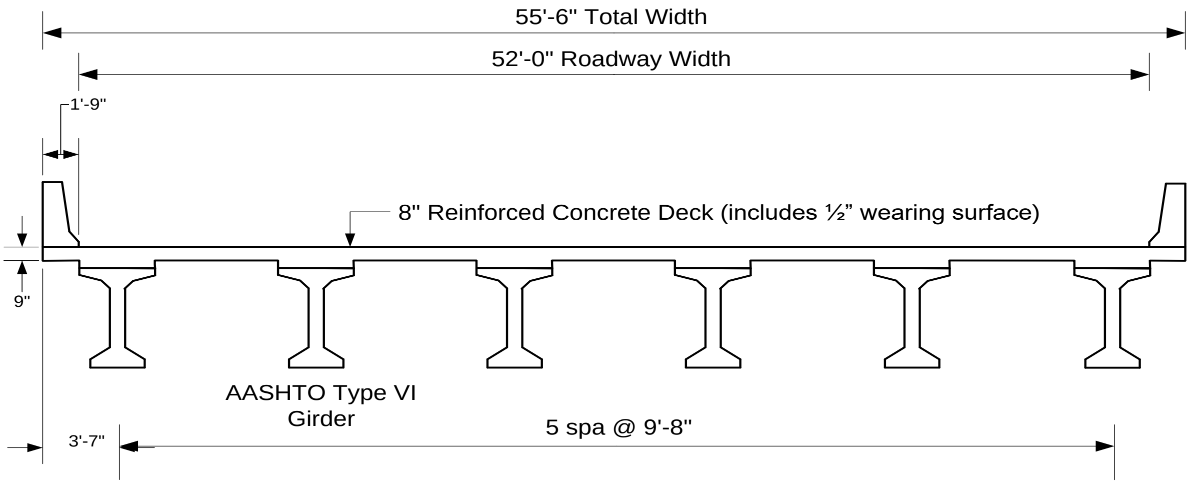
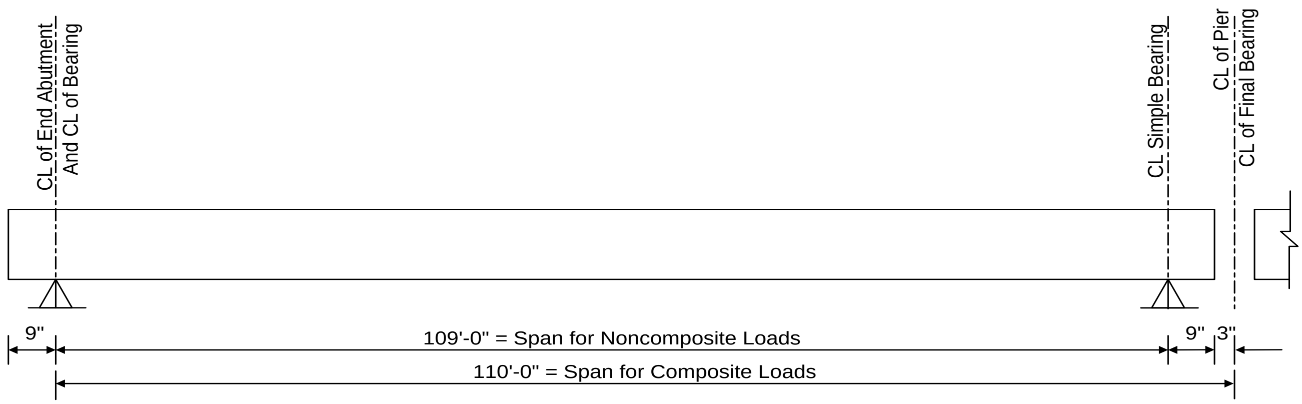
AASHTOWare BrDR 7.5.0

Prestress Tutorial 4

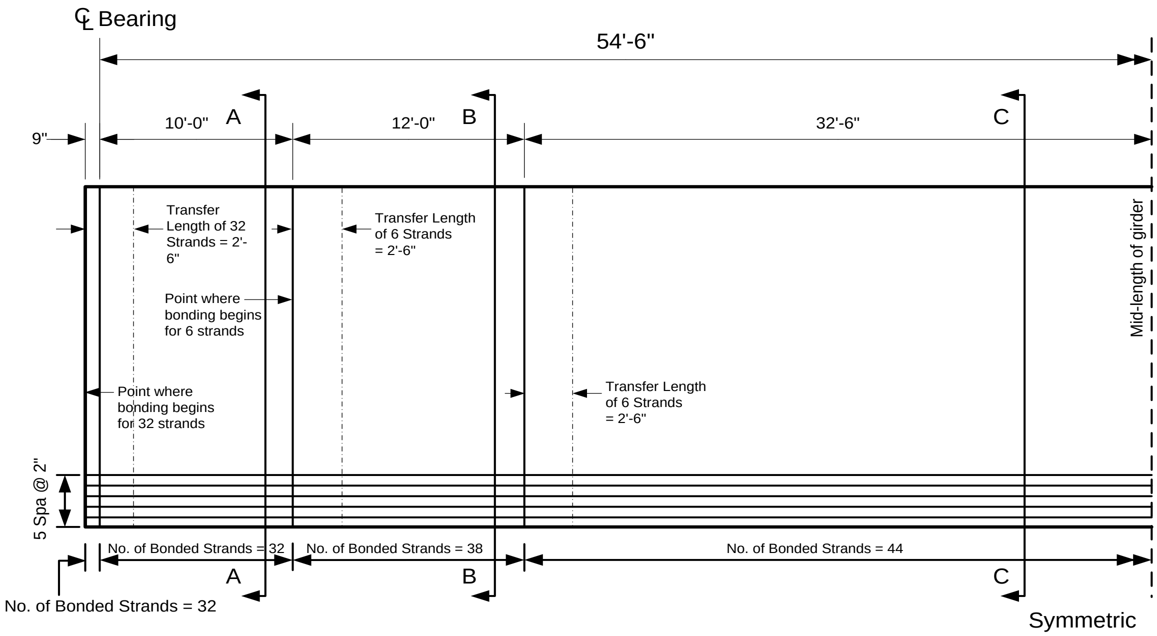
PS4 – Prestressed Concrete I Beam Using BrDR LRFD Engine



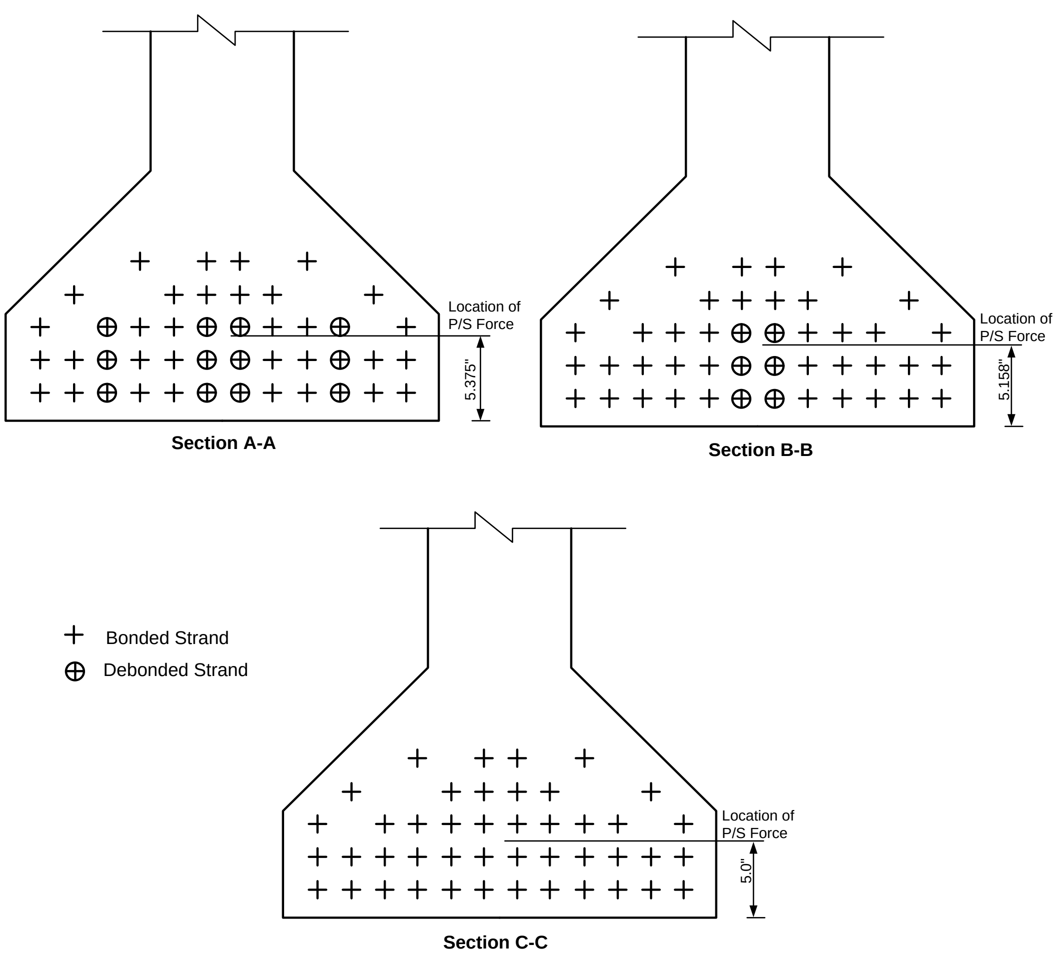
Structure Typical Section

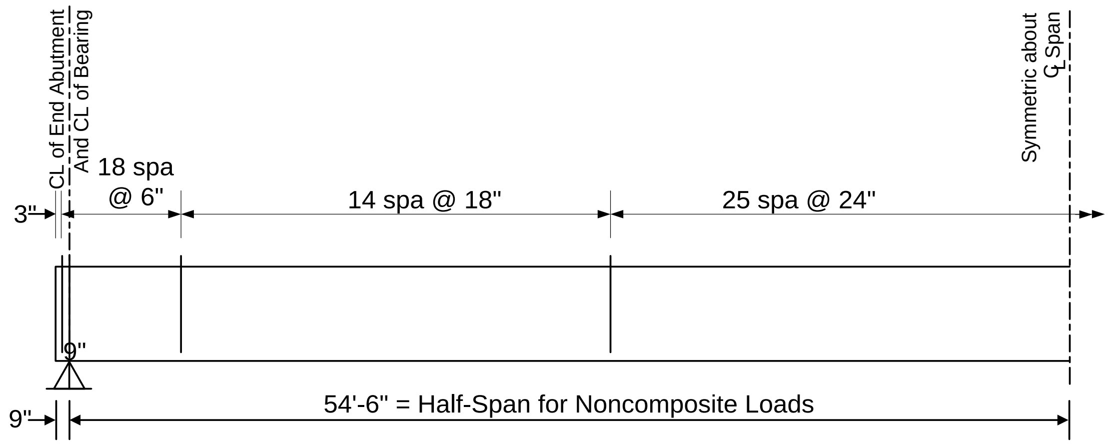


Span Elevation



Beam Elevation





Beam Elevation Showing Stirrups

BrDR Training

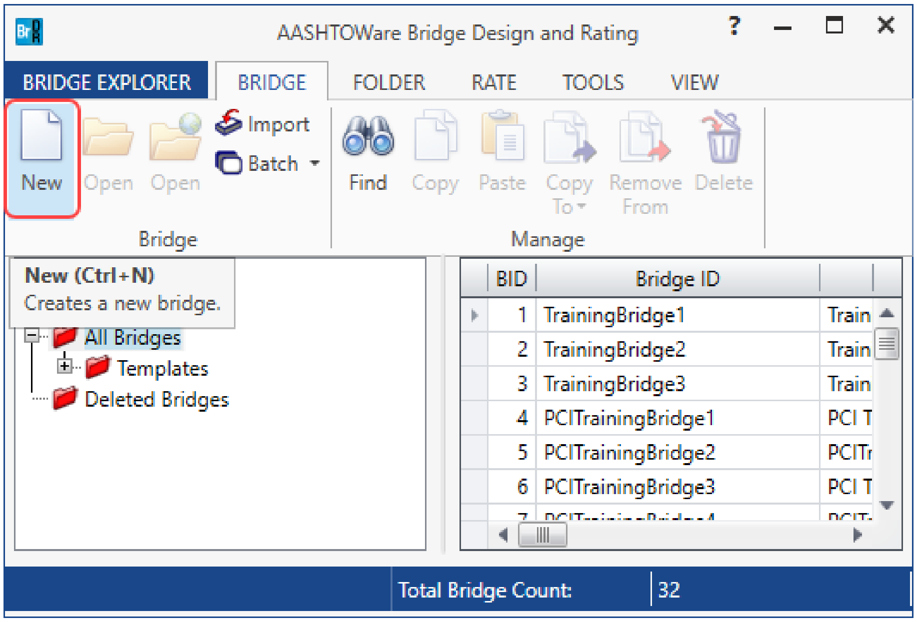
PS4 – Prestressed Concrete I Beam Using BrDR LRFD Engine

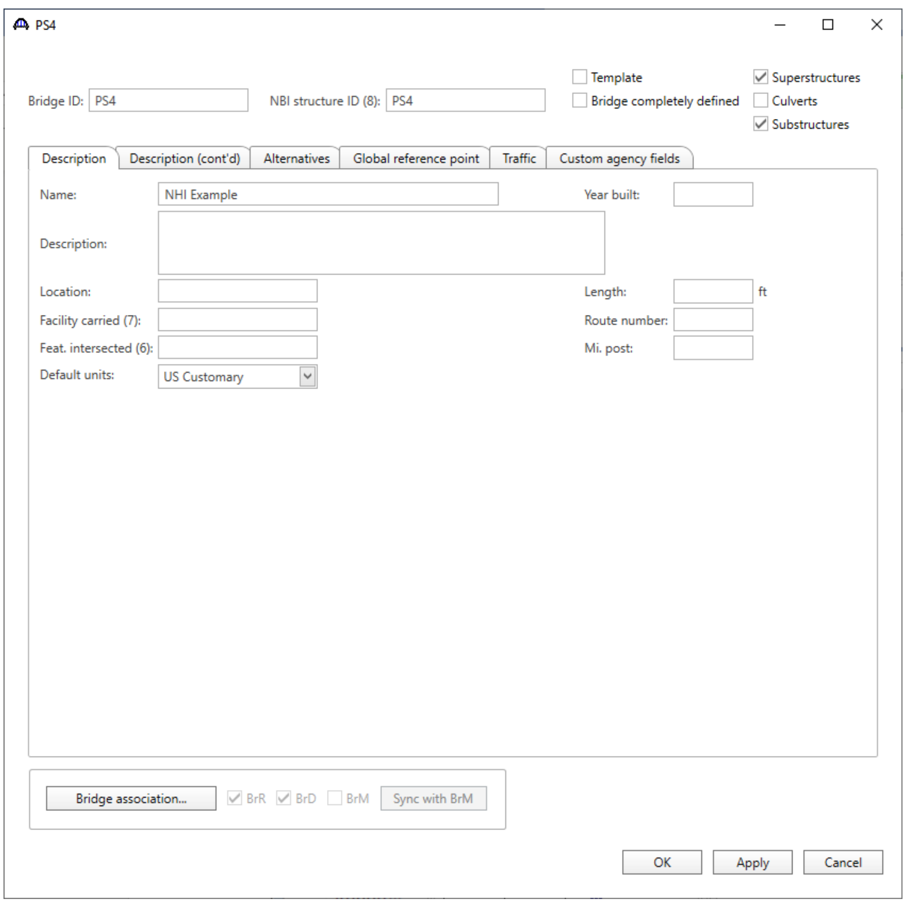
Topics Covered

- Prestressed concrete I beam with debonded strands input as girder system.
- Prestressed loss calculation methods
  - AASHTO Refined, AASHTO Approximate, Pre-2005 Interim methods.
- Prestressed multi-span modeling options.
  - Multi-span continuous
  - Multi-span continuous and simple span
- Export of prestressed concrete beams to the BrDR LRFD analysis engine
- BrDR LRFD specification checking

Prestressed concrete I beam with debonded strands input as girder system.

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

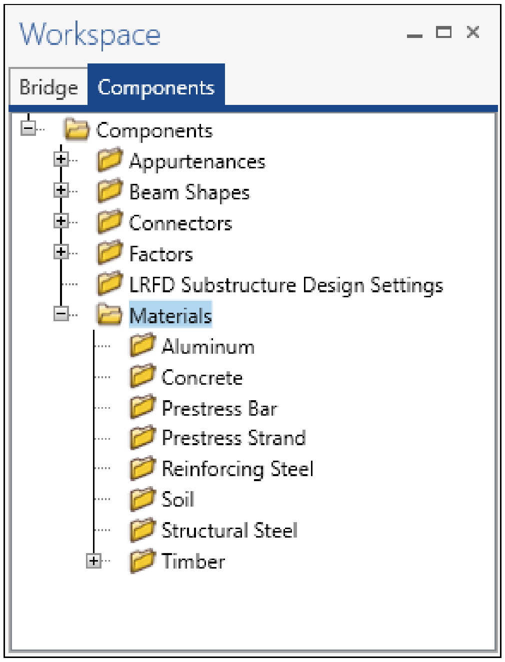




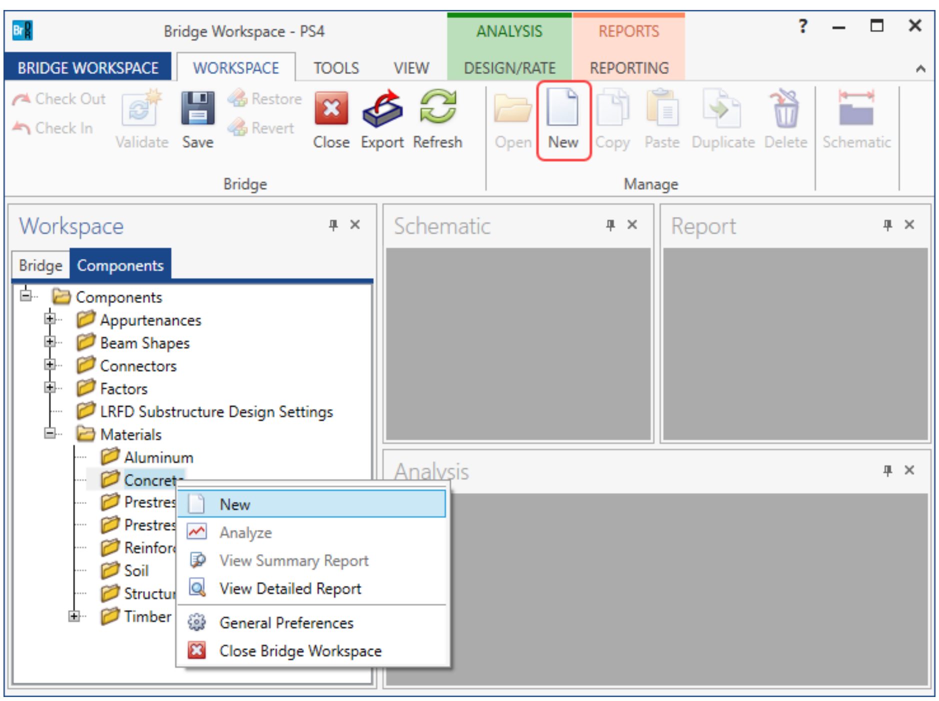
Click **OK** to apply the data and close the window.

Bridge Materials

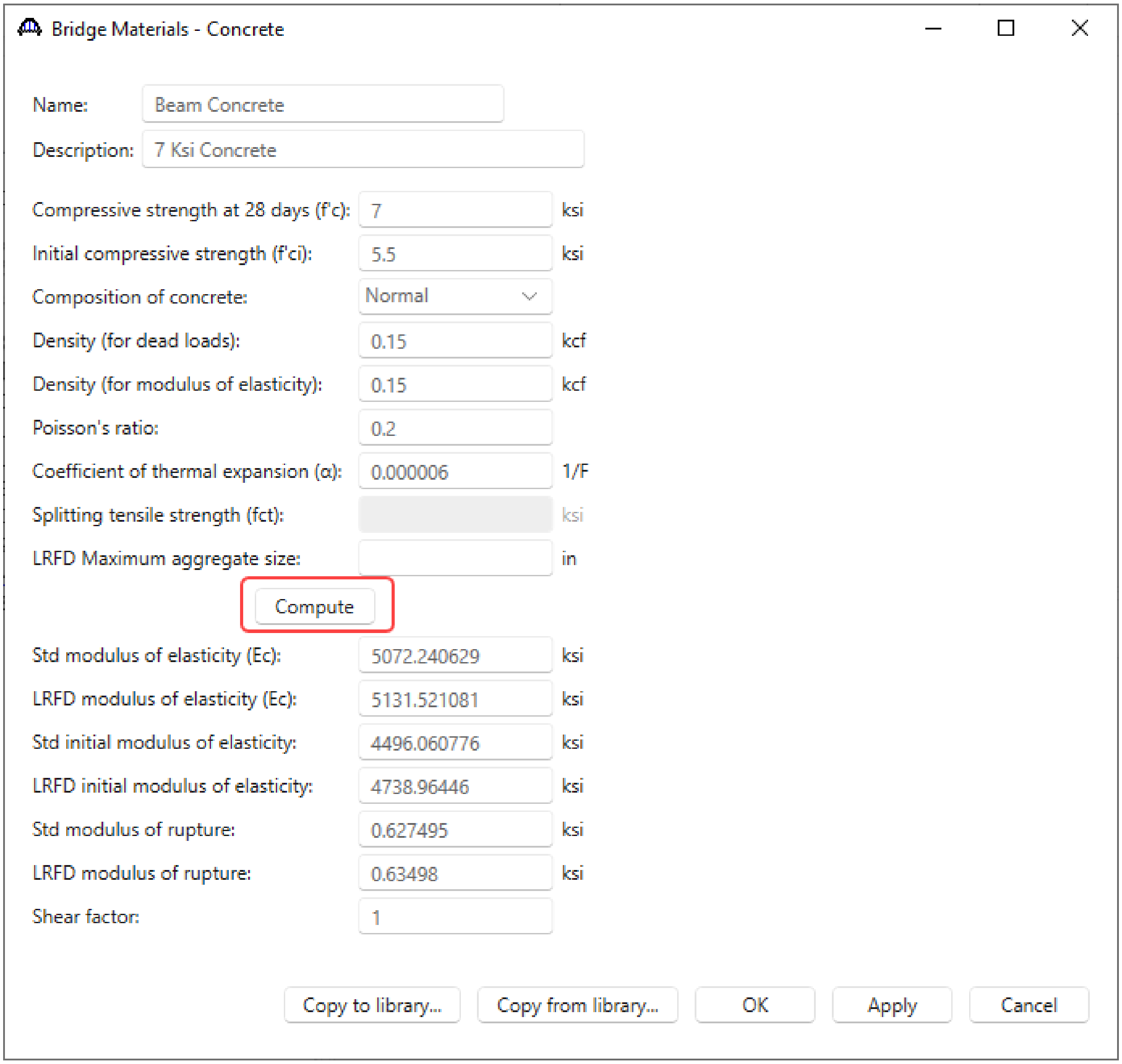
To enter the materials to be used by members of the bridge, open the **Components** tab, and click on the ⊞ button to expand the tree for **Materials**. The tree with the expanded **Materials** branch is shown below.



To add a new concrete material, in the **Components** tab of the **Bridge Workspace**, click on **Materials**, **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.

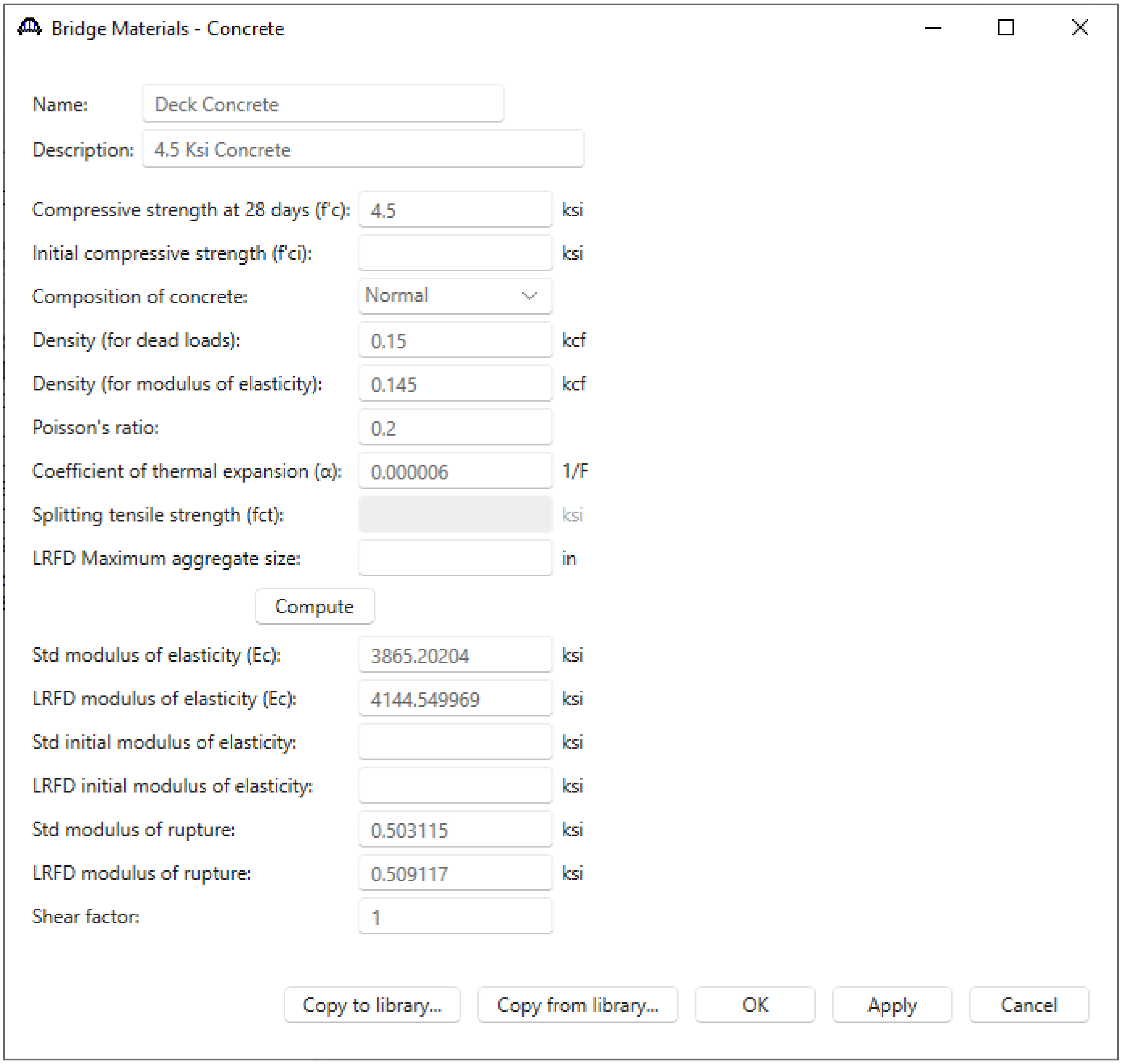


Enter the values shown above the **Compute** button and click the **Compute** button to compute the remaining values below them.



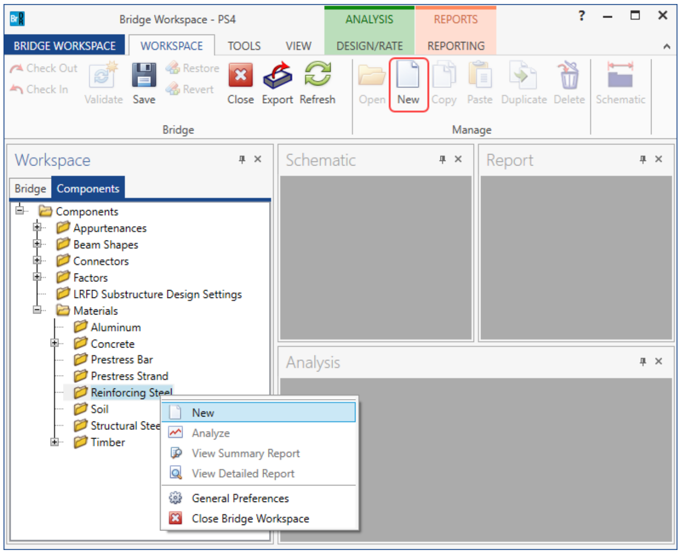
Click **OK** to apply this data and close the window.

Add concrete material for the **deck,** using the same techniques. Enter the data for deck concrete as shown below.

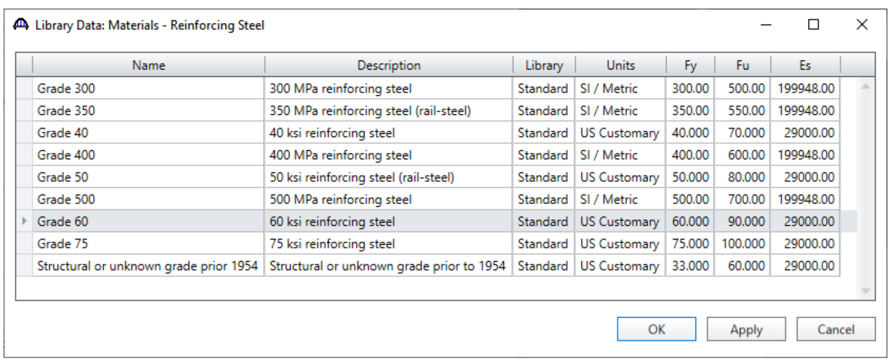


Click **OK** to apply this data and close the window.

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

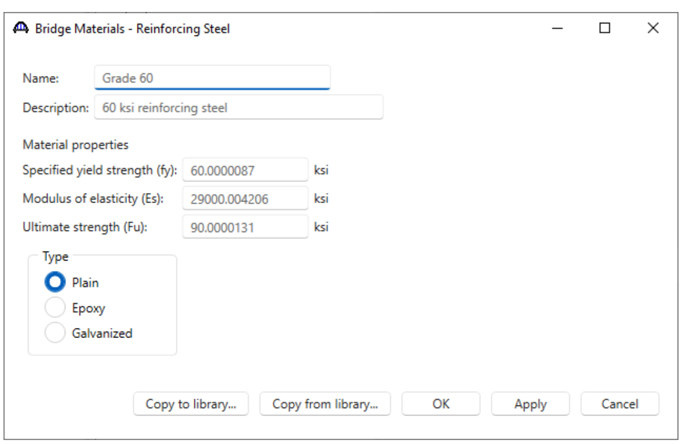


Add the reinforcing steel material by clicking the **Copy from library…** button. The following window opens.



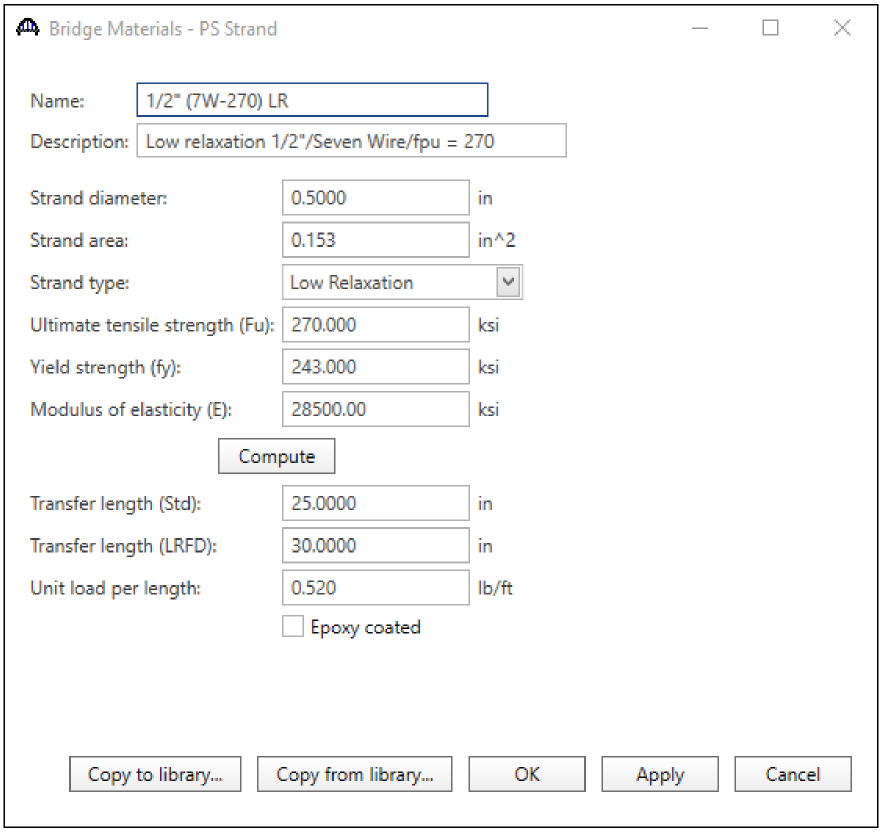
Name	Description	Library	Units	Fy	Fu	Es
Grade 300	300 MPa reinforcing steel	Standard	SI / Metric	300.00	500.00	199948.00
Grade 350	350 MPa reinforcing steel (rail-steel)	Standard	SI / Metric	350.00	550.00	199948.00
Grade 40	40 ksi reinforcing steel	Standard	US Customary	40.000	70.000	29000.00
Grade 400	400 MPa reinforcing steel	Standard	SI / Metric	400.00	600.00	199948.00
Grade 50	50 ksi reinforcing steel (rail-steel)	Standard	US Customary	50.000	80.000	29000.00
Grade 500	500 MPa reinforcing steel	Standard	SI / Metric	500.00	700.00	199948.00
Grade 60	60 ksi reinforcing steel	Standard	US Customary	60.000	90.000	29000.00
Grade 75	75 ksi reinforcing steel	Standard	US Customary	75.000	100.000	29000.00
Structural or unknown grade prior 1954	Structural or unknown grade prior to 1954	Standard	US Customary	33.000	60.000	29000.00

Select the **Grade 60** material and click **OK**. The selected material properties are copied to **the Bridge Materials – Reinforcing Steel** window as shown below.



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

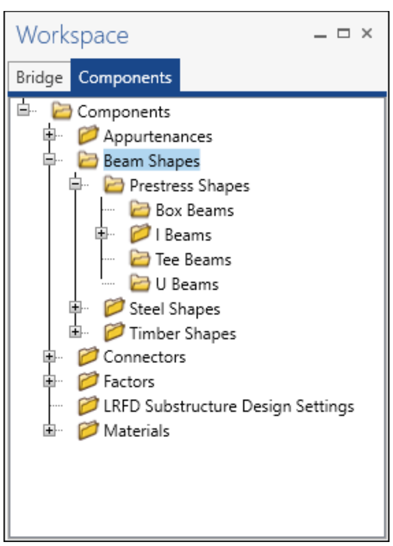
Add the prestress strand **1/2" (7W-270) LR** using the same technique as above. The window is populated as shown below.



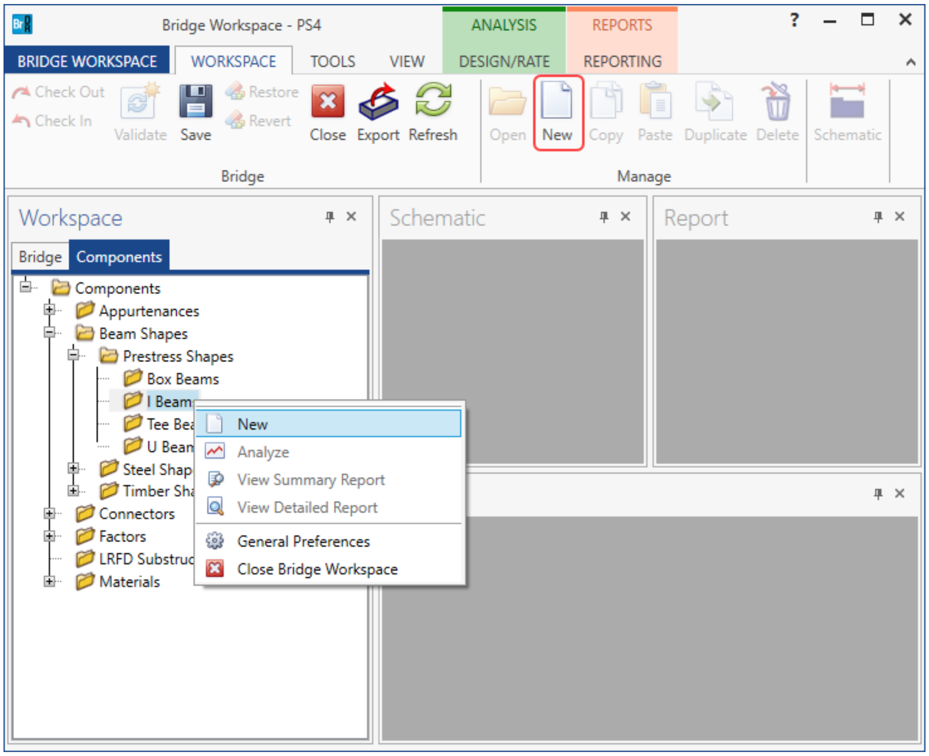
Click **OK** to apply this data and close the window.

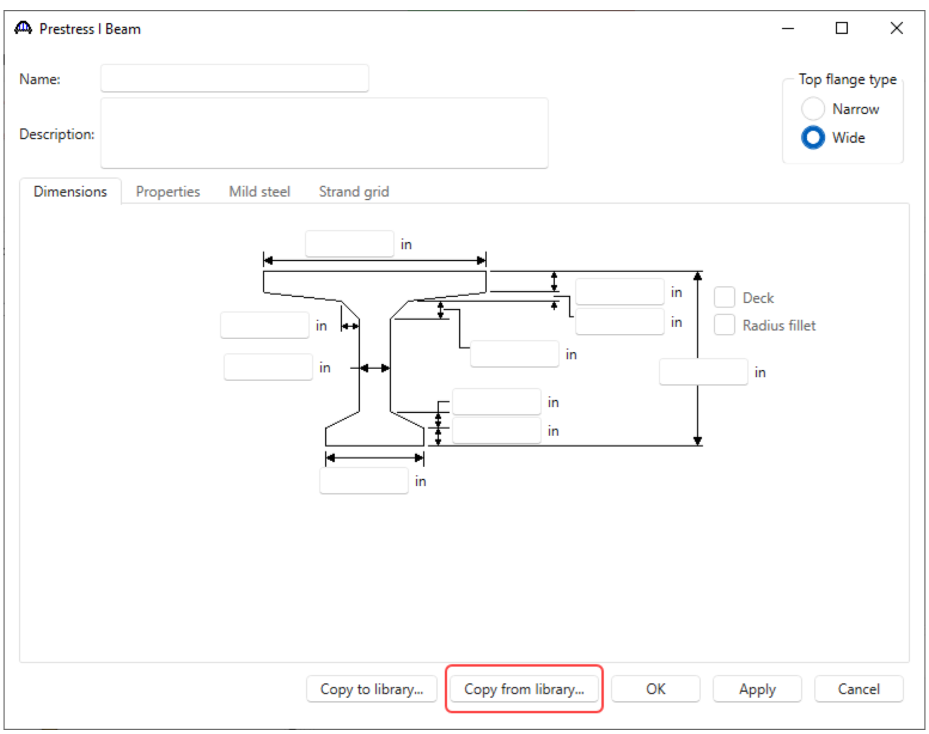
Beam Shapes

To enter a prestress beam shape to be used in this bridge expand the **Beam Shapes** node and **Prestress Shapes** node in the **Componenets** tree as shown below.

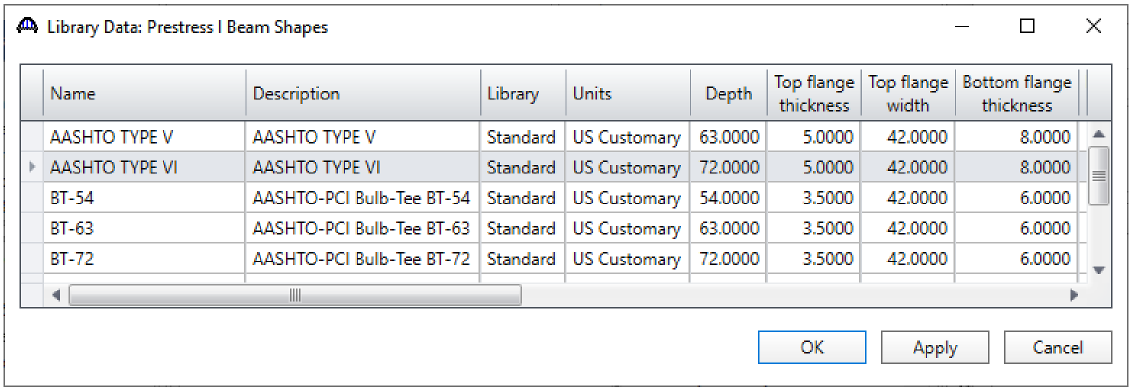


Click on the **I Beams** node in the **Components** tree and select **New** from the **Manage** group of the **WORKSPACE** ribbon (or right mouse click on **I Beams** and select **New** or double click on **I Beams** in the **Components** tree). The window shown below will open.

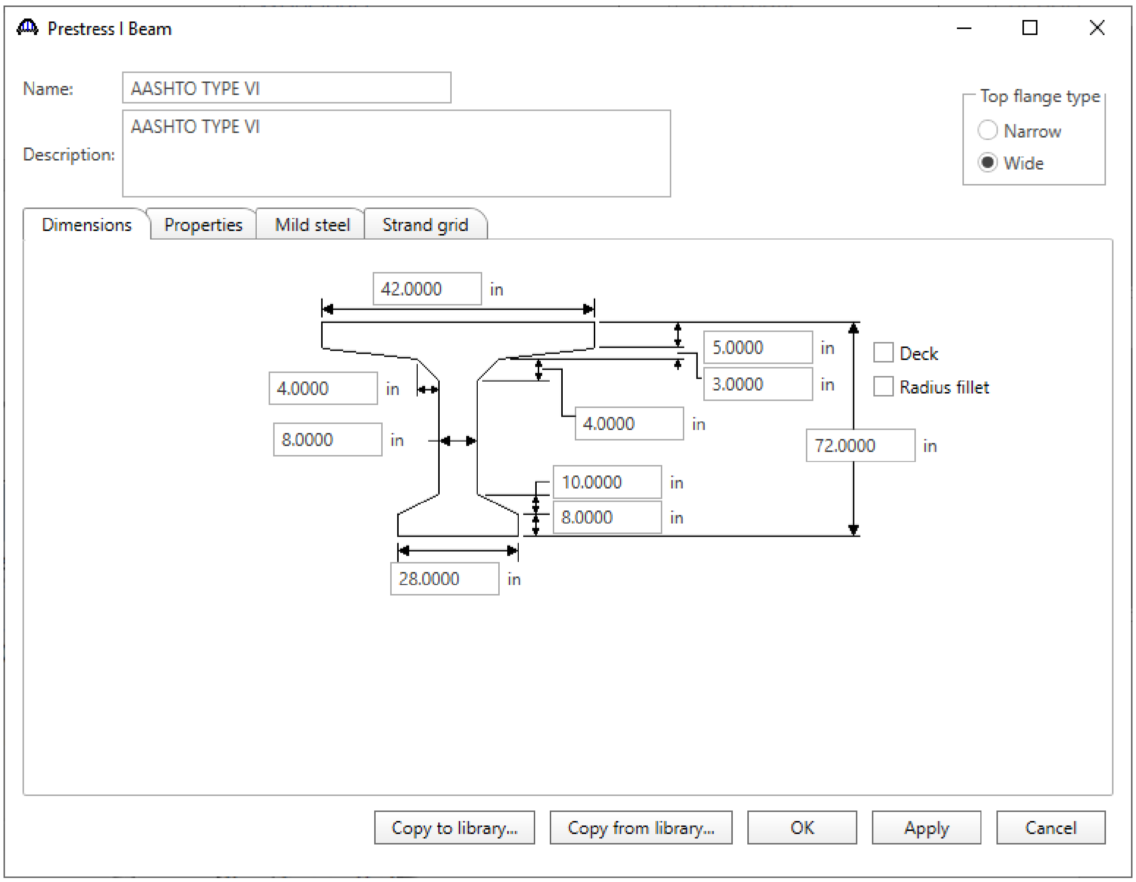




Select the **Top flange type** as **Wide** and click the **Copy from library…** button. Select **AASHTO Type VI** and click **OK**.



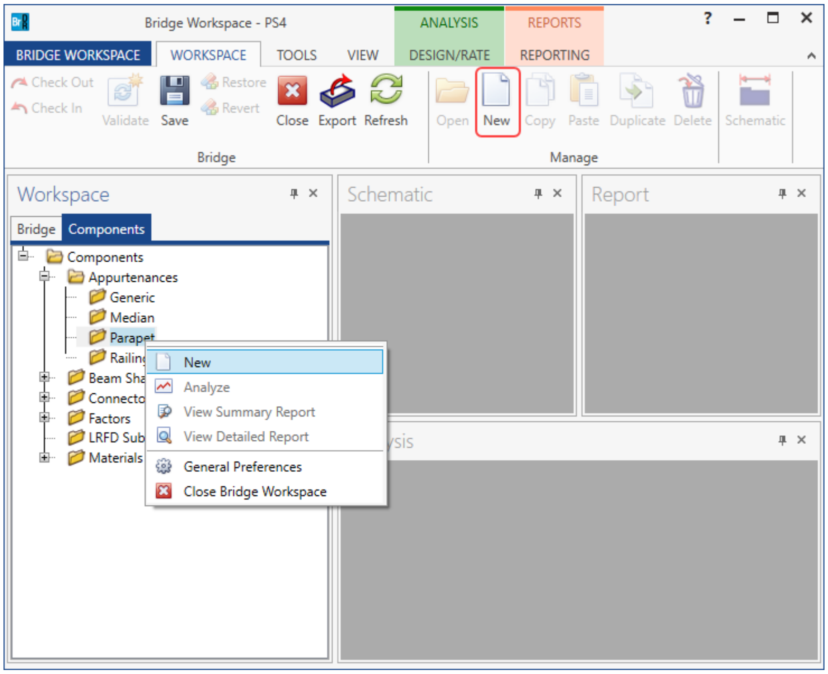
The beam properties are copied to the **Prestress I Beam** window as shown below.



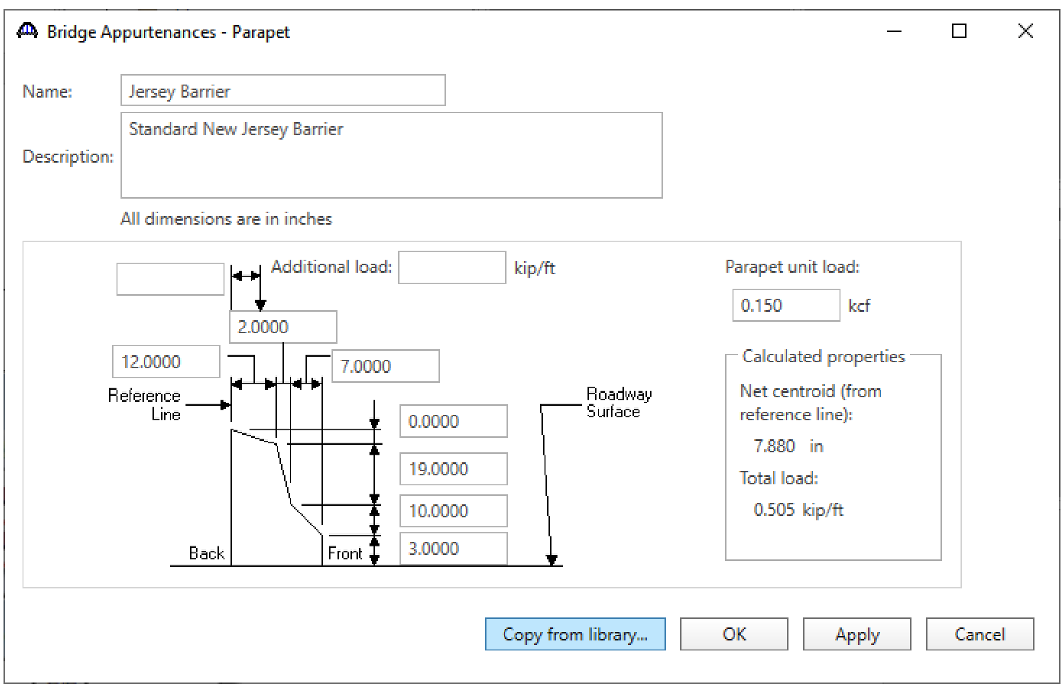
Click **OK** to apply this data and close the window.

Bridge - Appurtenances

To enter the appurtenances to be 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).



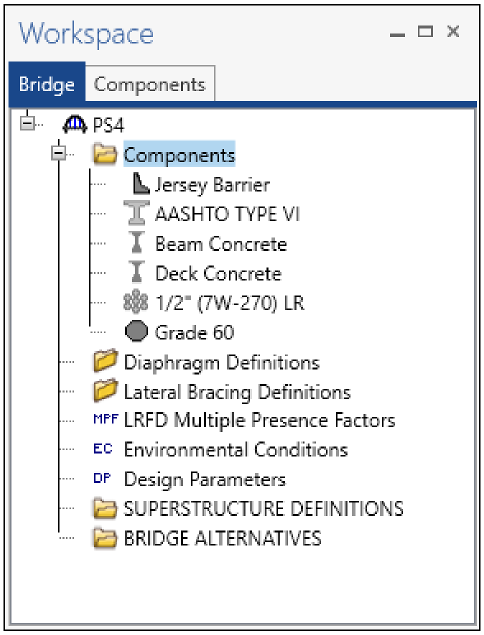
Enter the parapet details as shown below.



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

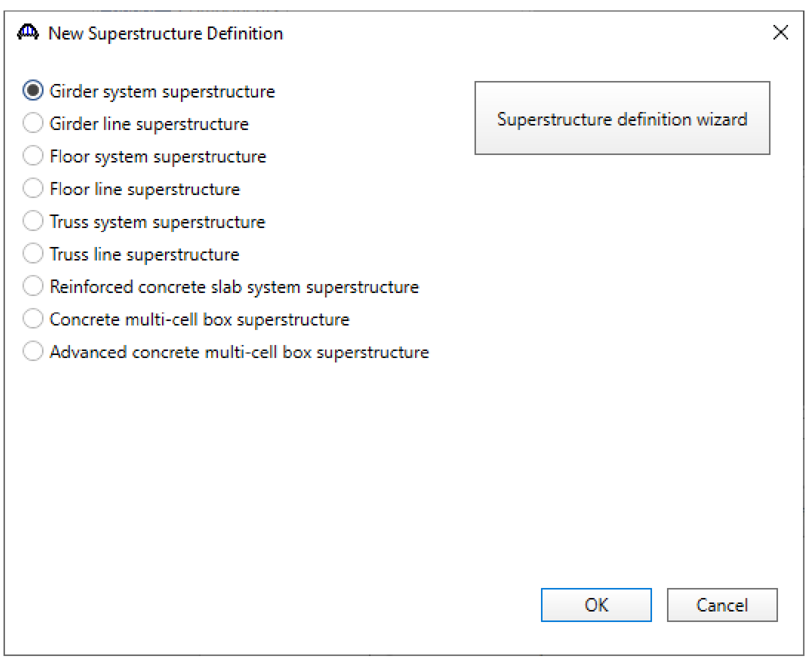
The default dynamic load allowance and default LRFD factors will be used.

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



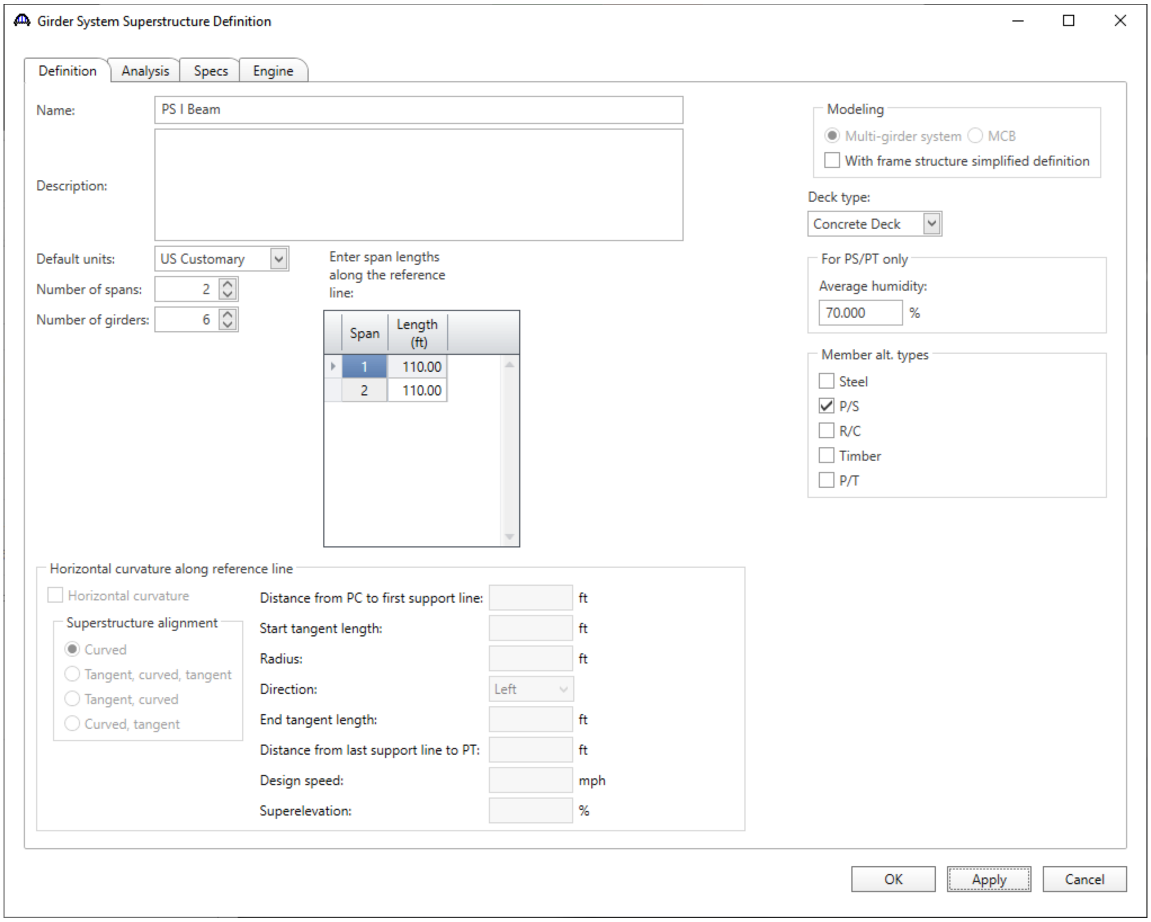
Superstructure Definition

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.

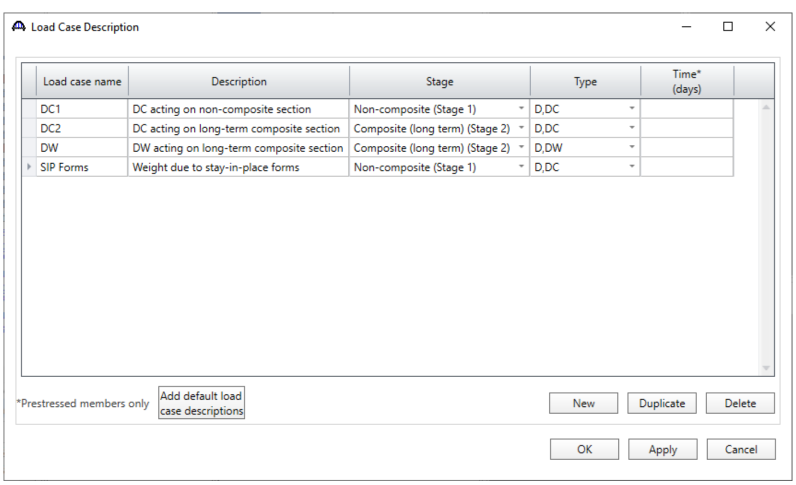
Enter the data as shown below.



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

Load Case Description

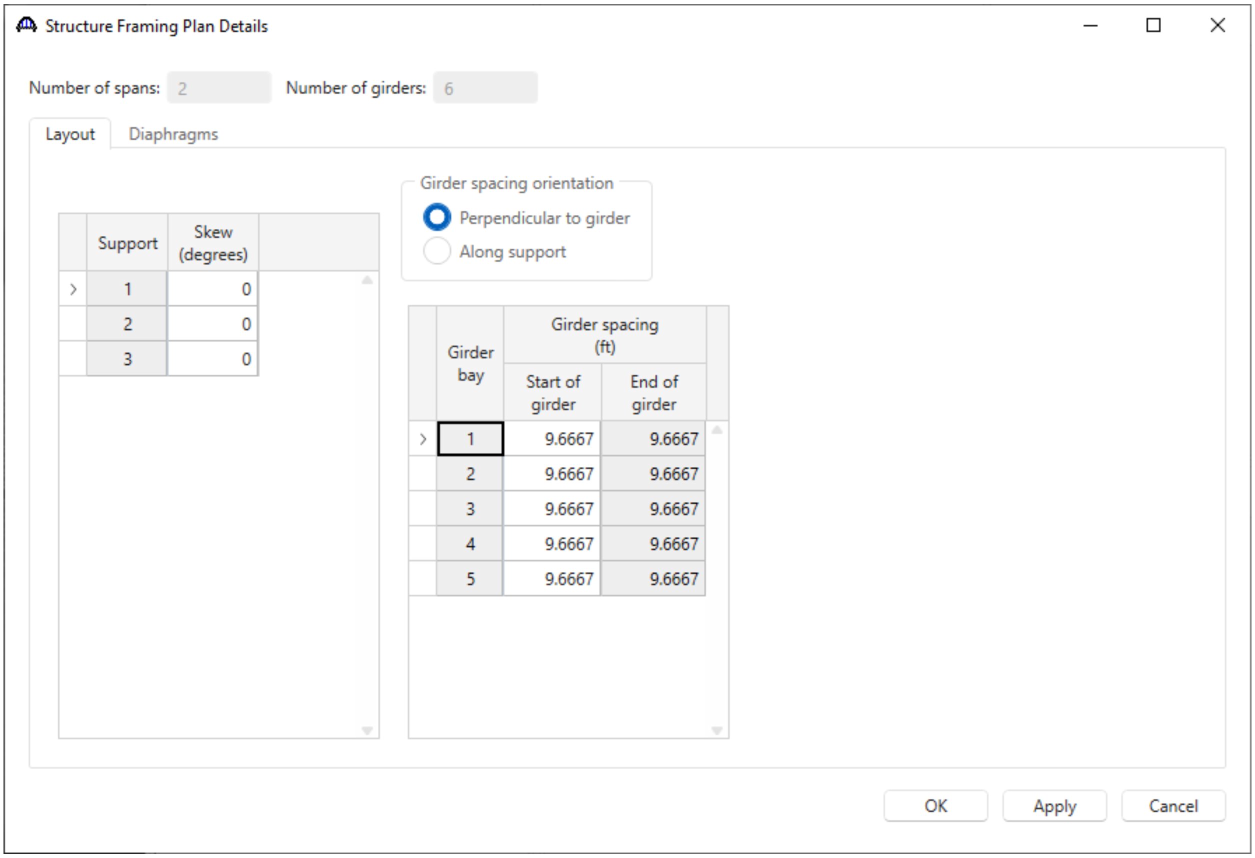
Double-click on the **Load Case Description** node in the **Bridge Workspace** tree to open the **Load Case Description window**. Click on the **Add default load case descriptions** button to create the following load cases.



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

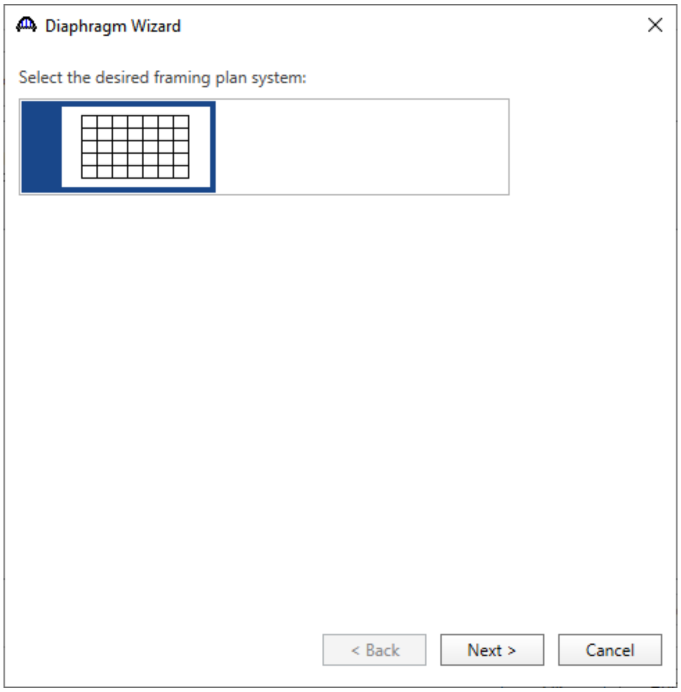
Structure Framing Plan Detail – Layout

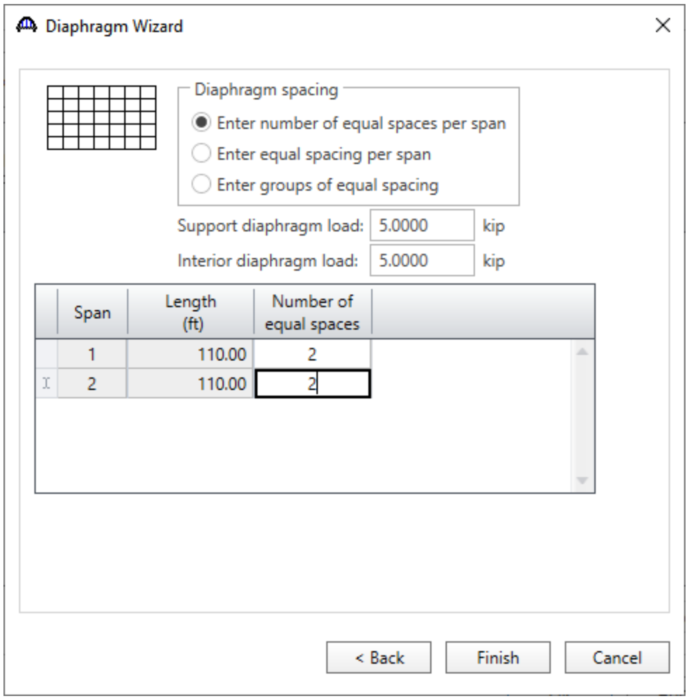
Double-click on **Framing Plan Detail** in the **Bridge Workspace** tree to describe the framing plan in the **Structure Framing Plan Details** window. Enter the data as shown below. In this example, enter all data to 4 significant digits. For example, enter the girder spacing of **9'-8"** as **9.6667.**



Structure Framing Plan Detail – Diaphragms

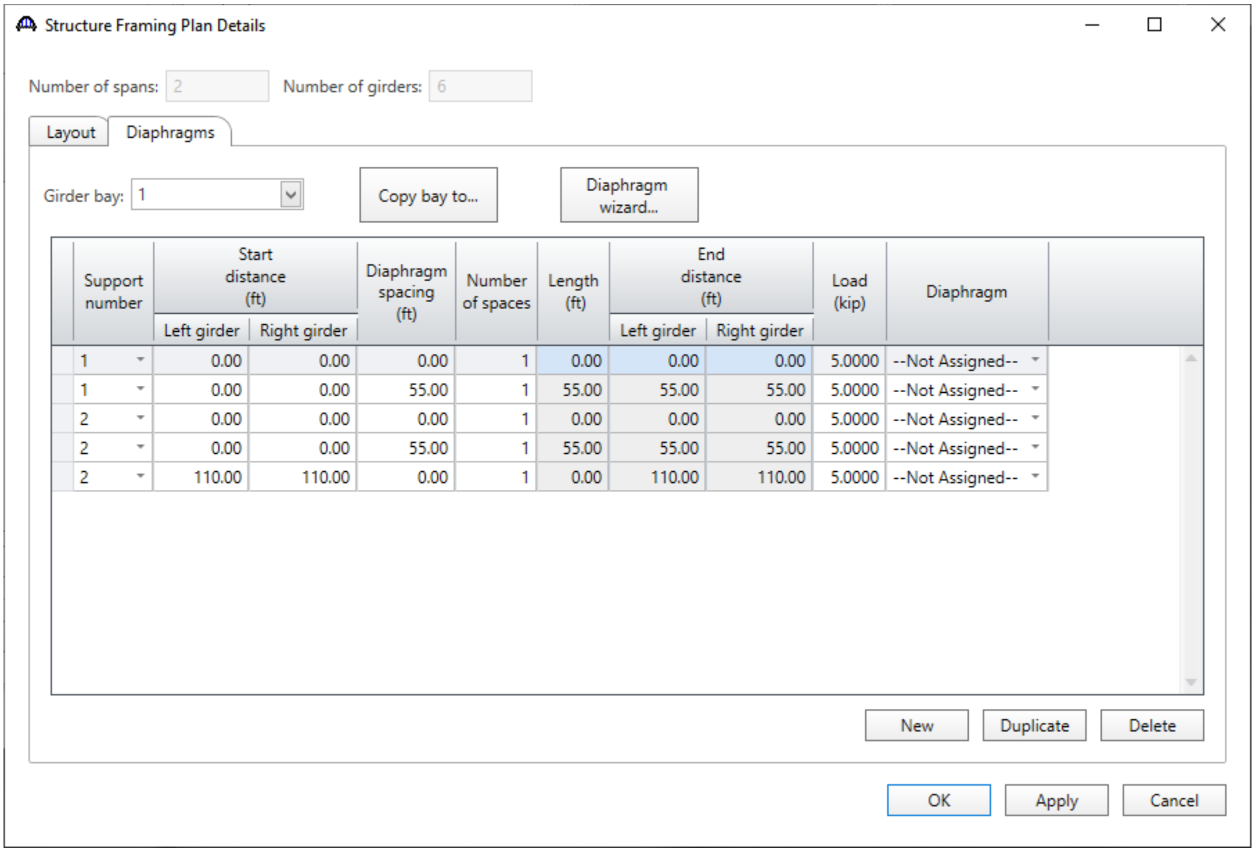
Switch to the **Diaphragms** tab to enter diaphragm spacing. Click the **Diaphragm wizard…** button to add diaphragms for the entire structure. **Select the desired framing plan system** and click the **Next** button. Enter the following data on the window shown below.





Click the **Finish** button to add the diaphragms. The **Diaphragm Wizard** will create diaphragms for all the girder bays in the structure.

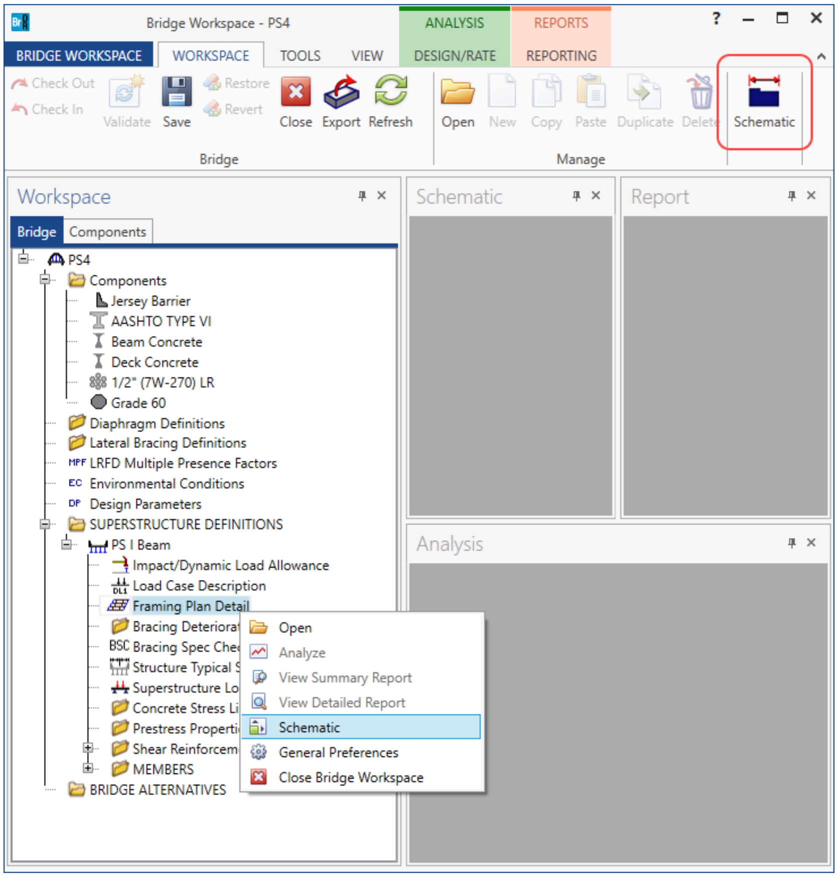
The diaphragms created for **Girder bay 1** are shown below.



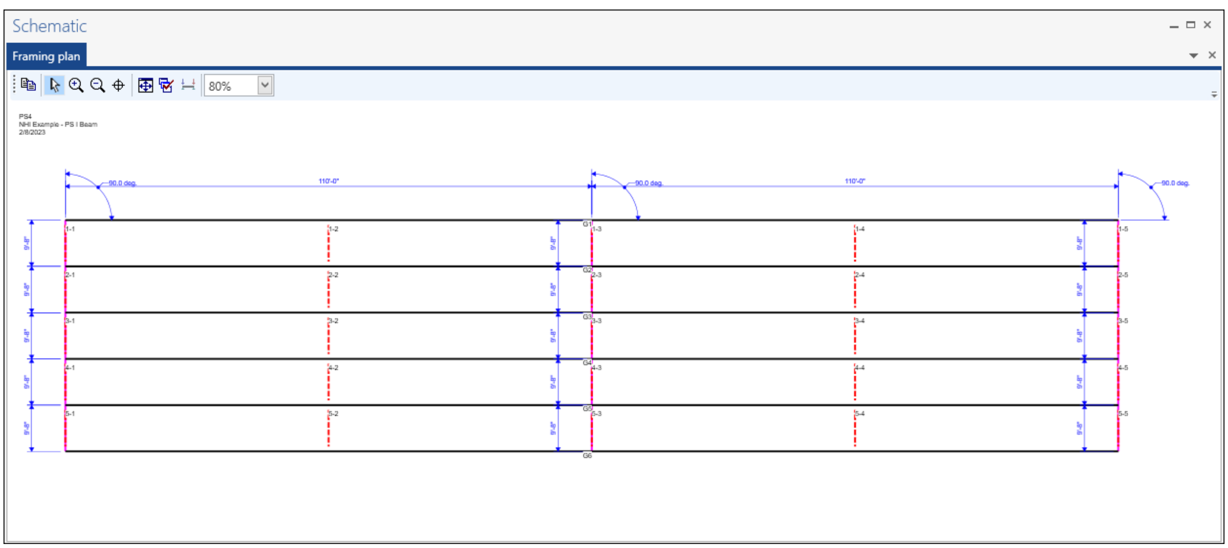
Click **OK** to apply this data and close the window.

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).

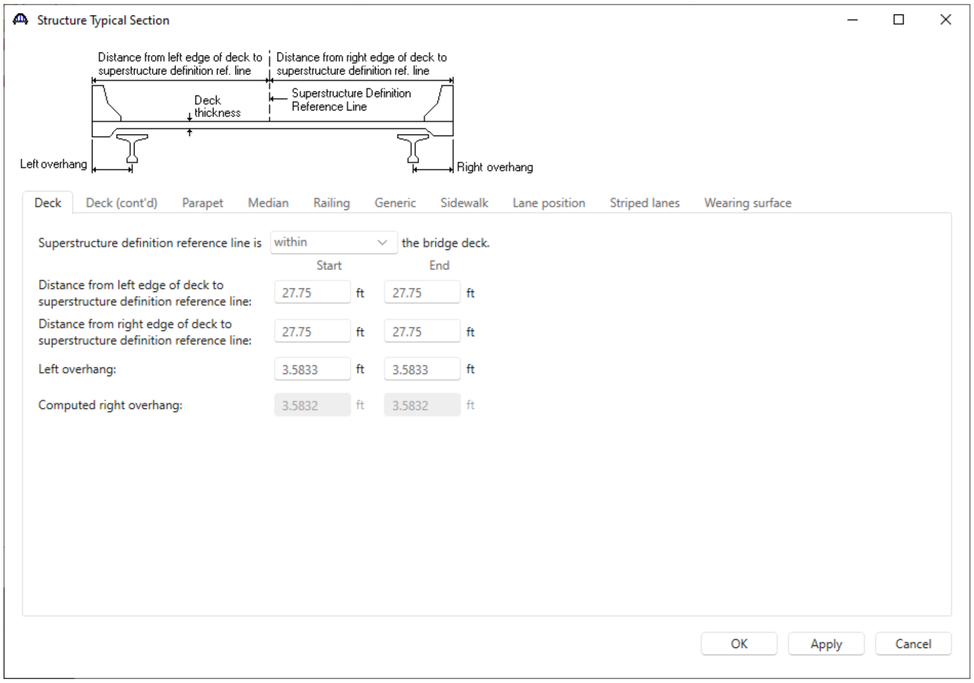


The following schematic will be displayed.



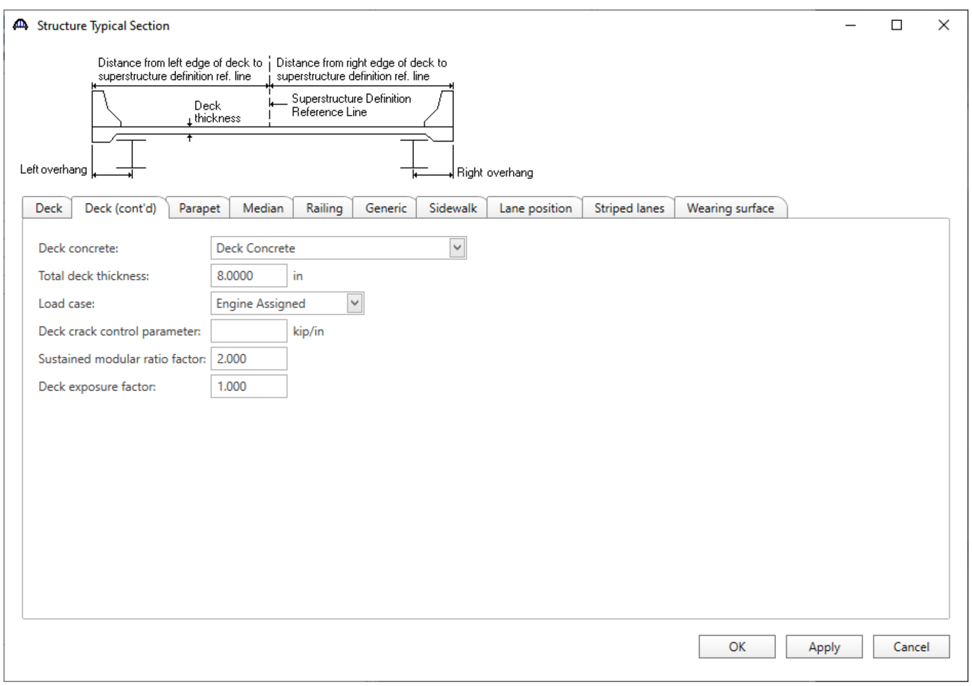
Structure Typical Section - Deck

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.



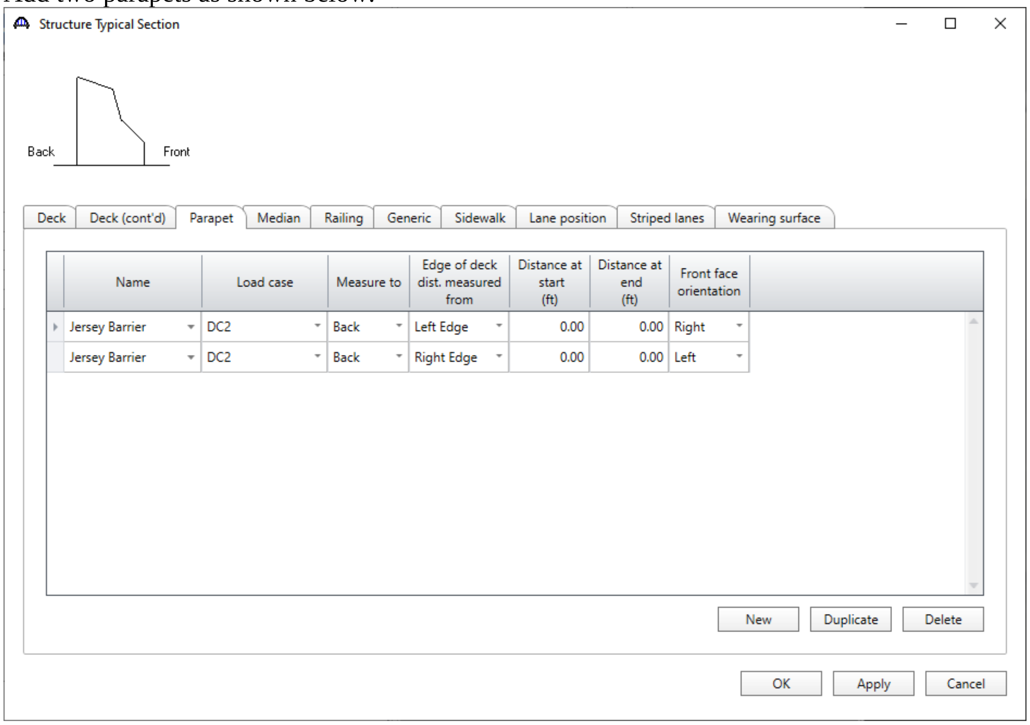
Structure Typical Section – Deck (cont'd)

The **Deck (cont'd)** tab 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.



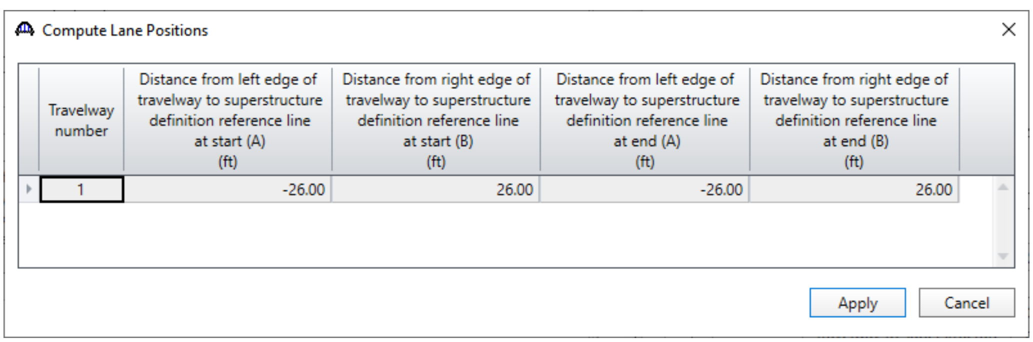
Structure Typical Section – Parapets

Add two parapets as shown below.

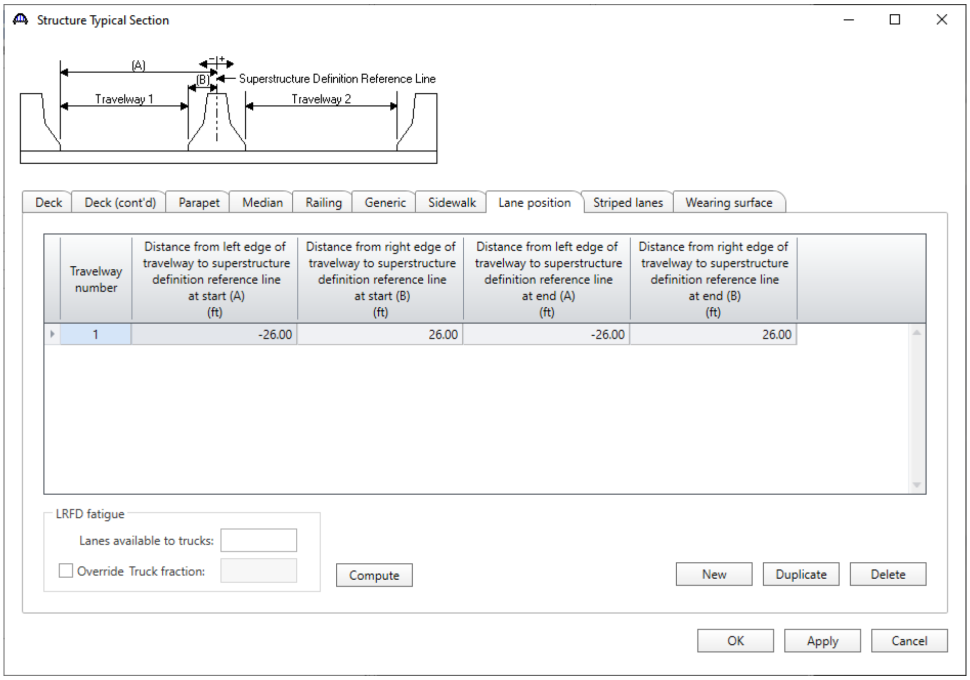


Structure Typical Section – Lane Positions

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.



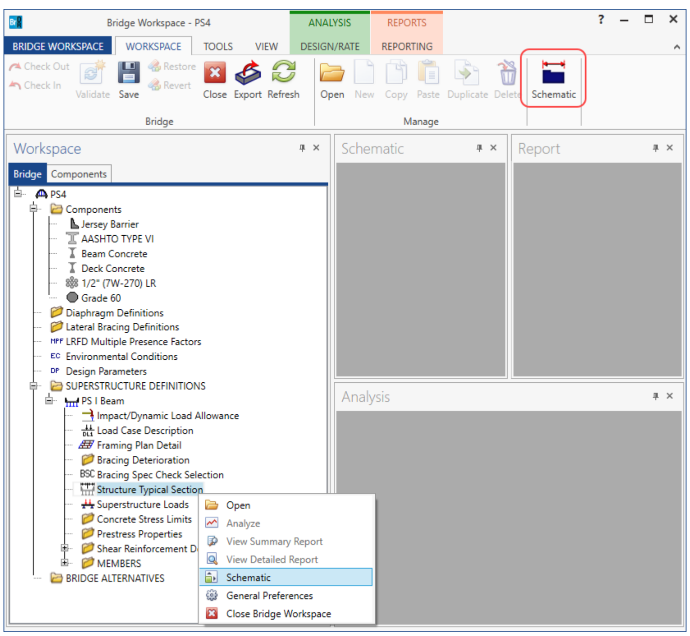
The **Lane Position** tab is populated as shown below. These lane positions are used by BrDR to compute the LRFD live load distribution factors.



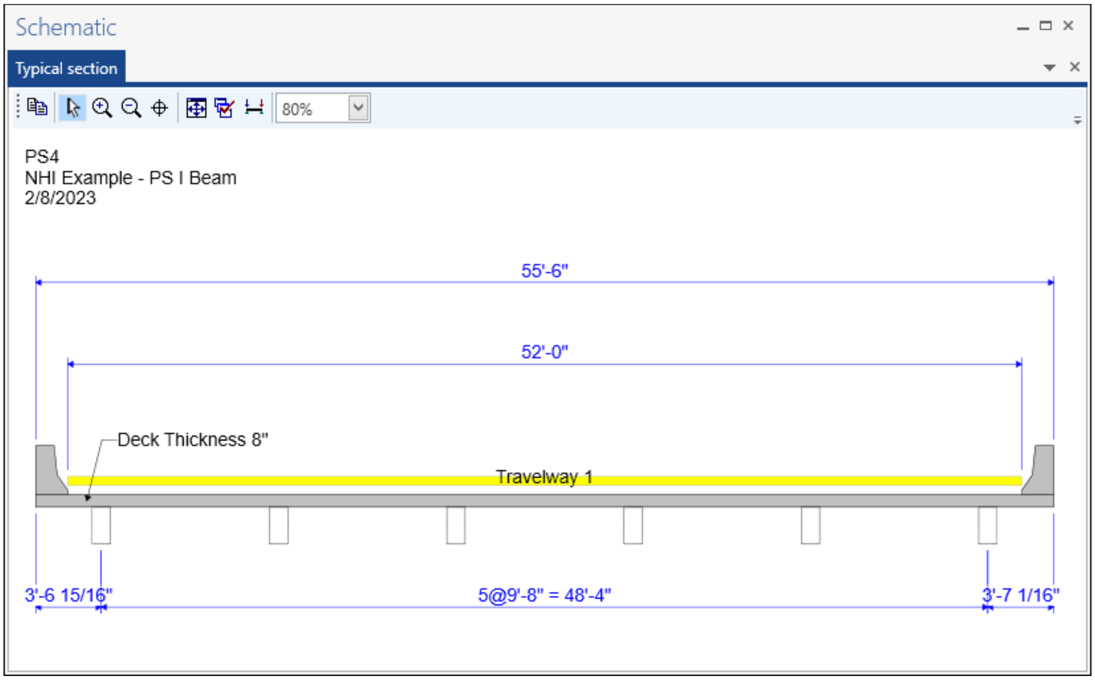
Click **OK** to apply this data and close the window.

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).

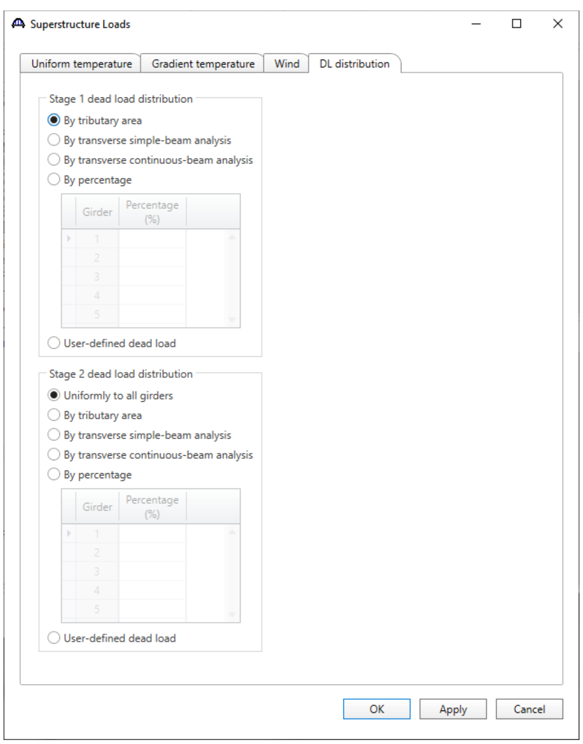


The schematic of the **Structure Typical Section** is shown below.



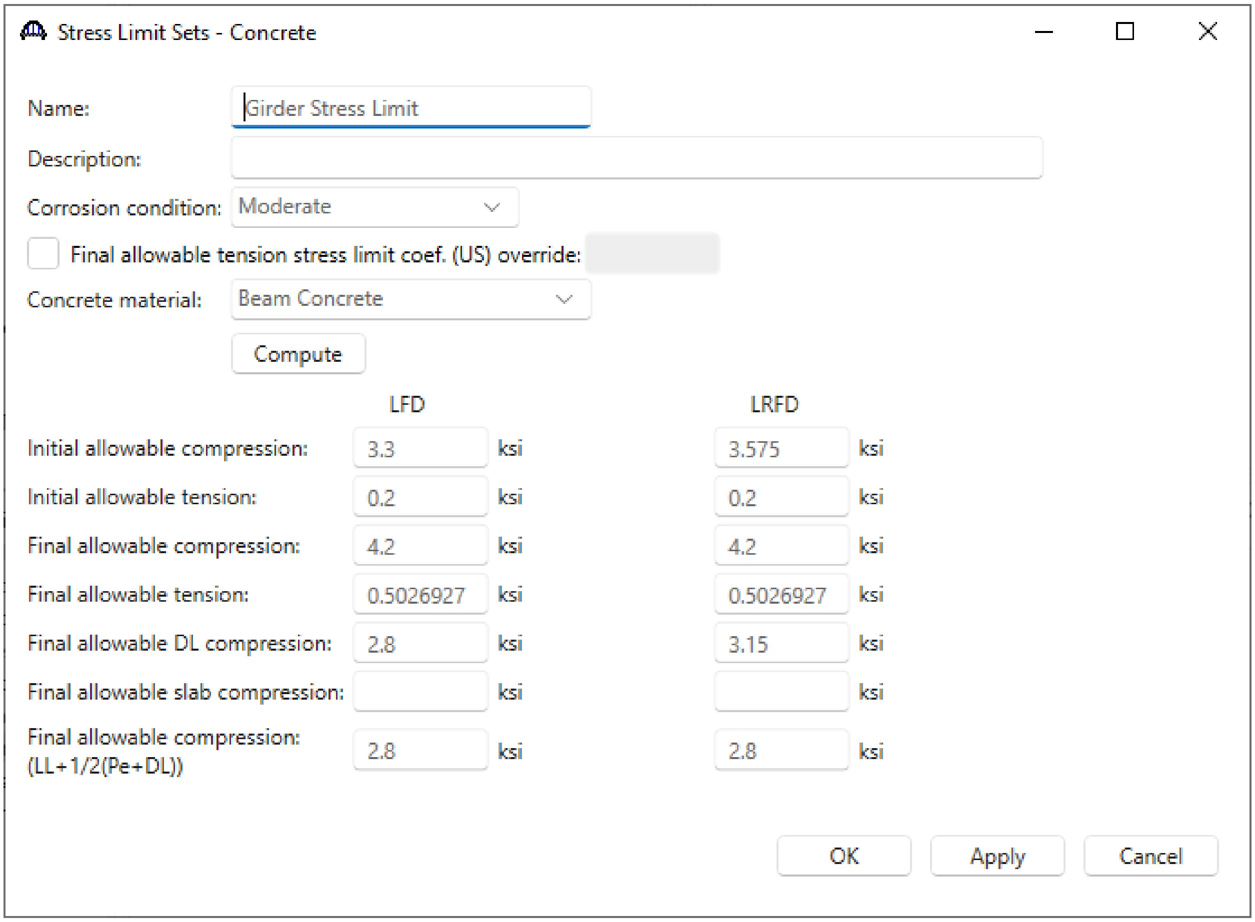
Superstructure Loads

Double click on the **Superstructure Loads** node in the **Bridge Workspace** tree to open the **Superstructure Loads** window. Navigate to the **DL distribution** tab in this window. Select options in this window as shown below. The BrDR LRFD engine does not support the transverse continuous beam analysis option.



Concrete Stress Limits

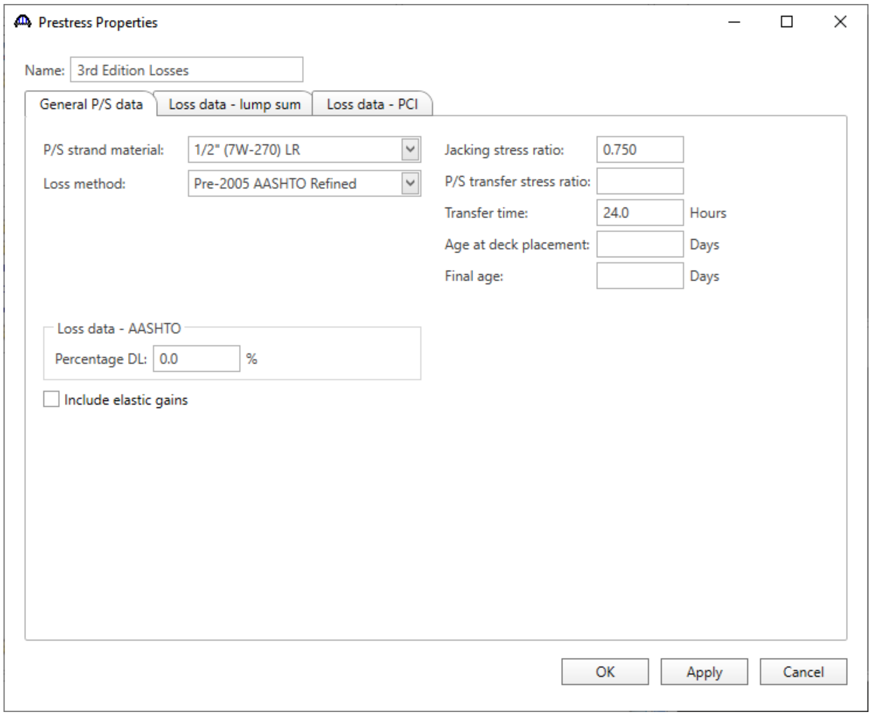
A Stress Limit defines the allowable concrete stresses for a given concrete material. Double click on the **Concrete Stress Limits** node in the **Bridge Workspace** tree to open the **Stress Limit Sets – Concrete** window. Enter the data shown above the **Compute** button and select the **Beam Concrete** 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.



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. Select the loss method as **Pre-2005 AASHTO Refined**. The losses will be computed by the BrDR LRFD engine using the refined method in the **Third edition, 2004 without interims**. Define the prestress properties as shown below.



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

Prestressed loss calculation methods

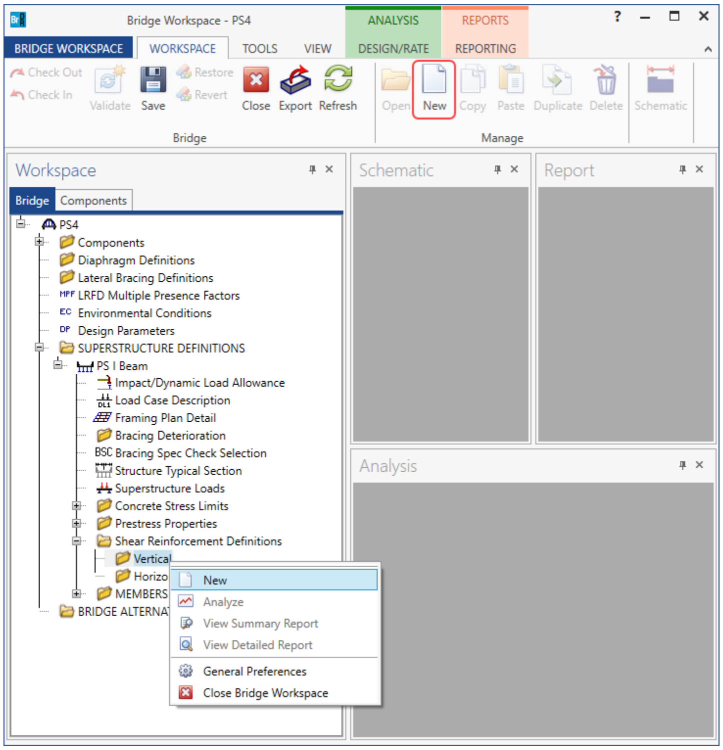
The following loss methods are available in the BrDR LRFD engine.

- AASHTO Approximate
- AASHTO Refined
- Lump Sum
- PCI
- Pre-2005 AASHTO Refined (AASHTO Refined, Third edition, 2004 without interims)

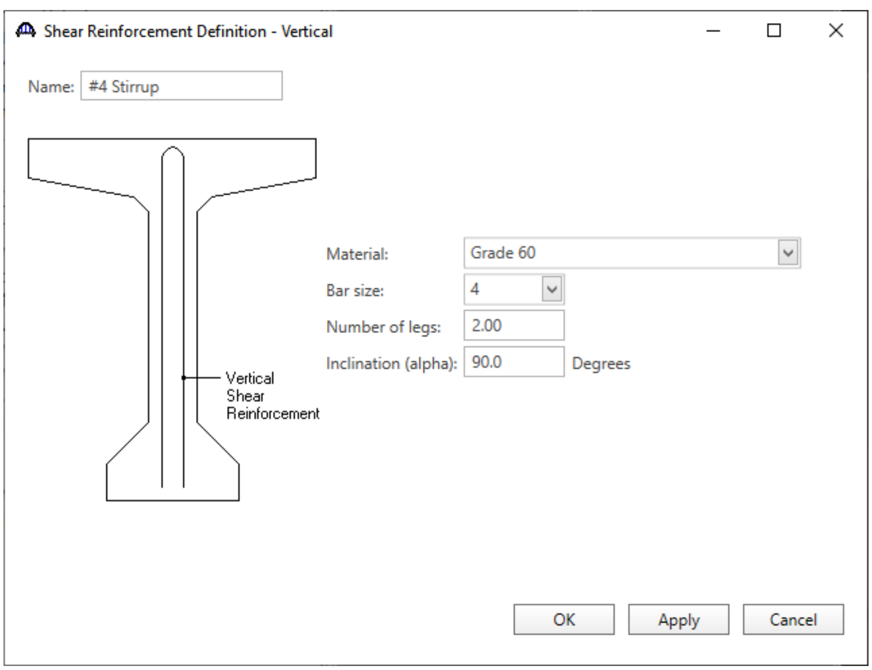
The AASHTO Approximate and refined loss methods correspond to the AASHTO LRFD Specifications, Ninth edition, by default in BrDR 7.5.0. Another feature for prestress loss calculations in the BrDR LRFD engine is the ability to include elastic gains and losses due to dead load application.

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)**.

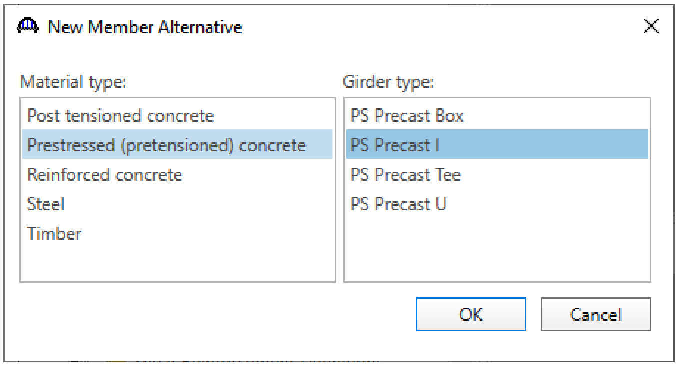


Define the stirrup as shown below. Click **OK** to apply the data and close the window.



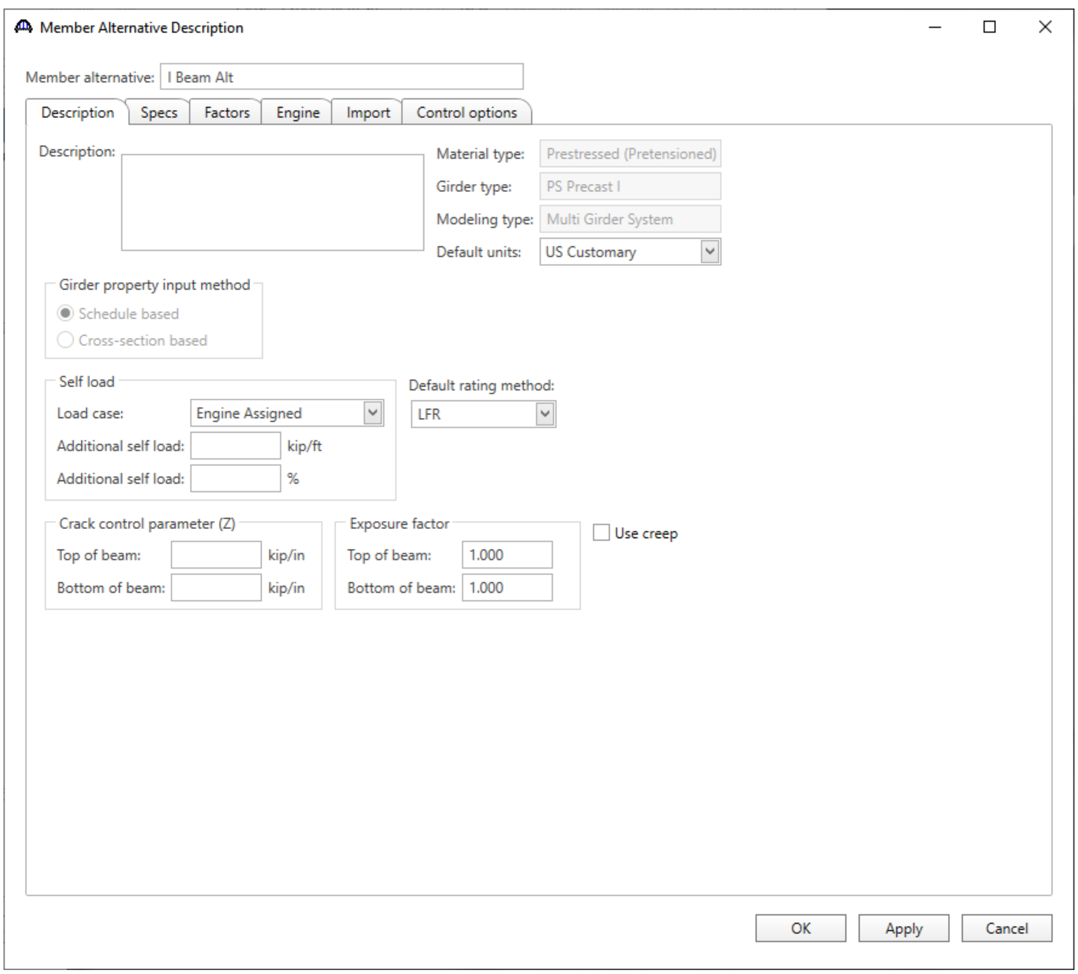
Defining a Member Alternative

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 **Prestressed (pretensioned) concrete** for the **Material type** and **PS Precast I** for the **Girder Type**.

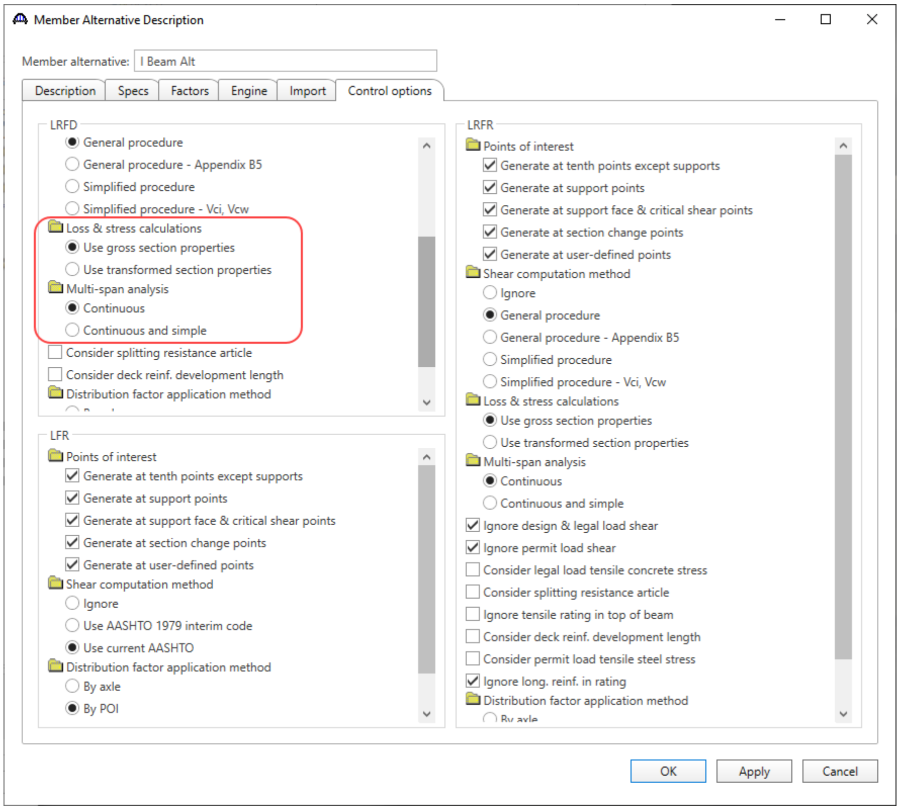


Click **OK** to close the window and create a new member alternative.

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



Navigate to the **Control options** tab in this window. The BrDR LRFD engine allows the selection of either gross or transformed section properties to be used in the loss and stress calculations. Note that the gross section properties are always used in structural analysis. Under LRFD section, select the **Use gross section properties** option for **Loss & stress calculations**, and the **Continuous** option for the **Multi-span analysis** as shown below.



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

Prestressed multi-span modeling options

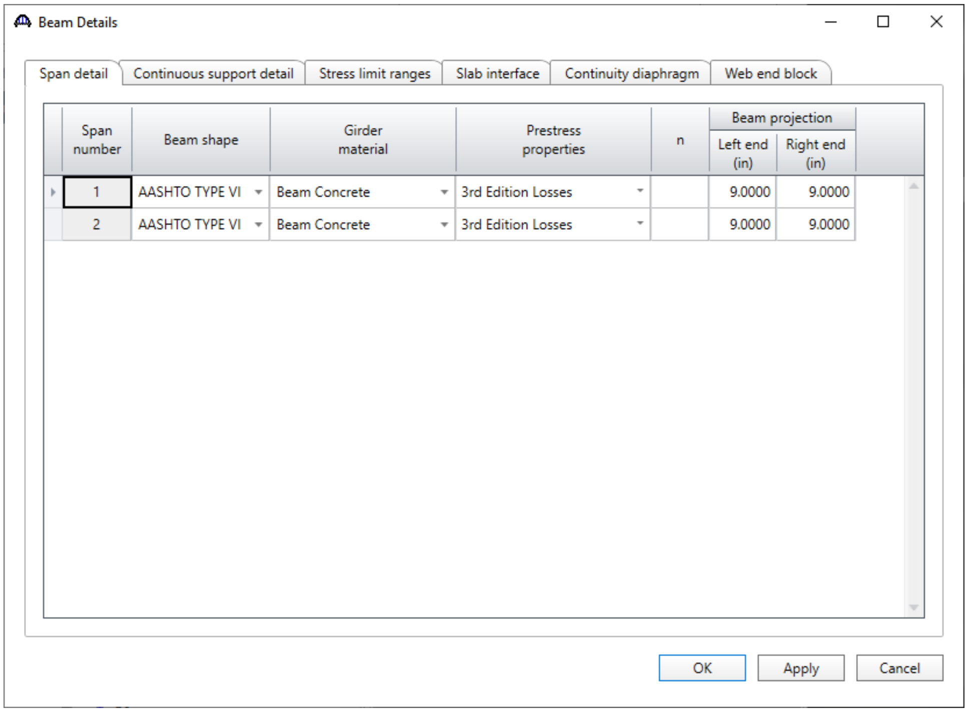
The BrDR LRFD engine allows the user to model prestress beams made continuous for live load in two ways:

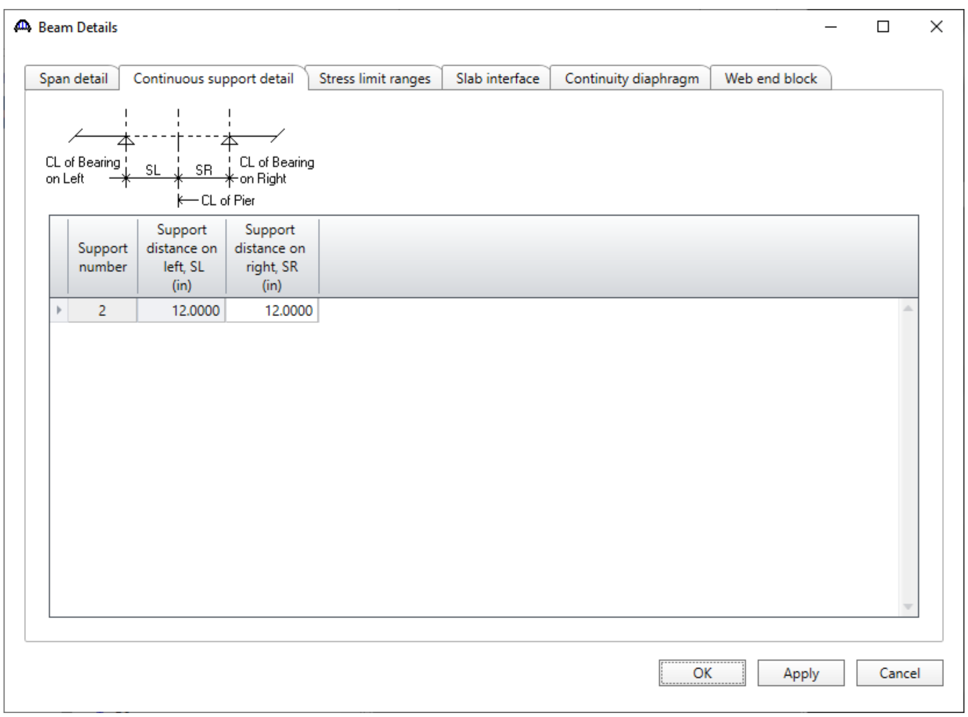
- The **Continuous** analysis method considers multi-span structures to be simply supported for beam self-weight and uncured deck and continuously supported for composite dead and live loads. This method takes advantage of the continuity connection to reduce the maximum positive moment at mid-spans.

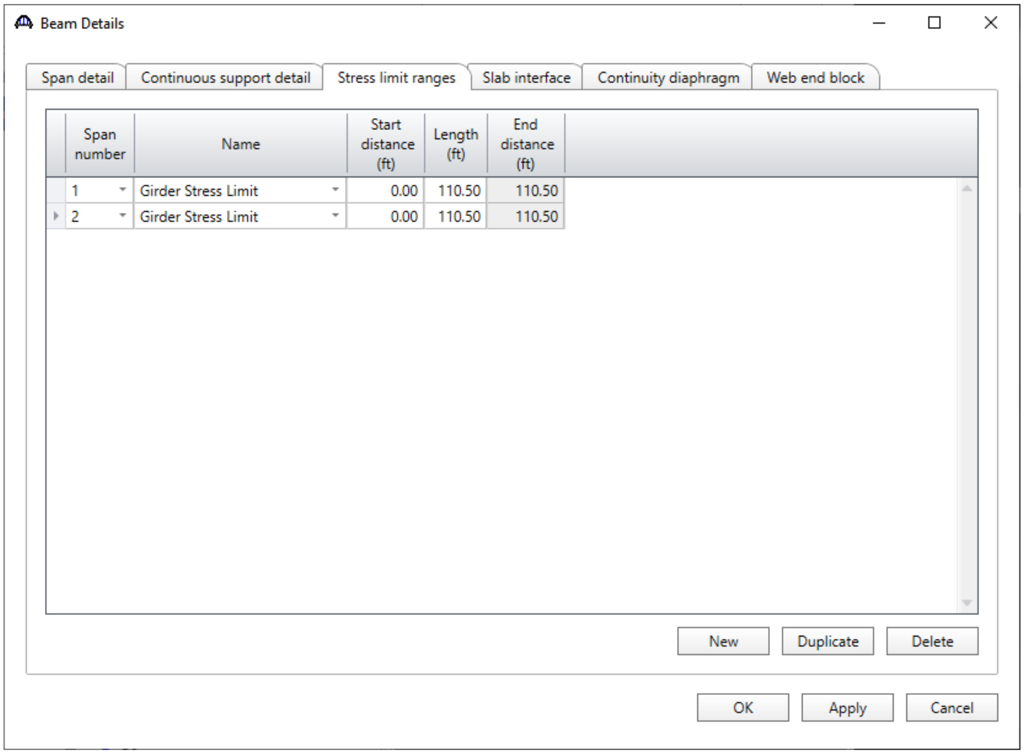
- The **Continuous** and **Simple** method analyzes the structure as simply supported for beam self-weight and uncured deck and both continuously and simply supported for composite dead and live loads. The maximum effects from the two analyses are then used in the specification checking. This method accounts for the condition where full continuity is not provided at the interior supports and does not reduce the maximum positive moment at mid-spans.

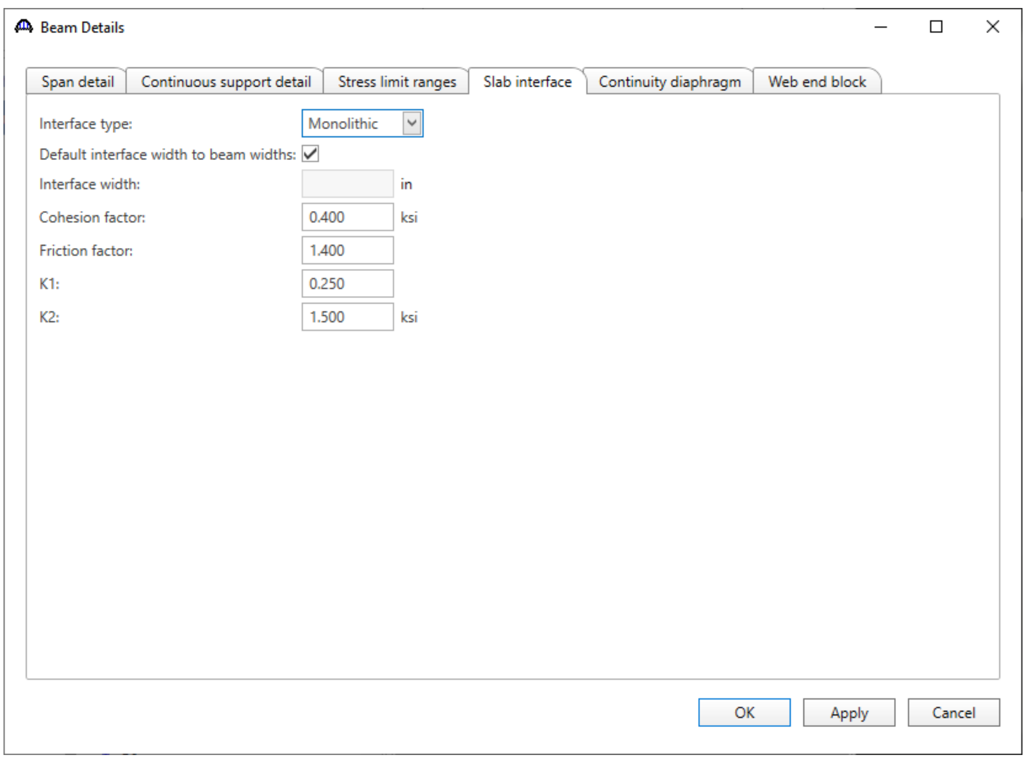
Beam Details

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.





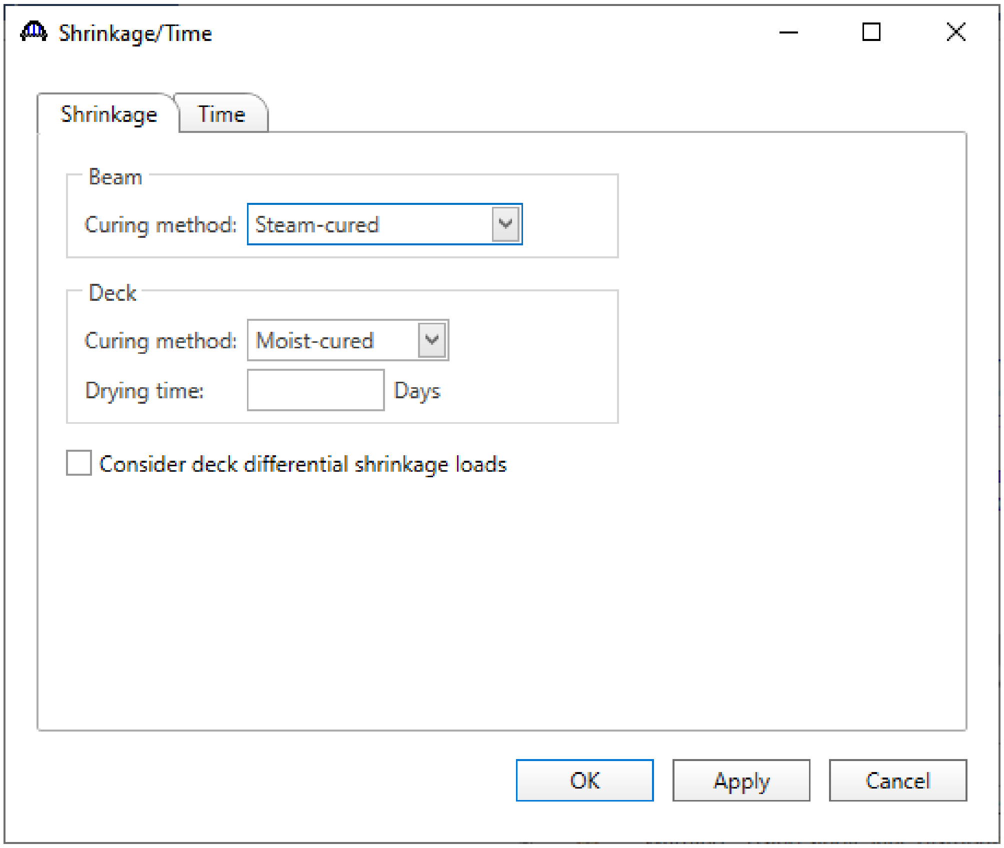




Click **OK** to apply this data and close the window.

Shrinkage Time

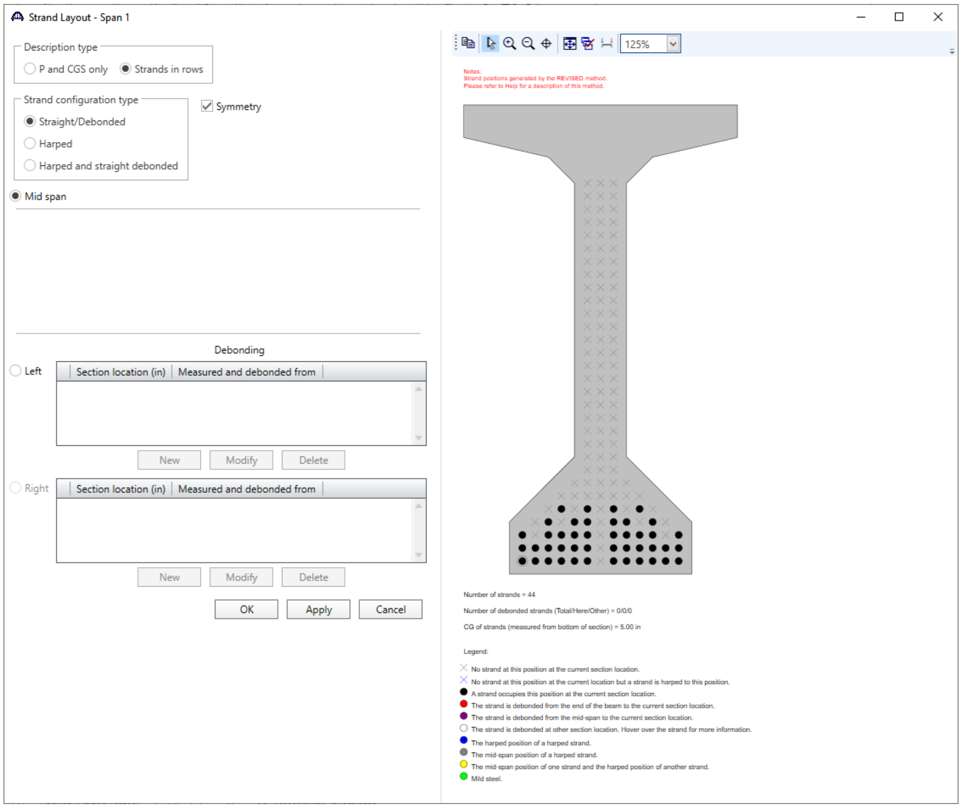
Double-click on the **Shrinkage Time** node in the **Bridge Workspace** tree to open the **Shrinkage/Time** window. Enter the data as shown below.



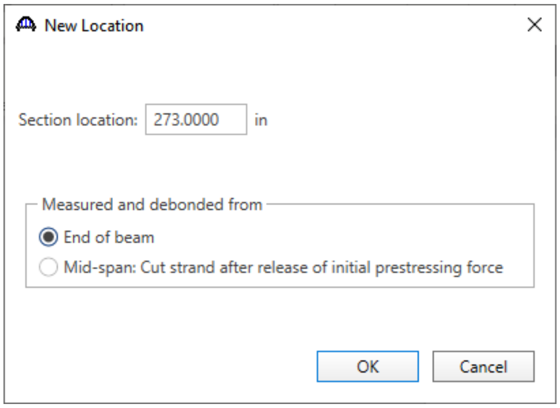
Click **OK** to apply this data and close the window.

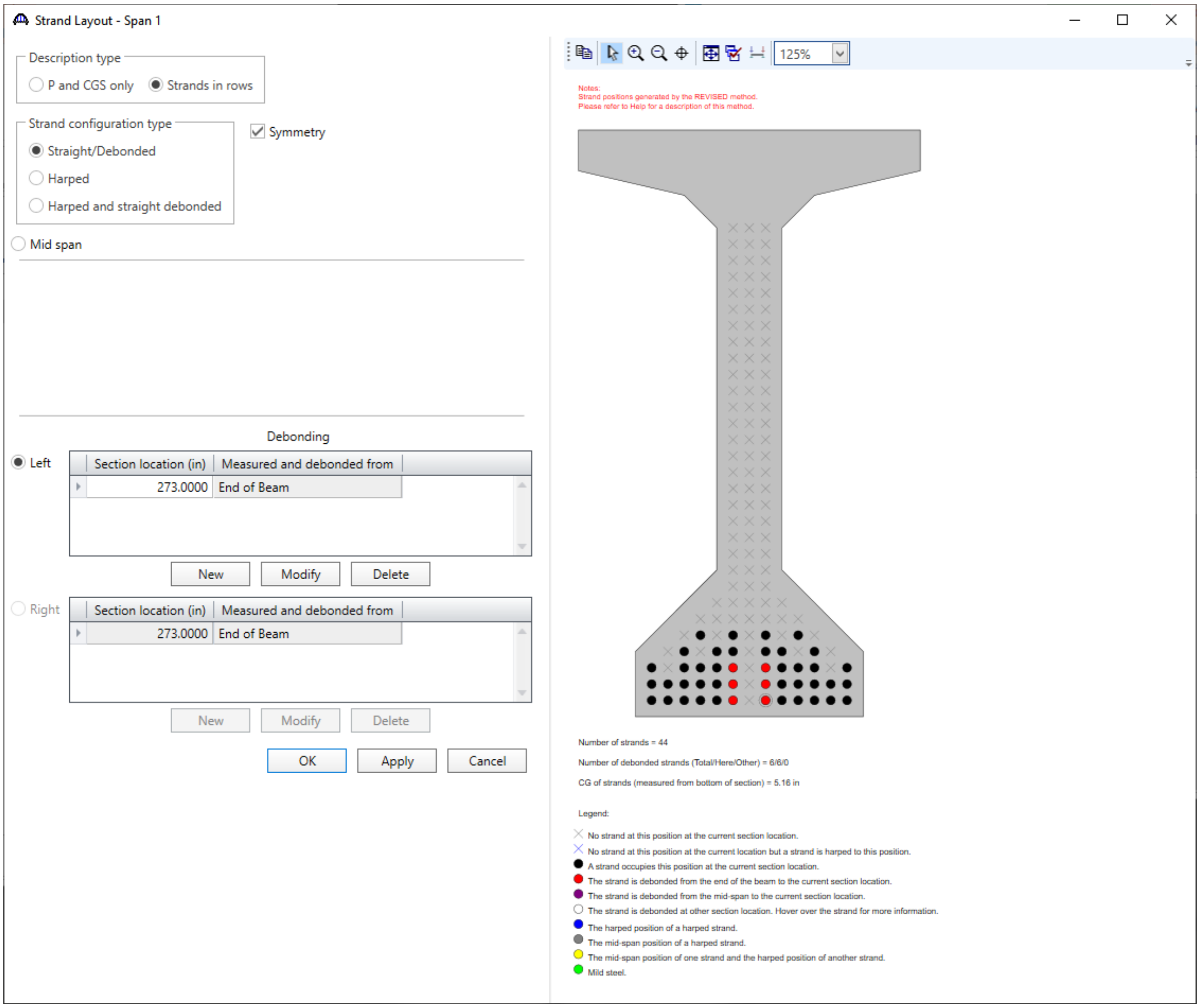
Strand Layout

Expand the **Strand Layout** node in the **Bridge Workspace** tree 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 **Straight/Debonded**. Define the following strand layout at midspan.

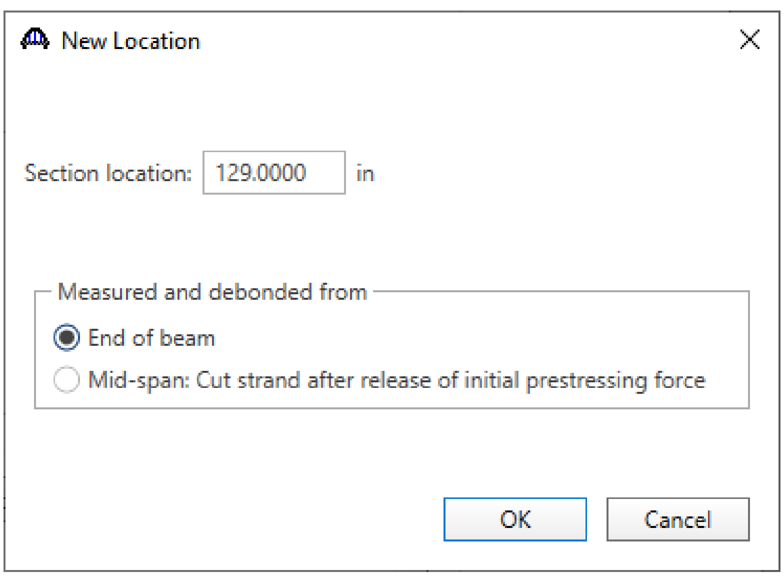


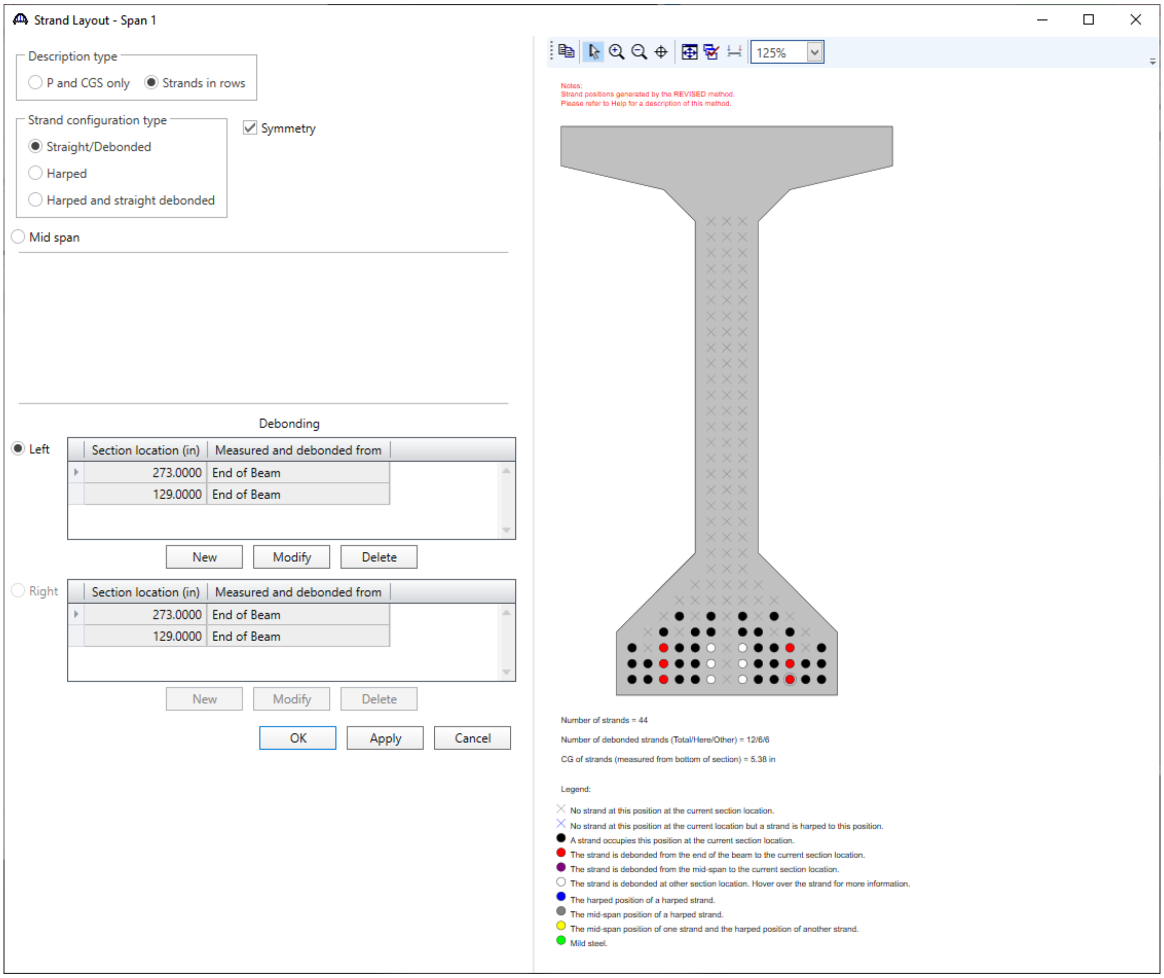
Now select the **Left end** radio button Under the Debonding section, select New to enter a left debonded section location as **273 inches**. This distance is measured from the left end of the precast beam. The strands can be defined at the left end of the span by selecting strand locations in the right hand schematic. Define the following debonded strands at this location.





Similarly, add an additional debonding location of 129 inches and debond the following strands.





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

Repeat the procedure used in **Strand Layout – Span 1** section to describe the same strand layout for **Span 2**.

Deck Profile

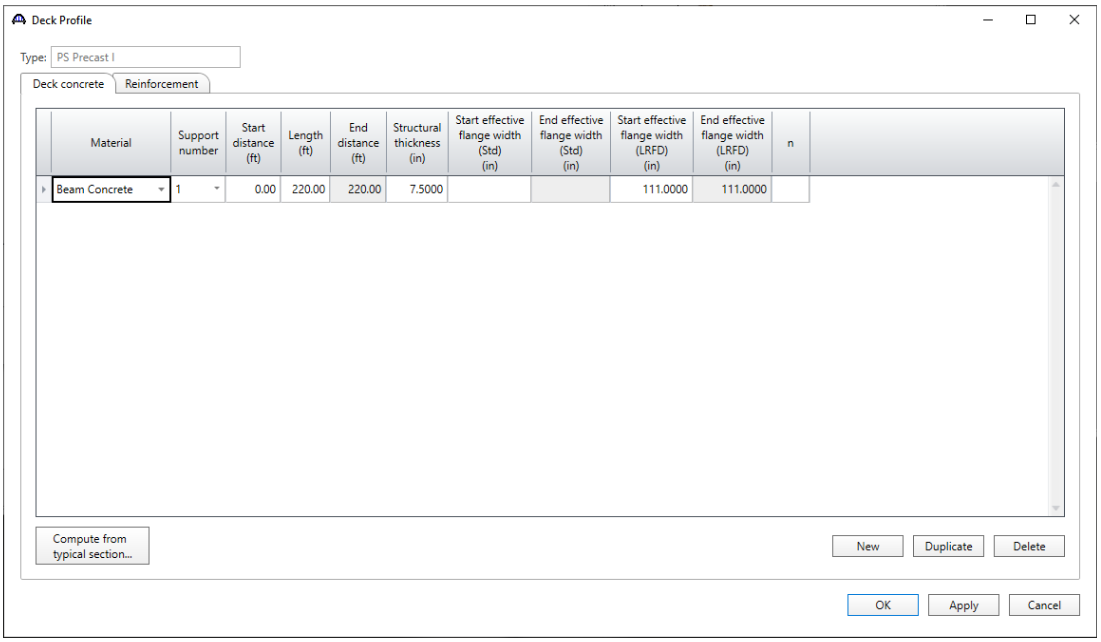
Next open the **Deck Profile** window by double-clicking the **Deck Profile** node in the **Bridge Workspace** tree and enter the data describing the structural properties of the deck. The window is shown below.

The LRFD effective flange width is computed as follows:

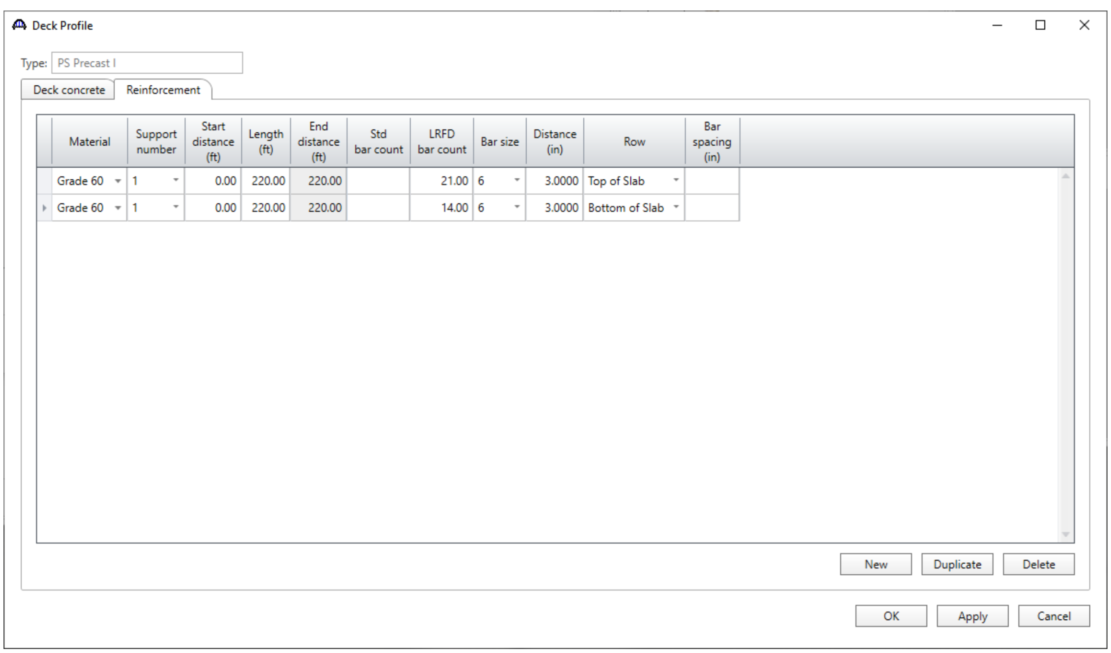
AASHTO LRFD Article 4.6.2.6.1

For interior beams, the effective flange width is taken as :

- average spacing of adjacent beams = 9.67' (12"/') = 116"



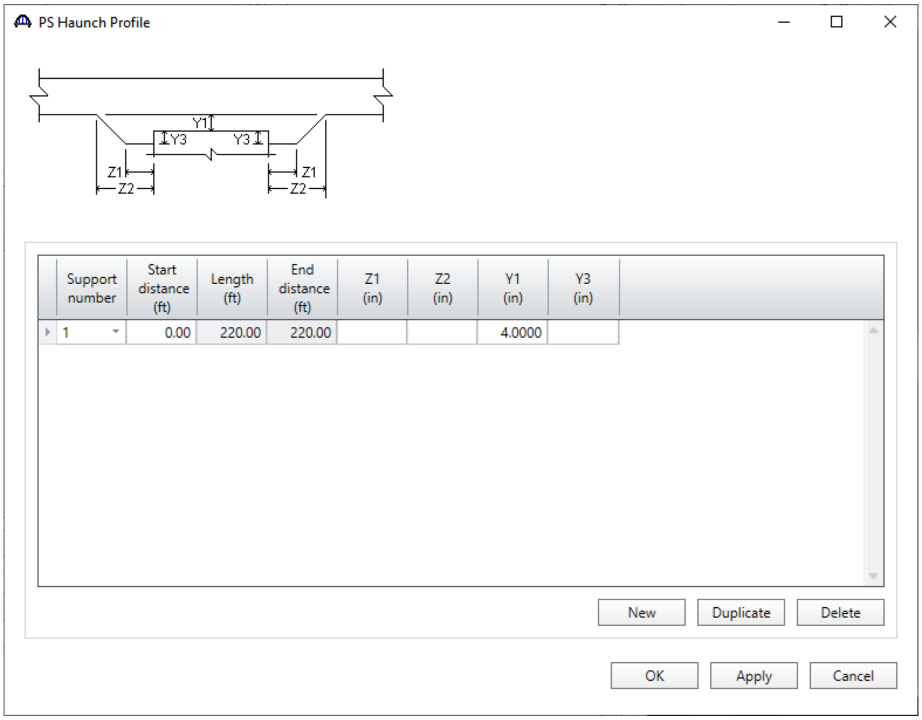
Navigate to the **Reinforcement** tab and enter the reinforcement data as shown below.



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

Haunch Profile

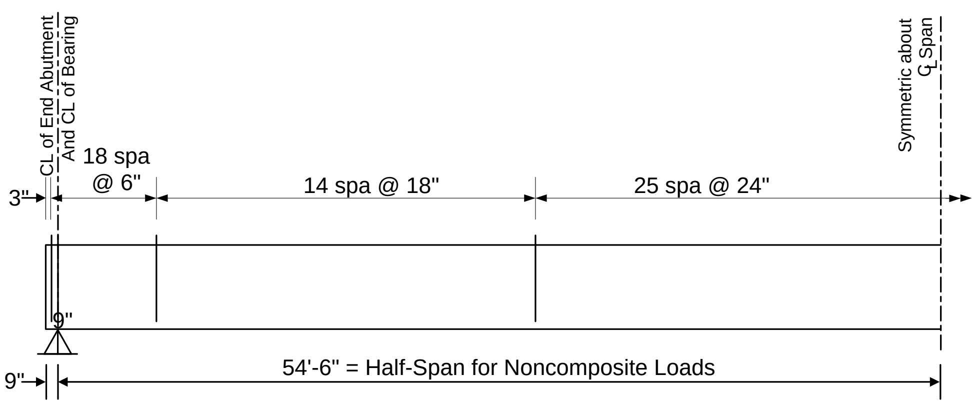
The haunch profile is defined by double-clicking on the **Haunch Profile** node in the **Bridge Workspace** tree. Enter data as shown below.



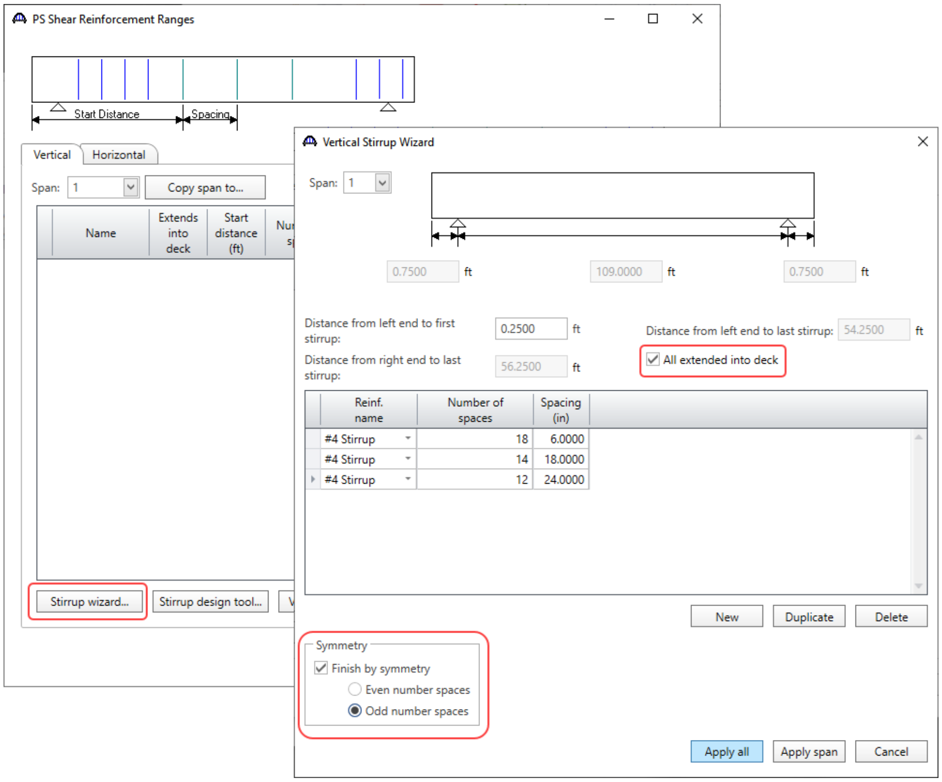
Click **OK** to apply this data and close the window.

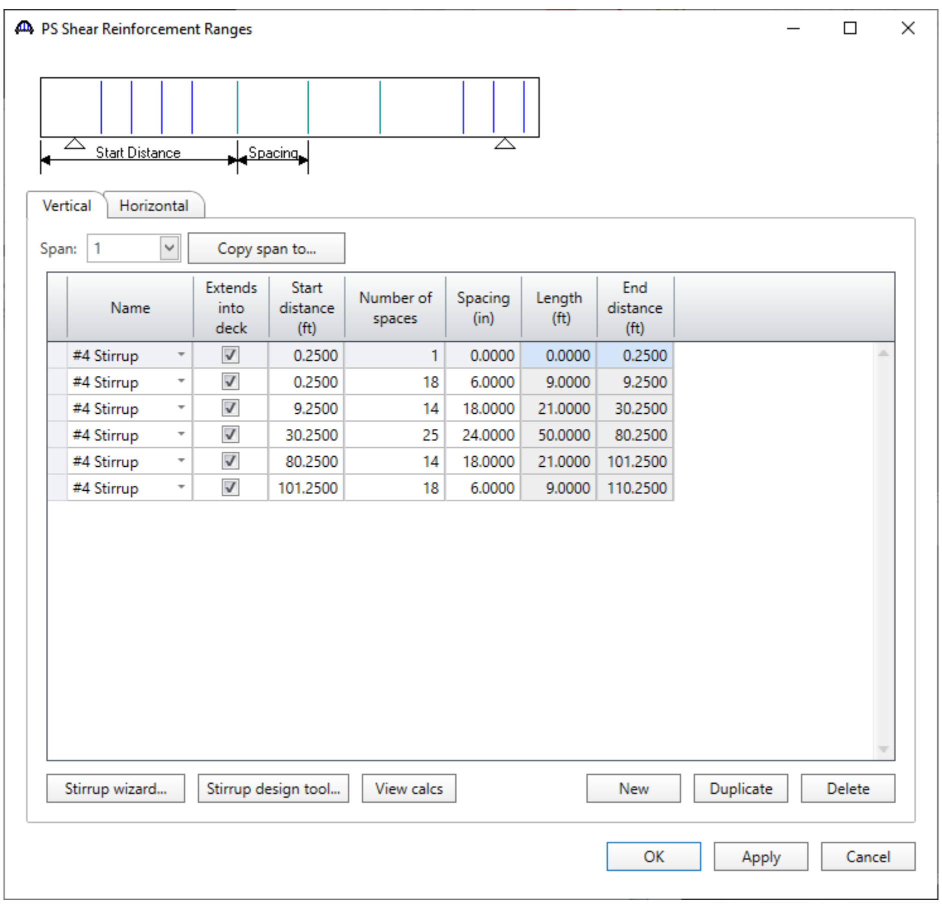
Shear Reinforcement Ranges

Double-click on the **Shear Reinforcement Ranges** node in the **Bridge Workspace** tree to open the **PS Shear Reinforcement Ranges** window. Use the **Stirrup wizard** to create the following shear stirrups.

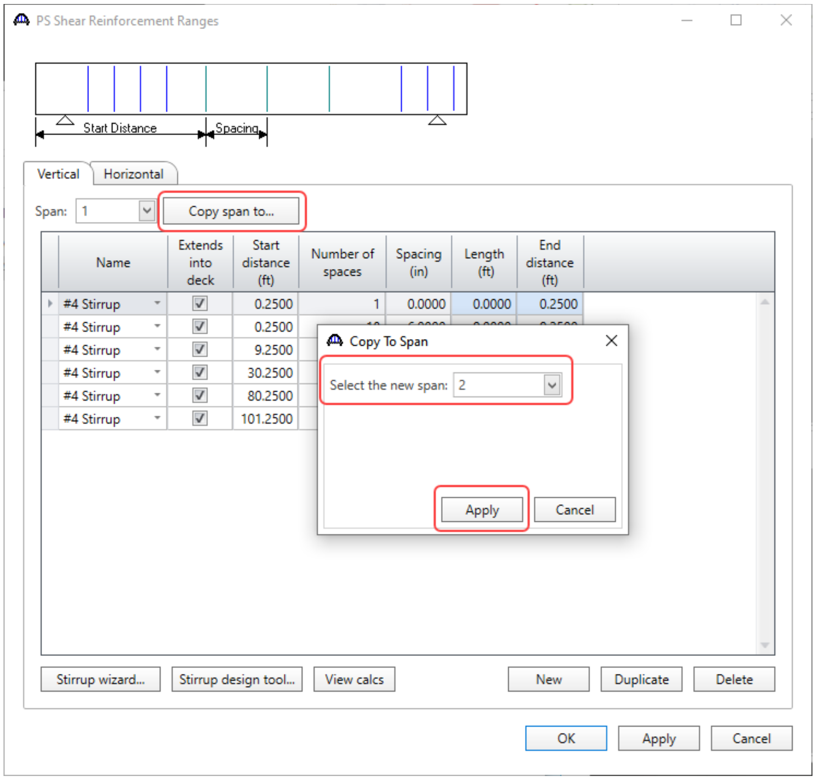


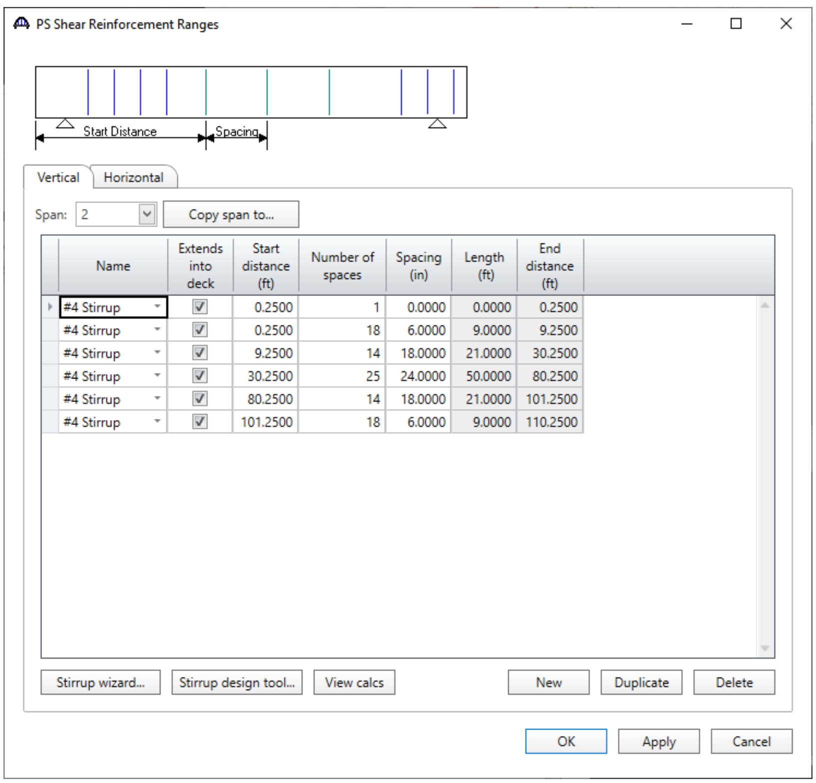
Beam Elevation Showing Stirrups


PS Shear Reinforcement Ranges
Start Distance
Spacing
Vertical
Horizontal
Span: 1
Copy span to...
Name
Extends into deck
Start distance (ft)
Stirrup wizard...
Stirrup design tool...
Vertical Stirrup Wizard
Span: 1
0.7500 ft
109.0000 ft
0.7500 ft
Distance from left end to first stirrup: 0.2500 ft
Distance from right end to last stirrup: 56.2500 ft
Distance from left end to last stirrup: 54.2500 ft
All extended into deck
Reinf. name | Number of spaces | Spacing (in)
#4 Stirrup | 18 | 6.0000
#4 Stirrup | 14 | 18.0000
#4 Stirrup | 12 | 24.0000
New
Duplicate
Delete
Symmetry
Finish by symmetry
Even number spaces
Odd number spaces
Apply all
Apply span
Cancel


PS Shear Reinforcement Ranges
Start Distance
Spacing
Vertical
Horizontal
Span: 1
Copy span to...
Name | Extends into deck | Start distance (ft) | Number of spaces | Spacing (in) | Length (ft) | End distance (ft)
#4 Stirrup | ☑ | 0.2500 | 1 | 0.0000 | 0.0000 | 0.2500
#4 Stirrup | ☑ | 0.2500 | 18 | 6.0000 | 9.0000 | 9.2500
#4 Stirrup | ☑ | 9.2500 | 14 | 18.0000 | 21.0000 | 30.2500
#4 Stirrup | ☑ | 30.2500 | 25 | 24.0000 | 50.0000 | 80.2500
#4 Stirrup | ☑ | 80.2500 | 14 | 18.0000 | 21.0000 | 101.2500
#4 Stirrup | ☑ | 101.2500 | 18 | 6.0000 | 9.0000 | 110.2500
Stirrup wizard...
Stirrup design tool...
View calcs
New
Duplicate
Delete
OK
Apply
Cancel

Then use the **Copy to span** button to copy the stirrups to **Span 2.**





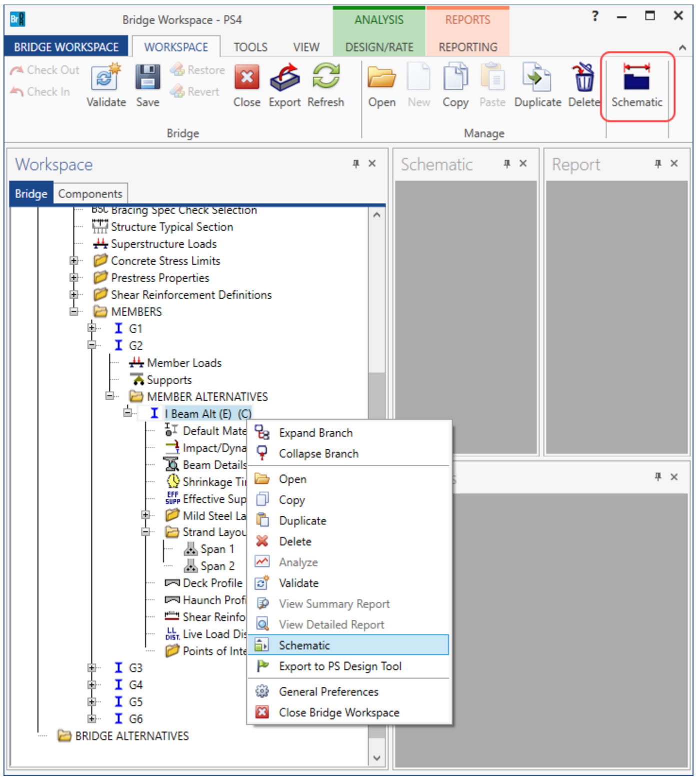
Click **OK** to apply this data and close the window.

Live Load Distribution

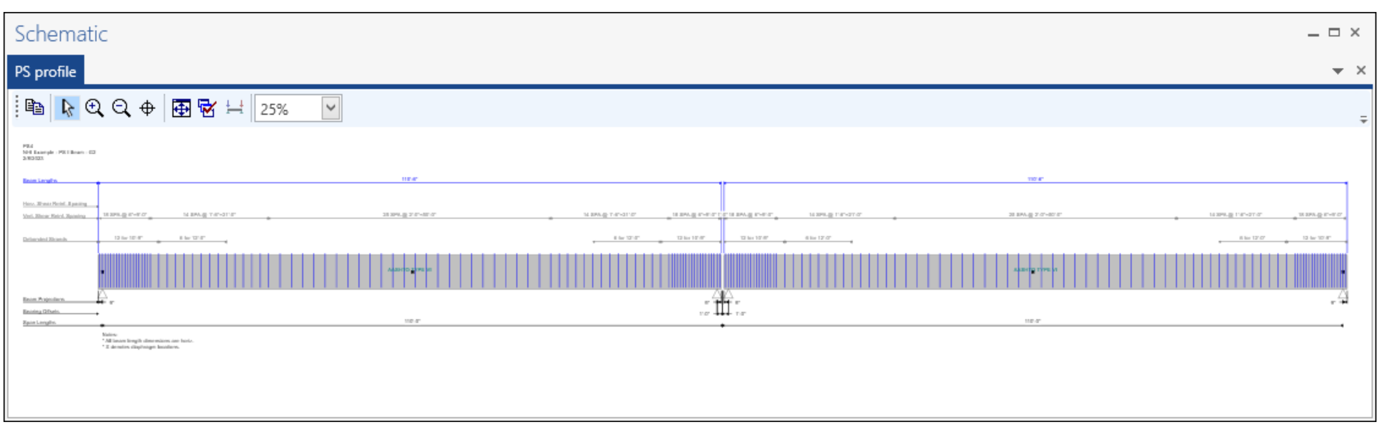
BrDR will compute the live load distribution factors during analysis. No changes are required in this window.

Schematic – I Beam Alt

While the member alternative **I Beam Alt (E) (C)** is selected in the **Bridge Workspace** tree, open the schematic for the member alternative by selecting the **Schematic** button on the **WORKSPACE** ribbon (or right click on **I Beam Alt (E) (C)** in the **Bridge Workspace** and select **Schematic** from the menu).

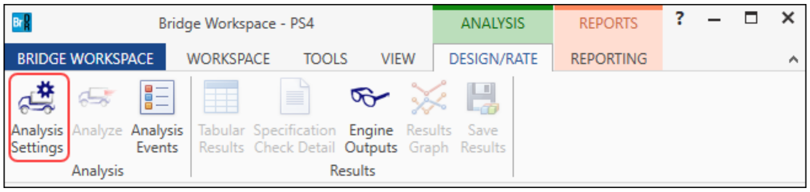


The member alternative schematic is shown below.

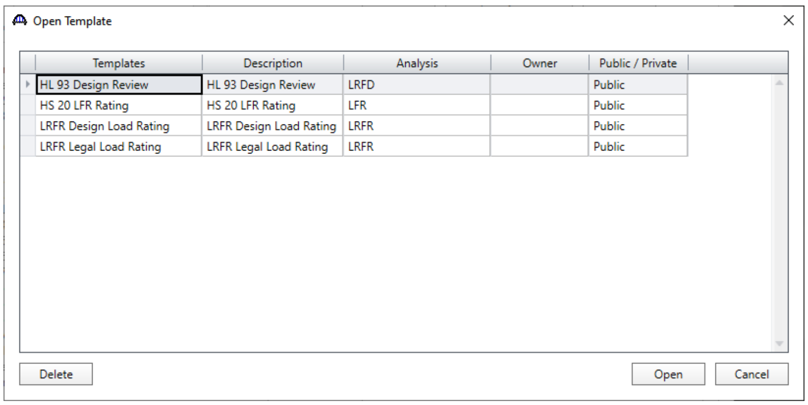


LRFD Design Review

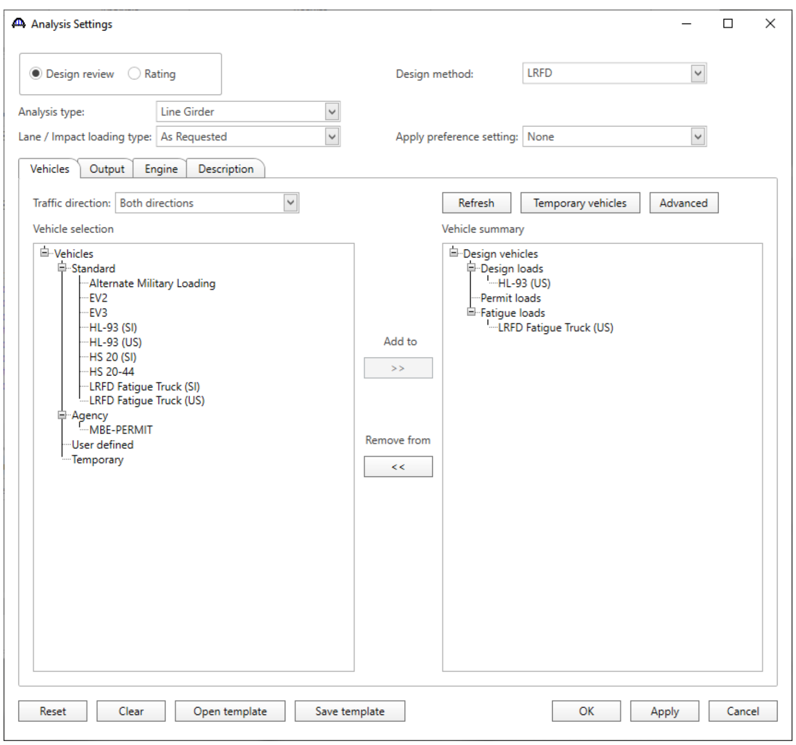
The member alternative can now be analyzed. To perform an **LRFD Design Review**, select the **Analysis Settings** button on the **Analysis** group of the **DESIGN/RATE** ribbon. The window shown below opens.



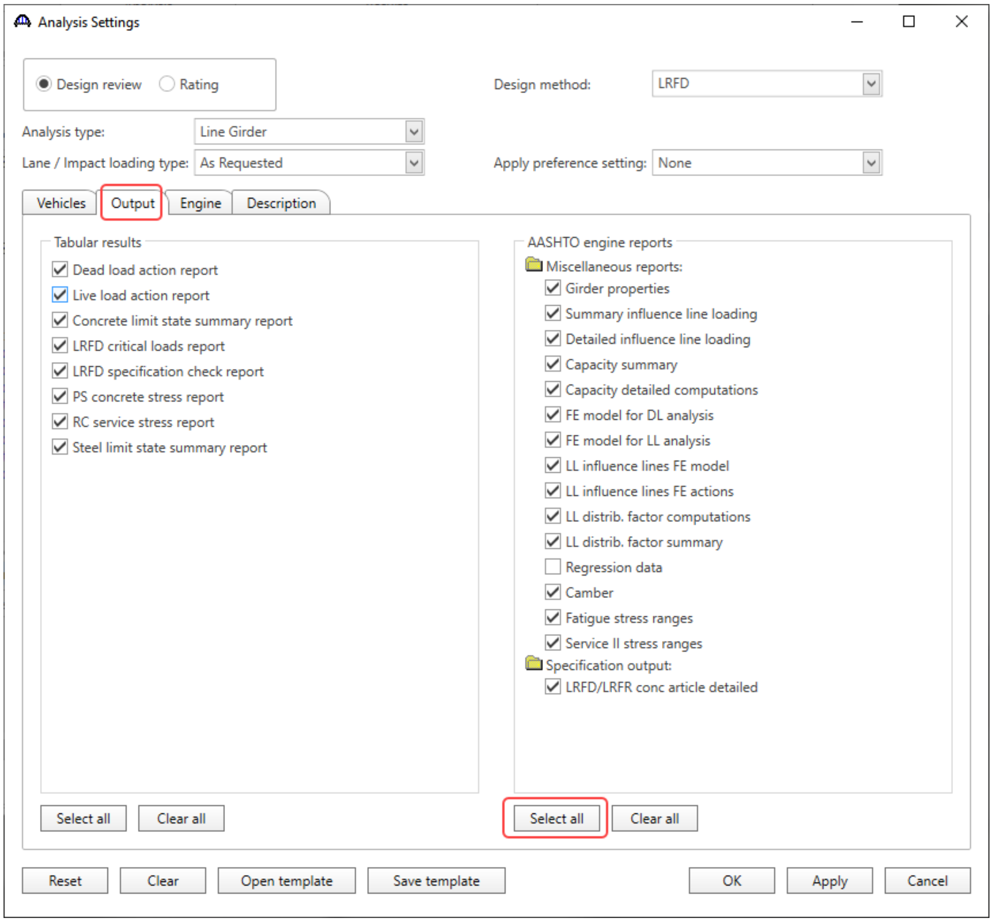
Click the **Open Template** button and select the **HL-93 Design Review** template to be used in the design review and click **Open**.



The Analysis Settings window will be populated as shown below.

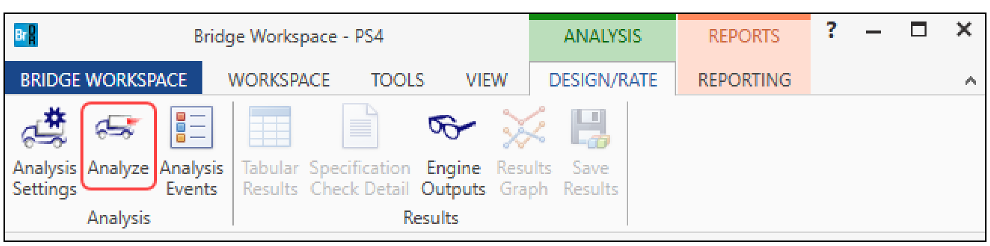


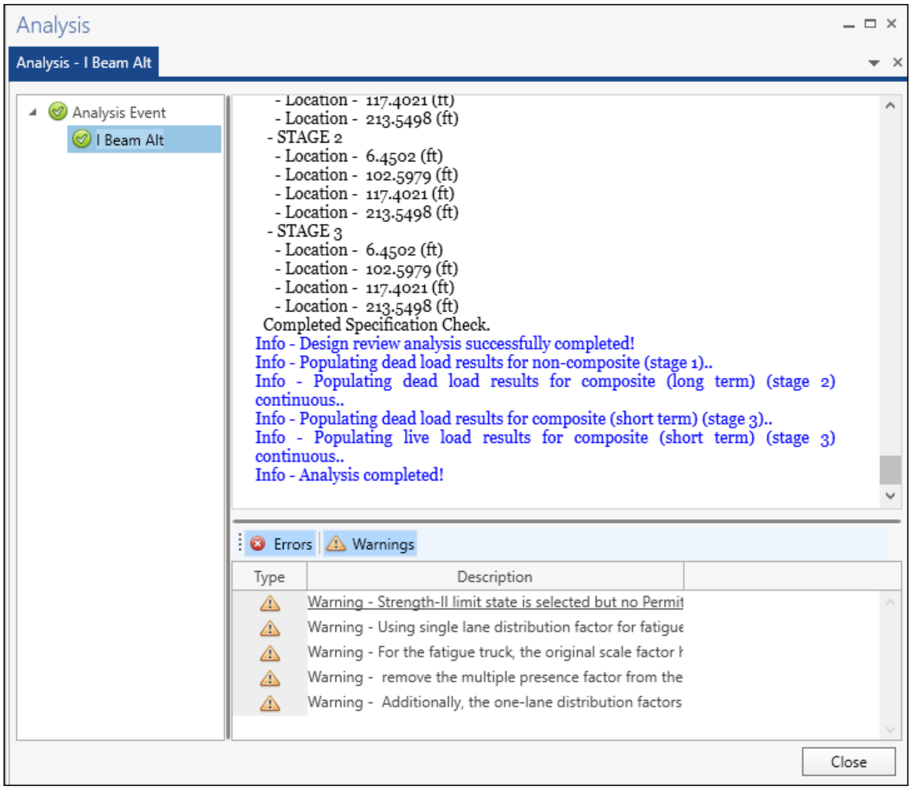
Navigate to the **Output** tab of this window and click on the **Select All** button under the **AASHTO engine reports** and click **OK.**



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

Next click the **Analyze** button on the **Analysis** group of the **DESIGN/RATE** ribbon to perform the design review. The **Analysis** window should be reviewed for any warning messages.





Export of prestressed concrete beams to the BrDR LRFD analysis engine

The following steps are performed during a design review of a multi-span prestressed beam using the BrDR LRFD analysis engine:

1. Finite element models are generated for the dead load and live load analyses. A Stage 1 FE model is generated for the dead loads on the non-composite simple span prestressed concrete beam.

   For Continuous method of analysis:

   A Stage 2 FE model is generated for the continuous final span condition for composite dead load analysis.

   A Stage 3 FE model is generated for the continuous final span condition for the live load analysis.

   For Continuous and Simple method of analysis:

   - Two Stage 2 FE models are generated:
     - Continuous final span condition
     - Simple span condition
   - Two Stage3 FE models are generated:
     - Continuous final span condition
     - Simple span condition

   Stage 2 models contain section properties corresponding to the sustained modular ratio factor entered in BrDR (e.g., 2n). Stage 3 models contain section properties corresponding to the modular ratio (n).

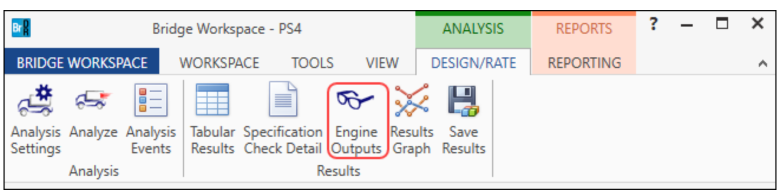
The model generated by the export to the BrDR LRFD analysis engine will always contain node points at the middle of each simple span, at simple support locations, at harp points, at debond locations and at prestress strand transfer length locations so that the prestress force distribution can be computed.

2. The Stage 1 and 2 FE models are analyzed for the dead load. The prestress loss calculations are then performed along with determining the prestress forces at transfer and the restraint effects for the creep and shrinkage analysis for multi-span structures.

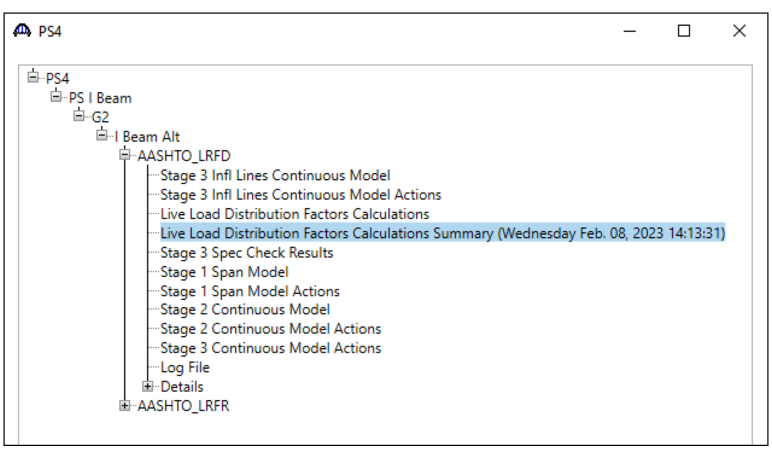
3. The final analysis then takes place. The prestress forces at transfer are applied to the Stage 1 FE model to determine the prestress camber in the beam. They are not included in the load combination generation. Creep and shrinkage forces are applied to the Stage 2 FE model.
   The Stage 1 and 2 FE models are analyzed for the dead load. The Stage 3 FE model is loaded with unit loads at each node to generate influence lines for the beam. The influence loads are then loaded with the selected vehicles to find the maximum live load effects.
4. Load combinations are generated for the loadings and specification checks are performed at each of the nodes in the finite element model. For the Continuous and Simple method of analysis, the maximum force effects between the 2 sets of models are used to generate the load combinations.

Engine Outputs

Click the **Engine Outputs** button from the **Results** group of the **DESIGN/RATE** ribbon to open the following window.

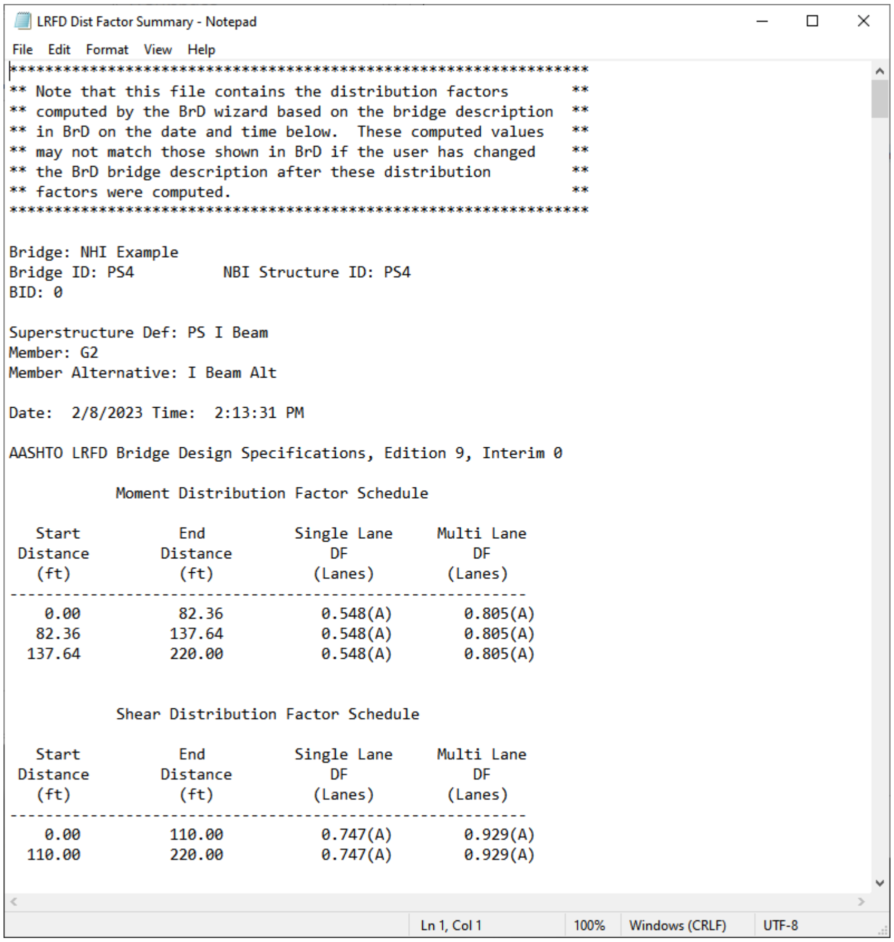


The window shown below will open. A summary and a detailed report of the computed live load distribution factors are available.



Double click on the **Live Load Distribution Factors Calculation Summary** option under the **AASHTO_LRFD** branch in this window.

The following file opens.

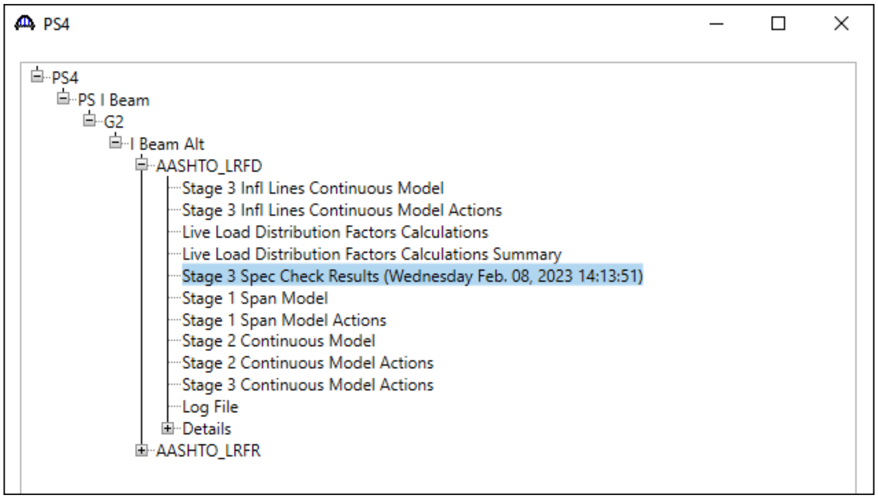


```
*****************************************************************
** Note that this file contains the distribution factors      **
** computed by the BrD wizard based on the bridge description  **
** in BrD on the date and time below.  These computed values   **
** may not match those shown in BrD if the user has changed    **
** the BrD bridge description after these distribution        **
** factors were computed.                                      **
*****************************************************************

Bridge: NHI Example
Bridge ID: PS4          NBI Structure ID: PS4
BID: 0

Superstructure Def: PS I Beam
Member: G2
Member Alternative: I Beam Alt

Date:  2/8/2023 Time:  2:13:31 PM

AASHTO LRFD Bridge Design Specifications, Edition 9, Interim 0

            Moment Distribution Factor Schedule

   Start          End         Single Lane     Multi Lane
 Distance       Distance          DF              DF
   (ft)           (ft)          (Lanes)         (Lanes)
----------------------------------------------------------
    0.00          82.36          0.548(A)        0.805(A)
   82.36         137.64          0.548(A)        0.805(A)
  137.64         220.00          0.548(A)        0.805(A)


            Shear Distribution Factor Schedule

   Start          End         Single Lane     Multi Lane
 Distance       Distance          DF              DF
   (ft)           (ft)          (Lanes)         (Lanes)
----------------------------------------------------------
    0.00         110.00          0.747(A)        0.929(A)
  110.00         220.00          0.747(A)        0.929(A)
```

BrDR LRFD Specification checking

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

Double click on the **Stage 3 Spec Check Results** option under the **AASHTO_LRFD** branch in this window.



Bridge ID : PS4
Bridge : NHI Example
Superstructure Def : PS I Beam
Member : G2
Analysis Preference Setting :

NBI Structure ID : PS4
Bridge Alt :
Member Alt : I Beam Alt

AASHTO LRFD Specification, Edition 9, Interim 0

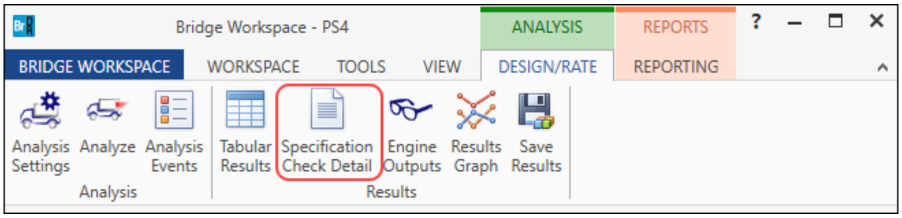
Specification Check Summary

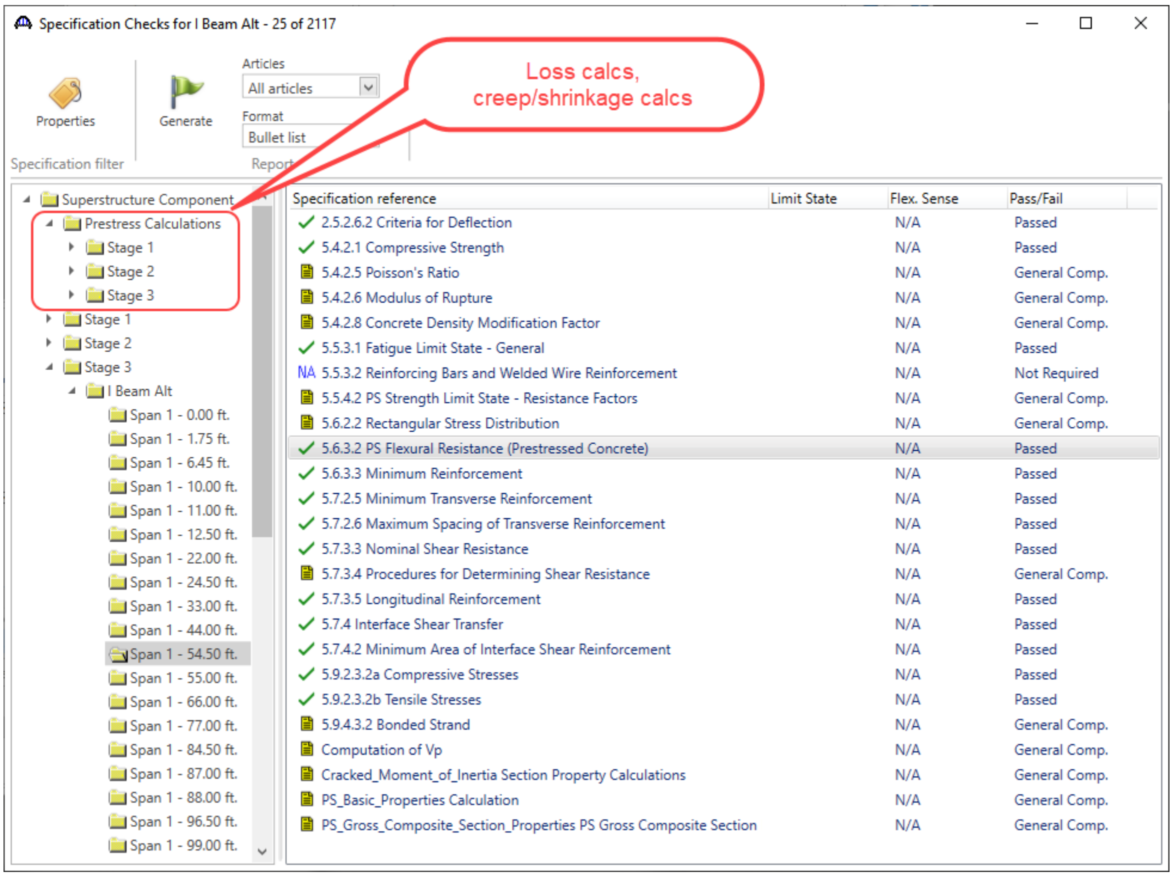
Article	Status
Initial Stress at Transfer (5.9.2.3.1a, 5.9.2.3.1b)	Fail
Splitting Resistance in Anchorage Zones (5.9.4.4.1)	Pass
Final Stress due to Permanent and Transient Loads (5.9.2.3.2a, 5.9.2.3.2b)	Pass
Flexure (5.6.3.2, 5.6.3.3)	Pass
Shear (5.7.3.3, 5.7.2.5, 5.7.2.6, 5.7.3.5)	Pass
Deflection (5.6.3.5.2)	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	0.160	-0.668	5.350	Pass
1.750	-3.575	0.470	-2.164	1.652	Pass
6.457	-3.575	0.319	-2.010	1.779	Pass
10.000	-3.575	0.215	-1.904	1.878	Pass
11.000	-3.575	0.228	-2.047	1.746	Pass
12.500	-3.575	0.249	-2.264	1.579	Pass
22.000	-3.575	0.023	-2.034	1.758	Pass
24.500	-3.575	0.078	-2.415	1.480	Pass
33.000	-3.575	-0.066	-2.268	1.576	Pass

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

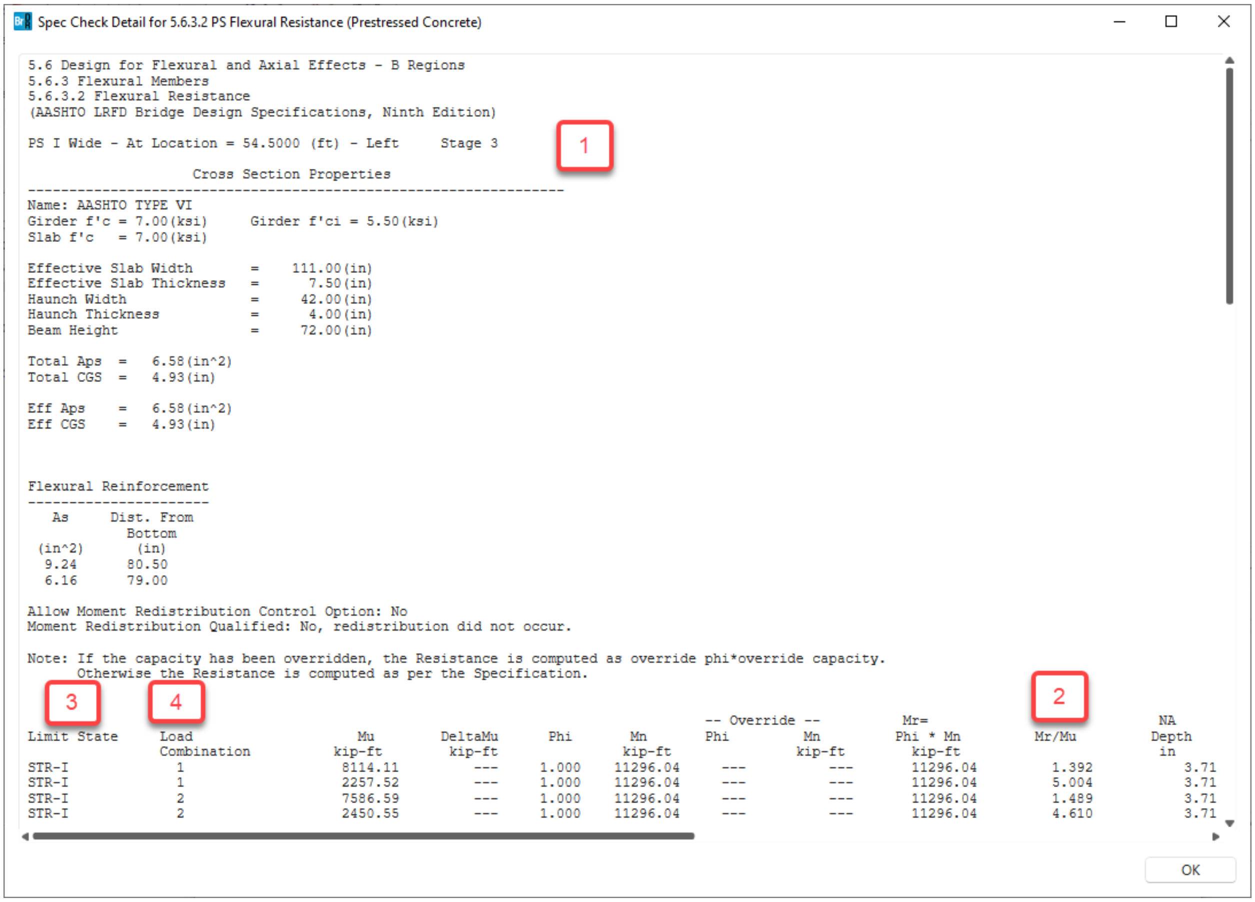




Open the spec check detail window for the flexural resistance at the middle of simple span 1. The following is noted for this window, other spec articles are similar:

1. For each spec check location, both the left and right sides of the point are evaluated. The Deflection article is an exception to this since deflection must be the same between the left and right sides of a point.
2. The design ratio is printed out for the article. The design ratio is the ratio of capacity to demand. A design ratio less than one indicates the demand is greater than the capacity and the spec article fails. A design ratio equal to 99.0 indicates the section is subject to zero demand.
3. The Strength-I, Service-I, Service III, and Fatigue limit states are the only limit states investigated. For each limit state, the max and min force effect is checked. Thus, each limit state shows two rows of data.

4. The LL load combination is shown in this column. If the location is not at a node in the FE model (e.g., the node is at a point where the rebar is fully developed), this column will list two load combinations separated by a comma. The first load combination is the combination considered at the left end and the second load combination is the combination considered at the right end of the FE element that contains this location. The resulting load displayed is a linear interpolation between the two displayed load cases.

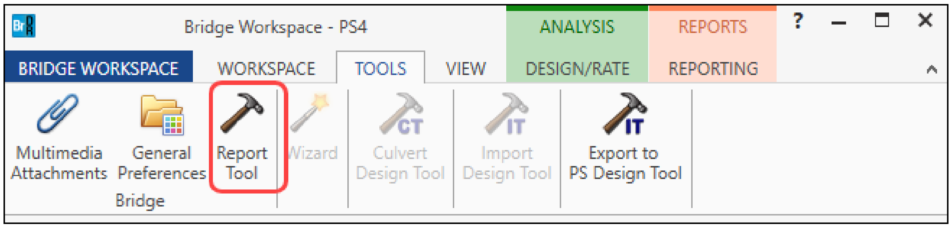



```
5.6 Design for Flexural and Axial Effects - B Regions
5.6.3 Flexural Members
5.6.3.2 Flexural Resistance
(AASHTO LRFD Bridge Design Specifications, Ninth Edition)

PS I Wide - At Location = 54.5000 (ft) - Left     Stage 3

                    Cross Section Properties
-----------------------------------------------------------------
Name: AASHTO TYPE VI
Girder f'c = 7.00(ksi)     Girder f'ci = 5.50(ksi)
Slab f'c   = 7.00(ksi)

Effective Slab Width       =    111.00(in)
Effective Slab Thickness   =      7.50(in)
Haunch Width               =     42.00(in)
Haunch Thickness           =      4.00(in)
Beam Height                =     72.00(in)

Total Aps  =   6.58(in^2)
Total CGS  =   4.93(in)

Eff Aps    =   6.58(in^2)
Eff CGS    =   4.93(in)


Flexural Reinforcement
----------------------
   As     Dist. From
            Bottom
 (in^2)      (in)
  9.24      80.50
  6.16      79.00

Allow Moment Redistribution Control Option: No
Moment Redistribution Qualified: No, redistribution did not 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.

                                                                          -- Override --           Mr=                         NA
Limit State     Load                    Mu       DeltaMu      Phi        Mn       Phi          Mn     Phi * Mn       Mr/Mu     Depth
                Combination           kip-ft     kip-ft               kip-ft                kip-ft     kip-ft                    in
STR-I             1                  8114.11       ---       1.000   11296.04     ---          ---   11296.04       1.392       3.71
STR-I             1                  2257.52       ---       1.000   11296.04     ---          ---   11296.04       5.004       3.71
STR-I             2                  7586.59       ---       1.000   11296.04     ---          ---   11296.04       1.489       3.71
STR-I             2                  2450.55       ---       1.000   11296.04     ---          ---   11296.04       4.610       3.71
```

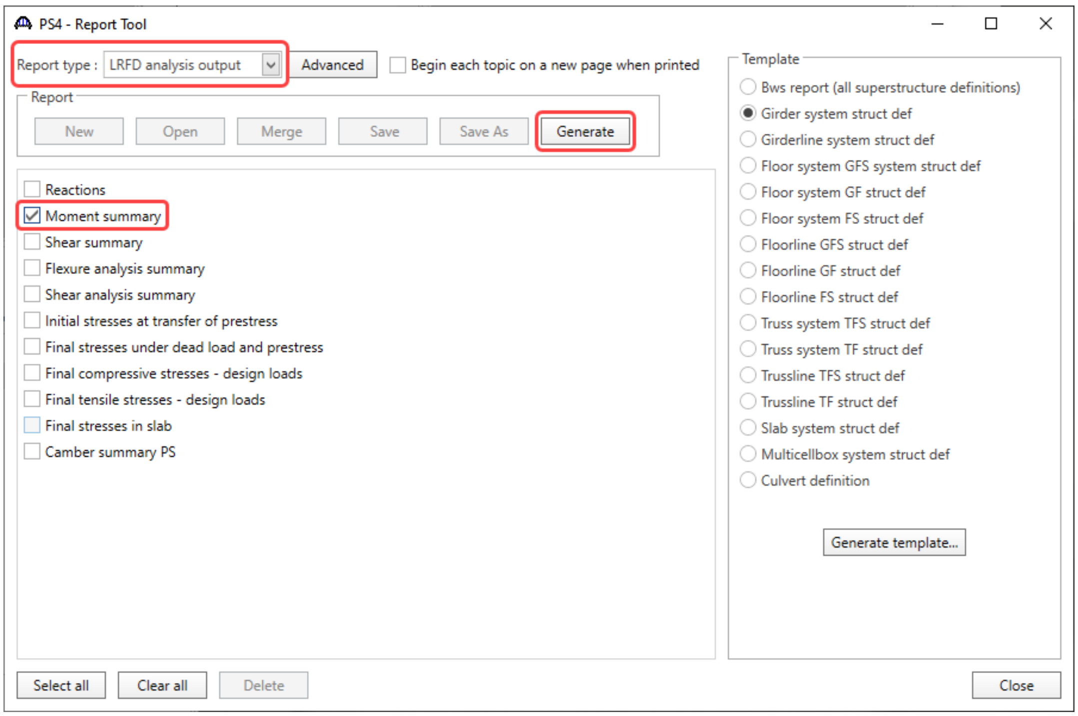
The loads making up the Mu = 8114.1 k-ft for the maximum Strength-I limit state can be tracked down in **Moment Summary** report.

Report Tool – Moment Summary

The **Moment Summary** report can be viewed by selecting the **Report Tool** button from the **Bridge** group of the **TOOLS** ribbon as shown below.



Select the **LRFD analysis output** as the **Report type**. Select the **Moment summary** checkbox and click on the **Generate** button to populate the moment summary report as shown below.



Bridge Name: NHI Example
NBI Structure ID: PS4
Bridge ID: PS4

Analyzed By: Bridge
Analyze Date: Wednesday, February 8, 2023 14:13:29
Analysis Engine: AASHTO LRFD Engine Version 7.5.0.1
Analysis Preference Setting: None

Report By: Bridge
Report Date: Wednesday, February 8, 2023 14:38:35

Structure Definition Name: PS I Beam
Member Name: G2
Member Alternative Name: I Beam Alt

Moment Summary (Simple span model)
Live Load: HL-93 (US)
Impact = %

Span 1

Location (ft)	Percent	DC (kip-ft)	DW (kip-ft)	+(LL+I) (kip-ft)	Controlling Live Load	-(LL+I) (kip-ft)	Controlling Live Load
0.00(R)	0.0	0.00	N/A	**		**	
1.75(B)	1.6	217.54	N/A	**		**	
10.00(B)	9.1	1149.35	N/A	**		**	
11.00(B)	10.0	1251.79	N/A	**		**	
12.50(B)	11.4	1401.19	N/A	**		**	
22.00(B)	20.0	2228.68	N/A	**		**	
24.50(B)	22.3	2412.37	N/A	**		**	
33.00(B)	30.0	2930.68	N/A	**		**	
44.00(B)	40.0	3357.78	N/A	**		**	
54.50(B)	49.5	3509.02	N/A	**		**	
55.00(L)	50.0	3509.98	N/A	**		**	
55.00(R)	50.0	3509.98	N/A	**		**	

(L) Left
(R) Right

Moment Summary (Continuous span model)
Live Load: HL-93 (US)
Impact = ** %

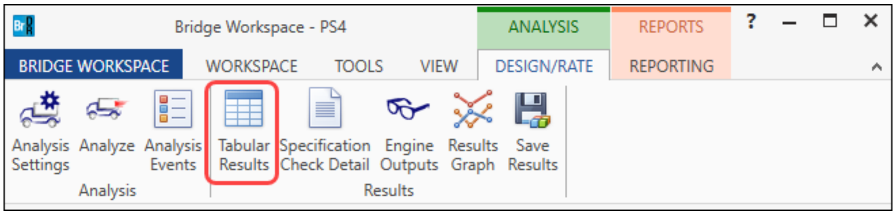
Span 1

Location (ft)	Percent	DC (kip-ft)	DW (kip-ft)	+(LL+I) (kip-ft)	Controlling Live Load	-(LL+I) (kip-ft)	Controlling Live Load
0.00(R)	0.0	0.00	N/A	0.00	Tandem + Lane	0.00	Tandem + Lane
1.75(B)	1.6	11.90	N/A	160.59	Truck + Lane	-18.65	Truck + Lane
10.00(B)	9.1	61.05	N/A	825.34	Truck + Lane	-106.55	Truck + Lane
11.00(B)	10.0	66.22	N/A	895.66	Truck + Lane	-117.21	Truck + Lane
12.50(B)	11.4	73.68	N/A	997.04	Truck + Lane	-133.19	Truck + Lane
22.00(B)	20.0	112.07	N/A	1525.54	Truck + Lane	-234.41	Truck + Lane
24.50(B)	22.3	119.65	N/A	1632.62	Truck + Lane	-261.05	Truck + Lane
33.00(B)	30.0	137.54	N/A	1903.23	Truck + Lane	-351.62	Truck + Lane
44.00(B)	40.0	142.64	N/A	2070.75	Truck + Lane	-468.83	Truck + Lane
54.50(B)	49.5	128.49	N/A	2038.41	Truck + Lane	-580.71	Truck + Lane
55.00(L)	50.0	127.35	N/A	2033.41	Truck + Lane	-586.04	Truck + Lane
55.00(R)	50.0	127.35	N/A	2033.41	Truck + Lane	-586.04	Truck + Lane
66.00(B)	60.0	91.70	N/A	1814.66	Truck + Lane	-703.24	Truck + Lane
77.00(B)	70.0	35.66	N/A	1406.07	Truck + Lane	-820.45	Truck + Lane
84.50(B)	76.8	-14.23	N/A	1034.44	Truck + Lane	-900.36	Truck + Lane
87.00(B)	79.1	-32.96	N/A	896.11	Truck + Lane	-927.00	Truck + Lane
88.00(B)	80.0	-40.75	N/A	838.23	Truck + Lane	-937.66	Truck + Lane
96.50(B)	87.7	-113.76	N/A	394.45	Tandem + Lane	-1154.60	90%(Truck Pair + Lane)
99.00(B)	90.0	-137.54	N/A	300.58	Tandem + Lane	-1299.89	90%(Truck Pair + Lane)
107.25(B)	97.5	-223.51	N/A	49.76	Truck + Lane	-1885.07	90%(Truck Pair + Lane)
109.00(L)	99.1	-243.22	N/A	17.46	Truck + Lane	-2022.18	90%(Truck Pair + Lane)
109.00(R)	99.1	-243.22	N/A	17.46	Truck + Lane	-2022.18	90%(Truck Pair + Lane)
110.00(L)	100.0	-254.71	N/A	0.00	Tandem + Lane	-2104.99	90%(Truck Pair + Lane)

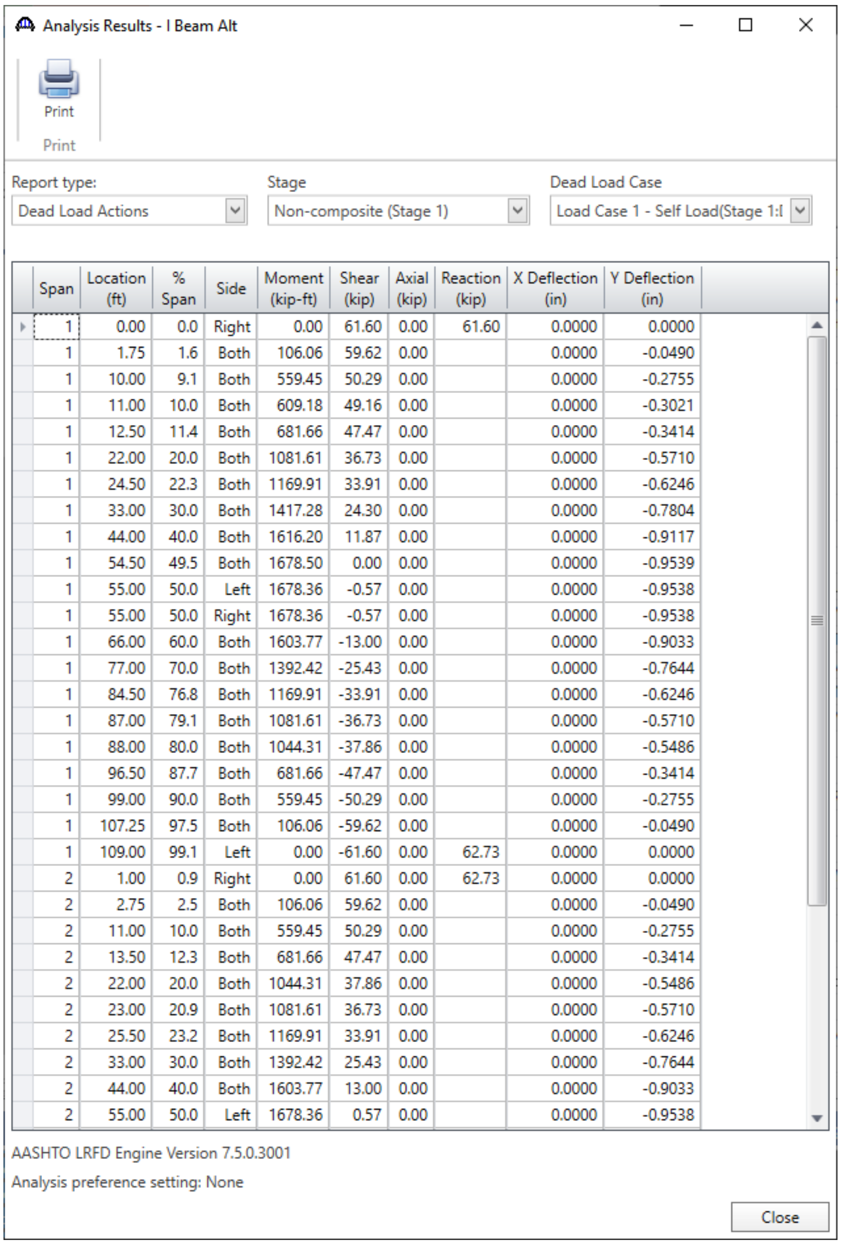
The resulting maximum moment for Strength-I at the midspan is equal to (1.25 * (3509.02 + 128.49)) + (1.75 * 2038.41) = 8114.1 kft.

Tabular Results

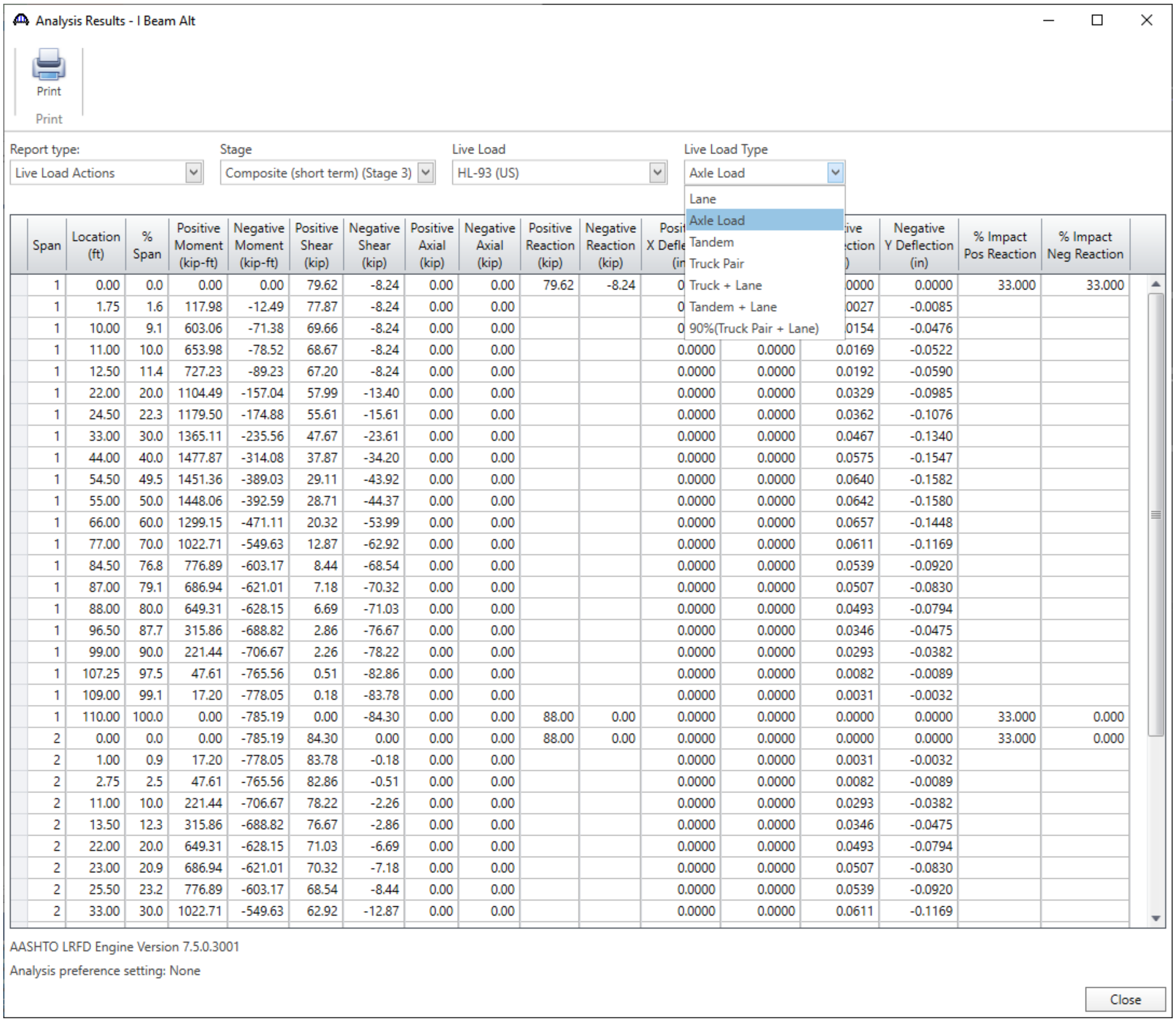
To review the dead load and live load analysis results, click on the **Tabular Results** button from the **Results** group of the **DESIGN/RATE** ribbon as shown below.



The **Analysis Results** window will open as shown below.



Span	Location (ft)	% Span	Side	Moment (kip-ft)	Shear (kip)	Axial (kip)	Reaction (kip)	X Deflection (in)	Y Deflection (in)
1	0.00	0.0	Right	0.00	61.60	0.00	61.60	0.0000	0.0000
1	1.75	1.6	Both	106.06	59.62	0.00		0.0000	-0.0490
1	10.00	9.1	Both	559.45	50.29	0.00		0.0000	-0.2755
1	11.00	10.0	Both	609.18	49.16	0.00		0.0000	-0.3021
1	12.50	11.4	Both	681.66	47.47	0.00		0.0000	-0.3414
1	22.00	20.0	Both	1081.61	36.73	0.00		0.0000	-0.5710
1	24.50	22.3	Both	1169.91	33.91	0.00		0.0000	-0.6246
1	33.00	30.0	Both	1417.28	24.30	0.00		0.0000	-0.7804
1	44.00	40.0	Both	1616.20	11.87	0.00		0.0000	-0.9117
1	54.50	49.5	Both	1678.50	0.00	0.00		0.0000	-0.9539
1	55.00	50.0	Left	1678.36	-0.57	0.00		0.0000	-0.9538
1	55.00	50.0	Right	1678.36	-0.57	0.00		0.0000	-0.9538
1	66.00	60.0	Both	1603.77	-13.00	0.00		0.0000	-0.9033
1	77.00	70.0	Both	1392.42	-25.43	0.00		0.0000	-0.7644
1	84.50	76.8	Both	1169.91	-33.91	0.00		0.0000	-0.6246
1	87.00	79.1	Both	1081.61	-36.73	0.00		0.0000	-0.5710
1	88.00	80.0	Both	1044.31	-37.86	0.00		0.0000	-0.5486
1	96.50	87.7	Both	681.66	-47.47	0.00		0.0000	-0.3414
1	99.00	90.0	Both	559.45	-50.29	0.00		0.0000	-0.2755
1	107.25	97.5	Both	106.06	-59.62	0.00		0.0000	-0.0490
1	109.00	99.1	Left	0.00	-61.60	0.00	62.73	0.0000	0.0000
2	1.00	0.9	Right	0.00	61.60	0.00	62.73	0.0000	0.0000
2	2.75	2.5	Both	106.06	59.62	0.00		0.0000	-0.0490
2	11.00	10.0	Both	559.45	50.29	0.00		0.0000	-0.2755
2	13.50	12.3	Both	681.66	47.47	0.00		0.0000	-0.3414
2	22.00	20.0	Both	1044.31	37.86	0.00		0.0000	-0.5486
2	23.00	20.9	Both	1081.61	36.73	0.00		0.0000	-0.5710
2	25.50	23.2	Both	1169.91	33.91	0.00		0.0000	-0.6246
2	33.00	30.0	Both	1392.42	25.43	0.00		0.0000	-0.7644
2	44.00	40.0	Both	1603.77	13.00	0.00		0.0000	-0.9033
2	55.00	50.0	Left	1678.36	0.57	0.00		0.0000	-0.9538

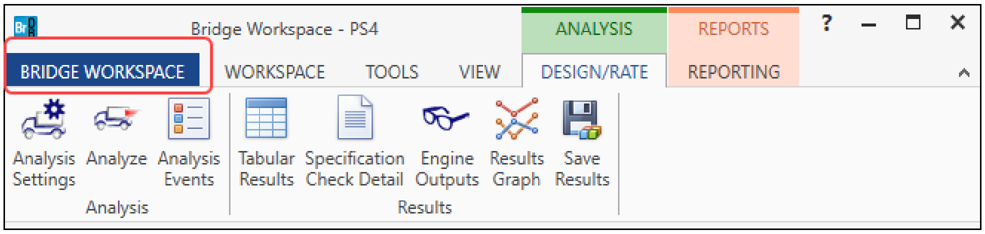


Span	Location (ft)	% Span	Positive Moment (kip-ft)	Negative Moment (kip-ft)	Positive Shear (kip)	Negative Shear (kip)	Positive Axial (kip)	Negative Axial (kip)	Positive Reaction (kip)	Negative Reaction (kip)	Posi… X Defle… (in…		…ive …ction …)	Negative Y Deflection (in)	% Impact Pos Reaction	% Impact Neg Reaction
1	0.00	0.0	0.00	0.00	79.62	-8.24	0.00	0.00	79.62	-8.24	0		0000	0.0000	33.000	33.000
1	1.75	1.6	117.98	-12.49	77.87	-8.24	0.00	0.00			0		0027	-0.0085		
1	10.00	9.1	603.06	-71.38	69.66	-8.24	0.00	0.00			0		0154	-0.0476		
1	11.00	10.0	653.98	-78.52	68.67	-8.24	0.00	0.00			0.0000	0.0000	0.0169	-0.0522		
1	12.50	11.4	727.23	-89.23	67.20	-8.24	0.00	0.00			0.0000	0.0000	0.0192	-0.0590		
1	22.00	20.0	1104.49	-157.04	57.99	-13.40	0.00	0.00			0.0000	0.0000	0.0329	-0.0985		
1	24.50	22.3	1179.50	-174.88	55.61	-15.61	0.00	0.00			0.0000	0.0000	0.0362	-0.1076		
1	33.00	30.0	1365.11	-235.56	47.67	-23.61	0.00	0.00			0.0000	0.0000	0.0467	-0.1340		
1	44.00	40.0	1477.87	-314.08	37.87	-34.20	0.00	0.00			0.0000	0.0000	0.0575	-0.1547		
1	54.50	49.5	1451.36	-389.03	29.11	-43.92	0.00	0.00			0.0000	0.0000	0.0640	-0.1582		
1	55.00	50.0	1448.06	-392.59	28.71	-44.37	0.00	0.00			0.0000	0.0000	0.0642	-0.1580		
1	66.00	60.0	1299.15	-471.11	20.32	-53.99	0.00	0.00			0.0000	0.0000	0.0657	-0.1448		
1	77.00	70.0	1022.71	-549.63	12.87	-62.92	0.00	0.00			0.0000	0.0000	0.0611	-0.1169		
1	84.50	76.8	776.89	-603.17	8.44	-68.54	0.00	0.00			0.0000	0.0000	0.0539	-0.0920		
1	87.00	79.1	686.94	-621.01	7.18	-70.32	0.00	0.00			0.0000	0.0000	0.0507	-0.0830		
1	88.00	80.0	649.31	-628.15	6.69	-71.03	0.00	0.00			0.0000	0.0000	0.0493	-0.0794		
1	96.50	87.7	315.86	-688.82	2.86	-76.67	0.00	0.00			0.0000	0.0000	0.0346	-0.0475		
1	99.00	90.0	221.44	-706.67	2.26	-78.22	0.00	0.00			0.0000	0.0000	0.0293	-0.0382		
1	107.25	97.5	47.61	-765.56	0.51	-82.86	0.00	0.00			0.0000	0.0000	0.0082	-0.0089		
1	109.00	99.1	17.20	-778.05	0.18	-83.78	0.00	0.00			0.0000	0.0000	0.0031	-0.0032		
1	110.00	100.0	0.00	-785.19	0.00	-84.30	0.00	0.00	88.00	0.00	0.0000	0.0000	0.0000	0.0000	33.000	0.000
2	0.00	0.0	0.00	-785.19	84.30	0.00	0.00	0.00	88.00	0.00	0.0000	0.0000	0.0000	0.0000	33.000	0.000
2	1.00	0.9	17.20	-778.05	83.78	-0.18	0.00	0.00			0.0000	0.0000	0.0031	-0.0032		
2	2.75	2.5	47.61	-765.56	82.86	-0.51	0.00	0.00			0.0000	0.0000	0.0082	-0.0089		
2	11.00	10.0	221.44	-706.67	78.22	-2.26	0.00	0.00			0.0000	0.0000	0.0293	-0.0382		
2	13.50	12.3	315.86	-688.82	76.67	-2.86	0.00	0.00			0.0000	0.0000	0.0346	-0.0475		
2	22.00	20.0	649.31	-628.15	71.03	-6.69	0.00	0.00			0.0000	0.0000	0.0493	-0.0794		
2	23.00	20.9	686.94	-621.01	70.32	-7.18	0.00	0.00			0.0000	0.0000	0.0507	-0.0830		
2	25.50	23.2	776.89	-603.17	68.54	-8.44	0.00	0.00			0.0000	0.0000	0.0539	-0.0920		
2	33.00	30.0	1022.71	-549.63	62.92	-12.87	0.00	0.00			0.0000	0.0000	0.0611	-0.1169		

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

Method of solution

A copy of the AASHTO LRFD engine **Method of Solution** manual is available for reference. To access this manual, click on the **Bridge Workspace** ribbon to open the **Support** window as shown below.



From the leftmost column, click on the **Help** button. Select the **AASHTO LRFD** option from the **Engine Help** column. The **Engine Help** and **Method of Solution** for the selected analysis engine will be displayed in the **Engine Help Configuration** column. Double-click on the **Method of Solution** option to open the **AASHTO LRFD/LRFR Superstructure Method of Solution** as shown below.