

*AASHTOWare BrDR 7.5.1*

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*Multi-Cell Box Tutorial*

*MCB5 - Advanced Multi-Cell Box Superstructure Example*

## MCB5 – Advanced Multi-Cell Box 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-tensioned forces after initial losses are applied to the stage 1 model. The stage 2 post-tensioning secondary moments are the result of the stage 2 post-tensioning forces after long-term losses and 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.

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

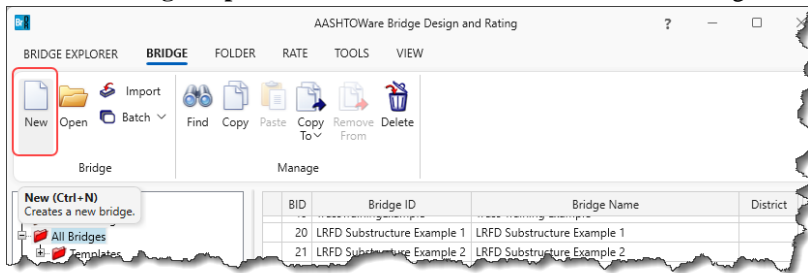
### Analysis Methods

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 weblane
- Single weblane

### 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.



### New Bridge

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

Bridge ID:  NBI structure ID (8):   Template  Bridge completely defined

Bridge Workspace View  
 Superstructures  
 Culverts  
 Substructures

Description	Description (cont'd)	Alternatives	Global reference point	Traffic	Custom agency fields
Name:	<input type="text" value="MCB5"/>			Year built:	<input type="text"/>
Description:	<input type="text" value="PT curved box"/>				
Location:	<input type="text"/>			Length:	<input type="text"/> ft
Facility carried (7):	<input type="text"/>			Route number:	<input type="text" value="1"/>
Feat. intersected (6):	<input type="text"/>			Mi. post:	<input type="text"/>
Default units:	<input type="text" value="US Customary"/>				

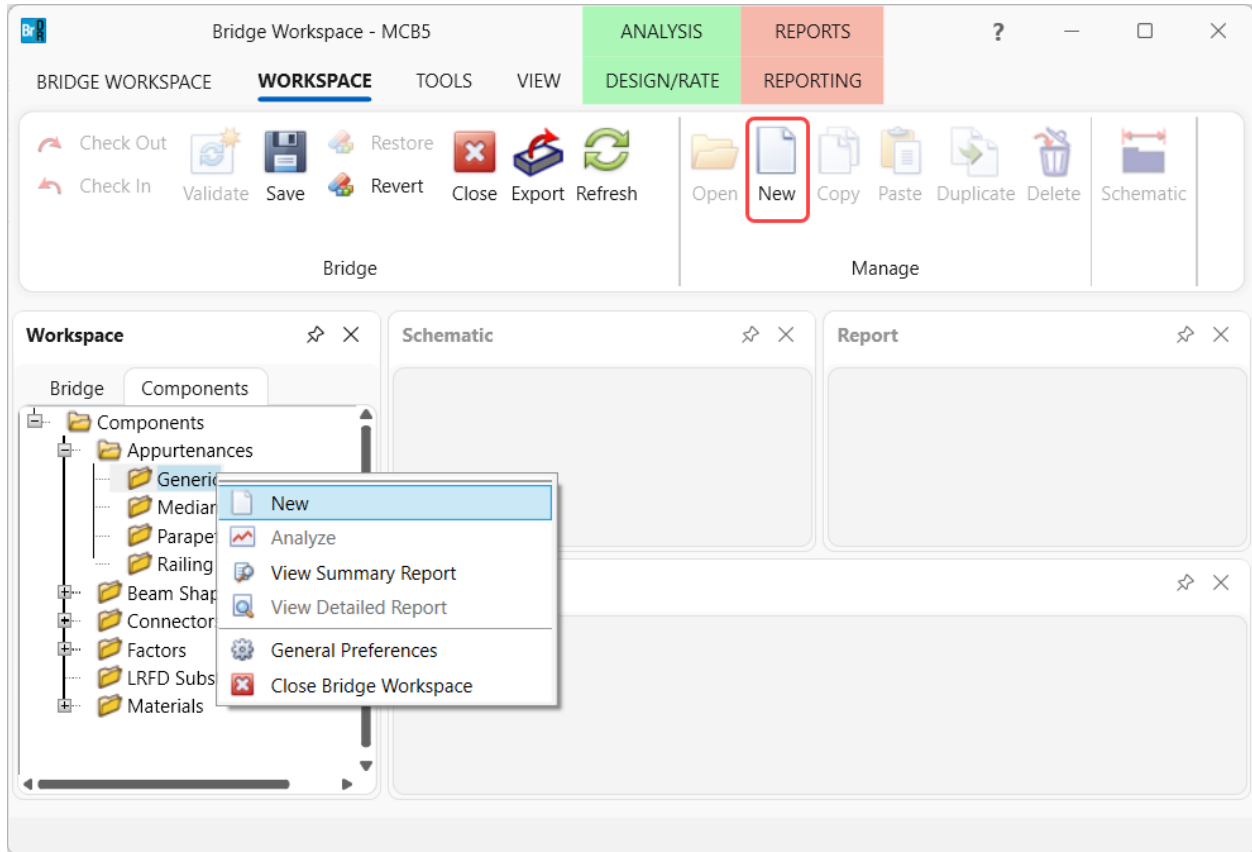
Click **OK** to apply the data and close the window.

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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.



# MCB5 – Advanced Multi-Cell Box Example

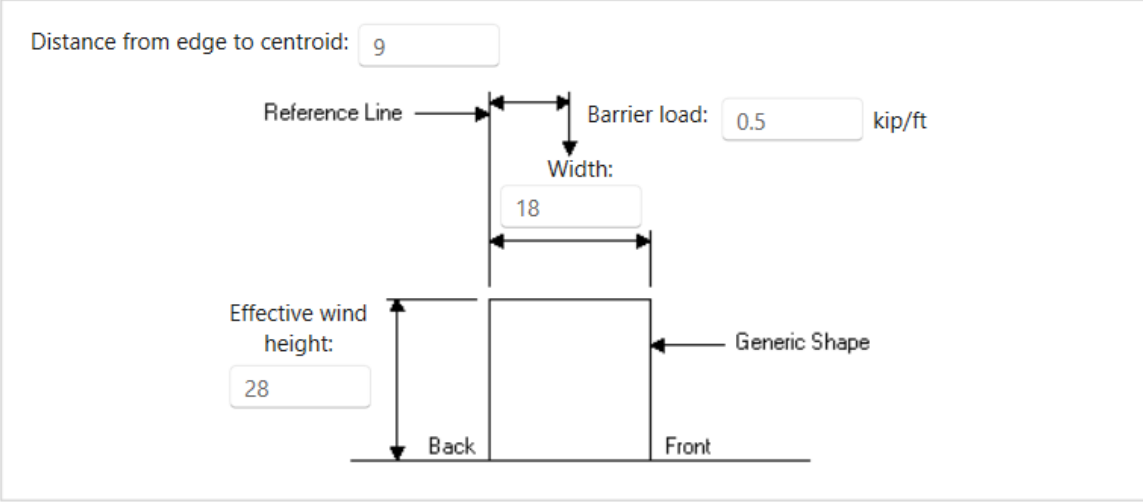
Bridge Appurtenances - Generic

Name:

Description:

All dimensions are in inches

Distance from edge to centroid:



The diagram shows a cross-section of a barrier. A vertical line on the left is labeled "Reference Line". A horizontal double-headed arrow below it is labeled "Width:" with a value of "18". A vertical double-headed arrow to the right of the barrier is labeled "Effective wind height:" with a value of "28". A horizontal double-headed arrow above the barrier is labeled "Barrier load:" with a value of "0.5" and the unit "kip/ft". The barrier is labeled "Generic Shape". The bottom edge is labeled "Back" on the left and "Front" on the right.

Barrier load:  kip/ft

Width:

Effective wind height:

Back Front

Generic Shape

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

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### 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.

Name:	<input type="text" value="Beam concrete"/>
Description:	<input type="text"/>
Compressive strength at 28 days (f'c):	<input type="text" value="4.5"/> ksi
Initial compressive strength (f'ci):	<input type="text" value="4"/> ksi
Composition of concrete:	<input type="text" value="Normal"/> ▾
Density (for dead loads):	<input type="text" value="0.15"/> kcf
Density (for modulus of elasticity):	<input type="text" value="0.145"/> kcf
Poisson's ratio:	<input type="text" value="0.2"/>
Coefficient of thermal expansion ( $\alpha$ ):	<input type="text" value="0.000006"/> 1/F
Splitting tensile strength (fct):	<input type="text" value=""/>
LRFD Maximum aggregate size:	<input type="text"/>
	<input type="button" value="Compute"/>
Std modulus of elasticity (Ec):	<input type="text" value="3865.20204"/> ksi
LRFD modulus of elasticity (Ec):	<input type="text" value="4144.549969"/> ksi
Std initial modulus of elasticity:	<input type="text" value="3644.147431"/> ksi
LRFD initial modulus of elasticity:	<input type="text" value="3986.54846"/> ksi
Std modulus of rupture:	<input type="text" value="0.503115"/> ksi
LRFD modulus of rupture:	<input type="text" value="0.509117"/> ksi
Shear factor:	<input type="text" value="1"/>
	<input type="button" value="Copy to library..."/> <input type="button" value="Copy from library..."/> <input type="button" value="OK"/> <input type="button" value="Apply"/> <input type="button" value="Cancel"/>

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

## MCB5 – Advanced Multi-Cell Box Example

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.

The screenshot shows a dialog box titled "Bridge Materials - Concrete" with the following fields and values:

Name:	Class A (US)
Description:	Class A cement concrete
Compressive strength at 28 days (f'c):	4.0000006 ksi
Initial compressive strength (f'ci):	
Composition of concrete:	Normal
Density (for dead loads):	0.15 kcf
Density (for modulus of elasticity):	0.145 kcf
Poisson's ratio:	0.2
Coefficient of thermal expansion ( $\alpha$ ):	0.000006 1/F
Splitting tensile strength (f'ct):	
LRFD Maximum aggregate size:	
<input type="button" value="Compute"/>	
Std modulus of elasticity (Ec):	3644.149254 ksi
LRFD modulus of elasticity (Ec):	3986.548657 ksi
Std initial modulus of elasticity:	
LRFD initial modulus of elasticity:	
Std modulus of rupture:	
LRFD modulus of rupture:	0.479857 ksi
Shear factor:	1

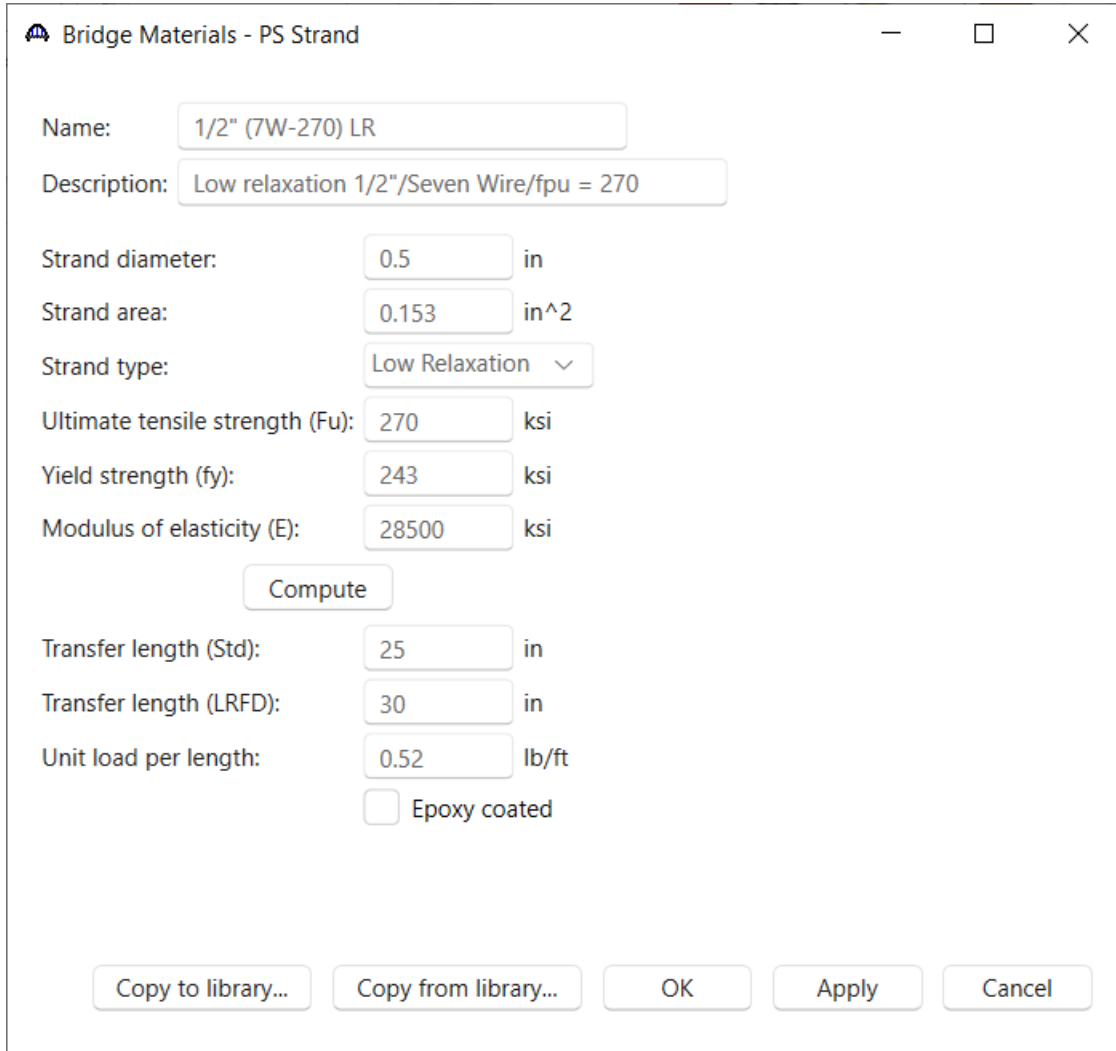
At the bottom of the dialog box, there are five buttons: "Copy to library...", "Copy from library...", "OK", "Apply", and "Cancel".

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

## MCB5 – Advanced Multi-Cell Box Example

### 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 Materials - PS Strand**

Name: 1/2" (7W-270) LR

Description: Low relaxation 1/2"/Seven Wire/fpu = 270

Strand diameter: 0.5 in

Strand area: 0.153 in<sup>2</sup>

Strand type: Low Relaxation

Ultimate tensile strength (Fu): 270 ksi

Yield strength (fy): 243 ksi

Modulus of elasticity (E): 28500 ksi

Compute

Transfer length (Std): 25 in

Transfer length (LRFD): 30 in

Unit load per length: 0.52 lb/ft

Epoxy coated

Copy to library... Copy from library... OK Apply Cancel

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



## MCB5 – Advanced Multi-Cell Box Example

### 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.

Bridge Materials - Reinforcing Steel

Name:

Description:

Material properties

Specified yield strength (fy):  ksi

Modulus of elasticity (Es):  ksi

Ultimate strength (Fu):  ksi

Type

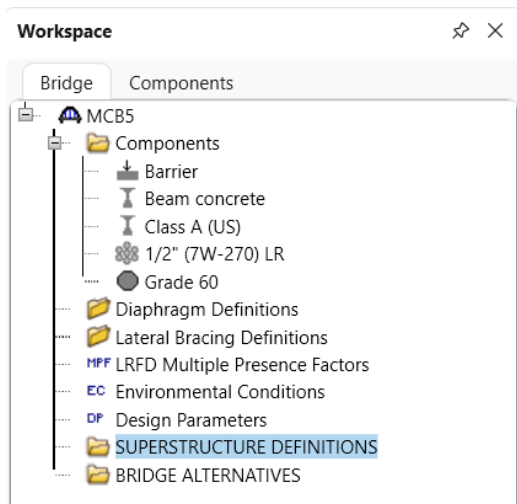
Plain

Epoxy

Galvanized

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

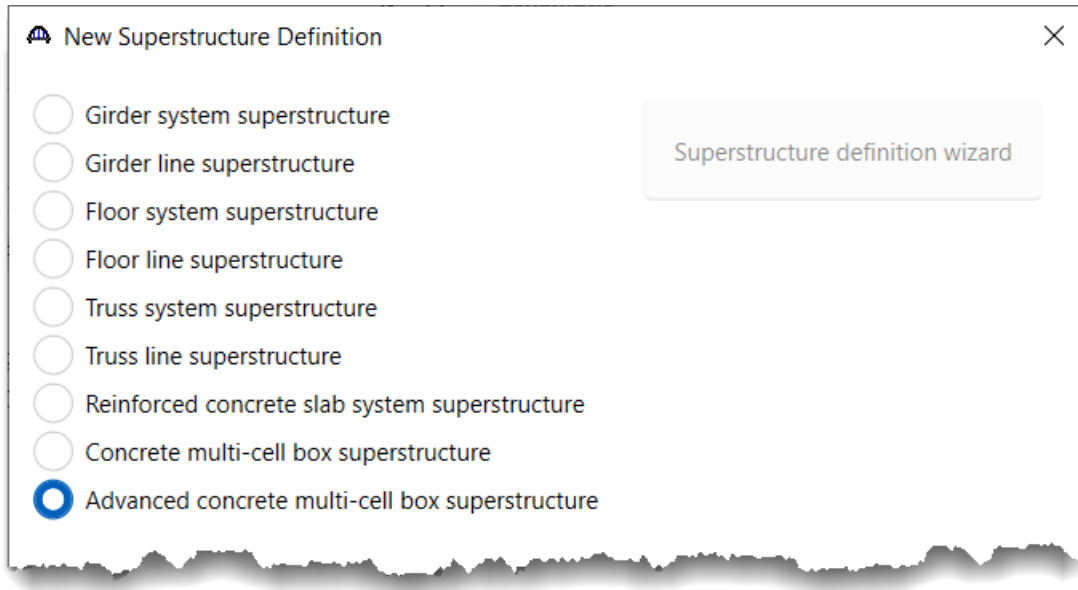
Navigate back to the **Bridge** tab of the **BWS** tree. The partially expanded tree is shown below.



## MCB5 – Advanced Multi-Cell Box Example

### 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**.



Enter the following data for the superstructure definition.

# MCB5 – Advanced Multi-Cell Box Example

Advanced Concrete Multi-Cell Box Superstructure Definition

Definition Analysis Specs Factors Engine Control options

Name: Curved PT

Description:

Default units: US Customary

Number of spans: 2

Number of segments: 1

End projections  
Left: 12 in  
Right: 12 in

Average humidity: 70 %

Structure type  
 Frame structure simplified definition  
 Integral with substructure  
 Consider substructure skew in FE section properties  
 Not integral with pier

Post-tensioned

Analyze webs only

Cross section orientation  
 Perpendicular to reference line  
 Along skew

Structure model for LLDf computation  
 Standalone  
 Left side connected to adjacent structure  
 Right side connected to adjacent structure

Span lengths Segment data Integral piers

Enter span lengths along the reference line:

Span	Length (ft)
1	125.25
> 2	136.25

Horizontal curvature along reference line  
 Horizontal curvature  
 Distance from PC to first support line: 180.42 ft  
 Start tangent length: ft  
 Radius: 625 ft  
 Direction: Left  
 End tangent length: ft  
 Distance from last support line to PT: 136.92 ft  
 Design speed: mph  
 Superelevation: %

Superstructure alignment  
 Curved  
 Tangent, curved, tangent  
 Tangent, curved  
 Curved, tangent

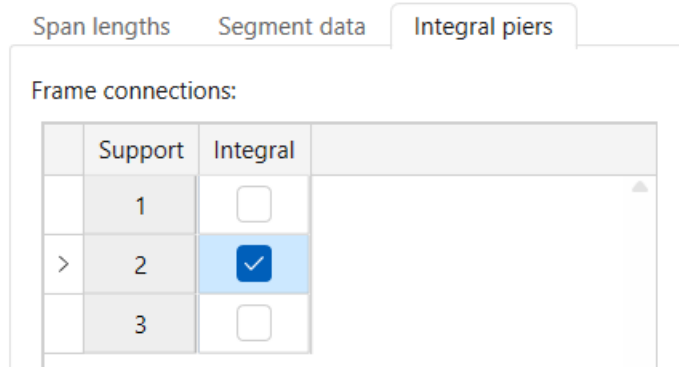
OK Apply Cancel

Span lengths Segment data Integral piers

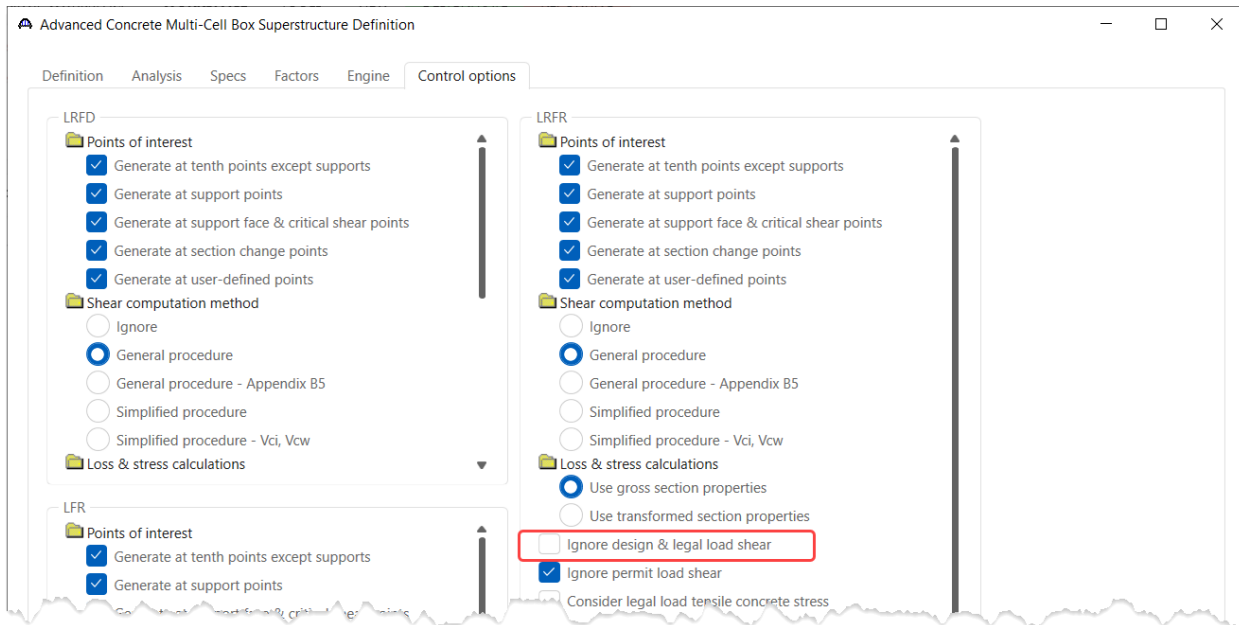
Enter segment lengths along the reference line:

Segment	Length (ft)	Number of cells	Include in analysis
> 1	261.5	2	<input checked="" type="checkbox"/>

## MCB5 – Advanced Multi-Cell Box Example



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

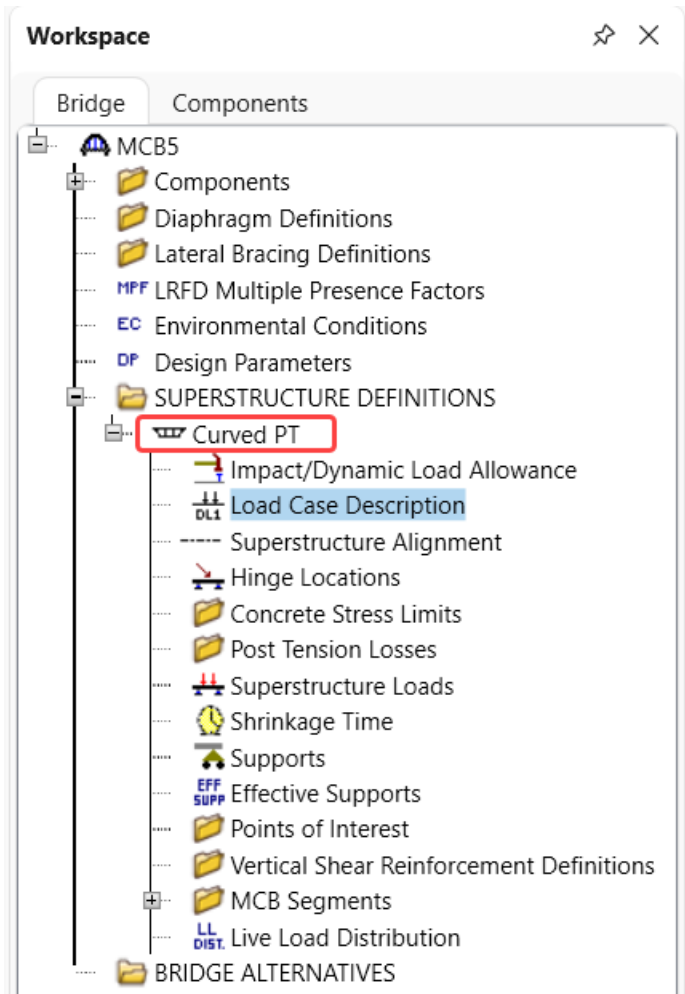


Click **OK** to create the superstructure definition and close the window.

## MCB5 – Advanced Multi-Cell Box Example

### 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.



## MCB5 – Advanced Multi-Cell Box Example

Load Case Description

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

\*Prestressed members only    Add default load case descriptions

New    Duplicate    Delete

OK    Apply    Cancel

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.

Superstructure Alignment

Superstructure definition reference line is To the Right of ▾ the following component:

Segment	Component	Distance at start (ft)	Distance at end (ft)
> 1	Left Edge of Deck ▾	16	16

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

## MCB5 – Advanced Multi-Cell Box Example

### 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

	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

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.

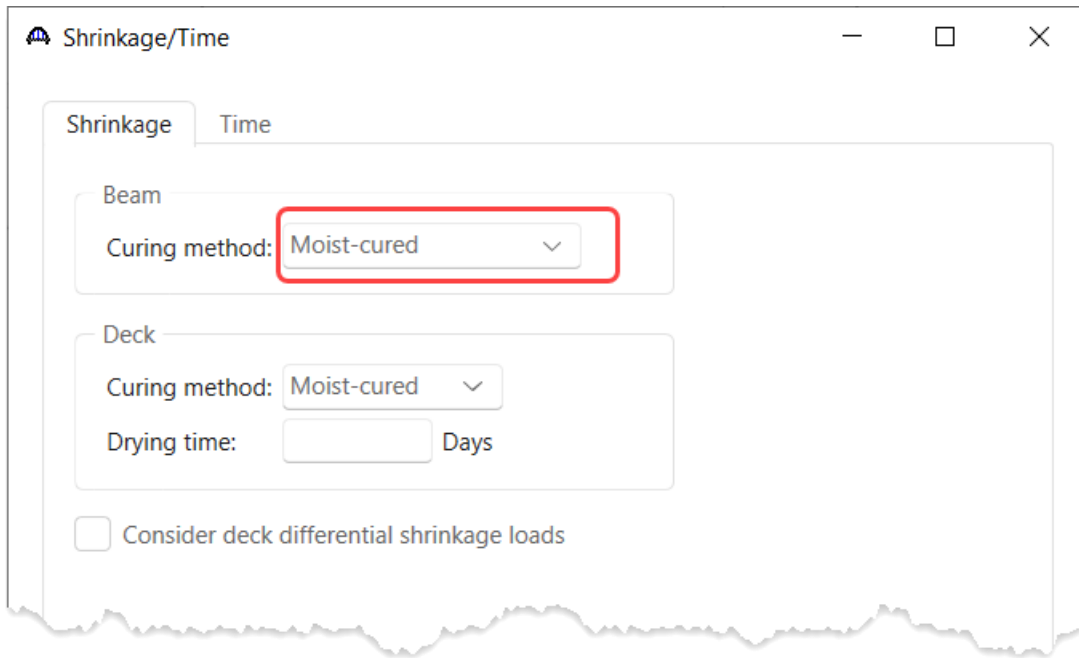
Anchor set:	0.375 in	Initial loss:	ksi
Coefficient of friction:	0.15	Final loss:	25 ksi
Wobble coefficient:	0.0002 per ft		
P/S transfer stress ratio:			
Transfer time:	Hours		
Age at deck placement:	Days		
Final age:	Days		

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.

## MCB5 – Advanced Multi-Cell Box Example

### Shrinkage/Time

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



Shrinkage/Time

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 multi-cell boxes. The supports for this structure are not skewed so there is no data to enter here.



Supports

Advanced support conditions

Skew General Elastic

	Support	Skew (degrees)
>	1	0
	2	0
	3	0

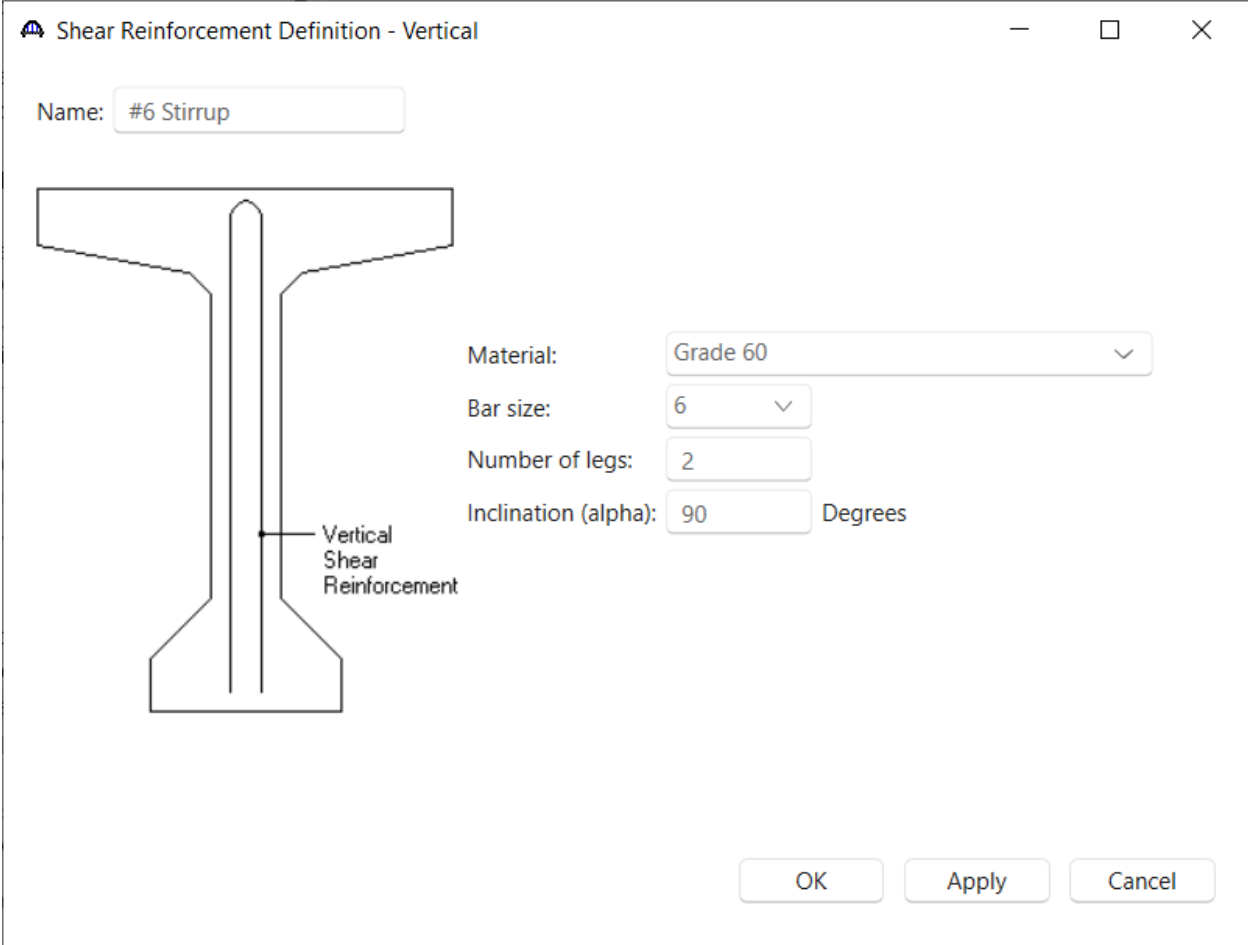
The **Advanced support conditions** checkbox allows the entry of different support conditions on the **General** and **Elastic** tabs for different stages. This example does not require different support conditions in different stages so do not check that checkbox. This example does not require changing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



# MCB5 – Advanced Multi-Cell Box Example

## Vertical Shear Reinforcement Definitions

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



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

## MCB5 – Advanced Multi-Cell Box Example

### 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.

MCB Segment

Name:

Description:

Number of cells:

Segment length:  ft

Post-tension input method  
 Full box  Web

	Segment location	Support	Distance (ft)	Skew (degrees)
>	Start	1	0	0
	End	2	136.25	0

OK Apply Cancel

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

# MCB5 – Advanced Multi-Cell Box Example

## Segment Structure Cross Sections

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

Structure Cross Sections - Segment 1
— □ ×

Name:       Number of cells:

Input method:  Simple    Advanced      Top slab concrete:       Other parts concrete:

Entry method:  Width    Slope      Top slab stress limit:       Other parts stress limit:

Overall   Cells   Fillets

	(ft)
D	8
CJ	
LW1	4
LW2	4
> RW1	4
RW2	4
LV	
RV	

	(in)
LT1	8
LT2	12
> RT1	8
RT2	12

W2:  ft

Properties

Area:  ft<sup>2</sup>

Ixx:  ft<sup>4</sup>

Iyy:  ft<sup>4</sup>

J:  ft<sup>4</sup>

# MCB5 – Advanced Multi-Cell Box Example

Overall **Cells** Fillets

Top left web thickness:  in W2:  ft

Bottom left web thickness:  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.

Structure Cross Sections - Segment 1

Name:  Number of cells:

Input method  
 Simple  Advanced  
 Top slab concrete:  Other parts concrete:

Entry method  
 Width  Slope  
 Top slab stress limit:  Other parts stress limit:

Overall Cells Fillets

	(ft)
D	8
CJ	
LW1	4
LW2	4
> RW1	4
RW2	4
LV	
RV	

	(in)
LT1	8
LT2	12
> RT1	8
RT2	12

W2:  ft

Properties

**Compute properties**

Area:  ft<sup>2</sup>  
 Ixx:  ft<sup>4</sup>  
 Iyy:  ft<sup>4</sup>  
 J:  ft<sup>4</sup>

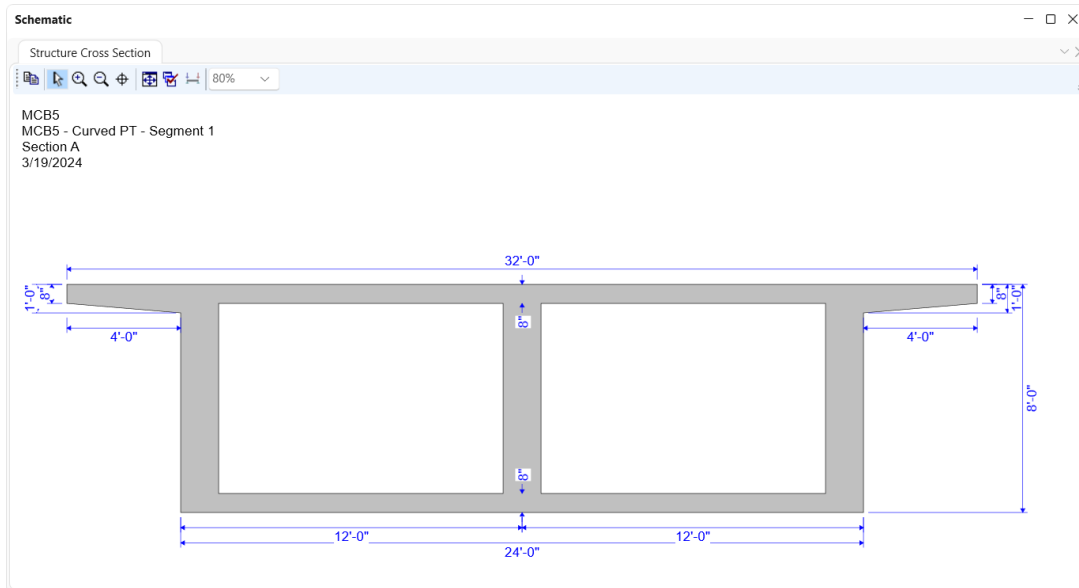
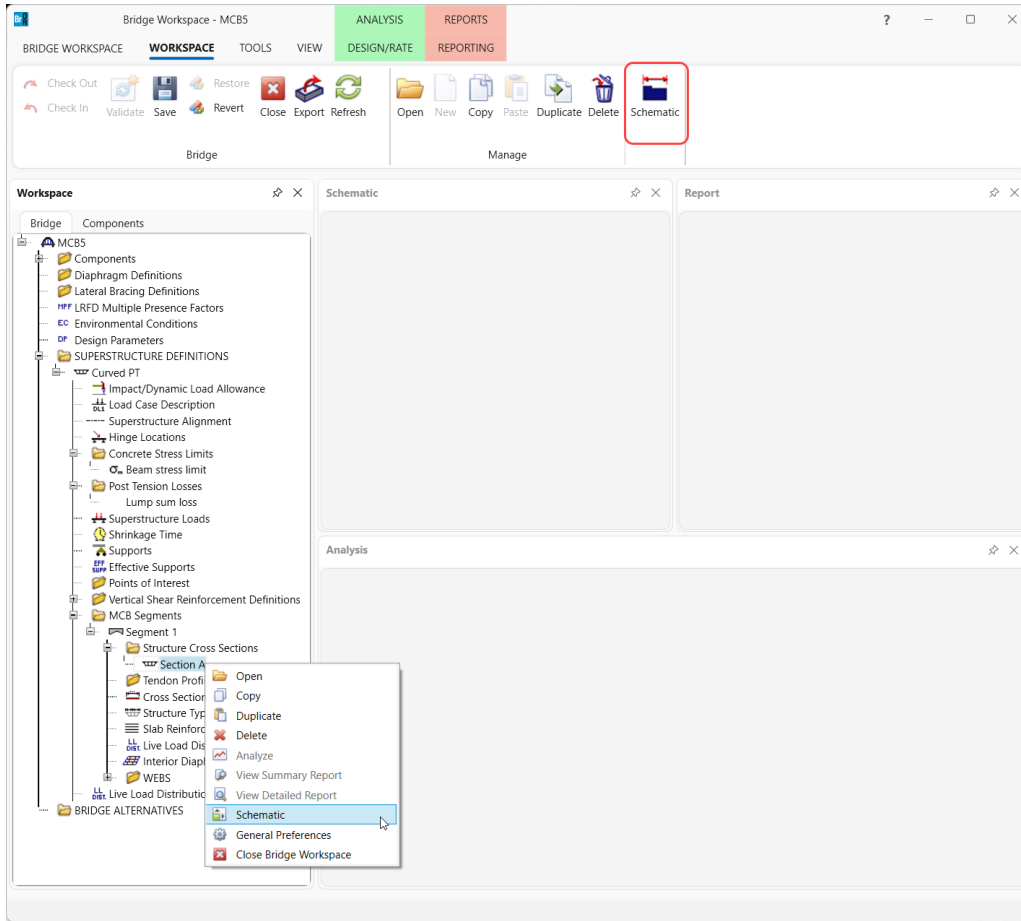
OK Apply Cancel

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

# MCB5 – Advanced Multi-Cell Box Example

## 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.



# MCB5 – Advanced Multi-Cell Box Example

## 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.

Tendon Profile Definition - Segment 1

Profile name: Full box tendon

Tendon distance from segment  
 Start distance from start: 0 ft  
 End distance from end: 0 ft

Tendon distance from support  
 Start distance from support: 1 0 ft  
 End distance from support: 3 0 ft

Stage: Non-composite (Stage 1)

Segment location	Span	Distance (ft)
From start of span	1	0
From end of span	2	0

Profile | Post tensioning | Stress limits

Inflection point entry method  
 Percentage  Distance

Span	Segment span length (ft)	Profile type	Inflection points			Vertical offset					
			Left (%)	Low (%)	Right (%)	Left end (in)	Measured from	Low (in)	Measured from	Right end (in)	Measured from
1	125.25	Type 3		40	10	29	Top	70	Top	16.5	Top
> 2	136.25	Type 4	10	60		16.5	Top	70	Top	29	Top

Profile | **Post tensioning** | Stress limits

Prestress material: 1/2" (7W-270) LR  
 Duct grouting: Grouted  
 Jacking end: Left End  
 Duct diameter: 5 in

Post tensioning

Input method  
 Jacking force  Strands  
 Jacking stress ratio: 0.75

Total jacking force: 8375 kip  
 Number of ducts per web: 0

Distribute equally

Web	Percentage (%)	Duct	Strands per duct
> WEB1	33.333333		
WEB2	33.333333		
WEB3	33.333333		

Profile | Post tensioning | **Stress limits**

	LRFD	ksi	LFD	ksi
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

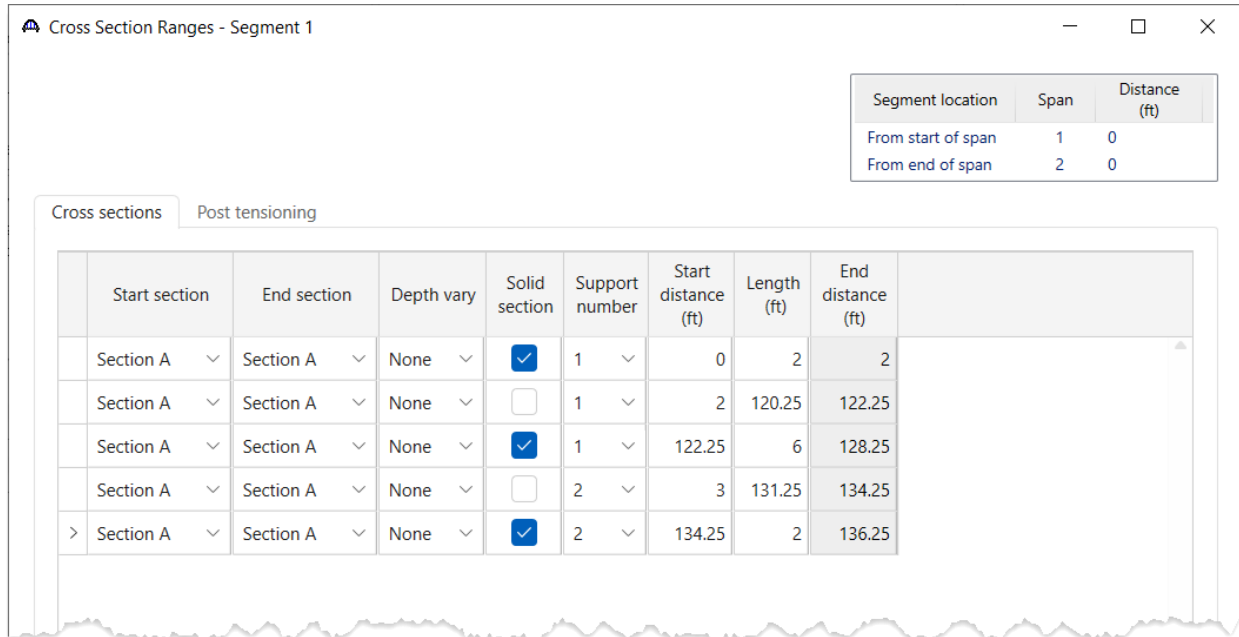
**Compute Values**

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

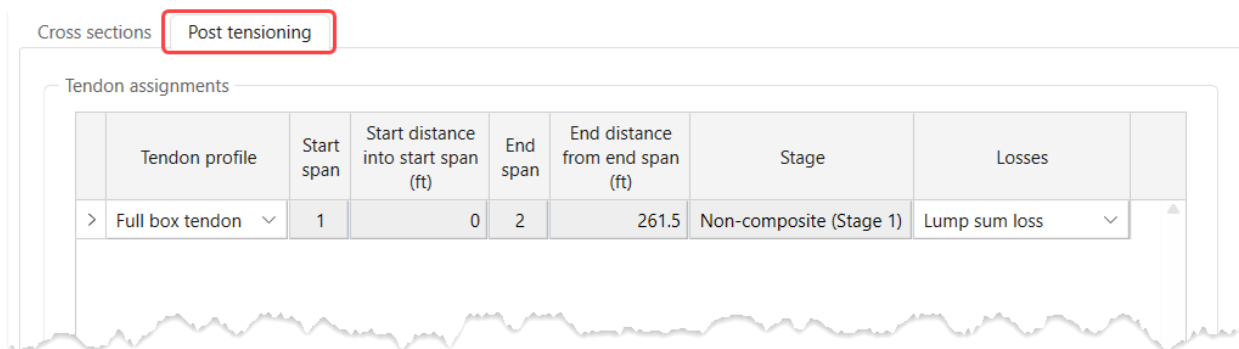
# MCB5 – Advanced Multi-Cell Box Example

## Cross Section Range Properties

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



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

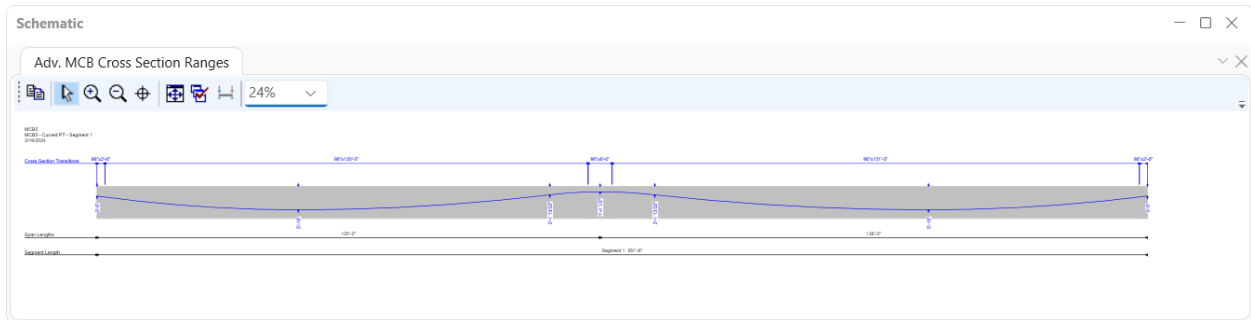
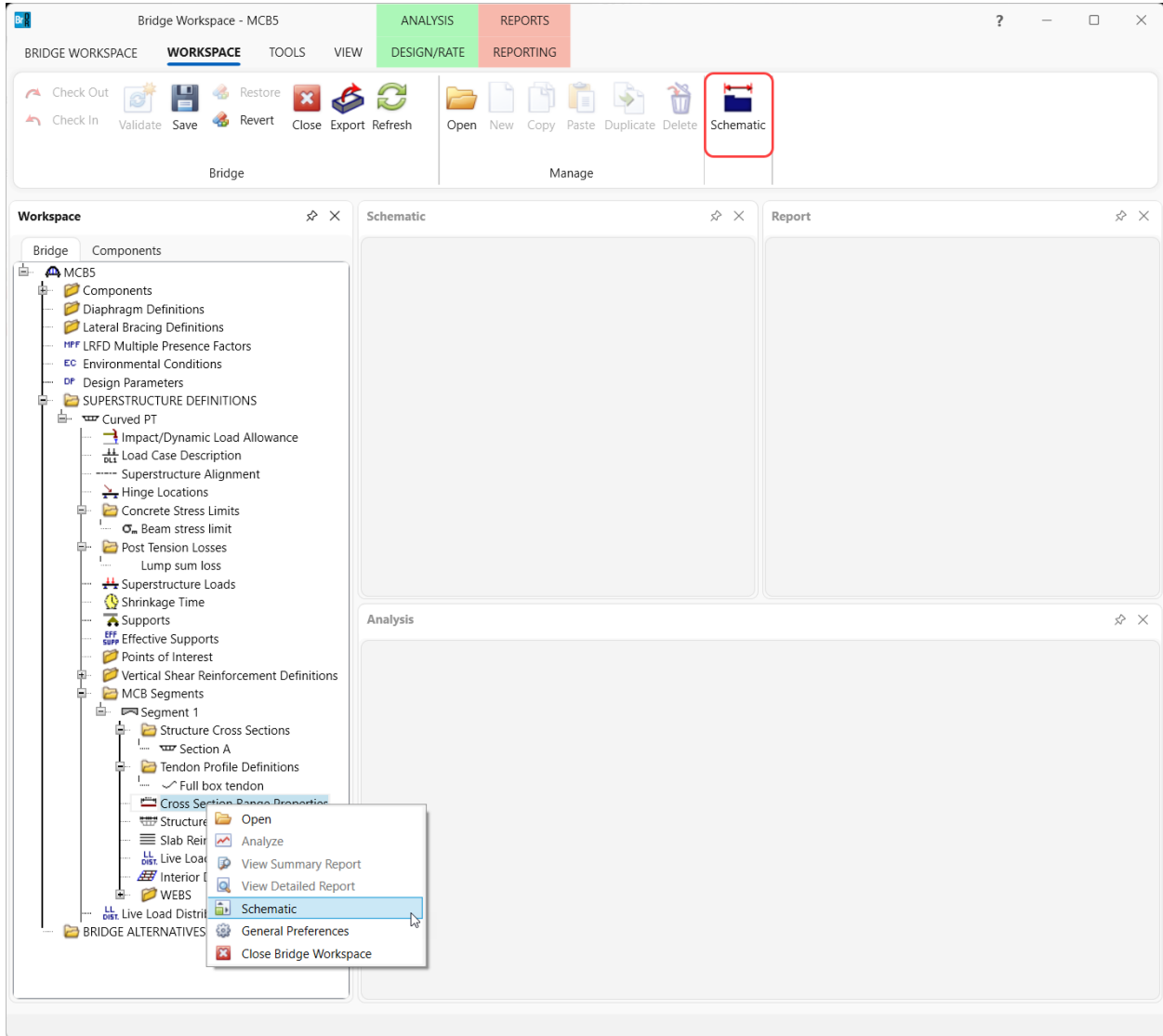


Click **OK** to apply the data and close the window. An informational message box will appear stating that web shear reinforcement ranges should be reviewed. Click **OK** to close the message box and the window.

# MCB5 – Advanced Multi-Cell Box Example

## 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.





# MCB5 – Advanced Multi-Cell Box Example

## Structure Typical Section

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

Segment location	Span	Distance (ft)
From start of span	1	0
From end of span	2	0

Name	Load case	Measure to	Edge of deck dist. measured from	Distance at start (ft)	Distance at end (ft)	Front face orientation
Barrier	DC2	Back	Left Edge	0	0	Right
> Barrier	DC2	Back	Right Ed...	0	0	Left

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

Segment location	Span	Distance (ft)
From start of span	1	0
From end of span	2	0

Travelway number	Support number	Start distance (ft)	Length (ft)	End distance (ft)	Left edge of travelway offset (ft)		Right edge of travelway offset (ft)	
					Start	End	Start	End
> 1	1	0	261.5	261.5	-14.5	-14.5	14.5	14.5

LRFD fatigue  
 Lanes available to trucks:   
 Override Truck fraction:

**Compute**      New      Duplicate      Delete

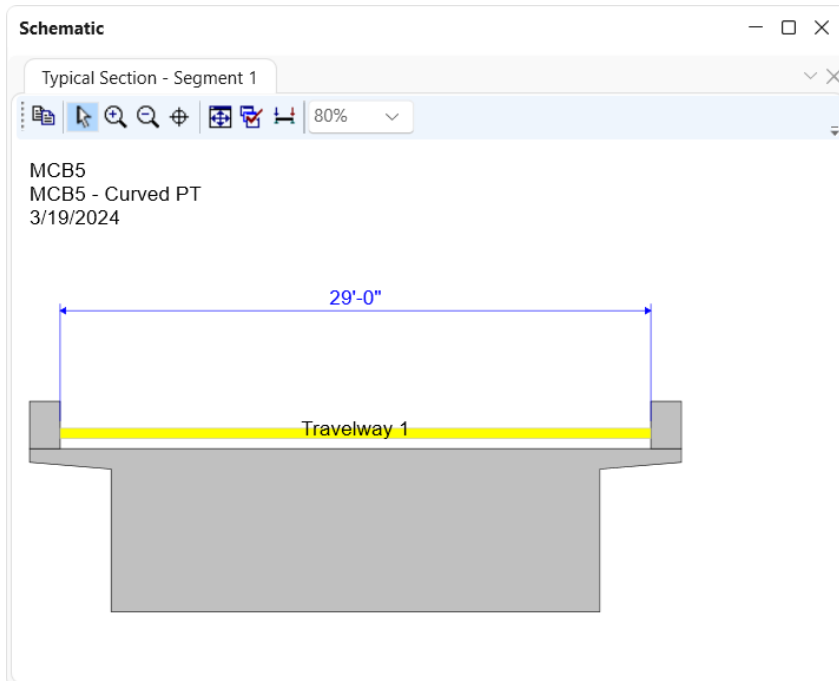
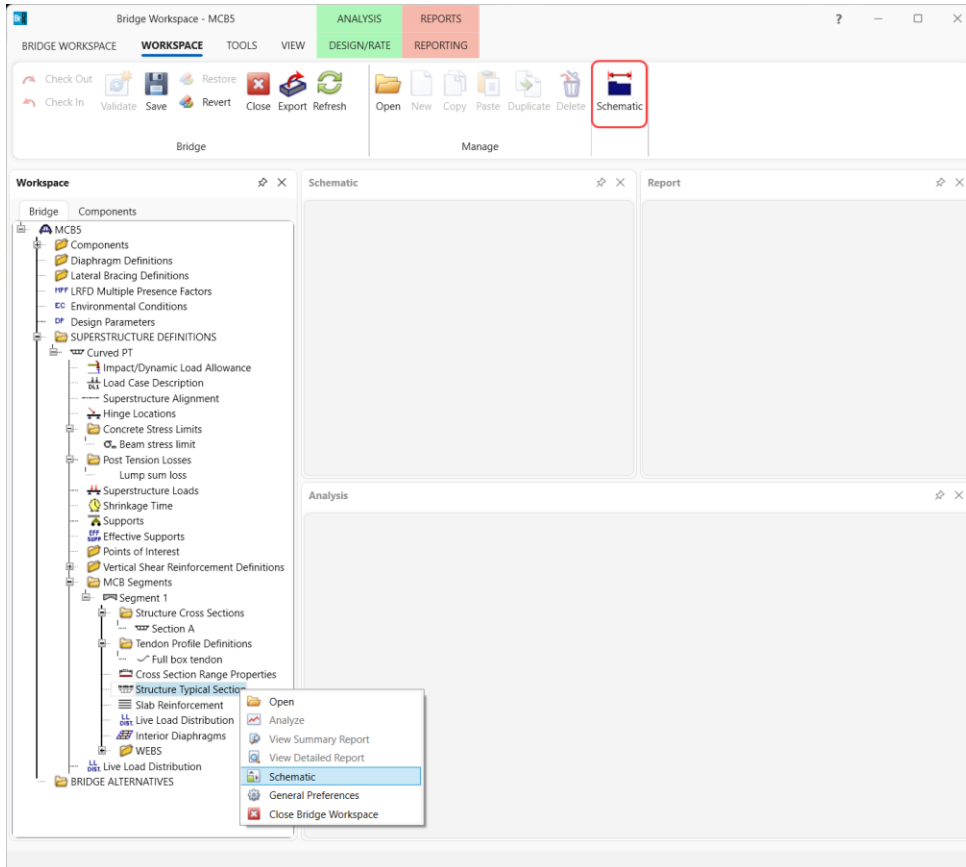
OK      Apply      Cancel

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

# MCB5 – Advanced Multi-Cell Box Example

## Schematics – Structure Typical Section

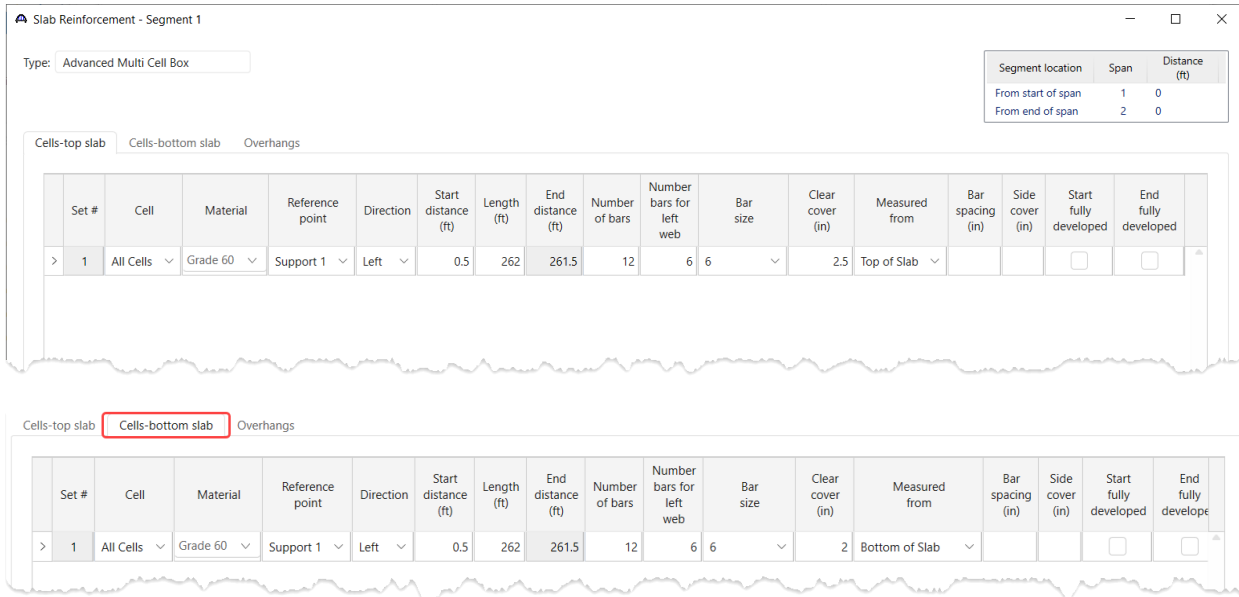
Select the **Structure Typical Section** node in the **BWS** tree and click the **Schematic** button from the **WORKSPACE** ribbon (or right click and select **Schematic**) as shown below.



# MCB5 – Advanced Multi-Cell Box Example

## Slab Reinforcement

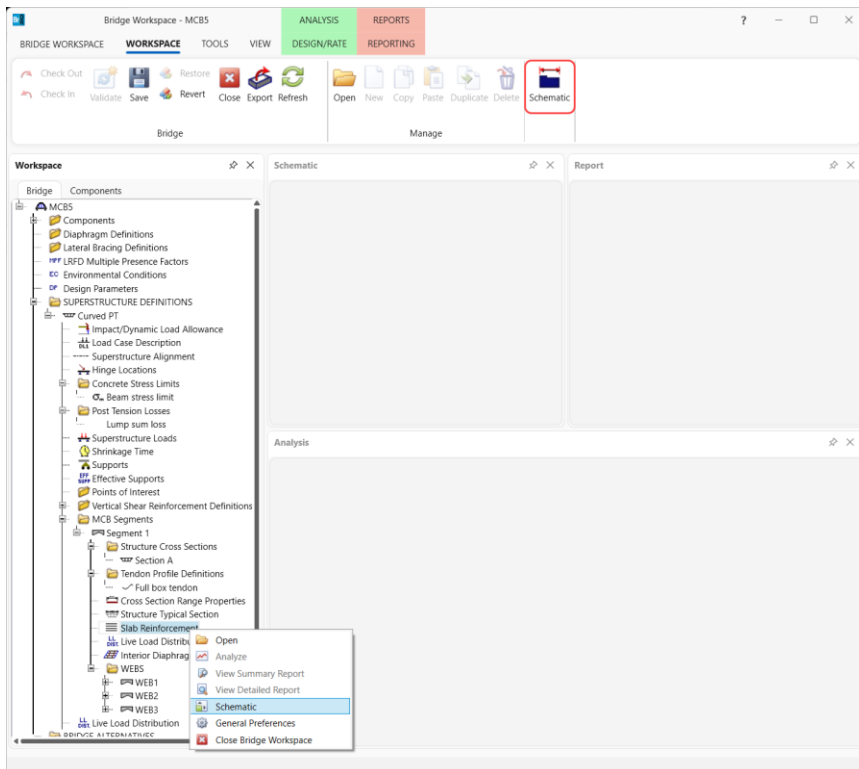
Double click on the **Slab Reinforcement** node in the **BWS** tree and enter the following data on the first two tabs.



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.



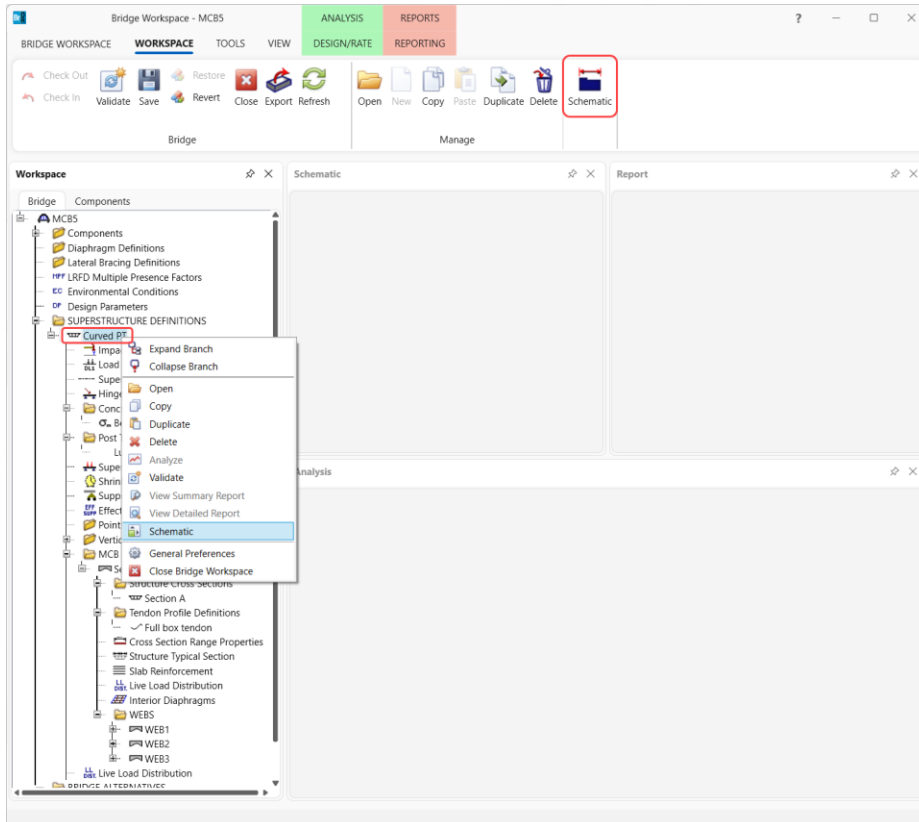
# MCB5 – Advanced Multi-Cell Box Example

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

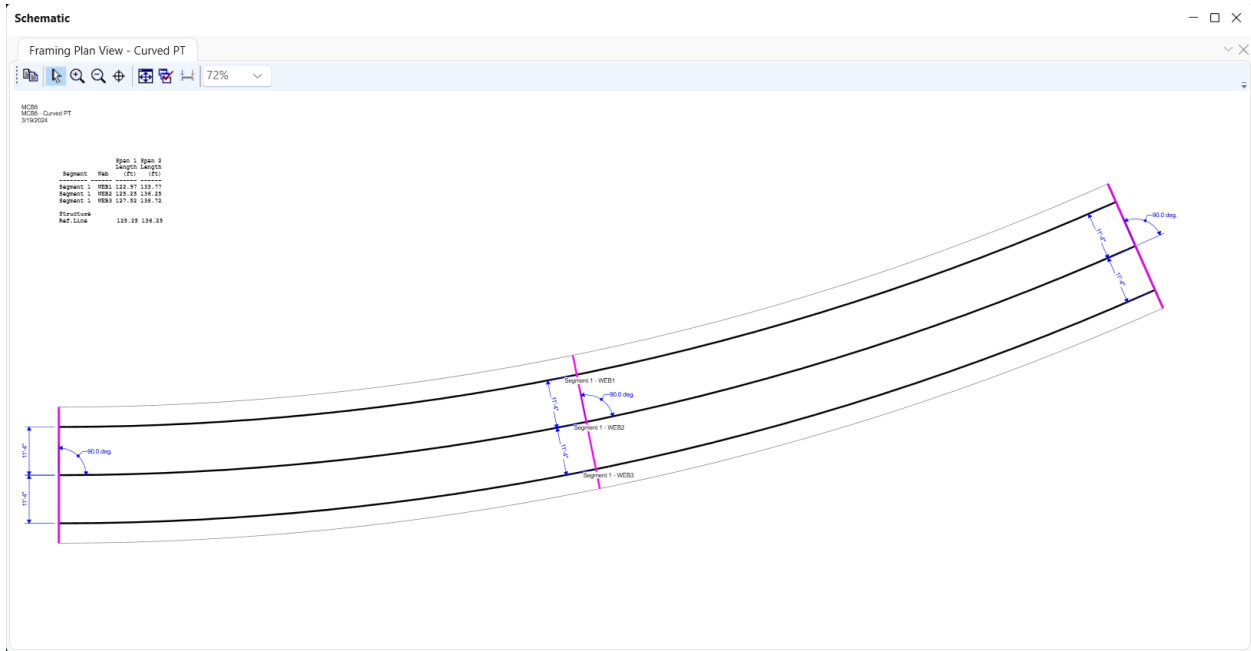


## Schematics – Superstructure Definition Plan View

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.

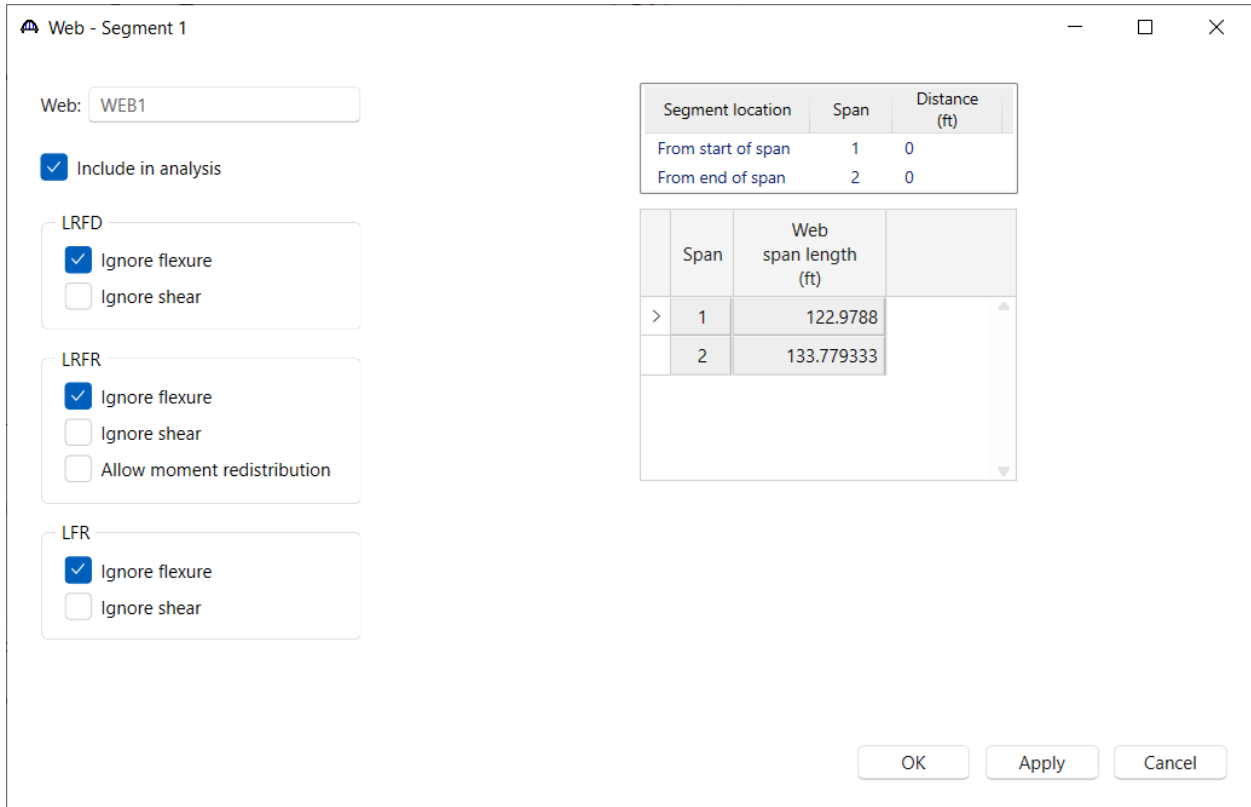


# MCB5 – Advanced Multi-Cell Box Example



## 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.



# MCB5 – Advanced Multi-Cell Box Example

## 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.

Stirrup Wizard

Input reference type:  Voids  Centerline bearings  Start of web

Span: 1 Maximum interior spacing: 9 in

Measured from left end of span

Segment start from left support: 0 ft

Start distance: 0 in

Name	Number of spaces	Spacing (in)
#6 Stirrup	30	6

Measured from right end of span

Segment end from right support: 0 ft

Start distance: 0 in

Name	Number of spaces	Spacing (in)
#6 Stirrup	30	6

Hinge solid sections

Location	Distance from (ft)	
	Left support	Right support
> Solid section start		
CL hinge		
Solid section end		

Apply all Apply span Cancel Help

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

Stirrup Wizard

Input reference type:  Voids  Centerline bearings  Start of web

Span: 2 Maximum interior spacing: 9 in

Measured from left end of span

Segment start from left support: 0 ft

Start distance: 0 in

Name	Number of spaces	Spacing (in)
> #6 Stirrup	30	6

Measured from right end of span

Segment end from right support: 0 ft

Start distance: 0 in

Name	Number of spaces	Spacing (in)
> #6 Stirrup	30	6

Hinge solid sections

Location	Distance from (ft)	
	Left support	Right support
> Solid section start		
CL hinge		
Solid section end		

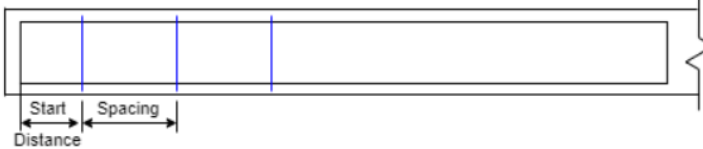
Apply all Apply span Cancel Help

## MCB5 – Advanced Multi-Cell Box Example

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

Span 1 will show the following data.

Web Shear Reinforcement Ranges - Segment 1 - WEB1



Segment location	Span	Distance (ft)
From start of span	1	0
From end of span	2	0

Input reference type:  Voids  Centerline bearings  Start of web

Linked with: None

Span ranges

Span: 1

Name	Start distance (ft)	Number of spaces	Spacing (in)	Length (ft)	End distance (ft)
#6 Stirrup	0	1	0	0	0
#6 Stirrup	0	30	6	15	15
#6 Stirrup	15	58	9	43.5	58.5
#6 Stirrup	58.5	1	2.7456	0.2288	58.7288
#6 Stirrup	58.7288	59	9	44.25	102.9788
#6 Stirrup	102.9788	30	6	15	117.9788

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

# MCB5 – Advanced Multi-Cell Box Example

## 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.

**Stirrup Wizard**

Diagram: Left Start Distance, Maximum Interior Spacing, Right Start Distance

Input reference type:  Voids  Centerline bearings  Start of web

Span: 1 Maximum interior spacing: 9 in

Measured from left end of span

Segment start from left support: 0 ft  
Start distance: 0 in

Name	Number of spaces	Spacing (in)
#6 Stirrup	30	6

Measured from right end of span

Segment end from right support: 0 ft  
Start distance: 0 in

Name	Number of spaces	Spacing (in)
#6 Stirrup	30	6

Hinge solid sections

Location	Distance from (ft)	
	Left support	Right support
> Solid section start		
CL hinge		
Solid section end		

Buttons: New Duplicate Delete (for both sections), Apply all Apply span Cancel Help

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

**Stirrup Wizard**

Diagram: Left Start Distance, Maximum Interior Spacing, Right Start Distance

Input reference type:  Voids  Centerline bearings  Start of web

Span: 2 Maximum interior spacing: 9 in

Measured from left end of span

Segment start from left support: 0 ft  
Start distance: 0 in

Name	Number of spaces	Spacing (in)
> #6 Stirrup	30	6

Measured from right end of span

Segment end from right support: 0 ft  
Start distance: 0 in

Name	Number of spaces	Spacing (in)
> #6 Stirrup	30	6

Hinge solid sections

Location	Distance from (ft)	
	Left support	Right support
> Solid section start		
CL hinge		
Solid section end		

Buttons: New Duplicate Delete (for both sections), Apply all Apply span Cancel Help



## MCB5 – Advanced Multi-Cell Box Example

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

Span 1 will show the following data.

Web Shear Reinforcement Ranges - Segment 1 - WEB2

Segment location	Span	Distance (ft)
From start of span	1	0
From end of span	2	0

Input reference type:  Voids  Centerline bearings  Start of web

Linked with: None

Span ranges

Span: 1

Name	Start distance (ft)	Number of spaces	Spacing (in)	Length (ft)	End distance (ft)
#6 Stirrup	0	1	0	0	0
#6 Stirrup	0	30	6	15	15
#6 Stirrup	15	60	9	45	60
#6 Stirrup	60	1	3	0.25	60.25
#6 Stirrup	60.25	60	9	45	105.25
#6 Stirrup	105.25	30	6	15	120.25

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

# MCB5 – Advanced Multi-Cell Box Example

## 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.

Stirrup Wizard

Input reference type:  Voids  Centerline bearings  Start of web

Span: 1 Maximum interior spacing: 9 in

Measured from left end of span

Segment start from left support: 0 ft  
Start distance: 0 in

Name	Number of spaces	Spacing (in)
#6 Stirrup	30	6

Measured from right end of span

Segment end from right support: 0 ft  
Start distance: 0 in

Name	Number of spaces	Spacing (in)
#6 Stirrup	30	6

Hinge solid sections

Location	Distance from (ft)	
	Left support	Right support
> Solid section start		
CL hinge		
Solid section end		

Buttons: Apply all, Apply span, Cancel, Help

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

Stirrup Wizard

Input reference type:  Voids  Centerline bearings  Start of web

Span: 2 Maximum interior spacing: 9 in

Measured from left end of span

Segment start from left support: 0 ft  
Start distance: 0 in

Name	Number of spaces	Spacing (in)
> #6 Stirrup	30	6

Measured from right end of span

Segment end from right support: 0 ft  
Start distance: 0 in

Name	Number of spaces	Spacing (in)
> #6 Stirrup	30	6

Hinge solid sections

Location	Distance from (ft)	
	Left support	Right support
> Solid section start		
CL hinge		
Solid section end		

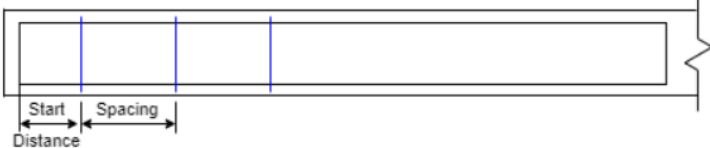
Buttons: Apply all, Apply span, Cancel, Help

## MCB5 – Advanced Multi-Cell Box Example

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

Span 1 will show the following data.

Web Shear Reinforcement Ranges - Segment 1 - WEB3



Segment location	Span	Distance (ft)
From start of span	1	0
From end of span	2	0

Input reference type

Voids
  Centerline bearings
  Start of web

Linked with:

Span ranges

Span:

Name	Start distance (ft)	Number of spaces	Spacing (in)	Length (ft)	End distance (ft)
#6 Stirrup	0	1	0	0	0
#6 Stirrup	0	30	6	15	15
#6 Stirrup	15	61	9	45.75	60.75
#6 Stirrup	60.75	1	3.2544	0.2712	61.0212
#6 Stirrup	61.0212	62	9	46.5	107.5212
#6 Stirrup	107.5212	30	6	15	122.5212

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

# MCB5 – Advanced Multi-Cell Box Example

## 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 Alternative

Alternative name: Bridge Alt

Description Substructures

Description:

Horizontal curvature

Reference line length: 261.5 ft

Start bearing  End bearing

Starting station: ft

Bearing: N 90° 0' 0.00" E

Global positioning

Distance: ft

Offset: ft

Elevation: ft

Bridge alignment

Curved  Tangent, curved, tangent  Tangent, curved  Curved, tangent

Start tangent length: ft

Curve length: 261.5 ft

Radius: 625 ft

Direction: Left

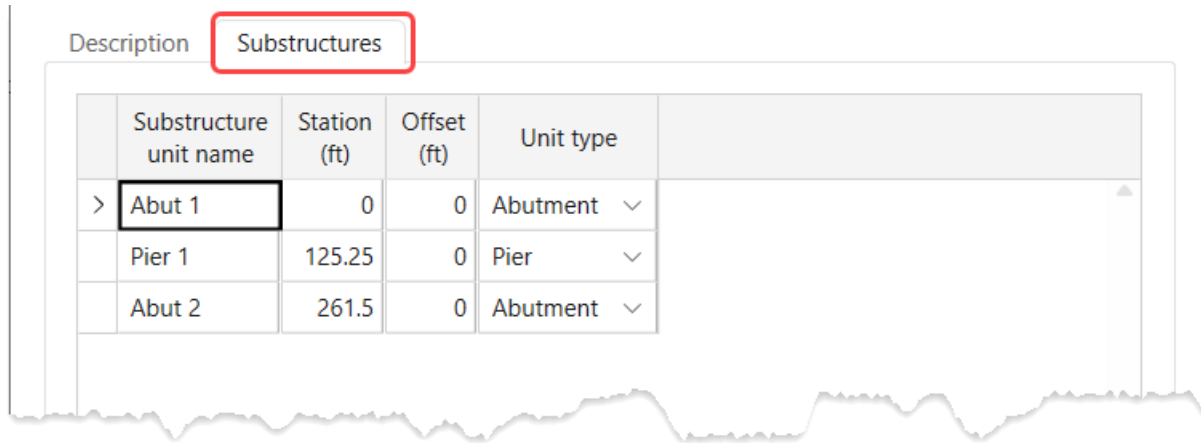
End tangent length: ft

Superstructure wizard... Culvert wizard...

OK Apply Cancel

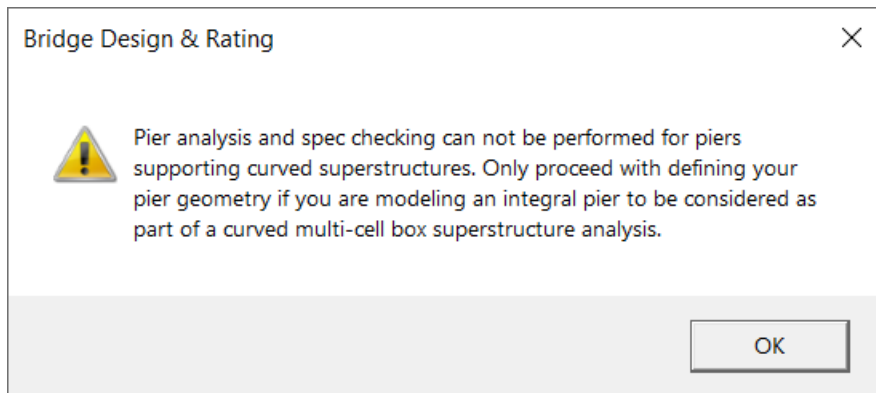
## MCB5 – Advanced Multi-Cell Box Example

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



	Substructure unit name	Station (ft)	Offset (ft)	Unit type
>	Abut 1	0	0	Abutment ▾
	Pier 1	125.25	0	Pier ▾
	Abut 2	261.5	0	Abutment ▾

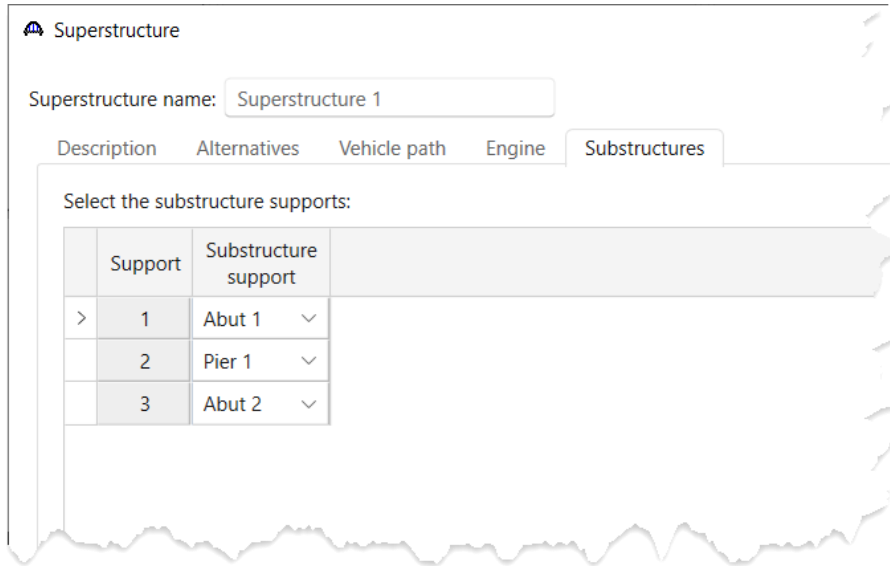
Click **OK** to apply the data and close the window. The following dialog box will appear explaining that the pier itself will not be analyzed or spec checked. Click **OK** to close the dialog box.



## MCB5 – Advanced Multi-Cell Box Example

### Superstructures

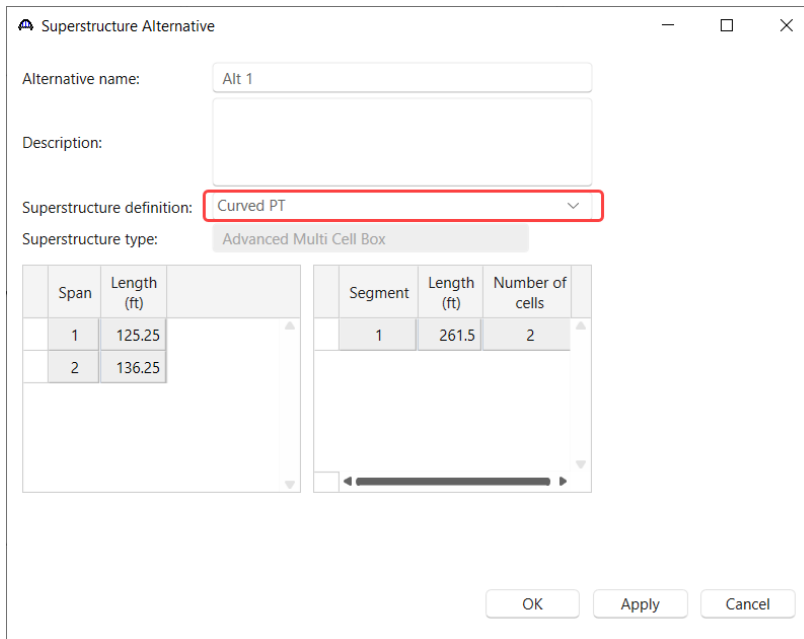
Double click on the **SUPERSTRUCTURES** folder and enter the name **Superstructure 1**. Move to the **Substructures** tab and assign substructures at each support.



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

### Superstructure Alternative

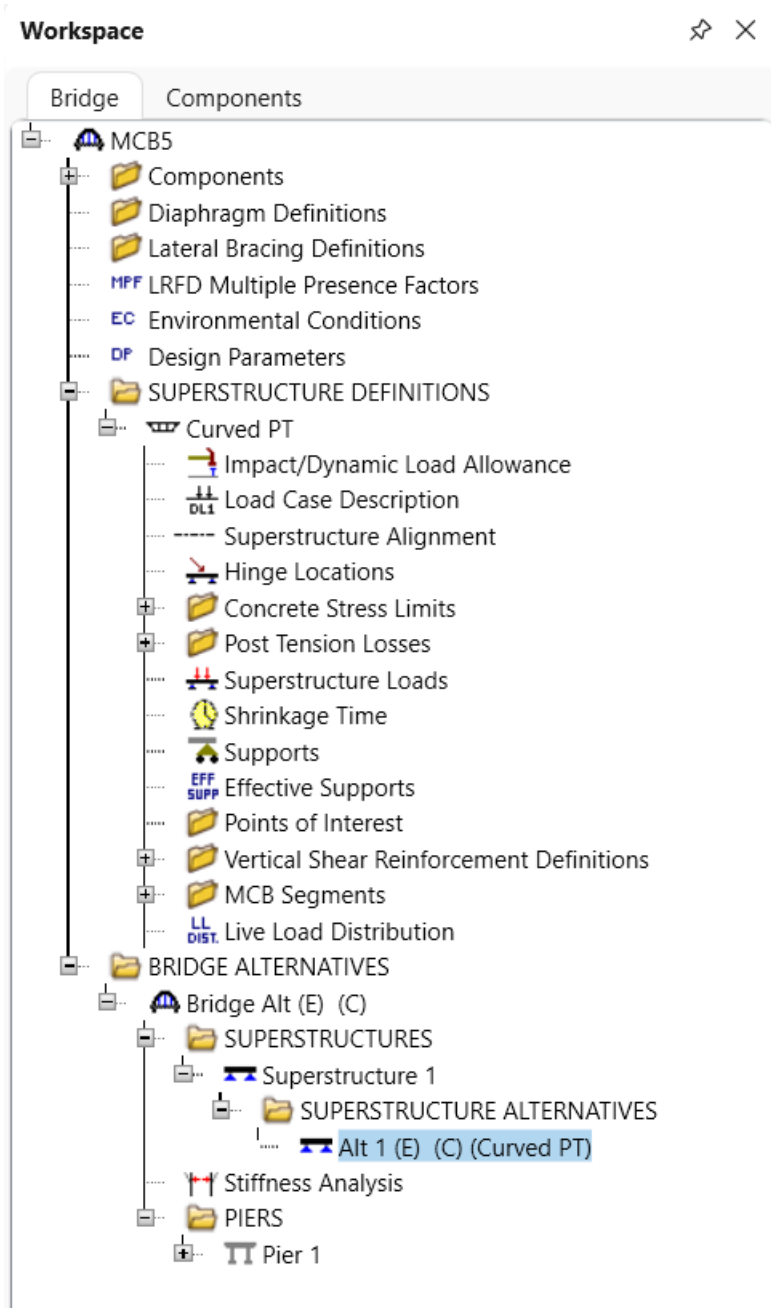
Double click on the **SUPERSTRUCTURE ALTERNATIVES** folder. Enter the name **Alt 1** and select **Curved PT** from the dropdown box.



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

# MCB5 – Advanced Multi-Cell Box Example

The **BWS** tree appears as follows.



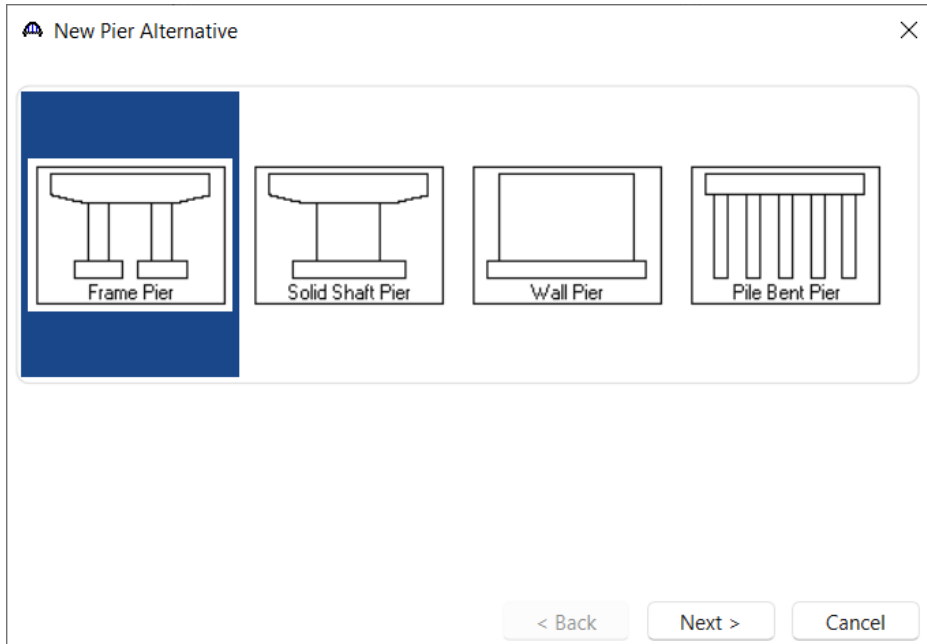
## MCB5 – Advanced Multi-Cell Box Example

### Pier Data Entry

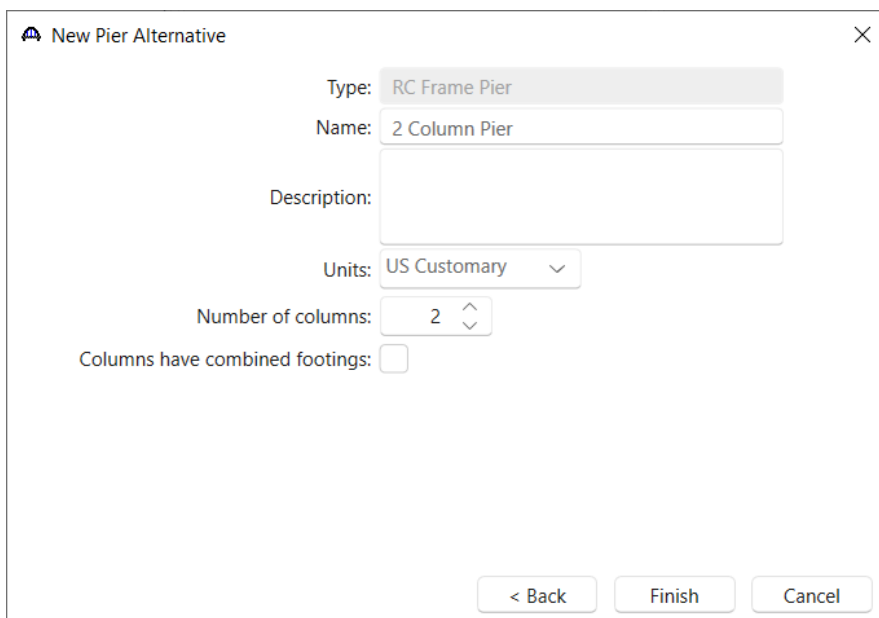
Integral piers and piers that support curved superstructures are not analyzed or spec checked. Therefore, only the geometry of the pier needs to be defined so the program can include the integral pier in the FE model as a support condition.

### 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**.



Enter the values shown and click **Finish**.



The screenshot shows the "New Pier Alternative" dialog box with the following configuration:

- Type: RC Frame Pier
- Name: 2 Column Pier
- Description: (empty text box)
- Units: US Customary (dropdown menu)
- Number of columns: 2 (spin box)
- Columns have combined footings:

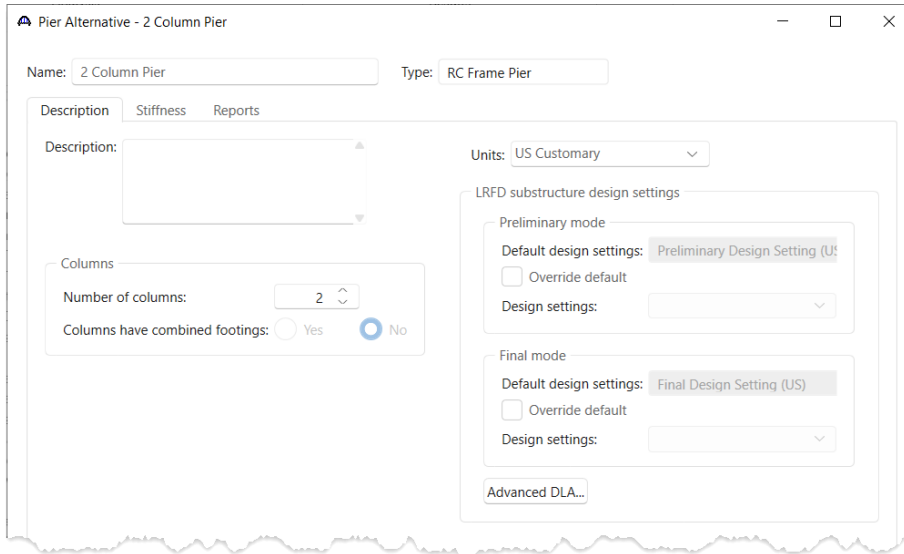
At the bottom of the dialog, there are three buttons: "< Back", "Finish", and "Cancel".



# MCB5 – Advanced Multi-Cell Box Example

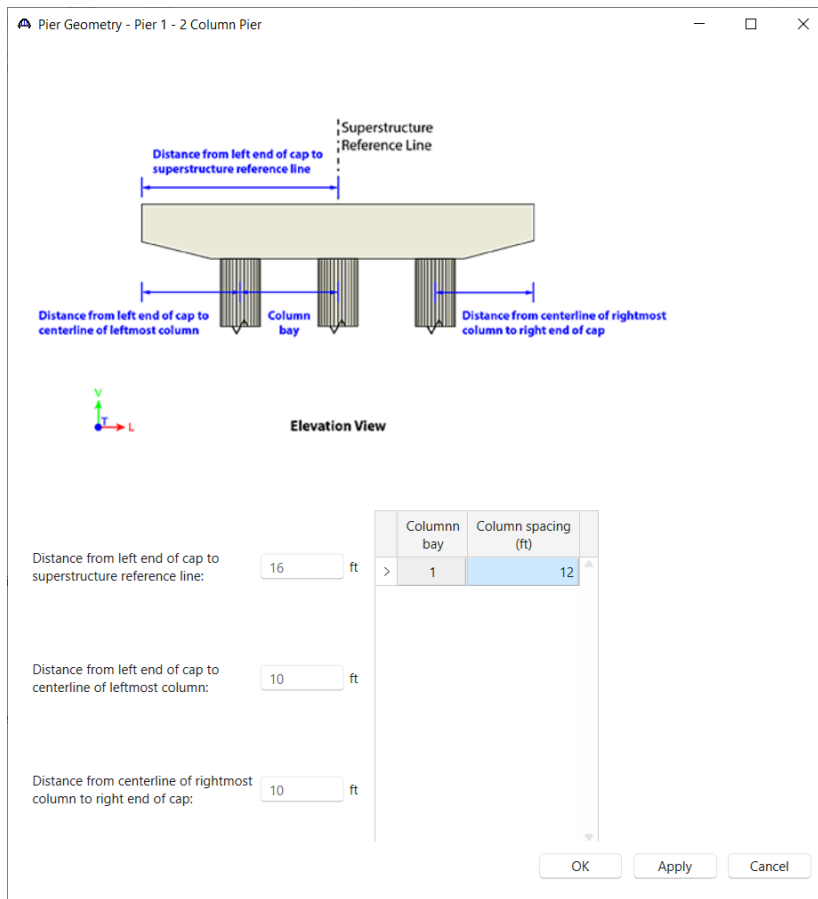
## Pier Alternative – Pier 1

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



## Pier Geometry – Pier 1 – 2 Column Pier

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

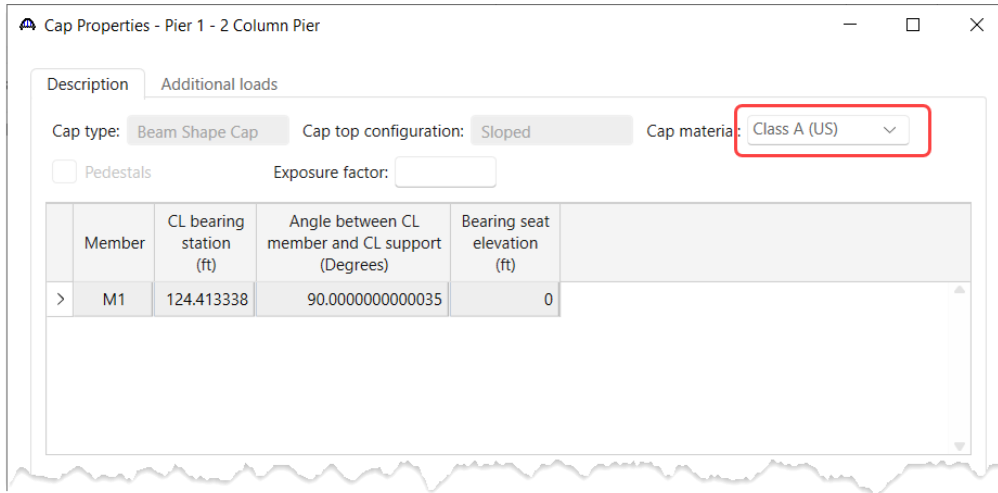


Click **OK** to apply the data and close the window.

# MCB5 – Advanced Multi-Cell Box Example

## Cap Properties – Pier 1 – 2 Column Pier

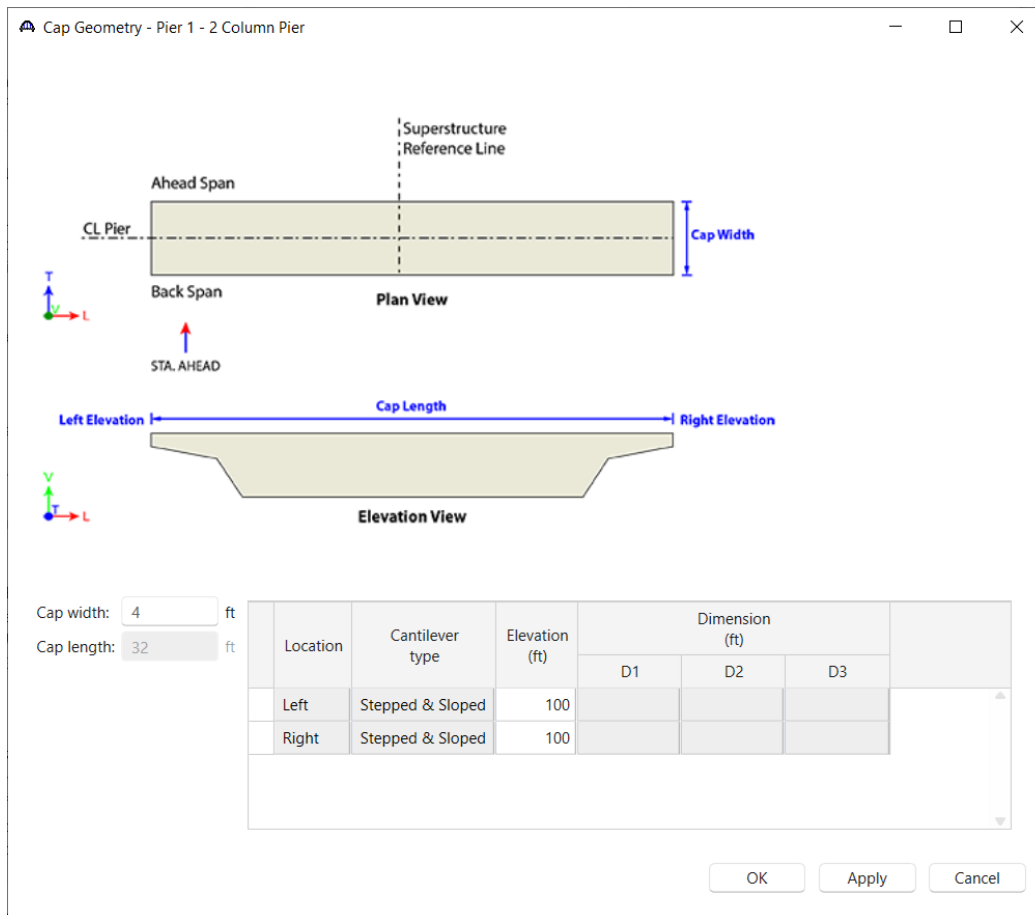
Open the **Cap** window and select the following cap concrete material.



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

## Cap Geometry – Pier 1 – 2 Column Pier

Open the Cap **Geometry** window and enter the following data for the pier cap geometry.

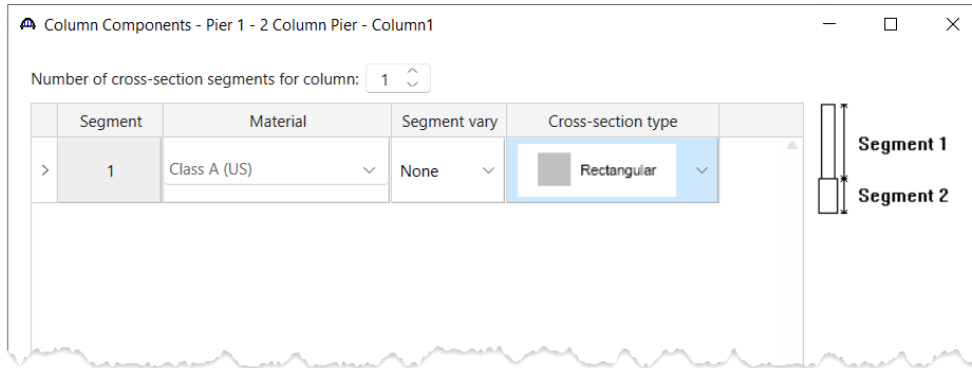


Click **OK** to apply the data and close the window.

# MCB5 – Advanced Multi-Cell Box Example

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

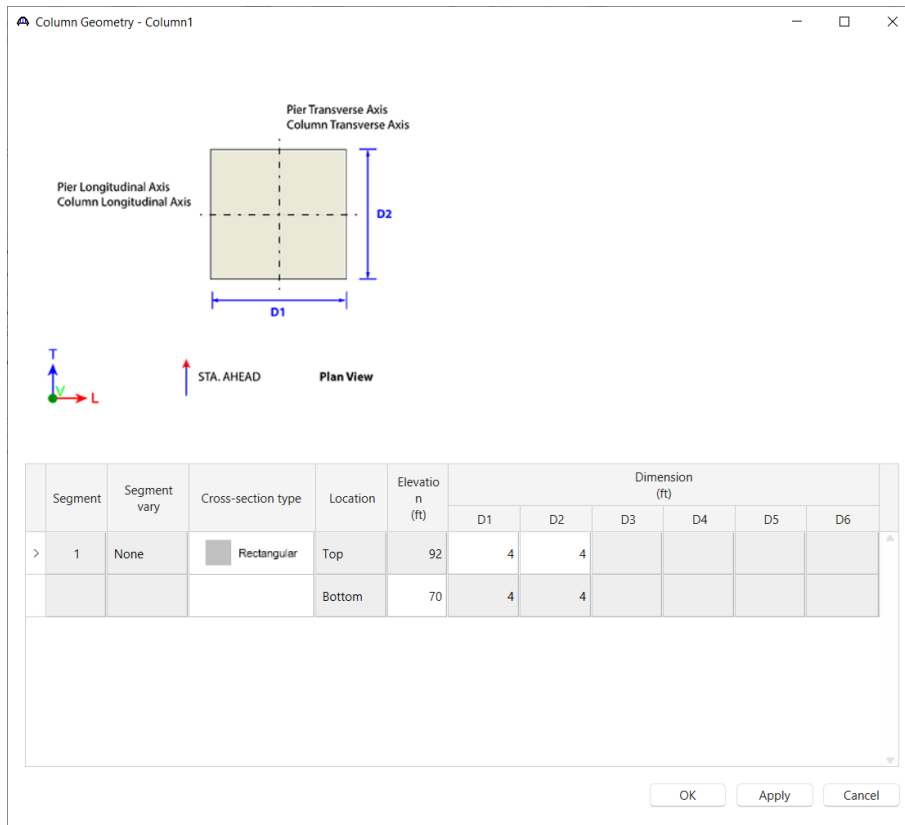
Open the Column1 **Components** window and select the following shape and concrete material.



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

## Column Geometry – Column1

Open the Column1 **Geometry** window and enter the following data.

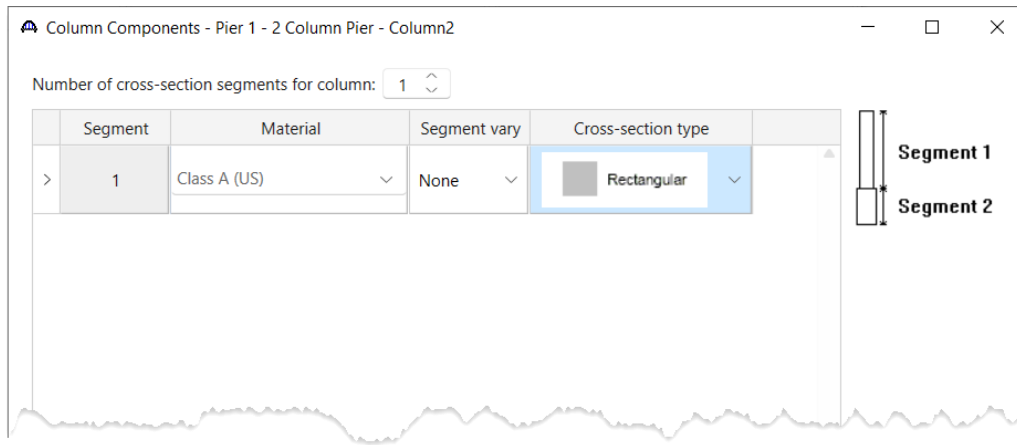


Click **OK** to apply the data and close the window.

# MCB5 – Advanced Multi-Cell Box Example

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

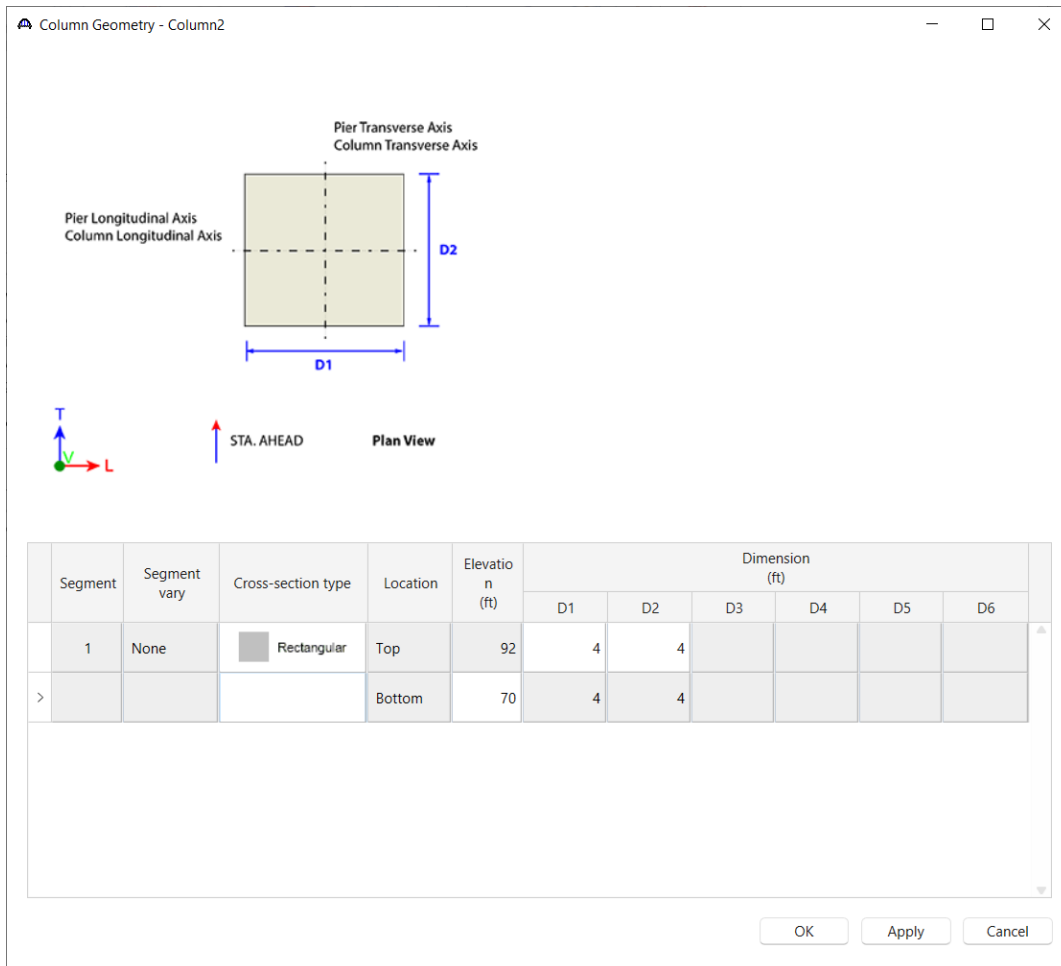
Open the Column2 **Components** window and select the following shape and concrete material.



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

## Column Geometry – Column2

Open the Column2 **Geometry** window and enter the following data.



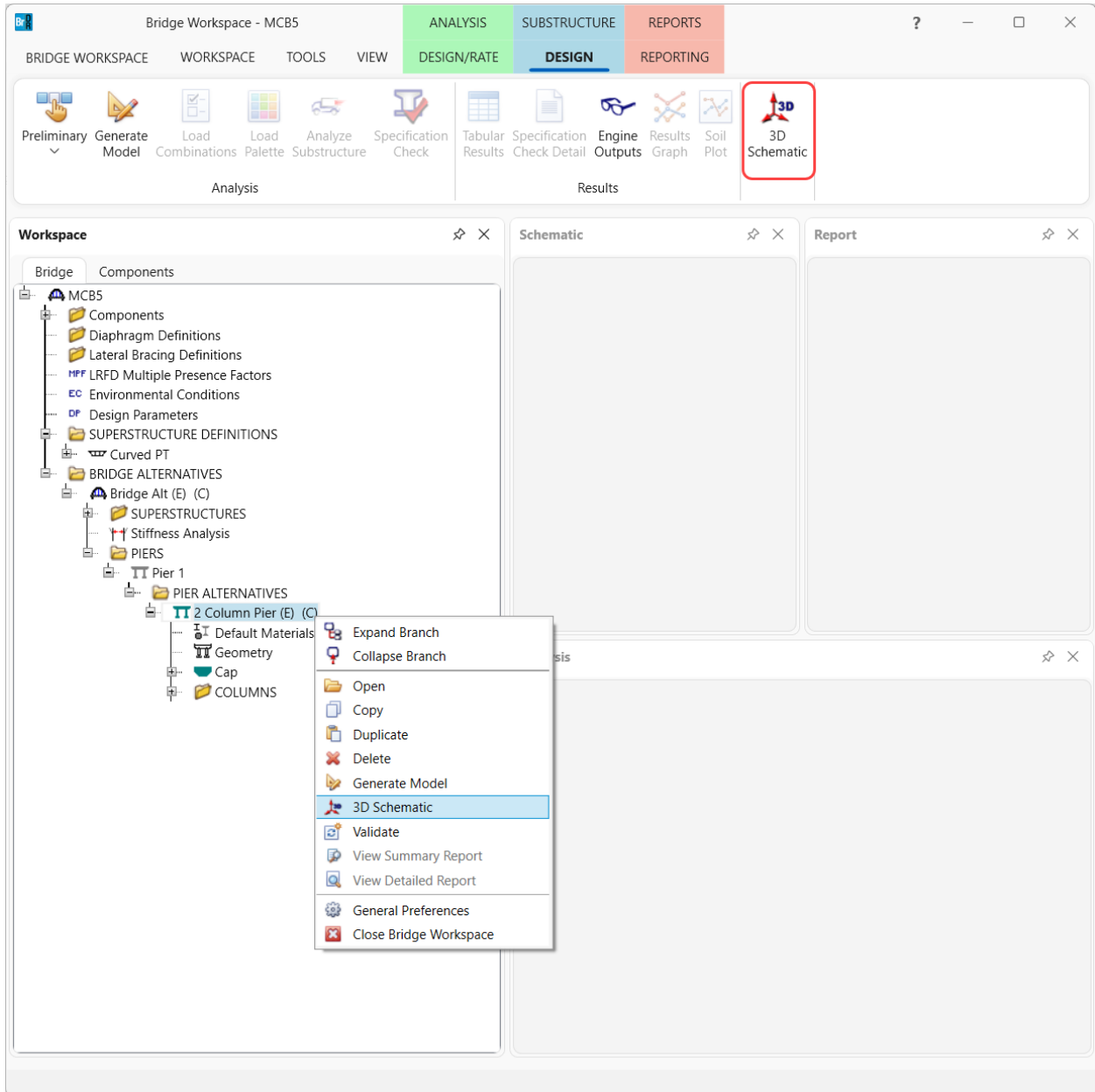
Click **OK** to apply the data and close the window.

## MCB5 – Advanced Multi-Cell Box Example

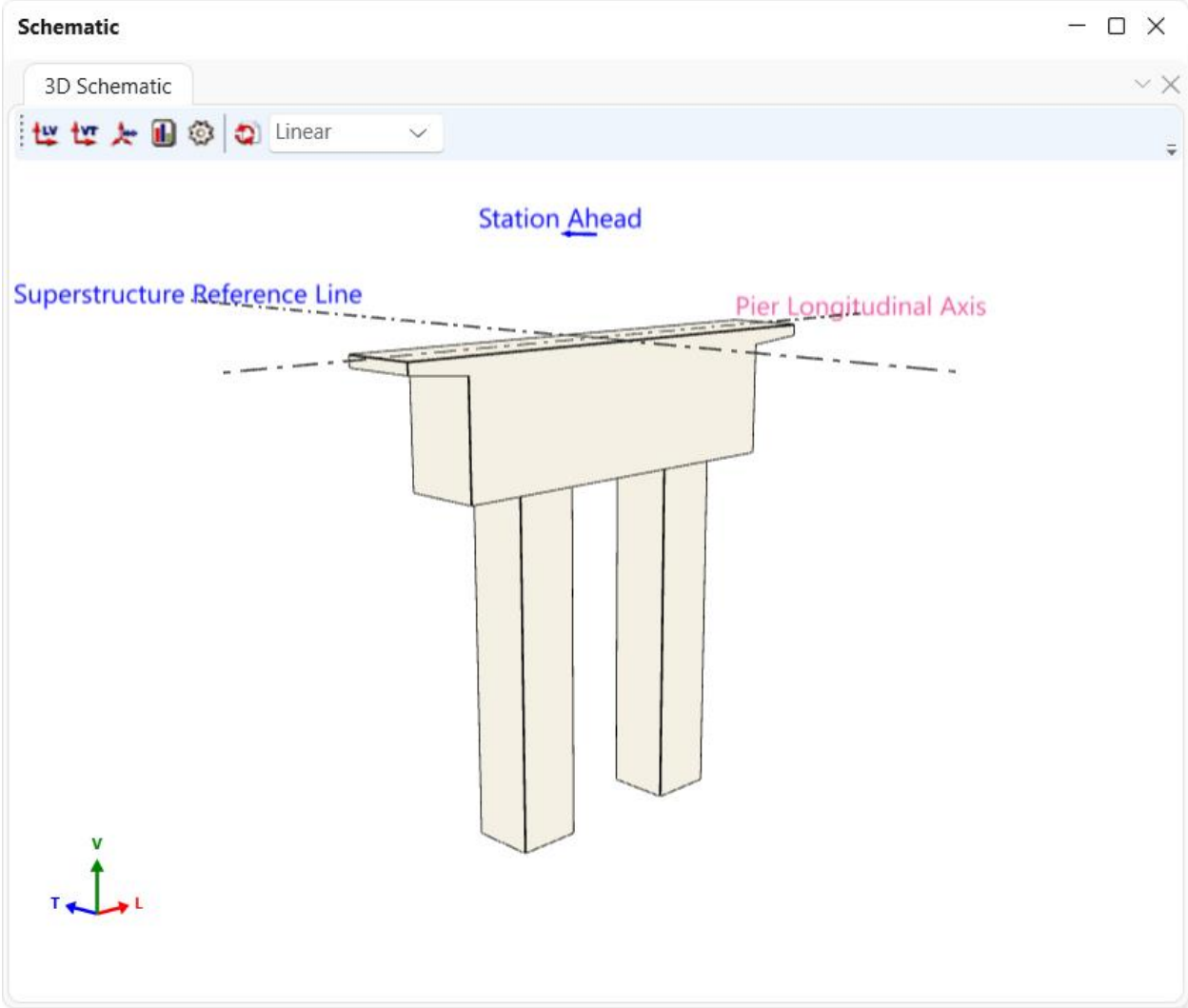
The pier is now sufficiently defined to be considered in the superstructure analysis. The columns will be considered fixed at the base of the column. This percent fixity can be adjusted on the **Pier Model Settings** window if desired. The FE model created during the superstructure analysis will include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



MCB5 – Advanced Multi-Cell Box Example



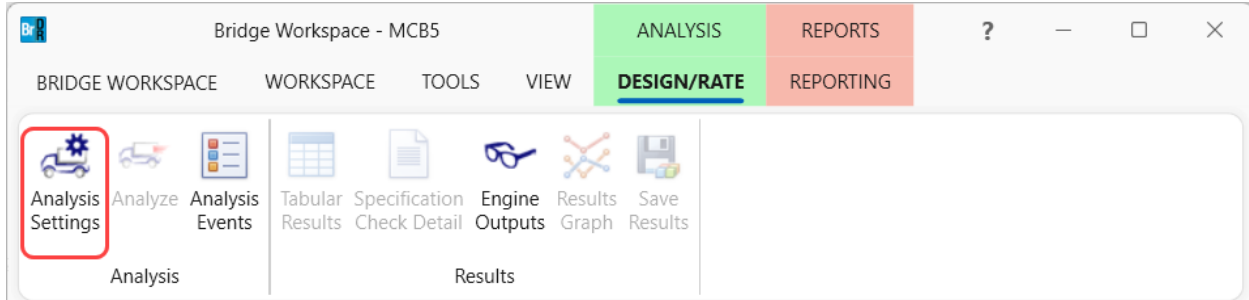
## MCB5 – Advanced Multi-Cell Box Example

### Analysis and Results

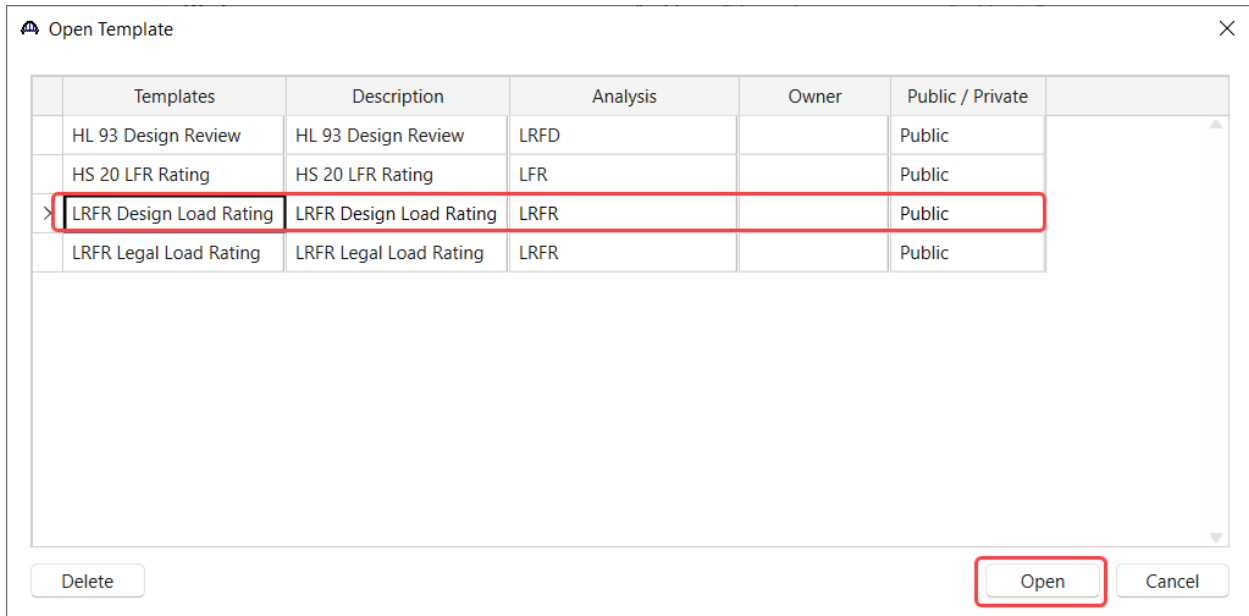
The superstructure is ready for analysis. Note that a design review of substructures for integral box girders cannot be performed at this time.

#### 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.

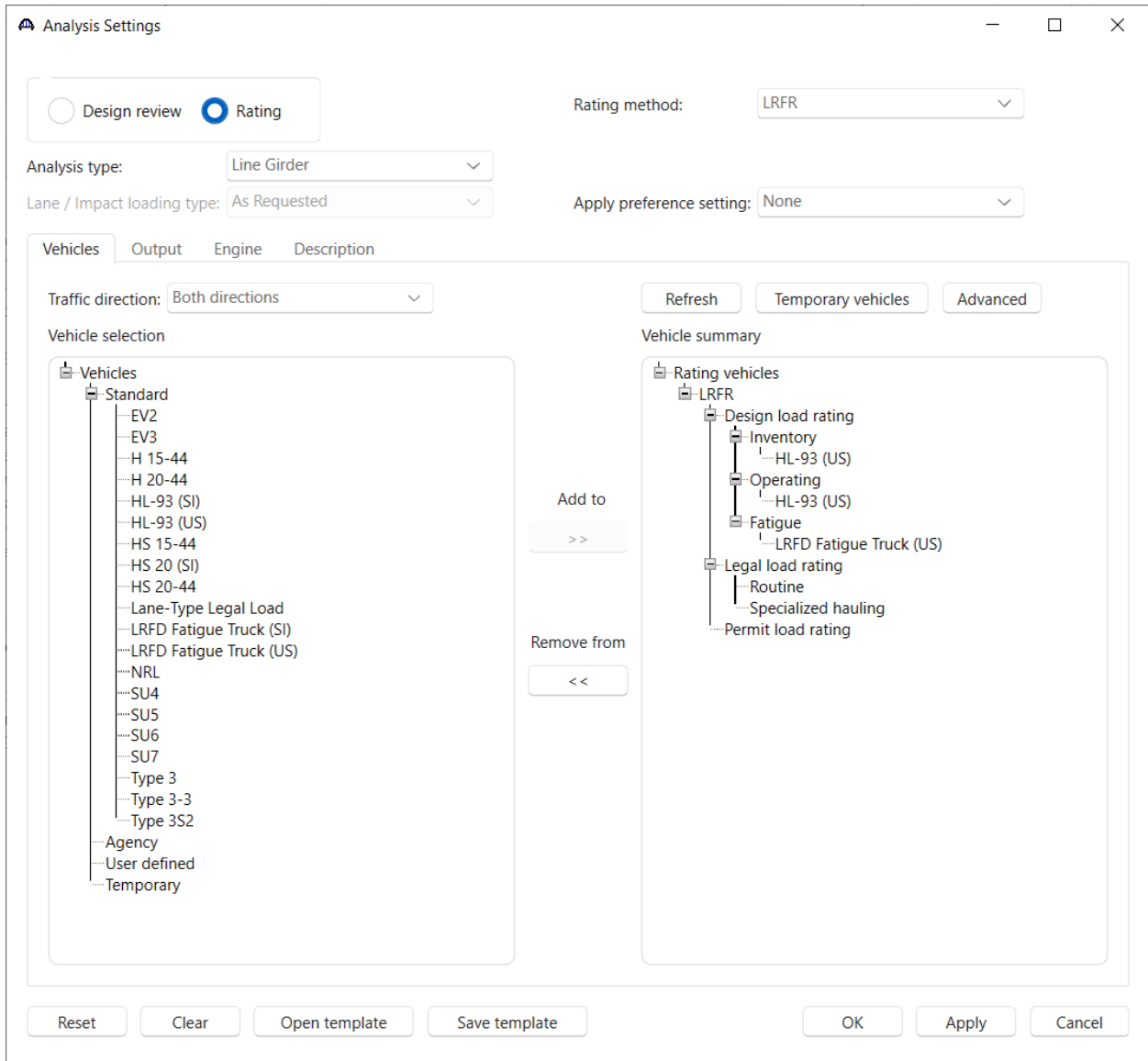


Click on the **Open template** button in the **Analysis Settings** window and select the **LRFR Design Load Rating** and click **Open**.



The **Analysis Settings** window is updated as shown below.

# MCB5 – Advanced Multi-Cell Box Example

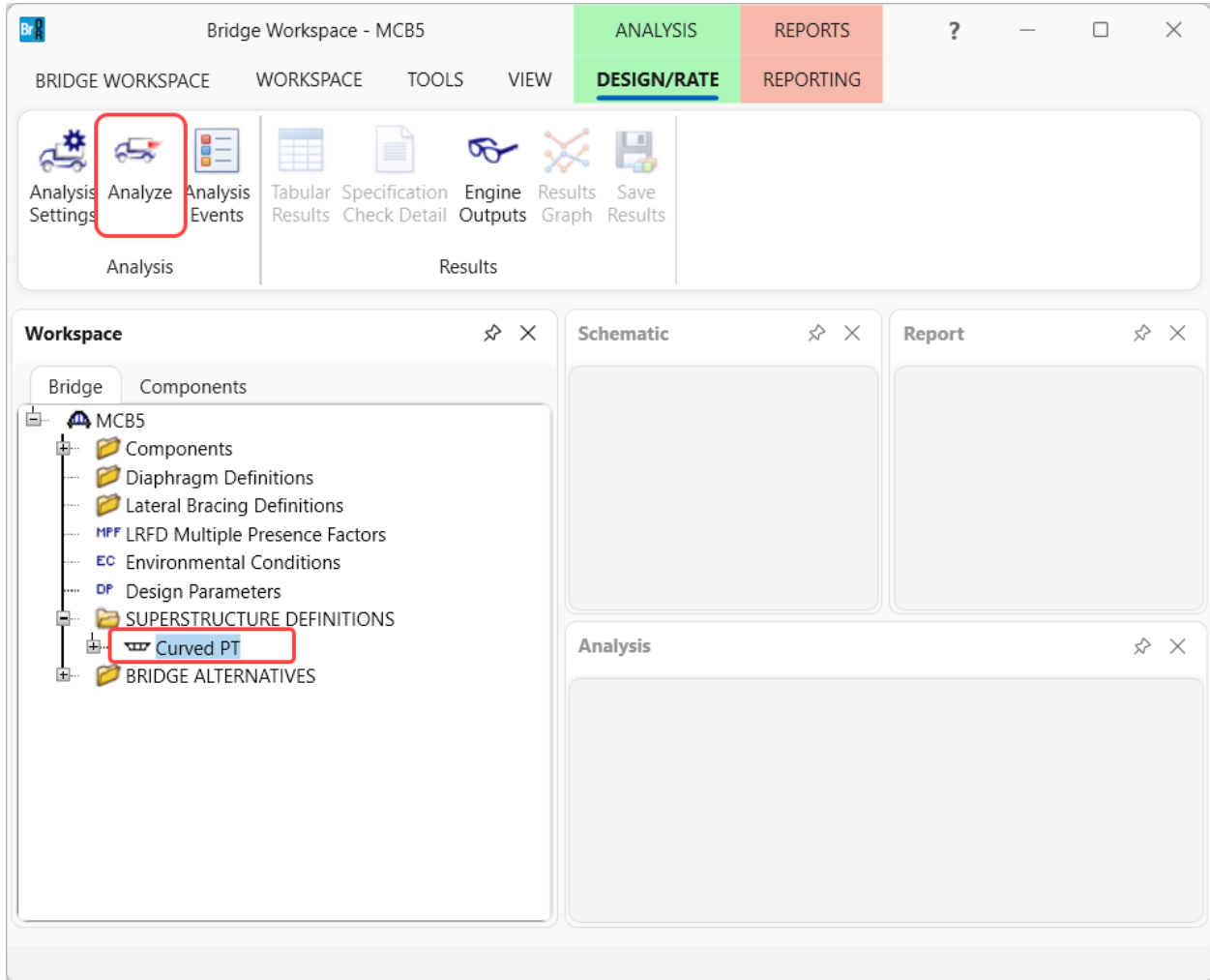


Click **OK** to apply the settings and close the window.



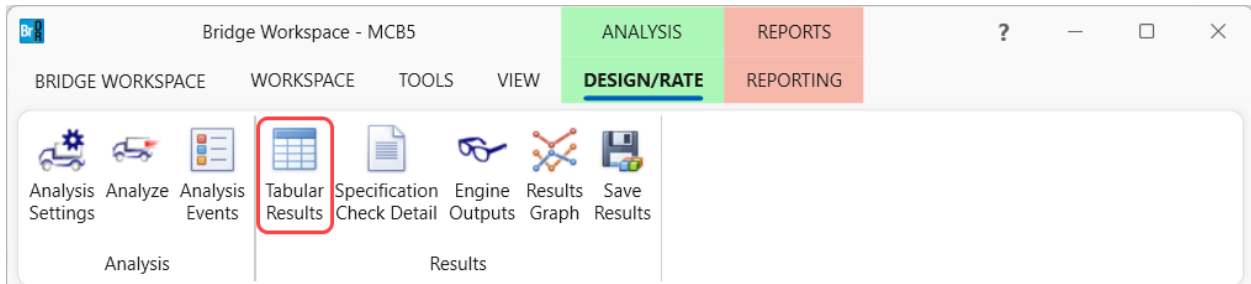
## MCB5 – Advanced Multi-Cell Box Example

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



### 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.



# MCB5 – Advanced Multi-Cell Box Example

Analysis Results - Curved PT

Print

Report type: Rating Results Summary

Lane/Impact loading type:  As requested  Detailed

Display Format: Single rating level per row

	Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor ^	Location (ft)	Location Span-(%)	Element Name	Limit State	Impact	Lane
>	HL-93 (US)	Truck + Lane	LRFR	Inventory	54.23	1.506	100.20	1 - (80.0)	CurvedPT	STRENGTH-I Concrete Shear	As Requested	As Requested
	HL-93 (US)	Tandem + Lane	LRFR	Inventory	74.01	2.056	100.20	1 - (80.0)	CurvedPT	STRENGTH-I Concrete Shear	As Requested	As Requested
	HL-93 (US)	Truck + Lane	LRFR	Operating	80.32	2.231	100.20	1 - (80.0)	CurvedPT	STRENGTH-I Concrete Shear	As Requested	As Requested
	HL-93 (US)	0%(Truck Pair + Lane)	LRFR	Inventory	80.32	2.231	125.25	2 - (0.0)	CurvedPT	STRENGTH-I Concrete Flexure	As Requested	As Requested
	HL-93 (US)	0%(Truck Pair + Lane)	LRFR	Operating	104.12	2.892	125.25	2 - (0.0)	CurvedPT	STRENGTH-I Concrete Flexure	As Requested	As Requested
	HL-93 (US)	Tandem + Lane	LRFR	Operating	116.58	3.238	247.87	2 - (90.0)	WEB2	STRENGTH-I Concrete Shear	As Requested	As Requested

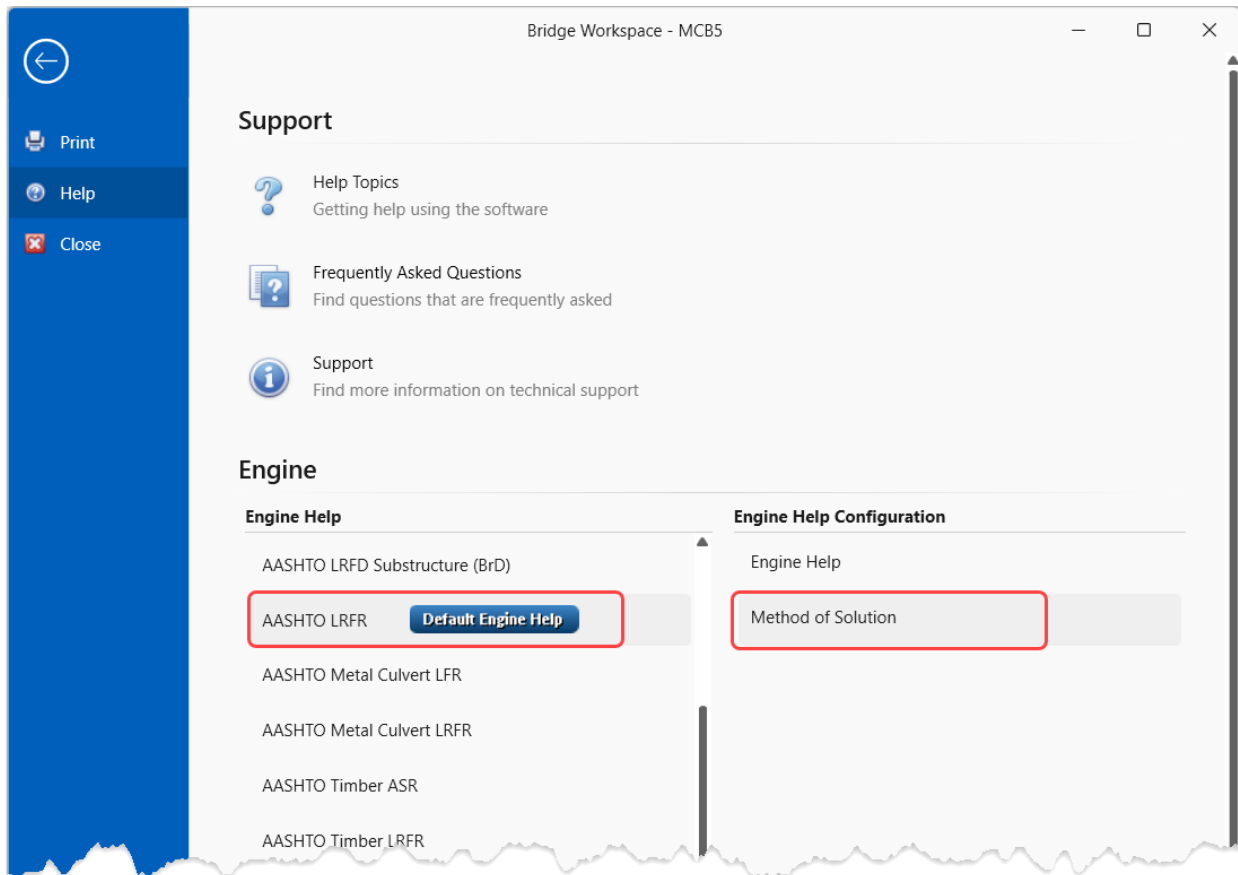
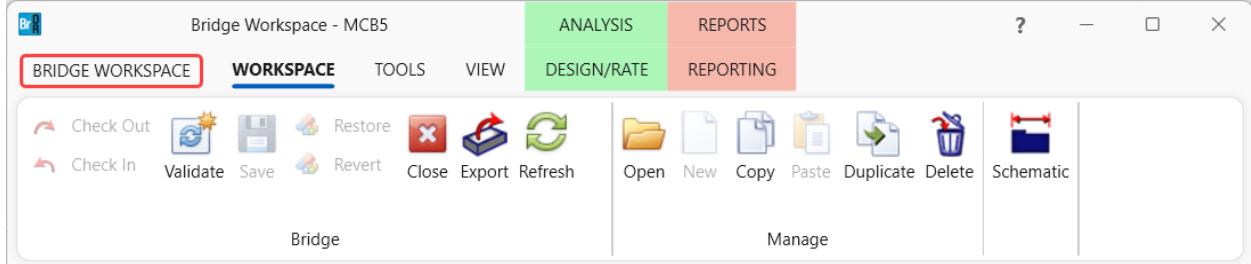
AASHTO LRFR Engine Version 7.5.1:3001  
Analysis preference setting: None

Close

# MCB5 – Advanced Multi-Cell Box Example

## 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.



## MCB5 – Advanced Multi-Cell Box Example

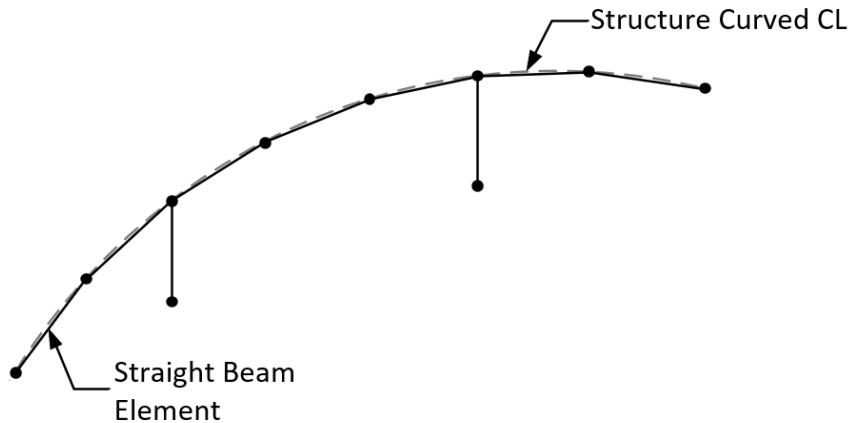
The following snippet from the method of solution table of contents shows the type of available information.

Transverse Deck Analysis.....	29
Multi-Cell Box Structure Analysis.....	29
Advanced Multi-Cell Box Structure Analysis.....	29
Horizontally Curved Advanced Multi-Cell Box Analysis.....	29
Finite Element Modeling.....	29
Torsion Loading.....	32
Full Box Analysis.....	33
Individual Web Analysis.....	34
Floor System Superstructure Analysis.....	35

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

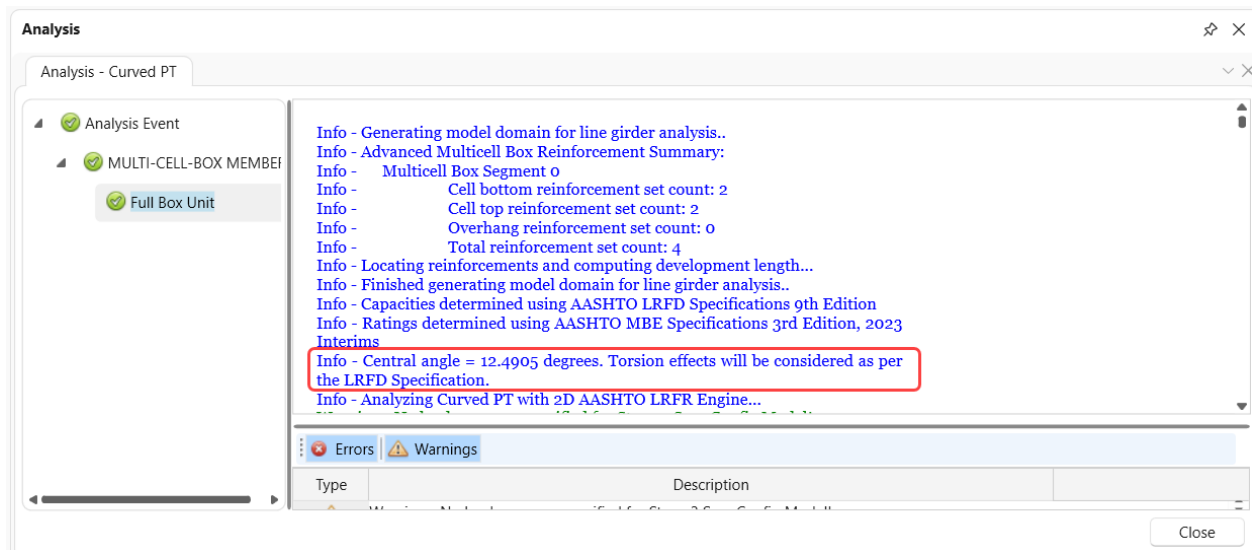
### Line Girder Analysis

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.

## MCB5 – Advanced Multi-Cell Box Example



### 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

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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,  $V_{eff}$ , that is used in place of the vertical shear,  $V_u$ , 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 and is ignored when it decreases the shear effect.