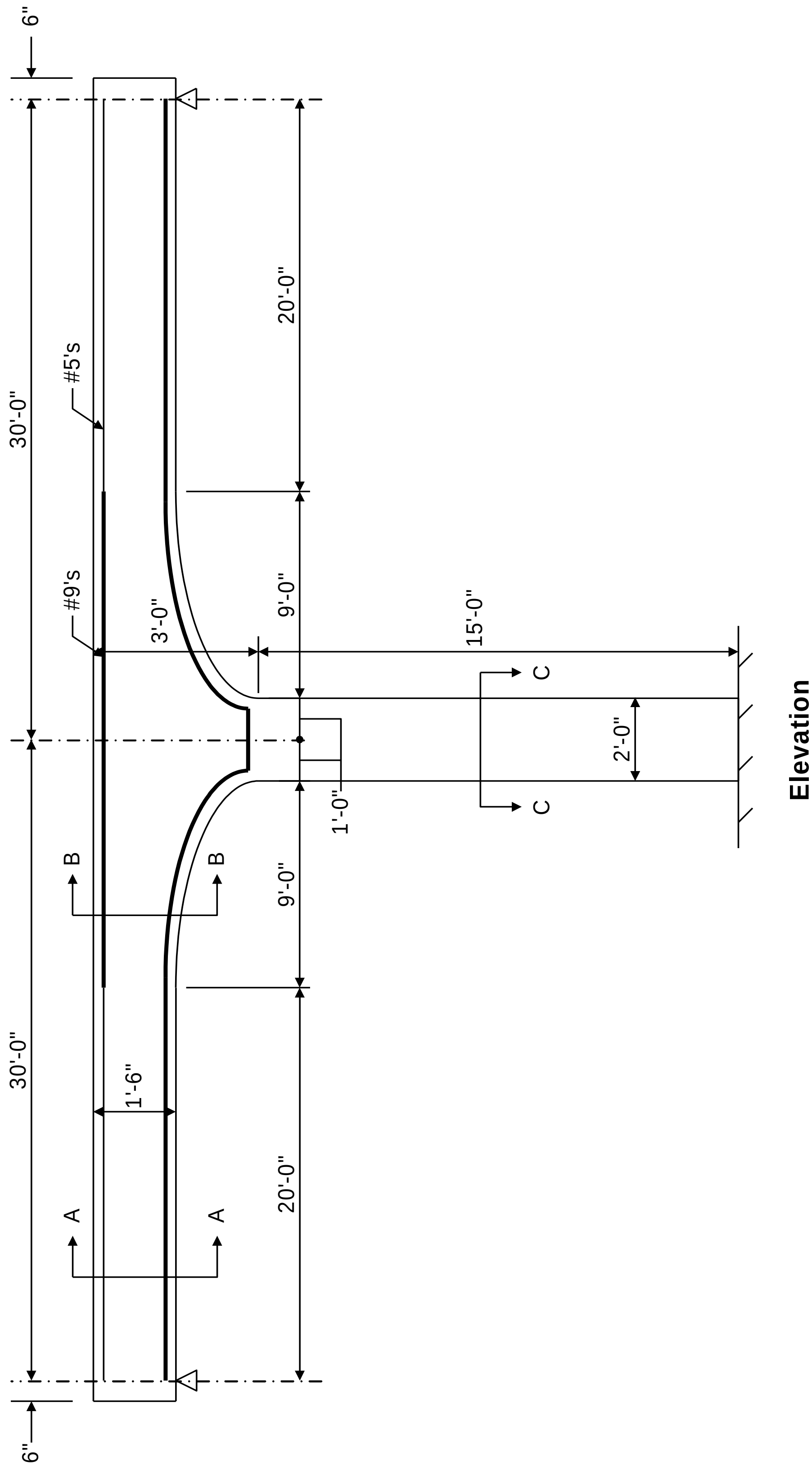
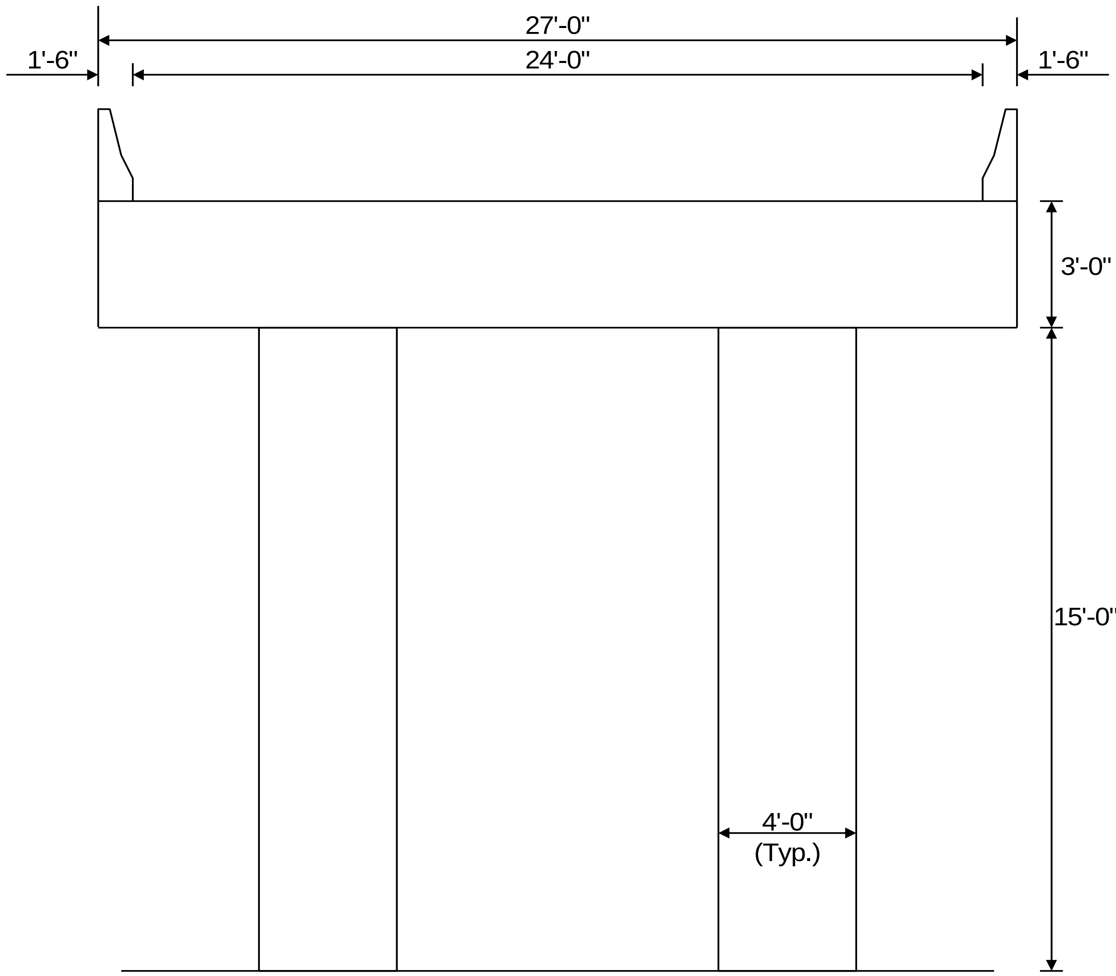
AASHTOWare BrD/BrR 6.8

Reinforced Concrete Structure Tutorial

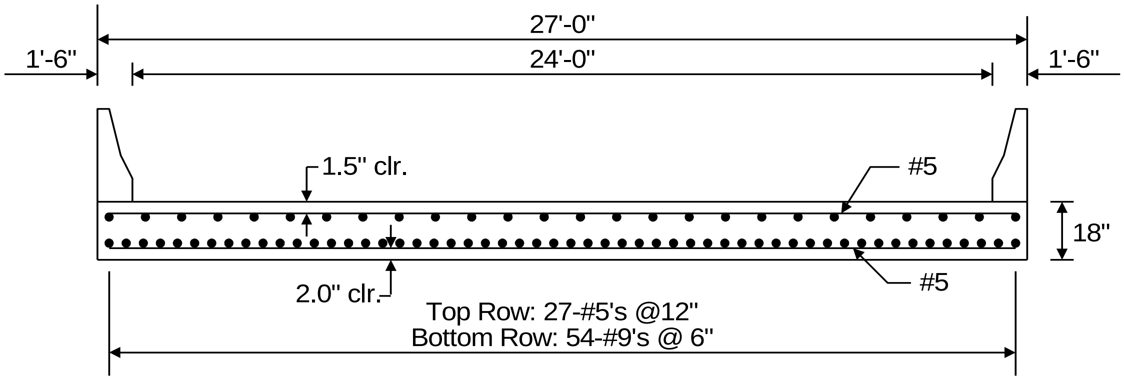
FRM1 – Reinforced Concrete Frame Example

FRM1- Two Span Reinforced Concrete Frame Example

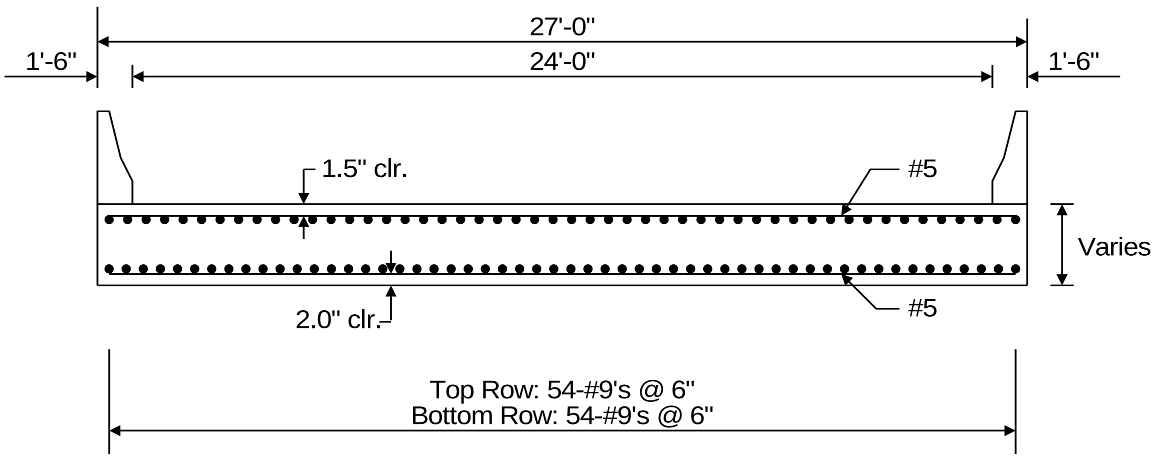




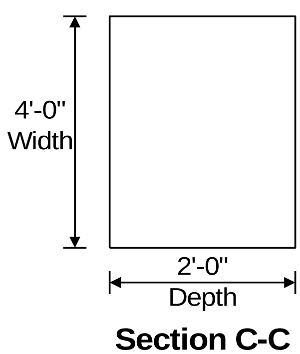
Structure Typical Section at Pier



Section A-A



Section B-B



Section C-C

Material Properties

Slab Concrete: Class A (US) f'c = 4.0 ksi, modular ratio n = 8

Slab Reinforcing Steel: AASHTO M31, Grade 60 with Fy = 60 ksi

Parapets

Weigh 300 lb/ft each. If slab cross section entered as 12" wide strip, member load due to parapets will be (2*300 lb/ft)/27' = 22 lb/ft.

BrR and BrD Training

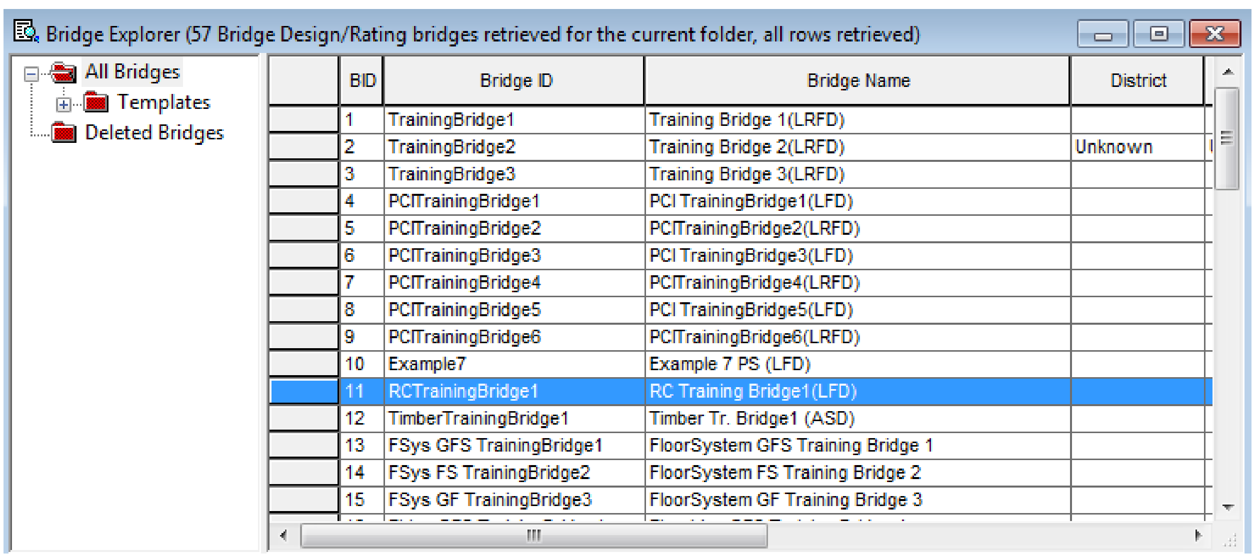
FRM1 – Reinforced Concrete Frame Example

Topics Covered

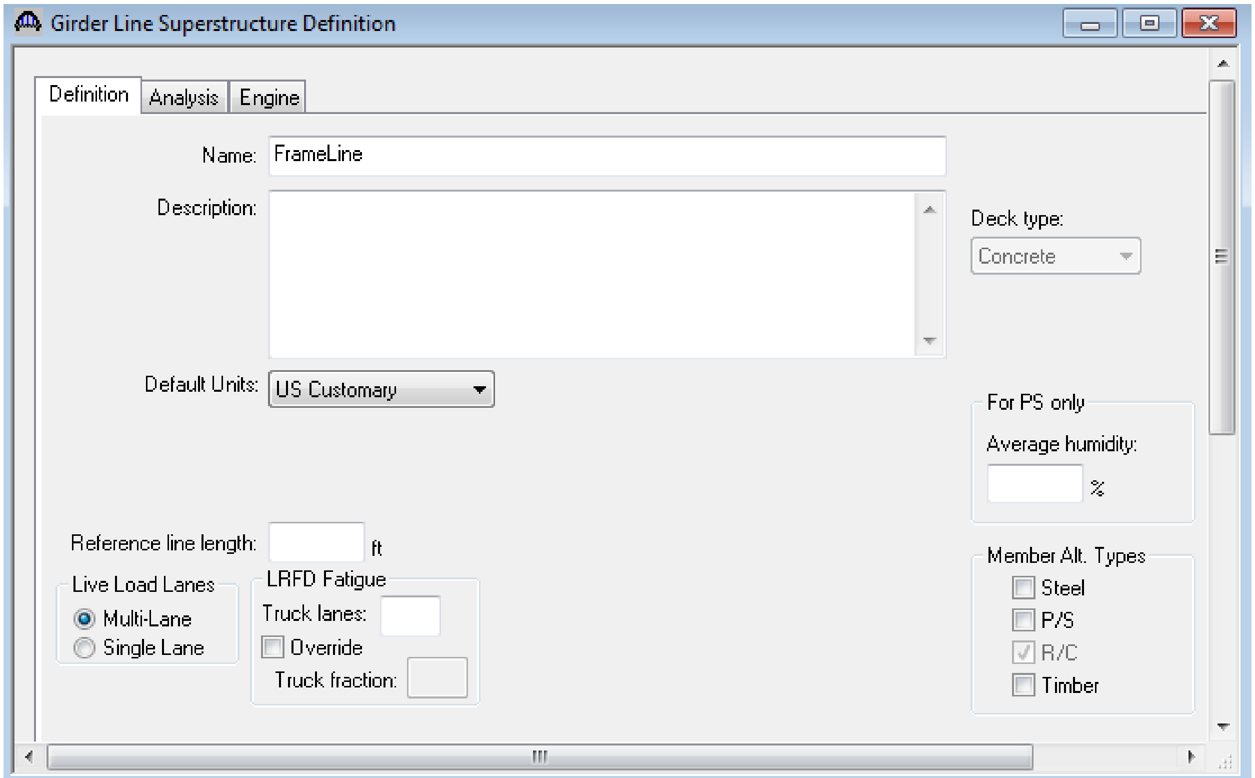
- Reinforced concrete slab input as girderline.
- Cross section based input.
- Slab depth varies parabolically over the pier.
- Frame leg support

This example demonstrates entering a reinforced concrete frame in BrR/BrD using the Compute Column Stiffness dialog.

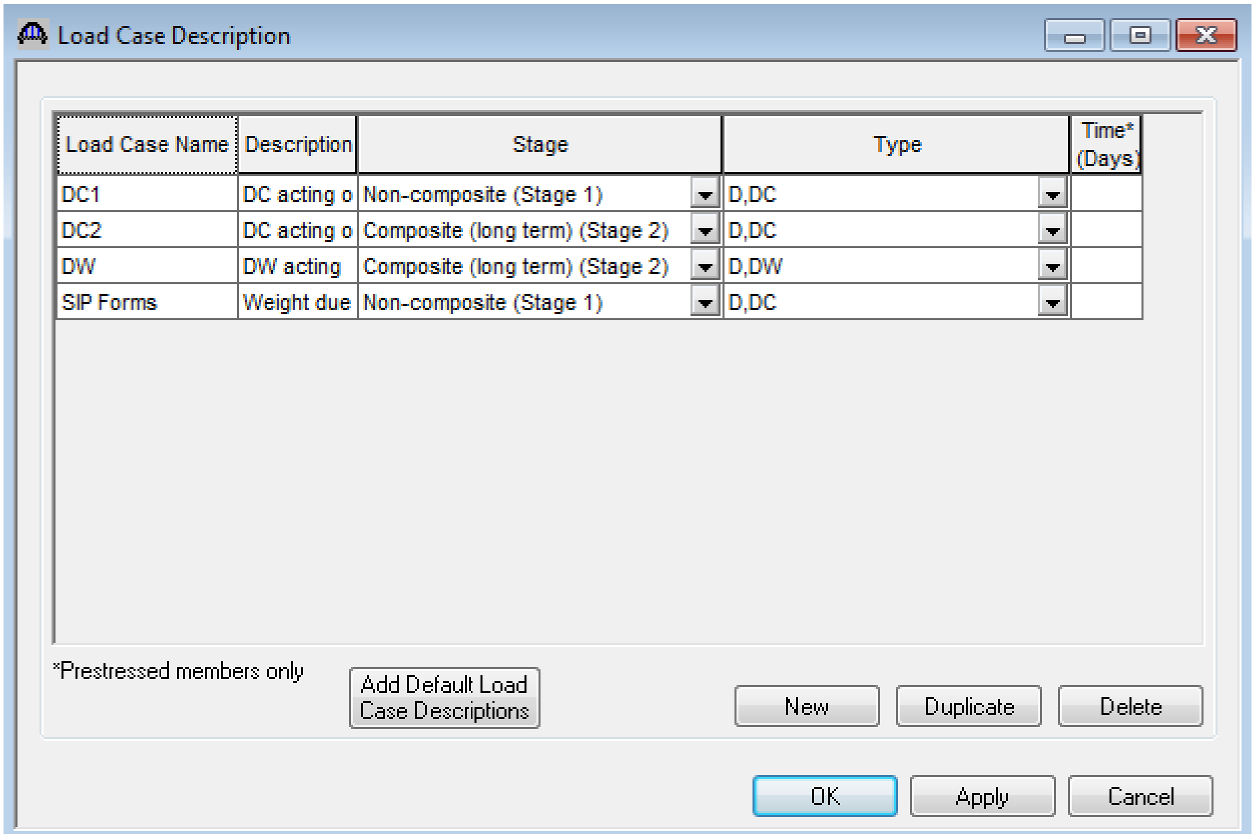
In this example we will add a girder line superstructure definition that has a frame leg support to RCTrainingBridge1. Select RCTrainingBridge1 on the right portion of the Bridge Explorer and open its Bridge Workspace tree.



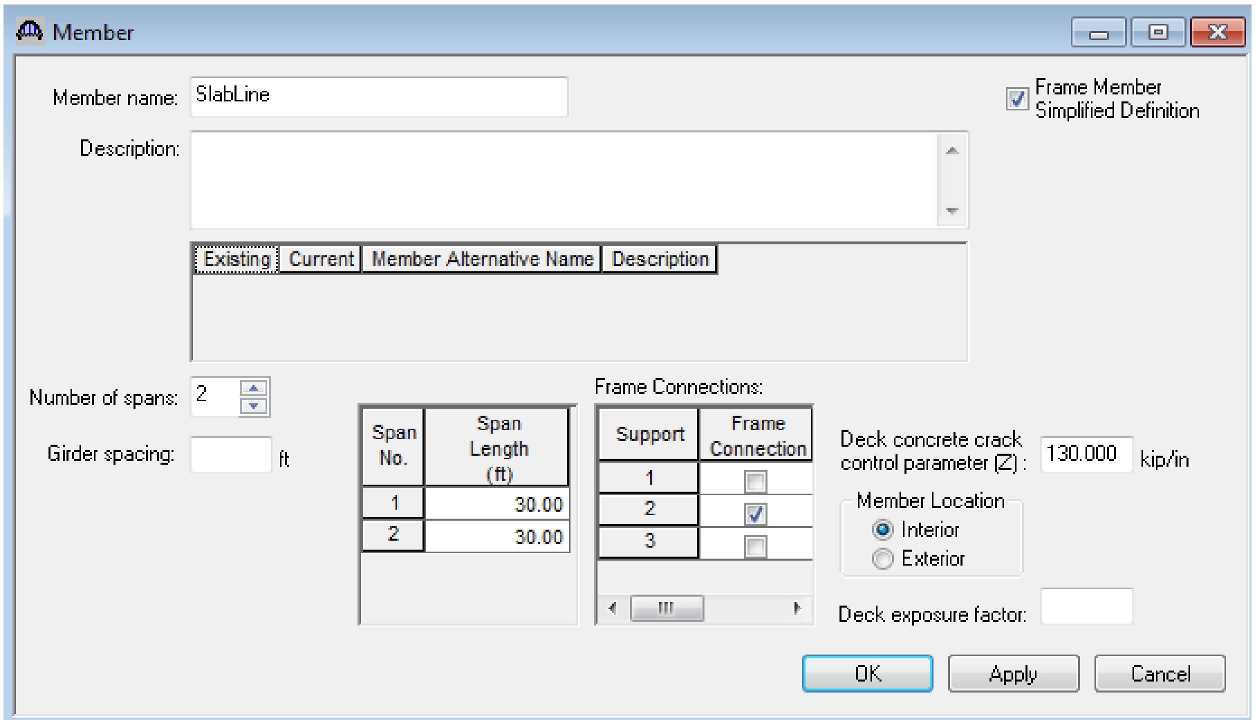
Create the following girder line superstructure definition.



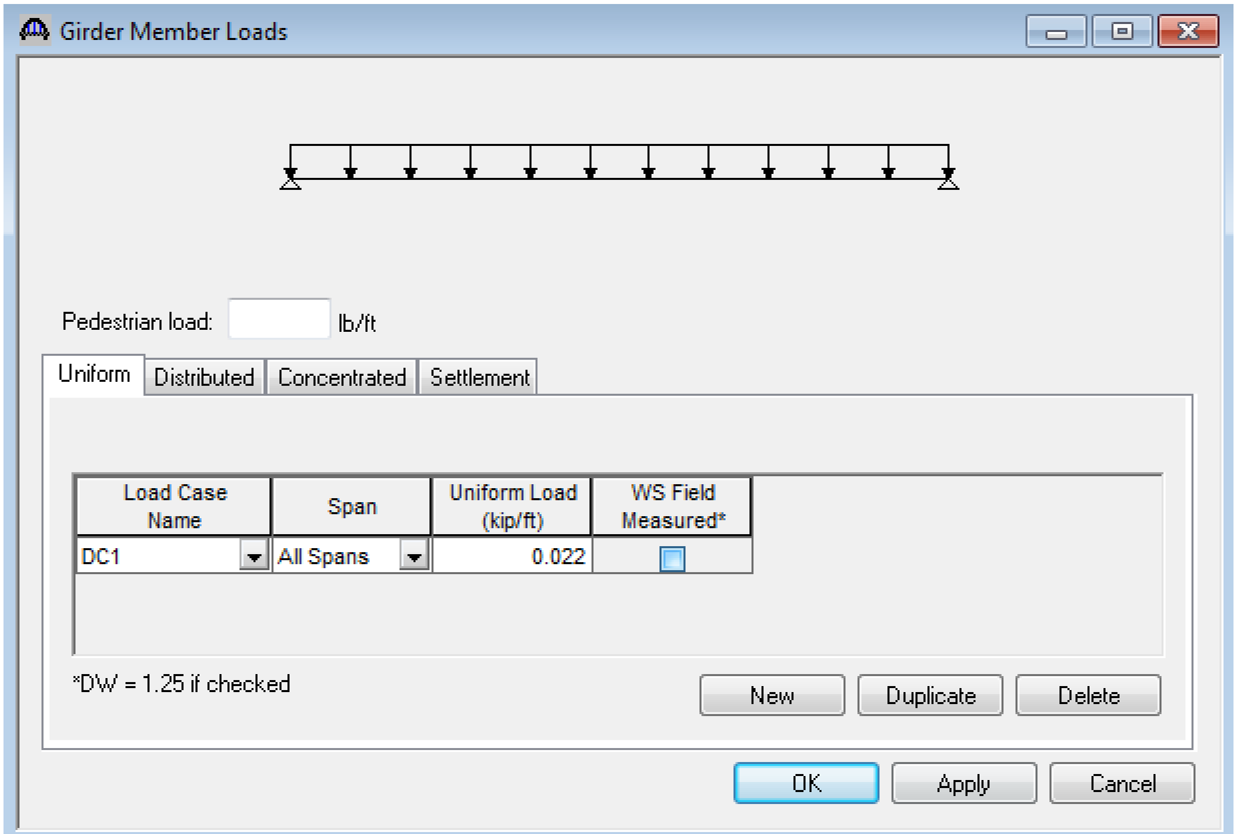
Open the Load Case Description window and use the "Add Default Load Case Descriptions" button to create the following load cases.



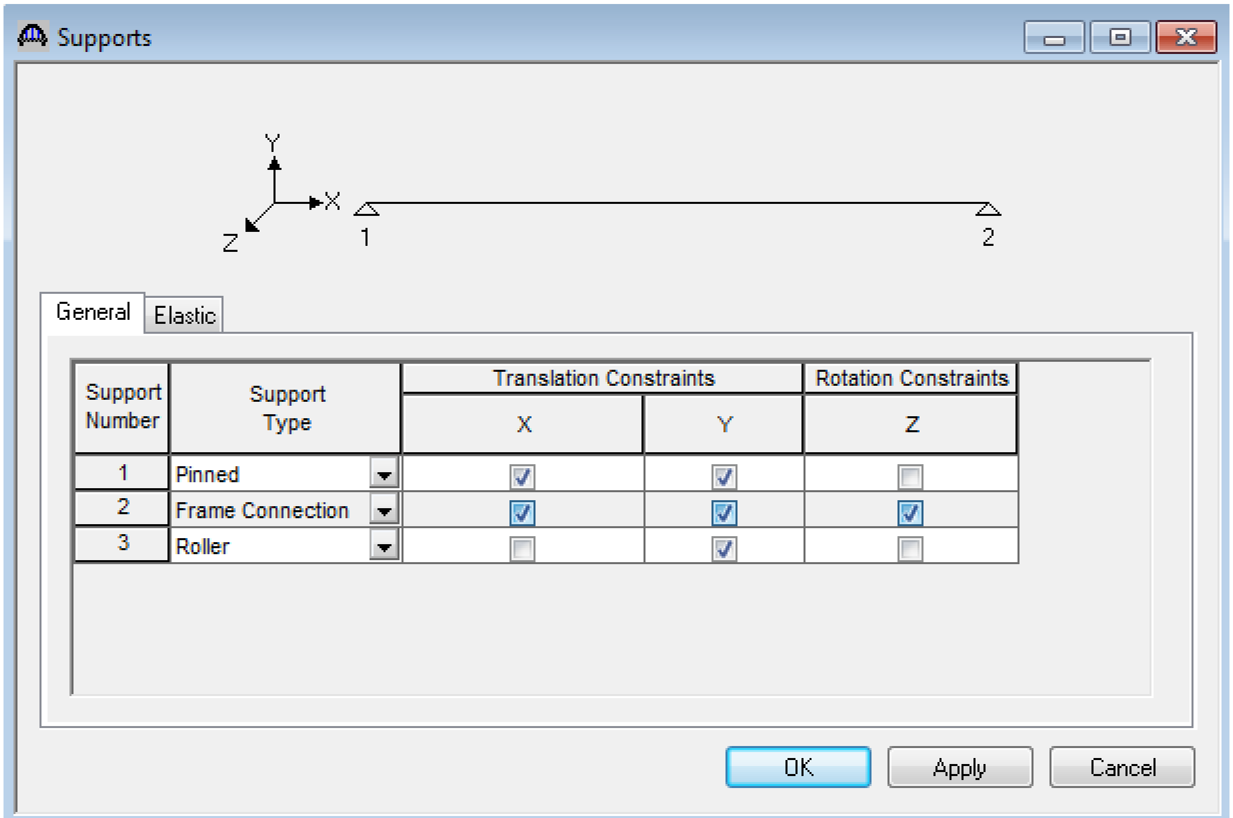
Create the following girder line member. Select the Frame Member Simplified Definition checkbox. Check "Support 2" in the Frame Connections grid to signify that support 2 of this member is supported by a frame leg that will be simplified as a support with spring constants.



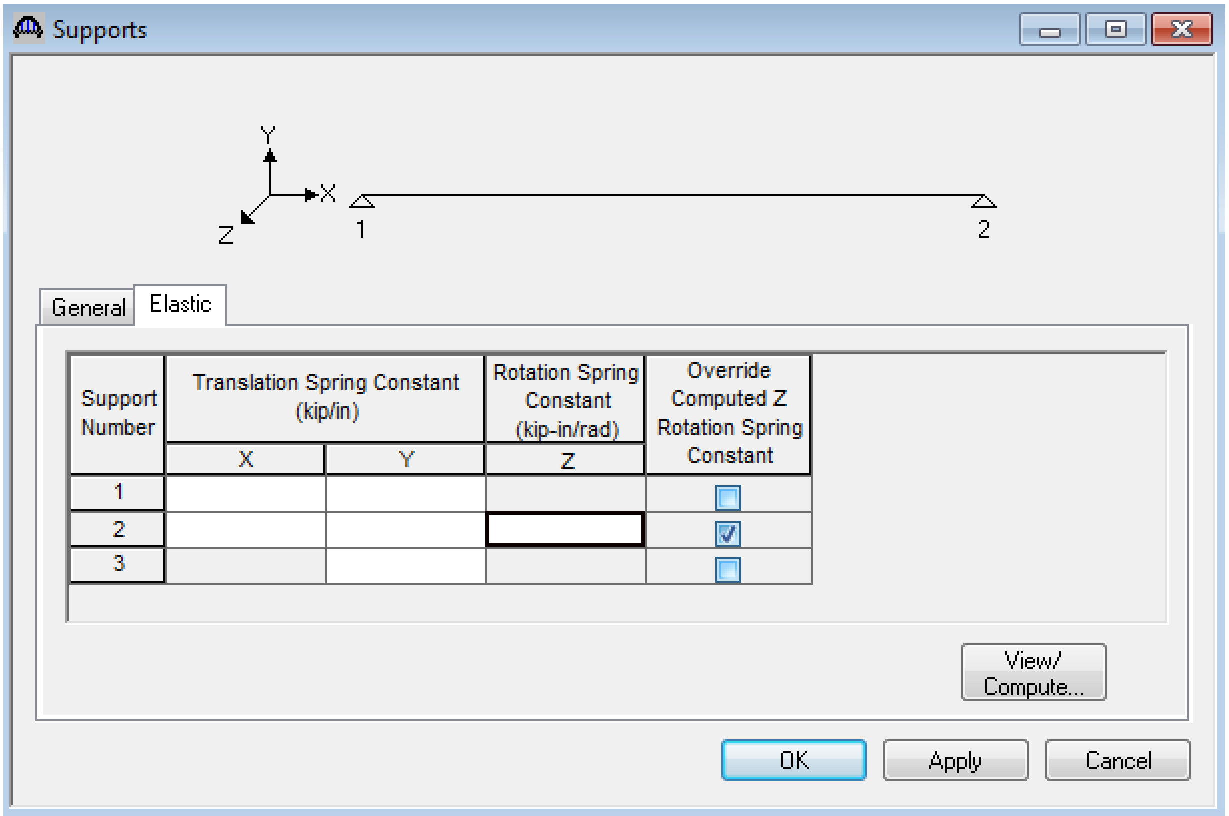
Double-click Member Loads to open the Member Loads window. This structure has 2 parapets each weighing 300 lb/ft. We are defining a 12” wide strip of slab as our member so the parapet load applied to this member will be (2*300 lb/ft)/27’ = 22 lb/ft.



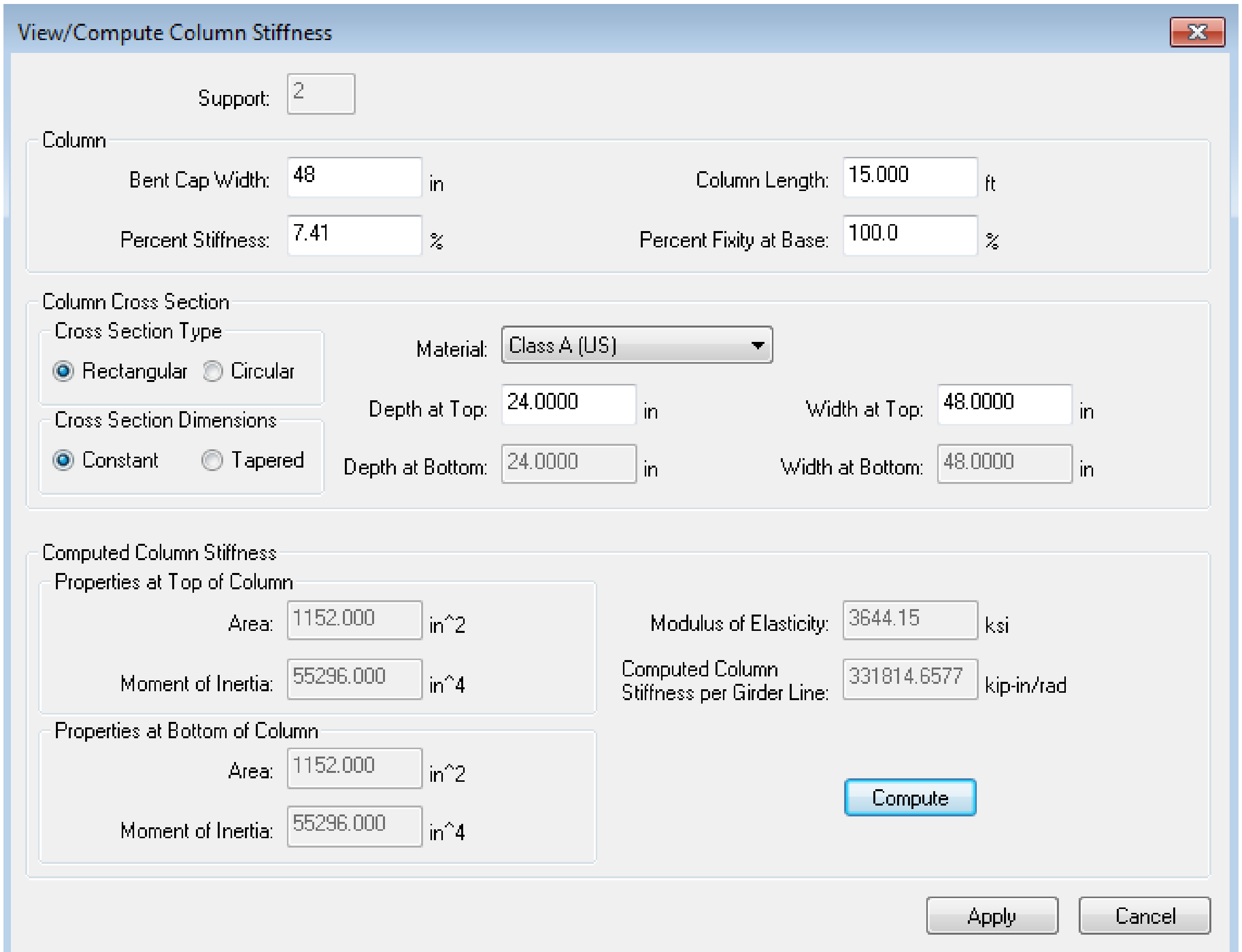
Since we selected "Frame Member Simplified Definition" on the Member window, the Supports window now displays Support 2 as a frame connection with all constraints fixed.



Select the "Rotation Spring Constant" cell for Support 2 on the Elastic tab. The "View/Compute…" button will now be activated.

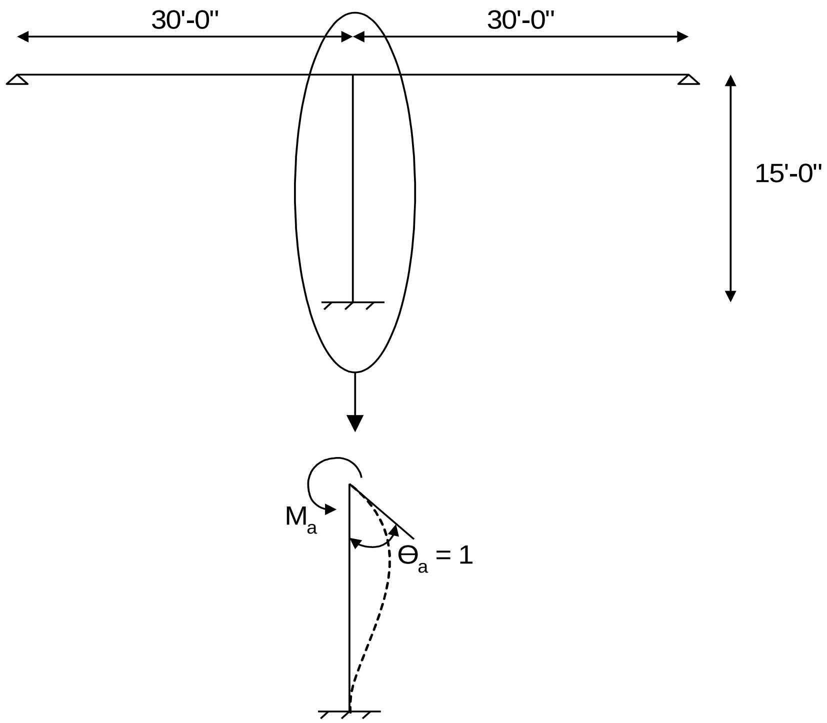


Select the "View/Compute…" button to open the View/Compute Column Stiffness Dialog. Enter the following data for the Column and click the Compute button to compute the column stiffness coefficient.



The column stiffness coefficient is computed using the Stiffness Method. In the stiffness method, a unit rotation in the Z direction is applied to the top of the column with all other displacements equal to zero. The member end loads that are required to produce this unit rotation are the stiffness coefficients. The moment applied at the top of the column to produce this unit rotation is the stiffness coefficient computed in this window.

The following diagram shows the frame leg and the moment applied to produce the unit rotation. You will need to use engineering judgement to determine the length of the frame leg based on the geometry and reinforcement of the frame structures you wish to analyze.



For this case, the moment required to produce a unit rotation at the top of the cantilever column is M_a = 4EI/L.

The "Percent Stiffness" field is the percent of one column's stiffness that is applied to this girderline member. For this example, the percent stiffness is computed as follows. You should use your own engineering judgement to determine the width of slab to model as a member and the percentage of the column to apply to this strip when entering slab structures with frame legs.

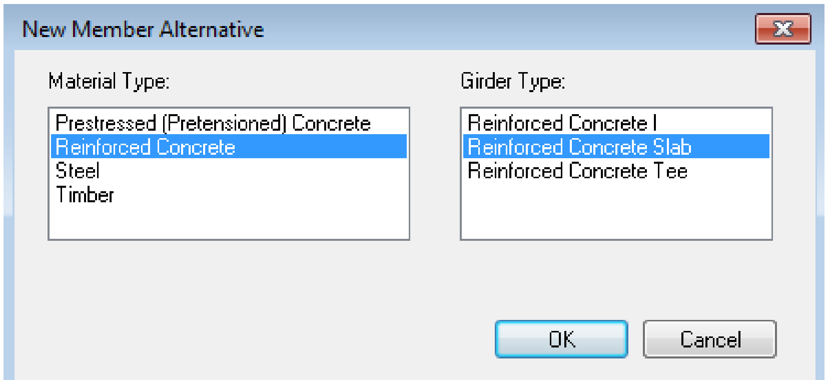
$$\frac{2\text{ columns}}{324''} \times 12''\text{strip} \times 100\% = 7.41\%\text{ column}$$

The column stiffness coefficient is computed as follows:

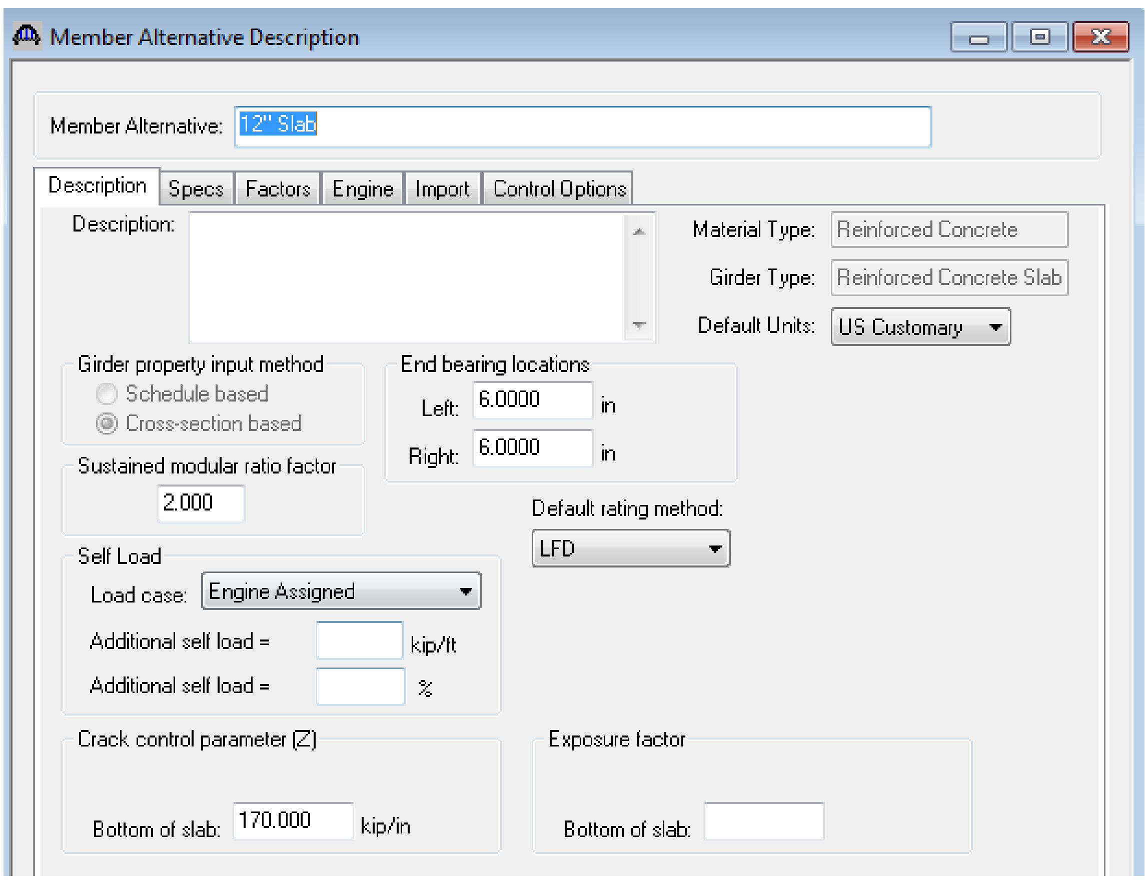
$$\frac{4EI}{L} \times Percentage = \frac{4(3644.15ksi)(55296in^4)}{180''} \times 7.41\% = 331{,}814.7 kip-in/rad$$

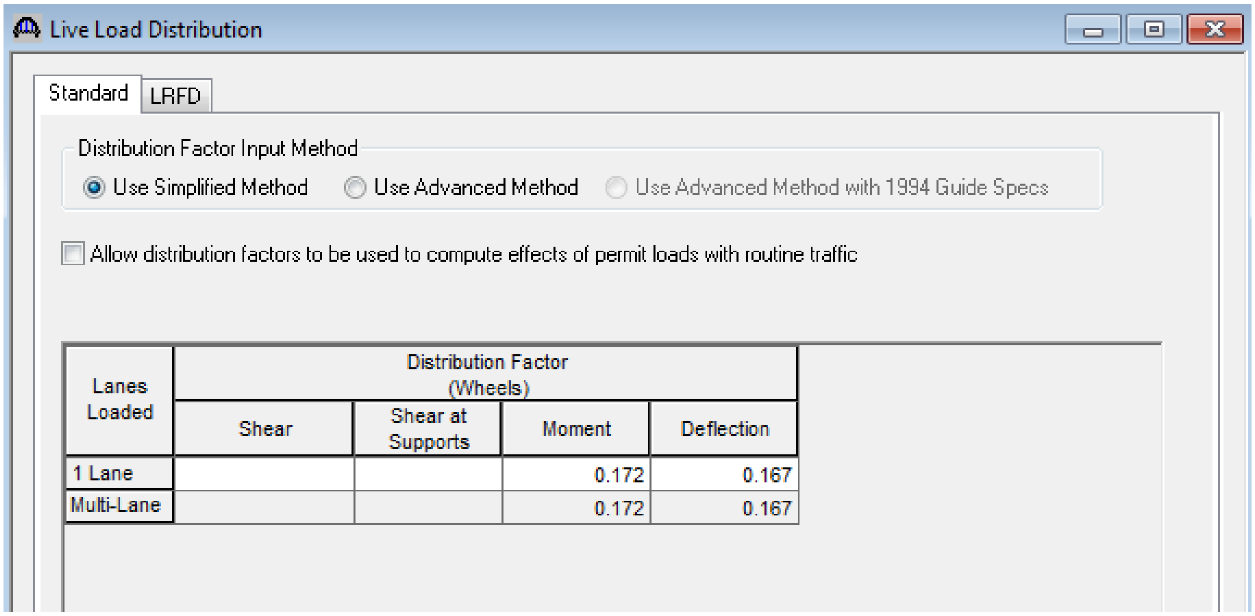
Click the Apply button to apply this stiffness coefficient to Support 2.

Create a reinforced concrete slab member alternative as follows.



The Member Alternative Description window will open. Enter the appropriate data as shown below. The Cross-section based Girder property input method is the only input method available for a reinforced concrete beam. AASHTO Article 3.24.4 states that concrete slabs designed in accordance with AASHTO Article 3.24.3 shall be considered satisfactory in bond and shear so we will select the LFD Ignore shear checkbox under the Shear computation method.





Lanes Loaded	Distribution Factor (Wheels)			
	Shear	Shear at Supports	Moment	Deflection
1 Lane			0.172	0.167
Multi-Lane			0.172	0.167

The distribution factor for a slab member is computed as follows:

AASHTO Article 3.24.3

Distribution width, E, for a wheel is $4 + 0.06S$ but shall not exceed 7'.

S = span length = 30'

$E = 4 + 0.06 * 30' = 5.8' \le 7'$

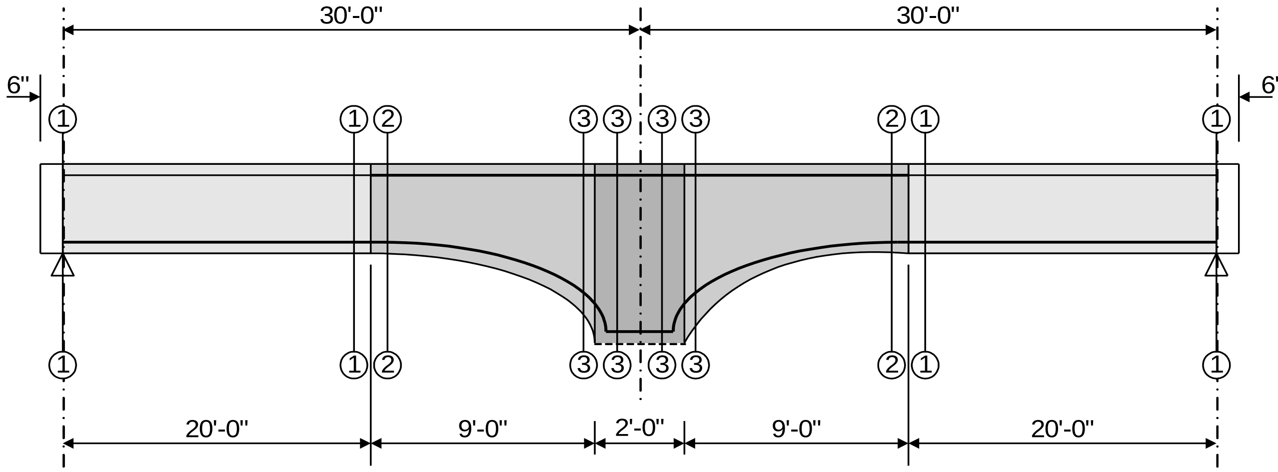
$$\text{Moment DF} = \frac{1\ \text{wheel}}{5.8'} = 0.1724\, wheel / ft$$

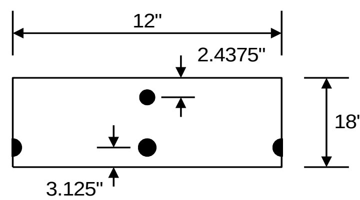
The cross section that we are going to enter for this member alternative is 12" wide so we will use the wheel distribution factor per foot. If we were entering a cross section that is 24" wide, we would enter the distribution factor as 2*0.1724=0.3448.

The deflection distribution factor is calculated as the number of lanes divided by the number of girders. For a reinforced concrete slab bridge, the number of girders is taken as the lane width divided by the strip width. Our lane width is 12 feet and our strip width is 12" or 1 foot.

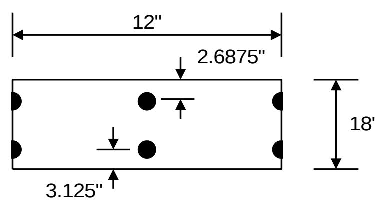
$$\text{Deflection DF} = \frac{1\ \text{lane} * 2\ \text{wheels/lane}}{(12'/1')} = 0.1667\, wheel / ft$$

We can now create a new cross section by double-clicking on Cross Section in the tree. This member contains three cross sections as illustrated below. The completed Cross Section windows follow.

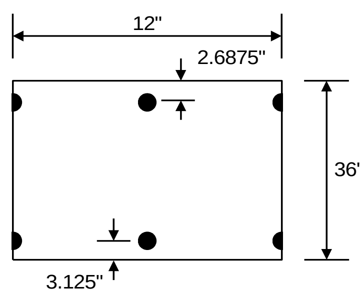




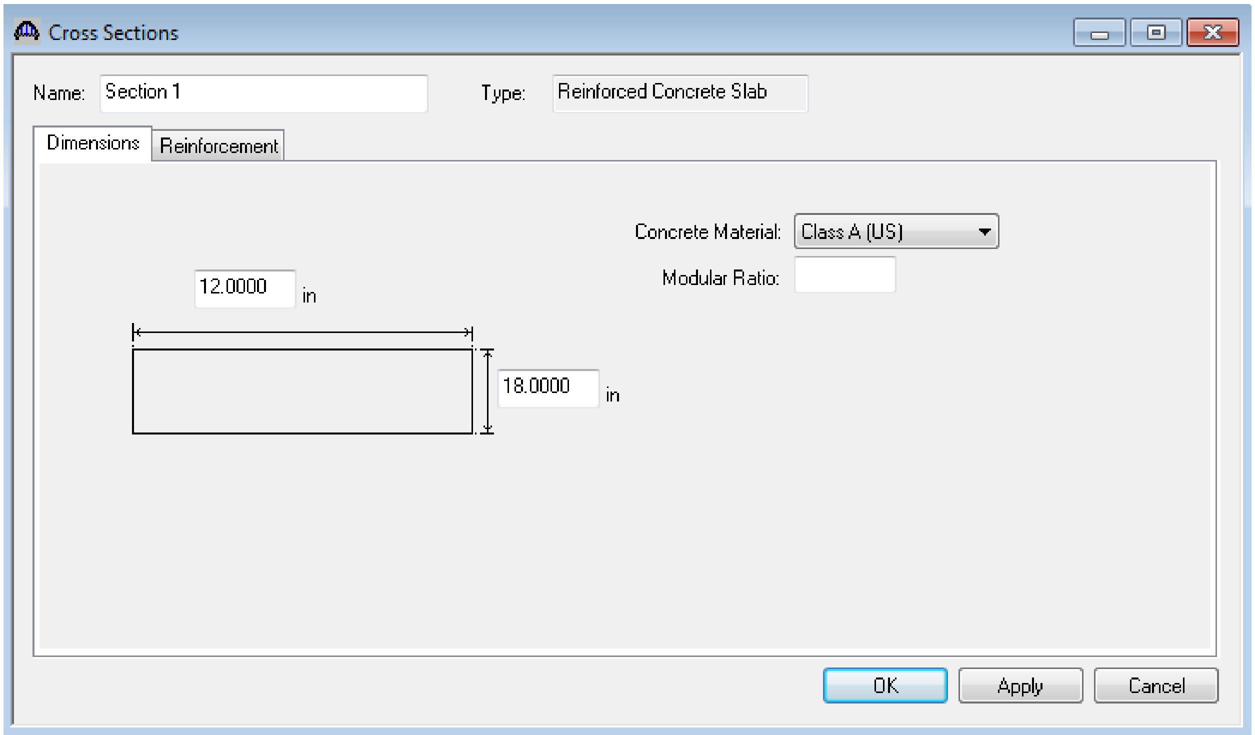
Section 1

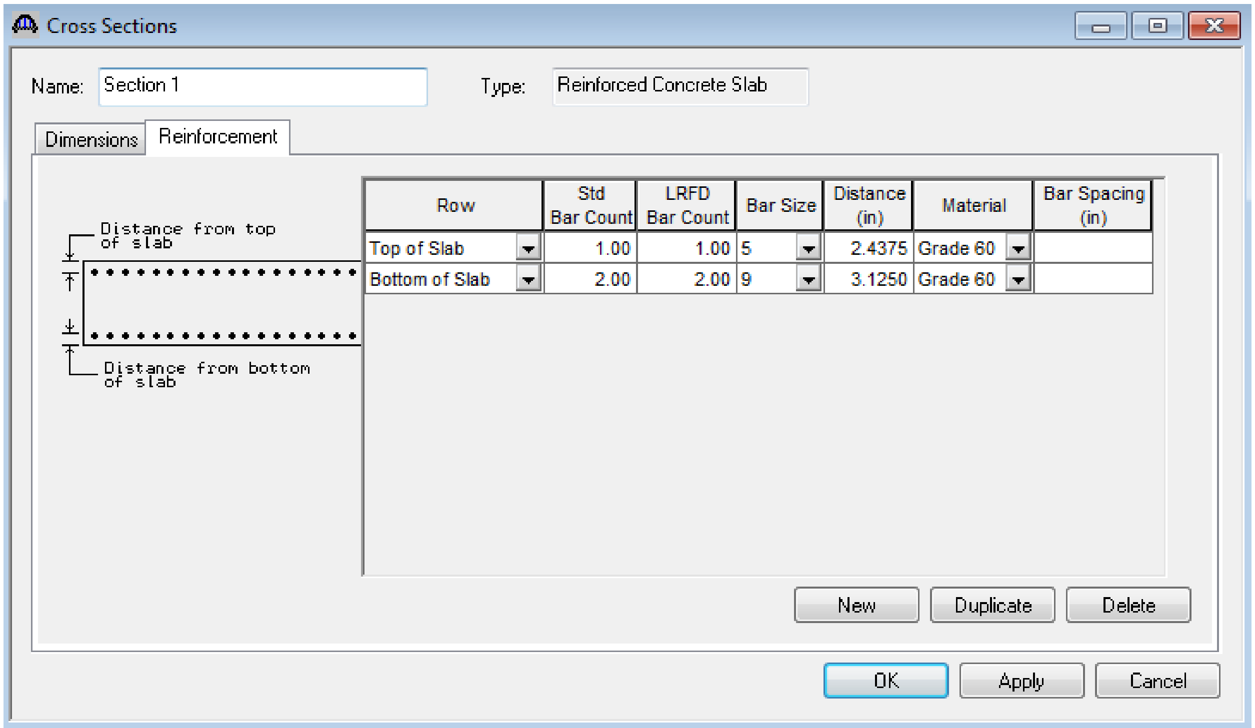


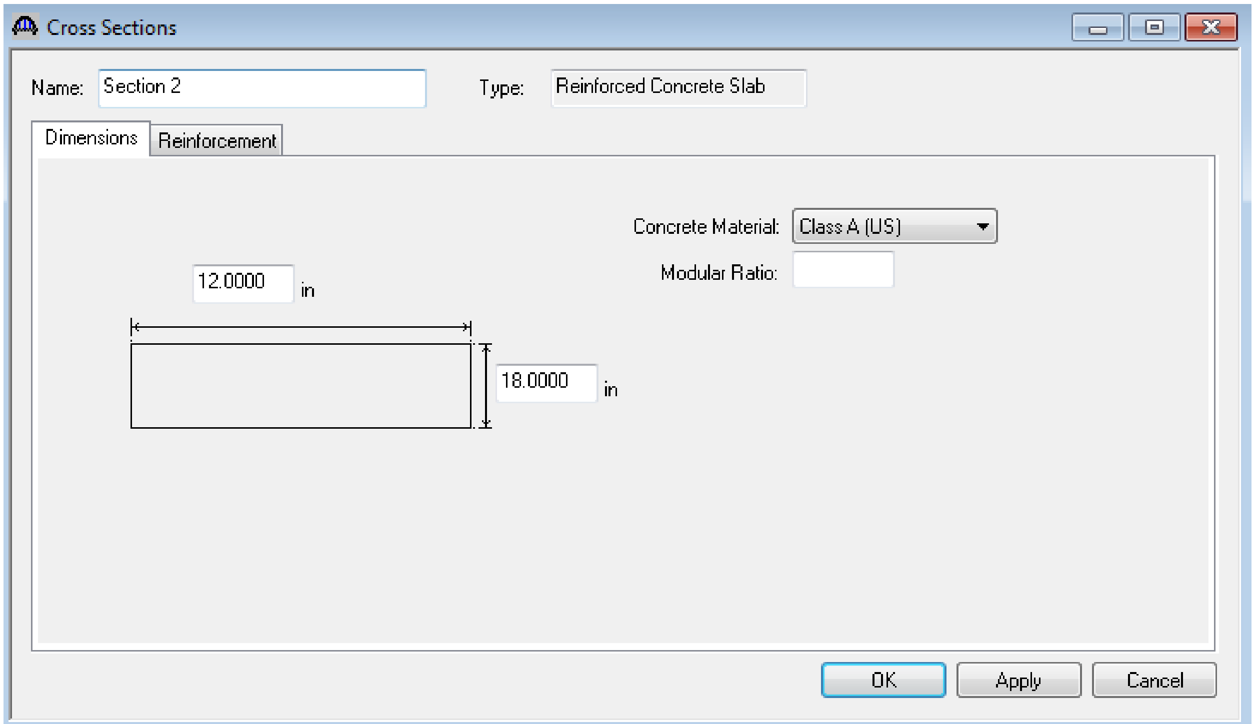
Section 2

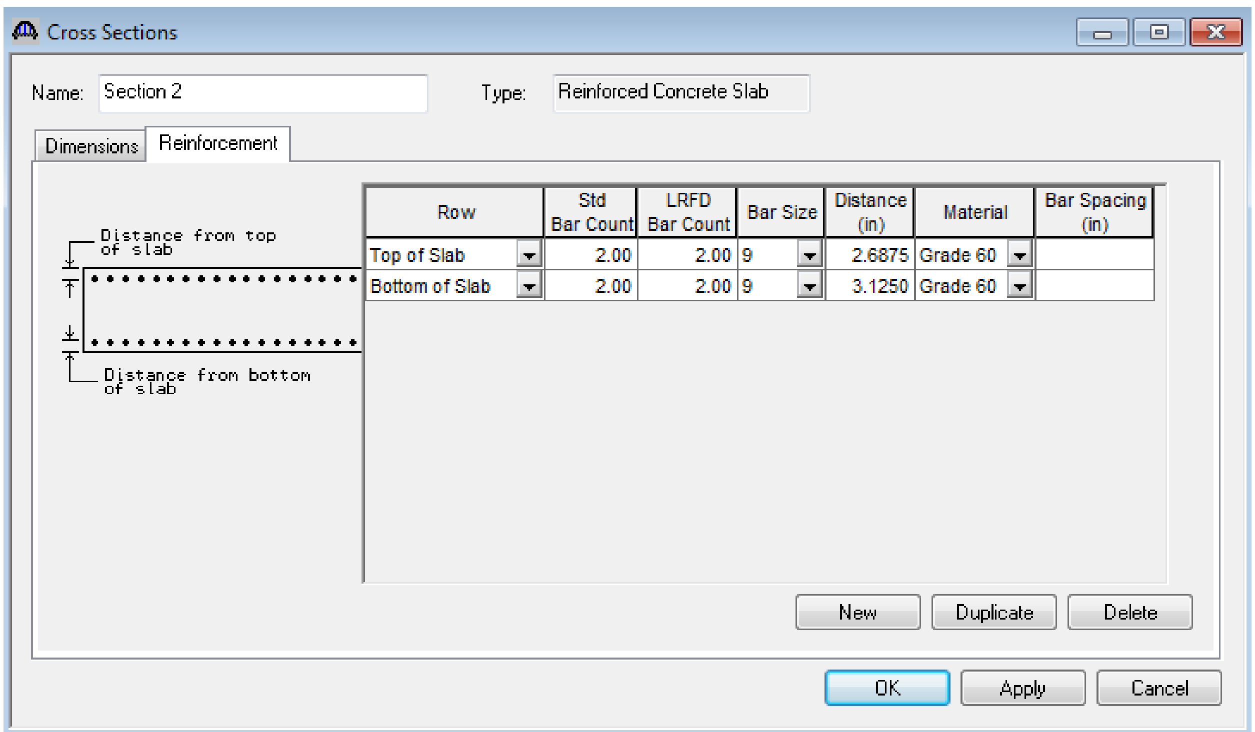


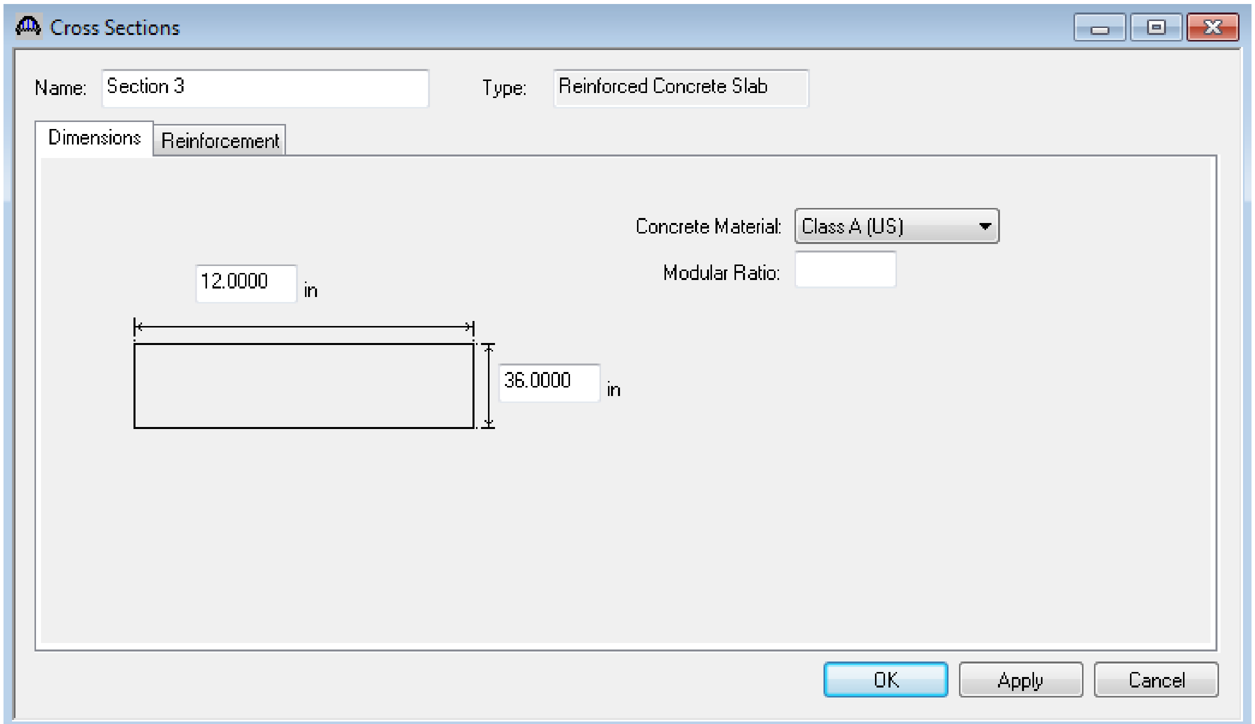
Section 3

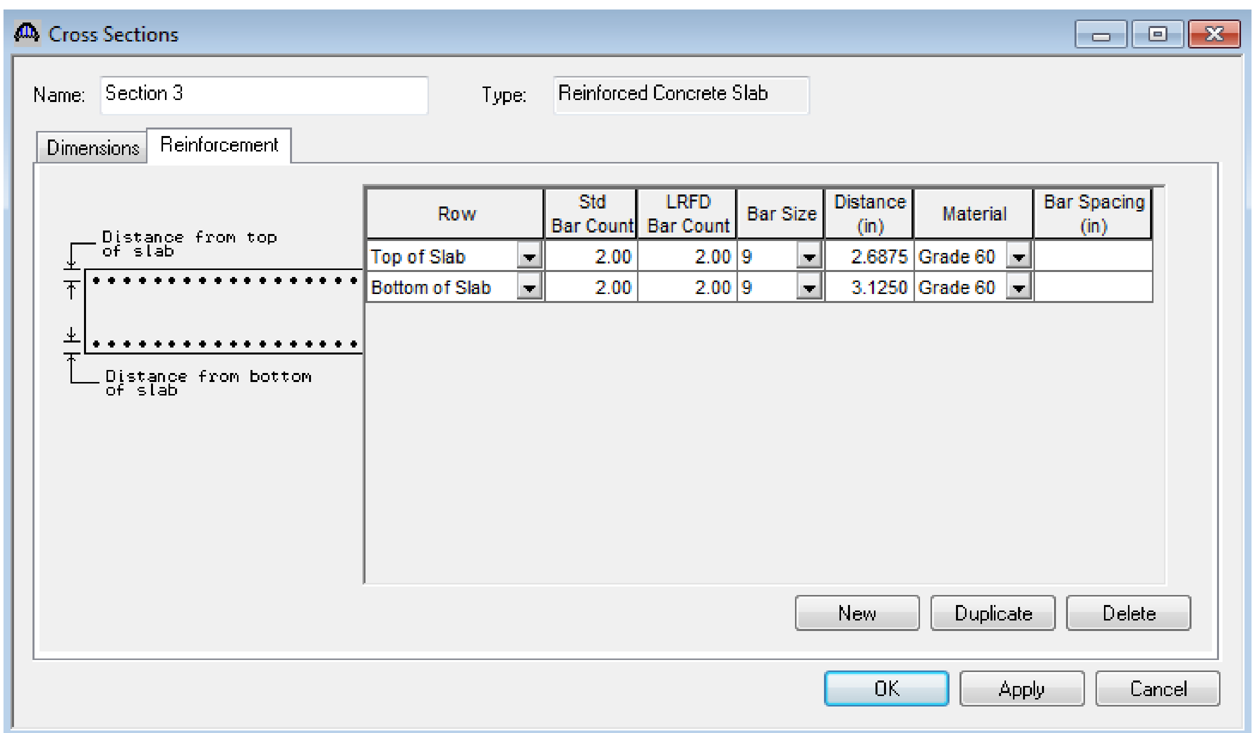

Cross Sections
Name:
Section 1
Type:
Reinforced Concrete Slab
Dimensions
Reinforcement
Concrete Material:
Class A (US)
Modular Ratio:
12.0000
in
18.0000
in
OK
Apply
Cancel


Cross Sections
Name:
Section 1
Type:
Reinforced Concrete Slab
Dimensions
Reinforcement
Distance from top of slab
Distance from bottom of slab
Row | Std Bar Count | LRFD Bar Count | Bar Size | Distance (in) | Material | Bar Spacing (in)
Top of Slab | 1.00 | 1.00 | 5 | 2.4375 | Grade 60
Bottom of Slab | 2.00 | 2.00 | 9 | 3.1250 | Grade 60
New
Duplicate
Delete
OK
Apply
Cancel

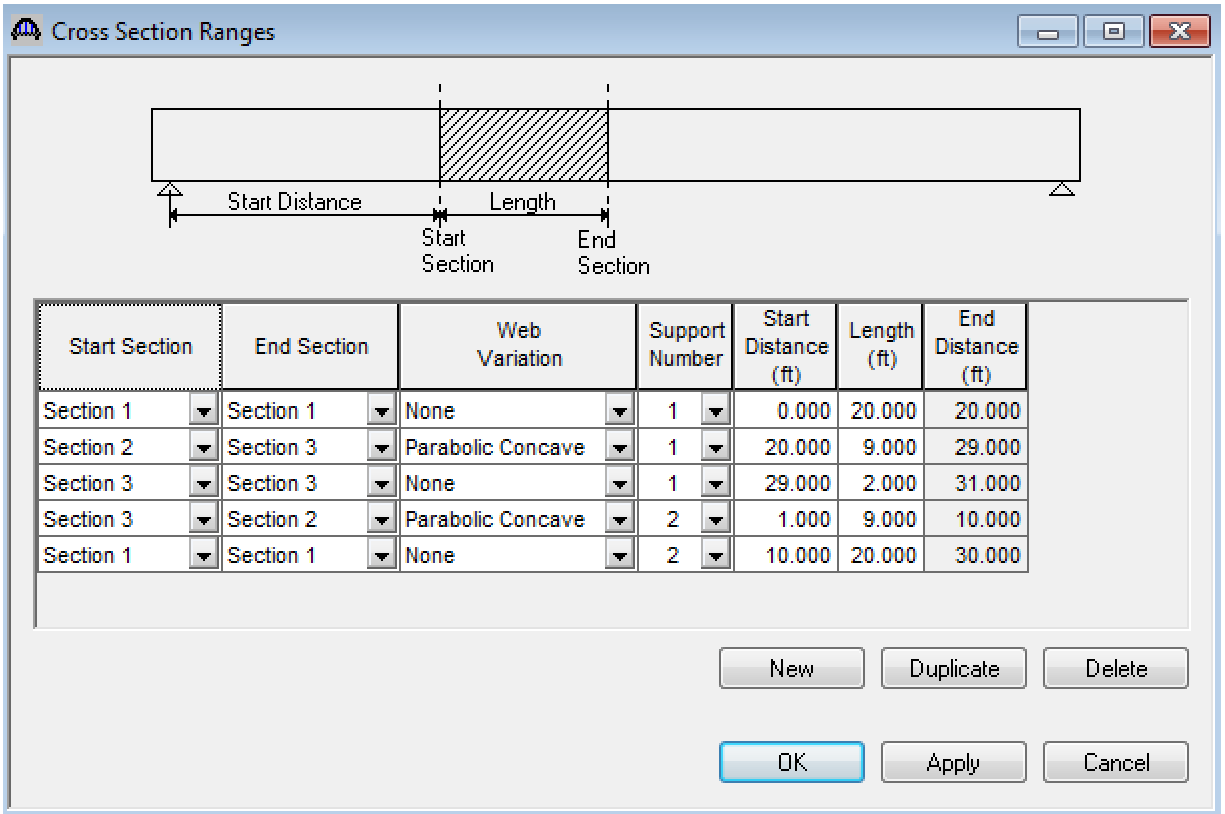

Cross Sections
Name: Section 2
Type: Reinforced Concrete Slab
Dimensions
Reinforcement
Concrete Material: Class A (US)
Modular Ratio:
12.0000 in
18.0000 in
OK
Apply
Cancel


Cross Sections
Name: Section 2
Type: Reinforced Concrete Slab
Dimensions
Reinforcement
Distance from top of slab
Distance from bottom of slab
Row
Std Bar Count
LRFD Bar Count
Bar Size
Distance (in)
Material
Bar Spacing (in)
Top of Slab 2.00 2.00 9 2.6875 Grade 60
Bottom of Slab 2.00 2.00 9 3.1250 Grade 60
New
Duplicate
Delete
OK
Apply
Cancel


Cross Sections
Name:
Section 3
Type:
Reinforced Concrete Slab
Dimensions
Reinforcement
Concrete Material:
Class A (US)
Modular Ratio:
12.0000
in
36.0000
in
OK
Apply
Cancel


Cross Sections
Name:
Section 3
Type:
Reinforced Concrete Slab
Dimensions
Reinforcement
Distance from top of slab
Distance from bottom of slab
Row | Std Bar Count | LRFD Bar Count | Bar Size | Distance (in) | Material | Bar Spacing (in)
Top of Slab | 2.00 | 2.00 | 9 | 2.6875 | Grade 60
Bottom of Slab | 2.00 | 2.00 | 9 | 3.1250 | Grade 60
New
Duplicate
Delete
OK
Apply
Cancel

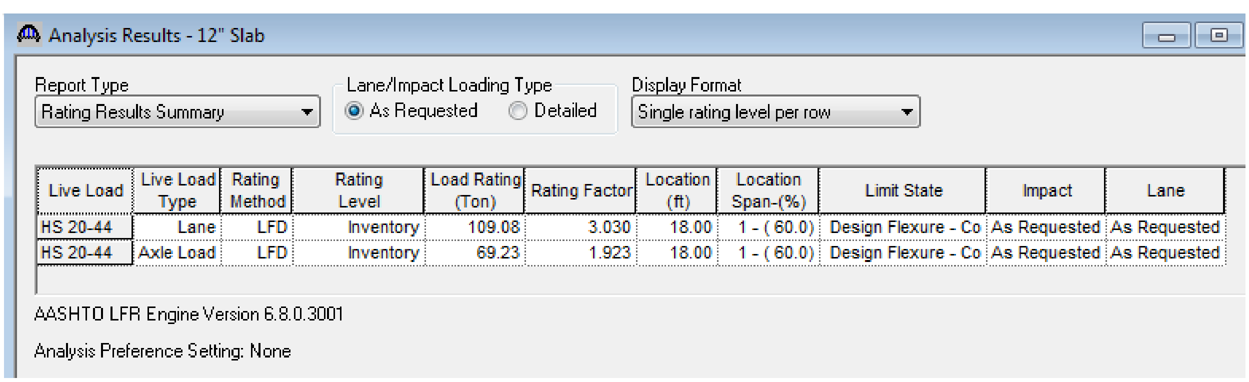
The cross sections are now applied over the length of the member using the Cross Section Ranges window as shown below:



Start Section	End Section	Web Variation	Support Number	Start Distance (ft)	Length (ft)	End Distance (ft)
Section 1	Section 1	None	1	0.000	20.000	20.000
Section 2	Section 3	Parabolic Concave	1	20.000	9.000	29.000
Section 3	Section 3	None	1	29.000	2.000	31.000
Section 3	Section 2	Parabolic Concave	2	1.000	9.000	10.000
Section 1	Section 1	None	2	10.000	20.000	30.000

Shear Reinforcement Ranges and Bracing Ranges are not applicable to this member so we will not enter any data in these windows. We also do not need to define any Points of Interest since we will not be overriding any information we have entered.

The description of this structure is complete. The results of an LFD analysis are shown below.



Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HS 20-44	Lane	LFD	Inventory	109.08	3.030	18.00	1 - (60.0)	Design Flexure - Co	As Requested	As Requested
HS 20-44	Axle Load	LFD	Inventory	69.23	1.923	18.00	1 - (60.0)	Design Flexure - Co	As Requested	As Requested

The live load distribution factors for LRFD analysis are calculated as shown below. For single lane, the distribution factor = 12” member*0.0066 lanes/inch = 0.079 lanes. For multi lane, the distribution factor = 12”*0.008lanes/” = 0.096 lanes. The window for Live Load Distribution LRFD is shown on the next page with values filled in for the moment distribution factors. Select Deflection and Shear in the Action list box and fill in their distribution factors the same way.

AASHTO Article 4.6.2.3

Equivalent width of strip per lane, E, for both shear and moment single lane

$$\mathrm{E} = 10.0 + 5.0\sqrt{\mathrm{L}_1 W_1}$$

L_1 = span length $\leq 60'$ = 30'

W_1 = modified edge-edge width of bridge $\leq 30'$ for single lane = 27'

$$E = 10 + 5.0 * \sqrt{(30)(27)} = 152''$$

$$\text{Moment and Shear DF} = \frac{1 \text{ lane}}{152''} = 0.0066 \, lane / inch$$

For multi lane:

$$\mathrm{E} = 84.0 + 1.44\sqrt{\mathrm{L}_1 W_1} \leq \frac{12.0W}{N_L}$$

W_1 = modified edge-edge width of bridge $\leq 60'$ for multi lane = 27'

W = width edge-edge of bridge = 27'

N_L = number of lanes

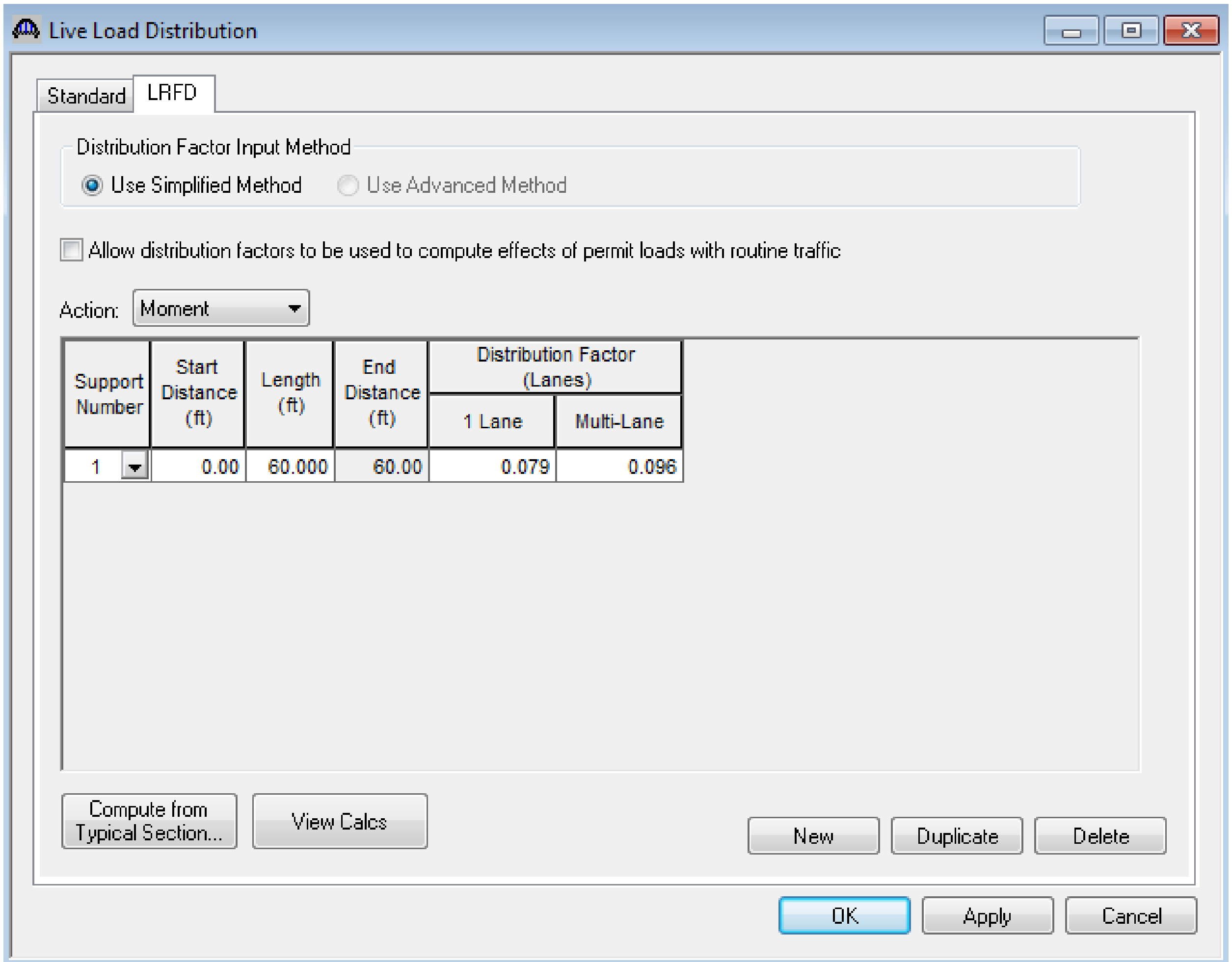
$$E = 84 + 1.44\sqrt{(30)(27)} = 125'' \leq \frac{12(27)}{2} = 162''$$

$$\text{Moment and Shear DF} = \frac{1 \text{ lane}}{125''} = 0.008 \, lane / inch$$

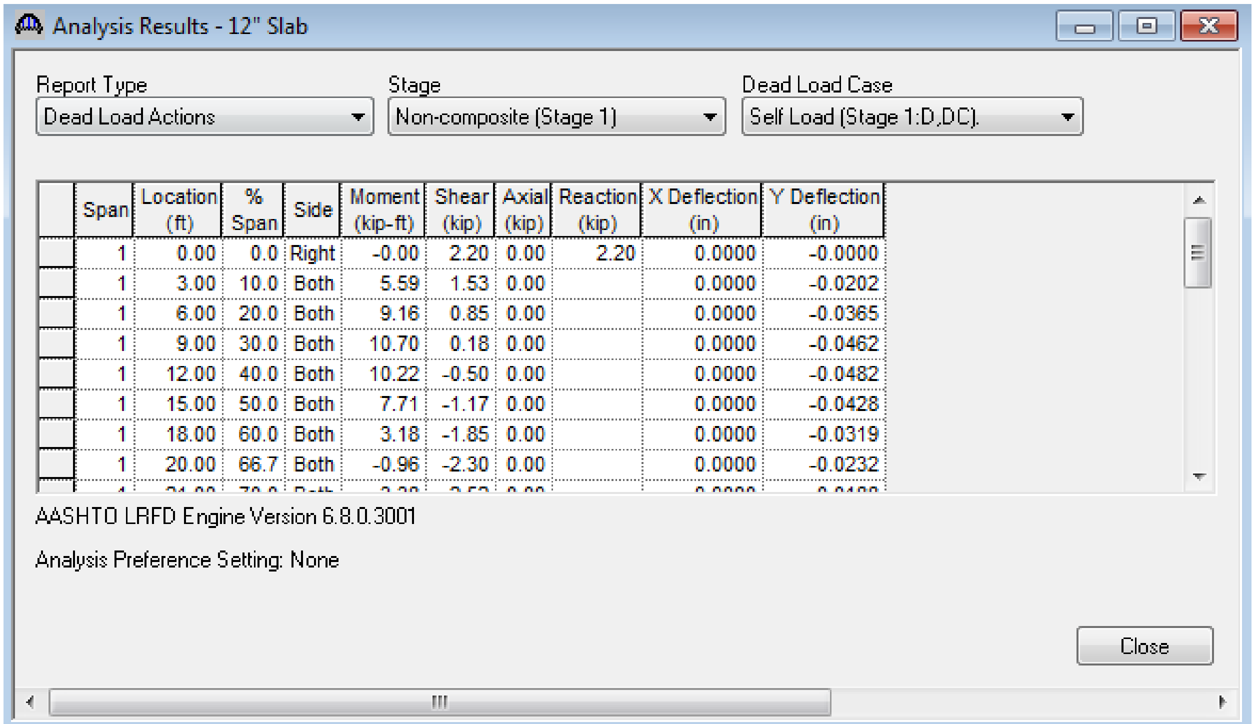
$$\text{Deflection DF} = \frac{\#\text{lanes}}{(\text{Lane width / Strip Width})} * \text{Multiple Presence Factor}$$

$$\text{Single lane Deflection DF} = \frac{1 \text{ lane}}{(12'/1')}(1.20) = 0.100 \, lanes$$

$$\text{Multi lane Deflection DF} = \frac{2 \text{ lanes}}{(12'*2/1')}(1.0) = 0.0833 \, lanes$$


Live Load Distribution
Standard
LRFD
Distribution Factor Input Method
Use Simplified Method
Use Advanced Method
Allow distribution factors to be used to compute effects of permit loads with routine traffic
Action:
Moment
Support Number
Start Distance (ft)
Length (ft)
End Distance (ft)
Distribution Factor (Lanes)
1 Lane
Multi-Lane
1
0.00
60.000
60.00
0.079
0.096
Compute from Typical Section...
View Calcs
New
Duplicate
Delete
OK
Apply
Cancel

The results of an LRFD analysis for the HL93 loading are shown below:



Span	Location (ft)	% Span	Side	Moment (kip-ft)	Shear (kip)	Axial (kip)	Reaction (kip)	X Deflection (in)	Y Deflection (in)
1	0.00	0.0	Right	-0.00	2.20	0.00	2.20	0.0000	-0.0000
1	3.00	10.0	Both	5.59	1.53	0.00		0.0000	-0.0202
1	6.00	20.0	Both	9.16	0.85	0.00		0.0000	-0.0365
1	9.00	30.0	Both	10.70	0.18	0.00		0.0000	-0.0462
1	12.00	40.0	Both	10.22	-0.50	0.00		0.0000	-0.0482
1	15.00	50.0	Both	7.71	-1.17	0.00		0.0000	-0.0428
1	18.00	60.0	Both	3.18	-1.85	0.00		0.0000	-0.0319
1	20.00	66.7	Both	-0.96	-2.30	0.00		0.0000	-0.0232