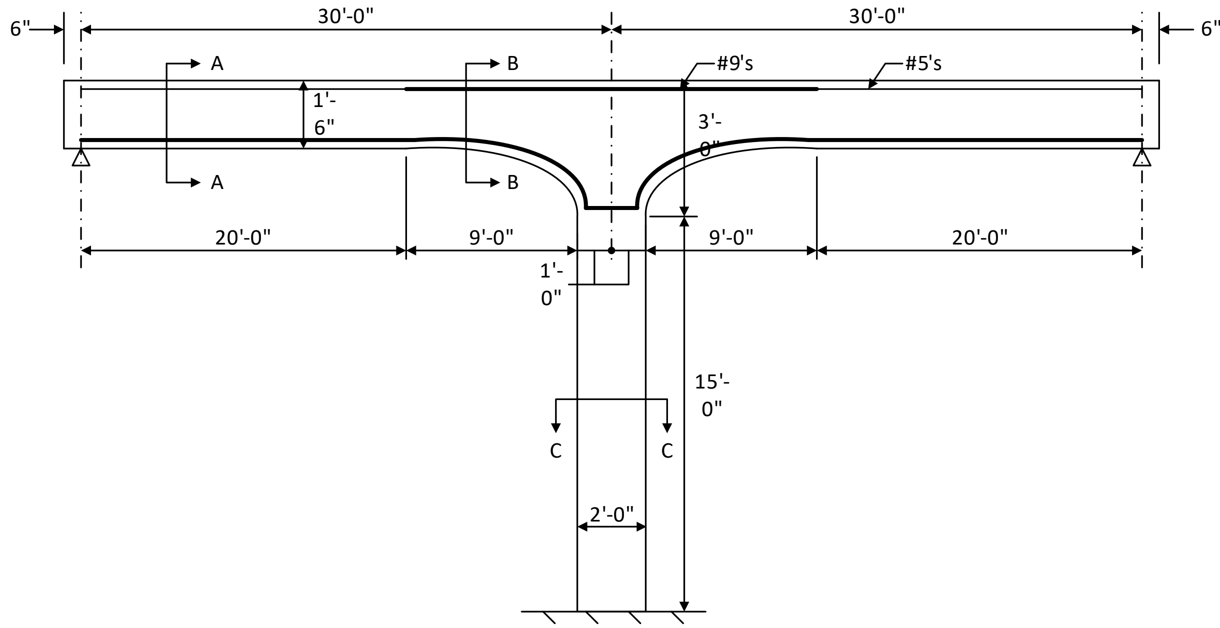
AASHTOWare BrDR 7.5.0

Reinforced Concrete Structure Tutorial

FRM1 – Reinforced Concrete Frame Example

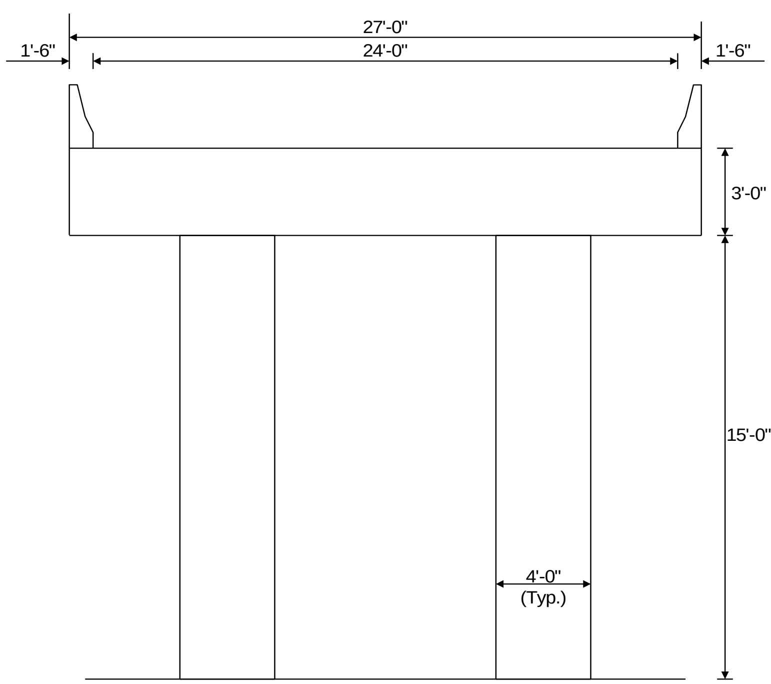
Introduction - Elevation

FRM1 – Two span reinforced concrete frame example

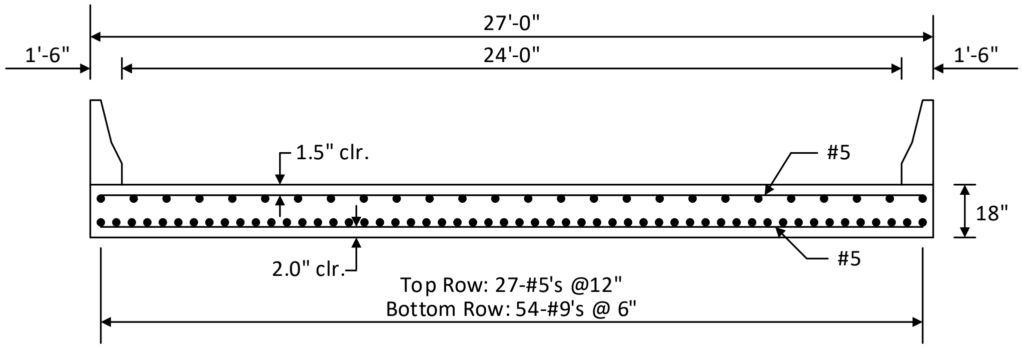


Elevation

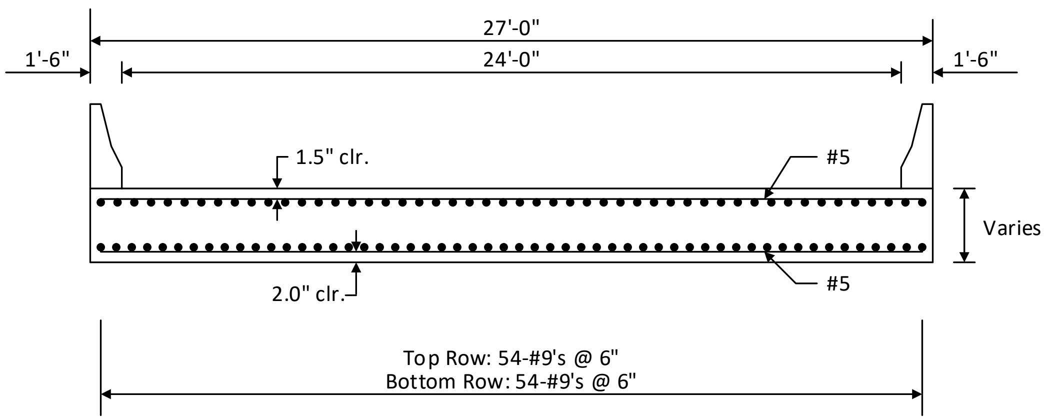
Structure typical section at Pier



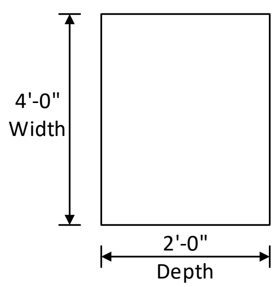
Structure Typical Section at Pier



Section A-A



Section B-B



Section C-C

<u>Material Properties</u>

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

<u>Parapets</u>

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.

BrDR Training

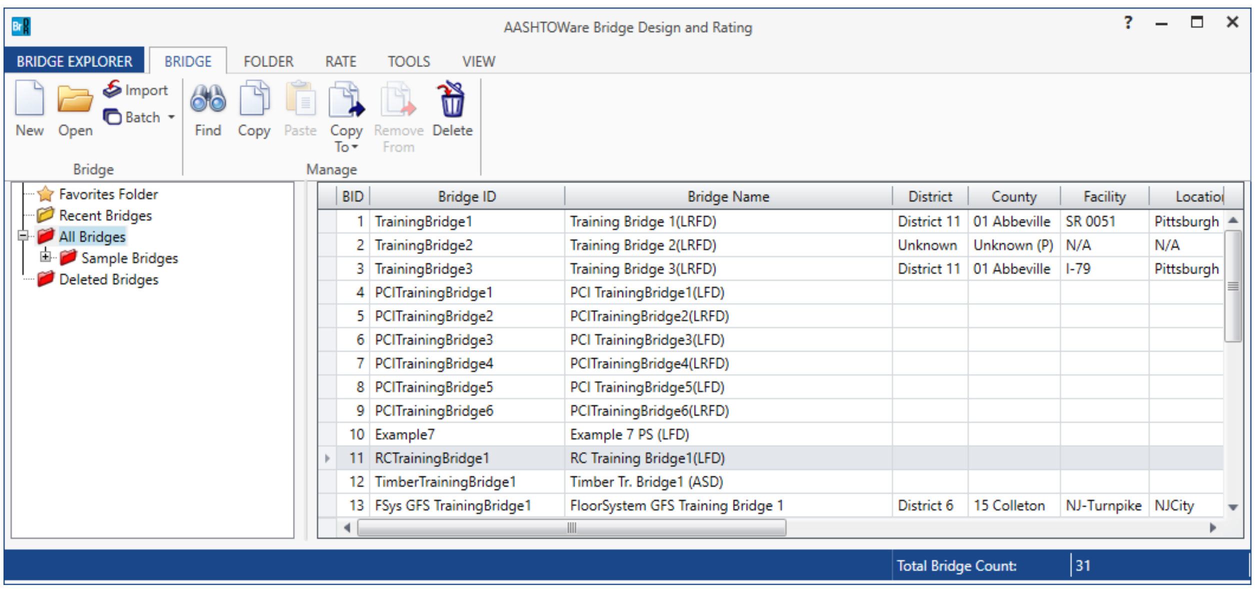
FRM1 – Reinforced Concrete Frame Example

Topics Covered

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

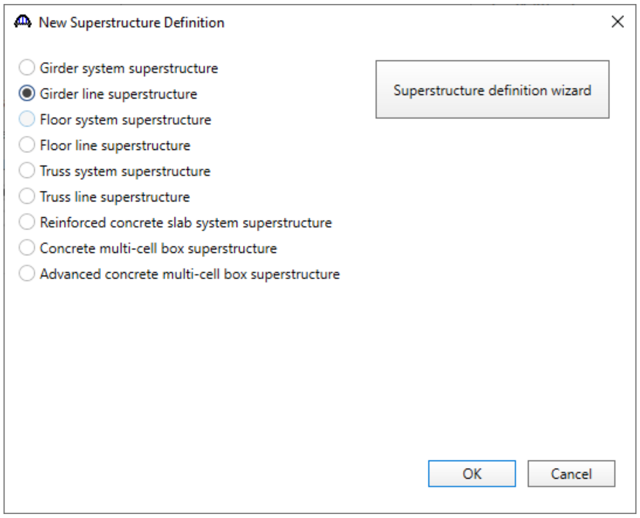
This example demonstrates entering a reinforced concrete frame in BrDR using the **Compute Bent Stiffness** window.

In this example a girder line superstructure definition that has a frame leg support will be added to **RCTrainingBridge1**. Double click on **BID11 RCTrainingBridge1** from the **Bridge Explorer** and open its **Bridge Workspace** tree.

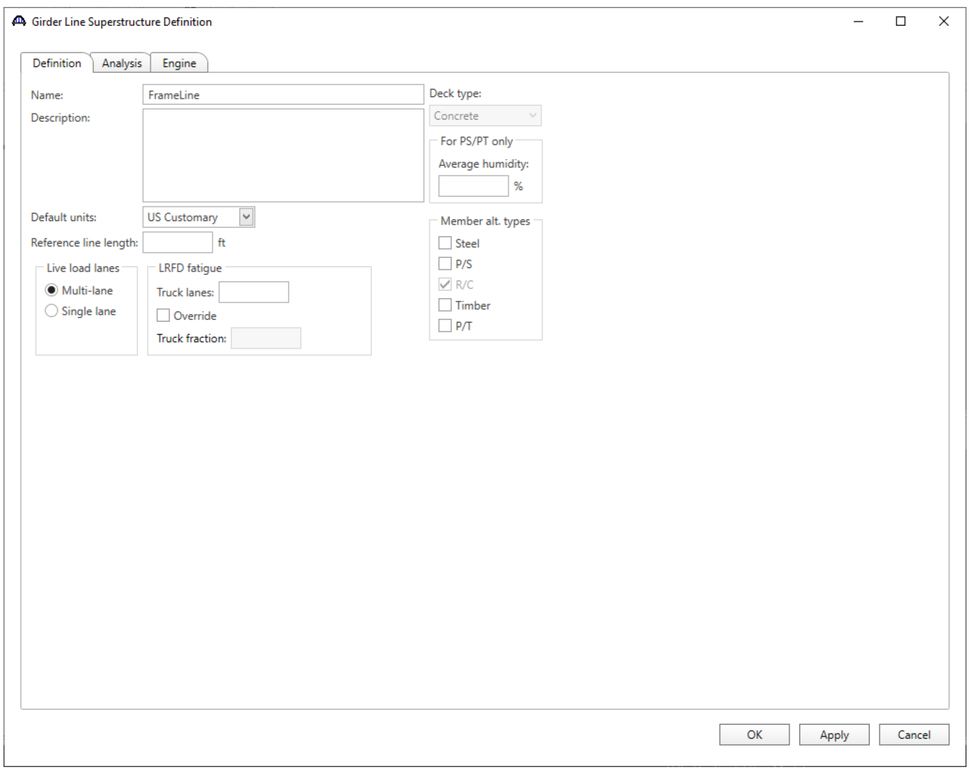


Superstructure Definition

Double click on **SUPERSTRUCTURE DEFINITIONS** (or click on **SUPERSTRUCTURE DEFINITIONS** and select **New** from the **Manage** group of the **WORKSPACE** ribbon or right mouse click on **SUPERSTRUCTURE DEFINITIONS** and select **New** from the popup menu) to create a new structure definition. The window shown below will appear.



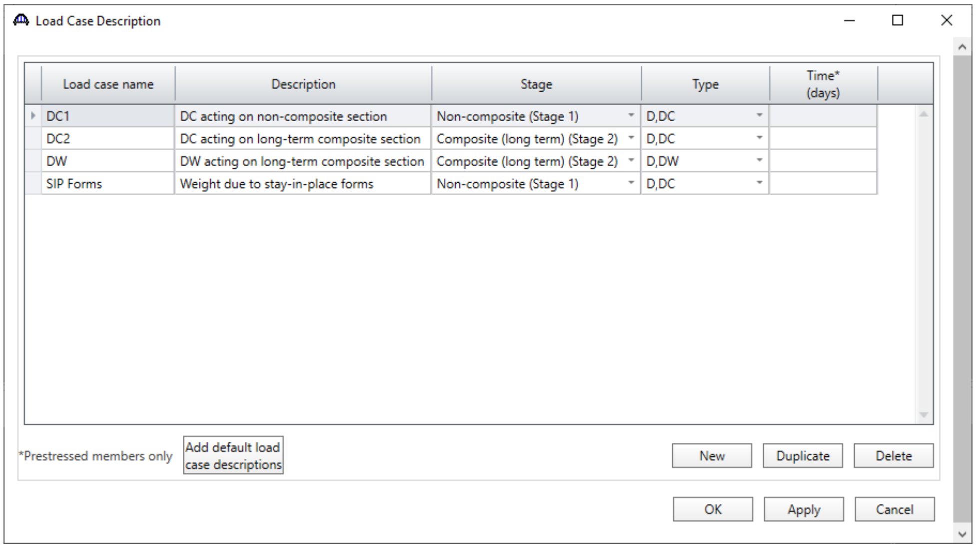
Select **Girder line superstructure**, click **OK** to open **Girder Line Superstructure Definition** window and enter data as shown below:



Click **OK** to apply the data and close the window.

Load Case Description

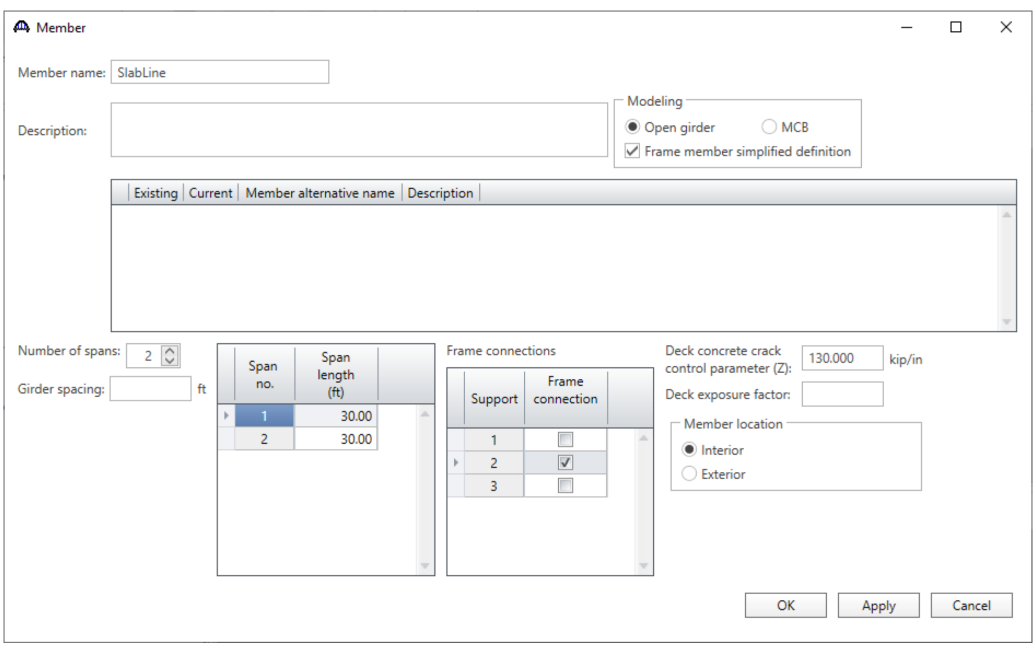
Open the **Load Case Description** window and use the **Add default load case descriptions** button to create the following load cases.



Click **OK** to apply the data and close the window.

Member

Create the following girder line member by double clicking on **Members** in the **Bridge Workspace** tree to open the **Member** window. 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. Enter data in this window as shown below.

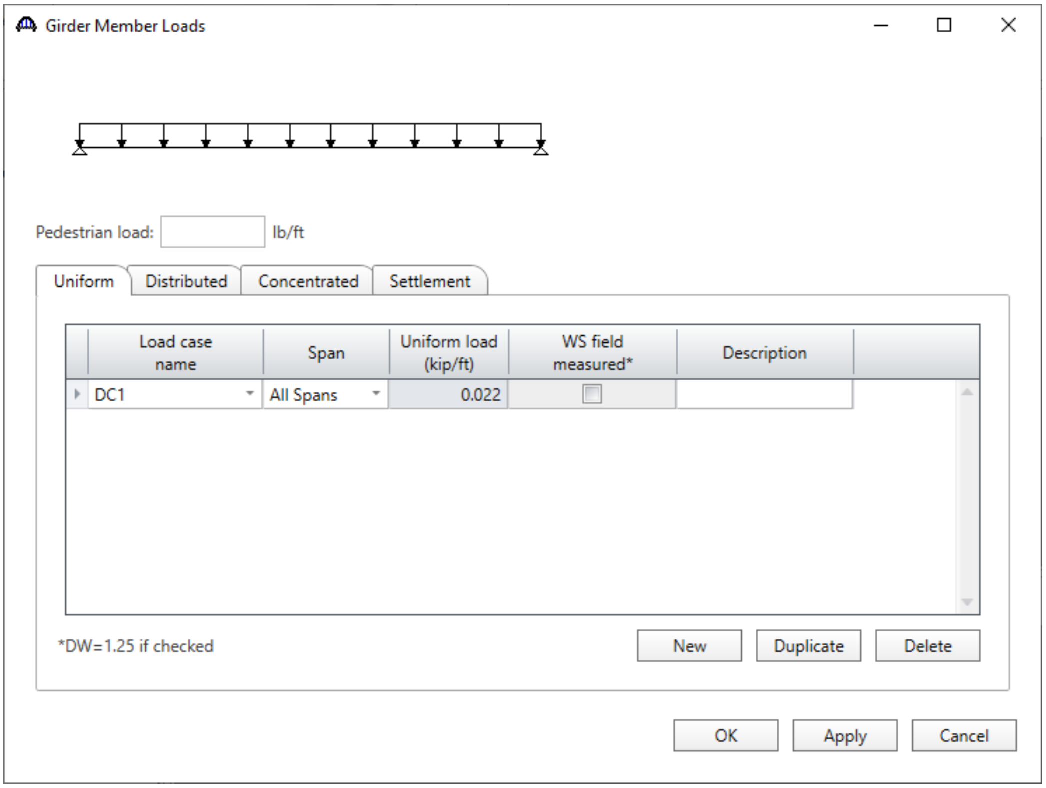


Click **OK** to apply the data and close the window.

Girder Member Loads

Expand the **SlabLine** member in the **BWS** tree and double click on **Member Loads** to open the **Girder Member Loads** window. This structure has 2 parapets each weighing 300 lb/ft. In this tutorial, a 12" wide strip of slab will be defined as the member so the parapet load applied to this member will be (2*300 lb/ft)/27' = 22 lb/ft.

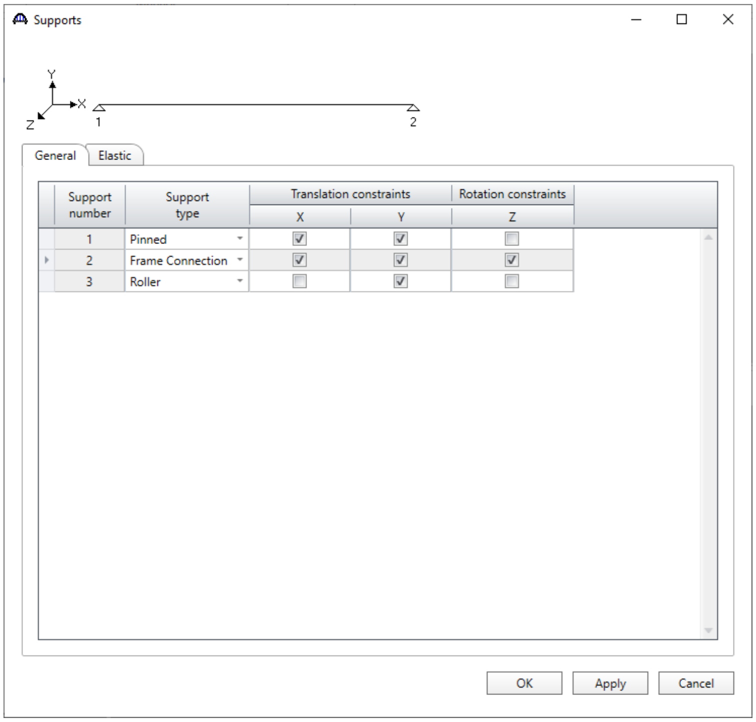
Click **New** to add a row in the **Uniform** tab and enter the data as shown below:



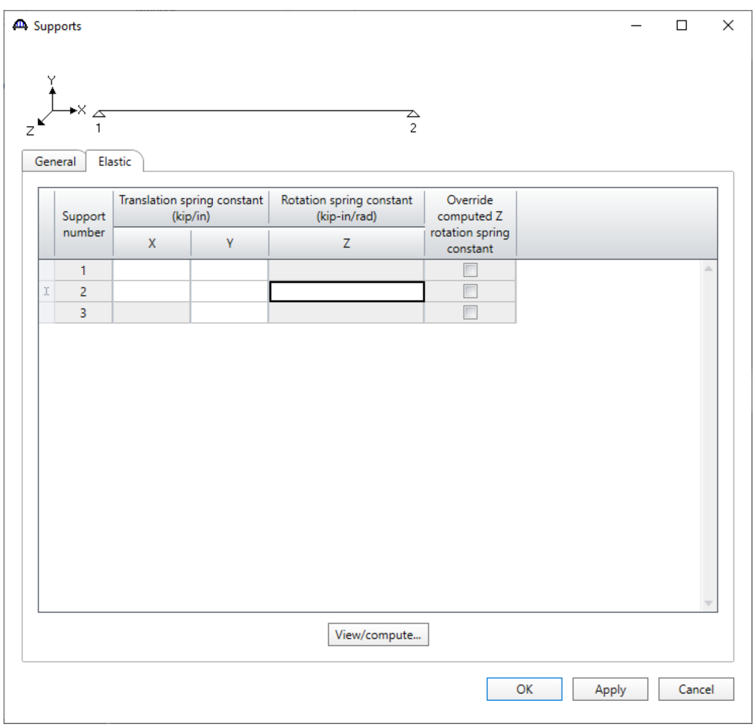
Click **OK** to apply the data and close the window.

Supports

Since **Frame member simplified definition** was selected on the Member window, the **Supports** window now displays **Support 2** as a frame connection with all constraints fixed.

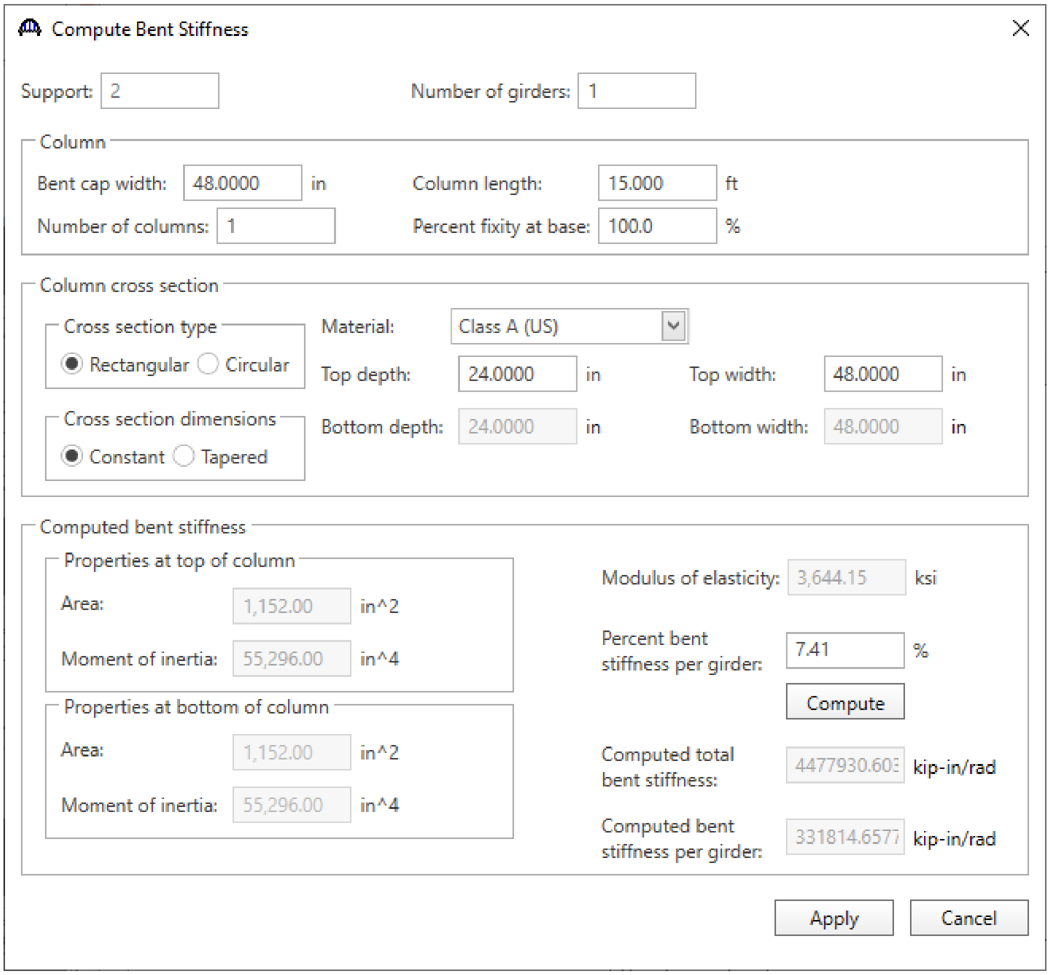


On the Elastic tab, select the **Rotation Spring Constant** cell for **Support 2**. The **View/Compute…** button will now be activated.



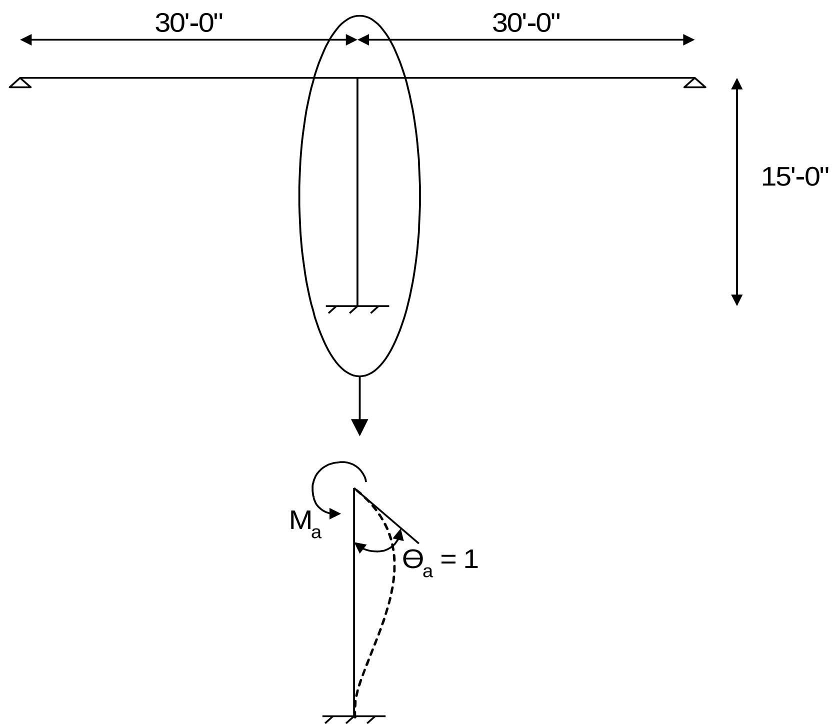
Compute Bent Stiffness

With **Z** column for support **2** selected, click the **View/Compute…** button to open the **Compute Bent Stiffness** window. 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. Engineering judgement needs to be applied to determine the length of the frame leg based on the geometry and reinforcement of the frame structures to be analyzed.



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 bent stiffness per girder** field is the percent of one column's stiffness that is applied to this girder line member. For this example, the percent stiffness is computed as follows. Engineering judgement needs to be applied 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.

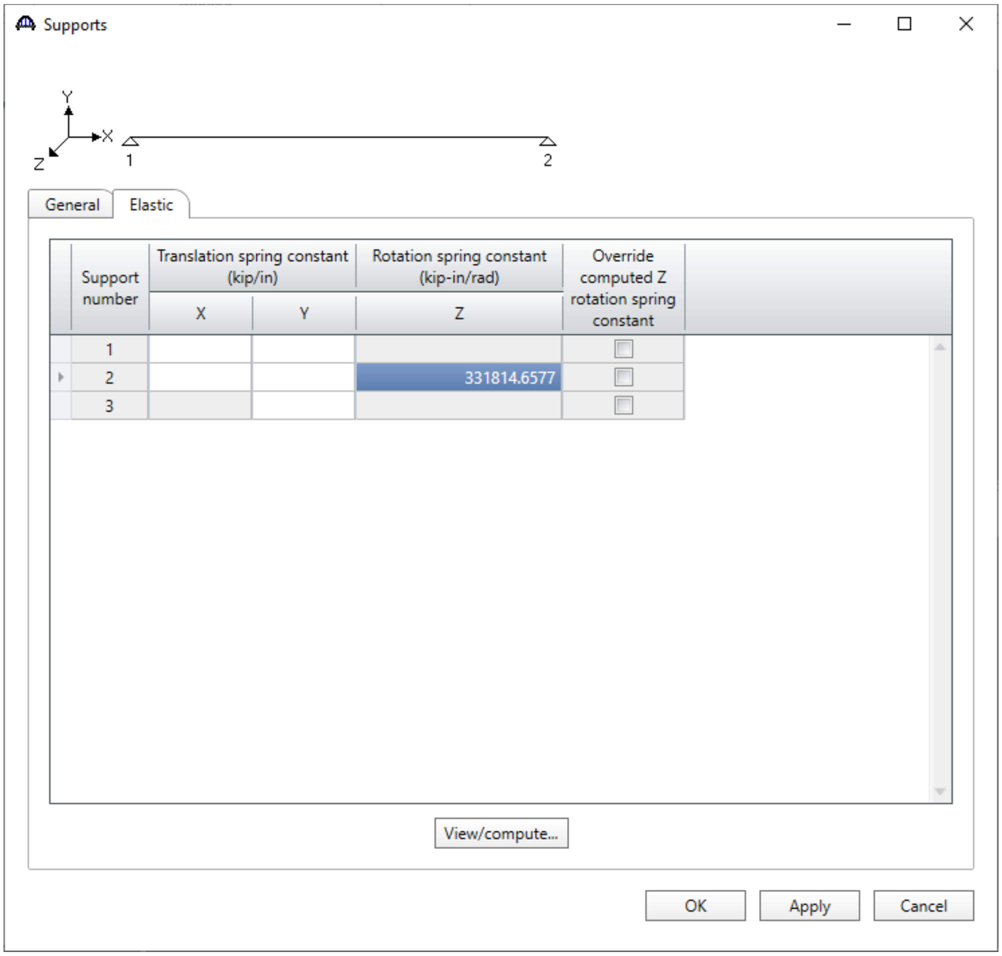
$$\frac{2\text{ columns}}{324''} \times 12''\text{strip} \times 100\% = 7.41\%\text{ column}$$

The column stiffness coefficient is computed as follows:

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

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

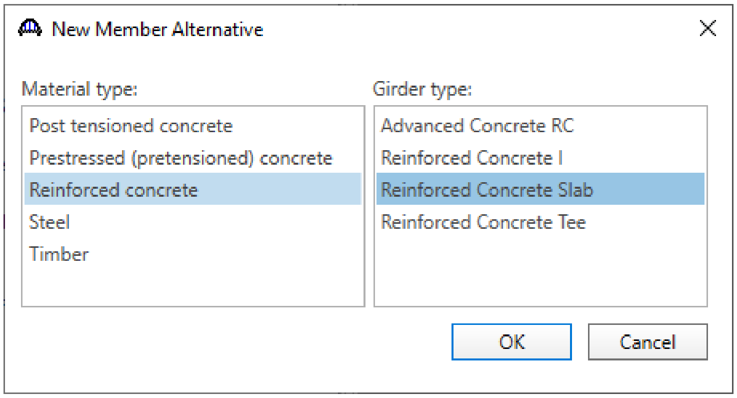
Supports window will be populated as shown below.



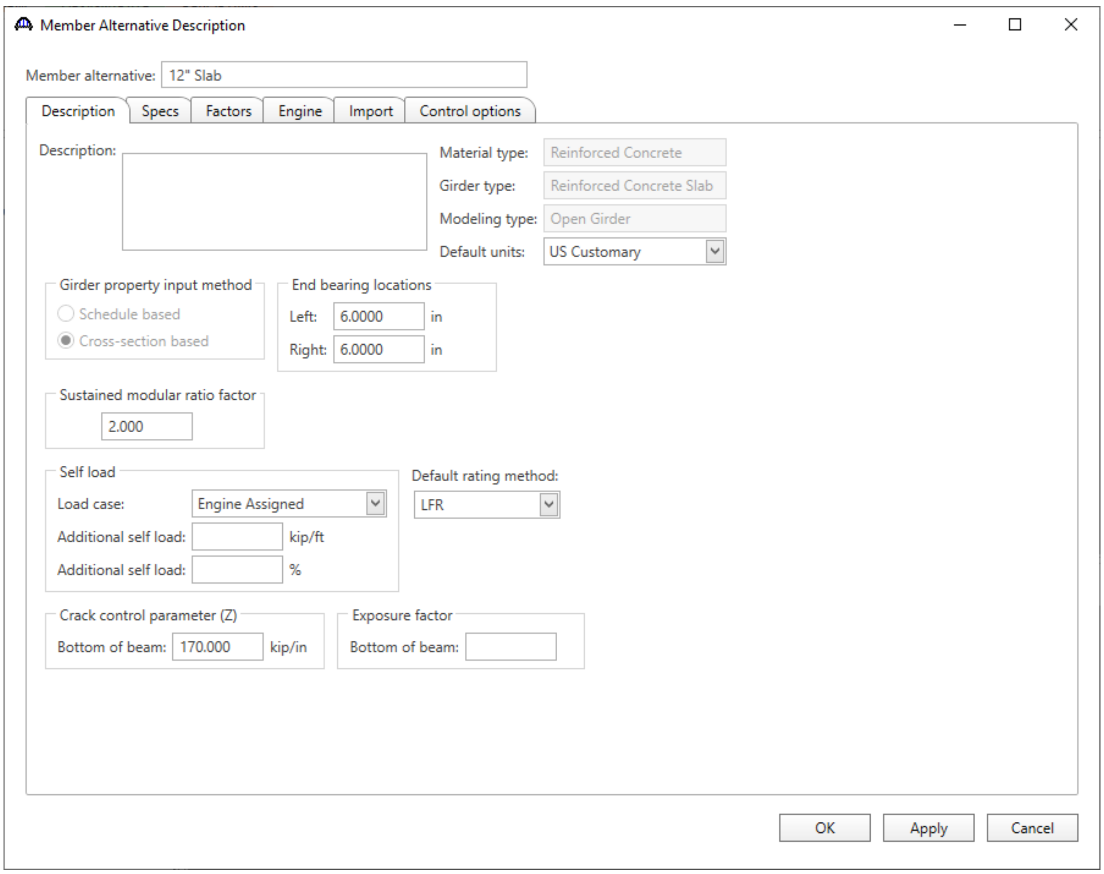
Click **OK** to apply the data and close the window.

Member Alternative

Create a reinforced concrete slab member alternative as follows. Double click on **MEMBER ALTERNATIVES** on the **Bridge Workspace** tree to open the window as shown below. Select **Reinforced Concrete** for **Material Type**, **Reinforced Concrete Slab** for **Girder Type** and click **OK**.



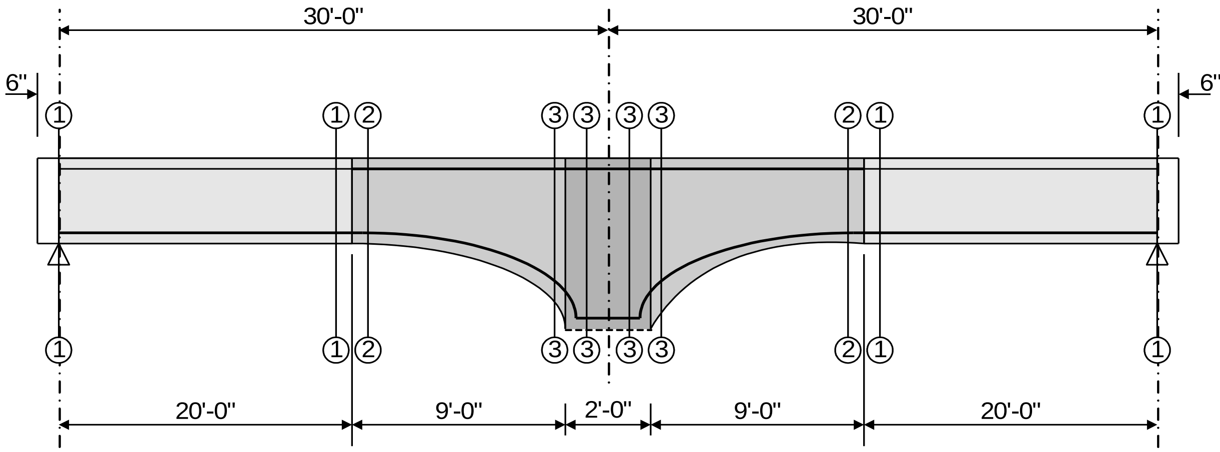
The **Member Alternative Description** window will open. Enter the data as shown below.

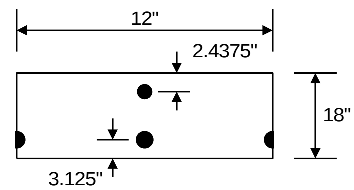


Click **OK** to apply the data and close the window.

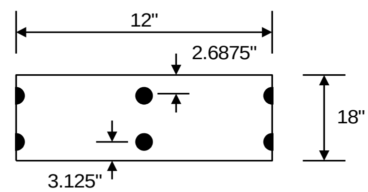
Cross - section based input.

Expand **12” Slab (E) (C)** member alternative on the **Bridge Workspace** tree and double click on the **Cross Sections** node to open the **Cross Sections** window and create a new cross section. This member contains three cross sections as illustrated below.

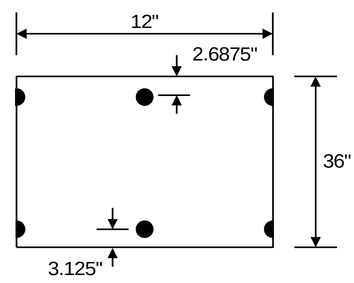




Section 1



Section 2

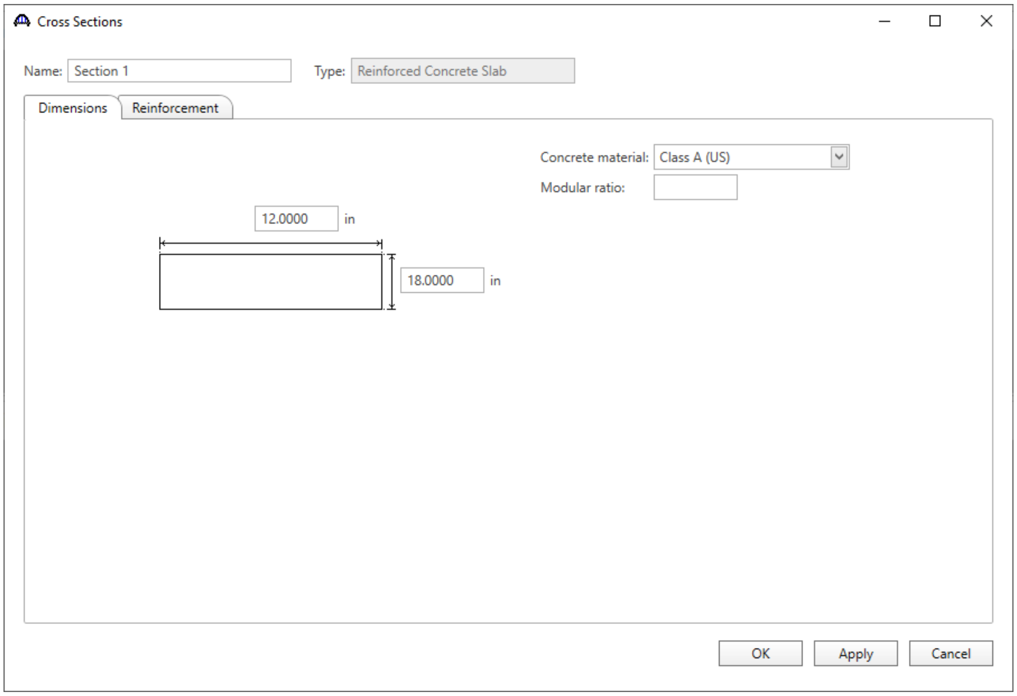


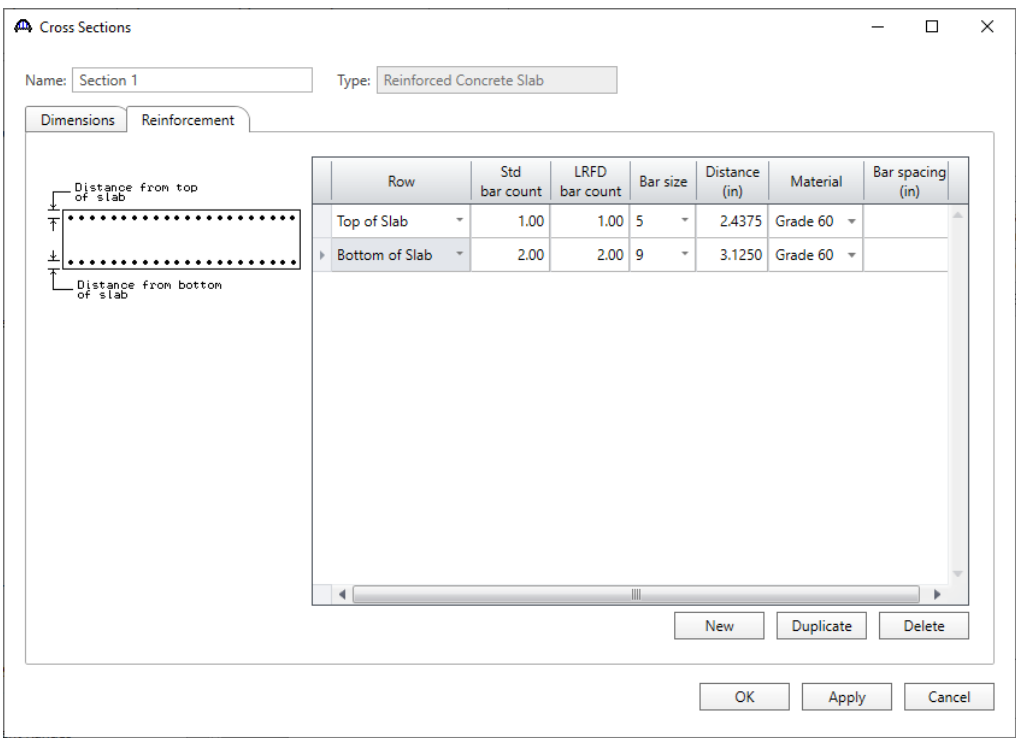
Section 3

Cross Sections

Enter each cross-section **Dimensions** and **Reinforcement** data as shown below:

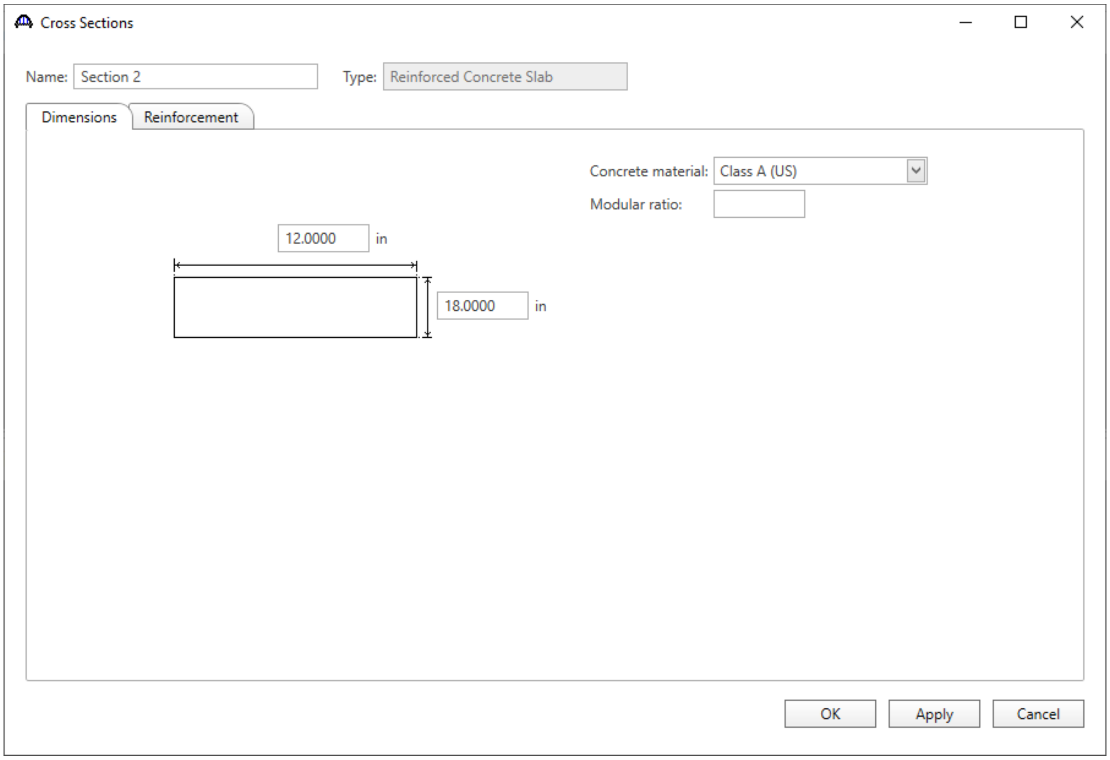
Section 1

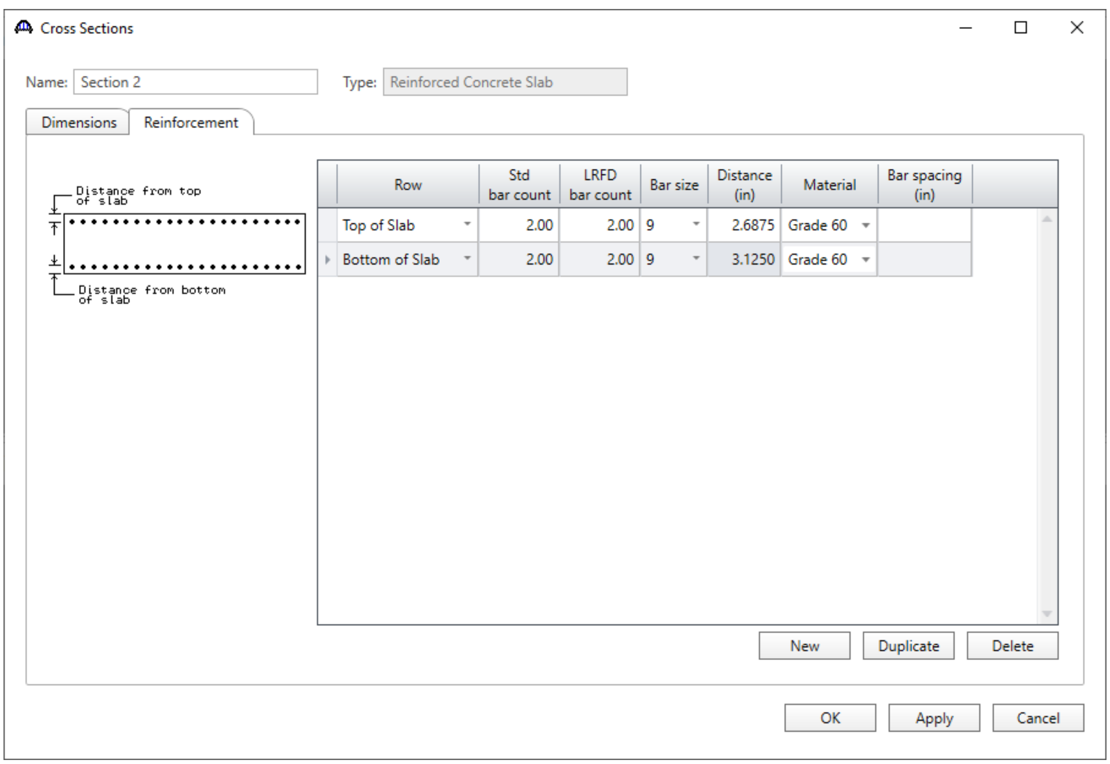




Click **OK** to apply the data and close the window.

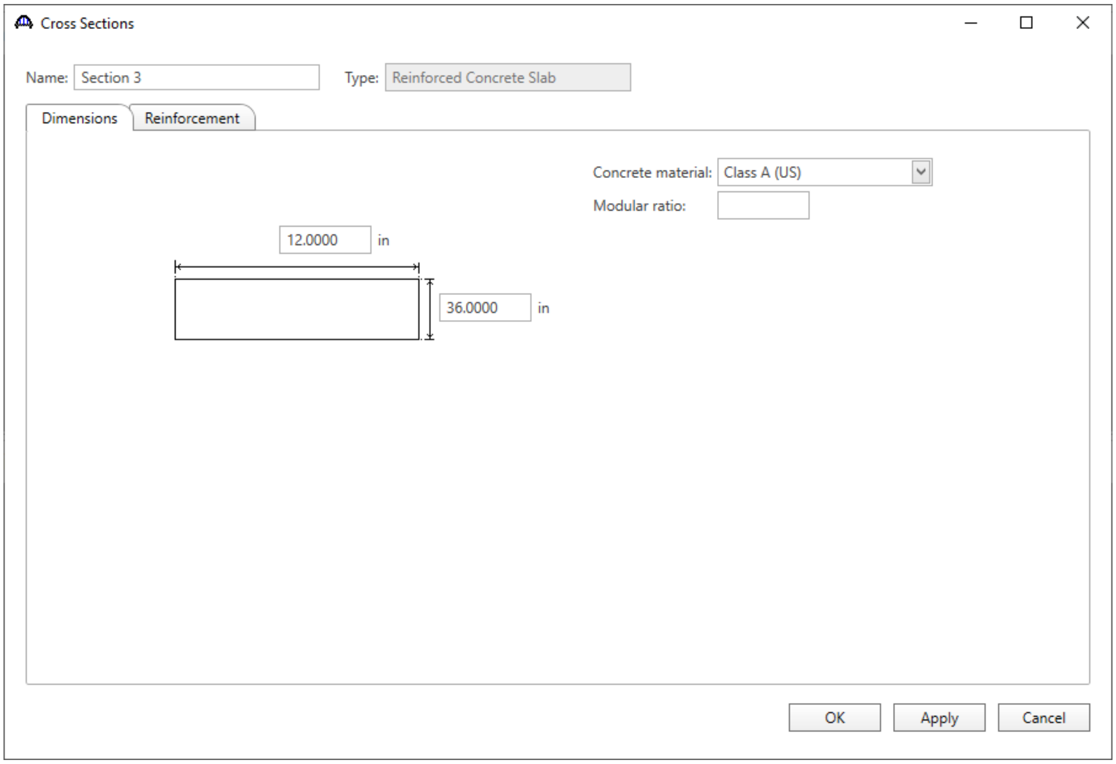
Section 2

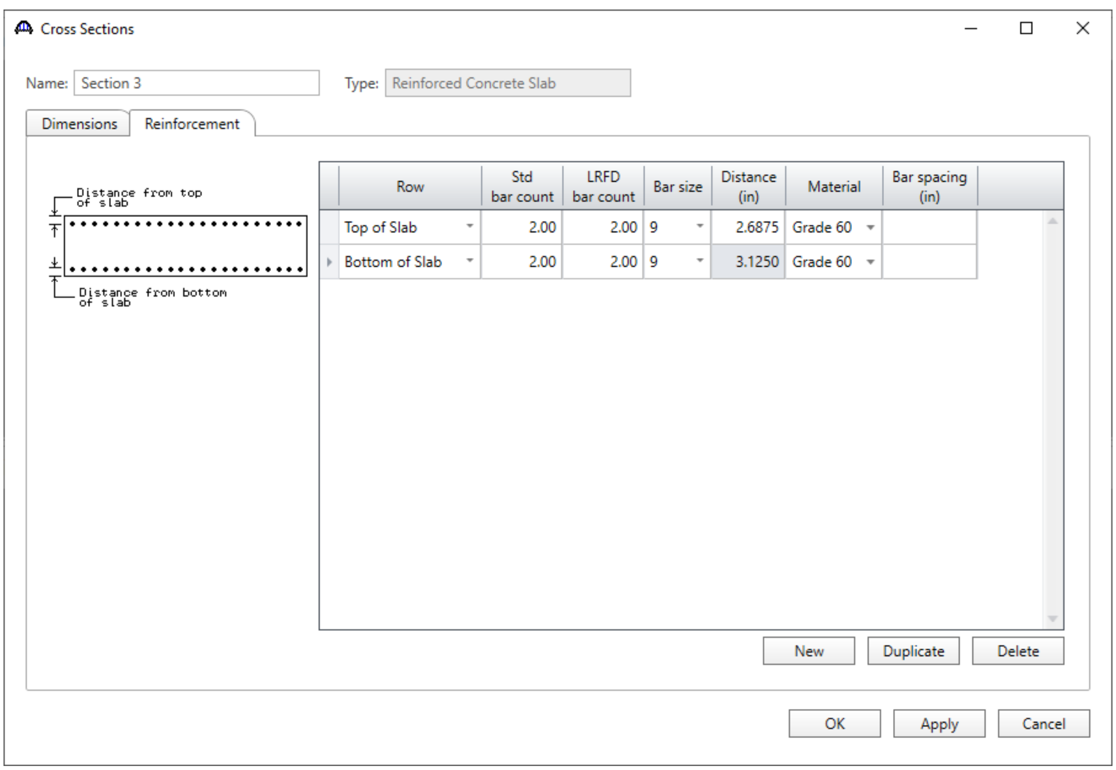




Click **OK** to apply the data and close the window.

Section 3

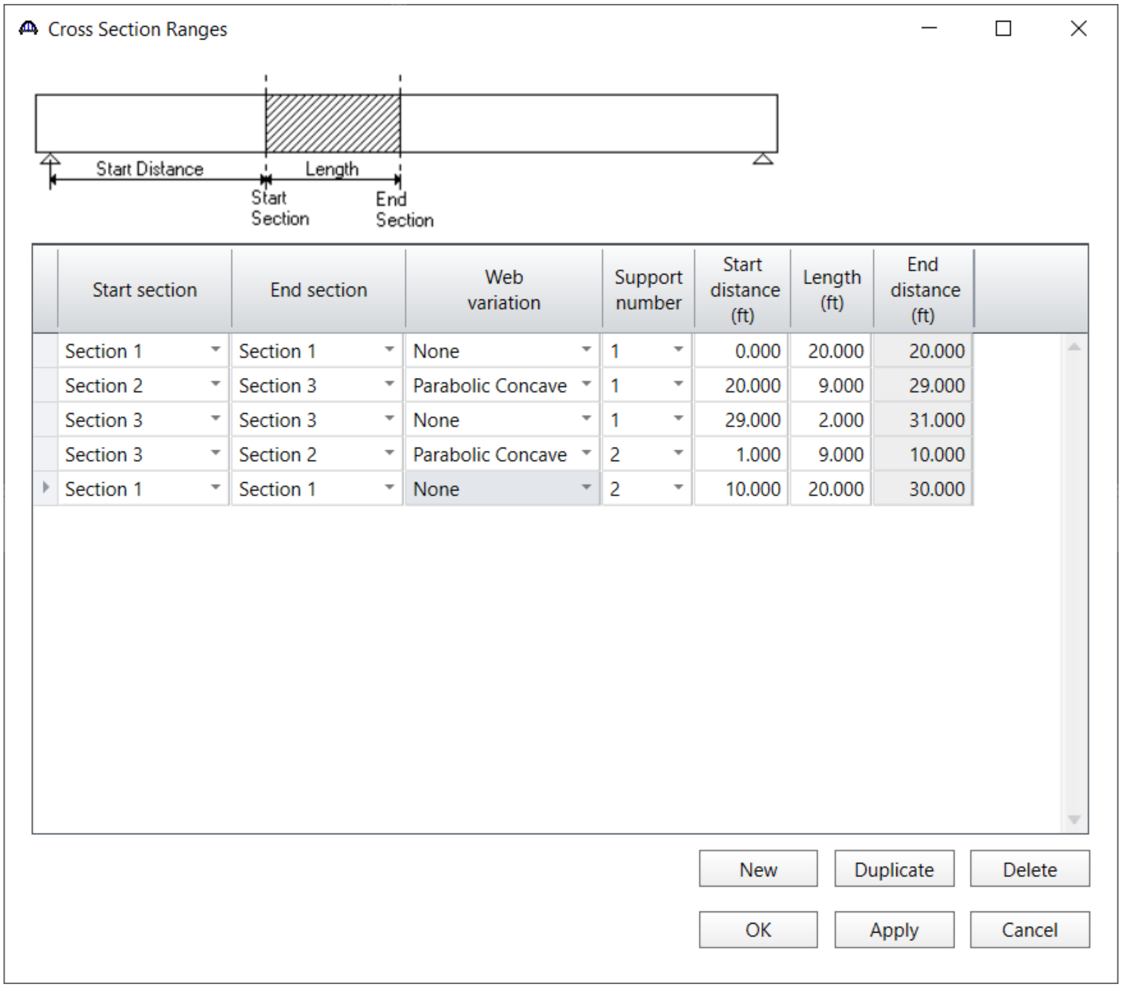




Click **OK** to apply the data and close the window.

Cross Section Ranges

Double click on the **Cross Section Ranges** node in the **Bridge Workspace** tree to input the cross sections over the length of the member as shown below.

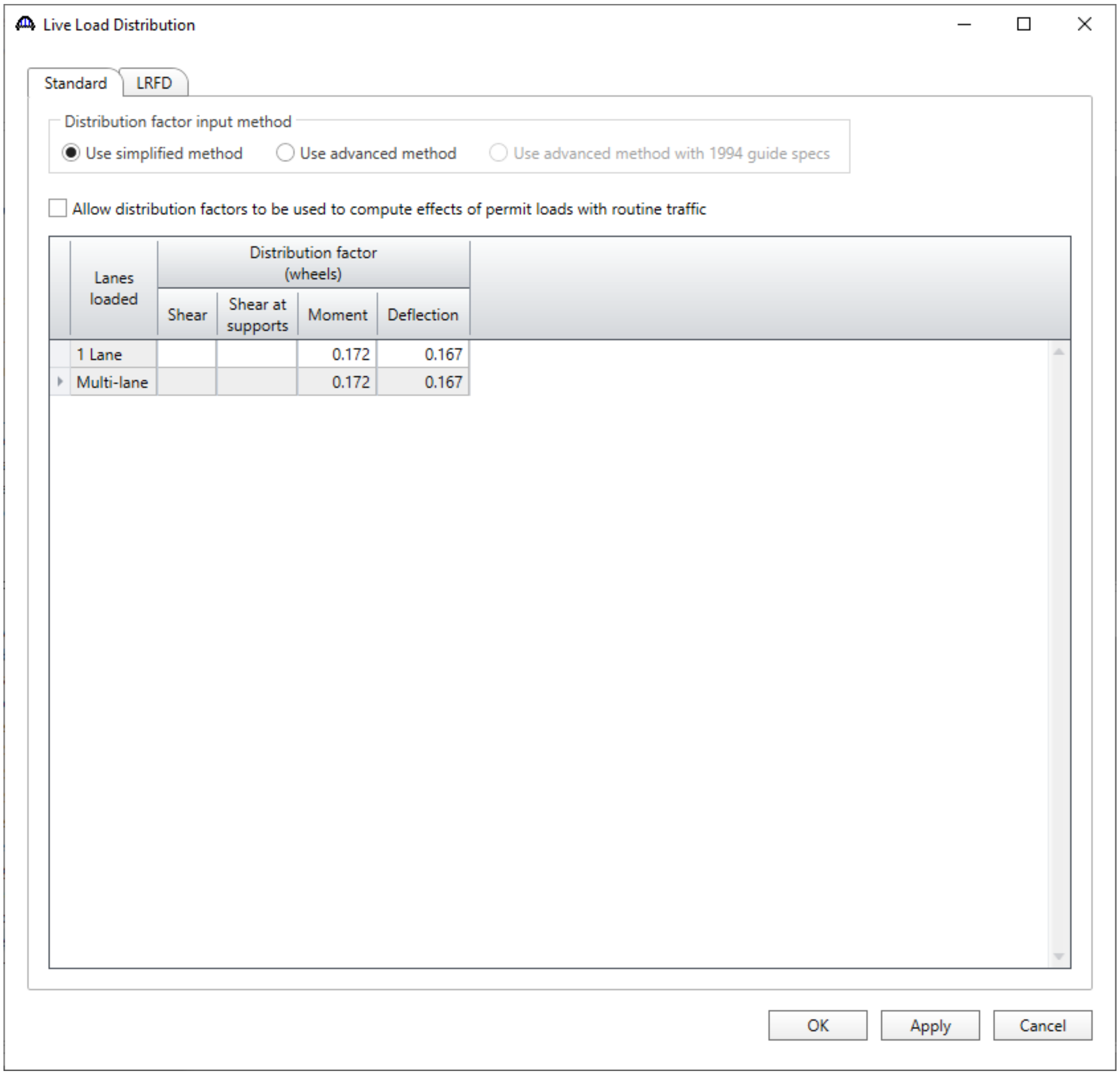


Click **OK** to apply the data and close the window.

Shear Reinforcement Ranges and **Bracing Ranges** are not applicable to this member so data will not be entered in these windows. **Points of Interest** will not be entered since there is no overriding information for this bridge.

Live Load Distribution

To enter the live load distribution factors, double click on **Live Load Distribution** on the **Bridge Workspace** tree and enter the **Standard** factors as shown below:



The Standard 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'

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

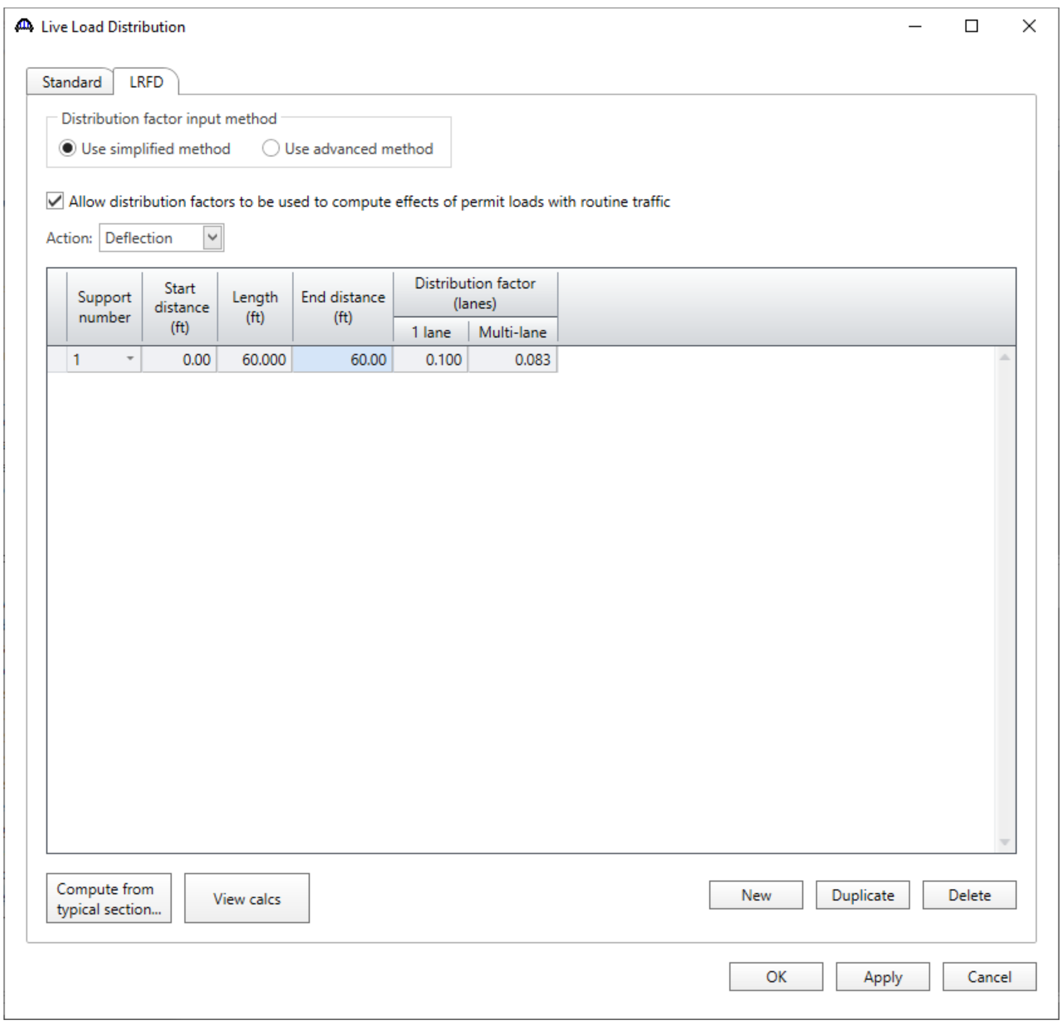
$$Moment\ DF = \frac{1\ wheel}{5.8'} = 0.1724\ wheel/\ ft$$

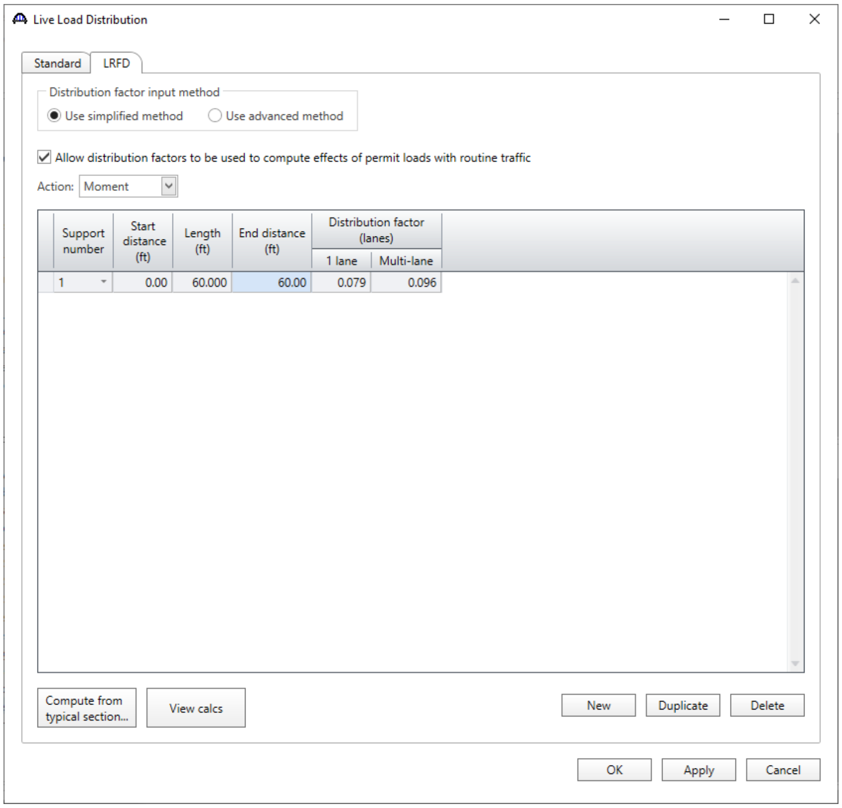
The cross section that will be entered for this member alternative is 12" wide so the wheel distribution factor is per foot. If the cross section were 24" wide, the distribution factor would be computed as 2*0.1724=0.3448.

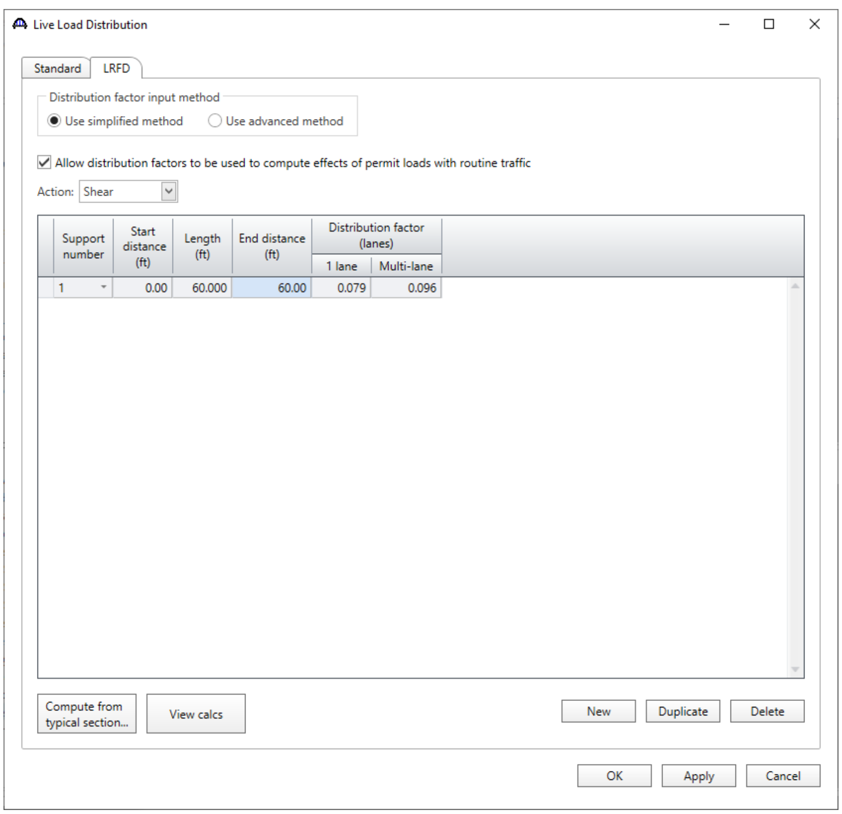
The deflection distribution factor is calculated as the number of lanes divided by the number of girders. For a reinforced concrete slab bridge, the number of girders is taken as the lane width divided by the strip width. Our lane width is 12 feet, and our strip width is 12" or 1 foot.

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

Navigate to the **LRFD** tab and enter the live load distribution factors for **each Action** as shown below:







Click **OK** to apply the data and close the window.

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.

AASHTO Article 4.6.2.3

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

$E = 10.0 + 5.0\sqrt{L_1 W_1}$

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

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

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

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

For multi lane:

$E = 84.0 + 1.44\sqrt{L_1 W_1} \leq \frac{12.0W}{N_L}$

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

$W = width\ edge - edge\ of\ bridge = 27'$

$N_L = number\ of\ lanes$

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

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

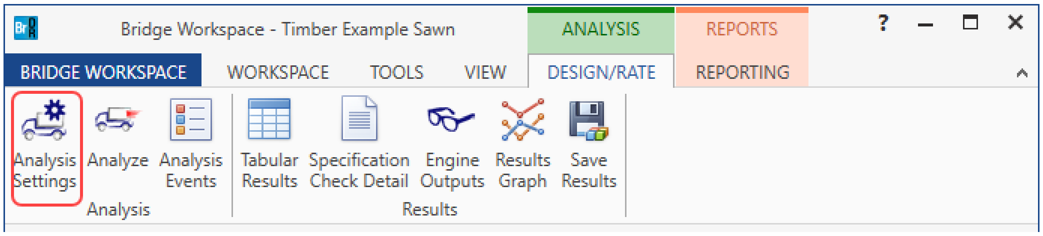
$Deflection\ DF = \frac{\#\ lanes}{(Lane\ width/\text{Strip width})} * Multiple\ Presence\ Factor$

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

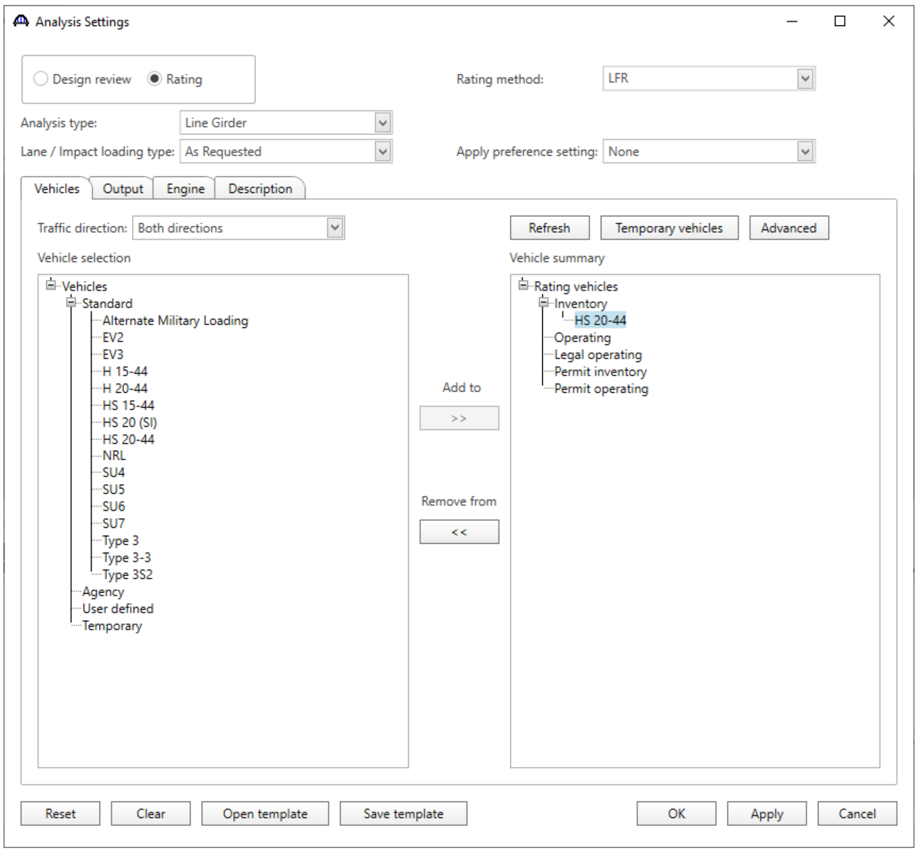
$Multi\ lane\ Deflection\ DF = \frac{2\ lanes}{(12' * 2\ /\ 1')}\ (1.0) = 0.0833\ lanes$

LFR Rating

The description of this structure is complete. To perform an **LFR** rating, click the **Analysis Settings** button on the Analysis group of the **DESIGN/RATE** ribbon which opens the **Analysis Settings** window.



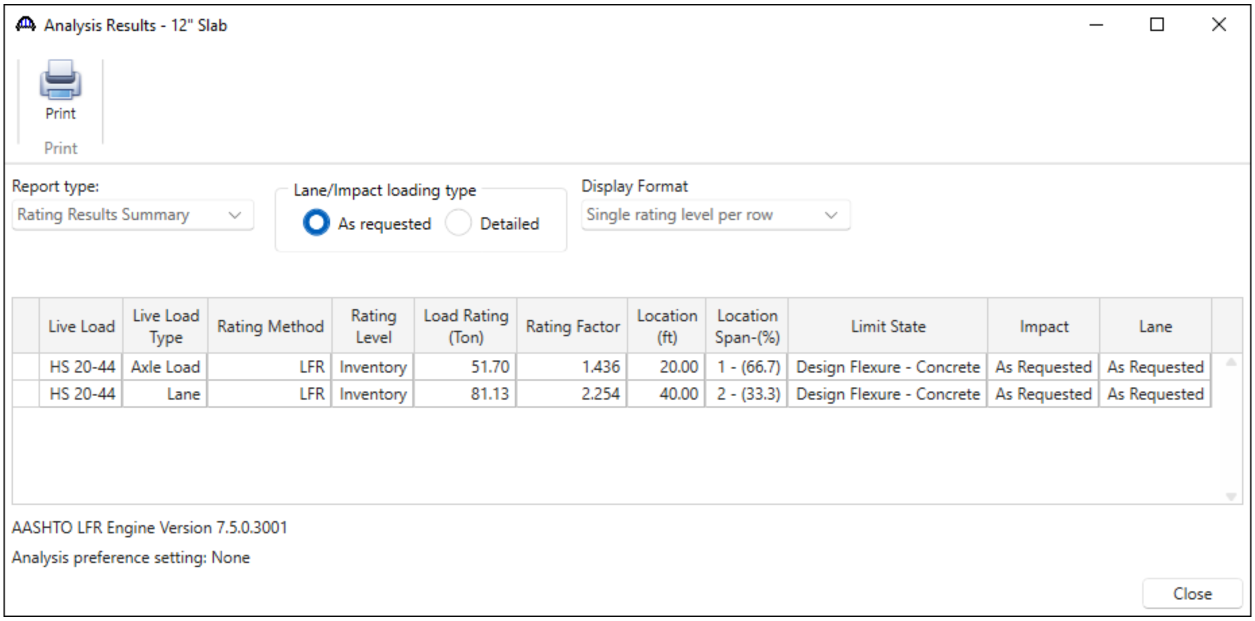
Select the vehicle to be used in the rating as shown below and click **OK**.



Tabular Results

Next click the **Analyze** button on the ribbon to perform the rating.

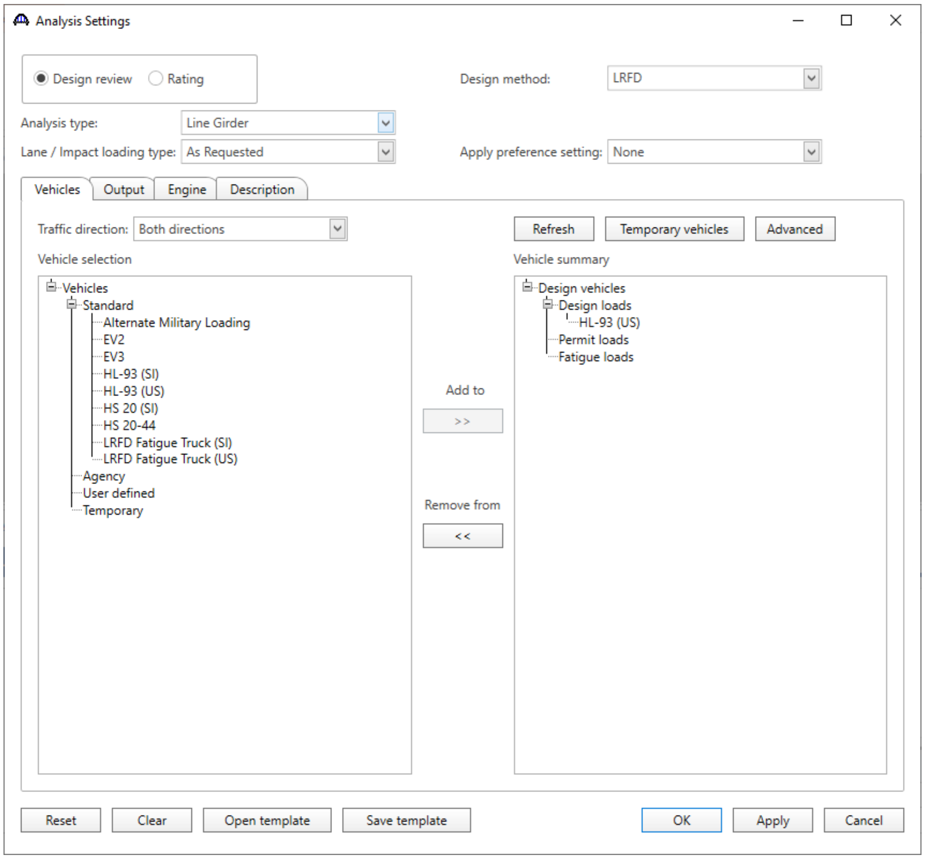
When the rating is complete the results can be reviewed by clicking the **Tabular Results** button from the **Results** group of the **DESIGN/RATE** ribbon. The window shown below will open.



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	Axle Load	LFR	Inventory	51.70	1.436	20.00	1 - (66.7)	Design Flexure - Concrete	As Requested	As Requested
HS 20-44	Lane	LFR	Inventory	81.13	2.254	40.00	2 - (33.3)	Design Flexure - Concrete	As Requested	As Requested

LRFD Analysis

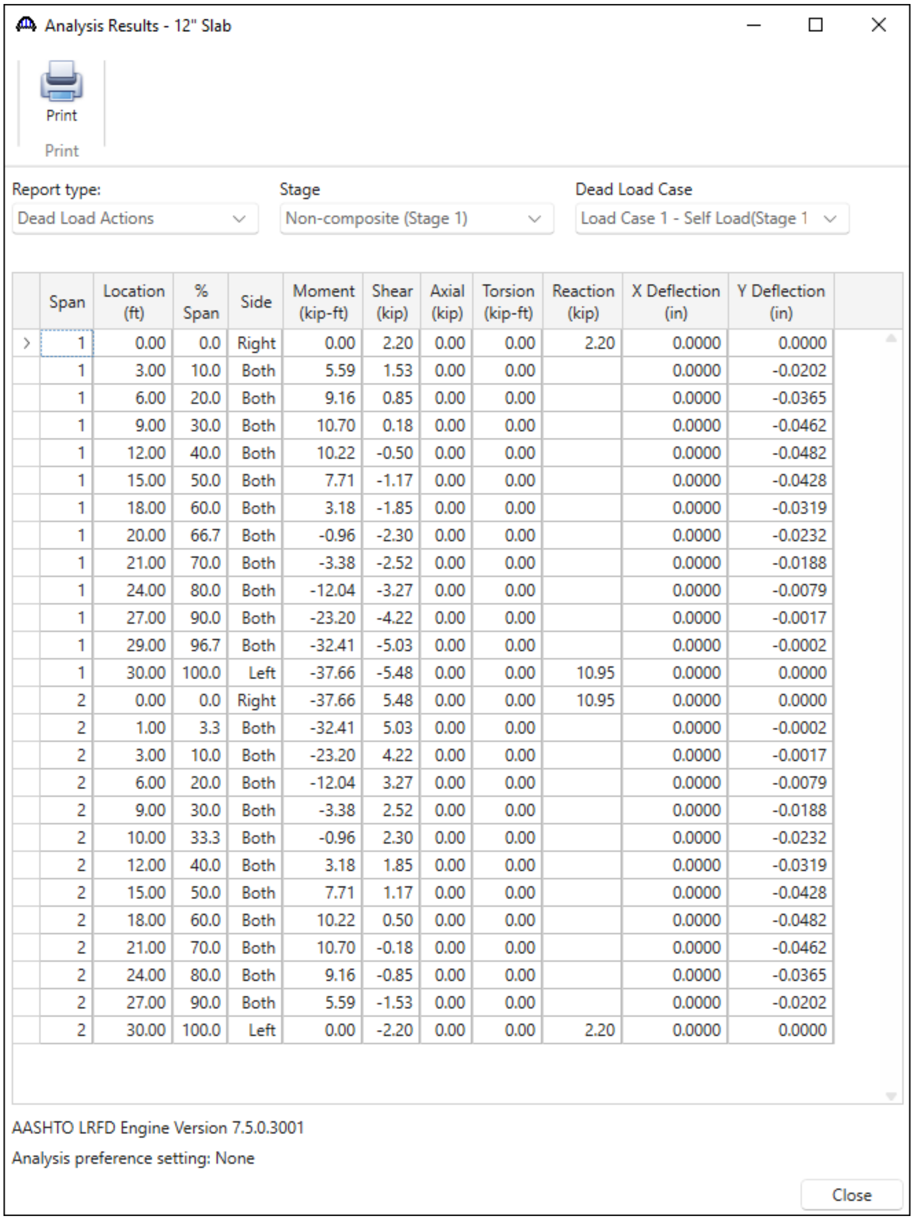
To perform an LRFD analysis, click the **Analysis Settings** button on the **Analysis** group of the **DESIGN/RATE** ribbon which opens the **Analysis Settings** window. Select the vehicle to be used in the analysis as shown below and click **OK**.



Tabular Results

Next click the **Analyze** button on the ribbon to perform the rating.

When the rating is finished the results can be reviewed by clicking the **Tabular Results** button on the **Results** group of the **DESIGN/RATE** ribbon. The window shown below will open.



Span	Location (ft)	% Span	Side	Moment (kip-ft)	Shear (kip)	Axial (kip)	Torsion (kip-ft)	Reaction (kip)	X Deflection (in)	Y Deflection (in)
1	0.00	0.0	Right	0.00	2.20	0.00	0.00	2.20	0.0000	0.0000
1	3.00	10.0	Both	5.59	1.53	0.00	0.00		0.0000	-0.0202
1	6.00	20.0	Both	9.16	0.85	0.00	0.00		0.0000	-0.0365
1	9.00	30.0	Both	10.70	0.18	0.00	0.00		0.0000	-0.0462
1	12.00	40.0	Both	10.22	-0.50	0.00	0.00		0.0000	-0.0482
1	15.00	50.0	Both	7.71	-1.17	0.00	0.00		0.0000	-0.0428
1	18.00	60.0	Both	3.18	-1.85	0.00	0.00		0.0000	-0.0319
1	20.00	66.7	Both	-0.96	-2.30	0.00	0.00		0.0000	-0.0232
1	21.00	70.0	Both	-3.38	-2.52	0.00	0.00		0.0000	-0.0188
1	24.00	80.0	Both	-12.04	-3.27	0.00	0.00		0.0000	-0.0079
1	27.00	90.0	Both	-23.20	-4.22	0.00	0.00		0.0000	-0.0017
1	29.00	96.7	Both	-32.41	-5.03	0.00	0.00		0.0000	-0.0002
1	30.00	100.0	Left	-37.66	-5.48	0.00	0.00	10.95	0.0000	0.0000
2	0.00	0.0	Right	-37.66	5.48	0.00	0.00	10.95	0.0000	0.0000
2	1.00	3.3	Both	-32.41	5.03	0.00	0.00		0.0000	-0.0002
2	3.00	10.0	Both	-23.20	4.22	0.00	0.00		0.0000	-0.0017
2	6.00	20.0	Both	-12.04	3.27	0.00	0.00		0.0000	-0.0079
2	9.00	30.0	Both	-3.38	2.52	0.00	0.00		0.0000	-0.0188
2	10.00	33.3	Both	-0.96	2.30	0.00	0.00		0.0000	-0.0232
2	12.00	40.0	Both	3.18	1.85	0.00	0.00		0.0000	-0.0319
2	15.00	50.0	Both	7.71	1.17	0.00	0.00		0.0000	-0.0428
2	18.00	60.0	Both	10.22	0.50	0.00	0.00		0.0000	-0.0482
2	21.00	70.0	Both	10.70	-0.18	0.00	0.00		0.0000	-0.0462
2	24.00	80.0	Both	9.16	-0.85	0.00	0.00		0.0000	-0.0365
2	27.00	90.0	Both	5.59	-1.53	0.00	0.00		0.0000	-0.0202
2	30.00	100.0	Left	0.00	-2.20	0.00	0.00	2.20	0.0000	0.0000