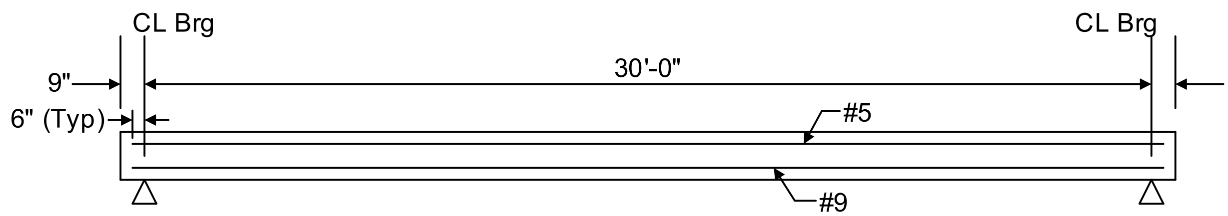
AASHTOWare BrDR 7.7.0

Reinforced Concrete Structure Tutorial

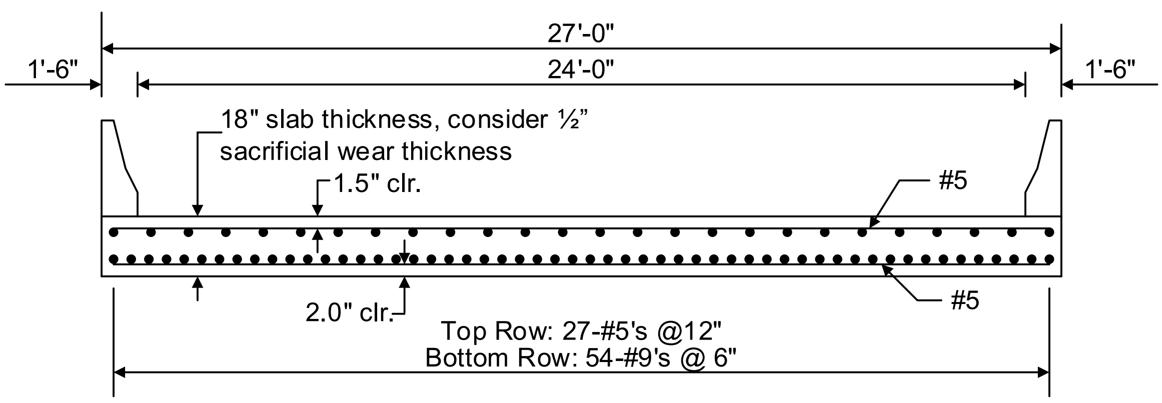
RC2 – Reinforced Concrete Slab Example

Introduction – Elevation and Typical section

RC2 - Reinforced Concrete Slab Example



Elevation



Typical Section

<u>Material Properties</u>

Slab Concrete: Class A (US) f'c = 4.0 ksi, modular ratio n = 8

Slab Reinforcing Steel: AASHTO M31, Grade 60 with Fy = 60 ksi

<u>Parapets</u>

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

BrDR Training

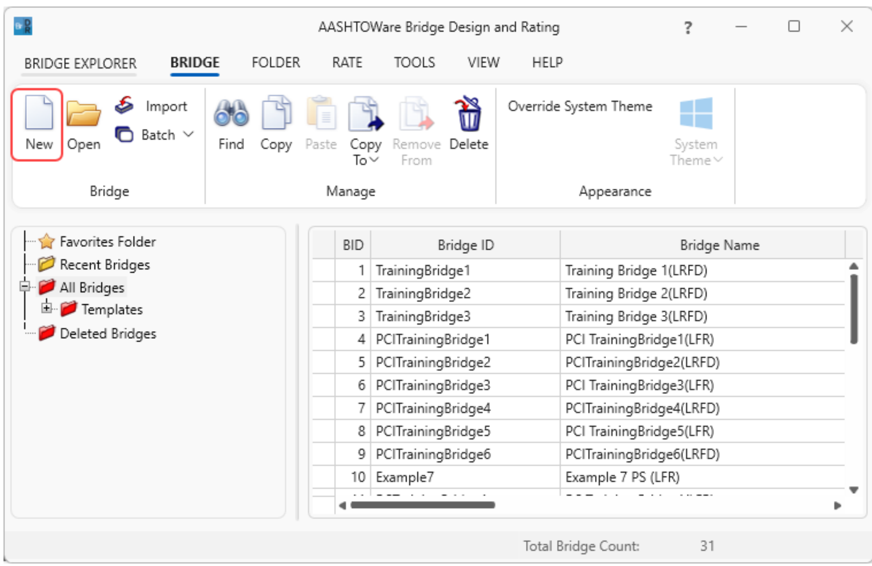
RC2 - Reinforced Concrete Slab Example

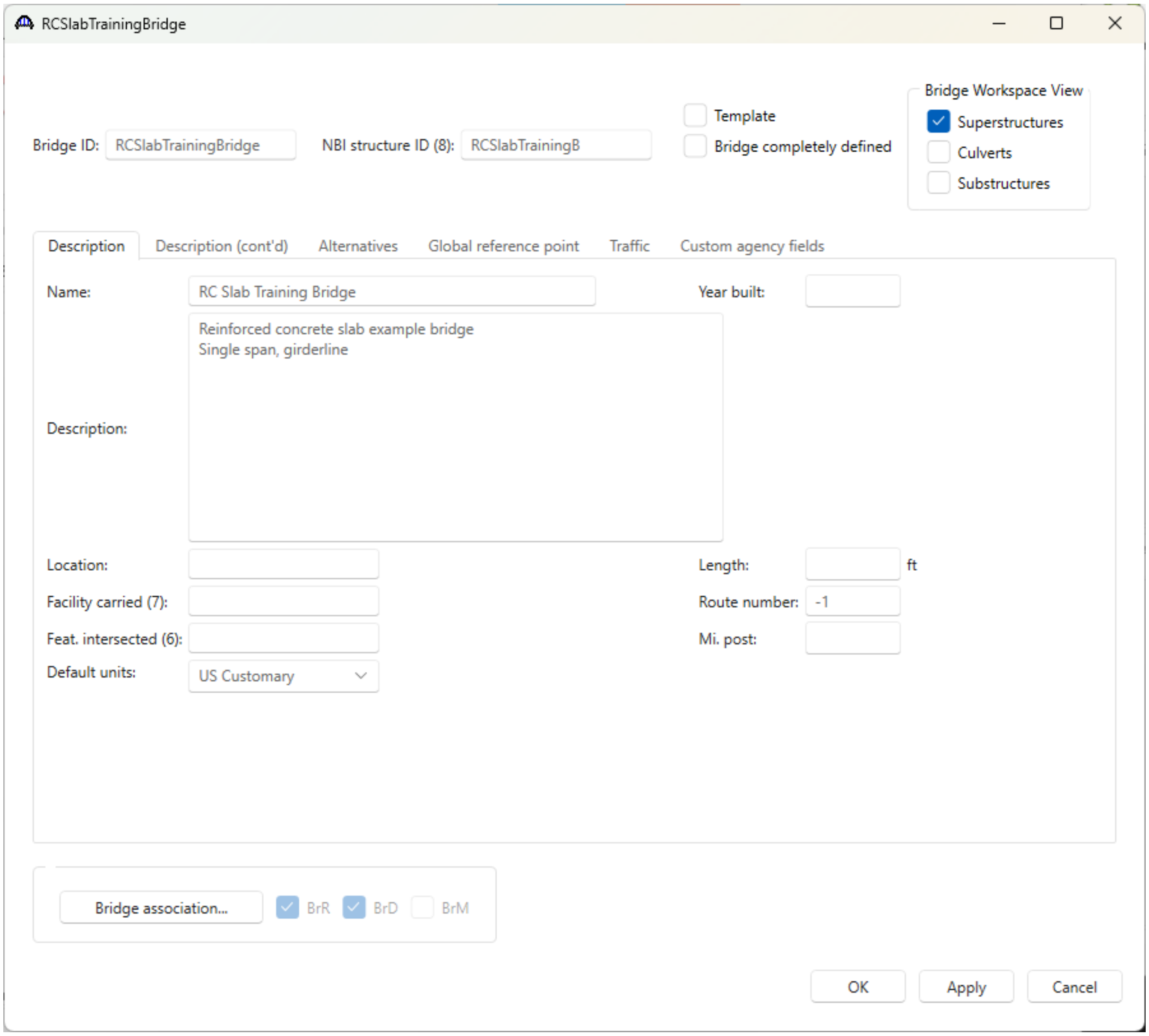
Topics Covered

- Single span reinforced concrete slab description
- Sacrificial wear thickness for a slab
- Cross-section based member alternative
- Schedule based member alternative

Single span reinforced concrete slab description.

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

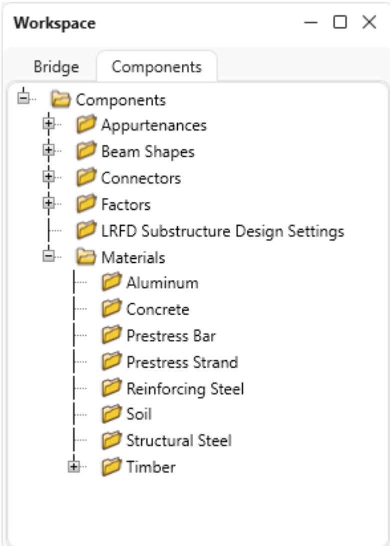




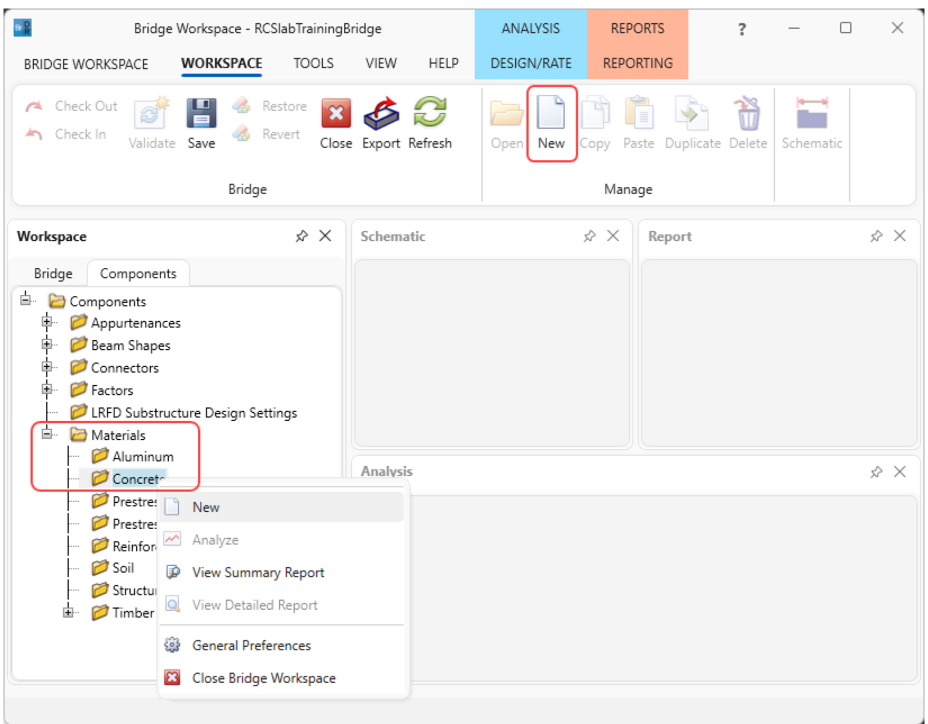
Close the window by clicking **OK**. This applies the data and closes the window.

Bridge Materials

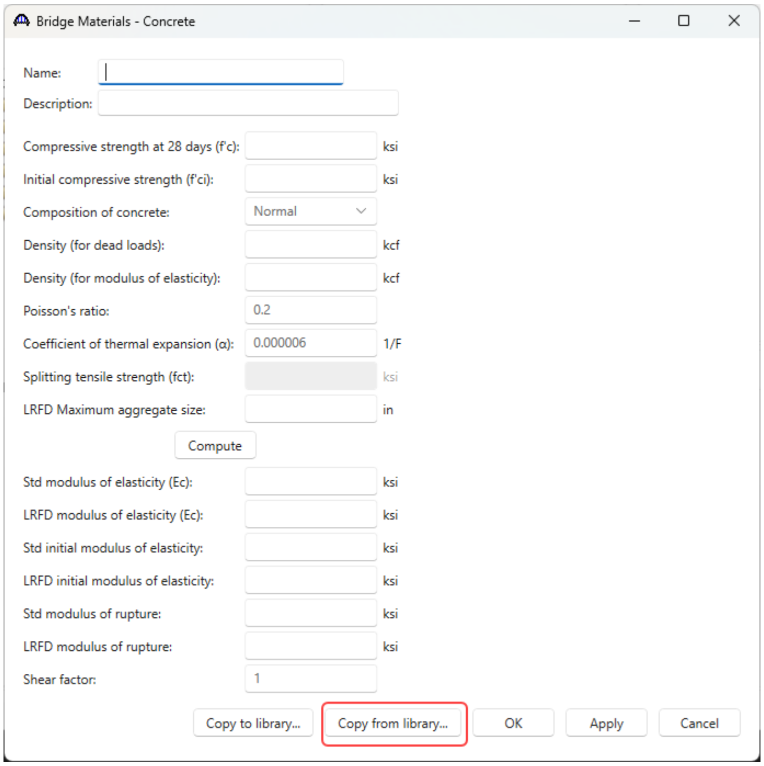
To enter the materials to be used by members of the bridge, click on the **Components** tab of **Bridge Workspace**, and expand the tree for Materials. The tree with the expanded **Materials** branch is shown below:



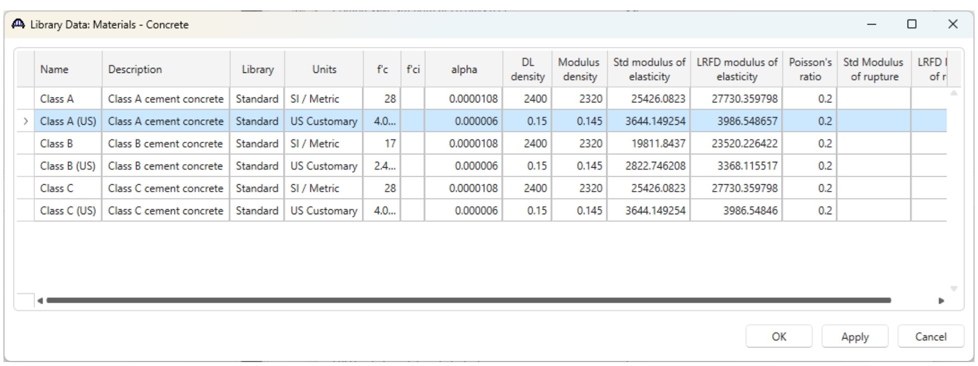
To add a new concrete material, click on **Concrete** in the **Components** tree and select **New** from the **Manage** group of the **WORKSPACE** ribbon (or right mouse click on **Concrete** and select **New**).



Add the concrete material by selecting from the Concrete Materials Library by clicking the **Copy from Library** button.

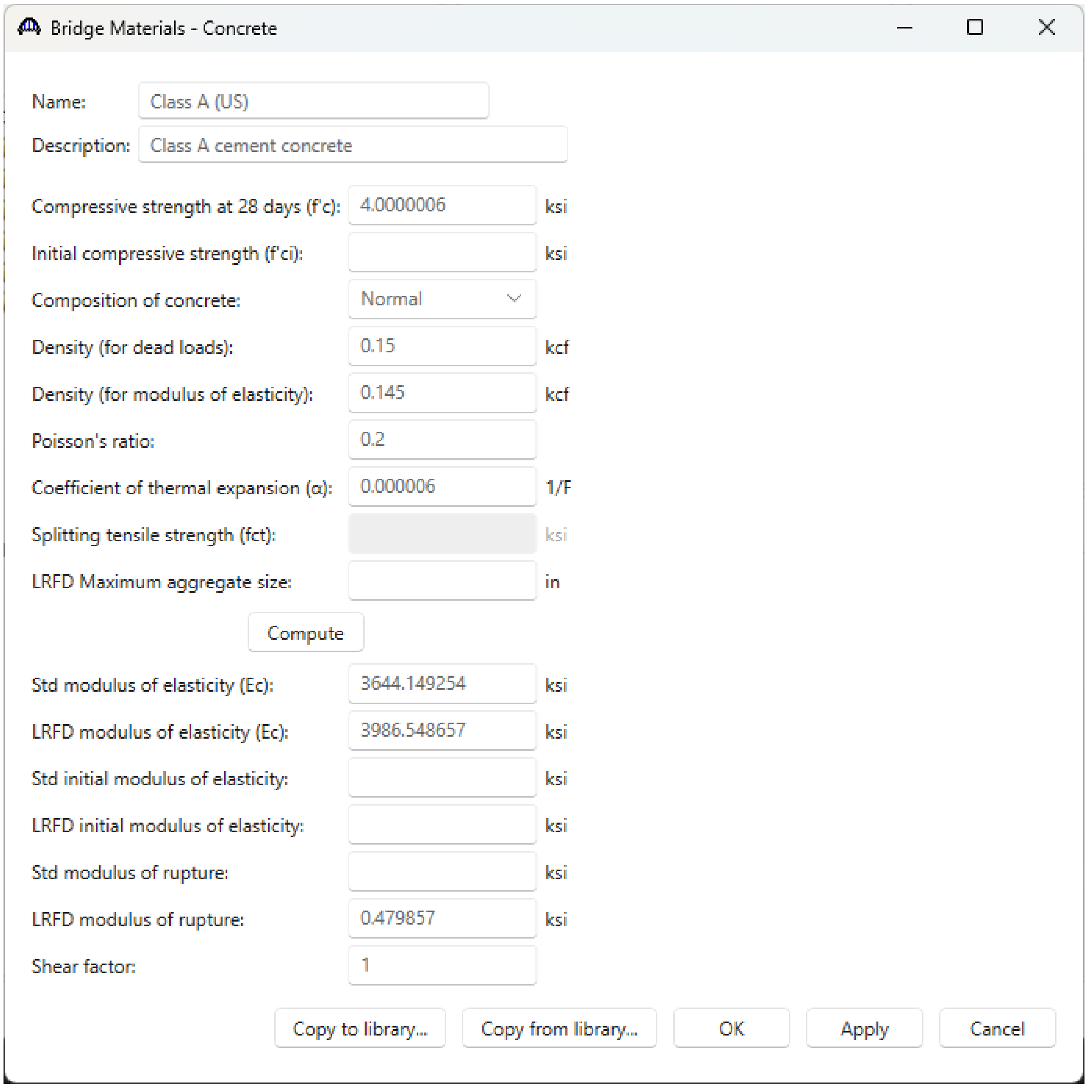


The following window opens:



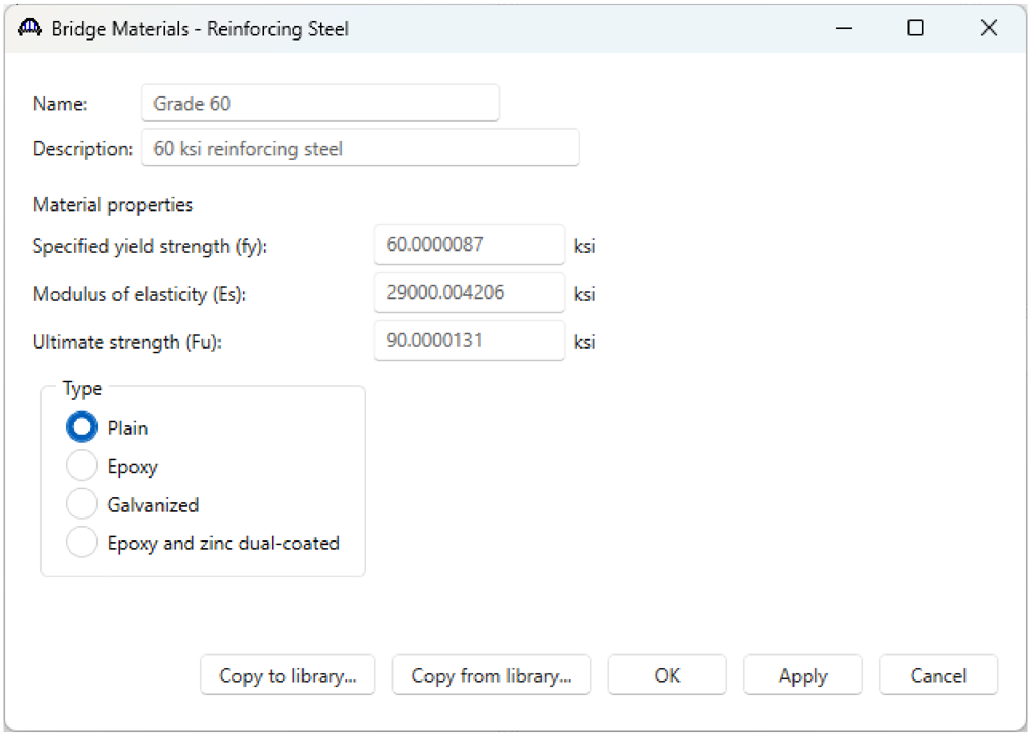
Select the **Class A (US)** material and click **OK.**

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



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

Add the following reinforcement steel in the same manner.



Since a reinforced concrete slab is used, beam shapes need not be defined. The slab will be entered later using two different methods, as a cross section and as a schedule based member alternative.

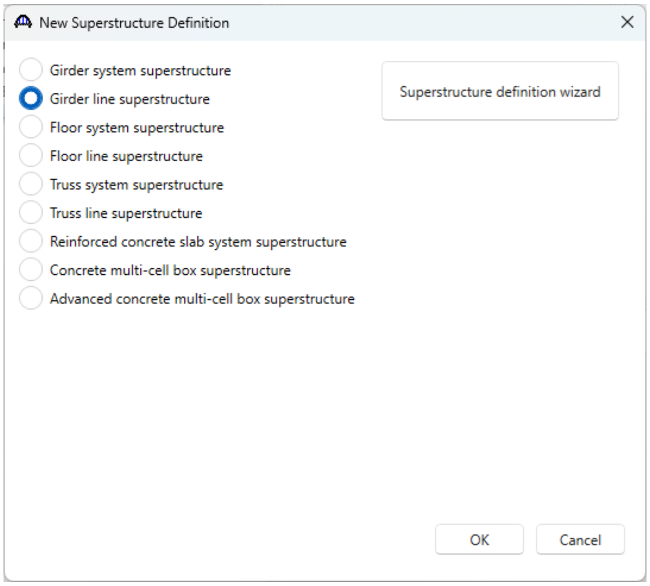
Reinforced concrete slabs may be entered as Girderline Superstructure Definitions in BrDR or as slab systems. This example uses the girderline option. Since a Structure Typical Section is not defined for girderline structures, appurtenances are not defined. The dead load due for the appurtenances will be entered later as member loads.

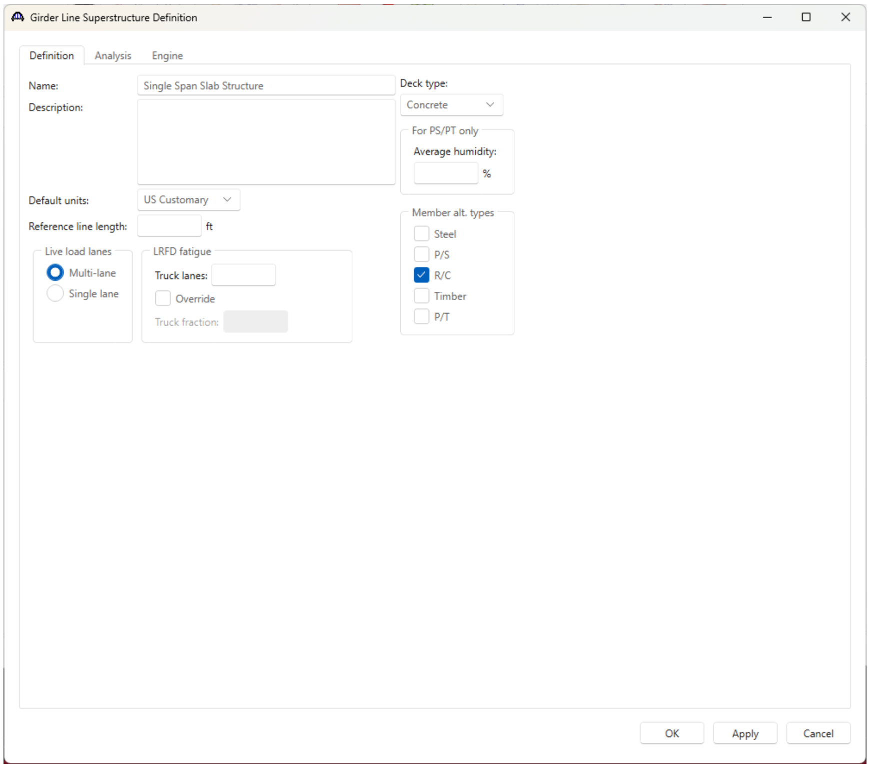
The default impact factors, standard LRFD and LFD factors will be used so the next step will be to define a Superstructure. Bridge Alternatives will be added after a superstructure is defined.

Superstructure Definition

Navigate back 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.

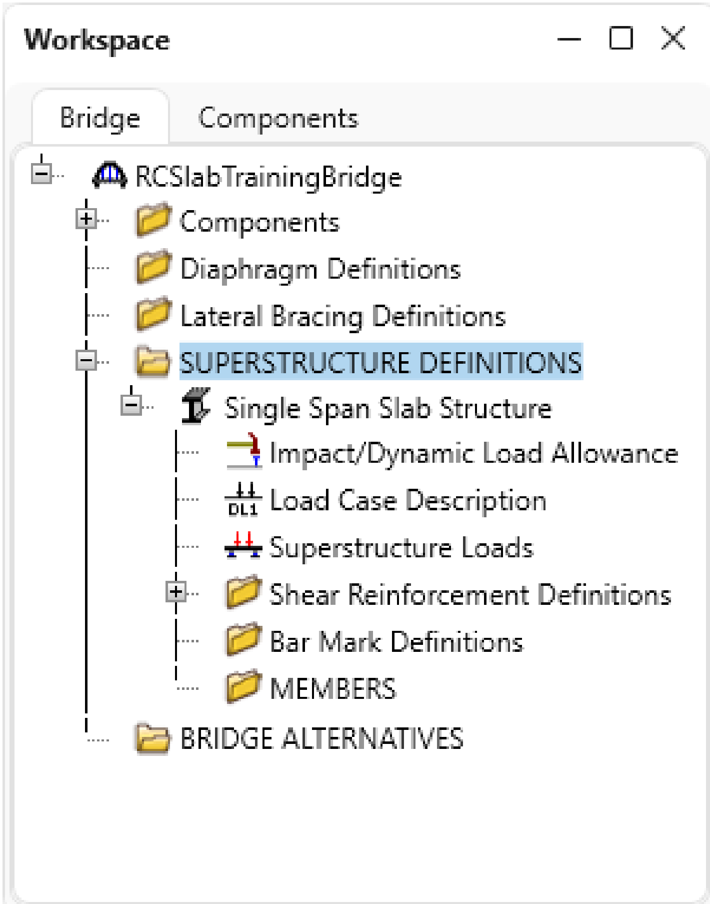
Select **Girder line superstructure** and click **OK**. The **Girder Line Superstructure Definition** window will open. Enter the data as shown below:





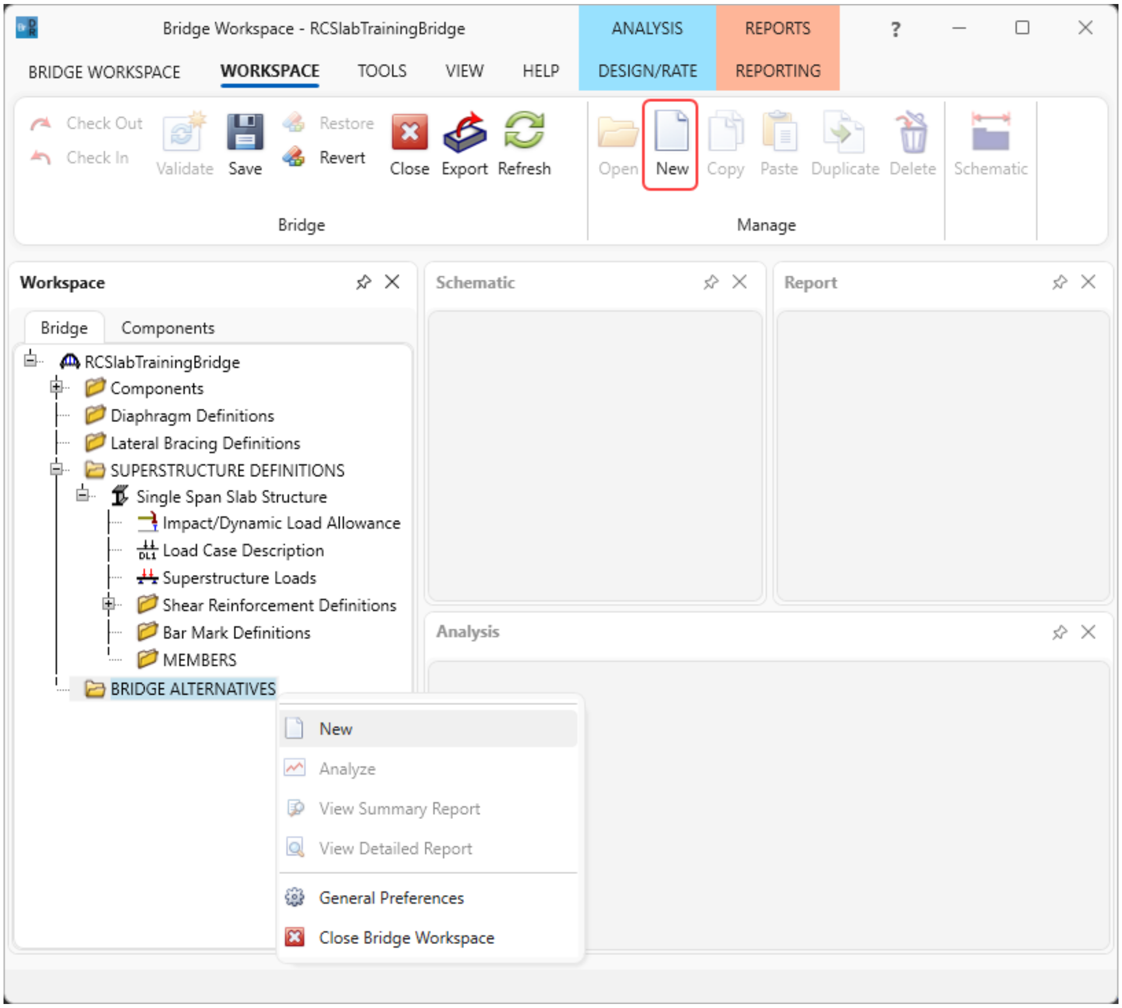
Click **OK** to apply the data and close the window.

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

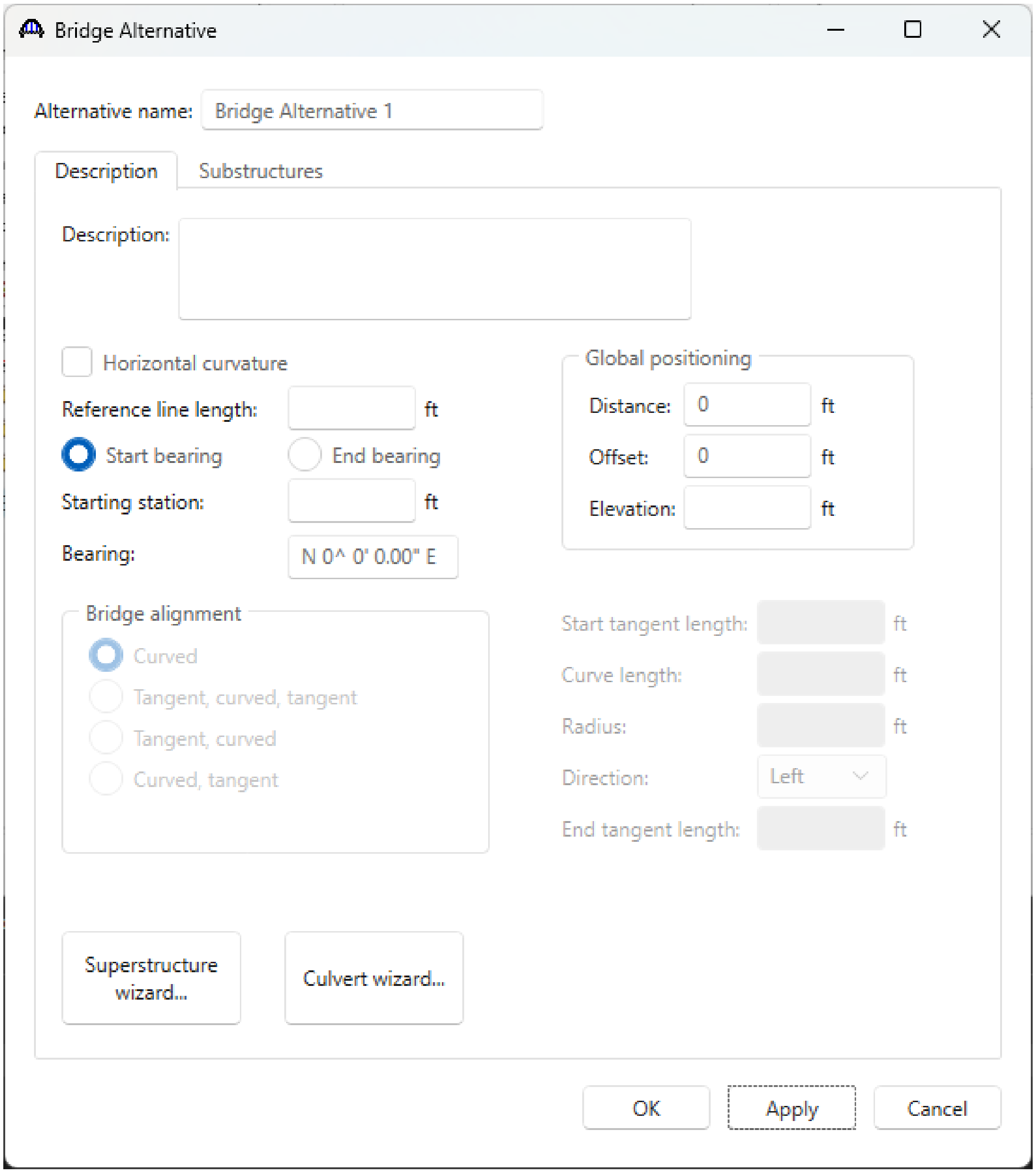


BRIDGE ALTERNATIVES

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).

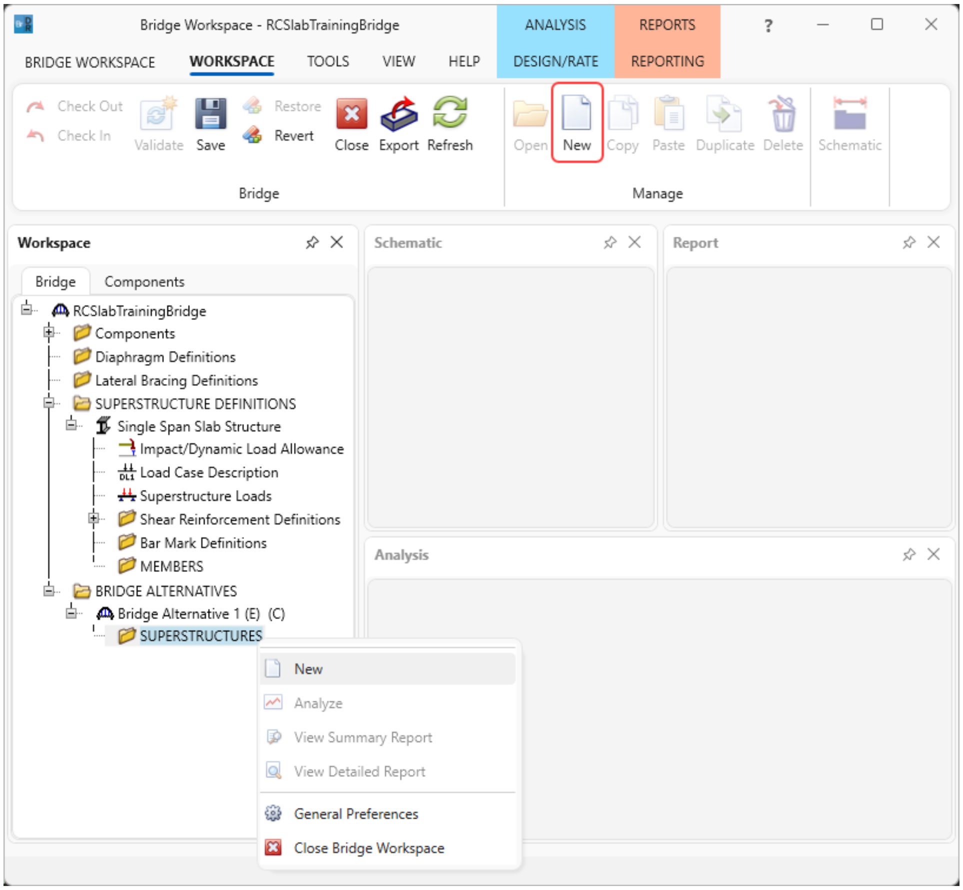


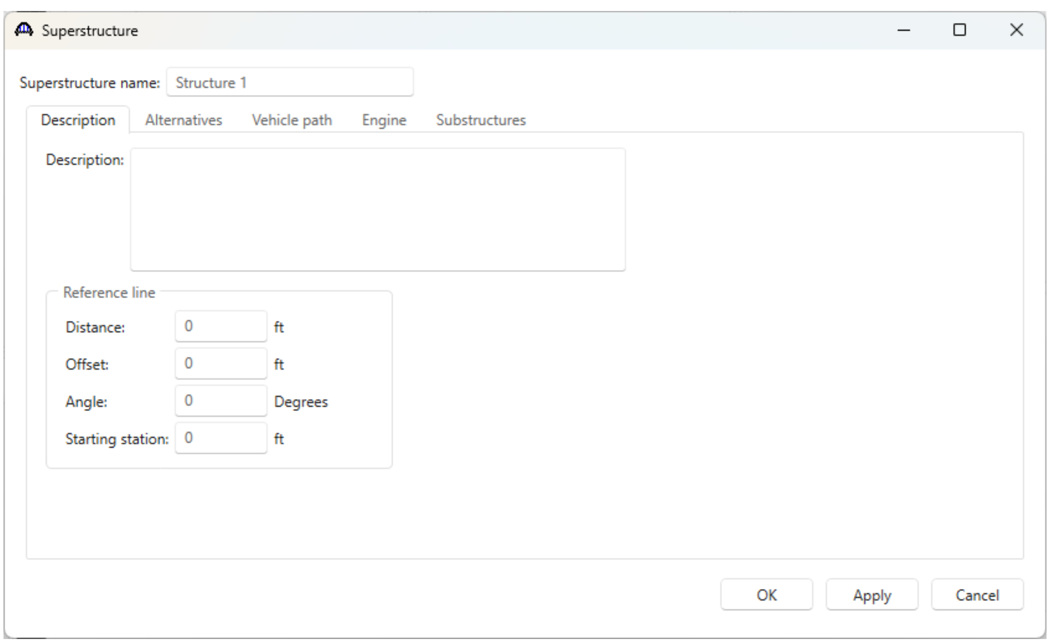
Enter the following data.



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

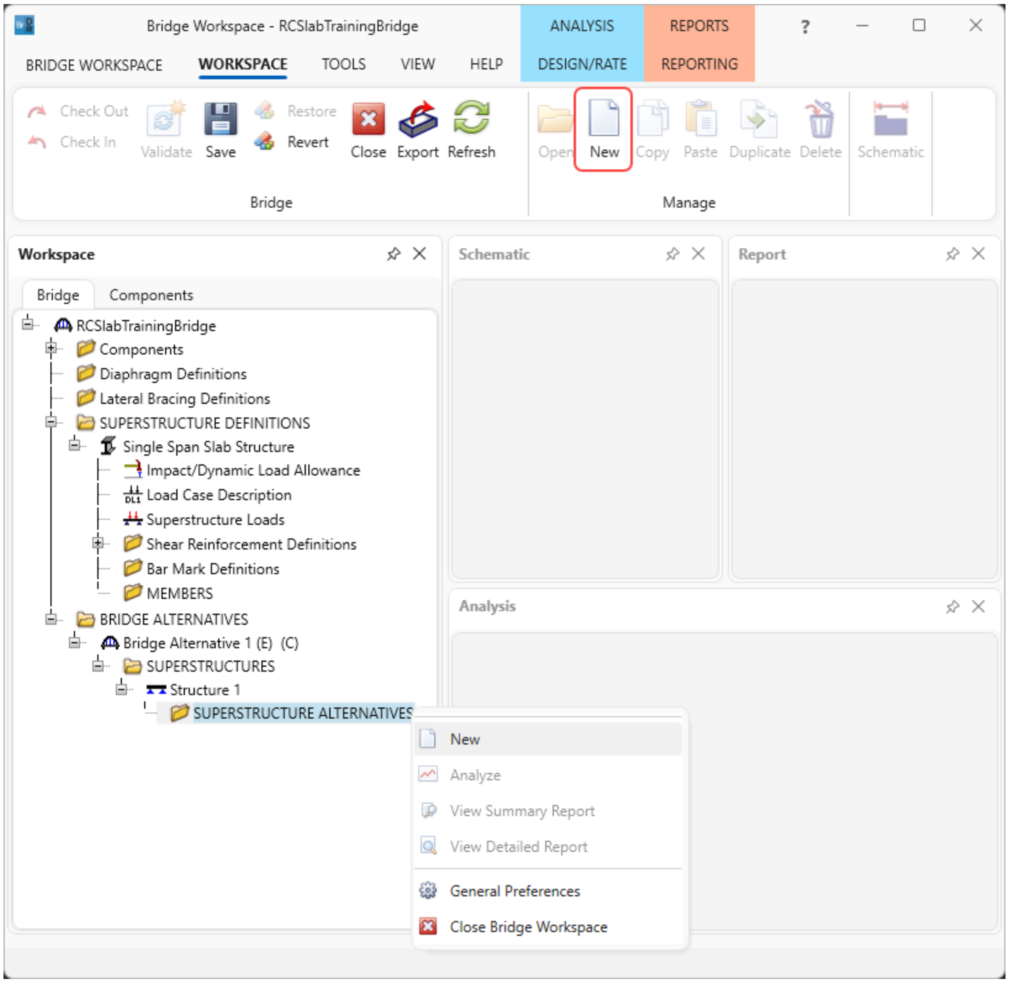
Expand the **Bridge Alternative 1** node in the **Bridge Workspace** tree by clicking the ⊞ button. Double-click on the **SUPERSTRUCTURES** node (or select **SUPERSTRUCTURES**, click **New** from the **Manage** group of the **WORKSPACE** ribbon) and enter the following new superstructure.



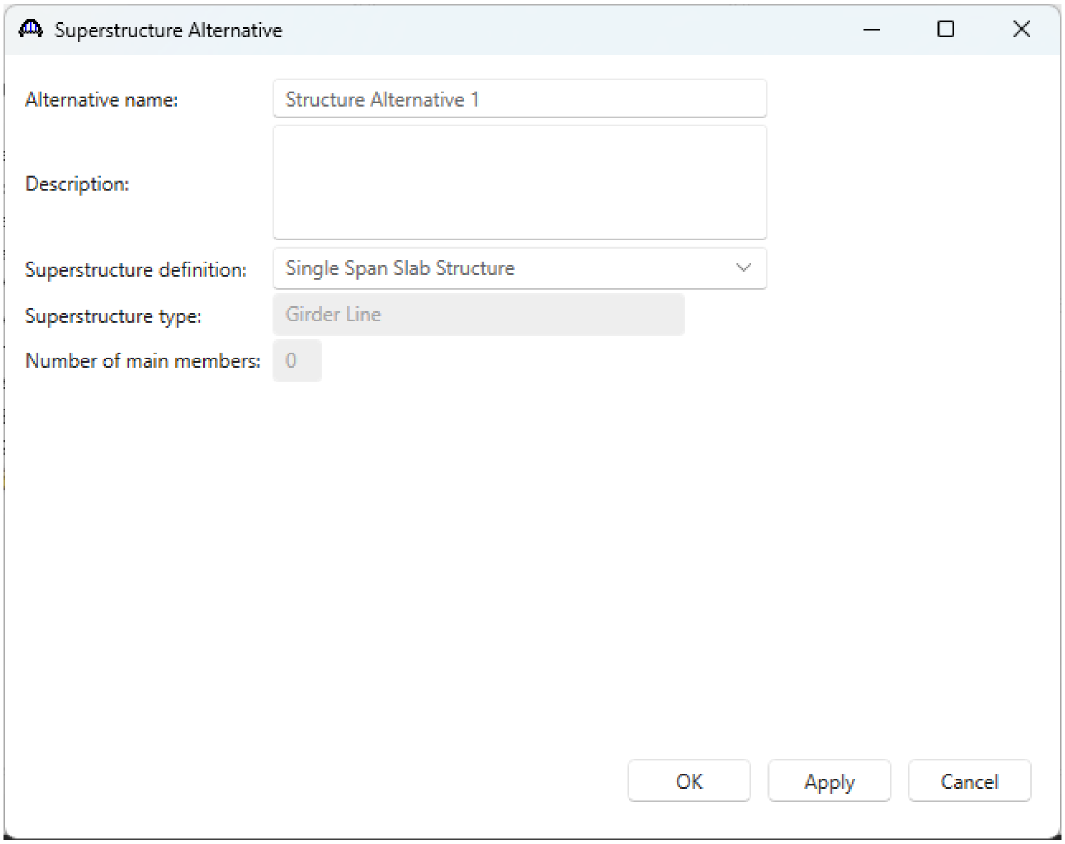


Click **OK** to apply the data and close the window.

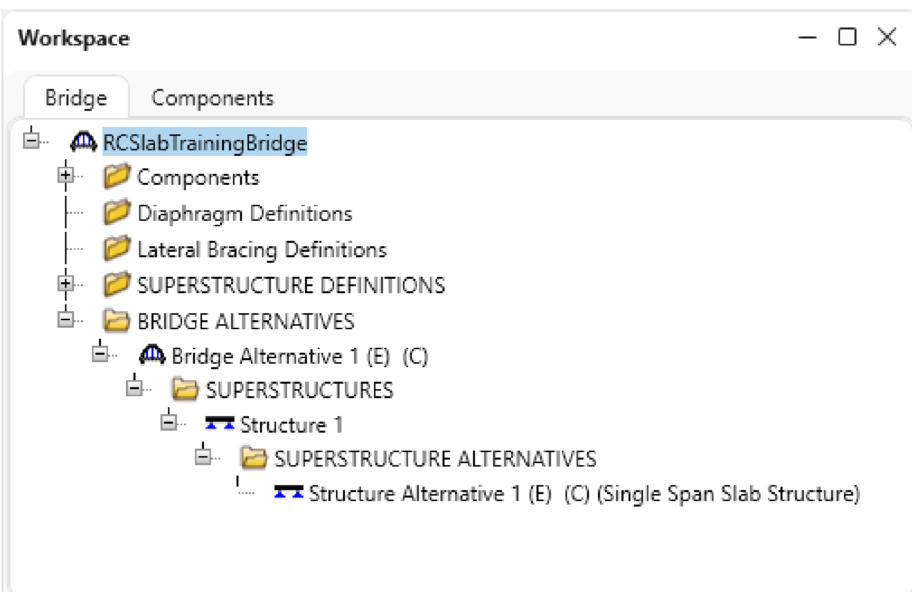
Expand the **Structure 1** node in the **Bridge Workspace** tree by clicking the ⊞ button. Double-click on the **SUPERSTRUCTURE ALTERNATIVES** node (or select **SUPERSTRUCTURE ALTERNATIVES** and click **New** from the **Manage** group of the **WORKSPACE** ribbon) and enter the following new superstructure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



Select the **Superstructure definition Single Span Slab Structure** as the current superstructure definition for this Superstructure Alternative.

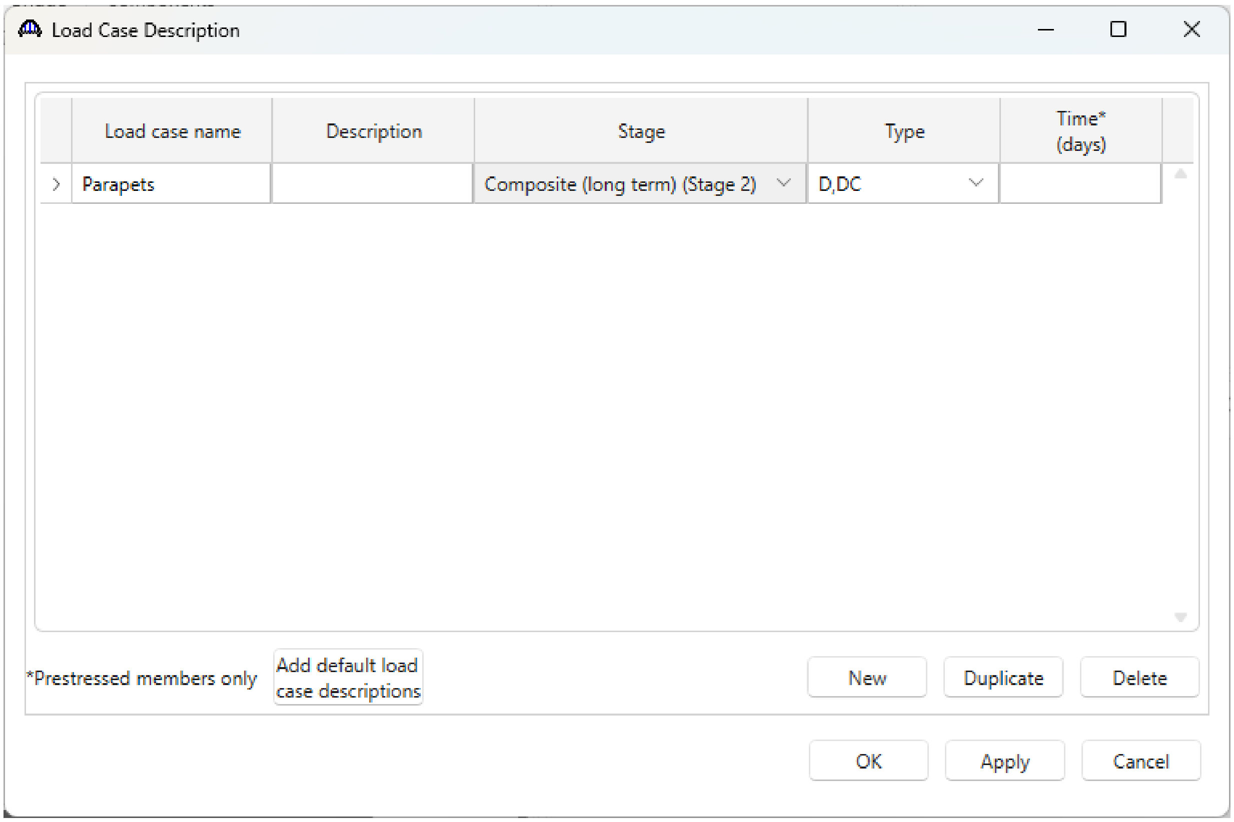


The partially expanded **Bridge Workspace tree** is shown below.



Load Case Description

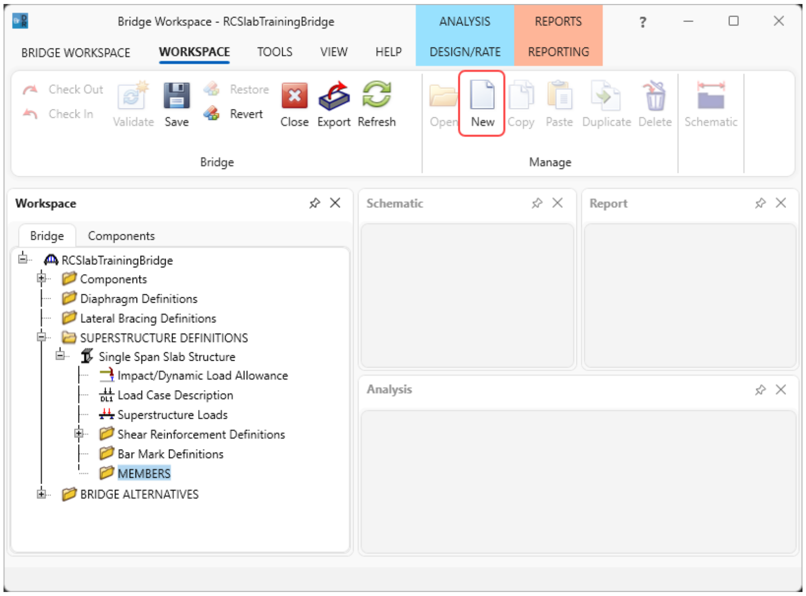
Navigate back to the superstructure definition **Single Span Slab Structure**. Double click on the **Load Case Description** node in the Bridge Workspace tree to open the **Load Case Description** window and define the dead load case as shown below. The completed **Load Case Description** window is shown below.



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

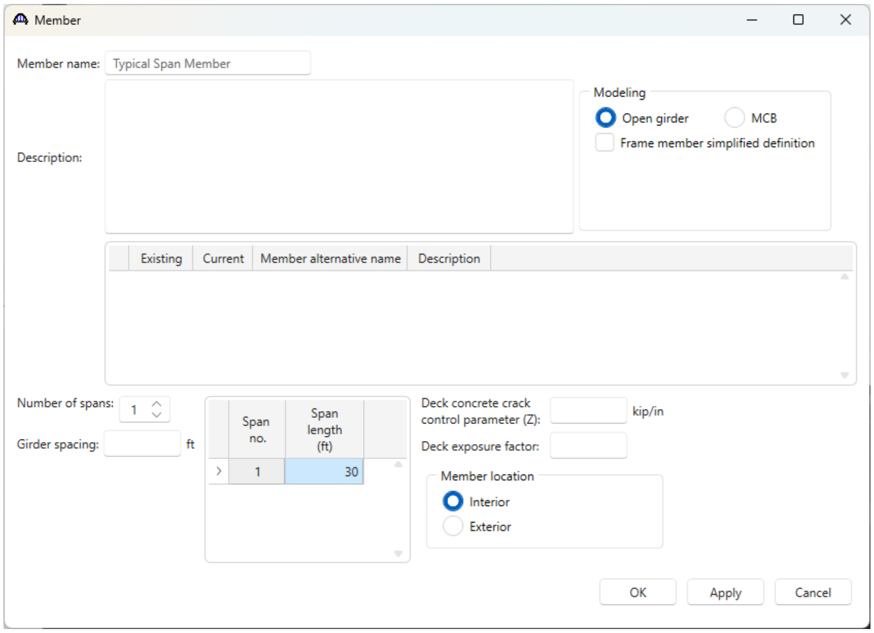
Member

Open the **Member** window by selecting **Member** in the **Bridge Workspace** tree and clicking on **New** from the **Manage** tab of the **WORKSPACE** ribbon (or by double clicking on **Member** in bridge workspace tree).



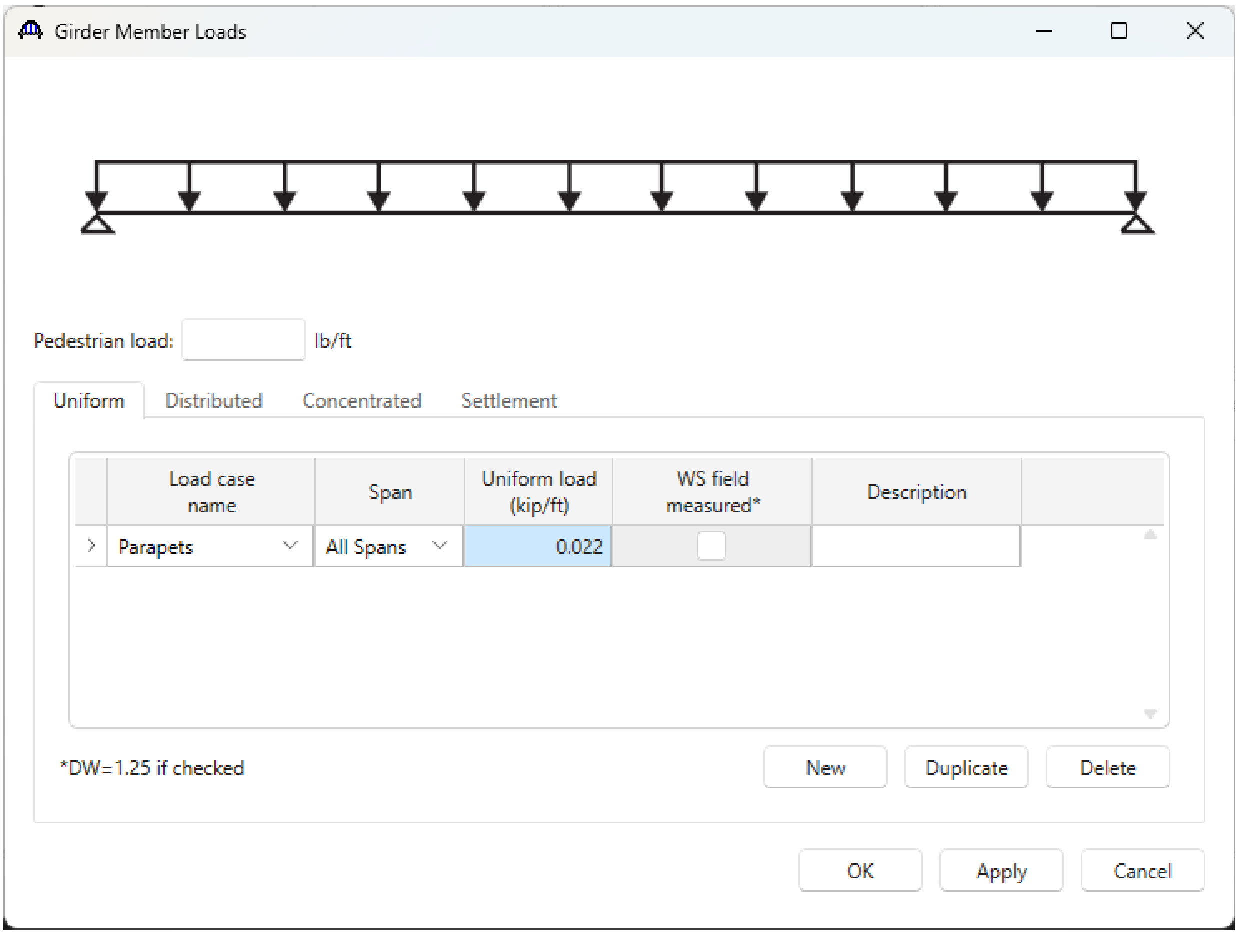
Fill in the window with the following information. If F1 is selected while this window is active, the Help topic for the **Member** window will be displayed. This help topic describes that the girder spacing, and member location are not required for a slab member so no data will be entered for those items.

The first **Member Alternative** that is created will automatically be assigned as the **Existing** and **Current** member alternative for this member.



Member Loads

Expand the newly added member node. Double-click on **Member Loads** in the **Bridge Workspace** tree to open the **Girder Member Loads** window. This structure has 2 parapets each weighing 300 lb/ft. A 12" wide strip of slab is defined as the member, and the width of the bridge cross section is 27 ft. So, the parapet load applied to this member will be (2*300 lb/ft)/27' = 22 lb/ft.



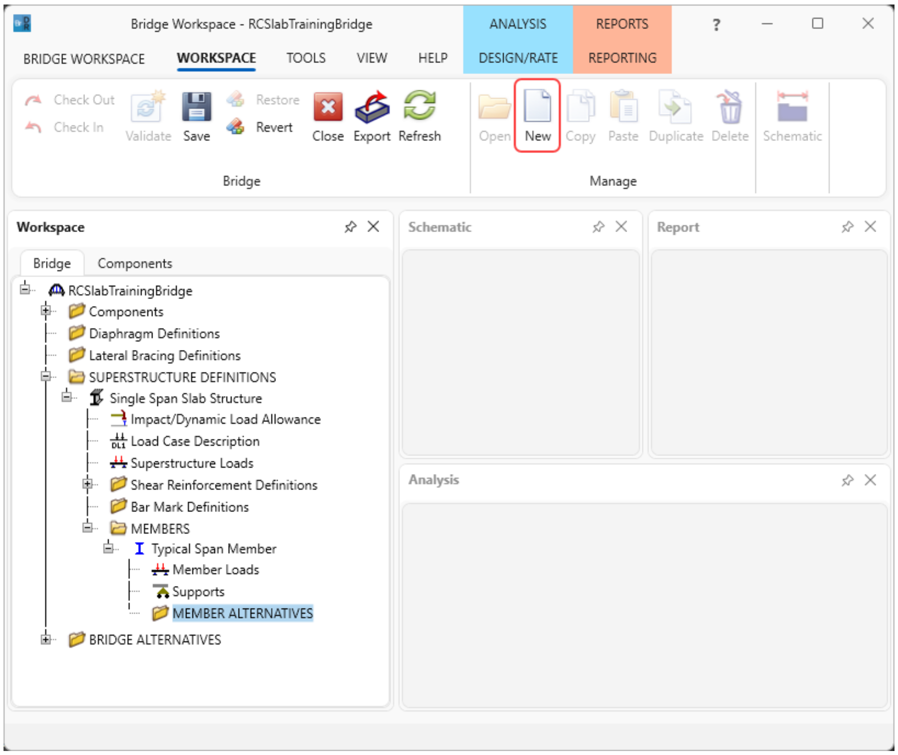
Click **OK** to apply the data and close the window.

Cross Section Based Member Alternative

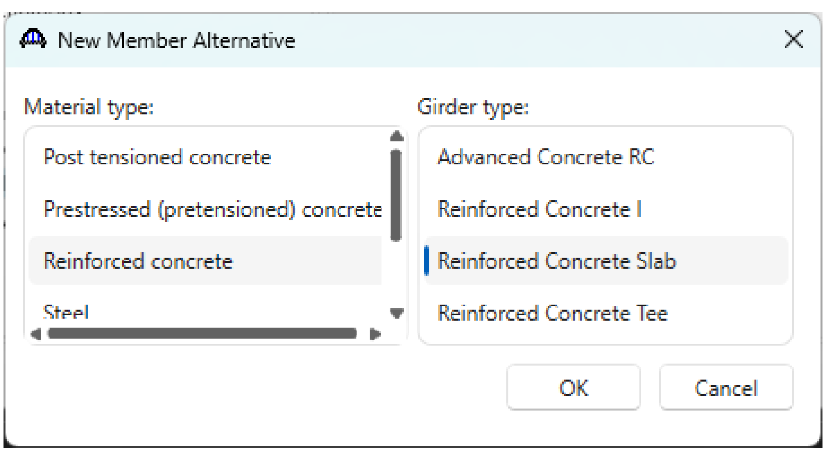
This portion of the example describes the creation of a cross-section based member alternative.

Defining a Member Alternative:

Select **MEMBER ALTERNATIVES** in the **Bridge Workspace** tree and click on **New** from the **Manage** group of the **WORKSPACE** ribbon (or double-click **MEMBER ALTERNATIVES** in the tree) to create a new alternative.

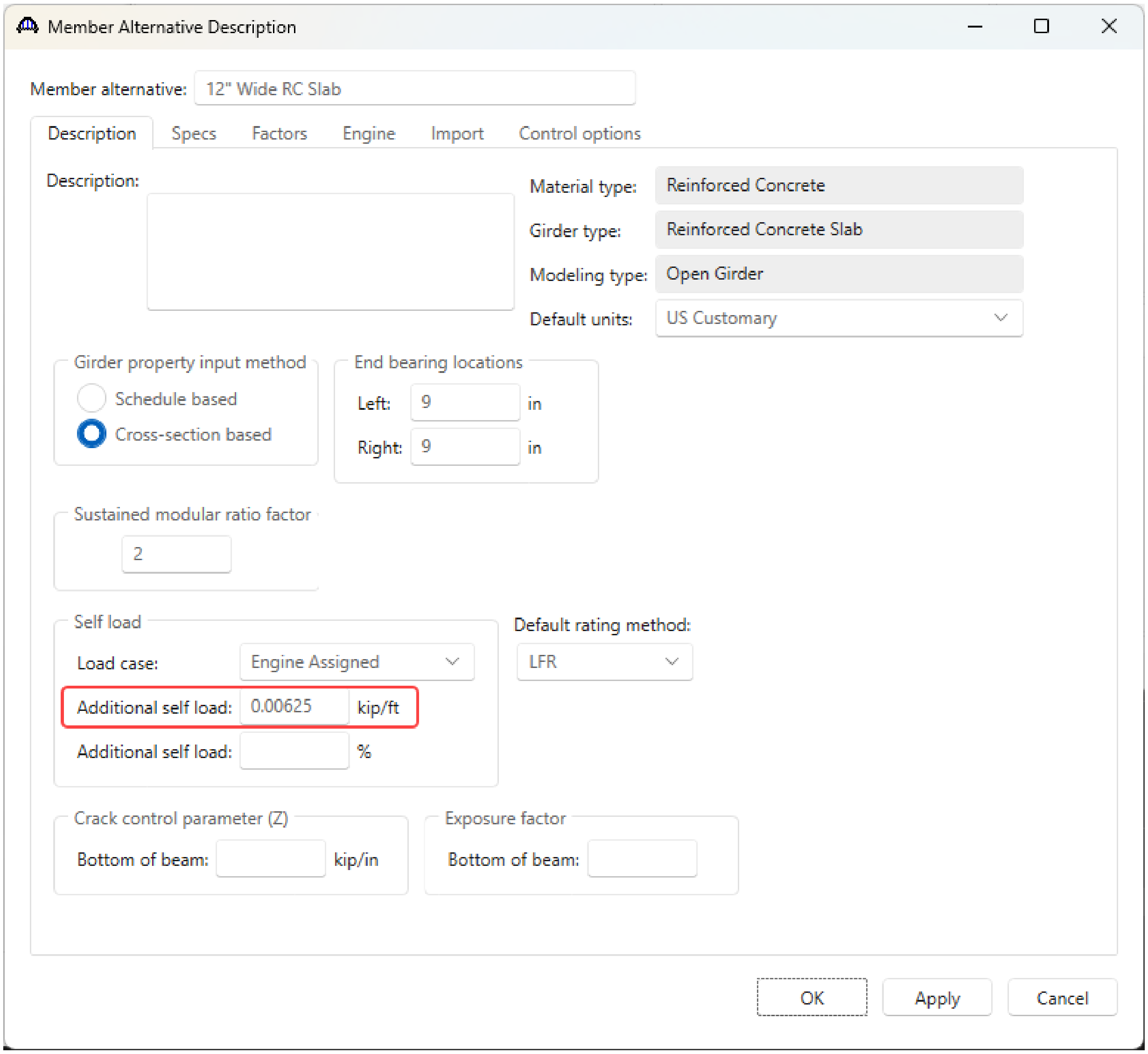


The **New Member Alternative** window shown below will open. Select **Reinforced Concrete** for the **Material type** and **Reinforced Concrete Slab** for the **Girder type**.



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.

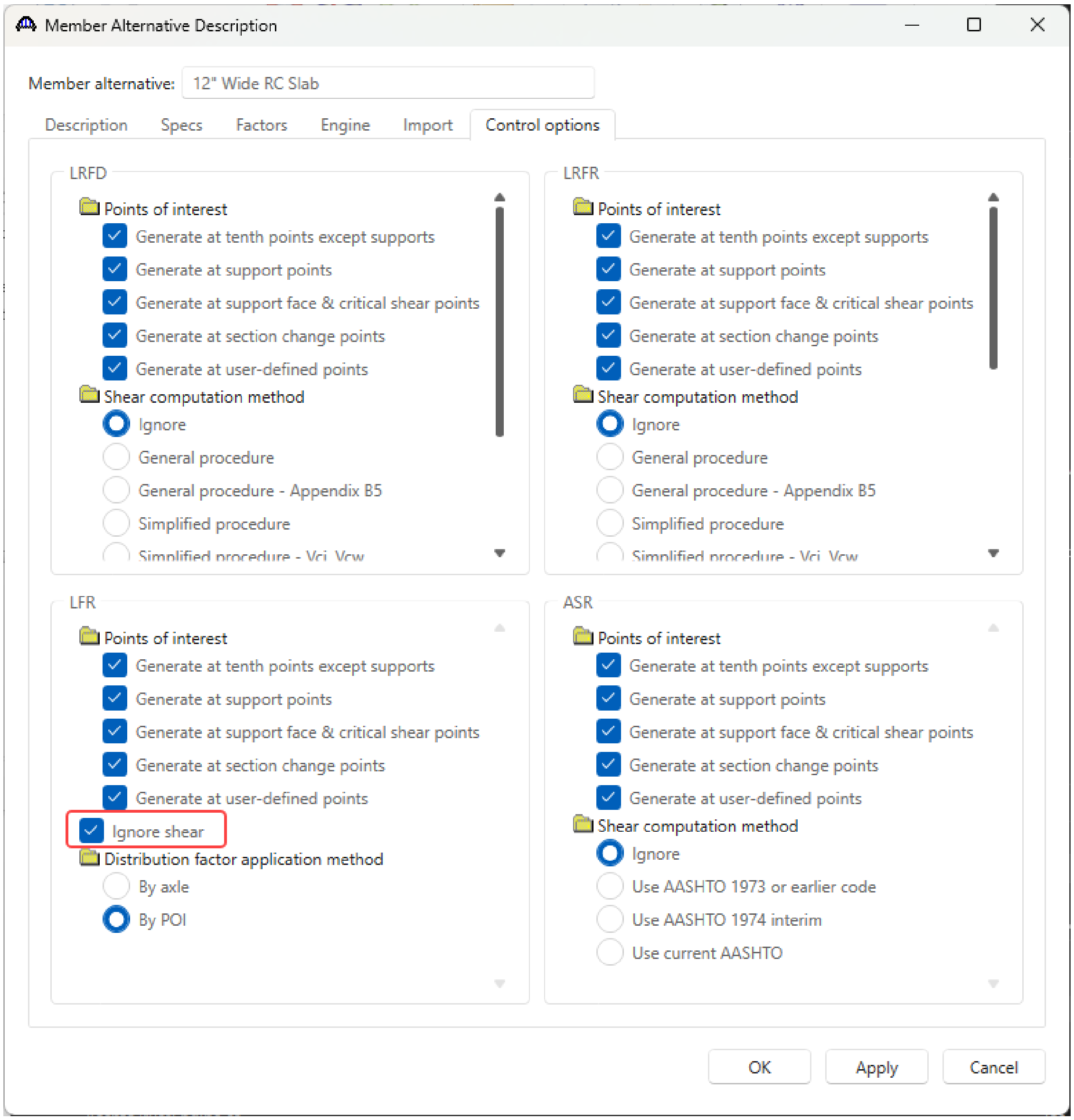


Sacrificial wear thickness for a slab

In this example, ½" of the slab is to be a sacrificial wear thickness. When the cross-section properties are entered later, the effective slab thickness will be entered. An **Additional self load** is entered here on the member alternative window to account for the ½" sacrificial wear.

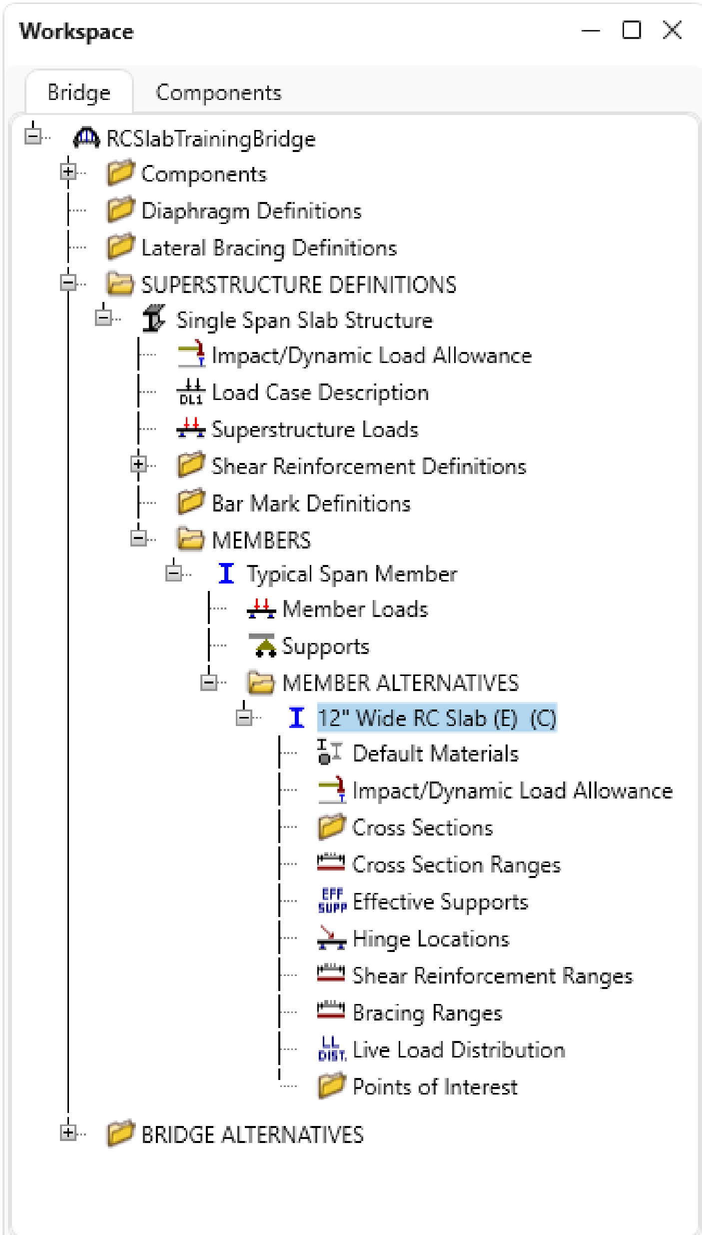
(½")/12 x 0.150 kcf = 0.0063 k/ft

AASHTO Article 3.24.4 states that concrete slabs designed in accordance with AASHTO Article 3.24.3 shall be considered satisfactory in bond and shear so navigate to the **Control options** tab select the **Ignore shear** checkbox under the **LFR** group of the **Control options** tab.



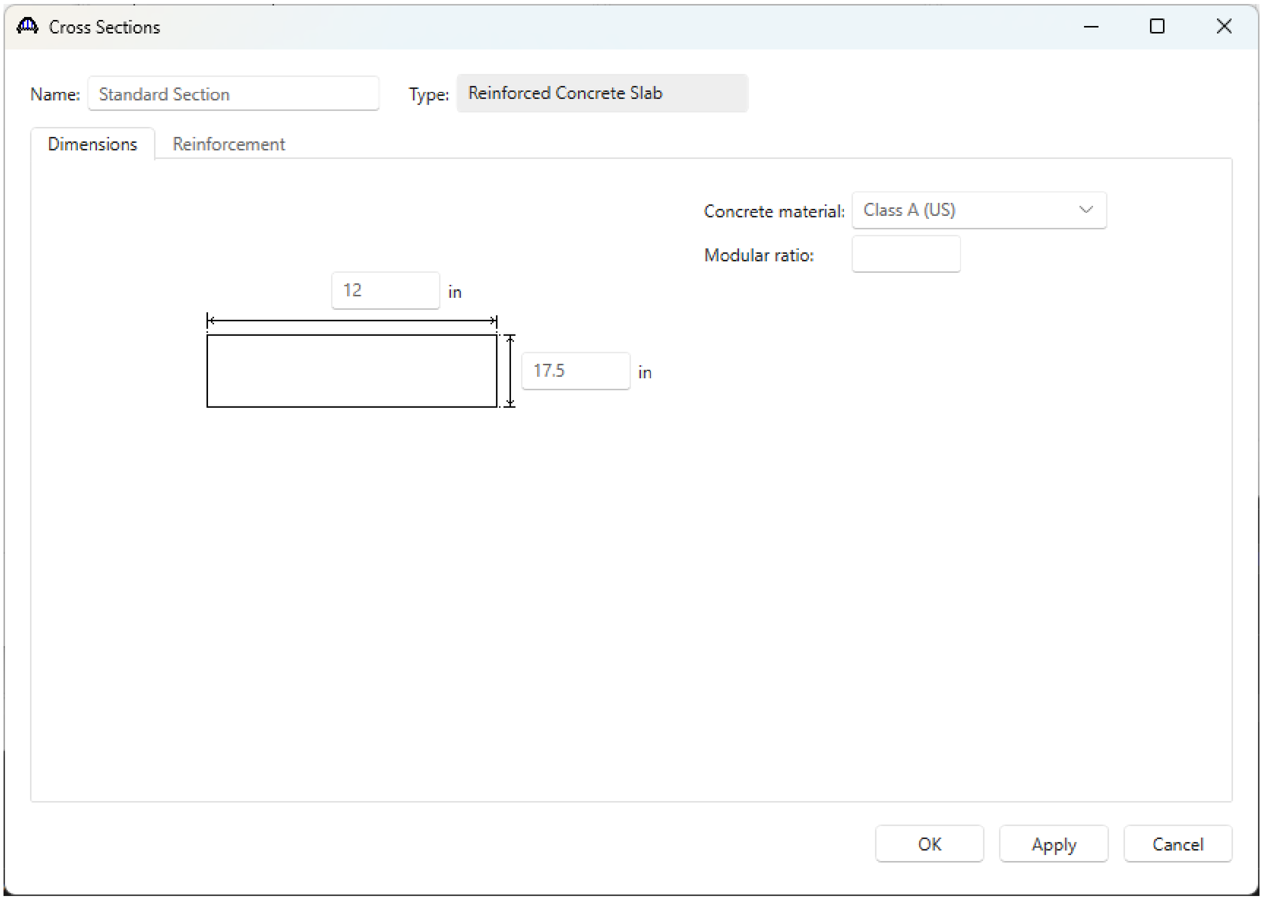
Click **OK** to apply the data and close the window.

Expand the newly added member alternative. The partially expanded **Bridge Workspace** tree is shown below.

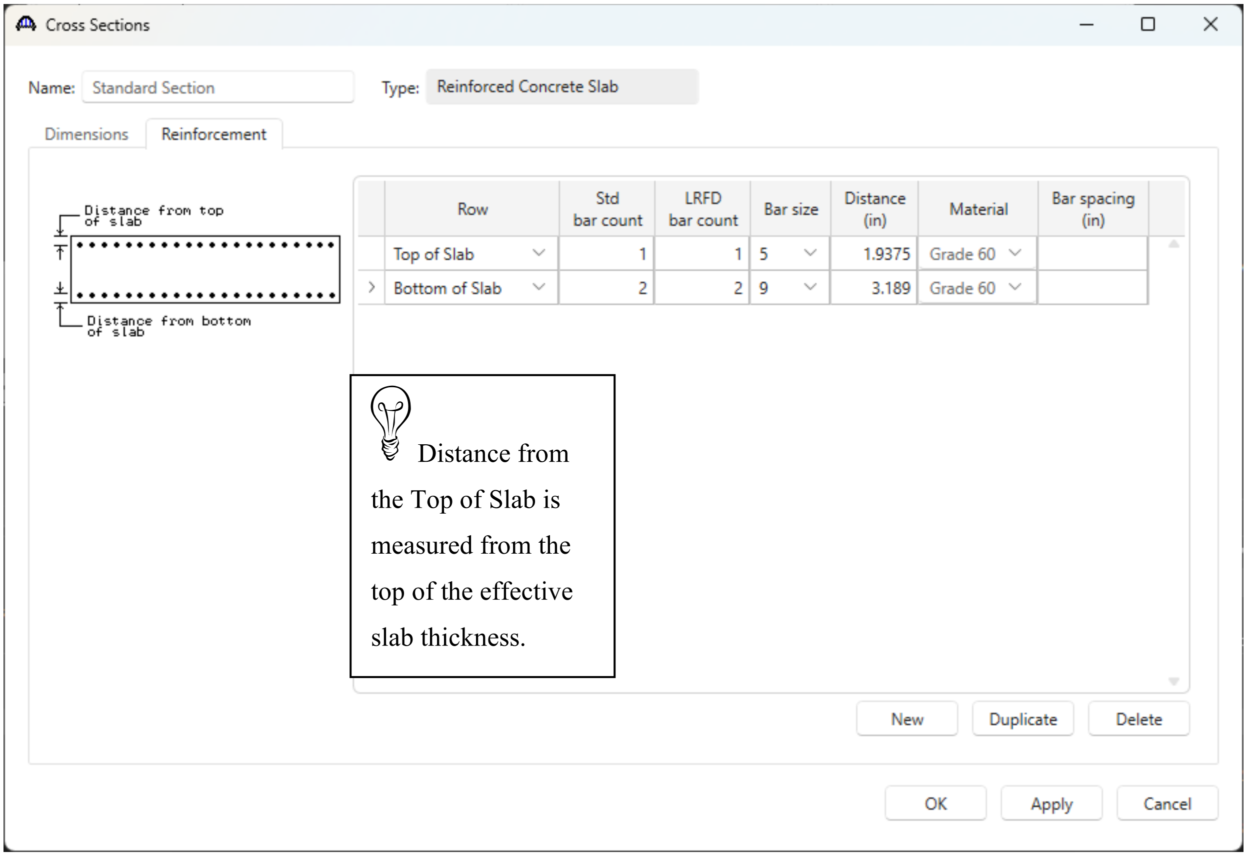


Cross Sections

New cross section can be defined by double-clicking on **Cross Sections** in the **Bridge Workspace** tree. Enter the data as shown below. The completed **Cross Sections** window is as follows. Note that the effective slab thickness is entered here.



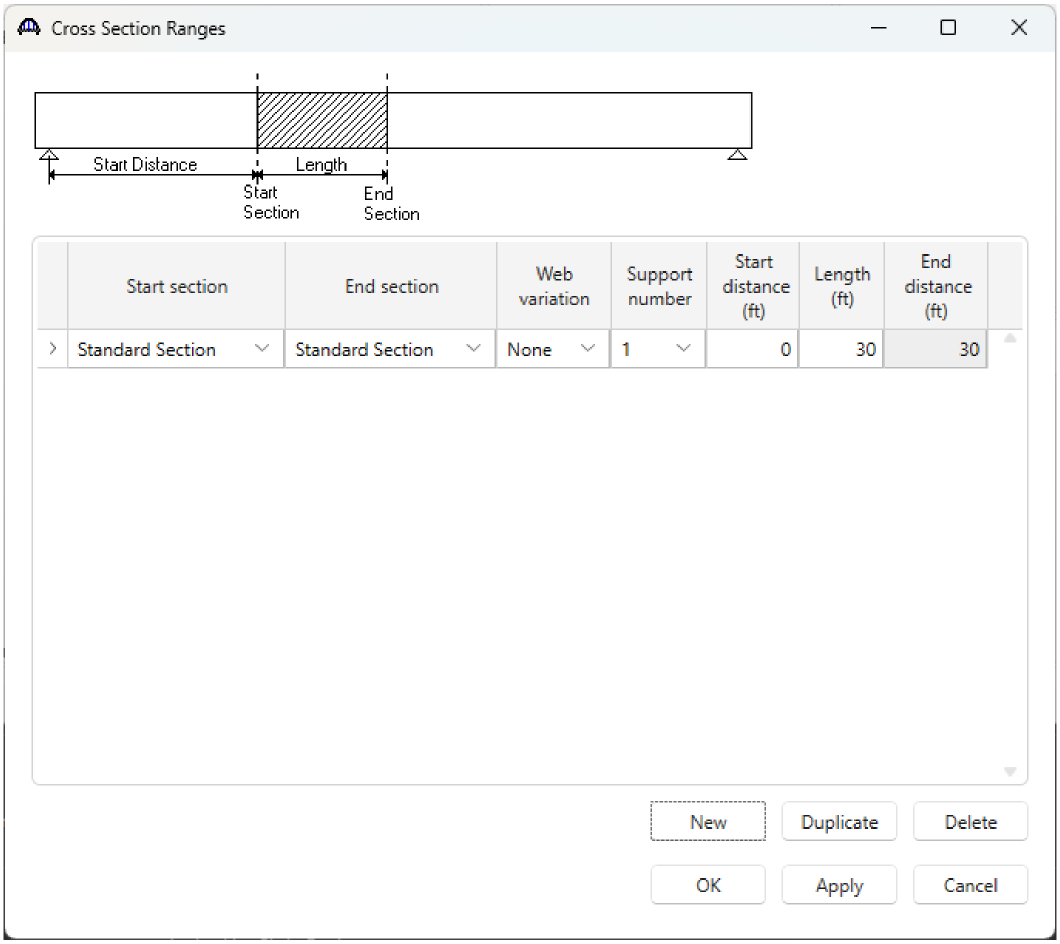
Switch to the **Reinforcement** tab of this window. The **reinforcement** for the section is shown below.



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

Cross Section Ranges

Open the **Cross Section Ranges** window from the **Bridge Workspace** tree. The cross section defined in the previous step is now applied over the length of the member as shown below.



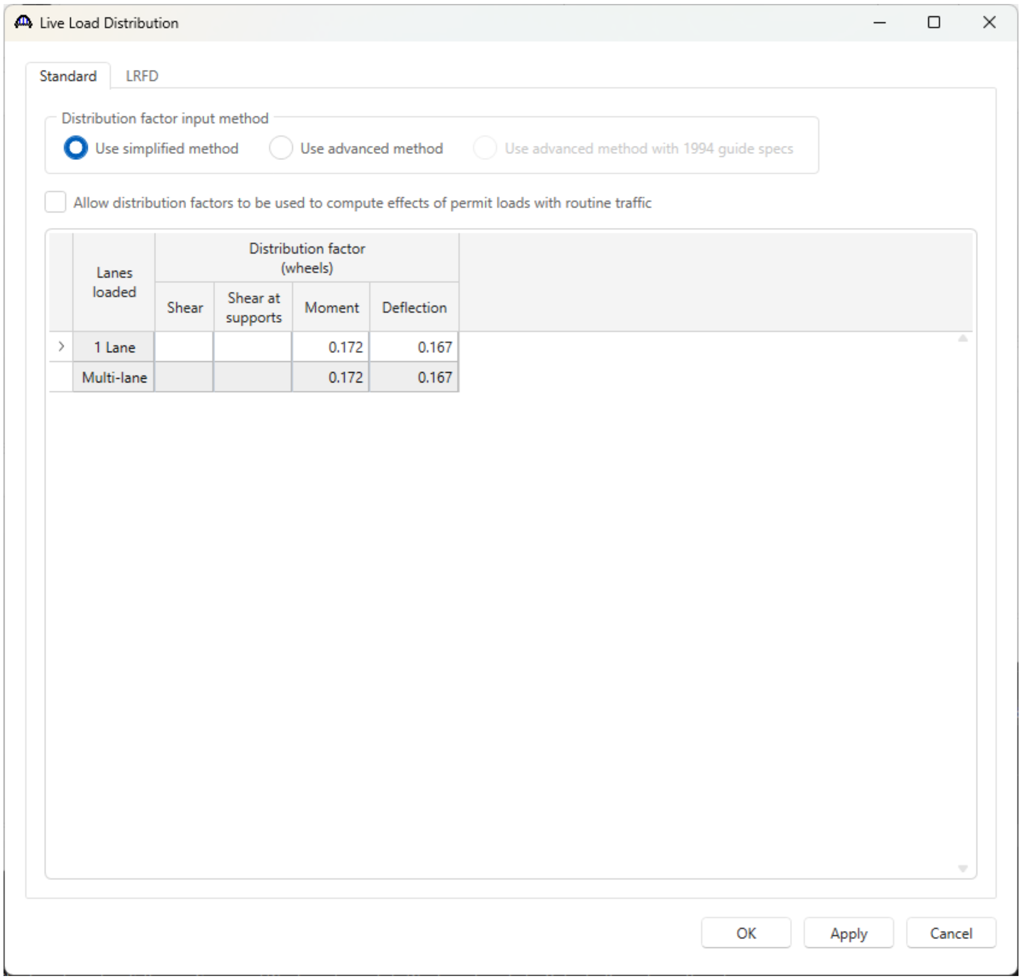
Shear Reinforcement Ranges and **Bracing Ranges** are not applicable to this member so no data will be entered in these windows.

Live Load Distribution

Double click on **Live Load Distribution** on the **Bridge Workspace** tree to open the **Live Load Distribution** window.

Standard:

Enter values as shown below and Click **Apply** to apply the standard live load distribution factors and keep the window open.



The Standard distribution factor for a slab member is computed as follows:

AASHTO Article 3.24.3.2

Distribution width, E, for a wheel is 4 + 0.06S but shall not exceed 7'.

S = span length = 30'

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

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

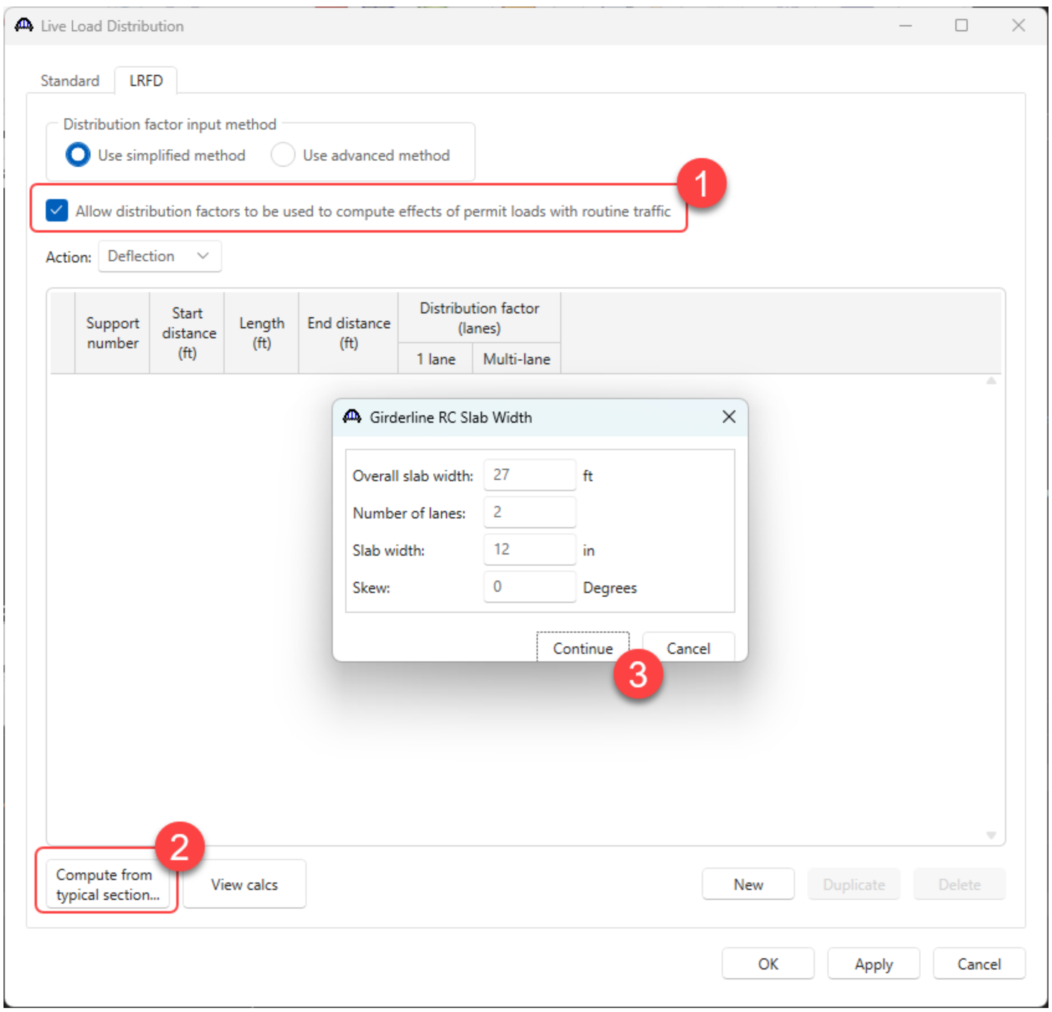
The cross section that will be entered for this member alternative is 12" wide so the wheel distribution factor is per foot. If the cross section were 24" wide, the distribution factor would be computed as 2*0.1724=0.3448.

The deflection distribution factor is calculated as the number of lanes divided by the number of girders. For a reinforced concrete slab bridge, the number of girders is taken as the lane width divided by the strip width. Our lane width is 12 feet, and our strip width is 12" or 1 foot.

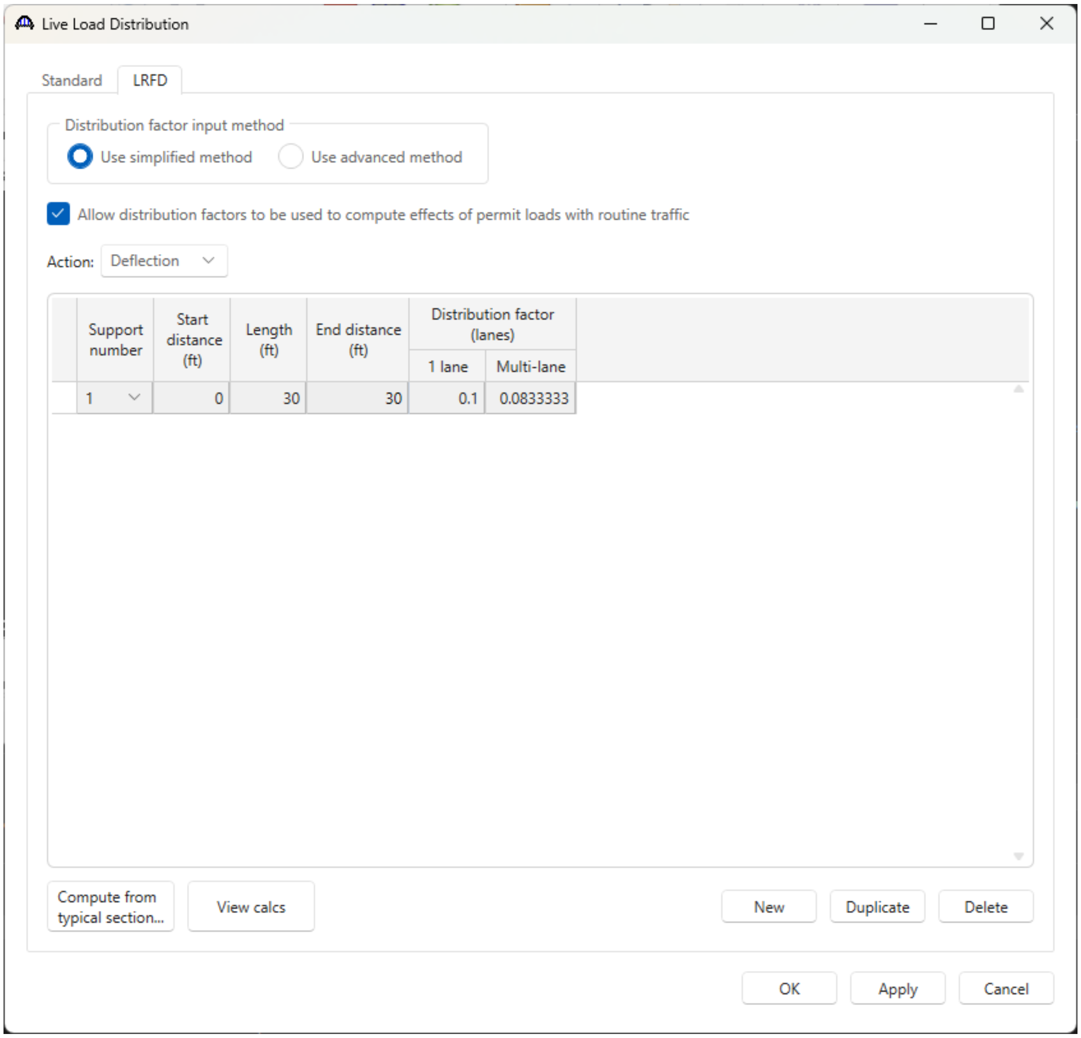
$$Deflection\ DF = \frac{1\ lane * 2\ wheels/lane}{(12'/\ 1')} = 0.1667\ wheel\ /\ ft$$

LRFD:

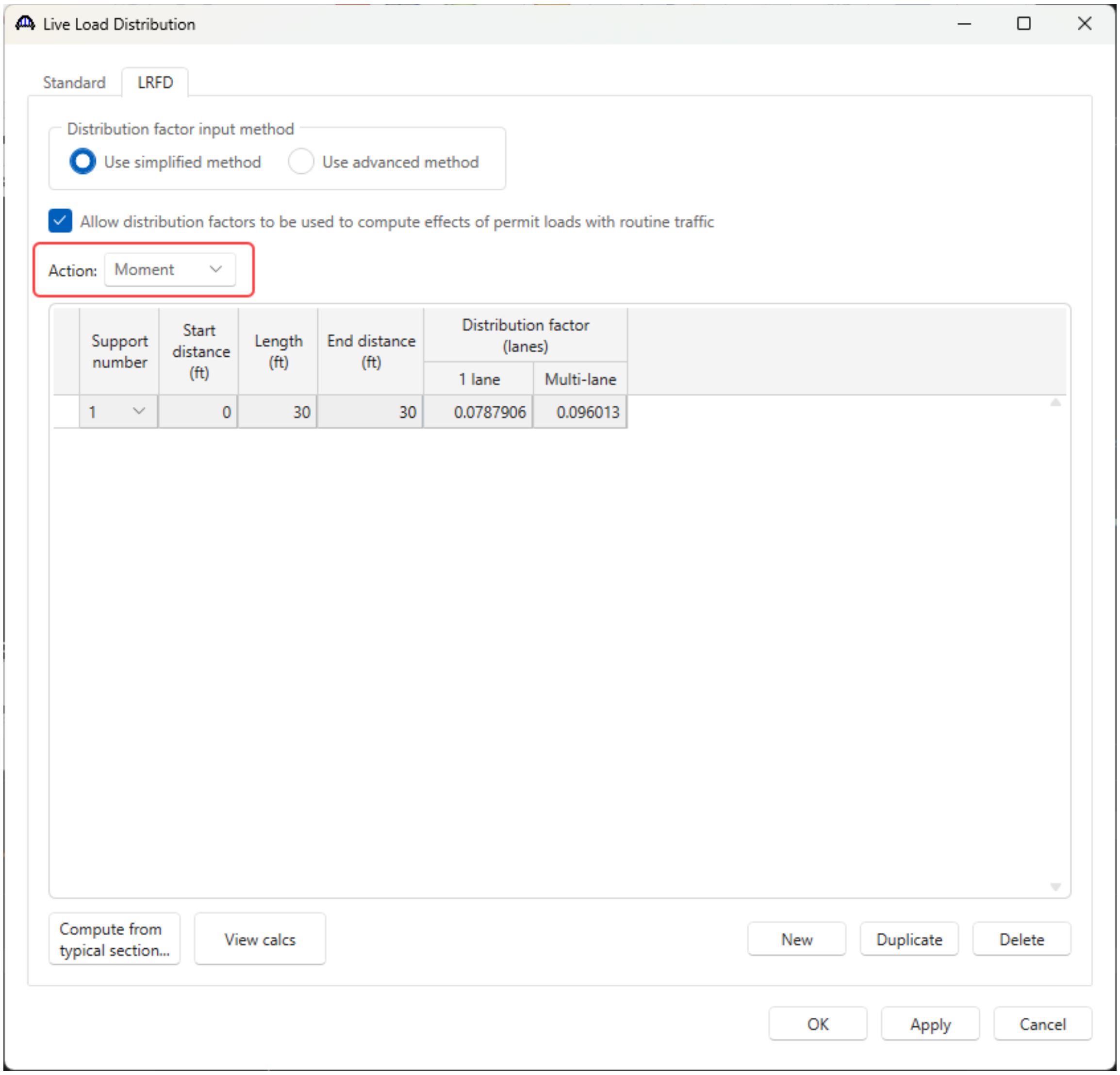
Navigate to the **LRFD** tab of the **Live Load Distribution** window and check the **Allow distribution factors to be used to compute effects of permit loads with routine traffic** box. Click the **Compute from typical section** button and enter the values shown below in the pop up window.



Click the **Continue** button, BrDR will compute LRFD live load distribution factors. Click **OK** on the **LRFD Distribution Factor Progress** window to close this progress window. The **Live Load Distribution** window will be populated as shown below.



Moment and shear have the same distribution factors. The moment distribution factor is shown below.



Drop down options for **Action** can be used to verify the computed distribution factors for each action (Deflection, Moment, and Shear). Click **OK** to apply the data and close the window.

The live load distribution factors for LRFD analysis are calculated as shown below.

AASHTO Article 4.6.2.3

Equivalent width of strip per lane, E, for both shear and moment single lane:

<u>Single lane</u>

$$E = 10.0 + 5.0\sqrt{L_1 W_1}$$

$$L_1 = span\ length\ \leq 60' = 30'$$

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

$$E = 10 + 5.0 * \sqrt{(30)(27)} = 152.302''$$

$$Moment\ and\ Shear\ DF = \frac{1\ lane}{152.302} = 0.0066\ lane/inch$$

For single lane, the moment and shear distribution factor = 12” member * 0.0066 lanes/inch = 0.079 lanes.

Multi lane

$$E = 84.0 + 1.44\sqrt{L_1 W_1}\ \leq \frac{12.0W}{N_L}$$

$$L_1 = span\ length\ \leq 60' = 30'$$

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

$$W = width\ edge - edge\ of\ bridge = 27'$$

$$N_L = number\ of\ lanes$$

$$E = 84.0 + 1.44\sqrt{(30)(27)} = 124.983\ \leq \frac{12(27)}{2} = 162''$$

$$Moment\ and\ Shear\ DF = \frac{1\ lane}{124.983} = 0.008\ lane/inch$$

For multi lane, the moment and shear distribution factor = 12” member * 0.008 lanes/inch = 0.096 lanes.

Deflection distribution factor:

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

$$Single\ lane\ Deflection\ DF = \frac{1\ lane}{(12'/1')}(1.2) = 0.100\ lanes$$

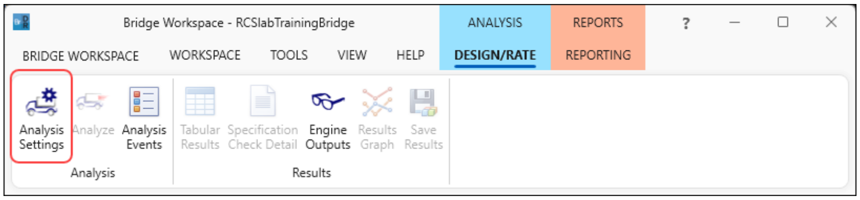
$$Multi\ lane\ Deflection\ DF = \frac{2\ lanes}{(12' * 2/1')}(1.0) = 0.0833\ lanes$$

There is no requirement to define any **points of interest** since none of the information entered will be overridden in this example.

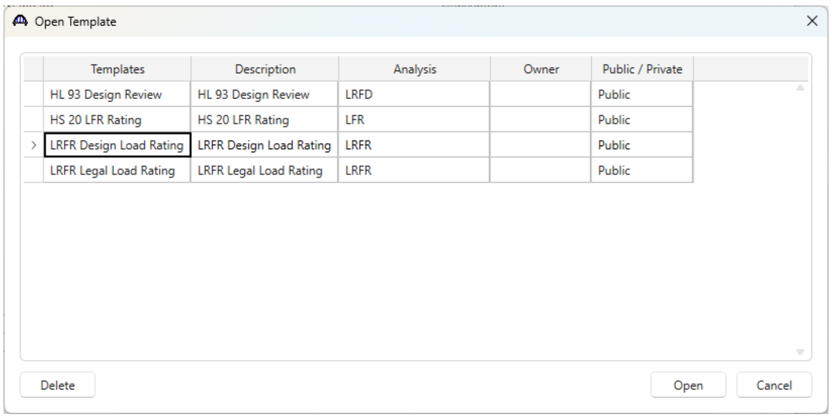
The description of this structure is complete.

LRFR Analysis

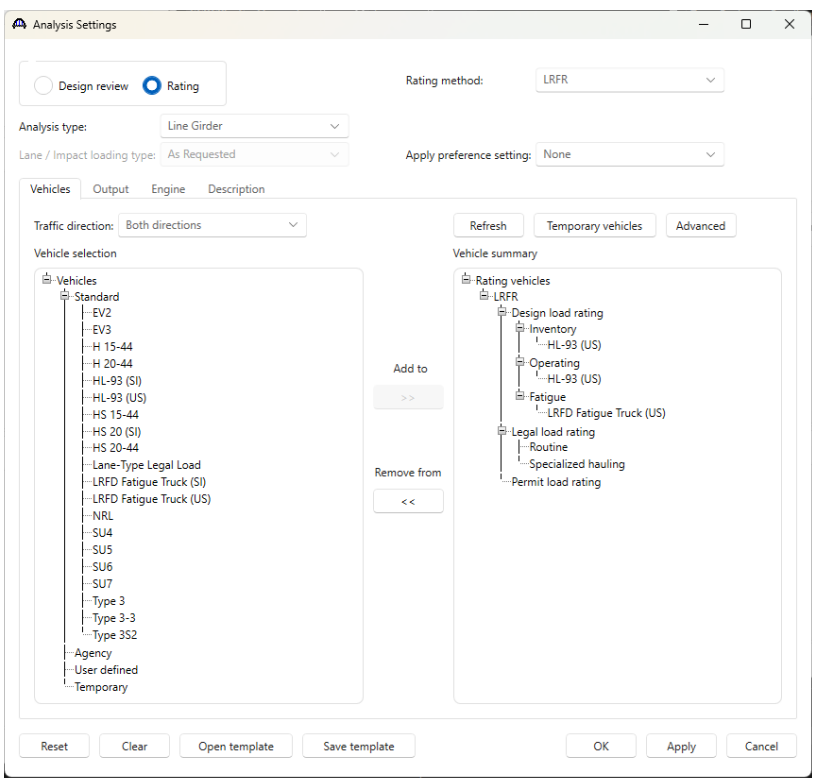
The member alternative created can now be analyzed. To perform an **LRFR** rating, select the **Analysis Settings** button on the **Analysis** group of the **DESIGN/RATE** ribbon to open the window shown below.



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

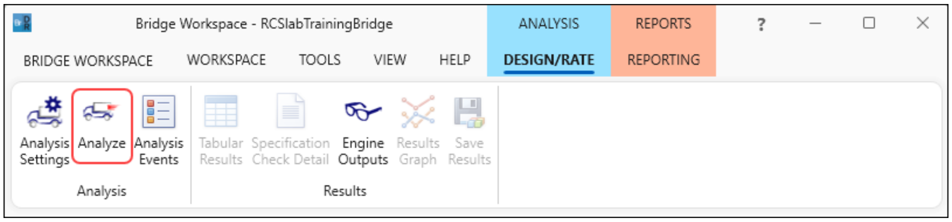


The **Analysis Settings** window will be updated as shown below.

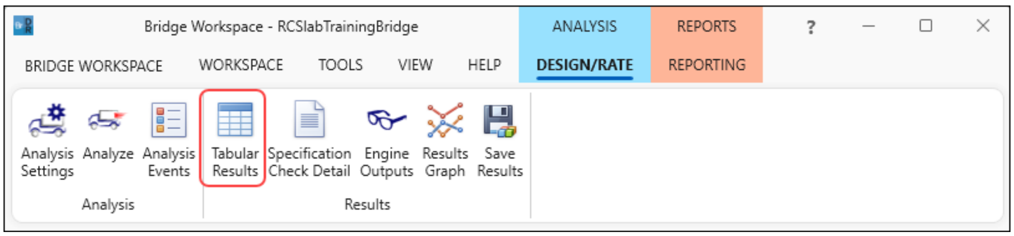


Tabular Results

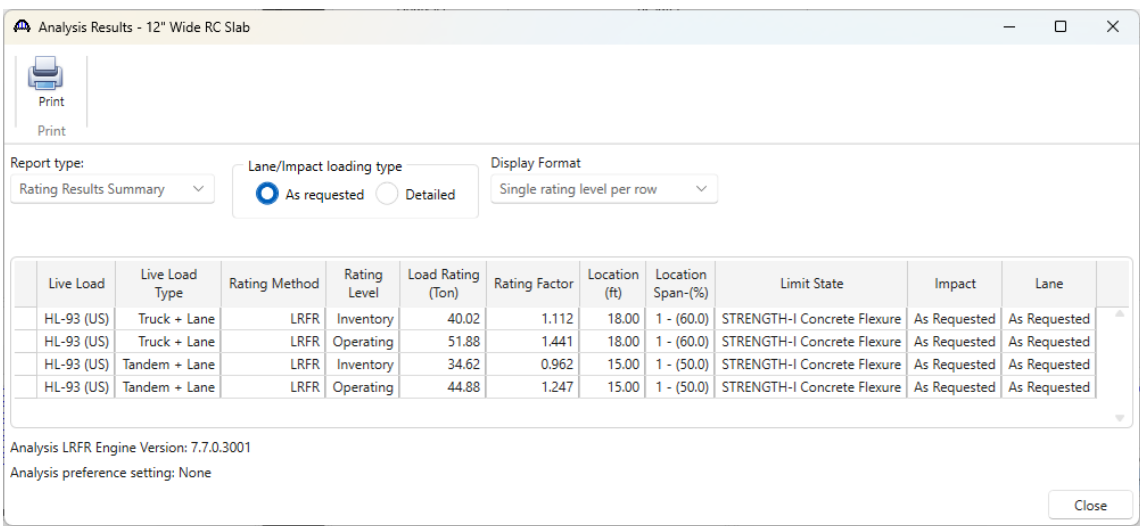
Next with the member alternative selected, click the **Analyze** button on the **Analysis** group of the **DESIGN/RATE** ribbon to perform the rating.



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

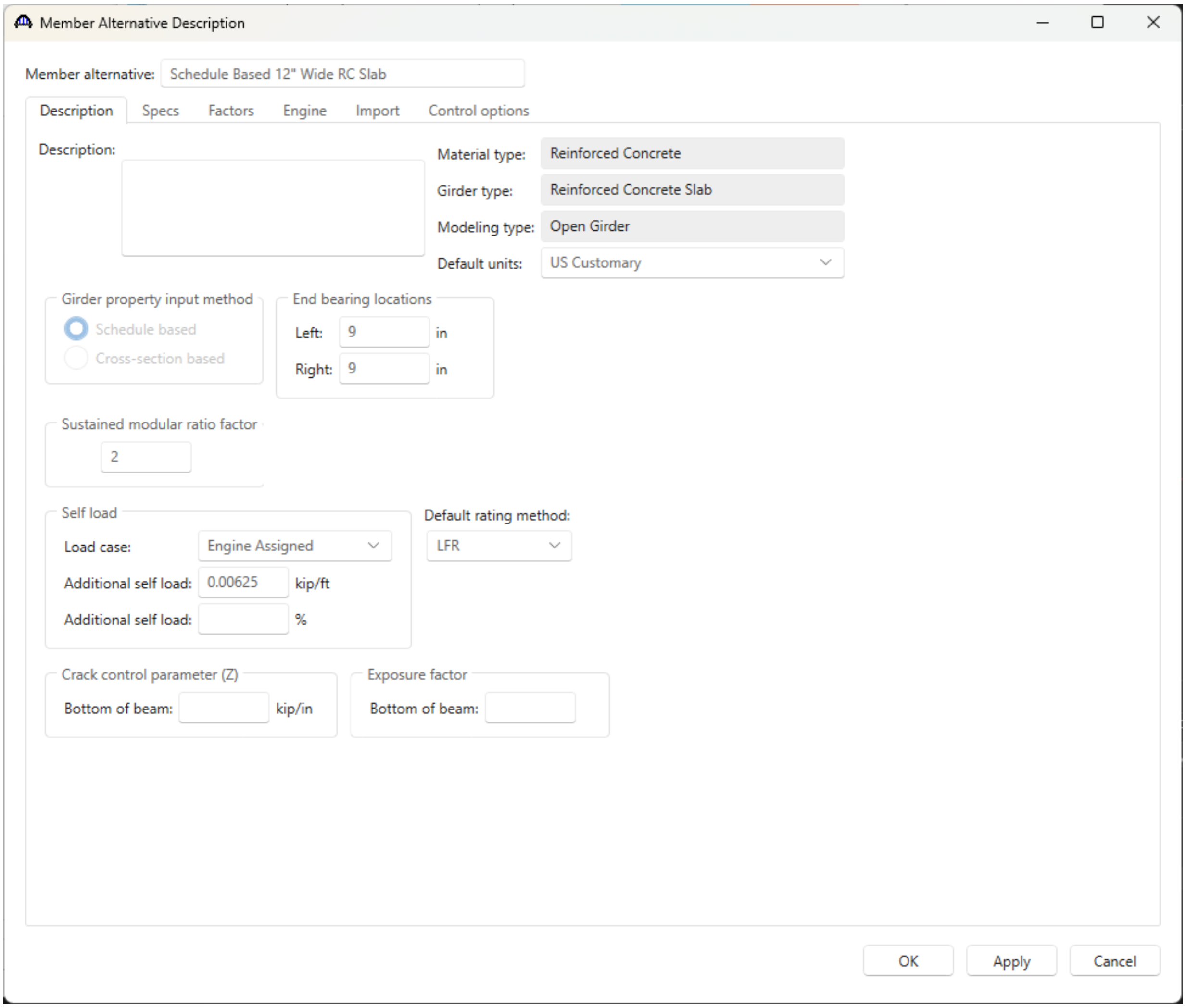


The window shown below will open.



Schedule Based Member Alternative

This portion of the example describes the creation of a schedule based member alternative. Create a new reinforced concrete member alternative (as per the steps shown in the previous section) for the member **Typical Slab Member** and enter the following data.



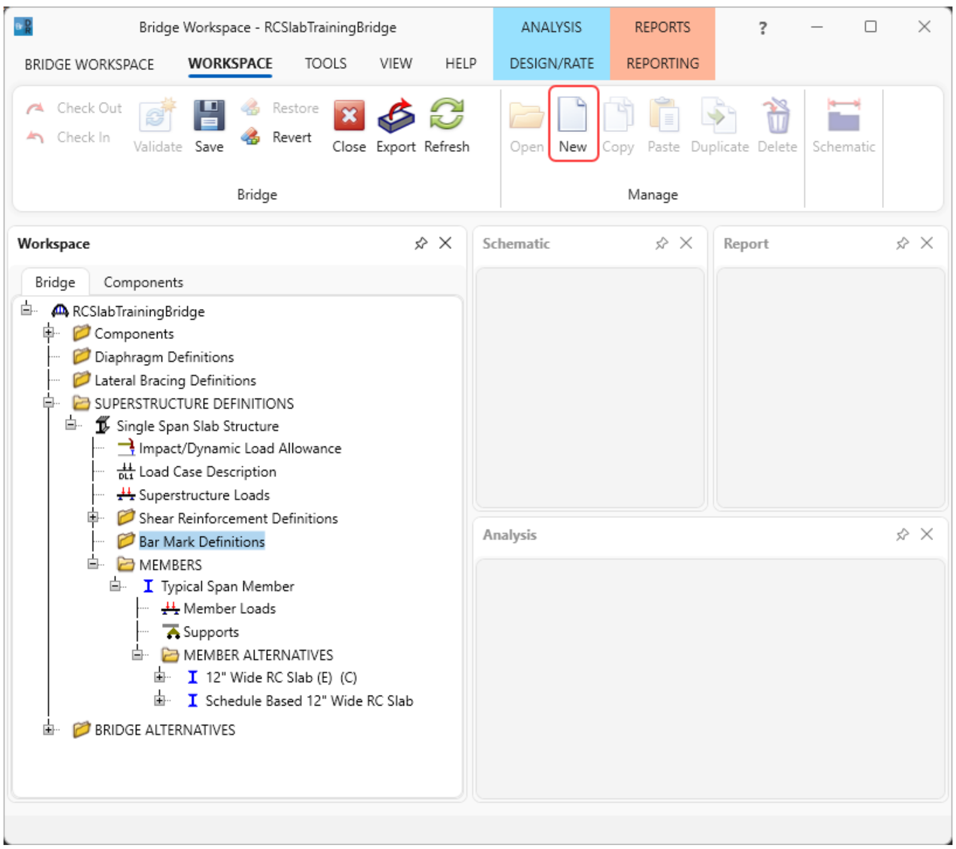
Since a slab member is described and since shear will be ignored using a control option, ignoring the shear in the slab in the following discussion does not affect this example. However, it is an important item to be aware of when considering shear in the member so it will be reviewed now.

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

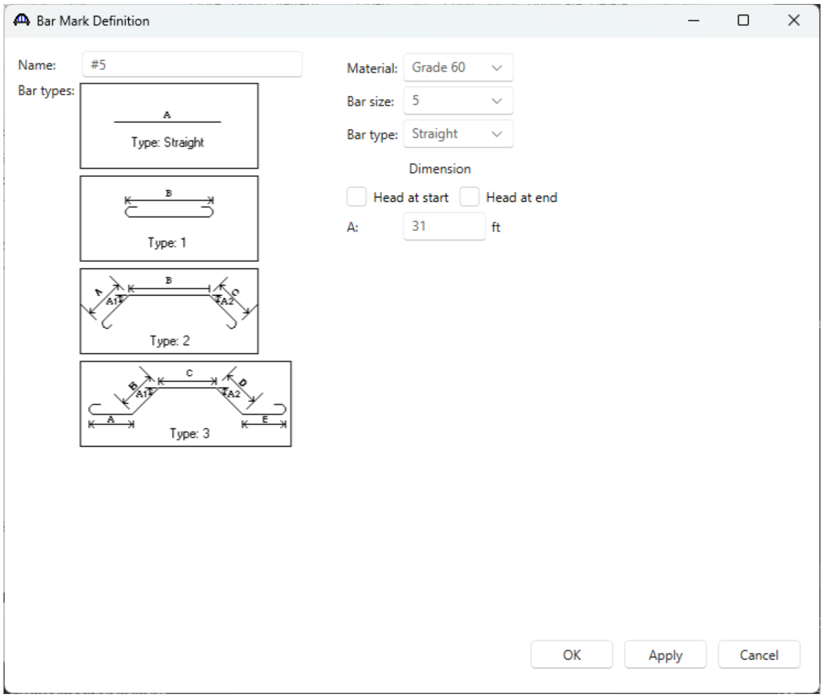
If the bars start to the left of the first support line and to the right of the last support line, BrDR will consider the bars to be partially developed at the centerline of the bearing. Then the analysis engine will be able to compute the **d** distance from the extreme compression fiber to the centroid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

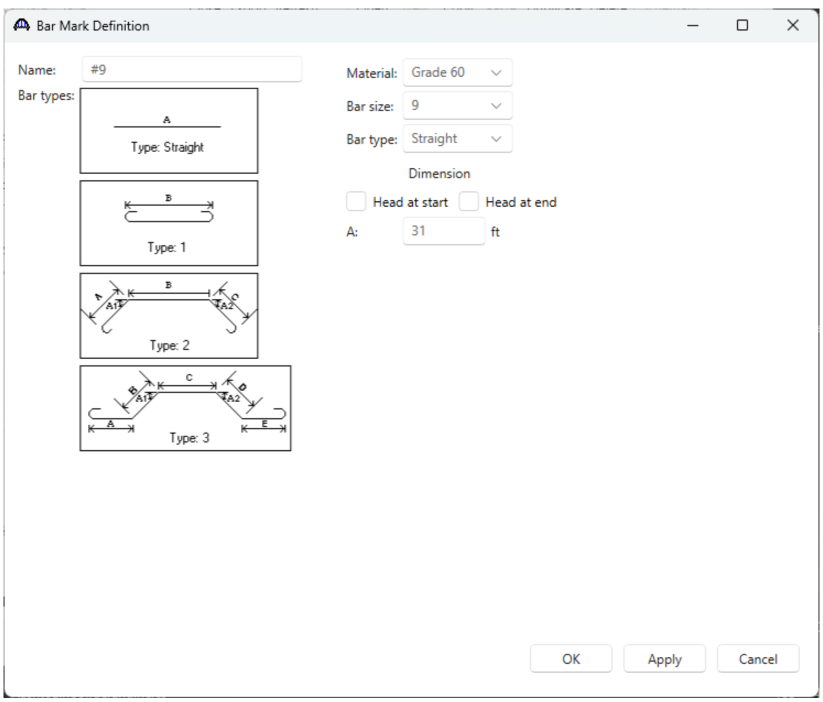
Bar Mark Definitions

Before defining the girder and reinforcement profile for the member alternative, **Bar Mark Definitions** need to be defined. **Bar Mark Definitions** are used to define the longitudinal flexural reinforcement in schedule based reinforced concrete members. Select **Bar Mark Definitions** from the Bridge Workspace tree and click the **New** button from the **Manage** group of the **WORKSPACE** ribbon.



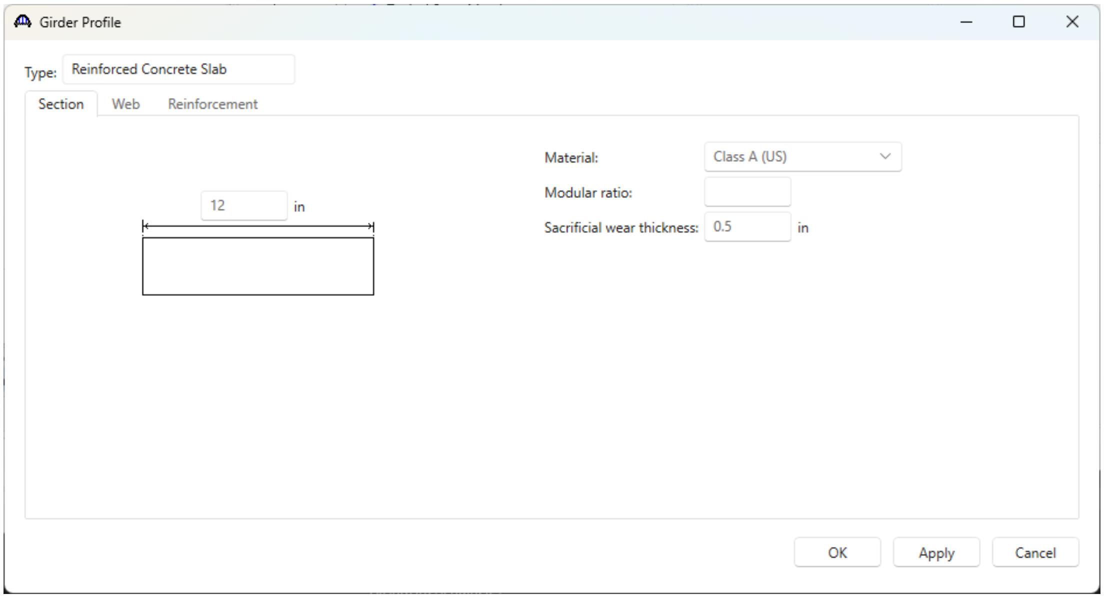
This bridge uses the following bar mark definitions. Add these definitions one by one.



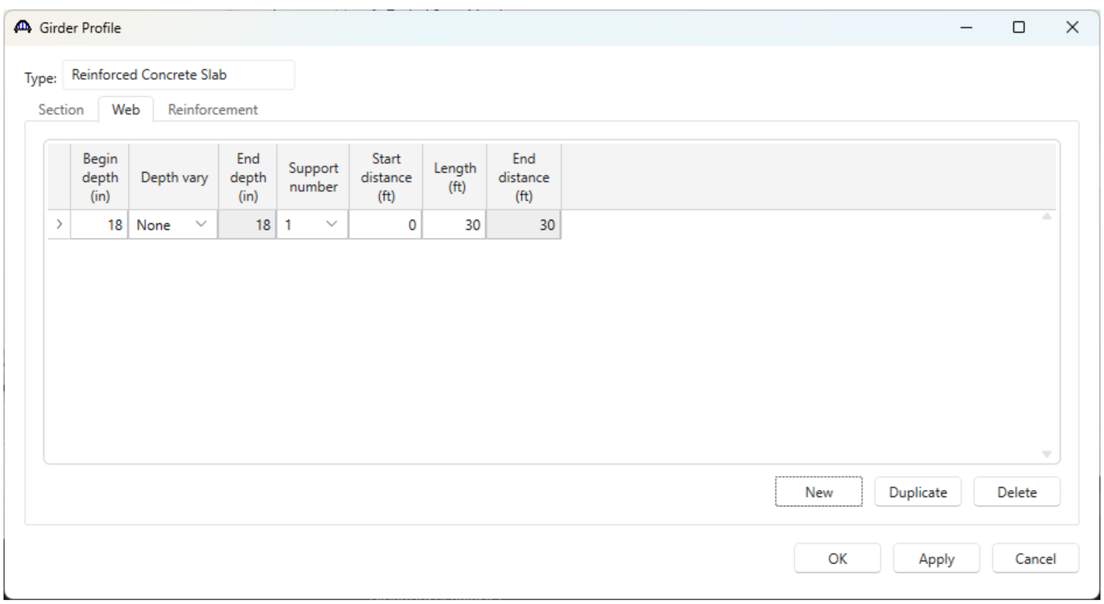


The **Girder Profile** can now be defined. Expand the **Schedule Based 12" Wide RC Slab** member alternative on the **Bridge Workspace** tree, double click on **Girder Profile** to open the **Girder Profile** window and enter the data on each tab as shown below:

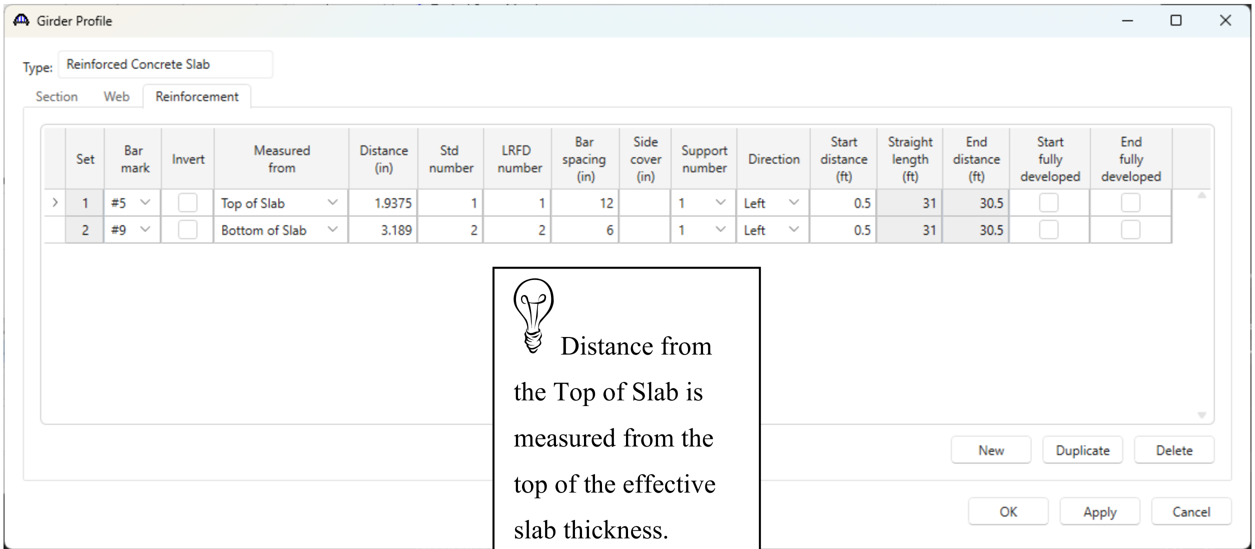
Girder Profile - Section



Girder Profile - Web



Girder Profile - Reinforcement



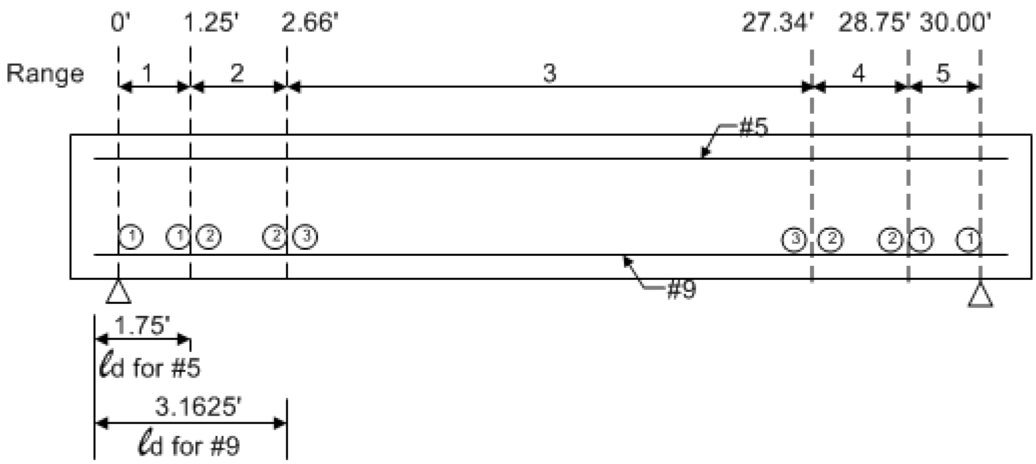
Distance from the Top of Slab is measured from the top of the effective slab thickness.

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

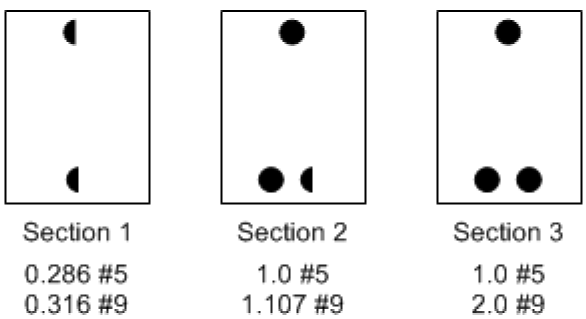
BrDR assumes that the user has described the schedule of reinforcement as it physically exists in the bridge. BrDR considers the required development length of the reinforcement when it exports cross sections for use by an analysis engine. If the user does not want BrDR to consider the required development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

The following shows the cross sections and cross section ranges that are generated for this example when the member alternative is analyzed.

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



Exported Cross Section Ranges



Exported Cross Sections

BrDR assumes the reinforcement develops in the bar in a linear fashion, starting with 0% development at the bar end and 100% development at the point of full development (l_d)

Three cross sections are generated in this example. At 0.0', the #5 bar is 28.6% developed and the #9 bars are 15.8% developed. These percentages are found as follows (note that the bars start 6" to the left of the centerline of the bearing):

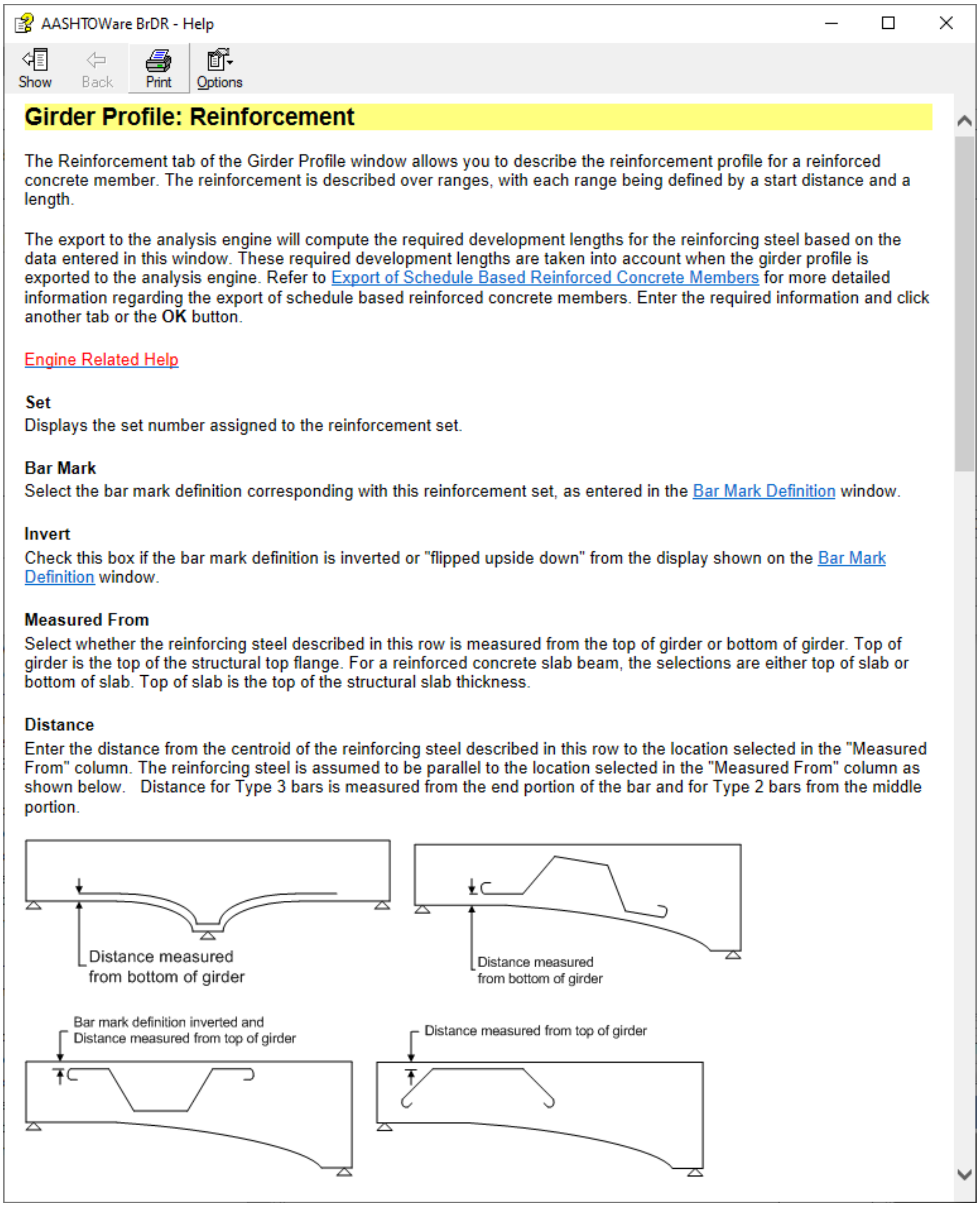
#5 bar 0.5'/1.75' = 0.286* 1 bar = 0.286 bar

#9 bar 0.5'/3.1625' = 0.158 * 2 bars = 0.316 bars

This cross section is applied from the 0.0' start of the member alternative to 1.25' where the #5 bar is fully developed.

A similar procedure is followed at 1.25' which is where the #5 bar is fully developed and at 2.66' which is where the #9 bars are fully developed.

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



AASHTOWare BrDR - Help

Show Back Print Options

Girder Profile: Reinforcement

The Reinforcement tab of the Girder Profile window allows you to describe the reinforcement profile for a reinforced concrete member. The reinforcement is described over ranges, with each range being defined by a start distance and a length.

The export to the analysis engine will compute the required development lengths for the reinforcing steel based on the data entered in this window. These required development lengths are taken into account when the girder profile is exported to the analysis engine. Refer to Export of Schedule Based Reinforced Concrete Members for more detailed information regarding the export of schedule based reinforced concrete members. Enter the required information and click another tab or the **OK** button.

Engine Related Help

Set
Displays the set number assigned to the reinforcement set.

Bar Mark
Select the bar mark definition corresponding with this reinforcement set, as entered in the Bar Mark Definition window.

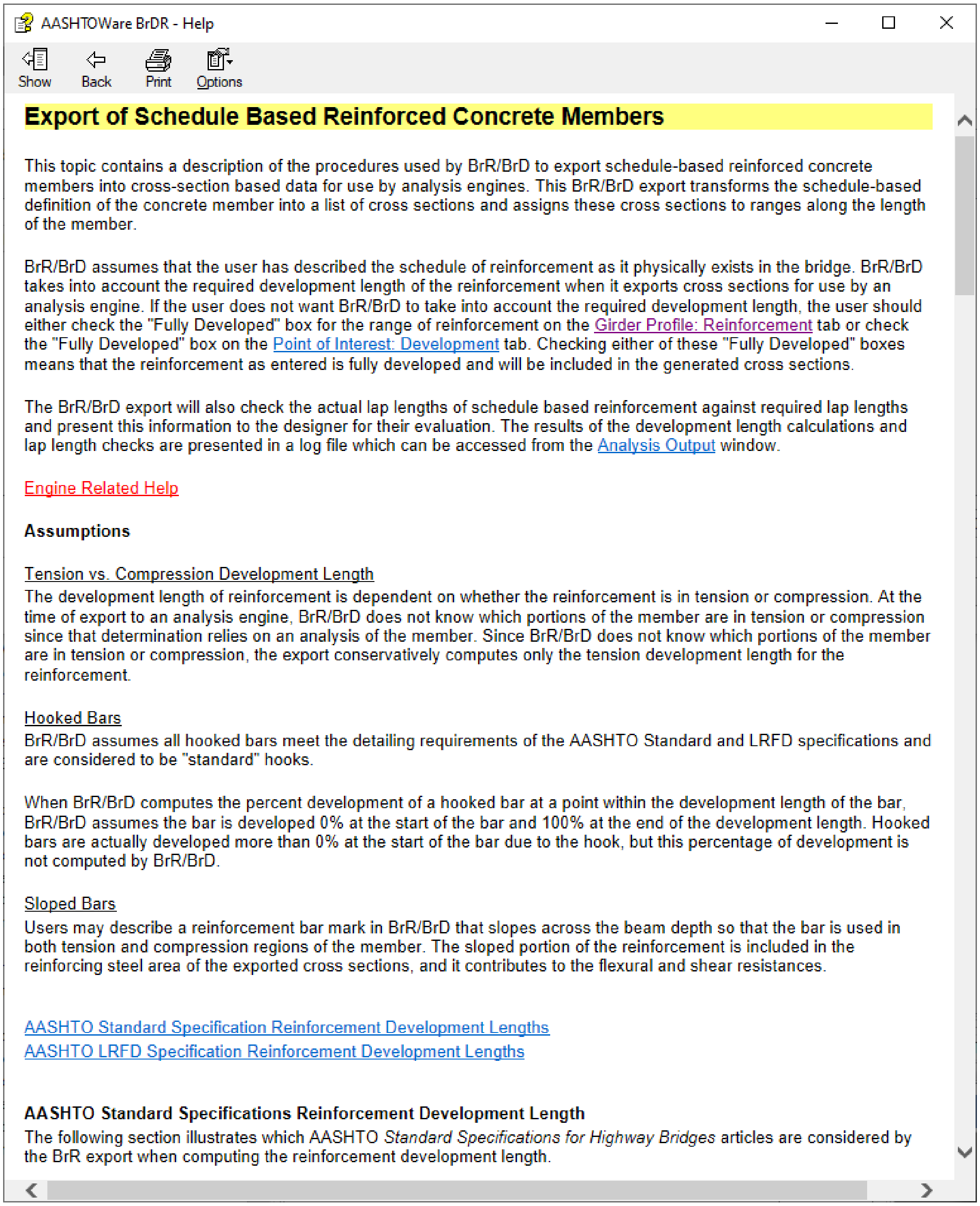
Invert
Check this box if the bar mark definition is inverted or "flipped upside down" from the display shown on the Bar Mark Definition window.

Measured From
Select whether the reinforcing steel described in this row is measured from the top of girder or bottom of girder. Top of girder is the top of the structural top flange. For a reinforced concrete slab beam, the selections are either top of slab or bottom of slab. Top of slab is the top of the structural slab thickness.

Distance
Enter the distance from the centroid of the reinforcing steel described in this row to the location selected in the "Measured From" column. The reinforcing steel is assumed to be parallel to the location selected in the "Measured From" column as shown below. Distance for Type 3 bars is measured from the end portion of the bar and for Type 2 bars from the middle portion.

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

The **Export of Schedule Based Reinforced Concrete Members** topic contains the rules and assumptions BrDR uses when exporting schedule based reinforced concrete members to the analysis engine.


AASHTOWare BrDR - Help

Show Back Print Options

Export of Schedule Based Reinforced Concrete Members

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

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

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

Engine Related Help

Assumptions

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

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

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

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

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

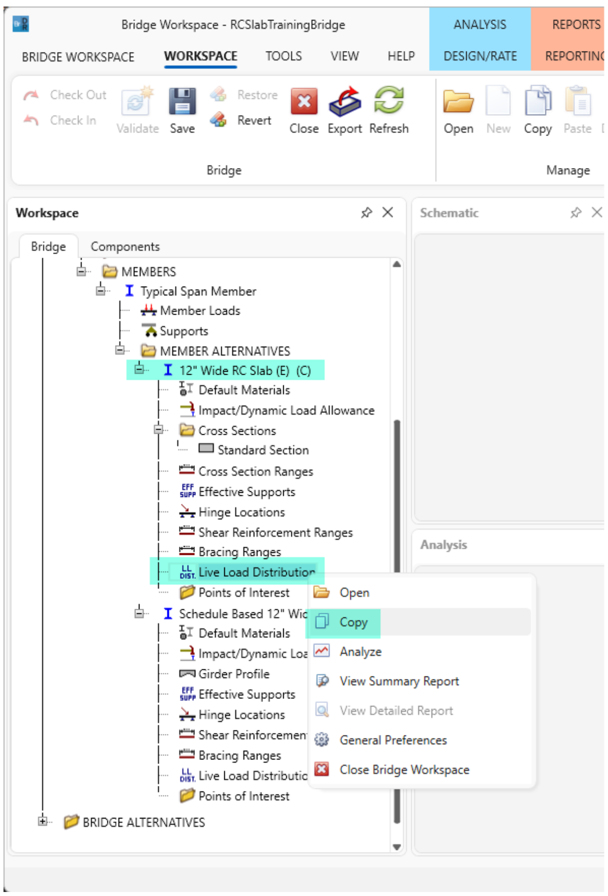
AASHTO Standard Specifications Reinforcement Development Length
The following section illustrates which AASHTO *Standard Specifications for Highway Bridges* articles are considered by the BrR export when computing the reinforcement development length.

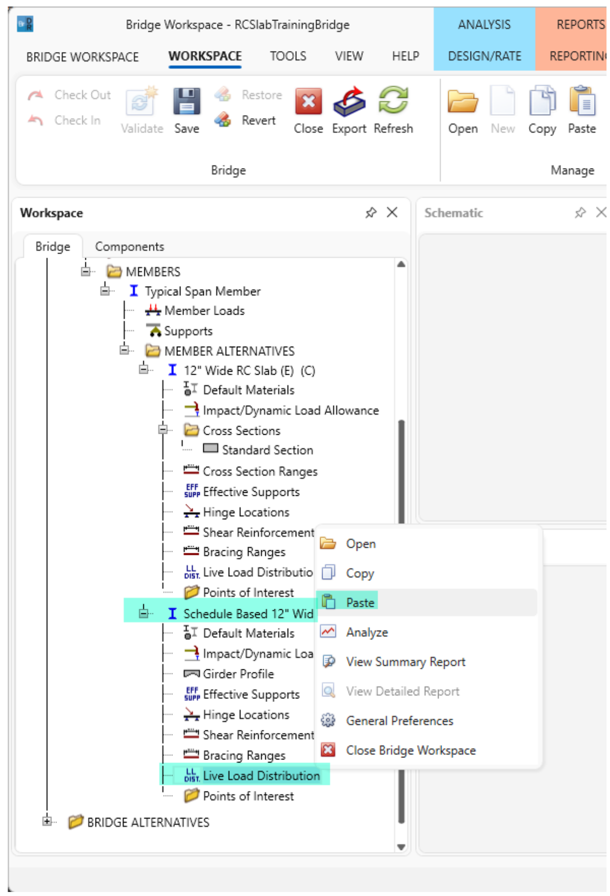
The BrDR export will also check the actual lap lengths of schedule-based reinforcement against required lap lengths and present this information to the designer for their evaluation. BrDR considers bars to be lapped if the vertical distance to their centroids is equal or if their clear cover is equal and the bars overlap along the length of the member. This example does not have any lapped bars .

Live Load Distribution

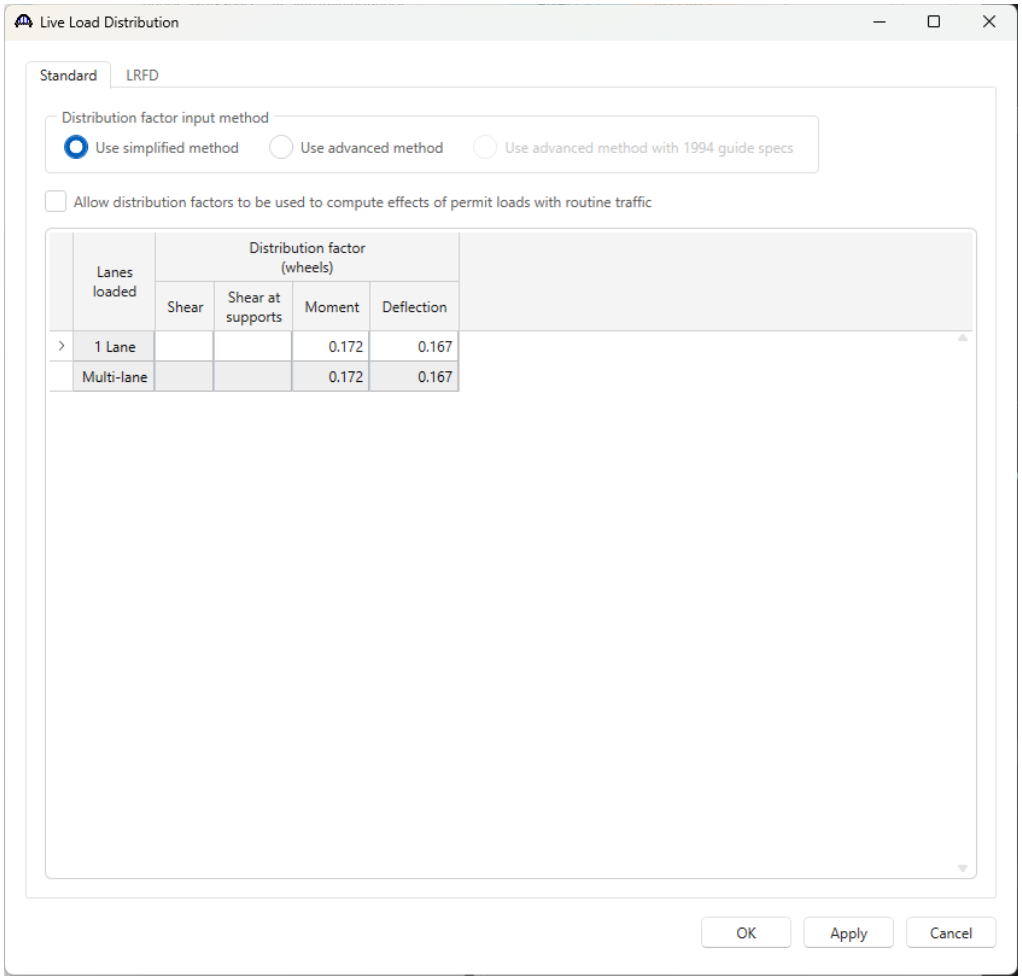
Double click on **Live Load Distribution** on the Bridge Workspace tree to open the **Live Load Distribution** window. Enter data on each tab as shown below:

(Note: In ***Standard*** *tab of this window, if the standard live load distribution factors are not entered, the values can be copied from the cross-section member alternative to the schedule-based member alternative. To copy, right click the* ***Live Load Distribution*** *label under the cross-section member alternative and select* ***Copy*** *from the menu. Then right click the* ***Live Load Distribution*** *label under the schedule-based member alternative and select* ***Paste****. If the Standard factors are not entered for the cross-section based member alternative, then, enter the following distribution factors manually.)*





Standard:



Enter values as shown above and Click **Apply** to apply the data and keep the window open.

The Standard distribution factor for a slab member is computed as follows:

AASHTO Article 3.24.3.2

Distribution width, E, for a wheel is 4 + 0.06S but shall not exceed 7'.

S = span length = 30'

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

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

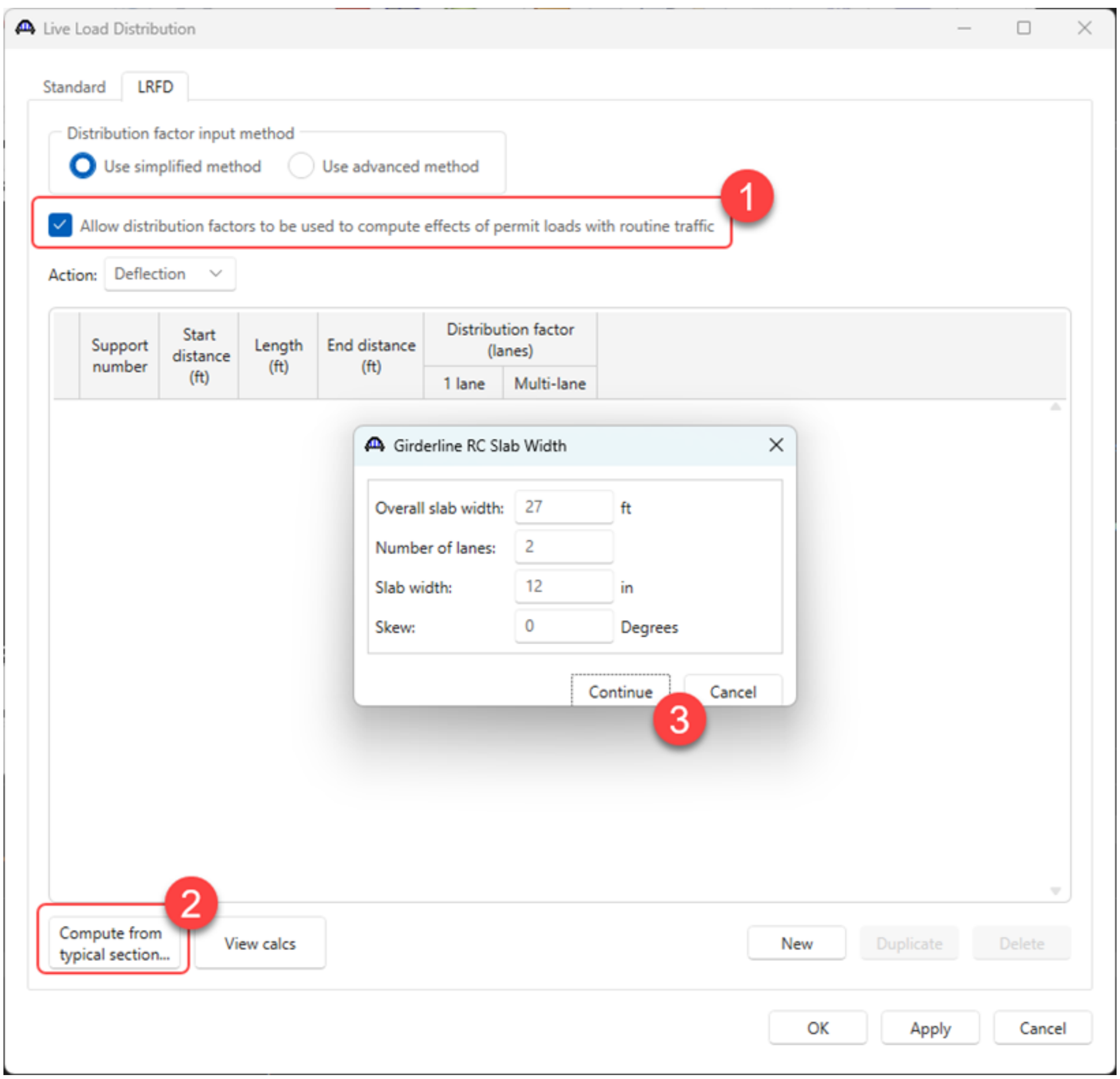
The cross section that will be entered for this member alternative is 12" wide so the wheel distribution factor is per foot. If the cross section were 24" wide, the distribution factor would be computed as 2*0.1724=0.3448.

The deflection distribution factor is calculated as the number of lanes divided by the number of girders. For a reinforced concrete slab bridge, the number of girders is taken as the lane width divided by the strip width. Our lane width is 12 feet, and our strip width is 12" or 1 foot.

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

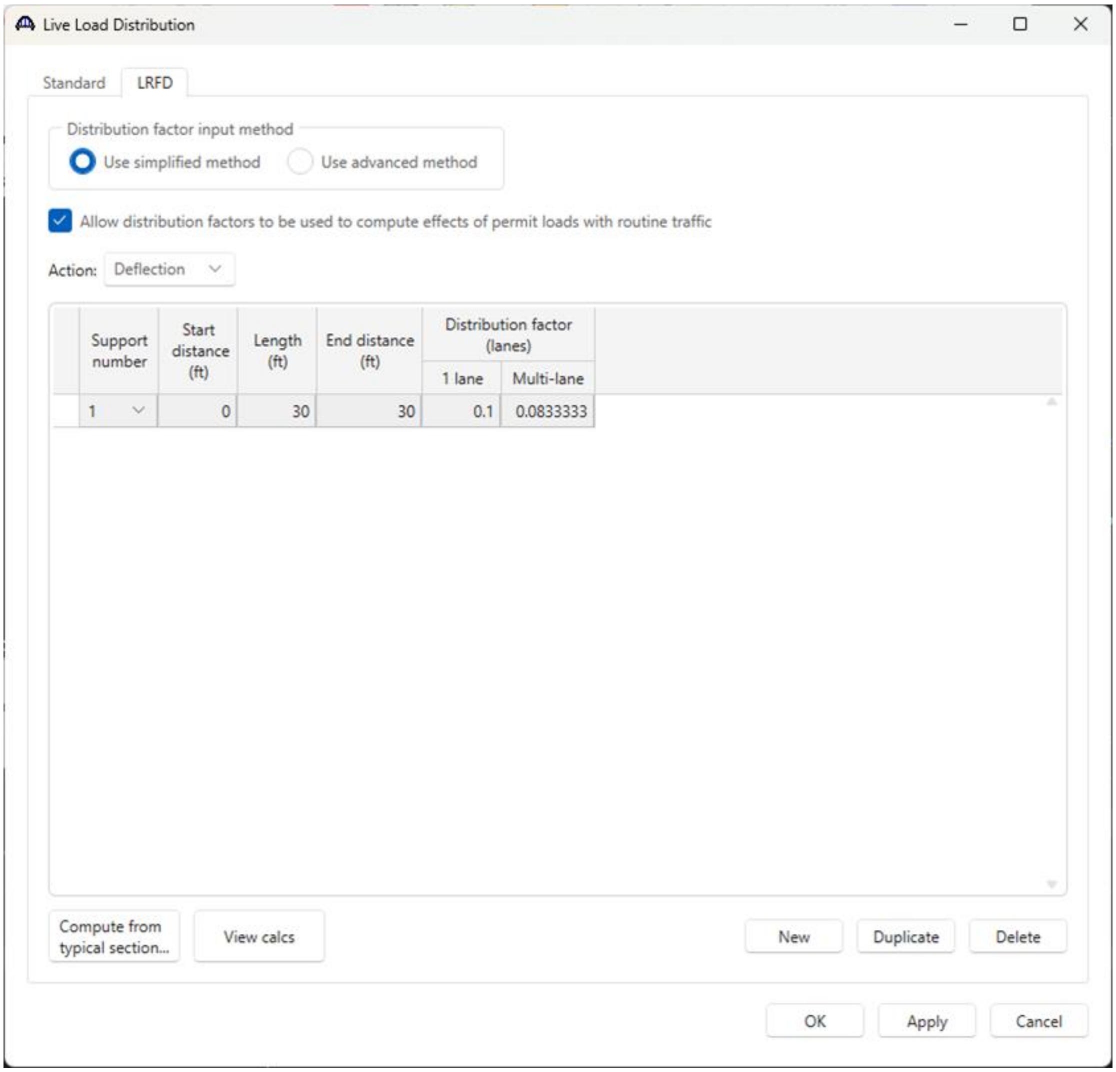
LRFD:

Open the **Live Load Distribution** window, **LRFD** tab. Click the **Compute from Typical Section** button and enter the values as shown below in the pop up window.

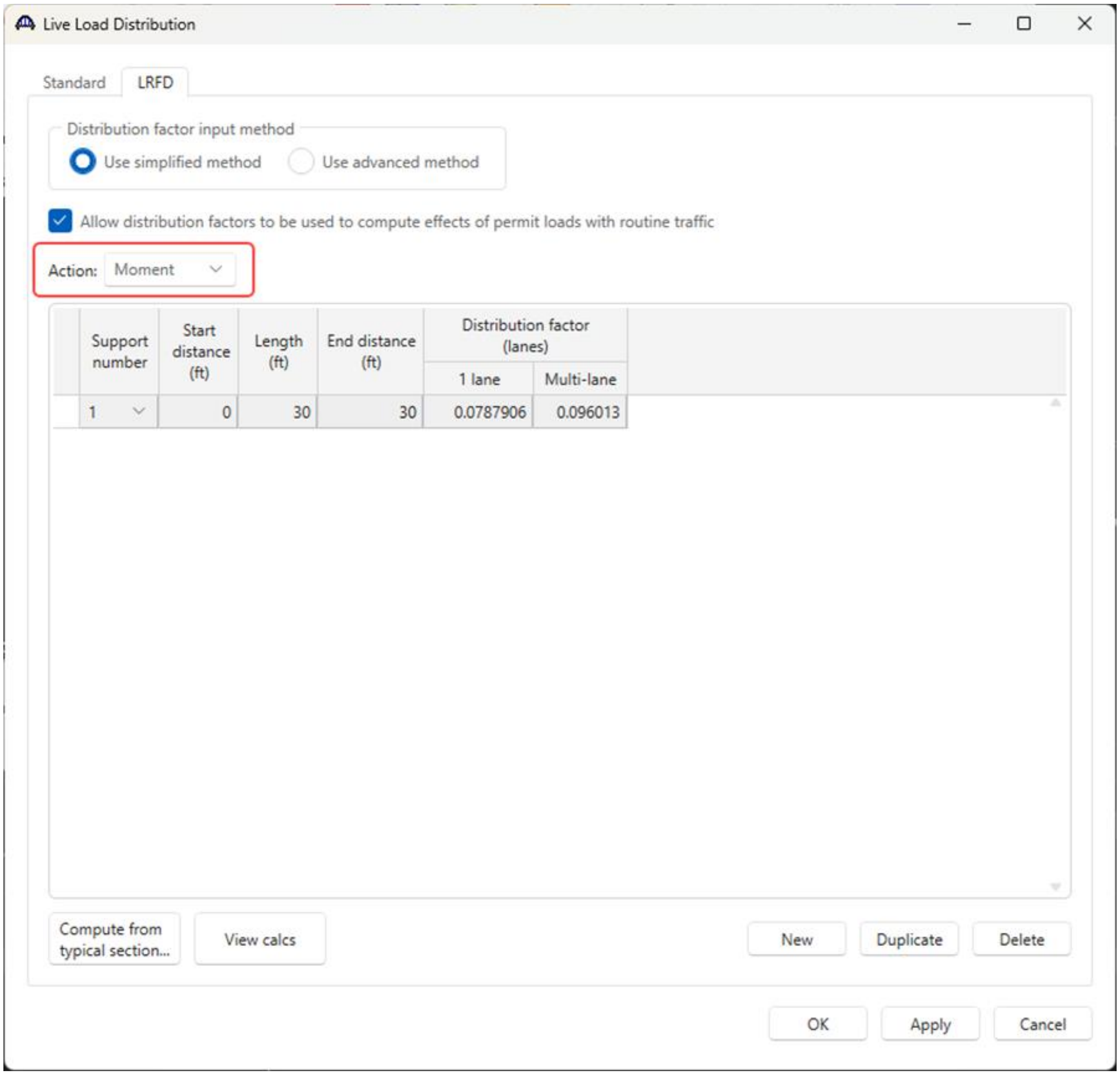


Click the **Continue** button, BrDR will compute the LRFD live load distribution factors. Click **OK** to close the analysis window. Live load distribution factors will be calculated as shown below.

Deflection distribution factors.



Moment and shear have the same distribution factors. The moment distribution factor is shown below.



The live load distribution factors for LRFD analysis are calculated as shown below.

AASHTO Article 4.6.2.3

Equivalent width of strip per lane, E, for both shear and moment single lane:

<u>Single lane</u>

$$E = 10.0 + 5.0\sqrt{L_1 W_1}$$

$$L_1 = span\ length\ \leq 60' = 30'$$

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

$$E = 10 + 5.0 * \sqrt{(30)(27)} = 152.302''$$

$$Moment\ and\ Shear\ DF = \frac{1\ lane}{152.302} = 0.0066\ lane/inch$$

For single lane, the moment and shear distribution factor = 12” member * 0.0066 lanes/inch = 0.079 lanes.

<u>Multi lane</u>

$$E = 84.0 + 1.44\sqrt{L_1 W_1} \ \leq \ \frac{12.0W}{N_L}$$

$L_1 = span\ length\ \ \leq 60' = 30'$

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

$W\ = width\ edge - edge\ of\ bridge = 27'$

$N_L = number\ of\ lanes$

$$E = 84.0 + 1.44\sqrt{(30)(27)} = 124.983\ \leq\ \frac{12(27)}{2} = 162"$$

$$Moment\ and\ Shear\ DF\ = \frac{1\ lane}{124.983} = 0.008\ lane/inch$$

For multi lane, the moment and shear distribution factor = 12” member * 0.008 lanes/inch = 0.096 lanes.

<u>Deflection distribution factor:</u>

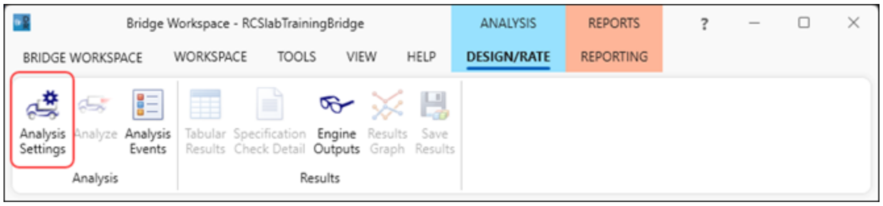
$$Deflection\ DF\ = \frac{\#\ lanes}{(\text{Lane width / Strip width})} * Multiple\ Presence\ Factor$$

$$Single\ lane\ Deflection\ DF\ = \frac{1\ lane}{(12'/1')}(1.2) = 0.100\ lanes$$

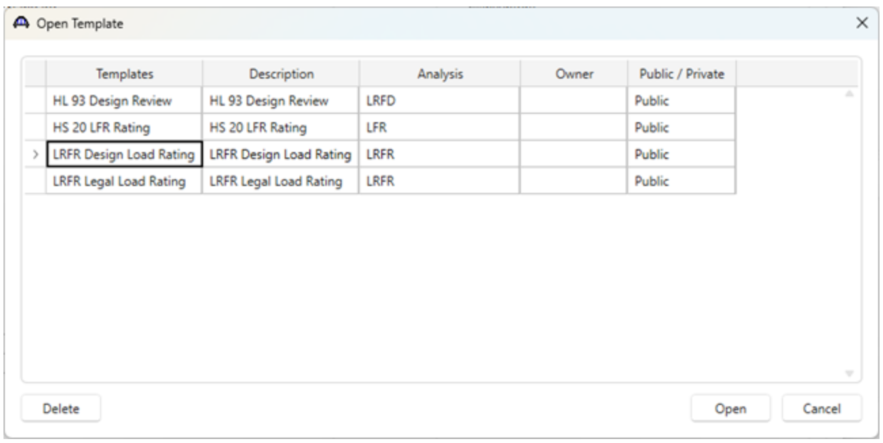
$$Multi\ lane\ Deflection\ DF\ = \frac{2\ lanes}{(12' * 2/1')}(1.0) = 0.0833\ lanes$$

LRFR Analysis

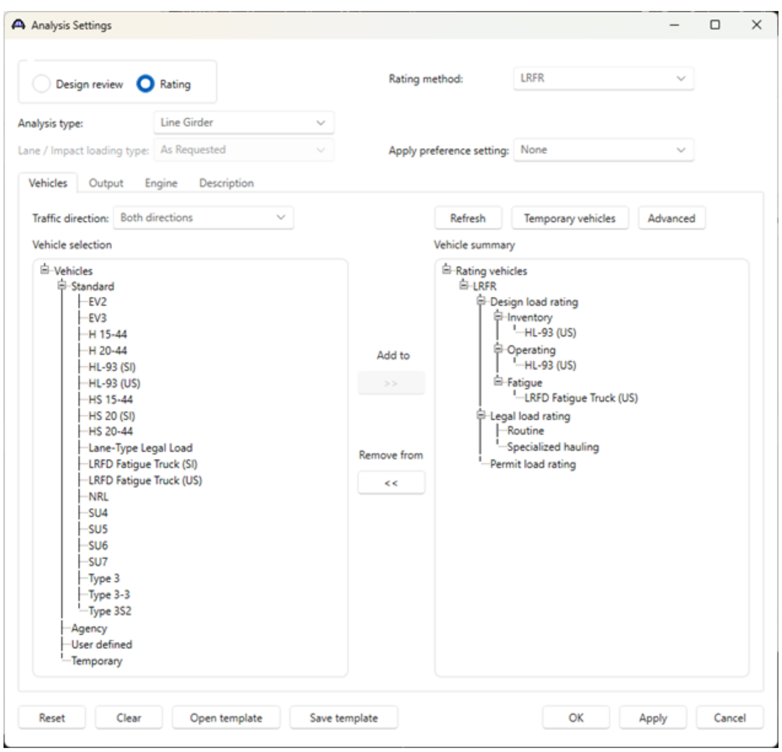
The member alternative can now be analyzed. To perform an **LRFR** rating, select the **Analysis Settings** button from the **Analysis** group of the **DESIGN/RATE** ribbon to open the **Analysis Settings** window as shown below.



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

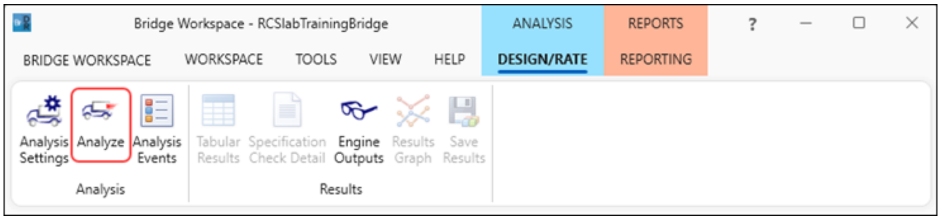


The **Analysis Settings** window will be updated as shown below.

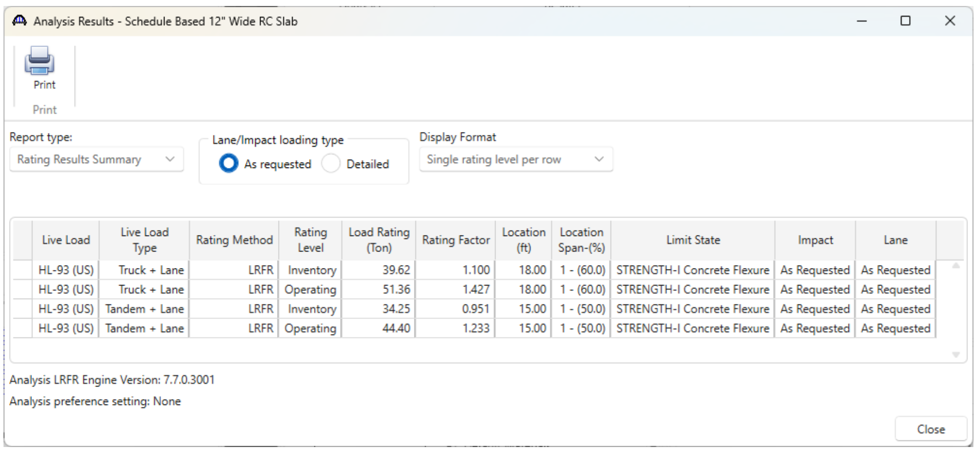


Tabular Results

With the schedule based member alternative – **Schedule Based 12” Wide RC Slab** selected, click the **Analyze** button from the **Analysis** group of the **DESIGN/RATE** ribbon to perform the rating.



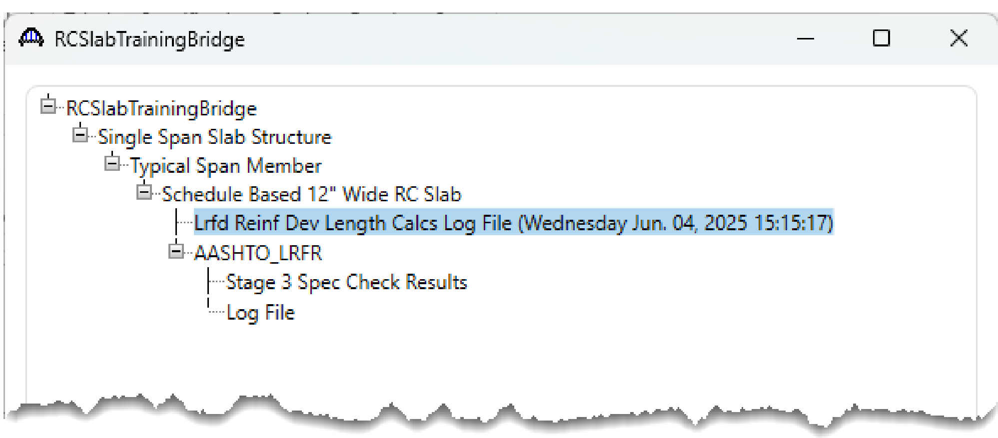
When the rating is finished the results can be reviewed by clicking the **Tabular Results** button on the **Results** group of the ribbon. The window shown below will open.



Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HL-93 (US)	Truck + Lane	LRFR	Inventory	39.62	1.100	18.00	1 - (60.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	51.36	1.427	18.00	1 - (60.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	34.25	0.951	15.00	1 - (50.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	44.40	1.233	15.00	1 - (50.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested

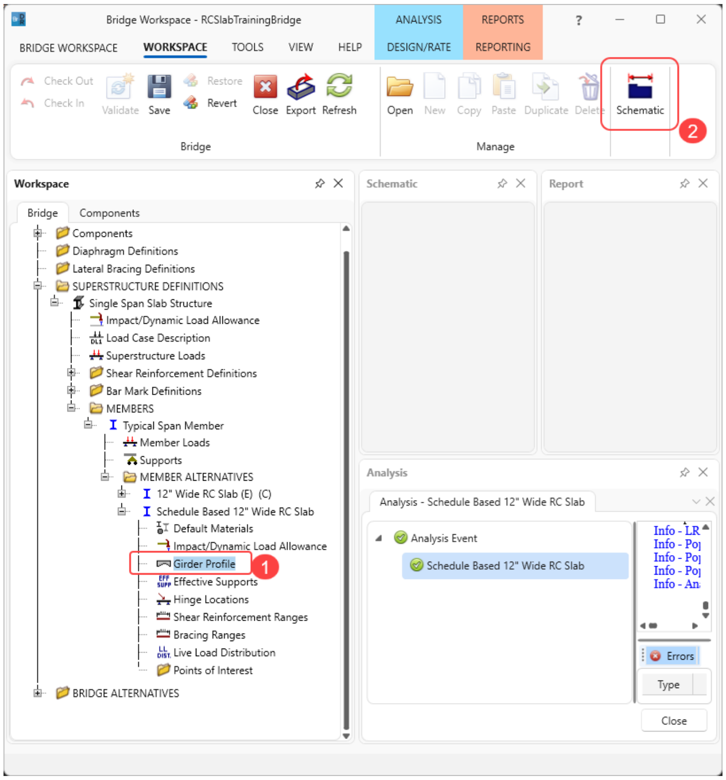
Engine Outputs

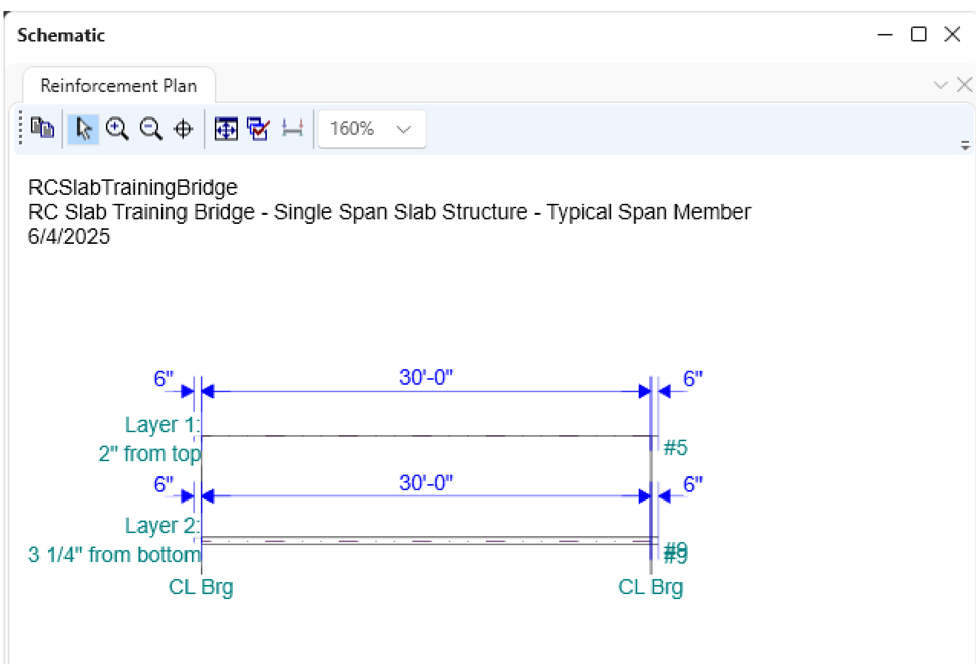
When an analysis or design review is run, a file is created that contains the input and output of the calculations BrDR performed to compute the required development lengths and to check the lap lengths. This file can be accessed from the **Engine Outputs** button on the **DESIGN/RATE** ribbon.



Schematic

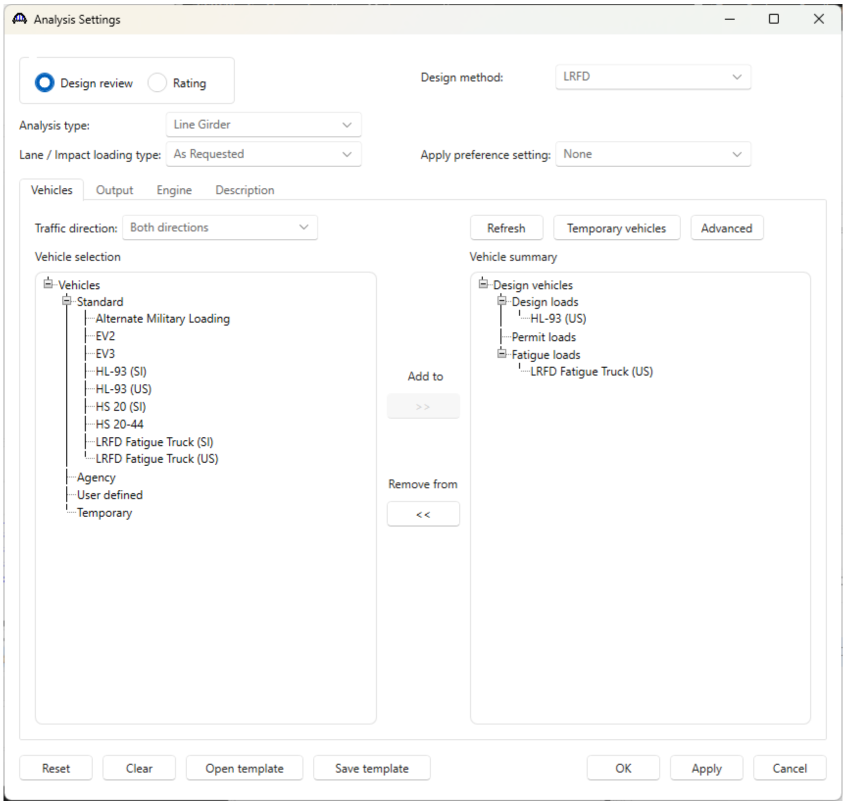
A schematic view of the reinforcement profile is available while the **Girder Profile** label is selected on the **Bridge Workspace** tree.





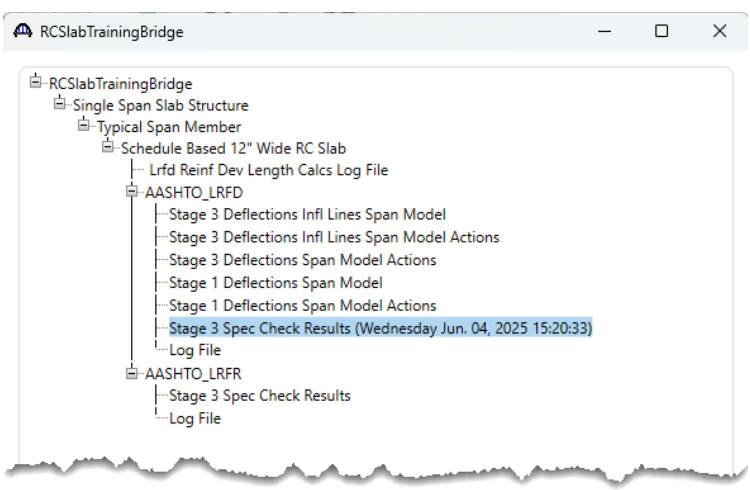
LRFD Design review

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



Engine Outputs

LRFD analysis will generate a spec check results file. Click on the **Engine Outputs** button on the **Results** group of the **Design/Rate** ribbon to open the following window. To view the spec check results, double click on the **Stage 3 Spec Check Results** in this window.



The Spec Check Results match the following results from the cross section based member alternative.

Stage 3 Spec Check Results

Bridge ID : RCSlabTrainingBridge
Bridge : RC Slab Training Bridge
Superstructure Def : Single Span Slab Structure
Member : Typical Span Member
Analysis Preference Setting :

NBI Structure ID : RCSlabTrainingB
Bridge Alt :
Member Alt : Schedule Based 12" Wide RC Slab

AASHTO LRFD Specification, Edition 10, Interim 0

Specification Check Summary

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

Girder Positive Flexure Analysis

Location (ft)	LS	Load Comb	Mr (kip-ft)	Mu (kip-ft)	Design Ratio Mr/Mu	Code
0.000	STR-I	1	24.62	0.00	99.000	Pass
1.222	STR-I	1	78.85	18.65	4.228	Pass
2.122	STR-I	1	116.22	32.38	3.590	Pass
3.000	STR-I	1	116.22	45.78	2.539	Pass
6.000	STR-I	2	116.22	79.70	1.458	Pass
9.000	STR-I	2	116.22	103.77	1.120	Pass
12.000	STR-I	2	116.22	117.31	0.991	Fail
15.000	STR-I	2	116.22	120.34	0.966	Fail
18.000	STR-I	2	116.22	117.31	0.991	Fail
21.000	STR-I	2	116.22	103.77	1.120	Pass
24.000	STR-I	2	116.22	79.70	1.458	Pass
27.000	STR-I	1	116.22	45.78	2.539	Pass
27.878	STR-I	1	116.22	32.38	3.590	Pass
28.778	STR-I	1	78.85	18.65	4.228	Pass
30.000	STR-I	1	24.62	0.00	99.000	Pass

NR = Spec check not required at this location