3.10 Mainline Segment 4 WB Rating

3.10.1 Rating Summary

URS

PROJECT: **Cline Avenue Mainline Seg 4 WB** CALCS BY: TSP DATE: 10/1/09

DESCRIPTION: **Rating Factor Summary** CHECKED BY: DATE:

AASHTO Lanes

Clear Table | Fill Table | Posting Values

Cline Avenue Load Rating Mainline Segment 4 WB			Inventory	Operating										
			LFR Design Loads	LFR Design Loads	InDOT Loadings									
			HL-93 or Tandem*	HL-93 or Tandem*	InDOT Legal Loads			InDOT Permit Loads						
					R1	R2	R3	R4	R5	S1	S2	S3	S4	S5
Gross Vehicle Weight (tons)			36	36	45	45	63	67	67.1	129	133.5	175	152.5	240
Longitudinal	Strength	Flexure	1.80	2.33	1.90	1.93	1.65	2.06	2.05	1.81	1.80	1.65	1.76	1.53
		Shear	0.93	1.21	0.86	0.87	0.72	0.84	0.84	0.62	0.62	0.54	0.47	0.47
	Service	Flexure	1.24	1.97	1.76	1.80	1.61	1.77	1.76	1.61	1.61	1.50	1.60	1.44
		Principal Stress	1.30	1.16	1.03	1.04	0.89	0.91	0.91	0.73	0.73	0.64	0.58	0.58
Transverse	Strength	Top Slab Centerline	1.69	2.19	2.47	2.59	2.76	2.21	2.14	2.12	2.13	1.88	2.17	1.97
		Top Slab Thickness Change	1.78	2.31	2.54	2.59	2.59	2.38	2.41	2.20	2.31	1.84	2.36	1.89
		Top Slab Webs & Cantilever	1.85	2.40	2.36	2.93	2.90	2.85	2.25	2.27	2.32	1.81	2.65	2.00
		Transverse Web Bending	0.49	0.64	0.52	0.61	0.61	0.60	0.52	0.52	0.52	0.38	0.54	0.42

Overall Rating Factor	0.49	0.64	0.52	0.38
Posting Value (tons) (Controlled by Truck with Lowest Rating Factor)		23.04	23.40	66.50

* Max number of lanes loaded = Per AASHTO LRFD

URS

PROJECT: **Cline Avenue Mainline Seg 4 WB** CALCS BY: TSP DATE: 10/1/09

DESCRIPTION: **Rating Factor Summary** CHECKED BY: DATE:

Striped Lanes

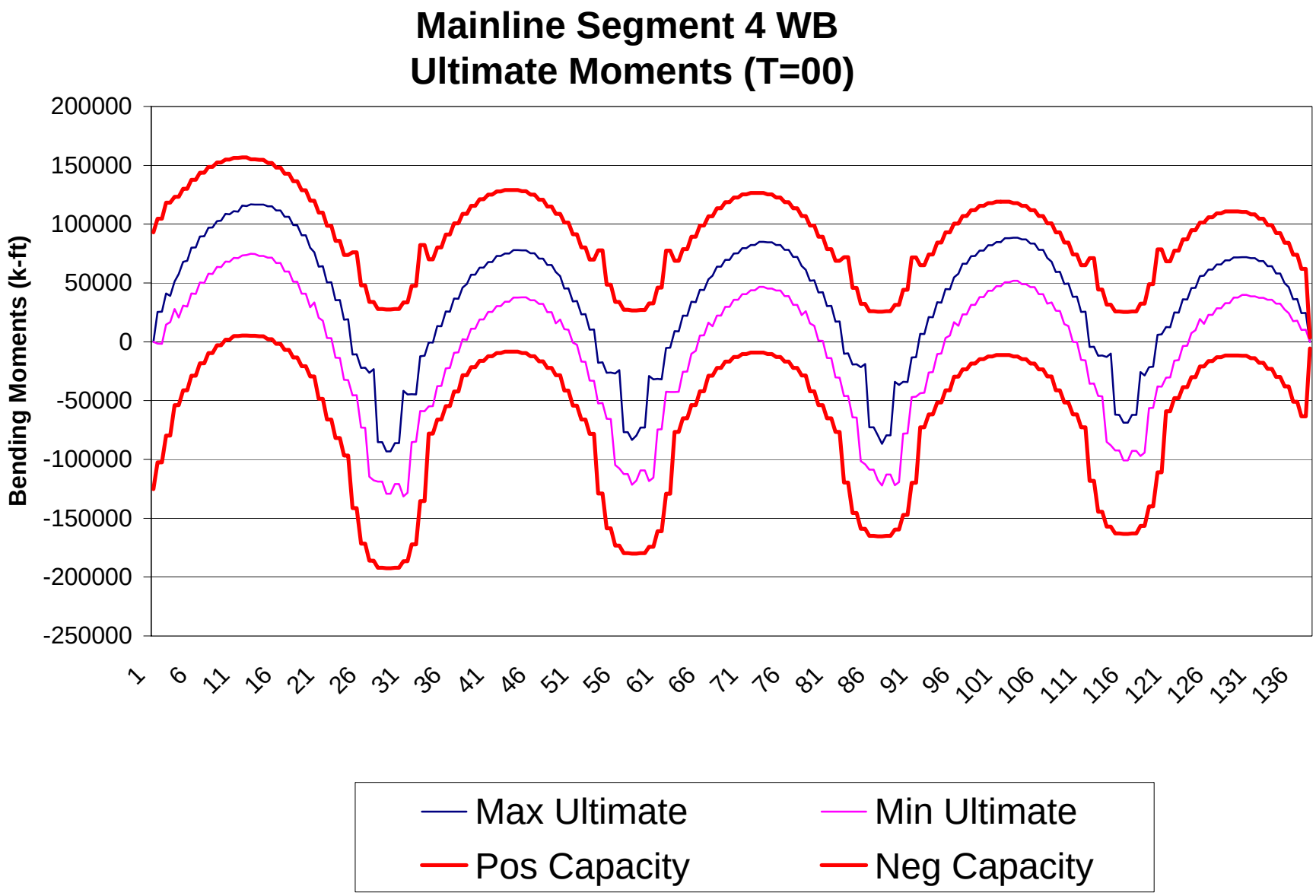
Clear Table | Fill Table | Posting Values

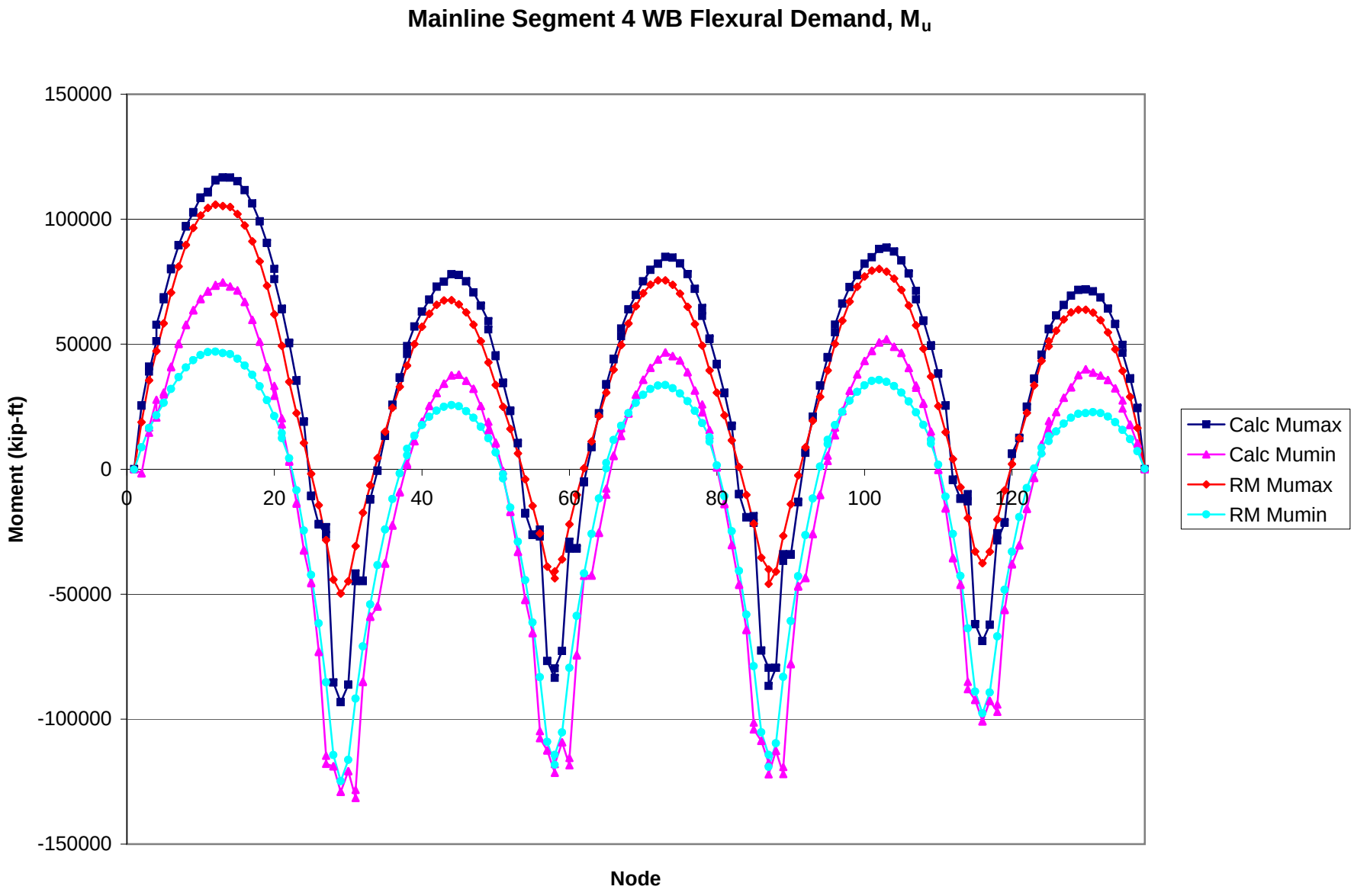
Cline Avenue Load Rating Mainline Segment 4 WB			Inventory	Operating											
			LFR Design Loads	LFR Design Loads	InDOT Loadings										
			HL-93 or Tandem*	HL-93 or Tandem*	InDOT Legal Loads			InDOT Permit Loads							
					R1	R2	R3	R4	R5	S1	S2	S3	S4	S5
Gross Vehicle Weight (tons)			36	36	45	45	63	67	67.1	129	133.5	175	152.5	240
Longitudinal	Strength	Flexure	1.84	2.39										
		Shear	1.00	1.34										
	Service	Flexure	1.26	1.98										
		Principal Stress	1.44	1.46										
Transverse	Strength	Top Slab Centerline	1.69	2.19										
		Top Slab Thickness Change	2.23	2.89										
		Top Slab Webs & Cantilever	3.02	3.92										
		Transverse Web Bending	2.59	3.47										

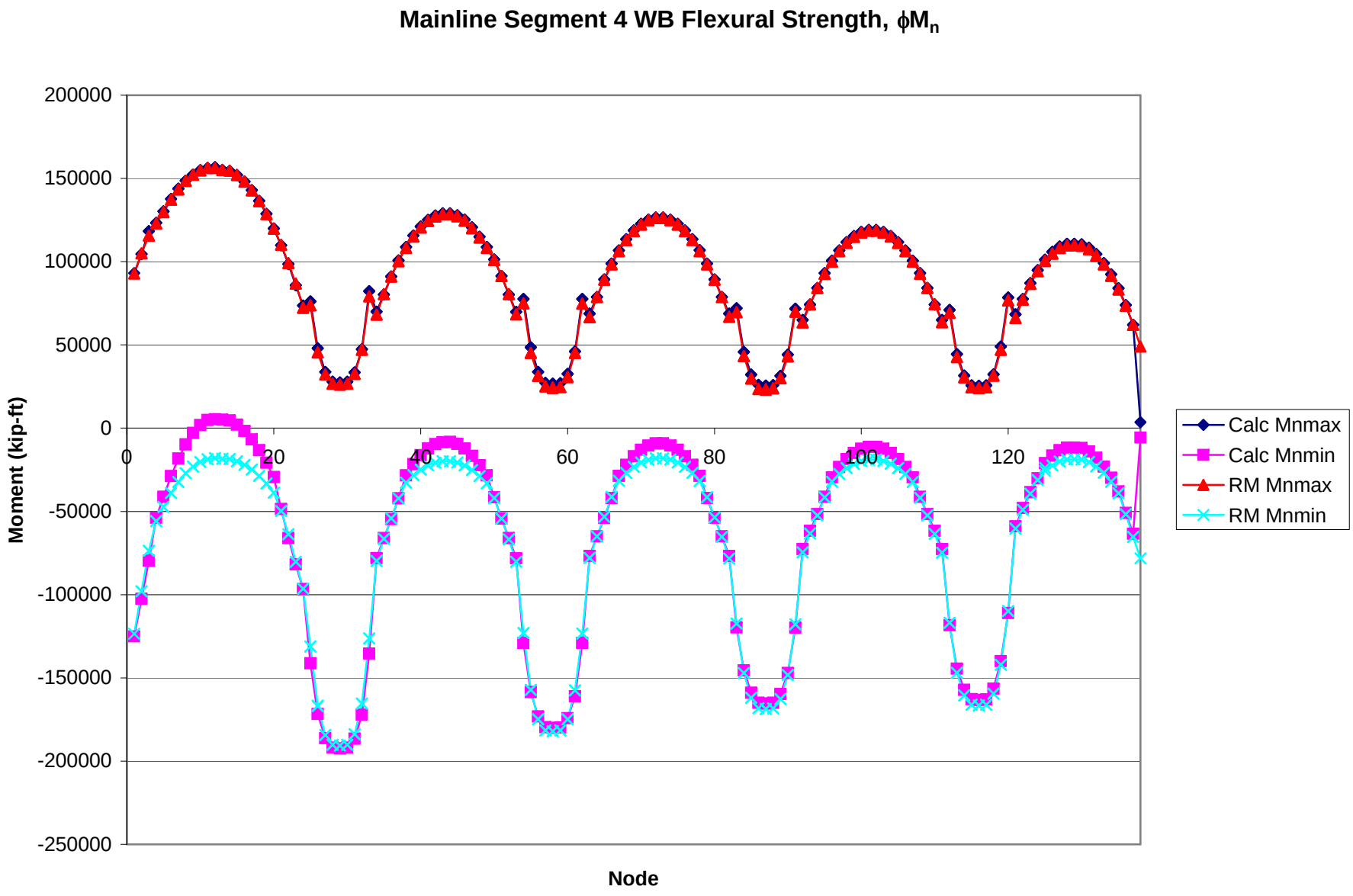
Overall Rating Factor	1.00	1.34	0.00	0.00
Posting Value (tons) (Controlled by Truck with Lowest Rating Factor)		48.24	0.00	0.00

* Max number of lanes loaded = Per AASHTO LRFD

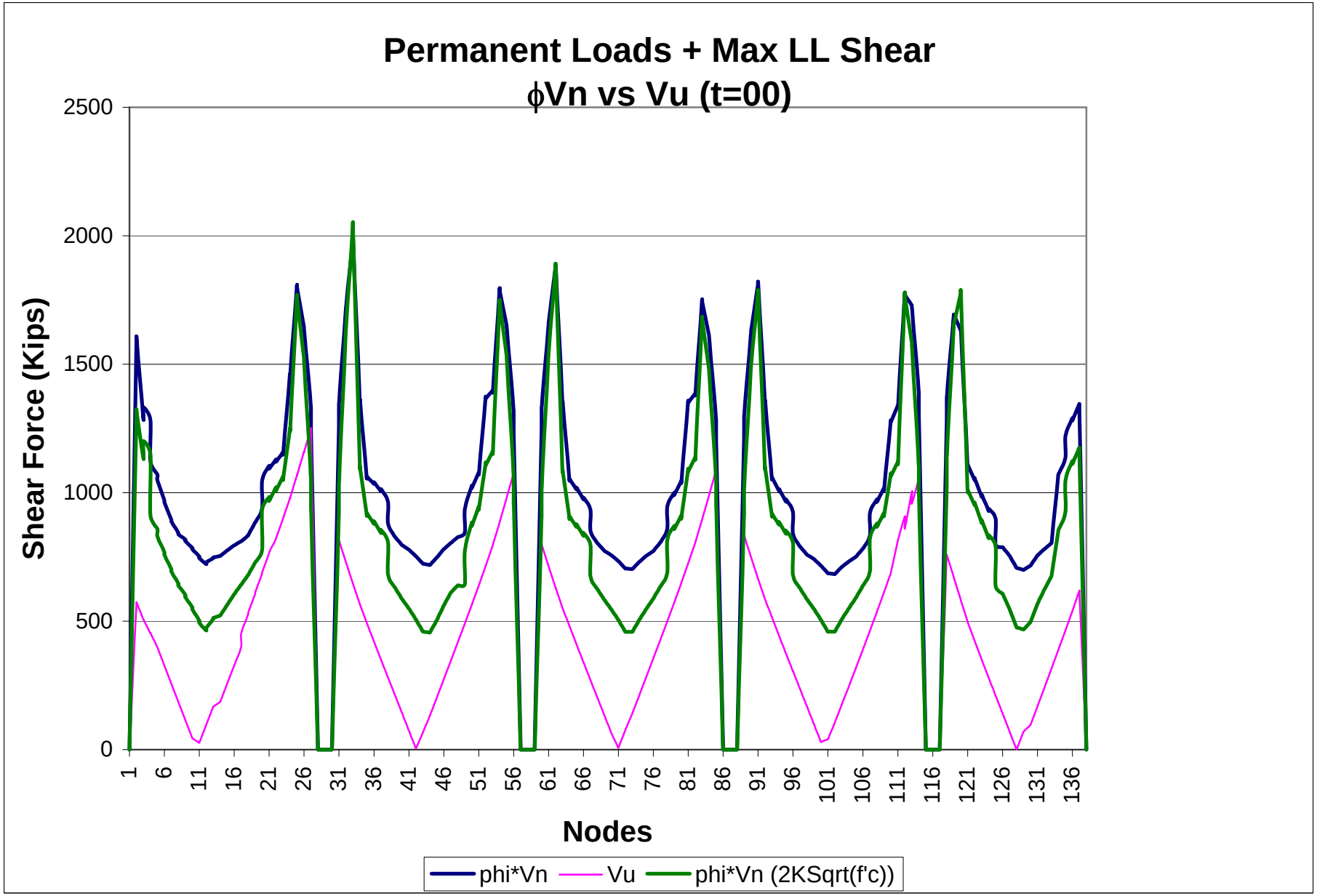
3.10.2 Strength I Flexure

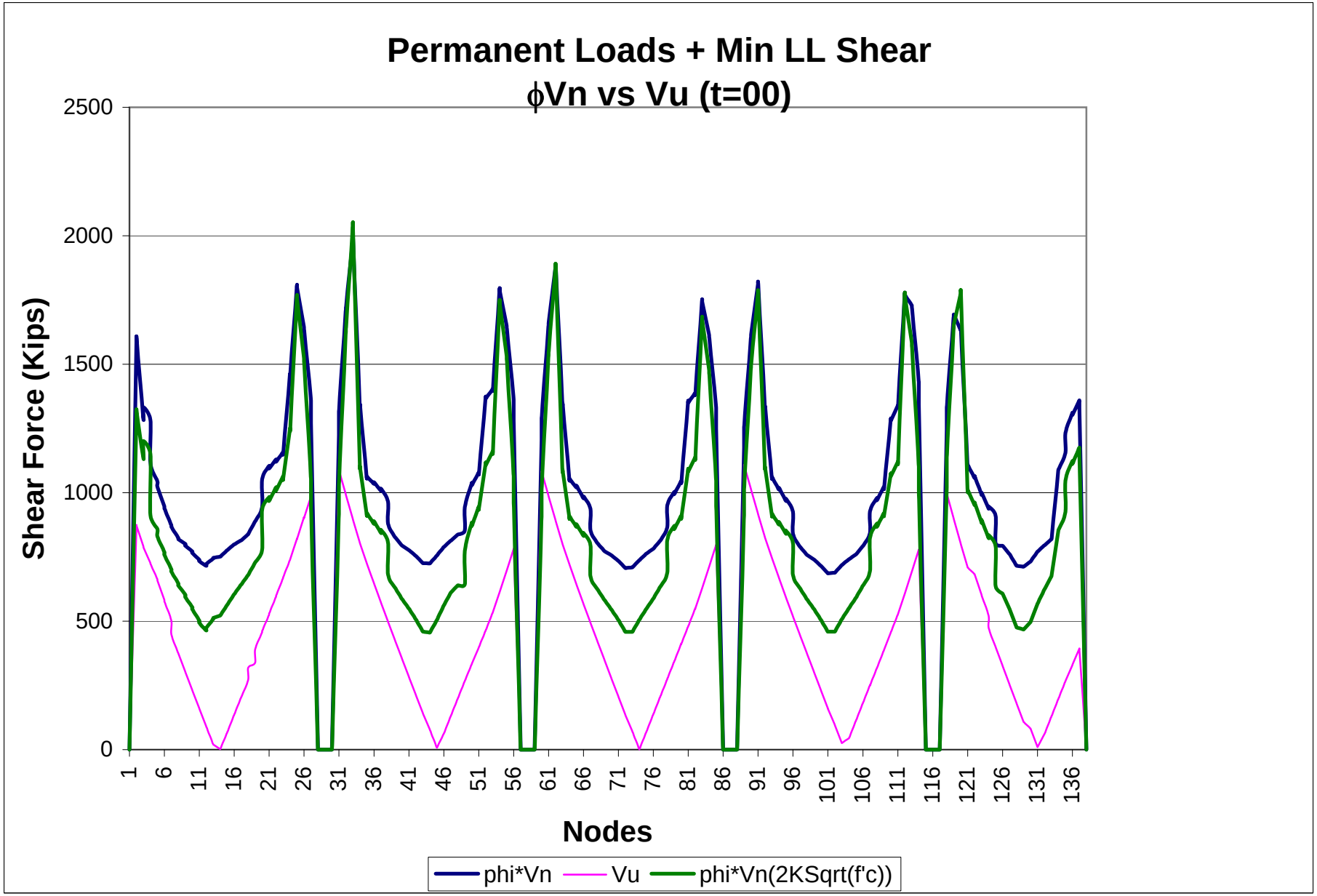

Mainline Segment 4 WB
Ultimate Moments (T=00)
Bending Moments (k-ft)
200000
150000
100000
50000
0
-50000
-100000
-150000
-200000
-250000
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
101
106
111
116
121
126
131
136
Max Ultimate
Min Ultimate
Pos Capacity
Neg Capacity

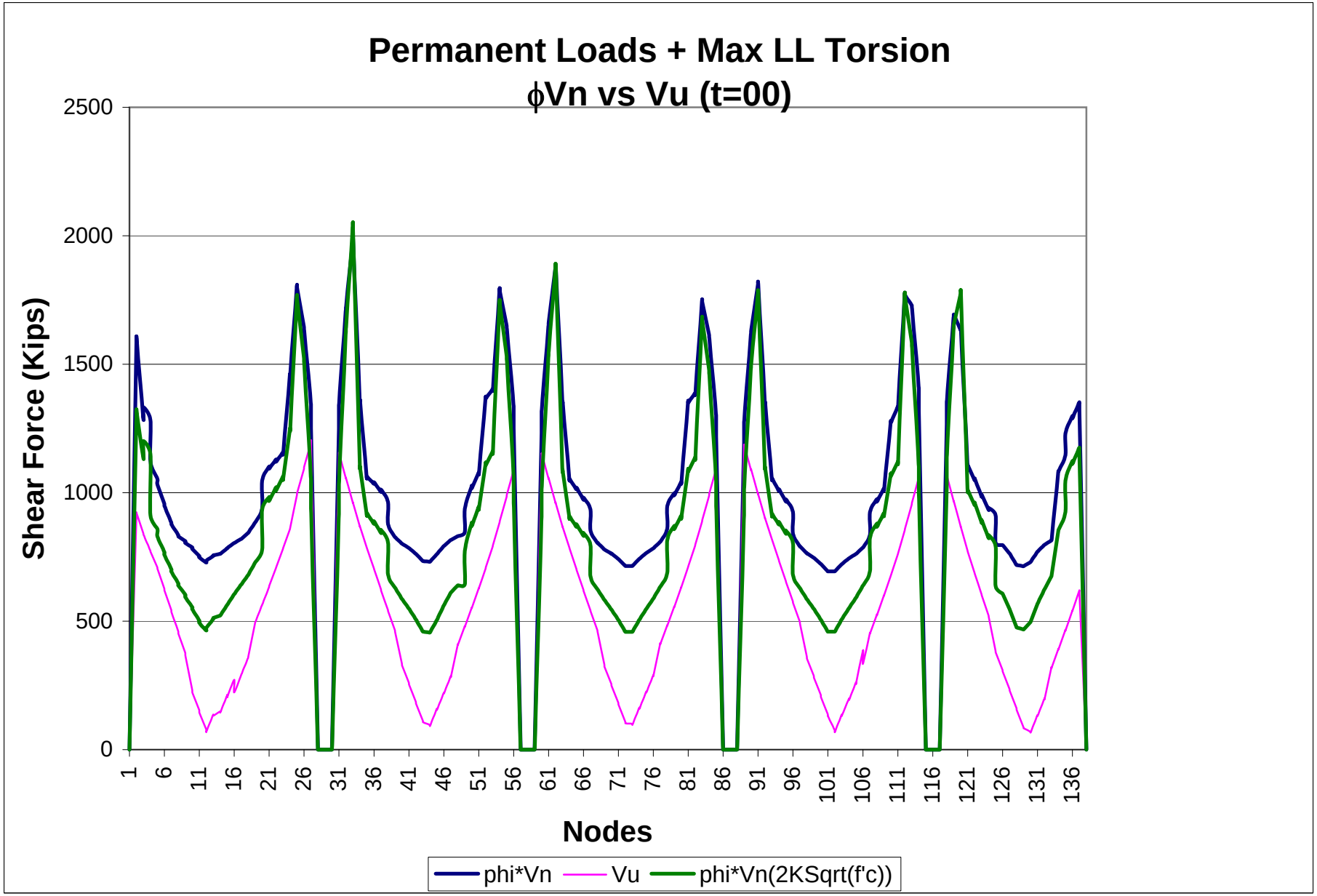

Mainline Segment 4 WB Flexural Demand, M_u
150000
100000
50000
0
-50000
-100000
-150000
Moment (kip-ft)
0
20
40
60
80
100
120
Node
Calc Mumax
Calc Mumin
RM Mumax
RM Mumin

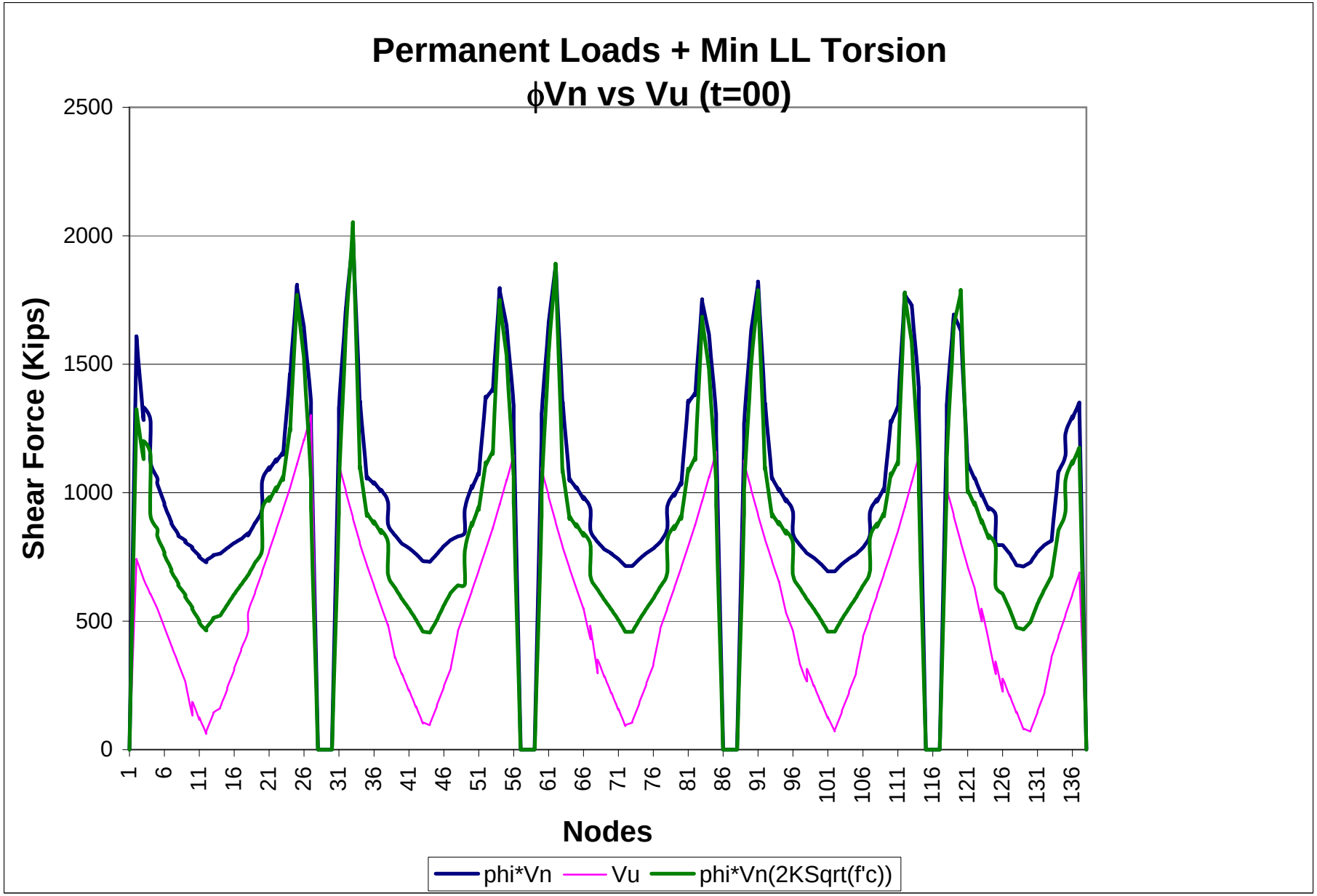

Mainline Segment 4 WB Flexural Strength, ϕM_n
200000
150000
100000
50000
0
-50000
-100000
-150000
-200000
-250000
0
20
40
60
80
100
120
Moment (kip-ft)
Node
Calc Mnmax
Calc Mnmin
RM Mnmax
RM Mnmin

3.10.3 Strength I Shear


Permanent Loads + Max LL Shear
ϕVn vs Vu (t=00)
Shear Force (Kips)
2500
2000
1500
1000
500
0
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
101
106
111
116
121
126
131
136
Nodes
phi*Vn
Vu
phi*Vn (2KSqrt(f'c))


Permanent Loads + Min LL Shear
ϕVn vs Vu (t=00)
Shear Force (Kips)
2500
2000
1500
1000
500
0
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
101
106
111
116
121
126
131
136
Nodes
phi*Vn
Vu
phi*Vn(2KSqrt(f'c))


Permanent Loads + Max LL Torsion
ϕVn vs Vu (t=00)
Shear Force (Kips)
2500
2000
1500
1000
500
0
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
101
106
111
116
121
126
131
136
Nodes
phi*Vn
Vu
phi*Vn(2KSqrt(f'c))


Permanent Loads + Min LL Torsion
ϕVn vs Vu (t=00)
Shear Force (Kips)
2500
2000
1500
1000
500
0
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
101
106
111
116
121
126
131
136
Nodes
phi*Vn
Vu
phi*Vn(2KSqrt(f'c))

File Location: V:\Projects\Cline Avenue\Load Rating Analysis\Revised LL Long Rating\MathCad Revised Vc AASHTO Lanes\Seg 4 WB\

Node := 27 Position := Ahead $b_{voverride}$:= 15

Objective

Calculations for Segmental Box Girder Load Rating--Shear Strength (HL-93 Operating Loading) considering Longitudinal Shear and Transverse Bending Independently--using finding of the Menn recommendations

Codes and Specifications

- ASHTO LRFD Bridge Design Specifications--Customary US Units, 4th Edition, 2007.
- AASHTO Guide Manual for the Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Hightway Bridges Specifications--Customary US Units, First Edition, 2004, with Interim Specifications through 2005.
- AASHTO Guide Specifications for Design and Construction of Segmental Concrete Bridges, Second Edition, 1999, with Interim Specifications through 2003.

Unit & Function Definitions

$psf \equiv \frac{lbf}{ft^2}$ $pcf \equiv \frac{lbf}{ft^3}$ $ksf \equiv \frac{kip}{ft^2}$ $tons \equiv 2000lbf$ $kips \equiv kip$

General Information

Permanant Loads:

$V_{dc_x} = 2047 \cdot kips$	$M_{dc_x} = -60947 \cdot kip \cdot ft$	$T_{dc_x} = -775\, ft \cdot kips$	$N_{dc_x} = 0 \cdot kips$	Dead Load
$V_{dw_x} = 247 \cdot kips$	$M_{dw_x} = -7899 \cdot kip \cdot ft$	$T_{dw_x} = -642 \cdot kip \cdot ft$	$N_{dw_x} = 0 \cdot kips$	Superimposed Dead Load
$V_{psec_x} = -104 \cdot kips$	$M_{psec_x} = 20516 \cdot kip \cdot ft$	$T_{psec_x} = -1112 \cdot kip \cdot ft$	$N_{psec_x} = 0 \cdot kips$	Secondary PT
$V_{ptls_x} = 0 \cdot kips$	$M_{ptls_x} = 0 \cdot kip \cdot ft$	$T_{ptls_x} = 0 \cdot kip \cdot ft$	$N_{ptls_x} = 0 \cdot kips$	Secondary Loss PT
$V_{crsh_x} = -17\, kip$	$M_{crsh_x} = 3421 \cdot kip \cdot ft$	$T_{crsh_x} = -122 \cdot kip \cdot ft$	$N_{crsh_x} = 0 \cdot kips$	Creep & Shrinkage

Live Loads (HL-93):

$V_{LLvmax_x} = 442 \cdot kips$	$M_{LLvmax_x} = -7636 \cdot kip \cdot ft$	$T_{LLvmax_x} = -124 \cdot kip \cdot ft$	$N_{LLvmax_x} = 0 \cdot kips$	Max Live Load Shear
$V_{LLvmin_x} = -11 \cdot kips$	$M_{LLvmin_x} = 2177 \cdot kip \cdot ft$	$T_{LLvmin_x} = -96 \cdot kip \cdot ft$	$N_{LLvmin_x} = 0 \cdot kips$	Min Live Load Shear
$V_{LLtmax_x} = 336 \cdot kips$	$M_{LLtmax_x} = -5177 \cdot kip \cdot ft$	$T_{LLtmax_x} = 4410 \cdot kip \cdot ft$	$N_{LLtmax_x} = 0 \cdot kips$	Max Live Load Torsion
$V_{LLtmin_x} = 320 \cdot kips$	$M_{LLtmin_x} = -1998 \cdot kip \cdot ft$	$T_{LLtmin_x} = -4867 \cdot kip \cdot ft$	$N_{LLtmin_x} = 0 \cdot kips$	Min Live Load Torsion

Post Tensioning Forces:

$V_{prim_x} = -821 \cdot kips$ Primary PT Shear

$N_{prim_x} = -18476 \cdot kips$ Primary PT Axial Force

$M_{prim_x} = 49658 \cdot kip \cdot ft$ Primary PT Moment

$N_{ptlo_x} = 1885 \cdot kips$ Primary PT Axial Force

Temperature/Transient Loads:

$V_{tu_x} = 5 \cdot kips$

$M_{tu_x} = -936 \cdot kip \cdot ft$

Temperature/Transient Loads:

$T_{tu_x} = 97 \cdot kip \cdot ft$

$N_{tu_x} = 0 \cdot kips$ Uniform Temperature

Girder Properties / Reinforcement:

$f_c := 5.0 \cdot ksi$ 28 day Concrete Strength

$\phi := 0.90$ Phi Factor for Shear

$\phi_b := 0.90$ Phi Factor for Transverse Bending

$A_{box_x} = 18482 \cdot in^2$ Area of Concrete Box Girder

$A_{o_x} = 38773 \cdot in^2$ Torsional Area of Box Girder

$n_{webs_x} = 3$ Number of Webs per Box

$A_{v_x} = 0.413 \cdot in^2$ Area of Shear Steel

$s := 12 \cdot in$ Spacing of Shear Steel

$f_y := 60 \cdot ksi$ Rebar Yield Strength

$f_{pu} := 270 \cdot ksi$ Post-Tensioning Steel Yield Str.

$$E_c := 33000 \cdot 0.145^{1.5} \cdot \sqrt{\frac{f_c}{ksi}} \cdot ksi = 4074 \cdot ksi$$

$E_s := 29000 \cdot ksi$ Elastic Modulus Mild Steel

$E_{ps} := 28500 \cdot ksi$ Elastic Modulus PT Steel

$cover := 1 \cdot in$ Transverse Bending Steel Cover

$d_b := 0.625 \cdot in$ Web Steel Diameter

$H_{box_x} = 108 \cdot in$ Height of Box

$y_{bot_x} = 57.923 \cdot in$ Centroid of Box Bottom

$b_{e_x} = 9 \cdot in$ Effective Width of Shear Flow Path

$b_{v_x} = 12.95 \cdot in$ Width of Single Web

$A_{b_x} = 0.243 \cdot in^2$ Area of Steel Req'd for Trans. Bend full width.

$A_{bd_x} = 0.121 \cdot in^2$ Area of Steel Req'd for Dead Trans. Bend full width.

$A_{bs_x} = 0.143 \cdot in^2$ Area of Steel Req'd for Trans. Bend restricted to striped lanes

$A_{bds_x} = 0.121 \cdot in^2$ Area of Steel Req'd for Dead Trans. Bend restricted to striped lanes

$A_{bn_x} = 0.0001 \cdot in^2$ Area of Steel Req'd for Trans. Bend no transverse bending

$A_{bdn_x} = 0.00001 \cdot in^2$ Area of Steel Req'd for Dead Trans. Bend no transverse bending

$A_{ps_x} = 154.287 \cdot in^2$ Area of Post-Tensioning Steel

$d_{t_x} = 96 \cdot in$ Depth for Torsion

$A_{s_x} = 11.2 \cdot in^2$ Area of Mild Steel on Flex Ten Side

$d_{s_x} = 105.75 \cdot in$ Depth of Mild Steel

Shear Strength Calculations: AASHTO LRFD Section 5.8--General Procedure

Operating Load Combinations:

Maximum and Corresponding Shear Combinations:

$$V_{uvmax_y} := 1.25 \cdot V_{dc_y} + 1.5 V_{dw_y} + 1.35 \cdot V_{LLvmax_y} + V_{psec_y} + V_{ptls_y} + 0.5 \cdot V_{crsh_y} + 0 \cdot \left| V_{tu_y} \right| \cdot \mathrm{sign}\left(V_{LLvmax_y} \right)$$

$$V_{uvmin_y} := 1.25 \cdot V_{dc_y} + 1.5 V_{dw_y} + 1.35 \cdot V_{LLvmin_y} + V_{psec_y} + V_{ptls_y} + 0.5 \cdot V_{crsh_y} + 0 \left| V_{tu_y} \right| \cdot \mathrm{sign}\left(V_{LLvmin_y} \right)$$

$$V_{utmax_y} := 1.25 \cdot V_{dc_y} + 1.5 V_{dw_y} + 1.35 \cdot V_{LLtmax_y} + V_{psec_y} + V_{ptls_y} + 0.5 \cdot V_{crsh_y} + 0 \cdot \left| V_{tu_y} \right| \cdot \mathrm{sign}\left(V_{LLtmax_y} \right)$$

$$V_{utmin_y} := 1.25 \cdot V_{dc_y} + 1.5 V_{dw_y} + 1.35 \cdot V_{LLtmin_y} + V_{psec_y} + V_{ptls_y} + 0.5 \cdot V_{crsh_y} + 0 \left| V_{tu_y} \right| \cdot \mathrm{sign}\left(V_{LLtmin_y} \right)$$

Maximum and Corresponding Torsion Combinations:

$$T_{uvmax_y} := 1.25 \cdot T_{dc_y} + 1.5 T_{dw_y} + 1.35 \cdot T_{LLvmax_y} + T_{psec_y} + T_{ptls_y} + 0.5 \cdot T_{crsh_y} + 0 \left| T_{tu_y} \right| \cdot \mathrm{sign}\left(T_{LLvmax_y} \right)$$

$$T_{uvmin_y} := 1.25 \cdot T_{dc_y} + 1.5 T_{dw_y} + 1.35 \cdot T_{LLvmin_y} + T_{psec_y} + T_{ptls_y} + 0.5 \cdot T_{crsh_y} + 0 \left| T_{tu_y} \right| \cdot \mathrm{sign}\left(T_{LLvmin_y} \right)$$

$$T_{utmax_y} := 1.25 \cdot T_{dc_y} + 1.5 T_{dw_y} + 1.35 \cdot T_{LLtmax_y} + T_{psec_y} + T_{ptls_y} + 0.5 \cdot T_{crsh_y} + 0 \left| T_{tu_y} \right| \cdot \mathrm{sign}\left(T_{LLtmax_y} \right)$$

$$T_{utmin_y} := 1.25 \cdot T_{dc_y} + 1.5 T_{dw_y} + 1.35 \cdot T_{LLtmin_y} + T_{psec_y} + T_{ptls_y} + 0.5 \cdot T_{crsh_y} + 0 \left| T_{tu_y} \right| \cdot \mathrm{sign}\left(T_{LLtmin_y} \right)$$

Corresponding Moment Combinations:

$$M_{uvmax_y} := 1.25 \cdot M_{dc_y} + 1.5 M_{dw_y} + 1.35 \cdot M_{LLvmax_y} + M_{psec_y} + M_{ptls_y} + 0.5 \cdot M_{crsh_y} + 0 \cdot \left| M_{tu_y} \right| \cdot \mathrm{sign}\left(M_{LLvmax_y} \right)$$

$$M_{uvmin_y} := 1.25 \cdot M_{dc_y} + 1.5 M_{dw_y} + 1.35 \cdot M_{LLvmin_y} + M_{psec_y} + M_{ptls_y} + 0.5 \cdot M_{crsh_y} + 0 \left| M_{tu_y} \right| \cdot \mathrm{sign}\left(M_{LLvmin_y} \right)$$

$$M_{utmax_y} := 1.25 \cdot M_{dc_y} + 1.5 M_{dw_y} + 1.35 \cdot M_{LLtmax_y} + M_{psec_y} + M_{ptls_y} + 0.5 \cdot M_{crsh_y} + 0 \cdot \left| M_{tu_y} \right| \cdot \mathrm{sign}\left(M_{LLtmax_y} \right)$$

$$M_{utmin_y} := 1.25 \cdot M_{dc_y} + 1.5 M_{dw_y} + 1.35 \cdot M_{LLtmin_y} + M_{psec_y} + M_{ptls_y} + 0.5 \cdot M_{crsh_y} + 0 \left| M_{tu_y} \right| \cdot \mathrm{sign}\left(M_{LLtmin_y} \right)$$

Corresponding Axial Force Combinations:

$$N_{uvmax_y} := 1.25 \cdot N_{dc_y} + 1.5 N_{dw_y} + 1.35 \cdot N_{LLvmax_y} + N_{psec_y} + N_{ptls_y} + 0.5 \cdot N_{crsh_y} + 0 \left| N_{tu_y} \right| \cdot \mathrm{sign}\left(N_{LLvmax_y} \right)$$

$$N_{uvmin_y} := 1.25 \cdot N_{dc_y} + 1.5 N_{dw_y} + 1.35 \cdot N_{LLvmin_y} + N_{psec_y} + N_{ptls_y} + 0.5 \cdot N_{crsh_y} + 0 \left| N_{tu_y} \right| \cdot \mathrm{sign}\left(N_{LLvmin_y} \right)$$

$$N_{utmax_y} := 1.25 \cdot N_{dc_y} + 1.5 N_{dw_y} + 1.35 \cdot N_{LLtmax_y} + N_{psec_y} + N_{ptls_y} + 0.5 \cdot N_{crsh_y} + 0 \left| N_{tu_y} \right| \cdot \mathrm{sign}\left(N_{LLtmax_y} \right)$$

$$N_{utmin_y} := 1.25 \cdot N_{dc_y} + 1.5 N_{dw_y} + 1.35 \cdot N_{LLtmin_y} + N_{psec_y} + N_{ptls_y} + 0.5 \cdot N_{crsh_y} + 0 \left| N_{tu_y} \right| \cdot \mathrm{sign}\left(N_{LLtmin_y} \right)$$

$V_{uvmax_x} = 3413 \cdot kips$	$T_{uvmax_x} = -3272 \cdot kip \cdot ft$	$M_{uvmax_x} = -76114\, ft \cdot kips$	$N_{uvmax_x} = 0 \cdot kips$
$V_{uvmin_x} = 2802 \cdot kips$	$T_{uvmin_x} = -3234 \cdot kip \cdot ft$	$M_{uvmin_x} = -62867\, ft \cdot kips$	$N_{uvmin_x} = 0 \cdot kips$
$V_{utmax_x} = 3270 \cdot kips$	$T_{utmax_x} = 2849 \cdot kip \cdot ft$	$M_{utmax_x} = -72795\, ft \cdot kips$	$N_{utmax_x} = 0 \cdot kips$
$V_{utmin_x} = 3249 \cdot kips$	$T_{utmin_x} = -9675 \cdot kip \cdot ft$	$M_{utmin_x} = -68503\, ft \cdot kips$	$N_{utmin_x} = 0 \cdot kips$

Calculate Variables Used for All Live Load Conditions:

$$f_{pc_y} := \frac{N_{prim_y}}{A_{box_y}} + \frac{N_{ptlo_y}}{A_{box_y}} + \frac{N_{psec_y}}{A_{box_y}} + \frac{N_{ptls_y}}{A_{box_y}}$$

$f_{pc_x} = -0.898\,ksi$

$K := \left| \begin{array}{l} \text{for } i \in 1..\,rows(DC) \\ \quad K_{1_i} \leftarrow \sqrt{1 - \dfrac{f_{pc_i}}{0.0632 \cdot ksi \cdot \sqrt{\dfrac{f_c}{ksi}}}} \\ \quad K_{2_i} \leftarrow 2 \\ \quad K_i \leftarrow \min\left(K_{1_i}, K_{2_i}\right) \\ K \end{array} \right.$

$K_x = 2$

$f_{po} := 0.7 \cdot f_{pu}$

$$T_{cr_y} := 0.0632 \cdot K_y \cdot \sqrt{\frac{f_c}{ksi}} \cdot ksi \cdot \left(2 \cdot A_{o_y} \cdot b_{e_y}\right)$$

$T_{cr_x} = 16438 \cdot kip \cdot ft$

$$d_{e_y} := \frac{\max\left(y_{bot_y} - \frac{M_{prim_y}}{N_{prim_y}}, H_{box_y} - y_{bot_y} + \frac{M_{prim_y}}{N_{prim_y}}\right) \cdot A_{ps_y} \cdot f_{po} + A_{s_y} \cdot f_y \cdot d_{s_y}}{A_{ps_y} \cdot f_{po} + A_{s_y} \cdot f_y}$$

$d_{e_x} = 90.526 \cdot in$

$$d_{v_y} := \max\left(0.72 \cdot H_{box_y}, 0.9\, d_{e_y}\right)$$

$d_{v_x} = 81.474 \cdot in$

Determing the Shear Requirement per Web--Max Pos Shear with Corresponding Torison

$\varepsilon_{svmax} := \left| \begin{array}{l} \text{for } i \in y \\ \quad \varepsilon_1 \leftarrow \dfrac{\left(\dfrac{\left|M_{uvmax_i}\right|}{d_{v_i}} + 0.5 \cdot N_{uvmax_i} + \left|\left|V_{uvmax_i}\right| - \left|V_{prim_i}\right|\right| - A_{ps_i} \cdot f_{po}\right)}{E_s \cdot A_{s_i} + E_{ps} \cdot A_{ps_i}} \\ \quad \varepsilon_2 \leftarrow \dfrac{\left(\dfrac{\left|M_{uvmax_i}\right|}{d_{v_i}} + 0.5 \cdot N_{uvmax_i} + \left|\left|V_{uvmax_i}\right| - \left|V_{prim_i}\right|\right| - A_{ps_i} \cdot f_{po}\right)}{E_s \cdot A_{s_i} + E_{ps} \cdot A_{ps_i} + 0.5 \cdot E_c \cdot A_{box_i}} \\ \quad \varepsilon_i \leftarrow \varepsilon_1 \quad \text{if} \quad \varepsilon_1 \ge 0 \\ \quad \varepsilon_i \leftarrow \max\left(\varepsilon_2, -0.0004\right) \quad \text{otherwise} \\ \varepsilon \end{array} \right.$

$\varepsilon_{svmax_x} = -0.00036$

$\theta_{vmax_y} := \left(29 + 3500 \cdot \varepsilon_{svmax_y}\right) \cdot deg$ $\qquad \theta_{vmax_x} = 27.731 \cdot deg$

$\beta_{vmax_y} := \dfrac{4.8}{\left(1 + 750 \cdot \varepsilon_{svmax_y}\right)}$ $\qquad \beta_{vmax_x} = 6.592$

$V_{cvmax_y} := 0.0316 \cdot \beta_{vmax_y} \cdot \sqrt{\dfrac{f_c}{ksi}} \cdot ksi \cdot b_{v_y} \cdot d_{v_y}$ $\qquad V_{cvmax_x} = 491.433 \cdot kips$

$$UseTorsionMaxShear := \left| \begin{array}{l} \text{for } i \in y \\ \quad \left| \begin{array}{l} T_u \leftarrow \left| T_{uvmax_i} \right| \\ z_i \leftarrow \text{"Yes"} \quad \text{if} \quad \phi \cdot \dfrac{T_{cr_i}}{3} < T_u \\ z_i \leftarrow \text{"No"} \quad \text{otherwise} \end{array} \right. \\ z \end{array} \right.$$

$UseTorsionMaxShear_x = \text{"No"}$

$$V_{dwebvmax_y} := \frac{V_{uvmax_y} - 1.35 \cdot V_{LLvmax_y}}{n_{webs_y}} + \left| \begin{array}{l} \dfrac{\left| T_{uvmax_y} - 1.35 \cdot T_{LLvmax_y} \right| \cdot d_{t_y}}{2 \cdot A_{o_y}} \quad \text{if} \quad UseTorsionMaxShear_y = \text{"Yes"} \\ (0 \cdot kips) \quad \text{otherwise} \end{array} \right.$$

$V_{dwebvmax_x} = 938.917\,kip$

$$V_{LLwebvmax_y} := \frac{1.35\, V_{LLvmax_y}}{n_{webs_y}} + \left| \begin{array}{l} \dfrac{\left| 1.35 \cdot T_{LLvmax_y} \cdot d_{t_y} \right|}{2 \cdot A_{o_y}} \quad \text{if} \quad UseTorsionMaxShear_y = \text{"Yes"} \\ (0 \cdot kips) \quad \text{otherwise} \end{array} \right.$$

$V_{LLwebvmax_x} = 198.9 \cdot kips$

$RF_{vpos} :=$ for $i \in y$

$$V_{s_i} \leftarrow \frac{2 \cdot A_{v_i} \cdot f_y \cdot d_{v_i}}{s \cdot \tan\left(\theta_{vmax_i}\right)}$$

$$V_p \leftarrow \left|V_{prim_i}\right|$$

$$\phi V_{n_i} \leftarrow \phi \cdot \left(V_{cvmax_i} + V_{s_i} + \frac{V_p}{n_{webs_i}}\right) \cdot \begin{cases} 1 & \text{if } V_{LLwebvmax_i} \geq 0 \cdot kips \\ (-1) & \text{otherwise} \end{cases}$$

$$RF_{1_i} \leftarrow \frac{\phi V_{n_i} - V_{dwebvmax_i}}{V_{LLwebvmax_i}}$$

$$RF_{2_i} \leftarrow \frac{A_{v_i} - A_{bd_i}}{A_{b_i} - A_{bd_i}}$$

$$RF_{i,1} \leftarrow \begin{cases} RF_{2_i} & \text{if } REBAR_{i,6} = \text{"P"} \\ \min\left(RF_{1_i}, RF_{2_i}\right) & \text{otherwise} \end{cases}$$

$$RF_{i,2} \leftarrow RF_{1_i}$$

$$RF_{i,3} \leftarrow RF_{2_i}$$

RF

$RF_{vpos_{x,1}} = 1.64$

Determing the Shear Requirement per Web--Min Pos Shear with Corresponding Torison

$\varepsilon_{svmin} :=$ for $i \in y$

$$\varepsilon_1 \leftarrow \frac{\left(\frac{\left|M_{uvmin_i}\right|}{d_{v_i}} + 0.5 \cdot N_{uvmin_i} + \left|\left|V_{uvmin_i}\right| - \left|V_{prim_i}\right|\right| - A_{ps_i} \cdot f_{po}\right)}{E_s \cdot A_{s_i} + E_{ps} \cdot A_{ps_i}}$$

$$\varepsilon_2 \leftarrow \frac{\left(\frac{\left|M_{uvmin_i}\right|}{d_{v_i}} + 0.5 \cdot N_{uvmin_i} + \left|\left|V_{uvmin_i}\right| - \left|V_{prim_i}\right|\right| - A_{ps_i} \cdot f_{po}\right)}{E_s \cdot A_{s_i} + E_{ps} \cdot A_{ps_i} + 0.5 \cdot E_c \cdot A_{box_i}}$$

$$\varepsilon_i \leftarrow \varepsilon_1 \quad \text{if } \varepsilon_1 \geq 0$$

$$\varepsilon_i \leftarrow \max\left(\varepsilon_2, -0.0004\right) \quad \text{otherwise}$$

ε

$\varepsilon_{svmin_x} = -0.0004$

$\theta_{vmin_y} := \left(29 + 3500 \cdot \varepsilon_{svmin_y}\right) \cdot deg$ $\qquad \theta_{vmin_x} = 27.6 \cdot deg$

$\beta_{vmin_y} := \dfrac{4.8}{\left(1 + 750 \cdot \varepsilon_{svmin_y}\right)}$ $\qquad \beta_{vmin_x} = 6.857$

$V_{cvmin_y} := 0.0316 \cdot \beta_{vmin_y} \cdot \sqrt{\dfrac{f_c}{ksi}} \cdot ksi \cdot b_{v_y} \cdot d_{v_y}$ $\qquad V_{cvmin_x} = 511.213 \cdot kips$

$UseTorsionMinShear := \left| \begin{array}{l} \text{for } i \in y \\ \quad \left| \begin{array}{l} T_u \leftarrow \left| T_{uvmin_i} \right| \\ z_i \leftarrow \text{"Yes"} \quad \text{if} \quad \phi \cdot \dfrac{T_{cr_i}}{3} < T_u \\ z_i \leftarrow \text{"No"} \quad \text{otherwise} \end{array} \right. \\ z \end{array} \right.$ $\qquad \boxed{UseTorsionMinShear_x = \text{"No"}}$

$V_{dwebvmin_y} := \dfrac{V_{uvmin_y} - 1.35 \cdot V_{LLvmin_y}}{n_{webs_y}} - \left| \begin{array}{l} \dfrac{\left| T_{uvmin_y} - 1.35 \cdot T_{LLvmin_y} \right| \cdot d_{t_y}}{2 \cdot A_{o_y}} \quad \text{if} \quad UseTorsionMinShear_y = \text{"Yes"} \\ (0 \cdot kips) \quad \text{otherwise} \end{array} \right.$

$V_{dwebvmin_x} = 938.917\, kip$

$V_{LLwebvmin_y} := \dfrac{1.35\, V_{LLvmin_y}}{n_{webs_y}} - \left| \begin{array}{l} \dfrac{\left| 1.35 \cdot T_{LLvmin_y} \cdot d_{t_y} \right|}{2 \cdot A_{o_y}} \quad \text{if} \quad UseTorsionMinShear_y = \text{"Yes"} \\ (0 \cdot kips) \quad \text{otherwise} \end{array} \right.$

$V_{LLwebvmin_y} = -4.95 \cdot kips$

$RF_{vneg} :=$ for $i \in y$

$$V_{s_i} \leftarrow \frac{2 \cdot A_{v_i} \cdot f_y \cdot d_{v_i}}{s \cdot \tan\left(\theta_{vmin_i}\right)}$$

$$V_p \leftarrow \left|V_{prim_i}\right|$$

$$\phi V_{n_i} \leftarrow \phi \cdot \left(V_{cvmin_i} + V_{s_i} + \frac{V_p}{n_{webs_i}}\right) \cdot \begin{cases} 1 & \text{if } V_{LLwebvmin_i} \geq 0 \cdot kips \\ (-1) & \text{otherwise} \end{cases}$$

$$RF_{1_i} \leftarrow \frac{\phi V_{n_i} - V_{dwebvmin_i}}{V_{LLwebvmin_i}}$$

$$RF_{2_i} \leftarrow \frac{A_{v_i} - A_{bd_i}}{A_{b_i} - A_{bd_i}}$$

$$RF_{i,1} \leftarrow \begin{cases} RF_{2_i} & \text{if } REBAR_{i,6} = \text{"P"} \\ \min\left(RF_{1_i}, RF_{2_i}\right) & \text{otherwise} \end{cases}$$

$$RF_{i,2} \leftarrow RF_{1_i}$$

$$RF_{i,3} \leftarrow RF_{2_i}$$

RF

$RF_{vneg_{x,1}} = 2.402$

Determing the Shear Requirement per Web--Max Pos Torsion with Corresponding Shear

$\varepsilon_{stmax} :=$ for $i \in y$

$$\varepsilon_1 \leftarrow \frac{\left(\frac{\left|M_{utmax_i}\right|}{d_{v_i}} + 0.5 \cdot N_{utmax_i} + \left|\left|V_{utmax_i}\right| - \left|V_{prim_i}\right|\right| - A_{ps_i} \cdot f_{po}\right)}{E_s \cdot A_{s_i} + E_{ps} \cdot A_{ps_i}}$$

$$\varepsilon_2 \leftarrow \frac{\left(\frac{\left|M_{utmax_i}\right|}{d_{v_i}} + 0.5 \cdot N_{utmax_i} + \left|\left|V_{utmax_i}\right| - \left|V_{prim_i}\right|\right| - A_{ps_i} \cdot f_{po}\right)}{E_s \cdot A_{s_i} + E_{ps} \cdot A_{ps_i} + 0.5 \cdot E_c \cdot A_{box_i}}$$

$$\varepsilon_i \leftarrow \varepsilon_1 \quad \text{if } \varepsilon_1 \geq 0$$

$$\varepsilon_i \leftarrow \max\left(\varepsilon_2, -0.0004\right) \quad \text{otherwise}$$

ε

$\varepsilon_{stmax_x} = -0.00038$

$\theta_{tmax_y} := \left(29 + 3500 \cdot \varepsilon_{stmax_y}\right) \cdot deg$ $\qquad \theta_{tmax_x} = 27.679 \cdot deg$

$\beta_{tmax_y} := \dfrac{4.8}{\left(1 + 750 \cdot \varepsilon_{stmax_y}\right)}$ $\qquad \beta_{tmax_x} = 6.695$

$V_{ctmax_y} := 0.0316 \cdot \beta_{tmax_y} \cdot \sqrt{\dfrac{f_c}{ksi}} \cdot ksi \cdot b_{v_y} \cdot d_{v_y}$ $\qquad V_{ctmax_x} = 499.101 \cdot kips$

$UseTorsionMaxTorsion := \left| \begin{array}{l} \text{for } i \in y \\ \quad \left| \begin{array}{l} T_u \leftarrow \left|T_{utmax_i}\right| \\ z_i \leftarrow \text{"Yes"} \quad \text{if} \quad \phi \cdot \dfrac{T_{cr_i}}{3} < T_u \\ z_i \leftarrow \text{"No"} \quad \text{otherwise} \end{array} \right. \\ z \end{array} \right.$ $\qquad UseTorsionMaxTorsion_x = \text{"No"}$

$T_{vmax_y} := sign\left(V_{LLtmax_y}\right)$

$V_{dwebtmax_y} := \dfrac{V_{utmax_y} - 1.35 \cdot V_{LLtmax_y}}{n_{webs_y}} + \left| \begin{array}{l} \dfrac{T_{vmax_y} \left|T_{utmax_y} - 1.35 \cdot T_{LLtmax_y}\right| \cdot d_{t_y}}{2 \cdot A_{o_y}} \quad \text{if} \quad UseTorsionMaxTorsion_y = \text{"} \\ (0 \cdot kips) \quad \text{otherwise} \end{array} \right.$

$V_{dwebtmax_x} = 938.917\, kip$

$V_{LLwebtmax_y} := \dfrac{1.35\, V_{LLtmax_y}}{n_{webs_y}} + \left| \begin{array}{l} \dfrac{T_{vmax_y} \left|1.35 \cdot T_{LLtmax_y} \cdot d_{t_y}\right|}{2 \cdot A_{o_y}} \quad \text{if} \quad UseTorsionMaxTorsion_y = \text{"Yes"} \\ (0 \cdot kips) \quad \text{otherwise} \end{array} \right.$

$V_{LLwebtmax_x} = 151.2 \cdot kips$

$RF_{tpos} :=$ for $i \in y$

$$V_{s_i} \leftarrow \frac{2 \cdot A_{v_i} \cdot f_y \cdot d_{v_i}}{s \cdot \tan\left(\theta_{tmax_i}\right)}$$

$$V_p \leftarrow \left|V_{prim_i}\right|$$

$$\phi V_{n_i} \leftarrow \phi \cdot \left(V_{ctmax_i} + V_{s_i} + \frac{V_p}{n_{webs_i}}\right) \cdot \begin{cases} 1 & \text{if } V_{LLwebtmax_i} \geq 0 \cdot kips \\ (-1) & \text{otherwise} \end{cases}$$

$$RF_{1_i} \leftarrow \frac{\phi V_{n_i} - V_{dwebtmax_i}}{V_{LLwebtmax_i}}$$

$$RF_{2_i} \leftarrow \frac{A_{v_i} - A_{bd_i}}{A_{b_i} - A_{bd_i}}$$

$$RF_{i,1} \leftarrow \begin{cases} RF_{2_i} & \text{if } REBAR_{i,6} = \text{"P"} \\ \min\left(RF_{1_i}, RF_{2_i}\right) & \text{otherwise} \end{cases}$$

$$RF_{i,2} \leftarrow RF_{1_i}$$

$$RF_{i,3} \leftarrow RF_{2_i}$$

RF

$RF_{tpos_{x,1}} = 2.211$

Determing the Shear Requirement per Web--Min Pos Torsion with Corresponding Shear

$\varepsilon_{stmin} :=$ for $i \in y$

$$\varepsilon_1 \leftarrow \frac{\left(\frac{\left|M_{utmin_i}\right|}{d_{v_i}} + 0.5 \cdot N_{utmin_i} + \left|\left|V_{utmin_i}\right| - \left|V_{prim_i}\right|\right| - A_{ps_i} \cdot f_{po}\right)}{E_s \cdot A_{s_i} + E_{ps} \cdot A_{ps_i}}$$

$$\varepsilon_2 \leftarrow \frac{\left(\frac{\left|M_{utmin_i}\right|}{d_{v_i}} + 0.5 \cdot N_{utmin_i} + \left|\left|V_{utmin_i}\right| - \left|V_{prim_i}\right|\right| - A_{ps_i} \cdot f_{po}\right)}{E_s \cdot A_{s_i} + E_{ps} \cdot A_{ps_i} + 0.5 \cdot E_c \cdot A_{box_i}}$$

$$\varepsilon_i \leftarrow \varepsilon_1 \quad \text{if} \quad \varepsilon_1 \geq 0$$

$$\varepsilon_i \leftarrow \max\left(\varepsilon_2, -0.0004\right) \quad \text{otherwise}$$

ε

$\varepsilon_{stmin_x} = -0.00039$

$\theta_{tmin_y} := \left(29 + 3500 \cdot \varepsilon_{stmin_y}\right) \cdot deg$ $\qquad \theta_{tmin_x} = 27.625 \cdot deg$

$\beta_{tmin_y} := \dfrac{4.8}{\left(1 + 750 \cdot \varepsilon_{stmin_y}\right)}$ $\qquad \beta_{tmin_x} = 6.804$

$V_{ctmin_y} := 0.0316 \cdot \beta_{tmin_y} \cdot \sqrt{\dfrac{f_c}{ksi}} \cdot ksi \cdot b_{v_y} \cdot d_{v_y}$ $\qquad V_{ctmin_x} = 507.287 \cdot kips$

$UseTorsionMinTorsion := \left| \begin{array}{l} \text{for } i \in y \\ \quad \left| \begin{array}{l} T_u \leftarrow \left|T_{utmin_i}\right| \\ z_i \leftarrow \text{"Yes"} \quad \text{if} \quad \phi \cdot \dfrac{T_{cr_i}}{3} < T_u \\ z_i \leftarrow \text{"No"} \quad \text{otherwise} \end{array} \right. \\ z \end{array} \right.$ $\qquad UseTorsionMinTorsion_x = \text{"Yes"}$

$T_{vmin_y} := sign\left(V_{LLtmin_y}\right)$

$V_{dwebtmin_y} := \dfrac{V_{utmin_y} - 1.35 \cdot V_{LLtmin_y}}{n_{webs_y}} + \left| \begin{array}{ll} \dfrac{T_{vmin_y} \left|T_{utmin_y} - 1.35 \cdot T_{LLtmin_y}\right| \cdot d_{t_y}}{2 \cdot A_{o_y}} & \text{if} \quad UseTorsionMinTorsion_y = \text{"Yes"} \\ (0 \cdot kips) & \text{otherwise} \end{array} \right.$

$V_{dwebtmin_x} = 985.04\, kip$

$V_{LLwebtmin_y} := \dfrac{1.35\, V_{LLtmin_y}}{n_{webs_y}} + \left| \begin{array}{ll} \dfrac{T_{vmin_y} \left|1.35 \cdot T_{LLtmin_y} \cdot d_{t_y}\right|}{2 \cdot A_{o_y}} & \text{if} \quad UseTorsionMinTorsion_y = \text{"Yes"} \\ (0 \cdot kips) & \text{otherwise} \end{array} \right.$

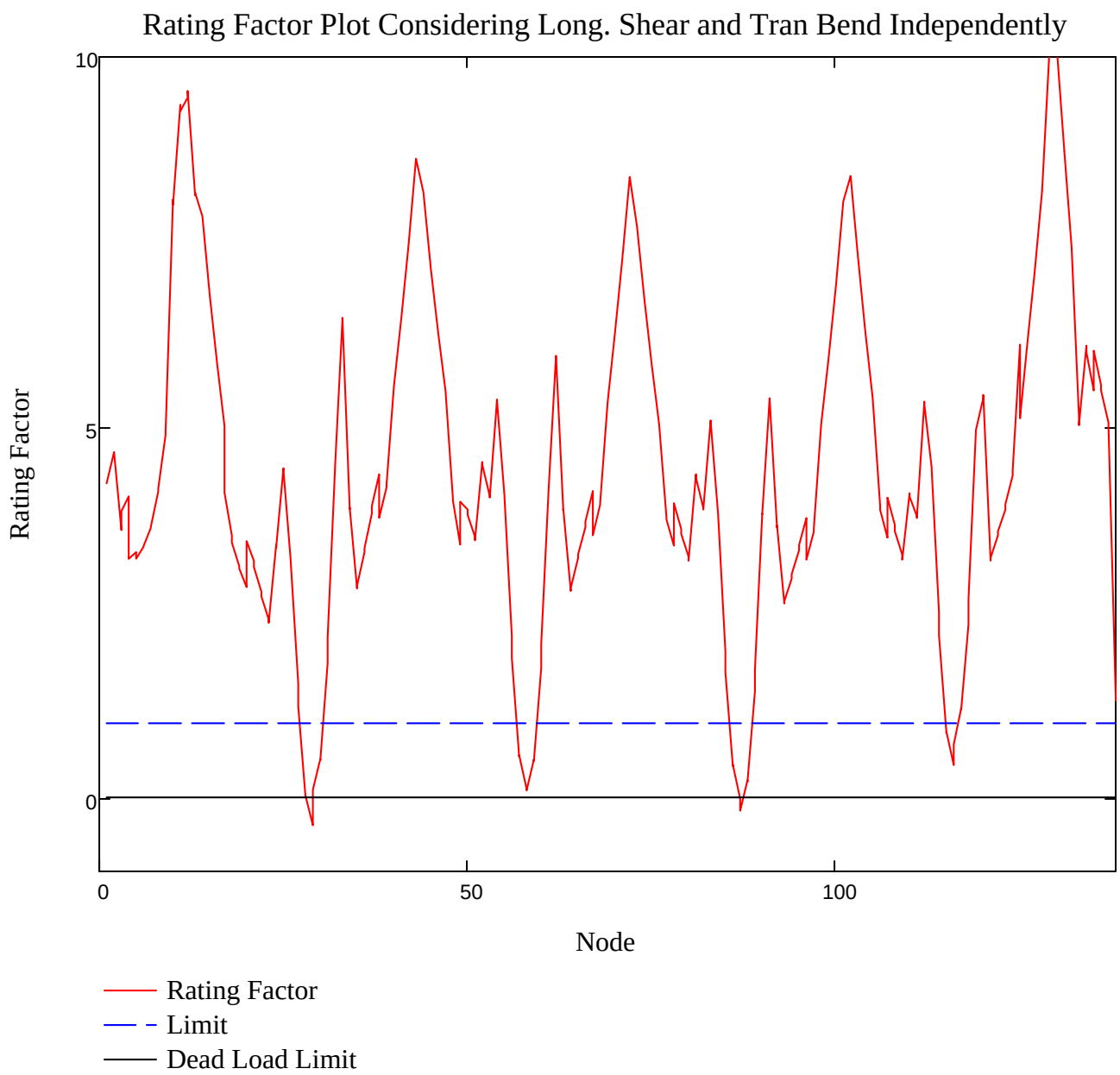
$V_{LLwebtmin_x} = 241.609 \cdot kips$

$$RF_{tneg} := \left| \begin{array}{l} \text{for } i \in y \\ \quad V_{s_i} \leftarrow \dfrac{2 \cdot A_{v_i} \cdot f_y \cdot d_{v_i}}{s \cdot \tan\left(\theta_{tmin_i}\right)} \\ \quad V_p \leftarrow \left| V_{prim_i} \right| \\ \quad \phi V_{n_i} \leftarrow \phi \cdot \left(V_{ctmin_i} + V_{s_i} + \dfrac{V_p}{n_{webs_i}} \right) \cdot \left| \begin{array}{ll} 1 & \text{if } V_{LLwebtmin_i} \geq 0 \cdot kips \\ (-1) & \text{otherwise} \end{array} \right. \\ \quad RF_{1_i} \leftarrow \dfrac{\phi V_{n_i} - V_{dwebtmin_i}}{V_{LLwebtmin_i}} \\ \quad RF_{2_i} \leftarrow \dfrac{A_{v_i} - A_{bd_i}}{A_{b_i} - A_{bd_i}} \\ \quad RF_{i,1} \leftarrow \left| \begin{array}{ll} RF_{2_i} & \text{if } REBAR_{i,6} = \text{"P"} \\ \min\left(RF_{1_i}, RF_{2_i}\right) & \text{otherwise} \end{array} \right. \\ \quad RF_{i,2} \leftarrow RF_{1_i} \\ \quad RF_{i,3} \leftarrow RF_{2_i} \\ RF \end{array} \right.$$

$$\boxed{RF_{tneg_{x,1}} = 1.229}$$

$$RF_{all} := \left| \begin{array}{l} \text{for } i \in y \\ \quad RF_{i,1} \leftarrow \min\left(RF_{vpos_{i,1}}, RF_{vneg_{i,1}}, RF_{tpos_{i,1}}, RF_{tneg_{i,1}}\right) \\ \quad RF_{i,2} \leftarrow \min\left(RF_{vpos_{i,2}}, RF_{vneg_{i,2}}, RF_{tpos_{i,2}}, RF_{tneg_{i,2}}\right) \\ \quad RF_{i,3} \leftarrow \min\left(RF_{vpos_{i,3}}, RF_{vneg_{i,3}}, RF_{tpos_{i,3}}, RF_{tneg_{i,3}}\right) \\ RF \end{array} \right.$$

$$Limit := \left| \begin{array}{l} \text{for } i \in y \\ \quad L_i \leftarrow 1 \\ L \end{array} \right. \qquad DLLimit := \left| \begin{array}{l} \text{for } i \in y \\ \quad D_i \leftarrow 0 \\ D \end{array} \right.$$



Minimum Rating Factor for Longitudinal Shear is $minRF_1 = 1.229$ at node $minRF_2 = 27$ $minRF_4 = \text{"Ahead"}$

Minimum Rating Factor for Transverse Bending is $minRF_3 = 0.705$

Determine the Rating Factor using the Method of Combining Transverse Bending and Shear per Menn to Verify Longitudinal Shear and Transverse Bending Act Independently

Determing the Shear Requirement per Web--Min Pos Shear with Corresponding Torison

$d_y := PROPS_{y,7} \cdot in - cover - d_b$ Use the web width used for Transverse Bending

$b_{bend} := 12 \cdot in$ Unit Length of Web

$V_{p_y} := \frac{V_{prim_y}}{n_{webs_y}}$

$m_{r_y} := \phi_b \cdot A_{b_y} \cdot f_y \cdot \left(d_y - \frac{A_{b_y} \cdot f_y}{2 \cdot 0.85 \cdot f_c \cdot b_{bend}} \right)$ $m_{r_x} = 160.248 \cdot kip \cdot in$

$m_{rd_y} := \phi_b \cdot A_{bd_y} \cdot f_y \cdot \left(d_y - \frac{A_{bd_y} \cdot f_y}{2 \cdot 0.85 \cdot f_c \cdot b_{bend}} \right)$ $m_{rd_x} = 80.261 \cdot kip \cdot in$

$b_{o_y} := b_{v_y} - 2 \cdot cover - d_b$ $b_{o_x} = 10.325 \cdot in$

$b' := cover + \frac{1}{2} \cdot d_b$ $b' = 1.313 \cdot in$

$$\beta_1 := \begin{cases} 0.85 & \text{if } f_c \le 4 \cdot ksi \\ \left[0.85 - 0.05 \cdot \left(\frac{f_c - 4 \cdot ksi}{ksi} \right) \right] & \text{if } 4 \cdot ksi < f_c \le 8 \cdot ksi \\ 0.65 & \text{otherwise} \end{cases}$$ $\beta_1 = 0.8$

$b_{1_y} := \frac{A_{b_y} \cdot f_y}{0.85 \cdot f_c \cdot b_{bend}}$ $b_{1_x} = 0.285 \cdot in$

$b_{1d_y} := \frac{A_{bd_y} \cdot f_y}{0.85 \cdot f_c \cdot b_{bend}}$ $b_{1d_x} = 0.142 \cdot in$

Using the Method prescribed by Menn--develop an interaction diagram to show the capacity of the web for Combined Transverse Bending and Longitudinal Shear

Case I: Transverse Bending Predominates--Use the maximum bending capacity and determine the resulting shear capacity

$y_{1_y} := b_{o_y} + b' - \frac{b_{1_y}}{2}$ $y_{1_x} = 11.495 \cdot in$

$F_{cu_y} := A_{v_y} \cdot f_y$ $F_{cu_x} = 24.8 \cdot kips$

$\phi M_{n_1} := \phi \cdot \left(F_{cu_x} \cdot y_{1_x} \right)$ $\phi M_{n_1} = 21.38 \cdot kip \cdot ft$

$\phi V_{n_1} := A_{v_x} \cdot f_y - F_{cu_x}$ $\phi V_{n_1} = 0 \cdot kips$

Case II: Shear Predominates--Calculate the resulting bending capacity and longitudinal shear when the net force in one bar is equal to 0

$B_{r2_y} := A_{v_y} \cdot f_y$ $\qquad B_{r2_x} = 24.8 \cdot kips$

$V_{s2_y} := \dfrac{A_{v_y} \cdot f_y \cdot d_{v_y} \cdot \cot(\theta_{vmax_y})}{s}$ $\qquad V_{s2_x} = 320.287 \cdot kips$

$\phi V_{n2_y} := \phi \cdot \left(V_{cvmax_y} + V_{s2_y} + \left|V_{p_y}\right|\right)$ $\qquad \phi V_{n2_x} = 976.848 \cdot kips$

$b_{wreq2_y} := \dfrac{V_{s2_y}}{0.85 \cdot f_c \cdot d_{v_y} \cdot \cot(\theta_{vmax_y})}$ $\qquad b_{wreq2_x} = 0.486 \cdot in$

$\phi M_{n_2} := \min\left[\phi \cdot \left[A_{v_x} \cdot f_y \cdot b_{o_x} - \dfrac{V_{s2_x} \cdot s}{d_{v_x} \cdot \cot(\theta_{vmax_x})} \cdot \left(\dfrac{b_{wreq2_x}}{2} - b'\right)\right], \phi M_{n_1}\right]$ $\qquad \phi M_{n_2} = 21.194 \cdot kip \cdot ft$

Case III: Shear Predominates--Use the maximum shear capacity and determine the resulting moment capacity

$V_{s3_y} := \dfrac{2 A_{v_y} \cdot f_y \cdot d_{v_y} \cdot \cot(\theta_{vmin_y})}{s}$ $\qquad V_{s3_x} = 644.158 \cdot kips$

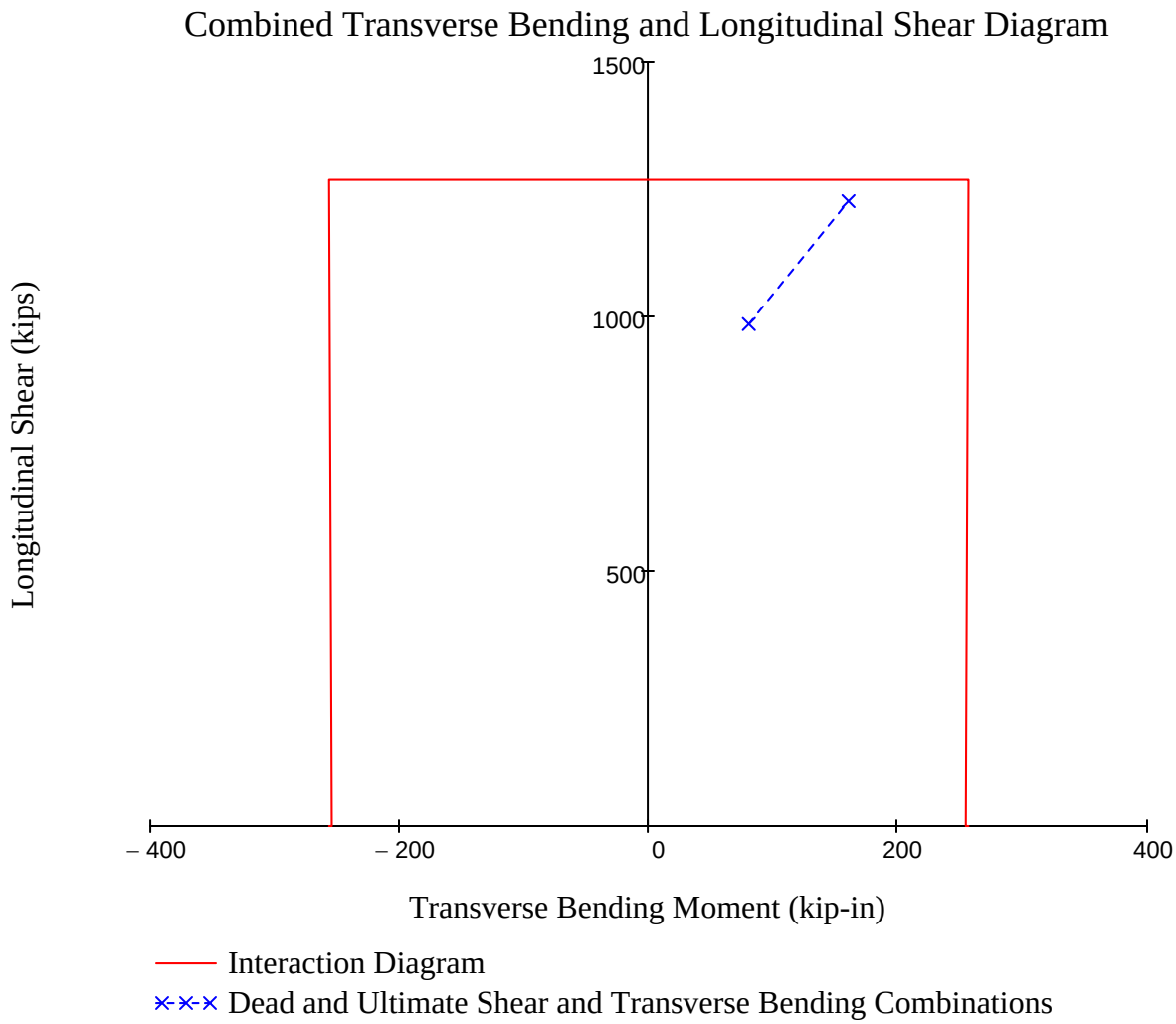
$\phi V_{n_3} := \phi \cdot \left(V_{cvmax_x} + V_{s3_x} + \left|V_{p_x}\right|\right)$ $\qquad \phi V_{n_3} = 1.268 \times 10^3 \cdot kips$

$b_{wreq3_y} := \dfrac{V_{s3_y}}{0.85 \cdot f_c \cdot d_{v_y} \cdot \cot(\theta_{vmax_y})}$ $\qquad b_{wreq3_x} = 0.978 \cdot in$

$\phi M_{n_3} := \min\left[\phi \left[A_{v_x} \cdot f_y \cdot b_{o_x} - \dfrac{V_{s3_x} \cdot s}{d_{v_x} \cdot \cot(\theta_{vmax_x})} \cdot \left(\dfrac{b_{wreq3_x}}{2} - b'\right)\right], \phi M_{n_1}\right]$ $\qquad \phi M_{n_3} = 21.38 \cdot kip \cdot ft$

Derive the Interaction Diagram:

$$\phi V_n := \left| \begin{array}{l} \text{for } i \in 1..3 \\ \quad \left| \begin{array}{l} V_{n_i} \leftarrow \phi V_{n_i} \\ V_{n_{7-i}} \leftarrow \phi V \end{array} \right. \\ V_n \end{array} \right. \qquad \phi M_n := \left| \begin{array}{l} \text{for } i \in 1..3 \\ \quad \left| \begin{array}{l} M_{n_i} \leftarrow \phi M_{n_i} \\ M_{n_{7-i}} \leftarrow -\phi M_{n_i} \end{array} \right. \\ M_n \end{array} \right. \qquad M_{u1} := \left| \begin{array}{l} \text{for } i \in 1 \\ \quad \left| \begin{array}{l} M_{u_i} \leftarrow m_{rd_x} \\ M_{u_{i+1}} \leftarrow m_{r_x} \end{array} \right. \\ M_u \end{array} \right. \qquad V_{u1} := \left| \begin{array}{l} \text{for } i \in 1 \\ \quad \left| \begin{array}{l} V_{u_i} \leftarrow \left|V_d\right| \\ V_{u_{i+1}} \leftarrow \left|V_d + V_{LL}\right| \end{array} \right. \\ V_u \end{array} \right.$$



The interaction diagram above shows that the longitudinal shear and transverse bending have not interaction--they are acting independently therefore the rating factors may be calculated seperately.

$$RF_{bend} := \frac{\phi M_{n_1} - m_{rd_x}}{m_{r_x} - m_{rd_x}}$$

$RF_{bend} = 2.204$

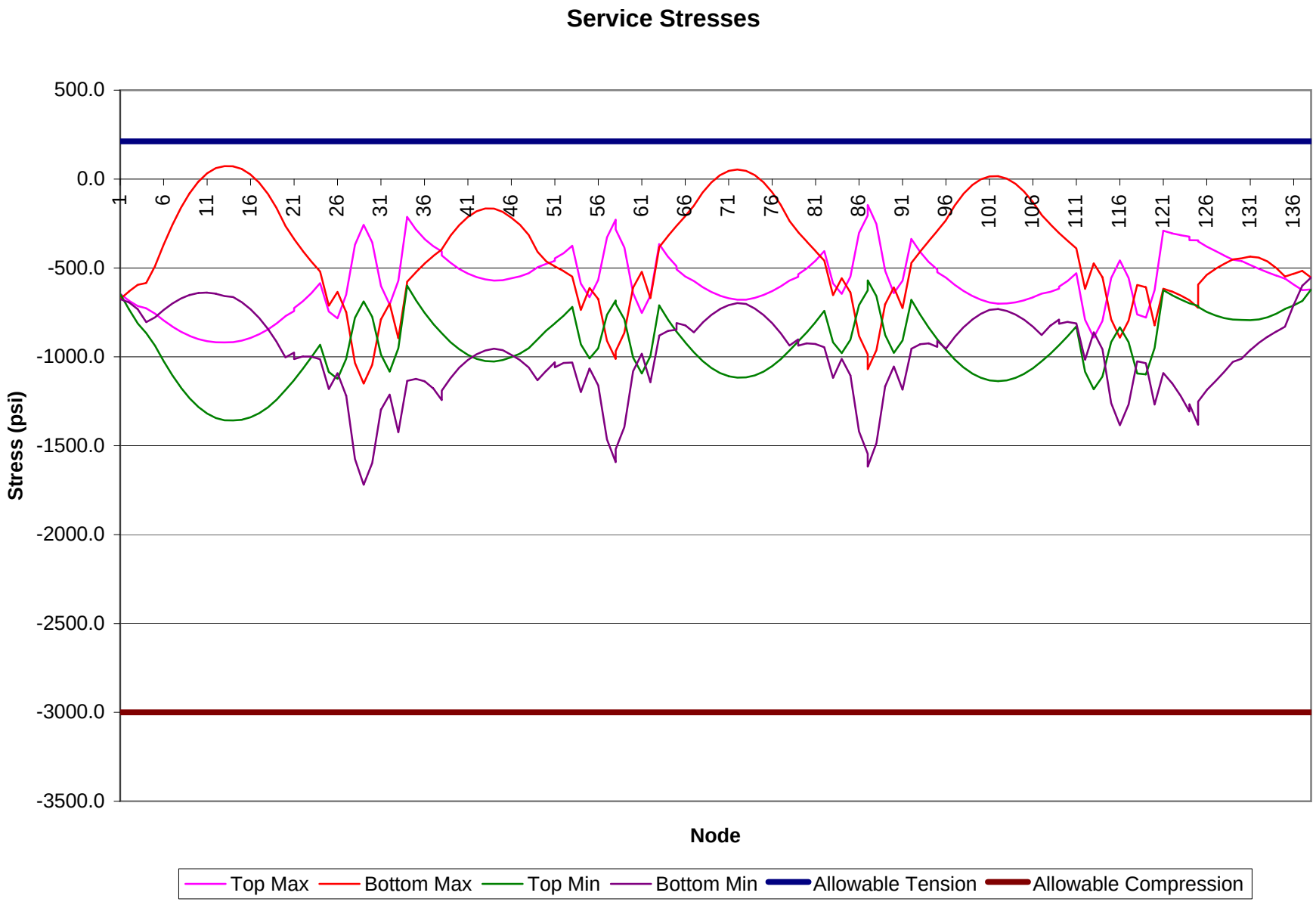
$$RF_{shear} := \min\left(\frac{\phi V_{n_3} - \left|V_{dwebvmax_x}\right|}{\left|V_{LLwebvmax_x}\right|}, \frac{\phi V_{n_3} - \left|V_{dwebvmin_x}\right|}{\left|V_{LLwebvmin_x}\right|}\right)$$

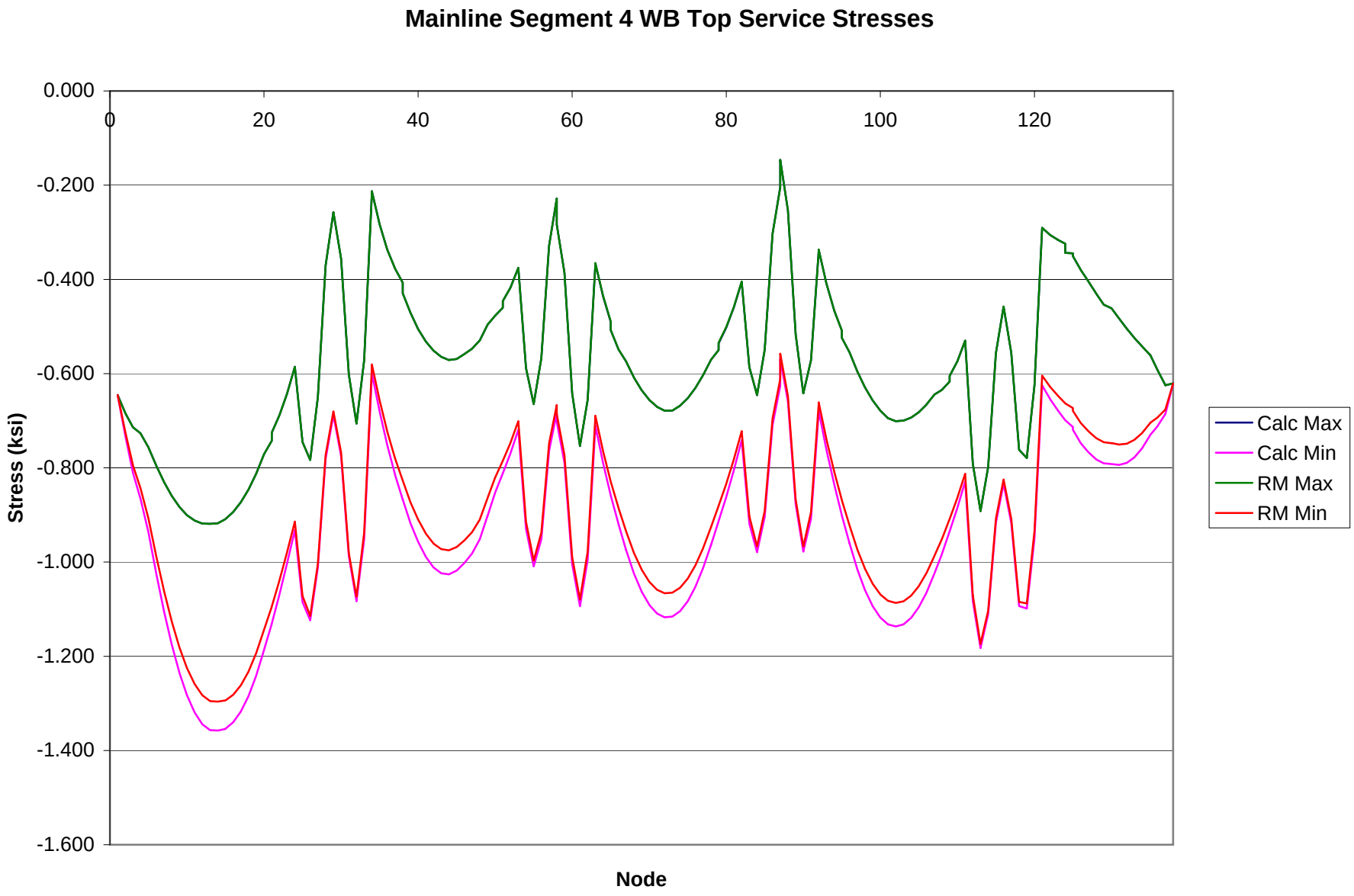
$RF_{shear} = 1.656$

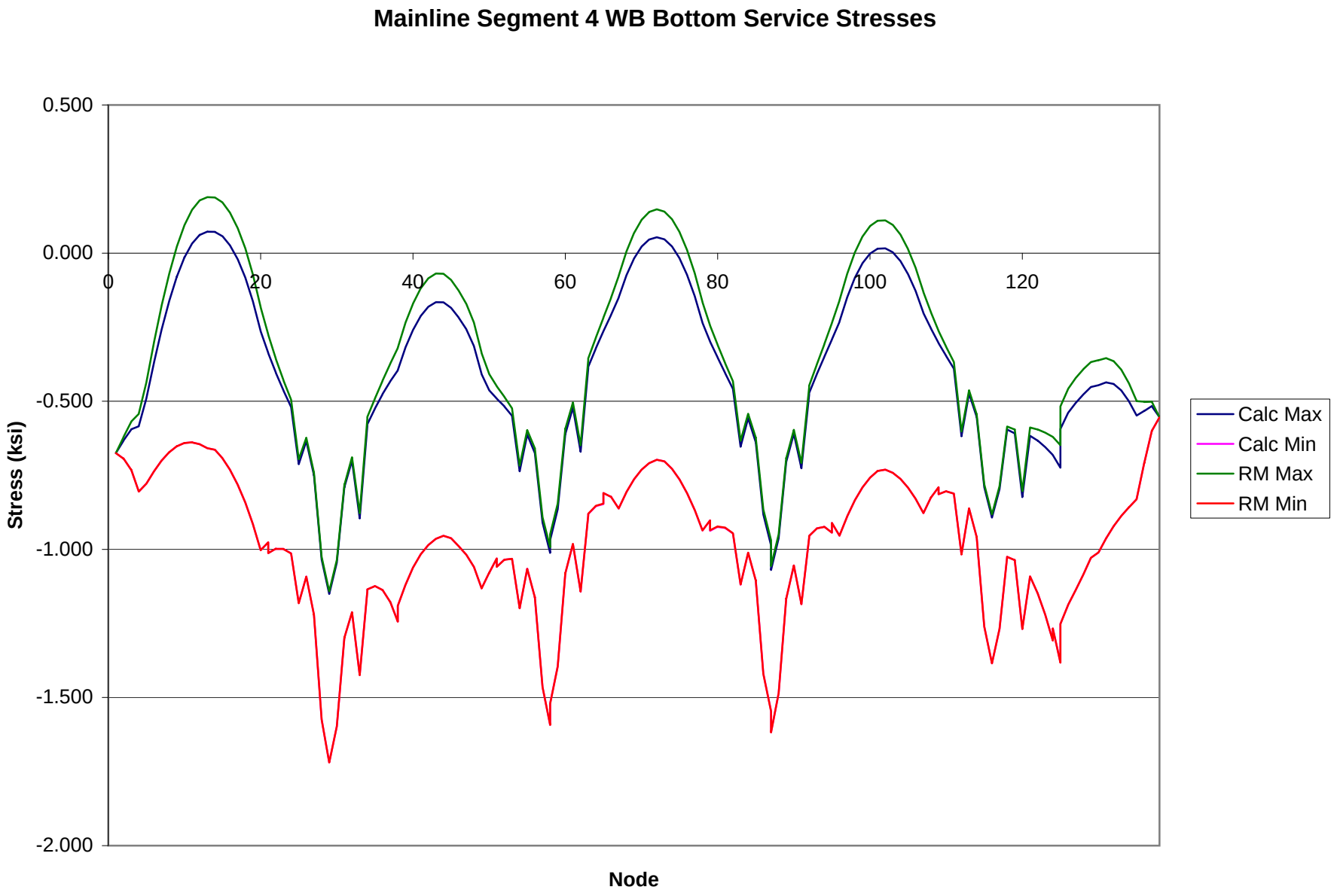
$$RF_{torsion} := \min\left(\frac{\phi V_{n_3} - \left|V_{dwebtmax_x}\right|}{\left|V_{LLwebtmax_x}\right|}, \frac{\phi V_{n_3} - \left|V_{dwebtmin_x}\right|}{\left|V_{LLwebtmin_x}\right|}\right)$$

$RF_{torsion} = 1.173$

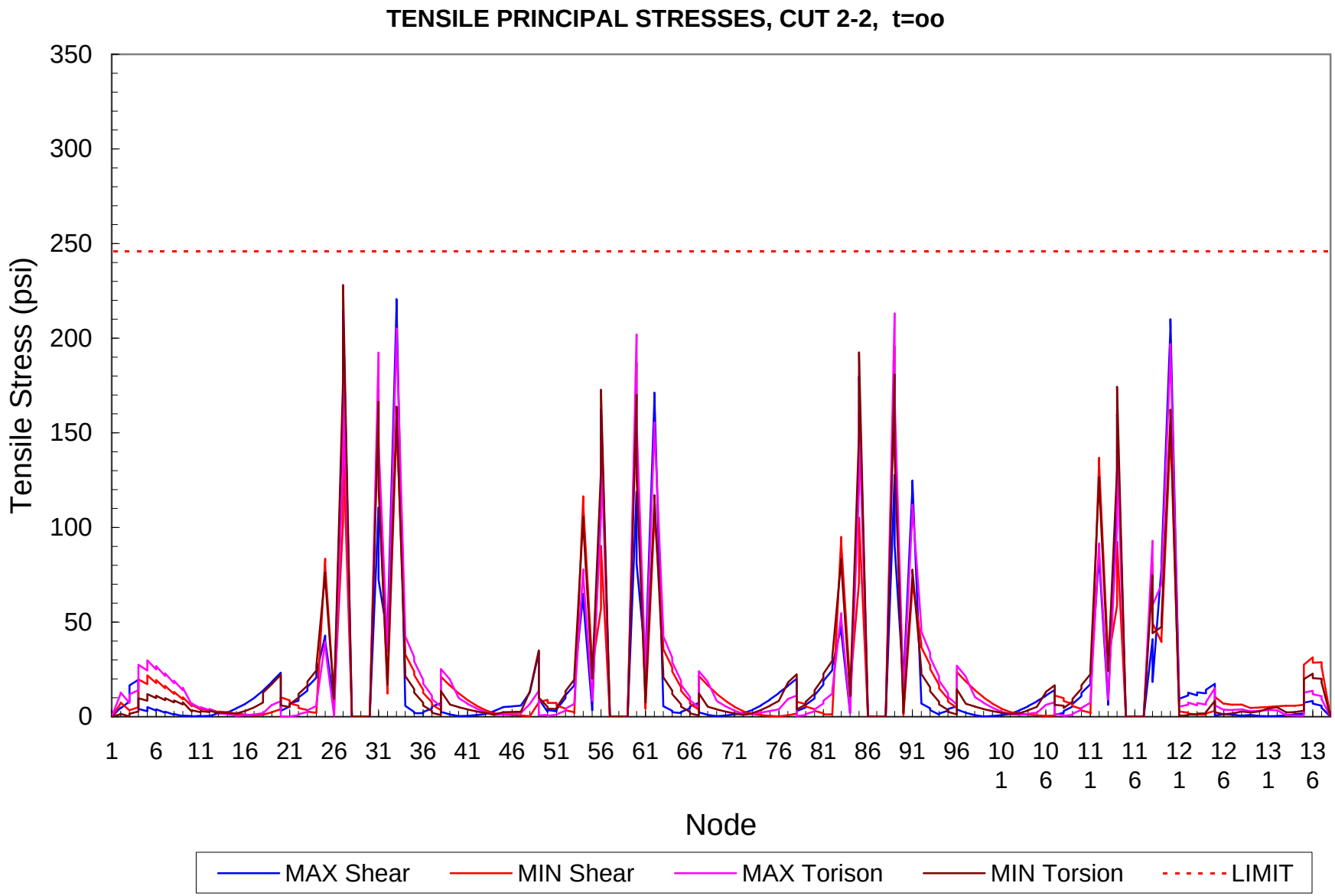
3.10.4 Service I Flexure (Service Stresses)


Service Stresses
500.0
0.0
-500.0
-1000.0
-1500.0
-2000.0
-2500.0
-3000.0
-3500.0
Stress (psi)
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
101
106
111
116
121
126
131
136
Node
Top Max
Bottom Max
Top Min
Bottom Min
Allowable Tension
Allowable Compression


Mainline Segment 4 WB Top Service Stresses
0.000
-0.200
-0.400
-0.600
-0.800
-1.000
-1.200
-1.400
-1.600
0
20
40
60
80
100
120
Stress (ksi)
Node
Calc Max
Calc Min
RM Max
RM Min


Mainline Segment 4 WB Bottom Service Stresses
0.500
0.000
-0.500
-1.000
-1.500
-2.000
0
20
40
60
80
100
120
Stress (ksi)
Node
Calc Max
Calc Min
RM Max
RM Min

3.10.5 Service I Principal Stresses


TENSILE PRINCIPAL STRESSES, CUT 2-2, t=oo
Tensile Stress (psi)
350
300
250
200
150
100
50
0
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136
Node
MAX Shear
MIN Shear
MAX Torison
MIN Torsion
LIMIT

Mainline Segment 4 WB Principal Stresses
0.600
0.400
0.200
0.000
-0.200
-0.400
-0.600
-0.800
-1.000
-1.200
-1.400
-1.600
0
20
40
60
80
100
120
Stress (ksi)
Node
Calc Max
Calc Min
RM Max
RM Min