AASHTOWare BrDR 7.5.0

Steel Tutorial

STL6 – Two Span Plate Girder Example

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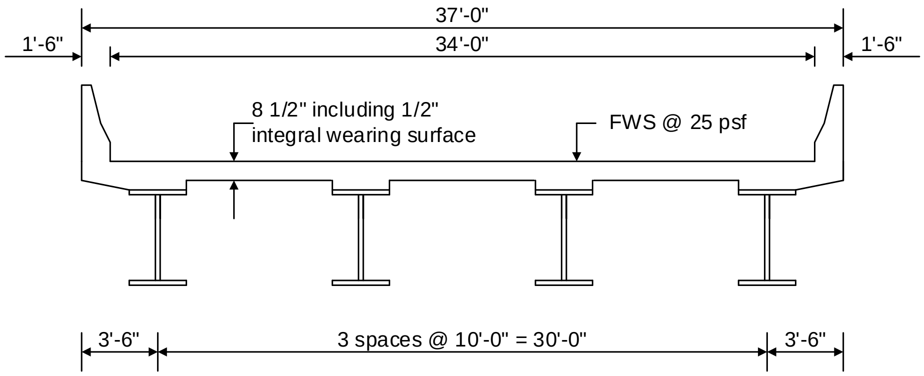
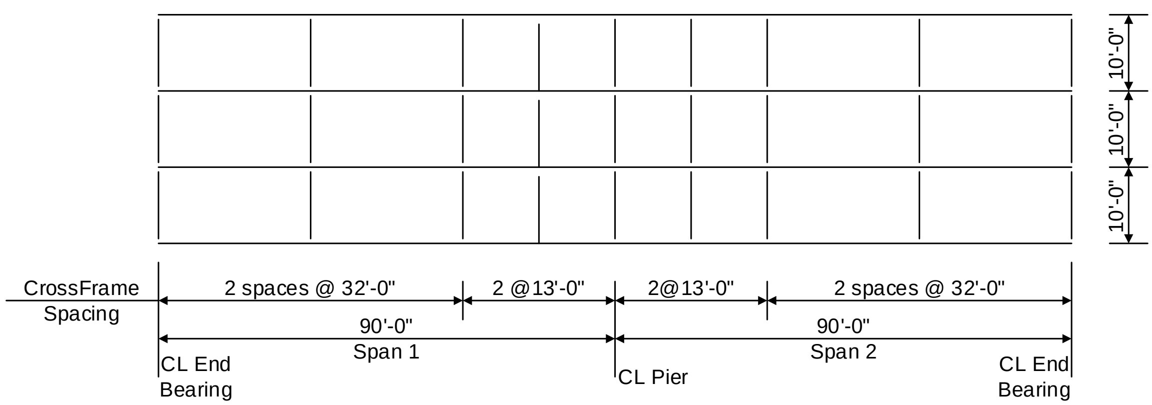
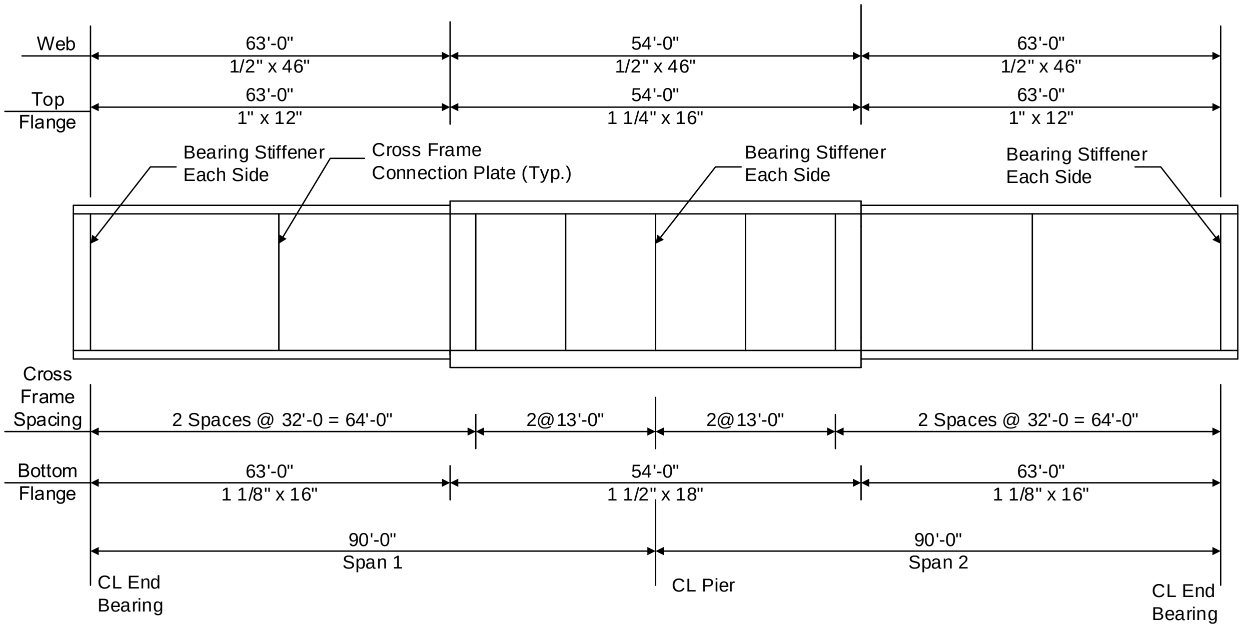
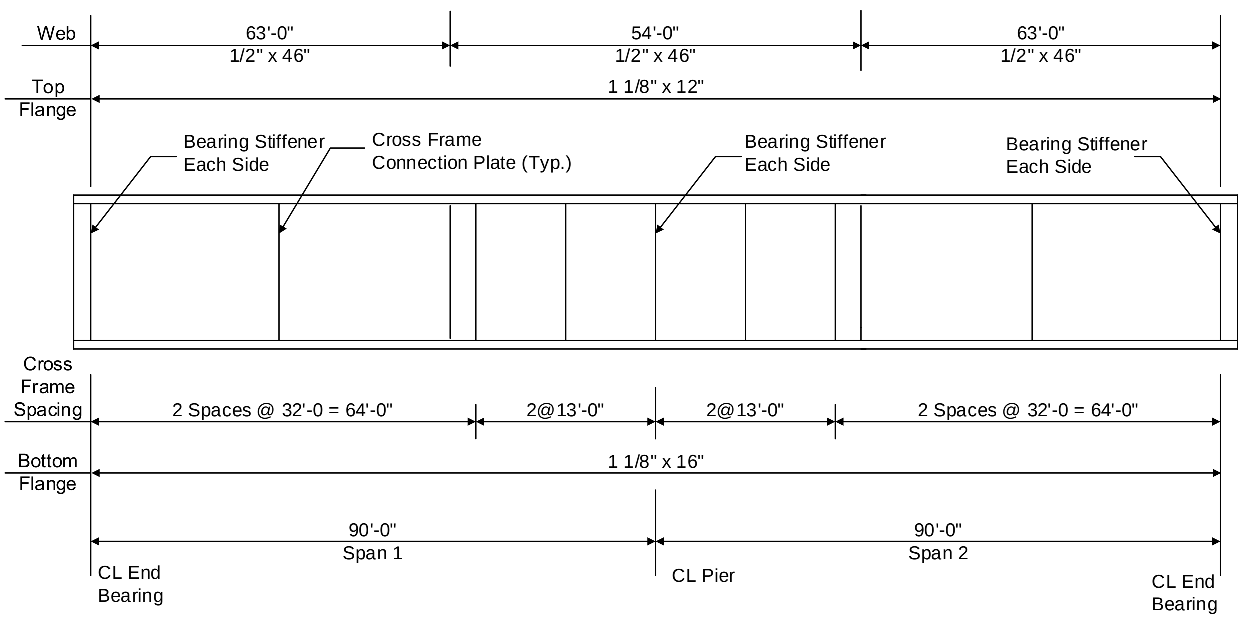




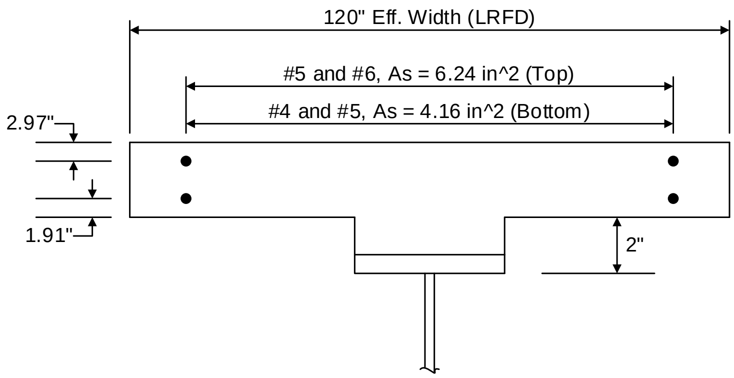
Framing Plan



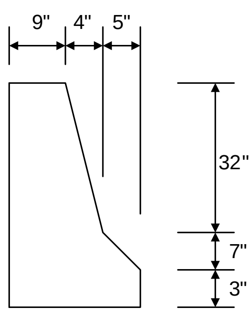
Elevation of Interior Girder



Elevation of Allow Moment Redistribution Girder

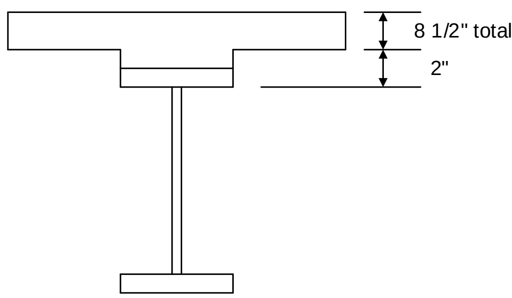


Composite Section at Pier



Weight = 536 plf

Parapet Detail



Haunch Detail

<u>Material Properties</u>

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"

BrDR Tutorial

Topics Covered

- Selection of Specification Edition
- Steel Member Alt Control Options
  - Moment redistribution
  - Use Appendix A6 for flexural resistance.
  - Allow plastic analysis.
  - Ignore longitudinal reinforcement in negative moment capacity.
  - Distribution factor application method.
- LRFD Design Review
- Export of steel girders to the AASHTO LRFD analysis engine
- AASHTO LRFD specification checking
- Tabular Results
- Distribution Factor application method
- FE model output
- Additional reporting (Report Tool)
- AASHTO LRFD Method of Solution
- Moment Redistribution
- Specialized hauling vehicles, overriding legal load factors, permit lane loads and gapping out the lane load.

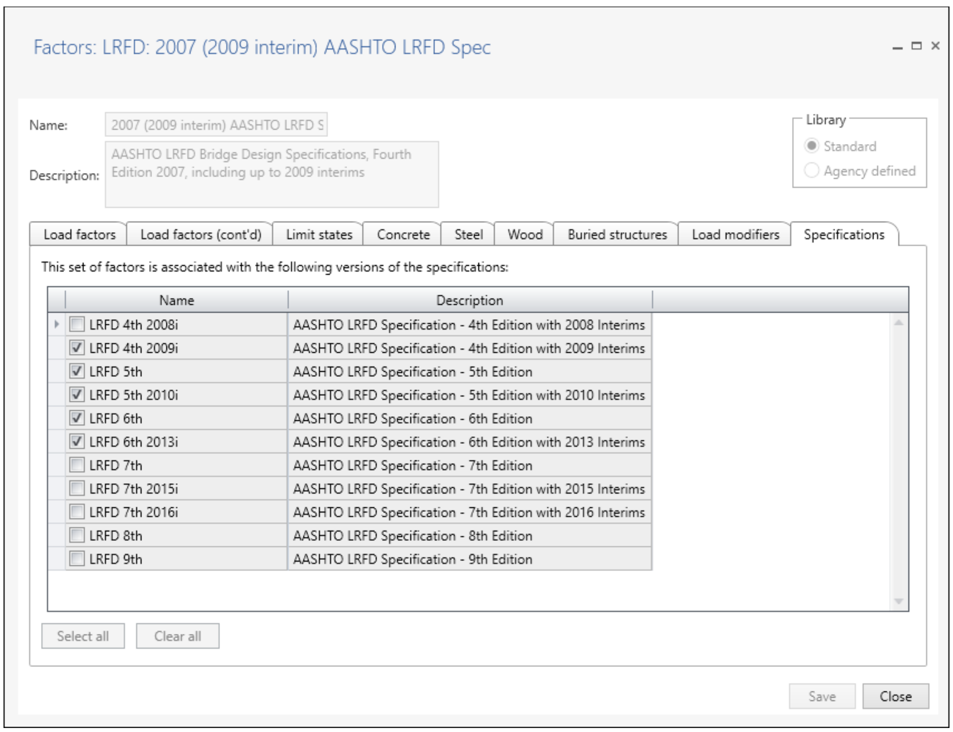
Selection of Specification Edition

BrDR Version 7.5.0 allows the user to pick from several versions of the AASHTO Specifications for the AASHTO analysis engines. The following LRFD and LRFR specifications are supported by the AASHTO engines.

- *AASHTO LRFD Bridge Design Specifications, 4th Edition, with 2008 interims*
- *AASHTO LRFD Bridge Design Specifications, 4th Edition, with 2009 interims*
- *AASHTO LRFD Bridge Design Specifications, 5th Edition*
- *AASHTO LRFD Bridge Design Specifications, 5th Edition, with 2010 interims*
- *AASHTO LRFD Bridge Design Specifications, 6th Edition*
- *AASHTO LRFD Bridge Design Specifications, 6th Edition, with 2013 interims*
- *AASHTO LRFD Bridge Design Specifications, 7th Edition*
- *AASHTO LRFD Bridge Design Specifications, 7th Edition, with 2015 interims*
- *AASHTO LRFD Bridge Design Specifications, 7th Edition, with 2016 interims*
- *AASHTO LRFD Bridge Design Specifications, 8th Edition*
- *AASHTO LRFD Bridge Design Specifications, 9th Edition*

- *AASHTO Manual for Bridge Evaluation, 1st Edition*
- *AASHTO Manual for Bridge Evaluation, 1st Edition, with 2010 interims*
- *AASHTO Manual for Bridge Evaluation, 2nd Edition*
- *AASHTO Manual for Bridge Evaluation, 2nd Edition, with 2011 interims*
- *AASHTO Manual for Bridge Evaluation, 2ndEdition, with 2013 interims*
- *AASHTO Manual for Bridge Evaluation, 2ndEdition, with 2014 interims*
- *AASHTO Manual for Bridge Evaluation, 2ndEdition, with 2015 interims*
- *AASHTO Manual for Bridge Evaluation, 2ndEdition, with 2016 interims*
- *AASHTO Manual for Bridge Evaluation, 3rd Edition*
- *AASHTO Manual for Bridge Evaluation, 3rd Edition, with 2019 interims*
- *AASHTO Manual for Bridge Evaluation, 3rd Edition, with 2020 interims*
- *AASHTO Manual for Bridge Evaluation, 3rd Edition, with 2022 interims*
- *AASHTO Manual for Bridge Evaluation, 3rd Edition, with 2023 interims*

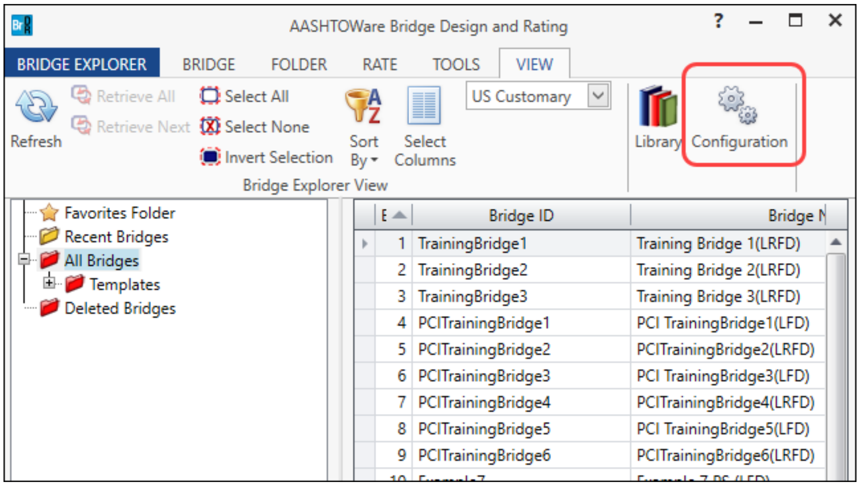
Along with this new feature, Factors are now associated with versions of the specification. This was done since different versions of the spec can have different limit states and load factors. Below is the **Library LRFD Factors** window for the factors that correspond to the **Fourth Edition with 2009 interims** specifications.



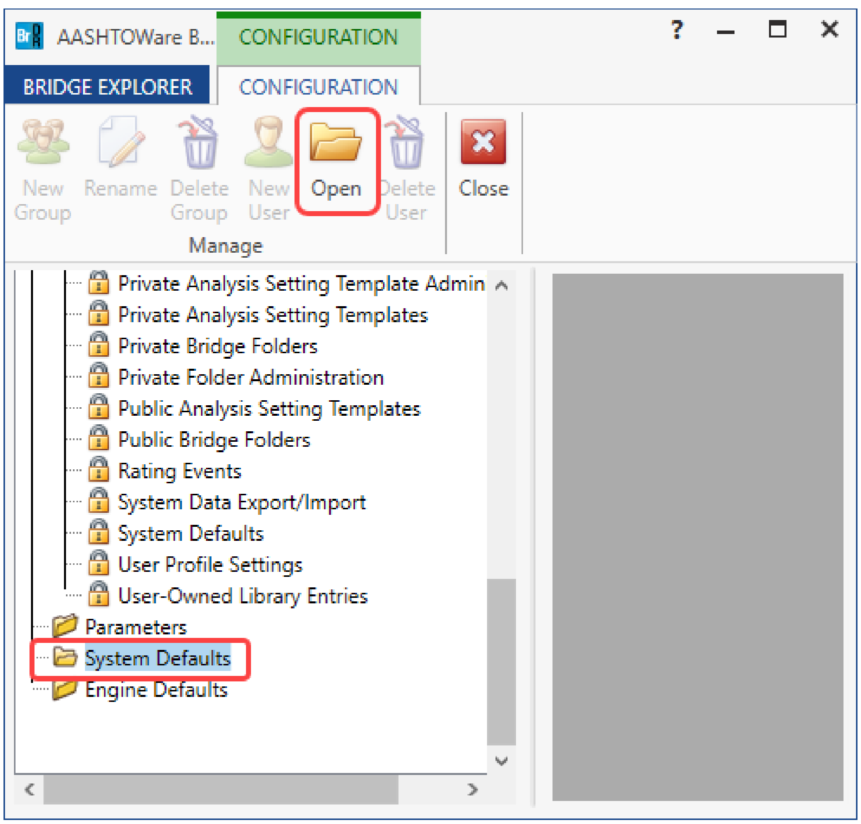
This set of factors cannot be applied to any versions of the specification prior to 2009 since they contain Fatigue I and Fatigue II limit states that were revised in the 2009 interims.

System Defaults - Specifications

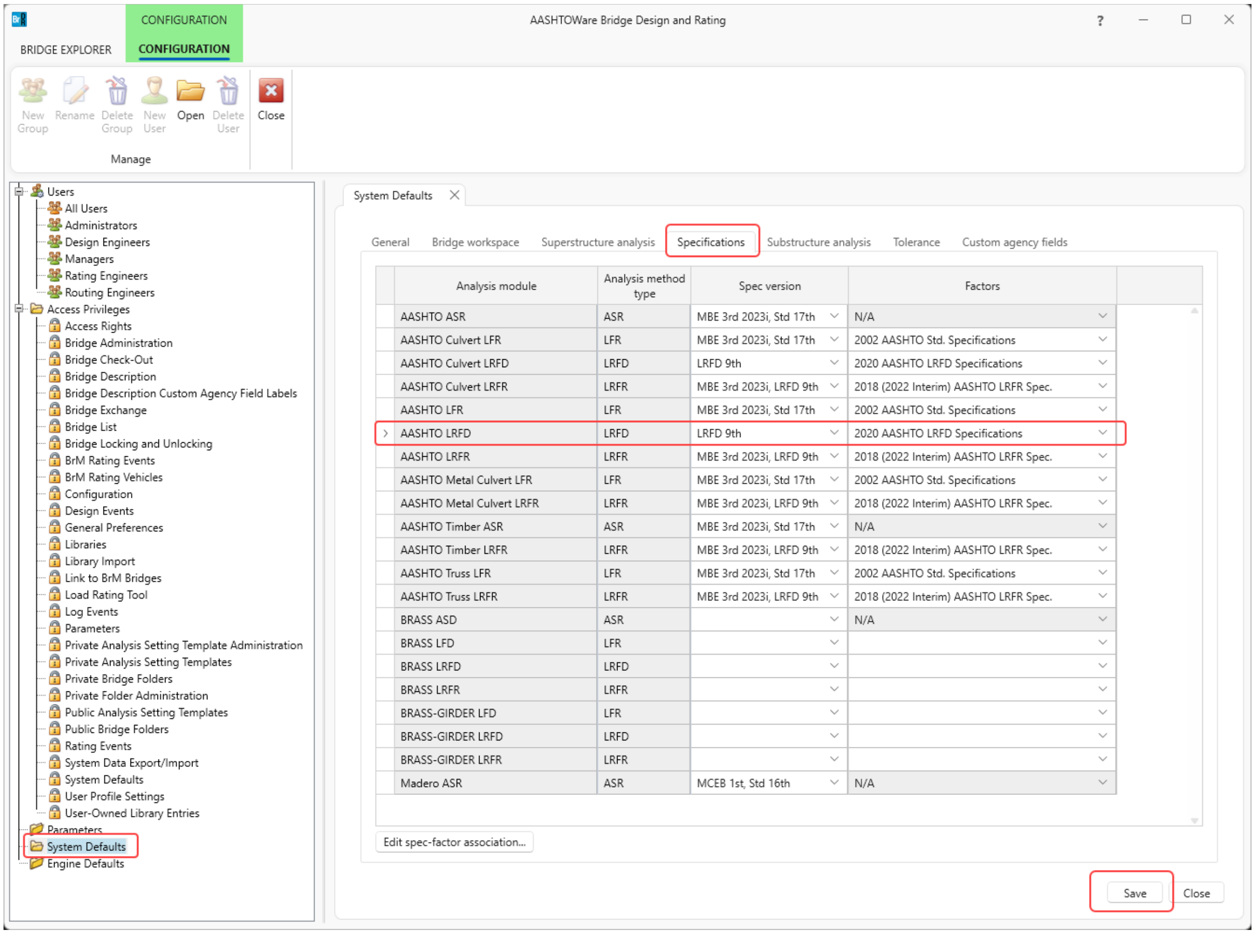
Default specifications can be set in the System Defaults as shown below. Open the **CONFIGURATION** browser by clicking on the **Configuration** button on the **VIEW** ribbon of the **Bridge Explorer**.



Click on the **System Defaults** node in the **CONFIGURATION** tree and select **Open** from the **Manage** group of the **CONFIGURATION** ribbon (or double click on System Defaults) as shown below.



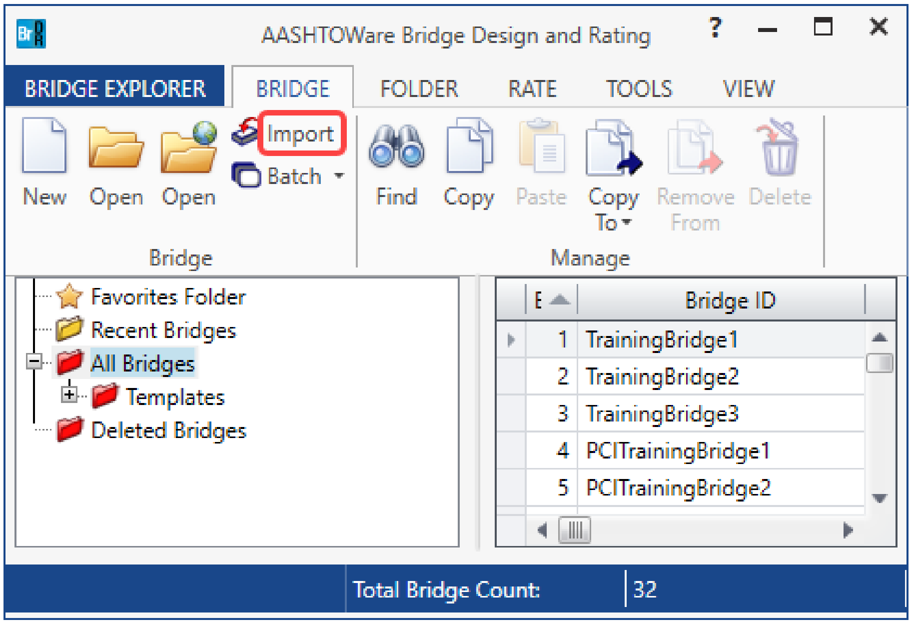
The **System Defaults** window is displayed as shown below. Navigate to the **Specifications** tab. Default **Spec Version** and **Factors** can be set for each **Analysis module**. The defaults set in this window will be used when new member alternatives are created. For this tutorial, set the **AASHTO LRFD** Spec version to **LRFD 9th** and use the **2020 AASHTO LRFD Specification** factors as shown below.



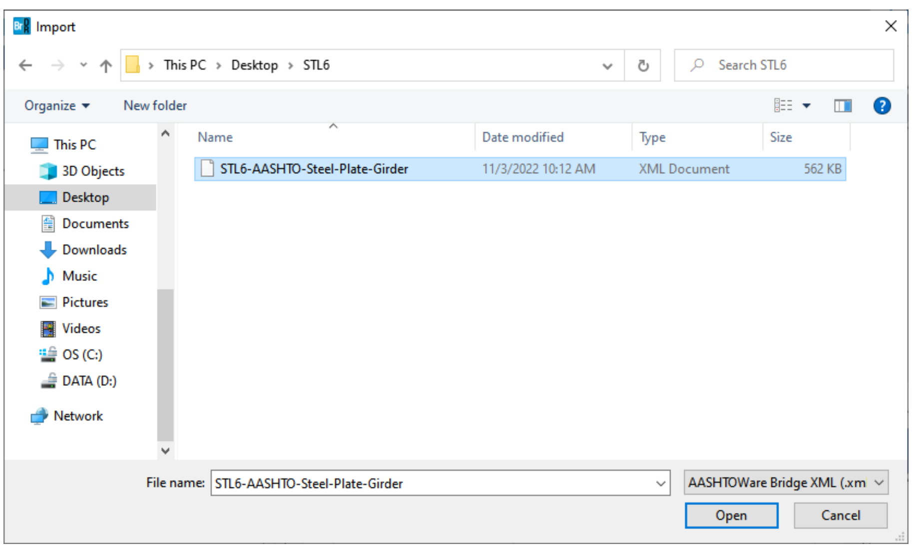
Click **Save** to save the default settings.

STL6 – Two Span Plate Girder Example

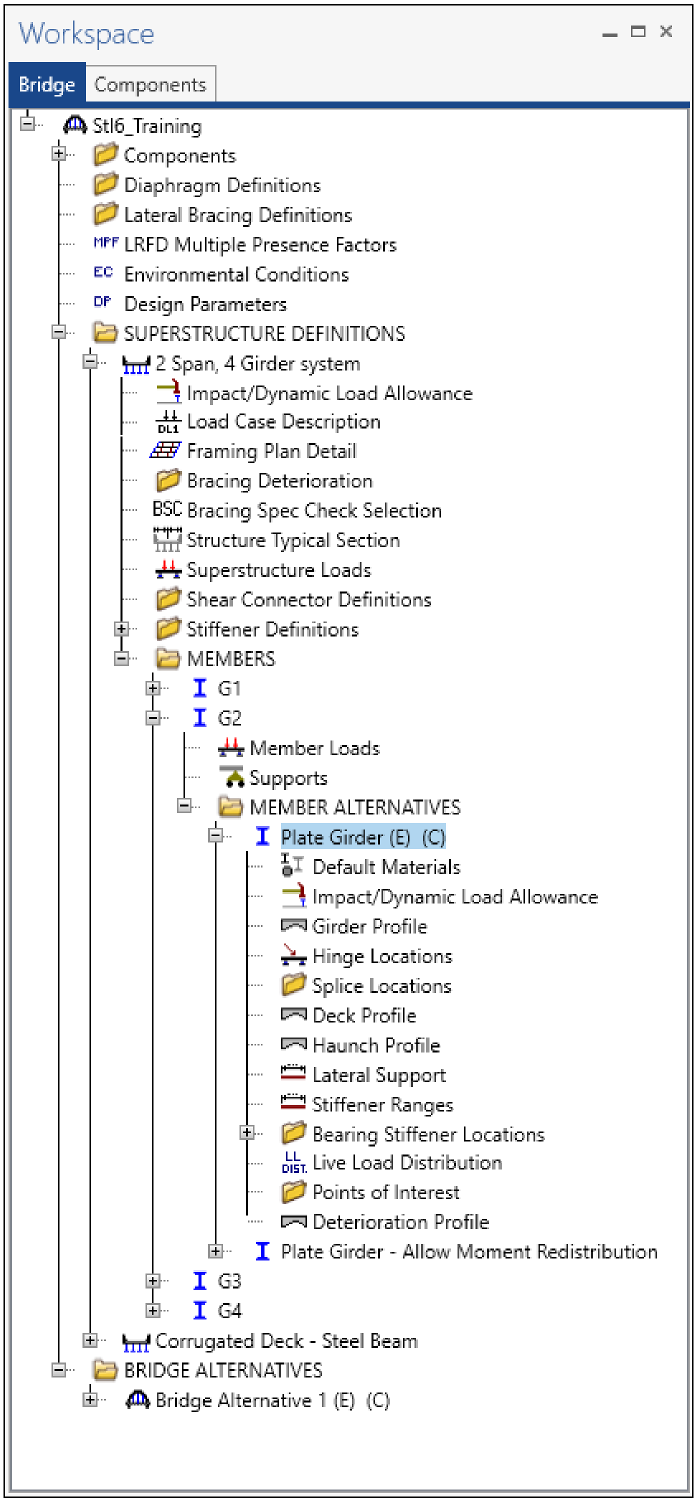
Use the **Import** function of **BrDR** to import the bridge **STL6-AASHTO-Steel-Plate-Girder.xml** provided for this tutorial. Open **BrDR** and click on the **Import** button from the **Bridge** group of the **BRIDGE** ribbon as shown below.



Select the bridge from the **STL6** tutorial and click the **Open** button to import this bridge into **BrDR**.

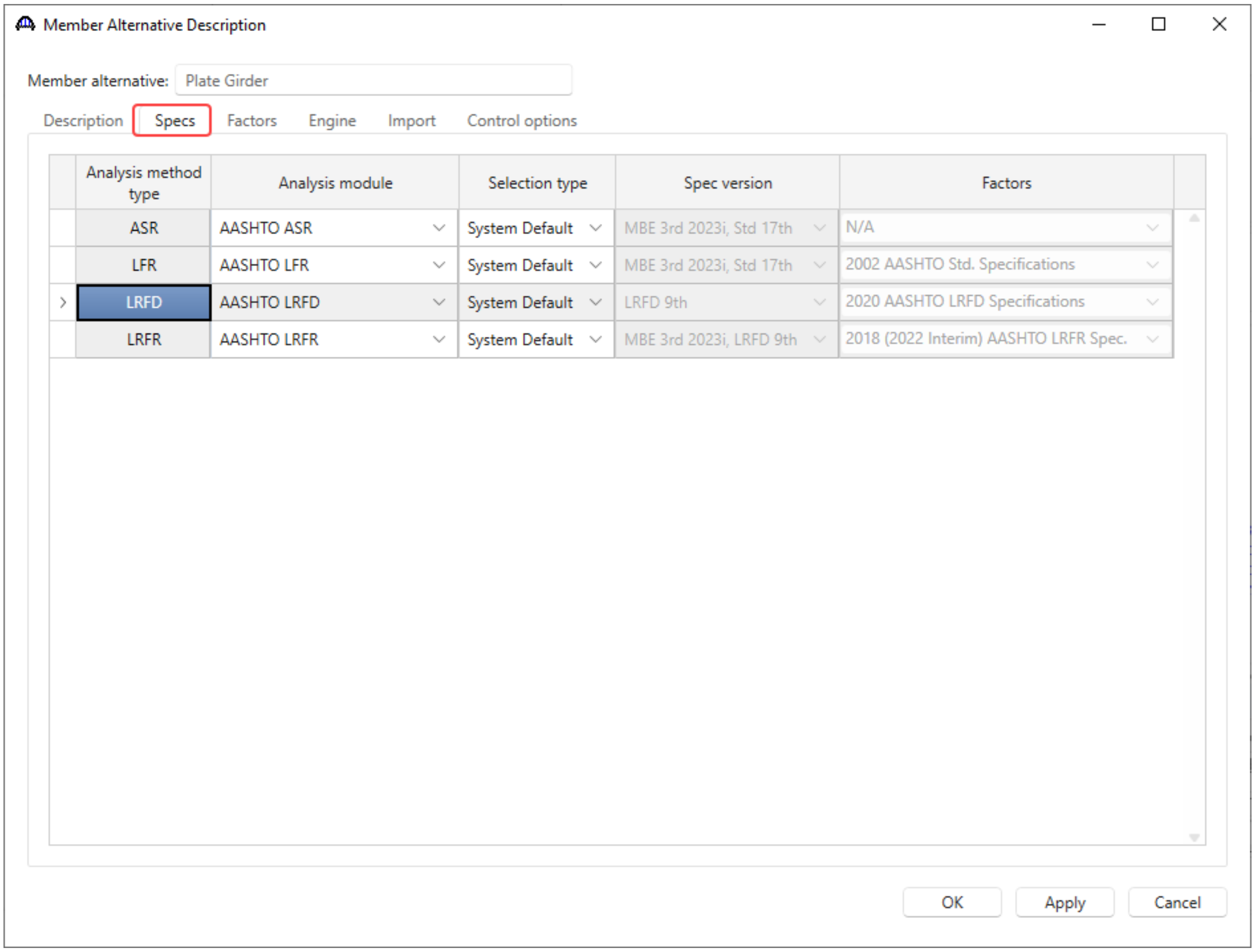


Expand the **Bridge Workspace** tree to show the member alternative for member **G2**. The partially expanded **Bridge Workspace** tree is shown below.



Member Alternative Description – Specs

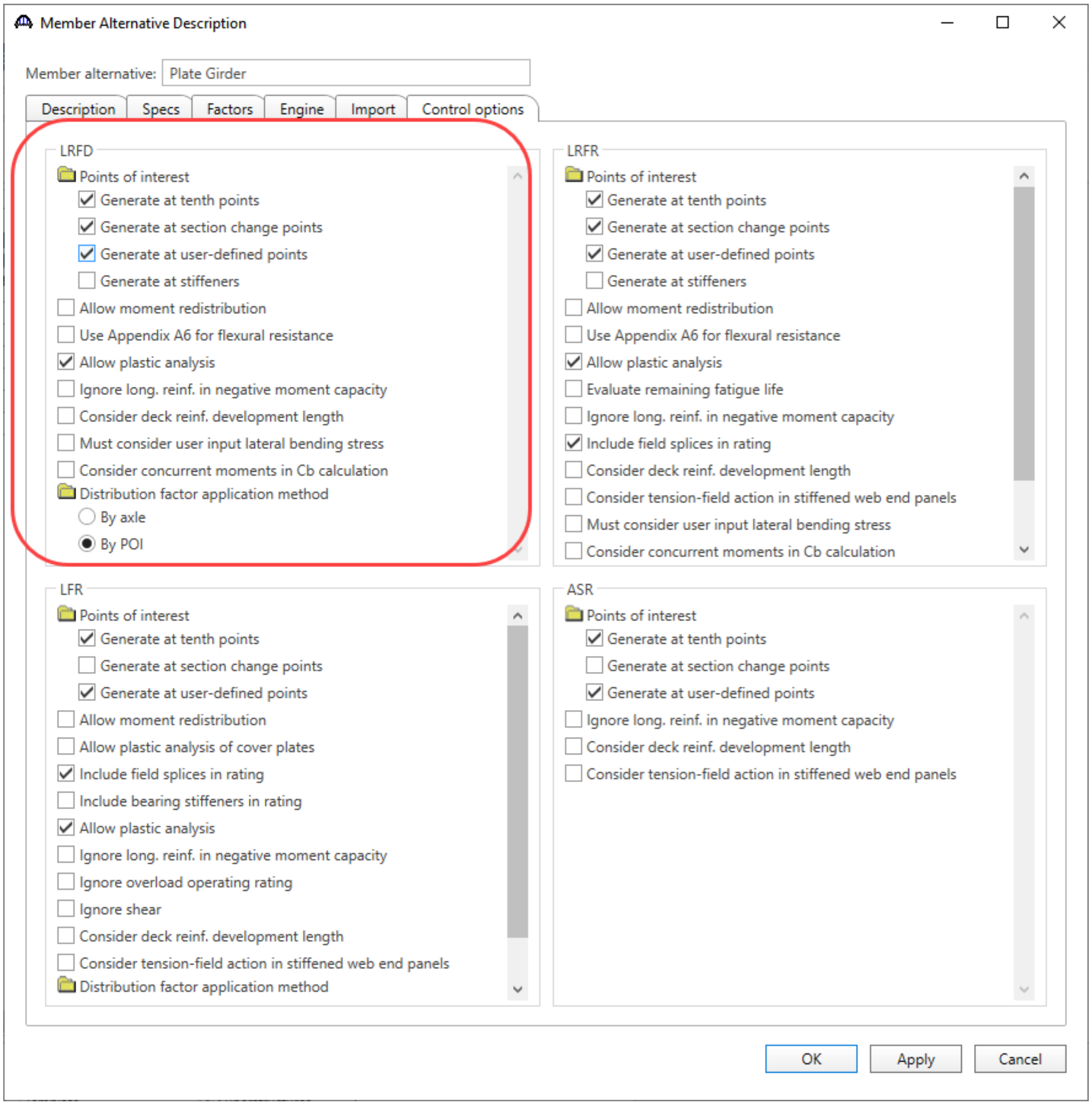
Double click on the **Plate Girder** member alternative for member **G2** in the **Bridge Workspace** tree to open the **Member Alternative Description** window and navigate to the **Specs** tab of this window as shown below.



The table above provides an **Analysis module** for each analysis method. With each engine there may be various specification editions to choose from. Each specification edition may provide various load factor sets. For this tutorial, select **System Default** under **Selection type** for each **Analysis method type**. This selection uses the **Spec version** and **Factors** that were set as default values earlier in the **System Defaults** window.

Member Alternative Description – Control options

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



Note: The article numbers referenced below are from AASHTO LRFD Bridge Design Specifications, 9th Edition and AASHTO Manual for Bridge Evaluation,3rd Edition with 2023 interims.

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.

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.

Distribution Factor Application Method

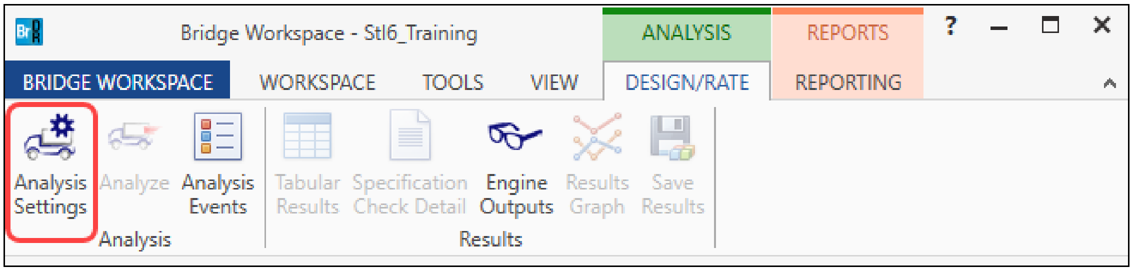
Select the method to be used for the application of live load distribution factors.

- By axle - causes the distribution factor at the location of the axle to be used for each axle.
- By POI - causes the distribution factor at the location of the point of interest to be used for all axles.

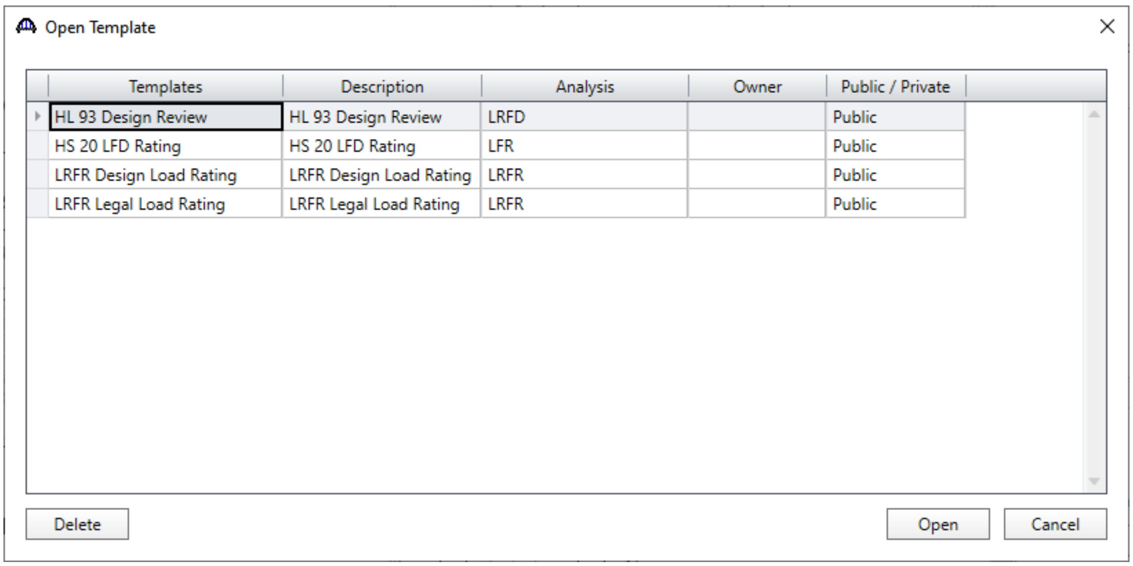
Similar behavior applies for lane load.

LRFD Design Review

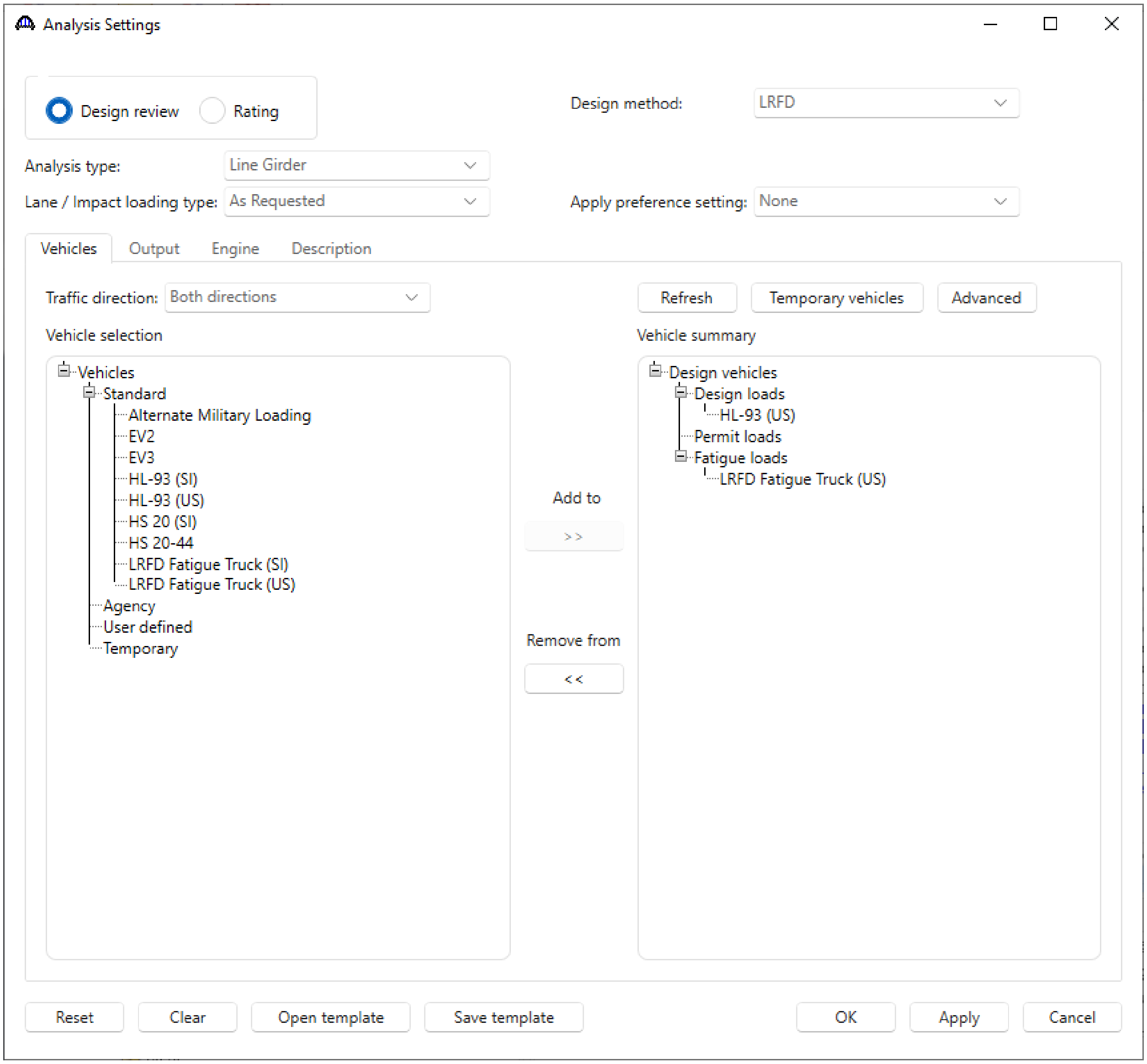
An LRFD design review of this girder for **HL93** loading can be performed by AASHTO LRFD. To perform an **LRFD** design review, select the **Analysis Settings** button on the **Analysis** group of the **DESIGN/RATE** ribbon.



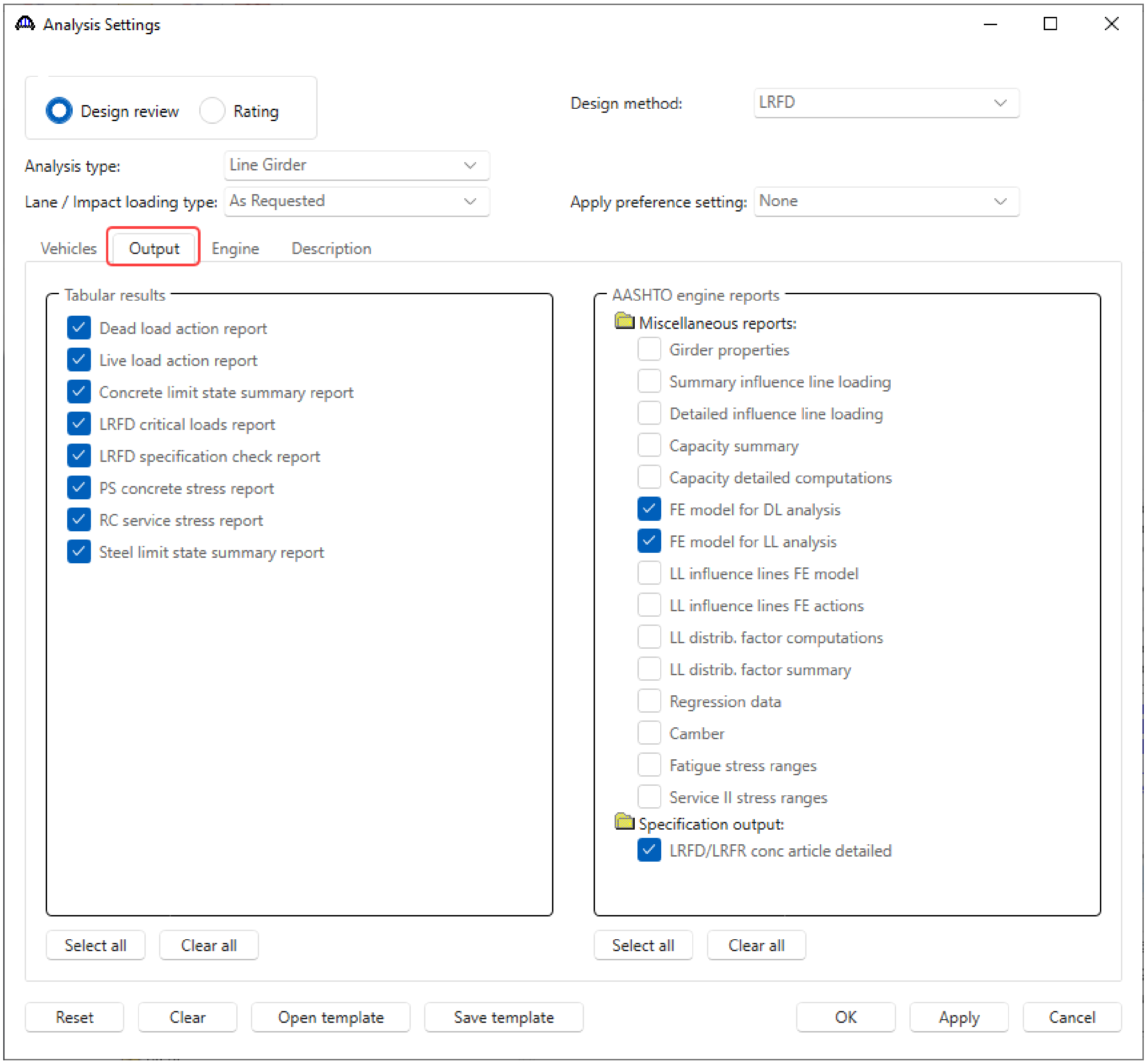
Click the **Open Template** button and select the **LRFR Design Load Rating** to be used in the rating and click **Open**.



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

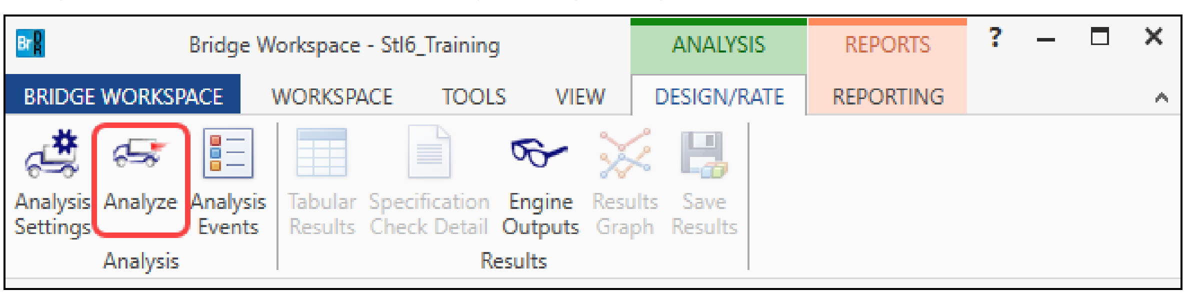


Navigate to the **Output** tab of this window and select the following reports to be generated during the analysis.



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

With **Plate Girder** member alternative for member **G2** of **2 Span, 4 Girder System** superstructure definition selected, click the **Analyze** button on the **Analysis** group of the **DESIGN/RATE** ribbon to perform the design review. The **Analysis** window should be reviewed for any warning messages.



Export of steel girders to the AASHTO LRFD analysis engine

The following steps are performed during the design review of a steel girder using the AASHTO LRFD 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 models contain section properties corresponding to the sustained modular ratio factor entered in BrDR (e.g., 3n). Stage 3 models contain section properties corresponding to the modular ratio (n). The FE model 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 - Control Options** tab, the model generated by the export to the AASHTO LRFD 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 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 subjected to. The second phase performs the specification checks taking into consideration the flexure type determined in the first phase.

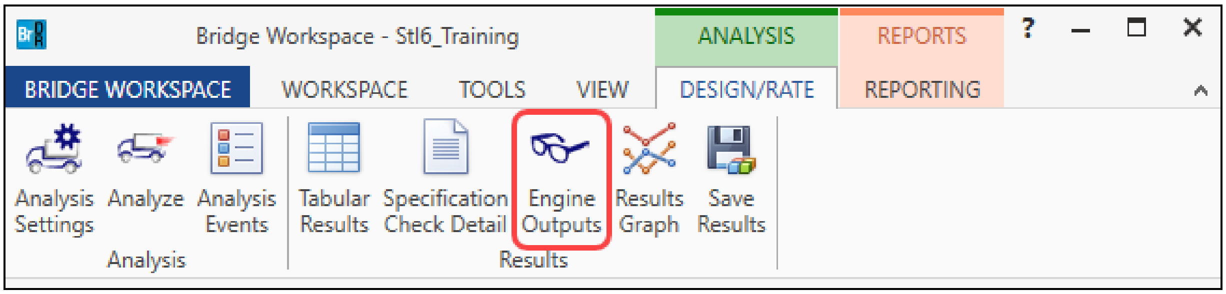
   Phase 1:
   Positive flexure is defined as the bending condition that produces compressive stress (denoted by a negative sign in the program) in the slab for composite construction or the top flange for non-composite construction. Negative flexure is defined as the bending condition that produces tensile 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.

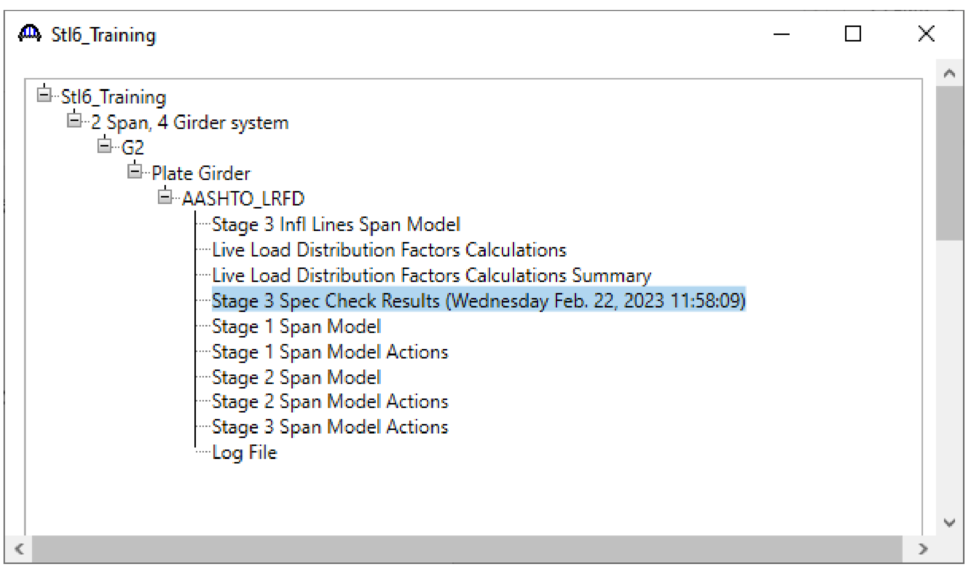
Phase 2:
The remaining articles are evaluated taking into consideration the flexure type determined in the first phase.

AASHTO LRFD Specification checking

AASHTO LRFD analysis will generate a spec check results file. Click the **Engine Outputs** button from the **Results** group of the **DESIGN/RATE** ribbon to open the following window.



This summary report lists the design ratios for each spec article at each spec check location point. The design ratio is the ratio of capacity to demand. A design ratio less than one indicates the demand is greater than the capacity and the spec article fails. A design ratio equal to 99.0 indicates the section is subject to zero demand.



Stage 3 Spec Check Results

Bridge ID : Stl6_Training
Bridge : 2 Span Plate Girder Training
Superstructure Def : 2 Span, 4 Girder system
Member : G2
Analysis Preference Setting :

NBI Structure ID : Stl6_Training
Bridge Alt :

Member Alt : Plate Girder

AASHTO LRFD Specification, Edition 9, Interim 0

Specification Check Summary

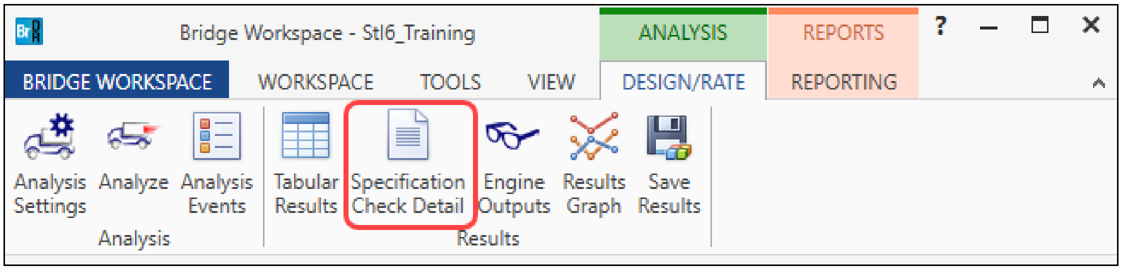
Article	Status
Flexure (6.10.7.1.1, 6.10.7.2.1, 6.10.8.1.1, 6.10.8.1.1, 6.10.8.1.1)	Pass
Shear (6.10.9)	Fail
Fatigue (6.10.5.3, 6.6.1.2.2)	Pass
Serviceability (6.10.4.2.2)	Pass
Constructability (6.10.3.2.1, 6.10.3.2.2, 6.10.3.2.3)	Pass
Transverse Stiffeners (6.10.11.1.2, 6.10.11.1.3)	Fail
Longitudinal Stiffeners (6.10.11.3.1, 6.10.11.3.2, 6.10.11.3.3)	NA
Bearing Stiffeners (6.10.11.2.2, 6.10.11.2.3, 6.10.11.2.4)	Pass
Shear Connector (6.10.10.1, 6.10.10.4)	NA
Field Splice (6.13.2.6, 6.13.2.7, 6.13.5.3, 6.13.6.1.3a, 6.13.6.1.3b, 6.13.6.1.3c)	NA
Minimum Negative Flexure Concrete Deck Reinforcement (6.10.1.7)	Pass
Deflection (2.5.2.6.2)	Pass

Girder Member Proportions and Compactness (Stage 3)

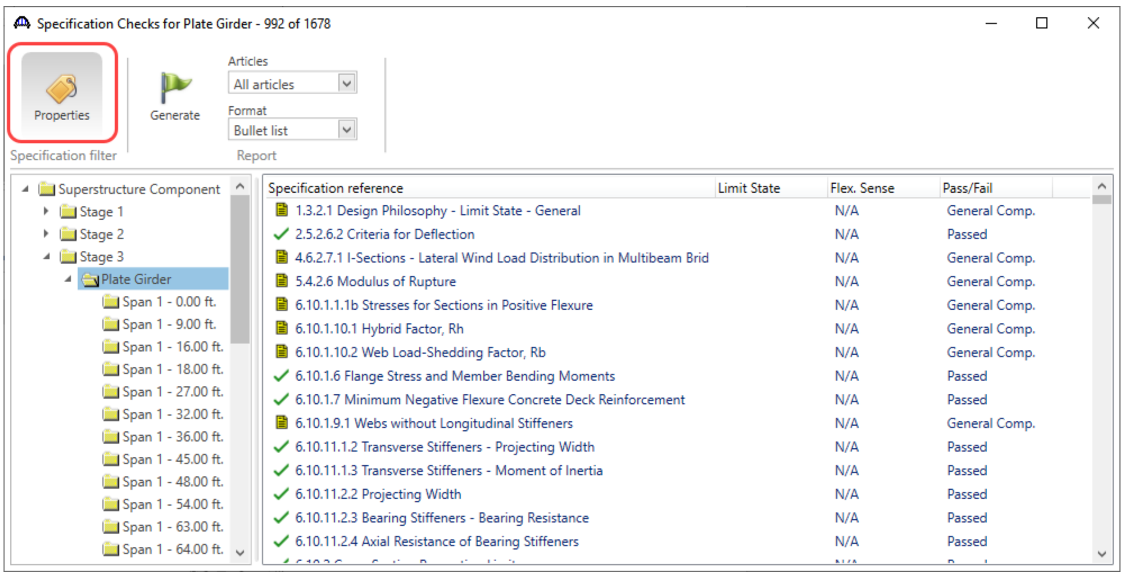
Location (ft)	Composite	Proportion Code	Code Check	Compact	Code Check
0.000	Yes	Pass	---	Compact	E
9.000	Yes	Pass	---	Compact	E
18.000	Yes	Pass	---	Compact	E
27.000	Yes	Pass	---	Compact	E

Specification Check Detail

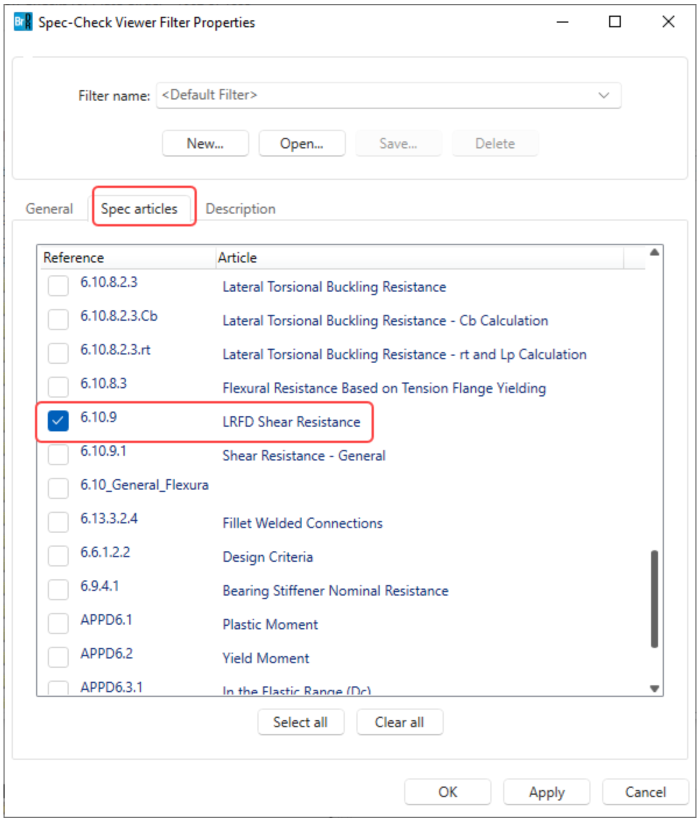
The specification checks can be viewed by selecting the **Specification Check Detail** button from the **Results** group of the **DESIGN/RATE** ribbon.



Select **Stage 3**, **Plate Girder** from the Specification Checks tree and click the **Properties** button from the **Specification filter** ribbon to open the **Spec-Check Viewer Filter Properties** window as shown below.

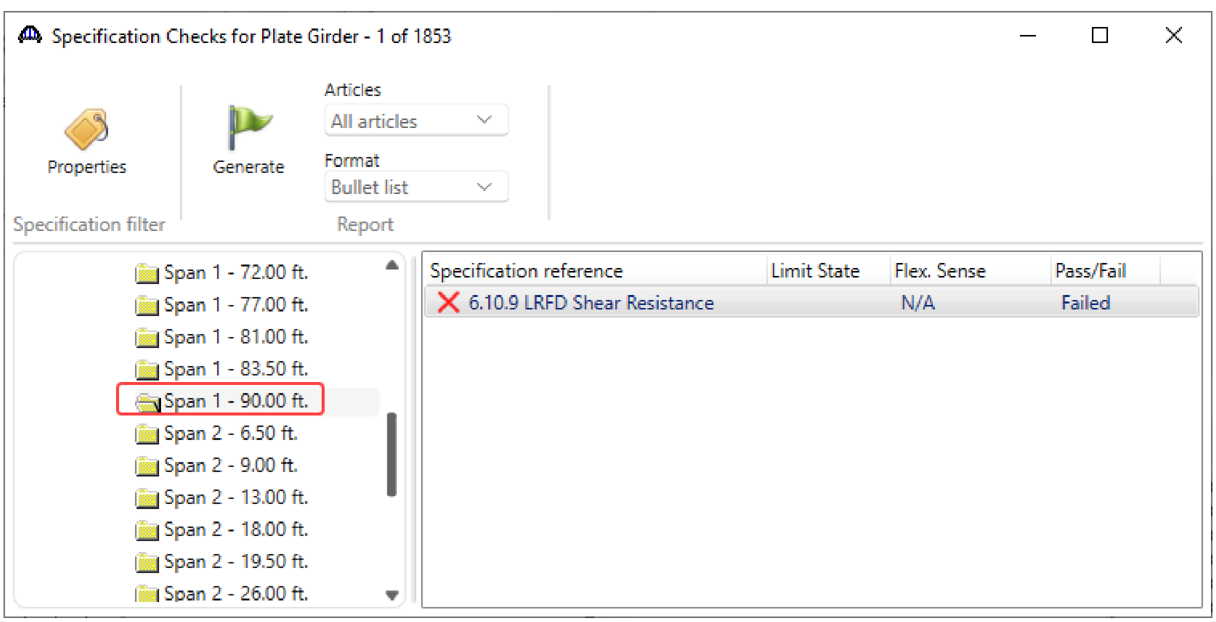


Navigate to the **Spec articles** tab. Click the **Clear all** button and select the article **6.10.9** from the **Reference** column as shown below.



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

From the window shown below, double click on the **6.10.9 Shear Resistance** article at **Span 1 – 90.00 ft** to view the selected spec article.



The selected spec article is shown below.

Spec Check Detail for 6.10.9 LRFD Shear Resistance

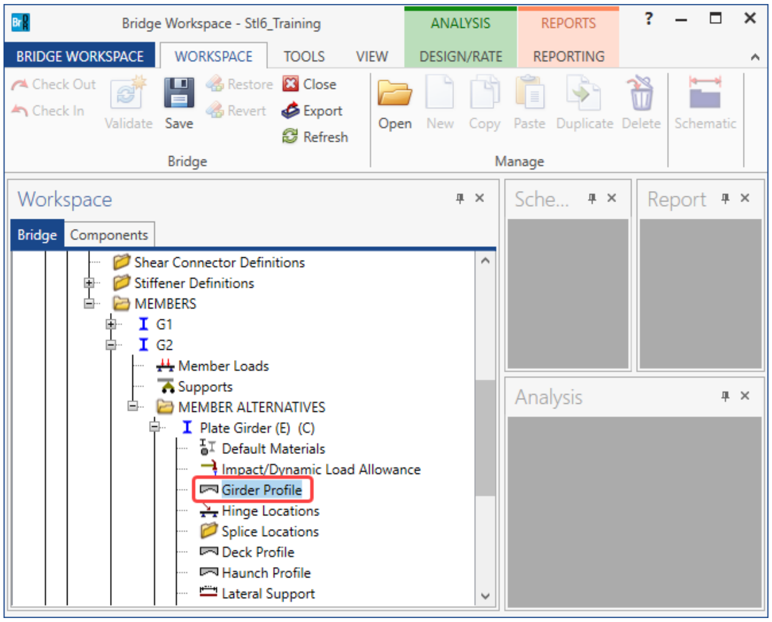
```
INPUT:
Top Flange bf =   16.0000 (in)
Top Flange tf =    1.2500 (in)
Web D         =   46.0000 (in)
Web tw        =    0.5000 (in)
Bot Flange bf =   18.0000 (in)
Bot Flange tf =    1.5000 (in)

Fyw =   50.0000 (ksi)
do  =  192.0000 (in)
phi =    1.0000

SUMMARY:

k = 5.0

D/tw = 92.0000

Limit 1:  1.12*SQRT(E*k/Fyw) = 60.3138

Limit 2:  1.40*SQRT(E*k/Fyw) = 75.3923

D/tw > Limit2 therefore

      1.57*(E*k/Fyw)
C =  ---------------                          (6.10.9.3.2-6)
        (D/tw)^2

C = 0.5379

Vn = Vcr = C * Vp                             (6.10.9.2-1)

Vp = 0.58*fyw*D*tw                            (6.10.9.2-2)

Vp = 667.0001 (kip)

Vn = 358.7962 (kip)

Vr = phi*Vn  = 358.80


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 Combo	Vu (kip)	--- Override --- Phi (kip)	Vn (kip)	Vr (kip)	Design Ratio	Code
STR-I	1	-104.19			-358.80	3.444	Pass
STR-I	1	-361.83			-358.80	0.992	Fail
STR-I	2	-104.19			-358.80	3.444	Pass
STR-I	2	-322.21			-358.80	1.114	Pass
STR-I	3	-104.19			-358.80	3.444	Pass

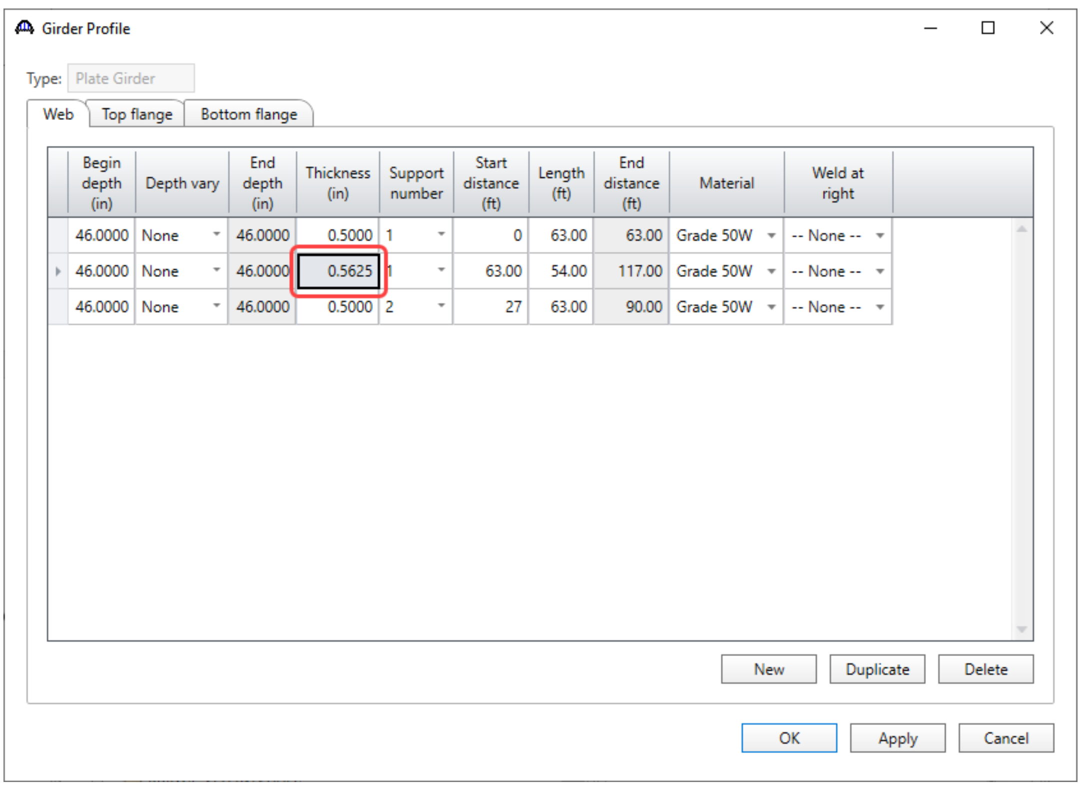
OK

Girder Profile

Return to the **G2** member alternative – **Plate Girder**. Open the **Girder Profile** window by double clicking on **Girder Profile** node in the **Bridge Workspace** tree.

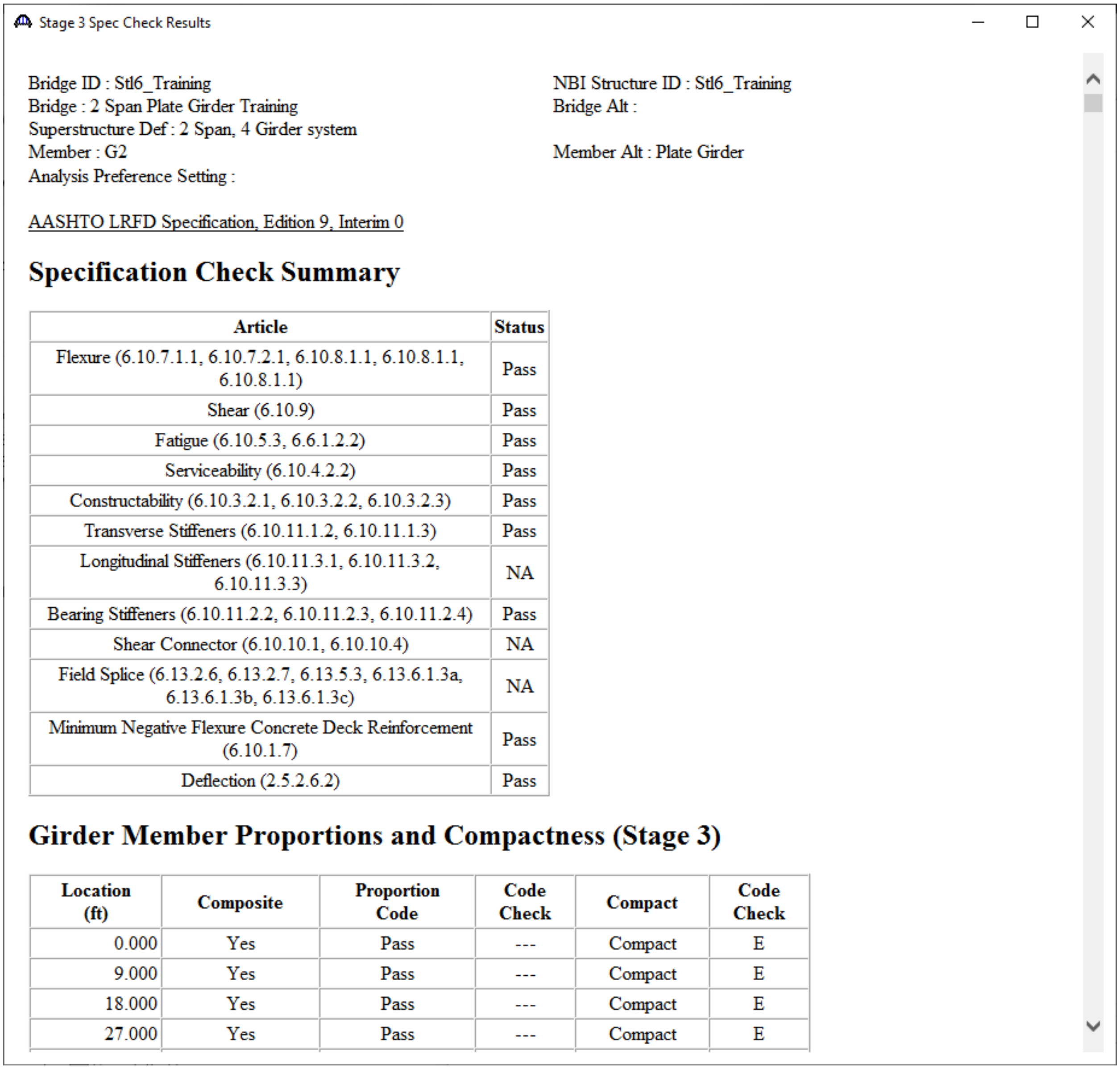


Revise the Web Thickness to **0.5625"** in the region near Pier 1.



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

Re-run the **LRFD Design review** and review the **Spec Check summary report** from **Engine Outputs** (as shown in the previous sections) as shown below.



Stage 3 Spec Check Results

Bridge ID : Stl6_Training
NBI Structure ID : Stl6_Training
Bridge : 2 Span Plate Girder Training
Bridge Alt :
Superstructure Def : 2 Span, 4 Girder system
Member : G2
Member Alt : Plate Girder
Analysis Preference Setting :

AASHTO LRFD Specification, Edition 9, Interim 0

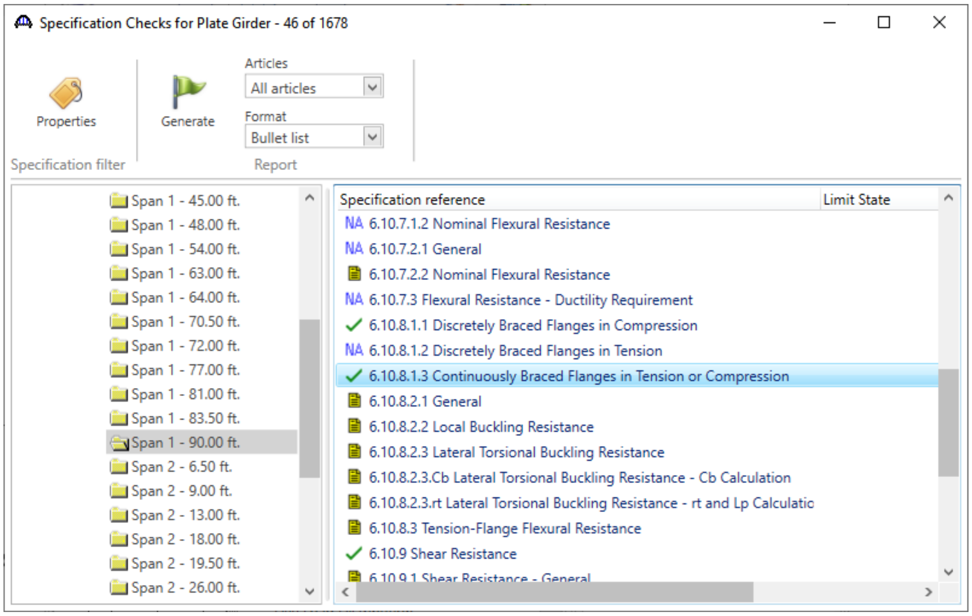
Specification Check Summary

Article	Status
Flexure (6.10.7.1.1, 6.10.7.2.1, 6.10.8.1.1, 6.10.8.1.1)	Pass
Shear (6.10.9)	Pass
Fatigue (6.10.5.3, 6.6.1.2.2)	Pass
Serviceability (6.10.4.2.2)	Pass
Constructability (6.10.3.2.1, 6.10.3.2.2, 6.10.3.2.3)	Pass
Transverse Stiffeners (6.10.11.1.2, 6.10.11.1.3)	Pass
Longitudinal Stiffeners (6.10.11.3.1, 6.10.11.3.2, 6.10.11.3.3)	NA
Bearing Stiffeners (6.10.11.2.2, 6.10.11.2.3, 6.10.11.2.4)	Pass
Shear Connector (6.10.10.1, 6.10.10.4)	NA
Field Splice (6.13.2.6, 6.13.2.7, 6.13.5.3, 6.13.6.1.3a, 6.13.6.1.3b, 6.13.6.1.3c)	NA
Minimum Negative Flexure Concrete Deck Reinforcement (6.10.1.7)	Pass
Deflection (2.5.2.6.2)	Pass

Girder Member Proportions and Compactness (Stage 3)

Location (ft)	Composite	Proportion Code	Code Check	Compact	Code Check
0.000	Yes	Pass	---	Compact	E
9.000	Yes	Pass	---	Compact	E
18.000	Yes	Pass	---	Compact	E
27.000	Yes	Pass	---	Compact	E

From the **Specification Check Detail** window, open Article **6.10.8.1.3** at **Span 1 – 90.00 ft** for **Stage 3**. The following is noted for this window and other spec articles are similar.



Spec Check Detail for 6.10.8.1.3 Continuously Braced Flanges in Tension or Compression

```
6 Steel Structures
6.10 I-Section Flexural Members
6.10.8 Flexural Resistance-Composite Sections in Negative Flexure and Noncomposite Sections
6.10.8.1 General
6.10.8.1.3 Continuously Braced Flanges in Tension or Compression
(AASHTO LRFD Bridge Design Specifications, Ninth Edition)

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

Section within Top Flange Continuous Bracing Region

Section at Bottom Flange Brace Point


INPUT:
Phif = 1.000

Section Type: Composite
Top Flange Continuously Laterally Supported: Yes
Allow Moment Redistribution Control Option: No
Moment Redistribution : No, Moment Redistribution did not occur

SUMMARY:

fbu <= Phif * Rh * Fyf                (6.10.8.1.3-1)

Resist = Phif * Rh * Fyf

Design Ratio = Resist/fbu


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 Combo	Flexure Type	Component	fbu (ksi)	frd (ksi)	Rh	Fyf (ksi)	Override Phi (ksi)	Override Fyf (ksi)	Resist (ksi)	Design Ratio	Status
STR-I	1	Neg	Top Flange	19.88	---	1.00	50.00	---	---	50.00	2.515	Pass
STR-I	1	Neg	Top Flange	42.87	---	1.00	50.00	---	---	50.00	1.166	Pass
STR-I	2	Neg	Top Flange	19.88	---	1.00	50.00	---	---	50.00	2.515	Pass
STR-I	2	Neg	Top Flange	40.75	---	1.00	50.00	---	---	50.00	1.227	Pass
STR-I	3	Neg	Top Flange	19.88	---	1.00	50.00	---	---	50.00	2.515	Pass
STR-I	3	Neg	Top Flange	48.50	---	1.00	50.00	---	---	50.00	1.031	Pass
STR-III	1	Neg	Top Flange	19.88	---	1.00	50.00	---	---	50.00	2.515	Pass
STR-III	1	Neg	Top Flange	28.57	---	1.00	50.00	---	---	50.00	1.750	Pass
STR-III	2	Neg	Top Flange	19.88	---	1.00	50.00	---	---	50.00	2.515	Pass
STR-III	2	Neg	Top Flange	28.57	---	1.00	50.00	---	---	50.00	1.750	Pass
STR-III	3	Neg	Top Flange	19.88	---	1.00	50.00	---	---	50.00	2.515	Pass
STR-III	3	Neg	Top Flange	28.57	---	1.00	50.00	---	---	50.00	1.750	Pass
STR-V	1	Neg	Top Flange	19.88	---	1.00	50.00	---	---	50.00	2.515	Pass
STR-V	1	Neg	Top Flange	39.60	---	1.00	50.00	---	---	50.00	1.263	Pass
STR-V	2	Neg	Top Flange	19.88	---	1.00	50.00	---	---	50.00	2.515	Pass
STR-V	2	Neg	Top Flange	37.97	---	1.00	50.00	---	---	50.00	1.317	Pass
STR-V	3	Neg	Top Flange	19.88	---	1.00	50.00	---	---	50.00	2.515	Pass
STR-V	3	Neg	Top Flange	43.94	---	1.00	50.00	---	---	50.00	1.138	Pass

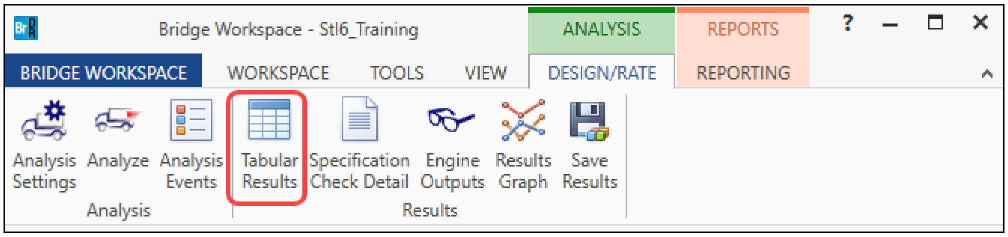
```
Load Combination Legend:

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

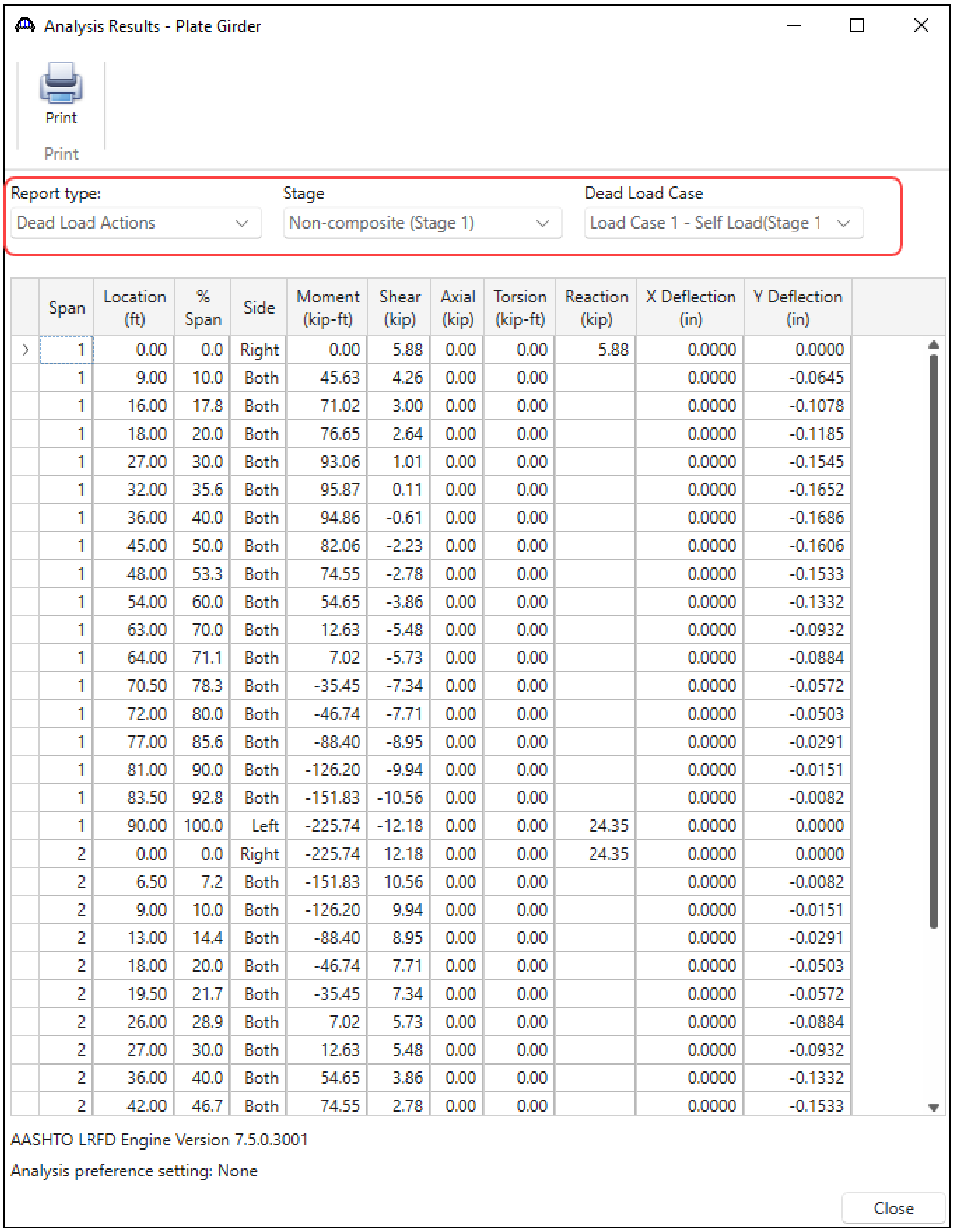
OK

1. For each spec check location, both the left and right sides of the point are evaluated. The Deflection article is an exception to this since deflection must be the same between the left and right sides of a point.
2. The design ratio is printed out for the article. The design ratio is the ratio of capacity to demand. A design ratio less than one indicates the demand is greater than the capacity and the spec article fails. A design ratio equal to 99.0 indicates the section is subject to zero demand.
3. For steel members, the Strength-I, Strength-II (for Permit vehicles), Strength-III, Strength-V, Service II and Fatigue limit states are the only limit states investigated. For each limit state, the max and min force effect is checked for each vehicle. Thus, each limit state shows two rows of data for each vehicle.
4. The LL vehicle is identified by the load combination shown in this column.
5. The ‘frd’ column displays the stresses due to the redistribution moments. If moment redistribution was not processed, this column shows ‘---‘.

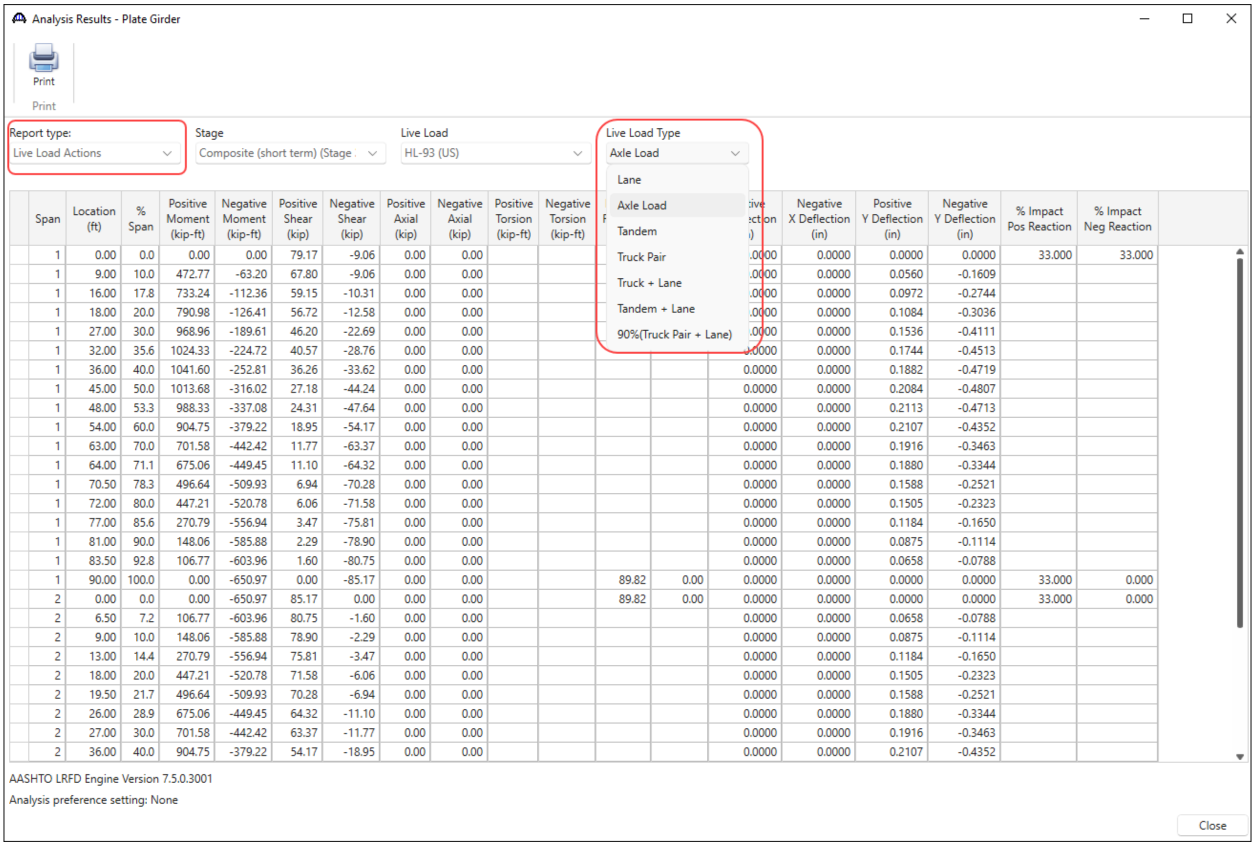
Tabular Results

Dead load and live load analysis results can be reviewed by clicking the **Tabular Results** button on the **Results** group of the **DESIGN/RATE** ribbon.





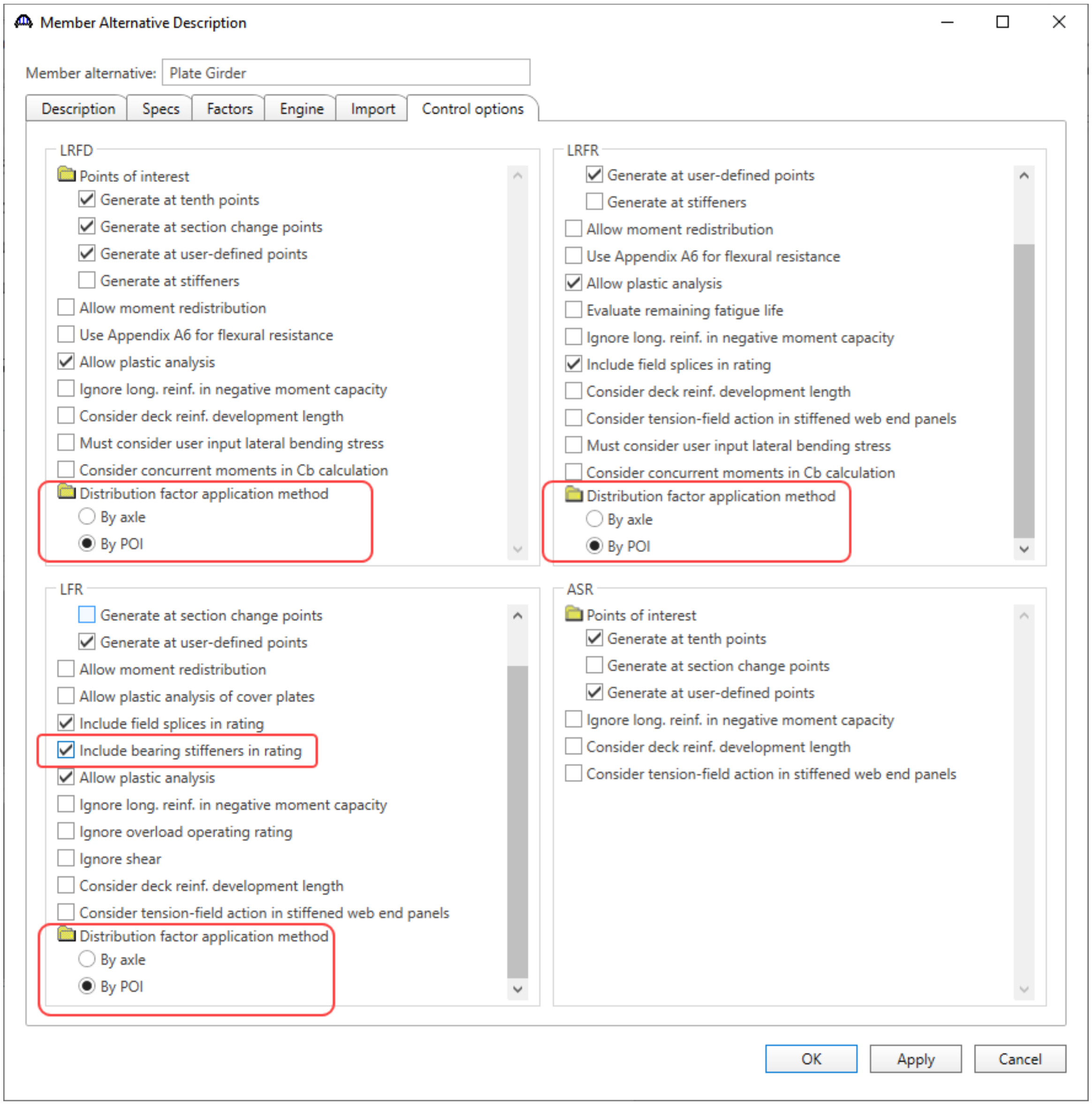
Span	Location (ft)	% Span	Side	Moment (kip-ft)	Shear (kip)	Axial (kip)	Torsion (kip-ft)	Reaction (kip)	X Deflection (in)	Y Deflection (in)
1	0.00	0.0	Right	0.00	5.88	0.00	0.00	5.88	0.0000	0.0000
1	9.00	10.0	Both	45.63	4.26	0.00	0.00		0.0000	-0.0645
1	16.00	17.8	Both	71.02	3.00	0.00	0.00		0.0000	-0.1078
1	18.00	20.0	Both	76.65	2.64	0.00	0.00		0.0000	-0.1185
1	27.00	30.0	Both	93.06	1.01	0.00	0.00		0.0000	-0.1545
1	32.00	35.6	Both	95.87	0.11	0.00	0.00		0.0000	-0.1652
1	36.00	40.0	Both	94.86	-0.61	0.00	0.00		0.0000	-0.1686
1	45.00	50.0	Both	82.06	-2.23	0.00	0.00		0.0000	-0.1606
1	48.00	53.3	Both	74.55	-2.78	0.00	0.00		0.0000	-0.1533
1	54.00	60.0	Both	54.65	-3.86	0.00	0.00		0.0000	-0.1332
1	63.00	70.0	Both	12.63	-5.48	0.00	0.00		0.0000	-0.0932
1	64.00	71.1	Both	7.02	-5.73	0.00	0.00		0.0000	-0.0884
1	70.50	78.3	Both	-35.45	-7.34	0.00	0.00		0.0000	-0.0572
1	72.00	80.0	Both	-46.74	-7.71	0.00	0.00		0.0000	-0.0503
1	77.00	85.6	Both	-88.40	-8.95	0.00	0.00		0.0000	-0.0291
1	81.00	90.0	Both	-126.20	-9.94	0.00	0.00		0.0000	-0.0151
1	83.50	92.8	Both	-151.83	-10.56	0.00	0.00		0.0000	-0.0082
1	90.00	100.0	Left	-225.74	-12.18	0.00	0.00	24.35	0.0000	0.0000
2	0.00	0.0	Right	-225.74	12.18	0.00	0.00	24.35	0.0000	0.0000
2	6.50	7.2	Both	-151.83	10.56	0.00	0.00		0.0000	-0.0082
2	9.00	10.0	Both	-126.20	9.94	0.00	0.00		0.0000	-0.0151
2	13.00	14.4	Both	-88.40	8.95	0.00	0.00		0.0000	-0.0291
2	18.00	20.0	Both	-46.74	7.71	0.00	0.00		0.0000	-0.0503
2	19.50	21.7	Both	-35.45	7.34	0.00	0.00		0.0000	-0.0572
2	26.00	28.9	Both	7.02	5.73	0.00	0.00		0.0000	-0.0884
2	27.00	30.0	Both	12.63	5.48	0.00	0.00		0.0000	-0.0932
2	36.00	40.0	Both	54.65	3.86	0.00	0.00		0.0000	-0.1332
2	42.00	46.7	Both	74.55	2.78	0.00	0.00		0.0000	-0.1533



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)	F		tive ection)	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	79.17	-9.06	0.00	0.00					.0000	0.0000	0.0000	0.0000	33.000	33.000
1	9.00	10.0	472.77	-63.20	67.80	-9.06	0.00	0.00					.0000	0.0000	0.0560	-0.1609		
1	16.00	17.8	733.24	-112.36	59.15	-10.31	0.00	0.00					.0000	0.0000	0.0972	-0.2744		
1	18.00	20.0	790.98	-126.41	56.72	-12.58	0.00	0.00					.0000	0.0000	0.1084	-0.3036		
1	27.00	30.0	968.96	-189.61	46.20	-22.69	0.00	0.00					.0000	0.0000	0.1536	-0.4111		
1	32.00	35.6	1024.33	-224.72	40.57	-28.76	0.00	0.00					0.0000	0.0000	0.1744	-0.4513		
1	36.00	40.0	1041.60	-252.81	36.26	-33.62	0.00	0.00					0.0000	0.0000	0.1882	-0.4719		
1	45.00	50.0	1013.68	-316.02	27.18	-44.24	0.00	0.00					0.0000	0.0000	0.2084	-0.4807		
1	48.00	53.3	988.33	-337.08	24.31	-47.64	0.00	0.00					0.0000	0.0000	0.2113	-0.4713		
1	54.00	60.0	904.75	-379.22	18.95	-54.17	0.00	0.00					0.0000	0.0000	0.2107	-0.4352		
1	63.00	70.0	701.58	-442.42	11.77	-63.37	0.00	0.00					0.0000	0.0000	0.1916	-0.3463		
1	64.00	71.1	675.06	-449.45	11.10	-64.32	0.00	0.00					0.0000	0.0000	0.1880	-0.3344		
1	70.50	78.3	496.64	-509.93	6.94	-70.28	0.00	0.00					0.0000	0.0000	0.1588	-0.2521		
1	72.00	80.0	447.21	-520.78	6.06	-71.58	0.00	0.00					0.0000	0.0000	0.1505	-0.2323		
1	77.00	85.6	270.79	-556.94	3.47	-75.81	0.00	0.00					0.0000	0.0000	0.1184	-0.1650		
1	81.00	90.0	148.06	-585.88	2.29	-78.90	0.00	0.00					0.0000	0.0000	0.0875	-0.1114		
1	83.50	92.8	106.77	-603.96	1.60	-80.75	0.00	0.00					0.0000	0.0000	0.0658	-0.0788		
1	90.00	100.0	0.00	-650.97	0.00	-85.17	0.00	0.00			89.82	0.00	0.0000	0.0000	0.0000	0.0000	33.000	0.000
2	0.00	0.0	0.00	-650.97	85.17	0.00	0.00	0.00			89.82	0.00	0.0000	0.0000	0.0000	0.0000	33.000	0.000
2	6.50	7.2	106.77	-603.96	80.75	-1.60	0.00	0.00					0.0000	0.0000	0.0658	-0.0788		
2	9.00	10.0	148.06	-585.88	78.90	-2.29	0.00	0.00					0.0000	0.0000	0.0875	-0.1114		
2	13.00	14.4	270.79	-556.94	75.81	-3.47	0.00	0.00					0.0000	0.0000	0.1184	-0.1650		
2	18.00	20.0	447.21	-520.78	71.58	-6.06	0.00	0.00					0.0000	0.0000	0.1505	-0.2323		
2	19.50	21.7	496.64	-509.93	70.28	-6.94	0.00	0.00					0.0000	0.0000	0.1588	-0.2521		
2	26.00	28.9	675.06	-449.45	64.32	-11.10	0.00	0.00					0.0000	0.0000	0.1880	-0.3344		
2	27.00	30.0	701.58	-442.42	63.37	-11.77	0.00	0.00					0.0000	0.0000	0.1916	-0.3463		
2	36.00	40.0	904.75	-379.22	54.17	-18.95	0.00	0.00					0.0000	0.0000	0.2107	-0.4352		

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

Due to a difference in how the live load distribution factors are applied, there might be differences in the live load values between various analysis engines. For example, the BRASS™ engine (which is no longer supported) applies the LL distribution factor based on the region where the analysis point is located. The AASHTO engines have a choice to do the same thing, or it applies the LL distribution factor based on the region where the axle is positioned. This can be defined by the user in the Member Alternative Description – Control options tab.



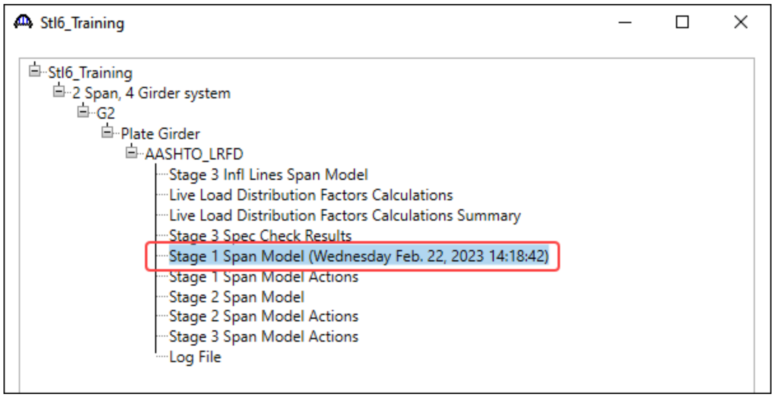
Explanation of the Distribution Factor Application Method

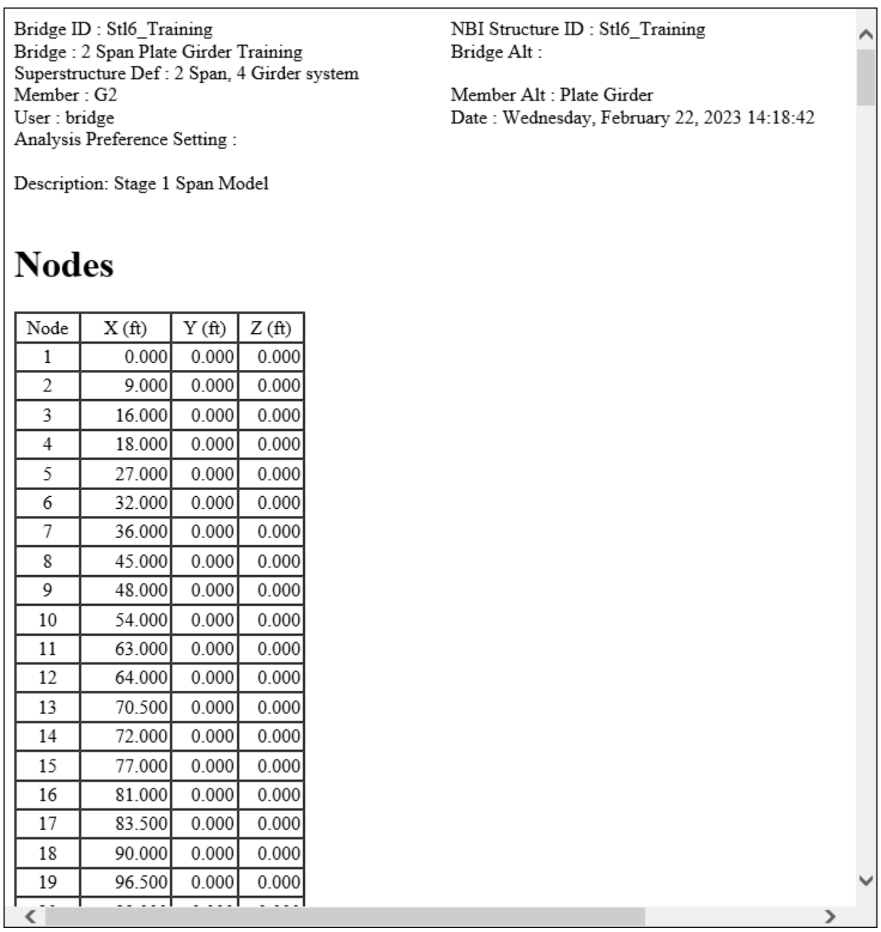
The user can select the method to be used for the application of live load distribution factors. The choices are:

- By axle - causes the distribution factor at the location of the axle to be used for each axle.
- By POI - causes the distribution factor at the location of the point of interest to be used for all axles.

Similar behavior applies for the lane load.

The **FE model output** that was turned on during the **LRFD** analysis in the **Output** tab of the **Analysis Settings** window is available from the **Engine Outputs** window as shown below.





Bridge ID : Stl6_Training
Bridge : 2 Span Plate Girder Training
Superstructure Def : 2 Span, 4 Girder system
Member : G2
User : bridge
Analysis Preference Setting :

NBI Structure ID : Stl6_Training
Bridge Alt :

Member Alt : Plate Girder
Date : Wednesday, February 22, 2023 14:18:42

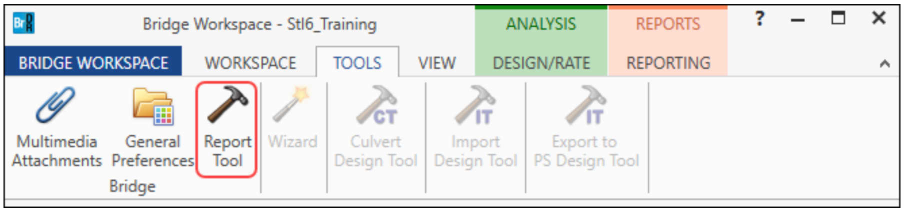
Description: Stage 1 Span Model

Nodes

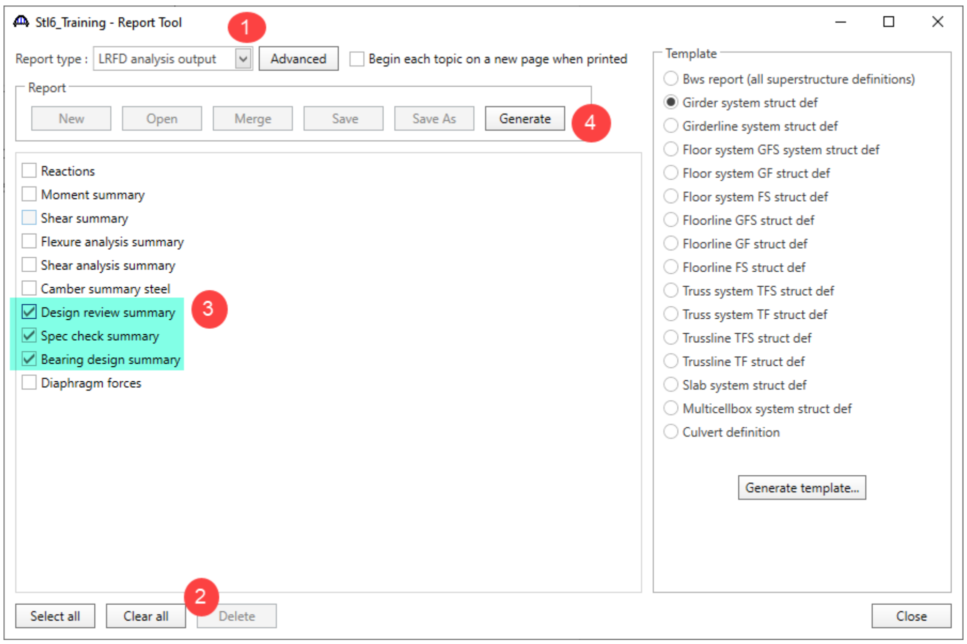
Node	X (ft)	Y (ft)	Z (ft)
1	0.000	0.000	0.000
2	9.000	0.000	0.000
3	16.000	0.000	0.000
4	18.000	0.000	0.000
5	27.000	0.000	0.000
6	32.000	0.000	0.000
7	36.000	0.000	0.000
8	45.000	0.000	0.000
9	48.000	0.000	0.000
10	54.000	0.000	0.000
11	63.000	0.000	0.000
12	64.000	0.000	0.000
13	70.500	0.000	0.000
14	72.000	0.000	0.000
15	77.000	0.000	0.000
16	81.000	0.000	0.000
17	83.500	0.000	0.000
18	90.000	0.000	0.000
19	96.500	0.000	0.000

Additional Reporting (Report Tool)

Additional reporting is available in the **Report Tool** for steel beams. Select the **Report Tool** button from the **Bridge** group of the **TOOLS** ribbon.



Select the **LRFD analysis output** as the **Report type**. Click the **Clear All** button and then select the 3 reports as shown below. Click the **Generate** button to generate the 3 selected reports.



Design review summary

This report contains the minimum design ratio at each analysis point along the beam.

Spec check summary

This report lists a summary of the spec check results for each article for each loading at each analysis point.

Bearing design summary

This report lists factored and unfactored bearing reactions and rotations to be used in a bearing design.

Report: LRFD Analysis

Bridge Name: 2 Span Plate Girder Training
NBI Structure ID: Stl6_Training
Bridge ID: Stl6_Training

Analyzed By: Bridge
Analyze Date: Thursday, February 15, 2024 10:42:42
Analysis Engine: AASHTO LRFD Engine Version 7.5.1.1
Analysis Preference Setting: None

Report By: Bridge
Report Date: Thursday, February 15, 2024 10:53:54

Structure Definition Name: 2 Span, 4 Girder system
Member Name: G2
Member Alternative Name: Plate Girder

Girder Design Review Summary

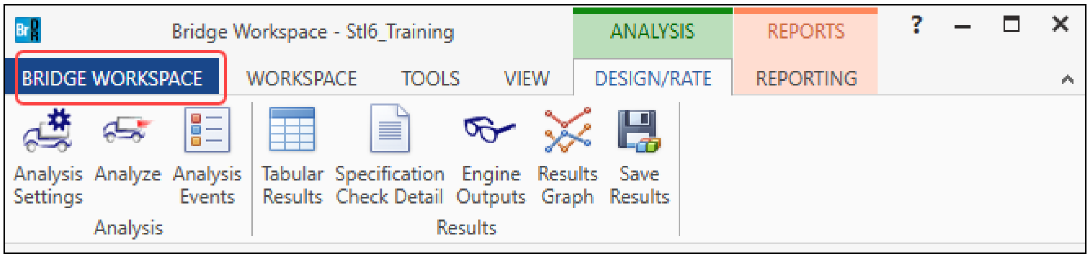
Span 1

Location	Percent	Type	Article	LS	Stage	Units	Action	Resist.	Design Ratio
0.00	0.0	Shear	6.10.9	STR-I	3	kip	264.61	358.80	1.356
9.00	10.0	Shear	6.10.9	STR-I	3	kip	212.26	358.80	1.690
18.00	20.0	Perm Deformations	6.10.4.2.2	SER-II	3	ksi	22.55	47.50	2.107
27.00	30.0	Perm Deformations	6.10.4.2.2	SER-II	3	ksi	27.63	47.50	1.719
36.00	40.0	Perm Deformations	6.10.4.2.2	SER-II	3	ksi	29.05	47.50	1.635
45.00	50.0	Perm Deformations	6.10.4.2.2	SER-II	3	ksi	26.86	47.50	1.769
54.00	60.0	Shear	6.10.9	STR-I	3	kip	-178.73	-358.80	2.008
63.00	70.0	Shear	6.10.9	STR-I	3	kip	-225.48	-358.80	1.591
72.00	80.0	Shear	6.10.9	STR-I	3	kip	-272.10	-510.86	1.877
81.00	90.0	Flexure	6.10.8.1.1	STR-I	3	ksi	-48.32	-50.00	1.035
83.50	92.8	Min Reinforcement	6.10.1.7		3	in^2	9.60	10.41	1.084
90.00	100.0	Flexure	6.10.8.1.3	STR-I	3	ksi	48.50	50.00	1.031

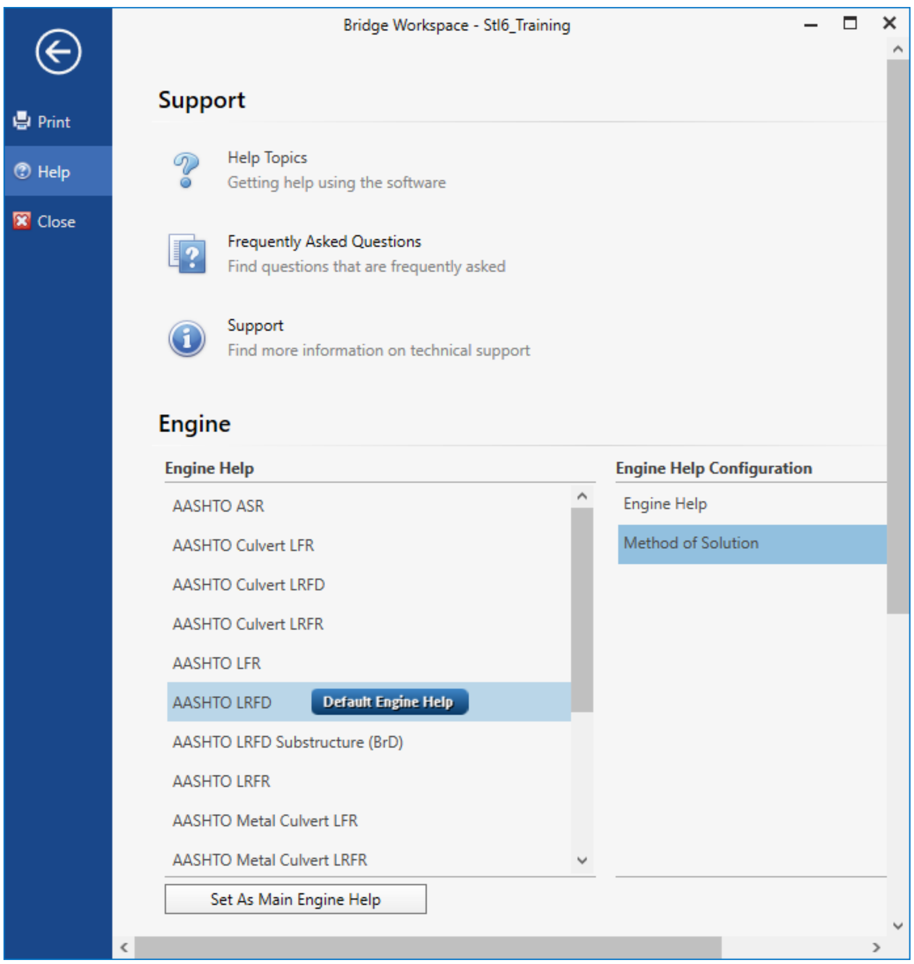
AASHTO LRFD Method of Solution

The **Method of solution** manual can be accessed from the **Help** menu in BrDR.

Click on the **Bridge Workspace** ribbon to access the **Support** menu.

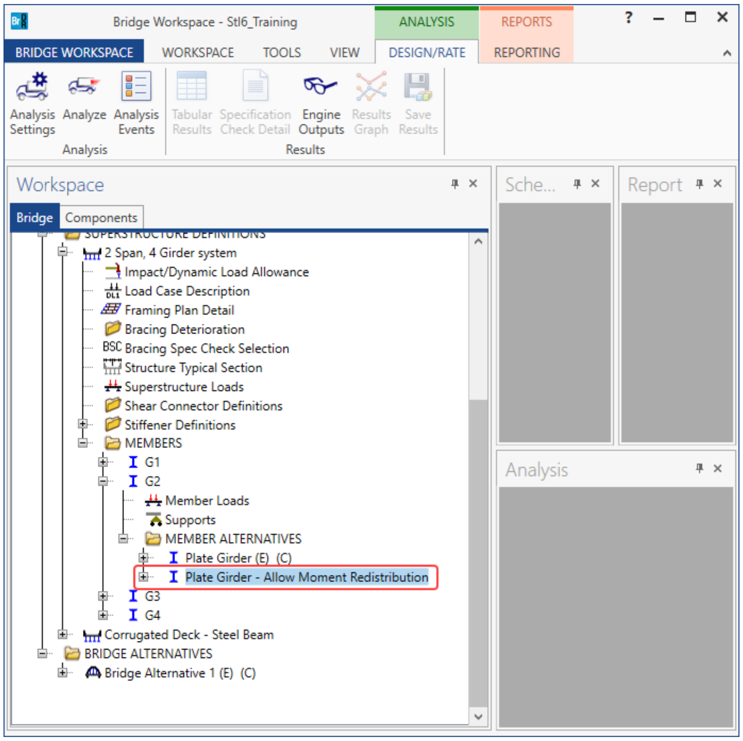


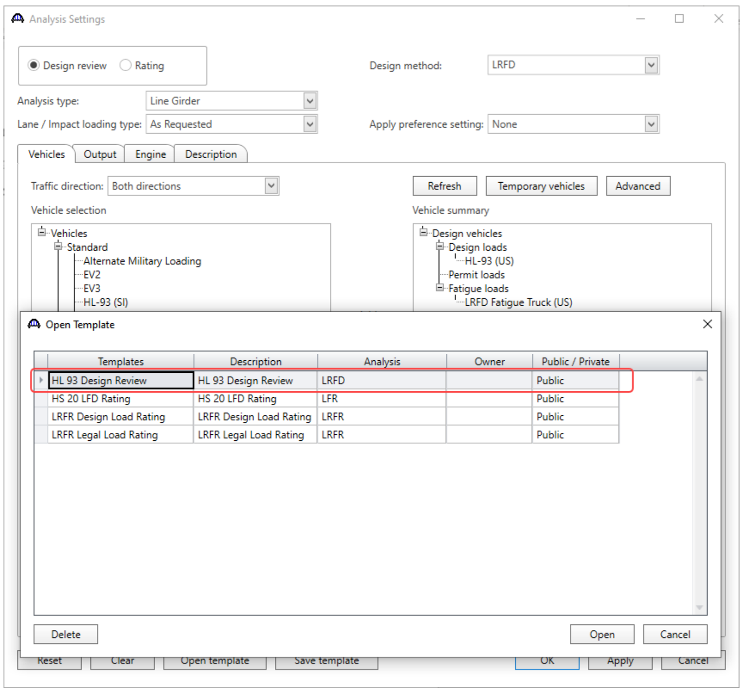
In the **Engine Help** column select **AASHTO LRFD** to access the **Engine Help** and **Method of Solution** for the selected engine. Double-click on **Method of Solution** from the **Engine Help Configuration** column to open the method of solution for the selected engine.

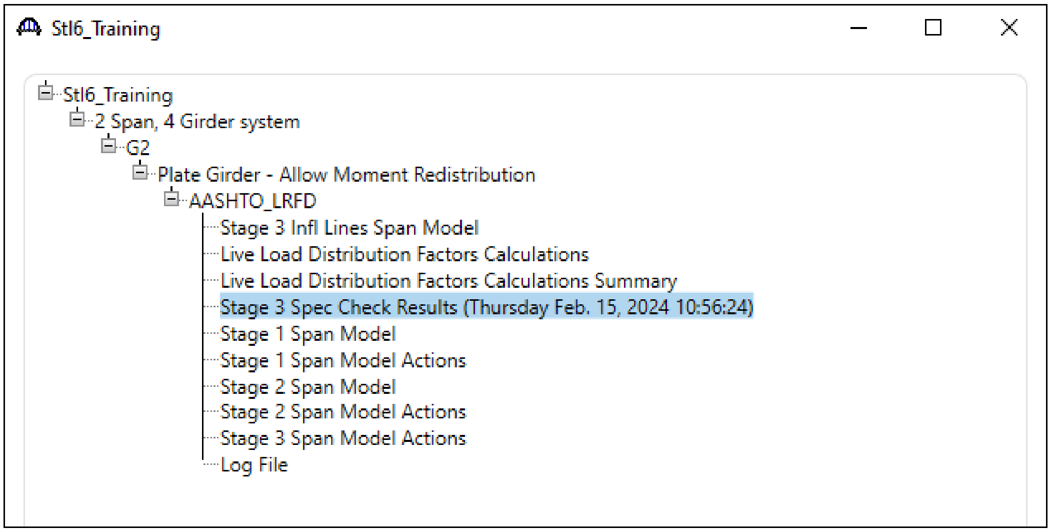


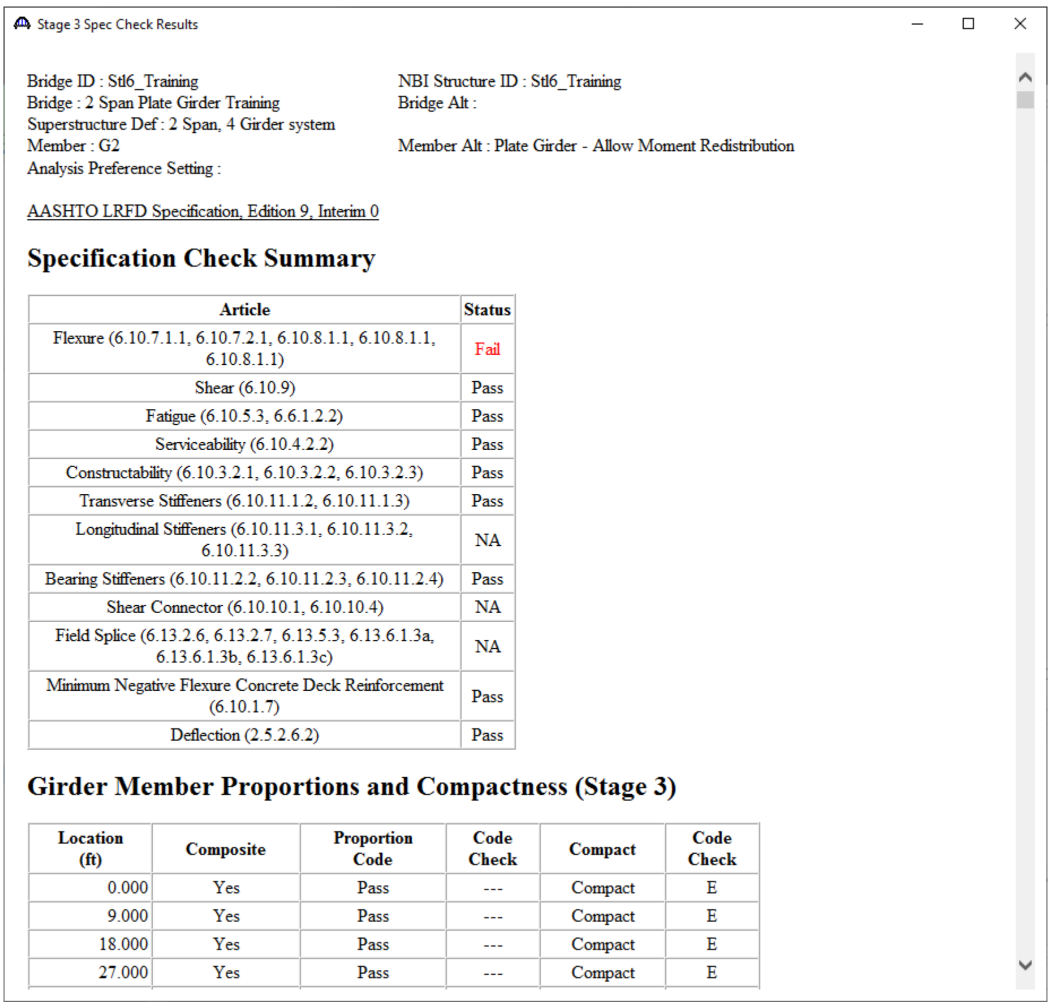
Moment Redistribution

Select the **Plate Girder – Allow Moment Redistribution** member alternative for member **G2** in **the Bridge Workspace** tree and run an LRFD design review using the **HL-93 Design Review** template. This is a streamlined version of the previous member alternative (**Plate Girder**). It does not contain any flange transitions. View the **Stage 3 - Spec Check Results** and notice that the flexure articles fails for this beam as shown below.








Stage 3 Spec Check Results

Bridge ID : Stl6_Training
Bridge : 2 Span Plate Girder Training
Superstructure Def : 2 Span, 4 Girder system
Member : G2
Analysis Preference Setting :

NBI Structure ID : Stl6_Training
Bridge Alt :

Member Alt : Plate Girder - Allow Moment Redistribution

AASHTO LRFD Specification, Edition 9, Interim 0

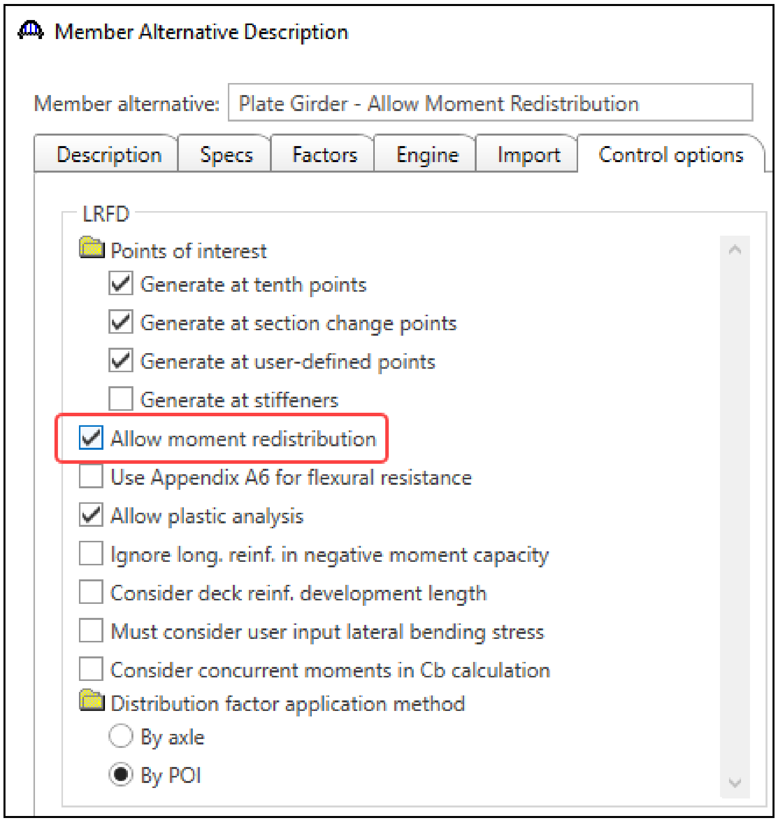
Specification Check Summary

Article	Status
Flexure (6.10.7.1.1, 6.10.7.2.1, 6.10.8.1.1, 6.10.8.1.1)	Fail
Shear (6.10.9)	Pass
Fatigue (6.10.5.3, 6.6.1.2.2)	Pass
Serviceability (6.10.4.2.2)	Pass
Constructability (6.10.3.2.1, 6.10.3.2.2, 6.10.3.2.3)	Pass
Transverse Stiffeners (6.10.11.1.2, 6.10.11.1.3)	Pass
Longitudinal Stiffeners (6.10.11.3.1, 6.10.11.3.2, 6.10.11.3.3)	NA
Bearing Stiffeners (6.10.11.2.2, 6.10.11.2.3, 6.10.11.2.4)	Pass
Shear Connector (6.10.10.1, 6.10.10.4)	NA
Field Splice (6.13.2.6, 6.13.2.7, 6.13.5.3, 6.13.6.1.3a, 6.13.6.1.3b, 6.13.6.1.3c)	NA
Minimum Negative Flexure Concrete Deck Reinforcement (6.10.1.7)	Pass
Deflection (2.5.2.6.2)	Pass

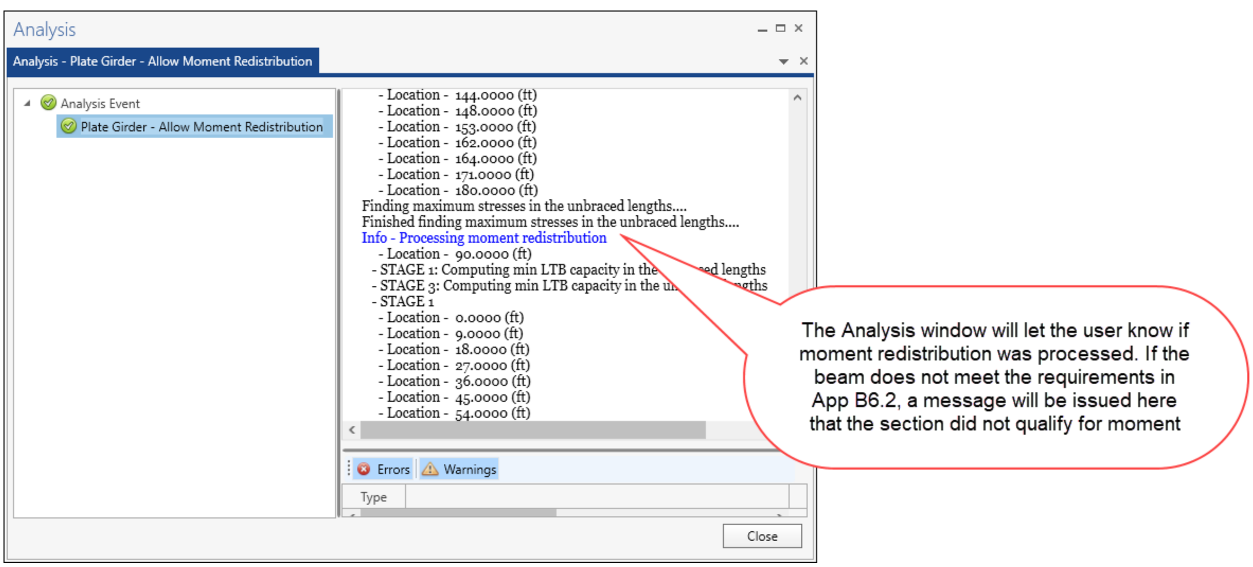
Girder Member Proportions and Compactness (Stage 3)

Location (ft)	Composite	Proportion Code	Code Check	Compact	Code Check
0.000	Yes	Pass	---	Compact	E
9.000	Yes	Pass	---	Compact	E
18.000	Yes	Pass	---	Compact	E
27.000	Yes	Pass	---	Compact	E

Navigate the **Member Alternative Description** window – **Control options** tab for this member alternative (**Plate Girder – Allow Moment Redistribution),** check the box **Allow moment redistribution** under **LRFD** to allow moment redistribution as shown below.



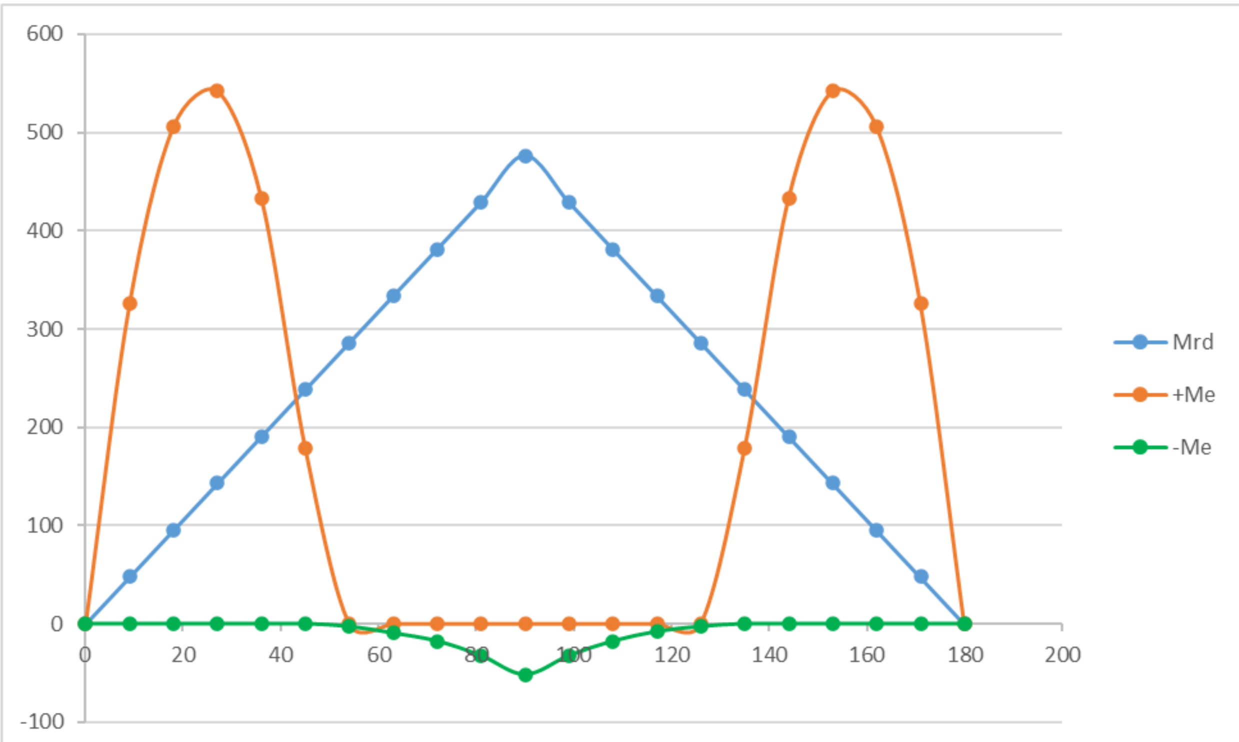
Re-run the **LRFD design review** for **HL-93 Design Review** template.



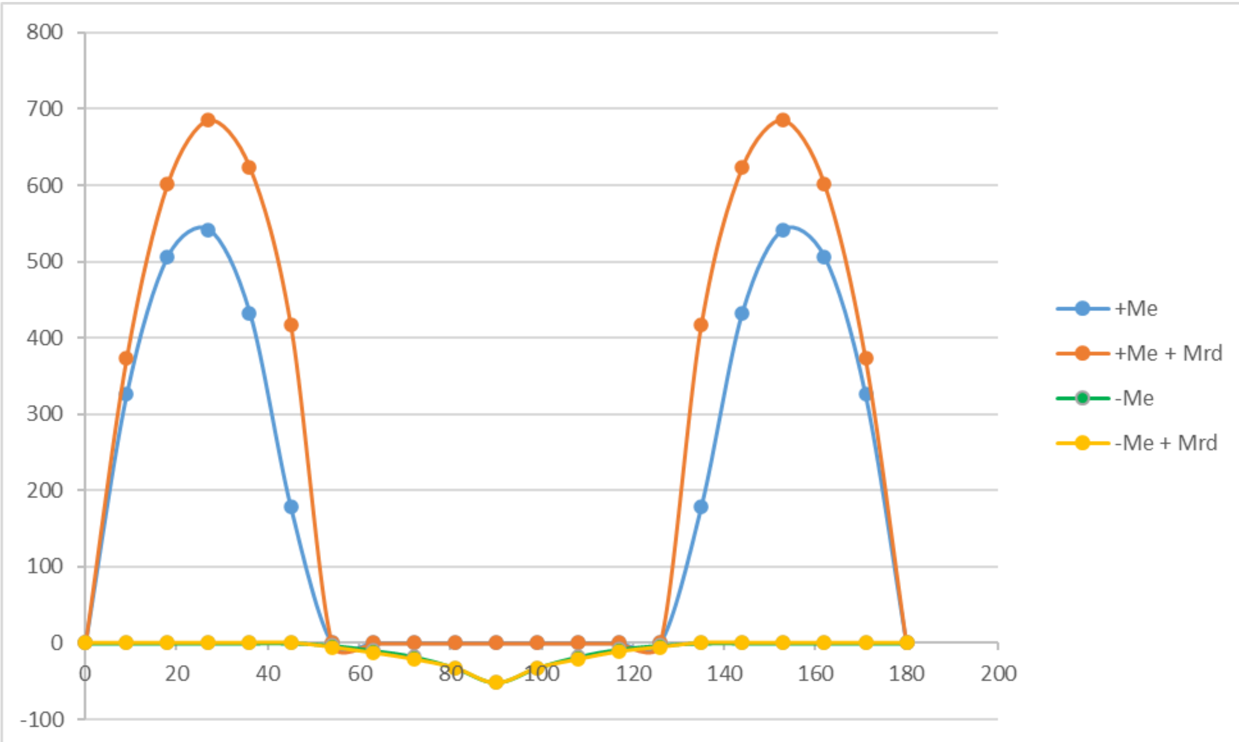
Moment redistribution takes some of the negative moment at the pier and distributes it to the positive moment regions. After the elastic stresses are computed in the first phase of spec checks, the articles in Appendix B6.2 are evaluated to determine if moment redistribution is permissible. If it is permissible, the effective plastic moment at the piers is determined. This moment is then used to compute the redistribution moments, Mrd, at the piers and at all other points using linear interpolation. After the redistribution moments are computed, the stresses due to the redistribution moments are computed. The redistribution stresses are then combined with the elastic stresses and the flexure type is re-determined for this total stress.

The specification articles then considers the redistribution stresses when computing the design ratios.

The following sketch shows the elastic moment envelope for Strength I and the computed Mrd envelope.

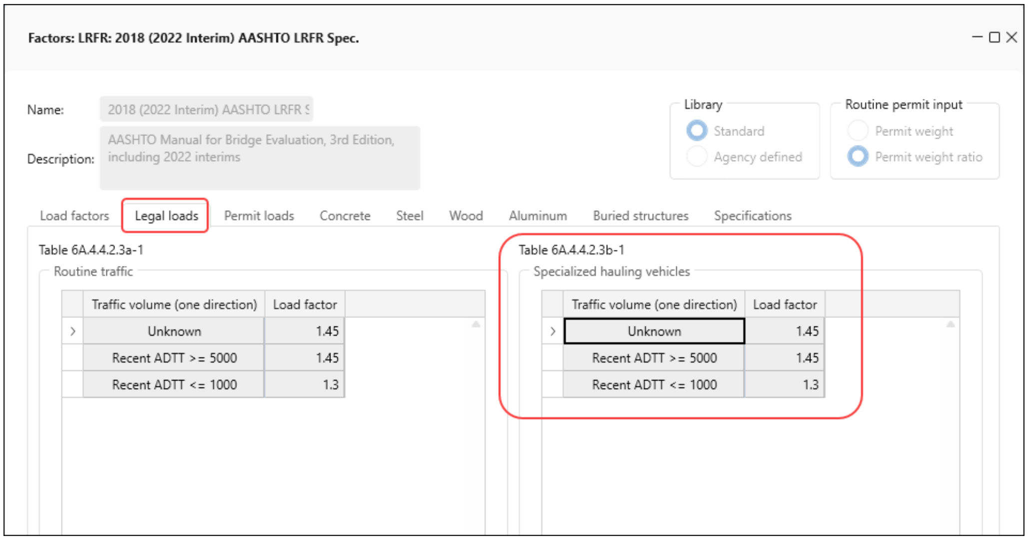


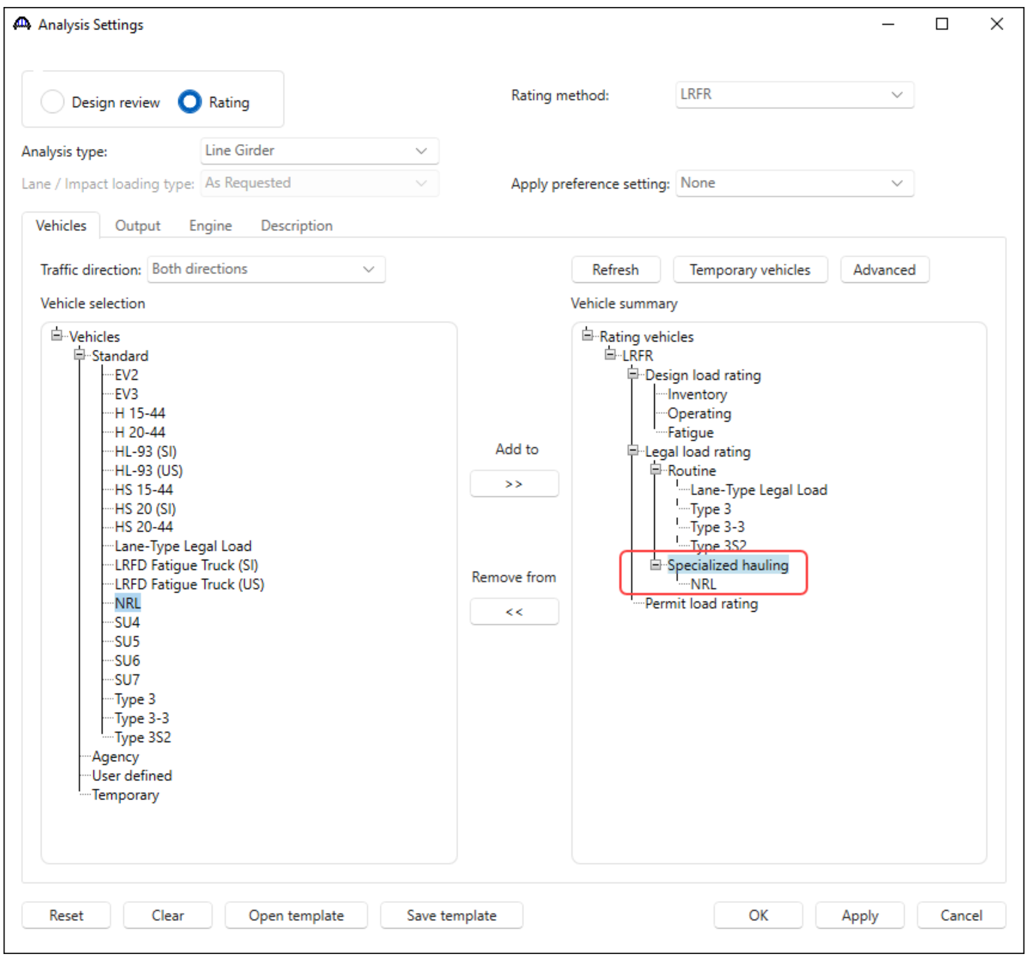
The following sketch shows how the redistribution moments increase the positive moments and reduce the negative moments.



Specialized Hauling Vehicles (SHV's)

A new category of **Legal loads** is available as per the MBE specifications. (See image below)





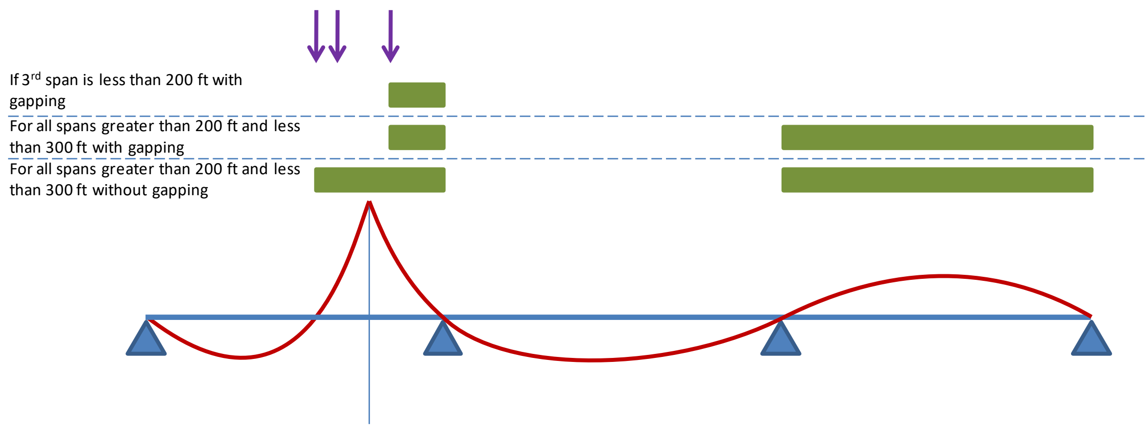
Permit Lane Load and "Gapping"

BrDR provides the ability to enter a lane load to be applied with a permit truck as specified by the MBE. Where the truck is placed the lane load is to be removed or **gapped**. The MBE does also allow the lane load to be superimposed on top of the permit vehicle for ease of analysis.

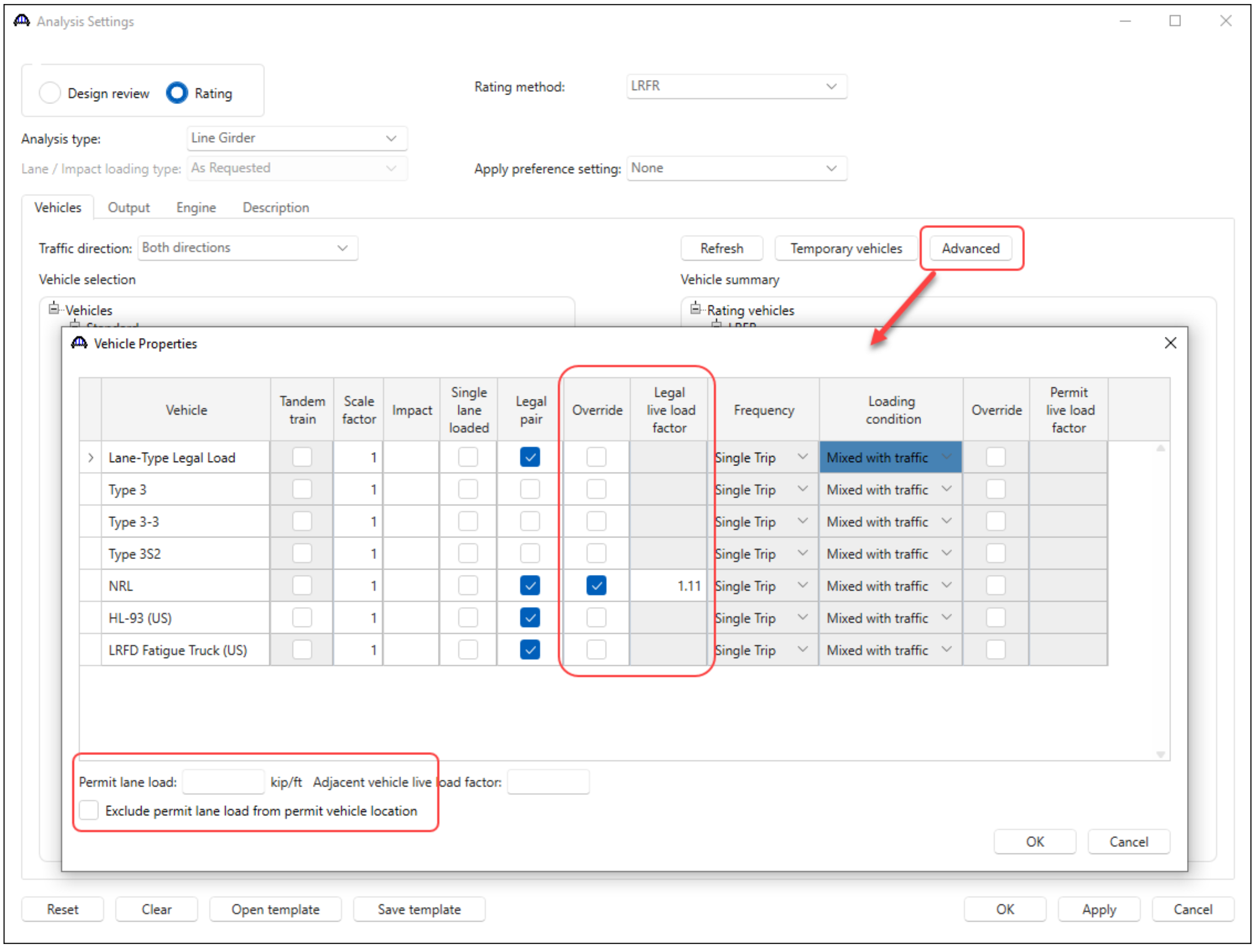
The permit lane load is applied as follows:

- For negative moment - lane load should always be applied for negative moment regions regardless of span length.
- For positive moment - apply the lane load for span length between 200 and 300 feet regardless of where the point of interest is.

The following illustrates this procedure for positive moment.



To exclude the lane load where the permit truck is placed, click on **Exclude permit lane load from permit vehicle location** in the **Vehicle Properties** window as shown below.



The user may also override the internal **Legal load live load factor** as shown above.