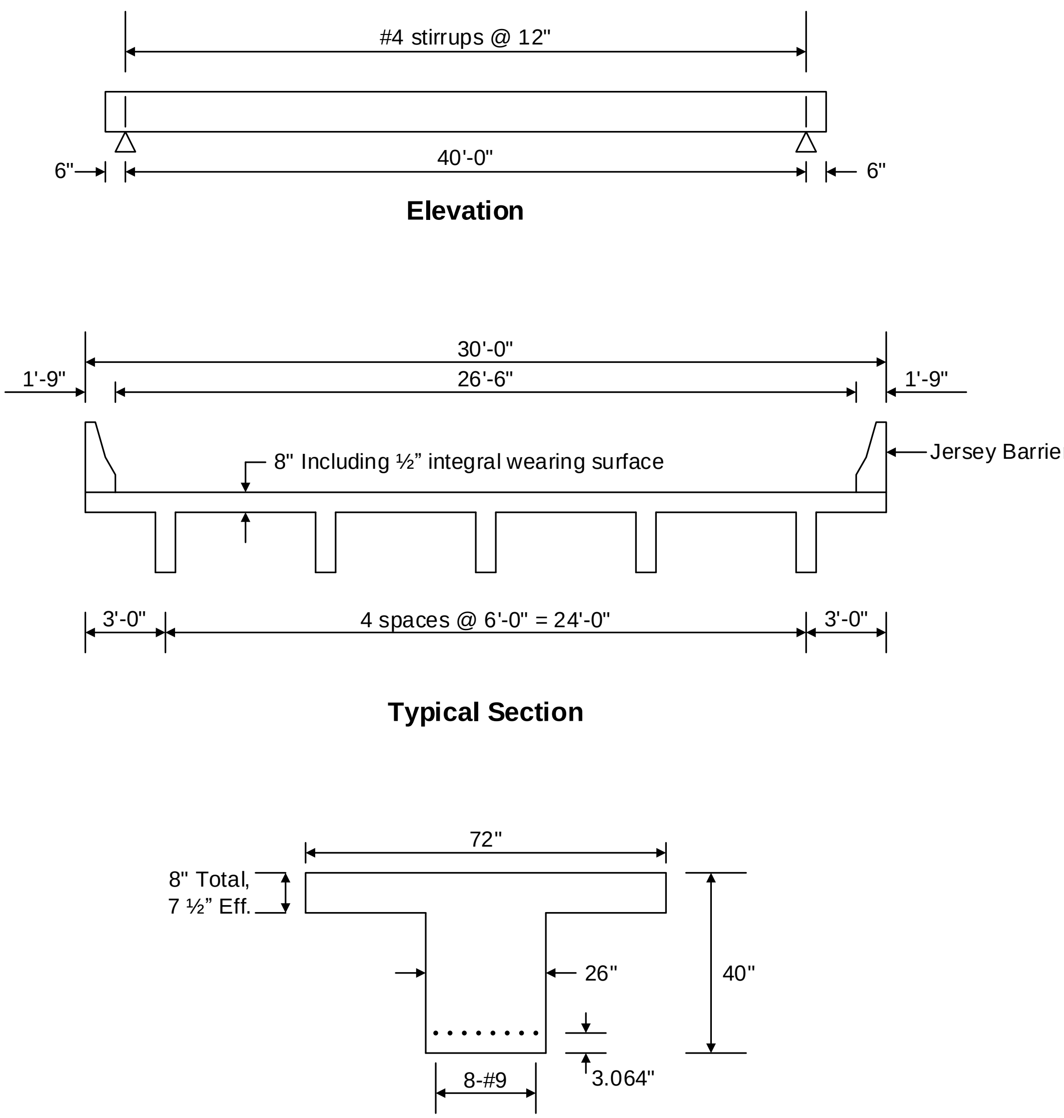
AASHTOWare BrDR 7.5.0

Reinforced Concrete Structure Tutorial

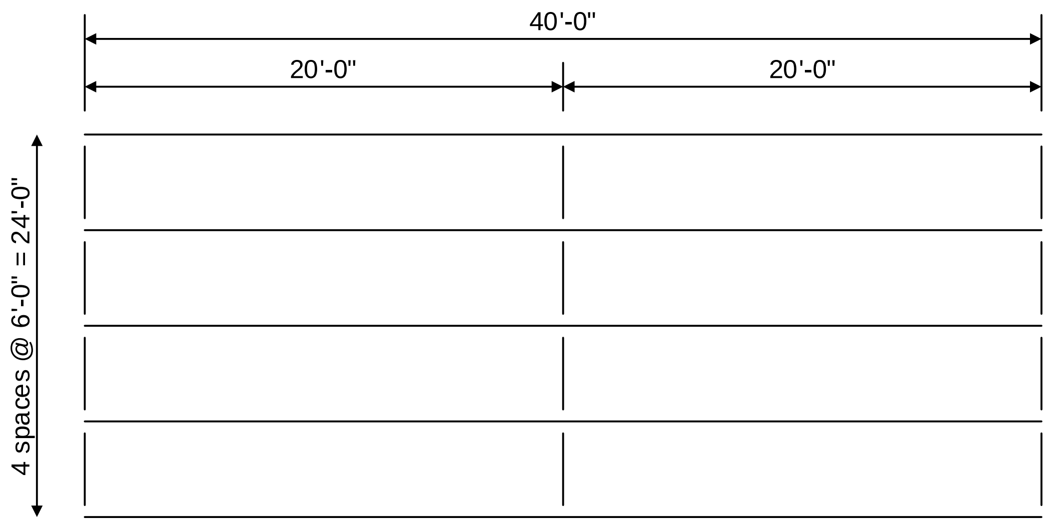
RC8 – Reinforced Concrete Tee Beam Using BrDR LRFD Engine

Introduction – Elevation and Section

RC6 – Reinforced Concrete Tee Beam Using BrDR AASHTO LRFD Engine



Framing Plan and Material Properties



Framing Plan

Diaphragm weight = 1.2 kips/.each

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

BrDR Training

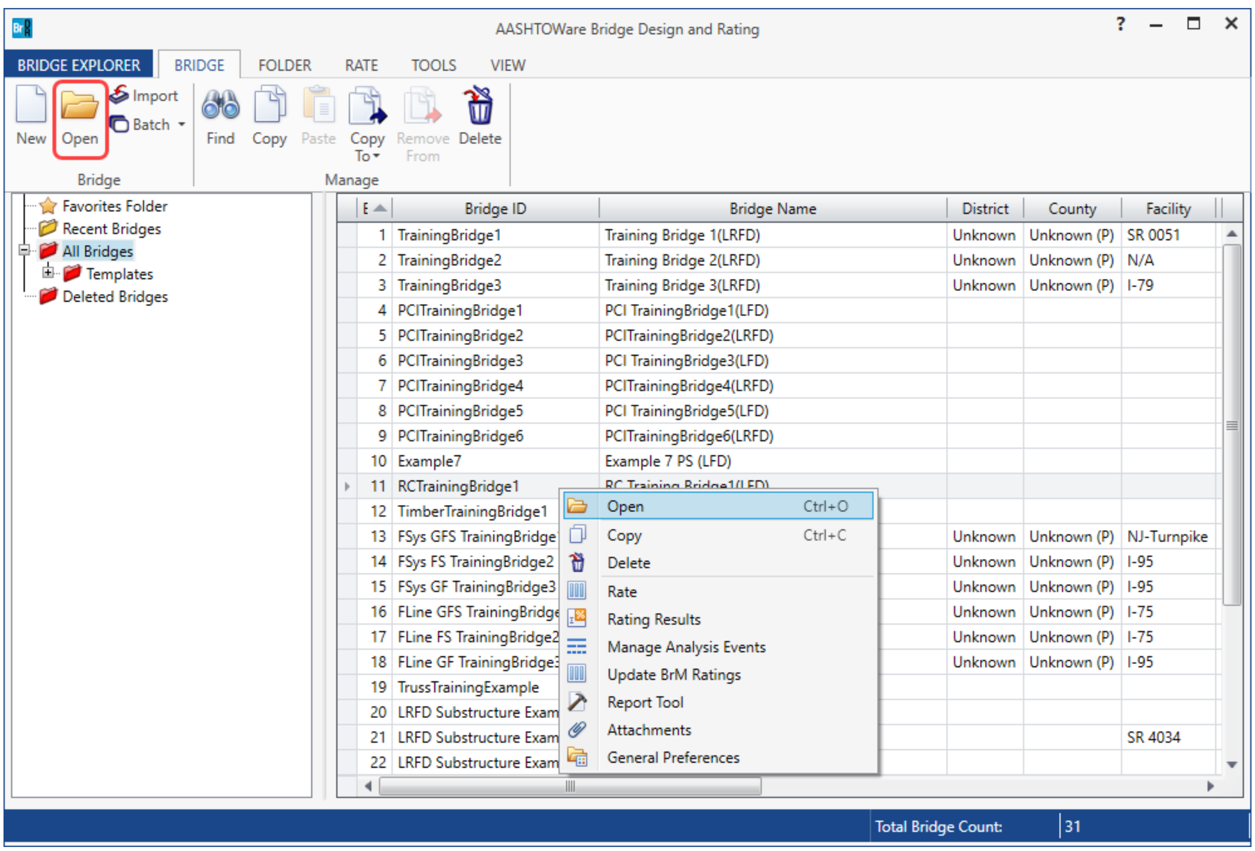
RC6 - Reinforced Concrete Tee Beam Using BrDR LRFD Engine

Topics Covered

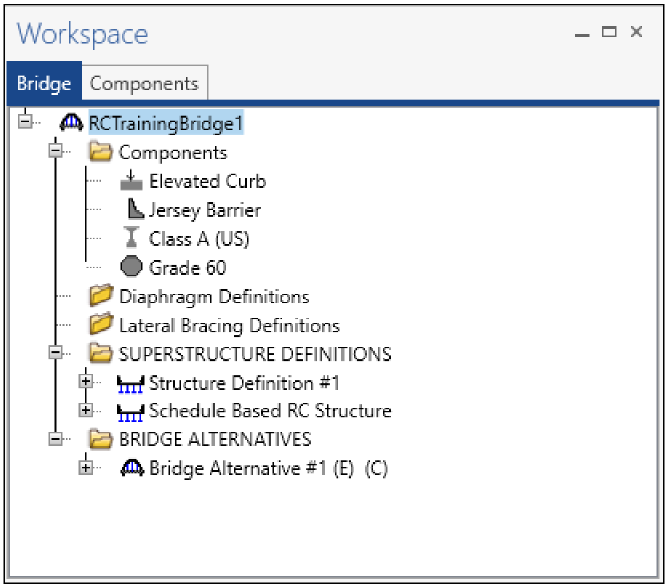
- Reinforced concrete schedule based tee input as girder system.
- Export of schedule based reinforced concrete beams to the BrDR LRFD analysis engine
- BrDR LRFD specification checking

Reinforced concrete schedule based tee input as girder system.

Open the **Bridge Workspace** for **BID 11, RCTrainingBridge1** from the **BRIDGE EXPLORER** by selecting the bridge in the **BRIDGE EXPLORER** and clicking the **Open** button from the **Bridge** group of the ribbon (or by right clicking the bridge and selecting **Open** from the drop-down menu) as shown below.

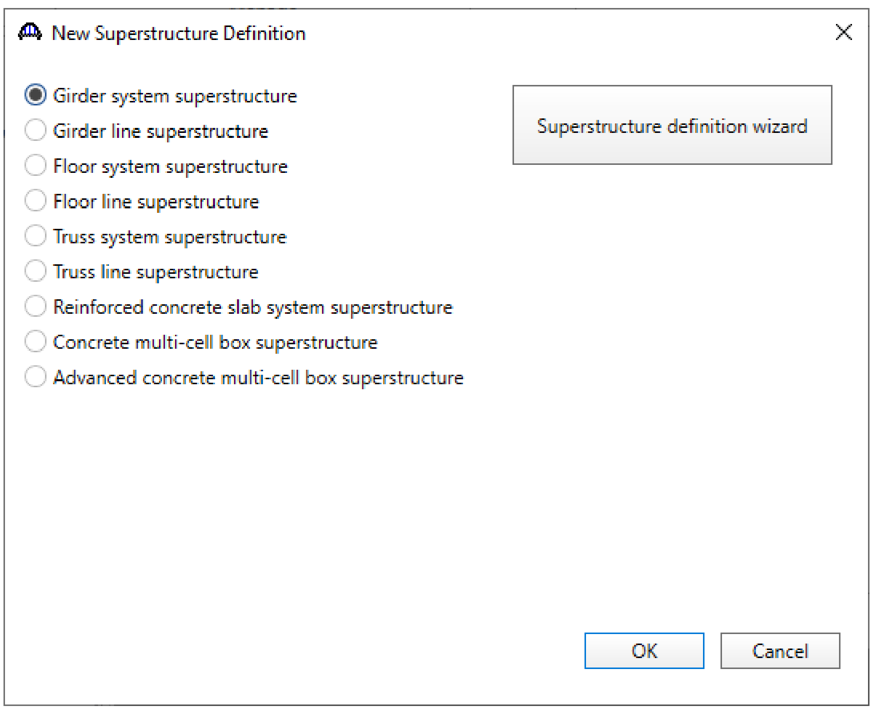


The **Bridge Workspace** is shown below.

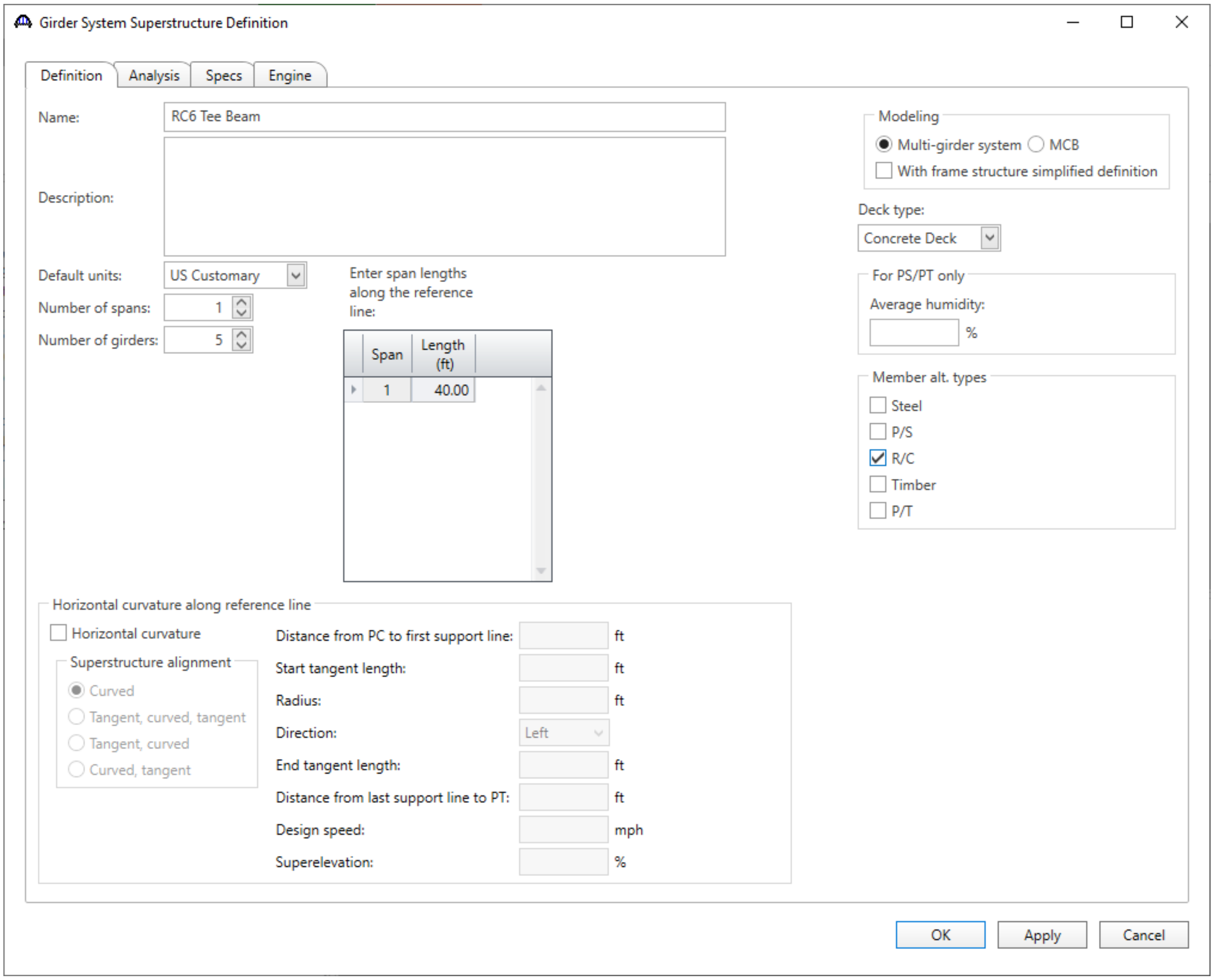


SUPERSTRUCTURE DEFINITION

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.



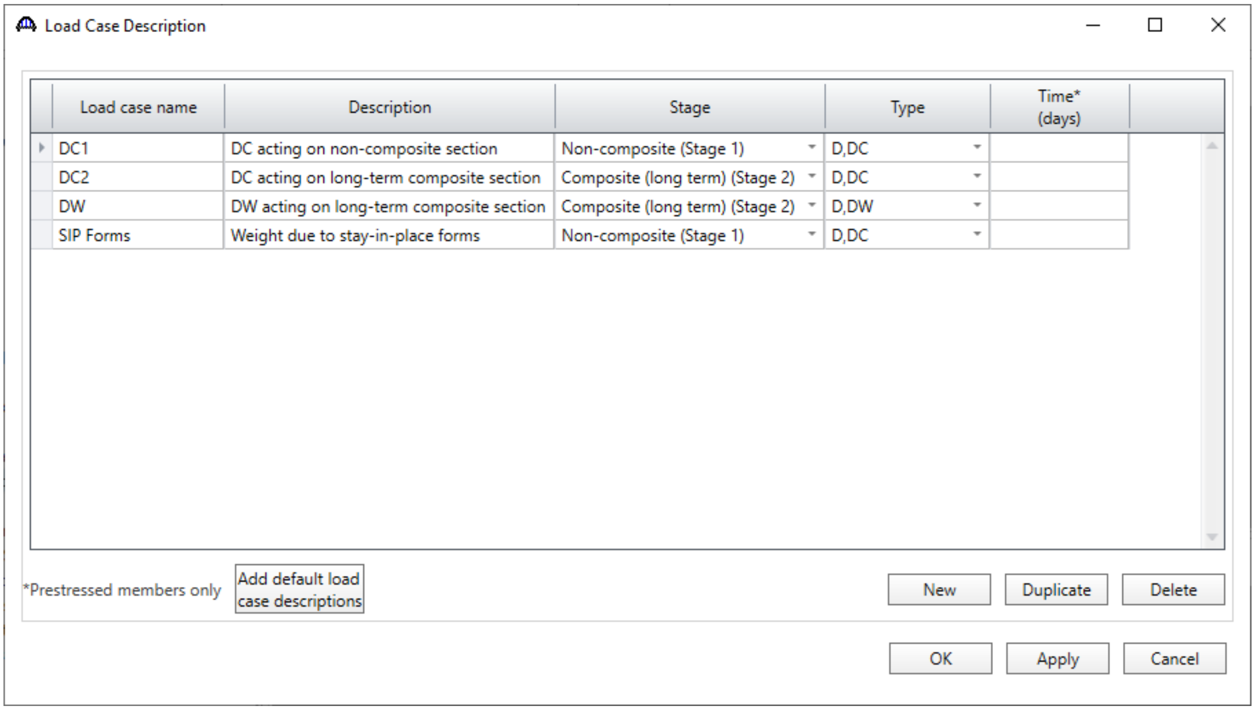
Select the **Girder system superstructure** and click **OK** to open the **Girder System Superstructure Definition** window. Enter the data as shown below.



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

Load Case Description

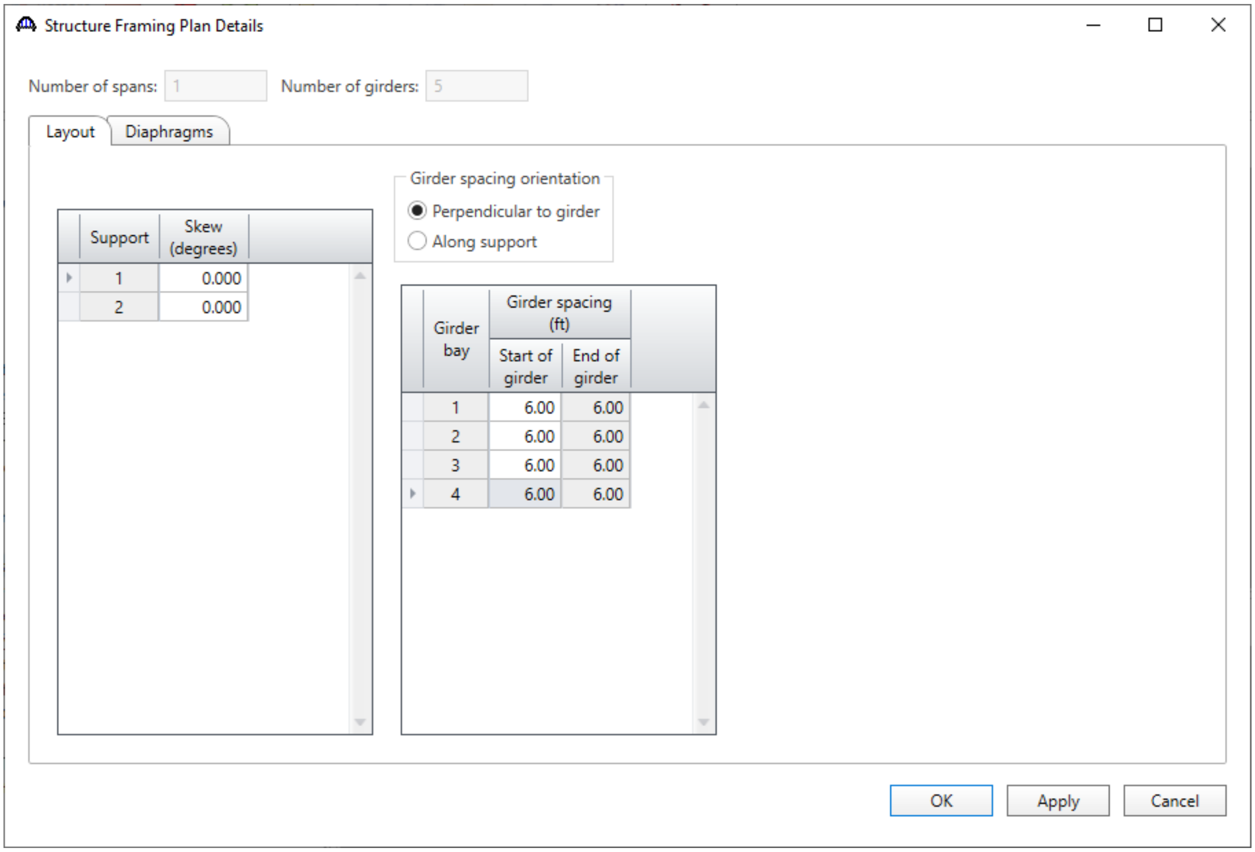
Expand the tree for **RC6 Tee Beam** superstructure and double click on the **Load Case Description** node in the **Bridge Workspace** tree to open the **Load Case Description** window and define the dead load cases. Use the **Add Default Load Case Descriptions** button to create the following load cases. The completed **Load Case Description** window is shown below.



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

Structure Framing Plan Detail - Layout

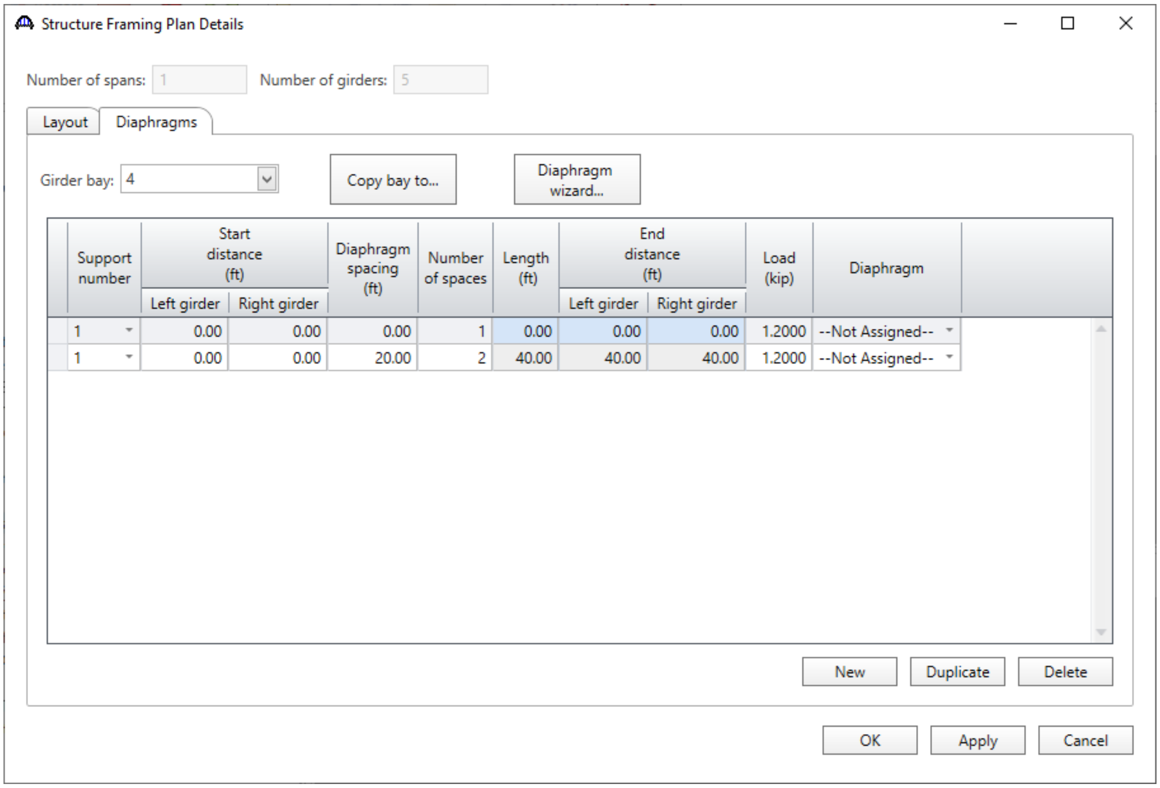
Double-click on **Framing Plan Detail** in the **Bridge Workspace** tree to describe the framing plan in the **Structure Framing Plan Details** window. Enter the data as shown below.



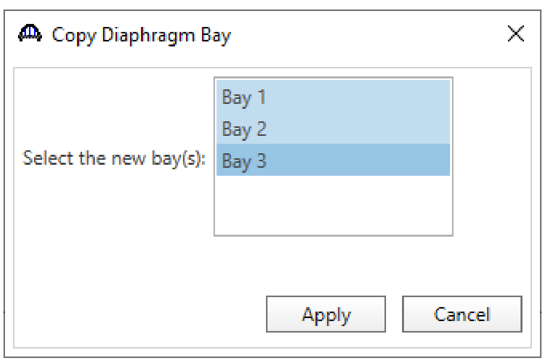
Click **OK** to apply the data and close the window.

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 diaphragm locations to bays 2 to 4.



Click on the **Copy bay to…** button. The **Copy Diaphragm Bay** window opens as shown below.

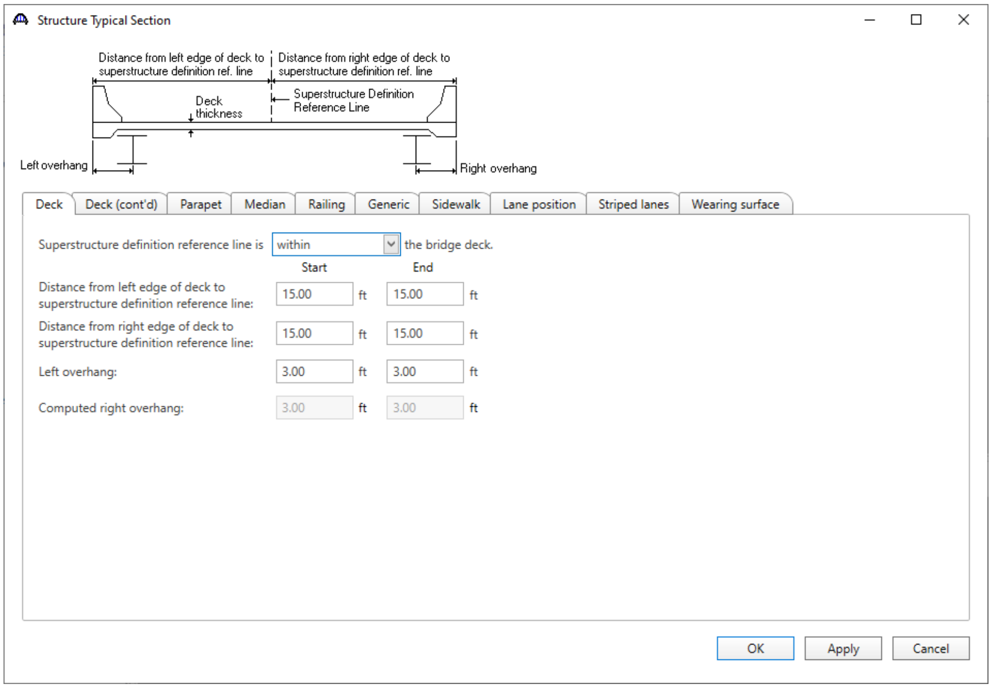


Select **Bay 2**, **Bay 3** and **Bay 4** and click **Apply** to copy the diaphragm locations to bays 2 to 4.

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

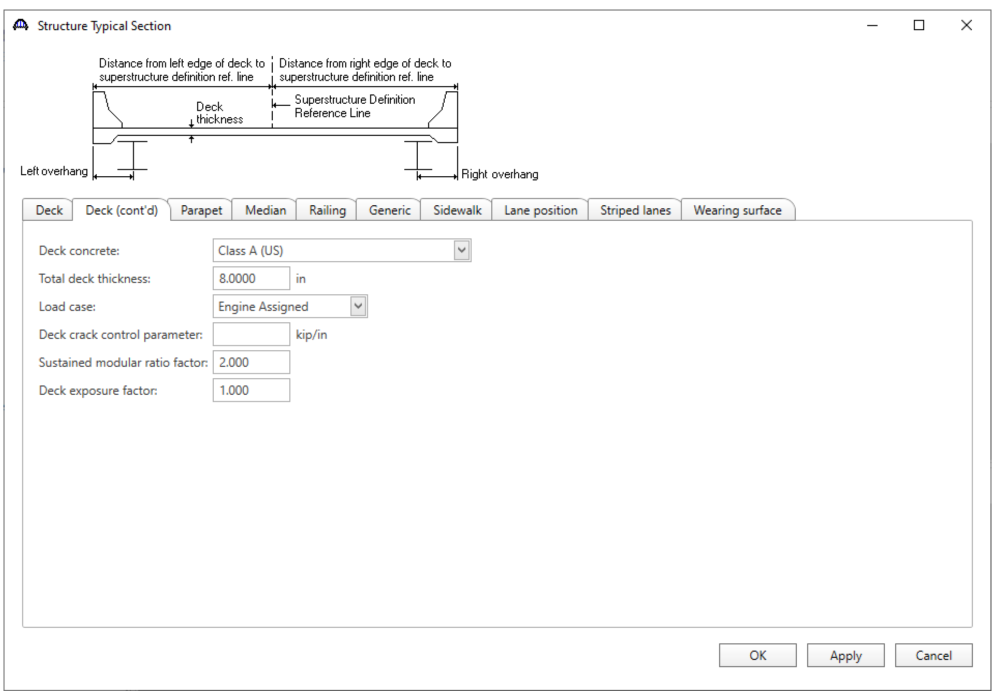
Structure Typical Section - Deck

Next 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)

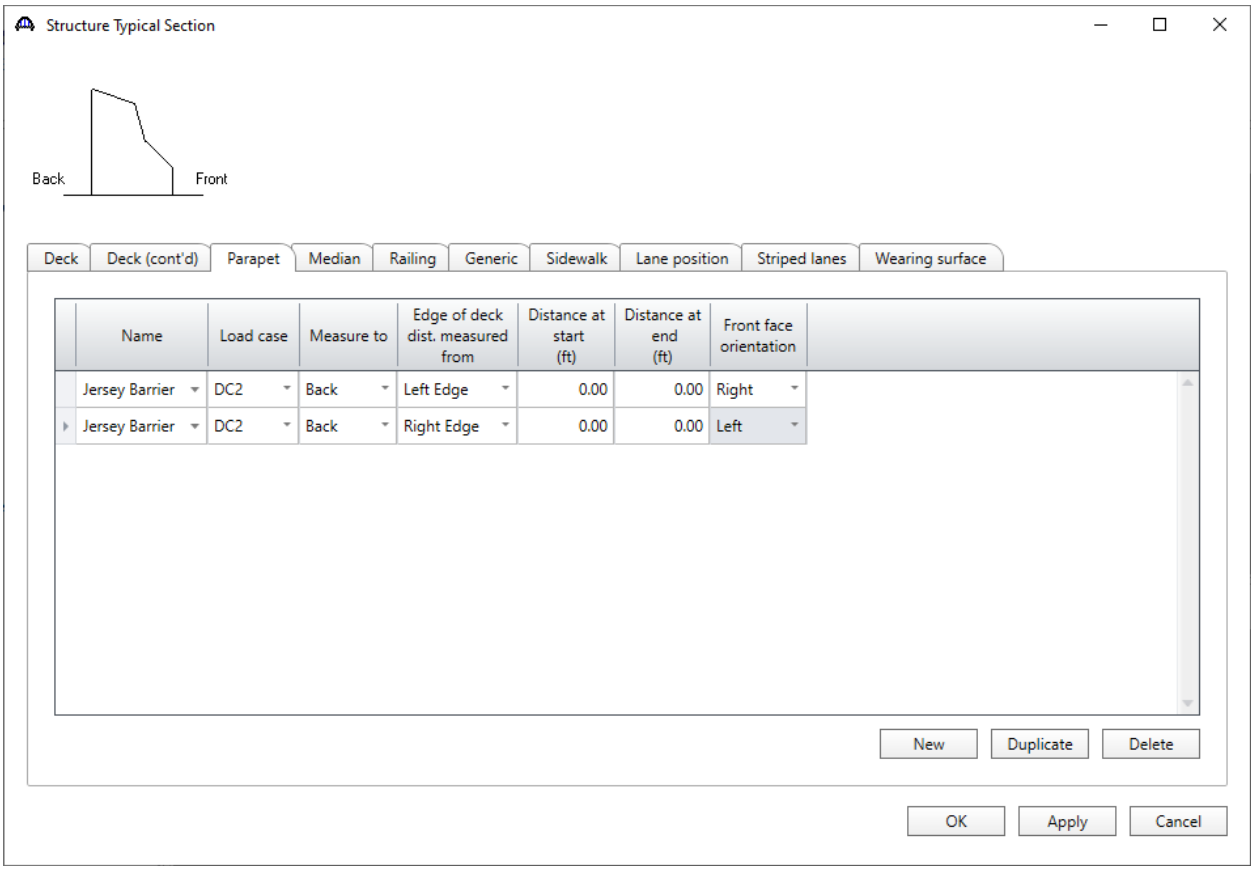
The **Deck (cont'd)** tab is used to enter information about the deck concrete and thickness. The material to be used for the deck concrete is selected from the list of bridge materials described previously. Enter data as shown below.



Structure Typical Section - Parapets

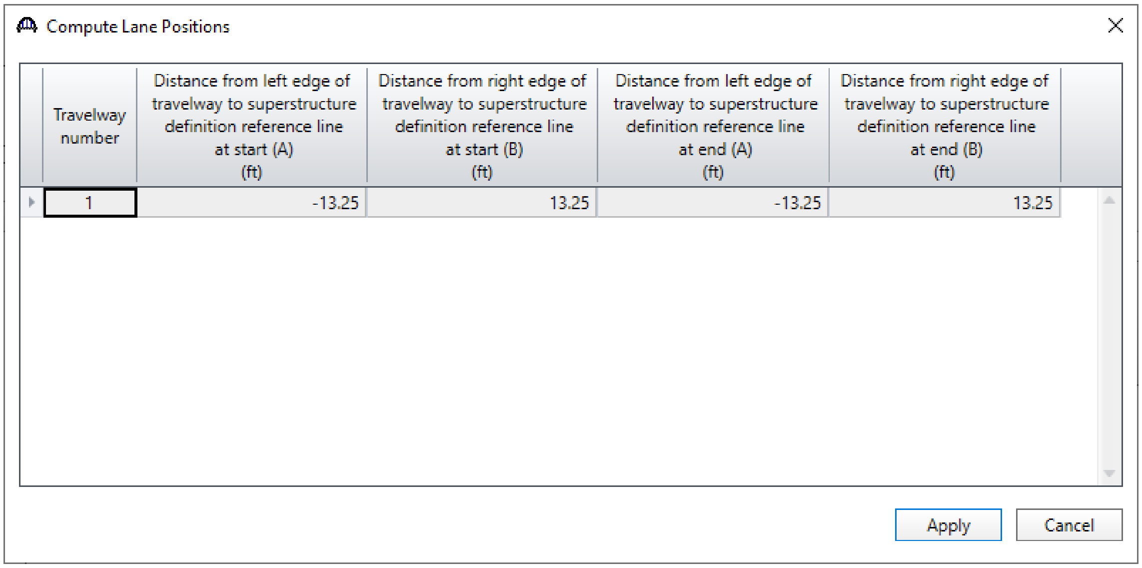
The two parapets are described using the **Parapet** tab. Click **New** to add a row to the table. The name of the parapet defaults to the only barrier described for the bridge. Change the **Load Case** to **DC2.** Reinforced concrete structures only have 1 stage but for this example, select **DC2** since the dead load of the parapets needs to be uniformly distributed to all girders and BrDR only allows that type of load distribution in stage 2.

Select **Back** in the **Measure to** field (we are locating the parapet on the deck by referencing the back of the parapet to the left edge of the deck). Enter **0.0** for the **Distance at start** and **Distance at end**. Change the **Front face orientation** to **Right**. The completed tab is shown below.

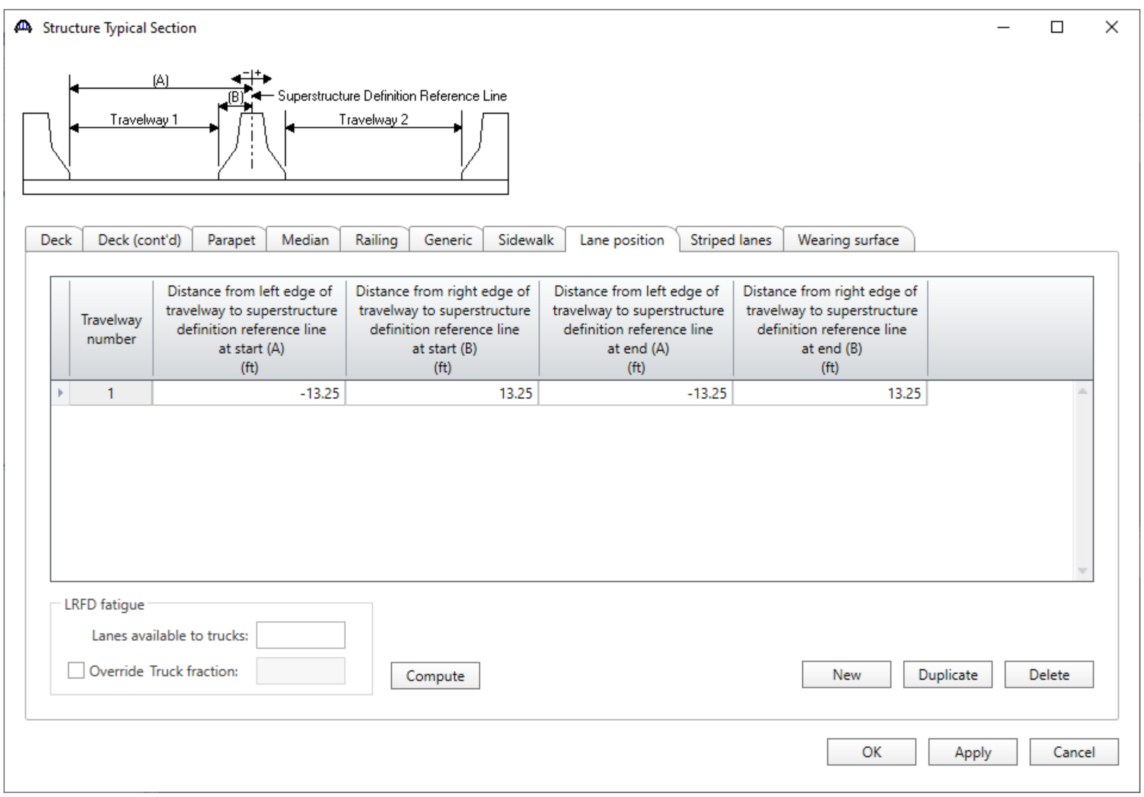


Structure Typical Section - Lane positions

Select the **Lane position** tab. Enter the values shown below or click the **Compute…** button to automatically compute the lane positions. A window showing the results of the computation opens.



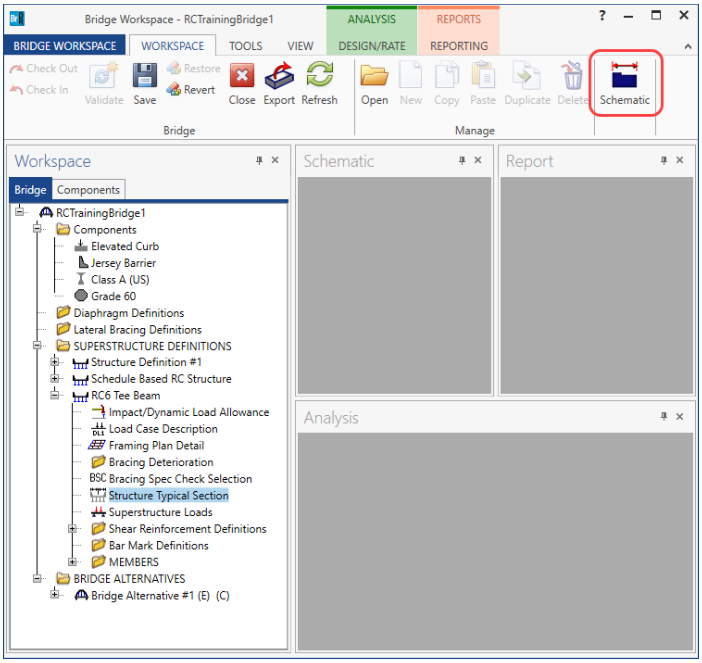
Click **Apply** to apply the computed values. The **Lane Position** tab is populated as shown below.



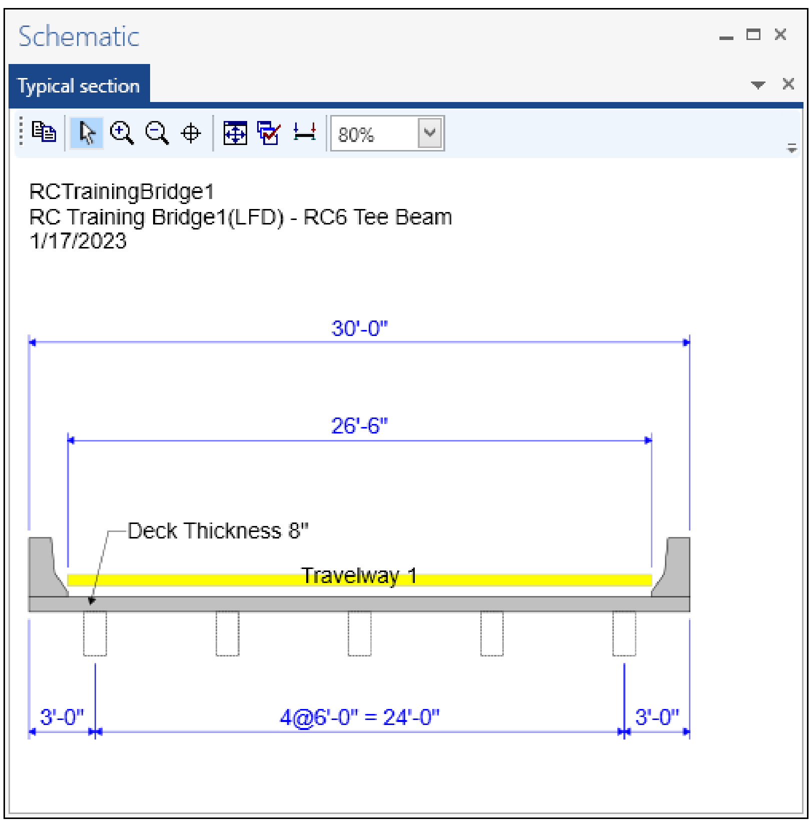
Click **OK** to apply the data and close the window.

Schematic – Structure Typical Section

A schematic view of the structure typical section is available while the **Structure Typical Section** node is selected on the Bridge Workspace tree.

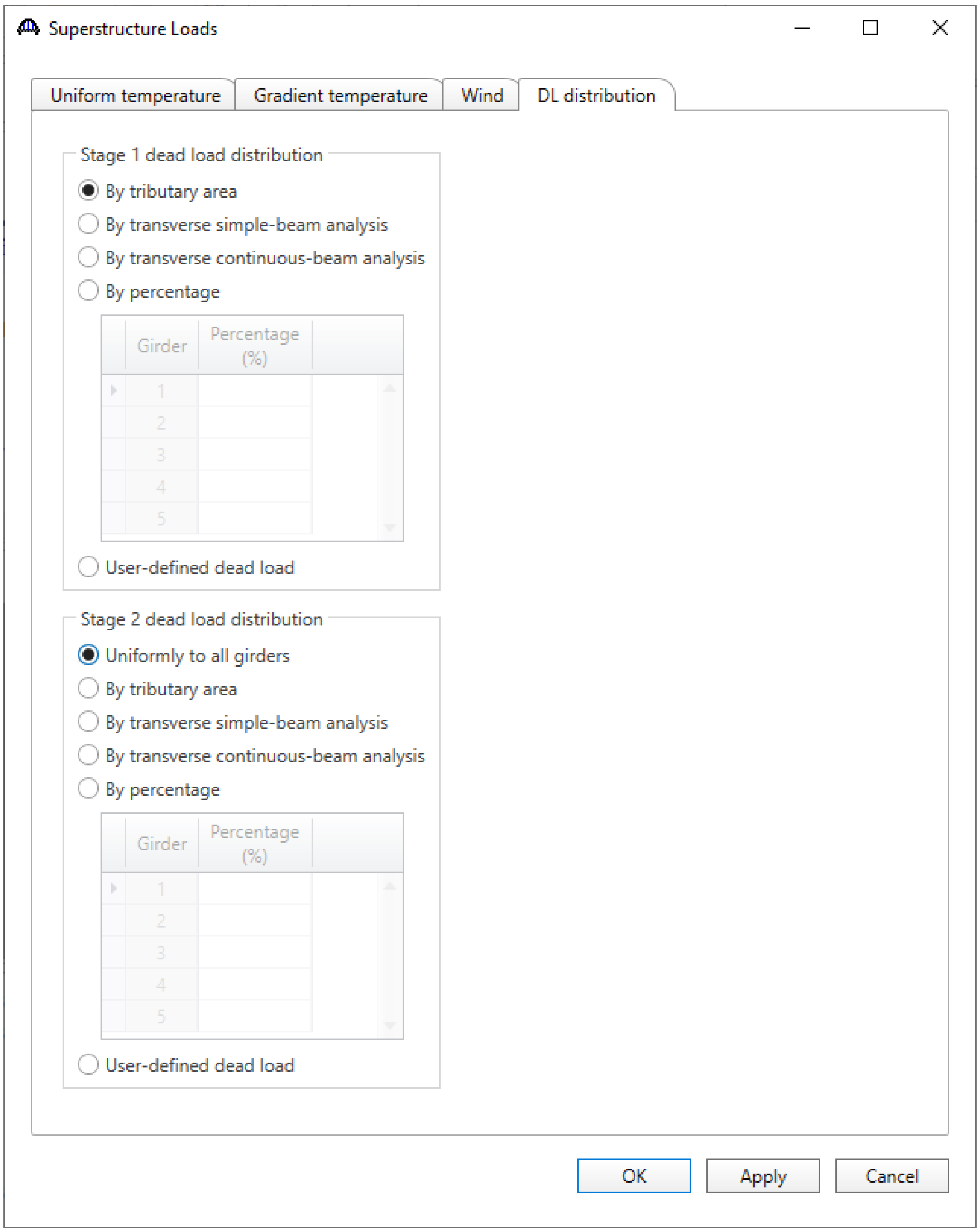


The schematic of the **Structure Typical Section** is shown below.



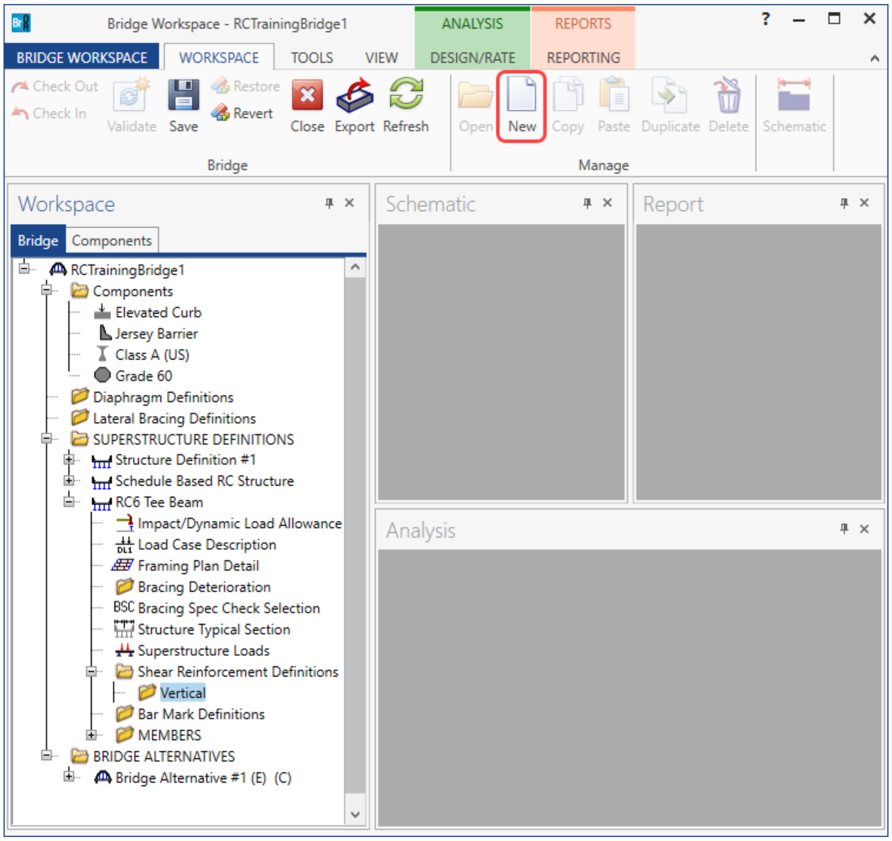
Superstructure Loads – DL Distribution

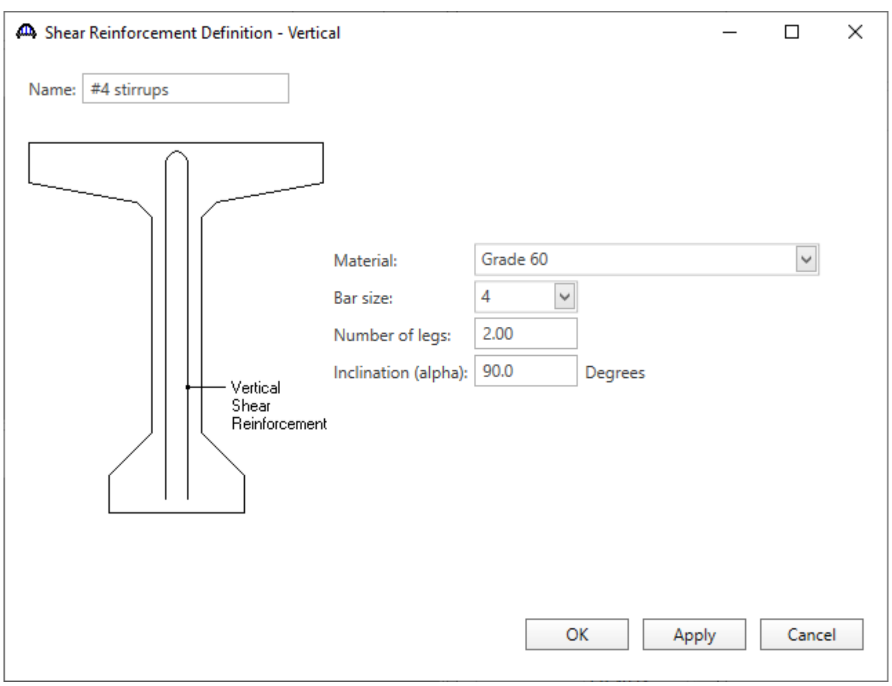
Double-click on the **Superstructure Loads** node in the Bridge Workspace tree to open the **Superstructure Loads** window. Navigate to the **DL Distribution** tab of this window. The **DL Distribution** tab of the **Superstructure Loads** window is shown below. BrDR only provides the **Uniformly to all girders** distribution option for stage 2 dead loads. Even though reinforced concrete only has 1 stage, we previously assigned our parapets to stage 2 on the Structure Typical Section window to take advantage of the **Uniformly to all girders** option. The export to the BrDR LRFD analysis engine will uniformly distribute the parapets to all girders and assign that load to the stage 1 model.



Shear Reinforcement

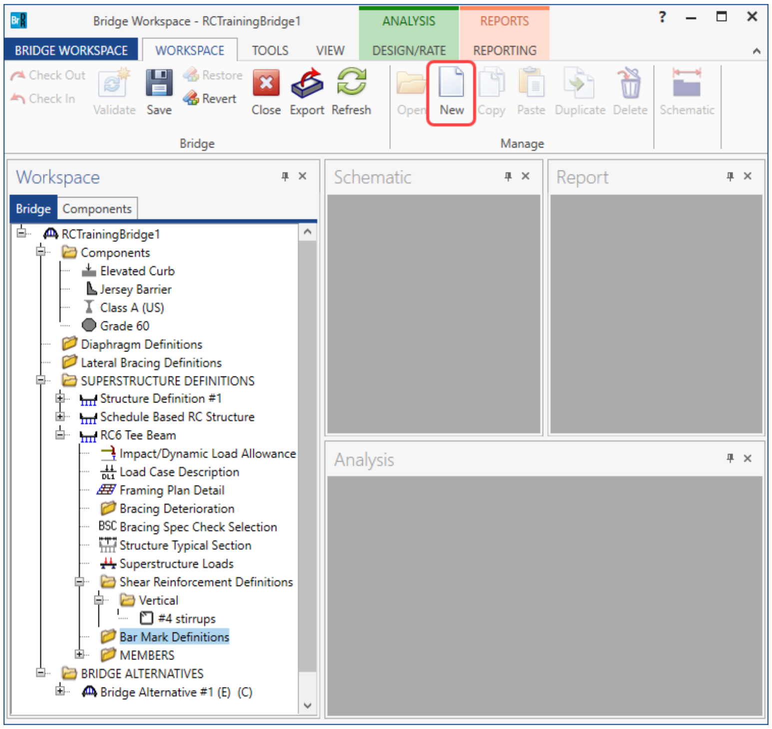
Define shear reinforcement to be used by the girders. Expand the **Shear Reinforcement Definitions** node on the Bridge Workspace tree, select **Vertical** and click on **New** from the **Manage** group of the Workspace ribbon (or double click on **Vertical)**. Define the stirrup as shown below. Click **OK** to apply the data and close the window.



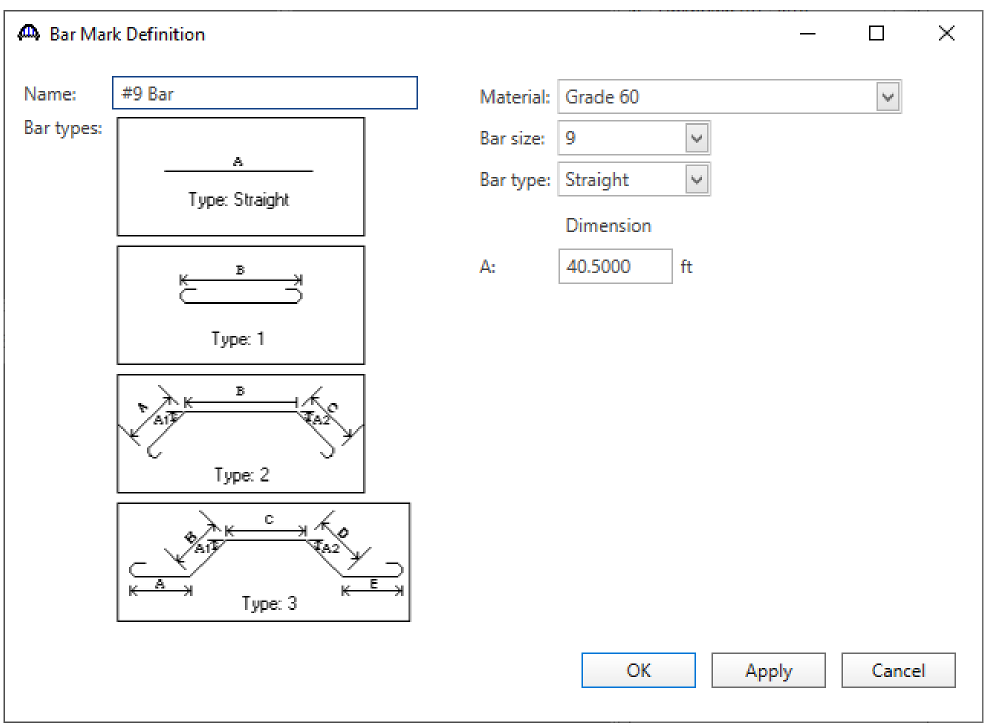


Bar Mark Definitions

Select **Bar Mark Definitions** from the Bridge Workspace tree and click the **New** button from the **Manage** group of the Workspace ribbon (or double click on **Bar Mark Definitions)** to open the **Bar Mark Definition** window.



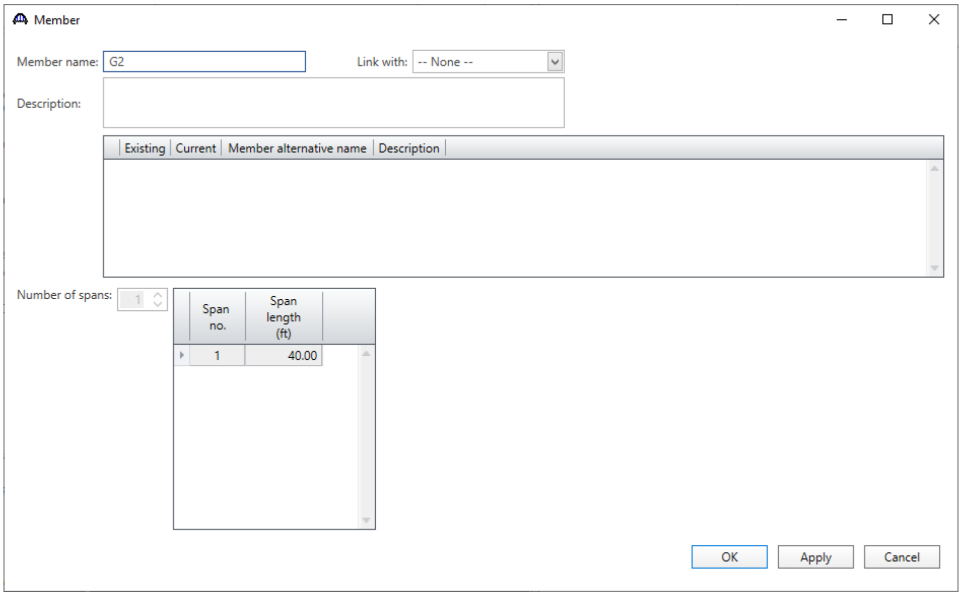
Create the following Bar Mark Definition to be used for the longitudinal reinforcement in the beam.



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

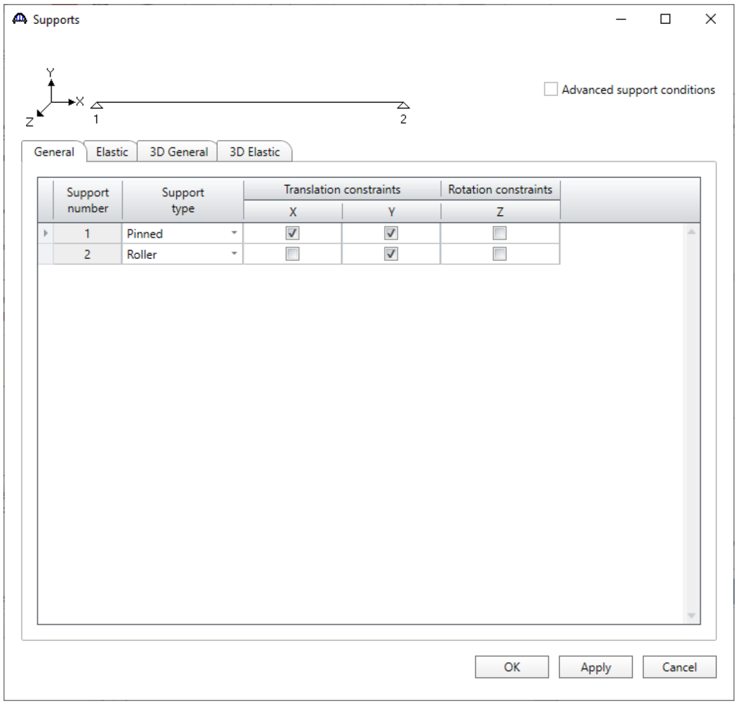
Describing member G2

The **Member** window for member **G2** shows the data that was generated when the structure definition was created. No changes are required at this time. After Member Alternatives are defined it will appear in the list of member alternatives.



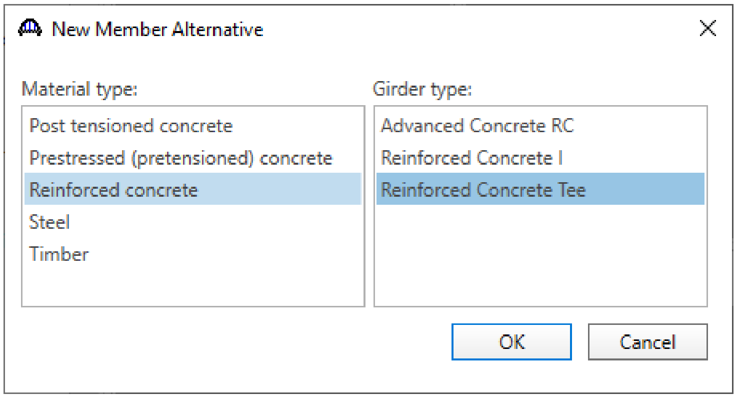
Supports

Expand the **G2** member on the **Bridge Workspace** tree and double click on **Supports** to open the **Supports** window. Support constraints were generated when the structure definition was created and are shown below. No changes are required.

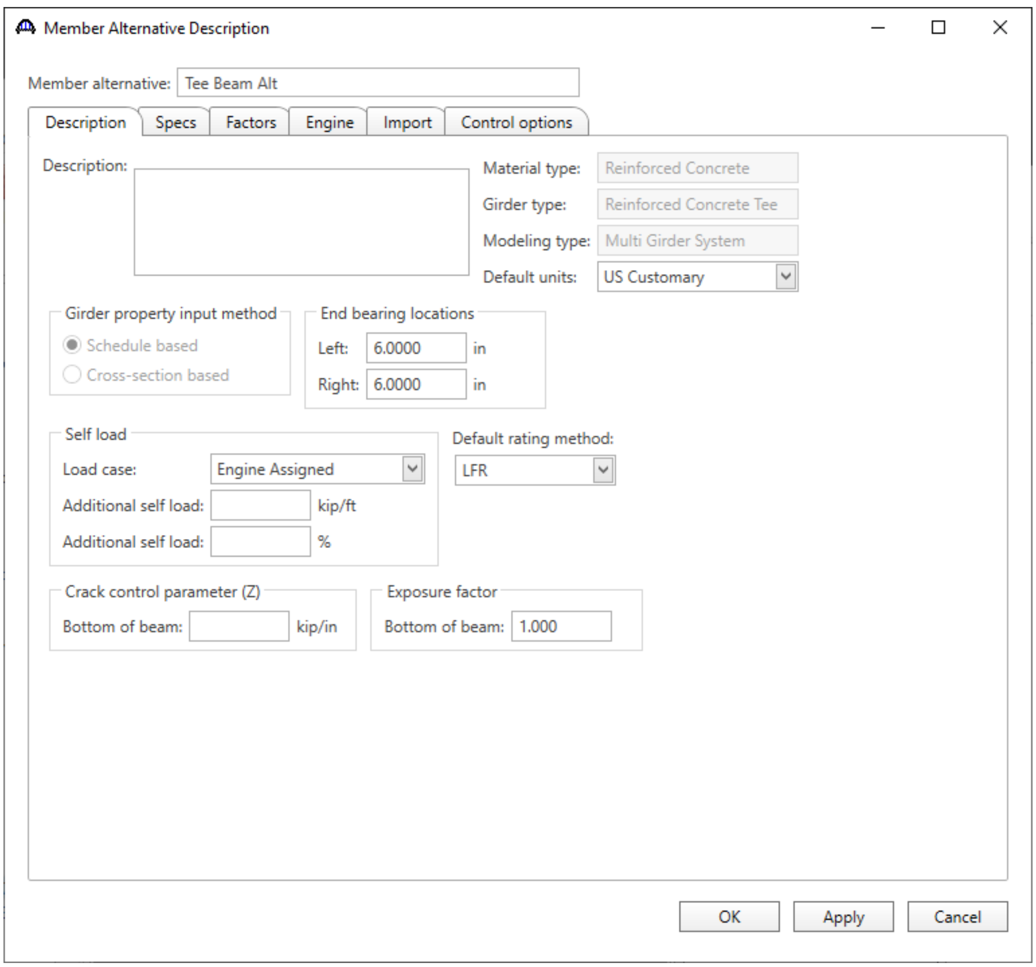


Defining a Member Alternative

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**.



Enter the following data in the Member Alternative window.



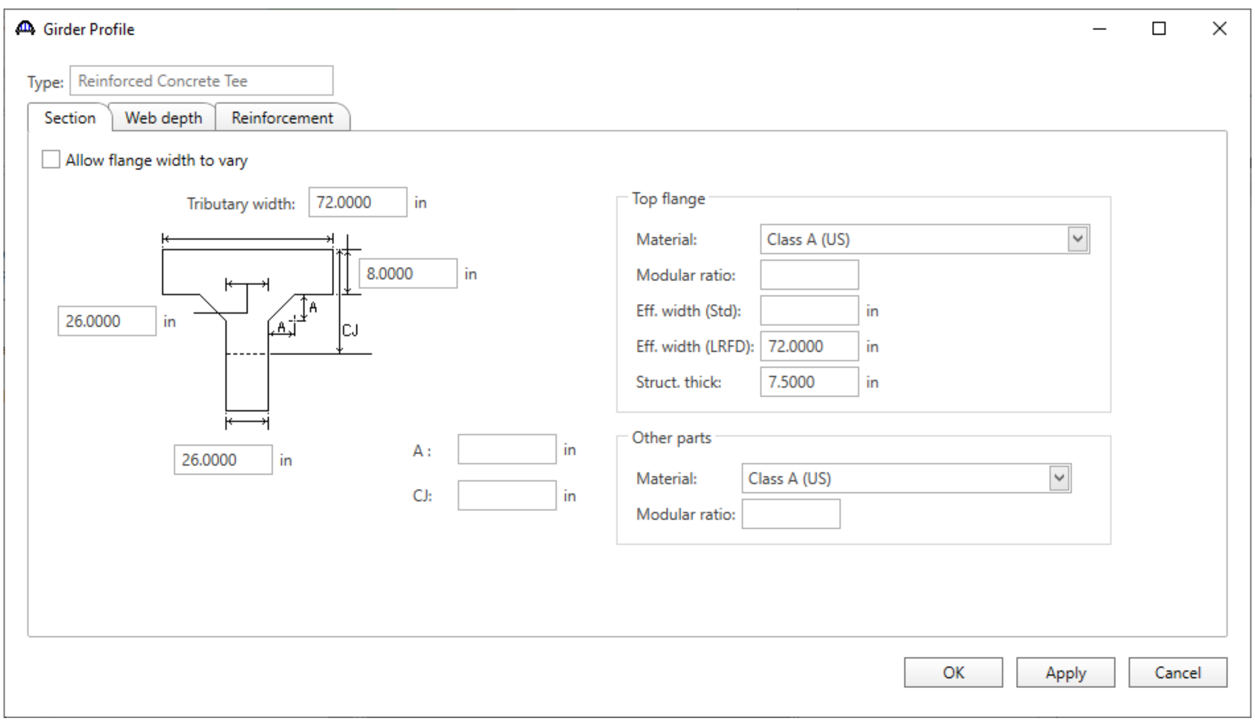
Click **OK** to apply the data and close the window.

For a schedule based reinforced concrete member, it is important to enter a value for the End Bearing Locations on 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 the 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 - Section

The girder profile can now be defined. Expand the **Tee Beam Alt** member alternative on the Bridge Workspace tree, double click on the **Girder Profile** node to open the **Girder Profile** window and enter the following section properties.



The LRFD effective flange width is computed as follows.

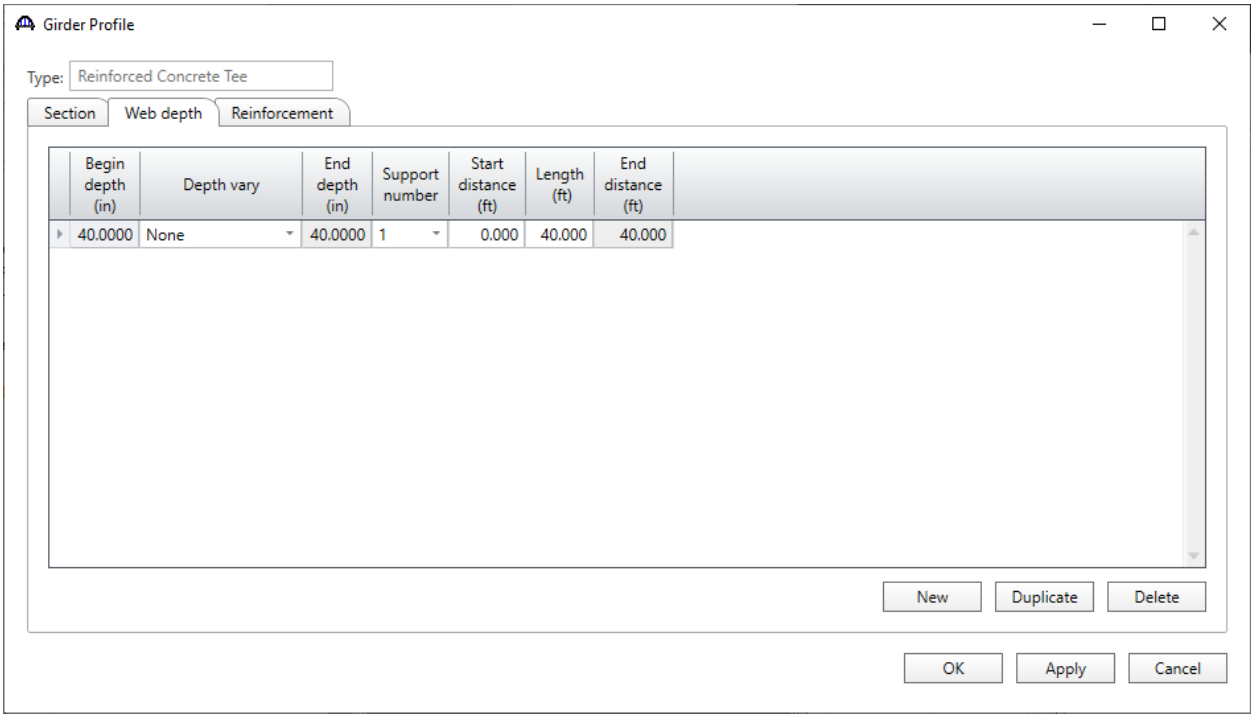
AASHTO LRFD Article 4.6.2.6.1

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

- average spacing of adjacent beams = 6’(12”/’) = 72”

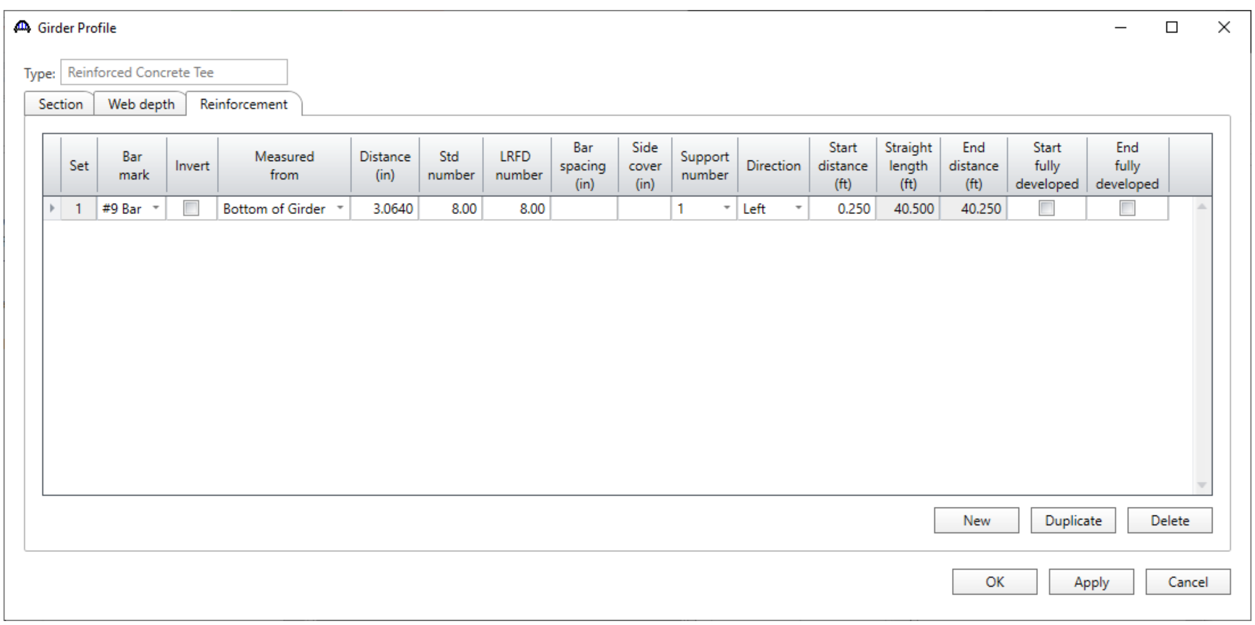
Girder Profile - Web

Enter the following data for the web.



Girder Profile – Reinforcement

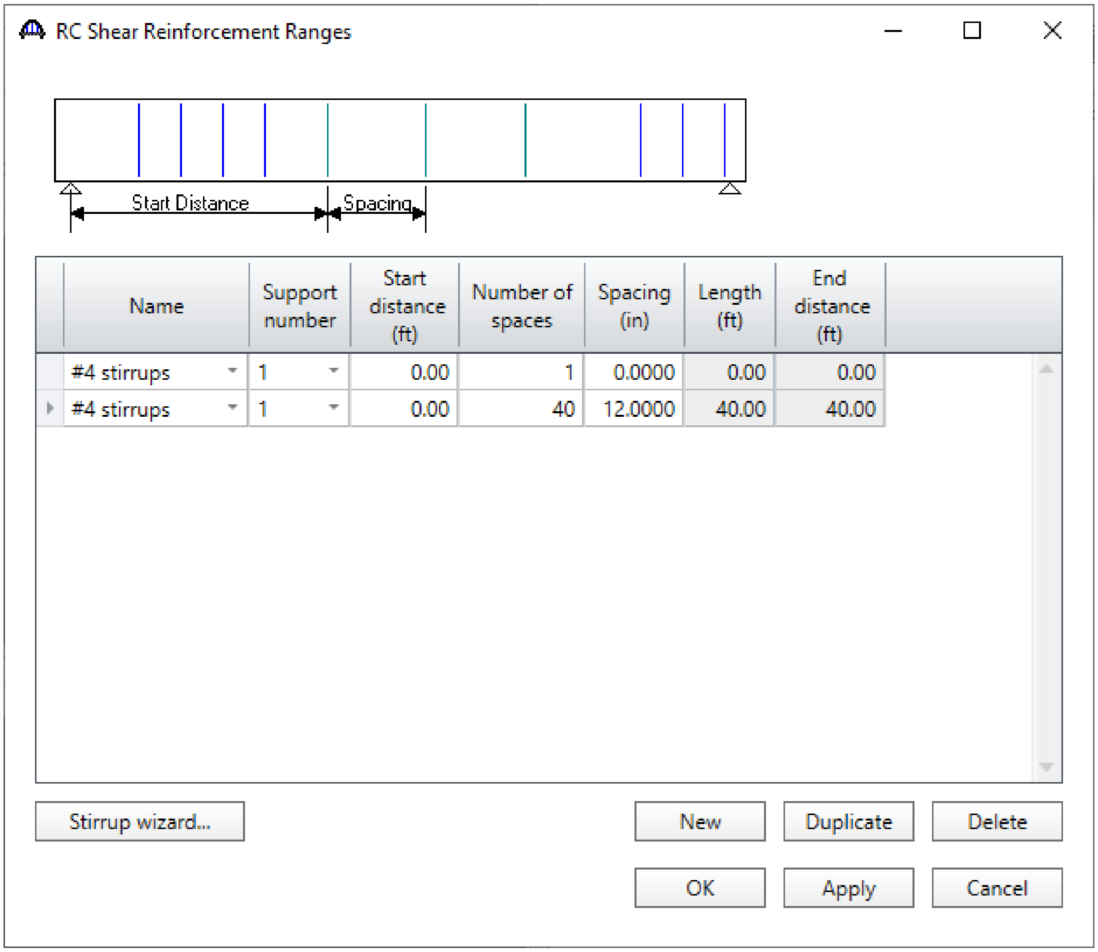
Enter the following data for the reinforcement.



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

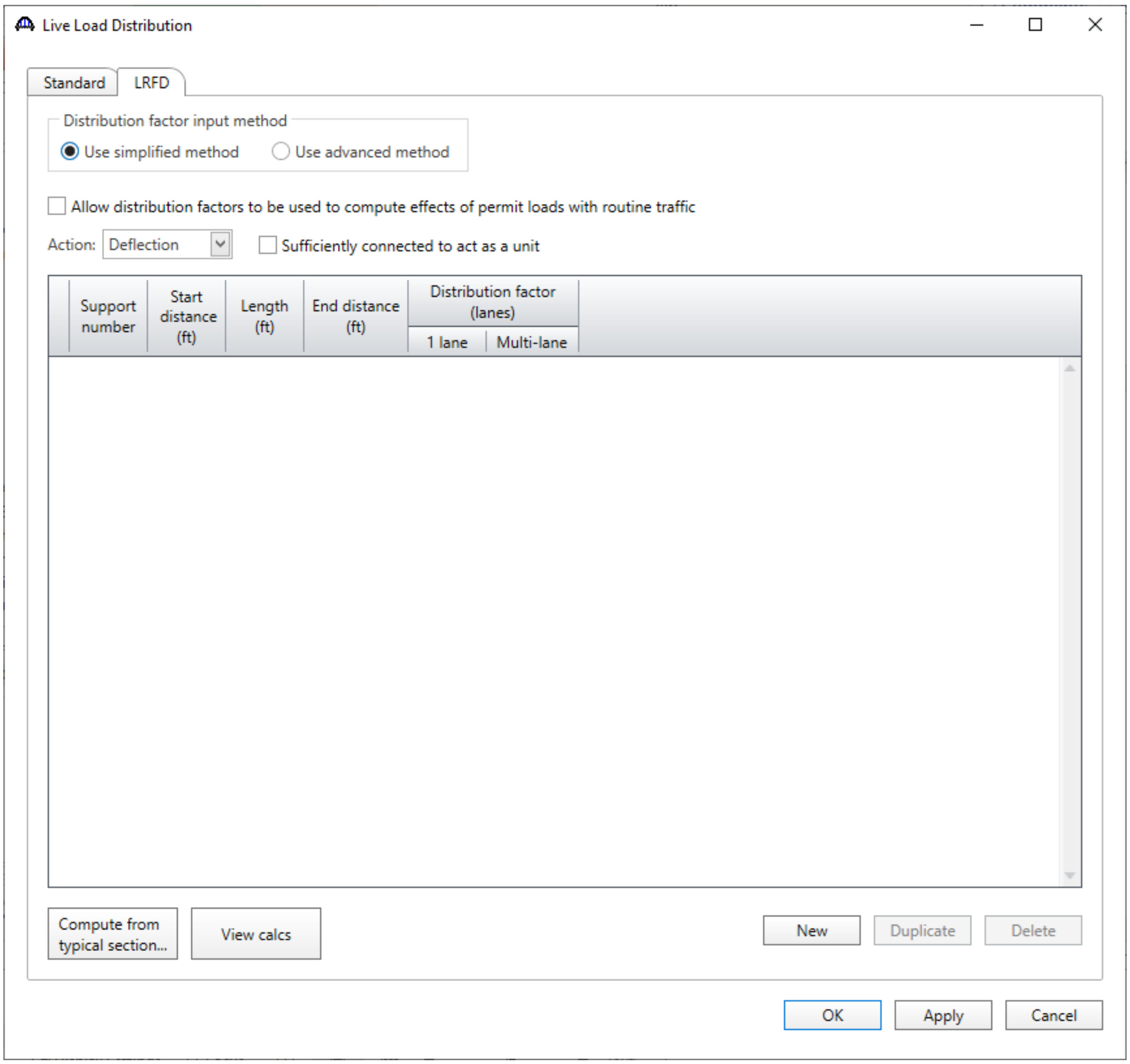
Shear Reinforcement Ranges

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



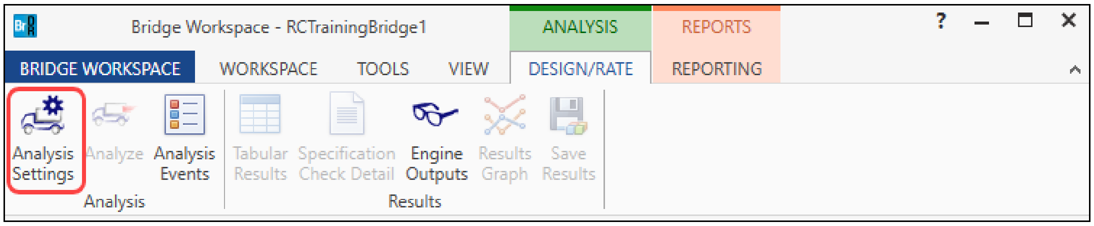
Live Load Distribution Factors

The BrDR LRFD analysis engine will compute the live load distribution factors. No values need to be entered if the user wants the BrDR engine to compute them.

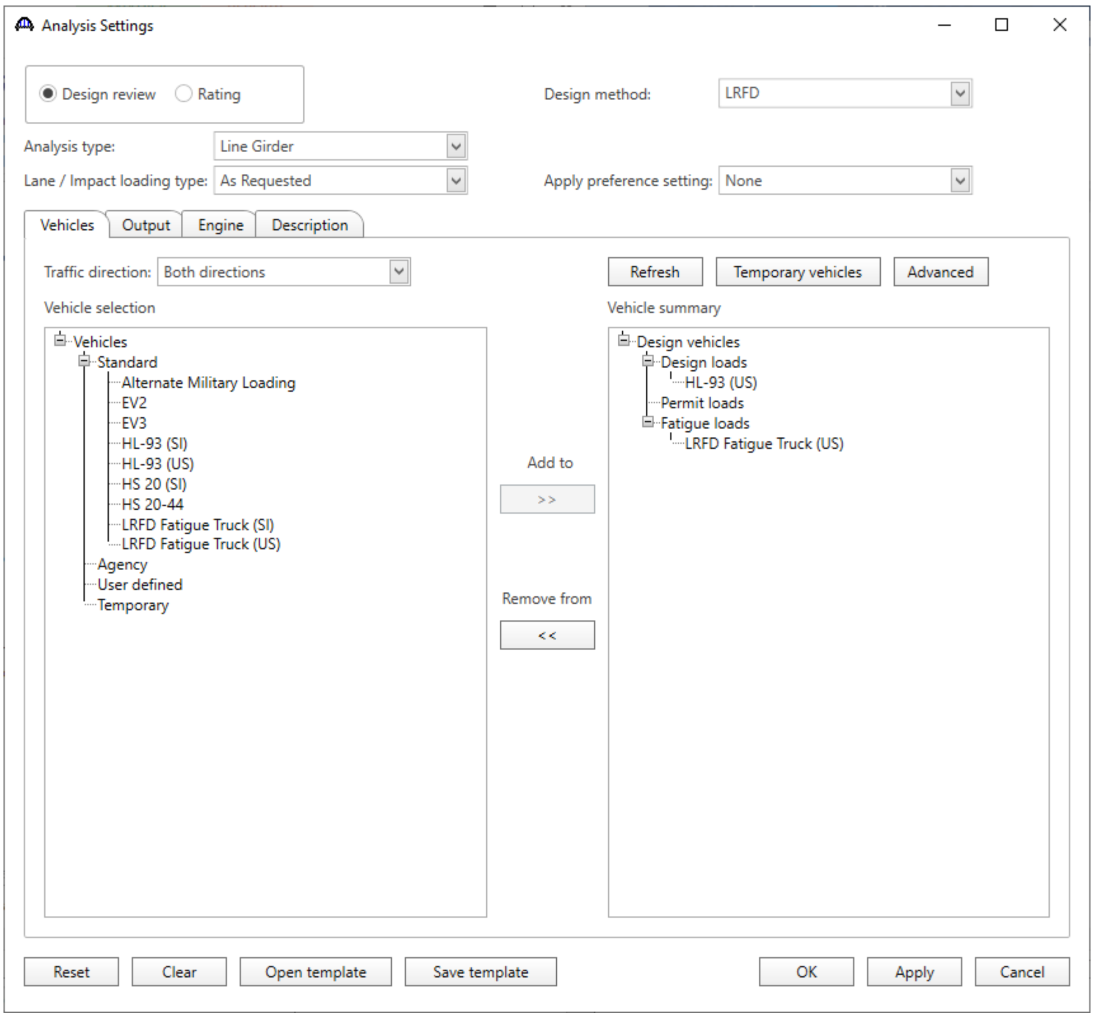


LRFD Design Review

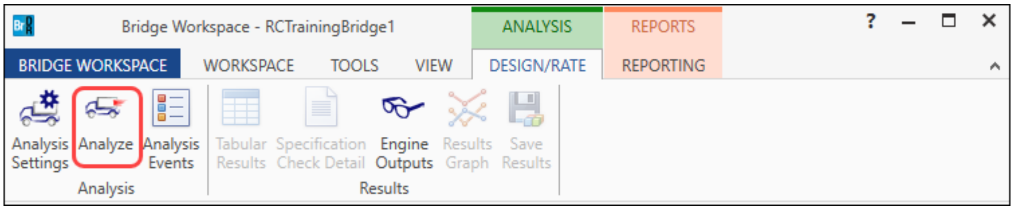
To perform an LRFD design review, click the **Analysis Settings** button on the **Analysis** group of the **DESIGN/RATE** ribbon which opens the **Analysis Settings** window.



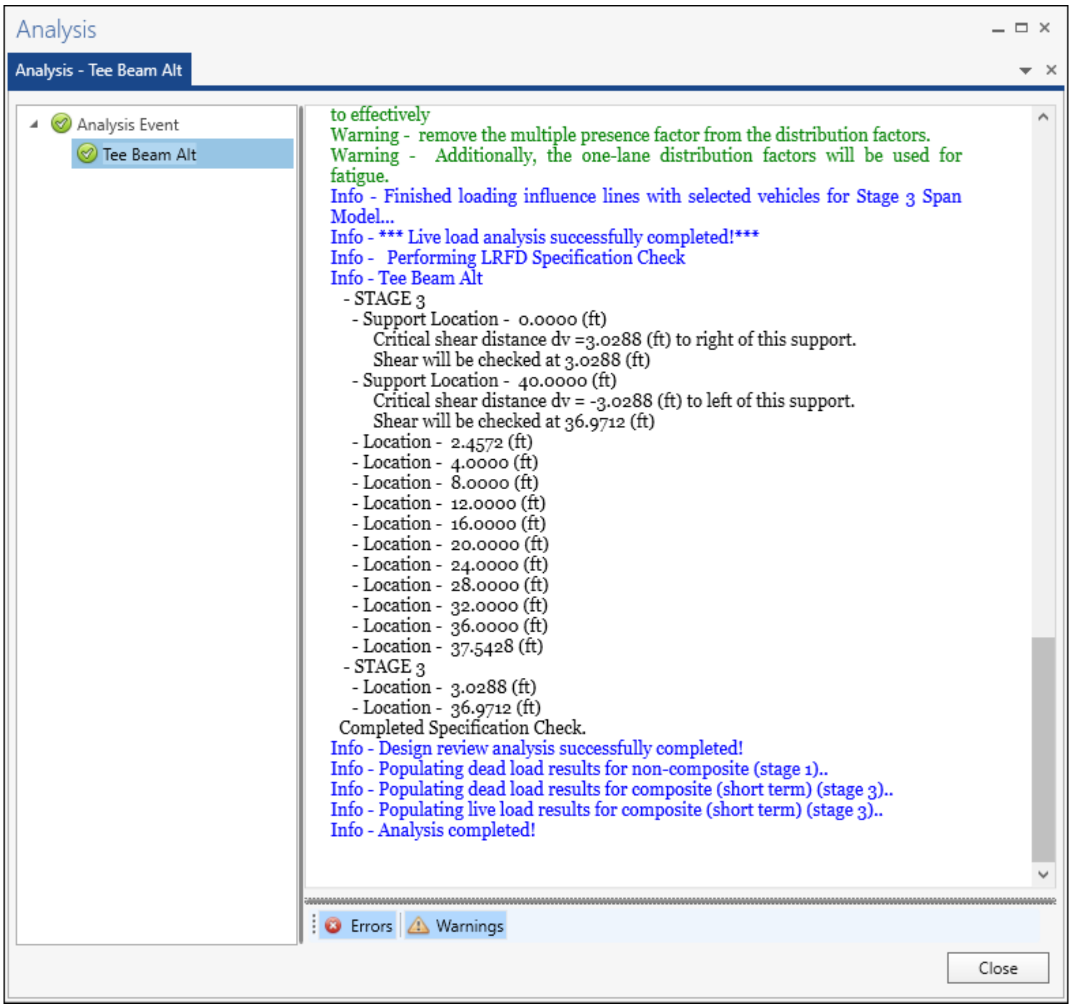
Click the **Open Template** button and select **HL-93 Design Review** to be used in the rating and click **OK**. The **Analysis Settings** window will appear as shown below.



Next click the **Analyze** button on the **Analysis** group of the **DESIGN/RATE** ribbon to perform the rating.



The Analysis log should always be reviewed when performing an analysis with the BrDR LRFD Engine. Informational messages are displayed in blue, warning messages are displayed in green and error messages are displayed in red font.



The following steps are performed in a design review using the BrDR LRFD analysis engine.

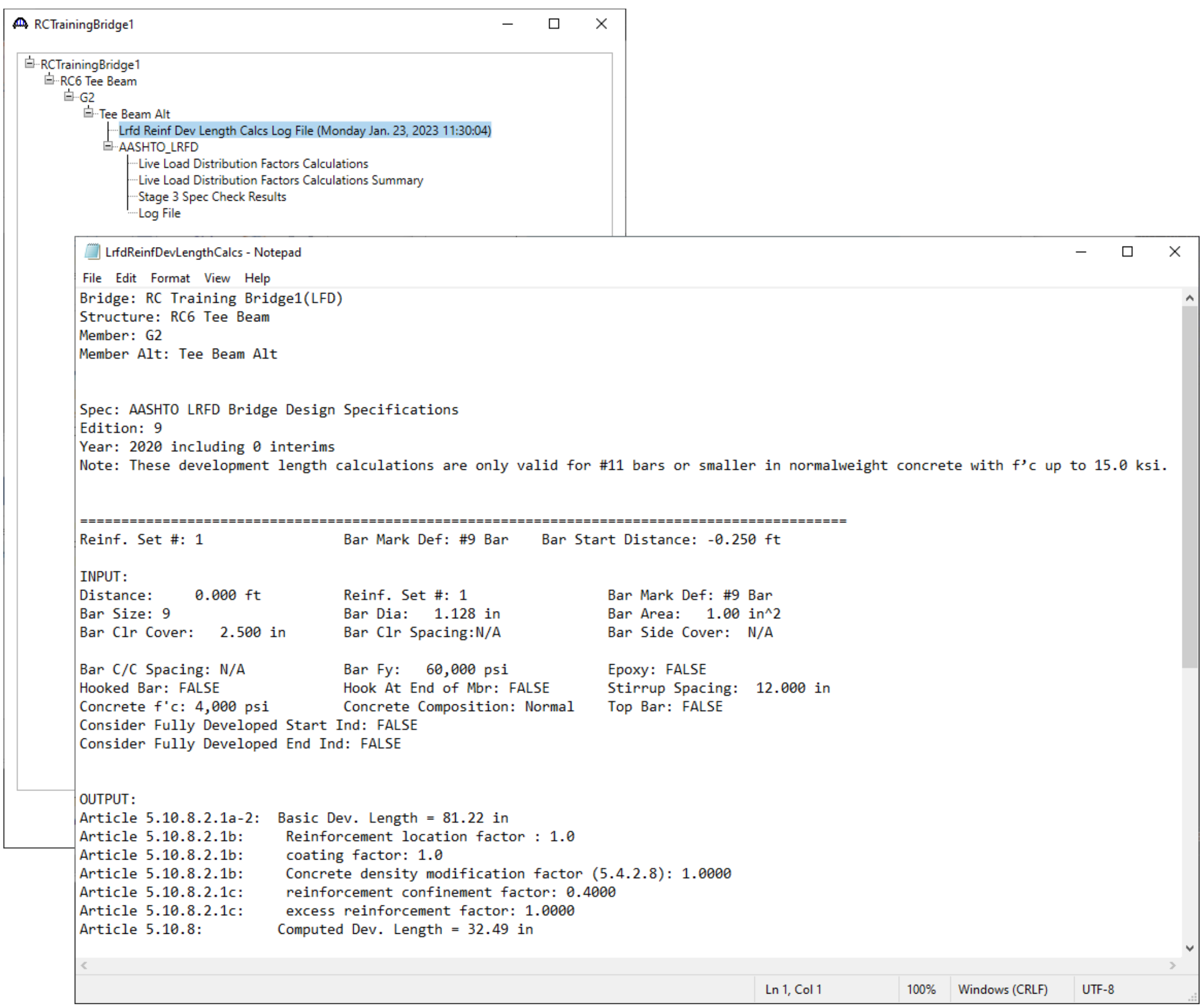
1. Finite element models are generated for the dead load and live load analyses. A Stage 1 FE model is generated for the dead loads on the reinforced concrete beam. A Stage 3 FE model is generated for the live load analysis. Reinforced concrete beams only have 1 stage so the Stage 1 and Stage 3 models contain the same cross section properties.

The model generated by the export to the BrDR LRFD analysis engine will contain node points at locations where the cross section properties change, span tenth points, support locations, and user defined points of interest.

2. The Stage 1 FE model is analyzed for the dead load. The Stage 3 FE model is loaded with unit loads at each node to generate influence lines for the beam. The influence loads are then loaded with the selected vehicles to find the maximum live load effects.

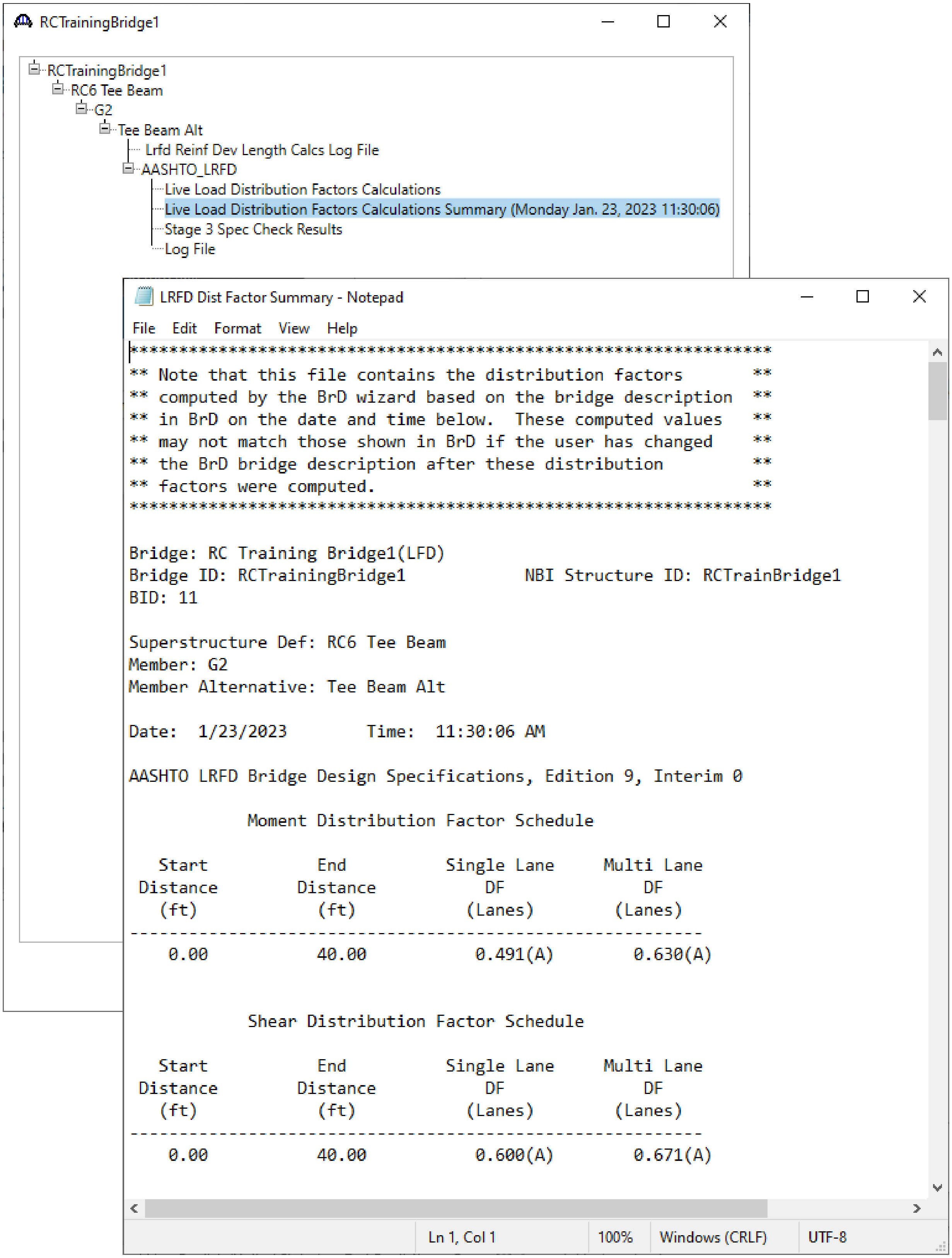
3. Load combinations are generated for the loadings and specification checks are performed at each of the nodes in the finite element model as well as the locations where schedule based reinforcement is developed.

The report containing the calculations of the rebar development locations is shown below.



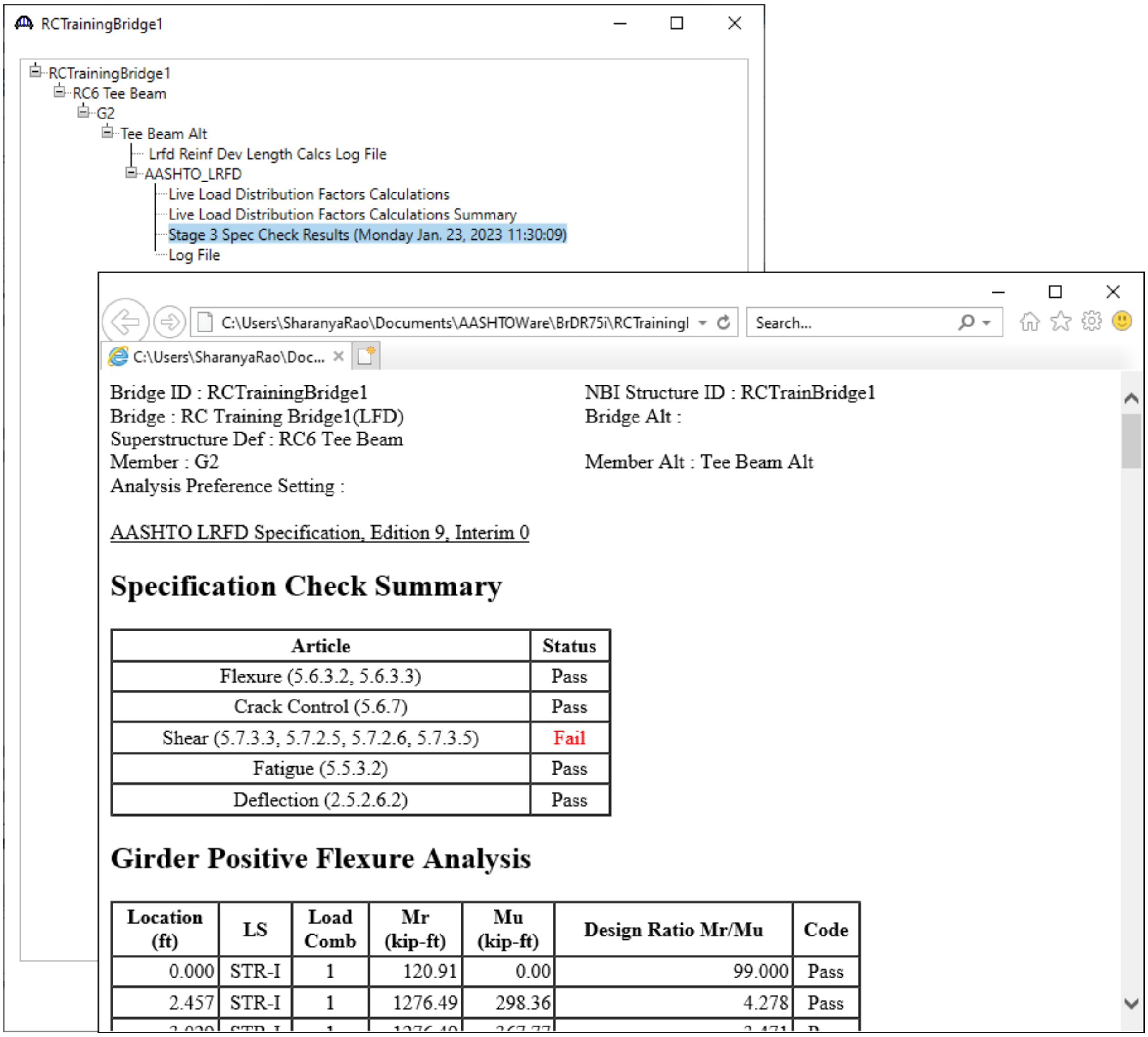

```
Bridge: RC Training Bridge1(LFD)
Structure: RC6 Tee Beam
Member: G2
Member Alt: Tee Beam Alt


Spec: AASHTO LRFD Bridge Design Specifications
Edition: 9
Year: 2020 including 0 interims
Note: These development length calculations are only valid for #11 bars or smaller in normalweight concrete with f'c up to 15.0 ksi.


==========================================================================================
Reinf. Set #: 1                Bar Mark Def: #9 Bar    Bar Start Distance: -0.250 ft

INPUT:
Distance:     0.000 ft         Reinf. Set #: 1                Bar Mark Def: #9 Bar
Bar Size: 9                    Bar Dia:    1.128 in           Bar Area:   1.00 in^2
Bar Clr Cover:   2.500 in      Bar Clr Spacing:N/A            Bar Side Cover:  N/A

Bar C/C Spacing: N/A           Bar Fy:   60,000 psi           Epoxy: FALSE
Hooked Bar: FALSE              Hook At End of Mbr: FALSE      Stirrup Spacing:  12.000 in
Concrete f'c: 4,000 psi        Concrete Composition: Normal   Top Bar: FALSE
Consider Fully Developed Start Ind: FALSE
Consider Fully Developed End Ind: FALSE


OUTPUT:
Article 5.10.8.2.1a-2:  Basic Dev. Length = 81.22 in
Article 5.10.8.2.1b:     Reinforcement location factor : 1.0
Article 5.10.8.2.1b:     coating factor: 1.0
Article 5.10.8.2.1b:     Concrete density modification factor (5.4.2.8): 1.0000
Article 5.10.8.2.1c:     reinforcement confinement factor: 0.4000
Article 5.10.8.2.1c:     excess reinforcement factor: 1.0000
Article 5.10.8:         Computed Dev. Length = 32.49 in
```

A summary and a detailed report of the computed live load distribution factors are available.



BrDR LRFD specification checking

A summary report of the specification check results is also available. This summary report lists the design ratios for each spec article at each spec check location point. The design ratio is the ratio of capacity to demand. A design ratio less than one indicates the demand is greater than the capacity and the spec article fails. A design ratio equal to 99.0 indicates the section is subject to zero demand.



Bridge ID : RCTrainingBridge1 NBI Structure ID : RCTrainBridge1
Bridge : RC Training Bridge1(LFD) Bridge Alt :
Superstructure Def : RC6 Tee Beam
Member : G2 Member Alt : Tee Beam Alt
Analysis Preference Setting :

AASHTO LRFD Specification, Edition 9, Interim 0

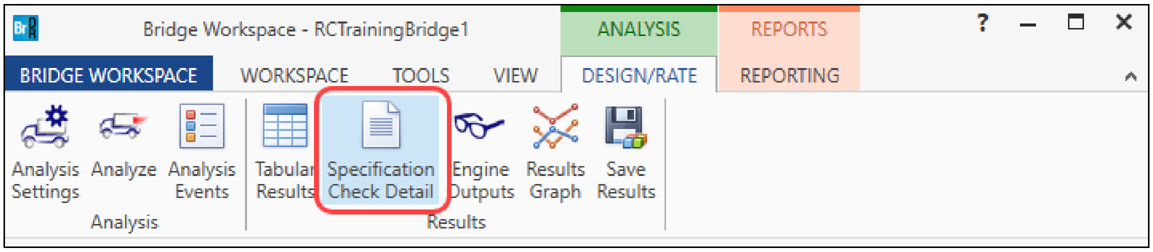
Specification Check Summary

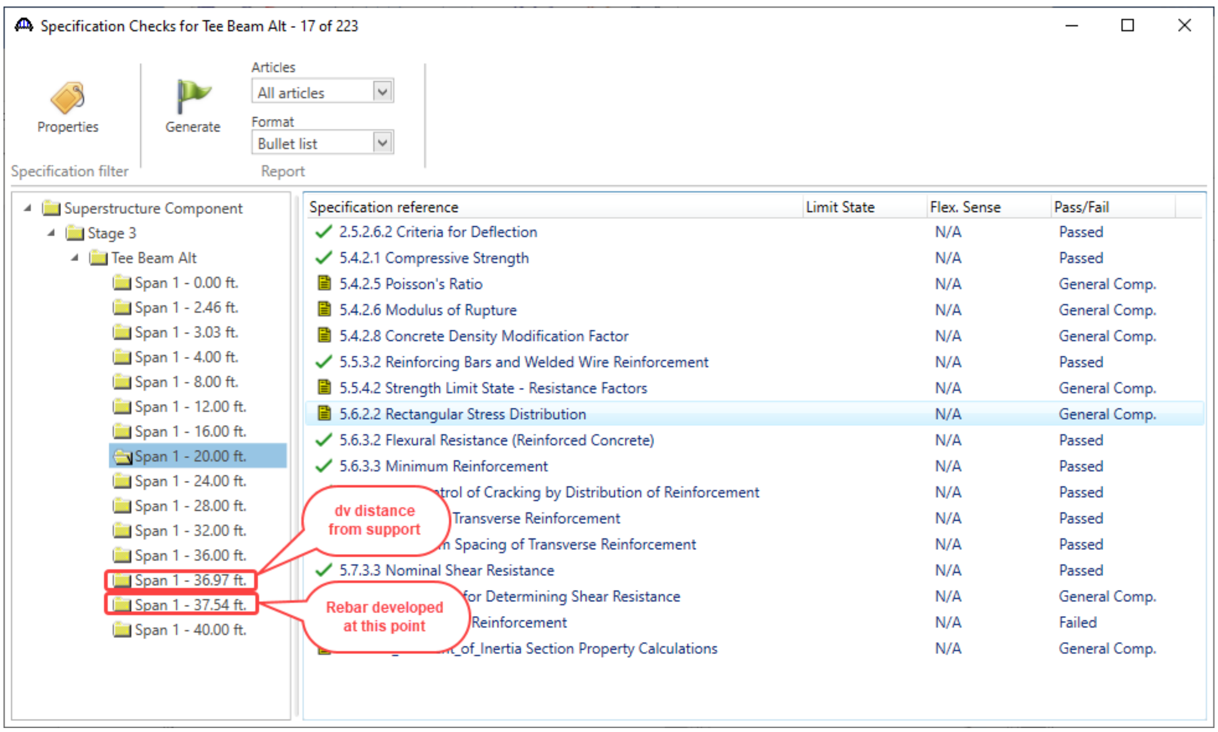
Article	Status
Flexure (5.6.3.2, 5.6.3.3)	Pass
Crack Control (5.6.7)	Pass
Shear (5.7.3.3, 5.7.2.5, 5.7.2.6, 5.7.3.5)	Fail
Fatigue (5.5.3.2)	Pass
Deflection (2.5.2.6.2)	Pass

Girder Positive Flexure Analysis

Location (ft)	LS	Load Comb	Mr (kip-ft)	Mu (kip-ft)	Design Ratio Mr/Mu	Code
0.000	STR-I	1	120.91	0.00	99.000	Pass
2.457	STR-I	1	1276.49	298.36	4.278	Pass

The specification checks can be viewed by selecting the **Specification Check Detail** on the **Results** group of the **DESIGN/RATE** ribbon.



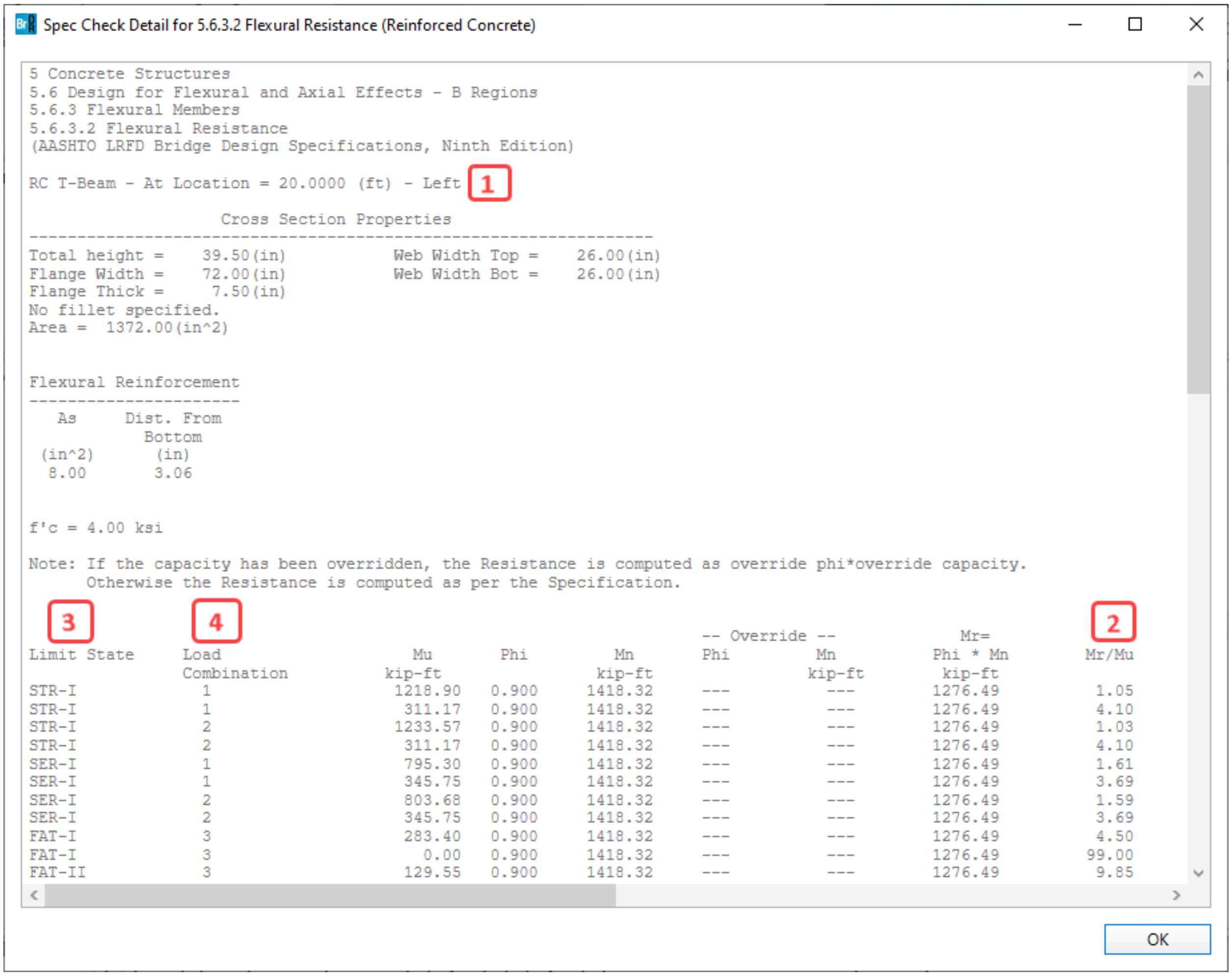


The BrDR RC LRFD engine performs spec checks at span tenth points, cross section property change points, and support locations. In addition, the program will perform spec checks at distance dv from the support and at locations where schedule based reinforcement starts/stops and is fully developed. The program will perform spec checks at user defined points of interest as well but note that a BrDR point of interest need not be created to have spec checks performed at the preceding locations.

Open the spec check detail window for the flexural resistance at midspan. The following is noted for this window, other spec articles are similar:

1. For each spec check location, both the left and right sides of the point are evaluated. The Deflection article is an exception to this since deflection must be the same between the left and right sides of a point.

2. The design ratio is printed out for the article. The design ratio is the ratio of capacity to demand. A design ratio less than one indicates the demand is greater than the capacity and the spec article fails. A design ratio equal to 99.0 indicates the section is subject to zero demand.
3. The Strength-I, Service-I and Fatigue limit states are the only limit states investigated. For each limit state, the max and min force effect is checked. Thus, each limit state shows two rows of data.
4. The LL load combination is shown in this column. If the location is not at a node in the FE model (e.g., the node is at a point where the rebar is fully developed), this column will list two load combinations separated by a comma. The first load combination is the combination considered at the left end and the second load combination is the combination considered at the right end of the FE element that contains this location. The resulting load displayed is a linear interpolation between the two displayed load cases.



Spec Check Detail for 5.6.3.2 Flexural Resistance (Reinforced Concrete)

5 Concrete Structures
5.6 Design for Flexural and Axial Effects - B Regions
5.6.3 Flexural Members
5.6.3.2 Flexural Resistance
(AASHTO LRFD Bridge Design Specifications, Ninth Edition)

RC T-Beam - At Location = 20.0000 (ft) - Left **1**

Cross Section Properties

Total height = 39.50(in)   Web Width Top = 26.00(in)
Flange Width = 72.00(in)   Web Width Bot = 26.00(in)
Flange Thick = 7.50(in)
No fillet specified.
Area = 1372.00(in^2)

Flexural Reinforcement

As (in^2)	Dist. From Bottom (in)
8.00	3.06

f'c = 4.00 ksi

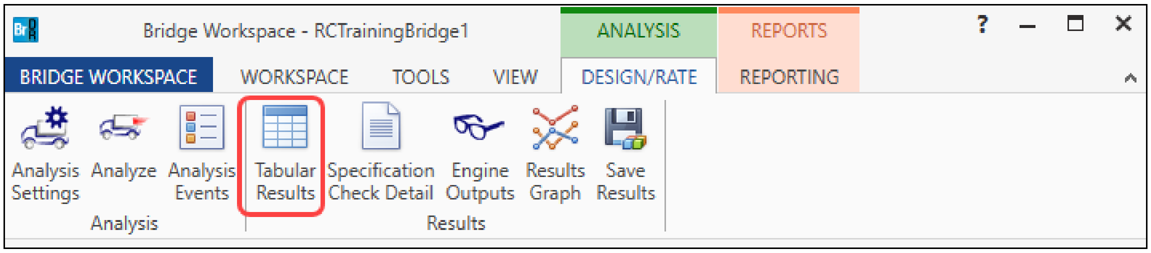
Note: If the capacity has been overridden, the Resistance is computed as override phi*override capacity.
Otherwise the Resistance is computed as per the Specification.

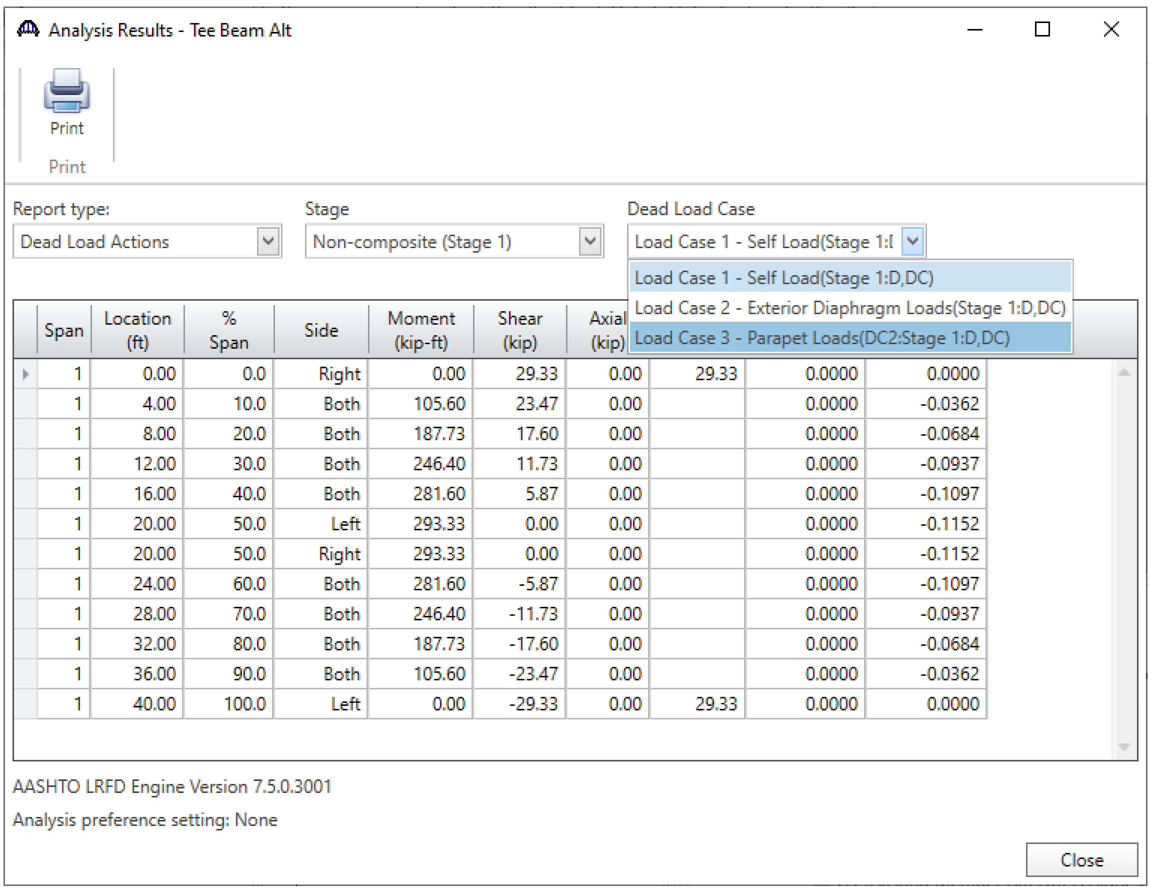
Limit State **3**	Load Combination **4**	Mu kip-ft	Phi	Mn kip-ft	-- Override -- Phi	-- Override -- Mn kip-ft	Mr= Phi * Mn kip-ft	Mr/Mu **2**
STR-I	1	1218.90	0.900	1418.32	---	---	1276.49	1.05
STR-I	1	311.17	0.900	1418.32	---	---	1276.49	4.10
STR-I	2	1233.57	0.900	1418.32	---	---	1276.49	1.03
STR-I	2	311.17	0.900	1418.32	---	---	1276.49	4.10
SER-I	1	795.30	0.900	1418.32	---	---	1276.49	1.61
SER-I	1	345.75	0.900	1418.32	---	---	1276.49	3.69
SER-I	2	803.68	0.900	1418.32	---	---	1276.49	1.59
SER-I	2	345.75	0.900	1418.32	---	---	1276.49	3.69
FAT-I	3	283.40	0.900	1418.32	---	---	1276.49	4.50
FAT-I	3	0.00	0.900	1418.32	---	---	1276.49	99.00
FAT-II	3	129.55	0.900	1418.32	---	---	1276.49	9.85

OK

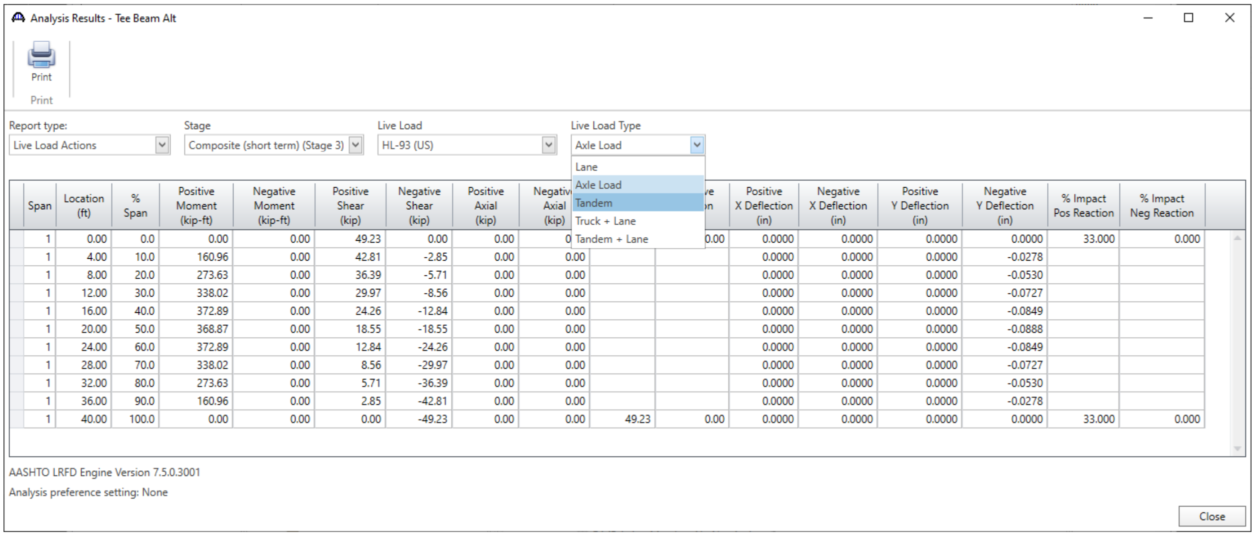
Tabular Results

Tabular dead load and live load analysis results are available in the Analysis Results window. They 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)			
1	0.00	0.0	Right	0.00	29.33	0.00	29.33	0.0000	0.0000
1	4.00	10.0	Both	105.60	23.47	0.00		0.0000	-0.0362
1	8.00	20.0	Both	187.73	17.60	0.00		0.0000	-0.0684
1	12.00	30.0	Both	246.40	11.73	0.00		0.0000	-0.0937
1	16.00	40.0	Both	281.60	5.87	0.00		0.0000	-0.1097
1	20.00	50.0	Left	293.33	0.00	0.00		0.0000	-0.1152
1	20.00	50.0	Right	293.33	0.00	0.00		0.0000	-0.1152
1	24.00	60.0	Both	281.60	-5.87	0.00		0.0000	-0.1097
1	28.00	70.0	Both	246.40	-11.73	0.00		0.0000	-0.0937
1	32.00	80.0	Both	187.73	-17.60	0.00		0.0000	-0.0684
1	36.00	90.0	Both	105.60	-23.47	0.00		0.0000	-0.0362
1	40.00	100.0	Left	0.00	-29.33	0.00	29.33	0.0000	0.0000



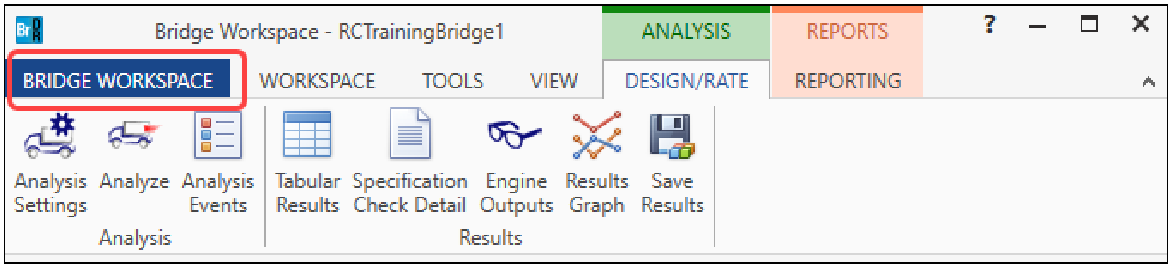
Span	Location (ft)	% Span	Positive Moment (kip-ft)	Negative Moment (kip-ft)	Positive Shear (kip)	Negative Shear (kip)	Positive Axial (kip)	Negativ Axial (kip)		ve on	Positive X Deflection (in)	Negative X Deflection (in)	Positive Y Deflection (in)	Negative Y Deflection (in)	% Impact Pos Reaction	% Impact Neg Reaction
1	0.00	0.0	0.00	0.00	49.23	0.00	0.00	0		0.00	0.0000	0.0000	0.0000	0.0000	33.000	0.000
1	4.00	10.0	160.96	0.00	42.81	-2.85	0.00	0.00			0.0000	0.0000	0.0000	-0.0278		
1	8.00	20.0	273.63	0.00	36.39	-5.71	0.00	0.00			0.0000	0.0000	0.0000	-0.0530		
1	12.00	30.0	338.02	0.00	29.97	-8.56	0.00	0.00			0.0000	0.0000	0.0000	-0.0727		
1	16.00	40.0	372.89	0.00	24.26	-12.84	0.00	0.00			0.0000	0.0000	0.0000	-0.0849		
1	20.00	50.0	368.87	0.00	18.55	-18.55	0.00	0.00			0.0000	0.0000	0.0000	-0.0888		
1	24.00	60.0	372.89	0.00	12.84	-24.26	0.00	0.00			0.0000	0.0000	0.0000	-0.0849		
1	28.00	70.0	338.02	0.00	8.56	-29.97	0.00	0.00			0.0000	0.0000	0.0000	-0.0727		
1	32.00	80.0	273.63	0.00	5.71	-36.39	0.00	0.00			0.0000	0.0000	0.0000	-0.0530		
1	36.00	90.0	160.96	0.00	2.85	-42.81	0.00	0.00			0.0000	0.0000	0.0000	-0.0278		
1	40.00	100.0	0.00	0.00	0.00	-49.23	0.00	0.00	49.23	0.00	0.0000	0.0000	0.0000	0.0000	33.000	0.000

Note these values include dynamic load allowance, distribution factors and any live load scale factor entered in the **Analysis Settings** window.

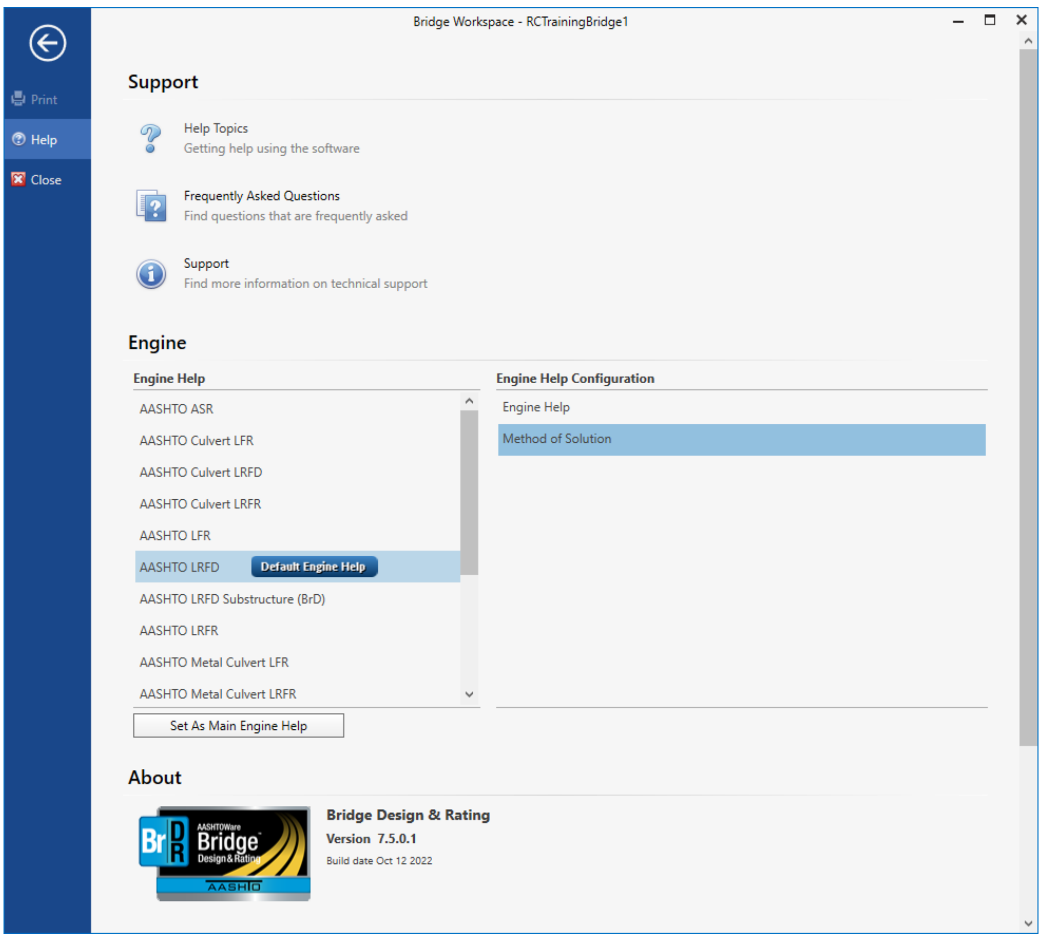
Method of Solution

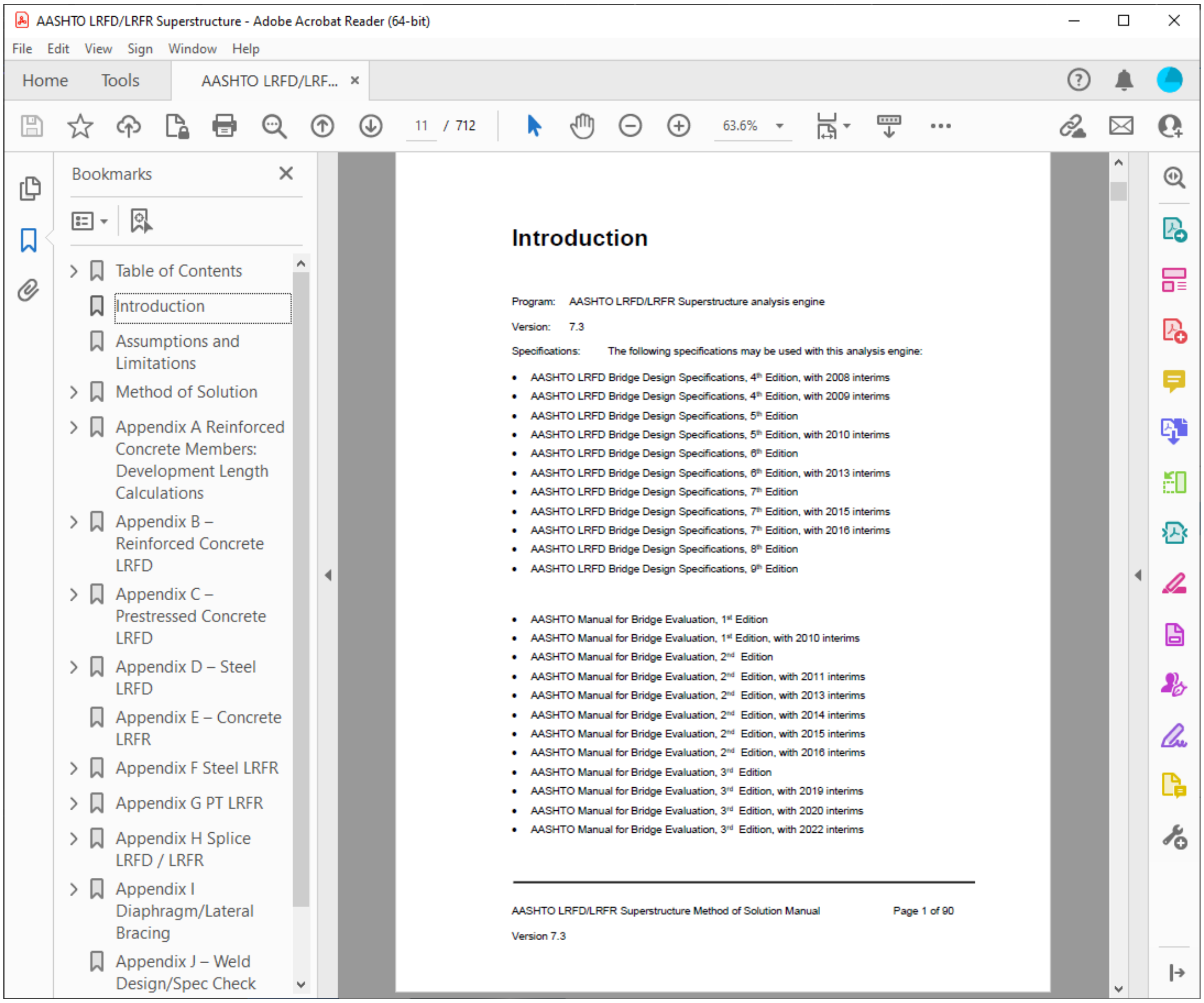
The Method of Solution manual can be accessed from the Help menu in BrDR.

Click on the **Bridge Workspace** ribbon to access the **Support** menu.



In the **Engine Help** column select **AASHTO LRFD** to access the **Engine Help** and **Method of Solution** for the selected engine. Double-click on **Method of Solution** from the **Engine Help Configuration** column to open the method of solution for the selected engine




AASHTO LRFD/LRFR Superstructure - Adobe Acrobat Reader (64-bit)
File Edit View Sign Window Help
Home Tools AASHTO LRFD/LRF...
11 / 712
63.6%
Bookmarks
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Introduction
Program: AASHTO LRFD/LRFR Superstructure analysis engine
Version: 7.3
Specifications: The following specifications may be used with this analysis engine:
AASHTO LRFD Bridge Design Specifications, 4th Edition, with 2008 interims
AASHTO LRFD Bridge Design Specifications, 4th Edition, with 2009 interims
AASHTO LRFD Bridge Design Specifications, 5th Edition
AASHTO LRFD Bridge Design Specifications, 5th Edition, with 2010 interims
AASHTO LRFD Bridge Design Specifications, 6th Edition
AASHTO LRFD Bridge Design Specifications, 6th Edition, with 2013 interims
AASHTO LRFD Bridge Design Specifications, 7th Edition
AASHTO LRFD Bridge Design Specifications, 7th Edition, with 2015 interims
AASHTO LRFD Bridge Design Specifications, 7th Edition, with 2016 interims
AASHTO LRFD Bridge Design Specifications, 8th Edition
AASHTO LRFD Bridge Design Specifications, 9th Edition
AASHTO Manual for Bridge Evaluation, 1st Edition
AASHTO Manual for Bridge Evaluation, 1st Edition, with 2010 interims
AASHTO Manual for Bridge Evaluation, 2nd Edition
AASHTO Manual for Bridge Evaluation, 2nd Edition, with 2011 interims
AASHTO Manual for Bridge Evaluation, 2nd Edition, with 2013 interims
AASHTO Manual for Bridge Evaluation, 2nd Edition, with 2014 interims
AASHTO Manual for Bridge Evaluation, 2nd Edition, with 2015 interims
AASHTO Manual for Bridge Evaluation, 2nd Edition, with 2016 interims
AASHTO Manual for Bridge Evaluation, 3rd Edition
AASHTO Manual for Bridge Evaluation, 3rd Edition, with 2019 interims
AASHTO Manual for Bridge Evaluation, 3rd Edition, with 2020 interims
AASHTO Manual for Bridge Evaluation, 3rd Edition, with 2022 interims
AASHTO LRFD/LRFR Superstructure Method of Solution Manual
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