AASHTOWare BrDR 7.5.1 Multi-Cell Box Tutorial MCB5 - Advanced Multi-Cell Box Superstructure Example

### **Topics Covered**

- Why use an Advanced Multi-Cell Box superstructure?
- Analysis methods
- Curved post-tensioned concrete multi-cell box data entry
- Integral pier data entry
- LRFR analysis and results
- Curved multi-cell box analysis

This example describes entering a curved post-tensioned concrete advanced multi-cell box superstructure with an integral pier into AASHTOWare BrDR. This example focuses on the additional features of advanced multi-cell box superstructures vs. regular multi-cell box superstructures.

### Why use an Advanced Multi-Cell Box superstructure?

#### Geometry

Multi-Cell Box superstructures can only model superstructures with a constant number of cells along the structure length and the superstructure must follow a straight alignment. Advanced Multi-Cell Box Superstructures provide the ability to define curved superstructures and those that have a varying number of cells along the structure length. Analysis

Post-tensioned Advanced Multi-Cell Box superstructures have several features that are not available in standard Multi-Cell Boxes:

- Ability to apply the post-tensioning in either stage 1 (non-composite) or stage 2 (long term composite). Elastic shortening losses are computed for each tendon profile in the profile's initial loading stage. When multiple tendon profiles are defined and some are stressed in stage 1 and others are stressed in stage 2, additional elastic shortening losses are computed in stage 2 for the stage 1 profiles to account for the additional elastic shortening losses that occur as a result of the stage 2 tendon forces. Post-tensioning secondary moments are computed in each loading stage too. The stage 1 post-tensioning secondary moments are the result of the stage 1 post-tensioning forces after initial losses are applied to the stage 1 model. The stage 2 post-tensioning secondary moments are the long-term losses from the stage 1 tendons applied to the stage 2 model. The total post-tensioning secondary effects are the sum of the stage 1 and stage 2 secondary effects. Standard Multi-Cell Boxes do not allow specification of post-tensioning application. In a standard multi-cell box, instantaneous loss is computed in stage 1 and long-term losses are computed on the stage 2 section. Secondary moments are computed after all losses have occurred on the stage 2 model.
- Ability to specify overlapping tendons.
- Ability to specify tendons along the full box or along each individual web.

• Ability to analyze individual webs in a post-tensioned box when the web lengths vary from the full box length.

### Analysis Methods

Post-tensioned concrete advanced multi-cell box (MCB) superstructures can be analyzed in the following ways:

- LRFR and LFR
- Full box section including each individual webline
- Single webline

### Curved Post-Tensioned Concrete Multi-Cell Box Data Entry

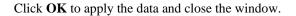
From the Bridge Explorer, use the New button to create a new bridge and enter the following data.

Ba B		AASHTOWare Bridge Design a	and Rating	?	_	- ž
BRIDGE EXPLORER BRID	GE FOLDER RAT	E TOOLS VIEW				>
New Open batch ~ Bridge		Copy Remove Delete To From				Ş
New (Ctrl+N) Creates a new bridge.	2	0 LRFD Substructure Example 1				District
E Templates		1 LRFD Substanting Example 2	2 LRFD Substructure Example 2	$\sim$	~~	m

### New Bridge

Check the Substructures checkbox to enable data entry of the integral pier.

A MCB5								_		×
Bridge ID: MCB5		NBI struct	ure ID (8):	MCB5		<ul> <li>Template</li> <li>Bridge completely define</li> </ul>		Bridge Works Superstr Culverts Substruc	uctures	)
Description De	escription (cont'd)	Alternative	s Globa	al reference point	Traffic	Custom agency fields				
Name:	MCB5					Year built:				
Description:	PT curved box									
Location:						Length:	ft			
Facility carried (7):						Route number: 1				
Feat. intersected (6	5):					Mi. post:				
Default units:	US Customary	$\sim$								
-	~~~~	~~~~/	$\sim$			man from the	~~		~	



Now begin adding the **Components** required to build the bridge model. Navigate to the **Components** tab of the **Bridge Workspace (BWS)**.

#### Bridge Appurtenances – Generic tab

Expand the **Appurtenances** tree and double click on the **Generic** folder (or right click and select **New** or click on the **New** button from the **Manage** group of the **WORKSPACE** ribbon) to define a generic barrier as shown below.

Bridge Workspace - MCB5 BRIDGE WORKSPACE TOOLS	VIEW	ANALYSIS DESIGN/RATE	REPOR		?	_		×
🗥 Check Out 📑 💾 🍐 Restore 💌	Export	8		opy Paste	Duplicate	) Delete	Schematic	
Bridge				Manage				
Workspace     Appurtenances       Bridge     Components       Components     Image: Components       Image: Components     Image: Components		3	\$ X	Report			\$	×
<ul> <li>Pailing</li> <li>View Summary Report</li> <li>View Detailed Report</li> <li>Connector</li> <li>Factors</li> <li>LRFD Subs</li> <li>Materials</li> </ul>							\$	×

🗛 Bridge Ap	purtenances - Generic —		×
Name:	Barrier		
Description:			
	All dimensions are in inches		
Distance f	from edge to centroid: 9 Reference Line Barrier load: 0.5 kip/ft Width: 18		
	Effective wind height: 28 Back Front		
	Copy from library OK Apply	Canc	el

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

### Bridge Materials - Concrete

To add a new concrete material, expand the **Materials** folder and double click on **Concrete** in the tree. The window shown below will open. Enter the values shown below for the concrete to be used in the multi-cell box. Use the **Compute** button to fill in the lower portion of the window.

Ӓ Bridge Mat	terials - Concrete						_		×
Name:	Beam concrete								
Description:									
Compressive	strength at 28 days (f'c):	4.5		ksi					
Initial compre	essive strength (f'ci):	4		ksi					
Composition	of concrete:	Normal	~						
Density (for a	dead loads):	0.15		kcf					
Density (for r	modulus of elasticity):	0.145		kcf					
Poisson's rati	io:	0.2							
Coefficient o	f thermal expansion (α):	0.000006		1/F					
Splitting tens	sile strength (fct):			ksi					
LRFD Maxim	um aggregate size:			in					
	Compute								
Std modulus	of elasticity (Ec):	3865.20204		ksi					
LRFD modul	us of elasticity (Ec):	4144.549969	)	ksi					
Std initial mo	odulus of elasticity:	3644.147431		ksi					
LRFD initial n	nodulus of elasticity:	3986.54846		ksi					
Std modulus	of rupture:	0.503115		ksi					
LRFD modul	us of rupture:	0.509117		ksi					
Shear factor:		1							
	Copy t	o library	Copy f	rom library	ОК	A	pply	Canc	el

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

To add another concrete material for use in the integral pier, double click on **Concrete** in the tree and click on **Copy from library...** button. Select the **Class A** (**US**) material and click **OK**. The selected material properties are copied to the **Bridge Materials – Concrete** window as shown below.

🗛 Bridge Mat	erials - Concre	ete					_		×
Name:	Class A (US)								
Description:	Class A ceme	ent concrete	e						
Compressive	strength at 28	3 days (f'c):	4.0000006		ksi				
Initial compre	essive strengtl	h (f'ci):			ksi				
Composition	of concrete:		Normal	~					
Density (for d	lead loads):		0.15		kcf				
Density (for n	nodulus of ela	asticity):	0.145		kcf				
Poisson's rati	o:		0.2		ĺ				
Coefficient of	f thermal expa	ansion (α):	0.000006		1/F				
Splitting tens	ile strength (f	ct):			ksi				
LRFD Maximu	um aggregate	size:			in				
	(	Compute			-				
Std modulus	of elasticity (E	ic):	3644.14925	54	ksi				
LRFD modulu	us of elasticity	(Ec):	3986.54865	57	ksi				
Std initial mo	dulus of elast	icity:			ksi				
LRFD initial m	nodulus of ela	sticity:			ksi				
Std modulus	of rupture:				ksi				
LRFD modulu	is of rupture:		0.479857		ksi				
Shear factor:			1						
		Copy t	o library	Copy	from library	ОК	Apply	Canc	el

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

#### Bridge materials – Prestress Strand

To add a new post-tensioning strand material, double click on **Prestress Strand** in the tree and click on **Copy from library...** button. Select the **1/2''** (**7W-270**) **LR** reinforcing steel and click **OK**. The selected material properties are copied to the **Bridge Materials – Prestress Strand** window as shown below.

🗛 Bridge Mat	terials - PS Strand					_		×
Name:	1/2" (7W-270) L	R						
Description:	Low relaxation 1	/2"/Seven Wi	re/fpu =	270				
Strand diame	eter:	0.5	in					
Strand area:		0.153	in^2					
Strand type:		Low Relaxati	on 🗸					
Ultimate tens	sile strength (Fu):	270	ksi					
Yield strengt	h (fy):	243	ksi					
Modulus of e	elasticity (E):	28500	ksi					
	Compute	•						
Transfer leng	th (Std):	25	in					
Transfer leng	th (LRFD):	30	in					
Unit load per	length:	0.52	lb/ft					
		Epoxy co	ated					
Сору	to library	Copy from lib	rary	ОК	Apply		Cance	el

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

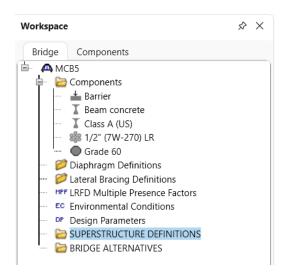
#### Bridge materials – Reinforcing Steel

To add a new reinforcing steel material, double click on **Reinforcing Steel** in the tree and click on **Copy from library...** button. Select the **Grade 60** reinforcing steel and click **OK**. The selected material properties are copied to the **Bridge Materials – Reinforcing Steel** window as shown below.

Ӓ Bridge Mat	terials - Reinforc	ing Steel						_		×
Name:	Grade 60									
Description:	60 ksi reinforci	ng steel			]					
Material prop	perties									
Specified yiel	ld strength (fy):	60.000087		ksi						
Modulus of e	elasticity (Es):	29000.004206	6 I	ksi						
Ultimate stre	ngth (Fu):	90.0000131		ksi						
Туре										
O Plair	n									
Epo										
Galv	vanized									
	Copy t	o library	Copy fro	om library		ОК	Appl	/	Cancel	
							-			

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

Navigate back to the Bridge tab of the BWS tree. The partially expanded tree is shown below.



### Superstructure Definitions

Double click on the **SUPERSTRUCTURE DEFINITIONS** folder in the **BWS** tree to create a new Advanced MCB (Multi-Cell box) superstructure definition. Select **Advanced concrete multi-cell box superstructure** and click **OK**.

A New Superstructure Definition		×
Girder system superstructure		
Girder line superstructure	Superstructure definition wizard	
Floor system superstructure		
Floor line superstructure		
Truss system superstructure		
Truss line superstructure		
Reinforced concrete slab system superstructure		
Concrete multi-cell box superstructure		
Advanced concrete multi-cell box superstructure		
		-

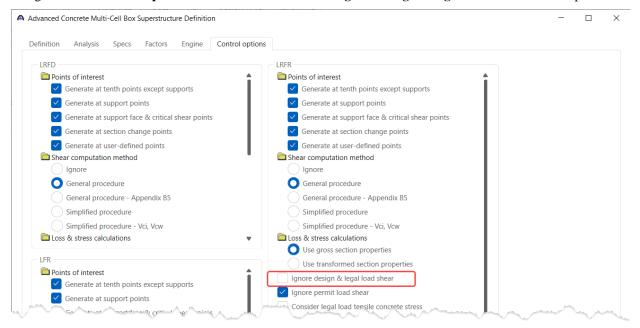
Enter the following data for the superstructure definition.

Advanced Concrete Multi-C	ell Box Superstr	ructure Definition					- 0	×
Definition Analysis	Specs Facto	rs Engine Con	trol options					
Name:	Curved PT							
Description:				See be	low		End projections Left: 12 in Right: 12 in	
Default units:	US Customary	<ul> <li>✓ Span I</li> </ul>	lengths Segm	ent data	Negral pier	s	Average humidity: 70 %	
Number of spans:	2 🗘	Enter	span lengths alo		ce line:		Structure type	
Number of segments:	1 🗘		Length				Frame structure simplified definition	
			Span (ft)				Integral with substructure	
		>	1 125.25 2 136.25				Consider substructure skew in FE section properties	
Structure model for LLD Standalone Left side connected Right side connected	d to adjacent str					Ŧ	Post-tensioned     Analyze webs only     Cross section orientation     Perpendicular to reference line     Along skew	
Horizontal curvature alo	-				1			
Horizontal curvatur     Superstructure align		Distance from PC to		180.42	ft			
Curved	intent	Start tangent length: Radius:		625	ft			
Tangent, curve	d, tangent	Direction:		Left V				
Tangent, curve		End tangent length:			ft			
Curved, tanger	nt	Distance from last su	pport line to PT:	136.92	ft			
		Design speed:			mph			
		Superelevation:			%			
							OK Apply Cancel	

pan	lengths	Segment	data	Inte	gral piers	
Ente	er segment l	engths alo	ong the i	refere	nce line:	
	Segment	Length (ft)	Numbe cell		Include in analysis	
>	1	261.5		2	$\checkmark$	

S	pan	lengths	Segment	t data	Integral piers	
F	ram	e connectio	ons:			
		Support	Integral			
		1				-
	>	2				
		3				

#### Navigate to the Control Options tab and uncheck the LRFR Ignore design & legal load shear control option.



Click **OK** to create the superstructure definition and close the window.

### Load Case Description

Expand the newly added superstructure definition **Curved PT** folder in the **BWS** tree and double click on the **Load Case Description** node. Use the **Add default load case descriptions** button to create the following load cases.

orkspace	,	☆	×
Bridge	Components		
A MC	:B5		
🖃 🖓 😥	Components		
📁	Diaphragm Definitions		
📁	Lateral Bracing Definitions		
···· MPF	LRFD Multiple Presence Factors		
EC	Environmental Conditions		
DP	Design Parameters		
- P )	SUPERSTRUCTURE DEFINITIONS		
<u> </u>	W Curved PT		
	Impact/Dynamic Load Allowance		
	Load Case Description		
	Superstructure Alignment		
	Hinge Locations		
	📁 Concrete Stress Limits		
	🧼 📁 Post Tension Losses		
	🕂 Superstructure Loads		
	👲 Shrinkage Time		
	💦 Supports		
	supports		
	📁 Points of Interest		
	📁 Vertical Shear Reinforcement Defi	nitic	ns
6	MCB Segments		
	LL Live Load Distribution		
· 🔁	BRIDGE ALTERNATIVES		

Load case name	Description	Stage		Тур	e	Time* (days)	
DC1	DC acting on non-composite section	Non-composite (Stage 1)	$\sim$	D,DC	$\sim$		
DC2	DC acting on long-term composite section	Composite (long term) (Stage 2)	$\sim$	D,DC	$\sim$		
DW	DW acting on long-term composite section	Composite (long term) (Stage 2)	$\sim$	D,DW	$\sim$		
SIP Forms	Weight due to stay-in-place forms	Non-composite (Stage 1)	$\sim$	D,DC	$\sim$		
				2,2 0	×		
	Add default load						

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

#### Superstructure Alignment

Double click on the **Superstructure Alignment** node. This window defines the location of the superstructure definition relative to the superstructure definition reference line by specifying where the superstructure definition reference line is located. Enter the following data.

🖪 Si	uperstructur	e Alignment				_		×
Sup	erstructure	definition reference line is	To the Right	of v t	ne following comp	onent:		
	Segment	Component	Distance at start (ft)	Distance at end (ft)				
>	1	Left Edge of Deck $$	16	16				
	I	Left Edge of Deck V	10	10		<b>.</b>	, par ser	

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

#### Concrete Stress Limits

Double click on the **Concrete Stress Limits** folder in the **BWS** tree and enter a **Name**, select the beam concrete material and click the **Compute** button to fill out the stress limit data for the beam concrete

A Stress Limit Sets - Concrete						-		×
Name: Beam stres	is limit							
Description:								
Corrosion condition: Moderate		~						
Final allowable tension stress	limit coef. (US	5) override:						
Concrete material: Beam conc	rete	~	]					
Compute								
	LFD			LRFD				
Initial allowable compression:	2.4	ksi		2.6	ksi			
Initial allowable tension:	0.1897367	ksi		0.1896	ksi			
Final allowable compression:	2.7	ksi		2.7	ksi			
Final allowable tension:	0.4030509	ksi		0.4030509	ksi			
Final allowable DL compression:	1.8	ksi		2.025	ksi			
Final allowable slab compression:		ksi			ksi			
Final allowable compression: (LL+1/2(Pe+DL))	1.8	ksi		1.8	ksi			
				C	ОК А	pply	Canc	el

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

#### Post Tension Losses

Double click on the Post Tension Losses folder in the BWS tree, select the Lump Sum Loss method and enter the

#### following data.

A Post Tension Losses					_		×
Name: Lump sum loss							
Loss method:	Lump Sum	~		– Lump sum I	osses		
Anchor set:	0.375	in		Initial loss:			ksi
Coefficient of friction:	0.15			Final loss:	25		ksi
Wobble coefficient:	0.0002	per ft					
P/S transfer stress ratio:							
Transfer time:		Hours					
Age at deck placement:		Days					
Final age:		Days					
			ОК	Apply	/	Car	ncel

Click **OK** to apply the data and close the window. An informational message box will appear stating that the window data should be reviewed. Click **OK** to close the message box and the window.

### Shrinkage/Time

Double click on the Shrinkage/Time node in the BWS tree and select Moist-cured for the beam curing method.

Shrinkage Time	
Beam	
Curing method: Moist-cured ~	
Deck	
Curing method: Moist-cured ~	
Drying time: Days	
Consider deck differential shrinkage loads	

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

#### Supports

Double click on the **Supports** node. The **Supports** window is where support skews are entered for advanced multicell boxes. The supports for this structure are not skewed so there is no data to enter here.

🗛 s	upp	orts		_		×
	) Ad	vanced supp	ort conditions			
5	kew	General	Elastic			
		Support	Skew (degrees)			
	>	1	0			-
		2	0			
		3	0			
سري		www	معمر		^	H

The **Advanced support conditions** checkbox allows the entry of different support conditions on the **General** and **Elastic** tabs for different stages. This example does not require different support conditions in different stages so do not check that checkbox. This example does not require changing any data on this window so click **Cancel** to close the window without saving any errant data changes.

### Vertical Shear Reinforcement Definitions

Double click the Vertical Shear Reinforcement Definitions node and create the following stirrup definition.

\land Shear	Reinforcement Definition - Verti	ical				_		×
Name:	#6 Stirrup	]						
		Material:	Grade	60			~	
		Bar size:	6	~				
		Number of legs:	2					
	Vertical	Inclination (alpha):	90		Degrees			
	Shear Reinforcemer	nt	(	0	K A	Apply	Cance	21

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

### Segment

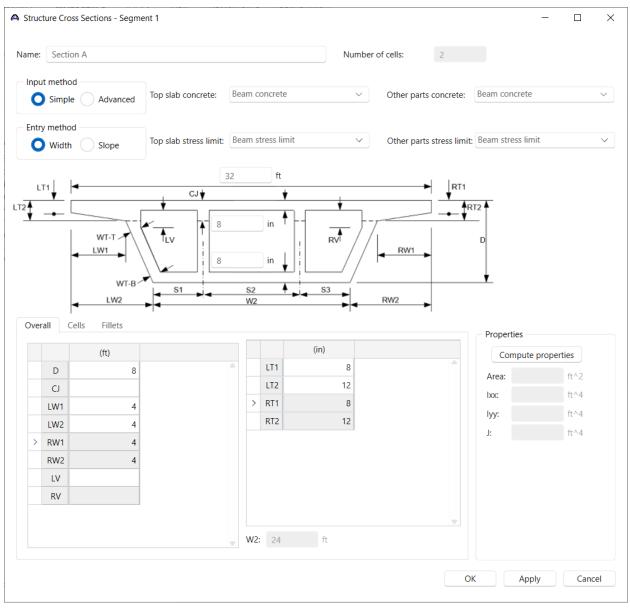
Open the Segment 1 window. The start of the segment skew field is always read only and displays the skew of the first support or the ending skew of the preceding segment if the segment is not the first segment in the superstructure. The end of this segment aligns with the last support skew of the structure so it displays the last support skew. Note that this end skew is not applied until **OK** is clicked for this window.

A N	ICB Segm	ent					_		×
Na	me:	Segment 1							
De	scription:								
Nu	mber of c	ells: 2							
Co.		gth: 261.5	ft		n input method -				
seg	gmentien	gun: 201.5	IL	O Full be	ox Web				
	Segmer location	nt Support	Distance (ft)	Skew (degrees)					
>	Start	1	0	0					
	End	2	136.25	0					
						ОК	Apply	Cano	el

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

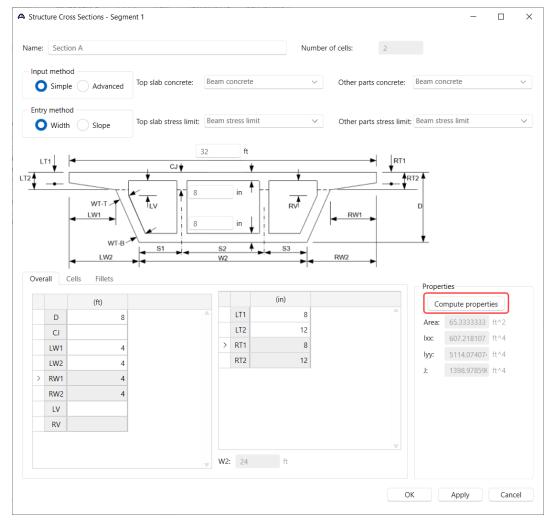
### Segment Structure Cross Sections

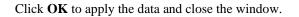
Double click on the Structure Cross Sections folder in the BWS tree and enter the following data.



Ove	erall	Cells Fille	ets			
Тор	left we	eb thickness:	16	in W2:	24	ft
Bott	tom lef	ft web thicknes	s: 16	in		
	Cell	S (ft)	Top right web thickness (in)	Bottom right web thickness (in)	Top slab thickness (in)	
	1	12	16	16	8	
>	2	12	16	16	8	

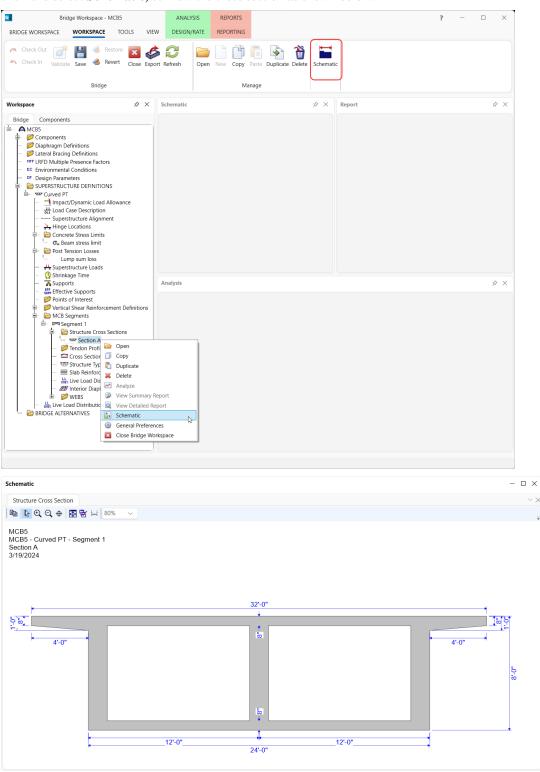
Now that all of the dimensions are entered, click the Compute properties button.





#### Schematic – Section A

With **Section A** selected in the **BWS** tree, click on the **Schematic** button from the **WORKSPACE** ribbon (or right click and select **Schematic**) to view the cross section as shown below.



### Tendon Profile Definition

Double click on the Tendon Profile Definition folder in the BWS tree and create the following tendon profile.

Enter the data shown below for the 3 tabs.

le nar	me: Full b	box tendon														
ndon	n distance f	from segment		Tendon distance fro	m support			Stage	Non-comp	osite (Stage	1) ~				Distance	
art di	listance fro	om start: 0	ft	Start distance from	support:	1 0		ft				Segment	location	Span	(ft)	
nd dis	stance fron	m end: 0	ft	End distance from s	support:	3 0		ft				From start From end			0 0	
Infle	ection poin	nt entry method -	ss limits													
Infle	ection poin	nt entry method – age Distance			In	flection poi	nts			Vertica	I offset					
Infle O	ection poin	nt entry method -		ïle type	In Left (%)	flection poin Low (%)	nts Right (%)	Left end (in)	Measured from	Vertica Low (in)	I offset Measured from	Right end (in)	Measured from			
0	ection poin Percentag	nt entry method – age Distance Segment span length		ïle type Type 3 →	Left	Low	Right			Low (in)	Measured	(in)	from			

uess i	material: 1/2	" (7W-270) LR 🛛 🗸	Duct grouting:	Grouted ~			
ing er	end: Lef	End 🗸	Duct diameter:	5 in			
ost ter	ensioning						
	put method —						
0	Jacking for	Strands Jacking	tress ratio: 0.75				
		Le Stranus					
		Strands					
	jacking force:		of ducts per web: 0				
Total j		8375 kip Numbe					
Total j	jacking force:	8375 kip Numbe					
Total j	jacking force: Distribute equa	8375 kip Numbe				Strands	
Total j	jacking force:	8375 kip Numbe			Duct	Strands per	
Total j	jacking force: Distribute equa Web	8375 kip Numbe	of ducts per web: 0	× .	Duct		
Total j	jacking force: Distribute equa Web WEB1	8375 kip Number Illy Percentage (%) 33.33333	of ducts per web: 0	~	Duct	per	
Total j	jacking force: Distribute equa Web	8375 kip Numbe	of ducts per web: 0	✓ ✓	Duct	per	A

Profile Post tensioning Stress limits				
	LRFD		LFD	
Prior to seating:	218.7	ksi	218.7	ksi
At anchorages and couplers immediately after anchor set:	189	ksi	189	ksi
Elsewhere along length of member immediately after anchor set:	199.8	ksi	201.69	ksi
At service limit state after losses:	194.4	ksi	194.4	ksi
Compute Values				
hanne hannen	$\wedge \neg \checkmark$	V	~~	

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

#### Cross Section Range Properties

Double click on the Cross Section Range Properties node in the BWS tree and assign the cross sections as follows.

								Sec	ment location	Span	Distance
											(ft)
									n start of span n end of span	1 2	0 0
.102	Start section	t tensioning End section	Depth vary	Solid section	Support number	Start distance (ft)	Length (ft)	End distance (ft)			
	Section A $\sim$	Section A $\sim$	None ~	<ul> <li></li> </ul>	1 ~	0	2	2			4
	Section A 🛛 🗸	Section A $\sim$	None 🗸		1 ~	2	120.25	122.25			
	Section A 🛛 🗸	Section A $\sim$	None 🗸		1 ~	122.25	6	128.25			
	Section A $\sim$	Section A $\sim$	None 🗸		2 ~	3	131.25	134.25			
>	Section A $\sim$	Section A $\sim$	None ~	$\checkmark$	2 ~	134.25	2	136.25			

Assign the post-tensioning tendon on the **Post tensioning** tab as follows.

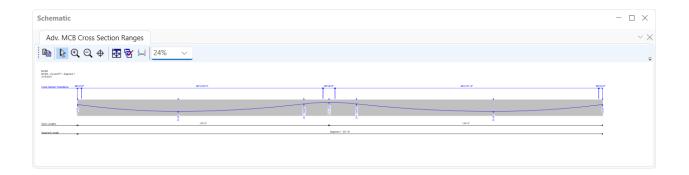
	Tendon profile	Start span	Start distance into start span (ft)	End span	End distance from end span (ft)	Stage	Losses		
>	Full box tendon $~~$	1	0	2	261.5	Non-composite (Stage 1)	Lump sum loss	~	-

Click **OK** to apply the data and close the window. An informational message box will appear stating that web shear reinforcement ranges should be reviewed. Click **OK** to close the message box and the window.

### Schematics – Cross Section Range Properties

Select the **Cross Section Range Properties** node in the **BWS** tree and click the **Schematic** button from the **WORKSPACE** ribbon (or right click and select **Schematic**) as shown below.

Bridge Workspace - MCB5	ANALYSIS	REPORTS				?	-		×
BRIDGE WORKSPACE TOOLS VIEW	DESIGN/RATE	REPORTING							
Check Out Aliciate Save & Revert Close Expo	rt Refresh Open	n New Copy Past	e Duplicate Delete	Schematic					
Bridge		Manag	9						
Workspace $ \not \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! $	Schematic			\$ ×	Report			×	* ×
Bridge       Components									
🔥 Shrinkage Time 🚡 Supports 🏭 Effective Supports	Analysis							×	s ×
Finite of Interest     Fonits of Interest     MCB Segments     MCB Segments     MCB Segments     Section A     Fonite Section A	- C2-								



### Structure Typical Section

Double click on the **Structure Typical Section** node and enter the following data on the **Generic** tab.

ack     Front       Deck     Deck (cont'd)       Parapet     Median       Railing     Generic       Sidewalk     Lane position       Striped lanes     Wearing surface	-
	. 0
Deck Deck (cont'd) Parapet Median Railing Generic Sidewalk Lane position Striped lanes Wearing surface	
from (ft) (ft)	
Barrier     V     DC2     V     Back     V     Left Edge     V     0     0     Right     V	
> Barrier	

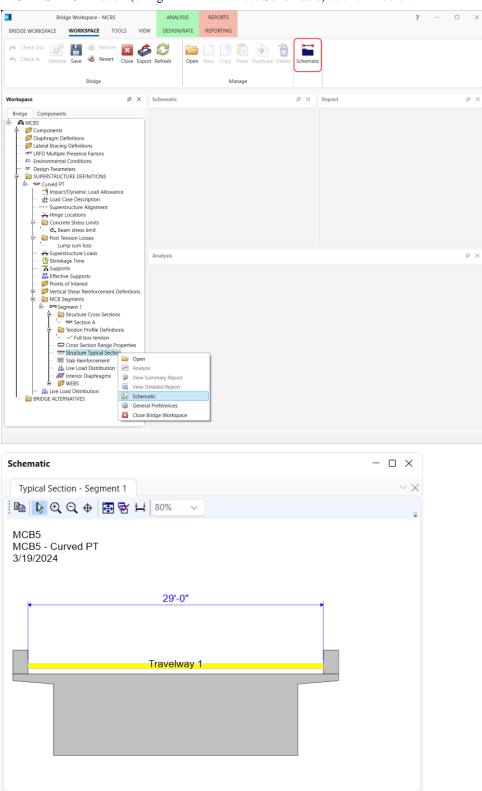
Navigate to the Lane Position tab. Click the Compute button and then click Apply to populate the following data.

+	Travel	(A)	(B)S											×
	Travel			uperstructu	ure Definition I	Reference Lin	ė							
4		way i			ravelway 2	↓	7				Segment location	Span	Distance (ft)	
<u> </u>			V								From start of span	1	0	
			7 ' \	i		- 7	_				From end of span	2	0	
eck	Deck (co	ont'd) l	Parapet	Median	Railing	Generic	Sidewalk	Lane pos	ition	Striped lanes	Wearing surface			
Edg	ge referenc	e												
0	Superstr	ucture refe	erence line	Edge	e of deck									
			Start		End	Left edg travelway		Right edg travelway						
	Travelway number	Support number	distance (ft)	Length (ft)	distance (ft)	(ft)		(ft)	onset					
			(11)		(11)	Start	End	Start	End					
>	1	1 ~	0	261.5	261.5	-14.5	-14.5	14.5	14.5	i			1	h
	FD fatique													
	ines availab	le to truck	s.											
		Truck fracti			_									
	Overnue		ion:		Com	pute					New Dup	licate	Delete	
											ОК	Apply	Cance	el 🛛

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

#### Schematics – Structure Typical Section

Select the **Structure Typical Section** node in the **BWS** tree and click the **Schematic** button from the **WORKSPACE** ribbon (or right click and select **Schematic**) as shown below.



#### Slab Reinforcement

Double click on the Slab Reinforcement node in the BWS tree and enter the following data on the first two tabs.

														Segment	location S	pan Dist	ft)
														rom start rom end		1 0 2 0	~
op slab Set #	Cell	Material	Reference point	Direction	Start distance (ft)	Length (ft)	End distance (ft)	Number of bars	Number bars for left web	Bar size	Clear cover (in)	Measured from	Bar spacing (in)	Side cover (in)	Start fully developed	End fully developed	
1	All Cells $\ \lor$	Grade 60 🗸	Support 1 🗸	Left 🗸	0.5	262	261.5	12	6	6 ×	2.5	Top of Slab $$					^
	Set #	Set # Cell	Set # Cell Material	Set # Cell Material Reference point	Set # Cell Material Reference point Direction	Set # Cell Material Reference point Direction (ft)	Set # Cell Material Reference point Direction (ft)	Set # Cell Material Reference point Direction Start distance (ft)	Set # Cell Material Reference point Direction distance (ft) Length distance (ft) of bars	Set # Cell Material Reference point Direction distance (ft) End distance (ft) veb	Set # Cell Material Reference point Direction distance (ft) Length (t) Reference (ft) Length (t) Reference (ft)	Set # Cell Material Reference point Direction Cft (ft) Direction (	Set # Cell Material Reference point Direction Start (ft) Length (ft) where the start (ft) the st	Set # Cell Material Reference point Direction Start (ft) Length (t) Provide the constant of th	Set # Cell Material Reference point distance (ft) Reference (ft) R	Set # Cell Material Reference point listance (ft) Length (stance (ft)) and (stance (	Set # Cell Material Reference point issues (ft) between the constraint of the constr

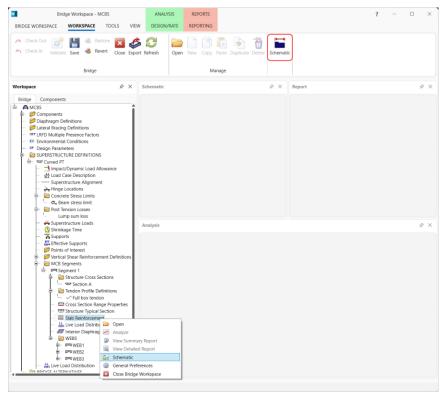
	Set #	Cell	Material	Reference point	Direction	Start distance (ft)	Length (ft)	End distance (ft)	Number of bars	Number bars for left web	Bar size	Clear cover (in)	Measured from	Bar spacing (in)	Side cover (in)	Start fully developed	End fully develope
>	1	All Cells $\ \lor$	Grade 60 🗸 🗸	Support 1 🗸	Left $\sim$	0.5	262	261.5	12	6	6 ~	2	Bottom of Slab $\sim$				

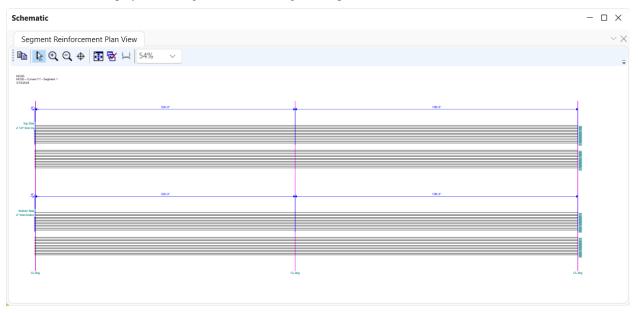
Click **OK** to apply the data and close the window.

Schematics – Slab Reinforcement

Select the Slab Reinforcement node in the BWS tree and click the Schematic button from the WORKSPACE

ribbon (or right click and select Schematic) as shown below.

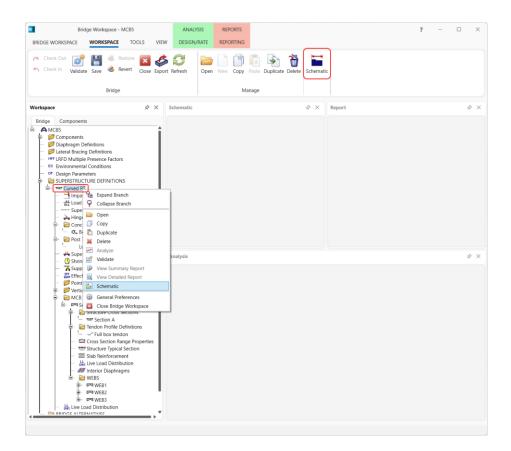


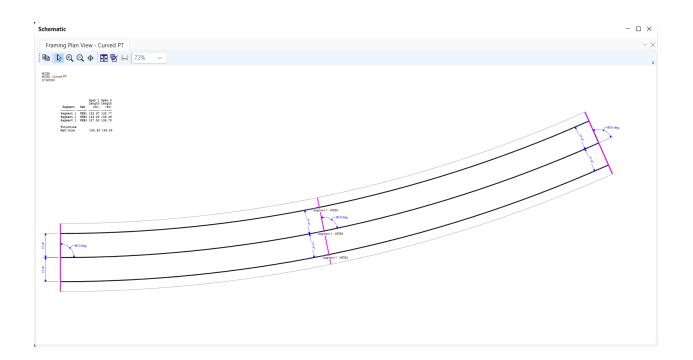


Note the bars are displayed as straight bars even though the superstructure is curved.

#### Schematics – Superstructure Definition Plan View

Select the **Curved PT** node in the **BWS** tree and click the **Schematic** button from the **WORKSPACE** ribbon (or right click and select **Schematic**) as shown below to display the framing plan schematic.





#### Web

Double click on the **Web 1** node in the **BWS** tree to view the following window. No changes are needed in this window so click the **Cancel** button to close the window without changing any data.

A Web - Segment 1						_		×
Web: WEB1	5	Segment	location Span	Distance (ft)				
Include in analysis		om start om end	t of span 1 of span 2	0 0				
LRFD Ignore flexure		Span	Web span length (ft)					
Ignore shear	>	1	122.9788					
LRFR		2	133.779333					
Ignore flexure         Ignore shear         Allow moment redistribution								
LFR gnore flexure								
Ignore shear								
				ОК	Ар	ply	Cano	el

### WEB1 - Shear Reinforcement Ranges

Expand the WEBS folder -> WEB1 and double click on the **Shear Reinforcement Ranges** node. Select the input reference type as **Voids**. Click the **Stirrup wizard** button and enter the following data.

												ce from ft)	
ft Star stance		Maximun	n interior Spa	icing >	I ← ' Right Start Distance				Locatio	'n	Left support	Right support	
nput r	reference type							>	Solid section	n start			
0 v	/oids 🔷 Ce	nterline bearii	ngs	Start of web					CL hinge				
G									Solid section	n end			
<b>n</b> : 1	<u> </u>	Maxir	num interio	r spacing: 9	in								
leasu	ired from left en	id of span				Meas	ured from r	ight e	nd of span				
Segn	nent start from l	eft support:	0	ft		Seg	ment end fr	om rig	ght support:	0	ft		
Start	distance:		0	in		Star	t distance:			0	in		
	Name	Number of spaces	Spacing (in)				Name		Number of spaces	Spacii (in)			
	#6 Stirrup 🗸	30	6		A		#6 Stirrup	$\sim$	30		6		-
					¥								4
			New	Duplicate De	elete					New	Du	plicate	Delete

Select **Span 2** in the Wizard and enter similar data for Span 2.

Ц											ce from it)	
eft Sta istan		Maximur	n interior Spa	icing >	I ← ' Right Start Distance				Location	Left support	Right support	
Input	reference type							>	Solid section start			
0	Voids 💮 Ce	nterline beari	ngs	Start of web					CL hinge			
									Solid section end			
an: 🛓	2 ~	Maxir	num interio	r spacing: 9	in							
Meas	sured from left en	d of span —				Mea	sured from rig	iht er	nd of span			
Seg	ment start from I	eft support:	0	ft		Seg	ment end fro	m rig	ht support: 0	ft		
Star	t distance:		0	in		Sta	t distance:		0	in		
	Name	Number of spaces	Spacing (in)				Name		Number of Spacin spaces (in)			
>	#6 Stirrup $\ \lor$	30	6			>	#6 Stirrup	~	30	6		
												v
			New	Duplicate De	elete				New	Du	olicate	Delete

Click the **Apply all** button to create the stirrup ranges for each span.

Span 1 will show the following data.

						Seg	ment location	Span	Distar (ft)
						From	start of span	1	0
spacing						From	end of span	2	0
/oids C	Centerline be	earings	Start	of web		Linked with:	Hone		
_									
Name	dist	tart tance ft)	Number of spaces	Spacing (in)	Length (ft)	End distance (ft)			
n: 1 v Name	dist	tance				distance			
n: 1 ~	dist (f	tance ft)	spaces	(in)	(ft)	distance (ft)	-		
Name #6 Stirrup #6 Stirrup	dist. (f	tance ft) 0	spaces	(in) 0	(ft) 0	distance (ft)			
Name #6 Stirrup	dist.     (f <ul> <li>(f</li> <li(f< li=""> <li(f< li=""> <li(f< li=""></li(f<></li(f<></li(f<></ul>	tance ft) 0 0	spaces 1 30	(in) 0	(ft) 0 15	distance (ft) 15	5 5		
Name #6 Stirrup #6 Stirrup #6 Stirrup	dist (f ~ ~ ~ ~	tance ft) 0 0 15	spaces 1 30 58	(in) 0 6 9	(ft) 0 15 43.5	distance (ft) 0 15 58.5	5 5 8		

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

### WEB2 - Shear Reinforcement Ranges

Expand the WEBS folder -> WEB2 and double click on the **Shear Reinforcement Ranges** node. Select the input reference type as **Voids**. Click the **Stirrup wizard** button and enter the following data.

									Locatio	_		ce from ft)	
ft Start stance	<	Maximun	m interior Spa	icing >	I ← Right Start Distance				Locatio	n	Left support	Right support	
nput ref	erence type							>	Solid section	n start			4
O Voi	ds 🔵 Ce	nterline bearii	ngs	Start of web					CL hinge				
_									Solid section	n end			
in: 1	$\sim$	Maxir	num interio	r spacing: 9	in								
<b>A</b> easure	d from left en	d of span				Meas	ured from rig	ght e	nd of span				
Segme	nt start from le	eft support:	0	ft		Seg	ment end fro	om rig	ght support:	0	ft		
Start di	stance:		0	in		Star	t distance:			0	in		
	Name	Number of spaces	Spacing (in)				Name		Number of spaces	Spacir (in)			
#6	5 Stirrup 🗸 🗸	30	6				#6 Stirrup	~	30		6		
					P								
			New	Duplicate	elete					New		plicate	Delete

Select **Span 2** in the Wizard and enter similar data for Span 2.

										ce from ft)	
I Start stance	Maximu	im interior Spa	acing >	I ← ' Right Start Distance				Location	Left support	Right support	
nput reference ty	e						>	Solid section start			
🔾 Voids 🗌	Centerline bear	ings (	Start of web					CL hinge			
								Solid section end			
n: 2 🗸		imum interio	r spacing: 9	in							
leasured from le	t end of span —					sured from rig					
Segment start fro	m left support:	0	ft		Seg	gment end fro	m rig	ght support: 0	ft		
Start distance:		0	in		Sta	rt distance:		0	in		
Name	Number of spaces	Spacing (in)				Name		Number of Spaci spaces (in)			
> #6 Stirrup	~ 30	6		A	>	#6 Stirrup	~	30	6		
				4							
		New	Duplicate	elete				New	Duj	olicate	Delete

Click the Apply all button to create the stirrup ranges for each span.

 $\bigcirc$  $\times$ A Web Shear Reinforcement Ranges - Segment 1 - WEB2 \_ Distance Span Segment location (ft) 1 0 From start of span Start Spacing 0 2 From end of span Distance Input reference type  $\sim$ Linked with: None O Voids Centerline bearings Start of web Span ranges Span: 1  $\sim$ End Start Number of Spacing Length Name distance distance (ft) spaces (in) (ft) (ft) #6 Stirrup  $\sim$ 0 1 0 0 0 15 #6 Stirrup  $\sim$ 0 30 6 15 #6 Stirrup  $\sim$ 15 60 9 45 60 1 #6 Stirrup  $\sim$ 60 3 0.25 60.25 #6 Stirrup  $\sim$ 60.25 60 9 45 105.25 105.25 30 6 #6 Stirrup  $\sim$ 15 120.25

Span 1 will show the following data.

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

#### WEB3 - Shear Reinforcement Ranges

Expand the WEBS folder -> WEB3 and double click on the **Shear Reinforcement Ranges** node. Select the input reference type as **Voids**. Click the **Stirrup wizard** button and enter the following data.

								Locatio			ce from (ft)	
eft Start istance	<	Maximur	m interior Spa	acing >	I ← I ← I Right Start Distance			Locatio	л	Left support	Right support	
nput ref	ference type						>	Solid section	n start			
O Voi	ids 🔷 Ce	nterline beari	ngs	Start of web				CL hinge				
								Solid section	n end			
an: 1	~	Maxir	num interio	r spacing: 9	in							
Measure	ed from left en	d of span —				Measured fror	n right e	nd of span —				
Segme	nt start from le	eft support:	0	ft		Segment end	from ri	ght support:	0	ft		
Start di	istance:		0	in		Start distance	e		0	in		
	Name	Number of spaces	Spacing (in)			Nar	ne	Number of spaces	Spacii (in)			
#(	5 Stirrup 🗸	30	6		A	#6 Stirru	р ~	30		6		
					V							
			New	Duplicate De	elete				New	Du	plicate	Delete

Select **Span 2** in the Wizard and enter similar data for Span 2.

_											ce from it)	
ft Sta stand		Maximu	m interior Spa	cing	I ← Right Start Distance				Location	Left support	Right support	
nput	reference type							>	Solid section start			
0	Voids Ce	nterline beari	ngs (	Start of web					CL hinge			
6									Solid section end			
n: 2			mum interio	spacing: 9	in							
	ured from left en						sured from rig					
-	ment start from I	eft support:		ft				m rig	ght support: 0	ft		
Star	t distance:		0	in		Sta	rt distance:		0	in		
	Name	Number of spaces	Spacing (in)				Name		Number of Spaci spaces (in)			
>	#6 Stirrup 🗸	30	6		A	>	#6 Stirrup	~	30	6		-
			New	Duplicate	elete				New	Dup	olicate	Delete

## Click the **Apply all** button to create the stirrup ranges for each span.

Span 1 will show the following data.

					Segr	ment location	Span	Distar (ft)
Spacing						start of span	1	0
> <del>&lt; pacing &gt;</del>					From	end of span	2	0
Voids Ce	enterline bearings		t of web					
n: 1 ~								
n: 1 v Name	Start distance (ft)	Number of spaces	Spacing (in)	Length (ft)	End distance (ft)			
Name	distance			-	distance			
Name #6 Stirrup	distance (ft)	spaces	(in)	(ft)	distance (ft)	-		
Name #6 Stirrup #6 Stirrup	distance (ft)	spaces	(in) 0	(ft) 0	distance (ft) 0			
Name #6 Stirrup #6 Stirrup	distance (ft)       ✓     0       ✓     0       ✓     15	spaces 1 30	(in) 0	(ft) 0 15	distance (ft) 0	5 5		
Name #6 Stirrup #6 Stirrup #6 Stirrup	distance (ft)       ✓     0       ✓     0       ✓     15	spaces 1 30 61	(in) 0 6 9	(ft) 0 15 45.75	distance (ft) 0 15 60.75			

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

# Bridge Alternatives

### Bridge alternative

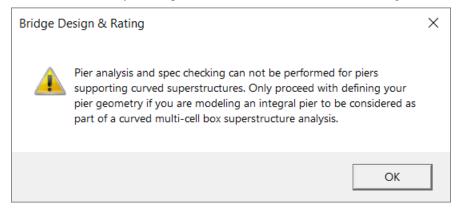
Since this superstructure is supported by an integral pier, the geometry of the pier must be defined. Double click the **BRIDGE ALTERNATIVES** folder and enter the information shown below.

🗛 Bridge Alternativ	re		_		×
Alternative name:	Bridge Alt				
Description	Substructures				
Description:					
Horizontal	curvature	Global positioning			
Reference line le	ength: 261.5 ft	Distance:	ft		
🔘 Start beari	ng End bearing	Offset:	ft		
Starting station:	: ft	Elevation:	ft		
Bearing:	N 90^ 0' 0.00" E				
Bridge alignm	nent	Start tangent length:		ft	
O Curved		Curve length:	261.5	ft	
	t, curved, tangent	Radius:	625	ft	
	t, curved	Direction:	Left v	Ĩ	
Curved,	tangent	End tangent length:		ft	
Superstructur wizard	re Culvert wizard				
		ОК	Apply	Cancel	

In the Substructures tab, define substructure locations as shown below.

	Substructure unit name	Station (ft)	Offset (ft)	Unit type	
>	Abut 1	0	0	Abutment $\sim$	
	Pier 1	125.25	0	Pier ~	
	Abut 2	261.5	0	Abutment 🗸	

Click **OK** to apply the data and close the window. The following dialog box will appear explaining that the pier itself will not be analyzed or spec checked. Click **OK** to close the dialog box.



### Superstructures

Double click on the **SUPERSTRUCTURES** folder and enter the name **Superstructure 1**. Move to the **Substructures** tab and assign substructures at each support.

perst	ructure nar	me: Superst	truc				
Desc	cription	Alternatives		path Engir	ne	Substructures	
Sele	ect the sub	structure sup	por				
	Support	Substructu support					
>	1	Abut 1	~				
	2	Pier 1	$\sim$				
	3	Abut 2	~				

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

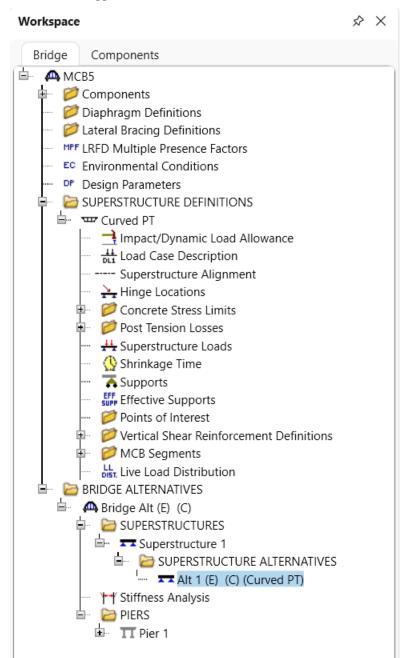
#### Superstructure Alternative

Double click on the **SUPERSTRUCTURE ALTERNATIVES** folder. Enter the name **Alt 1** and select **Curved PT** from the dropdown box.

<b>A</b> 9	Superstru	ucture Alte	rnativ	е							-	_		×
Alte	ernative	name:		Alt 1										
Des	cription	:												
Sup	erstruct	ure definit	ion: (	Curve	d PT					~]				
Sup	erstruct	ure type:		Adva	nced M	lulti (	Cell Box							
	Span	Length (ft)					Segment	Length (ft)	Number of cells					
	1	125.25					1	261.5	2	-				
	2	136.25												
					T		•							
									ОК		Apply		Canc	el

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

The **BWS** tree appears as follows.



## Pier Data Entry

Integral piers and piers that support curved superstructures are not analyzed or spec checked. Therefore, only the geometry of the pier needs to be defined so the program can include the integral pier in the FE model as a support condition.

### New Pier Alternative

Now create a 2 column frame pier alternative. Double click on the **Pier 1 PIER ALTERNATIVE** and select **Frame Pier** and click **Next**.

A New Pier Alternative				$\times$
Frame Pier	Diid Shaft Pier	Wall Pier	Pile Bent Pier	
		< Back	Next > Cancel	

Enter the values shown and click Finish.

A New Pier Alternative		×
Туре:	RC Frame Pier	
Name:	2 Column Pier	
Description:		
Units:	US Customary 🗸	
Number of columns:	2 🗘	
Columns have combined footings:		
	< Back Finish	Cancel

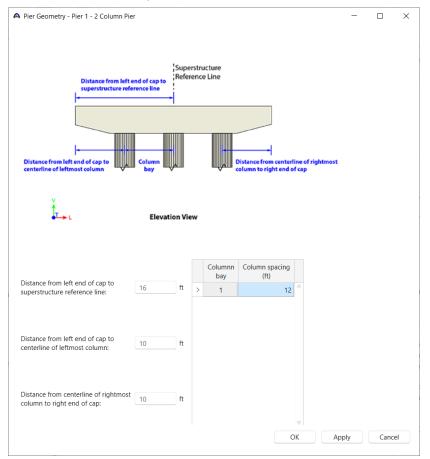
### Pier Alternative – Pier 1

No data needs to be changed on the resulting Pier Alternative window so click OK to close it.

ame: 2 Colur	nn Pier	Type:	RC Frame Pier			
Description	Stiffness Reports					
Description:	A		Units: US Customary	$\sim$		
			– LRFD substructure design set	ttings		
	▼		Preliminary mode			
- Columns -			Default design settings:	Preliminary D	esign Setting (US	
			Override default			
	of columns: 2		Design settings:			
Columns i	have combined footings: Ves	No	Final mode			
			Default design settings:	Final Design S	Setting (US)	
			Override default			
			Design settings:			
			Advanced DLA			

### Pier Geometry – Pier 1 – 2 Column Pier

Double click on Geometry under 2 Column Pier in the tree. Enter the data shown below.



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

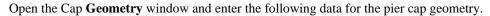
### Cap Properties – Pier 1 – 2 Column Pier

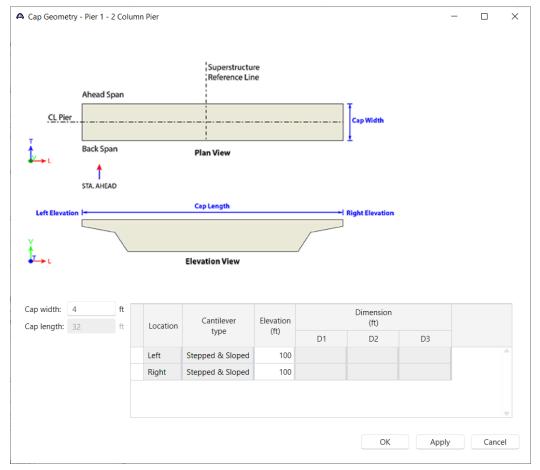
Open the Cap window and select the following cap concrete material.

Des	cription	Additional lo	ads			
Ca	p type: B	eam Shape Cap	Cap top configuratio	n: Sloped	Cap materia: Class A (US	
	Pedestal		Exposure factor:			
	Member	CL bearing station (ft)	Angle between CL member and CL support (Degrees)	Bearing seat elevation (ft)		
>	M1	124.413338	90.000000000035	0		

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

### Cap Geometry – Pier 1 – 2 Column Pier





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

### Column Components – Pier 1 – 2 Column Pier – Column1

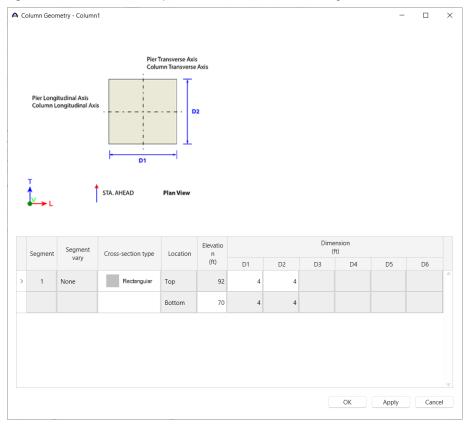
Open the Column1 Components window and select the following shape and concrete material.

	ection segments for c	olumn: 1	$\hat{\checkmark}$							
Segment	Material		Segmen	t vary	Cross-section type			$\prod$	_	
1	Class A (US)	~	None	~	Rectangular	~		Ц	0	
9	-								1 Class A (US) Vone V Rectangular V	Segmen

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

#### Column Geometry – Column1

Open the Column1 Geometry window and enter the following data.



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

### Column Components – Pier 1 – 2 Column Pier – Column2

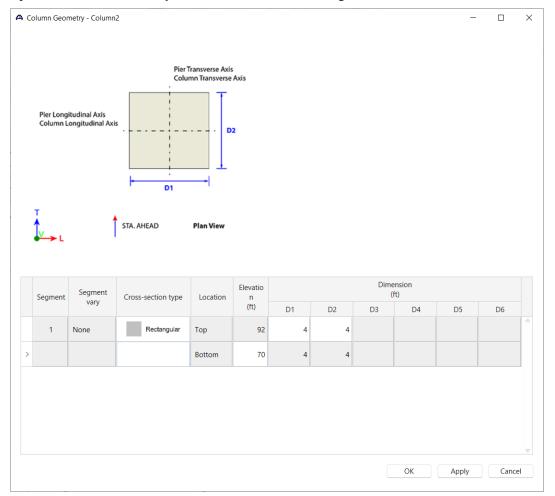
Open the Column2 Components window and select the following shape and concrete material.

	egment	Material		Segmer	nt vary	Cross-secti	ion type			Ĩ
>	1	Class A (US)	~	None	~	Rectan	igular	~	Ц	Segment * Segment

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

#### Column Geometry – Column2

Open the Column2 Geometry window and enter the following data.

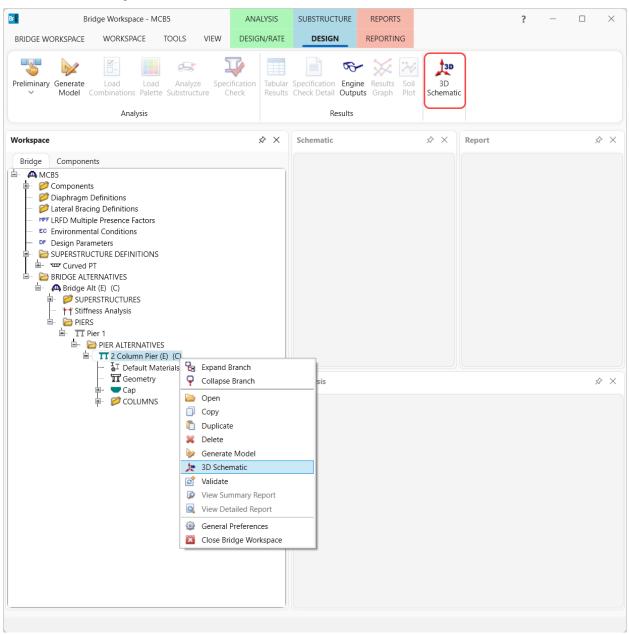


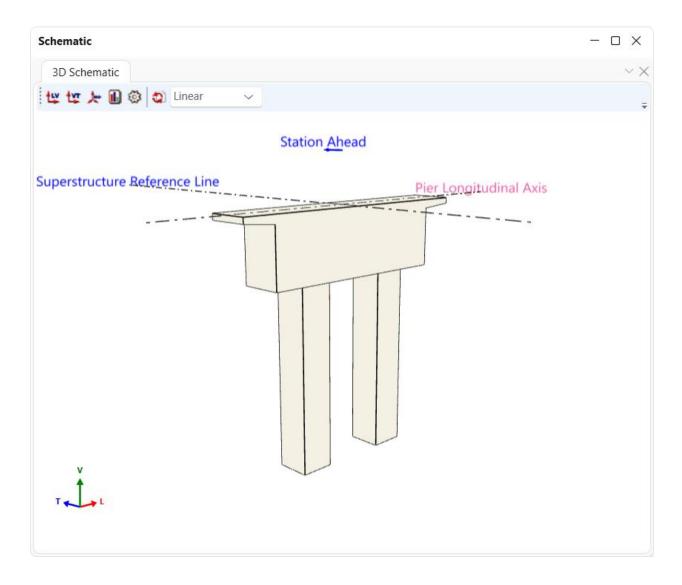
Click **OK** to apply the data and close the window.

The pier is now sufficiently defined to be considered in the superstructure analysis. The columns will be considered fixed at the base of the column. This percent fixity can be adjusted on the **Pier Model Settings** window if desired. The FE model created during the superstructure analysis will include an element modeling the column length and stiffness.

#### 3D Schematic – Pier Alternative

With pier alternative – 2 Column Pier selected, click on the 3D Schematic button from the SUBSTRUCTURE DESIGN ribbon (or right click and select 3D Schematic)



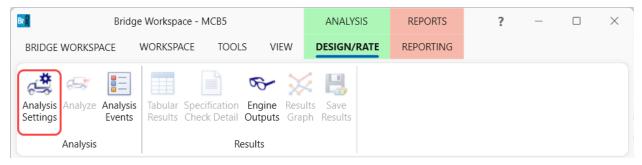


### Analysis and Results

The superstructure is ready for analysis. Note that a design review of substructures for integral box girders cannot be performed at this time.

### LRFR Analysis

To perform an LRFR analysis of the superstructure – **Curved PT**, click on the **Analysis Settings** button from the **Analysis** group of the **DESIGN/RATE** ribbon.



Click on the **Open template** button in the **Analysis Settings** window and select the **LRFR Design Load Rating** and click **Open**.

Templates	Description	Analysis	Owner	Public / Private	
HL 93 Design Review	HL 93 Design Review	LRFD		Public	
HS 20 LFR Rating	HS 20 LFR Rating	LFR		Public	
LRFR Design Load Rating	LRFR Design Load Rating	LRFR		Public	
LRFR Legal Load Rating	LRFR Legal Load Rating	LRFR		Public	

The Analysis Settings window is updated as shown below.

Design review <b>O</b> Rating	Rating method:	:	LRFR	~	
alysis type: Line Girder 🗸					
e / Impact loading type: As Requested $\sim$	Apply preference	ce setting:	None	~	
Pehicles Output Engine Description					
Traffic direction: Both directions	Re	fresh	Temporary vehicles	Advanced	
Vehicle selection	Vehic	le summary	/		
<ul> <li>Standard</li> <li>EV2</li> <li>EV3</li> <li>H 15-44</li> <li>H 20-44</li> <li>HL-93 (SI)</li> <li>HS 15-44</li> <li>HS 20 (SI)</li> <li>HS 20 (SI)</li> <li>HS 20 (A4</li> <li>Lane-Type Legal Load</li> <li>LRFD Fatigue Truck (SI)</li> <li>LRFD Fatigue Truck (US)</li> <li>NRL</li> <li>SU4</li> <li>SU5</li> <li>SU6</li> <li>SU7</li> <li>Type 3</li> <li>Type 3.3</li> <li>Type 3.3</li> <li>Type 3.3</li> <li>Type 3.3</li> <li>Type 3.3</li> <li>Type 3.3</li> <li>Type 3.4</li> <li>Sus defined</li> <li>Temporary</li> </ul>	Add to >> Remove from <<	È⊶lr È⊸C E⊶F; È⊸Legai I ~ R ∽S	gn load rating iventory HL-93 (US) iHL-93 (US) atigue LRFD Fatigue Truck (US) I load rating outine pecialized hauling it load rating		

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

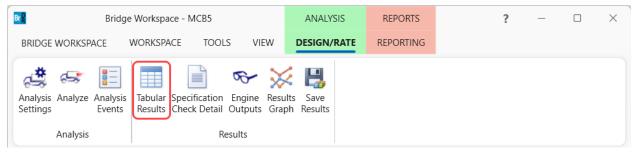
To run the analysis, with the superstructure – **Curved PT** selected, click on the Analyze button from the **Analysis** group of the **DESIGN/RATE** ribbon.

Bridge V	Workspace - MC	CB5		ANALYSIS	REPORTS	?	_		×
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Analysis Settings Analysis Analysis Analysis	Tabular Specific Results Check	cation En	gine Resu tputs Gra						
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Bridge Components	Definitions resence Factors onditions ers								
BRIDGE ALTERNA				Analysis				;	x x

### Tabular Results

Once the analysis is complete, results can be viewed by clicking on the Tabular Results button from the Results

### group of the **DESIGN/RATE** ribbon.



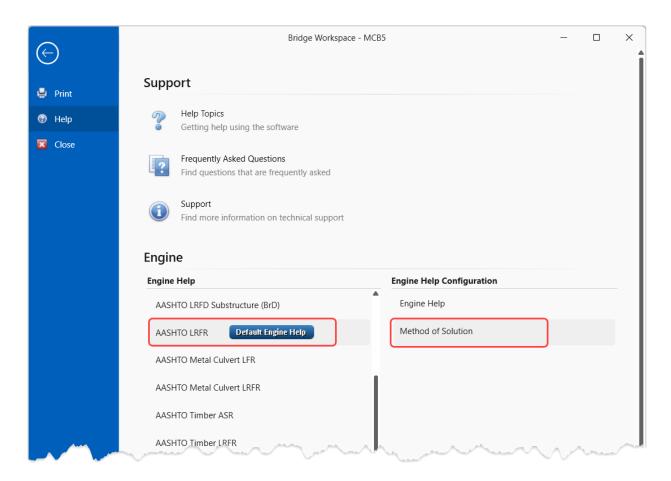
<b>A</b>	nalysis Results - Curv	red PT										- 🗆	$\times$
P	<b>Print</b>												
Repor	rt type:	- Lane/Imp	act loading type		Display Form	at							
Rating Results Summary V As requested Detailed			Single rating	level per row	$\sim$								
				retailed									
	Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor ^	Location (ft)	Location Span-(%)	Element Name	Limit State	Impact	Lane	
>	Live Load HL-93 (US)	Туре	Rating Method			Rating Factor ^			Name	Limit State STRENGTH-I Concrete Shear	Impact As Requested	Lane As Requeste	d
>		Type Truck + Lane	-	Level	(Ton)	-	(ft)	Span-(%)	Name CurvedPT				_
>	HL-93 (US)	Type Truck + Lane Tandem + Lane	LRFR	Level Inventory Inventory	(Ton) 54.23	1.506	(ft) 100.20	Span-(%) 1 - (80.0)	Name CurvedPT CurvedPT	STRENGTH-I Concrete Shear	As Requested	As Requeste	d
>	HL-93 (US) HL-93 (US) HL-93 (US)	Type Truck + Lane Tandem + Lane	LRFR LRFR	Level Inventory Inventory	(Ton) 54.23 74.01	1.506 2.056	(ft) 100.20 100.20	Span-(%) 1 - (80.0) 1 - (80.0)	Name CurvedPT CurvedPT CurvedPT	STRENGTH-I Concrete Shear STRENGTH-I Concrete Shear	As Requested As Requested	As Requeste As Requeste	ed ed
>	HL-93 (US) HL-93 (US) HL-93 (US) HL-93 (US)	Type Truck + Lane Tandem + Lane Truck + Lane	LRFR LRFR LRFR	Level Inventory Inventory Operating	(Ton) 54.23 74.01 80.32	1.506 2.056 2.231	(ft) 100.20 100.20 100.20	Span-(%) 1 - (80.0) 1 - (80.0) 1 - (80.0)	Name CurvedPT CurvedPT CurvedPT CurvedPT	STRENGTH-I Concrete Shear STRENGTH-I Concrete Shear STRENGTH-I Concrete Shear	As Requested As Requested As Requested	As Requeste As Requeste As Requeste	ed ed ed
>	HL-93 (US) HL-93 (US) HL-93 (US) HL-93 (US)	Type Truck + Lane Tandem + Lane Truck + Lane 0%(Truck Pair + Lane) 0%(Truck Pair + Lane)	LRFR LRFR LRFR LRFR LRFR	Level Inventory Inventory Operating Inventory	(Ton) 54.23 74.01 80.32 80.32	1.506 2.056 2.231 2.231	(ft) 100.20 100.20 100.20 125.25 125.25	Span-(%) 1 - (80.0) 1 - (80.0) 1 - (80.0) 2 - (0.0) 2 - (0.0)	Name CurvedPT CurvedPT CurvedPT CurvedPT CurvedPT	STRENGTH-I Concrete Shear STRENGTH-I Concrete Shear STRENGTH-I Concrete Shear STRENGTH-I Concrete Flexure	As Requested As Requested As Requested As Requested	As Requeste As Requeste As Requeste As Requeste	ed ed ed

Close

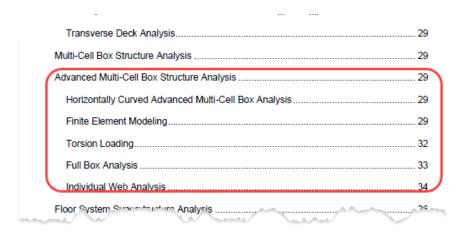
### Curved Multi-Cell Box Analysis

Refer to the AASHTO LRFR Method of Solution manual for detailed information on the analysis and spec checking of curved multi-cell box superstructures. Select **Bridge Workspace** from the ribbon and then double click the **AASHTO LRFR Method of Solution** manual to open the manual.

Bridge Workspace - MCB5	ANALYSIS REPORTS ?	? – 🗆 ×
BRIDGE WORKSPACE WORKSPACE TOOLS VIEW	DESIGN/RATE REPORTING	
<ul> <li>✓ Check Out</li> <li>✓ Check In</li> <li>✓ Validate</li> <li>✓ Save</li> <li>✓ Revert</li> <li>✓ Close</li> <li>Export F</li> </ul>		ematic
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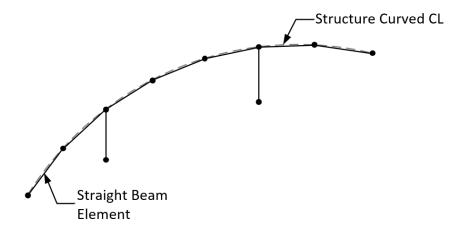
The following snippet from the method of solution table of contents shows the type of available information.



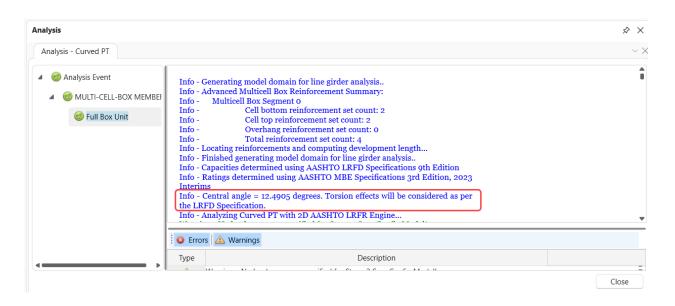
The following topics highlight the analysis and spec checking of curved multi-cell box superstructures.

#### Line Girder Analysis

Curved multi-cell boxes are analyzed using a line girder analysis which uses live load distribution factors. The FE model is a spine beam model with straight segments as shown below.



The program determines if consideration of torsion is required and if a spine beam model is appropriate for the degree of curvature as specified in LRFD 4.6.1.2.3. The Analysis Progress log displays the following informational message regarding these checks.



#### Full Box Torsion Loading

The controlling maximum and minimum torsion moments are found as the dead and live load torsional moment caused by the horizontal curvature of the model alignment. Dead load torsion effects are taken directly from the spine beam model finite element analysis. A curvature torsion influence line is generated for the full box for the torsional load effect due to a unit vertical force load applied along the full box spine model located along the full box centerline without any offset. Live load torsion effects are taken into consideration by loading the curvature torsion influence line with the vehicle multiplied by the maximum number of lanes that can fit on the bridge adjusted by the multiple presence factor.

The AASHTO shear distribution factors incorporate the shear effect from torsion created by the vehicle offset. Placing the live load along the spine model to produce the controlling shear thus results in only producing torsion due to the curvature of the structure. Concurrent torsion is found by loading the curvature torsion influence line with the vehicle placed at the location that produced maximum/minimum shear and multiplied by the maximum number of lanes that can fit on the bridge adjusted by the multiple presence factor.

#### Individual Web Torsion Loading

When an individual web is analyzed, the web is not loaded for torsion. Instead, the full box is analyzed for dead and live load torsion and the shear due to torsion is computed for the webs as described under the **Shear Effect Due to Torsion** section of this example. The dead load finite element analysis of the web will produce torsional dead load effects due to the curvature of the web but these torsional dead load effects are not used in the specification checking of the web.

#### Curved Multi-Cell Box Torsion Specification Checking

Specification articles related to torsion are always processed for curved multi-cell boxes unless the user selects both control options to ignore max torsion with concurrent shear and ignore max shear with concurrent torsion. When

evaluating torsion, an effective shear is computed which combines vertical shear and torsion. AASHTO LRFD Article 5.7.2.1 dictates that factored torsional demand greater than 25% of the factored torsional cracking moment requires the investigation of torsion. Torsional live load moment has two components: eccentric placement of vehicles and curvature torsion. Curvature torsion is taken into consideration by loading the Curvature Torsion influence line. The torsional effects from vehicle eccentricity are assumed to be included in the AASHTO shear live load distribution factors. As a result, the computed effective shear includes the effect of eccentricity and curvature. However, the computed torsion does not consider the total torsional demand on the structure. Therefore, the program takes a conservative approach and always considers torsional effects and does not consider the 25% threshold specified in LRFD 5.7.2.1.

#### Shear Effect Due to Torsion

The shear due to torsion is computed and combined with the vertical shear resulting in an effective shear, Veff, that is used in place of the vertical shear, Vu, in the shear specification articles. The program computes the effective shear as per AASHTO LRFD 5.7.3.4 unless the control option "Use rigid distribution for torsion" is selected. Using the AASHTO method, in a full box shear specification check, the computed shear due to torsion in the exterior web is added to the full box vertical shear. In a web shear specification check, the computed shear due to torsion is only considered in the exterior web.

If the "Use rigid distribution for torsion" control option is selected, the effective shear per web is calculated assuming a rigid section on elastic supports. In a full box shear specification check, the computed shear due to torsion in each web is combined and added to the full box vertical shear when it increases the shear effect and is ignored when it decreases the shear effect. In a web shear specification check, the web shear due to torsion is also only added to the vertical shear when it increases the shear effect.