

AASHTOWare BrDR 7.6.1

3D FEM Analysis Tutorial
Axial Rigidity Coefficient Example

3DFEM6 – Axial Rigidity Coefficient Example

AASHTOWare Bridge Design and Rating Training

3DFEM6-Axial-Rigidity-Coefficient-Example

Topics Covered

- Modifying 3DFEM2-Single-Span-Steel-3D-Example bridge
- Steel Diaphragm Connection Data Entry with Axial Rigidity Coefficient (ARC)
- Steel Diaphragm Spec Check Comparison

Features (Introduced in version 7.6.0 as a part of the LRFD 10th edition spec updates):

- LRFD/LRFR Axial Rigidity Coefficients

	Member	Shape	Section orientation	Section location	Material	LRFD/LRFR axial rigidity coefficients		
						Non-composite	Composite (long term)	Composite (short term)
>	AB	L 4x4x1/2	Vertical	Top Left	Fy= 33 ks			
	CD	L 4x4x1/2	Vertical	Top Left	Fy= 33 ks			
	AD	L 4x4x1/2	Vertical	Top Left	Fy= 33 ks			
	CB	L 4x4x1/2	Vertical	Top Left	Fy= 33 ks			

This tutorial demonstrates how to input Axial Rigidity Coefficients for different diaphragm members. In the 10th edition of the LRFD specifications, section 4.6.3.3.4c introduces equivalent axial rigidity in cross frame members. This gives the user the option to scale the axial terms from the stiffness matrix for steel cross frame members. Prior to version 7.6.0 of BrDR, users did not have the ability to enter in ARC coefficients for diaphragm members, as ARC values are introduced in the 10th edition of the LRFD specifications. In version 7.6.0 and beyond, the users will have this option. This may impact the computed axial forces within the diaphragm members. For single angle and horizontally oriented T-shaped diaphragm members, if the user does not enter axial rigidity coefficients, default values of 0.65 or 0.75 for non-composite or composite members respectively will be assumed. These default values are derived from section 4.6.3.3.4c of the specifications which state “the equivalent axial rigidity of single-angle and flange-connected tee-section cross-frame members to be taken as 0.65AE in the analysis model for the non-composite condition during construction.” Additionally, “taken as 0.75AE in the analysis model for the composite condition.”

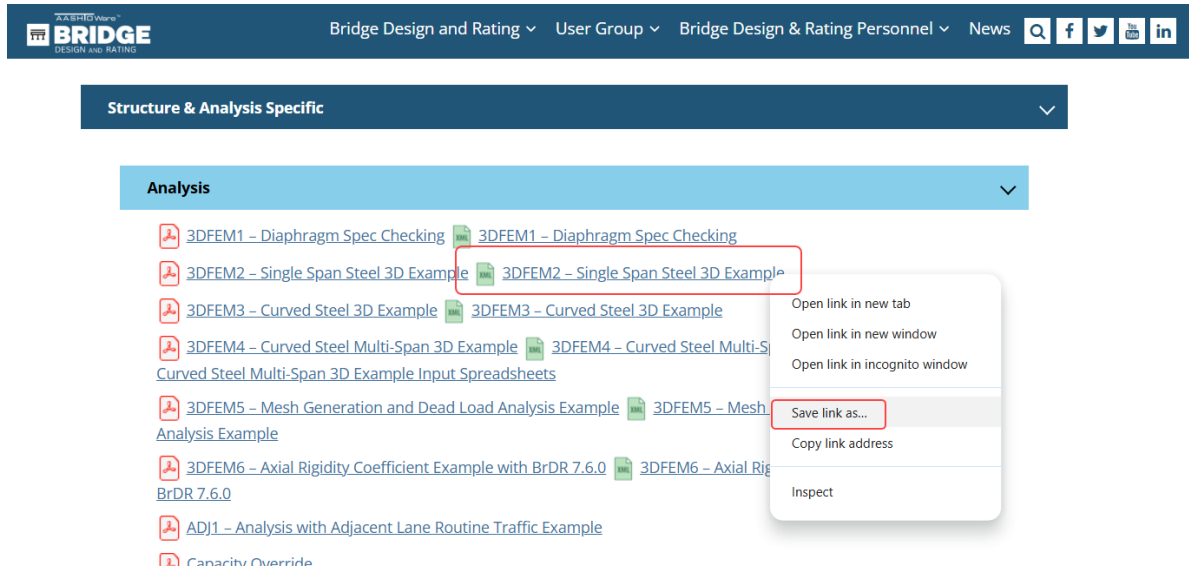
This bridge is a single span steel girder system with four rolled steel girders. Follow the steps to modify the structure definition. Two diaphragm member types, one with axial rigidity coefficient values < 1.0 and one with axial rigidity coefficient values = 1.0 will be input by the user and those results will be compared. Then one of the diaphragm member definitions will be modified, so that default behavior for axial rigidity coefficient values for single angle or horizontally oriented T-shaped members can be observed.

3DFEM6 – Axial Rigidity Coefficient Example

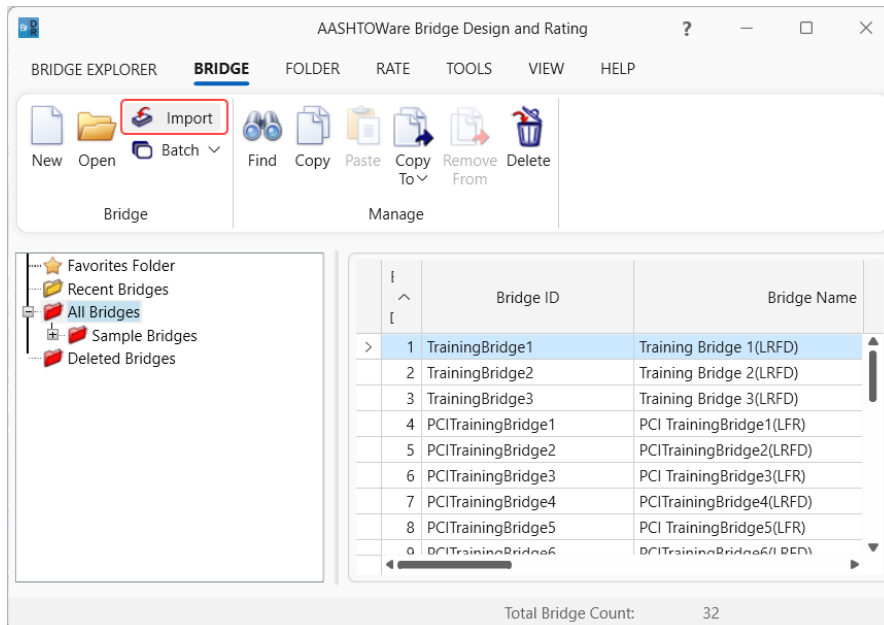
Modifying Steel Girder Bridge

Go to **AASHTO's** website to access the training files: <https://aashtowarebrdr.org/bridge-rating-and-design/training/>.

Then, right click on **3DFEM2 – Single Span Steel 3D Example** and select **Save link as...**



Once this is saved, it can be accessed in the next step to import into **BrDR**. From the **Bridge Explorer**, import the **3DFEM2-Single-Span-Steel-3D-Example.xml** file



3DFEM6 – Axial Rigidity Coefficient Example

Modify Superstructure

Change the **Bridge ID** and **NBI structure ID**, **Axial Rigidity Coefficient Training**, and **Name** to **Axial Rigidity Coefficient Training**. Click **OK** to apply the changes and close the **Bridge** window.

STL8

Bridge ID: Rigidity Coefficient Training NBI structure ID (8): Rigidity Coefficient Training

☐ Template
☐ Bridge completely defined

Bridge Workspace View
☒ Superstructures
☐ Culverts
☒ Substructures

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

Name: Axial Rigidity Coefficient Training Year built:

Description:

Location: Length: ft

Facility carried (7): Route number:

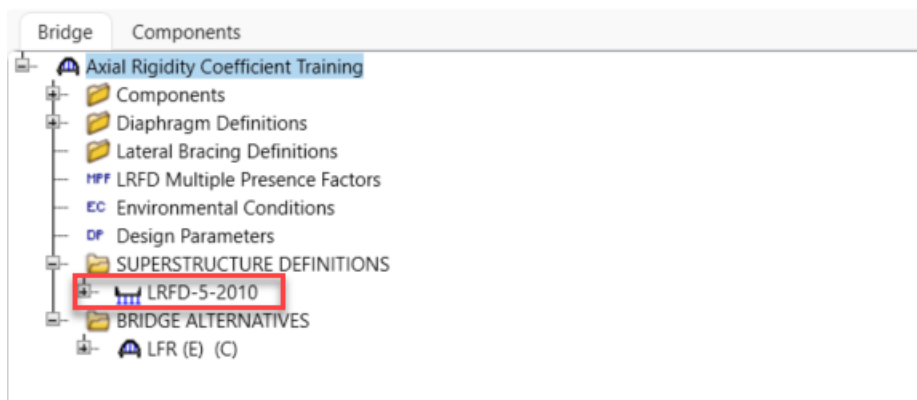
Feat. intersected (6): Mi. post:

Default units: US Customary

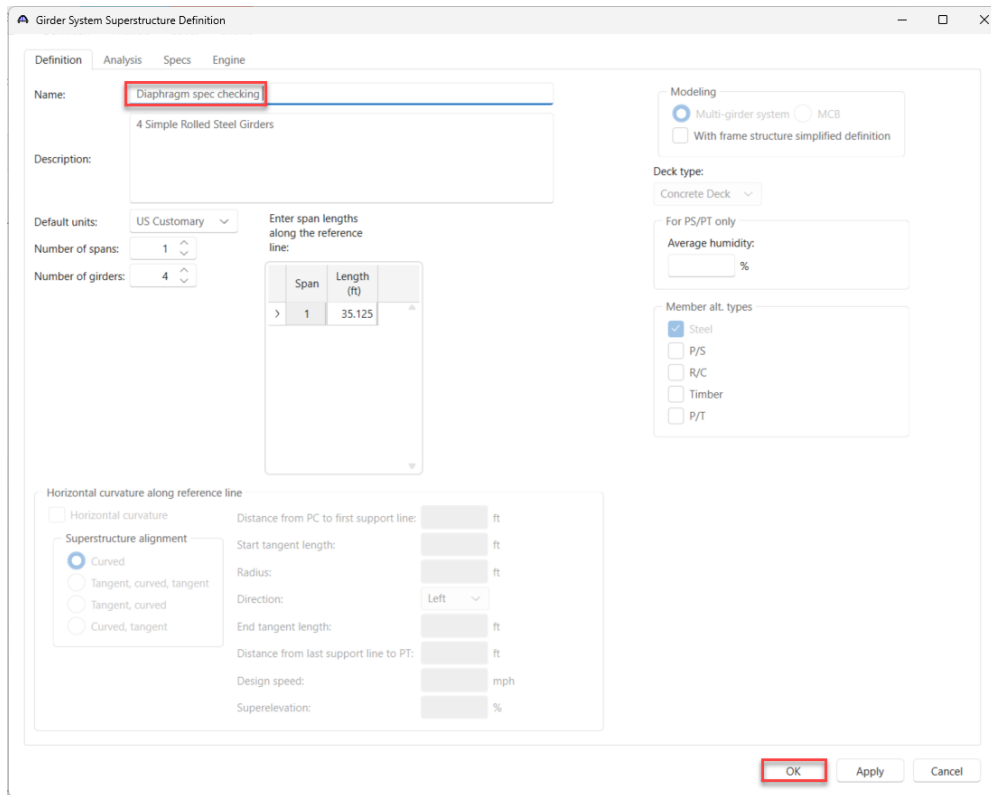
Bridge association... ☒ BrR ☒ BrD ☐ BrM

OK Apply Cancel

Next, change the superstructure name by double clicking on the **superstructure definition** and changing the name to **Diaphragm spec checking**. Then select **OK** to apply the changes and close the **Girder System Superstructure Definition** window.



3DFEM6 – Axial Rigidity Coefficient Example



The **Girder System Superstructure Definition** dialog box is shown with the **Definition** tab selected. The **Name** field is set to "Diaphragm spec checking" and the **Description** is "4 Simple Rolled Steel Girders". The **Default units** are set to "US Customary". The **Number of spans** is 1 and the **Number of girders** is 4. The **Span** and **Length (ft)** table shows a single span of 35.125 ft. The **Modeling** section has "Multi-girder system" selected. The **Deck type** is "Concrete Deck". The **Member alt. types** section has "Steel" selected. The **Horizontal curvature along reference line** section has "Curved" selected. The **OK** button is highlighted.

Name: Diaphragm spec checking

Description: 4 Simple Rolled Steel Girders

Default units: US Customary

Number of spans: 1

Number of girders: 4

Enter span lengths along the reference line:

Span	Length (ft)
1	35.125

Modeling: Multi-girder system (selected), MCB, With frame structure simplified definition

Deck type: Concrete Deck

For PS/PT only: Average humidity: %

Member alt. types: Steel (selected), P/S, R/C, Timber, P/T

Horizontal curvature along reference line: Horizontal curvature, Superstructure alignment: Curved (selected), Tangent, curved, tangent, Tangent, curved, Curved, tangent

Distance from PC to first support line: ft

Start tangent length: ft

Radius: ft

Direction: Left

End tangent length: ft

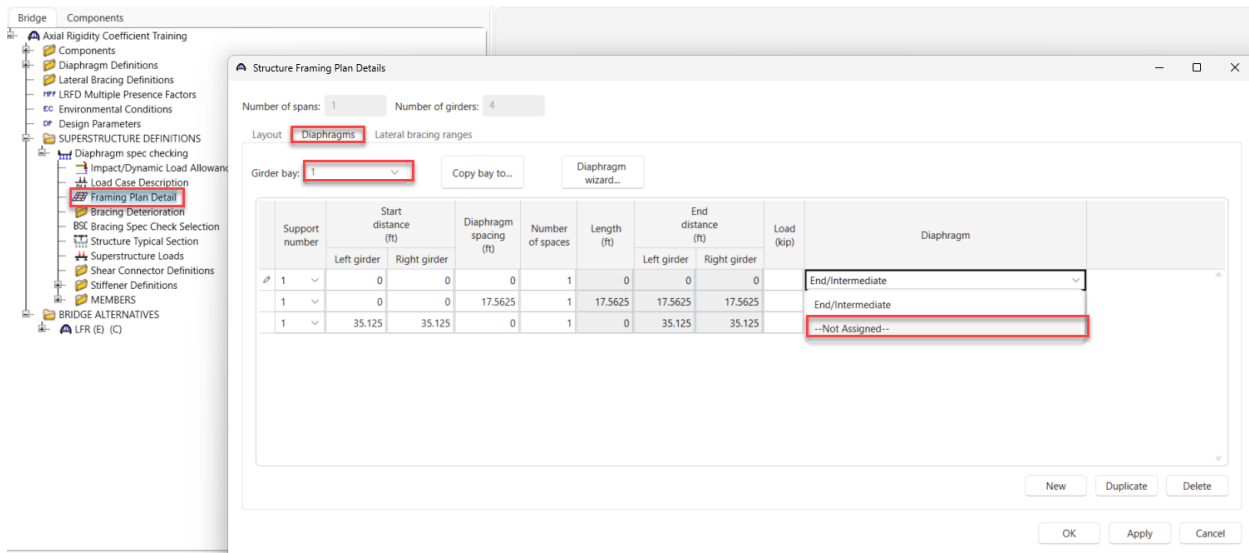
Distance from last support line to PT: ft

Design speed: mph

Superelevation: %

OK Apply Cancel

Next, open the **Framing Plan Detail** window by expanding **Diaphragm spec checking** and double-clicking **Framing Plan Detail**. Go to the **Diaphragms** tab and assign each diaphragm to **--Not Assigned--** for the diaphragm definition.



The **Structure Framing Plan Details** dialog box is shown with the **Diaphragms** tab selected. The **Number of spans** is 1 and the **Number of girders** is 4. The **Girder bay** is set to 1. The **Diaphragm** table shows three diaphragms, with the third one assigned to **--Not Assigned--**. The **OK** button is highlighted.

Number of spans: 1 **Number of girders:** 4

Layout: Diaphragms Lateral bracing ranges

Girder bay: 1 **Copy bay to...** **Diaphragm wizard...**

Support number	Start distance (ft)		Diaphragm spacing (ft)	Number of spaces	Length (ft)	End distance (ft)		Load (kip)	Diaphragm
	Left girder	Right girder				Left girder	Right girder		
1	0	0	0	1	0	0	0	End/Intermediate	
1	0	0	17.5625	1	17.5625	17.5625	17.5625	End/Intermediate	
1	35.125	35.125	0	1	0	35.125	35.125	--Not Assigned--	

New **Duplicate** **Delete**

OK **Apply** **Cancel**

3DFEM6 – Axial Rigidity Coefficient Example

Structure Framing Plan Details

Number of spans: 1 Number of girders: 4

Layout Diaphragms Lateral bracing ranges

Girder bay: 1 Copy bay to... Diaphragm wizard...

Support number	Start distance (ft)		Diaphragm spacing (ft)	Number of spaces	Length (ft)	End distance (ft)		Load (kip)	Diaphragm
	Left girder	Right girder				Left girder	Right girder		
1	0	0	0	1	0	0	0	--Not Assigned--	
1	0	0	17.5625	1	17.5625	17.5625	17.5625	--Not Assigned--	
1	35.125	35.125	0	1	0	35.125	35.125	--Not Assigned--	

New Duplicate Delete

OK Apply Cancel

Repeat this step for **Girder Bay 2** and **3**. If this window appears when switching between girder bays, select **Yes** and continue.

Bridge Design & Rating

?

Data in this grid has changed!
Do you want to save this data before switching to another Girder Bay ?

Yes No

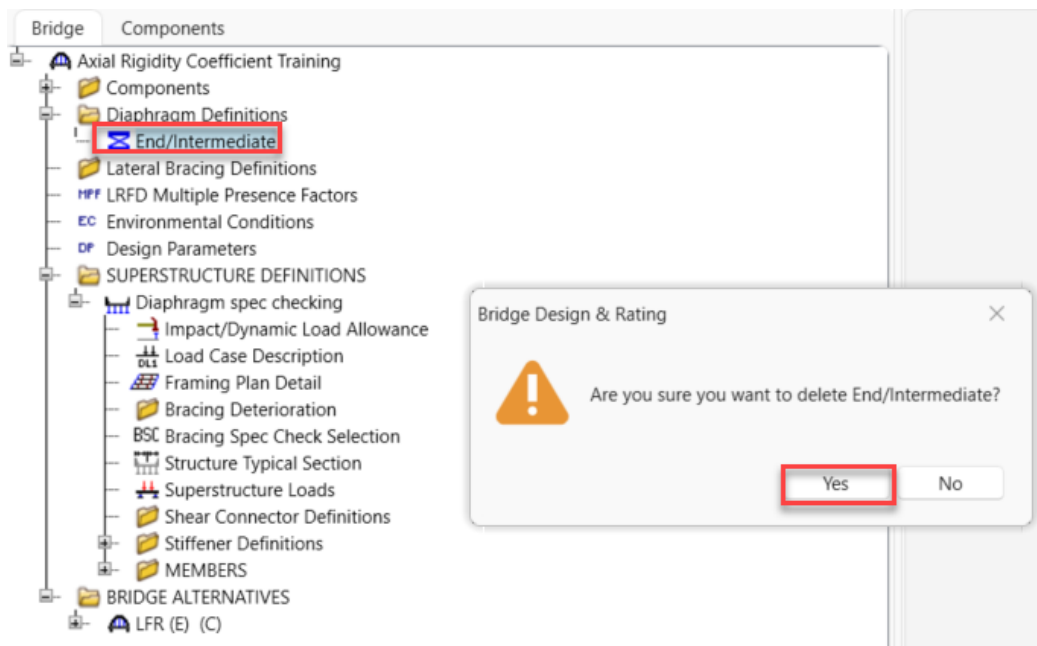
3DFEM6 – Axial Rigidity Coefficient Example

Verify that all girder bays have **--Not Assigned--** selected for the diaphragm location and select **OK** to apply the changes and close the **Structure Framing Plan Details** window.

The window shows the 'Diaphragms' tab. At the top, 'Number of spans' is 1 and 'Number of girders' is 4. Below, 'Girder bay' is set to 3. A table lists diaphragm data for three bays. The 'Diaphragm' column for all bays is set to '--Not Assigned--'. The 'OK' button is highlighted with a red box.

Support number	Start distance (ft)		Diaphragm spacing (ft)	Number of spaces	Length (ft)	End distance (ft)		Load (kip)	Diaphragm
	Left girder	Right girder				Left girder	Right girder		
1	0	0	0	1	0	0	0	--Not Assigned--	
1	0	0	17.5625	1	17.5625	17.5625	17.5625	--Not Assigned--	
> 1	35.125	35.125	0	1	0	35.125	35.125	--Not Assigned--	

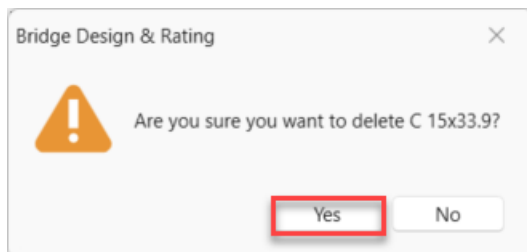
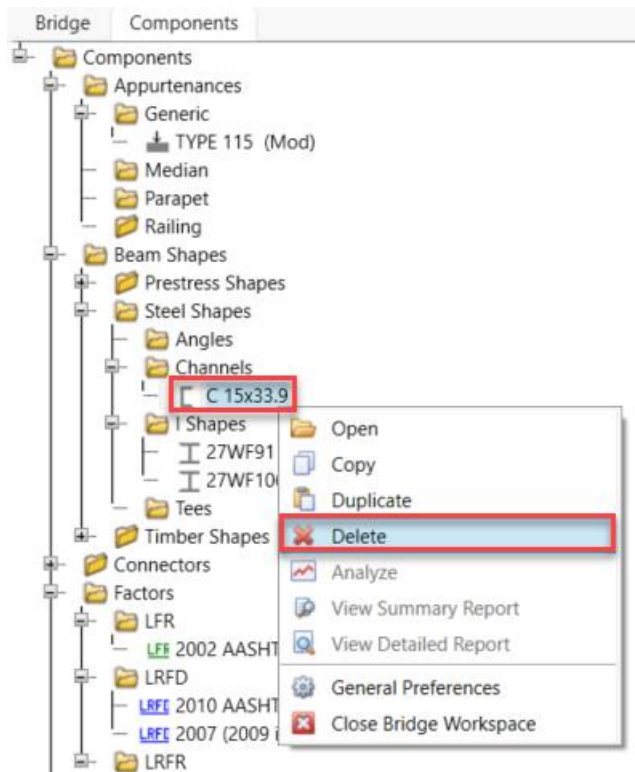
Next, delete the **diaphragm definition** by expanding the **Diaphragm Definitions** folder, then right clicking **End/Intermediate** and selecting **delete**. If the confirmation window pops up, select **Yes** and continue.



3DFEM6 – Axial Rigidity Coefficient Example

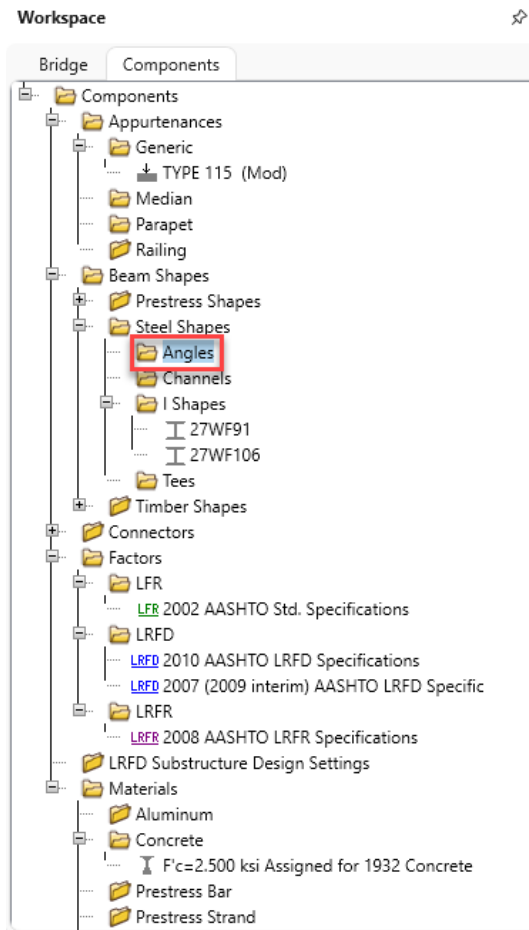
Diaphragm member steel shapes

Next, the Steel shapes need to be added to use for the diaphragms. In the **Components** tab of the **Bridge Workspace**, expand the **Beam Shapes** folder, then expand the **Steel Shapes** folder, then the expand **Channels** folder, finally right click and **delete** the **C 15x33.9** shape as this will not be needed anymore.

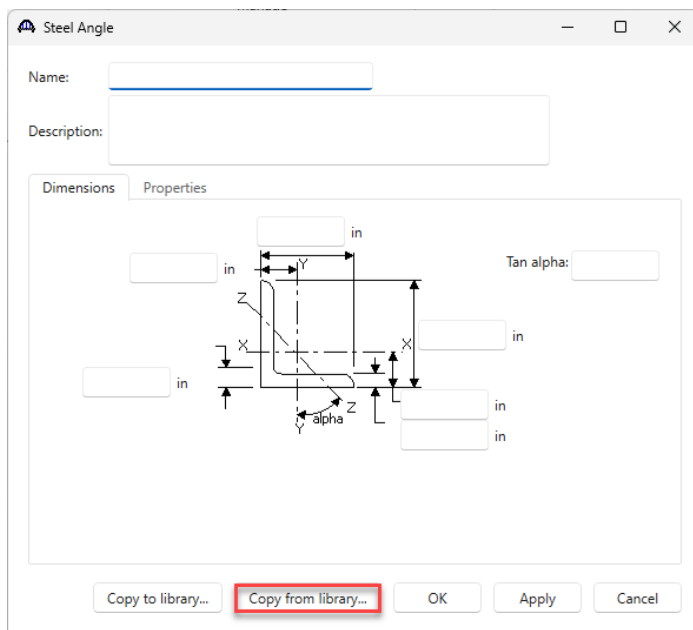


3DFEM6 – Axial Rigidity Coefficient Example

Next double click on the **Angles** folder or right click and select **new** to open the **Steel Angle** window.

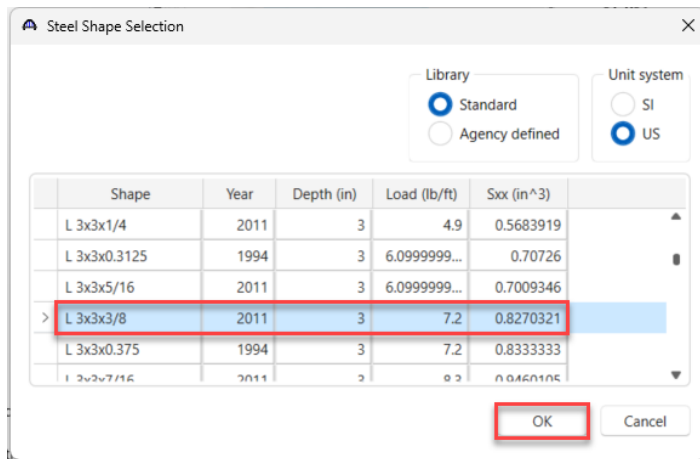


Then select **Copy from library...**

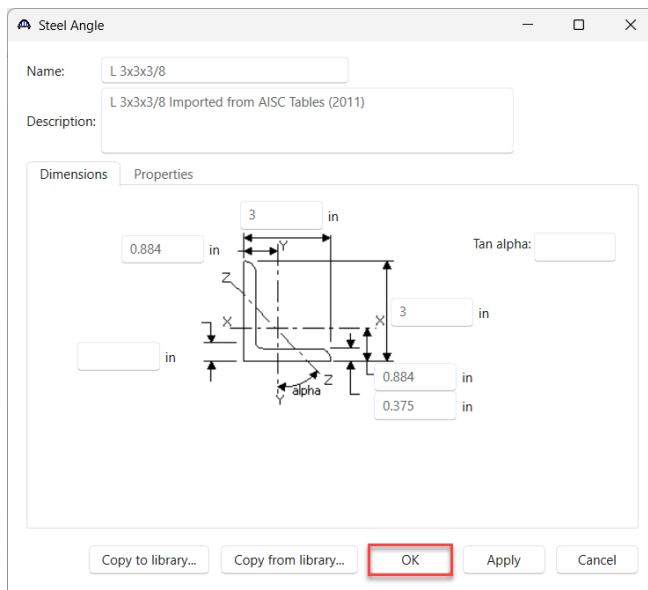


3DFEM6 – Axial Rigidity Coefficient Example

Scroll down to select **L 3x3x3/8**. Make sure to select the shape where the **Year** is **2011**. Then select **OK** to close the **Steel Shape Selection** window.

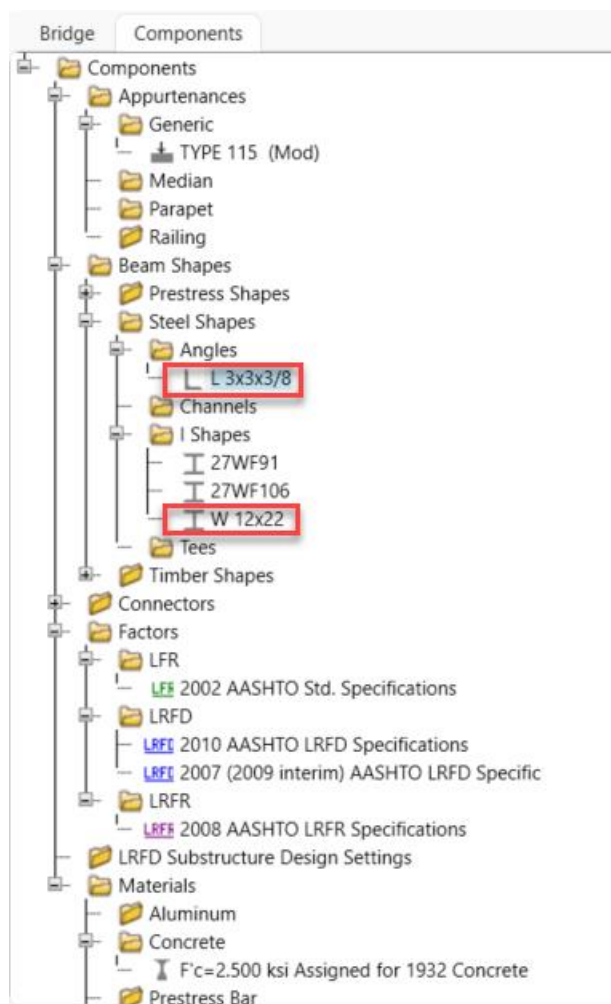


Then select **OK** to close the **Steel Angle** window.



Repeat these steps to add a **W 12x22** shape, again making sure the **Year** is **2011**. The **Components** tab should now have the **L 3x3x3/8** and **W 12x22** shapes added to the **Beam Shapes** folder.

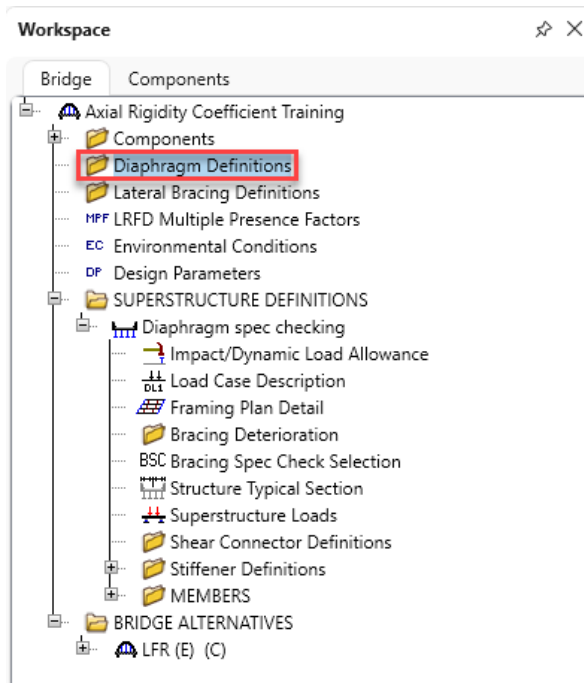
3DFEM6 – Axial Rigidity Coefficient Example



3DFEM6 – Axial Rigidity Coefficient Example

Diaphragm Definitions

Navigate back to the **Bridge** tab of the **Bridge Workspace**, double click the **Diaphragm Definitions** folder to open up the **Diaphragm Definitions** window.



Leave **Type 1** selected for the diaphragm type and enter in the following data, then select **OK**.

Diaphragm Definitions

Name: Type 1 Diaphragm - ARC = 1.0 Diaphragm type: Type 1 Number of elements in fixed member: 1 ☐ Tension-only diagonal system

Members Connections

Diaphragm types:

Type 1

Type 2

Type 3

Type 4

Member	Shape	Section orientation	Section location	Material	LRFD/LRFR axial rigidity coefficients		
					Non-composite	Composite (long term)	Composite (short term)
AB	W 12x22	Vertical		Fy= 33 ksi (fs=18 ksi)	1	1	1
CD	L 3x3x3/8	Vertical	Top Left	Fy= 33 ksi (fs=18 ksi)	1	1	1
AD	L 3x3x3/8	Vertical	Top Left	Fy= 33 ksi (fs=18 ksi)	1	1	1
CB	L 3x3x3/8	Vertical	Top Left	Fy= 33 ksi (fs=18 ksi)	1	1	1

Connection	Support type	Y (in)	Measured from
A	Pinned	4	Top of Web
B	Pinned	4	Top of Web
C	Pinned	4	Bottom of Web
D	Pinned	4	Bottom of Web

OK Apply Cancel

3DFEM6 – Axial Rigidity Coefficient Example

Repeat these steps to add a second diaphragm definition, this time with some ARC values < 1.0.

Diaphragm Definitions

Name: Type 1 Diaphragm - ARC's < 1.0 Diaphragm type: Type 1 Number of elements in fixed member: 1

☐ Tension-only diagonal system

Members Connections

Diaphragm types:

Type 1

Type 2

Type 3

Type 4

Member	Shape	Section orientation	Section location	Material	LRFD/LRFR axial rigidity coefficients		
					Non-composite	Composite (long term)	Composite (short term)
AB	W 12x22	Vertical		Fy= 33 ksi (fs=18 ksi)	1	0.85	0.85
CD	L 3x3x3/8	Vertical	Top Left	Fy= 33 ksi (fs=18 ksi)	1	0.78	0.78
AD	L 3x3x3/8	Vertical	Top Left	Fy= 33 ksi (fs=18 ksi)	1	0.78	0.78
CB	L 3x3x3/8	Vertical	Top Left	Fy= 33 ksi (fs=18 ksi)	1	0.78	0.78

Connection	Support type	Y (in)	Measured from
A	Pinned	4	Top of Web
B	Pinned	4	Top of Web
C	Pinned	4	Bottom of Web
D	Pinned	4	Bottom of Web

OK Apply Cancel

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

AASHTOWare BrDR - Help

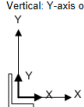
Contents | Index | Search | Type in the keyword to find: | List Topics

Select Topic to display:

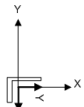
Select a steel beam shape for the member. Choose from previously defined members.

Section Orientation
Select the orientation. Choices are Vertical and Horizontal.

Vertical: Y-axis of the shape is parallel to the Y-axis of the section (see below)

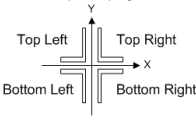


Horizontal: Y-axis of the shape is parallel to the X-axis of the section (see below)



Section Location
Select the location. (see table below)

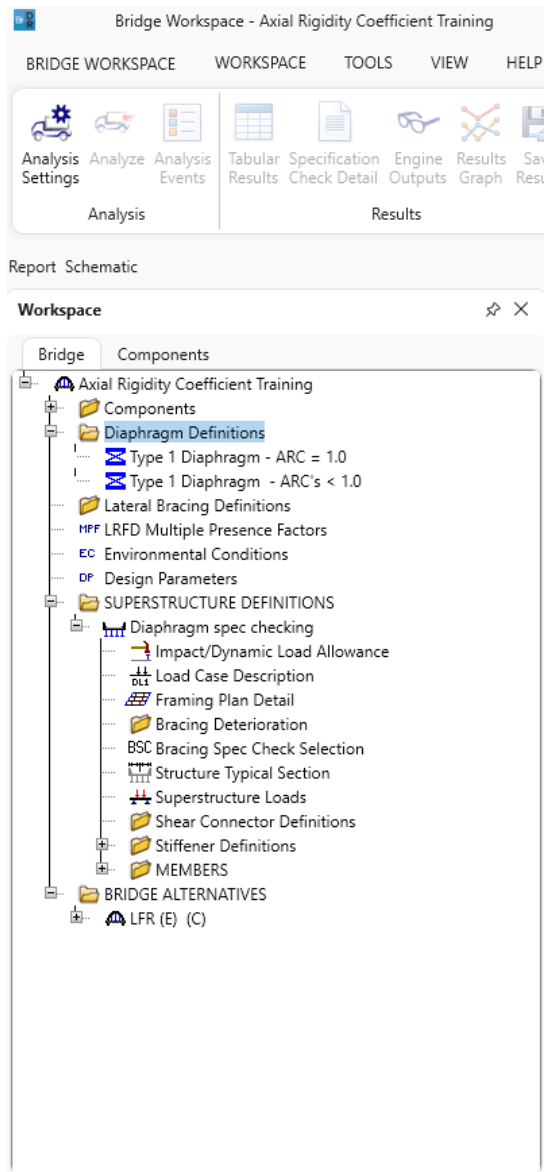
Shape	Choices
I Shapes	No choices, Section Location disabled
Angles	Choices are top left, Top Right, Bottom Left and Bottom Right (see below)



For Vertical Section Orientation: Choices are Left and Right (see below)

3DFEM6 – Axial Rigidity Coefficient Example

The two new diaphragm definitions should now be located within the **Diaphragm Definitions** folder.



3DFEM6 – Axial Rigidity Coefficient Example

Framing plan details – Diaphragm spec checking

Now that the diaphragm definitions have been added to the **Bridge Workspace**, they can be assigned to the existing diaphragm locations. Double click on **Framing Plan Detail** to open up the **Structure Framing Plan Details** window for this superstructure. Click on the **Diaphragms** tab within this window and assign each location in **Girder Bay 1** with the **Type 1 Diaphragm – ARC = 1.0** definition that was created earlier.

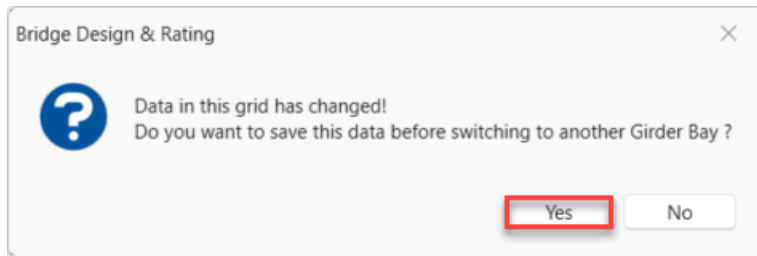
Support number	Start distance (ft)		Diaphragm spacing (ft)	Number of spaces	Length (ft)	End distance (ft)		Load (kip)	Diaphragm
	Left girder	Right girder				Left girder	Right girder		
1	0	0	0	1	0	0	0	Type 1 Diaphragm - ARC = 1.0	
1	0	0	17.5625	1	17.5625	17.5625	17.5625	Type 1 Diaphragm - ARC = 1.0	
> 1	35.125	35.125	0	1	0	35.125	35.125	Type 1 Diaphragm - ARC = 1.0	

After assigning each diaphragm location in **Girder Bay 1** with the **Type 1 Diaphragm – ARC = 1.0** definition, select **Copy bay to...** and copy this data over to the other bays.

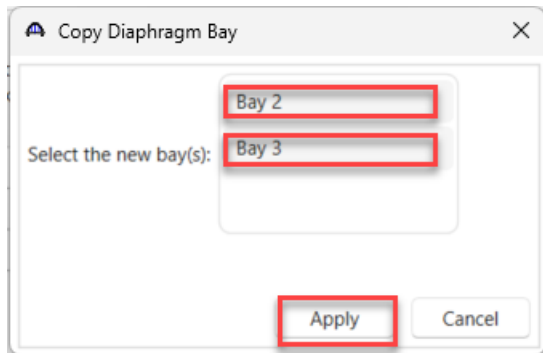
Support number	Start distance (ft)		Diaphragm spacing (ft)	Number of spaces	Length (ft)	End distance (ft)		Load (kip)	Diaphragm
	Left girder	Right girder				Left girder	Right girder		
1	0	0	0	1	0	0	0	Type 1 Diaphragm - ARC = 1.0	
1	0	0	17.5625	1	17.5625	17.5625	17.5625	Type 1 Diaphragm - ARC = 1.0	
1	35.125	35.125	0	1	0	35.125	35.125	Type 1 Diaphragm - ARC = 1.0	

3DFEM6 – Axial Rigidity Coefficient Example

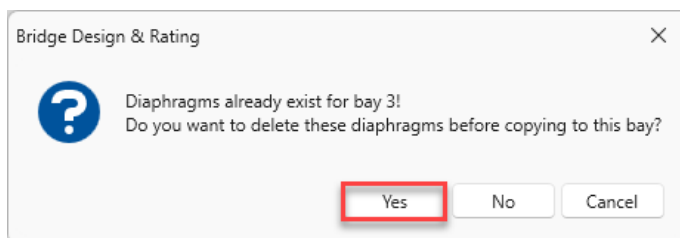
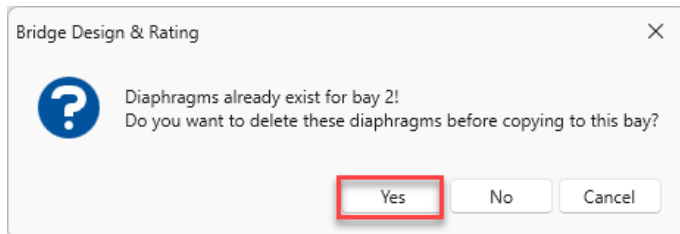
If this window pops up:



Select **Yes** and continue. Then select **Bay 2** and **Bay 3**, then select **Apply**.



A window will pop up and ask if it's okay to delete these diaphragms before copying. This is okay since the diaphragm data is the same for girder bays 2 and 3. Select **Yes** and continue.



3DFEM6 – Axial Rigidity Coefficient Example

After these bays have been successfully copied, select the drop down list for Girder bay and verify that girder bay 2 & 3 diaphragms have been assigned.

Structure Framing Plan Details

Number of spans: 1 Number of girders: 4

Layout: Diaphragms Lateral bracing ranges

Girder bay: 2 Copy bay to... Diaphragm wizard...

Verify that girder bay 2 and 3 diaphragms have been assigned.

Support number	Start distance (ft)		Diaphragm spacing (ft)	Number of spaces	Length (ft)	End distance (ft)		Load (kip)	Diaphragm
	Left girder	Right girder				Left girder	Right girder		
1	0	0	0	1	0	0	0	0	Type 1 Diaphragm - ARC = 1.0
1	0	0	17.5625	1	17.5625	17.5625	17.5625	0	Type 1 Diaphragm - ARC = 1.0
1	35.125	35.125	0	1	0	35.125	35.125	0	Type 1 Diaphragm - ARC = 1.0

New Duplicate Delete

OK Apply Cancel

Then select **OK** to apply the changes and close the **Structure Framing Plan Details** window.

Next, double click **G1** to open the **Member** window. Then make sure **Existing** and **Current** check boxes are checked. Select **OK** to close the window.

Workspace

Bridge Components

- Axial Rigidity Coefficient Training
 - Components
 - Diaphragm Definitions
 - Type 1 Diaphragm - ARC = 1.0
 - Type 1 Diaphragm - ARC's < 1.0
 - Lateral Bracing Definitions
 - LRFD Multiple Presence Factors
 - Environmental Conditions
 - Design Parameters
 - SUPERSTRUCTURE DEFINITIONS
 - Diaphragm spec checking
 - Impact/Dynamic Load Allowance
 - Load Case Description
 - Framing Plan Detail
 - Bracing Deterioration
 - BSC Bracing Spec Check Selection
 - Structure Typical Section
 - Superstructure Loads
 - Shear Connector Definitions
 - Stiffener Definitions
 - MEMBERS
 - G1
 - G2
 - G3
 - G4
 - BRIDGE ALTERNATIVES
 - LFR (E) (C)

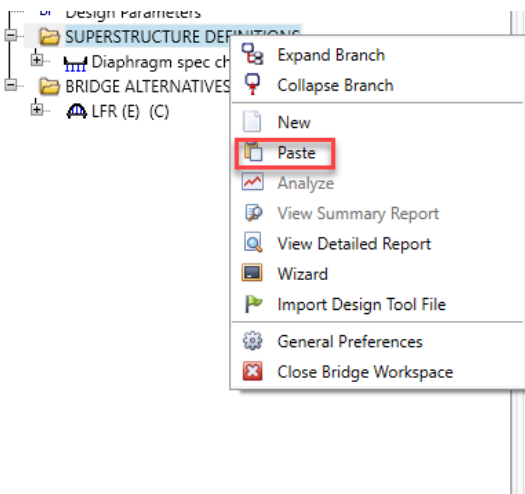
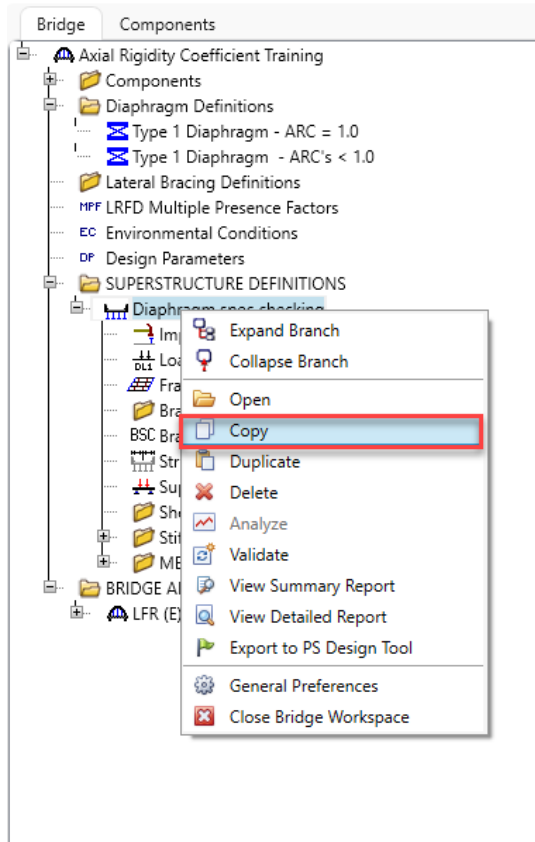
Open the remaining girders 2 through 4 to make sure **Existing** and **Current** check boxes are checked.

3DFEM6 – Axial Rigidity Coefficient Example

Copy superstructure

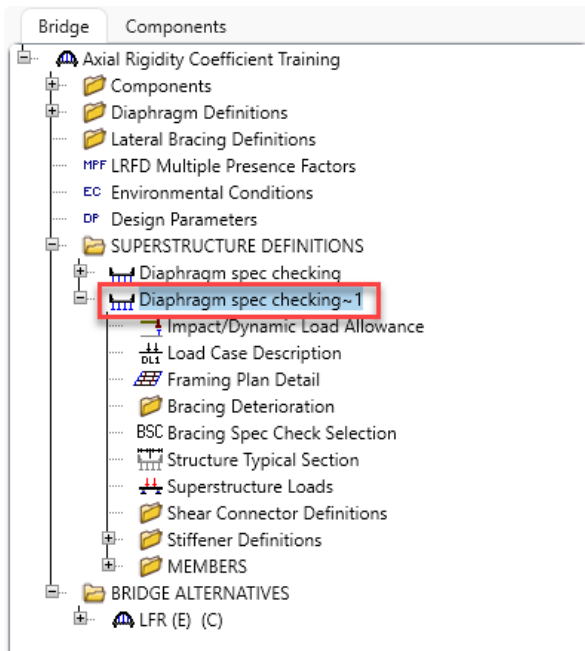
Diaphragm spec checking superstructure now has a diaphragm definition assigned to each location with the ARC values all set to 1.0. This superstructure can now be copied over and only the ARC values will need to be modified to compare diaphragm spec check results.

Right click on **Diaphragm spec checking** superstructure and select **Copy**. Then select the **SUPERSTRUCTURE DEFINITIONS** folder and right click to **paste** the superstructure.



3DFEM6 – Axial Rigidity Coefficient Example

Now double click on the superstructure definition that was created.



Change the superstructure name to the following and select **OK**.

The screenshot shows the 'Girder System Superstructure Definition' dialog box. The 'Name' field is highlighted with a red box and contains the text 'Diaphragm spec checking - with user input ARC vlaues:'. The 'Description' field contains '4 Simple Rolled Steel Girders'. The 'Default units' are set to 'US Customary'. The 'Number of spans' is 1 and the 'Number of girders' is 4. The 'Span' and 'Length (ft)' table shows a single span of 35.125 ft. The 'Horizontal curvature along reference line' section is expanded, showing 'Superstructure alignment' with 'Curved' selected. The 'Deck type' is 'Concrete Deck'. The 'Member alt. types' section shows 'Steel' selected. The 'OK' button is highlighted with a red box.

Span	Length (ft)
> 1	35.125

Distance from PC to first support line:	ft

Start tangent length:	ft

Radius:	ft

Direction:	Left

End tangent length:	ft

Distance from last support line to PT:	ft

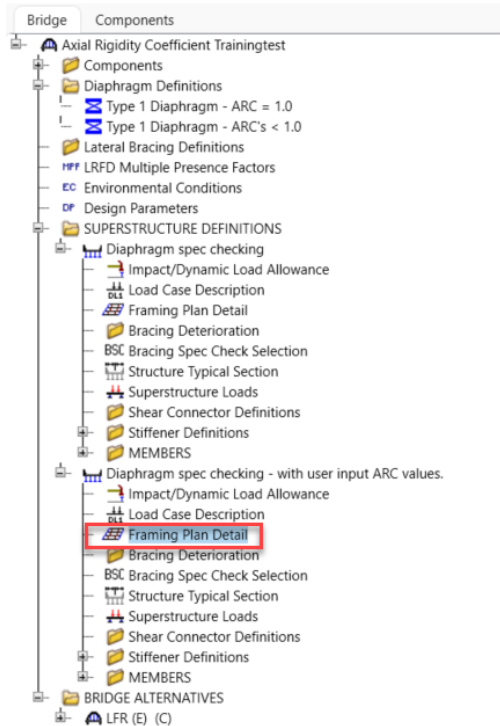
Design speed:	mph

Superelevation:	%

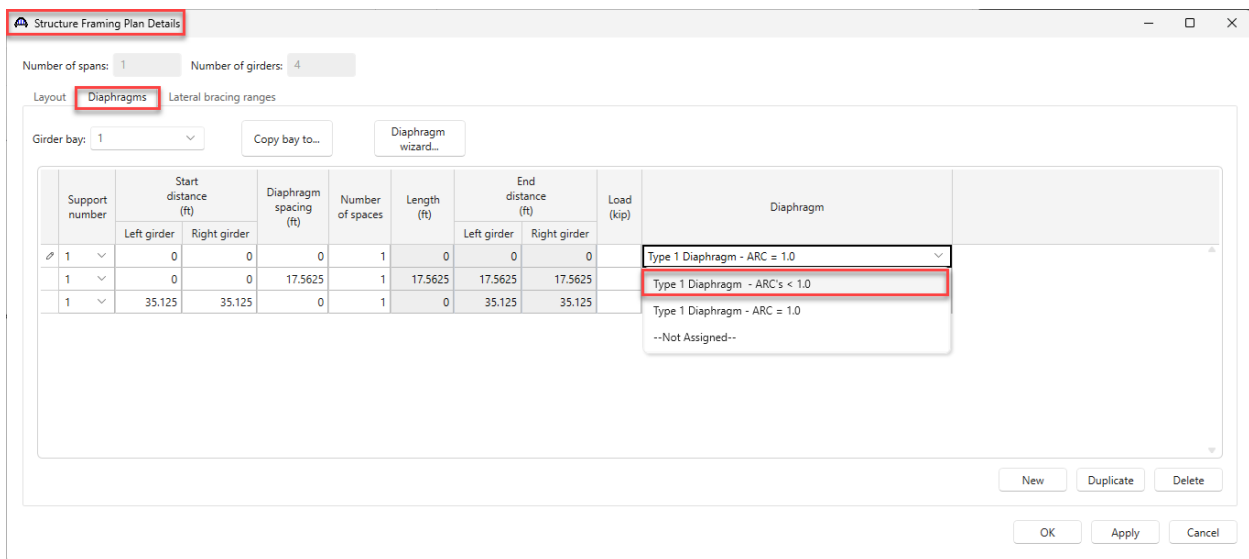
3DFEM6 – Axial Rigidity Coefficient Example

Framing plan details – Diaphragm spec checking – with user input ARC values

Now expand **Diaphragm spec checking – with user input ARC values** superstructure and double click on **Framing Plan Detail** to open the **Structure Framing Plan Details** window.



Switch over to the Diaphragms tab and begin assigning diaphragms to **Type 1 Diaphragm – ARC's < 1.0**.



3DFEM6 – Axial Rigidity Coefficient Example

Once **Girder bay 1** is completed, the other two girder bays can be copied over similar to when the diaphragms were assigned for the **Diaphragm spec checking** superstructure. To do this, use the **Copy bay to...** button like previously.

Structure Framing Plan Details

Number of spans: 1 Number of girders: 4

Layout: Diaphragms Lateral bracing ranges

Girder bay: 1 **Copy bay to...** Diaphragm wizard...

Support number	Start distance (ft)		Diaphragm spacing (ft)	Number of spaces	Length (ft)	End distance (ft)		Load (kip)	Diaphragm
	Left girder	Right girder				Left girder	Right girder		
> 1	0	0	0	1	0	0	0	Type 1 Diaphragm - ARC's < 1.0	
1	0	0	17.5625	1	17.5625	17.5625	17.5625	Type 1 Diaphragm - ARC's < 1.0	
1	35.125	35.125	0	1	0	35.125	35.125	Type 1 Diaphragm - ARC's < 1.0	

New Duplicate Delete

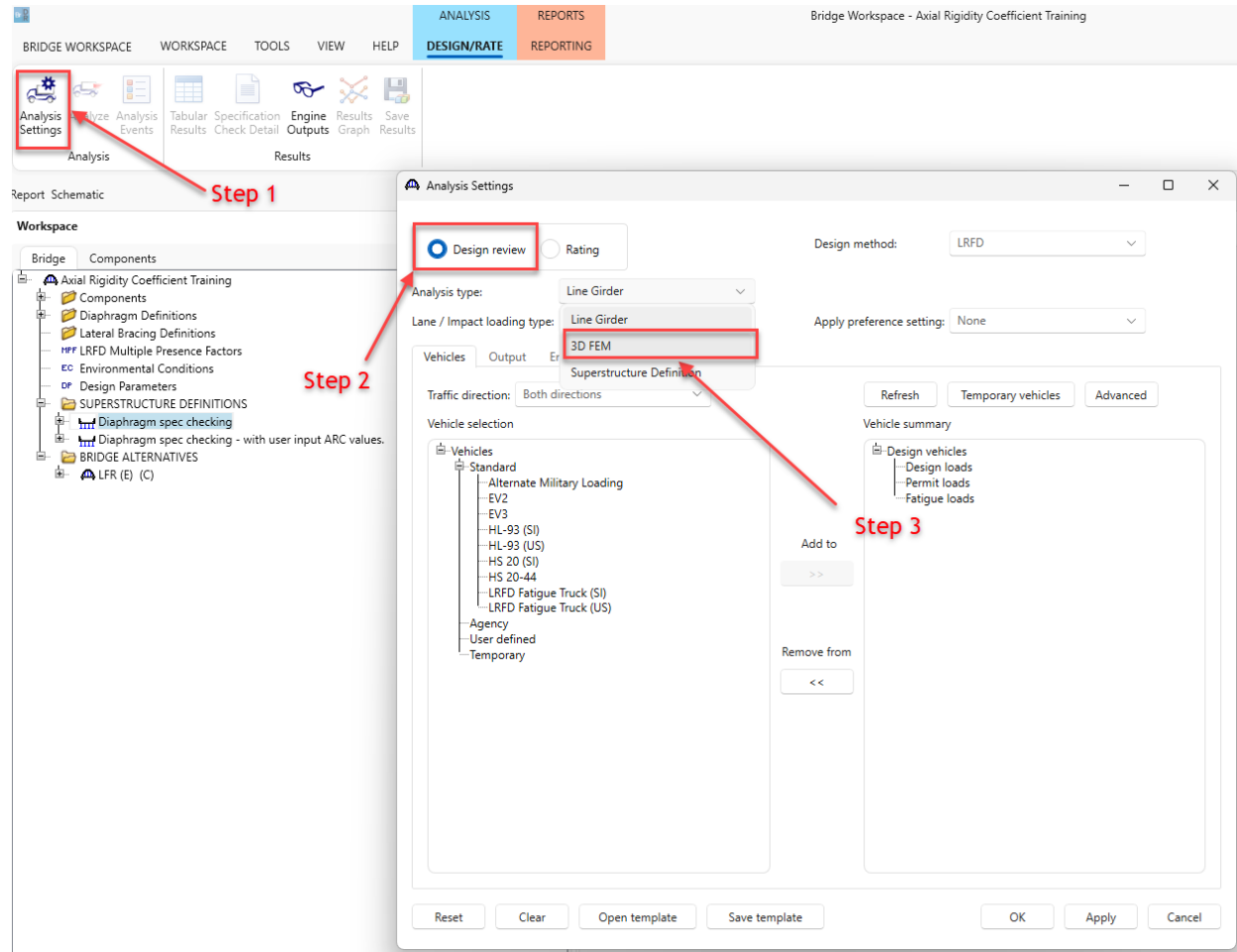
OK Apply Cancel

3DFEM6 – Axial Rigidity Coefficient Example

Diaphragm spec checking comparison

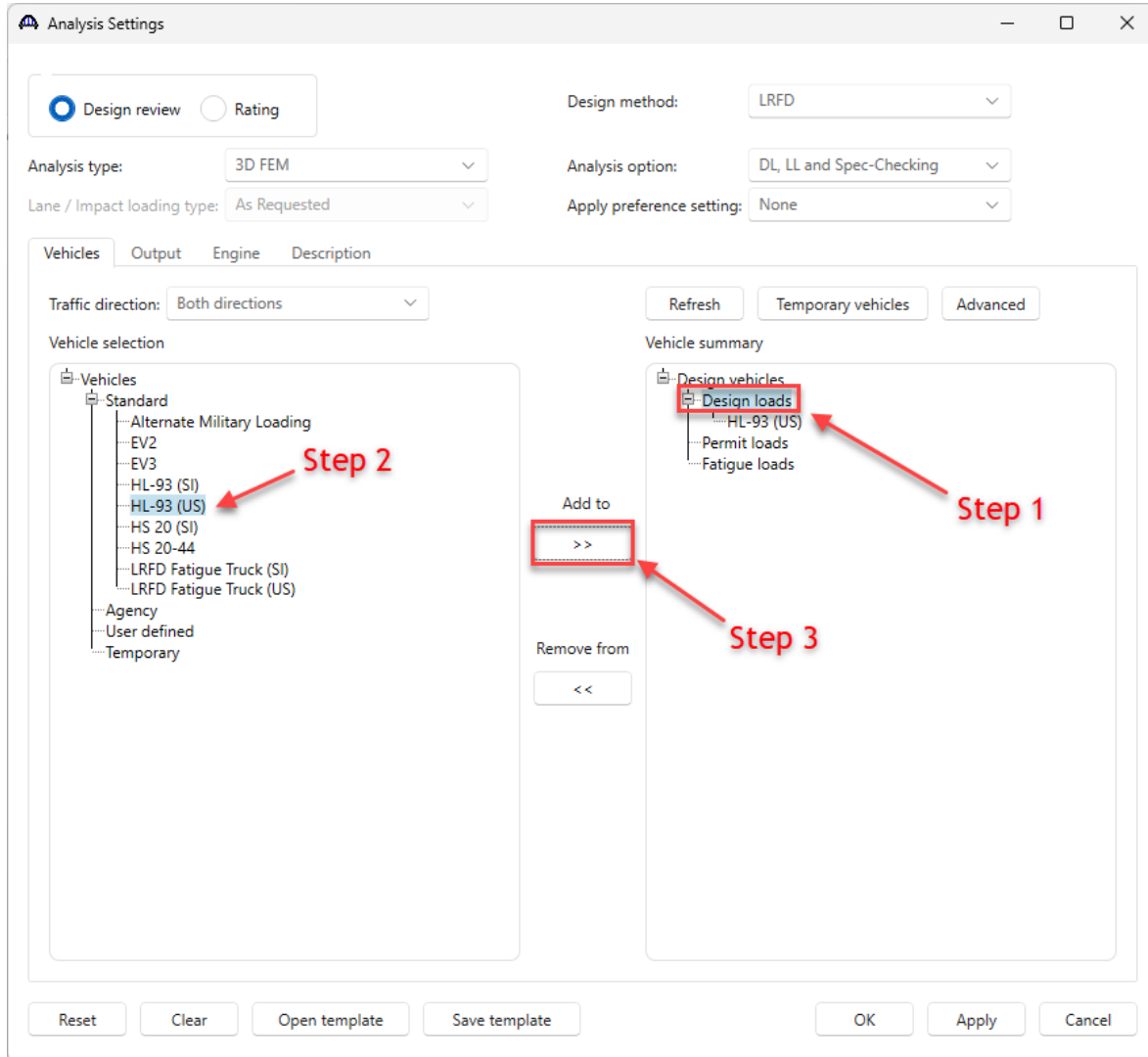
Analysis Settings

Now it's time to set up the analysis. Open the **Analysis Settings** window by clicking on **Analysis Settings** in the upper left corner of the **Bridge workspace**. Then, click on the **Design review** radio button. Next, click on the drop down menu to select the **Analysis type** and select **3D FEM**.



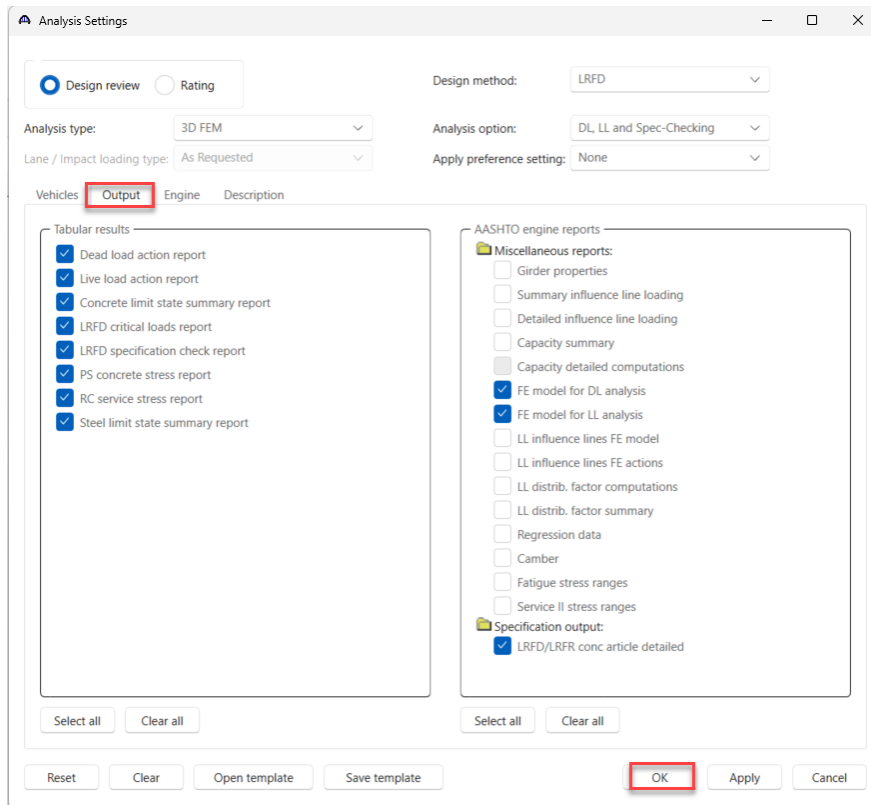
3DFEM6 – Axial Rigidity Coefficient Example

After **3D FEM** is selected for **Analysis type**, click on the **Design loads** to select **Vehicle Summary** and click on **HL-93 (US)** to select the vehicle, then select the >> button to add the **HL-93 (US)** vehicle to the Design loads.



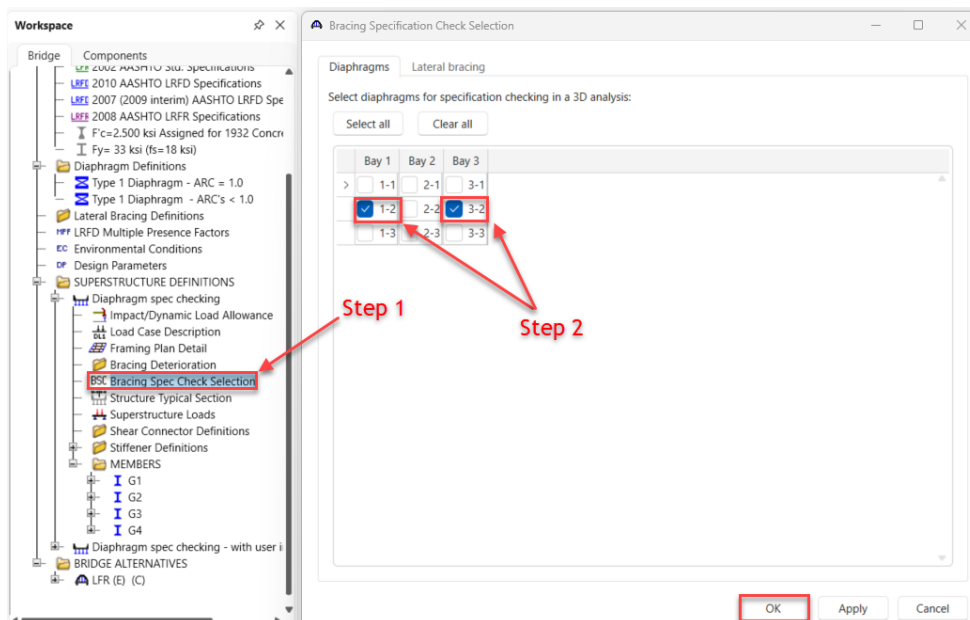
3DFEM6 – Axial Rigidity Coefficient Example

Next, select the **Output** tab and make sure the following items are checked.



Selecting diaphragms for spec checking

Next within the **Diaphragm spec checking** superstructure double click on **Bracing Spec Check Selection** to open the **Bracing Spec Check Selection** window. Then select diaphragms **1-2** and **3-2**. Then select **OK** to close the window.

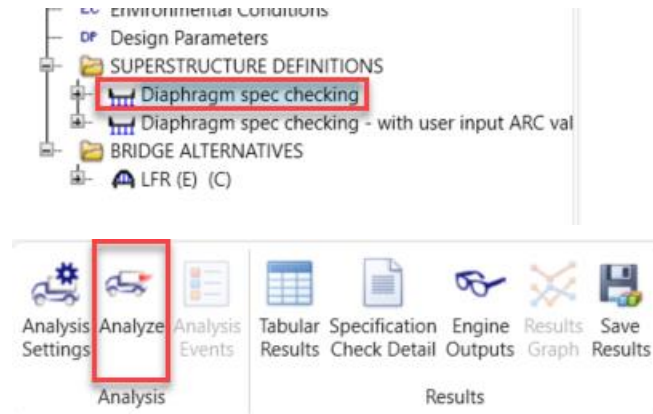


3DFEM6 – Axial Rigidity Coefficient Example

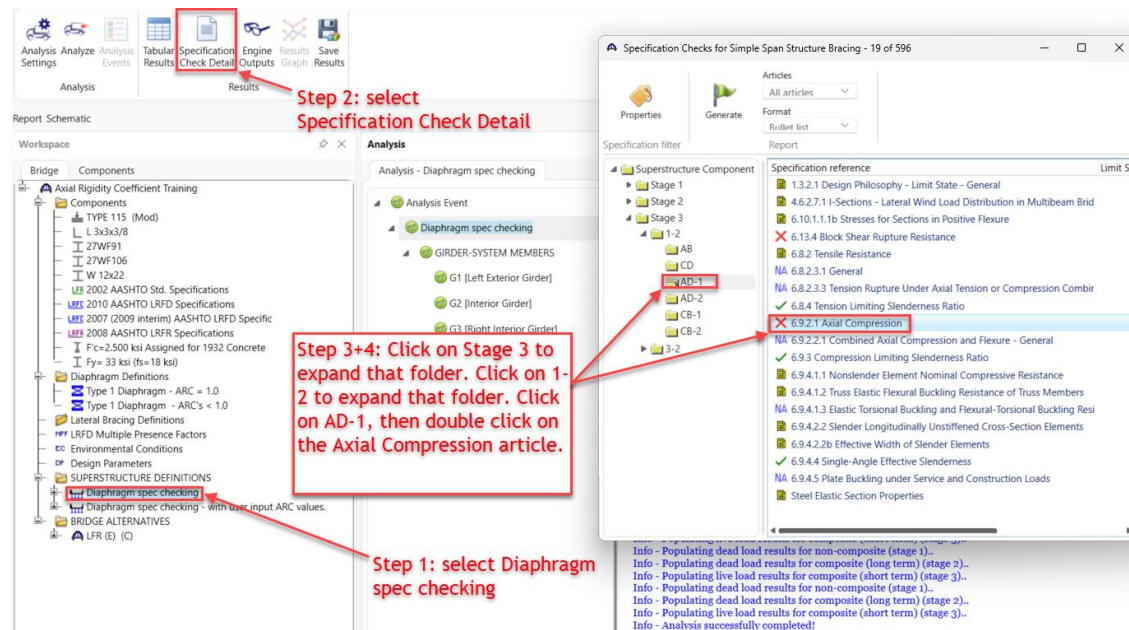
Follow these same steps to add the diaphragms **1-2** and **3-2** for the **Diaphragm spec checking – with user input ARC values** superstructure.

Analyzing Diaphragm spec checking superstructure

Finally, select the **Diaphragm spec checking** superstructure and select **Analyze**.

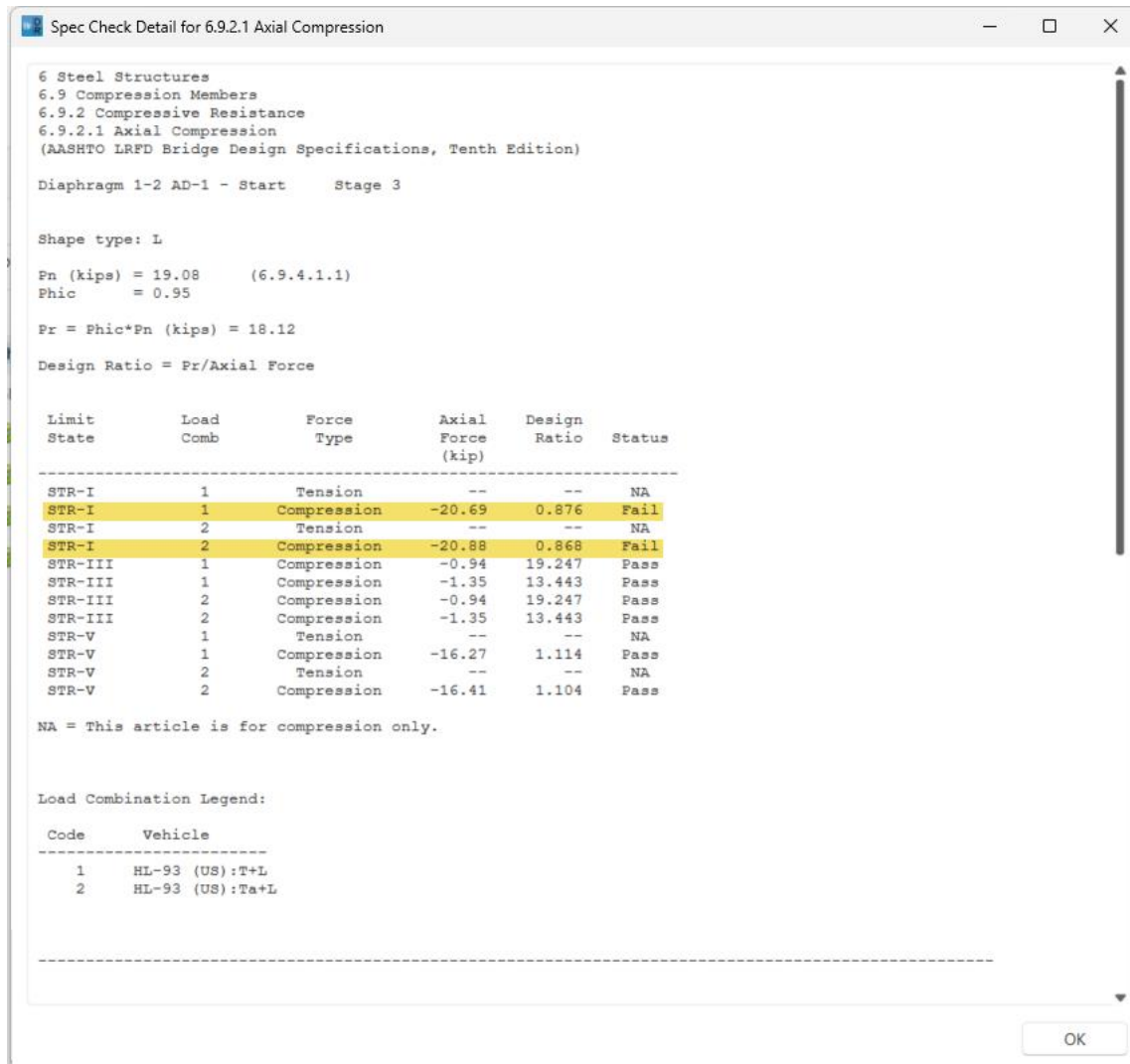


After the analysis has completed, open article **6.9.2.1 – Axial Compression** for Diaphragm 1-2, member AD-1. Follow these steps to open the article output.



3DFEM6 – Axial Rigidity Coefficient Example

Article 6.9.2.1 – Axial Compression for diaphragm 1-2, member AD-1 has two load cases that fail the spec check for this diaphragm member.



3DFEM6 – Axial Rigidity Coefficient Example

The effect that the axial rigidity coefficients have is in the FE model on the cross-frame member areas. To look at the individual beam element properties, click on **Diaphragm spec checking** superstructure, click on **Engine Outputs**, then double click on **S2 Span 3D Model** to bring up the stage 2 beam properties that were calculated for each individual beam element. Scroll to the section labeled **Beam Properties**. The second column shows the area of the individual beam elements. The diaphragm member areas are shown at the bottom of this table.

The screenshot displays the Bridge Workspace interface. The left pane shows the project tree with 'Diaphragm spec checking' and 'S2 Span 3D Model' highlighted. The main window shows a table of beam properties for the S2 Span 3D Model. The table has 11 columns: Element ID, Area (in²), Moment of Inertia (in⁴), Torsion (in⁴), Warping (in⁶), Axial Rigidity (kips/in), Flexural Rigidity (kips-in²), Torsional Rigidity (kips-in²), Warping Rigidity (kips-in²), and Diaphragm Area (in²). The table lists 14 elements (186-200) and 14 elements (201-214). The 'Diaphragm Area' column is highlighted in yellow for elements 186-190, 191-195, 196-200, 201-205, 206-210, 211-215, and 216-220. The 'Shell Properties' dialog is open at the bottom, showing the 'Shell Properties' section.

Element ID	Area (in²)	Moment of Inertia (in⁴)	Torsion (in⁴)	Warping (in⁶)	Axial Rigidity (kips/in)	Flexural Rigidity (kips-in²)	Torsional Rigidity (kips-in²)	Warping Rigidity (kips-in²)	Diaphragm Area (in²)
186	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
187	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
188	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
189	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
190	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
191	6.4800	0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490	0.00000650
192	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
193	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
194	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
195	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
196	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
197	6.4800	0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490	0.00000650
198	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
199	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
200	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
201	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
202	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
203	6.4800	0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490	0.00000650
204	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
205	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
206	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
207	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
208	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
209	6.4800	0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490	0.00000650
210	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
211	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
212	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
213	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650
214	2.1100	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650

Shell Properties

3DFEM6 – Axial Rigidity Coefficient Example

In the following steps, the analysis will be run on the **Diaphragm spec checking – with user input ARC values** and the scaled areas can be observed there.

Analyzing Diaphragm spec checking – with user input ARC values superstructure

To see the effect the ARC values have on the spec check results, run the same exact analysis on the **Diaphragm spec checking – with user input ARC values** superstructure. The results for this superstructure can be seen in the following screenshot

Workspace

Bridge Components

- Axial Rigidity Coefficient Training
 - Components
 - Diaphragm Definitions
 - Type 1 Diaphragm - ARC = 1.0
 - Type 1 Diaphragm - ARC's < 1.0
 - Lateral Bracing Definitions
 - LRFD Multiple Presence Factors
 - Environmental Conditions
 - Design Parameters
 - SUPERSTRUCTURE DEFINITIONS
 - Diaphragm spec checking
 - Diaphragm spec checking - with user input ARC values.
 - BRIDGE ALTERNATIVES
 - LFR (E) (C)

Analysis

Analysis - Diaphragm spec checking Analysis - Diaphragm spec checking - with user input ARC values.

Analysis Event

Spec Check Detail for 6.9.2.1 Axial Compression

6 Steel Structures

6.9 Compression Members

6.9.2 Compressive Resistance

6.9.2.1 Axial Compression

(AASHTO LRFD Bridge Design Specifications, Tenth Edition)

Diaphragm 1-2 AD-1 - Start Stage 3

Shape type: L

P_n (kips) = 19.08 (6.9.4.1.1)

Φ_{tc} = 0.95

$P_r = \Phi_{tc} P_n$ (kips) = 18.12

Design Ratio = P_r /Axial Force

Limit State	Load Comb	Force Type	Axial Force (kip)	Design Ratio	Status
STR-I	1	Tension	--	--	NA
STR-I	1	Compression	-17.42	1.040	Pass
STR-I	2	Tension	--	--	NA
STR-I	2	Compression	-17.58	1.031	Pass
STR-III	1	Compression	-0.88	20.693	Pass
STR-III	1	Compression	-1.25	14.490	Pass
STR-III	2	Compression	-0.88	20.693	Pass
STR-III	2	Compression	-1.25	14.490	Pass
STR-V	1	Tension	--	--	NA
STR-V	1	Compression	-13.72	1.321	Pass
STR-V	2	Tension	--	--	NA
STR-V	2	Compression	-13.84	1.309	Pass

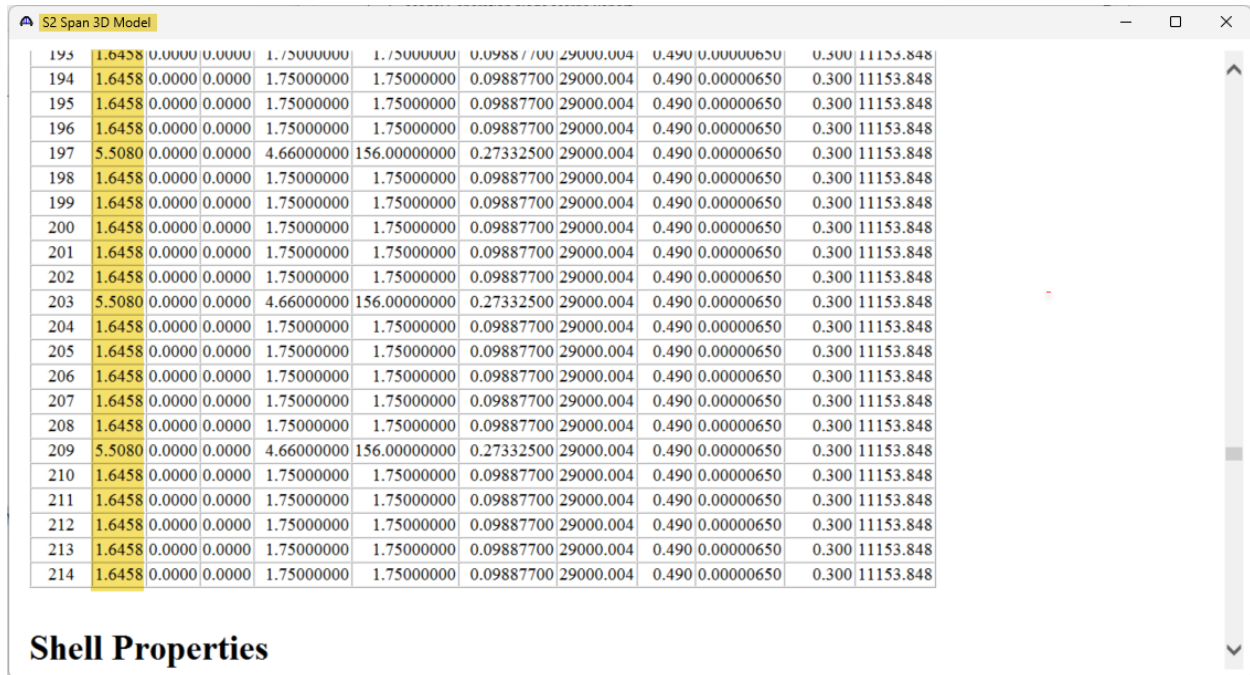
NA = This article is for compression only.

Load Combination Legend:

OK

3DFEM6 – Axial Rigidity Coefficient Example

This article passes for the same diaphragm member and same load cases. For the AD-2 diaphragm member, the stage 2 ARC value was input at 0.78 which reduced the axial stiffness on the diaphragm member. As the axial stiffness was reduced, this reduced the axial compression for this member. To see where the coefficients are used, open the **S2 Span 3D Model** file in the **Engine Outputs**. The areas of the individual cross frame members can be observed. Notice that the last few diaphragm member areas have been reduced to **1.6458 in²** which is equal to **2.11 in² * 0.78**.



Member ID	Area	Coef 1	Coef 2	Coef 3	Coef 4	Coef 5	Coef 6	Coef 7	Coef 8	Coef 9
193	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
194	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
195	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
196	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
197	5.5080	0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490	0.00000650	0.300
198	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
199	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
200	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
201	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
202	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
203	5.5080	0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490	0.00000650	0.300
204	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
205	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
206	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
207	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
208	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
209	5.5080	0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490	0.00000650	0.300
210	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
211	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
212	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
213	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300
214	1.6458	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300

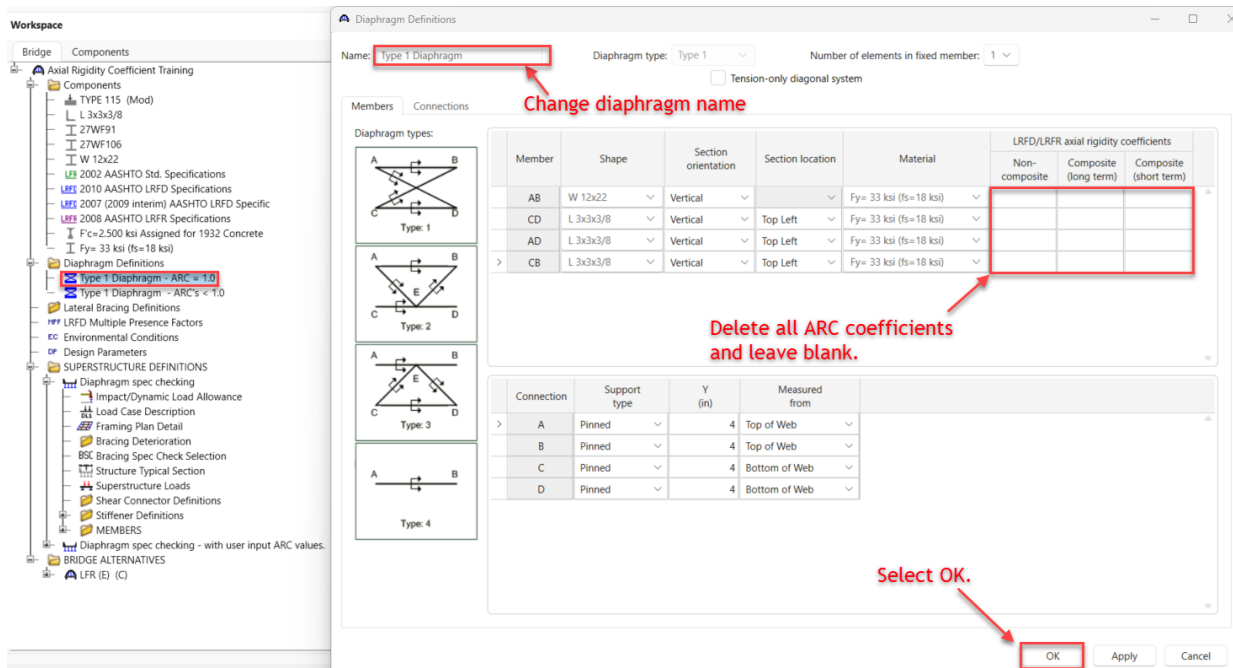
Shell Properties

[Modifying ARC values in diaphragm definition window for Diaphragm spec checking superstructure](#)

If the **3DFEM6-Axial-Rigidity-Coefficient-Example.xml** was imported, the following steps will need to be followed to observe the default behavior for ARC values.

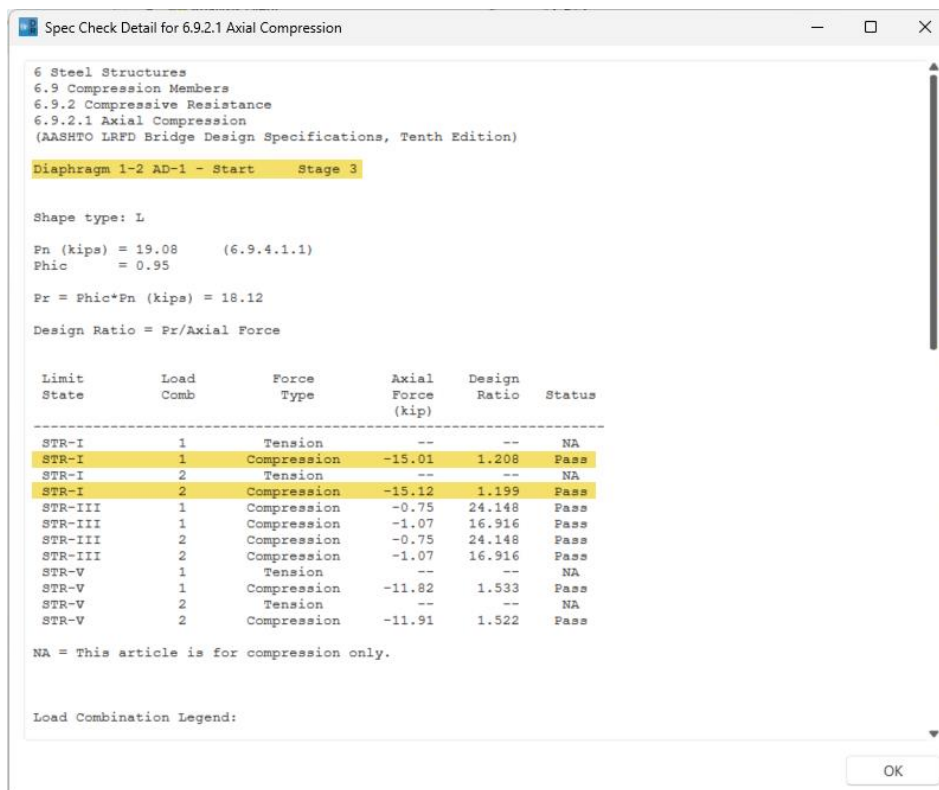
If ARC values are deleted and left blank and the diaphragm members are either single angle or horizontally oriented T-shaped, default coefficient values of 0.65 or 0.75 for non-composite or composite members respectively will be assumed. To see this behavior, double click on **Type 1 Diaphragm – ARC = 1.0**, change the name to **Type 1 Diaphragm**, delete all the ARC coefficients, and select **OK**.

3DFEM6 – Axial Rigidity Coefficient Example



Analyzing Diaphragm spec checking superstructure with default ARC behavior

Since this diaphragm definition is already assigned to the **Diaphragm spec checking** superstructure diaphragms, the analysis can be run again without needing to change anything else. The following results can be observed for this scenario.



3DFEM6 – Axial Rigidity Coefficient Example

Note, that the axial compression forces are now even lower on diaphragm 1-2, member **AD-1** because axial rigidity coefficients of 0.65 have been assumed compared to 0.78 from before. Again, looking at the **S2 Span 3D Model** file in the **Engine Outputs**, looking at the last few beam elements, the reduced area is $1.3715 \text{ in}^2 = 2.11 \text{ in}^2 * 0.65$.

Element ID	Area										
185	6.4800	0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490	0.00000650	0.300	11153.848
186	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
187	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
188	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
189	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
190	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
191	6.4800	0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490	0.00000650	0.300	11153.848
192	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
193	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
194	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
195	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
196	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
197	6.4800	0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490	0.00000650	0.300	11153.848
198	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
199	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
200	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
201	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
202	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
203	6.4800	0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490	0.00000650	0.300	11153.848
204	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
205	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
206	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
207	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
208	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
209	6.4800	0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490	0.00000650	0.300	11153.848
210	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
211	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
212	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
213	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848
214	1.3715	0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490	0.00000650	0.300	11153.848

Shell Properties

When reducing the area for the beam elements in the FE model, this will effectively reduce the axial stiffness for the cross-frame member beam elements which matches the intent of the 10th edition spec updates. Scaling the area instead of scaling the modulus of elasticity ensures that only the axial stiffness is reduced and not both the axial and flexural stiffness. The area for determining member capacities will not be reduced in the engine. This also ensures that the scaled areas that are used to calculate the member forces will not influence the individual member capacities.