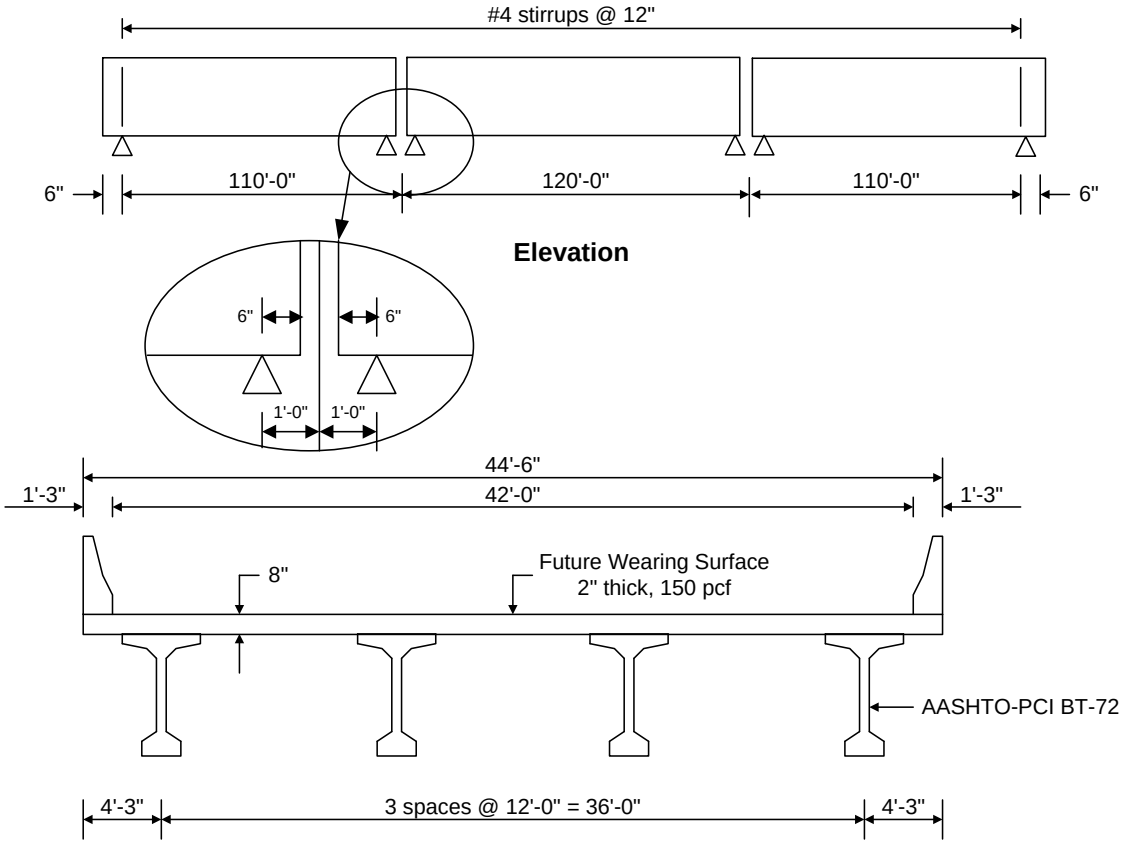
*AASHTOWare BrD 6.8*

# *BrR and BrD Tutorial*

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

**PS10 - Three Span Prestressed I Beam Stirrup Design Example (BrDR 6.8)**

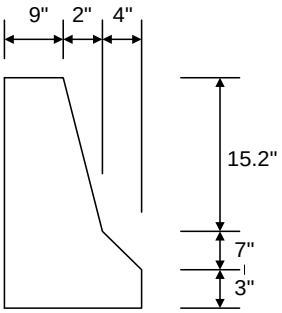



**Elevation**

**Typical Section**

**Material Properties**

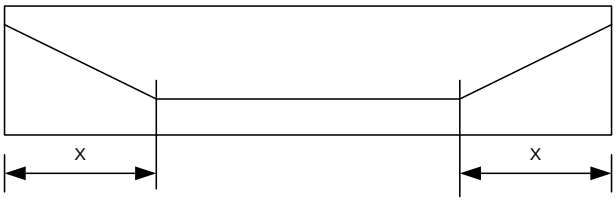
Beam Concrete: f'c = 7.0 ksi, f'ci = 5.5 ksi
Deck Concrete: f'c = 4.0 ksi
Prestressing Strand: 1/2" dia., 7 Wire strand, Fu = 270 ksi, Low Relaxation




Weight = 300 plf

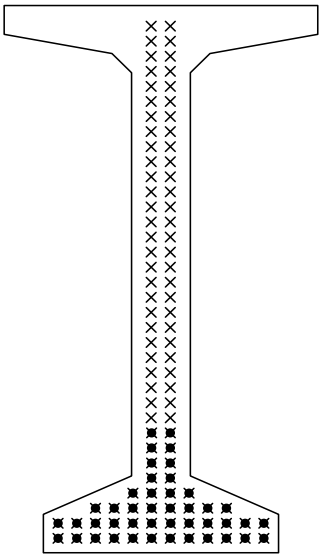
**Parapet Detail**

**Draped Strands**

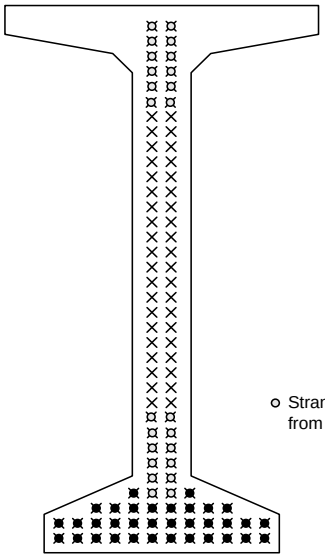



X = 32.00 ft (End Spans)
X = 35.50 ft (Mid Span)

**Strand Pattern for all Spans**



**Strand Pattern at Mid-Span**



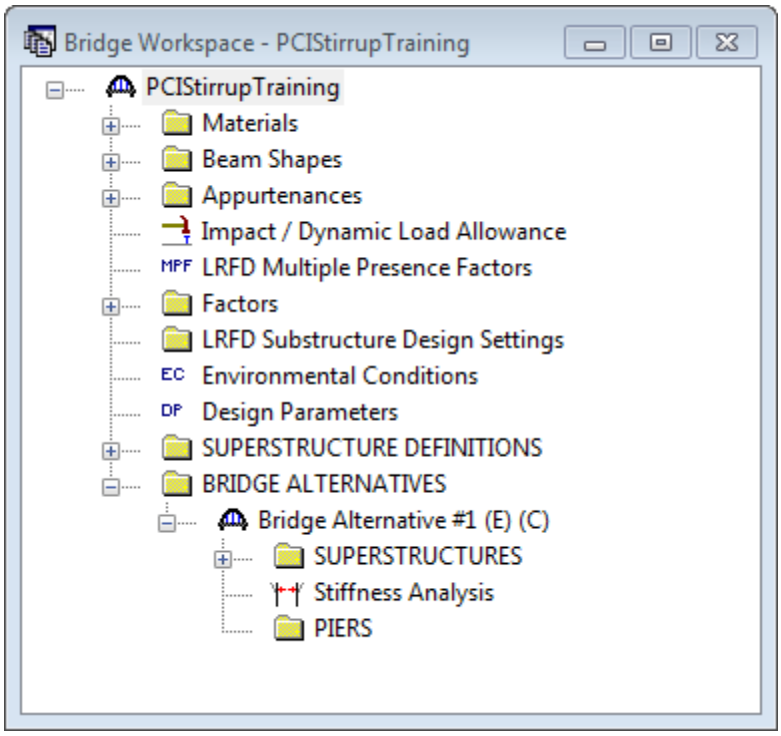
**Strand Pattern at End of Beam**

o Strand harped at 48.5' from end of beam

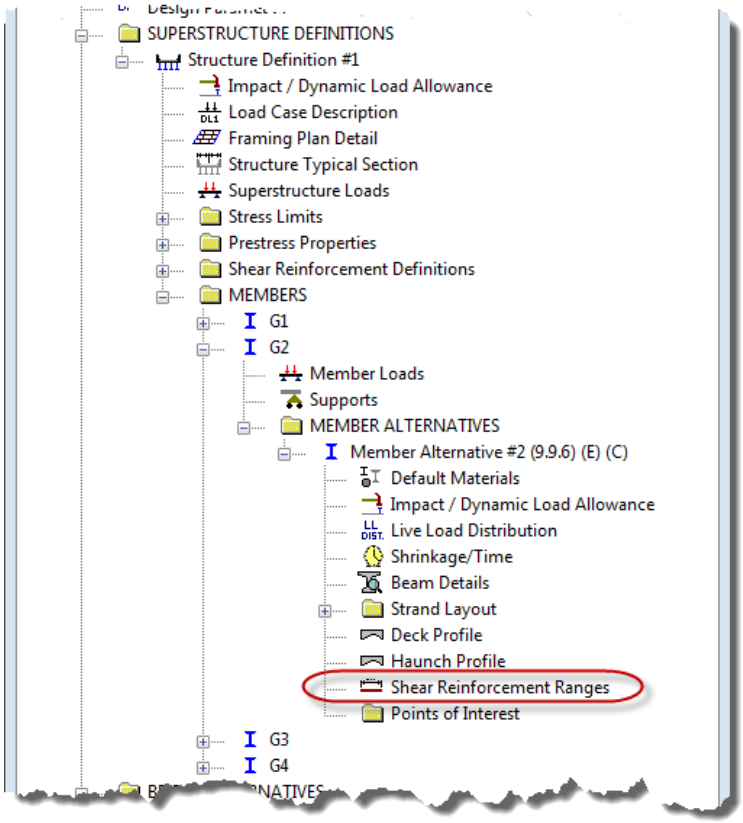
# BrR and BrD Training

## PS10 - Three Span Prestressed I Beam Stirrup Design Example

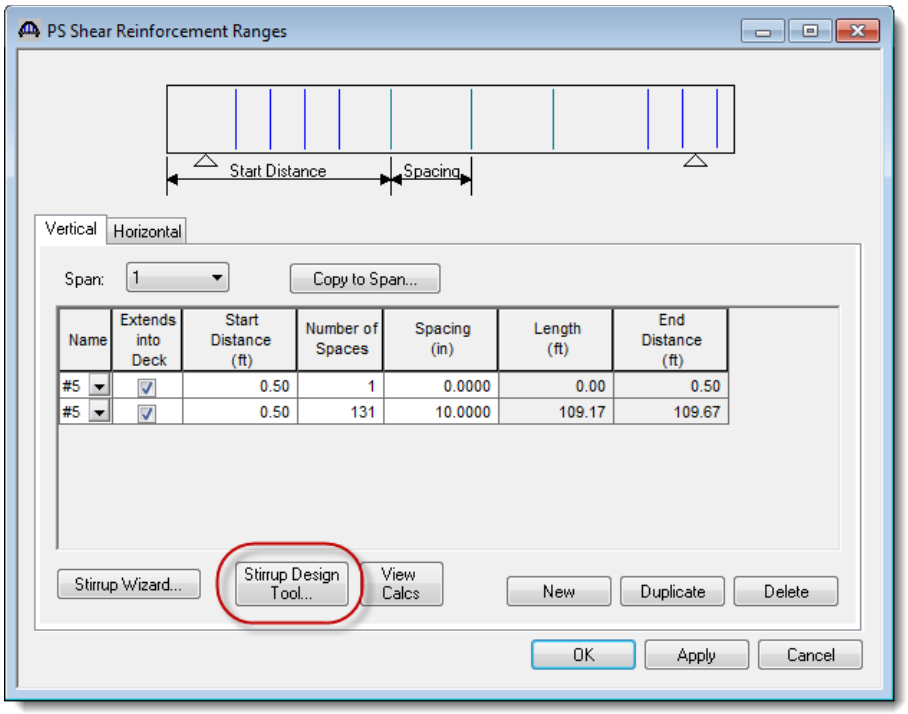
From the Bridge Explorer open the bridge PCITrainingBridge6 (BID 9).



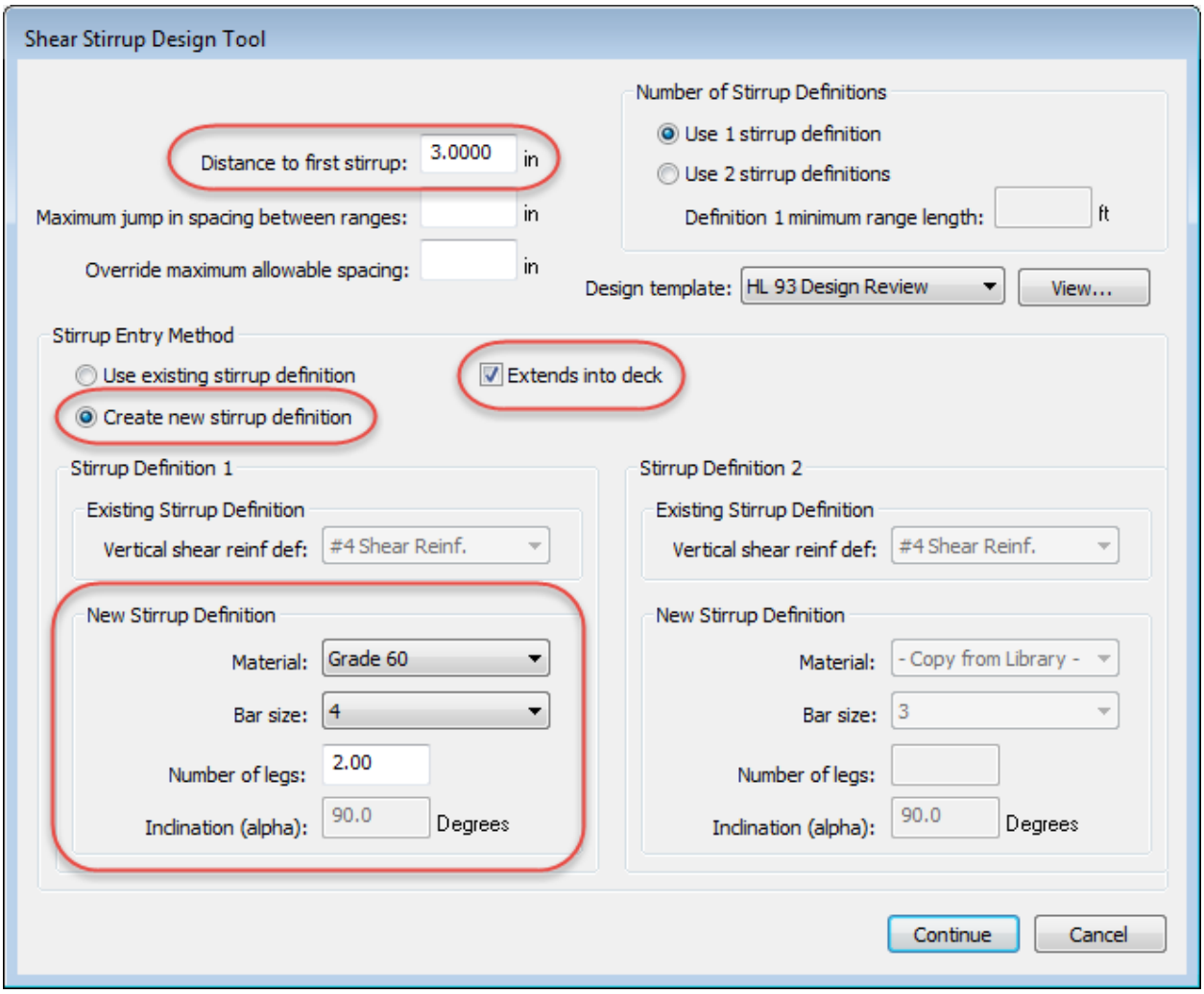

Expand the SUPERSTRUCTURE DEFINITIONS tree, and then expand the Structure Definition #1. Expand MEMBERS, then expand MEMBER ALTERNATIVES and finally expand Member Alternative #2.




Open the Shear Reinforcement Ranges to begin work on having BrD design the shear stirrup ranges. Click on the Stirrup Design Tool button.



The Shear Stirrup Design Tool dialog comes up.




Referring to the dialog box, let us go through the options and explain. 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. In this example, we will enter 3 inches.

**Maximum jump in spacing between ranges**

The maximum jump in stirrup spacing that the module assumes from one range to the next. If this value is not input, the default is taken as 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. For our example, we will leave this blank.

**Override maximum allowable spacing**

Enter a value for the desired maximum spacing of shear stirrups. If left blank, the software will use LRFD Article 5.8.2.7 to compute max allowable spacing. We will let the software 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. Our example will use 1 stirrup definition.

**Definition 1 minimum range length**

This range is the minimum distance from end of beam over which 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 we are using one stirrup definition, we need not consider this.

**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. We will have the design tool create a new definition for us.

**Extends into deck**

Check this box if the reinforcing bars extend into the concrete deck. In our design, we will extend the stirrups into the deck.

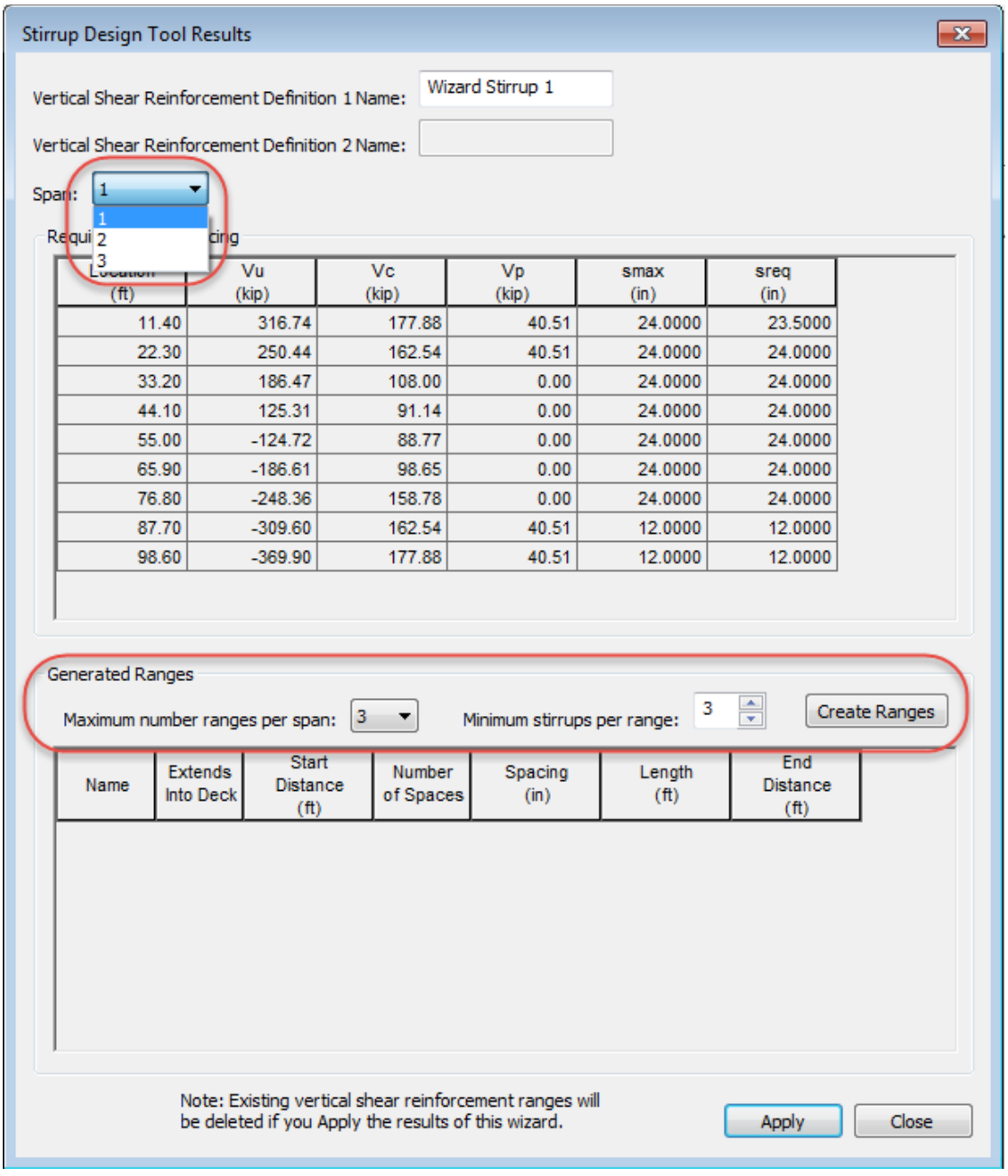
**Stirrup Definition (1 or 2)**

Under each of the Existing Stirrup Definition sections, select an existing Vertical Shear Reinforcement Definition from the drop list. This is available when the "Use existing stirrup definition" radio button is selected.

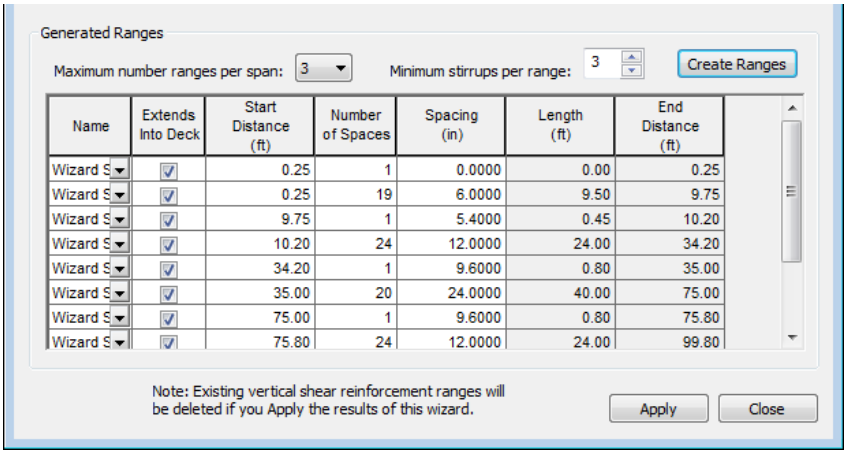
**New Stirrup Definition**

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 our example, we will use the provided 60 grade steel and will use #4 bars that have 2 legs.
Press Continue after entering the data for the example. The analysis will run and computed the required stirrup spacing at each tenth point and critical dv point.

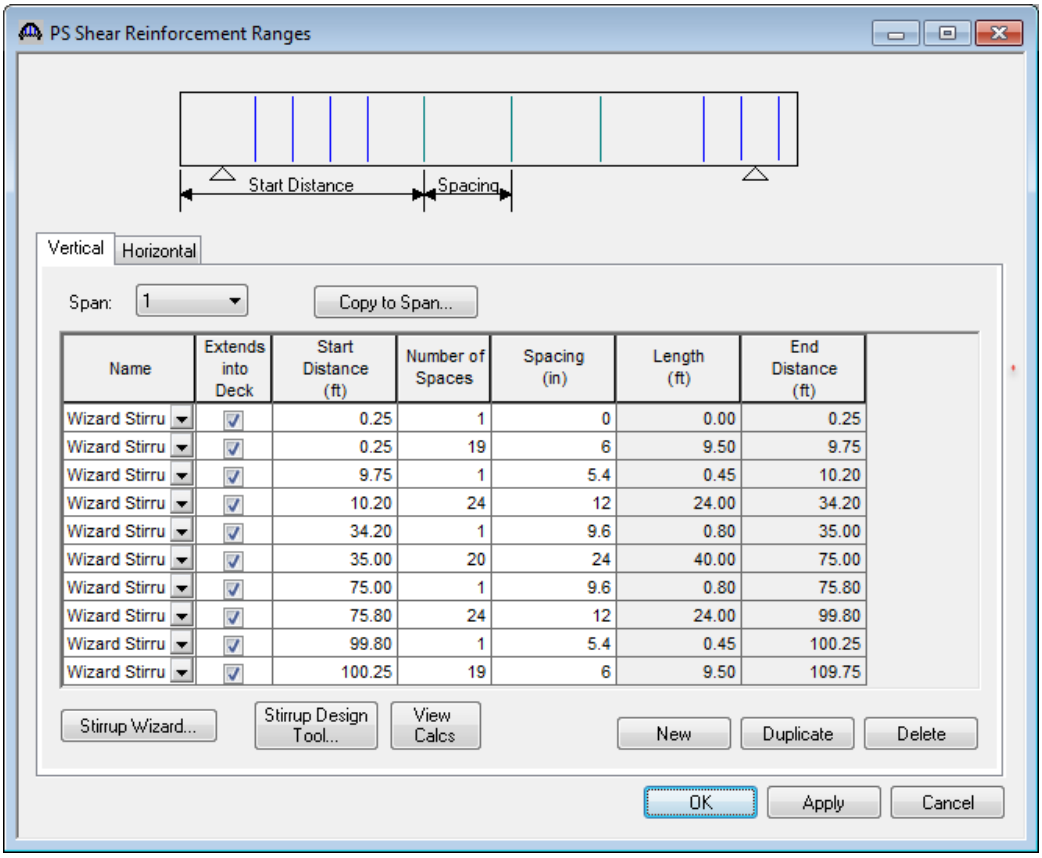
The Stirrup Design Tool Result dialog will appear.



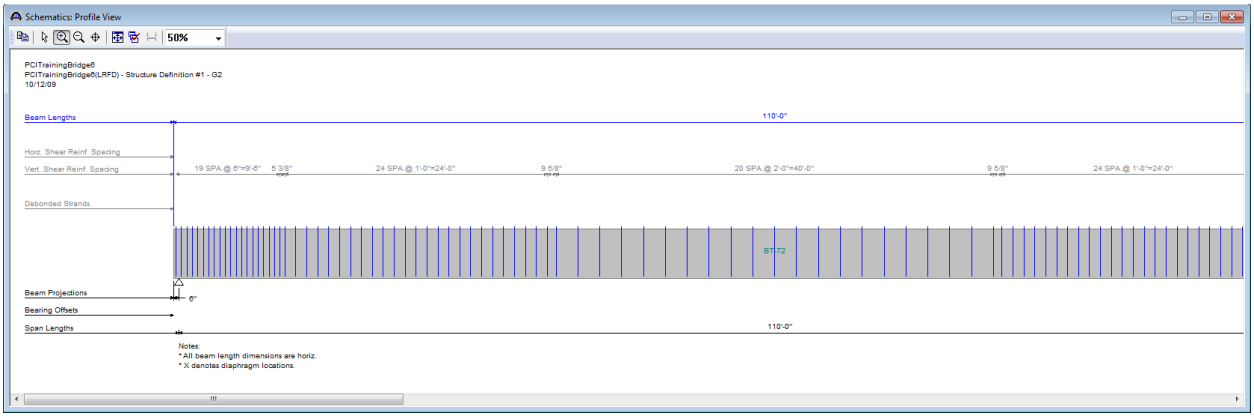
The dialog above has a table showing the required stirrup spacing at each analysis location throughout the beam for each span. The user can select the span from the drop-down list and see the results for each span. Using the results from the analysis the user can construct the desired stirrup layout scheme by selecting the maximum number of ranges and the number of minimum number of stirrups per range. In our case, we will use the default three ranges and require we have at least three stirrups per range. For each span, press Create Ranges and hit Apply. Once completed, Close the dialog.



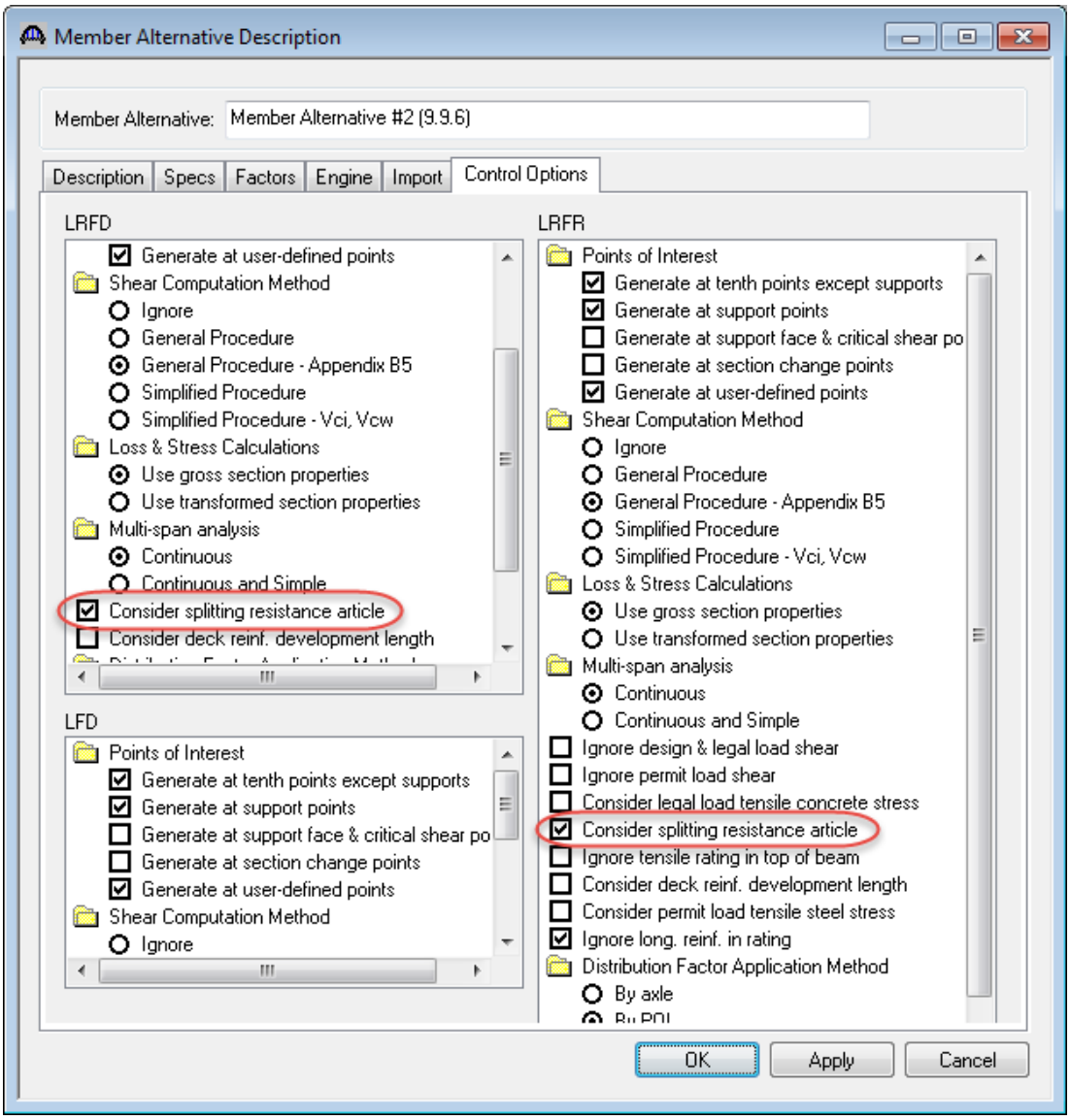

The results are displayed in the PS Shear Reinforcement Ranges dialog.



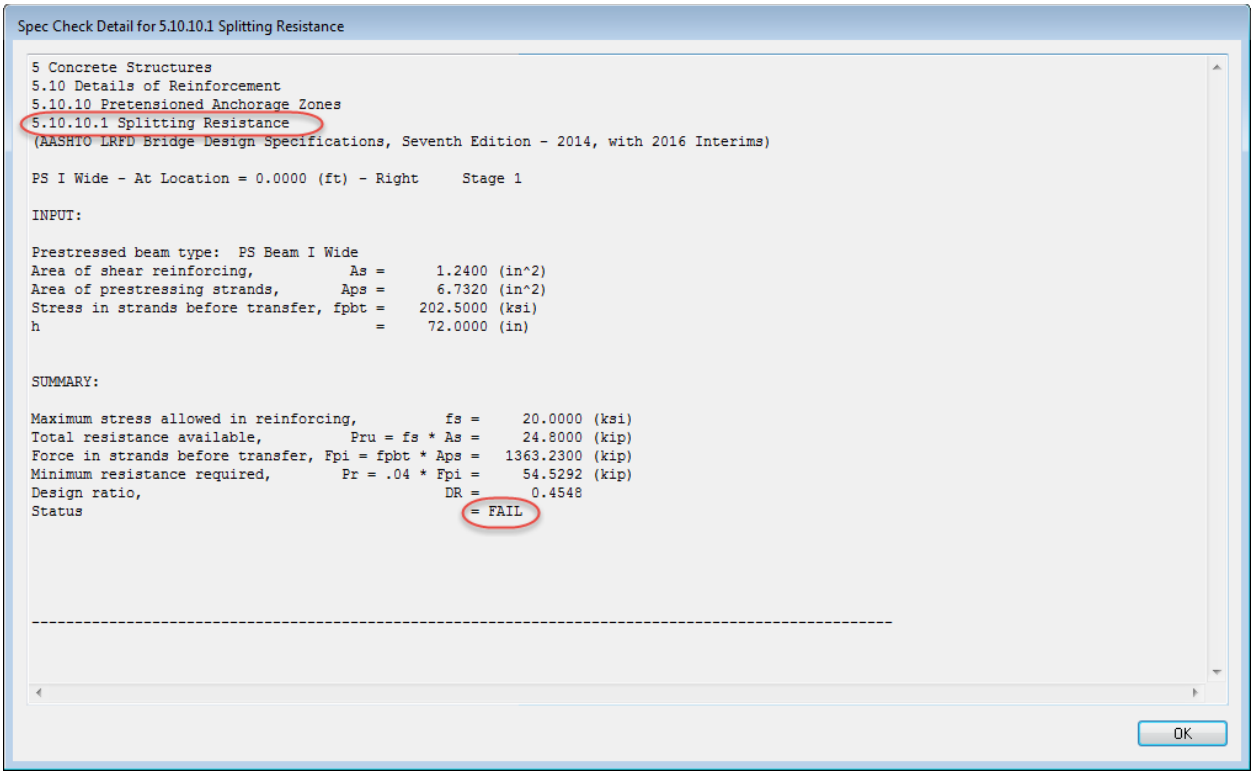
Look at the schematic of the beam.




**Prestressed Concrete Control Options for BrR BrD - Consider Splitting Resistance**



The user may select this option to consider the splitting resistance of the pretensioned anchorage zone as per LRFD 5.10.10.1. For this example turn on the splitting resistance article in the control options for LRFD and run the analysis. In the spec check, open the LRFD 5.10.10.1 article.




'As' is the area of steel within the distance from h/4 from the end of beam. We need to increase the area of steel in this zone.

Pru = 54.53 kips = fs x As.

As ≥ 2.73 in².

h/4 = 72 in / 4 = 18 in.

We have 3 #4 stirrups within the distance of h/2 at 6 in spacing.

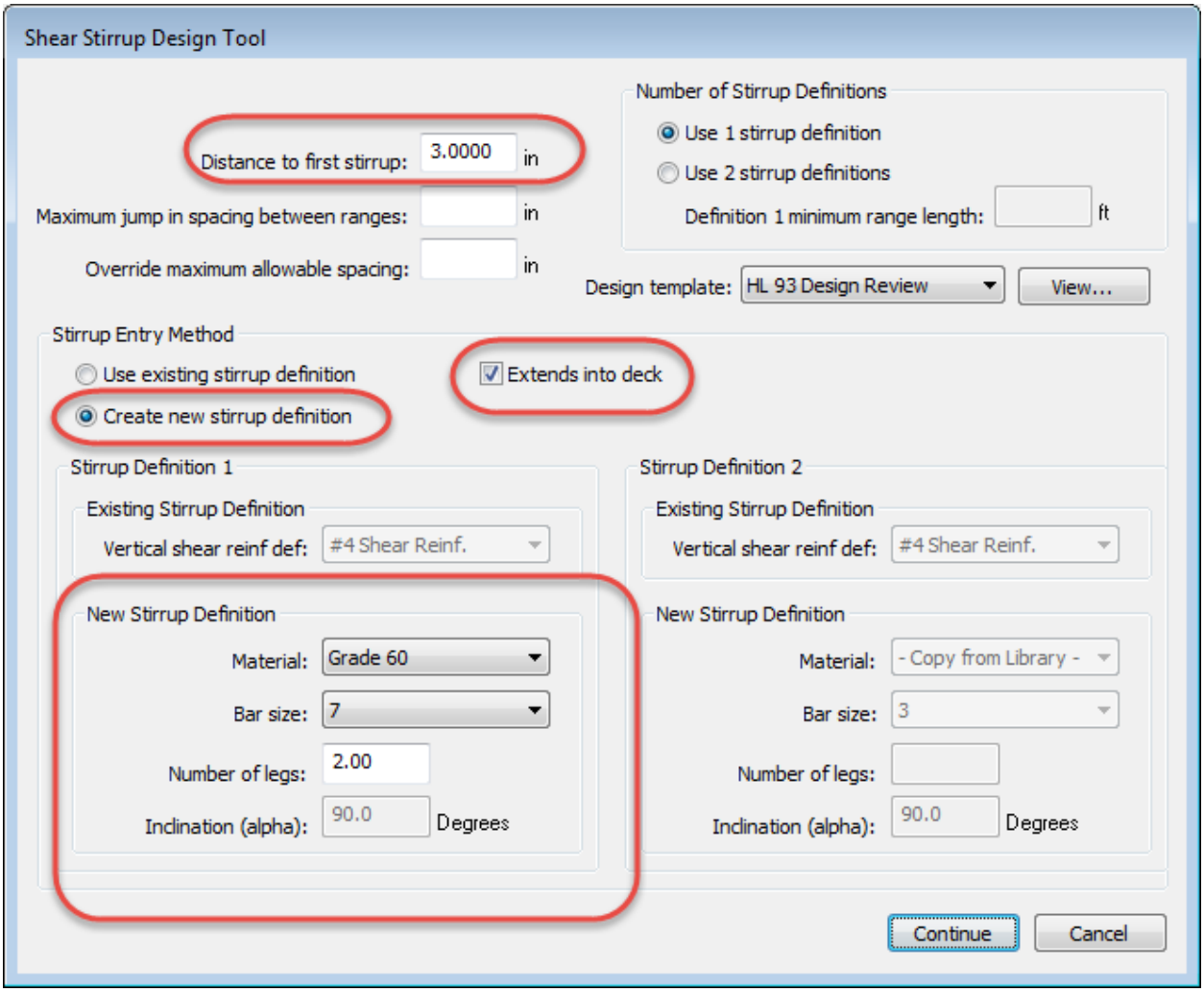
As = 3 x 0.20 in² x 2 legs = 1.2 in²

As of each bar = 2.73 in² / 3 = 0.91 in² for 6 in spacing or use 3 #7 bars or As = 3.6 in².

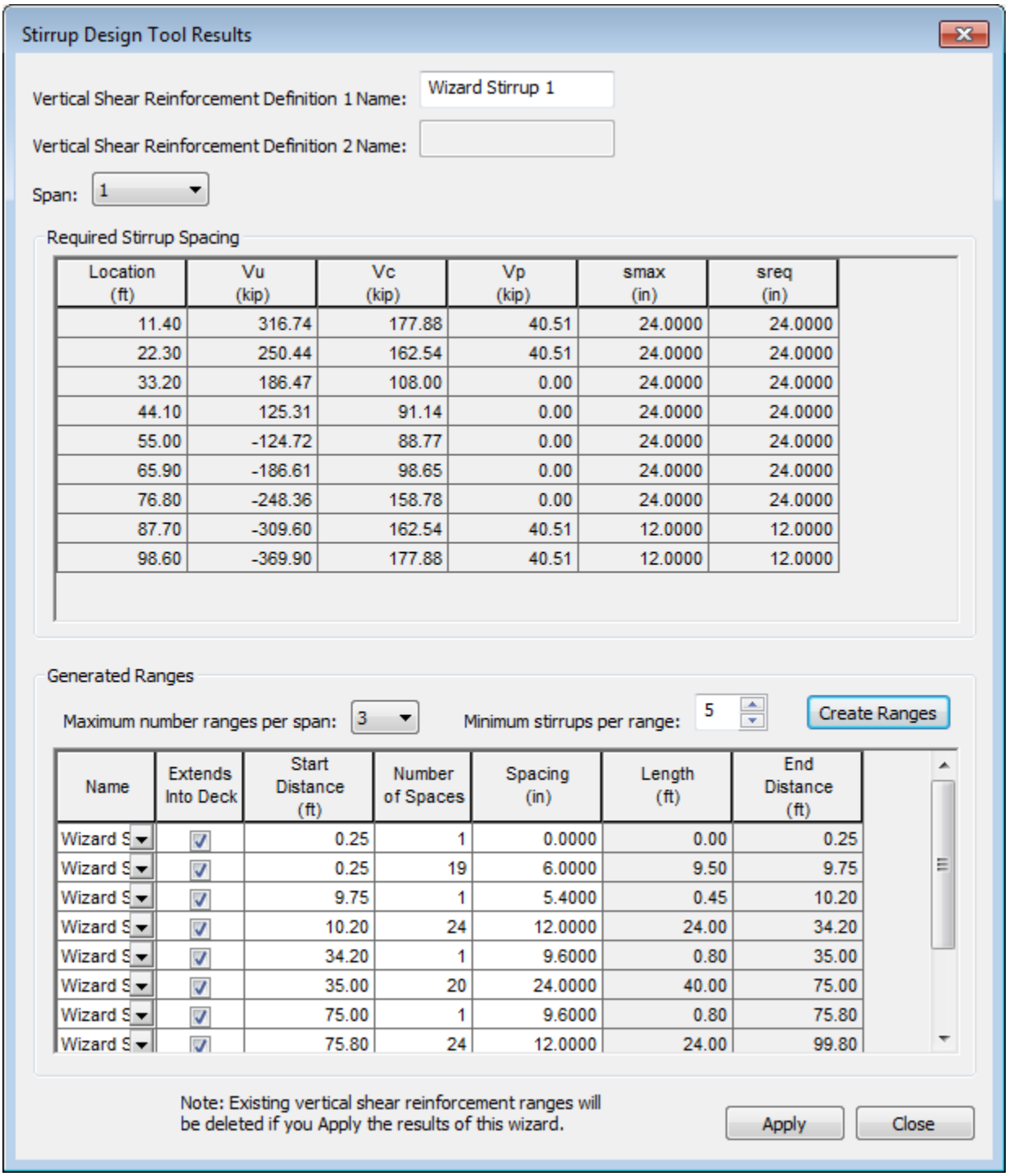
As of each bar = 2.73 in² / 5 = 0.55 in² for 4 in spacing or use 5 #5 bars or As = 3.1 in².

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

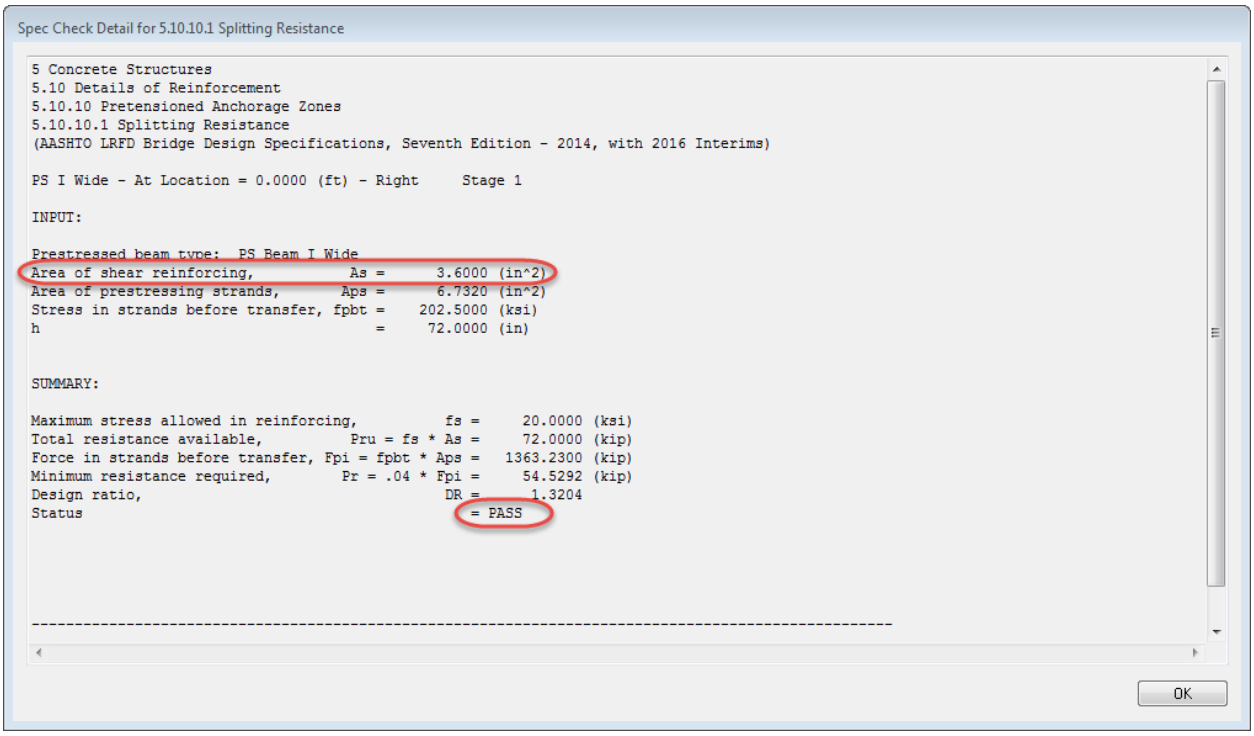
Go back to the Stirrup design tool and enter the following:



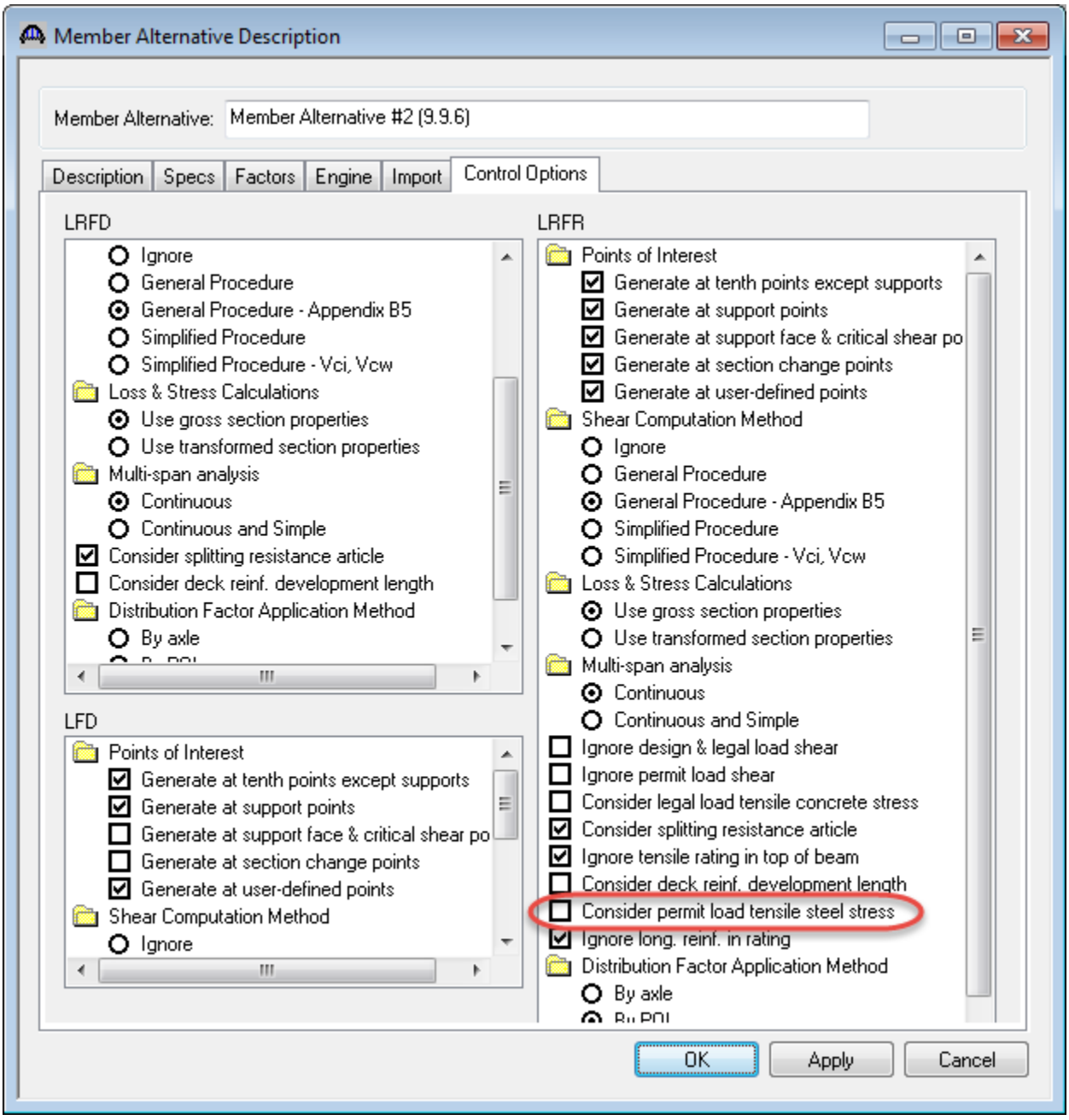
Set the minimum number of stirrups per range to 5. Create and Apply the ranges to all 3 spans.



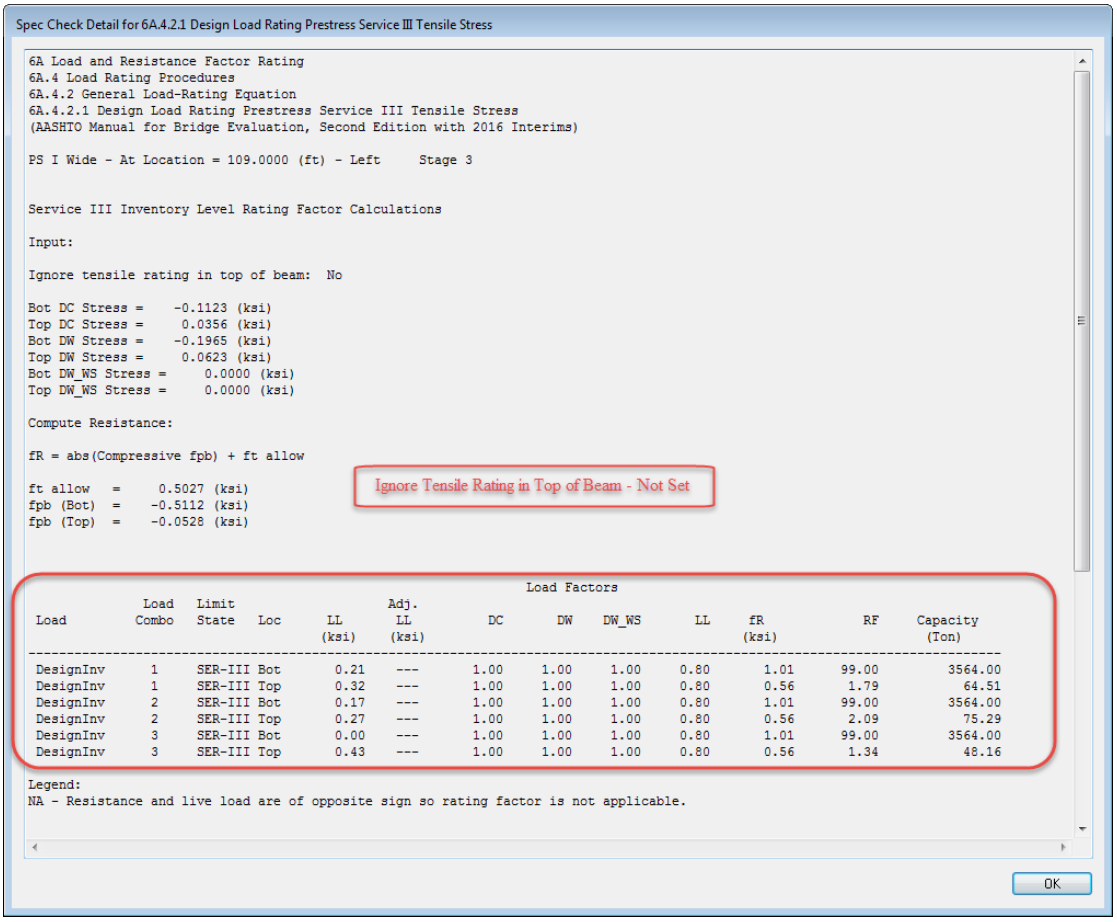
Rerun the AASHTO LRFD analysis and check the specification article LRFD 5.10.10.1.

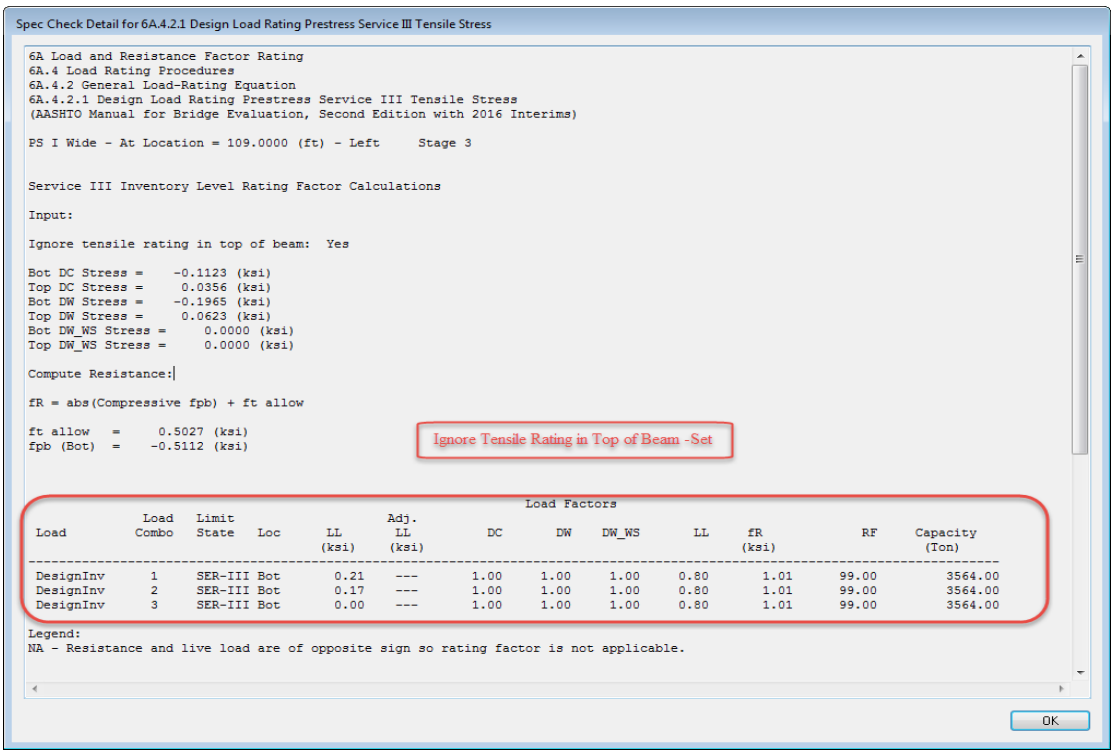


**Ignoring tensile rating in top of beam**

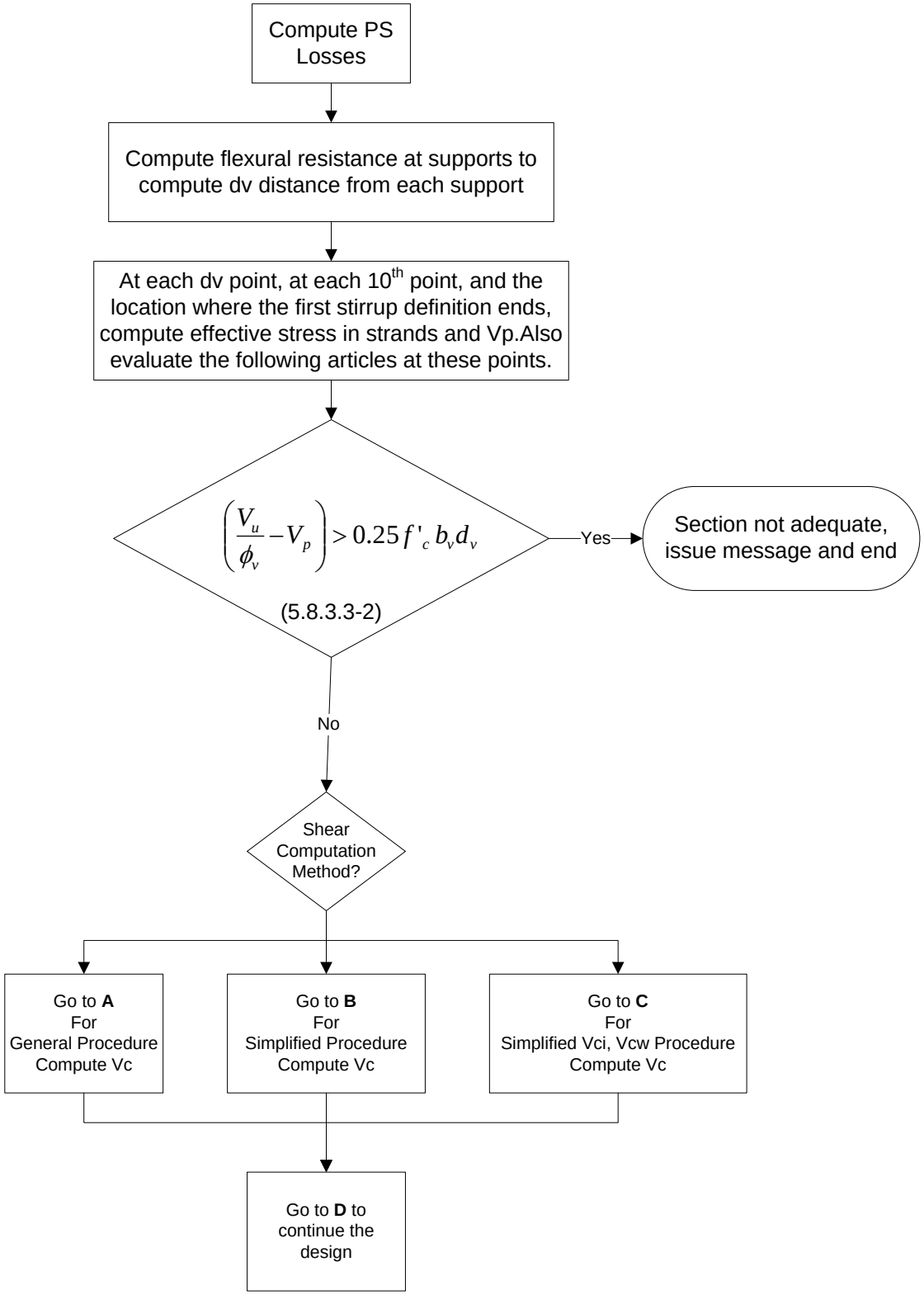



Run the AASHTO LRFR analysis for the above Control Option not set and set and then compare the specification LRFR 6A. to see the tensile ratings eliminated.

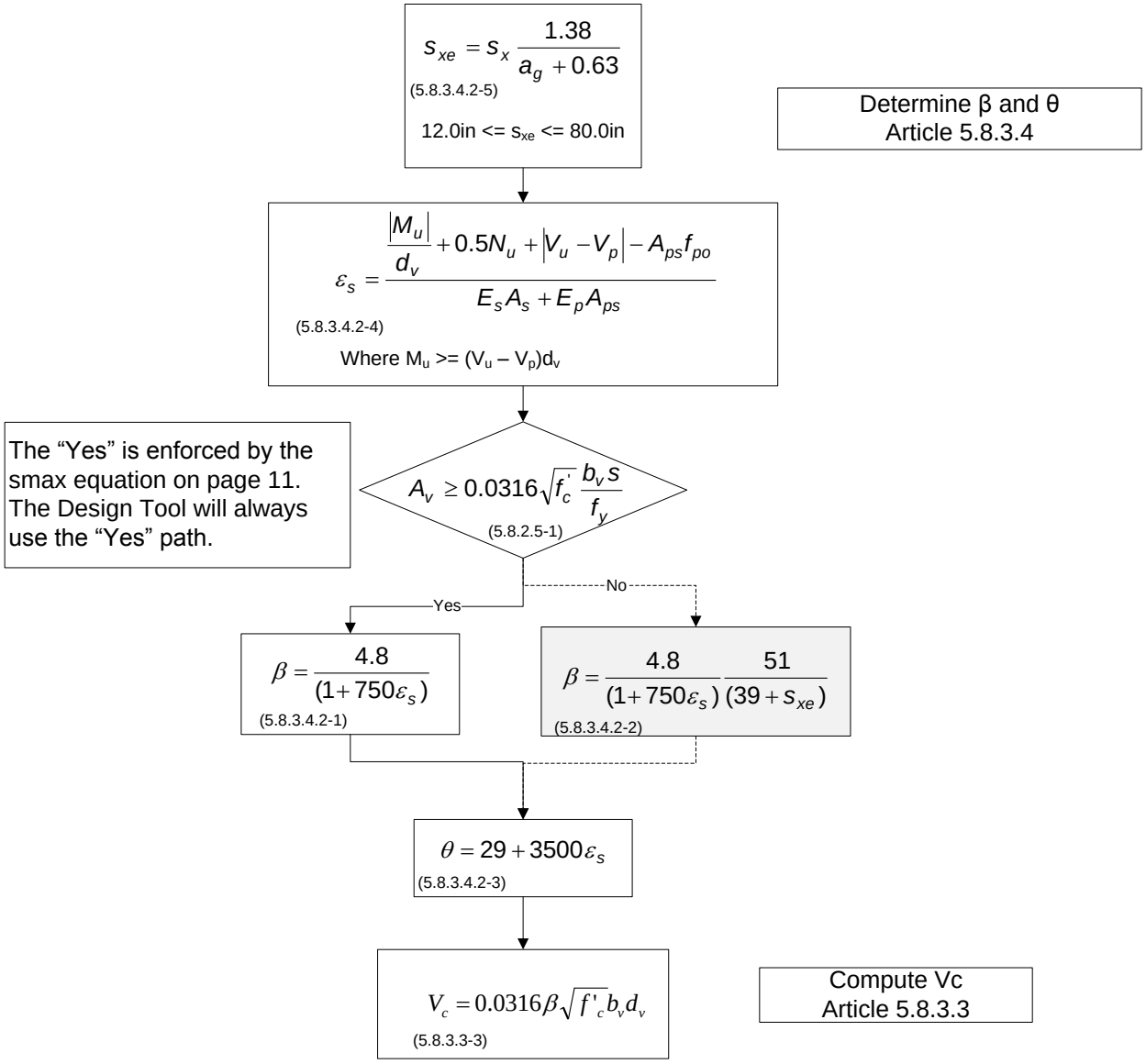

Spec Check Detail for 6A.4.2.1 Design Load Rating Prestress Service III Tensile Stress
6A Load and Resistance Factor Rating
6A.4 Load Rating Procedures
6A.4.2 General Load-Rating Equation
6A.4.2.1 Design Load Rating Prestress Service III Tensile Stress
(AASHTO Manual for Bridge Evaluation, Second Edition with 2016 Interims)
PS I Wide - At Location = 109.0000 (ft) - Left Stage 3
Service III Inventory Level Rating Factor Calculations
Input:
Ignore tensile rating in top of beam: No
Bot DC Stress = -0.1123 (ksi)
Top DC Stress = 0.0356 (ksi)
Bot DW Stress = -0.1965 (ksi)
Top DW Stress = 0.0623 (ksi)
Bot DW_WS Stress = 0.0000 (ksi)
Top DW_WS Stress = 0.0000 (ksi)
Compute Resistance:
fR = abs(Compressive fpb) + ft allow
ft allow = 0.5027 (ksi)
fpb (Bot) = -0.5112 (ksi)
fpb (Top) = -0.0528 (ksi)
Ignore Tensile Rating in Top of Beam - Not Set
Load Factors
Load Load Combo Limit State Loc LL (ksi) Adj. LL (ksi) DC DW DW_WS LL fR (ksi) RF Capacity (Ton)
DesignInv 1 SER-III Bot 0.21 --- 1.00 1.00 1.00 0.80 1.01 99.00 3564.00
DesignInv 1 SER-III Top 0.32 --- 1.00 1.00 1.00 0.80 0.56 1.79 64.51
DesignInv 2 SER-III Bot 0.17 --- 1.00 1.00 1.00 0.80 1.01 99.00 3564.00
DesignInv 2 SER-III Top 0.27 --- 1.00 1.00 1.00 0.80 0.56 2.09 75.29
DesignInv 3 SER-III Bot 0.00 --- 1.00 1.00 1.00 0.80 1.01 99.00 3564.00
DesignInv 3 SER-III Top 0.43 --- 1.00 1.00 1.00 0.80 0.56 1.34 48.16
Legend:
NA - Resistance and live load are of opposite sign so rating factor is not applicable.
OK


Spec Check Detail for 6A.4.2.1 Design Load Rating Prestress Service III Tensile Stress
6A Load and Resistance Factor Rating
6A.4 Load Rating Procedures
6A.4.2 General Load-Rating Equation
6A.4.2.1 Design Load Rating Prestress Service III Tensile Stress
(AASHTO Manual for Bridge Evaluation, Second Edition with 2016 Interims)
PS I Wide - At Location = 109.0000 (ft) - Left Stage 3
Service III Inventory Level Rating Factor Calculations
Input:
Ignore tensile rating in top of beam: Yes
Bot DC Stress = -0.1123 (ksi)
Top DC Stress = 0.0356 (ksi)
Bot DW Stress = -0.1965 (ksi)
Top DW Stress = 0.0623 (ksi)
Bot DW_WS Stress = 0.0000 (ksi)
Top DW_WS Stress = 0.0000 (ksi)
Compute Resistance:
fR = abs(Compressive fpb) + ft allow
ft allow = 0.5027 (ksi)
fpb (Bot) = -0.5112 (ksi)
Ignore Tensile Rating in Top of Beam -Set
Load Factors
Load Load Combo Limit State Loc LL (ksi) Adj. LL (ksi) DC DW DW_WS LL fR (ksi) RF Capacity (Ton)
DesignInv 1 SER-III Bot 0.21 --- 1.00 1.00 1.00 0.80 1.01 99.00 3564.00
DesignInv 2 SER-III Bot 0.17 --- 1.00 1.00 1.00 0.80 1.01 99.00 3564.00
DesignInv 3 SER-III Bot 0.00 --- 1.00 1.00 1.00 0.80 1.01 99.00 3564.00
Legend:
NA - Resistance and live load are of opposite sign so rating factor is not applicable.
OK

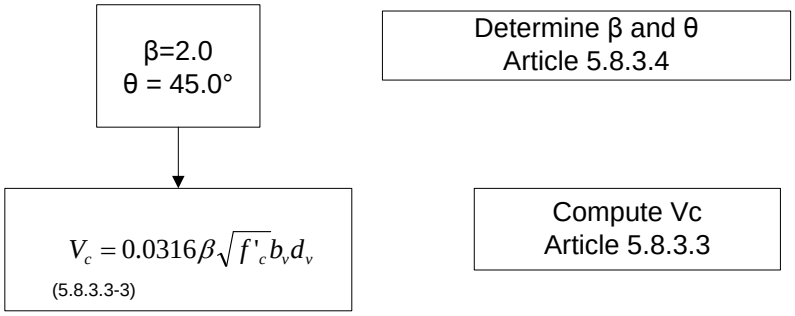
**Flowcharts for PS Stirrup Design Tool**



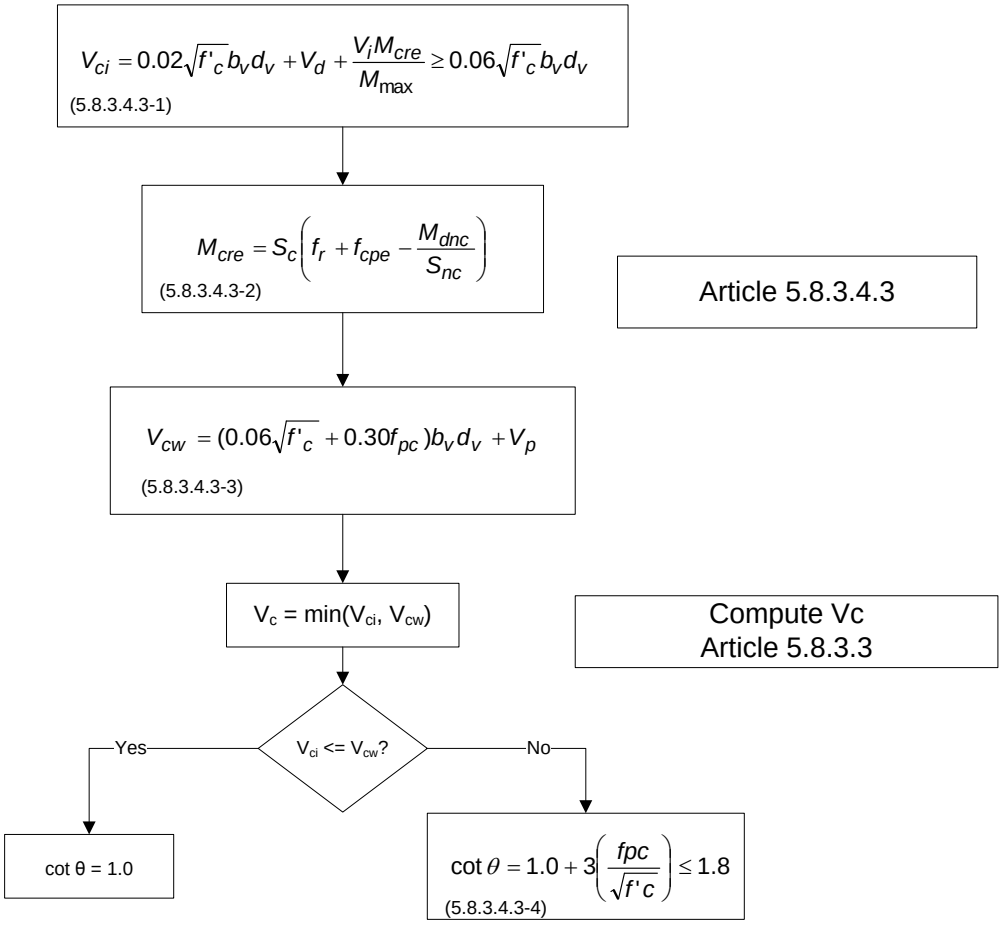
**A. General Procedure to Compute Vc**

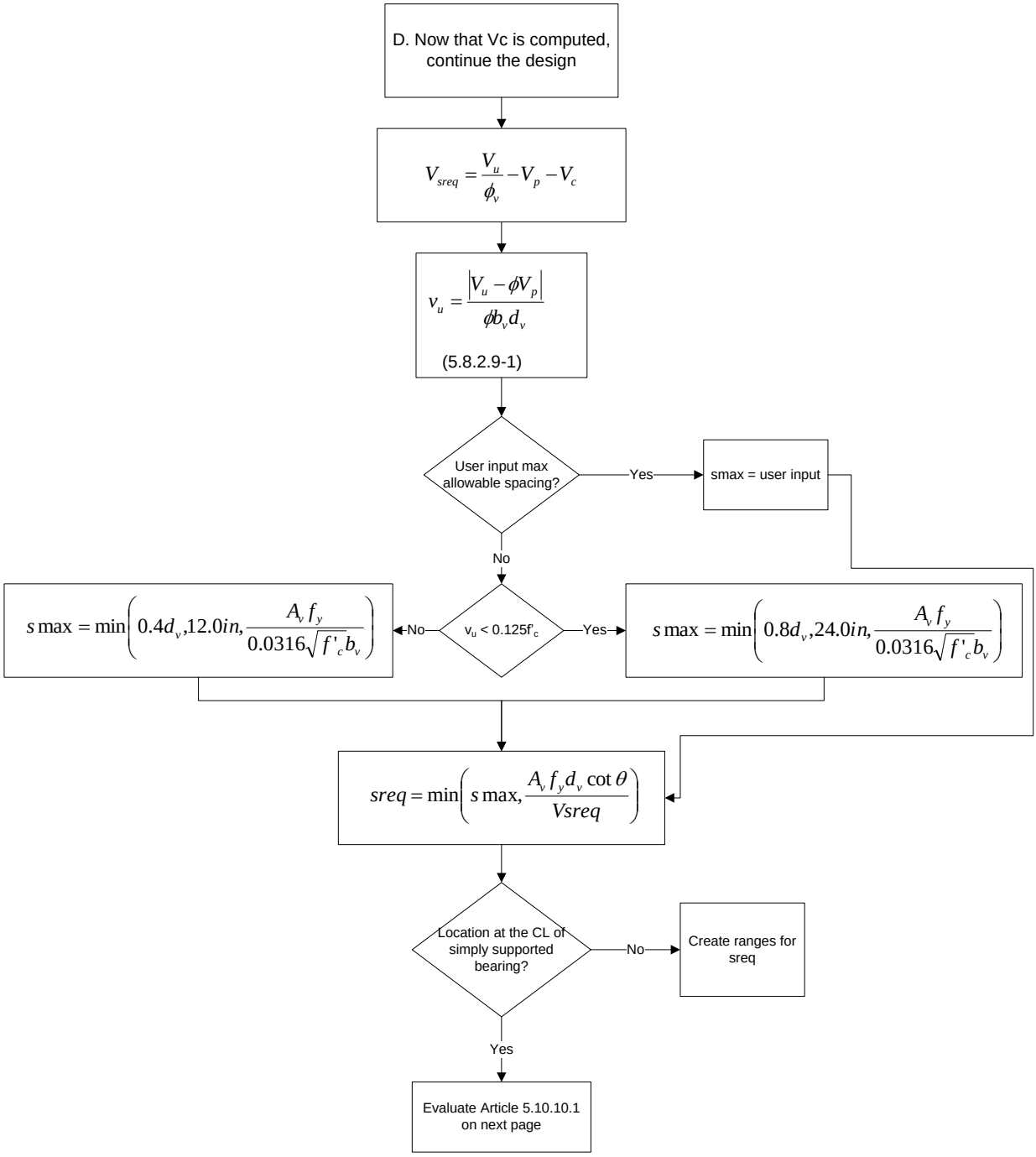


**B. Simplified Procedure to Compute Vc**




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




D. Now that Vc is computed, continue the design
$V_{sreq} = \frac{V_u}{\phi_v} - V_p - V_c$
$v_u = \frac{|V_u - \phi V_p|}{\phi b_v d_v}$
(5.8.2.9-1)
User input max allowable spacing?
Yes
smax = user input
No
$v_u < 0.125 f'_c$
No
Yes
$s\max = \min\left(0.4d_v, 12.0in, \frac{A_v f_y}{0.0316\sqrt{f'_c} b_v}\right)$
$s\max = \min\left(0.8d_v, 24.0in, \frac{A_v f_y}{0.0316\sqrt{f'_c} b_v}\right)$
$sreq = \min\left(s\max, \frac{A_v f_y d_v \cot\theta}{Vsreq}\right)$
Location at the CL of simply supported bearing?
No
Create ranges for sreq
Yes
Evaluate Article 5.10.10.1 on next page

$$P_r = 0.04(f_{pbt} * A_{ps})$$

(Article 5.10.10.1)

$$sreq = \min\left(sreq \text{ from prev page}, \frac{(A_s)*(h/4)}{P_r / f_s}\right)$$

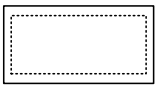
fs = service stress in the stirrup steel, limited to 20ksi

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.



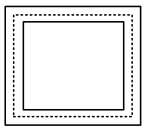
For box beams:

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



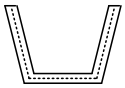
For U beams:

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

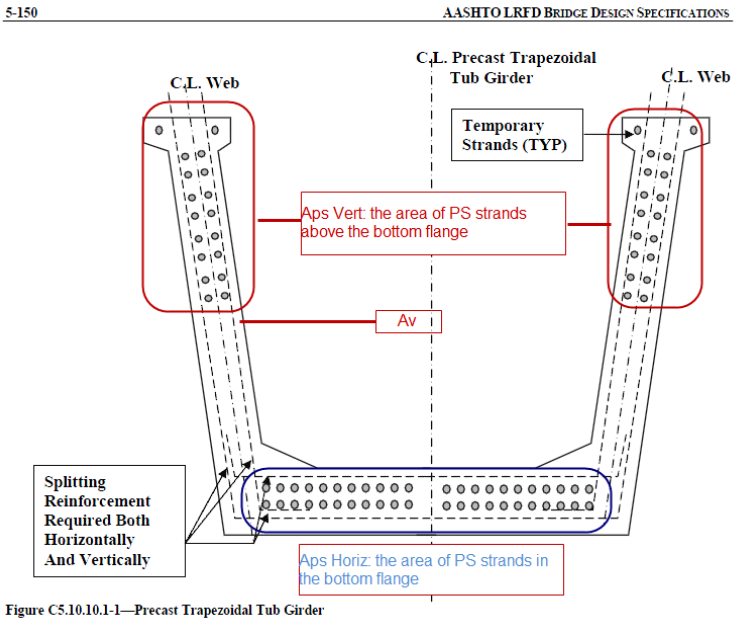
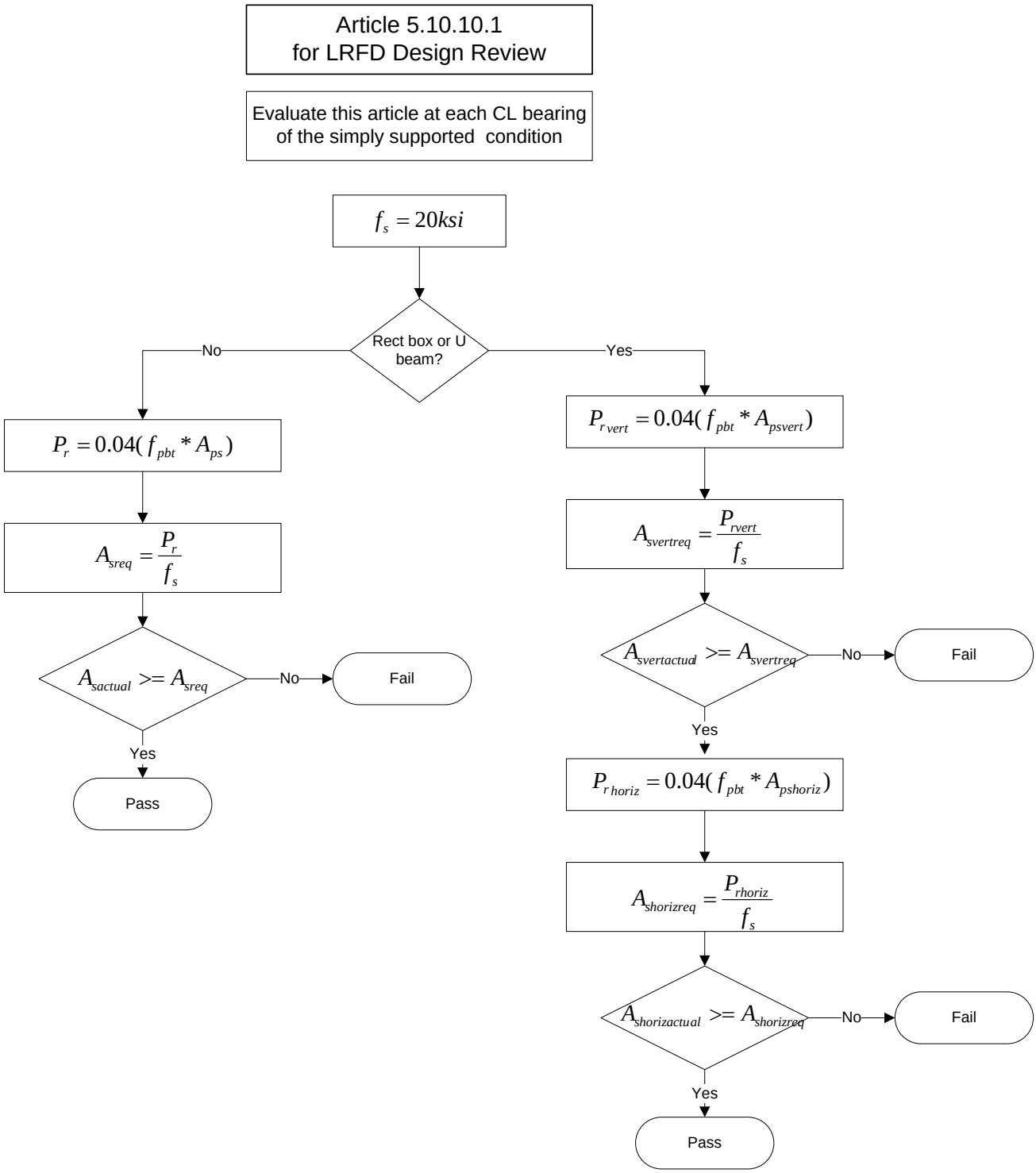



Figure C5.10.10.1-1—Precast Trapezoidal Tub Girder


Article 5.10.10.1
for LRFD Design Review
Evaluate this article at each CL bearing of the simply supported condition
$f_s = 20ksi$
Rect box or U beam?
No
Yes
$P_r = 0.04(f_{pbt} * A_{ps})$
$A_{sreq} = \frac{P_r}{f_s}$
$A_{sactual} >= A_{sreq}$
No
Fail
Yes
Pass
$P_{r\,vert} = 0.04(f_{pbt} * A_{psvert})$
$A_{svertreq} = \frac{P_{rvert}}{f_s}$
$A_{svertactual} >= A_{svertreq}$
No
Fail
Yes
$P_{r\,horiz} = 0.04(f_{pbt} * A_{pshoriz})$
$A_{shorizreq} = \frac{P_{rhoriz}}{f_s}$
$A_{shorizactual} >= A_{shorizreq}$
No
Fail
Yes
Pass