

AASHTOWare BrDR 7.5.0

LRFR Concrete Moment Redistribution Tutorial

Moment Redistribution in Three Span Spread PS Box Beam

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

Details, including flowcharts, about moment redistribution in concrete structures can be found in AASHTO LRFD LRFR Superstructure Method of Solution Manual accessible from the Help menu in BrDR.

Topics Covered

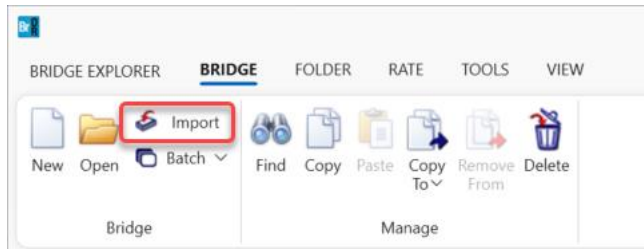
- Bridge Model
- Analysis Settings
- Member Alternative Description – Control options
- LRFR Rating
- Specification Check Detail
- LRFR Rating with Moment Redistribution
- Specification Check Detail with Moment Redistribution
- Moment Redistribution Report

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Bridge Model

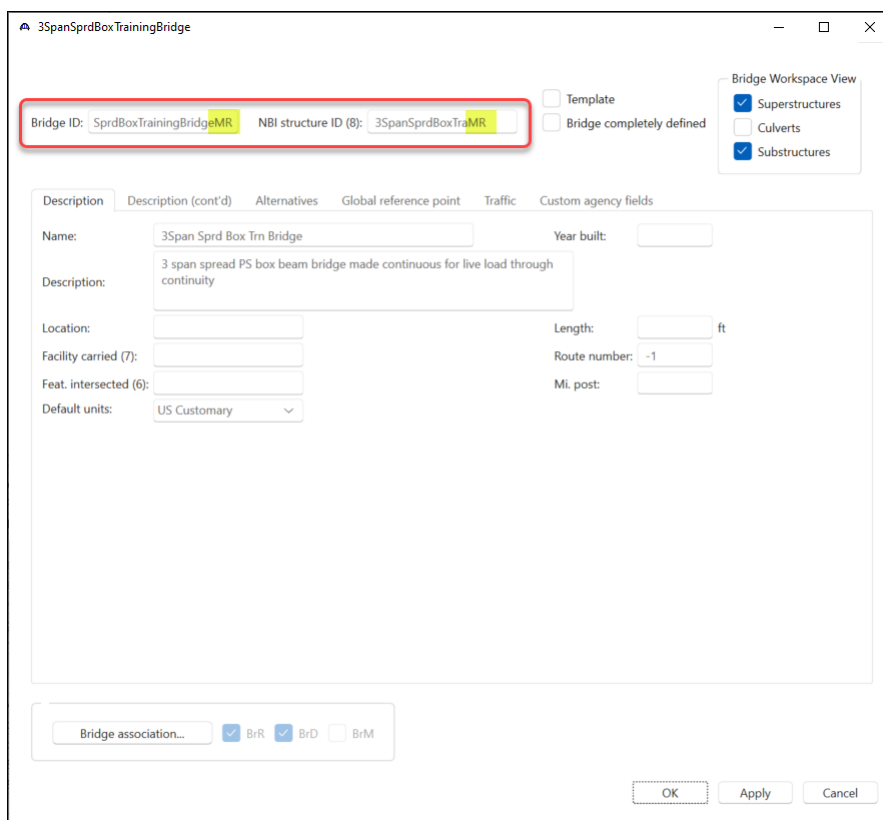
This tutorial uses the bridge created from prestressed concrete structure tutorial PS2 with some minor modifications to satisfy moment redistribution requirements and to illustrate the impact of moment redistribution on rating.

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



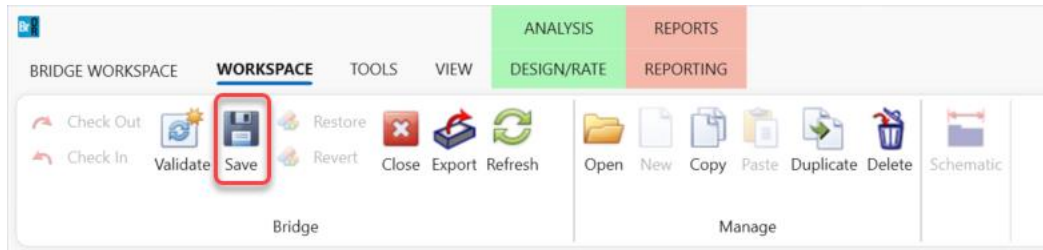
If information is displayed about the version of the imported file being different than the current version of the program, confirm by clicking **Yes** to have the imported file migrated to the current version of the program.

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

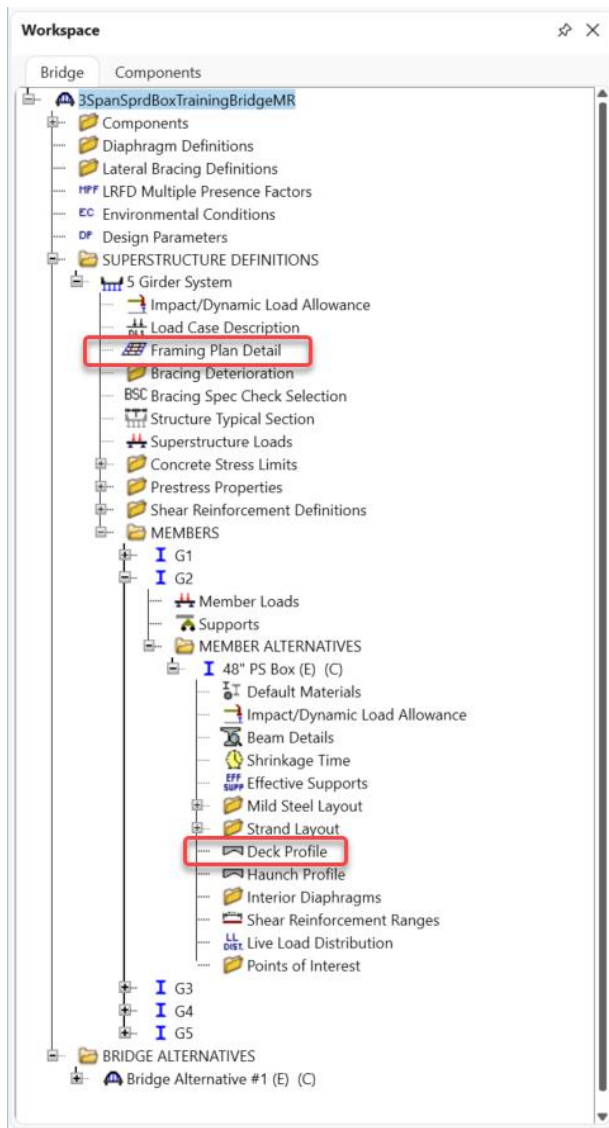
The image shows a 'Bridge Description' window titled '3SpanSprdBoxTrainingBridge'. At the top, there are two text fields: 'Bridge ID: SprdBoxTrainingBridgeMR' and 'NBI structure ID (8): 3SpanSprdBoxTraMR', both of which are highlighted with a red rectangular box. To the right of these fields are checkboxes for 'Template' and 'Bridge completely defined'. Further right is a 'Bridge Workspace View' section with checkboxes for 'Superstructures' (checked), 'Culverts', and 'Substructures' (checked). Below these are several tabs: 'Description', 'Description (cont'd)', 'Alternatives', 'Global reference point', 'Traffic', and 'Custom agency fields'. The 'Description' tab is active, showing fields for 'Name' (3Span Sprd Box Trn Bridge), 'Year built', 'Description' (3 span spread PS box beam bridge made continuous for live load through continuity), 'Location', 'Length' (ft), 'Facility carried (7)', 'Route number' (-1), 'Feat. intersected (6)', 'MI. post', and 'Default units' (US Customary). At the bottom, there is a 'Bridge association...' section with checkboxes for 'BrR' (checked), 'BrD' (checked), and 'BrM'. At the very bottom are 'OK', 'Apply', and 'Cancel' buttons.

Click OK to close the Bridge Description window.

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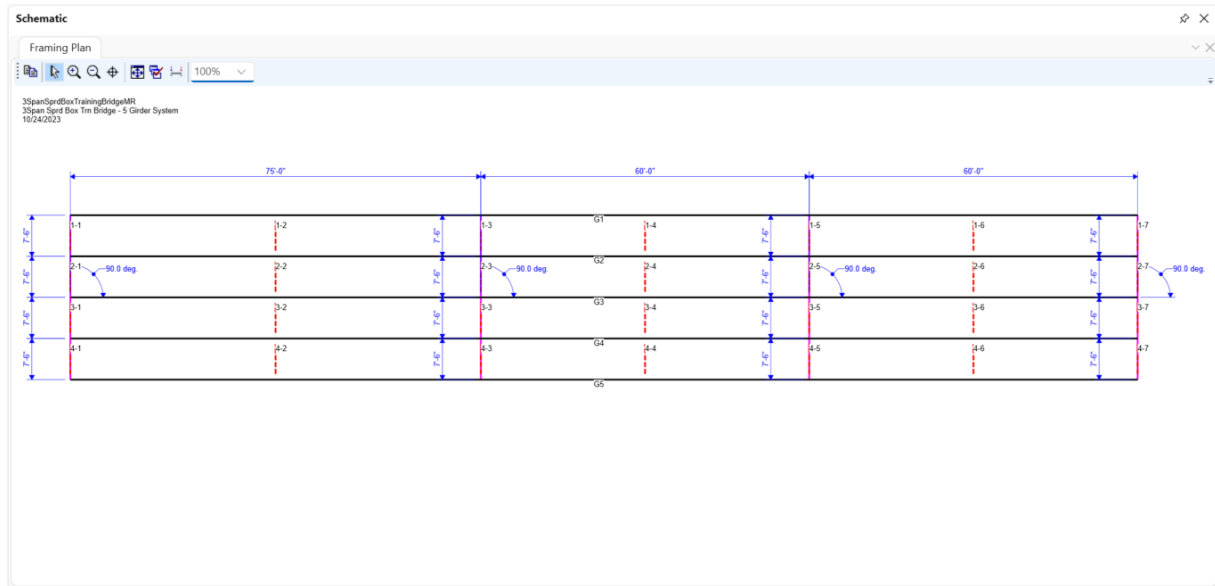


Save the imported bridge to the database using the **Save** button located on the **WORKSPACE** ribbon. The partially expanded **Bridge Workspace** tree is shown below:



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

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

Deck Profile

Type: PS Precast Box

Deck concrete Reinforcement

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

New Duplicate Delete

OK Apply Cancel

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

Moment Redistribution in Three Span Spread PS Box Beam

Deck Profile

Type: PS Precast Box

Deck concrete Reinforcement

| | Material | Support number | Start distance (ft) | Length (ft) | End distance (ft) | Std bar count | LRFD bar count | Bar size | Distance (in) | Row | Bar spacing (in) |
|---|----------|----------------|---------------------|-------------|-------------------|---------------|----------------|----------|---------------|----------------|------------------|
| > | Grade 60 | 1 | 55.00 | 100.00 | 155.00 | 9.00 | 9.00 | 6 | 3.5000 | Top of Slab | |
| | Grade 60 | 1 | 55.00 | 100.00 | 155.00 | 9.00 | 9.00 | 5 | 2.0000 | Bottom of Slab | |

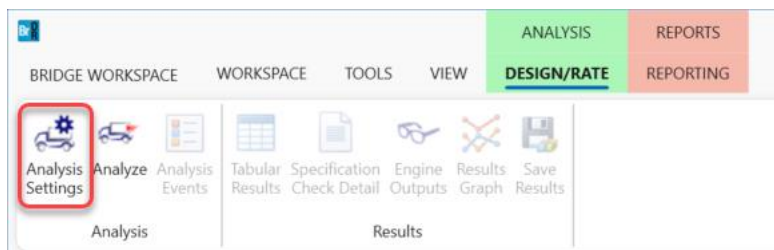
New Duplicate Delete

OK Apply Cancel

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

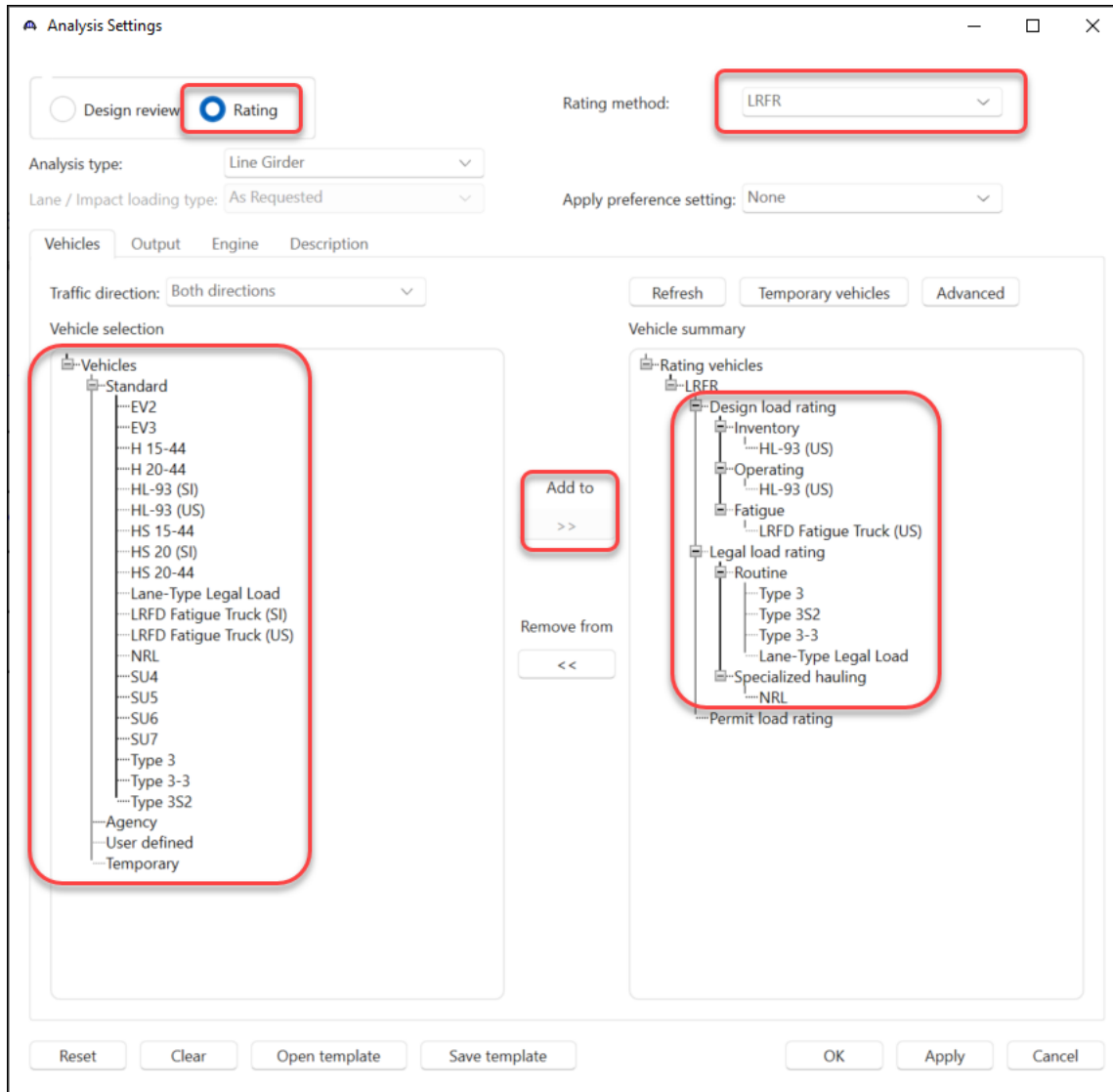
Analysis Settings

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



In the **Analysis Settings** window, select **Rating** and **LRFR** as the **Rating Method**. Then assign vehicles from the **Vehicle selection** tree on the left to the rating levels under the **Vehicle summary** tree on the right as shown in the screenshot below. The assignment is done in three steps. First clicking on a rating level, next by clicking on a vehicle,

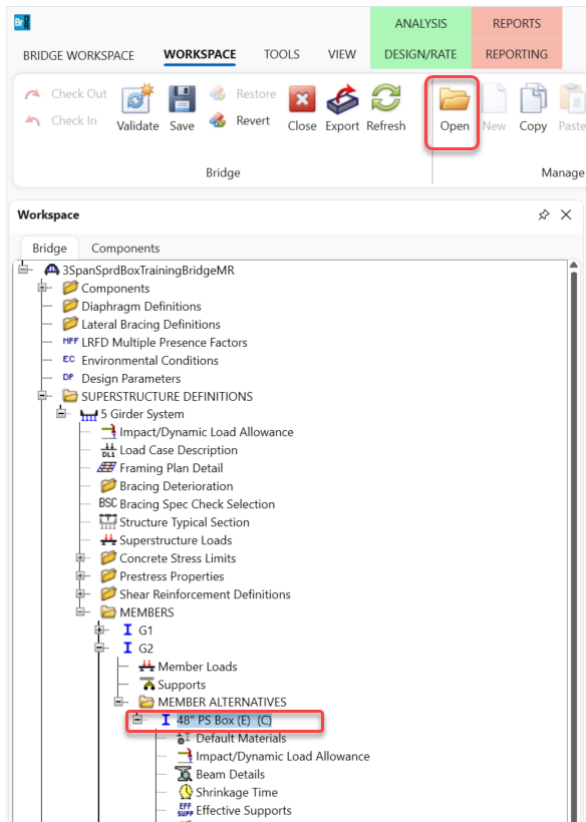
and then by clicking on the **Add to** button. To assign multiple vehicles to the same level, only the last two steps need to be repeated. Also, double-clicking on a vehicle has the same effect as the last two steps.



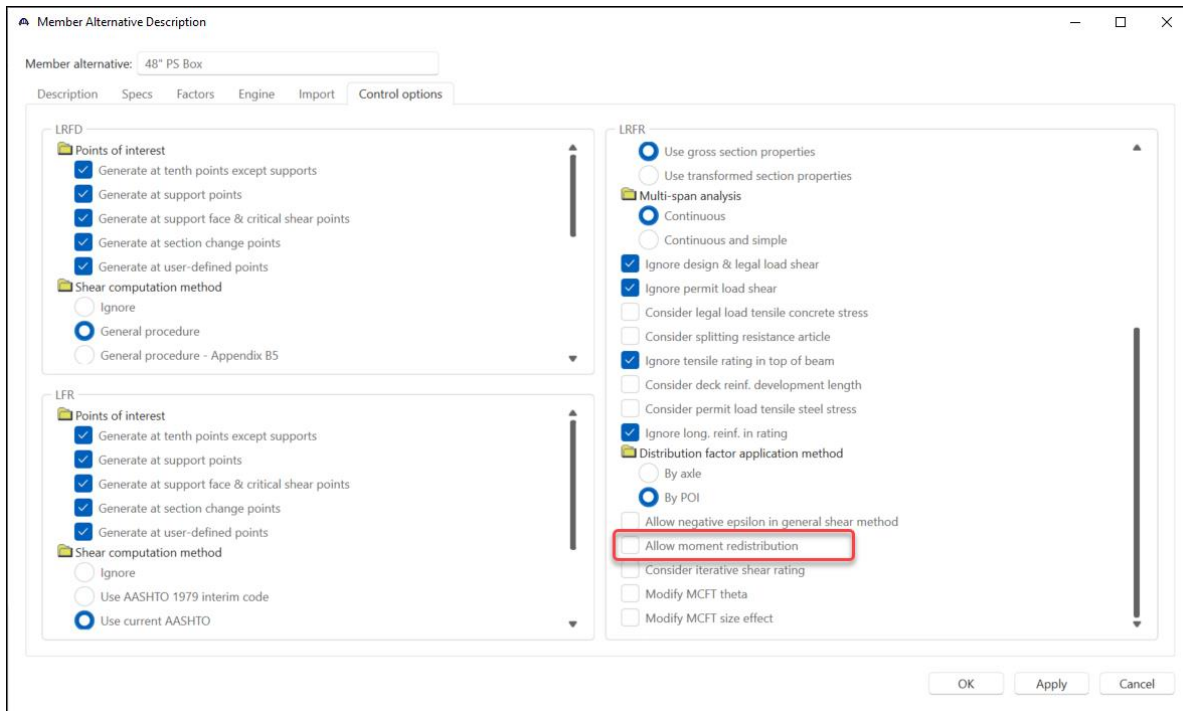
Member Alternative Description – Control options

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

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

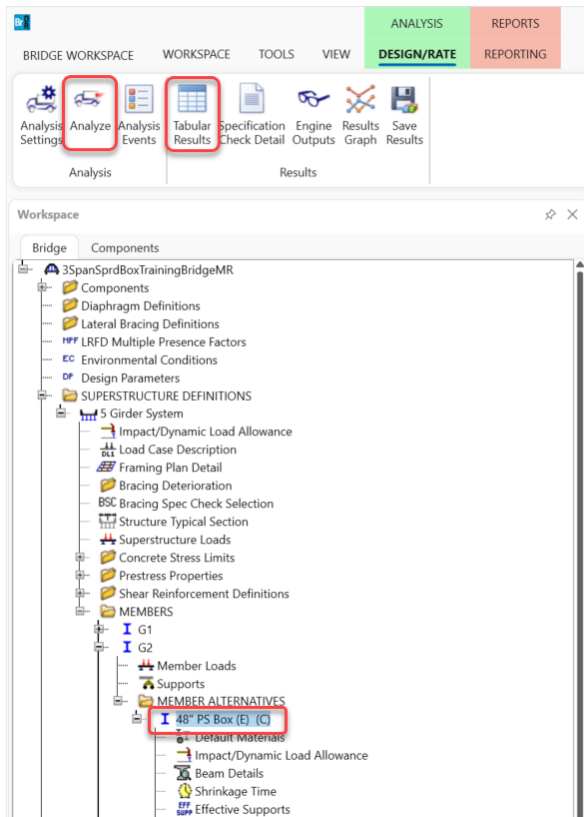


Moment Redistribution in Three Span Spread PS Box Beam

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

LRFR Rating

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



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

Moment Redistribution in Three Span Spread PS Box Beam

Analysis Results - 48" PS Box

Report type: Rating Results Summary Lane/Impact loading type: As requested 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 | 31.39 | 0.872 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| HL-93 (US) | Truck + Lane | LRFR | Operating | 40.69 | 1.130 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| HL-93 (US) | 90%(Truck Pair + Lane) | LRFR | Inventory | 28.50 | 0.792 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| HL-93 (US) | 90%(Truck Pair + Lane) | LRFR | Operating | 36.95 | 1.026 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| HL-93 (US) | Tandem + Lane | LRFR | Inventory | 37.06 | 1.029 | 37.13 | 1 - (49.5) | SERVICE-III PS Tensile Stress | As Requested | As Requested |
| HL-93 (US) | Tandem + Lane | LRFR | Operating | 49.11 | 1.364 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| Lane-Type Legal Load | Truck + Lane | LRFR | Legal | 3960.00 | 99.000 | 0.00 | 1 - (0.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| Lane-Type Legal Load | Truck Pair + Lane | LRFR | Legal | 69.73 | 1.743 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| NRL | Axle Load | LRFR | Legal | 61.57 | 1.539 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| NRL | Truck Pair | LRFR | Legal | 83.61 | 1.045 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| Type 3 | Axle Load | LRFR | Legal | 61.25 | 2.450 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| Type 3-3 | Axle Load | LRFR | Legal | 79.83 | 1.996 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| Type 3S2 | Axle Load | LRFR | Legal | 70.96 | 1.971 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |

AASHTO LRFR Engine Version 7.5.0.3001
Analysis preference setting: None

Specification Check Detail

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

Specification Checks for 48" PS Box - 12 of 1879

Properties Generate Articles: All articles Format: Bullet list Report

Specification filter

Superstructure Component

- Prestress Calculations
 - Stage 1
 - Stage 2
 - Stage 3
 - 48" PS Box
 - Span 1 - 0.00 ft.
 - Span 1 - 1.75 ft.
 - Span 1 - 7.50 ft.
 - Span 1 - 15.00 ft.
 - Span 1 - 21.75 ft.
 - Span 1 - 22.50 ft.
 - Span 1 - 30.00 ft.
 - Span 1 - 37.13 ft.
 - Span 1 - 45.00 ft.
 - Span 1 - 52.25 ft.
 - Span 1 - 52.50 ft.
 - Span 1 - 55.00 ft.
 - Span 1 - 60.00 ft.
 - Span 1 - 67.50 ft.
 - Span 1 - 72.25 ft.
 - Span 1 - 74.25 ft.
 - Span 1 - 75.00 ft.
 - Span 2 - 0.75 ft.
 - Span 2 - 2.75 ft.
 - Span 2 - 6.00 ft.
 - Span 2 - 12.00 ft.
 - Span 2 - 18.00 ft.
 - Span 2 - 19.25 ft.
 - Span 2 - 24.00 ft.
 - Span 2 - 30.00 ft.
 - Span 2 - 36.00 ft.

Specification reference

| Specification reference | Limit State | Flex. Sense | Pass/Fail |
|--|-------------|-------------|---------------|
| ✓ 5.4.2.1 Compressive Strength | | N/A | Passed |
| ✓ 5.4.2.5 Poisson's Ratio | | N/A | General Comp. |
| ✓ 5.4.2.6 Modulus of Rupture | | N/A | General Comp. |
| ✓ 5.4.2.8 Concrete Density Modification Factor | | N/A | General Comp. |
| ✓ 5.5.4.2 PS Strength Limit State - Resistance Factors | | N/A | General Comp. |
| ✓ 5.6.2.2 Rectangular Stress Distribution | | N/A | General Comp. |
| ✗ 5.6.3.2 PS Flexural Resistance (Prestressed Concrete) | | N/A | Failed |
| ✓ 5.6.3.3 Minimum Reinforcement | | N/A | Passed |
| ✗ 6A.4.2.1 General Load Rating Equation - Concrete Flexure | | N/A | Failed |
| ✓ Cracked_Moment_of_Inertia Section Property Calculations | | N/A | General Comp. |
| ✓ PS_Basic_Properties Calculation | | N/A | General Comp. |
| ✓ PS_Gross_Composite_Section_Properties PS Gross Composite Section | | N/A | General Comp. |

To review the flexure ratings at the 75.0 ft location, navigate to the **Stage 3** specification check detail for the analyzed member alternative, select the **Span 1 – 75.00 ft** point of interest, and then double-click on article **6A.4.2**

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

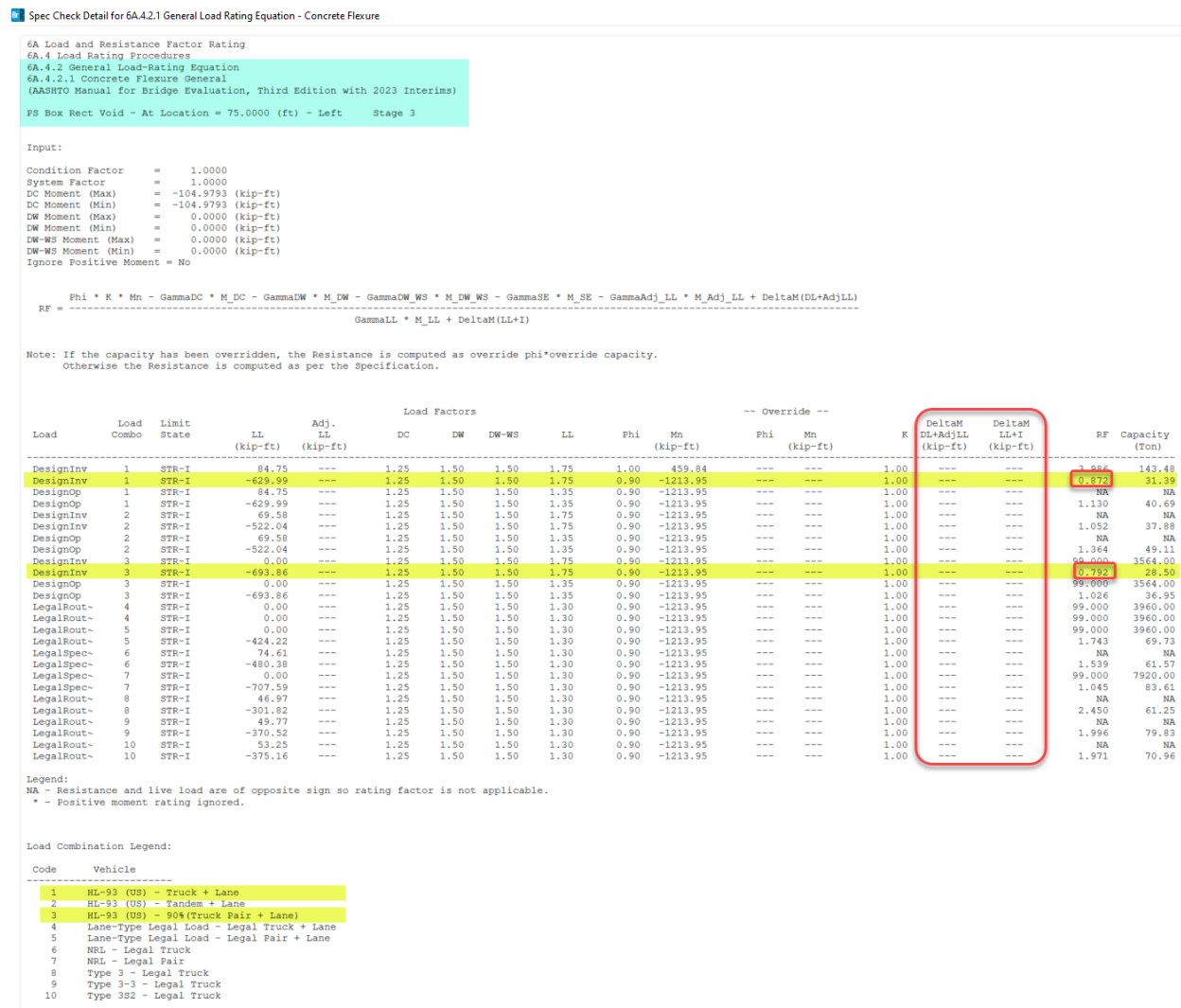
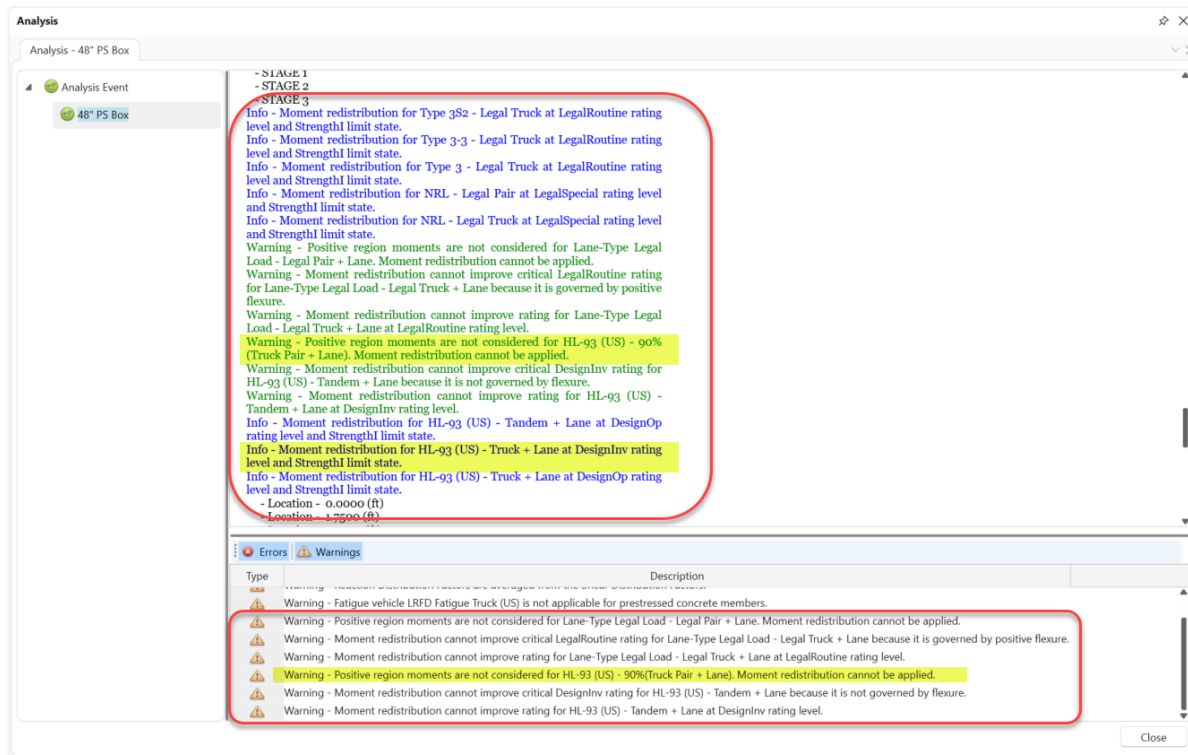


Figure 1 – 6A.4.2.1 Concrete Flexure General

LRFR Rating with Moment Redistribution

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

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

Analysis Results - 48" PS Box

Print

Report type: **Rating Results Summary** Lane/Impact loading type: ☒ As requested ☐ Detailed Display Format: **Single rating level per row**

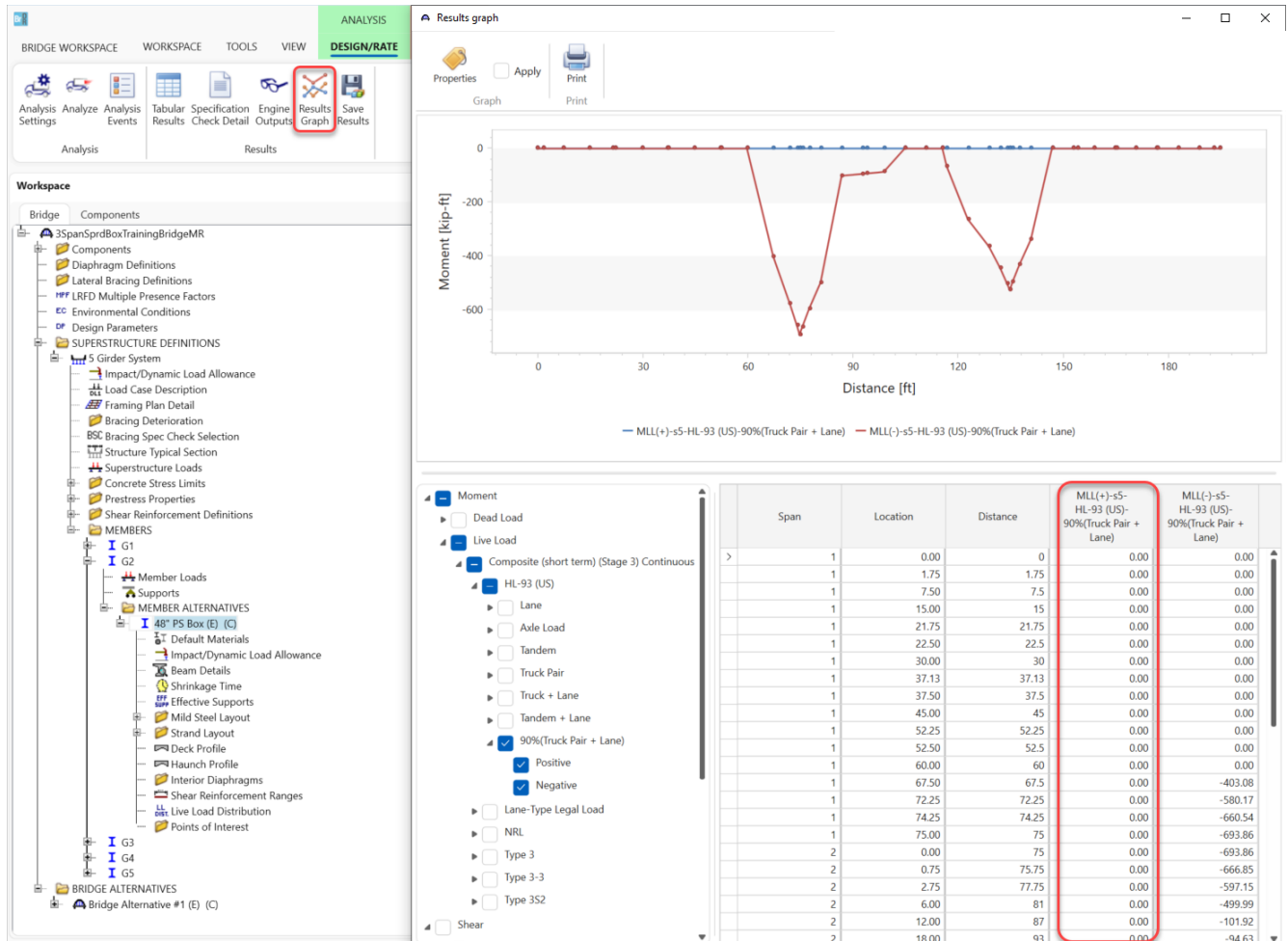
| Live Load | Live Load Type | Rating Method | Rating Level | Load Rating (Ton) | Rating Factor | Location (ft) | Location Span-(%) | Limit State | Impact | Lane |
|----------------------|------------------------|---------------|--------------|-------------------|---------------|---------------|-------------------|-------------------------------|--------------|--------------|
| HL-93 (US) | Truck + Lane | LRFR | Inventory | 32.87 | 0.913 | 37.13 | 1 - (49.5) | SERVICE-III PS Tensile Stress | As Requested | As Requested |
| HL-93 (US) | Truck + Lane | LRFR | Operating | 52.25 | 1.451 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| HL-93 (US) | 90%(Truck Pair + Lane) | LRFR | Inventory | 28.50 | 0.792 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| HL-93 (US) | 90%(Truck Pair + Lane) | LRFR | Operating | 36.95 | 1.026 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| HL-93 (US) | Tandem + Lane | LRFR | Inventory | 37.06 | 1.029 | 37.13 | 1 - (49.5) | SERVICE-III PS Tensile Stress | As Requested | As Requested |
| HL-93 (US) | Tandem + Lane | LRFR | Operating | 61.32 | 1.703 | 37.13 | 1 - (49.5) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| Lane-Type Legal Load | Truck + Lane | LRFR | Legal | 3960.00 | 99.000 | 0.00 | 1 - (0.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| Lane-Type Legal Load | Truck Pair + Lane | LRFR | Legal | 69.73 | 1.743 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| NRL | Axle Load | LRFR | Legal | 72.91 | 1.823 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| NRL | Truck Pair | LRFR | Legal | 107.36 | 1.342 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| Type 3 | Axle Load | LRFR | Legal | 71.59 | 2.864 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| Type 3-3 | Axle Load | LRFR | Legal | 102.51 | 2.563 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |
| Type 3S2 | Axle Load | LRFR | Legal | 91.12 | 2.531 | 75.00 | 1 - (100.0) | STRENGTH-I Concrete Flexure | As Requested | As Requested |

AASHTO LRFR Engine Version 7.5.0.3001
Analysis preference setting: None

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

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



Specification Check Detail with Moment Redistribution

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

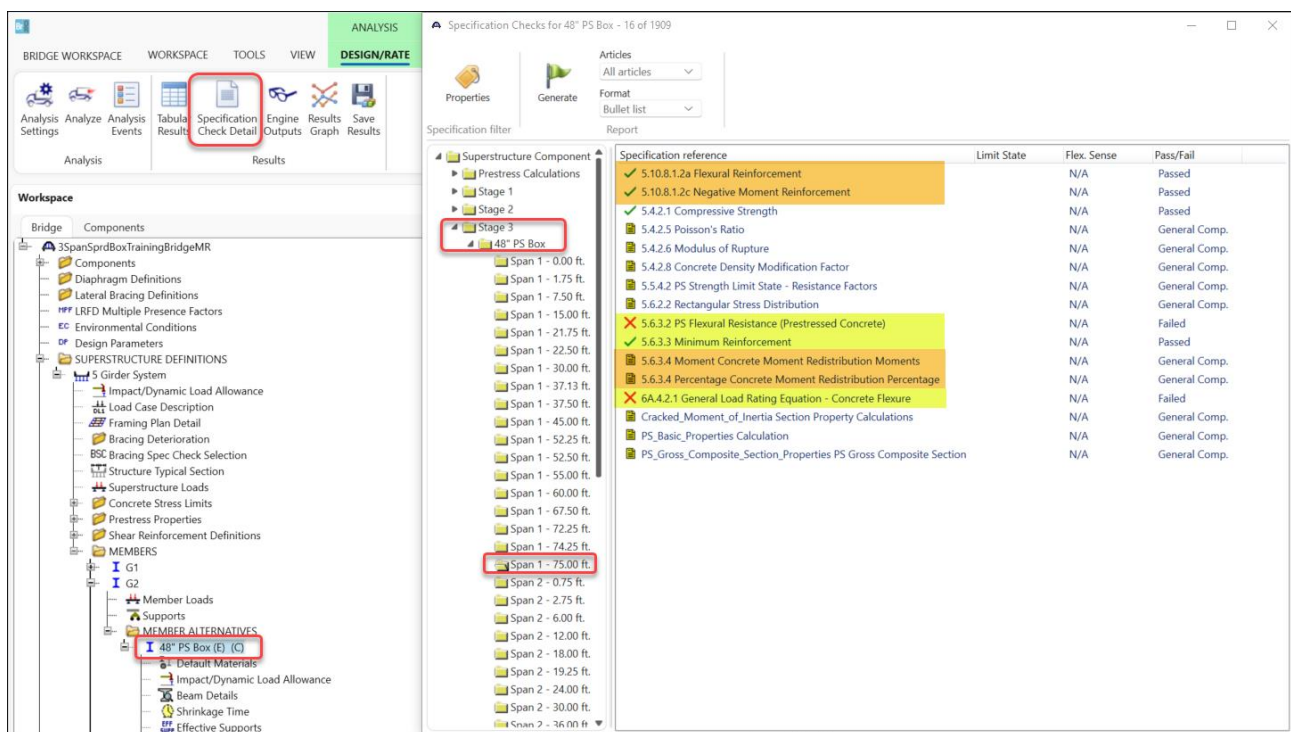
- 5.10.8.1.2a Flexural Reinforcement (in negative moment regions)
- 5.10.8.1.2c Negative Moment Reinforcement (at support locations)
- 5.6.3.4 Moment Redistribution Percentage (at support locations)
- 5.6.3.4 Maximum Allowable Moment Redistribution Moments (at support locations)

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

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

Open each of the highlighted articles and review their contents.



| Specification reference | Limit State | Flex. Sense | Pass/Fail |
|--|-------------|-------------|---------------|
| ✓ 5.10.8.1.2a Flexural Reinforcement | | N/A | Passed |
| ✓ 5.10.8.1.2c Negative Moment Reinforcement | | N/A | Passed |
| ✓ 5.4.2.1 Compressive Strength | | N/A | Passed |
| ✓ 5.4.2.5 Poisson's Ratio | | N/A | General Comp. |
| ✓ 5.4.2.6 Modulus of Rupture | | N/A | General Comp. |
| ✓ 5.4.2.8 Concrete Density Modification Factor | | N/A | General Comp. |
| ✓ 5.5.4.2 PS Strength Limit State - Resistance Factors | | N/A | General Comp. |
| ✓ 5.6.2.2 Rectangular Stress Distribution | | N/A | General Comp. |
| ✗ 5.6.3.2 PS Flexural Resistance (Prestressed Concrete) | | N/A | Failed |
| ✓ 5.6.3.3 Minimum Reinforcement | | N/A | Passed |
| ✓ 5.6.3.4 Moment Concrete Moment Redistribution Moments | | N/A | General Comp. |
| ✓ 5.6.3.4 Percentage Concrete Moment Redistribution Percentage | | N/A | General Comp. |
| ✗ 6A.4.2.1 General Load Rating Equation - Concrete Flexure | | N/A | Failed |
| ✓ Cracked_Moment_of_Inertia Section Property Calculations | | N/A | General Comp. |
| ✓ PS_Basic_Properties Calculation | | N/A | General Comp. |
| ✓ PS_Gross_Composite_Section_Properties PS Gross Composite Section | | N/A | General Comp. |

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

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

Moment Redistribution in Three Span Spread PS Box Beam

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

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

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

Input:

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

RF = $\frac{\Phi * K * M_n - \text{GammaDC} * M_{DC} - \text{GammaDW} * M_{DW} - \text{GammaWS} * M_{DW-WS} - \text{GammaSE} * M_{SE} - \text{GammaAdjLL} * M_{AdjLL} + \text{DeltaM}(\text{DL} + \text{AdjLL})}{\text{GammaLL} * M_{LL} + \text{DeltaM}(\text{LL} + \text{I})}$

Note: If the capacity has been overridden, the Resistance is computed as override phi*override capacity.
 Otherwise the Resistance is computed as per the Specification.

| Load | Load Combo | Limit State | LL (kip-ft) | Adj. LL (kip-ft) | Load Factors | | | | -- Override -- | | | | K | DeltaM DL+AdjLL (kip-ft) | DeltaM LL+I (kip-ft) | RF | Capacity (Ton) |
|-----------|------------|-------------|-------------|------------------|--------------|------|-------|------|----------------|-------------|-----|-------------|------|--------------------------|----------------------|--------|----------------|
| | | | | | DC | DW | DW-WS | LL | Phi | Mn (kip-ft) | Phi | Mn (kip-ft) | | | | | |
| DesignInv | 1 | STR-I | 84.75 | --- | 1.25 | 1.50 | 1.50 | 1.75 | 1.00 | 459.84 | --- | --- | 1.00 | 26.24 | 220.50 | 1.532 | 55.13 |
| DesignInv | 1 | STR-I | -629.99 | --- | 1.25 | 1.50 | 1.50 | 1.75 | 0.90 | -1213.95 | --- | --- | 1.00 | 26.24 | 220.50 | 1.120 | 40.31 |
| DesignOp | 1 | STR-I | 84.75 | --- | 1.25 | 1.50 | 1.50 | 1.35 | 1.00 | 459.84 | --- | --- | 1.00 | 26.24 | 170.10 | 1.985 | 71.47 |
| DesignOp | 1 | STR-I | -629.99 | --- | 1.25 | 1.50 | 1.50 | 1.35 | 0.90 | -1213.95 | --- | --- | 1.00 | 26.24 | 170.10 | 1.451 | 52.25 |
| DesignInv | 2 | STR-I | 69.58 | --- | 1.25 | 1.50 | 1.50 | 1.75 | 0.90 | -1213.95 | --- | --- | 1.00 | --- | --- | NA | NA |
| DesignInv | 2 | STR-I | -522.04 | --- | 1.25 | 1.50 | 1.50 | 1.75 | 0.90 | -1213.95 | --- | --- | 1.00 | --- | --- | 1.052 | 37.88 |
| DesignOp | 2 | STR-I | 69.58 | --- | 1.25 | 1.50 | 1.50 | 1.35 | 1.00 | 459.84 | --- | --- | 1.00 | 23.58 | 126.64 | 2.573 | 92.62 |
| DesignOp | 2 | STR-I | -522.04 | --- | 1.25 | 1.50 | 1.50 | 1.35 | 0.90 | -1213.95 | --- | --- | 1.00 | 23.58 | 126.64 | 1.704 | 61.33 |
| DesignInv | 3 | STR-I | 0.00 | --- | 1.25 | 1.50 | 1.50 | 1.75 | 0.90 | -1213.95 | --- | --- | 1.00 | --- | --- | 99.000 | 3564.00 |
| DesignInv | 3 | STR-I | -693.86 | --- | 1.25 | 1.50 | 1.50 | 1.75 | 0.90 | -1213.95 | --- | --- | 1.00 | --- | --- | 0.792 | 28.50 |
| DesignOp | 3 | STR-I | 0.00 | --- | 1.25 | 1.50 | 1.50 | 1.35 | 0.90 | -1213.95 | --- | --- | 1.00 | --- | --- | 99.000 | 3564.00 |
| DesignOp | 3 | STR-I | -693.86 | --- | 1.25 | 1.50 | 1.50 | 1.35 | 0.90 | -1213.95 | --- | --- | 1.00 | --- | --- | 1.026 | 36.95 |
| LegalRout | 4 | STR-I | 0.00 | --- | 1.25 | 1.50 | 1.50 | 1.30 | 0.90 | -1213.95 | --- | --- | 1.00 | --- | --- | 99.000 | 3960.00 |
| LegalRout | 4 | STR-I | 0.00 | --- | 1.25 | 1.50 | 1.50 | 1.30 | 0.90 | -1213.95 | --- | --- | 1.00 | --- | --- | 99.000 | 3960.00 |
| LegalRout | 5 | STR-I | 0.00 | --- | 1.25 | 1.50 | 1.50 | 1.30 | 0.90 | -1213.95 | --- | --- | 1.00 | --- | --- | 99.000 | 3960.00 |
| LegalRout | 5 | STR-I | -424.22 | --- | 1.25 | 1.50 | 1.50 | 1.30 | 0.90 | -1213.95 | --- | --- | 1.00 | --- | --- | 1.743 | 69.73 |
| LegalSpec | 6 | STR-I | 74.61 | --- | 1.25 | 1.50 | 1.50 | 1.30 | 1.00 | 459.84 | --- | --- | 1.00 | 18.30 | 87.09 | 3.112 | 124.46 |
| LegalSpec | 6 | STR-I | -480.38 | --- | 1.25 | 1.50 | 1.50 | 1.30 | 0.90 | -1213.95 | --- | --- | 1.00 | 18.30 | 87.09 | 1.823 | 72.91 |
| LegalSpec | 7 | STR-I | 0.00 | --- | 1.25 | 1.50 | 1.50 | 1.30 | 1.00 | 459.84 | --- | --- | 1.00 | 26.24 | 183.97 | 3.070 | 245.61 |
| LegalSpec | 7 | STR-I | -707.59 | --- | 1.25 | 1.50 | 1.50 | 1.30 | 0.90 | -1213.95 | --- | --- | 1.00 | 26.24 | 183.97 | 1.342 | 107.36 |
| LegalRout | 8 | STR-I | 46.97 | --- | 1.25 | 1.50 | 1.50 | 1.30 | 0.90 | -1213.95 | --- | --- | 1.00 | 16.97 | 50.73 | NA | NA |
| LegalRout | 8 | STR-I | -301.82 | --- | 1.25 | 1.50 | 1.50 | 1.30 | 0.90 | -1213.95 | --- | --- | 1.00 | 16.97 | 50.73 | 2.864 | 71.59 |
| LegalRout | 9 | STR-I | 49.77 | --- | 1.25 | 1.50 | 1.50 | 1.30 | 1.00 | 459.84 | --- | --- | 1.00 | 26.24 | 96.34 | 3.507 | 140.29 |
| LegalRout | 9 | STR-I | -370.52 | --- | 1.25 | 1.50 | 1.50 | 1.30 | 0.90 | -1213.95 | --- | --- | 1.00 | 26.24 | 96.34 | 2.563 | 102.51 |
| LegalRout | 10 | STR-I | 53.25 | --- | 1.25 | 1.50 | 1.50 | 1.30 | 1.00 | 459.84 | --- | --- | 1.00 | 26.24 | 97.54 | 3.387 | 121.93 |
| LegalRout | 10 | STR-I | -375.16 | --- | 1.25 | 1.50 | 1.50 | 1.30 | 0.90 | -1213.95 | --- | --- | 1.00 | 26.24 | 97.54 | 2.531 | 91.12 |

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

Load Combination Legend:

| Code | Vehicle |
|------|---|
| 1 | HL-93 (US) - Truck + Lane |
| 2 | HL-93 (US) - Tandem + Lane |
| 3 | HL-93 (US) - 90% (Truck Pair + Lane) |
| 4 | Lane-Type Legal Load - Legal Truck + Lane |
| 5 | Lane-Type Legal Load - Legal Pair + Lane |
| 6 | NRL - Legal Truck |
| 7 | NRL - Legal Pair |
| 8 | Type 3 - Legal Truck |
| 9 | Type 3-3 - Legal Truck |
| 10 | Type 3S2 - Legal Truck |

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

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

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

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

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

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

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

Moment Redistribution in Three Span Spread PS Box Beam

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

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

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

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

Cross Section Properties

Name: B11-48
Girder f'c = 6.00(ksi) Girder f'ci = 5.10(ksi)
Slab f'c = 4.00(ksi)

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

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

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

Flexural Reinforcement

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

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

Note: If the capacity has been overridden, the Resistance is computed as override phi*override capacity.
Otherwise the Resistance is computed as per the Specification.

| Limit State | Load Combination | Mu kip-ft | DeltaMu kip-ft | Phi | Mn kip-ft | Phi | Mn kip-ft | Mr/Mu | NA Depth in | Ac in^2 | Max Conc Stress ksi | Max Rebar Stress ksi | Temp. Cap |
|-------------|------------------|-----------|----------------|-------|-----------|-----|-----------|----------|-------------|---------|---------------------|----------------------|-----------|
| STR-I | 1, DesInv | 17.08 | 246.74 | 1.000 | 459.84 | --- | --- | 459.84 | 2.15 | 423.00 | 0.00 | 60.00 | |
| STR-I | 1, DesInv | -1333.71 | 246.74 | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 1, DesOp | -16.82 | 196.34 | 1.000 | 459.84 | --- | --- | 459.84 | 2.15 | 423.00 | 0.00 | 60.00 | |
| STR-I | 1, DesOp | -981.72 | 196.34 | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 2, DesInv | -9.46 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 2, DesInv | -1044.80 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 2, DesOp | -37.29 | 150.22 | 1.000 | 459.84 | --- | --- | 459.84 | 2.15 | 423.00 | 0.00 | 60.00 | |
| STR-I | 2, DesOp | -835.98 | 150.22 | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 3, DesInv | -131.22 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 3, DesInv | -1345.48 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 3, DesOp | -131.22 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 3, DesOp | -1067.94 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 4, LegalRout | -131.22 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 4, LegalRout | -131.22 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 5, LegalRout | -131.22 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 5, LegalRout | -682.71 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 6, LegalSpec | -34.24 | 105.39 | 1.000 | 459.84 | --- | --- | 459.84 | 2.15 | 423.00 | 0.00 | 60.00 | |
| STR-I | 6, LegalSpec | -755.72 | 105.39 | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 7, LegalSpec | -131.22 | 210.22 | 1.000 | 459.84 | --- | --- | 459.84 | 2.15 | 423.00 | 0.00 | 60.00 | |
| STR-I | 7, LegalSpec | -1051.09 | 210.22 | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 8, LegalRout | -70.16 | 67.70 | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 8, LegalRout | -523.59 | 67.70 | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 9, LegalRout | -66.52 | 122.58 | 1.000 | 459.84 | --- | --- | 459.84 | 2.15 | 423.00 | 0.00 | 60.00 | |
| STR-I | 9, LegalRout | -612.90 | 122.58 | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| STR-I | 10, LegalRout | -62.00 | 123.79 | 1.000 | 459.84 | --- | --- | 459.84 | 2.15 | 423.00 | 0.00 | 60.00 | |
| STR-I | 10, LegalRout | -618.93 | 123.79 | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 1, DesInv | -37.18 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 1, DesInv | -608.97 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 2, DesInv | -49.31 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 2, DesInv | -522.61 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 3, DesInv | -104.98 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 3, DesInv | -660.07 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 4, LegalRout | -104.98 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 4, LegalRout | -104.98 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 5, LegalRout | -104.98 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 5, LegalRout | -529.20 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 6, LegalSpec | -30.37 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 6, LegalSpec | -585.36 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 7, LegalSpec | -104.98 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 7, LegalSpec | -812.57 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 8, LegalRout | -58.01 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 8, LegalRout | -406.80 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 9, LegalRout | -55.21 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 9, LegalRout | -475.50 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 10, LegalRout | -51.73 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |
| SER-III | 10, LegalRout | -480.14 | --- | 0.900 | -1213.95 | --- | --- | -1092.55 | 2.42 | 873.52 | 0.00 | 60.00 | |

Load Combination Legend:

| Code | Vehicle |
|------|---|
| 1 | HL-93 (US) - Truck + Lane |
| 2 | HL-93 (US) - Tandem + Lane |
| 3 | HL-93 (US) - 90% (Truck Pair + Lane) |
| 4 | Lane-Type Legal Load - Legal Truck + Lane |
| 5 | Lane-Type Legal Load - Legal Pair + Lane |
| 6 | NRL - Legal Truck |
| 7 | NRL - Legal Pair |
| 8 | Type 3 - Legal Truck |
| 9 | Type 3-3 - Legal Truck |
| 10 | Type 3S2 - Legal Truck |

Figure 3 – 5.6.3.2 Flexural Resistance

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

Moment Redistribution in Three Span Spread PS Box Beam

Spec Check Detail for 5.6.3.3 Minimum Reinforcement

5 Concrete Structures

5.6 Design for Flexural and Axial Effects - 8 Regions

5.6.3 Flexural Members

5.6.3.3 Minimum Reinforcement

(AASHTO LRFD Bridge Design Specifications, Ninth Edition)

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

Cross Section Properties for Prestress box beam with Rectangular void

Name: BII-48

Girder f'c = 6.00(ksi)

Girder f'ci = 5.10(ksi)

Beam Height = 33.00(in)

Side Wall Thickness = 5.00(in)

Top Slab Width = 47.25(in)

Top Slab Thick = 5.50(in)

Bottom Slab Width = 48.00(in)

Bottom Slab Thick = 5.50(in)

Shear Key Top = 6.00(in)

Shear Key Height = 6.00(in)

Shear Key Depth = 0.75(in)

B1 = 3.00(in)

B2 = 3.00(in)

B3 = 3.00(in)

B4 = 3.00(in)

Slab f'c = 4.00(ksi)

Effective Slab Width = 90.00(in)

Haunch Width = 47.25(in)

Effective Slab Thickness = 7.50(in)

Haunch Thickness = 0.50(in)

Flexural Reinforcement

As Dist. From Bottom (in^2) (in)

1.86 3.00

3.96 37.50

2.79 35.50

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

Input:

fr beam = 0.59 (ksi)

fr deck = 0.48 (ksi)

Inertia = 249344.45 (in^4)

STop = -20120.01 (in^3)

yBot = 25.03 (in)

SBot = 9961.78 (in^3)

Gamma3 = Fy/Fu.

Gamma1 = 1.60

Gamma2 = 1.10

Gamma3 = 0.67

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

(Note: For reinforced concrete members Sc = Snc)

Mr1 = Mcr Article 5.6.3.3

Mr2 = 1.33 * Mu Article 5.6.3.3

MrMin = Min(Mr1, Mr2) Article 5.6.3.3

Allow Moment Redistribution Control Option: Yes

Moment Redistribution Qualified: Yes, redistribution did occur.

Note: If the capacity has been overridden, the Resistance is computed as override phi*override capacity. Otherwise the Resistance is computed as per the Specification.

Limit Load Mu DeltaMu Sc Mcr Mr1 Mr2 MrMin --- Override --- Mr DR =

State Comb (kip-ft) (kip-ft) (in^3) (kip-ft) (kip-ft) (kip-ft) (kip-ft) Phi (kip-ft) (kip-ft) Mr/MrMin

STR-I 1, DesInv 17.08 246.74 9961.78 520.56 520.56 350.88 350.88 --- --- 459.84 1.311 Pass

STR-I 1, DesInv -1233.71 246.74 -20120.01 -858.20 -858.20 -1312.67 -858.20 --- --- -1092.55 1.273 Pass

STR-I 1, DesOp -16.82 196.34 9961.78 520.56 520.56 238.77 238.77 --- --- 459.84 1.926 Pass

STR-I 1, DesOp -981.72 196.34 -20120.01 -858.20 -858.20 -1044.54 -858.20 --- --- -1092.55 1.273 Pass

STR-I 2, DesInv -9.46 --- -20120.01 -858.20 -858.20 -12.58 -12.58 --- --- -1092.55 86.856 Pass

STR-I 2, DesInv -1044.80 --- -20120.01 -858.20 -858.20 -1389.59 -858.20 --- --- -1092.55 1.273 Pass

STR-I 2, DesOp -37.29 150.22 9961.78 520.56 520.56 150.19 150.19 --- --- 459.84 3.062 Pass

STR-I 2, DesOp -835.98 150.22 -20120.01 -858.20 -858.20 -912.07 -858.20 --- --- -1092.55 1.273 Pass

STR-I 3, DesInv -131.22 --- -20120.01 -858.20 -858.20 -174.53 -174.53 --- --- -1092.55 6.260 Pass

STR-I 3, DesInv -1345.48 --- -20120.01 -858.20 -858.20 -1789.49 -858.20 --- --- -1092.55 1.273 Pass

STR-I 3, DesOp -131.22 --- -20120.01 -858.20 -858.20 -174.53 -174.53 --- --- -1092.55 6.260 Pass

STR-I 3, DesOp -1067.94 --- -20120.01 -858.20 -858.20 -1420.36 -858.20 --- --- -1092.55 1.273 Pass

STR-I 4, LegalRout -131.22 --- -20120.01 -858.20 -858.20 -174.53 -174.53 --- --- -1092.55 6.260 Pass

STR-I 4, LegalRout -131.22 --- -20120.01 -858.20 -858.20 -174.53 -174.53 --- --- -1092.55 6.260 Pass

STR-I 5, LegalRout -131.22 --- -20120.01 -858.20 -858.20 -174.53 -174.53 --- --- -1092.55 6.260 Pass

STR-I 5, LegalRout -682.71 --- -20120.01 -858.20 -858.20 -908.01 -858.20 --- --- -1092.55 1.273 Pass

STR-I 6, LegalSpec -34.24 105.39 9961.78 520.56 520.56 94.63 94.63 --- --- 459.84 4.859 Pass

STR-I 6, LegalSpec -755.72 105.39 -20120.01 -858.20 -858.20 -864.95 -858.20 --- --- -1092.55 1.273 Pass

STR-I 7, LegalSpec -210.22 210.22 9961.78 520.56 520.56 105.06 105.06 --- --- 459.84 4.377 Pass

STR-I 7, LegalSpec -1051.09 210.22 -20120.01 -858.20 -858.20 -1118.36 -858.20 --- --- -1092.55 1.273 Pass

STR-I 8, LegalRout -70.16 67.70 -20120.01 -858.20 -858.20 -3.28 -3.28 --- --- -1092.55 333.283 Pass

STR-I 8, LegalRout -523.59 67.70 -20120.01 -858.20 -858.20 -606.34 -606.34 --- --- -1092.55 1.802 Pass

STR-I 9, LegalRout -66.52 122.58 9961.78 520.56 520.56 74.56 74.56 --- --- 459.84 6.167 Pass

STR-I 9, LegalRout -612.90 122.58 -20120.01 -858.20 -858.20 -652.13 -652.13 --- --- -1092.55 1.675 Pass

STR-I 10, LegalRout -62.00 123.79 9961.78 520.56 520.56 82.18 82.18 --- --- 459.84 5.596 Pass

STR-I 10, LegalRout -618.93 123.79 -20120.01 -858.20 -858.20 -658.55 -658.55 --- --- -1092.55 1.659 Pass

SER-III 1, DesInv -37.18 --- -20120.01 -858.20 -858.20 -49.45 -49.45 --- --- -1092.55 22.093 Pass

SER-III 1, DesInv -608.97 --- -20120.01 -858.20 -858.20 -809.94 -809.94 --- --- -1092.55 1.349 Pass

SER-III 2, DesInv -49.31 --- -20120.01 -858.20 -858.20 -65.59 -65.59 --- --- -1092.55 16.658 Pass

SER-III 2, DesInv -522.61 --- -20120.01 -858.20 -858.20 -695.08 -695.08 --- --- -1092.55 1.572 Pass

SER-III 3, DesInv -104.98 --- -20120.01 -858.20 -858.20 -139.62 -139.62 --- --- -1092.55 7.825 Pass

SER-III 3, DesInv -660.07 --- -20120.01 -858.20 -858.20 -877.89 -858.20 --- --- -1092.55 1.273 Pass

SER-III 4, LegalRout -104.98 --- -20120.01 -858.20 -858.20 -139.62 -139.62 --- --- -1092.55 7.825 Pass

SER-III 4, LegalRout -104.98 --- -20120.01 -858.20 -858.20 -139.62 -139.62 --- --- -1092.55 7.825 Pass

SER-III 5, LegalRout -104.98 --- -20120.01 -858.20 -858.20 -139.62 -139.62 --- --- -1092.55 7.825 Pass

SER-III 5, LegalRout -529.20 --- -20120.01 -858.20 -858.20 -703.84 -703.84 --- --- -1092.55 1.552 Pass

SER-III 6, LegalSpec -30.37 --- -20120.01 -858.20 -858.20 -40.40 -40.40 --- --- -1092.55 27.045 Pass

SER-III 6, LegalSpec -585.36 --- -20120.01 -858.20 -858.20 -778.53 -778.53 --- --- -1092.55 1.403 Pass

SER-III 7, LegalSpec -104.98 --- -20120.01 -858.20 -858.20 -139.62 -139.62 --- --- -1092.55 7.825 Pass

SER-III 7, LegalSpec -812.57 --- -20120.01 -858.20 -858.20 -1080.71 -858.20 --- --- -1092.55 1.273 Pass

SER-III 8, LegalRout -58.01 --- -20120.01 -858.20 -858.20 -77.15 -77.15 --- --- -1092.55 14.161 Pass

SER-III 8, LegalRout -406.80 --- -20120.01 -858.20 -858.20 -541.04 -541.04 --- --- -1092.55 2.019 Pass

SER-III 9, LegalRout -55.21 --- -20120.01 -858.20 -858.20 -73.42 -73.42 --- --- -1092.55 14.880 Pass

SER-III 9, LegalRout -475.50 --- -20120.01 -858.20 -858.20 -632.42 -632.42 --- --- -1092.55 1.728 Pass

SER-III 10, LegalRout -51.73 --- -20120.01 -858.20 -858.20 -68.80 -68.80 --- --- -1092.55 15.880 Pass

SER-III 10, LegalRout -480.14 --- -20120.01 -858.20 -858.20 -638.59 -638.59 --- --- -1092.55 1.711 Pass

Load Combination Legend:

Code Vehicle

1 HL-93 (US) - Truck + Lane

2 HL-93 (US) - Tandem + Lane

3 HL-93 (US) - 90%Truck Pair + Lane

4 Lane-Type Legal Load - Legal Truck + Lane

5 Lane-Type Legal Load - Legal Pair + Lane

6 NRL - Legal Truck

7 NRL - Legal Pair

8 Type 3 - Legal Truck

9 Type 3-3 - Legal Truck

10 Type 3S2 - Legal Truck

Figure 4 – 5.6.3.3 Minimum Reinforcement

Moment Redistribution in Three Span Spread PS Box Beam

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

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

Spec Check Detail for 5.10.8.1.2a Flexural Reinforcement

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

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

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

Flexural Reinforcement

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

5.10.8.1.1 Basic Requirements, Nonprestressed Reinforcement Yield Strength

Max fy <= 100 ksi (5.10.8.1.1)

Max fy = 60.000 ksi <= 100 ksi Pass

5.10.8.1 General, Bar Size

Max Ab <= Ab (#11) = 1.56 in² (5.10.8.1)

Max Ab = Ab (#6) = 0.440 ksi <= 1.56 in² Pass

5.10.8.1 General, Concrete Compressive Strength

f'c <= 15 ksi (5.10.8.1)

f'c = 6.000 ksi <= 15 ksi Pass

5.10.8.2a General, Bar Termination

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

AsTop(Left) = 6.750 in²
AsTop(Right) = 6.750 in²
(LeftTerm) = 0.000 in² <= (RightTerm) = 3.375 in² Pass

Figure 5 – 5.10.8.1.2a Flexural Reinforcement

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

Moment Redistribution in Three Span Spread PS Box Beam

Spec Check Detail for 5.10.8.1.2c Negative Moment Reinforcement

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

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

Overall Depth = 41.00(in)
Effective Depth = 36.67(in)
Clear Span Length = 74.25(ft)
Distance To Inflection Point = 13.96(ft)
AsTension = 6.75(in²)

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

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

Then <Pass>

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

(LeftTerm) = 6.75 in² >= (RightTerm) = 2.25 in² <Pass>

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

Overall Depth = 41.00(in)
Effective Depth = 36.67(in)
Clear Span Length = 58.50(ft)
Distance To Inflection Point = 25.22(ft)
AsTension = 6.75(in²)

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

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

Then <Pass>

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

(LeftTerm) = 6.75 in² >= (RightTerm) = 2.25 in² <Pass>

Figure 6 – 5.10.8.1.2c Negative Moment Reinforcement

Spec Check Detail for 5.6.3.4 Percentage Concrete Moment Redistribution Percentage

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

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

If Et >= 1.5Et1 and Flexure Type is Neg, moment redistribution can occur
Maximum moment reduction percentage (MRP) = Max(20.0, 1000Et)

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

| Limit State | Load Combo | Flexure Type | Maximum Negative Mu (kip-ft) | Et | Et1 | 1.5Et1 | Redist. Can occur? | 1000Et (%) | Maximum Reduction Percentage (%) |
|-------------|------------|--------------|------------------------------|----------|-------|--------|--------------------|------------|----------------------------------|
| STR-I | 1, DesInv | Neg | -1233.71 | 0.043538 | 0.005 | 0.0075 | Yes | 43.54 | 20.00 |
| STR-I | 1, DesOp | Neg | -981.72 | 0.043538 | 0.005 | 0.0075 | Yes | 43.54 | 20.00 |
| STR-I | 2, DesInv | Neg | -1044.80 | 0.043538 | 0.005 | 0.0075 | Yes | 43.54 | 20.00 |
| STR-I | 2, DesOp | Neg | -835.98 | 0.043538 | 0.005 | 0.0075 | Yes | 43.54 | 20.00 |
| STR-I | 3, DesInv | Neg | -1345.48 | 0.043538 | 0.005 | 0.0075 | Yes | 43.54 | 20.00 |
| STR-I | 3, DesOp | Neg | -1067.94 | 0.043538 | 0.005 | 0.0075 | Yes | 43.54 | 20.00 |
| STR-I | 4, LegalR- | Neg | -131.22 | 0.043538 | 0.005 | 0.0075 | Yes | 43.54 | 20.00 |
| STR-I | 5, LegalR- | Neg | -682.71 | 0.043538 | 0.005 | 0.0075 | Yes | 43.54 | 20.00 |
| STR-I | 6, LegalS- | Neg | -755.72 | 0.043538 | 0.005 | 0.0075 | Yes | 43.54 | 20.00 |
| STR-I | 7, LegalS- | Neg | -1051.09 | 0.043538 | 0.005 | 0.0075 | Yes | 43.54 | 20.00 |
| STR-I | 8, LegalR- | Neg | -523.59 | 0.043538 | 0.005 | 0.0075 | Yes | 43.54 | 20.00 |
| STR-I | 9, LegalR- | Neg | -612.90 | 0.043538 | 0.005 | 0.0075 | Yes | 43.54 | 20.00 |
| STR-I | 10, Legal- | Neg | -618.93 | 0.043538 | 0.005 | 0.0075 | Yes | 43.54 | 20.00 |

Load Combination Legend:

| Code | Vehicle |
|------|---|
| 1 | HL-93 (US) - Truck + Lane |
| 2 | HL-93 (US) - Tandem + Lane |
| 3 | HL-93 (US) - 90%(Truck Pair + Lane) |
| 4 | Lane-Type Legal Load - Legal Truck + Lane |
| 5 | Lane-Type Legal Load - Legal Pair + Lane |
| 6 | NRL - Legal Truck |
| 7 | NRL - Legal Pair |
| 8 | Type 3 - Legal Truck |
| 9 | Type 3-3 - Legal Truck |
| 10 | Type 3B2 - Legal Truck |

Figure 7 – 5.6.3.4 Moment Redistribution Percentage

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

Moment Redistribution in Three Span Spread PS Box Beam

Spec Check Detail for 5.6.3.4 Moment Concrete Moment Redistribution Moments

5 Concrete Structures

5.6 DESIGN FOR FLEXURAL AND AXIAL FORCE EFFECTS - B REGIONS

5.6.3 Flexural Members

5.6.3.4 Maximum Allowable Moment Redistribution Moments - At Support Location (AASHTO LRFD Bridge Design Specifications, Ninth Edition)

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

Input:

M_DC = -104.98 kip-ft

M_DW = 0.00 kip-ft

M_DW-WS = 0.00 kip-ft

M_PT = 0.00 kip-ft

M_SE = 0.00 kip-ft

| Limit State | Load Combo | Flexure Type | MRP (%) | M_LL (kip-ft) | M_AdjLL (kip-ft) |
|-------------|------------|--------------|---------|---------------|------------------|
| STR-I | 1, DesInv | Neg | 20.00 | -629.99 | 0.00 |
| STR-I | 1, DesOp | Neg | 20.00 | -629.99 | 0.00 |
| STR-I | 2, DesInv | Neg | 20.00 | -522.04 | 0.00 |
| STR-I | 2, DesOp | Neg | 20.00 | -522.04 | 0.00 |
| STR-I | 3, DesInv | Neg | 20.00 | -693.86 | 0.00 |
| STR-I | 3, DesOp | Neg | 20.00 | -693.86 | 0.00 |
| STR-I | 4, LegalR- | Neg | 20.00 | 0.00 | 0.00 |
| STR-I | 5, LegalR- | Neg | 20.00 | -424.22 | 0.00 |
| STR-I | 6, LegalS- | Neg | 20.00 | -480.38 | 0.00 |
| STR-I | 7, LegalS- | Neg | 20.00 | -707.59 | 0.00 |
| STR-I | 8, LegalR- | Neg | 20.00 | -301.82 | 0.00 |
| STR-I | 9, LegalR- | Neg | 20.00 | -370.52 | 0.00 |
| STR-I | 10, Legal- | Neg | 20.00 | -375.16 | 0.00 |

Load Factors

| Limit State | Load Combo | DC | DW | DW-WS | SE | PT | LL | AdjLL |
|-------------|------------|------|------|-------|------|------|------|-------|
| STR-I | 1 | 1.25 | 1.50 | 1.50 | 0.00 | 0.00 | 1.75 | 0.00 |
| STR-I | 1 | 1.25 | 1.50 | 1.50 | 0.00 | 0.00 | 1.35 | 0.00 |
| STR-I | 2 | 1.25 | 1.50 | 1.50 | 0.00 | 0.00 | 1.75 | 0.00 |
| STR-I | 2 | 1.25 | 1.50 | 1.50 | 0.00 | 0.00 | 1.35 | 0.00 |
| STR-I | 3 | 1.25 | 1.50 | 1.50 | 0.00 | 0.00 | 1.75 | 0.00 |
| STR-I | 3 | 1.25 | 1.50 | 1.50 | 0.00 | 0.00 | 1.35 | 0.00 |
| STR-I | 4 | 1.25 | 1.50 | 1.50 | 0.00 | 0.00 | 1.30 | 0.00 |
| STR-I | 5 | 1.25 | 1.50 | 1.50 | 0.00 | 0.00 | 1.30 | 0.00 |
| STR-I | 6 | 1.25 | 1.50 | 1.50 | 0.00 | 0.00 | 1.30 | 0.00 |
| STR-I | 7 | 1.25 | 1.50 | 1.50 | 0.00 | 0.00 | 1.30 | 0.00 |
| STR-I | 8 | 1.25 | 1.50 | 1.50 | 0.00 | 0.00 | 1.30 | 0.00 |
| STR-I | 9 | 1.25 | 1.50 | 1.50 | 0.00 | 0.00 | 1.30 | 0.00 |
| STR-I | 10 | 1.25 | 1.50 | 1.50 | 0.00 | 0.00 | 1.30 | 0.00 |
| SER-III | 1 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.80 | 0.00 |
| SER-III | 2 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.80 | 0.00 |
| SER-III | 3 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 0.80 | 0.00 |
| SER-III | 4 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 |
| SER-III | 5 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 |
| SER-III | 6 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 |
| SER-III | 7 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 |
| SER-III | 8 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 |
| SER-III | 9 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 |
| SER-III | 10 | 1.00 | 1.00 | 1.00 | 0.00 | 0.00 | 1.00 | 0.00 |

Maximum Allowable Moment Redistribution Moments:

Max_Delta_M = -MRP * M

where:

MRP = maximum reduction percentage

M = elastic moment due to applied load

| Limit State | Load Combo | Flexure Type | MRP (%) | DC (kip-ft) | DW (kip-ft) | DW-WS (kip-ft) | SE (kip-ft) | PT (kip-ft) | LL (kip-ft) | AdjLL (kip-ft) | Factored Max Delta_M DL+AdjLL (kip-ft) | Factored Max Delta_M LL+I (kip-ft) |
|-------------|------------|--------------|---------|-------------|-------------|----------------|-------------|-------------|-------------|----------------|--|------------------------------------|
| STR-I | 1, DesInv | Neg | 20.00 | 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 126.00 | 0.00 | 26.24 | 220.50 |
| STR-I | 1, DesOp | Neg | 20.00 | 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 126.00 | 0.00 | 26.24 | 170.10 |
| STR-I | 2, DesInv | Neg | 20.00 | 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 104.41 | 0.00 | 26.24 | 182.72 |
| STR-I | 2, DesOp | Neg | 20.00 | 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 104.41 | 0.00 | 26.24 | 140.95 |
| STR-I | 3, DesInv | Neg | 20.00 | 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 138.77 | 0.00 | 26.24 | 242.85 |
| STR-I | 3, DesOp | Neg | 20.00 | 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 138.77 | 0.00 | 26.24 | 187.34 |
| STR-I | 4, LegalR- | Neg | 20.00 | 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 26.24 | 0.00 |
| STR-I | 5, LegalR- | Neg | 20.00 | 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 84.84 | 0.00 | 26.24 | 110.30 |
| STR-I | 6, LegalS- | Neg | 20.00 | 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 96.08 | 0.00 | 26.24 | 124.90 |
| STR-I | 7, LegalS- | Neg | 20.00 | 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 141.52 | 0.00 | 26.24 | 183.97 |
| STR-I | 8, LegalR- | Neg | 20.00 | 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 60.36 | 0.00 | 26.24 | 78.47 |
| STR-I | 9, LegalR- | Neg | 20.00 | 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 74.10 | 0.00 | 26.24 | 96.34 |
| STR-I | 10, Legal- | Neg | 20.00 | 21.00 | 0.00 | 0.00 | 0.00 | 0.00 | 75.03 | 0.00 | 26.24 | 97.54 |

Load Combination Legend:

| Code | Vehicle |
|------|---|
| 1 | HL-93 (US) - Truck + Lane |
| 2 | HL-93 (US) - Tandem + Lane |
| 3 | HL-93 (US) - 90% (Truck Pair + Lane) |
| 4 | Lane-Type Legal Load - Legal Truck + Lane |
| 5 | Lane-Type Legal Load - Legal Pair + Lane |
| 6 | NRL - Legal Truck |
| 7 | NRL - Legal Pair |
| 8 | Type 3 - Legal Truck |
| 9 | Type 3-3 - Legal Truck |
| 10 | Type 3S2 - Legal Truck |

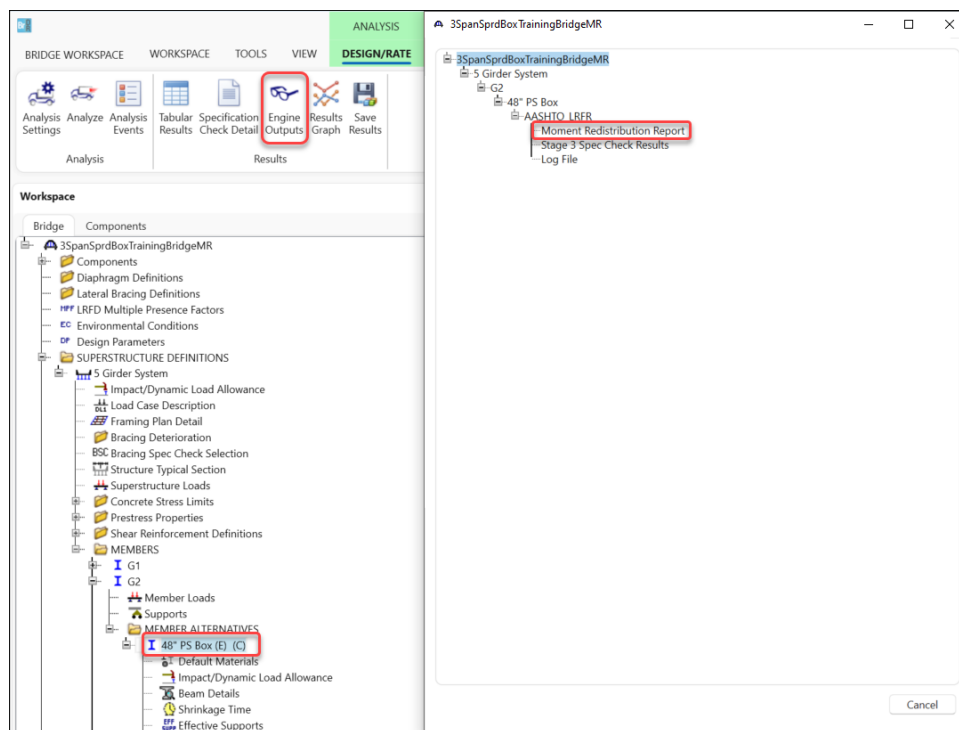
Figure 8 – 5.6.3.4 Maximum Allowable Moment Redistribution Moments

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

Moment Redistribution Report

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

Moment Redistribution in Three Span Spread PS Box Beam



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

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

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

Moment Redistribution in Three Span Spread PS Box Beam

MomentRedistributionReport.txt - Notepad
 File Edit Format View Help
 Moment redistribution for HL-93 (US) - Truck + Lane at Design Inventory rating level and Strength I limit state.

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

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

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

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

Moment Redistribution in Three Span Spread PS Box Beam

MomentRedistributionReport.txt - Notepad
 File Edit Format View Help
 Moment redistribution for Type 3 - Legal Truck at Legal Routine rating level and StrengthI limit state.

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

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

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

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