

AASHTOWare BrR/BrD 6.8

Reinforced Concrete Structure Tutorial

RC4 – Two Span Reinforced Concrete Slab Example

BrR and BrD Training

RC4 – Two Span Reinforced Concrete Slab Example

Topics Covered


- Reinforced concrete slab input as girderline.
- Cross section based input.
- Slab depth varies parabolically over the pier.

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

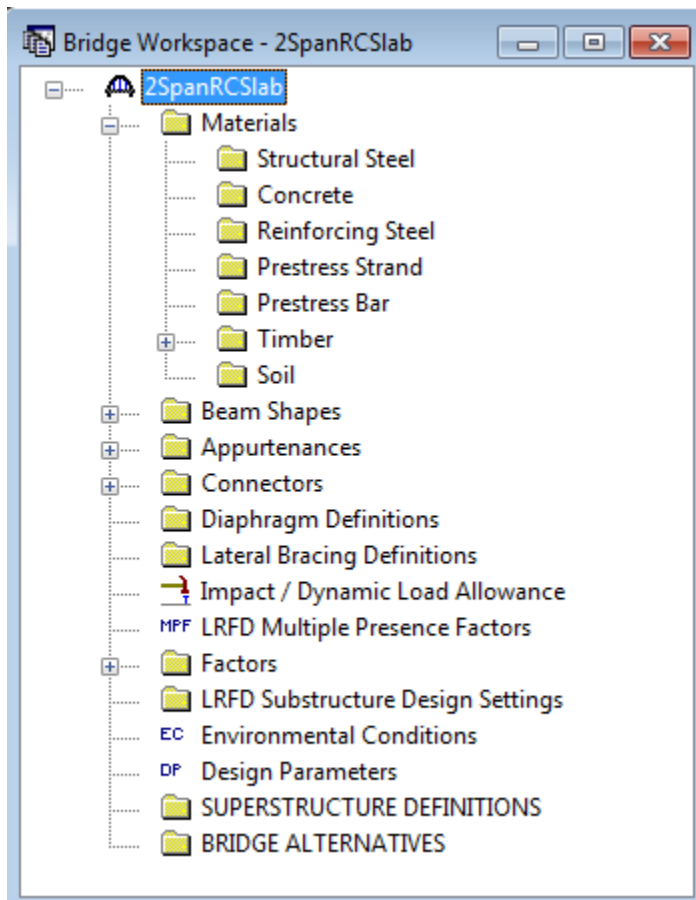
The screenshot shows the 'Description' tab of the Bridge Explorer software. The 'Bridge ID' and 'NBI Structure ID (8)' are both '2SpanRCSlab'. The 'Template' checkbox is unchecked, 'Superstructures' is checked, and 'Bridge Completely Defined' and 'Culverts' are unchecked. The 'Name' field contains '2 Span RC Slab' and 'Year Built' is empty. The 'Description' field is empty. 'Location' is empty, 'Length' is empty, 'Facility Carried (7)' is empty, 'Route Number' is '-1', 'Feat. Intersected (6)' is empty, and 'Mi. Post' is empty. 'Default Units' is set to 'US Customary'. At the bottom, there is an 'AASHTOWare Association...' button, checkboxes for 'BrR' (checked), 'BrD' (checked), and 'BrM' (unchecked), and 'OK', 'Apply', and 'Cancel' buttons.

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

RC4 – Two Span RC Concrete Slab

To enter the materials to be used by members of the bridge, click on the  to expand the tree for Materials.

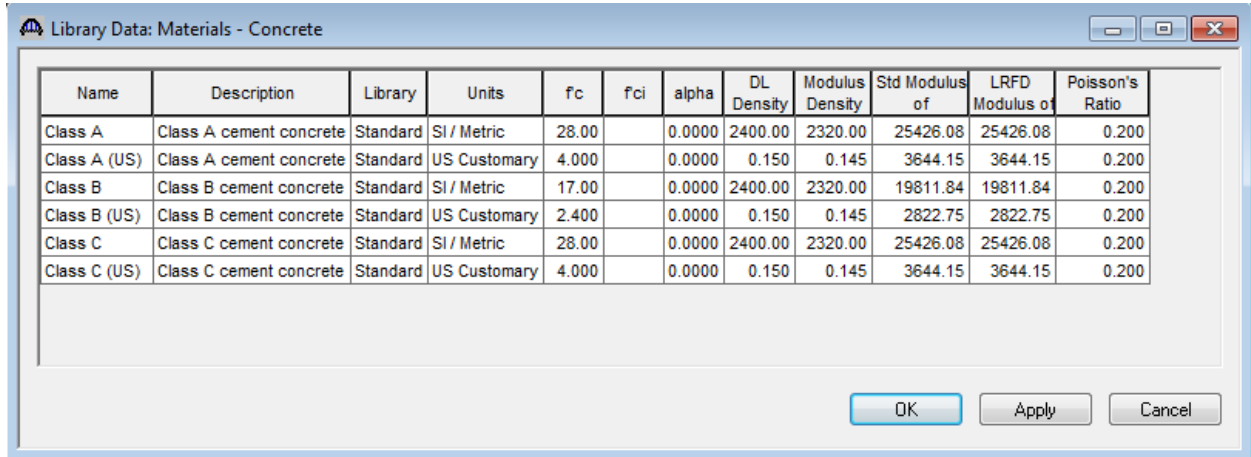
The tree with the expanded Materials branch is shown below:



RC4 – Two Span RC Concrete Slab

To add a new concrete material, click on Concrete in the tree and select File/New from the menu (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:

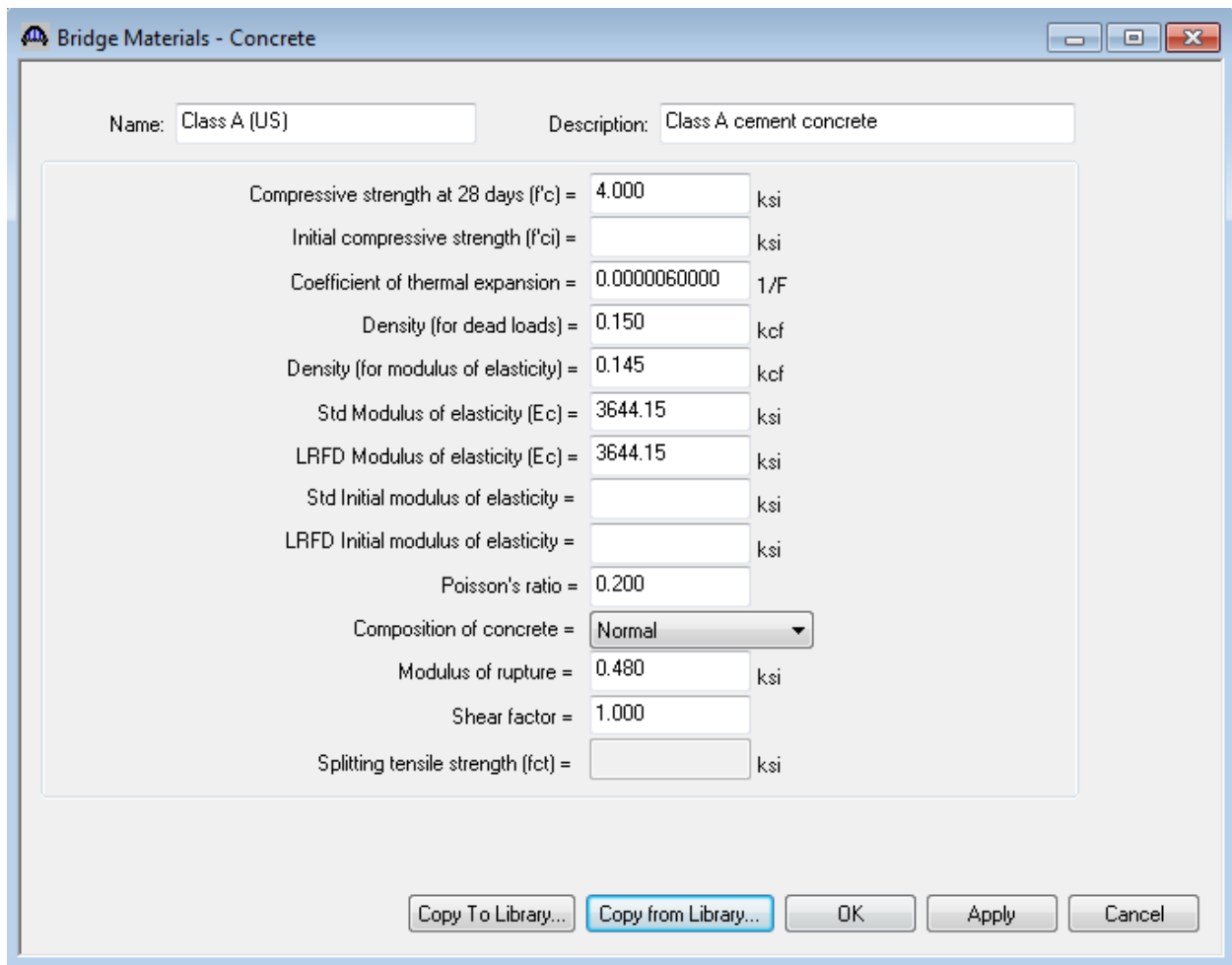


Name	Description	Library	Units	fc	fci	alpha	DL Density	Modulus Density	Std Modulus of	LRFD Modulus of	Poisson's Ratio
Class A	Class A cement concrete	Standard	SI / Metric	28.00		0.0000	2400.00	2320.00	25426.08	25426.08	0.200
Class A (US)	Class A cement concrete	Standard	US Customary	4.000		0.0000	0.150	0.145	3644.15	3644.15	0.200
Class B	Class B cement concrete	Standard	SI / Metric	17.00		0.0000	2400.00	2320.00	19811.84	19811.84	0.200
Class B (US)	Class B cement concrete	Standard	US Customary	2.400		0.0000	0.150	0.145	2822.75	2822.75	0.200
Class C	Class C cement concrete	Standard	SI / Metric	28.00		0.0000	2400.00	2320.00	25426.08	25426.08	0.200
Class C (US)	Class C cement concrete	Standard	US Customary	4.000		0.0000	0.150	0.145	3644.15	3644.15	0.200

Select the Class A (US) material and click Ok.

RC4 – Two Span RC Concrete Slab

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



The screenshot shows a software window titled "Bridge Materials - Concrete". It contains a form for defining material properties. The "Name" field is "Class A (US)" and the "Description" field is "Class A cement concrete". The form lists various material properties with input fields and units. The "Copy from Library..." button is highlighted.

Property	Value	Unit
Compressive strength at 28 days (f'_c) =	4.000	ksi
Initial compressive strength (f'_{ci}) =		ksi
Coefficient of thermal expansion =	0.0000060000	1/F
Density (for dead loads) =	0.150	kcf
Density (for modulus of elasticity) =	0.145	kcf
Std Modulus of elasticity (E_c) =	3644.15	ksi
LRFD Modulus of elasticity (E_c) =	3644.15	ksi
Std Initial modulus of elasticity =		ksi
LRFD Initial modulus of elasticity =		ksi
Poisson's ratio =	0.200	
Composition of concrete =	Normal	
Modulus of rupture =	0.480	ksi
Shear factor =	1.000	
Splitting tensile strength (f_{ct}) =		ksi

Click Ok to save the data to memory and close the window.

RC4 – Two Span RC Concrete Slab

Add the following reinforcement steel in the same manner.

Bridge Materials - Reinforcing Steel

Name: Description:

Material Properties

Specified yield strength (F_y) = ksi

Modulus of elasticity (E_s) = ksi

Ultimate strength (F_u) = ksi

Type

Plain
 Epoxy
 Galvanized
 Other

We do not need to define any beam shapes since we are using a reinforced concrete slab. The slab will be entered later as a cross section.

Reinforced concrete slab could be entered as Girderline Structure Definitions in BrR/BrD. Since we will not be defining a Structure Typical Section for a girderline structure, we do not need to define any appurtenances. The dead load due to the appurtenances will be entered later as member loads.

The default impact factors, standard LRFD and LFD factors will be used so we will skip to Structure Definition. Bridge Alternatives will be added after we enter the Structure Definition.

RC4 – Two Span RC Concrete Slab

Double click on SUPERSTRUCTURE DEFINITIONS (or click on SUPERSTRUCTURE DEFINITIONS and select File/New from the menu or right mouse click on SUPERSTRUCTURE DEFINITIONS and select New from the popup menu) to create a new structure definition.

Select Girder Line Superstructure, click Ok and the Structure Definition window will open. Enter the appropriate data as shown below:

The screenshot shows the 'Girder Line Superstructure Definition' dialog box with the following settings:

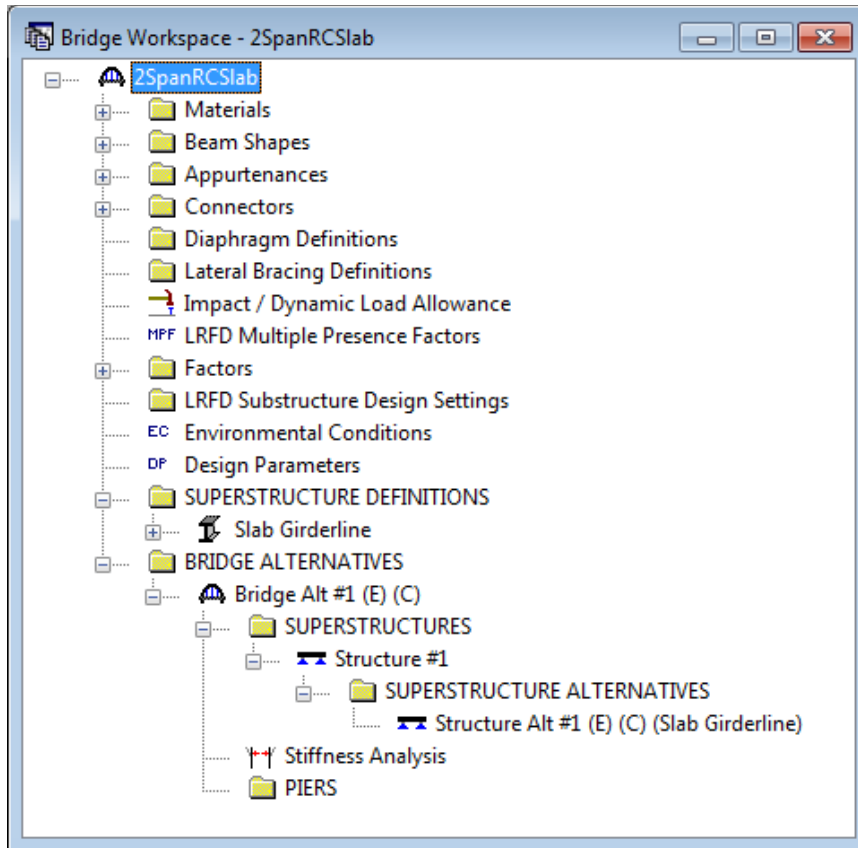
- Name:** Slab Girderline
- Description:** (Empty text area)
- Deck type:** Concrete
- Default Units:** US Customary
- Reference line length:** (Empty text box) ft
- Live Load Lanes:** Multi-Lane (selected), Single Lane
- LRFD Fatigue:** Truck lanes: (Empty text box), Override, Truck fraction: (Empty text box)
- For PS only:** Average humidity: (Empty text box) %
- Member Alt. Types:** Steel, P/S, R/C, Timber

Click on Ok to save the data to memory and close the window.

RC4 – Two Span RC Concrete Slab

We now go back to the Bridge Alternatives and create a new Bridge Alternative, a new Structure, and a new Structure Alternative as we did previously.

The partially expanded Bridge Workspace tree is shown below:



RC4 – Two Span RC Concrete Slab

Click Load Case Description to define the dead load cases. The completed Load Case Description window is shown below.

Load Case Name	Description	Stage	Type	Time* (Days)
Stage 1 DC DL	Parapets	Non-composite (Stage 1)	D,DC	

*Prestressed members only

Add Default Load Case Descriptions

New Duplicate Delete

OK Apply Cancel

RC4 – Two Span RC Concrete Slab

Describing a member:

Open the Member window by double clicking on Member in tree. Fill in the window with the following information. If we press F1 while this window is active, the Help topic for the Member window will be displayed. This help topic tells us that girder spacing and member location are not required for a slab member so we will not enter any data for those items.

The first Member Alternative that we create will automatically be assigned as the Existing and Current Member alternative for this Member.

Member name: 12" Slabline

Description:

Existing	Current	Member Alternative Name	Description

Number of spans: 2

Girder spacing: ft

Span No.	Span Length (ft)
1	30.00
2	30.00

Deck concrete crack control parameter (Z): 130.000 kip/in

Member Location

Interior

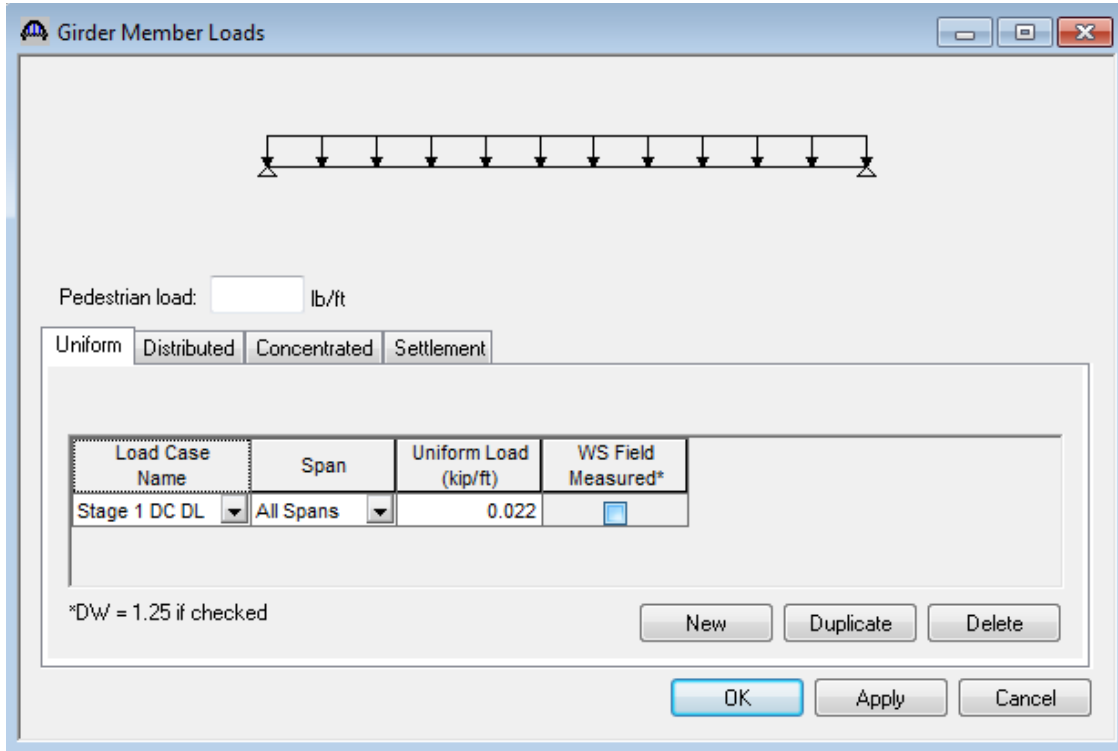
Exterior

Deck exposure factor:

OK Apply Cancel

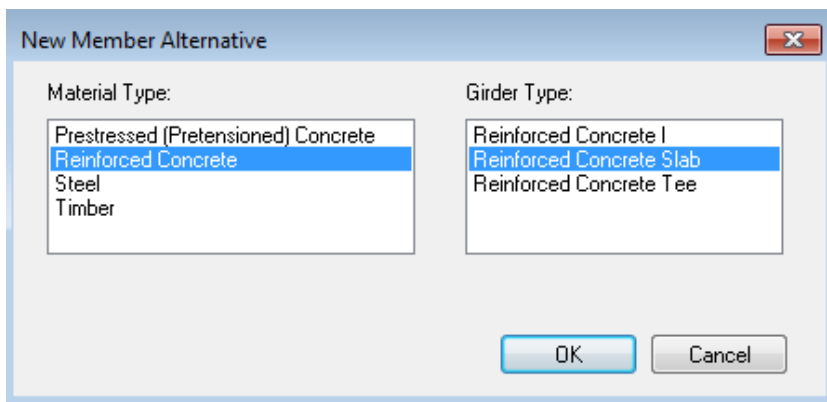
RC4 – Two Span RC Concrete Slab

Double-click Member Loads to open the Member Loads window. This structure has 2 parapets each weighing 300 lb/ft. We are defining a 12” wide strip of slab as our member, and the bridge cross section has a width of 27 ft. So the parapet load applied to this member will be $(2 \times 300 \text{ lb/ft}) \times 1' / 27' = 22 \text{ lb/ft}$.



Defining a Member Alternative:

Double-click MEMBER ALTERNATIVES in the tree to create a new alternative. The New Member Alternative dialog shown below will open. Select Reinforced Concrete for the Material Type and Reinforced Concrete Slab for the Girder Type.



Click Ok to close the dialog and create a new member alternative.

RC4 – Two Span RC Concrete Slab

The Member Alternative Description window will open. Enter the appropriate data as shown below. The Cross-section based Girder property input method is the only input method available for a reinforced concrete beam. 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 we will select the LFD Ignore shear checkbox under the Shear computation method.

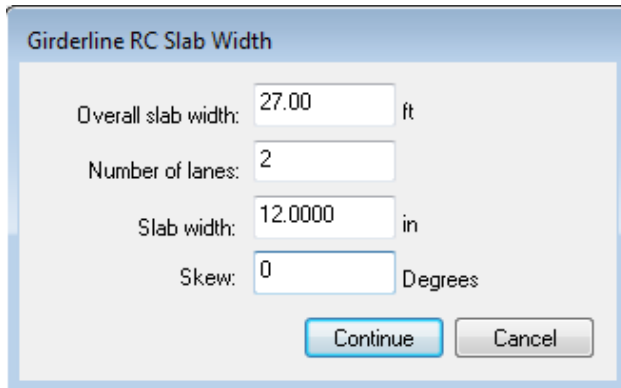
The screenshot shows the "Member Alternative Description" window with the following settings:

- Member Alternative: 12" wide slab line
- Description: (empty text area)
- Material Type: Reinforced Concrete
- Girder Type: Reinforced Concrete Slab
- Default Units: US Customary
- Girder property input method: Cross-section based
- End bearing locations: Left: 6.0000 in, Right: 6.0000 in
- Sustained modular ratio factor: 2.000
- Default rating method: LFD
- Self Load: Load case: Engine Assigned
- Additional self load = (empty) kip/ft
- Additional self load = (empty) %
- Crack control parameter (Z): Bottom of slab: 170.000 kip/in
- Exposure factor: Bottom of slab: (empty)

Buttons at the bottom: OK, Apply, Cancel

RC4 – Two Span RC Concrete Slab

We can now enter the live load distribution factors for this member. Open Live Load Distribution window, LRFD tab. Click Compute from Typical Section button, enter values as below in the pop up window.



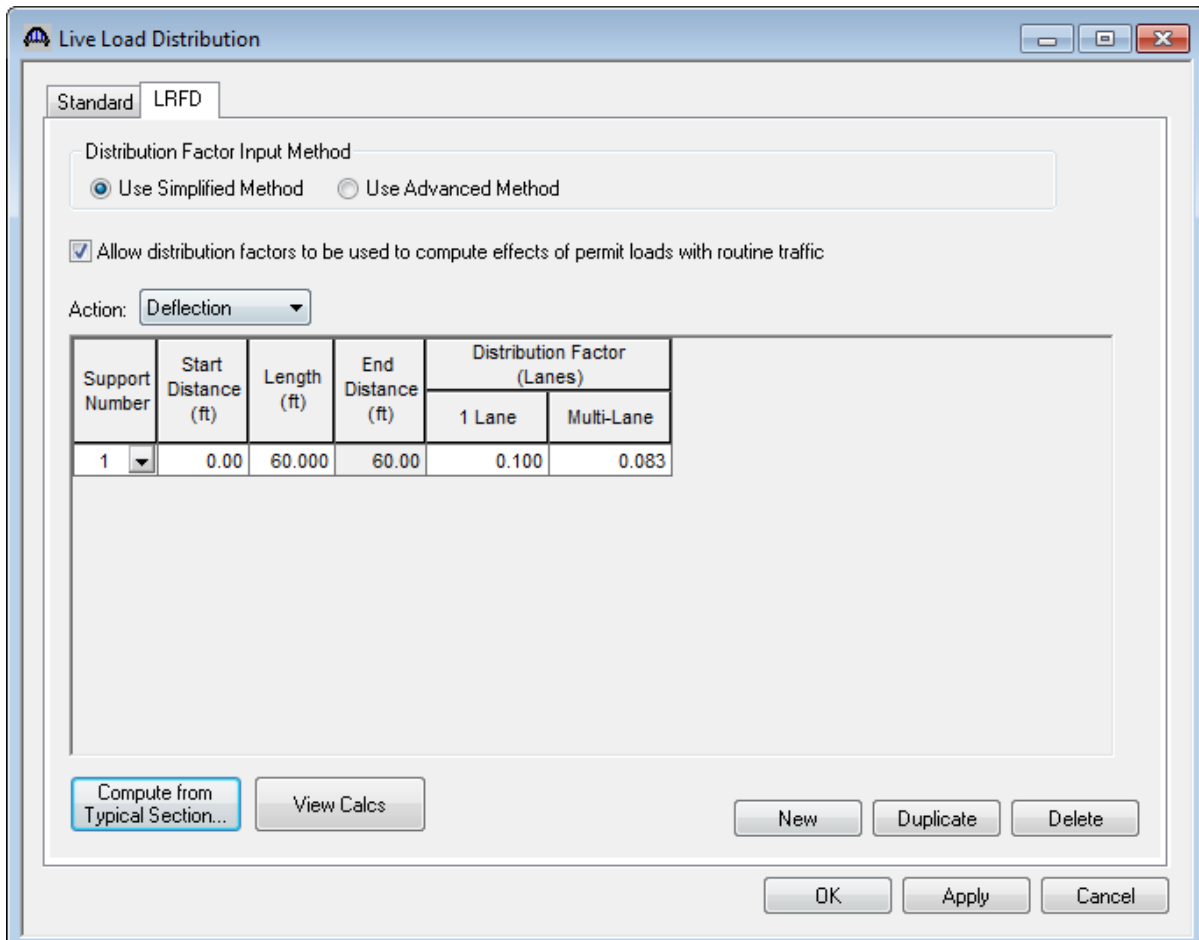
The dialog box titled "Girderline RC Slab Width" contains the following input fields:

- Overall slab width: 27.00 ft
- Number of lanes: 2
- Slab width: 12.0000 in
- Skew: 0 Degrees

Buttons: Continue, Cancel

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

Deflection distribution factors.



The "Live Load Distribution" dialog box is shown with the LRFD tab selected. The "Distribution Factor Input Method" is set to "Use Simplified Method". The checkbox "Allow distribution factors to be used to compute effects of permit loads with routine traffic" is checked. The "Action" dropdown is set to "Deflection".

Support Number	Start Distance (ft)	Length (ft)	End Distance (ft)	Distribution Factor (Lanes)	
				1 Lane	Multi-Lane
1	0.00	60.000	60.00	0.100	0.083

Buttons: Compute from Typical Section..., View Calcs, New, Duplicate, Delete, OK, Apply, Cancel

RC4 – Two Span RC Concrete Slab

Moment and shear have the same following distribution factors.

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

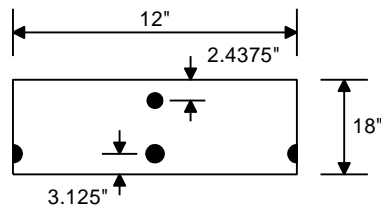
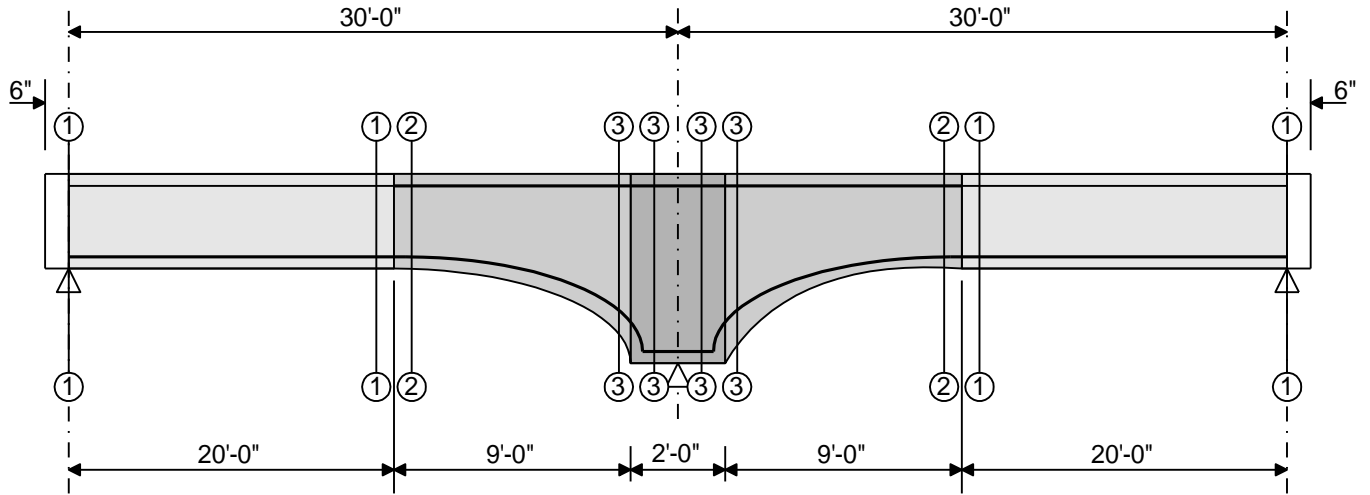
Action: Moment

Support Number	Start Distance (ft)	Length (ft)	End Distance (ft)	Distribution Factor (Lanes)	
				1 Lane	Multi-Lane
1	0.00	30.000	30.00	0.079	0.096
2	0.00	30.000	30.00	0.079	0.096

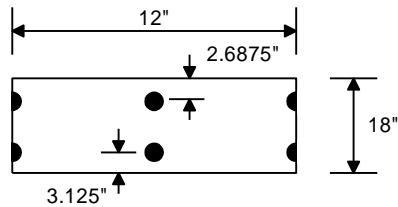
Compute from Typical Section... View Calcs New Duplicate Delete OK Apply Cancel

RC4 – Two Span RC Concrete Slab

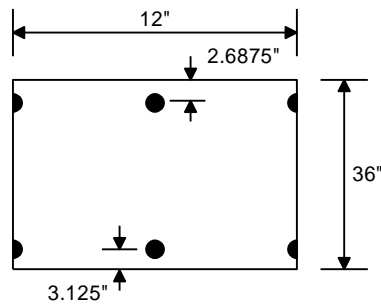
We can now create a new cross section by double-clicking on Cross Section in the tree. This member contains three cross sections as illustrated below. The completed Cross Section windows follow.



Section 1



Section 2



Section 3

RC4 – Two Span RC Concrete Slab

Cross Sections

Name: Type:

Dimensions Reinforcement

Concrete Material:

Modular Ratio:

12.0000 in

18.0000 in

OK Apply Cancel

Cross Sections

Name: Type:

Dimensions Reinforcement

Row	Std Bar Count	LRFD Bar Count	Bar Size	Distance (in)	Material	Bar Spacing (in)
Top of Slab	1.00	1.00	5	2.4375	Grade	
Bottom of Slab	2.00	2.00	9	3.1250	Grade	

Distance from top of slab

Distance from bottom of slab

New Duplicate Delete

OK Apply Cancel

RC4 – Two Span RC Concrete Slab

Cross Sections

Name: Section 2 Type: Reinforced Concrete Slab

Dimensions Reinforcement

Concrete Material: Class A (US) Modular Ratio:

12.0000 in 18.0000 in

OK Apply Cancel

Cross Sections

Name: Section 2 Type: Reinforced Concrete Slab

Dimensions Reinforcement

Row	Std Bar Count	LRFD Bar Count	Bar Size	Distance (in)	Material	Bar Spacing (in)
Top of Slab	2.00	2.00	9	2.6875	Grade 60	
Bottom of Slab	2.00	2.00	9	3.1250	Grade 60	

Distance from top of slab

Distance from bottom of slab

New Duplicate Delete

OK Apply Cancel

RC4 – Two Span RC Concrete Slab

Cross Sections

Name: Section 3 Type: Reinforced Concrete Slab

Dimensions Reinforcement

Concrete Material: Class A (US) Modular Ratio:

12.0000 in 36.0000 in

OK Apply Cancel

Cross Sections

Name: Section 3 Type: Reinforced Concrete Slab

Dimensions Reinforcement

Row	Std Bar Count	LRFD Bar Count	Bar Size	Distance (in)	Material	Bar Spacing (in)
Top of Slab	2.00	2.00	9	2.6875	Grade 60	
Bottom of Slab	2.00	2.00	9	3.1250	Grade 60	

Distance from top of slab

Distance from bottom of slab

New Duplicate Delete

OK Apply Cancel

RC4 – Two Span RC Concrete Slab

The cross sections are now applied over the length of the member using the Cross Section Ranges window as shown below:

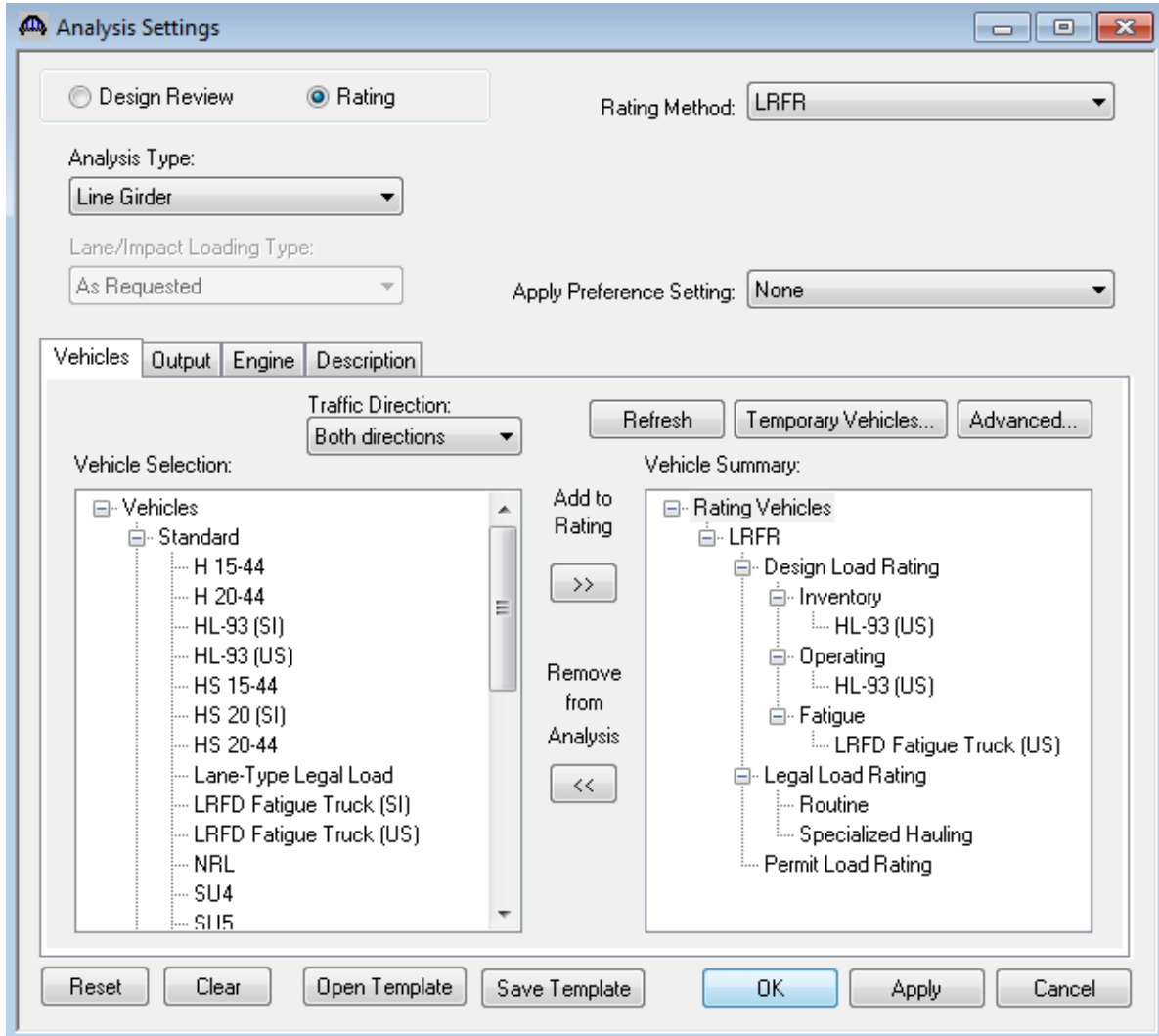
Start Section	End Section	Web Variation	Support Number	Start Distance (ft)	Length (ft)	End Distance (ft)
Section 1	Section 1	None	1	0.000	20.000	20.000
Section 2	Section 3	Parabolic Concave	1	20.000	9.000	29.000
Section 3	Section 3	None	1	29.000	2.000	31.000
Section 3	Section 2	Parabolic Concave	2	1.000	9.000	10.000
Section 1	Section 1	None	2	10.000	20.000	30.000

Shear Reinforcement Ranges and Bracing Ranges are not applicable to this member so we will not enter any data in these windows. We also do not need to define any Points of Interest since we will not be overriding any information we have entered.

The description of this structure is complete.

RC4 – Two Span RC Concrete Slab

The member alternative can now be analyzed. To perform LRFR rating, select the View Analysis Settings button on the toolbar to open the window shown below. Click Open Template button and select the LRFR Design Load Rating to be used in the rating and click Ok.



RC4 – Two Span RC Concrete Slab

Next click the Analyze button on the toolbar to perform the rating. When the rating is finished you can review the results by clicking the View analysis Report on the toolbar. The window shown below will open.

Analysis Results - 12" wide slab line

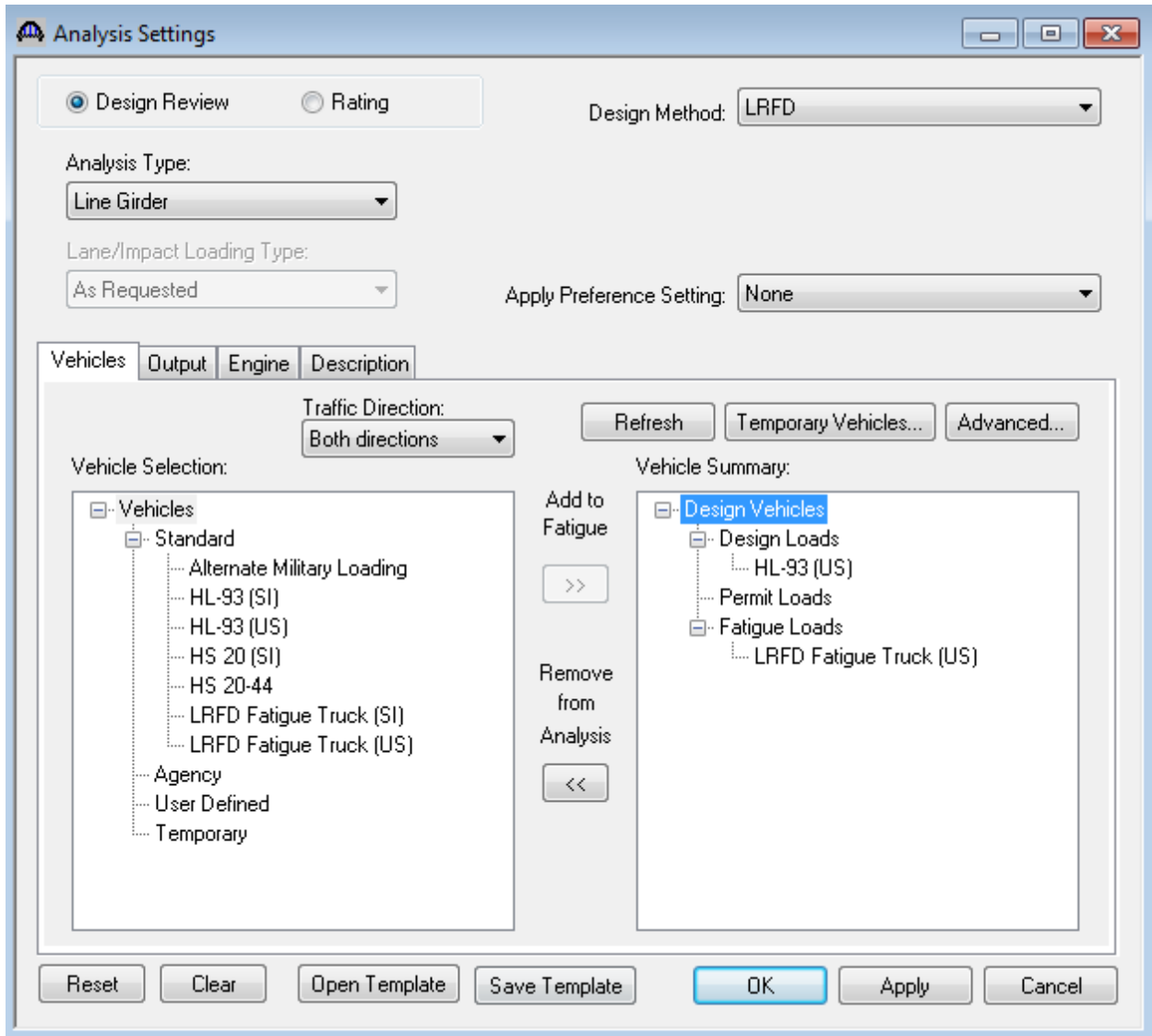
Report Type: Rating Results Summary | Lane/Impact Loading Type: As Requested Detailed | Display Format: Single rating level per row

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	30.11	0.836	40.00	2 - (33.3)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	39.03	1.084	40.00	2 - (33.3)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	29.30	0.814	40.00	2 - (33.3)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	37.98	1.055	40.00	2 - (33.3)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	90%(Truck Pair	LRFR	Inventory	34.23	0.951	40.00	2 - (33.3)	STRENGTH-I Concrete Flexure	As Requested	As Requested
HL-93 (US)	90%(Truck Pair	LRFR	Operating	44.37	1.233	40.00	2 - (33.3)	STRENGTH-I Concrete Flexure	As Requested	As Requested


AASHTO LRFR Engine Version 6.8.0.3001
Analysis Preference Setting: None

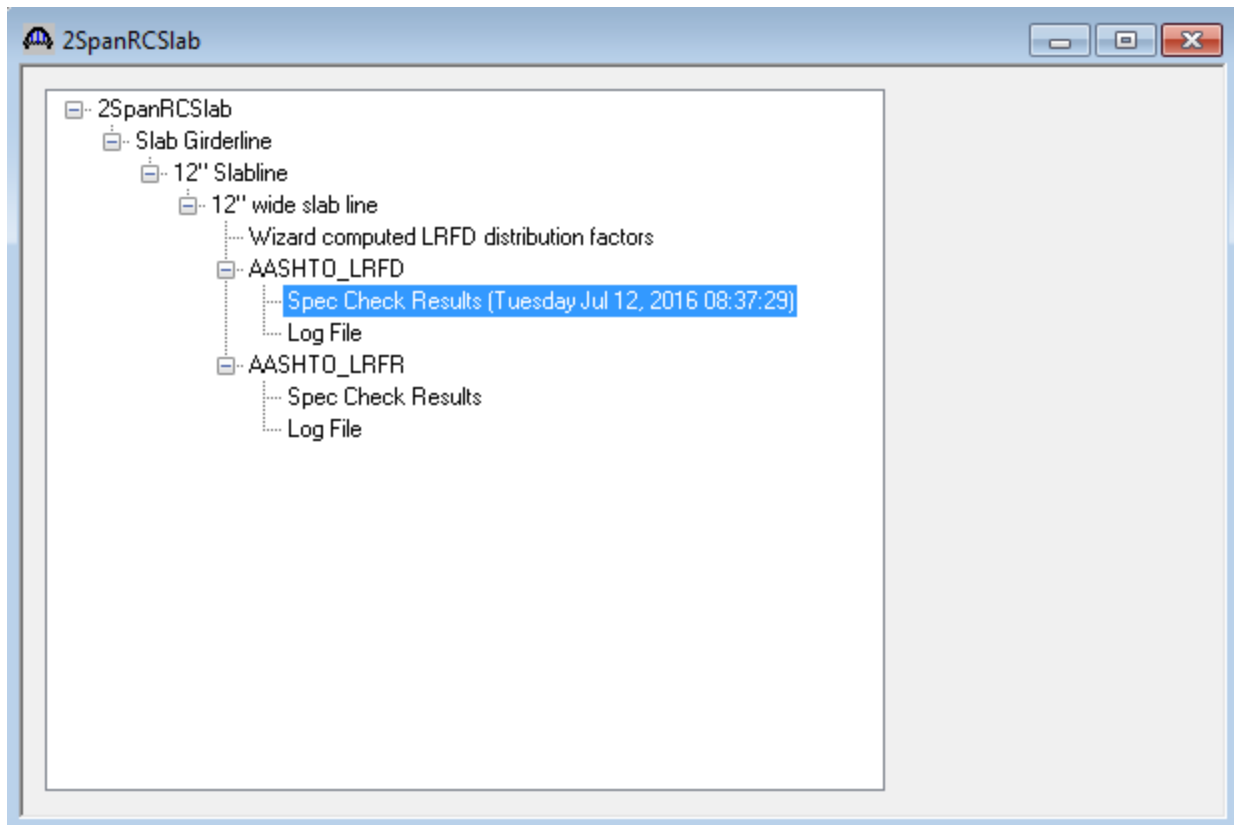
Close

An LRFD design review of this girder for HL93 loading can be performed by BrD LRFD. To do LRFD design review, enter the Analysis Settings window as shown below:



RC4 – Two Span RC Concrete Slab

BrD LRFD analysis will generate a spec check results file. Click  on tool bar to open the following window.



To view the spec check results, double click the Spec Check Results in this window.

Bridge ID : 450
 Bridge : 2 Span RC Slab
 Superstructure Def : Slab Girderline
 Member : 12" Slabline
 Analysis Preference Setting : None

NBI Structure ID : 2SpanRCSlab
 Bridge Alt :
 Member Alt : 12" wide slab line

AASHTO LRFD Specification, Edition 7, Interim 2016

Specification Check Summary

Article	Status
Flexure (5.7.3.2, 5.7.3.3.2)	Fail
Crack Control (5.7.3.4)	Fail
Shear (5.8.3.3, 5.8.2.5, 5.8.2.7, 5.8.3.5)	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)	Mr/Mu	Code
0.000	STR-I	1	120.79	0.00	99.00	Pass
3.000	STR-I	2	120.79	37.13	3.25	Pass
6.000	STR-I	2	120.79	61.74	1.96	Pass
9.000	STR-I	2	120.79	74.49	1.62	Pass
12.000	STR-I	2	120.79	76.38	1.58	Pass
15.000	STR-I	2	120.79	69.96	1.73	Pass
18.000	STR-I	2	120.79	55.51	2.18	Pass
20.000	STR-I	2	120.70	41.78	2.89	Pass
21.000	STR-I	2	122.75	34.50	3.56	Pass
24.000	STR-I	2	152.75	9.77	15.63	Pass