2024 RADBUG Annual Meeting

Training Materials

Buffalo, New York
August 6-7, 2024

2024 RADBUG Annual Meeting

AASHTOWare™

BRIDGE

DESIGN AND RATING

Fundamentals Training Session

Tuesday August 6, 2024
Part 1: 10:30 AM – 12:00 PM
Part 2: 1:00 PM – 3:00 PM

1. Overview – Instructor only
    - Introduction to the Bridge Explorer (Visual Reference)
    - Review the Bridge Workspace tree
    - On-line help and manuals
    - Review STL2
    - Output
2. Libraries (LIB1, Hands-on)
3. Two-Span Steel Plate Girder Example (STL2, Hands-on)
4. Simple Span Prestressed I Beam Example (PS1, Hands-on)
5. Available Help and Training (HLP1)

Introducing BrDR Environment

Guide to Using BrDR 7.5.1

Getting Started

AASHTOWare Bridge Design and Rating Overview

What is AASHTOWare Bridge Design and Rating?

AASHTOWare Bridge Design and Rating is a software package that aids in the design and load rating of bridges. The software includes the applications BrD (Bridge Design) and BrR (Bridge Rating) with analytical engines that support AASHTO ASR/LFR and LRFD/LRFR. Additional engines are available through third party developers.

BrR

BrR (Bridge Rating) is used for a variety of bridge superstructure and culvert load rating. The application features a graphical user interface that aid in the preparation of the data and application of the results. Using the AASHTO ASR/LFR/LRFR as its analytical engine for load rating, BrR provides an integrated database where rating inputs and outputs can readily be stored, reviewed, and reused.

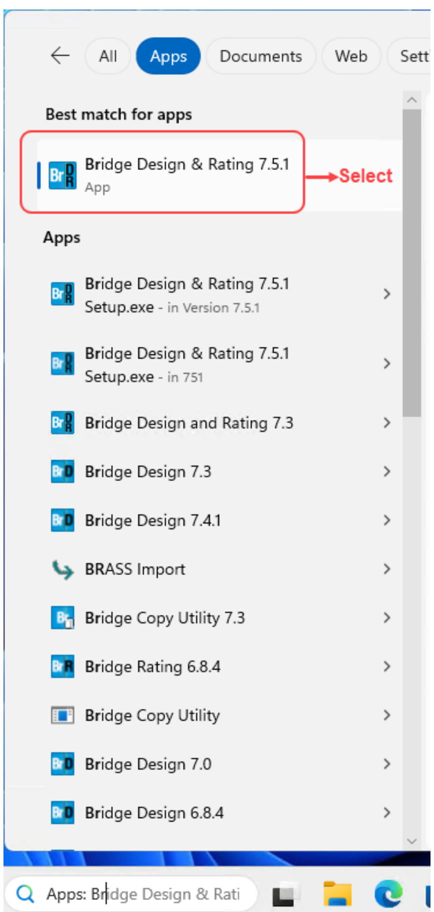
BrD

BrD (Bridge Design) is a bridge superstructure, substructure and culvert design software product using the AASHTO Load and Resistance Factor Design (LRFD) Bridge Specifications. BrD employs the same database and graphical user interface as BrR, and shares much of the same source code. Development of both products began in 1997. The AASHTO LRFD Engine provides the system's structural analysis and specification checking engines.

Starting AASHTOWare Bridge Design and Rating – Version 7.5.1

From the Desktop

The AASHTOWare Bridge Design and Rating software may be accessed through the desktop icon (see figure to the right). Using the BrDR icon provides the features of both BrD and BrR in one environment.

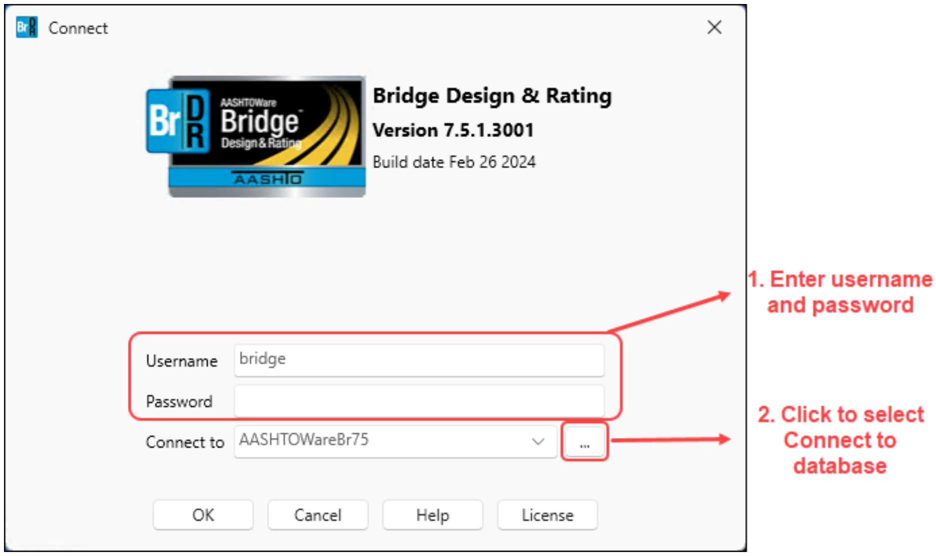


From the Start Menu

The software may also be accessed from the start menu if the icons are not in the desktop.

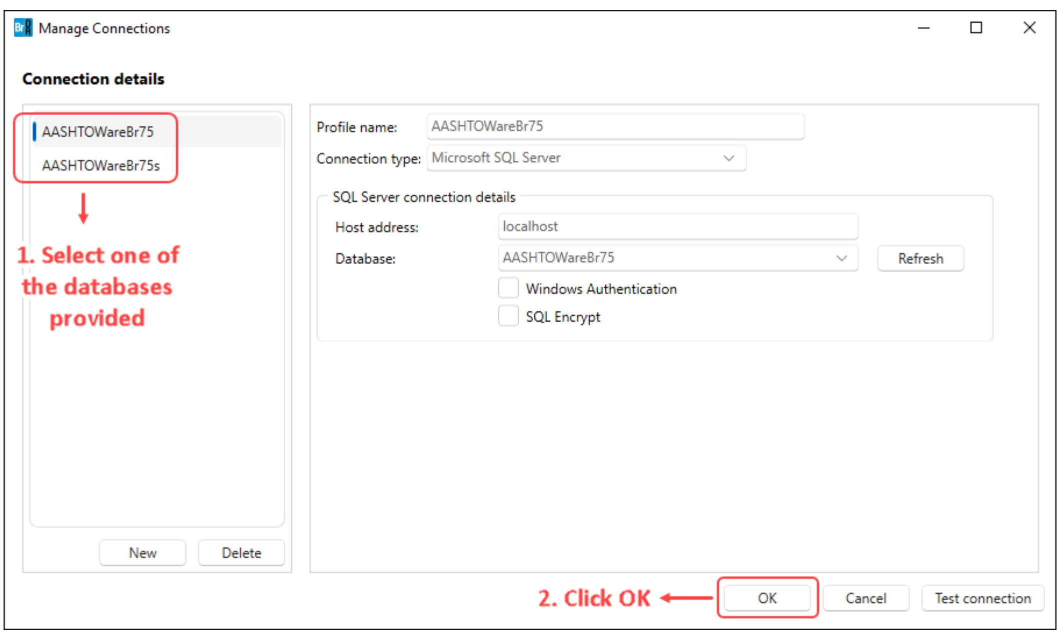
Entering Username and Password

Once initiated, the AASHTOWare Bridge Design and Rating **Connect** window will pop up. Enter the username and password in the provided fields. To connect to a different database, or if **Connect to** field is empty, click on the ellipsis button (**…**)



Connecting to the Database

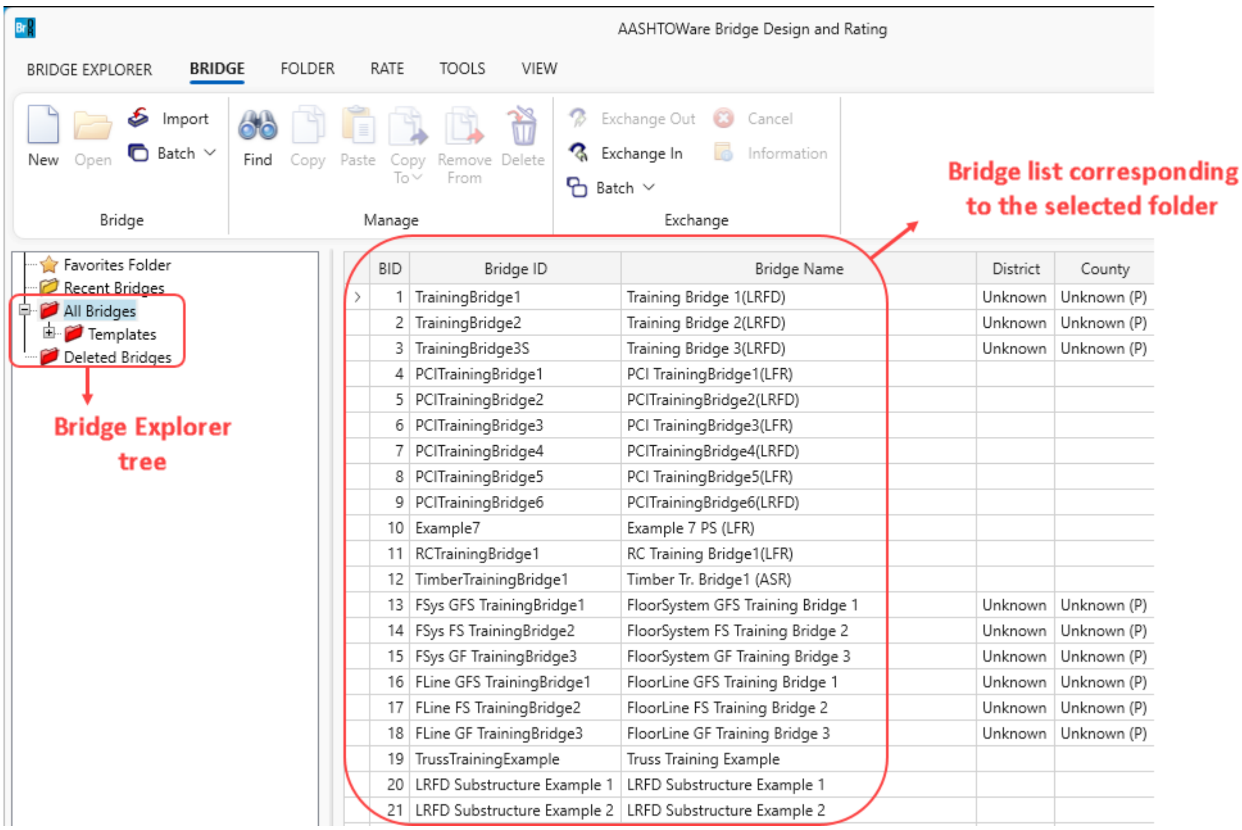
Once in the **Manage Connections** window, follow the instructions in the figure below.



AASHTOWare Bridge Design and Rating Basics

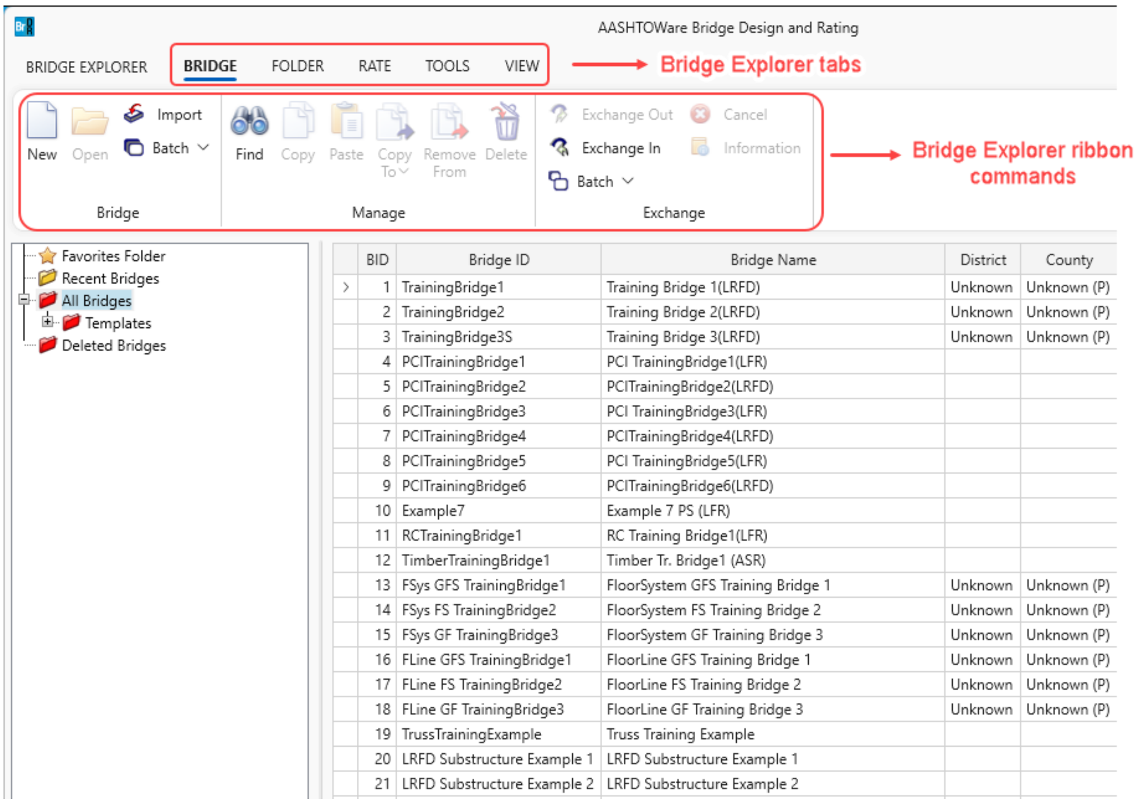
AASHTOWare Bridge Design and Rating Environment Tour

Once successfully connected, the **Bridge Explorer** opens. The **Bridge Explorer** allows the entry of new bridge information into BrD/BrR or access existing bridge information. The left portion of the **Bridge Explorer** contains a tree. Each tree item includes a button, a folder and a name. The right portion of the **Bridge Explorer** presents a complete list of the bridges corresponding to the folder selected on the tree.



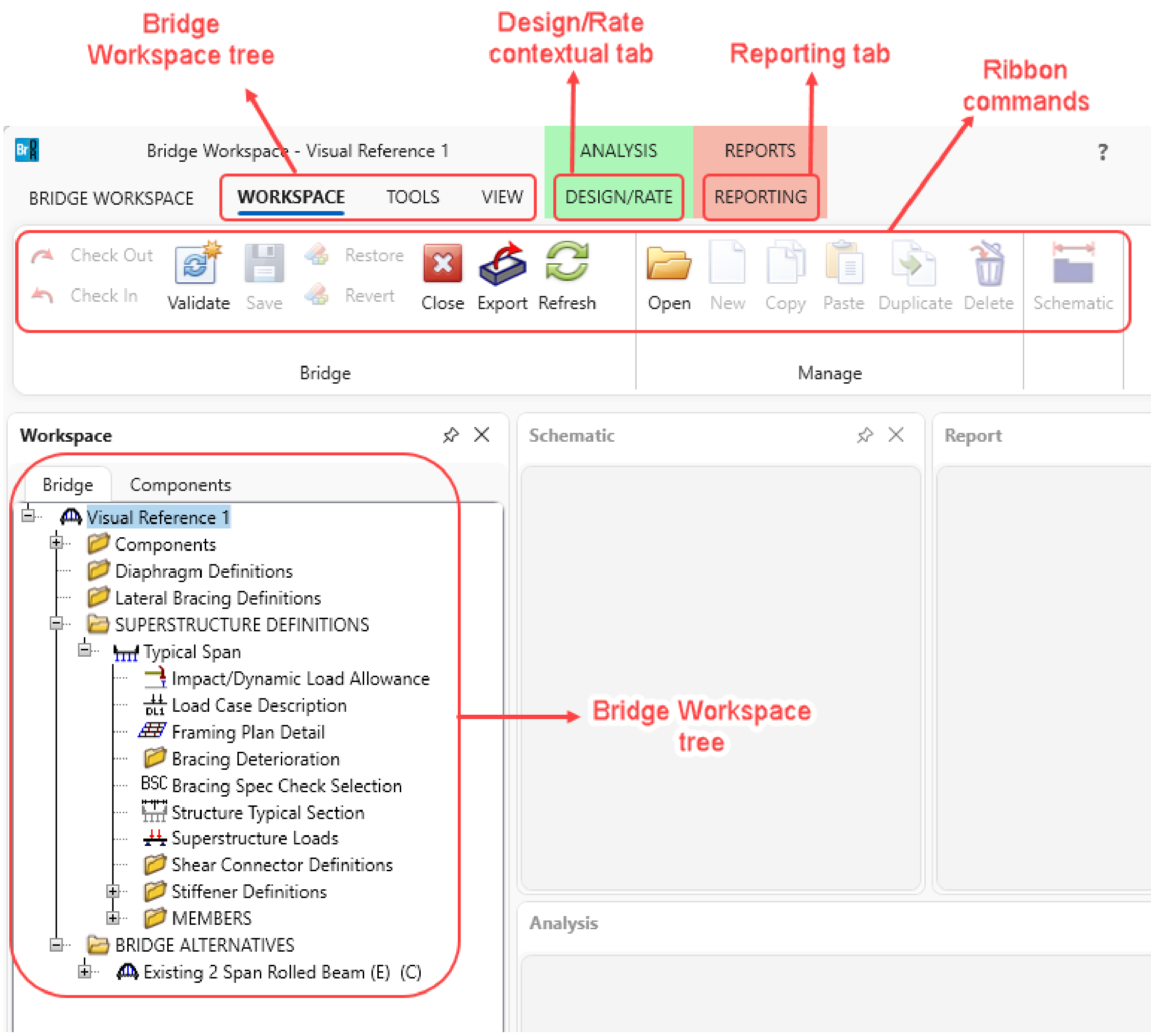
AASHTOWare Bridge Design and Rating Environment Overview

Bridge Explorer Window



AASHTOWare Bridge Design and Rating Environment Overview

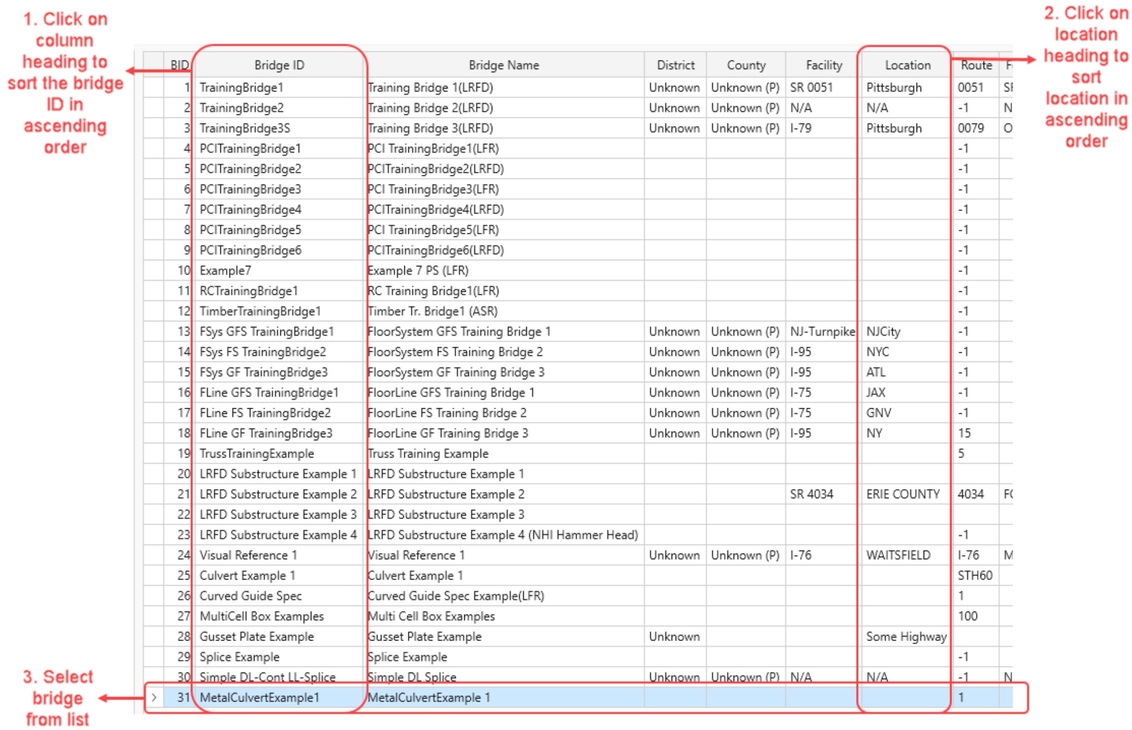
Bridge Workspace Window



Bridge Explorer Window

Sorting the Bridge List

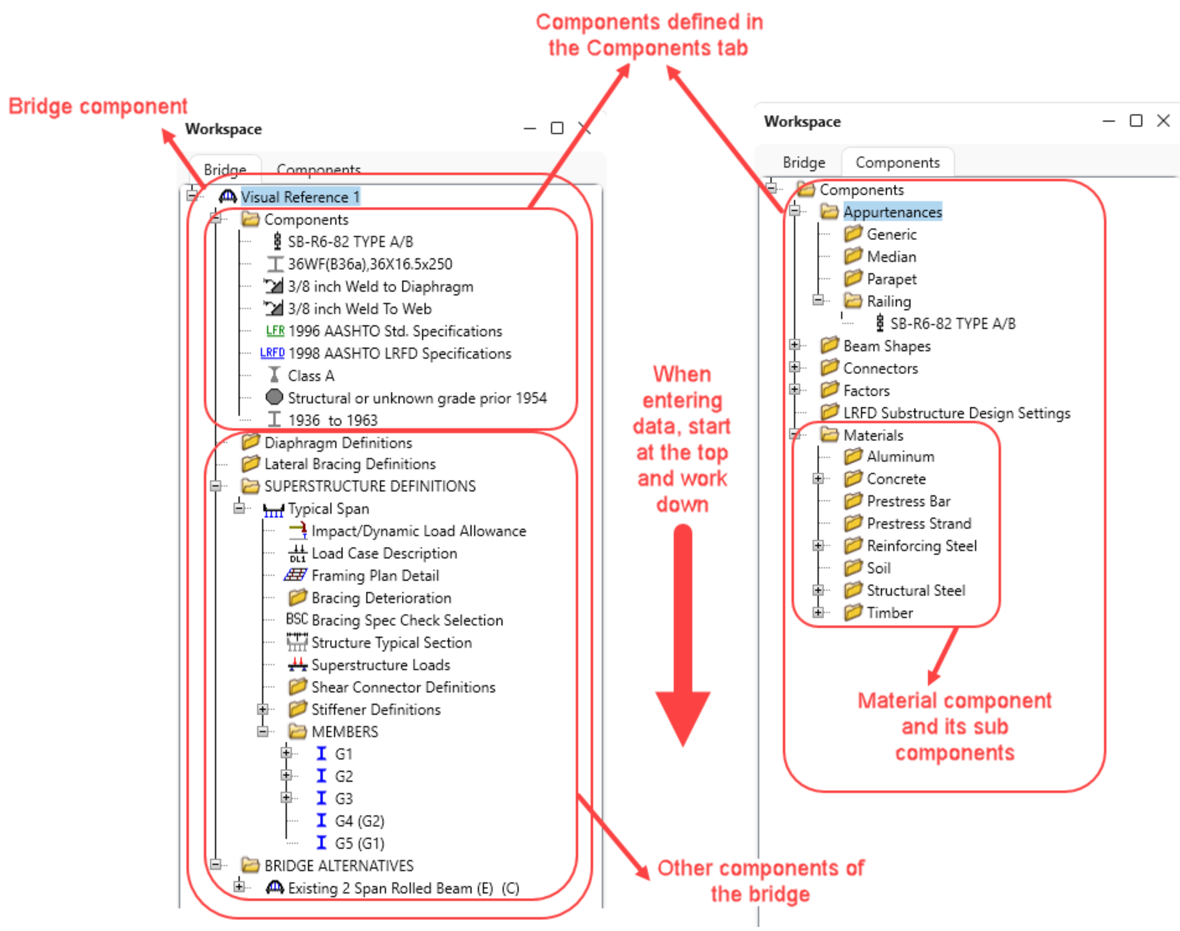
Once a folder is selected to find a bridge, the corresponding bridge list may be sorted to make the search easier. Sorting the bridge list requires double clicking on a column heading. The first time this is done, it will sort alphabetically in ascending order. Double clicking again will result in a descending sort. This sorting works for all the columns in the Bridge Explorer.



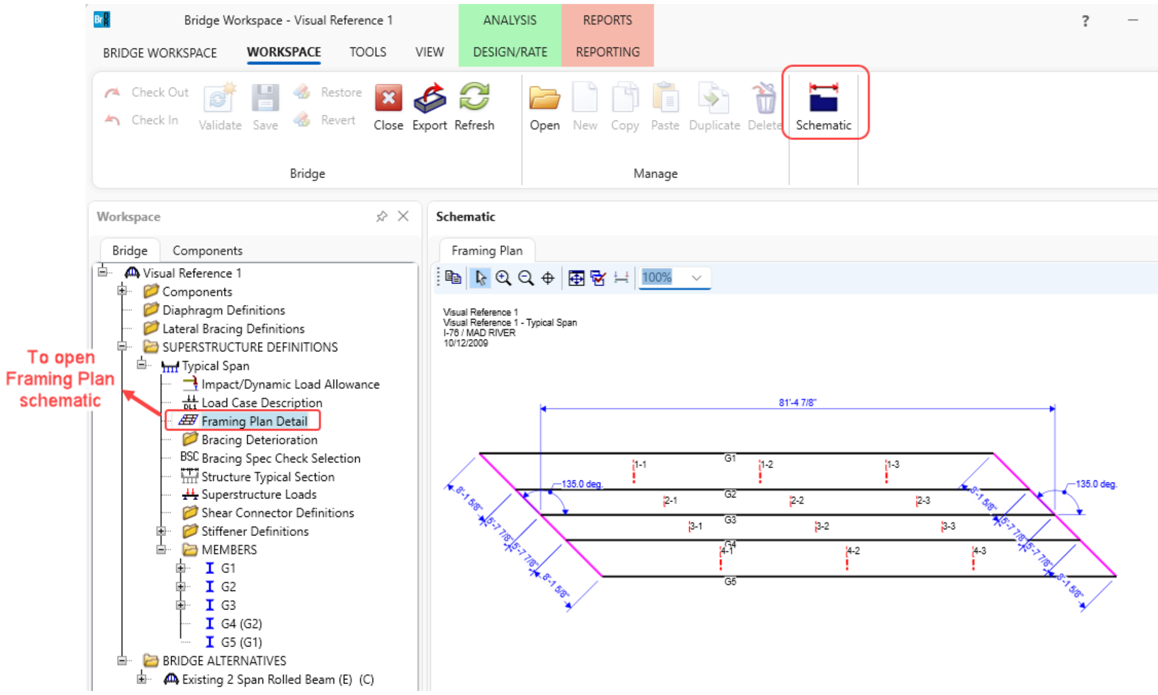
BID	Bridge ID	Bridge Name	District	County	Facility	Location	Route	F
1	TrainingBridge1	Training Bridge 1(LRFD)	Unknown	Unknown (P)	SR 0051	Pittsburgh	0051	S
2	TrainingBridge2	Training Bridge 2(LRFD)	Unknown	Unknown (P)	N/A	N/A	-1	N
3	TrainingBridge3S	Training Bridge 3(LRFD)	Unknown	Unknown (P)	I-79	Pittsburgh	0079	O
4	PCITrainingBridge1	PCI TrainingBridge1(LFR)					-1	
5	PCITrainingBridge2	PCITrainingBridge2(LRFD)					-1	
6	PCITrainingBridge3	PCI TrainingBridge3(LFR)					-1	
7	PCITrainingBridge4	PCITrainingBridge4(LRFD)					-1	
8	PCITrainingBridge5	PCI TrainingBridge5(LFR)					-1	
9	PCITrainingBridge6	PCITrainingBridge6(LRFD)					-1	
10	Example7	Example 7 PS (LFR)					-1	
11	RCTrainingBridge1	RC Training Bridge1(LFR)					-1	
12	TimberTrainingBridge1	Timber Tr. Bridge1 (ASR)					-1	
13	FSys GFS TrainingBridge1	FloorSystem GFS Training Bridge 1	Unknown	Unknown (P)	NJ-Turnpike	NJCity	-1	
14	FSys FS TrainingBridge2	FloorSystem FS Training Bridge 2	Unknown	Unknown (P)	I-95	NYC	-1	
15	FSys GF TrainingBridge3	FloorSystem GF Training Bridge 3	Unknown	Unknown (P)	I-95	ATL	-1	
16	FLine GFS TrainingBridge1	FloorLine GFS Training Bridge 1	Unknown	Unknown (P)	I-75	JAX	-1	
17	FLine FS TrainingBridge2	FloorLine FS Training Bridge 2	Unknown	Unknown (P)	I-75	GNV	-1	
18	FLine GF TrainingBridge3	FloorLine GF Training Bridge 3	Unknown	Unknown (P)	I-95	NY	15	
19	TrussTrainingExample	Truss Training Example					5	
20	LRFD Substructure Example 1	LRFD Substructure Example 1						
21	LRFD Substructure Example 2	LRFD Substructure Example 2			SR 4034	ERIE COUNTY	4034	F
22	LRFD Substructure Example 3	LRFD Substructure Example 3						
23	LRFD Substructure Example 4	LRFD Substructure Example 4 (NHI Hammer Head)					-1	
24	Visual Reference 1	Visual Reference 1	Unknown	Unknown (P)	I-76	WAITSFIELD	I-76	M
25	Culvert Example 1	Culvert Example 1					STH60	
26	Curved Guide Spec	Curved Guide Spec Example(LFR)					1	
27	MultiCell Box Examples	Multi Cell Box Examples					100	
28	Gusset Plate Example	Gusset Plate Example	Unknown			Some Highway		
29	Splice Example	Splice Example					-1	
30	Simple DL-Cont LL-Splice	Simple DL Splice	Unknown	Unknown (P)	N/A	N/A	-1	N
31	MetalCulvertExample1	MetalCulvertExample 1					1	

Double-clicking on a bridge from the bridge list opens the **Bridge Workspace**. The **Bridge Workspace** houses multiple docked panels namely **Workspace**, **Schematic**, **Report** and **Analysis**. These panels can be docked, undocked, moved, or resized.

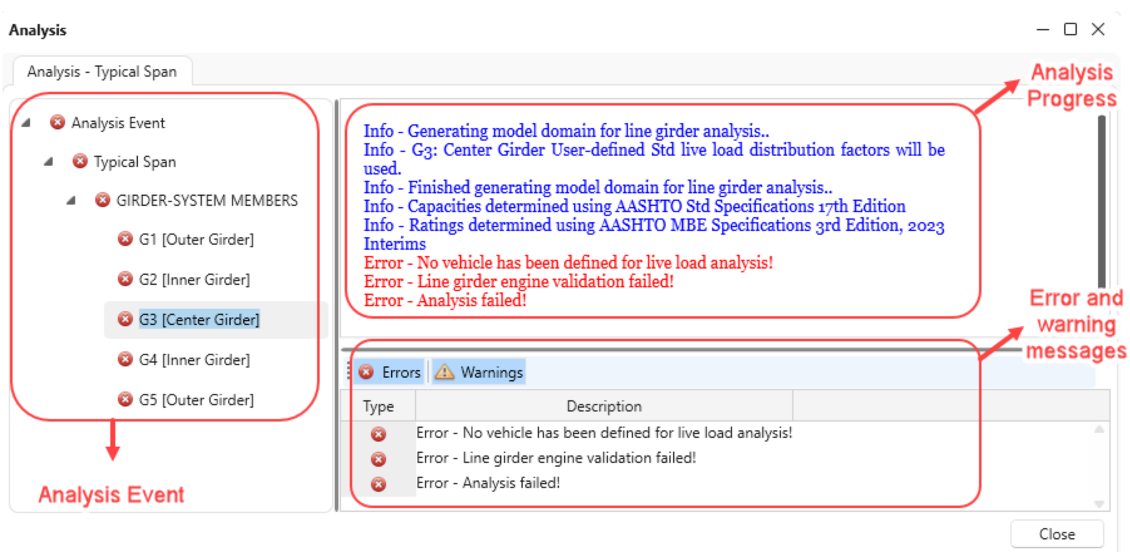
The **Workspace** window consists of **Bridge** and **Components** tab. The tree in these tabs work like the File Explorer file tree, except that instead of sorting files and folders, these tabs sort out different components of a bridge. The components include the items the bridge uses, girders or beams, and deck to name a few. The **Components** folder consists of all the items defined in the **Components** tab. Each major component has components unto itself. The **Materials** component of the **Components** tab, for example, is broken down into **Structural** and **Reinforcing Steel**, **Concrete**, **Prestress Strand/Bar**, **Soil** and **Timber**. These separate divisions are again broken down to the different materials of that division's type. For example, under Concrete, there may be a description for concrete class A, B and C.



The schematics of various items in **Bridge Workspace** can be viewed in the **Schematic** window. To view a schematic, highlight the item on the **Bridge Workspace** tree and click on the **Schematic** button on **WORKSPACE** tab.

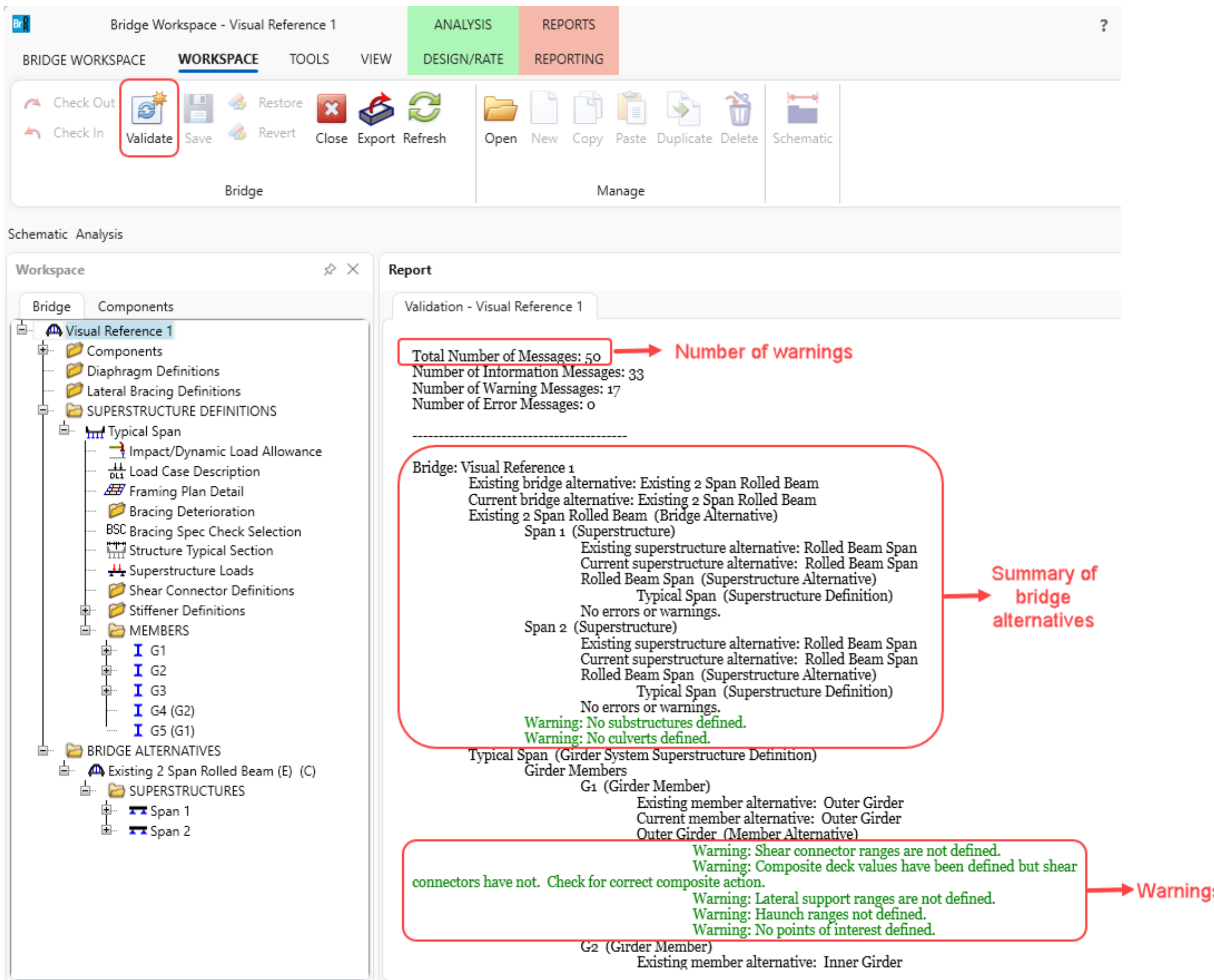


The **Analysis** Window of **Bridge Workspace** has panels to display the analysis event, analysis progress, and error/warning messages. The analysis progress and the error/warning messages displayed are corresponding to the highlighted item in the Analysis Event panel.



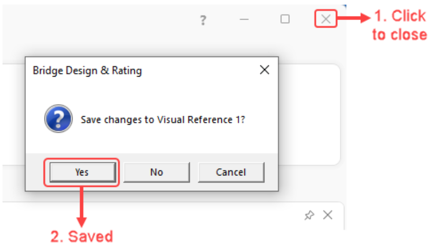
Checking Data Integrity

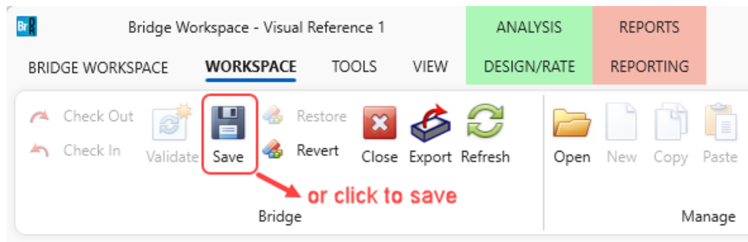
After completing data entry for a bridge, the next step is to check the data for missing components. In some cases, this may not be necessary, but in general practice, it is always good to ensure all the data is entered for bridge design or rating. To run the check, click on the **Validate** button from the **WORKSPACE** tab. The **Validation** tab will appear on the **Report** Window. This window will provide a summary of the bridge data that has been entered. It will also list a series of warnings regarding the data. If something is missing, it will be listed here. Use this as a guide to ensure data entry is complete.

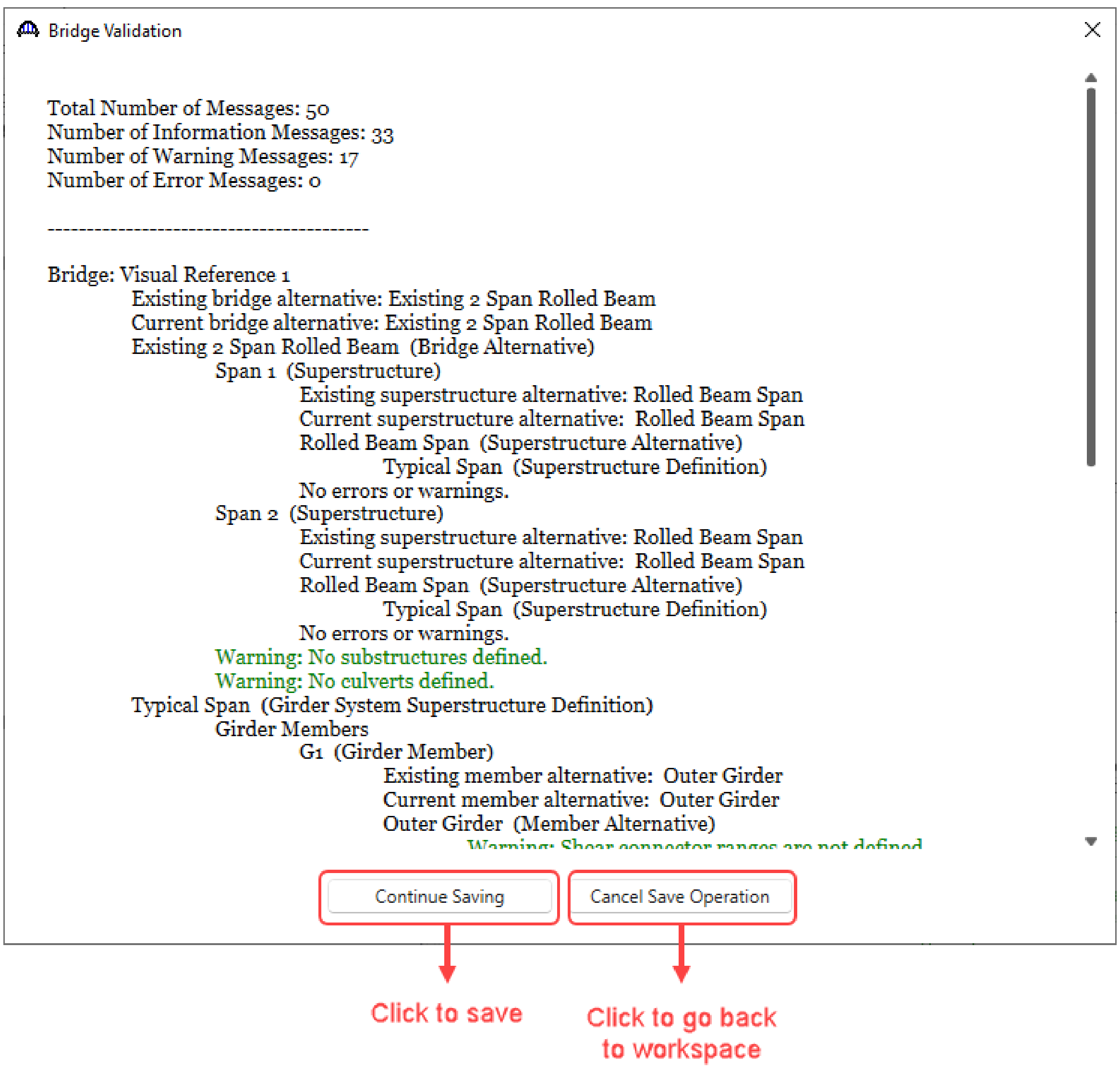


Saving the Bridge Data

Once the data has been entered and verified, click on the **Save** button from the **WORKSPACE** tab to save the data. If the bridge workspace is closed before saving, AASHTOWare Bridge Design and Rating will prompt to save the data. Before saving, AASHTOWare Bridge Design and Rating will validate the data and ask if you want to continue.







AASHTOWare BrDR 7.5.1

Library Tutorial

LIB1 - Libraries

LIB1 – Libraries

Library Concepts

The libraries of BrDR allow for the description of items that are standardized or used frequently in the description of a bridge or by analysis events. The libraries of BrDR currently define the following items:

- Appurtenances (parapets, medians, railings, etc.)
- Connectors (bolts, nails)
- Corrugated Metal Panel
- Factors
- LRFD DF Applicability Ranges
- LRFD Substructure Design Settings
- Materials (steel, concrete, etc.)
- Metal Box Culvert
- Metal Pipe Culvert (corrugated, spiral rib, structural plate)
- Prestress Shapes
- Steel Shapes
- Timber Shapes
- Vehicles

BrDR is pre-loaded with library items selected by AASHTO. These items were taken from various sources including the following:

- *AASHTO LRFD Bridge Design Specifications*
- *AASHTO Manual for Bridge Evaluation*
- *AASHTO Standard Specifications for Highway Bridges*
- *AASHTO Standard Specifications for Transportation Materials*
- *AISC Manual of Steel Construction*
- *PCI Precast Prestressed Concrete Bridge Design Manual*

Library Types

Three types of library items:

Standard Items added to database by AASHTO. Standard library items are not editable.

Agency All items added to the library by a user.

User Defined Only available for vehicles.

Using Library Data

Two methods to use library items:

Linking Library item associated with a bridge component or analysis event. If the library item is modified, then the updated data is used by the bridge component or analysis event. (Factors, Vehicles, LRFD DF Applicability Ranges)

Copying Data from library item copied from a library item to a bridge item. A change in the library item has no effect on bridge items that use data previously copied from library item. (Steel Shapes, PS Shapes, Timber Shapes, Factors, LRFD Substructure Design Settings, Materials, Appurtenances, Connections, Corrugated Metal Panel)

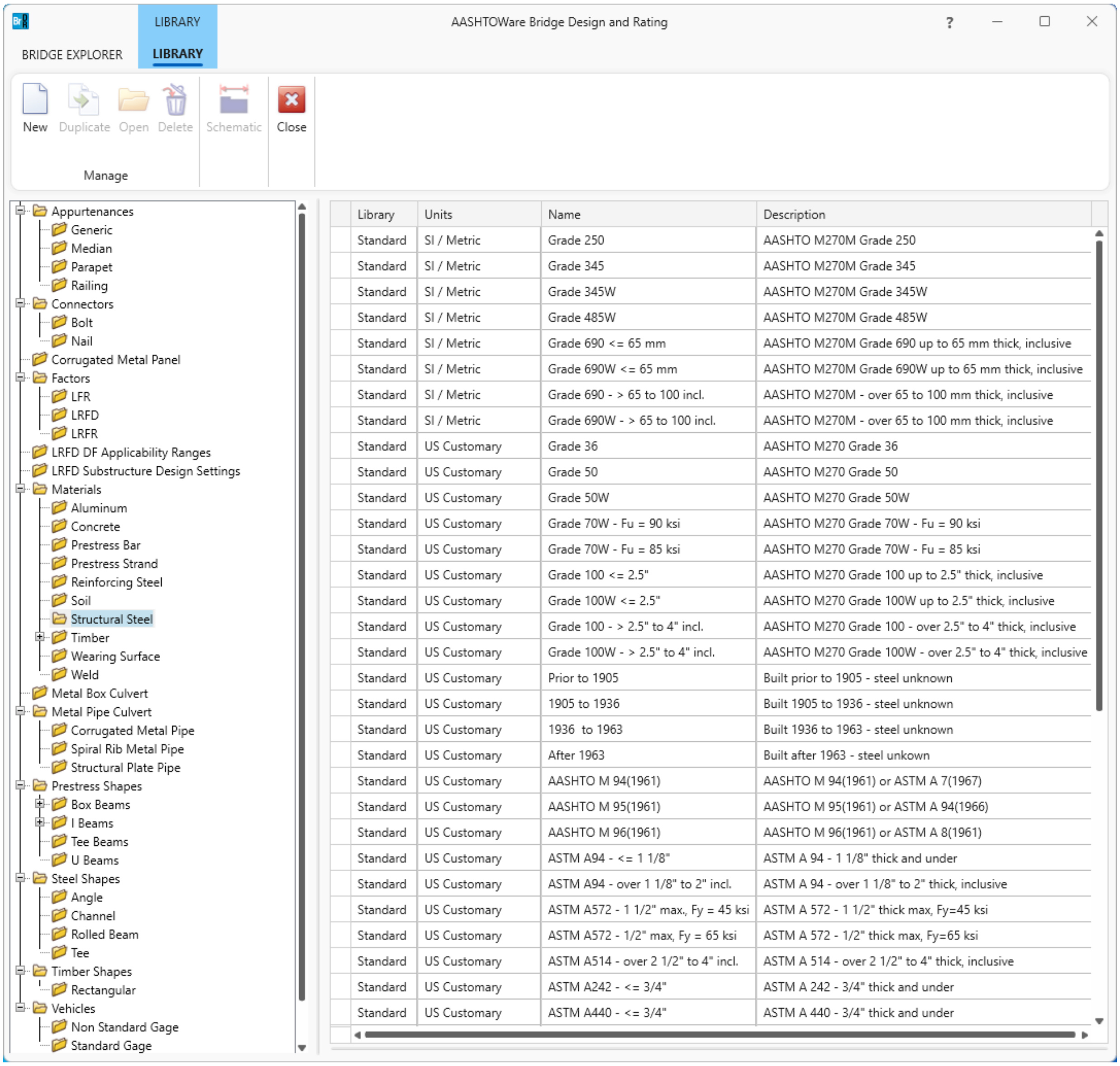
Linking is used to reduce amount of data stored in database for items that are unlikely to be modified.

Library Security

- Library access can be restricted for read, write, create, and delete access.
- Access restrictions apply to all libraries for a given user or group of users.
- Limit number of users with write, create, and delete access.
    - Reduce possibility of incorrect data.
    - Reduce duplicate items and inappropriate items.

Library Explorer

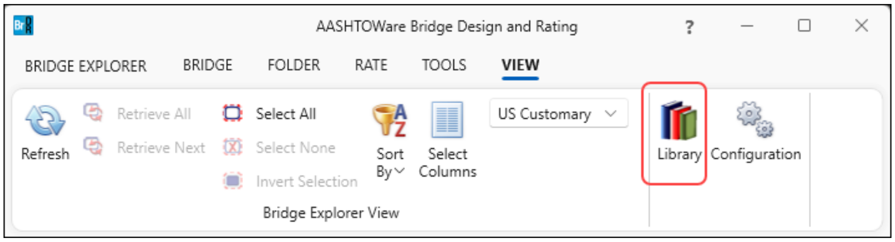
The Library Explorer is used to navigate the various libraries. The tree control in the left pane organizes the libraries. The item selected in the tree control determines the library items to be listed in the right pane of the window.



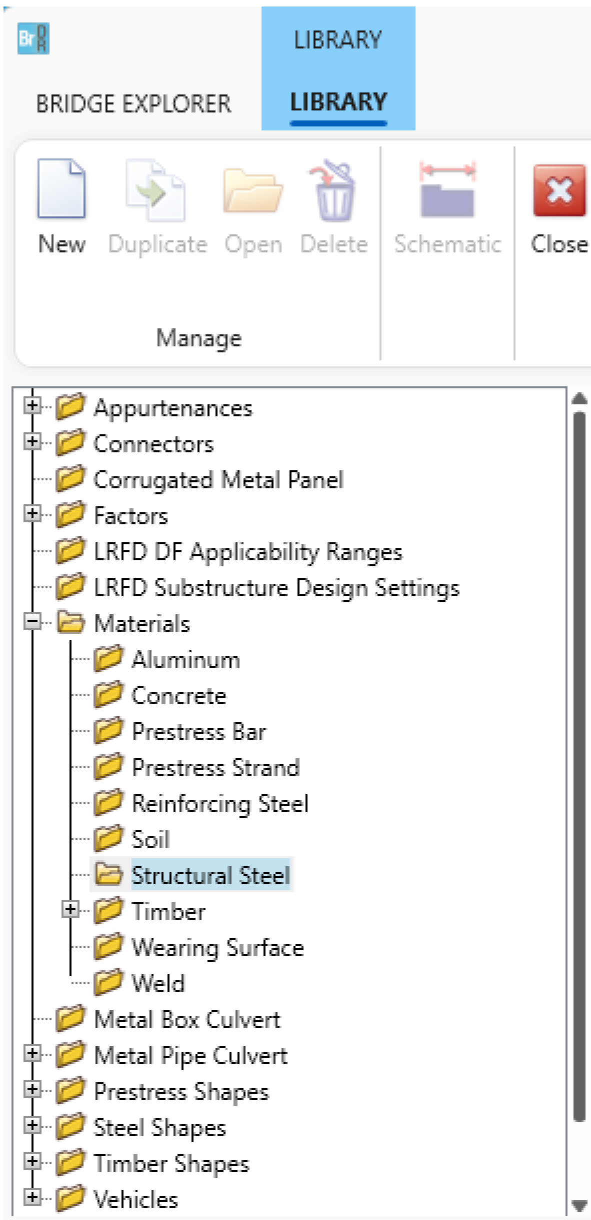
Exercise

Add Steel Material Library Item

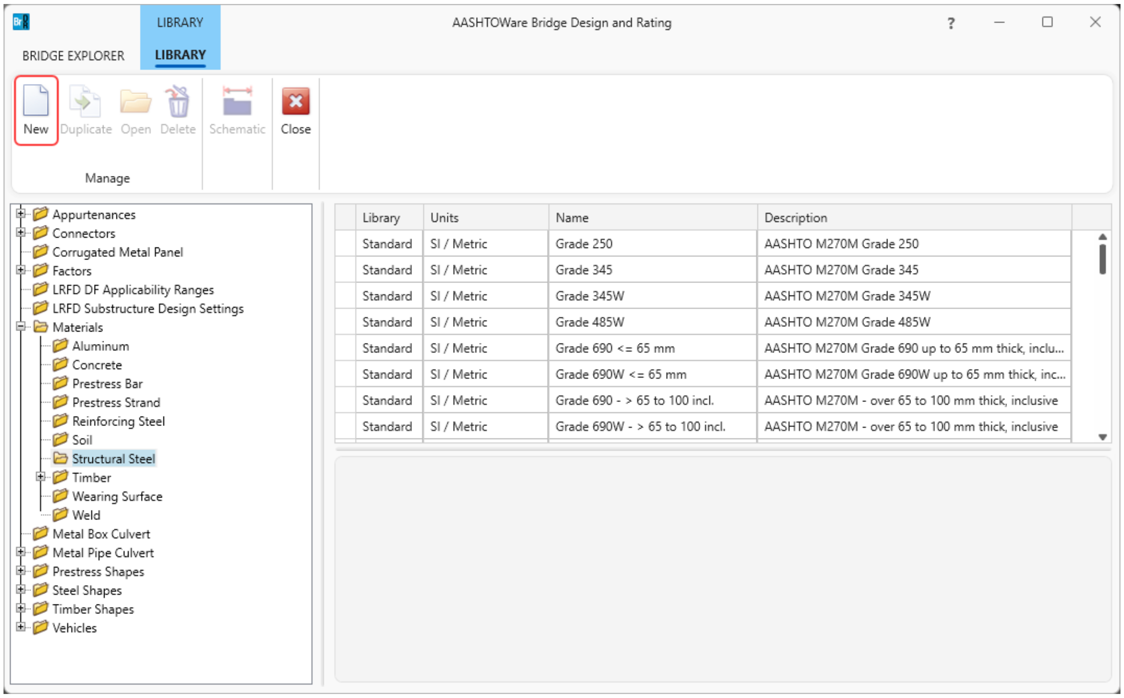
1. Click the **Library** button under the **VIEW** tab in the ribbon.



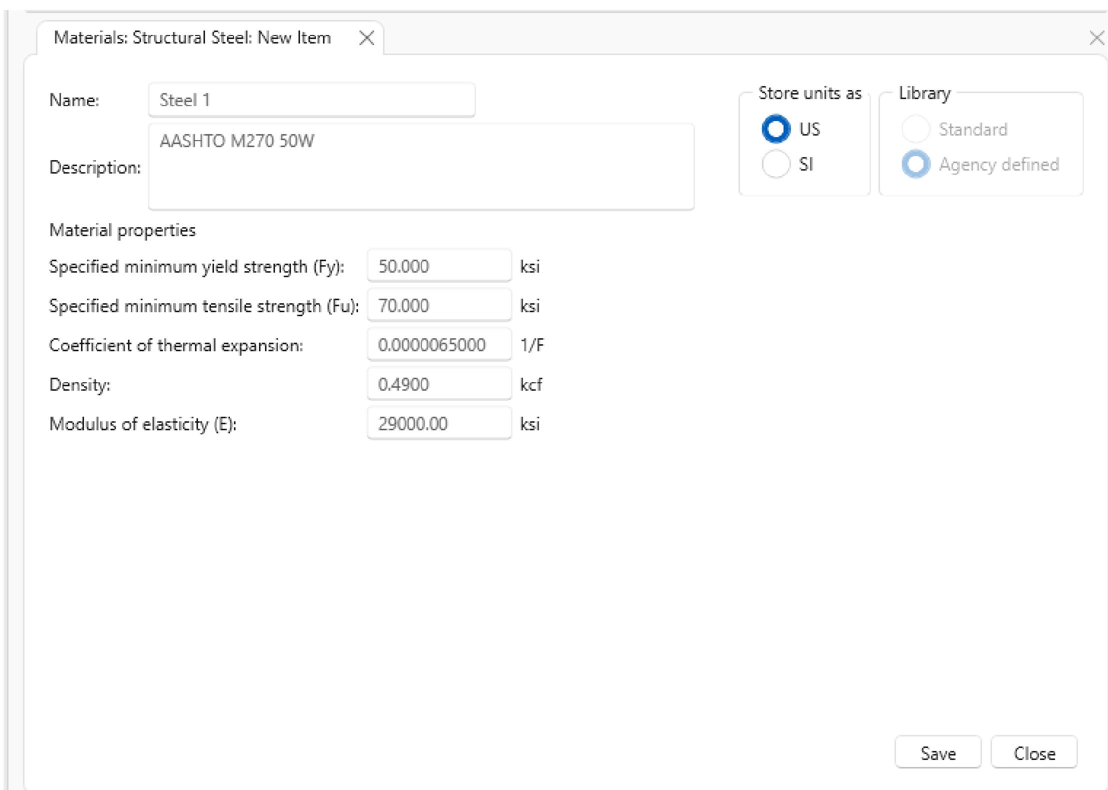
Select the tree item **Materials/Structural Steel** as shown below.



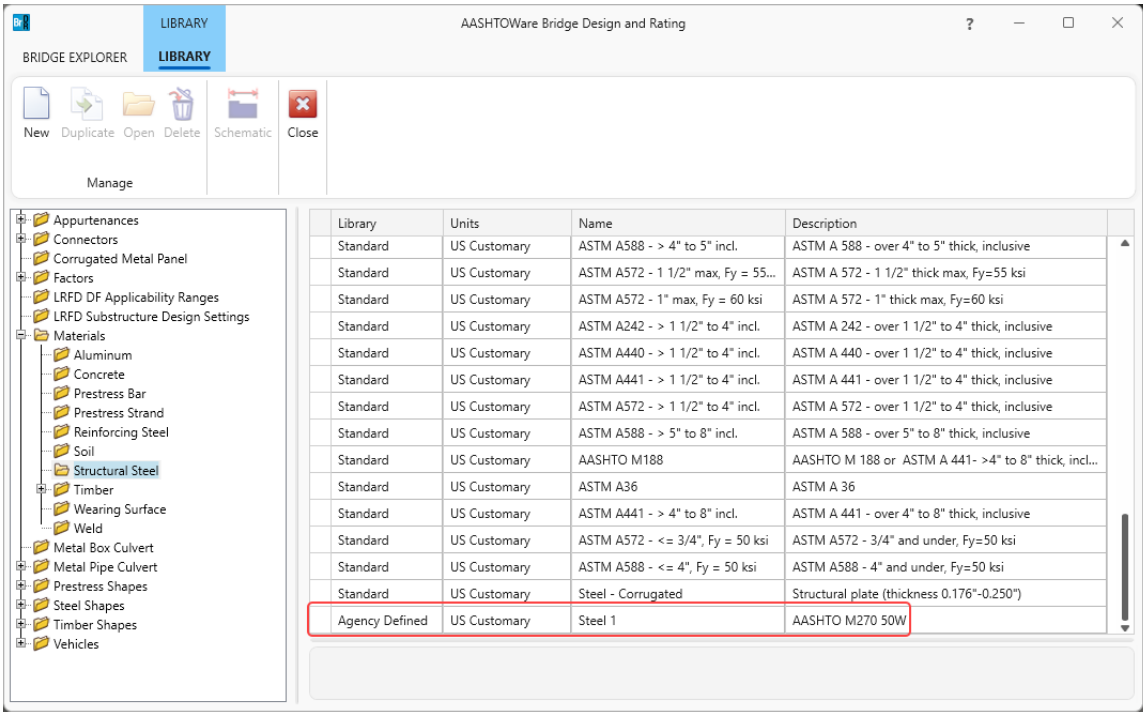
2. Click the **New** button in the ribbon. A **Materials: Structural Steel: New Item** window will appear in the panel below the list of Standard library items.



3. Select the system of units using the radio buttons and then fill in the structural steel information as shown below. Note that the name must be unique among all structural steel library items.

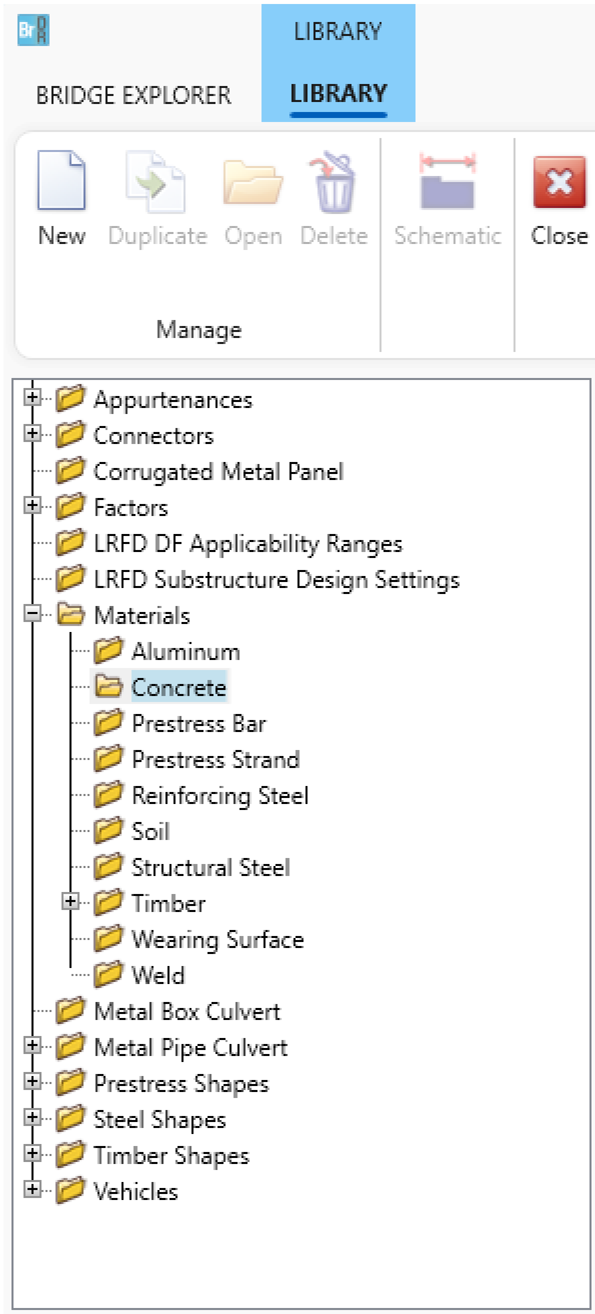


4. Click **Save**. The new structural steel material will now be listed in the right pane of the Library Explorer for the tree items **Materials/Structural Steel** as an Agency Defined item.

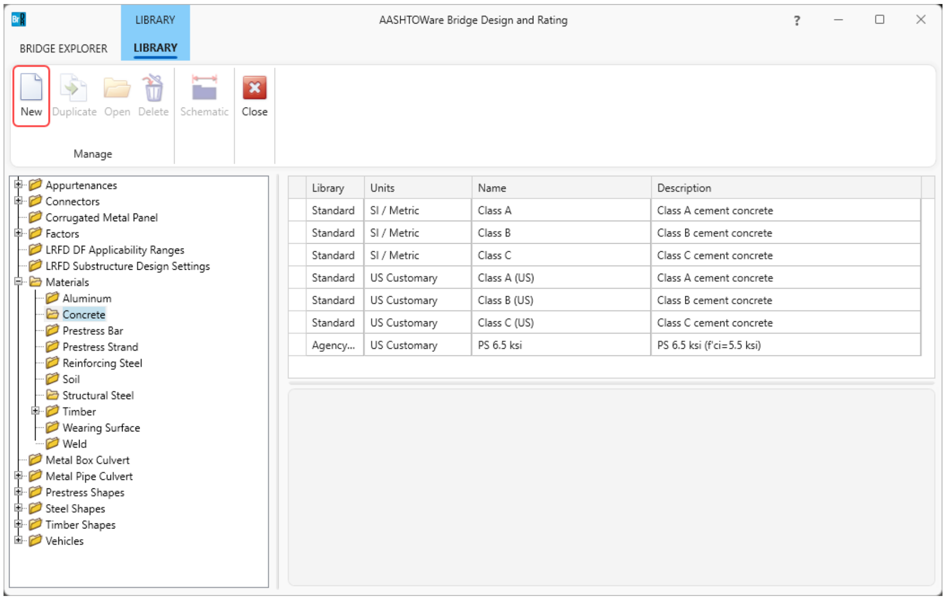


Add Concrete Material Library Item

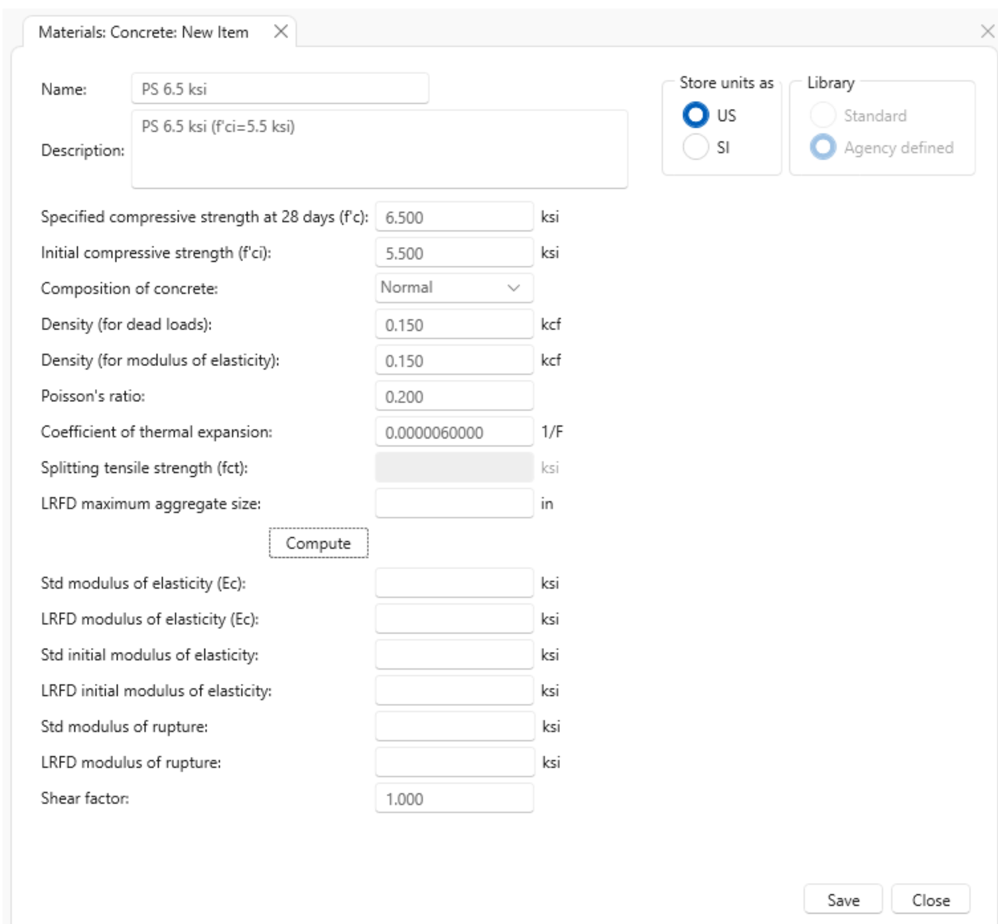
1. Select the tree item **Materials/Concrete** as shown below.



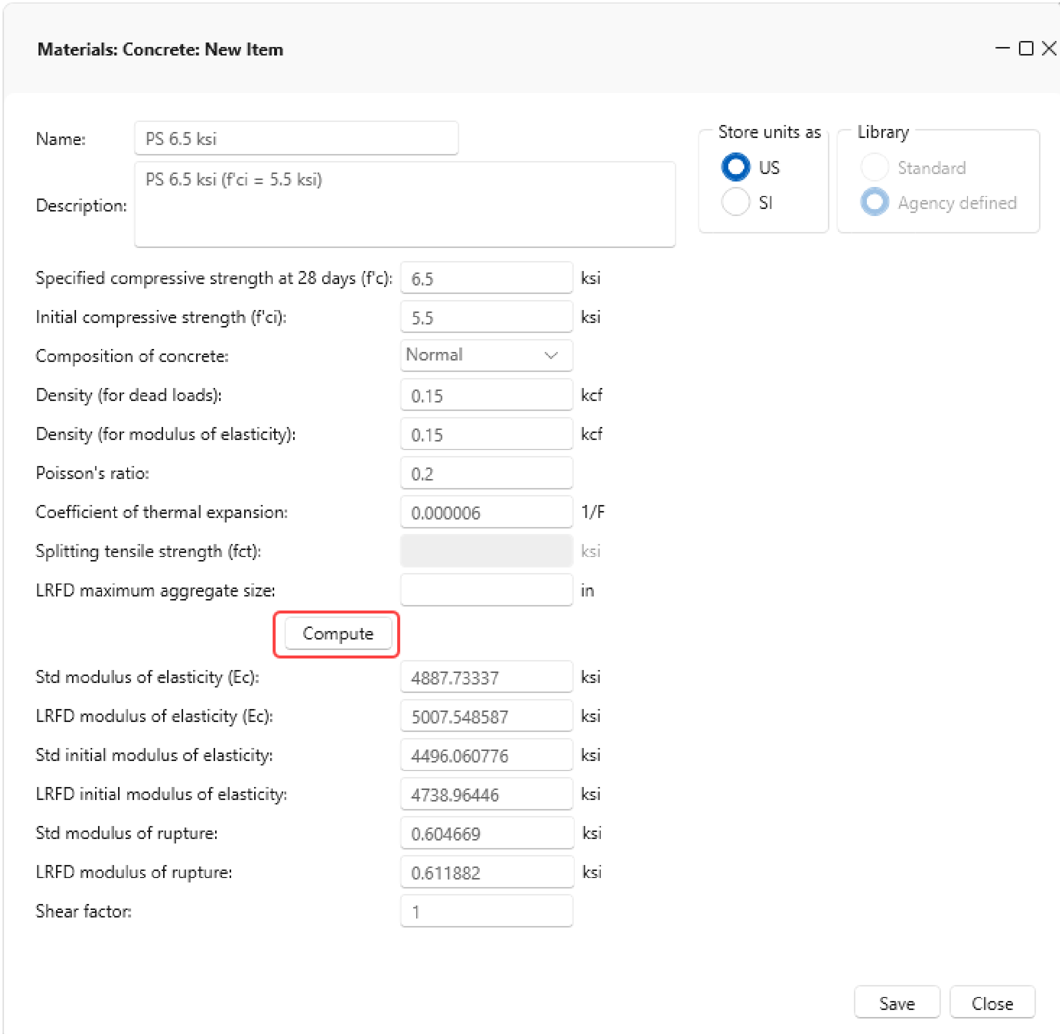
2. Click the **New** button in the ribbon. A **Materials: Concrete: New Item** window will appear in the panel below the list of Standard library items.



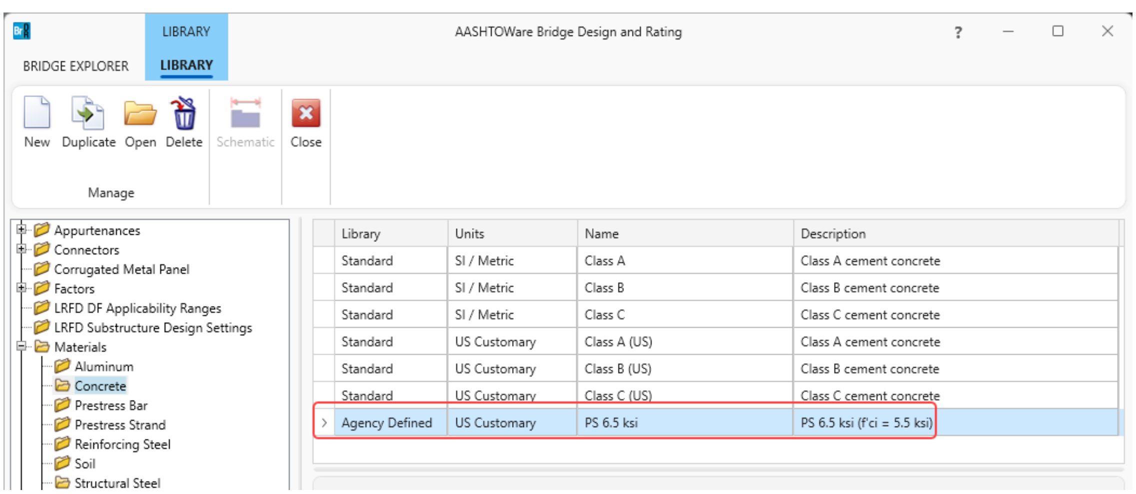
3. Select the system of units using the radio buttons and then fill in the concrete information as shown below. Note that the name must be unique among all concrete library items.



4. Click the **Compute** button to calculate the remaining properties or manually enter the values.

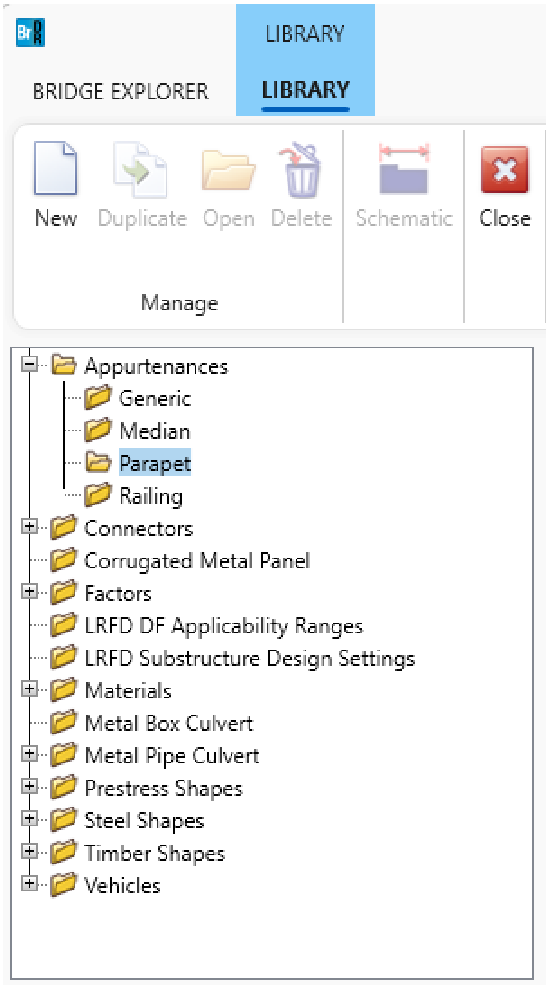


5. Click **Save**. The new concrete material will now be listed in the right pane of the Library Explorer for the tree items **Materials/Concrete** as an Agency Defined item.

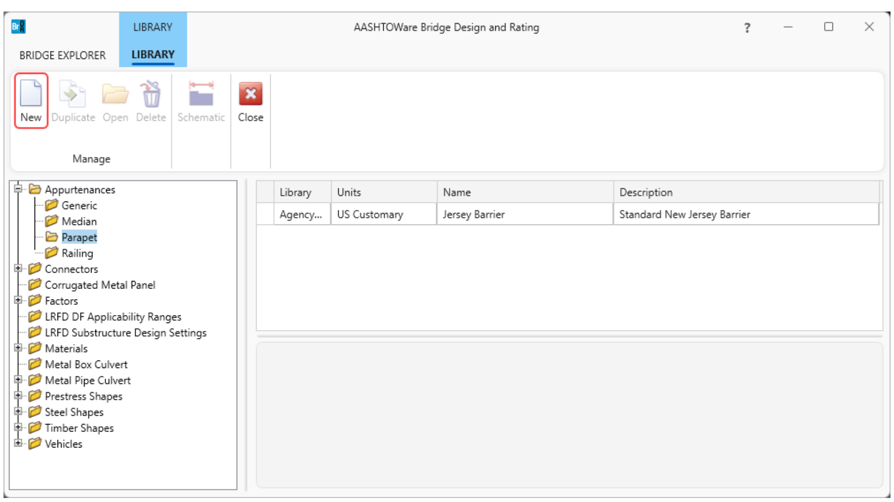


Add Parapet Library Item

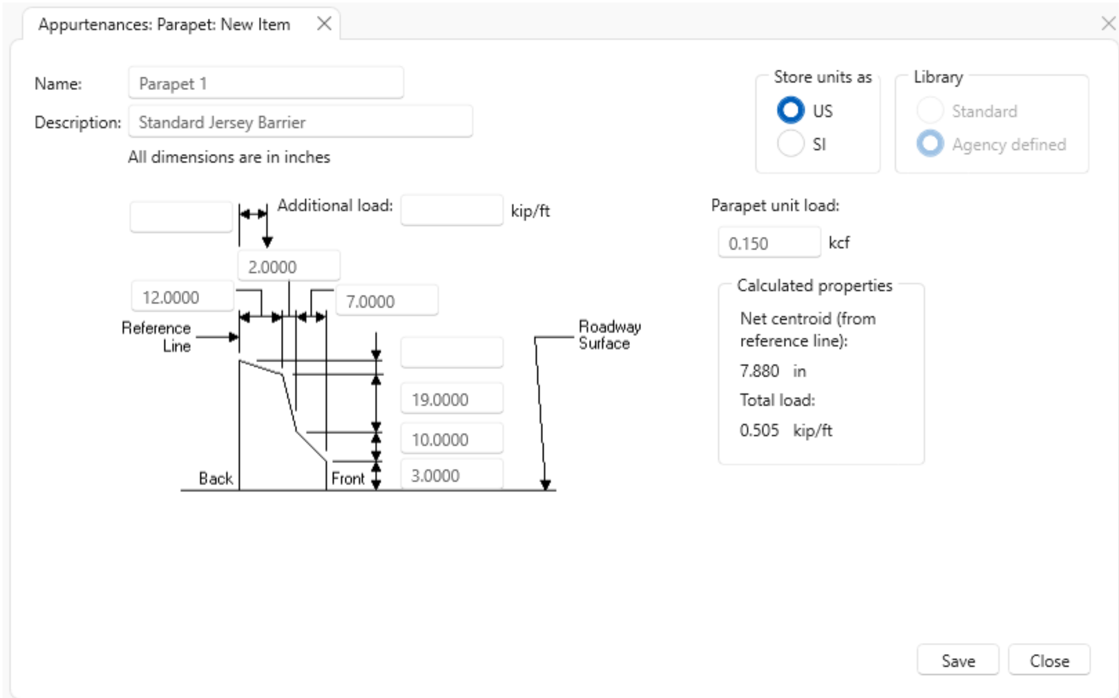
1. Select the tree item **Appurtenances/Parapet** as shown below.



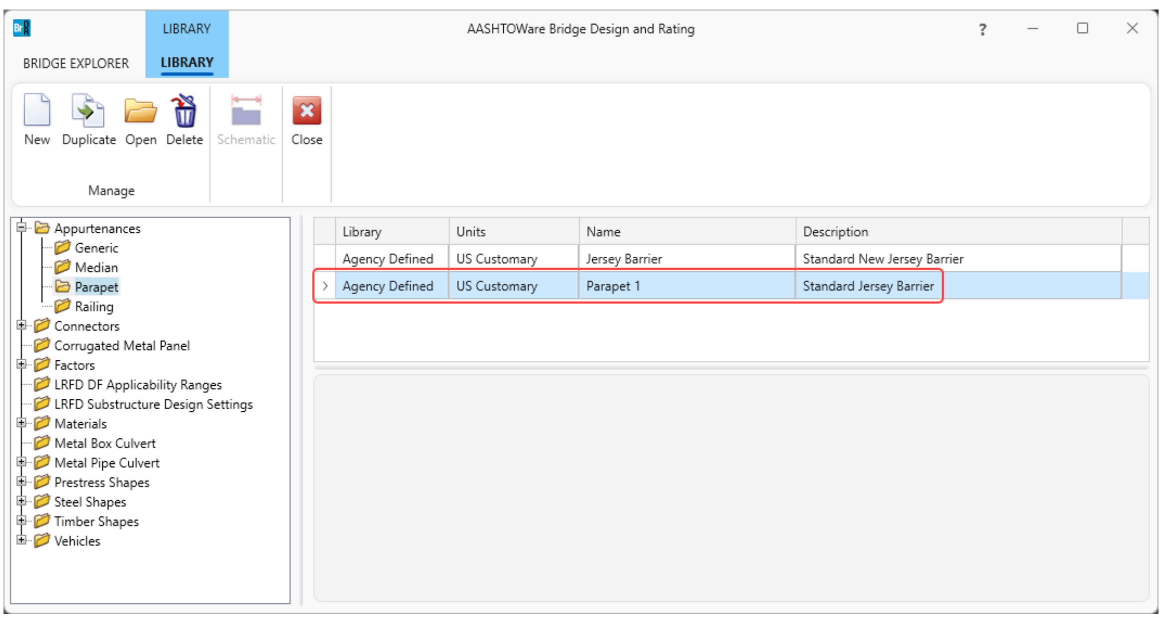
2. Click the **New** button in the ribbon. An **Appurtenances: Parapet: New Item** window will appear in the panel below the list of Standard library items.



3. Select the system of units using the radio buttons and then fill in the parapet information as shown below. Note that the name must be unique among all parapet library items.

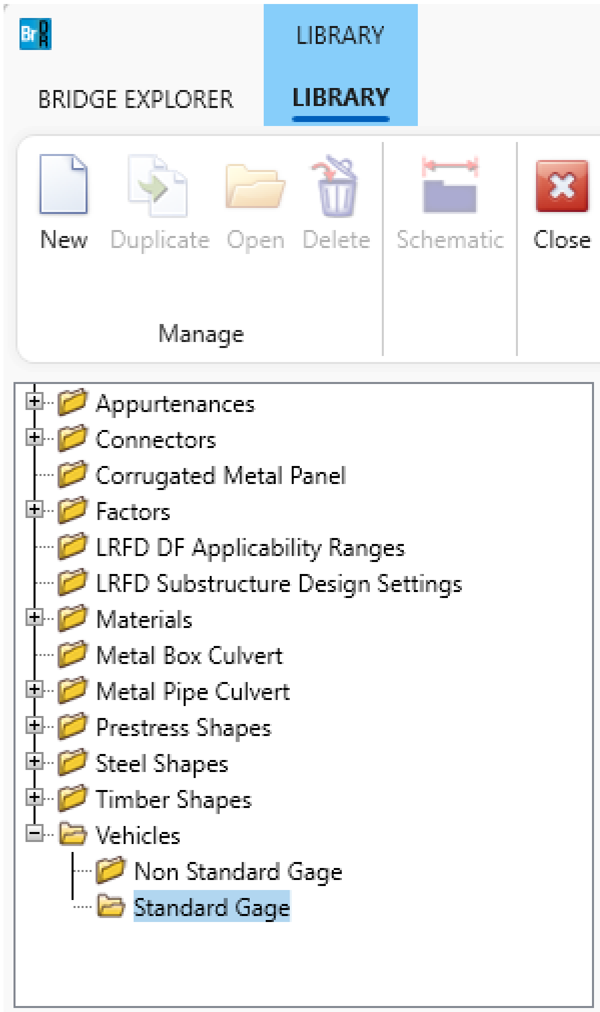


4. Click **Save**. The new parapet will now be listed in the right pane of the Library Explorer for the tree items **Appurtenances/Parapet** as an Agency Defined item.

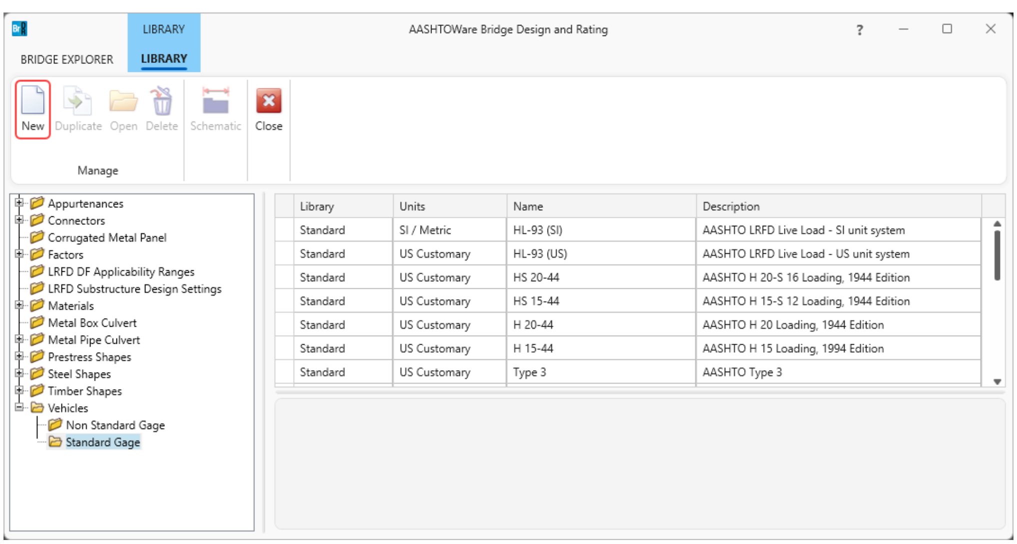


Add Vehicle Library Item

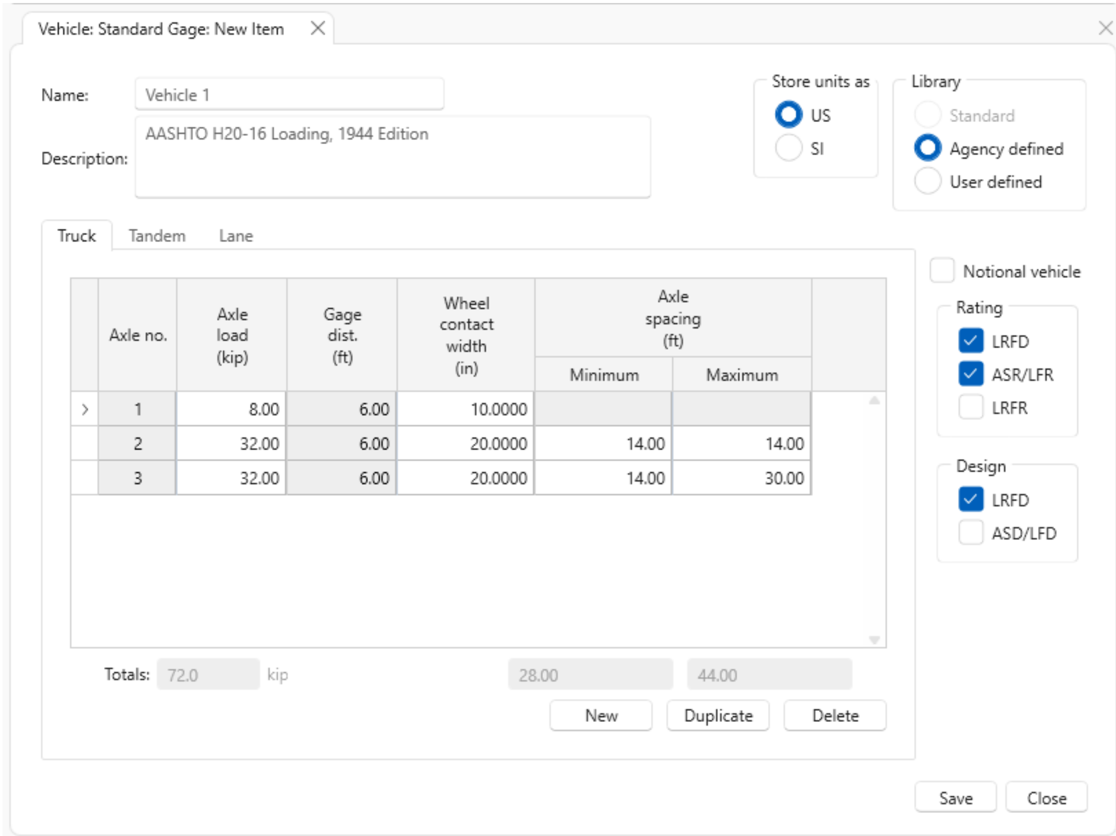
1. Select the tree item **Vehicles/Standard Gage** as shown below.



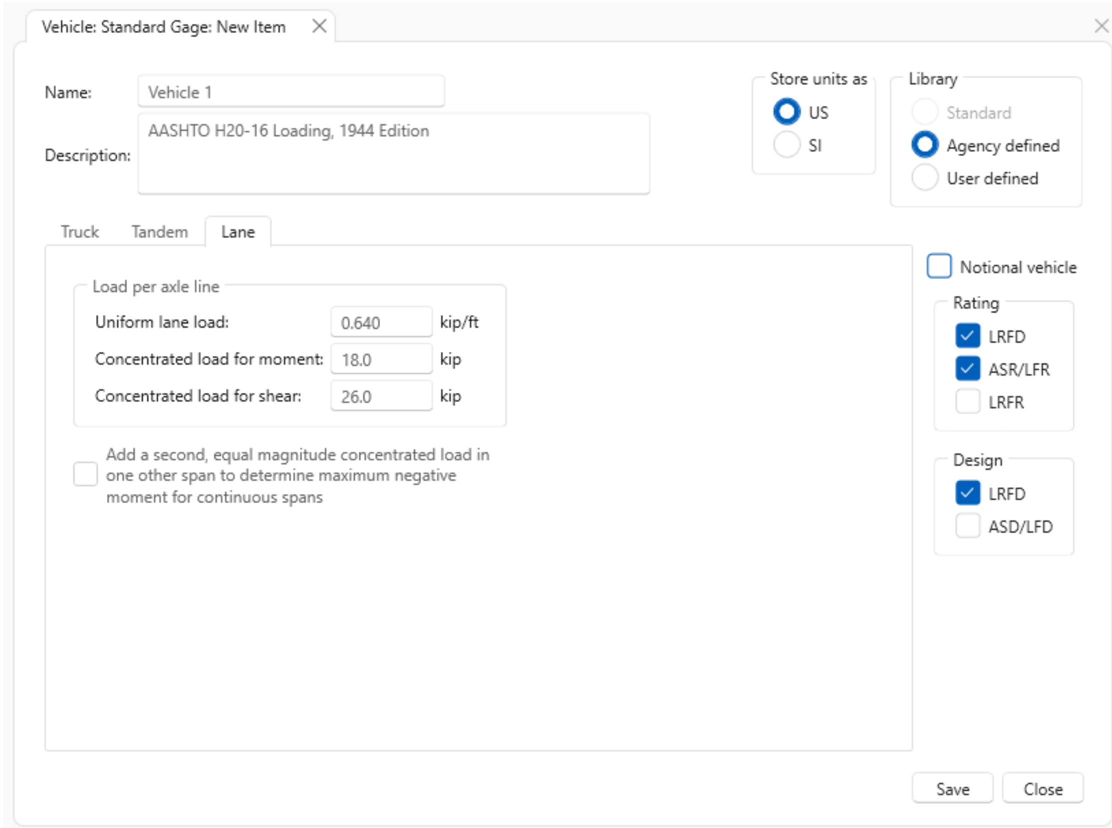
2. Click the **New** button in the ribbon. A **Vehicle: Standard Gage: New Item** window will appear.



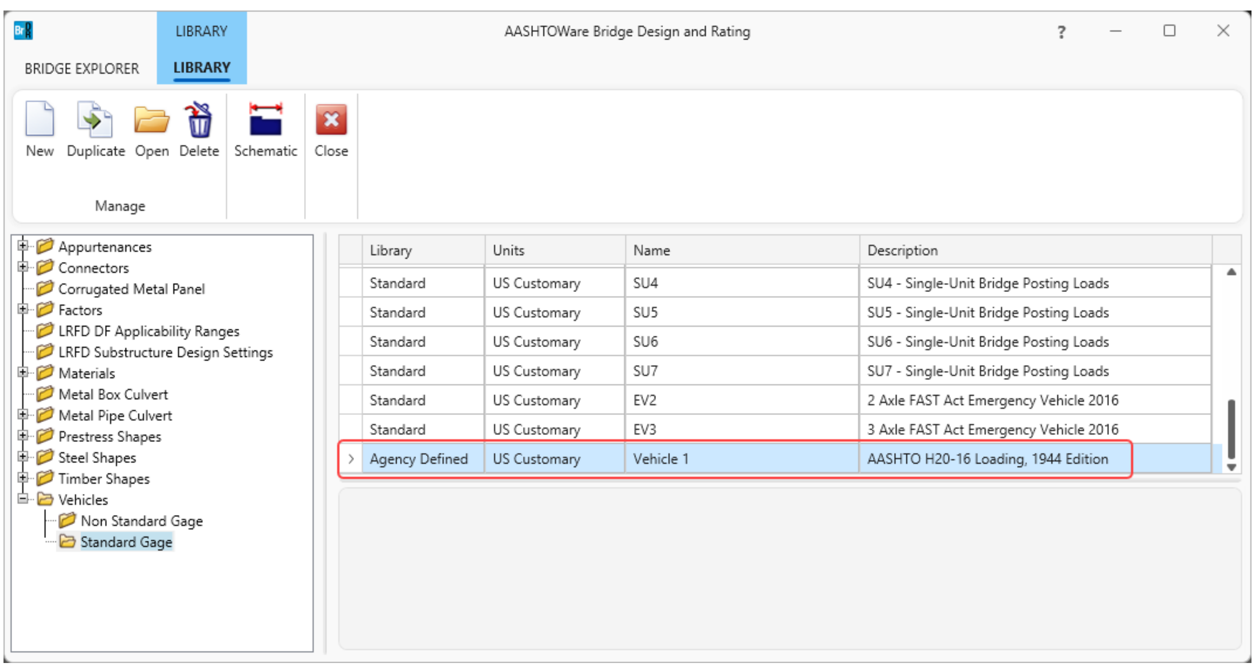
3. Select the system of units using the radio buttons and then fill in the vehicle information as shown below for all items not on the tab control. Note that the name must be unique among all vehicle library items. The checkboxes inside the **Design** and **Rating** groups are used to filter the vehicle during an analysis event based on the type of event and the type of analysis engine selected. The **Vehicle Library** has a library type called **User Defined**. This library allows users to add their own vehicles.



4. Click the **New** button to add an axle to the vehicle.
5. Enter the first axle's dimensions. (Axle spacing is not applicable for the first axle.)
6. Repeat steps 4 and 5 for each additional axle.
7. Select the **Lane Tab**. Enter data on the **Lane** tab as shown below.



8. Click **Save**. The new vehicle will now be listed in the right pane of the Library Explorer for the tree items **Vehicles/Standard Gage**.

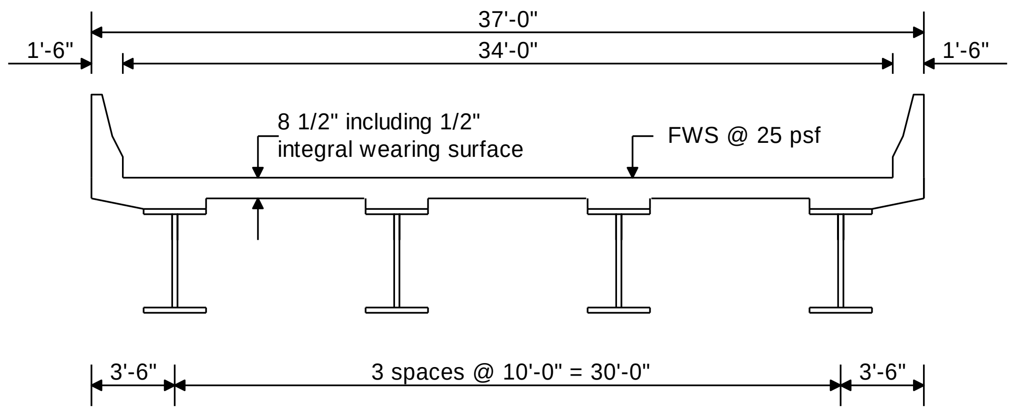


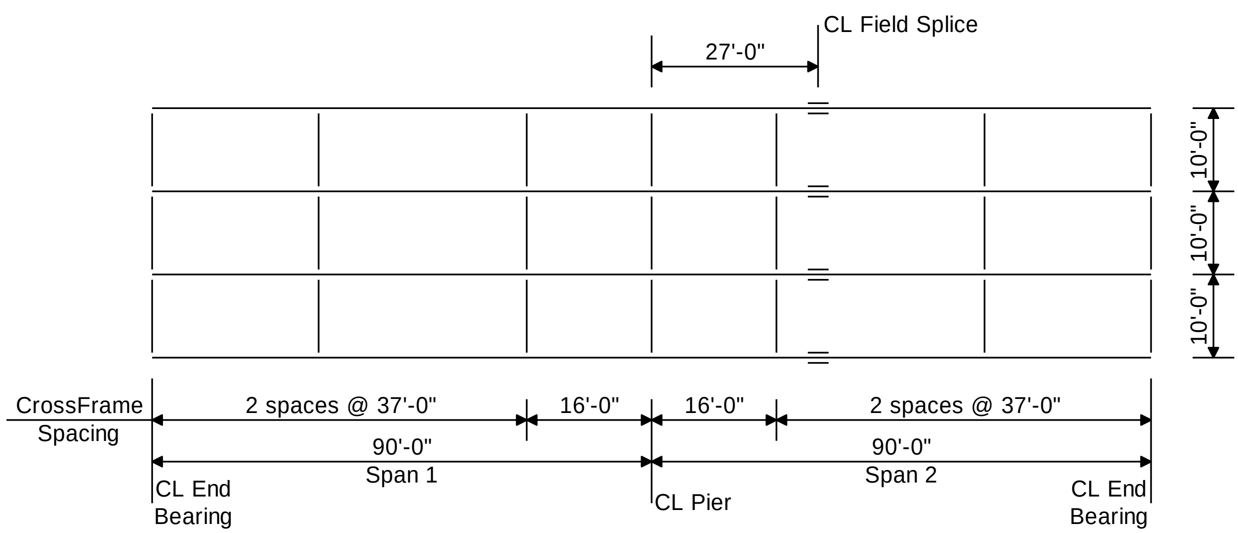
AASHTOWare BrDR 7.5.1

Steel Tutorial

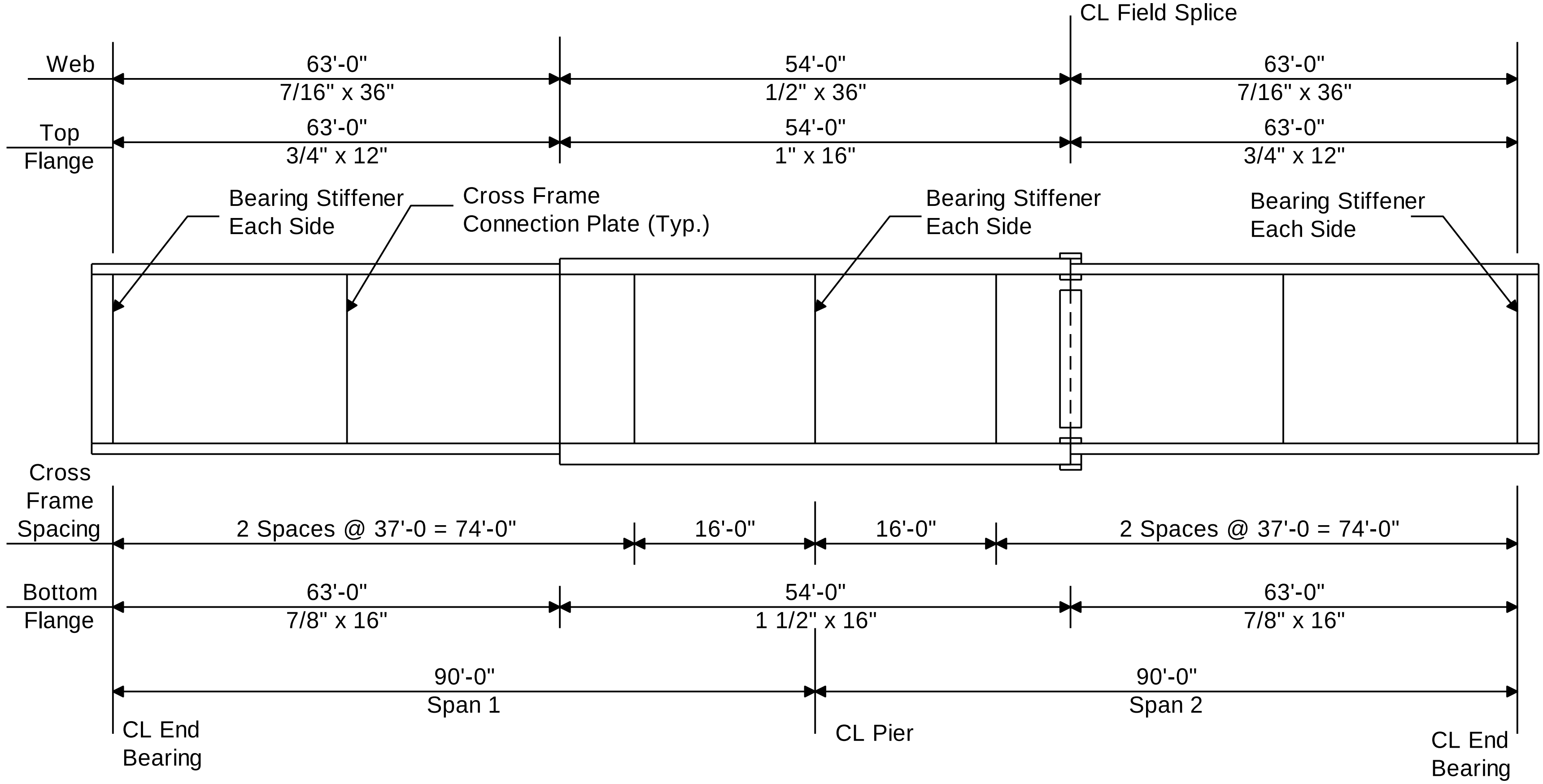
STL2 – Two Span Plate Girder Example

STL2 - Two Span Plate Girder Example

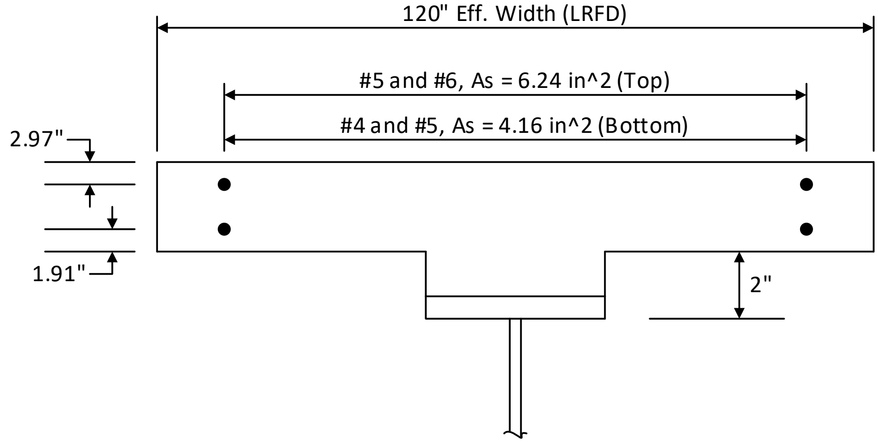




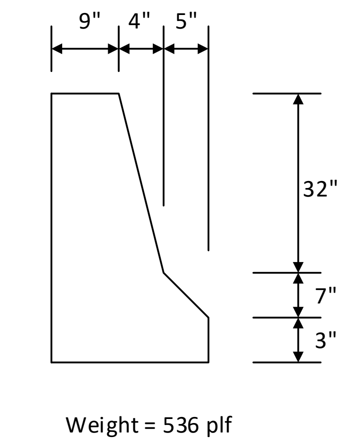
Framing Plan



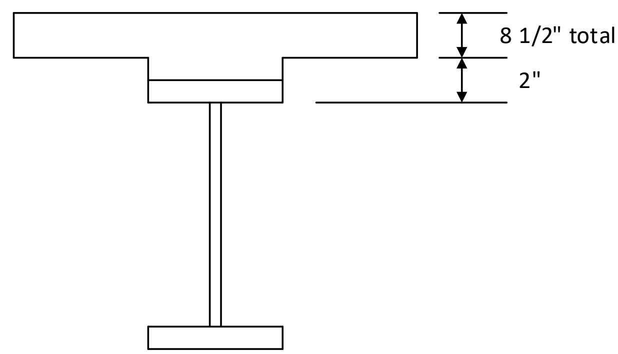
Elevation of Interior Girder



Composite Section at Pier



Parapet Detail



Haunch Detail

Note: The area of steel is provided in the section at the pier but the number of #4, #5, and #6 bars are not provided. For simplicity, the bars will be input using an equivalent number of #9 bars which have a unit area of 1.0 in^2.

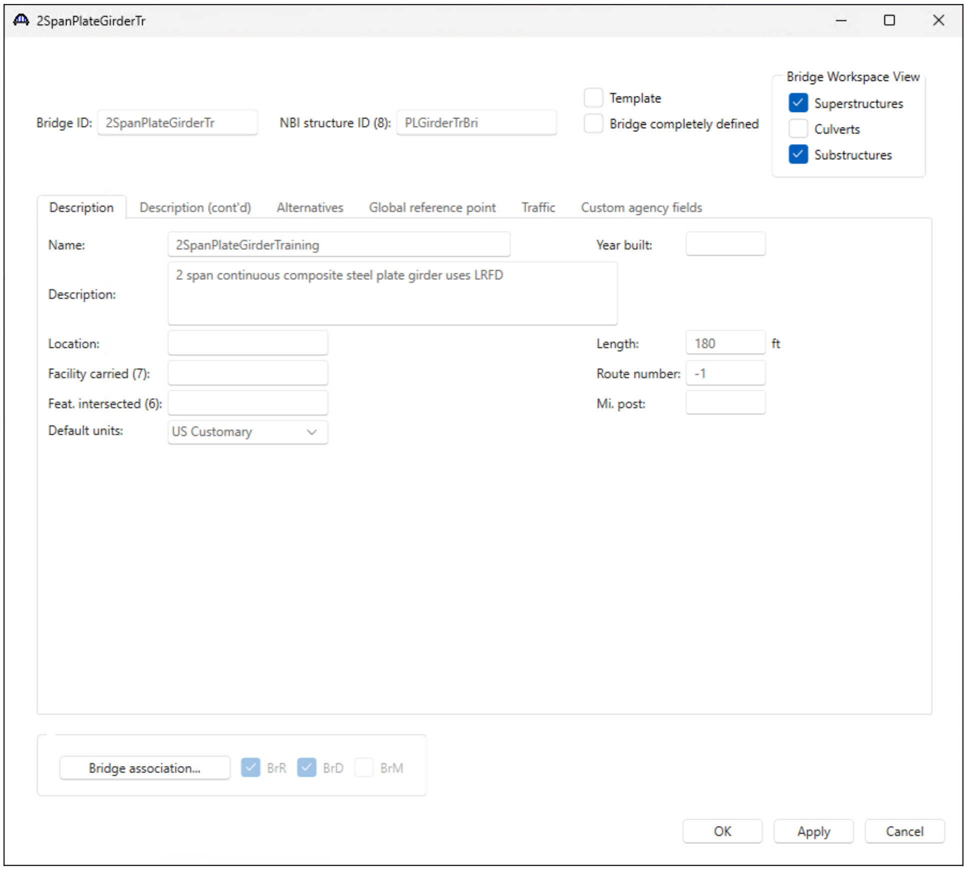
Material Properties

Structural Steel: AASHTO M270, Grade 50W uncoated weathering steel with Fy = 50 ksi
Deck Concrete: f'c = 4.0 ksi, modular ratio n = 8
Slab Reinforcing Steel: AASHTO M31, Grade 60 with Fy = 60 ksi

Cross Frame Connection Plates: 3/4" x 6"
Bearing Stiffener Plates: 7/8" x 9"

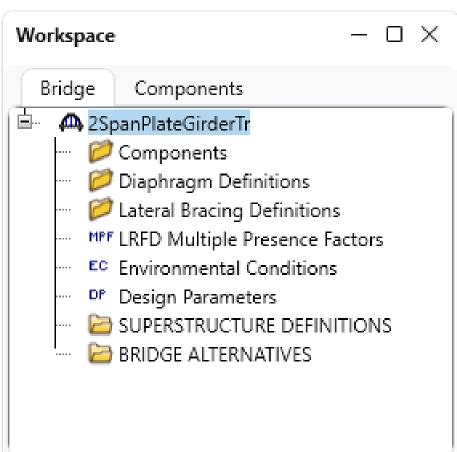
BrDR Tutorial

From the **Bridge Explorer** create a **New** bridge and enter the following description data.



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

The partially expanded **Bridge Workspace** tree is shown below.

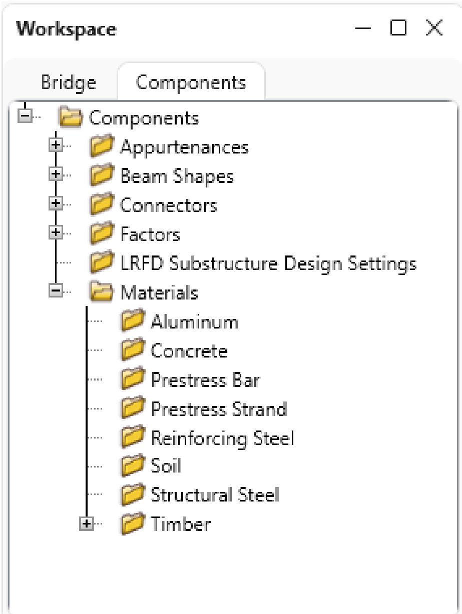


Bridge Components

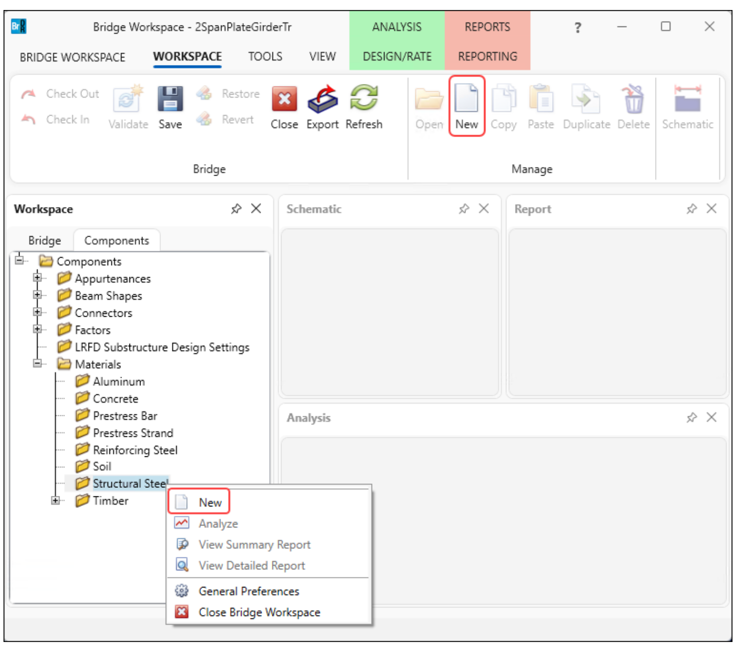
Bridge Materials

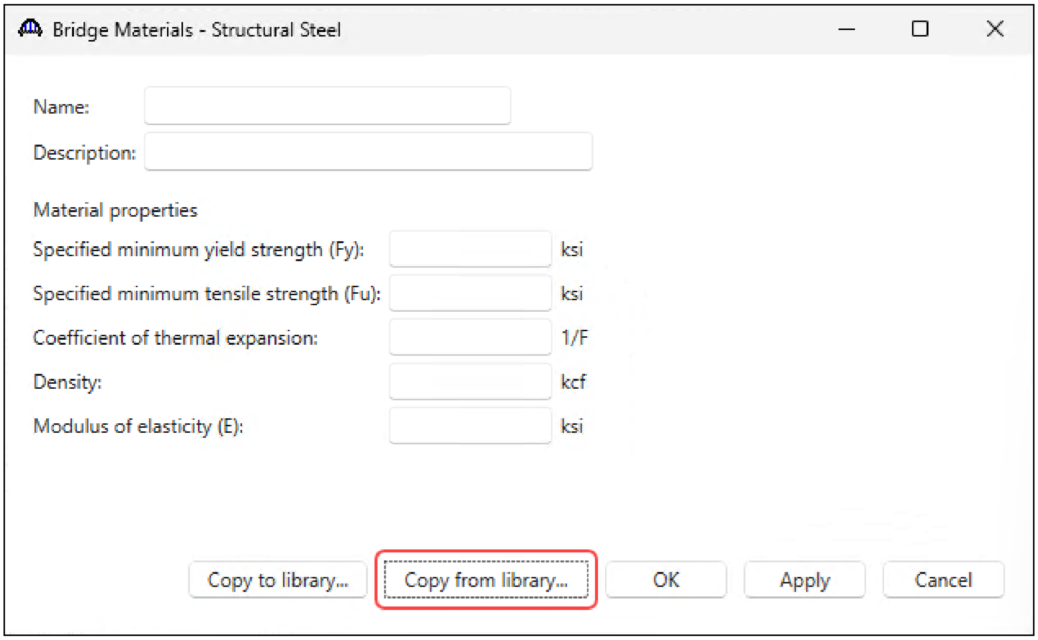
To enter the materials to be used by members of the bridge, in the **Components** tab of the **Bridge Workspace**, click on the ⊞ button to expand the tree for **Materials**.

The tree with the expanded **Materials** branch is shown below.

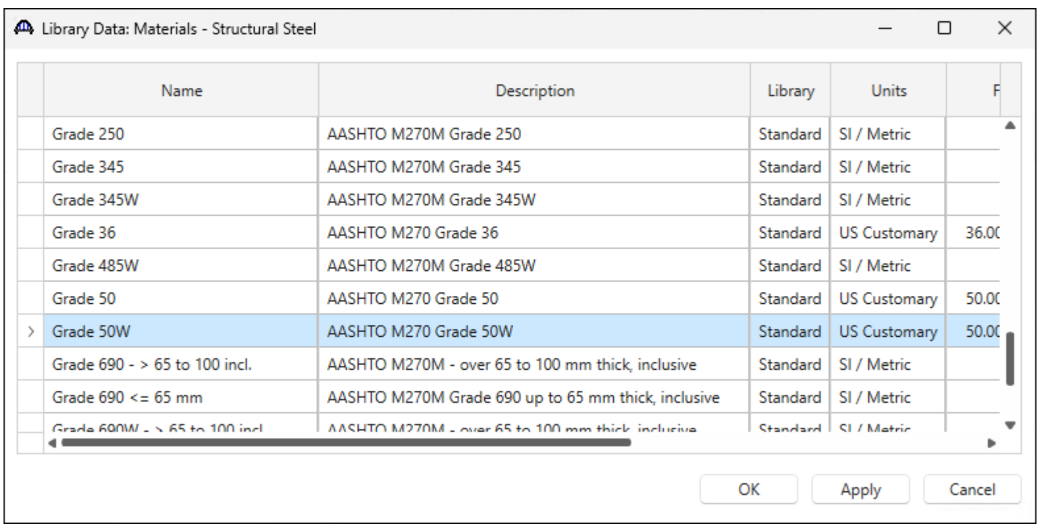


To add a new steel material, in the **Components** tab of the **Bridge Workspace**, click on **Materials**, **Structural Steel,** and select **New** from the **Manage** group of the **WORKSPACE** ribbon (or right mouse click on **Structural Steel** and select **New**). The window shown below will open.

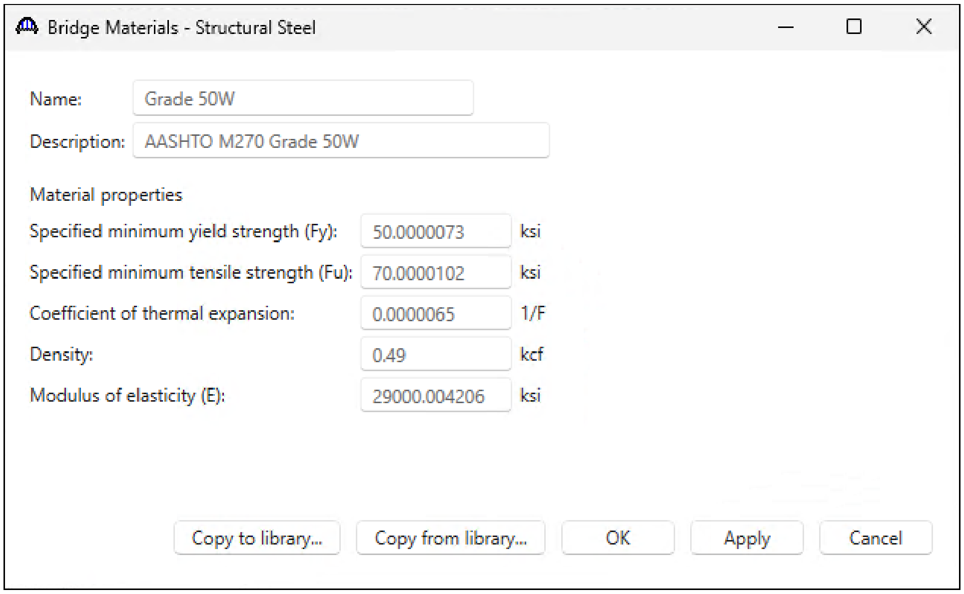




Add the structural steel material by clicking the **Copy from library…** button. The following window opens. Select the **AASHTO M270 Grade 50W** material and click **OK**.

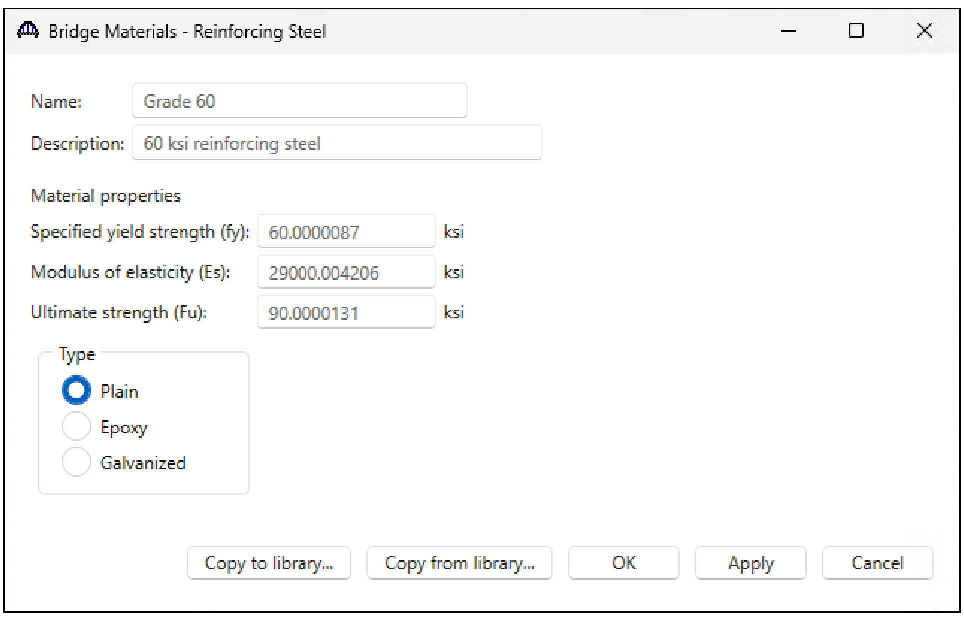


The selected material properties are copied to the Bridge Materials – Structural Steel window as shown below.

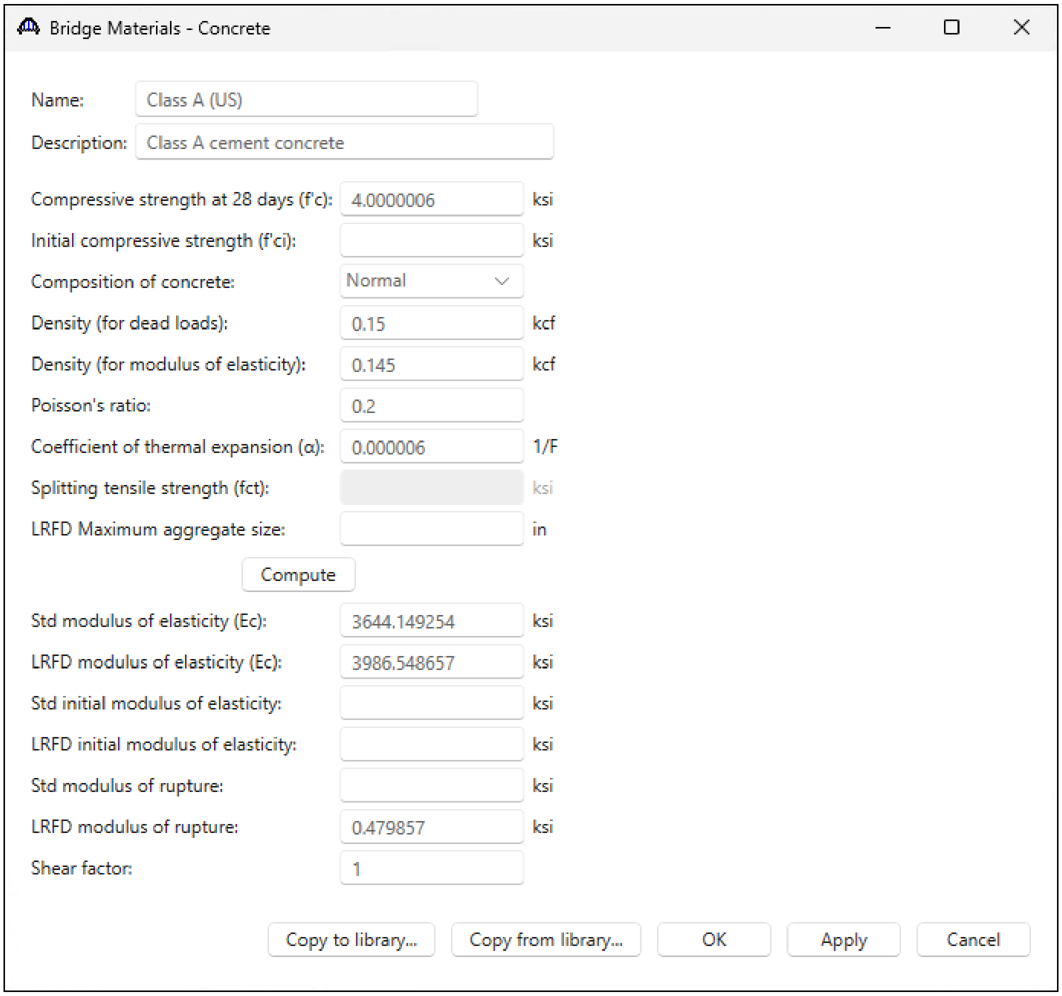


Click **OK** to apply the data and close the window.

Add the following reinforcing steel and concrete material using the same techniques.



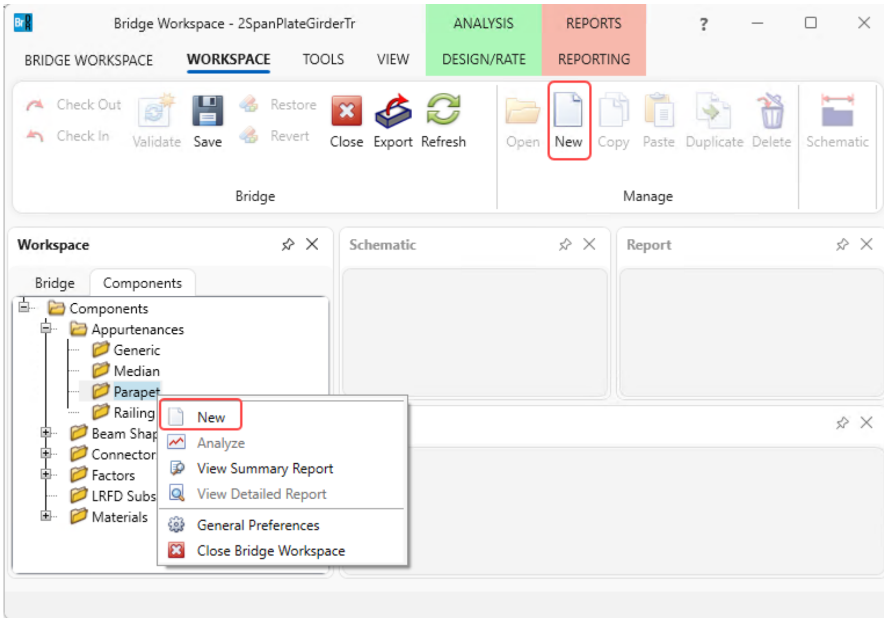
Click **OK** to apply the data and close the window.



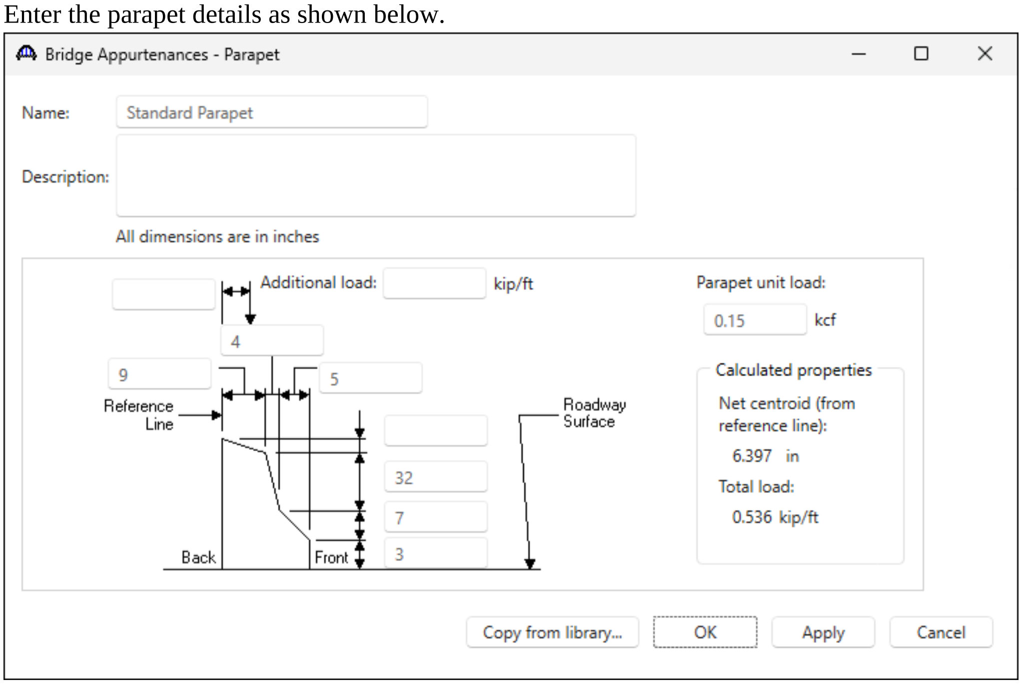
Click **OK** to apply the data and close the window.

Bridge Appurtenances

To enter the appurtenances used within the bridge, expand the tree branch labeled **Appurtenances**. To define a parapet, select **Parapet** and click on **New** from the **Manage** button on the **WORKSPACE** ribbon (or double click on **Parapet** in the **Components** tree).



Enter the parapet details as shown below.

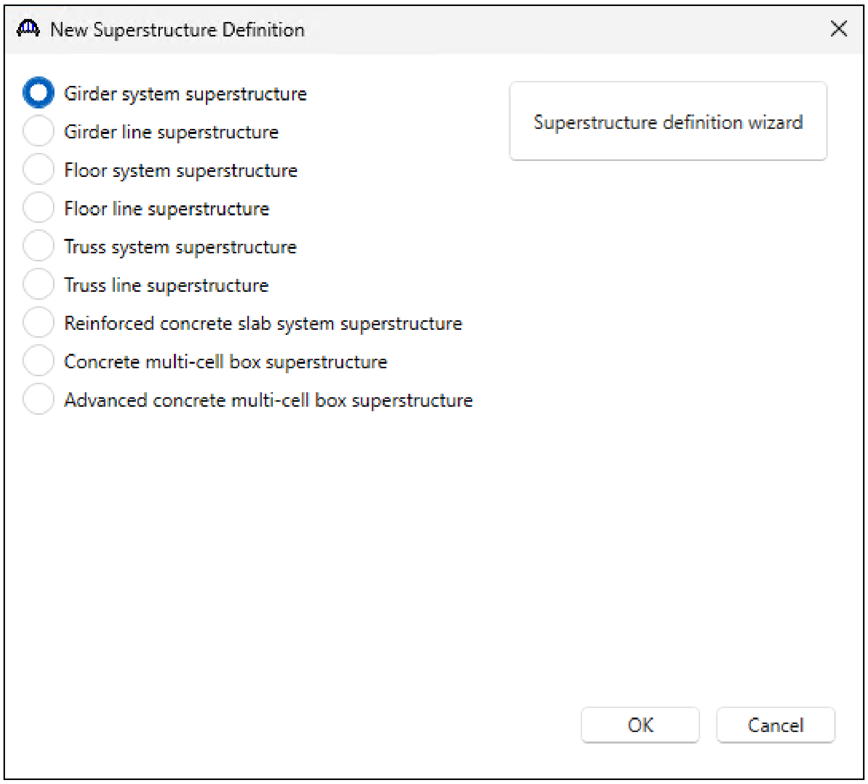


Click **OK** to apply the data and close the window.

The default standard LRFD and LFR factors will be used. Bridge alternatives will be added after entering the structure definition.

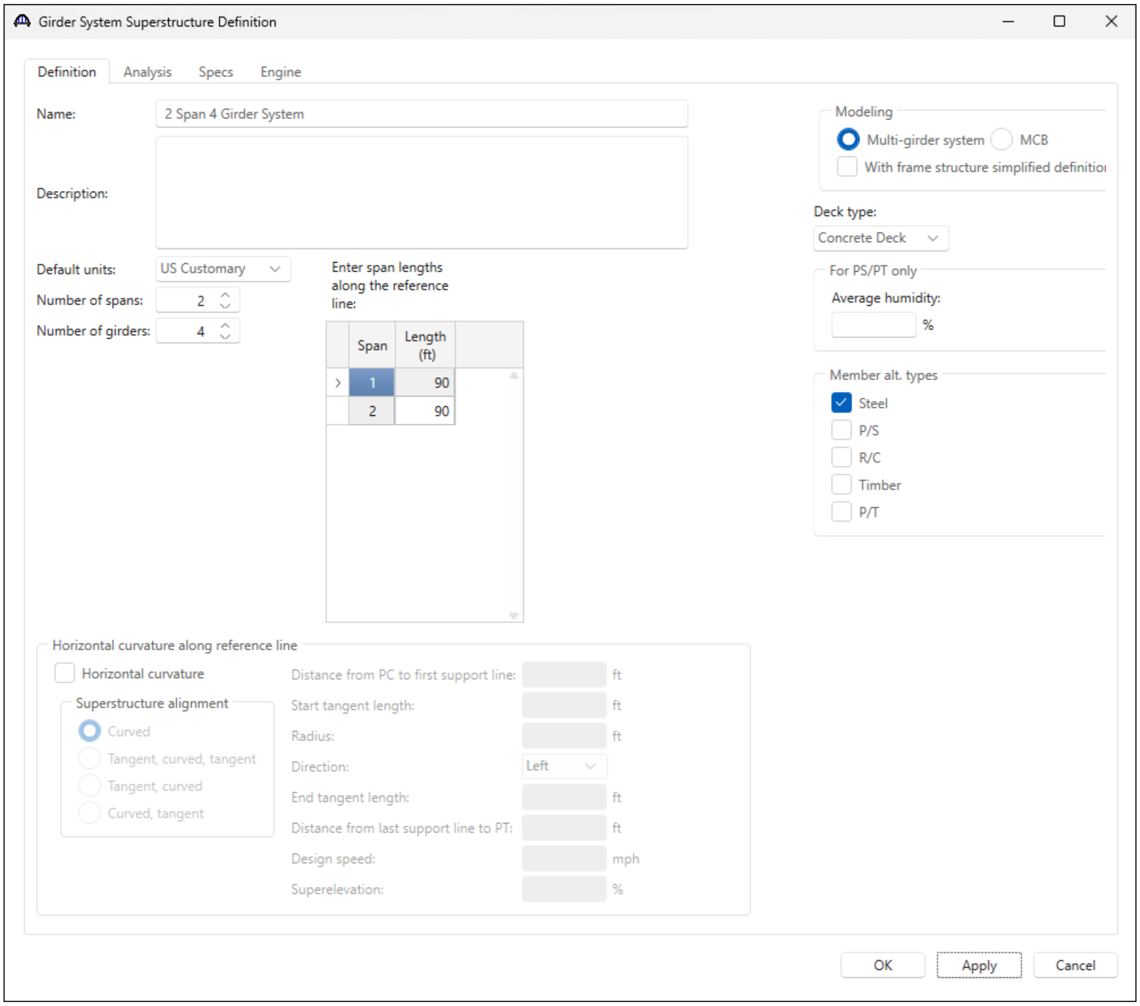
Superstructure Definition

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.

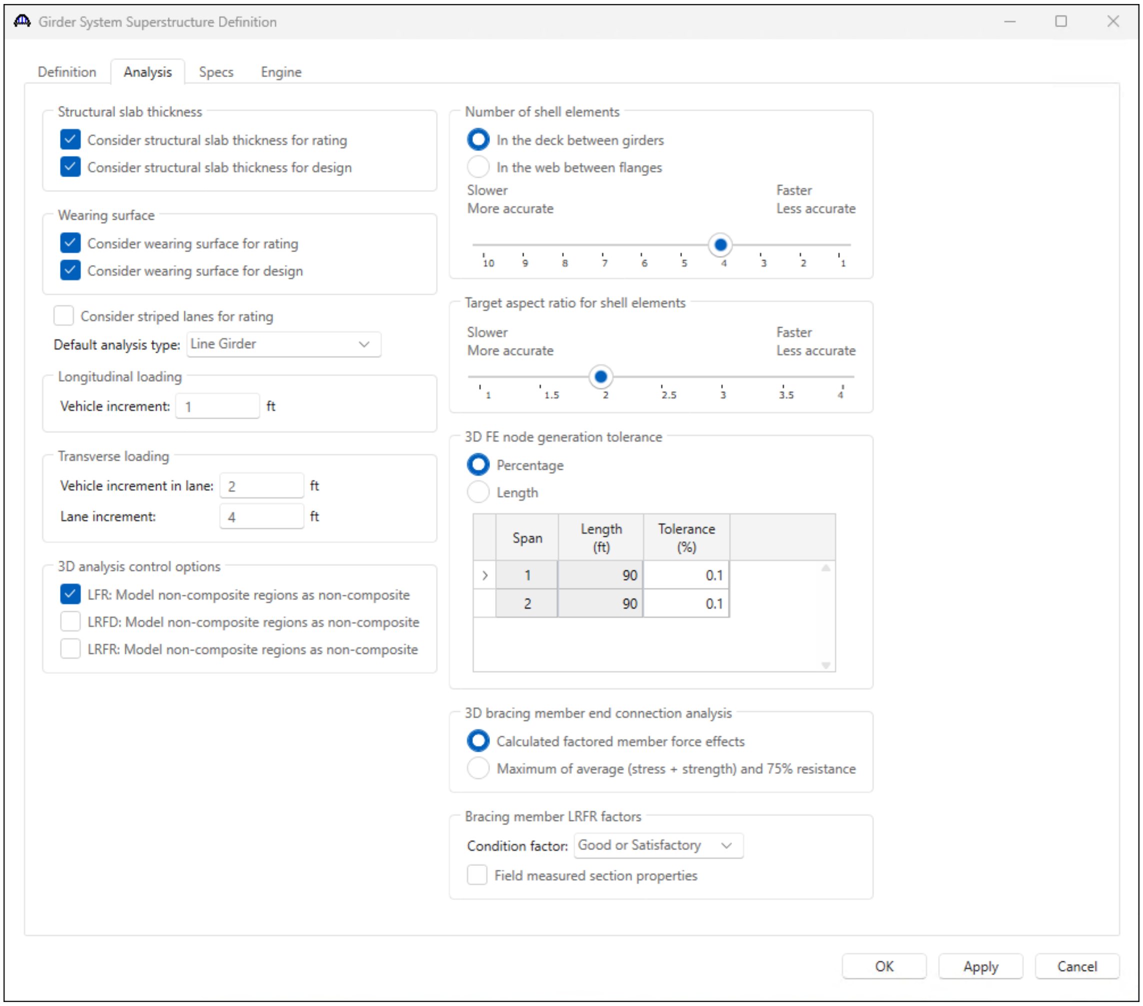


Select **Girder system superstructure**, click **OK** and the **Girder System Superstructure Definition** window will open.

Enter the data as shown below and click **Apply** to apply the data and keep the window open.



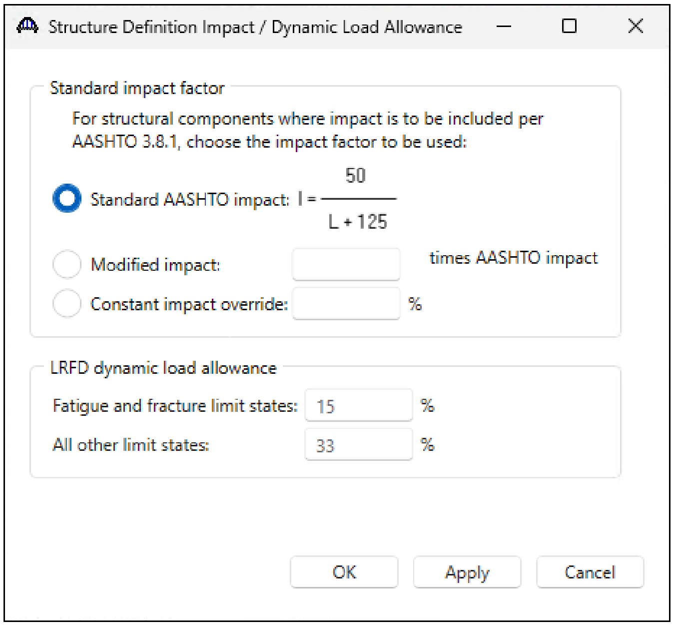
The **Analysis** tab is shown below with the default selections. For this example, the default values will not be overridden. No changes are required on this tab.



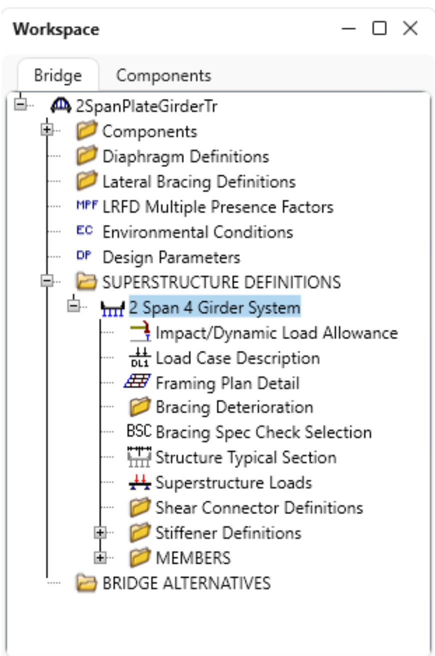
Click **OK** to apply the data and close the window.

Impact/Dynamic Load Allowance

Enter the impact to be used for the superstructure definition by double clicking on **Impact/Dynamic Load Allowance** in the **Bridge Workspace** tree. The **Structure Definition Impact / Dynamic Load Allowance** window shown below will open. The values shown below are default values. No changes are required to these values.

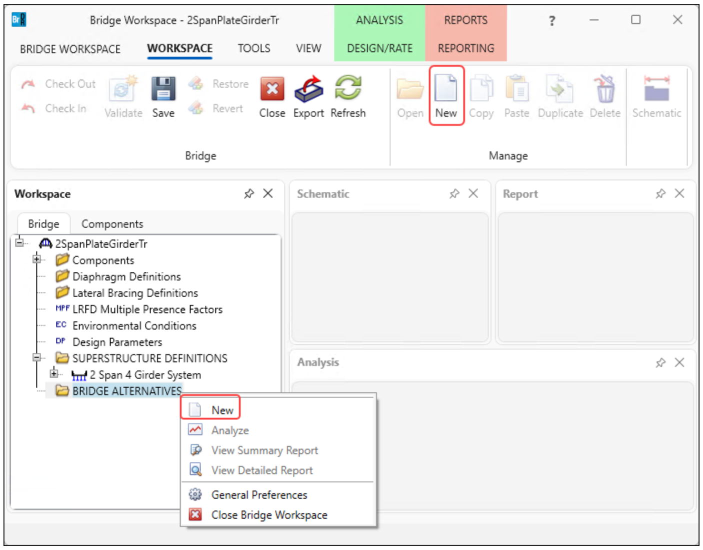


The partially expanded **Bridge Workspace** tree is shown below.

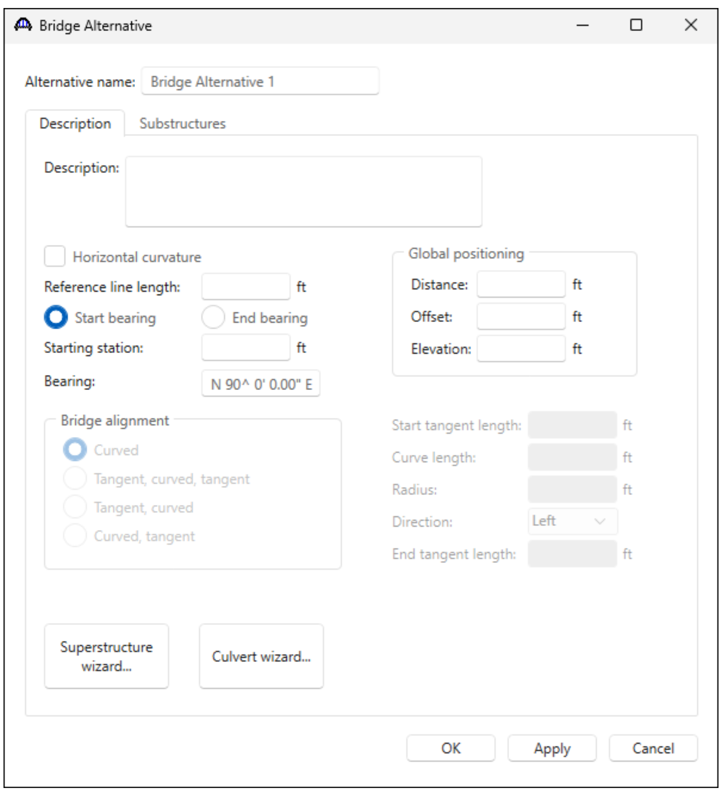


BRIDGE ALTERNATIVES

Navigate to the **BRIDGE ALTERNATIVES** node in the **Bridge Workspace** tree and create a new bridge alternative by double-clicking on **BRIDGE ALTERNATIVES** (or click on **BRIDGE ALTERNATIVES** and select **New** from the **Manage** group of the **WORKSPACE** ribbon).

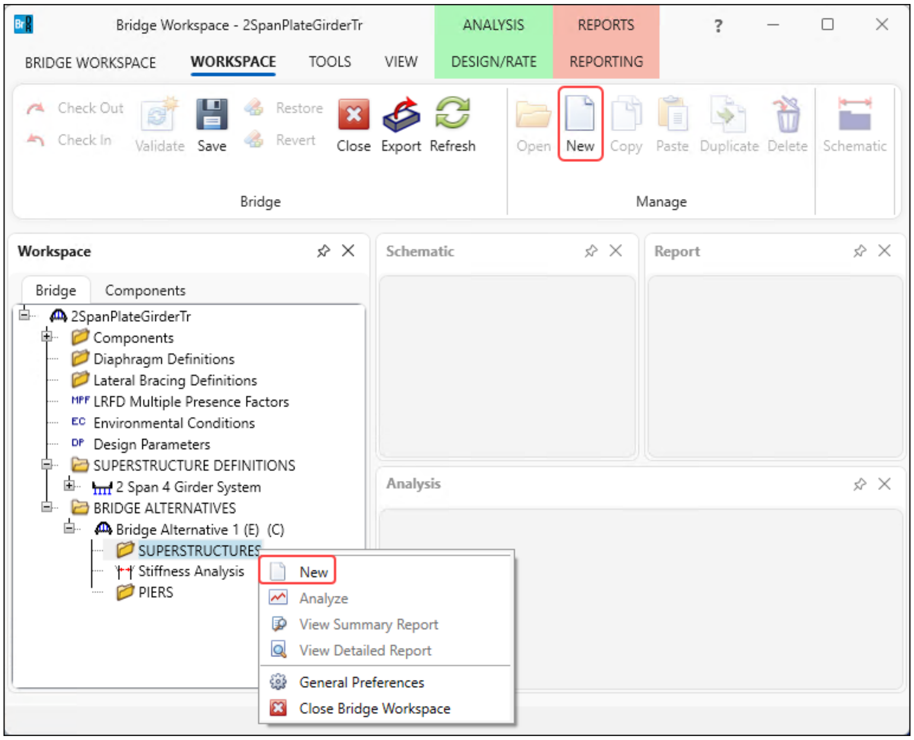


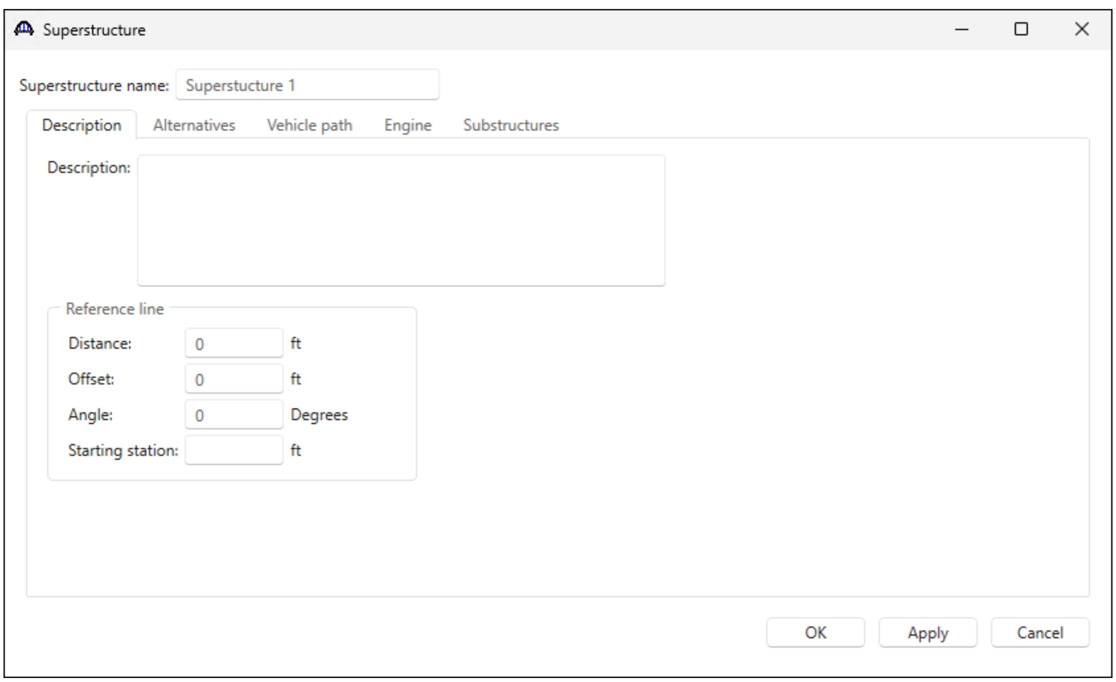
Enter the following data.



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

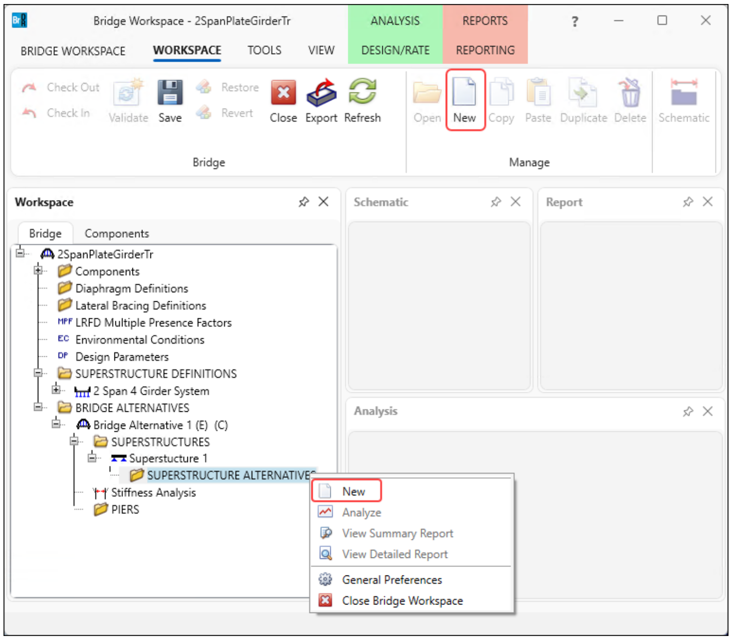
Expand the **Bridge Alternative 1** node in the **Bridge Workspace** tree by clicking the ⊞ button. Double-click on the **SUPERSTRUCTURES** node (or select **SUPERSTRUCTURES** and click **New** from the **Manage** group of the **WORKSPACE** ribbon) and enter the following new superstructure.



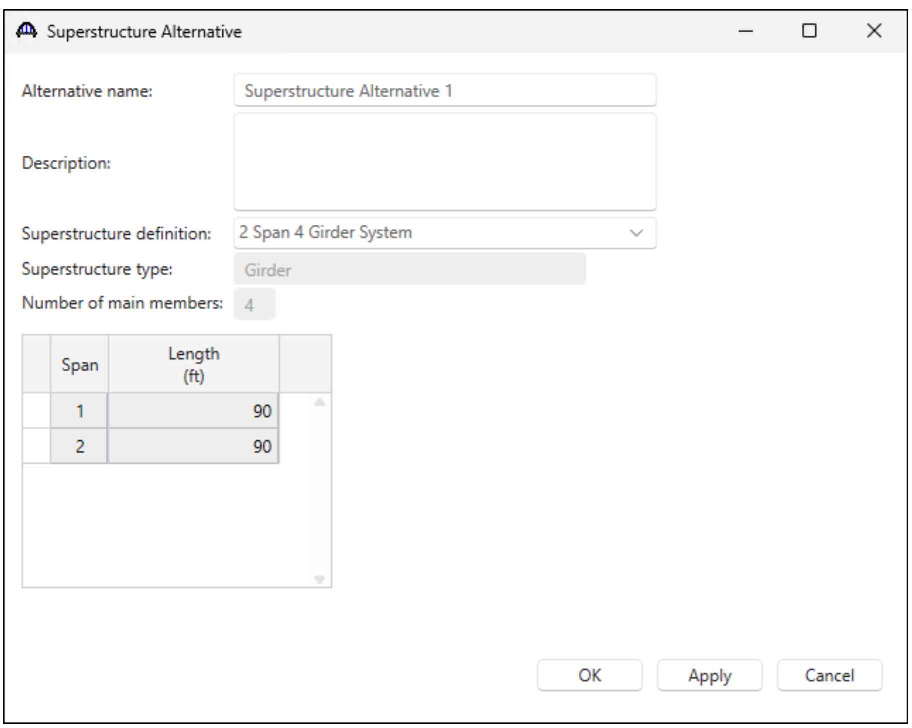


Click **OK** to apply the data and close the window.

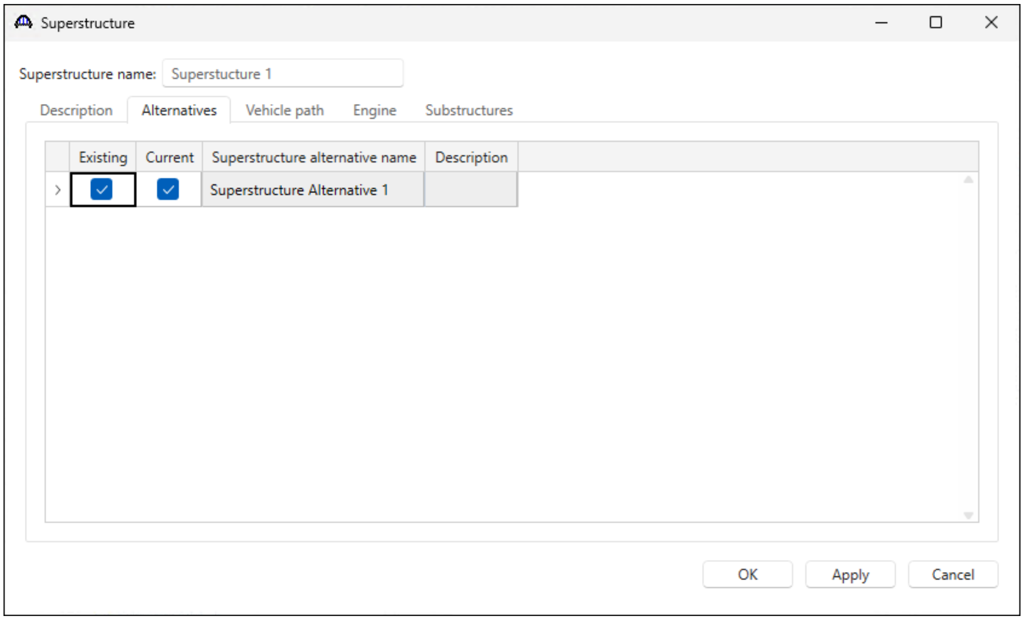
Expand the **Superstructure 1** node in the **Bridge Workspace** tree by clicking the ⊞ button. Double-click on the **SUPERSTRUCTURE ALTERNATIVES** node (or select **SUPERSTRUCTURE ALTERNATIVES** and click **New** from the **Manage** group of the **WORKSPACE** ribbon) and enter the following new superstructure alternative.



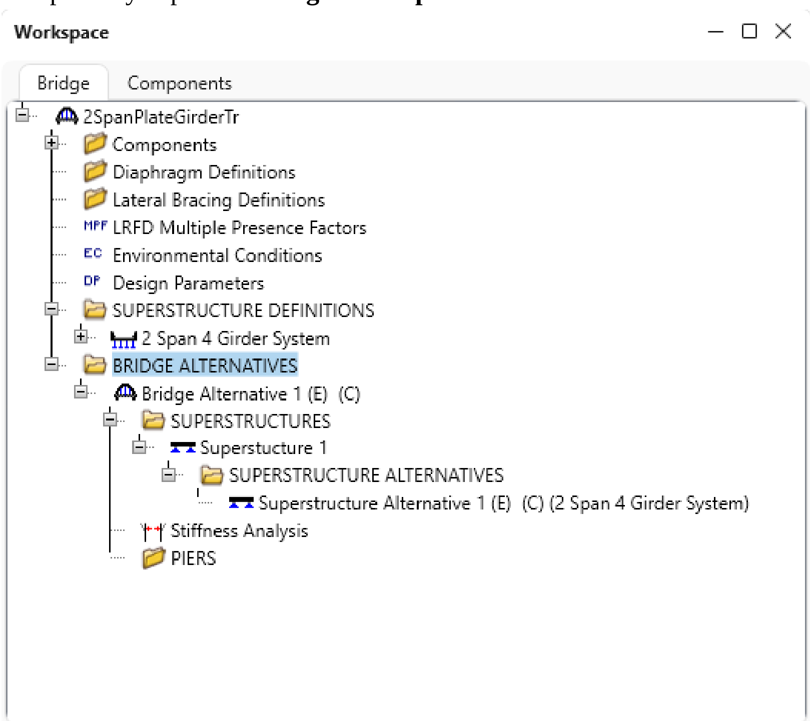
Select the **Superstructure definition 2 Span 4 Girder System** as the current superstructure definition for this Superstructure Alternative.



Re-open the **Superstructure 1** window and navigate to the **Alternatives** tab. The **Superstructure Alternative 1** linked to **2 Span 4 Girder System** is shown as the **Existing** and **Current** alternative for **Superstructure 1.**

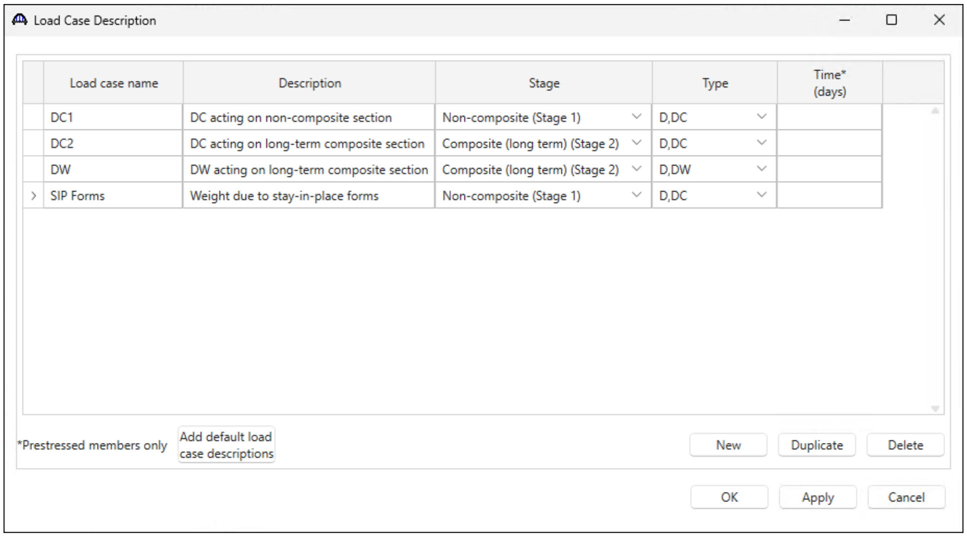


The partially expanded **Bridge Workspace** tree is shown below.



Load Case Description

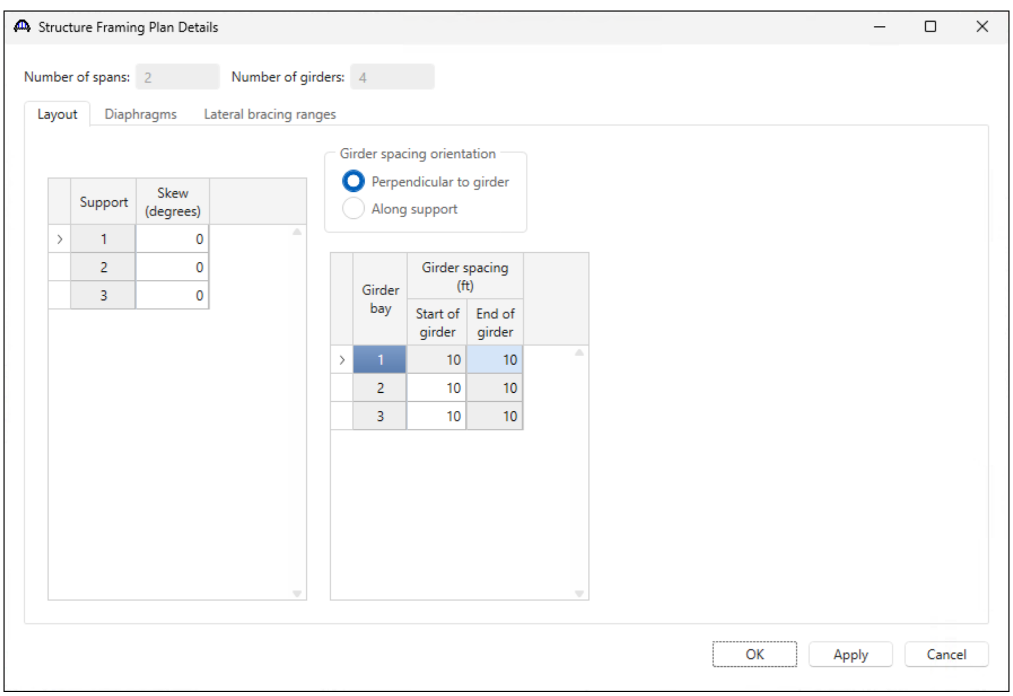
Navigate to the **2 Span 4 Girder System** superstructure definition and double-click on the **Load Case Description** node in the **Bridge Workspace** tree to open the **Load Case Description window.** Click on the **Add default load case description** button to create the following load cases.



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

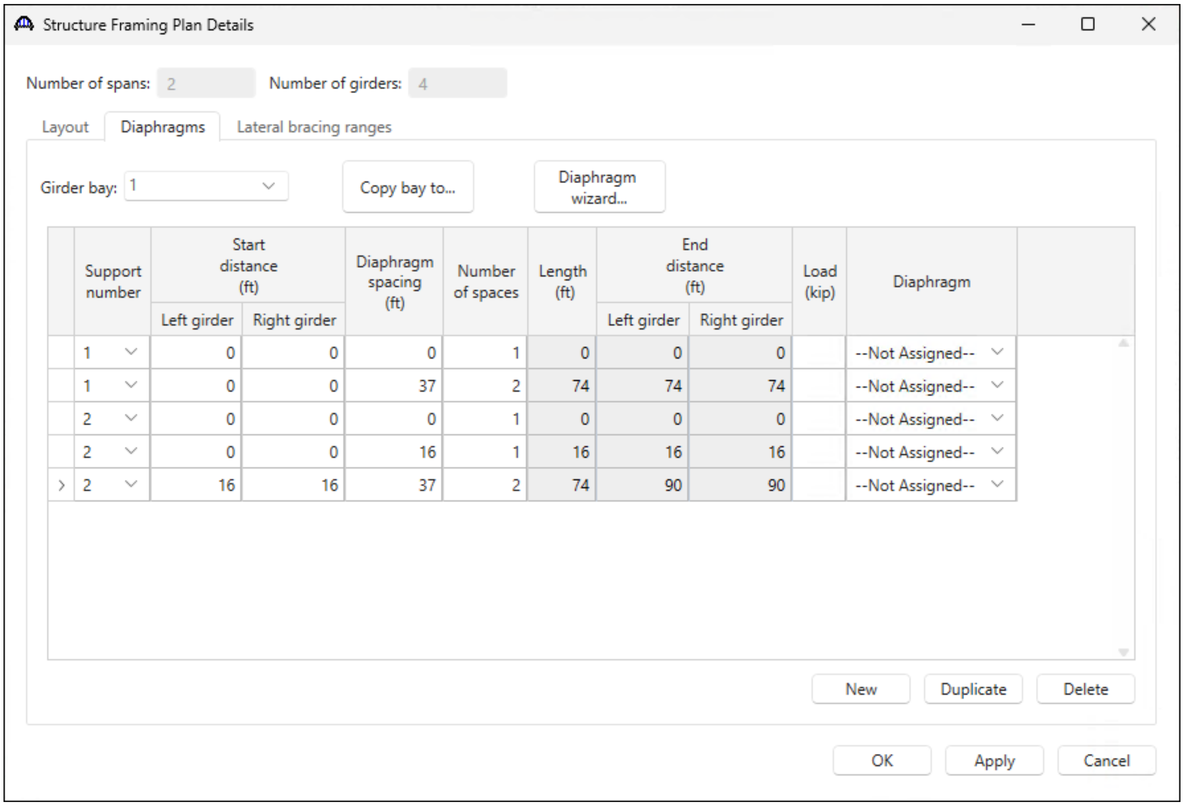
Structure Framing Plan Detail – Layout

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

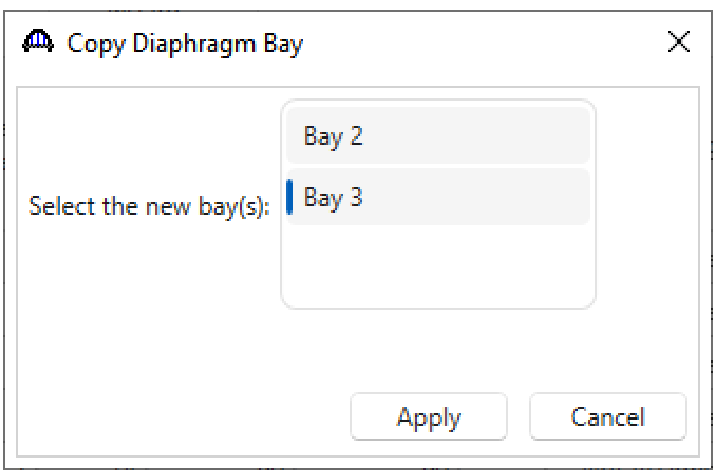


Structure Framing Plan Detail – Diaphragms

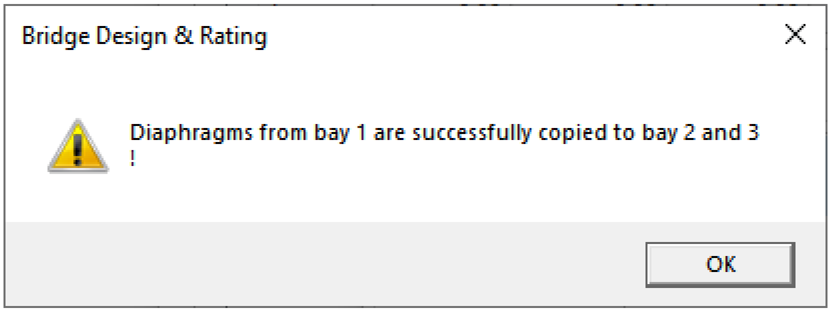
Switch to the **Diaphragms** tab to enter diaphragm spacing. Enter the following diaphragms for **Girder bay 1** as shown below and click the **Apply** button.



Click the **Copy bay to…** button to copy the diaphragms entered for bay 1 to the other bays. The following window appears. Select **Bay 2** and **Bay 3** by holding the **Ctrl** key and click **Apply**.



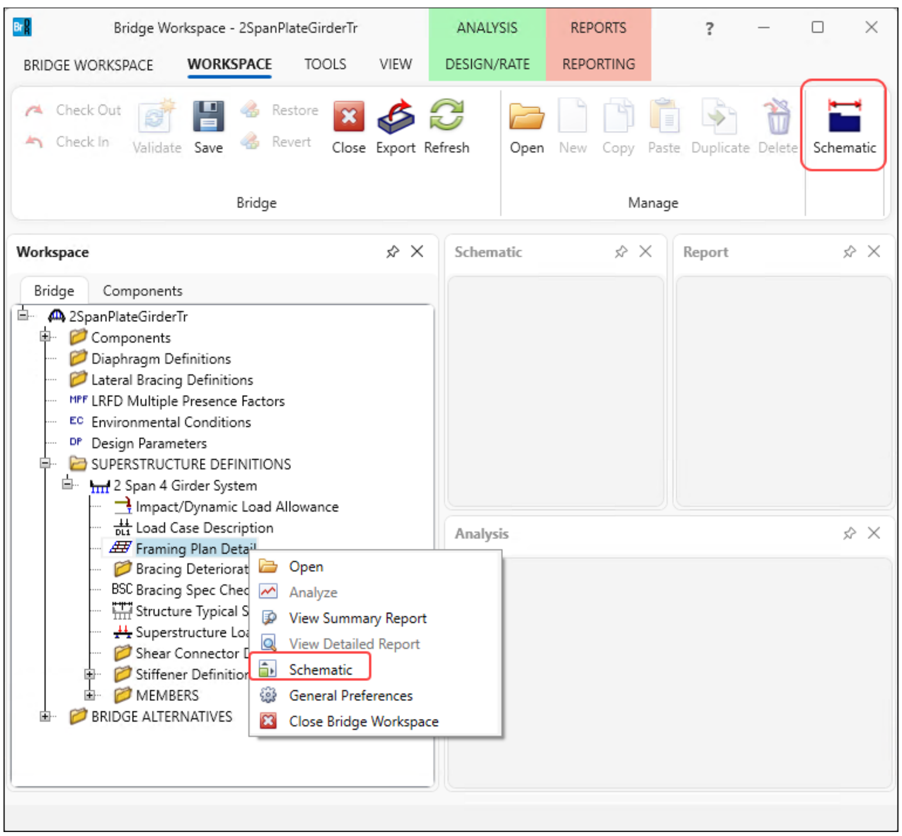
The following message appears indicating that the diaphragms have been copied. Click **OK**.



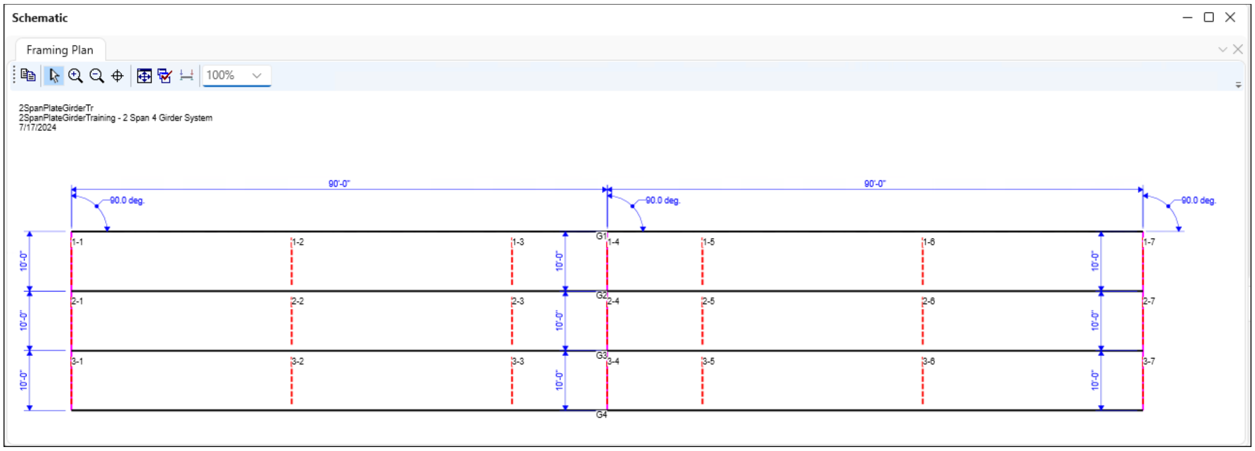
Click **OK** to apply the data and close the window.

Schematic - Framing Plan Detail

While the **Framing Plan Detail** is selected in the **Bridge Workspace** tree, open the schematic for the framing plan by selecting the **Schematic** button on the **WORKSPACE** ribbon (or right click on **Framing Plan Detail** in the Bridge Workspace and select **Schematic** from the menu).

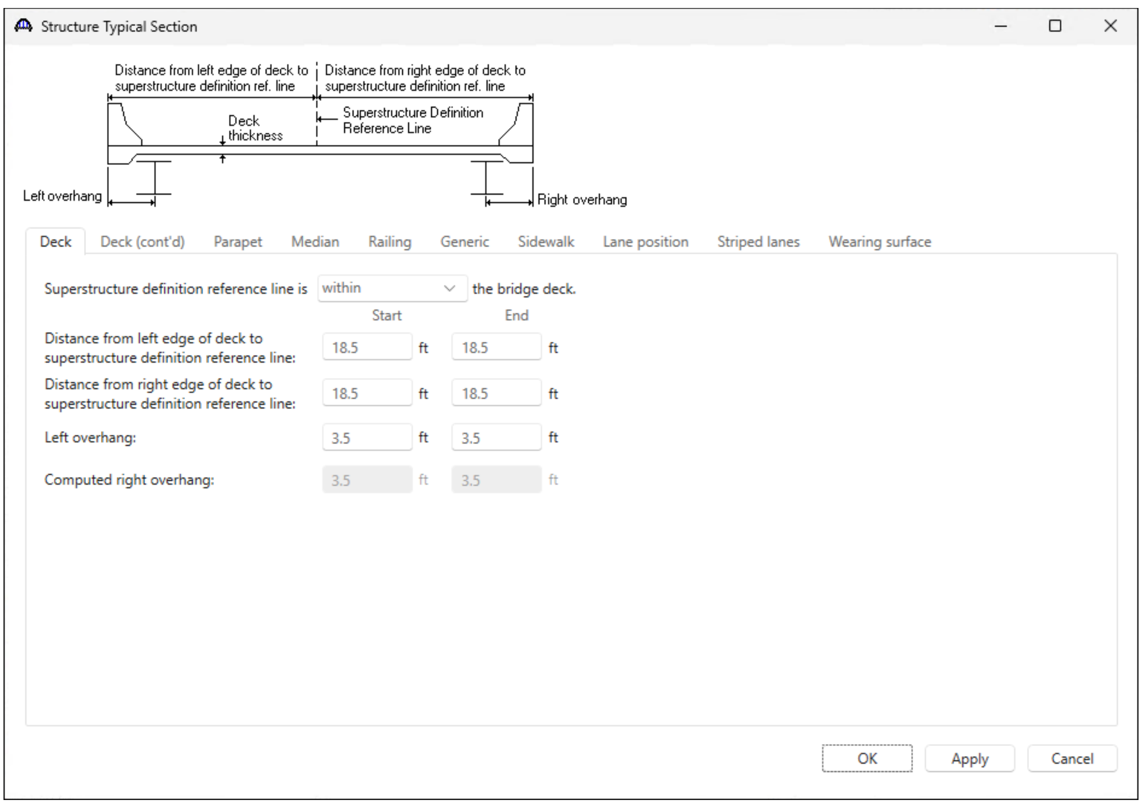


The following schematic is displayed.



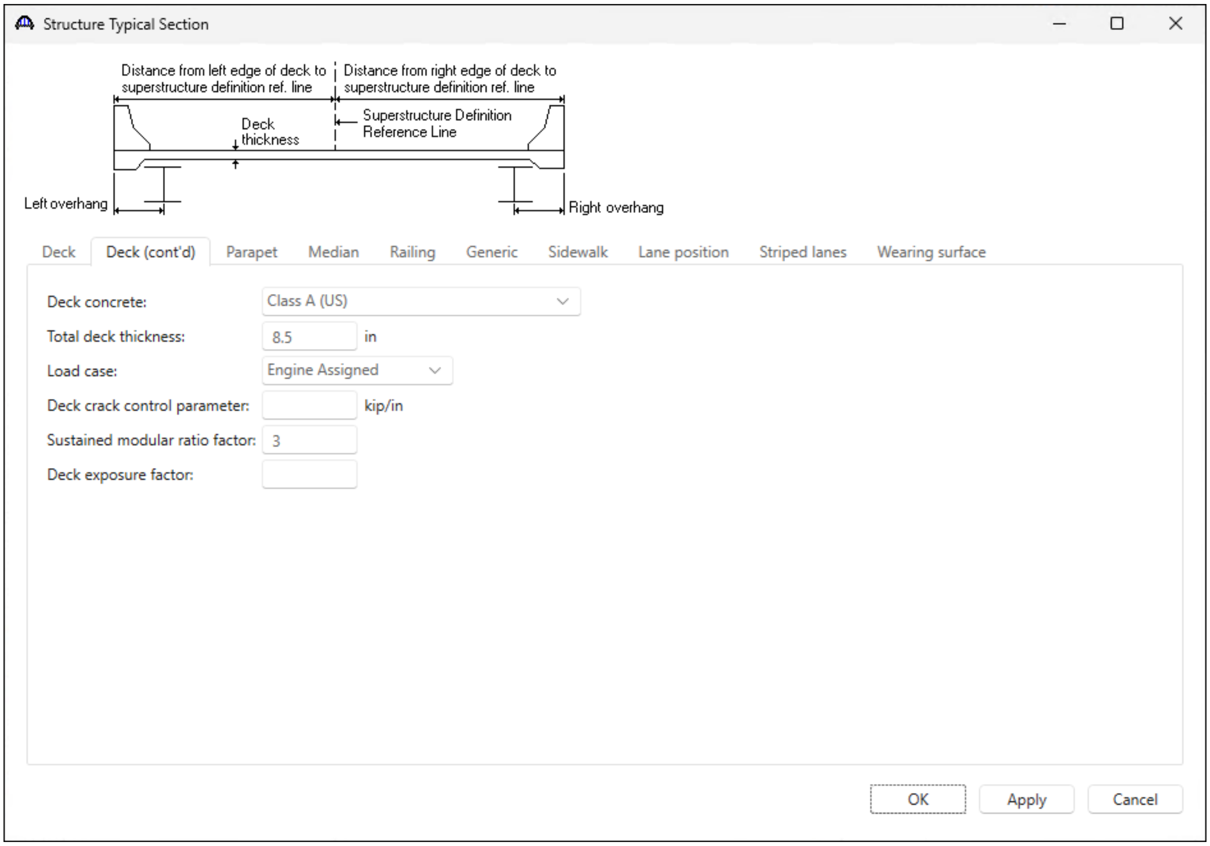
Structure Typical Section - Deck

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



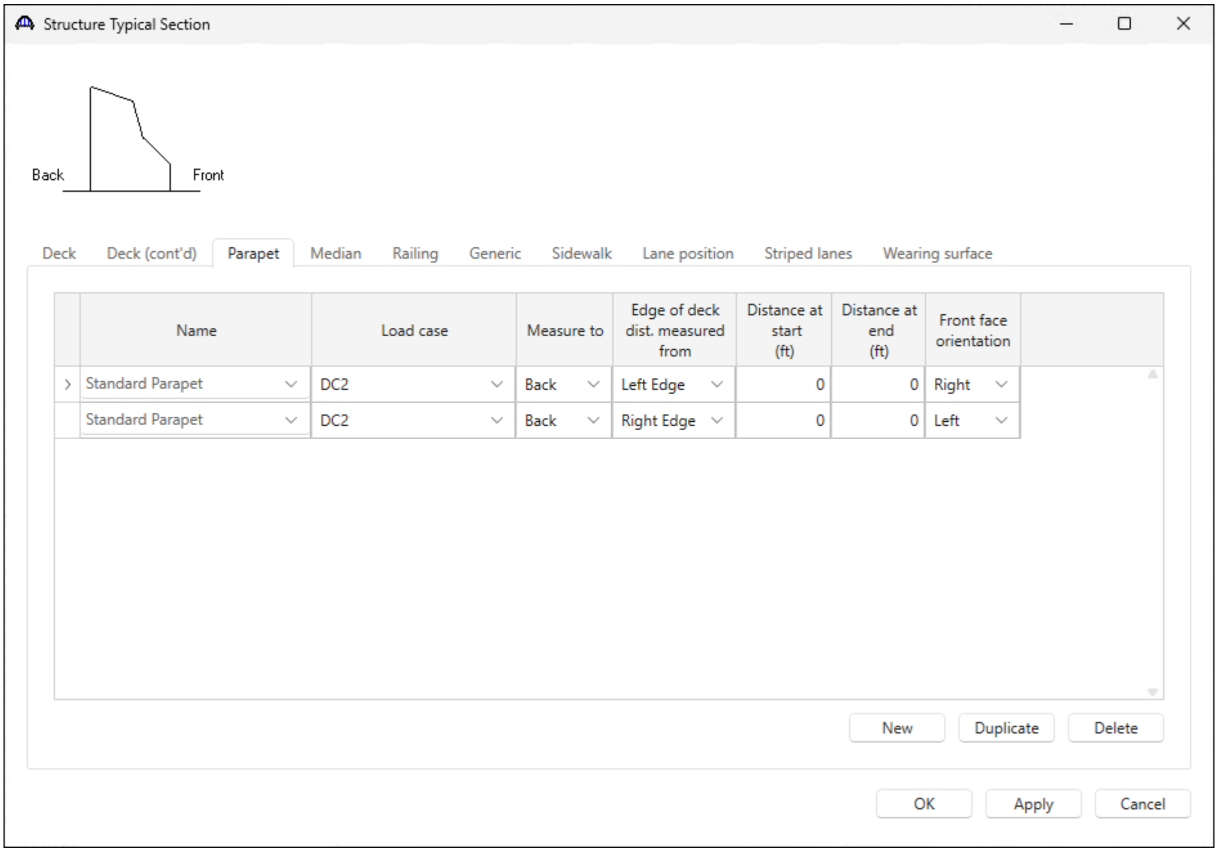
Structure Typical Section – Deck (cont'd)

The **Deck (cont'd)** tab provides input options for the **Deck concrete** and the **Total deck thickness**. The material for the deck concrete is selected from the list of bridge materials. Enter the data as shown below.



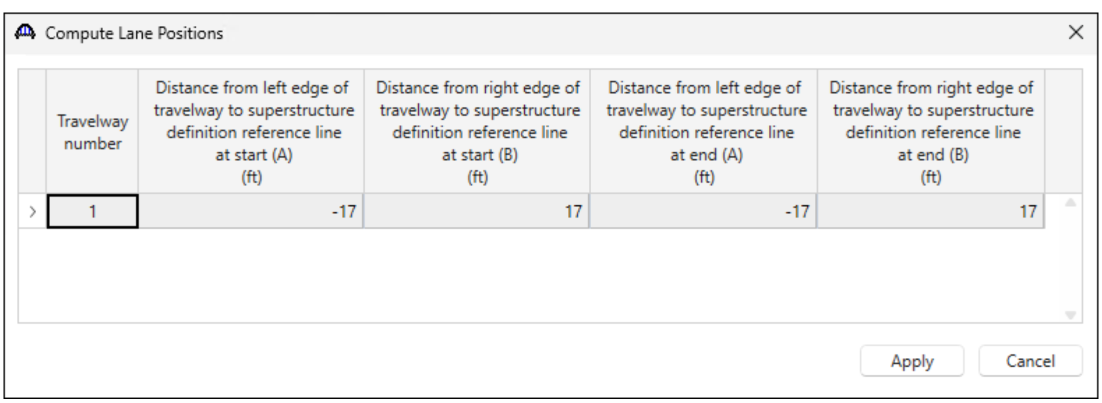
Structure Typical Section – Parapet

Navigate to the **Parapet** tab. Click the **New** button 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** and select **Back** in the **Measure to** column (in this example, locate 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**. Enter another parapet as shown below. The completed tab is shown below.

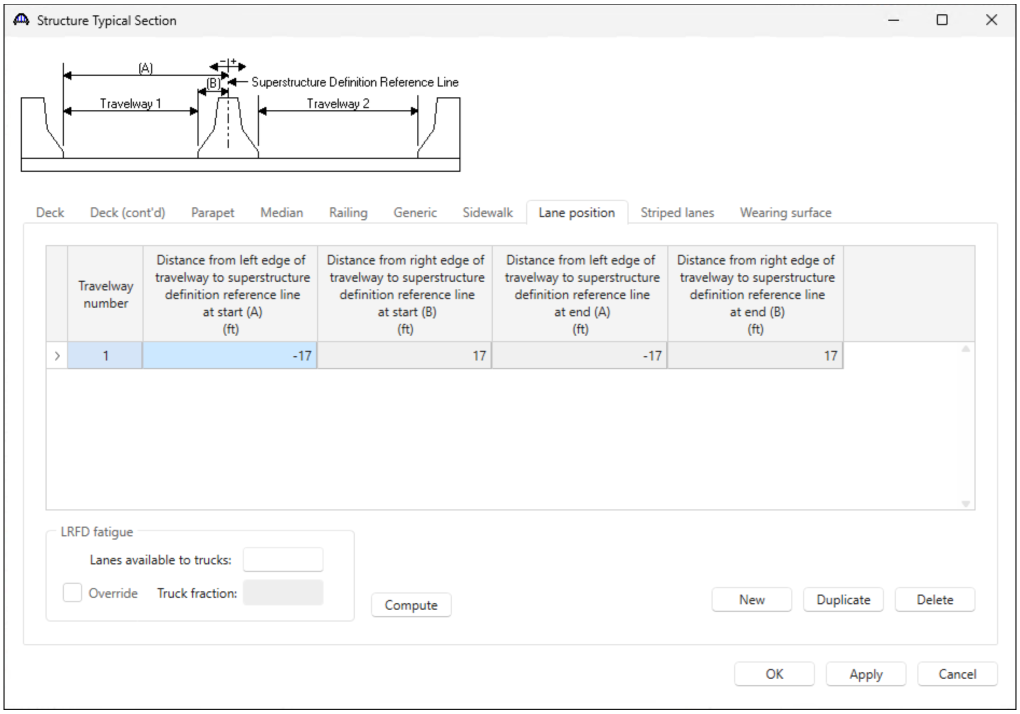


Structure Typical Section – Lane Positions

Select the **Lane position** tab and use the **Compute…** button to compute the lane positions. A window showing the results of the computation opens. Click **Apply** to apply the computed values.

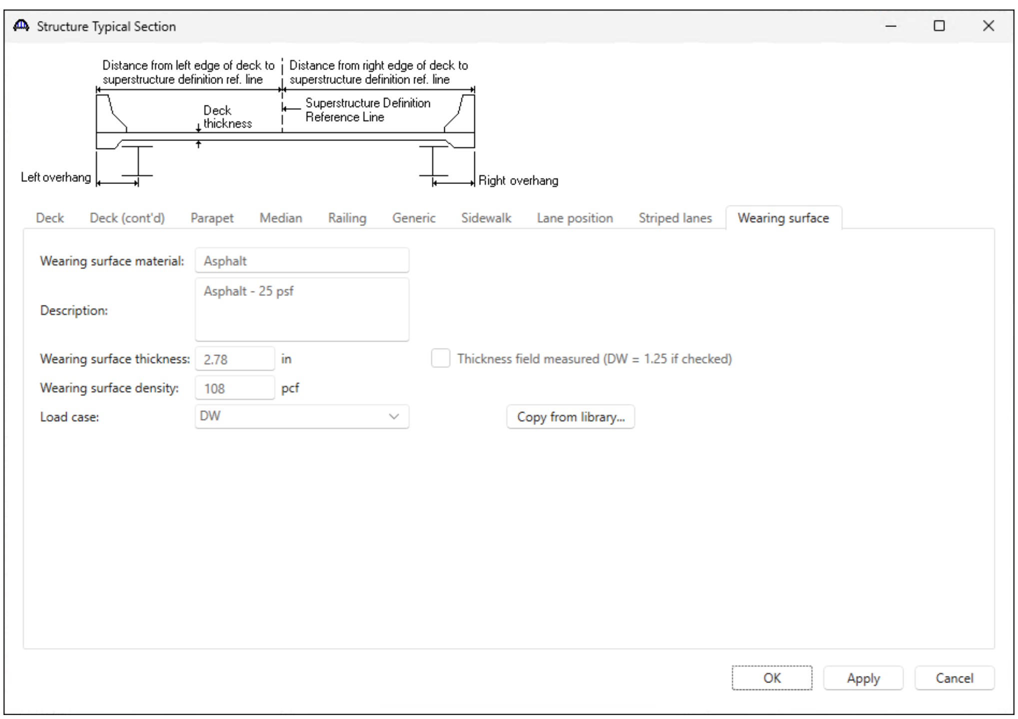


The **Lane Position** tab is populated as shown below.



Structure Typical Section – Wearing surface

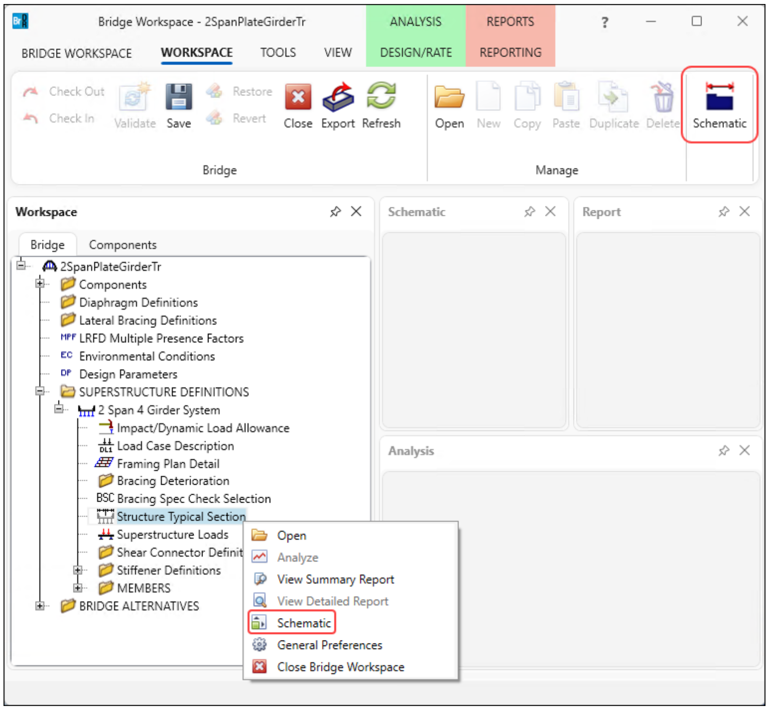
Navigate to the **Wearing surface** tab. Enter the data shown below.



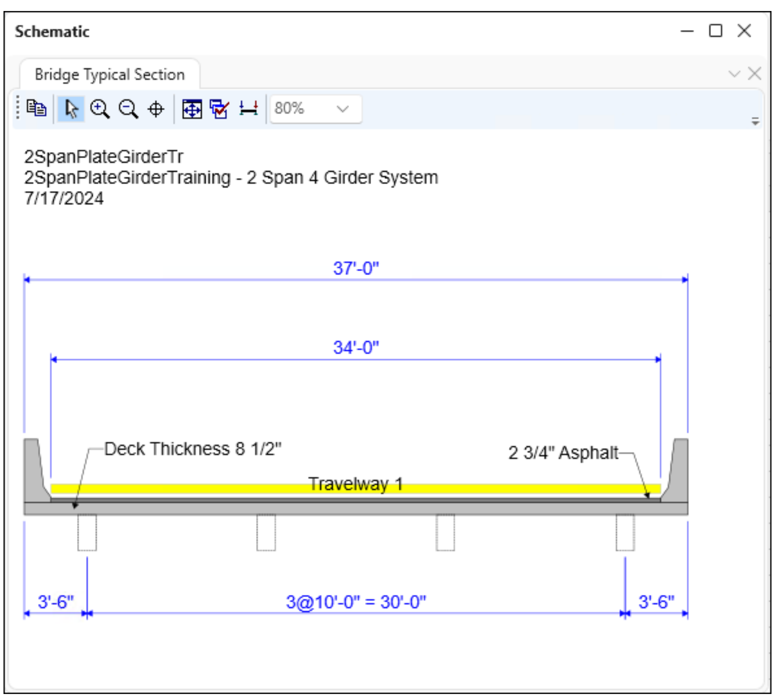
Click **OK** to apply the data and close the window.

Schematic – Structure Typical Section

While the **Structure Typical Section** is selected in the **Bridge Workspace** tree, open the schematic for the structure typical section by selecting the **Schematic** button on the **WORKSPACE** ribbon (or right click on **Structure Typical Section** in the **Bridge Workspace** and select **Schematic** from the menu).

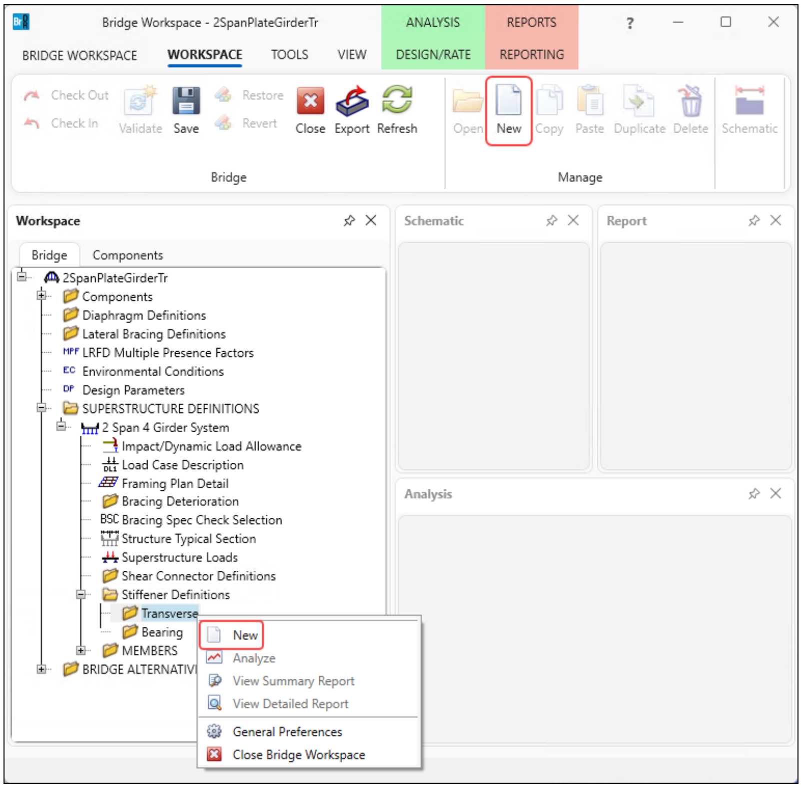


The following schematic is displayed. The girders are displayed as dashed boxes since they are not defined yet.

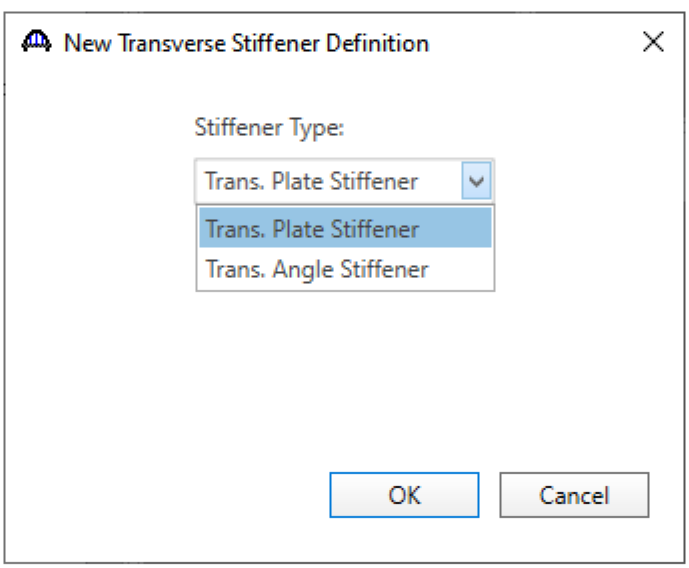


Stiffener Definitions – Transverse

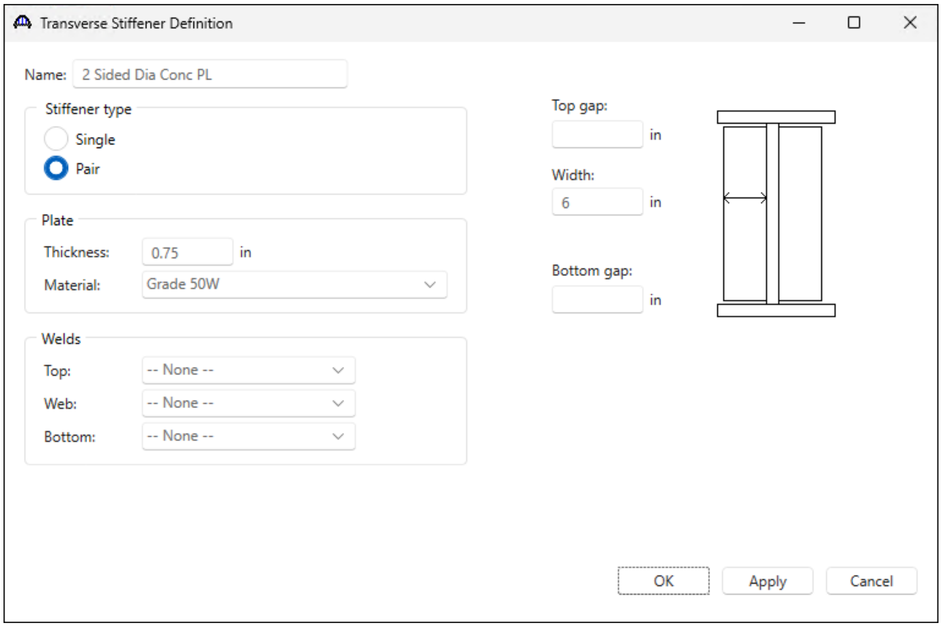
Define the transverse stiffeners to be used by the girders. Expand the **Stiffener Definitions** node in the **Bridge Workspace** tree, select **Transverse** and click on the **New** button from the **Manage** group of the **WORKSPACE** ribbon (or right click and select **New** from the drop-down menu) as shown below.



Select **Trans. Plate Stiffener** for **Stiffener Type** in the **New Transverse Stiffener Definition** window and click **OK** to open the **Transverse Stiffener Definition** window as shown below.



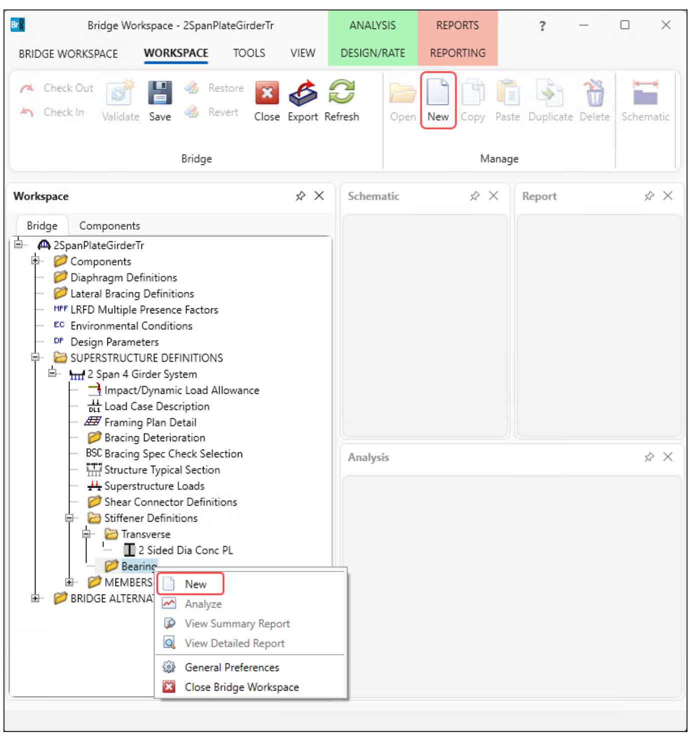
Define the stiffener as shown below.



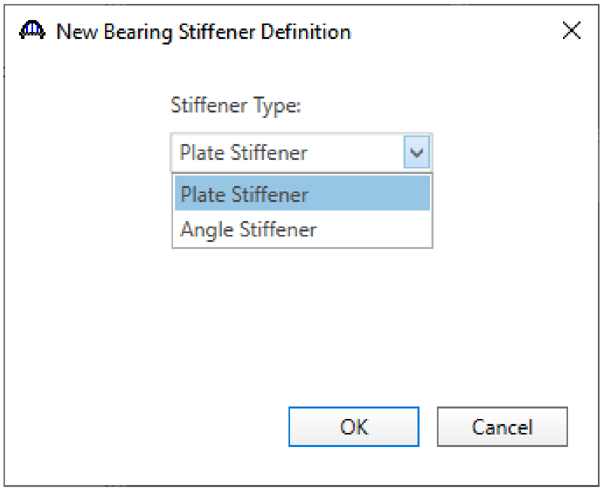
Click **OK** to apply the data and close the window.

Stiffener Definitions – Bearing

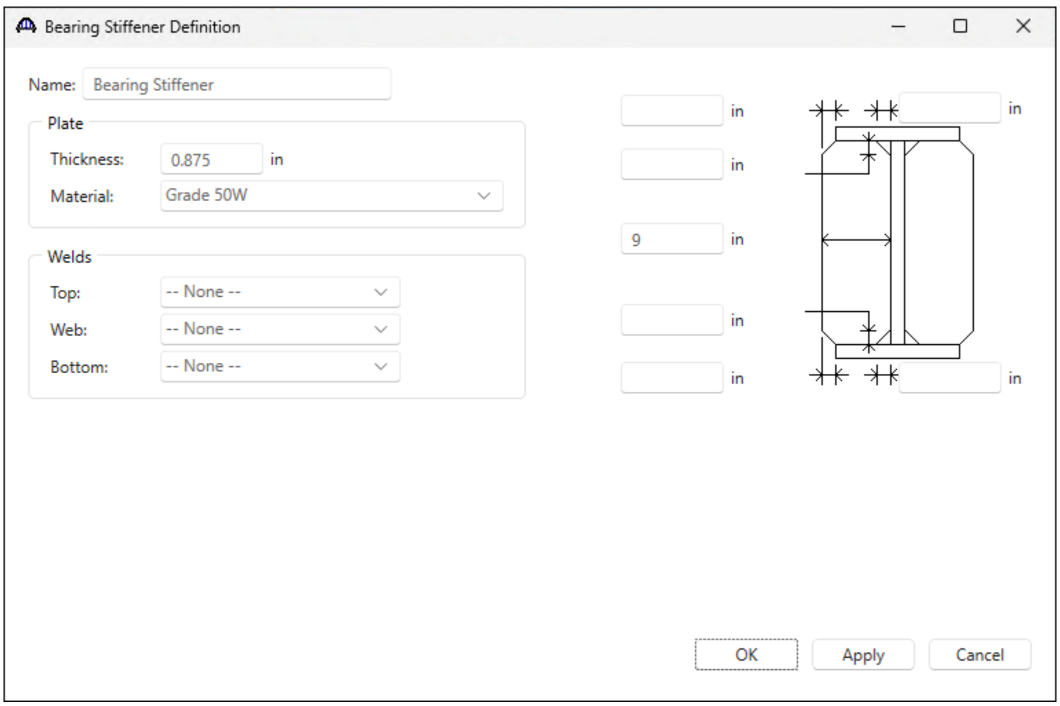
Define the bearing stiffeners to be used by the girders. Expand the **Stiffener Definitions** node in the **Bridge Workspace** tree, select **Bearing** and click on the **New** button from the **Manage** group of the **WORKSPACE** ribbon (or right click and select **New** from the drop-down menu) as shown below.



Select **Plate Stiffener** for **Stiffener type** in the **New Transverse Stiffener Definition** window and click **OK** to open the **Transverse Stiffener Definition** window as shown below.



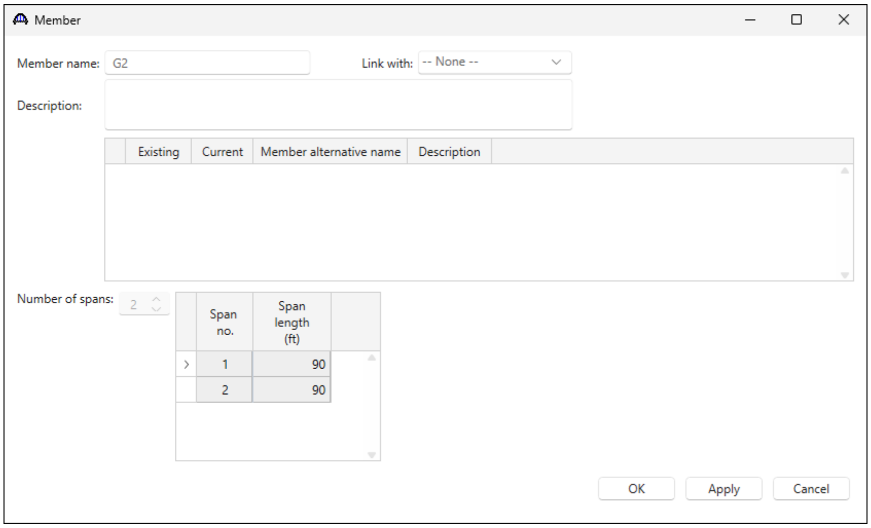
Define the stiffener as shown below.



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

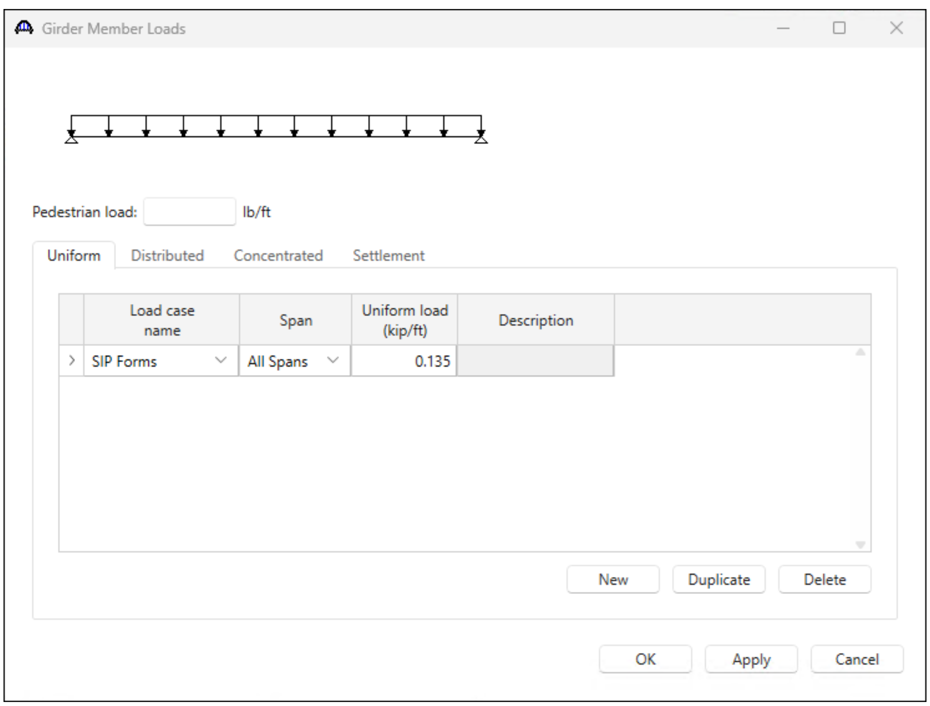
Describing a member

The **Member** window shows the data generated when the structure definition is created. Expand the **MEMBERS** folder and double click on **G2** node. No changes are required in this window. The first member alternative created will automatically be assigned as the **Existing** and **Current member alternative** for this member.



Member Loads

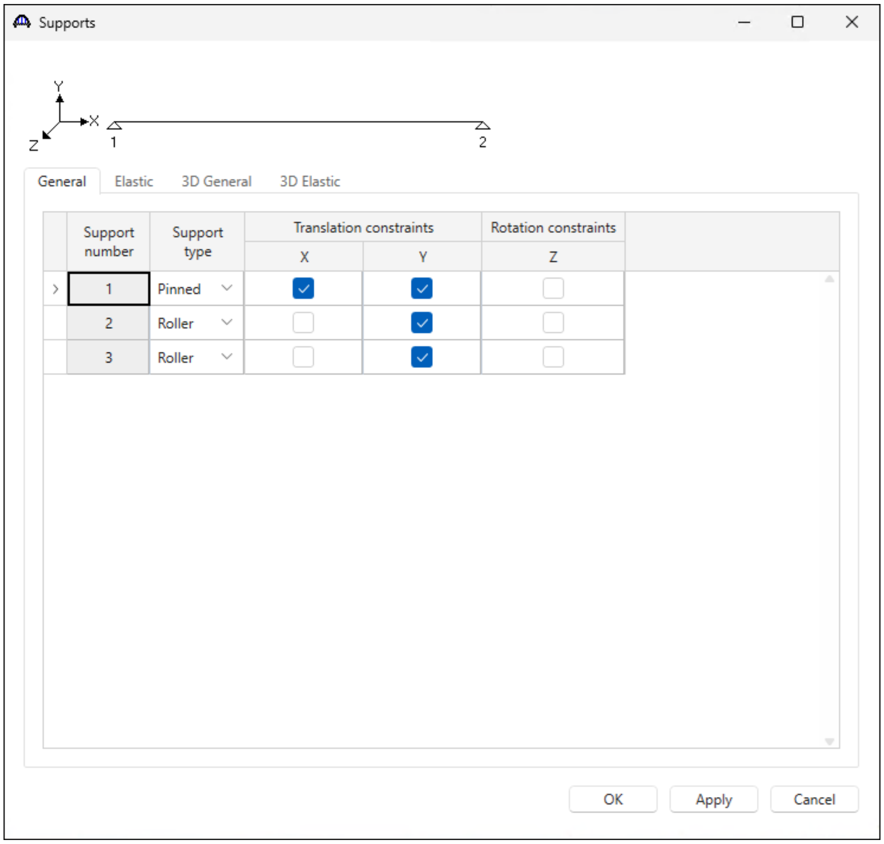
Expand the **G2** member node. Double-click on the **Member Loads** node in the **Bridge Workspace** tree to open the **Girder Member Loads** window. Add a new row and select **SIP Forms** from the options for **Load case name**. Enter the **Uniform load** due to the stay-in-place forms as shown below.



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

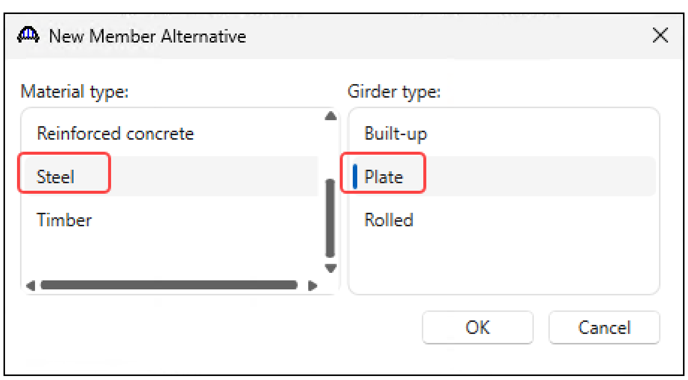
Supports

Double click on **Supports** node in the **Bridge Workspace** tree for member **G2** to open the **Supports** window. Support constraints generated when the structure definition is created and are shown below. No changes are required to this window.



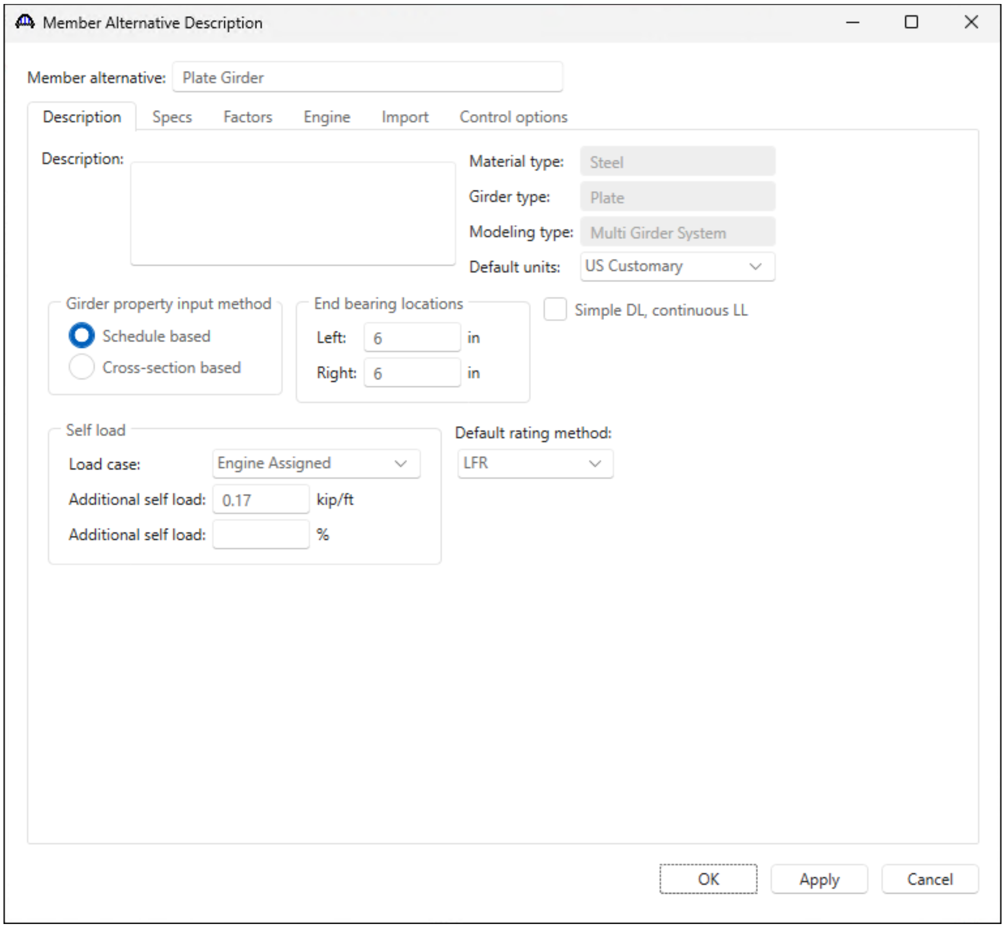
Defining a Member Alternative

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

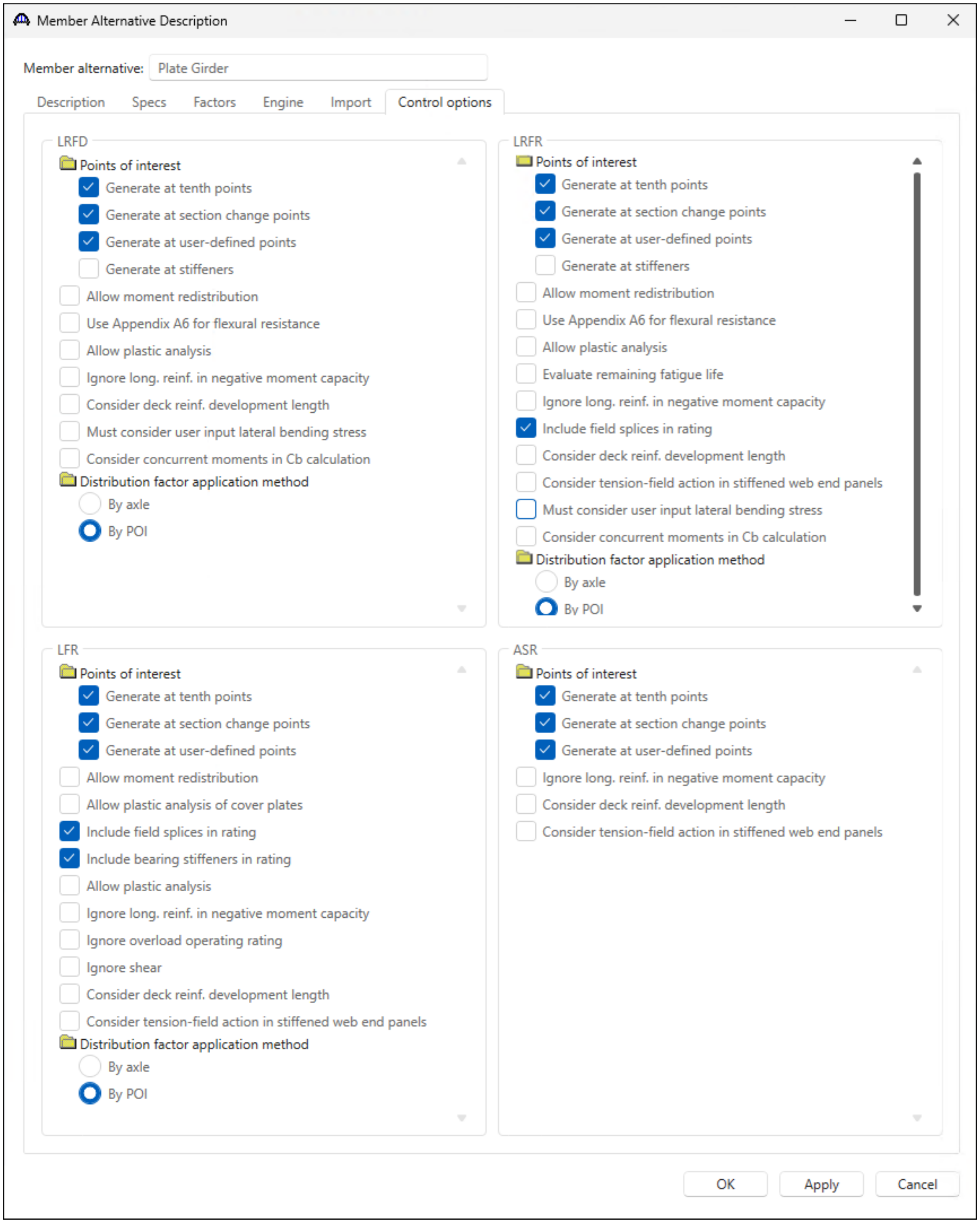


Click **OK** to close the window and create a new member alternative.

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

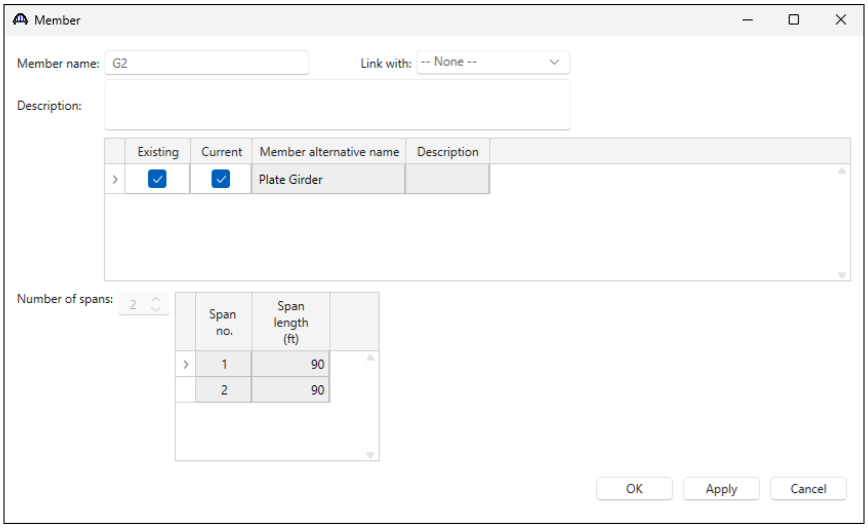


Navigate to the **Control options** tab of this window and select the options as shown below.



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

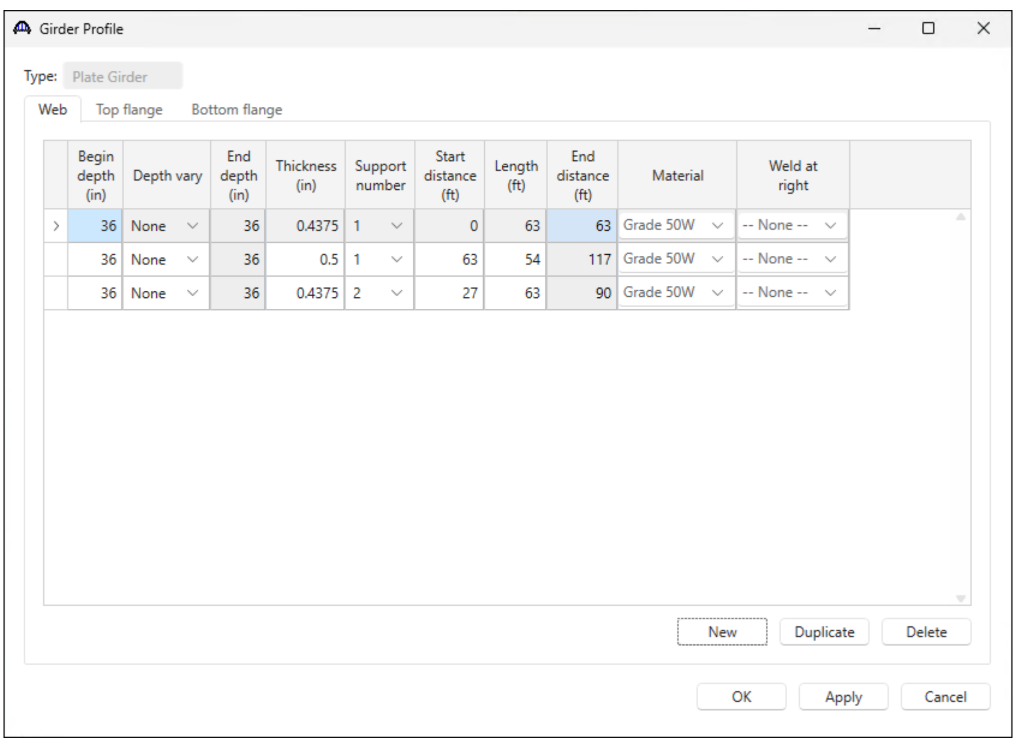
Reopen the member **G2** window. The newly added member alternative will automatically be assigned as the **Existing** and **Current** member alternative for this member.



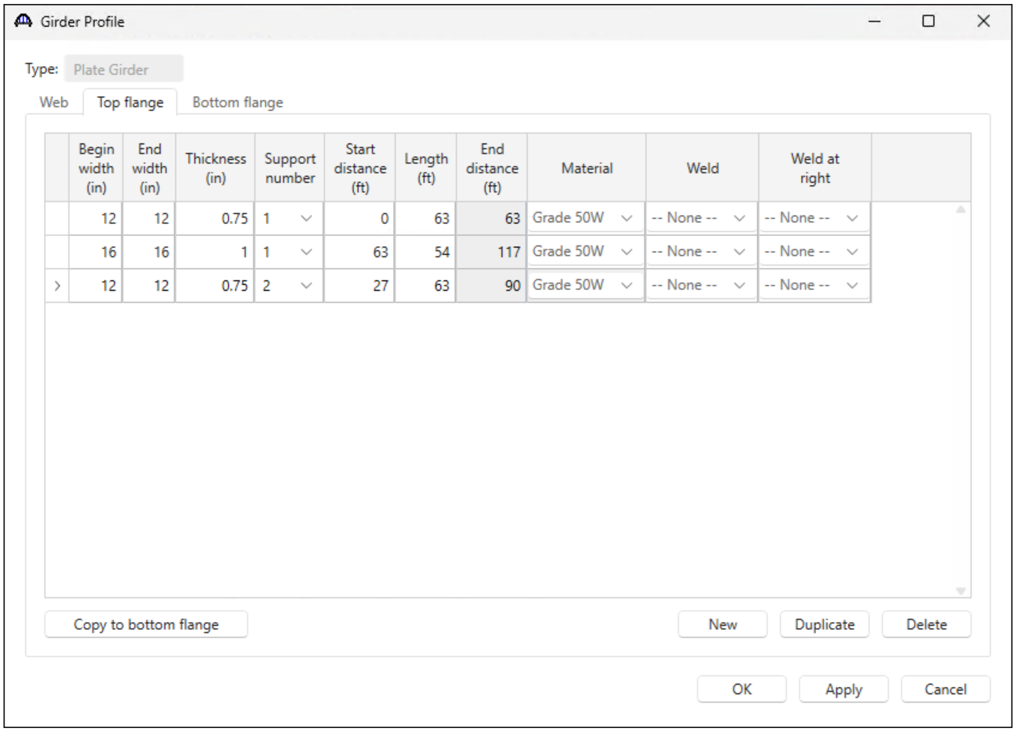
Girder Profile

Expand the newly added **Plate Girder** member alternative for member **G2**. Next describe the girder profile by double clicking on the **Girder Profile** node in the **Bridge Workspace** tree. Enter the data in each tab of the **Girder Profile** window as shown below.

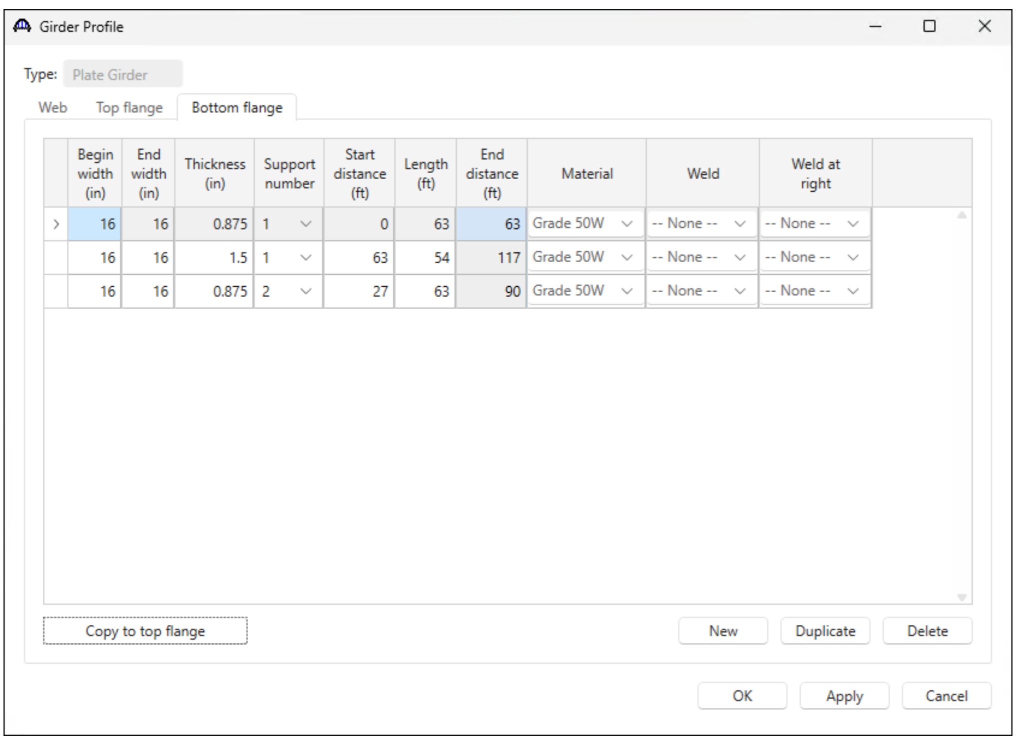
Web



Top flange



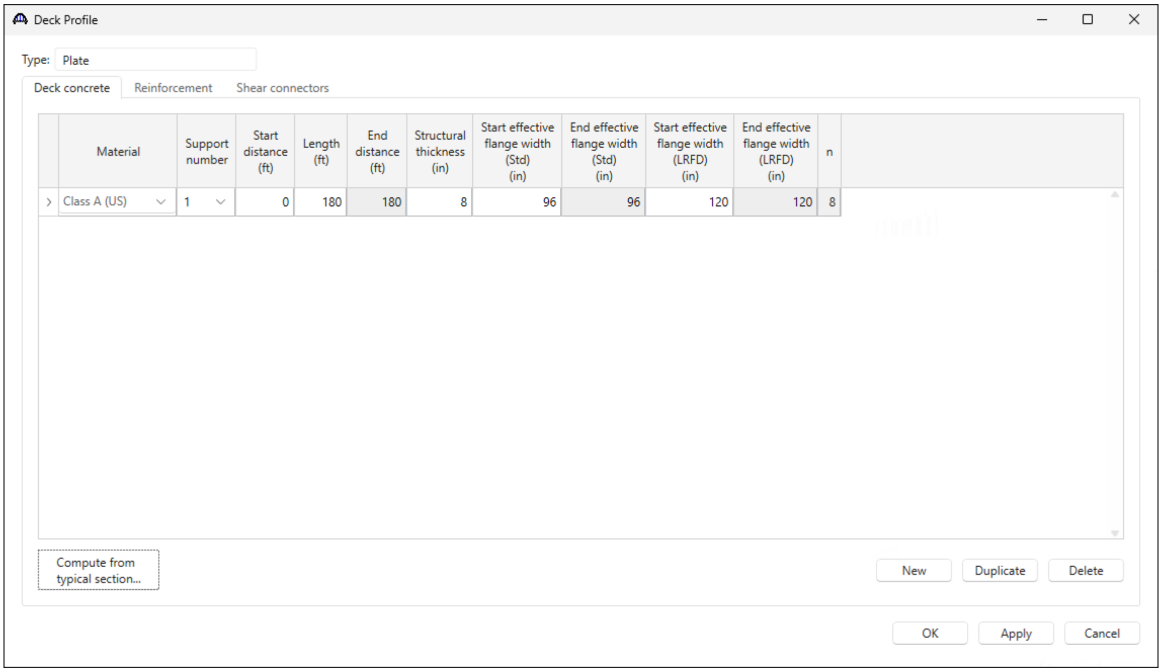
Bottom flange



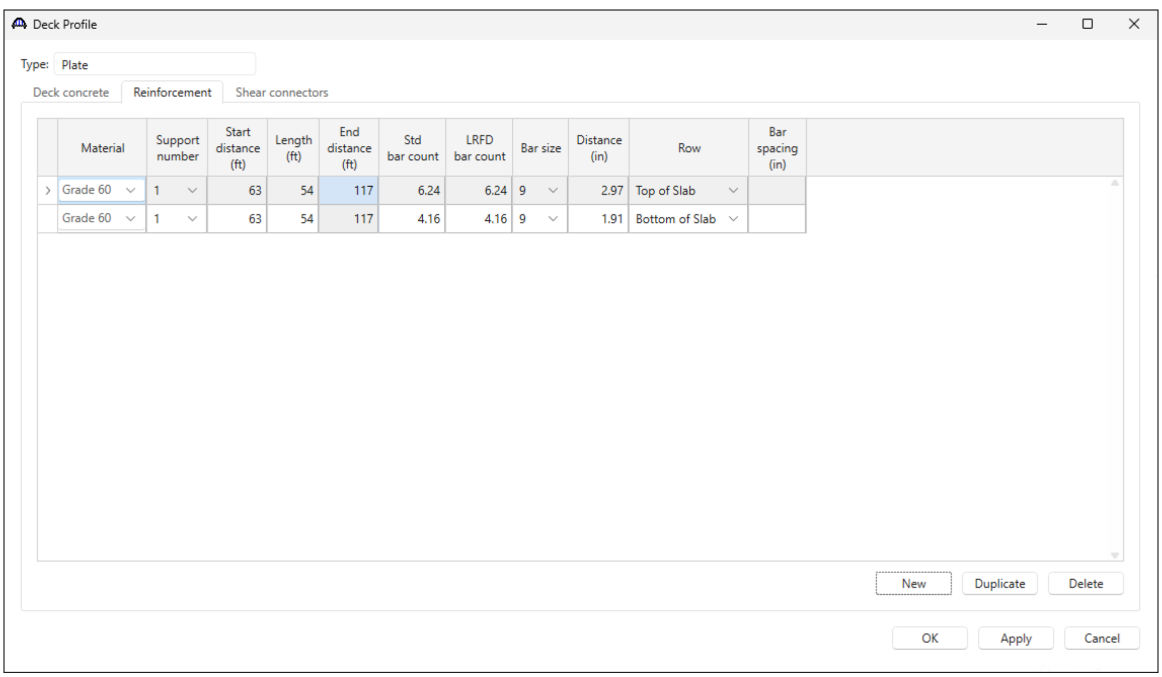
Click **OK** to apply the data and close the window.

Deck Profile

Next open the **Deck Profile** window by double-clicking the **Deck Profile** node in the **Bridge Workspace** tree and enter the data describing the structural properties of the deck. The window is as shown below.

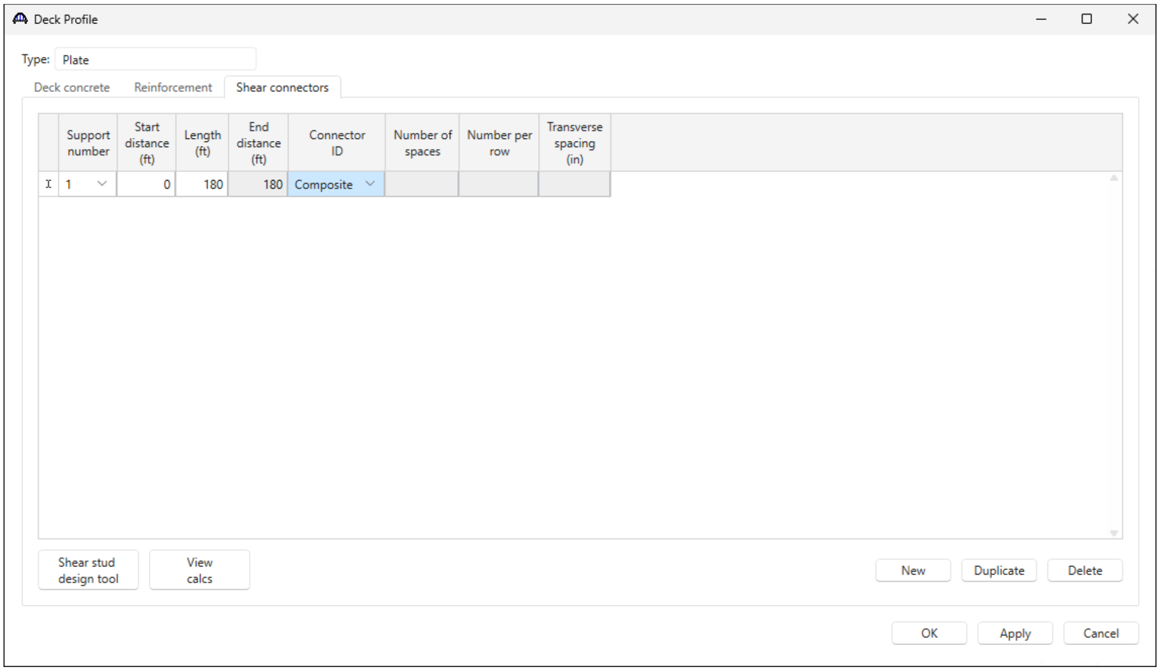


Enter the reinforcement data as shown below.



Note: As mentioned in the Note under the composite section details in Page 3 of this tutorial, for simplicity, the bars will be input using an equivalent number of #9 bars which have a unit area of 1.0 in^2.

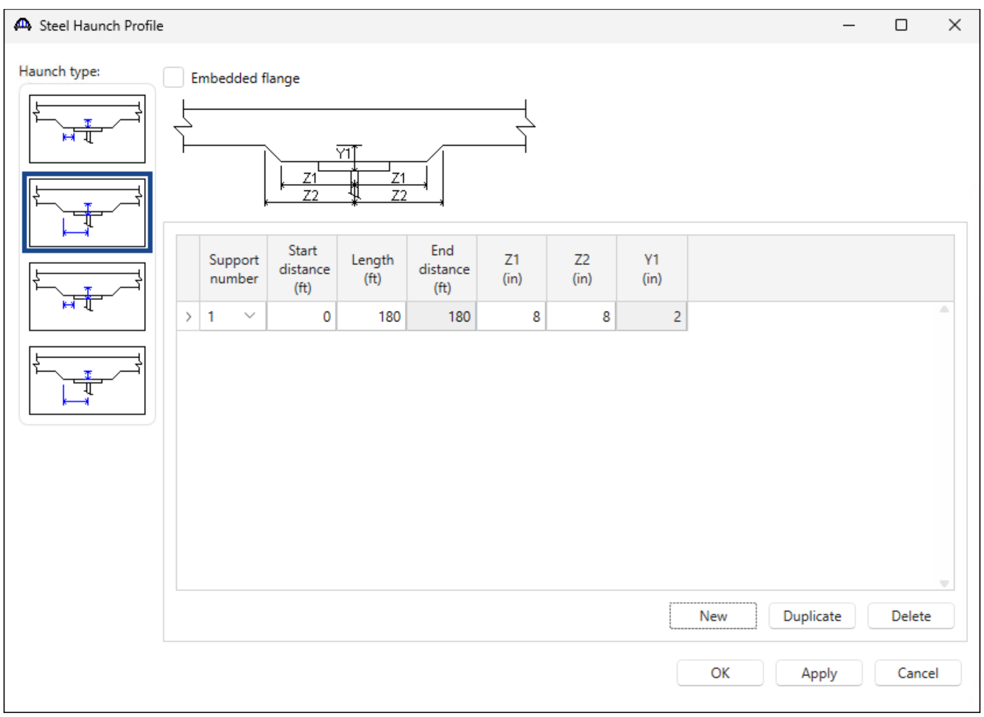
Composite regions described in the **Shear connectors** tab as shown below.



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

Haunch Profile

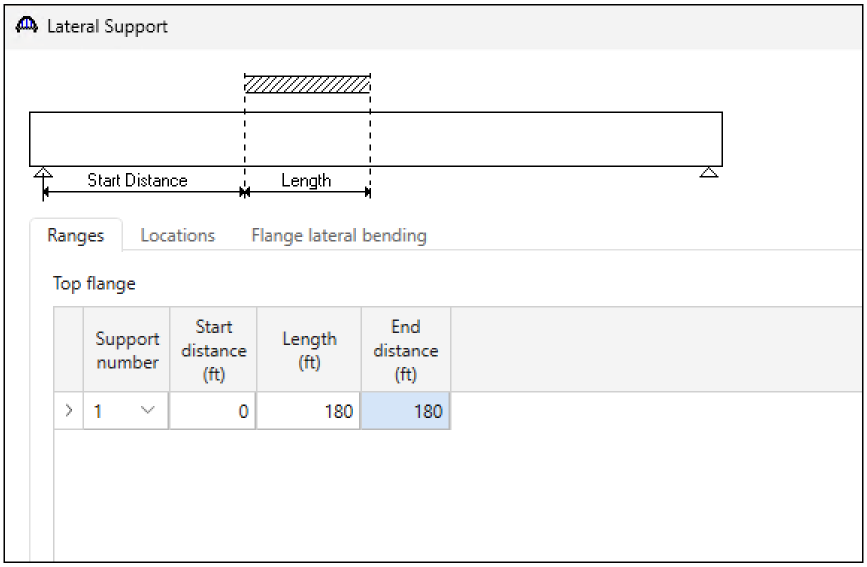
To define the haunch profile , double-click on the **Haunch Profile** node in the **Bridge Workspace** tree. Select the Haunch type and enter data as shown below.



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

Lateral Support

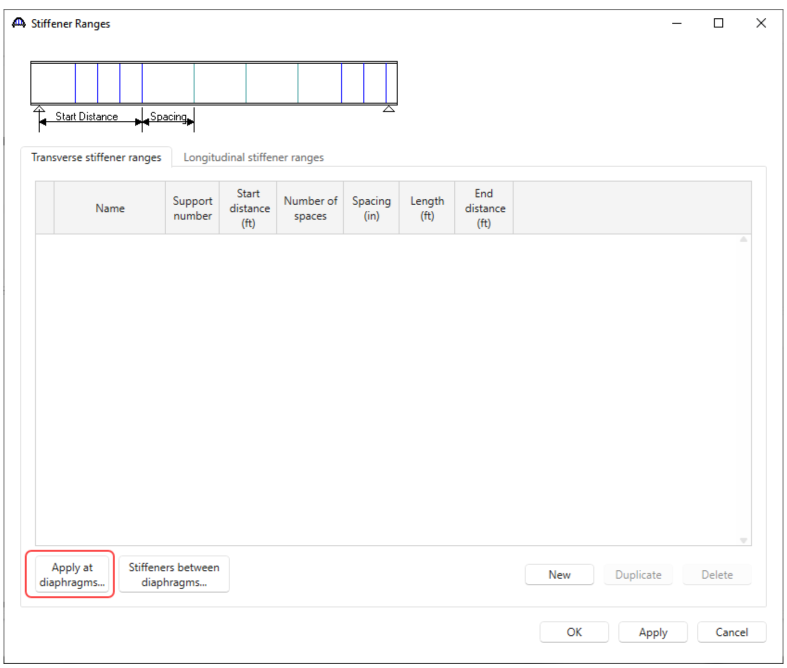
Open the **Lateral Support** window by double clicking on the **Lateral Support** node in the **Bridge Workspace** tree. Regions where the slab provides lateral support for the top flange are defined as shown below.



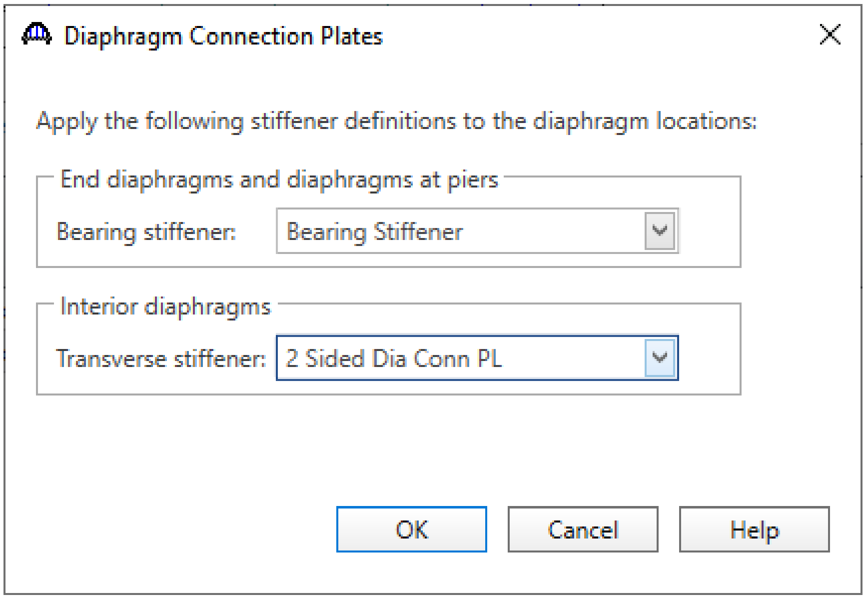
Click **OK** to apply the data and close the window.

Stiffener Ranges

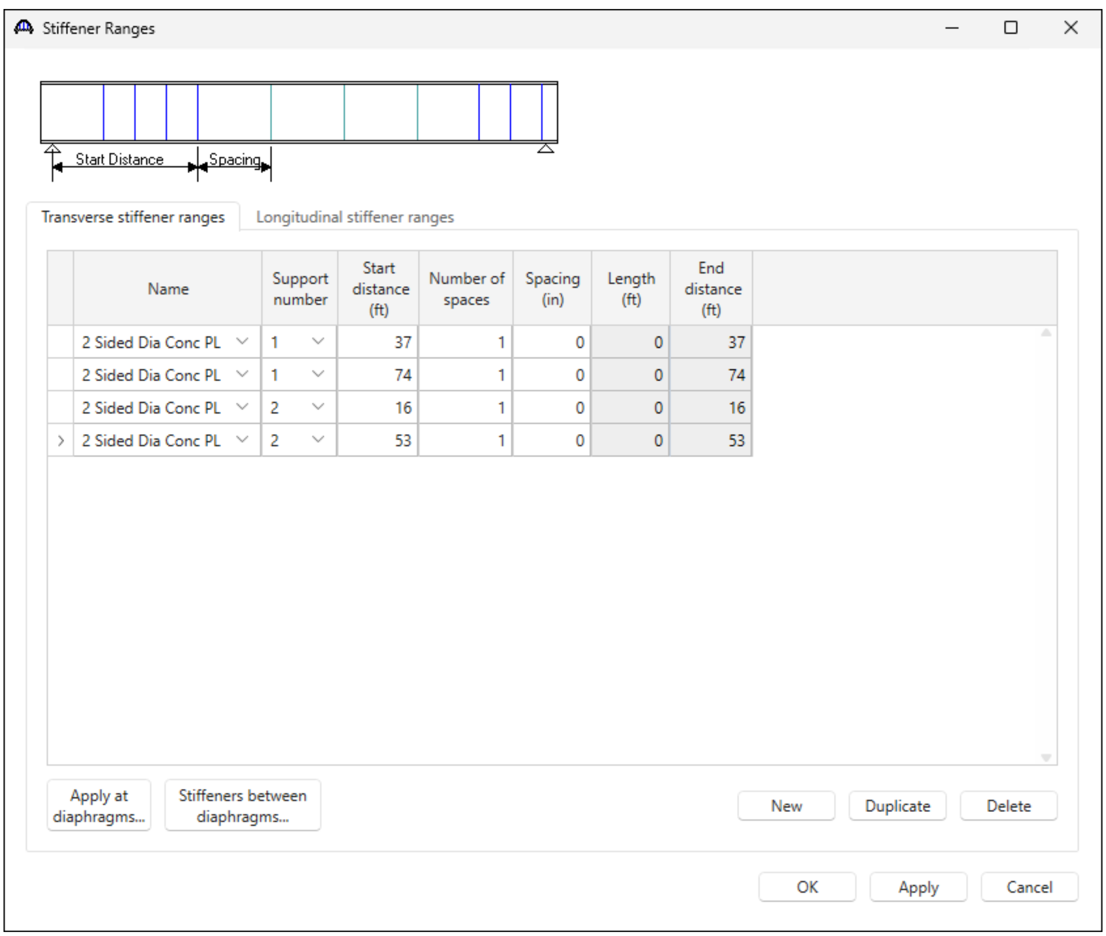
Double click on the **Stiffener Ranges** node in the **Bridge Workspace** to open the **Stiffener Ranges** window. Click the **Apply at diaphragms…** button to open the **Diaphragm Connection Plates** window.



Select the **2 Sided Conn PL** as the **Transverse Stiffener** to be applied at the interior diaphragms and click **OK.**



The **Stiffener Ranges** window will be updated as shown below.

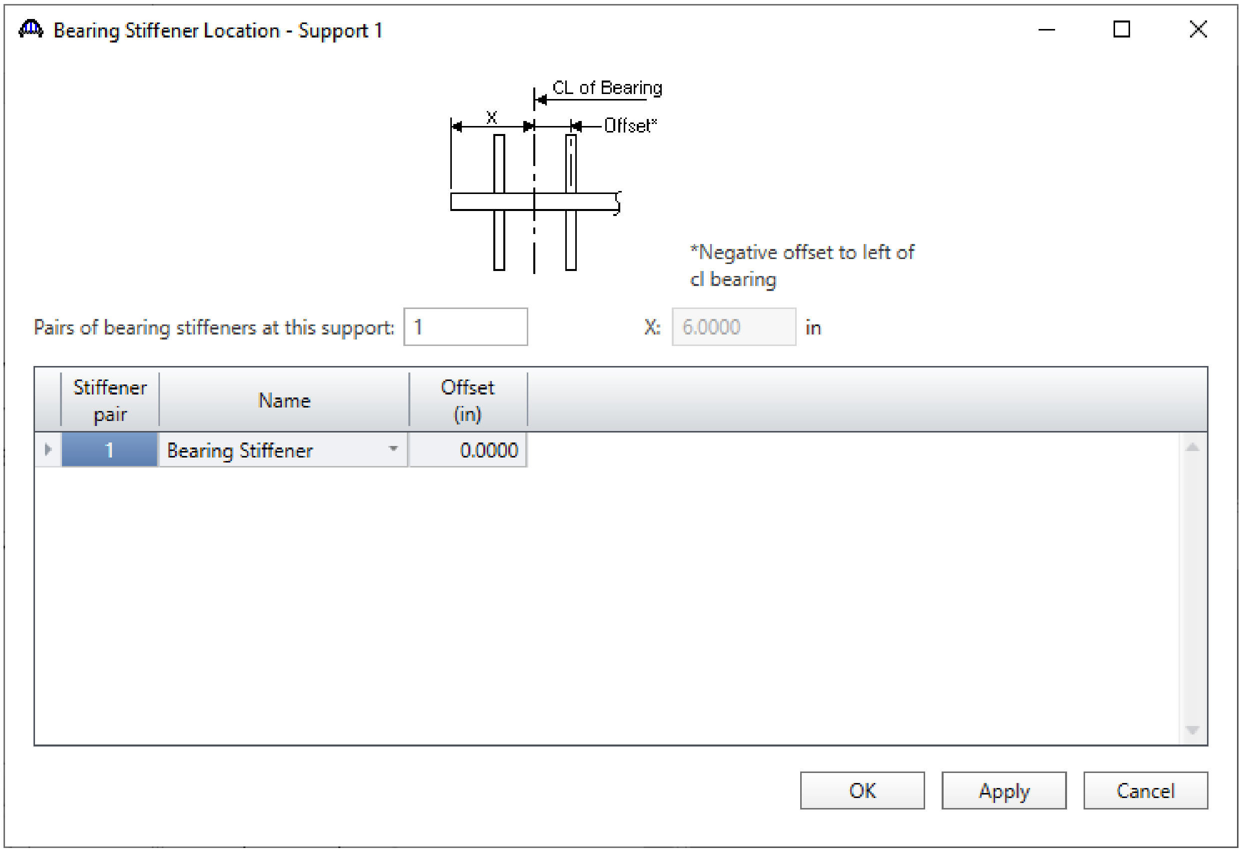


Name	Support number	Start distance (ft)	Number of spaces	Spacing (in)	Length (ft)	End distance (ft)
2 Sided Dia Conc PL	1	37	1	0	0	37
2 Sided Dia Conc PL	1	74	1	0	0	74
2 Sided Dia Conc PL	2	16	1	0	0	16
2 Sided Dia Conc PL	2	53	1	0	0	53

This example does not have any intermediate transverse stiffeners. Click **OK** to apply the data and close the window.

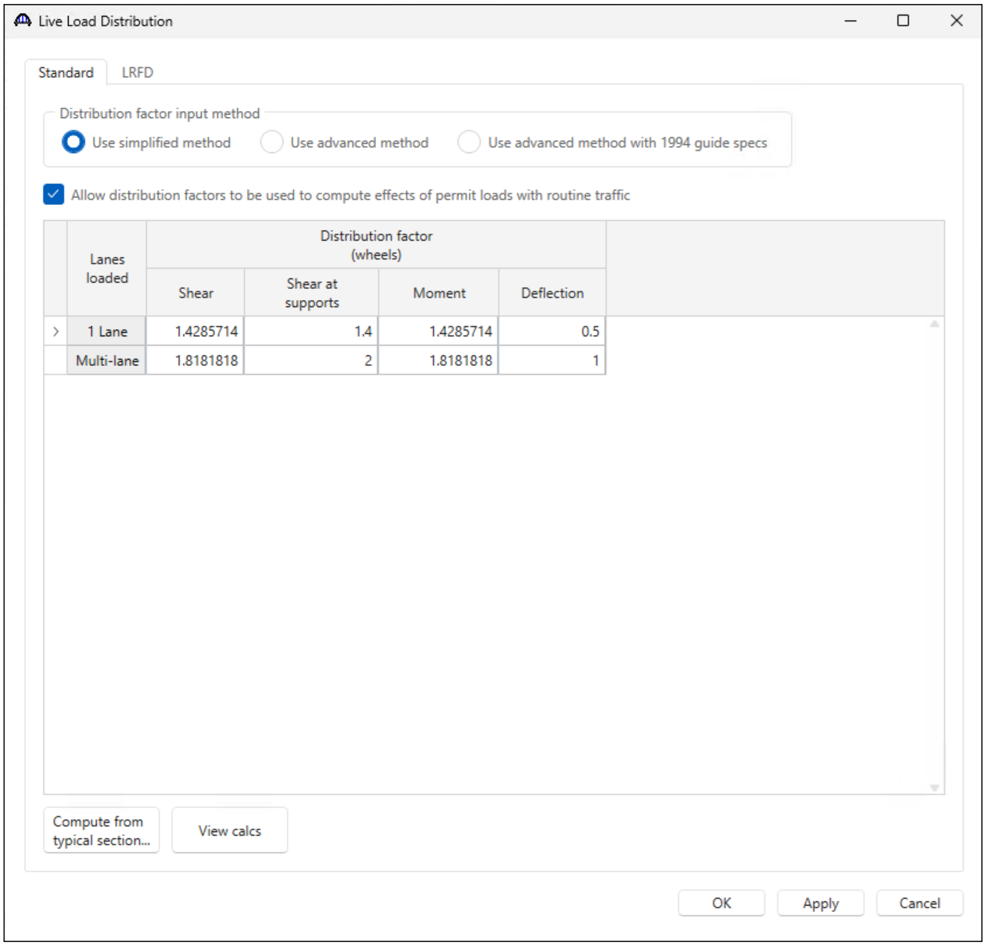
Bearing Stiffener Locations

Bearing stiffener definitions were assigned to locations when the **Apply at diaphragms…** option was used on the **Stiffener Ranges** window. The **Bearing Stiffener Location – Support 1** window is opened by expanding the **Bearing Stiffener Locations** node in the **Bridge Workspace** tree and double clicking on the **Support 1** node. The assignment for support 1 is shown below. No changes are required to this window.



Live Load Distribution

Open the **Live Load Distribution** window from the **Bridge Workspace** tree. Click the **Compute from typical section…** button to compute the standard live load distribution factors.



LRFD distribution factors are computed by the BrDR engine using the girder system structure definition.

Interior (LFR wheels)

Lanes Loaded	Shear	Shear at Support	Moment	Deflection
1 lane	1.43	1.4	1.43	0.5
Multi-lane	1.82	2.0	1.82	1.0

Interior (LRFD lanes)

Lanes Loaded	Shear	Shear at Support	Pos. Moment	Neg. Moment	Deflection
1 lane	0.76	0.76	0.480	0.499	0.3*
Multi-lane	0.952	0.952	0.692	0.720	0.5

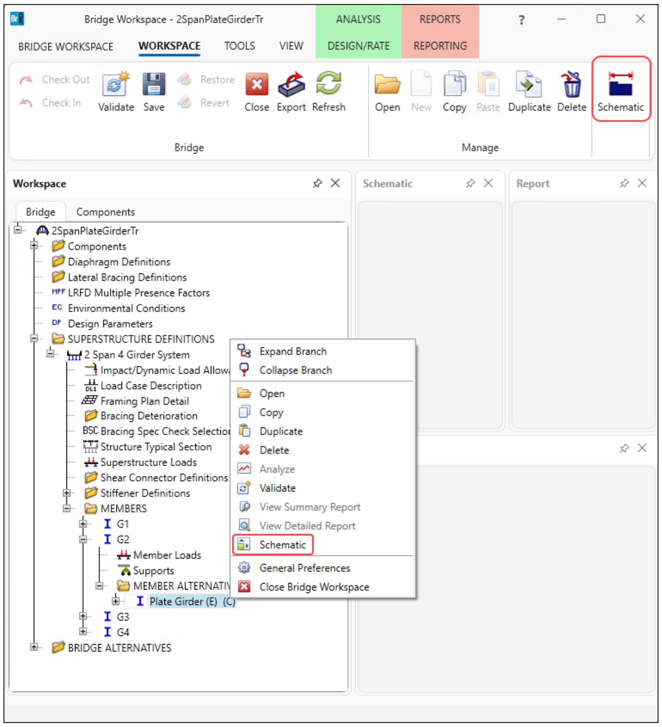
* includes 1.20 multiple presence factor

Live load distribution factor calculation details can be viewed by clicking the **View Calcs** button.

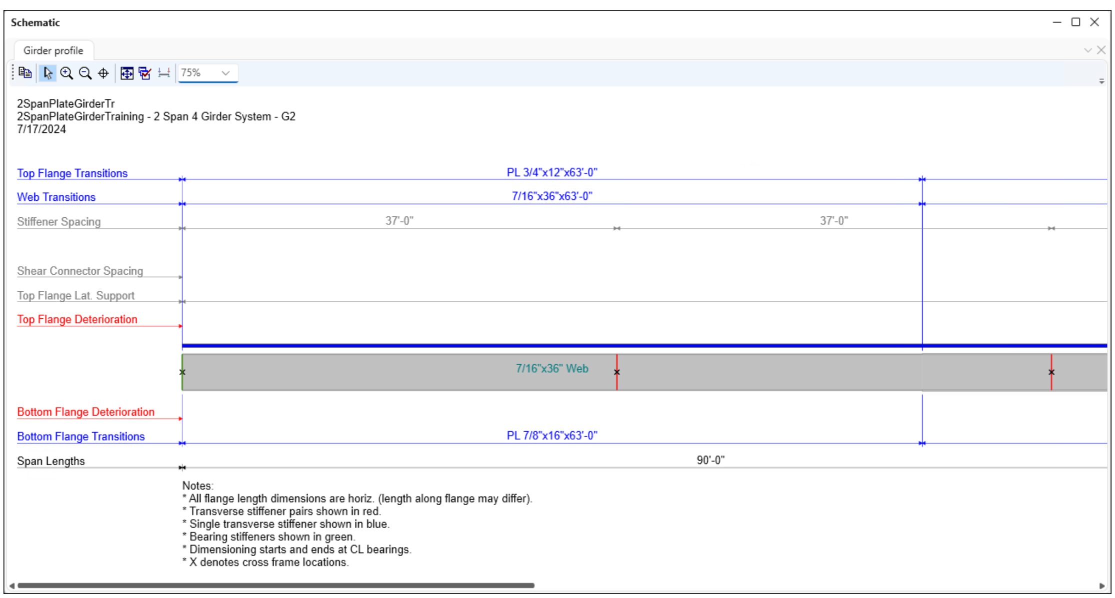
The description of an interior beam for the structure definition is complete.

Schematic – Member alternative

While the member alternative **Plate Girder** for member **G2** is selected in the **Bridge Workspace** tree, open the schematic for the girder profile by selecting the **Schematic** button on the **WORKSPACE** ribbon (or right click and select **Schematic** from the menu).

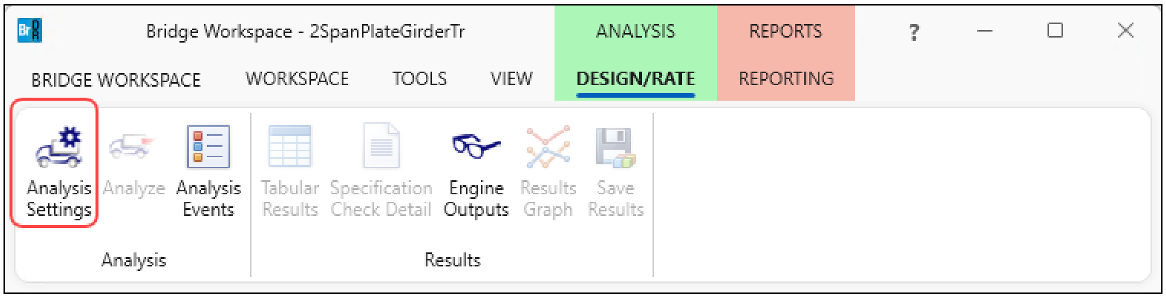


The following schematic will be displayed.

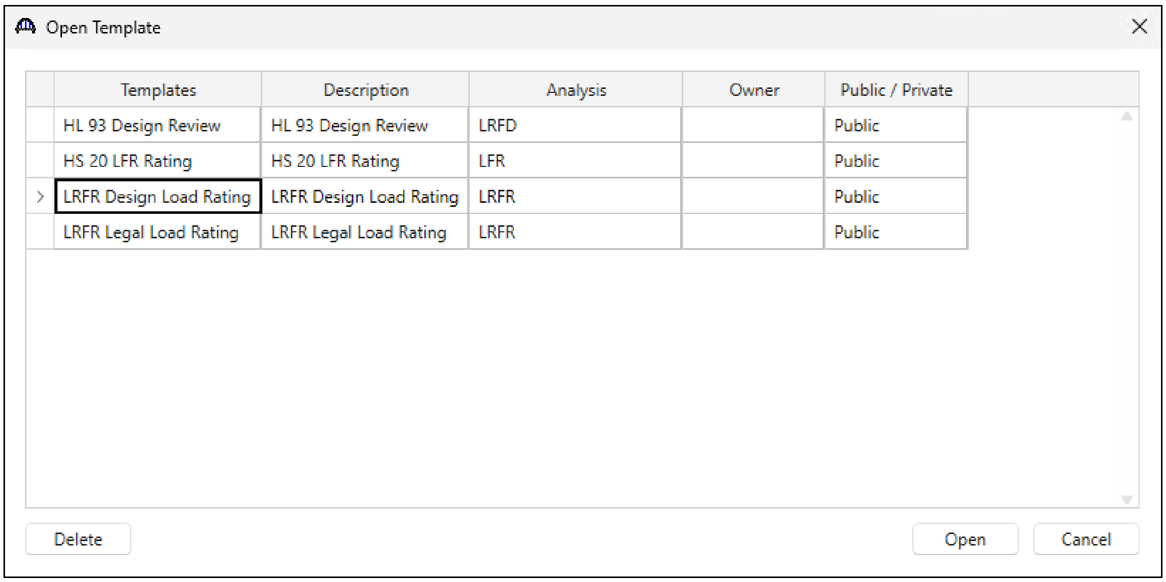


LRFR Analysis

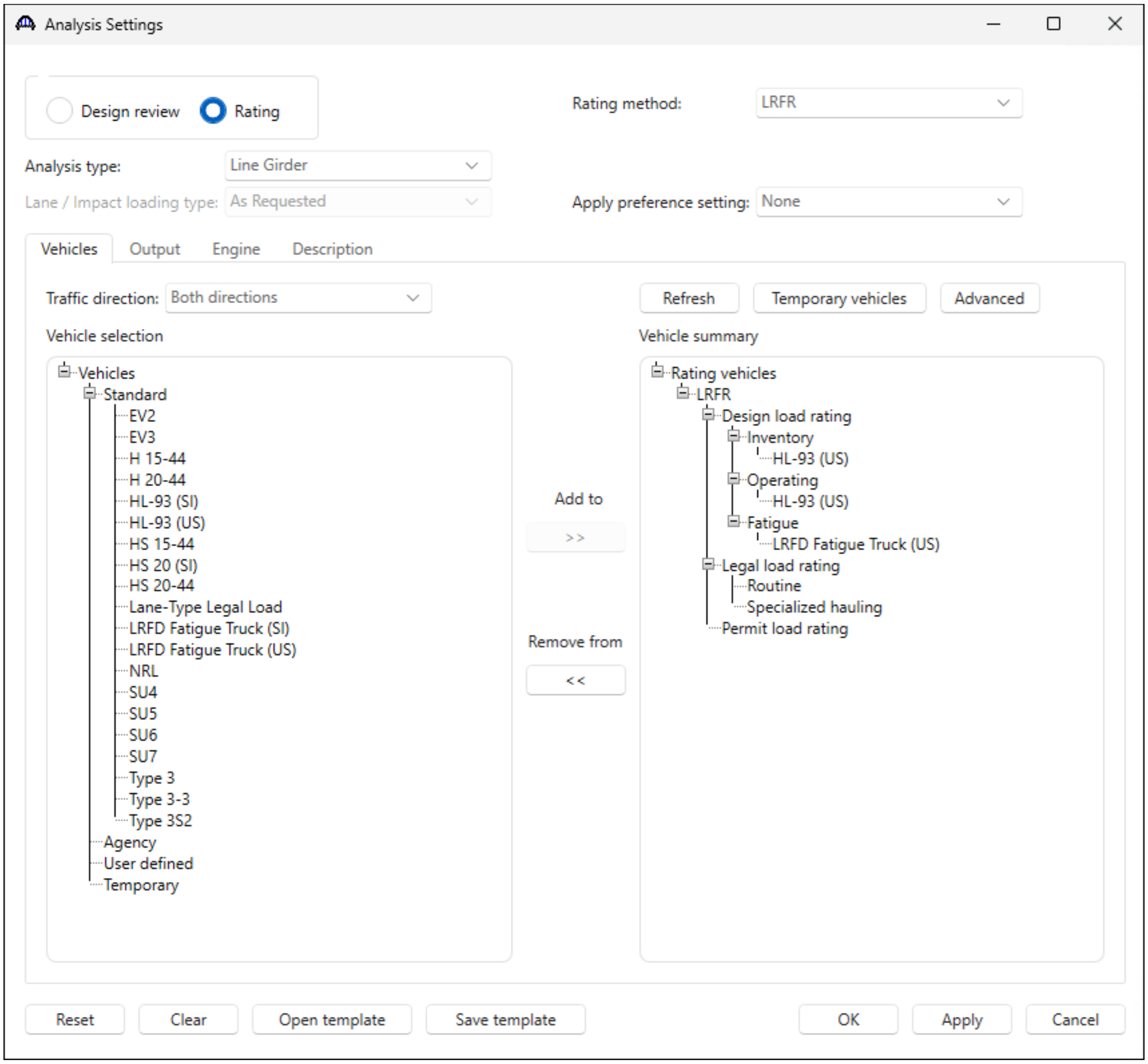
The interior member alternative can now be analyzed. To perform an **LRFR** rating, select the **Analysis Settings** button on the **Analysis** group of the **DESIGN/RATE** ribbon. The window shown below opens.



Click the **Open Template** button and select the **LRFR Design Load Rating** to use in the rating and click **Open**.



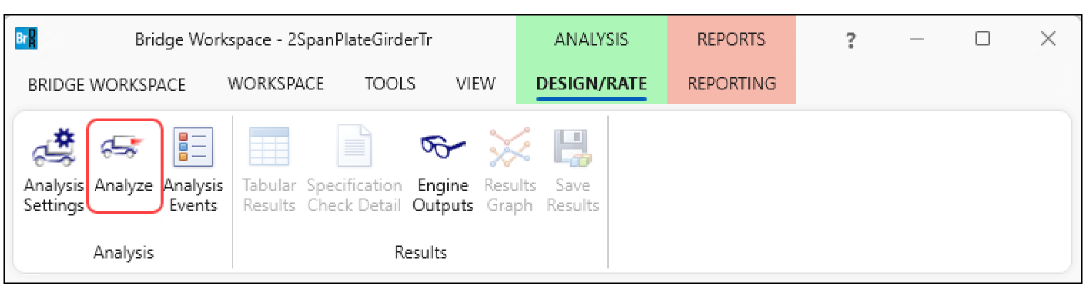
The **Analysis Settings** window will be populated as shown below.



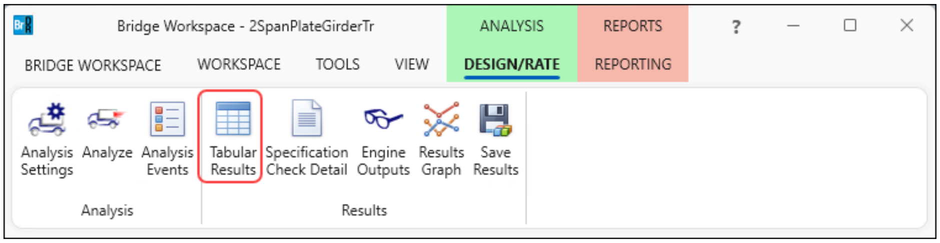
Click **OK** to apply the data and close the window.

Tabular Results

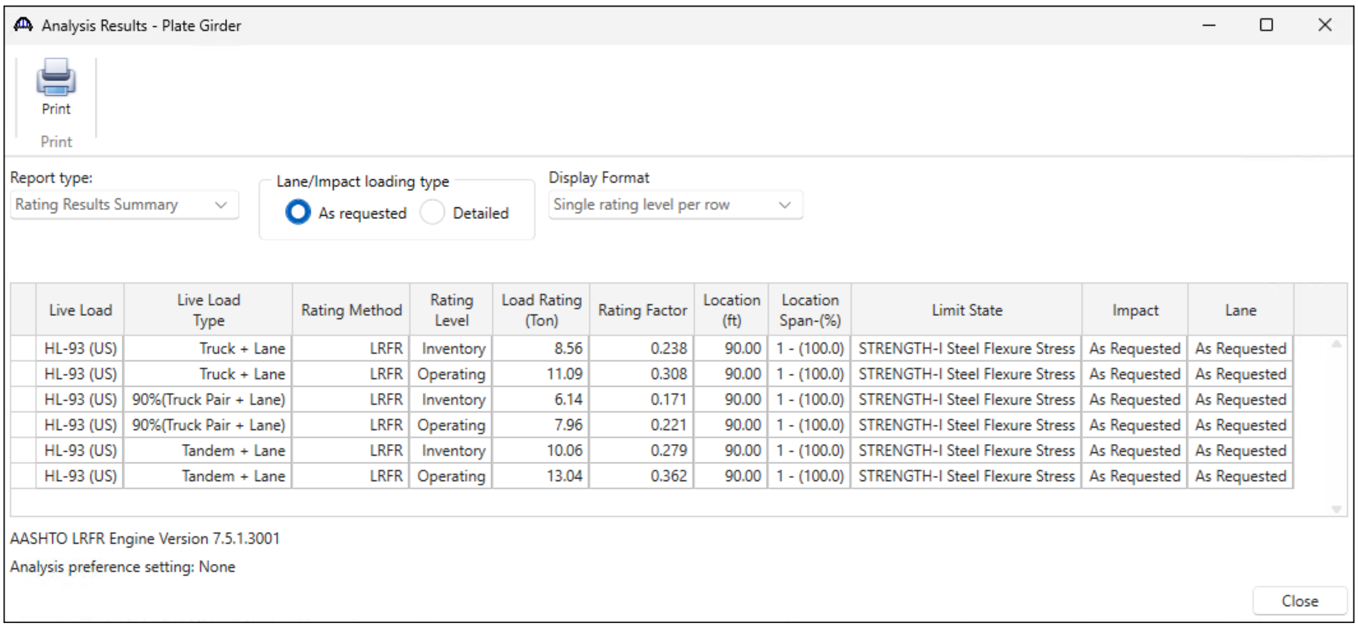
With **G2** member alternative – **Plate Girder** selected, click the **Analyze** button on the **Analysis** group of the **DESIGN/RATE** ribbon to perform the rating.



When the rating analysis is finished, results can be reviewed by clicking the **Tabular Results** button on the **Results** group of the ribbon.



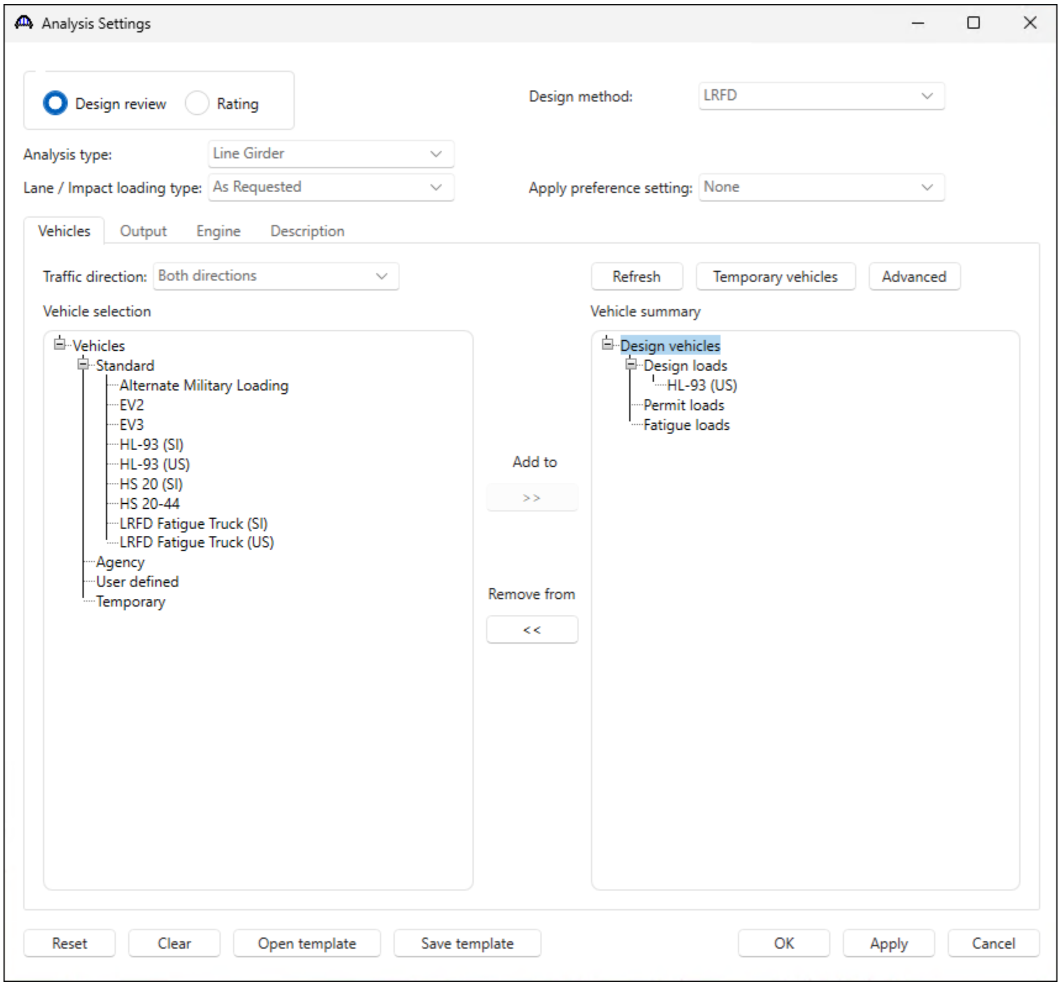
The window shown below will open. Select **Rating Results Summary** as the **Report Type** and **Single rating level per row** as the **Display Format** option to have the ratings arranged as shown below.



Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HL-93 (US)	Truck + Lane	LRFR	Inventory	8.56	0.238	90.00	1 - (100.0)	STRENGTH-I Steel Flexure Stress	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	11.09	0.308	90.00	1 - (100.0)	STRENGTH-I Steel Flexure Stress	As Requested	As Requested
HL-93 (US)	90%(Truck Pair + Lane)	LRFR	Inventory	6.14	0.171	90.00	1 - (100.0)	STRENGTH-I Steel Flexure Stress	As Requested	As Requested
HL-93 (US)	90%(Truck Pair + Lane)	LRFR	Operating	7.96	0.221	90.00	1 - (100.0)	STRENGTH-I Steel Flexure Stress	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	10.06	0.279	90.00	1 - (100.0)	STRENGTH-I Steel Flexure Stress	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	13.04	0.362	90.00	1 - (100.0)	STRENGTH-I Steel Flexure Stress	As Requested	As Requested

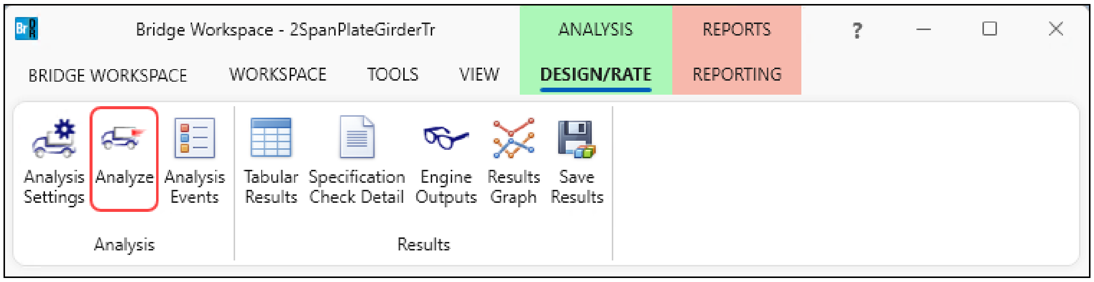
LRFD Design Review

An LRFD design review of this girder for **HL93** loading can be performed by AASHTO LRFD. To perform an LRFD design review, enter the **Analysis Settings** window as shown below.



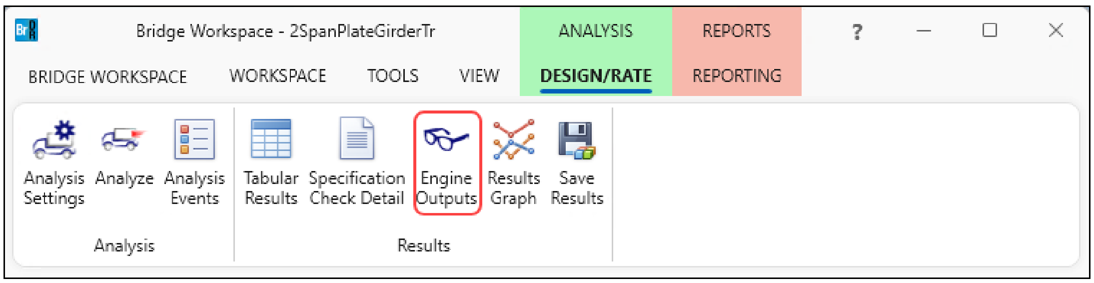
Click **OK** to apply the data and close the window.

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

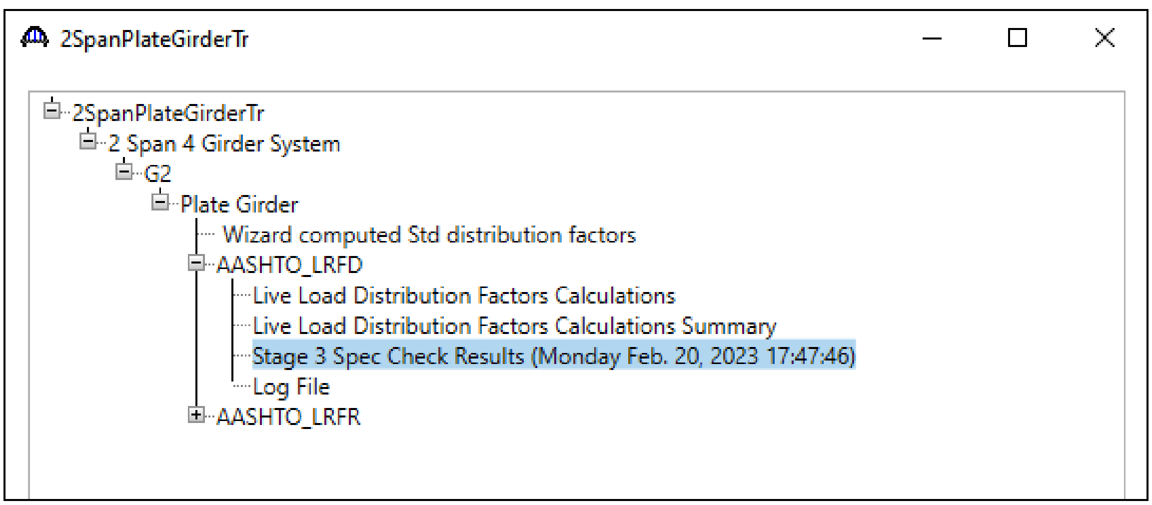


Engine Outputs

AASHTO LRFD analysis will generate a spec check results file. Click the **Engine Outputs** button from the **Results** group of the **DESIGN/RATE** ribbon to open the following window.



To view the LRFD spec check results (shown below), double click on the **Stage 3 Spec Check Results** under the **AASHTO_LRFD** branch in this window.

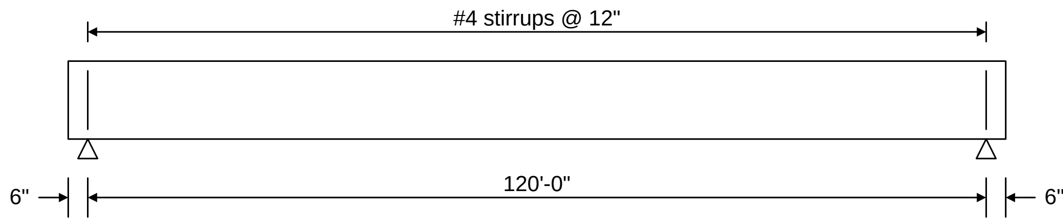


AASHTOWare BrDR 7.5.1

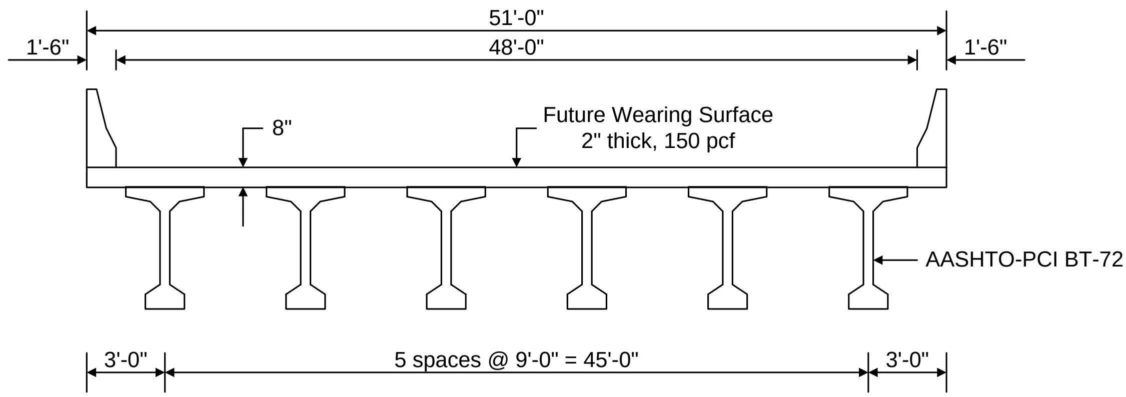
Prestress Tutorial 1

PS1 - Simple Span Prestressed I Beam Example

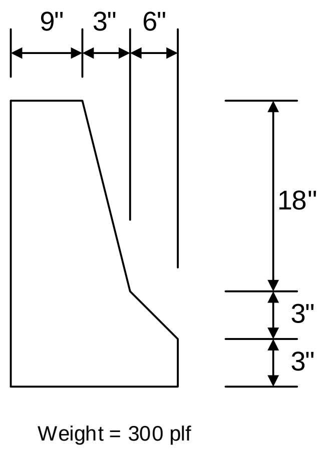
PS1 - Simple Span Prestressed I Beam Example



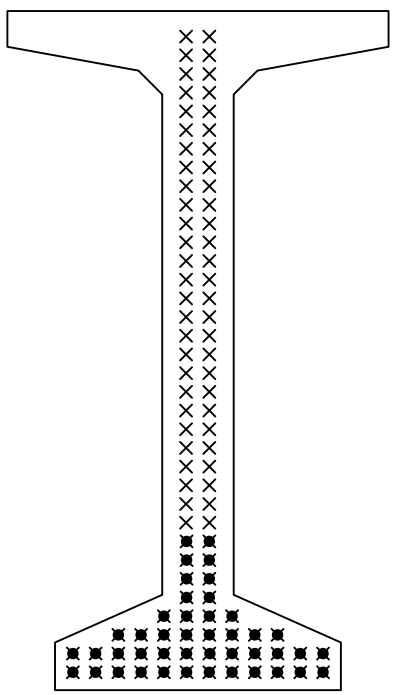
Elevation



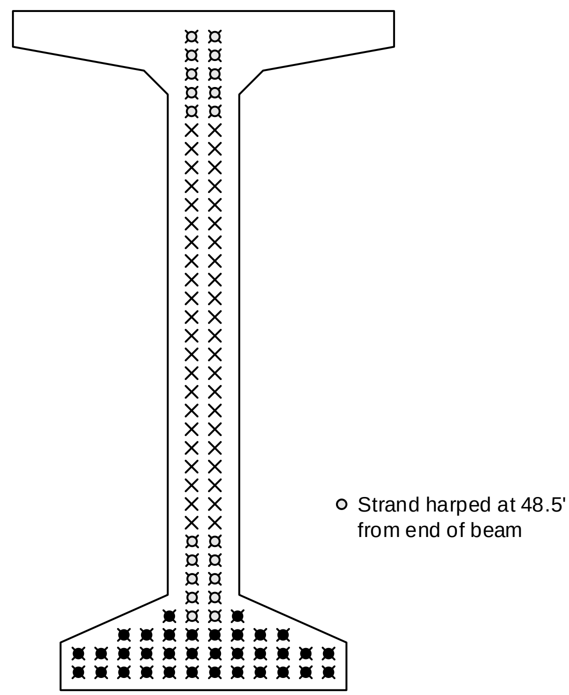
Typical Section



Parapet Detail



Strand Pattern at Mid-Span



Strand Pattern at End of Beam

Material Properties

Beam Concrete: f'c = 6.5 ksi, f'ci = 5.5 ksi

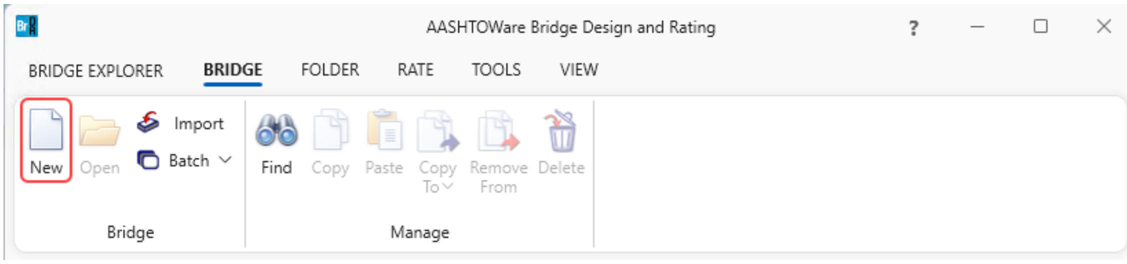
Deck Concrete: f'c = 4.5 ksi

Prestressing Strand: 1/2" dia., 7 Wire strand, Fu = 270 ksi, Low Relaxation

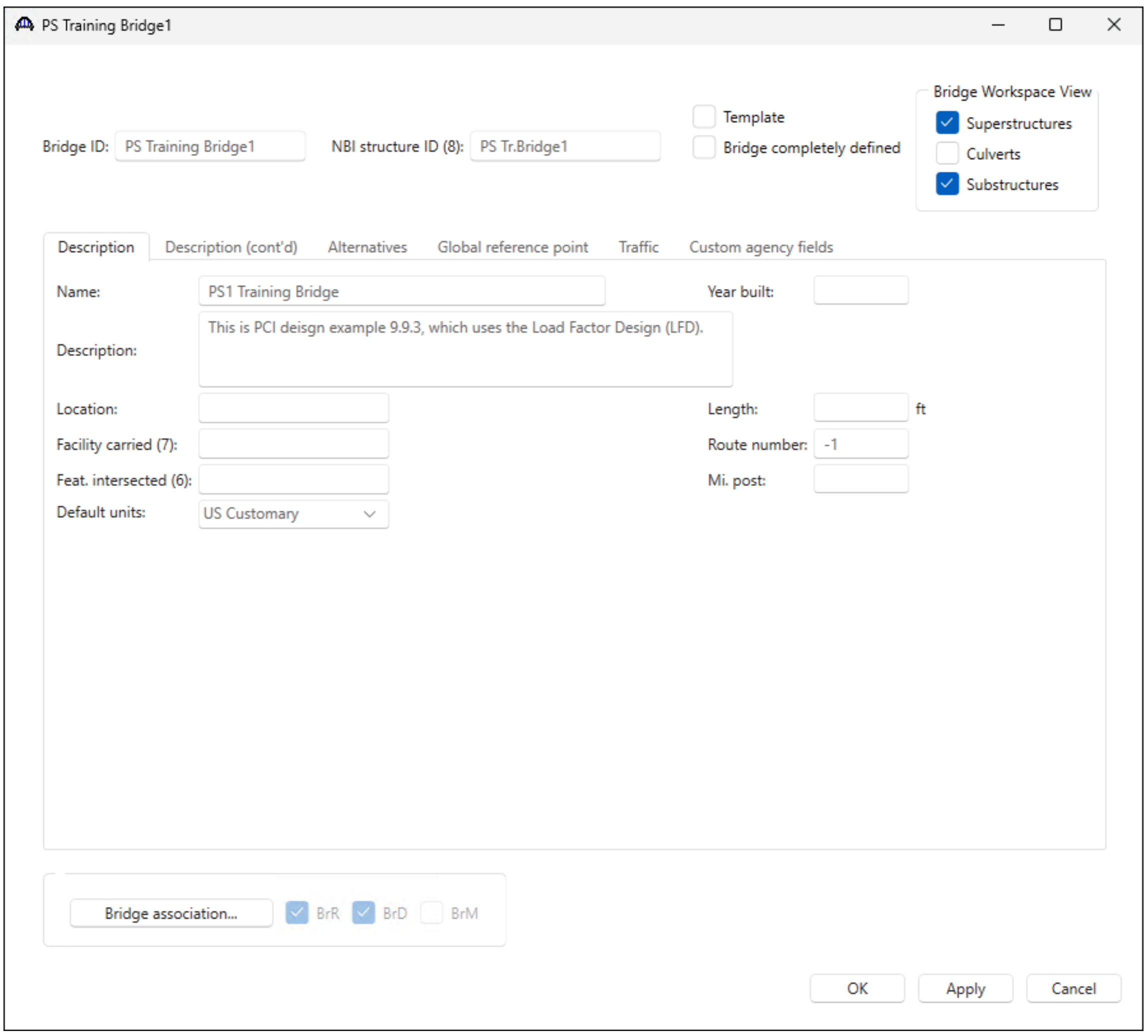
BrDR Training

PS1 – Simple Span PS I Beam Example

From the **Bridge Explorer** create a **new bridge** by clicking on the **New** button from the **BRIDGE** tab as shown below.



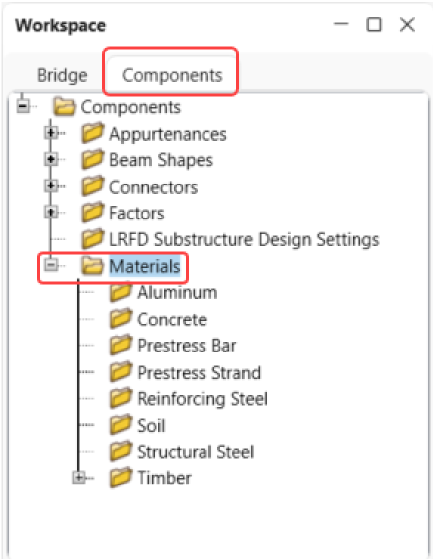
Enter the following description data.



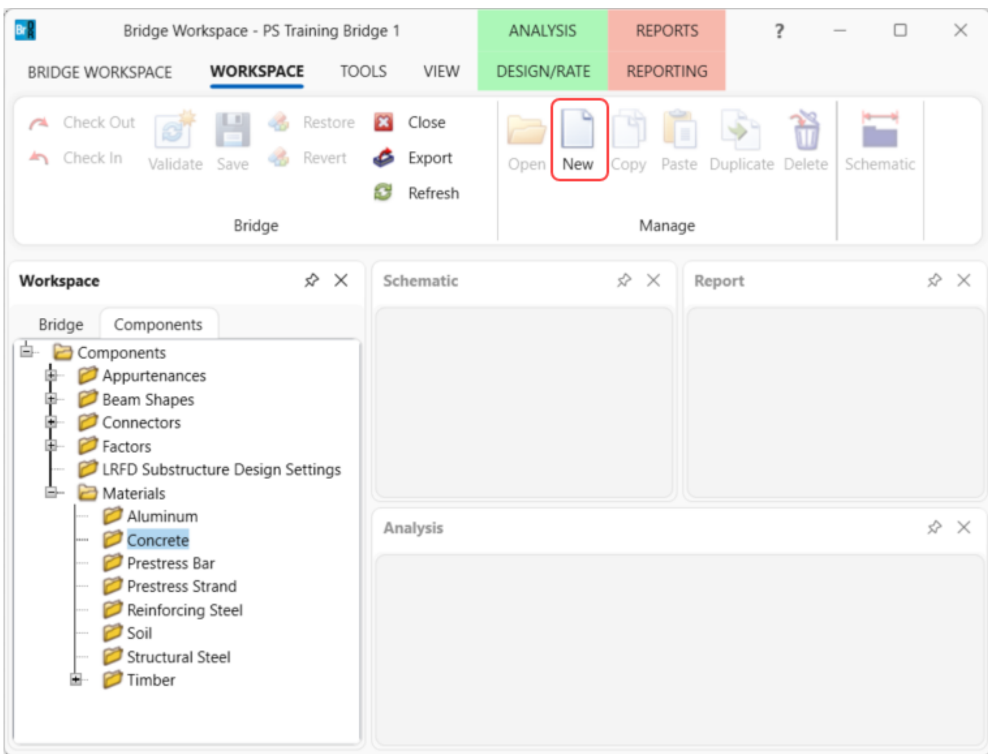
Click **OK** to apply the data and close the window.

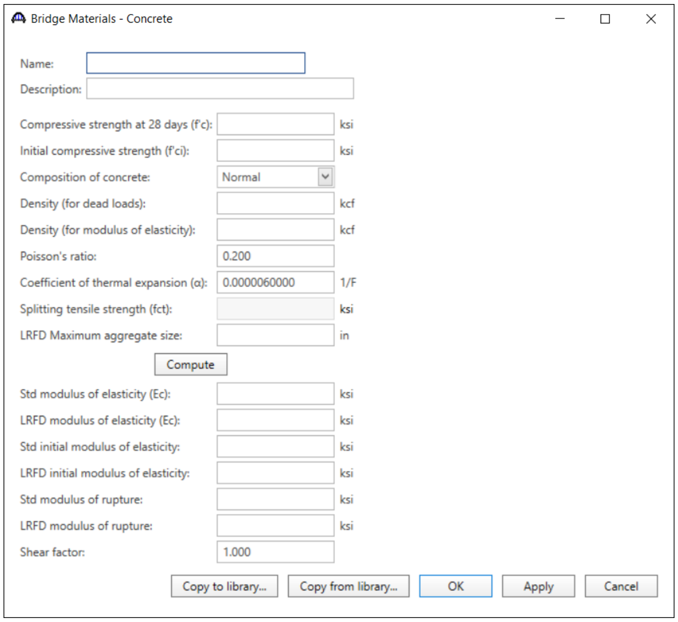
Bridge Materials

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

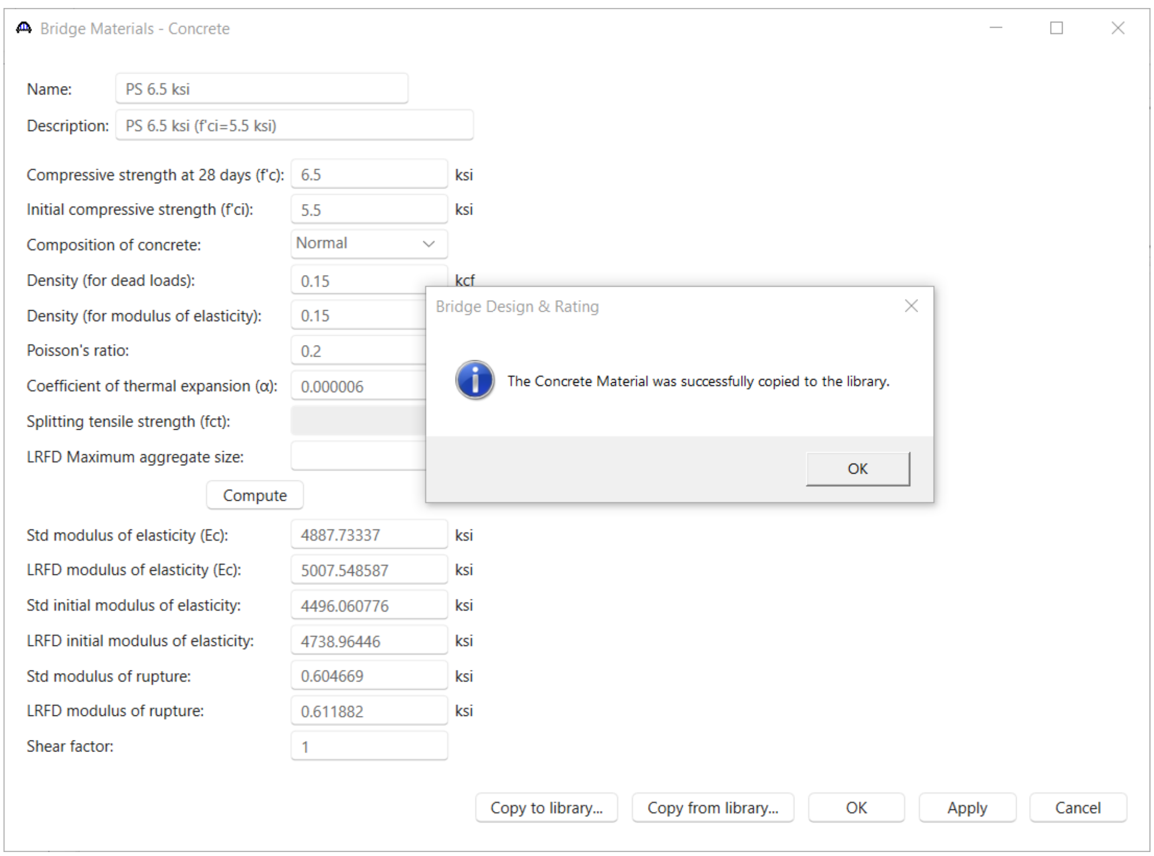


To add a new concrete material, click on **Concrete,** and select **New** from the **Manage** group of the **WORKSPACE** ribbon (or right mouse click on **Concrete** and select **New**). The window shown below will open.



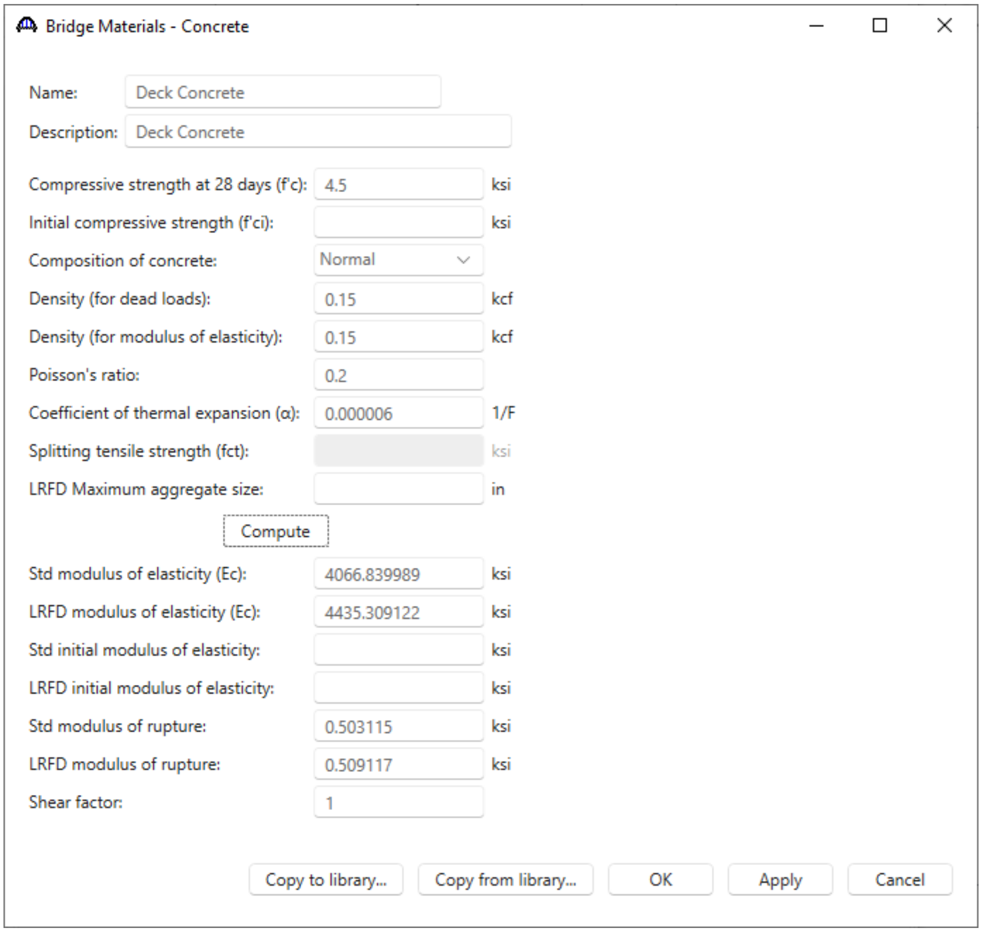


Enter the values shown above the **Compute** button and click the **Compute** button to compute the remaining values below them. Click the **Copy to library…** button to save this concrete material to the library.



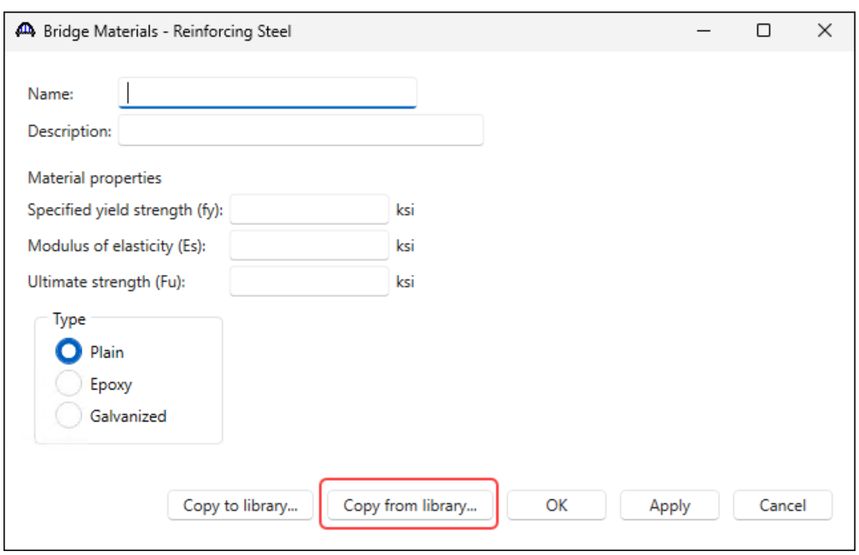
Click **OK** to apply the data and close the window.

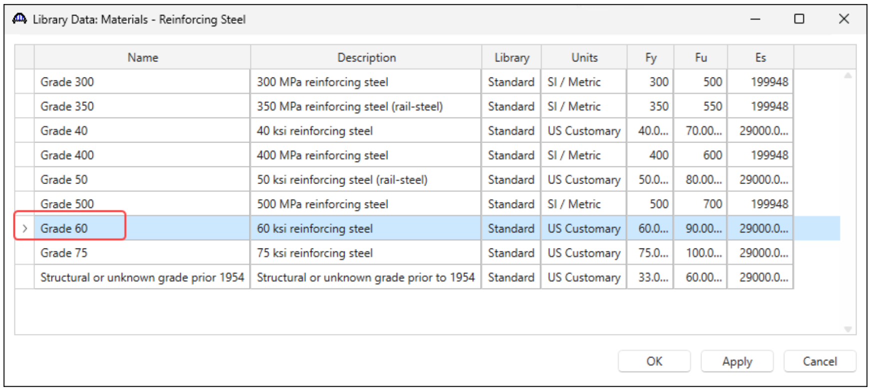
Add concrete material for the **deck** using the same technique. See below for deck concrete material.

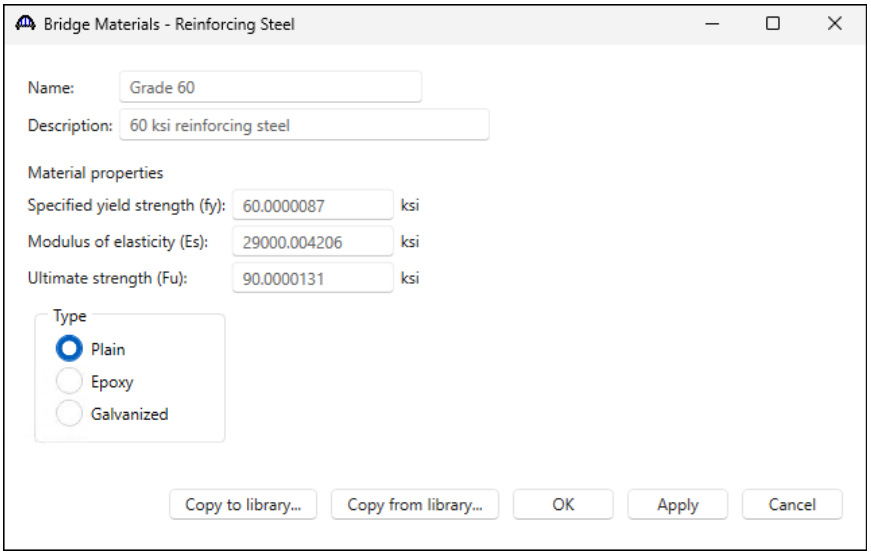


Reinforcement material and **Prestress strand** material can be added by using the **Copy from library** option and selecting the materials shown below**.**

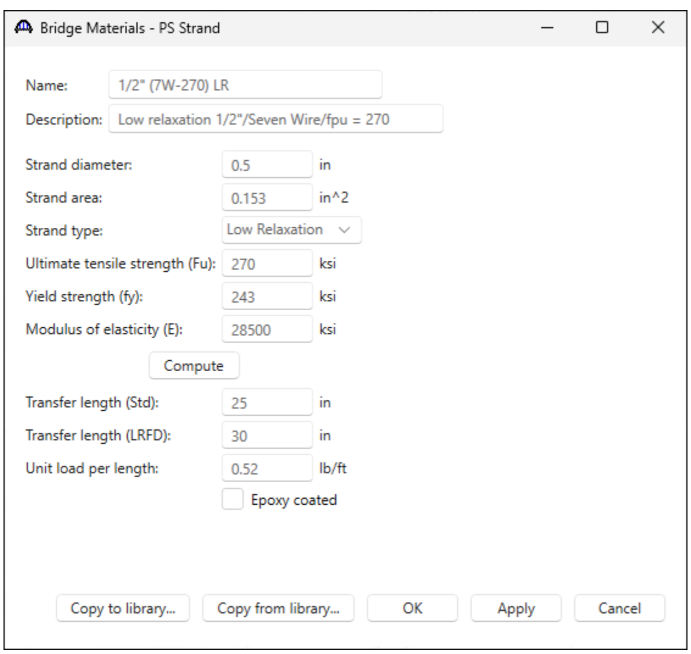
Reinforcing Steel





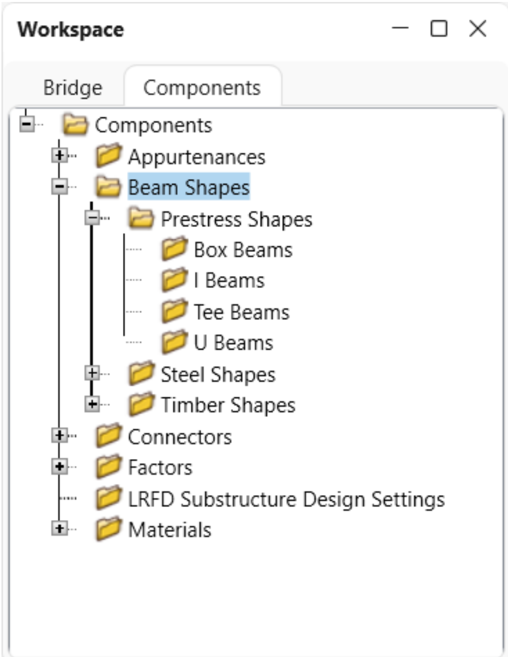


Similarly, copy the following **Prestress strand** material.

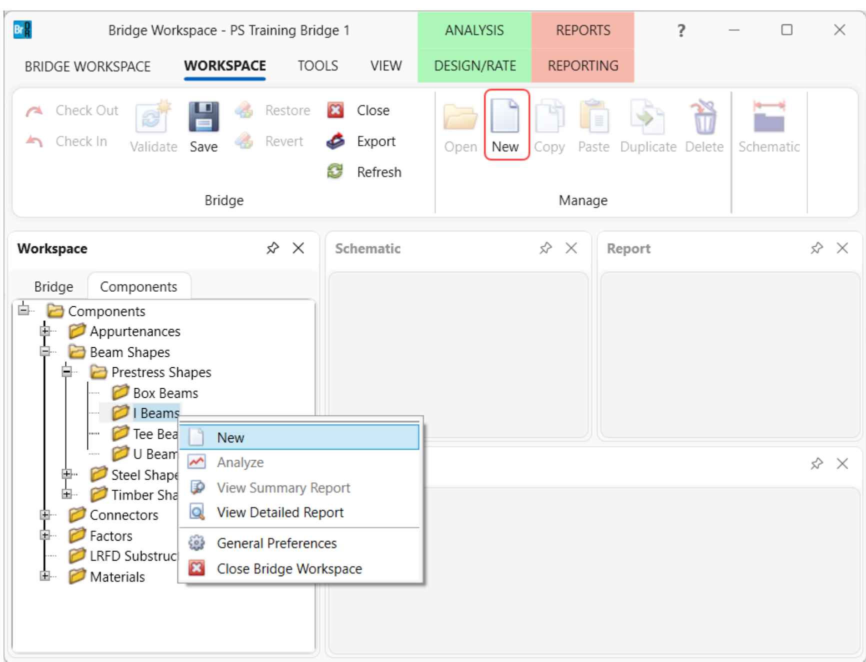


Beam Shapes

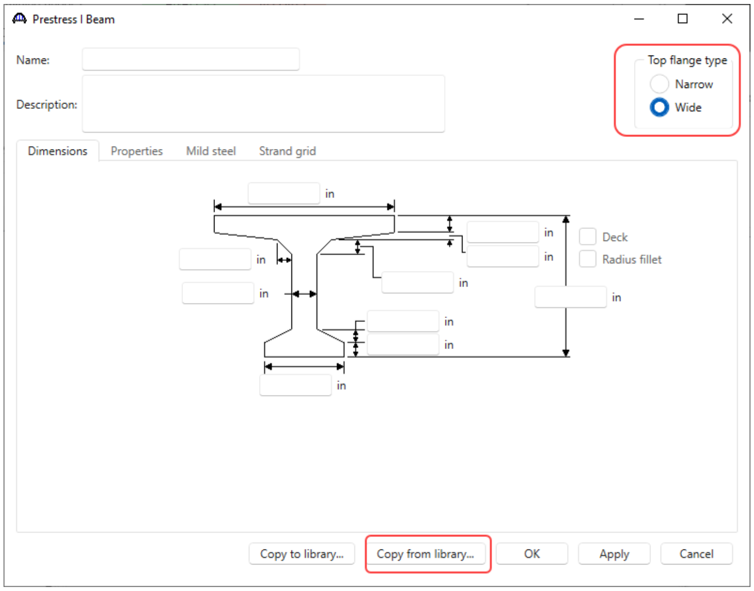
To enter a prestress beam shape, expand the tree labeled **Beam Shapes** and **Prestress Shapes** as shown below.



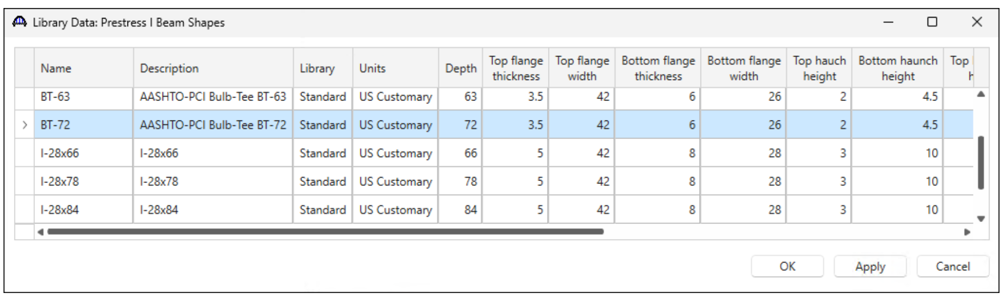
Click on the **I Beams** node in the **Components** tree and select **New** from the **Manage** group of the **WORKSPACE** ribbon (or right mouse click on **I Beams** and select **New** or double click on **I Beams** in the **Components** tree). The window shown below will open.

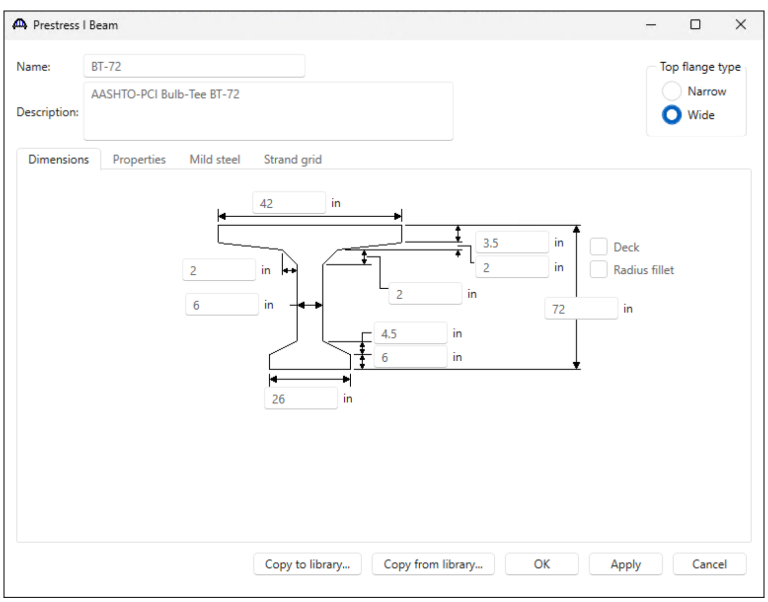


Select the **Top flange type** as **Wide** and click the **Copy from library…** button.



Select **BT-72 (AASHTO-PCI Bulb-Tee BT-72)** and click **OK**. The beam properties are copied to the **Prestress I Beam** window as shown below.

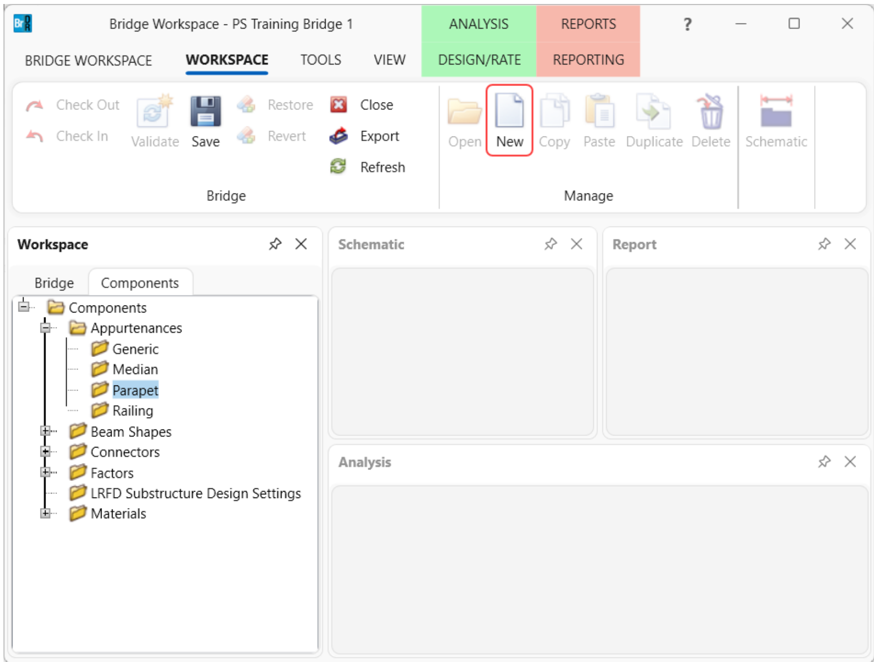




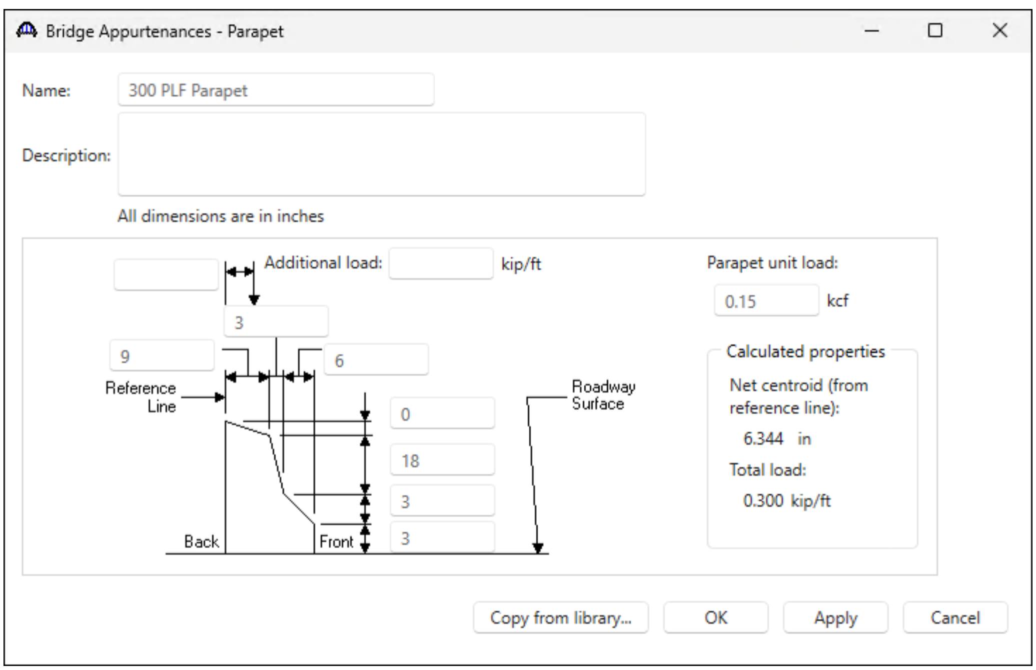
Click **OK** to apply the data and close the window.

Bridge - Appurtenances

To enter the appurtenances, expand the tree branch labeled **Appurtenances**. To define a parapet, select **Parapet** and click on **New** from the **Manage** button on the **WORKSPACE** ribbon (or double click on **Parapet** in the **Components** tree).



Enter the parapet details as shown below.

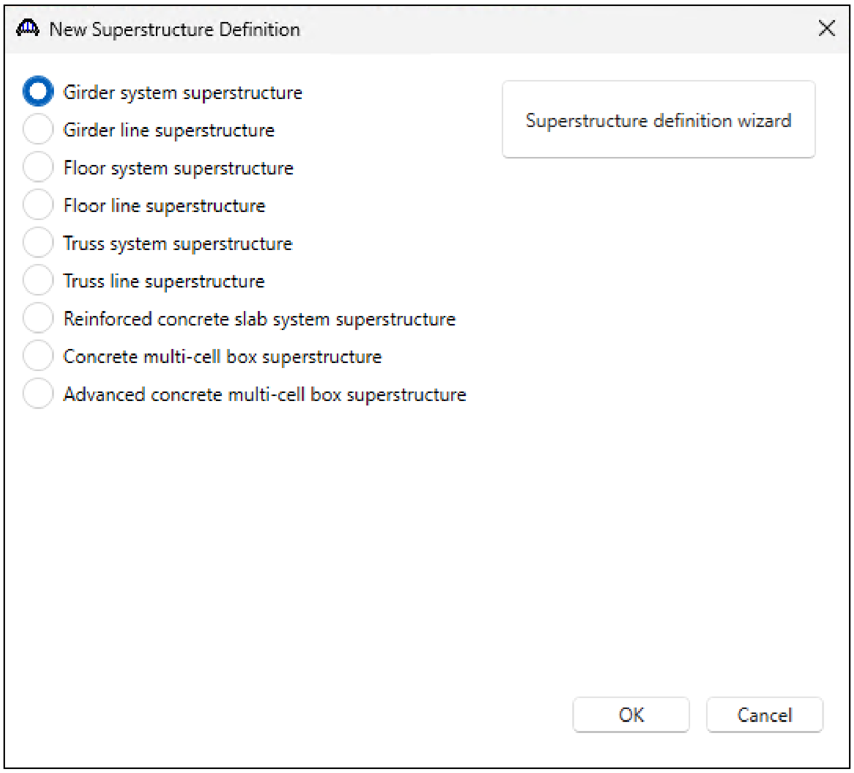


Click **OK** to apply the data and close the window.

The default impact factors, standard LRFD and LFR factors will be used**.** Bridge Alternatives will be added after entering the Structure Definition.

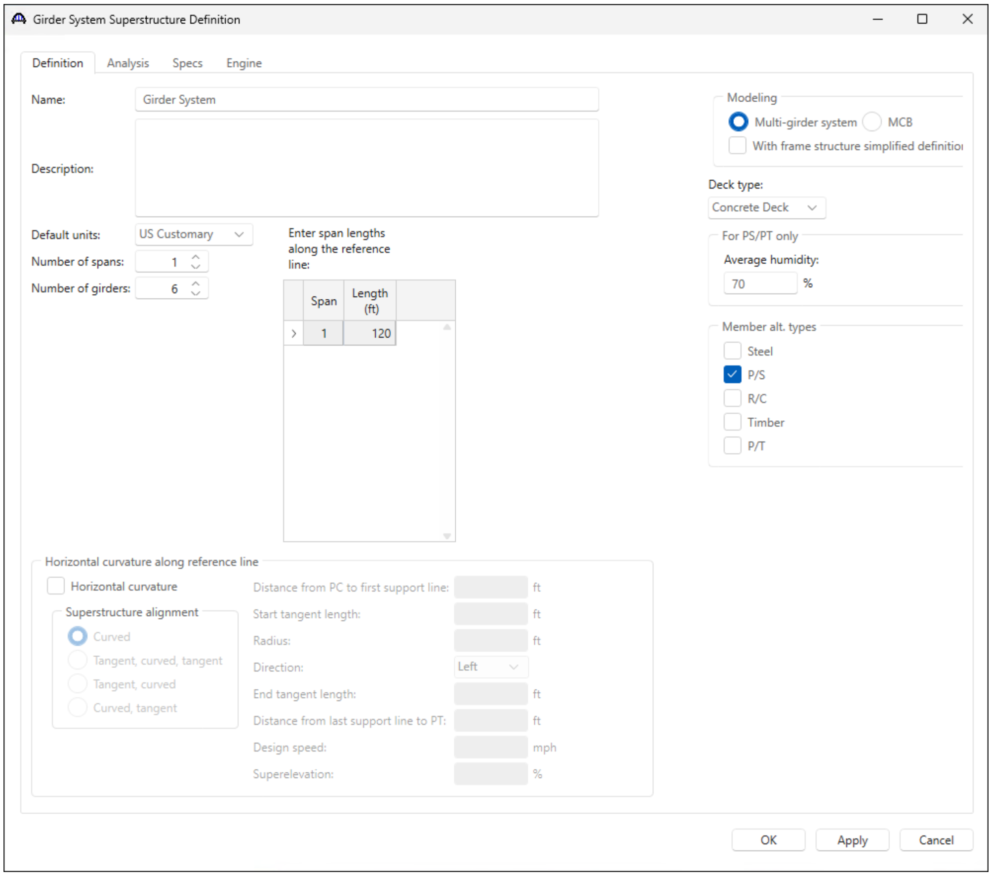
Superstructure definition

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.



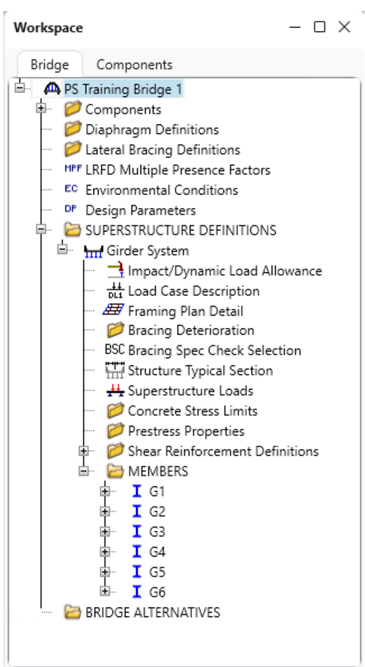
Select **Girder system superstructure**, click **OK**

The **Girder System Superstructure Definition** window will open. Enter the data as shown below.



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

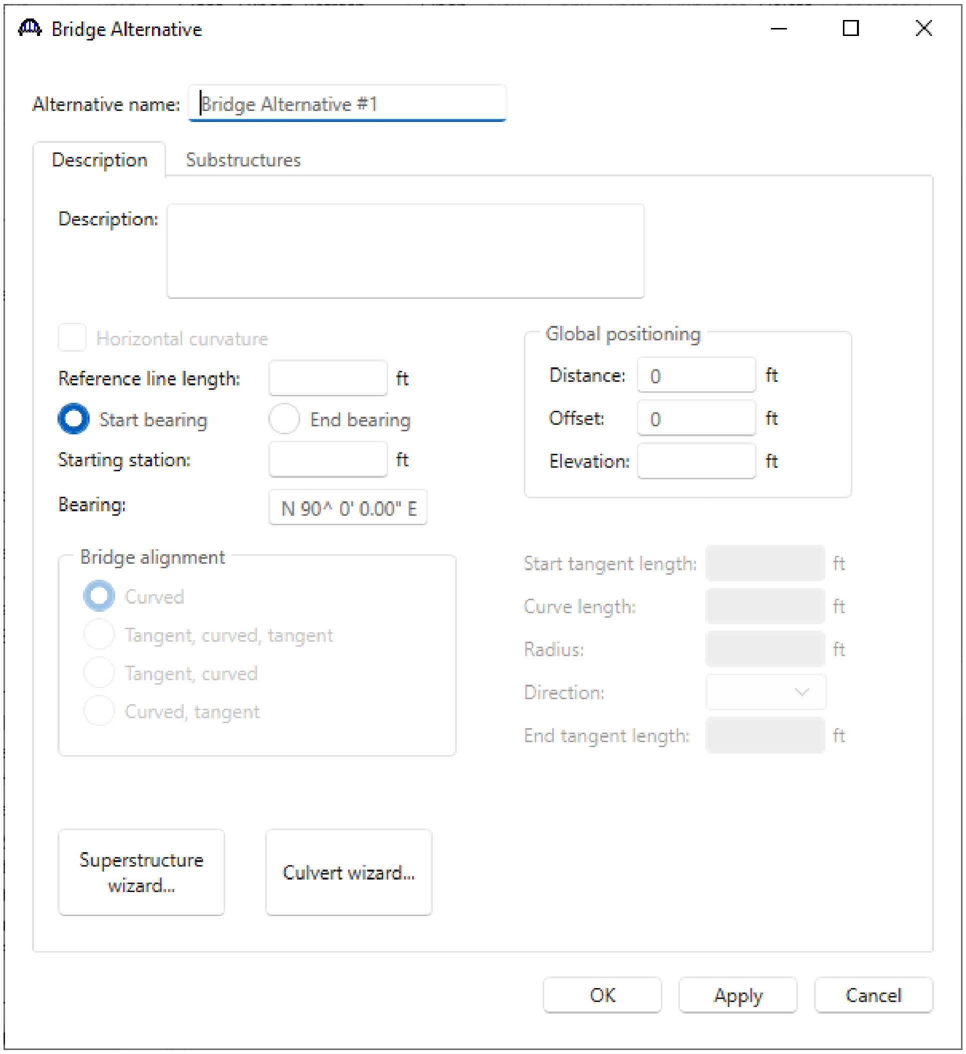
The partially expanded **Bridge Workspace** tree is shown below.



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 below.

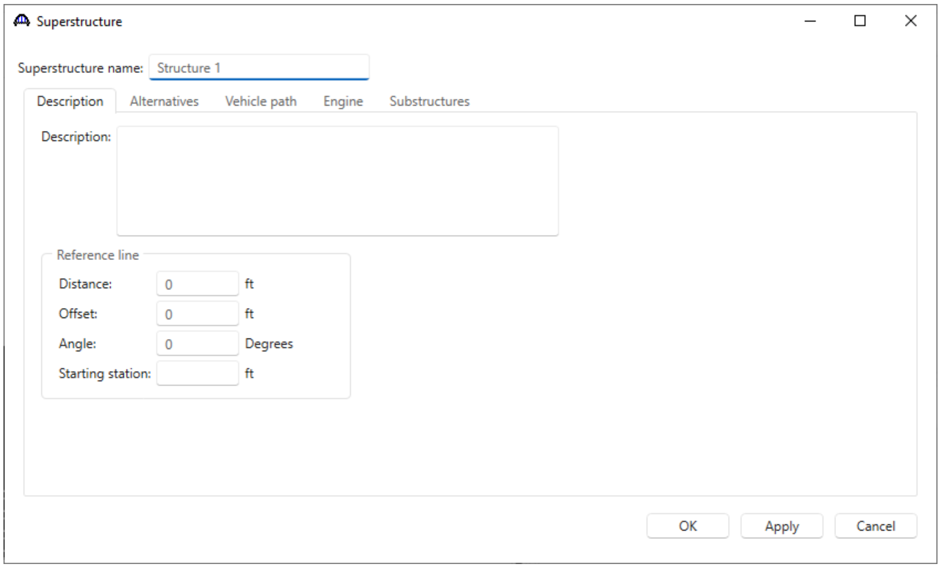
BRIDGE ALTERNATIVES

Navigate to the **BRIDGE ALTERNATIVES** node in the **Bridge Workspace** tree and create a new bridge alternative by double-clicking on **BRIDGE ALTERNATIVES** (or click on **BRIDGE ALTERNATIVES** and select **New** from the **Manage** group of the **WORKSPACE** ribbon). Enter the following data.



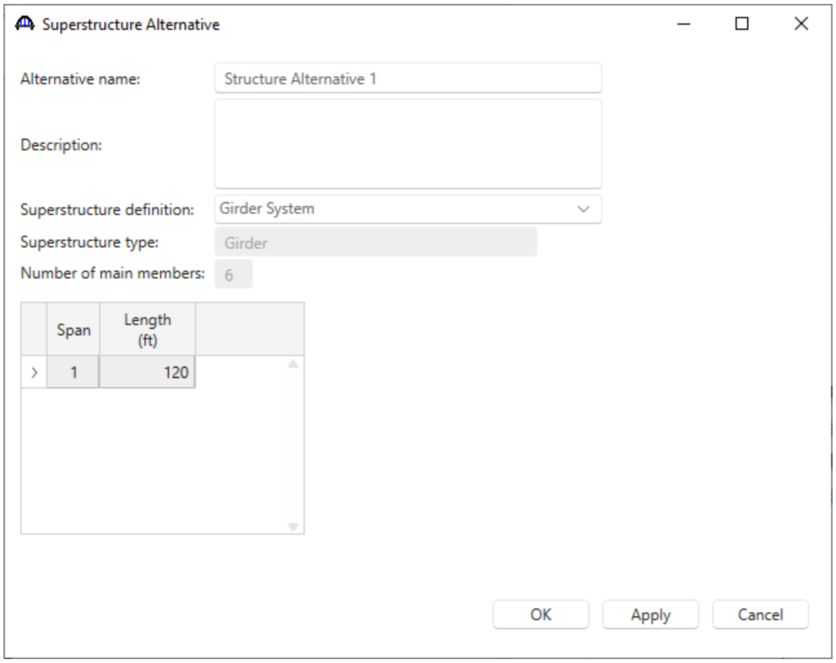
Click **OK** to apply the data and close the window.

Expand the **Bridge Alternative #1** node in the **Bridge Workspace** tree. Double-click on the **SUPERSTRUCTURES** node (or select **SUPERSTRUCTURES** and click **New** from the **Manage** group of the **WORKSPACE** ribbon) and enter the following new superstructure.



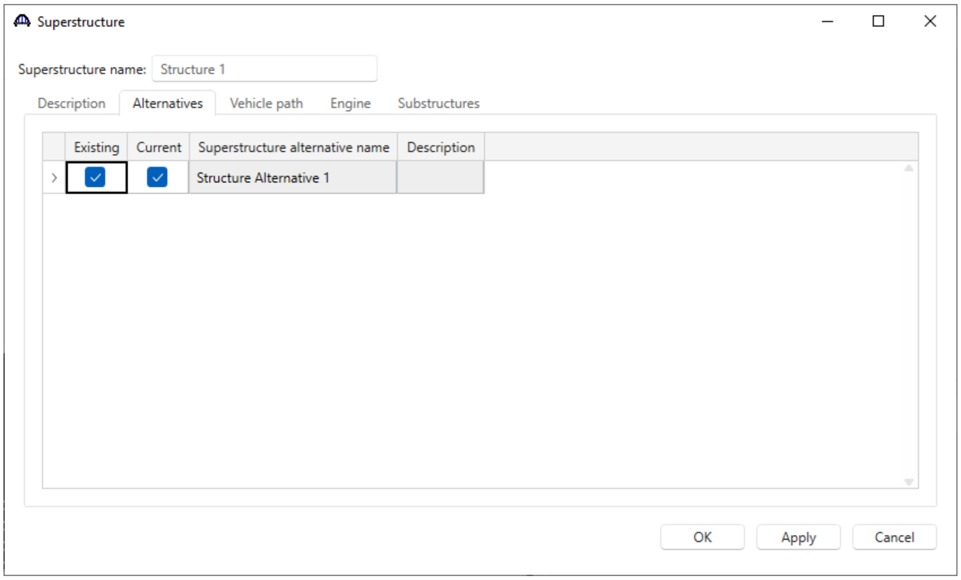
Click **OK** to apply the data and close the window.

Expand the **Structure 1** node in the **Bridge Workspace** tree. Double-click on the **SUPERSTRUCTURE ALTERNATIVES** node (or select **SUPERSTRUCTURE ALTERNATIVES** and click **New** from the **Manage** group of the **WORKSPACE** ribbon) and enter the following new superstructure alternative. Select the superstructure definition **Girder System** as the current superstructure definition for this **Superstructure Alternative**.

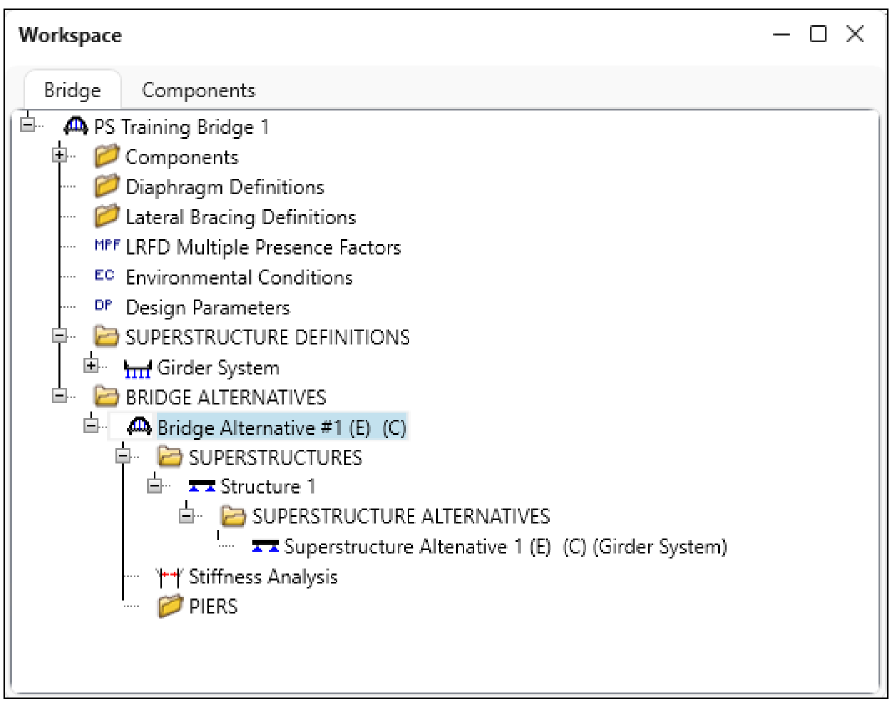


Click **OK** to apply the data and close the window.

Re-open the **Structure 1** window and navigate to the **Alternatives** tab. The **Structure Alternative #1** will be shown as the **Existing** and **Current** alternative for **Structure #1**.

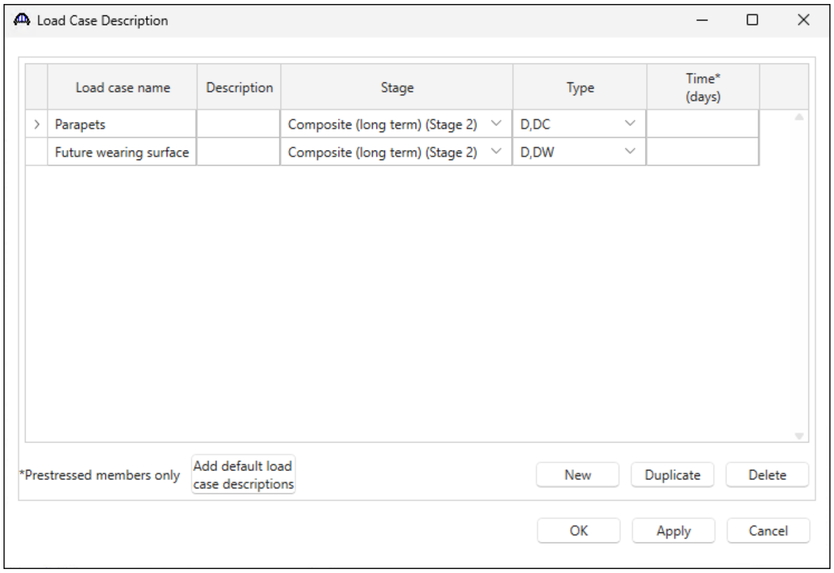


The partially expanded **Bridge Workspace** tree is shown below.



Load Case Description

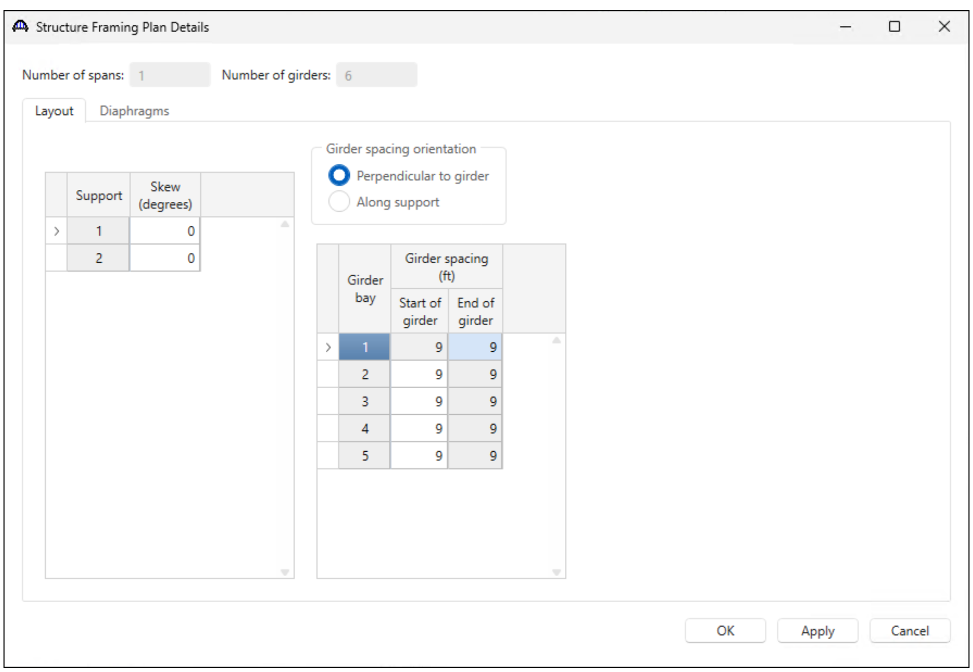
Navigate back to the superstructure definition – **Girder System**. Double-click on the **Load Case Description** node in the **Bridge Workspace** tree to open the **Load Case Description window** and define the dead load cases as shown below. The completed **Load Case Description** window is shown below.



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

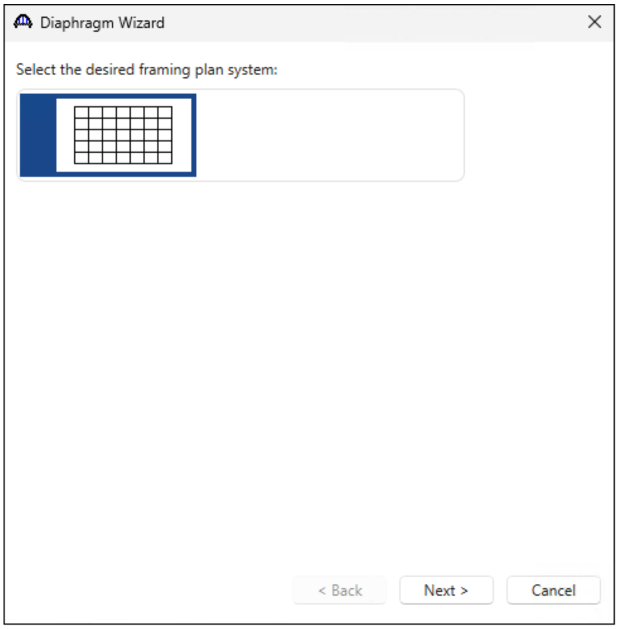
Structure Framing Plan Detail – Layout

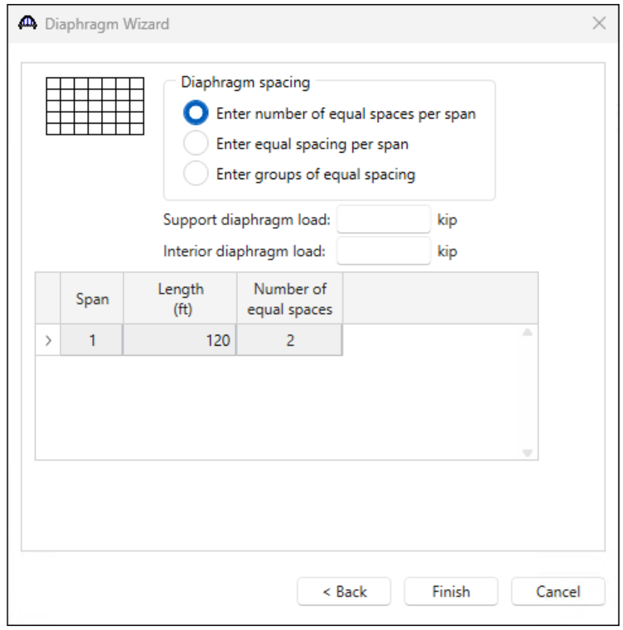
Double-click on **Framing Plan Detail** in the **Bridge Workspace** tree to describe the framing plan in the **Structure Framing Plan Details** window. Enter the data as shown below and click **Apply** to apply the data and not close the window.



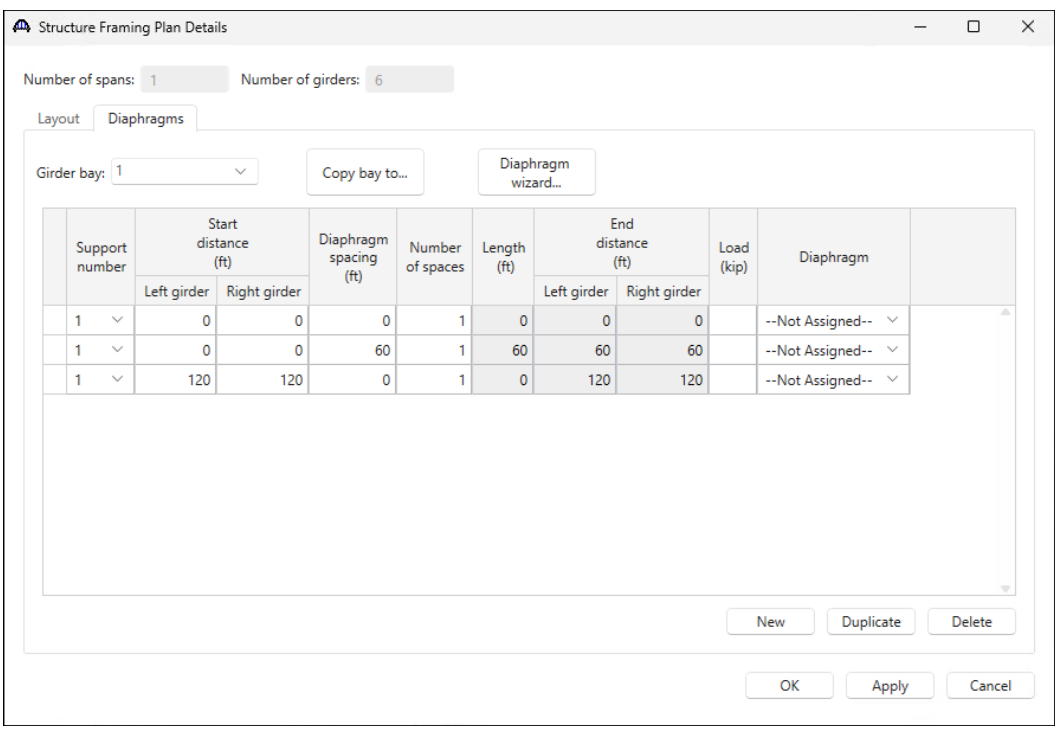
Structure Framing Plan Detail – Diaphragms

Switch to the **Diaphragms** tab to enter diaphragm spacing. Click the **Diaphragm wizard…** button to add diaphragms for the entire structure. **Select the desired framing plan system** and click the **Next** button. Enter the following data on the window shown below.





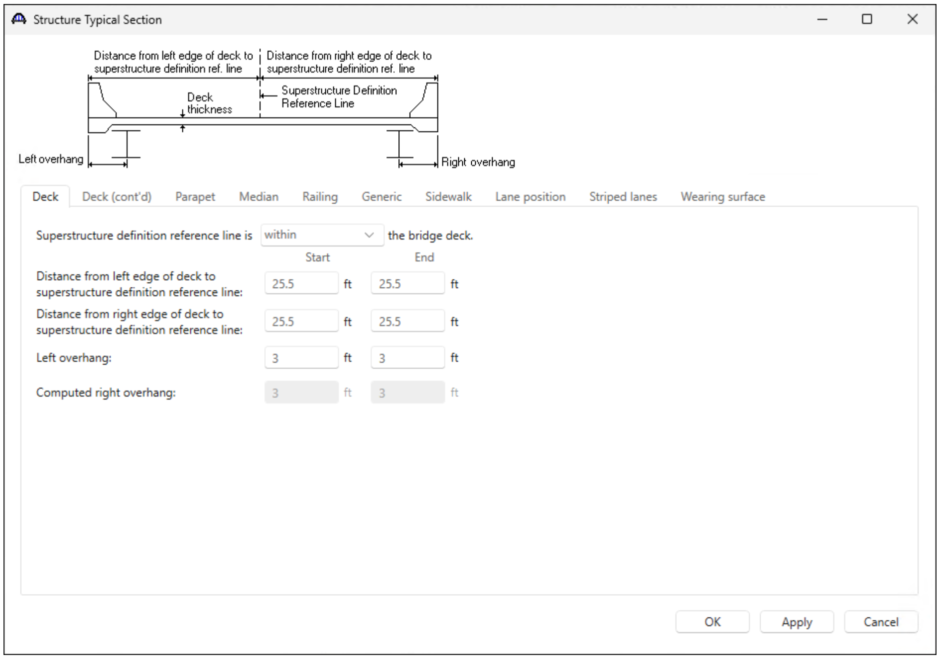
Click the **Finish** button to add the diaphragms. The **Diaphragm Wizard** will create diaphragms for all the girder bays in the structure. The diaphragms created for **Girder bay 1** are shown below.



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

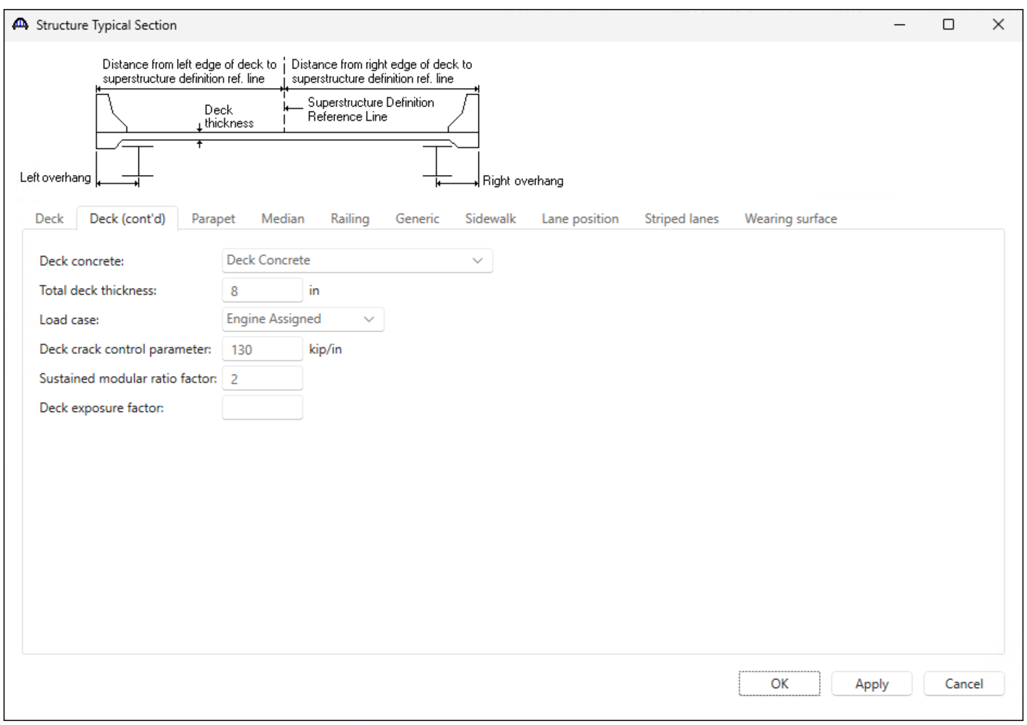
Structure Typical Section - Deck

Next define the structure typical section by double-clicking on **Structure Typical Section** node in the **Bridge Workspace** tree. Input the data describing the typical section in as shown below and click **Apply**.



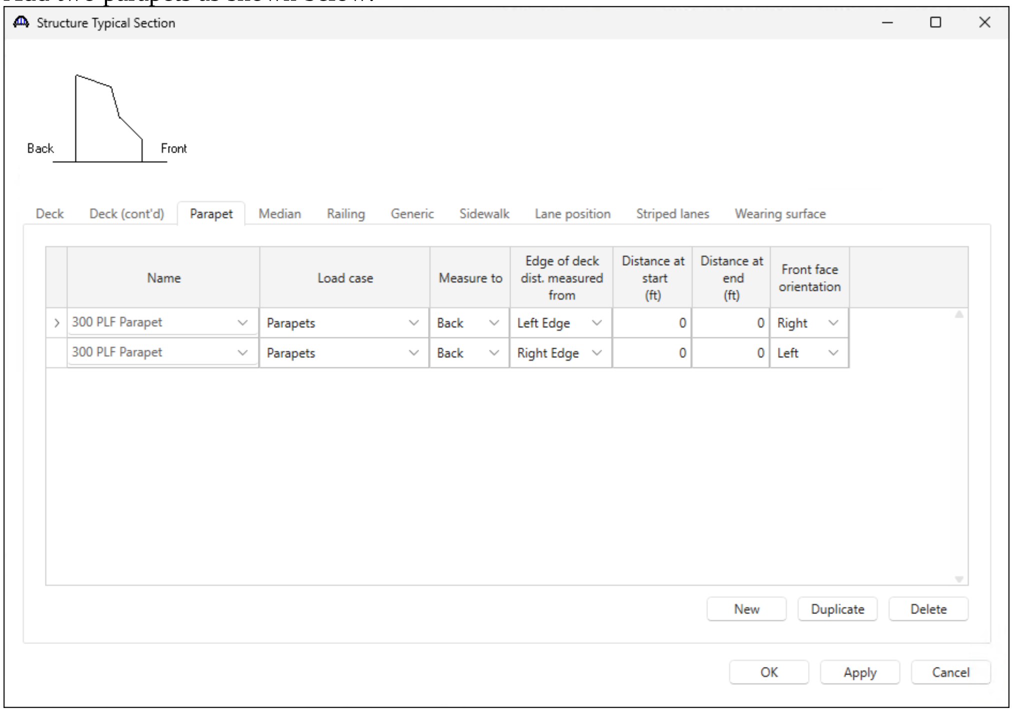
Structure Typical Section – Deck (cont'd)

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



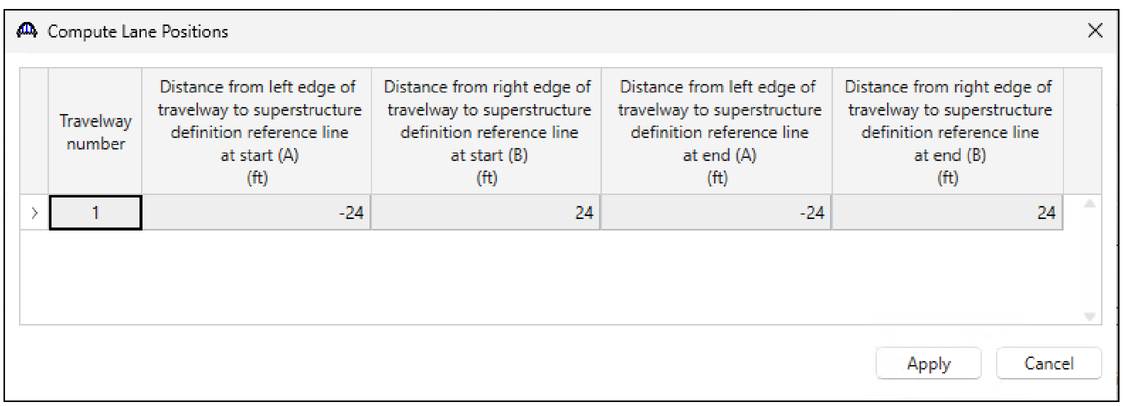
Structure Typical Section – Parapets

Add two parapets as shown below.

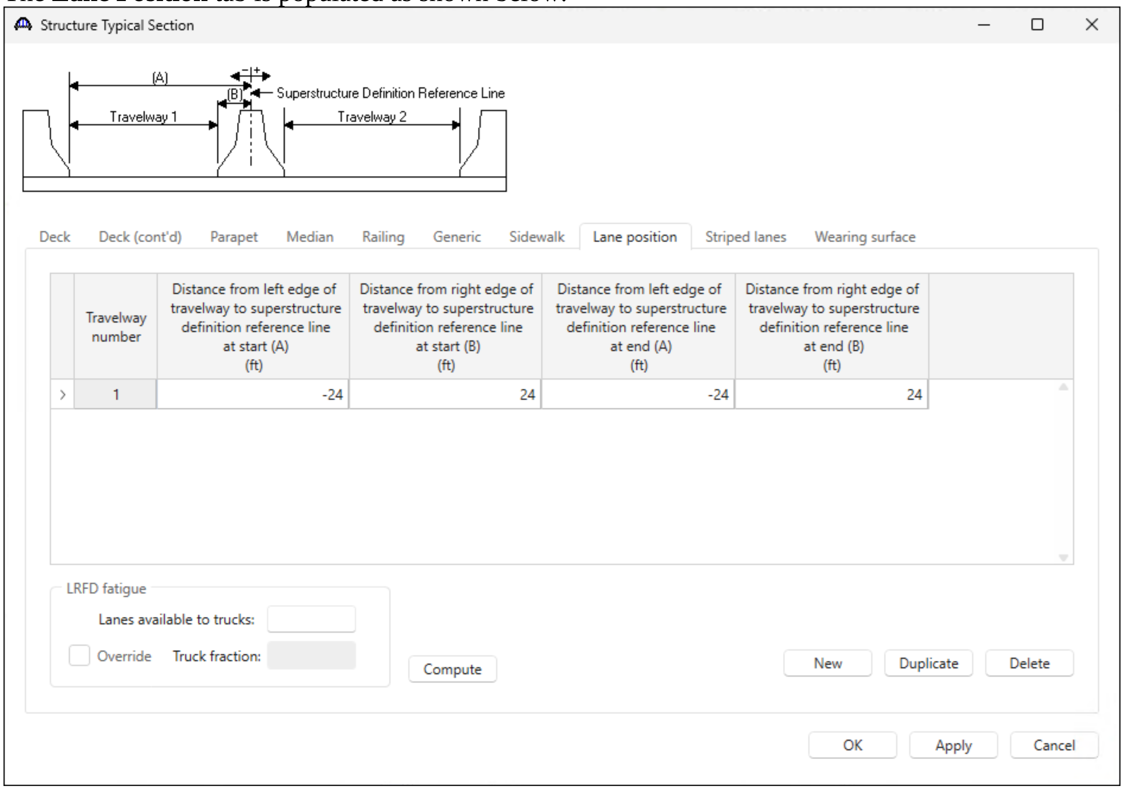


Structure Typical Section – Lane Positions

Select the **Lane position** tab and use the **Compute…** button to compute the lane positions. A window showing the results of the computation opens. Click **Apply** to apply the computed values.

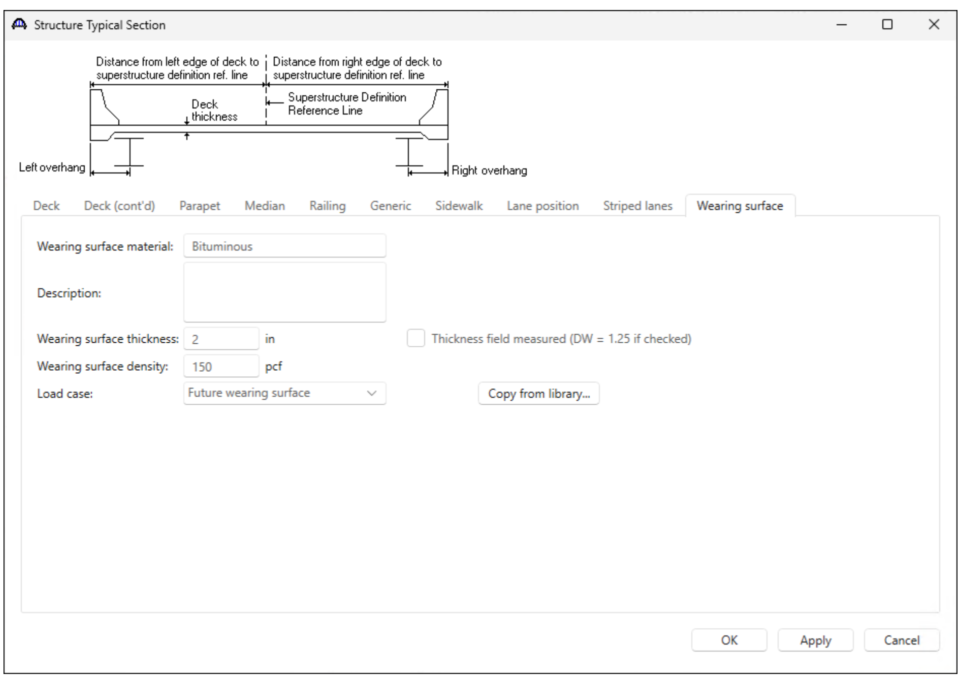


The **Lane Position** tab is populated as shown below.



Structure Typical Section – Wearing surface.

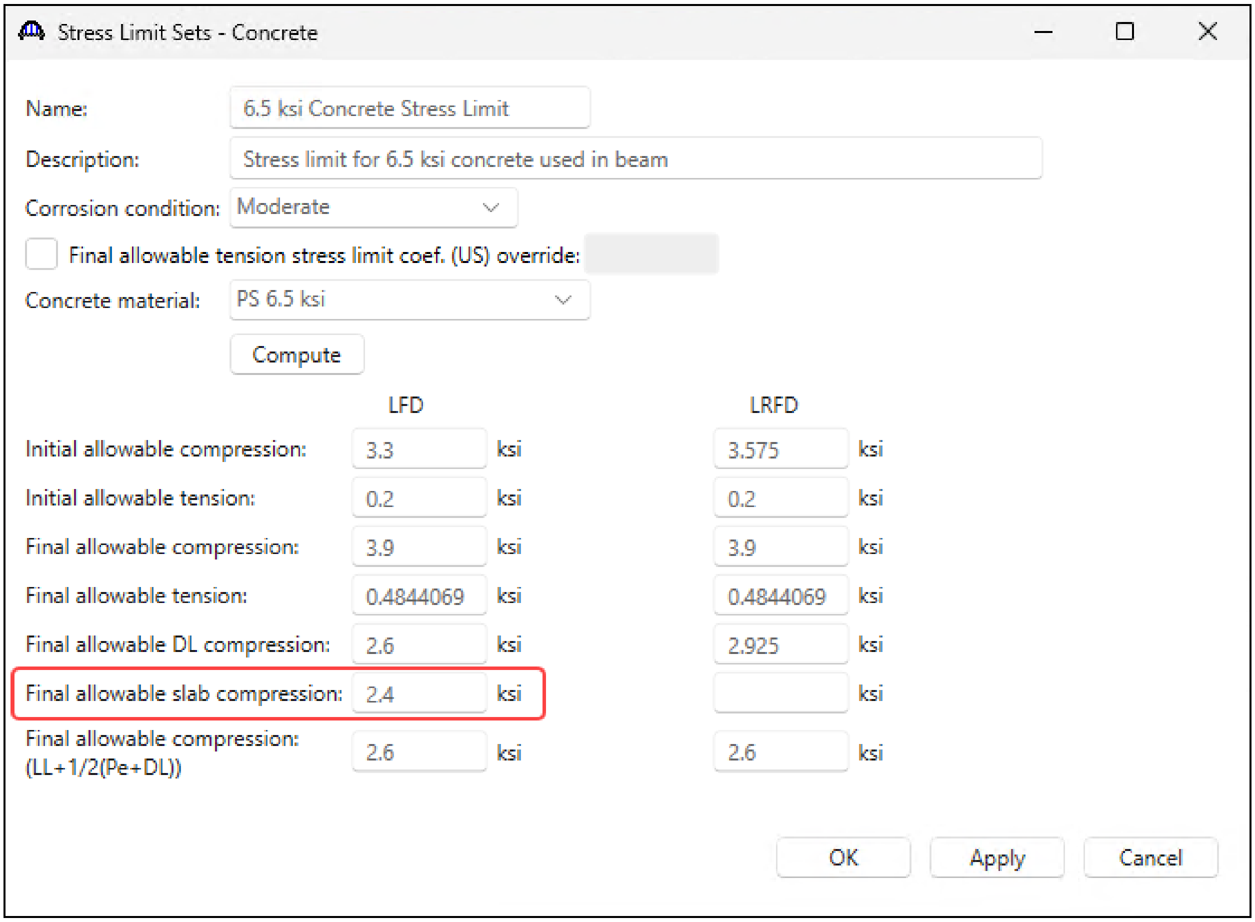
Enter the data shown below.



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

Concrete Stress Limits

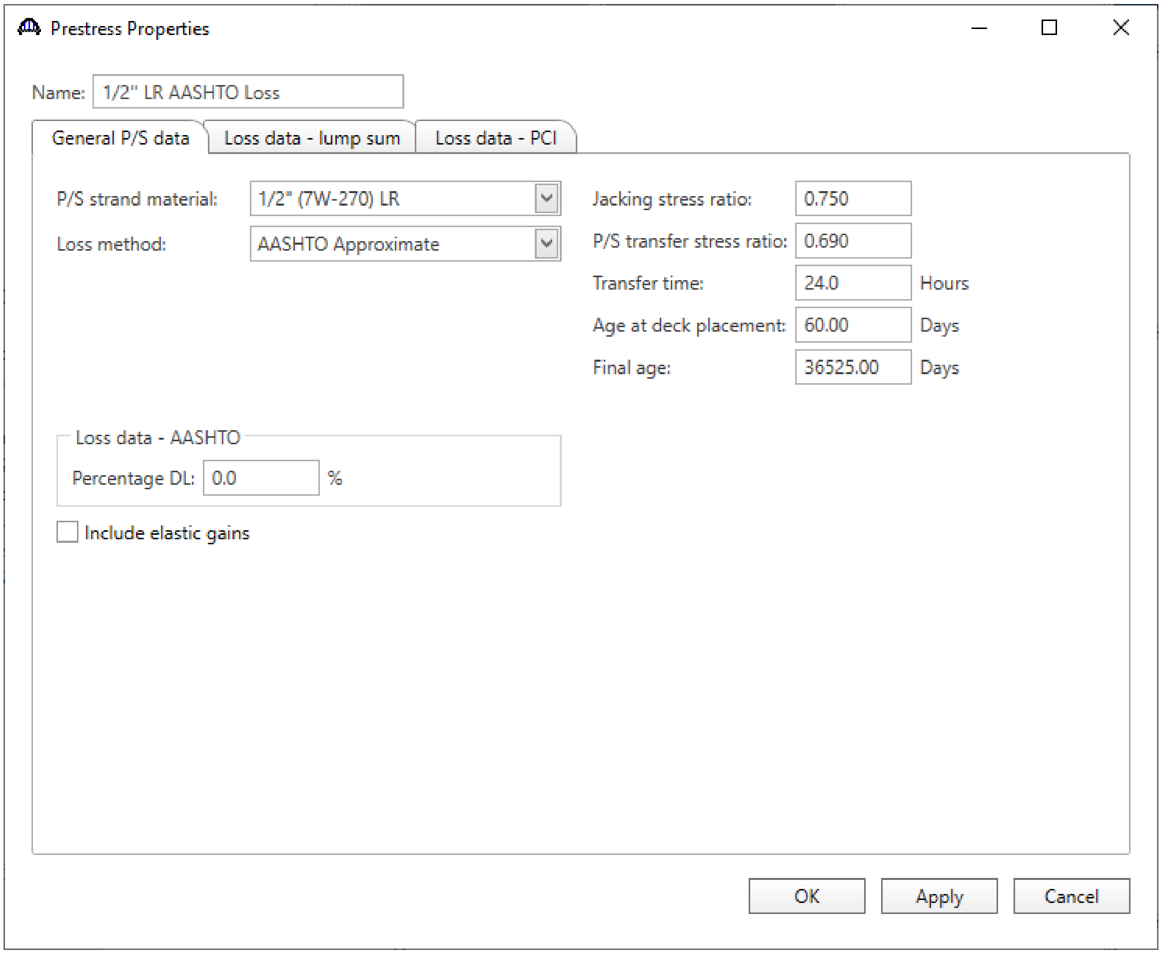
A Stress Limit defines the allowable concrete stresses for a given concrete material. Double click on the **Concrete Stress Limits** node in the **Bridge Workspace** tree to open the **Stress Limit Sets – Concrete** window. Enter data shown above the **Compute** button, select **Moderate** for the **Corrosion condition** and select the **PS 6.5 ksi** concrete material from the drop-down menu of the **Concrete material**. Click the **Compute** button. Default values for the allowable stresses will be computed based on the **Concrete material** selected and the AASHTO Specifications. A default value for the **Final allowable slab compression** is not computed since the deck concrete is typically different from the concrete used in the beam. Enter the value shown below for the **LFD Final allowable slab compression**.



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

Prestress Properties

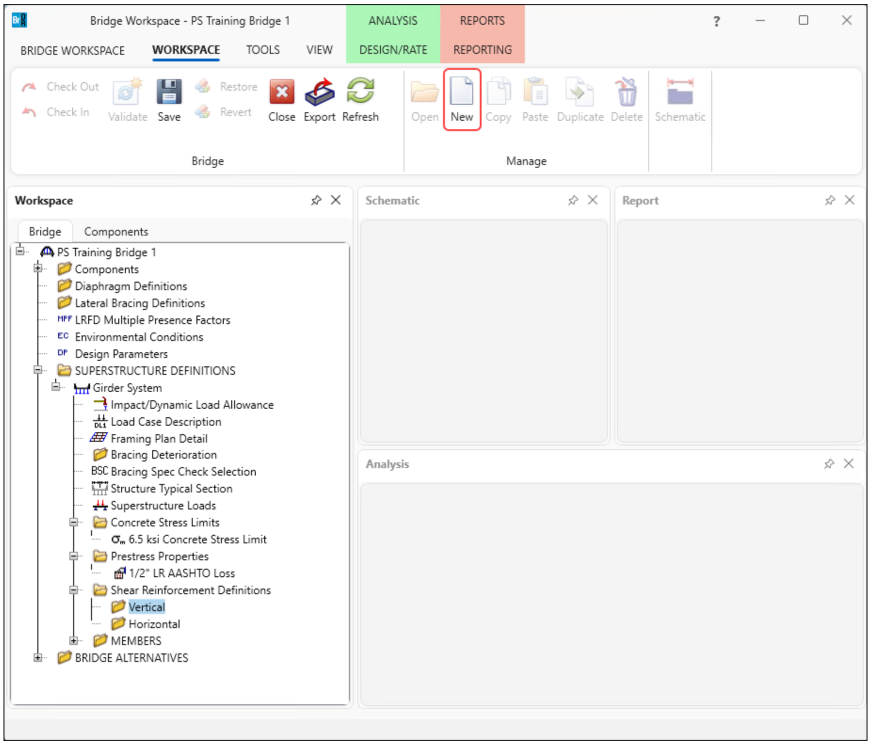
Double click on the **Prestress Properties** node in the **Bridge Workspace** tree to open the **Prestress Properties** window. Define the prestress properties as shown below. Since the **AASHTO Approximate** method is used to compute the losses, only the information on the **General P/S data** tab is required.



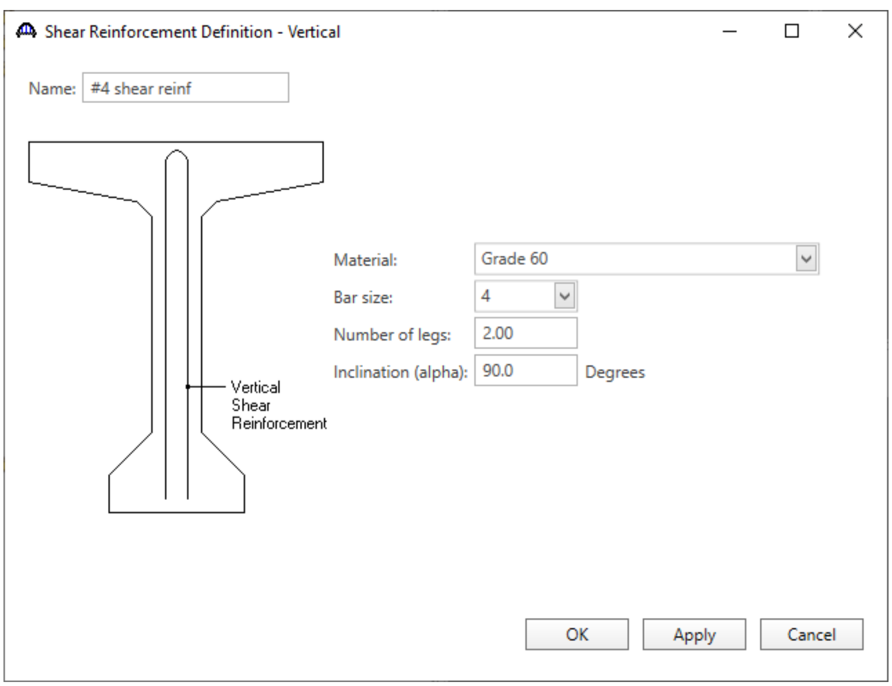
Click **OK** to apply the data and close the window.

Shear Reinforcement

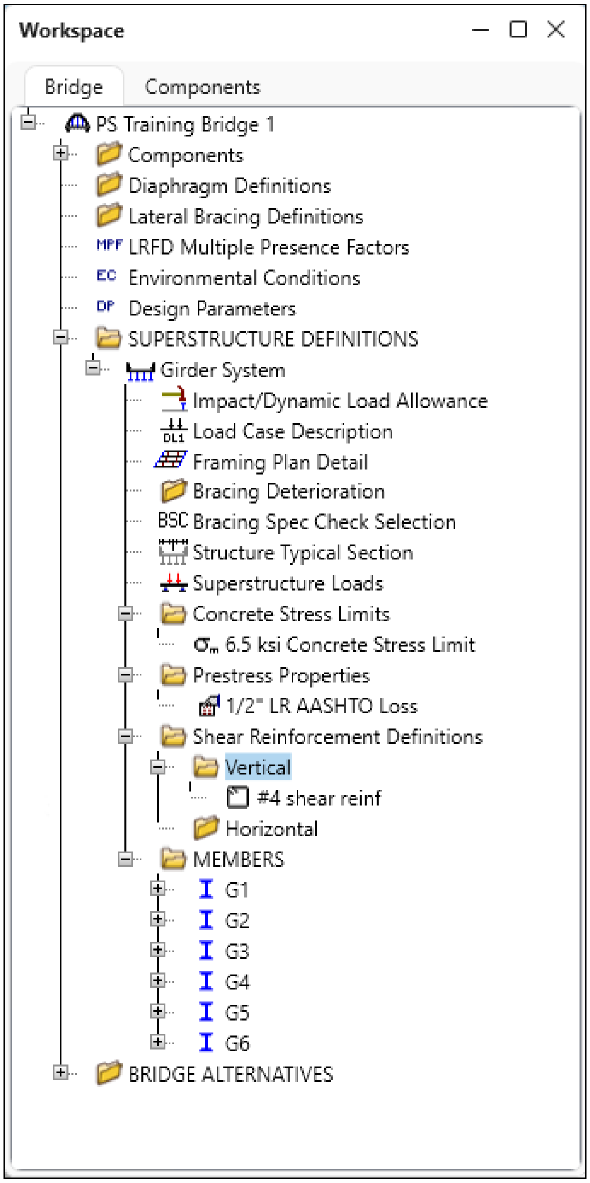
Define shear reinforcement to be used by the girders. Expand the **Shear Reinforcement Definitions** on the **Bridge Workspace** tree, select the **Vertical** node and click on **New** from the **Manage** group of the **WORKSPACE** ribbon (or double click on **Vertical)**.



Define the stirrup as shown below. Click **OK** to apply the data and close the window.

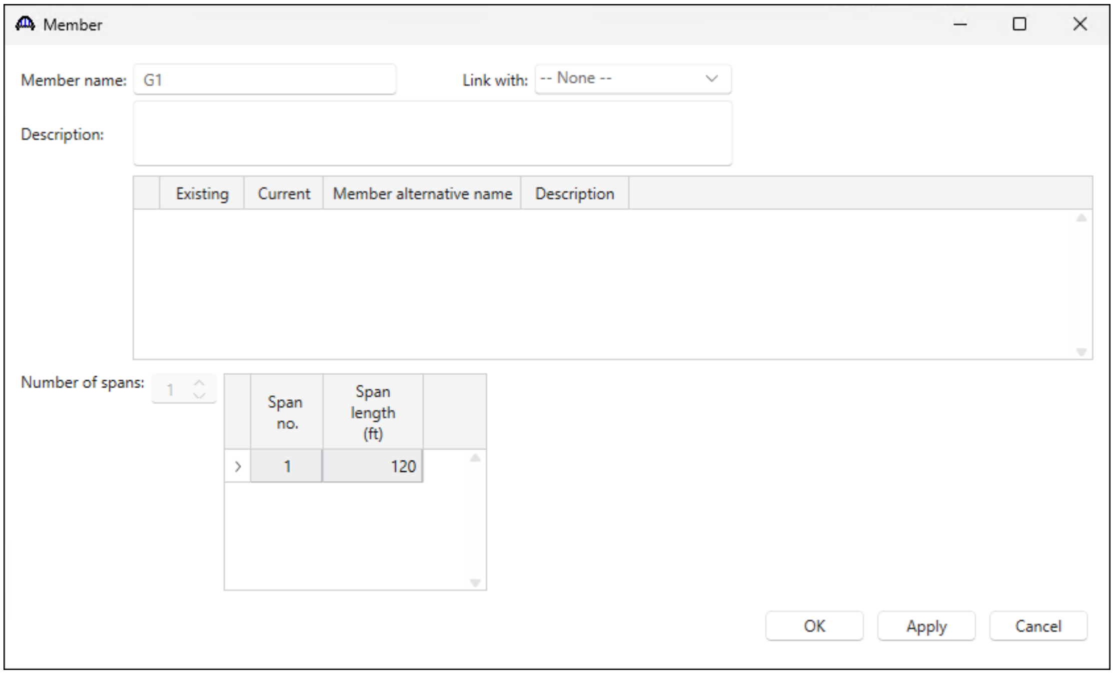


A partially expanded **Bridge Workspace** is shown below.



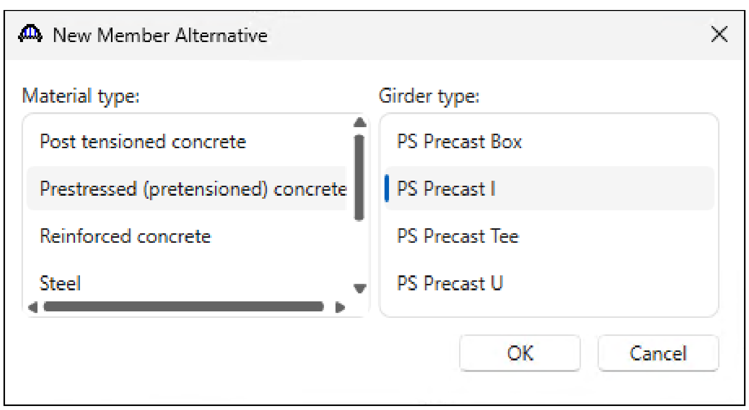
Describing a member:

The **Member** window shows the data that was generated when the structure definition was created. No changes are required in this window. The first Member Alternative created will automatically be assigned as the **Existing** and **Current member alternative** for this Member.



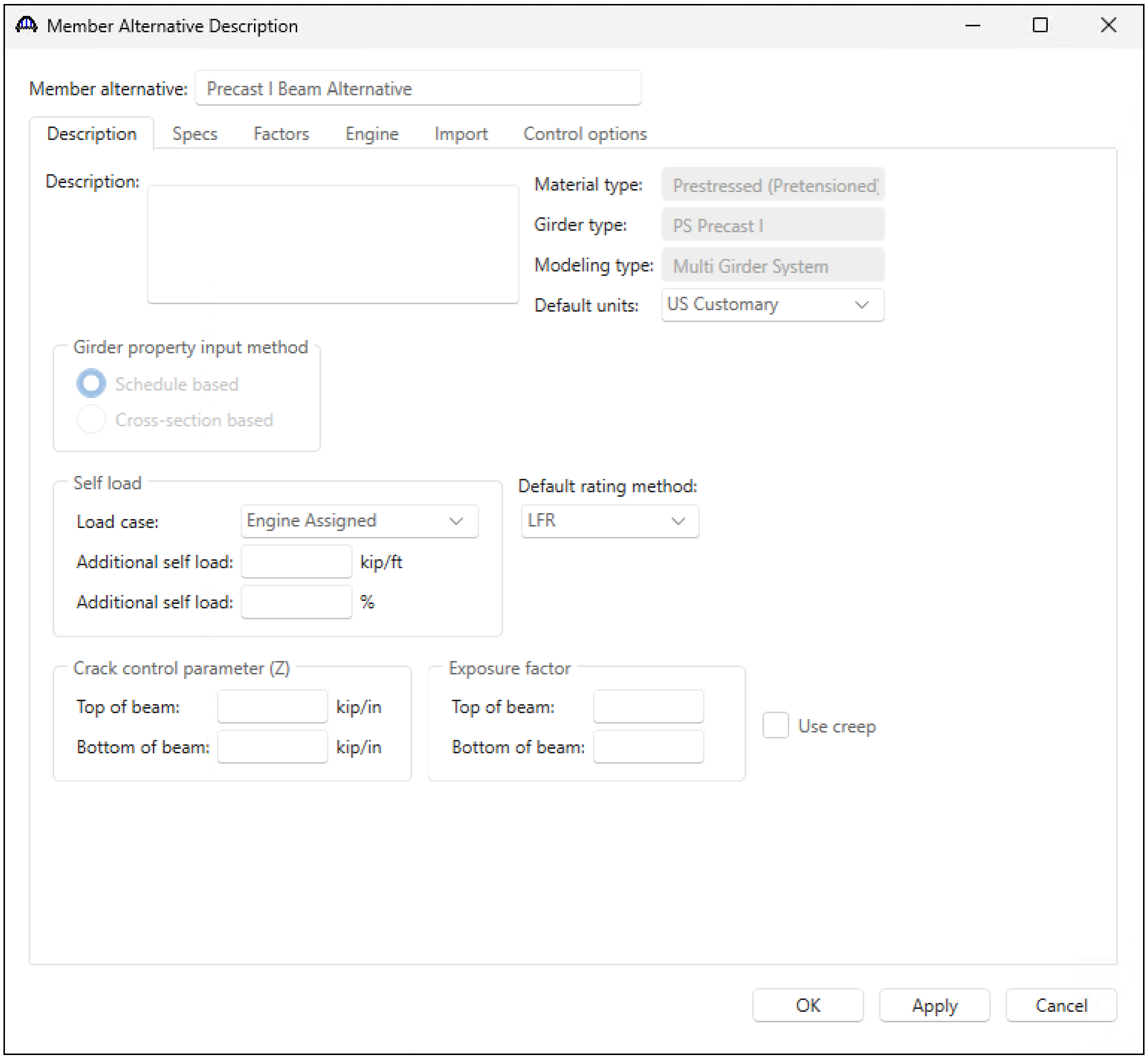
Defining a Member Alternative

Double-click on **MEMBER ALTERNATIVES** in the **Bridge Workspace** tree for member **G1** to create a new member alternative. The **New Member Alternative** window shown below will open. Select **Prestressed (pretensioned) concrete** for the **Material type** and **PS Precast I** for the **Girder Type**.



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

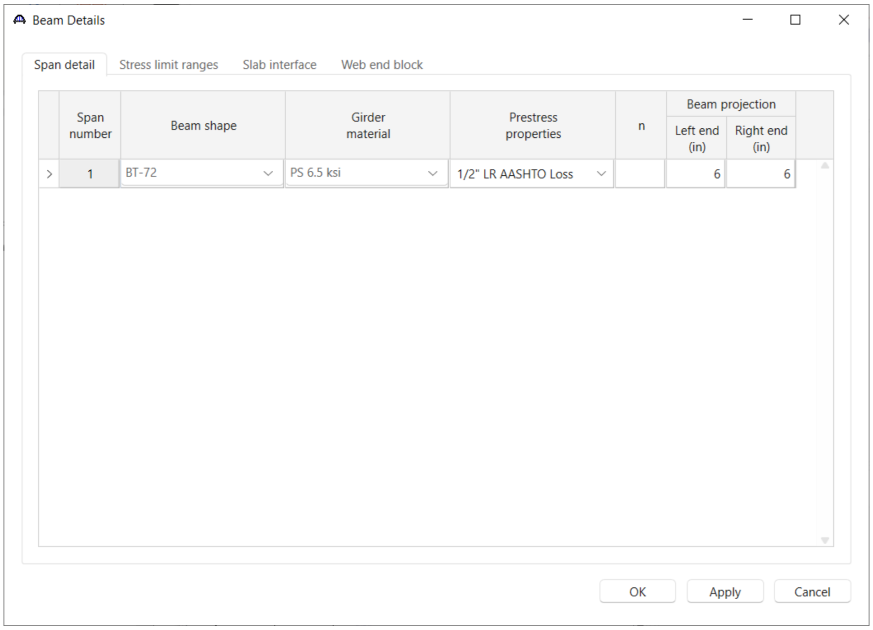
The **Member Alternative Description** window will open as shown below. Enter the data as shown below. The **Schedule based Girder property input method** is the only input method available for a prestressed concrete beam.



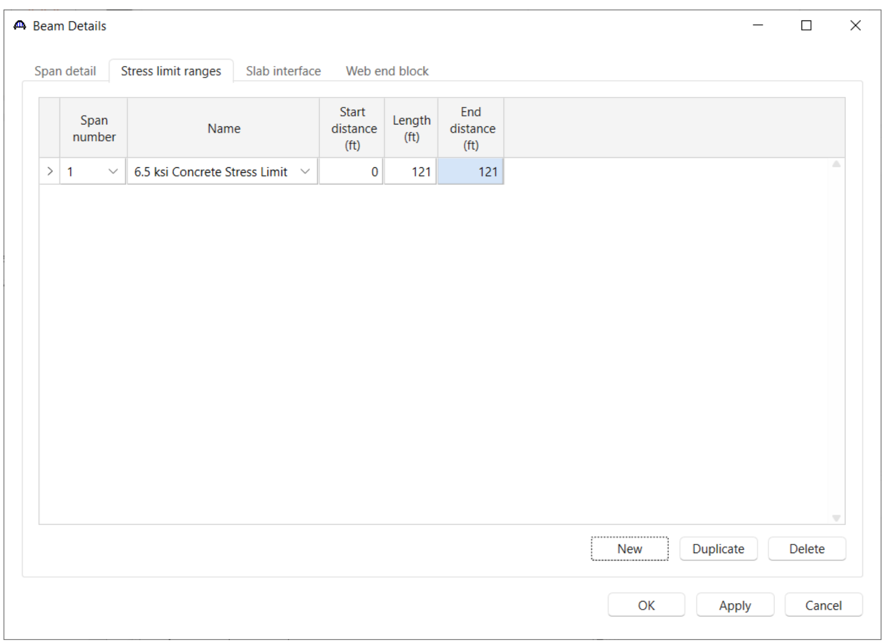
Click **OK** to close the window and create a new member alternative.

Beam Details

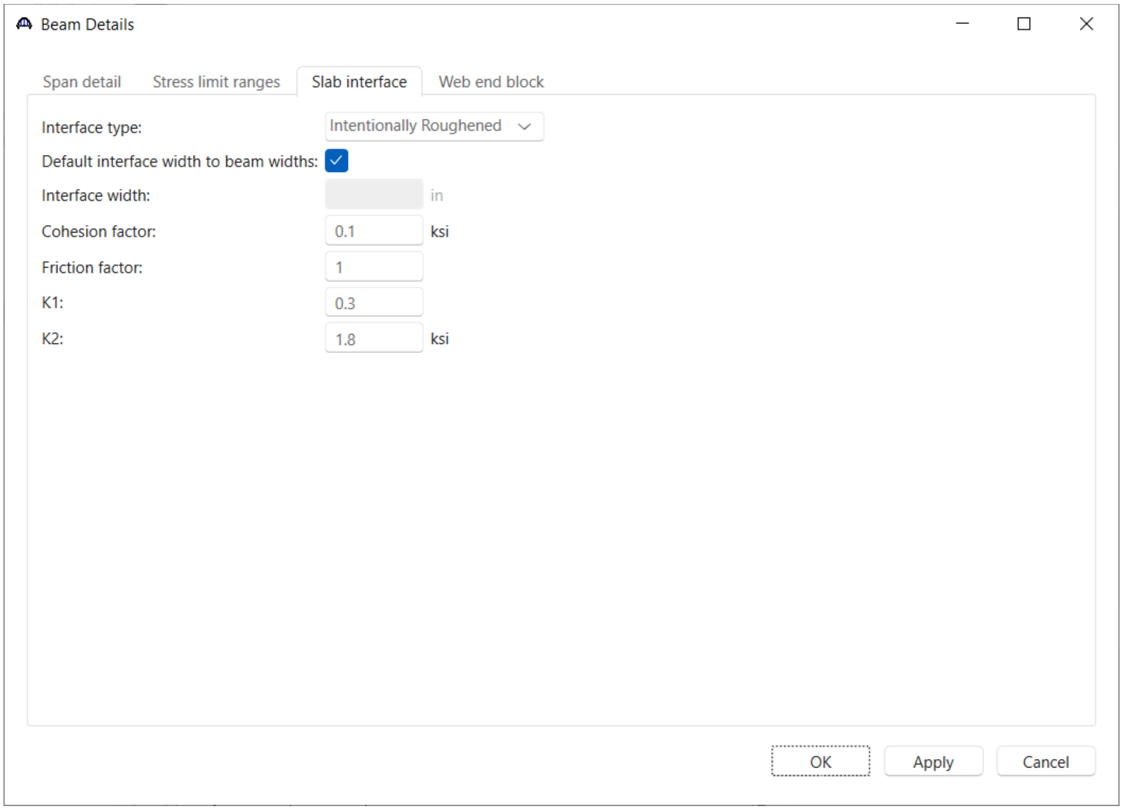
Expand the newly added member alternative in the workspace. Next describe the beam by double clicking on the **Beam Details** node in the **Bridge Workspace** tree. Enter the data in each tab of the **Beam Details** window as shown below.



Navigate to the **Stress limit ranges** tab and enter data as shown below. Note that the **Stress limit ranges** are defined over the entire length of the precast beam, including the projections of the beam past the centerline of bearing which were entered on the **Span detail** tab of this window.



Navigate to the **Slab interface** tab and enter data as shown below.

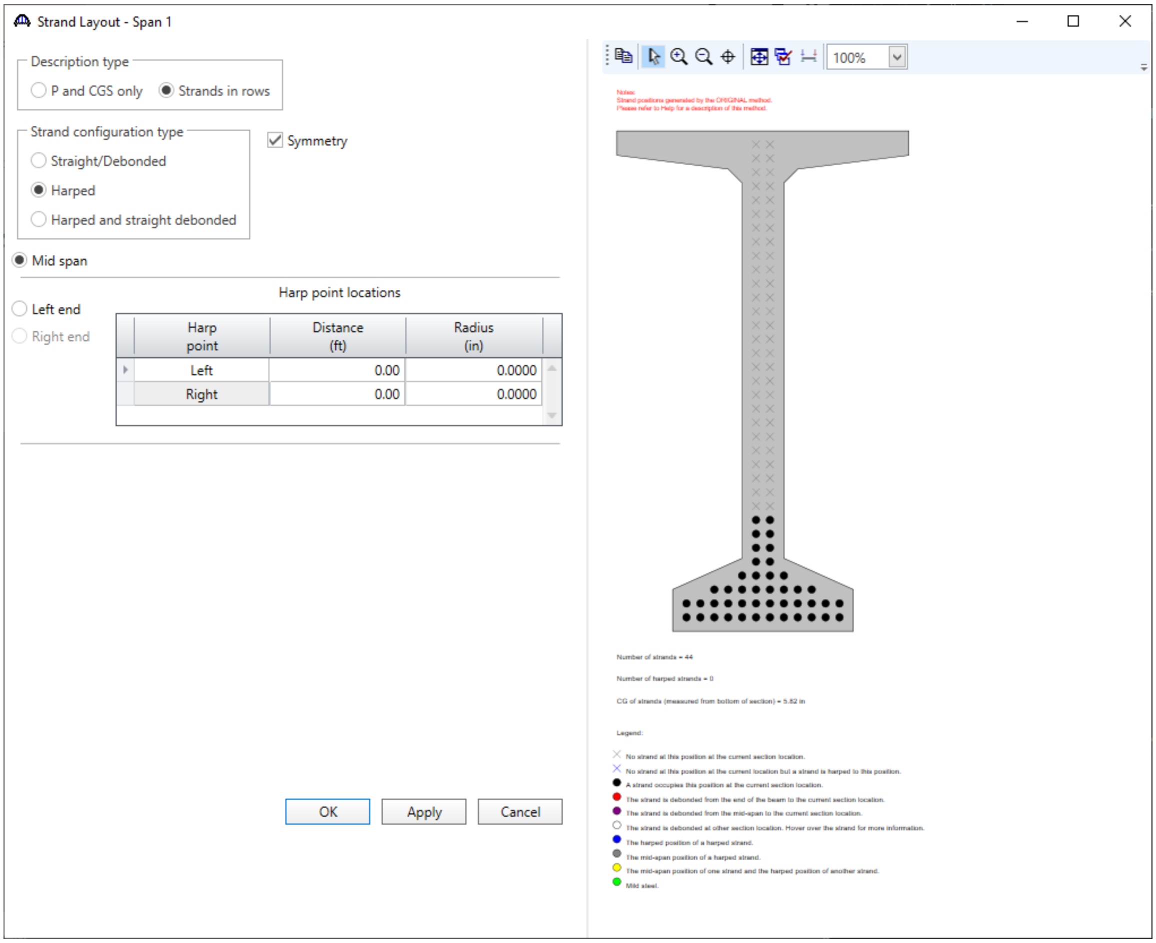


Click **OK** to apply the data and close the window.

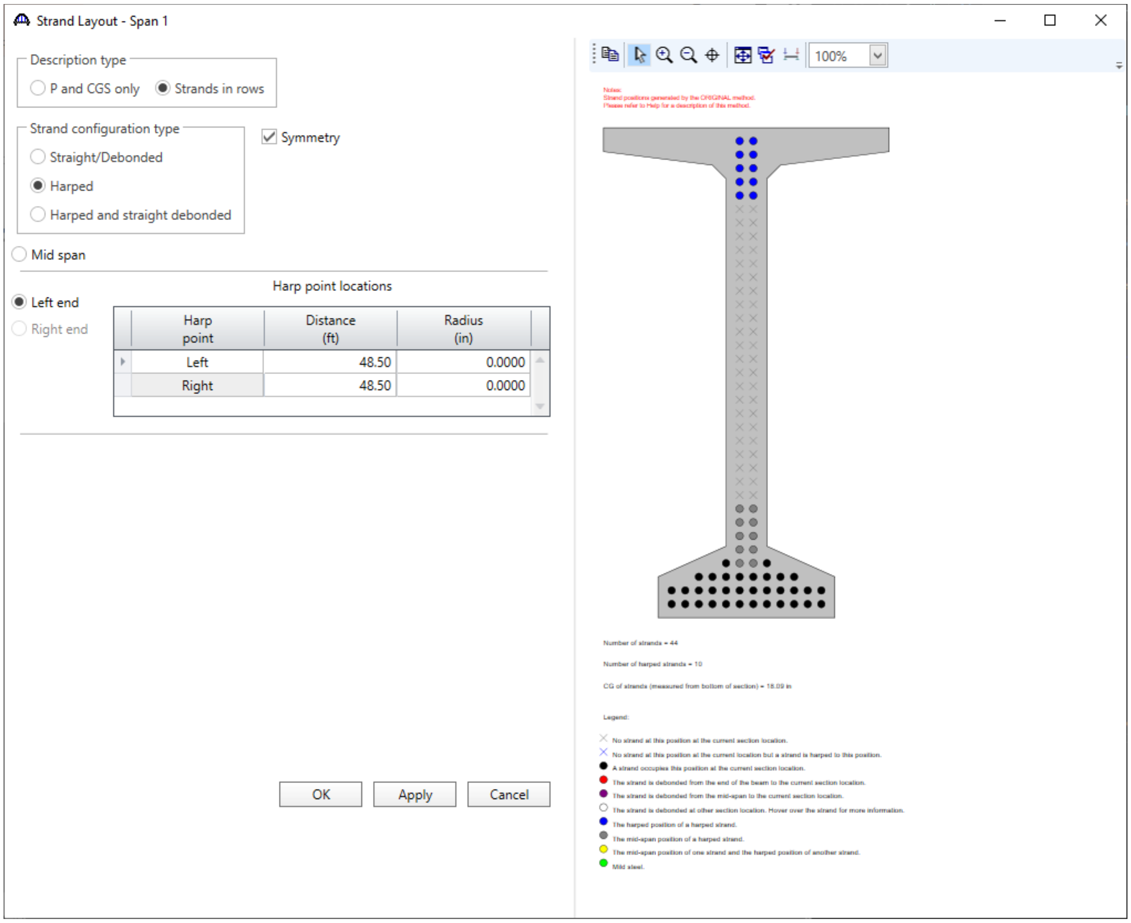
Strand Layout

Expand the tree under **Strand Layout** and open the **Span 1** window. Use the **Zoom** buttons on the right side of this window to shrink/expand the schematic of the beam shape so that the entire beam is visible.

Select the **Description type** as **Strands in rows** and the **Strand configuration type** as **Harped**. The **Mid span** radio button will now become active. Strands can now be defined at the middle of the span by selecting strands in the right hand schematic. Select the bottom 44 strands in the schematic so that the CG of the strands is 5.82 inches and click the **Apply** button.



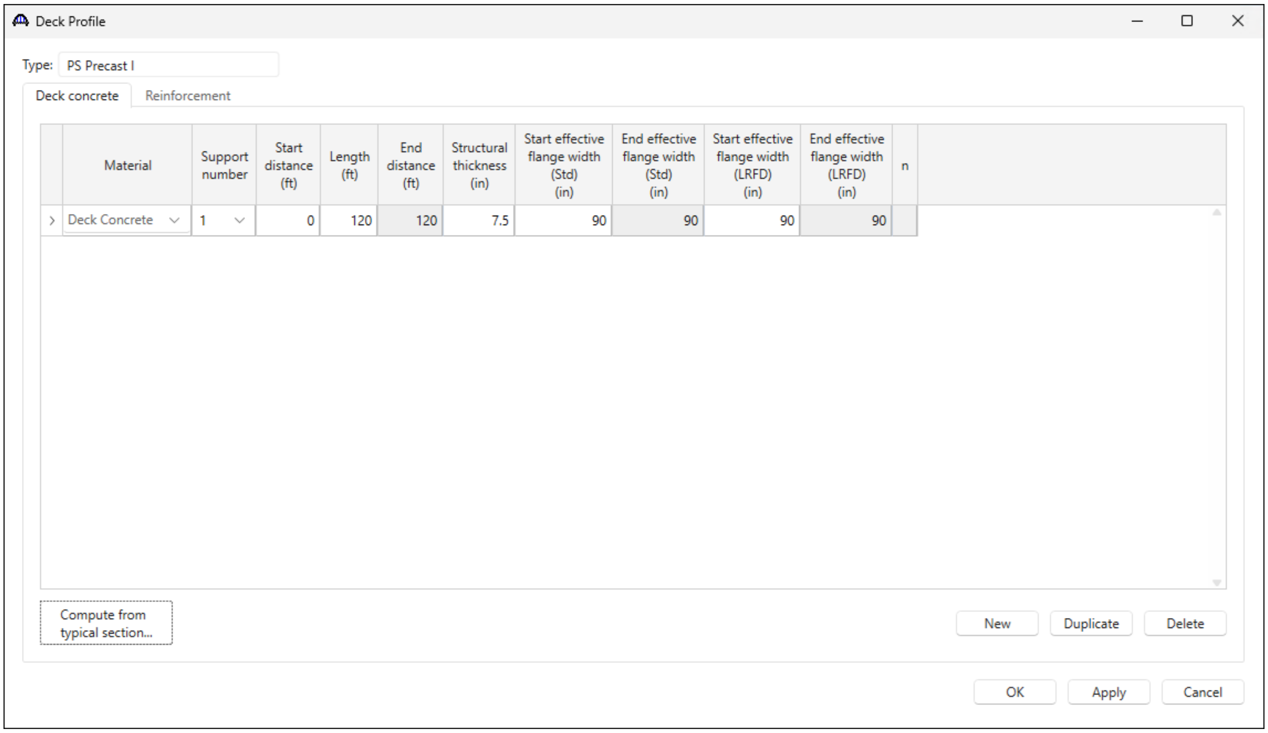
Now select the **Left end** radio button to enter the following harped strand locations at the left end of the precast beam. Place the cursor in the schematic view on the right side of the screen. The strands can be defined at the left end of the span by selecting strand locations in the right hand schematic. Select the top 10 strand locations in the schematic so that the CG of the strands is 18.09 inches.



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

Deck Profile

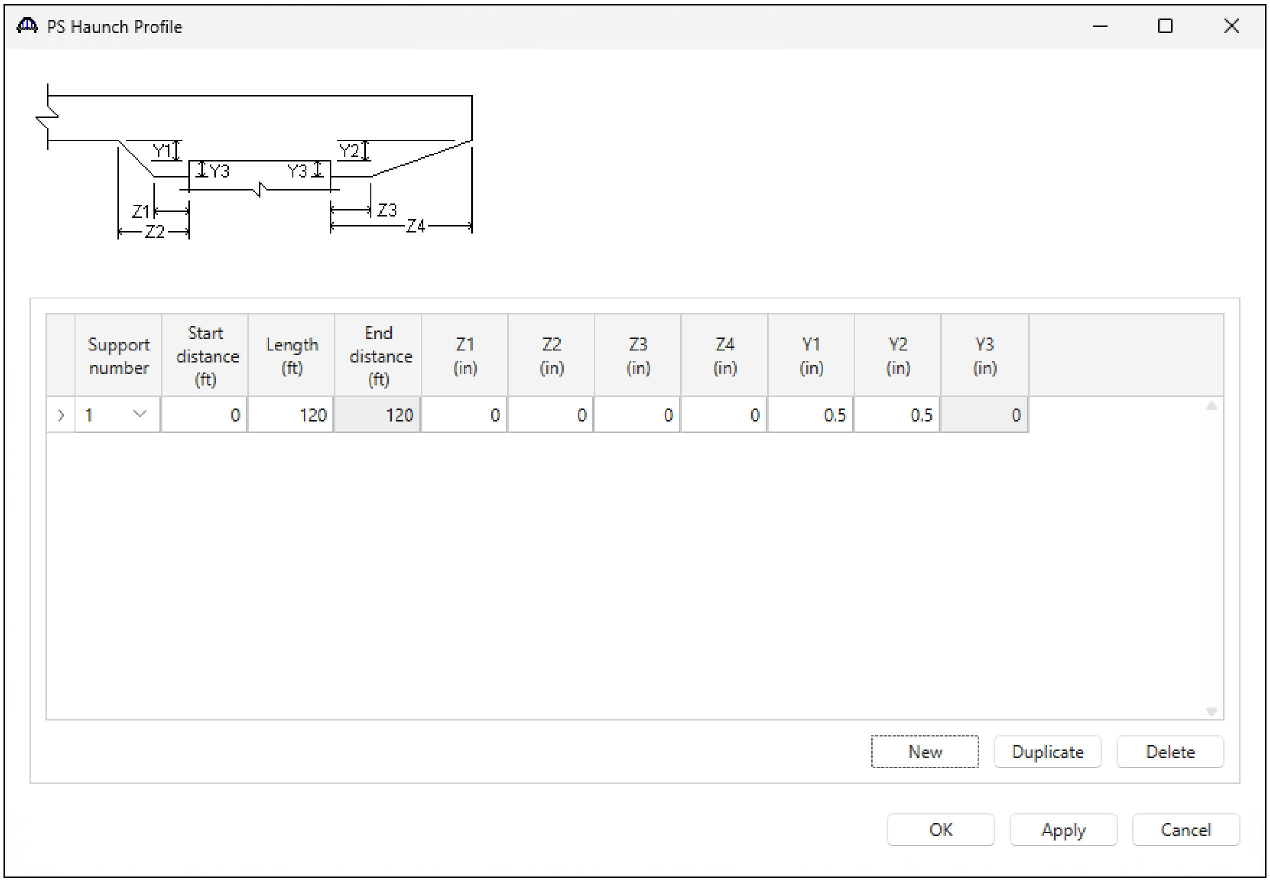
Next open the **Deck Profile** window by double-clicking the **Deck Profile** node in the **Bridge Workspace** tree and enter the data describing the structural properties of the deck. The window is shown below.



No reinforcement is described. Click **OK** to apply the data and close the window.

Haunch Profile

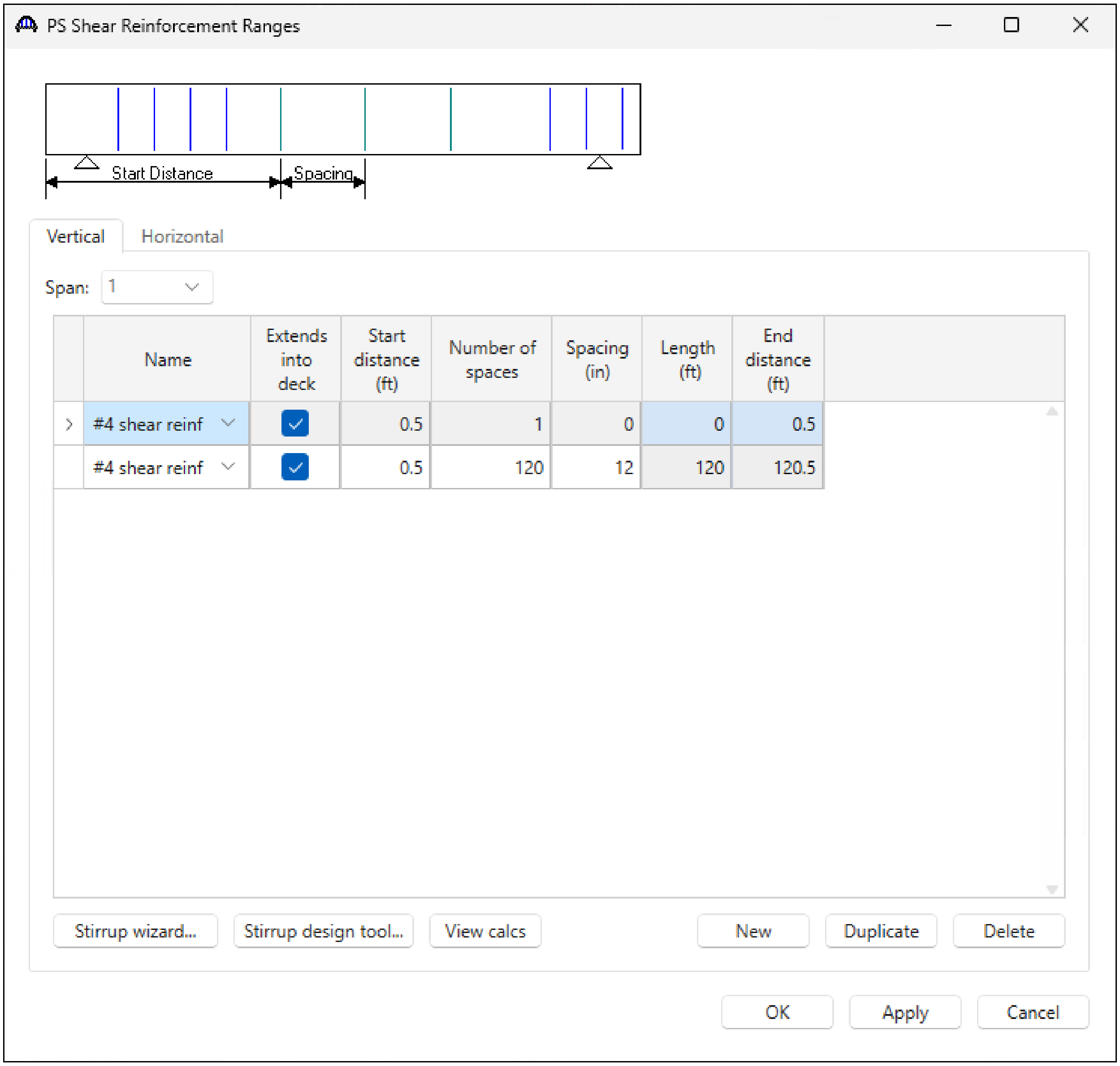
The haunch profile is defined by double-clicking on the **Haunch Profile** node in the **Bridge Workspace** tree. Enter data as shown below and Click **OK** to apply the data and close the window.



Support number	Start distance (ft)	Length (ft)	End distance (ft)	Z1 (in)	Z2 (in)	Z3 (in)	Z4 (in)	Y1 (in)	Y2 (in)	Y3 (in)
1	0	120	120	0	0	0	0	0.5	0.5	0

Shear Reinforcement Ranges

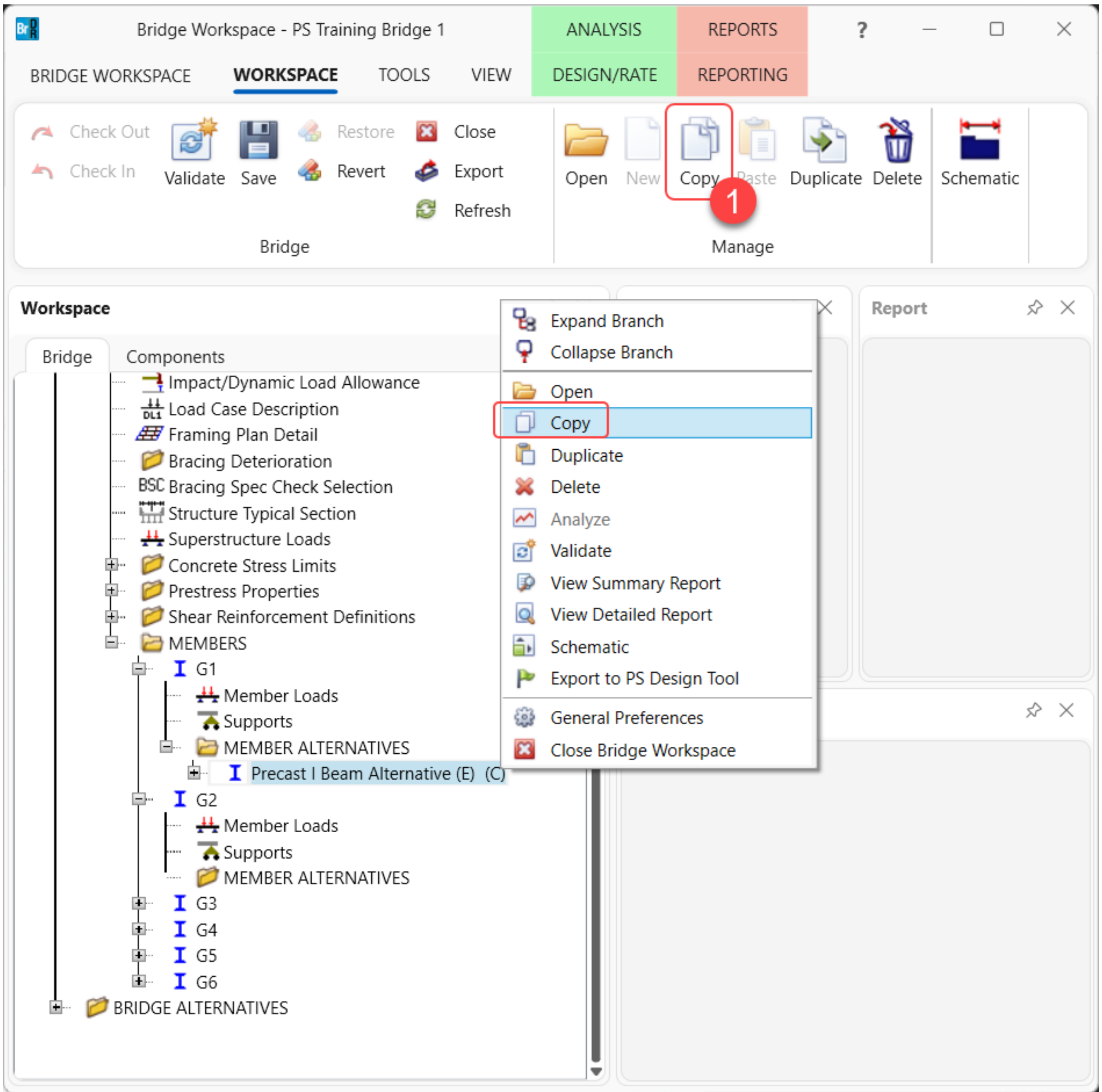
Double-click on the **Shear Reinforcement Ranges** node in the **Bridge Workspace** tree to open the **PS Shear Reinforcement Ranges** window. The shear reinforcement ranges are entered as described below. The vertical shear reinforcement is defined as extending into the deck on the **Vertical** tab of this window. This indicates composite action between the beam and the deck. Data does not have to be entered on the **Horizontal** tab to indicate composite action since that has been defined by extending the vertical bars into the deck.

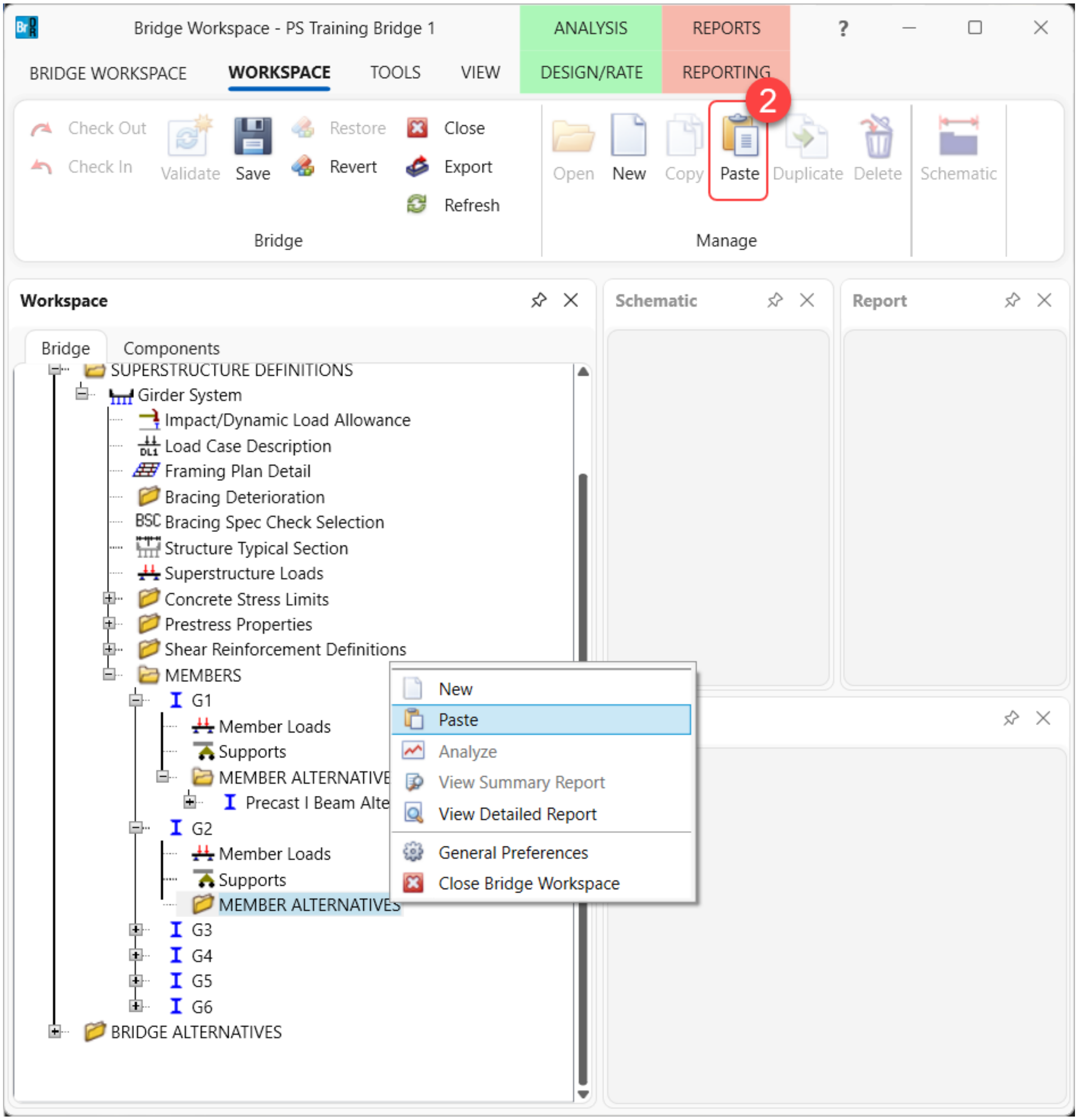


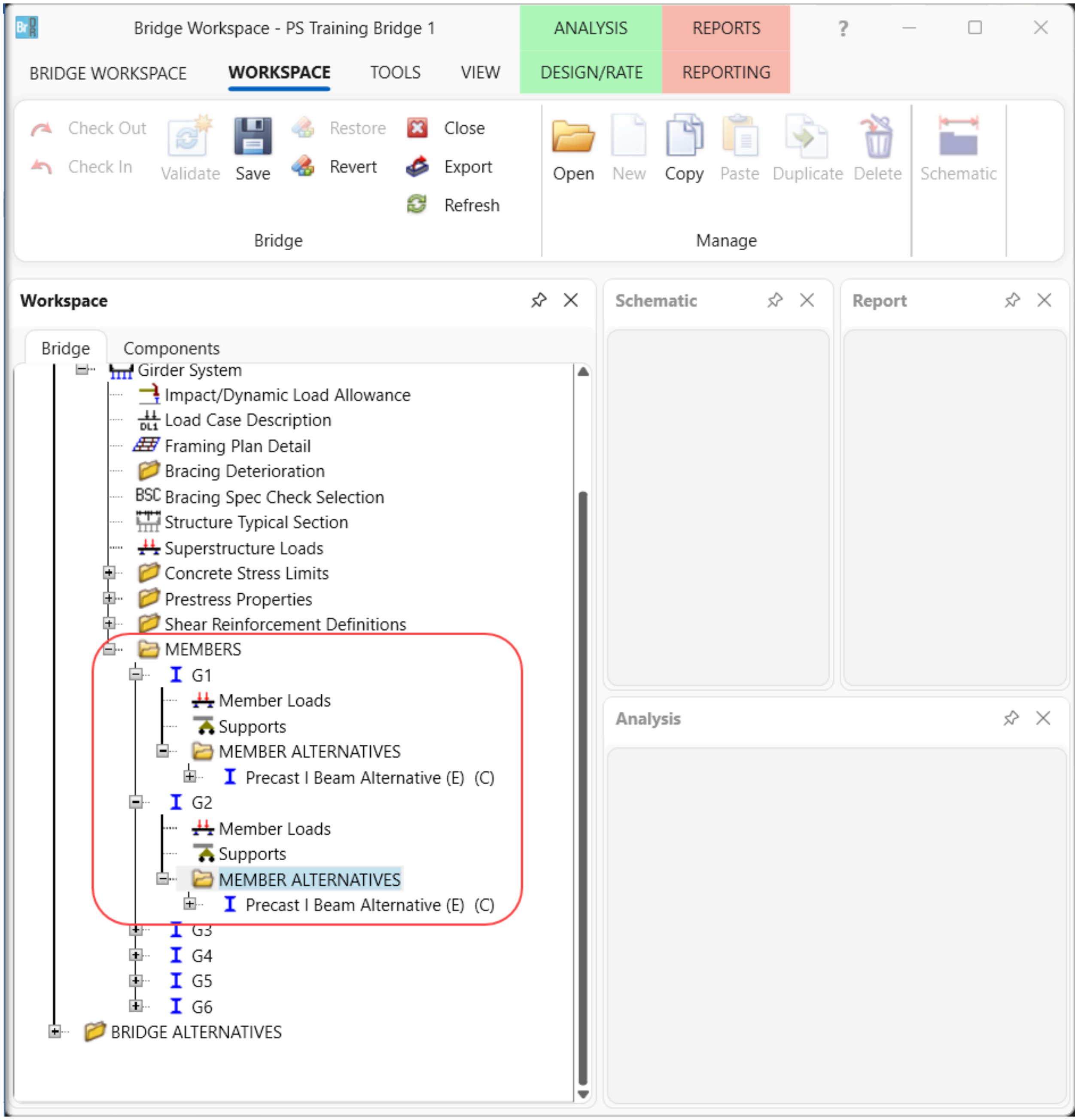
Click **OK** to apply the data and close the window.

Live Load Distribution

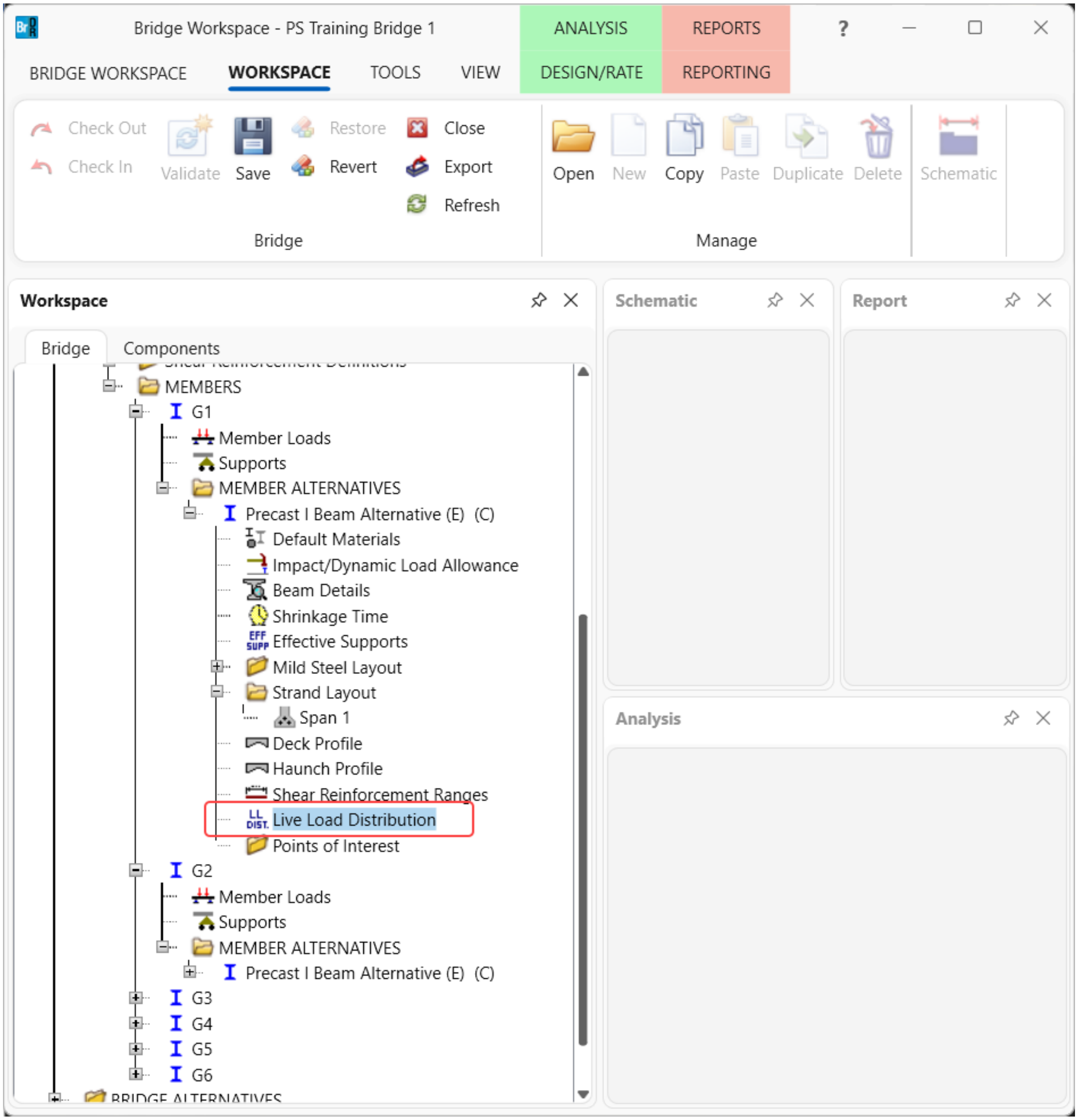
To compute the LRFD live load distribution factors, the interior girder adjacent to exterior girder must be defined. BrDR uses the beam shape assigned to this member alternative and the beam shapes assigned to the adjacent member alternatives to compute the distribution factors. If the **Compute from typical section…** button is used on this window without the adjacent girder defined, BrDR will throw a warning message indicating that since beam shapes are not assigned to adjacent member alternative, BrDR cannot calculate the distribution factors. In this case, the factors will have to be manually entered. For this example, copy the **Precast I Beam** member alternative of member **G1** and paste to **G2** as a member alternative.



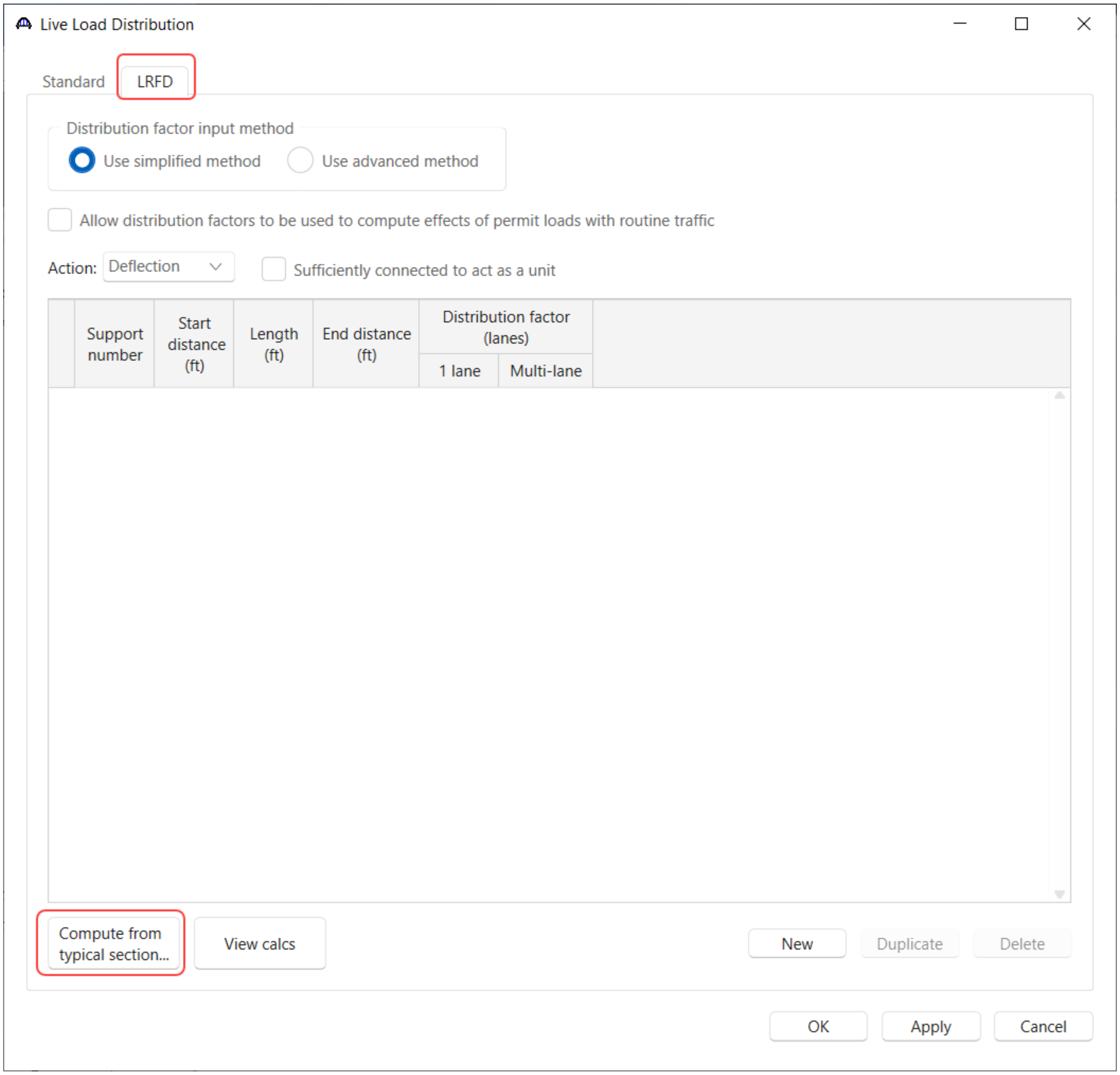

Bridge Workspace - PS Training Bridge 1
ANALYSIS
REPORTS
BRIDGE WORKSPACE
WORKSPACE
TOOLS
VIEW
DESIGN/RATE
REPORTING
Check Out
Check In
Validate
Save
Restore
Revert
Close
Export
Refresh
Bridge
Open
New
Copy
Paste
Duplicate
Delete
Schematic
Manage
2
Workspace
Schematic
Report
Bridge
Components
SUPERSTRUCTURE DEFINITIONS
Girder System
Impact/Dynamic Load Allowance
Load Case Description
Framing Plan Detail
Bracing Deterioration
Bracing Spec Check Selection
Structure Typical Section
Superstructure Loads
Concrete Stress Limits
Prestress Properties
Shear Reinforcement Definitions
MEMBERS
G1
Member Loads
Supports
MEMBER ALTERNATIVE
Precast I Beam Alte
G2
Member Loads
Supports
MEMBER ALTERNATIVES
G3
G4
G5
G6
BRIDGE ALTERNATIVES
New
Paste
Analyze
View Summary Report
View Detailed Report
General Preferences
Close Bridge Workspace


Bridge Workspace - PS Training Bridge 1
ANALYSIS
REPORTS
BRIDGE WORKSPACE
WORKSPACE
TOOLS
VIEW
DESIGN/RATE
REPORTING
Check Out
Check In
Validate
Save
Restore
Revert
Close
Export
Refresh
Bridge
Open
New
Copy
Paste
Duplicate
Delete
Schematic
Manage
Workspace
Schematic
Report
Analysis
Bridge
Components
Girder System
Impact/Dynamic Load Allowance
Load Case Description
Framing Plan Detail
Bracing Deterioration
Bracing Spec Check Selection
Structure Typical Section
Superstructure Loads
Concrete Stress Limits
Prestress Properties
Shear Reinforcement Definitions
MEMBERS
G1
Member Loads
Supports
MEMBER ALTERNATIVES
Precast I Beam Alternative (E) (C)
G2
Member Loads
Supports
MEMBER ALTERNATIVES
Precast I Beam Alternative (E) (C)
G3
G4
G5
G6
BRIDGE ALTERNATIVES

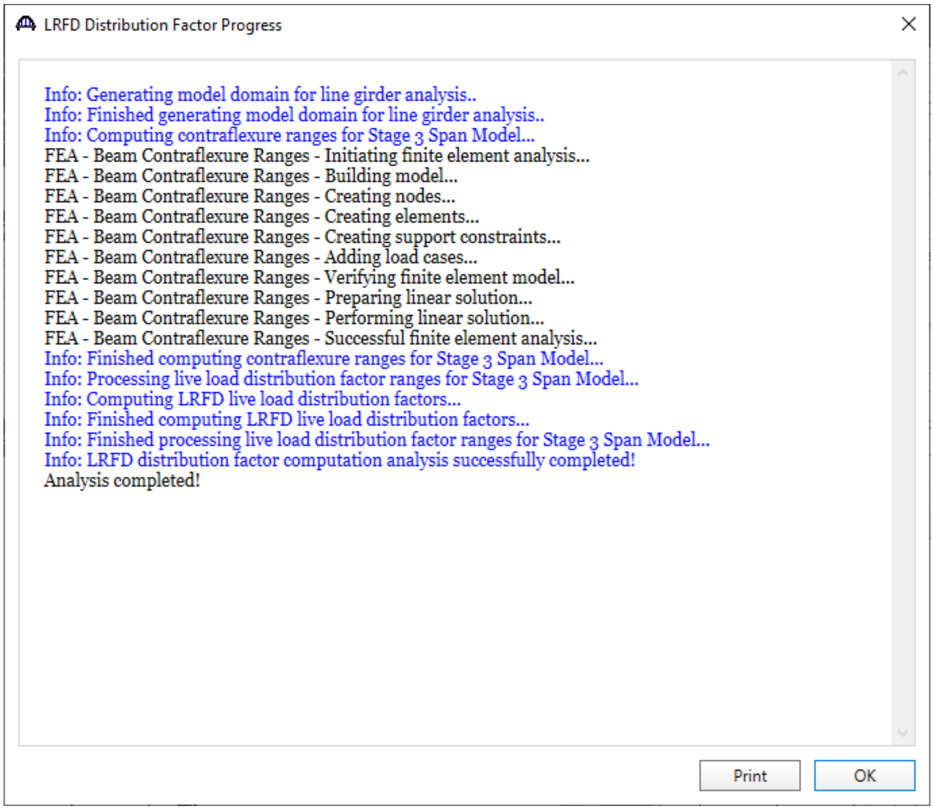
Double click on the **Live Load Distribution** node in the **Bridge Workspace** tree for member **G1** to open the **Live Load Distribution** window.



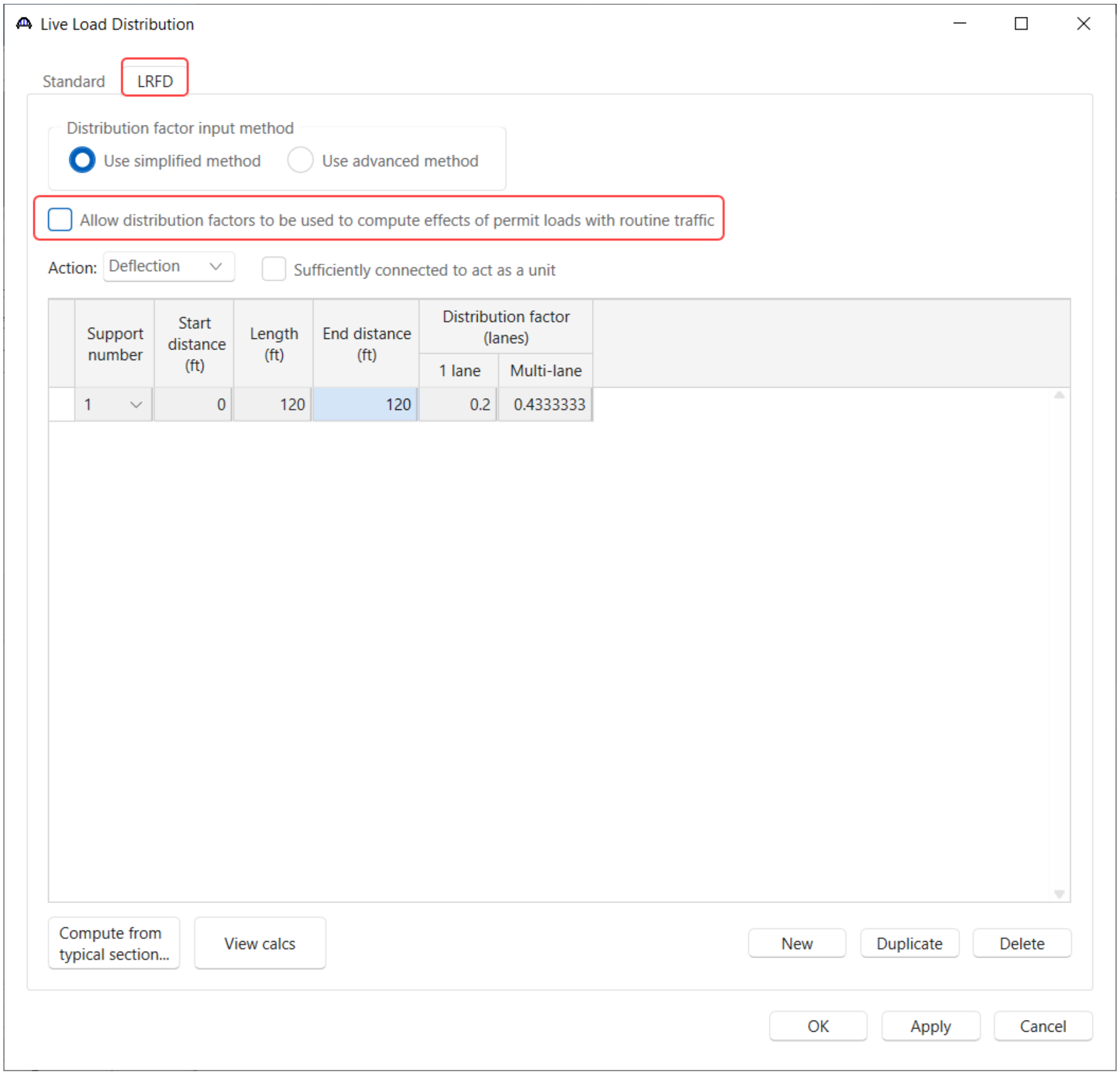
Navigate to the **LRFD** tab of this window. Click the **Compute from typical section . . .** button to compute the LRFD live load distribution factors.



The **LRFD Distribution Factor Progress** window opens as shown below.



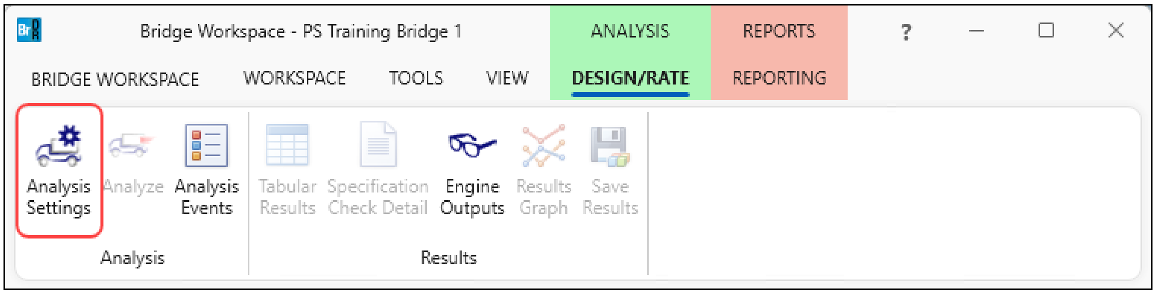
Once the analysis is complete, click **OK** to close this window. The **Live Load Distribution** window is now populated with the distribution factors. Uncheck the **Allow distribution factors to be used to compute effects of permit loads with routine traffic checkbox** and click **OK** to apply these factors and close the window. If these are left blank, BrDR will compute them during the analysis runtime.



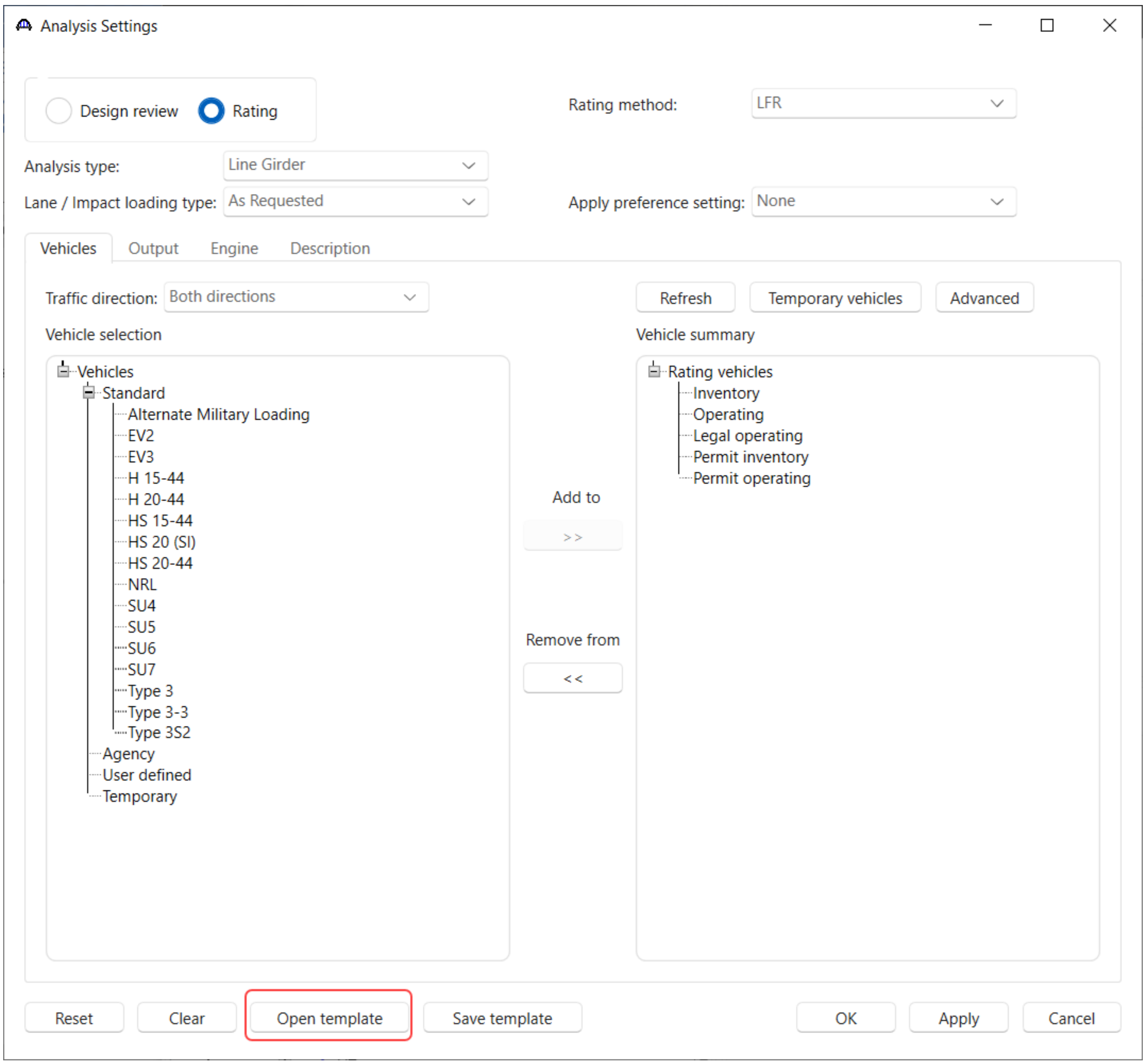
The description of an exterior beam for this structure definition is complete.

LRFR Analysis

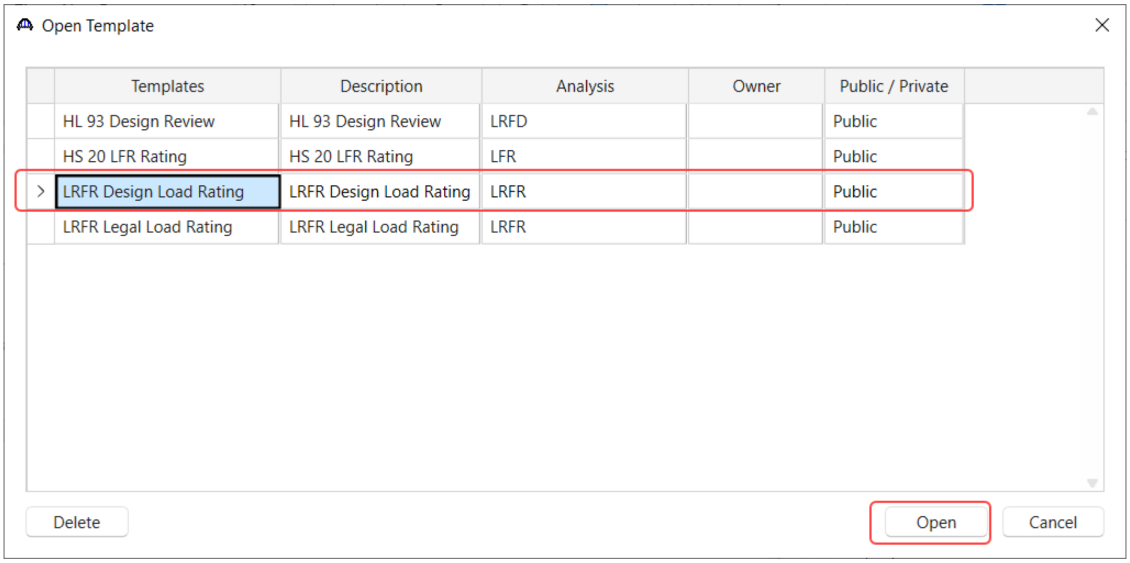
The member alternative for girder **G1** can now be analyzed. To perform an **LRFR** rating, select the **Analysis Settings** button on the **Analysis** group of the **DESIGN/RATE** ribbon.



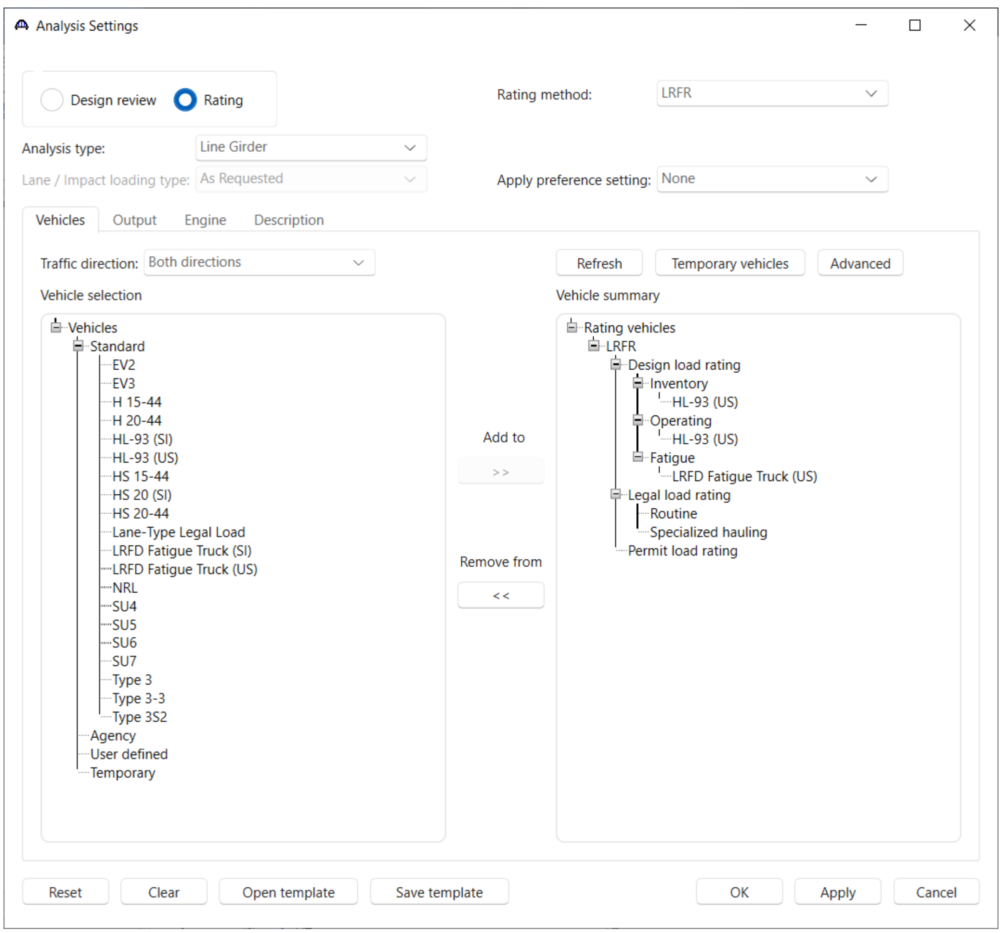
Click the **Open template** button.



Select the **LRFR Design Load Rating** to be used in the rating and click **Open**.



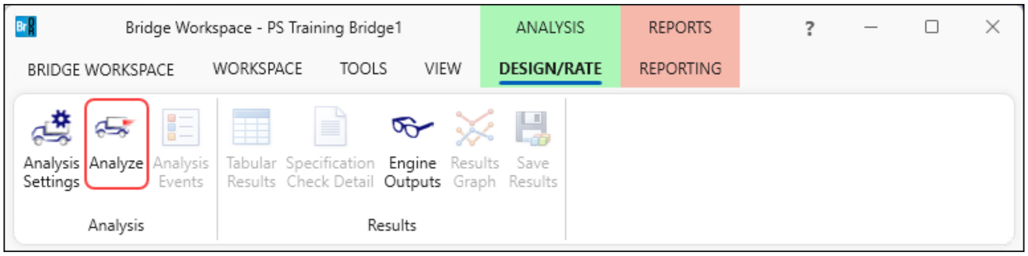
The **Analysis Settings** window will be populated as shown below.



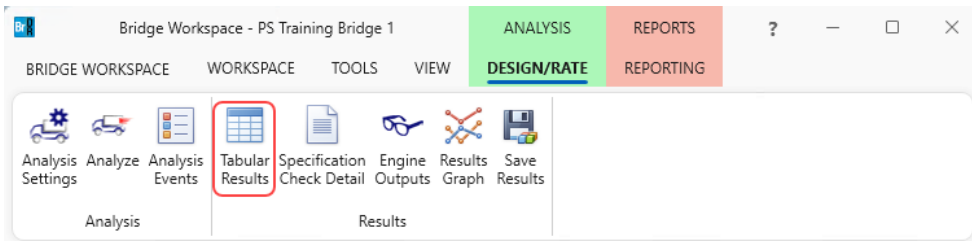
Click **OK** to apply the data and close the window.

Tabular Results

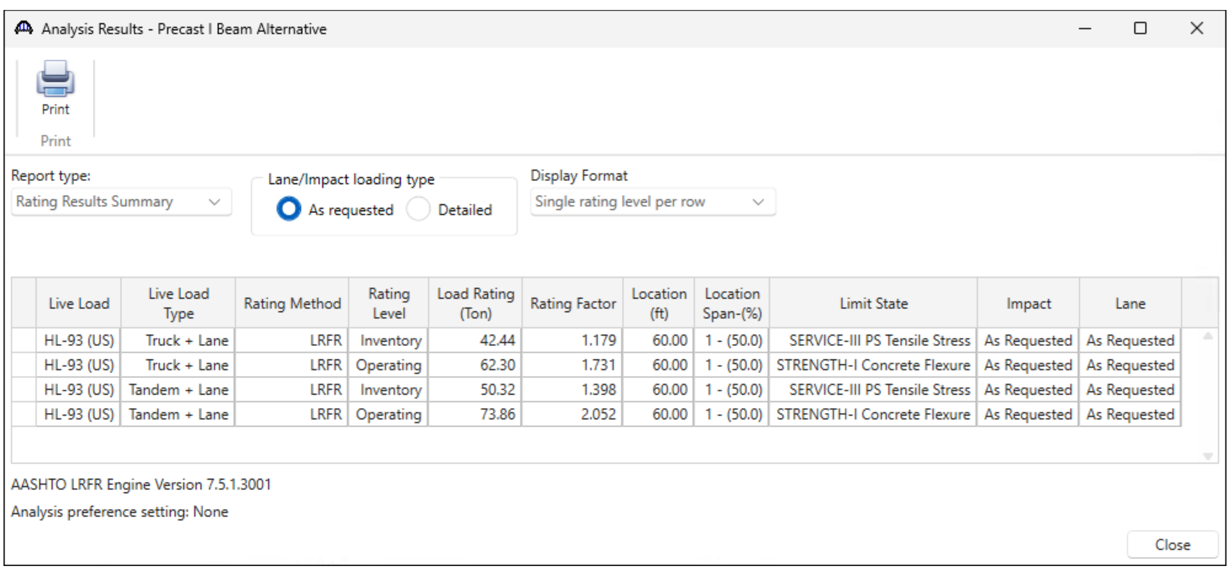
With member alternative **Precast I Beam Alternative** for member **G1** selected, click the **Analyze** button on the **Analysis** group of the **DESIGN/RATE** ribbon to perform the rating.



When the rating is finished results can be reviewed by clicking the **Tabular Results** button on the **Results** group of the ribbon.

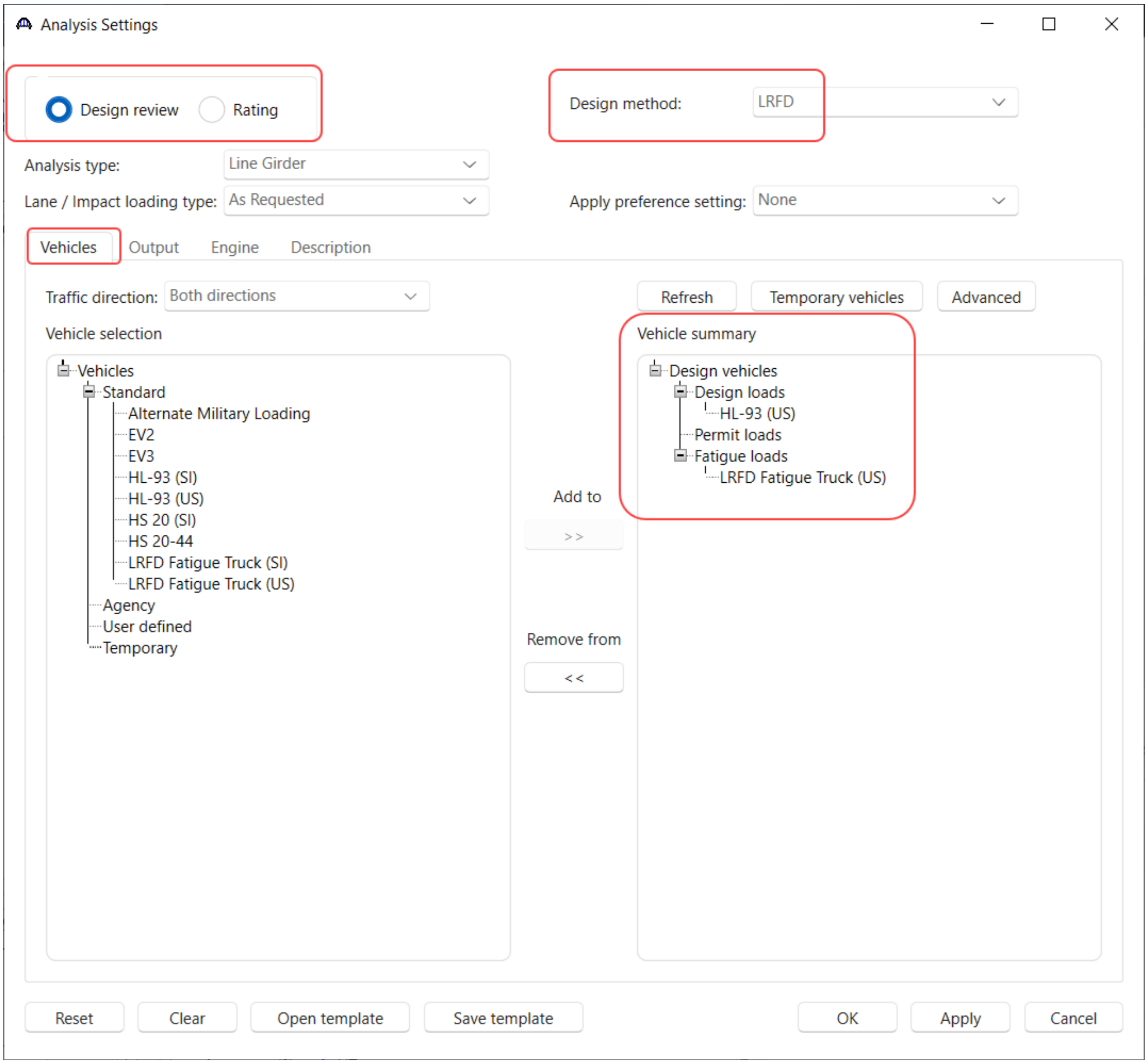


The window shown below will open. Select **Rating Results Summary** as the **Report Type** and **Single rating level per row** as the **Display Format** option to have the ratings arranged as shown below.



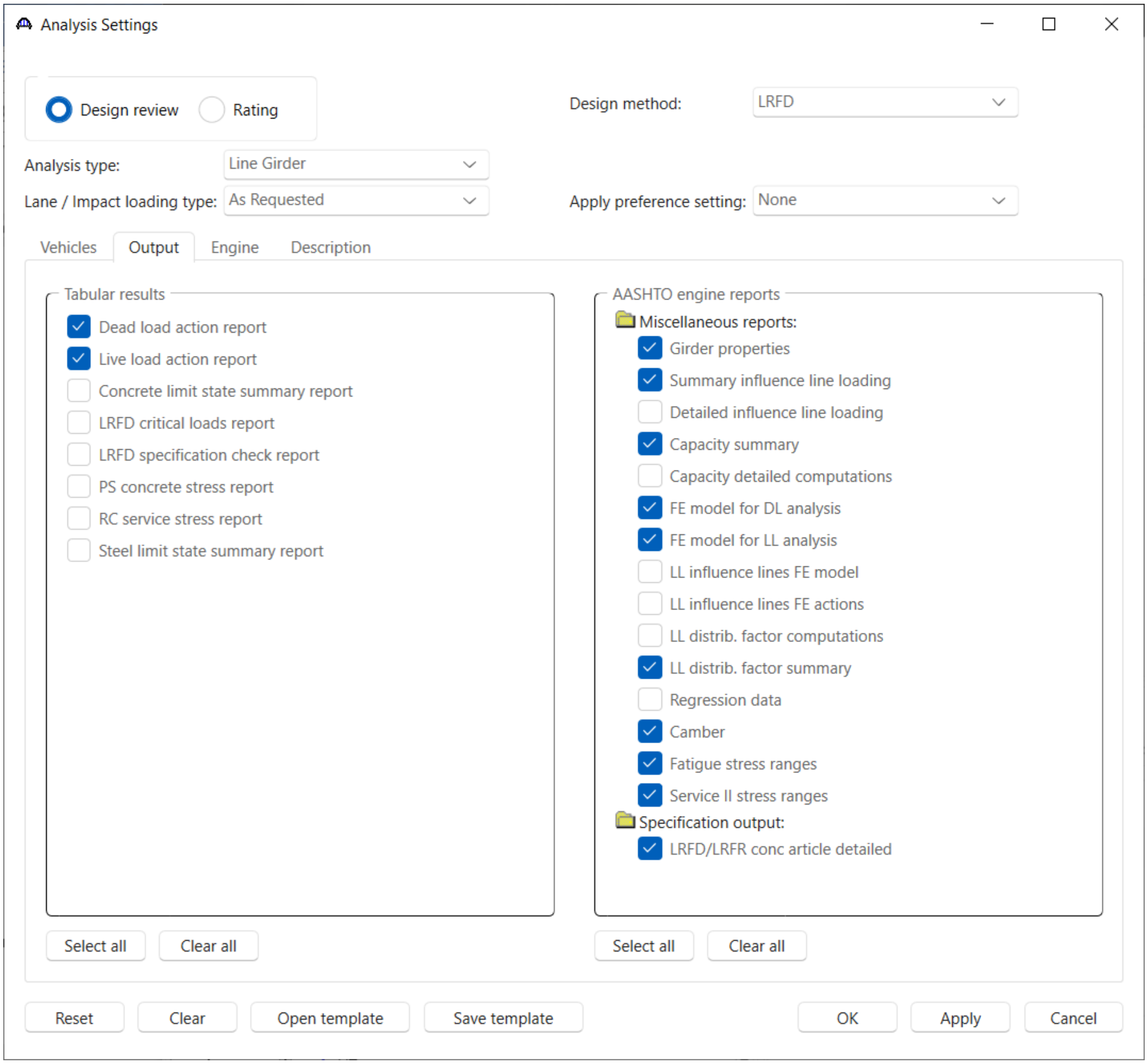
LRFD Design Review

An LRFD design review of this girder for **HL93** loading can be performed by AASHTO LRFD. To perform an LRFD design review, enter the **Analysis Settings** window as shown below or select the **HL 93 Design Review** template from the Open Template button as shown in the previous section.:



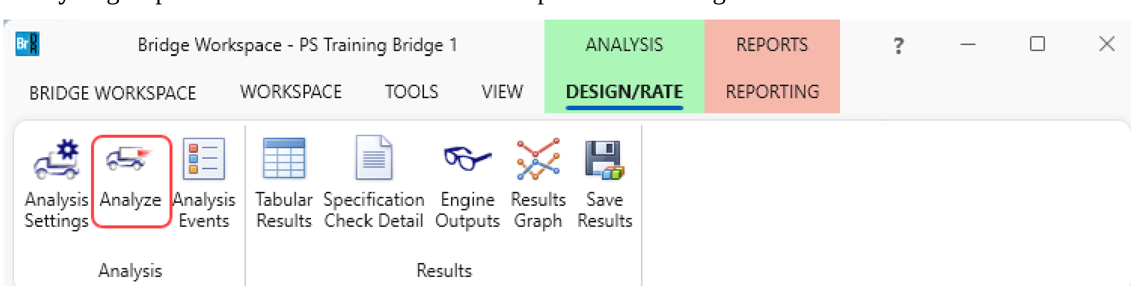
Analysis Settings - Output

Navigate to the **Output** tab and enter the **Analysis Settings** as shown below.

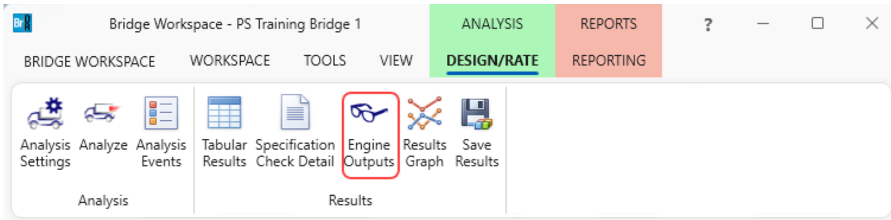


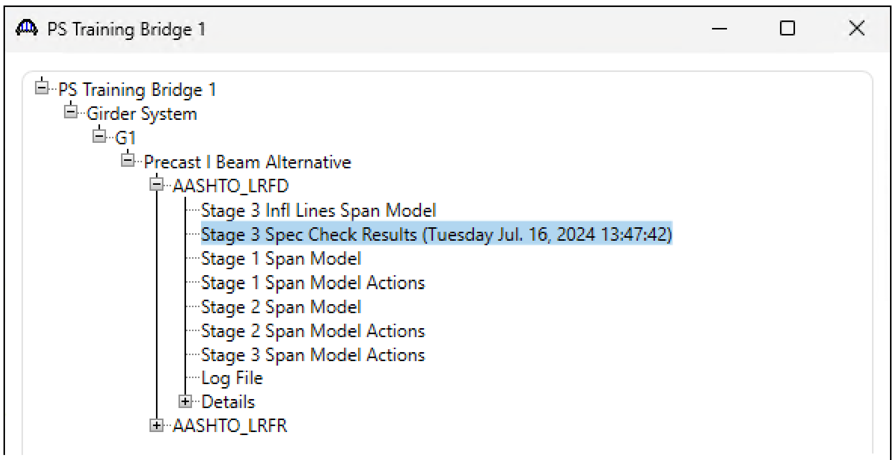
Engine Outputs

Next with member alternative **Precast I Beam Alternative** for member **G1** selected click the **Analyze** button on the **Analysis** group of the **DESIGN/RATE** ribbon to perform the design review.



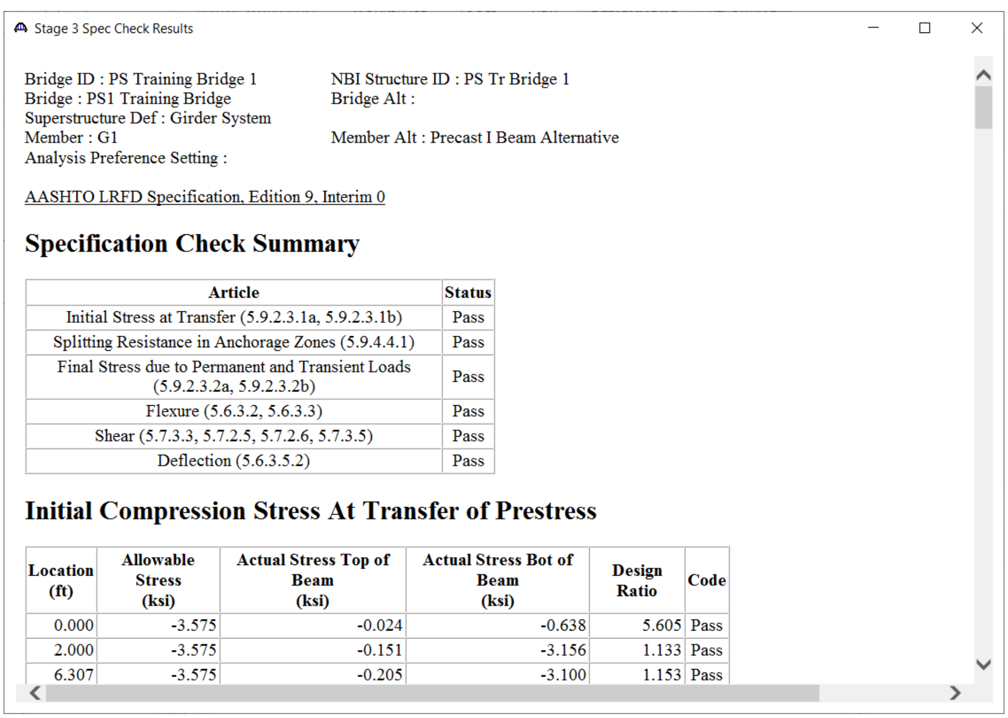
AASHTO LRFD analysis will generate a spec check results file. Click the **Engine Outputs** button from the **Results** group of the **DESIGN/RATE** ribbon to open the following window.





To view the LRFD spec check results (shown below), double click on the **Stage 3 Spec Check Results** under the AASHTO_LRFD branch in this window.

The following file opens.


Stage 3 Spec Check Results

Bridge ID : PS Training Bridge 1 NBI Structure ID : PS Tr Bridge 1
Bridge : PS1 Training Bridge Bridge Alt :
Superstructure Def : Girder System
Member : G1 Member Alt : Precast I Beam Alternative
Analysis Preference Setting :

AASHTO LRFD Specification, Edition 9, Interim 0

Specification Check Summary

Article	Status
Initial Stress at Transfer (5.9.2.3.1a, 5.9.2.3.1b)	Pass
Splitting Resistance in Anchorage Zones (5.9.4.4.1)	Pass
Final Stress due to Permanent and Transient Loads (5.9.2.3.2a, 5.9.2.3.2b)	Pass
Flexure (5.6.3.2, 5.6.3.3)	Pass
Shear (5.7.3.3, 5.7.2.5, 5.7.2.6, 5.7.3.5)	Pass
Deflection (5.6.3.5.2)	Pass

Initial Compression Stress At Transfer of Prestress

Location (ft)	Allowable Stress (ksi)	Actual Stress Top of Beam (ksi)	Actual Stress Bot of Beam (ksi)	Design Ratio	Code
0.000	-3.575	-0.024	-0.638	5.605	Pass
2.000	-3.575	-0.151	-3.156	1.133	Pass
6.307	-3.575	-0.205	-3.100	1.153	Pass

AASHTOWare BrDR 7.5.1

Feature Tutorial

HLP1– Help Features

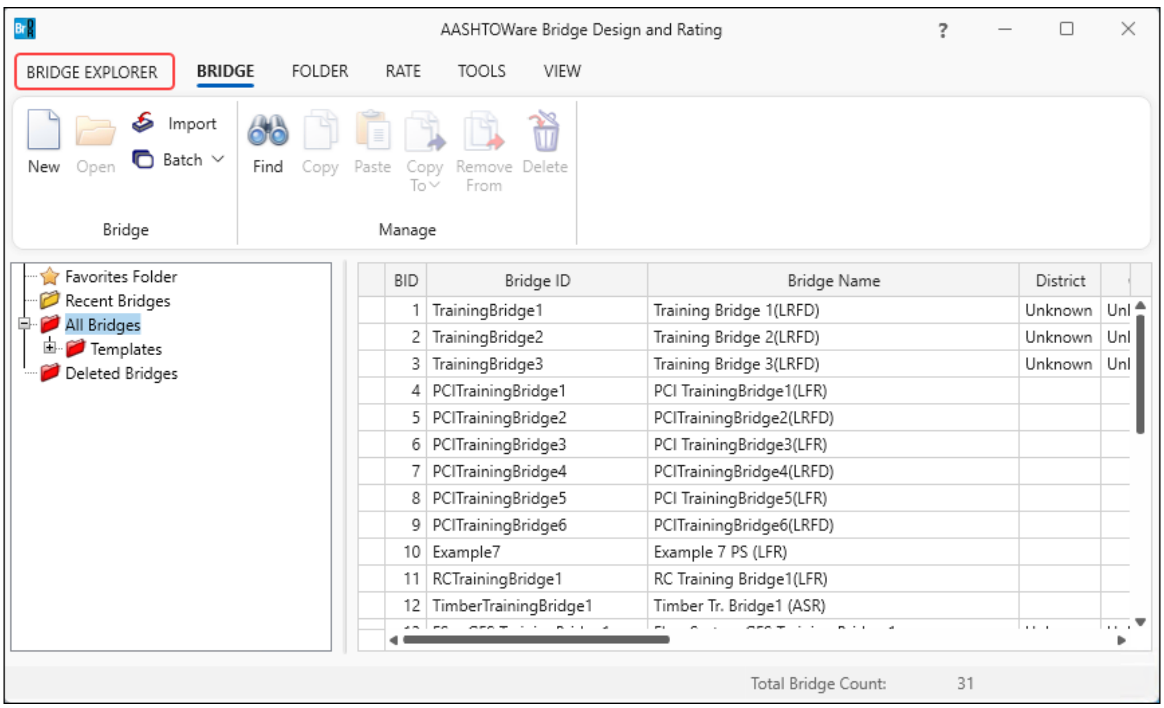
Topics Covered

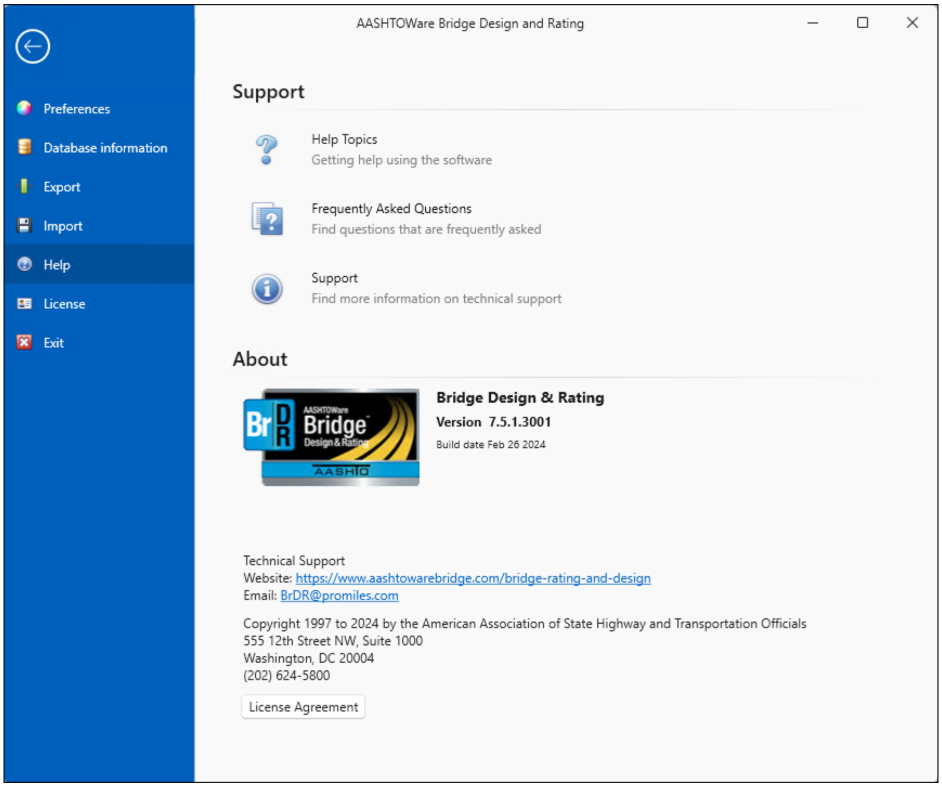
This topic describes the various help features and training available in BrDR.

- Online Help
- Engine Related Help
- Limitations Help Topic
- Training Aids

Online Help (BrDR 7.5.1)

There are many different online help files available in BrDR. To access BrDR help, open BrDR, click on **Bridge Explorer** and select **Help** from the left ribbon to open the following Help options.





- Selecting **Help Topics** from the menu opens the BrDR help file where you can view the **Contents**, the **Index** and **Search** for specific words.
- Selecting **Frequently Ask Questions** from the menu opens a BrDR help file containing Basic, Technical and Non-Technical frequently asked questions about BrDR.
- Selecting **Support** from the menu opens the Support page of BrDR help with technical support information and license support options.

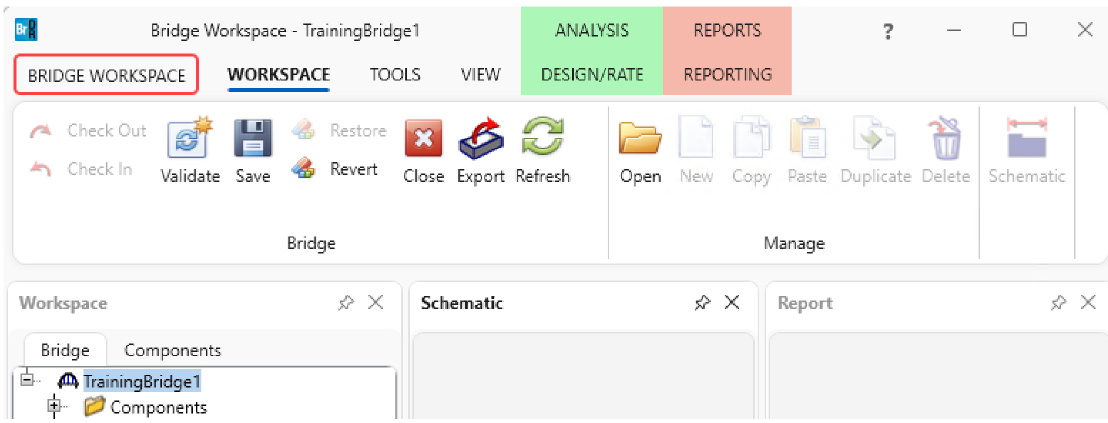
Online, context-sensitive help is available in each window of BrDR by clicking the F1 button while a window is open. This will open the BrDR help topic for that window.

Engine-Related Help

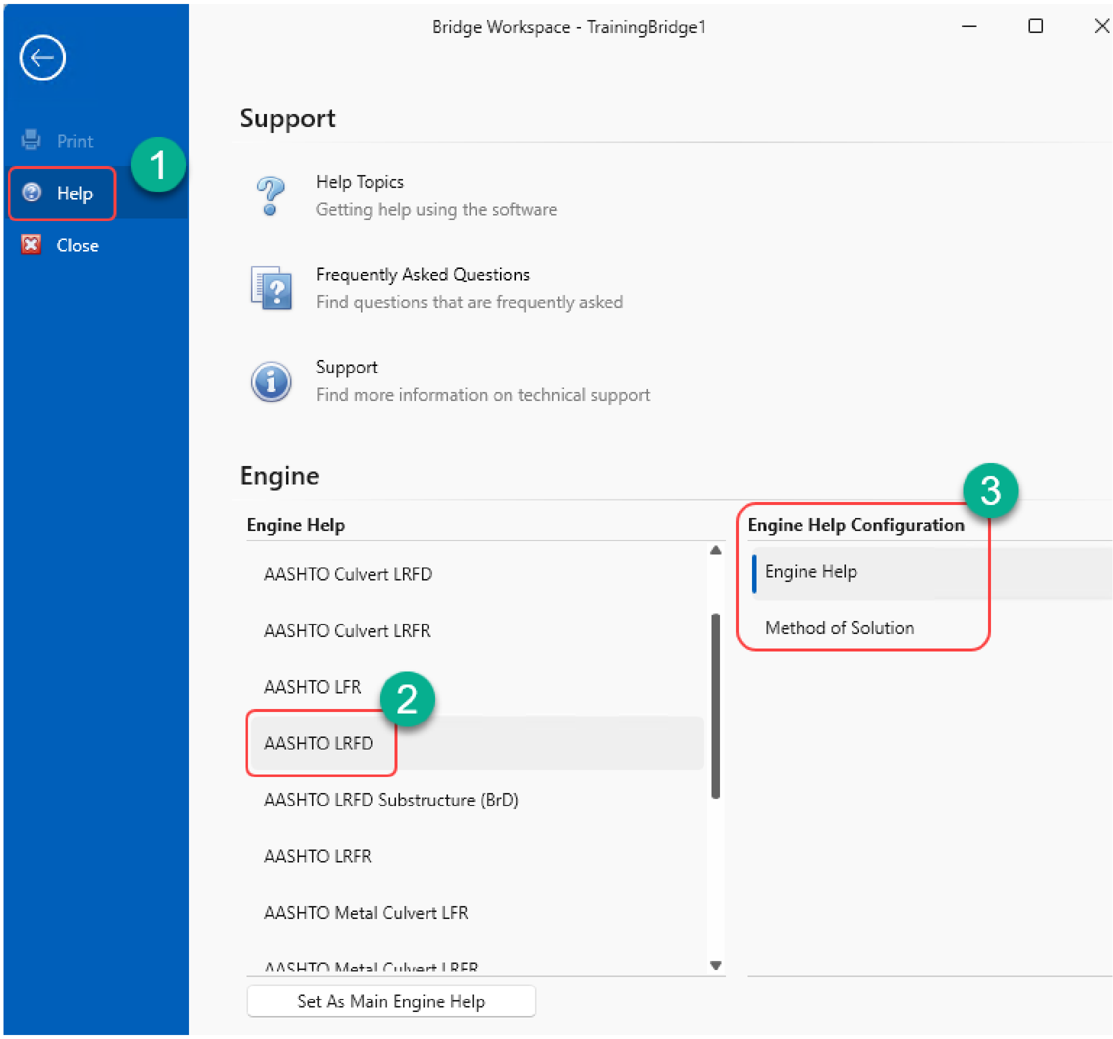
BrDR has been designed to enter data describing the physical characteristics of a bridge irrespective of the analysis engine that will be used to analyze the bridge. Therefore, there may be some data in BrDR that may not be used by a particular analysis engine. Each BrDR help topic contains a link to **Engine Related Help** that helps determine which data is not used by the configured engine.

Engine Related help can be configured from the **Bridge Workspace** for a selected bridge. The steps to configure Engine related help are as follows:

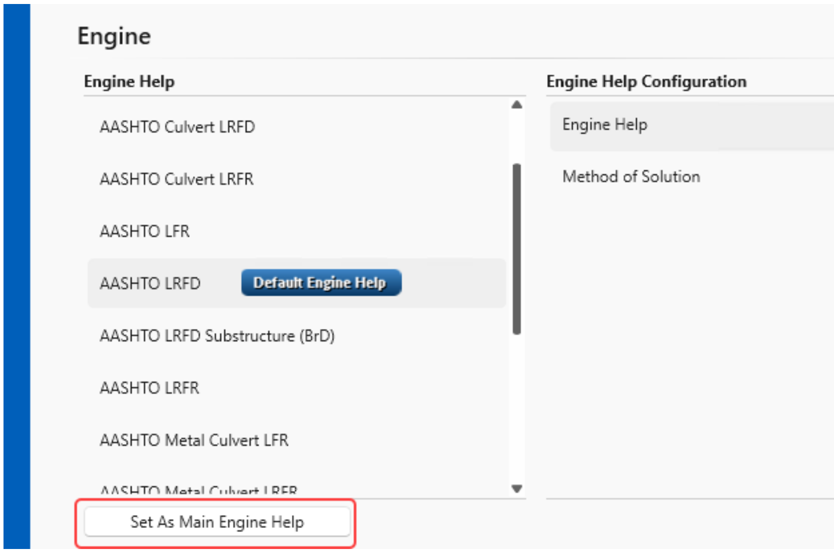
1. Open the **Bridge Workspace** for the bridge you wish to access/set up **Engine related help.**



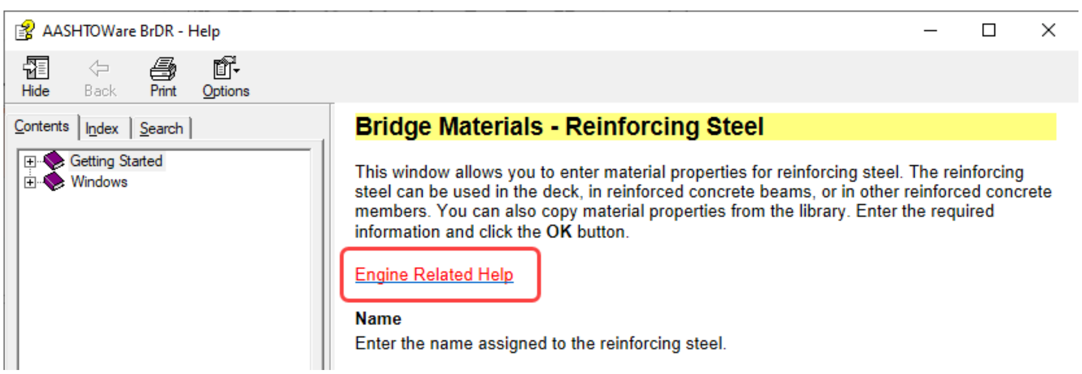
2. Click on the **Help** button (1) on the leftmost column. Select the relevant **Engine Help** (2) you wish to access for this bridge during this session from the **Engine Help** menu. The selected Engine Help and its Method of Solution gets populated on the **Engine Help Configuration** (3) menu on the right side, as shown below:



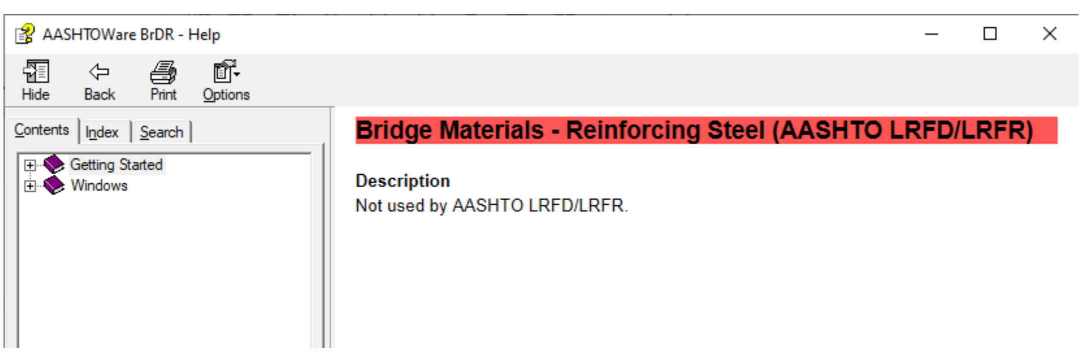
3. Click on the **Set As Main Engine Help** button to set the above selected engine help as the **Default Engine Help** as shown below:



4. The engine help has been configured and can be accessed from any help topic that contains an **Engine Related Help** link. For example, the BrDR help for Bridge Materials – Reinforcing Steel contains a link to its respective Engine Related Help as shown below:



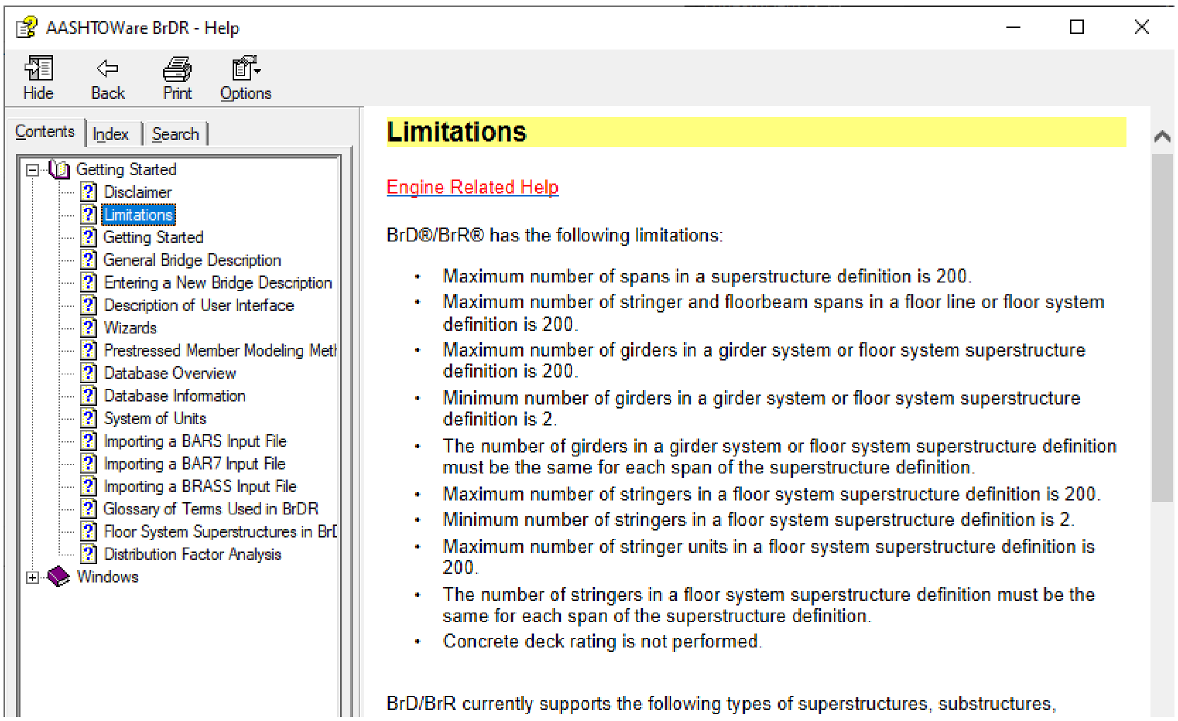
5. Clicking on the **Engine Related Help** link redirects to the **AASHTO LRFD Engine help** for Bridge Materials – Reinforcing Steel as shown below:



Limitations Help Topic

The **Limitations** help topic, available in **BrDR Help,** merits special attention. This topic should be reviewed to determine if BrDR supports a particular type of bridge. An **Engine Related Help** link is also available to describe any analysis engine limitations.

A portion of the BrDR **Limitations** help topic is shown below:



Training Aids

The BrDR Technical Support website contains example problems that can be used as self-study guides for new users. The BrDR Technical Support website address is

https://www.aashtowarebridge.com

The **Training** section of this website

https://www.aashtowarebridge.com/bridge-rating-and-design/training

contains approximately 150 example problems for various activities such as entering different bridge and girder types, importing/exporting, rating, etc.

2024 RADBUG Annual Meeting

AASHTOWare™
BRIDGE
DESIGN AND RATING

BrD Training Session

Wednesday August 7, 2024
10:00 AM – 12:00 AM

1. LRFD Cb Calculation using Concurrent Moments
2. Steel Design Tool – Two Span Girder Design

AASHTOWare BrDR 7.5.1

Steel Tutorial

STL14-LRFD Cb Calculation using Concurrent Moments Example

AASHTOWare Bridge Design and Rating Training

STL14 –LRFD Cb Calculation using Concurrent Moments Example

Topics Covered

- Modify STL2 Example Bridge
- Cb Calculation Control Option
- Cb Calculation Comparison

Features (introduced in version 7.5.0):

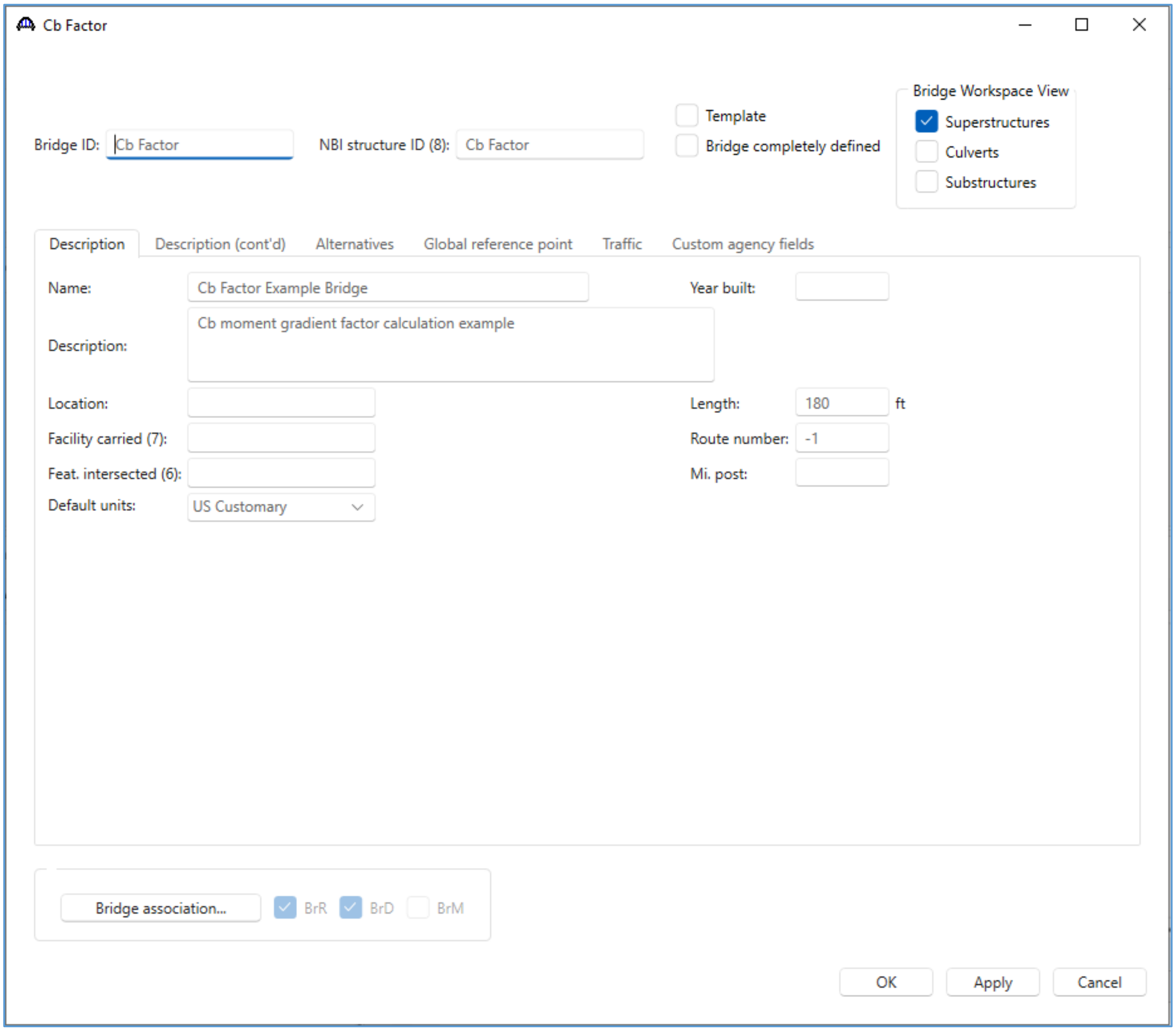
- LRFD Analysis Control option: “Consider concurrent moments in Cb calculation”
- LRFR Analysis Control option: “Consider concurrent moments in Cb calculation”

This tutorial demonstrates how to select the calculation method for the AASHTO LRFD Cb moment gradient factor. By default, the moment gradient factor is computed using the envelope actions at brace points. The control option to consider concurrent moments in Cb calculation will compute the factor using concurrent moments at brace points. The concurrent brace moment reports and the changes to the spec output for concurrent actions are presented.

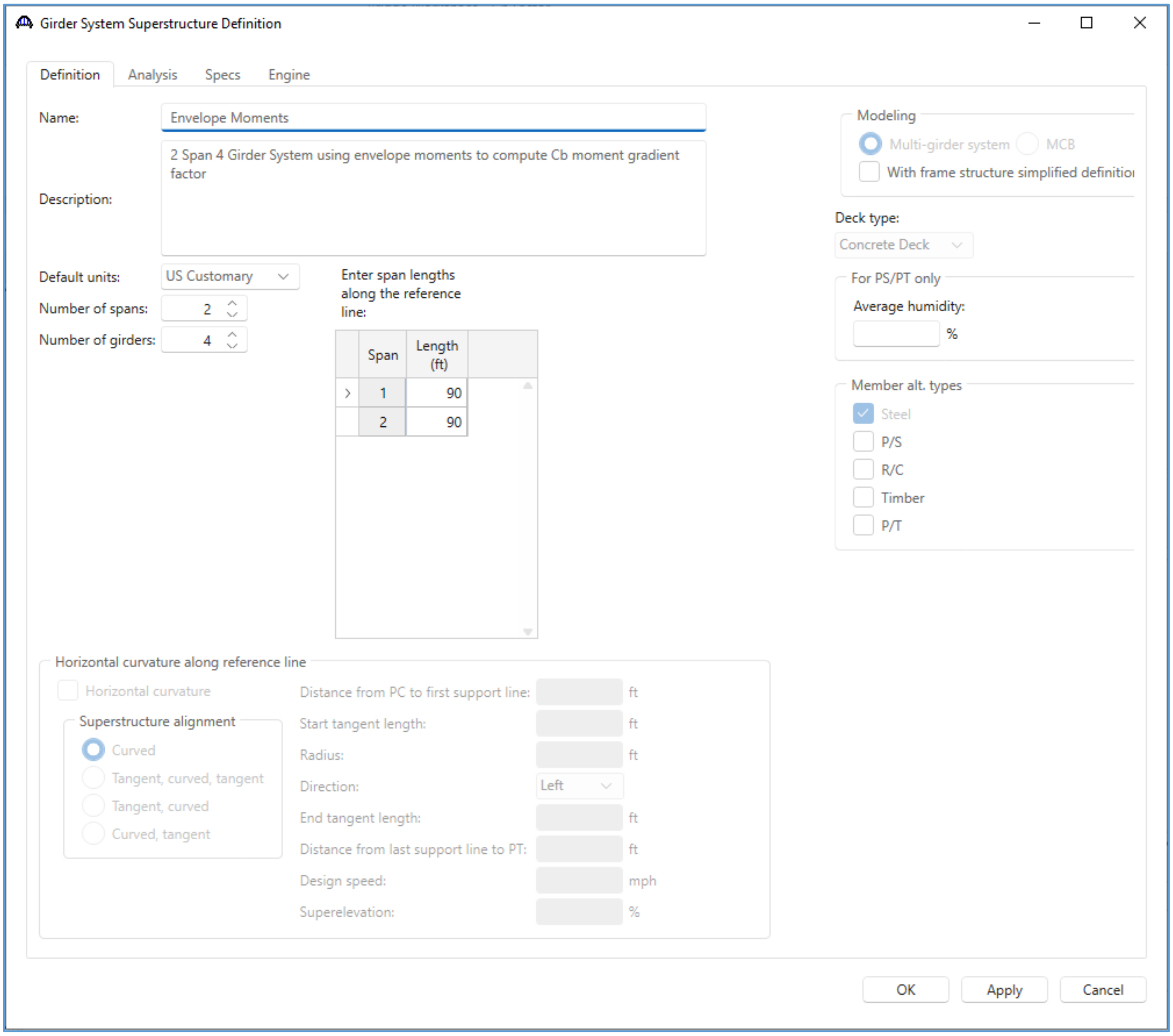
Modify STL2 Example Bridge

Start with the completed STL2 example bridge. This is a two-span steel girder system bridge with four girders. Follow the steps below to modify the structure definition. The moment gradient factor is used to compute the lateral torsional buckling resistance, so the girder is modified so that the lateral torsional buckling resistance controls the flexural capacity over the interior support.

Import the STL2 example bridge and open the copied structure. Update the **Bridge ID**, **NBI structure ID**, **Name** and **Description**. Select **OK** to apply the data and close the window.



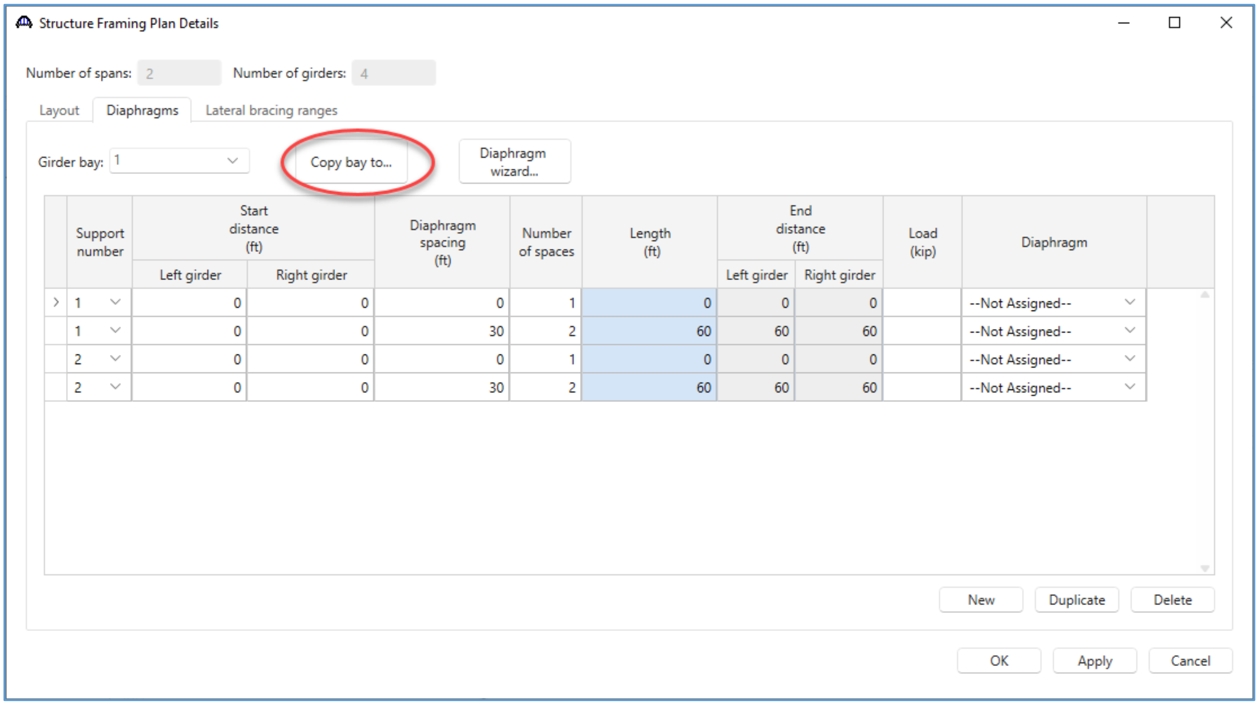
Open the **Superstructure Definition** window and update the superstructure name as shown below.



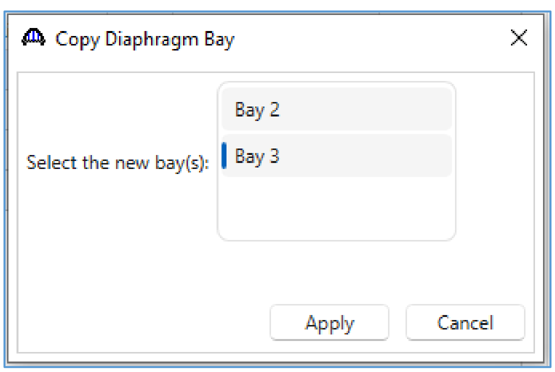
Structure Framing Plan Details

Within the **Framing Plan Detail window**, update the diaphragm definitions. Navigate to the **Diaphragms** tab and update the diaphragm spacing for **Girder bay 1** as shown below. Select **Apply** to apply the data and keep the window open. Then click on the **Copy bay to…** button and copy the diaphragms to **Bay 2** and **Bay 3** as shown below.

Girder Bay 1:

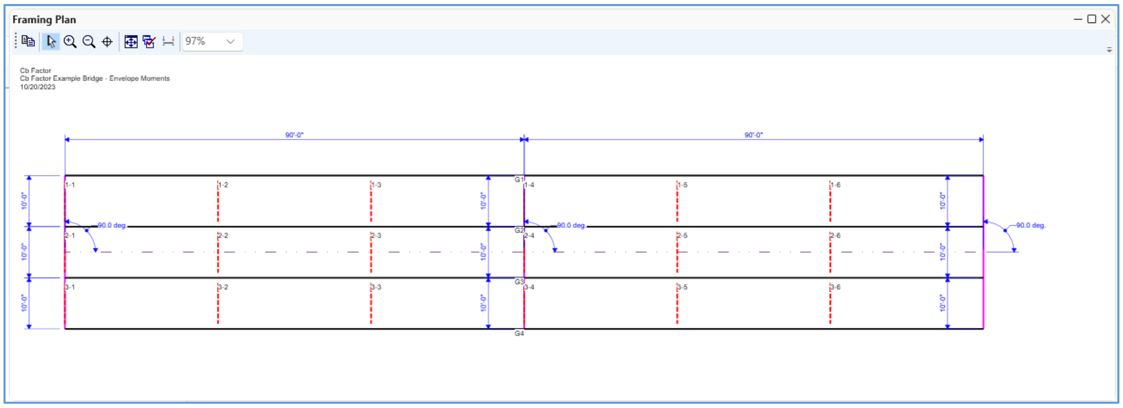


Girder Bays 2 and 3:



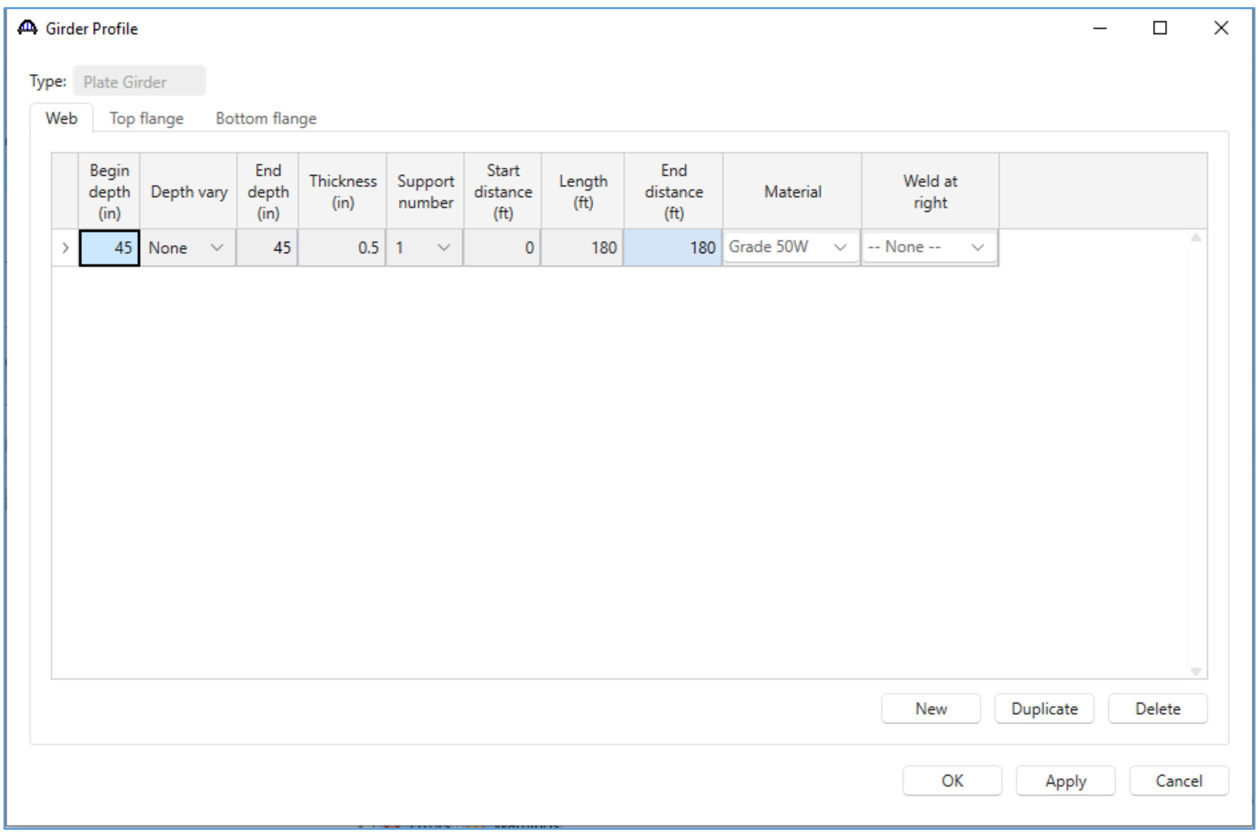
Framing Plan Schematic

Review the **framing plan schematic** to verify the framing plan details are correct.

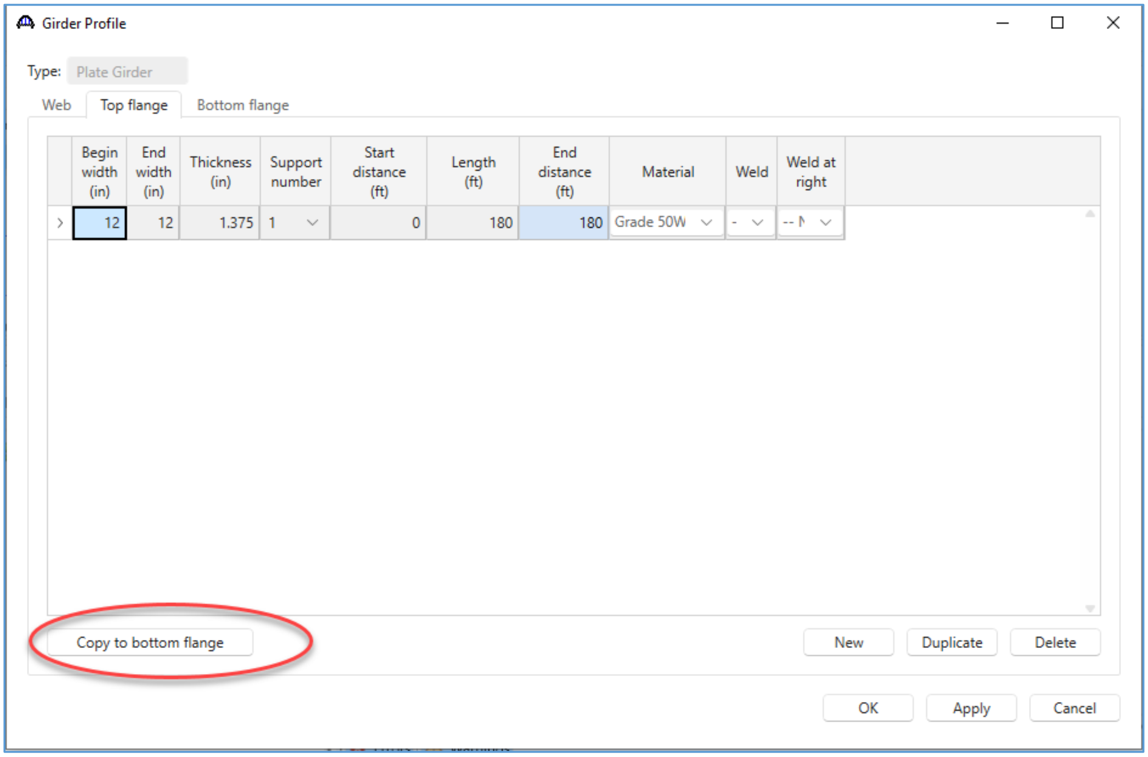


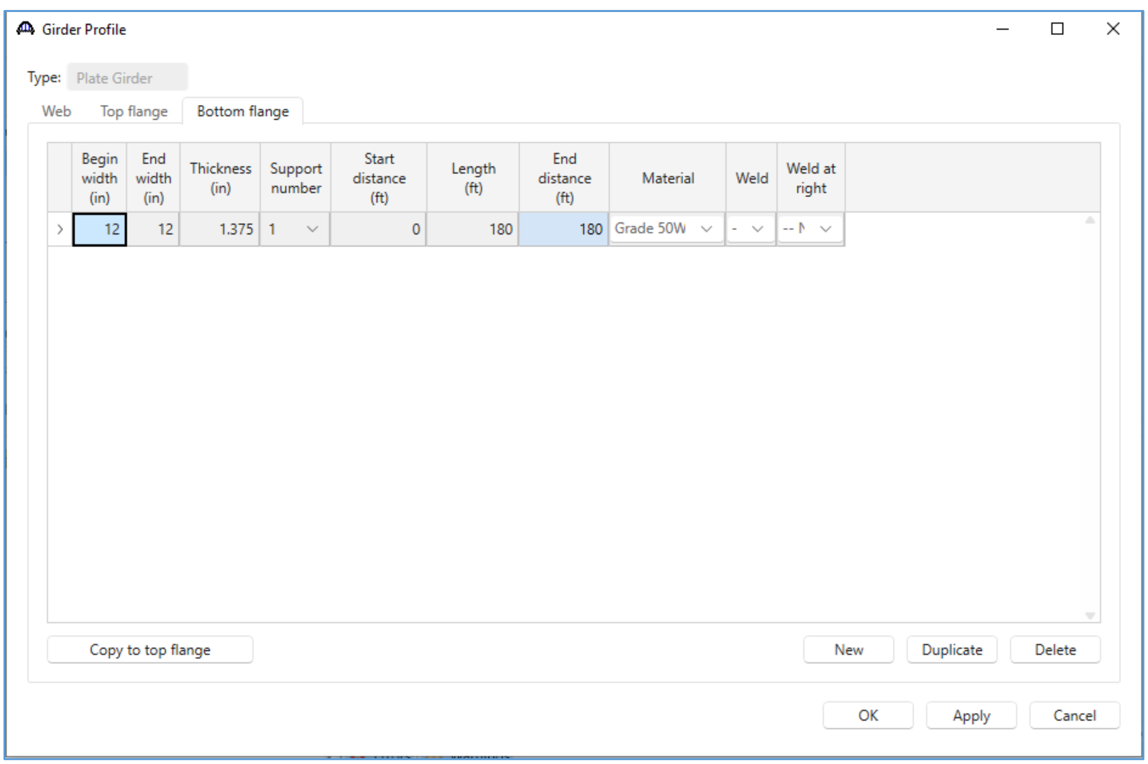
Girder Profile

Update the **girder profile** for the **G2** member alternative in each tab as shown below.



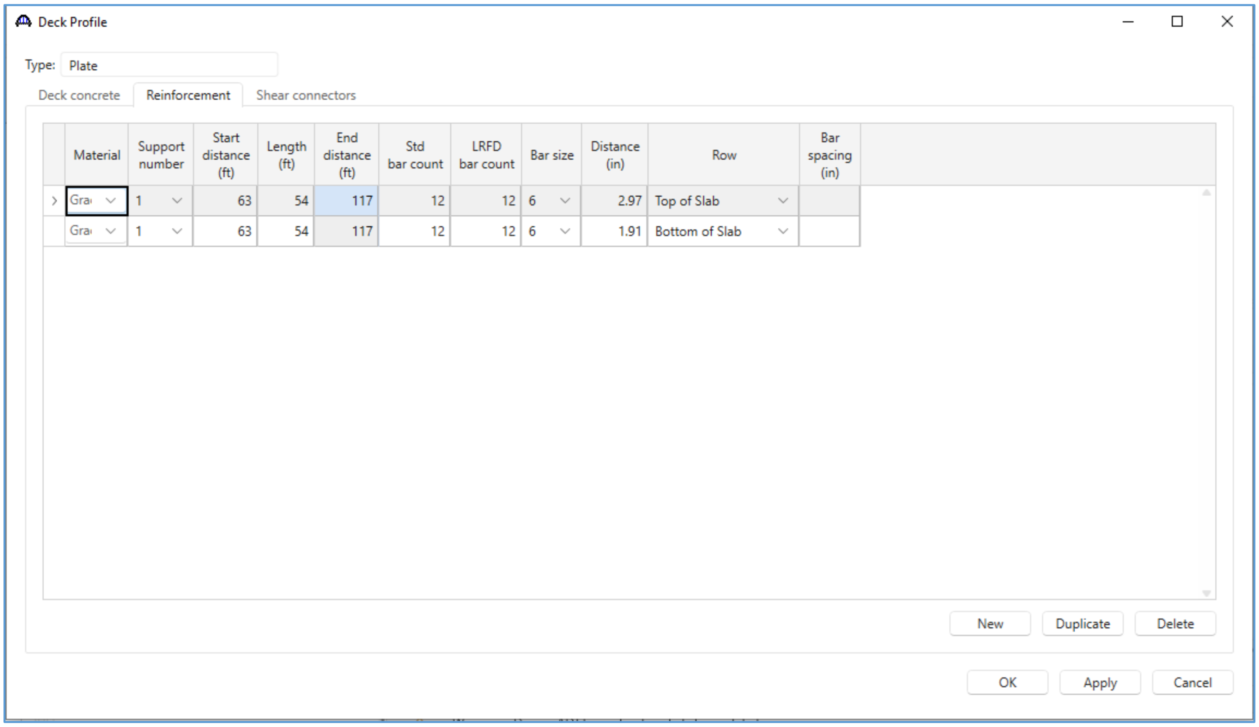
The top and bottom flange have the same definition, so to save time, the top flange can be input and then copied to the bottom flange with the **Copy to bottom flange** button. If there is any existing data for bottom flange, a warning will appear while copying. Click **OK** to proceed.





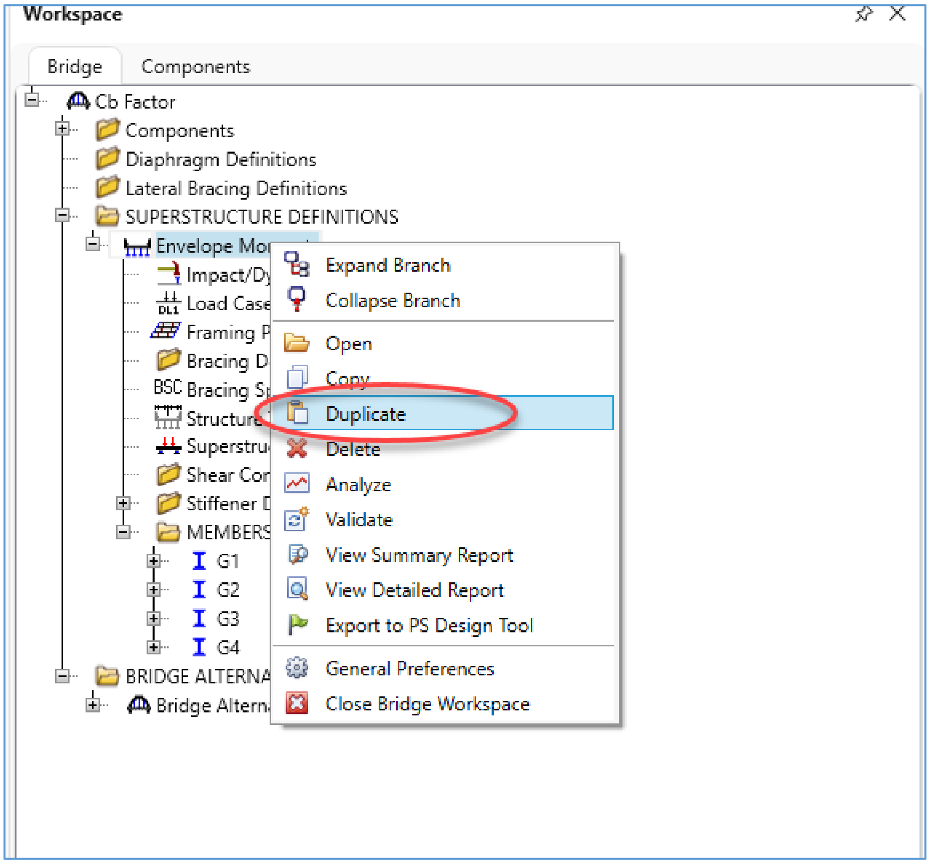
Deck Profile

Update the reinforcement within the **Deck Profile window** to satisfy the AASHTO LRFD 6.10.1.7 requirements.

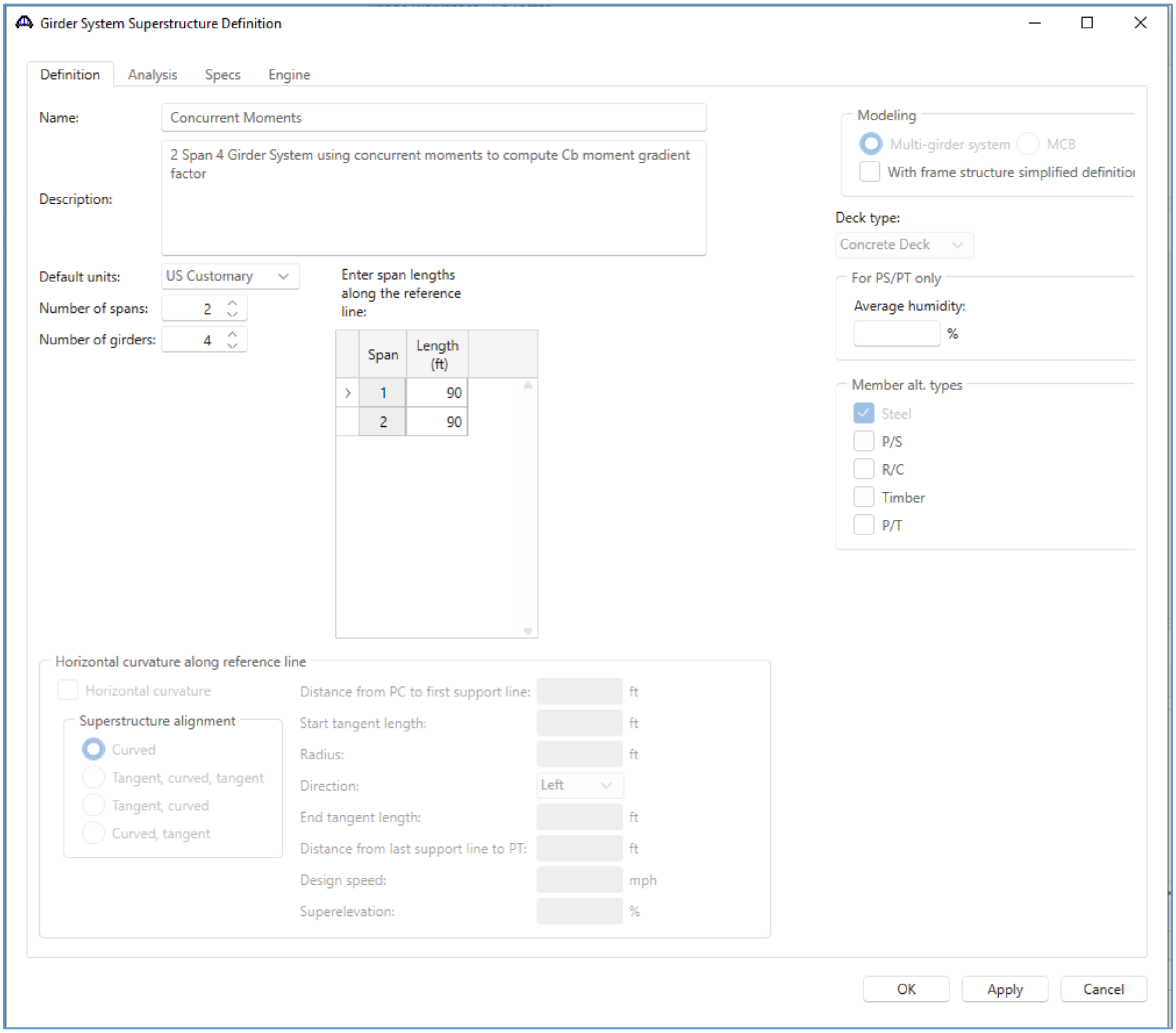


Duplicate the superstructure definition and modify the control options in the second structure to use concurrent moments for computing Cb.

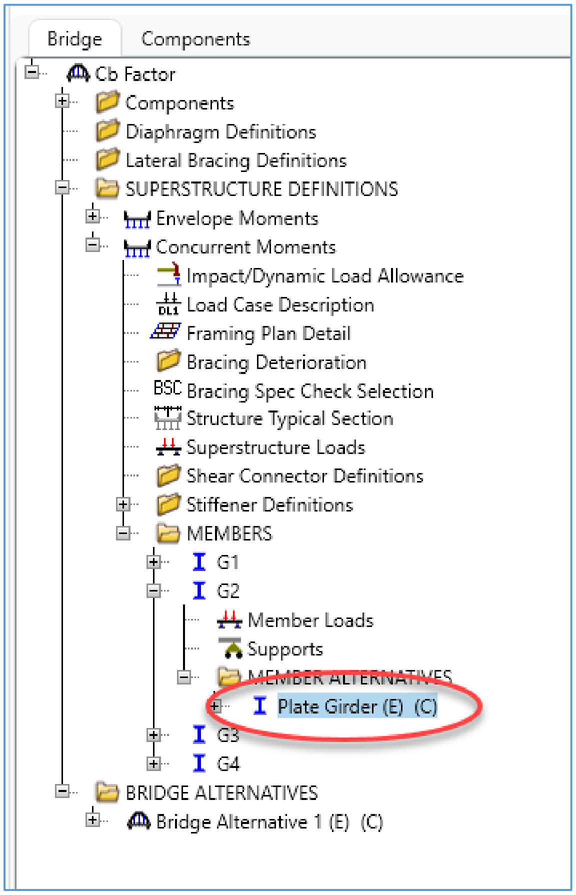
Right click on the **Envelope Moments** superstructure definition and select **Duplicate** from the menu to duplicate the superstructure definition.



Rename the new superstructure definition within the **Superstructure definition** window.

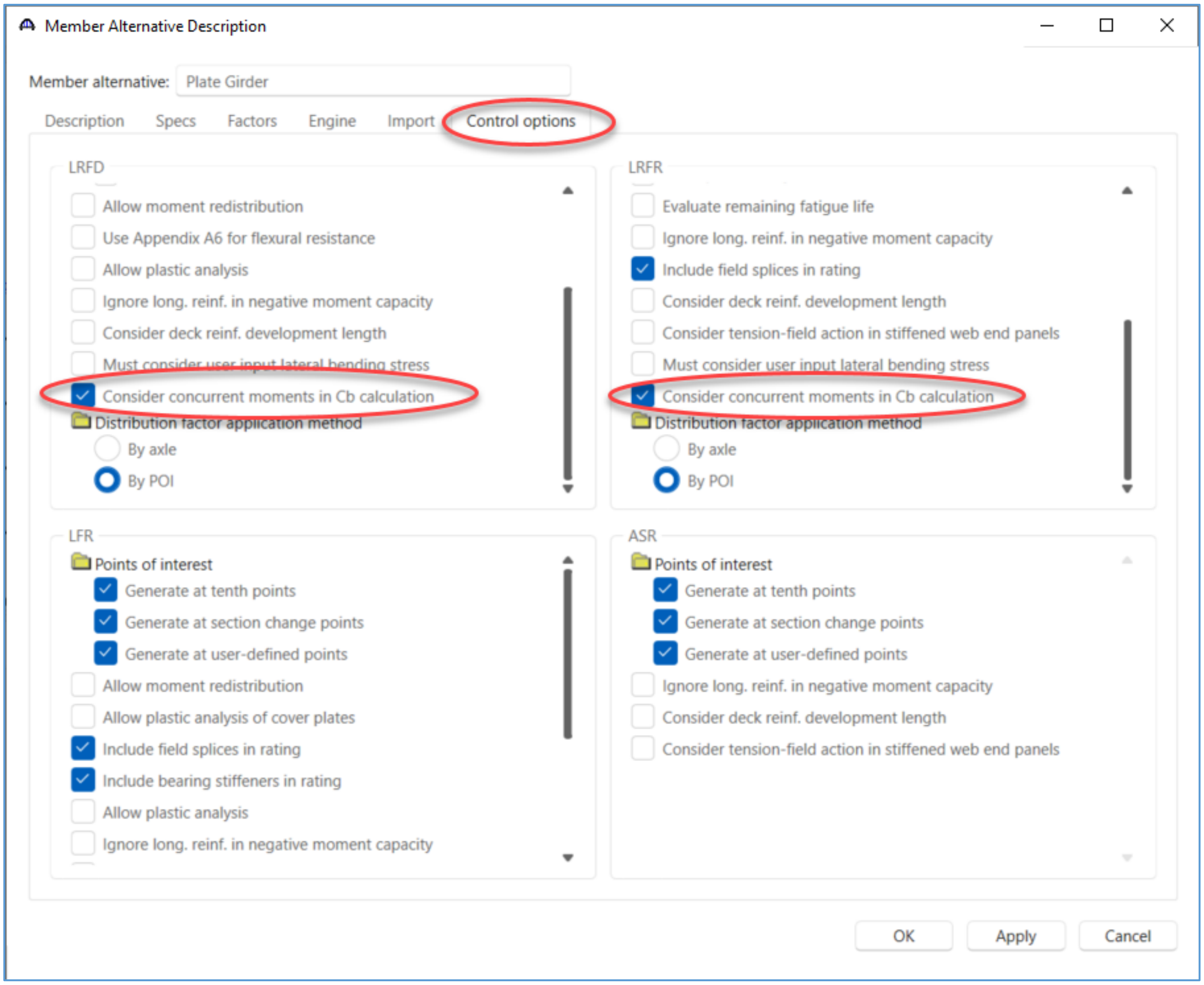


Expand the bridge workspace tree and open the **Member Alternative Description** window for the **G2 – Plate Girder** member alternative in the **Concurrent Moments** superstructure.

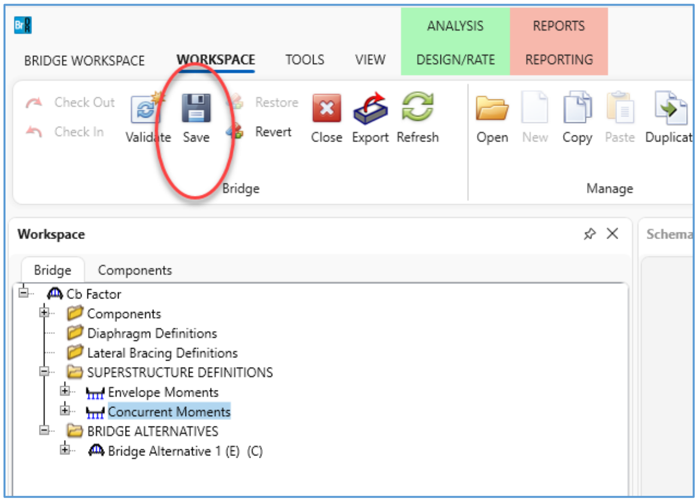


Cb Calculation Control Option

Navigate to the **Control options** tab in the window and select the **LRFD** and **LRFR** control options to **Consider concurrent moments in Cb calculation**.



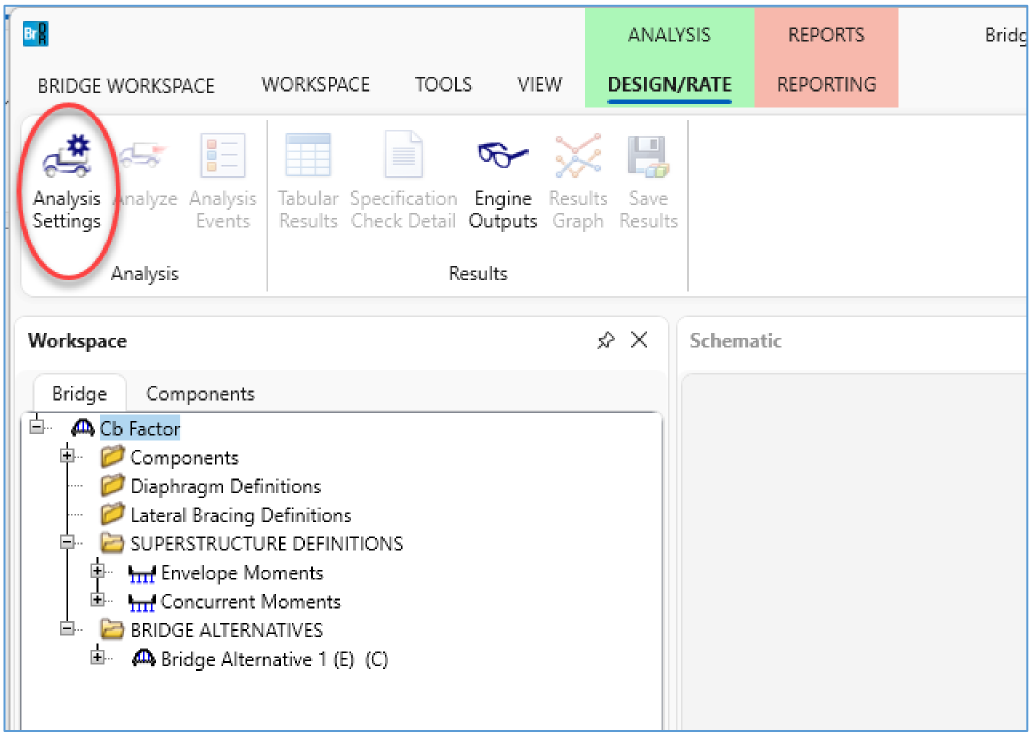
This completes the data entry for this example. Now is a good time to save the bridge to the database.



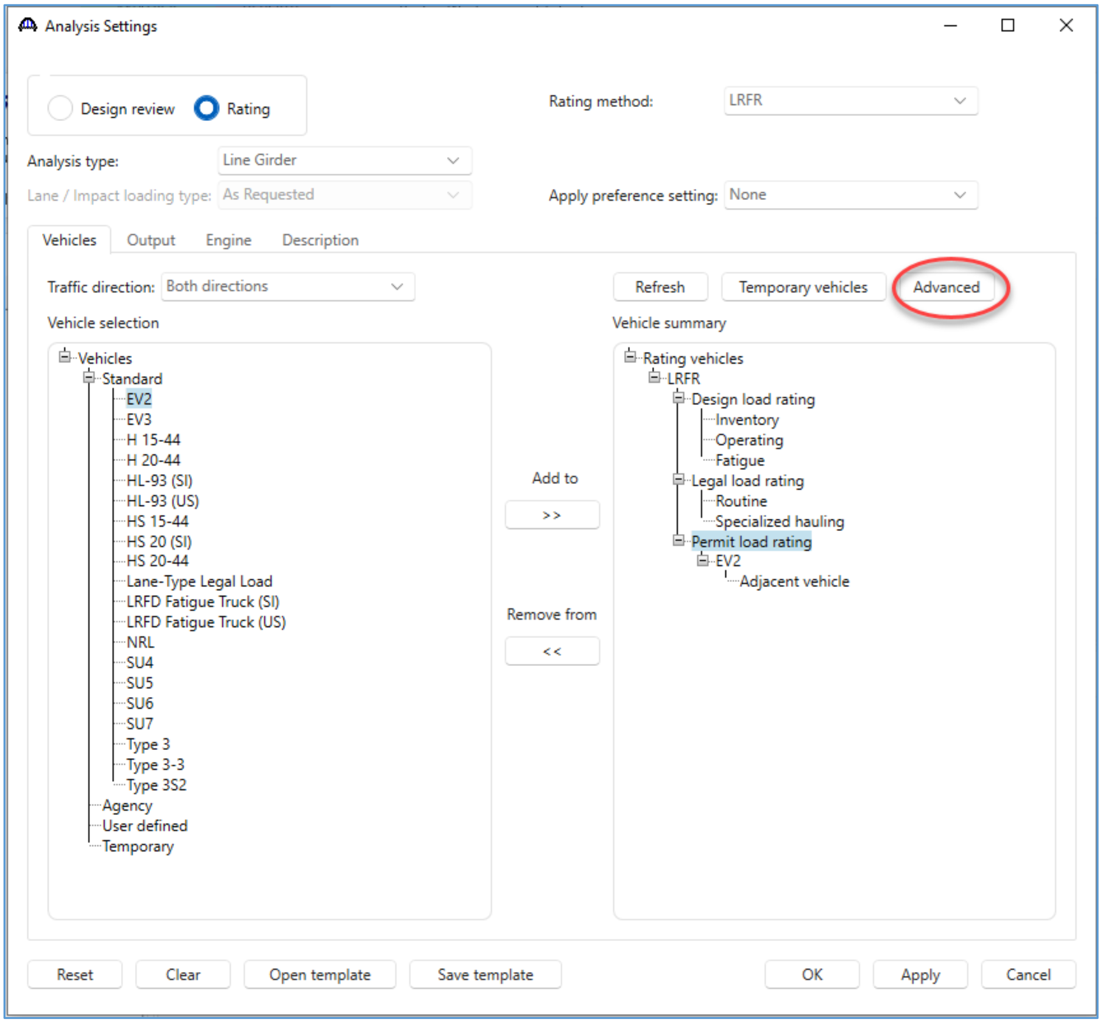
Cb Calculation comparison

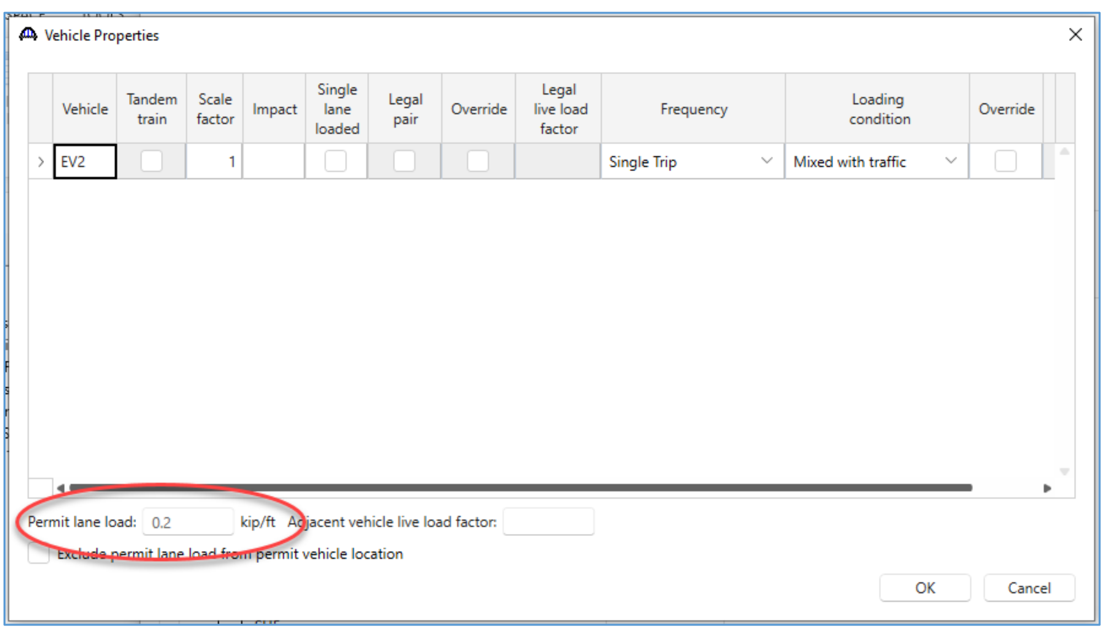
Follow the steps below to analyze the plate girder member alternative using envelope moments to compute Cb and the plate girder member alternative using concurrent moments to compute Cb.

Open the **Analysis Settings** window and add an **EV2** vehicle to the **LRFR Permit load rating** category. In the **Advanced** options define a 200plf permit lane load.



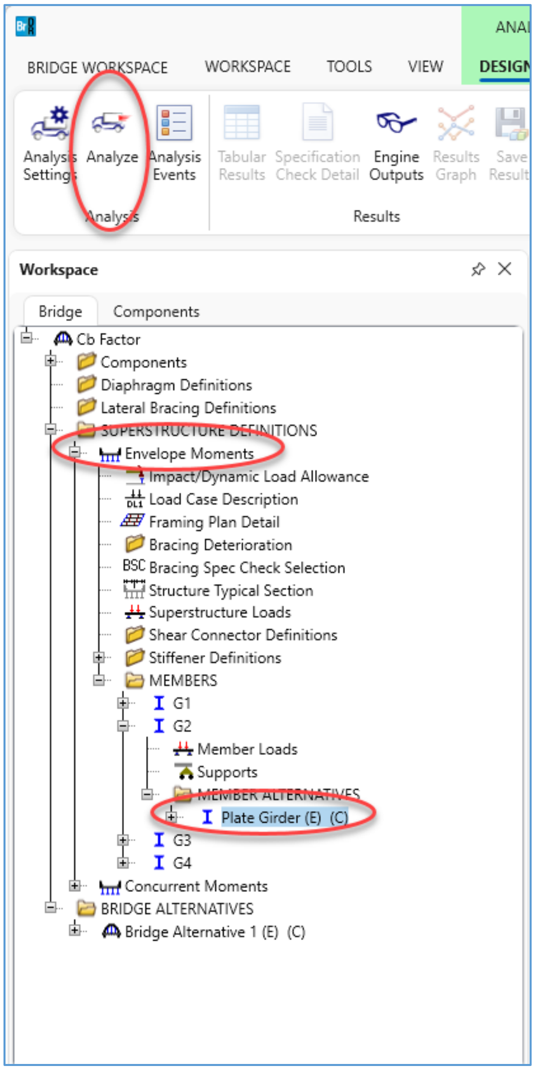
Analysis Settings



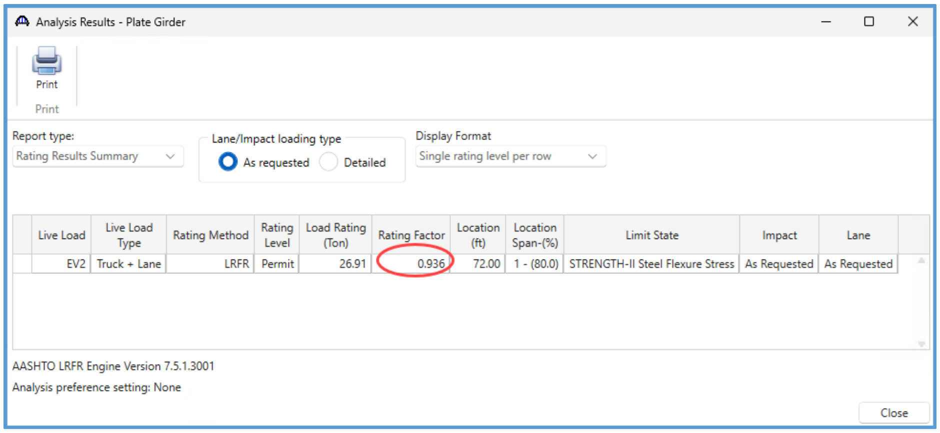


Analyzing Girder with Envelope Moment Cb Calculation

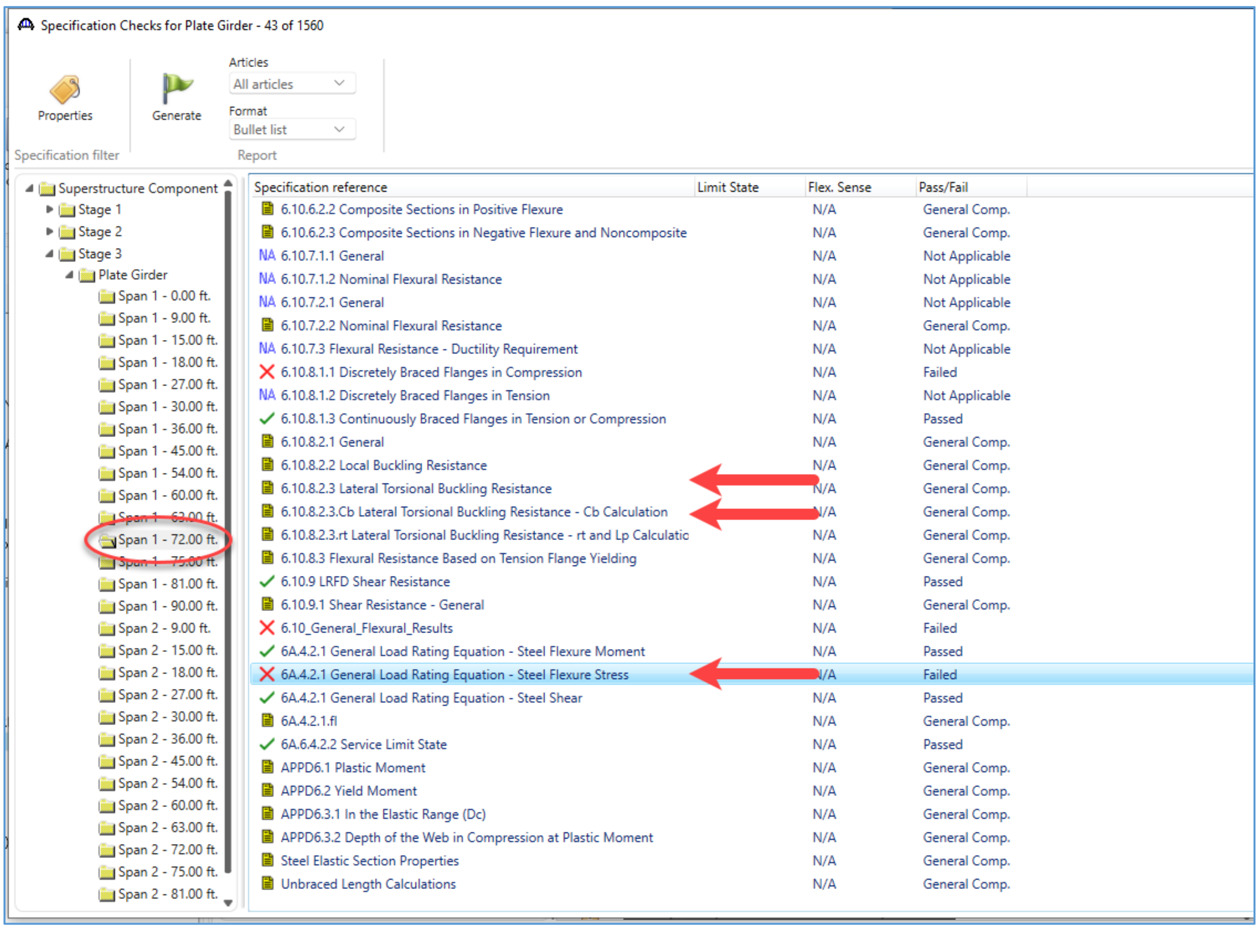
Analyze the plate girder member alternative within the **Envelope Moments** superstructure.



After the analysis is complete, review the results. Open the **Tabular Results** window to view the critical rating factor.



Open the **Specification Check Detail window** to review the specification calculations for the controlling location.



The rating is controlled by lateral torsional buckling within the negative flexure region over the interior pier. The Cb factor is computed in 6.10.8.2.3.Cb Lateral Torsional Buckling Resistance – Cb Calculation. Open this article to view the envelope Cb calculations.

Spec Check Detail for 6.10.8.2.3.Cb Lateral Torsional Buckling Resistance - Cb Calculation

```
6 Steel Structures
6.10 I-Section Flexural Members
6.10.8 Flexural Resistance-Composite Sections in Negative Flexure and Noncomposite Sections
6.10.8.2 Compression-Flange Flexural Resistance
6.10.8.2.3 Lateral Torsional Buckling Resistance - Cb Calculation
(AASHTO LRFD Bridge Design Specifications, Ninth Edition)

Steel Plate - At Location = 72.0000 (ft) - Left     Stage 3

Section within Top Flange Continuous Bracing Region


Moment Gradient Modifier, Cb, Calculation
-----------------------------------------

INPUT:
Section Prismatic in Top Flange Unbraced Length: Yes
Section Prismatic in Bottom Flange Unbraced Length: Yes
Section is Unbraced Cantilever:       No

Top Flange Left Brace Location               =    72.0000 (ft)
Top Flange Middle of Unbraced Length Location =   72.0000 (ft)
Top Flange Right Brace Location              =    72.0000 (ft)

Bot Flange Left Brace Location               =    60.0000 (ft)
Bot Flange Middle of Unbraced Length Location =   75.0000 (ft)
Bot Flange Right Brace Location              =    90.0000 (ft)

SUMMARY:

Cb = 1.0     (6.10.8.2.3-6)

Cb = 1.75 - 1.05*(f1/f2) + 0.3*(f1/f2)^2 <= 2.3      (6.10.8.2.3-7)

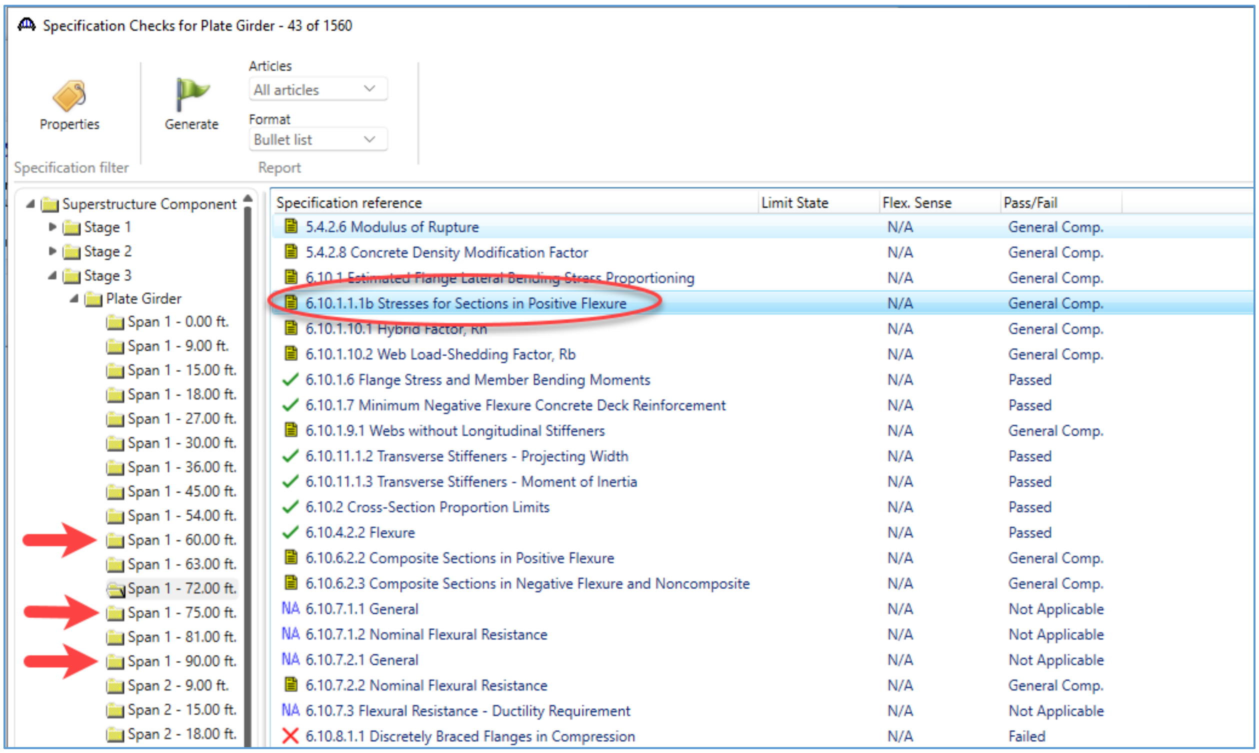
                                      |----------- Input ------------|------------------------ Output -------------------------|
 Limit             Load      Flexure    Left        Mid        Right      Concave
 State             Comb       Type     Stress      Stress     Stress      Moment        fmid        f2         f1       Eq.     Cb
                                        (ksi)       (ksi)      (ksi)                    (ksi)      (ksi)      (ksi)
-----------------------------------------------------------------------------------------------------------------------------------
 STR-II         1, Permit~  Negative     12.10      -7.05     -34.27      Yes            7.05      34.27     -12.10    7     2.1582
 STR-II         1, Permit~  Negative      4.49     -13.27     -39.35      Yes           13.27      39.35      -4.49    7     1.8738
 SER-II         1, Permit~  Negative      9.74      -5.44     -26.17      Yes            5.44      26.17      -9.74    7     2.1822
 SER-II         1, Permit~  Negative      3.79      -9.83     -29.64      Yes            9.83      29.64      -3.79    7     1.8890

Note: For Input Stresses, compression is negative, tension is positive.
      For Output Stresses signs are switched.  Compression is positive, tension is negative.


Load Combination Legend:

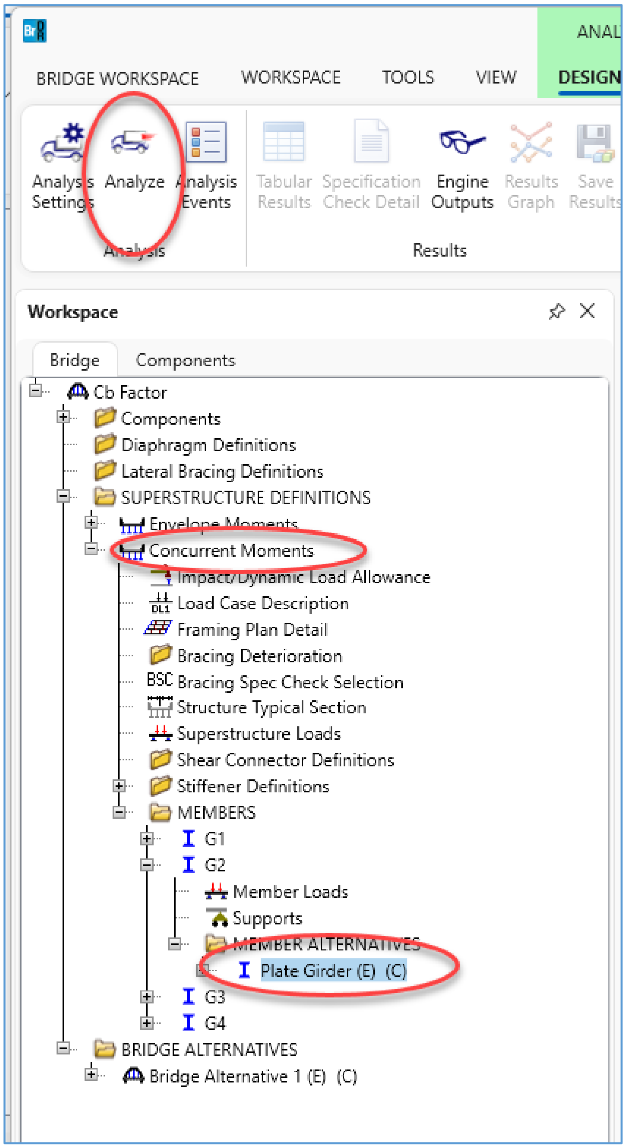
 Code      Vehicle
------------------------
    1     EV2 - Permit Truck + Lane
```

Since each of these load cases has negative flexure, the bottom flange brace points are used to compute Cb. The computed brace point stresses are computed within the 6.10.1.1.1b Stresses article for the POI at the brace point. Here, the left brace stresses are computed within the 6.10.1.1.1b article at the Span 1 – 60 ft POI on the right side, the mid stresses are computed at Span 1 – 75 ft and the right brace stresses are computed at 90 ft left.

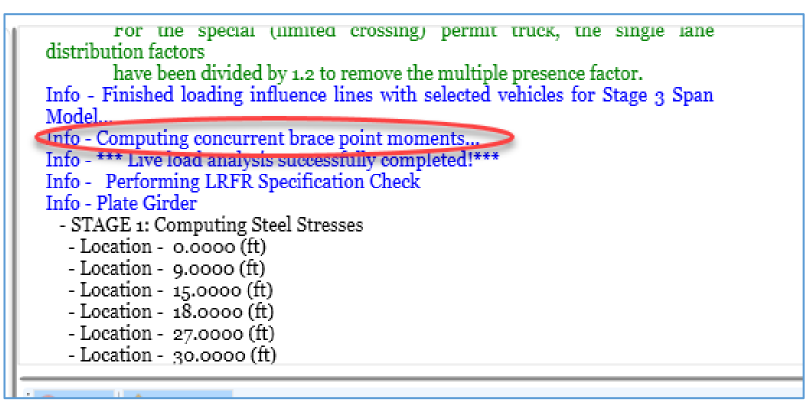


Analyzing Girder with Concurrent Moment Cb Calculation

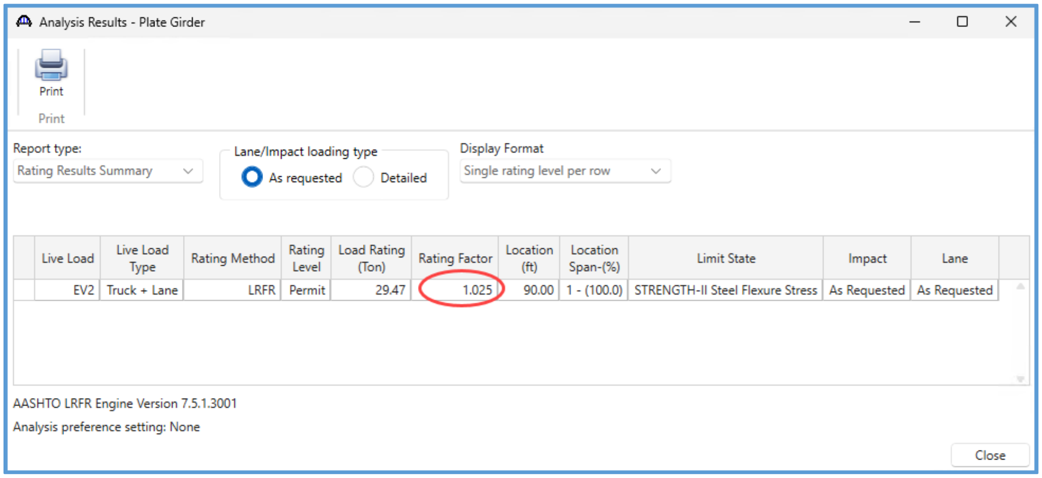
Next, analyze the **G2 – Plate Girder** member alternative within the **Concurrent Moments** superstructure.



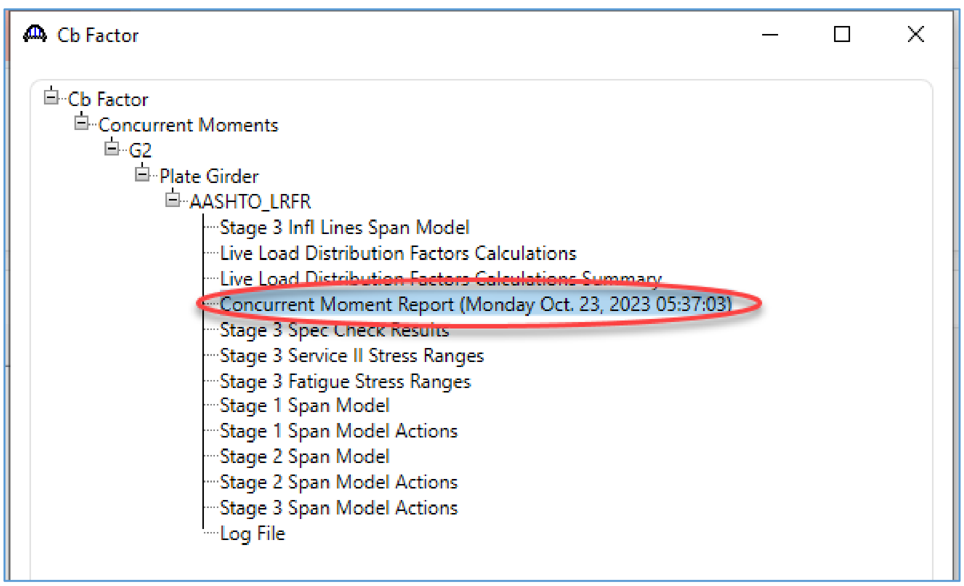
The analysis progress log will indicate when program is loading the concurrent moments at brace points.



Review the tabular results to see the critical rating factor. Using concurrent moments, the rating factor improves from 0.936 to 1.025.

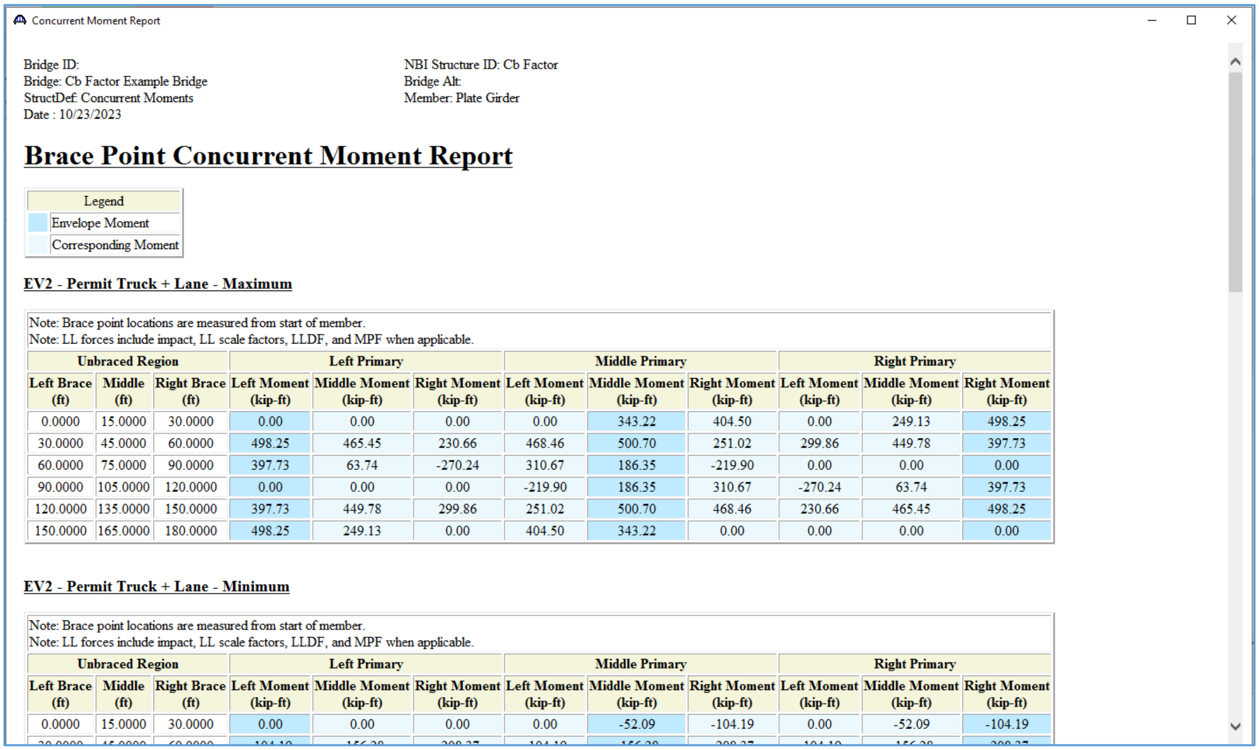


The **Engine Outputs** will include a **Concurrent Moment Report** which details the computed corresponding moments within all unbraced regions on the member.



Brace Point Concurrent Moment Report

Open the Concurrent Moment Report to view the computed corresponding moments at brace points.



Concurrent Moment Report

Bridge ID:
Bridge: Cb Factor Example Bridge
StructDef: Concurrent Moments
Date : 10/23/2023

NBI Structure ID: Cb Factor
Bridge Alt:
Member: Plate Girder

Brace Point Concurrent Moment Report

Legend
Envelope Moment
Corresponding Moment

EV2 - Permit Truck + Lane - Maximum

Note: Brace point locations are measured from start of member.
Note: LL forces include impact, LL scale factors, LLDF, and MPF when applicable.

Unbraced Region			Left Primary			Middle Primary			Right Primary		
Left Brace (ft)	Middle (ft)	Right Brace (ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)
0.0000	15.0000	30.0000	0.00	0.00	0.00	0.00	343.22	404.50	0.00	249.13	498.25
30.0000	45.0000	60.0000	498.25	465.45	230.66	468.46	500.70	251.02	299.86	449.78	397.73
60.0000	75.0000	90.0000	397.73	63.74	-270.24	310.67	186.35	-219.90	0.00	0.00	0.00
90.0000	105.0000	120.0000	0.00	0.00	0.00	-219.90	186.35	310.67	-270.24	63.74	397.73
120.0000	135.0000	150.0000	397.73	449.78	299.86	251.02	500.70	468.46	230.66	465.45	498.25
150.0000	165.0000	180.0000	498.25	249.13	0.00	404.50	343.22	0.00	0.00	0.00	0.00

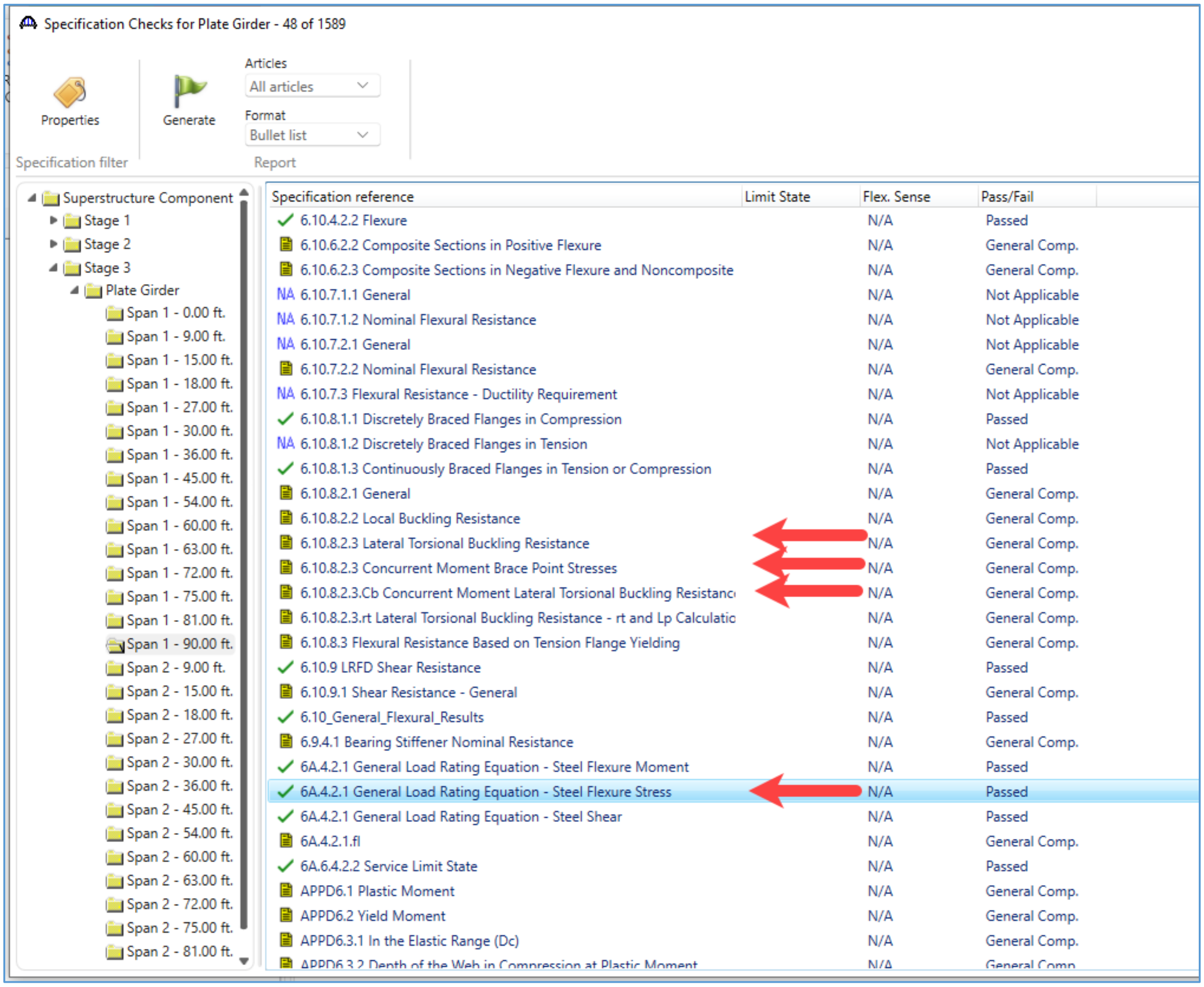
EV2 - Permit Truck + Lane - Minimum

Note: Brace point locations are measured from start of member.
Note: LL forces include impact, LL scale factors, LLDF, and MPF when applicable.

Unbraced Region			Left Primary			Middle Primary			Right Primary		
Left Brace (ft)	Middle (ft)	Right Brace (ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)
0.0000	15.0000	30.0000	0.00	0.00	0.00	0.00	-52.09	-104.19	0.00	-52.09	-104.19

Specification Check Detail

Open the **Specification Check Detail** window to review the specification calculations. The articles indicated with arrows below are particularly relevant to the LTB rating.



The brace point stresses for envelope actions are computed in the 6.10.1.1.1b stresses article. An additional article is included when the concurrent actions are enabled to compute the brace point stresses for concurrent actions. This is the 6.10.8.2.3 Concurrent Moment Brace Point Stresses article. As with the envelope stresses, these stresses are computed at the POI corresponding to the actual brace point location.

The Cb concurrent moment calculation article computes Cb for each loading scenario, left brace envelope, mid brace envelope and right brace envelope.

Spec Check Detail for 6.10.8.2.3.Cb Concurrent Moment Lateral Torsional Buckling Resistance - Cb Calculation

Cb = 1.75 - 1.05*(f1/f2) + 0.3*(f1/f2)^2 <= 2.3 (6.10.8.2.3-7)

Cb calculation for loading left brace

Limit State	Load Comb	Flexure Type	Input: Left Stress (ksi)	Input: Mid Stress (ksi)	Input: Right Stress (ksi)	Output: Concave Moment	Output: fmid (ksi)	Output: f2 (ksi)	Output: f1 (ksi)	Output: Eq.	Output: Cb
STR-II	1, PermitSpec	Neg	12.10	-8.61	-38.14	Yes	8.61	38.14	-12.10	7	2.1134
STR-II	1, PermitSpec	Neg	4.49	-13.25	-38.74	Yes	13.25	38.74	-4.49	7	1.8758
SER-II	1, PermitSpec	Neg	9.74	-6.64	-28.81	Yes	6.64	28.81	-9.74	7	2.1390
SER-II	1, PermitSpec	Neg	3.79	-9.82	-29.23	Yes	9.82	29.23	-3.79	7	1.8910

Note: For Input Stresses, compression is negative, tension is positive.
For Output Stresses signs are switched. Compression is positive, tension is negative.

Cb calculation for loading mid brace

Limit State	Load Comb	Flexure Type	Input: Left Stress (ksi)	Input: Mid Stress (ksi)	Input: Right Stress (ksi)	Output: Concave Moment	Output: fmid (ksi)	Output: f2 (ksi)	Output: f1 (ksi)	Output: Eq.	Output: Cb
STR-II	1, PermitSpec	Neg	11.08	-7.05	-37.42	Yes	7.05	37.42	-11.08	7	2.0871
STR-II	1, PermitSpec	Neg	4.68	-13.27	-38.96	Yes	13.27	38.96	-4.68	7	1.8806
SER-II	1, PermitSpec	Neg	8.88	-5.44	-28.32	Yes	5.44	28.32	-8.88	7	2.1088
SER-II	1, PermitSpec	Neg	3.90	-9.83	-29.37	Yes	9.83	29.37	-3.90	7	1.8949

Note: For Input Stresses, compression is negative, tension is positive.
For Output Stresses signs are switched. Compression is positive, tension is negative.

Cb calculation for loading right brace

Limit State	Load Comb	Flexure Type	Input: Left Stress (ksi)	Input: Mid Stress (ksi)	Input: Right Stress (ksi)	Output: Concave Moment	Output: fmid (ksi)	Output: f2 (ksi)	Output: f1 (ksi)	Output: Eq.	Output: Cb
STR-II	1, PermitSpec	Neg	7.42	-9.52	-34.27	Yes	9.52	34.27	-7.42	7	1.9913
STR-II	1, PermitSpec	Neg	12.30	-8.96	-39.35	Yes	8.96	39.35	-12.30	7	2.1075
SER-II	1, PermitSpec	Neg	5.83	-7.27	-26.17	Yes	7.27	26.17	-5.83	7	1.9989
SER-II	1, PermitSpec	Neg	9.90	-6.88	-29.64	Yes	6.88	29.64	-9.90	7	2.1342

Note: For Input Stresses, compression is negative, tension is positive.
For Output Stresses signs are switched. Compression is positive, tension is negative.

The article summary indicates the Cb factor which is used for each load case.

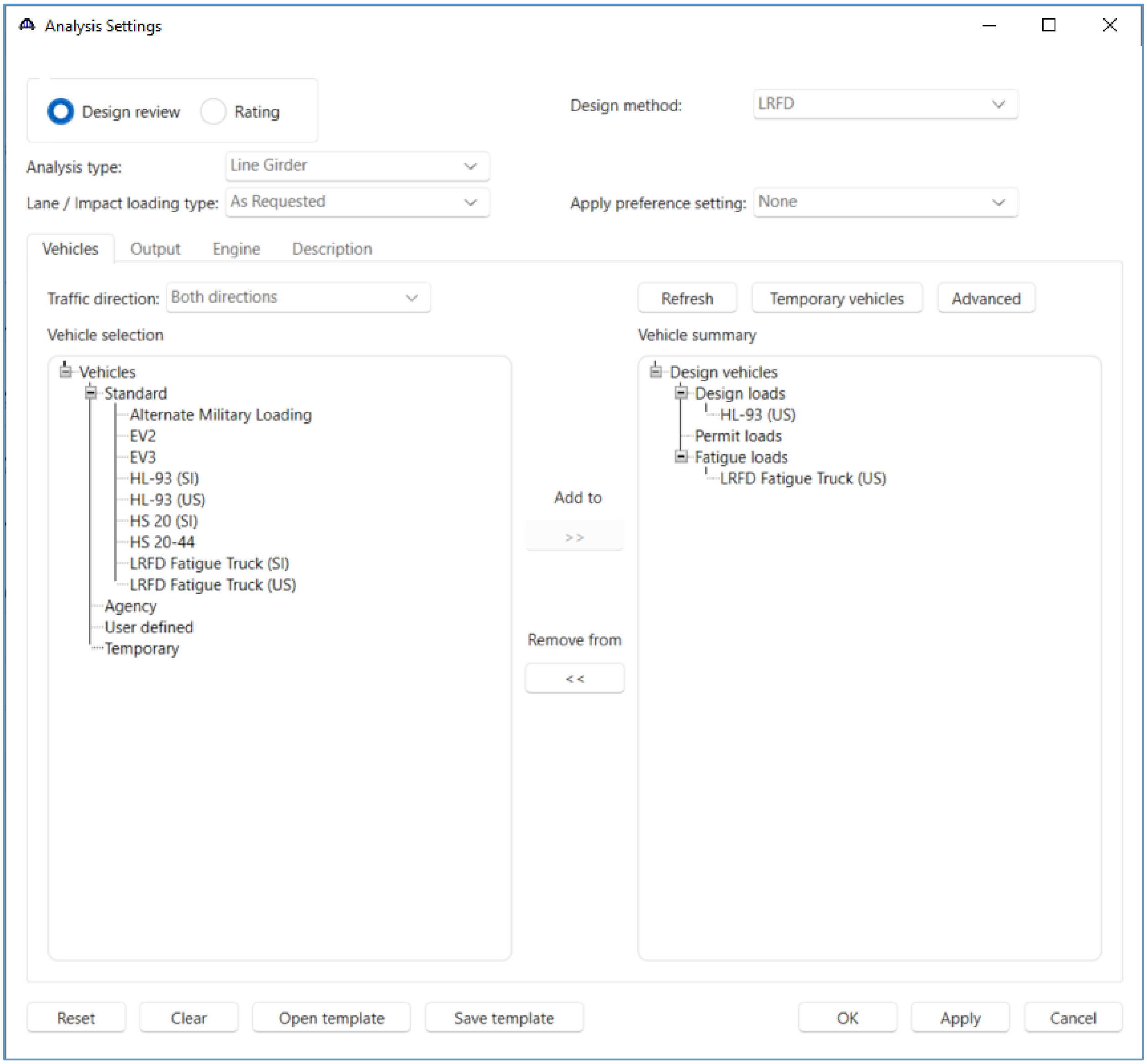
Cb calculation summary

Limit State	Load Comb	Cb	Critical Concurrent Loading
STR-II	1, PermitSpec	2.1134	Left brace
STR-II	1, PermitSpec	2.1075	Right brace
SER-II	1, PermitSpec	2.1390	Left brace
SER-II	1, PermitSpec	2.1342	Right brace

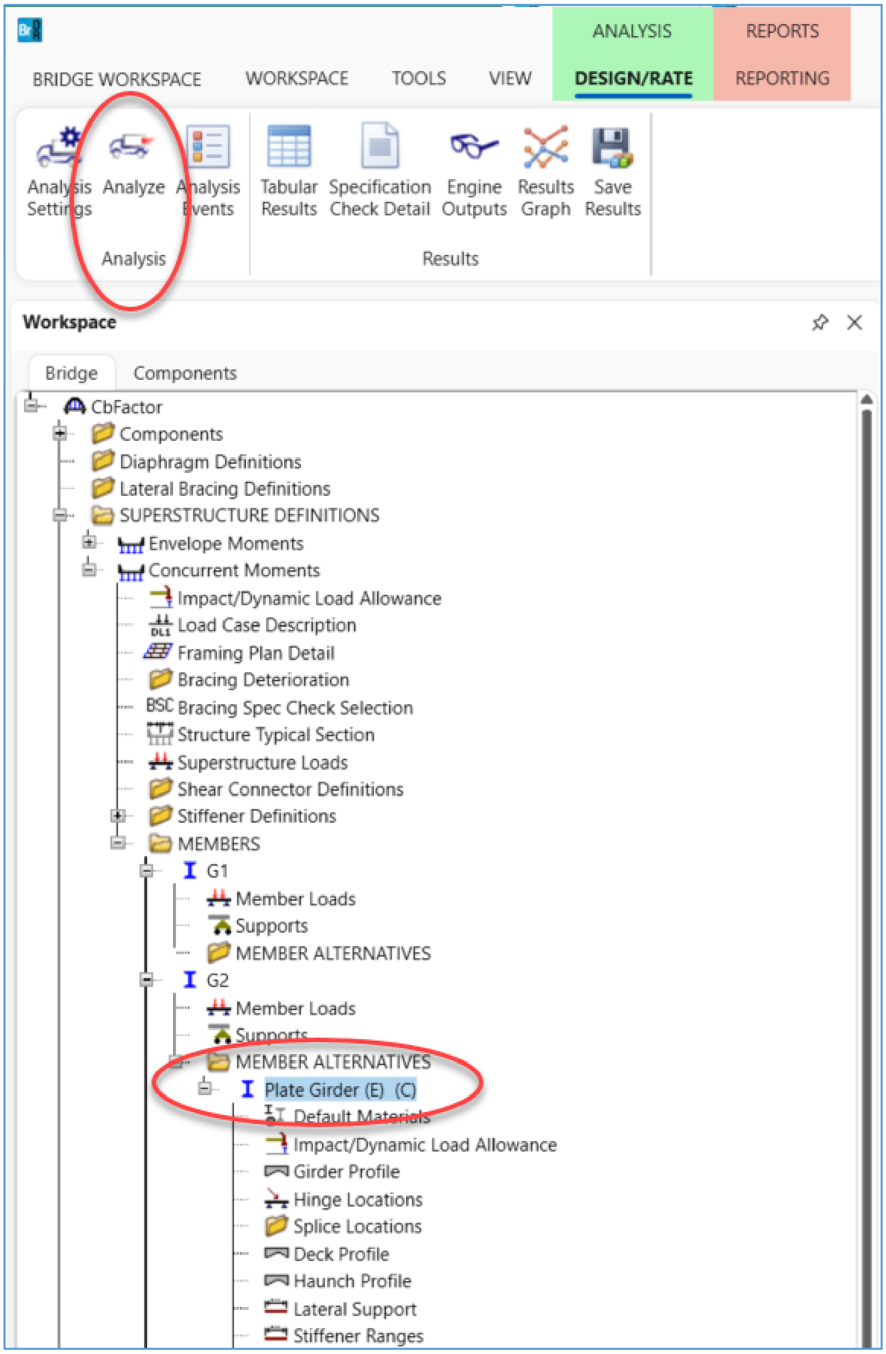
Note: Use Cb corresponding to brace point with largest compressive stress.

LRFD Design Review

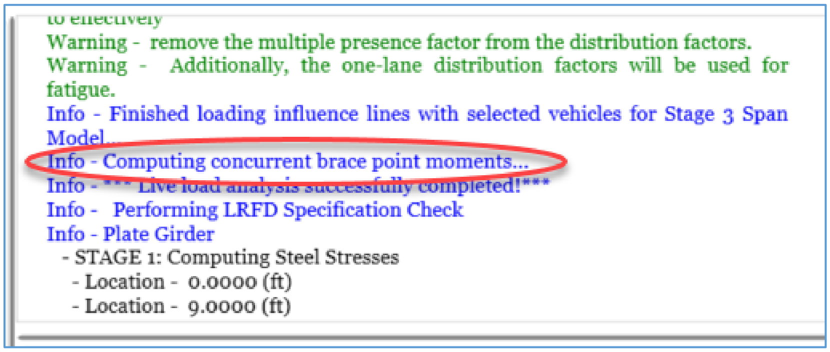
Open the **Analysis Settings window**. Open the **HL 93 Design Review** template to perform a design review using concurrent moments to compute the Cb factor.



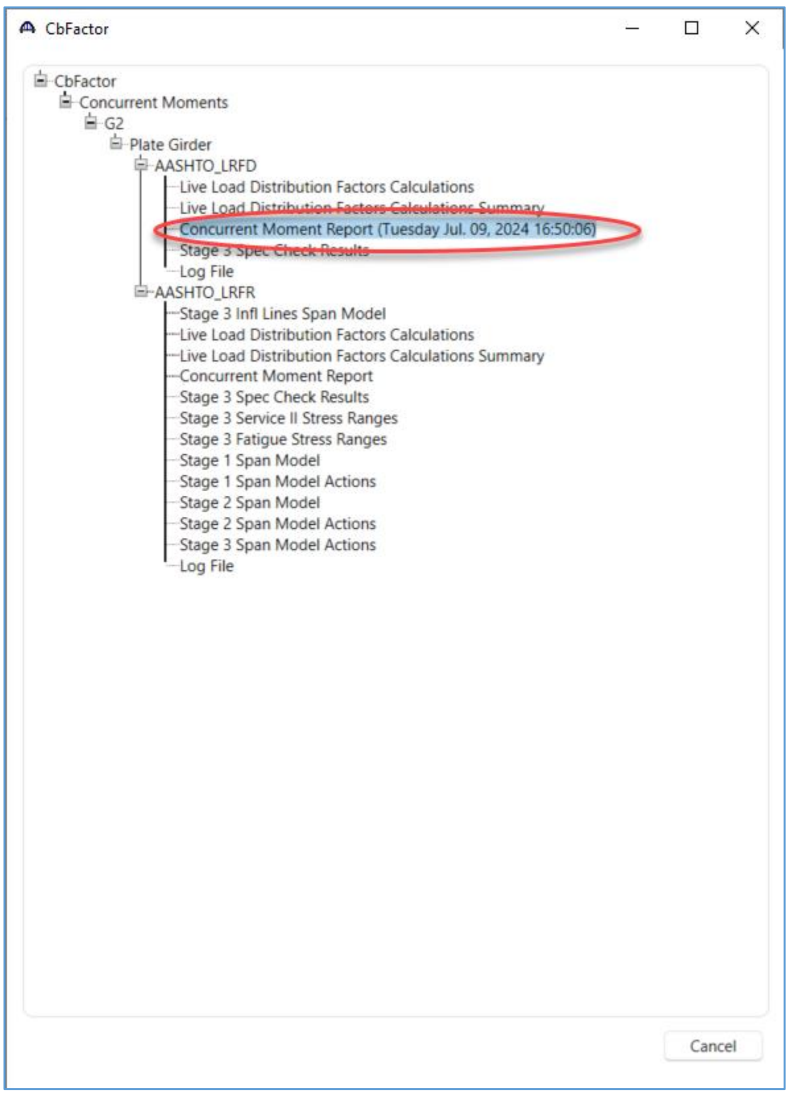
Analyze the **Plate Girder** member alternative under **G2** for the **Concurrent Moments** superstructure definition.



The analysis progress log will indicate when the program computes the concurrent brace point moments.



The **Engine Outputs** window includes a **Concurrent Moment Report** which shows the computed envelope and corresponding moments for each unbraced region along the member.



Open the report to review the computed actions. The report includes tables for each component of the vehicle live load. For the design vehicle this includes the load components such as truck and lane and the design combinations such as 90% truck pair plus lane.

Concurrent Moment Report

Bridge ID:
Bridge: Cb Factor Example Bridge
StructDef: Concurrent Moments
Date : 7/9/2024

NBI Structure ID: Cb Factor
Bridge Alt:
Member: Plate Girder

Brace Point Concurrent Moment Report

Legend
Envelope Moment
Corresponding Moment

HL-93 (US) - Design Truck + Lane - Maximum

Note: Brace point locations are measured from start of member.
Note: LL forces include impact, LL scale factors, LLDF, and MPF when applicable.

Unbraced Region			Left Primary			Middle Primary			Right Primary		
Left Brace (ft)	Middle (ft)	Right Brace (ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)
0.0000	15.0000	30.0000	0.00	0.00	0.00	0.00	926.63	1250.35	0.00	786.52	1358.94
30.0000	45.0000	60.0000	1358.94	1320.68	741.72	1321.36	1388.72	845.40	961.70	1284.69	1066.99
60.0000	75.0000	90.0000	1066.99	238.60	-803.89	898.06	423.93	-653.11	0.00	0.00	0.00
90.0000	105.0000	120.0000	0.00	0.00	0.00	-653.11	423.93	898.06	-803.89	238.60	1066.99
120.0000	135.0000	150.0000	1066.99	1284.69	961.70	845.40	1388.72	1321.36	741.72	1320.68	1358.94
150.0000	165.0000	180.0000	1358.94	786.52	0.00	1250.35	926.63	0.00	0.00	0.00	0.00

HL-93 (US) - Design Truck + Lane - Minimum

Note: Brace point locations are measured from start of member.
Note: LL forces include impact, LL scale factors, LLDF, and MPF when applicable.

Unbraced Region			Left Primary			Middle Primary			Right Primary		
Left Brace (ft)	Middle (ft)	Right Brace (ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)

AASHTOWare BrDR 7.5.1

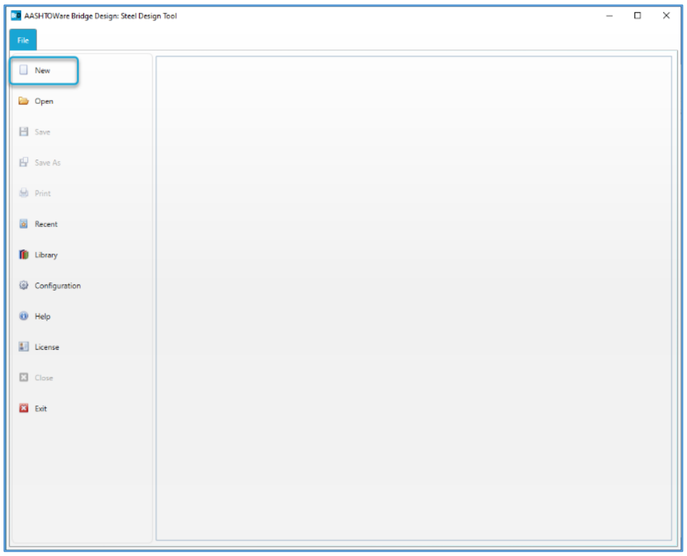
Steel Design Tool

Two Span Girder Design Example

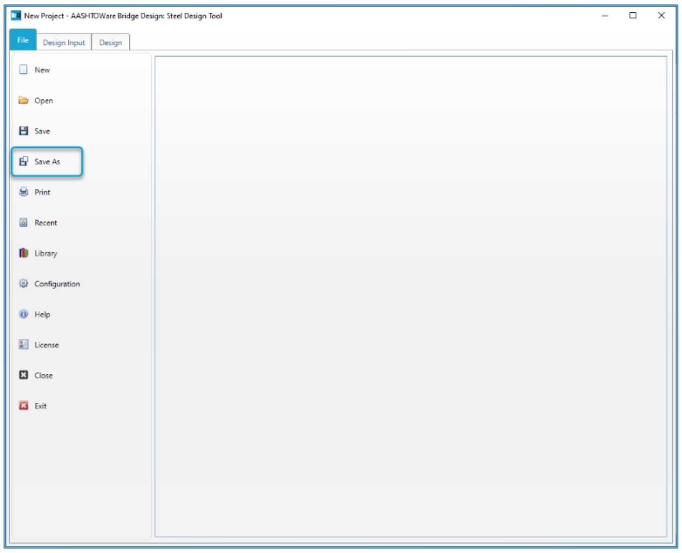
Two Span Girder Design Example

Start the **Steel Design Tool** program, create a new input file using the **File | New** command. The program will switch from the **File** tab to the **Design Input** tab.

File | New and **File | Save As**



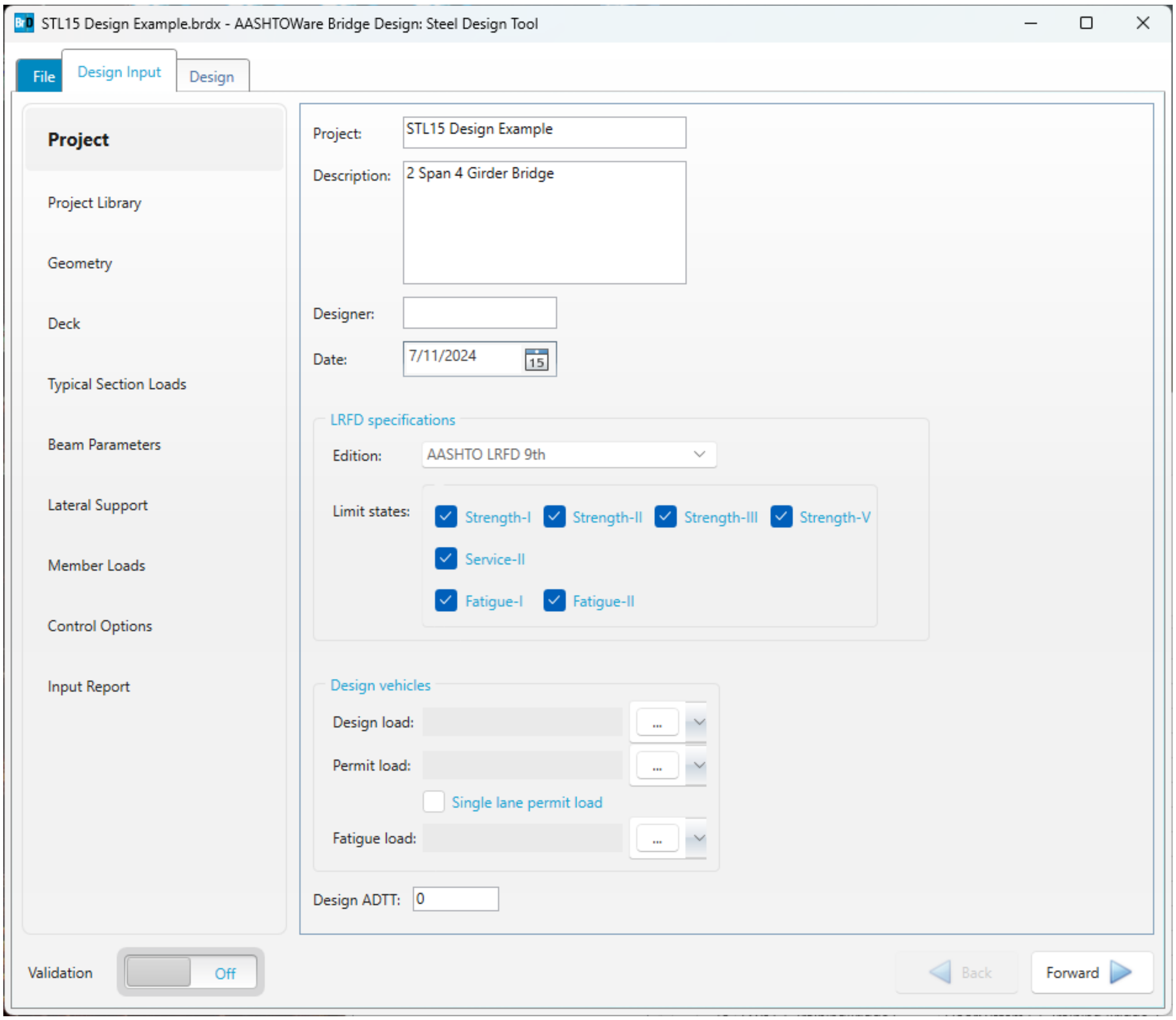
Before proceeding with **Design Input** return to the **File** tab and click **Save As** to rename the file from **New Project** to **STL15 Design Example**.



The new file name will appear in the program title bar and the program will again bring up the the **Design Input** with the **Project** input screen. The **Project** property will still say **New Project** and this will be changed in the next step. The **Project** property determines the name of the subfolder in the Documents\AASHTOWare\SteelDesign75\ folder where design run output files will be stored. In the bottom left corner of the program window, there is a **Validation** button that enables input validation. When validation is enabled, the program will mark sections and input boxes with missing or incorrect information. For the purposes of this example, the **Validation** will be disabled during input and will be enabled after all input is entered to verify that there are no validation errors.

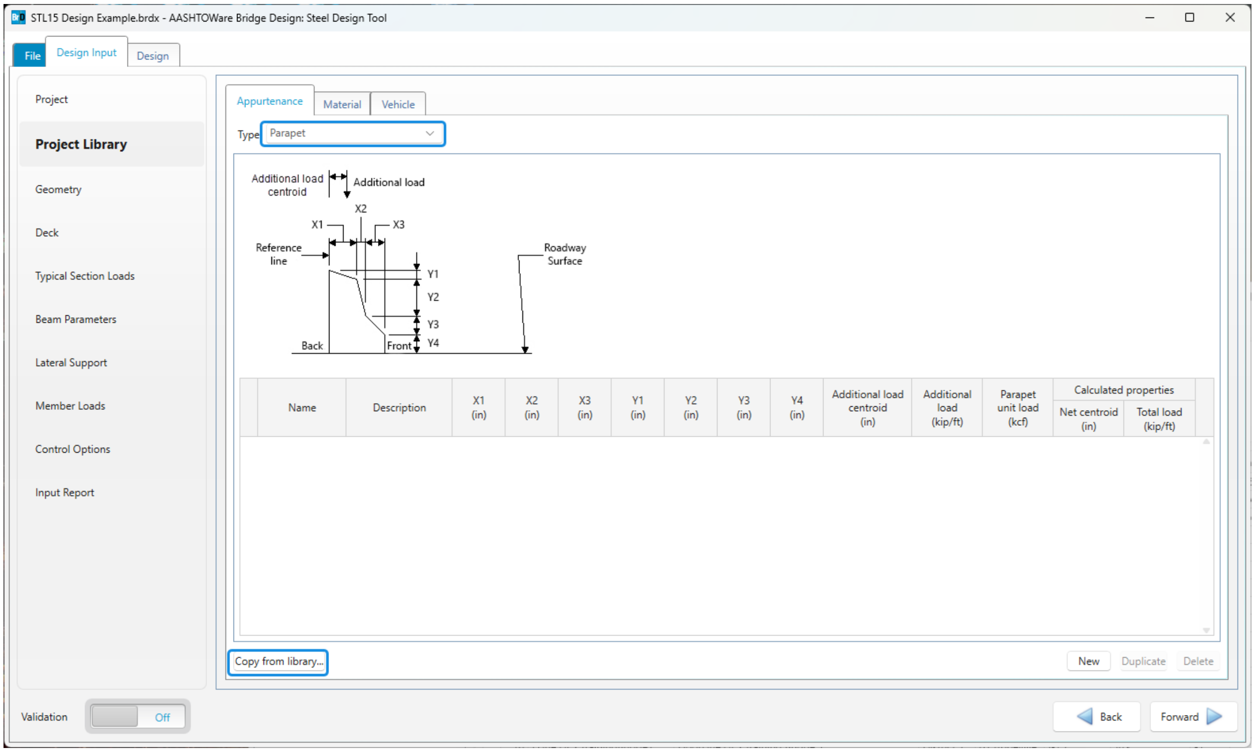
Design Input | Project

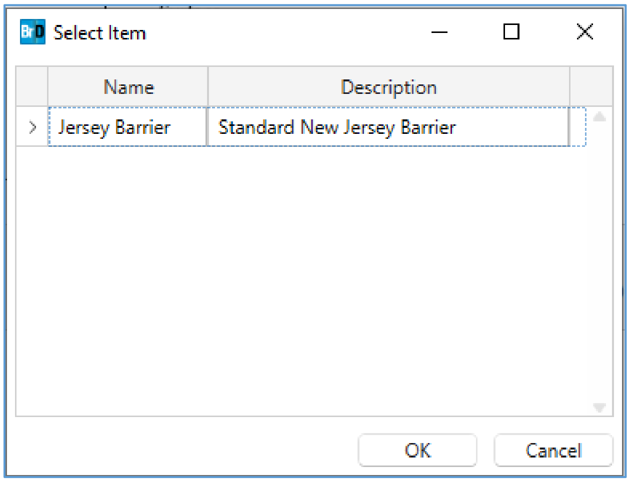
On the Design Input | **Project** input screen, enter the data as shown below.

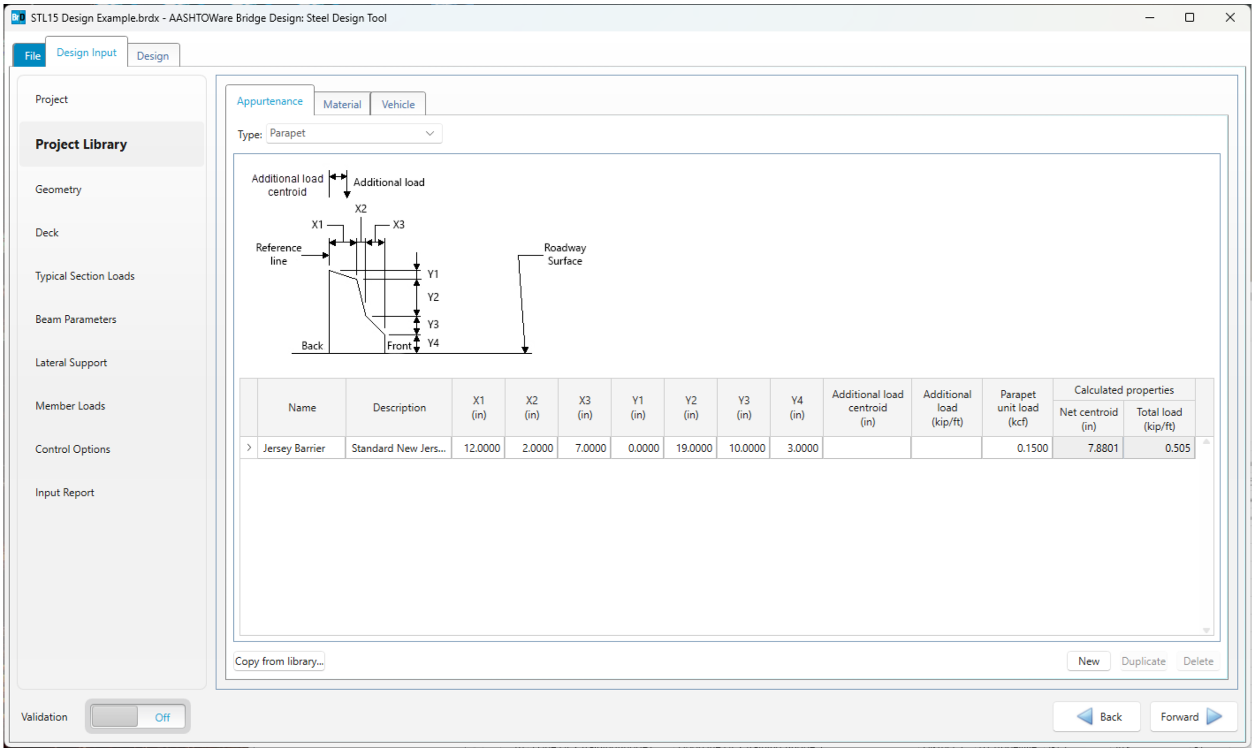


Design Input | Project Library | Appurtenance

On the **Apputenance** tab, select **Parapet** for **Type** from the drop down menu and click the **Copy from library** button to add a new parapet. Select the Jersey Barrier.



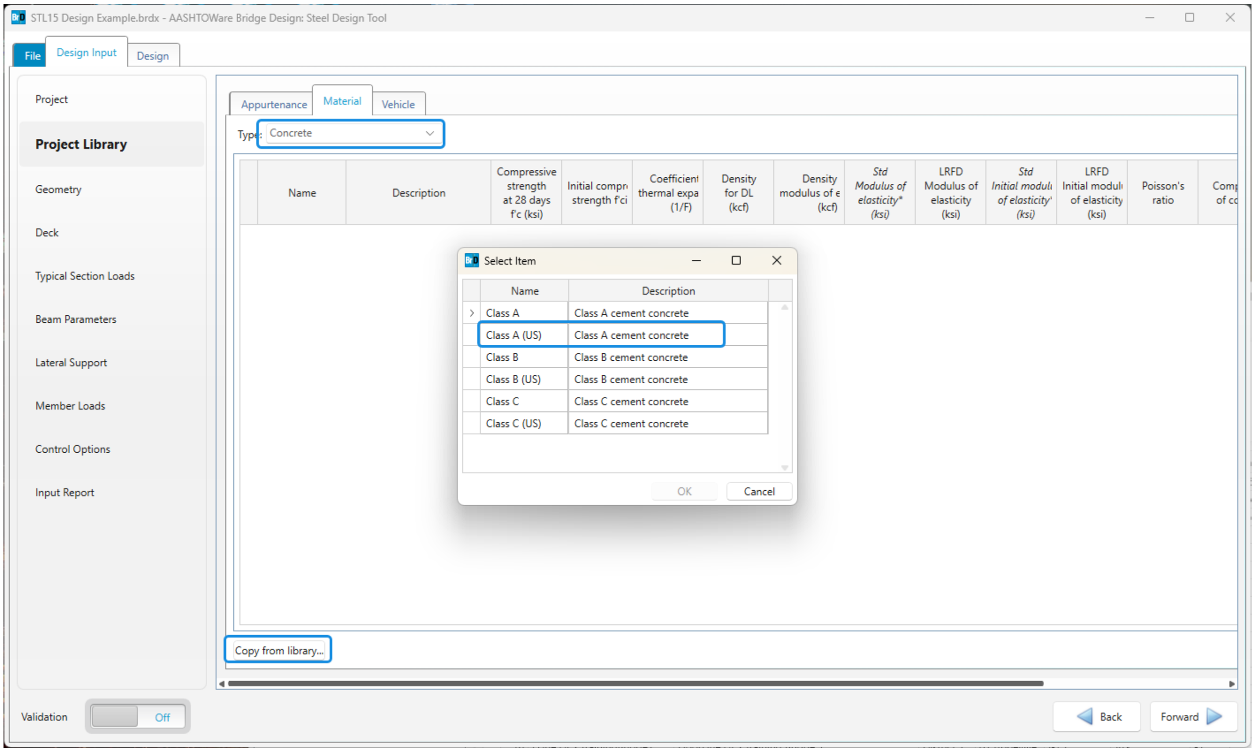




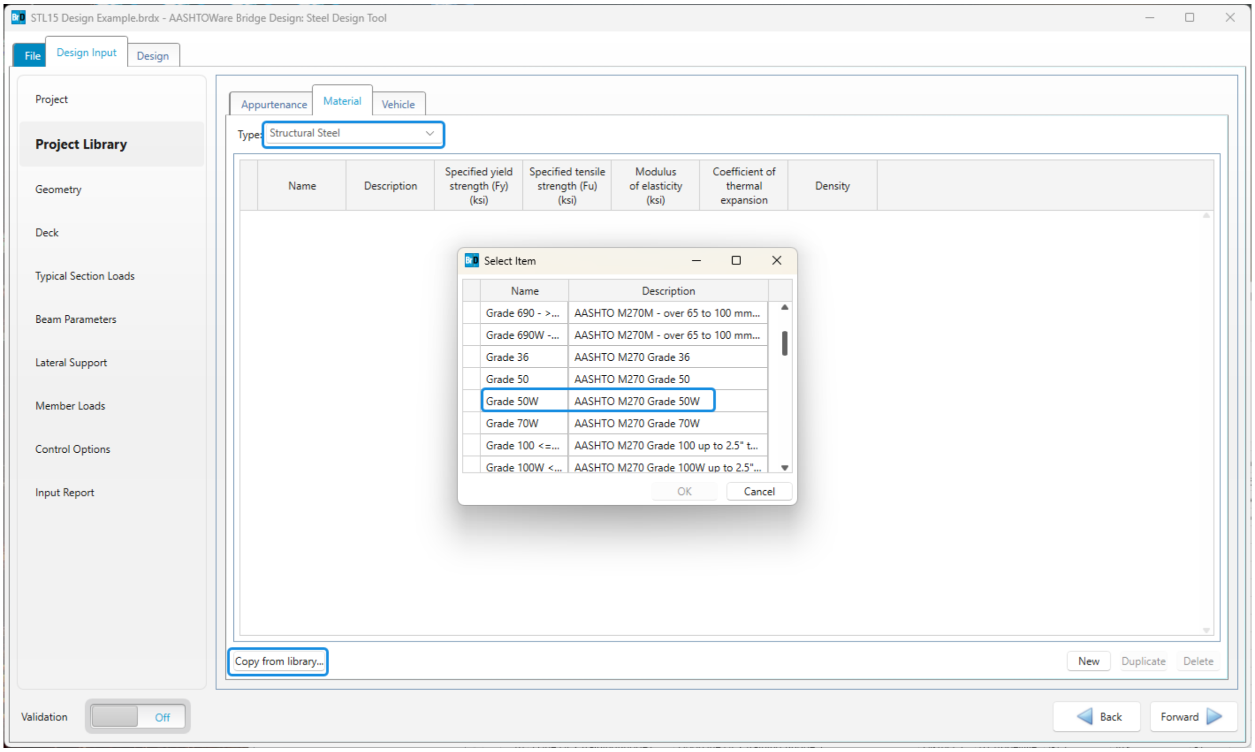
Name	Description	X1 (in)	X2 (in)	X3 (in)	Y1 (in)	Y2 (in)	Y3 (in)	Y4 (in)	Additional load centroid (in)	Additional load (kip/ft)	Parapet unit load (kcf)	Calculated properties: Net centroid (in)	Calculated properties: Total load (kip/ft)
Jersey Barrier	Standard New Jers...	12.0000	2.0000	7.0000	0.0000	19.0000	10.0000	3.0000			0.1500	7.8801	0.505

Design Input | Project Library | Material

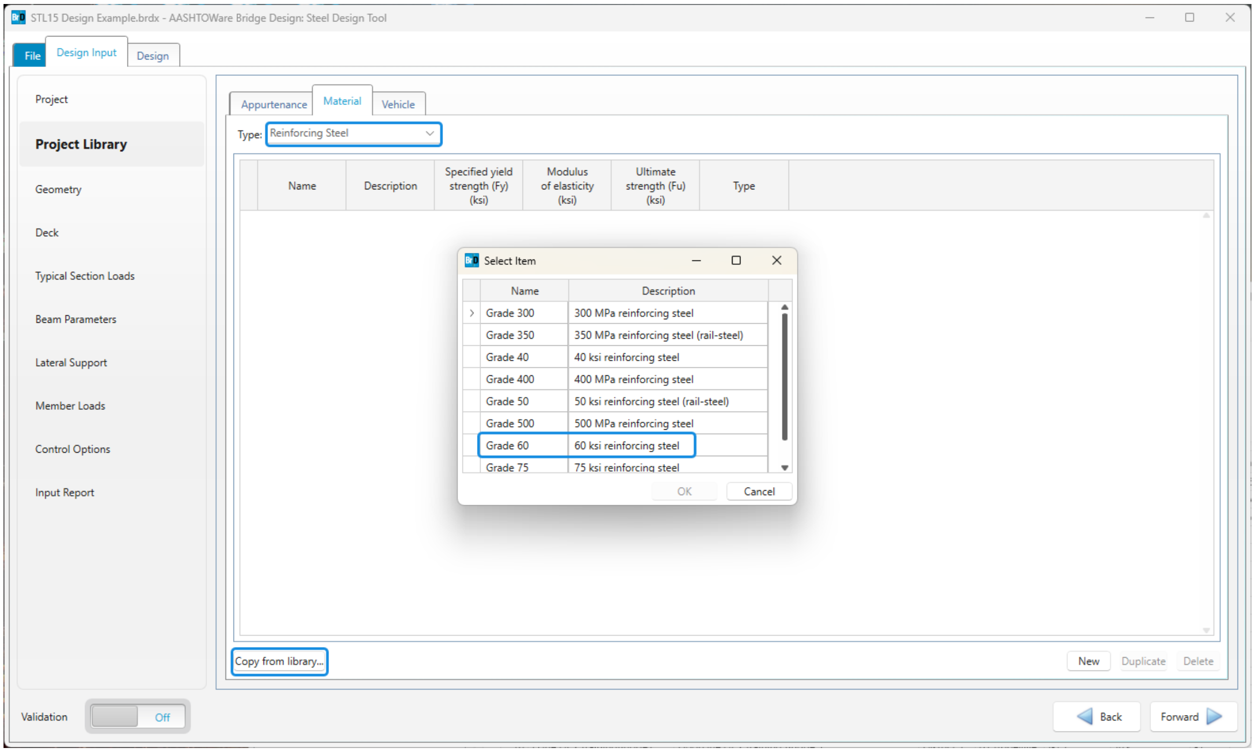
On the **Material** tab, select **Concrete** for **Type** from the drop down menu and click the **Copy from library** button to copy the **Class A (US)** concrete material definition from **File | Library** to the **Project Library**.



On the **Material** tab, select **Structural Steel** for **Type** from the drop down menu and click the **Copy from library** button to copy the **Grade 50W** steel material definition from **File | Library** to the **Project Library**.

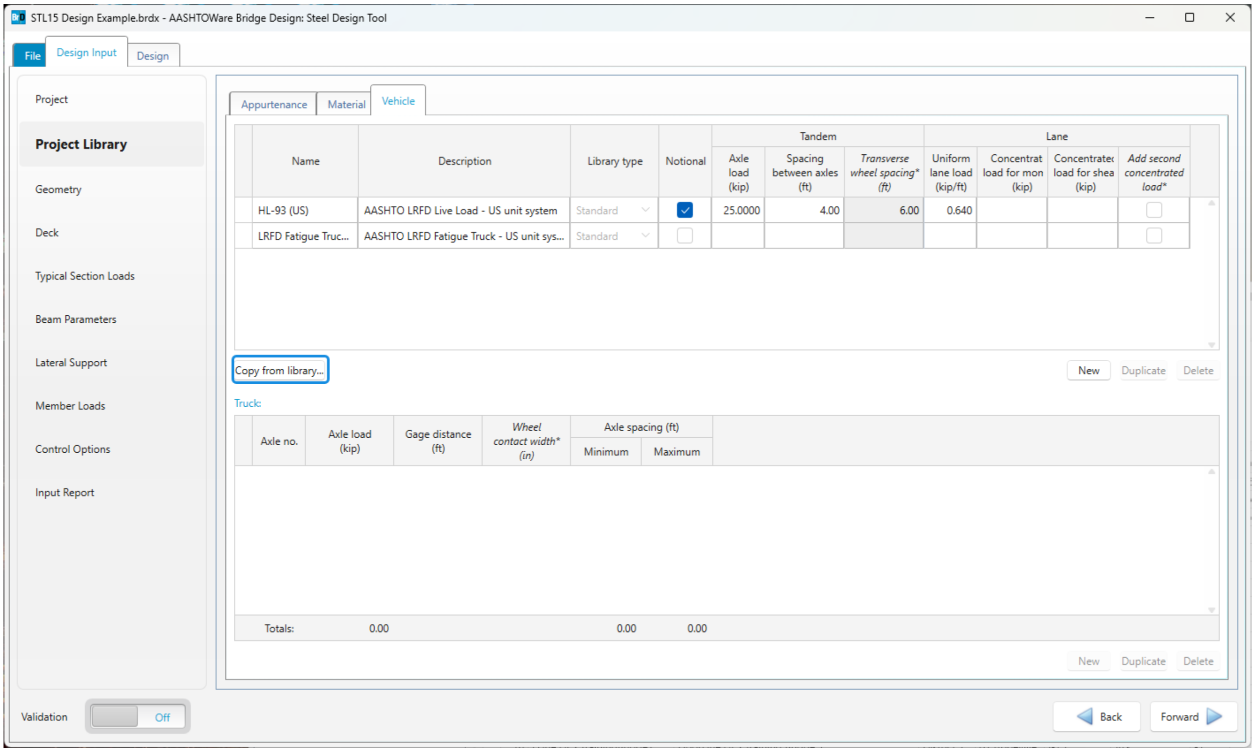


On the **Material** tab, select **Reinforcing Steel** for **Type** from the drop down menu and click the **Copy from library** button to copy the **Grade 60** reinforcing steel material definition from **File | Library** to the **Project Library**.



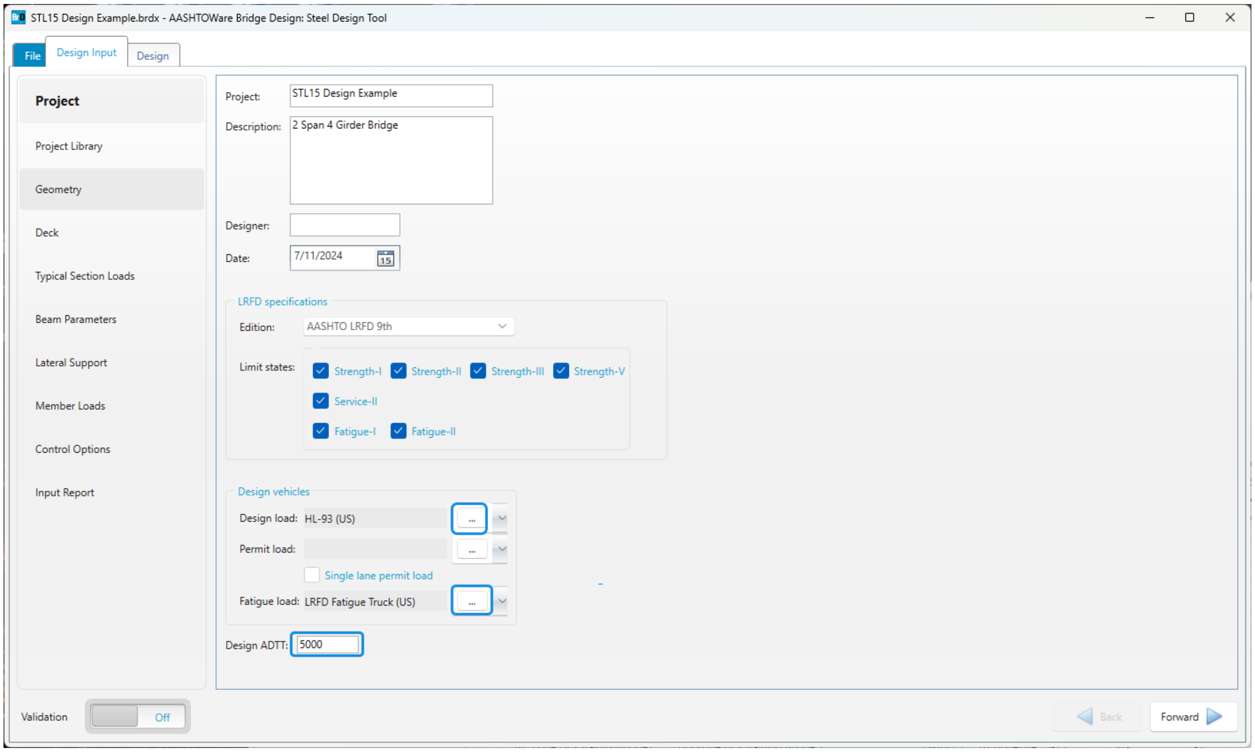
Design Input | Project Library | Vehicle

On the **Vehicle** tab, copy the HL-93 (US) and LRFD Fatigue Truck (US) vehicle definitions from library.



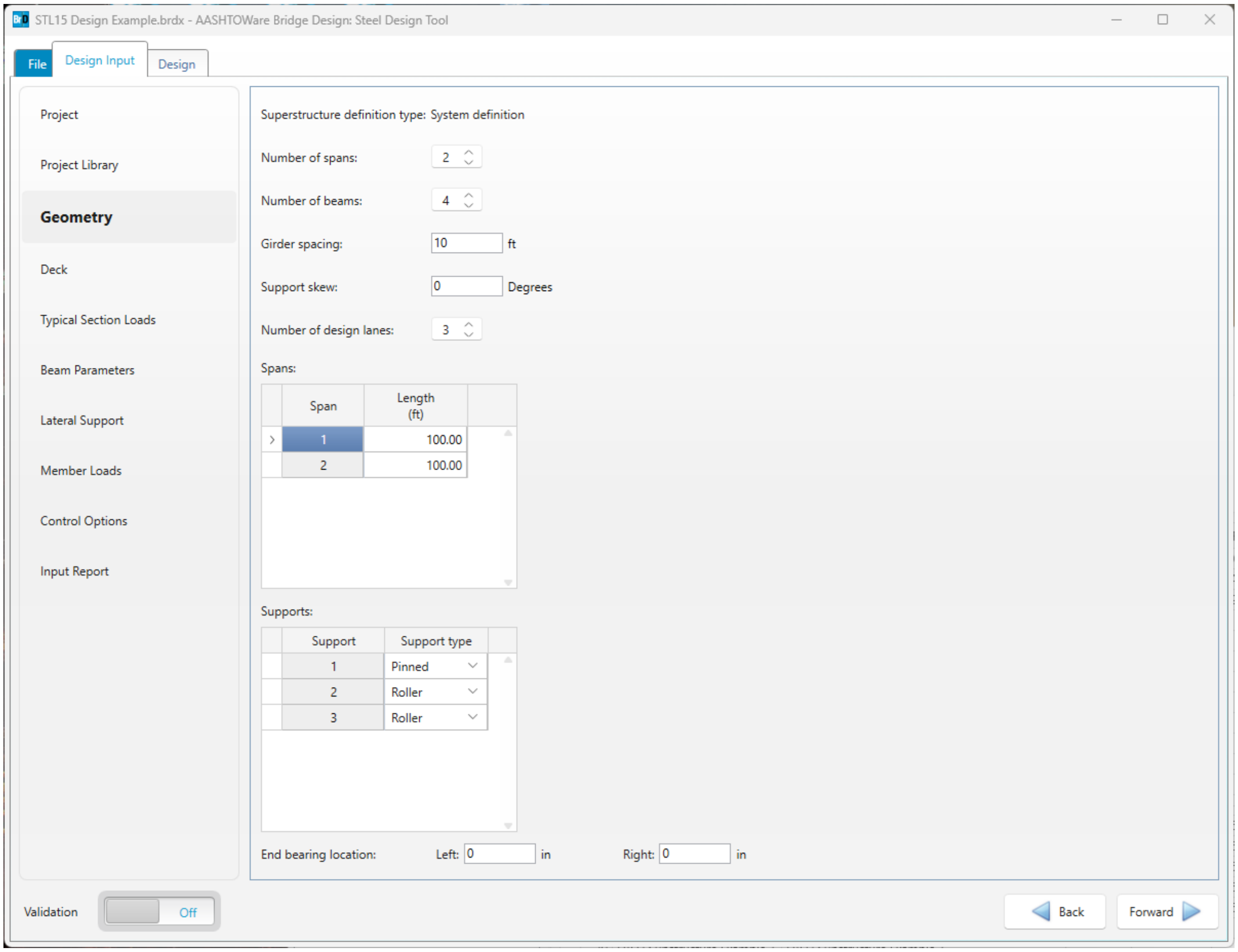
Design Input | Project

Return to the **Project** tab to define the vehicles for the girder design. Click on the ellipsis button to assign the HL-93 (US) vehicle as the design load and the LRFD Fatigue Truck (US) as the fatigue load. Leave the permit load blank. Define the design average daily truck traffic as 5000.



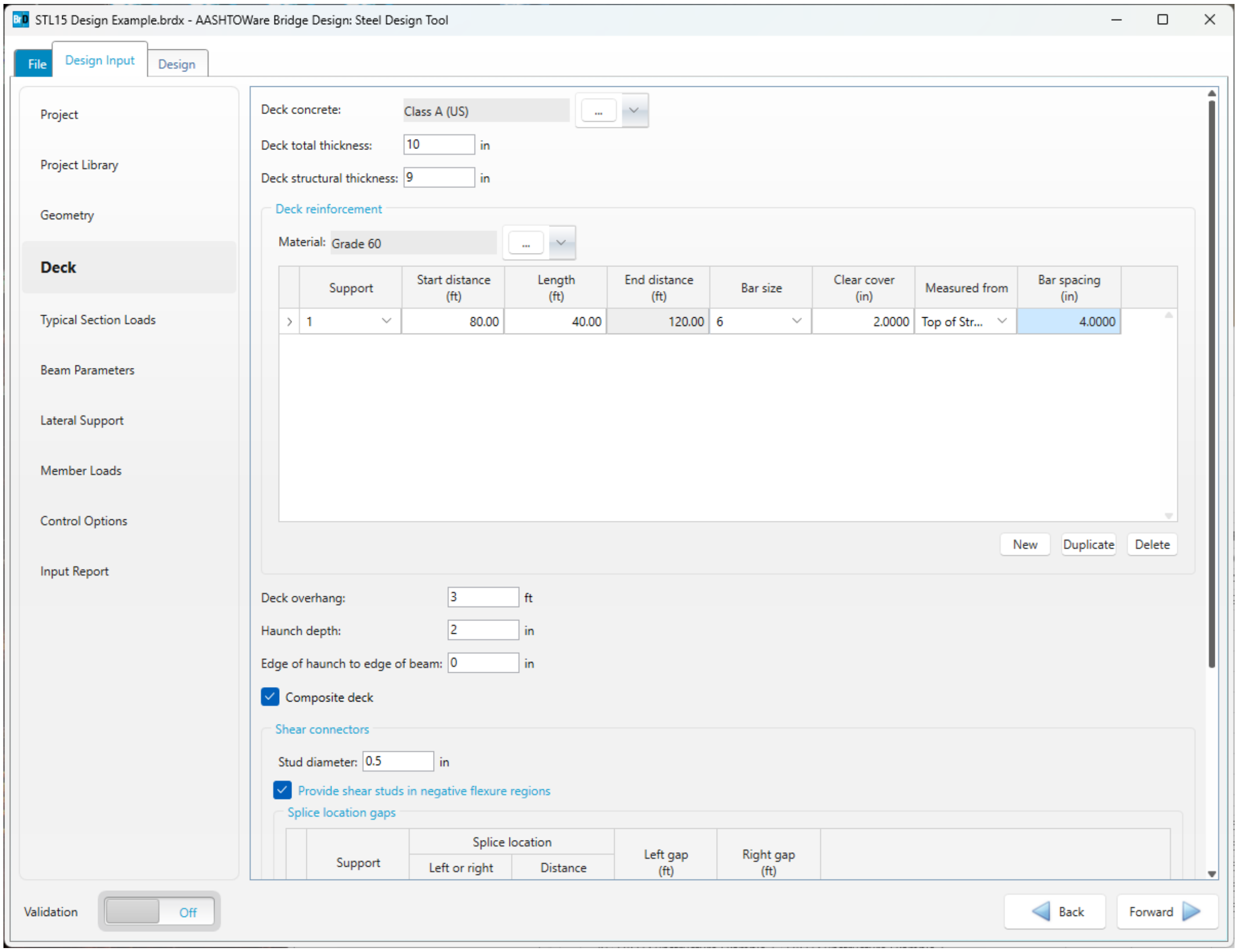
Design Input | Geometry

On the **Geometry** tab, enter the data as shown below. Depending on your screen resolution, scroll down to enter the **Support** information.



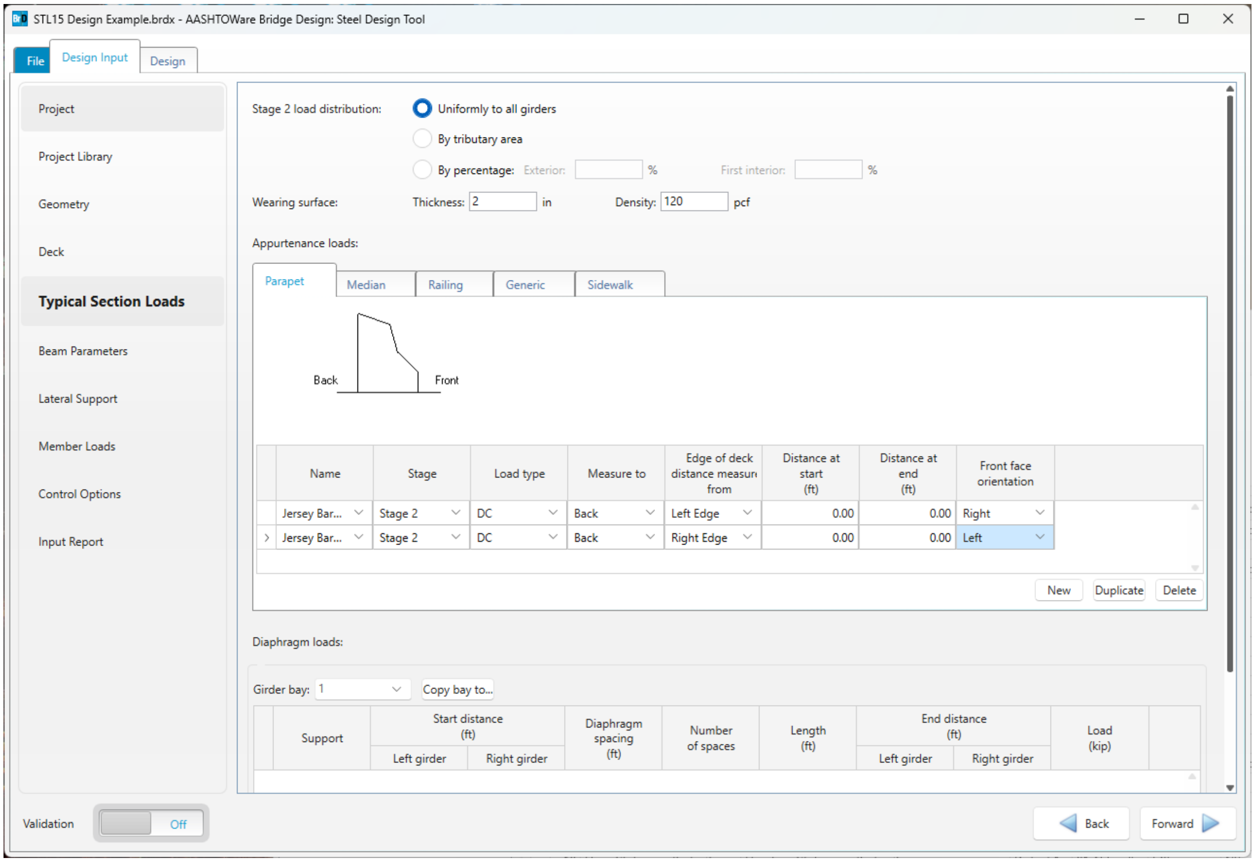
Design Input | Deck

On the **Deck** tab, enter the data as shown below. The **Splice location gaps** table can be used to input regions where the program should avoid placing shear studs. For this example, leave this table empty.

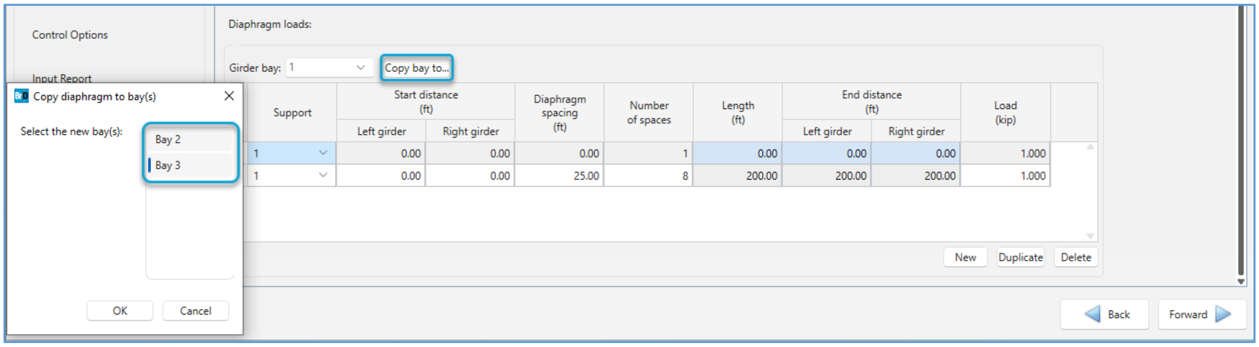


Design Input | Typical Section Loads

On the **Parapet** tab in **Typical Section Loads**, enter the data as shown below.

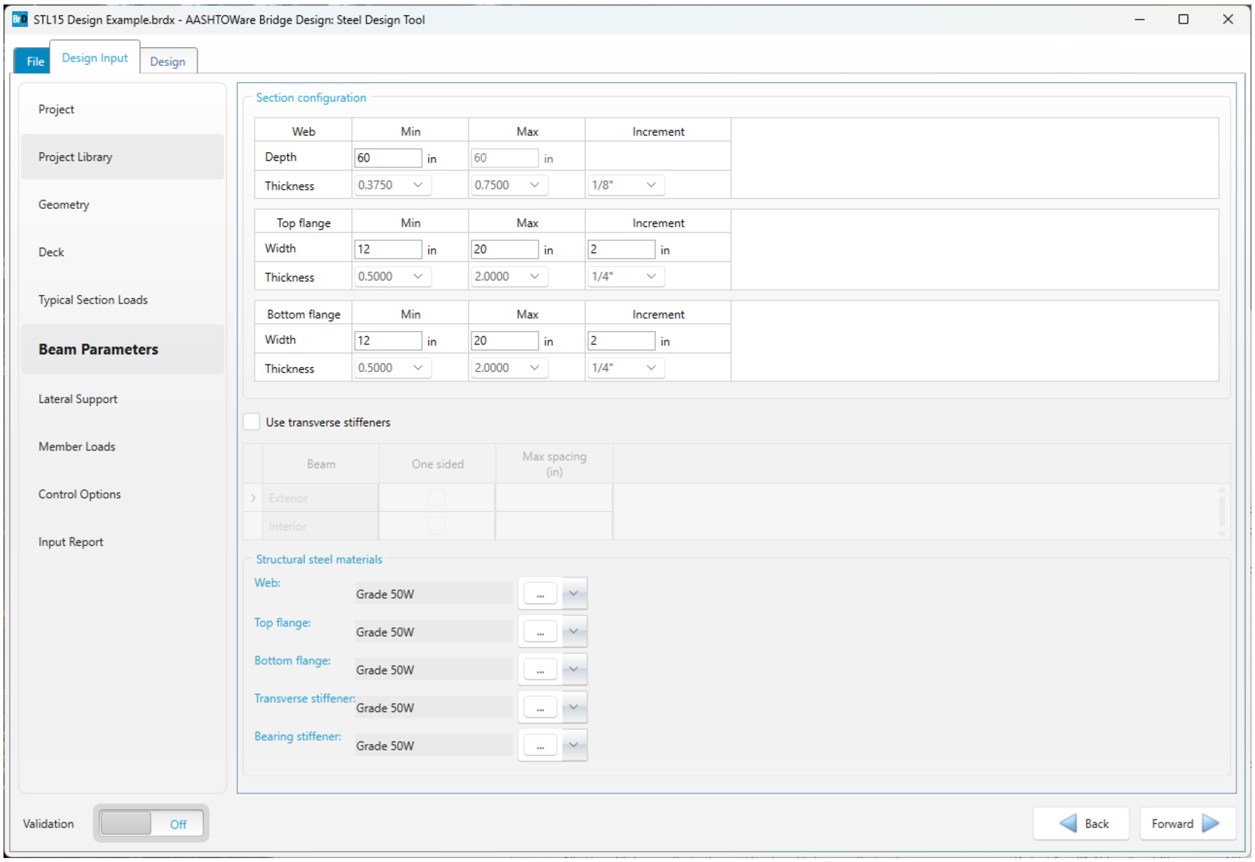


Make sure to scroll to the bottom of the page to define the diaphragm loads. Input the diaphragm loads as shown for Girder Bay 1 and use the **Copy bay to…** button to copy the loads to Girder Bay 2 and Girder Bay 3.



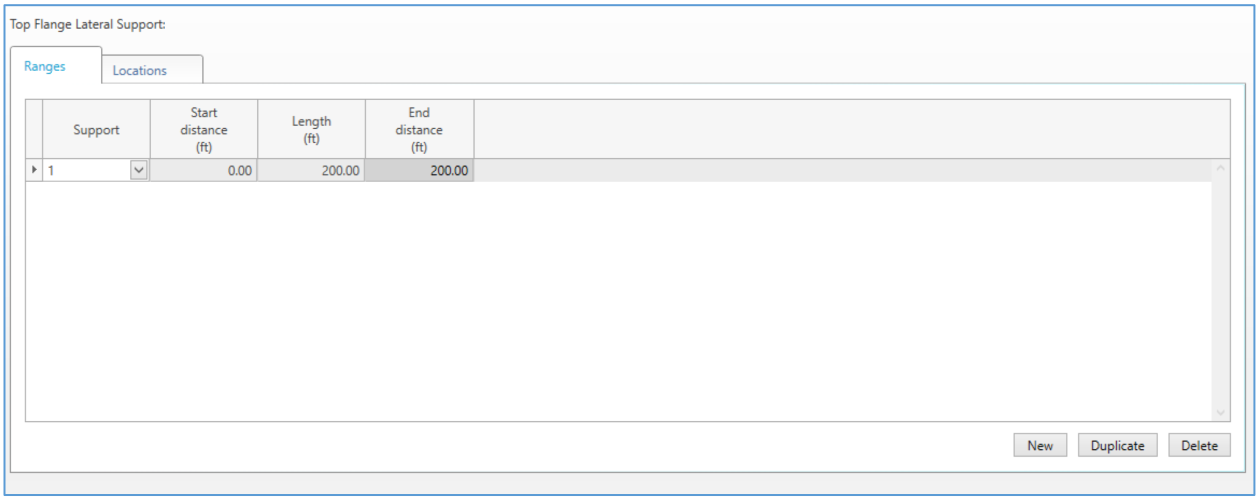
Design Input | Beam Parameters

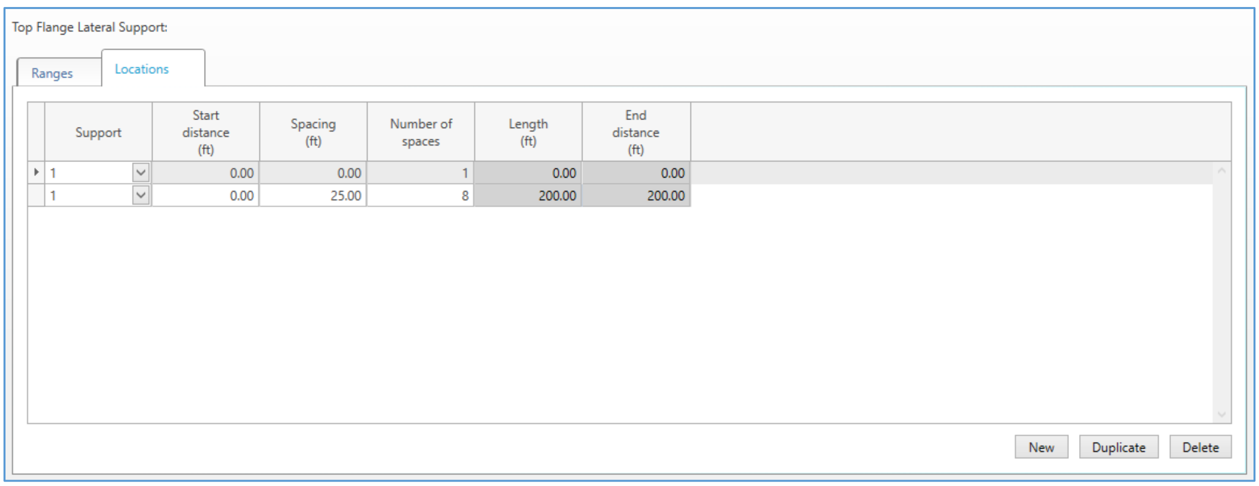
In the **Beam Parameters** input section, enter the data as shown below. All of the plate dimensions except for the web depth can be designed. Providing a larger range of values for any given parameter can help the design tool converge on a solution. The program will design transverse stiffeners for shear resistance if the **Use transverse stiffeners** button is selected. This example does not use this option.



Design Input | Lateral Support

In the **Lateral Support** input section, enter the data as shown below. Top flange lateral support ranges are regions where the top flange is continuously laterally supported and top flange lateral support locations are discrete points of lateral support.These entries define the top flange lateral support for Stage 2 and Stage 3.



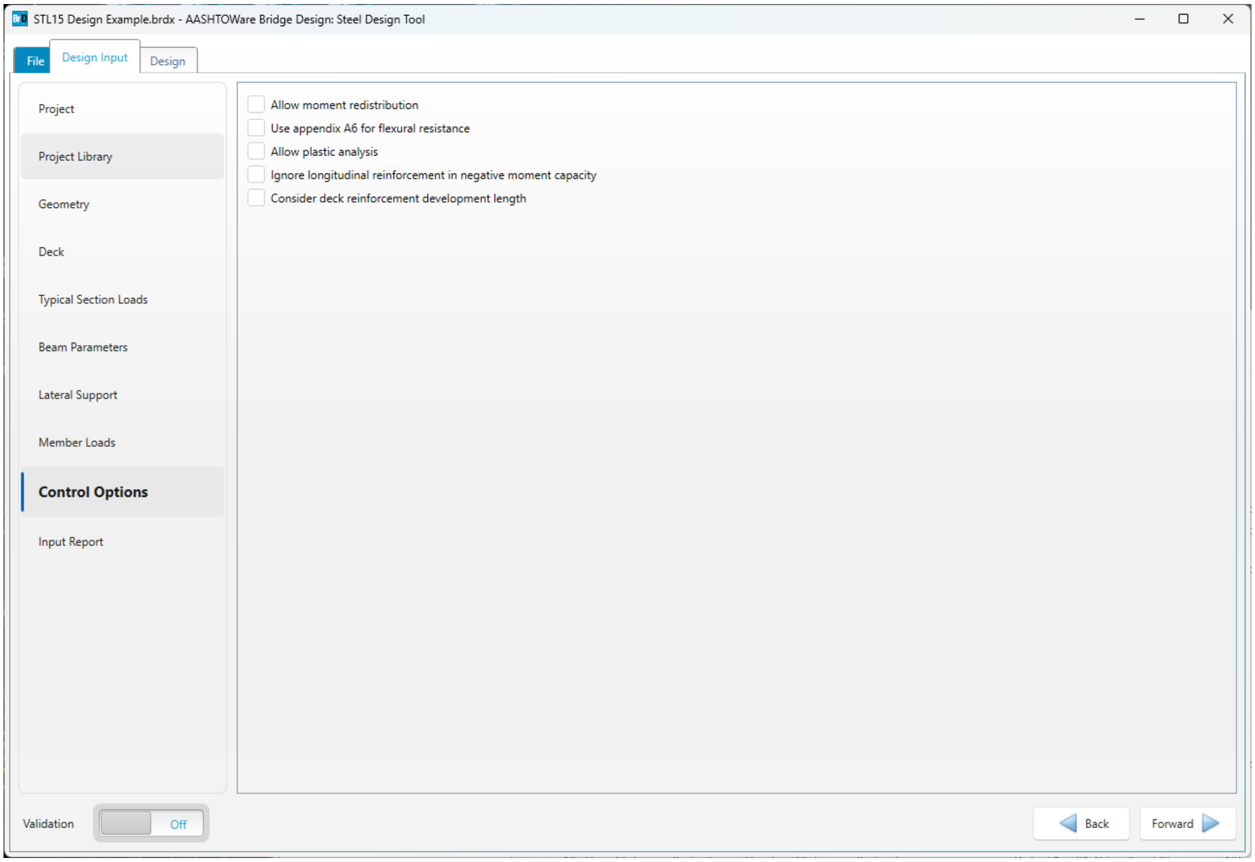


Design Input | Member Loads

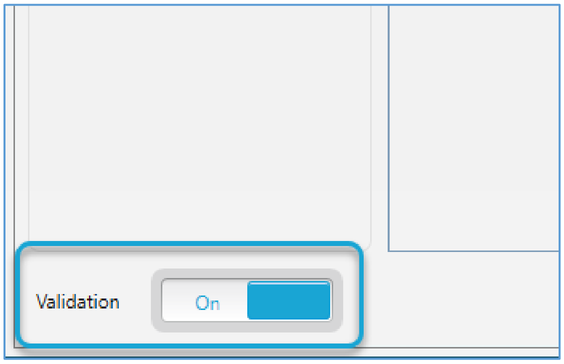
There are no member loads assigned in this example. Member concentrated loads, member distributed loads and pedestrian loads could be assigned here.

Design Input | Control Options

The **Control Options** input section provides options for analysis and design. For this example, leave the options as is.

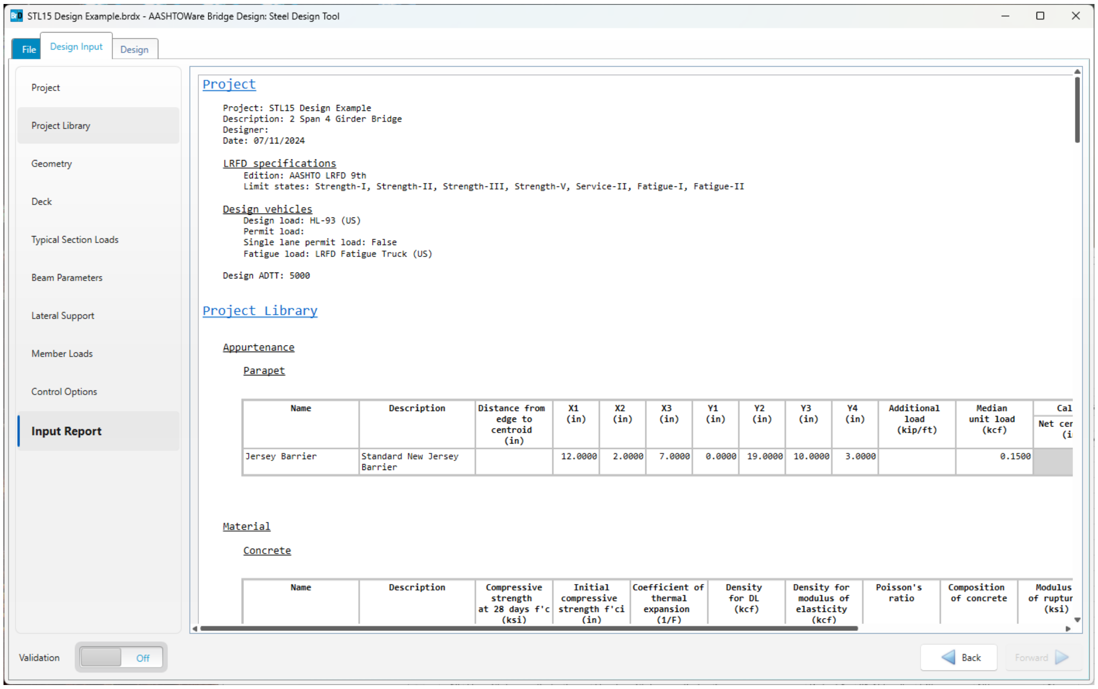


At this point, all design data has been defined. Turn **Validation** on and ensure that there are no validation error marks displayed next to the input section. Otherwise, go back to these sections and resolve the errors.



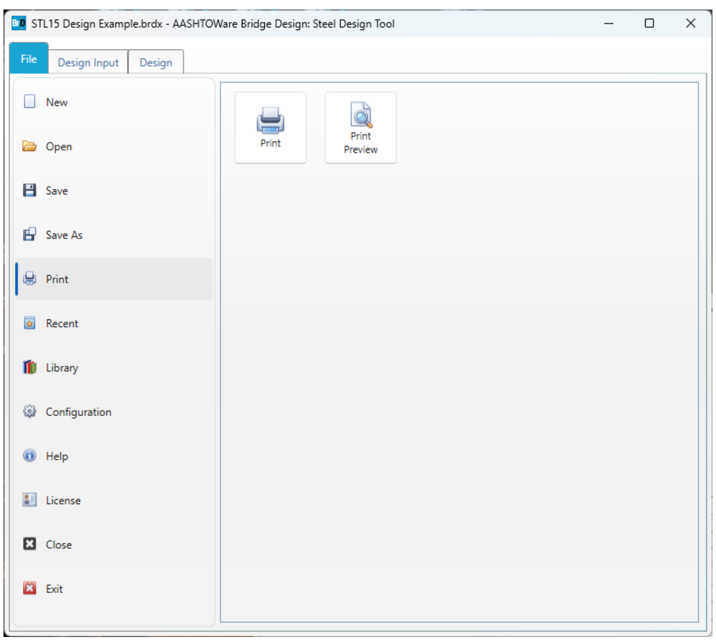
Design Input | Input Report

The **Input Report** section provides a detailed report of the input data.



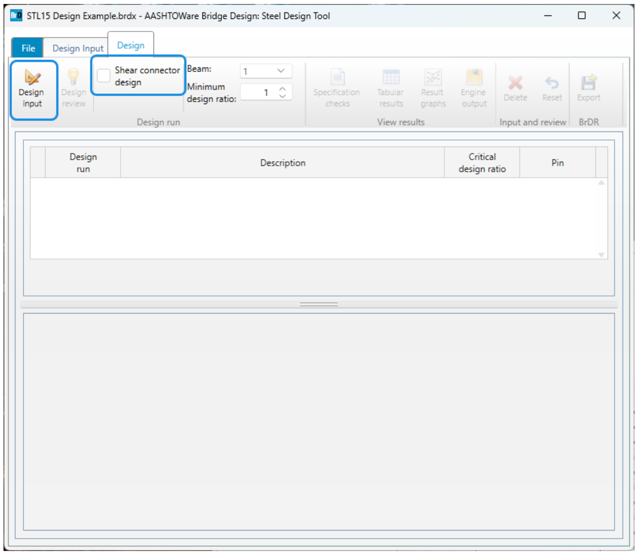
File | Print

The **Print** and **Print Preview** buttons in the **File | Print** section apply to the **Input Report**.



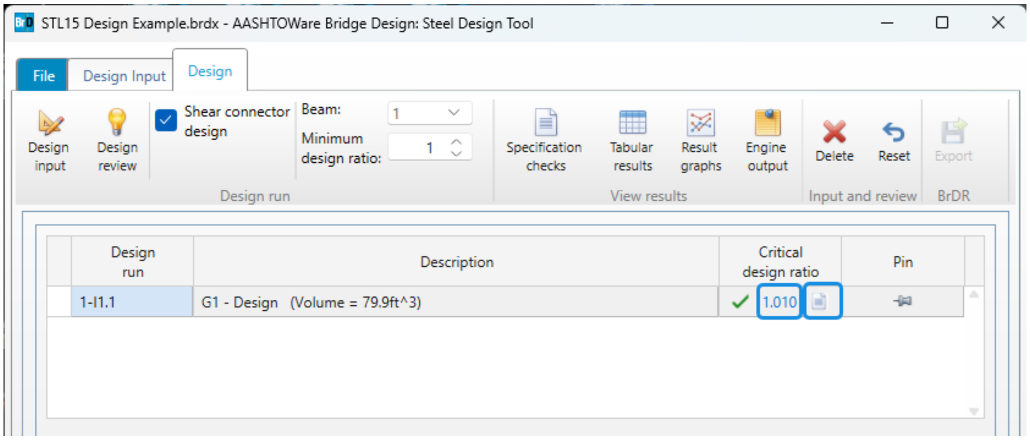
Design | Design Input

After the input data is entered and reviewed, **Design Input** run can be performed by clicking on the **Design Input** button located on the **Design ribbon**. **Design Input** run is based on the input data and produces a design that is displayed in the **Design Run** grid with a brief description and values of the critical design ratios. Select the checkbox for **Shear connector design** to design the shear connectors along with the girder in the composite regions. The beam dropdown is the selection for which girder the program will design and the input for minimum design ratio defines the target design ratio for which the girder will be designed.



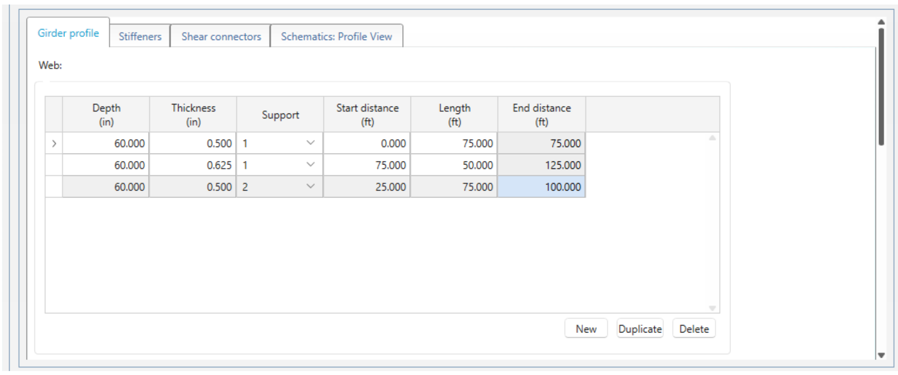
Design | Results Table

The results of the **Design Input** run are displayed in the table. The user can click on the **Critical design ratio** to open the **Analysis engine feedback report**, and on the page icon next to the **Critical design ratio** to open the **Specification Check Summary**.



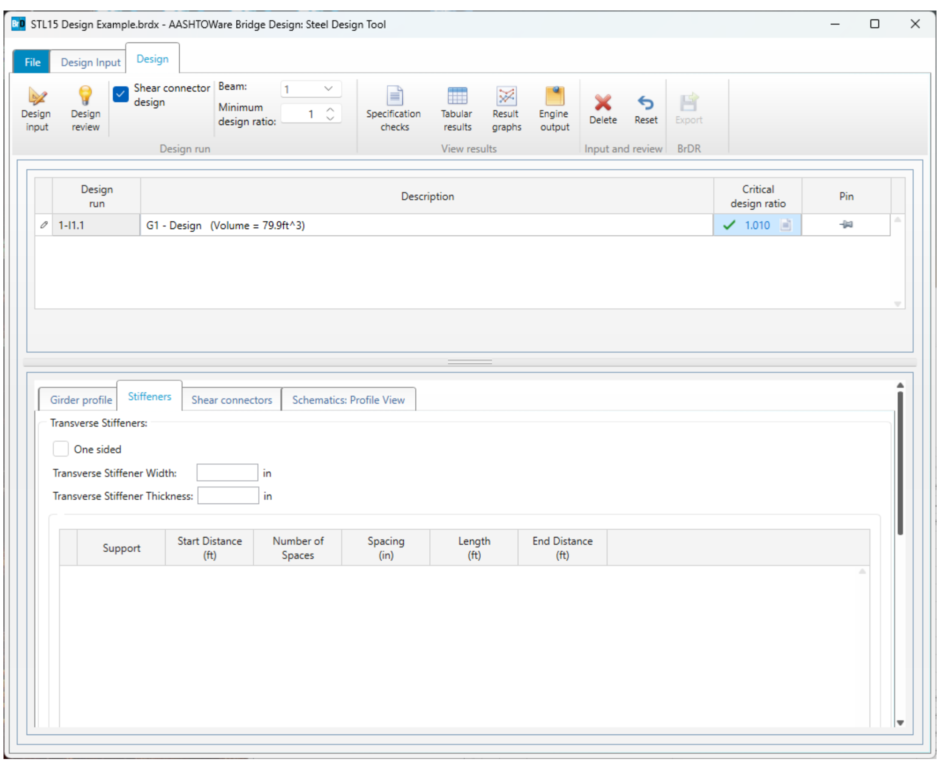
Design | Girder Profile

The **Girder Profile** tab displays the ranges for steel plates along the web and flanges. After a design input run is completed, these tables will display the program computed ranges. The user may modify these ranges and reanalyze the member using the **Design Review** option.



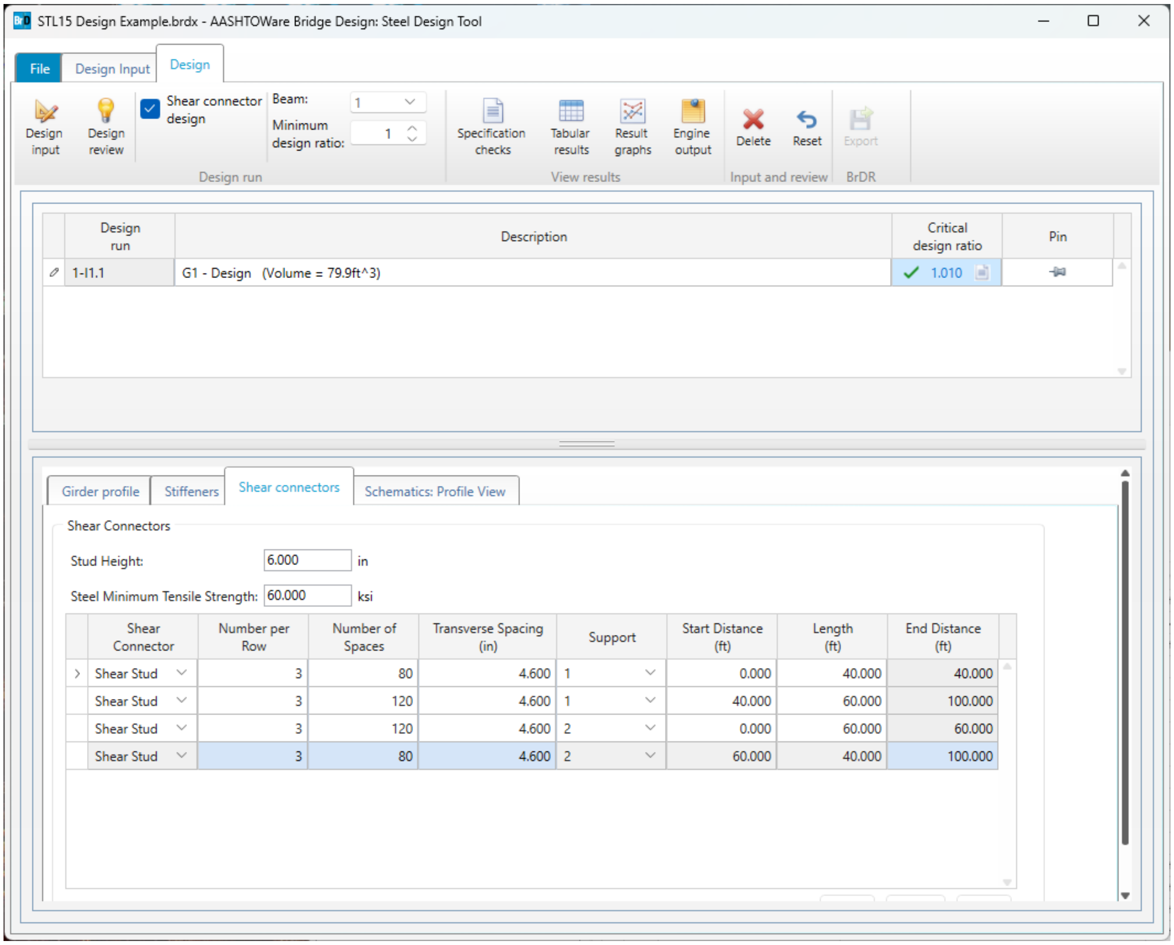
Design | Stiffeners

The **Stiffeners** tab displays the results of the stiffener design. This includes transverse stiffeners and bearing stiffeners. The transverse stiffeners will only be designed when the design input option to **Use Transverse Stiffeners** in the **Design Input | Beam Parameters** window is selected.



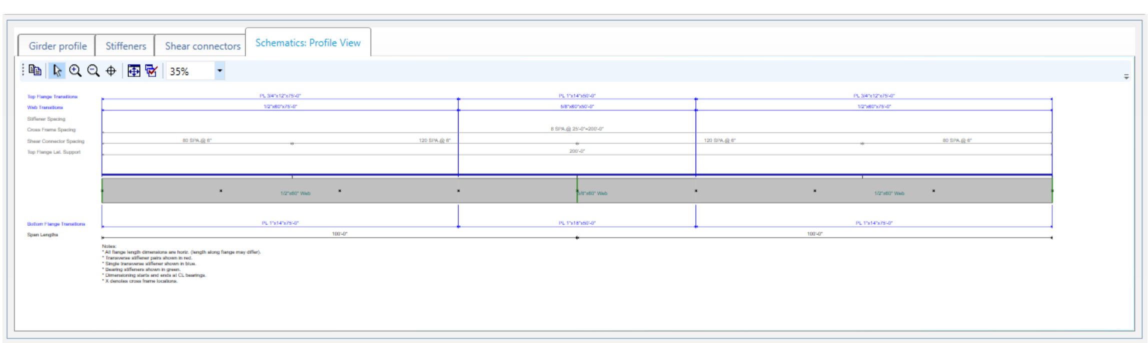
Design | Shear connectors

The **Shear connectors** tab shows the results of the shear connector design if enabled and if the member has composite regions.



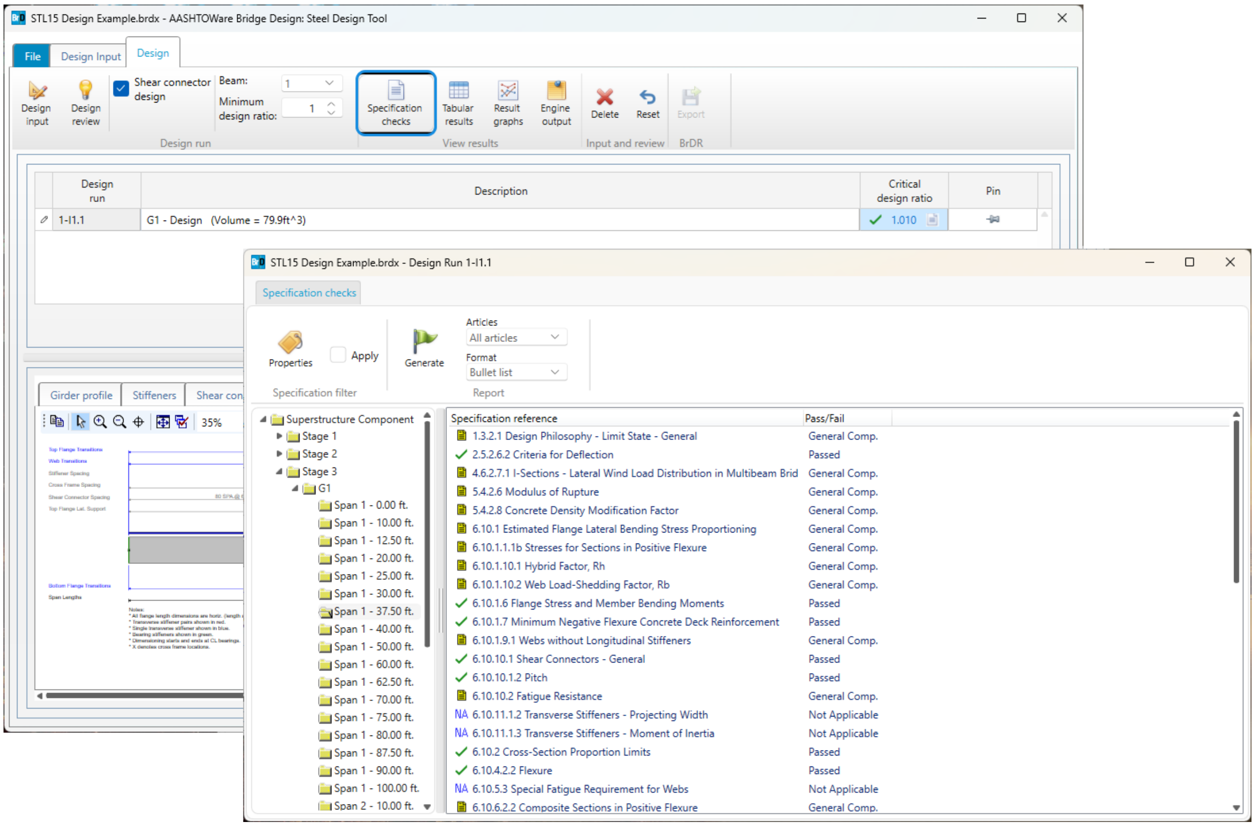
Design | Schematics: Profile View

The **Schematics: Profile View** tab shows a schematic of the girder design.



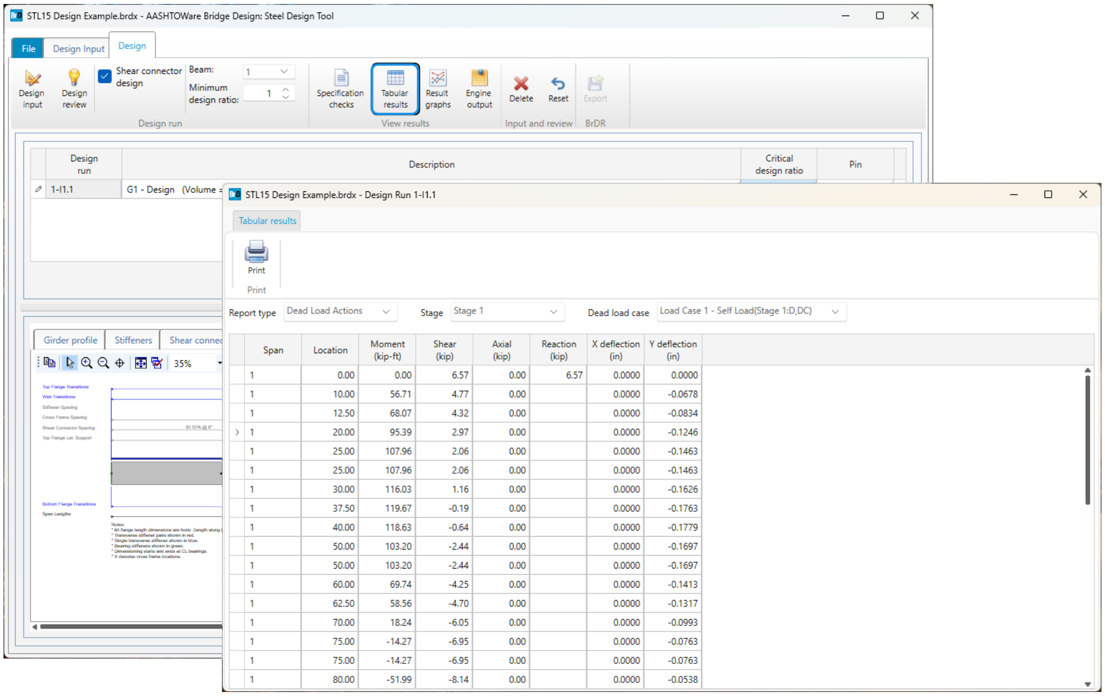
Design | Specification Check

To view the specification check results, click on the **Specification checks** button from the **View results** group of the **Design** ribbon.



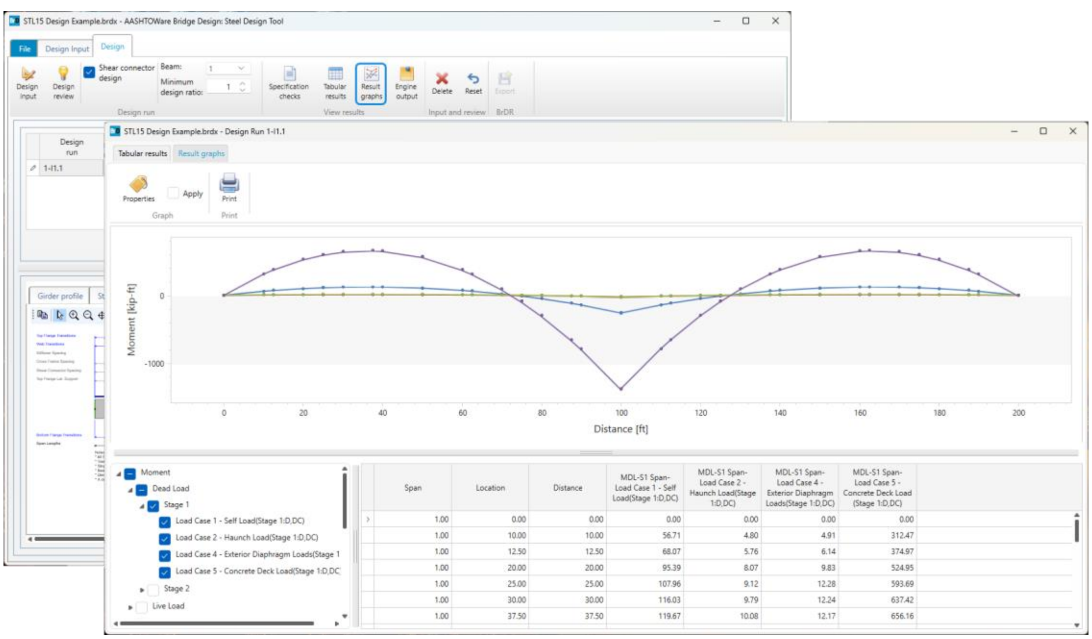
Design | Tabular Results

To view the tabular results, click on the **Tabular results** button from the **View results** group of the **Design** ribbon.



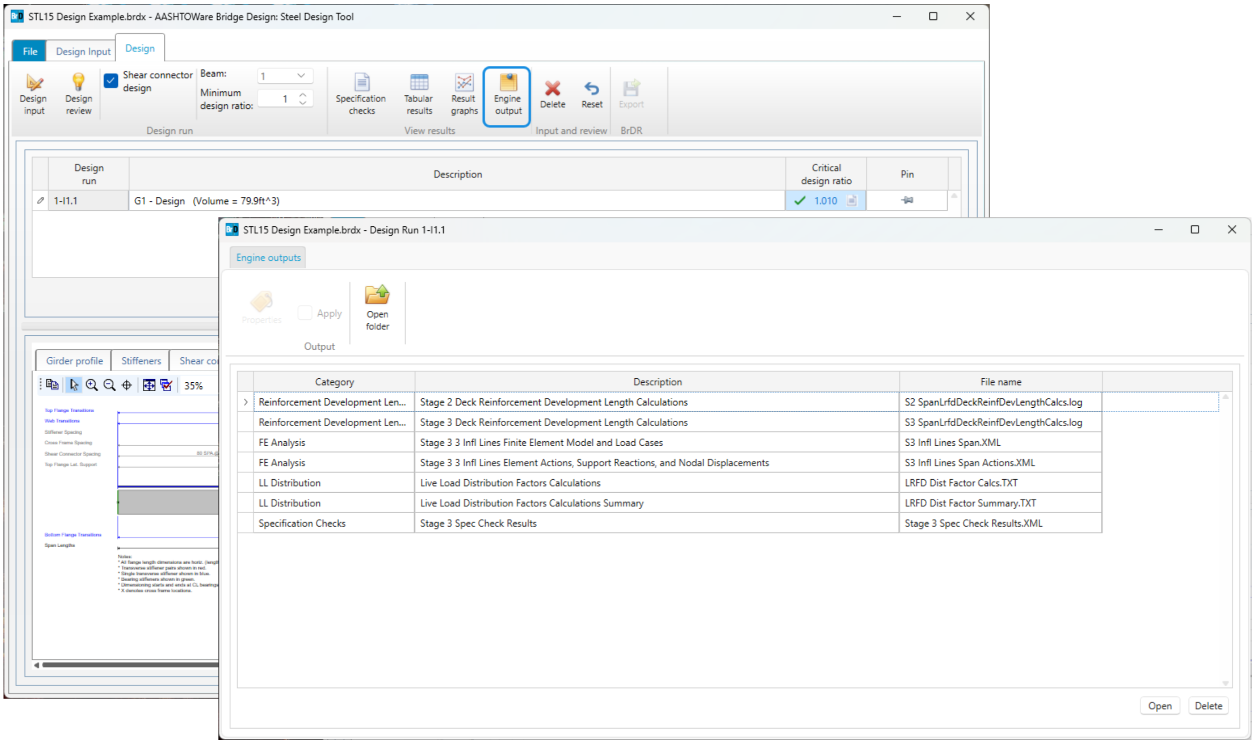
Design | Result Graphs

To view the result graphs, click on the **Result graphs** button from the **View results** group of the **Design** ribbon.



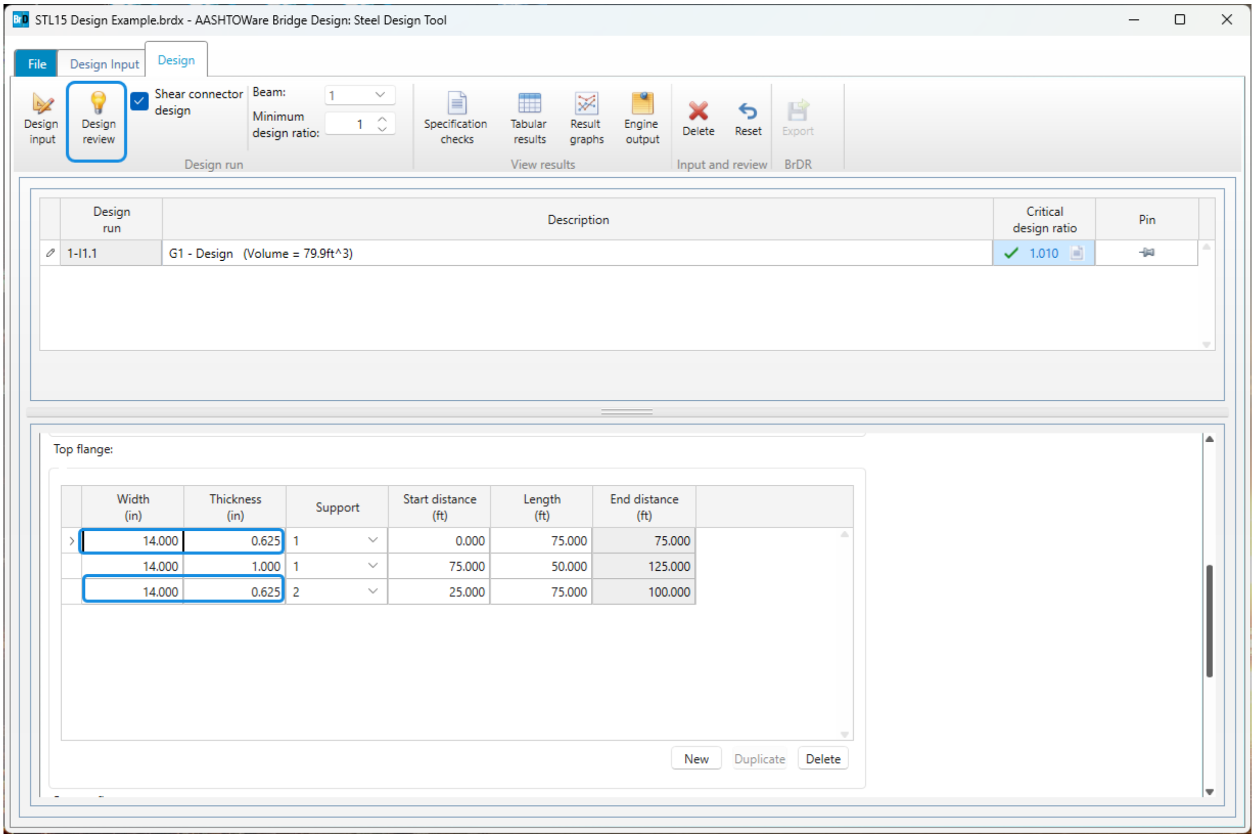
Design | Engine Outputs

To view the contents of the engine output files, click on the **Engine outputs** button from the **View results** group of the **Design** ribbon, and then double-click on the row corresponding to the required file.

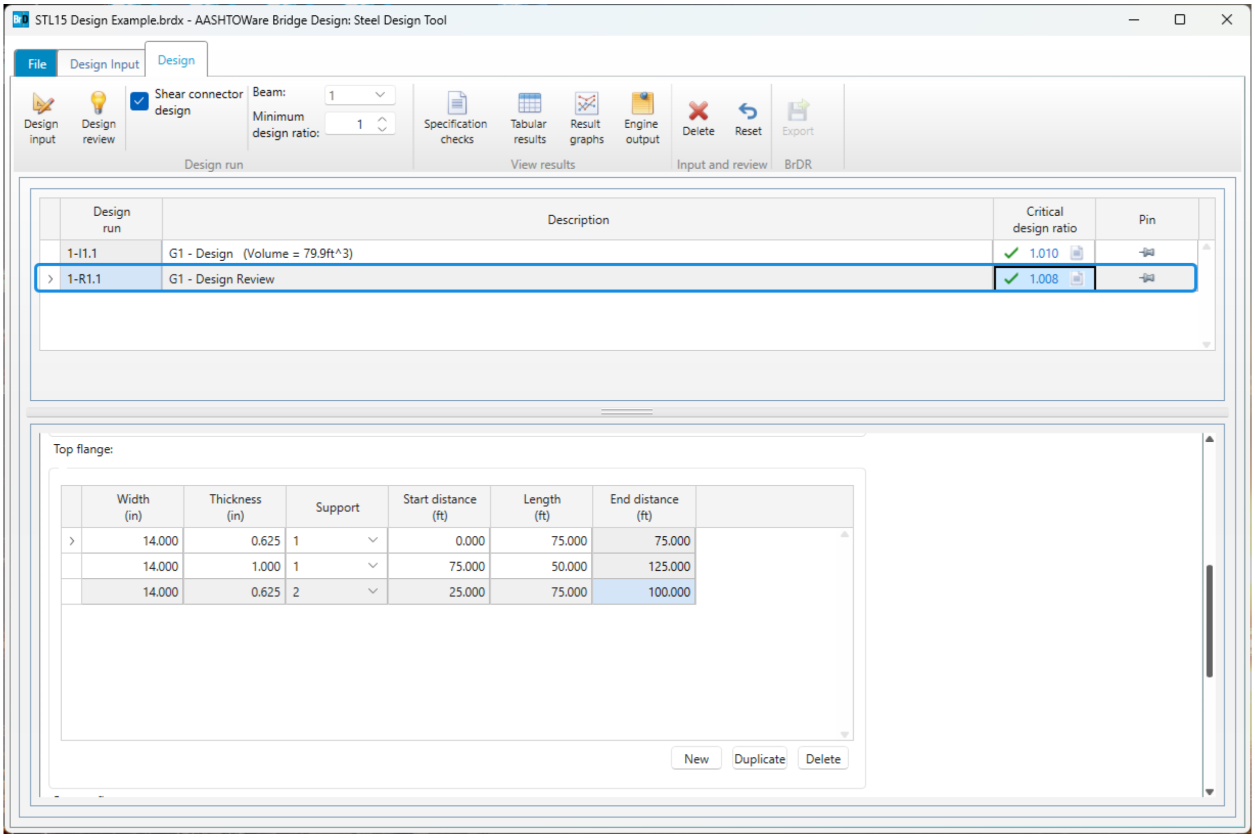


Design | Design Review

To illustrate the ability of the program to adjust results of the **Design Input** run, modify the **Top flange** table to define a top flange width of 14 inches for all ranges and a thickness of 0.625 for the first and third range as shown below. Select **Design Review** to analyze this modified design.



After the program finishes performing the design review, it will add another row to the design run grid. The design review runs are indicated with an **R** displayed in the **Design run** column in contrast to an **I** shown in that column for design input runs. The results for the **Design review** runs are displayed and can be reviewed or further modified the same way as design input runs. Additional design input runs can be performed by modifying the input on the **Design Input** tab. Each of the design runs, either input or review, stores a copy of its design input data that is reloaded every time the design input run is selected in the design run grid.



2024 RADBUG Annual Meeting

BrR Training Session

Wednesday August 7, 2024
10:00 AM – 12:00 AM

1. Concrete Shear LRFR Rating Iteration
2. LRFR Concrete Moment Redistribution

AASHTOWare BrDR 7.5.1

Concrete Shear LRFR Rating Iteration Tutorial

MBE 2023 Spec Interim Update – Shear Rating Iteration Example

BrDR Training

MBE 2023 Spec Interim Shear Rating Iteration Example

This example illustrates the effects of using concurrent load effects, iterative shear rating and Modified Compression Field Theory (MCFT) control options for Load and Resistance Factor Rating (LRFR) shear rating of concrete structures (prestressed, post tensioned and reinforced) based on the MBE 3rd edition, 2023 specification interim update.

Topics Covered

- Concurrent forces considered for non-iterative shear rating
- Control option added to consider iterative shear rating
- Control option added to consider modifying MCFT theta
- Control option added to consider modifying MCFT size effect
- MBE 2023 specification interim update for reinforced concrete box culverts

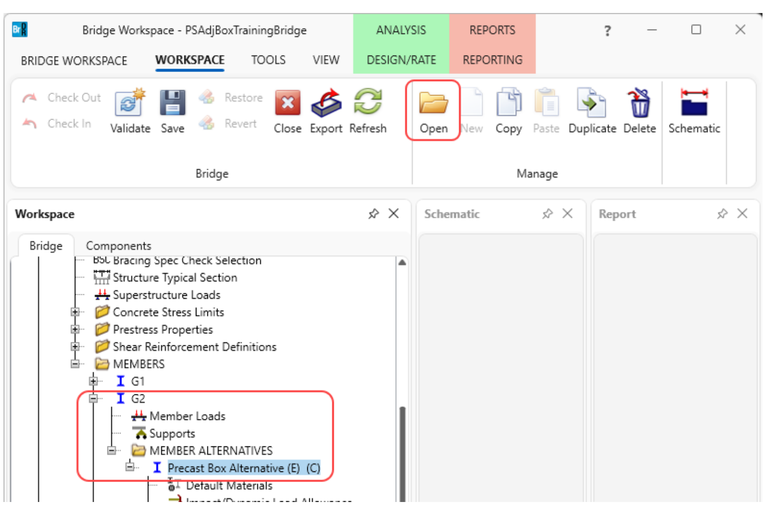
This tutorial uses the bridge from prestressed concrete structure tutorial PS3. From the **Bridge Explorer** import the bridge given with the PS3 tutorial.

Concurrent forces considered for non-iterative shear rating

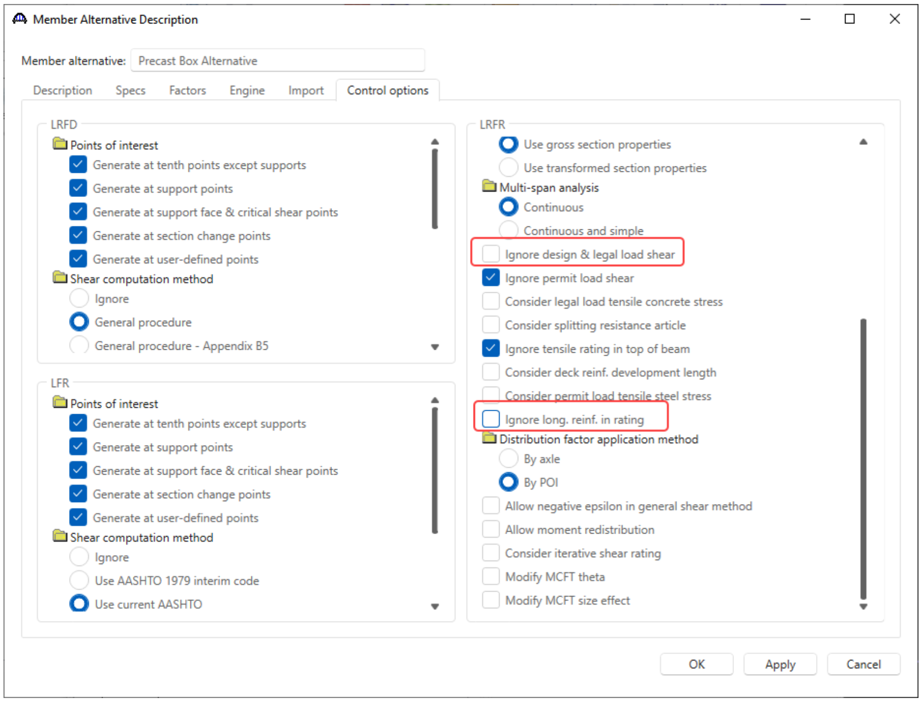
This section discusses the effects of using concurrent forces for LRFR shear rating of concrete bridges without any iterations. This is applicable to all concrete structures, i.e., reinforced concrete, prestressed concrete, post tensioned concrete and reinforced concrete box culverts.

Member Alternative Description – Control options

Navigate to the member alternative Precast Box Alternative of member **G2**, double click on it (or click the **Open** button from the **WORKSPACE** ribbon) to open its **Member Alternative Description** window. Navigate to the **Control options** tab as shown below.



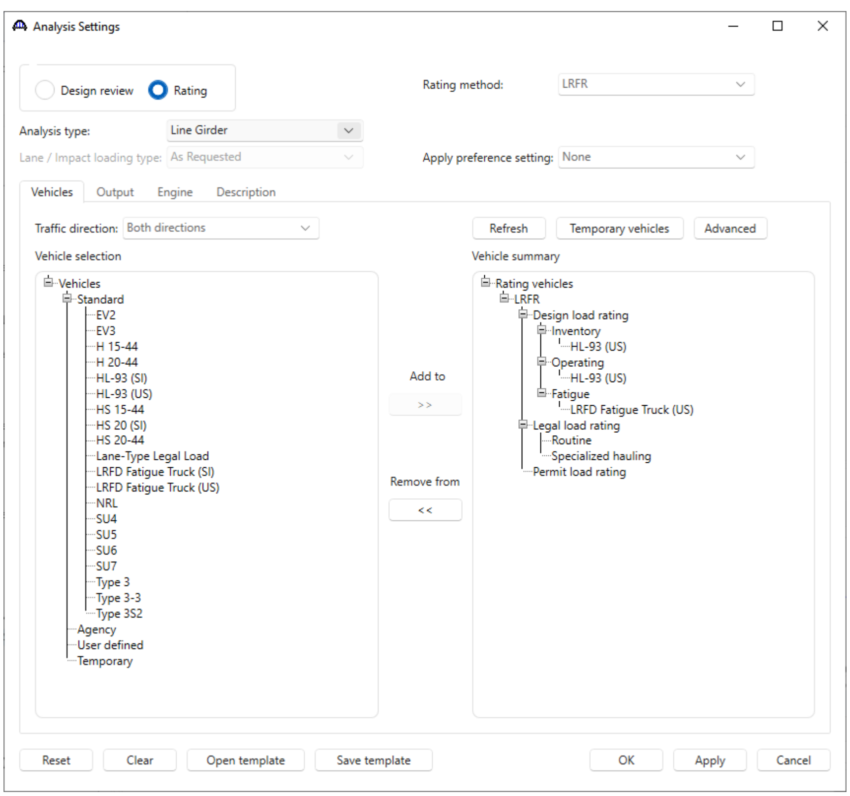
Uncheck the **Ignore design & legal load shear** and **Ignore long. reinf. in rating** for this example.



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

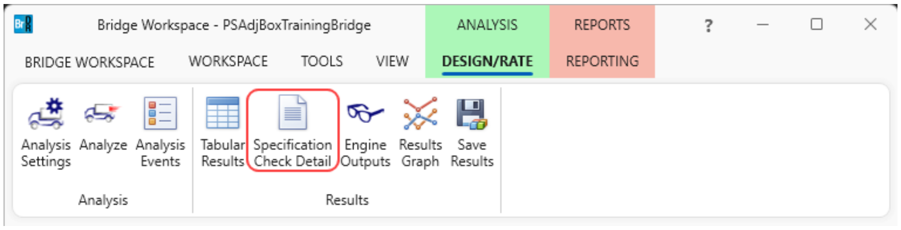
LRFR Rating

Perform an LRFR rating of the member alternative using the analysis settings shown below.

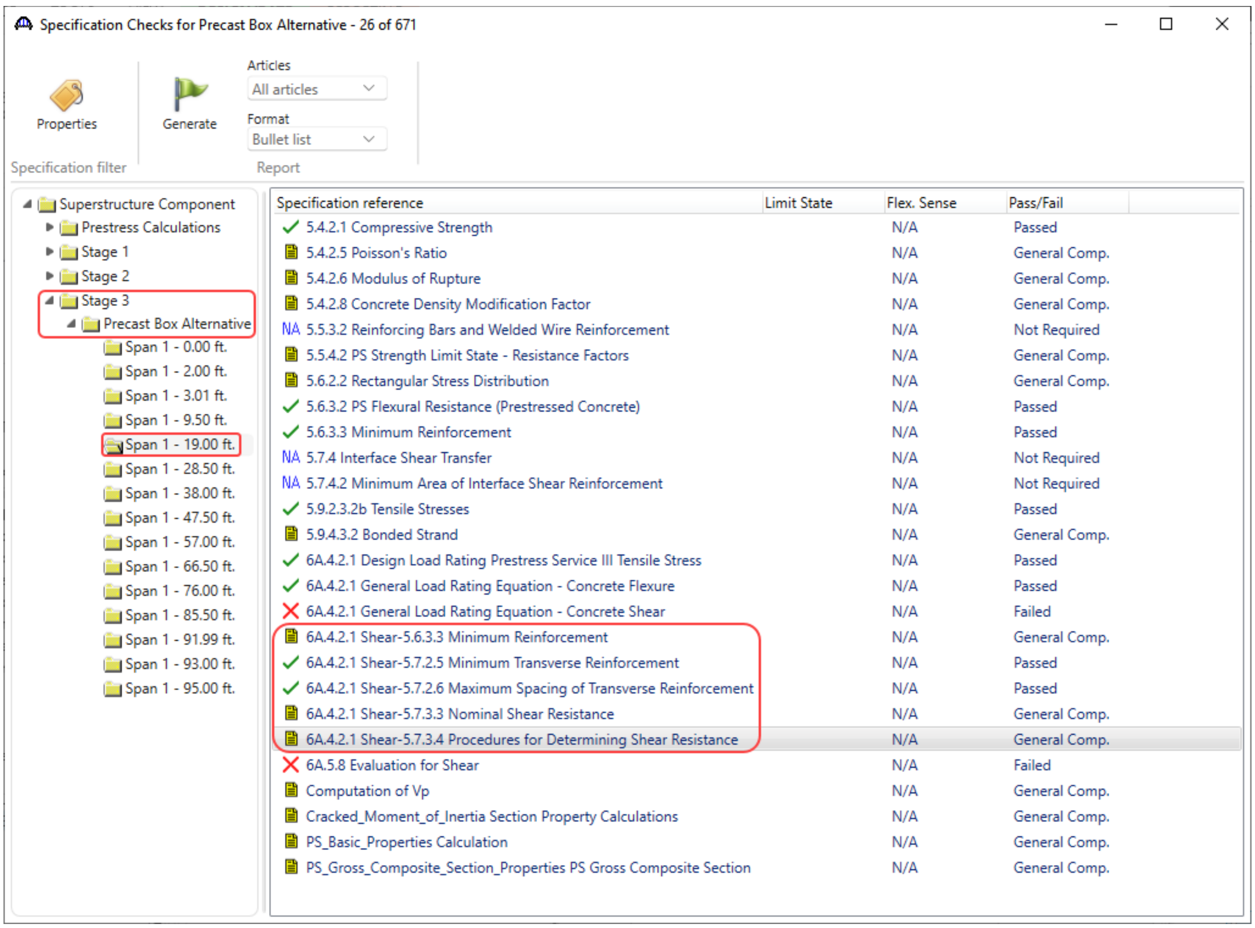


Specification Check Detail

When the rating is finished, the specification check detail can be reviewed by clicking the **Specification Check Detail** button from the **Results** group of the **DESIGN/RATE** ribbon.



The window shown below will open. Navigate to the **Stage 3** specification check detail for the analyzed member alternative and select the **Span 1 – 19.00 ft** point of interest.



The highlighted articles for MBE 6A.4.2.1 shear rating are available for an LRFR shear rating of concrete structures. These articles along with 6A.5.8 Evaluation of Shear and 6A.4.2.1 General Load Rating Equation – Concrete Shear articles, use the concurrent load effects to compute the shear capacity and rating factors.

Following sections highlight the MBE 3rd edition 2023 spec interim implementation for an LRFR analysis.

Article 6A.4.2.1 Shear-5.6.3.3 Minimum Reinforcement computes the cracking moment (Mcr) for each load case as shown below.

A new column – "Governing Action" has been added to indicate the primary action considered. For example, in 2022 interim, rating factors were computed using the envelope moment and shear values. In 2023 interim, shear concurrent actions with maximum (Max M) and minimum (Min M) moment, moment concurrent actions with maximum (Max V) and minimum (Min V) shear are being considered for load rating.

Spec Check Detail for 6A.4.2.1 Shear-5.6.3.3 Minimum Reinforcement

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.6 Design for Flexural and Axial Effects - B Regions
6A.4.2.1 Shear - 5.6.3 Flexural Members
6A.4.2.1 Shear - 5.6.3.3 Minimum Reinforcement
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Cross Section Properties for Prestress box beam with Rectangular void
-----------------------------------------------------------------
Name: BIII-48   Girder f'c = 5.00(ksi)     Girder f'ci = 4.00(ksi)

Beam Height              =   39.00(in)     Side Wall Thickness      =    5.00(in)
Top Slab Width           =   47.25(in)
Top Slab Thick           =    5.50(in)
Bottom Slab Width        =   48.00(in)
Bottom Slab Thick        =    5.50(in)
Shear Key Top            =    6.00(in)
Shear Key Height         =    6.00(in)
Shear Key Depth          =    0.75(in)
B1                       =    3.00(in)
B2                       =    3.00(in)
B3                       =    3.00(in)
B4                       =    3.00(in)

Slab f'c                 =      0.00(ksi)
Effective Slab Width     =      0.00(in)       Haunch Width             =      0.00(in)
Effective Slab Thickness =      0.00(in)       Haunch Thickness         =      0.00(in)

Input:
fr beam =        0.54ksi
ScTop   =    -8569.07in^3            Mdnc    =     8812.35kip-in
ScBot   =     8734.21in^3            SncBot  =     8734.21in^3
Gamma1 =  1.60
Gamma2 =  1.10
Gamma3 =  1.00 (Prestressed Concrete)
Gamma3 =  0.67 (Reinforced Concrete)

Mcr = Gamma3 * [( gamma1*fr + Gamma2*fcpe)*Sc - Mdnc * (Sc/Snc - 1)]      (5.6.3.3-1)
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	Load Comb	fcpe ksi	fr ksi	Gamma3	Governing Action	Mu kip-in	Vu kip	Sc in^3	Mcr kip-in
STR-I	1, DesInv	2.22	0.54	1.00	Max M	33228.57	127.29	8734.21	28801.18
STR-I	1, DesInv	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	1, DesInv	2.22	0.54	1.00	Max V	32064.13	128.56	8734.21	28801.18
STR-I	1, DesInv	2.22	0.54	1.00	Min V	22779.24	25.01	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Max M	28220.60	106.78	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Max V	27322.31	107.77	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Min V	20159.68	27.88	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Max M	29541.81	111.12	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Max V	28377.37	112.39	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Min V	23878.56	23.80	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Max M	25376.52	94.31	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Max V	24478.24	95.29	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Min V	21007.73	26.95	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Max M	18828.30	70.27	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Min M	8812.35	29.26	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Max V	18295.99	70.86	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Min V	14051.47	23.52	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Max M	17142.93	62.88	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Min M	8812.35	29.26	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Max V	16610.61	63.46	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Min V	14554.01	22.97	8734.21	28801.18

```
Load Combination Legend:

 Code      Vehicle
------------------------
   1     HL-93 (US) - Truck + Lane
   2     HL-93 (US) - Tandem + Lane
```

Figure 1 - 6A.4.2.1 Shear-5.6.3.3 Minimum Reinforcement

Note: Article "LRFD 5.6.3.3 Minimum Reinforcement" will only be applicable for determining Mcr for flexural resistance using the envelope moment.

Spec Check Detail for 6A.4.2.1 Shear-5.7.3.4 Procedures for Determining Shear Resistance

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.7 Shear and Torsion
6A.4.2.1 Shear - 5.7.3 Sectional Design Model
6A.4.2.1 Shear - 5.7.3.4 Procedures for Determining Shear Resistance
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Calculation of Beta/Theta
-------------------------

      Es = 0.000 (kips/in^2)
     phi = 0.900
     f'c = 5.000 (kips/in^2)
     fpc = 0.937 (kips/in^2)
      fy = 60.000 (kips/in^2)
Agg diam = 1.000 (in)
      Vp = 0.000 (kips)
      Ep = 28500.000 (kips/in^2)
 As(pos) = 0.000 (in^2)  (used for Positive Mu)
 As(neg) = 0.000 (in^2)  (used for Negative Mu)
Aps(pos) = 4.284 (in^2)  (used for Positive Mu)
Aps(neg) = 0.306 (in^2)  (used for Negative Mu)
     fpo = 189.000 (kips/in^2)
      Ec = 4592.232 (kips/in^2)

Beta Calc (used in table below) :
     (1) - Beta = 4.8 / (1 + 750 EpsilonS)
     (2) - Beta = ( 4.8 / (1 + 750 EpsilonS) ) * (51 / (39 + sxe) )
                 where:
                    sxe = sx * (1.38 / (ag + 0.63) )

  Mu_calc = Max(Mu, |Vu - Vp| * dv)

Modify MCFT Theta:   No

Modify MCFT Size Effect:   No
fpc / f'c = 0.19
```

Limit State	Load Comb	Epsilon	Theta	Beta	Governing Action	Mu (kip-in)	Mu Calc (kip-in)	Vu (kips)	Nu (kips)	bv (in)	dv (in)	Sx (in)	Sxe (in)	Beta Calc	Act (in^2)	Av (in^2)	As (in^2)
STR-I	1, DesInv	0.002471	37.65	1.68	Max M	33228.57	33228.57	127.29	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	1, DesInv	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	1, DesInv	0.002199	36.70	1.81	Max V	32064.13	32064.13	128.56	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	1, DesInv	0.000000	29.00	4.80	Min V	22779.24	22779.24	25.01	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	1, DesOp	0.001088	32.81	2.64	Max M	28220.60	28220.60	106.78	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	1, DesOp	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	1, DesOp	0.000879	32.08	2.89	Max V	27322.31	27322.31	107.77	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	1, DesOp	0.000000	29.00	4.80	Min V	20159.68	20159.68	27.88	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesInv	0.001444	34.06	2.30	Max M	29541.81	29541.81	111.12	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesInv	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesInv	0.001172	33.10	2.55	Max V	28377.37	28377.37	112.39	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesInv	0.000000	29.00	4.80	Min V	23878.56	23878.56	23.80	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesOp	0.000296	30.04	3.93	Max M	25376.52	25376.52	94.31	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesOp	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesOp	0.000087	29.30	4.51	Max V	24478.24	24478.24	95.29	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesOp	0.000000	29.00	4.80	Min V	21007.73	21007.73	26.95	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	1, DesInv	0.000000	29.00	4.80	Max M	18828.30	18828.30	70.27	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	1, DesInv	0.000000	29.00	4.80	Min M	8812.35	8812.35	29.26	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	1, DesInv	0.000000	29.00	4.80	Max V	18295.99	18295.99	70.86	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	1, DesInv	0.000000	29.00	4.80	Min V	14051.47	14051.47	23.52	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	2, DesInv	0.000000	29.00	4.80	Max M	17142.93	17142.93	62.88	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	2, DesInv	0.000000	29.00	4.80	Min M	8812.35	8812.35	29.26	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	2, DesInv	0.000000	29.00	4.80	Max V	16610.61	16610.61	63.46	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	2, DesInv	0.000000	29.00	4.80	Min V	14554.01	14554.01	22.97	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00

Load Combination Legend:

Code	Vehicle
1	HL-93 (US) - Truck + Lane
2	HL-93 (US) - Tandem + Lane

Figure 2 - 6A.4.2.1 Shear-5.7.3.4 Procedures for Determining Shear Resistance

Spec Check Detail for 6A.4.2.1 Shear-5.7.2.5 Minimum Transverse Reinforcement

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.7 Shear and Torsion
6A.4.2.1 Shear - 5.7.2 General Requirements
6A.4.2.1 Shear - 5.7.2.5 Minimum Transverse Reinforcement
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Check
 Vu > 0.5 * phi * (Vc + Vp)      (5.7.2.3 - 1)
 Av >= 0.0316 * lambda * SQRT(f'c) * bv * s / fy     (5.7.2.5 - 1)
 f'c = 5.000ksi
 fy = 60.000ksi
 phi = 0.900
 lambda = 1.000

Note: fy = Yield strength of transverse reinforcement (ksi) =< 100 ksi.
```

Limit State	Load Comb	Vc (kip)	Vp (kip)	Governing Action	Vu (kip)	Vu> 0.5*phi*(Vc+Vp)	s (in)	bv (in)	Av Provided(in^2)	>= 0.0316 *lambda *SQRT(f'c) *bv * s/fy	Pass/Fail
STR-I	1, DesInv	40.13	0.00	Max M	127.29	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	1, DesInv	114.52	0.00	Min M	37.57	No	12.00	10.00	0.40	----------------n/a----------------	
STR-I	1, DesInv	43.22	0.00	Max V	128.56	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	1, DesInv	114.52	0.00	Min V	25.01	No	12.00	10.00	0.40	----------------n/a----------------	
STR-I	1, DesOp	63.05	0.00	Max M	106.78	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	1, DesOp	114.52	0.00	Min M	37.57	No	12.00	10.00	0.40	----------------n/a----------------	
STR-I	1, DesOp	69.03	0.00	Max V	107.77	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	1, DesOp	114.52	0.00	Min V	27.88	No	12.00	10.00	0.40	----------------n/a----------------	
STR-I	2, DesInv	54.97	0.00	Max M	111.12	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	2, DesInv	114.52	0.00	Min M	37.57	No	12.00	10.00	0.40	----------------n/a----------------	
STR-I	2, DesInv	60.94	0.00	Max V	112.39	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	2, DesInv	114.52	0.00	Min V	23.80	No	12.00	10.00	0.40	----------------n/a----------------	
STR-I	2, DesOp	93.69	0.00	Max M	94.31	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	2, DesOp	114.52	0.00	Min M	37.57	No	12.00	10.00	0.40	----------------n/a----------------	
STR-I	2, DesOp	107.53	0.00	Max V	95.29	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	2, DesOp	114.52	0.00	Min V	26.95	No	12.00	10.00	0.40	----------------n/a----------------	
SER-III	1, DesInv	114.52	0.00	Max M	70.27	Yes	12.00	10.00	0.40	0.14	Pass
SER-III	1, DesInv	114.52	0.00	Min M	29.26	No	12.00	10.00	0.40	----------------n/a----------------	
SER-III	1, DesInv	114.52	0.00	Max V	70.86	Yes	12.00	10.00	0.40	0.14	Pass
SER-III	1, DesInv	114.52	0.00	Min V	23.52	No	12.00	10.00	0.40	----------------n/a----------------	
SER-III	2, DesInv	114.52	0.00	Max M	62.88	Yes	12.00	10.00	0.40	0.14	Pass
SER-III	2, DesInv	114.52	0.00	Min M	29.26	No	12.00	10.00	0.40	----------------n/a----------------	
SER-III	2, DesInv	114.52	0.00	Max V	63.46	Yes	12.00	10.00	0.40	0.14	Pass
SER-III	2, DesInv	114.52	0.00	Min V	22.97	No	12.00	10.00	0.40	----------------n/a----------------	

Load Combination Legend:

Code	Vehicle
1	HL-93 (US) - Truck + Lane
2	HL-93 (US) - Tandem + Lane

Figure 3 - 6A.4.2.1 Shear-5.7.2.5 Minimum Transverse Reinforcement

Spec Check Detail for 6A.4.2.1 Shear-5.7.2.6 Maximum Spacing of Transverse Reinforcement

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.7 Shear and Torsion
6A.4.2.1 Shear - 5.7.2 General Requirements
6A.4.2.1 Shear - 5.7.2.6 Maximum Spacing of Transverse Reinforcement
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Calculation of Shear Stress on the concrete
Vu > 0.5*phi * (Vc+Vp)      (5.8.2.4-1)
  phi = 0.9000
  f'c = 5.000ksi
 -------------------------------------------------------------
```

Limit State	Load Comb	Vc (kip)	Vp (kip)	Governing Action	Vu (kip)	Vu> 0.5*phi*(Vc+Vp)	bv (in)	dv (in)	vu (ksi)	vu< 0.125*f'c	s (in)	Spacing criteria	Status
STR-I	1, DesInv	40.13	0.00	Max M	127.29	TRUE	10.00	33.77	0.42	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	1, DesInv	114.52	0.00	Min M	37.57	FALSE	NA	NA	NA	NA	NA	----------------n/a~	Pass
STR-I	1, DesInv	43.22	0.00	Max V	128.56	TRUE	10.00	33.77	0.42	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	1, DesInv	114.52	0.00	Min V	25.01	FALSE	NA	NA	NA	NA	NA	----------------n/a~	Pass
STR-I	1, DesOp	63.05	0.00	Max M	106.78	TRUE	10.00	33.77	0.35	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	1, DesOp	114.52	0.00	Min M	37.57	FALSE	NA	NA	NA	NA	NA	----------------n/a~	Pass
STR-I	1, DesOp	69.03	0.00	Max V	107.77	TRUE	10.00	33.77	0.35	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	1, DesOp	114.52	0.00	Min V	27.88	FALSE	NA	NA	NA	NA	NA	----------------n/a~	Pass
STR-I	2, DesInv	54.97	0.00	Max M	111.12	TRUE	10.00	33.77	0.37	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	2, DesInv	114.52	0.00	Min M	37.57	FALSE	NA	NA	NA	NA	NA	----------------n/a~	Pass
STR-I	2, DesInv	60.94	0.00	Max V	112.39	TRUE	10.00	33.77	0.37	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	2, DesInv	114.52	0.00	Min V	23.80	FALSE	NA	NA	NA	NA	NA	----------------n/a~	Pass
STR-I	2, DesOp	93.69	0.00	Max M	94.31	TRUE	10.00	33.77	0.31	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	2, DesOp	114.52	0.00	Min M	37.57	FALSE	NA	NA	NA	NA	NA	----------------n/a~	Pass
STR-I	2, DesOp	107.53	0.00	Max V	95.29	TRUE	10.00	33.77	0.31	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	2, DesOp	114.52	0.00	Min V	26.95	FALSE	NA	NA	NA	NA	NA	----------------n/a~	Pass
SER-III	1, DesInv	114.52	0.00	Max M	70.27	TRUE	10.00	33.77	0.23	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
SER-III	1, DesInv	114.52	0.00	Min M	29.26	FALSE	NA	NA	NA	NA	NA	----------------n/a~	Pass
SER-III	1, DesInv	114.52	0.00	Max V	70.86	TRUE	10.00	33.77	0.23	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
SER-III	1, DesInv	114.52	0.00	Min V	23.52	FALSE	NA	NA	NA	NA	NA	----------------n/a~	Pass
SER-III	2, DesInv	114.52	0.00	Max M	62.88	TRUE	10.00	33.77	0.21	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
SER-III	2, DesInv	114.52	0.00	Min M	29.26	FALSE	NA	NA	NA	NA	NA	----------------n/a~	Pass
SER-III	2, DesInv	114.52	0.00	Max V	63.46	TRUE	10.00	33.77	0.21	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
SER-III	2, DesInv	114.52	0.00	Min V	22.97	FALSE	NA	NA	NA	NA	NA	----------------n/a~	Pass

```
Load Combination Legend:

 Code      Vehicle
------------------------
    1     HL-93 (US) - Truck + Lane
    2     HL-93 (US) - Tandem + Lane
```

Figure 4 - 6A.4.2.1 Shear-5.7.2.6 Maximum Spacing of Transverse Reinforcement

Spec Check Detail for 6A.4.2.1 Shear-5.7.3.3 Nominal Shear Resistance

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.7 Shear and Torsion
6A.4.2.1 Shear - 5.7.3 Sectional Design Model
6A.4.2.1 Shear - 5.7.3.3 Nominal Shear Resistance
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Calculation of Shear Resistance Vr
-----------------------------------
 Vc     = 0.0316 * Beta * lambda * SQRT(f'c) * bv * dv                              (5.7.3.3-3)

          Av1 * fy1 * dv (cot(theta) + cot(alpha1)) * sin(alpha1)
 Vs1    = ---------------------------------------------------------- * lambda_duct   (5.7.3.3-4)
                                  s

 Vs2    = Av2 * fy2 * sin(alpha2) * lambda_duct                                     (5.7.3.3-6)
 Vs2Max = 0.095 * lambda * SQRT(f'c) * bv * dv                                      (5.7.3.3-6)
 Vs     = Vs1 + min(Vs2, Vs2Max)

 Post tensioned = FALSE
 lambda_duct = 1.0000

 Vn1    = Vc + Vs + Vp                                                              (5.7.3.3-1)
 Vn2    = 0.25 * f'c * bv * dv + Vp                                                 (5.7.3.3-2)
 Vn     = min(Vn1, Vn2)
 Vr     = phi * Vn                                                                  (5.7.2.1-1)
 where:
 Vc:      Resistance due to concrete.
 Vs1:     Resistance due to stirrups.
 Vs2:     Resistance due to only center 3/4 of sloped portion of the longitudinal bars.   (Article 5.7.3.3)
 Vp:      Resistance due to prestressing.
 Vrs1:    Resistance due to force in inclined bars.
 *Note:   Vr includes the value Vrs1
 Av1:     Area of stirrups.
 fy1:     Yield Strength of stirrups.
 alpha1:  Angle of inclination of stirrups.
 Av2:     Area of bent up longitudinal rebars.
 fy2:     Yield Strength of bent up longitudinal rebars.
 alpha2:  Angle of inclination of bent up longitudinal rebars.
 -----------------------------------------------------------
 Input:
   phi    = 0.900
   f'c    = 5.000 (ksi)
   fy1    = 60.000 (ksi)
   alpha1 = 90.000 (Degrees)
   lambda = 1.000
   Consider inclined forces option: No
   Consider sloped portion of longitudinal rebar option: No
   Consider iterative shear rating option (applies only to General and GeneralAppB shear computation methods): No
   Consider MCFT theta option: No
   Shear computation method: General
   Iteration required:  No

 -----------------------------------------------------------
```

Figure 5 - 6A.4.2.1 Shear-5.7.3.3 Nominal Shear Resistance Part 1

Limit State	Load Combo	Governing Action	Mu (kip-in)	MuDL (kip-in)	MuLL (kip-in)	Vu (kip)	VuDL (kip)	VuLL (kip)	Nu (kip)	bv (in)	dv (in)	s (in)	Av1 (in^2)	Beta	cot (Theta)	Epsilon
STR-I	1, DesInv	Max M	33228.57	11318.68	21909.89	127.29	37.57	89.71	0.00	10.00	33.77	12.00	0.40	1.682	1.296	0.002471
STR-I	1, DesInv	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
STR-I	1, DesInv	Max V	32064.13	11318.68	20745.45	128.56	37.57	90.99	0.00	10.00	33.77	12.00	0.40	1.812	1.342	0.002199
STR-I	1, DesInv	Min V	22779.24	11318.68	11460.56	25.01	37.57	-12.57	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
STR-I	1, DesOp	Max M	28220.60	11318.68	16901.91	106.78	37.57	69.21	0.00	10.00	33.77	12.00	0.40	2.643	1.551	0.001088
STR-I	1, DesOp	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
STR-I	1, DesOp	Max V	27322.31	11318.68	16003.63	107.77	37.57	70.19	0.00	10.00	33.77	12.00	0.40	2.893	1.596	0.000879
STR-I	1, DesOp	Min V	20159.68	11318.68	8841.00	27.88	37.57	-9.69	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
STR-I	2, DesInv	Max M	29541.81	11318.68	18223.13	111.12	37.57	73.54	0.00	10.00	33.77	12.00	0.40	2.304	1.479	0.001444
STR-I	2, DesInv	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
STR-I	2, DesInv	Max V	28377.37	11318.68	17058.69	112.39	37.57	74.82	0.00	10.00	33.77	12.00	0.40	2.554	1.534	0.001172
STR-I	2, DesInv	Min V	23878.56	11318.68	12559.88	23.80	37.57	-13.77	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
STR-I	2, DesOp	Max M	25376.52	11318.68	14057.84	94.31	37.57	56.73	0.00	10.00	33.77	12.00	0.40	3.927	1.729	0.000296
STR-I	2, DesOp	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
STR-I	2, DesOp	Max V	24478.24	11318.68	13159.56	95.29	37.57	57.72	0.00	10.00	33.77	12.00	0.40	4.507	1.782	0.000087
STR-I	2, DesOp	Min V	21007.73	11318.68	9689.05	26.95	37.57	-10.62	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	1, DesInv	Max M	18828.30	8812.35	10015.95	70.27	29.26	41.01	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	1, DesInv	Min M	8812.35	8812.35	0.00	29.26	29.26	0.00	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	1, DesInv	Max V	18295.99	8812.35	9483.63	70.86	29.26	41.59	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	1, DesInv	Min V	14051.47	8812.35	5239.11	23.52	29.26	-5.74	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	2, DesInv	Max M	17142.93	8812.35	8330.57	62.88	29.26	33.62	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	2, DesInv	Min M	8812.35	8812.35	0.00	29.26	29.26	0.00	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	2, DesInv	Max V	16610.61	8812.35	7798.26	63.46	29.26	34.20	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	2, DesInv	Min V	14554.01	8812.35	5741.66	22.97	29.26	-6.30	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000

Load Combination Legend:

Code	Vehicle
1	HL-93 (US) - Truck + Lane
2	HL-93 (US) - Tandem + Lane

Figure 6 - 6A.4.2.1 Shear-5.7.3.3 Nominal Shear Resistance Part 2

Vc (kip)	Vs1 (kip)	Vs2 (kip)	Vs2Max (kip)	Vp (kip)	Vrs1 (kip)	Vn1 (kip)	Vn2 (kip)	--- Override --- Phi	Vn (kip)	Vr (kip)
40.13	87.53	0.00	71.73	0.00	0.00	127.67	422.06	---	---	114.90
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
43.22	90.61	0.00	71.73	0.00	0.00	133.83	422.06	---	---	120.45
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
63.05	104.75	0.00	71.73	0.00	0.00	167.80	422.06	---	---	151.02
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
69.03	107.76	0.00	71.73	0.00	0.00	176.78	422.06	---	---	159.11
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
54.97	99.91	0.00	71.73	0.00	0.00	154.88	422.06	---	---	139.39
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
60.94	103.58	0.00	71.73	0.00	0.00	164.51	422.06	---	---	148.06
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
93.69	116.79	0.00	71.73	0.00	0.00	210.48	422.06	---	---	189.43
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
107.53	120.32	0.00	71.73	0.00	0.00	227.86	422.06	---	---	205.07
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71

Figure 7 - 6A.4.2.1 Shear-5.7.3.3 Nominal Shear Resistance Part 3

In 2022 interim, the load cases shown in the LL column are only envelope shear actions.

Spec Check Detail for 6A.4.2.1 General Load Rating Equation - Concrete Shear

```
6A Load and Resistance Factor Rating
6A.4 Load Rating Procedures
6A.4.2 General Load-Rating Equation
6A.4.2.1 Concrete Shear General
(AASHTO Manual for Bridge Evaluation, Third Edition with 2022 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Shear Rating Factor Calculations

Input:

Condition Factor      =    1.0000
System Factor         =    1.0000
DC Shear (Max)        =   25.2718 (kip)
DC Shear (Min)        =   25.2718 (kip)
DW Shear (Max)        =    3.9900 (kip)
DW Shear (Min)        =    3.9900 (kip)
DW-WS Shear (Max)     =    0.0000 (kip)
DW-WS Shear (Min)     =    0.0000 (kip)

Ignore design & legal shear:  False
Ignore permit shear:  True

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.
```

Load	Load Combo	Limit State	LL (kip)	Adj. LL (kip)	Load Factors DC	DW	DW-WS	LL	Phi	Vn (kip)	-- Override -- Phi	Vn (kip)	RF	Capacity (Ton)
DesignInv	1	STR-I	51.99	---	1.25	1.50	1.50	1.75	0.90	127.44	---	---	0.848	30.51
DesignInv	1	STR-I	-7.18	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	19.917	717.02
DesignOp	1	STR-I	51.99	---	1.25	1.50	1.50	1.35	0.90	167.47	---	---	1.612	58.03
DesignOp	1	STR-I	-7.18	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	25.819	929.47
DesignInv	2	STR-I	42.75	---	1.25	1.50	1.50	1.75	0.90	154.53	---	---	1.357	48.84
DesignInv	2	STR-I	-7.87	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	18.174	654.26
DesignOp	2	STR-I	42.75	---	1.25	1.50	1.50	1.35	0.90	209.88	---	---	2.622	94.38
DesignOp	2	STR-I	-7.87	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	23.559	848.12

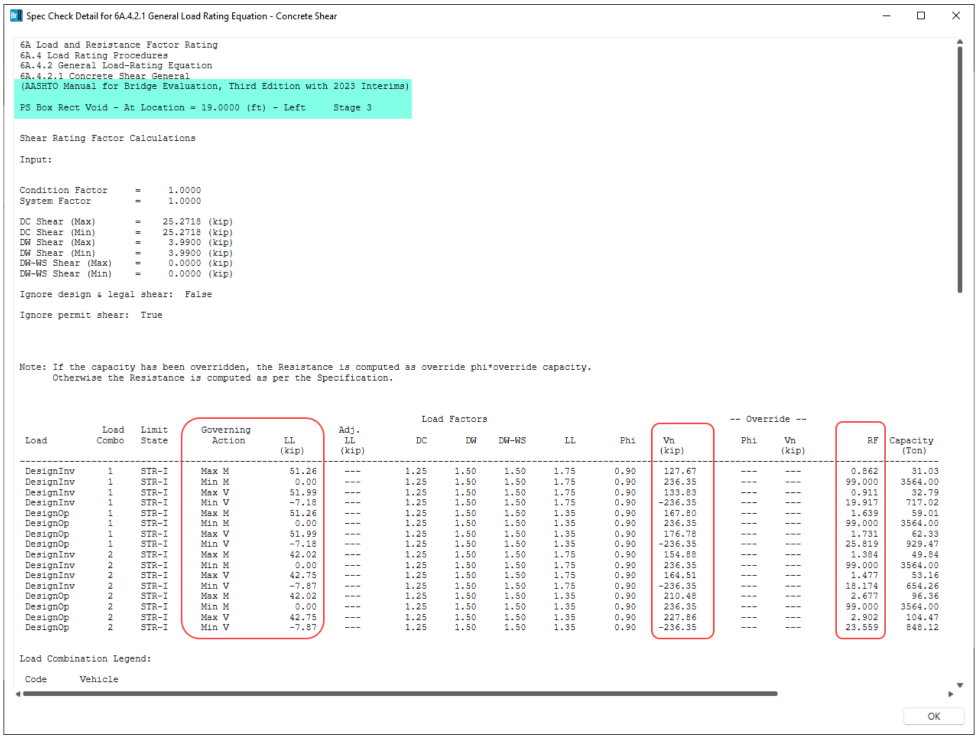
Load Combination Legend:

Code	Vehicle
1	HL-93 (US) - Truck + Lane

OK

Figure 8 - 6A.4.2.1 General Load Rating Equation - Concrete Shear MBE 3rd edition, 2022 interim

In 2023 interim, the LL values shown for governing action Max V and Min V are the envelope shear values. For govening action Max M and Min M, shear concurrent with moment are considered. This results in new load cases.



Spec Check Detail for 6A.4.2.1 General Load Rating Equation - Concrete Shear

6A Load and Resistance Factor Rating
6A.4 Load Rating Procedures
6A.4.2 General Load-Rating Equation
6A.4.2.1 Concrete Shear General
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left Stage 3

Shear Rating Factor Calculations

Input:

Condition Factor = 1.0000
System Factor = 1.0000

DC Shear (Max) = 25.2718 (kip)
DC Shear (Min) = 25.2718 (kip)
DW Shear (Max) = 3.9900 (kip)
DW Shear (Min) = 3.9900 (kip)
DW-WS Shear (Max) = 0.0000 (kip)
DW-WS Shear (Min) = 0.0000 (kip)

Ignore design & legal shear: False

Ignore permit shear: True

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.

Load	Load Combo	Limit State	Governing Action	LL (kip)	Adj. LL (kip)	Load Factors DC	DW	DW-WS	LL	Phi	Vn (kip)	-- Override -- Phi	Vn (kip)	RF	Capacity (Ton)
DesignInv	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.75	0.90	127.67	---	---	0.862	31.03
DesignInv	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.75	0.90	133.83	---	---	0.911	32.79
DesignInv	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	19.917	717.02
DesignOp	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.35	0.90	167.80	---	---	1.639	59.01
DesignOp	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.35	0.90	176.78	---	---	1.731	62.33
DesignOp	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	25.819	929.47
DesignInv	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.75	0.90	154.88	---	---	1.384	49.84
DesignInv	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.75	0.90	164.51	---	---	1.477	53.16
DesignInv	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	18.174	654.26
DesignOp	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.35	0.90	210.48	---	---	2.677	96.36
DesignOp	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.35	0.90	227.86	---	---	2.902	104.47
DesignOp	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	23.559	848.12

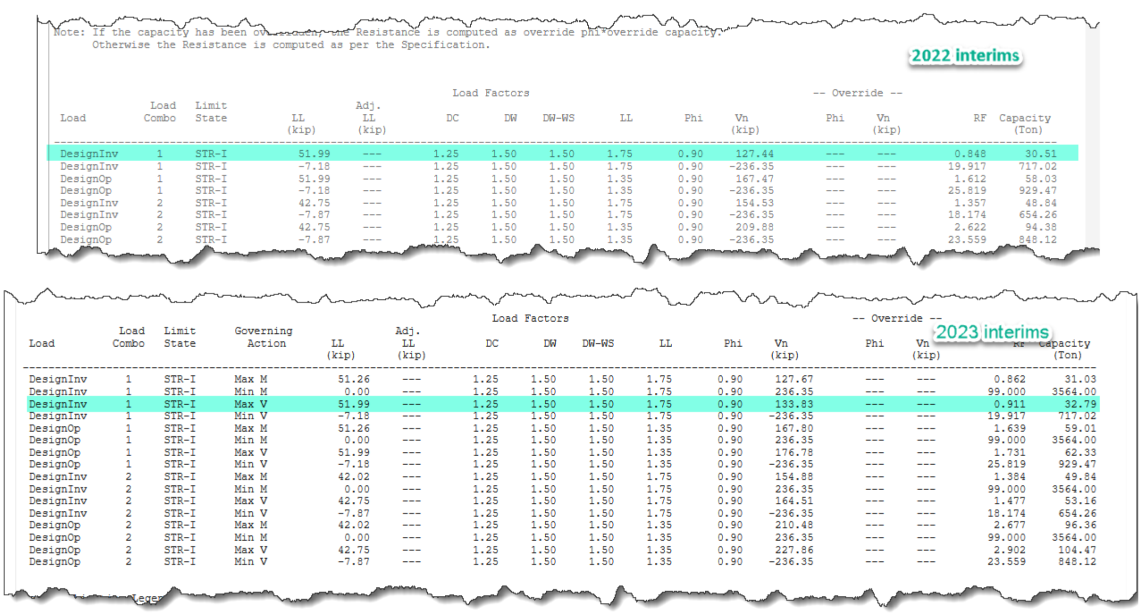
Load Combination Legend:

Code Vehicle

OK

Figure 9 - 6A.4.2.1 General Load Rating Equation -Concrete Shear MBE 3rd edition, 2023 interim

Highlighted portion in image below shows the improvement of rating factor from 0.848 in 2022 interim to 0.911 in 2023 interim for Design inventory, load case 1, STR-1 limit state.



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.

Load	Load Combo	Limit State	LL (kip)	Adj. LL (kip)	Load Factors DC	DW	DW-WS	LL	Phi	Vn (kip)	-- Override -- Phi	Vn (kip)	RF	Capacity (Ton)
DesignInv	1	STR-I	51.99	---	1.25	1.50	1.50	1.75	0.90	127.44	---	---	0.848	30.51
DesignInv	1	STR-I	-7.18	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	19.917	717.02
DesignOp	1	STR-I	51.99	---	1.25	1.50	1.50	1.35	0.90	167.47	---	---	1.612	58.03
DesignOp	1	STR-I	-7.18	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	25.819	929.47
DesignInv	2	STR-I	42.75	---	1.25	1.50	1.50	1.75	0.90	154.53	---	---	1.357	48.84
DesignInv	2	STR-I	-7.87	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	18.174	654.26
DesignOp	2	STR-I	42.75	---	1.25	1.50	1.50	1.35	0.90	209.88	---	---	2.622	94.38
DesignOp	2	STR-I	-7.87	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	23.559	848.12

Load	Load Combo	Limit State	Governing Action	LL (kip)	Adj. LL (kip)	Load Factors DC	DW	DW-WS	LL	Phi	Vn (kip)	-- Override -- Phi	Vn (kip)	RF	Capacity (Ton)
DesignInv	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.75	0.90	127.67	---	---	0.862	31.03
DesignInv	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.75	0.90	133.83	---	---	0.911	32.79
DesignInv	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	19.917	717.02
DesignOp	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.35	0.90	167.80	---	---	1.639	59.01
DesignOp	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.35	0.90	176.78	---	---	1.731	62.33
DesignOp	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	25.819	929.47
DesignInv	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.75	0.90	154.88	---	---	1.384	49.84
DesignInv	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.75	0.90	164.51	---	---	1.477	53.16
DesignInv	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	18.174	654.26
DesignOp	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.35	0.90	210.48	---	---	2.677	96.36
DesignOp	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.35	0.90	227.86	---	---	2.902	104.47
DesignOp	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	23.559	848.12

Figure 10 - 6A.4.2.1 General Load Rating Equation -Concrete Shear rating comparison

Spec Check Detail for 6A.5.8 Evaluation for Shear

```
6A Load and Resistance Factor Rating
6A.5 Concrete Structures
6A.5.8 Evaluation for Shear
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Longitudinal Reinforcement
--------------------------

From LRFD 5.7.3.5-1

LHS or Tr  = Aps*fps + As*fy

        |Mu|          Nu     /| Vu         |           \
RHS = -------- + 0.5 ----- + ||---- - Vp| -0.5 * Vs| * cot(theta)  (LRFD 5.7.3.5-1)
       dv*phif        phic   \|phiv        |           /

                    |MuDL|                     NuDL                |VuDL      |
T(DL) = SignMDL * -------- + 0.5 * SignNDL * ---- + (SignVDLp * |---- - Vp| - 0.5 * Vs) * cot(theta), where Vs = min(Vs, Vu/phiv)  (Based on LRFD 5.7.3.5-1 and MBE 6A.5.8)
                   dv*phif                     phic                |phiv      |

                    |MuLL|                     NuLL               |VuLL|
T(LL) = SignMLL * -------- + 0.5 * SignNLL * ---- + (SignVLL * |----| ) * cot(theta)                                  (Based on LRFD 5.7.3.5-1 and MBE 6A.5.8)
                   dv*phif                     phic               |phiv|

Where:

                                     VuDL + VuLL                VuDL
Mu = MuDL + MuLL; Nu = NuDL + NuLL; VT = ----------- - Vp; VuDLp = -------- - Vp
                                        phiv                    phiv

                  / MuDL \                   / NuDL \                    / VuDLp \                   / MuLL \                   / NuLL \                   / VuLL \
SignMDL = Sign of |------|; SignNDL = Sign of | ------ |; SignVDLp  = Sign of |  -----  |; SignMLL = Sign of |  -----  |; SignNLL = Sign of |  -----  |; SignVLL = Sign of |  -----  |
                  \  Mu  /                   \  Nu  /                    \  VT   /                   \  Mu  /                   \  Nu  /                   \  VT  /

     T(r) - T(DL)
RF = ------------
        T(LL)

Ignore design & legal shear      :  No
Ignore permit shear              :  Yes
Consider iterative shear rating  :  No
Consider MCFT theta              :  No
Shear computation method type    :  General
Iteration required               :  No

phif = 1.000
phic = 0.750
phiv = 0.900

 ---------------------------------------------------------

  As(pos)   =          0.000  (in^2)    (used for Positive Mu)
  As(neg)   =          0.000  (in^2)    (used for Negative Mu)
  fy(pos)   =          0.000  (ksi)     (used for Positive Mu)
  fy(neg)   =          0.000  (ksi)     (used for Negative Mu)
 Aps(pos)   =          4.284  (in^2)    (used for Positive Mu)
 Aps(neg)   =          0.306  (in^2)    (used for Negative Mu)
 fps(pos)   =        245.606  (ksi)     (used for Positive Mu)
 fps(neg)   =        141.252  (ksi)     (used for Negative Mu)
  Bv(pos)   =         10.000  (in)      (used for Positive Mu)
  Bv(neg)   =         10.000  (in)      (used for Negative Mu)
  Dv(pos)   =         33.765  (in)      (used for Positive Mu)
  Dv(neg)   =         28.080  (in)      (used for Negative Mu)
```

Figure 11 - 6A.5.8 Evaluation for Shear MBE 3rd edition, 2023 interim

Limit State	Load Comb	dv (in)	As*fy (kips)	Aps*fps (kips)	Tr (kips)	MuDL (kip-in)	NuDL (kips)	VuDL (kips)	Vp (kips)	Governing Action	MuLL (kip-in)	NuLL (kips)	VuLL (kips)	epsilon	beta	theta (Deg.)	Av (in^2)	s (in)	Vs (kips)	TDL (kips)	TLL (kips)	LHS/RHS	RF	Capacity (Ton)
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	21909.89	0.00	89.71	0.002471	1.68	37.65	0.40	12.00	87.53	332.60	778.10	0.95	0.925	33.29
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00	0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	3564.00
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	20745.45	0.00	90.99	0.002199	1.81	36.70	0.40	12.00	90.61	330.45	750.05	0.97	0.962	34.64
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	11460.56	0.00	-12.57	0.000000	4.80	29.00	0.40	12.00	121.83	385.47	314.23	1.50	2.122	76.38
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	16901.91	0.00	69.21	0.001088	2.64	32.81	0.40	12.00	104.75	318.74	619.85	1.12	1.183	42.60
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00	0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	3564.00
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	16003.63	0.00	70.19	0.000879	2.89	32.08	0.40	12.00	107.76	315.87	598.42	1.15	1.230	44.30
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	8841.00	0.00	-9.69	0.000000	4.80	29.00	0.40	12.00	121.83	382.59	242.41	1.68	2.762	99.44
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	18223.13	0.00	73.54	0.001444	2.30	34.06	0.40	12.00	99.91	323.08	660.60	1.07	1.104	39.73
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00	0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	3564.00
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	17058.69	0.00	74.82	0.001172	2.55	33.10	0.40	12.00	103.58	319.82	632.72	1.10	1.157	41.67
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	12559.88	0.00	-13.77	0.000000	4.80	29.00	0.40	12.00	121.83	386.68	344.37	1.44	1.932	69.57
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	14057.84	0.00	56.73	0.000296	3.93	30.04	0.40	12.00	116.79	316.81	525.36	1.25	1.400	50.39
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00	0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	3564.00
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	13159.56	0.00	57.72	0.000087	4.51	29.30	0.40	12.00	120.32	315.28	504.00	1.28	1.462	52.63
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	9689.05	0.00	-10.62	0.000000	4.80	29.00	0.40	12.00	121.83	383.53	265.66	1.62	2.517	90.61

Figure 12 - 6A.5.8 Evaluation for Shear MBE 3rd edition, 2023 interim

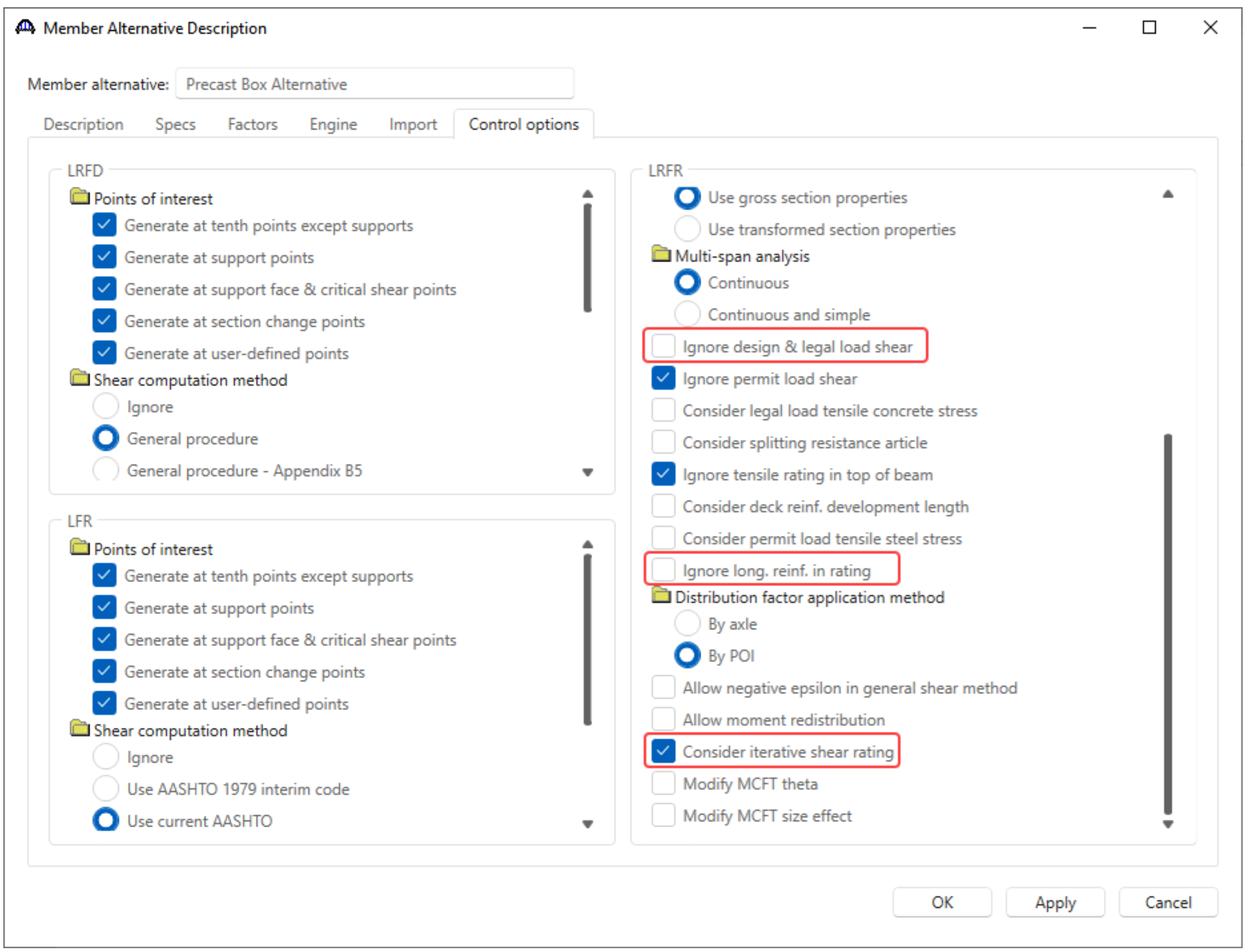
Control option added to consider iterative shear rating

This section details the effects of considering an iterative process to compute the shear capacity used in the LRFR shear rating of concrete bridges. The shear strength for a load rating with Modified Compression Field Theory (MCFT) is an iterative process due to the underlying differences in strain's role in determining shear capacity in design versus load rating. In the iterative process, the factored shear capacity (C = PhiC * PhiS * φVn) is compared to the applied Vu. If they are not equal, iterations will begin by updating Vu, Mu and Nu by proportionally increasing or decreasing the live load portion of these force effects until the C is equal to the applied Vu. This is applicable to all concrete structures, i.e., reinforced concrete, prestressed concrete, post tensioned concrete and reinforced concrete box culverts.

Member Alternative Description – Control options

Navigate to the member alternative Precast Box Alternative of member **G2**, double click on it (or click the **Open** button from the **WORKSPACE** ribbon) to open its **Member Alternative Description** window. Navigate to the **Control options** tab as shown below.

Check the box - **Consider iterative shear rating** as shown below.

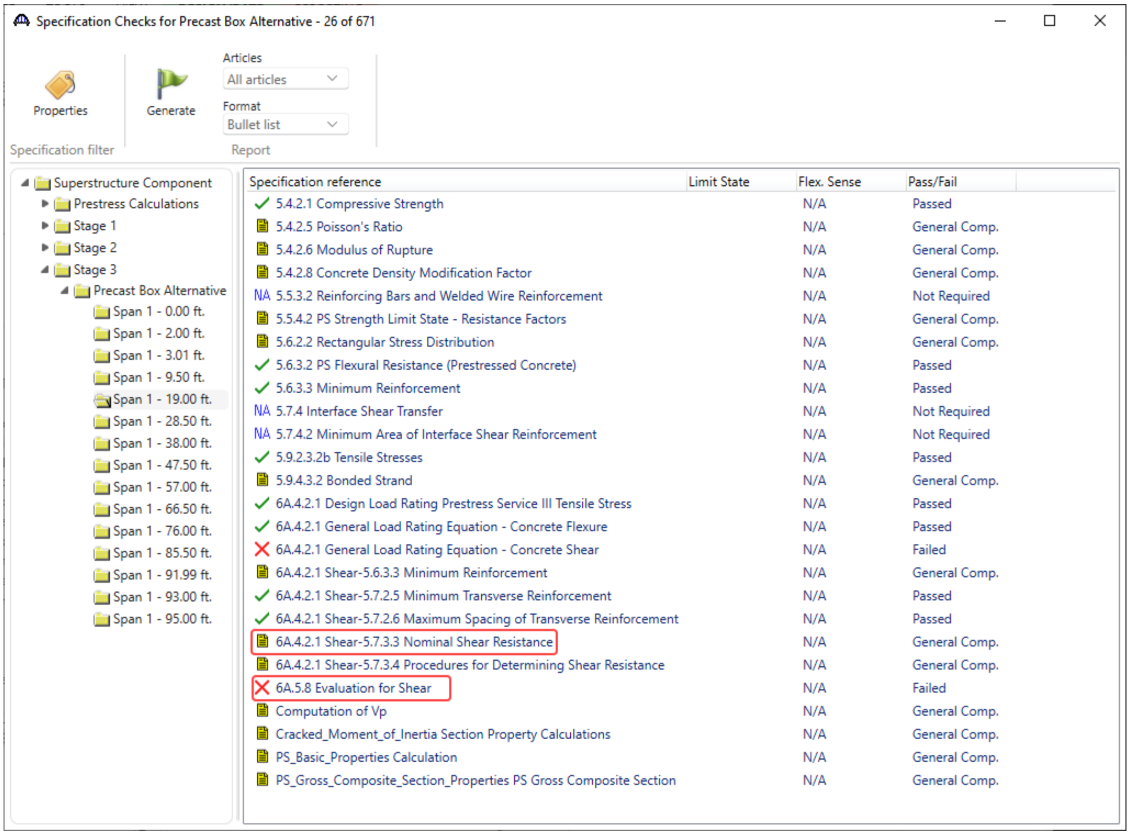


Click **OK** to apply the data and close the window.

Run an LRFR analysis using the analysis settings shown in the previous step.

Specification Check Detail

Once the analysis is complete, open the Specification Check Detail. The specification check articles for the analyzed member alternative for Stage 3 at Span 1 – 19.00 ft, is shown below. Highlighted are the articles where the iteration process is detailed.



Double click on the 6A.4.2.1 Shear-5.7.3.3 Nominal Shear Resistance article to view the iterations. Additional columns in the final iteration table (shown below) details the status of iteration, convergence, and any failure reason, if applicable, for each load case. If iterations for a given load case converge, then this table will show the result of the final iteration. The capacity from the final iteration is used in the rating equation. If the iteration process does not converge, then the corresponding row from the initial capacity table will be used.

Spec Check Detail for 6A.4.2.1 Shear-5.7.3.3 Nominal Shear Resistance

Limit State	Load Combo	Governing Action	Mu (kip-in)	MuDL (kip-in)	MuLL (kip-in)	Vu (kip)	VuDL (kip)	VuLL (kip)	Nu (kip)	bv (in)	dv (in)
STR-I	1, DesInv	Max M	33228.57	11318.68	21909.89	127.29	37.57	89.71	0.00	10.00	33.77
STR-I	1, DesInv	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77
STR-I	1, DesInv	Max V	32064.13	11318.68	20745.45	128.56	37.57	90.99	0.00	10.00	33.77
STR-I	1, DesInv	Min V	22779.24	11318.68	11460.56	25.01	37.57	-12.57	0.00	10.00	33.77
STR-I	1, DesOp	Max M	28220.60	11318.68	16901.91	106.78	37.57	69.21	0.00	10.00	33.77
STR-I	1, DesOp	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77
STR-I	1, DesOp	Max V	27322.31	11318.68	16003.63	107.77	37.57	70.19	0.00	10.00	33.77
STR-I	1, DesOp	Min V	20159.68	11318.68	8841.00	27.88	37.57	-9.69	0.00	10.00	33.77
STR-I	2, DesInv	Max M	29541.81	11318.68	18223.13	111.12	37.57	73.54	0.00	10.00	33.77
STR-I	2, DesInv	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77
STR-I	2, DesInv	Max V	28377.37	11318.68	17058.69	112.39	37.57	74.82	0.00	10.00	33.77
STR-I	2, DesInv	Min V	23878.56	11318.68	12559.88	23.80	37.57	-13.77	0.00	10.00	33.77
STR-I	2, DesOp	Max M	25376.52	11318.68	14057.84	94.31	37.57	56.73	0.00	10.00	33.77
STR-I	2, DesOp	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77
STR-I	2, DesOp	Max V	24478.24	11318.68	13159.56	95.29	37.57	57.72	0.00	10.00	33.77
STR-I	2, DesOp	Min V	21007.73	11318.68	9689.05	26.95	37.57	-10.62	0.00	10.00	33.77
SER-III	1, DesInv	Max M	18828.30	8812.35	10015.95	70.27	29.26	41.01	0.00	10.00	33.77
SER-III	1, DesInv	Min M	8812.35	8812.35	0.00	29.26	29.26	0.00	0.00	10.00	33.77
SER-III	1, DesInv	Max V	18295.99	8812.35	9483.63	70.86	29.26	41.59	0.00	10.00	33.77
SER-III	1, DesInv	Min V	14051.47	8812.35	5239.11	23.52	29.26	-5.74	0.00	10.00	33.77
SER-III	2, DesInv	Max M	17142.93	8812.35	8330.57	62.88	29.26	33.62	0.00	10.00	33.77
SER-III	2, DesInv	Min M	8812.35	8812.35	0.00	29.26	29.26	0.00	0.00	10.00	33.77
SER-III	2, DesInv	Max V	16610.61	8812.35	7798.26	63.46	29.26	34.20	0.00	10.00	33.77
SER-III	2, DesInv	Min V	14554.01	8812.35	5741.66	22.97	29.26	-6.30	0.00	10.00	33.77

Limit State	Load Combo	Governing Action	s (in)	Av1 (in^2)	Beta	cot (Theta)	Epsilon	Vc (kip)	Vs1 (kip)	Vs2 (kip)	Vs2Max (kip)	Vp (kip)	Vrsl (kip)	Vn1 (kip)	Vn2 (kip)	--- Override --- Phi	Vn (kip)	Vr (kip)
STR-I	1, DesInv	Max M	12.00	0.40	1.682	1.296	0.002471	40.13	87.53	0.00	71.73	0.00	0.00	127.67	422.06	---	---	114.90
STR-I	1, DesInv	Min M	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
STR-I	1, DesInv	Max V	12.00	0.40	1.812	1.342	0.002199	43.22	90.61	0.00	71.73	0.00	0.00	133.83	422.06	---	---	120.45
STR-I	1, DesInv	Min V	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
STR-I	1, DesOp	Max M	12.00	0.40	2.643	1.551	0.001088	63.05	104.75	0.00	71.73	0.00	0.00	167.80	422.06	---	---	151.02
STR-I	1, DesOp	Min M	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
STR-I	1, DesOp	Max V	12.00	0.40	2.893	1.596	0.000879	69.03	107.76	0.00	71.73	0.00	0.00	176.78	422.06	---	---	159.11
STR-I	1, DesOp	Min V	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
STR-I	2, DesInv	Max M	12.00	0.40	2.304	1.479	0.001444	54.97	99.91	0.00	71.73	0.00	0.00	154.88	422.06	---	---	139.39
STR-I	2, DesInv	Min M	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
STR-I	2, DesInv	Max V	12.00	0.40	2.554	1.534	0.001172	60.94	103.58	0.00	71.73	0.00	0.00	164.51	422.06	---	---	148.06
STR-I	2, DesInv	Min V	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
STR-I	2, DesOp	Max M	12.00	0.40	3.927	1.729	0.000296	93.69	116.79	0.00	71.73	0.00	0.00	210.48	422.06	---	---	189.43
STR-I	2, DesOp	Min M	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
STR-I	2, DesOp	Max V	12.00	0.40	4.507	1.782	0.000087	107.53	120.32	0.00	71.73	0.00	0.00	227.86	422.06	---	---	205.07
STR-I	2, DesOp	Min V	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
SER-III	1, DesInv	Max M	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
SER-III	1, DesInv	Min M	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
SER-III	1, DesInv	Max V	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
SER-III	1, DesInv	Min V	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
SER-III	2, DesInv	Max M	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
SER-III	2, DesInv	Min M	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
SER-III	2, DesInv	Max V	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
SER-III	2, DesInv	Min V	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71

```
NOTE: In the table below, live load is increased or decreased to achieve, if possible, the final shear capacity when
    C = VuDL + VuLL = Vu
  where shear rating capacity
    C = phiC * phiS * phi * Vn                                   (6A.4.2.1-2)
  with condition, system, and resistance factors
    phiC = 1.000
    phiS = 1.000
    phi  = 0.900
  and phiC * phiS >= 0.85
```

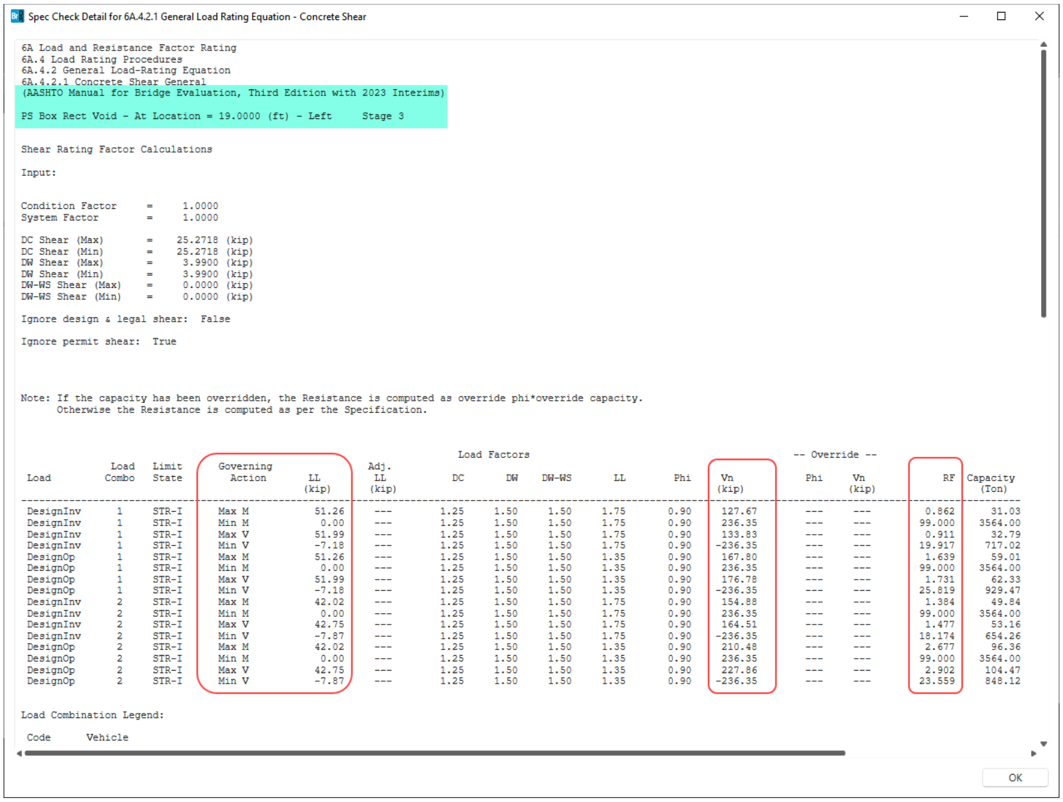
Limit State	Load Combo	Governing Action	Mu (kip-in)	MuDL (kip-in)	MuLL (kip-in)	Vu (kip)	VuDL (kip)	VuLL (kip)	Nu (kip)	bv (in)	dv (in)
STR-I	1, DesInv	Max M	31965.50	11318.68	20646.82	122.11	37.57	84.54	0.00	10.00	33.77
STR-I	1, DesInv	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77
STR-I	1, DesInv	Max V	31298.33	11318.68	19979.65	125.20	37.57	87.63	0.00	10.00	33.77
STR-I	1, DesInv	Min V	109188.20	11318.68	97869.52	-69.74	37.57	-107.31	0.00	10.00	33.77
STR-I	1, DesOp	Max M	31965.49	11318.68	20646.81	122.11	37.57	84.54	0.00	10.00	33.77
STR-I	1, DesOp	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77
STR-I	1, DesOp	Max V	31298.30	11318.68	19979.62	125.20	37.57	87.63	0.00	10.00	33.77
STR-I	1, DesOp	Min V	109188.16	11318.68	97869.48	-69.74	37.57	-107.31	0.00	10.00	33.77
STR-I	2, DesInv	Max M	32107.99	11318.68	20789.31	121.47	37.57	83.90	0.00	10.00	33.77
STR-I	2, DesInv	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77
STR-I	2, DesInv	Max V	31298.32	11318.68	19979.64	125.20	37.57	87.63	0.00	10.00	33.77
STR-I	2, DesInv	Min V	109188.22	11318.68	97869.53	-69.74	37.57	-107.31	0.00	10.00	33.77
STR-I	2, DesOp	Max M	32108.06	11318.68	20789.38	121.47	37.57	83.90	0.00	10.00	33.77
STR-I	2, DesOp	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77
STR-I	2, DesOp	Max V	31298.29	11318.68	19979.60	125.20	37.57	87.63	0.00	10.00	33.77
STR-I	2, DesOp	Min V	109188.17	11318.68	97869.49	-69.74	37.57	-107.31	0.00	10.00	33.77
SER-III	1, DesInv	Max M	31740.40	8812.35	22928.05	123.14	29.26	93.88	0.00	10.00	33.77
SER-III	1, DesInv	Min M	8812.35	8812.35	0.00	29.26	29.26	0.00	0.00	10.00	33.77
SER-III	1, DesInv	Max V	31006.19	8812.35	22193.84	126.60	29.26	97.34	0.00	10.00	33.77
SER-III	1, DesInv	Min V	99100.49	8812.35	90288.14	-69.74	29.26	-99.00	0.00	10.00	33.77
SER-III	2, DesInv	Max M	31897.41	8812.35	23085.06	122.42	29.26	93.16	0.00	10.00	33.77
SER-III	2, DesInv	Min M	8812.35	8812.35	0.00	29.26	29.26	0.00	0.00	10.00	33.77
SER-III	2, DesInv	Max V	31006.19	8812.35	22193.84	126.60	29.26	97.34	0.00	10.00	33.77
SER-III	2, DesInv	Min V	99100.50	8812.35	90288.14	-69.74	29.26	-99.00	0.00	10.00	33.77

Limit State	Load Combo	Governing Action	s (in)	Av1 (in^2)	Beta	cot (Theta)	Epsilon	Vc (kip)	Vs1 (kip)	Vs2 (kip)	Vs2Max (kip)	Vp (kip)	Vrsl (kip)	Vn1 (kip)	Vn2 (kip)	--- Override --- Phi	Vn (kip)	C (kip)	Iterated?	Converged?	Failure Reason
STR-I	1, DesInv	Max M	12.00	0.40	1.852	1.355	0.002122	44.18	91.50	0.00	71.73	0.00	0.00	135.68	422.06	---	---	122.12	Yes	Yes	--
STR-I	1, DesInv	Min M	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71	Yes	No	Zero live load
STR-I	1, DesInv	Max V	12.00	0.40	1.928	1.379	0.001986	46.00	93.12	0.00	71.73	0.00	0.00	139.12	422.06	---	---	125.21	Yes	Yes	--
STR-I	1, DesInv	Min V	12.00	0.40	0.873	0.839	0.006000	20.82	56.66	0.00	71.73	0.00	0.00	77.49	422.06	---	---	69.74	Yes	Yes	--
STR-I	1, DesOp	Max M	12.00	0.40	1.852	1.355	0.002122	44.18	91.50	0.00	71.73	0.00	0.00	135.68	422.06	---	---	122.12	Yes	Yes	--
STR-I	1, DesOp	Min M	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71	Yes	No	Zero live load
STR-I	1, DesOp	Max V	12.00	0.40	1.928	1.379	0.001986	46.00	93.12	0.00	71.73	0.00	0.00	139.12	422.06	---	---	125.21	Yes	Yes	--
STR-I	1, DesOp	Min V	12.00	0.40	0.873	0.839	0.006000	20.82	56.66	0.00	71.73	0.00	0.00	77.49	422.06	---	---	69.74	Yes	Yes	--
STR-I	2, DesInv	Max M	12.00	0.40	1.836	1.350	0.002152	43.81	91.16	0.00	71.73	0.00	0.00	134.97	422.06	---	---	121.47	Yes	Yes	--
STR-I	2, DesInv	Min M	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71	Yes	No	Zero live load
STR-I	2, DesInv	Max V	12.00	0.40	1.928	1.379	0.001986	46.00	93.12	0.00	71.73	0.00	0.00	139.12	422.06	---	---	125.21	Yes	Yes	--
STR-I	2, DesInv	Min V	12.00	0.40	0.873	0.839	0.006000	20.82	56.66	0.00	71.73	0.00	0.00	77.49	422.06	---	---	69.74	Yes	Yes	--
STR-I	2, DesOp	Max M	12.00	0.40	1.836	1.350	0.002152	43.81	91.16	0.00	71.73	0.00	0.00	134.97	422.06	---	---	121.47	Yes	Yes	--
STR-I	2, DesOp	Min M	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71	Yes	No	Zero live load
STR-I	2, DesOp	Max V	12.00	0.40	1.928	1.379	0.001986	46.00	93.12	0.00	71.73	0.00	0.00	139.12	422.06	---	---	125.21	Yes	Yes	--
STR-I	2, DesOp	Min V	12.00	0.40	0.873	0.839	0.006000	20.82	56.66	0.00	71.73	0.00	0.00	77.49	422.06	---	---	69.74	Yes	Yes	--
SER-III	1, DesInv	Max M	12.00	0.40	1.877	1.363	0.002076	44.78	92.04	0.00	71.73	0.00	0.00	136.82	422.06	---	---	123.14	Yes	Yes	--
SER-III	1, DesInv	Min M	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71	Yes	No	Zero live load
SER-III	1, DesInv	Max V	12.00	0.40	1.963	1.389	0.001927	46.84	93.83	0.00	71.73	0.00	0.00	140.67	422.06	---	---	126.60	Yes	Yes	--
SER-III	1, DesInv	Min V	12.00	0.40	0.873	0.839	0.006000	20.82	56.66	0.00	71.73	0.00	0.00	77.49	422.06	---	---	69.74	Yes	Yes	--
SER-III	2, DesInv	Max M	12.00	0.40	1.859	1.357	0.002109	44.36	91.66	0.00	71.73	0.00	0.00	136.03	422.06	---	---	122.42	Yes	Yes	--
SER-III	2, DesInv	Min M	12.00	0.40	4.800	1.804	0.000000	114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71	Yes	No	Zero live load
SER-III	2, DesInv	Max V	12.00	0.40	1.963	1.389	0.001927	46.84	93.83	0.00	71.73	0.00	0.00	140.67	422.06	---	---	126.60	Yes	Yes	--
SER-III	2, DesInv	Min V	12.00	0.40	0.873	0.839	0.006000	20.82	56.66	0.00	71.73	0.00	0.00	77.49	422.06	---	---	69.74	Yes	Yes	--

OK

Figure 13 - 6A.4.2.1 Shear-5.7.3.3 Nominal Shear Resistance

Here is a comparison of rating factors at this location with and without iterations.



Spec Check Detail for 6A.4.2.1 General Load Rating Equation - Concrete Shear

6A Load and Resistance Factor Rating
6A.4 Load Rating Procedures
6A.4.2 General Load-Rating Equation
6A.4.2.1 Concrete Shear General
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left Stage 3

Shear Rating Factor Calculations

Input:

Condition Factor = 1.0000
System Factor = 1.0000

DC Shear (Max) = 25.2718 (kip)
DC Shear (Min) = 25.2718 (kip)
DW Shear (Max) = 3.9900 (kip)
DW Shear (Min) = 3.9900 (kip)
DW-WS Shear (Max) = 0.0000 (kip)
DW-WS Shear (Min) = 0.0000 (kip)

Ignore design & legal shear: False

Ignore permit shear: True

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.

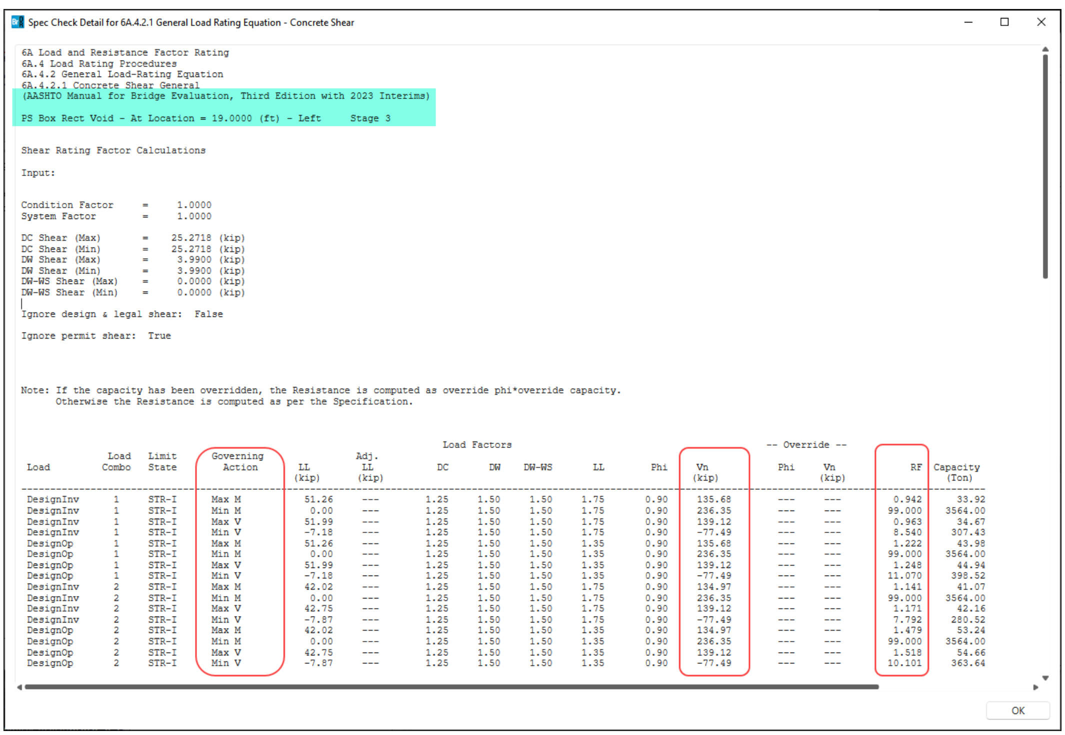
Load	Load Combo	Limit State	Governing Action	LL (kip)	Adj. LL (kip)	Load Factors DC	DW	DW-WS	LL	Phi	Vn (kip)	-- Override -- Phi	Vn (kip)	RF	Capacity (Ton)
DesignInv	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.75	0.90	127.67	---	---	0.862	31.03
DesignInv	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.75	0.90	133.83	---	---	0.911	32.79
DesignInv	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	19.917	717.02
DesignOp	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.35	0.90	167.80	---	---	1.639	59.01
DesignOp	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.35	0.90	176.78	---	---	1.731	62.33
DesignOp	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	25.819	929.47
DesignInv	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.75	0.90	154.88	---	---	1.384	49.84
DesignInv	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.75	0.90	164.51	---	---	1.477	53.16
DesignInv	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	18.174	654.26
DesignOp	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.35	0.90	210.48	---	---	2.677	96.36
DesignOp	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.35	0.90	227.86	---	---	2.902	104.47
DesignOp	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	23.559	848.12

Load Combination Legend:

Code Vehicle

OK

Figure 14 - 6A.4.2.1 General Load Rating Equation - Concrete Shear without iterations



Spec Check Detail for 6A.4.2.1 General Load Rating Equation - Concrete Shear

6A Load and Resistance Factor Rating
6A.4 Load Rating Procedures
6A.4.2 General Load-Rating Equation
6A.4.2.1 Concrete Shear General
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left Stage 3

Shear Rating Factor Calculations

Input:

Condition Factor = 1.0000
System Factor = 1.0000

DC Shear (Max) = 25.2718 (kip)
DC Shear (Min) = 25.2718 (kip)
DW Shear (Max) = 3.9900 (kip)
DW Shear (Min) = 3.9900 (kip)
DW-WS Shear (Max) = 0.0000 (kip)
DW-WS Shear (Min) = 0.0000 (kip)

Ignore design & legal shear: False

Ignore permit shear: True

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.

Load	Load Combo	Limit State	Governing Action	LL (kip)	Adj. LL (kip)	Load Factors DC	DW	DW-WS	LL	Phi	Vn (kip)	-- Override -- Phi	Vn (kip)	RF	Capacity (Ton)
DesignInv	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.75	0.90	135.68	---	---	0.942	33.92
DesignInv	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.75	0.90	139.12	---	---	0.963	34.67
DesignInv	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.75	0.90	-77.49	---	---	8.540	307.43
DesignOp	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.35	0.90	135.68	---	---	1.222	43.98
DesignOp	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.35	0.90	139.12	---	---	1.248	44.94
DesignOp	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.35	0.90	-77.49	---	---	11.070	398.52
DesignInv	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.75	0.90	134.97	---	---	1.141	41.07
DesignInv	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.75	0.90	139.12	---	---	1.171	42.16
DesignInv	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.75	0.90	-77.49	---	---	7.792	280.52
DesignOp	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.35	0.90	134.97	---	---	1.479	53.24
DesignOp	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.35	0.90	139.12	---	---	1.518	54.66
DesignOp	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.35	0.90	-77.49	---	---	10.101	363.64

OK

Figure 15 - 6A.4.2.1 General Load Rating Equation - Concrete Shear with iterations

Image below highlights some examples of improvements in rating factors with the iteration process.

With iterations

Load	Load Combo	Limit State	Governing Action	LL (kip)	Adj. LL (kip)	Load Factors DC	DW	DW-WS	LL	Phi	Vn (kip)	-- Override -- Phi	Vn (kip)	RF	Capacity (Ton)
DesignInv	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.75	0.90	135.68	---	---	0.942	33.92
DesignInv	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.75	0.90	139.12	---	---	0.963	34.67
DesignInv	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.75	0.90	-77.49	---	---	8.540	307.43
DesignOp	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.35	0.90	135.68	---	---	1.222	43.98
DesignOp	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.35	0.90	139.12	---	---	1.248	44.94
DesignOp	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.35	0.90	-77.49	---	---	11.070	398.52
DesignInv	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.75	0.90	134.97	---	---	1.141	41.07
DesignInv	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.75	0.90	139.12	---	---	1.171	42.16
DesignInv	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.75	0.90	-77.49	---	---	7.792	280.52
DesignOp	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.35	0.90	134.97	---	---	1.479	53.24
DesignOp	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.35	0.90	139.12	---	---	1.518	54.66
DesignOp	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.35	0.90	-77.49	---	---	10.101	363.64

Load Combination Legend:

Code Vehicle

OK

Without iterations

Load	Load Combo	Limit State	Governing Action	LL (kip)	Adj. LL (kip)	Load Factors DC	DW	DW-WS	LL	Phi	Vn (kip)	-- Override -- Phi	Vn (kip)	RF	Capacity (Ton)
DesignInv	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.75	0.90	127.67	---	---	0.862	31.03
DesignInv	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.75	0.90	133.83	---	---	0.911	32.79
DesignInv	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	19.917	717.02
DesignOp	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.35	0.90	167.80	---	---	1.639	59.01
DesignOp	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.35	0.90	176.78	---	---	1.731	62.33
DesignOp	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	25.819	929.47
DesignInv	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.75	0.90	154.88	---	---	1.384	49.84
DesignInv	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.75	0.90	164.51	---	---	1.477	53.16
DesignInv	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	18.174	654.26
DesignOp	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.35	0.90	210.48	---	---	2.677	96.36
DesignOp	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.35	0.90	227.86	---	---	2.902	104.47
DesignOp	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	23.559	848.12

Load Combination Legend:

Code Vehicle

OK

Figure 16 - 6A.4.2.1 General Load Rating Equation - Concrete Shear rating comparison

Longitudinal reinforcement evaluation for shear rating is based on the equilibrium of tensile capacity and demand of the longitudinal reinforcement (LRFD eq. 5.7.3.5-1) determined by iterating the live load component of Vu, Mu and Nu.

Spec Check Detail for 6A.5.8 Evaluation for Shear

```
6A Load and Resistance Factor Rating
6A.5 Concrete Structures
6A.5.8 Evaluation for Shear
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Longitudinal Reinforcement
--------------------------


From LRFD 5.7.3.5-1

LHS or Tr  = Aps*fps + As*fy

        |Mu|           Nu     /| Vu       |          \
RHS = -------- + 0.5 ----- + ||---- - Vp| -0.5 * Vs| * cot(theta)  (LRFD 5.7.3.5-1)
       dv*phif         phic   \|phiv      |          /


                    |MuDL|                 NuDL              |VuDL      |
T(DL) = SignMDL * -------- + 0.5 * SignNDL * ---- + (SignVDLp * |---- - Vp| - 0.5 * Vs) * cot(theta), where Vs = min(Vs, Vu/phiv)  (Based on LRFD 5.7.3.5-1 and MBE 6A.5.8)
                   dv*phif                 phic              |phiv      |


                    |MuLL|                 NuLL             |VuLL|
T(LL) = SignMLL * -------- + 0.5 * SignNLL * ---- + (SignVLL * |----| ) * cot(theta)                          (Based on LRFD 5.7.3.5-1 and MBE 6A.5.8)
                   dv*phif                 phic             |phiv|

Where:

                                          VuDL + VuLL                VuDL
Mu = MuDL + MuLL; Nu = NuDL + NuLL; VT = ----------- - Vp; VuDLp = -------- - Vp
                                             phiv                    phiv


                  / MuDL \                    / NuDL \                       / VuDLp \                     / MuLL \                    / NuLL \                    / VuLL \
SignMDL = Sign of |------|; SignNDL = Sign of | ------ |; SignVDLp  = Sign of |  -----  |; SignMLL = Sign of |  ----- |; SignNLL = Sign of |  ----- |; SignVLL = Sign of |  ----- |
                  \  Mu  /                    \  Nu  /                       \  VT   /                     \  Mu  /                    \  Nu  /                    \  VT  /


     T(r) - T(DL)
RF = ------------
        T(LL)

Ignore design & legal shear      :  No
Ignore permit shear              :  Yes
Consider iterative shear rating  :  Yes
Consider MCFT theta              :  No
Shear computation method type    :  General
Iteration required               :  Yes

phif = 1.000
phic = 0.750
phiv = 0.900
```

Figure 17 - 6A.5.8 Evaluation for shear – Part 1

Spec Check Detail for 6A.5.8 Evaluation for Shear

```
  As(pos)  =          0.000  (in^2)     (used for Positive Mu)
  As(neg)  =          0.000  (in^2)     (used for Negative Mu)
  fy(pos)  =          0.000  (ksi)      (used for Positive Mu)
  fy(neg)  =          0.000  (ksi)      (used for Negative Mu)
 Aps(pos)  =          4.284  (in^2)     (used for Positive Mu)
 Aps(neg)  =          0.306  (in^2)     (used for Negative Mu)
 fps(pos)  =        245.606  (ksi)      (used for Positive Mu)
 fps(neg)  =        141.252  (ksi)      (used for Negative Mu)
  Bv(pos)  =         10.000  (in)       (used for Positive Mu)
  Bv(neg)  =         10.000  (in)       (used for Negative Mu)
  Dv(pos)  =         33.765  (in)       (used for Positive Mu)
  Dv(neg)  =         28.080  (in)       (used for Negative Mu)
 Mcr(pos)  =      28801.178  (kips-in)  (used for Positive Mu)
 Mcr(neg)  =      -4929.748  (kips-in)  (used for Negative Mu)
 fy(shear) =         60.000  (ksi)
```

Limit State	Load Comb	dv (in)	As*fy (kips)	Aps*fps (kips)	Tr (kips)	MuDL (kip-in)	NuDL (kips)	VuDL (kips)	Vp (kips)	Governing Action	MuLL (kip-in)	NuLL (kips)	VuLL (kips)
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	21909.89	0.00	89.71
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	20745.45	0.00	90.99
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	11460.56	0.00	-12.57
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	16901.91	0.00	69.21
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	16003.63	0.00	70.19
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	8841.00	0.00	-9.69
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	18223.13	0.00	73.54
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	17058.69	0.00	74.82
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	12559.88	0.00	-13.77
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	14057.84	0.00	56.73
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	13159.56	0.00	57.72
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	9689.05	0.00	-10.62

Load Combination Legend:

Code	Vehicle
1	HL-93 (US) - Truck + Lane
2	HL-93 (US) - Tandem + Lane

Figure 18 - 6A.5.8 Evaluation for shear – Part 2

Shown below is a comparion of rating factors between non-iteration and iteration from LRFD equation 5.7.3.5-1

Non-Iterated										Iterated										
epsilon	beta	theta (Deg.)	Av (in^2)	s (in)	Vs (kips)	TDL (kips)	TLL (kips)	LHS/RHS	RF	epsilon	beta	theta (Deg.)	Av (in^2)	s (in)	Vs (kips)	TDL (kips)	TLL (kips)	LHS/RHS	RF	Capacity (Ton)
0.002471	1.68	37.65	0.40	12.00	87.53	332.60	778.10	0.95	0.925	--	--	--	--	--	--	--	--	--	--	33.29
0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	--	--	--	--	--	--	--	--	--	--	3564.00
0.002199	1.81	36.70	0.40	12.00	90.61	330.45	750.05	0.97	0.962	--	--	--	--	--	--	--	--	--	--	34.64
0.000000	4.80	29.00	0.40	12.00	121.83	385.47	314.23	1.50	2.122	0.002006	1.92	36.02	0.40	12.00	92.87	373.53	320.22	1.00	2.119	76.38
0.001088	2.64	32.81	0.40	12.00	104.75	318.74	619.85	1.12	1.183	0.001986	1.93	35.95	0.40	12.00	93.11	328.59	606.60	1.00	1.193	42.60
0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	--	--	--	--	--	--	--	--	--	--	3564.00
0.000879	2.89	32.08	0.40	12.00	107.76	315.87	598.42	1.15	1.230	0.001963	1.94	35.87	0.40	12.00	93.39	328.38	581.83	1.00	1.244	44.30
0.000000	4.80	29.00	0.40	12.00	121.83	382.59	242.41	1.68	2.762	0.002006	1.92	36.02	0.40	12.00	92.88	371.34	247.02	1.00	2.756	99.44
0.001444	2.30	34.06	0.40	12.00	99.91	323.08	660.60	1.07	1.104	0.001992	1.92	35.97	0.40	12.00	93.05	328.64	652.29	1.00	1.109	39.73
0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	--	--	--	--	--	--	--	--	--	--	3564.00
0.001172	2.55	33.10	0.40	12.00	103.58	319.82	632.72	1.10	1.157	0.001964	1.94	35.87	0.40	12.00	93.38	328.38	620.18	1.00	1.167	41.67
0.000000	4.80	29.00	0.40	12.00	121.83	386.68	344.37	1.44	1.932	0.002006	1.92	36.02	0.40	12.00	92.87	374.45	350.93	1.00	1.931	69.57
0.000296	3.93	30.04	0.40	12.00	116.79	316.81	525.36	1.25	1.400	0.001985	1.93	35.95	0.40	12.00	93.12	328.58	503.27	1.00	1.438	50.39
0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	--	--	--	--	--	--	--	--	--	--	3564.00
0.000087	4.51	29.30	0.40	12.00	120.32	315.28	504.00	1.28	1.462	0.001966	1.94	35.88	0.40	12.00	93.36	328.40	478.40	1.00	1.513	52.63
0.000000	4.80	29.00	0.40	12.00	121.83	383.53	265.66	1.62	2.517	0.002006	1.92	36.02	0.40	12.00	92.88	372.05	270.72	1.00	2.512	90.61

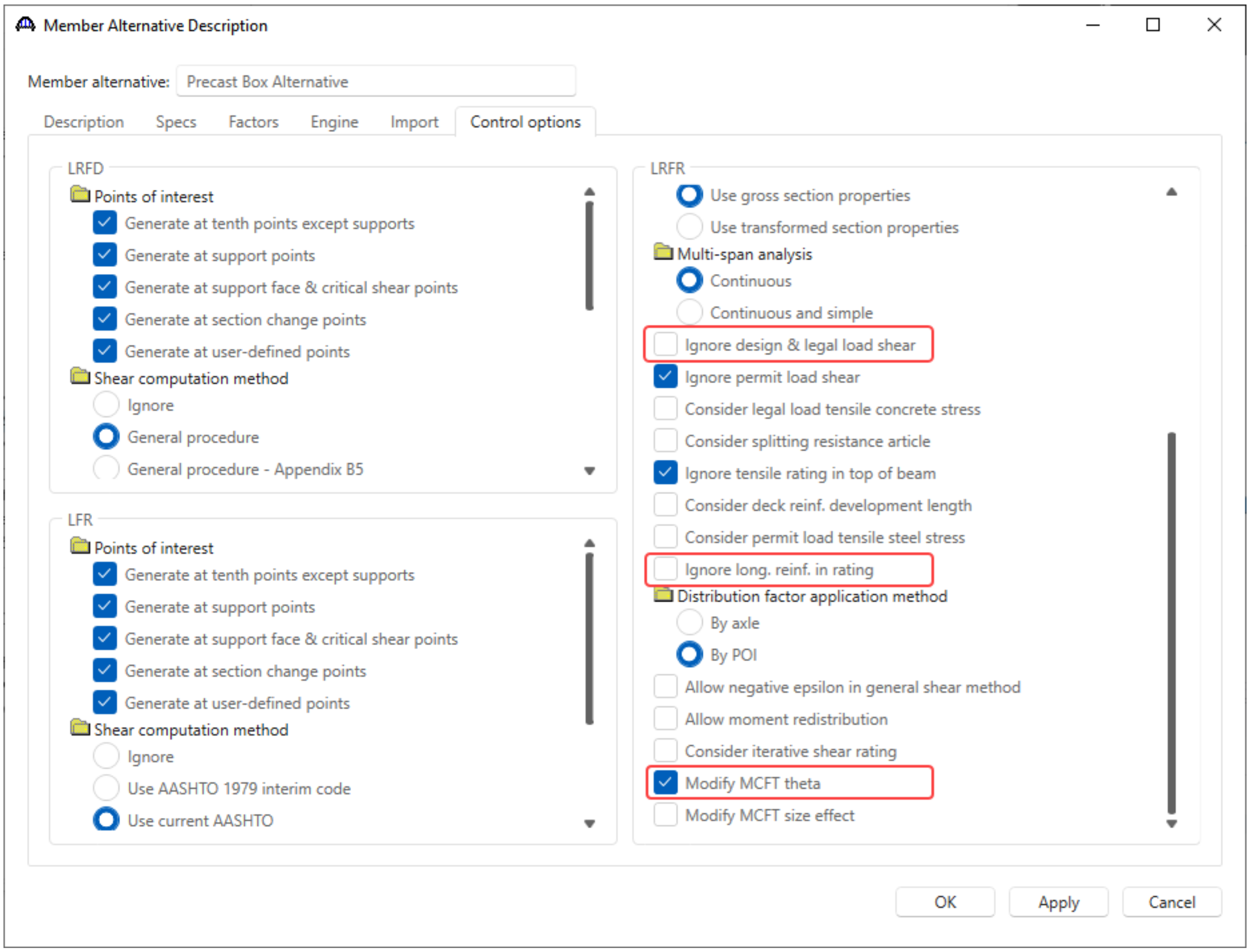
Figure 19 - 6A.5.8 Evaluation for shear – Part 3

Control option added to consider modifying MCFT theta

This section discusses the control option "Modify MCFT theta" added for all concrete structures, i.e., reinforced concrete, prestressed concrete, post tensioned concrete and reinforced concrete box culverts.

Member Alternative Description – Control options

Navigate to the member alternative **Precast Box Alternative** of member **G2**, double click on it (or click the **Open** button from the **WORKSPACE** ribbon) to open its **Member Alternative Description** window. Navigate to the **Control options** tab as shown below. Check the box - **Modify MCFT theta** as shown below.



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

Run an LRFR analysis using the analysis settings shown in the previous step.

Specification Check Detail

Once the analysis is complete, open the 6A.4.2.1 Shear-5.7.3.4 Procedures for Determining Shear Resistance article for the analyzed member alternative for Stage 3 at Span 1 – 19.00 ft. This article highlights the status of the "Modify MCFT Theta" control option. With this control option checked, in areas of low strain where the section remains uncracked i.e., if the factored moment at this section is less than the cracking moment (Mu < Mcr), the strain εs may be assumed to be zero regardless of the values of moment (Mu) and shear (Vu), therefore, "Theta" can be taken as 29°.

Spec Check Detail for 6A.4.2.1 Shear-5.6.3.3 Minimum Reinforcement

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.6 Design for Flexural and Axial Effects - B Regions
6A.4.2.1 Shear - 5.6.3 Flexural Members
6A.4.2.1 Shear - 5.6.3.3 Minimum Reinforcement
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left      Stage 3

Cross Section Properties for Prestress box beam with Rectangular void
------------------------------------------------------------------
Name: BIII-48   Girder f'c = 5.00(ksi)      Girder f'ci = 4.00(ksi)

Beam Height              =   39.00(in)      Side Wall Thickness      =    5.00(in)
Top Slab Width           =   47.25(in)
Top Slab Thick           =    5.50(in)
Bottom Slab Width        =   48.00(in)
Bottom Slab Thick        =    5.50(in)
Shear Key Top            =    6.00(in)
Shear Key Height         =    6.00(in)
Shear Key Depth          =    0.75(in)
B1                       =    3.00(in)
B2                       =    3.00(in)
B3                       =    3.00(in)
B4                       =    3.00(in)

Slab f'c                 =      0.00(ksi)
Effective Slab Width     =      0.00(in)        Haunch Width             =      0.00(in)
Effective Slab Thickness =      0.00(in)        Haunch Thickness         =      0.00(in)

Input:
fr beam =         0.54ksi
ScTop   =    -8569.07in^3             Mdnc    =     8812.35kip-in
ScBot   =     8734.21in^3             SncBot  =     8734.21in^3
Gamma1 =  1.60
Gamma2 =  1.10
Gamma3 =  1.00 (Prestressed Concrete)
Gamma3 =  0.67 (Reinforced Concrete)

Mcr = Gamma3 * [( gamma1*fr + Gamma2*fcpe)*Sc - Mdnc * (Sc/Snc - 1)]       (5.6.3.3-1)
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	Load Comb	fcpe ksi	fr ksi	Gamma3	Governing Action	Mu kip-in	Vu kip	Sc in^3	Mcr kip-in
STR-I	1, DesInv	2.22	0.54	1.00	Max M	33228.57	127.29	8734.21	28801.18
STR-I	1, DesInv	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	1, DesInv	2.22	0.54	1.00	Max V	32064.13	128.56	8734.21	28801.18
STR-I	1, DesInv	2.22	0.54	1.00	Min V	22779.24	25.01	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Max M	28220.60	106.78	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Max V	27322.31	107.77	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Min V	20159.68	27.88	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Max M	29541.81	111.12	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Max V	28377.37	112.39	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Min V	23878.56	23.80	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Max M	25376.52	94.31	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Max V	24478.24	95.29	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Min V	21007.73	26.95	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Max M	18828.30	70.27	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Min M	8812.35	29.26	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Max V	18295.99	70.86	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Min V	14051.47	23.52	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Max M	17142.93	62.88	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Min M	8812.35	29.26	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Max V	16610.61	63.46	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Min V	14554.01	22.97	8734.21	28801.18

Figure 20 6A.4.2.1 Shear 5.6.3.3 Minimum Reinforcement

Spec Check Detail for 6A.4.2.1 Shear-5.7.3.4 Procedures for Determining Shear Resistance

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.7 Shear and Torsion
6A.4.2.1 Shear - 5.7.3 Sectional Design Model
6A.4.2.1 Shear - 5.7.3.4 Procedures for Determining Shear Resistance
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left      Stage 3

Calculation of Beta/Theta
-------------------------


      Es = 0.000 (kips/in^2)
     phi = 0.900
     f'c = 5.000 (kips/in^2)
     fpc = 0.937 (kips/in^2)
      fy = 60.000 (kips/in^2)
Agg diam = 1.000 (in)
      Vp = 0.000 (kips)
      Ep = 28500.000 (kips/in^2)
 As(pos) = 0.000 (in^2)  (used for Positive Mu)
 As(neg) = 0.000 (in^2)  (used for Negative Mu)
Aps(pos) = 4.284 (in^2)  (used for Positive Mu)
Aps(neg) = 0.306 (in^2)  (used for Negative Mu)
     fpo = 189.000 (kips/in^2)
      Ec = 4592.232 (kips/in^2)

Beta Calc (used in table below) :
     (1) - Beta = 4.8 / (1 + 750 EpsilonS)
     (2) - Beta = ( 4.8 / (1 + 750 EpsilonS) ) * (51 / (39 + sxe) )
                 where:
                    sxe = sx * (1.38 / (ag + 0.63) )

  Mu_calc = Max(Mu, |Vu - Vp| * dv)

Modify MCFT Theta:    Yes

Modify MCFT Size Effect:    No
fpc / f'c = 0.19
```

Limit State	Load Comb	Epsilon	Theta	Beta	Governing Action	Mu (kip-in)
STR-I	1, DesInv	0.002471	37.65	1.68	Max M	33228.57
STR-I	1, DesInv	0.000000	29.00	4.80	Min M	11318.68
STR-I	1, DesInv	0.002199	36.70	1.81	Max V	32064.13
STR-I	1, DesInv	0.000000	29.00	4.80	Min V	22779.24
STR-I	1, DesOp	0.000000	29.00	4.80	Max M	28220.60
STR-I	1, DesOp	0.000000	29.00	4.80	Min M	11318.68
STR-I	1, DesOp	0.000000	29.00	4.80	Max V	27322.31
STR-I	1, DesOp	0.000000	29.00	4.80	Min V	20159.68
STR-I	2, DesInv	0.001444	34.06	2.30	Max M	29541.81
STR-I	2, DesInv	0.000000	29.00	4.80	Min M	11318.68
STR-I	2, DesInv	0.000000	29.00	4.80	Max V	28377.37
STR-I	2, DesInv	0.000000	29.00	4.80	Min V	23878.56
STR-I	2, DesOp	0.000000	29.00	4.80	Max M	25376.52
STR-I	2, DesOp	0.000000	29.00	4.80	Min M	11318.68
STR-I	2, DesOp	0.000000	29.00	4.80	Max V	24478.24
STR-I	2, DesOp	0.000000	29.00	4.80	Min V	21007.73
SER-III	1, DesInv	0.000000	29.00	4.80	Max M	18828.30
SER-III	1, DesInv	0.000000	29.00	4.80	Min M	8812.35
SER-III	1, DesInv	0.000000	29.00	4.80	Max V	18295.99
SER-III	1, DesInv	0.000000	29.00	4.80	Min V	14051.47
SER-III	2, DesInv	0.000000	29.00	4.80	Max M	17142.93
SER-III	2, DesInv	0.000000	29.00	4.80	Min M	8812.35
SER-III	2, DesInv	0.000000	29.00	4.80	Max V	16610.61
SER-III	2, DesInv	0.000000	29.00	4.80	Min V	14554.01

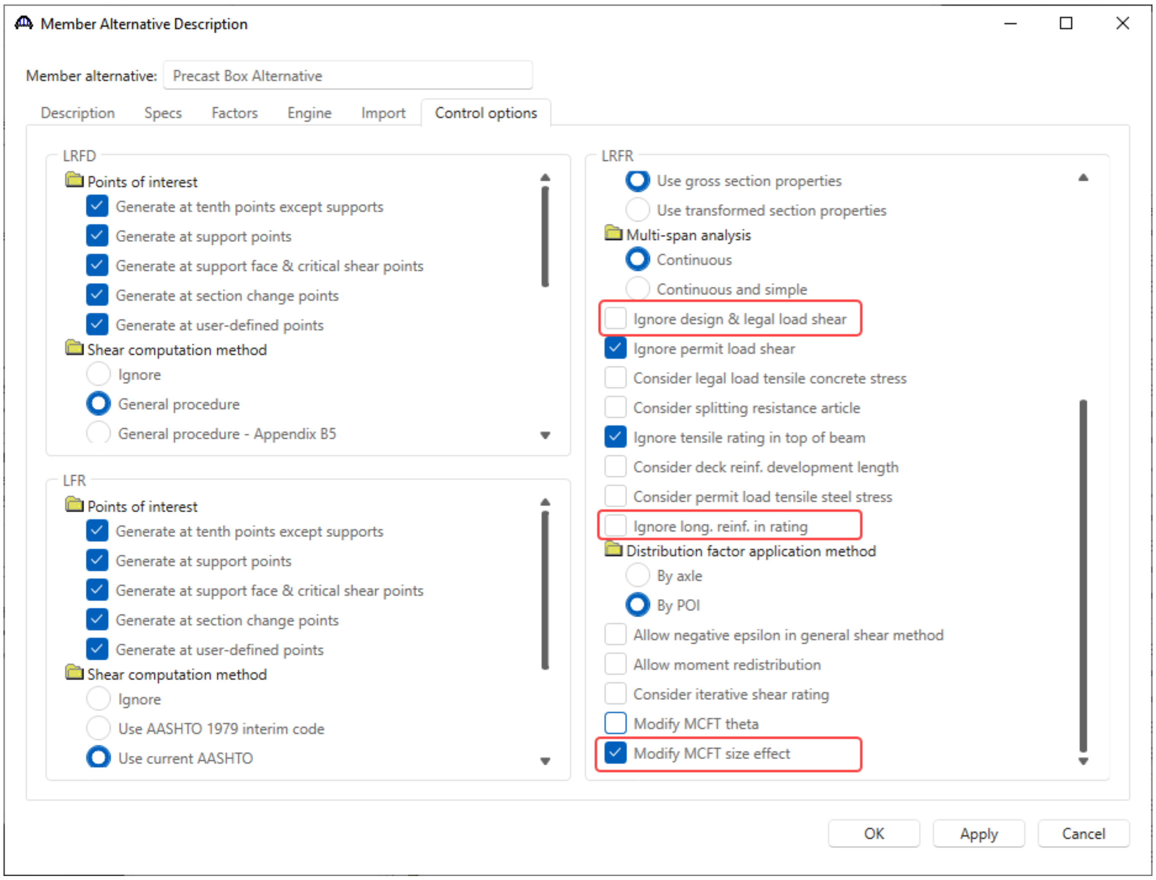
Figure 21 6A.4.2.1 Shear 5.7.3.4 Procedures for Determining Shear Resistance

Control option added to consider modifying MCFT size effect

This section discusses the control option “Modify MCFT size effect” added for prestressed concrete and post-tensioned concrete structures only. This does not apply to reinforced concrete structures and culverts.

Member Alternative Description – Control options

Navigate to the member alternative **Precast Box Alternative** of member **G2**, double click on it (or click the **Open** button from the **WORKSPACE** ribbon) to open its **Member Alternative Description** window. Navigate to the **Control options** tab as shown below. Check the box - **Modify MCFT size effect** as shown below.



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

Run an LRFR analysis using the analysis settings shown in the previous step.

Specification Check Detail

Once the analysis is complete, open the 6A.4.2.1 Shear-5.7.3.4 Procedures for Determining Shear Resistance article for the analyzed member alternative for Stage 3 at Span 1 – 19.00 ft. This article highlights the status of the “Modify MCFT size effect” control option. With this control option checked, if the ratio fpc/f’c is greater than 0.02, the size effect is neglected regardless of the amount of shear reinforcement present. The article is shown below.

Spec Check Detail for 6A.4.2.1 Shear-5.7.3.4 Procedures for Determining Shear Resistance

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.7 Shear and Torsion
6A.4.2.1 Shear - 5.7.3 Sectional Design Model
6A.4.2.1 Shear - 5.7.3.4 Procedures for Determining Shear Resistance
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Calculation of Beta/Theta
-------------------------


      Es = 0.000 (kips/in^2)
     phi = 0.900
     f'c = 5.000 (kips/in^2)
     fpc = 0.937 (kips/in^2)
      fy = 60.000 (kips/in^2)
Agg diam = 1.000 (in)
      Vp = 0.000 (kips)
      Ep = 28500.000 (kips/in^2)
 As(pos) = 0.000 (in^2)   (used for Positive Mu)
 As(neg) = 0.000 (in^2)   (used for Negative Mu)
Aps(pos) = 4.284 (in^2)   (used for Positive Mu)
Aps(neg) = 0.306 (in^2)   (used for Negative Mu)
     fpo = 189.000 (kips/in^2)
      Ec = 4592.232 (kips/in^2)

Beta Calc (used in table below) :
     (1) - Beta = 4.8 / (1 + 750 EpsilonS)
     (2) - Beta = ( 4.8 / (1 + 750 EpsilonS) ) * (51 / (39 + sxe) )
                  where:
                     sxe = sx * (1.38 / (ag + 0.63) )

  Mu_calc = Max(Mu, |Vu - Vp| * dv)

Modify MCFT Theta:   No

Modify MCFT Size Effect:   Yes
fpc / f'c = 0.19
```

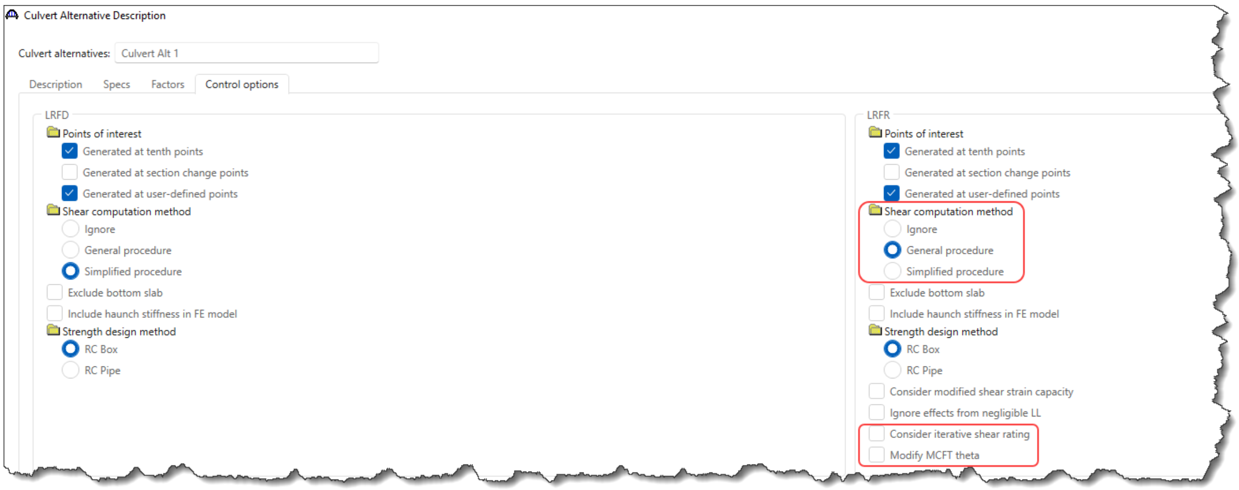
Limit State	Load Comb	Epsilon	Theta	Beta	Governing Action	Mu (kip-in)	Mu Calc (kip-in)	Vu (kips)	Nu (kips)	bv (in)	dv (in)	Sx (in)	Sxe (in)	Beta Calc
STR-I	1, DesInv	0.002471	37.65	1.68	Max M	33228.57	33228.57	127.29	0.00	10.00	33.77	33.77	--	(1)
STR-I	1, DesInv	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)
STR-I	1, DesInv	0.002199	36.70	1.81	Max V	32064.13	32064.13	128.56	0.00	10.00	33.77	33.77	--	(1)
STR-I	1, DesInv	0.000000	29.00	4.80	Min V	22779.24	22779.24	25.01	0.00	10.00	33.77	33.77	--	(1)
STR-I	1, DesOp	0.001088	32.81	2.64	Max M	28220.60	28220.60	106.78	0.00	10.00	33.77	33.77	--	(1)
STR-I	1, DesOp	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)
STR-I	1, DesOp	0.000879	32.08	2.89	Max V	27322.31	27322.31	107.77	0.00	10.00	33.77	33.77	--	(1)
STR-I	1, DesOp	0.000000	29.00	4.80	Min V	20159.68	20159.68	27.88	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesInv	0.001444	34.06	2.30	Max M	29541.81	29541.81	111.12	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesInv	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesInv	0.001172	33.10	2.55	Max V	28377.37	28377.37	112.39	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesInv	0.000000	29.00	4.80	Min V	23878.56	23878.56	23.80	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesOp	0.000296	30.04	3.93	Max M	25376.52	25376.52	94.31	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesOp	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesOp	0.000087	29.30	4.51	Max V	24478.24	24478.24	95.29	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesOp	0.000000	29.00	4.80	Min V	21007.73	21007.73	26.95	0.00	10.00	33.77	33.77	--	(1)
SER-III	1, DesInv	0.000000	29.00	4.80	Max M	18828.30	18828.30	70.27	0.00	10.00	33.77	33.77	--	(1)
SER-III	1, DesInv	0.000000	29.00	4.80	Min M	8812.35	8812.35	29.26	0.00	10.00	33.77	33.77	--	(1)
SER-III	1, DesInv	0.000000	29.00	4.80	Max V	18295.99	18295.99	70.86	0.00	10.00	33.77	33.77	--	(1)
SER-III	1, DesInv	0.000000	29.00	4.80	Min V	14051.47	14051.47	23.52	0.00	10.00	33.77	33.77	--	(1)
SER-III	2, DesInv	0.000000	29.00	4.80	Max M	17142.93	17142.93	62.88	0.00	10.00	33.77	33.77	--	(1)
SER-III	2, DesInv	0.000000	29.00	4.80	Min M	8812.35	8812.35	29.26	0.00	10.00	33.77	33.77	--	(1)
SER-III	2, DesInv	0.000000	29.00	4.80	Max V	16610.61	16610.61	63.46	0.00	10.00	33.77	33.77	--	(1)
SER-III	2, DesInv	0.000000	29.00	4.80	Min V	14554.01	14554.01	22.97	0.00	10.00	33.77	33.77	--	(1)

Figure 22 6A.4.2.1 Shear-5.7.3.4 Procedures for Determining Shear Resistance

MBE 2023 specification interim update for reinforced concrete box culverts

The specification update for culvert will impact culvert wall (6A.4.2.1-5.7.3.3 Nominal shear resistance) and culvert slab specification checking (6A.4.2.1-5.7.3.3 Nominal shear resistance and 6A.4.2.1-5.12.7.3 Nominal shear resistance).

Import the culvert bridge provided with the CVT1 tutorial. Expand the **Bridge Workspace** tree and navigate to the **CULVERT ALTERNATIVES** node. Double click on **Culvert Alt 1** to open the culvert alternative. Navigate to the **Control options** tab of the **Culvert Alternative Description** window to access the **LRFR** control options. **Consider iterative shear rating** and **Consider MCFT theta** control options are added for iterative shear rating.



These options are applicable when **General procedure** - Shear computation method is used. Select these options to perform iterative shear rating and consider modifying the MCFT theta value and view results as discussed in previous sections of this tutorial.

The following articles detail the iterative process of shear rating.

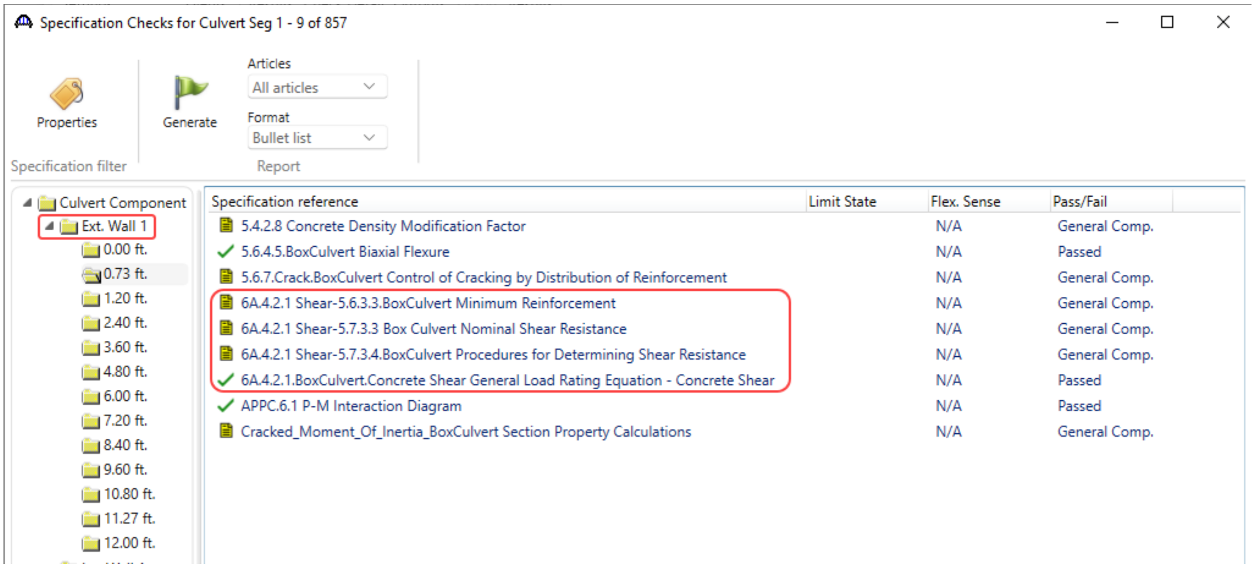


Figure 23 - Specification check article for Exterior wall 1

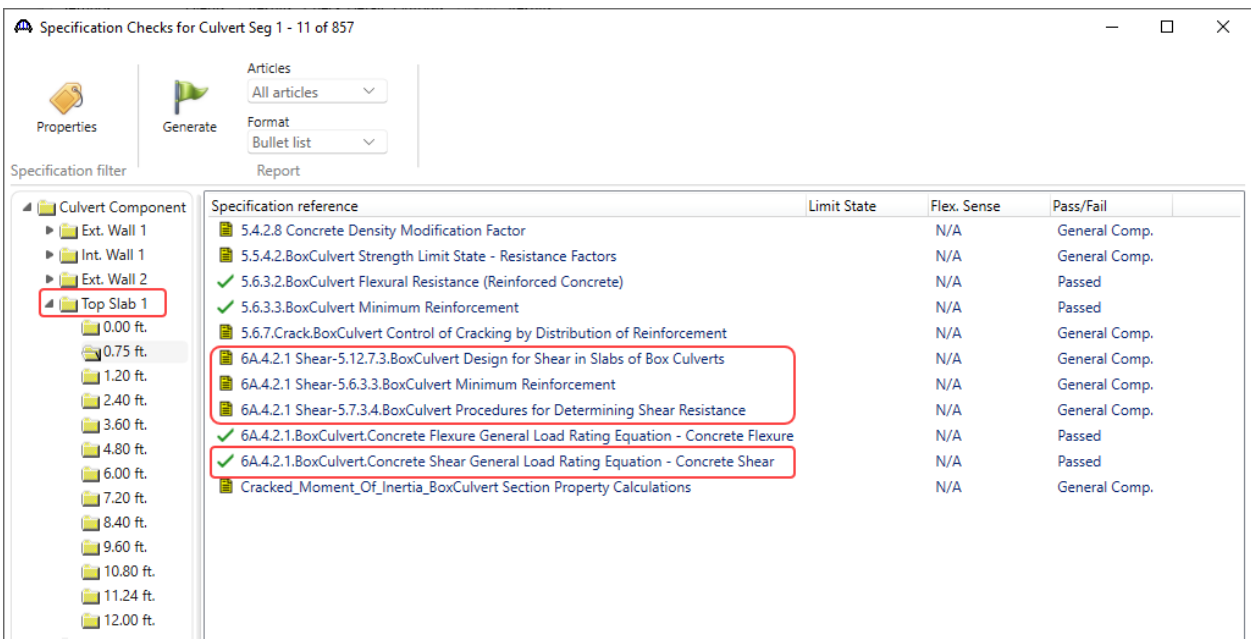


Figure 24 - Specification check articles for Top slab 1

AASHTOWare BrDR 7.5.1

LRFR Concrete Moment Redistribution Tutorial

Moment Redistribution in Three Span Spread PS Box Beam

LRFR Concrete Moment Redistribution Tutorial

Moment Redistribution in Three Span Spread PS Box Beam

This example illustrates the effects of moment redistribution for Load and Resistance Factor Rating (LRFR) flexure rating of concrete structures (prestressed, post tensioned, and reinforced). The moment redistribution option is available in BrDR 7.5 for the Manual for Bridge Evaluation (MBE) 3rd edition, with 2022 and 2023 specification interim updates.

Details, including flowcharts, about moment redistribution in concrete structures can be found in the AASHTO LRFD/LRFR Superstructure Method of Solution Manual accessible from the Help menu in BrDR (search for Concrete Moment Redistribution).

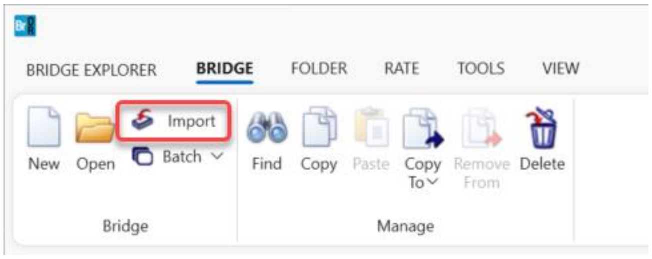
Topics Covered

- Bridge Model
- Analysis Settings
- Member Alternative Description – Control options
- LRFR Rating
- Specification Check Detail
- LRFR Rating with Moment Redistribution
- Specification Check Detail with Moment Redistribution
- Moment Redistribution Report

Bridge Model

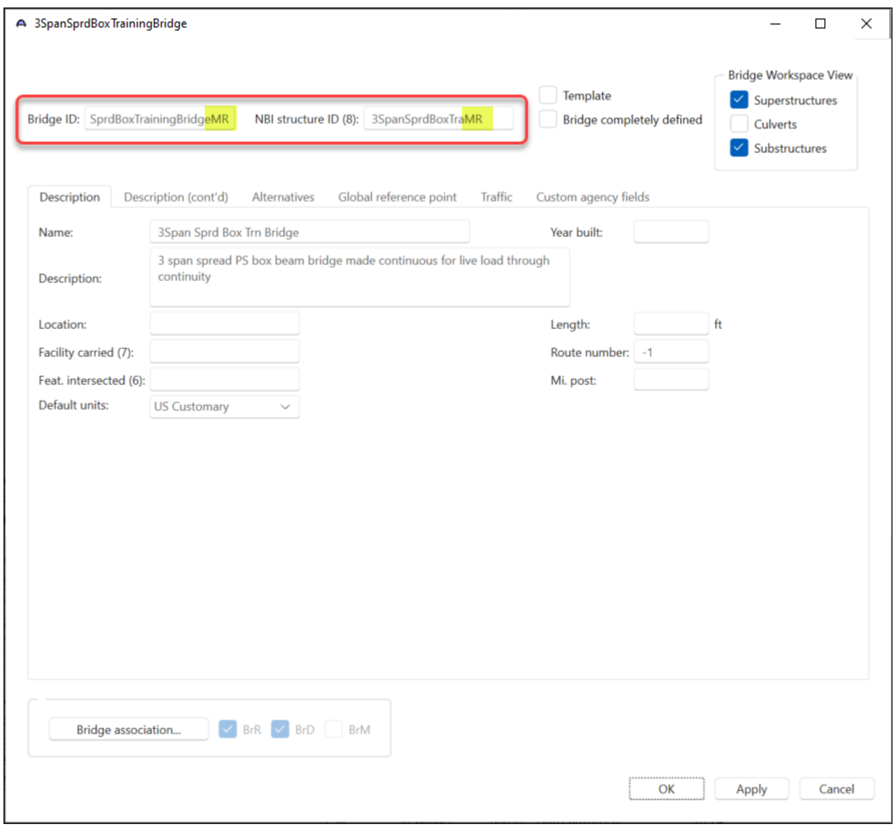
This tutorial uses the bridge created from prestressed concrete structure tutorial PS2 with some minor modifications to satisfy moment redistribution requirements and to illustrate the impact of moment redistribution on rating.

From the **Bridge Explorer** import the bridge given with the PS2 tutorial by selecting the **Import** option as shown below.



If information is displayed about the version of the imported file being different than the current version of the program, confirm by clicking **Yes** to have the imported file migrated to the current version of the program.

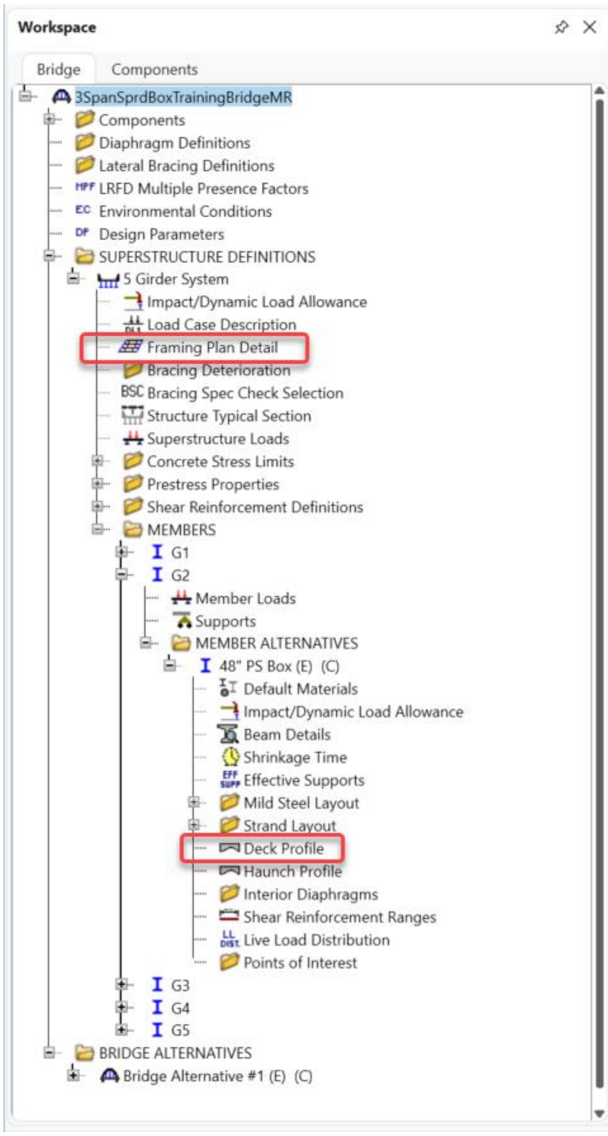
In the **Bridge Description** window, which pops up after the bridge is imported, add MR (for Moment Redistribution) to **Bridge ID** and **NBI structure ID** to distinguish this bridge from the PS2 example bridge.



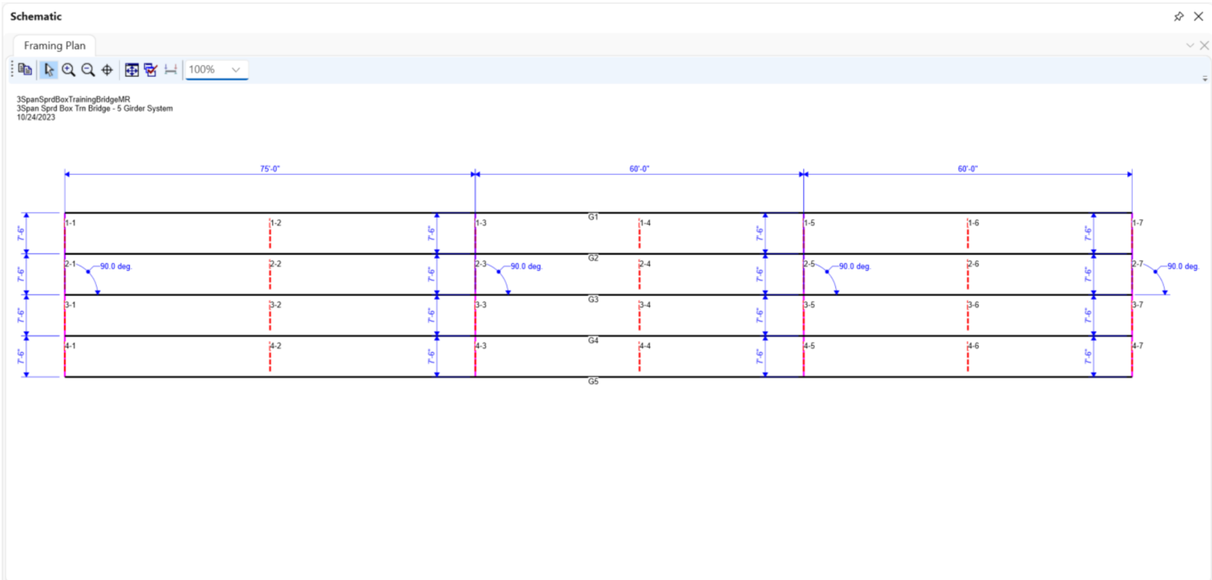
Click **OK** to close the Bridge Description window.

Save the imported bridge to the database using the **Save** button located on the **WORKSPACE** ribbon.

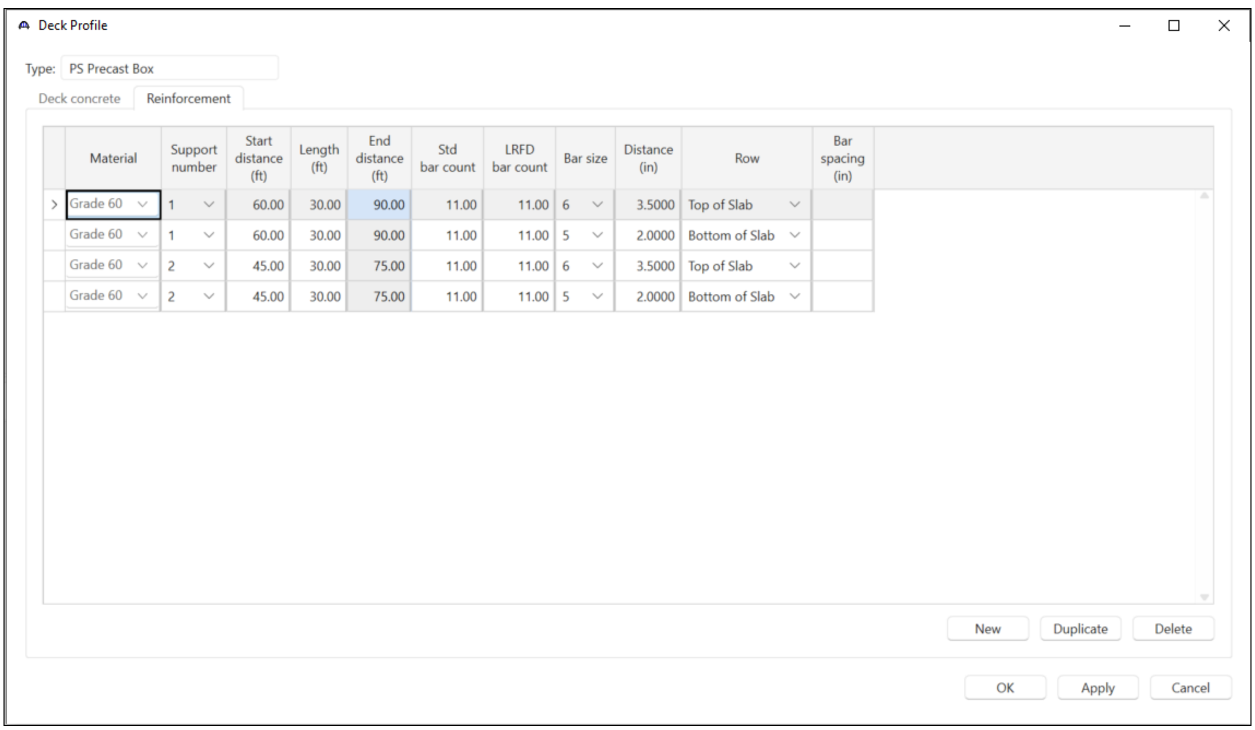
The partially expanded **Bridge Workspace** tree is shown below:



Right-click on the **Framing Plan Detail** and select **Schematic** to display the Framing Plan schematic showing a three span girder system with five girders and span lengths of 75.0, 60.0, and 60.0 ft.

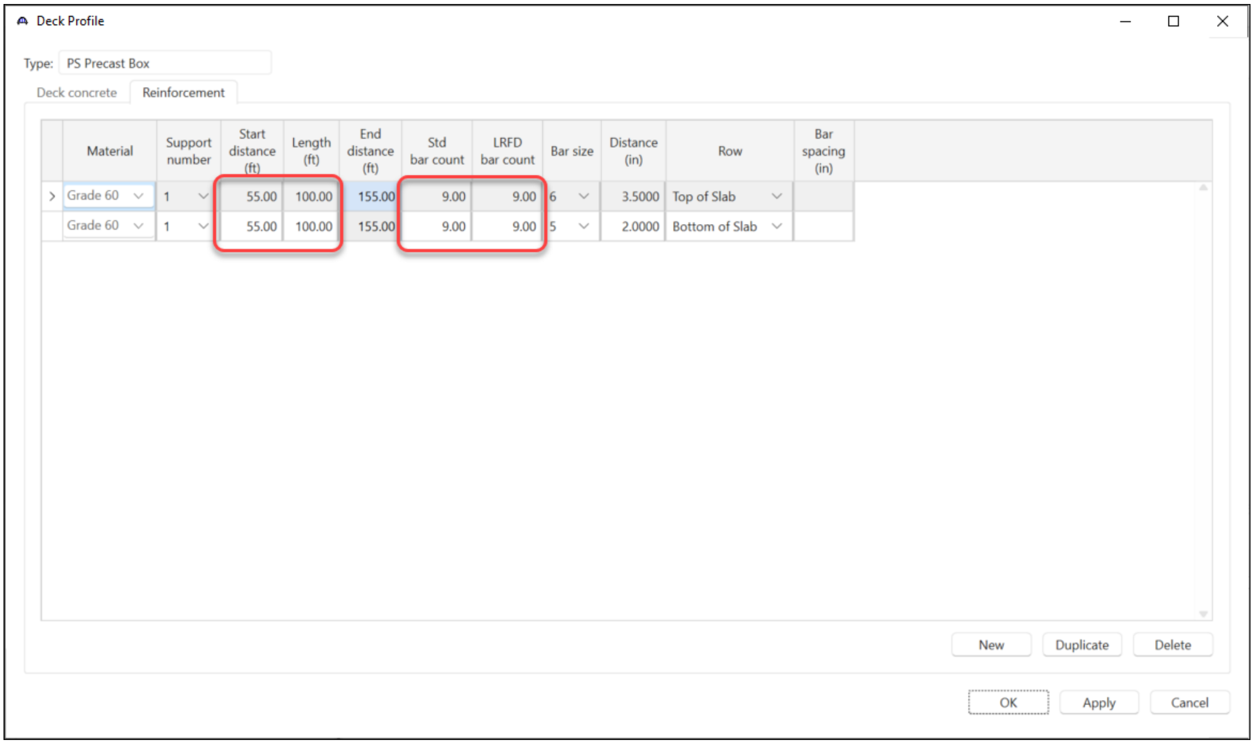


Double-click on the **Deck Profile** tree item of the G2 member alternative – 48" PS Box, to open the **Deck Profile** window and go to the **Reinforcement** tab. The reinforcement data imported from the PS2 example consists of two sets of top and bottom reinforcement that extend 15 ft in each direction over each interior support as shown here:



Material	Support number	Start distance (ft)	Length (ft)	End distance (ft)	Std bar count	LRFD bar count	Bar size	Distance (in)	Row	Bar spacing (in)
Grade 60	1	60.00	30.00	90.00	11.00	11.00	6	3.5000	Top of Slab	
Grade 60	1	60.00	30.00	90.00	11.00	11.00	5	2.0000	Bottom of Slab	
Grade 60	2	45.00	30.00	75.00	11.00	11.00	6	3.5000	Top of Slab	
Grade 60	2	45.00	30.00	75.00	11.00	11.00	5	2.0000	Bottom of Slab	

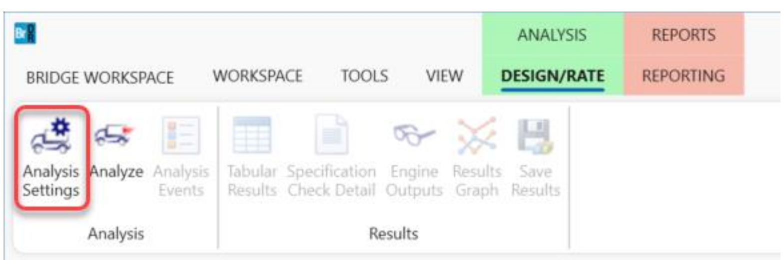
Delete the last two rows and modify start distance, length, and bar counts in the first two rows as shown below:



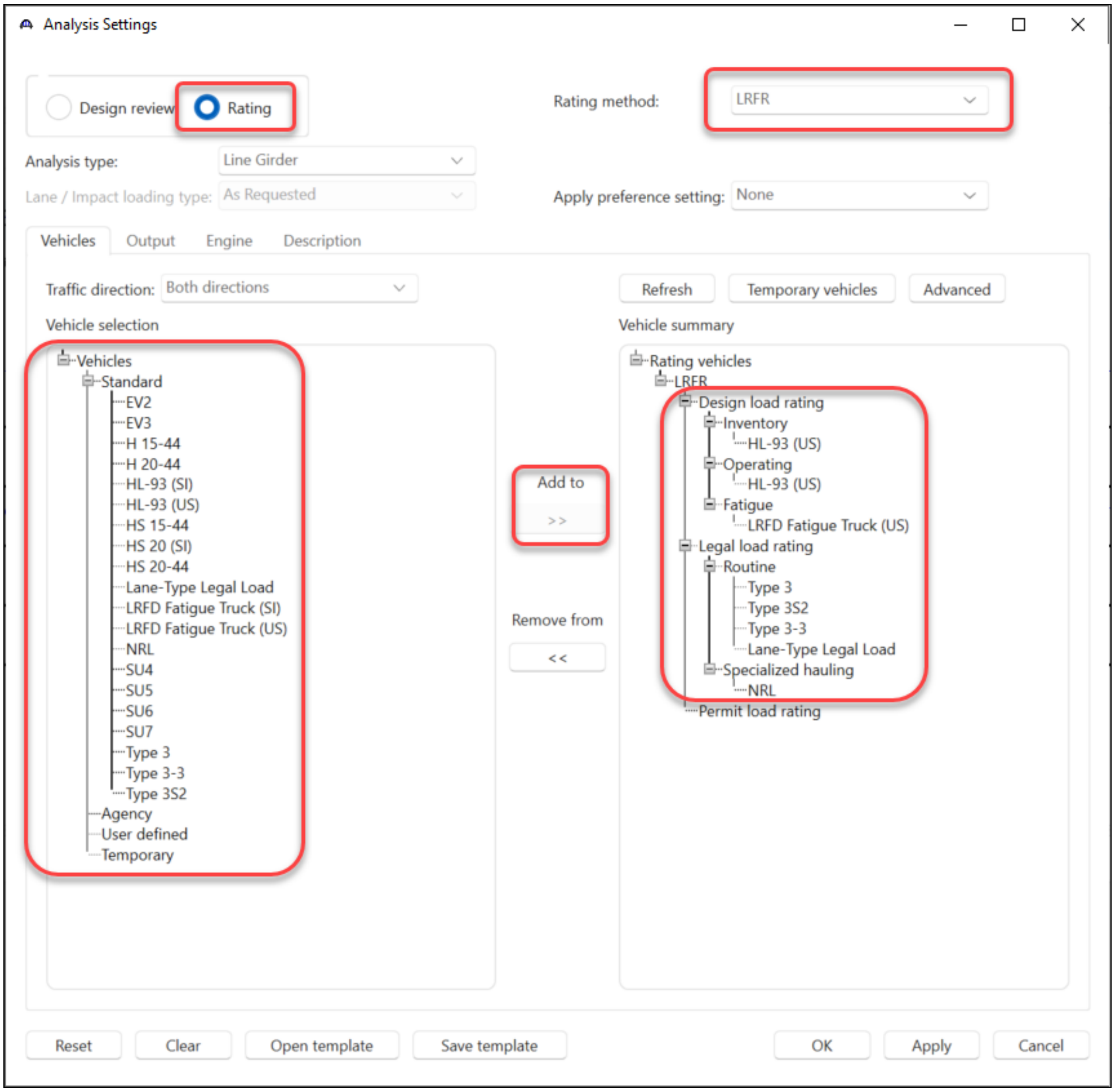
Deleting the last two rows and changing the start distance and length simplifies the reinforcement layout from two separate sets of top and bottom reinforcement over each internal support to one set of top and bottom reinforcement. The modified reinforcement now starts 20 ft before the first internal support in Span 1 and continues to pass over to Span 2 and then 20 ft after the second internal support into Span 3. This change is required to satisfy the moment redistribution requirements for reinforcement extension and termination which will be discussed later in the tutorial. The purpose of reducing bar counts is to decrease the flexure rating factors over interior supports and to examine whether applying moment redistribution helps to offset the reduction.

Analysis Settings

To select rating vehicles and rating levels, open the **Analysis Settings** window by clicking the **Analysis Settings** button on the **Analysis** group of the **DESIGN/RATE** ribbon.



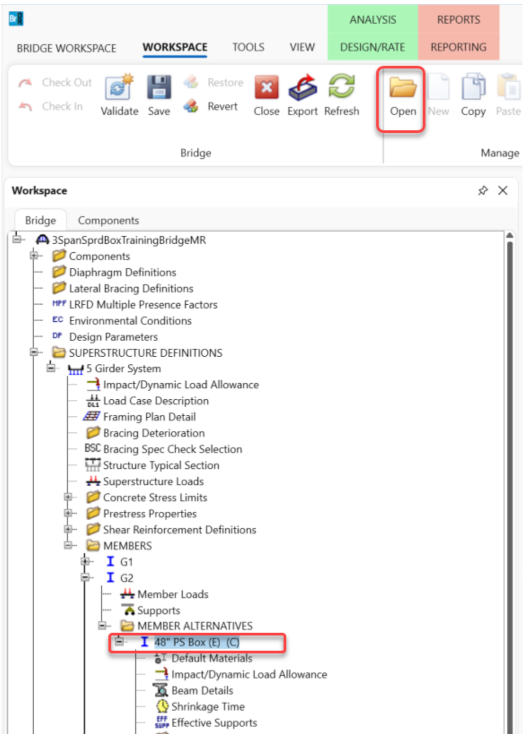
In the **Analysis Settings** window, select **Rating** and **LRFR** as the **Rating Method**. Then assign vehicles from the **Vehicle selection** tree on the left to the rating levels under the **Vehicle summary** tree on the right as shown in the screenshot below. The assignment is done in three steps. First clicking on a rating level, next by clicking on a vehicle, and then by clicking on the **Add to** button. To assign multiple vehicles to the same level, only the last two steps need to be repeated. Also, double-clicking on a vehicle has the same effect as the last two steps.



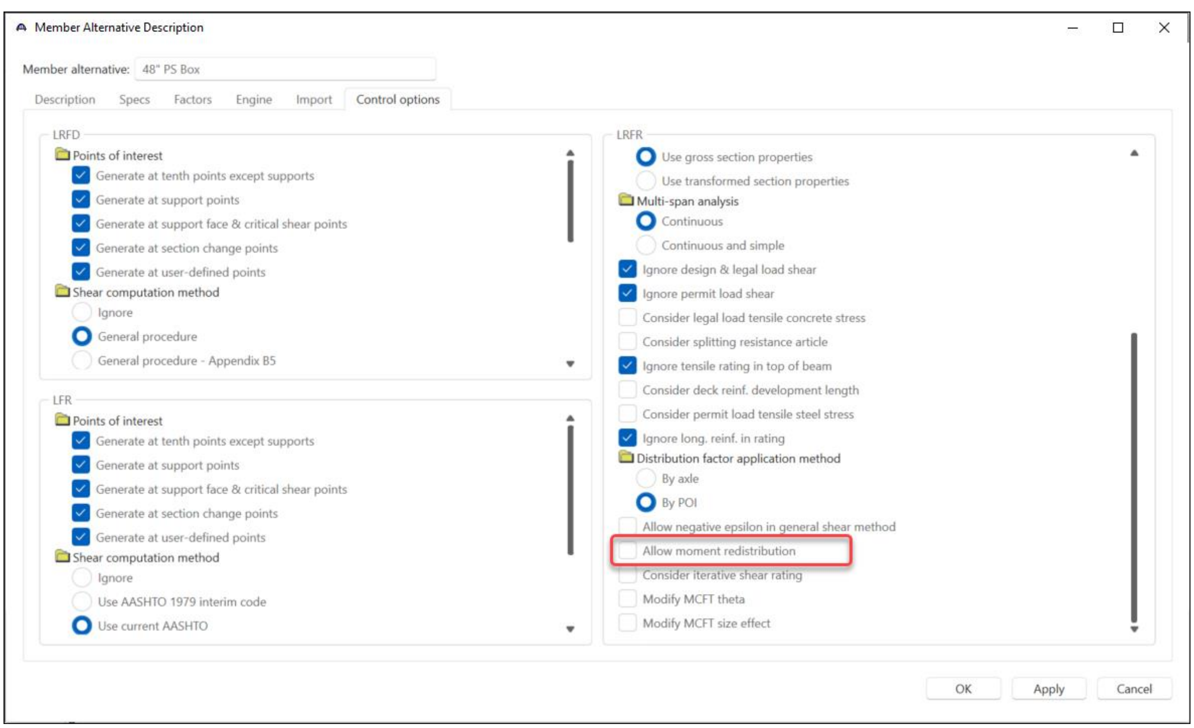
Click **OK** to apply the settings and close the window.

Member Alternative Description – Control options

Navigate to the **48” PS Box Member Alternative** of member **G2**, double click on it (or click the **Open** button from the **WORKSPACE** ribbon) to open its **Member Alternative Description** window.



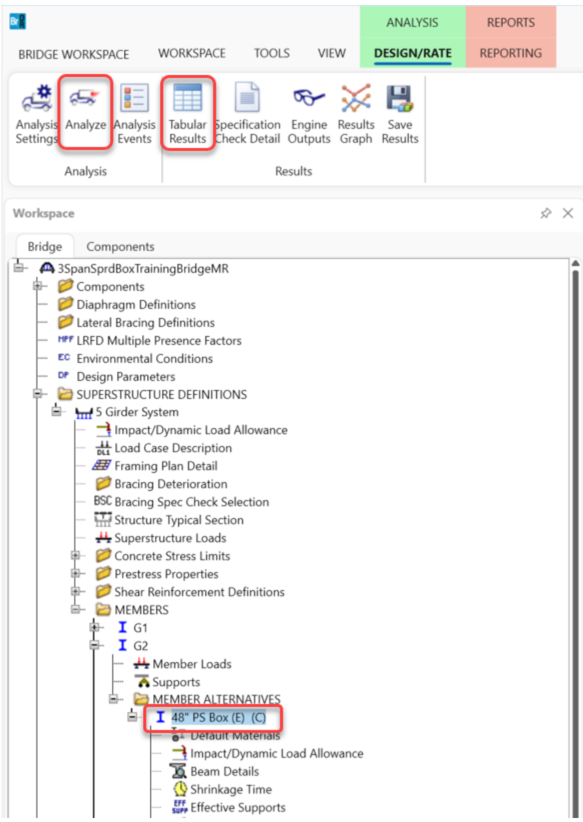
Navigate to the **Control options** tab where the option to allow moment redistribution is located as shown below.



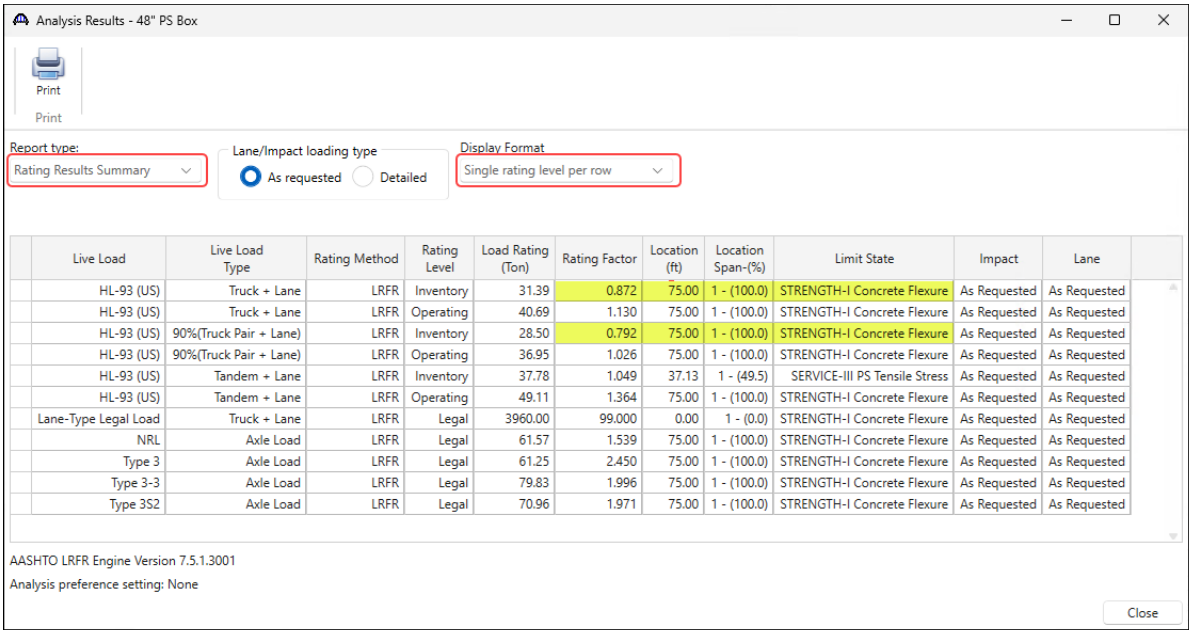
This option will be toggled to compare ratings without and with moment redistribution. The first analysis will be without moment redistribution so make sure the option is unchecked and click the **OK** button to apply the data and close the window.

LRFR Rating

To perform the rating select the **48” PS Box** member alternative in **Bridge Workspace** tree and click the **Analyze** button on the **Analysis** group of the **DESIGN/RATE** ribbon.



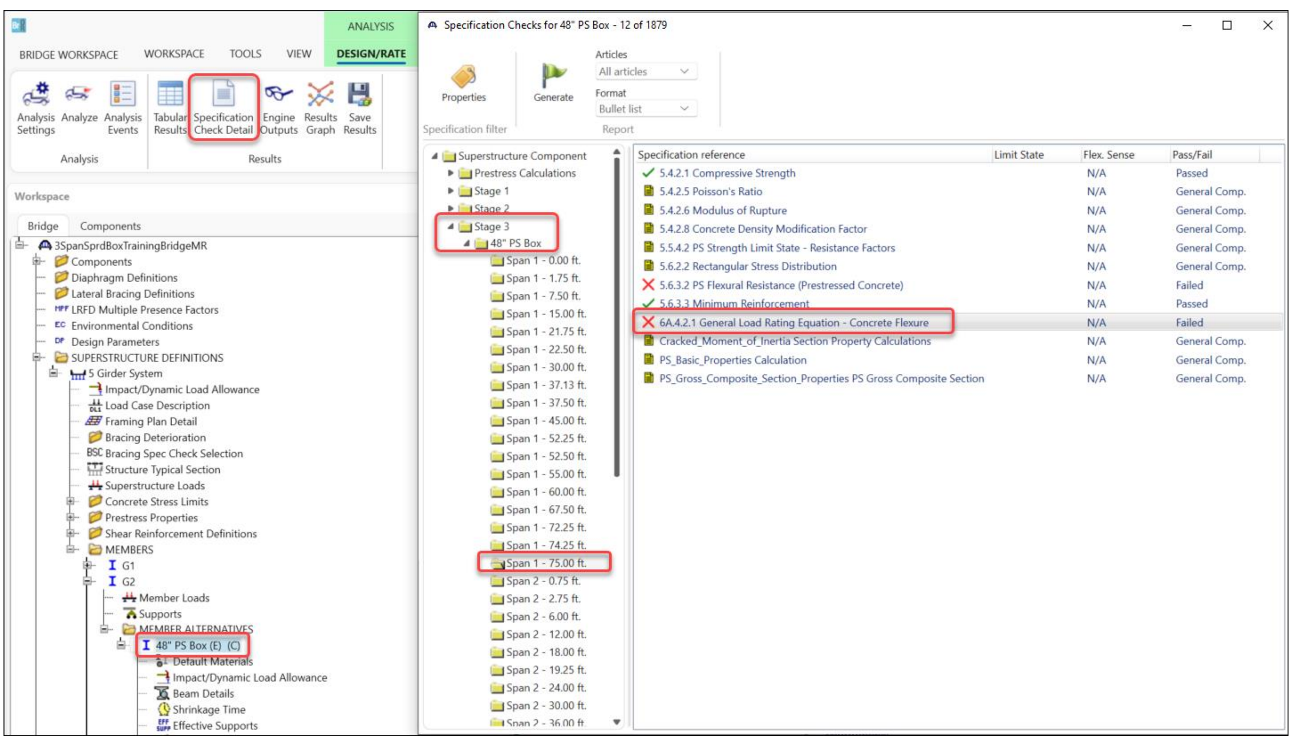
After the analysis is complete, click the **Tabular Results** button to display the ratings. Select **Rating Results Summary** as the **Report Type** and **Single rating level per row** as the **Display Format** option to have the ratings arranged as shown below. Notice there are two ratings less than 1.0 and they both happen due to flexure at the first interior support location at 75.00 ft for the STRENGTH-I limit state.



Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HL-93 (US)	Truck + Lane	LRFR	Inventory	31.39	0.872	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	40.69	1.130	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	90%(Truck Pair + Lane)	LRFR	Inventory	28.50	0.792	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	90%(Truck Pair + Lane)	LRFR	Operating	36.95	1.026	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	37.78	1.049	37.13	1 - (49.5)	SERVICE-III PS Tensile Stress	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	49.11	1.364	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
Lane-Type Legal Load	Truck + Lane	LRFR	Legal	3960.00	99.000	0.00	1 - (0.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
NRL	Axle Load	LRFR	Legal	61.57	1.539	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
Type 3	Axle Load	LRFR	Legal	61.25	2.450	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
Type 3-3	Axle Load	LRFR	Legal	79.83	1.996	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
Type 3S2	Axle Load	LRFR	Legal	70.96	1.971	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested

Specification Check Detail

The ratings displayed in the **Rating Results Summary** come from the rating specification articles that are processed during analysis. All specification check articles can be reviewed by clicking the **Specification Check Detail** button on the **Results** group of the **DESIGN/RATE** ribbon which opens the **Specification Check** window as shown below.



To review the flexure ratings at the 75.0 ft location, navigate to the **Stage 3** specification check detail for the analyzed member alternative, select the **Span 1 – 75.00 ft** point of interest, and then double-click on article **6A.4.2.1**

General Load Rating Equation – Concrete Flexure. This opens the **Spec Check Detail** window (see Figure 1) which shows the details of how the ratings were calculated. It is worth noting that since moment redistribution was not considered, the moment increments (DeltaM) for dead plus adjacent vehicle load (DL+AdjLL) and primary vehicle with impact (LL+I) are not available and they do not affect the rating factors (RF).

Spec Check Detail for 6A.4.2.1 General Load Rating Equation - Concrete Flexure

```
6A Load and Resistance Factor Rating
6A.4 Load Rating Procedures
6A.4.2 General Load-Rating Equation
6A.4.2.1 Concrete Flexure General
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 75.0000 (ft) - Left     Stage 3

Input:

Condition Factor      =     1.0000
System Factor         =     1.0000
DC Moment (Max)       =  -104.9793 (kip-ft)
DC Moment (Min)       =  -104.9793 (kip-ft)
DW Moment (Max)       =     0.0000 (kip-ft)
DW Moment (Min)       =     0.0000 (kip-ft)
DW-WS Moment (Max)    =     0.0000 (kip-ft)
DW-WS Moment (Min)    =     0.0000 (kip-ft)
Ignore Positive Moment = No


       Phi * K * Mn - GammaDC * M_DC - GammaDW * M_DW - GammaDW_WS * M_DW_WS - GammaSE * M_SE - GammaAdj_LL * M_Adj_LL + DeltaM(DL+AdjLL)
  RF = ------------------------------------------------------------------------------------------------------------------------------------
                                                      GammaLL * M_LL + DeltaM(LL+I)

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.
```

Load	Load Combo	Limit State	LL (kip-ft)	Adj. LL (kip-ft)	Load Factors DC	DW	DW-WS	LL	Phi	Mn (kip-ft)	-- Override -- Phi	Mn (kip-ft)	K	DeltaM DL+AdjLL (kip-ft)	DeltaM LL+I (kip-ft)	RF	Capacity (Ton)
DesignInv	1	STR-I	84.75	---	1.25	1.50	1.50	1.75	1.00	459.84	---	---	1.00	---	---	3.986	143.48
DesignInv	1	STR-I	-629.99	---	1.25	1.50	1.50	1.75	0.90	-1213.95	---	---	1.00	---	---	0.872	31.39
DesignOp	1	STR-I	84.75	---	1.25	1.50	1.50	1.35	0.90	-1213.95	---	---	1.00	---	---	NA	NA
DesignOp	1	STR-I	-629.99	---	1.25	1.50	1.50	1.35	0.90	-1213.95	---	---	1.00	---	---	1.130	40.69
DesignInv	2	STR-I	69.58	---	1.25	1.50	1.50	1.75	0.90	-1213.95	---	---	1.00	---	---	NA	NA
DesignInv	2	STR-I	-522.04	---	1.25	1.50	1.50	1.75	0.90	-1213.95	---	---	1.00	---	---	1.052	37.88
DesignOp	2	STR-I	69.58	---	1.25	1.50	1.50	1.35	0.90	-1213.95	---	---	1.00	---	---	NA	NA
DesignOp	2	STR-I	-522.04	---	1.25	1.50	1.50	1.35	0.90	-1213.95	---	---	1.00	---	---	1.364	49.11
DesignInv	3	STR-I	0.00	---	1.25	1.50	1.50	1.75	0.90	-1213.95	---	---	1.00	---	---	99.000	3564.00
DesignInv	3	STR-I	-693.86	---	1.25	1.50	1.50	1.75	0.90	-1213.95	---	---	1.00	---	---	0.792	28.50
DesignOp	3	STR-I	0.00	---	1.25	1.50	1.50	1.35	0.90	-1213.95	---	---	1.00	---	---	99.000	3564.00
DesignOp	3	STR-I	-693.86	---	1.25	1.50	1.50	1.35	0.90	-1213.95	---	---	1.00	---	---	1.026	36.95
LegalRout~	4	STR-I	0.00	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	---	---	99.000	3960.00
LegalRout~	4	STR-I	0.00	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	---	---	99.000	3960.00
LegalSpec~	5	STR-I	74.61	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	---	---	NA	NA
LegalSpec~	5	STR-I	-480.38	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	---	---	1.539	61.57
LegalRout~	6	STR-I	46.97	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	---	---	NA	NA
LegalRout~	6	STR-I	-301.82	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	---	---	2.450	61.25
LegalRout~	7	STR-I	49.77	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	---	---	NA	NA
LegalRout~	7	STR-I	-370.52	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	---	---	1.996	79.83
LegalRout~	8	STR-I	53.25	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	---	---	NA	NA
LegalRout~	8	STR-I	-375.16	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	---	---	1.971	70.96

```
Legend:
NA - Resistance and live load are of opposite sign so rating factor is not applicable.
 * - Positive moment rating ignored.

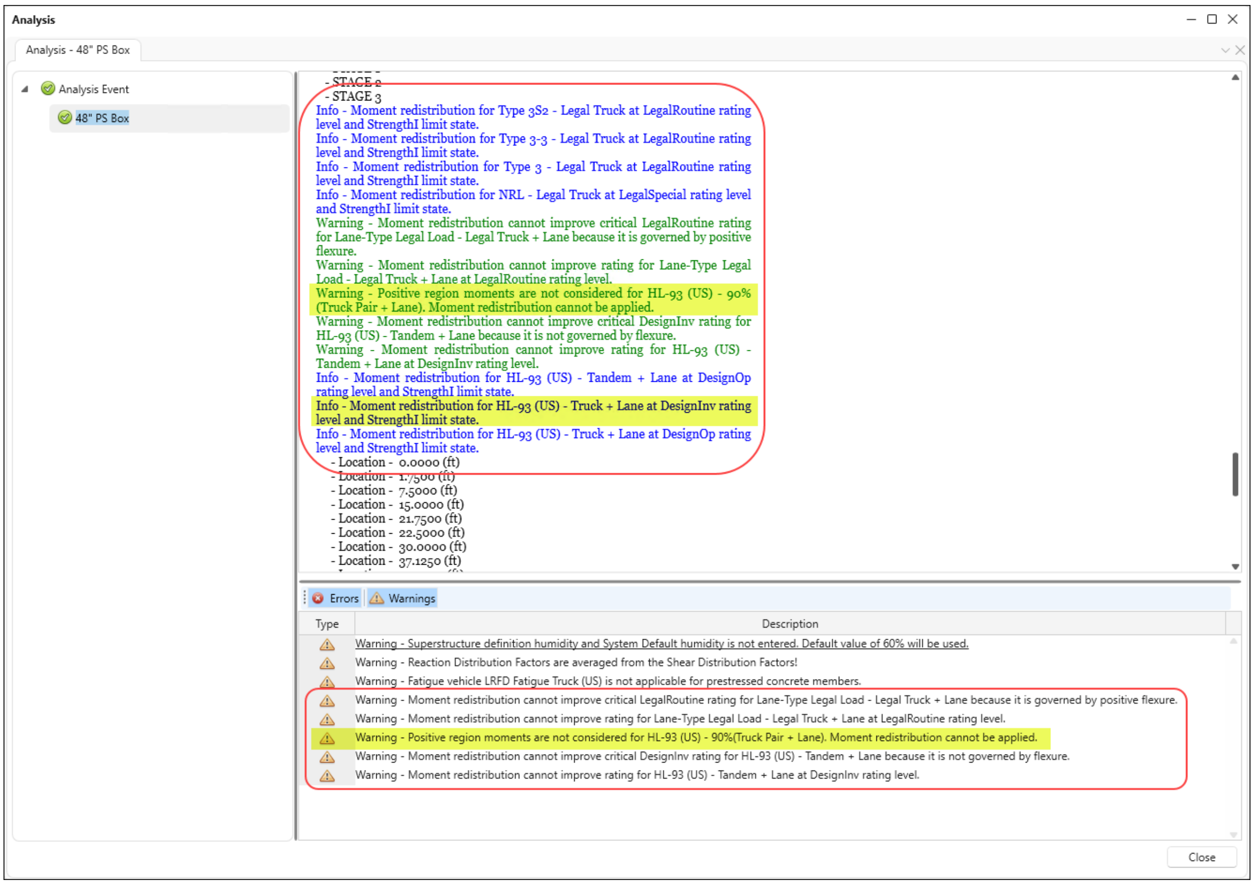

Load Combination Legend:

 Code      Vehicle
------------------------
   1      HL-93 (US) - Truck + Lane
   2      HL-93 (US) - Tandem + Lane
   3      HL-93 (US) - 90%(Truck Pair + Lane)
   4      Lane-Type Legal Load - Legal Truck + Lane
   5      NRL - Legal Truck
   6      Type 3 - Legal Truck
   7      Type 3-3 - Legal Truck
   8      Type 3S2 - Legal Truck
```

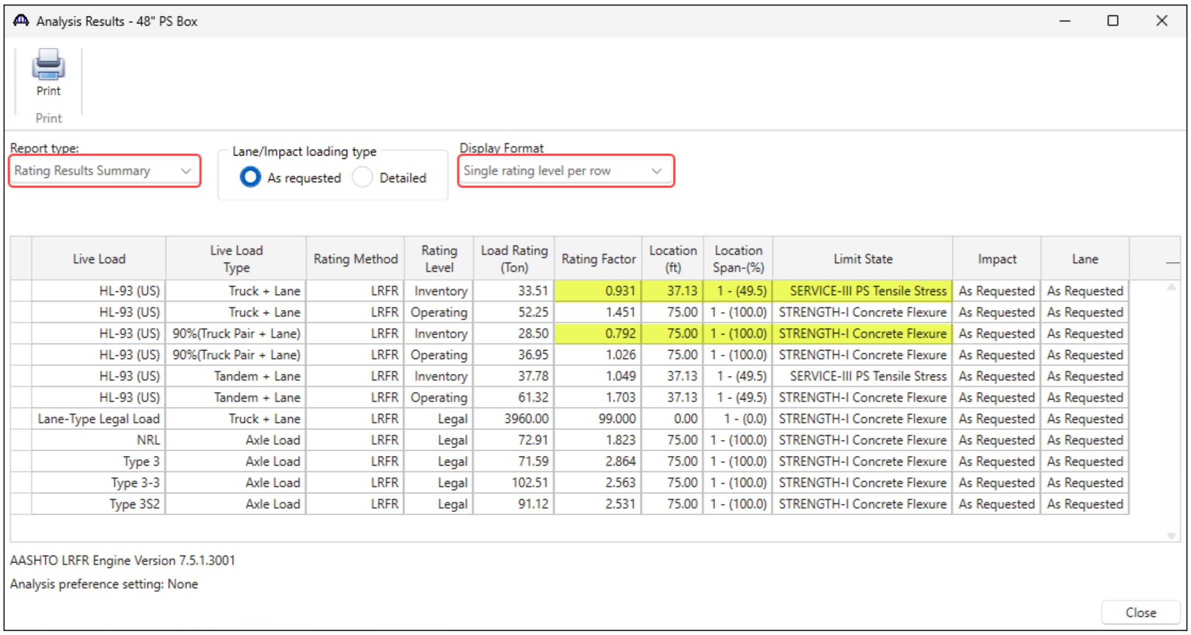
Figure 1 – 6A.4.2.1 Concrete Flexure General

LRFR Rating with Moment Redistribution

Select the control option to allow moment redistribution as shown in Member Alternative Description – Control options and rerun the analysis as shown in LRFR Rating. During analysis with the moment redistribution allowed, the program displays information and warnings about applying moment redistribution to the bending moments for the considered live load types. As shown in the screenshot below, moment redistribution was applied to the HL-93 – Truck + Lane vehicular load and the load rating for this load may improve. For the HL-93 – 90% (Truck Pair + Lane) load, however, moment redistribution could not be applied which means load rating for this load will not improve.



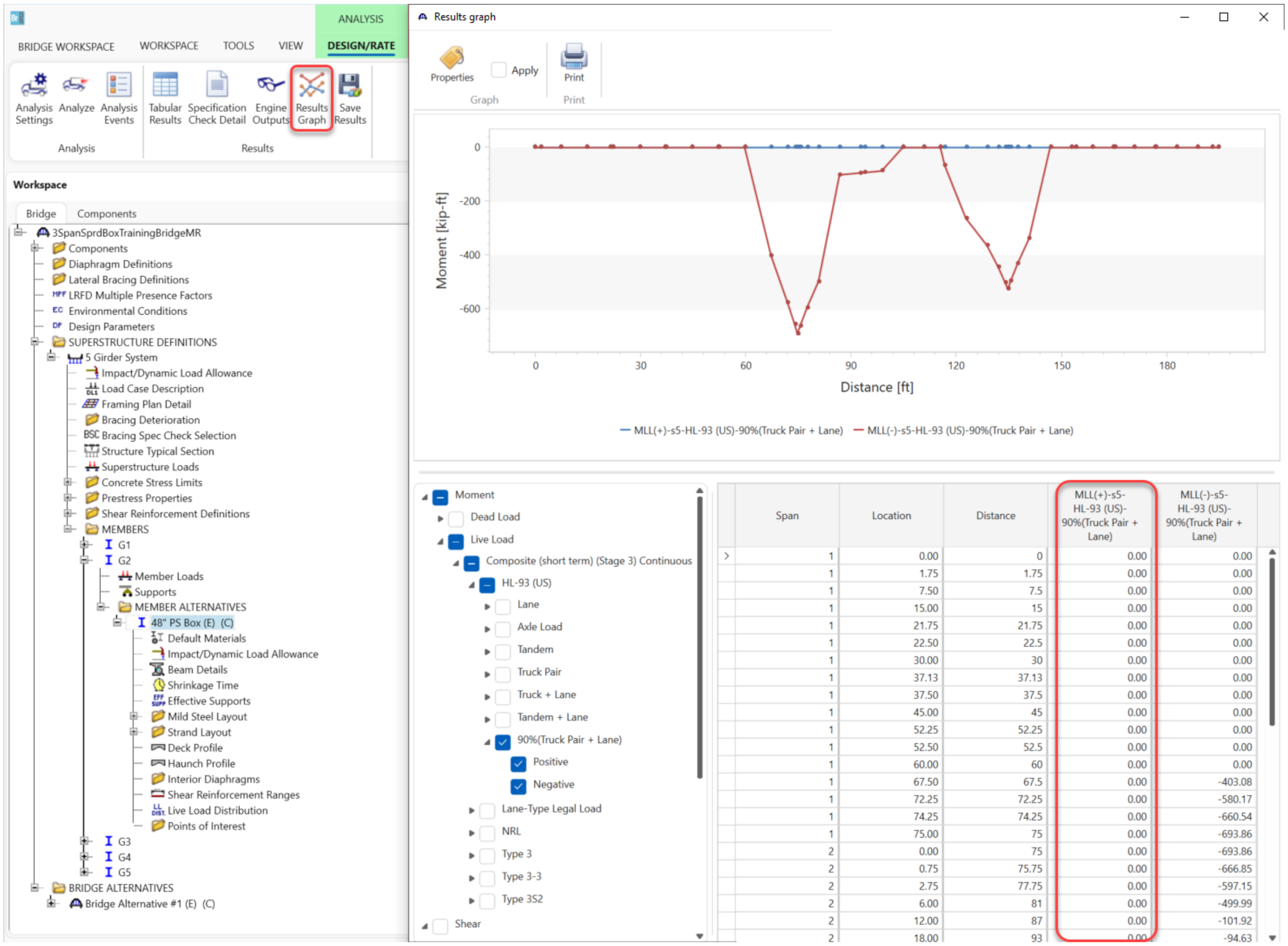
The new **Rating Results Summary** with moment redistribution allowed is as shown below and it can be observed that the critical rating factor for the HL-93 Truck + Lane load at inventory level increased with moment redistribution to 0.913 from 0.872 without moment redistribution. However, the new factor is now at a different location and due to SERVICE-III PS Tensile Stress and not due to STRENGTH-I Concrete Flexure. This means that tensile stress now controls for this load combination and the rating factor due to flexure is even higher which will be verified by reviewing the flexure rating article in Specification Check Detail with Moment Redistribution.



Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HL-93 (US)	Truck + Lane	LRFR	Inventory	33.51	0.931	37.13	1 - (49.5)	SERVICE-III PS Tensile Stress	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	52.25	1.451	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	90%(Truck Pair + Lane)	LRFR	Inventory	28.50	0.792	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	90%(Truck Pair + Lane)	LRFR	Operating	36.95	1.026	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	37.78	1.049	37.13	1 - (49.5)	SERVICE-III PS Tensile Stress	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	61.32	1.703	37.13	1 - (49.5)	STRENGTH-I Concrete Flexure	As Requested	As Requested
Lane-Type Legal Load	Truck + Lane	LRFR	Legal	3960.00	99.000	0.00	1 - (0.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
NRL	Axle Load	LRFR	Legal	72.91	1.823	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
Type 3	Axle Load	LRFR	Legal	71.59	2.864	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
Type 3-3	Axle Load	LRFR	Legal	102.51	2.563	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
Type 3S2	Axle Load	LRFR	Legal	91.12	2.531	75.00	1 - (100.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested

For the HL-93 – 90% (Truck Pair + Lane) load at the inventory level, moment redistribution could not be applied, and the rating remained the same at 0.792. This is because moment redistribution reduces negative moments over supports at the expense of increasing positive midspan moments. Since vehicular loads consisting of truck pair and lane load are only considered for negative bending moments, it is not possible to determine the increase of positive midspan moments and moment redistribution cannot be applied.

To confirm that only negative moments are considered for the HL-93 – 90% (Truck Pair + Lane) load, display the bending moment diagram using the **Results Graph** window as shown below.


ANALYSIS
BRIDGE WORKSPACE
WORKSPACE
TOOLS
VIEW
DESIGN/RATE
Analysis Settings
Analyze
Analysis Events
Tabular Results
Specification Check Detail
Engine Outputs
Results Graph
Save Results
Analysis
Results
Workspace
Bridge
Components
3SpanSprdBoxTrainingBridgeMR
SUPERSTRUCTURE DEFINITIONS
5 Girder System
MEMBERS
G1
G2
MEMBER ALTERNATIVES
48" PS Box (E) (C)
BRIDGE ALTERNATIVES
Bridge Alternative #1 (E) (C)
Results graph
Properties
Apply
Print
Graph
Moment [kip-ft]
Distance [ft]
MLL(+)-s5-HL-93 (US)-90%(Truck Pair + Lane)
MLL(-)-s5-HL-93 (US)-90%(Truck Pair + Lane)
Moment
Dead Load
Live Load
Composite (short term) (Stage 3) Continuous
HL-93 (US)
Lane
Axle Load
Tandem
Truck Pair
Truck + Lane
Tandem + Lane
90%(Truck Pair + Lane)
Positive
Negative
Lane-Type Legal Load
NRL
Type 3
Type 3-3
Type 3S2
Shear
Span
Location
Distance

Specification Check Detail with Moment Redistribution

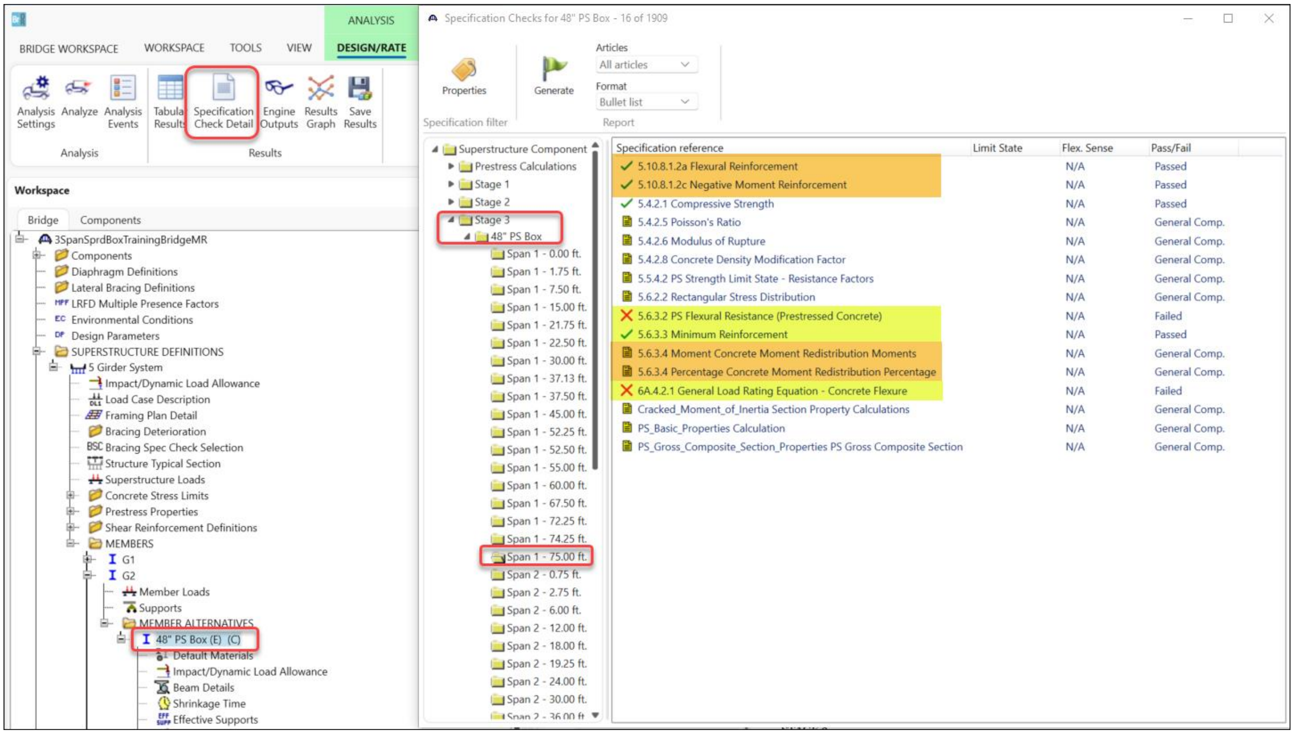
When the control option to allow moment redistribution is selected by the user, the program processes the following additional specification check articles during analysis:

- 5.10.8.1.2a Flexural Reinforcement (in negative moment regions)
- 5.10.8.1.2c Negative Moment Reinforcement (at support locations)
- 5.6.3.4 Moment Redistribution Percentage (at support locations)
- 5.6.3.4 Maximum Allowable Moment Redistribution Moments (at support locations)

As described in AASHTO LRFD/LRFR Superstructure Method of Solution Manual, these articles (highlighted in orange in the screenshot below) check if requirements for applying moment redistribution are satisfied and determine the maximum value of moment redistribution that can occur at support locations. Based on the support values and the redistribution optimization procedure, moment increments (denoted DeltaM) are interpolated at each POI between supports and applied to bending moments in the following specification check articles (highlighted in yellow in the screenshot below):

- 5.6.3.2 Flexural Resistance
- 5.6.3.3 Minimum Reinforcement
- 6A.4.2.1 General Load-Rating Equation – Concrete Flexure

Open each of the highlighted articles and review their contents.



To verify that the flexure load rating factor increased for HL-93 Truck + Lane load at inventory level, open the article titled **6A.4.2.1 General Load-Rating Equation – Concrete Flexure** (see Figure 2). On the second row in the table, the rating factor is now 1.120 which is an increase of 0.248 (28%) from the initial value of 0.872. This increase is due to the DeltaM moment increments which are the result of moment redistribution.

Since moment redistribution does not apply to the HL-93 – 90% (Truck Pair + Lane) vehicle, the DeltaM values for that vehicle are not calculated and its rating factor at the inventory level stayed the same at 0.792 with and without moment redistribution.

Spec Check Detail for 6A.4.2.1 General Load Rating Equation - Concrete Flexure

```
6A Load and Resistance Factor Rating
6A.4 Load Rating Procedures
6A.4.2 General Load-Rating Equation
6A.4.2.1 Concrete Flexure General
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 75.0000 (ft) - Left     Stage 3

Input:

Condition Factor      =     1.0000
System Factor         =     1.0000
DC Moment (Max)       =  -104.9793 (kip-ft)
DC Moment (Min)       =  -104.9793 (kip-ft)
DW Moment (Max)       =     0.0000 (kip-ft)
DW Moment (Min)       =     0.0000 (kip-ft)
DW-WS Moment (Max)    =     0.0000 (kip-ft)
DW-WS Moment (Min)    =     0.0000 (kip-ft)
Ignore Positive Moment = No

       Phi * K * Mn - GammaDC * M_DC - GammaDW * M_DW - GammaDW_WS * M_DW_WS - GammaSE * M_SE - GammaAdj_LL * M_Adj_LL + DeltaM(DL+AdjLL)
  RF = ----------------------------------------------------------------------------------------------------------------------------------
                                                      GammaLL * M_LL + DeltaM(LL+I)

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.
```

Load	Load Combo	Limit State	LL (kip-ft)	Adj. LL (kip-ft)	Load Factors DC	DW	DW-WS	LL	Phi	Mn (kip-ft)	-- Override -- Phi	Mn (kip-ft)	K	DeltaM DL+AdjLL (kip-ft)	DeltaM LL+I (kip-ft)	RF	Capacity (Ton)
DesignInv	1	STR-I	84.75	---	1.25	1.50	1.50	1.75	1.00	459.84	---	---	1.00	26.24	220.50	1.532	55.13
DesignInv	1	STR-I	-629.99	---	1.25	1.50	1.50	1.75	0.90	-1213.95	---	---	1.00	26.24	220.50	1.120	40.31
DesignOp	1	STR-I	84.75	---	1.25	1.50	1.50	1.35	1.00	459.84	---	---	1.00	26.24	170.10	1.985	71.47
DesignOp	1	STR-I	-629.99	---	1.25	1.50	1.50	1.35	0.90	-1213.95	---	---	1.00	26.24	170.10	1.451	52.25
DesignInv	2	STR-I	69.58	---	1.25	1.50	1.50	1.75	0.90	-1213.95	---	---	1.00	---	---	NA	NA
DesignInv	2	STR-I	-522.04	---	1.25	1.50	1.50	1.75	0.90	-1213.95	---	---	1.00	---	---	1.052	37.88
DesignOp	2	STR-I	69.58	---	1.25	1.50	1.50	1.35	1.00	459.84	---	---	1.00	23.58	126.64	2.573	92.62
DesignOp	2	STR-I	-522.04	---	1.25	1.50	1.50	1.35	0.90	-1213.95	---	---	1.00	23.58	126.64	1.704	61.33
DesignInv	3	STR-I	0.00	---	1.25	1.50	1.50	1.75	0.90	-1213.95	---	---	1.00	---	---	99.000	3564.00
DesignInv	3	STR-I	-693.86	---	1.25	1.50	1.50	1.75	0.90	-1213.95	---	---	1.00	---	---	0.792	28.50
DesignOp	3	STR-I	0.00	---	1.25	1.50	1.50	1.35	0.90	-1213.95	---	---	1.00	---	---	99.000	3564.00
DesignOp	3	STR-I	-693.86	---	1.25	1.50	1.50	1.35	0.90	-1213.95	---	---	1.00	---	---	1.026	36.95
LegalRout~	4	STR-I	0.00	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	---	---	99.000	3960.00
LegalRout~	4	STR-I	0.00	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	---	---	99.000	3960.00
LegalSpec~	5	STR-I	74.61	---	1.25	1.50	1.50	1.30	1.00	459.84	---	---	1.00	18.30	87.09	3.112	124.46
LegalSpec~	5	STR-I	-480.38	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	18.30	87.09	1.823	72.91
LegalRout~	6	STR-I	46.97	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	16.97	50.73	NA	NA
LegalRout~	6	STR-I	-301.82	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	16.97	50.73	2.864	71.59
LegalRout~	7	STR-I	49.77	---	1.25	1.50	1.50	1.30	1.00	459.84	---	---	1.00	26.24	96.34	3.507	140.29
LegalRout~	7	STR-I	-370.52	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	26.24	96.34	2.563	102.51
LegalRout~	8	STR-I	53.25	---	1.25	1.50	1.50	1.30	1.00	459.84	---	---	1.00	26.24	97.54	3.387	121.93
LegalRout~	8	STR-I	-375.16	---	1.25	1.50	1.50	1.30	0.90	-1213.95	---	---	1.00	26.24	97.54	2.531	91.12

```
Legend:
NA - Resistance and live load are of opposite sign so rating factor is not applicable.
 * - Positive moment rating ignored.


Load Combination Legend:

 Code      Vehicle
----------------------------
   1     HL-93 (US) - Truck + Lane
   2     HL-93 (US) - Tandem + Lane
   3     HL-93 (US) - 90%(Truck Pair + Lane)
   4     Lane-Type Legal Load - Legal Truck + Lane
   5     NRL - Legal Truck
   6     Type 3 - Legal Truck
   7     Type 3-3 - Legal Truck
   8     Type 3S2 - Legal Truck
```

Figure 2 – 6A.4.2.1 General Load-Rating Equation – Concrete Flexure

The flexural resistance article (see Figure 3) is also affected by moment redistribution through moment increments DeltaMu. For HL-93 Truck + Lane load at inventory level, the Mr/Mu ratio with moment redistribution is equal to:

$$\frac{M_r}{M_u} = \frac{-1092.55}{-1233.71 + 246.74} = 1.107$$

which is an increase from the ratio without moment redistribution that is equal to:

$$\frac{M_r}{M_u} = \frac{-1092.55}{-1233.71} = 0.886$$

In negative moment regions, moment redistribution can potentially increase flexure rating factor and design ratios, but it is worth remembering that in positive moment regions the rating factors and design ratios may decrease due to moment redistribution as the moment increments DeltaM will increase the positive moments.

The design ratios for the HL-93 – 90% (Truck Pair + Lane) vehicle are unchanged as moment redistribution does not apply to this vehicle and DeltaMu increments are not calculated.

The increments are also not calculated for any load combination under the SER-III limit state because moment redistribution applies only to the strength limit states.

Spec Check Detail for 5.6.3.2 PS Flexural Resistance (Prestressed Concrete)

```
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)

PS Box Rect Void - At Location = 75.0000 (ft) - Left      Stage 3

                     Cross Section Properties
-----------------------------------------------------------------
Name: BII-48
Girder f'c = 6.00(ksi)     Girder f'ci = 5.10(ksi)
Slab f'c   = 4.00(ksi)

Effective Slab Width          =     90.00(in)
Effective Slab Thickness      =      7.50(in)
Haunch Width                  =     47.25(in)
Haunch Thickness              =      0.50(in)
Beam Height                   =     33.00(in)

Total Aps  =   0.00(in^2)
Total CGS  =   0.00(in)

Eff Aps    =   0.00(in^2)
Eff CGS    =   0.00(in)


Flexural Reinforcement
----------------------
   As      Dist. From
             Bottom
 (in^2)       (in)
  1.86        3.00
  3.96       37.50
  2.79       35.50

Allow Moment Redistribution Control Option: Yes
Moment Redistribution Qualified: Yes, redistribution did occur.

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	Load Combination	Mu kip-ft	DeltaMu kip-ft	Phi	Mn kip-ft	-- Override -- Phi	Mn kip-ft	Mr= Phi * Mn kip-ft	Mr/Mu	NA Depth in	Ac in^2	Max Conc Stress ksi	Max Rebar Stress ksi	Tensi Capac ki
STR-I	1, DesInv	17.08	246.74	1.000	459.84	---	---	459.84	1.743	2.15	423.00	0.00	60.00	
STR-I	1, DesInv	-1233.71	246.74	0.900	-1213.95	---	---	-1092.55	1.107	2.42	902.44	0.00	60.00	
STR-I	1, DesOp	-16.82	196.34	1.000	459.84	---	---	459.84	2.561	2.15	423.00	0.00	60.00	
STR-I	1, DesOp	-981.72	196.34	0.900	-1213.95	---	---	-1092.55	1.391	2.42	902.44	0.00	60.00	
STR-I	2, DesInv	-9.46	---	0.900	-1213.95	---	---	-1092.55	99.000	2.42	902.44	0.00	60.00	
STR-I	2, DesInv	-1044.80	---	0.900	-1213.95	---	---	-1092.55	1.046	2.42	902.44	0.00	60.00	
STR-I	2, DesOp	-37.29	150.22	1.000	459.84	---	---	459.84	4.072	2.15	423.00	0.00	60.00	
STR-I	2, DesOp	-835.98	150.22	0.900	-1213.95	---	---	-1092.55	1.593	2.42	902.44	0.00	60.00	
STR-I	3, DesInv	-131.22	---	0.900	-1213.95	---	---	-1092.55	8.326	2.42	902.44	0.00	60.00	
STR-I	3, DesInv	-1345.48	---	0.900	-1213.95	---	---	-1092.55	0.812	2.42	902.44	0.00	60.00	
STR-I	3, DesOp	-131.22	---	0.900	-1213.95	---	---	-1092.55	8.326	2.42	902.44	0.00	60.00	
STR-I	3, DesOp	-1067.94	---	0.900	-1213.95	---	---	-1092.55	1.023	2.42	902.44	0.00	60.00	
STR-I	4, LegalRout	-131.22	---	0.900	-1213.95	---	---	-1092.55	8.326	2.42	902.44	0.00	60.00	
STR-I	4, LegalRout	-131.22	---	0.900	-1213.95	---	---	-1092.55	8.326	2.42	902.44	0.00	60.00	
STR-I	5, LegalSpec	-34.24	105.39	1.000	459.84	---	---	459.84	6.463	2.15	423.00	0.00	60.00	
STR-I	5, LegalSpec	-755.72	105.39	0.900	-1213.95	---	---	-1092.55	1.680	2.42	902.44	0.00	60.00	
STR-I	6, LegalRout	-70.16	67.70	0.900	-1213.95	---	---	-1092.55	99.000	2.42	902.44	0.00	60.00	
STR-I	6, LegalRout	-523.59	67.70	0.900	-1213.95	---	---	-1092.55	2.397	2.42	902.44	0.00	60.00	
STR-I	7, LegalRout	-66.52	122.58	1.000	459.84	---	---	459.84	8.202	2.15	423.00	0.00	60.00	
STR-I	7, LegalRout	-612.90	122.58	0.900	-1213.95	---	---	-1092.55	2.228	2.42	902.44	0.00	60.00	
STR-I	8, LegalRout	-62.00	123.79	1.000	459.84	---	---	459.84	7.442	2.15	423.00	0.00	60.00	
STR-I	8, LegalRout	-618.93	123.79	0.900	-1213.95	---	---	-1092.55	2.207	2.42	902.44	0.00	60.00	
SER-III	1, DesInv	-37.18	---	0.900	-1213.95	---	---	-1092.55	29.383	2.42	902.44	0.00	60.00	

```
Load Combination Legend:

 Code       Vehicle
-------------------------
   1       HL-93 (US) - Truck + Lane
   2       HL-93 (US) - Tandem + Lane
   3       HL-93 (US) - 90%(Truck Pair + Lane)
   4       Lane-Type Legal Load - Legal Truck + Lane
   5       NRL - Legal Truck
   6       Type 3 - Legal Truck
   7       Type 3-3 - Legal Truck
   8       Type 3S2 - Legal Truck
```

Figure 3 – 5.6.3.2 Flexural Resistance

One more specification check article affected by moment redistribution is the minimum reinforcement article (see Figure 4). When moment redistribution is applied to Mu through the DeltaMu increment, the Mr/MrMin ratio may change if MrMin is governed by Mr2 which in turn is equal to 1.33 Mu.

Spec Check Detail for 5.6.3.3 Minimum Reinforcement

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

PS Box Rect Void - At Location = 75.0000 (ft) - Left     Stage 3

Cross Section Properties for Prestress box beam with Rectangular void
---------------------------------------------------------------------
Name: BII-48   Girder f'c = 6.00(ksi)     Girder f'ci = 5.10(ksi)

Beam Height              =   33.00(in)     Side Wall Thickness      =    5.00(in)
Top Slab Width           =   47.25(in)
Top Slab Thick           =    5.50(in)
Bottom Slab Width        =   48.00(in)
Bottom Slab Thick        =    5.50(in)
Shear Key Top            =    6.00(in)
Shear Key Height         =    6.00(in)
Shear Key Depth          =    0.75(in)
B1                       =    3.00(in)
B2                       =    3.00(in)
B3                       =    3.00(in)
B4                       =    3.00(in)

Slab f'c                 =     4.00(ksi)
Effective Slab Width     =    90.00(in)       Haunch Width             =     47.25(in)
Effective Slab Thickness =     7.50(in)       Haunch Thickness         =      0.50(in)


Flexural Reinforcement
----------------------
   As     Dist. From
            Bottom
  (in^2)      (in)
  1.86       3.00
  3.96      37.50
  2.79      35.50


Cross section is located in the region over the pier between the simple span bearings.
Section will be analyzed as a reinforced concrete section.

Input:
fr beam =        0.59 (ksi)              fr deck =        0.48 (ksi)
Inertia =   253622.51 (in^4)             STop    =   -19754.87 (in^3)
yBot    =       25.29 (in)               SBot    =    10027.05 (in^3)

Gamma3 = Fy/Fu.

Gamma1 =  1.60
Gamma2 =  1.10
Gamma3 =  0.67

Mcr = Gamma3 * [( gamma1*fr + Gamma2*fcpe)*Sc - Mdnc * (Sc/Snc - 1)]      (5.6.3.3-1)

(Note:  For reinforced concrete members Sc = Snc)


Mr1 = Mcr              Article 5.6.3.3
Mr2 = 1.33 * Mu        Article 5.6.3.3

MrMin = Min(Mr1, Mr2)     Article 5.6.3.3


Allow Moment Redistribution Control Option: Yes
Moment Redistribution Qualified: Yes, redistribution did occur.

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	Load Comb	Mu (kip-ft)	DeltaMu (kip-ft)	Sc (in^3)	Mcr (kip-ft)	Mr1 (kip-ft)	Mr2 (kip-ft)	MrMin (kip-ft)	--- Override --- Phi	Mnr (kip-ft)	Mr (kip-ft)	DR = Mr/MrMin	
STR-I	1, DesInv	17.08	246.74	10027.05	523.97	523.97	350.88	350.88	---	---	459.84	1.311	Pass
STR-I	1, DesInv	-1233.71	246.74	-19754.87	-842.87	-842.87	-1312.67	-842.87	---	---	-1092.55	1.296	Pass
STR-I	1, DesOp	-16.82	196.34	10027.05	523.97	523.97	238.77	238.77	---	---	459.84	1.926	Pass
STR-I	1, DesOp	-981.72	196.34	-19754.87	-842.87	-842.87	-1044.54	-842.87	---	---	-1092.55	1.296	Pass
STR-I	2, DesInv	-9.46	---	-19754.87	-842.87	-842.87	-12.58	-12.58	---	---	-1092.55	86.856	Pass
STR-I	2, DesInv	-1044.80	---	-19754.87	-842.87	-842.87	-1389.59	-842.87	---	---	-1092.55	1.296	Pass
STR-I	2, DesOp	-37.29	150.22	10027.05	523.97	523.97	150.19	150.19	---	---	459.84	3.062	Pass
STR-I	2, DesOp	-835.98	150.22	-19754.87	-842.87	-842.87	-912.07	-842.87	---	---	-1092.55	1.296	Pass
STR-I	3, DesInv	-131.22	---	-19754.87	-842.87	-842.87	-174.53	-174.53	---	---	-1092.55	6.260	Pass
STR-I	3, DesInv	-1345.48	---	-19754.87	-842.87	-842.87	-1789.49	-842.87	---	---	-1092.55	1.296	Pass
STR-I	3, DesOp	-131.22	---	-19754.87	-842.87	-842.87	-174.53	-174.53	---	---	-1092.55	6.260	Pass
STR-I	3, DesOp	-1067.94	---	-19754.87	-842.87	-842.87	-1420.36	-842.87	---	---	-1092.55	1.296	Pass
STR-I	4, LegalRout	-131.22	---	-19754.87	-842.87	-842.87	-174.53	-174.53	---	---	-1092.55	6.260	Pass
STR-I	4, LegalRout	-131.22	---	-19754.87	-842.87	-842.87	-174.53	-174.53	---	---	-1092.55	6.260	Pass
STR-I	5, LegalSpec	-34.24	105.39	10027.05	523.97	523.97	94.63	94.63	---	---	459.84	4.859	Pass
STR-I	5, LegalSpec	-755.72	105.39	-19754.87	-842.87	-842.87	-864.95	-842.87	---	---	-1092.55	1.296	Pass
STR-I	6, LegalRout	-70.16	67.70	-19754.87	-842.87	-842.87	-3.28	-3.28	---	---	-1092.55	333.283	Pass
STR-I	6, LegalRout	-523.59	67.70	-19754.87	-842.87	-842.87	-606.34	-606.34	---	---	-1092.55	1.802	Pass
STR-I	7, LegalRout	-66.52	122.58	10027.05	523.97	523.97	74.56	74.56	---	---	459.84	6.167	Pass
STR-I	7, LegalRout	-612.90	122.58	-19754.87	-842.87	-842.87	-652.13	-652.13	---	---	-1092.55	1.675	Pass
STR-I	8, LegalRout	-62.00	123.79	10027.05	523.97	523.97	82.18	82.18	---	---	459.84	5.596	Pass
STR-I	8, LegalRout	-618.93	123.79	-19754.87	-842.87	-842.87	-658.55	-658.55	---	---	-1092.55	1.659	Pass
SER-III	1, DesInv	-37.18	---	-19754.87	-842.87	-842.87	-49.45	-49.45	---	---	-1092.55	22.093	Pass
SER-III	1, DesInv	-608.97	---	-19754.87	-842.87	-842.87	-809.94	-809.94	---	---	-1092.55	1.349	Pass
SER-III	2, DesInv	-49.31	---	-19754.87	-842.87	-842.87	-65.59	-65.59	---	---	-1092.55	16.658	Pass
SER-III	2, DesInv	-522.61	---	-19754.87	-842.87	-842.87	-695.08	-695.08	---	---	-1092.55	1.572	Pass
SER-III	3, DesInv	-104.98	---	-19754.87	-842.87	-842.87	-139.62	-139.62	---	---	-1092.55	7.825	Pass
SER-III	3, DesInv	-660.07	---	-19754.87	-842.87	-842.87	-877.89	-842.87	---	---	-1092.55	1.296	Pass
SER-III	4, LegalRout	-104.98	---	-19754.87	-842.87	-842.87	-139.62	-139.62	---	---	-1092.55	7.825	Pass
SER-III	4, LegalRout	-104.98	---	-19754.87	-842.87	-842.87	-139.62	-139.62	---	---	-1092.55	7.825	Pass
SER-III	5, LegalSpec	-30.37	---	-19754.87	-842.87	-842.87	-40.40	-40.40	---	---	-1092.55	27.045	Pass
SER-III	5, LegalSpec	-585.36	---	-19754.87	-842.87	-842.87	-778.53	-778.53	---	---	-1092.55	1.403	Pass
SER-III	6, LegalRout	-58.01	---	-19754.87	-842.87	-842.87	-77.15	-77.15	---	---	-1092.55	14.161	Pass
SER-III	6, LegalRout	-406.80	---	-19754.87	-842.87	-842.87	-541.04	-541.04	---	---	-1092.55	2.019	Pass
SER-III	7, LegalRout	-55.21	---	-19754.87	-842.87	-842.87	-73.42	-73.42	---	---	-1092.55	14.880	Pass
SER-III	7, LegalRout	-475.50	---	-19754.87	-842.87	-842.87	-632.42	-632.42	---	---	-1092.55	1.728	Pass
SER-III	8, LegalRout	-51.73	---	-19754.87	-842.87	-842.87	-68.80	-68.80	---	---	-1092.55	15.880	Pass
SER-III	8, LegalRout	-480.14	---	-19754.87	-842.87	-842.87	-638.59	-638.59	---	---	-1092.55	1.711	Pass

```
Load Combination Legend:

 Code      Vehicle
------------------------
    1     HL-93 (US) - Truck + Lane
    2     HL-93 (US) - Tandem + Lane
    3     HL-93 (US) - 90%(Truck Pair + Lane)
    4     Lane-Type Legal Load - Legal Truck + Lane
    5     NRL - Legal Truck
    6     Type 3 - Legal Truck
    7     Type 3-3 - Legal Truck
    8     Type 3S2 - Legal Truck
```

Figure 4 – 5.6.3.3 Minimum Reinforcement

All specification check articles affected by moment redistribution are related to flexure only because moment redistribution does not apply to shear effects. In the bridge model considered in this tutorial, shear effects are ignored, and no shear related articles are shown but even if shear was not ignored and shear articles were processed, they would not be affected by moment redistribution.

The additional specification check articles processed only when the moment redistribution is allowed by the user are shown in Figure 5 through Figure 8. Open each article and review its contents.

Spec Check Detail for 5.10.8.1.2a Flexural Reinforcement

```
5 Concrete Structures
5.10 Reinforcement
5.10.8 Development and Splices of Reinforcement
5.10.8.1 General
5.10.8.1.2 Flexural Reinforcement
5.10.8.1.2a General
(AASHTO LRFD Bridge Design Specifications, Ninth Edition)

PS Box Rect Void - At Location = 75.0000 (ft) - Left     Stage 3

INPUT:
Concrete Type: Normalweight
f'c <= 6.000 ksi

Flexural Reinforcement
----------------------
 Dist. From           Bar       Bar                                                  Length     Length
   Bottom     Bar   Diameter    Area      Number       As          fy        Before     After
    (in)      Size     (in)     (in^2)    of Bars     (in^2)      (ksi)       (ksi)      (ft)
-------------------------------------------------------------------------------------------------
       3.00    5          0.63      0.31       6.00       1.86      60.00       7.50      0.000
      37.50    6          0.75      0.44       9.00       3.96      60.00      20.00     80.000
      35.50    5          0.63      0.31       9.00       2.79      60.00      20.00     80.000

5.10.8.1.1 Basic Requirements, Nonprestressed Reinforcement Yield Strength
--------------------------------------------------------------------------
Max fy <= 100 ksi                                                (5.10.8.1.1)

Max fy = 60.000 ksi <= 100 ksi                                           Pass

5.10.8.1 General, Bar Size
--------------------------
Max Ab <= Ab (#11) = 1.56 in^2                                     (5.10.8.1)

Max Ab = Ab (#6) = 0.440 ksi <= 1.56 in^2                                Pass

5.10.8.1 General, Concrete Compressive Strength
-----------------------------------------------
f'c <= 15 ksi                                                      (5.10.8.1)

f'c = 6.000 ksi <= 15 ksi                                                Pass

5.10.8.2a General, Bar Termination
----------------------------------
Abs(AsTop(Left) - AsTop(Right)) <= 0.5 * Max(AsTop(Left), AsTop(Right))
           (LeftTerm)           <=                (RightTerm)   (5.10.8.2a)

AsTop(Left)  = 6.750 in^2
AsTop(Right) = 6.750 in^2
(LeftTerm) = 0.000 in^2 <= (RightTerm) = 3.375 in^2                      Pass
```

Figure 5 – 5.10.8.1.2a Flexural Reinforcement

The articles shown in Figure 5 and Figure 6 check several reinforcement requirements that must pass for moment redistribution to be applied. For instance, in the negative moment reinforcement article (Figure 6), the required length of the reinforcement on the right side of the first interior support is calculated to be 28.881 ft which is almost half of the 60.0 ft span between interior supports. Since the reinforcement in the original imported bridge model extended only 15.0 ft from the support, the reinforcement length had to be adjusted. Otherwise, the length check would fail, and redistribution would not be applied at all.

Spec Check Detail for 5.10.8.1.2c Negative Moment Reinforcement

```
5 Concrete Structures
5.10 Reinforcement
5.10.8 Development and Splices of Reinforcement
5.10.8.1 General
5.10.8.1.2 Flexural Reinforcement
5.10.8.1.2c Negative Moment Reinforcement
(AASHTO LRFD Bridge Design Specifications, Ninth Edition)

PS Box Rect Void - At Location = 75.0000 (ft) - Left     Stage 3

Overall Depth                = 41.00(in)
Effective Depth              = 36.67(in)
Clear Span Length            = 74.25(ft)
Distance To Inflection Point = 13.96(ft)
AsTension                    = 6.75(in^2)

Top Bar Required Extension   = Max(Effective Depth, 1/16 * Clear Span Length, 12 * Bar Diameter)
Top Bar Required Length      = (Distance To Inflection Point) + (Top Bar Required Extension)

If (Sum of Top Bar As with Required Length Satisfied) >= (AsTension / 3) Then <Pass>
                (LeftTerm)                            >=   (RightTerm)
   Then <Pass>
```

Dist. From Bottom (in)	Bar Size	Bar Diameter (in)	Bar Area (in^2)	Number of Bars	As (in^2)	Length (ft)	Required Extension (ft)	Required Length (ft)	Required Length Satisfied
37.50	6	0.75	0.44	9.00	3.96	20.000	4.641	18.603	Yes
35.50	5	0.63	0.31	9.00	2.79	20.000	4.641	18.603	Yes

```
(LeftTerm) = 6.75 in^2 >= (RightTerm) = 2.25 in^2 <Pass>

PS Box Rect Void - At Location = 75.0000 (ft) - Right     Stage 3

Overall Depth                = 41.00(in)
Effective Depth              = 36.67(in)
Clear Span Length            = 58.50(ft)
Distance To Inflection Point = 25.22(ft)
AsTension                    = 6.75(in^2)

Top Bar Required Extension   = Max(Effective Depth, 1/16 * Clear Span Length, 12 * Bar Diameter)
Top Bar Required Length      = (Distance To Inflection Point) + (Top Bar Required Extension)

If (Sum of Top Bar As with Required Length Satisfied) >= (AsTension / 3) Then <Pass>
                (LeftTerm)                            >=   (RightTerm)
   Then <Pass>
```

Dist. From Bottom (in)	Bar Size	Bar Diameter (in)	Bar Area (in^2)	Number of Bars	As (in^2)	Length (ft)	Required Extension (ft)	Required Length (ft)	Required Length Satisfied
37.50	6	0.75	0.44	9.00	3.96	80.000	3.656	28.881	Yes
35.50	5	0.63	0.31	9.00	2.79	80.000	3.656	28.881	Yes

```
(LeftTerm) = 6.75 in^2 >= (RightTerm) = 2.25 in^2 <Pass>
```

Figure 6 – 5.10.8.1.2c Negative Moment Reinforcement

Spec Check Detail for 5.6.3.4 Percentage Concrete Moment Redistribution Percentage

```
5 Concrete Structures
5.6 DESIGN FOR FLEXURAL AND AXIAL FORCE EFFECTS - B REGIONS
5.6.3 Flexural Members
5.6.3.4 Moment Redistribution Percentage - At Support Location
(AASHTO LRFD Bridge Design Specifications, Ninth Edition)

PS Box Rect Void - At Location = 75.0000 (ft) - Left     Stage 3

If Et >= 1.5Etl and Flexure Type is Neg, moment redistribution can occur
Maximum moment reduction percentage (MRP) = Max(20.0, 1000Et)

Minimum value of left side MRP and right side MRP will be used as MRP on both sides of this support.
```

Limit State	Load Combo	Flexure Type	Maximum Negative Mu (kip-ft)	Et	Etl	1.5Etl	Redist. Can occur?	1000Et (%)	Maximum Reduction Percentage (%)
STR-I	1, DesInv	Neg	-1233.71	0.043538	0.005	0.0075	Yes	43.54	20.00
STR-I	1, DesOp	Neg	-981.72	0.043538	0.005	0.0075	Yes	43.54	20.00
STR-I	2, DesInv	Neg	-1044.80	0.043538	0.005	0.0075	Yes	43.54	20.00
STR-I	2, DesOp	Neg	-835.98	0.043538	0.005	0.0075	Yes	43.54	20.00
STR-I	3, DesInv	Neg	-1345.48	0.043538	0.005	0.0075	Yes	43.54	20.00
STR-I	3, DesOp	Neg	-1067.94	0.043538	0.005	0.0075	Yes	43.54	20.00
STR-I	4, LegalR~	Neg	-131.22	0.043538	0.005	0.0075	Yes	43.54	20.00
STR-I	5, LegalS~	Neg	-755.72	0.043538	0.005	0.0075	Yes	43.54	20.00
STR-I	6, LegalR~	Neg	-523.59	0.043538	0.005	0.0075	Yes	43.54	20.00
STR-I	7, LegalR~	Neg	-612.90	0.043538	0.005	0.0075	Yes	43.54	20.00
STR-I	8, LegalR~	Neg	-618.93	0.043538	0.005	0.0075	Yes	43.54	20.00

Load Combination Legend:

Code	Vehicle
1	HL-93 (US) - Truck + Lane
2	HL-93 (US) - Tandem + Lane
3	HL-93 (US) - 90%(Truck Pair + Lane)
4	Lane-Type Legal Load - Legal Truck + Lane
5	NRL - Legal Truck
6	Type 3 - Legal Truck
7	Type 3-3 - Legal Truck
8	Type 3S2 - Legal Truck

Figure 7 – 5.6.3.4 Moment Redistribution Percentage

In the moment redistribution percentage article (Figure 7), strain requirements are checked to determine if moment redistribution can be applied. Also, the maximum percentages of moment reduction at supports are calculated. Based on the percentages, the maximum moment increments (DeltaM) at supports are calculated in the maximum allowable moment redistribution moments article (Figure 8).

Spec Check Detail for 5.6.3.4 Moment Concrete Moment Redistribution Moments

5 Concrete Structures
5.6 DESIGN FOR FLEXURAL AND AXIAL FORCE EFFECTS - B REGIONS
5.6.3 Flexural Members
5.6.3.4 Maximum Allowable Moment Redistribution Moments - At Support Location
(AASHTO LRFD Bridge Design Specifications, Ninth Edition)

PS Box Rect Void - At Location = 75.0000 (ft) - Left   Stage 3

Input:
M_DC = -104.98 kip-ft
M_DW = 0.00 kip-ft
M_DW-WS = 0.00 kip-ft
M_PT = 0.00 kip-ft
M_SE = 0.00 kip-ft

Limit State	Load Combo	Flexure Type	MRP (%)	M_LL (kip-ft)	M_AdjLL (kip-ft)
STR-I	1, DesInv	Neg	20.00	-629.99	0.00
STR-I	1, DesOp	Neg	20.00	-629.99	0.00
STR-I	2, DesInv	Neg	20.00	-522.04	0.00
STR-I	2, DesOp	Neg	20.00	-522.04	0.00
STR-I	3, DesInv	Neg	20.00	-693.86	0.00
STR-I	3, DesOp	Neg	20.00	-693.86	0.00
STR-I	4, LegalR~	Neg	20.00	0.00	0.00
STR-I	5, LegalS~	Neg	20.00	-480.38	0.00
STR-I	6, LegalR~	Neg	20.00	-301.82	0.00
STR-I	7, LegalR~	Neg	20.00	-370.52	0.00
STR-I	8, LegalR~	Neg	20.00	-375.16	0.00

		Load Factors						
Limit State	Load Combo	DC	DW	DW-WS	SE	PT	LL	AdjLL
STR-I	1	1.25	1.50	1.50	0.00	0.00	1.75	0.00
STR-I	1	1.25	1.50	1.50	0.00	0.00	1.35	0.00
STR-I	2	1.25	1.50	1.50	0.00	0.00	1.75	0.00
STR-I	2	1.25	1.50	1.50	0.00	0.00	1.35	0.00
STR-I	3	1.25	1.50	1.50	0.00	0.00	1.75	0.00
STR-I	3	1.25	1.50	1.50	0.00	0.00	1.35	0.00
STR-I	4	1.25	1.50	1.50	0.00	0.00	1.30	0.00
STR-I	5	1.25	1.50	1.50	0.00	0.00	1.30	0.00
STR-I	6	1.25	1.50	1.50	0.00	0.00	1.30	0.00
STR-I	7	1.25	1.50	1.50	0.00	0.00	1.30	0.00
STR-I	8	1.25	1.50	1.50	0.00	0.00	1.30	0.00
SER-III	1	1.00	1.00	1.00	0.00	0.00	0.80	0.00
SER-III	2	1.00	1.00	1.00	0.00	0.00	0.80	0.00
SER-III	3	1.00	1.00	1.00	0.00	0.00	0.80	0.00
SER-III	4	1.00	1.00	1.00	0.00	0.00	1.00	0.00
SER-III	5	1.00	1.00	1.00	0.00	0.00	1.00	0.00
SER-III	6	1.00	1.00	1.00	0.00	0.00	1.00	0.00
SER-III	7	1.00	1.00	1.00	0.00	0.00	1.00	0.00
SER-III	8	1.00	1.00	1.00	0.00	0.00	1.00	0.00

Maximum Allowable Moment Redistribution Moments:
Max_Delta_M = -MRP * M

where:
MRP = maximum reduction percentage
M = elastic moment due to applied load

				Unfactored Max_Delta_M							Factored Max_Delta_M	
Limit State	Load Combo	Flexure Type	MRP (%)	DC (kip-ft)	DW (kip-ft)	DW-WS (kip-ft)	SE (kip-ft)	PT (kip-ft)	LL (kip-ft)	AdjLL (kip-ft)	DL+AdjLL (kip-ft)	LL+I (kip-ft)
STR-I	1, DesInv	Neg	20.00	21.00	0.00	0.00	0.00	0.00	126.00	0.00	26.24	220.50
STR-I	1, DesOp	Neg	20.00	21.00	0.00	0.00	0.00	0.00	126.00	0.00	26.24	170.10
STR-I	2, DesInv	Neg	20.00	21.00	0.00	0.00	0.00	0.00	104.41	0.00	26.24	182.72
STR-I	2, DesOp	Neg	20.00	21.00	0.00	0.00	0.00	0.00	104.41	0.00	26.24	140.95
STR-I	3, DesInv	Neg	20.00	21.00	0.00	0.00	0.00	0.00	138.77	0.00	26.24	242.85
STR-I	3, DesOp	Neg	20.00	21.00	0.00	0.00	0.00	0.00	138.77	0.00	26.24	187.34
STR-I	4, LegalR~	Neg	20.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00	26.24	0.00
STR-I	5, LegalS~	Neg	20.00	21.00	0.00	0.00	0.00	0.00	96.08	0.00	26.24	124.90
STR-I	6, LegalR~	Neg	20.00	21.00	0.00	0.00	0.00	0.00	60.36	0.00	26.24	78.47
STR-I	7, LegalR~	Neg	20.00	21.00	0.00	0.00	0.00	0.00	74.10	0.00	26.24	96.34
STR-I	8, LegalR~	Neg	20.00	21.00	0.00	0.00	0.00	0.00	75.03	0.00	26.24	97.54

Load Combination Legend:

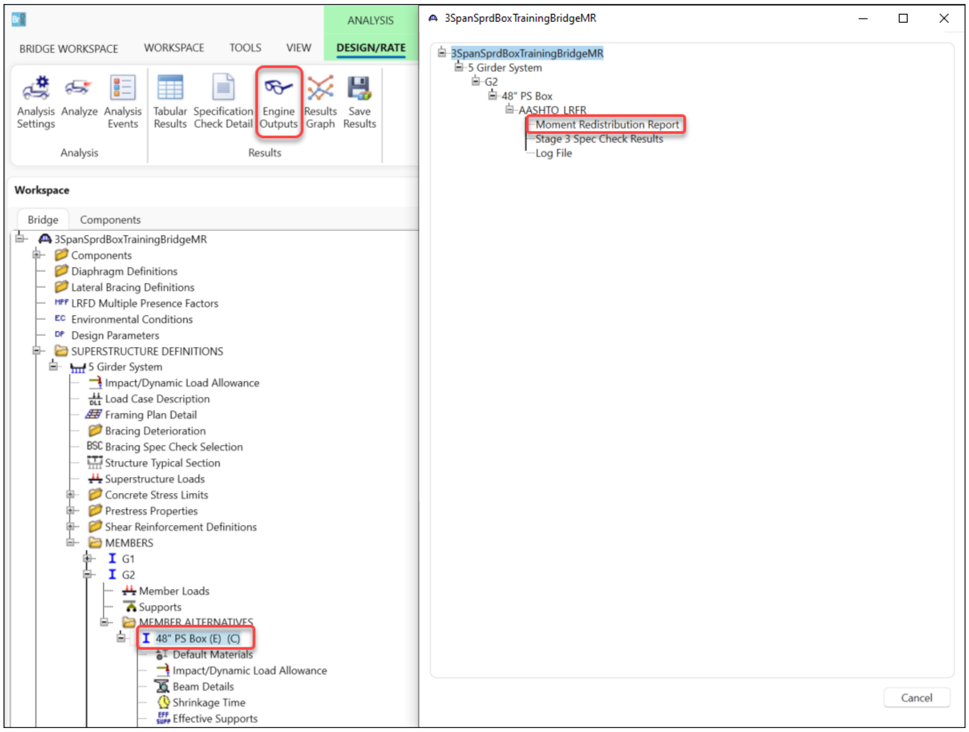
Code	Vehicle
1	HL-93 (US) - Truck + Lane
2	HL-93 (US) - Tandem + Lane
3	HL-93 (US) - 90%(Truck Pair + Lane)
4	Lane-Type Legal Load - Legal Truck + Lane
5	NRL - Legal Truck
6	Type 3 - Legal Truck
7	Type 3-3 - Legal Truck
8	Type 3S2 - Legal Truck

Figure 8 – 5.6.3.4 Maximum Allowable Moment Redistribution Moments

The actual amount of moment redistribution applied for each vehicle is reported in the **Moment Redistribution Report** discussed in the next section.

Moment Redistribution Report

Detailed information about the amount of moment redistribution applied for each vehicle at each location and how moment redistribution affects the flexure rating factors is available in the **Moment Redistribution Report**. To view the report, click on the **Engine Output** button located on the **Results** group of the **DESIGN/RATE** ribbon and then double-click on the **Moment Redistribution Report** item in the tree showing the available engine output files as shown in the screenshot below.



The report is a text file, and it will be open in the default text viewer. The format of the report file is shown in Figure 9 and Figure 10 which include locations from the first span for selected vehicles. Highlighted in the figures are the controlling rating factors before and after moment redistribution, and the percentages of applied moment redistribution at the first interior supports.

For the HL-93 Truck + Lane vehicle (Figure 9), the applied redistribution percentage at Support 2 (first interior support) is 20% which is equal to the maximum redistribution percentage. This is because even when the maximum redistribution percentage is applied, the minimum negative flexure rating factor is still smaller than the positive flexure rating factor, so it is beneficial overall to apply as much redistribution as allowed.

On the other hand, for the Type 3 Legal Truck vehicle (Figure 10), the applied redistribution percentage at Support 2 (first interior support) is 12.93% which is smaller than the maximum redistribution percentage of 20%. This is because if the maximum redistribution percentage was applied the minimum positive flexure rating factor would become smaller than the negative flexure rating factor. In other words, too much redistribution would be applied and the detrimental effect of moment redistribution in the positive flexure would exceed the beneficial effect in negative flexure. In such cases, the program attempts to optimize the amount of applied moment redistribution by reducing the applied redistribution percentages at supports so that the rating factors in positive and negative flexure after moment redistribution are equal. Reducing the applied redistribution percentage to 12.93% achieves this goal and both positive and negative flexure rating factors after moment redistribution are equal to 2.864 which is an increase of 0.414 (16.9%) from the controlling negative flexure rating factor before moment redistribution of 2.450.

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Moment redistribution for HL-93 (US) - Truck + Lane at Design Inventory rating level and StrengthI limit state.

Before moment redistribution:
  Minimum positive flexure rating factor = 1.252 @ 37.125 ft
  Minimum negative flexure rating factor = 0.872 @ 75.000 ft
After moment redistribution:
  Minimum positive flexure rating factor = 1.151 @ 37.125 ft
  Minimum negative flexure rating factor = 1.120 @ 75.000 ft

Location (ft)	Support	Side	Span	Location in Span (ft)	Percent in Span (%)	DL+AdjLL (kip-ft)	LL+I (kip-ft)	Max Redistribution Percentage (%)	Applied Redistribution Percentage (%)
0.000	1	Right	1	0.000	0.000	0.00	0.00	0.000	0.000
75.000	2	Left	1	75.000	100.000	-131.22	-1102.49	20.000	20.000
75.000	2	Right	2	0.000	0.000	-131.22	-1102.49	20.000	20.000
135.000	3	Left	2	60.000	100.000	-80.87	-807.27	20.000	20.000
135.000	3	Right	3	0.000	0.000	-80.87	-807.27	20.000	20.000
195.000	4	Left	3	60.000	100.000	0.00	0.00	0.000	0.000

Location (ft)	Side	Span	Location in Span (ft)	Percent in Span (%)	Positive Flexure Capacity (kip-ft)	Negative Flexure Capacity (kip-ft)	Initial Flexure Capacity (kip-ft)	Initial DL+AdjLL (kip-ft)	Initial LL+I (kip-ft)	Initial Controlling Flexure RF	Max Delta DL+AdjLL (kip-ft)	Max Delta LL+I (kip-ft)	Applied Delta DL+AdjLL (kip-ft)	Applied Delta LL+I (kip-ft)	Positive Flexure RF	Negative Flexure RF
0.000	Right	1	0.000	0.000	596.96	-87.16	596.96	0.00	0.00	99.000	0.00	0.00	0.00	0.00	99.000	99.000
1.750	Left	1	1.750	2.333	1931.13	-231.92	1931.13	138.81	165.56	10.826	0.61	5.14	0.61	5.14	10.496	99.000
1.750	Right	1	1.750	2.333	1931.13	-231.92	1931.13	138.81	165.56	10.826	0.61	5.14	0.61	5.14	10.496	99.000
7.500	Left	1	7.500	10.000	2764.96	-234.38	2764.96	547.41	629.93	3.520	2.62	22.05	2.62	22.05	3.397	99.000
7.500	Right	1	7.500	10.000	2764.96	-234.38	2764.96	547.41	629.93	3.520	2.62	22.05	2.62	22.05	3.397	99.000
15.000	Left	1	15.000	20.000	3095.55	-142.67	3095.55	970.89	1057.44	2.009	5.25	44.10	5.25	44.10	1.924	99.000
15.000	Right	1	15.000	20.000	3095.55	-142.67	3095.55	970.89	1057.44	2.009	5.25	44.10	5.25	44.10	1.924	99.000
21.750	Left	1	21.750	29.000	3202.96	-54.32	3202.96	1246.07	1278.76	1.530	7.61	63.94	7.61	63.94	1.452	99.000
21.750	Right	1	21.750	29.000	3202.96	0.00	3202.96	1246.07	1278.76	1.530	7.61	63.94	7.61	63.94	1.452	99.000
22.500	Left	1	22.500	30.000	3202.96	0.00	3202.96	1270.45	1296.81	1.490	7.87	66.15	7.87	66.15	1.412	99.000
22.500	Right	1	22.500	30.000	3202.96	0.00	3202.96	1270.45	1296.81	1.490	7.87	66.15	7.87	66.15	1.412	99.000
30.000	Left	1	30.000	40.000	3202.96	0.00	3202.96	1446.09	1395.08	1.259	10.50	88.20	10.50	88.20	1.177	99.000
30.000	Right	1	30.000	40.000	3202.96	0.00	3202.96	1446.09	1395.08	1.259	10.50	88.20	10.50	88.20	1.177	99.000
37.125	Left	1	37.125	49.500	3202.96	0.00	3202.96	1498.15	1361.17	1.252	12.99	109.15	12.99	109.15	1.151	99.000
37.125	Right	1	37.125	49.500	3202.96	0.00	3202.96	1498.15	1361.17	1.252	12.99	109.15	12.99	109.15	1.151	99.000
37.500	Left	1	37.500	50.000	3202.96	0.00	3202.96	1497.79	1357.21	1.256	13.12	110.25	13.12	110.25	1.153	99.000
37.500	Right	1	37.500	50.000	3202.96	0.00	3202.96	1497.79	1357.21	1.256	13.12	110.25	13.12	110.25	1.153	99.000
45.000	Left	1	45.000	60.000	3202.96	0.00	3202.96	1408.70	1195.36	1.501	15.75	132.30	15.75	132.30	1.340	99.000
45.000	Right	1	45.000	60.000	3202.96	0.00	3202.96	1408.70	1195.36	1.501	15.75	132.30	15.75	132.30	1.340	99.000
52.250	Left	1	52.250	69.667	3202.96	0.00	3202.96	1204.78	908.51	2.199	18.28	153.61	18.28	153.61	1.864	99.000
52.250	Right	1	52.250	69.667	3202.96	-54.32	3202.96	1204.78	908.51	2.199	18.28	153.61	18.28	153.61	1.864	99.000
52.500	Left	1	52.500	70.000	3198.98	-56.97	3198.98	1195.68	896.81	2.234	18.37	154.35	18.37	154.35	1.888	99.000
52.500	Right	1	52.500	70.000	3198.98	-56.97	3198.98	1195.68	896.81	2.234	18.37	154.35	18.37	154.35	1.888	99.000
55.000	Left	1	55.000	73.333	3159.20	-87.73	3159.20	1083.36	762.75	2.722	19.25	161.70	19.25	161.70	2.225	99.000
55.000	Right	1	55.000	73.333	3170.05	-1105.95	3170.05	1083.36	762.75	2.736	19.25	161.70	19.25	161.70	2.236	99.000
60.000	Left	1	60.000	80.000	3091.18	-1172.08	3091.18	858.73	494.63	4.513	21.00	176.40	21.00	176.40	3.296	99.000
60.000	Right	1	60.000	80.000	3091.18	-1172.08	3091.18	858.73	494.63	4.513	21.00	176.40	21.00	176.40	3.296	99.000
67.500	Left	1	67.500	90.000	2631.54	-1259.15	-1259.15	397.86	-497.68	3.329	23.62	198.45	23.62	198.45	99.000	5.617
67.500	Right	1	67.500	90.000	2944.68	-1261.62	-1261.62	397.86	-497.68	3.334	23.62	198.45	23.62	198.45	99.000	5.625
72.250	Left	1	72.250	96.333	2265.85	-1267.13	-1267.13	41.88	-861.37	1.520	25.28	212.41	25.28	212.41	99.000	2.056
72.250	Right	1	72.250	96.333	2265.85	-1267.13	-1267.13	41.88	-861.37	1.520	25.28	212.41	25.28	212.41	99.000	2.056
74.250	Left	1	74.250	99.000	826.20	-1133.46	-1133.46	-122.88	-1035.74	0.976	25.98	218.29	25.98	218.29	99.000	1.268
75.000	Left	1	75.000	100.000	459.84	-1092.55	-1092.55	-131.22	-1102.49	0.872	26.24	220.50	26.24	220.50	99.000	1.120
75.000	Right	2	0.000	0.000	459.84	-1092.55	-1092.55	-131.22	-1102.49	0.872	26.24	220.50	26.24	220.50	99.000	1.120

Figure 9 – Moment redistribution for HL-93 (US) - Truck + Lane at Design Inventory rating level and Strength I limit state

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Moment redistribution for Type 3 - Legal Truck at Legal Routine rating level and StrengthI limit state.

Before moment redistribution:
  Minimum positive flexure rating factor = 3.005 @ 37.125 ft
  Minimum negative flexure rating factor = 2.450 @ 75.000 ft
After moment redistribution:
  Minimum positive flexure rating factor = 2.864 @ 37.125 ft
  Minimum negative flexure rating factor = 2.864 @ 75.000 ft
```

Location (ft)	Support	Side	Span	Location in Span (ft)	Percent in Span (%)	DL+AdjLL (kip-ft)	LL+I (kip-ft)	Max Redistribution Percentage (%)	Applied Redistribution Percentage (%)
0.000	1	Right	1	0.000	0.000	0.00	0.00	0.000	0.000
75.000	2	Left	1	75.000	100.000	-131.22	-392.37	20.000	12.930
75.000	2	Right	2	0.000	0.000	-131.22	-392.37	20.000	12.930
135.000	3	Left	2	60.000	100.000	-80.87	-282.98	20.000	20.000
135.000	3	Right	3	0.000	0.000	-80.87	-282.98	20.000	20.000
195.000	4	Left	3	60.000	100.000	0.00	0.00	0.000	0.000

Location (ft)	Side	Span	Location in Span (ft)	Percent in Span (%)	Positive Flexure Capacity (kip-ft)	Negative Flexure Capacity (kip-ft)	Initial Flexure Capacity (kip-ft)	Initial DL+AdjLL (kip-ft)	Initial LL+I (kip-ft)	Initial Controlling Flexure RF	Max Delta DL+AdjLL (kip-ft)	Max Delta LL+I (kip-ft)	Applied Delta DL+AdjLL (kip-ft)	Applied Delta LL+I (kip-ft)	Positive Flexure RF	Negative Flexure RF
0.000	Right	1	0.000	0.000	596.96	-87.16	596.96	0.00	0.00	99.000	0.00	0.00	0.00	0.00	99.000	99.000
1.750	Left	1	1.750	2.333	1931.13	-231.92	1931.13	138.81	70.29	25.499	0.61	1.83	0.40	1.18	25.071	99.000
1.750	Right	1	1.750	2.333	1931.13	-231.92	1931.13	138.81	70.29	25.499	0.61	1.83	0.40	1.18	25.071	99.000
7.500	Left	1	7.500	10.000	2764.96	-234.38	2764.96	547.41	266.82	8.311	2.62	7.85	1.70	5.07	8.150	99.000
7.500	Right	1	7.500	10.000	2764.96	-234.38	2764.96	547.41	266.82	8.311	2.62	7.85	1.70	5.07	8.150	99.000
15.000	Left	1	15.000	20.000	3095.55	-142.67	3095.55	970.89	445.96	4.764	5.25	15.69	3.39	10.15	4.651	99.000
15.000	Right	1	15.000	20.000	3095.55	-142.67	3095.55	970.89	445.96	4.764	5.25	15.69	3.39	10.15	4.651	99.000
21.750	Left	1	21.750	29.000	3202.96	-54.32	3202.96	1246.07	537.01	3.644	7.61	22.76	4.92	14.71	3.538	99.000
21.750	Right	1	21.750	29.000	3202.96	0.00	3202.96	1246.07	537.01	3.644	7.61	22.76	4.92	14.71	3.538	99.000
22.500	Left	1	22.500	30.000	3202.96	0.00	3202.96	1270.45	544.31	3.550	7.87	23.54	5.09	15.22	3.445	99.000
22.500	Right	1	22.500	30.000	3202.96	0.00	3202.96	1270.45	544.31	3.550	7.87	23.54	5.09	15.22	3.445	99.000
30.000	Left	1	30.000	40.000	3202.96	0.00	3202.96	1446.09	583.96	3.009	10.50	31.39	6.79	20.29	2.896	99.000
30.000	Right	1	30.000	40.000	3202.96	0.00	3202.96	1446.09	583.96	3.009	10.50	31.39	6.79	20.29	2.896	99.000
37.125	Left	1	37.125	49.500	3202.96	0.00	3202.96	1498.15	567.28	3.005	12.99	38.84	8.40	25.11	2.864	99.000
37.125	Right	1	37.125	49.500	3202.96	0.00	3202.96	1498.15	567.28	3.005	12.99	38.84	8.40	25.11	2.864	99.000
37.500	Left	1	37.500	50.000	3202.96	0.00	3202.96	1497.79	565.46	3.016	13.12	39.24	8.48	25.37	2.872	99.000
37.500	Right	1	37.500	50.000	3202.96	0.00	3202.96	1497.79	565.46	3.016	13.12	39.24	8.48	25.37	2.872	99.000
45.000	Left	1	45.000	60.000	3202.96	0.00	3202.96	1408.70	497.47	3.607	15.75	47.08	10.18	30.44	3.379	99.000
45.000	Right	1	45.000	60.000	3202.96	0.00	3202.96	1408.70	497.47	3.607	15.75	47.08	10.18	30.44	3.379	99.000
52.250	Left	1	52.250	69.667	3202.96	0.00	3202.96	1204.78	383.16	5.215	18.28	54.67	11.82	35.34	4.746	99.000
52.250	Right	1	52.250	69.667	3202.96	-54.32	3202.96	1204.78	383.16	5.215	18.28	54.67	11.82	35.34	4.746	99.000
52.500	Left	1	52.500	70.000	3198.98	-56.97	3198.98	1195.68	378.52	5.292	18.37	54.93	11.88	35.51	4.810	99.000
52.500	Right	1	52.500	70.000	3198.98	-56.97	3198.98	1195.68	378.52	5.292	18.37	54.93	11.88	35.51	4.810	99.000
55.000	Left	1	55.000	73.333	3159.20	-87.73	3159.20	1083.36	326.97	6.349	19.25	57.55	12.44	37.20	5.666	99.000
55.000	Right	1	55.000	73.333	3170.05	-1105.95	3170.05	1083.36	326.97	6.382	19.25	57.55	12.44	37.20	5.696	99.000
60.000	Left	1	60.000	80.000	3091.18	-1172.08	3091.18	858.73	223.88	9.972	21.00	62.78	13.57	40.59	8.390	99.000
60.000	Right	1	60.000	80.000	3091.18	-1172.08	3091.18	858.73	223.88	9.972	21.00	62.78	13.57	40.59	8.390	99.000
67.500	Left	1	67.500	90.000	2631.54	-1259.15	2631.54	397.86	54.95	40.646	23.62	70.63	15.27	45.66	22.049	99.000
67.500	Right	1	67.500	90.000	2944.68	-1261.62	2944.68	397.86	54.95	46.344	23.62	70.63	15.27	45.66	25.161	99.000
72.250	Left	1	72.250	96.333	2265.85	-1267.13	-1267.13	41.88	-303.03	4.320	25.28	75.60	16.34	48.87	99.000	5.215
72.250	Right	1	72.250	96.333	2265.85	-1267.13	-1267.13	41.88	-303.03	4.320	25.28	75.60	16.34	48.87	99.000	5.215
74.250	Left	1	74.250	99.000	826.20	-1133.46	-1133.46	-122.88	-368.13	2.745	25.98	77.69	16.80	50.22	99.000	3.232
75.000	Left	1	75.000	100.000	459.84	-1092.55	-1092.55	-131.22	-392.37	2.450	26.24	78.47	16.97	50.73	99.000	2.864
75.000	Right	2	0.000	0.000	459.84	-1092.55	-1092.55	-131.22	-392.37	2.450	26.24	78.47	16.97	50.73	99.000	2.864

Figure 10 – Moment redistribution for Type 3 - Legal Truck at Legal Routine rating level and Strength I limit state