Areq,y = Nyaj / fyd***

*Calculate required Rebar Area in tension layer.*

# 7. Shell Design

## *Procedure of Shell Design*

### *Calculate Force of reinforcement(Tension Layer) and concrete(Compression Layer)*



$$N_{xk} < -|N_{xyk}|,\ N_{yk} \geq -|N_{xky}|$$

$$N_{xak} = 0$$

$$\alpha_k = \arctan\left(\frac{|N_{xyk}|}{-N_{xk}}\right)$$

$$N_{yak} = N_{yk} + |N_{xyk}| \tan\alpha_k$$

$$N_{ck} = |N_{xyk}|(\tan\alpha_k + \cot\alpha_k)$$

$$N_{yk} \geq -|N_{xyk}|,\ N_{xk} \geq -|N_{xky}|$$

$$\alpha_k = 45°$$

$$N_{xak} = N_{xk} + |N_{xyk}| \cot\alpha_k = N_{xk} + |N_{xyk}|$$

$$N_{yak} = N_{yk} + |N_{xyk}| \tan\alpha_k = N_{yk} + |N_{xyk}|$$

$$N_{ck} = |N_{xyk}|(\tan\alpha_k + \cot\alpha_k) = 2|N_{xyk}|$$

$$N_{xk} < -|N_{xyk}|,\ N_{yk} < -|N_{xyk}|$$

$$N_{xak} = N_{yak} = 0$$

$$N_{ck} = \frac{1}{2}(N_{xk} + N_{yk}) - \frac{1}{2}\sqrt{(N_{xk} - N_{yk})^2 + 4N_{xyk}^2}$$

$$N_{yk} < -|N_{xyk}|,\ N_{xk} \geq -|N_{xky}|$$

$$N_{yak} = 0$$

$$\alpha_k = \arctan\left(\frac{-N_{yk}}{|N_{xyk}|}\right)$$

$$N_{xak} = N_{xk} + |N_{xyk}| \cot\alpha_k$$

$$N_{ck} = |N_{xyk}|(\tan\alpha_k + \cot\alpha_k)$$

***$N_{xak}$, $N_{yak}$ : tension forces in reinforcement placed in x and y direction in layer k***

***$N_{ck}$ : Concrete compression force in layer k***

## 7. Shell Design

### *Procedure of Shell Design*

**_Modification of Tension force by considering the location of rebar_**

*Distance from center section to center of outerRebar*

*Distance from center section to center of sandwich thickness*

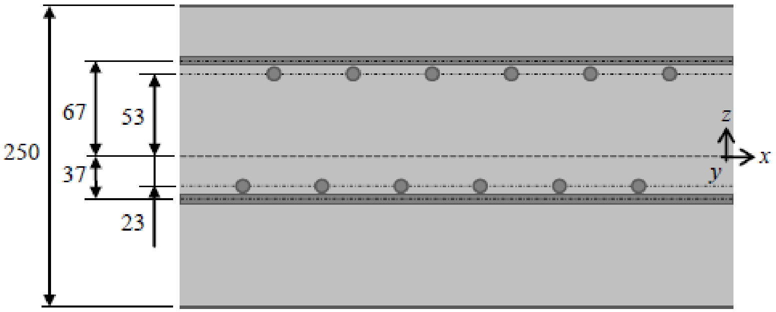
$$z_{ya} = \frac{N_{yat}\boxed{z_{yat}} + N_{yab}\boxed{z_{yab}}}{\sum N_{ya}} = \frac{168.71 \cdot 67 + 229.47(-80)}{398.18} = -17.72\ mm$$

The actual positions of $y$ reinforcement in top and bottom layer are $z^{*}_{yat} = 53$ mm and $z^{*}_{yab} = -23$ mm, the corresponding tension forces at those levels, $N^{*}_{yat}$ and $N^{*}_{yab}$, can be obtained from:

$$N^{*}_{yat} = \sum N_{ya} \frac{z_{ya} - z^{*}_{yab}}{z^{*}_{yat} - z^{*}_{yab}} = 398.18 \frac{-17.72 + 23}{53 + 23} = 27.68\ N/mm$$

$$N^{*}_{yab} = \sum N_{ya} \frac{z^{*}_{yat} - z_{ya}}{z^{*}_{yat} - z^{*}_{yab}} = 398.18 \frac{53 + 17.72}{53 + 23} = 370.50\ N/mm$$

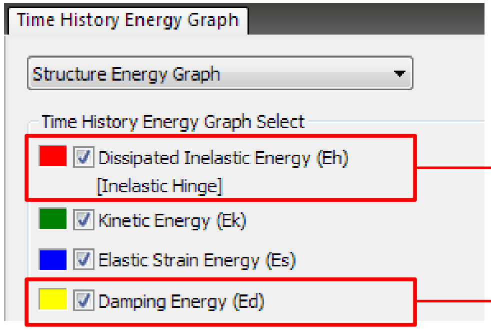
All the measurements in mm



# 1. Energy Result Graph for Time History Analysis

- Print out energy results graph for isolator and vibration control devices in the nonlinear time history analysis.

- ***Result > T.H. Graph/Text > Time History Energy Graph***

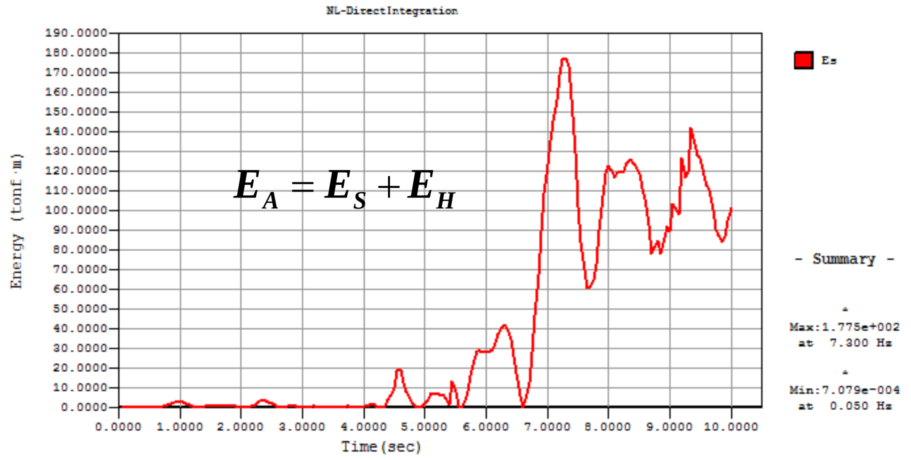


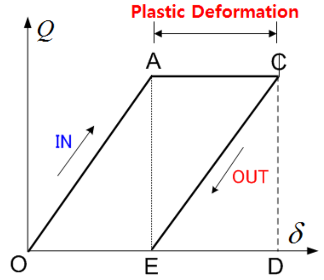
Time History Energy Graph

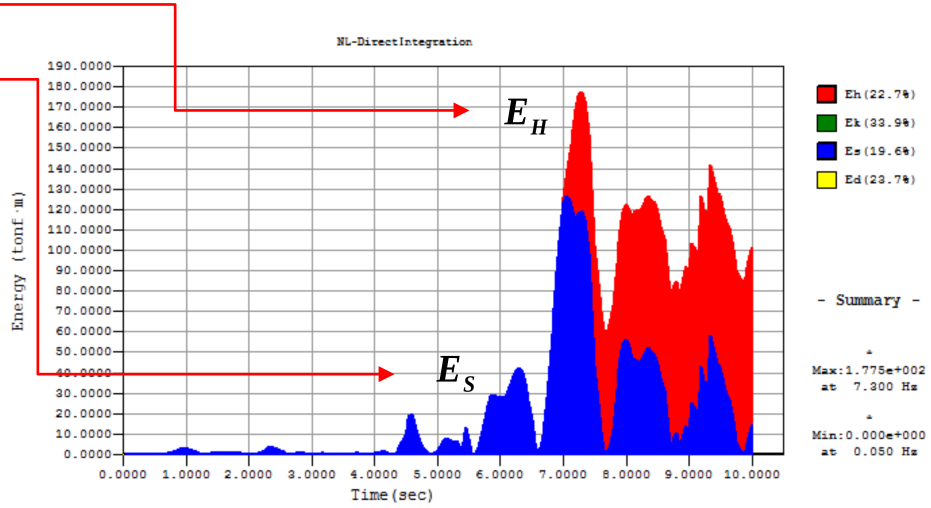
Structure Energy Graph

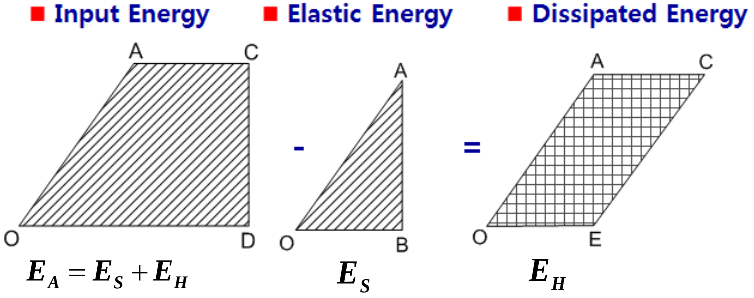
Time History Energy Graph Select

- 🟥 ☑ Dissipated Inelastic Energy (Eh) [Inelastic Hinge]
- 🟩 ☑ Kinetic Energy (Ek)
- 🟦 ☑ Elastic Strain Energy (Es)
- 🟨 ☑ Damping Energy (Ed)



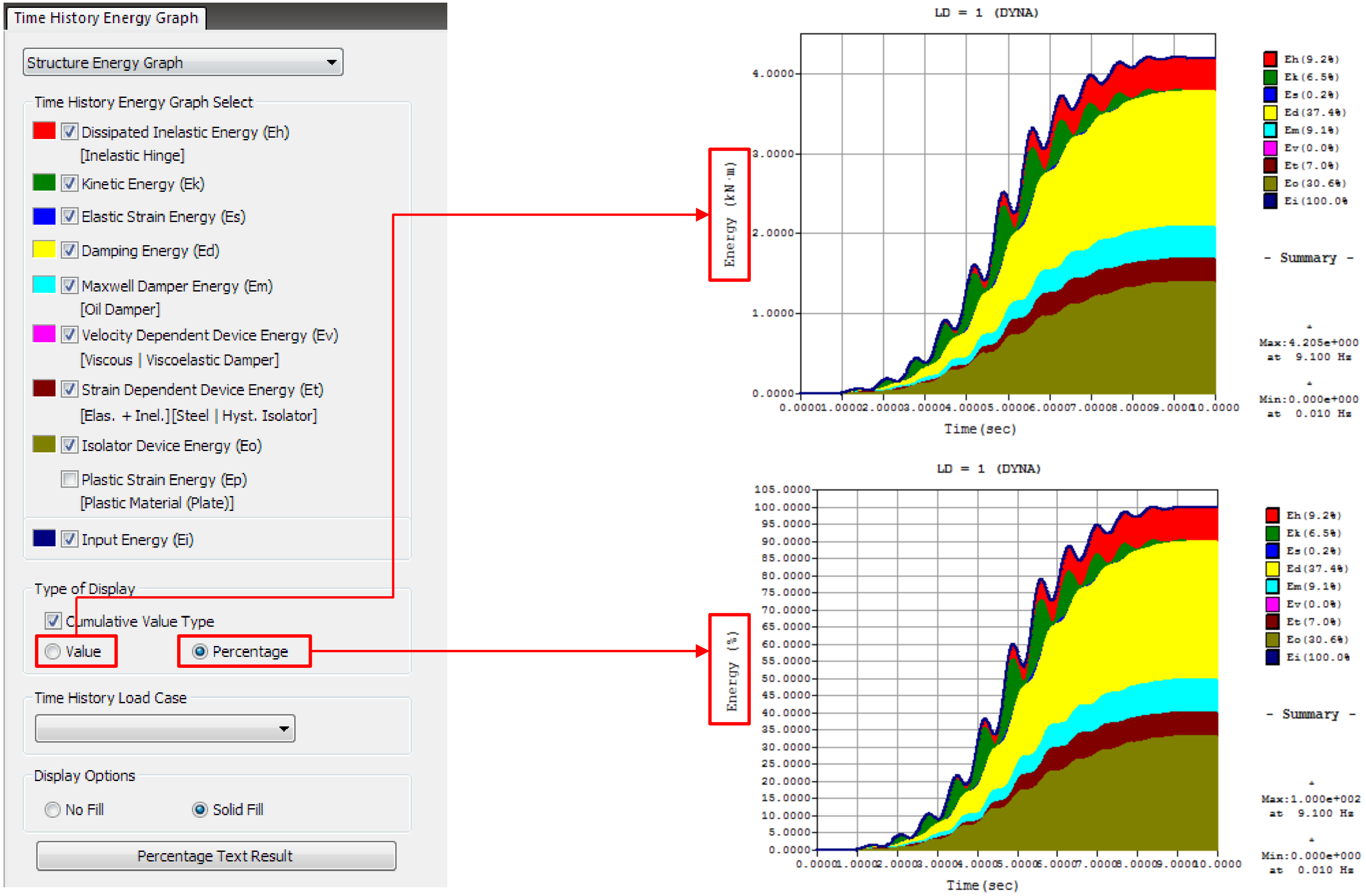






## 1. Energy Result Graph for Time History Analysis

- ***Result > T.H. Graph/Text > Time History Energy Graph***



Time History Energy Graph

Structure Energy Graph

Time History Energy Graph Select

- 🟥 ☑ Dissipated Inelastic Energy (Eh) [Inelastic Hinge]
- 🟩 ☑ Kinetic Energy (Ek)
- 🟦 ☑ Elastic Strain Energy (Es)
- 🟨 ☑ Damping Energy (Ed)
- ☑ Maxwell Damper Energy (Em) [Oil Damper]
- 🟪 ☑ Velocity Dependent Device Energy (Ev) [Viscous | Viscoelastic Damper]
- 🟫 ☑ Strain Dependent Device Energy (Et) [Elas. + Inel.][Steel | Hyst. Isolator]
- ☑ Isolator Device Energy (Eo)
- ☐ Plastic Strain Energy (Ep) [Plastic Material (Plate)]
- ☑ Input Energy (Ei)

Type of Display

☑ Cumulative Value Type

○ Value ● Percentage

Time History Load Case

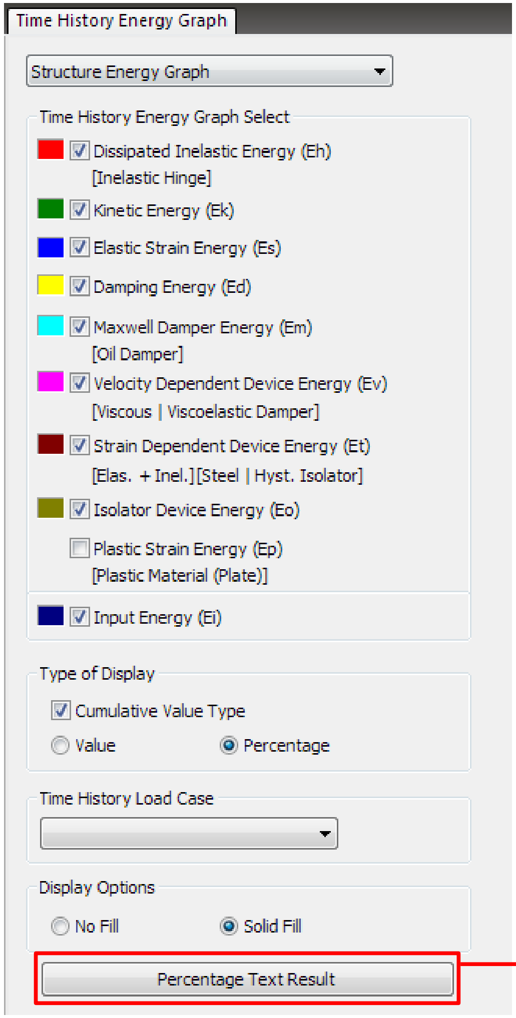
Display Options

○ No Fill ● Solid Fill

Percentage Text Result

## 1. Energy Result Graph for Time History Analysis

- ***Result > T.H. Graph/Text > Time History Energy Graph***



Time History Energy Graph

Structure Energy Graph

Time History Energy Graph Select

- 🟥 ☑ Dissipated Inelastic Energy (Eh) [Inelastic Hinge]
- 🟩 ☑ Kinetic Energy (Ek)
- 🟦 ☑ Elastic Strain Energy (Es)
- 🟨 ☑ Damping Energy (Ed)
- ☑ Maxwell Damper Energy (Em) [Oil Damper]
- ☑ Velocity Dependent Device Energy (Ev) [Viscous | Viscoelastic Damper]
- ☑ Strain Dependent Device Energy (Et) [Elas. + Inel.][Steel | Hyst. Isolator]
- ☑ Isolator Device Energy (Eo)
- ☐ Plastic Strain Energy (Ep) [Plastic Material (Plate)]
- ☑ Input Energy (Ei)

Type of Display

☑ Cumulative Value Type

○ Value ● Percentage

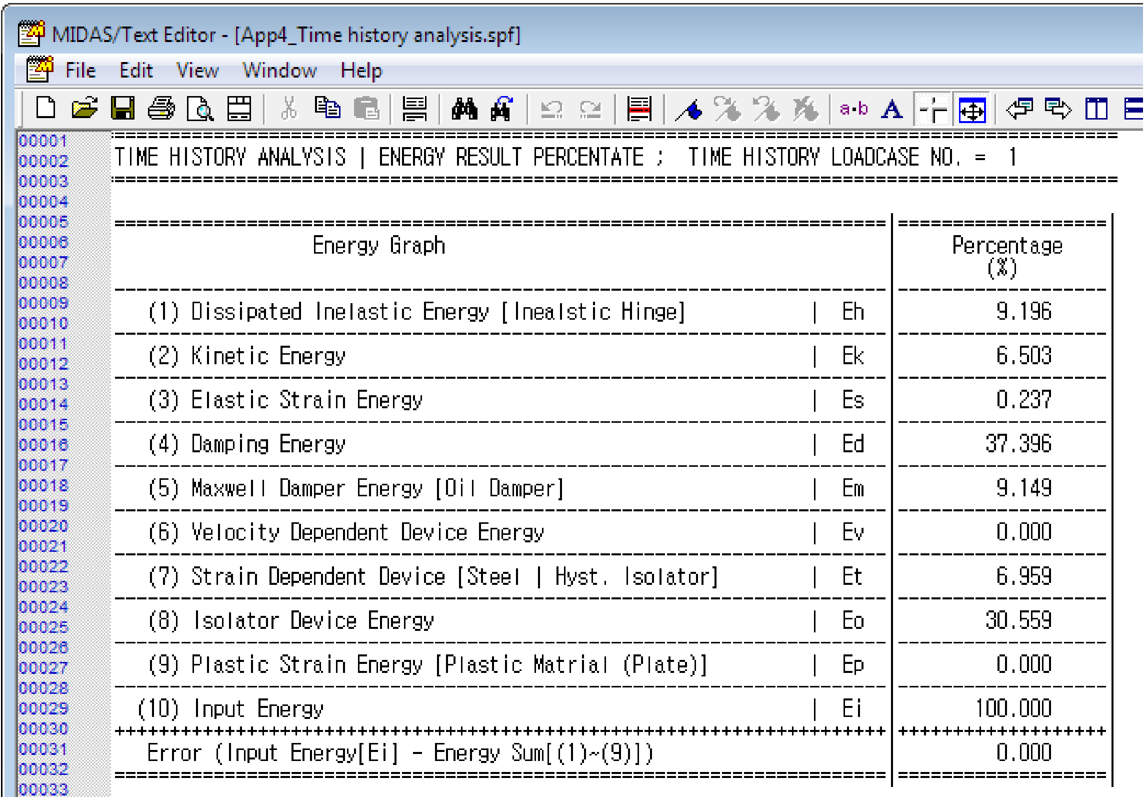
Time History Load Case

Display Options

○ No Fill ● Solid Fill

Percentage Text Result

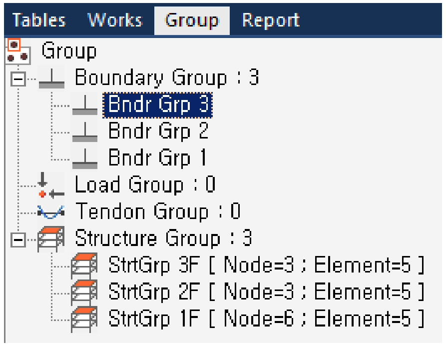
< Text result of the each energy ratio >



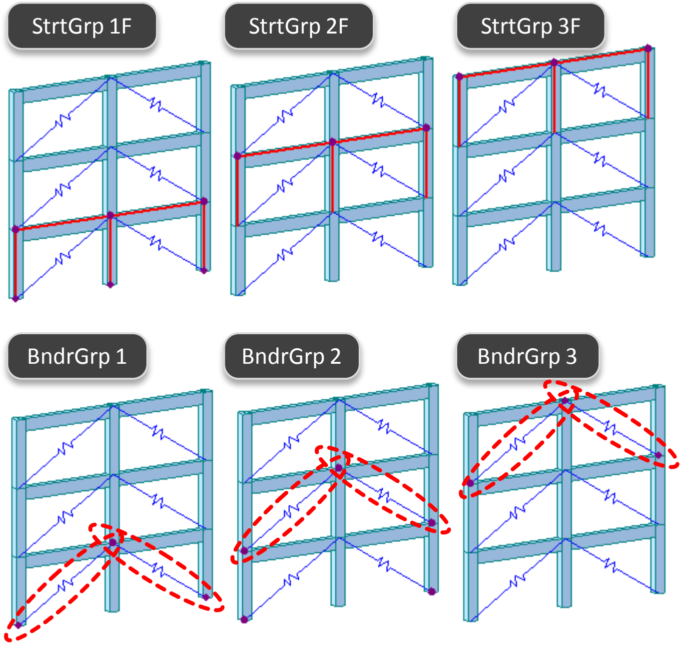
```
==================================================================================================
TIME HISTORY ANALYSIS | ENERGY RESULT PERCENTATE ;  TIME HISTORY LOADCASE NO. =  1
==================================================================================================

==================================================================== | ===================
                       Energy Graph                                  |     Percentage
                                                                     |        (%)
-------------------------------------------------------------------- | -------------------
   (1) Dissipated Inelastic Energy [Inealstic Hinge]          |  Eh  |        9.196
-------------------------------------------------------------------- | -------------------
   (2) Kinetic Energy                                         |  Ek  |        6.503
-------------------------------------------------------------------- | -------------------
   (3) Elastic Strain Energy                                  |  Es  |        0.237
-------------------------------------------------------------------- | -------------------
   (4) Damping Energy                                         |  Ed  |       37.396
-------------------------------------------------------------------- | -------------------
   (5) Maxwell Damper Energy [Oil Damper]                     |  Em  |        9.149
-------------------------------------------------------------------- | -------------------
   (6) Velocity Dependent Device Energy                       |  Ev  |        0.000
-------------------------------------------------------------------- | -------------------
   (7) Strain Dependent Device [Steel | Hyst. Isolator]       |  Et  |        6.959
-------------------------------------------------------------------- | -------------------
   (8) Isolator Device Energy                                 |  Eo  |       30.559
-------------------------------------------------------------------- | -------------------
   (9) Plastic Strain Energy [Plastic Matrial (Plate)]        |  Ep  |        0.000
-------------------------------------------------------------------- | -------------------
  (10) Input Energy                                           |  Ei  |      100.000
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++ | +++++++++++++++++++
   Error (Input Energy[Ei] - Energy Sum[(1)~(9)])                    |        0.000
==================================================================== | ===================
```

# 1. Energy Result Graph for Time History Analysis

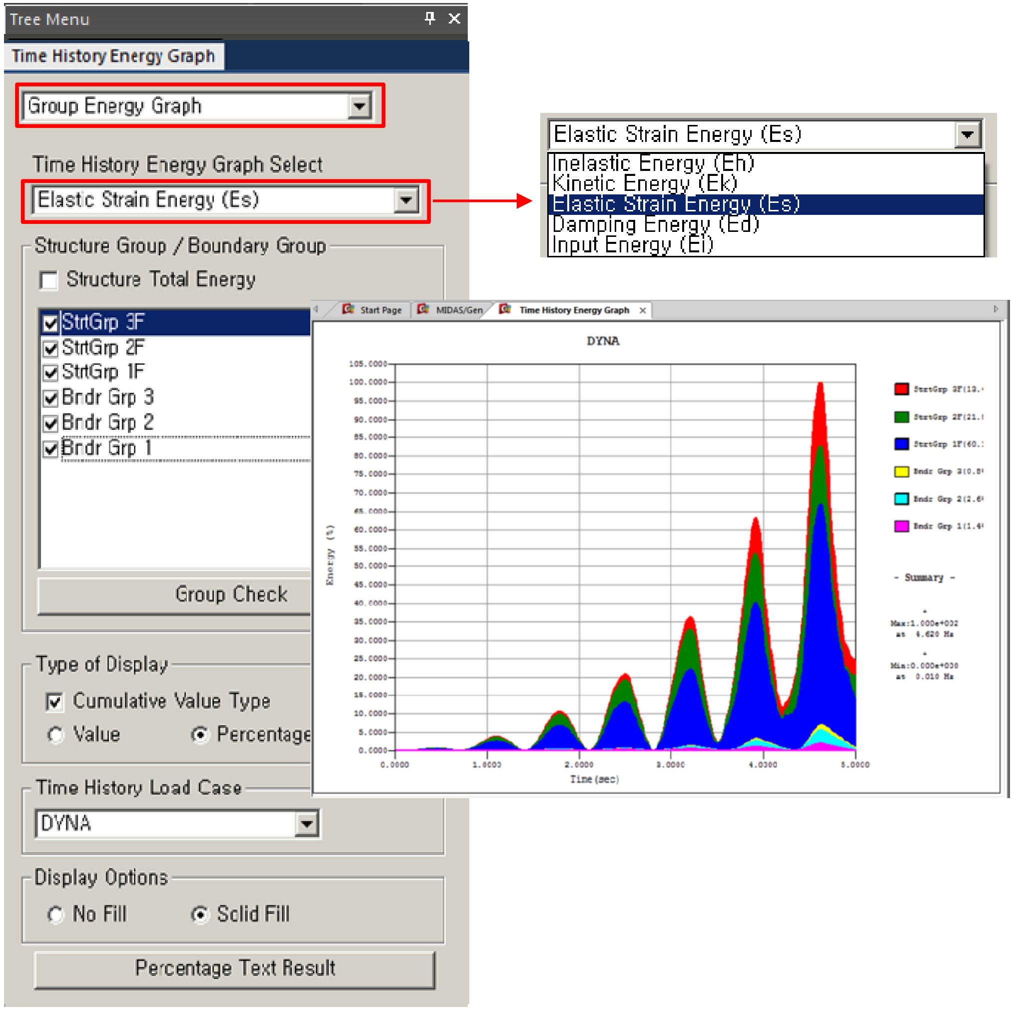
- ***Result > T.H. Graph/Text >*** ***Time History Energy Graph***



Group
- Boundary Group : 3
  - Bndr Grp 3
  - Bndr Grp 2
  - Bndr Grp 1
- Load Group : 0
- Tendon Group : 0
- Structure Group : 3
  - StrtGrp 3F [ Node=3 ; Element=5 ]
  - StrtGrp 2F [ Node=3 ; Element=5 ]
  - StrtGrp 1F [ Node=6 ; Element=5 ]



< Result output of group distribution for each energy item >



Group Energy Graph

Time History Energy Graph Select: Elastic Strain Energy (Es)

- Elastic Strain Energy (Es)
  - Inelastic Energy (Eh)
  - Kinetic Energy (Ek)
  - Elastic Strain Energy (Es)
  - Damping Energy (Ed)
  - Input Energy (Ei)

Structure Group / Boundary Group
- ☐ Structure Total Energy
- ☑ StrtGrp 3F
- ☑ StrtGrp 2F
- ☑ StrtGrp 1F
- ☑ Bndr Grp 3
- ☑ Bndr Grp 2
- ☑ Bndr Grp 1

Type of Display
- ☑ Cumulative Value Type
- ○ Value ● Percentage

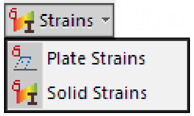
Time History Load Case: DYNA

Display Options
- ○ No Fill ● Solid Fill

## 2. Strain Output for Material Nonlinear Analysis

- Strain results are provided for plastic materials, i.e. Tresca, Von Mises, Mohr-Coulomb, Drucker-Prager, and Concrete Damage.
- Damage ratios for compression and tension are provided for the 'Concrete Damage' model.

- ***Results > Results > Strains > Plate Strains/ Solid Strains***



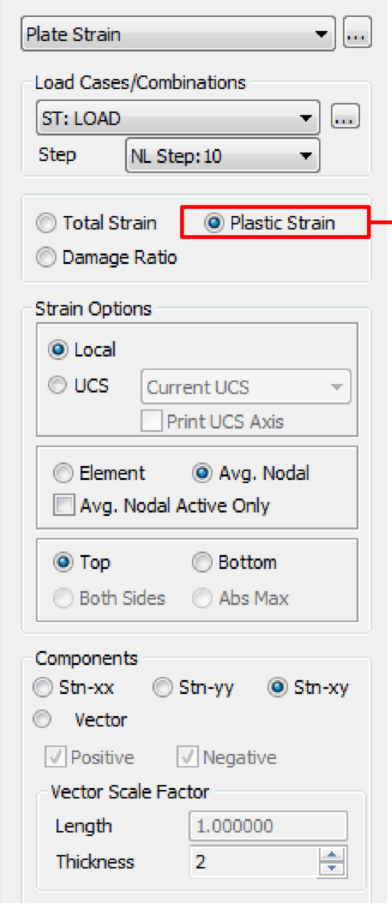


Plate Strain

Load Cases/Combinations: ST: LOAD

Step: NL Step:10

○ Total Strain ● Plastic Strain
○ Damage Ratio

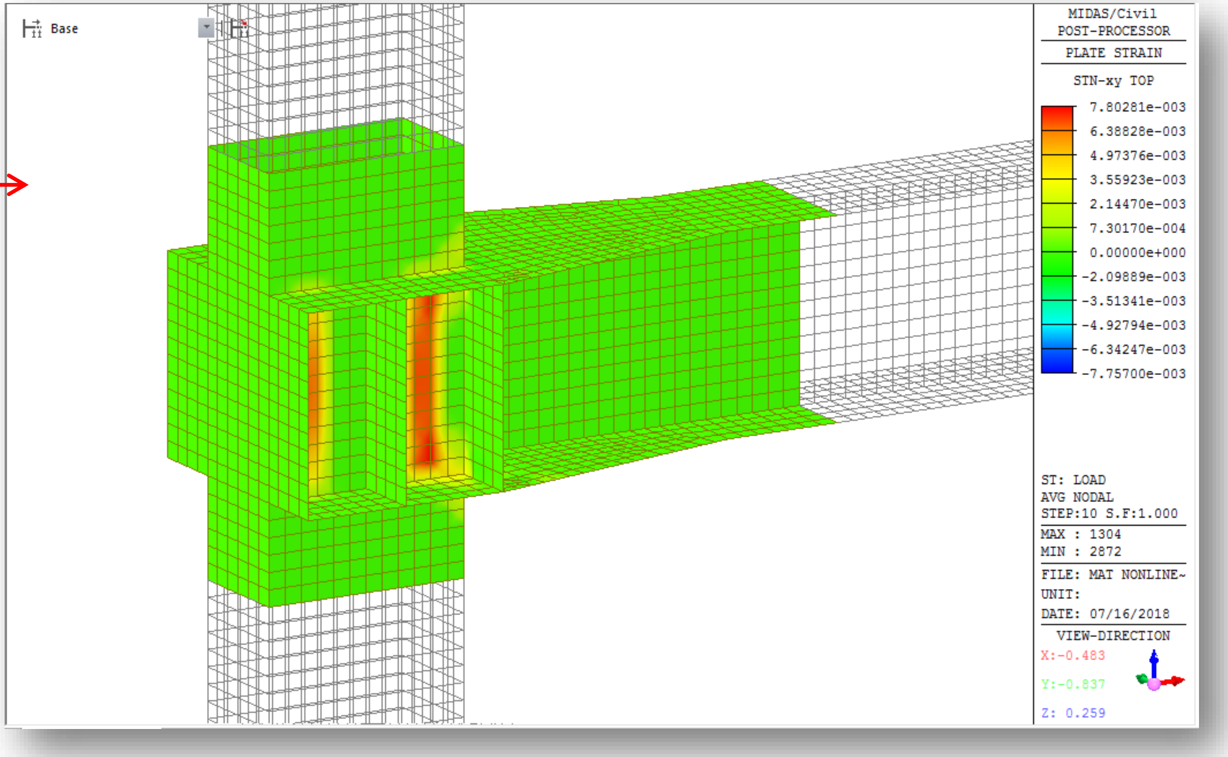
Strain Options
● Local
○ UCS Current UCS
☐ Print UCS Axis

○ Element ● Avg. Nodal
☐ Avg. Nodal Active Only

● Top ○ Bottom
○ Both Sides ○ Abs Max

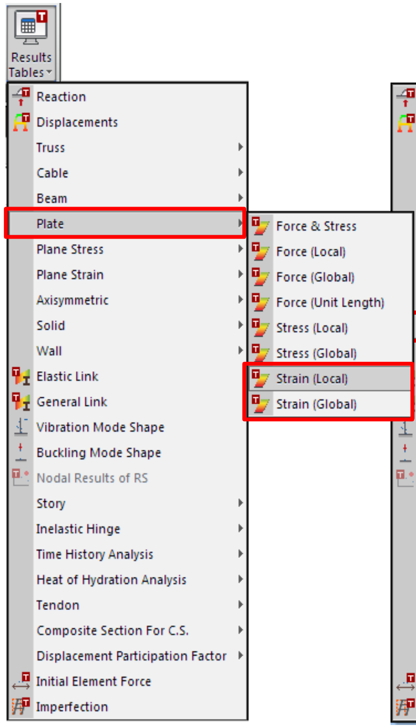
Components
○ Stn-xx ○ Stn-yy ● Stn-xy
○ Vector
☑ Positive ☑ Negative

Vector Scale Factor
Length: 1.000000
Thickness: 2

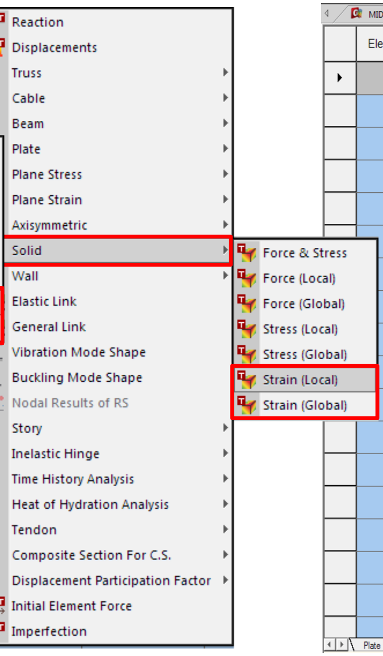


## 2. Strain Output for Material Nonlinear Analysis

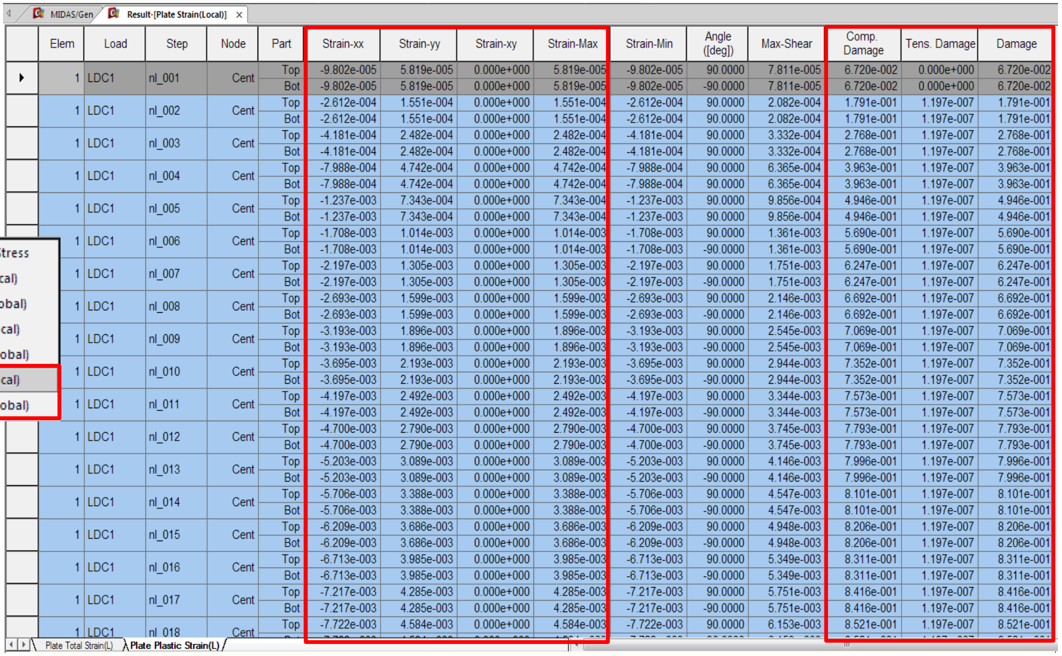
- ***Results > Tables > Results Tables > Plate/ Solid > Strain(local)/ Strain(Global)***



<Plate Strain (local) menu>



<Solid Strain (local) menu>



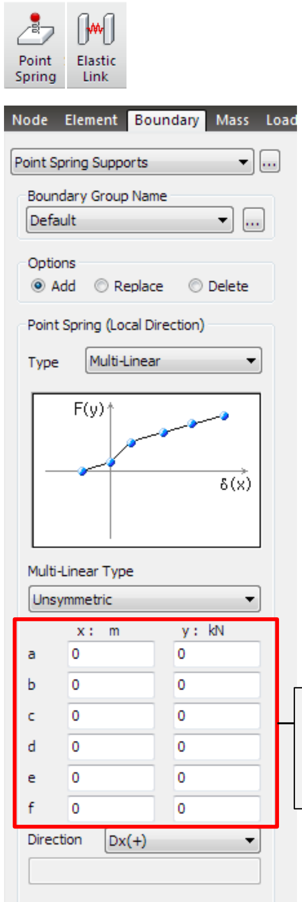
| Elem | Load | Step | Node | Part | Strain-xx | Strain-yy | Strain-xy | Strain-Max | Strain-Min | Angle ([deg]) | Max-Shear | Comp. Damage | Tens. Damage | Damage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | LDC1 | nl_001 | Cent | Top | -9.802e-005 | 5.819e-005 | 0.000e+000 | 5.819e-005 | -9.802e-005 | 90.0000 | 7.811e-005 | 6.720e-002 | 0.000e+000 | 6.720e-002 |
| | | | | Bot | -9.802e-005 | 5.819e-005 | 0.000e+000 | 5.819e-005 | -9.802e-005 | -90.0000 | 7.811e-005 | 6.720e-002 | 0.000e+000 | 6.720e-002 |
| 1 | LDC1 | nl_002 | Cent | Top | -2.612e-004 | 1.551e-004 | 0.000e+000 | 1.551e-004 | -2.612e-004 | 90.0000 | 2.082e-004 | 1.791e-001 | 1.197e-007 | 1.791e-001 |
| | | | | Bot | -2.612e-004 | 1.551e-004 | 0.000e+000 | 1.551e-004 | -2.612e-004 | 90.0000 | 2.082e-004 | 1.791e-001 | 1.197e-007 | 1.791e-001 |
| 1 | LDC1 | nl_003 | Cent | Top | -4.181e-004 | 2.482e-004 | 0.000e+000 | 2.482e-004 | -4.181e-004 | 90.0000 | 3.332e-004 | 2.768e-001 | 1.197e-007 | 2.768e-001 |
| | | | | Bot | -4.181e-004 | 2.482e-004 | 0.000e+000 | 2.482e-004 | -4.181e-004 | 90.0000 | 3.332e-004 | 2.768e-001 | 1.197e-007 | 2.768e-001 |
| 1 | LDC1 | nl_004 | Cent | Top | -7.988e-004 | 4.742e-004 | 0.000e+000 | 4.742e-004 | -7.988e-004 | 90.0000 | 6.365e-004 | 3.963e-001 | 1.197e-007 | 3.963e-001 |
| | | | | Bot | -7.988e-004 | 4.742e-004 | 0.000e+000 | 4.742e-004 | -7.988e-004 | 90.0000 | 6.365e-004 | 3.963e-001 | 1.197e-007 | 3.963e-001 |
| 1 | LDC1 | nl_005 | Cent | Top | -1.237e-003 | 7.343e-004 | 0.000e+000 | 7.343e-004 | -1.237e-003 | 90.0000 | 9.856e-004 | 4.946e-001 | 1.197e-007 | 4.946e-001 |
| | | | | Bot | -1.237e-003 | 7.343e-004 | 0.000e+000 | 7.343e-004 | -1.237e-003 | 90.0000 | 9.856e-004 | 4.946e-001 | 1.197e-007 | 4.946e-001 |
| 1 | LDC1 | nl_006 | Cent | Top | -1.708e-003 | 1.014e-003 | 0.000e+000 | 1.014e-003 | -1.708e-003 | 90.0000 | 1.361e-003 | 5.690e-001 | 1.197e-007 | 5.690e-001 |
| | | | | Bot | -1.708e-003 | 1.014e-003 | 0.000e+000 | 1.014e-003 | -1.708e-003 | -90.0000 | 1.361e-003 | 5.690e-001 | 1.197e-007 | 5.690e-001 |
| 1 | LDC1 | nl_007 | Cent | Top | -2.197e-003 | 1.305e-003 | 0.000e+000 | 1.305e-003 | -2.197e-003 | 90.0000 | 1.751e-003 | 6.247e-001 | 1.197e-007 | 6.247e-001 |
| | | | | Bot | -2.197e-003 | 1.305e-003 | 0.000e+000 | 1.305e-003 | -2.197e-003 | -90.0000 | 1.751e-003 | 6.247e-001 | 1.197e-007 | 6.247e-001 |
| 1 | LDC1 | nl_008 | Cent | Top | -2.693e-003 | 1.599e-003 | 0.000e+000 | 1.599e-003 | -2.693e-003 | 90.0000 | 2.146e-003 | 6.692e-001 | 1.197e-007 | 6.692e-001 |
| | | | | Bot | -2.693e-003 | 1.599e-003 | 0.000e+000 | 1.599e-003 | -2.693e-003 | -90.0000 | 2.146e-003 | 6.692e-001 | 1.197e-007 | 6.692e-001 |
| 1 | LDC1 | nl_009 | Cent | Top | -3.193e-003 | 1.896e-003 | 0.000e+000 | 1.896e-003 | -3.193e-003 | 90.0000 | 2.545e-003 | 7.069e-001 | 1.197e-007 | 7.069e-001 |
| | | | | Bot | -3.193e-003 | 1.896e-003 | 0.000e+000 | 1.896e-003 | -3.193e-003 | -90.0000 | 2.545e-003 | 7.069e-001 | 1.197e-007 | 7.069e-001 |
| 1 | LDC1 | nl_010 | Cent | Top | -3.695e-003 | 2.193e-003 | 0.000e+000 | 2.193e-003 | -3.695e-003 | 90.0000 | 2.944e-003 | 7.352e-001 | 1.197e-007 | 7.352e-001 |
| | | | | Bot | -3.695e-003 | 2.193e-003 | 0.000e+000 | 2.193e-003 | -3.695e-003 | -90.0000 | 2.944e-003 | 7.352e-001 | 1.197e-007 | 7.352e-001 |
| 1 | LDC1 | nl_011 | Cent | Top | -4.197e-003 | 2.492e-003 | 0.000e+000 | 2.492e-003 | -4.197e-003 | 90.0000 | 3.344e-003 | 7.573e-001 | 1.197e-007 | 7.573e-001 |
| | | | | Bot | -4.197e-003 | 2.492e-003 | 0.000e+000 | 2.492e-003 | -4.197e-003 | -90.0000 | 3.344e-003 | 7.573e-001 | 1.197e-007 | 7.573e-001 |
| 1 | LDC1 | nl_012 | Cent | Top | -4.700e-003 | 2.790e-003 | 0.000e+000 | 2.790e-003 | -4.700e-003 | 90.0000 | 3.745e-003 | 7.793e-001 | 1.197e-007 | 7.793e-001 |
| | | | | Bot | -4.700e-003 | 2.790e-003 | 0.000e+000 | 2.790e-003 | -4.700e-003 | -90.0000 | 3.745e-003 | 7.793e-001 | 1.197e-007 | 7.793e-001 |
| 1 | LDC1 | nl_013 | Cent | Top | -5.203e-003 | 3.089e-003 | 0.000e+000 | 3.089e-003 | -5.203e-003 | 90.0000 | 4.146e-003 | 7.996e-001 | 1.197e-007 | 7.996e-001 |
| | | | | Bot | -5.203e-003 | 3.089e-003 | 0.000e+000 | 3.089e-003 | -5.203e-003 | -90.0000 | 4.146e-003 | 7.996e-001 | 1.197e-007 | 7.996e-001 |
| 1 | LDC1 | nl_014 | Cent | Top | -5.706e-003 | 3.388e-003 | 0.000e+000 | 3.388e-003 | -5.706e-003 | 90.0000 | 4.547e-003 | 8.101e-001 | 1.197e-007 | 8.101e-001 |
| | | | | Bot | -5.706e-003 | 3.388e-003 | 0.000e+000 | 3.388e-003 | -5.706e-003 | -90.0000 | 4.547e-003 | 8.101e-001 | 1.197e-007 | 8.101e-001 |
| 1 | LDC1 | nl_015 | Cent | Top | -6.209e-003 | 3.686e-003 | 0.000e+000 | 3.686e-003 | -6.209e-003 | 90.0000 | 4.948e-003 | 8.206e-001 | 1.197e-007 | 8.206e-001 |
| | | | | Bot | -6.209e-003 | 3.686e-003 | 0.000e+000 | 3.686e-003 | -6.209e-003 | -90.0000 | 4.948e-003 | 8.206e-001 | 1.197e-007 | 8.206e-001 |
| 1 | LDC1 | nl_016 | Cent | Top | -6.713e-003 | 3.985e-003 | 0.000e+000 | 3.985e-003 | -6.713e-003 | 90.0000 | 5.349e-003 | 8.311e-001 | 1.197e-007 | 8.311e-001 |
| | | | | Bot | -6.713e-003 | 3.985e-003 | 0.000e+000 | 3.985e-003 | -6.713e-003 | -90.0000 | 5.349e-003 | 8.311e-001 | 1.197e-007 | 8.311e-001 |
| 1 | LDC1 | nl_017 | Cent | Top | -7.217e-003 | 4.285e-003 | 0.000e+000 | 4.285e-003 | -7.217e-003 | 90.0000 | 5.751e-003 | 8.416e-001 | 1.197e-007 | 8.416e-001 |
| | | | | Bot | -7.217e-003 | 4.285e-003 | 0.000e+000 | 4.285e-003 | -7.217e-003 | -90.0000 | 5.751e-003 | 8.416e-001 | 1.197e-007 | 8.416e-001 |
| 1 | LDC1 | nl_018 | Cent | Top | -7.722e-003 | 4.584e-003 | 0.000e+000 | 4.584e-003 | -7.722e-003 | 90.0000 | 6.153e-003 | 8.521e-001 | 1.197e-007 | 8.521e-001 |

Plate Strain Table

## 3. Multi-linear force-deformation function for Point Spring Support and Elastic Link

- Multi-linear curve for Point Spring Support and Elastic Link can be defined as a function without limitation in terms of number of data.

< Previous version >



Point Spring Supports

Boundary Group Name: Default

Options: ● Add ○ Replace ○ Delete

Point Spring (Local Direction)

Type: Multi-Linear

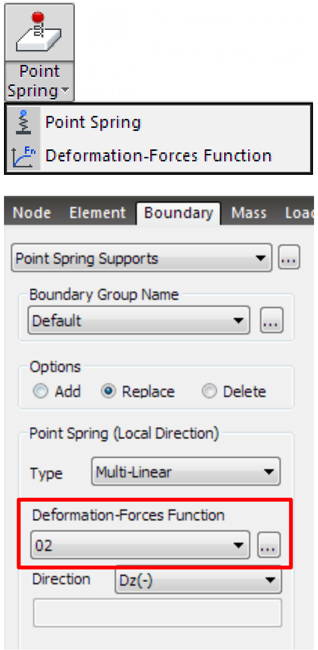
Multi-Linear Type: Unsymmetric

| | x : m | y : kN |
|---|---|---|
| a | 0 | 0 |
| b | 0 | 0 |
| c | 0 | 0 |
| d | 0 | 0 |
| e | 0 | 0 |
| f | 0 | 0 |

Direction: Dx(+)

Multi-linear is defined as 6 points in the previous version.

< Civil 2019 (v1.1) >



Point Spring Supports

Boundary Group Name: Default

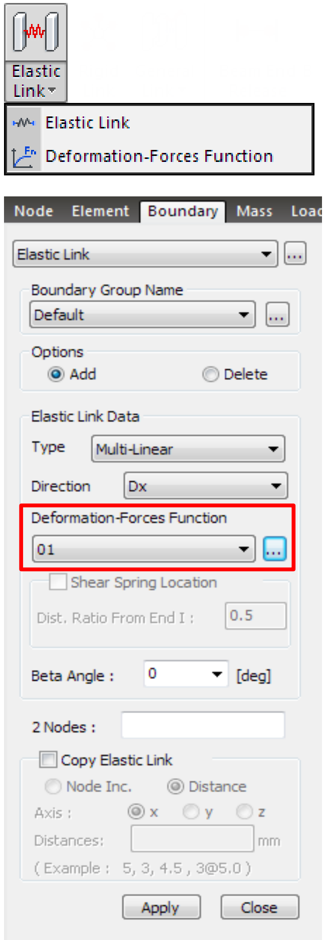
Options: ○ Add ● Replace ○ Delete

Point Spring (Local Direction)

Type: Multi-Linear

Deformation-Forces Function: 02

Direction: Dz(-)



Elastic Link

Boundary Group Name: Default

Options: ● Add ○ Delete

Elastic Link Data

Type: Multi-Linear

Direction: Dx

Deformation-Forces Function: 01

☐ Shear Spring Location

Dist. Ratio From End I : 0.5

Beta Angle : 0 [deg]

2 Nodes :

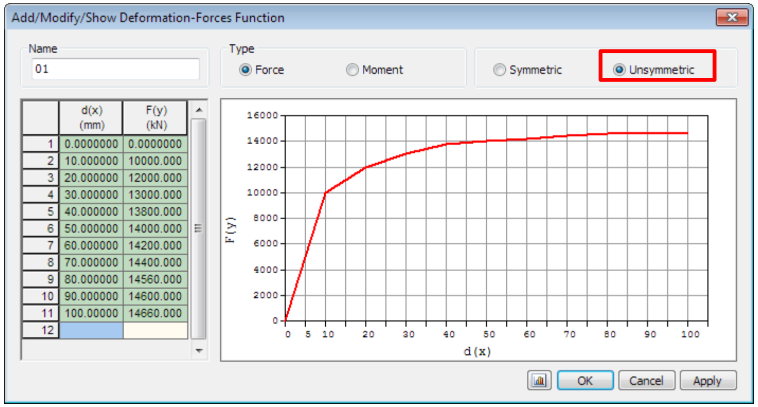
☐ Copy Elastic Link

○ Node Inc. ● Distance

Axis : ● x ○ y ○ z

Distances: mm

( Example : 5, 3, 4.5 , 3@5.0 )

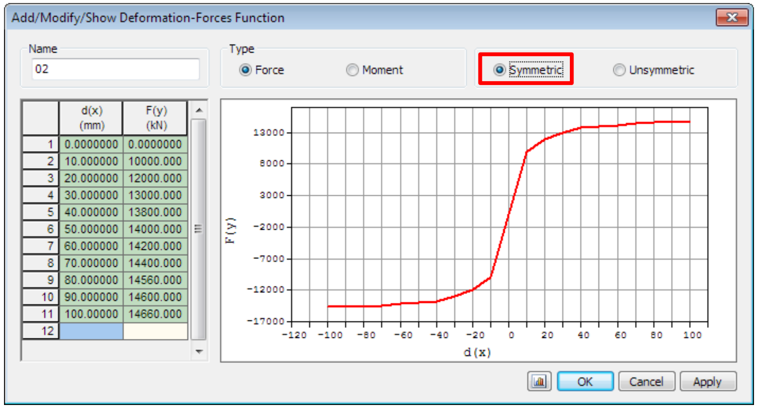


Add/Modify/Show Deformation-Forces Function

Name: 01

Type: ● Force ○ Moment ○ Symmetric ● Unsymmetric

| | d(x) (mm) | F(y) (kN) |
|---|---|---|
| 1 | 0.0000000 | 0.0000000 |
| 2 | 10.000000 | 10000.000 |
| 3 | 20.000000 | 12000.000 |
| 4 | 30.000000 | 13000.000 |
| 5 | 40.000000 | 13800.000 |
| 6 | 50.000000 | 14000.000 |
| 7 | 60.000000 | 14200.000 |
| 8 | 70.000000 | 14400.000 |
| 9 | 80.000000 | 14560.000 |
| 10 | 90.000000 | 14600.000 |
| 11 | 100.000000 | 14660.000 |
| 12 | | |



Add/Modify/Show Deformation-Forces Function

Name: 02

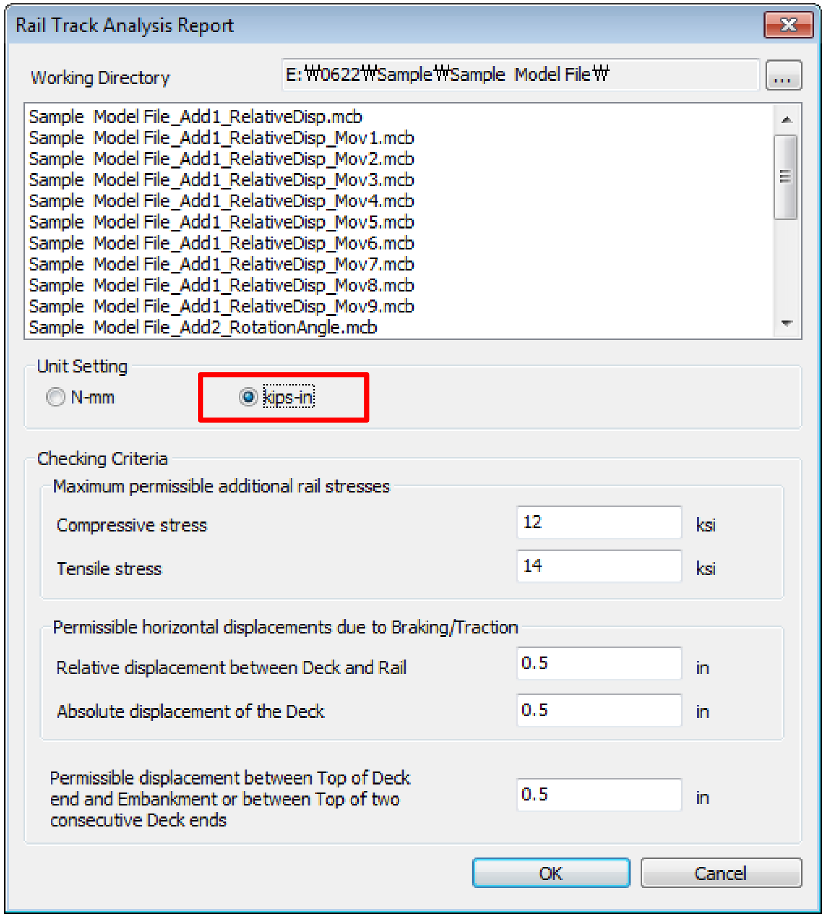
Type: ● Force ○ Moment ● Symmetric ○ Unsymmetric

| | d(x) (mm) | F(y) (kN) |
|---|---|---|
| 1 | 0.0000000 | 0.0000000 |
| 2 | 10.000000 | 10000.000 |
| 3 | 20.000000 | 12000.000 |
| 4 | 30.000000 | 13000.000 |
| 5 | 40.000000 | 13800.000 |
| 6 | 50.000000 | 14000.000 |
| 7 | 60.000000 | 14200.000 |
| 8 | 70.000000 | 14400.000 |
| 9 | 80.000000 | 14560.000 |
| 10 | 90.000000 | 14600.000 |
| 11 | 100.000000 | 14660.000 |
| 12 | | |

## 4. Rail Track Analysis Report with the US Unit Setting

- Rail Track Analysis report supports the US unit system as well as SI unit system.

- ***Structure > Wizard > Rail Track Analysis Model > Rail Track Analysis Report***



Rail Track Analysis Report

Working Directory: E:₩0622₩Sample₩Sample Model File₩

Sample Model File_Add1_RelativeDisp.mcb
Sample Model File_Add1_RelativeDisp_Mov1.mcb
Sample Model File_Add1_RelativeDisp_Mov2.mcb
Sample Model File_Add1_RelativeDisp_Mov3.mcb
Sample Model File_Add1_RelativeDisp_Mov4.mcb
Sample Model File_Add1_RelativeDisp_Mov5.mcb
Sample Model File_Add1_RelativeDisp_Mov6.mcb
Sample Model File_Add1_RelativeDisp_Mov7.mcb
Sample Model File_Add1_RelativeDisp_Mov8.mcb
Sample Model File_Add1_RelativeDisp_Mov9.mcb
Sample Model File_Add2_RotationAngle.mcb

Unit Setting: ○ N-mm ● kips-in

Checking Criteria

Maximum permissible additional rail stresses

Compressive stress: 12 ksi

Tensile stress: 14 ksi

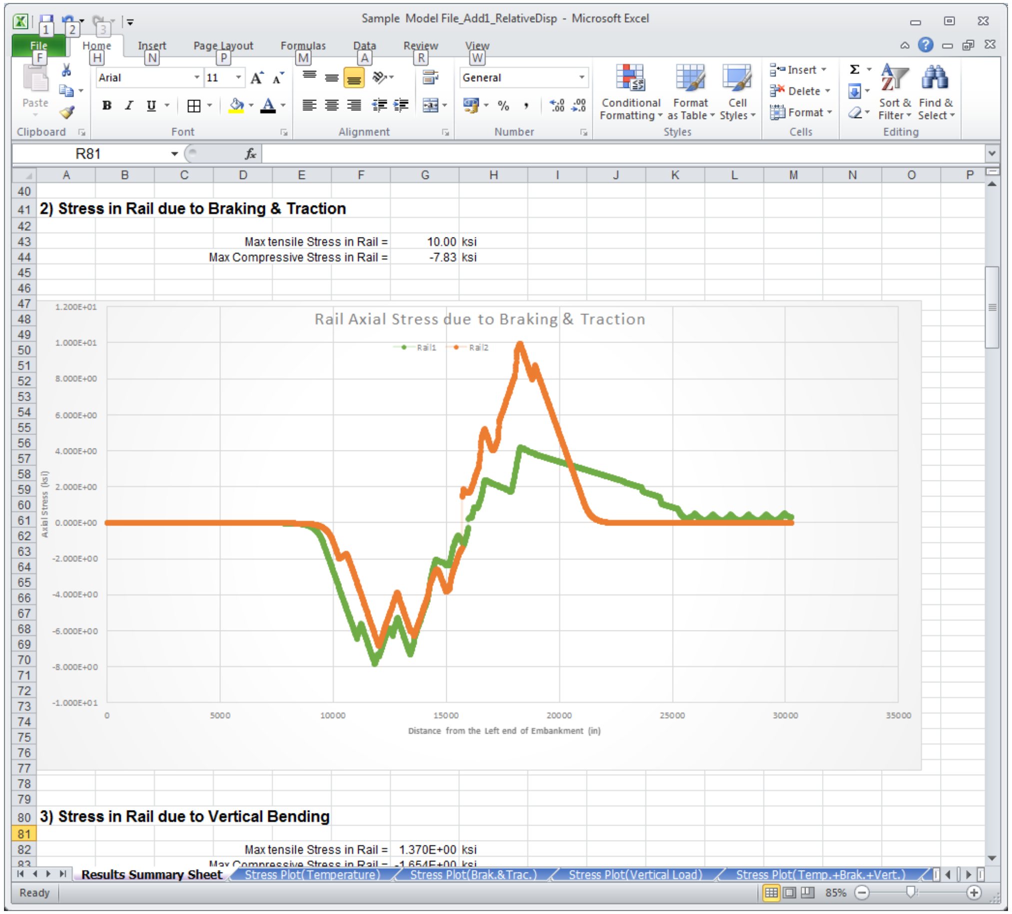
Permissible horizontal displacements due to Braking/Traction

Relative displacement between Deck and Rail: 0.5 in

Absolute displacement of the Deck: 0.5 in

Permissible displacement between Top of Deck end and Embankment or between Top of two consecutive Deck ends: 0.5 in

Report Setting to the US unit



Sample Model File_Add1_RelativeDisp - Microsoft Excel

R81

**2) Stress in Rail due to Braking & Traction**

Max tensile Stress in Rail = 10.00 ksi
Max Compressive Stress in Rail = -7.83 ksi

**3) Stress in Rail due to Vertical Bending**

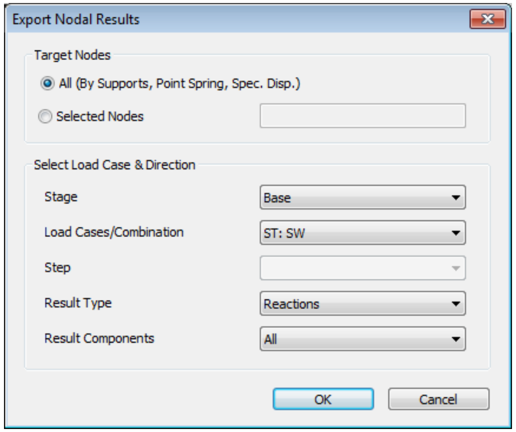
Max tensile Stress in Rail = 1.370E+00 ksi
Max Compressive Stress in Rail = -1.654E+00 ksi

Rail Track Analysis Report

## 5. Data Interface with GTS NX

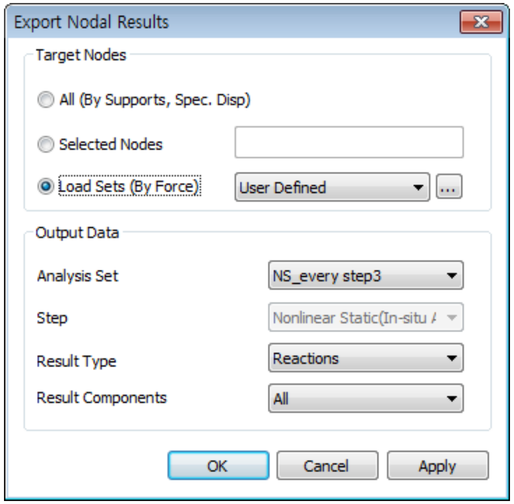
- Reactions from Point Spring Support can be exported to GTS NX.
- Force-displacement results of soil can be imported from GTS NX into midas Civil, and the input data of the multi-linear Point Spring Supports are updated.

- ***File > Export > Nodal Results for GTS***
- ***File > Import > Nodal Results for GTS***


Export Nodal Results

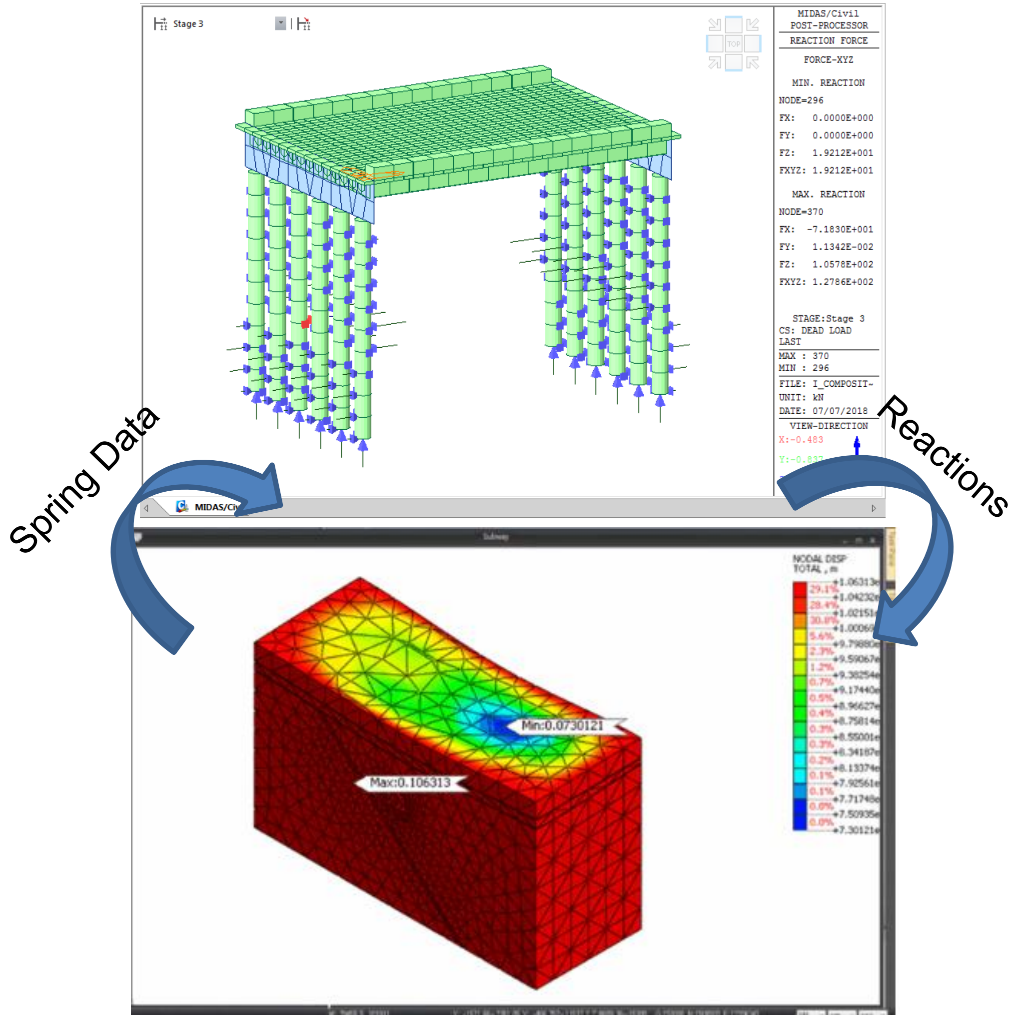
Target Nodes
● All (By Supports, Point Spring, Spec. Disp.)
○ Selected Nodes

Select Load Case & Direction
Stage: Base
Load Cases/Combination: ST: SW
Step:
Result Type: Reactions
Result Components: All


Export Nodal Results

Target Nodes
○ All (By Supports, Spec. Disp)
○ Selected Nodes
● Load Sets (By Force): User Defined

Output Data
Analysis Set: NS_every step3
Step: Nonlinear Static(In-situ /
Result Type: Reactions
Result Components: All

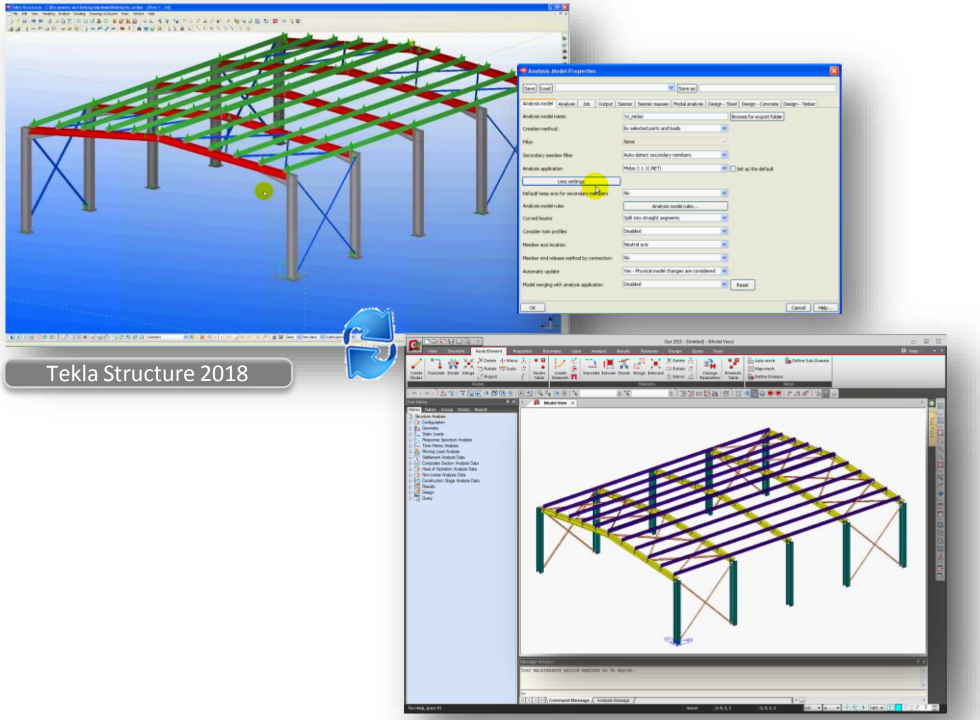


```
MIDAS/Civil
POST-PROCESSOR
REACTION FORCE
FORCE-XYZ
MIN. REACTION
NODE=296
FX:   0.0000E+000
FY:   0.0000E+000
FZ:   1.9212E+001
FXYZ: 1.9212E+001
MAX. REACTION
NODE=370
FX:  -7.1830E+001
FY:   1.1342E-002
FZ:   1.0578E+002
FXYZ: 1.2786E+002

STAGE:Stage 3
CS: DEAD LOAD
LAST
MAX : 370
MIN : 296
FILE: I_COMPOSIT~
UNIT: kN
DATE: 07/07/2018
VIEW-DIRECTION
X:-0.483
Y:-0.837
```

## 6. Tekla Structure 2018 Interface

- Tekla Structures interface is a tool provided to speed up the entire modeling, analysis, and design procedure of a structure by direct data transfer with midas Civil.
- Data transfer is limited to structural elements.
- Tekla Structure interface enables us to directly transfer a Tekla model data to midas Civil, and delivery back to the Tekla model file. midas Civil text file (*.mct) is used for the roundtrip.

- ***File > Import > midas Civil MCT File***
- ***File > Export > midas Civil MCT File***



Tekla Structure 2018

Civil 2019

| Category | Features | Tekla <> Gen |
|---|---|---|
| **MATERIAL** | concrete | <> |
| | steel | <> |
| | pre cast - wood and other types | <> |
| | Material user defined | <> |
| **ELEMENT TYPE/ ROTATIONS** | vertical column | <> |
| | inclined column | <> |
| | straight beam | <> |
| | curved beam | > |
| | Slab | <> |
| | vertical panel | > |
| **2D ELEMENTS** | Concrete panels and slab | <> |
| **BOUNDARY CONDITIONS** | support | > |
| | beam end release | <> |
| | section offset | > |
| **STATIC LOAD** | self weigth | > |
| | linear load (uniform or trapezoidal) | <> |
| **MERGE OPTION** | new element | <> |
| | new element that divide other elements | <> |
| | topology changes | <> |