AASHTOWare BrDR 7.5.0 Prestressed Concrete Structure Tutorial PS12 – Three Span Prestressed I Beam Stirrup Design Example



**Typical Section** 



### **Material Properties**

Beam Concrete: f'c = 7.0 ksi, f'ci = 5.5 ksi Deck Concrete: f'c = 4.0 ksi Prestressing Strand: 1/2" dia., 7 Wire strand, Fu = 270 ksi, Low Relaxation

### **BrDR** Training

### PS12 - Three Span Prestressed I Beam Stirrup Design Example

From the **Bridge Explorer** open the bridge **PCITrainingBridge6** (**BID 9**) by double clicking on **BID 9** (or by selecting **BID 9** and clicking on the **Open** button from the **BRIDGE** ribbon or right click and select **Open**) as shown below.

Br				AASHTOWare B	ridge Des	ign a	nd Rating			?	_		$\times$	
BRIDGE EXPLORER BRIDG	FOLDER	. 1	RATE	TOOLS VIEV	v (	_								
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	0°0 📋					þ	Сору		Ctrl+C					
New Open Batch V	Find Copy	Paste	Cop To`	y Remove <b>Delete</b> ✓ From		ð	Delete							
Bridge		Manage			III Rate									
Eavorites Folder				B. 1		1 🔀	Rating Resu	lts			Distin			
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🖻 📁 All Bridges		ges		PCITrainingBridge1	ainingBridge2			-						
E Sample Bridges	Sample Bridges Deleted Bridges		6	PCITrainingBridge3									-1	
Deleted Bridges			7 PCITrainingBridge4			Attachments							-1	
				8	PCITrainingBridge5		L.	General Pre	ferences					-1
		Þ	9	PCITrainingBridge6		PCITIainingbridgeo(EKPD)								
			10	Example7		Exa	mple 7 PS (Li	FR)						
			11	RCTrainingBridge1		RC	Training Brid	ge1(LFR)						
			12	TimberTrainingBridg	e1	Tim	ber Tr. Bridge	e1 (ASR)						
			13	FSys GFS TrainingBri	dge1	Flo	orSystem GFS	Training Brid	ge 1		District 6	15 Co	lletc	
			14	FSys FS TrainingBrid	ge2	Flo	orSystem FS	Training Bridg	e 2		District 11	333 N	lorfc	
			15	FSys GF TrainingBrid	ge3	Flo	orSystem GF	Training Bridg	e 3		District 7	06 Ba	rnw	
			16	El ine GES TrainingBridge1		Floorline GES Training Bridge 1				District 1	01 AH	hav T		
								Total Brid	ge Count:	3	1			

The partially expanded Bridge Workspace tree is shown below.



Expand the **SUPERSTRUCTURE DEFINITIONS** tree, and then expand the **Structure Definition** #1. Expand **MEMBERS**, **G2**, **MEMBER ALTERNATIVES** and finally expand **Member Alternative** #2 (9.9.6) (E)(C).



### PS Shear Reinforcement Ranges

Select the **Shear Reinforcement Ranges** node in the **Bridge Workspace** tree and click the **Open** button from the **Manage** group of the **WORKSPACE** ribbon (or right click on the **Shear Reinforcement Ranges** node and select **Open** from the drop-down menu).

Bridge Workspace - PCITrainingBridge6	ANALYSIS	REPORTS	? – 🗆 ×			
BRIDGE WORKSPACE WORKSPACE TOOLS VIEW	DESIGN/RATE	REPORTING	^			
Check Out Check In Validate Save	esh Open Ne	ew Copy Paste Du	pplicate Delete			
Bridge		Manage				
Workspace	<mark>я</mark> ж S	chematic # >	K Report # X			
Bridge Components						
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Span: 1	Copy span	to							,
Name	Extends into deck	Start distance (ft)	Number of spaces	Spacing (in)	Length (ft)	End distance (ft)			
+ #5 Shear Reinf.	- 1	0.50	1	0.0000	0.00	0.50		-	
#5 Shear Reinf.	- V	0.50	131	10.0000	109.17	109.67			
			Viewander				Dualizata		
Stirrup wizard	Stirrup desig	n tool	View calcs			OK	Duplicate	elete Cance	]

### Click on the Stirrup design tool button to open the Shear Stirrup Design Tool.

## Enter the data in the Shear Stirrup Design Tool window and click on the Continue button as shown below.

Distance to first stirrup:	3.0000	in	Number of stirrup definitions				
Aaximum jump in spacing between ranges:		in	• Use 1 stirrup defin	ition			
Override maximum allowable spacing:	in	Use 2 stirrup defin	itions range length	: ft			
			Design template: HL 93	Design Revie	w View		
Stirrup entry method	🖌 Extend	ds into deck					
Create new stirrup definition     Stirrup definition 1			− Stirrup definition 2 −−				
Existing stirrup definition Vertical shear reinf def: #4 Shear Reir	nf.	~	Existing stirrup def Vertical shear reinf	inition def: #4 Shea	ar Reinf. 🗸 🗸		
New stirrup definition			New stirrup definition				
Material: Grade 60		~	Material:	Grade 60	$\sim$		
Bar size: 4		~	Bar size:	3	$\sim$		
Number of legs: 2.00			Number of legs:				
Inclination (alpha): 90.0 Deg	grees		Inclination (alpha):	90.0	Degrees		

Using the design tool causes previously entered stirrup data to be deleted and replaced by newly computed stirrup data.

#### Distance to first stirrup

This is the distance to the first stirrup from the end of the beam. Typically, this will be 2 to 4 inches. Entering a number too high will provide a stirrup range that starts too far from the support. This will result in zero ratings and failed end shear resistance. Not entering a value will incorrectly put the first stirrup at the end face of the beam. Enter **3** inches for this example.

#### Maximum jump in spacing between ranges

This is the maximum jump in stirrup spacing that the module assumes from one range to the next. If this value is not entered, the default value used is **24**" (i.e., the maximum stirrup spacing).

The effect of leaving this field blank and using the default value of **24**" permits a change in spacing from range to range of any amount (since the maximum allowable spacing is **24**"). This will provide the most efficient stirrup ranges. Leave this value blank for this example.

#### Override maximum allowable spacing.

Enter a value for the desired maximum spacing of shear stirrups. If left blank, BrDR will use LRFD Article 5.8.2.7 to compute the maximum allowable spacing. For this example, this value will be left blank and allow the application to calculate the maximum shear steel spacing.

#### Number of Stirrup Definitions

The user may set the design tool to use one or two stirrup definitions. Some beams may benefit by having more robust steel sizes at the beam-ends where shear resistance is required and less robust steel sizes within the span where the shear resistance is less necessary. This example will use 1 stirrup definition.

#### **Definition 1 minimum range length**

This range is the minimum distance from end of beam over which the Stirrup Definition 1 is to be used. This is disabled when one stirrup definition is being used. The design of the bars is based on the stirrup area entered for each 1/10th point location (and critical distance). When those values are passed into the design module that calculate the final ranges, the shear areas for the design are based on the minimum range length and are then carried along as the ranges are being developed. The range length is a minimum and the final range length computed by the stirrup module will always be greater than or equal to this input. Since one stirrup definition is used, this need not be considered.

### **Stirrup Entry Method**

Choose to either use existing stirrup definition(s) or create new stirrup definition(s). The user can define stirrups in the **Bridge Workspace** tree, or a new definition can be created using the design tool. For this example, use the design tool to create a new definition.

### Extends into deck

Check this box if the reinforcing bars extend into the concrete deck. In this example, stirrups will be extended into the deck.

#### **Stirrup Definition (1 or 2)**

Under each of the **Existing stirrup definition** sections, select an existing **Vertical Shear Reinforcement Definition** from the drop down menu. This is available when the **Use existing stirrup definition** button is selected.

### **New Stirrup Definition**

When using the design tool to create a stirrup definition, this section will be available. The user will enter the material and a bar size from the two drop-down lists. The number of legs is then entered. The inclination is always 90 degrees. In this example, **Grade 60** will be used as the **Material** and **#4 Bar size** that have **2 legs**.

Click **Continue** to compute the required stirrup spacing at each tenth point and the critical dv point. The **Ps Stirrup Design Tool Progress** window appears. Once the analysis is complete, click **OK**.

Info: Finished generating PS creep forces load case for Stage 2 Continuous Model Starting FEA Stage 1 Model Method: Span FEA - Initiating finite element analysis	^
Info: Finished generating PS creep forces load case for Stage 2 Continuous Model Starting FEA Stage 1 Model Method: Span FEA - Initiating finite element analysis	^
Starting FEA Stage 1 Model Method: Span FEA - Initiating finite element analysis	
Stage 1 Model Method: Span FEA - Initiating finite element analysis	
FEA - Initiating finite element analysis	
FEA - Building model	
FEA - Creating nodes	
FEA - Creating elements	
FEA - Creating support constraints	
FEA - Adding load cases	
FEA - Verifying finite element model	
FEA - Preparing linear solution	
FEA - Performing linear solution	
FEA - Successful finite element analysis	
Stage 2 Model Method: Continuous	
FEA - Initiating finite element analysis	
FEA - Building model	
FEA - Creating nodes	
FEA - Creating elements	
FEA - Creating support constraints	
FEA - Adding load cases	
FEA - Verifying finite element model	
FEA - Preparing linear solution	
FEA - Performing linear solution	
FEA - Successful finite element analysis	
FEA - Complete	
Info: Performing Shear Design LRFD Specification Checks	
Completed Shear Design Specification Checks.	
Stirrup Design - Beginning Stirrup Design	
Stirrup Design - Successful Stirrup Design	
Info: PS stirrup design analysis successfully completed!	
Analysis completed!	
	$\sim$
	_
Print O	K

The **Stirrup Design Tool Results** window will appear as shown below. This window has a table showing the **Required stirrup spacing** at each analysis location throughout the beam for each span. The user can select the **Span** from the drop-down list and see the results for each span. Using the results from the analysis the user can construct the desired stirrup layout scheme by selecting the **maximum number of ranges** and the number of **minimum stirrups per range**. In this example, default value of **3** ranges and at least **3** stirrups per range will be used. For each span, enter the data as shown below and click on the **Create ranges** button and then click **Apply**. Once completed, close the window by clicking on the **Close** button.

A	Sti	rrup Design Too	Results					×
Ve	rtica	al shear reinforce	ement definitio	n 1 name: W	izard Stirrup 1			
Ve	rtica	al shear reinforce	ement definitio	on 2 name:				
Sp	an:	1	~					
Г	Req	1	g					
		3	Yu	Vc	Vp	smax	sreq	
		(tt)	(lip)	(kip)	(kip)	(in)	(in)	
	►	6.75	345.85	178.57	40.51	24.00	19.00	<b>A</b>
		11.40	316.73	177.88	40.51	24.00	23.50	
		22.30	250.42	162.54	40.51	24.00	24.00	
		33.20	186.47	107.96	0.00	24.00	24.00	
		44.10	125.26	90.69	0.00	24.00	24.00	
		55.00	-124.73	88.78	0.00	24.00	24.00	
		65.90	-186.60	97.93	0.00	24.00	24.00	
		76.80	-248.37	156.79	0.00	24.00	24.00	
		87.70	-309.62	162.54	40.51	12.00	12.00	
		98.60	-369.96	177.88	40.51	12.00	12.00	•
	Ger	erated ranges –						
	Ma	ximum number	ranges per spa	n: 3 🗸	Minimum st	tirrups per rang	je: 3 🗘	Create ranges
		Name	Extends into deck	Start distance (ft)	lumber Spac f spaces (in	ing Length 1) (ft)	End distance (ft)	
								*
			Note: Ex be delet	isting vertical s ed if you apply	shear reinforcer the results of t	nent ranges wi this wizard.	11	Apply Close

aximum number ran	ges per span	3 🗸	Minimum s	tirrups per ra	nge: 3 🗸		Create range
Name	Extends into deck	Start distance (ft)	Number of spaces	Spacing (in)	Length (ft)	End distance (ft)	
Wizard Sti $$	<ul> <li>Image: A set of the set of the</li></ul>	0.25	1	0	0	0.25	í
Wizard Sti $$		0.25	19	6	9.5	9.75	
Wizard Sti $$		9.75	2	4.7	0.783333	10.533333	
Wizard Sti $$		10.533333	34	8.5	24.083333	34.616666	
Wizard Sti $$		34.616667	2	14.3	2.383333	37	
Wizard Sti $$		37	18	24	36	73	
Wizard Sti 🗸 🗸		73	2	14 3	2 282222	75 383333	

The results are displayed in the PS Shear Reinforcement Ranges window as shown below.



#### Schematic – Structure Typical Section

A schematic view of the member alternative can be viewed by selecting the member alternative **Member Alternative** #2 (9.9.6) node in **the Bridge Workspace** tree and clicking on the **Schematic** button from the **WORKSPACE** ribbon (or by right clicking on the **Member Alternative** #2 (9.9.6) node and selecting **Schematic** from the menu) as shown below.



### Prestressed Concrete Control Options for BrDR - Consider splitting resistance

Double click on the member alternative **Member Alternative #2 (9.9.6)** in the **Bridge Workspace** tree to open the **Member Alternative Description** window and navigate to the **Control options** tab as shown below.



The user may select this option to consider the splitting resistance of the pretensioned anchorage zone as per **LRFD 5.9.4.4.1.** For this example, turn on the splitting resistance article in the control options for LRFD and run the LRFD analysis as shown below. In the spec check, open the **LRFD 5.9.4.4.1** article.

### LRFD Design Review

To perform an LRFD design review on the member alternative Member Alternative #2 (9.9.6), select the Analysis Settings button on the Analysis group of the DESIGN/RATE ribbon to open the window shown below.

Bridge Workspace - PCITrainingBridge6	ANALYSIS	REPORTS	?	-	×
BRIDGE WORKSPACE WORKSPACE TOOLS VIEW	DESIGN/RATE	REPORTING			^
Analysis Settings Analysis Analysis Analysis Analysis Analysis	ults Save Results				

Select the Design Review button, LRFD as the Design method and HL-93 (US) vehicle in Design Loads as shown

below.

Analysis Settings	- 🗆 X
Design review     C Rating	Design method:
Analysis type: Line Girder  Lane / Impact loading type: As Requested Vehicles Output Engine Description	Apply preference setting: None
Traffic direction: Both directions	Refresh Temporary vehicles Advanced
	Add to Remove from <<
Reset Clear Open template Save te	mplate OK Apply Cancel

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



Next click the Analyze button on the Analysis group of the DESIGN/RATE ribbon to perform the rating.

#### Specification Check Details

The specification checks can be viewed by selecting the **Specification Check Detail** button from the **Results** group of the **DESIGN/RATE** ribbon.

Bridge Workspace - PCITrainingBridge6	ANALYSIS	REPORTS	?	-	×
BRIDGE WORKSPACE WORKSPACE TOOLS VIEW	DESIGN/RATE	REPORTING			^
Analysis Settings Analysis Ana	ults Save ph Results				

Expand the Stage 1 node in the Superstructure Component tree and select Span 1 - 0.00 ft. Double-click on the article 5.9.4.4.1 Splitting Resistance to open the article details.

A Specification Cl	necks for Memb	er Alternative #2	(9.9.6	) - 9 of 1766			- 🗆	×
Properties Specification filter	Generate	Articles All articles Format Bullet list Report	~					
🔺 🚞 Superstruct	ure Component		^	Specification reference	Limit State	Flex. Sense	Pass/Fail	
Prestress Calculations				5.4.2.5 Poisson's Ratio		N/A	General Comp.	
🔺 🚞 Stage 1				5.4.2.6 Modulus of Rupture		N/A	General Comp.	
🔺 🚞 Men	Member Alternative #2 (9.9.6)			5.4.2.8 Concrete Density Modification F	actor	N/A	General Comp.	
🔁 S	Span 1 - 0.00 ft.			5.6.2.2 Rectangular Stress Distribution		N/A	General Comp.	
🔲 S	Span 1 - 11.00 ft			✓ 5.9.2.3.1a Compressive Stresses		N/A	Passed	
🚞 S	Span 1 - 22.00 ft			<ul> <li>5.9.2.3.1b Tensile Stresses</li> </ul>		N/A	Passed	
i i i i i i i i i i i i i i i i i i i	Span 1 - 33.00 ft			× 5.9.4.4.1 Splitting Resistance		N/A	Failed	
E S 🗐	Span 1 - 44.00 ft			PS_Basic_Properties Calculation		N/A	General Comp.	
i i i i i i i i i i i i i i i i i i i	Span 1 - 55.00 ft			Strand Stress Calculations		N/A	General Comp.	
i i i i i i i i i i i i i i i i i i i	Span 1 - 66.00 ft							
🚞 S	Span 1 - 77.00 ft							
📋 S	Span 1 - 88.00 ft							
i i i i i i i i i i i i i i i i i i i	Span 1 - 99.00 ft							
🗀 S	Span 2 - 1.00 ft.							
<u> </u>	Span 2 - 1.70 ft.		~					

```
B Spec Check Detail for 5.9.4.4.1 Splitting Resistance
                                                                                                                                   \times
 5 Concrete Structures
 5.9 Prestressing
 5.9.4 Details for Pretensioning
  5.9.4.4 Pretensioned Anchorage Zones
5.9.4.4.1 Splitting Resistance
  (AASHTO LRFD Bridge Design Specifications, Ninth Edition)
  PS I Wide - At Location = 0.0000 (ft) - Right
                                                               Stage 1
  INPUT:
 Prestressed beam type: PS Beam I Wide
 Prestressed beam type:PS Beam I WideArea of shear reinforcing,As =1.2000 (in^2)Area of prestressing strands,Aps =6.7320 (in^2)Jacking stress,fj =202.5000 (ksi)Initial losses,ES Loss =18.7478 (ksi)Stress in strands at transfer,fpt =183.7522 (ksi)h=72.0000 (in)
 SUMMARY:
                                                              20.0000 (ksi)
24.0000 (kip)
 Maximum stress allowed in reinforcing,
                                                      fs =
 Force in strands at transfer, Fpt = fpt * Aps = 1237.0200 (kip)
 DR =
 Design ratio,
                                                                     0.485
 Status
                                                                                                                              OK
```

As is the area of steel within the distance from h/4 from the end of beam. The area of steel in this zone needs to be increased.

 $P_{ru} = 54.53 \ kips = f_s * A_s$   $A_s \ge 2.73 \ in^2$   $h/4 = 72 \ in / 4 = 18 \ in$ We have 3 #4 stirrups within the distance of h/2 at 6 in spacing.  $A_s = 3 * 0.20 \ in^2 * 2 \ legs = 1.2 \ in^2$ As of each bar = 2.73 in<sup>2</sup> / 3 = 0.91 in<sup>2</sup> for 6 in spacing or use 3 #7 bars or As = 3.6 in<sup>2</sup>.
As of each bar = 2.73 in<sup>2</sup> / 5 = 0.55 in<sup>2</sup> for 4 in spacing or use 5 #5 bars or As = 3.1 in<sup>2</sup>.

The #5 bars at 4 inches over 16 inches from the first stirrup will be used. The stirrups will be pushed 1 inch closer to the end of the beam to ensure the stirrups fall within the h/4 distance.

Navigate back to the Stirrup design tool in Shear Reinforcement Ranges window and enter the following data.

A Shear Stirrup Design Tool				×			
Distance to first stirrup:     3.00       Maximum jump in spacing between ranges:	000 in	Number of stirrup definitions  Use 1 stirrup definition  Use 2 stirrup definitions					
Override maximum allowable spacing:	Definition 1 minimum range length: ft						
Stirrup entry method Use existing stirrup definition Create new stirrup definition Stirrup definition 1	Extends into deck	└─ Stirrup definition 2 ──					
Existing stirrup definition Vertical shear reinf def: #4 Shear Reinf.	~	Existing stirrup definition Vertical shear reinf def: #4 Shear Reinf.					
New stirrup definition		New stirrup definition					
Material: Grade 60	~	Material:	Grade 60	$\sim$			
Bar size: 7	~	Bar size:	3	$\sim$			
Number of legs: 2.00		Number of legs:					
Inclination (alpha): 90.0 Degree	25	Inclination (alpha):	90.0	Degrees			
				Continue Cancel			

# Set the **Minimum number of stirrups per range** to **5**. **Create ranges** and **Apply** the ranges to all 3 spans.

	shear reinforcem	nent defi	nition 1 nan	ne: Wizaro	l Stirrup 2				
ical	shear reinforcem	nent defi	nition 2 nan	ne:					
n: 🗌	1 🗸	'							
	ired stirrup spaci	ng							
- qui									
	Location (ft)	Vu (kip)	(ki	c (a	Vp (kip)	smax (in)	S	req (in)	
•	6.75	345.	85	178.57	40.51	24.0	00	24.00	
	11.40	316.	73 .	177.88	40.51	24.0	00	24.00	[
	22.30	250.	42 .	162.54	40.51	24.0	00	24.00	
	33.20	186.	47 <sup>·</sup>	107.96	0.00	24.0	00	24.00	
	44.10	125.	26	90.69	0.00	24.0	00	24.00	
	55.00	-124.	73	88.78	0.00	24.0	00	24.00	
	65.90	-186.	60	97.93	0.00	24.0	00	24.00	
	76.80	-248.	37 .	156.79	0.00	24.0	00	24.00	
	87.70	-309.	62 <sup>·</sup>	162.54	40.51	12.0	00	12.00	
	98.60	-369	96 <sup>.</sup>	177.88	40.51	12.0	00	12.00	
ono	rated ranges —								
laxi	mum number rai	nges per	span: 3	<b>~</b>	/linimum sti	rrups per ra	ange:	5	Create ranges
1axi	mum number rai	nges per	span: 3 Extends into deck	Start distance (ft)	Ainimum stir Number of spaces	rrups per ra Spacing (in)	Length (ft)	5 C End distance (ft)	Create ranges
1axi	mum number rai Name Vizard Stirrup 2	nges per	Extends into deck	Start distance (ft) 0.25	Vinimum stir Number of spaces 1	rups per ra Spacing (in) 0.0000	Length (ft) 0.00	5 C End distance (ft) 0.25	Create ranges
1axi V	num number rai Name Vizard Stirrup 2 Vizard Stirrup 2	nges per	span: 3 Extends into deck	Start distance (ft) 0.25 0.25	Ainimum stir Number of spaces 1 3	rrups per ra Spacing (in) 0.0000 6.0000	Length (ft) 0.00 1.50	5 C End distance (ft) 0.25 1.75	Create ranges
V V V	Name Nizard Stirrup 2 Vizard Stirrup 2 Vizard Stirrup 2	nges per	Extends into deck	Start distance (ft) 0.25 0.25 1.75	Ainimum stii Number of spaces 1 3 2	Spacing (in) 0.0000 6.0000 4.5000	Length (ft) 0.00 1.50 0.75	5 C End distance (ft) 0.25 1.75 2.50	Create ranges
V V V V	Name Name Vizard Stirrup 2 Vizard Stirrup 2 Vizard Stirrup 2 Vizard Stirrup 2	nges per	span: 3 Extends into deck	Start           distance           (ft)           0.25           0.25           1.75           2.50	Ainimum stir Number of spaces 1 3 2 2 15	Spacing (in) 0.0000 6.0000 4.5000 6.0000	Length (ft) 0.00 1.50 0.75 7.50	5 C End distance (ft) 0.25 1.75 2.50 10.00	Create ranges
V V V V V	Name Nizard Stirrup 2 Vizard Stirrup 2 Vizard Stirrup 2 Vizard Stirrup 2 Vizard Stirrup 2 Vizard Stirrup 2	nges per	span: 3 Extends into deck	Start           distance           (ft)           0.25           0.25           1.75           2.50           10.00	Ainimum stir Number of spaces 1 3 2 15 2 2	Spacing (in) 0.0000 6.0000 4.5000 6.0000 7.2000	Length (ft) 0.00 1.50 0.75 7.50 1.20	5 C End distance (ft) 0.25 1.75 2.50 10.00 11.20	Create ranges
V V V V V V V	Name Name Vizard Stirrup 2 Vizard Stirrup 2 Vizard Stirrup 2 Vizard Stirrup 2 Vizard Stirrup 2 Vizard Stirrup 2 Vizard Stirrup 2	nges per	span: 3 Extends into deck V V V V	Start         M           Start         distance           (ft)         0.25           0.25         1.75           2.50         10.00           11.20         11.20	Ainimum stir Number of spaces 1 3 2 15 2 2 2 3	Spacing (in)           0.0000           6.0000           4.5000           6.0000           7.2000           12.0000	Length (ft) 0.00 1.50 0.75 7.50 1.20 23.00	5 C End distance (ft) 0.25 1.75 2.50 10.00 11.20 34.20	Create ranges
V V V V V V V V V V V V V V V V V V	Name Nizard Stirrup 2	nges per	span: 3 Extends into deck	Start           Start           distance           (ft)           0.25           0.25           1.75           2.50           10.00           11.20           34.20	Animum stir Number of spaces 1 3 2 15 2 2 2 3 2 3 2 3 2 2	Spacing (in)           0.0000           6.0000           4.5000           6.0000           7.2000           12.0000           16.8000	Length (ft) 0.00 1.50 0.75 7.50 1.20 23.00 2.80	5 C End distance (ft) 0.25 1.75 2.50 10.00 11.20 34.20 37.00	Create ranges
V V V V V V V V V V V V V V V V V V V	Milea Hangeo mum number rai Name Vizard Stirrup 2 Vizard Stirrup 2	nges per	span: 3 Extends into deck	Start           Start           distance           (ft)           0.25           0.25           1.75           2.50           10.00           11.20           34.20           37.00	Ainimum stir Number of spaces 1 3 2 15 2 2 3 2 2 3 2 18	Spacing (in)           0.0000           6.0000           4.5000           6.0000           7.2000           12.0000           16.8000           24.0000	Length (ft) 0.00 1.50 0.75 7.50 1.20 23.00 2.80 36.00	5 C End distance (ft) 0.25 1.75 2.50 10.00 11.20 34.20 37.00 73.00	Create ranges
V V V V V V V V V V V V V V V V	Mame Name Name Vizard Stirrup 2 Vizard Stirrup 2	nges per	span: 3 Extends into deck V V V V V V V V V V V V	Start           Start           distance           (ft)           0.25           0.25           1.75           2.50           10.00           11.20           34.20           37.00           73.00	Animum stir Number of spaces 1 3 2 15 2 2 3 2 3 2 3 2 3 2 3 2 3 2 3 2 3 2 3	Spacing (in)           0.0000           6.0000           4.5000           6.0000           7.2000           12.0000           16.8000           16.8000	Length (ft) 0.00 1.50 0.75 7.50 1.20 23.00 2.80 36.00 2.80	5 C End distance (ft) 0.25 1.75 2.50 10.00 11.20 34.20 34.20 37.00 73.00	Create ranges

Rerun the AASHTO LRFD analysis and check the specification article LRFD 5.9.4.4.1 at Span 1 – 0.0' for Stage 1.

Spec Check Detail for 5.9.4.4.1 Splitting Resistance	-	_		Х
<pre>5 Concrete Structures 5.9 Prestressing 5.9.4 Details for Pretensioning 5.9.4.4 Pretensioned Anchorage Zones 5.9.4.4.1 Splitting Resistance (AASHTO LRFD Bridge Design Specifications, Ninth Edition) PS I Wide - At Location = 0.0000 (ft) - Right Stage 1 INPUT:</pre>				
Prestressed beam type:PS Beam I WideArea of shear reinforcing,As =3.6000 (in^2)Area of prestressing strands,Aps =6.7320 (in^2)Jacking stress,fj =202.5000 (ksi)Initial losses,ES Loss =18.7478 (ksi)Stress in strands at transfer, fpt =183.7522 (ksi)h=72.0000 (in)				
SUMMARY: Maximum stress allowed in reinforcing, fs = 20.0000 (ksi) Total resistance available, Pru = fs * As = 72.0000 (kip) Force in strands at transfer, Fpt = fpt * Aps = 1237.0200 (kip) Minimum resistance required, Pr = .04 * Fpt = 49.4808 (kip) Design ratio, DR = 1.455 Status = PASS				
			OK	

### Tensile rating in the top of the beam

This section compares LRFR rating results when tensile rating in the top of the beam is considered vs ignored.

#### Consider tensile rating in the top of the beam.

#### Member Alternative Description – Control options

Double click on the member alternative **Member Alternative #2 (9.9.6)** in the **Bridge Workspace** tree to open the **Member Alternative Description** window and navigate to the **Control options** tab as shown below. Uncheck the **Ignore tensile rating in top of beam** checkbox under **LRFR**.



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

### LRFR Analysis

To perform an **LRFR** rating, select the **Analysis Settings** button on the **Analysis** group of the **DESIGN/RATE** ribbon to open the window shown below.

Bridge Workspace - PCITrainingBridge6	ANALYSIS	REPORTS	?	-	×
BRIDGE WORKSPACE WORKSPACE TOOLS VIEW	DESIGN/RATE	REPORTING			^
Analysis Analysis Analysis Analysis Analysis	Ilts Save Results				



O Design review	Rating method:	LRFR	~	
alysis type: Line Girder 👻				
ne / Impact loading type: As Requested V	Apply preference setting:	None	~	
Vehicles Output Engine Description				
Traffic direction: Both directions	Refresh	Temporary vehicles	Advanced	
Vehicle selection	Vehicle summa	У		
<ul> <li>➡ Standard</li> <li>➡ EV2</li> <li>➡ EV3</li> <li>➡ H 15-44</li> <li>➡ H_L-93 (SI)</li> <li>➡ H_L-93 (US)</li> <li>➡ HS 15-44</li> <li>➡ HS 20 (SI)</li> <li>➡ HS 20 (SI)</li> <li>➡ HS 20.44</li> <li>\_ Lare Type Legal Load</li> <li>\_ LRFD Fatigue Truck (US)</li> <li>➡ NRL</li> <li>➡ SU4</li> <li>➡ SU5</li> <li>➡ SU6</li> <li>➡ SU7</li> <li>➡ Type 3-3</li> <li>➡ Type 3-3</li></ul>	Add to	ign load rating Inventory - HL-93 (US) Operating Tatigue al load rating Routine Specialized hauling nit load rating		

Click **OK** to save the analysis settings and close the window.

Next click the Analyze button on the Analysis group of the DESIGN/RATE ribbon to perform the rating.

Bridge Work	space - PCITrainingBridge6	ANALYSIS	REPORTS	?	-	×
BRIDGE WORKSPACE	WORKSPACE TOOLS VIEW	DESIGN/RATE	REPORTING			~
Analysis Settings Analysis Analysis	Tabular Specification Engine Res Results Check Detail Outputs Gra Results	ults Save aph Results				

#### Specification Check Details

Once the analysis is complete, the specification checks can be viewed by selecting the **Specification Check Detail** button from the **Results** group of the **DESIGN/RATE** ribbon.



Expand the **Stage 3** node in the **Superstructure Component** tree and select **Span 1 – 99.00 ft**. Double-click on the article **6A.4.2.1 Design Load Rating Prestress Service III Tensile Stress** to open the article details.



Ignore tensile rating in the top of the beam.

Member Alternative Description - Control options

Double click on the member alternative Member Alternative #2 (9.9.6) in the Bridge Workspace tree to open the Member Alternative Description window and navigate to the Control options tab as shown below. Check the Ignore tensile rating in top of beam checkbox under LRFR.



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

## LRFR Analysis

Re-run the **LRFR analysis** as described in the previous section and compare the same specification article **6A.4.2.1 Design Load Rating Prestress Service III Tensile Stress.** at the same location. (See image below.)

	4.4.2.1 Design Load F	Rating Prestress S	Service III Ten	sile Stress						— C	
6A Load and Resista 6A.4 Load Rating Pr 6A.4.2 General Load 6A.4.2.1 Design Loa (AASHTO Manual for	nce Factor Rat: cocedures 1-Rating Equation ad Rating Prest: Bridge Evaluat:	ing on ress Service ion, Third E	III Tens: dition wit	ile Stress th 2023 Int	cerims)						
PS I Wide - At Loca	ation = 99.0000	(ft) - Left	Stage	e 3							
Service III Invento	ory Level Rating	g Factor Cal	culations								
input:											
ígnore tensile rati	ng in top of be	eam: Yes									
Bot DC Stress = Top DC Stress = Bot DW Stress = Top DW Stress = Bot DW_WS Stress = Top DW_WS Stress =	0.7473 (ksi) -0.7601 (ksi) -0.1008 (ksi) 0.0319 (ksi) 0.0000 (ksi 0.0000 (ksi	i) i)									
Compute Resistance:											
<pre>fR = abs(Compressiv</pre>	ve fpb) + ft all	low									
ft allow = 0.	5027 (ksi)										
ft allow = $0.$ fpb (Bot) = $-2.$	5027 (ksi) 8773 (ksi)										
ft allow = 0. fpb (Bot) = -2.	5027 (ksi) 8773 (ksi)				Load Fac	tors					<b>`</b>
ft allow = 0. Tpb (Bot) = -2. Load Load Combo	5027 (ksi) 8773 (ksi) d Limit o State Loc	LL (ksi)	Adj. LL (ksi)	DC	Load Fac	tors DW_WS	LL	fR (ksi)	RF	Capacity (Ion)	
ft allow = 0. fpb (Bot) = -2. Load Load Combo DesignInv 1 DesignInv 2 DesignInv 3	5027 (ksi) 8773 (ksi) i Limit o State Loc SER-III Bot SER-III Bot	LL (ksi) 0.23 0.26 0.00	Adj. LL (ksi)  	DC 1.00 1.00 1.00	Load Fac DW 1.00 1.00 1.00	DW_WS 1.00 1.00 1.00	LL 0.80 0.80 0.80 0.80	fR (ksi) 3.38 3.38 3.38 3.38	RF 14.738 13.088 99.000	Capacity (Ton) 530.57 471.15 3564.00	
ft allow = 0. fpb (Bot) = -2. Load Load Combo DesignInv 1 DesignInv 2 DesignInv 3 Legend: NA - Resistance and Load Combination Le Code Vehicle	5027 (ksi) 8773 (ksi)	LL (ksi) 0.23 0.26 0.00 of opposite	Adj. LL (ksi)  sign so y	DC 1.00 1.00 1.00	Load Fac DW 1.00 1.00 1.00	DW_WS 1.00 1.00 1.00	LL 0.80 0.80 0.80 ble.	fR (kst) 3.38 3.38 3.38 3.38	RF 14.738 13.088 99.000	Capacity (Ton) 530.57 471.15 3564.00	

Flowcharts for PS Stirrup Design Tool









## C. Simplified Vci, Vcw Procedure to Compute Vc







fs = service stress in the stirrup steel, limited to 20ksi

For I beams:

As is the total area of vertical reinforcement within h/4 from the end of member where h = height of beam.

For box beams with no voids or circular voids:

As is the total area of horizontal reinforcement within h/4 from the end of member where h = overall width of beam. Opis will assume that each vertical leg of stirrup contributes 1 horizontal leg of reinforcement.

For box beams:

As is the area of vertical or horizontal reinforcement within h/4 from the end of member where h = min(overall height, overall width) of beam. Opis will assume that each vertical leg of stirrup contributes 1 horizontal leg of reinforcement.

Pr is evaluated twice:

once for the Aps in the bottom flange and the horizontal As

and once for the Aps above the bottom flange and the vertical As

For U beams:

As is the area of vertical or horizontal reinforcement within h/4 from the end of member where h = min(overall height, overall width) of beam. Opis will assume that 2 vertical legs of stirrup contributes 1 horizontal leg of reinforcement.

Pr is evaluated twice:

once for the Aps in the bottom flange and the horizontal As

and once for the Aps above the bottom flange and the vertical As

For T beams:

As is the total area of vertical reinforcement within h/4 from the end of member where h = overall height of beam.

fpbt = stress in prestress steel at transfer (= jacking stress without losses)

Aps = area of prestressing steel, does not take into account the reduced area at the CL bearing due to transfer and development length



Figure C5.10.10.1-1—Precast Trapezoidal Tub Girder







