AASHTOWare BrDR 7.5.1

Concrete Shear LRFR Rating Iteration Tutorial

MBE 2023 Spec Interim Update – Shear Rating Iteration Example

BrDR Training

MBE 2023 Spec Interim Shear Rating Iteration Example

This example illustrates the effects of using concurrent load effects, iterative shear rating and Modified Compression Field Theory (MCFT) control options for Load and Resistance Factor Rating (LRFR) shear rating of concrete structures (prestressed, post tensioned and reinforced) based on the MBE 3rd edition, 2023 specification interim update.

Topics Covered

- Concurrent forces considered for non-iterative shear rating
- Control option added to consider iterative shear rating
- Control option added to consider modifying MCFT theta
- Control option added to consider modifying MCFT size effect
- MBE 2023 specification interim update for reinforced concrete box culverts

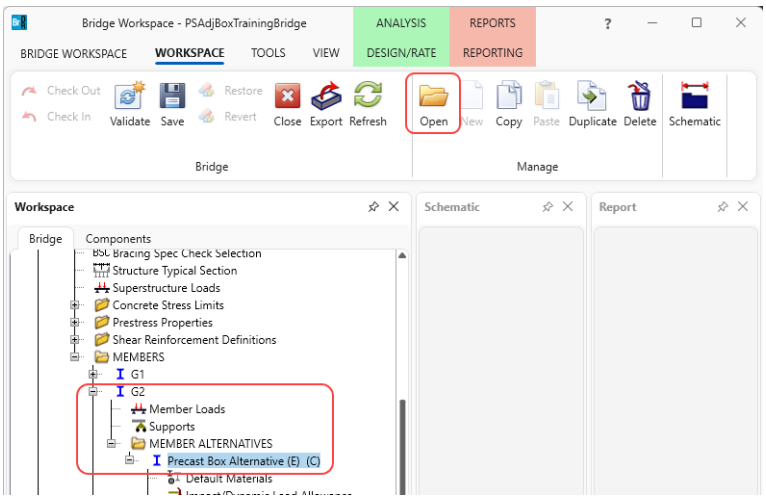
This tutorial uses the bridge from prestressed concrete structure tutorial PS3. From the **Bridge Explorer** import the bridge given with the PS3 tutorial.

Concurrent forces considered for non-iterative shear rating

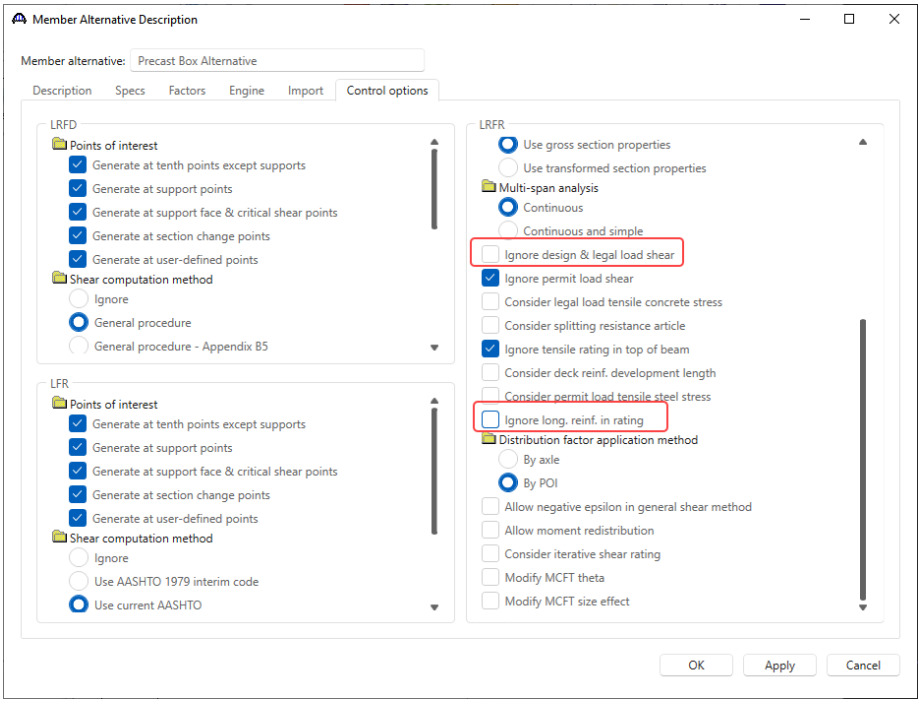
This section discusses the effects of using concurrent forces for LRFR shear rating of concrete bridges without any iterations. This is applicable to all concrete structures, i.e., reinforced concrete, prestressed concrete, post tensioned concrete and reinforced concrete box culverts.

Member Alternative Description – Control options

Navigate to the member alternative Precast Box Alternative of member **G2**, double click on it (or click the **Open** button from the **WORKSPACE** ribbon) to open its **Member Alternative Description** window. Navigate to the **Control options** tab as shown below.



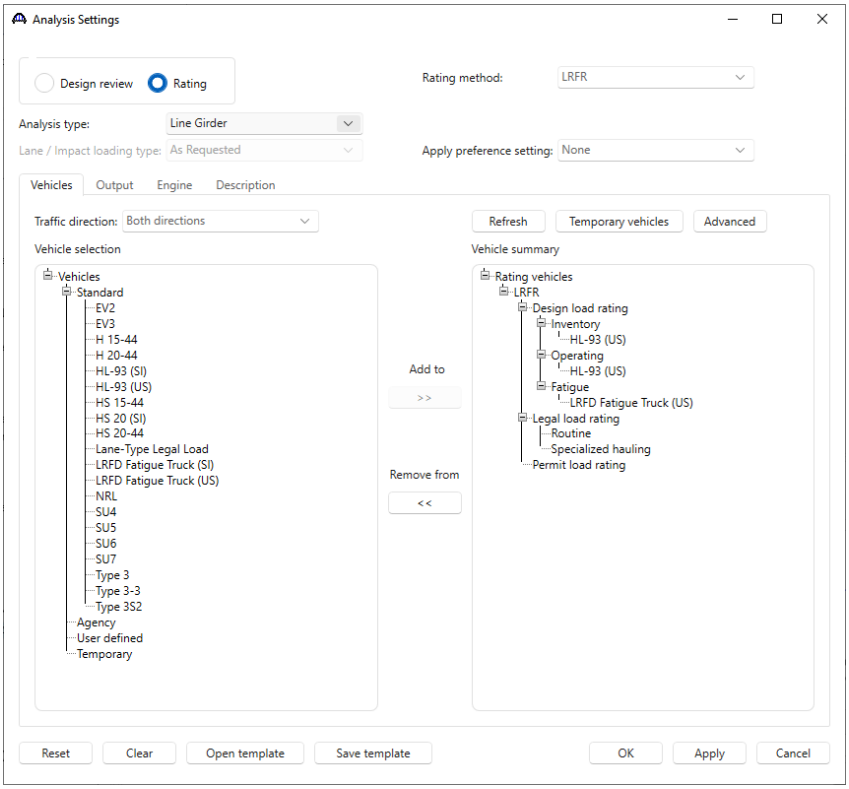
Uncheck the **Ignore design & legal load shear** and **Ignore long. reinf. in rating** for this example.



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

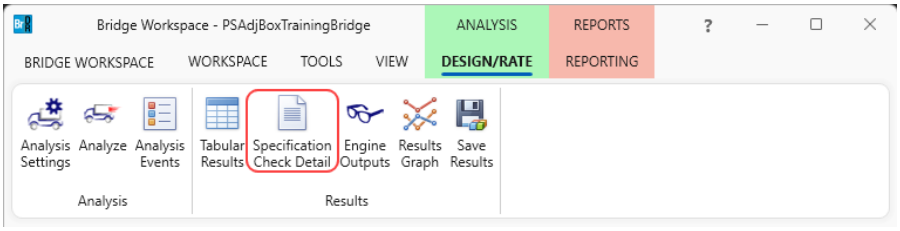
LRFR Rating

Perform an LRFR rating of the member alternative using the analysis settings shown below.

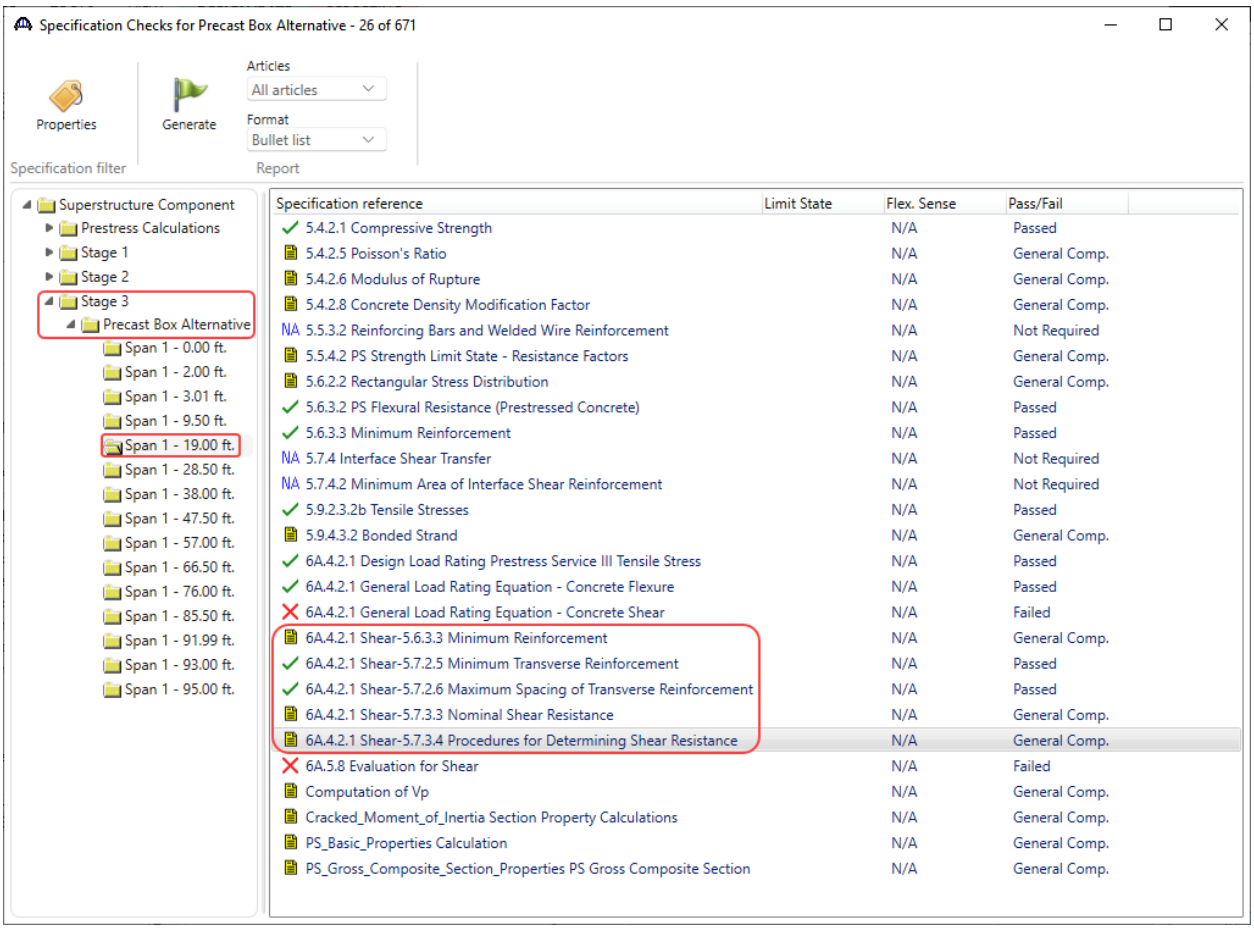


Specification Check Detail

When the rating is finished, the specification check detail can be reviewed by clicking the **Specification Check Detail** button from the **Results** group of the **DESIGN/RATE** ribbon.



The window shown below will open. Navigate to the **Stage 3** specification check detail for the analyzed member alternative and select the **Span 1 – 19.00 ft** point of interest.



The highlighted articles for MBE 6A.4.2.1 shear rating are available for an LRFR shear rating of concrete structures. These articles along with 6A.5.8 Evaluation of Shear and 6A.4.2.1 General Load Rating Equation – Concrete Shear articles, use the concurrent load effects to compute the shear capacity and rating factors.

Following sections highlight the MBE 3rd edition 2023 spec interim implementation for an LRFR analysis.

Article 6A.4.2.1 Shear-5.6.3.3 Minimum Reinforcement computes the cracking moment (Mcr) for each load case as shown below.

A new column – “Governing Action” has been added to indicate the primary action considered. For example, in 2022 interim, rating factors were computed using the envelope moment and shear values. In 2023 interim, shear concurrent actions with maximum (Max M) and minimum (Min M) moment, moment concurrent actions with maximum (Max V) and minimum (Min V) shear are being considered for load rating.

Spec Check Detail for 6A.4.2.1 Shear-5.6.3.3 Minimum Reinforcement

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6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.6 Design for Flexural and Axial Effects - B Regions
6A.4.2.1 Shear - 5.6.3 Flexural Members
6A.4.2.1 Shear - 5.6.3.3 Minimum Reinforcement
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Cross Section Properties for Prestress box beam with Rectangular void
-----------------------------------------------------------------
Name: BIII-48   Girder f'c = 5.00(ksi)     Girder f'ci = 4.00(ksi)

Beam Height             =   39.00(in)     Side Wall Thickness      =    5.00(in)
Top Slab Width          =   47.25(in)
Top Slab Thick          =    5.50(in)
Bottom Slab Width       =   48.00(in)
Bottom Slab Thick       =    5.50(in)
Shear Key Top           =    6.00(in)
Shear Key Height        =    6.00(in)
Shear Key Depth         =    0.75(in)
B1                      =    3.00(in)
B2                      =    3.00(in)
B3                      =    3.00(in)
B4                      =    3.00(in)

Slab f'c                =      0.00(ksi)
Effective Slab Width    =      0.00(in)        Haunch Width             =      0.00(in)
Effective Slab Thickness =     0.00(in)        Haunch Thickness         =      0.00(in)

Input:
fr beam =        0.54ksi
ScTop   =    -8569.07in^3            Mdnc    =     8812.35kip-in
ScBot   =     8734.21in^3            SncBot  =     8734.21in^3
Gamma1 =  1.60
Gamma2 =  1.10
Gamma3 =  1.00 (Prestressed Concrete)
Gamma3 =  0.67 (Reinforced Concrete)

Mcr = Gamma3 * [( gamma1*fr + Gamma2*fcpe)*Sc - Mdnc * (Sc/Snc - 1)]      (5.6.3.3-1)
Note: If the capacity has been overridden, the Resistance is computed as override phi*override capacity.
      Otherwise the Resistance is computed as per the Specification.
```

Limit State	Load Comb	fcpe ksi	fr ksi	Gamma3	Governing Action	Mu kip-in	Vu kip	Sc in^3	Mcr kip-in
STR-I	1, DesInv	2.22	0.54	1.00	Max M	33228.57	127.29	8734.21	28801.18
STR-I	1, DesInv	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	1, DesInv	2.22	0.54	1.00	Max V	32064.13	128.56	8734.21	28801.18
STR-I	1, DesInv	2.22	0.54	1.00	Min V	22779.24	25.01	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Max M	28220.60	106.78	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Max V	27322.31	107.77	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Min V	20159.68	27.88	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Max M	29541.81	111.12	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Max V	28377.37	112.39	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Min V	23878.56	23.80	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Max M	25376.52	94.31	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Max V	24478.24	95.29	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Min V	21007.73	26.95	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Max M	18828.30	70.27	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Min M	8812.35	29.26	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Max V	18295.99	70.86	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Min V	14051.47	23.52	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Max M	17142.93	62.88	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Min M	8812.35	29.26	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Max V	16610.61	63.46	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Min V	14554.01	22.97	8734.21	28801.18

```
Load Combination Legend:
```

Code	Vehicle
1	HL-93 (US) - Truck + Lane
2	HL-93 (US) - Tandem + Lane

Figure 1 - 6A.4.2.1 Shear-5.6.3.3 Minimum Reinforcement

Note: Article “LRFD 5.6.3.3 Minimum Reinforcement” will only be applicable for determining Mcr for flexural resistance using the envelope moment.

Spec Check Detail for 6A.4.2.1 Shear-5.7.3.4 Procedures for Determining Shear Resistance

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.7 Shear and Torsion
6A.4.2.1 Shear - 5.7.3 Sectional Design Model
6A.4.2.1 Shear - 5.7.3.4 Procedures for Determining Shear Resistance
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left      Stage 3

Calculation of Beta/Theta
-------------------------

      Es = 0.000 (kips/in^2)
     phi = 0.900
     f'c = 5.000 (kips/in^2)
     fpc = 0.937 (kips/in^2)
      fy = 60.000 (kips/in^2)
Agg diam = 1.000 (in)
      Vp = 0.000 (kips)
      Ep = 28500.000 (kips/in^2)
 As(pos) = 0.000 (in^2)  (used for Positive Mu)
 As(neg) = 0.000 (in^2)  (used for Negative Mu)
Aps(pos) = 4.284 (in^2)  (used for Positive Mu)
Aps(neg) = 0.306 (in^2)  (used for Negative Mu)
     fpo = 189.000 (kips/in^2)
      Ec = 4592.232 (kips/in^2)

Beta Calc (used in table below) :
     (1) - Beta = 4.8 / (1 + 750 EpsilonS)
     (2) - Beta = ( 4.8 / (1 + 750 EpsilonS) ) * (51 / (39 + sxe) )
                where:
                   sxe = sx * (1.38 / (ag + 0.63) )

  Mu_calc = Max(Mu, |Vu - Vp| * dv)

Modify MCFT Theta:   No

Modify MCFT Size Effect:   No
fpc / f'c = 0.19
```

Limit State	Load Comb	Epsilon	Theta	Beta	Governing Action	Mu (kip-in)	Mu Calc (kip-in)	Vu (kips)	Nu (kips)	bv (in)	dv (in)	Sx (in)	Sxe (in)	Beta Calc	Act (in^2)	Av (in^2)	As (in^2)
STR-I	1, DesInv	0.002471	37.65	1.68	Max M	33228.57	33228.57	127.29	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	1, DesInv	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	1, DesInv	0.002199	36.70	1.81	Max V	32064.13	32064.13	128.56	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	1, DesInv	0.000000	29.00	4.80	Min V	22779.24	22779.24	25.01	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	1, DesOp	0.001088	32.81	2.64	Max M	28220.60	28220.60	106.78	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	1, DesOp	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	1, DesOp	0.000879	32.08	2.89	Max V	27322.31	27322.31	107.77	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	1, DesOp	0.000000	29.00	4.80	Min V	20159.68	20159.68	27.88	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesInv	0.001444	34.06	2.30	Max M	29541.81	29541.81	111.12	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesInv	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesInv	0.001172	33.10	2.55	Max V	28377.37	28377.37	112.39	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesInv	0.000000	29.00	4.80	Min V	23878.56	23878.56	23.80	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesOp	0.000296	30.04	3.93	Max M	25376.52	25376.52	94.31	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesOp	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesOp	0.000087	29.30	4.51	Max V	24478.24	24478.24	95.29	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
STR-I	2, DesOp	0.000000	29.00	4.80	Min V	21007.73	21007.73	26.95	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	1, DesInv	0.000000	29.00	4.80	Max M	18828.30	18828.30	70.27	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	1, DesInv	0.000000	29.00	4.80	Min M	8812.35	8812.35	29.26	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	1, DesInv	0.000000	29.00	4.80	Max V	18295.99	18295.99	70.86	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	1, DesInv	0.000000	29.00	4.80	Min V	14051.47	14051.47	23.52	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	2, DesInv	0.000000	29.00	4.80	Max M	17142.93	17142.93	62.88	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	2, DesInv	0.000000	29.00	4.80	Min M	8812.35	8812.35	29.26	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	2, DesInv	0.000000	29.00	4.80	Max V	16610.61	16610.61	63.46	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00
SER-III	2, DesInv	0.000000	29.00	4.80	Min V	14554.01	14554.01	22.97	0.00	10.00	33.77	33.77	--	(1)	413.00	0.40	0.00

```
Load Combination Legend:

 Code      Vehicle
-------------------------
    1     HL-93 (US) - Truck + Lane
    2     HL-93 (US) - Tandem + Lane
```

Figure 2 - 6A.4.2.1 Shear-5.7.3.4 Procedures for Determining Shear Resistance

Spec Check Detail for 6A.4.2.1 Shear-5.7.2.5 Minimum Transverse Reinforcement

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.7 Shear and Torsion
6A.4.2.1 Shear - 5.7.2 General Requirements
6A.4.2.1 Shear - 5.7.2.5 Minimum Transverse Reinforcement
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left      Stage 3

Check
 Vu > 0.5 * phi * (Vc + Vp)       (5.7.2.3 - 1)
 Av >= 0.0316 * lambda * SQRT(f'c) * bv * s / fy      (5.7.2.5 - 1)
 f'c = 5.000ksi
 fy = 60.000ksi
 phi = 0.900
 lambda = 1.000

Note: fy = Yield strength of transverse reinforcement (ksi) =< 100 ksi.
 ---------------------------------------------
```

Limit State	Load Comb	Vc (kip)	Vp (kip)	Governing Action	Vu (kip)	Vu> 0.5*phi*(Vc+Vp)	s (in)	bv (in)	Av Provided(in^2)	>= 0.0316 *lambda *SQRT(f'c) *bv * s/fy	Pass/Fail
STR-I	1, DesInv	40.13	0.00	Max M	127.29	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	1, DesInv	114.52	0.00	Min M	37.57	No	12.00	10.00	0.40	n/a	
STR-I	1, DesInv	43.22	0.00	Max V	128.56	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	1, DesInv	114.52	0.00	Min V	25.01	No	12.00	10.00	0.40	n/a	
STR-I	1, DesOp	63.05	0.00	Max M	106.78	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	1, DesOp	114.52	0.00	Min M	37.57	No	12.00	10.00	0.40	n/a	
STR-I	1, DesOp	69.03	0.00	Max V	107.77	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	1, DesOp	114.52	0.00	Min V	27.88	No	12.00	10.00	0.40	n/a	
STR-I	2, DesInv	54.97	0.00	Max M	111.12	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	2, DesInv	114.52	0.00	Min M	37.57	No	12.00	10.00	0.40	n/a	
STR-I	2, DesInv	60.94	0.00	Max V	112.39	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	2, DesInv	114.52	0.00	Min V	23.80	No	12.00	10.00	0.40	n/a	
STR-I	2, DesOp	93.69	0.00	Max M	94.31	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	2, DesOp	114.52	0.00	Min M	37.57	No	12.00	10.00	0.40	n/a	
STR-I	2, DesOp	107.53	0.00	Max V	95.29	Yes	12.00	10.00	0.40	0.14	Pass
STR-I	2, DesOp	114.52	0.00	Min V	26.95	No	12.00	10.00	0.40	n/a	
SER-III	1, DesInv	114.52	0.00	Max M	70.27	Yes	12.00	10.00	0.40	0.14	Pass
SER-III	1, DesInv	114.52	0.00	Min M	29.26	No	12.00	10.00	0.40	n/a	
SER-III	1, DesInv	114.52	0.00	Max V	70.86	Yes	12.00	10.00	0.40	0.14	Pass
SER-III	1, DesInv	114.52	0.00	Min V	23.52	No	12.00	10.00	0.40	n/a	
SER-III	2, DesInv	114.52	0.00	Max M	62.88	Yes	12.00	10.00	0.40	0.14	Pass
SER-III	2, DesInv	114.52	0.00	Min M	29.26	No	12.00	10.00	0.40	n/a	
SER-III	2, DesInv	114.52	0.00	Max V	63.46	Yes	12.00	10.00	0.40	0.14	Pass
SER-III	2, DesInv	114.52	0.00	Min V	22.97	No	12.00	10.00	0.40	n/a	

```
Load Combination Legend:

 Code      Vehicle
-------------------------
    1     HL-93 (US) - Truck + Lane
    2     HL-93 (US) - Tandem + Lane
```

Figure 3 - 6A.4.2.1 Shear-5.7.2.5 Minimum Transverse Reinforcement

Spec Check Detail for 6A.4.2.1 Shear-5.7.2.6 Maximum Spacing of Transverse Reinforcement

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.7 Shear and Torsion
6A.4.2.1 Shear - 5.7.2 General Requirements
6A.4.2.1 Shear - 5.7.2.6 Maximum Spacing of Transverse Reinforcement
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Calculation of Shear Stress on the concrete
Vu > 0.5*phi * (Vc+Vp)      (5.8.2.4-1)
  phi = 0.9000
  f'c = 5.000ksi
 ------------------------------------------------------------
```

Limit State	Load Comb	Vc (kip)	Vp (kip)	Governing Action	Vu (kip)	Vu> 0.5*phi*(Vc+Vp)	bv (in)	dv (in)	vu (ksi)	vu< 0.125*f'c	s (in)	Spacing criteria	Status
STR-I	1, DesInv	40.13	0.00	Max M	127.29	TRUE	10.00	33.77	0.42	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	1, DesInv	114.52	0.00	Min M	37.57	FALSE	NA	NA	NA	NA	NA	----------n/a-	Pass
STR-I	1, DesInv	43.22	0.00	Max V	128.56	TRUE	10.00	33.77	0.42	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	1, DesInv	114.52	0.00	Min V	25.01	FALSE	NA	NA	NA	NA	NA	----------n/a-	Pass
STR-I	1, DesOp	63.05	0.00	Max M	106.78	TRUE	10.00	33.77	0.35	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	1, DesOp	114.52	0.00	Min M	37.57	FALSE	NA	NA	NA	NA	NA	----------n/a-	Pass
STR-I	1, DesOp	69.03	0.00	Max V	107.77	TRUE	10.00	33.77	0.35	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	1, DesOp	114.52	0.00	Min V	27.88	FALSE	NA	NA	NA	NA	NA	----------n/a-	Pass
STR-I	2, DesInv	54.97	0.00	Max M	111.12	TRUE	10.00	33.77	0.37	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	2, DesInv	114.52	0.00	Min M	37.57	FALSE	NA	NA	NA	NA	NA	----------n/a-	Pass
STR-I	2, DesInv	60.94	0.00	Max V	112.39	TRUE	10.00	33.77	0.37	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	2, DesInv	114.52	0.00	Min V	23.80	FALSE	NA	NA	NA	NA	NA	----------n/a-	Pass
STR-I	2, DesOp	93.69	0.00	Max M	94.31	TRUE	10.00	33.77	0.31	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	2, DesOp	114.52	0.00	Min M	37.57	FALSE	NA	NA	NA	NA	NA	----------n/a-	Pass
STR-I	2, DesOp	107.53	0.00	Max V	95.29	TRUE	10.00	33.77	0.31	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
STR-I	2, DesOp	114.52	0.00	Min V	26.95	FALSE	NA	NA	NA	NA	NA	----------n/a-	Pass
SER-III	1, DesInv	114.52	0.00	Max M	70.27	TRUE	10.00	33.77	0.23	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
SER-III	1, DesInv	114.52	0.00	Min M	29.26	FALSE	NA	NA	NA	NA	NA	----------n/a-	Pass
SER-III	1, DesInv	114.52	0.00	Max V	70.86	TRUE	10.00	33.77	0.23	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
SER-III	1, DesInv	114.52	0.00	Min V	23.52	FALSE	NA	NA	NA	NA	NA	----------n/a-	Pass
SER-III	2, DesInv	114.52	0.00	Max M	62.88	TRUE	10.00	33.77	0.21	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
SER-III	2, DesInv	114.52	0.00	Min M	29.26	FALSE	NA	NA	NA	NA	NA	----------n/a-	Pass
SER-III	2, DesInv	114.52	0.00	Max V	63.46	TRUE	10.00	33.77	0.21	TRUE	12.00	s<=Min(0.8*dv, 24	Pass
SER-III	2, DesInv	114.52	0.00	Min V	22.97	FALSE	NA	NA	NA	NA	NA	----------n/a-	Pass

```
Load Combination Legend:

 Code      Vehicle
 ----------------------
    1     HL-93 (US) - Truck + Lane
    2     HL-93 (US) - Tandem + Lane
```

Figure 4 - 6A.4.2.1 Shear-5.7.2.6 Maximum Spacing of Transverse Reinforcement

Spec Check Detail for 6A.4.2.1 Shear-5.7.3.3 Nominal Shear Resistance

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.7 Shear and Torsion
6A.4.2.1 Shear - 5.7.3 Sectional Design Model
6A.4.2.1 Shear - 5.7.3.3 Nominal Shear Resistance
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Calculation of Shear Resistance Vr
-----------------------------------
 Vc     = 0.0316 * Beta * lambda * SQRT(f'c) * bv * dv                          (5.7.3.3-3)

          Av1 * fy1 * dv (cot(theta) + cot(alpha1)) * sin(alpha1)
 Vs1    = ------------------------------------------------------- * lambda_duct  (5.7.3.3-4)
                                  s

 Vs2    = Av2 * fy2 * sin(alpha2) * lambda_duct                                 (5.7.3.3-6)
 Vs2Max = 0.095 * lambda * SQRT(f'c) * bv * dv                                  (5.7.3.3-6)
 Vs     = Vs1 + min(Vs2, Vs2Max)

 Post tensioned = FALSE
 lambda_duct = 1.0000

 Vn1    = Vc + Vs + Vp                                                          (5.7.3.3-1)
 Vn2    = 0.25 * f'c * bv * dv + Vp                                             (5.7.3.3-2)
 Vn     = min(Vn1, Vn2)
 Vr     = phi * Vn                                                              (5.7.2.1-1)
 where:
 Vc:      Resistance due to concrete.
 Vs1:     Resistance due to stirrups.
 Vs2:     Resistance due to only center 3/4 of sloped portion of the longitudinal bars.   (Article 5.7.3.3)
 Vp:      Resistance due to prestressing.
 Vrs1:    Resistance due to force in inclined bars.
 *Note:   Vr includes the value Vrs1
 Av1:     Area of stirrups.
 fy1:     Yield Strength of stirrups.
 alpha1:  Angle of inclination of stirrups.
 Av2:     Area of bent up longitudinal rebars.
 fy2:     Yield Strength of bent up longitudinal rebars.
 alpha2:  Angle of inclination of bent up longitudinal rebars.
 ------------------------------------------------------------
 Input:
   phi    = 0.900
   f'c    = 5.000 (ksi)
   fy1    = 60.000 (ksi)
   alpha1 = 90.000 (Degrees)
   lambda = 1.000
   Consider inclined forces option: No
   Consider sloped portion of longitudinal rebar option: No
   Consider iterative shear rating option (applies only to General and GeneralAppB shear computation methods): No
   Consider MCFT theta option: No
   Shear computation method: General
   Iteration required:  No

 ------------------------------------------------------------
```

Figure 5 - 6A.4.2.1 Shear-5.7.3.3 Nominal Shear Resistance Part 1

Limit State	Load Combo	Governing Action	Mu (kip-in)	MuDL (kip-in)	MuLL (kip-in)	Vu (kip)	VuDL (kip)	VuLL (kip)	Nu (kip)	bv (in)	dv (in)	s (in)	Av1 (in^2)	Beta	cot (Theta)	Epsilon
STR-I	1, DesInv	Max M	33228.57	11318.68	21909.89	127.29	37.57	89.71	0.00	10.00	33.77	12.00	0.40	1.682	1.296	0.002471
STR-I	1, DesInv	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
STR-I	1, DesInv	Max V	32064.13	11318.68	20745.45	128.56	37.57	90.99	0.00	10.00	33.77	12.00	0.40	1.812	1.342	0.002199
STR-I	1, DesInv	Min V	22779.24	11318.68	11460.56	25.01	37.57	-12.57	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
STR-I	1, DesOp	Max M	28220.60	11318.68	16901.91	106.78	37.57	69.21	0.00	10.00	33.77	12.00	0.40	2.643	1.551	0.001088
STR-I	1, DesOp	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
STR-I	1, DesOp	Max V	27322.31	11318.68	16003.63	107.77	37.57	70.19	0.00	10.00	33.77	12.00	0.40	2.893	1.596	0.000879
STR-I	1, DesOp	Min V	20159.68	11318.68	8841.00	27.88	37.57	-9.69	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
STR-I	2, DesInv	Max M	29541.81	11318.68	18223.13	111.12	37.57	73.54	0.00	10.00	33.77	12.00	0.40	2.304	1.479	0.001444
STR-I	2, DesInv	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
STR-I	2, DesInv	Max V	28377.37	11318.68	17058.69	112.39	37.57	74.82	0.00	10.00	33.77	12.00	0.40	2.554	1.534	0.001172
STR-I	2, DesInv	Min V	23878.56	11318.68	12559.88	23.80	37.57	-13.77	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
STR-I	2, DesOp	Max M	25376.52	11318.68	14057.84	94.31	37.57	56.73	0.00	10.00	33.77	12.00	0.40	3.927	1.729	0.000296
STR-I	2, DesOp	Min M	11318.68	11318.68	0.00	37.57	37.57	0.00	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
STR-I	2, DesOp	Max V	24478.24	11318.68	13159.56	95.29	37.57	57.72	0.00	10.00	33.77	12.00	0.40	4.507	1.782	0.000087
STR-I	2, DesOp	Min V	21007.73	11318.68	9689.05	26.95	37.57	-10.62	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	1, DesInv	Max M	18828.30	8812.35	10015.95	70.27	29.26	41.01	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	1, DesInv	Min M	8812.35	8812.35	0.00	29.26	29.26	0.00	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	1, DesInv	Max V	18295.99	8812.35	9483.63	70.86	29.26	41.59	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	1, DesInv	Min V	14051.47	8812.35	5239.11	23.52	29.26	-5.74	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	2, DesInv	Max M	17142.93	8812.35	8330.57	62.88	29.26	33.62	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	2, DesInv	Min M	8812.35	8812.35	0.00	29.26	29.26	0.00	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	2, DesInv	Max V	16610.61	8812.35	7798.26	63.46	29.26	34.20	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000
SER-III	2, DesInv	Min V	14554.01	8812.35	5741.66	22.97	29.26	-6.30	0.00	10.00	33.77	12.00	0.40	4.800	1.804	0.000000

Load Combination Legend:

Code	Vehicle
1	HL-93 (US) - Truck + Lane
2	HL-93 (US) - Tandem + Lane

Figure 6 - 6A.4.2.1 Shear-5.7.3.3 Nominal Shear Resistance Part 2

Vc (kip)	Vs1 (kip)	Vs2 (kip)	Vs2Max (kip)	Vp (kip)	Vrs1 (kip)	Vn1 (kip)	Vn2 (kip)	--- Override --- Phi	Vn (kip)	Vr (kip)
40.13	87.53	0.00	71.73	0.00	0.00	127.67	422.06	---	---	114.90
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
43.22	90.61	0.00	71.73	0.00	0.00	133.83	422.06	---	---	120.45
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
63.05	104.75	0.00	71.73	0.00	0.00	167.80	422.06	---	---	151.02
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
69.03	107.76	0.00	71.73	0.00	0.00	176.78	422.06	---	---	159.11
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
54.97	99.91	0.00	71.73	0.00	0.00	154.88	422.06	---	---	139.39
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
60.94	103.58	0.00	71.73	0.00	0.00	164.51	422.06	---	---	148.06
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
93.69	116.79	0.00	71.73	0.00	0.00	210.48	422.06	---	---	189.43
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
107.53	120.32	0.00	71.73	0.00	0.00	227.86	422.06	---	---	205.07
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71
114.52	121.83	0.00	71.73	0.00	0.00	236.35	422.06	---	---	212.71

Figure 7 - 6A.4.2.1 Shear-5.7.3.3 Nominal Shear Resistance Part 3

In 2022 interim, the load cases shown in the LL column are only envelope shear actions.

Spec Check Detail for 6A.4.2.1 General Load Rating Equation - Concrete Shear

6A Load and Resistance Factor Rating
6A.4 Load Rating Procedures
6A.4.2 General Load-Rating Equation
6A.4.2.1 Concrete Shear General
(AASHTO Manual for Bridge Evaluation, Third Edition with 2022 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left   Stage 3

Shear Rating Factor Calculations

Input:

Condition Factor = 1.0000
System Factor = 1.0000
DC Shear (Max) = 25.2718 (kip)
DC Shear (Min) = 25.2718 (kip)
DW Shear (Max) = 3.9900 (kip)
DW Shear (Min) = 3.9900 (kip)
DW-WS Shear (Max) = 0.0000 (kip)
DW-WS Shear (Min) = 0.0000 (kip)

Ignore design & legal shear: False
Ignore permit shear: True

Note: If the capacity has been overridden, the Resistance is computed as override phi*override capacity.
Otherwise the Resistance is computed as per the Specification.

Load	Load Combo	Limit State	LL (kip)	Adj. LL (kip)	Load Factors DC	DW	DW-WS	LL	Phi	Vn (kip)	-- Override -- Phi	Vn (kip)	RF	Capacity (Ton)
DesignInv	1	STR-I	51.99	---	1.25	1.50	1.50	1.75	0.90	127.44	---	---	0.848	30.51
DesignInv	1	STR-I	-7.18	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	19.917	717.02
DesignOp	1	STR-I	51.99	---	1.25	1.50	1.50	1.35	0.90	167.47	---	---	1.612	58.03
DesignOp	1	STR-I	-7.18	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	25.819	929.47
DesignInv	2	STR-I	42.75	---	1.25	1.50	1.50	1.75	0.90	154.53	---	---	1.357	48.84
DesignInv	2	STR-I	-7.87	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	18.174	654.26
DesignOp	2	STR-I	42.75	---	1.25	1.50	1.50	1.35	0.90	209.88	---	---	2.622	94.38
DesignOp	2	STR-I	-7.87	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	23.559	848.12

Load Combination Legend:

Code	Vehicle
1	HL-93 (US) - Truck + Lane

OK

Figure 8 - 6A.4.2.1 General Load Rating Equation - Concrete Shear MBE 3rd edition, 2022 interim

In 2023 interim, the LL values shown for governing action Max V and Min V are the envelope shear values. For govening action Max M and Min M, shear concurrent with moment are considered. This results in new load cases.

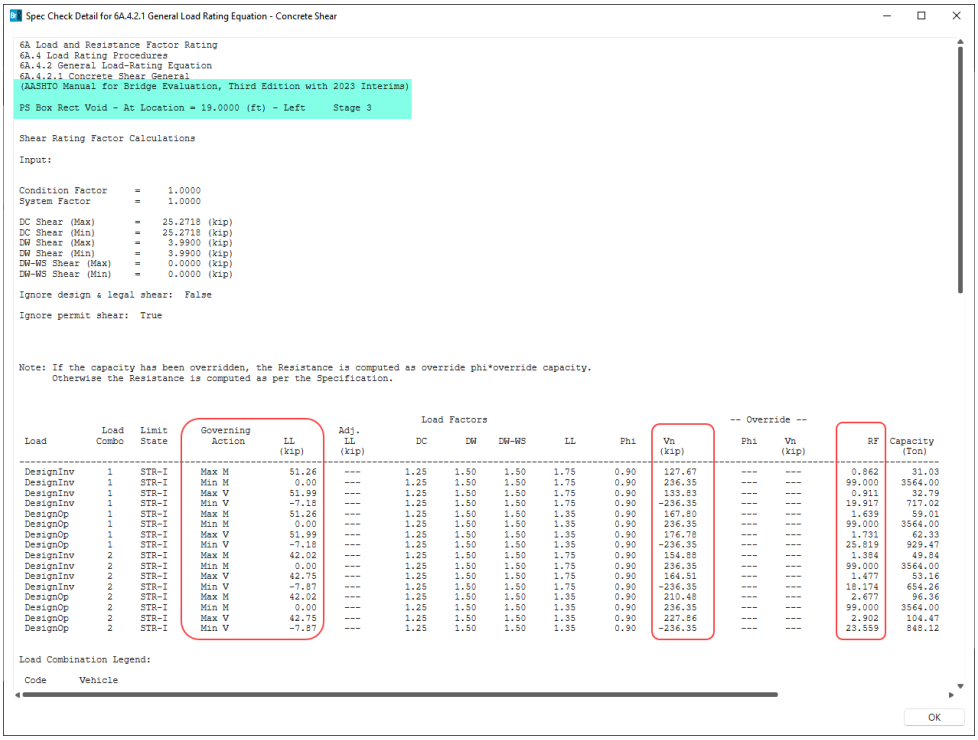


Figure 9 - 6A.4.2.1 General Load Rating Equation -Concrete Shear MBE 3rd edition, 2023 interim

Highlighted portion in image below shows the improvement of rating factor from 0.848 in 2022 interim to 0.911 in 2023 interim for Design inventory, load case 1, STR-1 limit state.

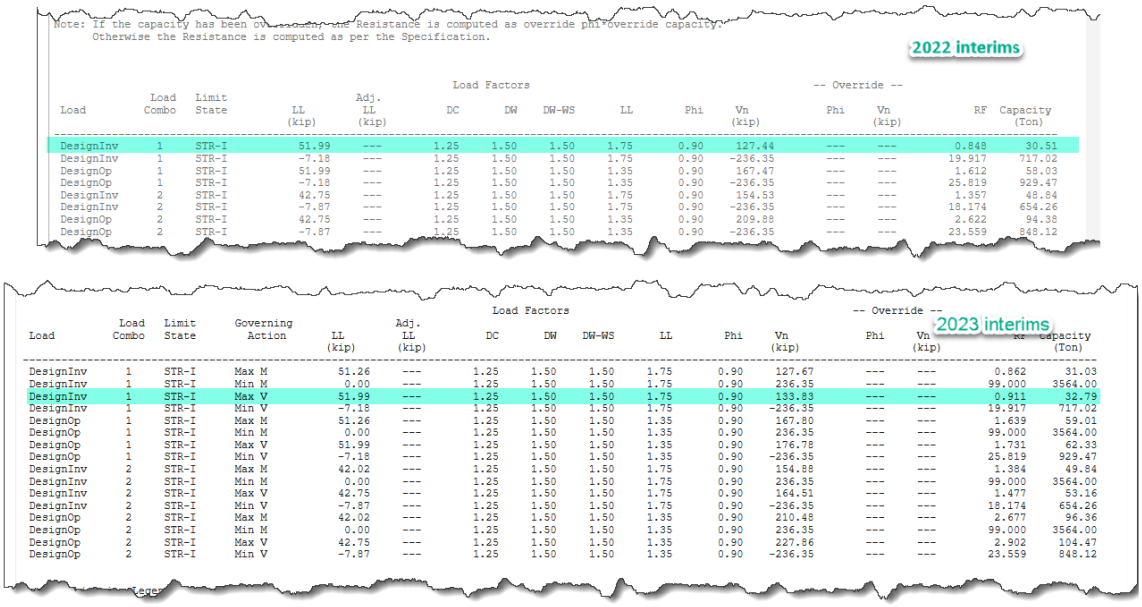


Figure 10 - 6A.4.2.1 General Load Rating Equation -Concrete Shear rating comparison

Spec Check Detail for 6A.5.8 Evaluation for Shear

```
6A Load and Resistance Factor Rating
6A.5 Concrete Structures
6A.5.8 Evaluation for Shear
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Longitudinal Reinforcement
--------------------------

From LRFD 5.7.3.5-1

LHS or Tr  = Aps*fps + As*fy

        |Mu|           Nu      /| Vu        |         \
RHS = -------- + 0.5 ----- + ||---- - Vp| -0.5 * Vs| * cot(theta)  (LRFD 5.7.3.5-1)
       dv*phif         phic    \|phiv       |         /

                     |MuDL|                 NuDL               |VuDL        |
T(DL) = SignMDL * -------- + 0.5 * SignNDL * ---- + (SignVDLp * |---- - Vp| - 0.5 * Vs) * cot(theta), where Vs = min(Vs, Vu/phiv)  (Based on LRFD 5.7.3.5-1 and MBE 6A.5.8)
                   dv*phif                   phic               |phiv       |

                     |MuLL|                 NuLL               |VuLL|
T(LL) = SignMLL * -------- + 0.5 * SignNLL * ---- + (SignVLL * |----| ) * cot(theta)                                    (Based on LRFD 5.7.3.5-1 and MBE 6A.5.8)
                   dv*phif                   phic               |phiv|

Where:

                                          VuDL + VuLL              VuDL
Mu = MuDL + MuLL; Nu = NuDL + NuLL; VT = ----------- - Vp; VuDLp = -------- - Vp
                                             phiv                  phiv

                   / MuDL \                    / NuDL \                      / VuDLp \                    / MuLL \                    / NuLL \                    / VuLL \
SignMDL = Sign of |------|; SignNDL = Sign of | ------ |; SignVDLp  = Sign of |  -----  |; SignMLL = Sign of |  -----  |; SignNLL = Sign of |  -----  |; SignVLL = Sign of |  -----  |
                   \  Mu  /                    \  Nu  /                      \  VT  /                     \  Mu  /                    \  Nu  /                    \  VT  /

     T(r) - T(DL)
RF = ------------
        T(LL)

Ignore design & legal shear      :  No
Ignore permit shear              :  Yes
Consider iterative shear rating  :  No
Consider MCFT theta              :  No
Shear computation method type    :  General
Iteration required               :  No

phif = 1.000
phic = 0.750
phiv = 0.900

 ----------------------------------------------------------

 As(pos)   =         0.000  (in^2)    (used for Positive Mu)
 As(neg)   =         0.000  (in^2)    (used for Negative Mu)
 fy(pos)   =         0.000  (ksi)     (used for Positive Mu)
 fy(neg)   =         0.000  (ksi)     (used for Negative Mu)
Aps(pos)   =         4.284  (in^2)    (used for Positive Mu)
Aps(neg)   =         0.306  (in^2)    (used for Negative Mu)
fps(pos)   =       245.606  (ksi)     (used for Positive Mu)
fps(neg)   =       141.252  (ksi)     (used for Negative Mu)
 Bv(pos)   =        10.000  (in)      (used for Positive Mu)
 Bv(neg)   =        10.000  (in)      (used for Negative Mu)
 Dv(pos)   =        33.765  (in)      (used for Positive Mu)
 Dv(neg)   =        28.080  (in)      (used for Negative Mu)
```

Figure 11 - 6A.5.8 Evaluation for Shear MBE 3rd edition, 2023 interim

Limit State	Load Comb	dv (in)	As*fy (kips)	Aps*fps (kips)	Tr (kips)	MuDL (kip-in)	NuDL (kips)	VuDL (kips)	Vp (kips)	Governing Action	MuLL (kip-in)	NuLL (kips)	VuLL (kips)	epsilon	beta	theta (Deg.)	Av (in^2)	s (in)	Vs (kips)	TDL (kips)	TLL (kips)	LHS/RHS	RF	Capacity (Ton)
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	21909.89	0.00	89.71	0.002471	1.68	37.65	0.40	12.00	87.53	332.60	778.10	0.95	0.925	33.29
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00	0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	3564.00
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	20745.45	0.00	90.99	0.002199	1.81	36.70	0.40	12.00	90.61	330.45	750.05	0.97	0.962	34.64
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	11460.56	0.00	-12.57	0.000000	4.80	29.00	0.40	12.00	121.83	385.47	314.23	1.50	2.122	76.38
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	16901.91	0.00	69.21	0.001088	2.64	32.81	0.40	12.00	104.75	318.74	619.85	1.12	1.183	42.60
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00	0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	3564.00
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	16003.63	0.00	70.19	0.000879	2.89	32.08	0.40	12.00	107.76	315.87	598.42	1.15	1.230	44.30
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	8841.00	0.00	-9.69	0.000000	4.80	29.00	0.40	12.00	121.83	382.59	242.41	1.68	2.762	99.44
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	18223.13	0.00	73.54	0.001444	2.30	34.06	0.40	12.00	99.91	323.08	660.60	1.07	1.104	39.73
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00	0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	3564.00
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	17058.69	0.00	74.82	0.001172	2.55	33.10	0.40	12.00	103.58	319.82	632.72	1.10	1.157	41.67
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	12559.88	0.00	-13.77	0.000000	4.80	29.00	0.40	12.00	121.83	386.68	344.37	1.44	1.932	69.57
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	14057.84	0.00	56.73	0.000296	3.93	30.04	0.40	12.00	116.79	316.81	525.36	1.25	1.400	50.39
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00	0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	3564.00
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	13159.56	0.00	57.72	0.000087	4.51	29.30	0.40	12.00	120.32	315.28	504.00	1.28	1.462	52.63
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	9689.05	0.00	-10.62	0.000000	4.80	29.00	0.40	12.00	121.83	383.53	265.66	1.62	2.517	90.61

Figure 12 - 6A.5.8 Evaluation for Shear MBE 3rd edition, 2023 interim

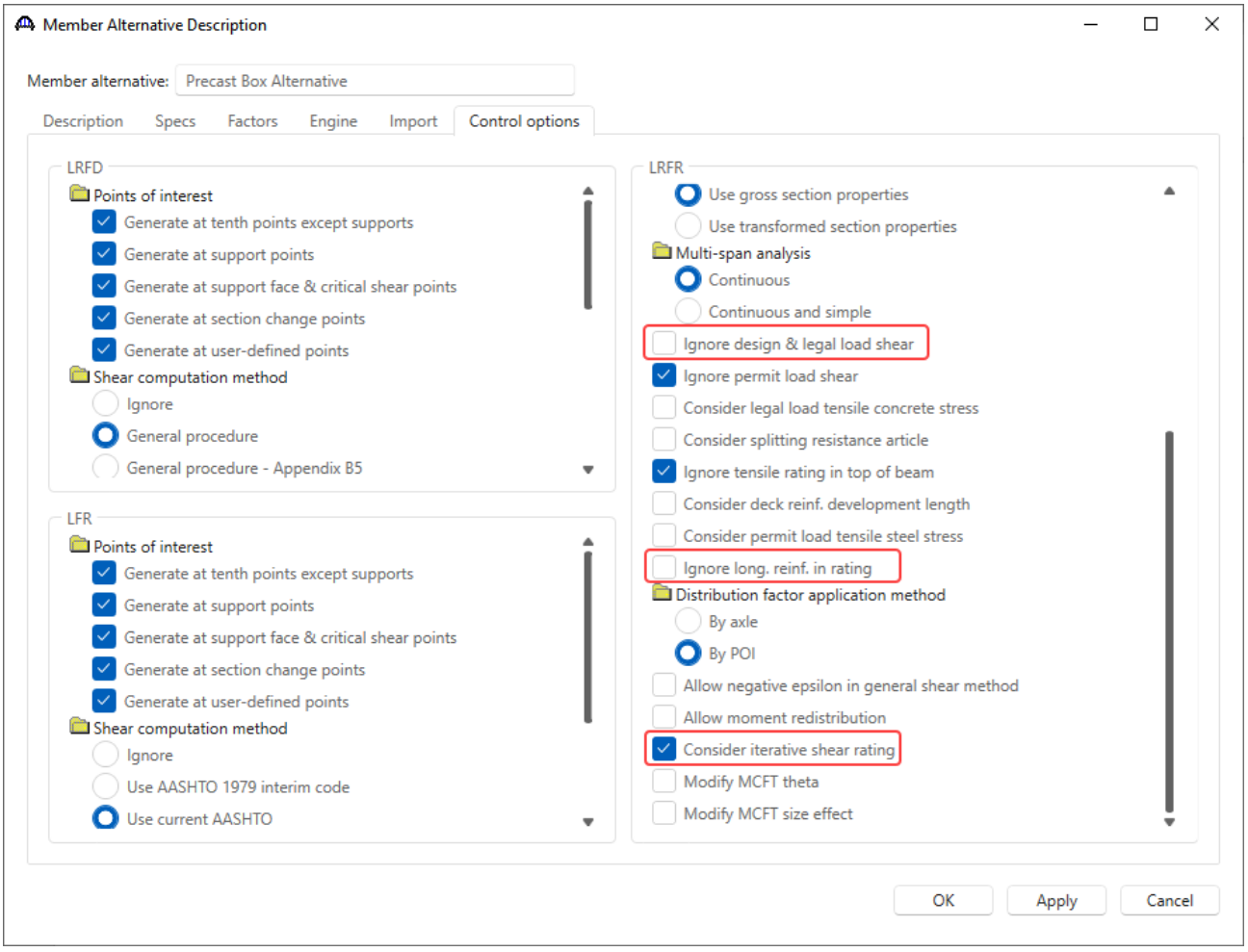
Control option added to consider iterative shear rating

This section details the effects of considering an iterative process to compute the shear capacity used in the LRFR shear rating of concrete bridges. The shear strength for a load rating with Modified Compression Field Theory (MCFT) is an iterative process due to the underlying differences in strain's role in determining shear capacity in design versus load rating. In the iterative process, the factored shear capacity (C = PhiC * PhiS * φVn) is compared to the applied Vu. If they are not equal, iterations will begin by updating Vu, Mu and Nu by proportionally increasing or decreasing the live load portion of these force effects until the C is equal to the applied Vu. This is applicable to all concrete structures, i.e., reinforced concrete, prestressed concrete, post tensioned concrete and reinforced concrete box culverts.

Member Alternative Description – Control options

Navigate to the member alternative Precast Box Alternative of member **G2**, double click on it (or click the **Open** button from the **WORKSPACE** ribbon) to open its **Member Alternative Description** window. Navigate to the **Control options** tab as shown below.

Check the box - **Consider iterative shear rating** as shown below.

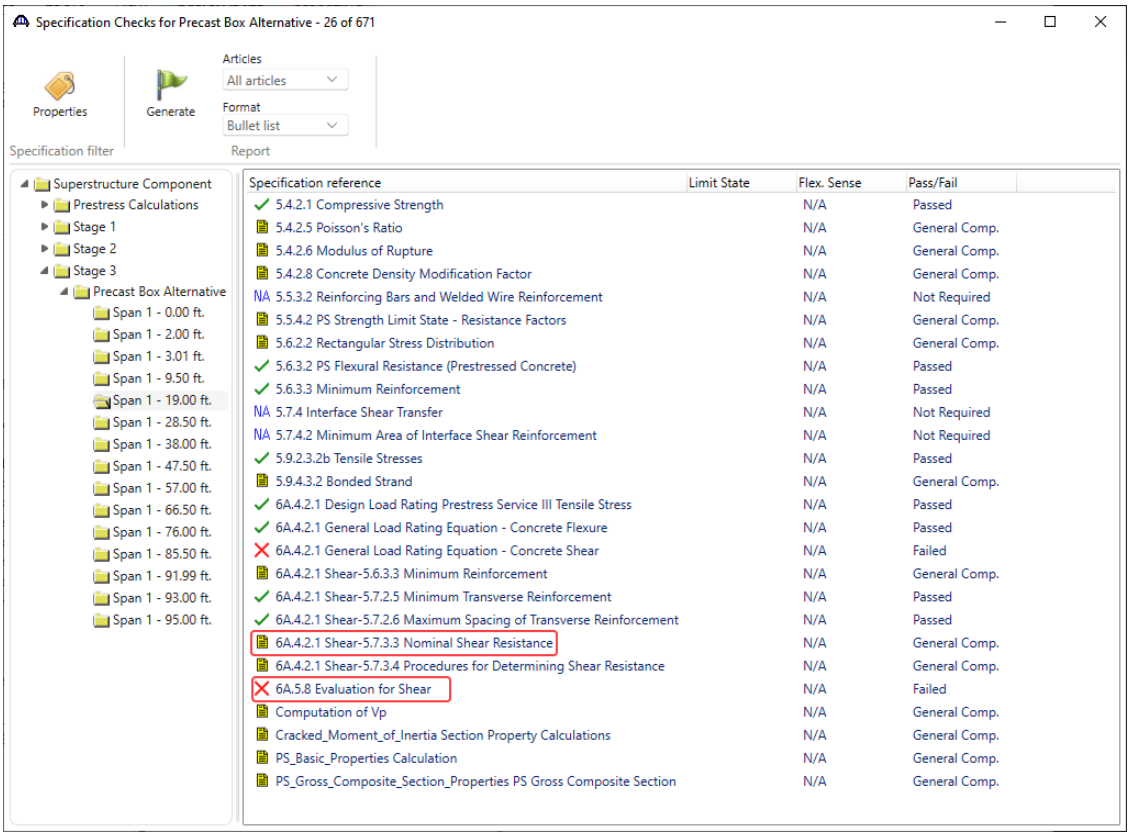


Click **OK** to apply the data and close the window.

Run an LRFR analysis using the analysis settings shown in the previous step.

Specification Check Detail

Once the analysis is complete, open the Specification Check Detail. The specification check articles for the analyzed member alternative for Stage 3 at Span 1 – 19.00 ft, is shown below. Highlighted are the articles where the iteration process is detailed.



Double click on the 6A.4.2.1 Shear-5.7.3.3 Nominal Shear Resistance article to view the iterations. Additional columns in the final iteration table (shown below) details the status of iteration, convergence, and any failure reason, if applicable, for each load case. If iterations for a given load case converge, then this table will show the result of the final iteration. The capacity from the final iteration is used in the rating equation. If the iteration process does not converge, then the corresponding row from the initial capacity table will be used.

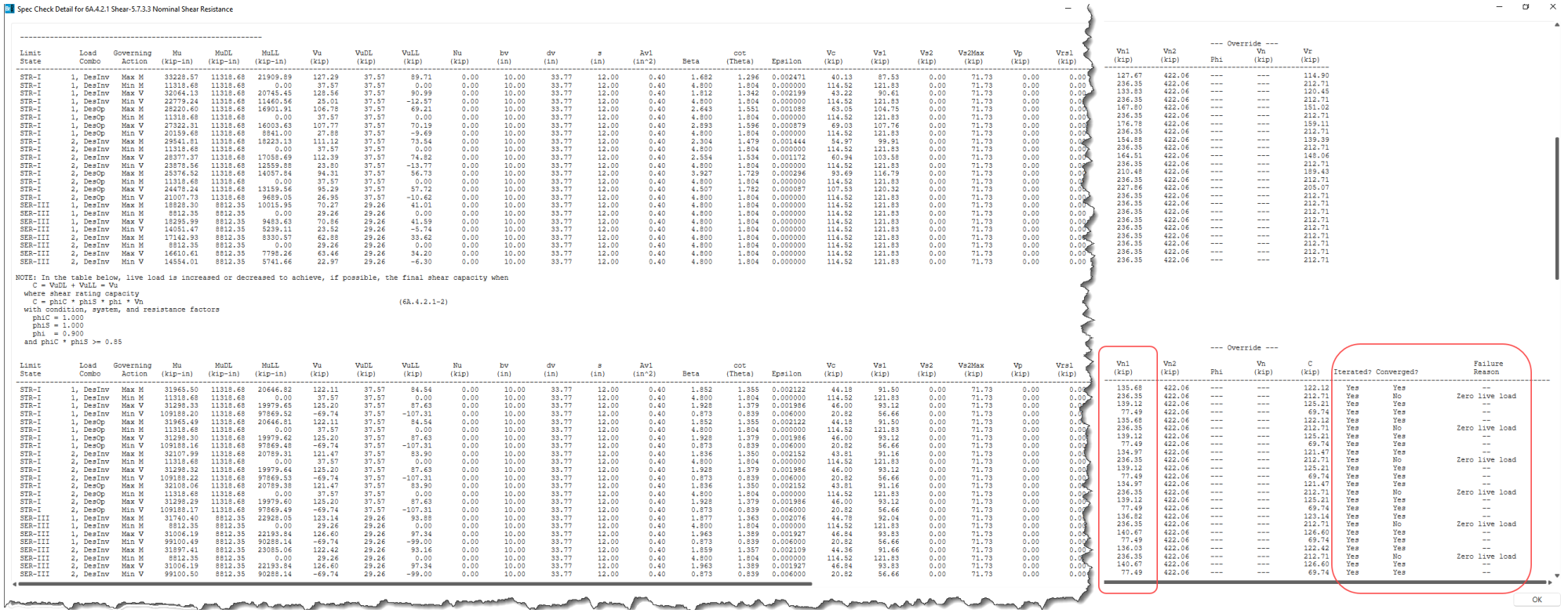
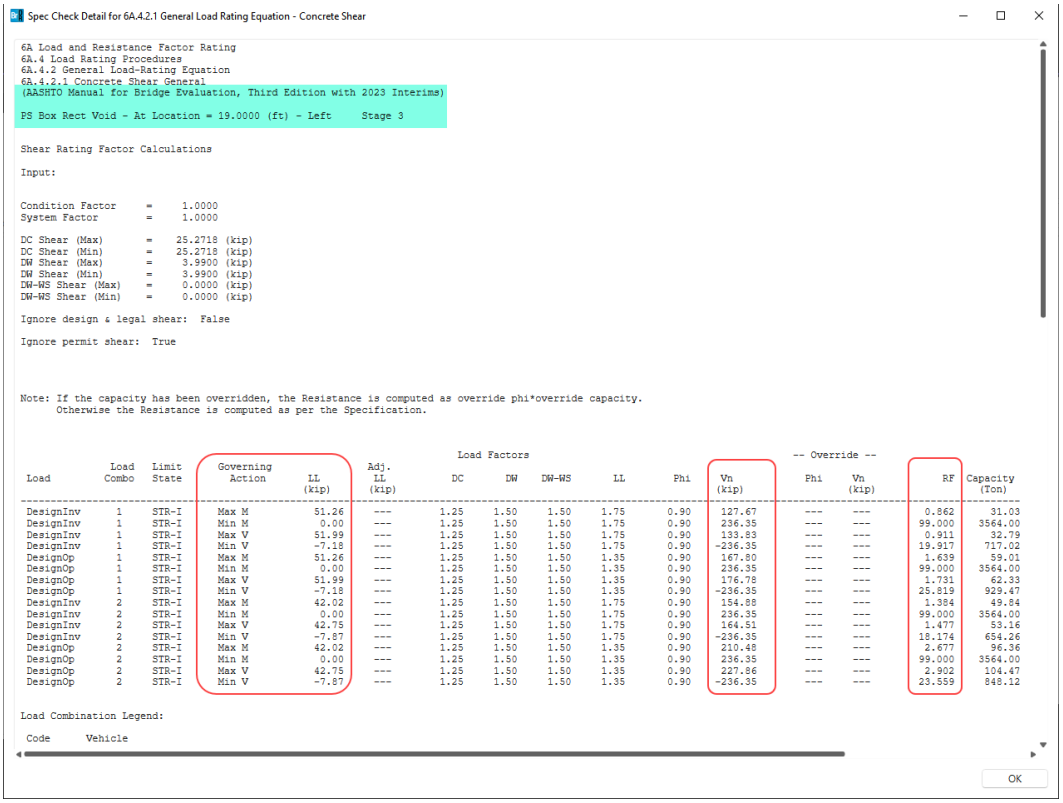


Figure 13 - 6A.4.2.1 Shear-5.7.3.3 Nominal Shear Resistance

Here is a comparison of rating factors at this location with and without iterations.



Spec Check Detail for 6A.4.2.1 General Load Rating Equation - Concrete Shear

```
6A Load and Resistance Factor Rating
6A.4 Load Rating Procedures
6A.4.2 General Load-Rating Equation
6A.4.2.1 Concrete Shear General
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3


Shear Rating Factor Calculations

Input:


Condition Factor     =     1.0000
System Factor        =     1.0000

DC Shear (Max)       =    25.2718 (kip)
DC Shear (Min)       =    25.2718 (kip)
DW Shear (Max)       =     3.9900 (kip)
DW Shear (Min)       =     3.9900 (kip)
DW-WS Shear (Max)    =     0.0000 (kip)
DW-WS Shear (Min)    =     0.0000 (kip)

Ignore design & legal shear:  False

Ignore permit shear:  True



Note: If the capacity has been overridden, the Resistance is computed as override phi*override capacity.
      Otherwise the Resistance is computed as per the Specification.
```

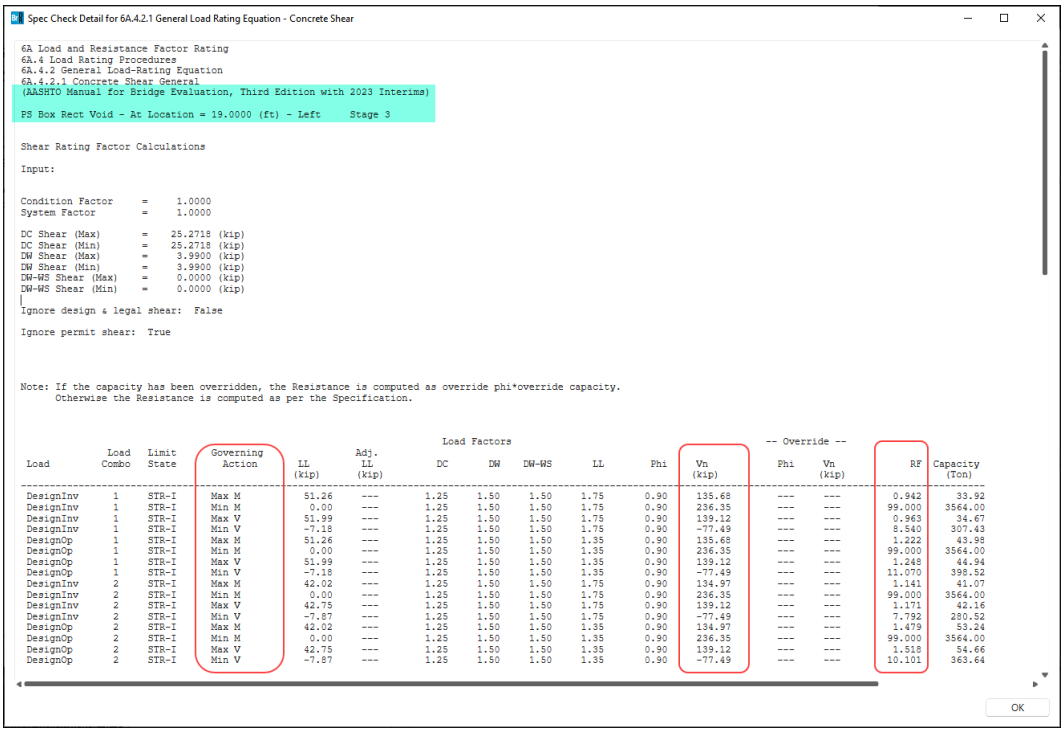
					Load Factors					-- Override --				
Load	Load Combo	Limit State	Governing Action	LL (kip)	Adj. LL (kip)	DC	DW	DW-WS	LL	Phi	Vn (kip)	Phi	Vn (kip)	RF	Capacity (Ton)
DesignInv	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.75	0.90	127.67	---	---	0.862	31.03
DesignInv	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.75	0.90	133.83	---	---	0.911	32.79
DesignInv	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	19.917	717.02
DesignOp	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.35	0.90	167.80	---	---	1.639	59.01
DesignOp	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.35	0.90	176.78	---	---	1.731	62.33
DesignOp	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	25.819	929.47
DesignInv	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.75	0.90	154.88	---	---	1.384	49.84
DesignInv	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.75	0.90	164.51	---	---	1.477	53.16
DesignInv	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	18.174	654.26
DesignOp	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.35	0.90	210.48	---	---	2.677	96.36
DesignOp	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.35	0.90	227.86	---	---	2.902	104.47
DesignOp	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	23.559	848.12

```
Load Combination Legend:

 Code      Vehicle
```

OK

Figure 14 - 6A.4.2.1 General Load Rating Equation - Concrete Shear without iterations



Spec Check Detail for 6A.4.2.1 General Load Rating Equation - Concrete Shear

```
6A Load and Resistance Factor Rating
6A.4 Load Rating Procedures
6A.4.2 General Load-Rating Equation
6A.4.2.1 Concrete Shear General
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3


Shear Rating Factor Calculations

Input:


Condition Factor     =     1.0000
System Factor        =     1.0000

DC Shear (Max)       =    25.2718 (kip)
DC Shear (Min)       =    25.2718 (kip)
DW Shear (Max)       =     3.9900 (kip)
DW Shear (Min)       =     3.9900 (kip)
DW-WS Shear (Max)    =     0.0000 (kip)
DW-WS Shear (Min)    =     0.0000 (kip)

Ignore design & legal shear:  False

Ignore permit shear:  True



Note: If the capacity has been overridden, the Resistance is computed as override phi*override capacity.
      Otherwise the Resistance is computed as per the Specification.
```

					Load Factors					-- Override --				
Load	Load Combo	Limit State	Governing Action	LL (kip)	Adj. LL (kip)	DC	DW	DW-WS	LL	Phi	Vn (kip)	Phi	Vn (kip)	RF	Capacity (Ton)
DesignInv	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.75	0.90	135.68	---	---	0.942	33.92
DesignInv	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.75	0.90	139.12	---	---	0.963	34.67
DesignInv	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.75	0.90	-77.49	---	---	8.540	307.43
DesignOp	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.35	0.90	135.68	---	---	1.222	43.98
DesignOp	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.35	0.90	139.12	---	---	1.248	44.94
DesignOp	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.35	0.90	-77.49	---	---	11.070	398.52
DesignInv	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.75	0.90	134.97	---	---	1.141	41.07
DesignInv	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.75	0.90	139.12	---	---	1.171	42.16
DesignInv	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.75	0.90	-77.49	---	---	7.792	280.52
DesignOp	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.35	0.90	134.97	---	---	1.479	53.24
DesignOp	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.35	0.90	139.12	---	---	1.518	54.66
DesignOp	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.35	0.90	-77.49	---	---	10.101	363.64

OK

Figure 15 - 6A.4.2.1 General Load Rating Equation - Concrete Shear with iterations

Image below highlights some examples of improvements in rating factors with the iteration process.

With iterations

Load	Load Combo	Limit State	Governing Action	LL (kip)	Adj. LL (kip)	Load Factors DC	Load Factors DW	Load Factors DW-WS	Load Factors LL	Phi	Vn (kip)	-- Override -- Phi	-- Override -- Vn (kip)	RF	Capacity (Ton)
DesignInv	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.75	0.90	135.68	---	---	0.942	33.92
DesignInv	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.75	0.90	139.12	---	---	0.963	34.67
DesignInv	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.75	0.90	-77.49	---	---	8.540	307.43
DesignOp	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.35	0.90	135.68	---	---	1.222	43.98
DesignOp	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.35	0.90	139.12	---	---	1.248	44.94
DesignOp	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.35	0.90	-77.49	---	---	11.070	398.52
DesignInv	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.75	0.90	134.97	---	---	1.141	41.07
DesignInv	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.75	0.90	139.12	---	---	1.171	42.16
DesignInv	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.75	0.90	-77.49	---	---	7.792	280.52
DesignOp	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.35	0.90	134.97	---	---	1.479	53.24
DesignOp	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.35	0.90	139.12	---	---	1.518	54.66
DesignOp	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.35	0.90	-77.49	---	---	10.101	363.64

Load Combination Legend:

Code Vehicle

OK

Without iterations

Load	Load Combo	Limit State	Governing Action	LL (kip)	Adj. LL (kip)	Load Factors DC	Load Factors DW	Load Factors DW-WS	Load Factors LL	Phi	Vn (kip)	-- Override -- Phi	-- Override -- Vn (kip)	RF	Capacity (Ton)
DesignInv	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.75	0.90	127.67	---	---	0.862	31.03
DesignInv	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.75	0.90	133.83	---	---	0.911	32.79
DesignInv	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	19.917	717.02
DesignOp	1	STR-I	Max M	51.26	---	1.25	1.50	1.50	1.35	0.90	167.80	---	---	1.639	59.01
DesignOp	1	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	1	STR-I	Max V	51.99	---	1.25	1.50	1.50	1.35	0.90	176.78	---	---	1.731	62.33
DesignOp	1	STR-I	Min V	-7.18	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	25.819	929.47
DesignInv	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.75	0.90	154.88	---	---	1.384	49.84
DesignInv	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.75	0.90	236.35	---	---	99.000	3564.00
DesignInv	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.75	0.90	164.51	---	---	1.477	53.16
DesignInv	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.75	0.90	-236.35	---	---	18.174	654.26
DesignOp	2	STR-I	Max M	42.02	---	1.25	1.50	1.50	1.35	0.90	210.48	---	---	2.677	96.36
DesignOp	2	STR-I	Min M	0.00	---	1.25	1.50	1.50	1.35	0.90	236.35	---	---	99.000	3564.00
DesignOp	2	STR-I	Max V	42.75	---	1.25	1.50	1.50	1.35	0.90	227.86	---	---	2.902	104.47
DesignOp	2	STR-I	Min V	-7.87	---	1.25	1.50	1.50	1.35	0.90	-236.35	---	---	23.559	848.12

Load Combination Legend:

Code Vehicle

OK

Figure 16 - 6A.4.2.1 General Load Rating Equation - Concrete Shear rating comparison

Longitudinal reinforcement evaluation for shear rating is based on the equilibrium of tensile capacity and demand of the longitudinal reinforcement (LRFD eq. 5.7.3.5-1) determined by iterating the live load component of Vu, Mu and Nu.

Spec Check Detail for 6A.5.8 Evaluation for Shear

```
6A Load and Resistance Factor Rating
6A.5 Concrete Structures
6A.5.8 Evaluation for Shear
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Longitudinal Reinforcement
--------------------------

From LRFD 5.7.3.5-1

LHS or Tr  = Aps*fps + As*fy

       |Mu|          Nu     /| Vu       |         \
RHS = -------- + 0.5 ----- + ||---- - Vp| -0.5 * Vs| * cot(theta)  (LRFD 5.7.3.5-1)
      dv*phif        phic   \|phiv      |         /

                   |MuDL|                  NuDL                 |VuDL      |
T(DL) = SignMDL * -------- + 0.5 * SignNDL * ---- + (SignVDLp * |---- - Vp| - 0.5 * Vs) * cot(theta), where Vs = min(Vs, Vu/phiv)  (Based on LRFD 5.7.3.5-1 and MBE 6A.5.8)
                  dv*phif                  phic                 |phiv      |

                   |MuLL|                  NuLL                |VuLL|
T(LL) = SignMLL * -------- + 0.5 * SignNLL * ---- + (SignVLL * |----| ) * cot(theta)                (Based on LRFD 5.7.3.5-1 and MBE 6A.5.8)
                  dv*phif                  phic                |phiv|

Where:

                                     VuDL + VuLL              VuDL
Mu = MuDL + MuLL; Nu = NuDL + NuLL; VT = ----------- - Vp; VuDLp = -------- - Vp
                                        phiv                  phiv

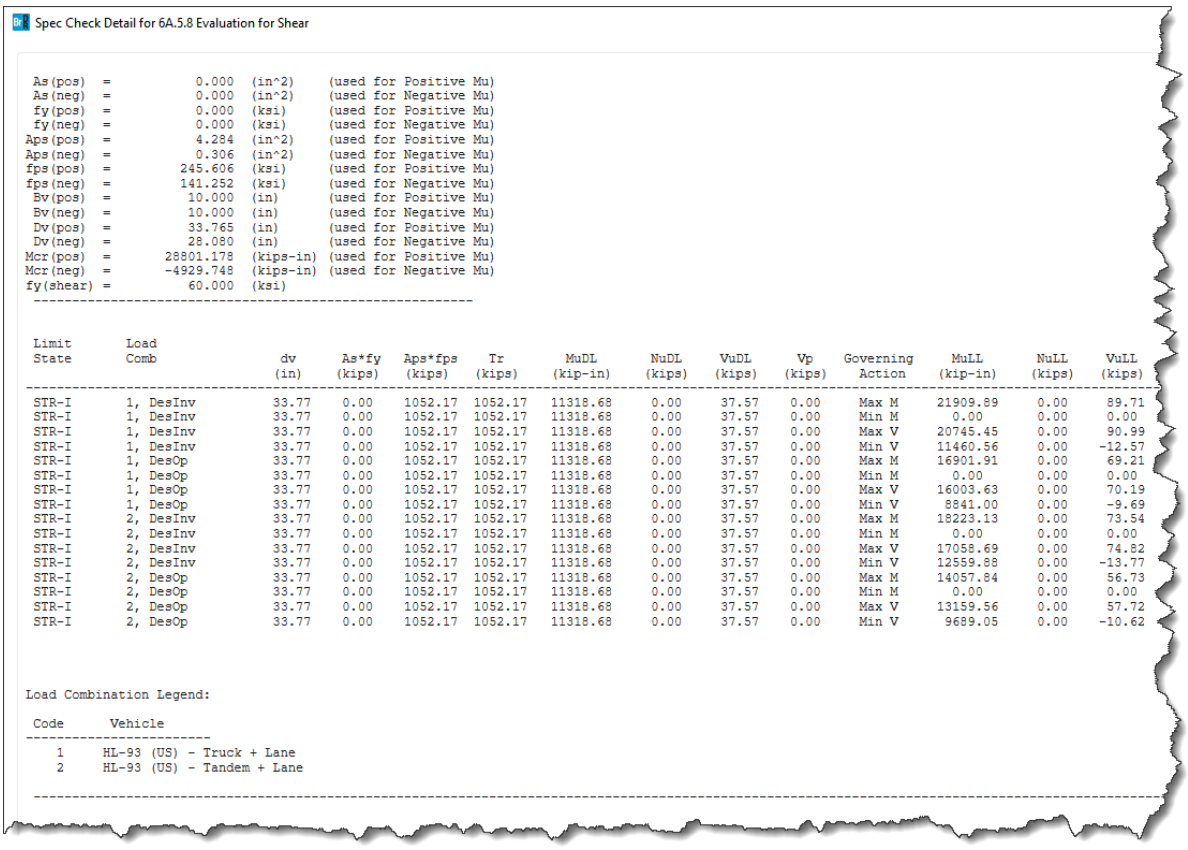
                   / MuDL \                    / NuDL \                        / VuDLp \                   / MuLL \                   / NuLL \                   / VuLL \
SignMDL = Sign of |------|; SignNDL = Sign of | ------ |; SignVDLp  = Sign of |  -----  |; SignMLL = Sign of |  ----- |; SignNLL = Sign of |  ----- |; SignVLL = Sign of |  ----- |
                   \  Mu  /                    \  Nu  /                        \  VT   /                   \  Mu  /                   \  Nu  /                   \  VT  /

     T(r) - T(DL)
RF = ------------
        T(LL)

Ignore design & legal shear      :  No
Ignore permit shear              :  Yes
Consider iterative shear rating  :  Yes
Consider MCFT theta              :  No
Shear computation method type    :  General
Iteration required               :  Yes

phif = 1.000
phic = 0.750
phiv = 0.900
```

Figure 17 - 6A.5.8 Evaluation for shear – Part 1



Spec Check Detail for 6A.5.8 Evaluation for Shear

As(pos)	= 0.000	(in^2)	(used for Positive Mu)
As(neg)	= 0.000	(in^2)	(used for Negative Mu)
fy(pos)	= 0.000	(ksi)	(used for Positive Mu)
fy(neg)	= 0.000	(ksi)	(used for Negative Mu)
Aps(pos)	= 4.284	(in^2)	(used for Positive Mu)
Aps(neg)	= 0.306	(in^2)	(used for Negative Mu)
fps(pos)	= 245.606	(ksi)	(used for Positive Mu)
fps(neg)	= 141.252	(ksi)	(used for Negative Mu)
Bv(pos)	= 10.000	(in)	(used for Positive Mu)
Bv(neg)	= 10.000	(in)	(used for Negative Mu)
Dv(pos)	= 33.765	(in)	(used for Positive Mu)
Dv(neg)	= 28.080	(in)	(used for Negative Mu)
Mcr(pos)	= 28801.178	(kips-in)	(used for Positive Mu)
Mcr(neg)	= -4929.748	(kips-in)	(used for Negative Mu)
fy(shear)	= 60.000	(ksi)	

Limit State	Load Comb	dv (in)	As*fy (kips)	Aps*fps (kips)	Tr (kips)	MuDL (kip-in)	NuDL (kips)	VuDL (kips)	Vp (kips)	Governing Action	MuLL (kip-in)	NuLL (kips)	VuLL (kips)
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	21909.89	0.00	89.71
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	20745.45	0.00	90.99
STR-I	1, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	11460.56	0.00	-12.57
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	16901.91	0.00	69.21
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	16003.63	0.00	70.19
STR-I	1, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	8841.00	0.00	-9.69
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	18223.13	0.00	73.54
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	17058.69	0.00	74.82
STR-I	2, DesInv	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	12559.88	0.00	-13.77
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max M	14057.84	0.00	56.73
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min M	0.00	0.00	0.00
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Max V	13159.56	0.00	57.72
STR-I	2, DesOp	33.77	0.00	1052.17	1052.17	11318.68	0.00	37.57	0.00	Min V	9689.05	0.00	-10.62

Load Combination Legend:

Code	Vehicle
1	HL-93 (US) - Truck + Lane
2	HL-93 (US) - Tandem + Lane

Figure 18 - 6A.5.8 Evaluation for shear – Part 2

Shown below is a comparion of rating factors between non-iteration and iteration from LRFD equation 5.7.3.5-1

Non-Iterated										Iterated										
epsilon	beta	theta (Deg.)	Av (in^2)	s (in)	Vs (kips)	TDL (kips)	TLL (kips)	LHS/RHS	RF	epsilon	beta	theta (Deg.)	Av (in^2)	s (in)	Vs (kips)	TDL (kips)	TLL (kips)	LHS/RHS	RF	Capacity (Ton)
0.002471	1.68	37.65	0.40	12.00	87.53	332.60	778.10	0.95	0.925	--	--	--	--	--	--	--	--	--	--	33.29
0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	--	--	--	--	--	--	--	--	--	--	3564.00
0.002199	1.81	36.70	0.40	12.00	90.61	330.45	750.05	0.97	0.962	--	--	--	--	--	--	--	--	--	--	34.64
0.000000	4.80	29.00	0.40	12.00	121.83	385.47	314.23	1.50	2.122	0.002006	1.92	36.02	0.40	12.00	92.87	373.53	320.22	1.00	2.119	76.38
0.001088	2.64	32.81	0.40	12.00	104.75	318.74	619.85	1.12	1.183	0.001986	1.93	35.95	0.40	12.00	93.11	328.59	606.60	1.00	1.193	42.60
0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	--	--	--	--	--	--	--	--	--	--	3564.00
0.000879	2.89	32.08	0.40	12.00	107.76	315.87	598.42	1.15	1.230	0.001963	1.94	35.87	0.40	12.00	93.39	328.38	581.83	1.00	1.244	44.30
0.000000	4.80	29.00	0.40	12.00	121.83	382.59	242.41	1.68	2.762	0.002006	1.92	36.02	0.40	12.00	92.88	371.34	247.02	1.00	2.756	99.44
0.001444	2.30	34.06	0.40	12.00	99.91	323.08	660.60	1.07	1.104	0.001992	1.92	35.97	0.40	12.00	93.05	328.64	652.29	1.00	1.109	39.73
0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	--	--	--	--	--	--	--	--	--	--	3564.00
0.001172	2.55	33.10	0.40	12.00	103.58	319.82	632.72	1.10	1.157	0.001964	1.94	35.87	0.40	12.00	93.38	328.38	620.18	1.00	1.167	41.67
0.000000	4.80	29.00	0.40	12.00	121.83	386.68	344.37	1.44	1.932	0.002006	1.92	36.02	0.40	12.00	92.87	374.45	350.93	1.00	1.931	69.57
0.000296	3.93	30.04	0.40	12.00	116.79	316.81	525.36	1.25	1.400	0.001985	1.93	35.95	0.40	12.00	93.12	328.58	503.27	1.00	1.438	50.39
0.000000	4.80	29.00	0.40	12.00	121.83	372.88	0.00	2.82	99.000	--	--	--	--	--	--	--	--	--	--	3564.00
0.000087	4.51	29.30	0.40	12.00	120.32	315.28	504.00	1.28	1.462	0.001966	1.94	35.88	0.40	12.00	93.36	328.40	478.40	1.00	1.513	52.63
0.000000	4.80	29.00	0.40	12.00	121.83	383.53	265.66	1.62	2.517	0.002006	1.92	36.02	0.40	12.00	92.88	372.05	270.72	1.00	2.512	90.61

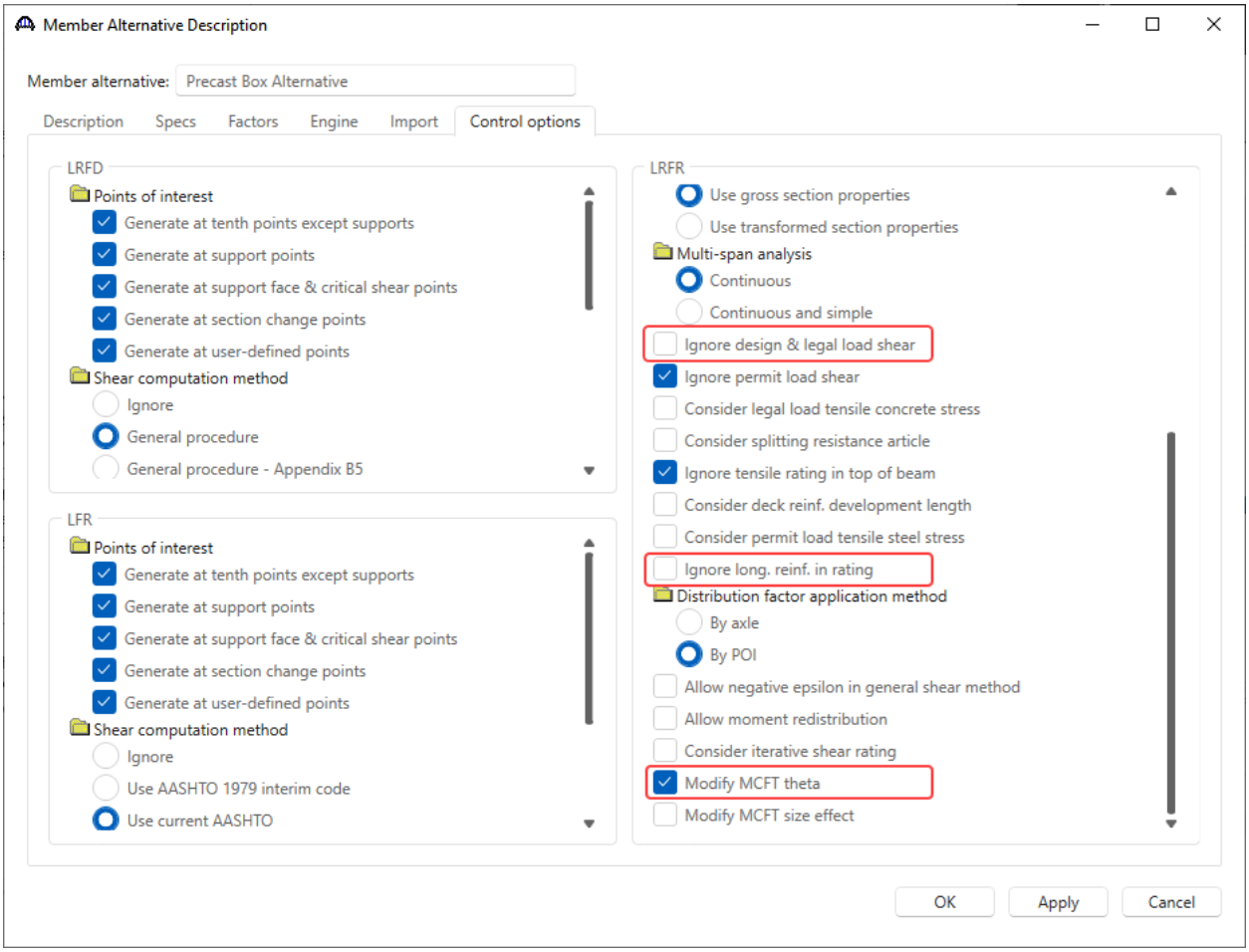
Figure 19 - 6A.5.8 Evaluation for shear – Part 3

Control option added to consider modifying MCFT theta

This section discusses the control option "Modify MCFT theta" added for all concrete structures, i.e., reinforced concrete, prestressed concrete, post tensioned concrete and reinforced concrete box culverts.

Member Alternative Description – Control options

Navigate to the member alternative **Precast Box Alternative** of member **G2**, double click on it (or click the **Open** button from the **WORKSPACE** ribbon) to open its **Member Alternative Description** window. Navigate to the **Control options** tab as shown below. Check the box - **Modify MCFT theta** as shown below.



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

Run an LRFR analysis using the analysis settings shown in the previous step.

Specification Check Detail

Once the analysis is complete, open the 6A.4.2.1 Shear-5.7.3.4 Procedures for Determining Shear Resistance article for the analyzed member alternative for Stage 3 at Span 1 – 19.00 ft. This article highlights the status of the "Modify MCFT Theta" control option. With this control option checked, in areas of low strain where the section remains uncracked i.e., if the factored moment at this section is less than the cracking moment (Mu < Mcr), the strain εs may be assumed to be zero regardless of the values of moment (Mu) and shear (Vu), therefore, "Theta" can be taken as 29°.

Spec Check Detail for 6A.4.2.1 Shear-5.6.3.3 Minimum Reinforcement

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.6 Design for Flexural and Axial Effects - B Regions
6A.4.2.1 Shear - 5.6.3 Flexural Members
6A.4.2.1 Shear - 5.6.3.3 Minimum Reinforcement
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Cross Section Properties for Prestress box beam with Rectangular void
-----------------------------------------------------------------
Name: BIII-48   Girder f'c = 5.00(ksi)     Girder f'ci = 4.00(ksi)

Beam Height             =   39.00(in)     Side Wall Thickness      =    5.00(in)
Top Slab Width          =   47.25(in)
Top Slab Thick          =    5.50(in)
Bottom Slab Width       =   48.00(in)
Bottom Slab Thick       =    5.50(in)
Shear Key Top           =    6.00(in)
Shear Key Height        =    6.00(in)
Shear Key Depth         =    0.75(in)
B1                      =    3.00(in)
B2                      =    3.00(in)
B3                      =    3.00(in)
B4                      =    3.00(in)

Slab f'c                =      0.00(ksi)
Effective Slab Width    =      0.00(in)        Haunch Width              =      0.00(in)
Effective Slab Thickness =     0.00(in)        Haunch Thickness          =      0.00(in)

Input:
fr beam =        0.54ksi
ScTop   =    -8569.07in^3            Mdnc    =     8812.35kip-in
ScBot   =     8734.21in^3            SncBot  =     8734.21in^3
Gamma1 =  1.60
Gamma2 =  1.10
Gamma3 =  1.00 (Prestressed Concrete)
Gamma3 =  0.67 (Reinforced Concrete)

Mcr = Gamma3 * [( gamma1*fr + Gamma2*fcpe)*Sc - Mdnc * (Sc/Snc - 1)]      (5.6.3.3-1)
Note: If the capacity has been overridden, the Resistance is computed as override phi*override capacity.
      Otherwise the Resistance is computed as per the Specification.
```

Limit State	Load Comb	fcpe ksi	fr ksi	Gamma3	Governing Action	Mu kip-in	Vu kip	Sc in^3	Mcr kip-in
STR-I	1, DesInv	2.22	0.54	1.00	Max M	33228.57	127.29	8734.21	28801.18
STR-I	1, DesInv	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	1, DesInv	2.22	0.54	1.00	Max V	32064.13	128.56	8734.21	28801.18
STR-I	1, DesInv	2.22	0.54	1.00	Min V	22779.24	25.01	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Max M	28220.60	106.78	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Max V	27322.31	107.77	8734.21	28801.18
STR-I	1, DesOp	2.22	0.54	1.00	Min V	20159.68	27.88	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Max M	29541.81	111.12	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Max V	28377.37	112.39	8734.21	28801.18
STR-I	2, DesInv	2.22	0.54	1.00	Min V	23878.56	23.80	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Max M	25376.52	94.31	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Min M	11318.68	37.57	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Max V	24478.24	95.29	8734.21	28801.18
STR-I	2, DesOp	2.22	0.54	1.00	Min V	21007.73	26.95	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Max M	18828.30	70.27	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Min M	8812.35	29.26	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Max V	18295.99	70.86	8734.21	28801.18
SER-III	1, DesInv	2.22	0.54	1.00	Min V	14051.47	23.52	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Max M	17142.93	62.88	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Min M	8812.35	29.26	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Max V	16610.61	63.46	8734.21	28801.18
SER-III	2, DesInv	2.22	0.54	1.00	Min V	14554.01	22.97	8734.21	28801.18

Figure 20 6A.4.2.1 Shear 5.6.3.3 Minimum Reinforcement

Spec Check Detail for 6A.4.2.1 Shear-5.7.3.4 Procedures for Determining Shear Resistance

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.7 Shear and Torsion
6A.4.2.1 Shear - 5.7.3 Sectional Design Model
6A.4.2.1 Shear - 5.7.3.4 Procedures for Determining Shear Resistance
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Calculation of Beta/Theta
-------------------------

      Es = 0.000 (kips/in^2)
     phi = 0.900
     f'c = 5.000 (kips/in^2)
     fpc = 0.937 (kips/in^2)
      fy = 60.000 (kips/in^2)
Agg diam = 1.000 (in)
      Vp = 0.000 (kips)
      Ep = 28500.000 (kips/in^2)
 As(pos) = 0.000 (in^2)   (used for Positive Mu)
 As(neg) = 0.000 (in^2)   (used for Negative Mu)
Aps(pos) = 4.284 (in^2)   (used for Positive Mu)
Aps(neg) = 0.306 (in^2)   (used for Negative Mu)
     fpo = 189.000 (kips/in^2)
      Ec = 4592.232 (kips/in^2)

Beta Calc (used in table below) :
     (1) - Beta = 4.8 / (1 + 750 EpsilonS)
     (2) - Beta = ( 4.8 / (1 + 750 EpsilonS) ) * (51 / (39 + sxe) )
                where:
                   sxe = sx * (1.38 / (ag + 0.63) )

  Mu_calc = Max(Mu, |Vu - Vp| * dv)

Modify MCFT Theta:   Yes

Modify MCFT Size Effect:   No
fpc / f'c = 0.19
```

Limit State	Load Comb	Epsilon	Theta	Beta	Governing Action	Mu (kip-in)
STR-I	1, DesInv	0.002471	37.65	1.68	Max M	33228.57
STR-I	1, DesInv	0.000000	29.00	4.80	Min M	11318.68
STR-I	1, DesInv	0.002199	36.70	1.81	Max V	32064.13
STR-I	1, DesInv	0.000000	29.00	4.80	Min V	22779.24
STR-I	1, DesOp	0.000000	29.00	4.80	Max M	28220.60
STR-I	1, DesOp	0.000000	29.00	4.80	Min M	11318.68
STR-I	1, DesOp	0.000000	29.00	4.80	Max V	27322.31
STR-I	1, DesOp	0.000000	29.00	4.80	Min V	20159.68
STR-I	2, DesInv	0.001444	34.06	2.30	Max M	29541.81
STR-I	2, DesInv	0.000000	29.00	4.80	Min M	11318.68
STR-I	2, DesInv	0.000000	29.00	4.80	Max V	28377.37
STR-I	2, DesInv	0.000000	29.00	4.80	Min V	23878.56
STR-I	2, DesOp	0.000000	29.00	4.80	Max M	25376.52
STR-I	2, DesOp	0.000000	29.00	4.80	Min M	11318.68
STR-I	2, DesOp	0.000000	29.00	4.80	Max V	24478.24
STR-I	2, DesOp	0.000000	29.00	4.80	Min V	21007.73
SER-III	1, DesInv	0.000000	29.00	4.80	Max M	18828.30
SER-III	1, DesInv	0.000000	29.00	4.80	Min M	8812.35
SER-III	1, DesInv	0.000000	29.00	4.80	Max V	18295.99
SER-III	1, DesInv	0.000000	29.00	4.80	Min V	14051.47
SER-III	2, DesInv	0.000000	29.00	4.80	Max M	17142.93
SER-III	2, DesInv	0.000000	29.00	4.80	Min M	8812.35
SER-III	2, DesInv	0.000000	29.00	4.80	Max V	16610.61
SER-III	2, DesInv	0.000000	29.00	4.80	Min V	14554.01

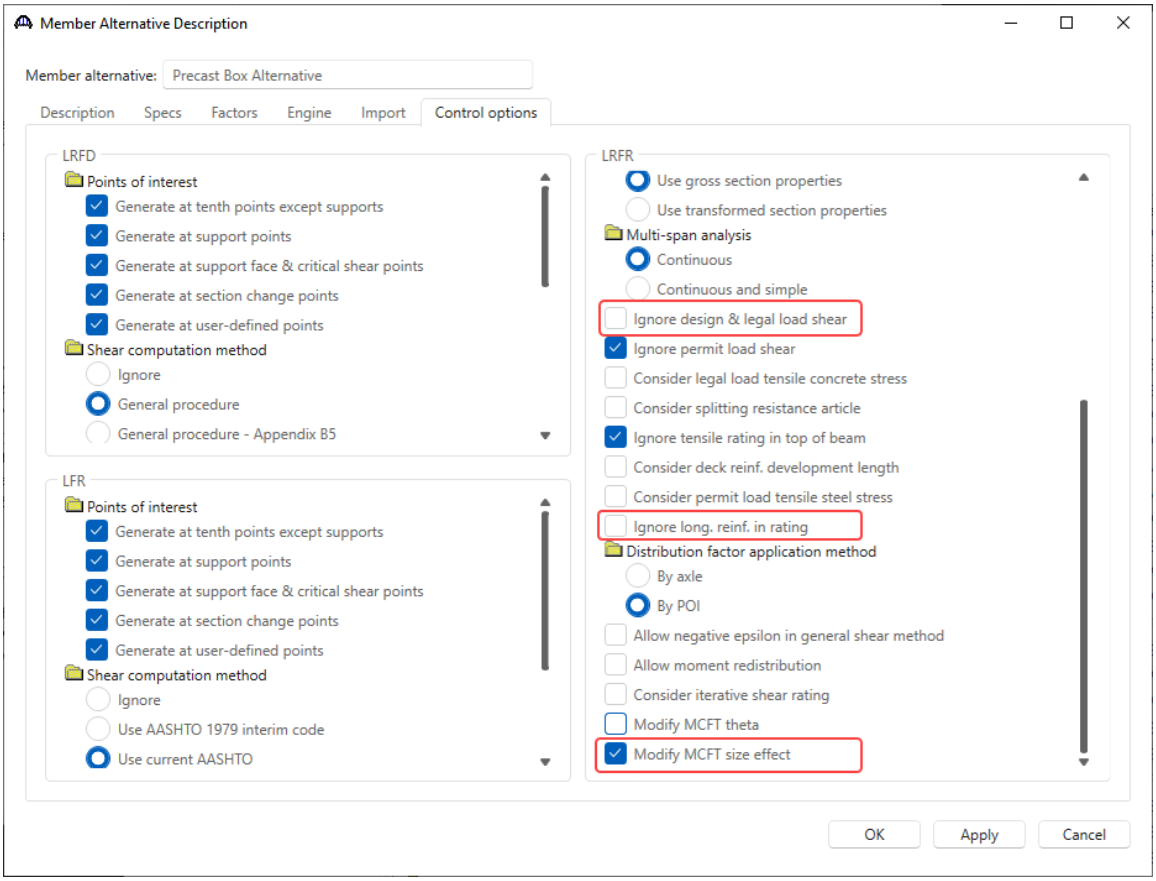
Figure 21 6A.4.2.1 Shear 5.7.3.4 Procedures for Determining Shear Resistance

Control option added to consider modifying MCFT size effect

This section discusses the control option "Modify MCFT size effect" added for prestressed concrete and post-tensioned concrete structures only. This does not apply to reinforced concrete structures and culverts.

Member Alternative Description – Control options

Navigate to the member alternative **Precast Box Alternative** of member **G2**, double click on it (or click the **Open** button from the **WORKSPACE** ribbon) to open its **Member Alternative Description** window. Navigate to the **Control options** tab as shown below. Check the box - **Modify MCFT size effect** as shown below.



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

Run an LRFR analysis using the analysis settings shown in the previous step.

Specification Check Detail

Once the analysis is complete, open the 6A.4.2.1 Shear-5.7.3.4 Procedures for Determining Shear Resistance article for the analyzed member alternative for Stage 3 at Span 1 – 19.00 ft. This article highlights the status of the "Modify MCFT size effect" control option. With this control option checked, if the ratio fpc/f'c is greater than 0.02, the size effect is neglected regardless of the amount of shear reinforcement present. The article is shown below.

Spec Check Detail for 6A.4.2.1 Shear-5.7.3.4 Procedures for Determining Shear Resistance

```
6A.4.2.1 Shear - 5 Concrete Structures
6A.4.2.1 Shear - 5.7 Shear and Torsion
6A.4.2.1 Shear - 5.7.3 Sectional Design Model
6A.4.2.1 Shear - 5.7.3.4 Procedures for Determining Shear Resistance
(AASHTO Manual for Bridge Evaluation, Third Edition with 2023 Interims)

PS Box Rect Void - At Location = 19.0000 (ft) - Left     Stage 3

Calculation of Beta/Theta
-------------------------

      Es = 0.000 (kips/in^2)
     phi = 0.900
     f'c = 5.000 (kips/in^2)
     fpc = 0.937 (kips/in^2)
      fy = 60.000 (kips/in^2)
Agg diam = 1.000 (in)
      Vp = 0.000 (kips)
      Ep = 28500.000 (kips/in^2)
 As(pos) = 0.000 (in^2)  (used for Positive Mu)
 As(neg) = 0.000 (in^2)  (used for Negative Mu)
Aps(pos) = 4.284 (in^2)  (used for Positive Mu)
Aps(neg) = 0.306 (in^2)  (used for Negative Mu)
     fpo = 189.000 (kips/in^2)
      Ec = 4592.232 (kips/in^2)

Beta Calc (used in table below) :
     (1) - Beta = 4.8 / (1 + 750 EpsilonS)
     (2) - Beta = ( 4.8 / (1 + 750 EpsilonS) ) * (51 / (39 + sxe) )
                where:
                   sxe = sx * (1.38 / (ag + 0.63) )

  Mu_calc = Max(Mu, |Vu - Vp| * dv)

Modify MCFT Theta:   No

Modify MCFT Size Effect:   Yes
fpc / f'c = 0.19
```

Limit State	Load Comb	Epsilon	Theta	Beta	Governing Action	Mu (kip-in)	Mu Calc (kip-in)	Vu (kips)	Nu (kips)	bv (in)	dv (in)	Sx (in)	Sxe (in)	Beta Calc
STR-I	1, DesInv	0.002471	37.65	1.68	Max M	33228.57	33228.57	127.29	0.00	10.00	33.77	33.77	--	(1)
STR-I	1, DesInv	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)
STR-I	1, DesInv	0.002199	36.70	1.81	Max V	32064.13	32064.13	128.56	0.00	10.00	33.77	33.77	--	(1)
STR-I	1, DesInv	0.000000	29.00	4.80	Min V	22779.24	22779.24	25.01	0.00	10.00	33.77	33.77	--	(1)
STR-I	1, DesOp	0.001088	32.81	2.64	Max M	28220.60	28220.60	106.78	0.00	10.00	33.77	33.77	--	(1)
STR-I	1, DesOp	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)
STR-I	1, DesOp	0.000879	32.08	2.89	Max V	27322.31	27322.31	107.77	0.00	10.00	33.77	33.77	--	(1)
STR-I	1, DesOp	0.000000	29.00	4.80	Min V	20159.68	20159.68	27.88	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesInv	0.001444	34.06	2.30	Max M	29541.81	29541.81	111.12	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesInv	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesInv	0.001172	33.10	2.55	Max V	28377.37	28377.37	112.39	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesInv	0.000000	29.00	4.80	Min V	23878.56	23878.56	23.80	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesOp	0.000296	30.04	3.93	Max M	25376.52	25376.52	94.31	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesOp	0.000000	29.00	4.80	Min M	11318.68	11318.68	37.57	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesOp	0.000087	29.30	4.51	Max V	24478.24	24478.24	95.29	0.00	10.00	33.77	33.77	--	(1)
STR-I	2, DesOp	0.000000	29.00	4.80	Min V	21007.73	21007.73	26.95	0.00	10.00	33.77	33.77	--	(1)
SER-III	1, DesInv	0.000000	29.00	4.80	Max M	18828.30	18828.30	70.27	0.00	10.00	33.77	33.77	--	(1)
SER-III	1, DesInv	0.000000	29.00	4.80	Min M	8812.35	8812.35	29.26	0.00	10.00	33.77	33.77	--	(1)
SER-III	1, DesInv	0.000000	29.00	4.80	Max V	18295.99	18295.99	70.86	0.00	10.00	33.77	33.77	--	(1)
SER-III	1, DesInv	0.000000	29.00	4.80	Min V	14051.47	14051.47	23.52	0.00	10.00	33.77	33.77	--	(1)
SER-III	2, DesInv	0.000000	29.00	4.80	Max M	17142.93	17142.93	62.88	0.00	10.00	33.77	33.77	--	(1)
SER-III	2, DesInv	0.000000	29.00	4.80	Min M	8812.35	8812.35	29.26	0.00	10.00	33.77	33.77	--	(1)
SER-III	2, DesInv	0.000000	29.00	4.80	Max V	16610.61	16610.61	63.46	0.00	10.00	33.77	33.77	--	(1)
SER-III	2, DesInv	0.000000	29.00	4.80	Min V	14554.01	14554.01	22.97	0.00	10.00	33.77	33.77	--	(1)

Figure 22 6A.4.2.1 Shear-5.7.3.4 Procedures for Determining Shear Resistance

MBE 2023 specification interim update for reinforced concrete box culverts

The specification update for culvert will impact culvert wall (6A.4.2.1-5.7.3.3 Nominal shear resistance) and culvert slab specification checking (6A.4.2.1-5.7.3.3 Nominal shear resistance and 6A.4.2.1-5.12.7.3 Nominal shear resistance).

Import the culvert bridge provided with the CVT1 tutorial. Expand the **Bridge Workspace** tree and navigate to the **CULVERT ALTERNATIVES** node. Double click on **Culvert Alt 1** to open the culvert alternative. Navigate to the **Control options** tab of the **Culvert Alternative Description** window to access the **LRFR** control options. **Consider iterative shear rating** and **Consider MCFT theta** control options are added for iterative shear rating.

These options are applicable when **General procedure** - Shear computation method is used. Select these options to perform iterative shear rating and consider modifying the MCFT theta value and view results as discussed in previous sections of this tutorial.

The following articles detail the iterative process of shear rating.

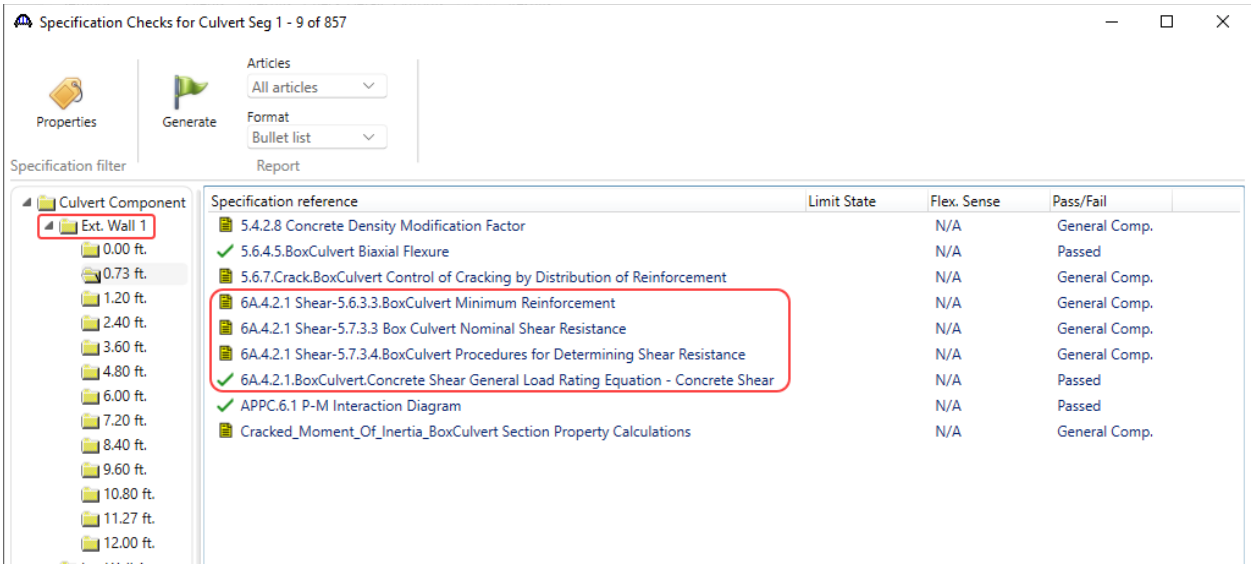


Figure 23 - Specification check article for Exterior wall 1

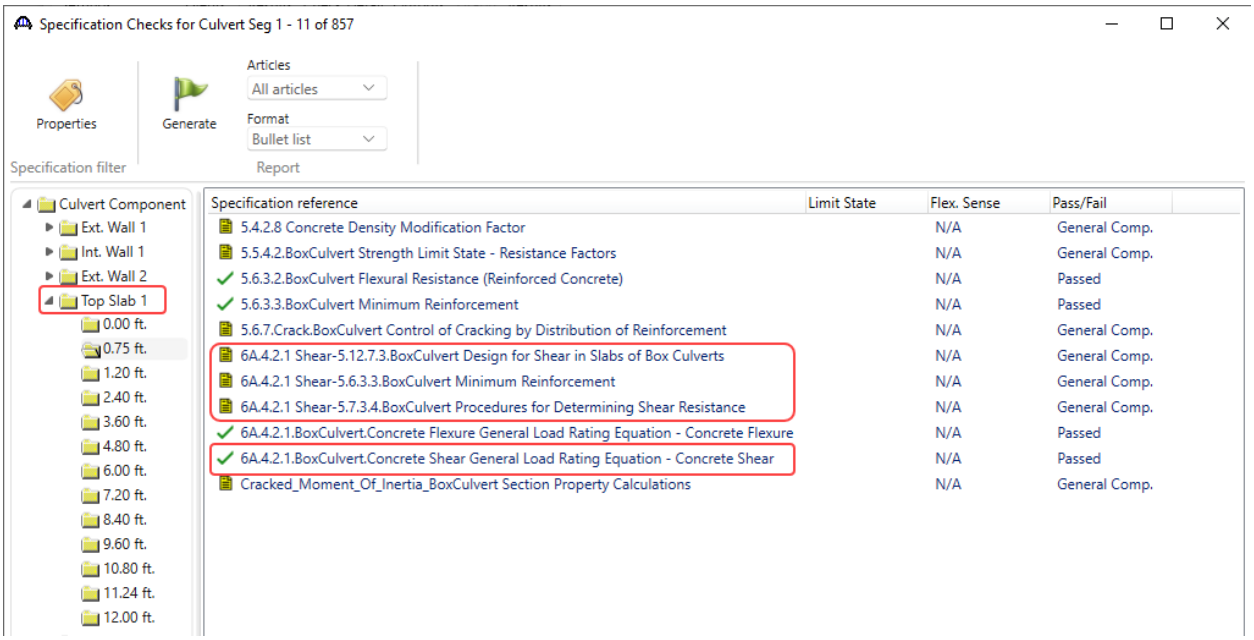


Figure 24 - Specification check articles for Top slab 1