AASHTOWare BrDR 7.6.0 3D FEM Analysis Tutorial Axial Rigidity Coefficient Example AASHTOWare Bridge Design and Rating Training 3DFEM6-Axial-Rigidty-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

			Section			LRFD/LRF	R axial rigidity o	oefficients
	Member	Shape	orientation	Section location	Material	Non- composite	Composite (long term)	Composite (short term)
)	AB	L 4x4x1/2 ∨	Vertical $$	Top Left 🛛 🗸	Fy= 33 ks ${}^{\scriptstyle \vee}$			
	CD	L 4x4x1/2 ~	Vertical $$	Top Left 🛛 🗸	Fy= 33 ks $^{\vee}$			
	AD	L 4x4x1/2 ∨	Vertical \vee	Top Left 🛛 🗸	Fy= 33 ks ∨			
	CB	L 4x4x1/2 ∨	Vertical \vee	Top Left 🛛 🗸	Fy= 33 ks $^{\vee}$			

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."

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.

Modifying Steel Girder Bridge

Go to **AASHTO's** website to access the training files: <u>https://aashtowarebrdr.org/bridge-rating-and-design/training/</u>. Then, right click on **3DFEM2 – Single Span Steel 3D Example** and select **Save link as...**

Tutorials		
3D FEM Analysis		-
3DFEM1 – Diaphragm Spec Checking 3DFEM1 – Diaphragm Spec Checking 3DFEM1 – Diaphragm Spec Checking 3DFEM2 – Sizeda Second State		
3DFEM2 - Single Span Steel 3D Exam 3DFEM2 - Single Span Steel 3D Exam 3DFEM3 - Curved Steel 3D Exa	ole Open link in new tab	
3DFEM3 – Curved Steel 3D Exat 3DFEM4 – Curved Steel Multi-S	Open link in new window Open link in incognito window	
3DFEM4 – Curved Steel Multi-S 3DFEM4 – Curved Steel Multi-S 3DFEM5 – Mesh Generation an	Save link as Copy link address	
3DFEM5 – Mesh Generation an	Block element	
Advanced Concrete	Inspect	+

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

Br 🖁	AASH	ITOWar	e Brid	ge Design ar	nd Rating	?	_		\times
BRIDGE EXPLORER BRIDG	E FOLDE	ER	RATE	TOOLS	VIEW				
New Open D Batch ~	Find Copy) [e Co To	y Remove From) Delete				
Bridge		I	Manag	e					
Favorites Folder			٤٨	В	ridge ID			Brid	lge
Recent Bridges		>	1	TrainingBric	lge1	Trai	ning Brid	ge 1(LRFD)
H Gample Bridges			2	TrainingBric	lge2	Trair	ning Brid	ge 2(LRFD))
Deleted Bridges			3	TrainingBric	lge3	Trai	ning Brid	ge 3(LRFD))
- Deleted billages			4	PCITraining	Bridge1	PCI	TrainingE	Bridge1(LF	R)
			5	PCITraining	Bridge2	PCI	FrainingB	ridge2(LR	FD)
			6	PCITraining	Bridge3	PCI	TrainingE	3ridge3(LF	R)
			7	PCITraining	Bridge4	PCI	FrainingB	ridge4(LR	FD)
			8	PCITraining	Bridge5	PCI	TrainingE	Bridge5(LF	R)
			9	PCITraining	Bridge6	PCI	FrainingB	ridge6(LR	FD)
			10	Example7		Exar	mple 7 PS	S (LFR)	
			11	DOTesisina	ridaa1	DC 1	Frainina B	Pridaa1/16	D\ •
				Total Br	idge Count:	4	5		

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.

A STL8					-		×
Bridge ID: igidity Coe	fficient Training NBI stru	cture ID (8): igidity Coefficient Ti	Template	pletely defined	Bridge Workspanner Superstruct Culverts Substructu	ace View ctures ures	
Description Desc	cription (cont'd) Alternati	ves Global reference point	Traffic Custom agency f	ïelds			
Name:	Axial Rigidity Coefficient Tr	aining	Year built:				
Description:							
Location:			Length:		ft		
Facility carried (7):			Route number				
Feat. intersected (6):			Mi. post:				
Bridge associa	ation	3rD BrM					
				ОК	Apply	Cance	ł

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.



	Diaphragm spec ch 4 Simple Rolled Ste	eel Girders		Modeling Multi-girder system MCB
escription:				Deck type:
efault units: lumber of spans:	US Customary V	Enter span lengths along the reference line:		For PS/PT only Average humidity:
umber of girders	a 4 ↓	Span Length (ft)		%
		/ 1 53.123		Steel P/S R/C Timber
				□ P/T
Horizontal curva	ature along reference curvature	line	unor ft	Р/Т
Horizontal curva	ature along reference curvature ure alignment	line Distance from PC to first support I	The second secon	РЛ
Horizontal curva Horizontal Superstructu	ature along reference curvature ure alignment	line Distance from PC to first support I Start tangent length:	v ine: ft ft	РЛ
Horizontal curva Horizontal Superstructu O Curved Tanger	ature along reference curvature ure alignment d nt, curved, tangent	line Distance from PC to first support I Start tangent length: Radius:	v	РЛ
Horizontal curva Horizontal Superstructu Curved Tanger Tanger	ature along reference curvature ure alignment d. nt, curved, tangent nt, curved	line Distance from PC to first support I Start tangent length: Radius: Direction:	v ft ft ft Left V	P/T
Horizontal curve Horizontal Superstructu Curved Tanger Tanger Curved	ature along reference curvature ure alignment d nt, curved, tangent nt, curved d, tangent	line Distance from PC to first support I Start tangent length: Radius: Direction: End tangent length:	v	P/T
Horizontal curve Horizontal Superstructu Curved Tanger Curved	ature along reference curvature gre alignment it, curved, tangent it, curved i, tangent	line Distance from PC to first support I Start tangent length: Radius: Direction: End tangent length: Distance from last support line to	▼ ine:	Р/Т
Horizontal curva Horizontal Superstructu Tanger Tanger Curved	ature along reference curvature i it, curved, tangent it, curved j, tangent	line Distance from PC to first support I Start tangent length: Radius: Direction: End tangent length: Distance from last support line to Design speed:	▼ ine:	Ρ/Τ

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.

Bridge Components															
🖥 - 🙇 Axial Rigidity Coefficient Training															
+- 📁 Components															
Diaphragm Definitions	A	Struct	ure Frami	ing Plan Detail									_		×
 — <i>i</i> Lateral Bracing Definitions 															
 HT LRFD Multiple Presence Factors 															
 Environmental Conditions 	Nu	mber	of spans	1	Number of g	irders: 4									
 Design Parameters 															
- 🔁 SUPERSTRUCTURE DEFINITIONS		ayout	t Diap	bhragms La	teral bracing ra	nges									
Diaphragm spec checking															
 Impact/Dynamic Load Allowanc 	0	Sirder	bay: 1		\sim	Copy bay to		Diaphragm							
- H Load Case Description					_			wizard							
- 🛲 Framing Plan Detail															
 Bracing Deterioration 					start	Dianhragm			E	nd					
 BSL Bracing Spec Check Selection 			Support	di	distance (ft) Left girder Right girder		Number	Length	dis	ance	Load	Diaphragm			
- In Structure Typical Section			number		00	(ft)	of spaces	(ft)		10	(kip)				
Superstructure Loads				Left girder	Right girder				Left girder	Right girder					
Stiffener Definitions		0	1 ~	0	0	0	1	0	0	0		End/Intermediate ~		-	
E- 2 MEMBERS			1			17 5625	- 1	17 56 35	17 5635	17 5625					
BRIDGE ALTERNATIVES			· ·	0		17.3023		17.3023	17.3023	17.5025		End/Intermediate			
🕮 - 🗛 LFR (E) (C)			1 ~	35.125	35.125	0	1	0	35.125	35.125		Not Assigned			
												New	Duplicate	Delete	
												New	Duplicate	velete	
												OK	Apply	Cancel	
												- OK		cancer	

Struc	ture Frami	ng Plan Details										-		×
imbe Layou	r of spans: it Diap	1 hragms Lat	Number of g	irders: 4										
Girde	r bay: 1		~	Copy bay to		Diaphragm wizard								
	Support number	St dist (tart tance (ft)	Diaphragm spacing	Number of spaces	Length (ft)	E dis	nd tance (ft)	Load (kip)	Diaphragm				
		Left girder	Right girder	(ft)			Left girder	Right girder						
0	1 ~	0	0	0	1	0	0	0		Not Assigned	\sim			^
	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	~			
										Ne	w	Duplicate	Delete	
											ОК	Apply	Can	cel

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



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.

A Stru	ictu	ure Framin	ıg Plan Details											_		\times
Numb	er	of spans:	1	Number of g	rders: 4											
Law		Diapl	tragma la	toral bracing ray												
Layu	Jui	Diapi			iges											
Gird	ler	bay: 3		~	Copy bay to		Diaphragm wizard									
		Support	S dis	Start stance (ft)	Diaphragm spacing	Number of spaces	Length (ft)	l	End tance (ft)	Load (kip)	Diaphragm					
			Left girder	Right girder	(ft)			Left girder	Right girder	(
	1	1 ~	0	0	0	1	0	0	0		Not Assigned	~				÷
	1	1 ~	0	0	17.5625	1	17.5625	17.5625	17.5625		Not Assigned	~				
>	1	1 ~	35.125	35.125	0	1	0	35.125	35.125		Not Assigned	\sim				
												New	Duplicate		Delete	
												OK	Apply		Canc	el

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.



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.





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



Then select Copy from library...



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.

s S	teel Shape Selection			Library St	andard gency defined	Unit system
	Shape	Year	Depth (in)	Load (lb/ft)	Sxx (in^3)	
	L 3x3x1/4	2011	3	4.9	0.5683919	A
	L 3x3x0.3125	1994	3	6.09999999	0.70726	
	L 3x3x5/16	2011	3	6.0999999	0.7009346	
>	L 3x3x3/8	2011	3	7.2	0.8270321	
	L 3x3x0.375	1994	3	7.2	0.8333333	
	1 2v2v7/16	2011	2	9.2	0.0460105	
					ОК	Cancel

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.



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.



	ARC =	.0	Diaphragm	type:	Type 1		Num	ber of elements in fixed me	mber:	1				
							Tension-o	nly diagonal system						
lembers Connections														
iaphragm types:										LRFD/LRF	R axial rigidity o	coefficients		
		Member	Shape		Section orientatio	on	Section location	Material		Non- composite	Composite (long term)	Composite (short term)		
	>	AB	W 12x22	~	Vertical	\sim	~	Fy= 33 ksi (fs=18 ksi)	\sim	1	1	1		
C G D		CD	L 3x3x3/8	~	Vertical	\sim	Top Left V	Fy= 33 ksi (fs=18 ksi)	\sim	1	1	1		
1,100.1		AD	L 3x3x3/8	~	Vertical	\sim	Top Left V	Fy= 33 ksi (fs=18 ksi)	\sim	1	1	1		
A B		CB	L 3x3x3/8	~	Vertical	\sim	Top Left 🛛 🗸	Fy= 33 ksi (fs=18 ksi)	\sim	1	1	1		
A B B														
A B C Type: 3		Connection	n Support type		Y (in)		Measured from							
A B C Type: 3		Connection	Support type Pinned	~	Y (in)	4 T	Measured from op of Web	~						
A the B		Connection A B	Support type Pinned Pinned	~	Y (in)	4 T 4 T	Measured from op of Web op of Web	<u>~</u>						
A B A B C Type: 3		Connection A B C	Support type Pinned Pinned Pinned	> > >	Y (in)	4 T 4 T 4 B	Measured from op of Web op of Web iottom of Web	× × ×						
A B Type: 4		Connection A B C D	Support type Pinned Pinned Pinned Pinned	> > > >	Y (in)	4 T 4 T 4 B 4 B	Measured from op of Web op of Web ottom of Web ottom of Web	> > > > > > > > > > > > > > > > > > >						
A B Type: 3		Connection A B C D	Support type Pinned Pinned Pinned Pinned	> > > >	Y (in)	4 T 4 T 4 B 4 B	Measured from op of Web op of Web iottom of Web iottom of Web	> > > >						
A B Type: 4		Connection A B C D	Support type Pinned Pinned Pinned Pinned Pinned	> > > >	Y (in)	4 T 4 T 4 B 4 B	Measured from op of Web op of Web ottom of Web ottom of Web	> > > >						
A B Type: 4		Connection A B C D	Support type Pinned Pinned Pinned Pinned	> > >	Y (in)	4 T 4 T 4 B	Measured from op of Web op of Web ottom of Web ottom of Web	> > > >						
A B Type: 4		Connection A B C D	Support type Pinned Pinned Pinned Pinned	> > >	Y (in)	4 T 4 T 4 B 4 B	Measured from op of Web otom of Web ottom of Web	> > > >						
A B Type: 4		Connection A B C D	Support type Pinned Pinned Pinned Pinned	> > > >	Y (in)	4 T 4 T 4 B	Measured from op of Web otom of Web ottom of Web							

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

				Section				LRFD/LRFF	R axial rigidity c	oefficients	
	Member	Shape		orientation	Section location	Material		Non- composite	Composite (long term)	Composite (short term)	
	> AB	W 12x22	\sim	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	
Type. 1	AD	L 3x3x3/8	\sim	Vertical ~	Top Left 🛛 🗸	Fy= 33 ksi (fs=18 ksi)	\sim	1	0.78	0.78	
B	CB	L 3x3x3/8	\sim	Vertical \checkmark	Top Left 🗸 🗸	Fy= 33 ksi (fs=18 ksi)	\sim	1	0.78	0.78	
Type: 3		type		(in)	from						
	> A	Pinned	\sim	4 To	op of Web	~					
					on of Web	\sim					
в	В	Pinned	~	4 To	op or web	_					
B B	B	Pinned Pinned	~	4 Ti 4 Bi	ottom of Web	~					
Type: 4	B	Pinned Pinned Pinned	× × ×	4 Tr 4 B 4 B	ottom of Web ottom of Web	~ ~					
Type: 4	B C D	Pinned Pinned Pinned	~ ~	4 Tr 4 B 4 B	ottom of Web ottom of Web	~ ~					
Type: 4	B C D	Pinned Pinned Pinned	> >	4 Ti 4 B 4 B	ottom of Web	~ ~					

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

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			-	×
Hide Back Print Options				
Contents Index Search	Select a steel b	eam shape for the member. Choose from previously defined members.		~
Type in the keyword to find:	Section Orient	tation		
·····	Select the orier	tation. Choices are Vertical and Horizontal.		
List Topics	Vertical: Y-axis	of the shape is parallel to the Y-axis of the section (see below).		
Select Topic to display:	Ŷ			
	Ť			
	∏ ≜ Y			
	□ └ → ×→ :	x		
	Harizantali V a	via of the share is excelled to the V suis of the section (see below)		
	Y	As of the shape is parallel to the X-axis of the section (see below).		
				
		~		
		^		
	^			
	Section Locat	ion		
	Select the local	ion. (see table below)		
	Shape	Choices		
	I Shapes	No choices, Section Location disabled		
		Choices are top left, Top Right, Bottom Left and Bottom Right (see below)		
		Top Left Top Right		
	Analas			
	Angles			
		Bottom Left Bottom Right		
		For Vertical Section Orientation: Choices are Left and Right (see below)		
Display		Υ Υ		\sim
	1			

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

🕞 Bridge Worksp	ace - Axial Rigi	dity Coefficie	ent Training	
BRIDGE WORKSPACE	NORKSPACE	TOOLS	VIEW H	HELP
Analysis Settings	Tabular Speci Results Check	fication Engl	Gine Results Graph	Sav Resi
Analysis		Result	5	
Report Schematic				
Workspace			Ŕ	×
Bridge Components				
 Type 1 Diaph Type 1 Diaph Lateral Bracing I HF LRFD Multiple P EC Environmental C DP Design Paramete SUPERSTRUCTU Im Diaphragm s Im Structure Im Structure	rragm - ARC = rragm - ARC's Definitions resence Factors onditions ers RE DEFINITION: spec checking lynamic Load A e Description Plan Detail Deterioration spec Check Sele Typical Section acture Loads nnector Definiti Definitions S ATIVES	1.0 < 1.0 S Ilowance		

Framing plan details – Diaphragm spec checking

Now that the diaphragm definitions have been added to the **Bridge Workspace**, they can be assigned to the exisiting diaphragm locations. Double click on **Framing Plan Detail** to open up the **Structure Framing Plan Details** widow 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.

A	Struct	ture	Framin	g Plan Details	5									- 1	- ×	
Nu	mber	r of :	spans:	1	Number of g	irders: 4										
	.ayou	ıt	Diapł	nragms La	teral bracing ra	nges										
(irde	r ba	y: 1		~	Copy bay to		Diaphragn wizard	n							
		Su	upport umber	dis	Start stance (ft)	Diaphragm spacing	Number of spaces	Length (ft)	l	ind tance (ft)	Load (kip)	Diaphragm				
				Left girder	Right girder	(ft)			Left girder	Right girder	v-17					
		1	\sim	0	0	0	1	0	0	0		Type 1 Diaphragm - ARC = 1.0 \checkmark			^	
		1	\sim	0	0	17.5625	1	17.5625	17.5625	17.5625		Type 1 Diaphragm - ARC = 1.0 \checkmark				
	>	1	\sim	35.125	35.125	0	1	0	35.125	35.125		Type 1 Diaphragm - ARC = 1.0 $$				
															v.	
													New Duplicate	De	lete	
													ОК Аррі		Cancel	

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.

🗛 Str	ucti	ure l	Framin	g Plan Details										-		×
Num	ber	of s	spans:	1	Number of gi	rders: 4										
La	/out	F F	Dianh	aragms Lat	teral bracing rar	nes										
	- u		o apr	ingino con		iges										
Gir	der	bay	/: 1		~ (Copy bay to		Diaphragm wizard								
				s	itart				F	nd						
		Sup	pport	dis	tance (ft)	Diaphragm spacing	Number	Length	dis	tance (ft)	Load	Diaphragm				
		nui	mber	Left girder	Right girder	(ft)	of spaces	(ft)	Left girder	Right girder	(кір)					
		1	\sim	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 \checkmark				
		1	\sim	35.125	35.125	0	1	0	35.125	35.125		Type 1 Diaphragm - ARC = 1.0 \checkmark				
													New Duplica	te	Delete	
													ОК Ар	ply	Cance	el

If this window pops up:



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

🗛 Copy Diaphragm B	ay			×
Select the new bay(s):	Bay 2 Bay 3			
		Apply	Can	cel

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.

Bridge Desig	in & Rating X
6	Diaphragms already exist for bay 2! Do you want to delete these diaphragms before copying to this bay?
	Yes No Cancel
Bridge Desig	in & Rating X
6	Diaphragms already exist for bay 3! Do you want to delete these diaphragms before copying to this bay?
	Yes No Cancel

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.

1	Struc	ture	Framir	ıg Plan Details	;									-		×
	Numbe	r of s	spans:	1	Number of gi	rders: 4										
	Layou	ıt	Diapl	hragms La	teral bracing rar	nges				Verit	y th	at girder bay 2 and 3				
	Girde	r bay	y: 2		~	Copy bay to		Diaphragm wizard		diap	hrag	ms have been assigned.				
1		Su	ipport imber	dis	Start stance (ft)	Diaphragm spacing	Number of spaces	Length (ft)	E dist (ind tance (ft)	Load (kip)	Diaphragm				
				Left girder	Right girder	(11)			Left girder	Right girder						
		1	\sim	0	0	0	1	0	0	0		Type 1 Diaphragm - ARC = 1.0 V				
		1	\sim	0	0	17.5625	1	17.5625	17.5625	17.5625		Type 1 Diaphragm - ARC = 1.0 V				
		1	~	35.125	35.125	0	1	0	35.125	35.125		Type 1 Diaphragm - ARC = 1.0 \lor				
E E R																
													New Duplica	ite	Delete	
													OK A¢	ply	Cance	el.

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	X Analysis	
Bridge Components	A Member	- 0 ×
Avial Rigidity Coefficient Training Components Components Training Yope 1 Diaphragm - ARC = 1.0 Yope 1 Diaphragm - ARC = 1.0 Sype 1 Diap	Member name: G1 Link with: None V Description:	
Load Case Description BF Framing Plan Detail BF Framing Plan Detail BSt Bracing Spec Check Selection HSt Bracing Spec Check Selection HSt Structure Typical Section HSt Superstructure Loads Superstructure Loads Start Connector Definitions Stuffener Definitions MEMBERS MEMBERS	Existin Curren Member alternative name Description g t Member alternative name n Verification Verification Number of spans: 1	
Image: G2 Image: Image: G3 Image: Image: G4 Image: G4 <t< td=""><td>Image: Product of the state of the stat</td><td>Apply Cancel</td></t<>	Image: Product of the state of the stat	Apply Cancel

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

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 seelct the **SUPERSTRUCTURE DEFINITIONS** folder and right click to **paste** the superstructure.





Now double click on the superstructure definition that was created.



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

ame: Diaphragm spec o	hecking:	- with	user in	put ARC (vlaues.			Modeling
4 Simple Rolled St	teel Gird	ers						Multi-girder system MCB With frame structure simplified definiti
escription:								Deck type:
								Concrete Deck 🛛 🗠
efault units: US Customary	~	Ente	r span l g the re	engths ference				For PS/PT only Average humidity:
umber of girders: 4 0		inter	Span	Length				%
		>	1	35.12	5			Member alt. types
								Steel P/S R/C Timber P/T
Horizontal curvature along reference	line —	ince fr	om PC t	o first su	The second secon		ft	
Superstructure alignment	Start	tange	nt lenat	he			ft	
O Curved	Radi	us:					ft	
Tangent, curved, tangent	Direc	tion:				Left \sim		
Curved, tangent	End	tanger	t lengti	12			ft	
	Dista	ince fr	om last	support l	ine to PT:		ft	
	Deri	gn spe	ed:				mph	
	Low any							

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**.

													-	~
her	of spans:	1	Number of a	rders: 4										
vout	Dianh	raome La	teral bracing rat	nger										
your	Diapr		terar bracing rai	iges										
der	bay: 1		~	Copy bay to		Diaphragm wizard								
	Support	S dis	itart tance (ft)	Diaphragm spacing	Number of spaces	Length (ft)	E dist (nd tance ft)	Load (kip)	Diaphragm				
		Left girder	Right girder	(#)			Left girder	Right girder						
0	1 ~	0	0	0	1	0	0	0		Type 1 Diaphragm - ARC = 1.0 \checkmark				÷
	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 = 1.0				
										Not Assigned				
											New Duplicate		Delete	
											ОК Арр	ly	Canc	el
2	9	Out Diaph der bay: 1 % 1 % 1 % 1	out Diaphragms La der bay: 1 Support dis number 1 ~ 0 1 ~ 0 1 ~ 0 1 ~ 35.125	Out Diaphragms Lateral bracing rai der bay: 1 ✓ Support number Start distance (ft) distance (ft) 1 ✓ 0 1 ✓ 0 1 ✓ 0 1 ✓ 0 1 ✓ 0 1 ✓ 0	Support Start distance (ft) Diaphragms pacing pacing (ft) Diaphragm pacing (ft) 1 V 0 0 1 V 0 0 1 V 0 0 1 V 0 0 1 V 0 0 1 V 0 0 1 V 0 0	Support Start (ft) Diaphragm spacing (ft) Number spacing (ft) 1 V 0 0 1 1 V 0 0 1 1 V 0 0 1 1 V 0 0 1 1 V 0 0 1	Lateral bracing ranges Diaphragm der bay: 1 \checkmark Copy bay to Diaphragm Support number $\frac{Start}{(ft)}$ $\frac{Diaphragm}{spacing}$ Number Length of spaces 1 \checkmark 0 0 1 0 1 \checkmark 35.125 35.125 0 1 0	Support Start (ft) Diaphragm wizard. Leral bracing ranges Support 1 Copy bay to Diaphragm wizard. Length (ft) distance (ft) Diaphragm spacing (ft) Number of spaces Length (ft) Length (ft)	Lateral bracing ranges Diaphragm wizard Support number Copy bay to Diaphragm wizard End distance (ft) End distance (ft) Right girder Rig	Diaphragm Diaphragm Support Start distance (ft) Diaphragm spacing (ft) Length of spaces End distance (ft) Load Length (ft) Load distance (ft) Load Length (ft) Length left girder End distance (ft) Load Load 1 0 0 0 1 0	Support number Start (ft) Diaphragm wizard. Length (ft) End (ft) Load (ft) Diaphragm (kip) Diaphragm 1 0 0 0 1 0 0 0 Type 1 Diaphragm Diaphragm 1 0 0 0 1 0 0 Type 1 Diaphragm ARC = 1.0 1 0 0 1 0 0 0 Type 1 Diaphragm ARC = 1.0 1 35.125 0 1 0 35.125 Type 1 Diaphragm ARC = 1.0 1 35.125 0 1 0 35.125 Type 1 Diaphragm Type 1 Diaphragm Type 1.0	Support Start (t) Diaphragm wizard. Diaphragm wizard. Diaphragm wizard. Support Start (t) Diaphragm (t) Number (t) End distance (t) Load (kp) Diaphragm 1 0 0 1 0 0 Type 1 Diaphragm V 1 0 0 1 0 0 Type 1 Diaphragm V V 1 0 0 17.5625 117.5625 17.5625 Type 1 Diaphragm - ARC's 1.0 V 1 35.125 35.125 0 1 0 35.125 Type 1 Diaphragm - ARC's 1.0 V Vige 1 Vige 1 Diaphragm - ARC's 1.0 Vige 1 Diaphragm - ARC's 1.0<	Support number Start (ft) Diaphragm wizard. Long (ft) Diaphragm wizard. Long (ft) Diaphragm wizard. Support number Start (ft) Diaphragm (ft) Number (ft) End (ft) Long (ft) Diaphragm Diaphragm 1 0 0 1 0 0 0 Type 1 Diaphragm - ARC = 1.0 1 0 0 1 0 0 0 Type 1 Diaphragm - ARC = 1.0 1 35.125 35.125 0 1 0 35.125 Type 1 Diaphragm - ARC = 1.0 Not Assigned	Out Diaphragm inter bar; Leter bar; Copy bey to Diaphragm inter bar; Diaphragm inter bar; Number (ft) End distance (ft) Length distance (ft) Length distance (ft) <thlength distance (ft) Length dist</thlength

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.

🐴 Str	uctu	ure Framin	g Plan Details										-		×
Num	ber o	of spans:	1	Number of gi	rders: 4										
Lay	out	Diaph	ragms Lat	teral bracing rar	nges										
Gir	der l	bay: 1		~	Copy bay to		Diaphragm wizard								
		Support number	S dis	Start stance (ft)	Diaphragm spacing	Number of spaces	Length (ft)	E dist (nd ance ft)	Load (kip)	Diaphragm				
			Left girder	Right girder	(ft)			Left girder	Right girder						
	> 1	1 ~	0	0	0	1	0	0	0		Type 1 Diaphragm - ARC's < 1.0 \vee				
	1	1 ~	0	0	17.5625	1	17.5625	17.5625	17.5625		Type 1 Diaphragm - ARC's < 1.0 V				
	1	1 ~	35.125	35.125	0	1	0	35.125	35.125		Type 1 Diaphragm - ARC's < 1.0 V				
												New	Duplicate	Delete	
												ОК	Apply	Cance	el

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**.



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.

Design review Rating Analysis type: 3D FEM Analysis type: 3D FEM Lane / Impact loading type: As Requested Vehicle: Output Engine: Both directions Vehicle: Both directions: Vehicle: Both directions: Vehicle: Step 2 -HL=33 (US) -HL=33 (US)	Analysis Settings				– 🗆 X
Analysis type: 30 FEM Analysis option: DL LL and Spec-Checking Lane / Impact loading type As Requested Apply preference setting: None Vehicles Output Engine Description Traffic direction: Both directions Refresh Temporary vehicles Vehicles selection Vehicle summary Vehicles Step 2 HL-93 (US) Step 2 HL-93 (US) Step 1 VS (S) Step 1 Vehicles faigue Truck (S) Add to Vehicles faigue Truck (S) Step 1 USF defined Remove from Temporary Step 3 Reset Clear Open template Save template OK Apply	O Design review	Rating	Design method:	LRFD	~
Lane / Impact loading type: As Requested Apply preference setting: None Vehicles Output Engine Description Traffic direction: Both directions: Refresh Temporary vehicles Advanced Vehicle selection Vehicle summary Perior vehicles Vehicle summary PV2 Step 2 HL93 (05) Step 2 HL93 (05) Step 2 HL93 (05) Step 1 Perior vehicles Step 1 Perior vehicles Step 1 PU2 Stop 4 Fatigue Truck (SI) Step 1 HL93 (05) Add to Step 1 Step 1 Perior vehicles Remove from Step 3 Step 1 User defined Remove from Step 3 Reset Open template Save template OK Apply Cancel	Analysis type:	3D FEM	 Analysis option: 	DL, LL and Spec-Checking	a ~
Vehicles Output Engine Description Traffic direction: Both directions Refresh Temporary vehicles Advanced Vehicle selection Vehicle summary Perior vehicles Advanced Vehicle summary Image: Provide selection Image: Perior vehicles Perior vehicles Image: Perior vehicles Image: Perior vehicles Image: Provide selection Image: Perior vehicles Image: Perior vehicles Image: Perior vehicles Image: Perior vehicles Image: Provide selection Image: Perior vehicles Image: Perior vehicles Image: Perior vehicles Image: Perior vehicles Image: Provide selection Image: Perior vehicles Image: Perior vehicles Image: Perior vehicles Image: Perior vehicles Image: Provide selection Image: Perior vehicles Image: Perior vehicles Image: Perior vehicles Image: Perior vehicles Image: Provide selection Image: Perior vehicles Image: Perior vehicles Image: Perior vehicles Image: Perior vehicles Image: Perior vehicles Image: Perior vehicles Image: Perior vehicles Image: Perior vehiclese	Lane / Impact loading type:	As Requested	 Apply preference 	e setting: None	~
Traffic direction: Both directions Refresh Temporary vehicles Advanced Vehicle selection Vehicle summary Vehicle summary Vehicle sign vehicles Step 2 Period vehicles Period vehicles Vehicle summary Add to Period vehicles Step 1 HL-93 (US) HL-93 (US) Period vehicles Step 1 HS 20 (SI) HS 20 (SI) Step 1 Step 1 HS 20 (SI) HS 20 (SI) Step 1 Step 1 User defined Remove from <	Vehicles Output Er	ngine Description			
Vehicle selection Vehicle summary Image: Standard of the stand	Traffic direction: Both di	irections \checkmark	Re	efresh Temporary vehicles	Advanced
Image: Standard Alternate Military Loading EV2 EV3 Step 2 HL-93 (S) HS 20 (S)	Vehicle selection		Vehic	le summary	
Reset Clear Open template Save template OK Apply Cancel		Truck (SI) Truck (US)	Add to >> Remove from <<	Step 3	Step 1
	Reset Clear	Open template	Save template	ОК	Apply Cancel

Design review Rating	Design method:	LRFD	\sim	
lysis type: 3D FEM V	Analysis option:	DL, LL and Spec-Checking	~	
e / Impact loading type: As Requested V	Apply preference setting:	None	~	
ehicles Output Engine Description				
- labular results	AASHTO engine i	reports		
Dead load action report	Girder pr	s reports:		
 Live load action report 		vinfluence line leading		
Concrete limit state summary report	Detailed	influence line loading		
 LRFD critical loads report 	Cenerity	initiative line loading		
LRFD specification check report	Capacity	summary		
PS concrete stress report	Capacity	detailed computations		
RC service stress report	FE mode	I for DL analysis		
Steel limit state summary report	FE mode	I for LL analysis		
	LL influer	nce lines FE model		
	LL influer	nce lines FE actions		
	LL distrib	factor computations		
	LL distrib	factor summary		
	Regressio	on data		
	Camber			
	Fatigue s	tress ranges		
	Service II	stress ranges		
	Specification	output:		
	LRFD/LR	FR conc article detailed		
		Classa - II		

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.

Workspace	* × 4	Bracing Specification Check Selection	-		×
Workspace Bridge Components US COMPONENTID Students US COMPONENTIA US	s> × 4 specifications 5 Specifications ASSHT0 LRED Spe R Specifications and for 1932 Concrus si) - ARC = 1.0 - ARC = 1.0 - ARC ≤ 1.0 ons E factors ons SINITIONS tecking c Load Allowance ription	▶ Bracing Specification Check Selection Diaphragms Lateral bracing Select diaphragms for specification checking in a 3D analysis: Select all Clear all > 1-1 ≥ 1-2 2-3 3-3 Step 1 Step 2			*
→ → </td <td>ration neck Selection al Section Loads or Definitions iions</td> <td></td> <td></td> <td></td> <td></td>	ration neck Selection al Section Loads or Definitions iions				
4		ОК Арр	oly	Cance	el

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.



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.

```
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
 Pn (kips) = 19.08
Phic = 0.95
                     (6.9.4.1.1)
 Phic
 Pr = Phic*Pn (kips) = 18.12
 Design Ratio = Pr/Axial Force
  Limit
                                           Axial
                Load
                             Force
                                                   Design
                Comb
                                                     Ratio
                                                             Status
  State
                                           Force
                              Type
                                            (kip)
                                            ----
  STR-I
                  1
                            Tension
                                              ---
                                                        ---
                                                               NA
                        Compression
                                           -20.69
                                                   0.876
                                                               Fail
  STR-I
  STR-I
                  2
                            Tension
                                           -20.88
                                                               NA
  STR-I
STR-III
                           Compression
                                                      0.868
                   2
                                                               Fail
                                            -0.94
                                                     19.247
                                                               Pass
                           Compression
                                           -1.35
  STR-III
STR-III
                                                    13.443
                 1
                          Compression
                                                              Pass
                  2
                          Compression
                                                               Pass
  STR-III
                  2
                          Compression
                                          -1.35
                                                    13.443
                                                              Pass
                  1
  STR-V
                            Tension
                                                               NA
  STR-V
                  1
                         Compression -16.27
                                                   1.114
                                                              Pass
  STR-V
                 2
                            Tension
                                                               NA
                         Compression -16.41
                  2
                                                   1.104
  STR-V
                                                             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
                                                                                                             OK
```

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.

BRIDGE WORKSPACE WORKSPACE TOOLS VIEW HELP	ANALYSIS REPORTS E	ge Workspace - Axial Rigidity Coefficient Training	? – 🗆 🗙
Analysis Analyze Analysis Settings Analysis Analyze Analysis Settings Analysis Analyze Analysis Analysis Analyze Analyze Analysis Analysis Analyze Analyze Analysis Analysis Analyze Analyze Analyze Analysis Analysis Analyze Analy	s	A 52 Span 3D Model	×
Axial Bioidity Coe	efficient Training		0.0.00000650 0.200 11152 848
Report Schematic	bec checking	186 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0.00000650 0.300 11153.848
Workspace AASHIO_L Model	I Generation Node Merge Report	188 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
Bridge Components S1 Spai	in 3D Model	189 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
-S1 Spai -S1 Spai -S1 Spai	in 3D FE Model Graphics in 3D Model Actions	190 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
Components S2 Spare	in 3D Model (Tuesday Nov. 19, 2024 15:12:30)	191 6.4800 0.0000 0.0000 4.66000000 156.0000000 0.27332500 29000.004 0.4	0 0.00000650 0.300 11153.848
⇒ Diaphragm Definitions S2 Spainter S3 Spainter S2 Spainter S2 Spainter S2 Spainter S2 Spainter S2 Spai	in 3D FE Model Graphics	192 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
Type 1 Diaphragm - ARC's < 1.0	in 3D Model	193 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
- 📁 Lateral Bracing Definitions	in 3D FE Model Graphics	194 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
LRFD Multiple Presence Factors Stability Stability	ty Bracing Force Report	195 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
Design Parameters Design Parameters	e	196 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
- SUPERSTRUCTURE DEFINITIONS	ft Exterior Girder	197 6.4800 0.0000 0.0000 4.66000000 156.0000000 0.27332500 29000.004 0.4	0 0.00000650 0.300 11153.848
The Diaphragm spec checking	Stage 3 Spec Check Results	198 2.1100 0.0000 0.0000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
Diaphragm spec checking - with u	erior Girder	199 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
- H Load Case Description	Stage 3 Spec Check Results	200 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
- # Framing Plan Detail	table of the Circles	201 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
Bracing Deterioration	Stage 3 Spec Check Results	202 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
G4		203 6.4800 0.0000 0.0000 4.66000000 156.0000000 0.27332500 29000.004 0.4	0 0.00000650 0.300 11153.848
- High Superstructure Loads	ht Exterior Girder	204 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
- 💋 Shear Connector Definitions 🖶 G1	stage 5 spec check nesults	205 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
Stiffener Definitions	terior Girder	206 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
ili I G1	SHIO_LRFD -Live Load Distribution Factors Calculations	207 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
- I G2	Live Load Distribution Factors Calculations Summar	208 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
🕂 🖬 🖬 🖬	-Stage 3 Spec Check Results	209 6.4800 0.0000 0.0000 4.66000000 156.0000000 0.27332500 29000.004 0.4	0 0.00000650 0.300 11153.848
BIDGE ALTERNATIVES	cog rife	210 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
	r Girder	211 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
E AAC	-Live Load Distribution Factors Calculations	212 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
	Live Load Distribution Factors Calculations Summar	213 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
	Stage 3 Spec Check Results	214 2.1100 0.0000 0.0000 1.75000000 1.75000000 0.09887700 29000.004 0.4	0 0.00000650 0.300 11153.848
₽-G3	Logine		
i⊞-Right Ir	Interior Girder		
E-AAS	SHIU LRU	Shell Properties	
		I	*
			>

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	× &	Analysis						
Bridge Components		Analysis - Diaphragm	spec checking	Analysis -	Diaphragm spec	checking - with user	input ARC values.	
🚽 🗛 Axial Rigidity Coefficient Training								
🕸- 💋 Components		Analysis Event			- CB	-1		
 P Diaphragm Definitions P Z Type 1 Diaphragm - ARC = 1.0 	Spec Check Detail for	r 6.9.2.1 Axial Compression					- 0	×
	6 Steel Structure 6.9 Compression N 6.9.2 Compressive 6.9.2.1 Axial Com (AASHTO LRFD Brid Diaphragm 1-2 AD- Shape type: L Pn (kips) = 19.08 Phic = 0.95 Pr = Phic*Pn (kip Design Ratio = Pr	<pre>ss tembers > Resistance upression ige Design Specificati -1 - Start Stage : (6.9.4.1.1) ss) = 18.12 r/Axial Force</pre>	ions, Tenth 3	Edition)				Î
	Limit Lo State Co	oad Force omb Type	Axial Force (kip)	Design Ratio	Status			
		4						
	STR-I	1 Tension	-17 40	1 040	NA			
	STR-1 97D-T	2 Tension	-1/.42	1.040	NA			
	STR-T	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 of	only.					Ţ
							C	ок

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 in^2** which is equal to **2.11 in^2 * 0.78**.

							-		
A	S2 Span	3D Model						-	
	193	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	194	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	195	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	196	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	197	5.5080 0.0000 0.0000	4.66000000 156.00000000	0.27332500 29000.004	0.490 0.00000650	0.300 11153.848			
	198	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	199	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	200	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	201	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	202	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	203	5.5080 0.0000 0.0000	4.66000000 156.00000000	0.27332500 29000.004	0.490 0.00000650	0.300 11153.848			
	204	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	205	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	206	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	207	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	208	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	209	5.5080 0.0000 0.0000	4.66000000 156.00000000	0.27332500 29000.004	0.490 0.00000650	0.300 11153.848			
	210	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	211	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	212	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	213	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	214	1.6458 0.0000 0.0000	1.75000000 1.75000000	0.09887700 29000.004	0.490 0.00000650	0.300 11153.848			
	Shel	I Properties	S						~
									_

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.

/orkspace	A Diaphragm Definitions								- 0
Bridge Components	Name: Type 1 Diaphragm		Diaphragm typ	e: Type 1	V Number	er of elements in fixed member:	1 ~		
Axial Rigidity Coefficient Training Components ▲ TYPE 115 (Mod) L 3x3x3/8	1: Training d. Specifications tPD Specific	ension-only diagonal sy e	stem						
- I 27WF91 - T 27WF106	Diaphragm types:						LRFD/LRF	R axial rigidity	coefficients
- I W 12x22 - LE 2002 AASHTO Std. Specifications	A B	Member	Shape	Section orientation	Section location	Material	Non- composite	Composite (long term)	Composite (short term)
LEFE 2010 AASHTO LRFD Specifications USE 2007 (2009 interim) AASHTO LRFD Specific		AB	W 12x22 V	Vertical	~ ~	Fy= 33 ksi (fs=18 ksi) V			/
- LEFE 2008 AASHTO LRFR Specifications	C G D Type: 1	CD	L 3x3x3/8 V	Vertical	\sim Top Left \sim	Fy= 33 ksi (fs=18 ksi) V			
Fc=2.500 ksi Assigned for 1932 Concrete T Fy= 33 ksi (fs=18 ksi)		AD	L 3x3x3/8 ∨	Vertical	\sim Top Left \sim	Fy= 33 ksi (fs=18 ksi) V			
- 🔁 Diaphragm Definitions		> CB	L 3x3x3/8 V	Vertical	${}^{\scriptstyle\bigvee}$ Top Left ${}^{\scriptstyle\bigvee}$	Fy= 33 ksi (fs=18 ksi) V			
Use SUPERSTRUCTURE DEFINITIONS Use Superstructure Definitions Use Superstructure Definitions Use Superstructure Description Use Superstructure Descriptio	E	Connectio	n Support type	Y (in)	Measured from		xed member: 1 ~ rial LRFD/LR 8 ks0 ~ 6 8 ks0 ~ 8 8 ks0 ~ 8 8 ks0 ~ 7 8 ks0 ~		
- # Framing Plan Detail	Type: 3	> A	Pinned	4	Top of Web	~			
P Bracing Deterioration BSC Bracing Spec Check Selection		В	Pinned	4	Top of Web	~			
- III Structure Typical Section	A B	С	Pinned	· 4	Bottom of Web	~			
H Superstructure Loads Bear Connector Definitions	— <u></u>	D	Pinned	4	Bottom of Web	~			
 Interpretation Interpretation<!--</td--><td>Type: 4</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td>	Type: 4								
B → L Diaphragm spec checking - with user input ARC values. B RDROE ALTERNATIVES A LFR (E) (C)						Select OK.			
								K Ap	ply Cance

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.

6 Steel Stru							0	
.9 Compress .9.2 Compre .9.2.1 Axia AASHTO LRFD	ctures ion Member ssive Resi l Compress Bridge De	s stance ion sign Specificatio	ons, Tenth	Edition)				
iaphragm 1-	2 AD-1 - S	tart Stage 3						
hape type: 3	L							
Pn (kips) =	19.08	(6.9.4.1.1)						
Phic =	0.95							
Dr = Dhiath-	(king) =	10 10						
FI - FRIC*Ph	(kips) =	10.12						
Design Ratio	= Pr/Axia	l Force						
separate manage								
obrău unoro								
Limit	Load	Force	Axial	Design				
Limit State	Load Comb	Force Type	Axial Force	Design Ratio	Status			
Limit State	Load Comb	Force Type	Axial Force (kip)	Design Ratio	Status			
Limit State	Load Comb	Force Type	Axial Force (kip)	Design Ratio	Status			
Limit State	Load Comb	Force Type Tension	Axial Force (kip)	Design Ratio	Status NA			
Limit State STR-I STR-I STR-I	Load Comb	Force Type Tension Compression Tension	Axial Force (kip) 	Design Ratio	Status NA Pass NA			
Limit State STR-I STR-I STR-I STR-I	Load Comb	Force Type Tension Compression Tension Compression	Axial Force (kip) -15.01 -15.12	Design Ratio 1.208 	Status NA Pass NA Pass			
Limit State STR-I STR-I STR-I STR-I STR-I STR-I	Load Comb 1 1 2 2 1	Force Type Tension Compression Compression Compression	Axial Force (kip) 	Design Ratio 1.208 1.199 24.148	Status NA Pass NA Pass Pass			
Limit State STR-I STR-I STR-I STR-III STR-III	Load Comb 1 1 2 2 1 1	Force Type Tension Compression Compression Compression	Axial Force (kip) -15.01 -15.12 -0.75 -1.07	Design Ratio 1.208 1.199 24.148 16.916	Status NA Pass NA Pass Pass Fass			
Limit State STR-I STR-I STR-I STR-III STR-III STR-III	Load Comb 1 2 2 1 1 2	Force Type Tension Compression Compression Compression Compression	Axial Force (kip) 	Design Ratio 1.208 1.199 24.148 16.916 24.148	Status NA Pass NA Pass Pass Pass Pass			
Limit State STR-I STR-I STR-I STR-III STR-III STR-III STR-III STR-III	Load Comb	Force Type Tension Compression Compression Compression Compression Compression	Axial Force (kip) 	Design Ratio 1.208 	Status NA Pass NA Pass Pass Pass Pass Pass			
Limit State STR-I STR-I STR-I STR-III STR-III STR-III STR-III STR-V	Load Comb 1 2 2 1 1 2 2 1 2 2 1	Force Type Tension Compression Compression Compression Compression Compression Tension	Axial Force (kip) 	Design Ratio 1.208 24.148 16.916 24.148 16.916	Status NA Pass NA Pass Pass Pass Pass Pass Pass NA			
Limit State STR-I STR-I STR-I STR-II STR-III STR-III STR-V STR-V STR-V	Load Comb 1 2 2 1 1 2 2 1 1 2 2 1 1	Force Type Tension Compression Compression Compression Compression Compression Tension Compression	Axial Force (kip) 	Design Ratio 1.208 1.199 24.148 16.916 24.148 16.916 1.533	Status NA Pass NA Pass Pass Pass Pass Pass Pass NA Pass			
Limit State STR-I STR-I STR-I STR-II STR-III STR-III STR-V STR-V STR-V	Load Comb 1 2 2 1 1 2 2 1 1 2 2 1 1 2 2 1 1 2	Force Type Tension Compression Compression Compression Compression Compression Tension Compression Tension	Axial Force (kip) 	Design Ratio 1.208 1.199 24.148 16.916 24.148 16.916 1.533	Status NA Pass NA Pass Pass Pass Pass NA Pass NA			

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 in^2 = 2.11 in^2 * 0.65.

2 Spai	n 3D Model								-	
185	6.4800 0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490 0.00000650	0.300	11153.84	48
186	1.3715 0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
187	1.3715 0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
188	1.3715 0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	18
189	1.3715 0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
190	1.3715 0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
191	6.4800 0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490 0.00000650	0.300	11153.84	48
192	1.3715 0.000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
193	1.3715 0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
194	1.3715 0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
195	1.3715 0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
196	1.3715 0.0000	0.0000 0	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
197	6.4800 0.0000	0.0000	4.66000000	156.00000000	0.27332500	29000.004	0.490 0.00000650	0.300	11153.84	48
198	1.3715 0.0000	0.0000 0	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
199	1.3715 0.0000	0.0000 0	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
200	1.3715 0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
201	1.3715 0.0000	0.0000 0	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
202	1.3715 0.000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
203	6.4800 0.0000	0.0000 0	4.66000000	156.00000000	0.27332500	29000.004	0.490 0.00000650	0.300	11153.84	48
204	1.3715 0.0000	0.0000 0	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
205	1.3715 0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
206	1.3715 0.0000	0.0000 0	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	18
207	1.3715 0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
208	1.3715 0.0000	0.0000 0	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
209	6.4800 0.0000	0.0000 0	4.66000000	156.00000000	0.27332500	29000.004	0.490 0.00000650	0.300	11153.84	48
210	1.3715 0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
211	1.3715 0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
212	1.3715 0.0000	0.0000	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
213	1.3715 0.0000	0.0000 0	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48
214	1.3715 0.0000	0.0000 0	1.75000000	1.75000000	0.09887700	29000.004	0.490 0.00000650	0.300	11153.84	48

Shell Pronerties

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.