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2016

Title: All-In-One Super and Sub Structure Design

NAME Edgar De Los Santos / MIDAS IT – United States

Substructure Training Series

- **Session 1:**
  3D substructure analysis and design

- **Session 2:**
  All-In-One Super & Sub Structure Design

- **Session 3:**
  Essential Soil-Structure Interaction for Bridge

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Content

- Midas Civil: All-in-one Solution
- Advantages of full model
- MIDAS Modeling
  - Superstructure and substructure interaction
  - Boundary conditions
- Midas Civil Design
  - RC Design
    - Pier Cap Design
    - Column Design

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Midas Civil All-In-One Solution

midas Civil – All-in-one Solution

- Steel Plate Girder Bridge
- Precast Girder Bridge
- Push Over Analysis
- Dynamic Analysis
- Concrete Arch Bridge
- Extradosed Bridge
- Culvert
- Slab Bridge
- Moving Load
- Integral Abutment
- Movable Scaffolding Bridge
- Nonlinear Dynamic Analysis
- Steel Arch Bridge
- Truss Bridge
- Cable Stayed Bridge
- PSC Bridge
- Incremental Launching Bridge
- Precast Segmental Bridge
- Steel Box Girder Bridge
- Multi-Cell Box Girder Bridge
- Suspension Bridge
- Long Span Bridge
- Balanced Cantilever Bridge
- Full Staging Bridge

Importance of Full Model Analysis

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Advantages of Full Model Analysis

-More accurate results

The entire structure works together as a system. The behavior of the superstructure influences the substructure and vice versa. Separating them, creates a discrepancy with its real behavior. In the case of Seismic analysis, for example, the period of the structure is influenced by the stiffness of the substructure. It changes with the stiffness and geometry of the substructure.

-No need for multiple files

Everything can be done in one model file.

-Less time modeling

Since everything is modeled in one file, there is no time waste transferring the information from one program to the other.

-More realistic behavior (Parameters are not assumed)

Modeling the entire system can be very useful because the amount of assumed parameters is reduced. Providing us a more realistic behavior, displacements, stresses, etc.

-More economical design

Having the entire system modeled gives us a less conservative/ more accurate analysis which gives us a more economical structure.

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Pier & Abutments

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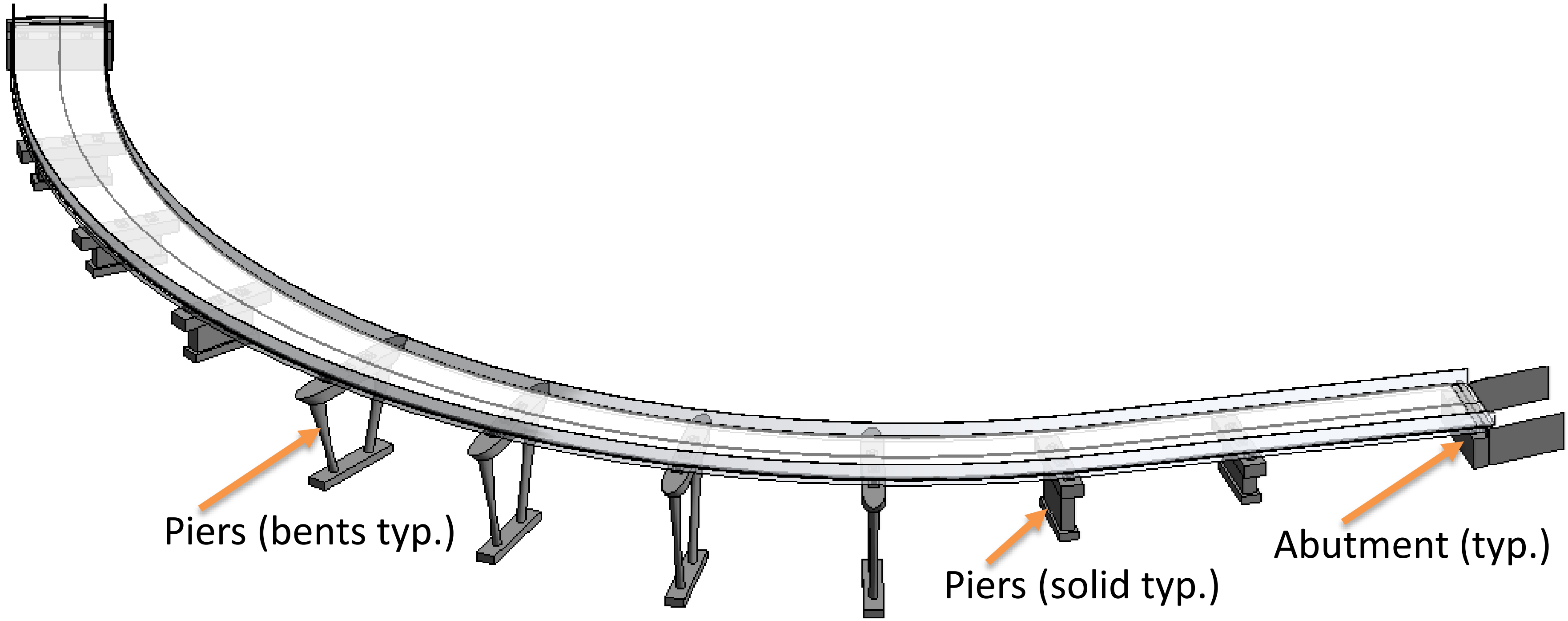
Piers & Abutments

an integral part of the load path between the superstructure and the foundation

Functions of Piers:

- To transfer the superstructure vertical loads to the foundation
- To resist all horizontal forces acting on the bridge

Abutments in addition to the above functions of piers are used at the ends of bridges to retain the embankment



Superstructure and Substructure Modeling

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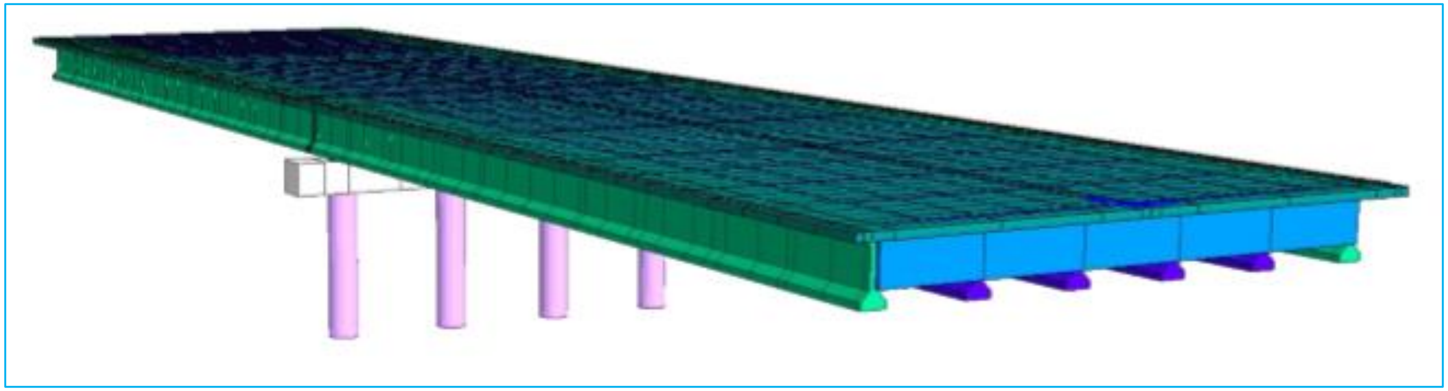
Bridge modeling

System model, analysis and design
Best modeling approach
#1: Wizard
#2: Manual / CAD Import

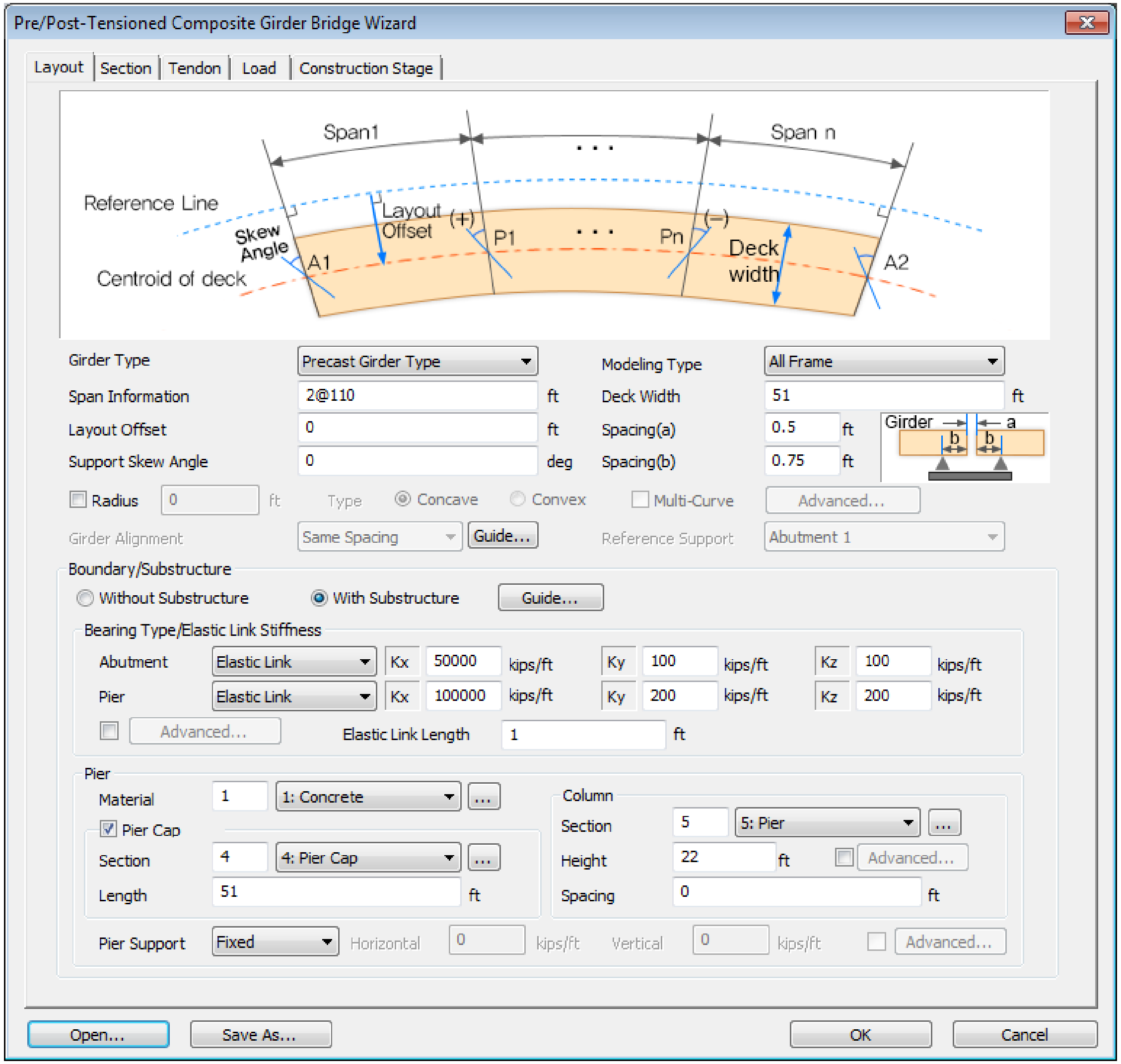


What is the Composite Girder Wizard?

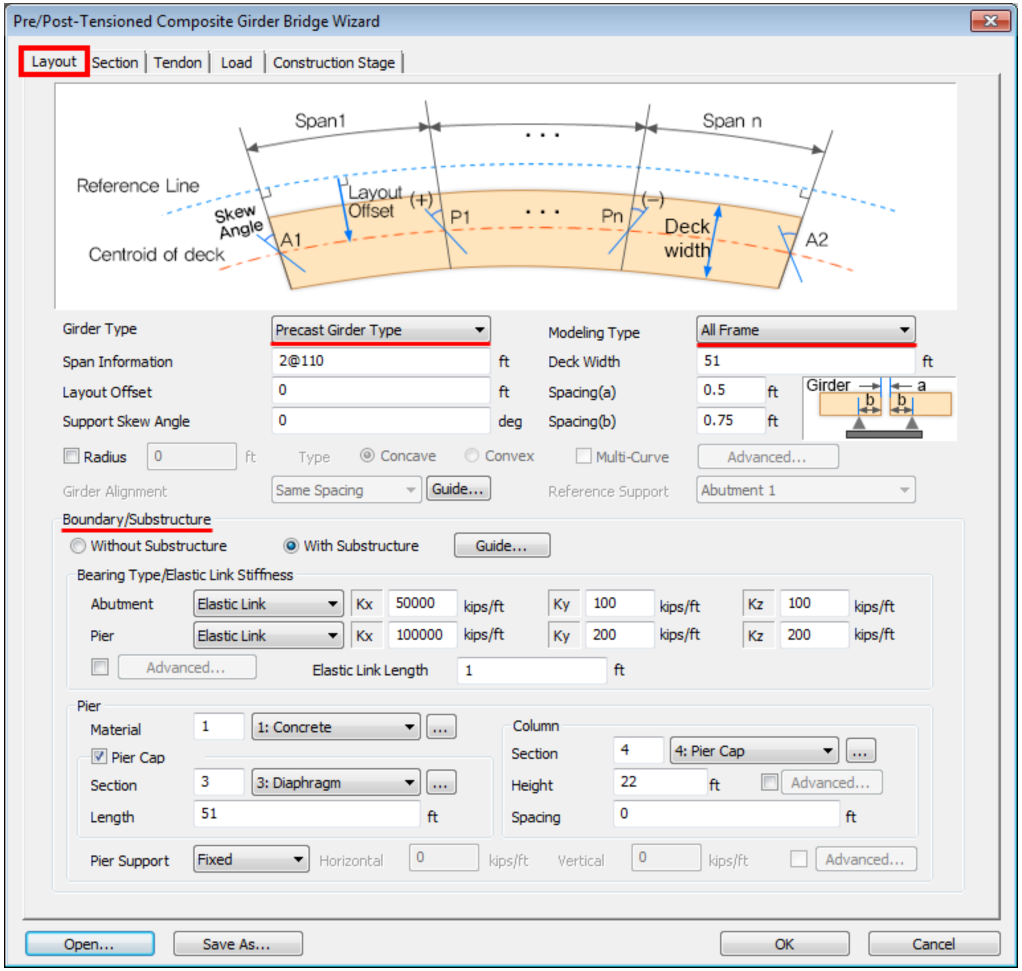
- **Wizard-modeling**
  - Steel Composite Bridge
  - PSC Composite Bridge

- Report Generation for design & load rating check
- AASHTO
  - Steel Composite
  - PSC Composite
  - RC Pier
  - Cross-frames
- Canada Code (Will be updated this year)
  - Steel Composite
  - PSC Composite

PSC Composite Girder Wizard

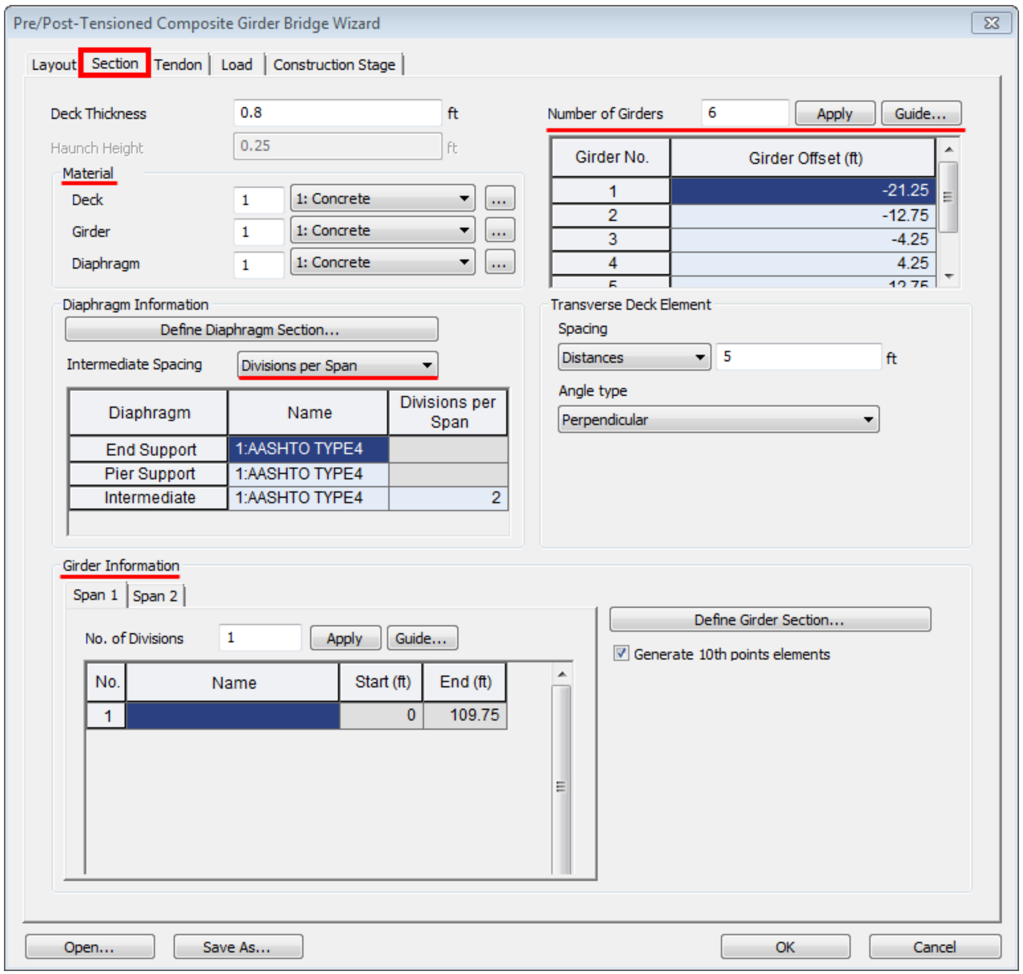


Wizard : Layout



- **Girder Type**
  - Precast / Splice
- **Modeling Type**
  - All Frame
  - Girder as frame, Deck as plate
- **Bridge dimension input**
  - Span length, curvature gap spacing
  - Girder alignment options
    - Same spacing
    - Offset spacing
- **Bridge dimension input**
  - Sub-structure definition

Wizard : Section



- **Girder information**
  - **Number of girder**
  - **Section assignment per spans**
- **Design material selection**
  - **Deck / Girder / Diaphragm**
- **Diaphragm distribution options**
  - **Distance**
  - **Division per Span**

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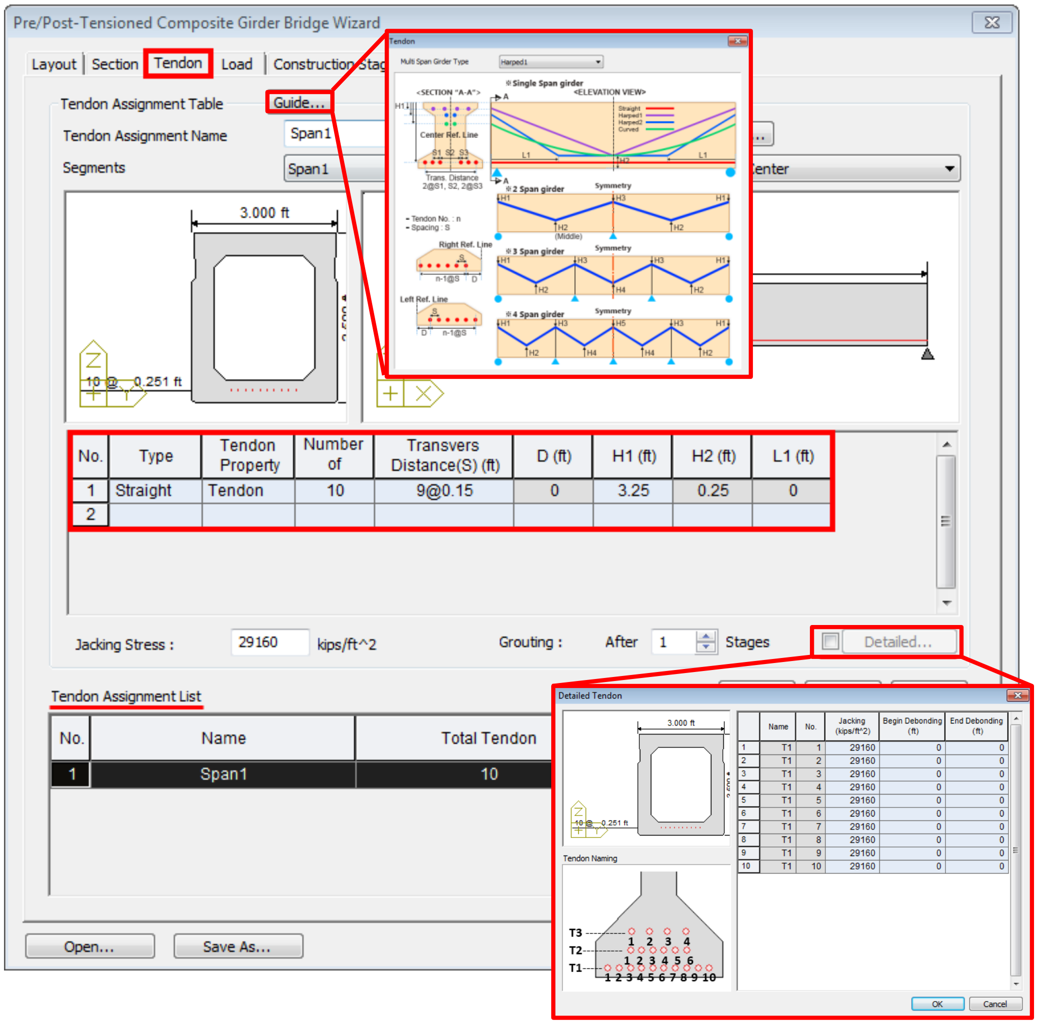
Wizard : Tendon



- **Tendon type**
  - Straight
  - Harped 1 & 2
  - Curved
- **Tendon definition table**
  - Number of tendons
  - Distribution distance
  - Vertical displacement
- **Tendon Assignment List**
  - Different tendon assignment per spans
  - As many assignment as user wants
- **Detailed tendon table**

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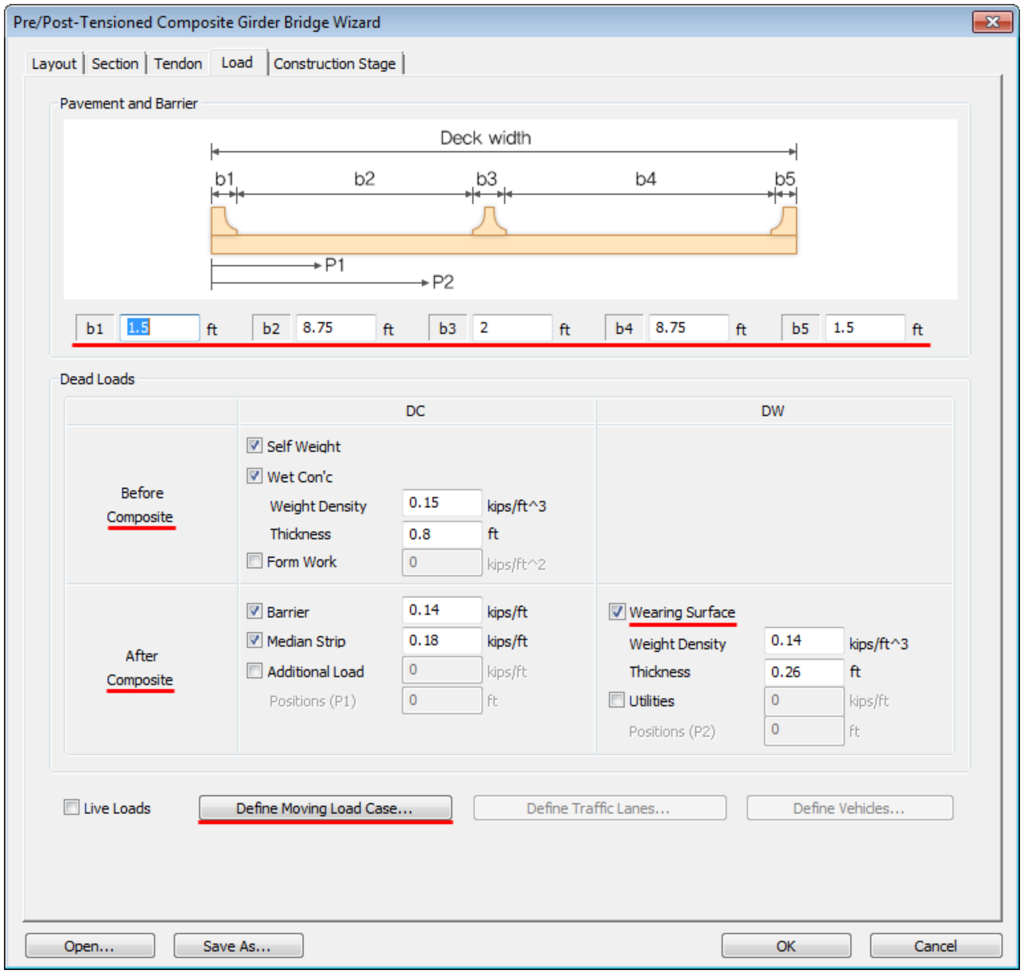
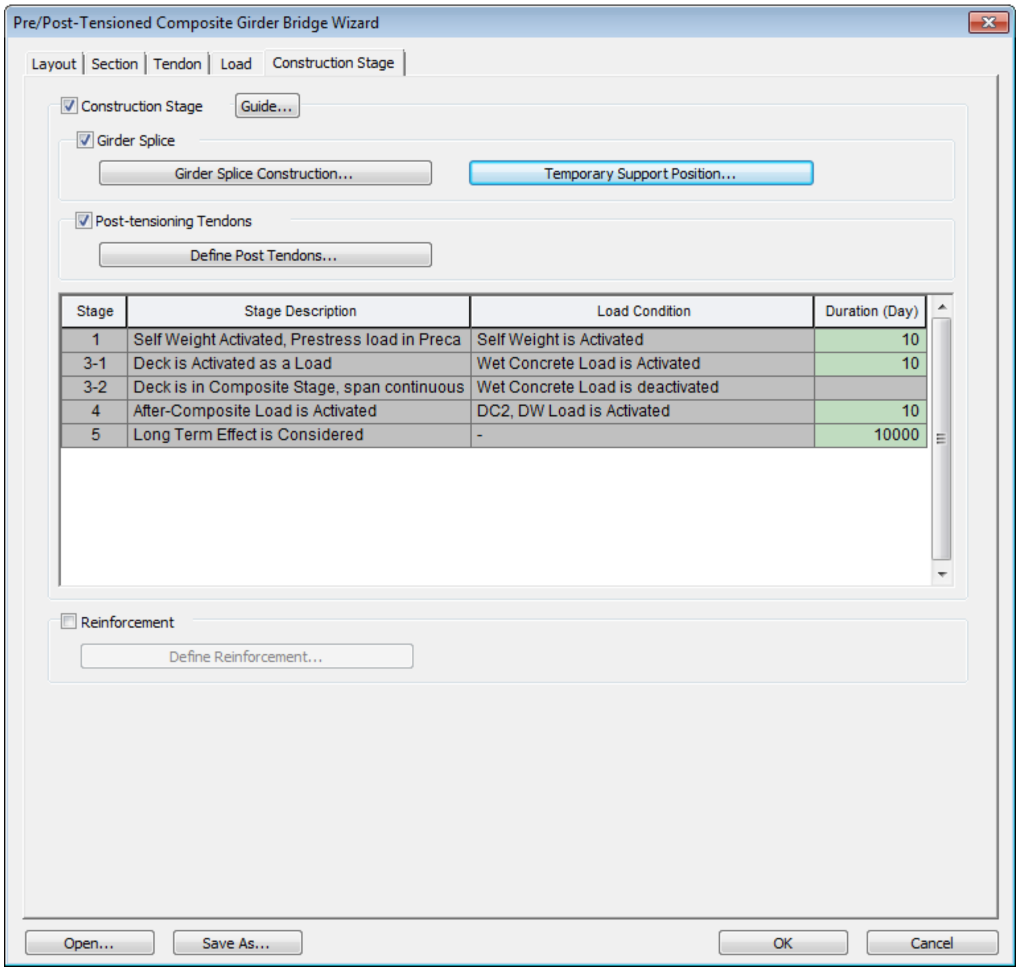
Wizard : Load



- Pavement and Barrier
- Composite load cases
  - Pre-composite load cases (DC 1-1)
  - Post-composite load case (DC 1-2)
  - Wearing surface & additional (DC 2)
- Moving load analysis
  - Moving load code selection
  - Lane definition
  - Vehicle selection

Wizard : Construction Stage



- **Visual guide for construction sequence**
- **Concrete pouring sequence**
  - **Splice girder pouring sequence**
  - **Temporary support position**
- **Stage duration input**
- **Girder reinforcement definition**

Bridge Bearings

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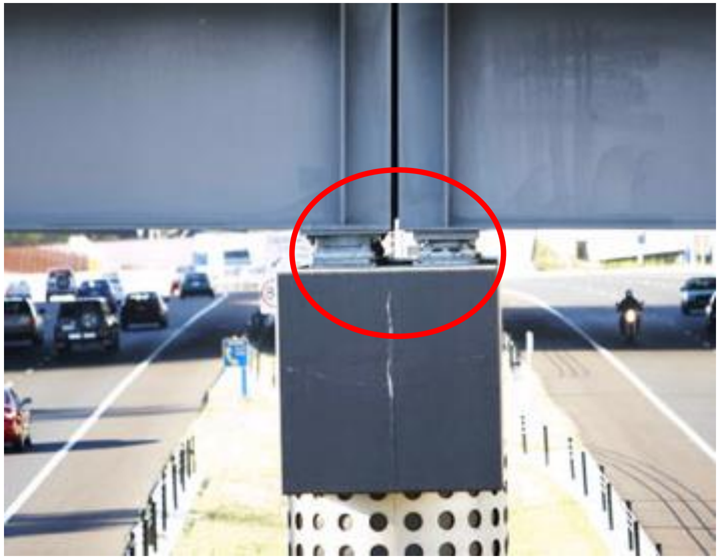
Bridge Bearings:

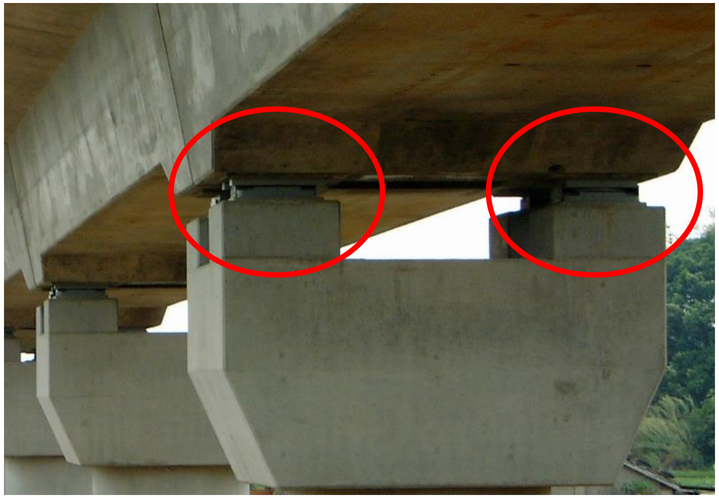
Functions of bridge bearings:

- Transfer forces from superstructure to Substructure
- Provide rotational &/or translational Restraints



To accommodate the deformations occurring due to:

- Thermal expansion/contraction
- Elastic deformation under live load
- Seismic forces
- Creep and shrinkage of concrete
- Settlement of supports
- Longitudinal forces - tractive/ braking
- Wind loads



Bearing Modeling

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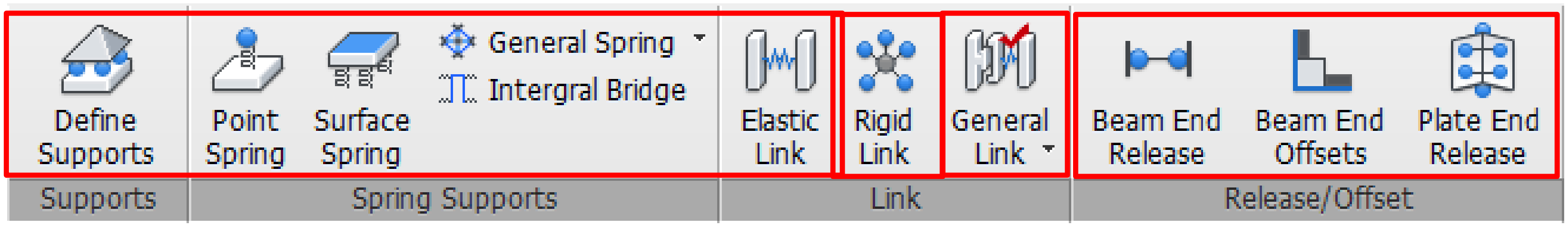
Boundary Conditions



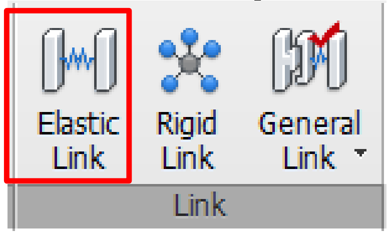
Nodal boundary conditions

- Constraint for degree of freedom (Supports)
- Elastic boundary element (Spring supports)
  - Point Spring Supports
  - Surface Spring Supports
  - General Spring Supports
- Elastic link element (Elastic Link)
- General Link element (General Link)
  - Element Type
  - Force Type

Element boundary conditions

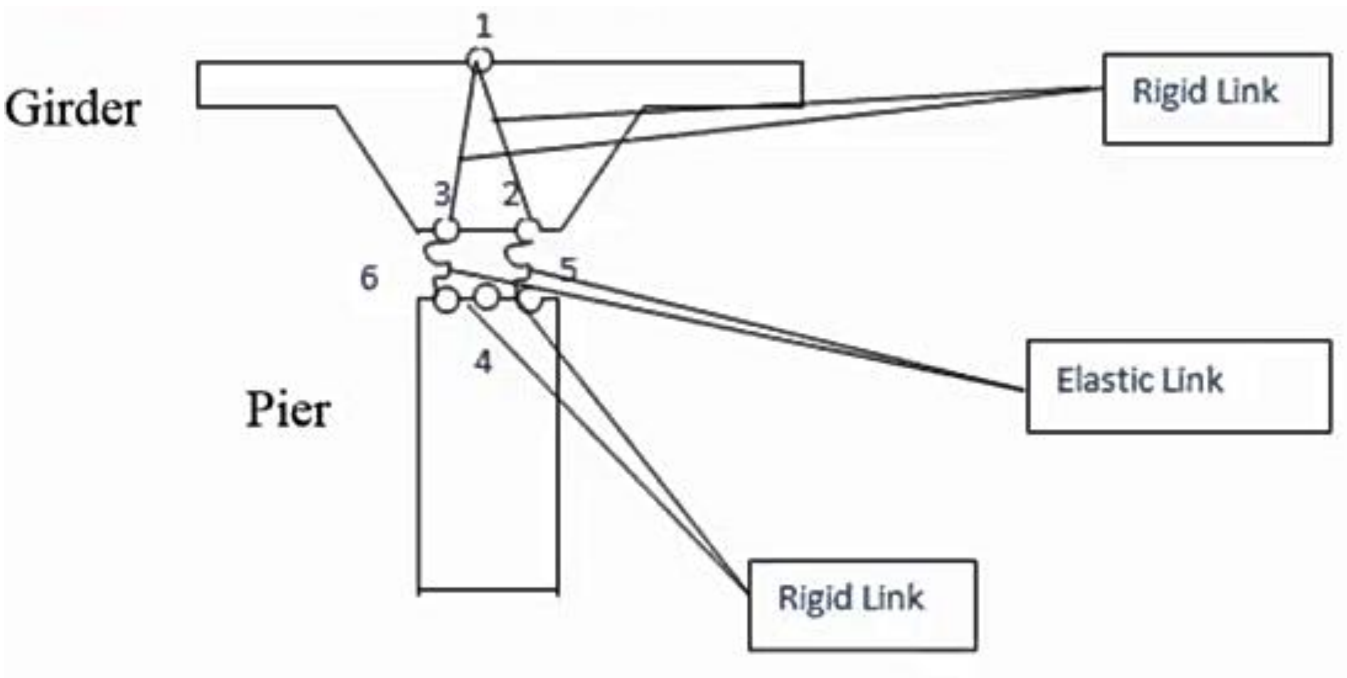
- Element End Release
  - Beam End Release
  - Plate End Release
- Rigid End Offset distance (Beam End Offset)
- Rigid Link

Boundary Conditions

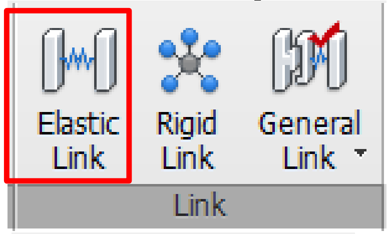


Usage

- Elastic bearings of a bridge structure, which separate the bridge deck from the piers.
- Used to simulate the support conditions
- Compression-only Elastic link : the soil boundary conditions.
- Rigid Link : Connects two nodes with an "infinite" stiffness



Boundary Conditions



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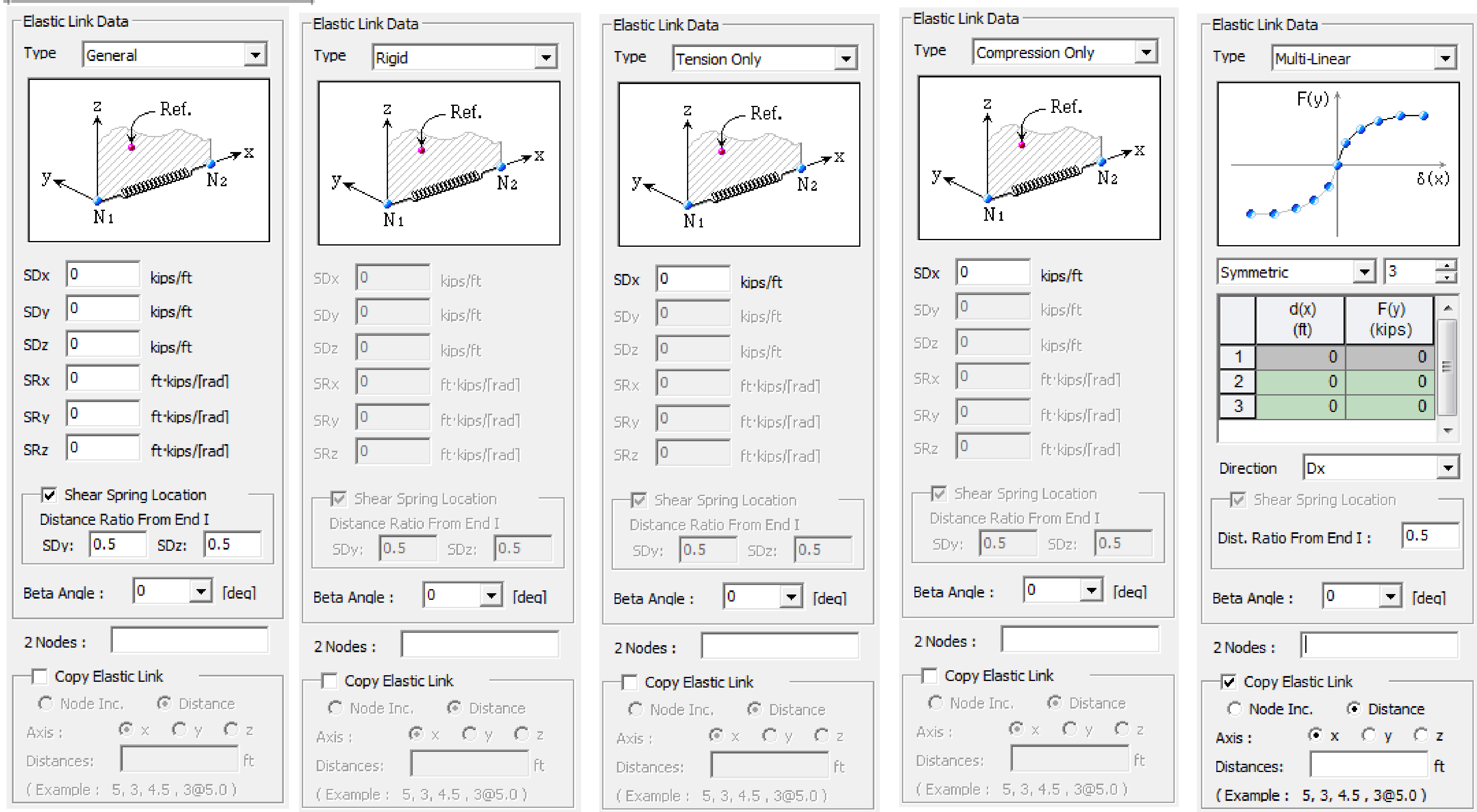
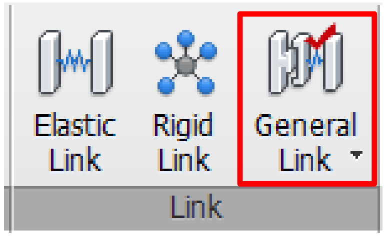
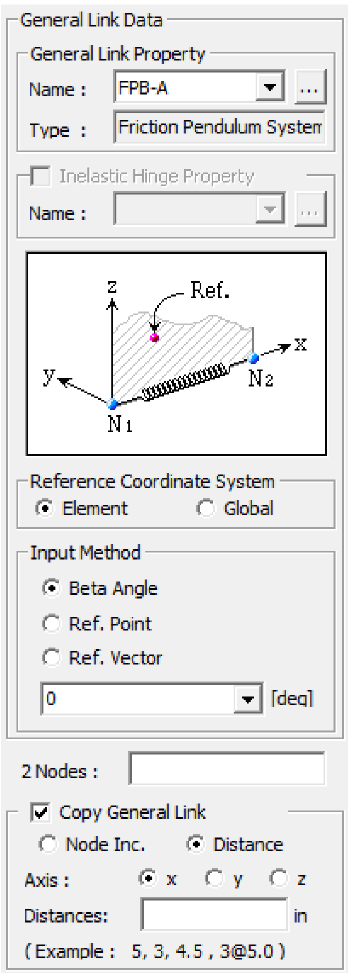


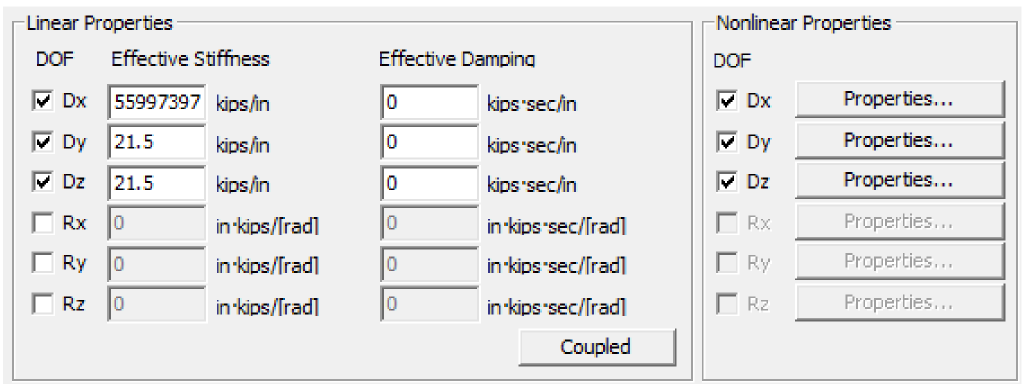
Boundary Conditions

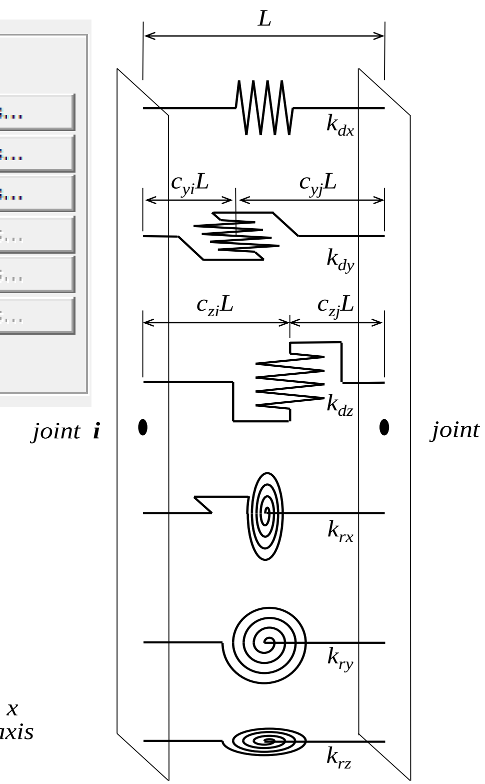


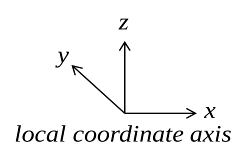
Usage

- Dampers, base isolators, compression-only element, tension-only element, plastic hinges, soil springs
- Used as linear and nonlinear elements
- Element type: Spring, Dashpot, Spring and Dashpot
- Force type: Viscoelastic Damper, Hysteretic System, Seismic isolators (Lead Rubber Bearing Isolator, Friction Pendulum System Isolator)









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Midas Superstructure Design

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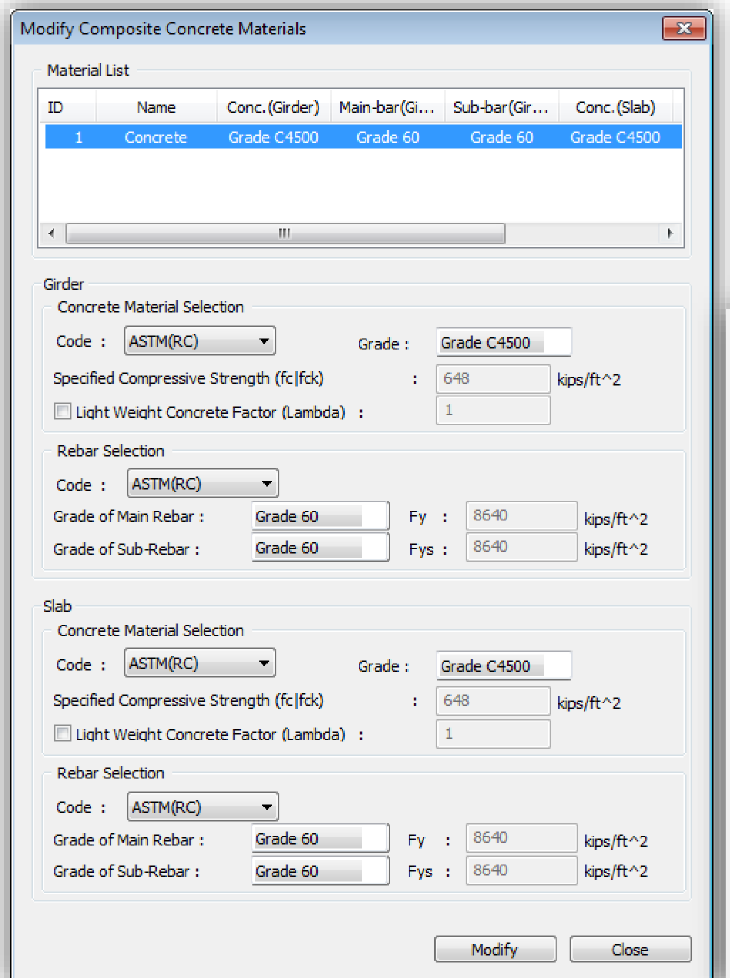
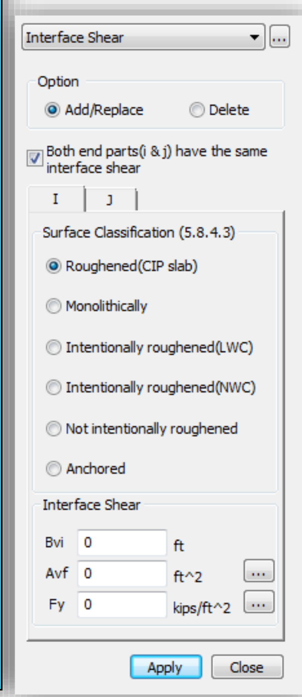
PSC Composite
Design check & Load rating

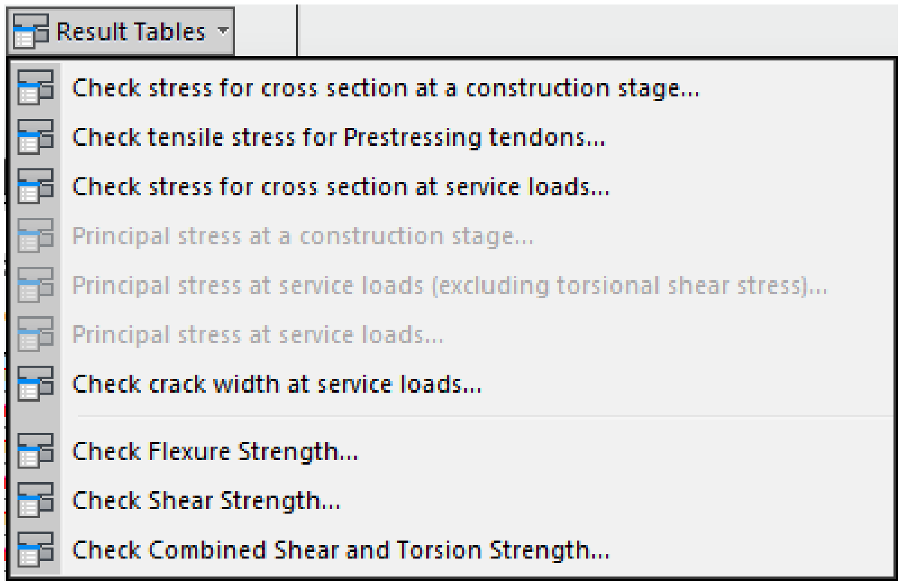
PSC Composite Design check





- **Material selection**
  - Separate material definition girder and slab
  - Light concrete factor
- **Interface shear consideration**
  - Surface classification by 5.8.4.3
  - Shear reinforcement definition

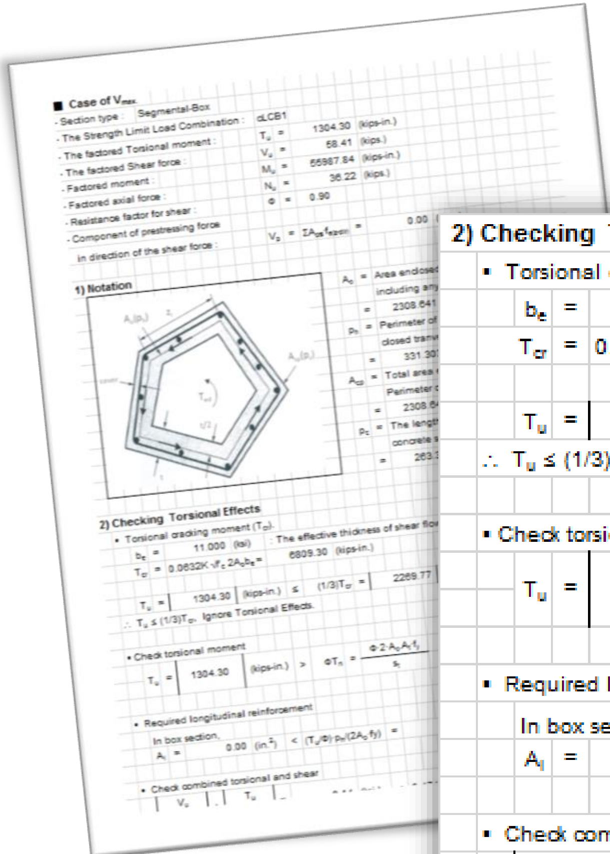
Design result table



- **Strength**
  - Flexure
  - Shear
  - Combined shear and Torsion
- **Stress**
  - Sectional & Principal stress
    - Per construction stage
    - Under service load case
  - Tendon tensile stress
- **Crack width under service load**

Elem	Part	Positive/ Negative	LCom Name	Type	CHK	Muy (ft*kips)	Mcr (ft*kips)	Mny (ft*kips)	PhiMny (ft*kips)	Ratio (Muy/PhiMny)	PhiMny/ min(1.33Muy,Mcr)
84	I[11]	Negative	cLCB1	FX-MIN	OK	0.0000	-2307.5010	23.9942	17.9956	0.0000	2159474.8861
84	I[11]	Positive	cLCB1	FX-MAX	OK	26.5598	12754.2249	13540.6330	13540.6330	0.0020	383.3216
84	J[534]	Negative	cLCB1	FX-MIN	OK	-11.5115	-2310.6930	23.9942	17.9956	0.6397	1.1754
84	J[534]	Positive	cLCB1	FX-MAX	OK	20.9491	12774.9135	13540.6330	13540.6330	0.0015	485.9838
85	I[534]	Negative	cLCB1	FX-MIN	OK	0.0000	-2322.7463	23.9942	17.9956	0.0000	2159474.8861
85	I[534]	Positive	cLCB1	FX-MAX	OK	58.3551	12770.0263	13540.6330	13540.6330	0.0043	174.4650
85	J[25]	Negative	cLCB1	FX-MIN	OK	0.0000	-2741.8921	23.9942	17.9956	0.0000	2159474.8861
85	J[25]	Positive	cLCB1	FX-MAX	OK	561.1422	12770.9129	13540.6330	13540.6330	0.0414	18.1432
86	I[25]	Negative	cLCB1	FX-MIN	OK	0.0000	-2741.9097	23.9942	17.9956	0.0000	2159474.8861
86	I[25]	Positive	cLCB1	FX-MAX	OK	555.7808	12770.9179	13540.6330	13540.6330	0.0410	18.3182
86	J[535]	Negative	cLCB1	FX-MIN	OK	0.0000	-3521.2853	23.9942	17.9956	0.0000	2159474.8861
86	J[535]	Positive	cLCB1	FX-MAX	OK	1376.3223	12759.6580	13540.6330	13540.6330	0.1016	7.3972

Design result Report



2) Checking Torsional Effects

- Torsional cracking moment (T_{cr}).

b_e = 11.000 (ksi) : The effective thickness of shear flow path of elements

$T_{cr} = 0.0632K\sqrt{f'_c}\,2A_o b_e =$ 6809.30 (kips-in.) *(Eq. 5.8.6.3-2)*

T_u = 1304.30 (kips-in.) $\le$ $(1/3)T_{cr}$ = 2269.77 (kips-in.) *(Eq. 5.8.6.3-1)*

$\therefore$ $T_u \le (1/3)T_{cr}$, Ignore Torsional Effects.

- Check torsional moment *(Eq. 5.8.6.4-2)*

T_u = 1304.30 (kips-in.) > $\Phi T_n = \dfrac{\Phi \cdot 2 \cdot A_o A_t \cdot f_y}{s_t}$ = 0.00 (kips-in.) NG

- Required longitudinal reinforcement

In box section, *(Eq. 5.8.3.6.3-2)*

A_l = 0.00 (in.^{2}) < $(T_u/\Phi)\cdot p_h/(2A_o\cdot fy)$ = 1.73 (in.^{2}) NG

- Check combined torsional and shear *(Eq. 5.8.6.5-5)*

$\dfrac{V_u}{b_v d_v} + \dfrac{T_u}{2A_o b_e}$ = 0.14 (ksi.) < $0.474\sqrt{f'_c}$ = 1.01 (ksi.) OK

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Design as per AASHTO LRFD

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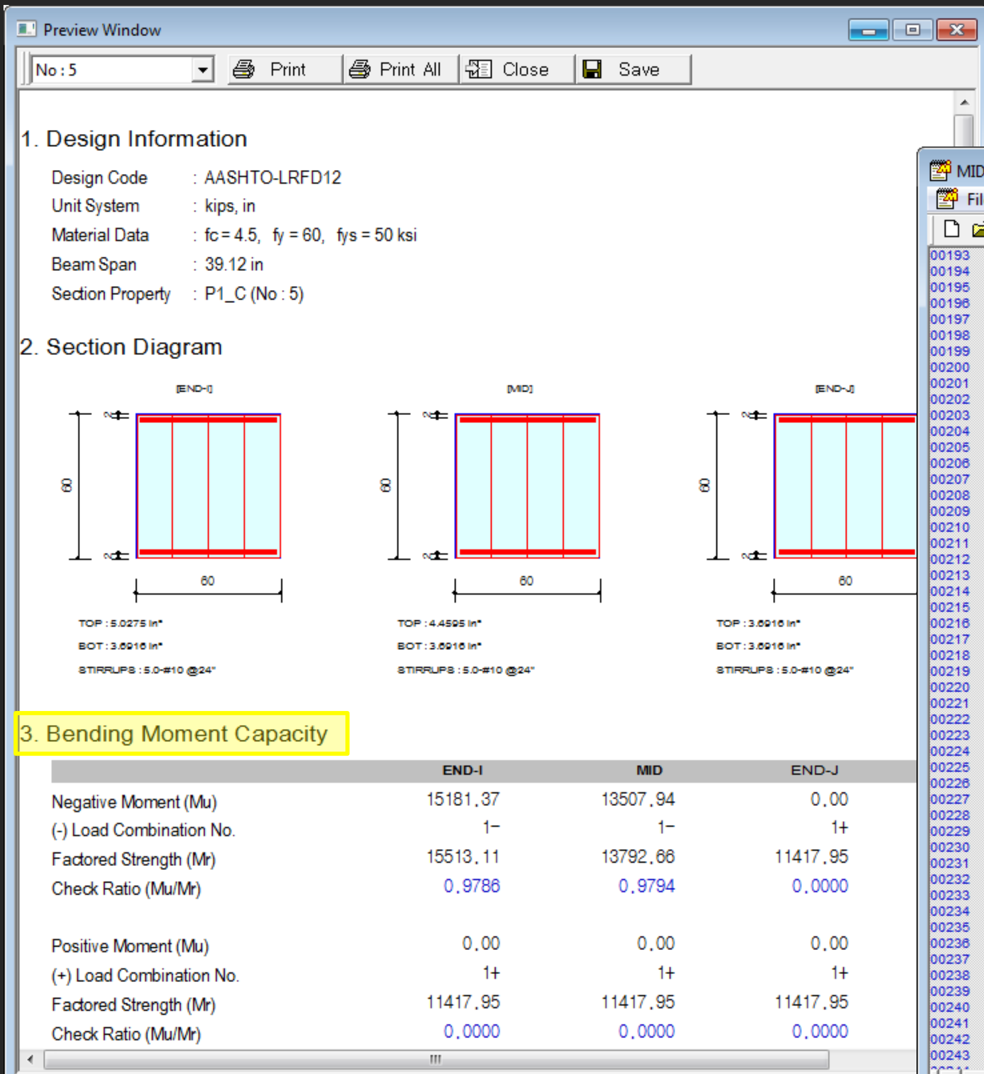
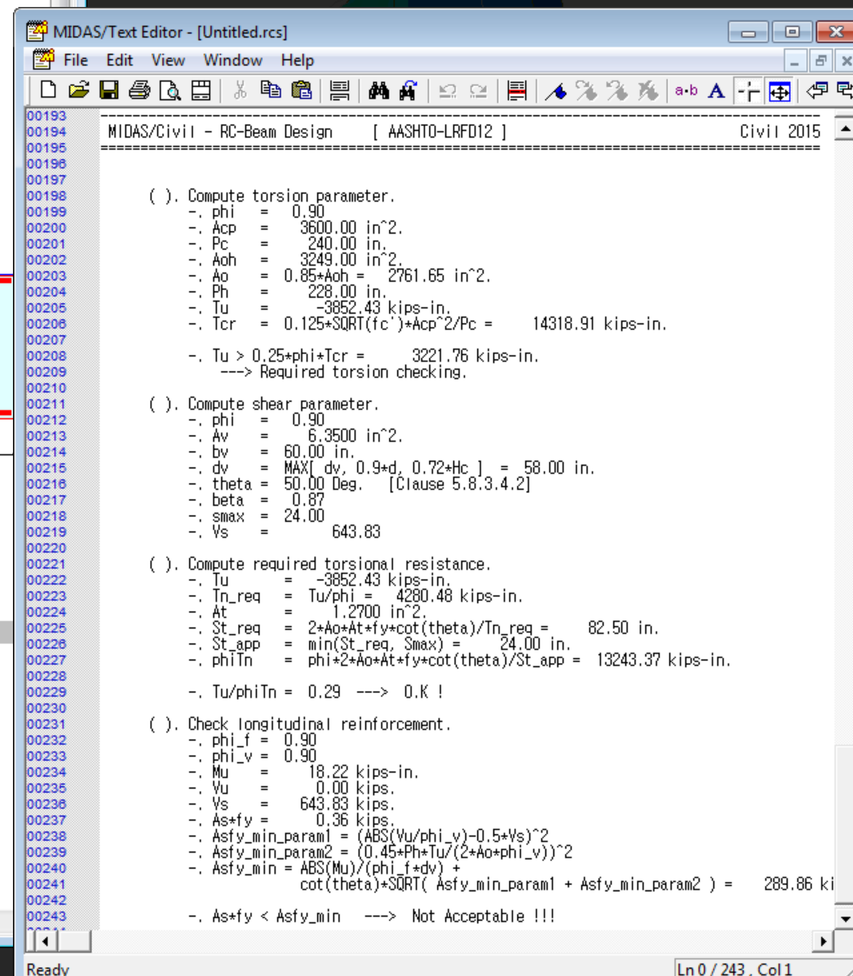
Substructure Design





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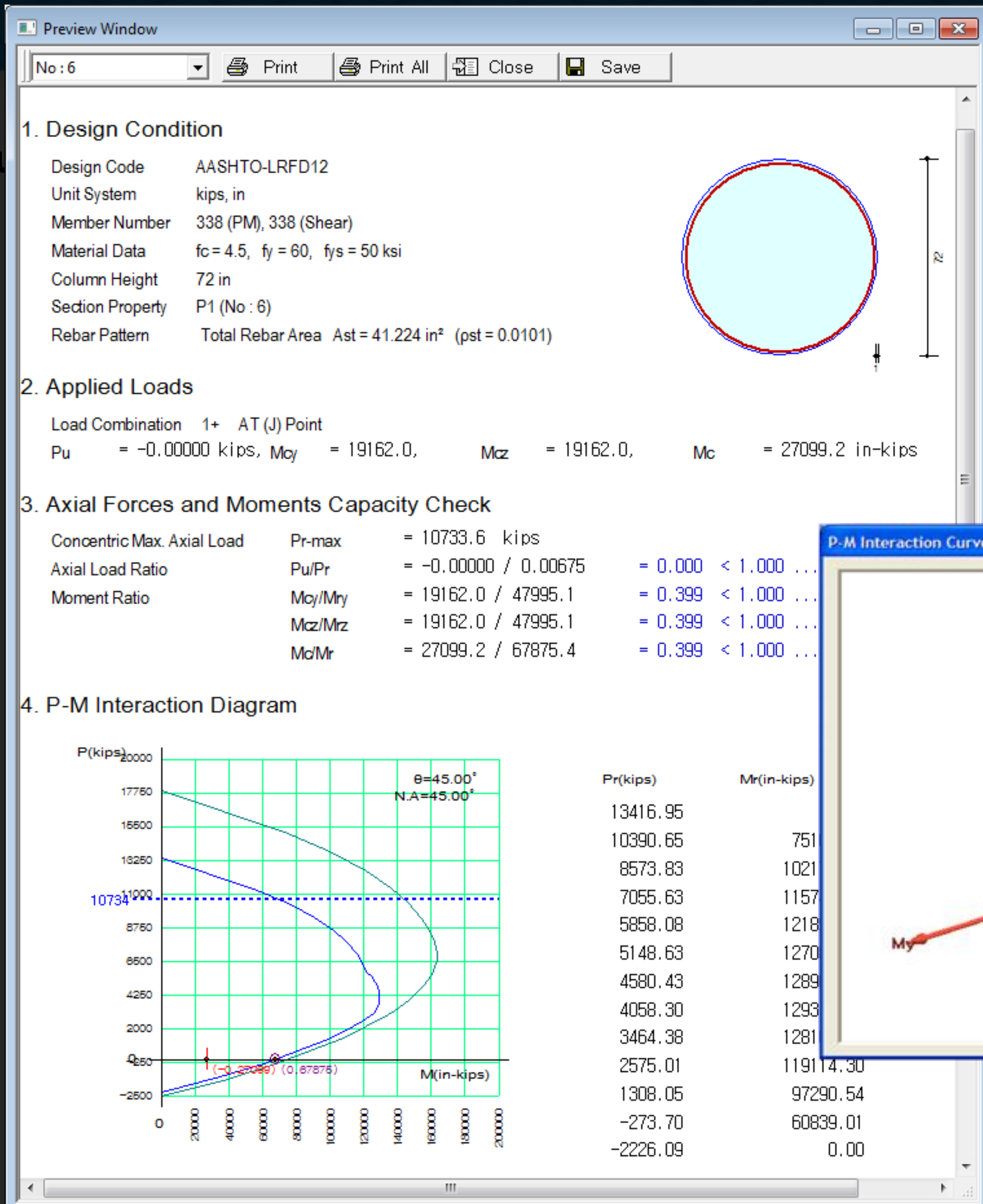


Preview Window

No : 6 | Print | Print All | Close | Save

1. Design Condition

Design Code AASHTO-LRFD12
Unit System kips, in
Member Number 338 (PM), 338 (Shear)
Material Data fc = 4.5, fy = 60, fys = 50 ksi
Column Height 72 in
Section Property P1 (No : 6)
Rebar Pattern Total Rebar Area Ast = 41.224 in² (pst = 0.0101)

2. Applied Loads

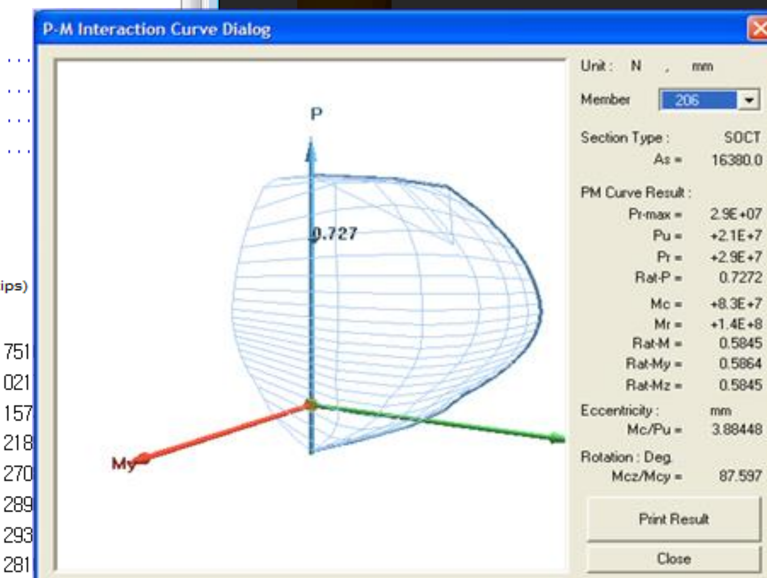
Load Combination 1+ AT (J) Point
Pu = -0.00000 kips, Mcy = 19162.0, Mcz = 19162.0, Mc = 27099.2 in-kips

3. Axial Forces and Moments Capacity Check

Concentric Max. Axial Load	Pr-max	= 10733.6 kips		
Axial Load Ratio	Pu/Pr	= -0.00000 / 0.00675	= 0.000	< 1.000 ...
Moment Ratio	Mcy/Mry	= 19162.0 / 47995.1	= 0.399	< 1.000 ...
	Mcz/Mrz	= 19162.0 / 47995.1	= 0.399	< 1.000 ...
	Mc/Mr	= 27099.2 / 67875.4	= 0.399	< 1.000 ...

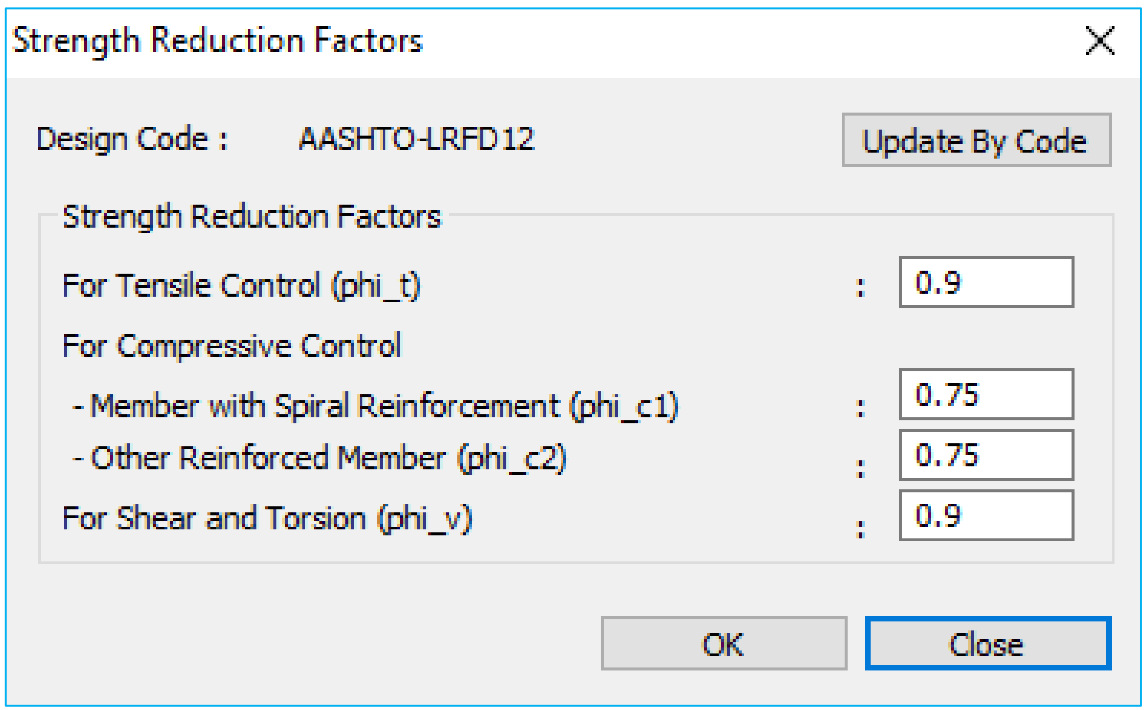
4. P-M Interaction Diagram

Pr(kips)	Mr(in-kips)
13416.95	
10390.65	751
8573.83	1021
7055.63	1157
5858.08	1218
5148.63	1270
4580.43	1289
4058.30	1293
3464.38	1281
2575.01	119114.30
1308.05	97290.54
-273.70	60839.01
-2226.09	0.00



Strength Reduction Factor

Enter the strength reduction factors, which are a form of safety factors to account for the difference between the nominal and real strengths of the materials; the difference in member strengths between the design and manufacturing or construction; uncertainties related to inaccuracies in the design equations; and the ductility and importance of the member.

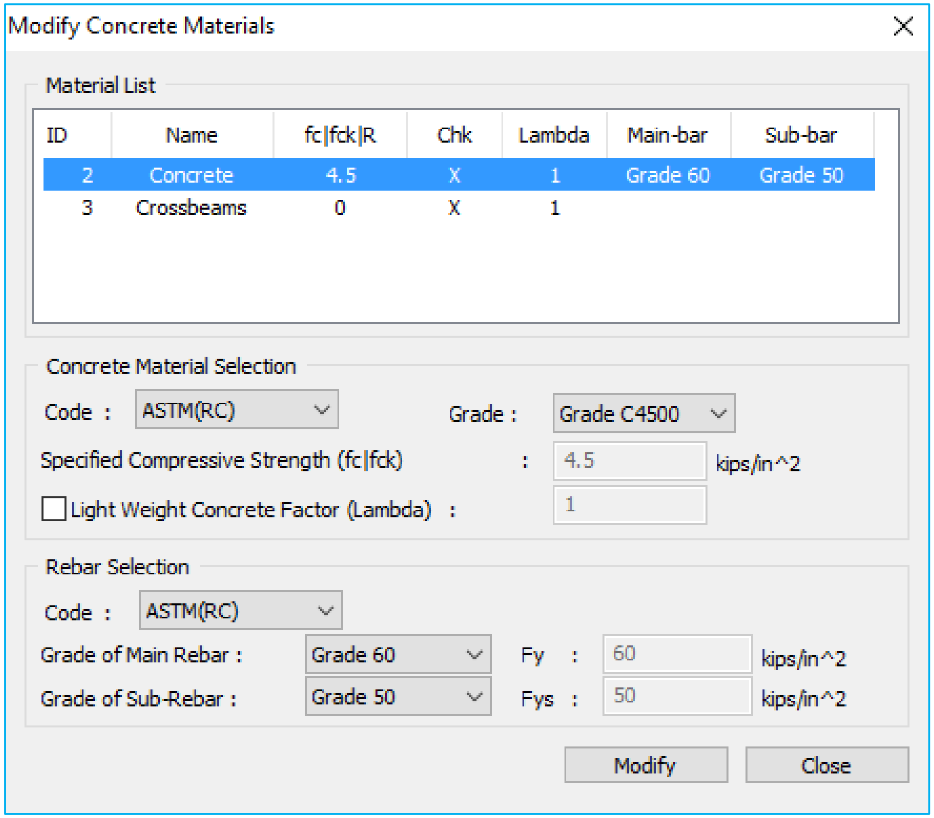


Modify Concrete Materials

Use this function to modify a part of the steel rebar and concrete material property data, entered during the creation of the analysis model, or to change the material property data. Modifications that are made here will not affect the analysis results, but will only be used for automatic design and strength verification

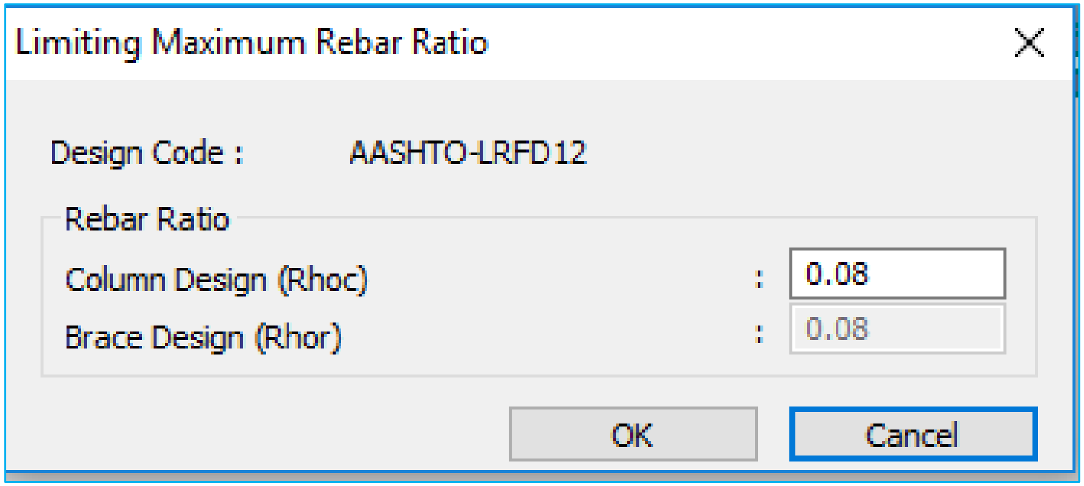
(1) ASTM(RC)

NAME	= Grade C4000 (4000 lb/in^2)
Grade of Main Rebar	= Grade 60 (Fy=60000 lb/in^2)
Grade of Sub Rebar	= Grade 60 (Fy=60000 lb/in^2)
Wc	= 150 lb/ft^3.
Ec(lb/in^2, for analysis)	= 33 X Wc$^{1.5}$ X f'c$^{0.5}$
Es	= 2.9 X 10^7 lb/in^2



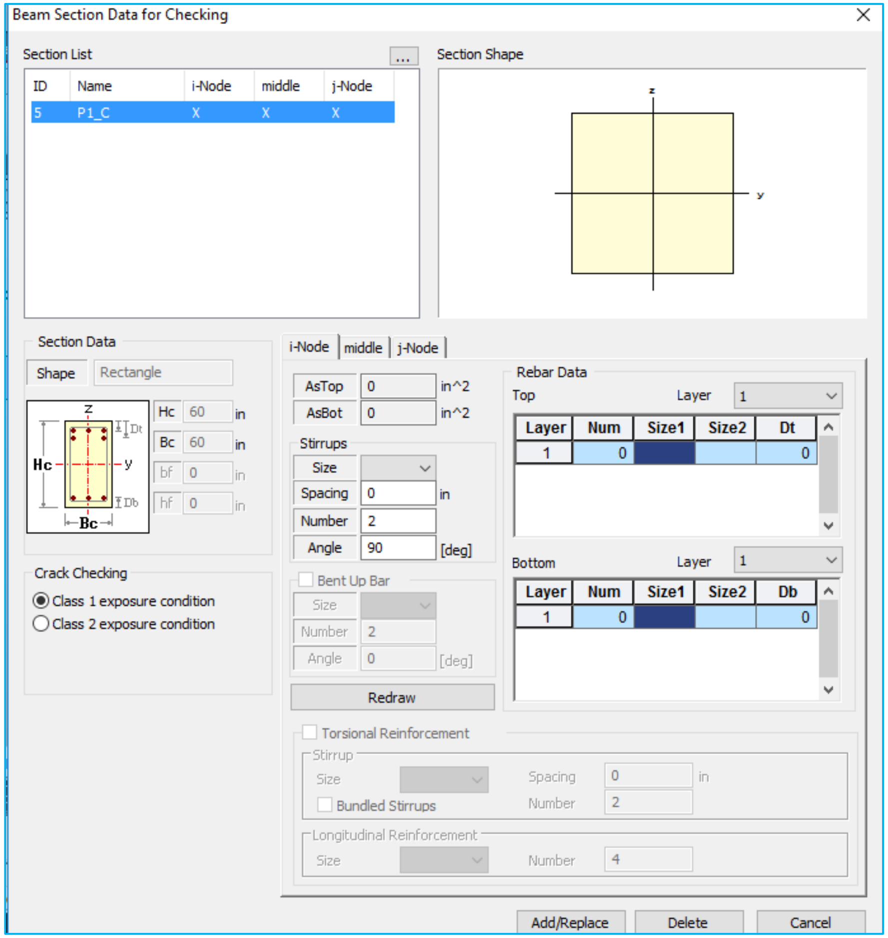
Limiting Maximum Rebar Ratio

Enter the maximum allowable rebar ratio of Reinforced Concrete



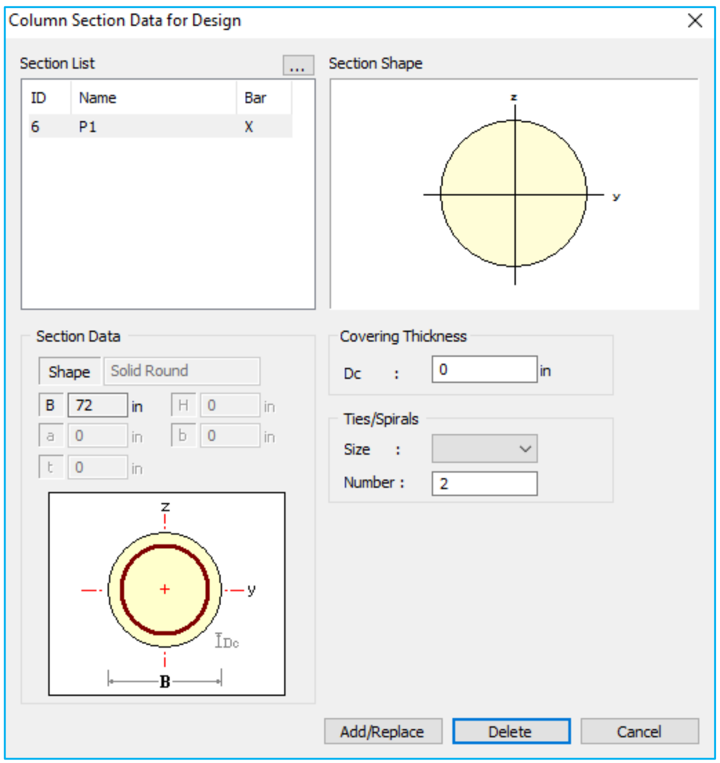
Beam Section Data for Design

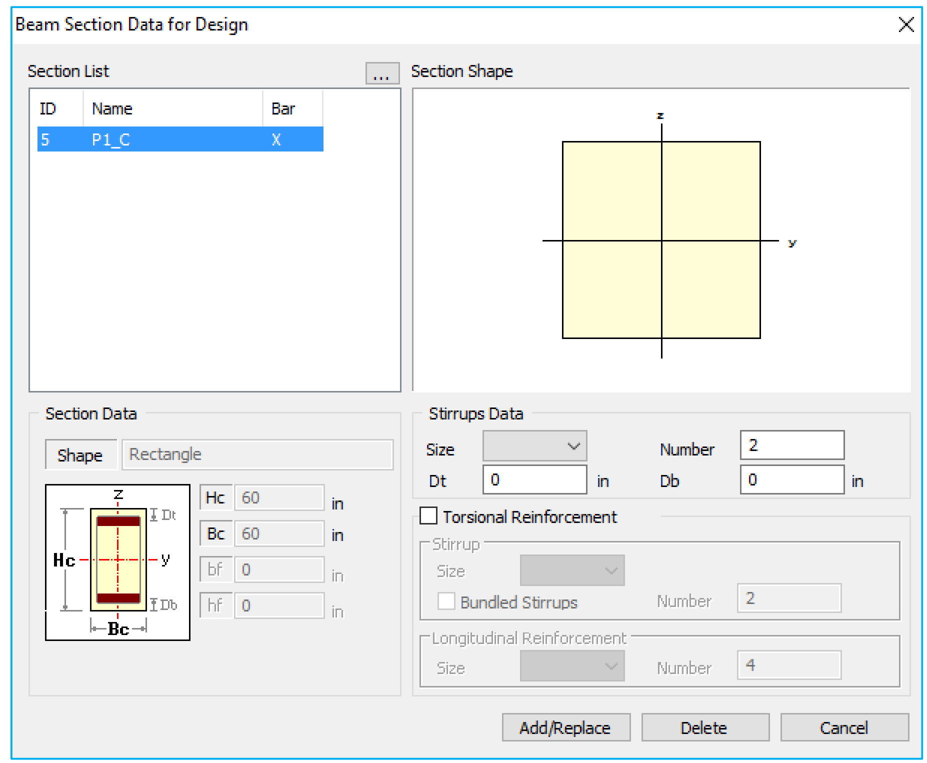
Enter the section dimensions including the covers and rebar data for RC beam members to be applied to section design.



Beam and Column Section Data for Design

Enter the section dimensions including the covers and rebar data for RC beam members to be applied to section design.





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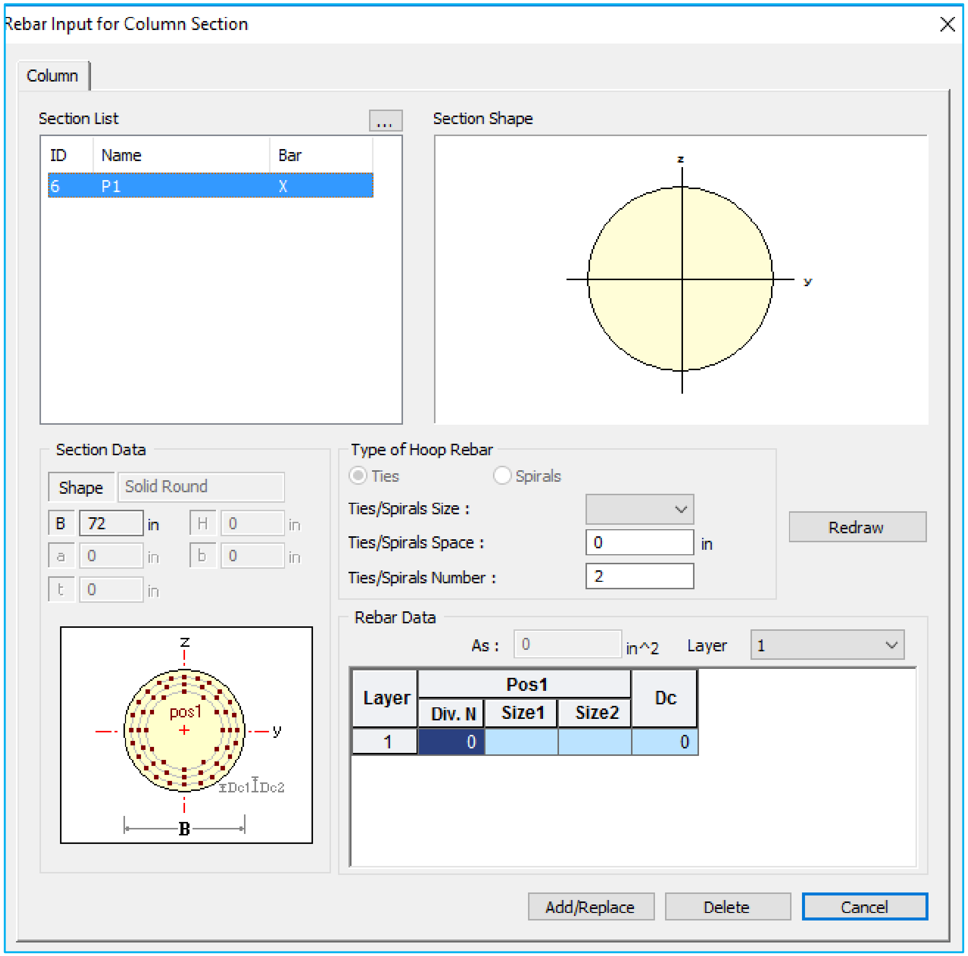
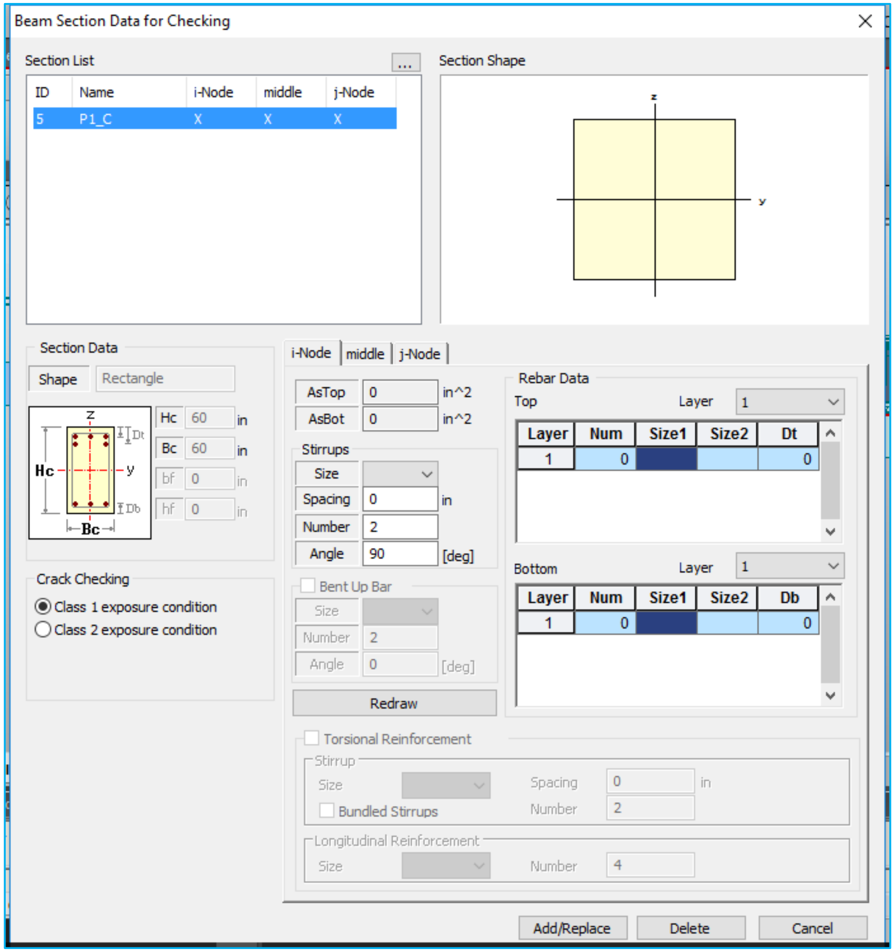
Beam and Column Section Data for Checking

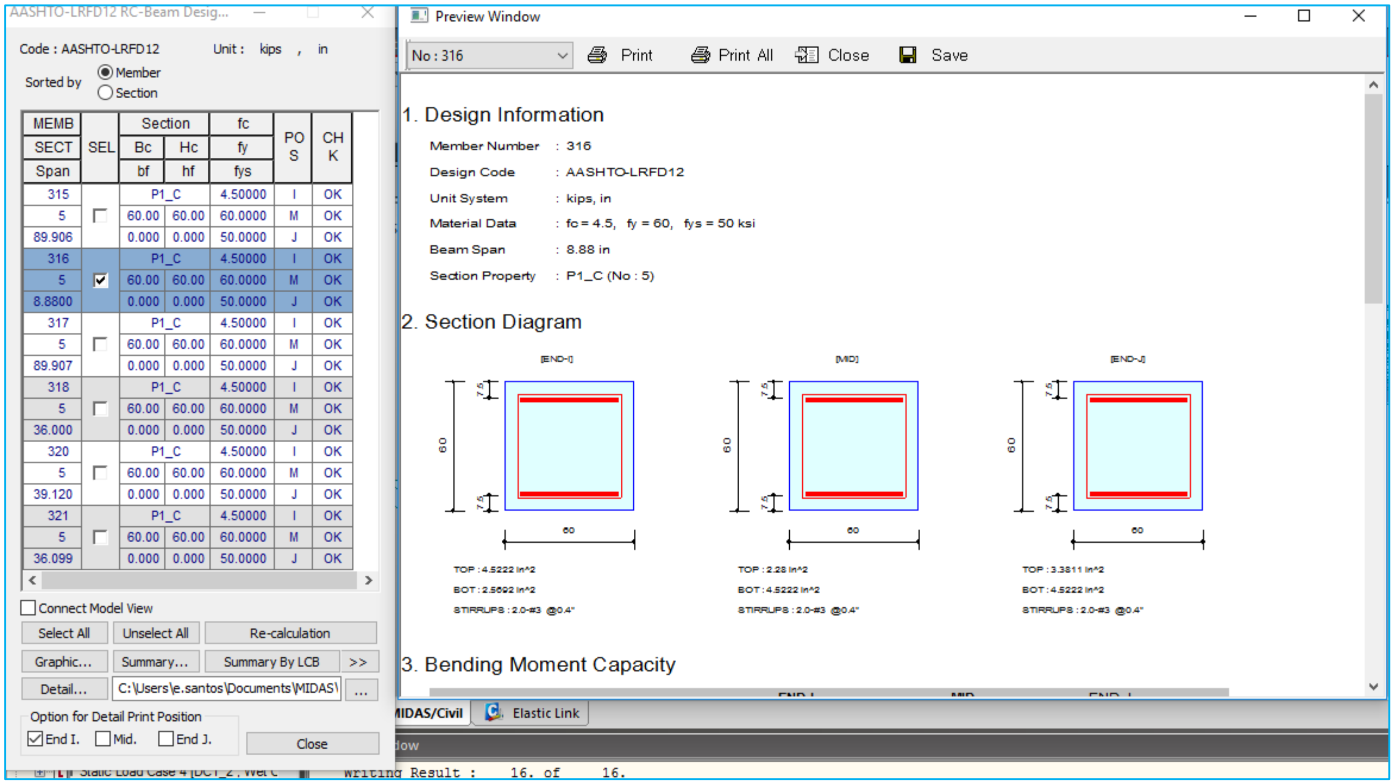
Enter the section dimensions, exposure condition and rebar data for reinforced concrete beam members to check for strength and section cracking.





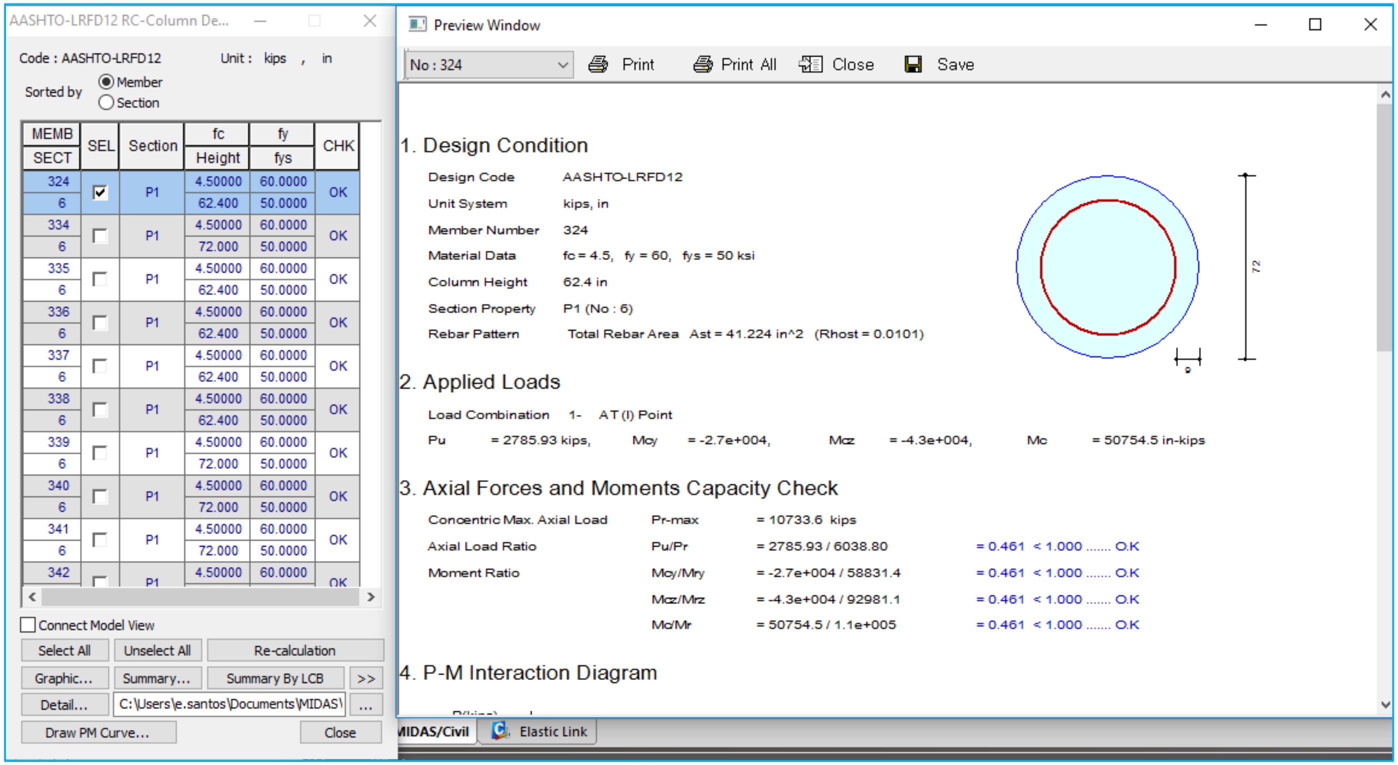
Beam Design

Using the results obtained from the analysis of the entire structure and additional design data, automatically design concrete beam members according to the following design codes: American Association of State Highway and Transportation Officials, Section 5 - Concrete Structures (AASHTO-LRFD02), American Association of State Highway and Transportation Officials (AASHTO-LFD96), Concrete Structure Design Code of the American Concrete Institute (ACI318-02), (CSA-S6-00).



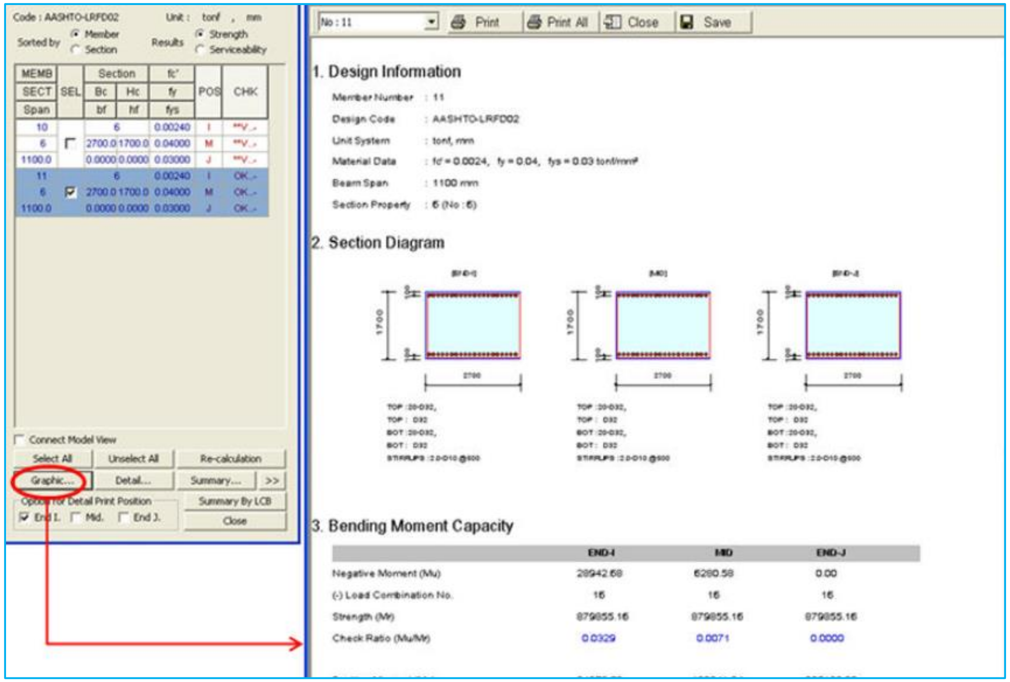
Column Design

Using the results obtained from the analysis of the entire structure and additional design data, automatically design concrete column members according to the following design codes: American Association of State Highway and Transportation Officials, Section 5 - Concrete Structures (AASHTO-LRFD02), American Association of State Highway and Transportation Officials (AASHTO-LFD96), Concrete Structure Design Code of the American Concrete Institute (ACI318-02), (CSA-S6-00).



Beam and Column Checking

Using the results obtained from the analysis of the entire structure and additional design data, verify the strengths of concrete beam members according to the following design codes: American Association of State Highway and Transportation Officials, Section 5 - Concrete Structures (AASHTO-LRFD02), American Association of State Highway and Transportation Officials (AASHTO-LFD96), Concrete Structure Design Code of the American Concrete Institute (ACI318-02), (CSA-S6-00).



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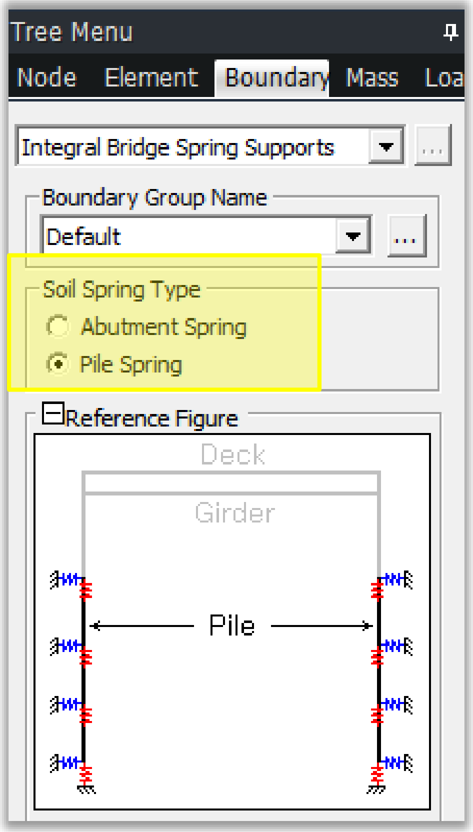

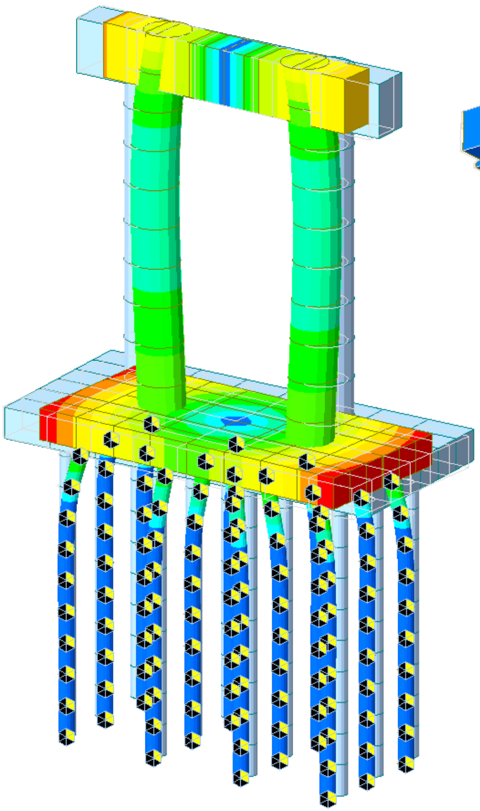

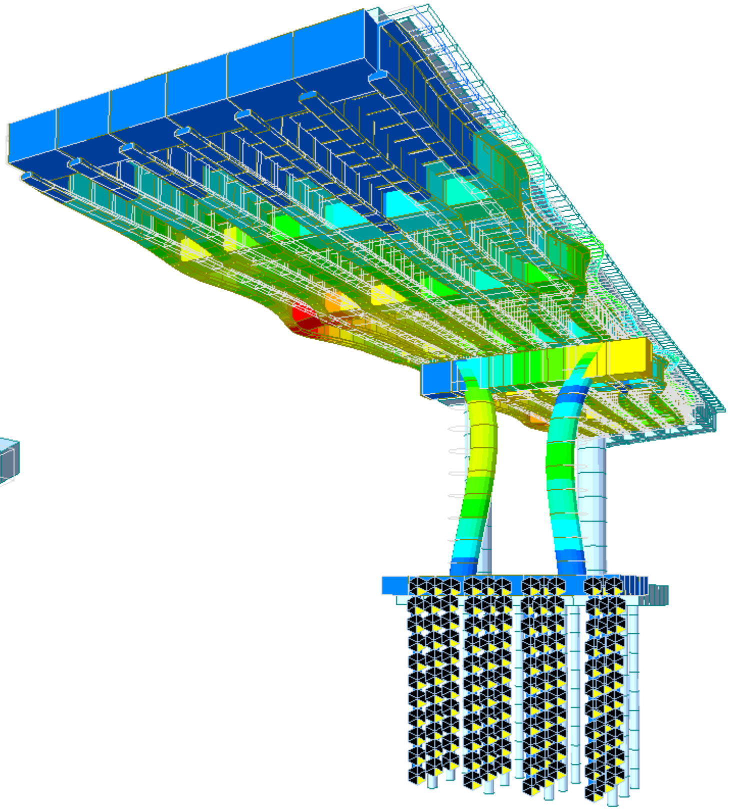

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Thank you