AASHTOWare BrDR 7.5.0

3D FEM Analysis Tutorial

Steel Diaphragm and Lateral Bracing Specification Checking Example

BrDR Training

3DFEM1 - Steel Diaphragm and Lateral Bracing Specification Checking Example

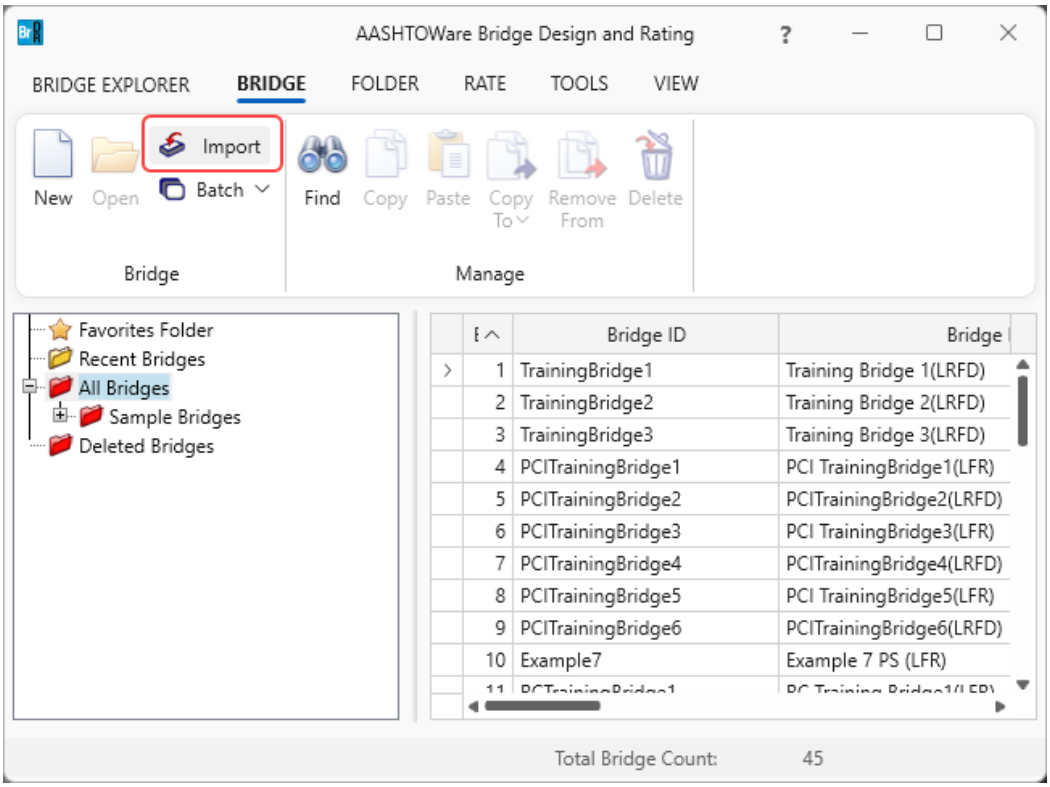
Topics Covered

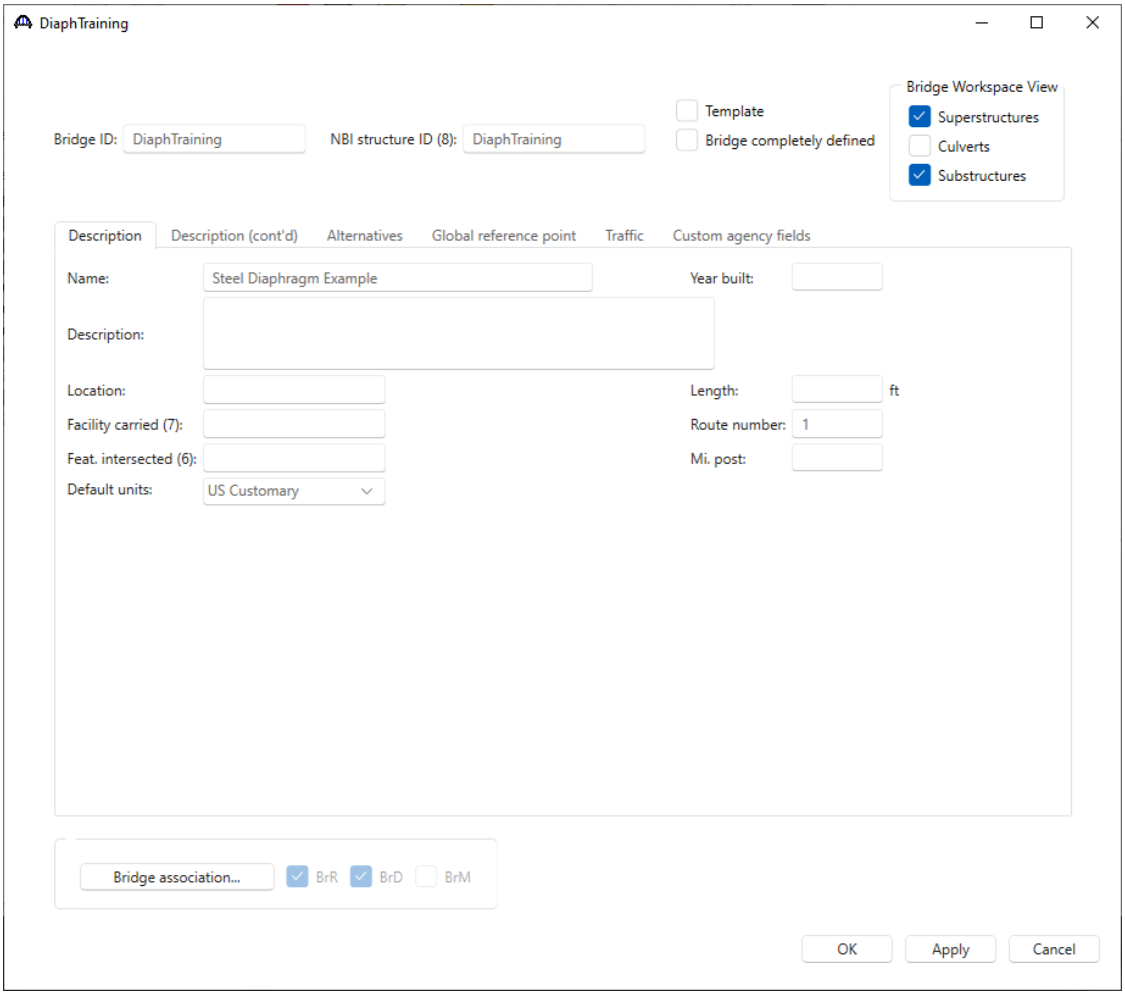
- Steel Diaphragm Connection Data Entry
- Bracing Deterioration
- Bracing Specification Checking

Steel Diaphragm Connection Data Entry

This example describes data entry and specification checking for a steel diaphragm. Bottom flange lateral bracing members have the same features as diaphragms.

From the **Bridge Explorer**, import the **3DFEM1-Diaphragm-Spec-Checking.xml** file provided with this tutorial into **BrDR**.

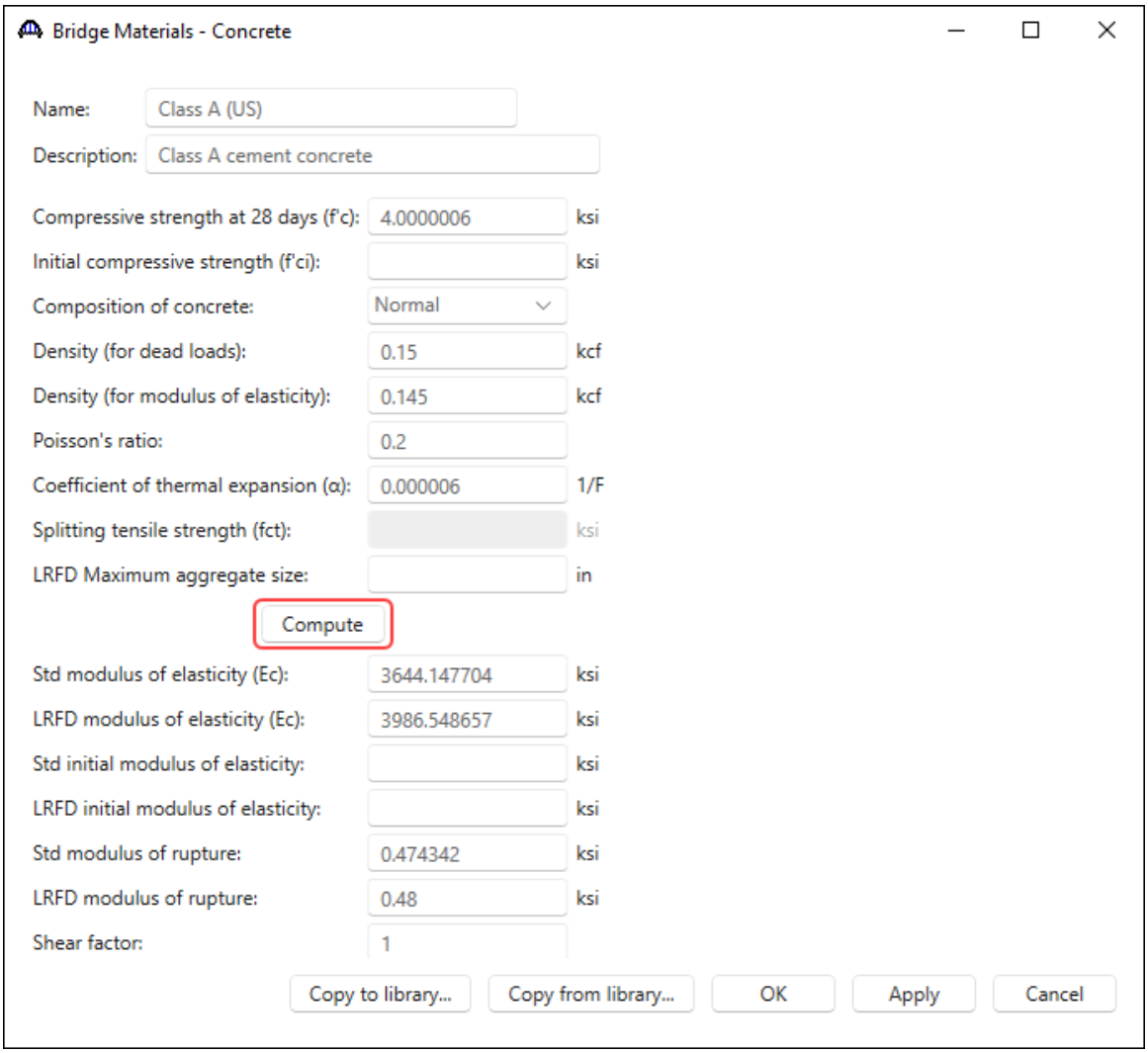




Click **OK** to close the **Bridge** window.

Bridge Materials – Concrete

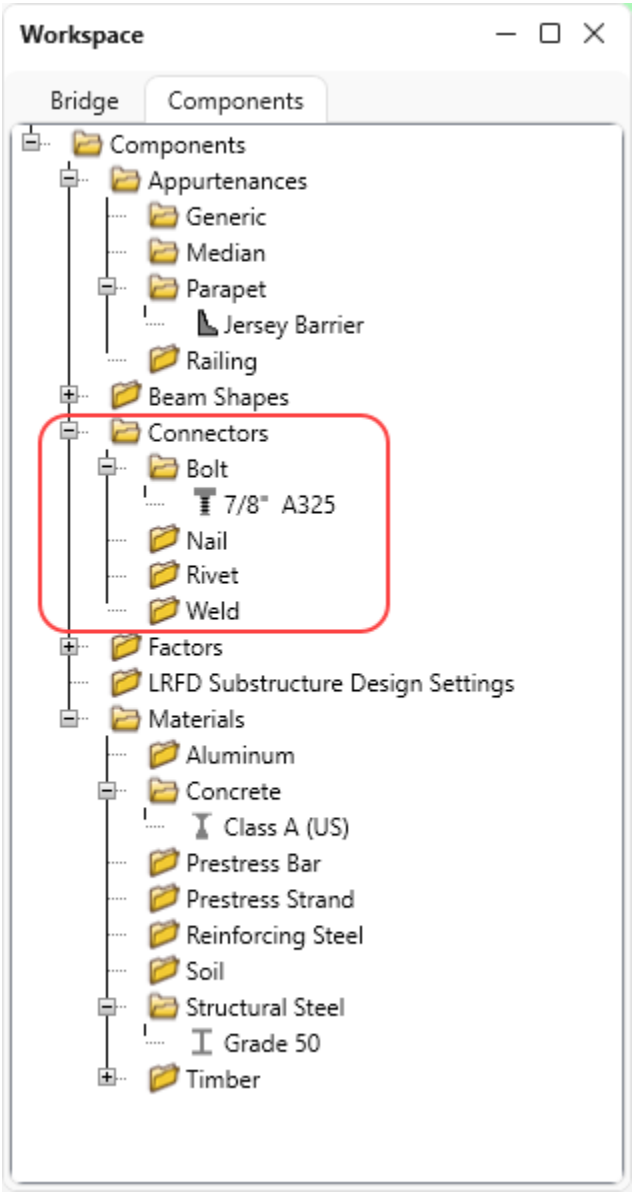
Navigate to the **Components** tab of the **Bridge Workspace** and expand the **Materials** -> **Concrete** folders. Double click on the **Class A (US)** concrete material. Click on the **Compute** button to compute the values based on the input.



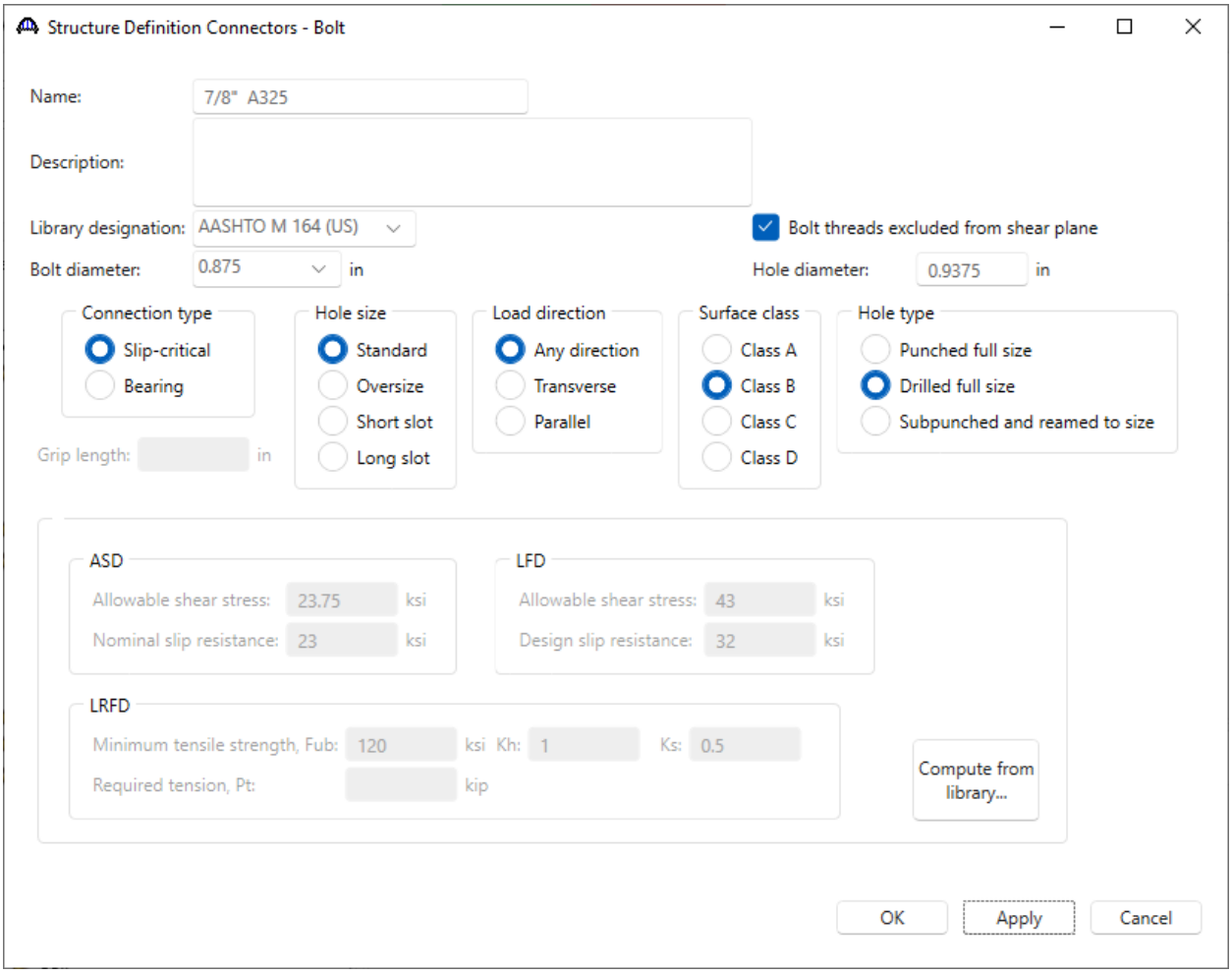
Click **OK** to apply the data and close the window.

Connectors

In the **Components** tab of the **Bridge Workspace** and expand the **Connectors** node. The **Connectors** folder is provided to add **Bolt**, **Nail**, **Rivet** and **Weld** definitions.

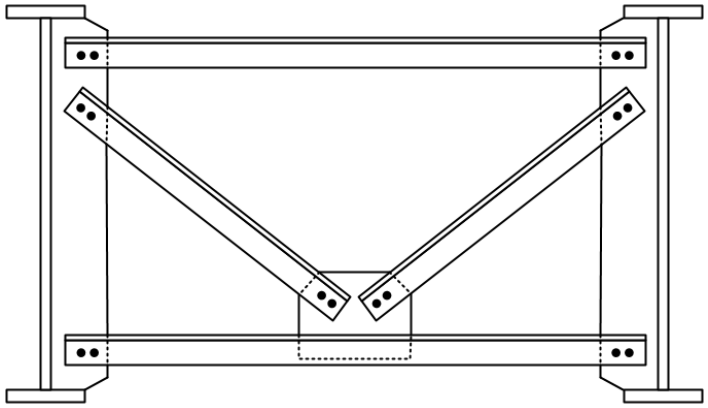


Double click on the **7/8" A325** bolt definition to review the bolt to be used in the diaphragms.

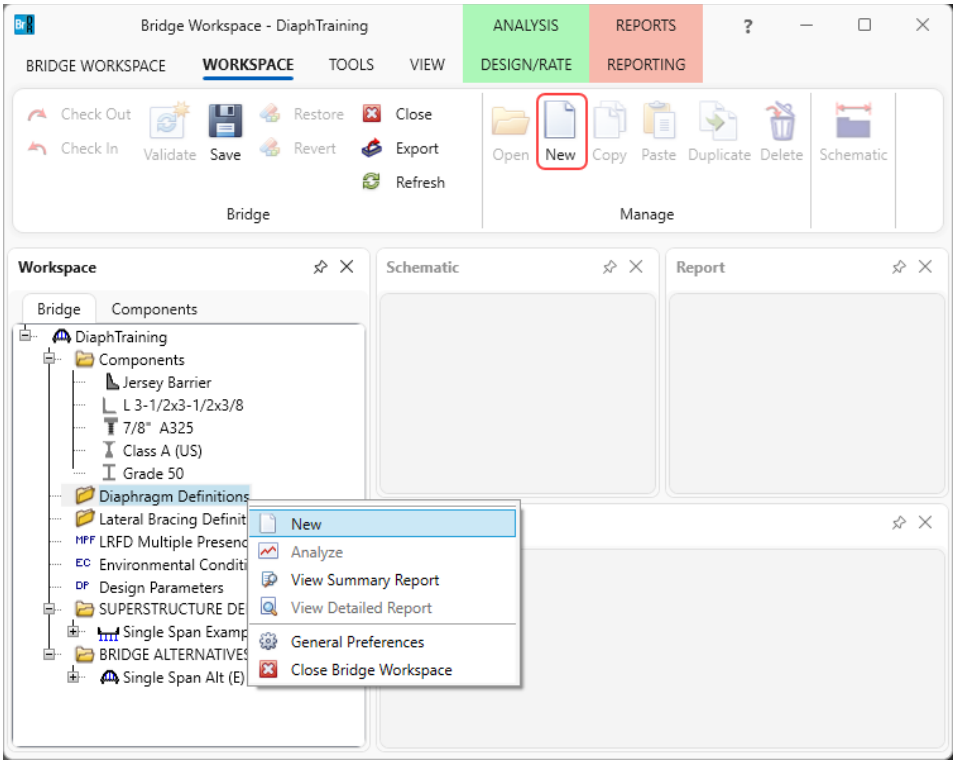


Diaphragm Definitions

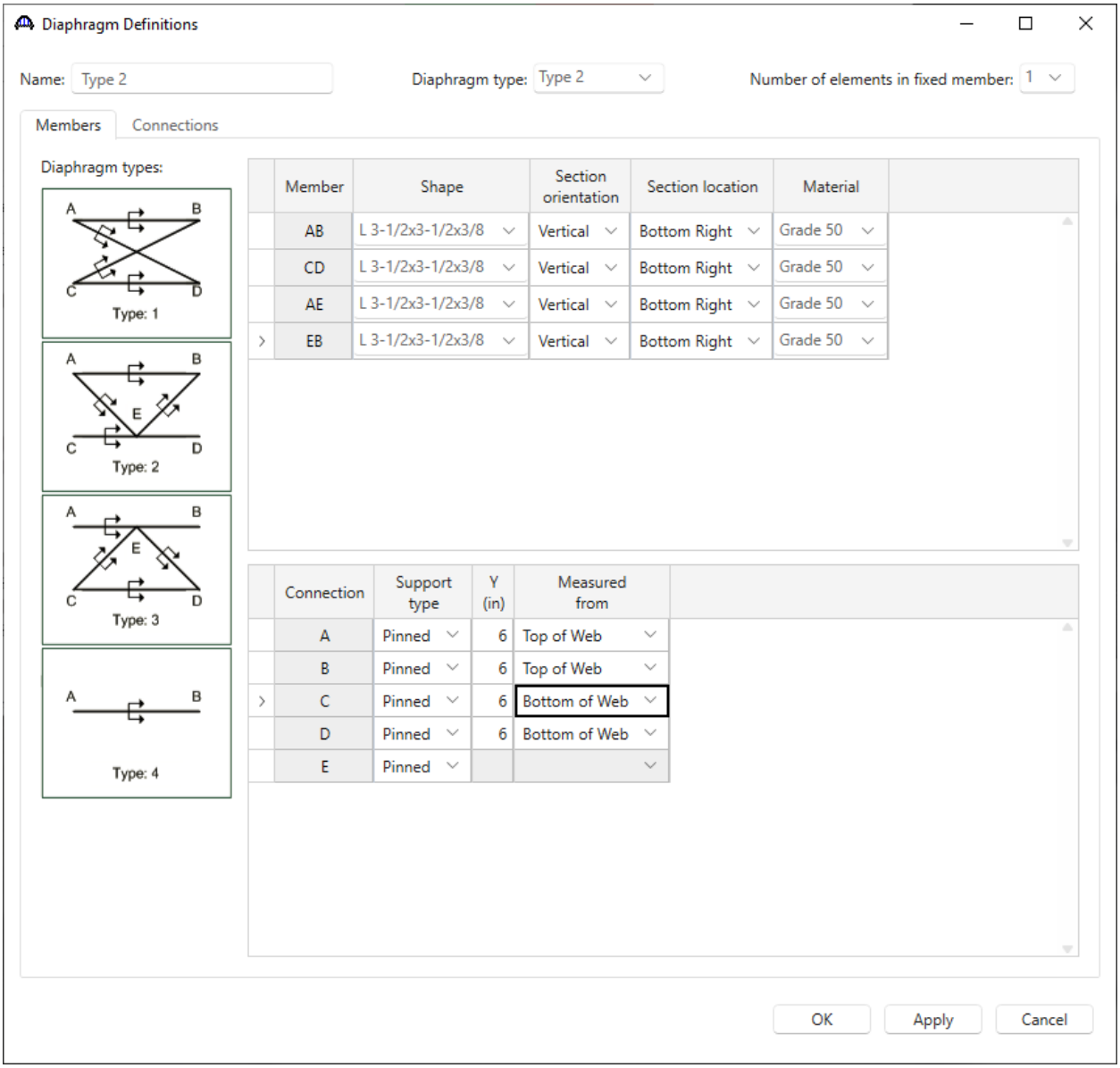
The following sketch illustrates the intermediate diaphragm that will be described for this example.



Navigate to the **Bridge** tab of the **Bridge Workspace** tree and double-click on the **Diaphragm Definitions** folder (or click on **New** from the **Manage** group of the **WORKSPACE** ribbon, or right click and select **New**) to create a new diaphragm definition as shown below.

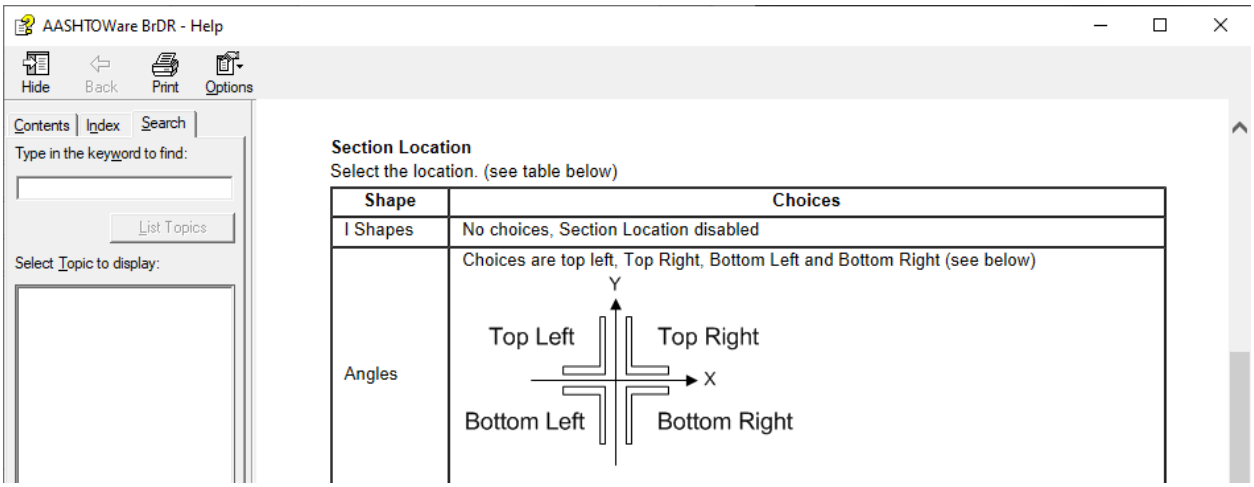


Create the following diaphragm definition.

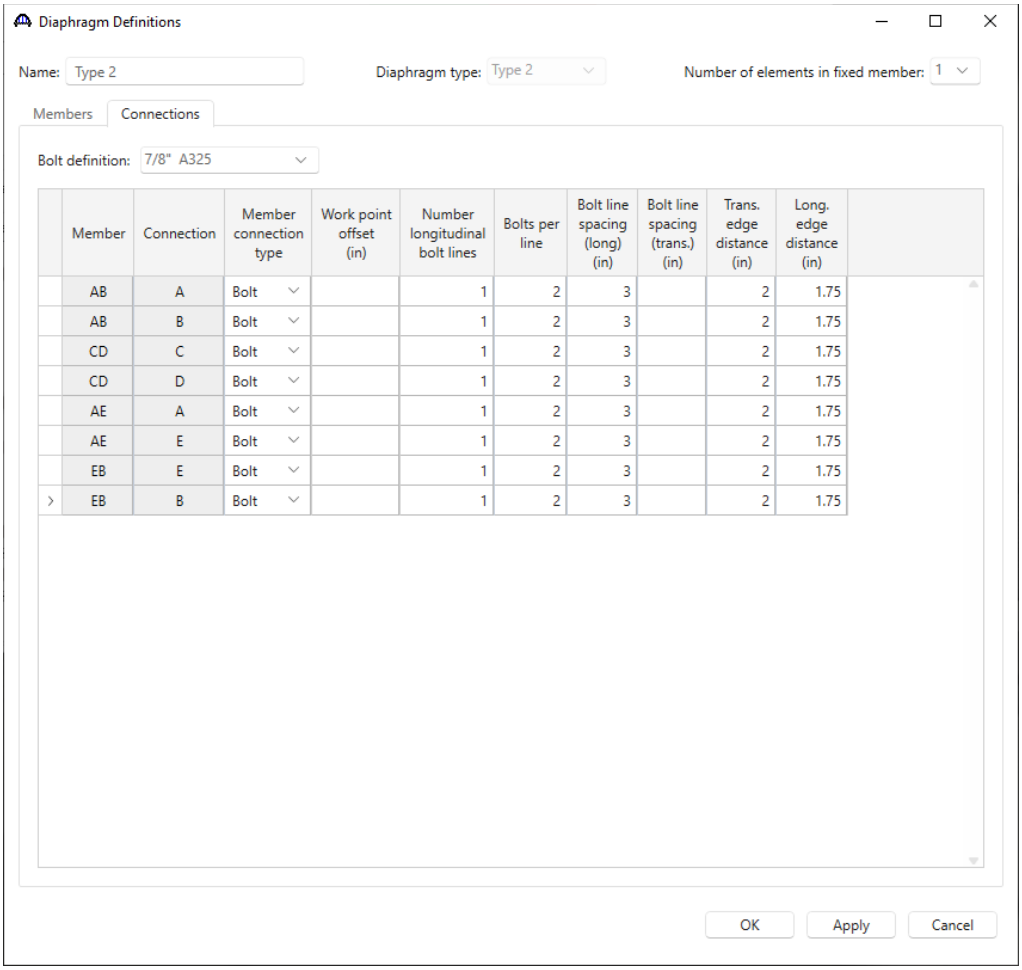


Click the **Apply** button to save.

The following sketch from the **AASHTOWare BrDR Help** illustrates the **Section Location** selection. This can be accessed by hitting the **F1** key on this window.



Navigate to the **Connections** tab. Enter the following data to describe the bolts in the diaphragm.

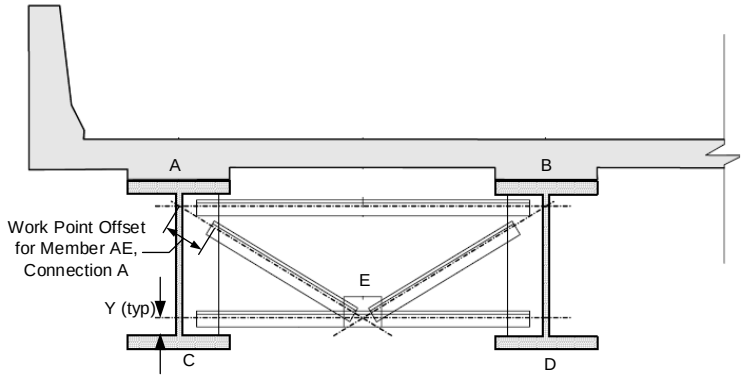


Member	Connection	Member connection type	Work point offset (in)	Number longitudinal bolt lines	Bolts per line	Bolt line spacing (long) (in)	Bolt line spacing (trans.) (in)	Trans. edge distance (in)	Long. edge distance (in)
AB	A	Bolt		1	2	3		2	1.75
AB	B	Bolt		1	2	3		2	1.75
CD	C	Bolt		1	2	3		2	1.75
CD	D	Bolt		1	2	3		2	1.75
AE	A	Bolt		1	2	3		2	1.75
AE	E	Bolt		1	2	3		2	1.75
EB	E	Bolt		1	2	3		2	1.75
EB	B	Bolt		1	2	3		2	1.75

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

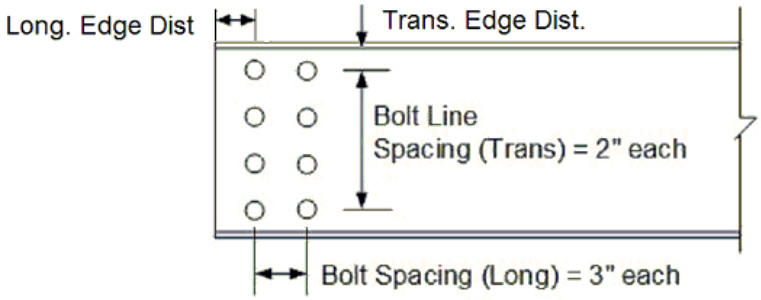
The following sketch from the **AASHTOWare BrDR Help** provides a description of the **Work Point Offset**. This can be accessed by hitting the **F1** key on this window.

Description of the Work Point Offset:



Dashed lines show the member lengths as computed based on the girder spacing and Y offsets entered by the user. The user can enter the Work Point Offset shown to reduce the length of member AE used in the slenderness ratio (Kl/r) calculations.

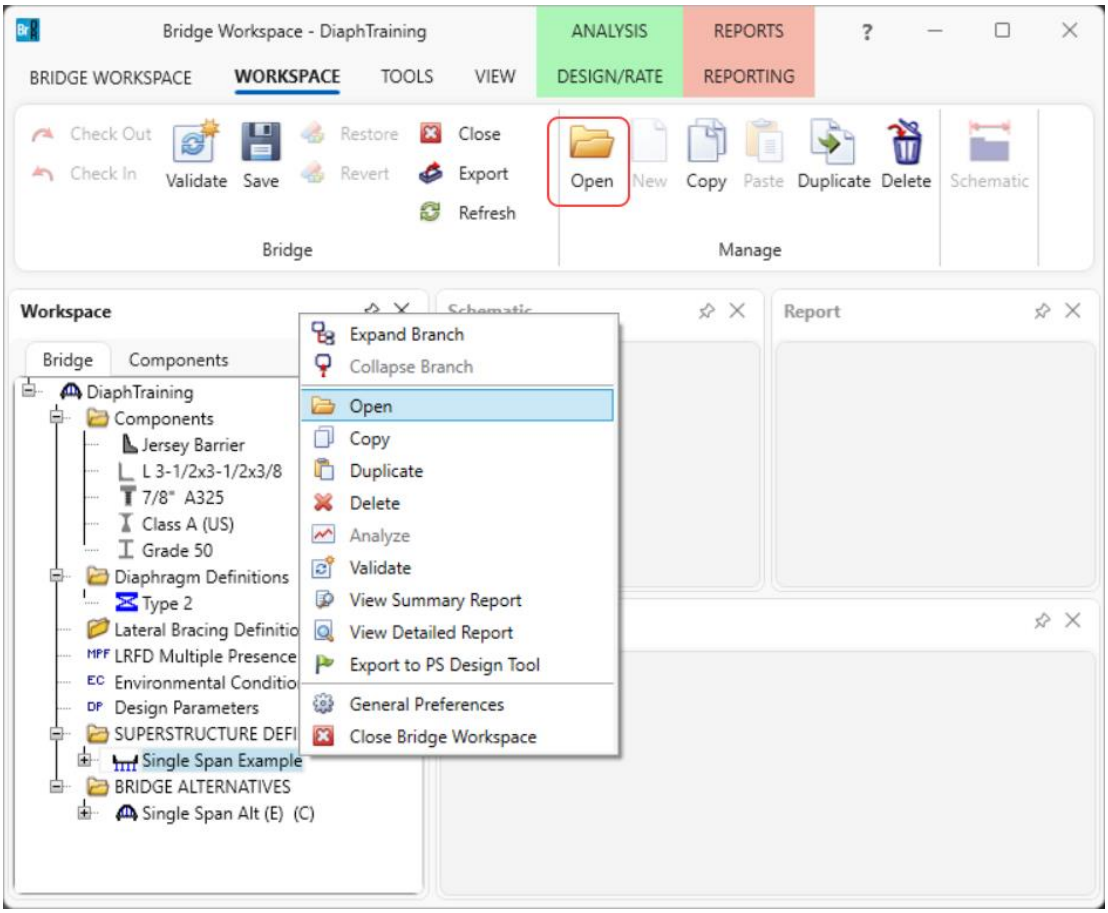
The following sketch from the **AASHTOWare BrDR Help** describes the bolt entry fields. For this example, 1 longitudinal bolt line that contains 2 bolts per line is described.



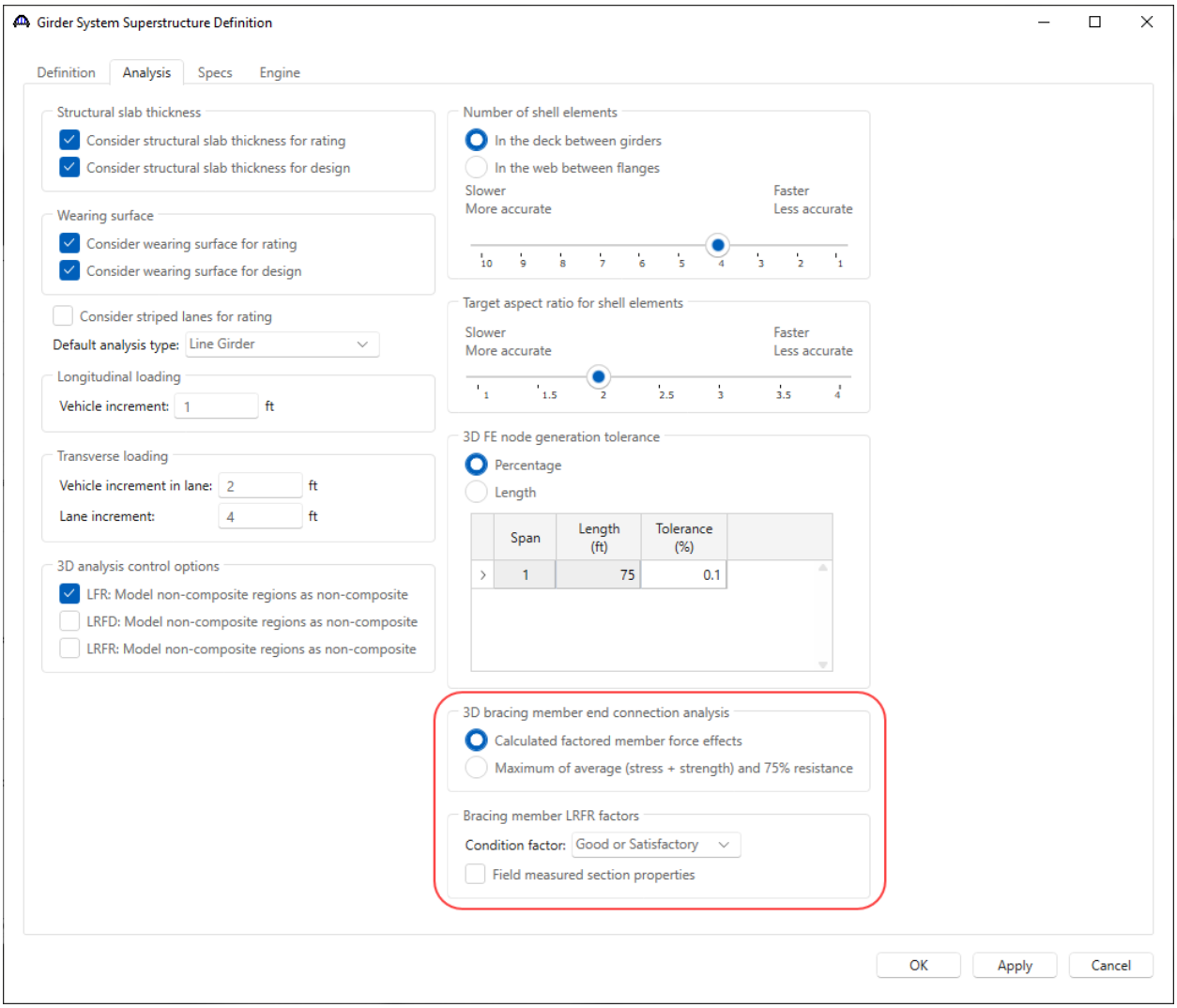
After reviewing the **AASHTOWare BrDR Help**, click **OK** on the **Diaphragm Definitions** window to create the diaphragm and close the window.

Girder System Superstructure Definition

Double click on the superstructure definition **Single Span Example** in the **Bridge Workspace** tree (or click **Open** from the **Manage** group of the **WORKSPACE** ribbon, or right click and select **Open**) and navigate to the **Analysis** tab**.**



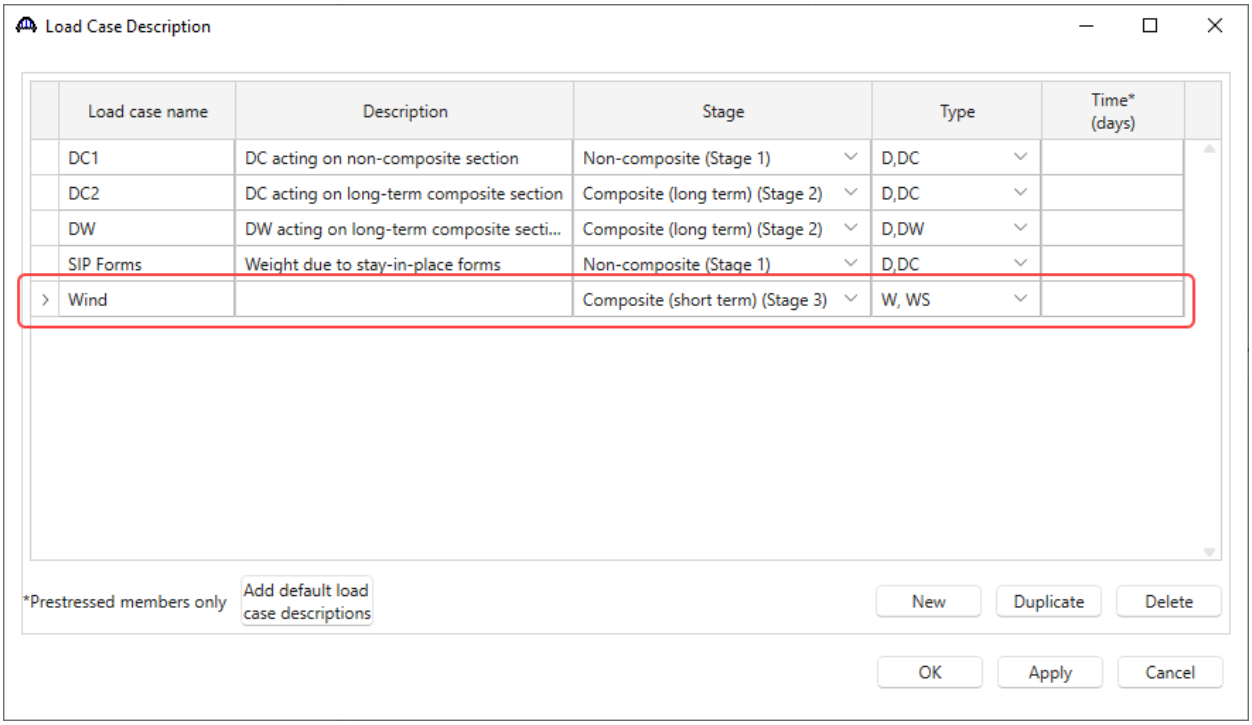
The following options on the **Analysis** tab of the **Girder System Superstructure Definition** window control the bracing specification checking. Options under **3D bracing member end connection analysis** allows the user to specify what forces should be used when connection specification checking is implemented in the future. The **Bracing member LRFR factor** data selected here will be used for all bracing members unless the bracing member has different factor data entered on the **Bracing Deterioration** window.



Select the options shown above and click **OK** to apply the selections and close the window.

Load Case Description

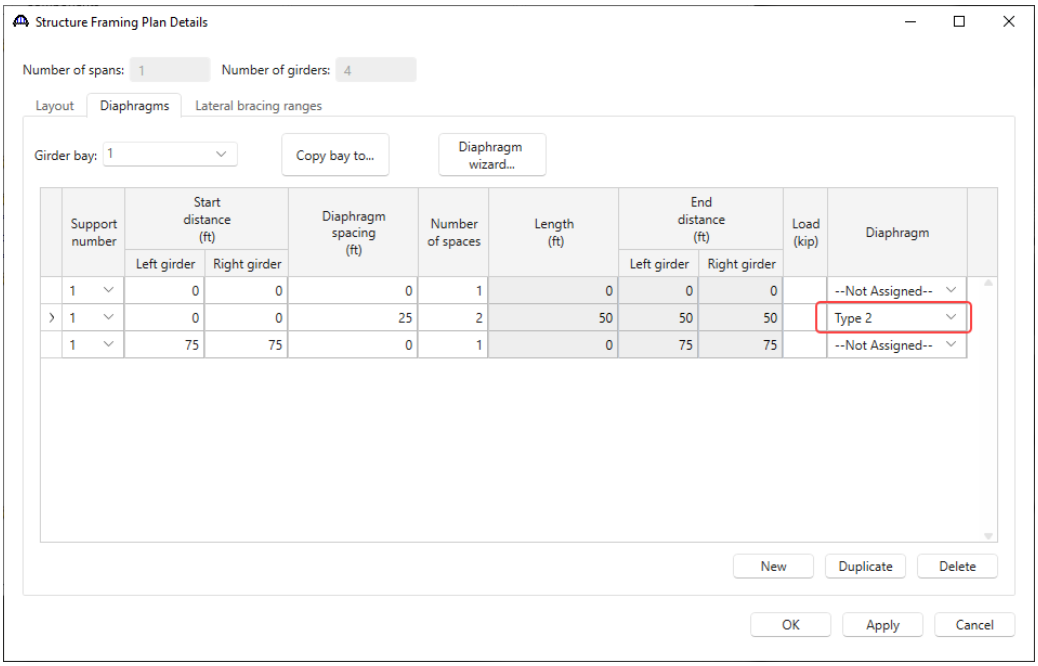
The finite element analysis can consider wind load applied to the FE model. Open the **Load Case Description** window by double clicking on the **Load Case Description** node in the **Bridge Workspace** tree. Add the following load case for the wind load.



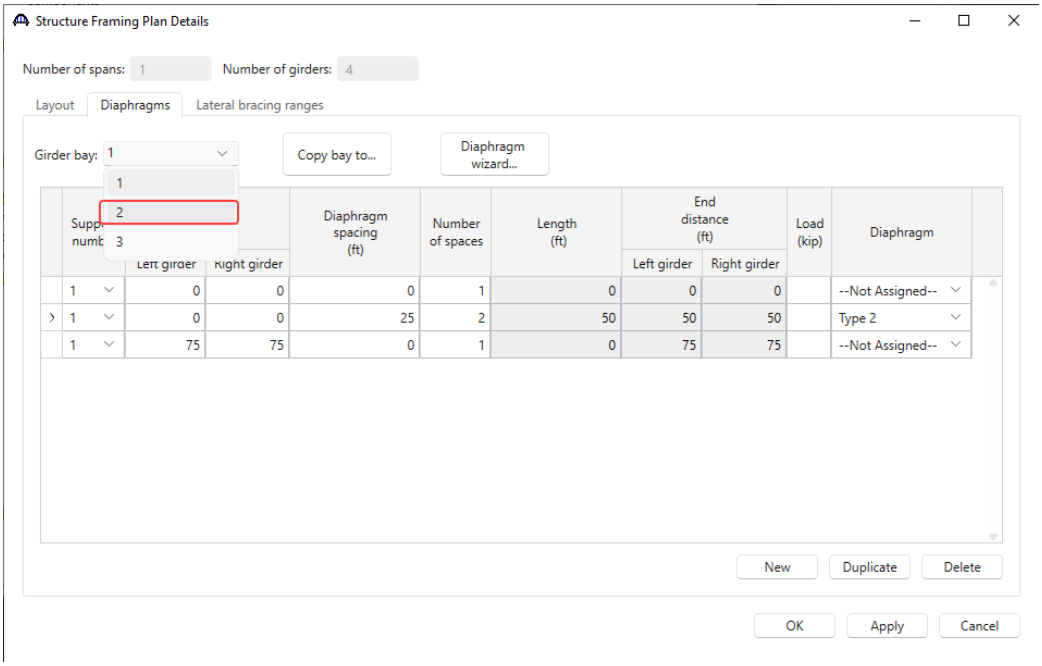
Click **OK** to apply the data and close the window.

Framing Plan Details

Double click on the **Framing Plan Detail** node in the **Bridge Workspace tree** and navigate to the Diaphragms tab. Assign the diaphragm definitions to the interior diaphragm locations for all 3 girder bays as shown below.

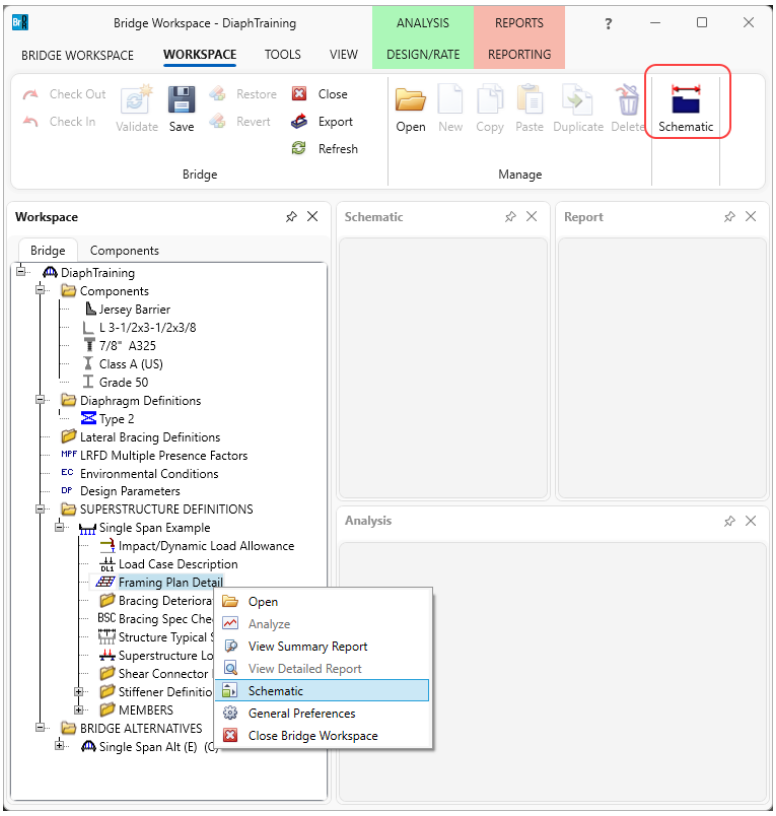


Select **Girder bay 2** from the drop down options and apply the same diaphragm definition. Do this for **Girder bay 3** as well. Once done, click **OK** to apply the data and close the window.

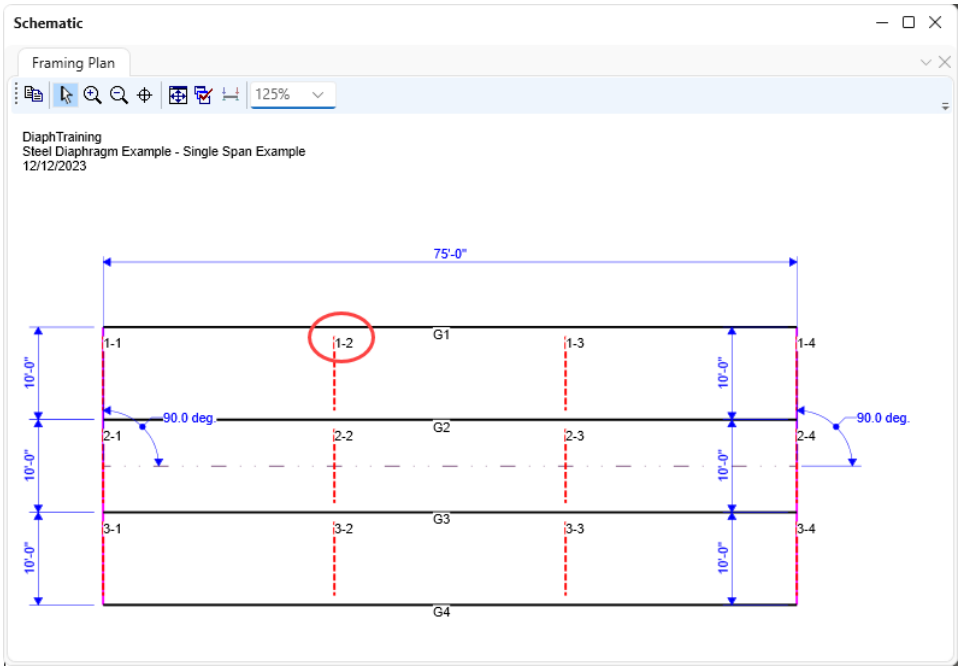


Schematic – Framing Plan Details

With **Framing Plan Detail** selected in the **Bridge Workspace** tree, click on the **Schematic** button on the **WORKSPACE** ribbon (or right click and select **Schematic**) to view the framing plan as shown below.

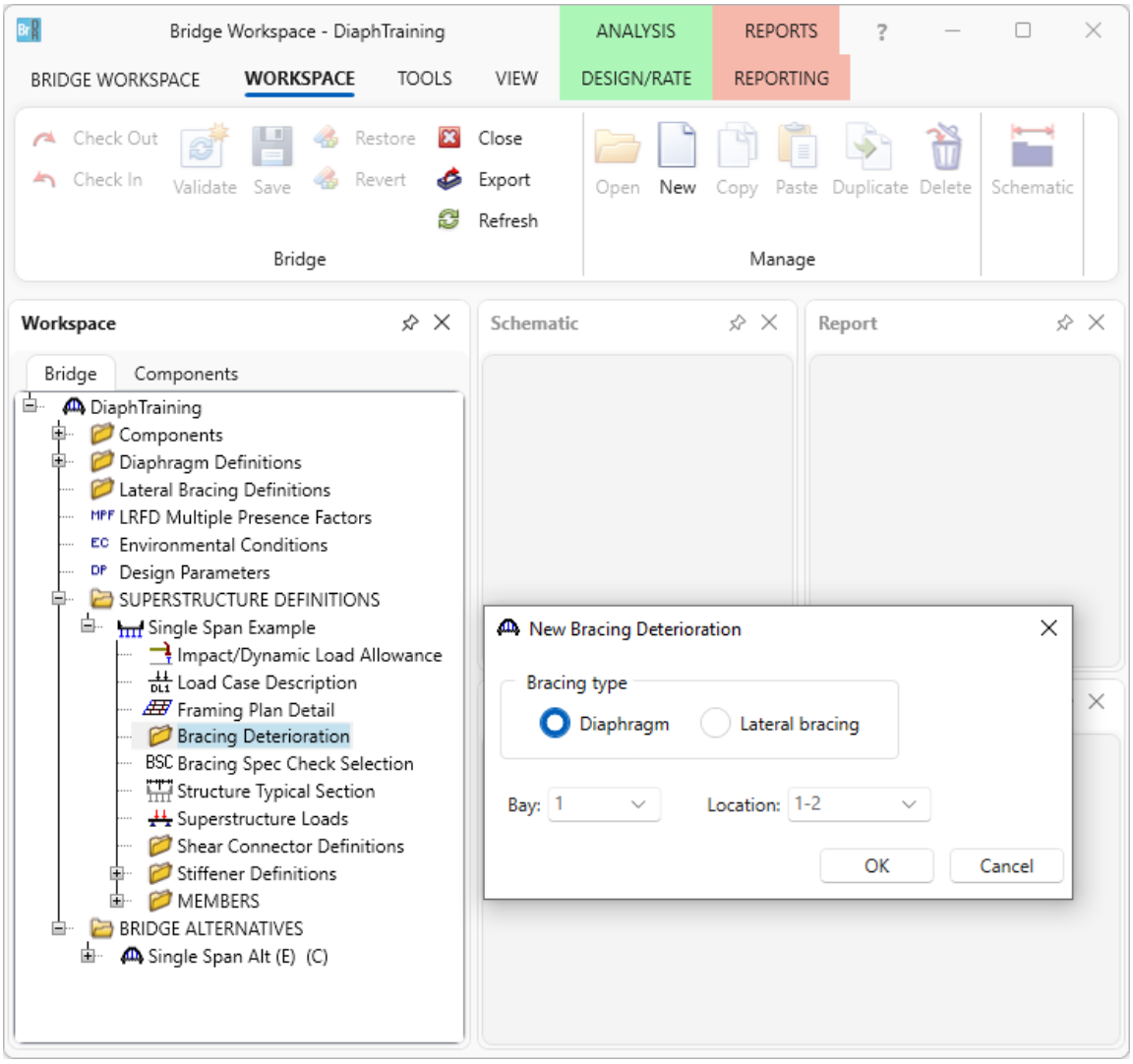


The **Framing Plan Schematic** displays the location labels for the bracing members as shown below.

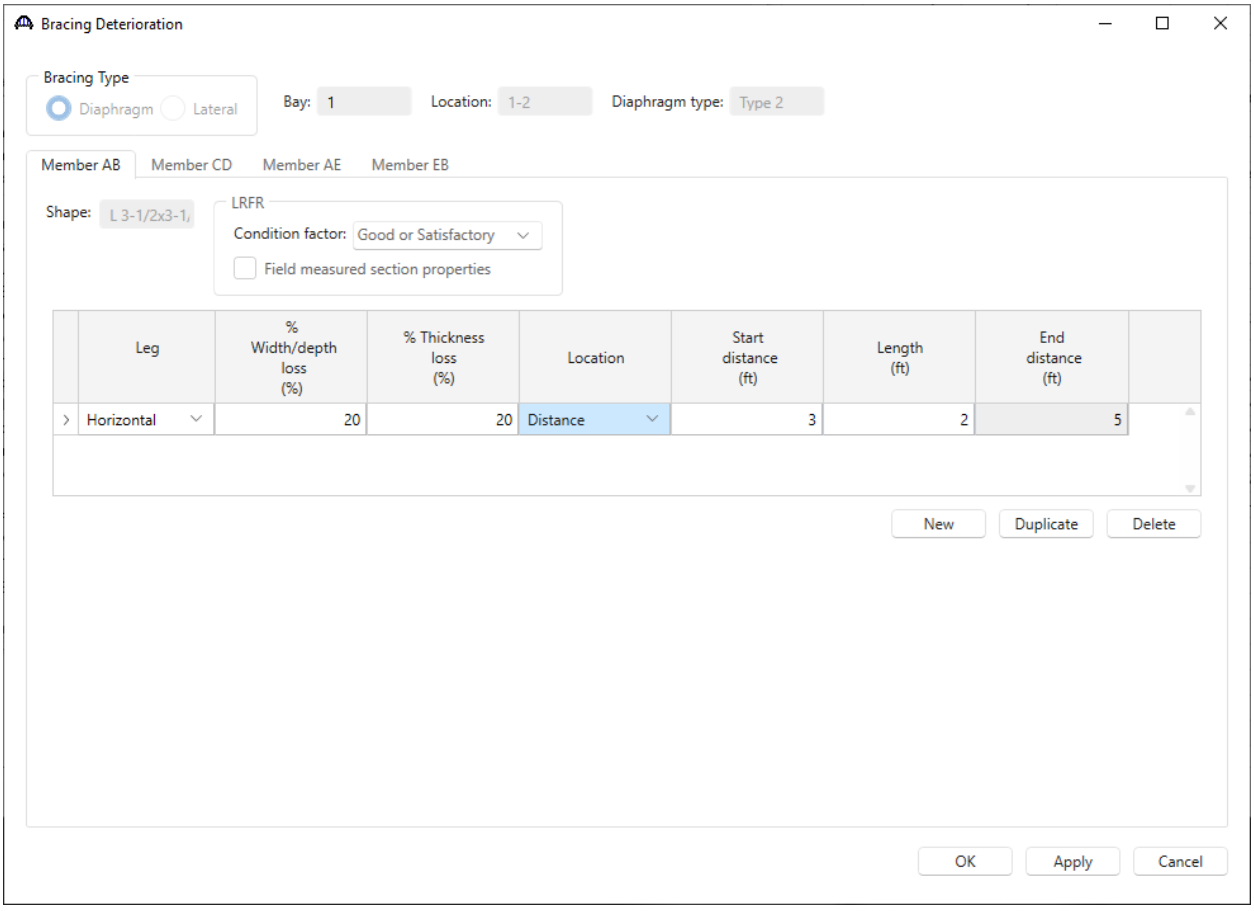


Bracing Deterioration

The **Bracing Deterioration** window allows the user to describe deterioration on the bracing members. Double-click on the **Bracing Deterioration** node in the **BWS** tree and create a new deterioration description for the diaphragm assigned to **Location 1-2** in **Bay 1** as shown below.



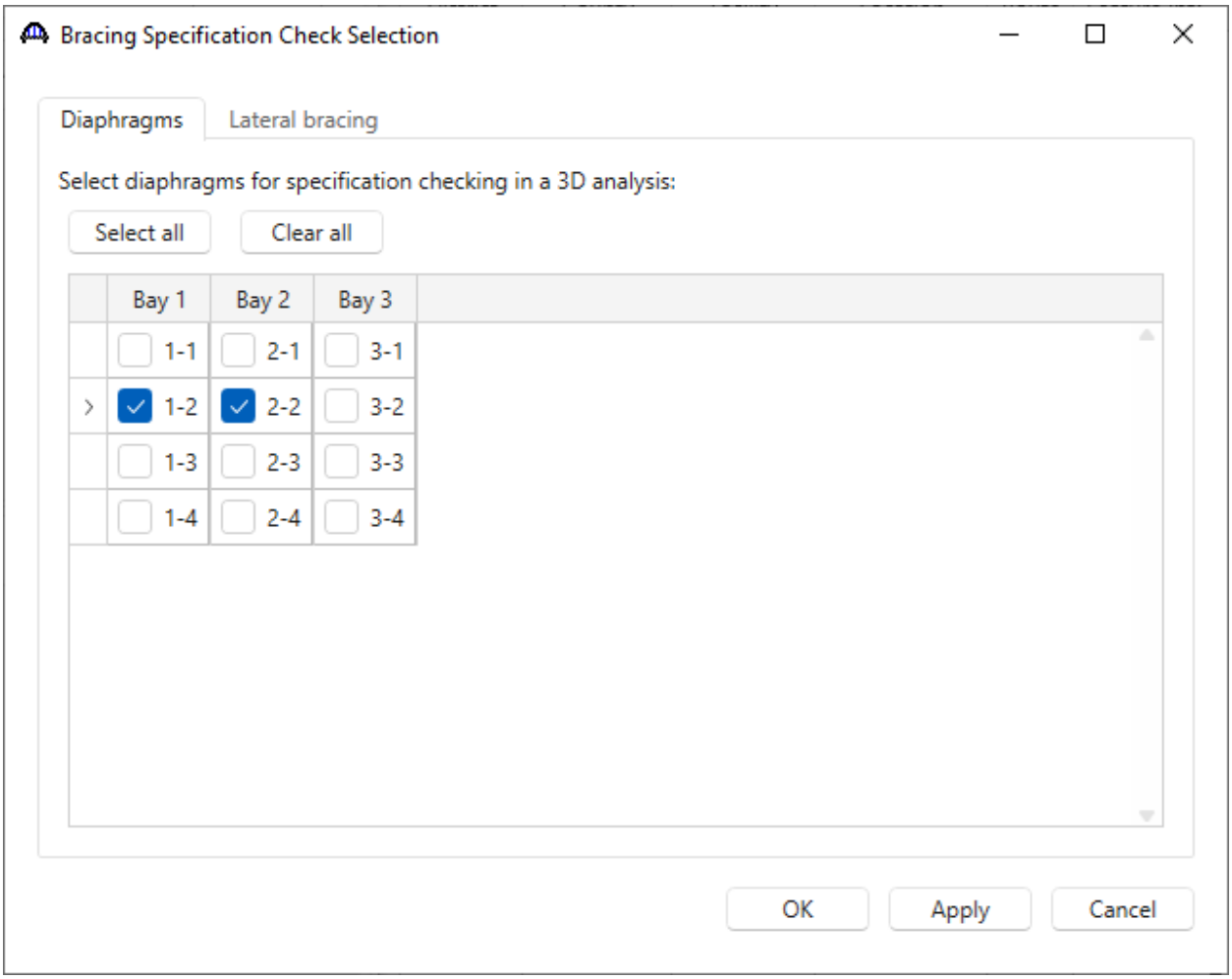
Enter the following values for section loss on **Member AB**. This section loss will be used in rating, not in design review. The superstructure definition **LRFR Condition factor** can also be overriden for this particular member on this tab.



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

Bracing Spec Check Selection

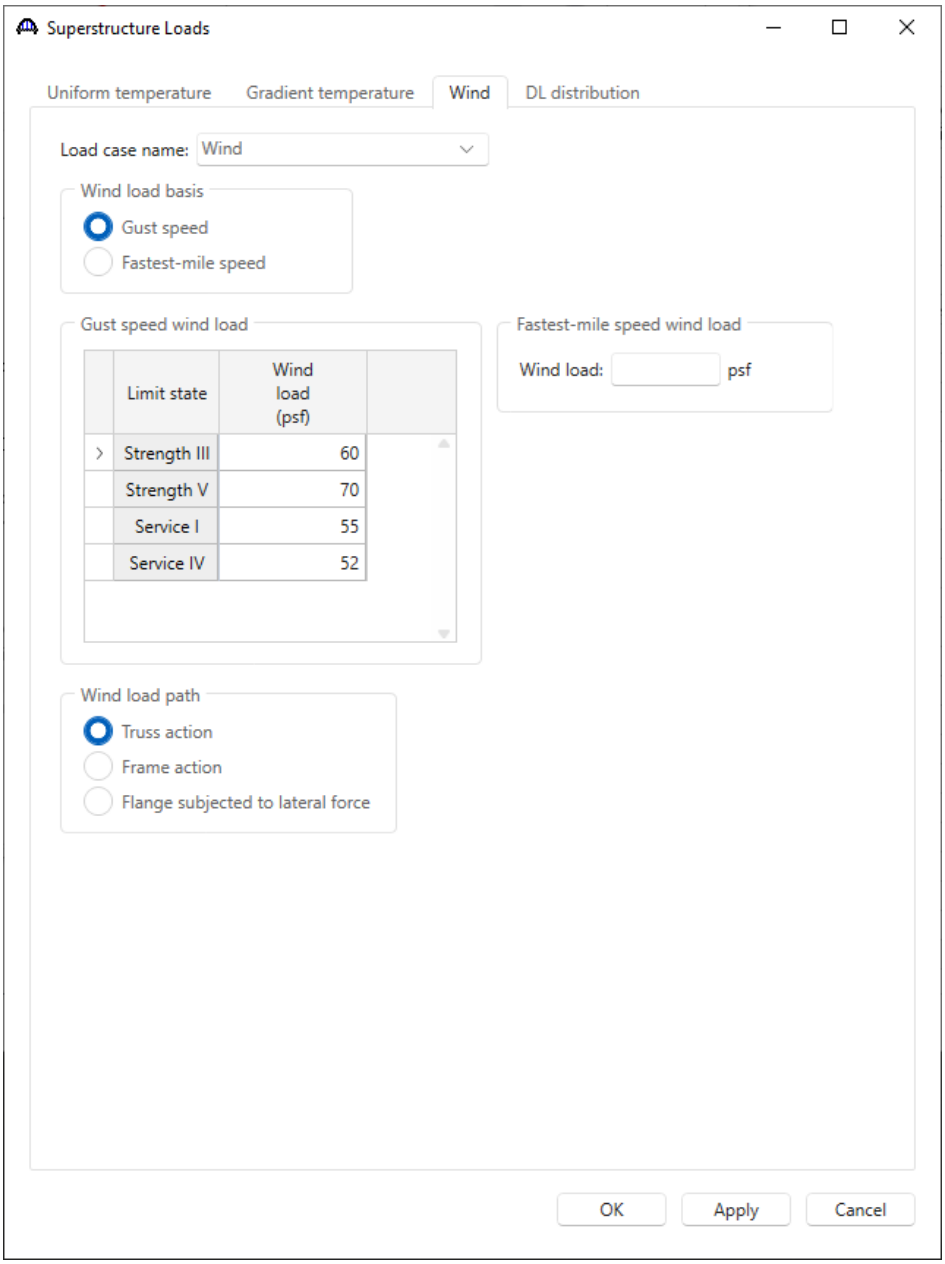
The **Bracing Specification Check Selection** window allows the user to select which diaphragms and lateral bracing should be specification-checked. Double click on **Bracing Spec Check Selection** node in the **BWS** tree and make the following selections.



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

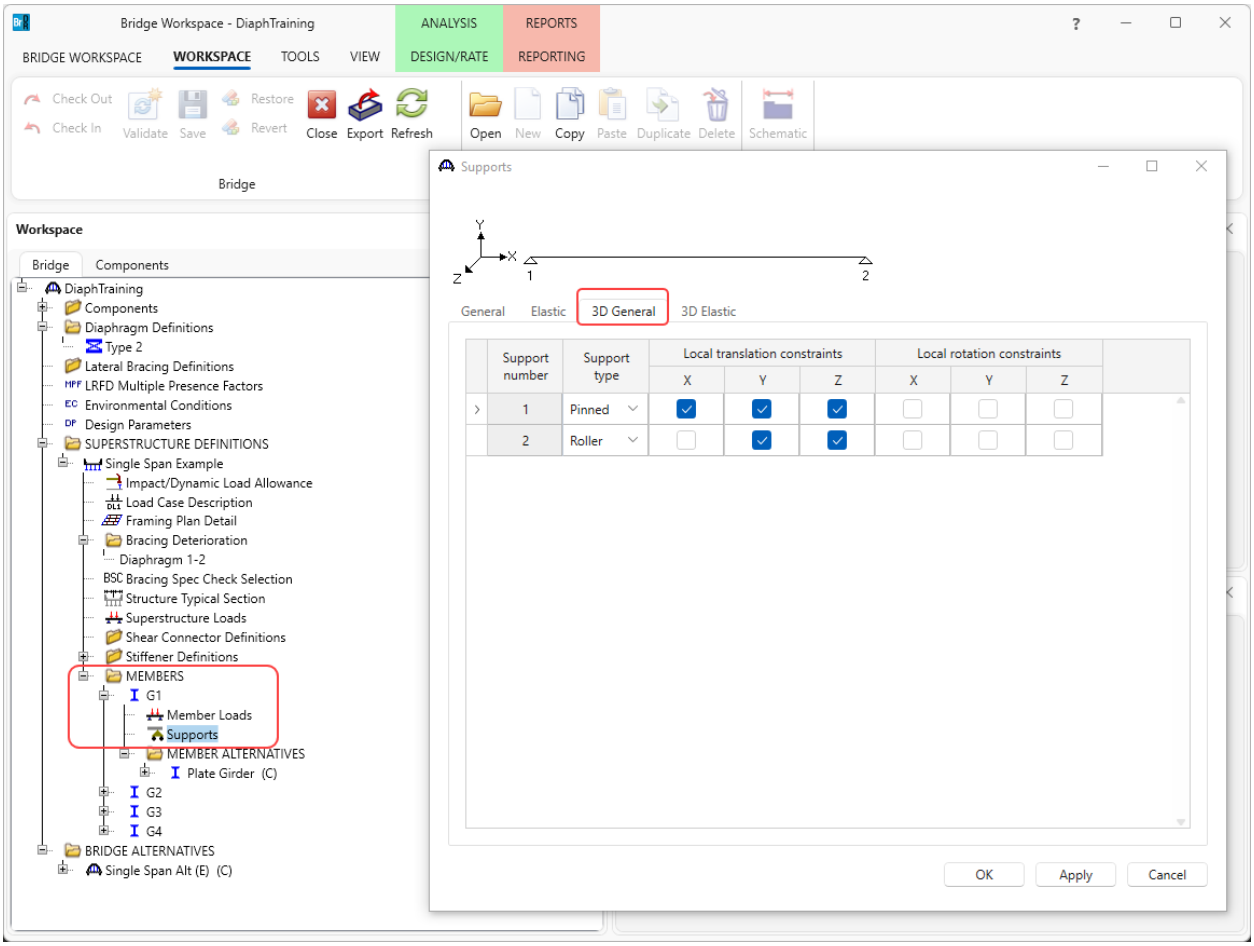
Superstructure Loads

Double click on the **Superstructure Loads** in the **BWS** tree and navigate to the **Wind** tab to enter the following information. Note that wind is only considered in an LRFD design review, not in a rating. The wind load path data only applies to line girder analysis where the wind load is approximated on the exterior girder.



Supports – Member G1

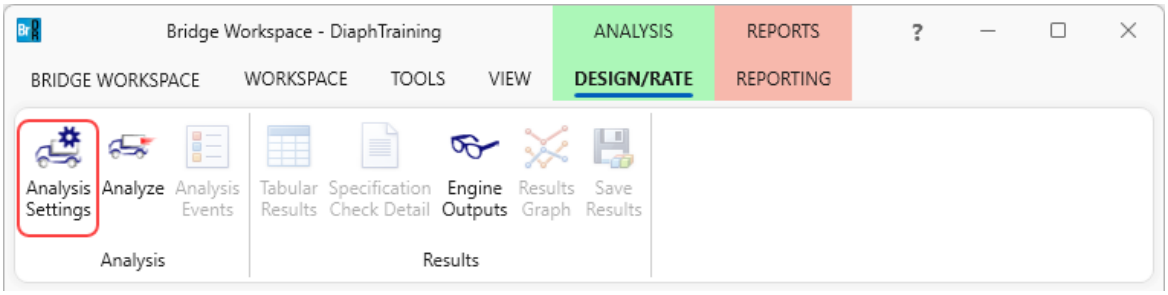
Expand the **G1** member and double click on the **Supports** node for **G1**. Navigate to the **3D General** tab of this window. Since wind is a horizontal load that is now being considered, at least 2 bearings should be constrained in the Z direction for at least 1 girder. Review the selections in this tab. No change is required at this time.



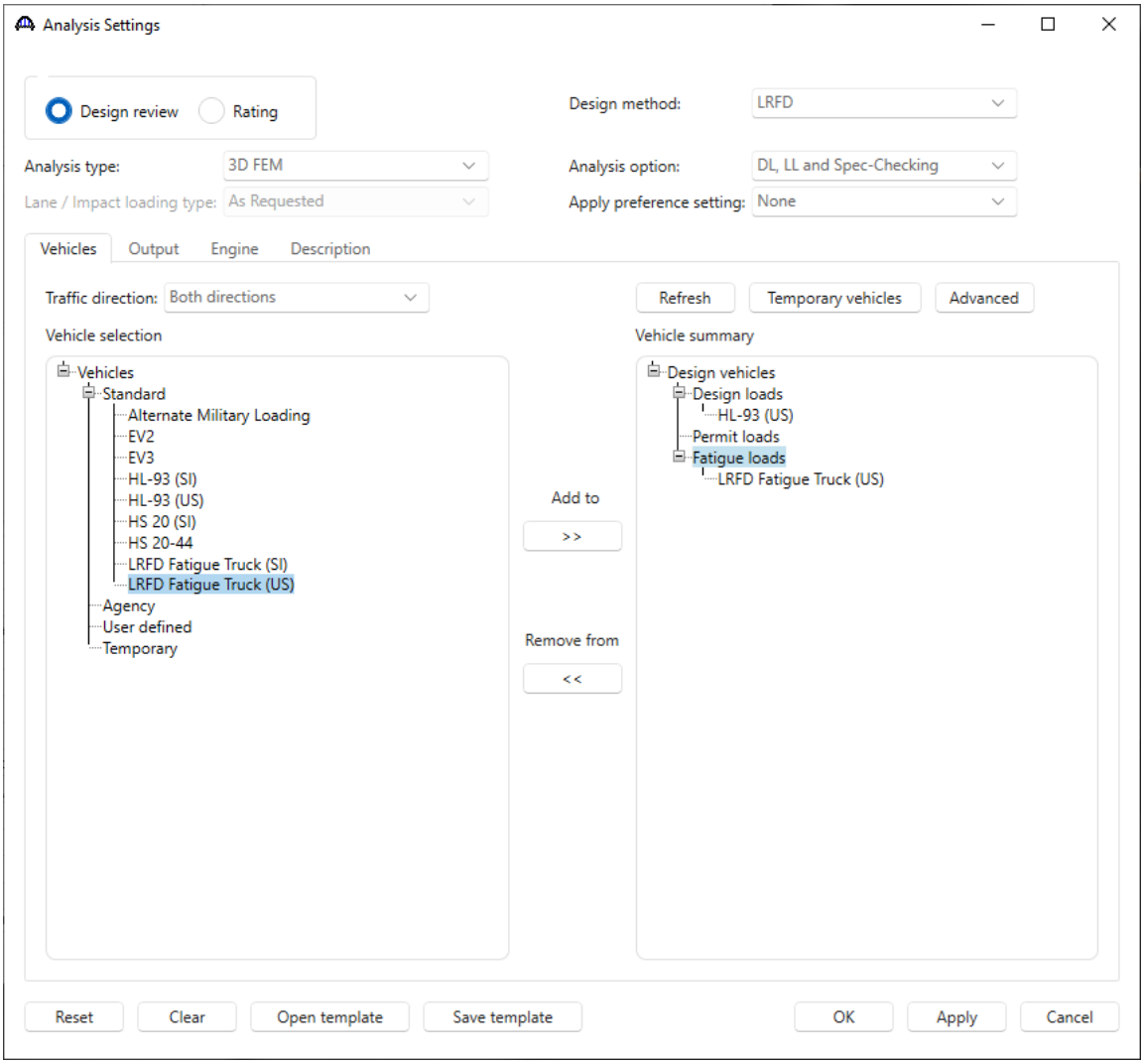
LRFD Design Review

Analysis Settings

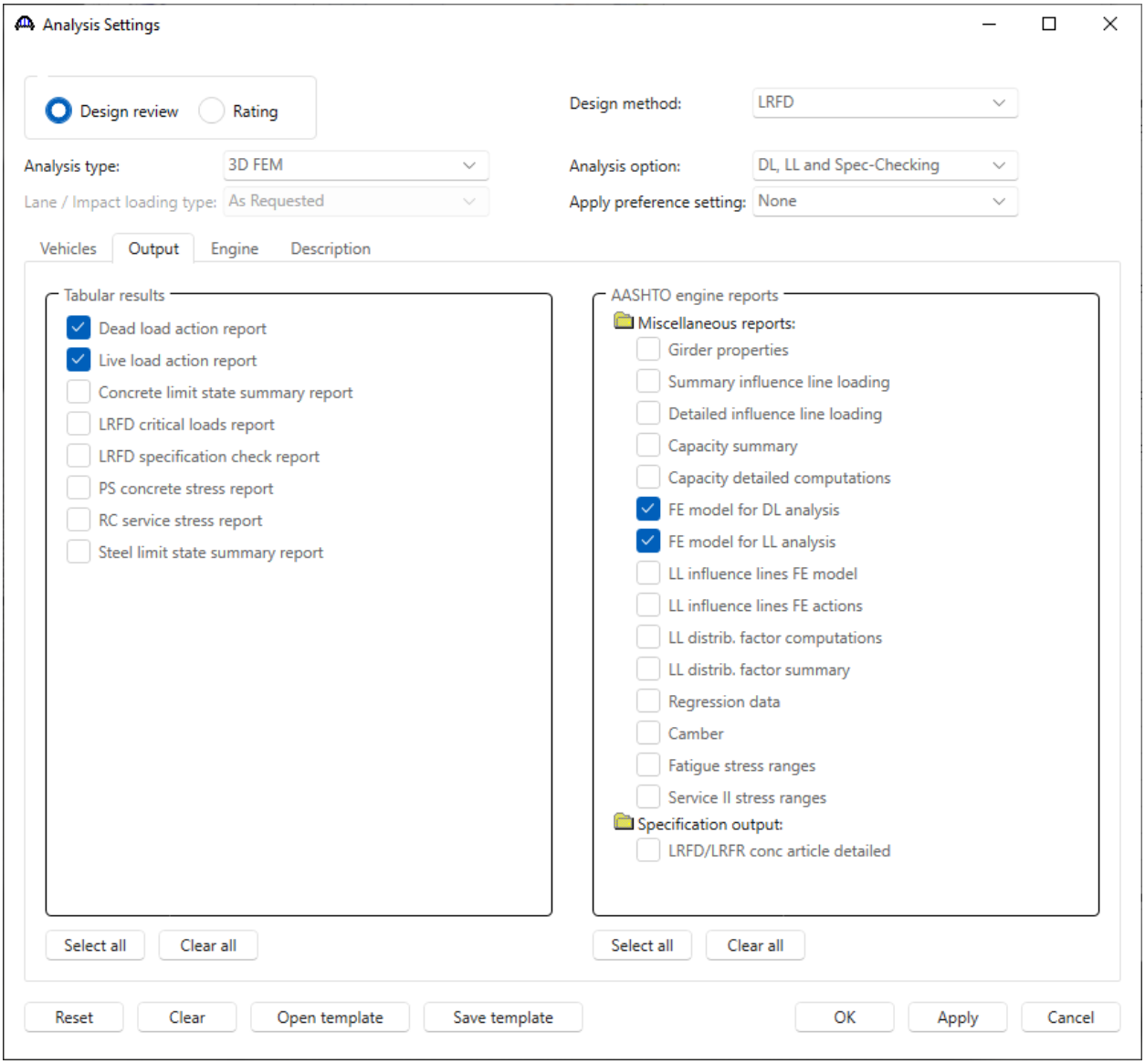
To run a **3D LRFD design review for** the superstructure definition, from the **Analysis** group of the **DESIGN/RATE** ribbon, click on **Analysis Settings** button to open the **Analysis Settings** window as shown below.



Select the following setttings for a 3D LRFD design review.



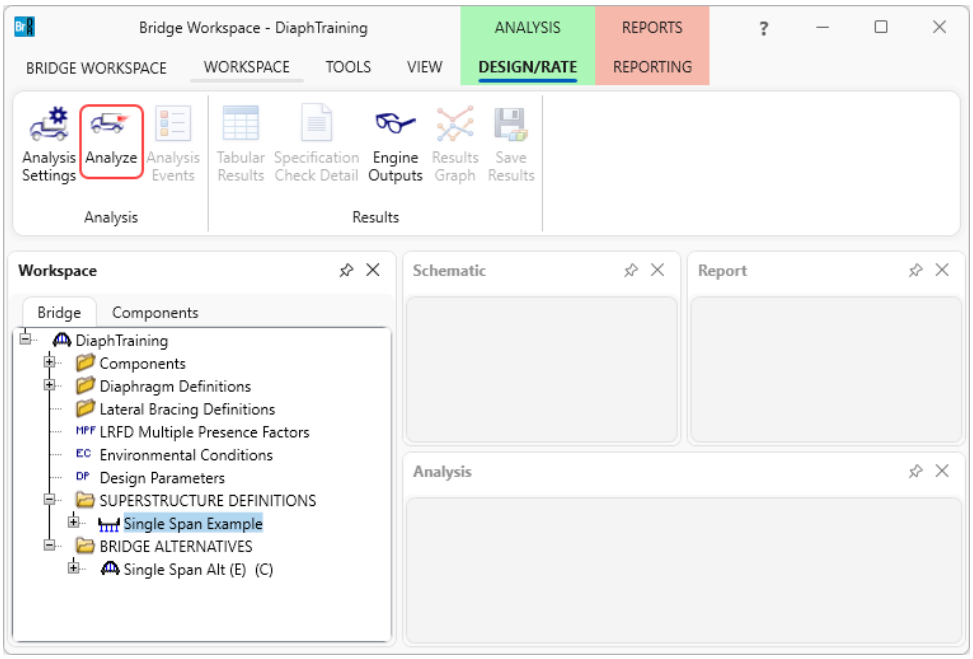
Navigate to the **Output** tab of this window and make the following selections for this design review.



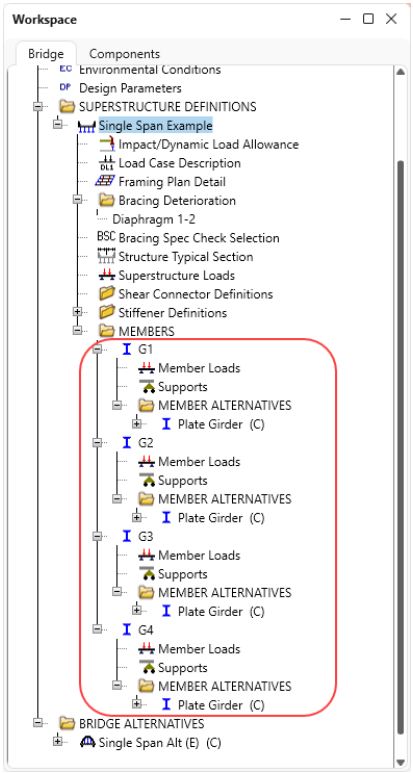
Click **OK** to apply these settings for the design review and close the window.

Design Review

With the **Single Span Example** superstructure node selected, click the **Analyze** button from the **Analysis** group of the **DESIGN/RATE** ribbon.

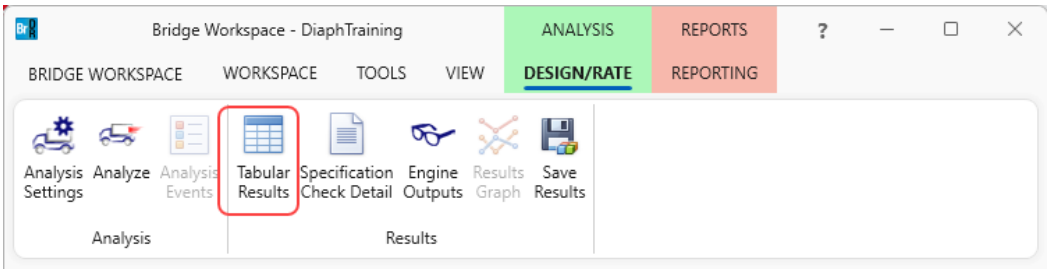


In this example, only the selected diaphragms will be analyzed and specification checked. None of the girder members have member alternatives marked as Existing (E), so they are not included in the analysis.



Tabular Results

After the analysis completes, open the **Tabular Results** window by clicking on the **Tabular Results** button from the **Results** group of the **DESIGN/RATE** ribbon while the superstructure definition is selected to see the bracing member results.



Analysis Results - Simple Span Structure Bracing

Print

Print

Report type: Dead Load Actions | Stage: Non-composite (Stage 1) | Dead Load Case: Self Load(Stage 1:D,DC). | Girder Bay: All Bays

Bracing	Element	Bracing Member	Node	Axial (kip)	Y Shear (kip)	Z Shear (kip)	Torsion (kip-ft)	Y Moment (kip-ft)	Z Moment (kip-ft)
1-2	321	AB	22	-0.012	0.000	0.000	0.000	0.000	0.000
			85	0.012	0.000	0.000	0.000	0.000	0.000
	322	CD1	24	0.000	0.000	0.000	0.000	0.000	0.000
			253	0.000	0.000	0.000	0.000	0.000	0.000
	323	CD2	253	0.024	0.000	0.000	0.000	0.000	0.000
			87	-0.024	0.000	0.000	0.000	0.000	0.000
	324	AE	22	0.016	0.000	0.000	0.000	0.000	0.000
			253	-0.016	0.000	0.000	0.000	0.000	0.000
	325	EB	253	-0.016	0.000	0.000	0.000	0.000	0.000
			85	0.016	0.000	0.000	0.000	0.000	0.000
2-2	331	AB	85	-0.104	0.000	0.000	0.000	0.000	0.000
			148	0.104	0.000	0.000	0.000	0.000	0.000
	332	CD1	87	0.024	0.000	0.000	0.000	0.000	0.000
			255	-0.024	0.000	0.000	0.000	0.000	-0.001
	333	CD2	255	0.183	0.000	0.000	0.000	0.000	0.000
			150	-0.183	0.000	0.000	0.000	0.000	0.000
	334	AE	85	0.103	0.000	0.000	0.000	0.000	0.000
			255	-0.103	0.000	0.000	0.000	0.000	0.000
	335	EB	255	-0.103	0.000	0.000	0.000	0.000	0.001

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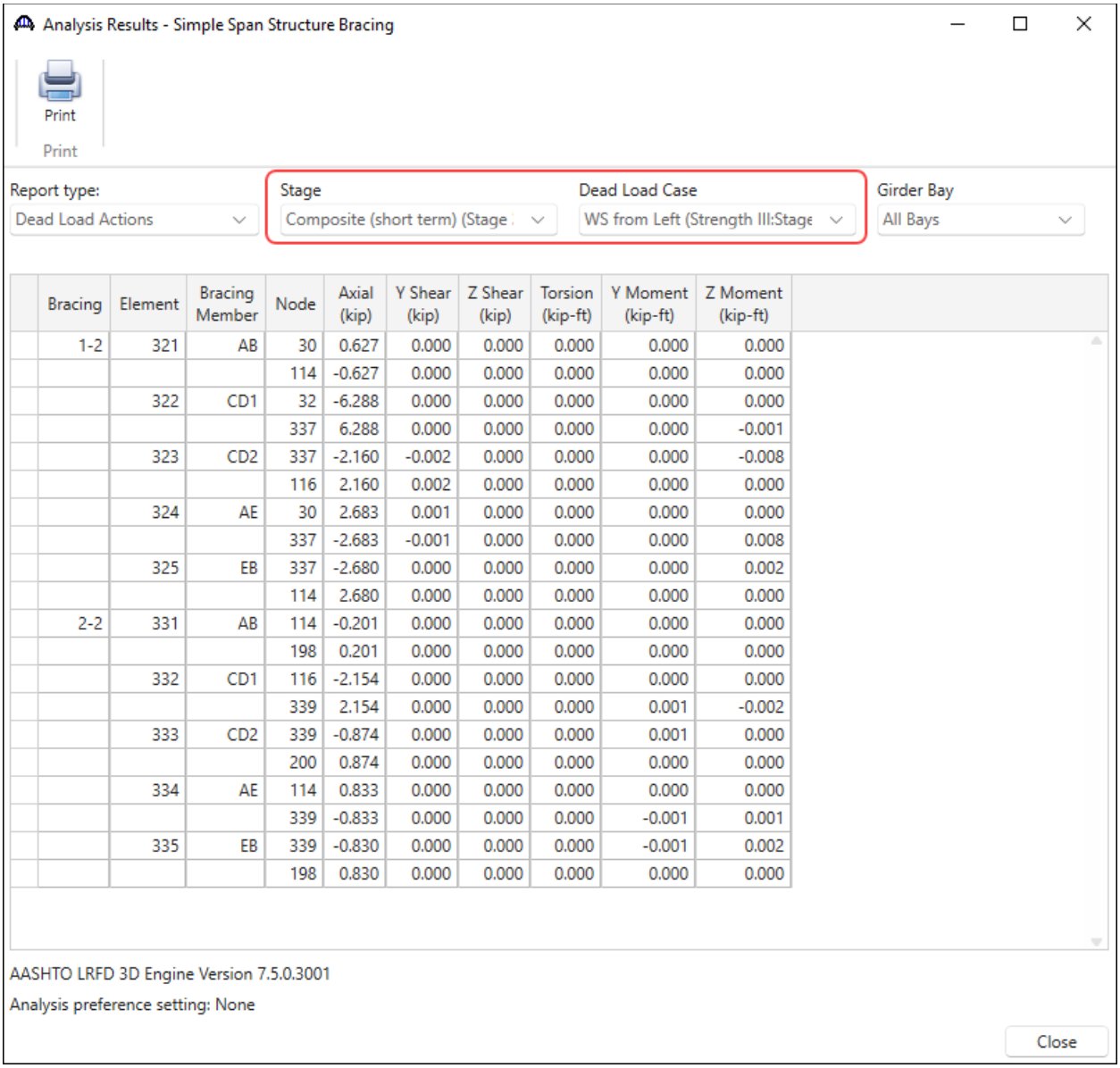
Analysis preference setting: None

Close

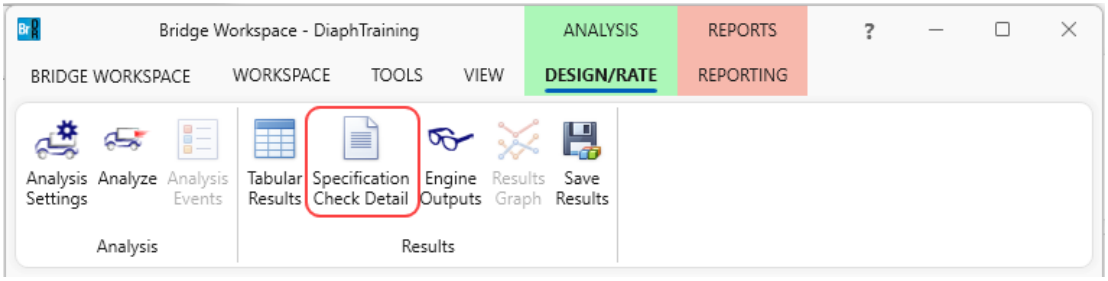
The wind load results can also be viewed in this window as shown below.

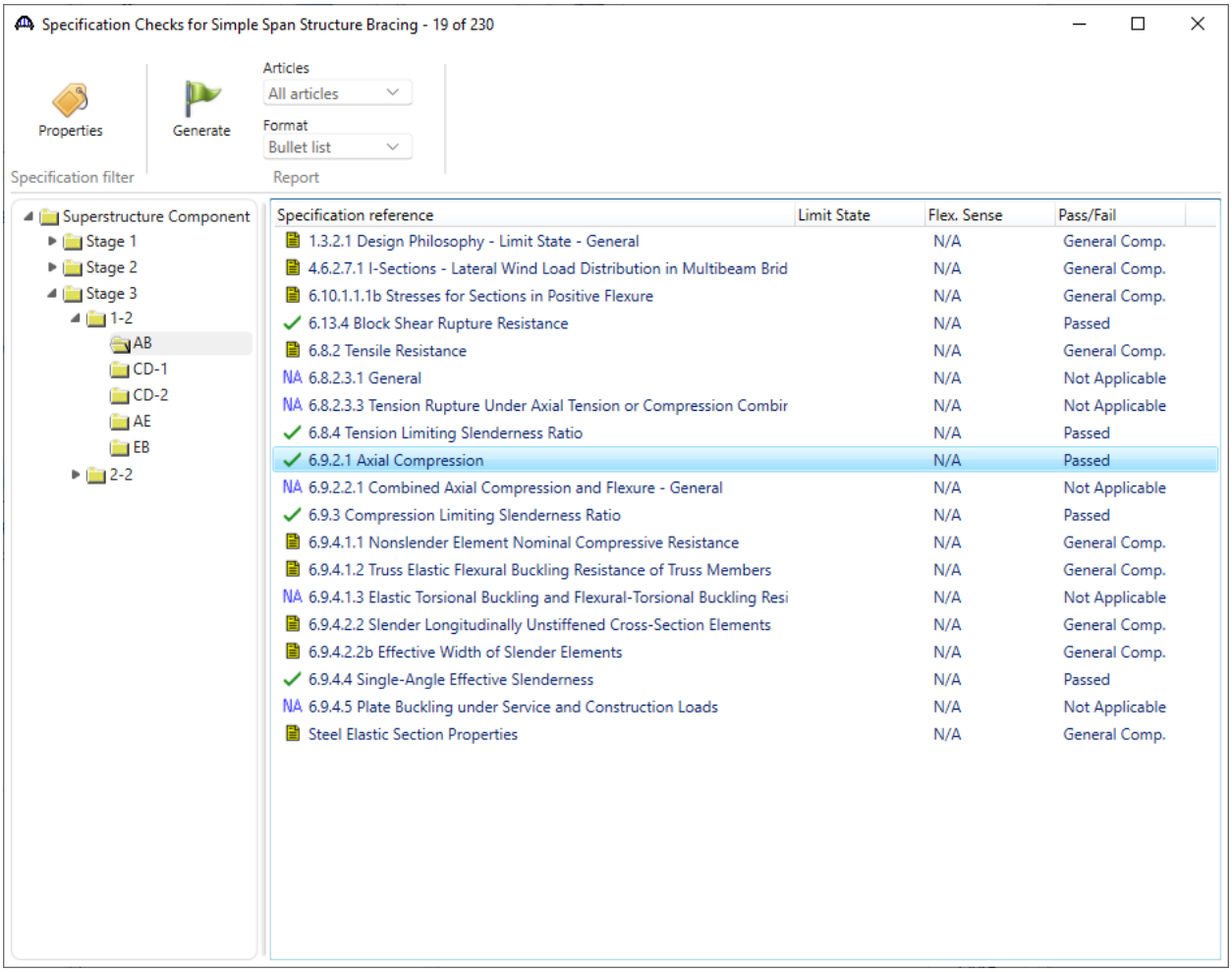


Bracing	Element	Bracing Member	Node	Axial (kip)	Y Shear (kip)	Z Shear (kip)	Torsion (kip-ft)	Y Moment (kip-ft)	Z Moment (kip-ft)
1-2	321	AB	30	0.627	0.000	0.000	0.000	0.000	0.000
			114	-0.627	0.000	0.000	0.000	0.000	0.000
	322	CD1	32	-6.288	0.000	0.000	0.000	0.000	0.000
			337	6.288	0.000	0.000	0.000	0.000	-0.001
	323	CD2	337	-2.160	-0.002	0.000	0.000	0.000	-0.008
			116	2.160	0.002	0.000	0.000	0.000	0.000
	324	AE	30	2.683	0.001	0.000	0.000	0.000	0.000
			337	-2.683	-0.001	0.000	0.000	0.000	0.008
	325	EB	337	-2.680	0.000	0.000	0.000	0.000	0.002
			114	2.680	0.000	0.000	0.000	0.000	0.000
2-2	331	AB	114	-0.201	0.000	0.000	0.000	0.000	0.000
			198	0.201	0.000	0.000	0.000	0.000	0.000
	332	CD1	116	-2.154	0.000	0.000	0.000	0.000	0.000
			339	2.154	0.000	0.000	0.000	0.001	-0.002
	333	CD2	339	-0.874	0.000	0.000	0.000	0.001	0.000
			200	0.874	0.000	0.000	0.000	0.000	0.000
	334	AE	114	0.833	0.000	0.000	0.000	0.000	0.000
			339	-0.833	0.000	0.000	0.000	-0.001	0.001
	335	EB	339	-0.830	0.000	0.000	0.000	-0.001	0.002
			198	0.830	0.000	0.000	0.000	0.000	0.000

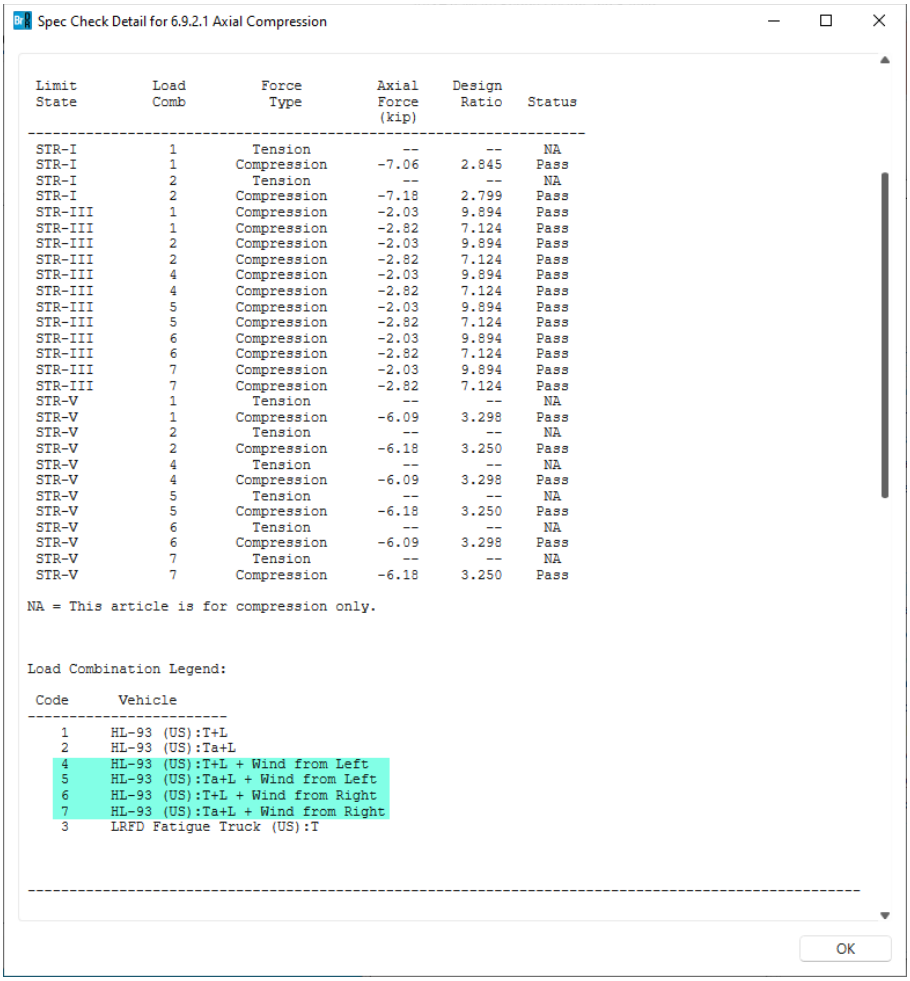
Specificatiton Check Details

Specification Check Details can be viewed for the bracing members by clicking on the **Specification Check Detail** button from the **Results** group of the **DESIGN/RATE** ribbon.





The following specification article illustrates how the wind load is combined with the live load:



Limit State	Load Comb	Force Type	Axial Force (kip)	Design Ratio	Status
STR-I	1	Tension	--	--	NA
STR-I	1	Compression	-7.06	2.845	Pass
STR-I	2	Tension	--	--	NA
STR-I	2	Compression	-7.18	2.799	Pass
STR-III	1	Compression	-2.03	9.894	Pass
STR-III	1	Compression	-2.82	7.124	Pass
STR-III	2	Compression	-2.03	9.894	Pass
STR-III	2	Compression	-2.82	7.124	Pass
STR-III	4	Compression	-2.03	9.894	Pass
STR-III	4	Compression	-2.82	7.124	Pass
STR-III	5	Compression	-2.03	9.894	Pass
STR-III	5	Compression	-2.82	7.124	Pass
STR-III	6	Compression	-2.03	9.894	Pass
STR-III	6	Compression	-2.82	7.124	Pass
STR-III	7	Compression	-2.03	9.894	Pass
STR-III	7	Compression	-2.82	7.124	Pass
STR-V	1	Tension	--	--	NA
STR-V	1	Compression	-6.09	3.298	Pass
STR-V	2	Tension	--	--	NA
STR-V	2	Compression	-6.18	3.250	Pass
STR-V	4	Tension	--	--	NA
STR-V	4	Compression	-6.09	3.298	Pass
STR-V	5	Tension	--	--	NA
STR-V	5	Compression	-6.18	3.250	Pass
STR-V	6	Tension	--	--	NA
STR-V	6	Compression	-6.09	3.298	Pass
STR-V	7	Tension	--	--	NA
STR-V	7	Compression	-6.18	3.250	Pass

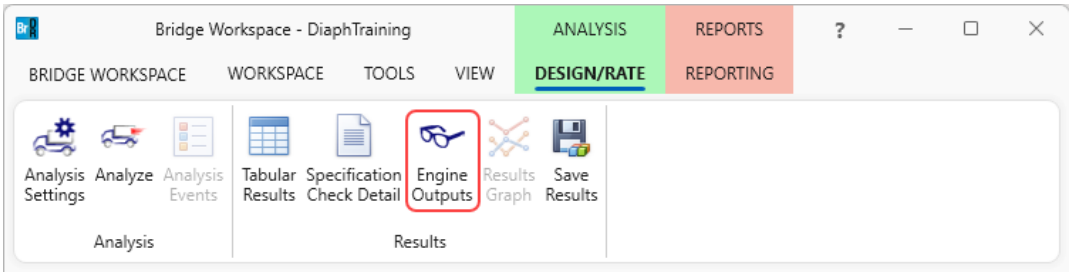
NA = This article is for compression only.

Load Combination Legend:

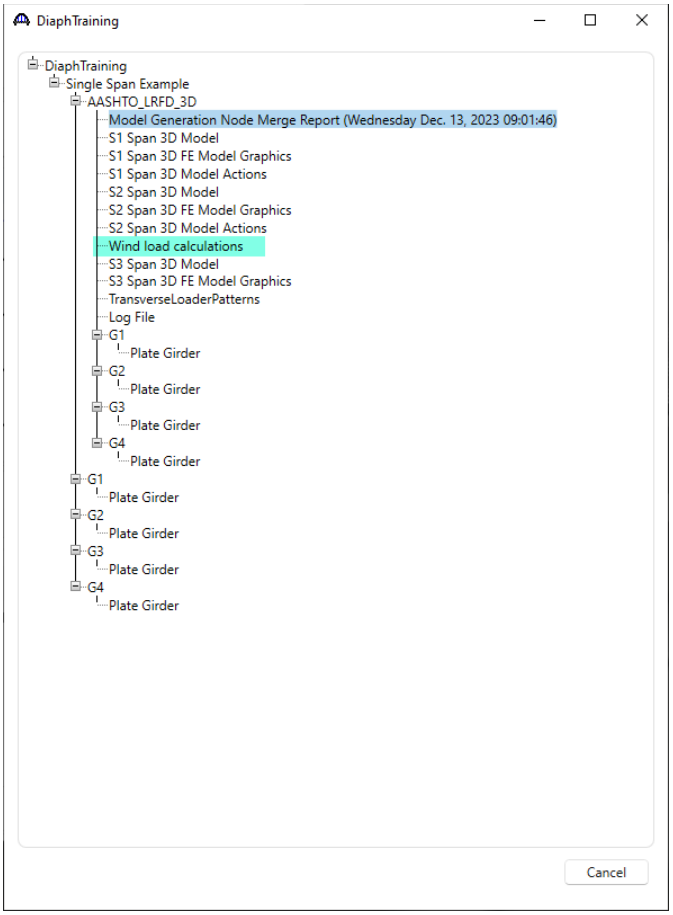
Code	Vehicle
1	HL-93 (US):T+L
2	HL-93 (US):Ta+L
4	HL-93 (US):T+L + Wind from Left
5	HL-93 (US):Ta+L + Wind from Left
6	HL-93 (US):T+L + Wind from Right
7	HL-93 (US):Ta+L + Wind from Right
3	LRFD Fatigue Truck (US):T

Engine Outputs

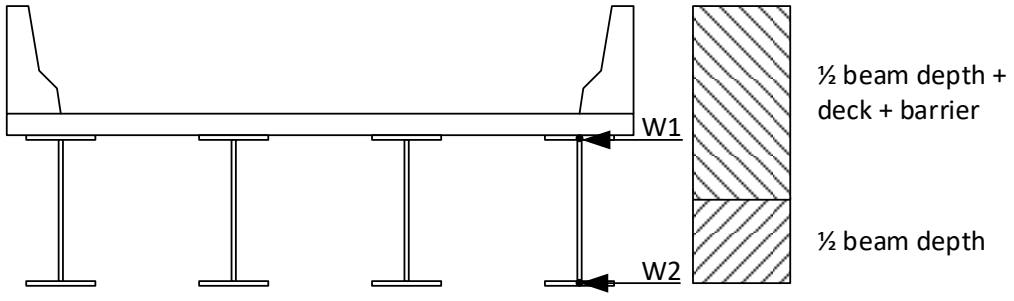
To view **Engine Output** files, click on the **Engine Outputs** button from the **Results** group of the **DESIGN/RATE** ribbon as shown below.



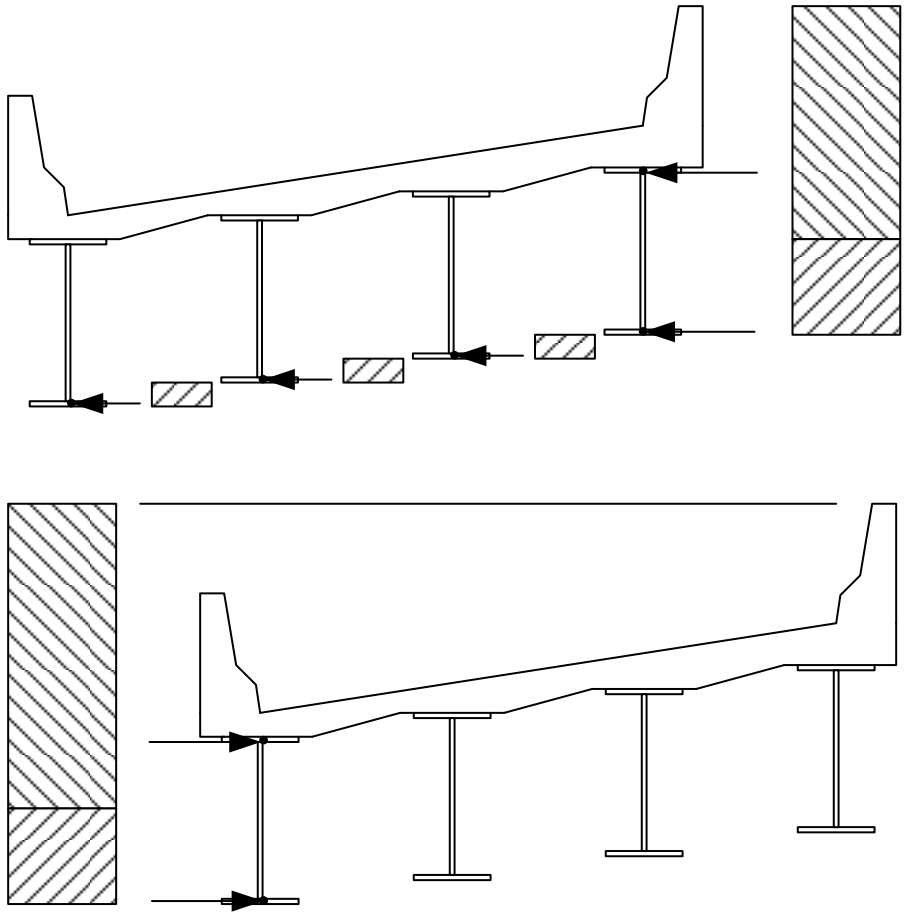
The following output files are available.



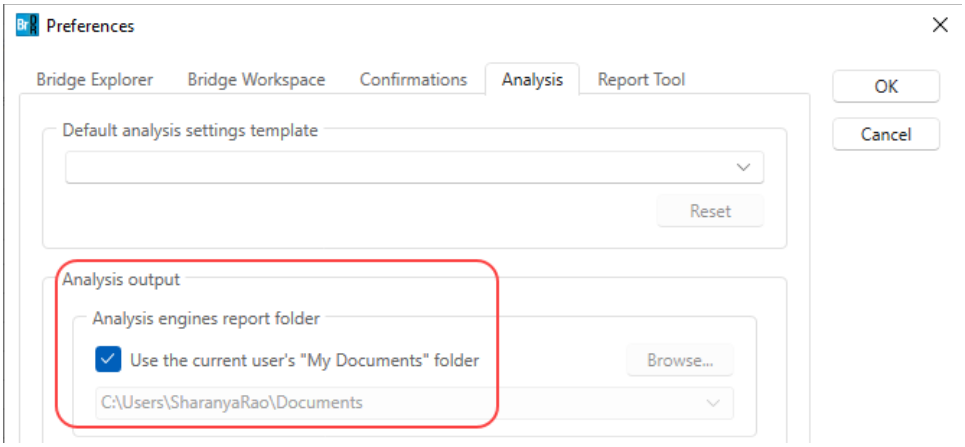
Wind load is calculated based on the projected area of the superstructure elevation. Wind load on the barrier, deck and ½ the girder depth (as measured between the top flange and bottom flange nodes in the FE model) is applied to the top flange node in the windward side exterior beam. Wind load on the bottom ½ the girder depth is applied to the bottom flange node in the windward side exterior beam.

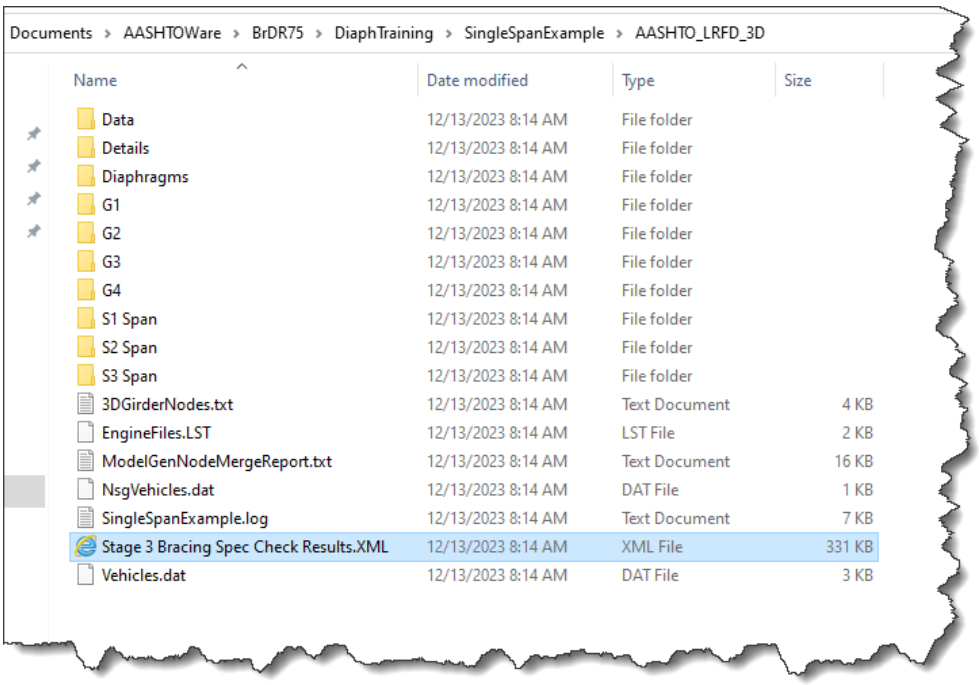


For curved structures, wind is applied along the chord length. This is done by adjusting the user input wind pressure by the ratio of the chord length divided by the arc length. For curved girder systems with superelevation, wind load is also computed for the additional height of exposed barrier and additional exposed beam depth.



A summary of the bracing specification check results is also available from the results folder saved in the location prefered by the user (as shown in the **Preferences** window shown below).





BrDR XML Report Viewer

AASHTO LRFD Specification, Edition 9, Interim 0

Specification Check Summary

Article	Status
Flexure (6.10.8.1.1, 6.10.8.1.2, 6.8.2.3, 6.9.2.2)	NA
Axial Tension (6.8.2)	NA
Axial Compression (6.9.4.1.1)	Fail
Block Shear Rupture (6.13.4)	Pass

Tensile Resistance

Bracing	Bracing Member	LS	LC	Pu (kip)	Pr (kip)	Design Ratio	Code

Compressive Resistance

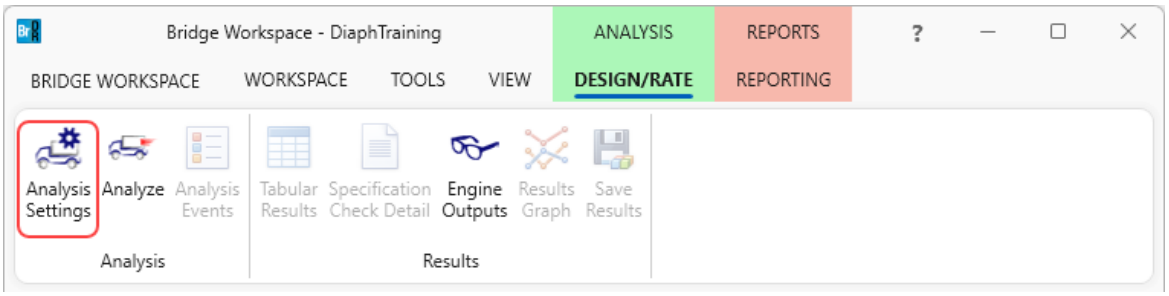
Bracing	Bracing Member	LS	LC	Pu (kip)	Pr (kip)	Design Ratio	Code
1-2	AB	STR-I	1	11.62	20.09	99.000	NA
	AB	STR-I	1	-7.06	20.09	2.845	Pass
	AB	STR-I	2	12.31	20.09	99.000	NA
	AB	STR-I	2	-7.18	20.09	2.799	Pass
	AB	STR-III	1	-2.03	20.09	9.894	Pass
	AB	STR-III	1	-2.82	20.09	7.124	Pass
	AB	STR-III	2	-2.03	20.09	9.894	Pass
	AB	STR-III	2	-2.82	20.09	7.124	Pass
	AB	STR-III	4	-2.03	20.09	9.894	Pass
	AB	STR-III	4	-2.82	20.09	7.124	Pass
	AB	STR-III	5	-2.03	20.09	9.894	Pass
	AB	STR-III	5	-2.82	20.09	7.124	Pass

LRFR/LFR Rating

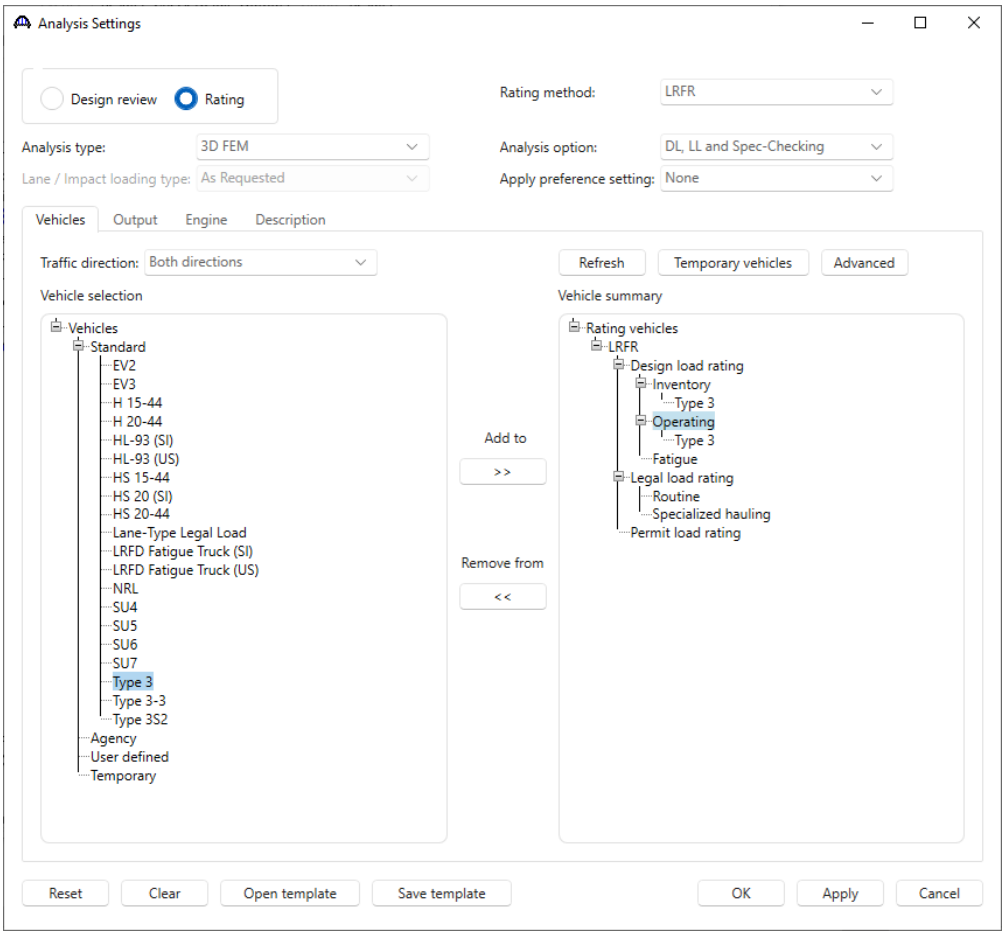
Analysis Settings

In a similar manner, an LRFR or LFR rating can be performed. Note that wind load is not included in the rating analysis but section loss is.

To run an **LRFR rating** on the superstructure definition, from the **Analysis** group of the **DESIGN/RATE** ribbon click on **Analysis Settings** to open the **Analysis Settings** window as shown below.

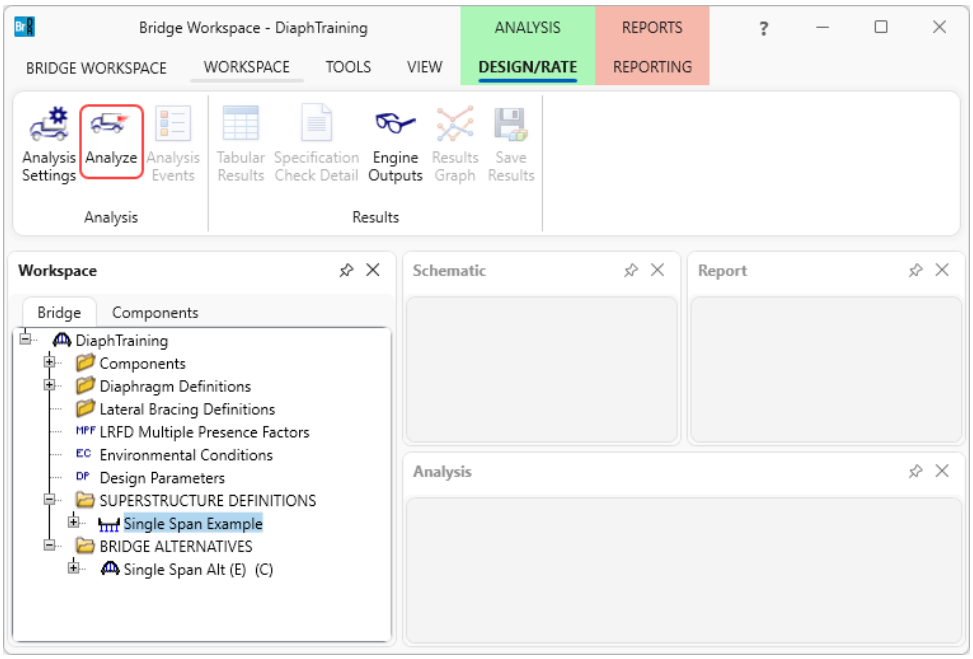


Select the vehicles to be used in the rating as shown below.



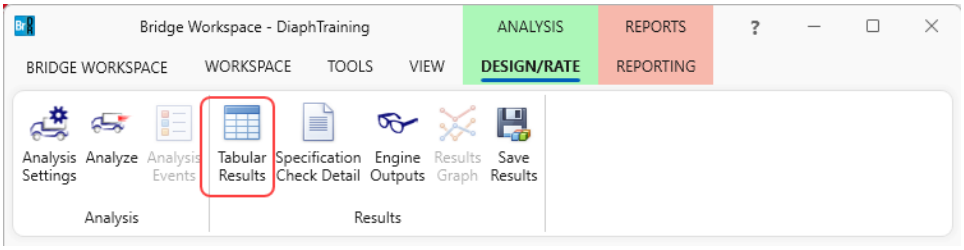
Analyze

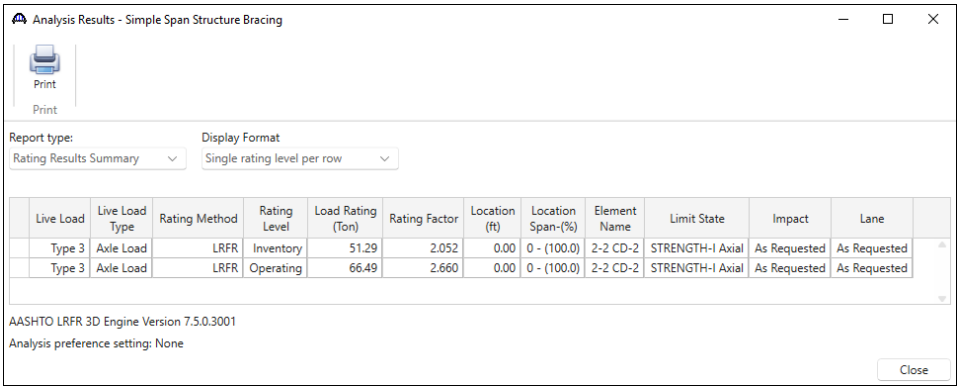
With the **Single Span Example** superstructure node selected, click the **Analyze** button from the **Analysis** group of the **DESIGN/RATE** ribbon.



Tabular Results

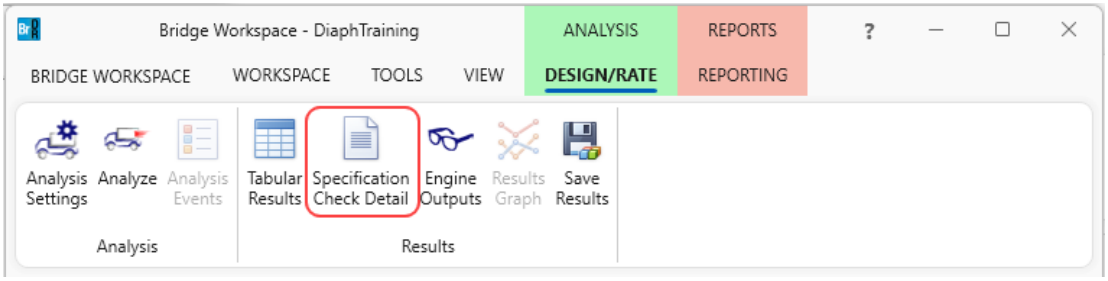
After the analysis completes, open the **Tabular Results** window by clicking on the **Tabular Results** button from the **Results** group of the **DESIGN/RATE** ribbon while the superstructure definition is selected to see the bracing member results.



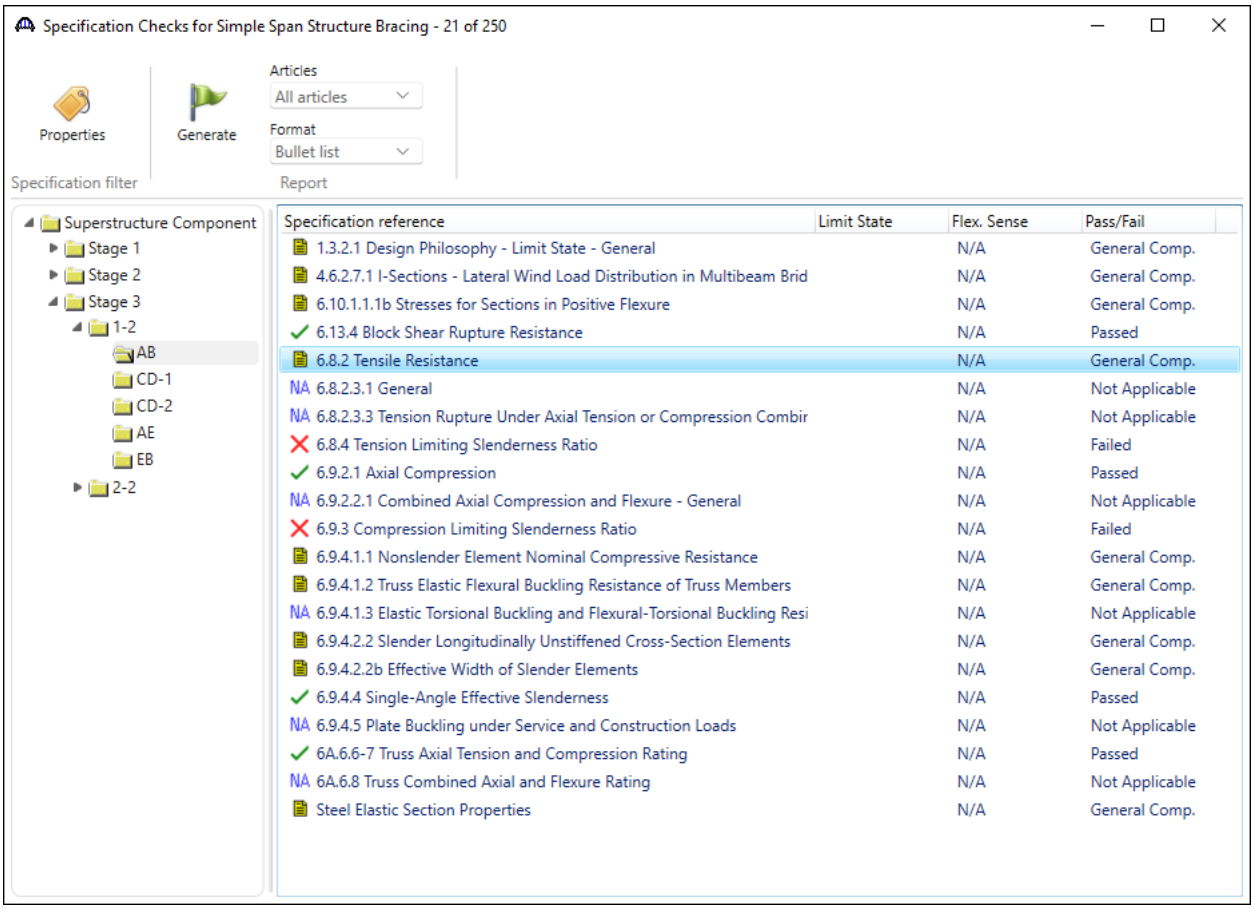


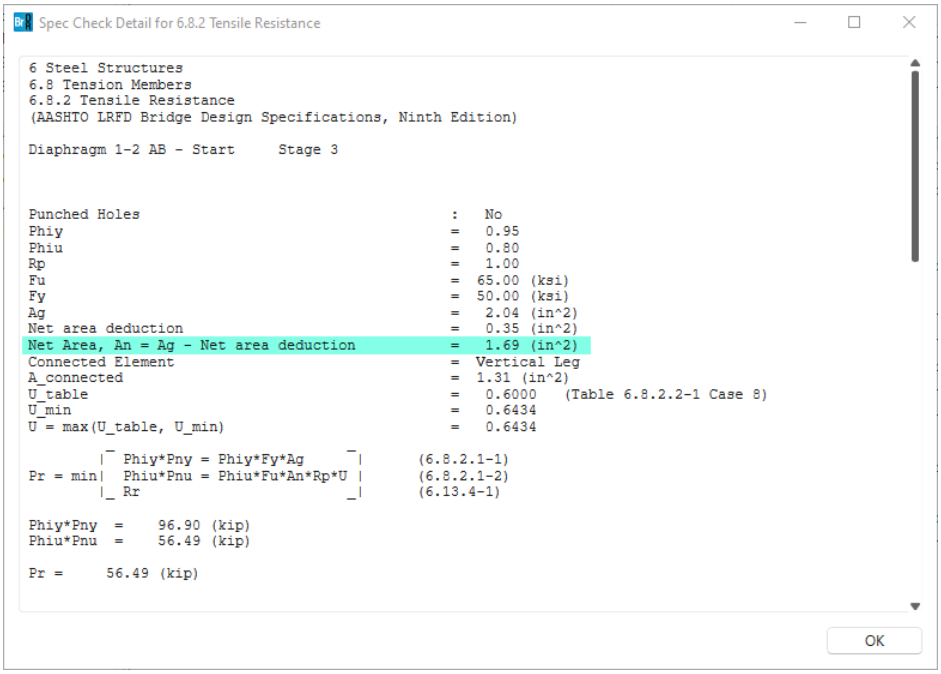
Specificatiton Check Details

Specification check details can be viewed by clicking on the **Specification Check Detail** button from the **Results** group of the **DESIGN/RATE** ribbon.



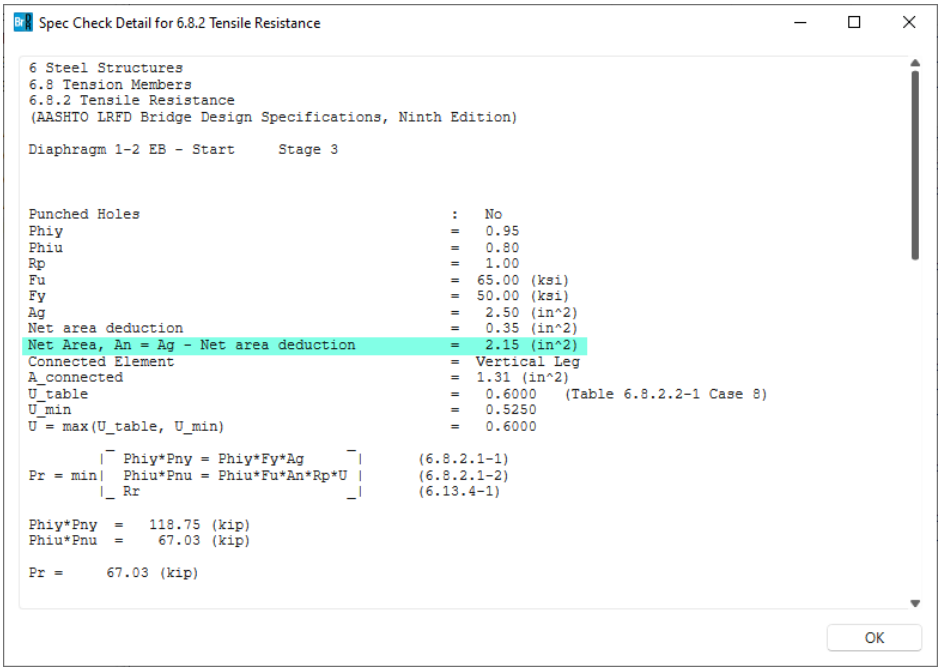
The section loss that was entered for member **AB** in diaphragm **1-2** is considered as shown below.



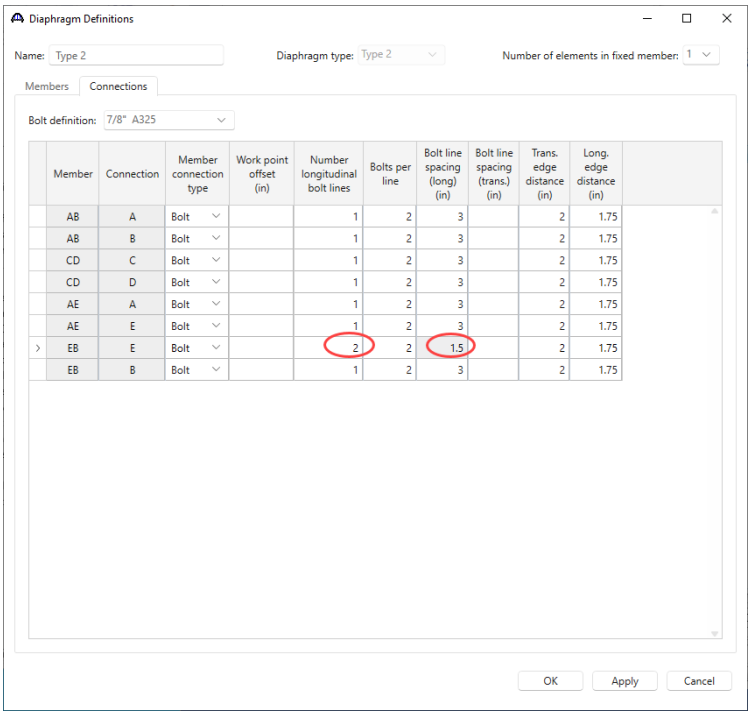


If the user wants to change a piece of data that does not directly impact the FE analysis or results, such as the bolt details in a diaphragm, the **Analysis Settings** window allows the user to process just a specification check without re-doing a full analysis.

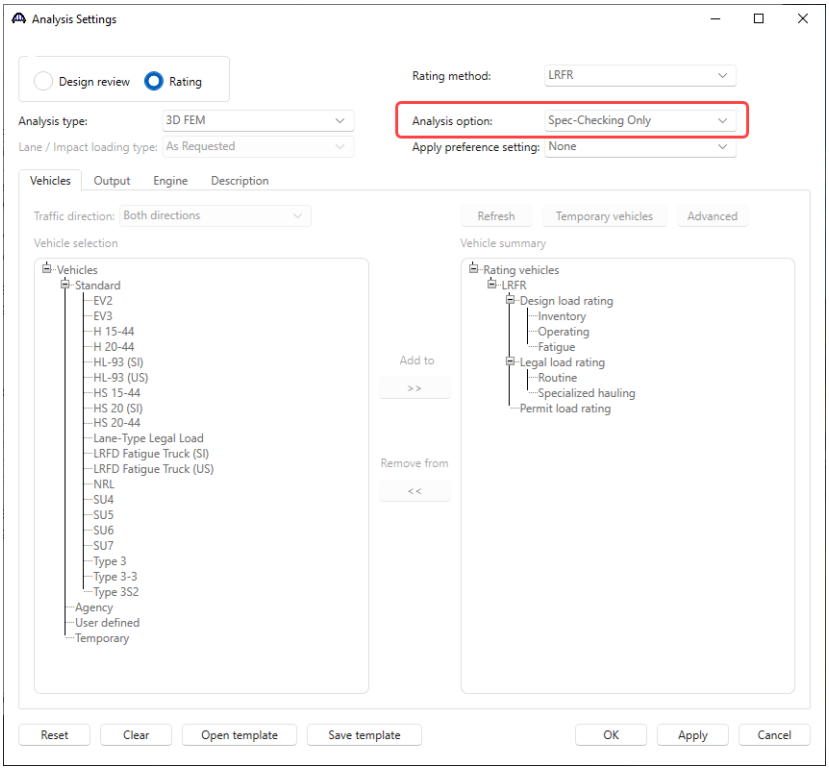
The following shows the details for Article **6.8.2 Tensile Resistance** for member **EB** in the diaphragm **1-2**. Note the **Net Area**.



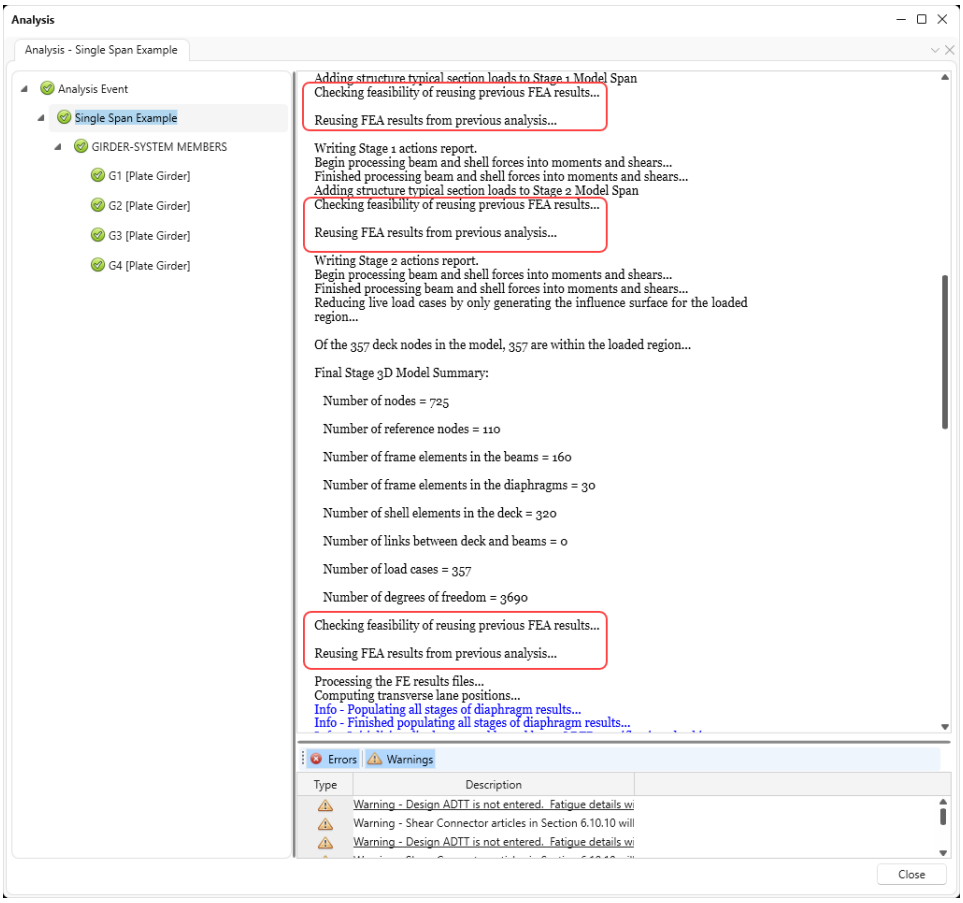
Open the **Diaphragm Definitions** window for the **Type 2** diaphragm, navigate to the **Connections** tab and modify the bolt details for member **EB** by adding an extra line of bolts:



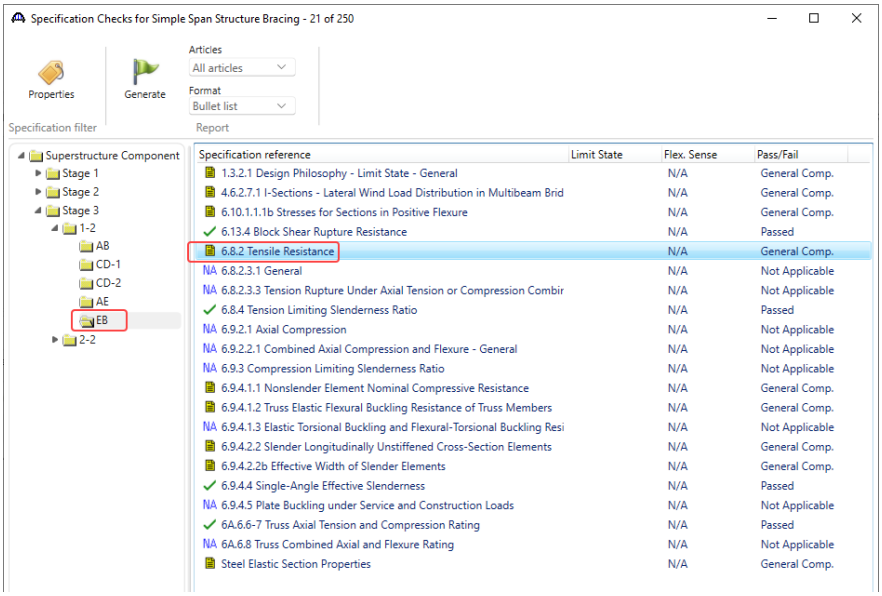
Open the **Analysis Settings** window and select the **Spec-Checking only** option under **Analysis Option**. Click **OK** and run the analysis again.

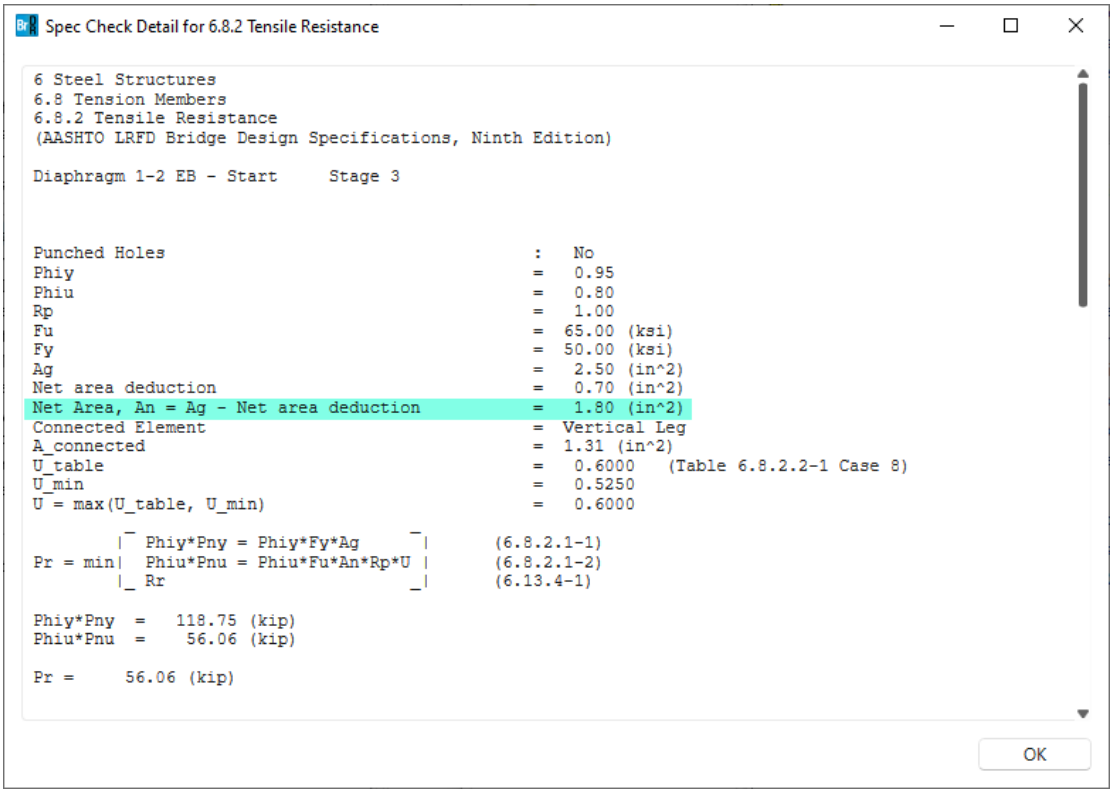


BrDR will regenerate the FE Models and compare them to the previously generated FE models. Since the models are the same, the previous FE results are re-used and the specification checking considers the revised details:



Open specification check article **6.8.2 Tensile Resistance** for member **EB** as shown below.




Spec Check Detail for 6.8.2 Tensile Resistance
6 Steel Structures
6.8 Tension Members
6.8.2 Tensile Resistance
(AASHTO LRFD Bridge Design Specifications, Ninth Edition)
Diaphragm 1-2 EB - Start Stage 3
Punched Holes : No
Phiy = 0.95
Phiu = 0.80
Rp = 1.00
Fu = 65.00 (ksi)
Fy = 50.00 (ksi)
Ag = 2.50 (in^2)
Net area deduction = 0.70 (in^2)
Net Area, An = Ag - Net area deduction = 1.80 (in^2)
Connected Element = Vertical Leg
A_connected = 1.31 (in^2)
U_table = 0.6000 (Table 6.8.2.2-1 Case 8)
U_min = 0.5250
U = max(U_table, U_min) = 0.6000
Pr = min(Phiy*Pny = Phiy*Fy*Ag (6.8.2.1-1)
Phiu*Pnu = Phiu*Fu*An*Rp*U (6.8.2.1-2)
Rr (6.13.4-1)
Phiy*Pny = 118.75 (kip)
Phiu*Pnu = 56.06 (kip)
Pr = 56.06 (kip)
OK