AASHTOWare BrDR 7.5.0

Reinforced Concrete Structure Tutorial

RC5 – Schedule Based Tee Example

BrDR Training

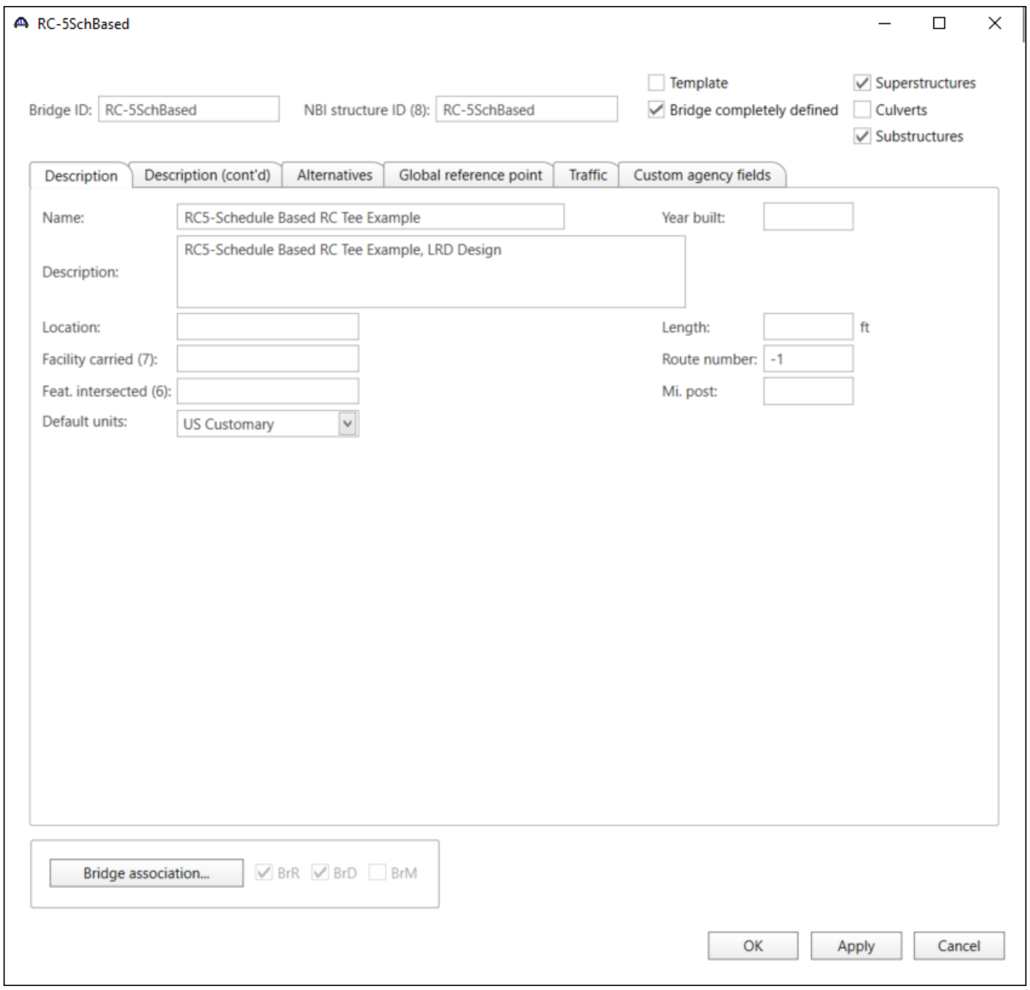
RC5 –Schedule Based Tee Example

Topics Covered

- Reinforced concrete schedule based tee input as girder system.
- Export of schedule based reinforced concrete beams to an analysis engine
- Schedule based reinforced concrete Point of Interest wizard

Reinforced concrete schedule based tee input as girder system

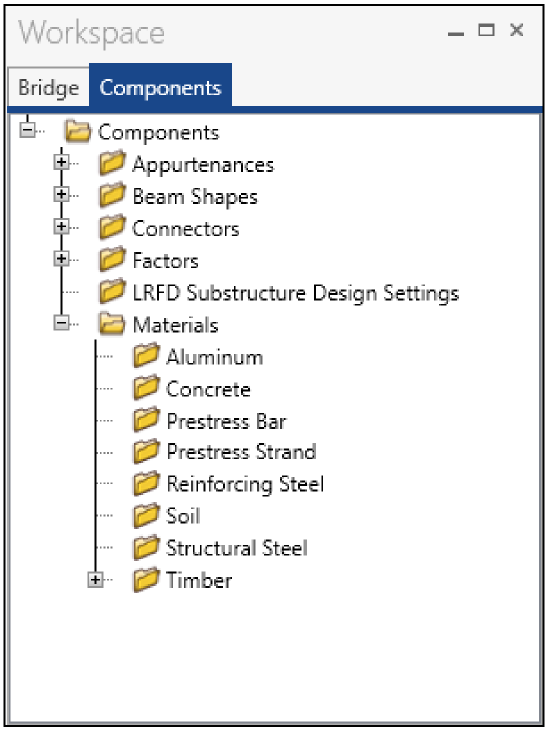
From the Bridge Explorer create a new bridge and enter the following description data:



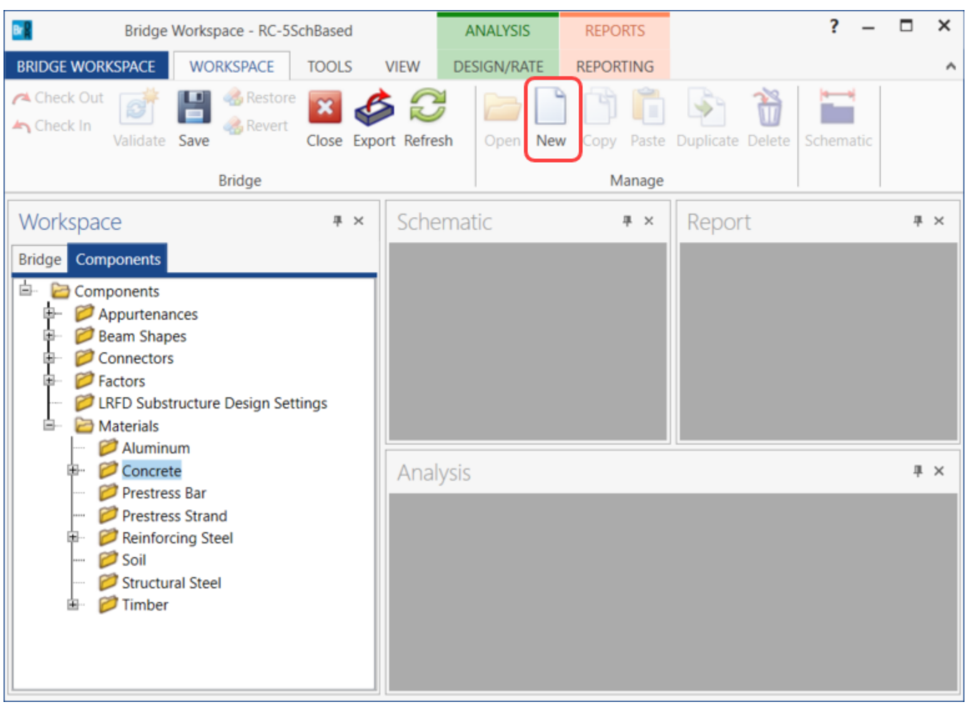
Close the window by clicking **OK**. This saves the data to memory and closes the window.

Bridge Components

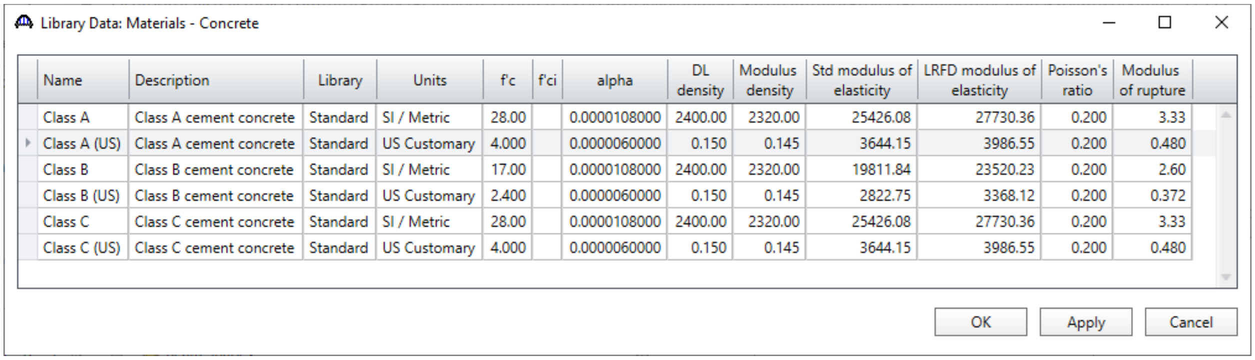
To enter the materials to be used by members of the bridge, click on the **Components** tab of **Bridge Workspace**, and expand the tree for Materials. The tree with the expanded **Materials** branch is shown below.



To add a new concrete material, click on **Concrete** in the **Components** tree and select **New** from the **Manage** group of the **WORKSPACE** ribbon (or right mouse click on **Concrete** and select **New**).



Add the concrete material by selecting from the Concrete Materials Library by clicking the **Copy from Library** button. The following window opens:

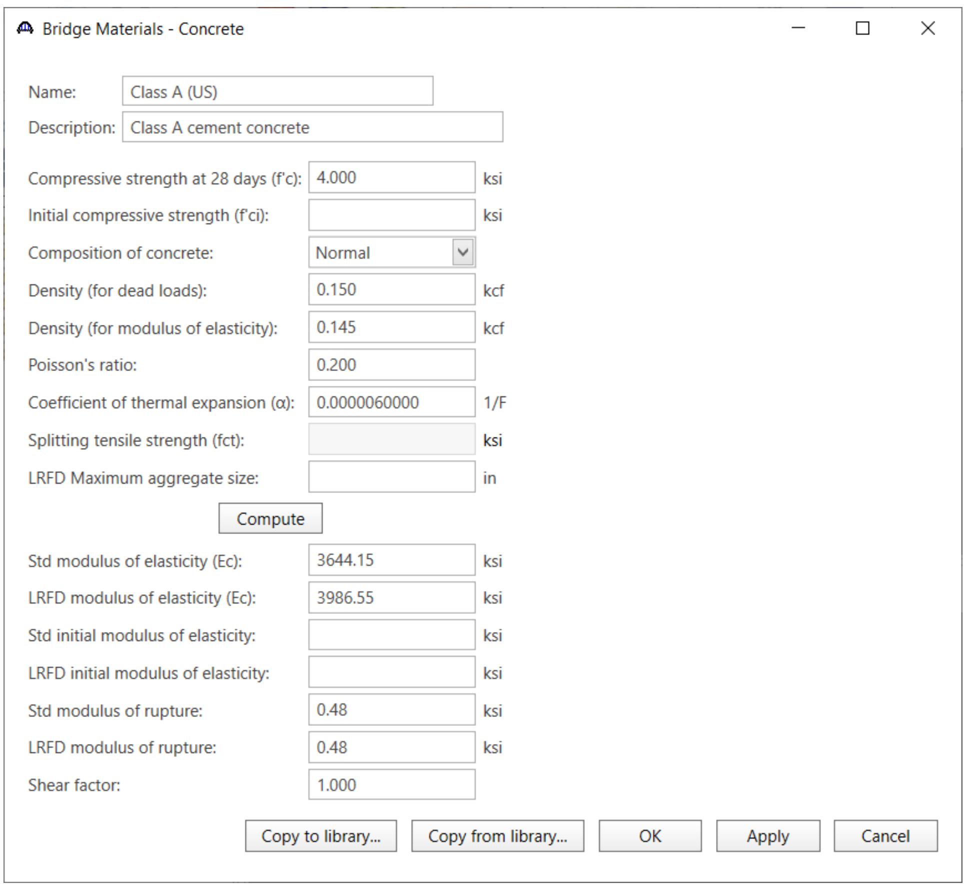


Library Data: Materials - Concrete

Name	Description	Library	Units	f'c	f'ci	alpha	DL density	Modulus density	Std modulus of elasticity	LRFD modulus of elasticity	Poisson's ratio	Modulus of rupture
Class A	Class A cement concrete	Standard	SI / Metric	28.00		0.0000108000	2400.00	2320.00	25426.08	27730.36	0.200	3.33
Class A (US)	Class A cement concrete	Standard	US Customary	4.000		0.0000060000	0.150	0.145	3644.15	3986.55	0.200	0.480
Class B	Class B cement concrete	Standard	SI / Metric	17.00		0.0000108000	2400.00	2320.00	19811.84	23520.23	0.200	2.60
Class B (US)	Class B cement concrete	Standard	US Customary	2.400		0.0000060000	0.150	0.145	2822.75	3368.12	0.200	0.372
Class C	Class C cement concrete	Standard	SI / Metric	28.00		0.0000108000	2400.00	2320.00	25426.08	27730.36	0.200	3.33
Class C (US)	Class C cement concrete	Standard	US Customary	4.000		0.0000060000	0.150	0.145	3644.15	3986.55	0.200	0.480

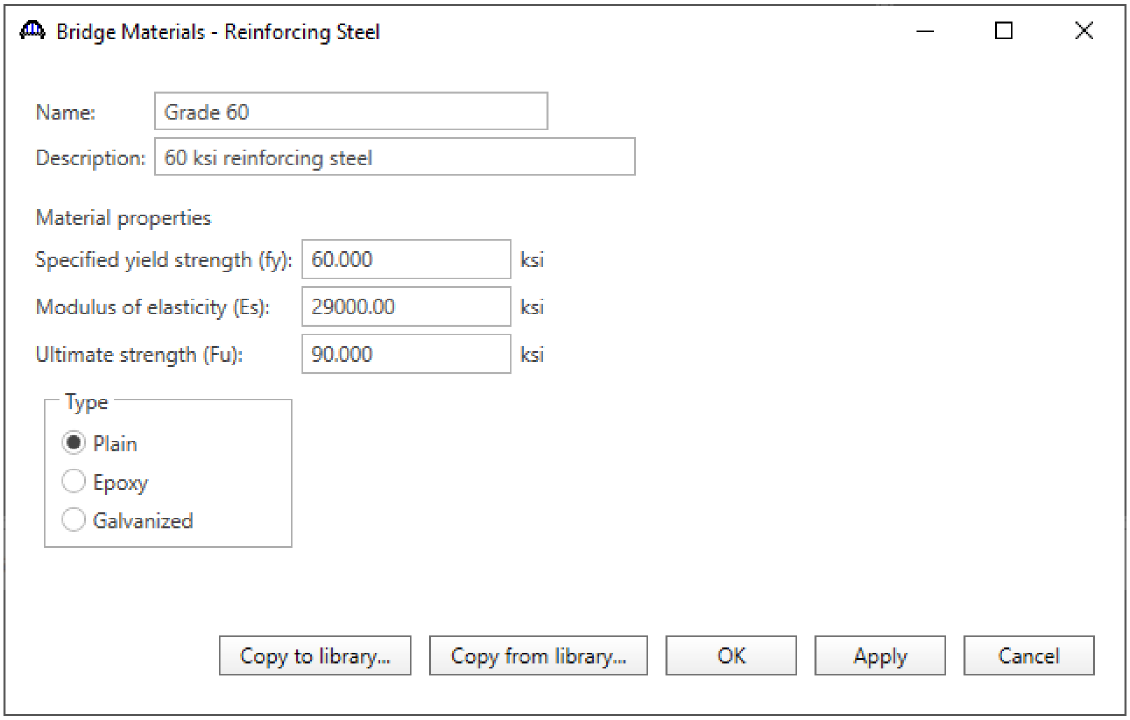
OK Apply Cancel

Select the **Class A (US)** material and click **OK.** The selected material properties are copied to the **Bridge Materials – Concrete** window as shown below.



Click **OK** to save the data to memory and close the window.

Add the **reinforcement steel** in the same manner.

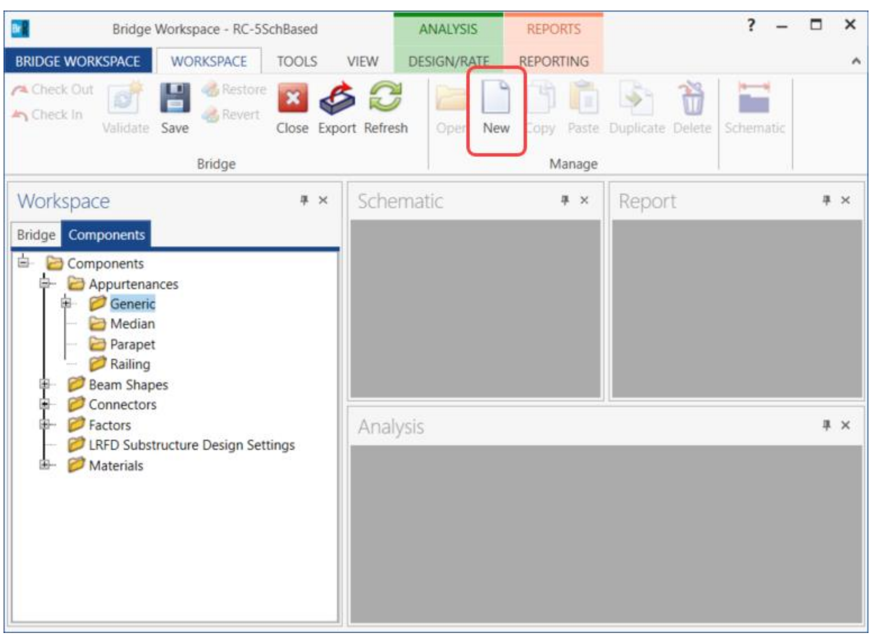


Since reinforced tee girder is used, beam shapes need not be defined.

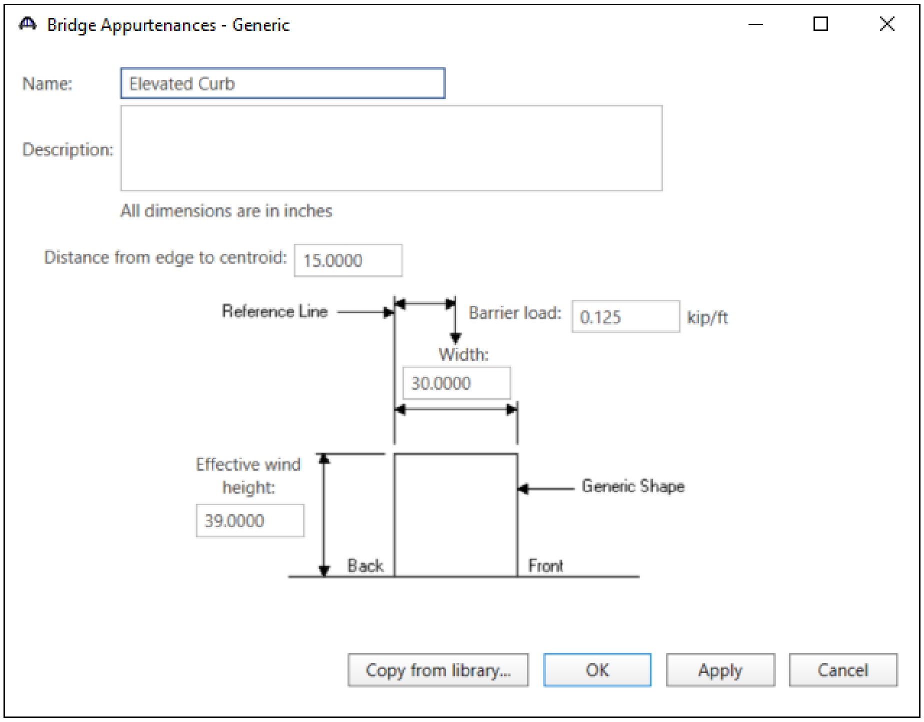
Since this is a girder system structure, an appurtenance needs to be defined.

Bridge Appurtenances

To enter an appurtenance to be used within the bridge, expand the tree branch labeled **Appurtenances** in the **Components** tab. Select **Generic** and click on **New** from the **Manage** button on the **WORKSPACE** ribbon (or double click on **Generic**).



Enter the following data to model the elevated curb on this structure.

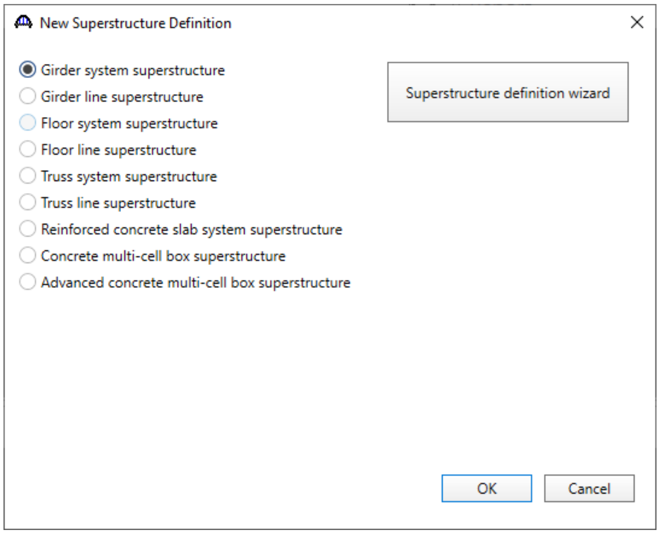


Click **OK** to save the data to memory and close the window. This appurtenance will be used on both the left and right side of the typical section which will be defined later in this example.

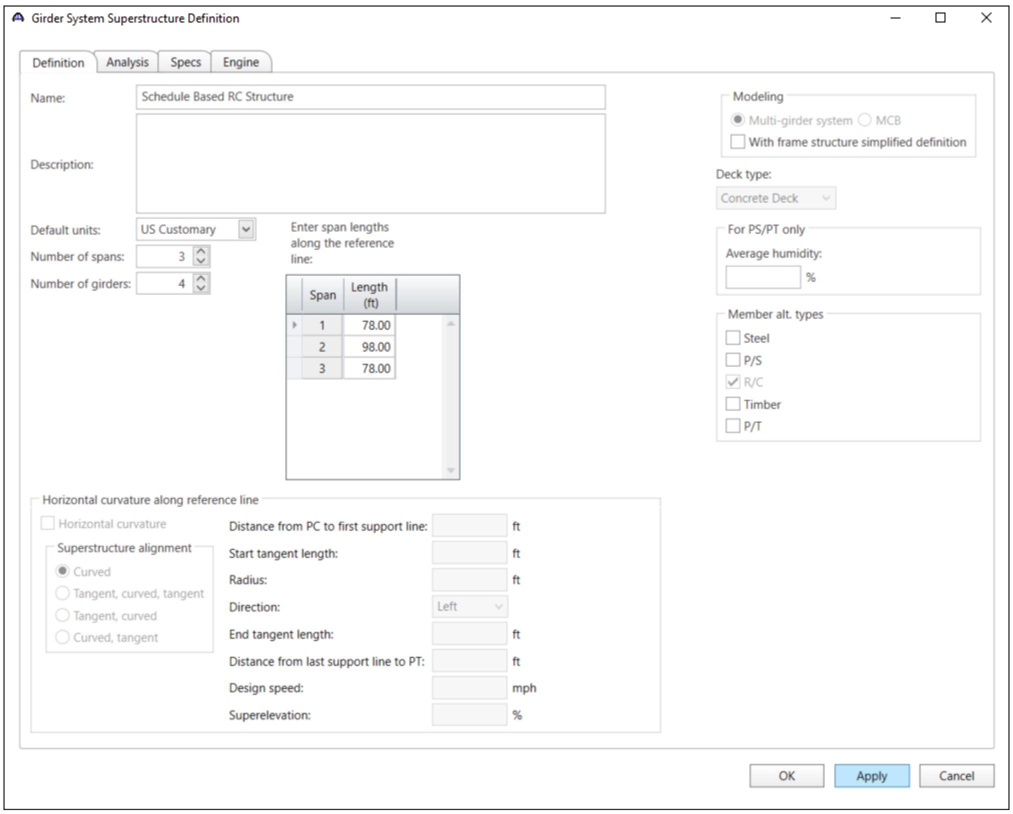
The default impact factors, standard LRFD and LFD factors will be used so the next step will be to define a Superstructure. Bridge Alternatives will be added after a superstructure is defined.

Superstructure Definition

Returning to the **Bridge** tab of the **Bridge Workspace**, 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.



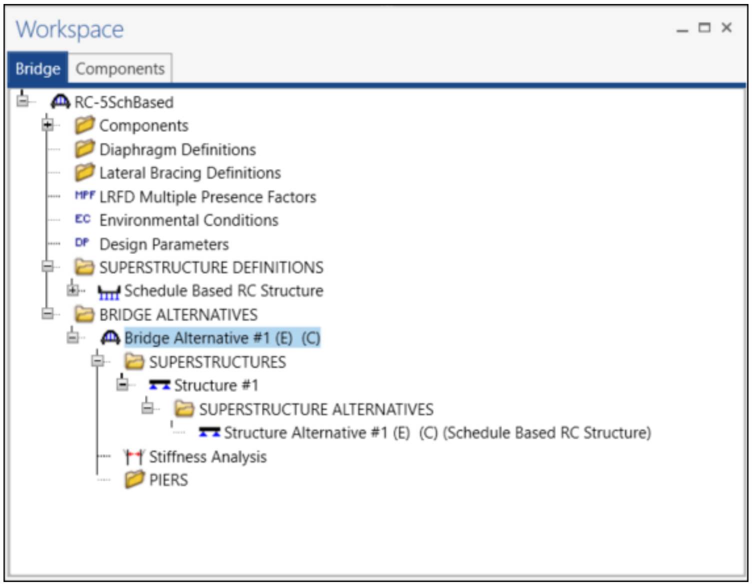
Select **Girder system superstructure**, click **OK** and the **Superstructure Definition** window will open. Enter the data as shown below.



Click **OK** to save the data to memory and close the window.

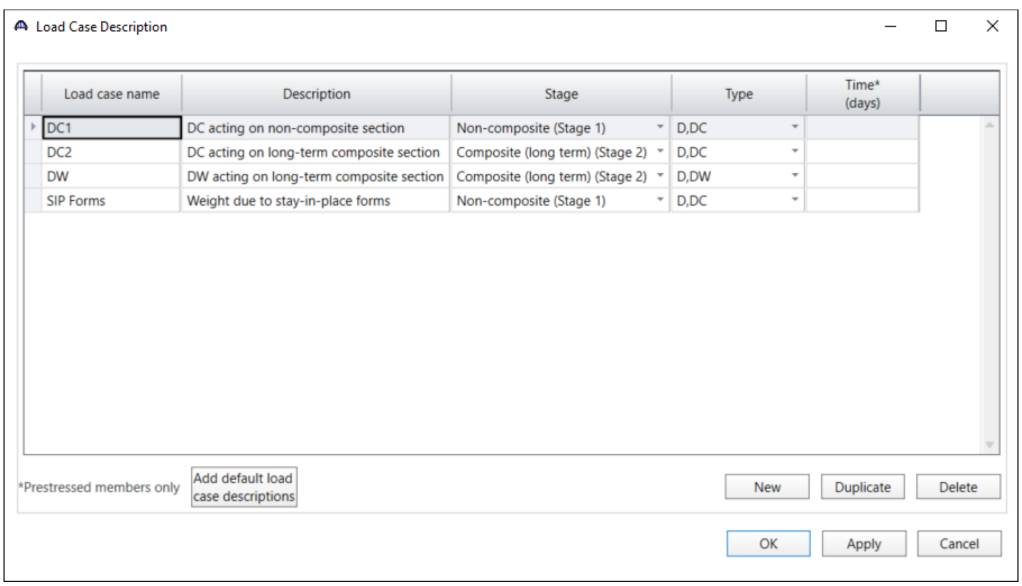
Navigate to the **Bridge Alternatives** node in the Bridge Workspace tree and create a new **Bridge Alternative**, a new **Structure**, and a new **Structure Alternative** as shown in **STL1 tutorial**.

The partially expanded Bridge Workspace tree is shown below.



Load Case Description

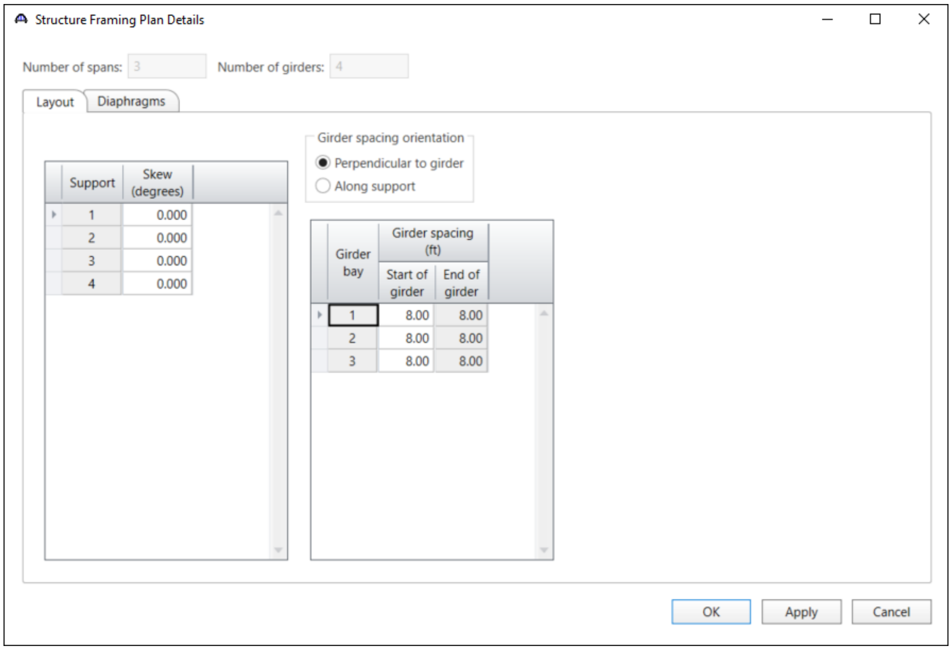
Click **Load Case Description** in the Bridge Workspace tree to define the dead load cases. Select the **Add Default Load Case Descriptions** button to create the following load cases.



Click **OK** to save the data to memory and close the window.

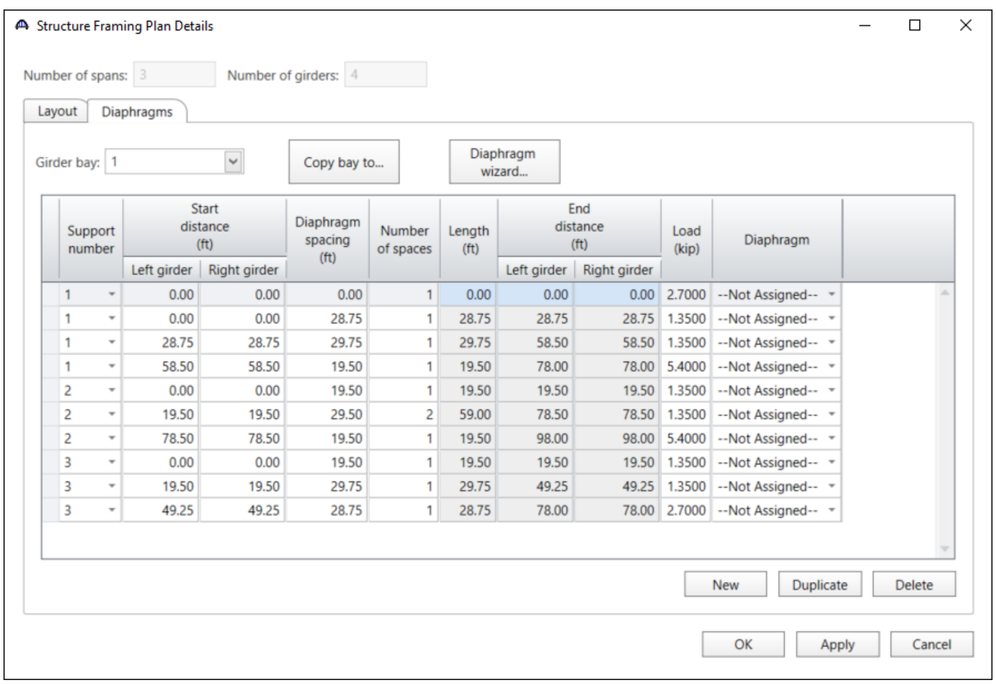
Structure Framing Plan Details

Double-click on **Framing Plan Detail** in the Bridge Workspace tree to describe the framing plan in the **Structure Framing Plan Details** window. Enter the data as shown below.



Structure Framing Plan Detail - Diaphragms

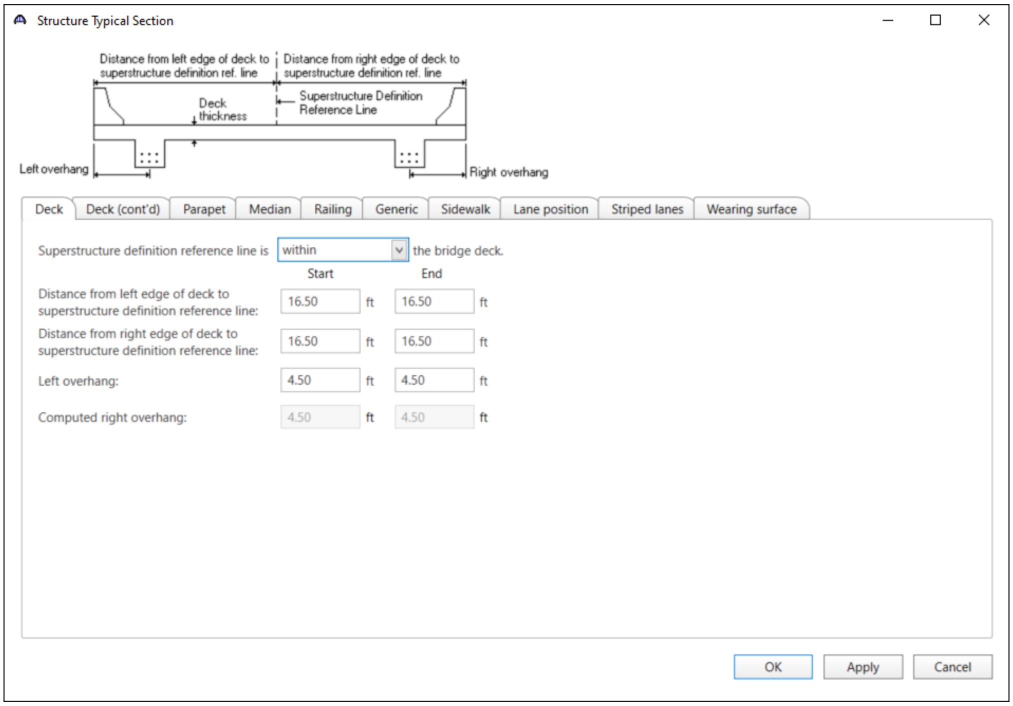
Switch to the **Diaphragms** tab to enter diaphragm spacing. Enter the diaphragm locations shown below for **girder bay 1**. Click on the **Copy bay to…** button to copy the diaphragms to the other 2 bays in the structure.



Click **OK** to save the data to memory and close the window.

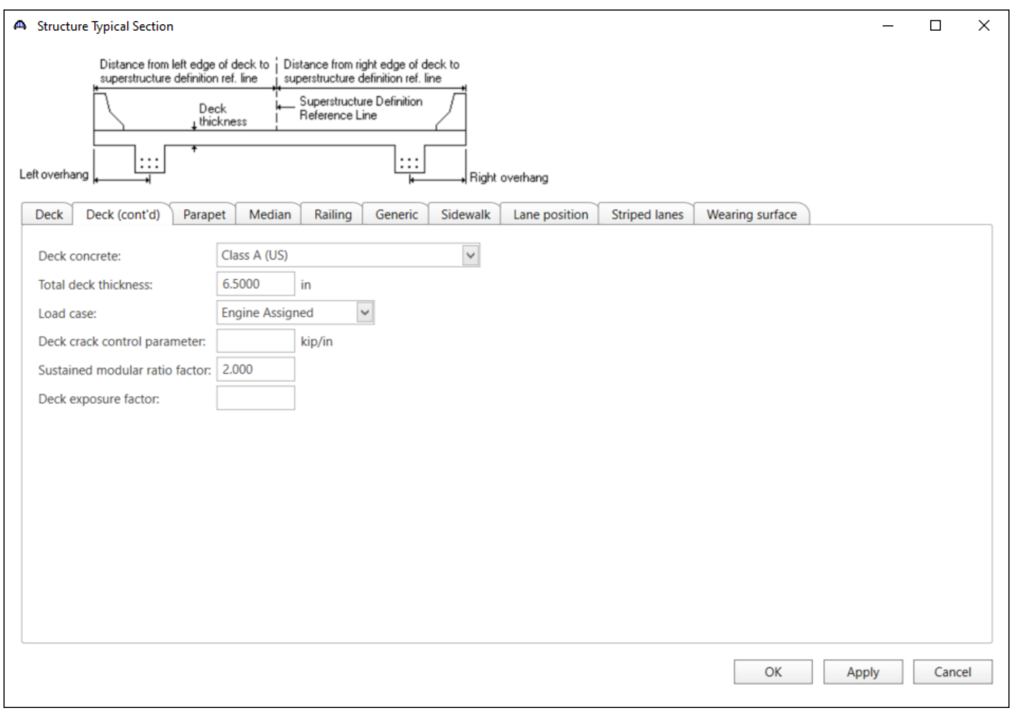
Structure Typical Section - Deck

Define the structure typical section by double-clicking on **Structure Typical Section** in the **Bridge Workspace** tree. Input the data describing the typical section as shown below.



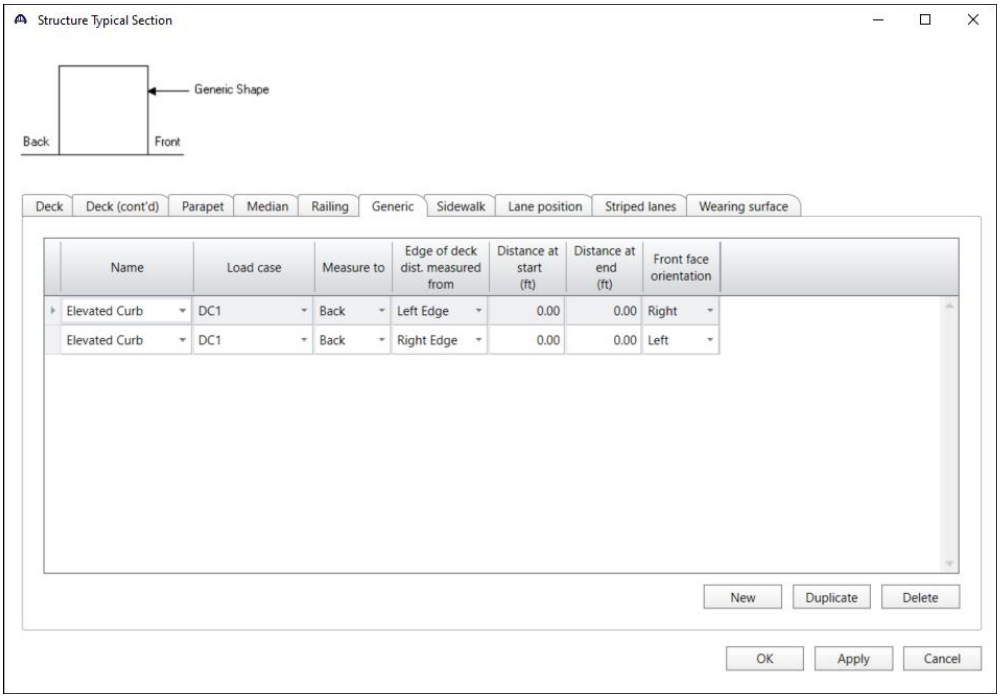
Structure Typical Section – Deck (cont'd)

Select the Deck(cont'd) tab. Enter the values shown below.



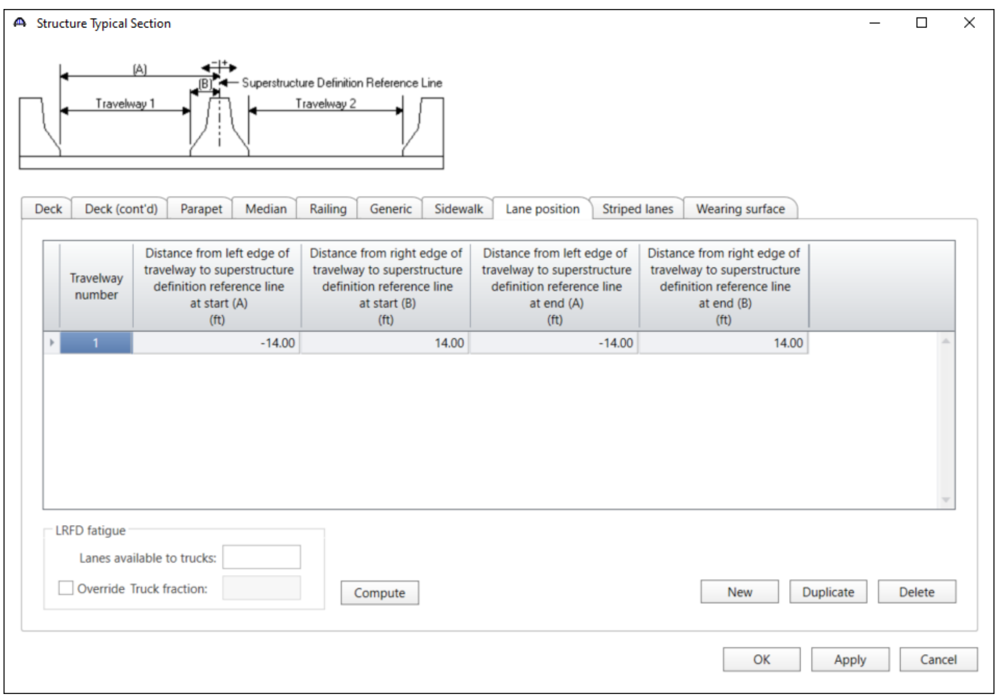
Structure Typical Section - Generic

Select the Generic tab. Enter the values shown below. The previously defined appurtenance will be used here.



Structure Typical Section – Lane Position

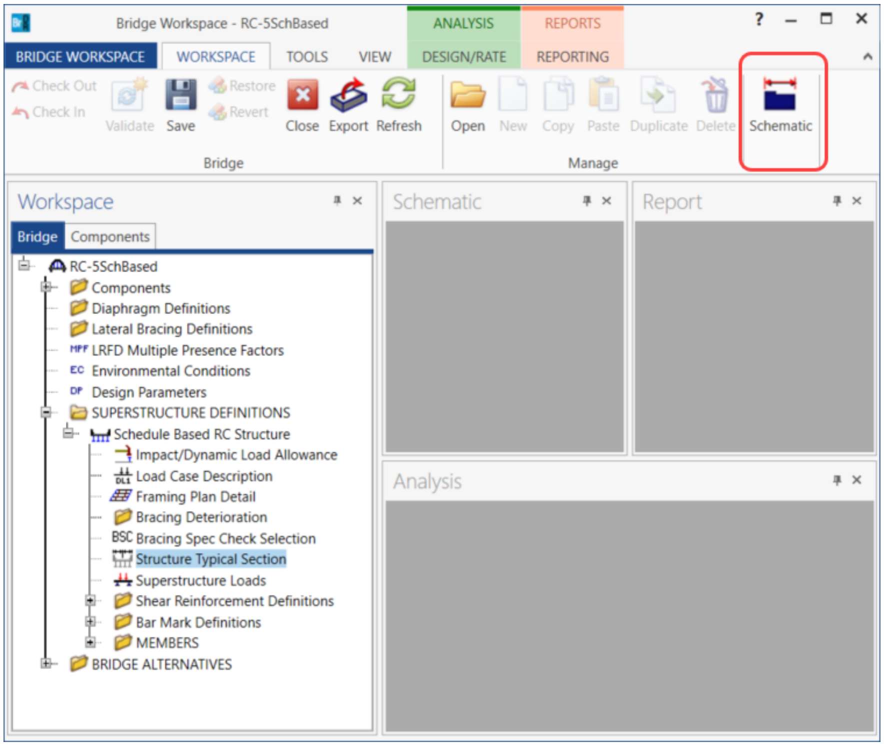
Select the **Lane position** tab. Enter the values shown below.



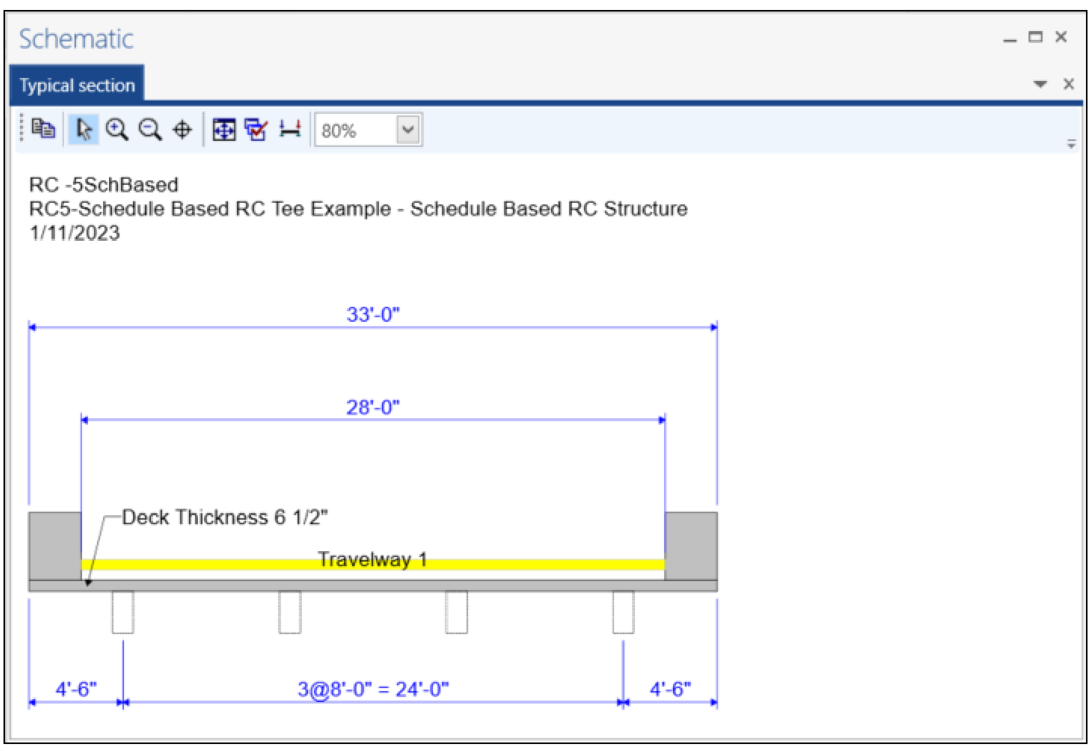
Click **OK** to save the data to memory and close the window.

Structure Typical Section - Schematic

A schematic of the structure typical section can be viewed by selecting the **Structure Typical Section** node on the **Bridge Workspace** tree and clicking on the **Schematic** button on the **WORKSPACE** ribbon.

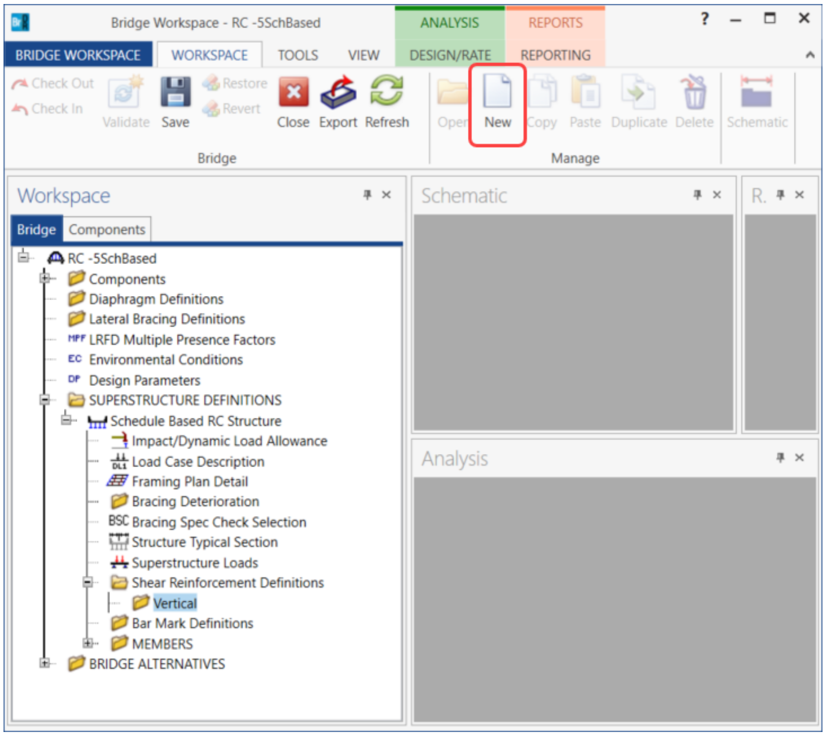


The Structure Typical Section schematic is displayed below.

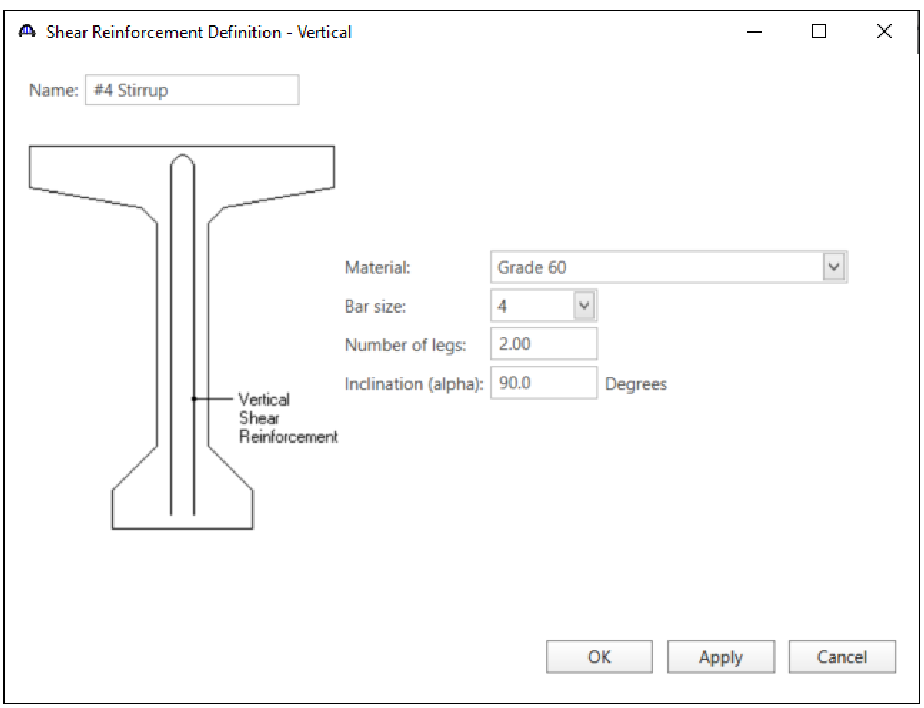


Shear Reinforcement

Expand the **Shear Reinforcement Definitions** node in the **Bridge Workspace** tree, select **Vertical** and click on **New** from the **Manage** group of the **WORKSPACE** ribbon (or double click on **Vertical)**.



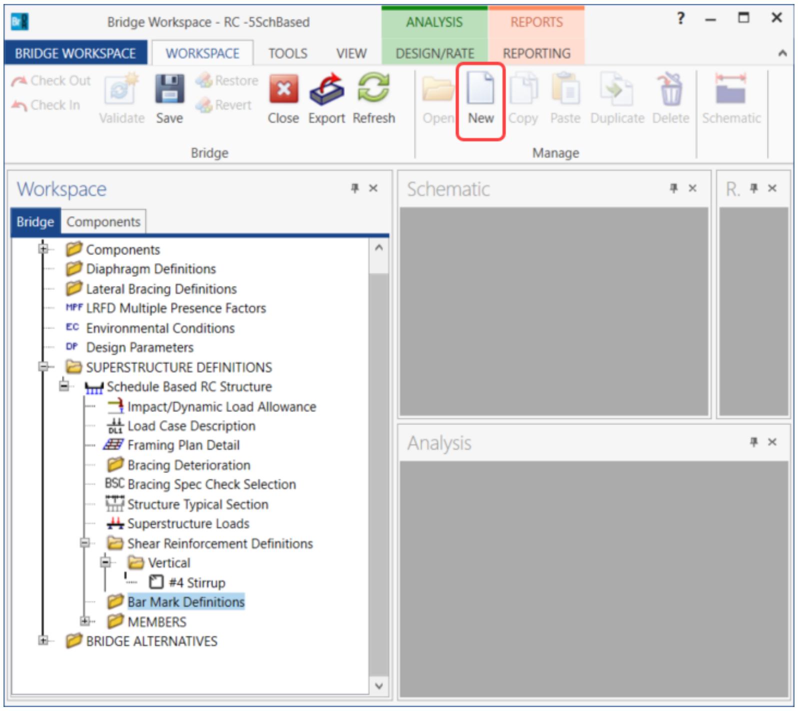
Define the stirrup as shown below.



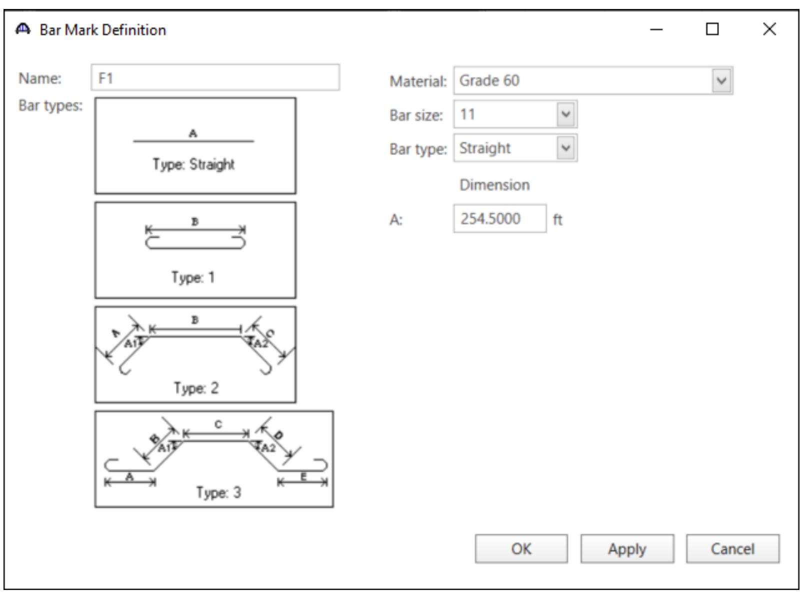
Click **OK** to save to memory and close the window.

Bar Mark Definitions

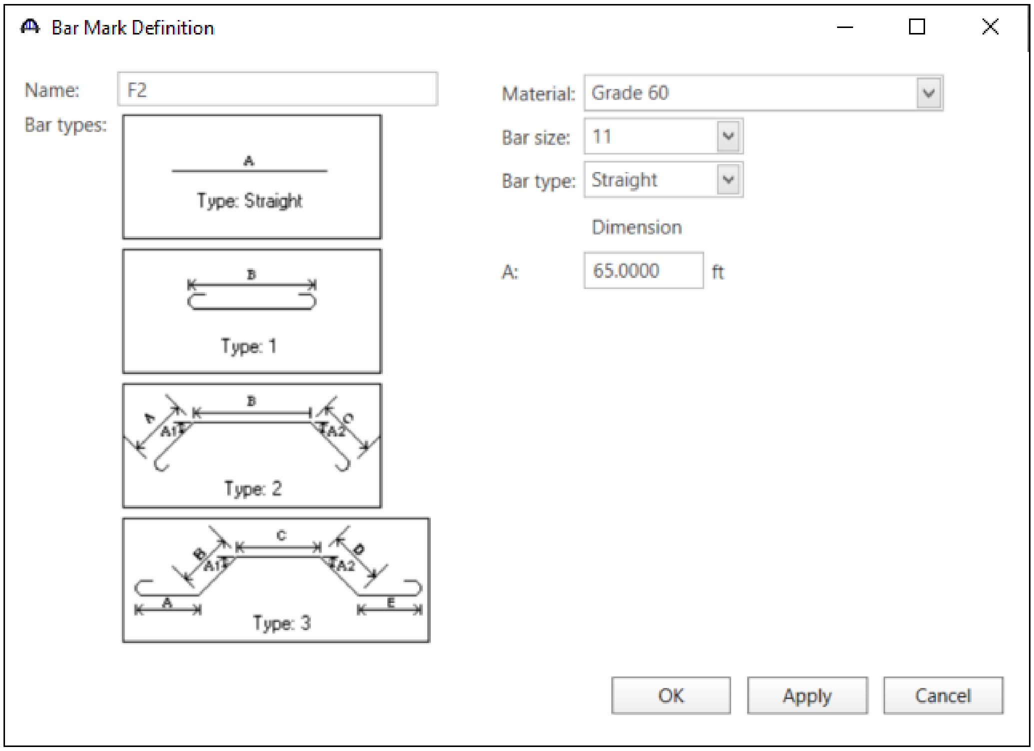
Bar Mark Definitions are used to define the longitudinal flexural reinforcement in schedule based reinforced concrete members. Select **Bar Mark Definitions** in the **Bridge Workspace** tree and click the **New** button from the **Manage** group of the **WORKSPACE** ribbon.



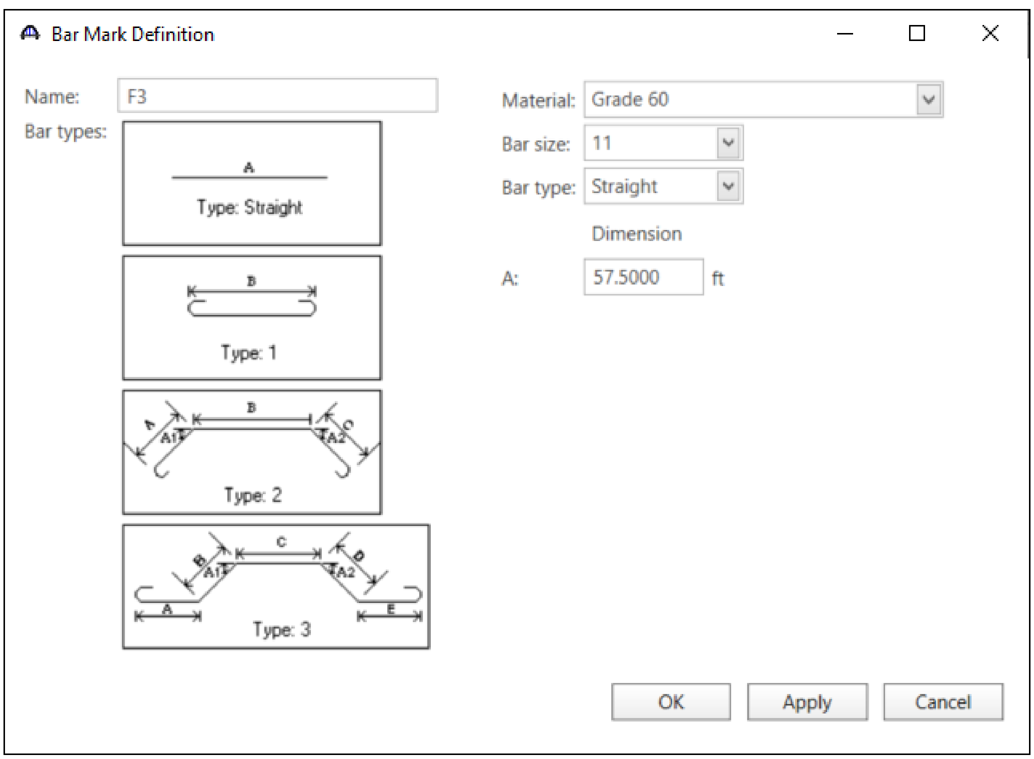
This bridge uses the following bar mark definitions. Add these definitions.



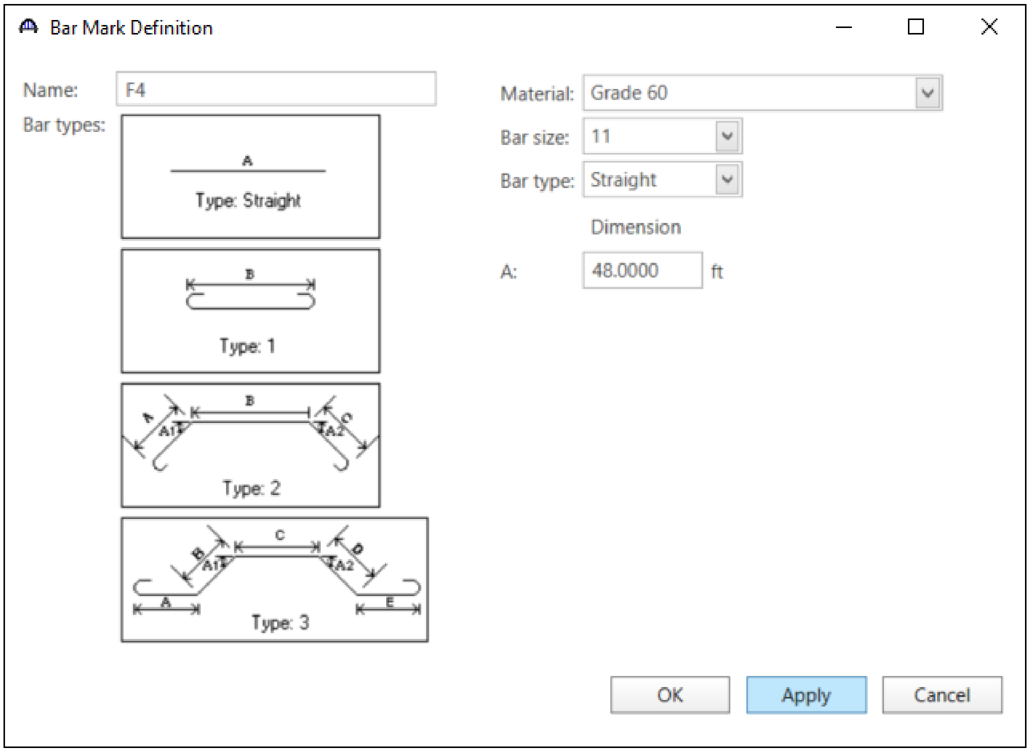
Click **OK** to save to memory and close the window.



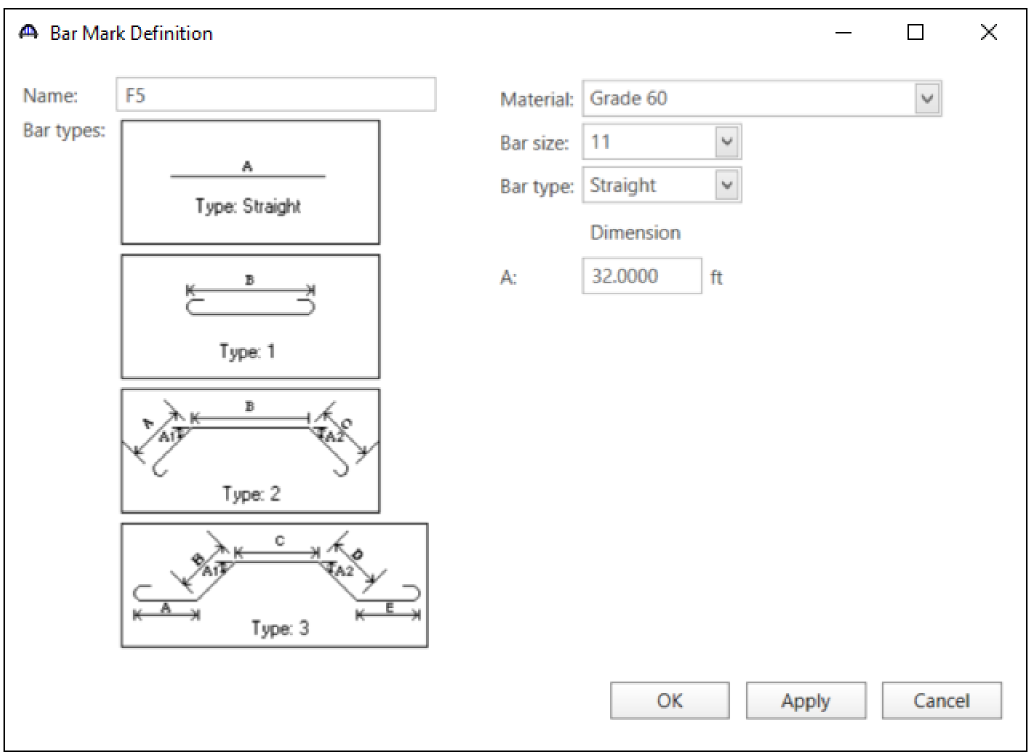
Click **OK** to save to memory and close the window.



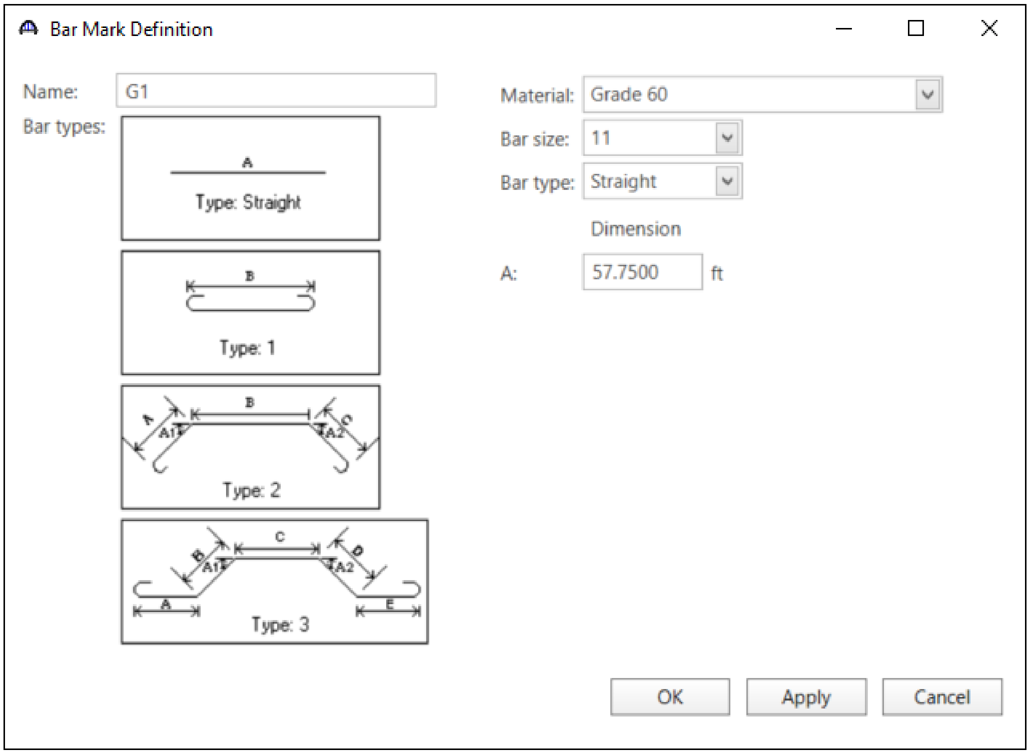
Click **OK** to save to memory and close the window.



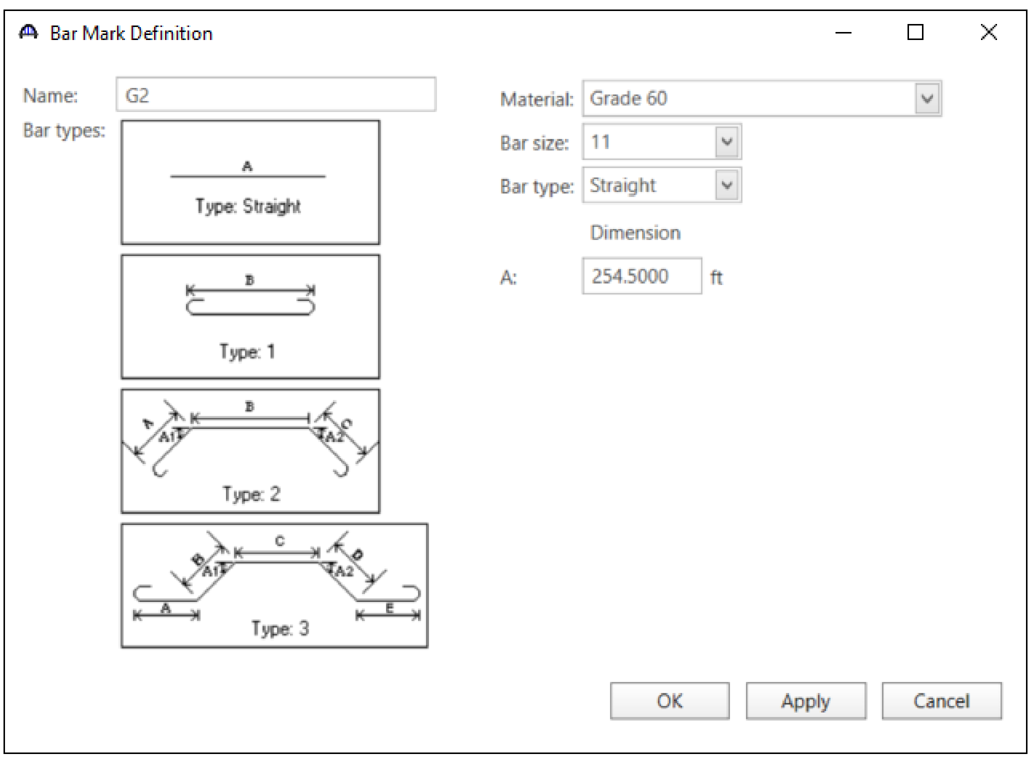
Click **OK** to save to memory and close the window.



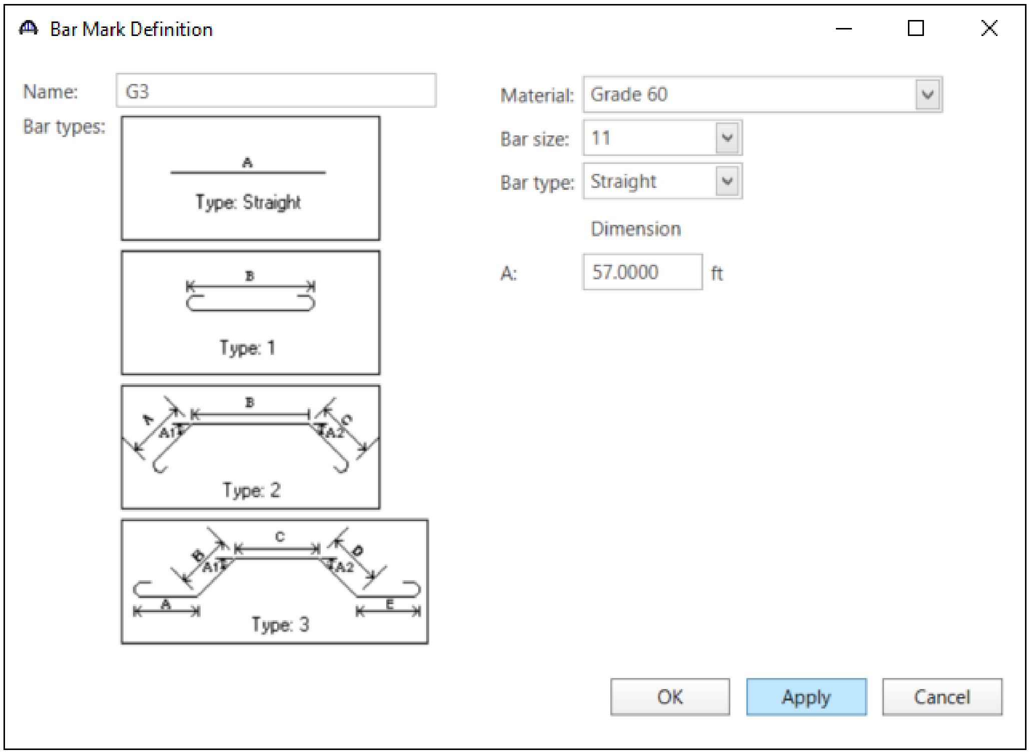
Click **OK** to save to memory and close the window.



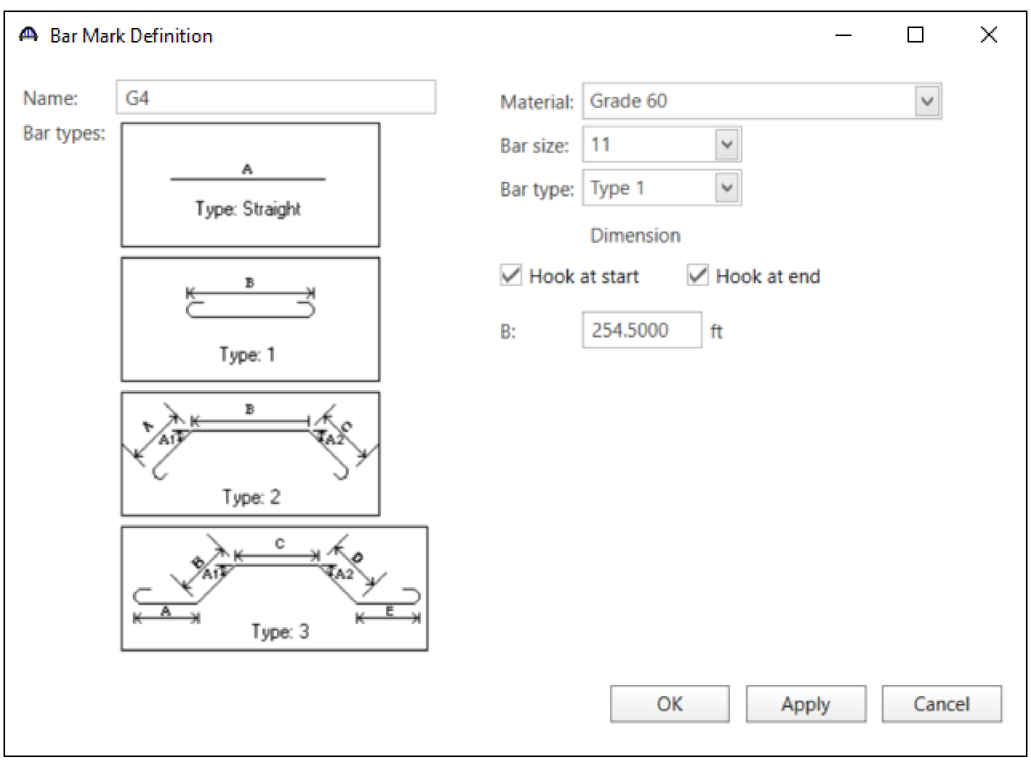
Click **OK** to save to memory and close the window.



Click **OK** to save to memory and close the window.



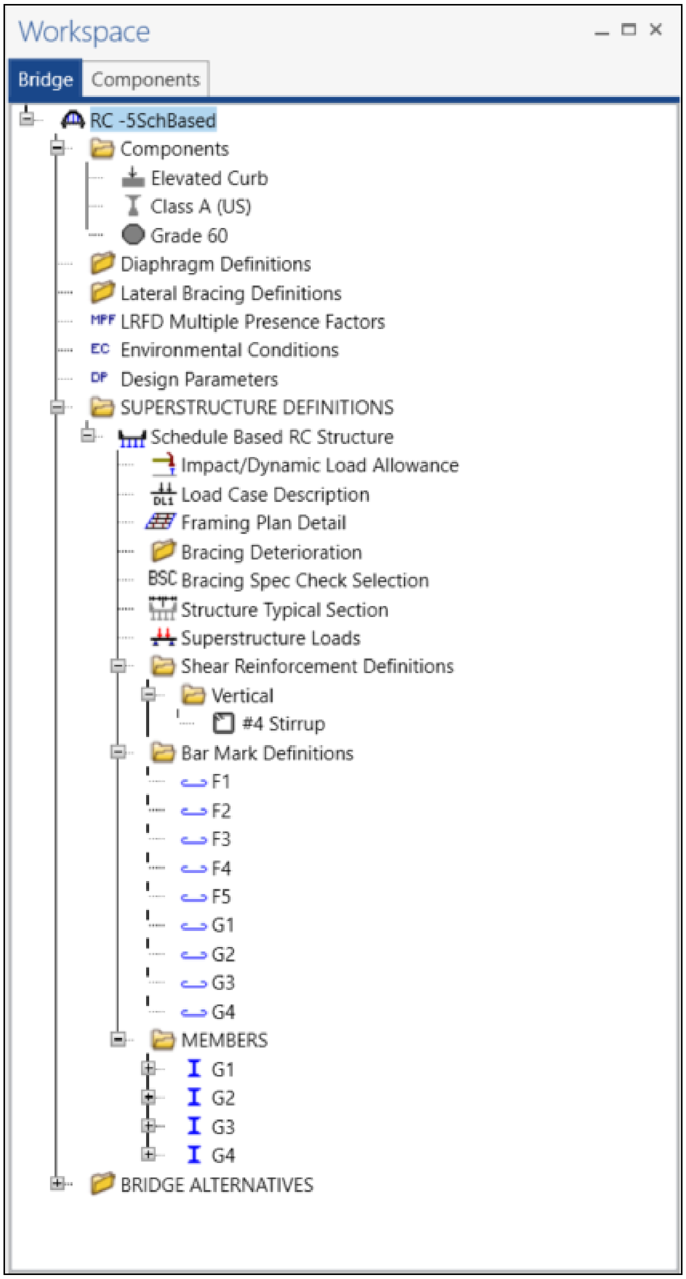
Click **OK** to save to memory and close the window.



Click **OK** to save to memory and close the window.

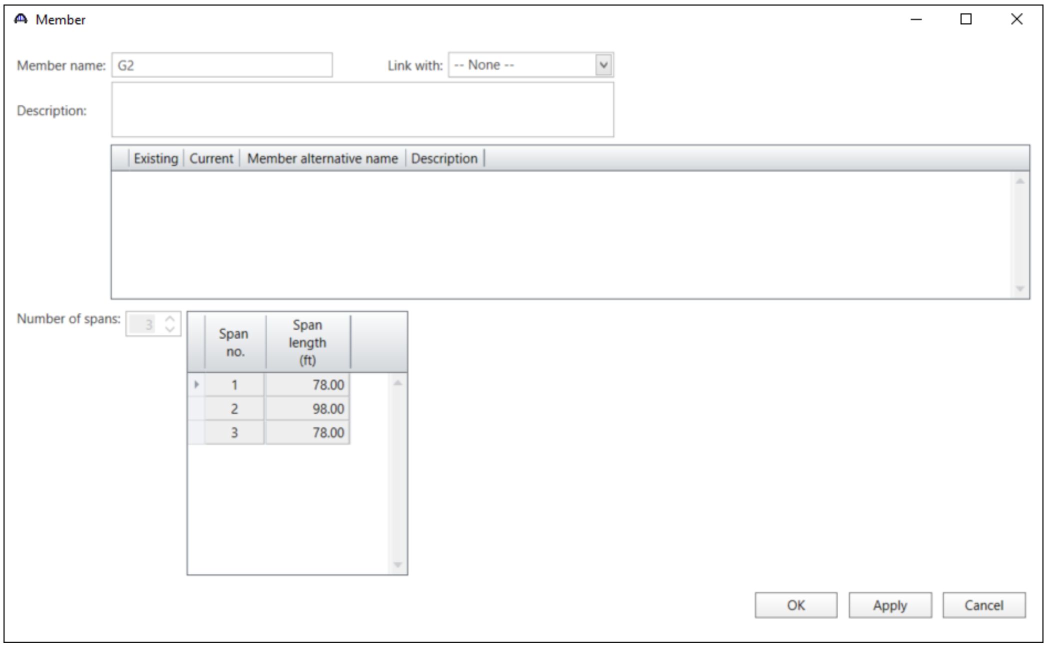
RC5 – Schedule Based Tee Example

The expanded **Bridge Workspace Tree** is shown below.



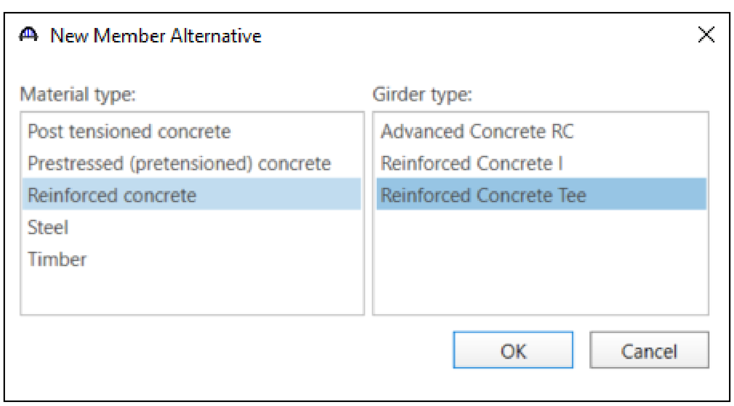
Describing a member

Open the **G2** Member window by double clicking on **G2** in the bridge workspace tree. This member does not require any additional information to be entered. The first Member Alternative created will automatically be assigned as the **Existing** and **Current** Member alternative for this Member.



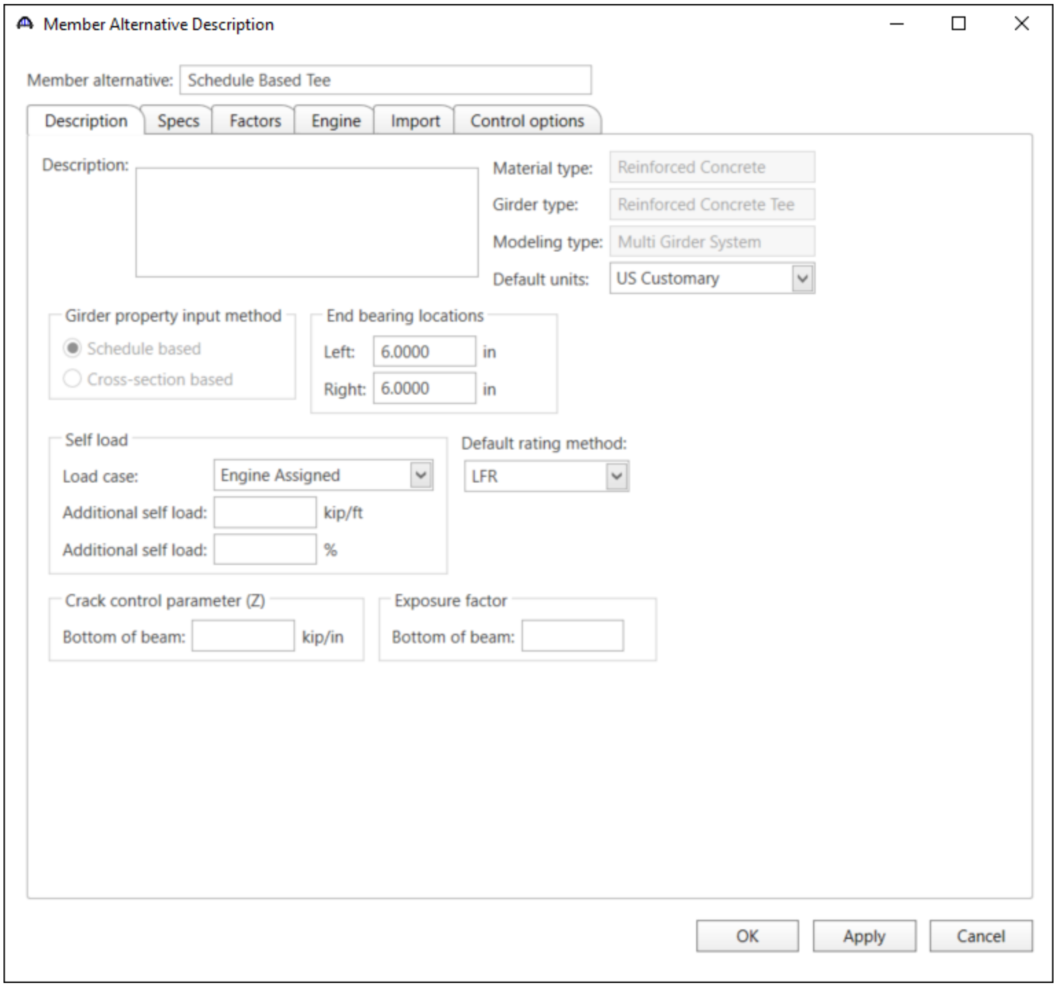
Defining a Member Alternative

Double-click on **MEMBER ALTERNATIVES** in the **Bridge Workspace** tree for member **G2** to create a new alternative. The **New Member Alternative** window shown below will open. Select **Reinforced Concrete** for the **Material Type** and **Reinforced Concrete Tee** for the **Girder Type**.



Click **OK** to close the window and create a new member alternative.

The **Member Alternative Description** window will open as shown below. Enter the data as shown and Click **OK** to save to memory and close the window.



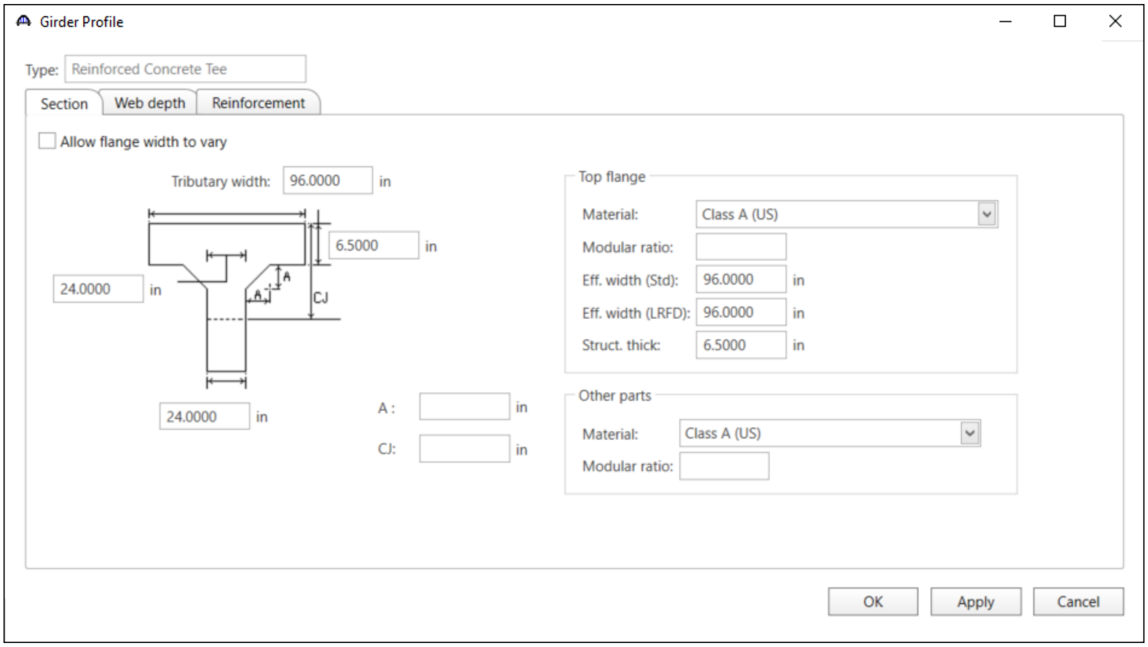
For a schedule based reinforced concrete member, it is important to enter a value for the **End Bearing Locations** in this window. This data describes the distance from the physical end of the beam to the centerline of the end bearings. It is important to enter this value here so that when bar mark definitions are assigned to the reinforcement profile, the bars can start to the left of the first support line and to the right of the last support line.

If the bars start to the left of the first support line and to the right of the last support line, BrDR will consider the bars to be partially developed at the centerline of the bearing. Then the analysis engine will be able to compute the **d** distance from the extreme compression fiber to the centroid of the tension reinforcement. This **d** value is required to compute the shear capacity of the section. If the rebar starts at the centerline of the bearing, it will be considered as zero percent developed at this point so a **d** distance cannot be computed, and the shear capacity of the beam will be zero.

Girder Profile

Expand the **Schedule Based Tee** member alternative on the **Bridge Workspace** tree, double click on **Girder Profile** to open the **Girder Profile** window and enter the data on each tab as shown below:

Girder Profile - Section



The Std. effective flange width of this interior girder is computed as follows:

AASHTO Article 8.10.1:

Total effective flange width shall not exceed ¼ Span Length = 78’/4 = 19.5’ = 234”

Effective flange width overhanging each side of web <= 6(ts) = 6*(6.5”) = 39” or ½ clear distance to next web = 6’/2 = 3’ = 36”.

Beam spacing = 8’ therefore ½ clear distance to next web = (8’(12”/’) – 24”)/2 = 72”/2 = 36”.

Effective flange width = 36” + 24” web + 36” = 96”.

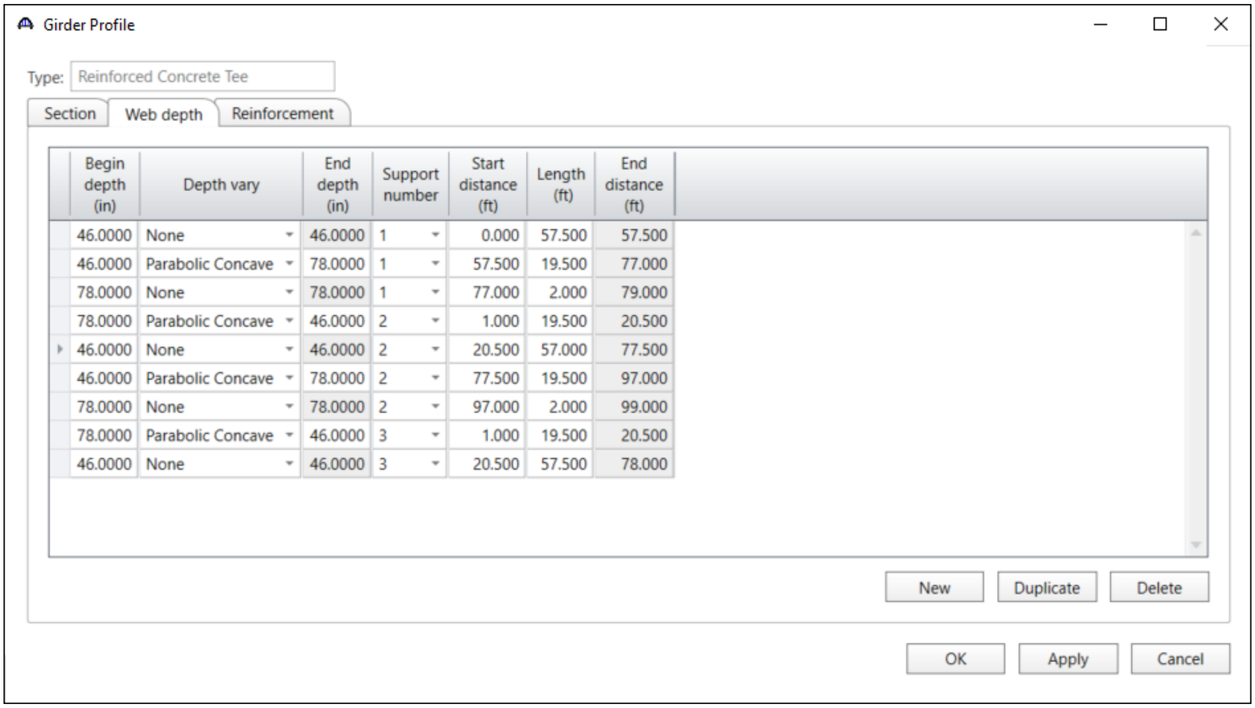
The LRFD effective flange width is computed as follows:

AASHTO LRFD Article 4.6.2.6.1:

For interior beams, effective flange width taken as the least of:

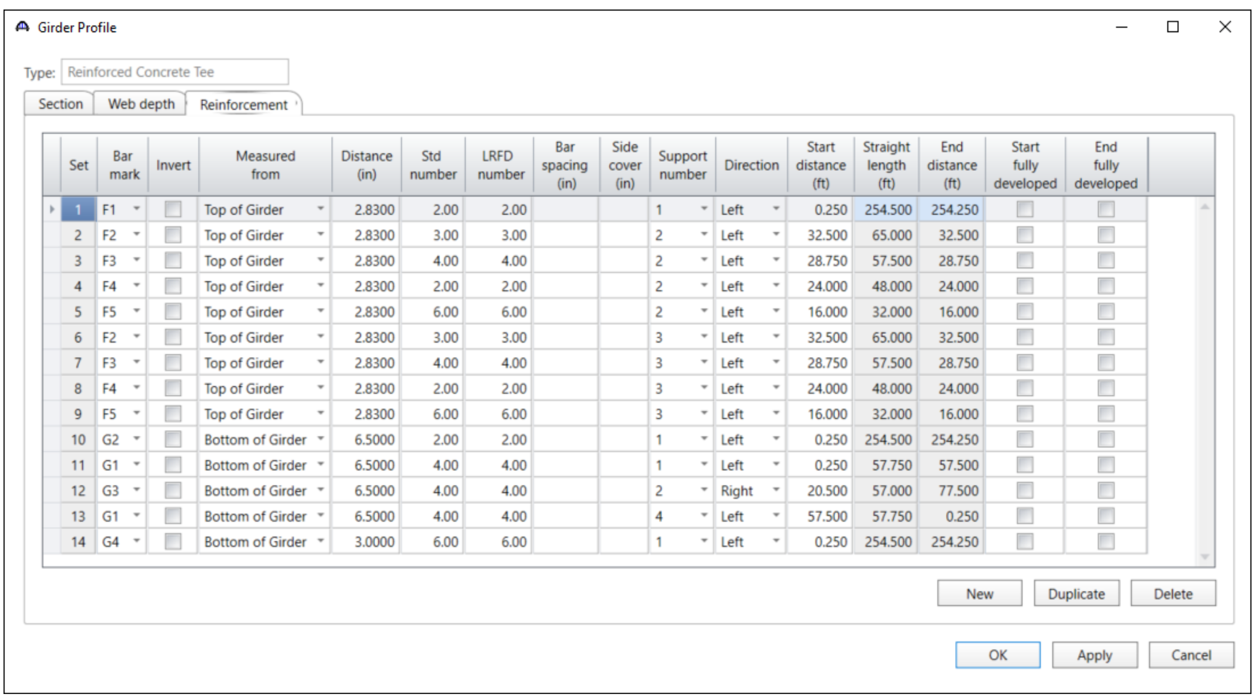
average spacing of adjacent beams = 8’(12”/’) = 96”

Girder Profile - Web



Begin depth (in)	Depth vary	End depth (in)	Support number	Start distance (ft)	Length (ft)	End distance (ft)
46.0000	None	46.0000	1	0.000	57.500	57.500
46.0000	Parabolic Concave	78.0000	1	57.500	19.500	77.000
78.0000	None	78.0000	1	77.000	2.000	79.000
78.0000	Parabolic Concave	46.0000	2	1.000	19.500	20.500
46.0000	None	46.0000	2	20.500	57.000	77.500
46.0000	Parabolic Concave	78.0000	2	77.500	19.500	97.000
78.0000	None	78.0000	2	97.000	2.000	99.000
78.0000	Parabolic Concave	46.0000	3	1.000	19.500	20.500
46.0000	None	46.0000	3	20.500	57.500	78.000

Girder Profile - Reinforcement



Set	Bar mark	Invert	Measured from	Distance (in)	Std number	LRFD number	Bar spacing (in)	Side cover (in)	Support number	Direction	Start distance (ft)	Straight length (ft)	End distance (ft)	Start fully developed	End fully developed
1	F1	☐	Top of Girder	2.8300	2.00	2.00			1	Left	0.250	254.500	254.250	☐	☐
2	F2	☐	Top of Girder	2.8300	3.00	3.00			2	Left	32.500	65.000	32.500	☐	☐
3	F3	☐	Top of Girder	2.8300	4.00	4.00			2	Left	28.750	57.500	28.750	☐	☐
4	F4	☐	Top of Girder	2.8300	2.00	2.00			2	Left	24.000	48.000	24.000	☐	☐
5	F5	☐	Top of Girder	2.8300	6.00	6.00			2	Left	16.000	32.000	16.000	☐	☐
6	F2	☐	Top of Girder	2.8300	3.00	3.00			3	Left	32.500	65.000	32.500	☐	☐
7	F3	☐	Top of Girder	2.8300	4.00	4.00			3	Left	28.750	57.500	28.750	☐	☐
8	F4	☐	Top of Girder	2.8300	2.00	2.00			3	Left	24.000	48.000	24.000	☐	☐
9	F5	☐	Top of Girder	2.8300	6.00	6.00			3	Left	16.000	32.000	16.000	☐	☐
10	G2	☐	Bottom of Girder	6.5000	2.00	2.00			1	Left	0.250	254.500	254.250	☐	☐
11	G1	☐	Bottom of Girder	6.5000	4.00	4.00			1	Left	0.250	57.750	57.500	☐	☐
12	G3	☐	Bottom of Girder	6.5000	4.00	4.00			2	Right	20.500	57.000	77.500	☐	☐
13	G1	☐	Bottom of Girder	6.5000	4.00	4.00			4	Left	57.500	57.750	0.250	☐	☐
14	G4	☐	Bottom of Girder	3.0000	6.00	6.00			1	Left	0.250	254.500	254.250	☐	☐

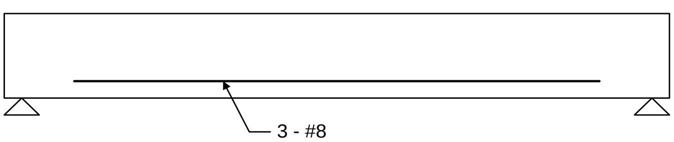
Export of schedule based reinforced concrete beams to an analysis engine

The BrDR **export** to the analysis engine will compute the required development lengths for the reinforcing steel based on the data entered in this window. These required development lengths are considered when the girder profile is exported to the analysis engine. In the export, BrDR transforms the schedule-based definition of the concrete member into a list of cross sections and assigns these cross sections to ranges along the length of the member. Cross sections are **cut** where the reinforcing steel is developed.

BrDR assumes that the user has described the schedule of reinforcement as it physically exists in the bridge. BrDR considers the required development length of the reinforcement when it exports cross sections for use by an analysis engine. If you do not want BrDR to consider the required development length, either the **Start/End fully developed** box for the range of reinforcement on the **Girder Profile: Reinforcement** tab should be checked or the **Fully developed** box on the **Point of Interest: Development** tab needs to be checked. Checking either of these fully developed boxes means that the reinforcement as entered is fully developed and the full length of the bar will be included in the generated cross sections.

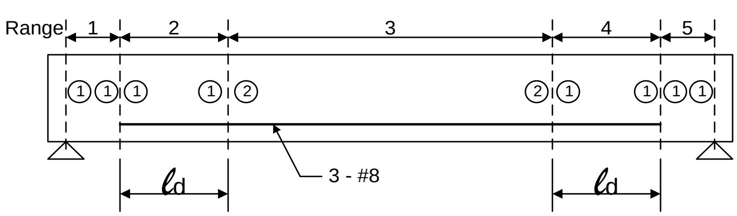
The following simplified example illustrates how cross sections are generated:

The reinforcement profile consists of three #8 bars.



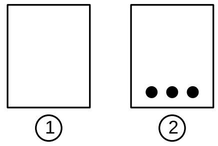
Reinforcement Profile

BrDR computes the development length of the bars as ℓ_d. The bars are fully developed at the ℓ_d distance from the end of the bar.



Exported Cross Section Ranges

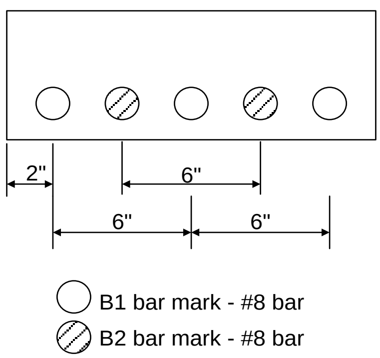
RC5 – Schedule Based Tee Example

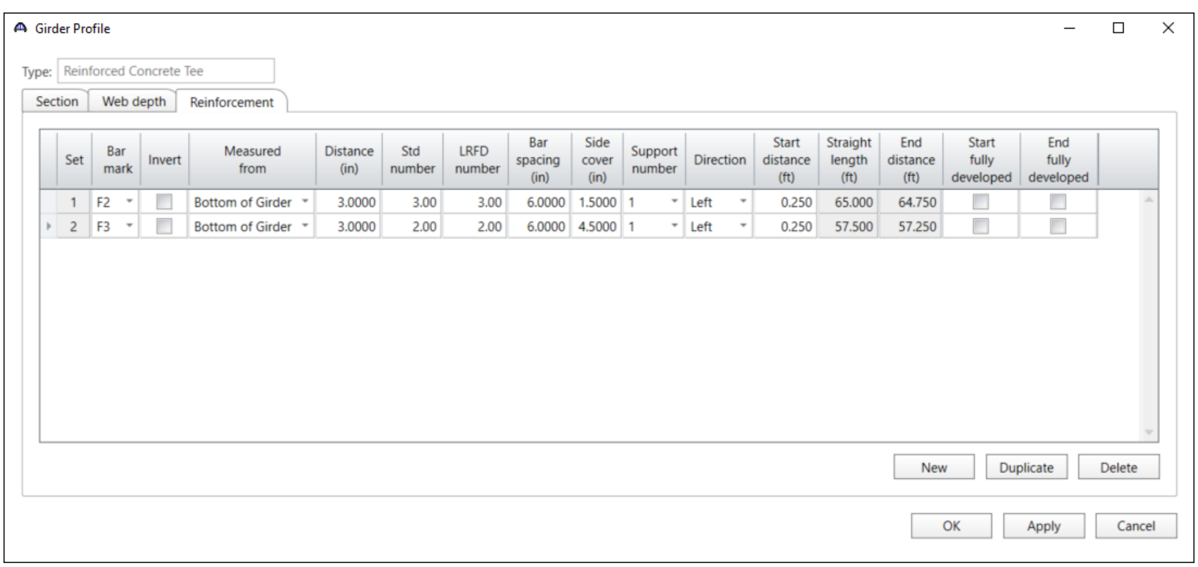


Exported Cross Sections

Two cross sections are generated in this example. Cross Section 1 contains zero rebar. Cross Section 2 contains all three rebars. Cross Section 1 is applied from the end of the beam to the point where the bars become fully developed. Cross Section 2 is applied over the length where the bars are fully developed.

In this example the Bar Spacing or Side Cover values are not entered, as illustrated by the blank cells in the Reinforcement window shown previously. Since these values were not entered, BrDR will not consider the AASHTO specifications that deal with development length modification factors related to these items. It is important to keep in mind that if these values were entered, the bar spacing, and side cover will apply to the bars being described in this row of the table not all the bars in that layer of reinforcement. The following example illustrates this:




Girder Profile

Type: Reinforced Concrete Tee

Section | Web depth | Reinforcement

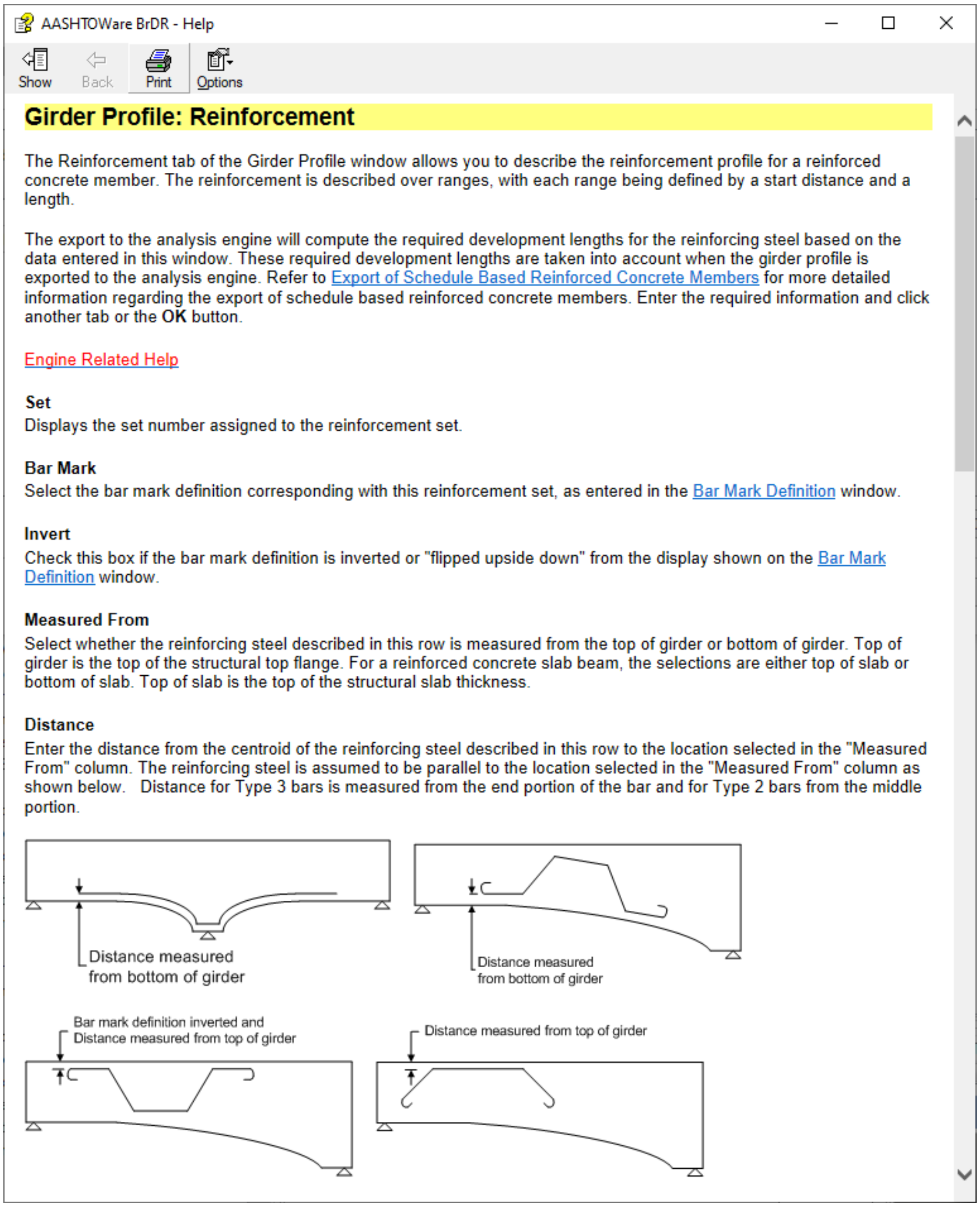
Set	Bar mark	Invert	Measured from	Distance (in)	Std number	LRFD number	Bar spacing (in)	Side cover (in)	Support number	Direction	Start distance (ft)	Straight length (ft)	End distance (ft)	Start fully developed	End fully developed
1	F2		Bottom of Girder	3.0000	3.00	3.00	6.0000	1.5000	1	Left	0.250	65.000	64.750		
2	F3		Bottom of Girder	3.0000	2.00	2.00	6.0000	4.5000	1	Left	0.250	57.500	57.250		

New | Duplicate | Delete

OK | Apply | Cancel

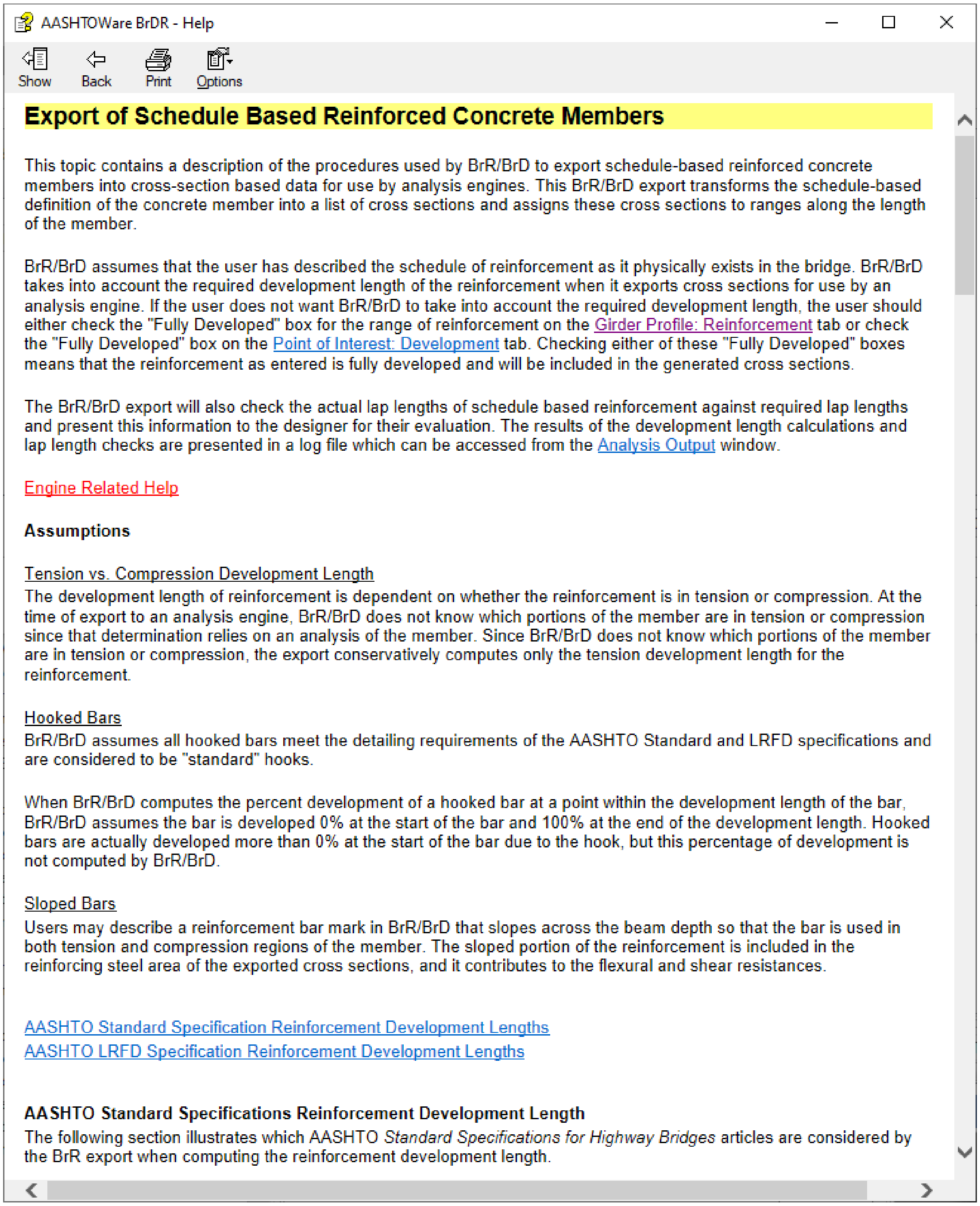
BrDR uses the bar spacing and side cover of all the bars at the same vertical distance to compute the horizontal locations of the bars when determining the modification factors related to bar spacing and side cover.

If we select **F1** while the Reinforcement tab is open, the BrDR help topic for this window will open as shown below. This help topic contains very important information regarding the data on this window and it should be thoroughly reviewed prior to using the schedule based reinforcement features in BrDR.



This help topic contains links to several other useful topics that should be reviewed prior to defining schedule-based reinforcement in BrDR.

The **Export of Schedule Based Reinforced Concrete Members** topic contains the rules and assumptions BrDR uses when exporting schedule based reinforced concrete members to the analysis engine.
This topic also has links to flowcharts which can be referred to determine how BrDR exports the schedule based reinforced concrete members.


AASHTOWare BrDR - Help

Show Back Print Options

Export of Schedule Based Reinforced Concrete Members

This topic contains a description of the procedures used by BrR/BrD to export schedule-based reinforced concrete members into cross-section based data for use by analysis engines. This BrR/BrD export transforms the schedule-based definition of the concrete member into a list of cross sections and assigns these cross sections to ranges along the length of the member.

BrR/BrD assumes that the user has described the schedule of reinforcement as it physically exists in the bridge. BrR/BrD takes into account the required development length of the reinforcement when it exports cross sections for use by an analysis engine. If the user does not want BrR/BrD to take into account the required development length, the user should either check the "Fully Developed" box for the range of reinforcement on the Girder Profile: Reinforcement tab or check the "Fully Developed" box on the Point of Interest: Development tab. Checking either of these "Fully Developed" boxes means that the reinforcement as entered is fully developed and will be included in the generated cross sections.

The BrR/BrD export will also check the actual lap lengths of schedule based reinforcement against required lap lengths and present this information to the designer for their evaluation. The results of the development length calculations and lap length checks are presented in a log file which can be accessed from the Analysis Output window.

Engine Related Help

Assumptions

Tension vs. Compression Development Length
The development length of reinforcement is dependent on whether the reinforcement is in tension or compression. At the time of export to an analysis engine, BrR/BrD does not know which portions of the member are in tension or compression since that determination relies on an analysis of the member. Since BrR/BrD does not know which portions of the member are in tension or compression, the export conservatively computes only the tension development length for the reinforcement.

Hooked Bars
BrR/BrD assumes all hooked bars meet the detailing requirements of the AASHTO Standard and LRFD specifications and are considered to be "standard" hooks.

When BrR/BrD computes the percent development of a hooked bar at a point within the development length of the bar, BrR/BrD assumes the bar is developed 0% at the start of the bar and 100% at the end of the development length. Hooked bars are actually developed more than 0% at the start of the bar due to the hook, but this percentage of development is not computed by BrR/BrD.

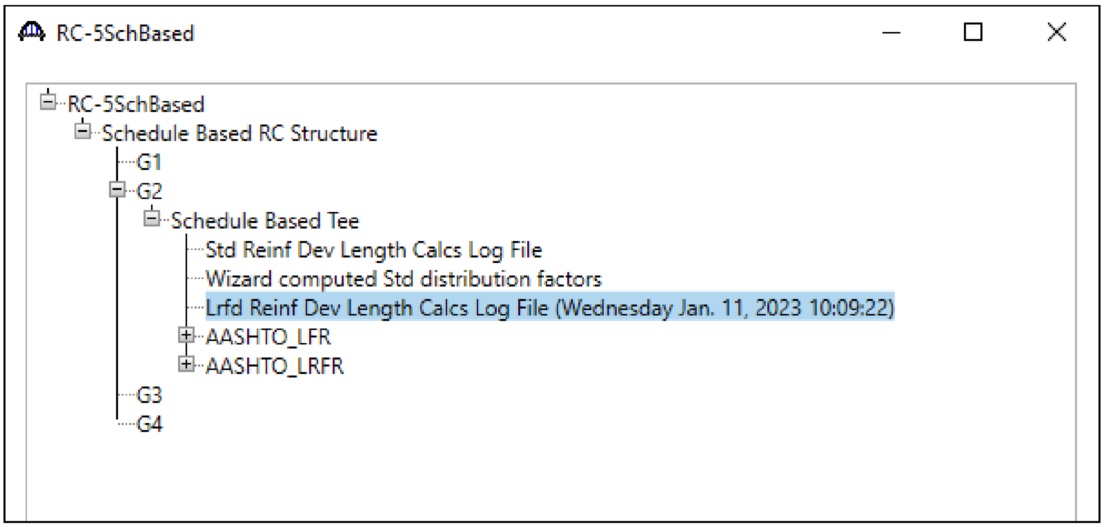
Sloped Bars
Users may describe a reinforcement bar mark in BrR/BrD that slopes across the beam depth so that the bar is used in both tension and compression regions of the member. The sloped portion of the reinforcement is included in the reinforcing steel area of the exported cross sections, and it contributes to the flexural and shear resistances.

AASHTO Standard Specification Reinforcement Development Lengths
AASHTO LRFD Specification Reinforcement Development Lengths

AASHTO Standard Specifications Reinforcement Development Length
The following section illustrates which AASHTO *Standard Specifications for Highway Bridges* articles are considered by the BrR export when computing the reinforcement development length.

The BrDR export to the analysis engine will also check the actual lap lengths of schedule based reinforcement against required lap lengths and provide this information to the user for evaluation. BrDR considers bars to be lapped if the vertical distance to their centroids is equal or if their clear cover is equal and the bars overlap along the length of the member.

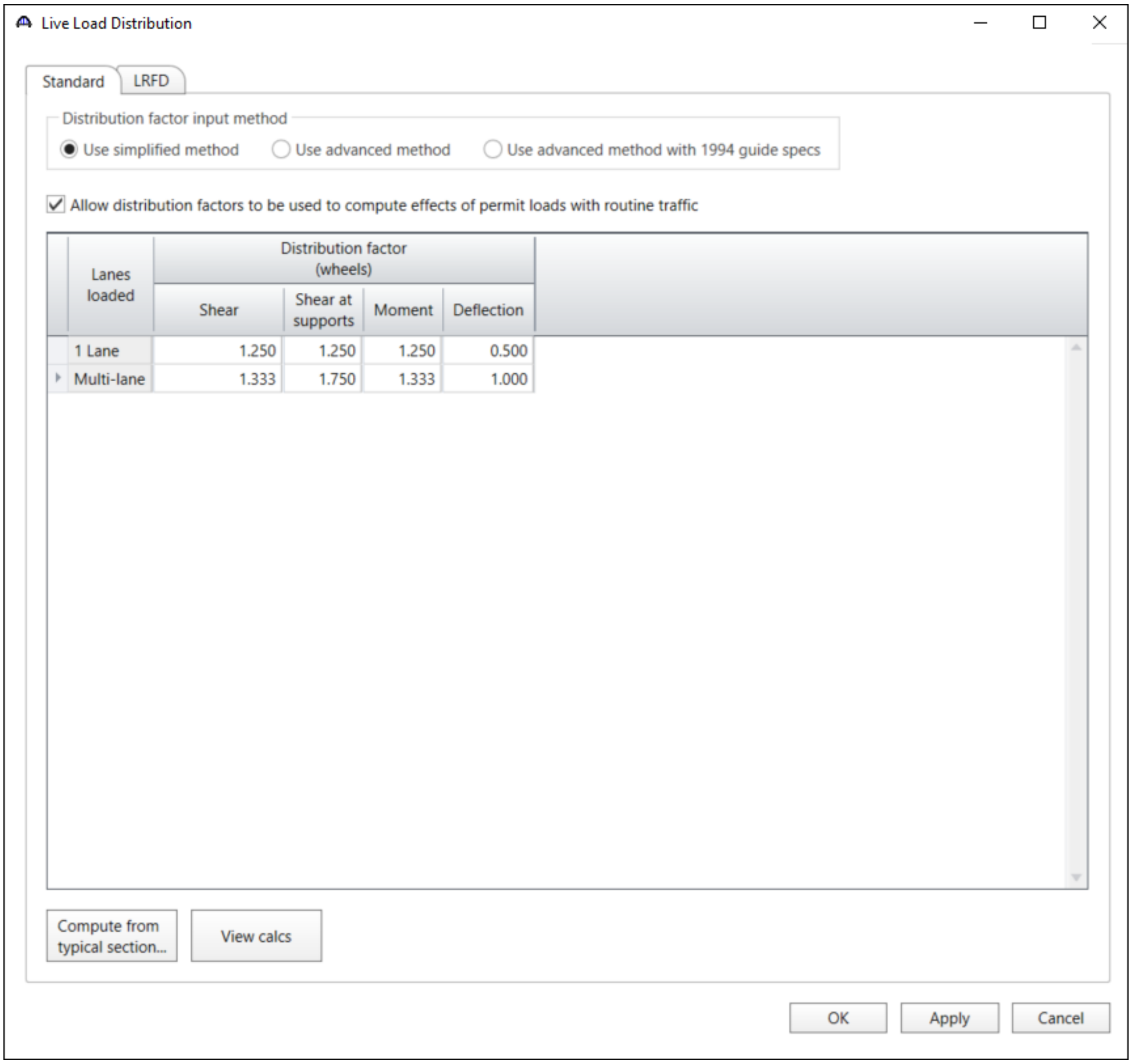
When an analysis or design review is run, a file is created that contains the input and output of the calculations BrDR performed to compute the required development lengths and to check the lap lengths. This file can be accessed from the **Engine Outputs** button from the **Results** group of the **DESIGN/RATE** ribbon.



Live Load Distribution factors

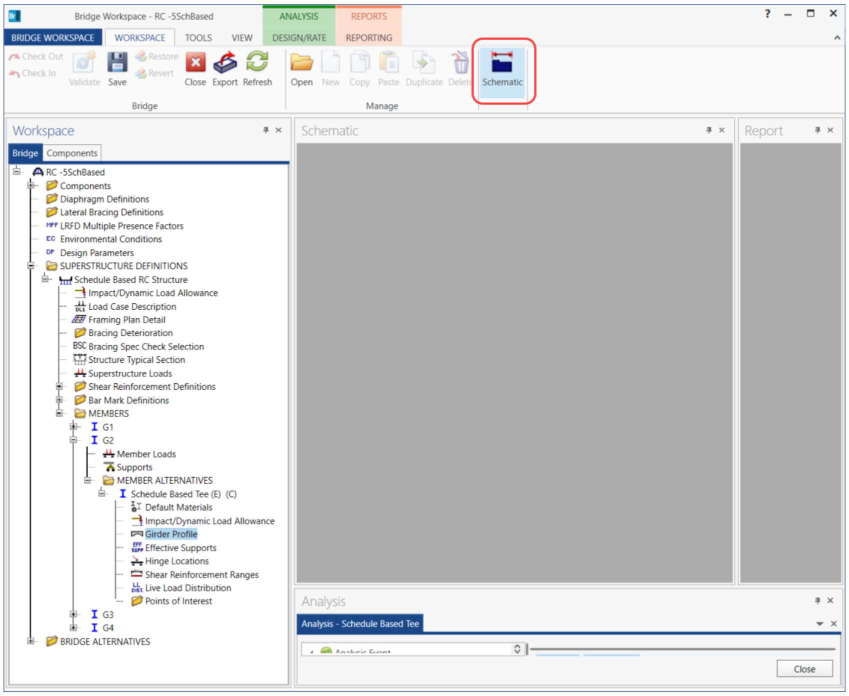
Open the **Live Load Distribution** window from the **Bridge Workspace** tree to open the **Live Load Distribution** window.

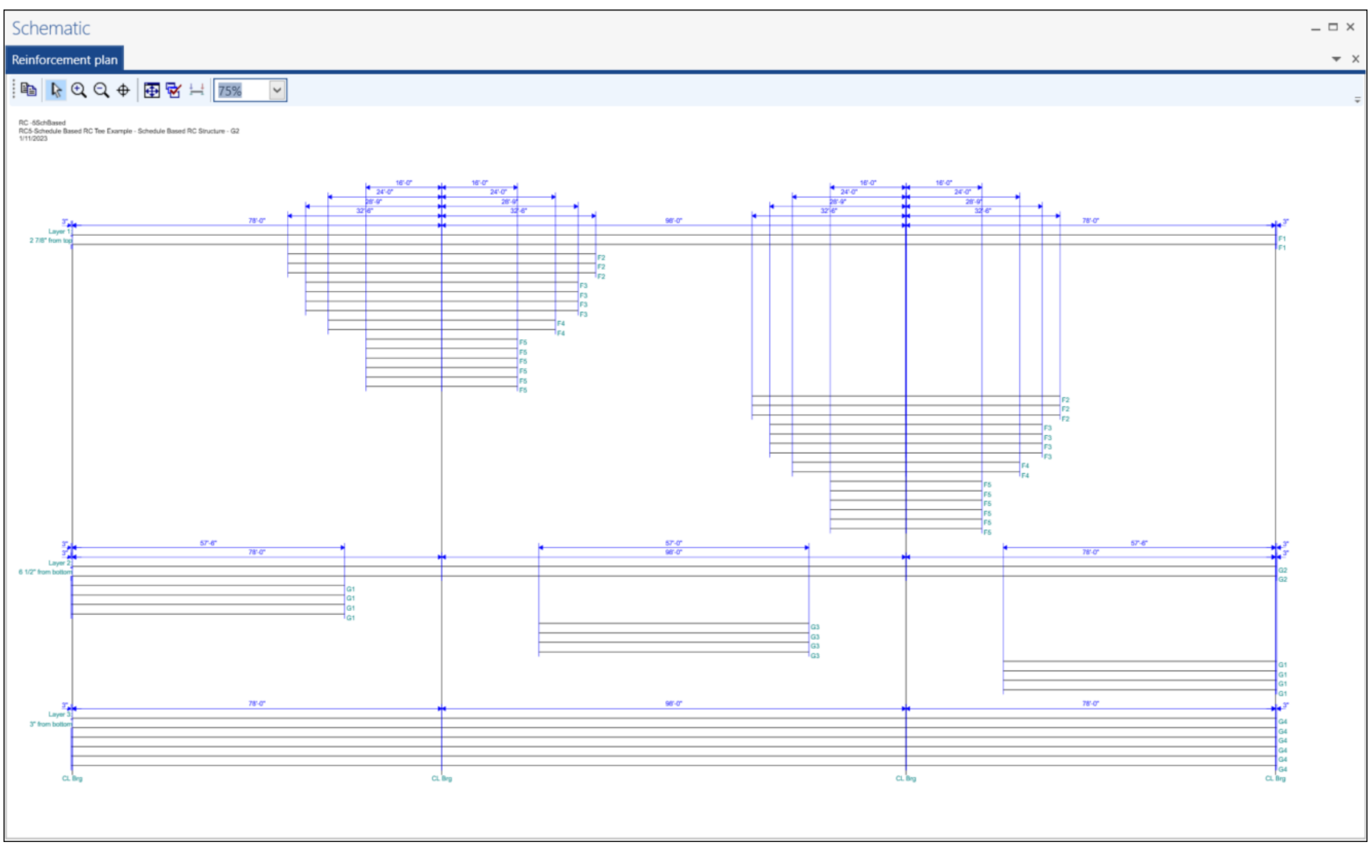
Click the **Compute from Typical Section…** button to compute the live load distribution factors for this member. The completed **Live Load Distribution** window is shown below.



Girder Profile - Schematic

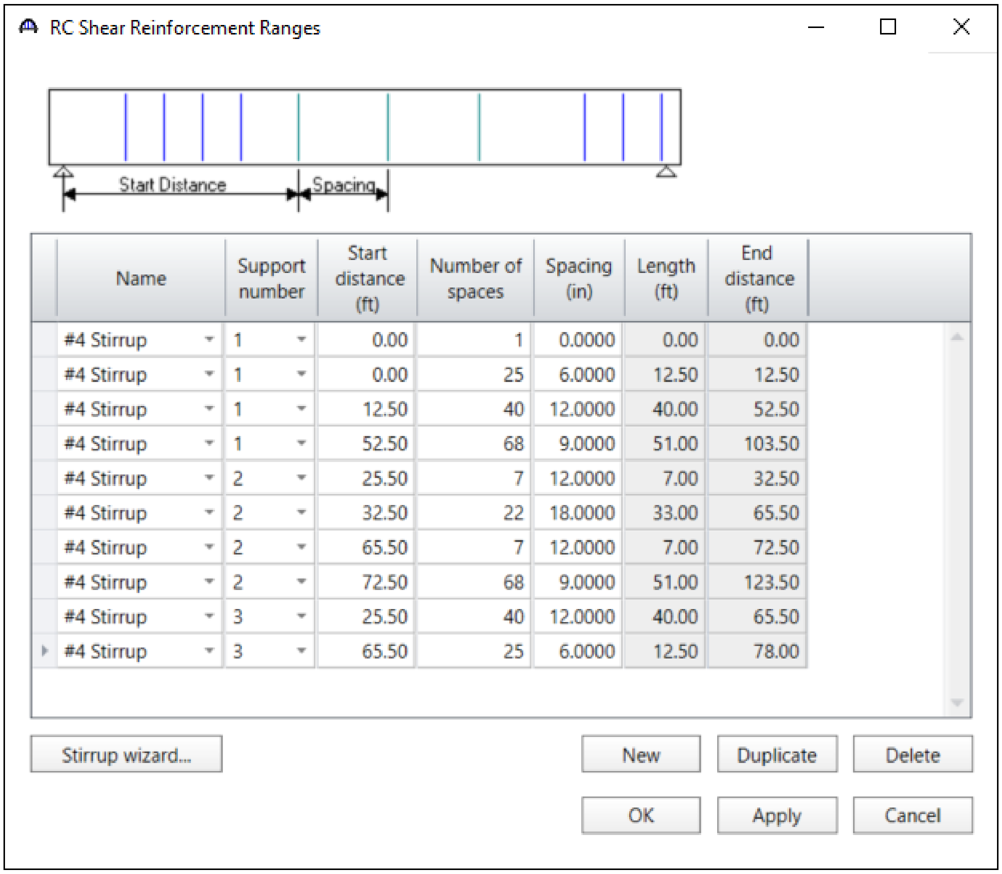
A **schematic** view of the reinforcement profile is available while the **Girder Profile** label is selected on the Bridge Workspace tree. See below.





Shear Reinforcement Ranges

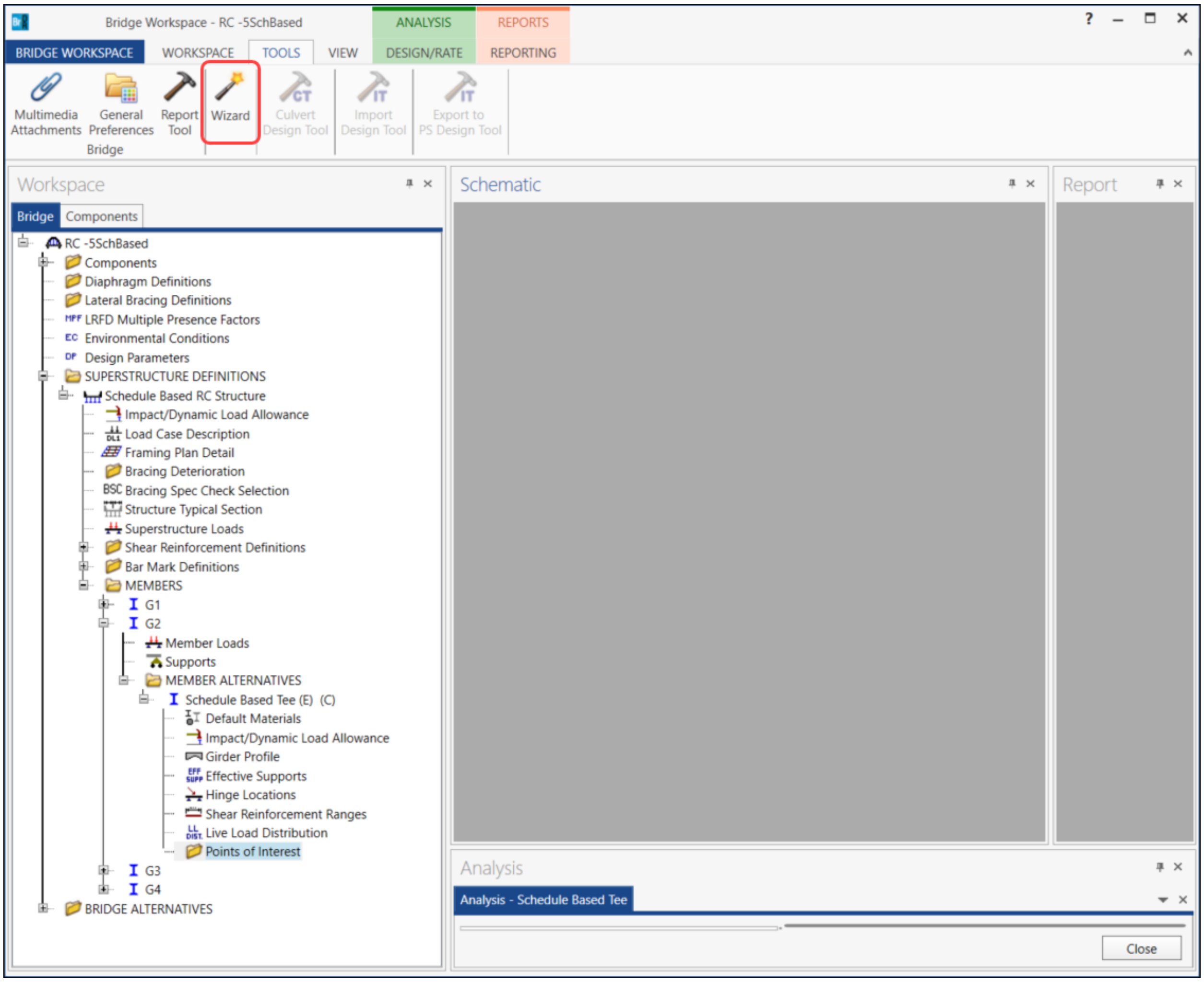
Double-click on **Shear Reinforcement Ranges** in the Bridge Workspace tree to open the RC Shear Reinforcement Ranges window and enter values as shown below.



Name	Support number	Start distance (ft)	Number of spaces	Spacing (in)	Length (ft)	End distance (ft)
#4 Stirrup	1	0.00	1	0.0000	0.00	0.00
#4 Stirrup	1	0.00	25	6.0000	12.50	12.50
#4 Stirrup	1	12.50	40	12.0000	40.00	52.50
#4 Stirrup	1	52.50	68	9.0000	51.00	103.50
#4 Stirrup	2	25.50	7	12.0000	7.00	32.50
#4 Stirrup	2	32.50	22	18.0000	33.00	65.50
#4 Stirrup	2	65.50	7	12.0000	7.00	72.50
#4 Stirrup	2	72.50	68	9.0000	51.00	123.50
#4 Stirrup	3	25.50	40	12.0000	40.00	65.50
#4 Stirrup	3	65.50	25	6.0000	12.50	78.00

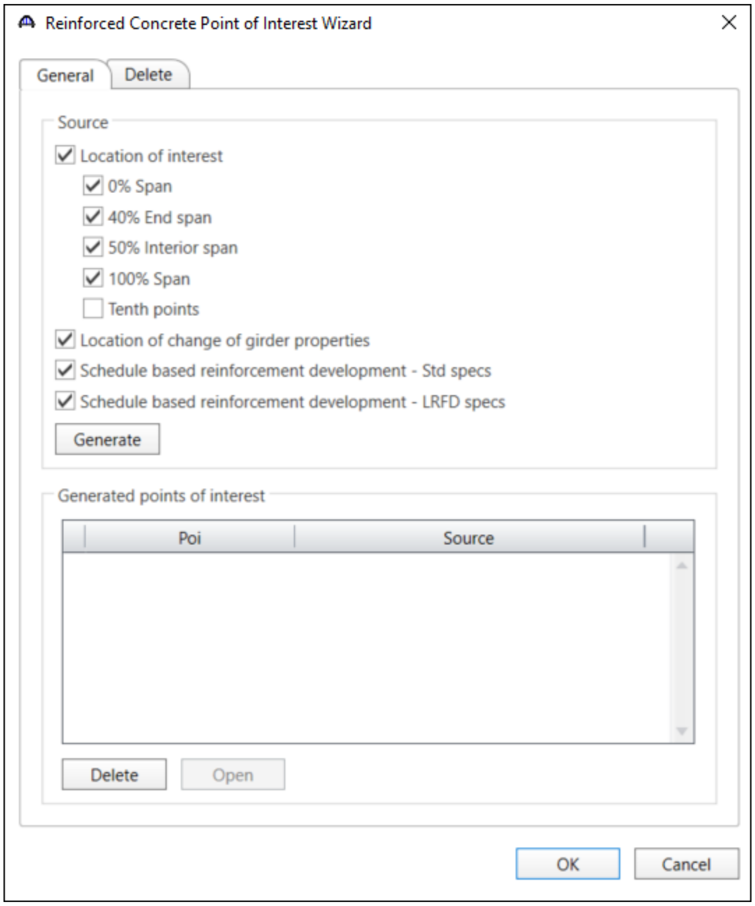
Schedule based reinforced concrete Point of Interest wizard

Schedule based reinforced concrete members have a wizard to help create points of interest for a member. The wizard can be accessed by selecting **Points of Interest** in the Bridge Workspace tree and clicking the **Wizard** button on the **Tools** ribbon as shown below:



RC5 – Schedule Based Tee Example

This wizard helps to quickly create points of interest based on criteria that is selected in the wizard. Select options as shown in the window below and click **Generate.**



If the user selects to use the reinforcement development source type, by checking any of the options under the **Source** section of this window, BrDR creates 6 points of interest for each reinforcement profile entered in the **Girder Profile** window. As detailed in the help, these 6 points are:

1 - Physical start of bar

2 - Point to determine where bar is no longer required to resist flexure, max of (effective depth of member, 15db, 1/20 clear span) from start of bar

3 - Point where bar is 100% developed at the start of bar

4 - Point where bar is 100% developed at the end of bar

5 - Point to determine where bar is no longer required to resist flexure, max of (effective depth of member, 15db, 1/20 clear span) from end of bar

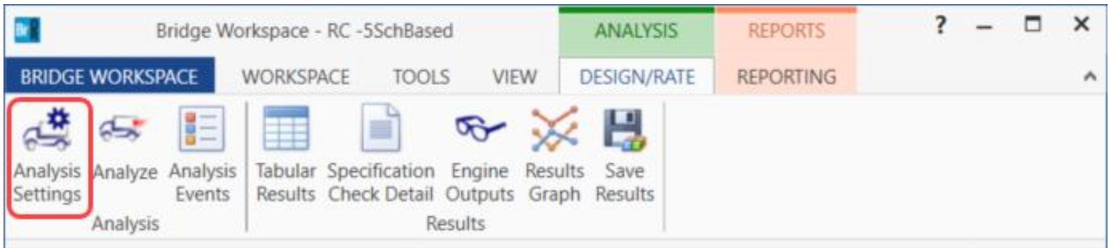
6 - Physical end of bar

If more than one point of interest is generated at a location, then the wizard will delete duplicate points of interest when the **OK** button is selected.

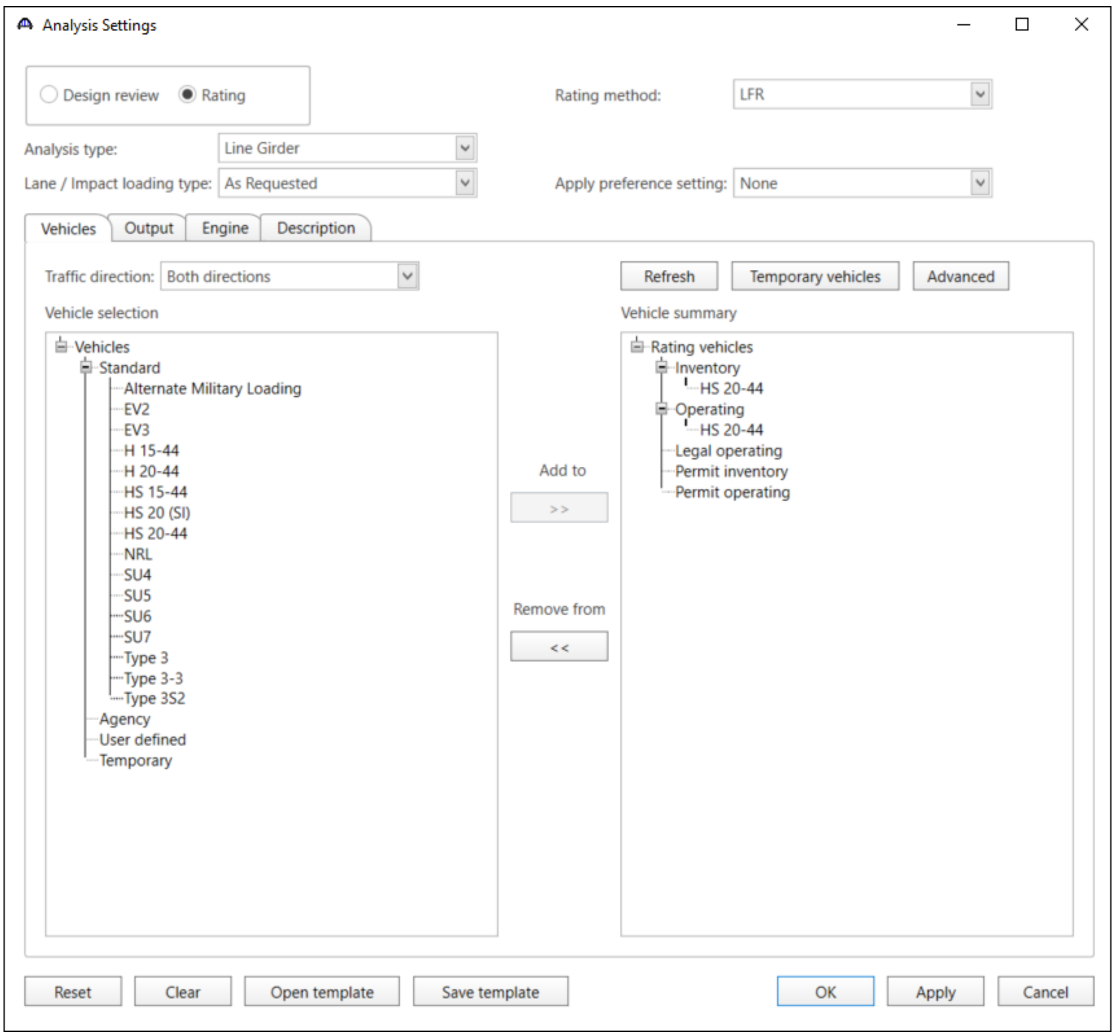
The member alternative can now be analyzed.

LFR Analysis

To perform an **LFR** rating, select the **Analysis Settings** button from the **Analysis** group of the **DESIGN/RATE** ribbon to open the **Analysis Settings** window as shown below.

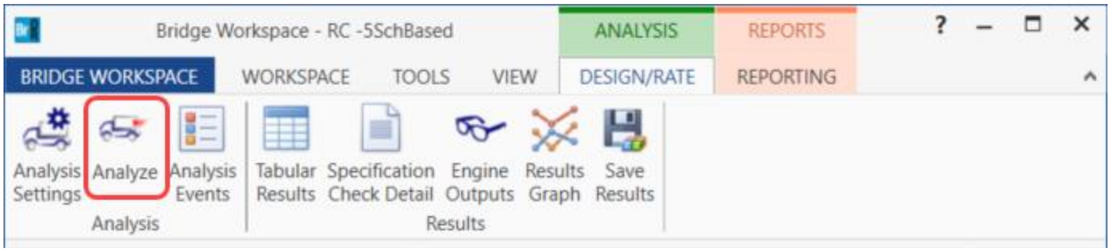


Select the vehicles to be used in the rating as shown below and click **OK**.

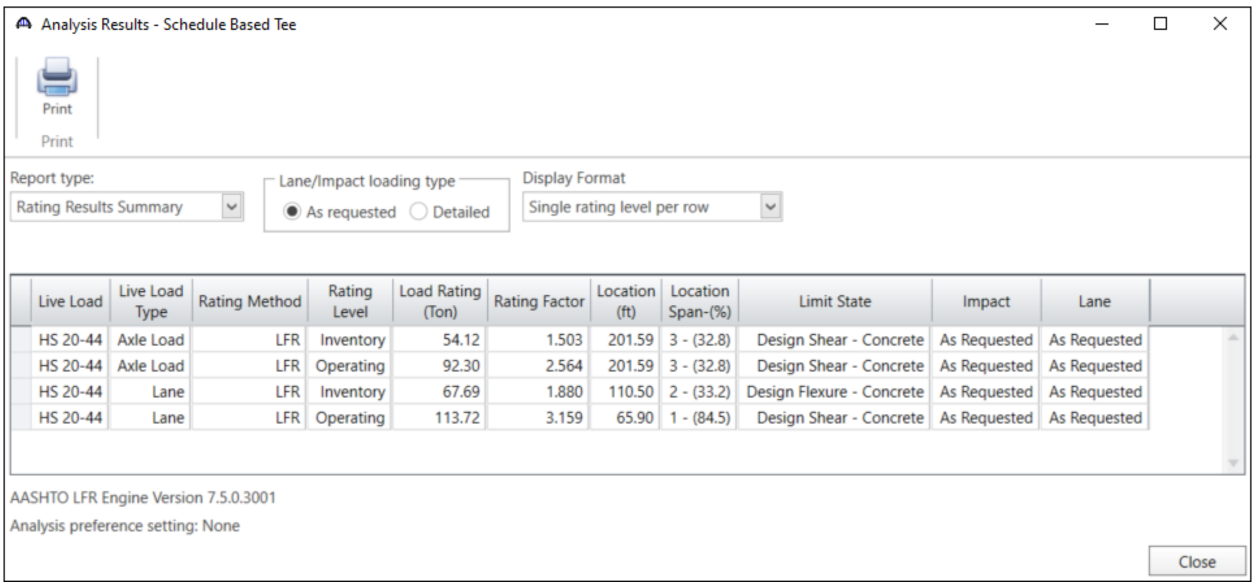


Tabular Results

Next click the **Analyze** button from the **Analysis** group of the **DESIGN/RATE** 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 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	54.12	1.503	201.59	3 - (32.8)	Design Shear - Concrete	As Requested	As Requested
HS 20-44	Axle Load	LFR	Operating	92.30	2.564	201.59	3 - (32.8)	Design Shear - Concrete	As Requested	As Requested
HS 20-44	Lane	LFR	Inventory	67.69	1.880	110.50	2 - (33.2)	Design Flexure - Concrete	As Requested	As Requested
HS 20-44	Lane	LFR	Operating	113.72	3.159	65.90	1 - (84.5)	Design Shear - Concrete	As Requested	As Requested