

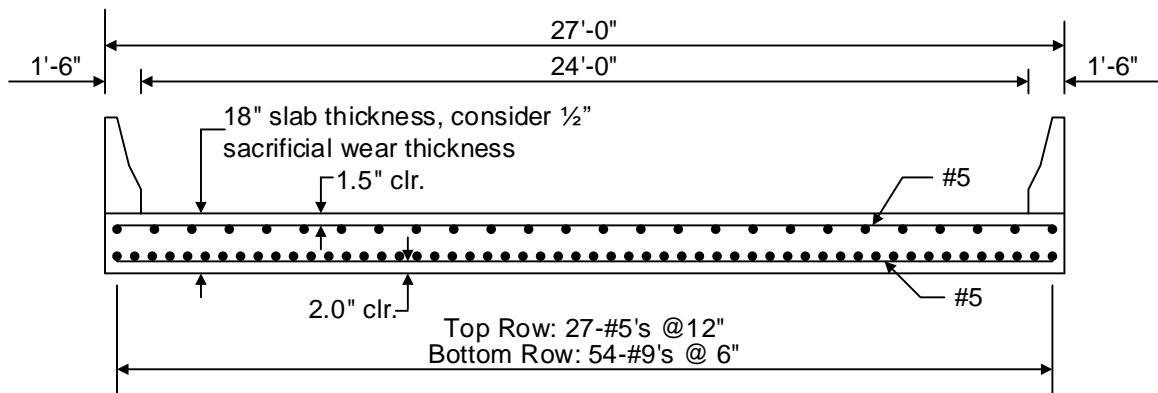
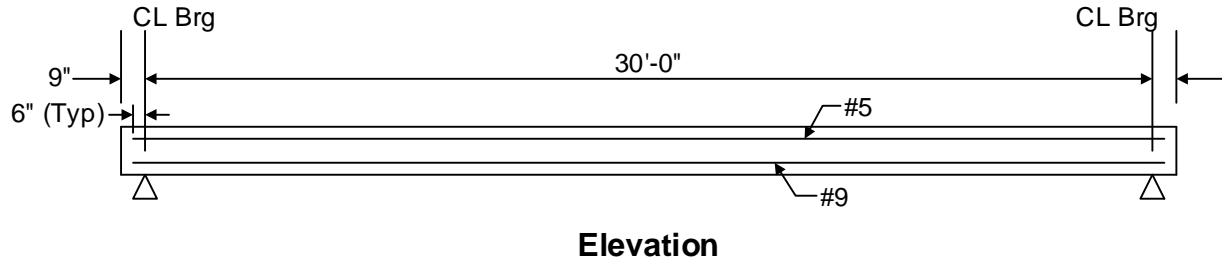
AASHTOWare BrDR 7.5.0

Reinforced Concrete Structure Tutorial
RC2 – Reinforced Concrete Slab Example

RC2 – Reinforced Concrete Slab Example

Introduction – Elevation and Typical section

RC2 - Reinforced Concrete Slab Example



Material Properties

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

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

Parapets

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

RC2 – Reinforced Concrete Slab Example

BrDR Training

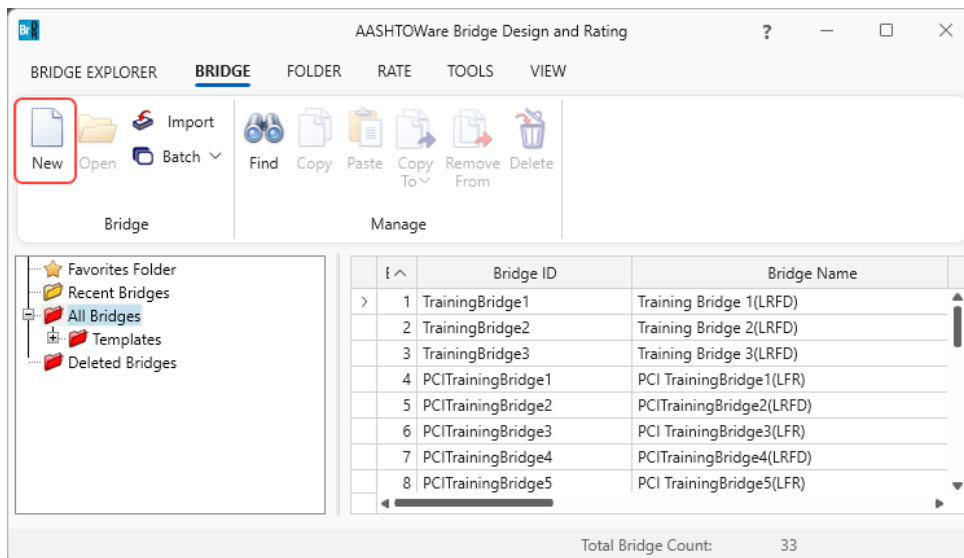
RC2 - Reinforced Concrete Slab Example

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:



RC2 – Reinforced Concrete Slab Example

The screenshot shows a software dialog box titled "RC Slab Training Bridge". At the top, there are two text input fields: "Bridge ID:" containing "RC Slab Training Bridge" and "NBI structure ID (8):" containing "RC Slab Training B". To the right of these fields are three checkboxes: "Template" (unchecked), "Bridge completely defined" (unchecked), and "Superstructures" (checked). Below these are two more checkboxes: "Culverts" (unchecked) and "Substructures" (unchecked).

The main area of the dialog is divided into several tabs: "Description", "Description (cont'd)", "Alternatives", "Global reference point", "Traffic", and "Custom agency fields". The "Description" tab is active. It contains the following fields:

- "Name:" with the text "RC Slab Training Bridge".
- "Year built:" with an empty text input field.
- "Description:" with a text area containing "Reinforced concrete slab example bridge" and "Single span, girderline".
- "Location:" with an empty text input field.
- "Length:" with an empty text input field followed by "ft".
- "Facility carried (7):" with an empty text input field.
- "Route number:" with the text "-1".
- "Feat. intersected (6):" with an empty text input field.
- "Mi. post:" with an empty text input field.
- "Default units:" with a dropdown menu set to "US Customary".

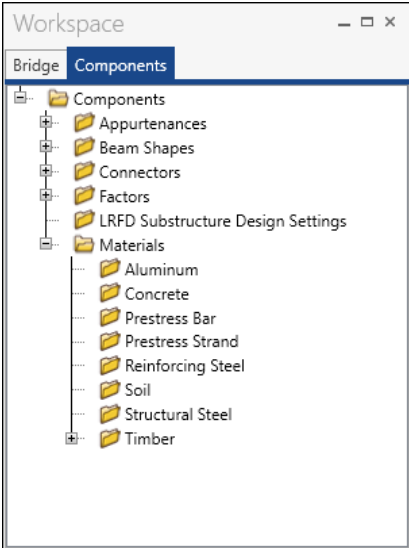
At the bottom left, there is a "Bridge association..." button and three checkboxes: "BrR" (checked), "BrD" (checked), and "BrM" (unchecked). At the bottom right, there are three buttons: "OK", "Apply", and "Cancel".

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

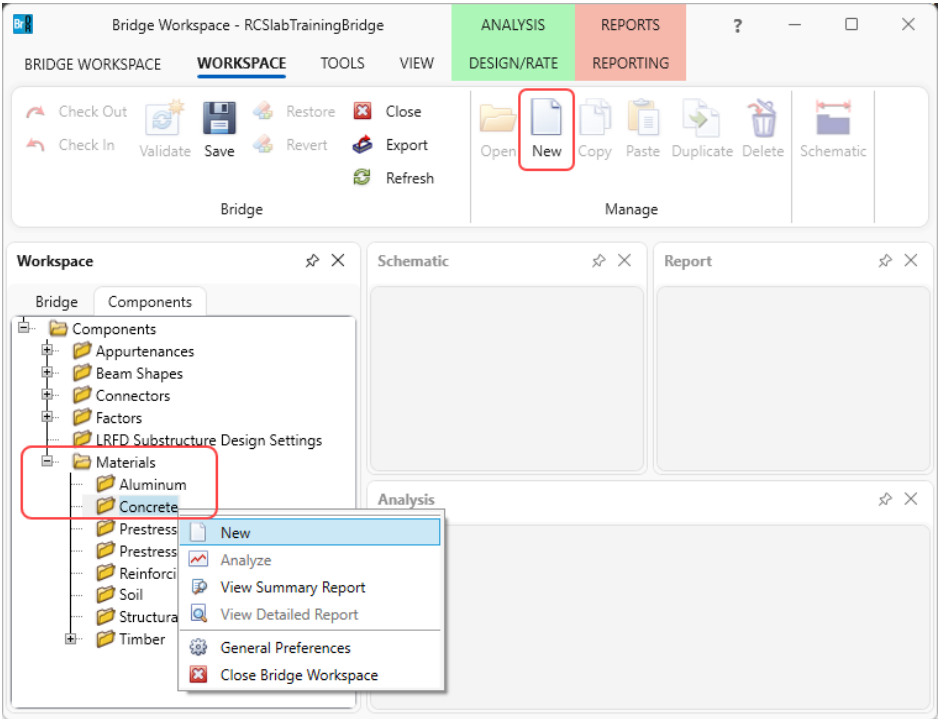
RC2 – Reinforced Concrete Slab Example

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:

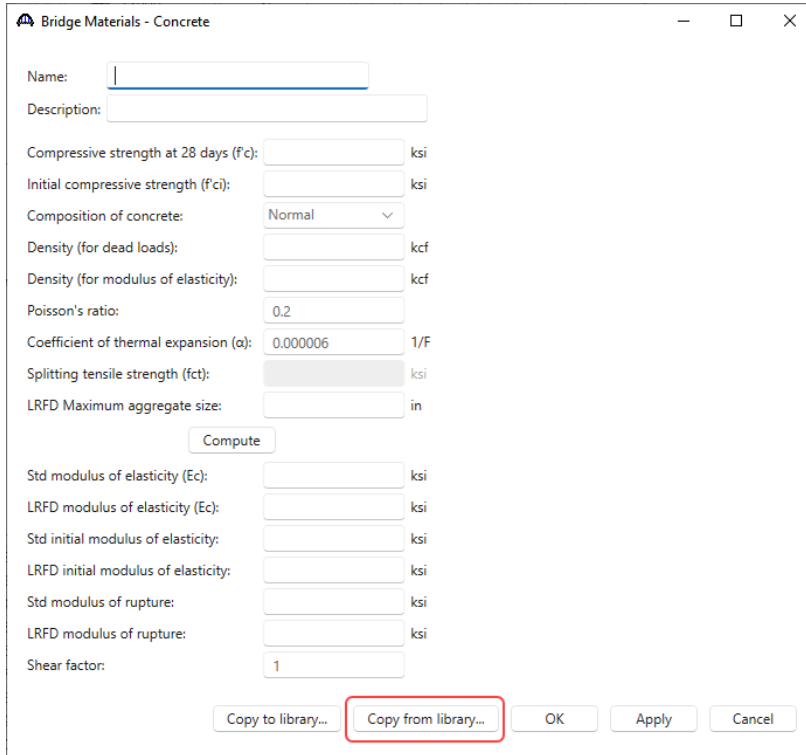


To add a new concrete material, click on **Concrete** in the **Components** tree and select **New** from the **Manage** group of the **WORKSPACE** ribbon (or right mouse click on **Concrete** and select **New**).



RC2 – Reinforced Concrete Slab Example

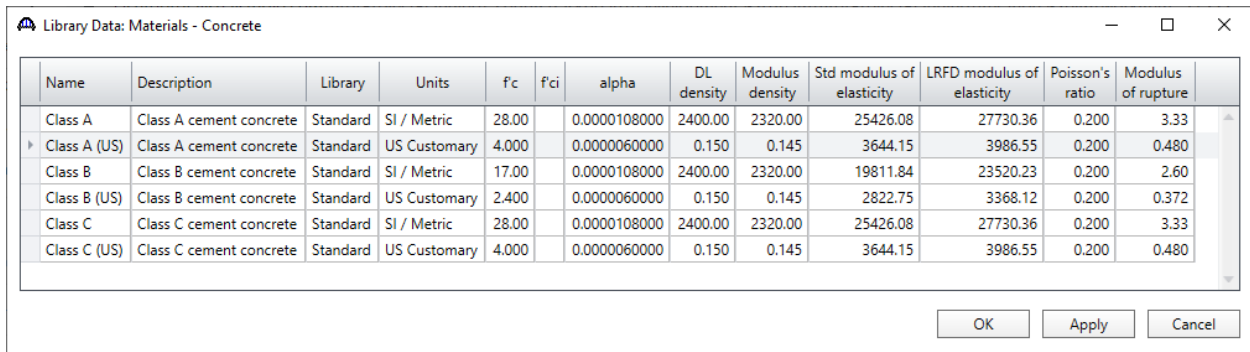
Add the concrete material by selecting from the Concrete Materials Library by clicking the **Copy from Library** button.



The dialog box titled "Bridge Materials - Concrete" contains the following fields and controls:

- Name:
- Description:
- Compressive strength at 28 days (f_c): ksi
- Initial compressive strength (f_{ci}): ksi
- Composition of concrete: Normal (dropdown)
- Density (for dead loads): kcf
- Density (for modulus of elasticity): kcf
- Poisson's ratio: 0.2
- Coefficient of thermal expansion (α): 0.000006 1/F
- Splitting tensile strength (f_{ct}): ksi
- LRFD Maximum aggregate size: in
- Compute button
- Std modulus of elasticity (E_c): ksi
- LRFD modulus of elasticity (E_c): ksi
- Std initial modulus of elasticity: ksi
- LRFD initial modulus of elasticity: ksi
- Std modulus of rupture: ksi
- LRFD modulus of rupture: ksi
- Shear factor: 1
- Buttons: Copy to library..., Copy from library... (highlighted with a red box), OK, Apply, Cancel

The following window opens:



The dialog box titled "Library Data: Materials - Concrete" displays a table of concrete materials:

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

Buttons: OK, Apply, Cancel

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

RC2 – Reinforced Concrete Slab Example

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

The screenshot shows a dialog box titled "Bridge Materials - Concrete" with the following fields and values:

Property	Value	Unit
Name:	Class A (US)	
Description:	Class A cement concrete	
Compressive strength at 28 days (f _c):	4.0000006	ksi
Initial compressive strength (f _{ci}):		ksi
Composition of concrete:	Normal	
Density (for dead loads):	0.15	kcf
Density (for modulus of elasticity):	0.145	kcf
Poisson's ratio:	0.2	
Coefficient of thermal expansion (α):	0.000006	1/F
Splitting tensile strength (f _{ct}):		ksi
LRFD Maximum aggregate size:		in
Compute		
Std modulus of elasticity (E _c):	3644.149254	ksi
LRFD modulus of elasticity (E _c):	3986.548657	ksi
Std initial modulus of elasticity:		ksi
LRFD initial modulus of elasticity:		ksi
Std modulus of rupture:		ksi
LRFD modulus of rupture:	0.479857	ksi
Shear factor:	1	

Buttons at the bottom: Copy to library..., Copy from library..., OK, Apply, Cancel

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

RC2 – Reinforced Concrete Slab Example

Add the following reinforcement steel in the same manner.

Bridge Materials - Reinforcing Steel

Name: Grade 60

Description: 60 ksi reinforcing steel

Material properties

Specified yield strength (fy): 60.0000087 ksi

Modulus of elasticity (Es): 29000.004206 ksi

Ultimate strength (Fu): 90.0000131 ksi

Type

Plain

Epoxy

Galvanized

Copy to library... Copy from library... OK Apply Cancel

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.

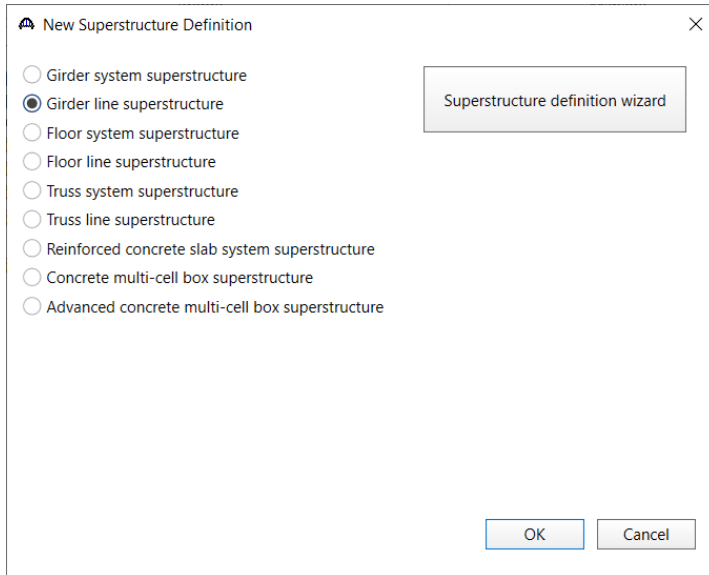
RC2 – Reinforced Concrete Slab Example

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:



New Superstructure Definition

Girder system superstructure

Girder line superstructure

Floor system superstructure

Floor line superstructure

Truss system superstructure

Truss line superstructure

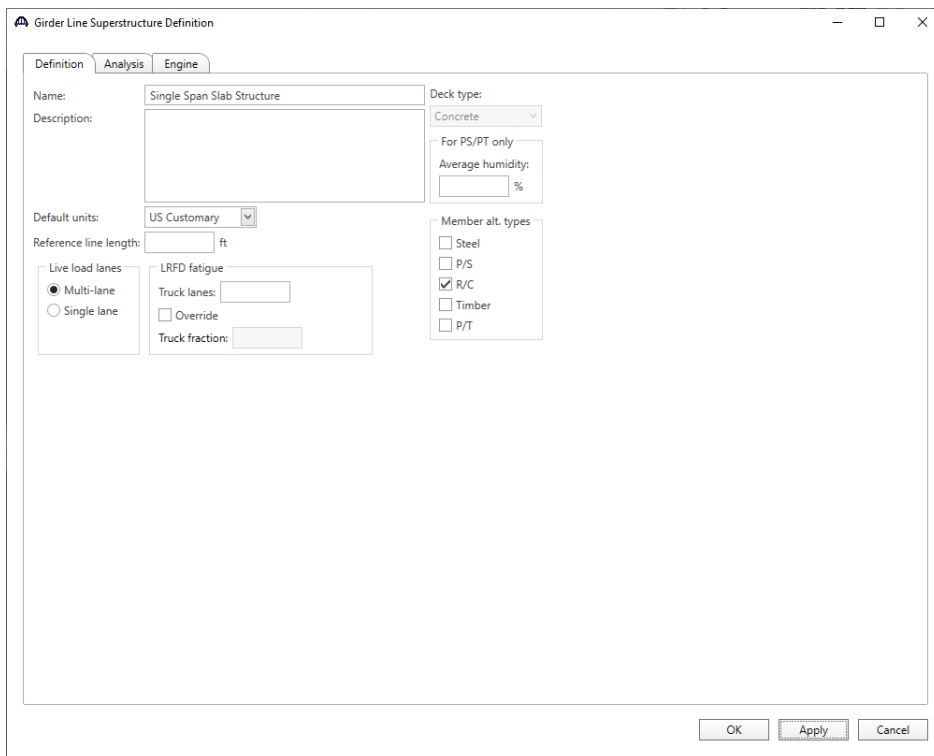
Reinforced concrete slab system superstructure

Concrete multi-cell box superstructure

Advanced concrete multi-cell box superstructure

Superstructure definition wizard

OK Cancel



Girder Line Superstructure Definition

Definition Analysis Engine

Name: Single Span Slab Structure

Description:

Deck type: Concrete

For PS/PT only

Average humidity: %

Default units: US Customary

Reference line length: ft

Live load lanes

Multi-lane

Single lane

LRFD fatigue

Truck lanes:

Override

Truck fraction:

Member alt. types

Steel

P/S

R/C

Timber

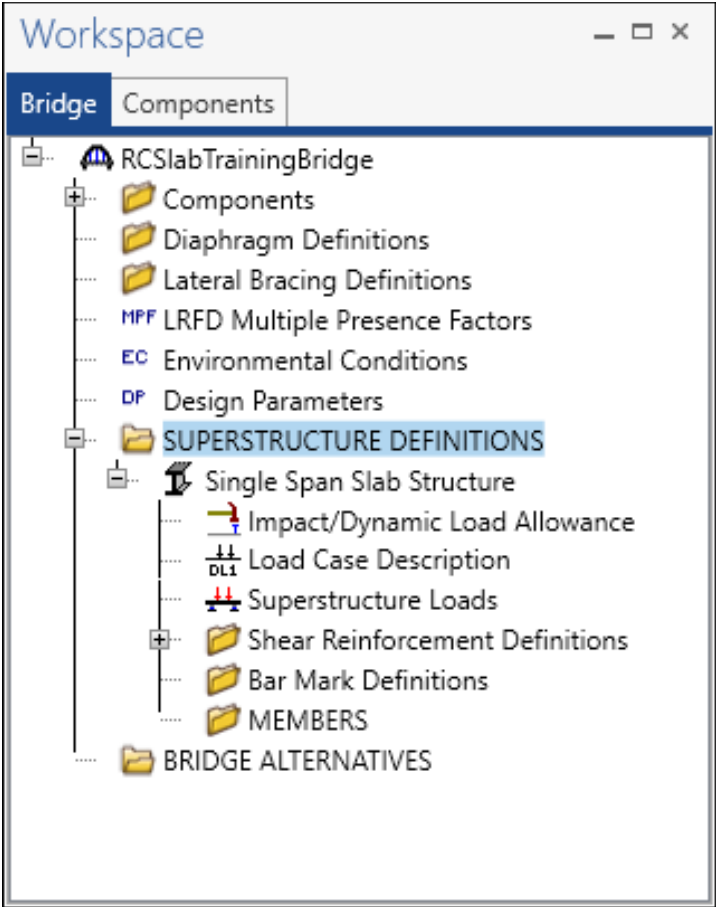
P/T

OK Apply Cancel

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

RC2 – Reinforced Concrete Slab Example

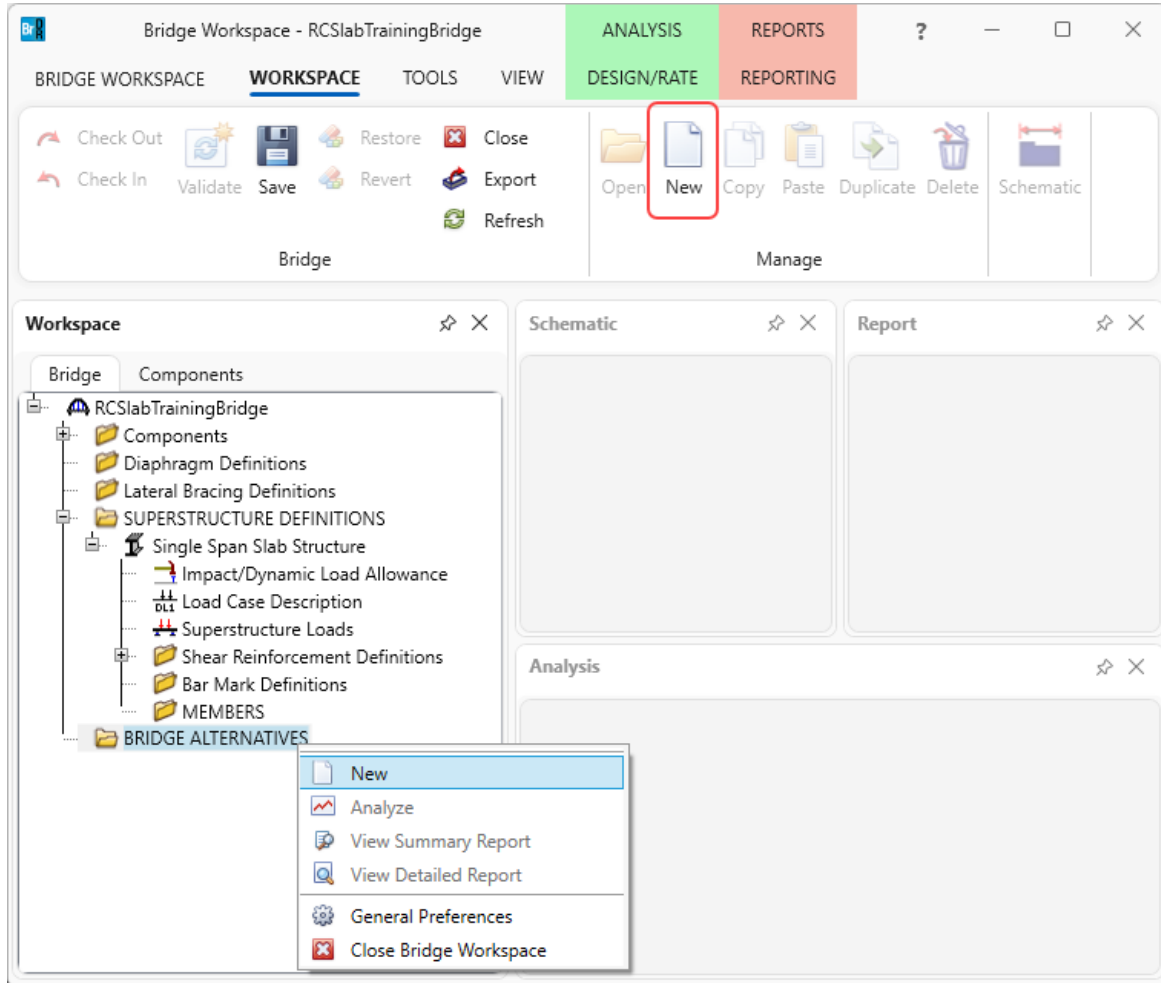
The partially expanded **Bridge Workspace** tree is shown below:



RC2 – Reinforced Concrete Slab Example

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).



RC2 – Reinforced Concrete Slab Example

Enter the following data.

Bridge Alternative

Alternative name: Bridge Alternative 1

Description Substructures

Description:

Horizontal curvature

Reference line length: ft

Start bearing End bearing

Starting station: ft

Bearing: N 0° 0' 0.00" E

Global positioning

Distance: 0 ft

Offset: 0 ft

Elevation: ft

Bridge alignment

Curved

Tangent, curved, tangent

Tangent, curved

Curved, tangent

Start tangent length: ft

Curve length: ft

Radius: ft

Direction: Left

End tangent length: ft

Superstructure wizard...

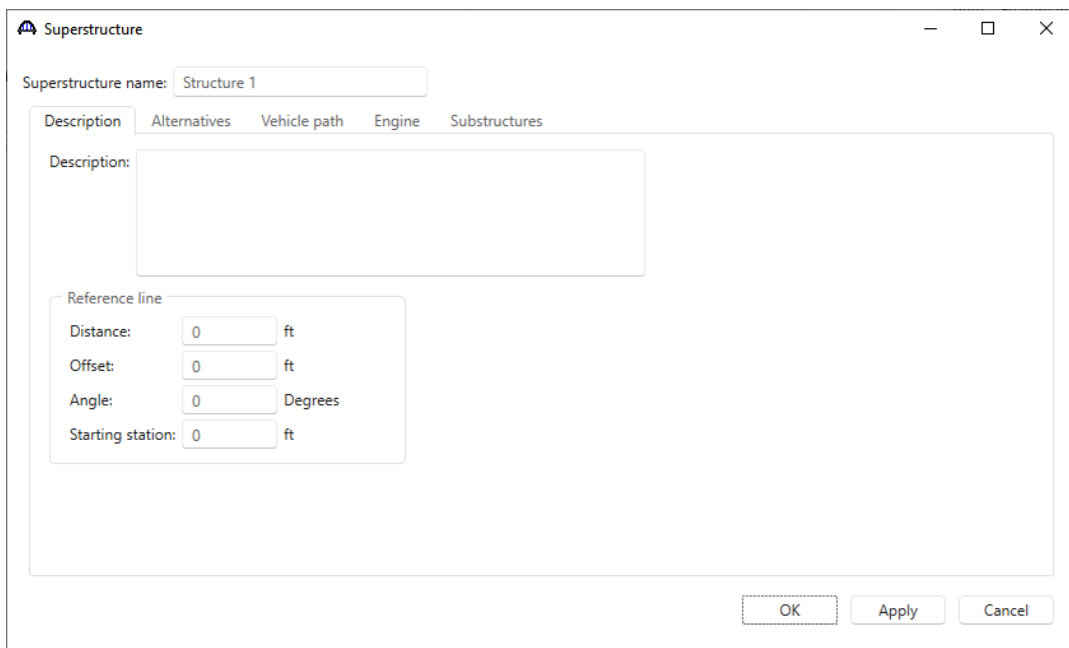
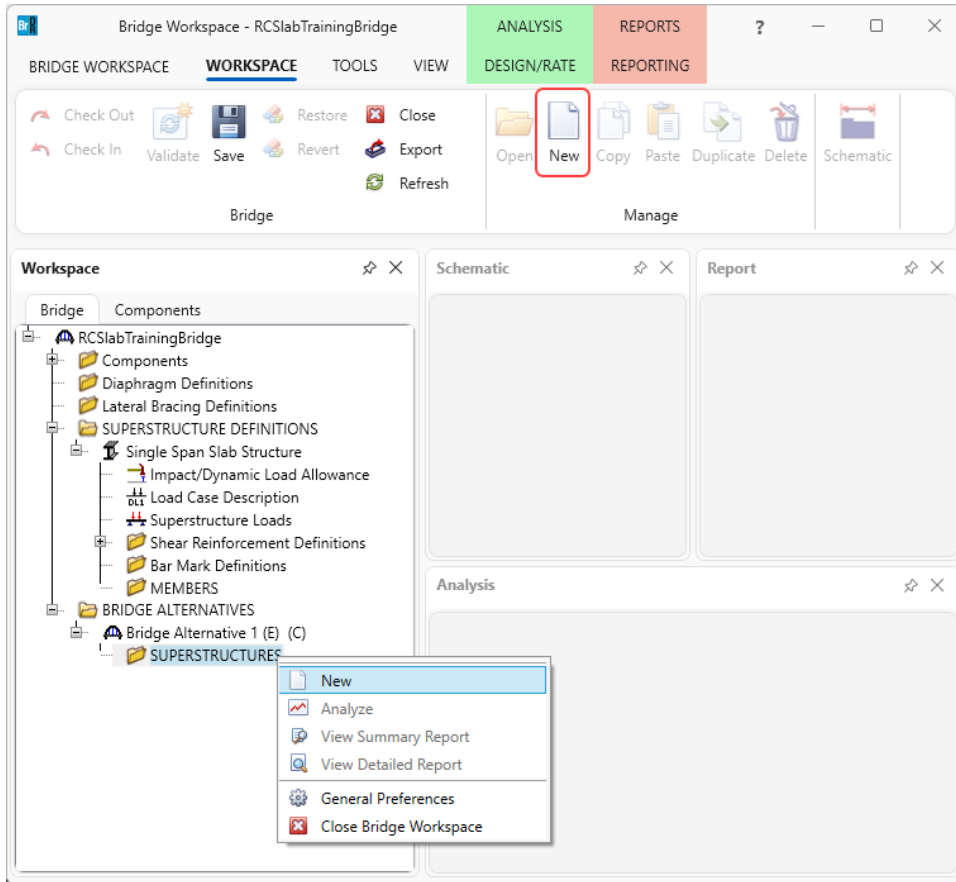
Culvert wizard...

OK Apply Cancel

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

RC2 – Reinforced Concrete Slab Example

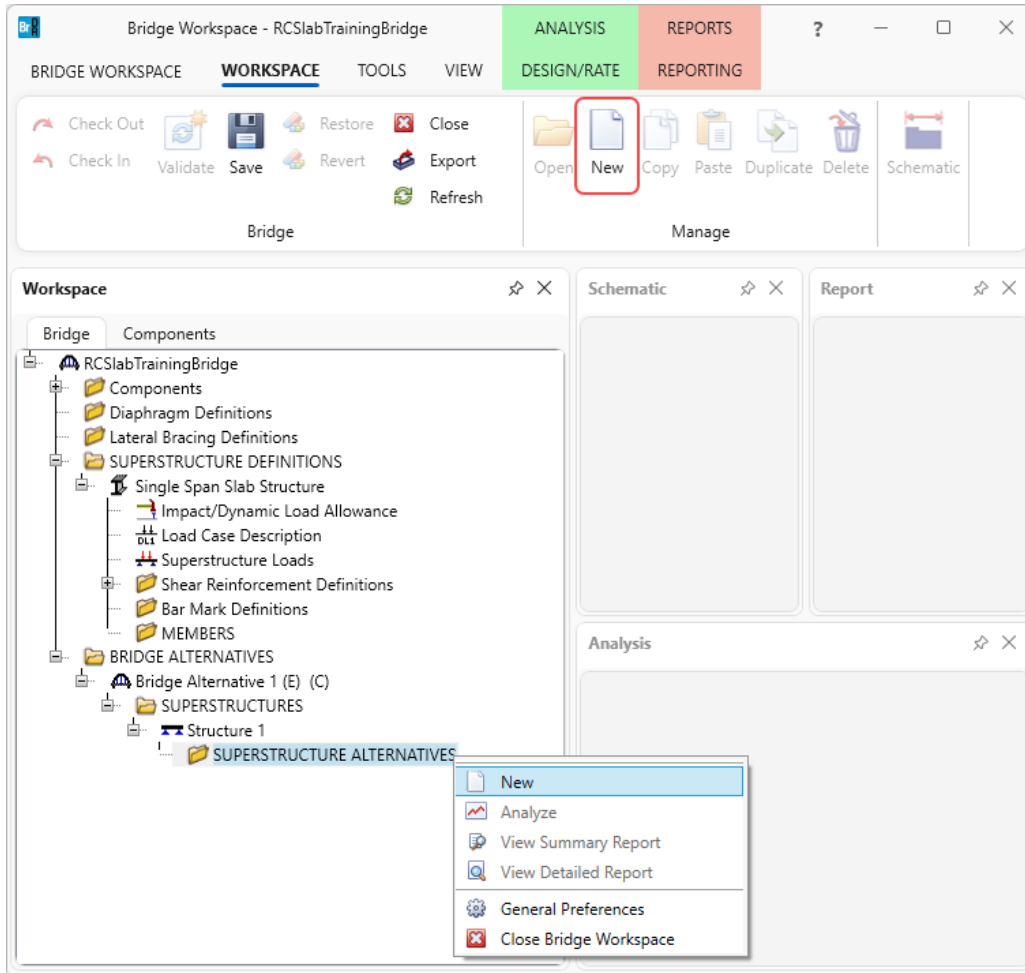
Expand the **Bridge Alternative 1** node in the **Bridge Workspace** tree by clicking the **+** button. Double-click on the **SUPERSTRUCTURES** node (or select **SUPERSTRUCTURES**, click **New** from the **Manage** group of the **WORKSPACE** ribbon) and enter the following new superstructure.



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

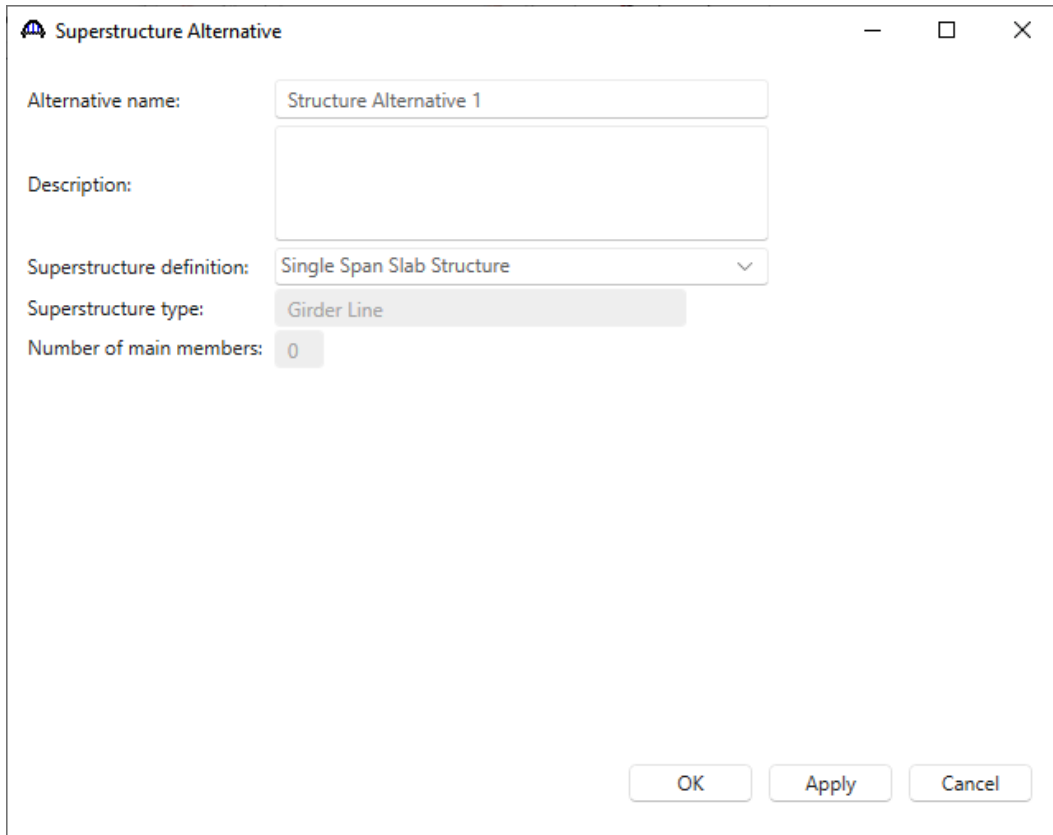
RC2 – Reinforced Concrete Slab Example

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.



RC2 – Reinforced Concrete Slab Example

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

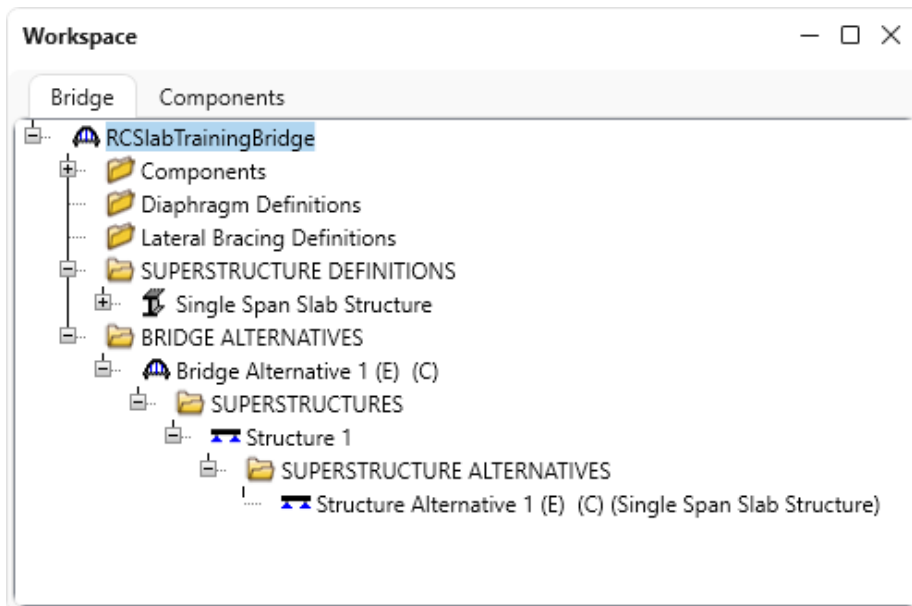


The screenshot shows a dialog box titled "Superstructure Alternative". It contains the following fields and controls:

- Alternative name:** A text input field containing "Structure Alternative 1".
- Description:** An empty text area.
- Superstructure definition:** A dropdown menu with "Single Span Slab Structure" selected.
- Superstructure type:** A dropdown menu with "Girder Line" selected.
- Number of main members:** A text input field containing "0".

At the bottom right of the dialog, there are three buttons: "OK", "Apply", and "Cancel".

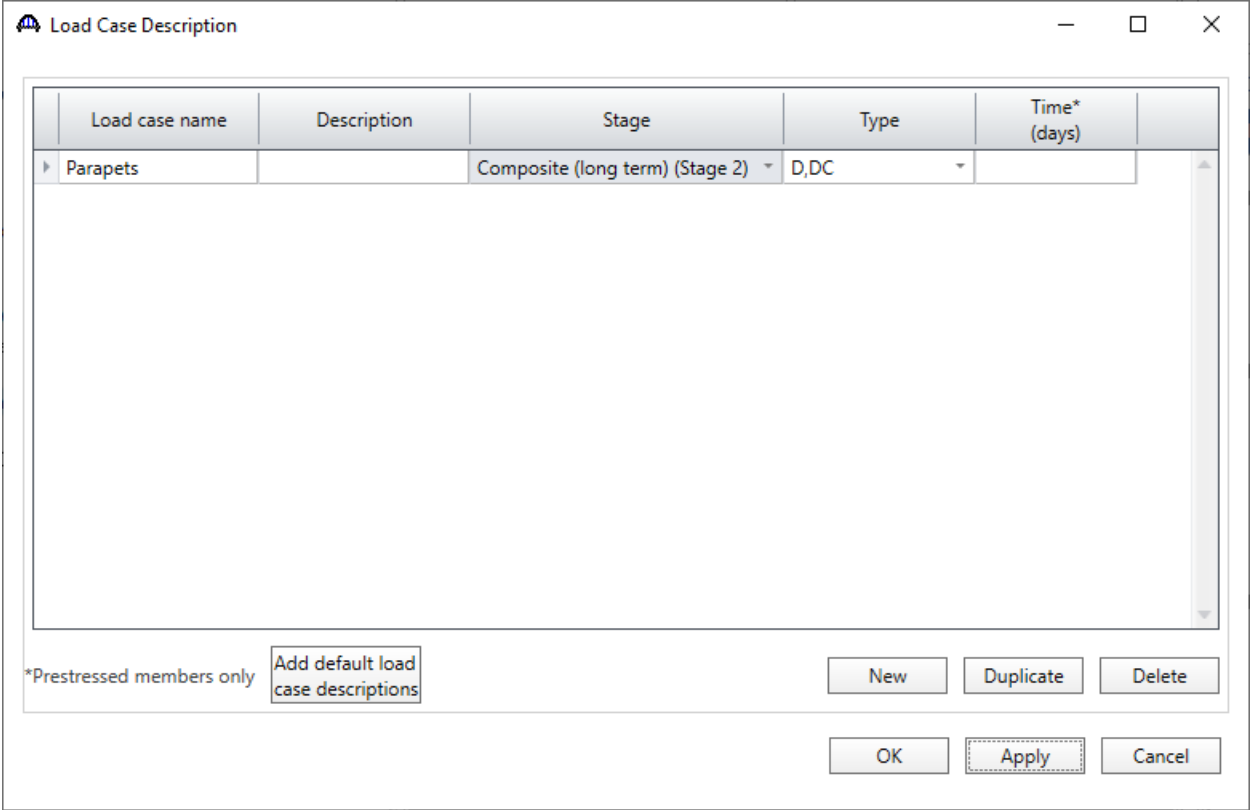
The partially expanded **Bridge Workspace tree** is shown below.



RC2 – Reinforced Concrete Slab Example

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.

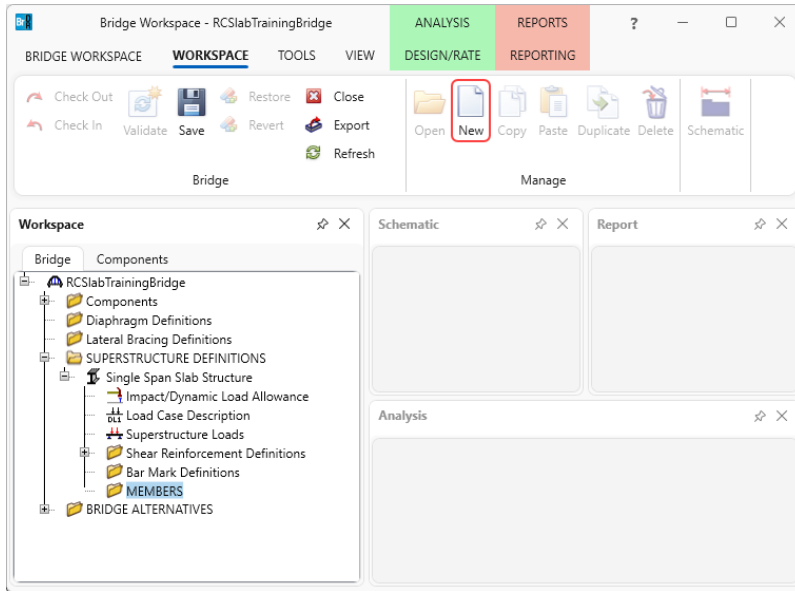


Click **OK** to apply the data and close the window.

RC2 – Reinforced Concrete Slab Example

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 name: Typical Span Member

Description:

Modeling
 Open girder MCB
 Frame member simplified definition

Existing	Current	Member alternative name	Description
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Number of spans: 1
Girder spacing: ft

Span no.	Span length (ft)
> 1	30

Deck concrete crack control parameter (Z): kip/in
Deck exposure factor:

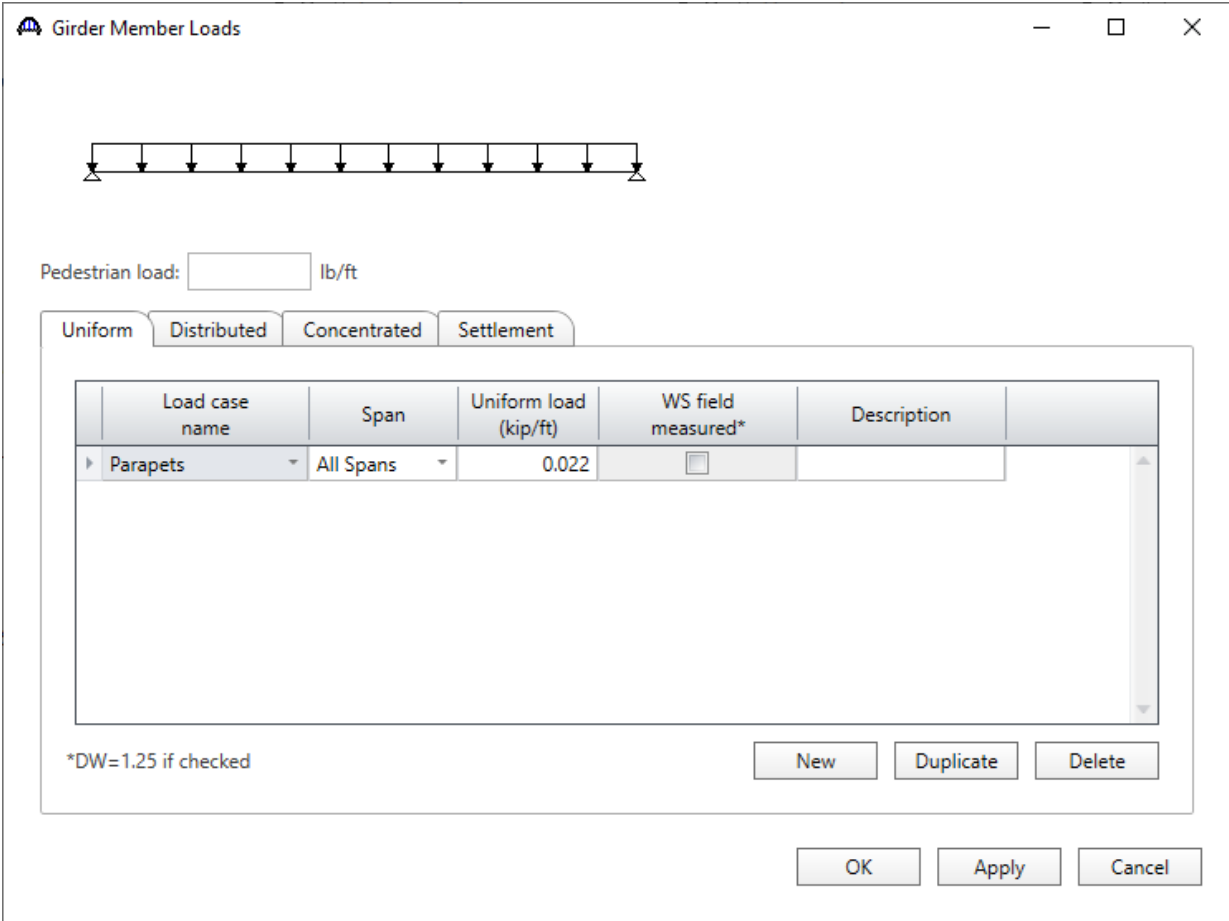
Member location
 Interior Exterior

OK Apply Cancel

RC2 – Reinforced Concrete Slab Example

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 $(2*300 \text{ lb/ft})/27' = 22 \text{ lb/ft}$.



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

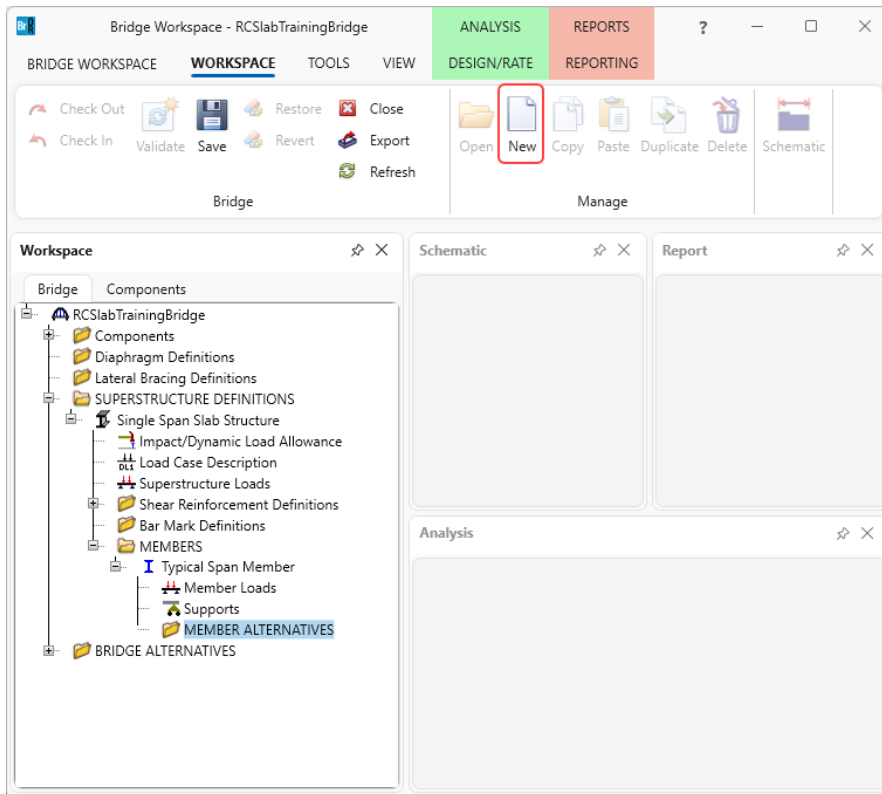
RC2 – Reinforced Concrete Slab Example

Cross Section Based Member Alternative

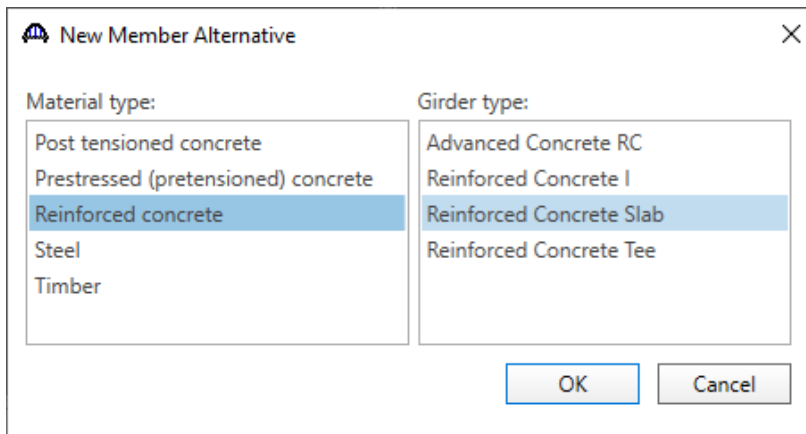
This portion of the example describes the creation of a cross-section based member alternative.

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.

RC2 – Reinforced Concrete Slab Example

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

The screenshot shows the 'Member Alternative Description' dialog box. The 'Member alternative' is '12" Wide RC Slab'. The 'Description' tab is active. The 'Material type' is 'Reinforced Concrete', 'Girder type' is 'Reinforced Concrete Slab', and 'Modeling type' is 'Open Girder'. The 'Default units' are 'US Customary'. Under 'Girder property input method', 'Cross-section based' is selected. 'End bearing locations' are 'Left: 9 in' and 'Right: 9 in'. The 'Sustained modular ratio factor' is '2'. Under 'Self load', 'Load case' is 'Engine Assigned' and 'Default rating method' is 'LFR'. The 'Additional self load' is '0.00625 kip/ft', which is highlighted with a red box. Other fields for 'Additional self load' (percentage), 'Crack control parameter (Z)', and 'Exposure factor' are empty.

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.

$$(\frac{1}{2}\text{''})/12 \times 0.150 \text{ kcf} = 0.0063 \text{ k/ft}$$

RC2 – Reinforced Concrete Slab Example

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.

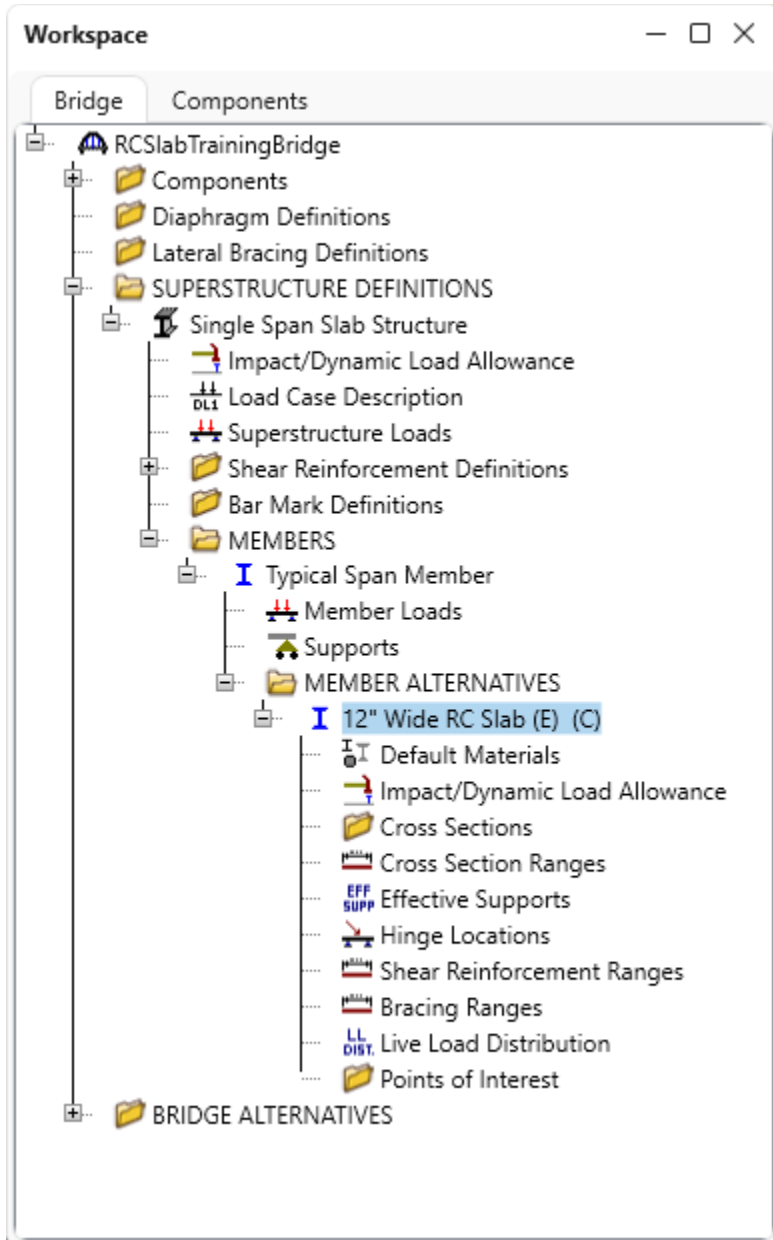
The screenshot shows the 'Member Alternative Description' dialog box with the 'Control options' tab selected. The member alternative is '12" Wide RC Slab'. The dialog is divided into four sections: LRFD, LRFR, LFR, and ASR. Each section contains a list of options with checkboxes and radio buttons. The 'Ignore shear' checkbox in the LFR section is checked and highlighted with a red box. The 'OK' button is highlighted with a blue border.

Section	Option	State
LRFD	Generate at tenth points except supports	Checked
	Generate at support points	Checked
	Generate at support face & critical shear points	Checked
	Generate at section change points	Checked
	Generate at user-defined points	Checked
Shear computation method	Ignore	Selected
	General procedure	Not Selected
	General procedure - Appendix B5	Not Selected
	Simplified procedure	Not Selected
LRFR	Generate at tenth points except supports	Checked
	Generate at support points	Checked
	Generate at support face & critical shear points	Checked
	Generate at section change points	Checked
	Generate at user-defined points	Checked
Shear computation method	Ignore	Selected
	General procedure	Not Selected
	General procedure - Appendix B5	Not Selected
	Simplified procedure	Not Selected
LFR	Generate at tenth points except supports	Checked
	Generate at support points	Checked
	Generate at support face & critical shear points	Checked
	Generate at section change points	Checked
	Generate at user-defined points	Checked
Ignore shear	Checked	
Distribution factor application method	By axle	Not Selected
	By POI	Selected
ASR	Generate at tenth points except supports	Checked
	Generate at support points	Checked
	Generate at support face & critical shear points	Checked
	Generate at section change points	Checked
Shear computation method	Ignore	Selected
	Use AASHTO 1973 or earlier code	Not Selected
	Use AASHTO 1974 interim	Not Selected
	Use current AASHTO	Not Selected

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

RC2 – Reinforced Concrete Slab Example

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



RC2 – Reinforced Concrete Slab Example

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.

Cross Sections

Name: Type:

Dimensions Reinforcement

Concrete material:

Modular ratio:

12.0000 in

17.5000 in

OK Apply Cancel

RC2 – Reinforced Concrete Slab Example

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

Distance from top of slab

Distance from bottom of slab

Row	Std bar count	LRFD bar count	Bar size	Distance (in)	Material	Bar spacing (in)
Top of Slab	1.00	1.00	5	1.9375	Grade 60	
Bottom of Slab	2.00	2.00	9	3.1890	Grade 60	

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

New Duplicate Delete

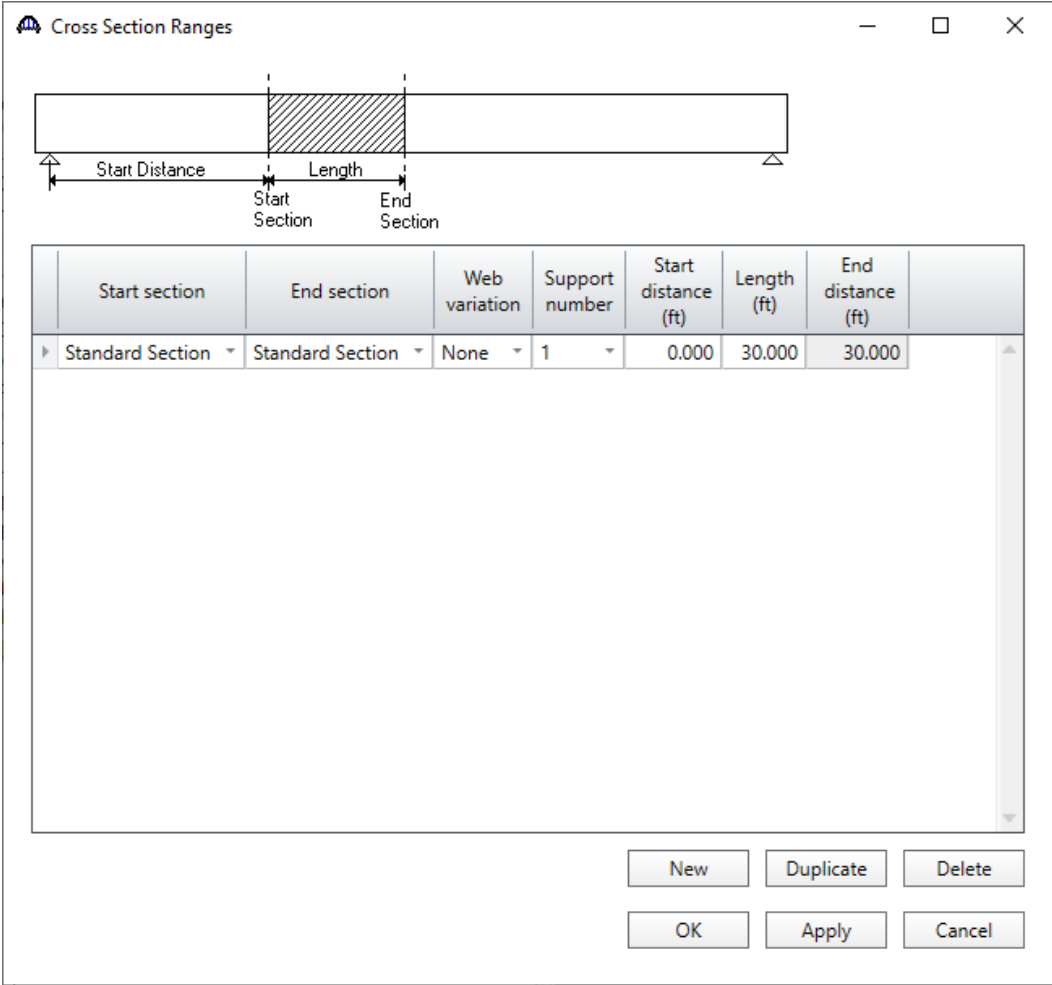
OK Apply Cancel

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

RC2 – Reinforced Concrete Slab Example

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

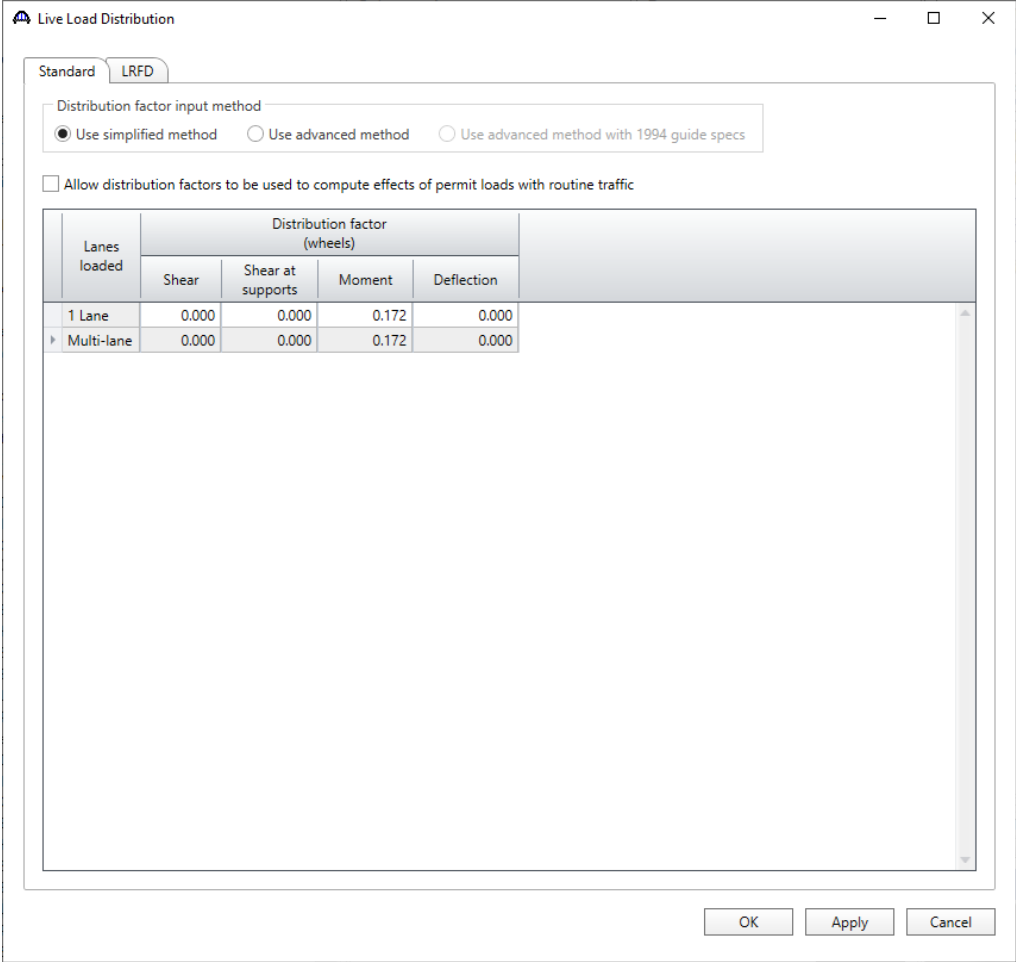
RC2 – Reinforced Concrete Slab Example

Live Load Distribution

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

Standard:

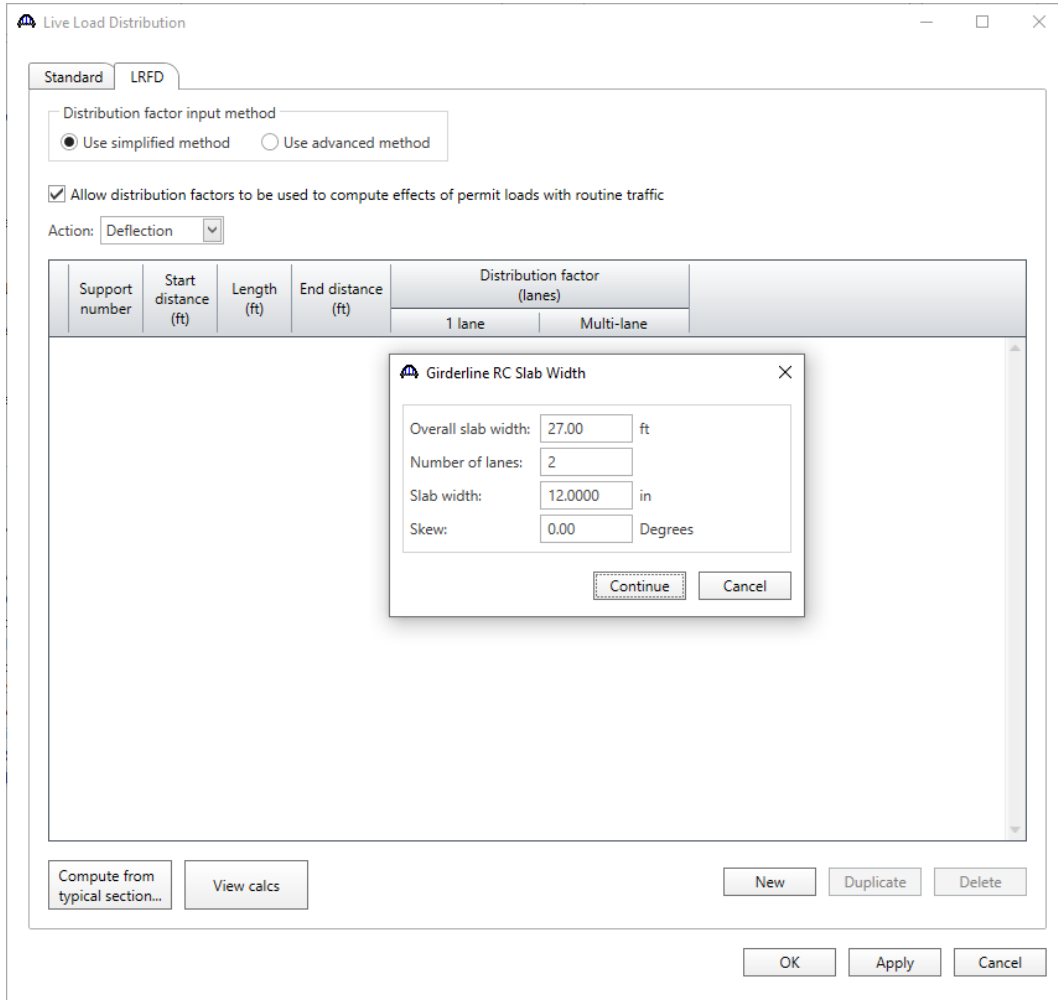
Enter values as shown below and Click **Apply** to apply the standard live load distribution factors and keep the window open.



RC2 – Reinforced Concrete Slab Example

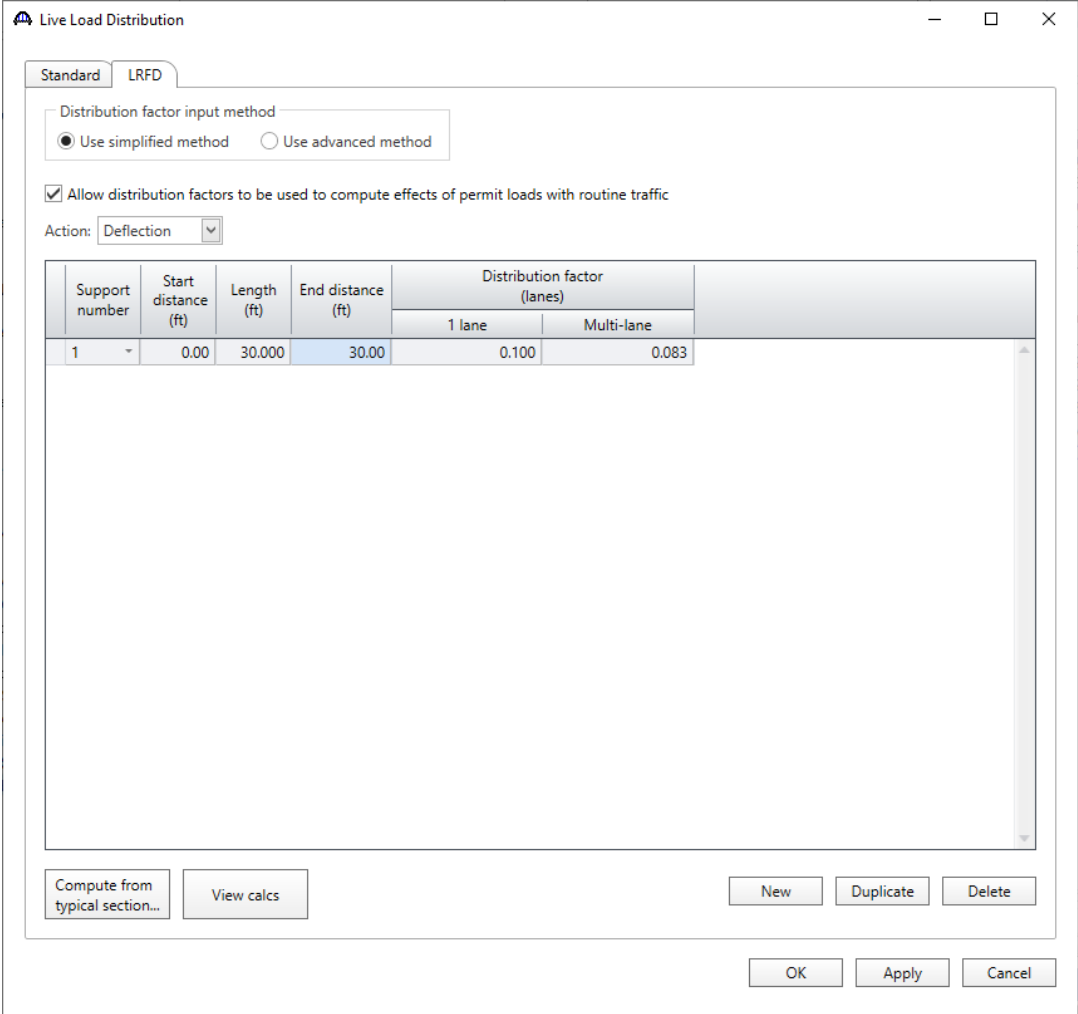
LRFD:

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.

RC2 – Reinforced Concrete Slab Example



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.

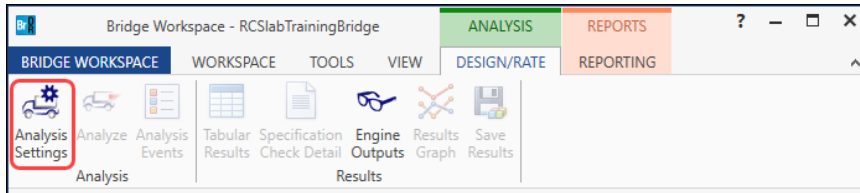
There is no requirement to define any **points of interest** since none of the information entered will be overridden in this example.

The description of this structure is complete.

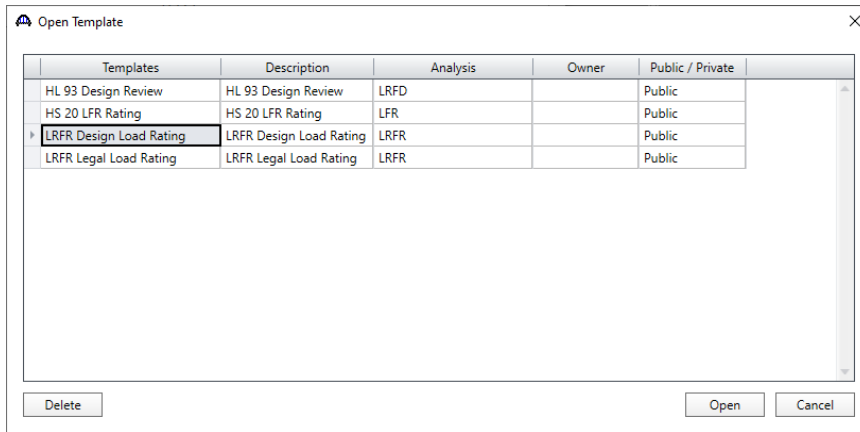
RC2 – Reinforced Concrete Slab Example

LRFR Analysis

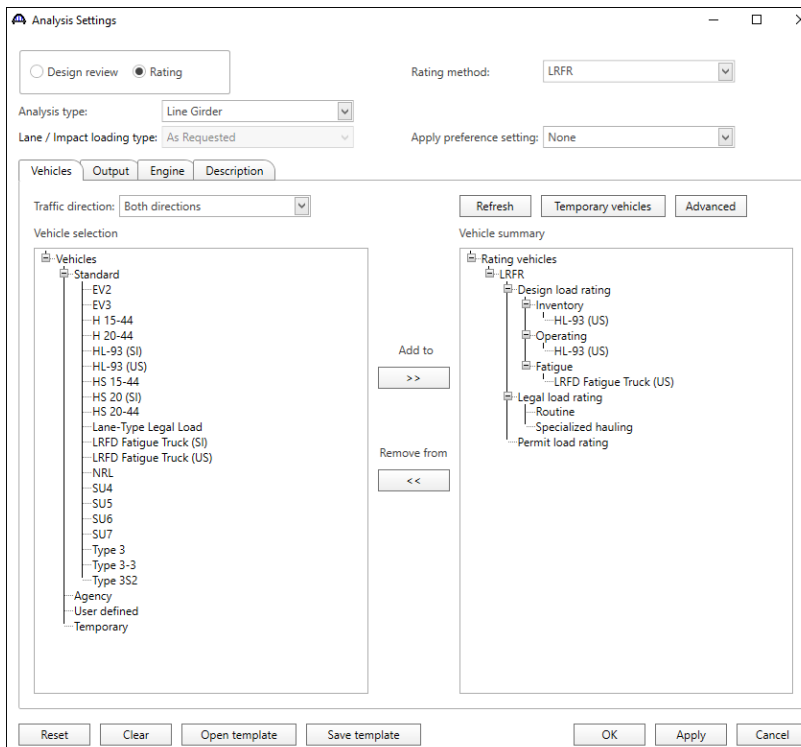
The member alternative created can now be analyzed. To perform an **LRFR** rating, select the **Analysis Settings** button on the **Analysis** group of the **DESIGN/RATE** ribbon to open the window shown below.



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



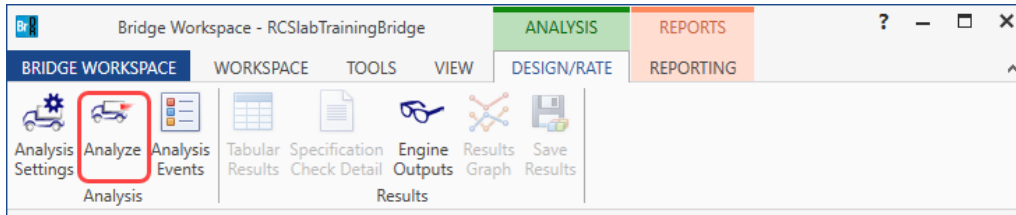
The **Analysis Settings** window will be updated as shown below.



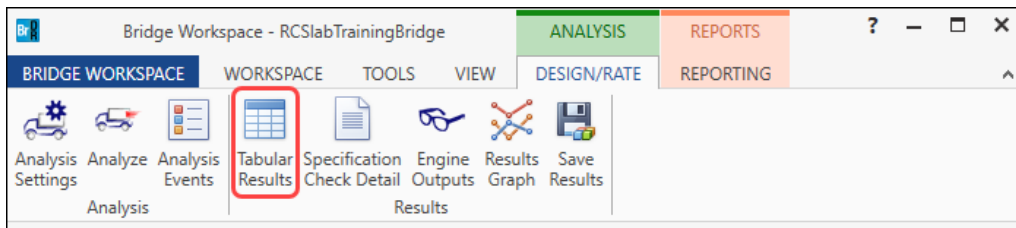
RC2 – Reinforced Concrete Slab Example

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.

Analysis Results - 12" Wide RC Slab

Print

Report type: Rating Results Summary

Lane/Impact loading type: As requested Detailed

Display Format: Single rating level per row

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	40.02	1.112	12.00	1 - (40.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	51.88	1.441	12.00	1 - (40.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	34.62	0.962	15.00	1 - (50.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	44.88	1.247	15.00	1 - (50.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested

AASHTO LRFR Engine Version 7.5.0.3001
Analysis preference setting: None

Close

RC2 – Reinforced Concrete Slab Example

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.

The screenshot shows the 'Member Alternative Description' dialog box. The title bar reads 'Member Alternative Description'. The 'Member alternative:' field contains 'Schedule Based 12" Wide RC Slab'. The 'Description' tab is active, showing a large empty text box for the description. To the right, the 'Material type' is 'Reinforced Concrete', 'Girder type' is 'Reinforced Concrete Slab', 'Modeling type' is 'Open Girder', and 'Default units' is 'US Customary'. Under 'Girder property input method', 'Schedule based' is selected with a radio button. The 'End bearing locations' section has 'Left: 9 in' and 'Right: 9 in'. The 'Sustained modular ratio factor' is set to '2'. The 'Self load' section has 'Load case: Engine Assigned', 'Additional self load: 0.00625 kip/ft', and an empty percentage field. The 'Default rating method' is 'LFR'. The 'Crack control parameter (Z)' section has 'Bottom of beam: [empty] kip/in'. The 'Exposure factor' section has 'Bottom of beam: [empty]'. At the bottom right are 'OK', 'Apply', and 'Cancel' buttons.

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

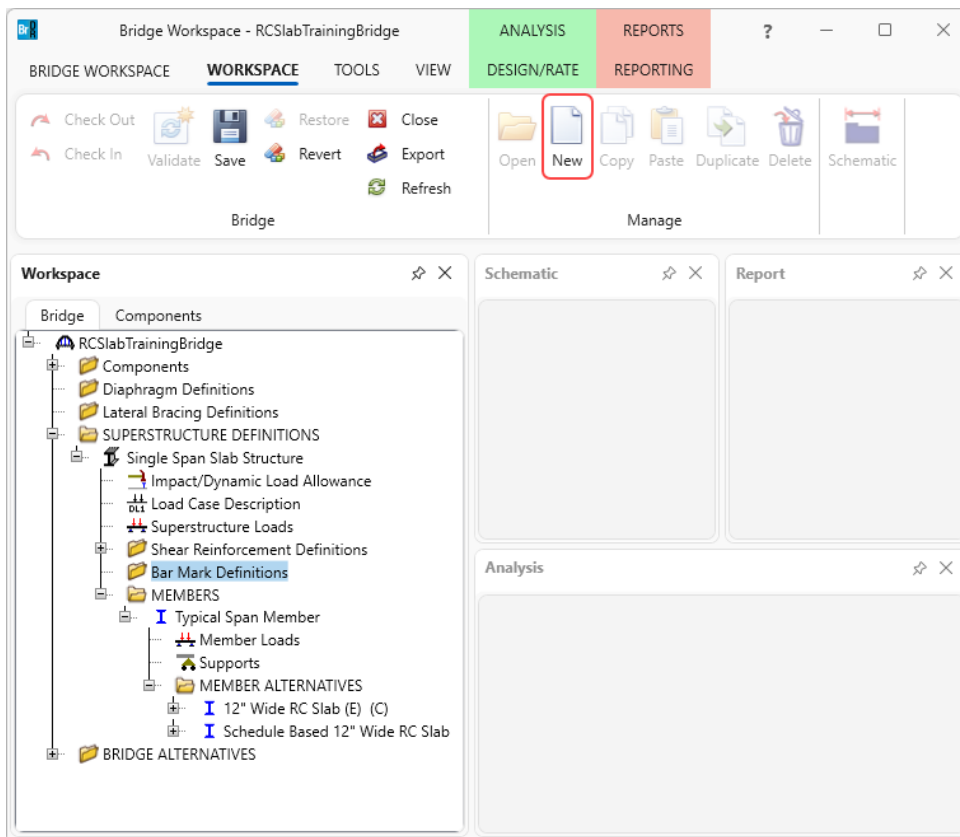
RC2 – Reinforced Concrete Slab Example

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.



RC2 – Reinforced Concrete Slab Example

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

Bar Mark Definition

Name: #5

Material: Grade 60

Bar size: 5

Bar type: Straight

Dimension

A: 31.0000 ft

Bar types:

- Type: Straight (Diagram A)
- Type: 1 (Diagram B)
- Type: 2 (Diagram C)
- Type: 3 (Diagram D)

OK Apply Cancel

Bar Mark Definition

Name: #9

Material: Grade 60

Bar size: 9

Bar type: Straight

Dimension

A: 31.0000 ft

Bar types:

- Type: Straight (Diagram A)
- Type: 1 (Diagram B)
- Type: 2 (Diagram C)
- Type: 3 (Diagram D)

OK Apply Cancel

RC2 – Reinforced Concrete Slab Example

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

Type: Reinforced Concrete Slab

Section Web Reinforcement

Material: Class A (US)

Modular ratio:

Sacrificial wear thickness: 0.5000 in

12.0000 in

OK Apply Cancel

Girder Profile - Web

Type: Reinforced Concrete Slab

Section Web Reinforcement

Begin depth (in)	Depth vary	End depth (in)	Support number	Start distance (ft)	Length (ft)	End distance (ft)
18.0000	None	18.0000	1	0.000	30.000	30.000


New Duplicate Delete

OK Apply Cancel

RC2 – Reinforced Concrete Slab Example

Girder Profile - Reinforcement

Set	Bar mark	Invert	Measured from	Distance (in)	Std number	LRFD number	Bar spacing (in)	Side cover (in)	Support number	Direction	Start distance (ft)	Straight length (ft)	End distance (ft)	Start fully developed	End fully developed
1	#5	<input type="checkbox"/>	Top of Slab	1.9375	1	1	12		1	Left	0.5	31	30.5	<input type="checkbox"/>	<input type="checkbox"/>
> 2	#9	<input type="checkbox"/>	Bottom of Slab	3.189	2	2	6		1	Left	0.5	31	30.5	<input type="checkbox"/>	<input type="checkbox"/>

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

New Duplicate Delete

OK Apply Cancel

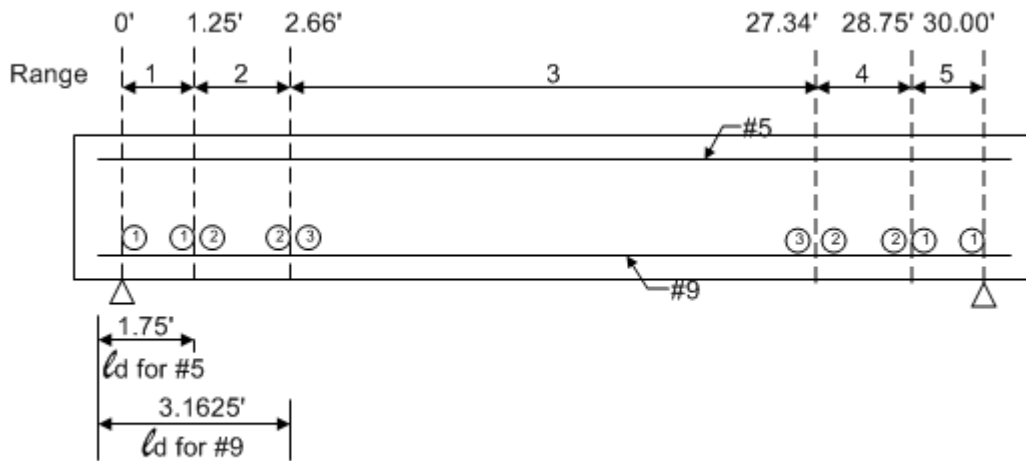
The BrDR export to the analysis engine will compute the required development lengths for the reinforcing steel based on the data entered in this window. These required development lengths are considered when the girder profile is exported to the analysis engine. In the export, BrDR transforms the schedule-based 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.

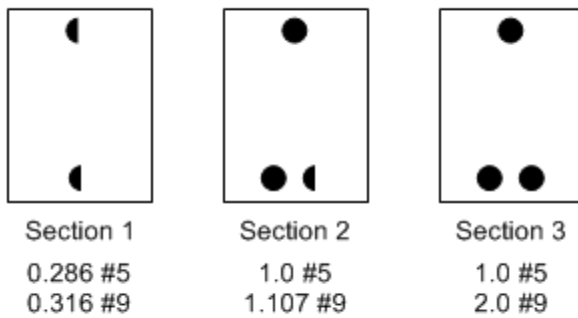
The following shows the cross sections and cross section ranges that are generated for this example when the member alternative is analyzed.

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.

RC2 – Reinforced Concrete Slab Example



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):

$$\#5 \text{ bar } 0.5' / 1.75' = 0.286 * 1 \text{ bar} = 0.286 \text{ bar}$$

$$\#9 \text{ bar } 0.5' / 3.1625' = 0.158 * 2 \text{ bars} = 0.316 \text{ bars}$$

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

RC2 – Reinforced Concrete Slab Example

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.

Distance measured from bottom of girder

Distance measured from bottom of girder

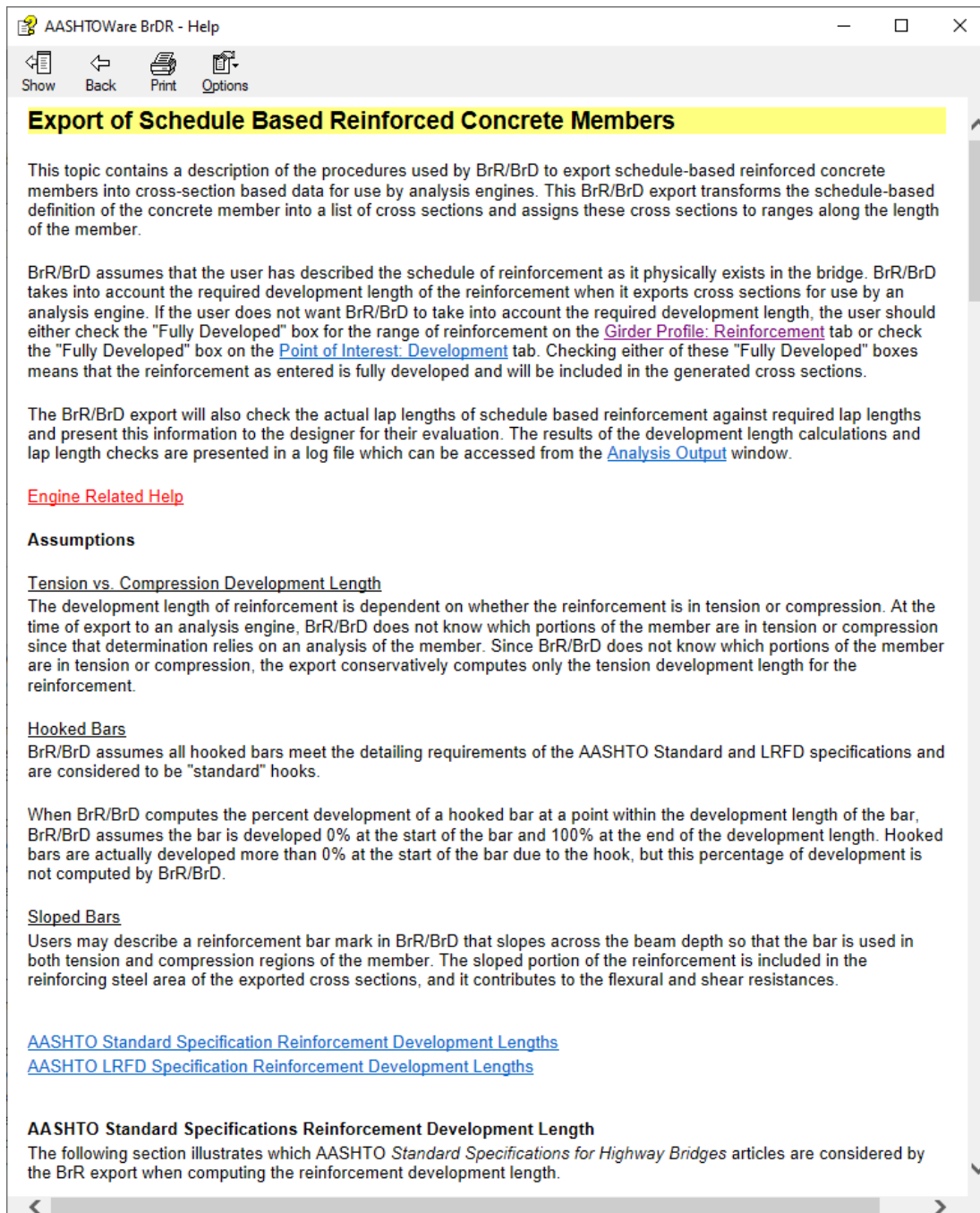
Bar mark definition inverted and Distance measured from top of girder

Distance measured from top of girder

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

RC2 – Reinforced Concrete Slab Example

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.



The screenshot shows a help window titled "AASHTOWare BrDR - Help". The main heading is "Export of Schedule Based Reinforced Concrete Members". The text describes the export process, assumptions, and related help topics.

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.



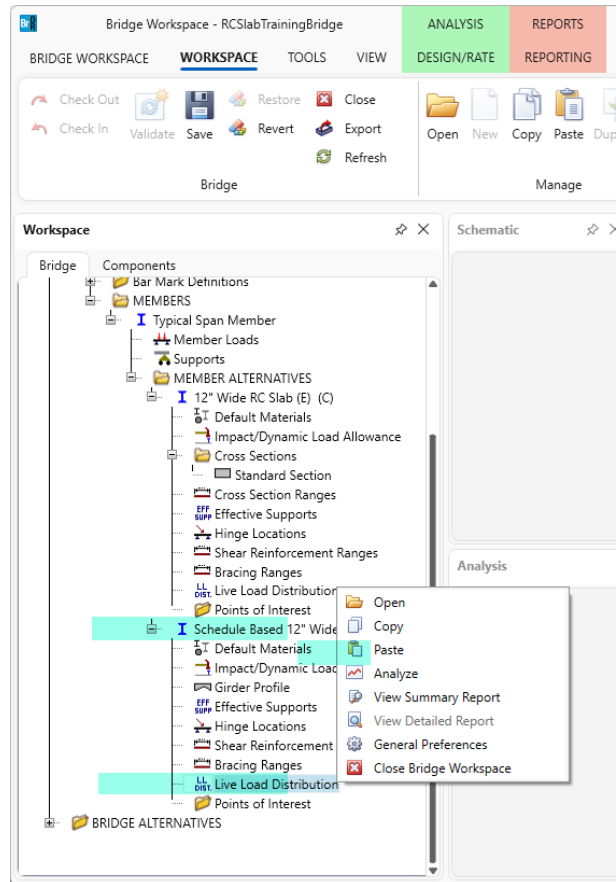
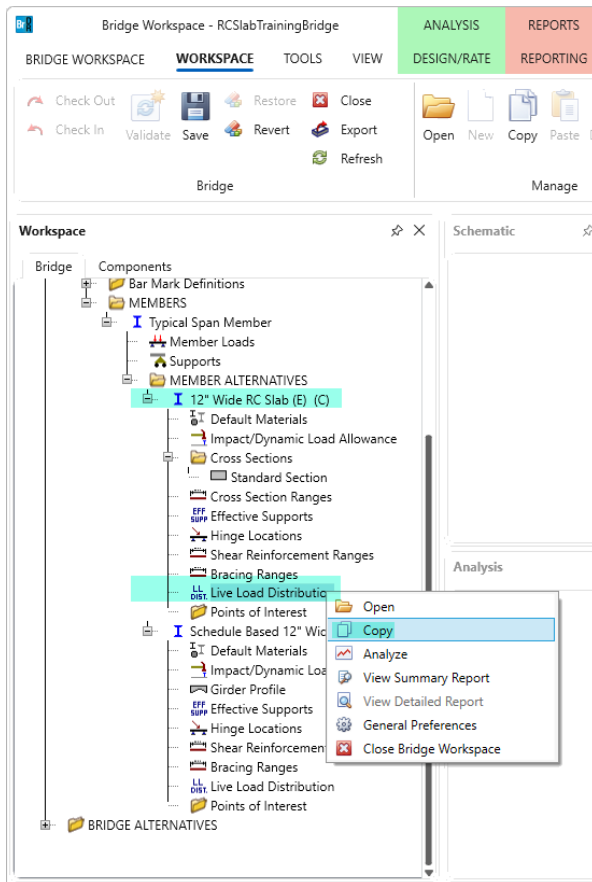
The BrDR export will also check the actual lap lengths of schedule-based reinforcement against required lap lengths and present this information to the designer for their evaluation. BrDR considers bars to be lapped if the vertical distance to their centroids is equal or if their clear cover is equal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

RC2 – Reinforced Concrete Slab Example

Live Load Distribution

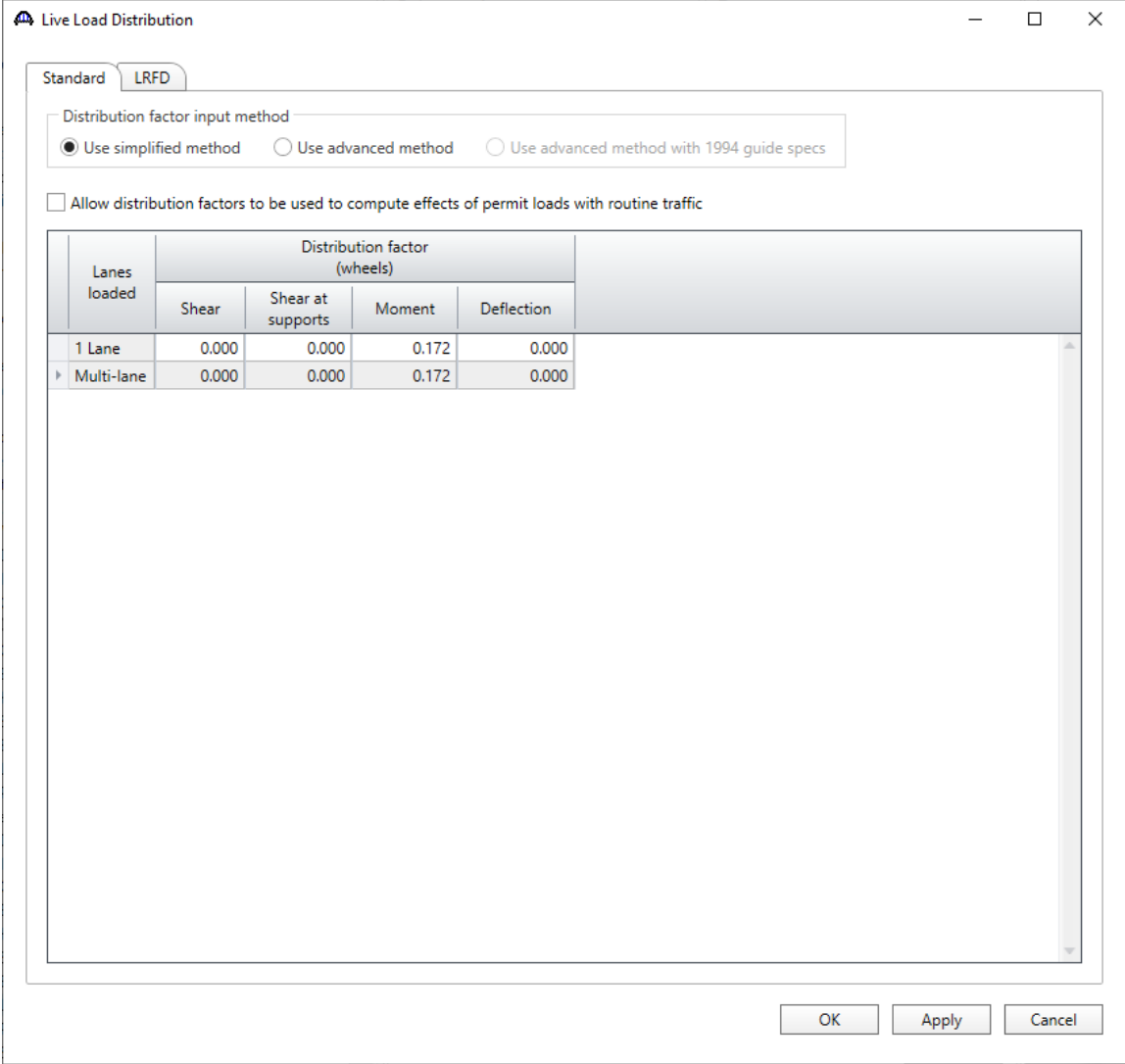
Double click on **Live Load Distribution** on the Bridge Workspace tree to open the **Live Load Distribution** window. Enter data on each tab as shown below:

(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.)



RC2 – Reinforced Concrete Slab Example

Standard:

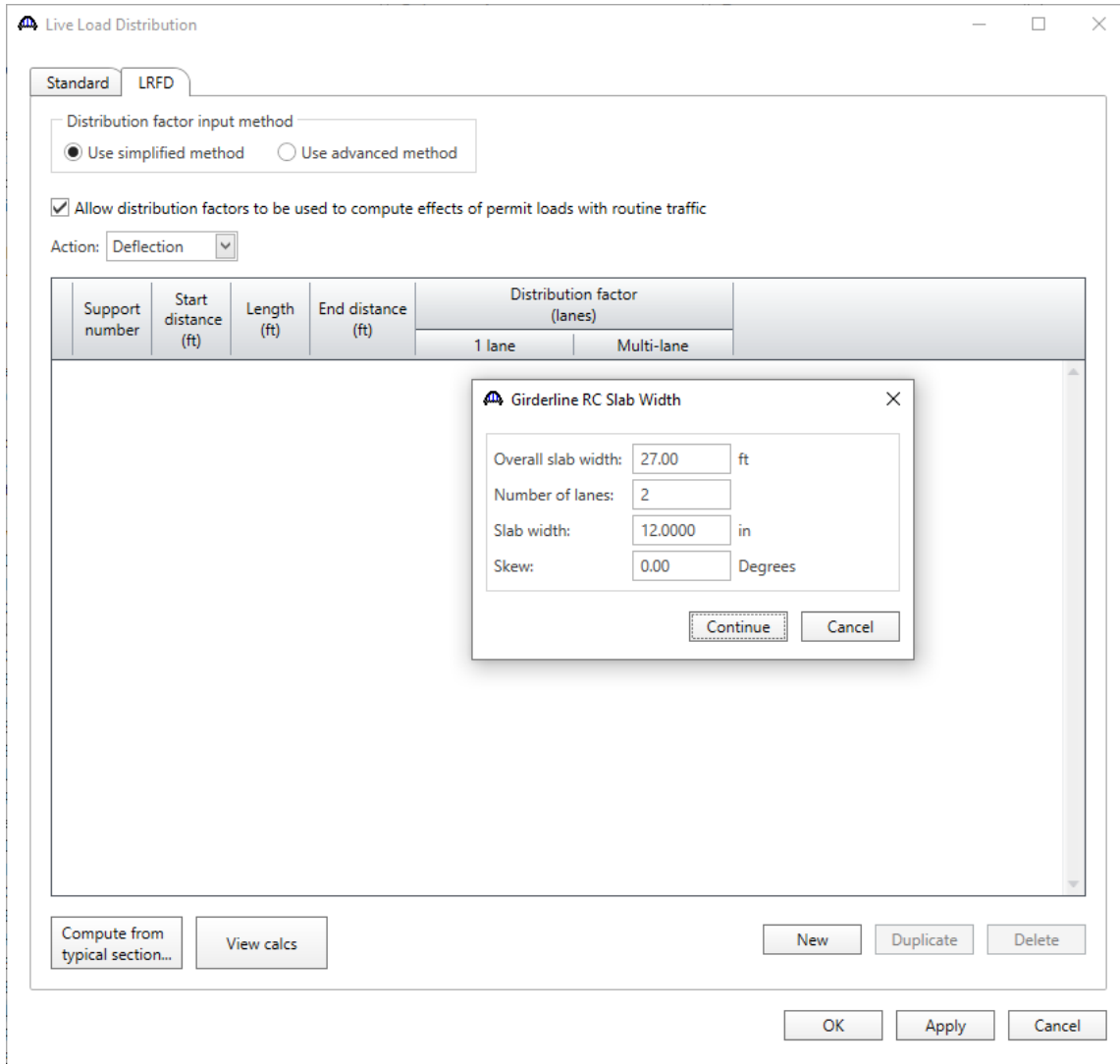


Enter values as shown above and Click **Apply** to apply the data and keep the window open.

RC2 – Reinforced Concrete Slab Example

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.

RC2 – Reinforced Concrete Slab Example

Deflection distribution factors.

The screenshot shows a software dialog box titled "Live Load Distribution". It has two tabs: "Standard" and "LRFD", with "LRFD" selected. Under "Distribution factor input method", the "Use simplified method" radio button is selected. A checked checkbox indicates "Allow distribution factors to be used to compute effects of permit loads with routine traffic". A dropdown menu labeled "Action:" is set to "Deflection". Below this is a table with the following data:

Support number	Start distance (ft)	Length (ft)	End distance (ft)	Distribution factor (lanes)	
				1 lane	Multi-lane
1	0	30	30	0.1	0.0833333

At the bottom of the dialog, there are buttons for "Compute from typical section...", "View calcs", "New", "Duplicate", "Delete", "OK", "Apply", and "Cancel".

RC2 – Reinforced Concrete Slab Example

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

Distribution factor input method

Use simplified method Use advanced method

Allow distribution factors to be used to compute effects of permit loads with routine traffic

Action: **Moment** ▾

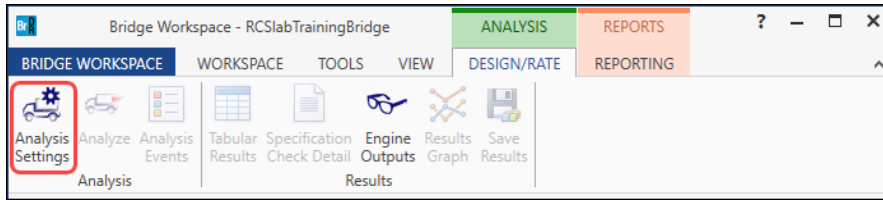
Support number	Start distance (ft)	Length (ft)	End distance (ft)	Distribution factor (lanes)	
				1 lane	Multi-lane
1 ▾	0	30	30	0.0787906	0.096013

Compute from typical section... View calcs New Duplicate Delete OK Apply Cancel

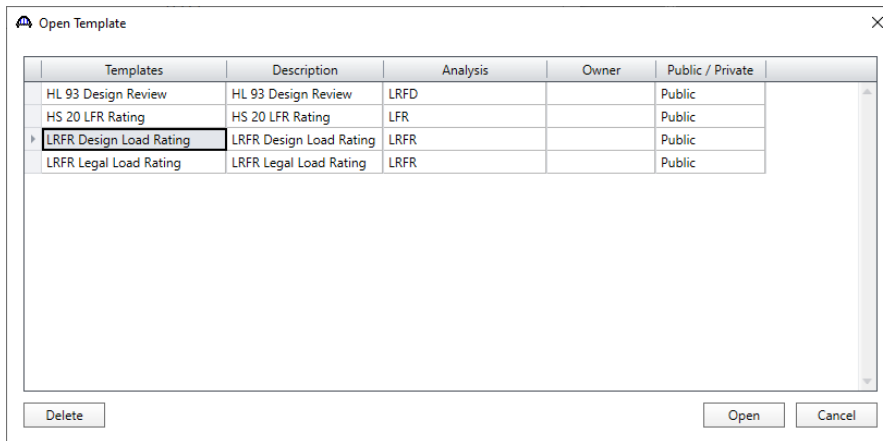
RC2 – Reinforced Concrete Slab Example

LRFR Analysis

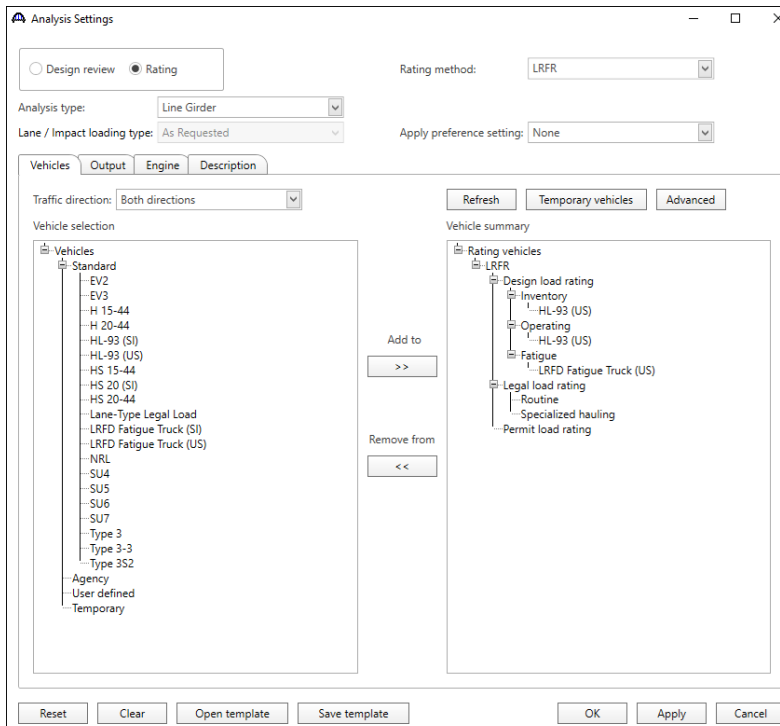
The member alternative can now be analyzed. To perform an **LRFR** rating, select the **Analysis Settings** button from the **Analysis** group of the **DESIGN/RATE** ribbon to open the **Analysis Settings** window as shown below.



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



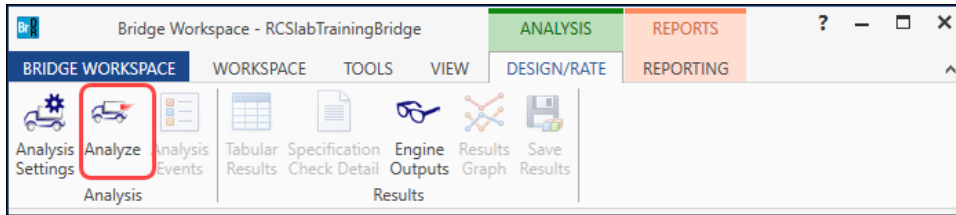
The **Analysis Settings** window will be updated as shown below.



RC2 – Reinforced Concrete Slab Example

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.

The screenshot shows the **Analysis Results - Schedule Based 12" Wide RC Slab** window. It includes a **Print** button, **Report type:** (Rating Results Summary), **Lane/Impact loading type:** (As requested), and **Display Format:** (Single rating level per row). The table below shows the results:

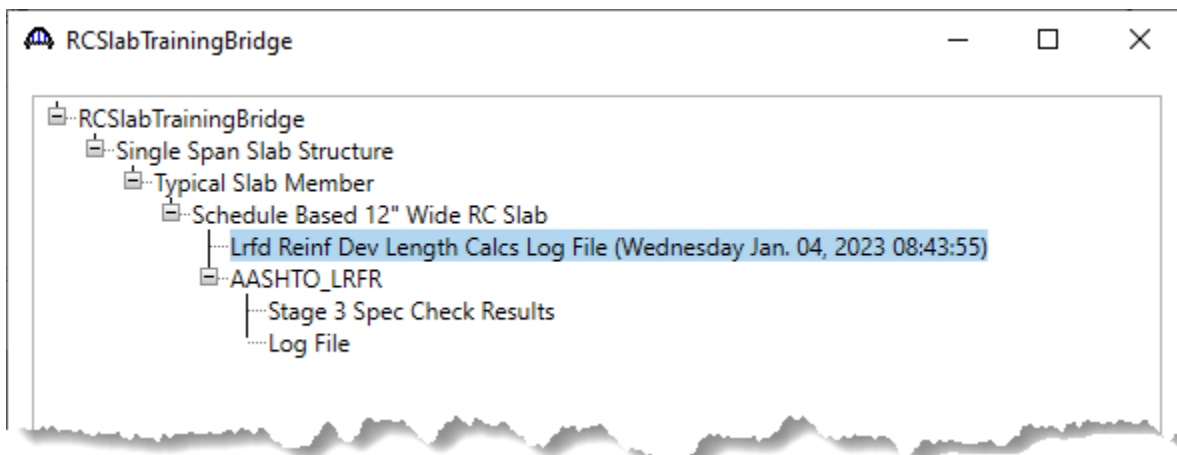
Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HL-93 (US)	Truck + Lane	LRFR	Inventory	39.62	1.100	12.00	1 - (40.0)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	51.36	1.427	12.00	1 - (40.0)	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

AASHTO LRFR Engine Version 7.5.0.3001
Analysis preference setting: None

Engine Outputs



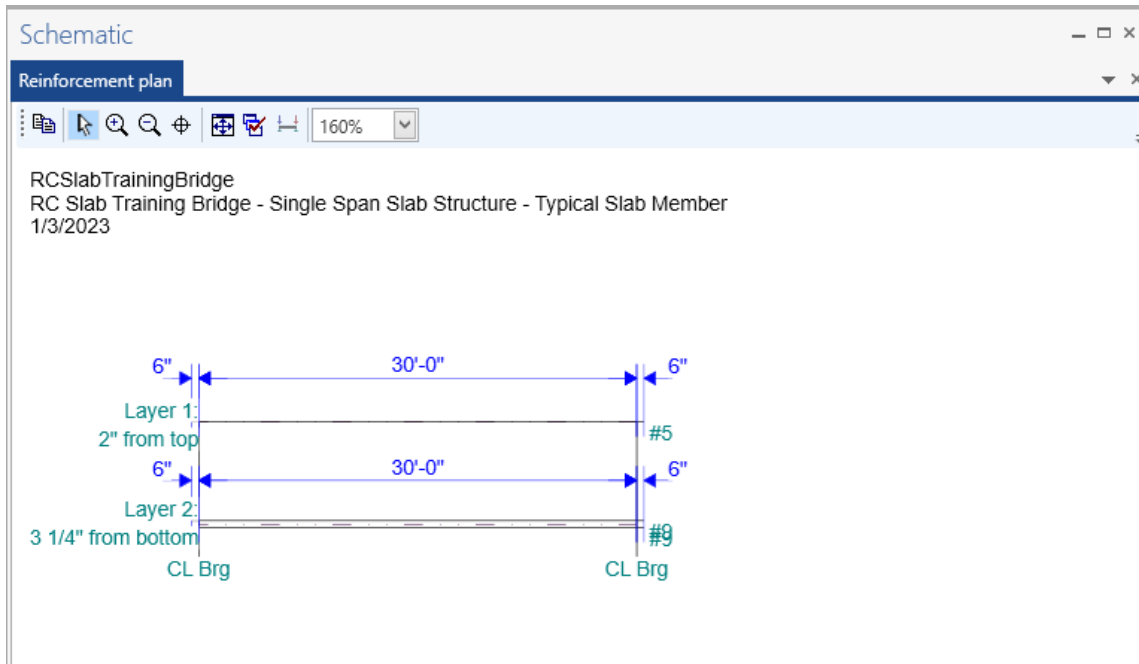
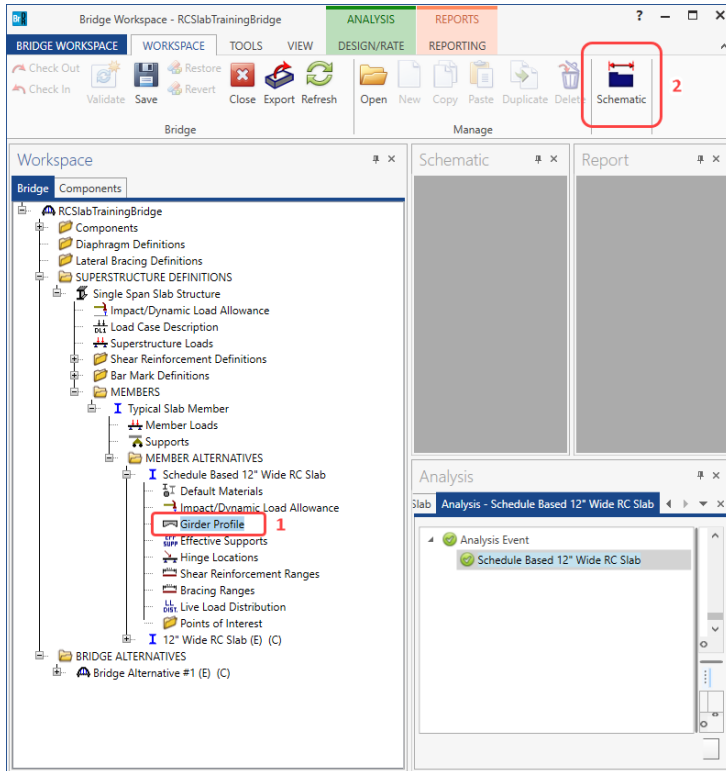
When an analysis or design review is run, a file is created that contains the input and output of the calculations BrDR performed to compute the required development lengths and to check the lap lengths. This file can be accessed from the **Engine Outputs** button on the **DESIGN/RATE** ribbon.



RC2 – Reinforced Concrete Slab Example

Schematic

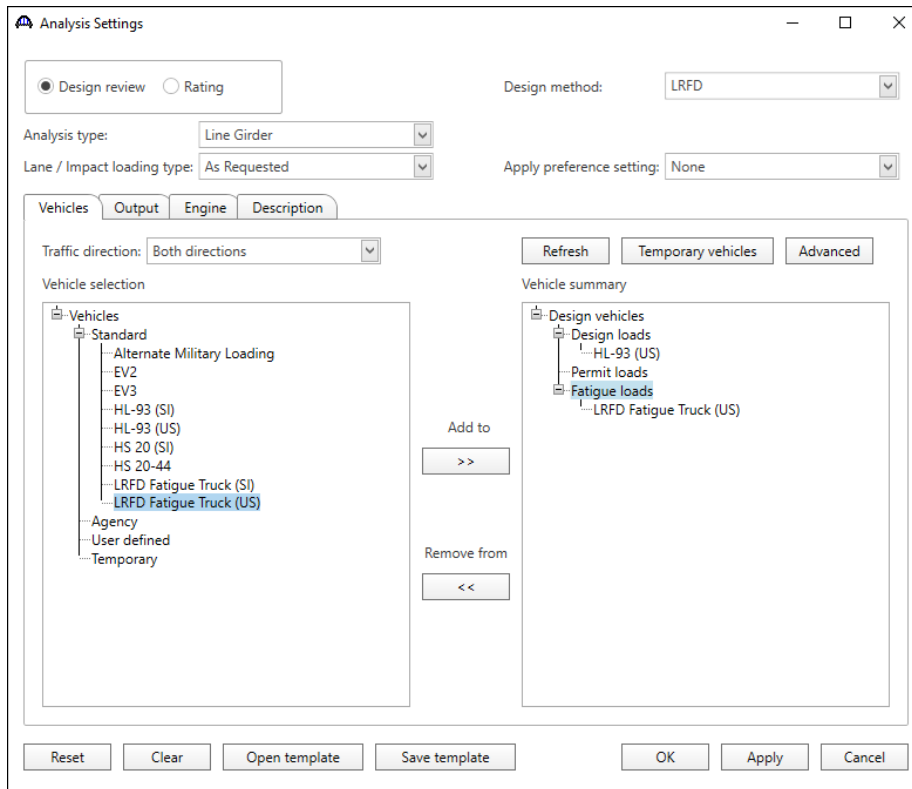
A schematic view of the reinforcement profile is available while the **Girder Profile** label is selected on the **Bridge Workspace tree**.



RC2 – Reinforced Concrete Slab Example

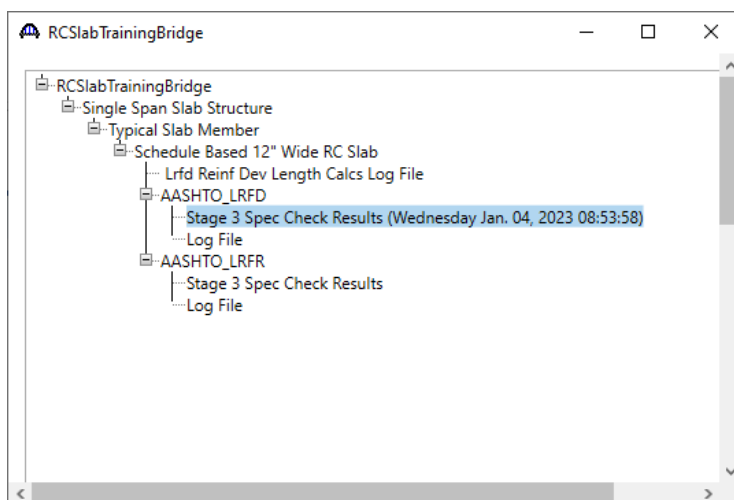
LRFD Design review

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.



RC2 – Reinforced Concrete Slab Example

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

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

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

AASHTO LRFD Specification, Edition 9, 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)	Pass

Girder Positive Flexure Analysis

Location (ft)	LS	Load Comb	Mr (kip-ft)	Mu (kip-ft)	Design Ratio Mr/Mu	Code
0.000	STR-I	1	23.84	0.00	99.000	Pass
1.450	STR-I	1	85.97	22.13	3.885	Pass
2.207	STR-I	1	116.22	33.68	3.451	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
27.793	STR-I	1	116.22	33.68	3.451	Pass
28.550	STR-I	1	85.97	22.13	3.885	Pass
30.000	STR-I	1	23.84	0.00	99.000	Pass

NR = Spec check not required at this location