

AASHTOWare BrDR 7.5.1

Steel Tutorial

STL14-LRFD Cb Calculation using Concurrent Moments Example

STL14 – LRFD Cb Calculation using Concurrent Moments Example

AASHTOWare Bridge Design and Rating Training

STL14 –LRFD Cb Calculation using Concurrent Moments Example

Topics Covered

- Modify STL2 Example Bridge
- Cb Calculation Control Option
- Cb Calculation Comparison

Features (introduced in version 7.5.0):

- LRFD Analysis Control option: “Consider concurrent moments in Cb calculation”
- LRFR Analysis Control option: “Consider concurrent moments in Cb calculation”

This tutorial demonstrates how to select the calculation method for the AASHTO LRFD Cb moment gradient factor. By default, the moment gradient factor is computed using the envelope actions at brace points. The control option to consider concurrent moments in Cb calculation will compute the factor using concurrent moments at brace points. The concurrent brace moment reports and the changes to the spec output for concurrent actions are presented.

STL14 – LRFD Cb Calculation using Concurrent Moments Example

Modify STL2 Example Bridge

Start with the completed STL2 example bridge. This is a two-span steel girder system bridge with four girders. Follow the steps below to modify the structure definition. The moment gradient factor is used to compute the lateral torsional buckling resistance, so the girder is modified so that the lateral torsional buckling resistance controls the flexural capacity over the interior support.

Import the STL2 example bridge and open the copied structure. Update the **Bridge ID**, **NBI structure ID**, **Name** and **Description**. Select **OK** to apply the data and close the window.

Cb Factor

Bridge ID: NBI structure ID (8):

Template
 Bridge completely defined

Bridge Workspace View
 Superstructures
 Culverts
 Substructures

Description | Description (cont'd) | Alternatives | Global reference point | Traffic | Custom agency fields

Name: Year built:

Description:

Location: Length: ft

Facility carried (7): Route number:

Feat. intersected (6): Mi. post:

Default units:

Bridge association... BrR BrD BrM

OK Apply Cancel

STL14 – LRFD Cb Calculation using Concurrent Moments Example

Open the **Superstructure Definition** window and update the superstructure name as shown below.

Girder System Superstructure Definition

Definition Analysis Specs Engine

Name:

Description:

Default units:

Number of spans:

Number of girders:

Enter span lengths along the reference line:

Span	Length (ft)
1	90
2	90

Modeling

Multi-girder system MCB

With frame structure simplified definition

Deck type:

For PS/PT only

Average humidity:

Member alt. types

Steel

P/S

R/C

Timber

P/T

Horizontal curvature along reference line

Horizontal curvature

Superstructure alignment

Curved

Tangent, curved, tangent

Tangent, curved

Curved, tangent

Distance from PC to first support line: ft

Start tangent length: ft

Radius: ft

Direction:

End tangent length: ft

Distance from last support line to PT: ft

Design speed: mph

Superelevation: %

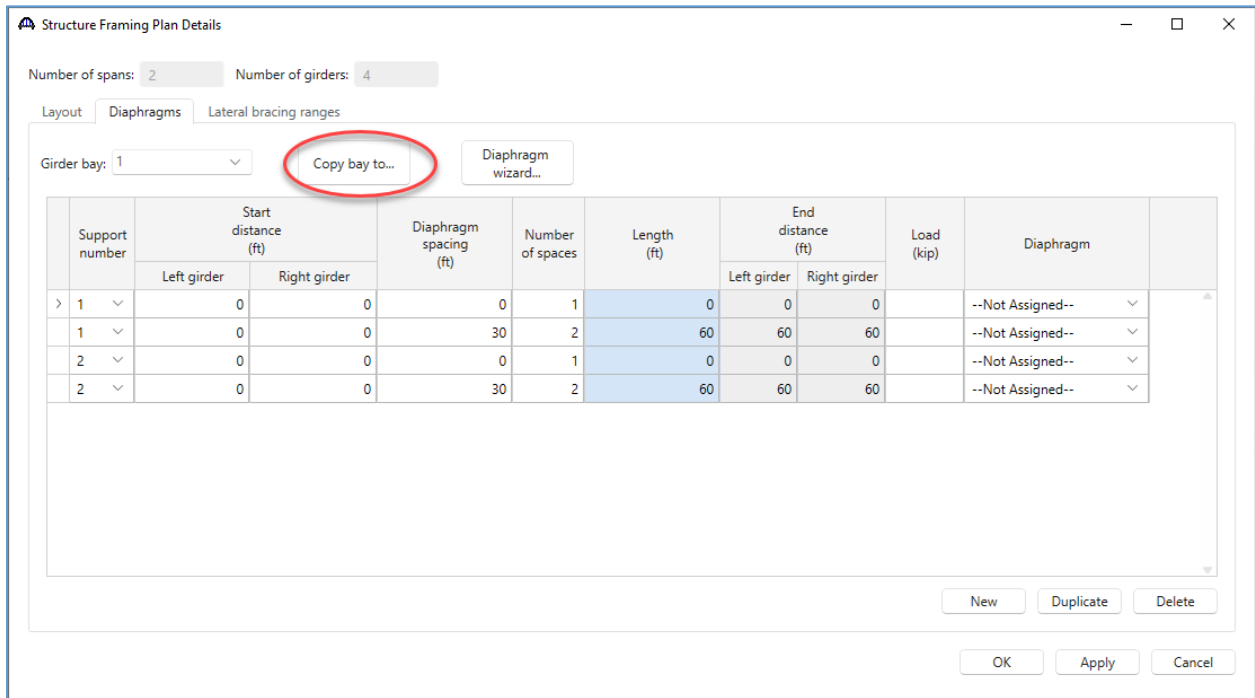
OK Apply Cancel

STL14 – LRFD Cb Calculation using Concurrent Moments Example

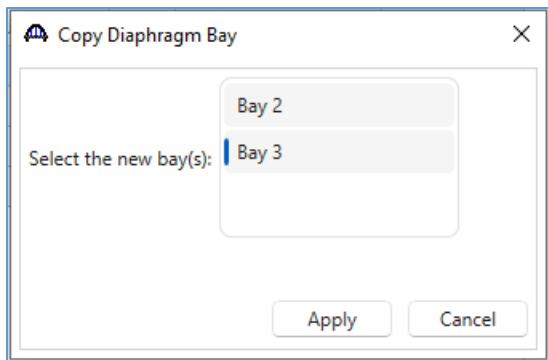
Structure Framing Plan Details

Within the **Framing Plan Detail** window, update the diaphragm definitions. Navigate to the **Diaphragms** tab and update the diaphragm spacing for **Girder bay 1** as shown below. Select **Apply** to apply the data and keep the window open. Then click on the **Copy bay to...** button and copy the diaphragms to **Bay 2** and **Bay 3** as shown below.

Girder Bay 1:



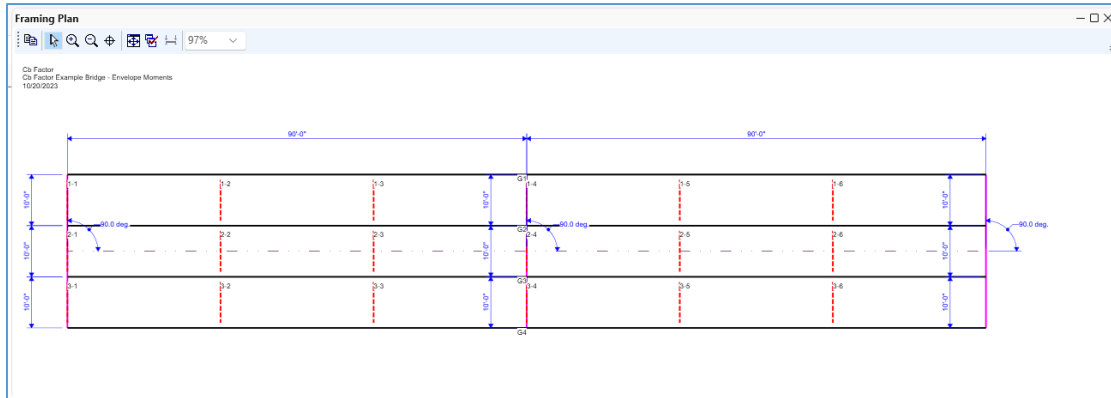
Girder Bays 2 and 3:



STL14 – LRFD Cb Calculation using Concurrent Moments Example

Framing Plan Schematic

Review the **framing plan schematic** to verify the framing plan details are correct.



Girder Profile

Update the **girder profile** for the **G2** member alternative in each tab as shown below.

The Girder Profile dialog box is shown with the 'Web' tab selected. The table below contains the profile details for the girder.

Begin depth (in)	Depth vary	End depth (in)	Thickness (in)	Support number	Start distance (ft)	Length (ft)	End distance (ft)	Material	Weld at right
45	None	45	0.5	1	0	180	180	Grade 50W	-- None --

Buttons: New, Duplicate, Delete, OK, Apply, Cancel

STL14 – LRFD Cb Calculation using Concurrent Moments Example

The top and bottom flange have the same definition, so to save time, the top flange can be input and then copied to the bottom flange with the **Copy to bottom flange** button. If there is any existing data for bottom flange, a warning will appear while copying. Click **OK** to proceed.

The screenshot shows the 'Girder Profile' dialog box with the 'Top flange' tab selected. A table contains the following data:

Begin width (in)	End width (in)	Thickness (in)	Support number	Start distance (ft)	Length (ft)	End distance (ft)	Material	Weld	Weld at right
12	12	1.375	1	0	180	180	Grade 50W	-	-- ↑

The 'Copy to bottom flange' button is circled in red. Other buttons include 'New', 'Duplicate', 'Delete', 'OK', 'Apply', and 'Cancel'.

The screenshot shows the 'Girder Profile' dialog box with the 'Bottom flange' tab selected. The table contains the same data as the previous screenshot:

Begin width (in)	End width (in)	Thickness (in)	Support number	Start distance (ft)	Length (ft)	End distance (ft)	Material	Weld	Weld at right
12	12	1.375	1	0	180	180	Grade 50W	-	-- ↑

The 'Copy to top flange' button is visible. Other buttons include 'New', 'Duplicate', 'Delete', 'OK', 'Apply', and 'Cancel'.

STL14 – LRFD Cb Calculation using Concurrent Moments Example

Deck Profile

Update the reinforcement within the **Deck Profile window** to satisfy the AASHTO LRFD 6.10.1.7 requirements.

The screenshot shows the 'Deck Profile' window with the 'Reinforcement' tab selected. The window title is 'Deck Profile' and the 'Type' is set to 'Plate'. The table below shows the reinforcement details:

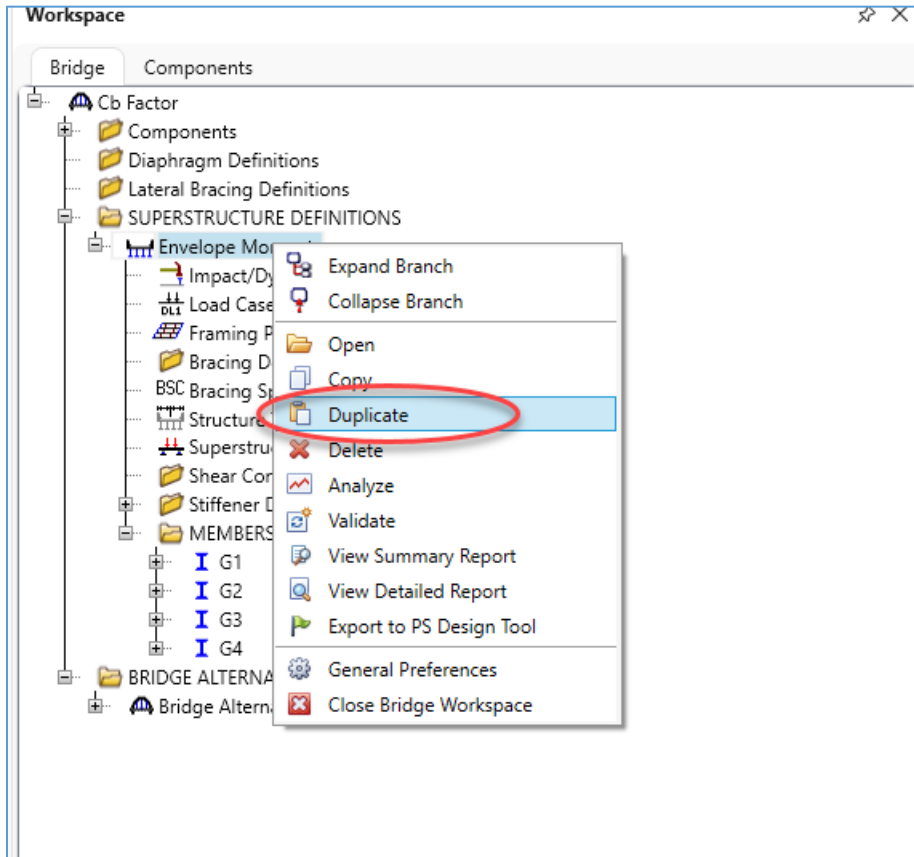
Material	Support number	Start distance (ft)	Length (ft)	End distance (ft)	Std bar count	LRFD bar count	Bar size	Distance (in)	Row	Bar spacing (in)
Gr	1	63	54	117	12	12	6	2.97	Top of Slab	
Gr	1	63	54	117	12	12	6	1.91	Bottom of Slab	

Buttons at the bottom of the window include 'New', 'Duplicate', 'Delete', 'OK', 'Apply', and 'Cancel'.

STL14 – LRFD Cb Calculation using Concurrent Moments Example

Duplicate the superstructure definition and modify the control options in the second structure to use concurrent moments for computing Cb.

Right click on the **Envelope Moments** superstructure definition and select **Duplicate** from the menu to duplicate the superstructure definition.



STL14 – LRFD Cb Calculation using Concurrent Moments Example

Rename the new superstructure definition within the **Superstructure definition** window.

Girder System Superstructure Definition

Definition Analysis Specs Engine

Name: Concurrent Moments

Description: 2 Span 4 Girder System using concurrent moments to compute Cb moment gradient factor

Default units: US Customary

Number of spans: 2

Number of girders: 4

Enter span lengths along the reference line:

Span	Length (ft)
1	90
2	90

Modeling: Multi-girder system MCB

With frame structure simplified definition

Deck type: Concrete Deck

For PS/PT only: Average humidity: %

Member alt. types: Steel P/S R/C Timber P/T

Horizontal curvature along reference line: Horizontal curvature

Superstructure alignment: Curved Tangent, curved, tangent Tangent, curved Curved, tangent

Distance from PC to first support line: ft

Start tangent length: ft

Radius: ft

Direction: Left

End tangent length: ft

Distance from last support line to PT: ft

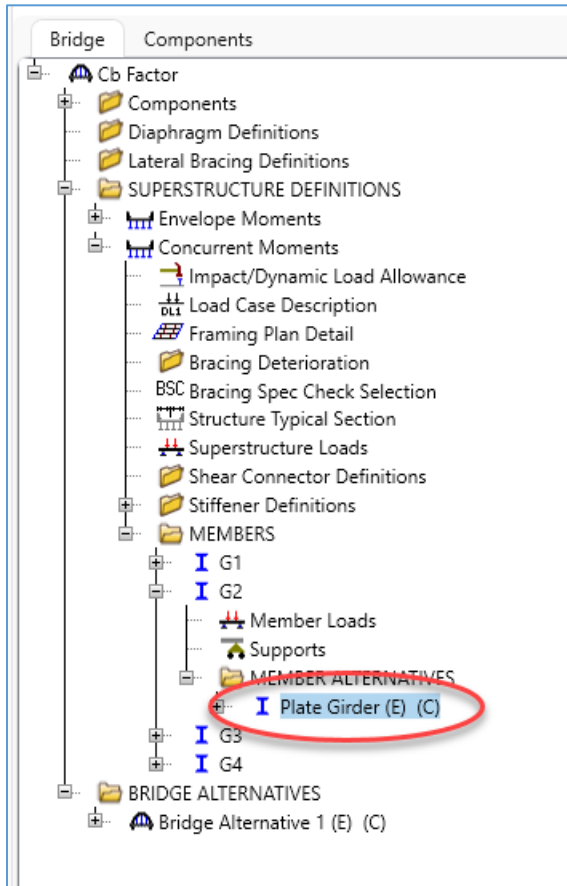
Design speed: mph

Superelevation: %

OK Apply Cancel

STL14 – LRFD Cb Calculation using Concurrent Moments Example

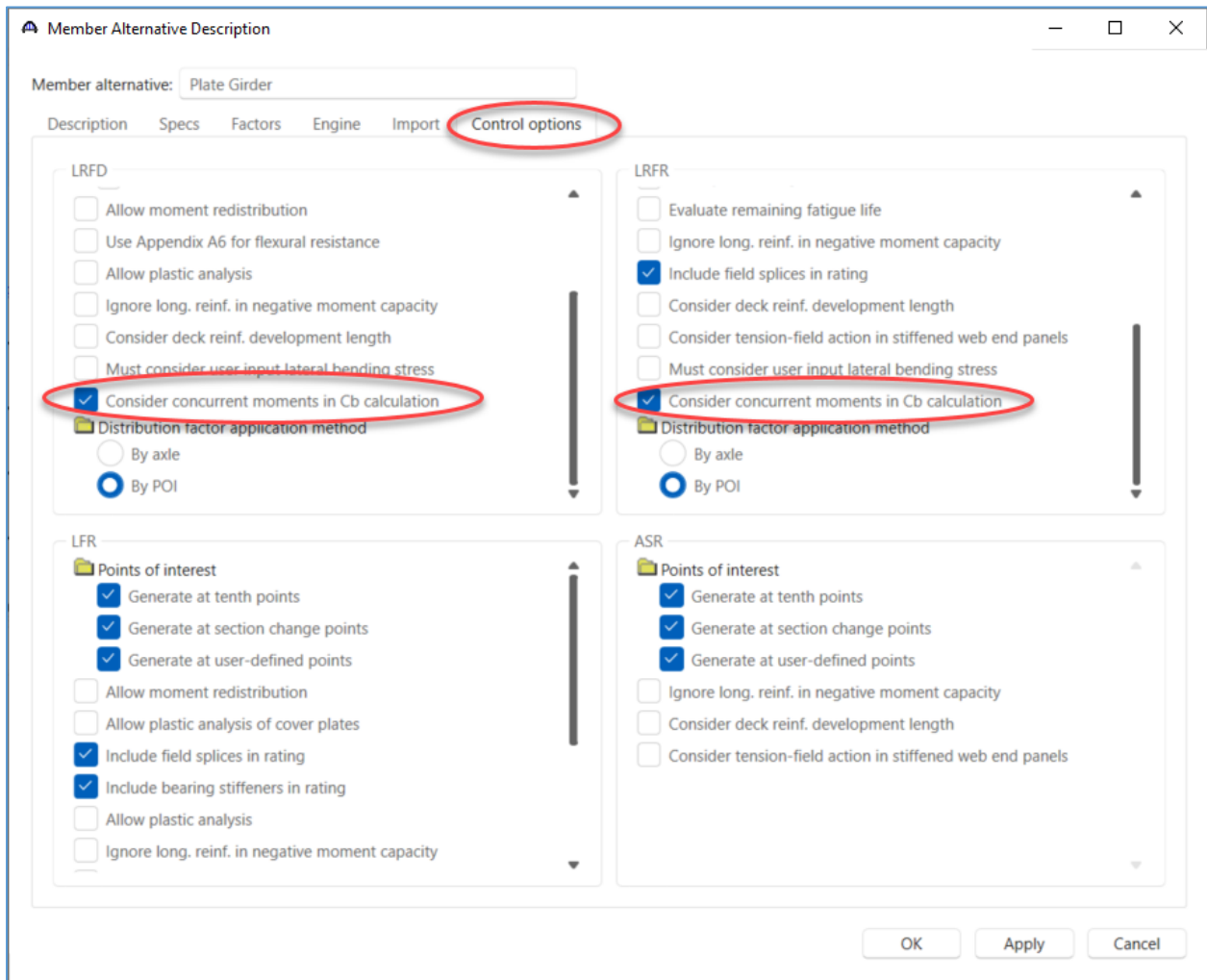
Expand the bridge workspace tree and open the **Member Alternative Description** window for the **G2 – Plate Girder** member alternative in the **Concurrent Moments** superstructure.



STL14 – LRFD Cb Calculation using Concurrent Moments Example

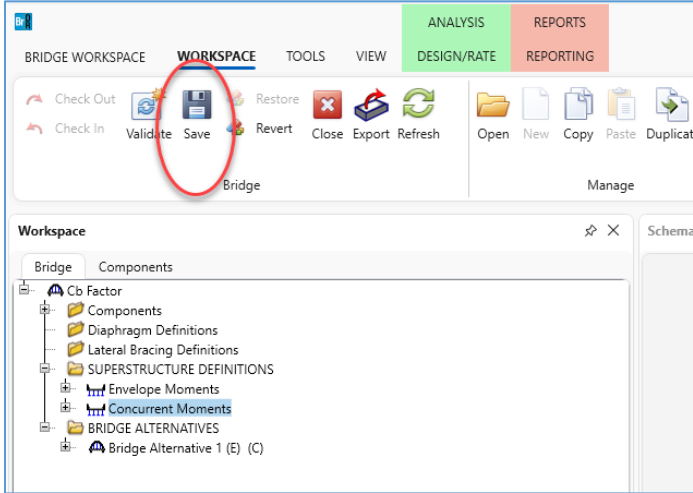
Cb Calculation Control Option

Navigate to the **Control options** tab in the window and select the **LRFD** and **LRFR** control options to **Consider concurrent moments in Cb calculation**.



STL14 – LRFD Cb Calculation using Concurrent Moments Example

This completes the data entry for this example. Now is a good time to save the bridge to the database.

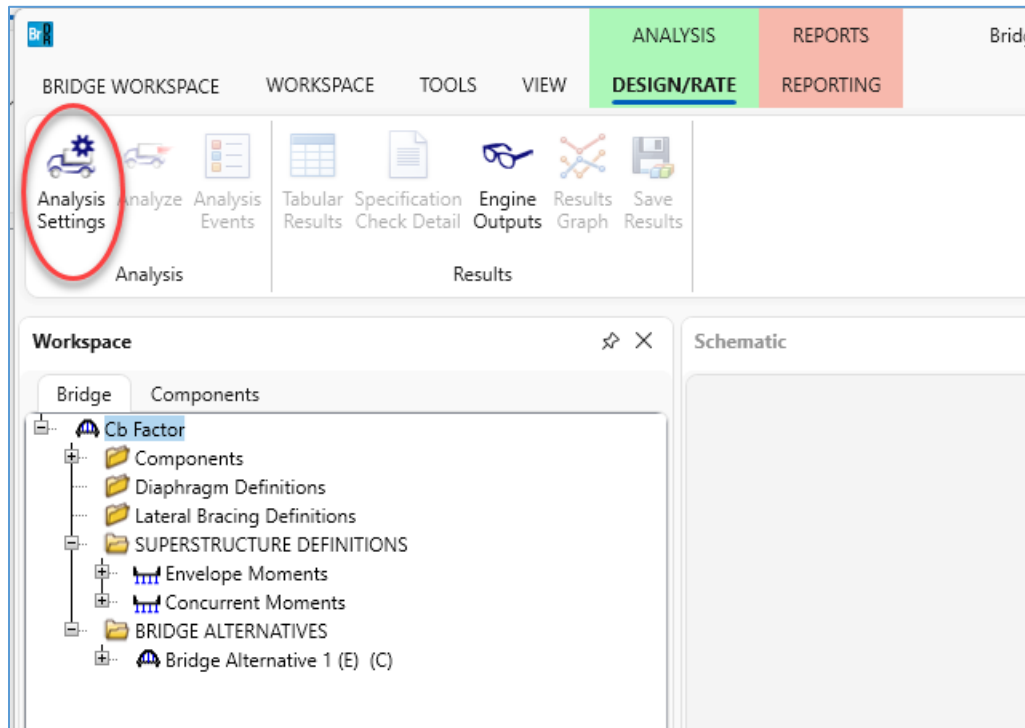


STL14 – LRFD Cb Calculation using Concurrent Moments Example

Cb Calculation comparison

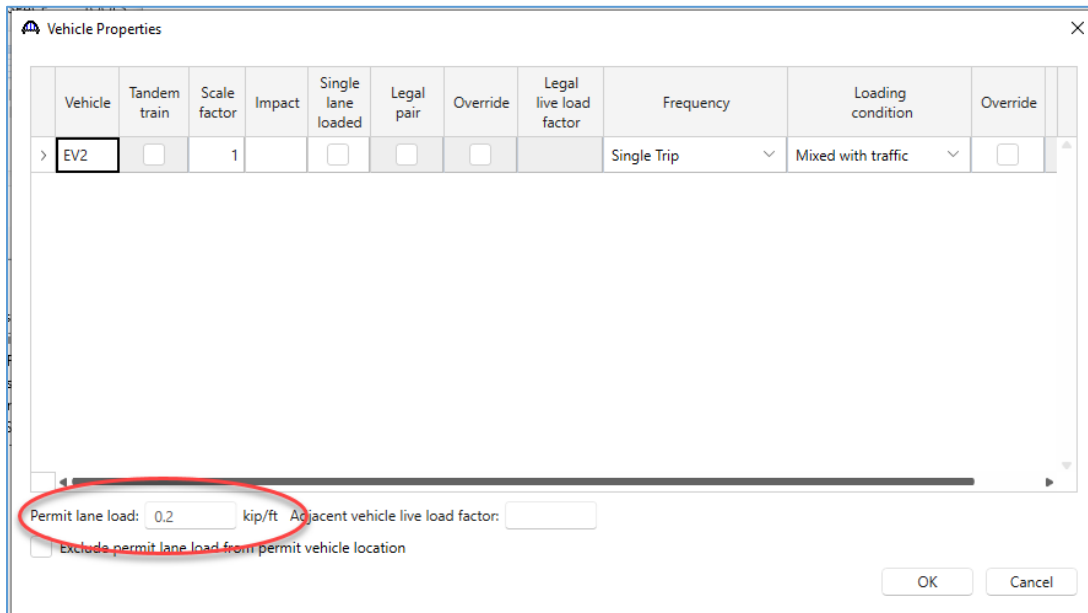
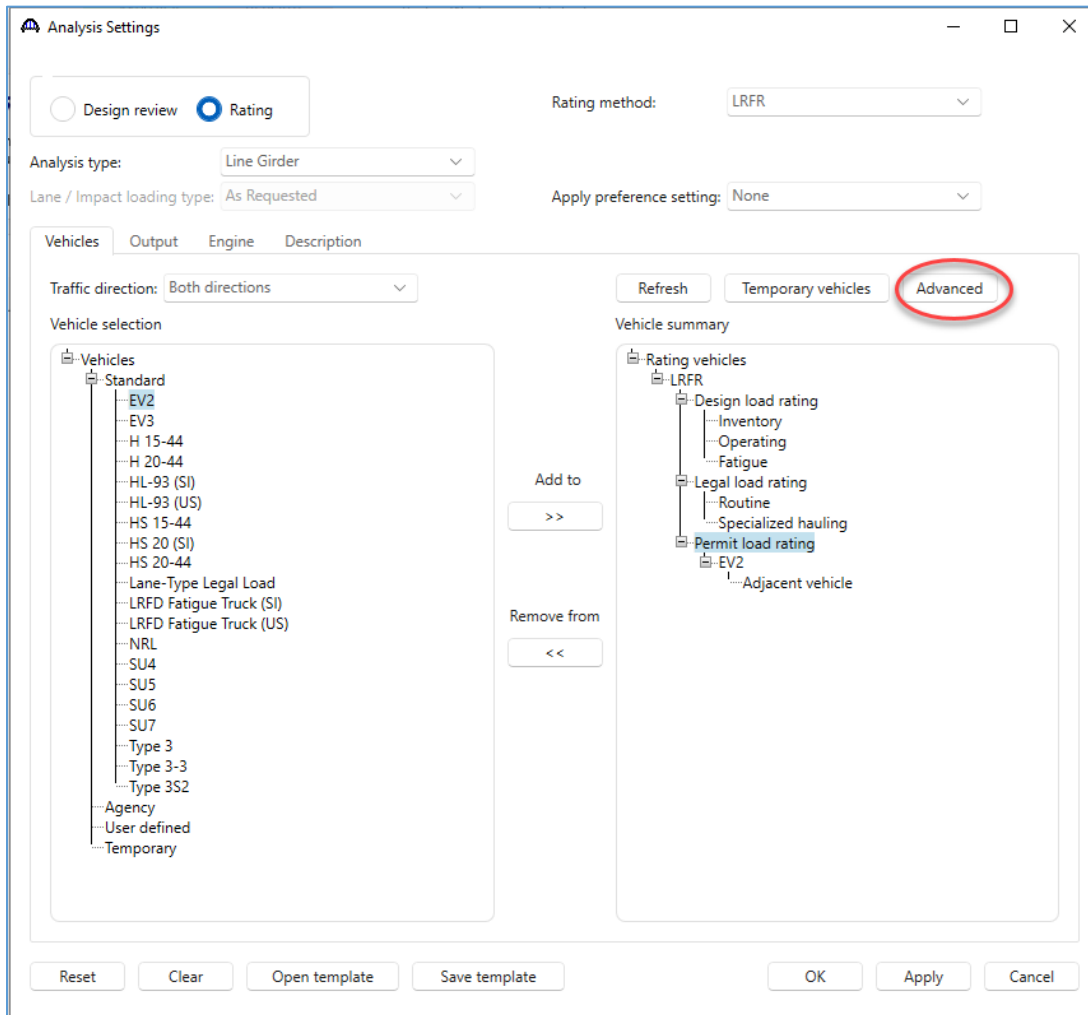
Follow the steps below to analyze the plate girder member alternative using envelope moments to compute Cb and the plate girder member alternative using concurrent moments to compute Cb.

Open the **Analysis Settings** window and add an **EV2** vehicle to the **LRFR Permit load rating** category. In the **Advanced** options define a 200plf permit lane load.



STL14 – LRFD Cb Calculation using Concurrent Moments Example

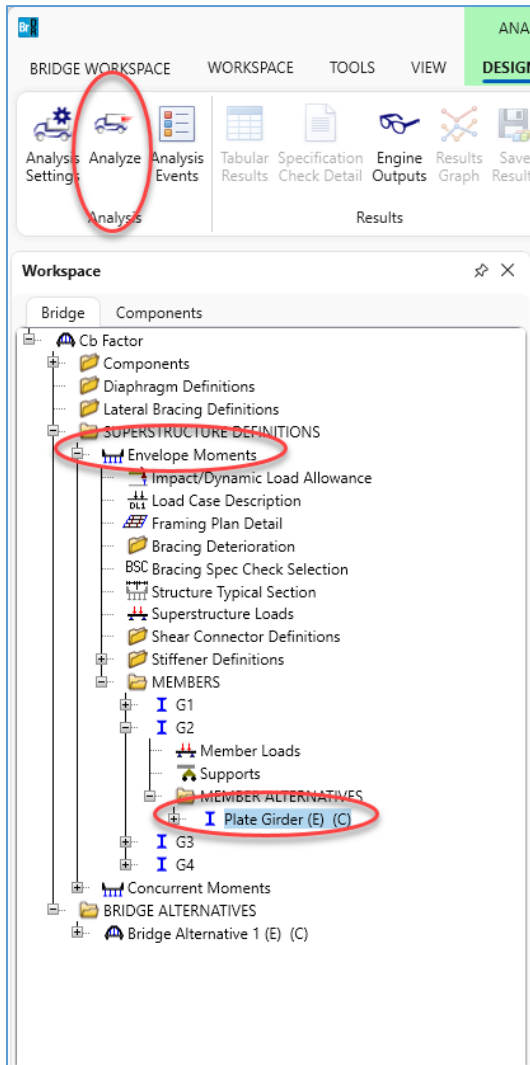
Analysis Settings



STL14 – LRFD Cb Calculation using Concurrent Moments Example

Analyzing Girder with Envelope Moment Cb Calculation

Analyze the plate girder member alternative within the **Envelope Moments** superstructure.



STL14 – LRFD Cb Calculation using Concurrent Moments Example

After the analysis is complete, review the results. Open the **Tabular Results** window to view the critical rating factor.

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
EV2	Truck + Lane	LRFR	Permit	26.91	0.936	72.00	1 - (80.0)	STRENGTH-II Steel Flexure Stress	As Requested	As Requested

AASHTO LRFR Engine Version 7.5.1.3001
Analysis preference setting: None

Open the **Specification Check Detail** window to review the specification calculations for the controlling location.

Specification reference	Limit State	Flex. Sense	Pass/Fail
6.10.6.2.2 Composite Sections in Positive Flexure		N/A	General Comp.
6.10.6.2.3 Composite Sections in Negative Flexure and Noncomposite		N/A	General Comp.
NA 6.10.7.1.1 General		N/A	Not Applicable
NA 6.10.7.1.2 Nominal Flexural Resistance		N/A	Not Applicable
NA 6.10.7.2.1 General		N/A	Not Applicable
6.10.7.2.2 Nominal Flexural Resistance		N/A	General Comp.
NA 6.10.7.3 Flexural Resistance - Ductility Requirement		N/A	Not Applicable
✗ 6.10.8.1.1 Discretely Braced Flanges in Compression		N/A	Failed
NA 6.10.8.1.2 Discretely Braced Flanges in Tension		N/A	Not Applicable
✓ 6.10.8.1.3 Continuously Braced Flanges in Tension or Compression		N/A	Passed
6.10.8.2.1 General		N/A	General Comp.
6.10.8.2.2 Local Buckling Resistance		N/A	General Comp.
6.10.8.2.3 Lateral Torsional Buckling Resistance		N/A	General Comp.
6.10.8.2.3.Cb Lateral Torsional Buckling Resistance - Cb Calculation		N/A	General Comp.
6.10.8.2.3.rt Lateral Torsional Buckling Resistance - rt and Lp Calculati		N/A	General Comp.
6.10.8.3 Flexural Resistance Based on Tension Flange Yielding		N/A	General Comp.
✓ 6.10.9 LRFD Shear Resistance		N/A	Passed
6.10.9.1 Shear Resistance - General		N/A	General Comp.
✗ 6.10.General_Flexural_Results		N/A	Failed
✓ 6A.4.2.1 General Load Rating Equation - Steel Flexure Moment		N/A	Passed
✗ 6A.4.2.1 General Load Rating Equation - Steel Flexure Stress		N/A	Failed
✓ 6A.4.2.1 General Load Rating Equation - Steel Shear		N/A	Passed
6A.4.2.1.fl		N/A	General Comp.
✓ 6A.6.4.2.2 Service Limit State		N/A	Passed
APPD6.1 Plastic Moment		N/A	General Comp.
APPD6.2 Yield Moment		N/A	General Comp.
APPD6.3.1 In the Elastic Range (Dc)		N/A	General Comp.
APPD6.3.2 Depth of the Web in Compression at Plastic Moment		N/A	General Comp.
Steel Elastic Section Properties		N/A	General Comp.
Unbraced Length Calculations		N/A	General Comp.

STL14 – LRFD Cb Calculation using Concurrent Moments Example

The rating is controlled by lateral torsional buckling within the negative flexure region over the interior pier. The Cb factor is computed in 6.10.8.2.3.Cb Lateral Torsional Buckling Resistance – Cb Calculation. Open this article to view the envelope Cb calculations.

Spec Check Detail for 6.10.8.2.3.Cb Lateral Torsional Buckling Resistance - Cb Calculation

6 Steel Structures
 6.10 I-Section Flexural Members
 6.10.8 Flexural Resistance-Composite Sections in Negative Flexure and Noncomposite Sections
 6.10.8.2 Compression-Flange Flexural Resistance
 6.10.8.2.3 Lateral Torsional Buckling Resistance - Cb Calculation
 (AASHTO LRFD Bridge Design Specifications, Ninth Edition)

Steel Plate - At Location = 72.0000 (ft) - Left Stage 3
 Section within Top Flange Continuous Bracing Region

Moment Gradient Modifier, Cb, Calculation

INPUT:
 Section Prismatic in Top Flange Unbraced Length: Yes
 Section Prismatic in Bottom Flange Unbraced Length: Yes
 Section is Unbraced Cantilever: No

Top Flange Left Brace Location = 72.0000 (ft)
 Top Flange Middle of Unbraced Length Location = 72.0000 (ft)
 Top Flange Right Brace Location = 72.0000 (ft)

Bot Flange Left Brace Location = 60.0000 (ft)
 Bot Flange Middle of Unbraced Length Location = 75.0000 (ft)
 Bot Flange Right Brace Location = 90.0000 (ft)

SUMMARY:

Cb = 1.0 (6.10.8.2.3-6)
 $Cb = 1.75 - 1.05*(f1/f2) + 0.3*(f1/f2)^2 \leq 2.3$ (6.10.8.2.3-7)

Limit State	Load Comb	Flexure Type	Input				Output				
			Left Stress (ksi)	Mid Stress (ksi)	Right Stress (ksi)	Concave Moment	fmid (ksi)	f2 (ksi)	f1 (ksi)	Eq.	Cb
STR-II	1, Permit~	Negative	12.10	-7.05	-34.27	Yes	7.05	34.27	-12.10	7	2.1582
STR-II	1, Permit~	Negative	4.49	-13.27	-39.35	Yes	13.27	39.35	-4.49	7	1.8738
SER-II	1, Permit~	Negative	9.74	-5.44	-26.17	Yes	5.44	26.17	-9.74	7	2.1822
SER-II	1, Permit~	Negative	3.79	-9.83	-29.64	Yes	9.83	29.64	-3.79	7	1.8890

Note: For Input Stresses, compression is negative, tension is positive.
 For Output Stresses signs are switched. Compression is positive, tension is negative.

Load Combination Legend:

Code	Vehicle
1	EV2 - Permit Truck + Lane

STL14 – LRFD Cb Calculation using Concurrent Moments Example

Since each of these load cases has negative flexure, the bottom flange brace points are used to compute Cb. The computed brace point stresses are computed within the 6.10.1.1.b Stresses article for the POI at the brace point. Here, the left brace stresses are computed within the 6.10.1.1.b article at the Span 1 – 60 ft POI on the right side, the mid stresses are computed at Span 1 – 75 ft and the right brace stresses are computed at 90 ft left.

Specification Checks for Plate Girder - 43 of 1560

Articles: All articles
Format: Bullet list

Specification filter: Report

Specification reference	Limit State	Flex. Sense	Pass/Fail
5.4.2.6 Modulus of Rupture		N/A	General Comp.
5.4.2.8 Concrete Density Modification Factor		N/A	General Comp.
6.10.1 Estimated Flange Lateral Bending Stress Proportioning		N/A	General Comp.
6.10.1.1.b Stresses for Sections in Positive Flexure		N/A	General Comp.
6.10.1.10.1 Hybrid Factor, K_h		N/A	General Comp.
6.10.1.10.2 Web Load-Shedding Factor, R_b		N/A	General Comp.
6.10.1.6 Flange Stress and Member Bending Moments		N/A	Passed
6.10.1.7 Minimum Negative Flexure Concrete Deck Reinforcement		N/A	Passed
6.10.1.9.1 Webs without Longitudinal Stiffeners		N/A	General Comp.
6.10.11.1.2 Transverse Stiffeners - Projecting Width		N/A	Passed
6.10.11.1.3 Transverse Stiffeners - Moment of Inertia		N/A	Passed
6.10.2 Cross-Section Proportion Limits		N/A	Passed
6.10.4.2.2 Flexure		N/A	Passed
6.10.6.2.2 Composite Sections in Positive Flexure		N/A	General Comp.
6.10.6.2.3 Composite Sections in Negative Flexure and Noncomposite		N/A	General Comp.
6.10.7.1.1 General	NA	N/A	Not Applicable
6.10.7.1.2 Nominal Flexural Resistance	NA	N/A	Not Applicable
6.10.7.2.1 General	NA	N/A	Not Applicable
6.10.7.2.2 Nominal Flexural Resistance	NA	N/A	General Comp.
6.10.7.3 Flexural Resistance - Ductility Requirement	NA	N/A	Not Applicable
6.10.8.1.1 Discretely Braced Flanges in Compression	X	N/A	Failed

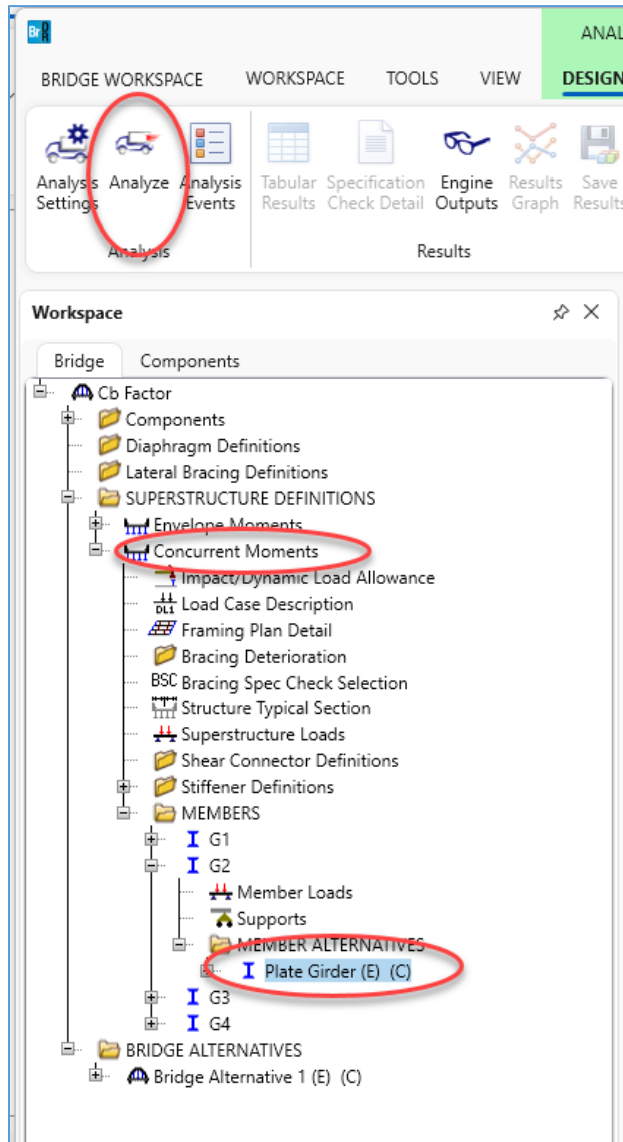
Superstructure Component

- Stage 1
- Stage 2
- Stage 3
 - Plate Girder
 - Span 1 - 0.00 ft.
 - Span 1 - 9.00 ft.
 - Span 1 - 15.00 ft.
 - Span 1 - 18.00 ft.
 - Span 1 - 27.00 ft.
 - Span 1 - 30.00 ft.
 - Span 1 - 36.00 ft.
 - Span 1 - 45.00 ft.
 - Span 1 - 54.00 ft.
 - Span 1 - 60.00 ft.
 - Span 1 - 63.00 ft.
 - Span 1 - 72.00 ft.
 - Span 1 - 75.00 ft.
 - Span 1 - 81.00 ft.
 - Span 1 - 90.00 ft.
 - Span 2 - 9.00 ft.
 - Span 2 - 15.00 ft.
 - Span 2 - 18.00 ft.

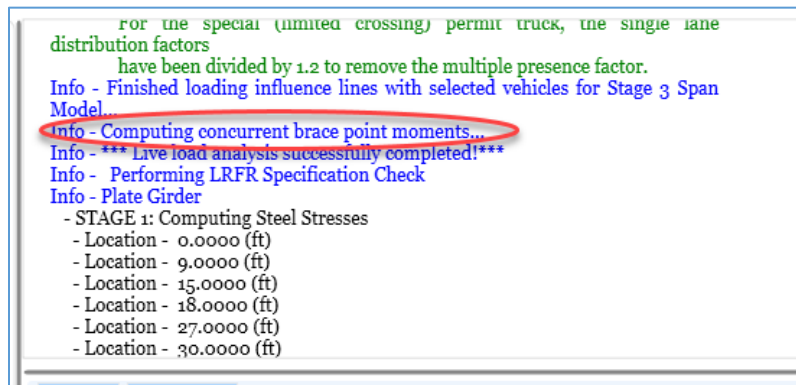
STL14 – LRFD Cb Calculation using Concurrent Moments Example

Analyzing Girder with Concurrent Moment Cb Calculation

Next, analyze the **G2 – Plate Girder** member alternative within the **Concurrent Moments** superstructure.

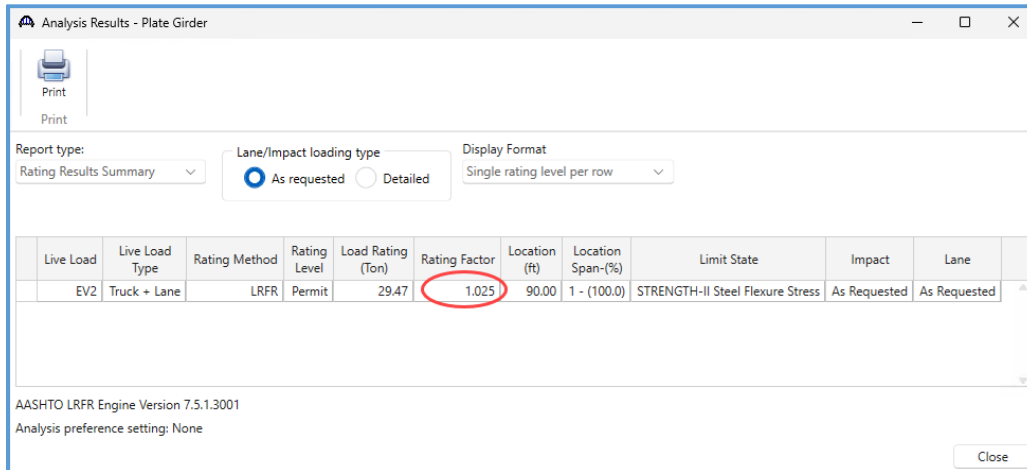


The analysis progress log will indicate when program is loading the concurrent moments at brace points.



STL14 – LRFD Cb Calculation using Concurrent Moments Example

Review the tabular results to see the critical rating factor. Using concurrent moments, the rating factor improves from 0.936 to 1.025.



Analysis Results - Plate Girder

Report type: Rating Results Summary

Lane/Impact loading type: As requested Detailed

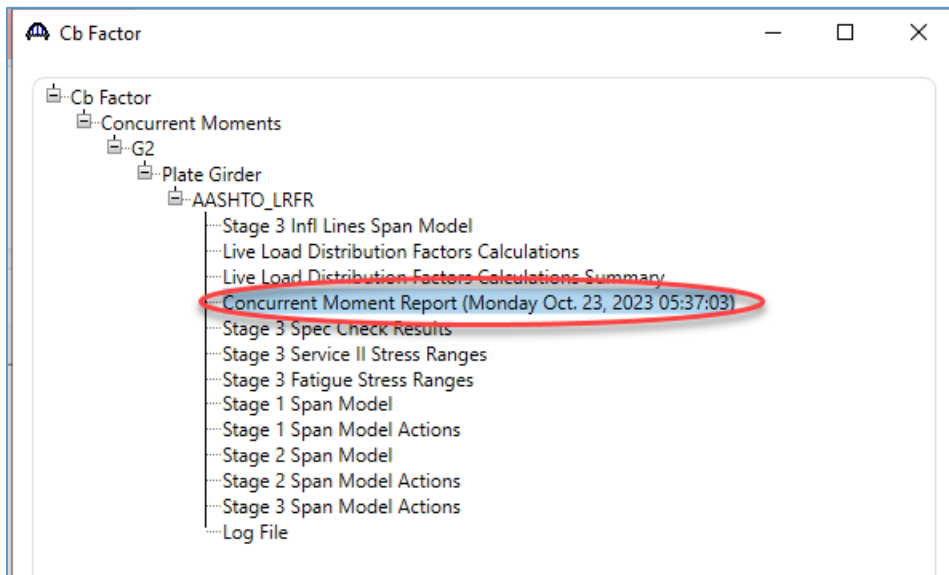
Display Format: Single rating level per row

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
EV2	Truck + Lane	LRFR	Permit	29.47	1.025	90.00	1 - (100.0)	STRENGTH-II Steel Flexure Stress	As Requested	As Requested

AASHTO LRFR Engine Version 7.5.1.3001
Analysis preference setting: None

Close

The **Engine Outputs** will include a **Concurrent Moment Report** which details the computed corresponding moments within all unbraced regions on the member.



Cb Factor

- Cb Factor
 - Concurrent Moments
 - G2
 - Plate Girder
 - AASHTO_LRFR
 - Stage 3 Infl Lines Span Model
 - Live Load Distribution Factors Calculations
 - Live Load Distribution Factors Calculations Summary
 - Concurrent Moment Report (Monday Oct. 23, 2023 05:37:03)**
 - Stage 3 Spec Check Results
 - Stage 3 Service II Stress Ranges
 - Stage 3 Fatigue Stress Ranges
 - Stage 1 Span Model
 - Stage 1 Span Model Actions
 - Stage 2 Span Model
 - Stage 2 Span Model Actions
 - Stage 3 Span Model Actions
 - Log File

STL14 – LRFD Cb Calculation using Concurrent Moments Example

Brace Point Concurrent Moment Report

Open the Concurrent Moment Report to view the computed corresponding moments at brace points.

Concurrent Moment Report

Bridge ID: NBI Structure ID: Cb Factor
 Bridge: Cb Factor Example Bridge Bridge Alt:
 StructDef: Concurrent Moments Member: Plate Girder
 Date: 10/23/2023

Brace Point Concurrent Moment Report

Unbraced Region			Left Primary			Middle Primary			Right Primary		
Left Brace (ft)	Middle (ft)	Right Brace (ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)
0.0000	15.0000	30.0000	0.00	0.00	0.00	0.00	343.22	404.50	0.00	249.13	498.25
30.0000	45.0000	60.0000	498.25	465.45	230.66	468.46	500.70	251.02	299.86	449.78	397.73
60.0000	75.0000	90.0000	397.73	63.74	-270.24	310.67	186.35	-219.90	0.00	0.00	0.00
90.0000	105.0000	120.0000	0.00	0.00	0.00	-219.90	186.35	310.67	-270.24	63.74	397.73
120.0000	135.0000	150.0000	397.73	449.78	299.86	251.02	500.70	468.46	230.66	465.45	498.25
150.0000	165.0000	180.0000	498.25	249.13	0.00	404.50	343.22	0.00	0.00	0.00	0.00

EV2 - Permit Truck + Lane - Maximum

Note: Brace point locations are measured from start of member.
 Note: LL forces include impact, LL scale factors, LLDF, and MPF when applicable.

Unbraced Region			Left Primary			Middle Primary			Right Primary		
Left Brace (ft)	Middle (ft)	Right Brace (ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)
0.0000	15.0000	30.0000	0.00	0.00	0.00	0.00	-52.09	-104.19	0.00	-52.09	-104.19

EV2 - Permit Truck + Lane - Minimum

Note: Brace point locations are measured from start of member.
 Note: LL forces include impact, LL scale factors, LLDF, and MPF when applicable.

Unbraced Region			Left Primary			Middle Primary			Right Primary		
Left Brace (ft)	Middle (ft)	Right Brace (ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)
0.0000	15.0000	30.0000	0.00	0.00	0.00	0.00	-52.09	-104.19	0.00	-52.09	-104.19

STL14 – LRFD Cb Calculation using Concurrent Moments Example

Specification Check Detail

Open the **Specification Check Detail** window to review the specification calculations. The articles indicated with arrows below are particularly relevant to the LTB rating.

Specification reference	Limit State	Flex. Sense	Pass/Fail
✓ 6.10.4.2.2 Flexure		N/A	Passed
6.10.6.2.2 Composite Sections in Positive Flexure		N/A	General Comp.
6.10.6.2.3 Composite Sections in Negative Flexure and Noncomposite		N/A	General Comp.
NA 6.10.7.1.1 General		N/A	Not Applicable
NA 6.10.7.1.2 Nominal Flexural Resistance		N/A	Not Applicable
NA 6.10.7.2.1 General		N/A	Not Applicable
6.10.7.2.2 Nominal Flexural Resistance		N/A	General Comp.
NA 6.10.7.3 Flexural Resistance - Ductility Requirement		N/A	Not Applicable
✓ 6.10.8.1.1 Discretely Braced Flanges in Compression		N/A	Passed
NA 6.10.8.1.2 Discretely Braced Flanges in Tension		N/A	Not Applicable
✓ 6.10.8.1.3 Continuously Braced Flanges in Tension or Compression		N/A	Passed
6.10.8.2.1 General		N/A	General Comp.
6.10.8.2.2 Local Buckling Resistance		N/A	General Comp.
6.10.8.2.3 Lateral Torsional Buckling Resistance		N/A	General Comp.
6.10.8.2.3 Concurrent Moment Brace Point Stresses		N/A	General Comp.
6.10.8.2.3 Cb Concurrent Moment Lateral Torsional Buckling Resistance		N/A	General Comp.
6.10.8.2.3.rt Lateral Torsional Buckling Resistance - rt and Lp Calculatic		N/A	General Comp.
6.10.8.3 Flexural Resistance Based on Tension Flange Yielding		N/A	General Comp.
✓ 6.10.9 LRFD Shear Resistance		N/A	Passed
6.10.9.1 Shear Resistance - General		N/A	General Comp.
✓ 6.10_General_Flexural_Results		N/A	Passed
6.9.4.1 Bearing Stiffener Nominal Resistance		N/A	General Comp.
✓ 6A.4.2.1 General Load Rating Equation - Steel Flexure Moment		N/A	Passed
✓ 6A.4.2.1 General Load Rating Equation - Steel Flexure Stress		N/A	Passed
✓ 6A.4.2.1 General Load Rating Equation - Steel Shear		N/A	Passed
6A.4.2.1.fl		N/A	General Comp.
✓ 6A.6.4.2.2 Service Limit State		N/A	Passed
APPD6.1 Plastic Moment		N/A	General Comp.
APPD6.2 Yield Moment		N/A	General Comp.
APPD6.3.1 In the Elastic Range (Dc)		N/A	General Comp.
APPD6.3.2 Depth of the Web in Compression at Plastic Moment		N/A	General Comp.

The brace point stresses for envelope actions are computed in the 6.10.1.1.1b stresses article. An additional article is included when the concurrent actions are enabled to compute the brace point stresses for concurrent actions. This is the 6.10.8.2.3 Concurrent Moment Brace Point Stresses article. As with the envelope stresses, these stresses are computed at the POI corresponding to the actual brace point location.

STL14 – LRFD Cb Calculation using Concurrent Moments Example

The Cb concurrent moment calculation article computes Cb for each loading scenario, left brace envelope, mid brace envelope and right brace envelope.

Spec Check Detail for 6.10.8.2.3.Cb Concurrent Moment Lateral Torsional Buckling Resistance - Cb Calculation

$$Cb = 1.75 - 1.05*(f1/f2) + 0.3*(f1/f2)^2 \leq 2.3 \quad (6.10.8.2.3-7)$$

Cb calculation for loading left brace

Limit State	Load Comb	Flexure Type	Left Stress (ksi)	Mid Stress (ksi)	Right Stress (ksi)	Concave Moment	fmid (ksi)	f2 (ksi)	f1 (ksi)	Eq.	Cb
STR-II	1, PermitSpec	Neg	12.10	-8.61	-38.14	Yes	8.61	38.14	-12.10	7	2.1134
STR-II	1, PermitSpec	Neg	4.49	-13.25	-38.74	Yes	13.25	38.74	-4.49	7	1.8758
SER-II	1, PermitSpec	Neg	9.74	-6.64	-28.81	Yes	6.64	28.81	-9.74	7	2.1390
SER-II	1, PermitSpec	Neg	3.79	-9.82	-29.23	Yes	9.82	29.23	-3.79	7	1.8910

Note: For Input Stresses, compression is negative, tension is positive.
For Output Stresses signs are switched. Compression is positive, tension is negative.

Cb calculation for loading mid brace

Limit State	Load Comb	Flexure Type	Left Stress (ksi)	Mid Stress (ksi)	Right Stress (ksi)	Concave Moment	fmid (ksi)	f2 (ksi)	f1 (ksi)	Eq.	Cb
STR-II	1, PermitSpec	Neg	11.08	-7.05	-37.42	Yes	7.05	37.42	-11.08	7	2.0871
STR-II	1, PermitSpec	Neg	4.68	-13.27	-38.96	Yes	13.27	38.96	-4.68	7	1.8806
SER-II	1, PermitSpec	Neg	8.88	-5.44	-28.32	Yes	5.44	28.32	-8.88	7	2.1088
SER-II	1, PermitSpec	Neg	3.90	-9.83	-29.37	Yes	9.83	29.37	-3.90	7	1.8949

Note: For Input Stresses, compression is negative, tension is positive.
For Output Stresses signs are switched. Compression is positive, tension is negative.

Cb calculation for loading right brace

Limit State	Load Comb	Flexure Type	Left Stress (ksi)	Mid Stress (ksi)	Right Stress (ksi)	Concave Moment	fmid (ksi)	f2 (ksi)	f1 (ksi)	Eq.	Cb
STR-II	1, PermitSpec	Neg	7.42	-9.52	-34.27	Yes	9.52	34.27	-7.42	7	1.9913
STR-II	1, PermitSpec	Neg	12.30	-8.96	-39.35	Yes	8.96	39.35	-12.30	7	2.1075
SER-II	1, PermitSpec	Neg	5.83	-7.27	-26.17	Yes	7.27	26.17	-5.83	7	1.9989
SER-II	1, PermitSpec	Neg	9.90	-6.88	-29.64	Yes	6.88	29.64	-9.90	7	2.1342

Note: For Input Stresses, compression is negative, tension is positive.
For Output Stresses signs are switched. Compression is positive, tension is negative.

The article summary indicates the Cb factor which is used for each load case.

Cb calculation summary

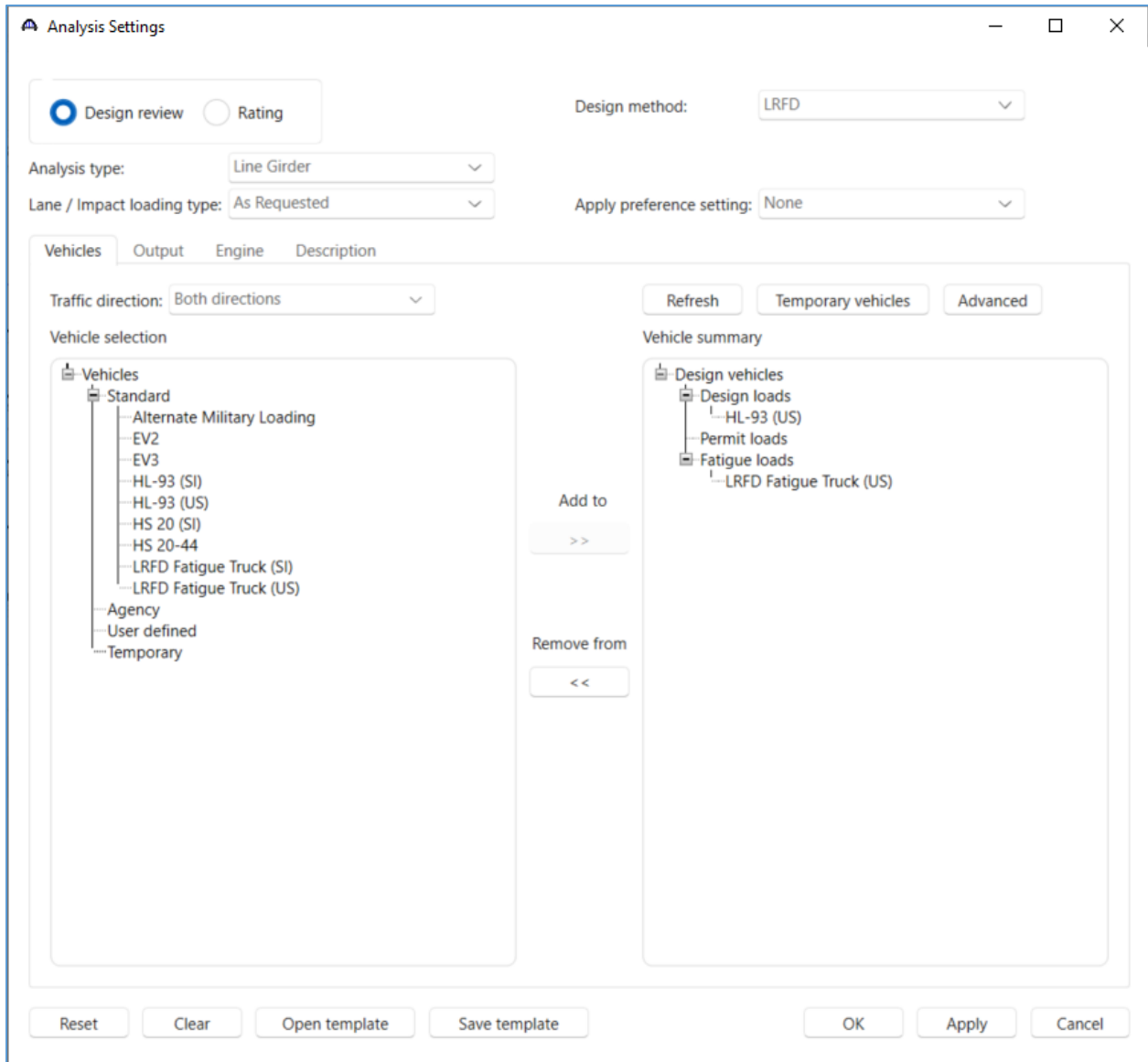
Limit State	Load Comb	Cb	Critical Concurrent Loading
STR-II	1, PermitSpec	2.1134	Left brace
STR-II	1, PermitSpec	2.1075	Right brace
SER-II	1, PermitSpec	2.1390	Left brace
SER-II	1, PermitSpec	2.1342	Right brace

Note: Use Cb corresponding to brace point with largest compressive stress.

STL14 – LRFD Cb Calculation using Concurrent Moments Example

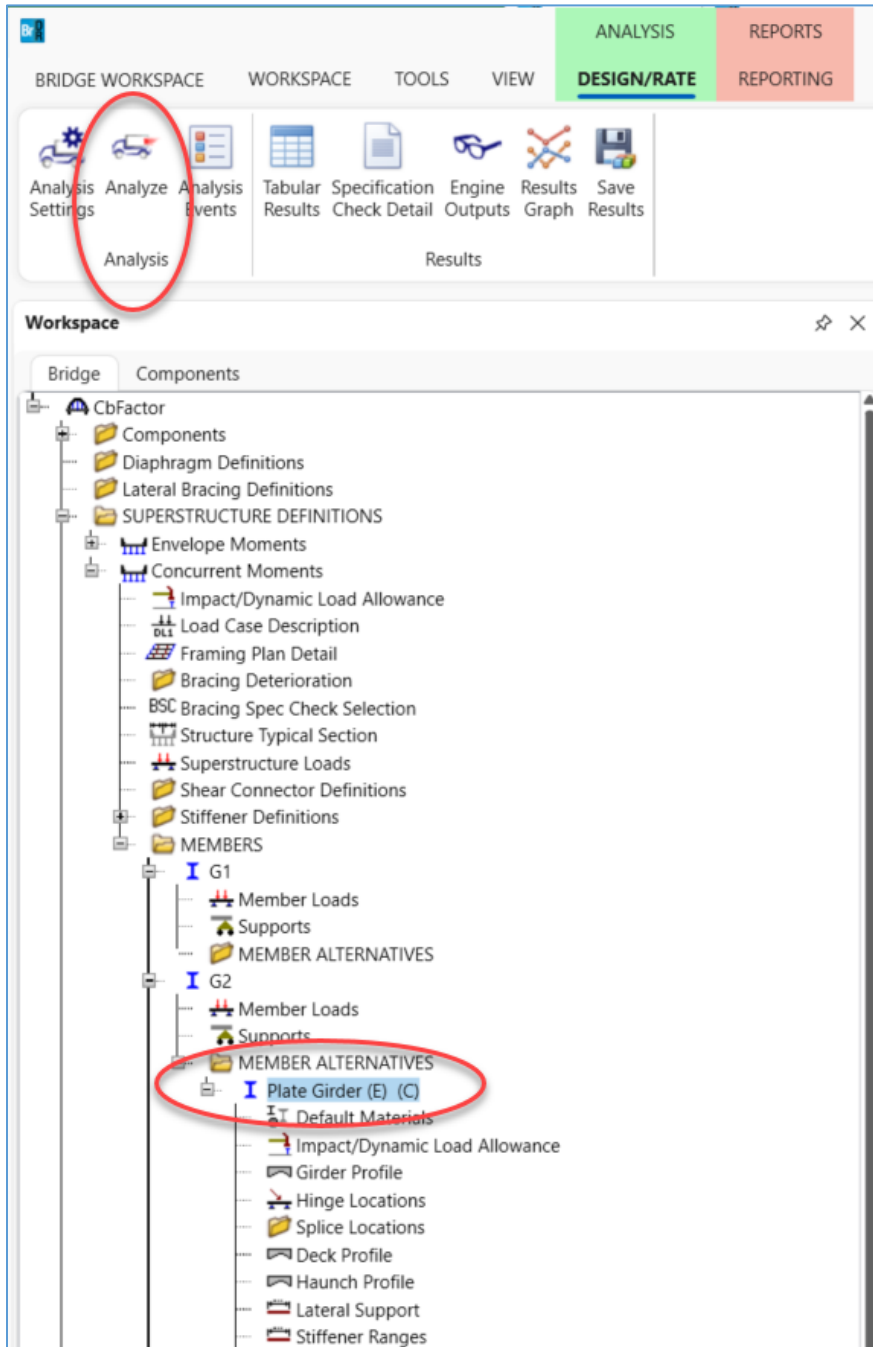
LRFD Design Review

Open the **Analysis Settings** window. Open the **HL 93 Design Review** template to perform a design review using concurrent moments to compute the Cb factor.



STL14 – LRFD Cb Calculation using Concurrent Moments Example

Analyze the **Plate Girder** member alternative under **G2** for the **Concurrent Moments** superstructure definition.

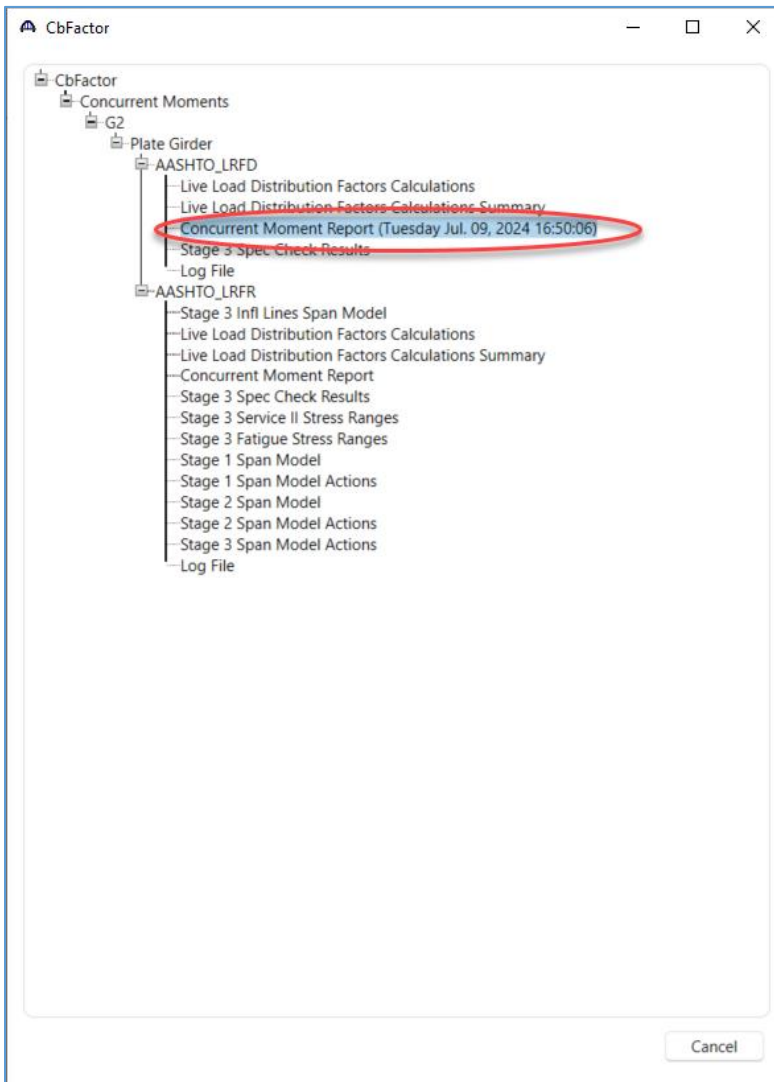


STL14 – LRFD Cb Calculation using Concurrent Moments Example

The analysis progress log will indicate when the program computes the concurrent brace point moments.

```
to enecutely
Warning - remove the multiple presence factor from the distribution factors.
Warning - Additionally, the one-lane distribution factors will be used for
fatigue.
Info - Finished loading influence lines with selected vehicles for Stage 3 Span
Model
Info - Computing concurrent brace point moments...
Info - *** Live load analysis successfully completed!***
Info - Performing LRFD Specification Check
Info - Plate Girder
  - STAGE 1: Computing Steel Stresses
  - Location - 0.0000 (ft)
  - Location - 9.0000 (ft)
```

The **Engine Outputs** window includes a **Concurrent Moment Report** which shows the computed envelope and corresponding moments for each unbraced region along the member.



STL14 – LRFD Cb Calculation using Concurrent Moments Example

Open the report to review the computed actions. The report includes tables for each component of the vehicle live load. For the design vehicle this includes the load components such as truck and lane and the design combinations such as 90% truck pair plus lane.

Concurrent Moment Report

Bridge ID: NBI Structure ID: Cb Factor
 Bridge: Cb Factor Example Bridge
 StructDef: Concurrent Moments
 Date: 7/9/2024

Member: Plate Girder

Brace Point Concurrent Moment Report

Legend

Envelope Moment

Corresponding Moment

HL-93 (US) - Design Truck + Lane - Maximum

Note: Brace point locations are measured from start of member.
 Note: LL forces include impact, LL scale factors, LLDf, and MPF when applicable.

Unbraced Region			Left Primary			Middle Primary			Right Primary		
Left Brace (ft)	Middle (ft)	Right Brace (ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)	Left Moment (kip-ft)	Middle Moment (kip-ft)	Right Moment (kip-ft)
0.0000	15.0000	30.0000	0.00	0.00	0.00	0.00	926.63	1250.35	0.00	786.52	1358.94
30.0000	45.0000	60.0000	1358.94	1320.68	741.72	1321.36	1388.72	845.40	961.70	1284.69	1066.99
60.0000	75.0000	90.0000	1066.99	238.60	-803.89	898.06	423.93	-653.11	0.00	0.00	0.00
90.0000	105.0000	120.0000	0.00	0.00	0.00	-653.11	423.93	898.06	-803.89	238.60	1066.99
120.0000	135.0000	150.0000	1066.99	1284.69	961.70	845.40	1388.72	1321.36	741.72	1320.68	1358.94
150.0000	165.0000	180.0000	1358.94	786.52	0.00	1250.35	926.63	0.00	0.00	0.00	0.00

HL-93 (US) - Design Truck + Lane - Minimum

Note: Brace point locations are measured from start of member.
 Note: LL forces include impact, LL scale factors, LLDf, and MPF when applicable.

Unbraced Region			Left Primary			Middle Primary			Right Primary		
Left Brace (ft)	Middle (ft)	Right Brace (ft)	Left Moment (kin-ft)	Middle Moment (kin-ft)	Right Moment (kin-ft)	Left Moment (kin-ft)	Middle Moment (kin-ft)	Right Moment (kin-ft)	Left Moment (kin-ft)	Middle Moment (kin-ft)	Right Moment (kin-ft)
0.0000	15.0000	30.0000	0.00	0.00	0.00	0.00	926.63	1250.35	0.00	786.52	1358.94
30.0000	45.0000	60.0000	1358.94	1320.68	741.72	1321.36	1388.72	845.40	961.70	1284.69	1066.99
60.0000	75.0000	90.0000	1066.99	238.60	-803.89	898.06	423.93	-653.11	0.00	0.00	0.00
90.0000	105.0000	120.0000	0.00	0.00	0.00	-653.11	423.93	898.06	-803.89	238.60	1066.99
120.0000	135.0000	150.0000	1066.99	1284.69	961.70	845.40	1388.72	1321.36	741.72	1320.68	1358.94
150.0000	165.0000	180.0000	1358.94	786.52	0.00	1250.35	926.63	0.00	0.00	0.00	0.00