

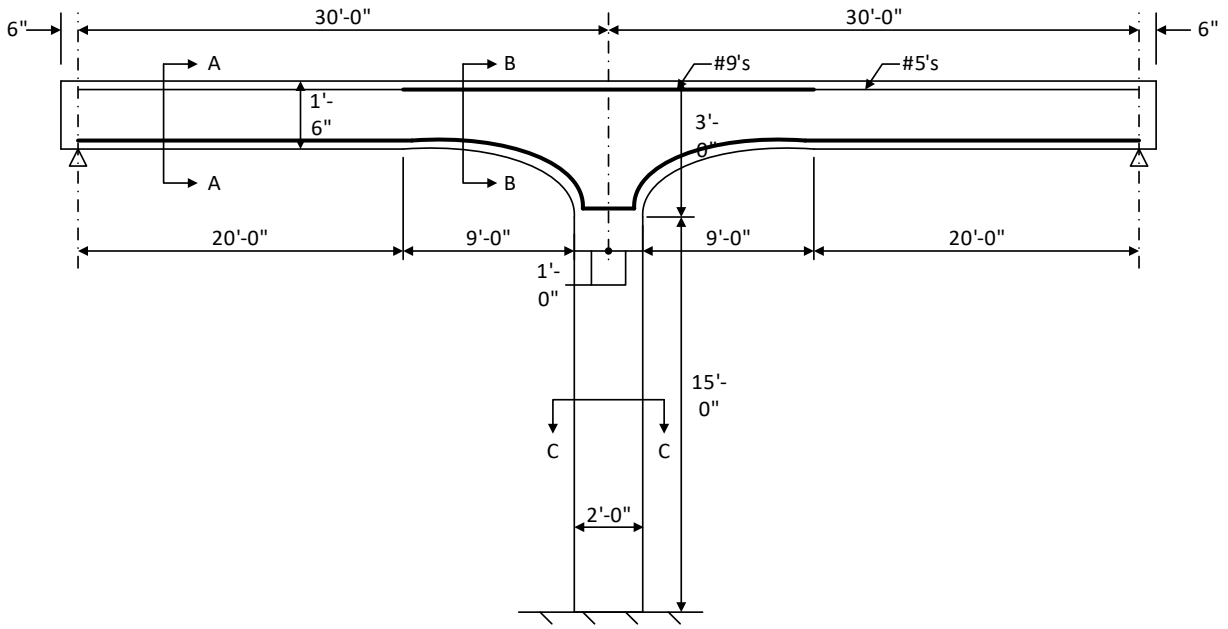
AASHTOWare BrDR 7.5.0

Reinforced Concrete Structure Tutorial
FRM1 – Reinforced Concrete Frame Example

FRM1 – Reinforced Concrete Frame Example

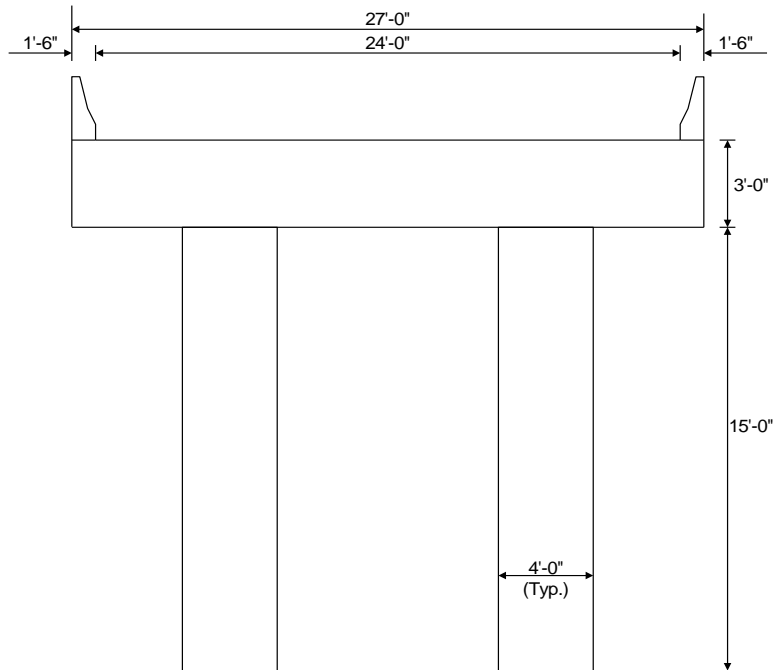
Introduction - Elevation

FRM1 – Two span reinforced concrete frame example



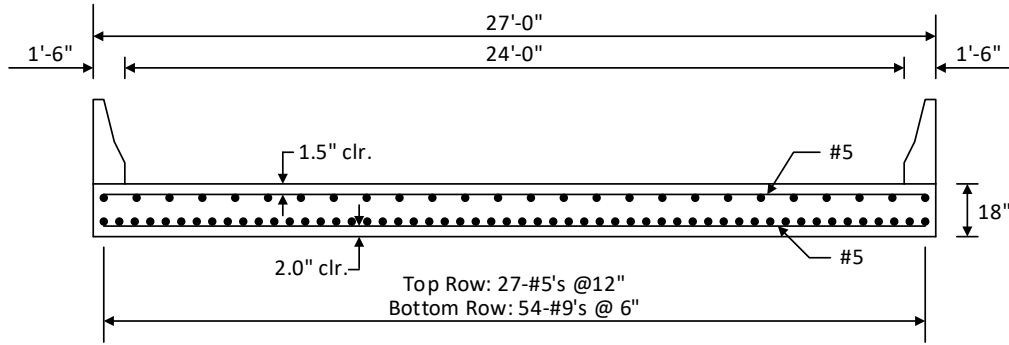
Elevation

Structure typical section at Pier

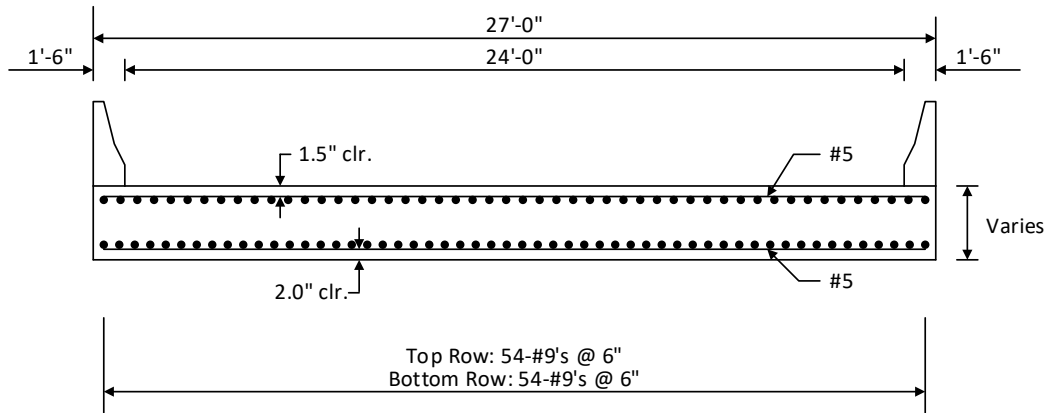


Structure Typical Section at Pier

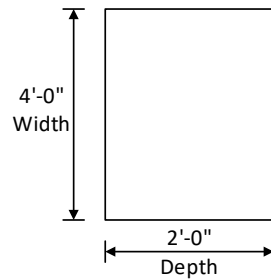
FRM1 – Reinforced Concrete Frame Example



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 $F_y = 60$ ksi

Parapets

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

FRM1 – Reinforced Concrete Frame Example

BrDR Training

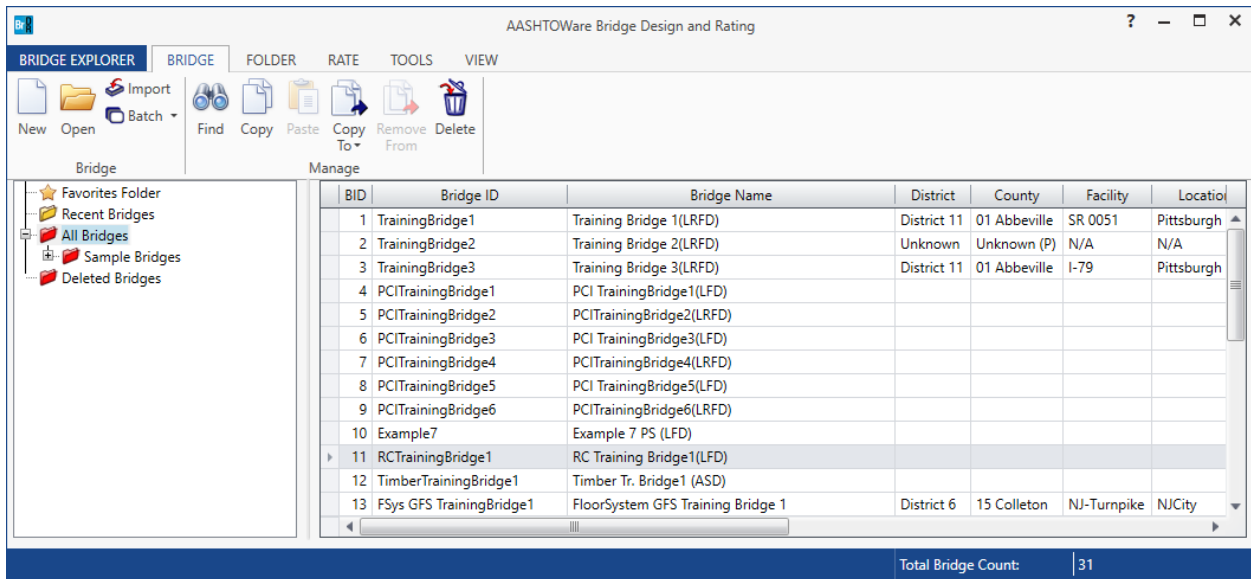
FRM1 – Reinforced Concrete Frame Example

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.

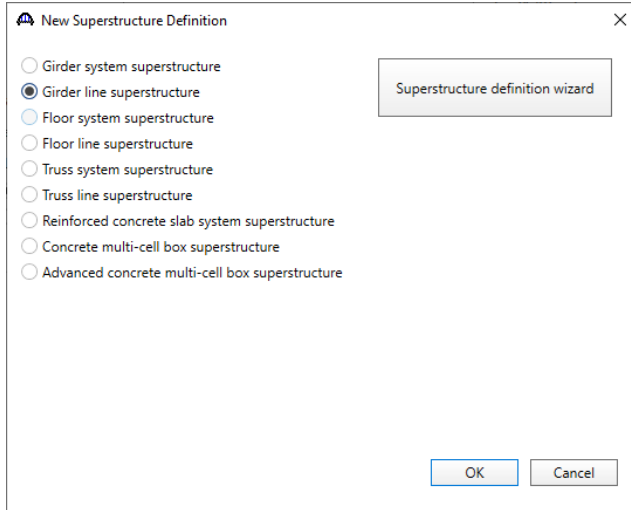
In this example a girder line superstructure definition that has a frame leg support will be added to **RCTrainingBridge1**. Double click on **BID11 RCTrainingBridge1** from the **Bridge Explorer** and open its **Bridge Workspace** tree.



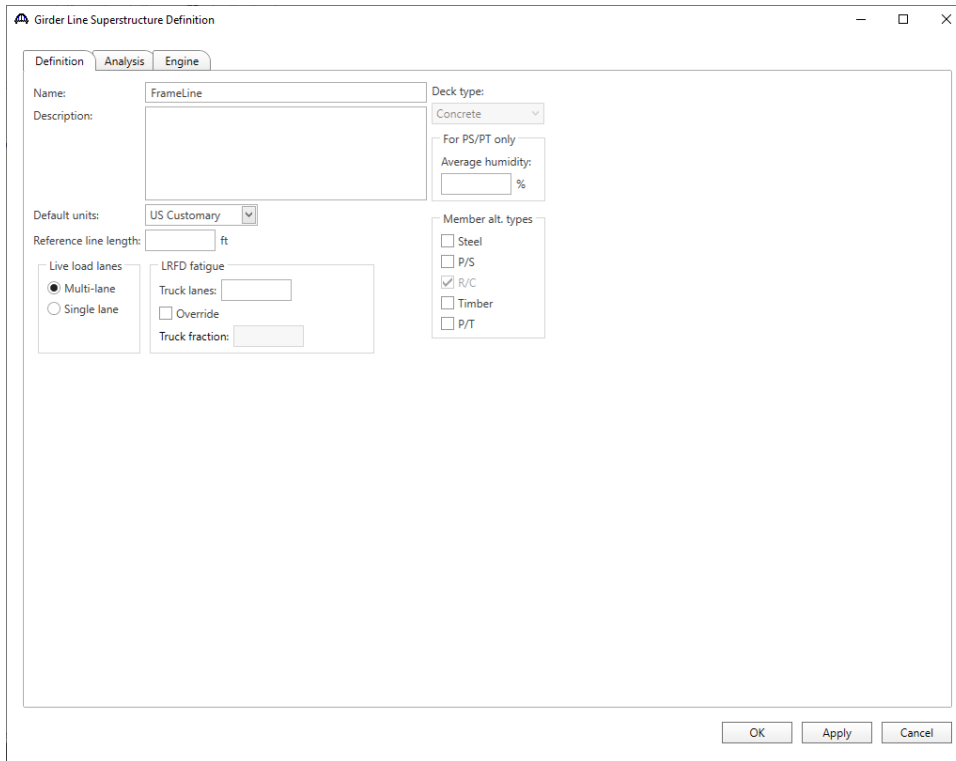
FRM1 – Reinforced Concrete Frame Example

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:

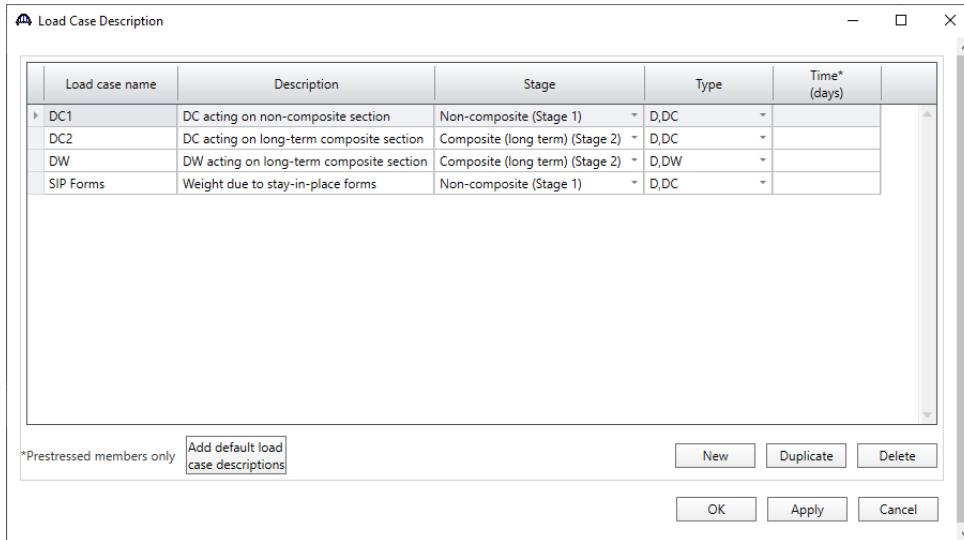


Click **OK** to apply the data and close the window.

FRM1 – Reinforced Concrete Frame Example

Load Case Description

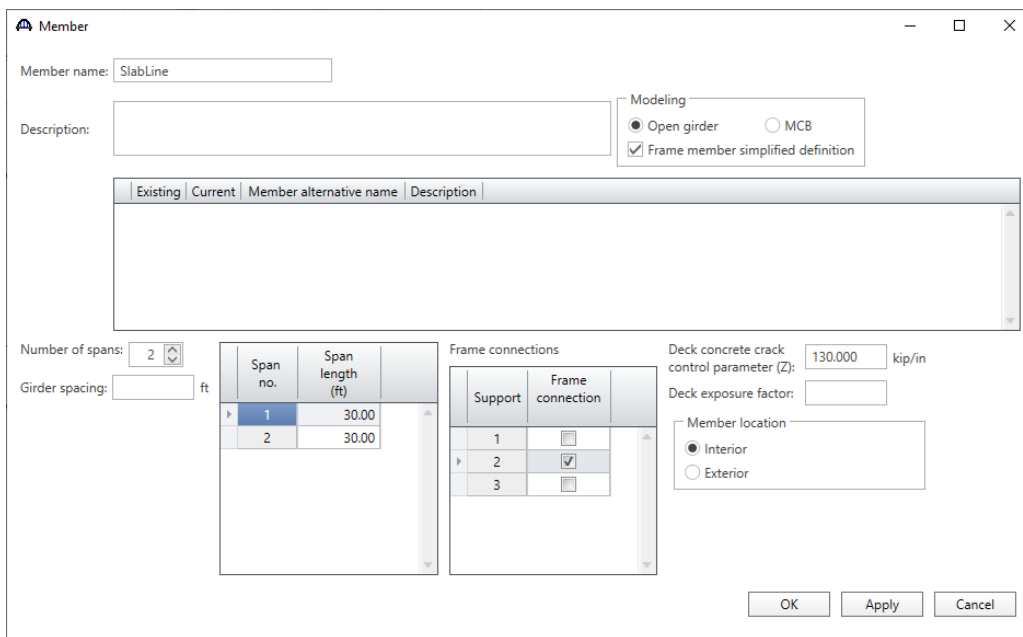
Open the **Load Case Description** window and use the **Add default load case descriptions** button to create the following load cases.



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.



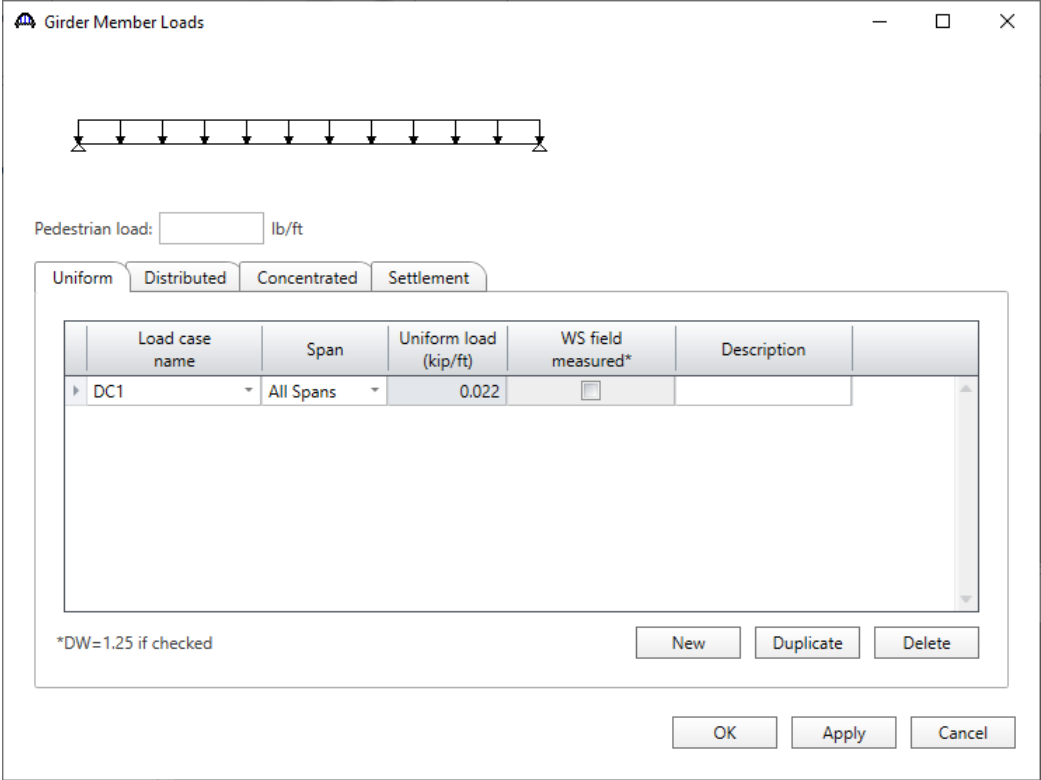
Click **OK** to apply the data and close the window.

FRM1 – Reinforced Concrete Frame Example

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 $(2*300 \text{ lb/ft})/27' = 22 \text{ lb/ft}$.

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

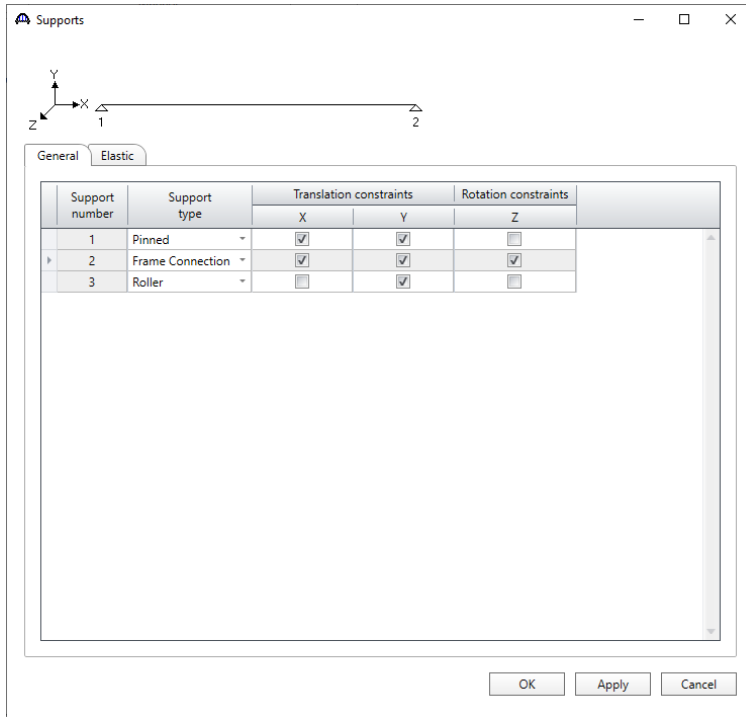


Click **OK** to apply the data and close the window.

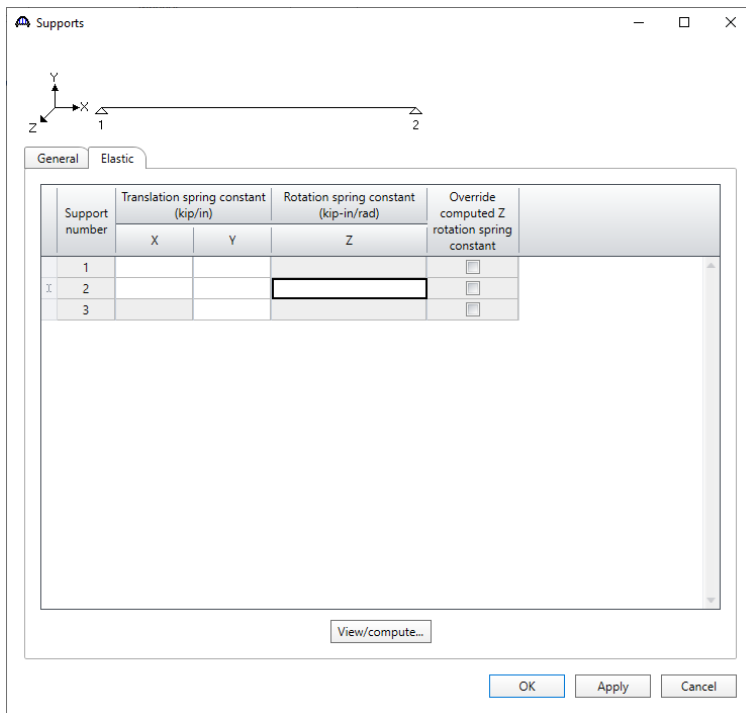
FRM1 – Reinforced Concrete Frame Example

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.



FRM1 – Reinforced Concrete Frame Example

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.

Support: 2 Number of girders: 1

Column

Bent cap width: 48.0000 in Column length: 15.000 ft
Number of columns: 1 Percent fixity at base: 100.0 %

Column cross section

Cross section type: Rectangular Circular Material: Class A (US) Top depth: 24.0000 in Top width: 48.0000 in
Cross section dimensions: Constant Tapered Bottom depth: 24.0000 in Bottom width: 48.0000 in

Computed bent stiffness

Properties at top of column

Area: 1,152.00 in² Modulus of elasticity: 3,644.15 ksi
Moment of inertia: 55,296.00 in⁴ Percent bent stiffness per girder: 7.41 %

Properties at bottom of column

Area: 1,152.00 in² Computed total bent stiffness: 4477930.603 kip-in/rad
Moment of inertia: 55,296.00 in⁴ Computed bent stiffness per girder: 331814.6577 kip-in/rad

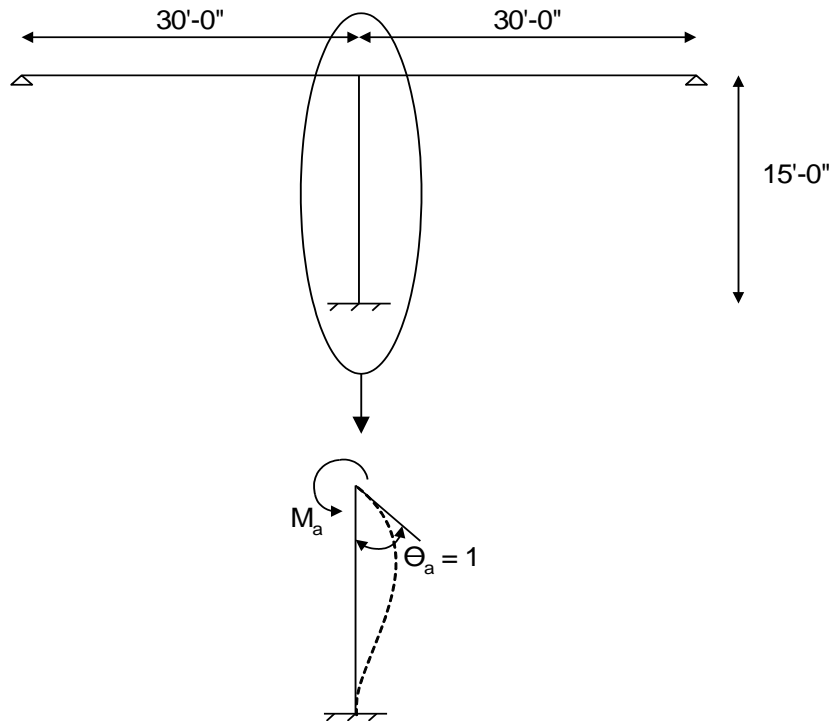
Compute

Apply Cancel

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.

FRM1 – Reinforced Concrete Frame Example



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.

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

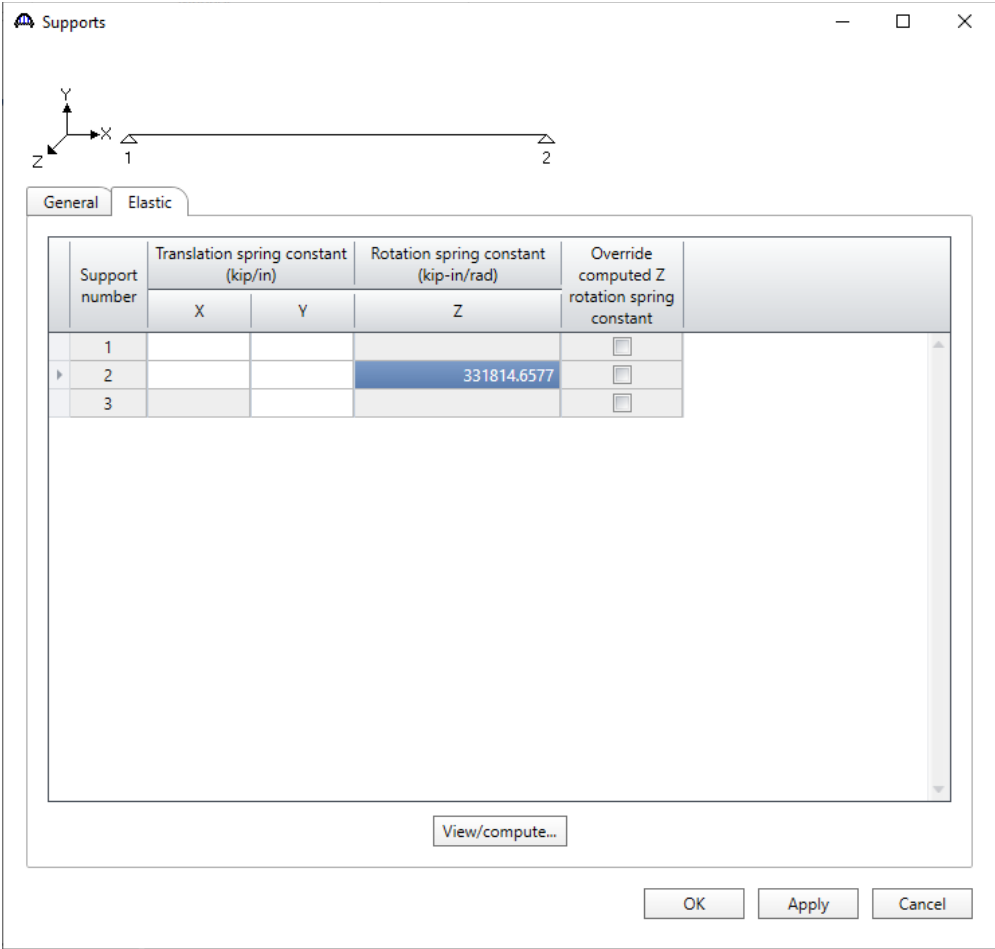
The column stiffness coefficient is computed as follows:

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

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

FRM1 – Reinforced Concrete Frame Example

Supports window will be populated as shown below.

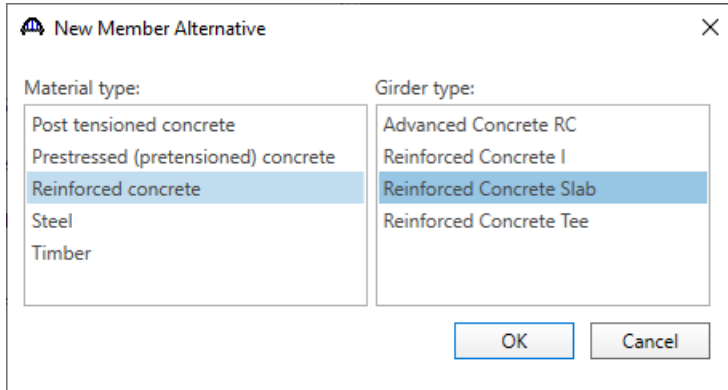


Click **OK** to apply the data and close the window.

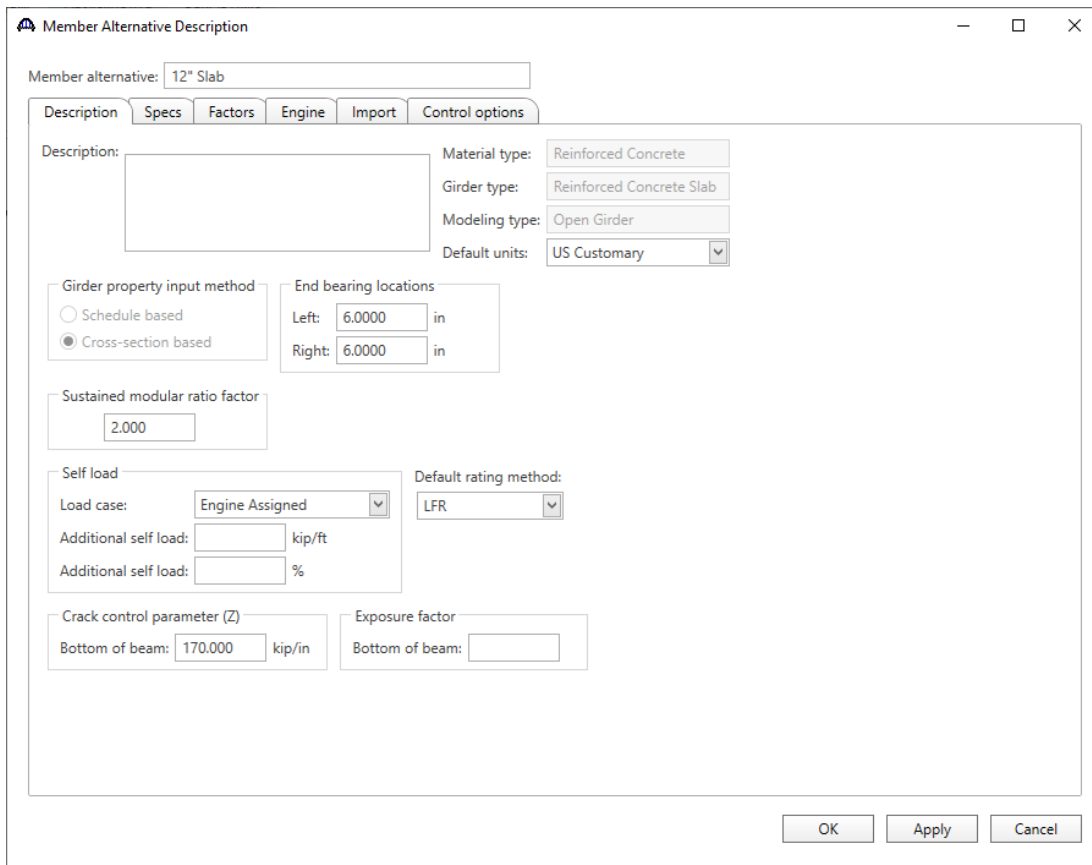
FRM1 – Reinforced Concrete Frame Example

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.

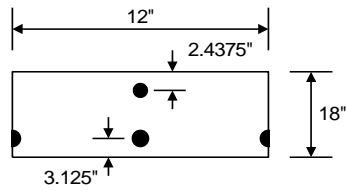
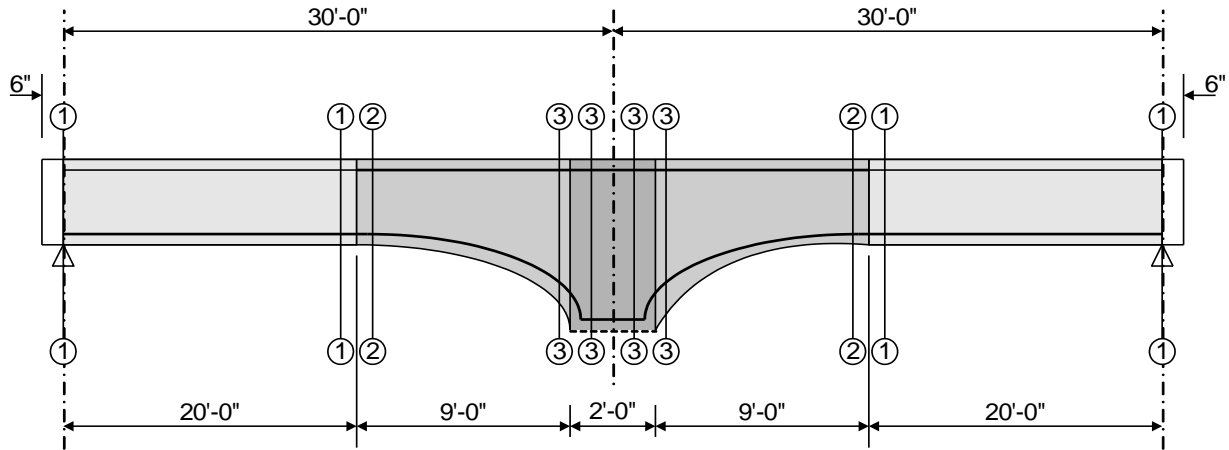


Click **OK** to apply the data and close the window.

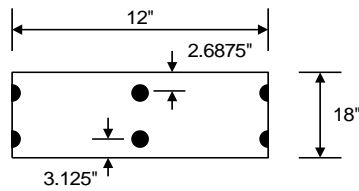
FRM1 – Reinforced Concrete Frame Example

Cross - section based input.

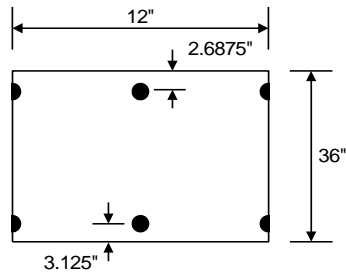
Expand **12" Slab (E) (C)** member alternative on the **Bridge Workspace** tree and double click on the **Cross Sections** node to open the **Cross Sections** window and create a new cross section. This member contains three cross sections as illustrated below.



Section 1



Section 2



Section 3

FRM1 – Reinforced Concrete Frame Example

Cross Sections

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

Section 1

Concrete material: Class A (US)
Modular ratio:

12.0000 in
18.0000 in

OK Apply Cancel

| 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

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

FRM1 – Reinforced Concrete Frame Example

Section 2

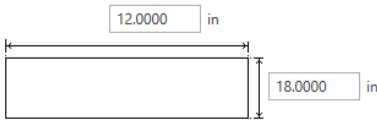
Cross Sections

Name: Type:

Dimensions Reinforcement

Concrete material:

Modular ratio:



12.0000 in

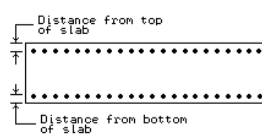
18.0000 in

OK Apply Cancel

Cross Sections

Name: Type:

Dimensions Reinforcement



| 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

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

FRM1 – Reinforced Concrete Frame Example

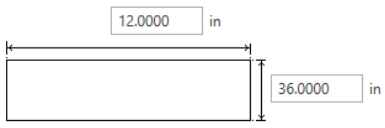
Section 3

Cross Sections

Name: Type:

Dimensions Reinforcement

Concrete material:
Modular ratio:

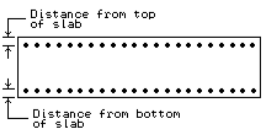


12.0000 in
36.0000 in

Cross Sections

Name: Type:

Dimensions Reinforcement



| 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 | |

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

FRM1 – Reinforced Concrete Frame Example

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.

| 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 |

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

FRM1 – Reinforced Concrete Frame Example

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:

| Lanes loaded | Distribution factor (wheels) | | | |
|--------------|------------------------------|-------------------|--------|------------|
| | Shear | Shear at supports | Moment | Deflection |
| 1 Lane | | | 0.172 | 0.167 |
| Multi-lane | | | 0.172 | 0.167 |

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 $7'$.

$S = \text{span length} = 30'$

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

FRM1 – Reinforced Concrete Frame Example

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

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.

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

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

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: Deflection

| Support number | Start distance (ft) | Length (ft) | End distance (ft) | Distribution factor (lanes) | |
|----------------|---------------------|-------------|-------------------|-----------------------------|------------|
| | | | | 1 lane | Multi-lane |
| 1 | 0.00 | 60.000 | 60.00 | 0.100 | 0.083 |

Compute from typical section... View calcs

New Duplicate Delete

OK Apply Cancel

FRM1 – Reinforced Concrete Frame Example

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

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: Shear

| 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

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

FRM1 – Reinforced Concrete Frame Example

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

$$E = 10.0 + 5.0\sqrt{L_1W_1}$$

$$L_1 = \text{span length} \leq 60' = 30'$$

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

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

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

For multi lane:

$$E = 84.0 + 1.44\sqrt{L_1W_1} \leq \frac{12.0W}{N_L}$$

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

$$W = \text{width edge - edge of bridge} = 27'$$

$$N_L = \text{number of lanes}$$

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

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

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

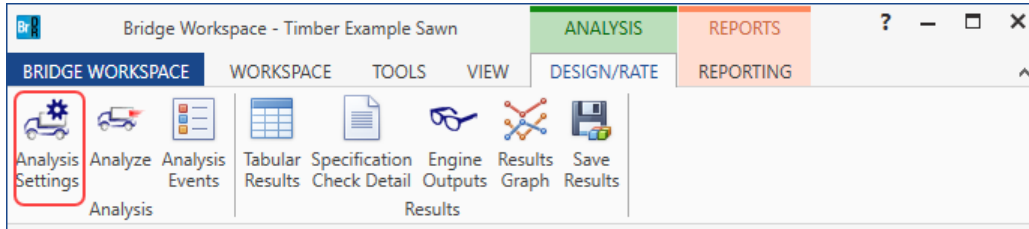
$$\text{Single lane Deflection DF} = \frac{1 \text{ lane}}{(12'/1')} (1.20) = 0.100 \text{ lanes}$$

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

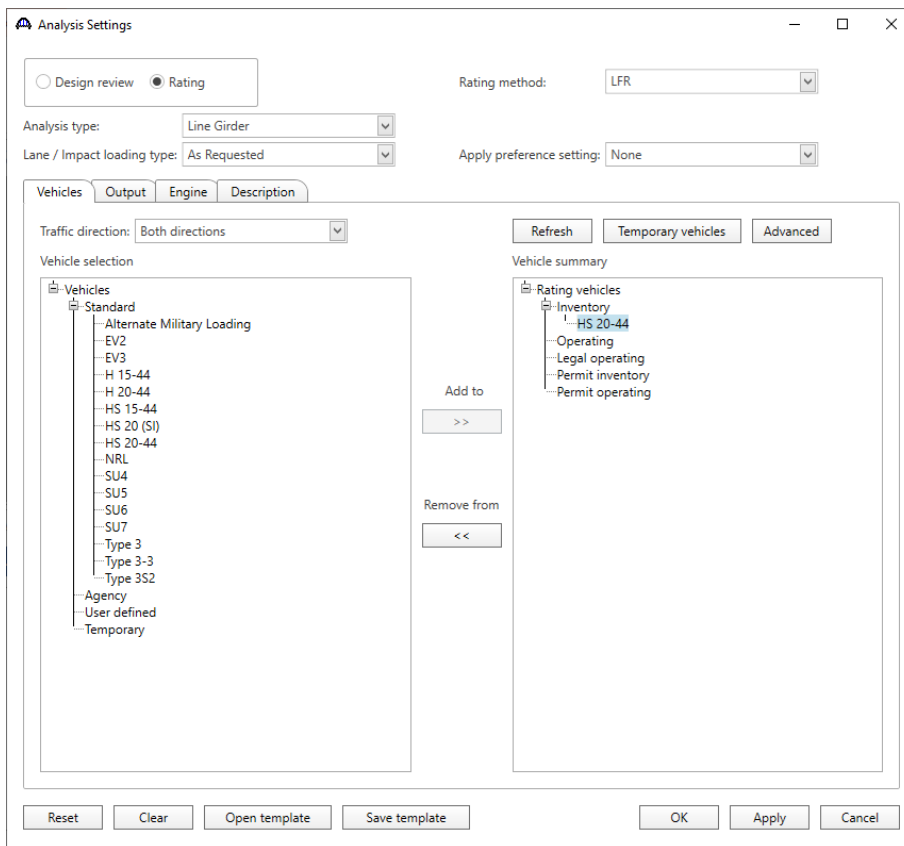
FRM1 – Reinforced Concrete Frame Example

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**.



FRM1 – Reinforced Concrete Frame Example

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.

Analysis Results - 12" Slab

Print

Report type: Rating Results Summary

Lane/Impact loading type: As requested Detailed

Display Format: Single rating level per row

| 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 |

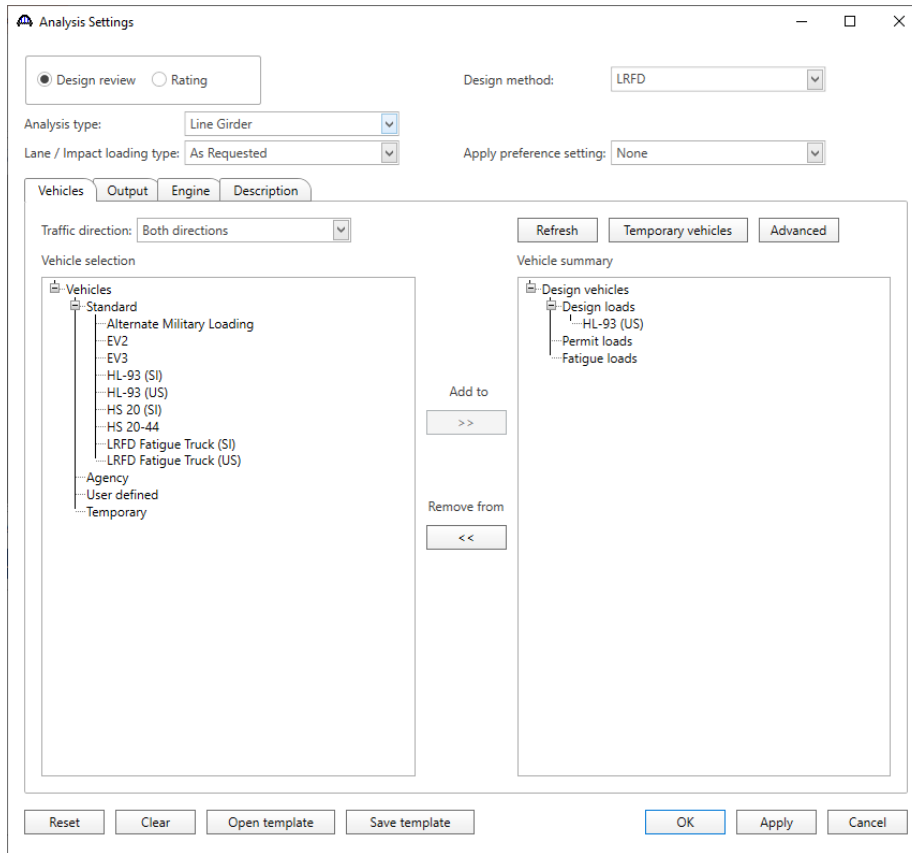
AASHTO LFR Engine Version 7.5.0.3001
Analysis preference setting: None

Close

FRM1 – Reinforced Concrete Frame Example

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**.




FRM1 – Reinforced Concrete Frame Example

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.

Analysis Results - 12" Slab
— □ ×



Print

Report type: Dead Load Actions | Stage: Non-composite (Stage 1) | Dead Load Case: Load Case 1 - Self Load(Stage 1)

| 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 |

AASHTO LRFD Engine Version 7.5.0.3001
 Analysis preference setting: None

Close