

AASHTOWare BrDR 7.5.0

3D FEM Analysis Tutorial

Steel Diaphragm and Lateral Bracing Specification Checking

Example

3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

BrDR Training

3DFEM1 - Steel Diaphragm and Lateral Bracing Specification Checking Example

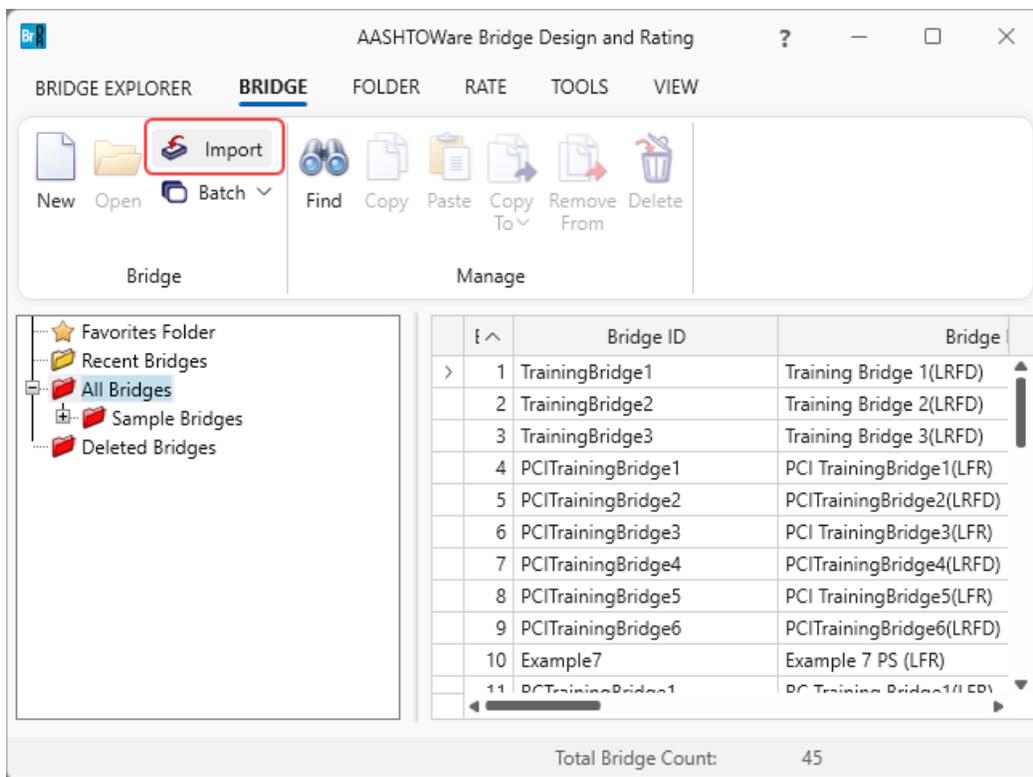
Topics Covered

- 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**.



3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

The screenshot shows the DiaphTraining software window. At the top, there are fields for Bridge ID and NBI structure ID (8), both containing the text "DiaphTraining". To the right, there are checkboxes for "Template" and "Bridge completely defined", both of which are unchecked. Further right is a "Bridge Workspace View" panel with three checkboxes: "Superstructures" (checked), "Culverts" (unchecked), and "Substructures" (checked). Below this is a tabbed interface with tabs for "Description", "Description (cont'd)", "Alternatives", "Global reference point", "Traffic", and "Custom agency fields". The "Description" tab is active, showing fields for Name (containing "Steel Diaphragm Example"), Year built, Description, Location, Facility carried (7), Feat. intersected (6), Default units (set to "US Customary"), Length (ft), Route number (set to "1"), and Mi. post. At the bottom left, there is a "Bridge association..." button and three checkboxes: "BrR" (checked), "BrD" (checked), and "BrM" (unchecked). At the bottom right, there are "OK", "Apply", and "Cancel" buttons.

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

3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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.

Bridge Materials - Concrete

Name:

Description:

Compressive strength at 28 days (f'c): ksi

Initial compressive strength (f'ci): ksi

Composition of concrete: ▼

Density (for dead loads): kcf

Density (for modulus of elasticity): kcf

Poisson's ratio:

Coefficient of thermal expansion (α): 1/F

Splitting tensile strength (fct): ksi

LRFD Maximum aggregate size: in

Compute

Std modulus of elasticity (Ec): ksi

LRFD modulus of elasticity (Ec): ksi

Std initial modulus of elasticity: ksi

LRFD initial modulus of elasticity: ksi

Std modulus of rupture: ksi

LRFD modulus of rupture: ksi

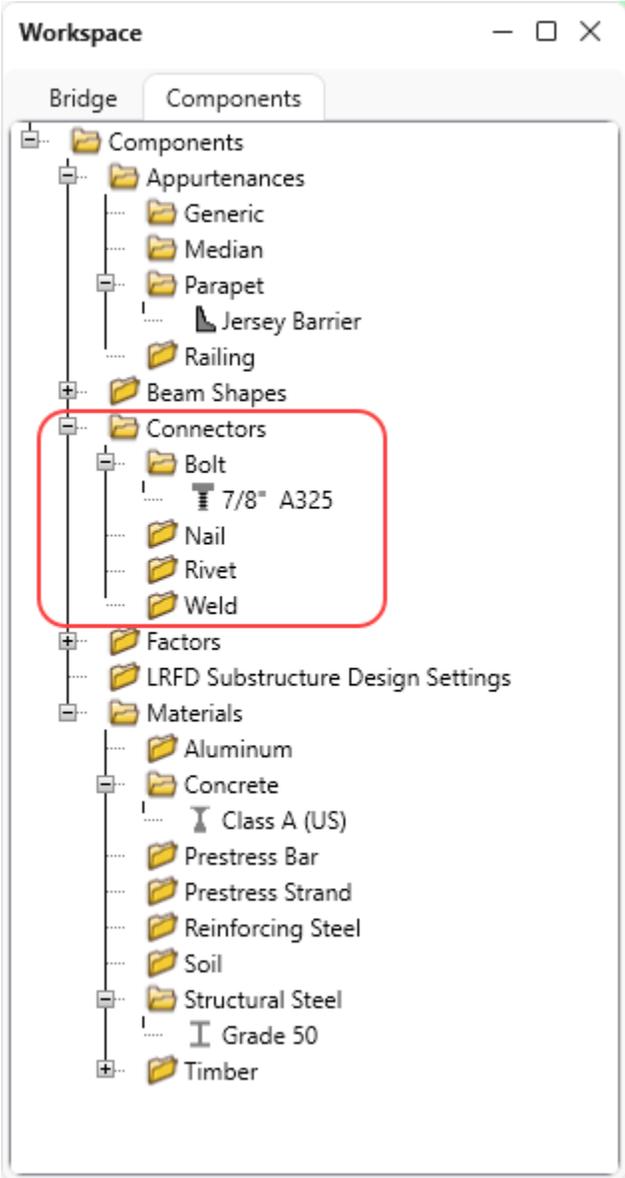
Shear factor:

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

3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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.



3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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

Structure Definition Connectors - Bolt

Name: 7/8" A325

Description:

Library designation: AASHTO M 164 (US) Bolt threads excluded from shear plane

Bolt diameter: 0.875 in Hole diameter: 0.9375 in

Connection type: Slip-critical Bearing

Hole size: Standard Oversize Short slot Long slot

Load direction: Any direction Transverse Parallel

Surface class: Class A Class B Class C Class D

Hole type: Punched full size Drilled full size Subpunched and reamed to size

Grip length: in

ASD
Allowable shear stress: 23.75 ksi
Nominal slip resistance: 23 ksi

LFD
Allowable shear stress: 43 ksi
Design slip resistance: 32 ksi

LRFD
Minimum tensile strength, Fub: 120 ksi Kh: 1 Ks: 0.5
Required tension, Pt: kip

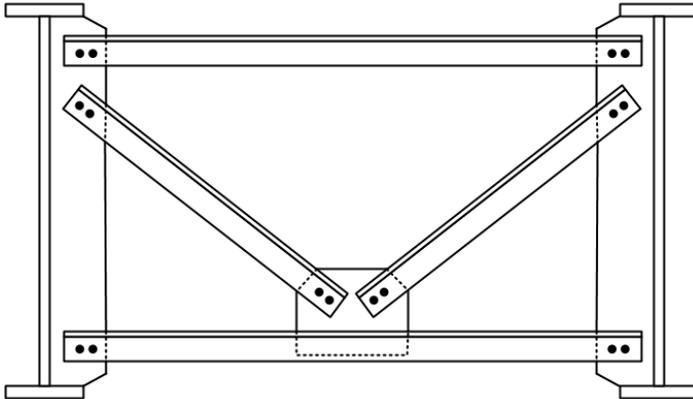
Compute from library...

OK Apply Cancel

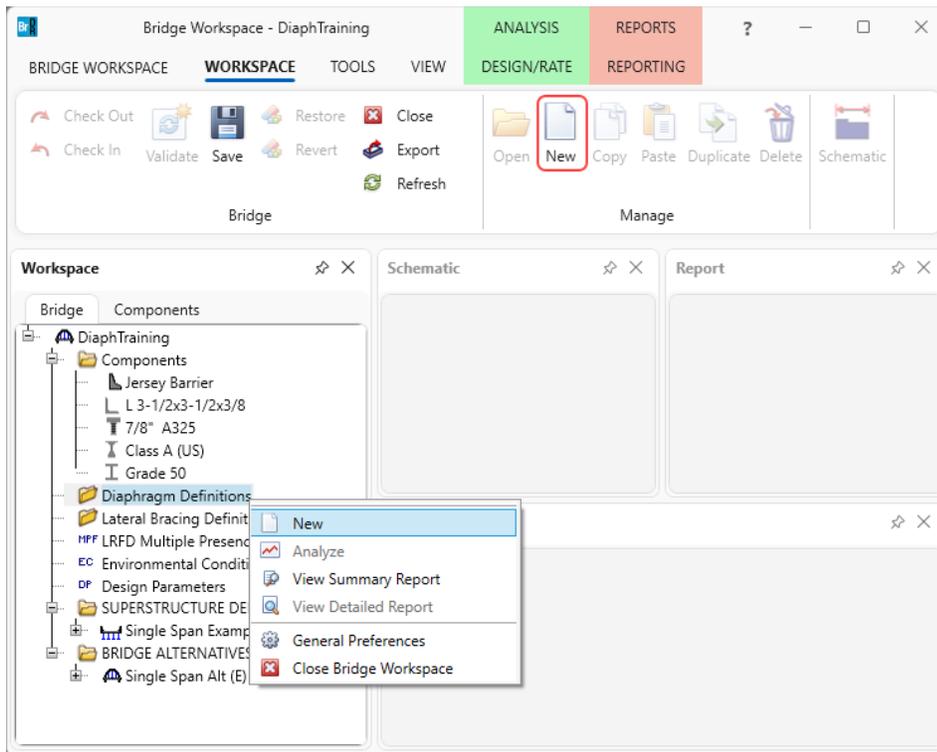
3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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.



3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

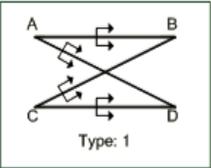
Create the following diaphragm definition.

Diaphragm Definitions
— □ ×

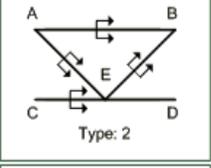
Name: Diaphragm type: Number of elements in fixed member:

Members Connections

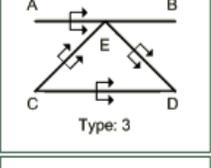
Diaphragm types:



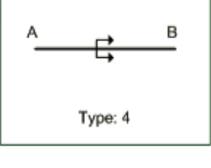
Type: 1



Type: 2



Type: 3



Type: 4

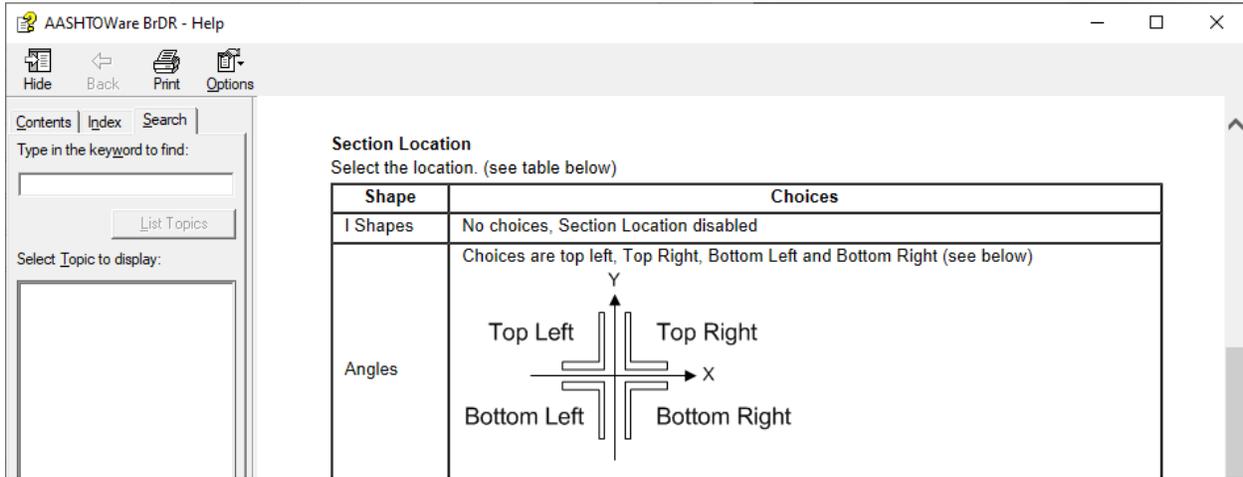
Member	Shape	Section orientation	Section location	Material
AB	L 3-1/2x3-1/2x3/8	Vertical	Bottom Right	Grade 50
CD	L 3-1/2x3-1/2x3/8	Vertical	Bottom Right	Grade 50
AE	L 3-1/2x3-1/2x3/8	Vertical	Bottom Right	Grade 50
EB	L 3-1/2x3-1/2x3/8	Vertical	Bottom Right	Grade 50

Connection	Support type	Y (in)	Measured from
A	Pinned	6	Top of Web
B	Pinned	6	Top of Web
C	Pinned	6	Bottom of Web
D	Pinned	6	Bottom of Web
E	Pinned		

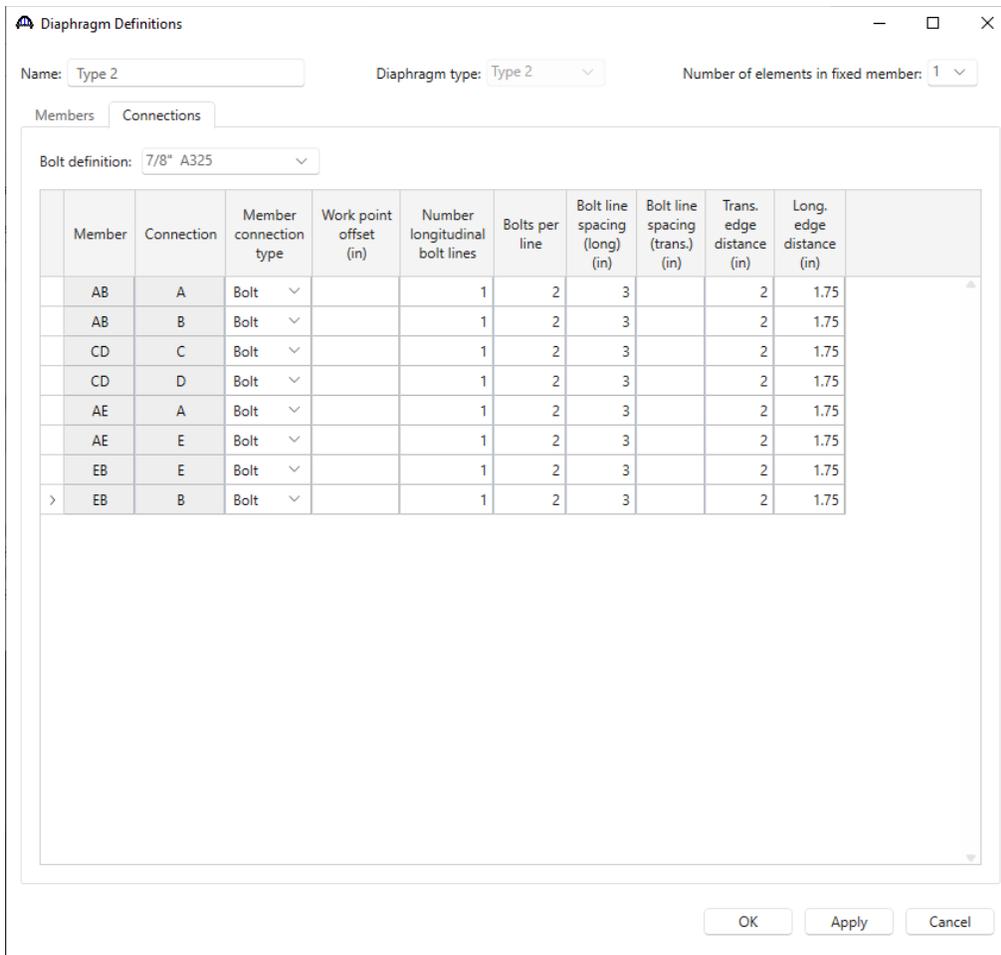
Click the **Apply** button to save.

3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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.

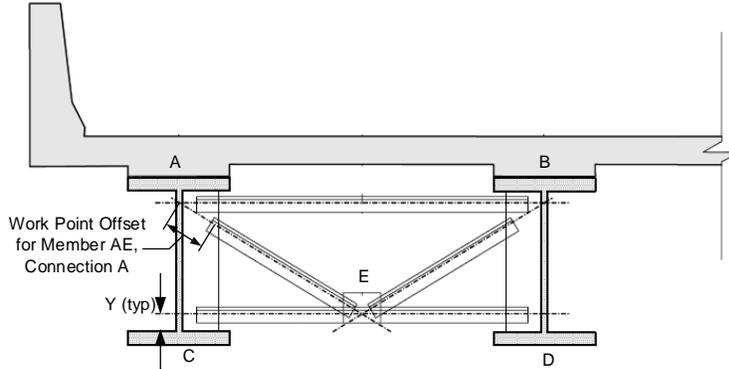


Click **OK** to apply the data and close the window.

3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

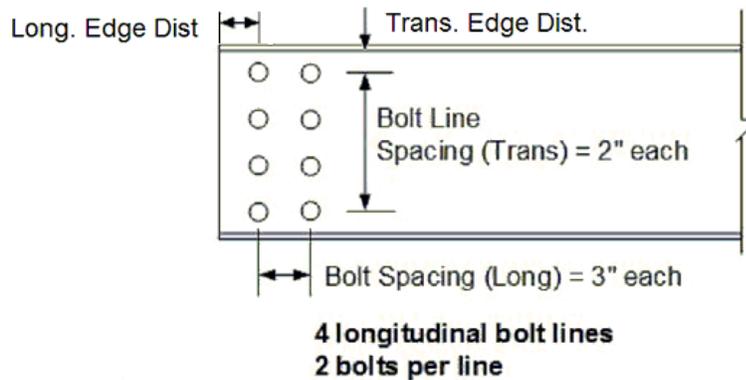
The following sketch from the **AASHTOWare BrDR Help** provides a description of the **Work Point Offset**. This can be accessed by hitting the **F1** key on this window.

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.

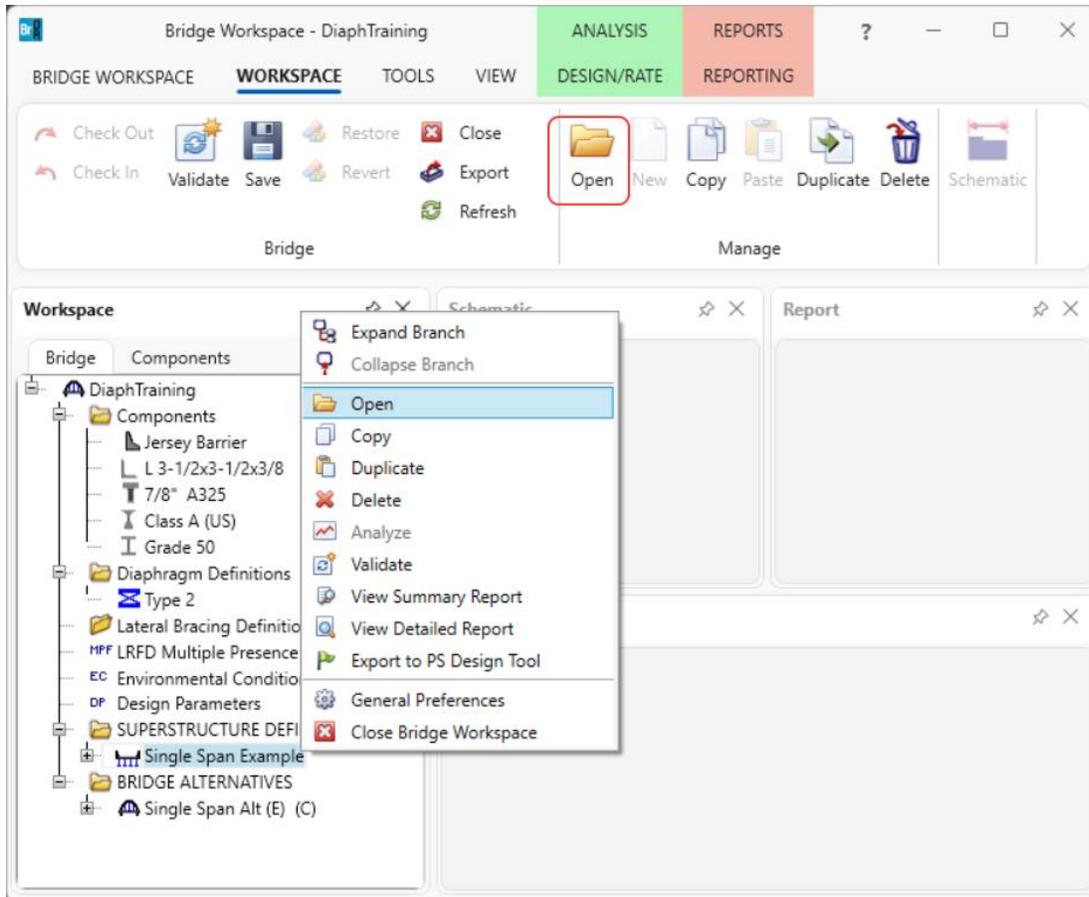


After reviewing the **AASHTOWare BrDR Help**, click **OK** on the **Diaphragm Definitions** window to create the diaphragm and close the window.

3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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.



3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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.

The screenshot shows the 'Girder System Superstructure Definition' window with the 'Analysis' tab selected. The '3D bracing member end connection analysis' section is highlighted with a red box. The options in this section are:

- Calculated factored member force effects
- Maximum of average (stress + strength) and 75% resistance

Below this section, the 'Bracing member LRFR factors' section is visible, with the 'Condition factor' set to 'Good or Satisfactory' and 'Field measured section properties' unchecked.

Span	Length (ft)	Tolerance (%)
> 1	75	0.1

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

3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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.

Load case name	Description	Stage	Type	Time* (days)
DC1	DC acting on non-composite section	Non-composite (Stage 1) ▾	D,DC ▾	
DC2	DC acting on long-term composite section	Composite (long term) (Stage 2) ▾	D,DC ▾	
DW	DW acting on long-term composite secti...	Composite (long term) (Stage 2) ▾	D,DW ▾	
SIP Forms	Weight due to stay-in-place forms	Non-composite (Stage 1) ▾	D,DC ▾	
> Wind		Composite (short term) (Stage 3) ▾	W, WS ▾	

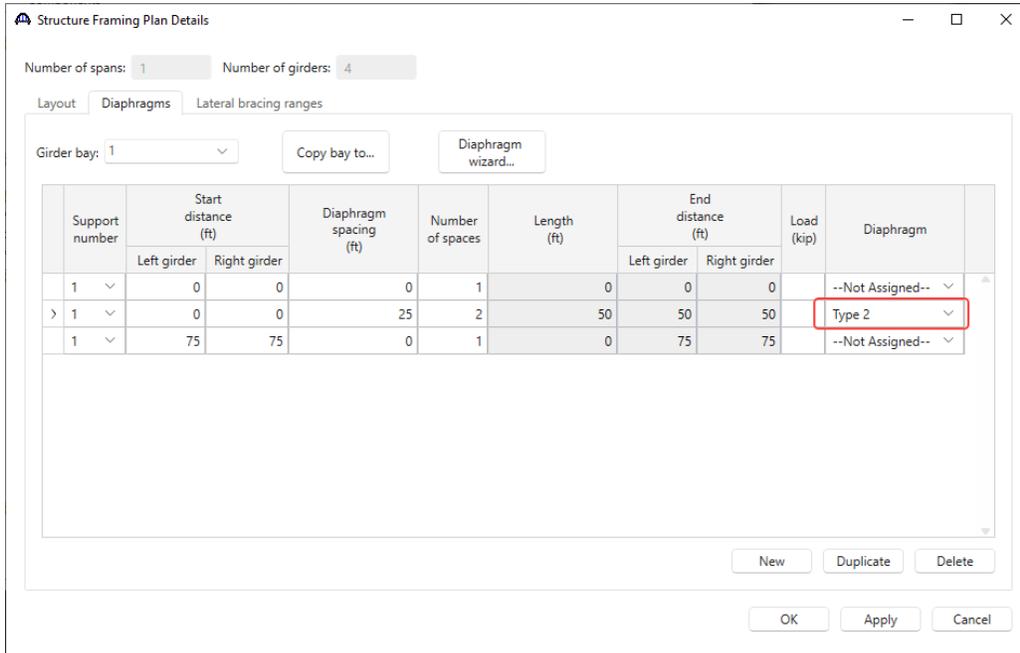
*Prestressed members only

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

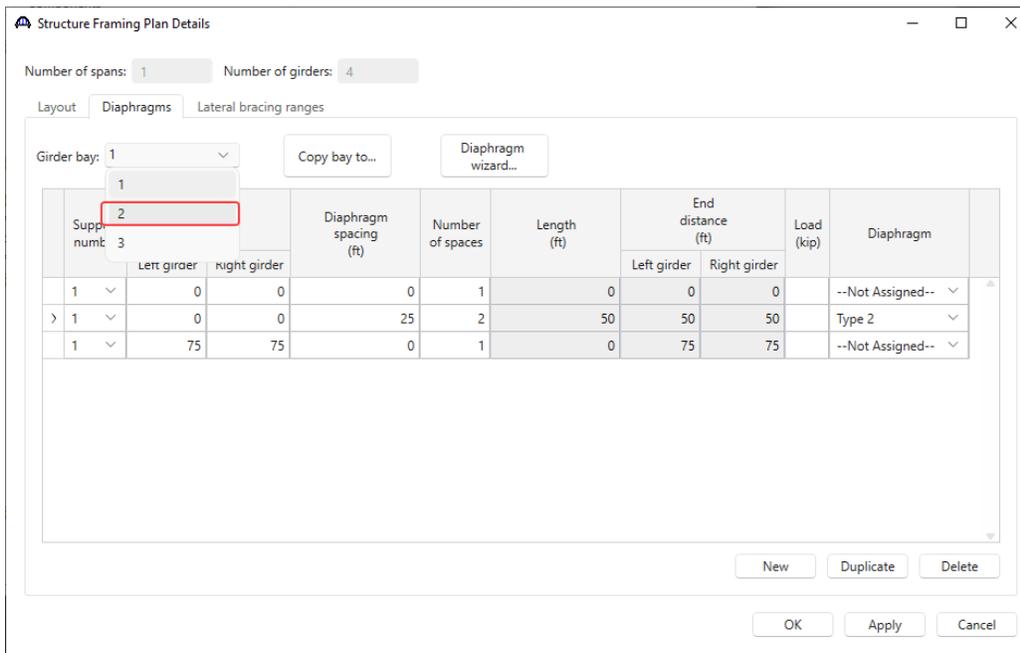
3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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.



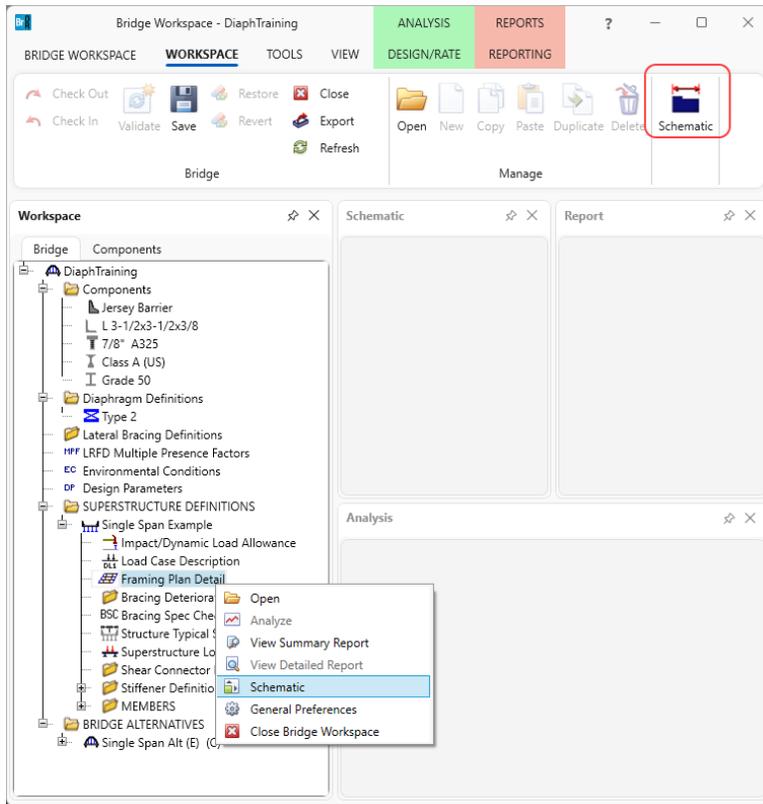
Select **Girder bay 2** from the drop down options and apply the same diaphragm definition. Do this for **Girder bay 3** as well. Once done, click **OK** to apply the data and close the window.



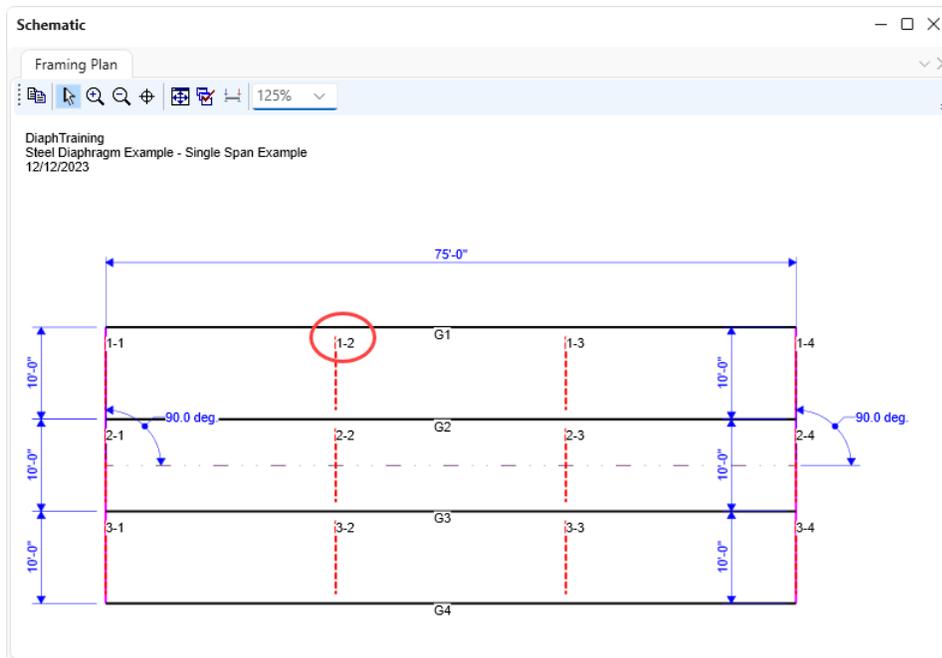
3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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.



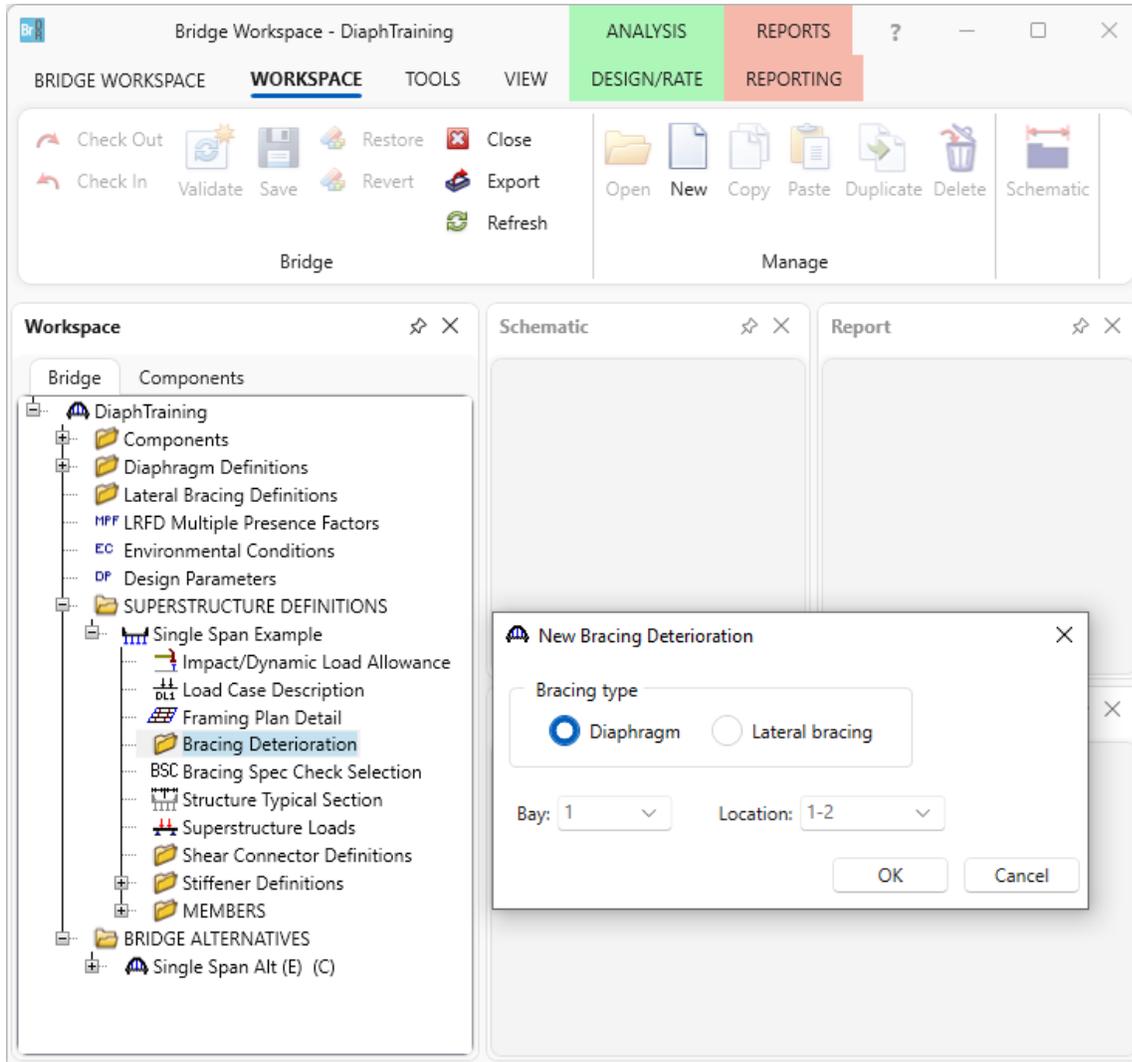
The **Framing Plan Schematic** displays the location labels for the bracing members as shown below.



3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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.



3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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 overridden for this particular member on this tab.

Bracing Deterioration

Bracing Type: Diaphragm Lateral

Bay: 1 Location: 1-2 Diaphragm type: Type 2

Member AB Member CD Member AE Member EB

Shape: L 3-1/2x3-1

LRFR Condition factor: Good or Satisfactory

Field measured section properties

Leg	% Width/depth loss (%)	% Thickness loss (%)	Location	Start distance (ft)	Length (ft)	End distance (ft)	
> Horizontal	20	20	Distance	3	2	5	

New Duplicate Delete

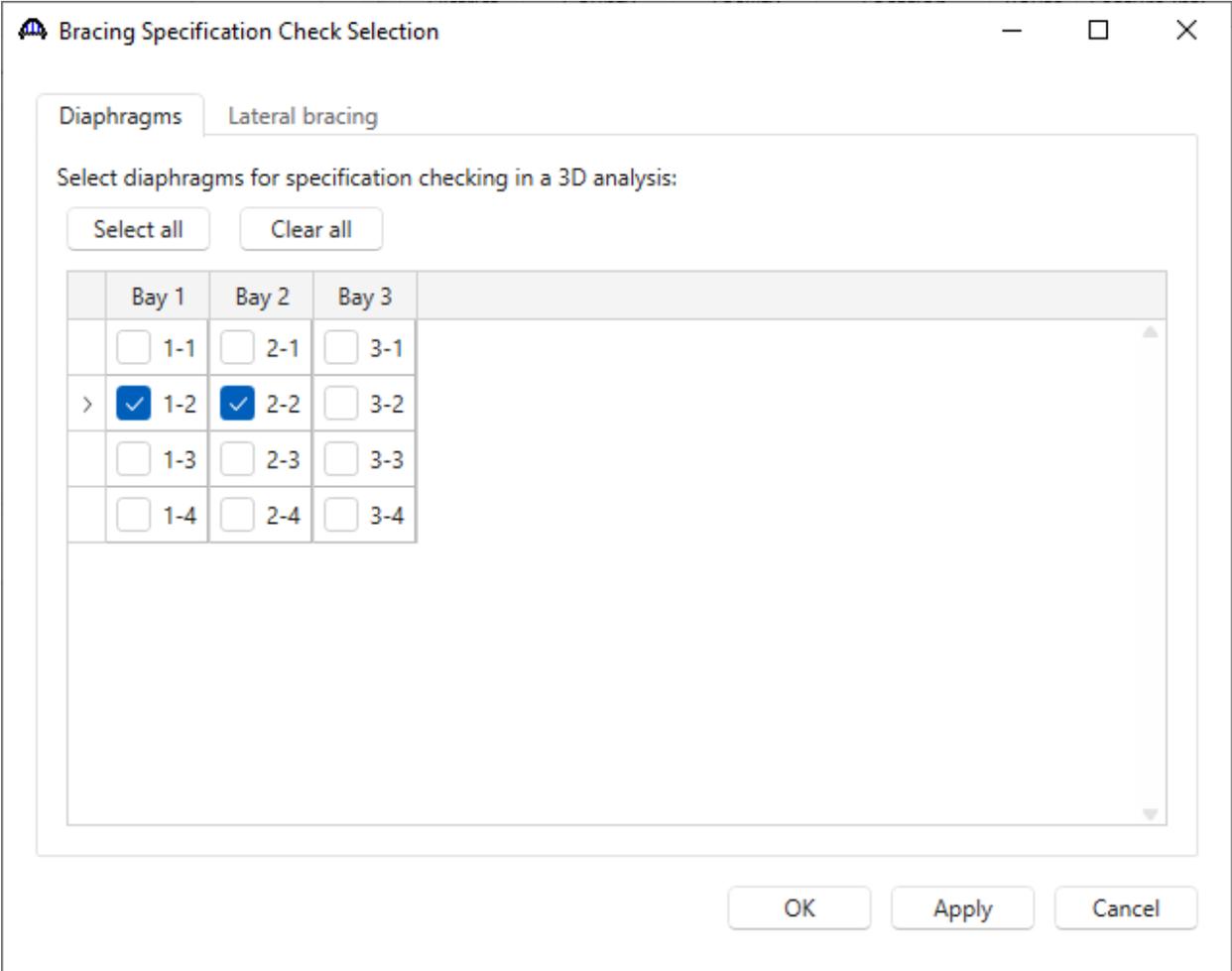
OK Apply Cancel

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

3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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.

3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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.

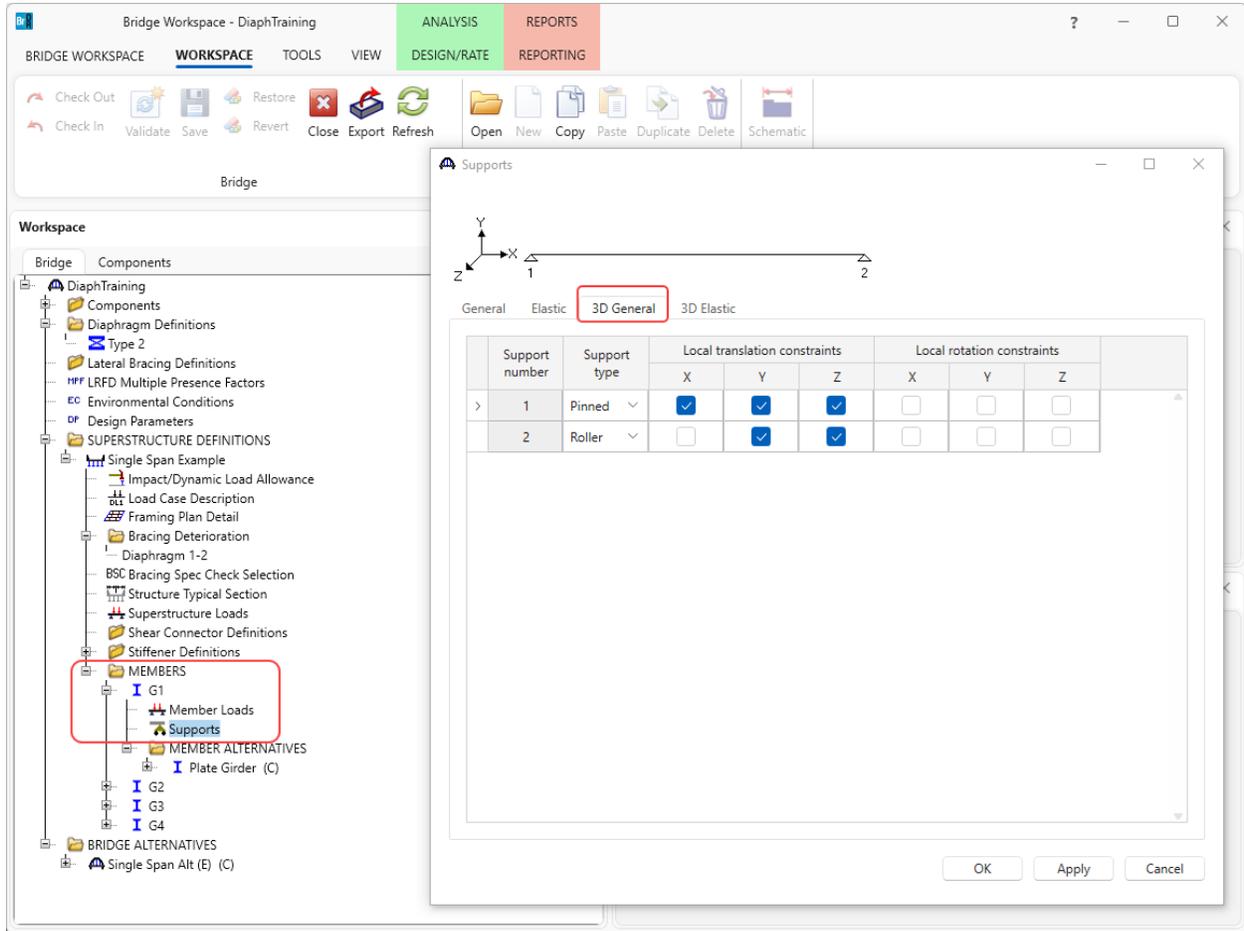
The screenshot shows the 'Superstructure Loads' dialog box with the 'Wind' tab selected. The 'Load case name' is set to 'Wind'. Under 'Wind load basis', 'Gust speed' is selected. The 'Gust speed wind load' table is shown below. To the right, the 'Fastest-mile speed wind load' section has an empty 'Wind load' field. Under 'Wind load path', 'Truss action' is selected. The dialog has 'OK', 'Apply', and 'Cancel' buttons at the bottom.

Limit state	Wind load (psf)
> Strength III	60
Strength V	70
Service I	55
Service IV	52

3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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.

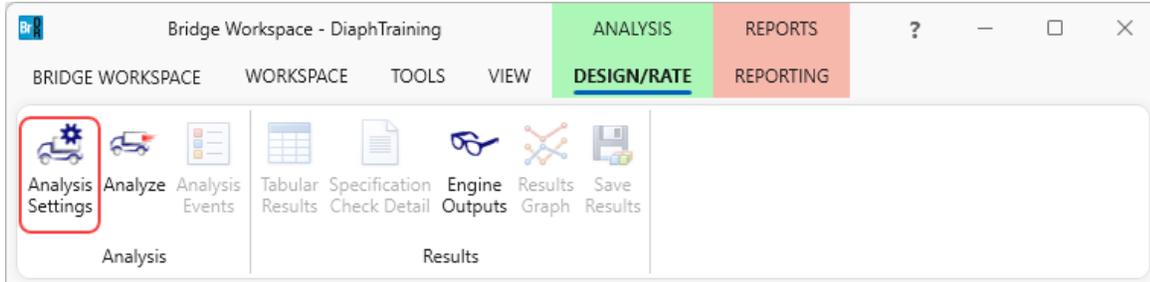


3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

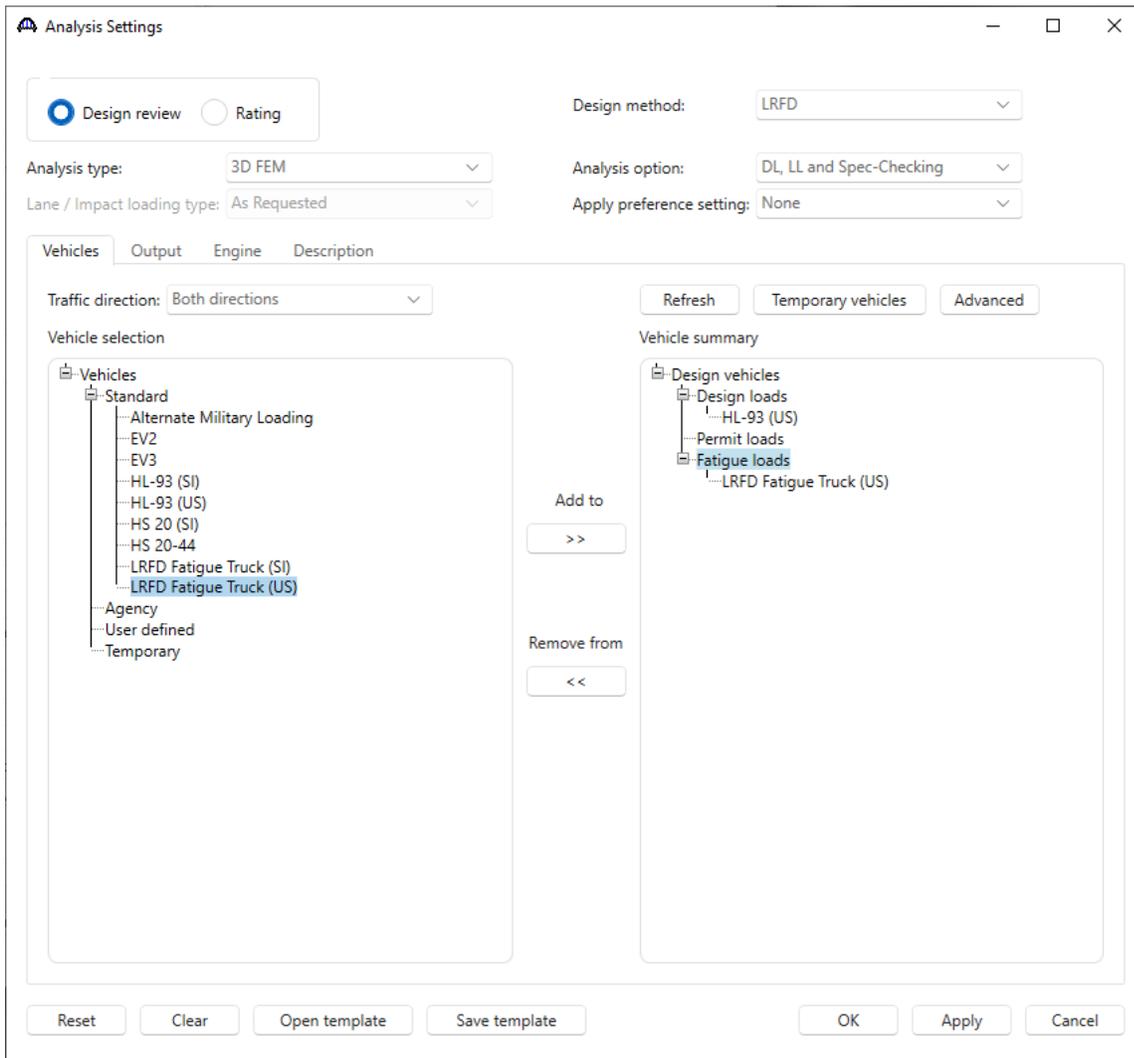
LRFD Design Review

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 settings for a 3D LRFD design review.



3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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

The screenshot shows the 'Analysis Settings' dialog box with the 'Output' tab selected. The 'Design review' radio button is selected. The 'Design method' is set to 'LRFD', 'Analysis type' is '3D FEM', 'Analysis option' is 'DL, LL and Spec-Checking', and 'Apply preference setting' is 'None'. The 'Output' tab contains two columns of checkboxes. The 'Tabular results' column has 'Dead load action report' and 'Live load action report' checked. The 'AASHTO engine reports' column has 'FE model for DL analysis' and 'FE model for LL analysis' checked. At the bottom, there are buttons for 'Reset', 'Clear', 'Open template', 'Save template', 'OK', 'Apply', and 'Cancel'.

Analysis Settings

Design review Rating

Design method: LRFD

Analysis type: 3D FEM

Analysis option: DL, LL and Spec-Checking

Lane / Impact loading type: As Requested

Apply preference setting: None

Vehicles **Output** Engine Description

Tabular results

- Dead load action report
- Live load action report
- Concrete limit state summary report
- LRFD critical loads report
- LRFD specification check report
- PS concrete stress report
- RC service stress report
- Steel limit state summary report

Select all Clear all

AASHTO engine reports

Miscellaneous reports:

- Girder properties
- Summary influence line loading
- Detailed influence line loading
- Capacity summary
- Capacity detailed computations
- FE model for DL analysis
- FE model for LL analysis
- LL influence lines FE model
- LL influence lines FE actions
- LL distrib. factor computations
- LL distrib. factor summary
- Regression data
- Camber
- Fatigue stress ranges
- Service II stress ranges

Specification output:

- LRFD/LRFR conc article detailed

Select all Clear all

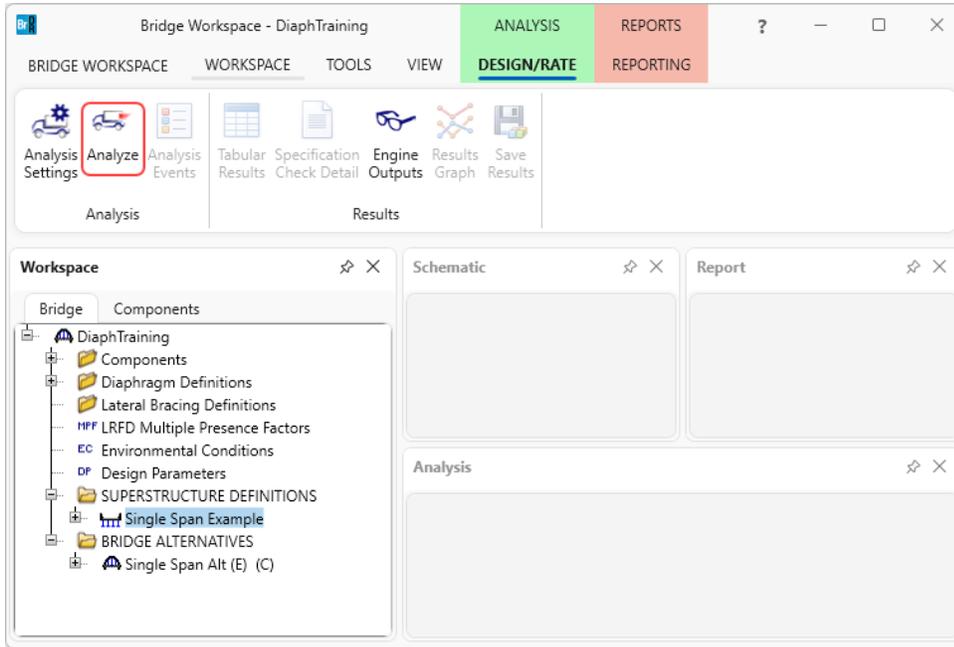
Reset Clear Open template Save template OK Apply Cancel

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

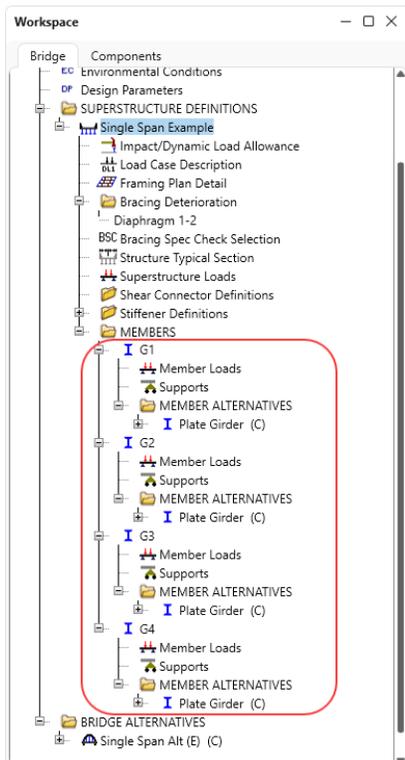
3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

Design Review

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



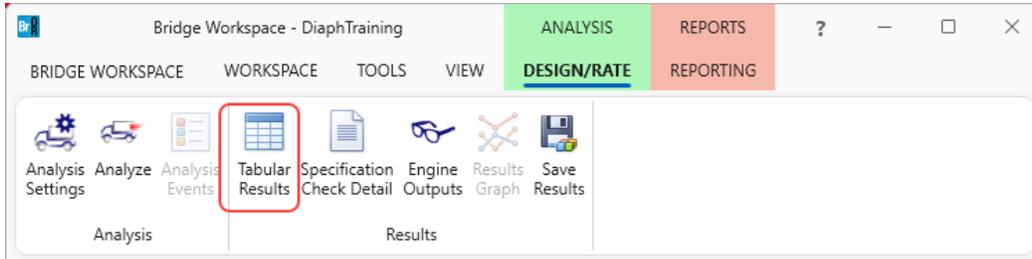
In this example, only the selected diaphragms will be analyzed and specification checked. None of the girder members have member alternatives marked as Existing (E), so they are not included in the analysis.



3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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

Report type: Stage: Dead Load Case: Girder Bay:

	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

AASHTO LRFD 3D Engine Version 7.5.0.3001
Analysis preference setting: None

Close

3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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

Analysis Results - Simple Span Structure Bracing
— □ ×

Print
 Print

Report type:
 Dead Load Actions v

Stage
 Composite (short term) (Stage v)

Dead Load Case
 WS from Left (Strength III:Stage v)

Girder Bay
 All Bays v

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	0.000
			116	2.160	0.002	0.000	0.000	0.000	0.000
2-2	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	0.000	-0.001	0.002
		198	0.830	0.000	0.000	0.000	0.000	0.000	0.000

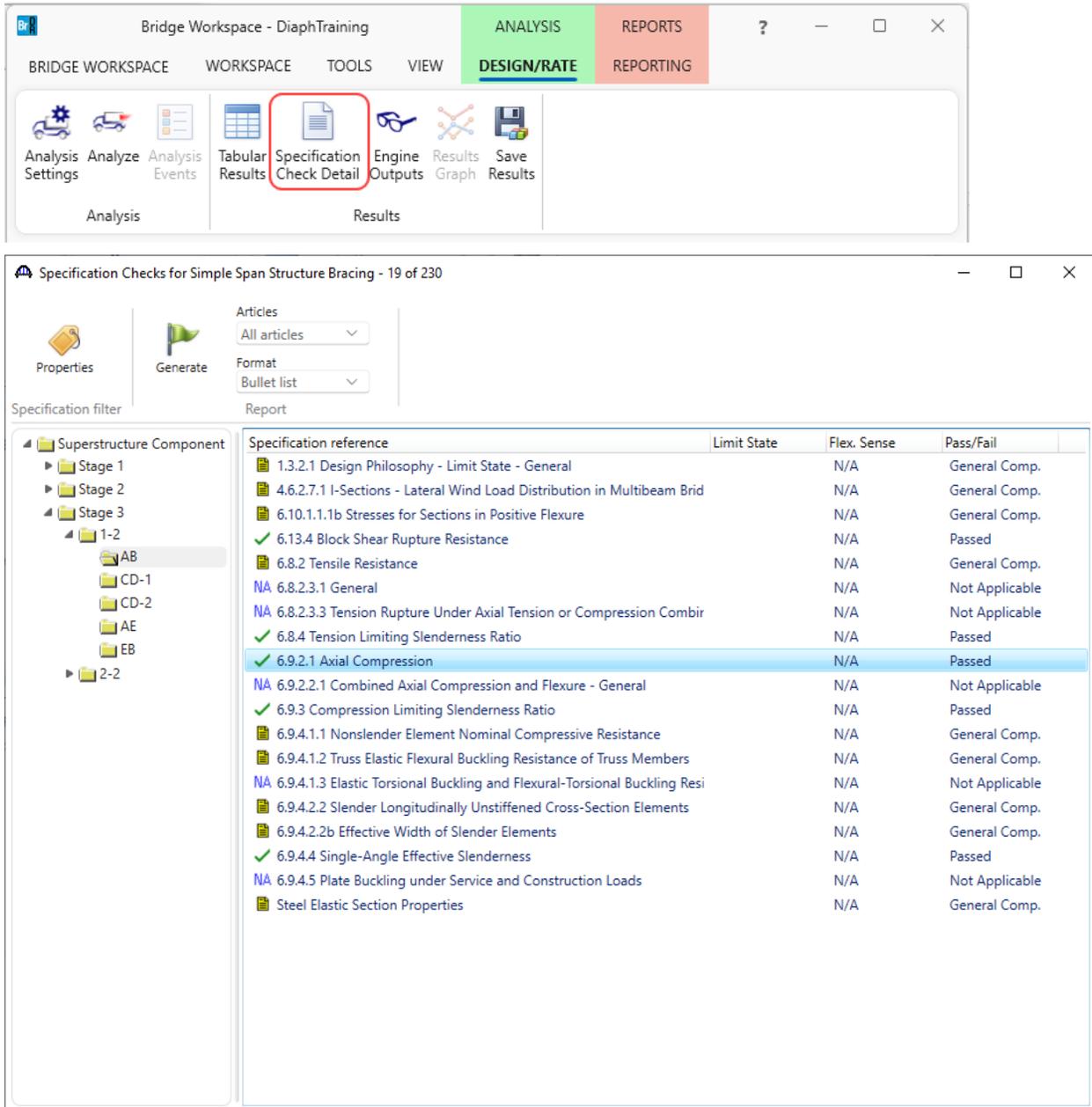
AASHTO LRFD 3D Engine Version 7.5.0.3001
 Analysis preference setting: None

Close

3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

Specification 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.



3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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

Spec Check Detail for 6.9.2.1 Axial Compression

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.

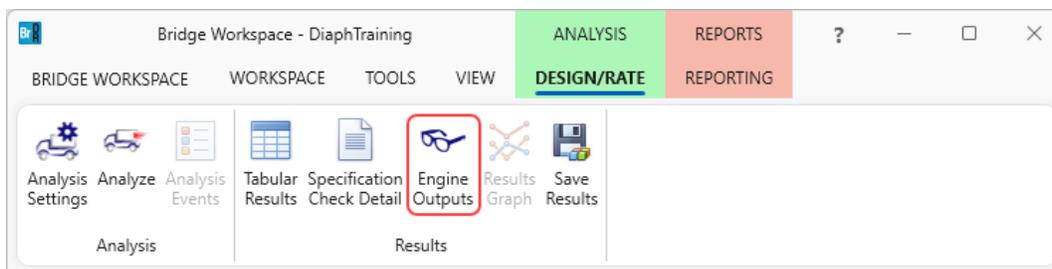
Load Combination Legend:

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

OK

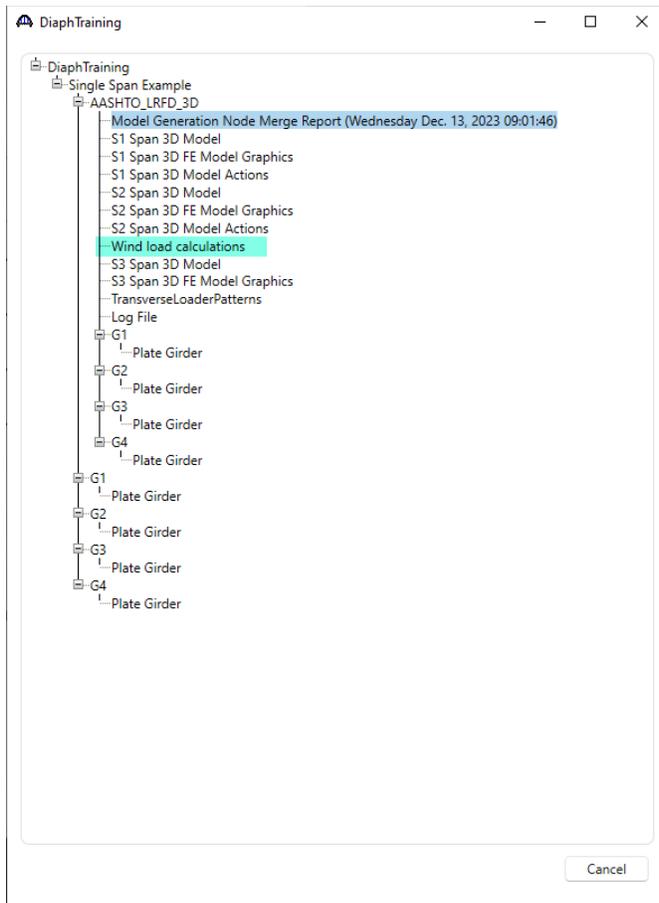
Engine Outputs

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

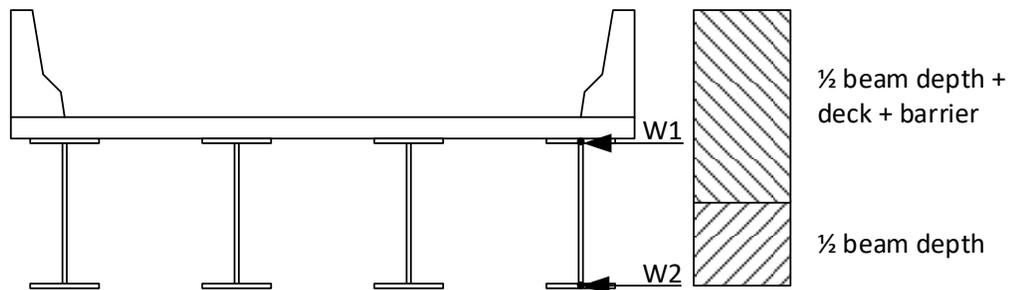


3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

The following output files are available.

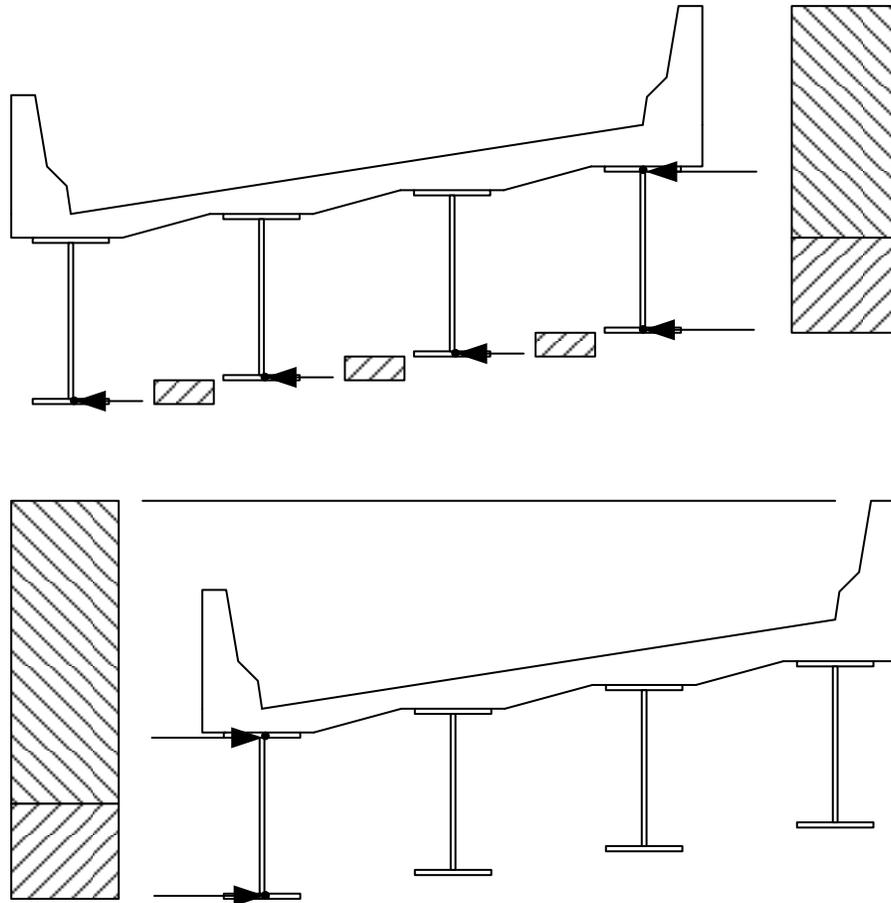


Wind load is calculated based on the projected area of the superstructure elevation. Wind load on the barrier, deck and $\frac{1}{2}$ the girder depth (as measured between the top flange and bottom flange nodes in the FE model) is applied to the top flange node in the windward side exterior beam. Wind load on the bottom $\frac{1}{2}$ the girder depth is applied to the bottom flange node in the windward side exterior beam.

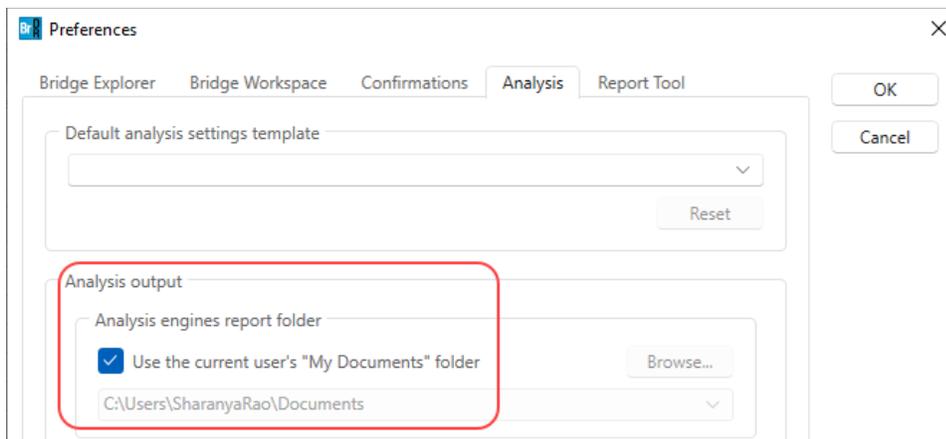


For curved structures, wind is applied along the chord length. This is done by adjusting the user input wind pressure by the ratio of the chord length divided by the arc length. For curved girder systems with superelevation, wind load is also computed for the additional height of exposed barrier and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

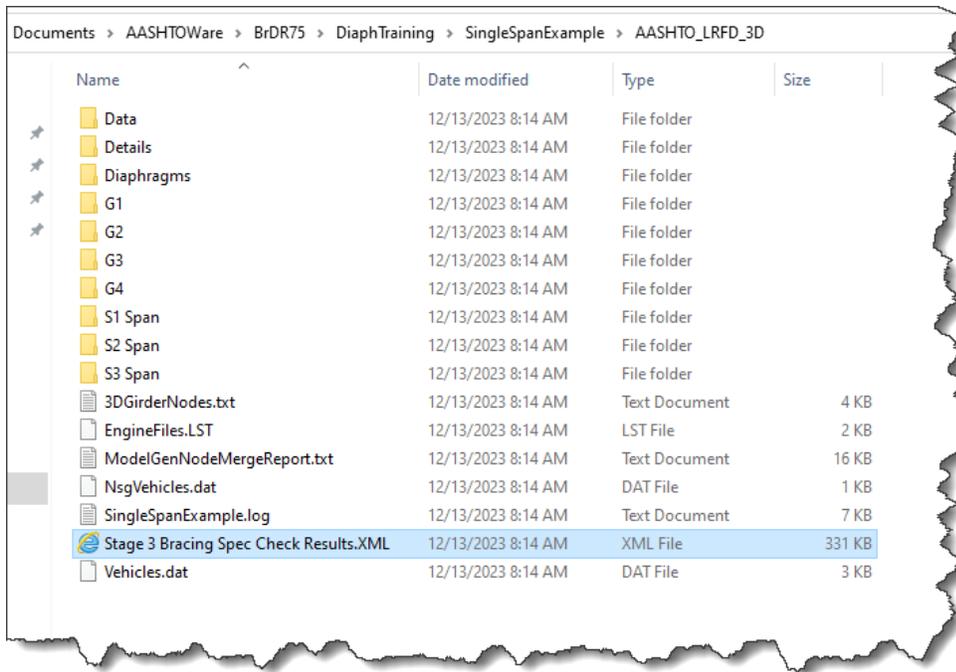
3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example



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



3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example



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
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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

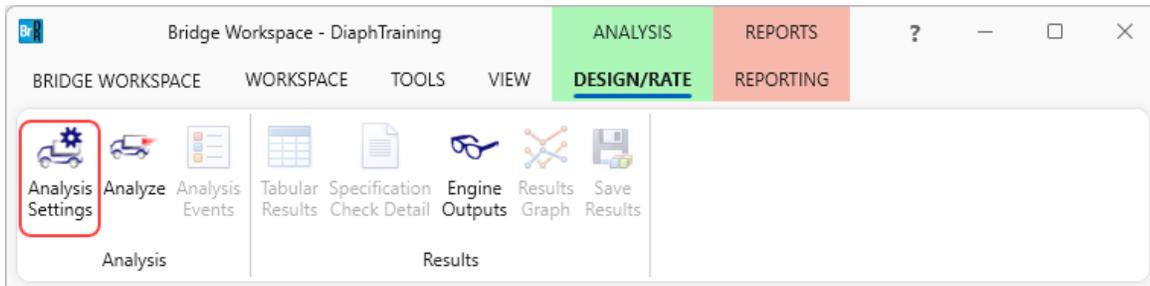
3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

LRFR/LFR Rating

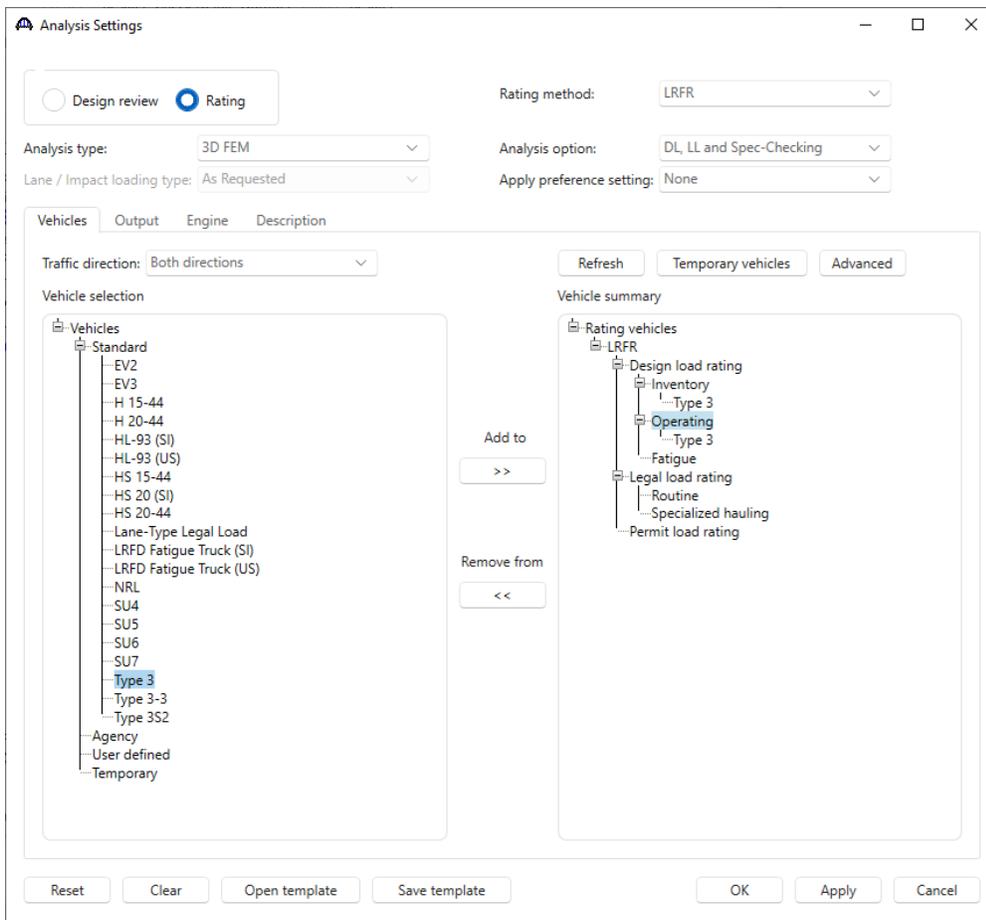
Analysis Settings

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.



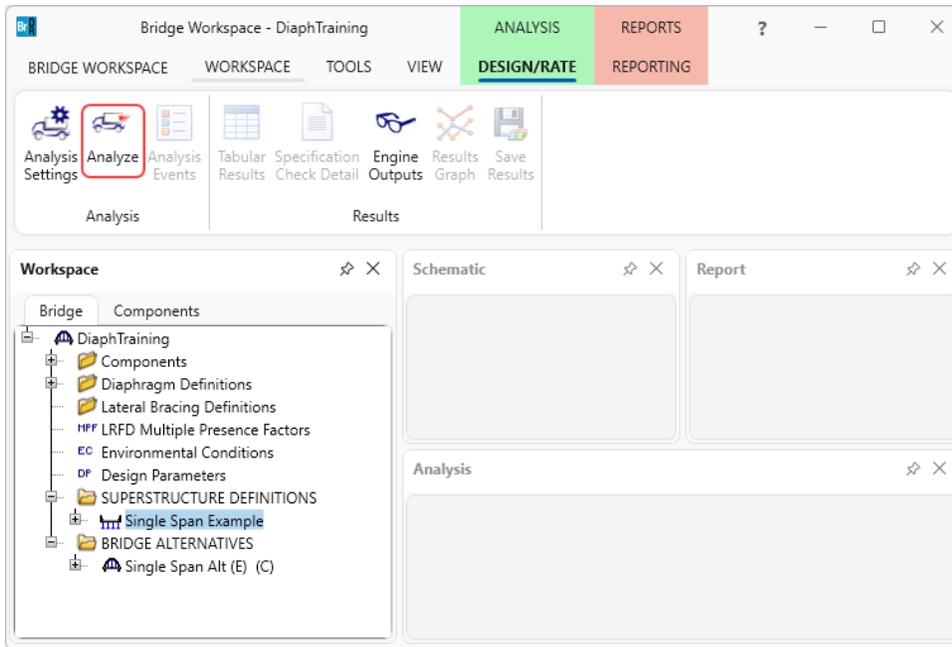
Select the vehicles to be used in the rating as shown below.



3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

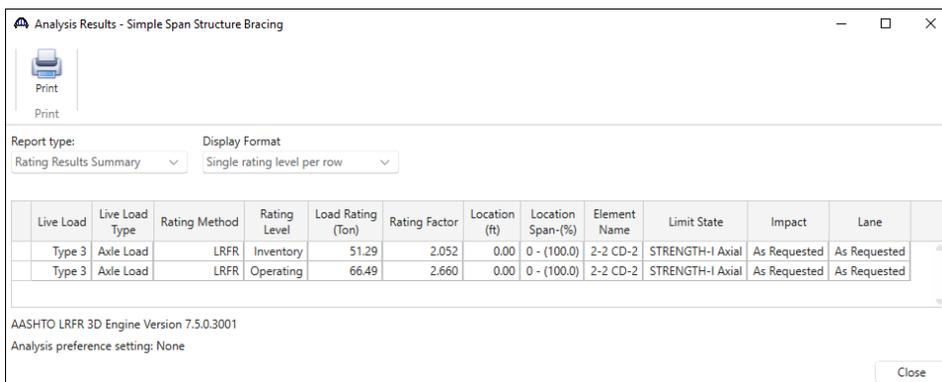
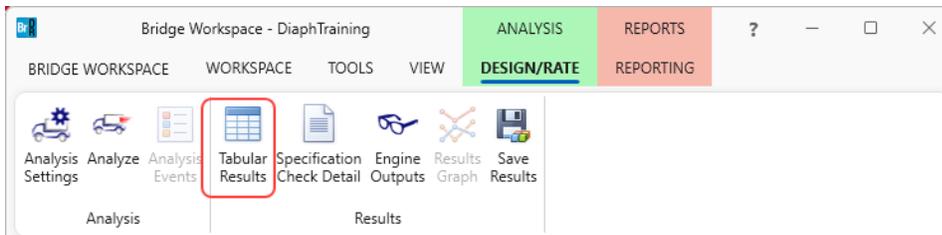
Analyze

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



Tabular Results

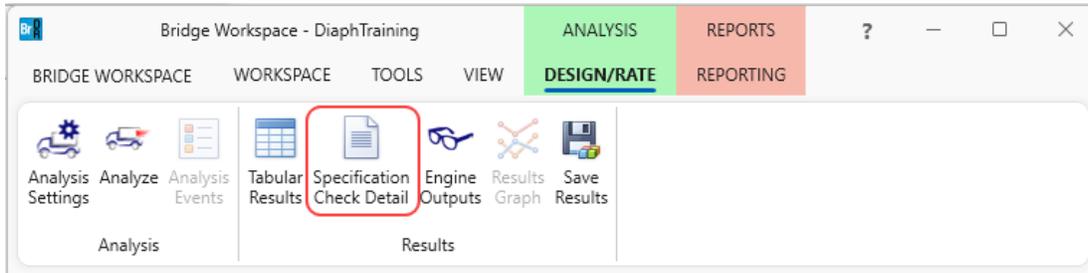
After the analysis completes, open the **Tabular Results** window by clicking on the **Tabular Results** button from the **Results** group of the **DESIGN/RATE** ribbon while the superstructure definition is selected to see the bracing member results.



3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

Specification 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.

Specification Checks for Simple Span Structure Bracing - 21 of 250

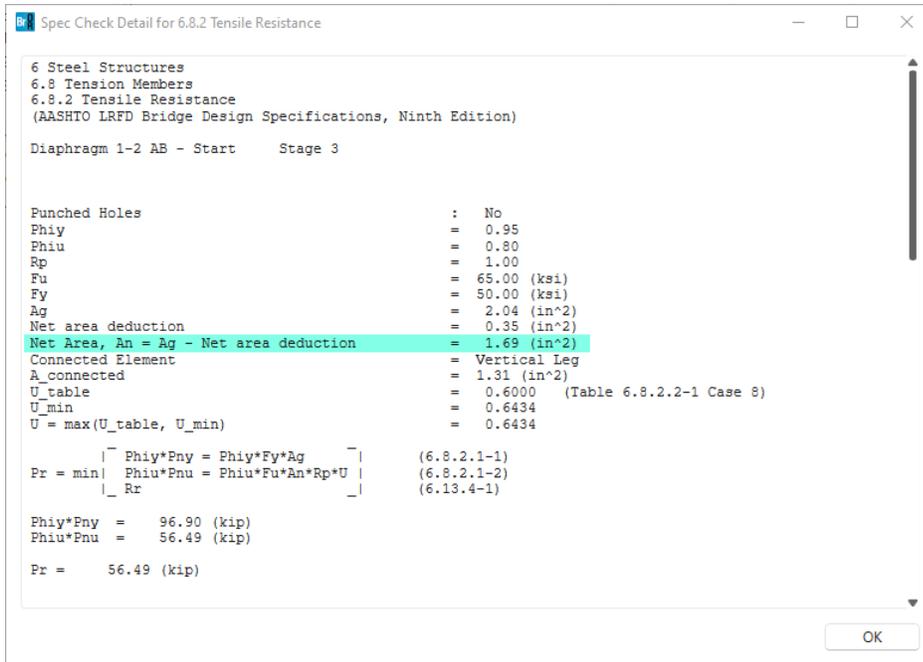
Articles: All articles
Format: Bullet list

Specification filter: Superstructure Component

- Stage 1
- Stage 2
- Stage 3
 - 1-2
 - AB**
 - CD-1
 - CD-2
 - AE
 - EB
 - 2-2

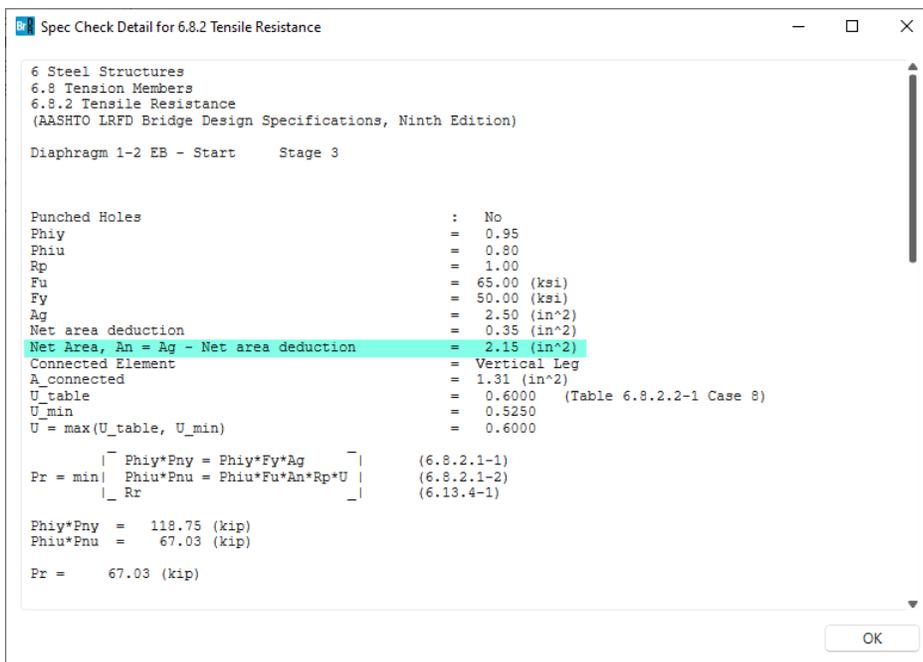
Specification reference	Limit State	Flex. Sense	Pass/Fail
1.3.2.1 Design Philosophy - Limit State - General		N/A	General Comp.
4.6.2.7.1 I-Sections - Lateral Wind Load Distribution in Multibeam Brid		N/A	General Comp.
6.10.1.1.1b Stresses for Sections in Positive Flexure		N/A	General Comp.
6.13.4 Block Shear Rupture Resistance		N/A	Passed
6.8.2 Tensile Resistance		N/A	General Comp.
NA 6.8.2.3.1 General		N/A	Not Applicable
NA 6.8.2.3.3 Tension Rupture Under Axial Tension or Compression Combir		N/A	Not Applicable
✗ 6.8.4 Tension Limiting Slenderness Ratio		N/A	Failed
✓ 6.9.2.1 Axial Compression		N/A	Passed
NA 6.9.2.2.1 Combined Axial Compression and Flexure - General		N/A	Not Applicable
✗ 6.9.3 Compression Limiting Slenderness Ratio		N/A	Failed
6.9.4.1.1 Nonslender Element Nominal Compressive Resistance		N/A	General Comp.
6.9.4.1.2 Truss Elastic Flexural Buckling Resistance of Truss Members		N/A	General Comp.
NA 6.9.4.1.3 Elastic Torsional Buckling and Flexural-Torsional Buckling Resi		N/A	Not Applicable
6.9.4.2.2 Slender Longitudinally Unstiffened Cross-Section Elements		N/A	General Comp.
6.9.4.2.2b Effective Width of Slender Elements		N/A	General Comp.
✓ 6.9.4.4 Single-Angle Effective Slenderness		N/A	Passed
NA 6.9.4.5 Plate Buckling under Service and Construction Loads		N/A	Not Applicable
✓ 6A.6.6-7 Truss Axial Tension and Compression Rating		N/A	Passed
NA 6A.6.8 Truss Combined Axial and Flexure Rating		N/A	Not Applicable
Steel Elastic Section Properties		N/A	General Comp.

3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example



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 redoing 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**.



3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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:

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		2	2	1.5		2	1.75
EB	B	Bolt		1	2	3		2	1.75

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

Analysis Settings

Design review Rating

Rating method: LRFR

Analysis type: 3D FEM

Analysis option: Spec-Checking Only

Lane / Impact loading type: As Requested

Apply preference setting: None

Vehicles Output Engine Description

Traffic direction: Both directions

Refresh Temporary vehicles Advanced

Vehicle selection

Rating vehicles

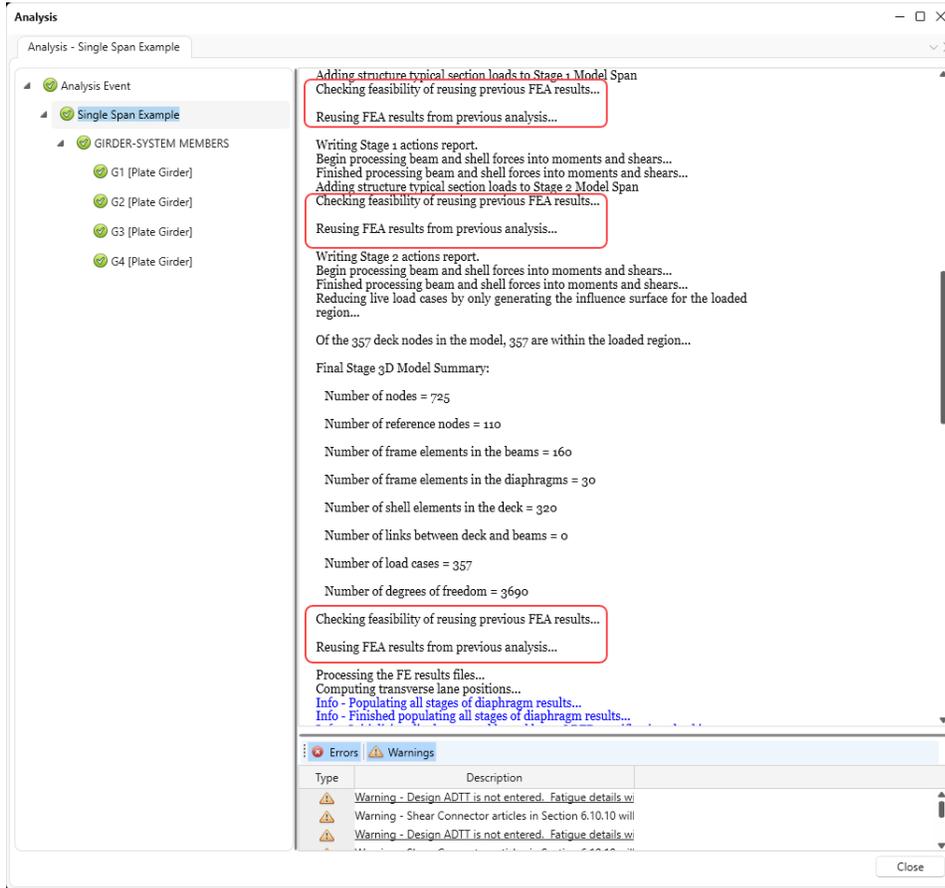
LRFR

- Design load rating
 - Inventory
 - Operating
 - Fatigue
- Legal load rating
 - Routine
 - Specialized hauling
 - Permit load rating

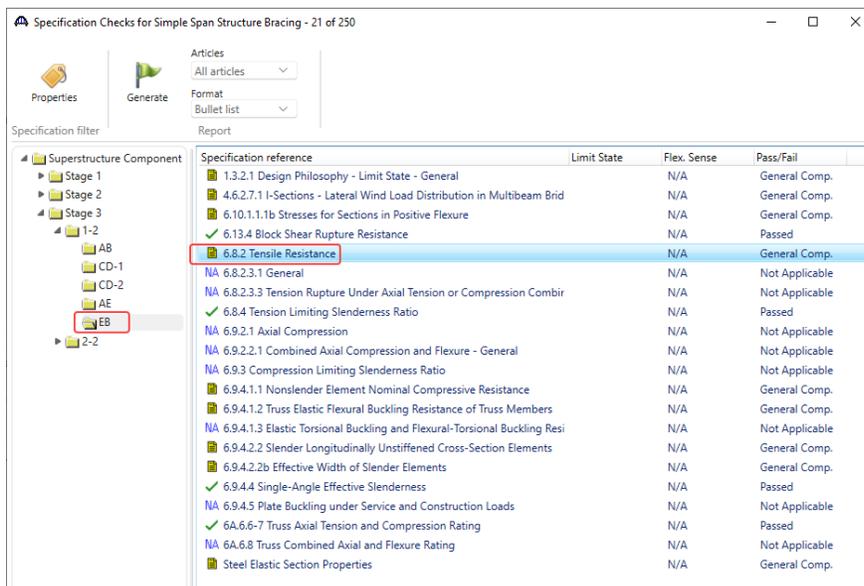
Reset Clear Open template Save template OK Apply Cancel

3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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.



3DFEM1 – Steel Diaphragm and Lateral Bracing Specification Checking Example

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