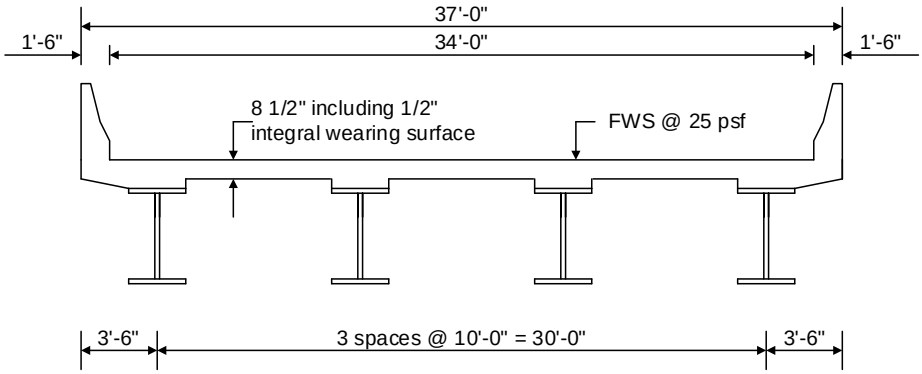
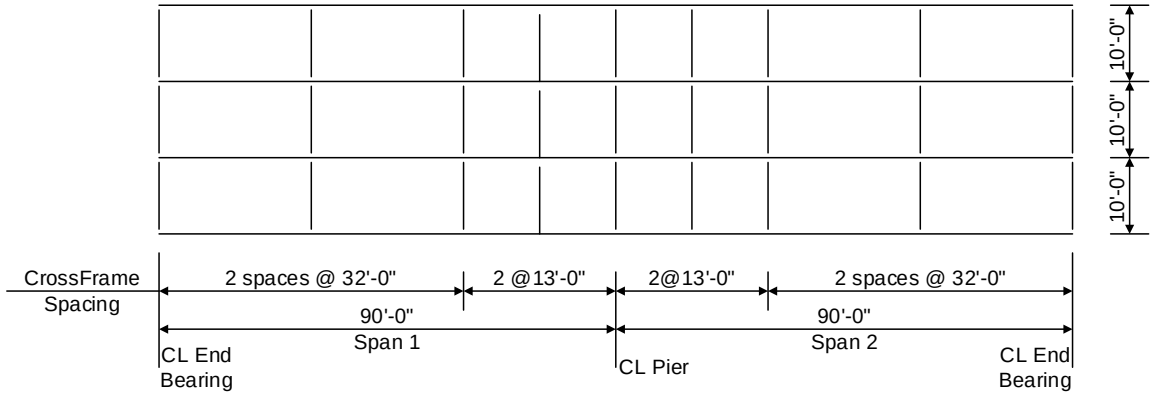
AASHTOWare BrDR 7.5.0

Steel Tutorial

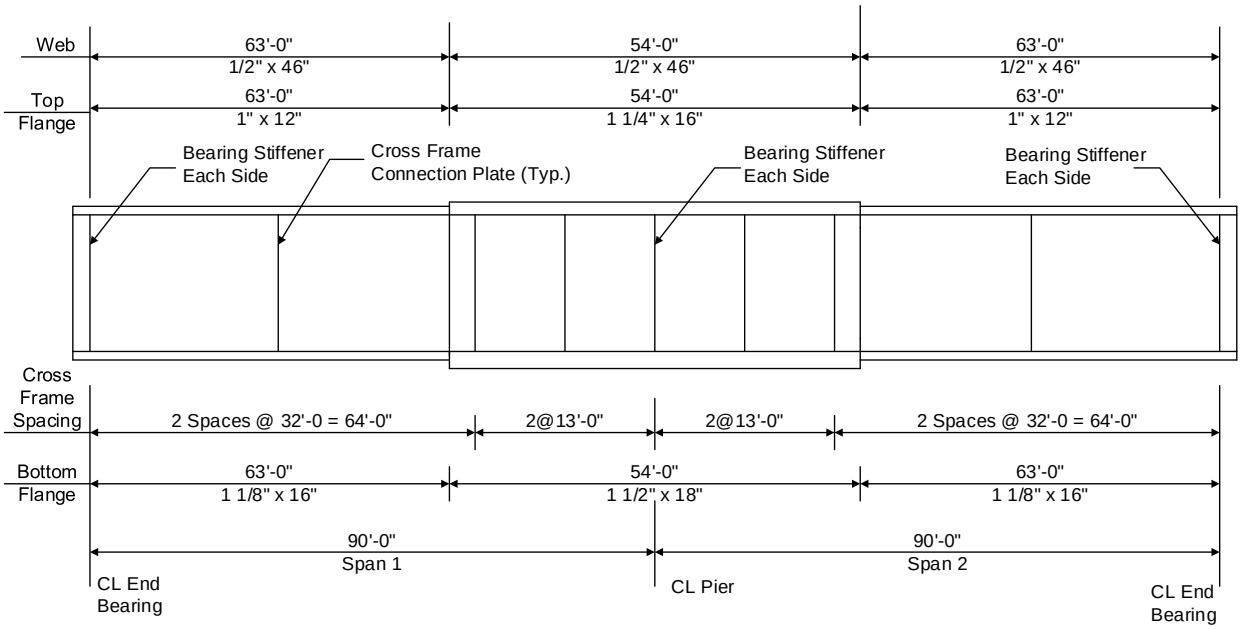
STL11 – Steel Plate Girder Using LRFR Engine

STL6 - Two Span Plate Girder Example





Framing Plan



Elevation of Interior Girder

Material Properties

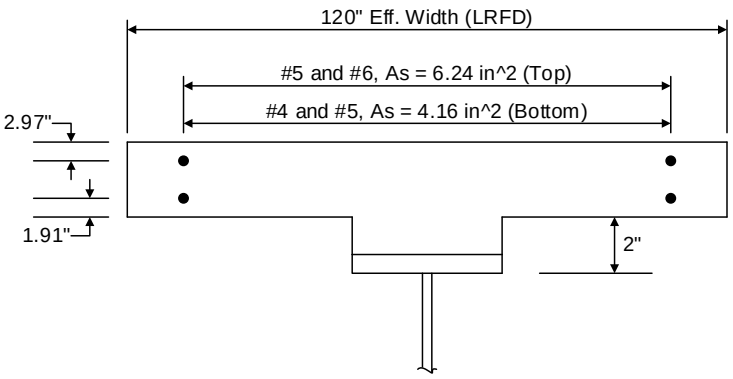
Structural Steel: AASHTO M270, Grade 50W uncoated weathering steel with Fy = 50 ksi

Deck Concrete: f'c = 4.0 ksi, modular ratio n = 8

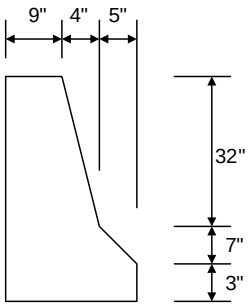
Slab Reinforcing Steel: AASHTO M31, Grade 60 with Fy = 60 ksi

Cross Frame Connection Plates: 3/4" x 6"

Bearing Stiffener Plates: 7/8" x 9"

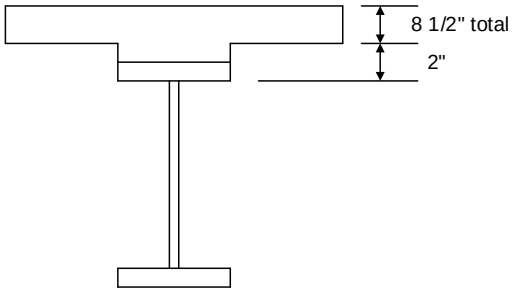


Composite Section at Pier



Weight = 536 plf

Parapet Detail



Haunch Detail

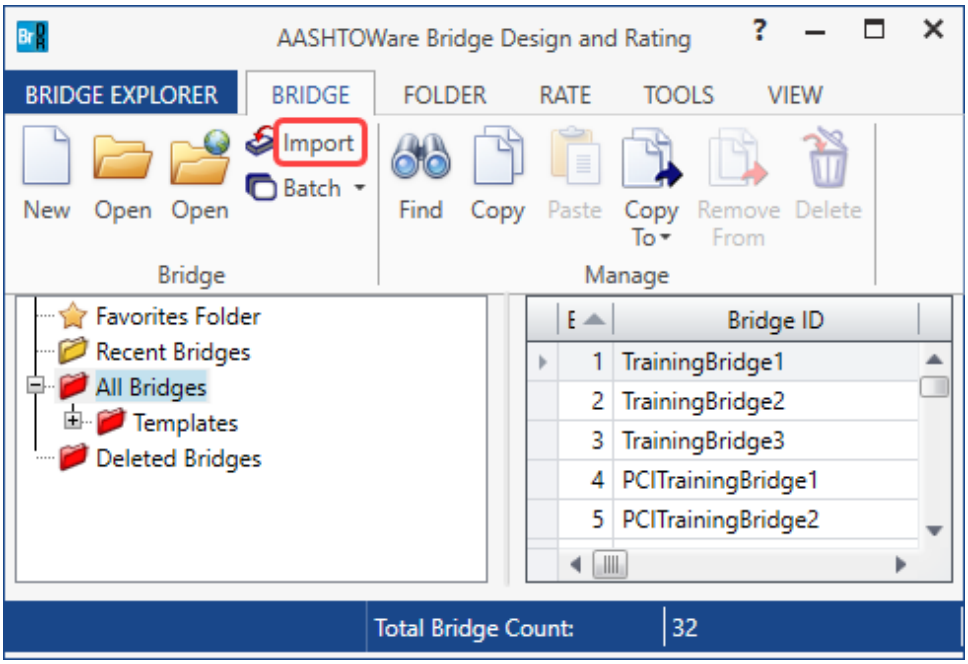
BrDR Tutorial

Topics Covered

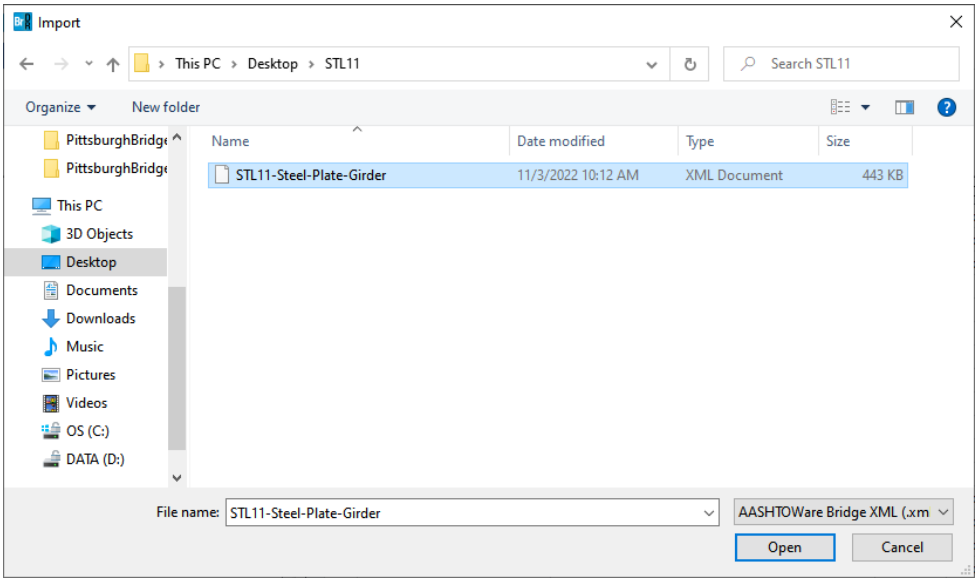
- LRFD distribution factor calculation wizard for steel members
- Using AASHTO LRFD Bridge Design Specifications – 9th Edition
- Using AASHTO Manual of Bridge Evaluation, 3rd Edition with 2023 interims
- Steel Member Alternative Control Options
  - Moment redistribution
  - Use Appendix A6 for flexural resistance.
  - Allow plastic analysis.
  - Evaluate remaining fatigue life.
  - Ignore longitudinal reinforcement in negative moment capacity.
- Export of steel girders to the BrDR LRFR analysis engine
- BrDR LRFR analysis
- Output review

LRFD distribution factor calculation wizard for steel members

Use the **Import** function of **BrDR** to import the bridge **STL11-Steel-Plate-Girder.xml** provided for this tutorial. Open **BrDR** and click on the **Import** button from the **Bridge** group of the **BRIDGE** ribbon as shown below.

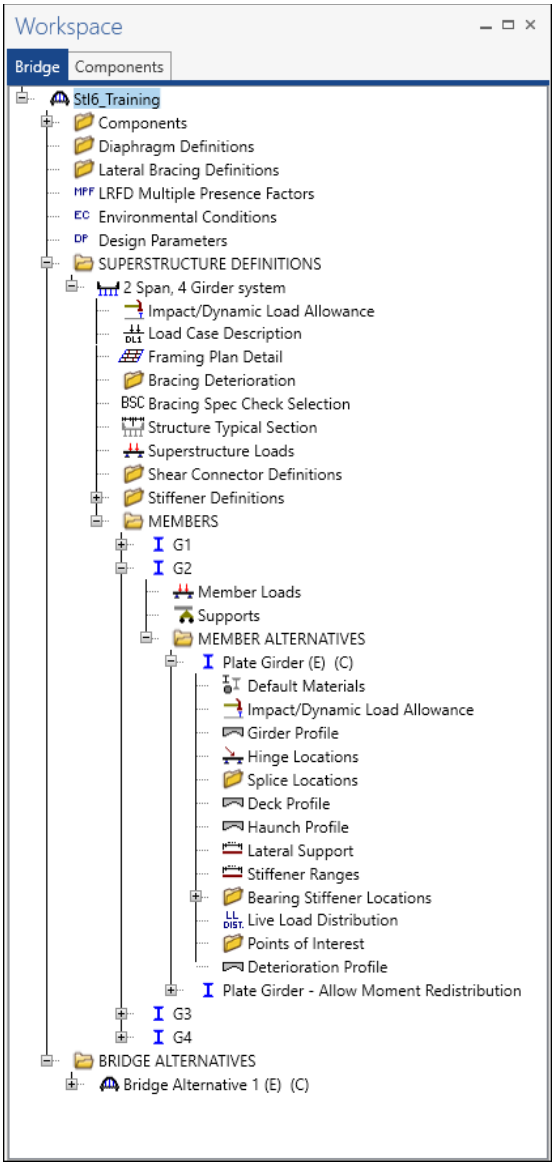


Select the bridge from the **STL11** tutorial and click the **Open** button to import this bridge into **BrDR**.



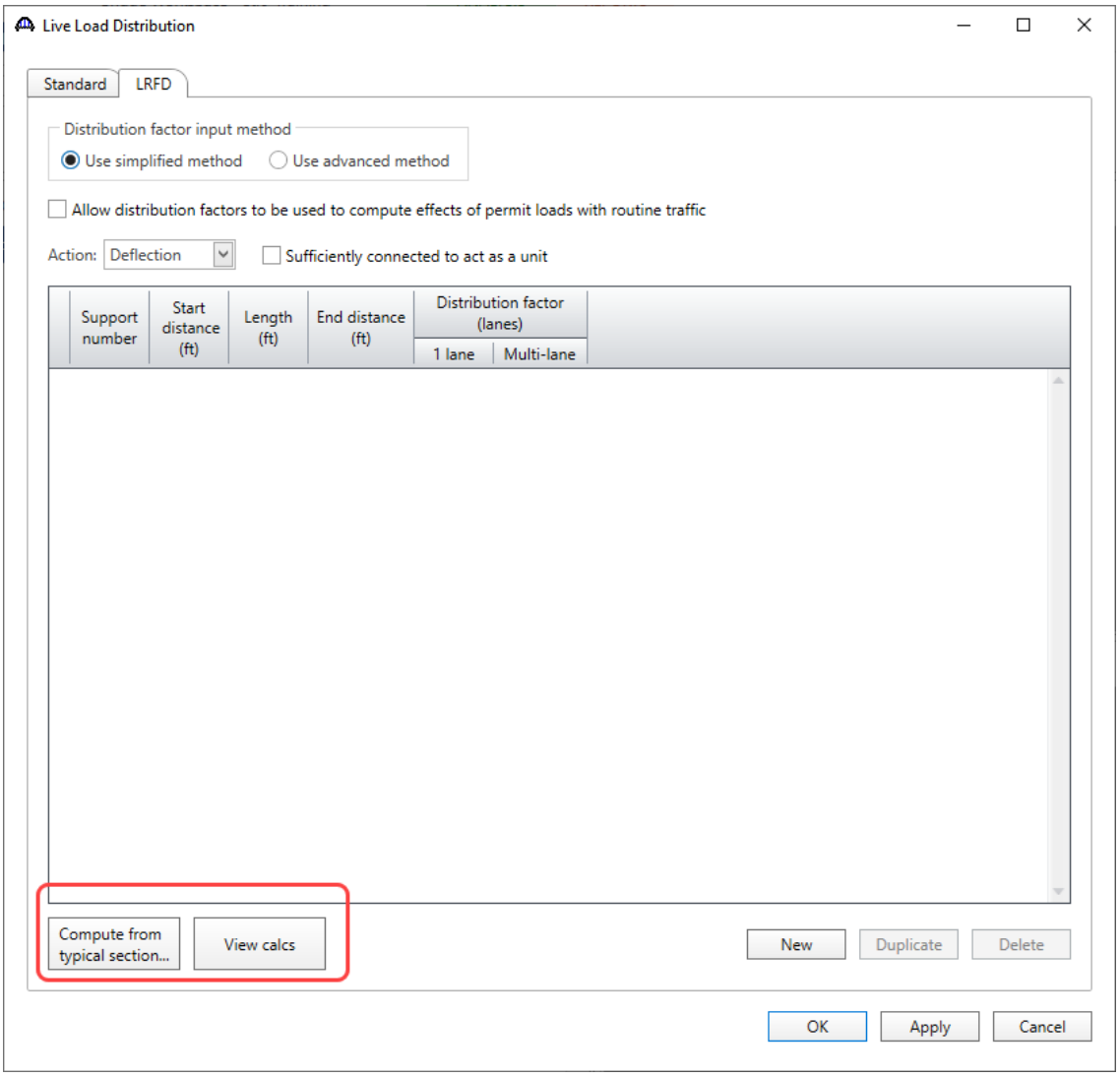
Open the **Bridge Workspace** tree for **Stl6_Training** to show the member alternative **Plate Girder** for member **G2**.

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



Live Load Distribution Factor - LRFD

BrDR can compute the LRFD live load distribution factors for steel girder with concrete decks. Double click on the **Live Load Distribution** node in the **Bridge Workspace** tree for member alternative **Plate Girder** to open the **Live Load Distribution** window and navigate to the **LRFD** tab as shown below.

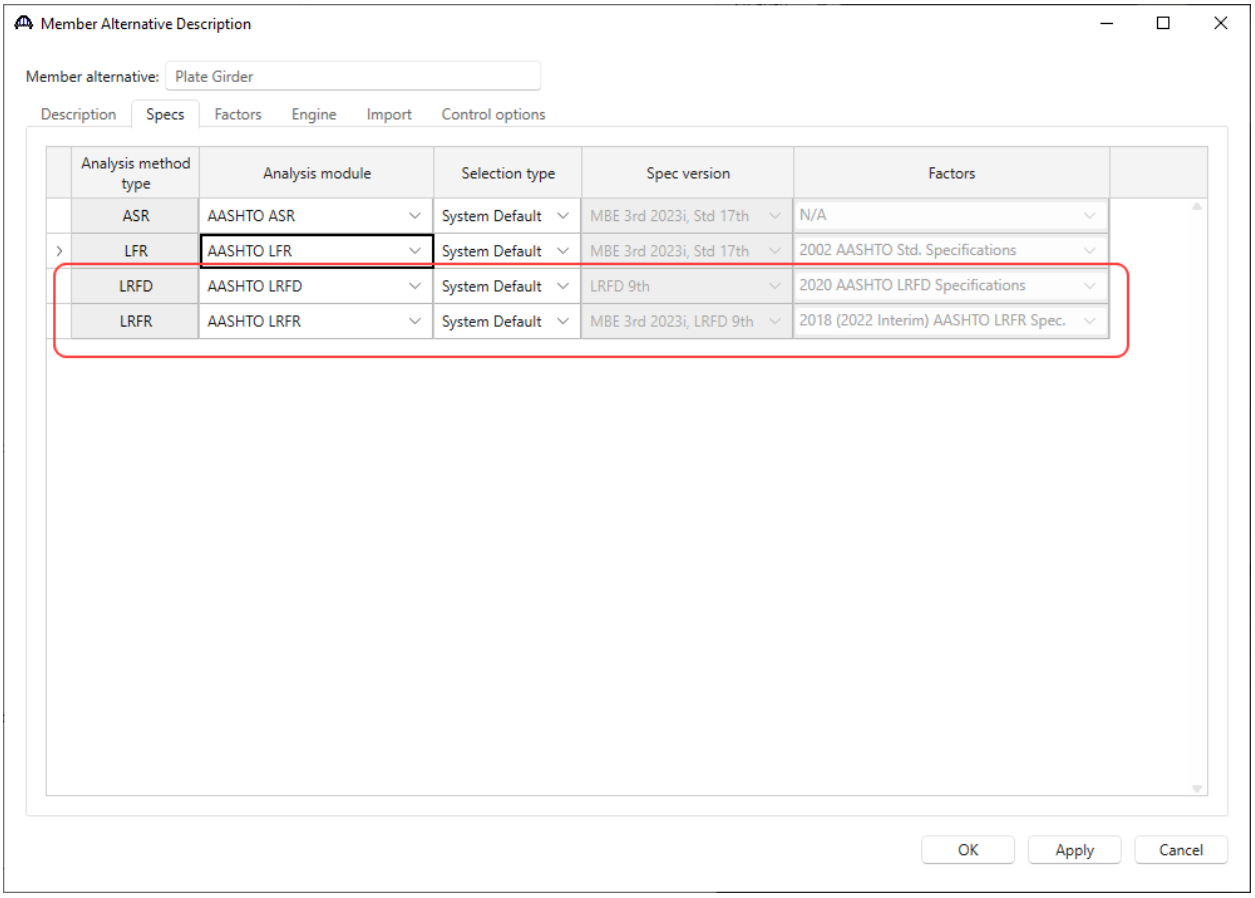


Click the **Compute from typical section…** button and BrDR will compute the distribution factors. If these fields are left blank, then the AASHTO LRFR engine will compute the distribution factors during the analysis. For this example, these fields will be left blank allowing the AASHTO LRFR engine to compute these values.

Member Alternative Description – Specs

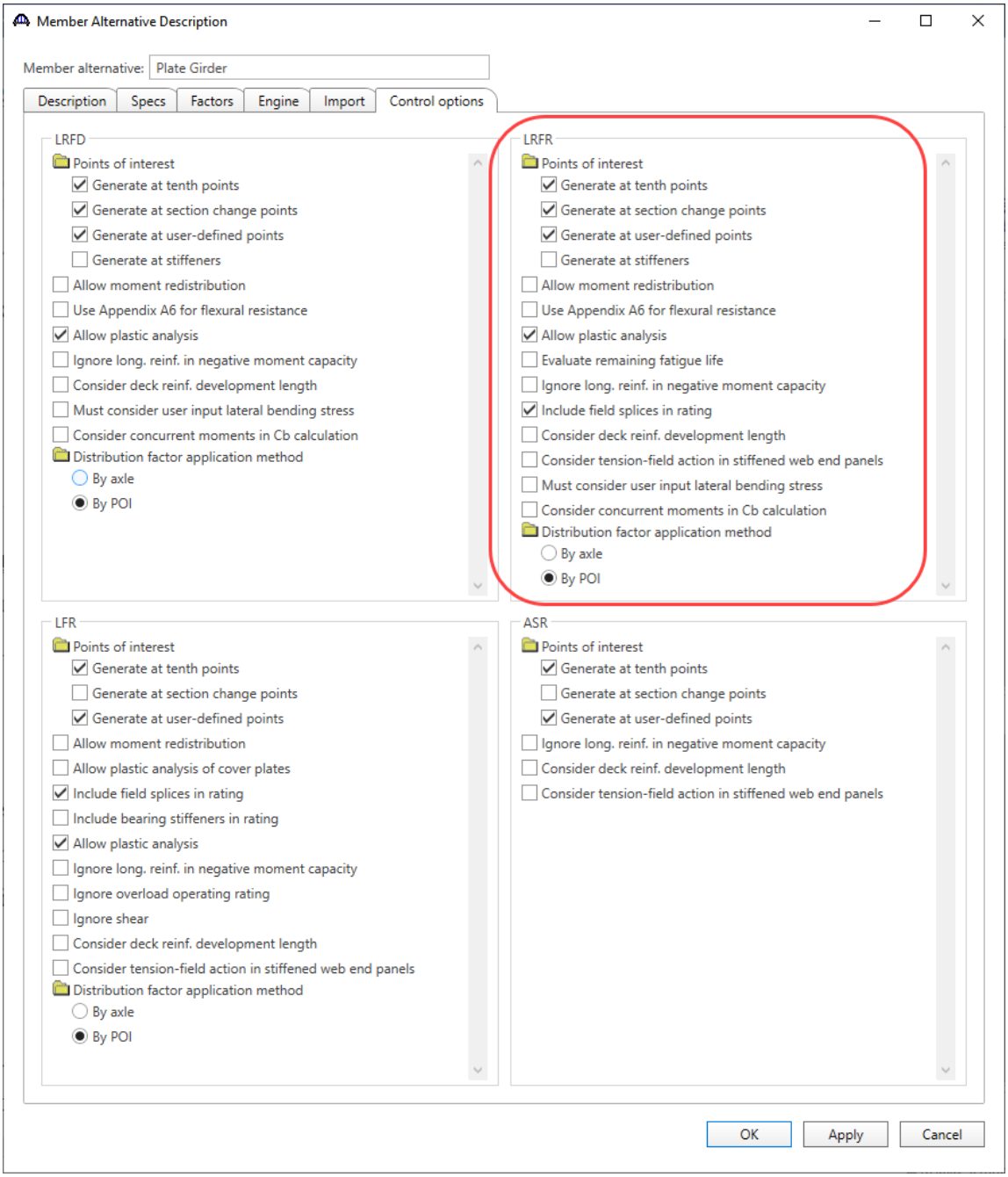
Double click on the **Plate Girder** member alternative for member **G2** in the **Bridge Workspace** tree to open the **Member Alternative Description** window and navigate to the **Specs** tab of this window as shown below.

AASHTO LRFR engine is selected as the **LRFR Analysis module.**



Member Alternative Description – Control options

Navigate to the **Control options** tab of this window. This tab allows the user to select the analysis features.



Allow moment redistribution

This control option considers moment redistribution as per Appendix B6 of the specifications. In the moment redistribution process, some of the negative moment at the pier is redistributed along the beam. This option will first initiate the spec checks in Appendix B6.2 to determine if moment redistribution is permissible as per the specifications. If redistribution is not permissible, then it will not occur even if this option is selected.

Use Appendix A6 for flexural resistance

This control option considers Appendix A6 of the Specifications for flexural resistance. Using Appendix A6 can result in flexural resistances greater than the yield moment, My, for certain types of sections. The program will first check if Appendix A6 is permissible by checking the requirements in Article 6.10.6.2.3. If the use of Appendix A6 is not permissible, then it will not be used even if this option has been selected.

Allow plastic analysis

This control option considers the plastic moment capacity for compact, composite sections in positive flexure. If this option is selected, the program will evaluate Articles 6.10.7.1.1 and 6.10.7.1.2. If this option is not selected, Articles 6.10.7.1.1 and 6.10.7.1.2 will not be evaluated and all positive flexure sections will be considered non-compact.

Evaluate remaining fatigue life

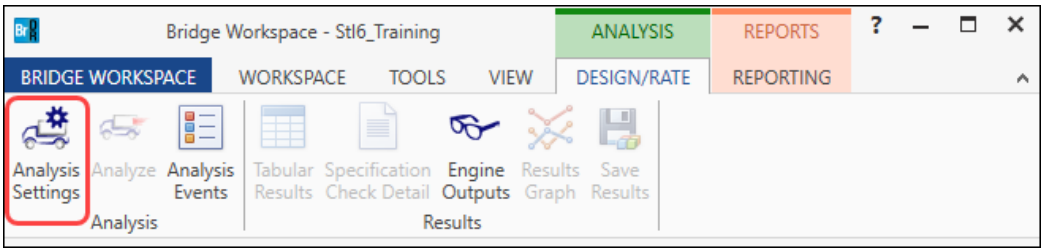
This control option evaluates the remaining fatigue life specified in MBE 7.2. If this option is not selected, MBE 7.2 will still be evaluated but the remaining fatigue life will not be computed.

Ignore long. reinforcement in negative moment capacity

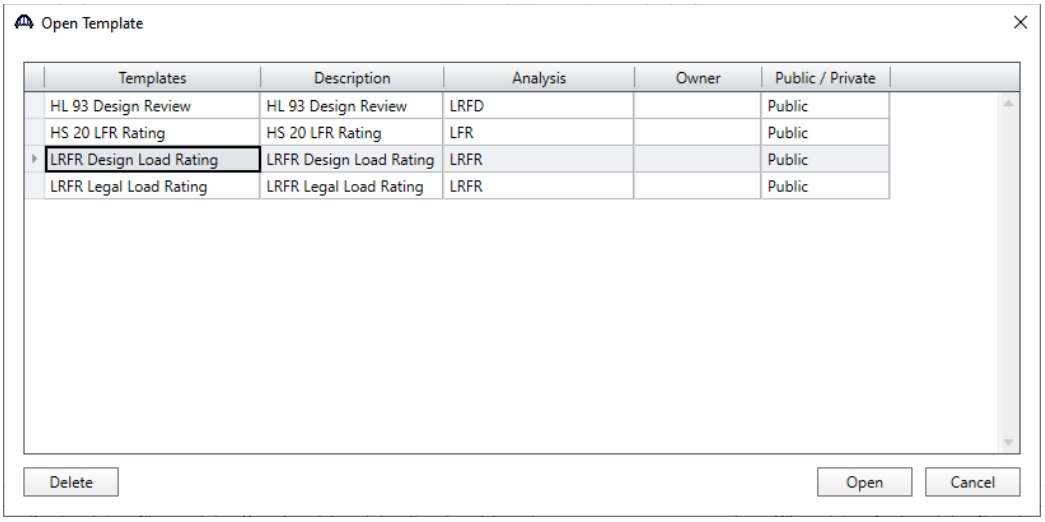
This control option allows the user to ignore the contribution of the longitudinal deck reinforcement when computing the negative moment capacity of the section.

LRFR Rating

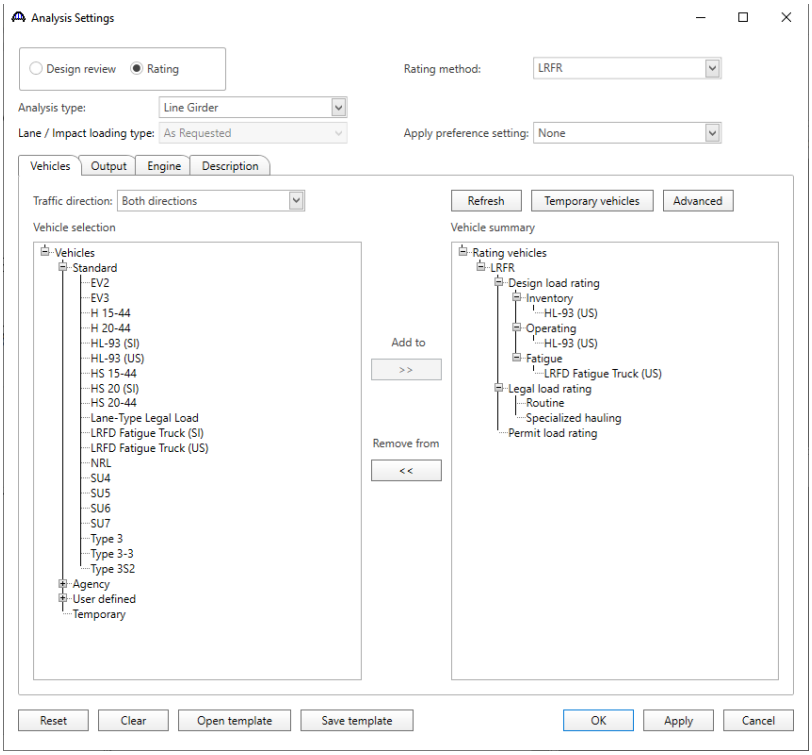
To perform an **LRFR** rating, select the **Analysis Settings** button on the **Analysis** group of the **DESIGN/RATE** ribbon.



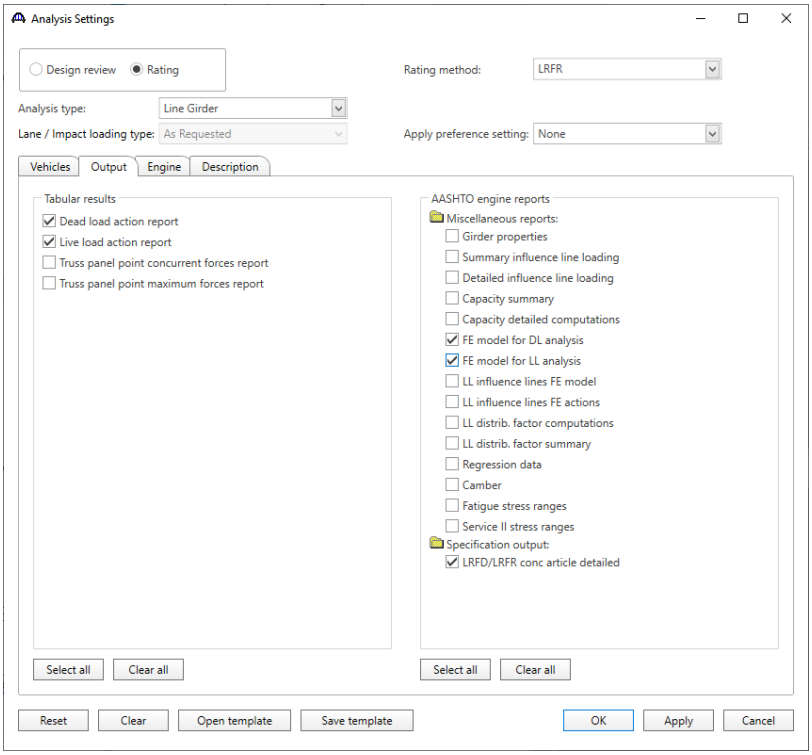
Click the **Open Template** button and select the **LRFR Design Load Rating** to be used in the rating and click **Open**.



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

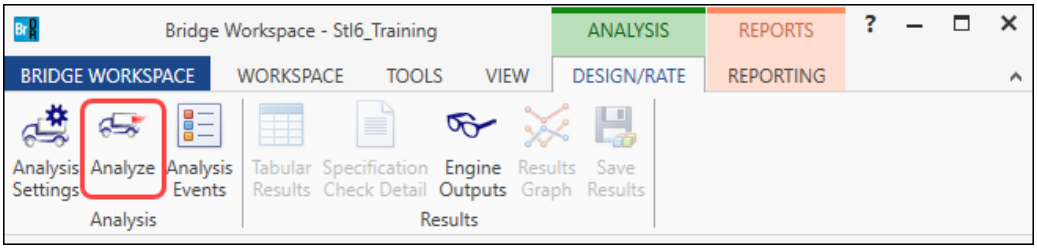


Navigate to the **Output** tab of this window and select the following reports to be generated during the analysis.



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

Next click the **Analyze** button on the **Analysis** group of the **DESIGN/RATE** ribbon to perform the rating. The **Analysis** window should be reviewed for any warning messages.



Export of steel girders to the AASHTO LRFR analysis engine

The following steps are performed when performing an LRFR analysis of a steel girder using the BrDR LRFR analysis engine:

1. Finite element models are generated for the dead load and live load analyses. A Stage 1 FE model is generated for the beam dead load and non-composite dead loads. A Stage 2 FE model is generated for dead loads applied to the long-term composite section properties. A Stage 3 FE model is generated for the live load analysis.

   Stage 2 FE model contains section properties corresponding to the sustained modular ratio factor entered in BrDR (e.g. 3n). Stage 3 FE model contains section properties corresponding to the modular ratio (n). The FE models will consider the presence of shear connectors when setting the composite properties in the FE models. Regions that do not contain shear connectors will use non-composite section properties in the Stage 2 and 3 FE models.

   In addition to the points selected on the **Member Alternative Description** window's **Control options** tab, the model generated by the export to the BrDR LRFR analysis engine will always contain node points at brace point locations and locations midway between the brace points. Only the articles required to compute stresses are processed at these points if the point is not being processed for one of the options chosen on this tab. The stresses at these locations are required when determining the flexural capacity of the steel girders.
2. The specification checks required for the LRFR analysis will be performed. The specification checking occurs in two phases. The first phase determines the type of flexure present at each point for each controlling load combination. This is necessary because the flexural articles to be considered in the specification are dependent on the type of flexure the beam is subject to. The second phase performs the specification checks taking into consideration the flexure type determined in the first phase.

   Phase 1:

   Positive flexure is defined as the bending condition that produces compressive stress (denoted by a negative sign in the program) in the slab for composite construction or the top flange for non-composite construction. Negative flexure is defined as the bending condition that produces tensile stress (denoted by a positive sign) in the slab or top flange. As per Article 6.10.1.1.1b, the stress in the top of the slab (or top flange for non-composite construction) is first computed using the positive flexure section properties. If this stress is compressive, the stresses in each component of the beam (slab, longitudinal reinforcement, flanges, cover plates, and web) are computed using the positive flexure section properties. If the stress in the top of the slab (or top flange for non-

composite construction) is tensile, the stresses in each component of the beam are computed using the negative section properties.

If the resulting computed stress in the bottom flange is tensile, the beam is in positive flexure for the load combination. If the resulting computed stress in the bottom flange is compressive, the beam is in negative flexure for the load combination.

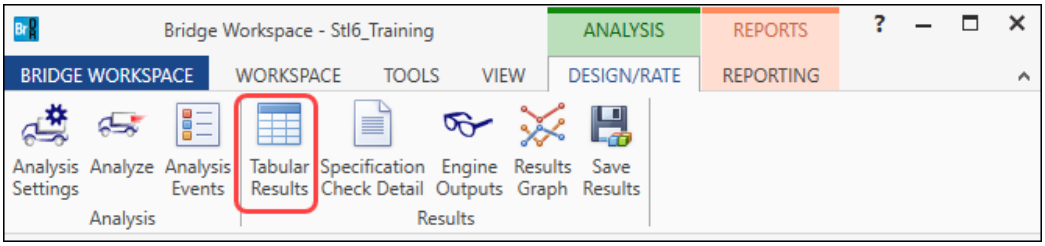
Phase 2:

The remaining articles are evaluated taking into consideration the flexure type determined in the first phase.

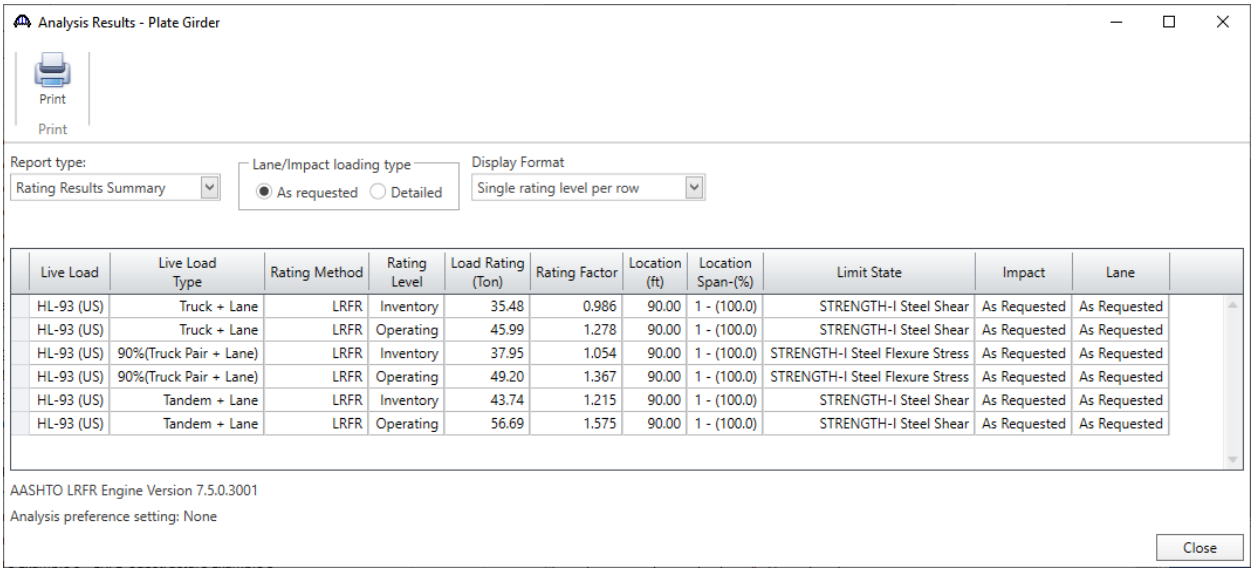
Output Review

Tabular Results – Rating Results Summary

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



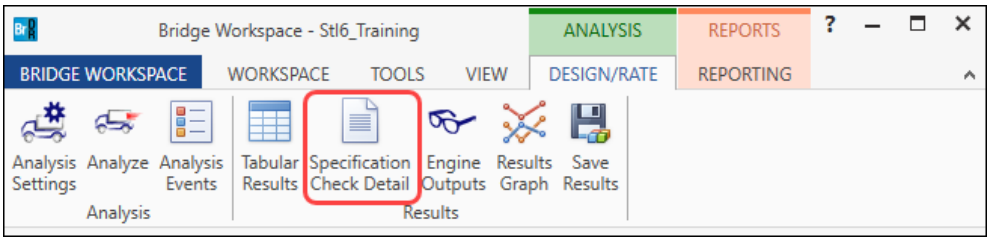
The **Rating Results Summary** is shown below. The critical inventory rating factor for **Truck + Lane** is **0.986**. The controlling location is at the pier and the limit state is **Strength-I Steel Shear**.



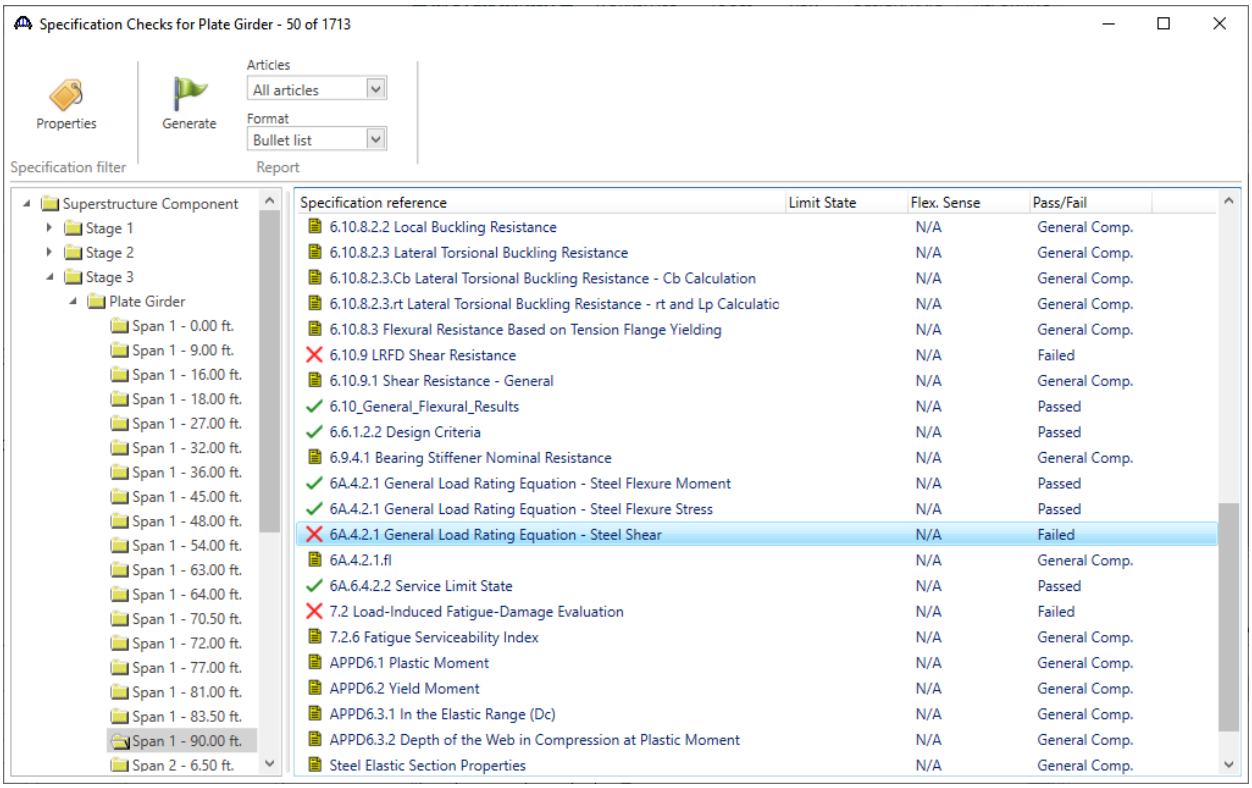
Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HL-93 (US)	Truck + Lane	LRFR	Inventory	35.48	0.986	90.00	1 - (100.0)	STRENGTH-I Steel Shear	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	45.99	1.278	90.00	1 - (100.0)	STRENGTH-I Steel Shear	As Requested	As Requested
HL-93 (US)	90%(Truck Pair + Lane)	LRFR	Inventory	37.95	1.054	90.00	1 - (100.0)	STRENGTH-I Steel Flexure Stress	As Requested	As Requested
HL-93 (US)	90%(Truck Pair + Lane)	LRFR	Operating	49.20	1.367	90.00	1 - (100.0)	STRENGTH-I Steel Flexure Stress	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	43.74	1.215	90.00	1 - (100.0)	STRENGTH-I Steel Shear	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	56.69	1.575	90.00	1 - (100.0)	STRENGTH-I Steel Shear	As Requested	As Requested

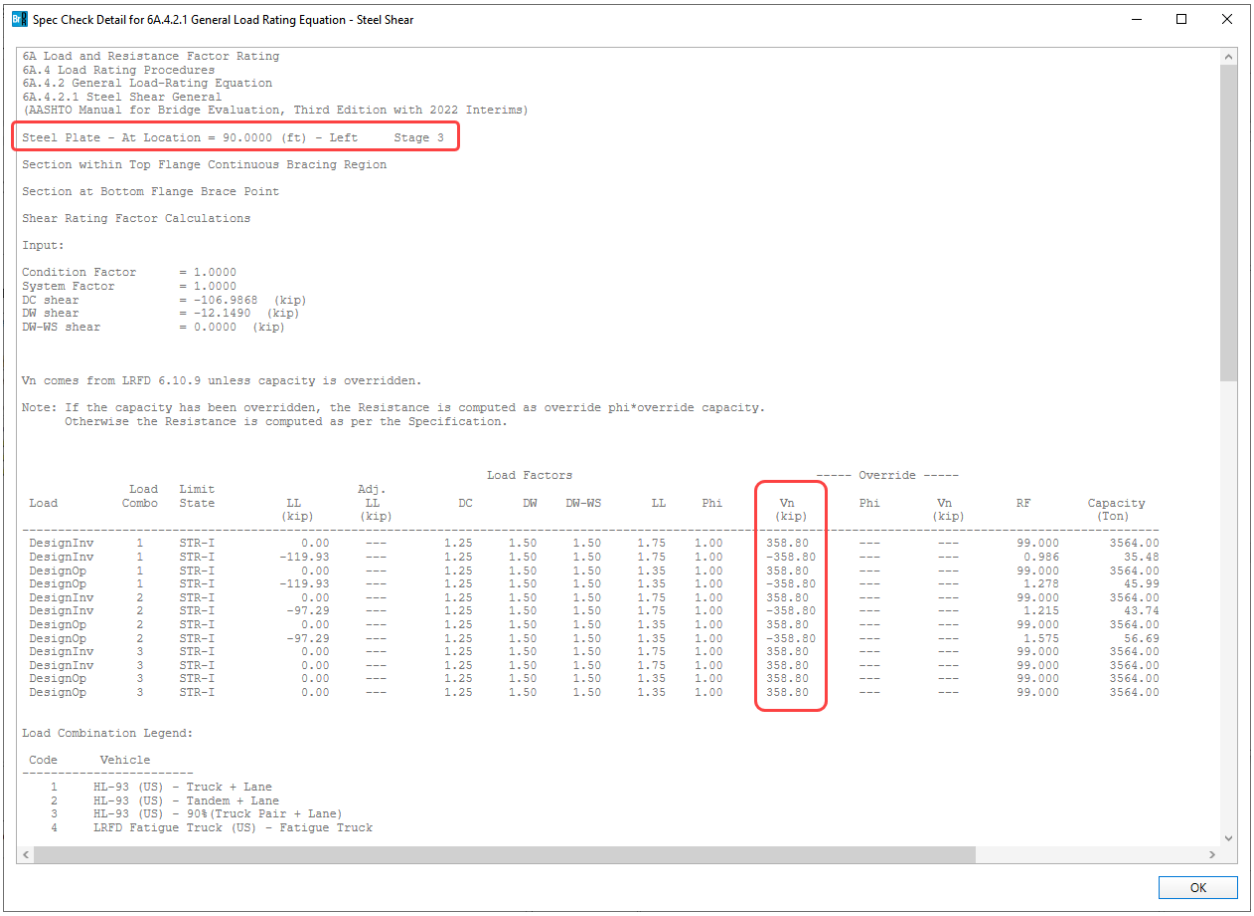
Specification Check Detail

The specification checks can be viewed by selecting the **Specification Check Detail** button from the **Results** group of the **DESIGN/RATE** ribbon.



Select **Stage 3**, **Plate Girder** from the **Specification Checks** tree and open the article **6A.4.2.1 General Load Rating Equation – Steel Shear @ Span 1 – 90.00 ft.** by double clicking on the article as shown below.





Spec Check Detail for 6A.4.2.1 General Load Rating Equation - Steel Shear

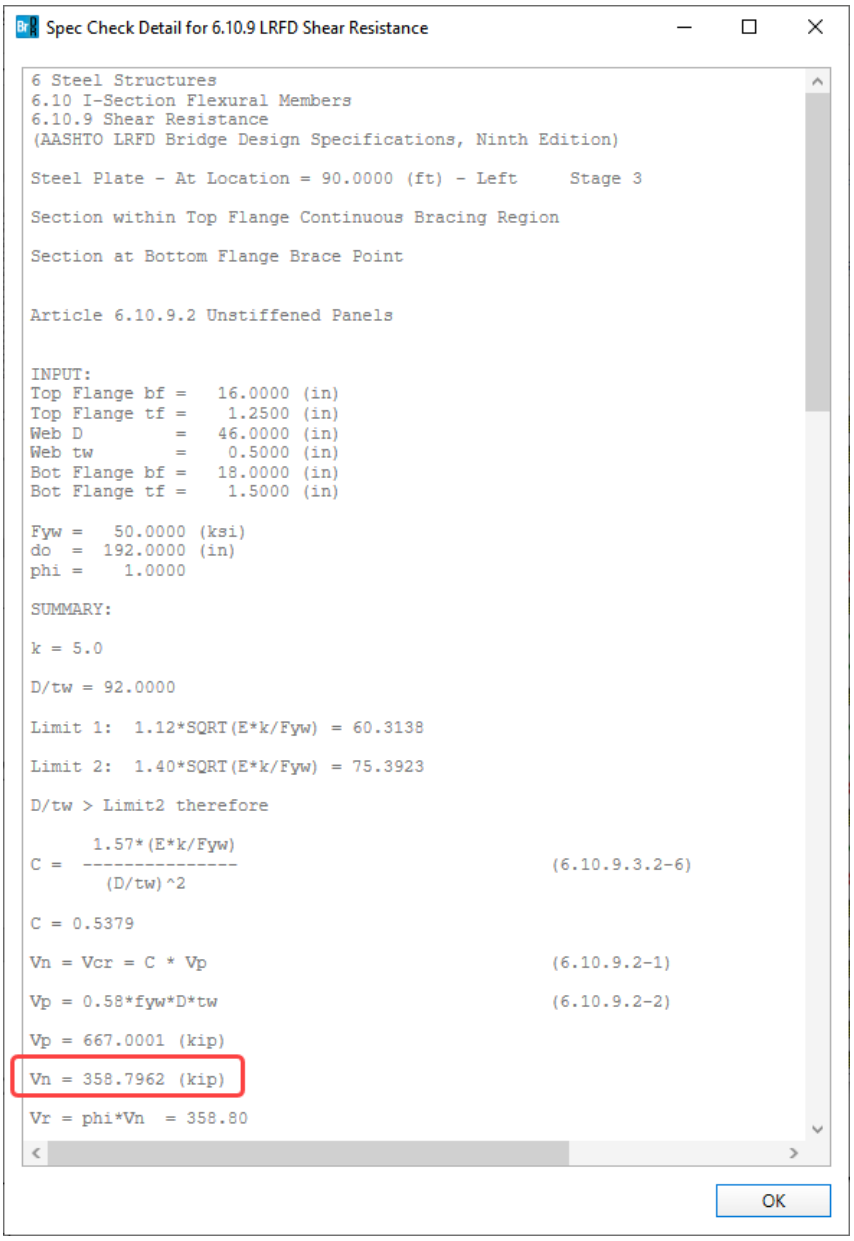
```
6A Load and Resistance Factor Rating
6A.4 Load Rating Procedures
6A.4.2 General Load-Rating Equation
6A.4.2.1 Steel Shear General
(AASHTO Manual for Bridge Evaluation, Third Edition with 2022 Interims)

Steel Plate - At Location = 90.0000 (ft) - Left     Stage 3

Section within Top Flange Continuous Bracing Region

Section at Bottom Flange Brace Point

Shear Rating Factor Calculations

Input:

Condition Factor      = 1.0000
System Factor         = 1.0000
DC shear              = -106.9868  (kip)
DW shear              = -12.1490  (kip)
DW-WS shear           = 0.0000  (kip)


Vn comes from LRFD 6.10.9 unless capacity is overridden.

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 Factors					----- Override -----				
Load	Load Combo	Limit State	LL (kip)	Adj. LL (kip)	DC	DW	DW-WS	LL	Phi	Vn (kip)	Phi	Vn (kip)	RF	Capacity (Ton)
DesignInv	1	STR-I	0.00	---	1.25	1.50	1.50	1.75	1.00	358.80	---	---	99.000	3564.00
DesignInv	1	STR-I	-119.93	---	1.25	1.50	1.50	1.75	1.00	-358.80	---	---	0.986	35.48
DesignOp	1	STR-I	0.00	---	1.25	1.50	1.50	1.35	1.00	358.80	---	---	99.000	3564.00
DesignOp	1	STR-I	-119.93	---	1.25	1.50	1.50	1.35	1.00	-358.80	---	---	1.278	45.99
DesignInv	2	STR-I	0.00	---	1.25	1.50	1.50	1.75	1.00	358.80	---	---	99.000	3564.00
DesignInv	2	STR-I	-97.29	---	1.25	1.50	1.50	1.75	1.00	-358.80	---	---	1.215	43.74
DesignOp	2	STR-I	0.00	---	1.25	1.50	1.50	1.35	1.00	358.80	---	---	99.000	3564.00
DesignOp	2	STR-I	-97.29	---	1.25	1.50	1.50	1.35	1.00	-358.80	---	---	1.575	56.69
DesignInv	3	STR-I	0.00	---	1.25	1.50	1.50	1.75	1.00	358.80	---	---	99.000	3564.00
DesignInv	3	STR-I	0.00	---	1.25	1.50	1.50	1.75	1.00	358.80	---	---	99.000	3564.00
DesignOp	3	STR-I	0.00	---	1.25	1.50	1.50	1.35	1.00	358.80	---	---	99.000	3564.00
DesignOp	3	STR-I	0.00	---	1.25	1.50	1.50	1.35	1.00	358.80	---	---	99.000	3564.00

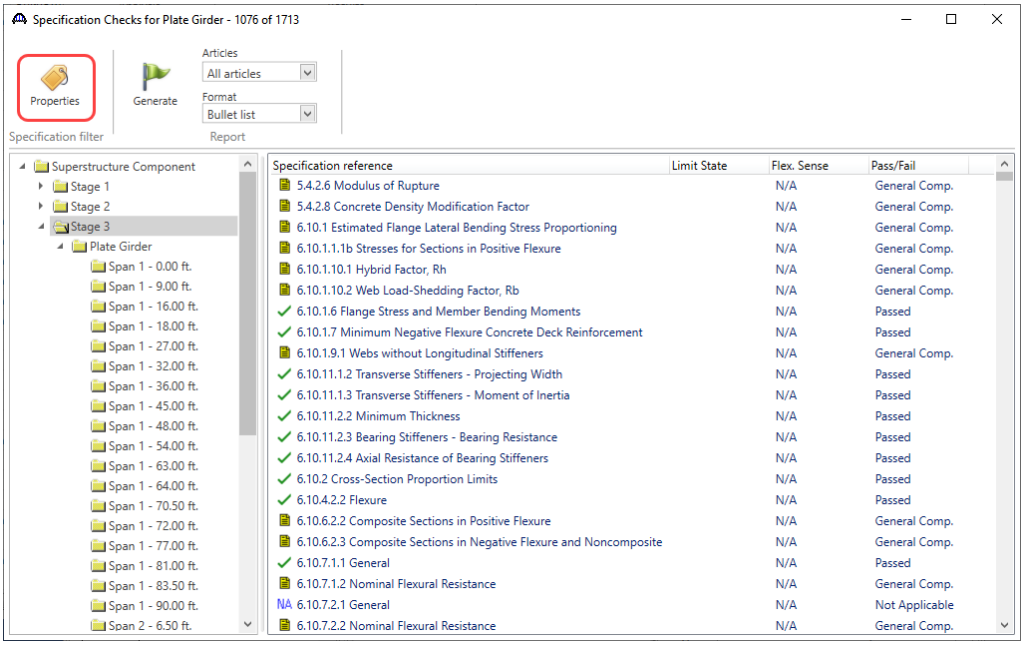
```
Load Combination Legend:

 Code      Vehicle
-----------------------
    1     HL-93 (US) - Truck + Lane
    2     HL-93 (US) - Tandem + Lane
    3     HL-93 (US) - 90%(Truck Pair + Lane)
    4     LRFD Fatigue Truck (US) - Fatigue Truck
```

OK

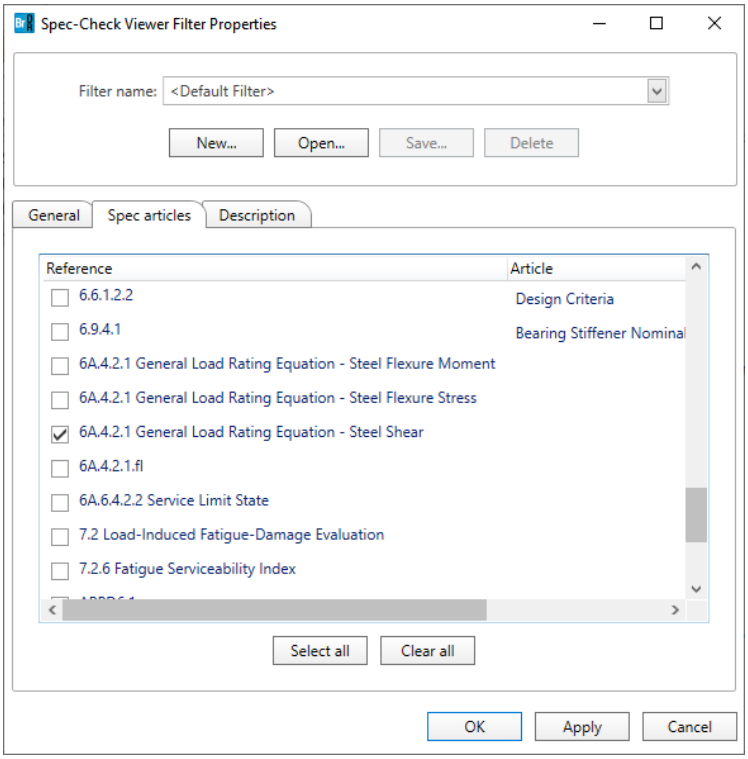
To review the **Vn** computation at this location, double click on the **6.10.9 LRFD Shear Resistance** article. The article is shown below.



To generate a **Spec Check Report** for the **6A.4.2.1 Steel Shear General Load Rating Equation check** for all the locations, click on the **Properties** button from the **Specification filter** ribbon to open the **Spec-Check Viewer Filter Properties** window as shown below.

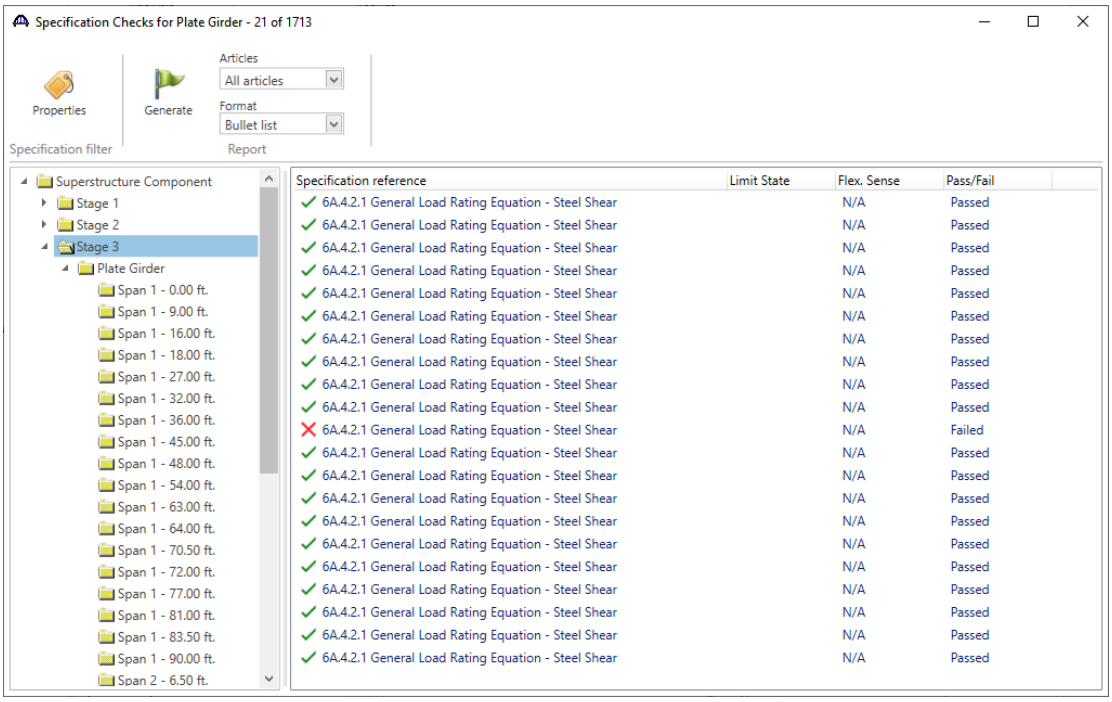


Navigate to the **Spec articles** tab. Click the **Clear all** button and select the article **6A.4.2.1 General Load Rating Equation – Steel Shear** from the **Reference** column as shown below.

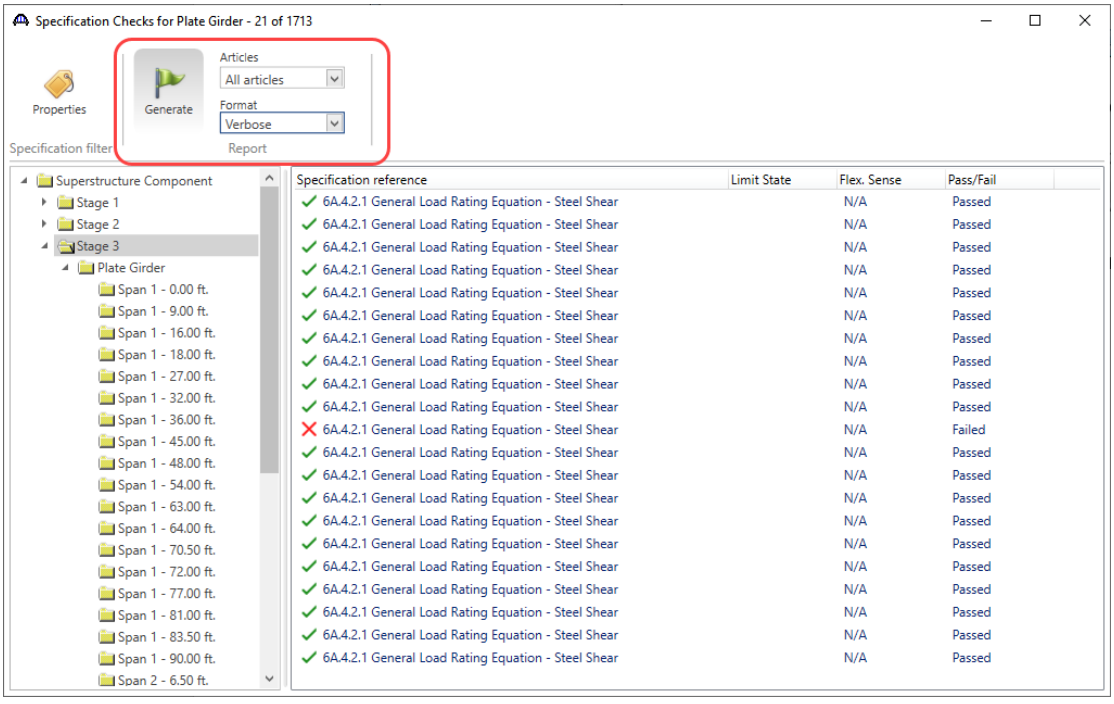


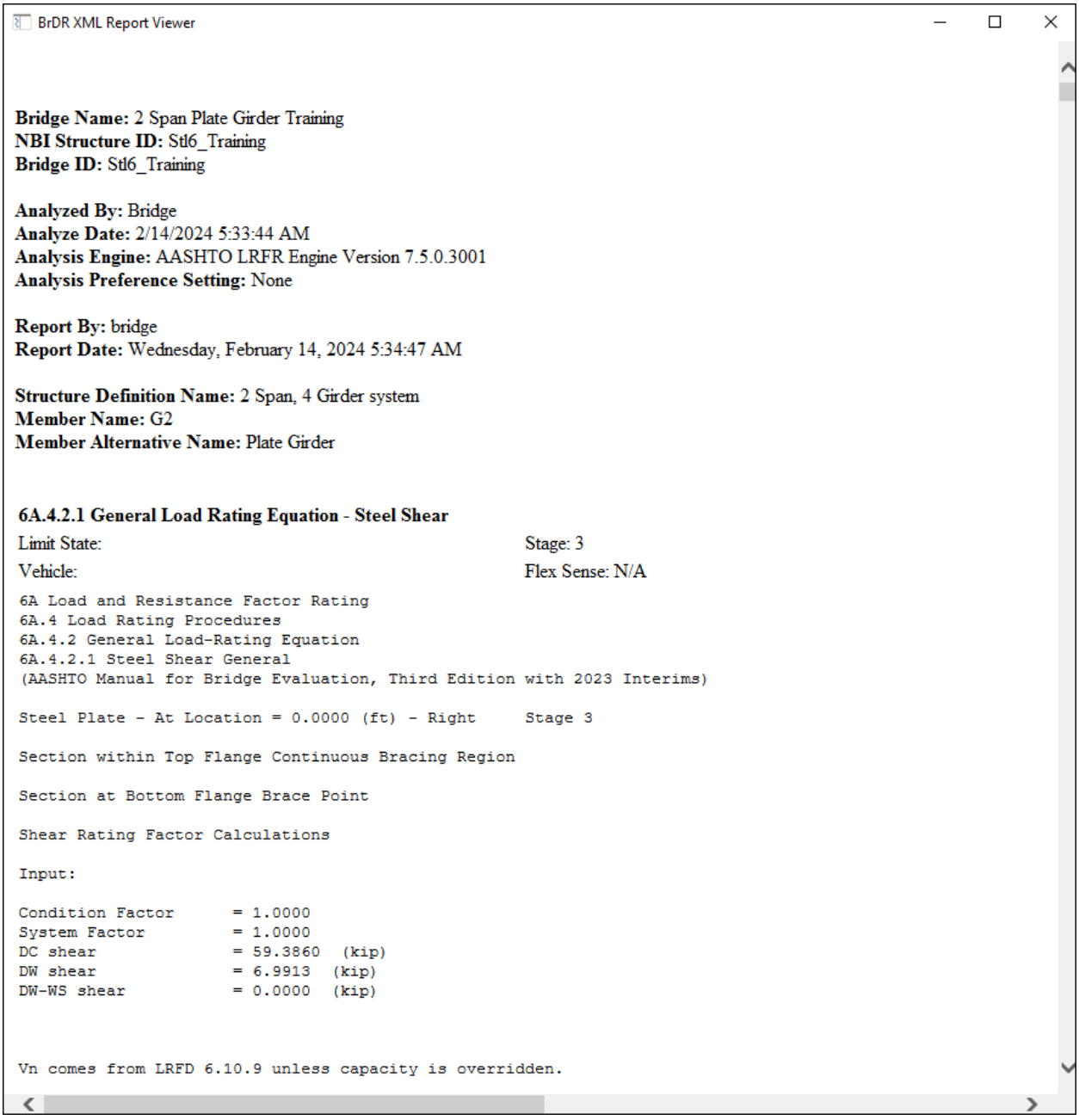
Click **OK** to apply the filter and close this window.

Select the **Stage 3** in the **Superstructure Component Tree** to filter all the **6A.4.2.1 General Load Rating Equation – Steel Shear** checks in **Stage 3**.



In the **Report** group of the ribbon, select **All articles** under **Articles** and **Verbose** under **Format** and click the **Generate** button to generate a report **(.xml)** as shown below.



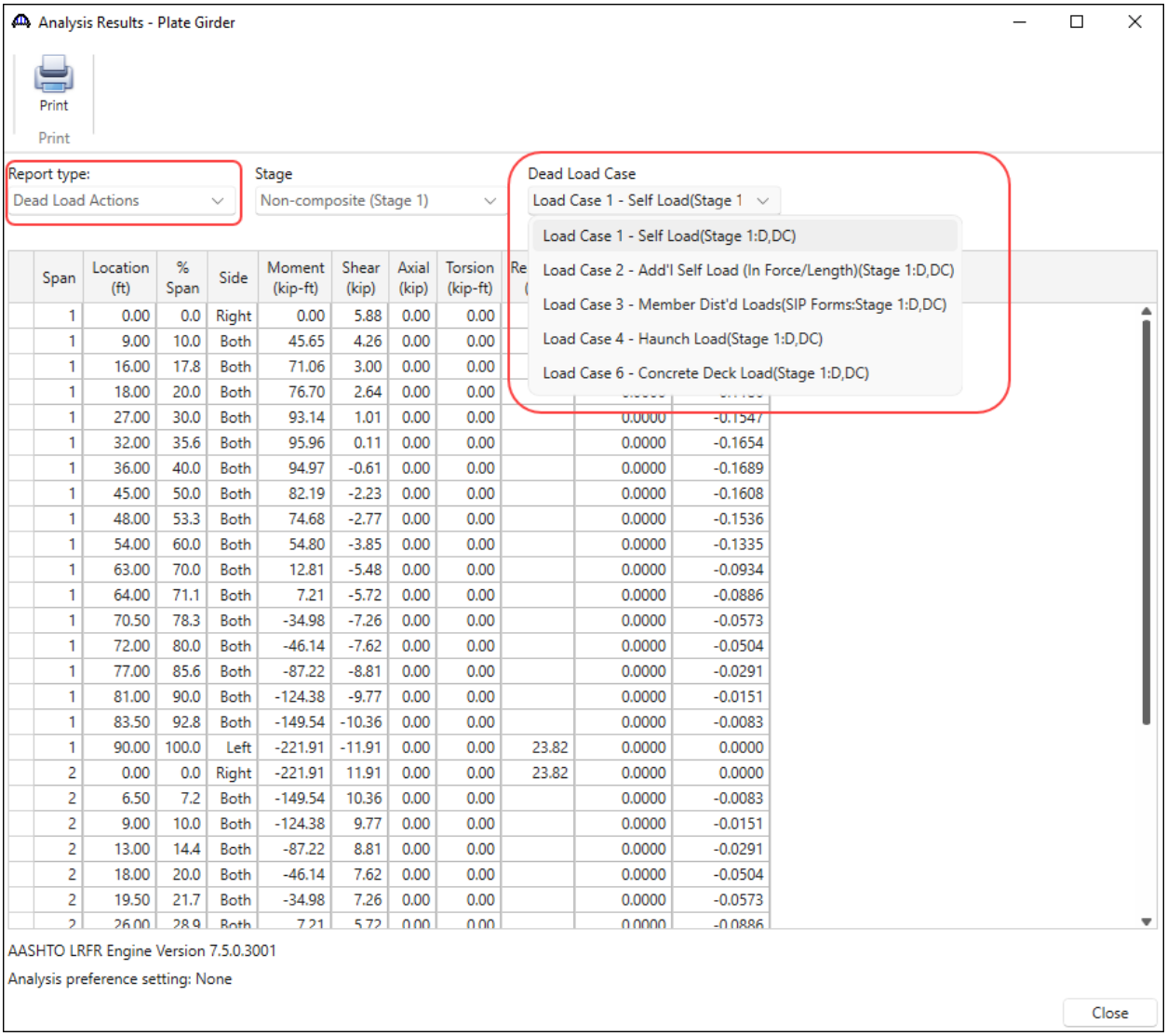

BrDR XML Report Viewer
Bridge Name: 2 Span Plate Girder Training
NBI Structure ID: Stl6_Training
Bridge ID: Stl6_Training
Analyzed By: Bridge
Analyze Date: 2/14/2024 5:33:44 AM
Analysis Engine: AASHTO LRFR Engine Version 7.5.0.3001
Analysis Preference Setting: None
Report By: bridge
Report Date: Wednesday, February 14, 2024 5:34:47 AM
Structure Definition Name: 2 Span, 4 Girder system
Member Name: G2
Member Alternative Name: Plate Girder
6A.4.2.1 General Load Rating Equation - Steel Shear
Limit State:
Stage: 3
Vehicle:
Flex Sense: N/A
6A Load and Resistance Factor Rating
6A.4 Load Rating Procedures
6A.4.2 General Load-Rating Equation
6A.4.2.1 Steel Shear General
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)
Steel Plate - At Location = 0.0000 (ft) - Right Stage 3
Section within Top Flange Continuous Bracing Region
Section at Bottom Flange Brace Point
Shear Rating Factor Calculations
Input:
Condition Factor = 1.0000
System Factor = 1.0000
DC shear = 59.3860 (kip)
DW shear = 6.9913 (kip)
DW-WS shear = 0.0000 (kip)
Vn comes from LRFD 6.10.9 unless capacity is overridden.

Tabular Results – Dead Load / Live Load Actions

Tabular dead load and live load analysis results are available in the **Analysis Results** window.

Dead Load

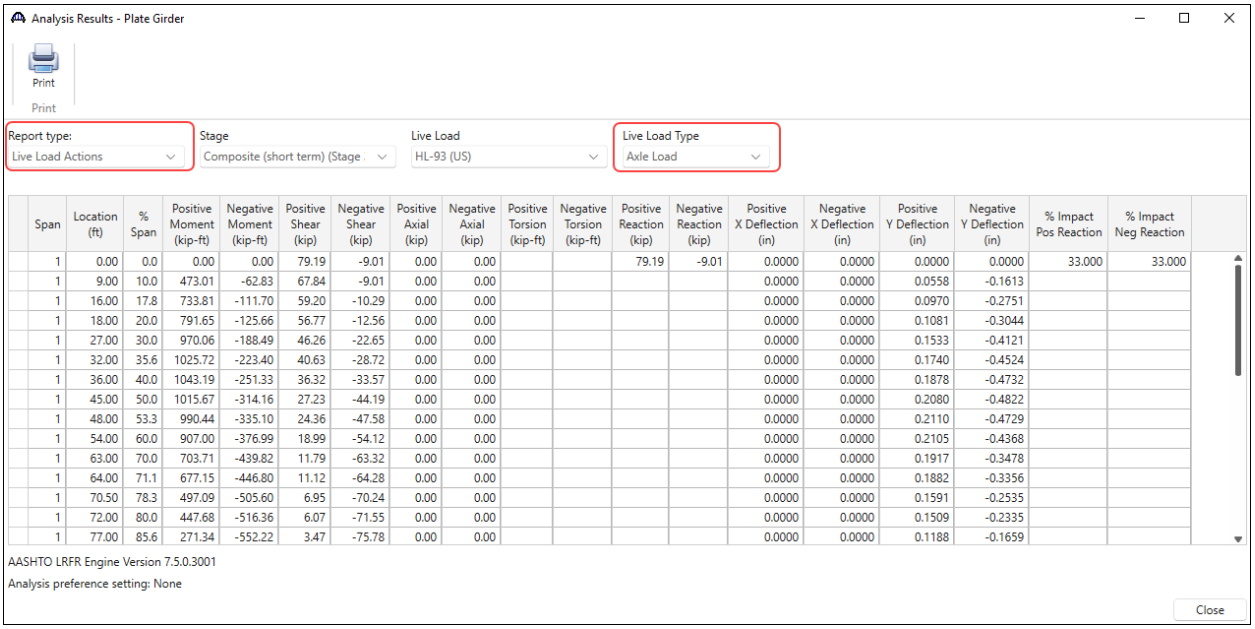
Select **Dead Load Actions** under **Report Type**. The **Dead Load Case** description contains all the load cases used in this analysis.



Span	Location (ft)	% Span	Side	Moment (kip-ft)	Shear (kip)	Axial (kip)	Torsion (kip-ft)	Re		
1	0.00	0.0	Right	0.00	5.88	0.00	0.00			
1	9.00	10.0	Both	45.65	4.26	0.00	0.00			
1	16.00	17.8	Both	71.06	3.00	0.00	0.00			
1	18.00	20.0	Both	76.70	2.64	0.00	0.00			
1	27.00	30.0	Both	93.14	1.01	0.00	0.00		0.0000	-0.1547
1	32.00	35.6	Both	95.96	0.11	0.00	0.00		0.0000	-0.1654
1	36.00	40.0	Both	94.97	-0.61	0.00	0.00		0.0000	-0.1689
1	45.00	50.0	Both	82.19	-2.23	0.00	0.00		0.0000	-0.1608
1	48.00	53.3	Both	74.68	-2.77	0.00	0.00		0.0000	-0.1536
1	54.00	60.0	Both	54.80	-3.85	0.00	0.00		0.0000	-0.1335
1	63.00	70.0	Both	12.81	-5.48	0.00	0.00		0.0000	-0.0934
1	64.00	71.1	Both	7.21	-5.72	0.00	0.00		0.0000	-0.0886
1	70.50	78.3	Both	-34.98	-7.26	0.00	0.00		0.0000	-0.0573
1	72.00	80.0	Both	-46.14	-7.62	0.00	0.00		0.0000	-0.0504
1	77.00	85.6	Both	-87.22	-8.81	0.00	0.00		0.0000	-0.0291
1	81.00	90.0	Both	-124.38	-9.77	0.00	0.00		0.0000	-0.0151
1	83.50	92.8	Both	-149.54	-10.36	0.00	0.00		0.0000	-0.0083
1	90.00	100.0	Left	-221.91	-11.91	0.00	0.00	23.82	0.0000	0.0000
2	0.00	0.0	Right	-221.91	11.91	0.00	0.00	23.82	0.0000	0.0000
2	6.50	7.2	Both	-149.54	10.36	0.00	0.00		0.0000	-0.0083
2	9.00	10.0	Both	-124.38	9.77	0.00	0.00		0.0000	-0.0151
2	13.00	14.4	Both	-87.22	8.81	0.00	0.00		0.0000	-0.0291
2	18.00	20.0	Both	-46.14	7.62	0.00	0.00		0.0000	-0.0504
2	19.50	21.7	Both	-34.98	7.26	0.00	0.00		0.0000	-0.0573
2	26.00	28.9	Both	7.21	5.72	0.00	0.00		0.0000	-0.0886

Live Load

Select **Live Load Actions** under **Report Type** and **Axle Load** under **Live Load Type.**



	Span	Location (ft)	% Span	Positive Moment (kip-ft)	Negative Moment (kip-ft)	Positive Shear (kip)	Negative Shear (kip)	Positive Axial (kip)	Negative Axial (kip)	Positive Torsion (kip-ft)	Negative Torsion (kip-ft)	Positive Reaction (kip)	Negative Reaction (kip)	Positive X Deflection (in)	Negative X Deflection (in)	Positive Y Deflection (in)	Negative Y Deflection (in)	% Impact Pos Reaction	% Impact Neg Reaction
	1	0.00	0.0	0.00	0.00	79.19	-9.01	0.00	0.00			79.19	-9.01	0.0000	0.0000	0.0000	0.0000	33.000	33.000
	1	9.00	10.0	473.01	-62.83	67.84	-9.01	0.00	0.00					0.0000	0.0000	0.0558	-0.1613		
	1	16.00	17.8	733.81	-111.70	59.20	-10.29	0.00	0.00					0.0000	0.0000	0.0970	-0.2751		
	1	18.00	20.0	791.65	-125.66	56.77	-12.56	0.00	0.00					0.0000	0.0000	0.1081	-0.3044		
	1	27.00	30.0	970.06	-188.49	46.26	-22.65	0.00	0.00					0.0000	0.0000	0.1533	-0.4121		
	1	32.00	35.6	1025.72	-223.40	40.63	-28.72	0.00	0.00					0.0000	0.0000	0.1740	-0.4524		
	1	36.00	40.0	1043.19	-251.33	36.32	-33.57	0.00	0.00					0.0000	0.0000	0.1878	-0.4732		
	1	45.00	50.0	1015.67	-314.16	27.23	-44.19	0.00	0.00					0.0000	0.0000	0.2080	-0.4822		
	1	48.00	53.3	990.44	-335.10	24.36	-47.58	0.00	0.00					0.0000	0.0000	0.2110	-0.4729		
	1	54.00	60.0	907.00	-376.99	18.99	-54.12	0.00	0.00					0.0000	0.0000	0.2105	-0.4368		
	1	63.00	70.0	703.71	-439.82	11.79	-63.32	0.00	0.00					0.0000	0.0000	0.1917	-0.3478		
	1	64.00	71.1	677.15	-446.80	11.12	-64.28	0.00	0.00					0.0000	0.0000	0.1882	-0.3356		
	1	70.50	78.3	497.09	-505.60	6.95	-70.24	0.00	0.00					0.0000	0.0000	0.1591	-0.2535		
	1	72.00	80.0	447.68	-516.36	6.07	-71.55	0.00	0.00					0.0000	0.0000	0.1509	-0.2335		
	1	77.00	85.6	271.34	-552.22	3.47	-75.78	0.00	0.00					0.0000	0.0000	0.1188	-0.1659		

Note these values include dynamic load allowance, distribution factors and any live load scale factor entered on the **Analysis Settings** window.

AASHTO LRFR FE model outputs

The **FE model outputs** that was turned on in the **Analysis Settings** window is available from the **Engine Outputs** window. Click the **Engine Outputs** button from the **Results** group of the **DESIGN/RATE** ribbon to open the following window.