

**NCHRP Project 12-71**  
Design Specifications and Commentary for Horizontally Curved Concrete Box-Girder  
Highway Bridges

**Appendix B**  
Example Problems



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*Horizontally Curved Concrete Box-Girder Highway Bridges*

**APPENDIX B - EXAMPLE PROBLEMS**

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## EXAMPLE B-1 - COMPREHENSIVE EXAMPLE PROBLEM DESCRIPTION

The example problem is a three span continuous box girder bridge that is 700 ft. long with span lengths of 200, 300 and 200 ft. It is assumed the bridge will be cast on falsework. Plan, elevation and section views are shown on the following pages. The centerline of the bridge lies on a 400 ft radius and the cross-section is a two cell box that is 43'-0" wide. This example generally follows the AASHTO LRFD Bridge Design Specifications (4<sup>th</sup> Edition) and the recommended specification changes developed in this project.

Although the bridge parameters are near the limit of the type of bridge likely to be encountered in normal practice, the proposed specifications allow it to be analyzed for global response using a 3-dimensional spine beam. The first part of the example uses this analysis method. The analysis in this example was performed using the LARSA 4D Plus computer program. Most commercially available 3D structural analysis software is also suitable for this analysis. The example follows the Analysis Guidelines included in Appendix C.

The following example illustrates how components critical to a curved bridge are designed for dead and live load, but is not a complete design of the entire bridge. The example includes determination of longitudinal stress distribution; section design for shear, torsion and regional bending; and determination of bearing design forces.

The number of live load lanes applied to the bridge is based on the whole-width design approach described in AASHTO when primary bending and shear response of the individual girder lines is determined. A different number of lanes are applied when determining axial force, torsion and lateral bending and shear of the entire cross-section. In this case only the live load lanes that can fit on the bridge are considered. Our research indicated that this approach yielded conservative results compared to placing individual live loads (lanes and trucks) eccentric to the centerline of the bridge and then combining these loads for maximum effect.

This approach is also preferred to an individual girder line approach (i.e. individual girder distribution factors) because it provides for a more direct combination of the multiple member actions encountered in a curved bridge of this type. It also simplifies the application of live load. Design for local tendon confinement is not included in this example, but can be found in examples B-2 and B-3.

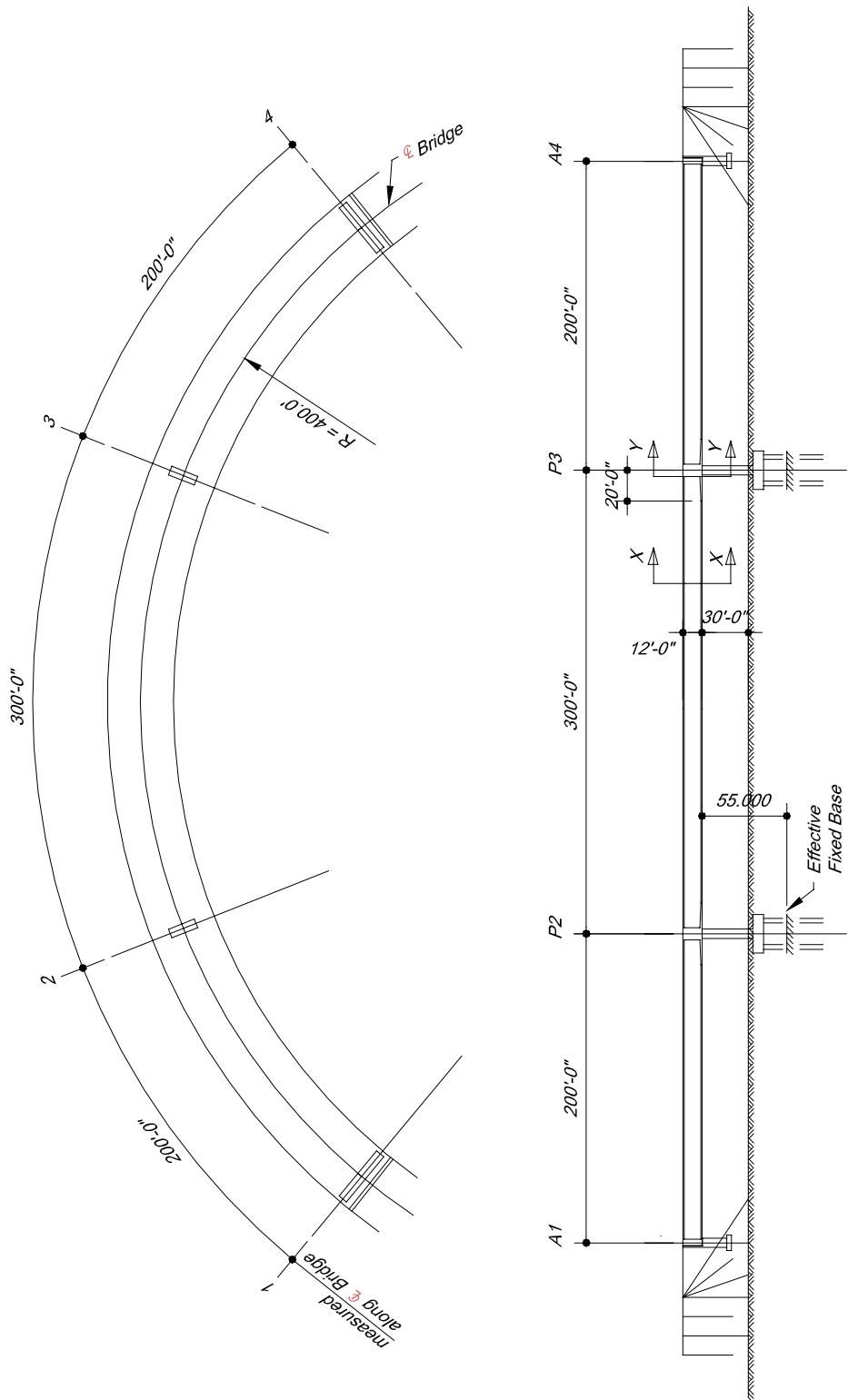


Figure B-1 Plan and Elevation of Example Problem Bridge

$P_{JACK} = 16,347$  kips (Use 4 - 31 strand tendons per web)

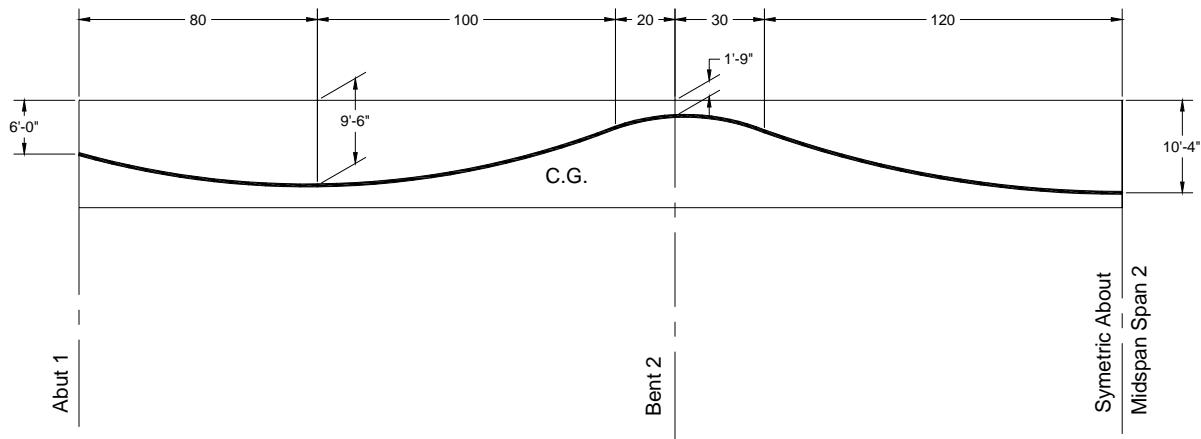


Figure B-2 Prestress Path

In addition to the 3-dimensional spine beam analysis, a grillage analogy analysis, also performed with LARSA 4D Plus, is presented. This analysis would not be required by the proposed specifications for this bridge, but is included to illustrate the analysis technique and for comparison of results.

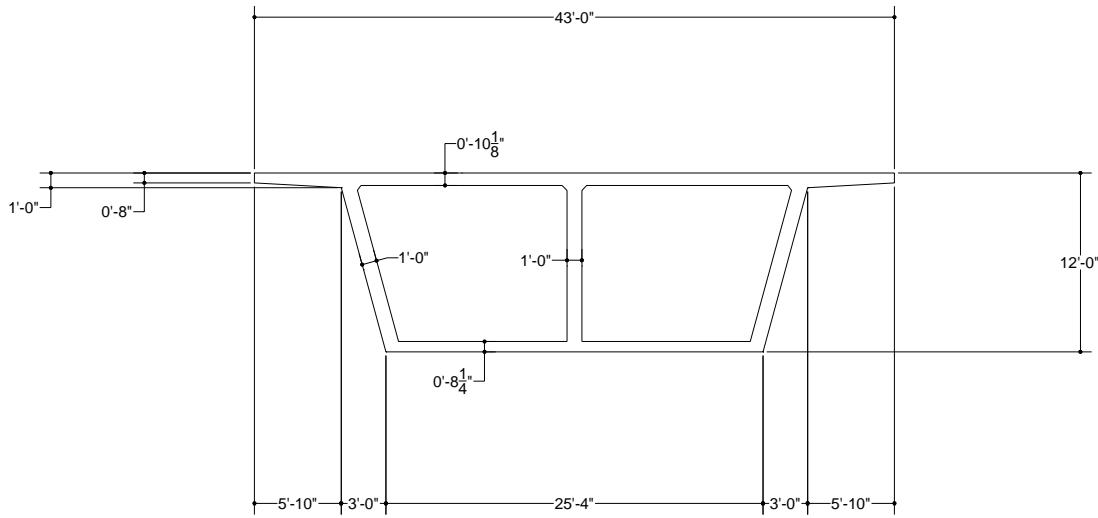


Figure B-3 – Typical Section - SECTION X-X

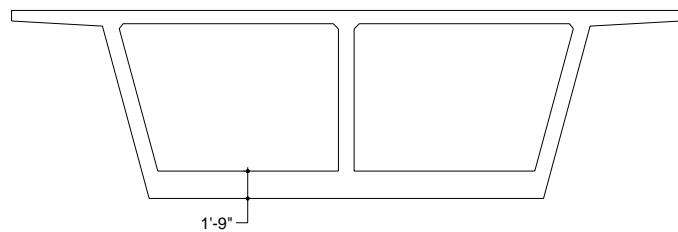


Figure B-4 – Section at Bent - SECTION Y-Y

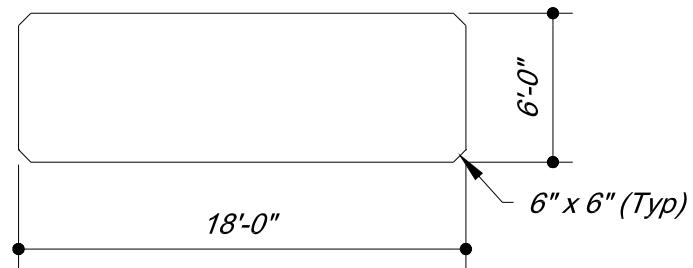


Figure B-5 - Column Section

## Analysis Parameters

Section Properties (From STAAD Section Wizaed):

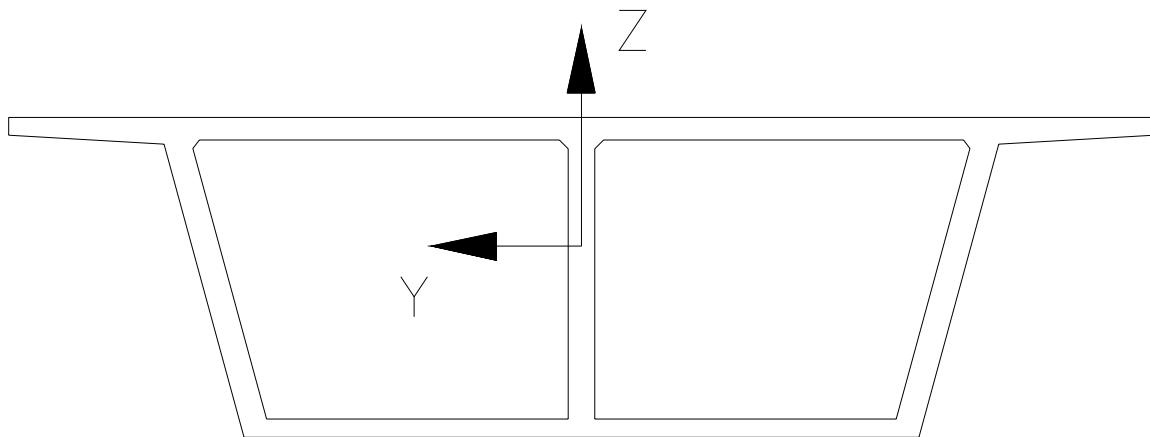
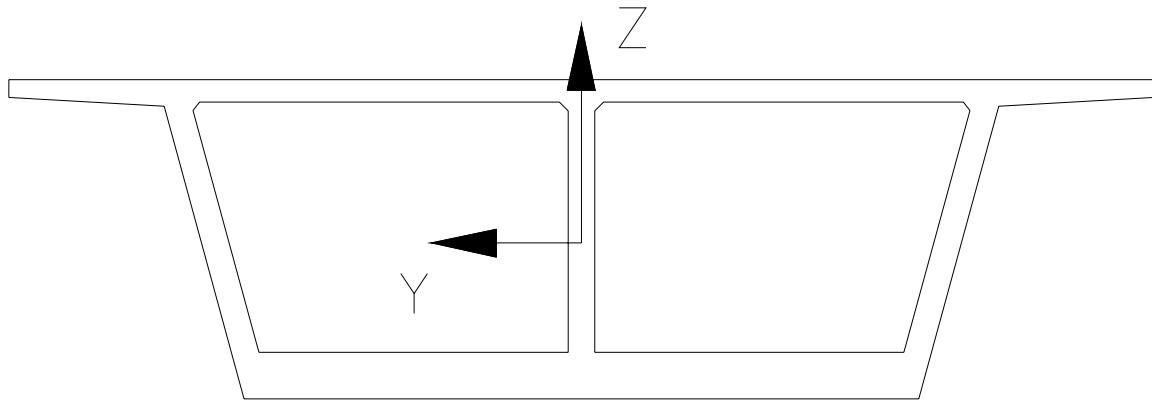


Figure B-6 -Typical Section Properties

Overall dimensions 43.0 ft x 12.0 ft

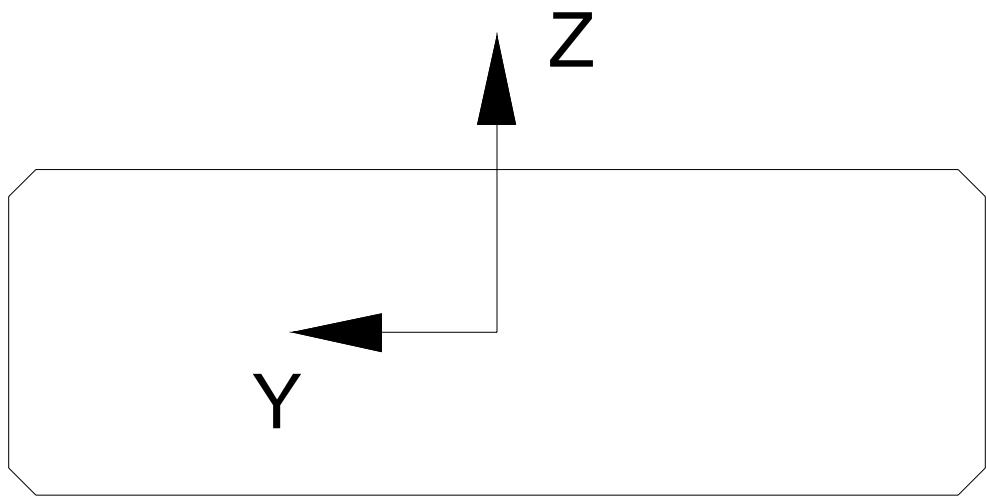
$A_x$	Sectional area	86.09 $\text{ft}^2$
$A_{v,y}$	Conventional shearing area along Y-axis	16.35 $\text{ft}^2$
$A_{v,z}$	Conventional shearing area along Z-axis	8.812 $\text{ft}^2$
$I_y$	Moment of inertia about centroidal Y-axis	1,870 $\text{ft}^4$
$I_z$	Moment of inertia about centroidal Z-axis	10,580 $\text{ft}^4$
$I_x$	Torsional moment of inertia (St. Venant)	4166 $\text{ft}^4$
$S_z$	Section modulus about Z-axis	492.1 $\text{ft}^3$
$S_{yb}$	Bottom section modulus about Y-axis	260.7 $\text{ft}^3$
$S_{yt}$	Top section modulus about Y-axis	387.4 $\text{ft}^3$
$z_M$	Distance from soffit to center of gravity along Z-axis	7.173 ft



**Figure B-7 -Superstructure Section Properties at Bent**

**Overall dimensions 43.0 ft x 12 ft**

$A_x$	Sectional area	110.4	$\text{ft}^2$
$A_{v,y}$	Conventional shearing area along Y-axis	32.67	$\text{ft}^2$
$A_{v,z}$	Conventional shearing area along Z-axis	16.56	$\text{ft}^2$
$I_y$	Moment of inertia about centroidal Y-axis	2,545	$\text{ft}^4$
$I_z$	Moment of inertia about centroidal Z-axis	11,790	$\text{ft}^4$
$I_x$	Torsional moment of inertia (St. Venant)	5,079	$\text{ft}^4$
$S_z$	Section modulus about Z-axis	548.5	$\text{ft}^3$
$S_y$	Top section modulus about Y-axis	414.5	$\text{ft}^3$
$S_b$	Bottom section modulus about Y-axis	434.2	$\text{ft}^3$
$z_m$	Distance to the center of gravity from soffit	5.861	ft



**Figure B-8 -Pier Section Properties**

Overall dimensions 18.0 ft x 6.0 ft

$A_x$	Sectional area	107.5 $\text{ft}^2$
$A_{v,z}$	Conventional shearing area along Z-axis	81.25 $\text{ft}^2$
$A_{v,y}$	Conventional shearing area along Y-axis	89.62 $\text{ft}^2$
$I_y$	Moment of inertia about centroidal Y-axis	320.0 $\text{ft}^4$
$I_z$	Moment of inertia about centroidal Z-axis	2877 $\text{ft}^4$
$I_x$	Torsional moment of inertia (St. Venant)	996.2 $\text{ft}^4$
$S_z$	Section modulus about Z-axis	319.7 $\text{ft}^3$
$S_y$	Section modulus about Y-axis	106.7 $\text{ft}^3$

Loads:

DC: Based on 150 pcf and member cross-section areas.

$$\text{Abutment Diaphragms} = (A_{CP} - A_X) \times W_D \times .150 = (352.76 - 86.09) \times 4.0 \times .150 = 160 \text{ kips}$$

DW:  $w_{DW} = w_{DECK}(w_{OVERLAY}) + 2w_{RAIL} = 43.0(.035) + 2(0.5) = 2.51 \text{ kips/ft}$

PS<sub>FINAL</sub>:

$$P_{JACK} = N_{STRAND} * A_{STRAND} * f_{PS} * 0.75 = 31 * 3 * 4 * (.217)(270)(.75) = 16,347 \text{ kips}$$

Anchor Set = 0.375 inches

$$\mu = 0.2$$

$$\kappa = .0002$$

Use Low Relaxation Strand

$$f'_c = 5000 \text{ psi}$$

Live Load Truck: Use HL93 with LARSA Live Load generator. Use one design truck per bridge and scale results by number of factored design lanes ( $N_L$ ) as determined on page B-37

Live Load Lane: Use 0.64 kips/ft/lane. Use one lane and scale results by number of factored design lanes ( $N_L$ ) as determined on page B-37. The maximum response from the following load cases and combinations was used.

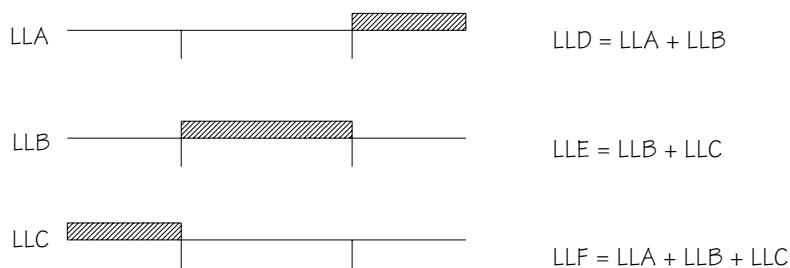


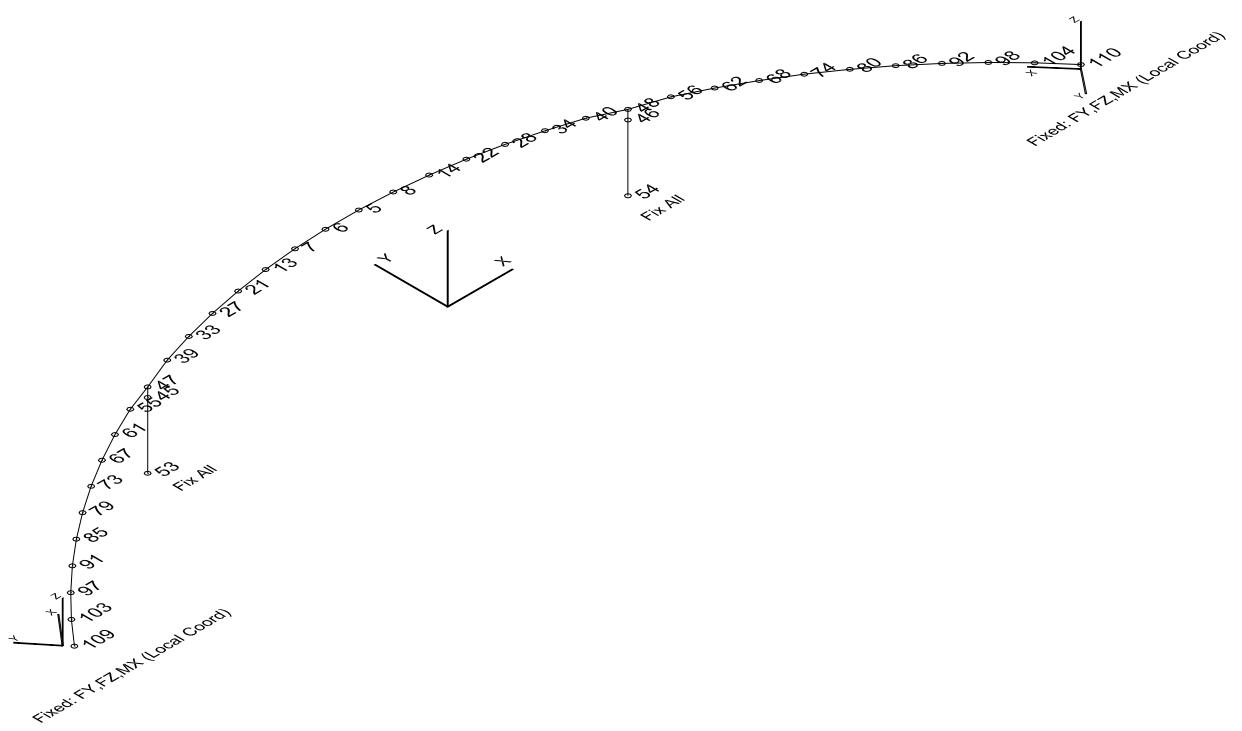
Figure B-9 – Elevation of Bridge Showing Positions of Live Load Lane Loadings

IM: Vehicle dynamic effect on design truck = 0.33

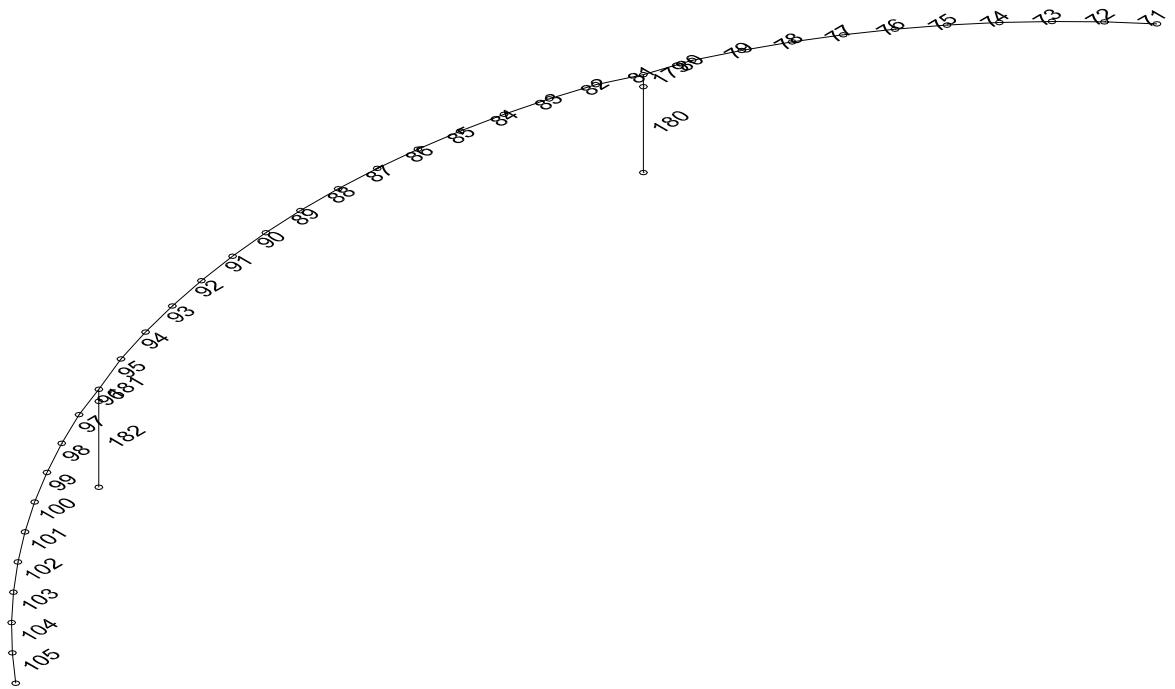


Global Spine Beam Analysis Input and Results  
LARSA Computer Output





LARSA Node Points



LARSA Member Numbers

LARSA Input Data for Spine Model

**INPUT : Material Properties**

Name	Modulus of Elasticity (lb/in <sup>2</sup> )	Poisson Ratio	Shear Modulus (lb/in <sup>2</sup> )	Unit Weight (lb/in <sup>3</sup> )	Thermal Expansion (1/ <sup>°F *10<sup>-6</sup>)</sup>	Assigned
Fc_5	4031000	0.1704	1722000	0.0868	5.5	Yes
WEIGHTLESS	4031000	0.1704	1722000	0	5.5	Yes
PSS	28500000	0.29	11000000	0.278	5.5	Yes

**INPUT : UCSs**

Name	Type	Origin X (ft)	Origin Y (ft)	Origin Z (ft)	Axis Point X (ft)	Axis Point Y (ft)	Axis Point Z (ft)	Point on XY Plane X (ft)	Point on XY Plane Y (ft)	Point on XY Plane Z (ft)	Angle Z	Angle X	Angle Y	Assigned
ABUT1	Cartesian	319.7489	-1608.5897	0	332.9472	-1593.5656	0	309.6219	-1600.1323	0				Yes
ABUT4	Cartesian	933.7837	-1608.5897	0	920.5854	-1593.5656	0	923.6567	-1617.047	0				Yes

**INPUT : Sections**

Name	Section Area (ft <sup>2</sup> )	Shear Area in yy (ft <sup>2</sup> )	Shear Area in zz (ft <sup>2</sup> )	Torsion Constant (ft <sup>4</sup> )	Inertia Izz (ft <sup>4</sup> )	Inertia Iyy (ft <sup>4</sup> )	Plastic Modulus Zyy (ft <sup>3</sup> )	Plastic Modulus Zzz (ft <sup>3</sup> )	Perimeter (ft)	Creep/Shrinkage Type	Ductility	Residual Strength (%)	Assigned
Superstructure	86.09	16.35	8.812	4166	10580	1870	0	0	0	(NONE)	50	0	Yes
SuperBent	110.4	16.56	32.67	5079	11790	2545	0	0	0	(NONE)	50	0	Yes
Column	107.5	107.5	107.5	1279.92	2876.979	319.979	0	0	0	(NONE)	50	0	Yes
Rigid	107.5	107.5	107.5	1000000	1000000	1000000	0	0	0	(NONE)	50	0	Yes

**INPUT : Joints**

ID	X (ft)	Y (ft)	Z (ft)	Translation DOF	Rotation DOF	Displacement UCS	Assignment
5	636.7653	-1465.1134	0	all free	all free	Global	Yes
6	616.4375	-1465.1218	0	all free	all free	Global	Yes
7	596.7944	-1466.1129	0	all free	all free	Global	Yes
8	656.7382	-1466.1129	0	all free	all free	Global	Yes
13	576.8964	-1468.1093	0	all free	all free	Global	Yes
14	676.6362	-1468.1093	0	all free	all free	Global	Yes
21	557.123	-1471.0978	0	all free	all free	Global	Yes
22	696.4096	-1471.0978	0	all free	all free	Global	Yes
27	537.5238	-1475.0708	0	all free	all free	Global	Yes
28	716.0088	-1475.0708	0	all free	all free	Global	Yes
33	518.1475	-1480.0183	0	all free	all free	Global	Yes
34	735.3851	-1480.0183	0	all free	all free	Global	Yes
39	499.0428	-1485.9281	0	all free	all free	Global	Yes
40	754.4898	-1485.9281	0	all free	all free	Global	Yes
45	480.2573	-1492.7853	-6.899	all free	all free	Global	Yes
46	773.2753	-1492.7853	-6.899	all free	all free	Global	Yes
47	480.2573	-1492.7853	-1.312	all free	all free	Global	Yes
48	773.2753	-1492.7853	-1.312	all free	all free	Global	Yes
53	480.2573	-1492.7853	-46.9	all fixed	all fixed	Global	Yes
54	773.2753	-1492.7853	-46.9	all fixed	all fixed	Global	Yes
55	461.838	-1500.5729	0	all free	all free	Global	Yes
56	791.6946	-1500.5729	0	all free	all free	Global	Yes
61	443.8309	-1509.2713	0	all free	all free	Global	Yes
62	809.7017	-1509.2713	0	all free	all free	Global	Yes
67	426.2811	-1518.8588	0	all free	all free	Global	Yes
68	827.2515	-1518.8588	0	all free	all free	Global	Yes
73	409.2324	-1529.3115	0	all free	all free	Global	Yes
74	844.3002	-1529.3115	0	all free	all free	Global	Yes
79	392.7274	-1540.6031	0	all free	all free	Global	Yes
80	860.8052	-1540.6031	0	all free	all free	Global	Yes
85	376.8074	-1552.7056	0	all free	all free	Global	Yes
86	876.7252	-1552.7056	0	all free	all free	Global	Yes

91	361.5121	-1565.5886	0	all free	all free	Global	Yes
92	892.0205	-1565.5886	0	all free	all free	Global	Yes
97	346.8799	-1579.22	0	all free	all free	Global	Yes
98	906.6527	-1579.22	0	all free	all free	Global	Yes
103	332.9472	-1593.5656	0	all free	all free	Global	Yes
104	920.5854	-1593.5656	0	all free	all free	Global	Yes
109	319.75	-1608.59	0	y, z fixed	x fixed	ABUT1	Yes
110	933.78	-1608.59	0	y, z fixed	x fixed	ABUT4	Yes

INPUT : Members

ID	I-Joint	J-Joint	Span	Type	Section at Start	Section at End	Material	Prestress Force (kips)	Length (ft)	Rigid Zone from Start (x/L)	Rigid Zone from End (x/L)	Orientation Angle (deg)	Casting (day)	Structure / Construction Group
71	110	104	-	Beam	Superstructure (same as start)	Fc_5	0	19.9957	0	0	0	0	0	All
72	104	98	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
73	98	92	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
74	92	86	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
75	86	80	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
76	80	74	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
77	74	68	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
78	68	62	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
79	62	56	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
80	56	48	-	Beam	Superstructure	SuperBent	Fc_5	0	20.0409	0	0	0	0	All
81	48	40	-	Beam	Superstructure	SuperBent	Fc_5	0	20.0409	0	0	0	0	All
82	40	34	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
83	34	28	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
84	28	22	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
85	22	14	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
86	14	8	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
87	8	5	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
88	5	6	-	Beam	Superstructure (same as start)	Fc_5	0	20.3277	0	0	0	0	0	All
89	6	7	-	Beam	Superstructure (same as start)	Fc_5	0	19.6681	0	0	0	0	0	All
90	7	13	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
91	13	21	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
92	21	27	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
93	27	33	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
94	33	39	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
95	39	47	-	Beam	Superstructure	SuperBent	Fc_5	0	20.0409	0	0	0	0	All
96	47	55	-	Beam	Superstructure	SuperBent	Fc_5	0	20.0409	0	0	0	0	All
97	55	61	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
98	61	67	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
99	67	73	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
100	73	79	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
101	79	85	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
102	85	91	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
103	91	97	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
104	97	103	-	Beam	Superstructure (same as start)	Fc_5	0	19.9979	0	0	0	0	0	All
105	103	109	-	Beam	Superstructure (same as start)	Fc_5	0	19.9975	0	0	0	0	0	All
179	48	46	-	Beam	Rigid (same as start)	WEIGHTLESS	0	5.587	0	0	21.5	0	0	All
180	46	54	-	Beam	Column (same as start)	Fc_5	0	40.001	0	0	21.5	0	0	All
181	47	45	-	Beam	Rigid (same as start)	WEIGHTLESS	0	5.587	0	0	-21.5	0	0	All
182	45	53	-	Beam	Column (same as start)	Fc_5	0	40.001	0	0	-21.5	0	0	All

**INPUT : Tendons**

Tendon Name	Design Group	Material	Exposure	Strand Area (per strand)	# of Strands	Proposed Jacking Force (kips)	Applied Jacking Force @ Start (kips)	Applied Jacking Force @ End (kips)	Jacking End	Anchor Set (ft)	Wobble Coefficient	Curvature Friction Coefficient	Peak Stress Ratio - Ends	Peak Stress Ratio - Interior	Elongation After Pull 1
LONG	(none)	PSS	Internal	0.0015	124	5,449.0000	5,341.1287	5,346.8436	Start, then End	0.0300	0.0002	0.1500	0.7000	0.7000	3.9348
LONG (2)	(none)	PSS	Internal	0.0015	124	5,449.0000	5,338.8629	5,345.0311	Start, then End	0.0300	0.0002	0.1500	0.7000	0.7000	3.8038
LONG (3)	(none)	PSS	Internal	0.0015	124	5,449.0000	5,342.7083	5,348.3423	Start, then End	0.0300	0.0002	0.1500	0.7000	0.7000	4.064

**TENDON LONG**

Point Type	Reference Object Type	Reference Object or Range	Offset X (ft)	Offset Y (ft)	Offset Z (ft)	X Reference	Y Reference	Z Reference	Curvature Type		
geometry	member	71	0.0000	0.0000	-6.0000	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	72	0.0000	0.0000	-7.5300	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	73	0.0000	0.0000	-8.6300	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	74	0.0000	0.0000	-9.2800	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	75	0.0000	0.0000	-9.5000	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	76	0.0000	0.0000	-9.2400	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	77	0.0000	0.0000	-8.4660	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	78	0.0000	0.0000	-7.1740	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	79	0.0000	0.0000	-5.3660	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	80	0.0000	0.0000	-3.0400	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	81	0.0000	0.0000	-1.7500	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	82	0.0000	0.0000	-2.5130	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	83	0.0000	0.0000	-4.4814	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	84	0.0000	0.0000	-6.2685	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	85	0.0000	0.0000	-7.7306	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	86	0.0000	0.0000	-8.8678	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	87	0.0000	0.0000	-9.6800	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	88	0.0000	0.0000	-10.1680	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	88	10.0000	0.0000	-10.3300	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	89	0.0000	0.0000	-10.1680	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	90	0.0000	0.0000	-9.6800	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	91	0.0000	0.0000	-8.8678	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	92	0.0000	0.0000	-7.7306	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	93	0.0000	0.0000	-6.2685	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	94	0.0000	0.0000	-4.4814	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	95	0.0000	0.0000	-2.5130	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	96	0.0000	0.0000	-1.7500	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	97	0.0000	0.0000	-3.0400	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	98	0.0000	0.0000	-5.3660	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	99	0.0000	0.0000	-7.1740	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	100	0.0000	0.0000	-8.4660	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	101	0.0000	0.0000	-9.2400	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	102	0.0000	0.0000	-9.5000	Start	Reference Line	+Z1 Local Edge	No Curve		

### TENDON LONG

Point Type	Reference Object Type	Reference Object or Range	Offset X (ft)	Offset Y (ft)	Offset Z (ft)	X Reference	Y Reference	Z Reference	Curvature Type		
geometry	member	103	0.0000	0.0000	-9.2800	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	104	0.0000	0.0000	-8.6300	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	105	0.0000	0.0000	-7.7300	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	105	0.0000	0.0000	-6.0000	End	Reference Line	+Z1 Local Edge	No Curve		

### TENDON LONG (2)

Point Type	Reference Object Type	Reference Object or Range	Offset X (ft)	Offset Y (ft)	Offset Z (ft)	X Reference	Y Reference	Z Reference	Curvature Type		
geometry	member	71	0.0000	13.7500	-6.0000	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	72	0.0000	13.7500	-7.5300	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	73	0.0000	13.7500	-8.6300	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	74	0.0000	13.7500	-9.2800	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	75	0.0000	13.7500	-9.5000	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	76	0.0000	13.7500	-9.2400	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	77	0.0000	13.7500	-8.4660	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	78	0.0000	13.7500	-7.1740	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	79	0.0000	13.7500	-5.3660	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	80	0.0000	13.7500	-3.0400	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	81	0.0000	13.7500	-1.7500	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	82	0.0000	13.7500	-2.5130	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	83	0.0000	13.7500	-4.4814	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	84	0.0000	13.7500	-6.2685	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	85	0.0000	13.7500	-7.7306	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	86	0.0000	13.7500	-8.8678	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	87	0.0000	13.7500	-9.6800	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	88	0.0000	13.7500	-10.1680	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	88	10.0000	13.7500	-10.3300	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	89	0.0000	13.7500	-10.1680	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	90	0.0000	13.7500	-9.6800	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	91	0.0000	13.7500	-8.8678	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	92	0.0000	13.7500	-7.7306	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	93	0.0000	13.7500	-6.2685	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	94	0.0000	13.7500	-4.4814	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	95	0.0000	13.7500	-2.5130	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	96	0.0000	13.7500	-1.7500	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	97	0.0000	13.7500	-3.0400	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	98	0.0000	13.7500	-5.3660	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	99	0.0000	13.7500	-7.1740	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	100	0.0000	13.7500	-8.4660	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	101	0.0000	13.7500	-9.2400	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	102	0.0000	13.7500	-9.5000	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	103	0.0000	13.7500	-9.2800	Start	Reference Line	+Z1 Local Edge	No Curve		

### TENDON LONG (2)

Point Type	Reference Object Type	Reference Object or Range	Offset X (ft)	Offset Y (ft)	Offset Z (ft)	X Reference	Y Reference	Z Reference	Curvature Type		
geometry	member	104	0.0000	13.7500	-8.6300	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	105	0.0000	13.7500	-7.7300	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	105	0.0000	13.7500	-6.0000	End	Reference Line	+Z1 Local Edge	No Curve		

### TENDON LONG (3)

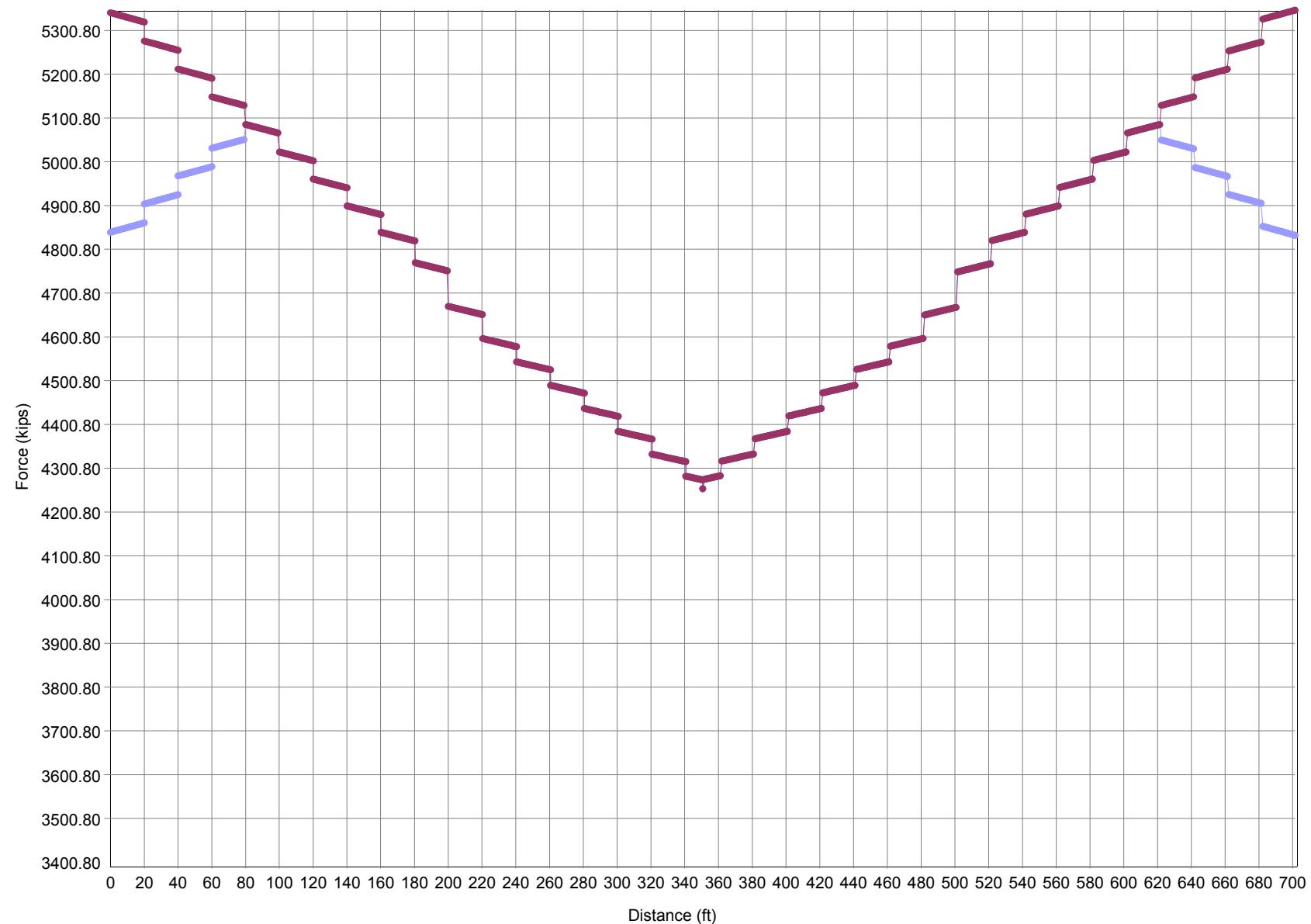
Point Type	Reference Object Type	Reference Object or Range	Offset X (ft)	Offset Y (ft)	Offset Z (ft)	X Reference	Y Reference	Z Reference	Curvature Type		
geometry	member	71	0.0000	-13.7500	-6.0000	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	72	0.0000	-13.7500	-7.5300	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	73	0.0000	-13.7500	-8.6300	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	74	0.0000	-13.7500	-9.2800	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	75	0.0000	-13.7500	-9.5000	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	76	0.0000	-13.7500	-9.2400	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	77	0.0000	-13.7500	-8.4660	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	78	0.0000	-13.7500	-7.1740	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	79	0.0000	-13.7500	-5.3660	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	80	0.0000	-13.7500	-3.0400	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	81	0.0000	-13.7500	-1.7500	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	82	0.0000	-13.7500	-2.5130	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	83	0.0000	-13.7500	-4.4814	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	84	0.0000	-13.7500	-6.2685	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	85	0.0000	-13.7500	-7.7306	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	86	0.0000	-13.7500	-8.8678	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	87	0.0000	-13.7500	-9.6800	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	88	0.0000	-13.7500	-10.1680	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	88	10.0000	-13.7500	-10.3300	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	89	0.0000	-13.7500	-10.1680	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	90	0.0000	-13.7500	-9.6800	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	91	0.0000	-13.7500	-8.8678	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	92	0.0000	-13.7500	-7.7306	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	93	0.0000	-13.7500	-6.2685	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	94	0.0000	-13.7500	-4.4814	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	95	0.0000	-13.7500	-2.5130	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	96	0.0000	-13.7500	-1.7500	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	97	0.0000	-13.7500	-3.0400	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	98	0.0000	-13.7500	-5.3660	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	99	0.0000	-13.7500	-7.1740	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	100	0.0000	-13.7500	-8.4660	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	101	0.0000	-13.7500	-9.2400	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	102	0.0000	-13.7500	-9.5000	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	103	0.0000	-13.7500	-9.2800	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	104	0.0000	-13.7500	-8.6300	Start	Reference Line	+Z1 Local Edge	No Curve		

**TENDON LONG (3)**

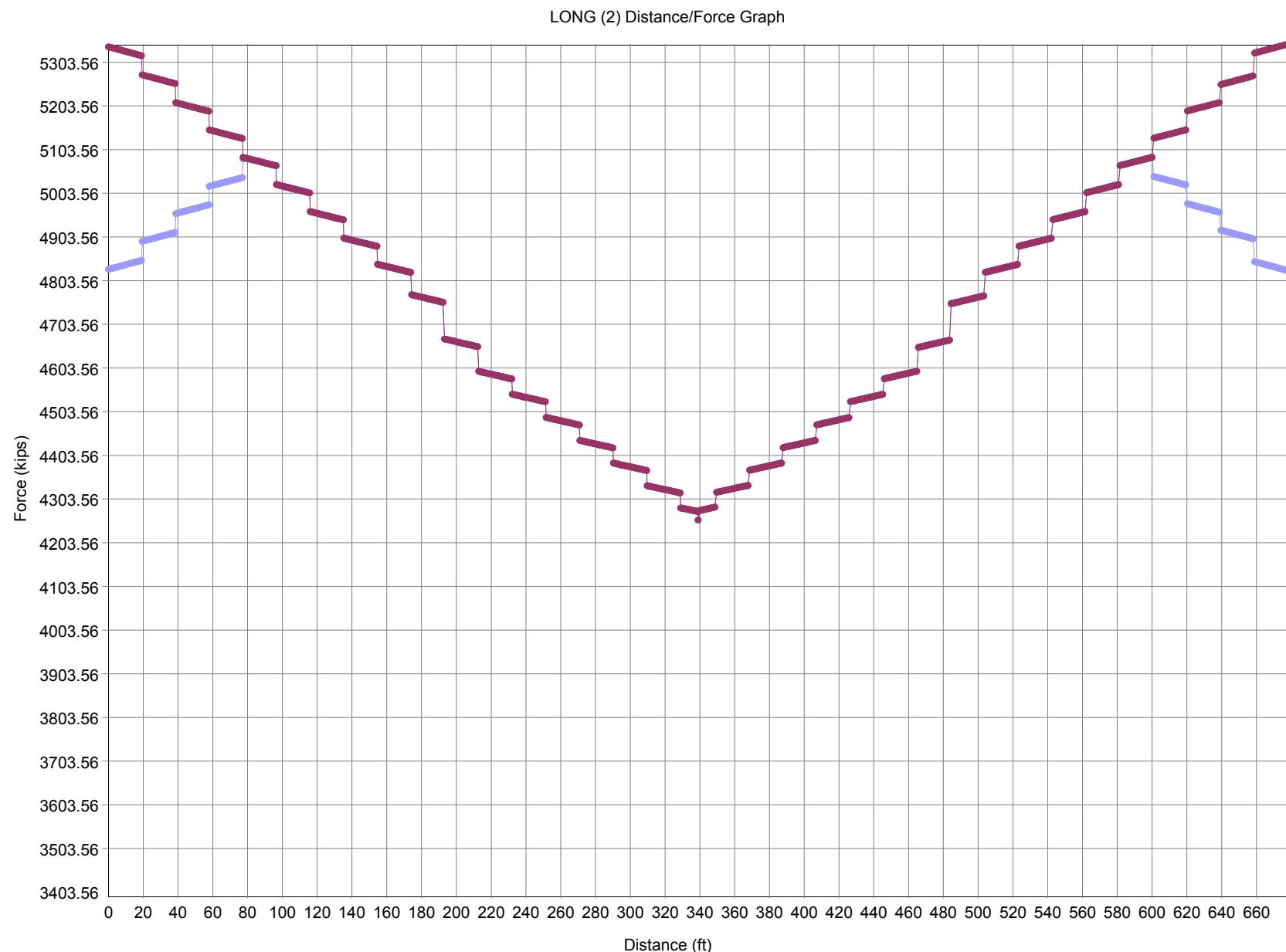
Point Type	Reference Object Type	Reference Object or Range	Offset X (ft)	Offset Y (ft)	Offset Z (ft)	X Reference	Y Reference	Z Reference	Curvature Type		
geometry	member	105	0.0000	-13.7500	-7.7300	Start	Reference Line	+Z1 Local Edge	No Curve		
geometry	member	105	0.0000	-13.7500	-6.0000	End	Reference Line	+Z1 Local Edge	No Curve		

## TENDON LONG, Graph

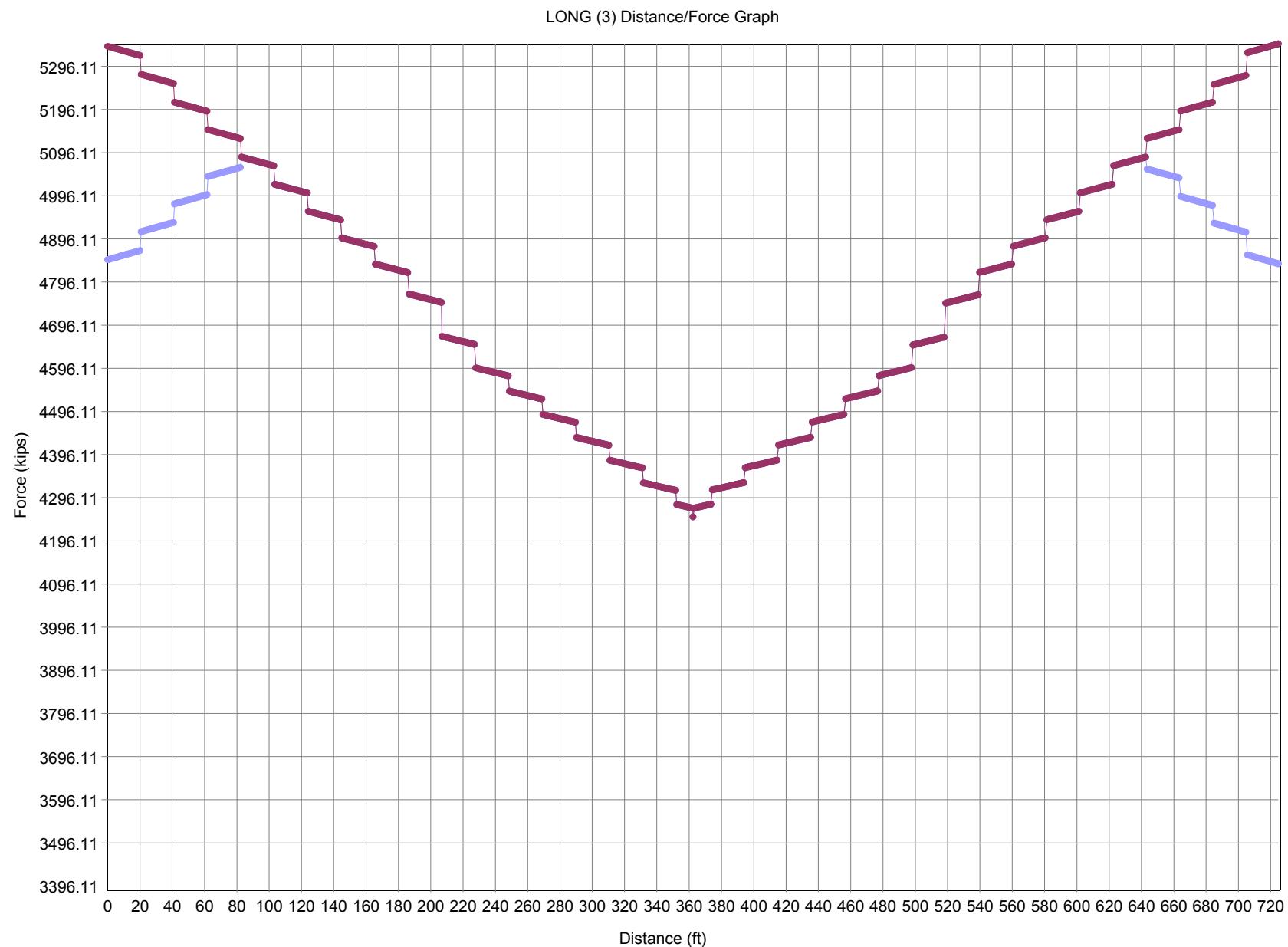
LONG Distance/Force Graph



## TENDON LONG (2), Graph



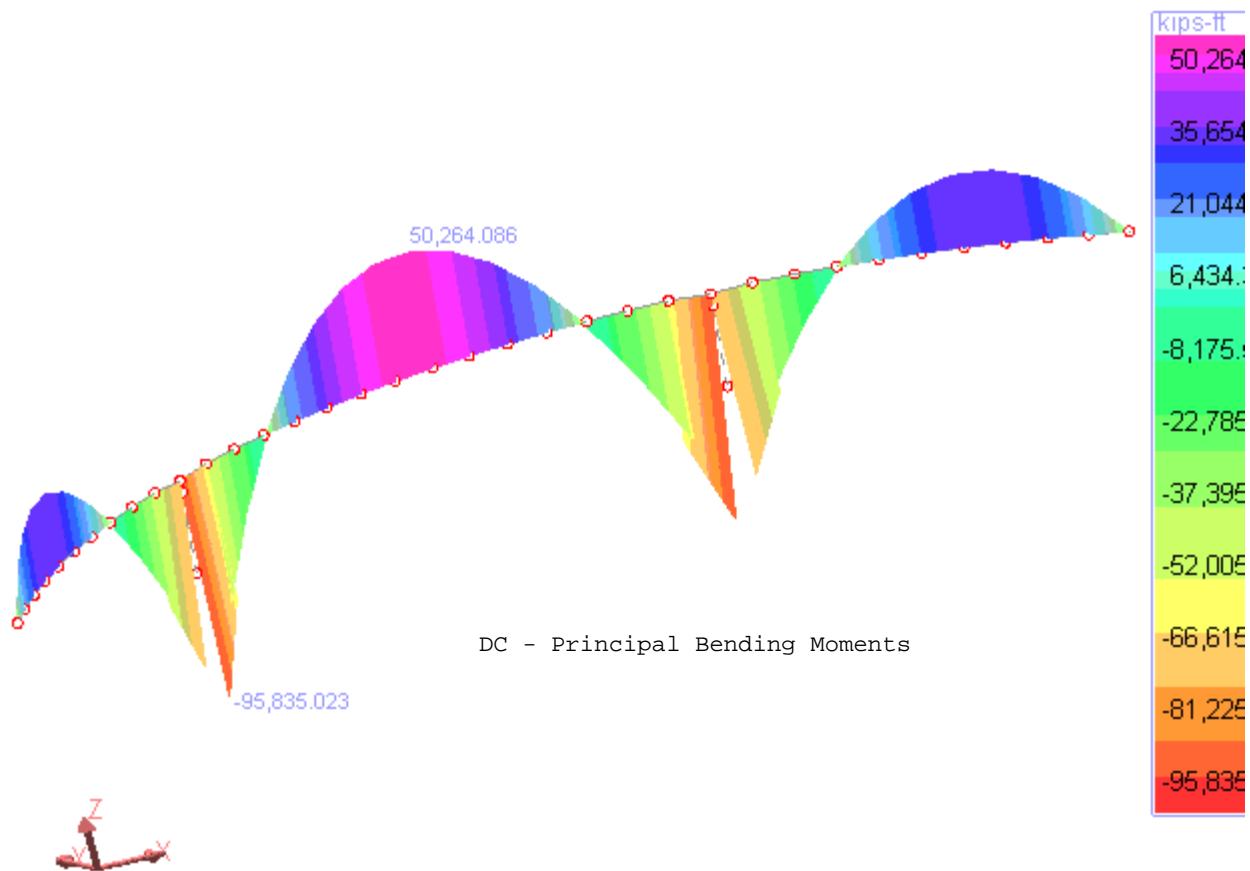
## TENDON LONG (3), Graph



LARSA Dead Load Results								
<b>RESULT : Reactions</b>								
Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)	
110	DC	24	21	898	2963	-3373	0	
110	DW	5	4	175	576	-655	0	
<b>RESULT : Member End Forces (Local)</b>								
Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
81	48	DC	637	186	1936	-2657	-95834	6936
81	40	DC	-618	-186	-1642	2657	59979	-3214
83	34	DC	525	134	1420	-7287	-28445	-168
83	28	DC	-525	-134	-1162	7287	2622	2849
84	28	DC	531	108	1162	-7409	-2255	-2849
84	22	DC	-531	-108	-904	7409	-18404	5001
88	5	DC	542	0	129	21	50264	-8242
88	6	DC	-542	0	133	-21	-50221	8238
81	48	DW	123	36	369	-515	-18559	1346
81	40	DW	-120	-36	-319	515	11661	-624
83	34	DW	102	26	276	-1415	-5532	-33
83	28	DW	-102	-26	-226	1415	513	553
84	28	DW	103	21	226	-1439	-442	-553
84	22	DW	-103	-21	-176	1439	-3573	971
88	5	DW	105	0	25	4	9766	-1600
88	6	DW	-105	0	26	-4	-9757	1599

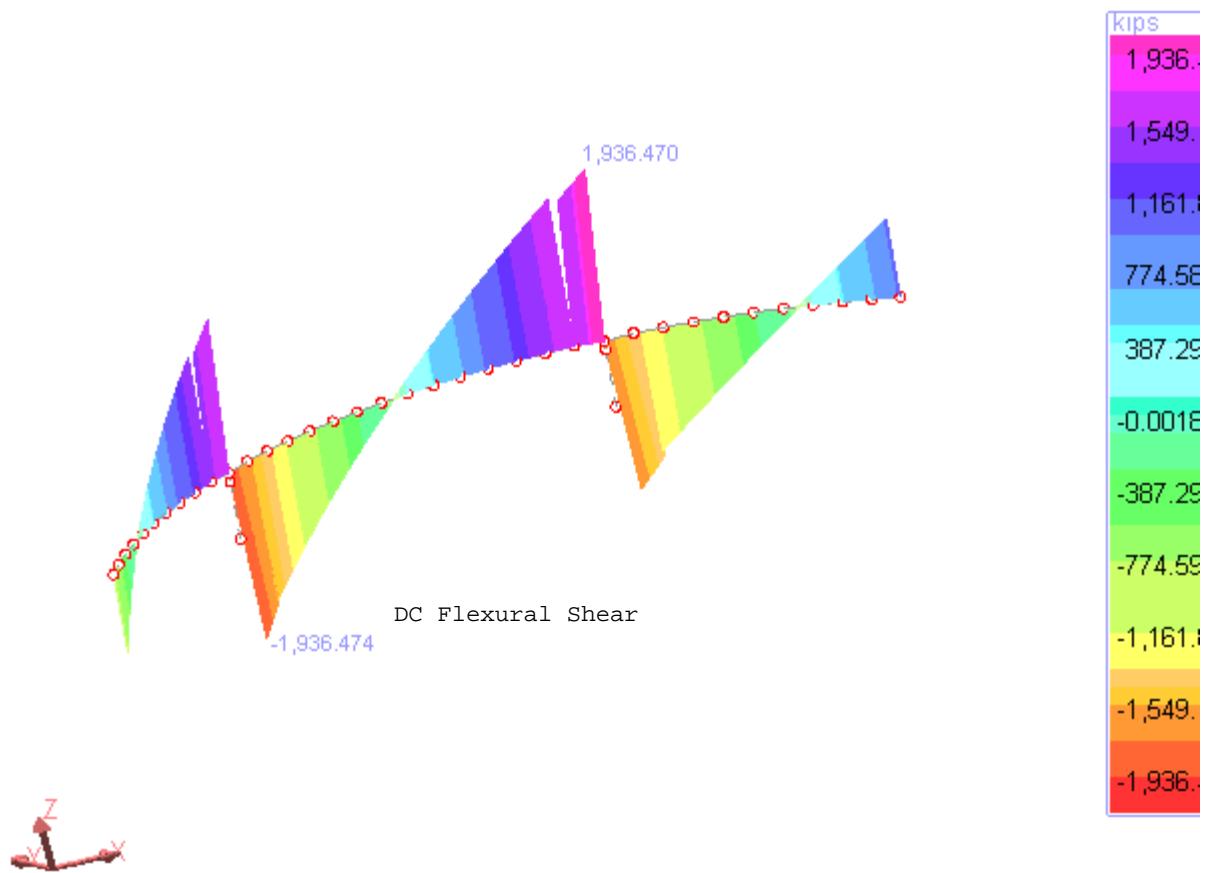
## Graphics View 1

Zoom 2.120X  
Member Forces - Moment My - DC



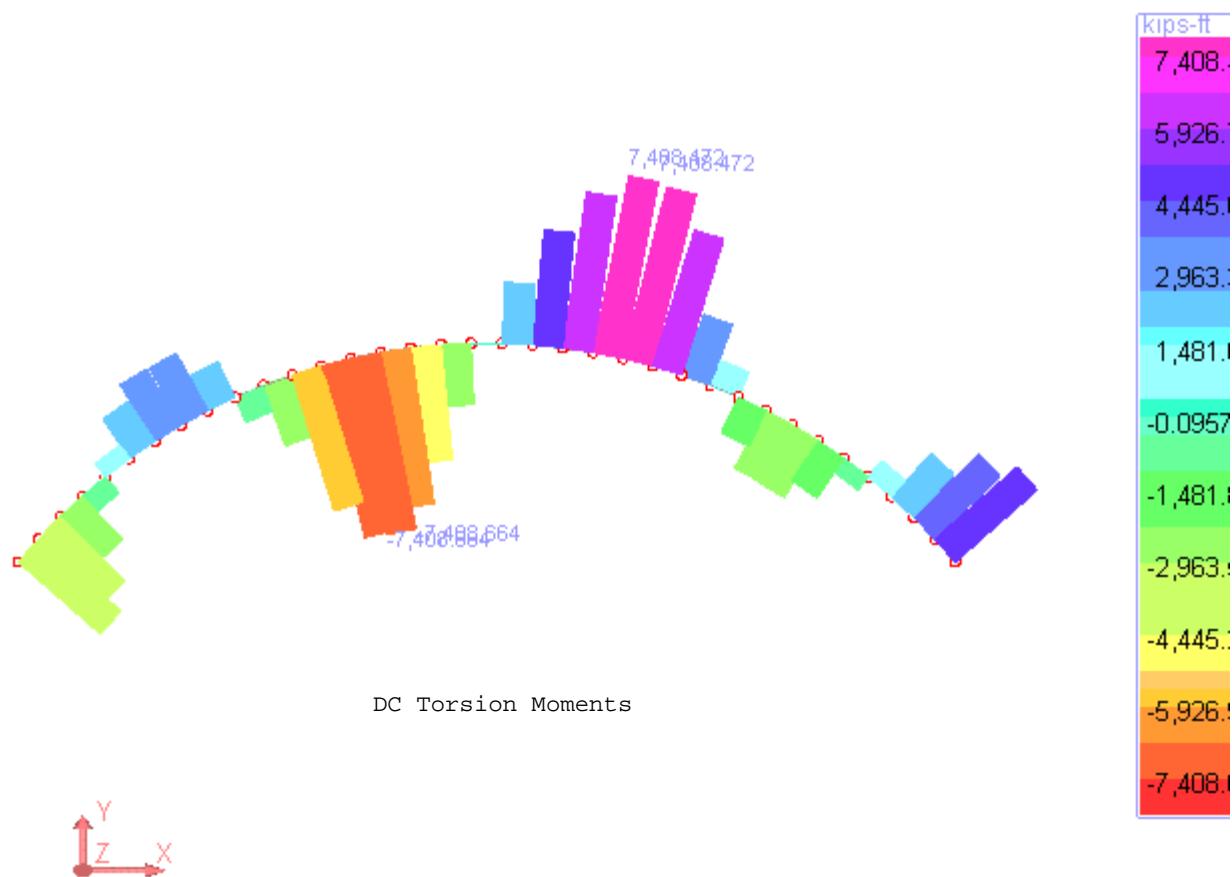
## Graphics View 1

Zoom 1.500X  
Member Forces - Shear Fz - DC



## Graphics View 1

Zoom 1.500X  
Member Forces - Torsion Mx - DC



### LARSA Results for Live Load Lane Loading

#### RESULT ENVELOPE :Reactions @ Force Z (kips)

Joint	Result Case	Force X/R (kips)	Force Y/Theta/Phi (kips)	Force Z/Theta (kips)	Moment X/R (kips-ft)	Moment Y Theta/Phi (kips-ft)	Moment Z/Theta (kips-ft)
110	LLLANEE	0	-3	-9	121	0	0
110	LLLANEA	0	1	54	-343	0	0

#### RESULT ENVELOPE :Member End Forces (Local) @ Force Z (kips)

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
81	48	LLLANEC	-23	-8	-5	2	594	-322
81	48	LLLANED	50	17	100	-141	-5343	655
81	40	LLLANED	-50	-17	-88	141	3463	-305
81	40	LLLANEC	23	8	5	-2	-494	152
83	34	LLLANEC	-24	-6	-6	49	380	-5
83	34	LLLANED	49	13	76	-411	-1787	0
83	28	LLLANED	-49	-13	-63	411	396	252
83	28	LLLANEC	24	6	6	-49	-269	-118
84	28	LLLANEC	-24	-5	-6	63	267	118
84	28	LLLANED	50	10	63	-430	-375	-252
84	22	LLLANED	-50	-10	-50	430	-759	456
84	22	LLLANEC	24	5	6	-63	-156	-217
88	5	LLLANEC	-24	0	-6	59	-190	370
88	5	LLLANED	51	0	12	-58	2684	-766
88	6	LLLANEA	24	0	-6	59	188	-370
88	6	LLLANEE	-51	0	12	-60	-2680	766

#### RESULT ENVELOPE :Member End Forces (Local) @ Moment X (kips-ft)

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
81	48	LLLANEB	73	26	94	-301	-4266	944
81	48	LLLANEA	-23	-8	6	160	-1077	-290
81	40	LLLANEA	23	8	-6	-160	955	125
81	40	LLLANEB	-72	-26	-81	301	2509	-430
83	34	LLLANEB	73	19	70	-483	-931	-21
83	34	LLLANEA	-24	-6	6	72	-856	21
83	28	LLLANEA	24	6	-6	-72	745	-139
83	28	LLLANEB	-73	-19	-58	483	-348	392
84	28	LLLANEB	74	15	58	-465	372	-392
84	28	LLLANEC	-24	-5	-6	63	267	118
84	22	LLLANEC	24	5	6	-63	-156	-217
84	22	LLLANEB	-74	-15	-45	465	-1396	690
88	5	LLLANEA	-24	0	6	-59	-301	373
88	5	LLLANEE	51	0	1	60	2795	-768
88	6	LLLANEE	-51	0	12	-60	-2680	766
88	6	LLLANEA	24	0	-6	59	188	-370

#### RESULT ENVELOPE :Member End Forces (Local) @ Moment Y (kips-ft)

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
81	48	LLLANED	50	17	100	-141	-5343	655
81	48	LLLANE	-23	-8	-5	2	594	-322
81	40	LLLANEC	23	8	5	-2	-494	152
81	40	LLLANED	-50	-17	-88	141	3463	-305
83	34	LLLANED	49	13	76	-411	-1787	0
83	34	LLLANEC	-24	-6	-6	49	380	-5
83	28	LLLANEE	-49	-12	-52	434	-618	274
83	28	LLLANEA	24	6	-6	-72	745	-139
84	28	LLLANEA	-24	-5	6	35	-747	139
84	28	LLLANEE	50	10	52	-403	639	-274
84	22	LLLANEE	-50	-10	-39	403	-1552	473
84	22	LLLANEA	24	5	-6	-35	637	-234
88	5	LLLANEA	-24	0	6	-59	-301	373
88	5	LLLANEB	75	0	6	1	2985	-1139
88	6	LLLANEB	-75	0	7	-1	-2983	1138
88	6	LLLANEC	24	0	6	-59	303	-373

**LARSA Results for Truck Load plus Impact (1 lane)**

**RESULT ENVELOPE :Reactions @ Force Z (kips)**

Joint	Result Case	Force X/R (kips)	Force Y/Theta/Phi (kips)	Force Z/Theta (kips)	Moment X/R (kips-ft)	Moment Y/Theta/Phi (kips-ft)	Moment Z/Theta (kips-ft)
110	Dist: 320.00	0	-2	-6	73	0	0
110	Dist: 30.00	0	0	67	-92	0	0

**RESULT ENVELOPE :Reactions @ Moment X (kips-ft)**

Joint	Result Case	Force X/R (kips)	Force Y/Theta/Phi (kips)	Force Z/Theta (kips)	Moment X/R (kips-ft)	Moment Y/Theta/Phi (kips-ft)	Moment Z/Theta (kips-ft)
110	Dist: 90.00	0	1	39	-318	0	0
110	Dist: 305.00	0	-2	-6	74	0	0

**RESULT ENVELOPE :Member End Forces (Local) @ Force Z (kips)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
81	48	Dist: 605.00	-19.74	-7.28	-4.28	1.35	509.54	-275.79
81	48	Dist: 230.00	7.20	1.98	70.20	-48.62	-492.28	70.67
83	28	Dist: 290.00	-29.43	-7.43	-58.21	254.73	-1277.00	165.63
83	28	Dist: 255.00	-17.04	-4.29	5.93	104.98	-850.31	97.65
84	28	Dist: 255.00	17.23	3.43	-5.93	-62.35	854.49	-97.65
84	28	Dist: 290.00	29.76	5.95	58.21	-190.58	1288.20	-165.63
88	5	Dist: 335.00	40.13	-0.06	-26.04	85.12	2219.70	-609.50
88	5	Dist: 370.00	42.34	-0.02	35.59	-2.27	2647.60	642.49
88	6	Dist: 390.00	-41.45	-0.01	-29.64	62.16	-2637.00	629.01
88	6	Dist: 360.00	-42.19	0.03	33.42	-28.97	-2403.90	639.79

**RESULT ENVELOPE :Member End Forces (Local) @ Moment X (kips-ft)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
81	48	Dist: 310.00	34.78	12.16	52.17	-212.21	-2464.90	440.47
81	48	Dist: 135.00	-19.57	-7.08	5.22	137.32	-923.46	-249.15
83	28	Dist: 135.00	20.30	5.08	-4.75	-62.16	638.91	-119.18
83	28	Dist: 335.00	-38.89	-9.89	-45.96	327.63	-201.07	213.37
84	28	Dist: 350.00	40.84	8.25	41.56	-325.78	-14.97	-219.72
84	28	Dist: 605.00	-20.50	-4.26	-4.75	53.55	228.95	101.11
88	5	Dist: 430.00	35.02	0.06	18.27	-98.68	1055.50	-530.87
88	5	Dist: 310.00	35.65	-0.08	-19.01	99.75	1491.70	-541.82
88	6	Dist: 310.00	-35.65	0.08	19.01	-99.75	-1105.30	540.12
88	6	Dist: 430.00	-35.02	-0.06	-18.27	98.68	-1426.90	532.00

**RESULT ENVELOPE :Member End Forces (Local) @ Moment Y (kips-ft)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
81	48	Dist: 335.00	38.81	13.72	45.04	-202.98	-2566.20	500.05
81	48	Dist: 605.00	-19.74	-7.28	-4.28	1.35	509.54	-275.79
83	28	Dist: 275.00	-24.64	-6.21	-29.80	195.31	-1357.70	139.77
83	28	Dist: 130.00	20.31	5.08	-4.75	-62.10	639.19	-119.37
84	28	Dist: 130.00	-20.54	-4.06	4.75	30.08	-641.50	119.37
84	28	Dist: 275.00	24.92	4.97	29.80	-127.21	1365.70	-139.77
88	5	Dist: 130.00	-20.94	0.11	4.75	-50.74	-257.98	319.71
88	5	Dist: 355.00	41.98	-0.04	8.08	44.82	2746.70	-637.22
88	6	Dist: 375.00	-42.26	0.01	-2.11	20.17	-2754.10	641.11
88	6	Dist: 605.00	20.94	0.09	4.75	-50.56	259.63	-319.61

LARSA Results for Final Prestress								
RESULT : Reactions								
Joint	Result Case	Force X/R (kips)	Force Y/Theta/Phi (kips)	Force Z/Theta (kips)	Moment X/R (kips-ft)	Moment Y/Theta/Phi (kips-ft)	Moment Z/Theta (kips-ft)	
110	Final Prestress	0	35	85	-1748	0	0	
RESULT : Member End Forces (Local)								
Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
81	48	Final Prestress	12550	-584	-876	-16453	88026	-8711
83	28	Final Prestress	-11866	-172	1009	6673	-12476	-8237
84	28	Final Prestress	11860	-422	-1009	-6041	12794	8237
88	5	Final Prestress	11267	-206	-229	-673	-33644	18653
88	6	Final Prestress	-11256	-206	-230	-1730	33550	-18253
RESULT : Total Tendon Forces @ Member Ends								
Member	Location	Stage	Fx (kips)	Fy (kips)	Fz (kips)	Primary Mx (kips-ft)	Primary My (kips-ft)	Primary Mz (kips-ft)
81	Start	Final Prestress	13523	246	-746	2523	58644	688
81	End	Final Prestress	13189	406	-1837	-3939	30529	549
83	Start	Final Prestress	13016	346	-1165	-453	4334	362
83	End	Final Prestress	12887	343	-944	222	-18709	322
84	Start	Final Prestress	12887	343	-944	222	-18709	322
84	End	Final Prestress	12755	127	-726	156	-37139	288
88	Start	Final Prestress	12310	330	-200	1764	-65773	218
88	End	Final Prestress	12315	124	306	759	-65730	13

## Structural Calculations

### Live Load Distribution Factors

L = 300' Max

R = 400' @ centerline bridge

L/R = 300/400 = 0.75 < 0.8      OK to use whole-width design with distribution factor for a straight bridge described in AASHTO LRFD Article 4.6.2.2.1 as follows:  
“Cast-in-place multicell concrete box girder bridge types may be designed as whole-width structures. Such cross-sections shall be designed for the live load distribution factors in Articles 4.6.2.2.2 and 4.6.2.2.3 for interior girders, multiplied by the number of girders, i.e., webs.”

Check range of applicability of LRFD Tables 4.6.2.2.2b-1 and 4.6.2.2.3a-1 (cross-section type (d))

Table B-1 – Live Load Distribution Factor Evaluation

Table 4.6.2.2.2b-1	Table 4.6.2.2.3a-1	Actual	
$7.0 \leq S \leq 13.0$	$6.0 \leq S \leq 13.0$	$S = 15.31'$	N.G.
$60 \leq L \leq 240$	$20 \leq L \leq 240$	$L = 300'$	N.G.
$N_C \geq 3$	$N_C \geq 3$	$N_C = 2$	N.G.
	$35 \leq d \leq 100$	$d = 144"$	N.G.

Since range of applicability has been exceeded for web spacing, s, use lever rule to determine distribution factor to interior girder (see next sheet).

Interior Girder – Live Load Distribution Factor

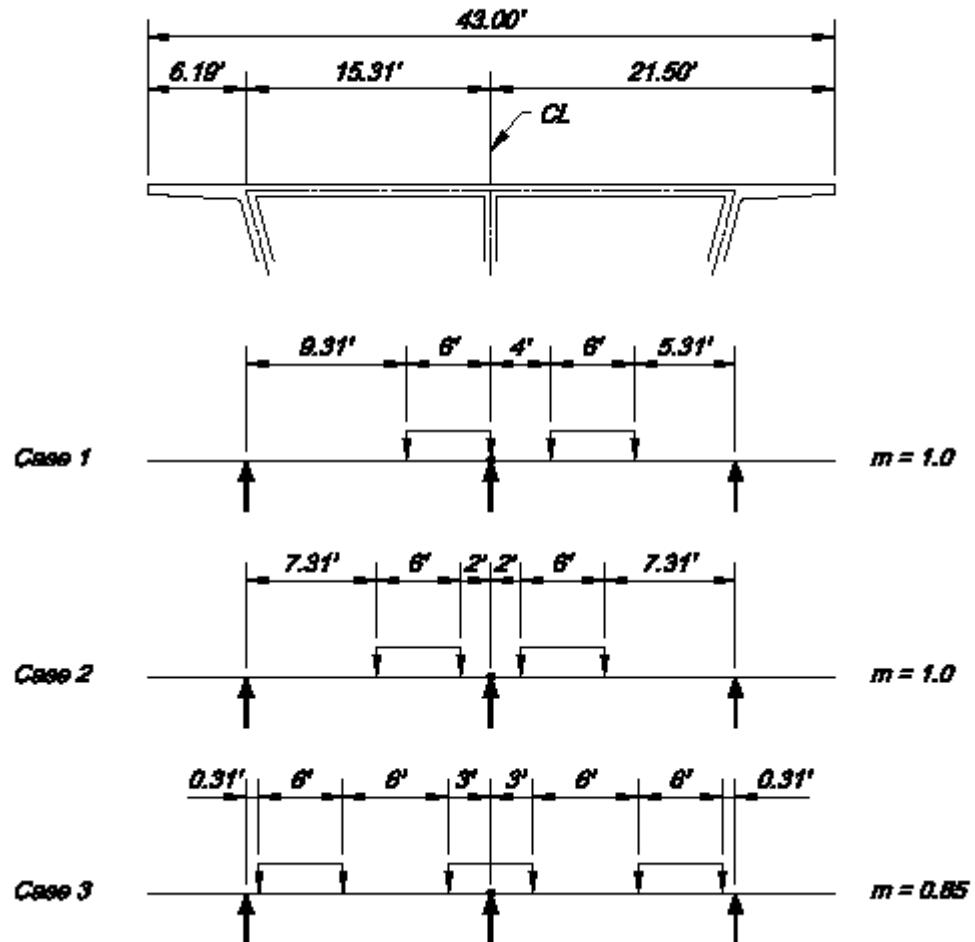


Figure B-10 – Live Load Lane Positions

$$\text{Case 1: } 1.0(9.31 + 15.31 + 5.31 + 11.31) / (2 \times 15.31) = 1.347$$

$$\text{Case 2: } 1.0(7.31 + 13.31) \times 2 / (2 \times 15.31) = 1.347$$

$$\text{Case 3: } 0.85(0.31 + 6.31 + 12.31) \times 2 / (2 \times 15.31) = 1.051$$

Maximum Distribution Factor =  $d_{f(\max)} = 1.347$

### Whole Width Live Load Distribution Factor

Verify  $W_e < s$ , where  $W_e = 15.31/2 + 6.19 = 13.85 < 15.31$  OK

Interior Girder Distribution Factor =  $d_{f(\max)} = 1.347$

Number of Girders =  $N_L = 3$

Whole Width Distribution Factor (Article 4.6.2.2.1)

$$d_{f(ww)} = N_L \times d_{f(\max)} = 3 \times 1.347 = 4.041$$

Use for primary bending and flexural shear response

### Distribution Factor for Live Load Global Response (i.e. axial, torsion, and lateral bending and shear)

Clear distance between traffic barriers: 40.0 ft

Integer number of 12' lanes -  $N_L$ : 3

Multiple Presence factor -  $m$  0.85 Table 3.6.1.1.2-1

$d_{f(t)} = m \times N_L$ : 2.55

### Computer Output Live Load Multiplication Factors

The computer analysis was run for a single live load lane. First the AASHTO design truck was placed at incremental locations down the length of the bridge using the live load generator capabilities of the computer program. The program identified the critical loading condition for each member. Secondly the design lane loading (640 lbs per ft of lane) was placed in various spans and span combinations and the critical lane loading identified. Each of the critical loadings (truck and lane loadings) was factored by the number of design lanes present on the bridge for the whole-width design case for principal flexure and shear or for the remaining global superstructure member actions as required. The vehicle dynamic effect was added to yield the following live load plus impact load multipliers to be applied to the computer results.

Impact Factor =  $I = 1 + .33 = 1.33$

### *Whole-Width Design for Principal Web Flexure and Shear*

For Truck Load:  $C_{truck} = d_{f(ww)} \times I = 4.041 \times 1.33 = 5.375$

For Lane Load:  $C_{lane} = d_{f(ww)} = 4.041$

### *Global Superstructure Design (Remaining Member Actions)*

For Truck Load:  $C_{truck} = d_{f(t)} \times I = 2.55 \times 1.33 = 3.39$

For Lane Load:  $C_{lane} = d_{f(t)} = 2.55$



Longitudinal Stress Check (Flexure):

@ Midspan Span 2 (LARSA Member 88 – Average of Node 5 & 6)

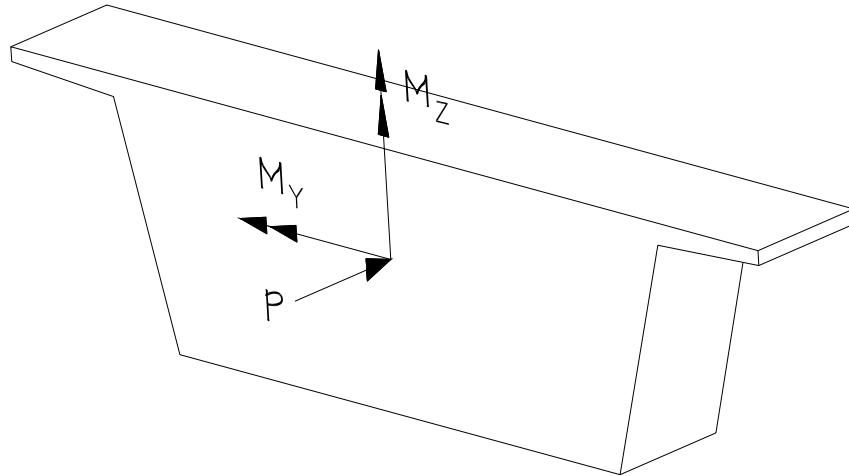


Figure B-11 – Member Force Convention

Table B-2 – Average Member 88 Forces at Nodes 5 and 6

Load	P - kips	M <sub>y</sub> – ft-kips	M <sub>z</sub> – ft-kips
DC	542	50,242	-8240
DW	105	9,761	-1,599
PS <sub>FINAL</sub>	11,262	-33,597	18,453
LL <sub>TRUCK+IM</sub>	142	14,784	-2,166
LL <sub>LANE</sub>	191	12,057	-2,903
DC+DW+PS <sub>FINAL</sub>	11,909	26,406	8,614
DC+DW+PS <sub>FINAL</sub> +LL	12,242	53,247	3,545

Live Load results from LARSA output for  $M_y$  for one lane are adjusted for the number of lanes for whole width design ( $N_L=5.375$  for LL<sub>TRUCK+IM</sub> and  $N_L=4.041$  for LL<sub>LANE</sub>). P and  $M_z$  are adjusted for  $N_L=3.39$  for LL<sub>TRUCK+IM</sub> and  $N_L=2.55$  for LL<sub>LANE</sub>.

Stress Distribution at Midspan of Span 2 (from STAAD Section Wizard):

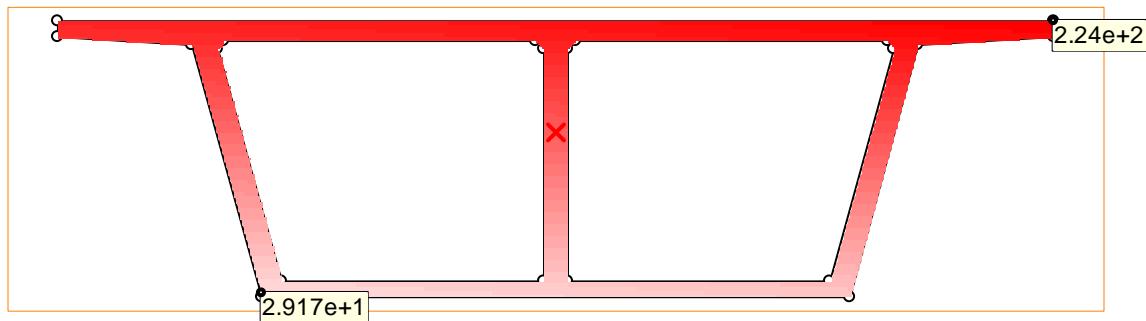


Figure B-12 - Stress Distribution at Midspan of Span 2 (ksf)

DC+DW+PS<sub>FINAL</sub>

Red = Compression ( $224$  ksf  $\Rightarrow 1556$  psi max)

Blue = Tension (None – in compression)

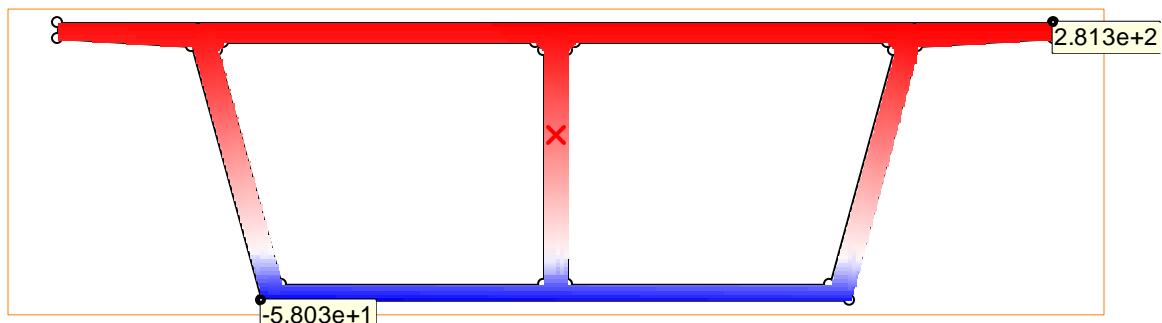


Figure B-13 - Stress Distribution at Midspan of Span 2 (ksf)

DC+DW+PSFINAL+LL+IM

Red = Compression ( $281.3$  ksf  $\Rightarrow 1953$  psi max)

Blue = Tension ( $58.03$  ksf  $\Rightarrow 403$  psi max)

@ Bent 3 - Span 2 (LARSA Member 81 –Node 48)

Table B-3 –Member 81 Forces at Node 48

Load	P - kips	M <sub>y</sub> - ft-kips	M <sub>z</sub> - ft-kips
DC	637	-95,834	6,936
DW	123	-18,559	1,346
PS <sub>FINAL</sub>	12,550	88,026	-8,710
LL <sub>TRUCK+IM</sub>	132	-13,794	1,695
LL <sub>LANE</sub>	127	-21,590	1,669
DC+DW+PS <sub>FINAL</sub>	13,310	-26,367	-428
DC+DW+PS <sub>FINAL</sub> +LL	13,569	-61,751	2,936

Live Load results from LARSA output for M<sub>y</sub> for one lane are adjusted for the number of lanes for whole width design (N<sub>L</sub>=5.375 for LL<sub>TRUCK+IM</sub> and N<sub>L</sub>=4.041 for LL<sub>LANE</sub>). P and M<sub>z</sub> are adjusted for N<sub>L</sub>=3.39 for LL<sub>TRUCK+IM</sub> and N<sub>L</sub>=2.55 for LL<sub>LANE</sub>.

Stress Distribution over Bent 3 (From STAAD Section Wizard):

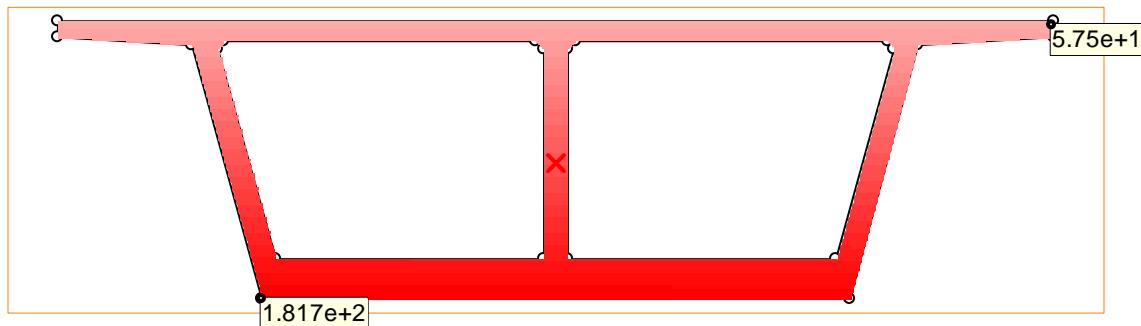


Figure B-14 - Stress Distribution at Bent 3 – Span 2 (ksf)

DC+DW+PS<sub>FINAL</sub>

Red = Compression (181.7 ksf  $\Rightarrow$  1262 psi max)

Blue = Tension (None  $\Rightarrow$  399 psi compression)

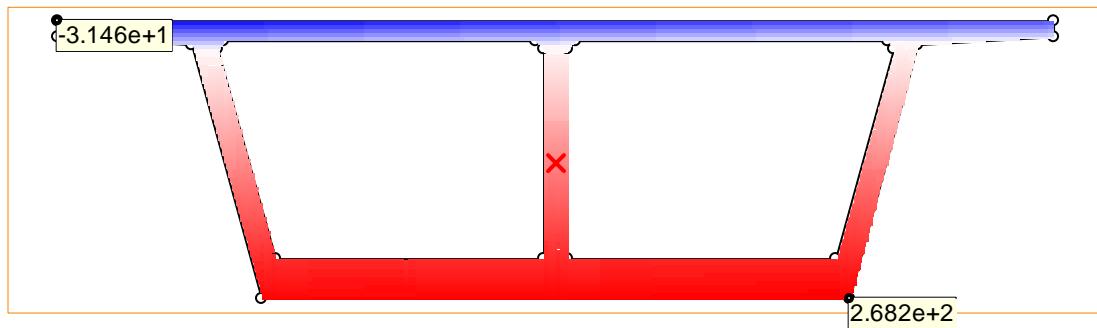


Figure B-15 - Stress Distribution at Bent 3 – Span 2 (ksf)  
DC+DW+PSFINAL+LL+IM  
Red = Compression ( $268.2$  ksf  $\Rightarrow 1863$  psi max)  
Blue = Tension ( $31.46$  ksf  $\Rightarrow 218$  psi max)

## Member End Forces at 0.8 Point of Span 2

This point was selected as the point to demonstrate the calculation of section forces because it has relatively high shear and torsion demands. Forces are derived by averaging the member end forces for the members on either side of node 28, which is at the 0.8 point of span 2 as shown in Figure B-16. Table B-4 shows the results from a 3-D Spine Beam analysis and how they are averaged. This approach should be used to determine section forces at all critical sections.

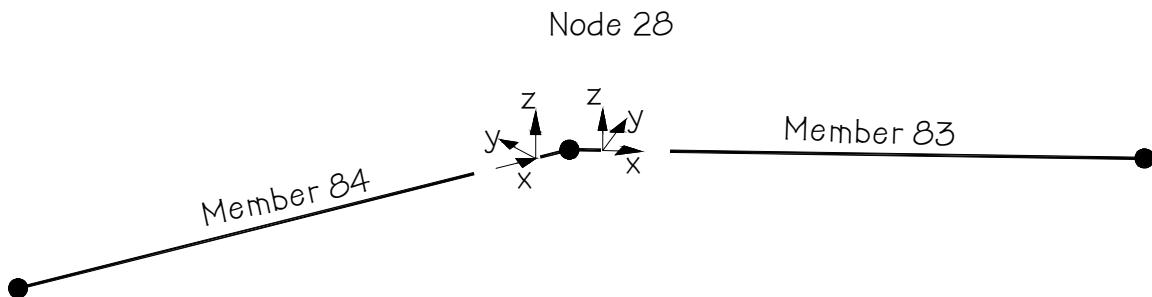


Figure B-16 – Local Coordinate System

Table B-4 – Summary of 3D Spine Beam Analysis Results from LARSA

	Member	Force X Kips	Force Y Kips	Force Z Kips	Moment X Ft-Kips	Moment Y Ft-kips	Moment Z Ft-kips
DC	83	-525	-134	-1162	7287	2622	2848
	84	531	108	1162	-7408	-2255	-2848
	AVERAGE	528	121	1162	-7348	-2439	-2848
DW	83	-102	-26	-226	1415	513	553
	84	103	21	226	-1439	-442	-553
	AVERAGE	103	24	226	-1427	-478	-553
PS <sub>FINAL</sub>	83	-11866	172	1009	6673	-12476	-8237
	84	11860	-422	-1009	-6041	12794	8237
	AVERAGE	11863	-297	-1009	-6357	12635	8237
PRIMARY PS		12887	343	-944	222	18709	322
EL		-1024	-640	-65	-6579	-6074	7915

Notes:

1. Member 83 end forces are in local sign convention for “end” of member
2. Member 84 end forces, Average, Primary PS, and EL are in local sign convention for “start” of member
3. Average of member 83 and 84 forces at Joint 28 are used for design. This approximation corrects for angle break of chorded elements along curved alignment.
4. Primary PS based on average tendon forces at Joint 28 from LARSA output. EL, the secondary prestress force, is the difference between Primary PS and PS<sub>FINAL</sub>.

Table B-5 – Summary of 3D Spine Beam Live Load Analysis Results

	Member	Force X Kips	Force Y Kips	Force Z Kips	Moment X Ft-Kips	Moment Y Ft-kips	Moment Z Ft-kips
<u>Truck + IM</u> <u>Max Moment X</u>	83	-38.89	-9.89	-45.96	327.63	-201.07	213.37
	84	40.84	8.25	41.56	-325.78	-14.97	-219.72
	AVERAGE	39.87	9.07	43.76	-326.71	93.05	-216.55
	N <sub>L</sub>	3.39	3.39	5.375	3.39	5.375	3.39
	Total Force	135	31	235	-1108	500	-734
<u>Truck + IM</u> <u>Max Force Z</u>	83	-29.43	-7.43	-58.21	254.73	-1277.03	165.63
	84	29.76	5.95	58.21	-190.59	1288.16	-165.63
	AVERAGE	29.60	6.69	58.21	-222.66	1283.60	-165.63
	N <sub>L</sub>	3.39	3.39	5.375	3.39	5.375	3.39
	Total Force	100	23	313	-755	6900	561
<u>Lane</u> <u>Max Moment X</u>	83	-72.68	-18.56	-57.59	483.26	-348.44	391.84
	84	73.51	14.90	57.59	-465.24	372.16	-391.84
	AVERAGE	73.10	16.73	57.59	-474.25	360.30	-391.84
	N <sub>L</sub>	2.55	2.55	4.041	2.55	4.041	2.55
	Total Force	186	43	233	-1209	1456	-999
<u>Lane</u> <u>Max Force Z</u>	83	-49.001	-12.64	-63.13	411.19	396.35	252.45
	84	49.57	10.17	63.13	-430.48	-375.31	-252.45
	AVERAGE	49.29	11.41	63.13	-420.84	-385.83	-252.45
	N <sub>L</sub>	2.55	2.55	4.041	2.55	4.041	2.55
	Total Force	126	29	255	-1073	-1559	-644

Notes:

1. Member 83 end forces are in local sign convention for “end” of member
2. Member 84 end forces, and Average are in local sign convention for “start” of member
3. Average of member 83 and 84 forces at Joint 28 are used for design. This approximation corrects for angle break of chorded elements along curved alignment.
4. Values for NL are determined as shown previously.

Table B6 – Summary of Design Loads (Unfactored)

	Case	Force X Kips	Force Y Kips	Force Z Kips	Moment X Ft-Kips	Moment Y Ft-kips	Moment Z Ft-kips
DC		528	121	1162	-7348	-2439	-2848
DW		103	24	226	-1427	-478	-553
EL		-1024	-640	-65	-6579	-6074	7915
LL+IM	(Max Moment X)	321	74	468	-2317	1956	-1733
LL+IM	(Max Force Z)	226	52	568	-1828	5341	-83

1. LL+IM cases are a sum of the factored (by  $C_L$ ) truck and lane load values from Table B5

Table B7 – Summary of Strength I, Maximum  $\gamma_p$  - Design Loads (Factored)

	Case	Load Factor	Force X Kips	Force Y Kips	Force Z Kips	Moment X Ft-Kips	Moment Y Ft-kips	Moment Z Ft-kips
DC		1.25	660	151	1453	-9185	-3049	-3560
DW		1.50	155	36	339	-2141	-717	-830
EL		1.00	-1024	-640	-65	-6579	-6074	7915
LL+IM	Mom X	1.75	562	130	819	-4055	2898	-3032
LL+IM	Force Z	1.75	396	91	994	-3199	9347	-145
STRENGTH I – MAX MOMENT X			353	-323	2546	-21960	-6942	-493
STRENGTH I – MAX FORCE Z			187	-362	2721	-21104	-493	3380

Notes:

1. Force Z and Moment X due to DC, DW, and LL+IM are additive in all cases. No need to investigate Minimum  $\gamma_p$  cases.

## TORSION

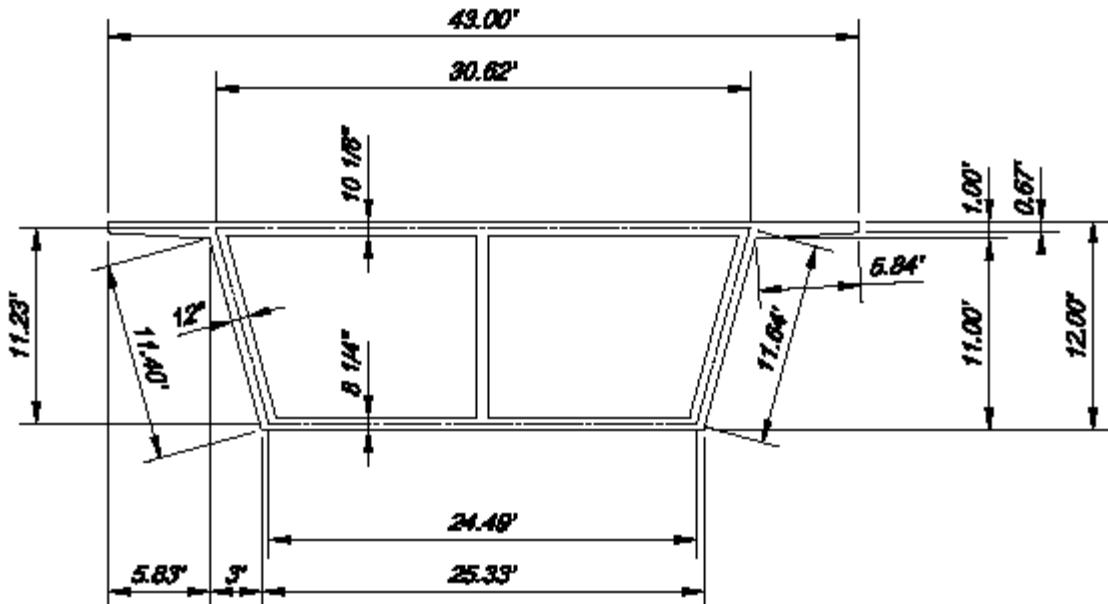


Figure B-17 – Typical Cross-Section Dimensions

Area Enclosed by Shear Flow Path (Article 5.8.3.6.2 ):

$$A_0 = \frac{1}{2}(30.62 + 24.49) \cdot 11.23 = 309.44 \text{ sqft} > 44,560 \text{ in}^2$$

Duct Diameter (Grouted);

$$\phi_d = 4.75"$$

Effective Web Width: (Article 5.8.2.9)

$$b_v = t_w - \phi_d = 12 - 4.75/4$$

Area Enclosed by Outside Perimeter (Article 5.8.2.1)

$$A_{CP} = 43 \cdot 12 - 2 \cdot 5.83 \cdot 11.17 - 2 \cdot \frac{1}{2} \cdot 3 \cdot 11 = 352.76 \text{ ft}^2 > 50,797 \text{ in}^2$$

Outside Perimeter of Section (Article 5.8.2.1):

$$P_C = 43 + 2(6.67 + 5.84 + 11.40) + 25.33 = 104.15 \text{ ft} > 1250 \text{ in}$$

$$T_{cr} = 0.125 \sqrt{f_c} \frac{A_{CP}^2}{P_c} \sqrt{1 + \frac{f_{pc}}{0.125 \sqrt{f_c}}} \quad (\text{Eqn. 5.8.2.1-4})$$

where:

$$f_{pc} = \frac{P_f}{A_x} = \frac{12,887}{86.059 \cdot 144} = 1.040 \text{ ksi}$$

**Equation 5.8.2.1-5:**

$$\frac{A_{CP}^2}{P_c} = \frac{50,797^2}{1250} = 2,064,268 \text{ in}^3 \leq 2A_0 b_v = 2 \cdot 44.560 \cdot 8.25 = 735,240 \text{ in}^2$$

Note: Since bottom slab thickness (8.25) < b<sub>v</sub> (10.81) use 8.25" for b<sub>v</sub> in Eqn. 5.8.2.1-5.

$$\therefore T_{cr} = 0.125\sqrt{5} \cdot 735240 \sqrt{1 + \frac{1.040}{0.125\sqrt{5}}} = 446,512 \text{ in-kips} > 37,209 \text{ ft-kips}$$

Torsional Effects shall be investigated where:

$$T_u > 0.25\phi T_{cr} = 0.25 \cdot 0.90 \cdot 37,209 = 8,372 \text{ ft-kips} < 21,104 \text{ ft-kips}$$

Therefore, torsion must be investigated.

Note that torsion must be investigated in both Case 1 and Case 2. Therefore, the equivalent factored shear force shall be taken as:

$$V_u + \frac{T_u d_s}{2 \cdot A_0} \quad (\text{Eqn. 5.8.2.1-7})$$

**Case 1 – Maximum Torsion:**

$$V_u(\text{web}) = V_u/N_w = 2546/3 = 849 \text{ kip/web (shear only)} *$$

$$T_u d_s / (2 \cdot A_0) = 21960 \cdot 11.64 / (2 \cdot 309.44) = 413 \text{ kips/web (torsion only)} **$$

\* In vertical direction

\*\* Along centerline of web (inclined)

Consider vertical component of shear due to torsion (web angle = 15.26°)

$$= 413 \text{ kips} \cdot \cos 15.26^\circ = 398 \text{ kips/web}$$

$$\therefore \text{Combined Shear} = 849 + 398 = 1247 \text{ kips/web *}$$

**Case 2 – Maximum Shear:**

$$V_u(\text{web}) = V_u/N_w = 2721/3 = 907 \text{ kip/web (shear only)} *$$

$$T_u d_s / (2 \cdot A_0) = 21104 \cdot 11.64 / (2 \cdot 309.44) = 397 \text{ kips/web (torsion only)} **$$

Consider vertical component of shear due to torsion (web angle = 15.26°)

$$= 397 \text{ kips} \cdot \cos 15.26^\circ = 383 \text{ kips/web}$$

$$\therefore \text{Combined Shear} = 907 + 383 = 1290 \text{ kips/web *}$$

For brevity, remainder of example will consider Case 2 only. In an actual design, both cases would be evaluated.

Check Web Width:

$$V_u \leq \phi V_n$$

$$V_n \leq 0.25 \cdot f_c' b_v d_v + V_p \quad (\text{Eqn. 5.8.3.3-2})$$

$$b_v = 10.81"$$

$$d_v = 0.72h = 0.72 \cdot 144 = 103.7"$$

$$f_c' = 5 \text{ ksi}$$

$$V_p(\text{web}) = V_p/N_w = 944 \text{ kips}/3 = 315 \text{ kips/web}$$

$$\therefore V_n \leq 0.25 \cdot 5 \cdot 10.81 \cdot 103.7 + 315 = 1401 + 315 = 1716 \text{ kips}$$

$$\phi V_n = 0.9 \cdot 1716 = 1544 \text{ kips} > 1290 \text{ kips * OK}$$

\*  $\phi V_n$  is compared to sum of flexural shear plus torsional shear at the exterior web.

Web width is adequate.

Calculate Shear Stress

Equivalent Shear Force,  $V_u$ , is taken as sum of flexural shear plus torsional shear at the exterior web.

$$V_u = (V_u - \phi V_p) / (\phi b_v d_v) = (1290 - 0.9 \cdot 315) / (0.9 \cdot 10.81 \cdot 103.7) \quad (\text{Eqn. 5.8.2.9-1}) \\ = 1007/1009 = 0.998 \text{ ksi}$$

$$V_u / f_c' = 0.998/5 = 0.199$$

Calculate  $\varepsilon_x$  – Whole-width design considering exterior web where shear and torsion are additive

$$\varepsilon_x = \frac{\left\{ \frac{|M_u|}{d_v} + 0.5N_u + 0.5|V_u - V_p| \cot \theta - A_{ps} f_{po} \right\}}{2(E_s A_s + E_p A_{ps})}$$

$$M_u = -493 \text{ ft-kips} \triangleright -5916 \text{ in-kips}$$

$$d_v = 103.7 \text{ inches}$$

$$N_u = -187 \text{ kips} \quad (\text{compression from Table B7})$$

$$V_u = N_w \cdot V_u(\text{web}) = 3 \cdot 1290 \text{ kips} = 3870 \text{ kips}$$

This quantity is used to calculate  $\varepsilon_x$ ,  $\theta$ ,  $\beta$  and  $V_c$  for the exterior web where flexural shear and torsional shear are additive.

$$V_p = 944 \text{ kips}$$

$$A_{ps} f_{po} = P_f = 12,887 \text{ kips} \quad (\text{Primary prestress force from Table B-4})$$

$$E_s = 29,000 \text{ psi}$$

$$A_s = 0 \quad \text{Conservatively ignore mild reinforcement for this example}$$

$$E_p = 28,500 \text{ psi}$$

$$A_{ps} = N_w \cdot N_{tpw} \cdot N_{spt} \cdot A_{strand} = 3 \cdot 4 \cdot 31 \cdot 0.217 = 80.72 \text{ in}^2$$

$$\begin{aligned} \varepsilon_x &= \frac{\left\{ \frac{M_u}{d_v} + 0.5N_u + 0.5|V_u - V_p| \cot \theta - P_f \right\}}{2(0 + E_{ps} A_p)} = \frac{\left\{ \frac{5916}{103.7} - 0.5 \cdot 187 + 0.5|3870 - 944| \cot \theta - 12,887 \right\}}{2(0 + 28,500 \cdot 80.72)} \\ &= \frac{57 - 94 + 1463 \cot \theta - 12,887}{4,601,000} = \frac{1463 \cot \theta - 12,924}{4,601,000} \end{aligned}$$

Try  $\theta = 27.4^\circ$ ;  $\varepsilon_x = -0.002 \leq 0$  OK as assumed -  $\beta = 2.51$       Table 5.8.3.4.2-1

### Transverse Reinforcement for Shear (per web)

$$V_u \leq \phi V_n$$

$$V_u = 907 \text{ kips/web} \quad (\text{Flexural shear only})$$

$$V_n = V_c + V_s + V_p \quad (5.8.3.3-1)$$

$$V_u/\phi \leq V_c + V_s + V_p$$

$$V_s \geq V_u/\phi - V_c - V_p$$

$$V_c = 0.0316 \beta \sqrt{f'_c} b_v d_v = 0.0316 \cdot 2.51 \sqrt{5} \cdot 10.81 \cdot 103.7 = 199 \text{ kips}$$

$$V_s \geq 907/0.9 - 199 - 315 \geq 494 \text{ kips/web}$$

$$V_s = (A_v f_y d_v \cot \theta)/s \quad (C5.8.3.3-1)$$

$$A_v/s = V_s / (f_y d_v \cot \theta) = 494 / (60 \cdot 103.7 \cot 27.4^\circ) = 0.041 \text{ in}^2/\text{in/web}$$

Note that this does not include transverse reinforcement required for torsion.

### Transverse Reinforcement for Torsion:

$$T_u \leq \phi T_n$$

$$T_u = 21,104 \text{ ft-kips}$$

$$T_n = (2A_0 A_t f_y \cot \theta) / s \quad (5.8.3.6.2-1)$$

$$A_t / s = T_n / (2A_0 f_y \cot \theta) = (21,104 \cdot 12 / 0.9) / (2 \cdot 44,560 \cdot 60 \cdot \cot 27.4^\circ)$$

$$= 0.027 \text{ in}^2/\text{inch per exterior web or top or bottom slabs}$$

### Combined Transverse Reinforcement:

The combined area of both stirrup legs in the web,  $A_{\text{stirrups}}$ , contribute to  $A_v$  and  $A_t$ . The maximum spacing of the stirrups,  $s_{\max}$ , is given by:

$$s_{\max} = A_{\text{stirrups}} / \left( \frac{A_v}{s} + \frac{A_t}{s} \right)$$

For #6 stirrups:

$$s_{\max} = (2 \cdot 0.44) / (0.041 + 0.027) = 12.94 \text{ in}$$

$$A_v = 0.82 \text{ in}^2/\text{ft for both legs}$$

Note that this does not account for regional bending of the web or tendon confinement.

## Longitudinal Reinforcement: Whole Width Design

For Flexural Shear: (5.8.3.5-1)

$$\begin{aligned}
 A_{ps}f_{ps} + A_s f_y &\geq \frac{|M_u|}{d_v \phi_f} + 0.5 \frac{N_u}{\phi_c} + \left\{ \left| \frac{V_u}{\phi_v} - V_p \right| - 0.5 V_s \right\} \cot \theta \\
 &= \frac{5916}{103.7 \cdot 1.0} + \frac{0.5(-1166)}{1.0} + \left\{ \left| \frac{2721}{0.9} - 944 \right| - 0.5(3 \cdot 494) \right\} \cot 27.4^\circ \\
 &= 57 - 583 + \{2079 - 741\} \cot 27.4^\circ \\
 &= 2055 \text{ kips}
 \end{aligned}$$

For Torsion:

$$A_l = \frac{T_n p_h}{2 A_0 f_y} \quad (5.8.3.6.3-2)$$

$$A_l f_y = T_n p_h / (2 A_0)$$

$$p_h = 30.62 + 2 \cdot 11.64 + 24.49 = 78.39 \text{ ft} = 940 \text{ in}$$

$$A_l f_y = (21,104 \cdot 12 / 0.90) \cdot 940 / (2 \cdot 44,560) = 2968 \text{ kips}$$

Combined Tension Force:

$$T = 2055 + 2968 = 5023 \text{ kips}$$

Note that the final prestress force acting on the section is 12,887 kips and therefore sufficient to satisfy the combined tension force requirement.

### Regional Web Bending:

Determine flexural reinforcement required for regional bending of web independent of other load effects. Notice that  $F_{u-in}$  is based on the final prestress force because it will be combined with a live load case and is in the exterior girder, which has the highest combined torsion and flexural shear. From proposed equation 5.10.4.3.1-7 of the proposed specification:

$$M_u = \psi F_{u-in} h_c / 4 = 0.7 \cdot \frac{1.2 \cdot 4296}{413.78} \cdot \frac{10.47}{4} = 22.83 \text{ ft-kips/ft}$$

Assume 2" cover to #6 stirrups

$$d = 12 - 2 - 0.75/2 = 9.62 \text{ in}$$

Design charts frequently express  $M_u$  as:

$$M_u = k_n b d^2$$

This yields a value of  $k_n$  and the corresponding reinforcing ratio from charts:

$$k_n = M_u / (bd^2) = 22,830 \cdot 12 / (12 \cdot 9.62^2) = 247$$

$$\rho = 0.0055 \quad \text{From design charts}$$

$$A_s = \rho b d = 0.0055 \cdot 12 \cdot 9.62 = 0.63 \text{ in}^2/\text{ft} \quad \text{One leg}$$

Check ultimate moment capacity of this reinforcement

$$A_s f_y = 0.63 \cdot 60 = 37.8 \text{ kips}$$

$$a = A_s f_y / (0.85 f'_c b) = 0.63 \cdot 60 / (0.85 \cdot 5 \cdot 12) = 0.74 \text{ in}$$

$$\phi M_n = \phi A_s f_y (d - a/2) = 0.90 \cdot 37.8 (9.62 - 0.74/2) \frac{1}{12} = 26.22 \text{ ft-kips/ft} > 22.83 \text{ OK}$$

Check minimum reinforcement per LRFD 5.7.3.3.2

$$S_c = b t^2 / 6 = 12 \cdot 12^2 / 6 = 288 \text{ in}^3/\text{ft}$$

$$f_r = 0.37 \sqrt{f'_c} = 0.37 \sqrt{5} = 0.827 \text{ ksi} \quad (\text{LRFD 5.4.2.6})$$

$$M_{cr} = S_c f_r = 288 \cdot 0.827 = 238 \text{ in-kips/ft} > 19.85 \text{ ft-kips}$$

$$1.2M_{cr} = 1.2 \cdot 19.85 = 23.8 \text{ ft-kips} < \phi M_n$$

Required  $A_s = 0.63 \text{ in}^2/\text{ft}$  for one leg for regional bending only (#6 @ 8-1/4")

#### Transverse Web Reinforcement for Combined Actions:

Consider Article 5.8.1.5 for combining transverse reinforcement for combined actions of shear, torsion, and regional bending. Tendon confinement is covered in other examples and not repeated here.

Sum of reinforcement required for shear, torsion, and regional bending

Shear and torsion = 0.82 in<sup>2</sup>/ft for 2 legs = 0.41 in<sup>2</sup>/ft for one leg

Regional bending = 0.63 in<sup>2</sup>/ft " "

$\Sigma$  = 1.04 in<sup>2</sup>/ft " "

∴ Use #6 @ 5"

Note: The effect of dead load of the top slab on transverse web moment is not included in the above calculation because nearly balanced moments are produced over the top of the exterior web. The same is true of a truck live load, because the wheel lines straddle the exterior web and produce very little net transverse moment in the web. However, in a condition where this is not true, these loads should be considered.

### Abutment Bearing Forces:

Abutment bearing forces are determined by resolving the vertical shear and torsion moments at the abutment into the bearing forces.

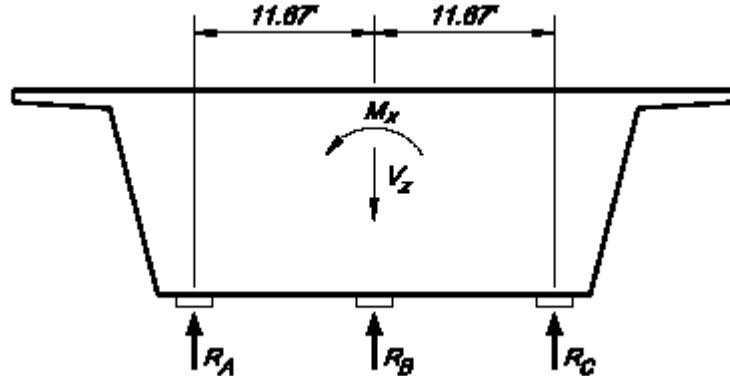


Figure B-18 -Resolution of Member 71 Forces to Individual Bearing Forces

Table B-8 – Summary of Forces at Abutment Support Node

Load Case	V <sub>z</sub> - kips	M <sub>x</sub> - ft-kips
DC	898	4,489
DC <sub>DIAPHRAGM</sub>	160	-
DW	175	872
PS <sub>FINAL</sub>	85	1748
(LL <sub>TRUCK</sub> + IM)*3.39 (V <sub>z</sub> max)	225	312
LL <sub>LANE</sub> *2.55 (V <sub>z</sub> & M <sub>x</sub> max)	137	874
(LL <sub>TRUCK</sub> + IM)*3.39 (M <sub>x</sub> max)	132	1080
DC+DW+PS <sub>FINAL</sub>	1,326	7109
DC+DW+PS <sub>FINAL</sub> +LL <sub>TRUCK</sub> +LL <sub>LANE</sub> +IM (I)	1,688	8295
DC+DW+PS <sub>FINAL</sub> +LL <sub>TRUCK</sub> +LL <sub>LANE</sub> +IM (II)	1,595	9063

### Bearing Forces – DC+DW+PS<sub>FINAL</sub>:

$$R_A = \frac{V_z}{3} + \frac{M_x}{2(11.67)} = \frac{1326}{3} + \frac{7109}{23.34} = 442 + 305 = 747 \text{ kips}$$

$$R_B = \frac{V_z}{3} = \frac{1326}{3} = 442 \text{ kips}$$

$$R_C = \frac{V_z}{3} - \frac{M_x}{2(11.67)} = \frac{1326}{3} - \frac{7109}{23.34} = 442 - 305 = 137 \text{ kips}$$

Bearing Forces – DC+DW+PS<sub>FINAL</sub>+LL<sub>TRUCK</sub>+LL<sub>LANE</sub>+IM (I):

$$R_A = \frac{V_z}{3} + \frac{M_x}{2(11.67)} = \frac{1688}{3} + \frac{8295}{23.34} = 563 + 355 = 918 \text{ kips}$$

$$R_B = \frac{V_z}{3} = \frac{1688}{3} = 563 \text{ kips}$$

$$R_C = \frac{V_z}{3} - \frac{M_x}{2(11.67)} = \frac{1688}{3} - \frac{8295}{23.34} = 563 - 355 = 208 \text{ kips}$$

Bearing Forces – DC+DW+PS<sub>FINAL</sub>+LL<sub>TRUCK</sub>+LL<sub>LANE</sub>+IM (II):

$$R_A = \frac{V_z}{3} + \frac{M_x}{2(11.67)} = \frac{1595}{3} + \frac{9063}{23.34} = 532 + 388 = 920 \text{ kips}$$

$$R_B = \frac{V_z}{3} = \frac{1595}{3} = 532 \text{ kips}$$

$$R_C = \frac{V_z}{3} - \frac{M_x}{2(11.67)} = \frac{1595}{3} - \frac{9063}{23.34} = 532 - 388 = 144 \text{ kips}$$

Case II Controls

Bearing forces should be investigated for the potential long term redistribution of these forces due to the time dependent properties of concrete. In lieu of a rigorous time dependent analysis, the torsion moments for permanent loadings should be increased by 20%. The effect of a super imposed live load should also be considered.

Bearing Forces – DC+DW+PS<sub>FINAL</sub> (Long Term):

$$R_A = \frac{V_z}{3} + \frac{M_x}{2(11.67)} = \frac{1326}{3} + \frac{1.2 \cdot 7109}{23.34} = 442 + 366 = 808 \text{ kips}$$

$$R_B = \frac{V_z}{3} = \frac{1326}{3} = 442 \text{ kips}$$

$$R_C = \frac{V_z}{3} - \frac{M_x}{2(11.67)} = \frac{1326}{3} - \frac{1.2 \cdot 7109}{23.34} = 442 - 366 = 76 \text{ kips}$$

Bearing Forces – DC+DW+PS<sub>FINAL</sub>+LL<sub>TRUCK</sub>+LL<sub>LANE</sub>+IM (II) (Long Term):

$$R_A = \frac{V_z}{3} + \frac{M_x}{2(11.67)} = \frac{1595}{3} + \frac{1.2 \cdot 7109 + 1954}{23.34} = 532 + 449 = 981 \text{ kips}$$

$$R_B = \frac{V_z}{3} = \frac{1595}{3} = 532 \text{ kips}$$

$$R_C = \frac{V_z}{3} - \frac{M_x}{2(11.67)} = \frac{1595}{3} - \frac{1.2 \cdot 7109 + 1954}{23.34} = 532 - 449 = 83 \text{ kips}$$

## LARSA Grillage Analysis

The following pages illustrate how a grillage analogy analysis would be performed for the bridge used in the example problem. Such an analysis would not be required by the specifications, but is included here to illustrate this analysis technique. Results are compared with the spine beam analysis used in the example problem. See spine beam analysis example for input data not shown here.

Grillage Model:

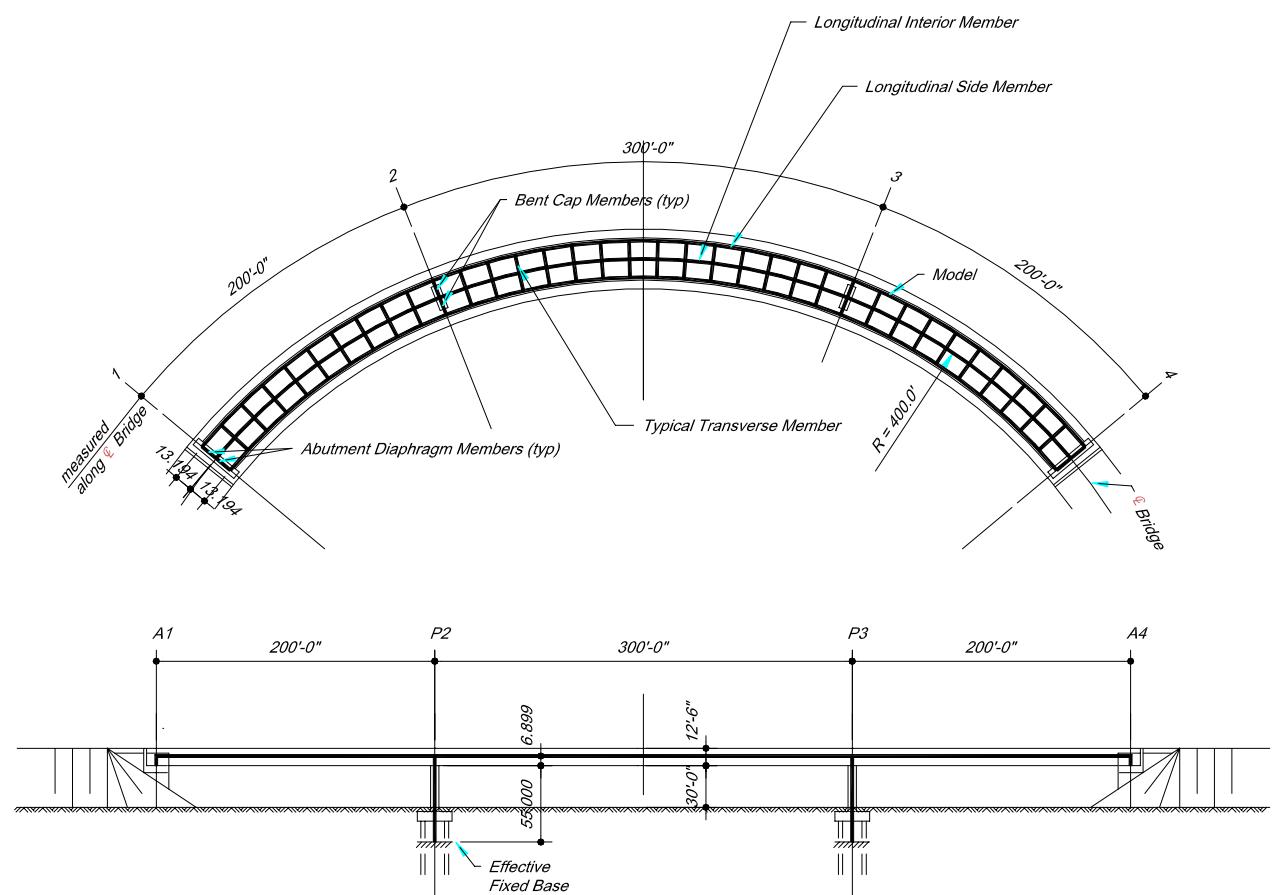


Figure B-19 – Plan and Elevation of Grillage Model

Member Properties:

Longitudinal Side Member:

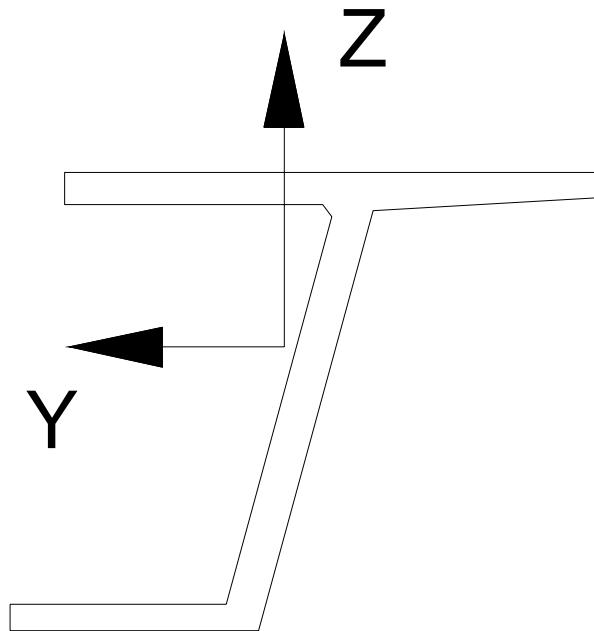


Figure B-20 - Section Properties for Grillage Model

Longitudinal Side Member

Overall dimensions 15.34 x 12.0 ft

$A_x$	Sectional area	$27.12 \text{ ft}^2$
$A_{v,z}$	Shear area along local z axis – Use area of web – $1.0 \times 12.0$	$12.001 \text{ ft}^2$
$A_{v,y}$	Shear area along local y axis – Use area of slabs – $0.69 \times 6.58 + .84 \times 13.92$	$16.65 \text{ ft}^2$
$I_y$	Moment of Inertia about local Y-axis	$554.1 \text{ ft}^4$
$I_z$	Moment of Inertia about local Z-axis	$289.8 \text{ ft}^4$
$I_x$	Torsional moment of inertia (St. Venant) = $I_x \text{ GROSS} / N_w = 4166/3$	$1389 \text{ ft}^4$
$y_M$	Distance from centerline of bridge to the center of gravity along Y-axis	$13.34 \text{ ft}$
$z_M$	Distance from the soffit to the center of gravity along Z-axis	$7.434 \text{ ft}$

Longitudinal Interior Member

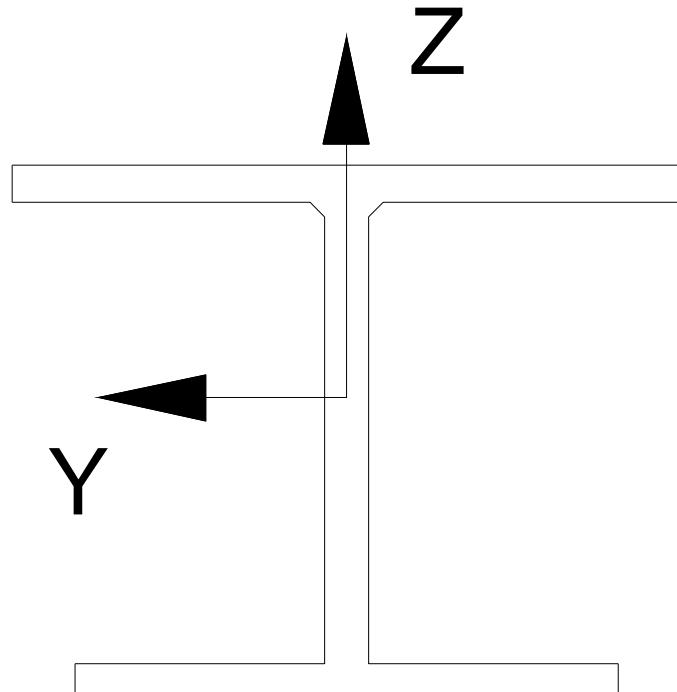


Figure B-21 – Section Properties for Grillage Model  
Longitudinal Interior Model  
Overall dimensions 15.17 x 12.0 ft

$A_x$	Sectional area	31.85 ft <sup>2</sup>
$A_{v,z}$	Conventional shearing area along Z-axis (Web area)	12.0 ft <sup>2</sup>
$A_{v,y}$	Conventional shearing area along Y-axis (Slab area)	21.38 ft <sup>2</sup>
$I_y$	Moment of Inertia about local Y-axis	751.9 ft <sup>4</sup>
$I_z$	Moment of inertia about local Z-axis	353.6 ft <sup>4</sup>
$I_x$	Torsional moment of inertia (St. Venant) = $I_x \text{ GROSS} / N_w = 4166/3$	1389 ft <sup>4</sup>
$y_M$	Distance from centerline of bridge to center of gravity along Y-axis	0 ft
$z_M$	Distance from soffit to center of gravity along Z-axis	6.73 ft

Longitudinal Side Member @ Face of Bent Cap:

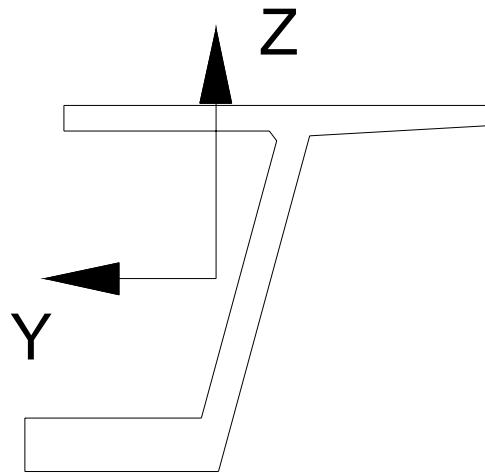


Figure B-22 – Section Properties for Grillage Model  
 Longitudinal Edge Member at Face of Bent Cap  
 Overall dimensions 15.2 x 12.0 ft

$A_x$	Sectional area	33.03 $\text{ft}^2$
$A_{v,z}$	Conventional shearing area along Z-axis (Web)	12.00 $\text{ft}^2$
$A_{w,y}$	Conventional shearing area along Y-axis (Slabs)	22.44 $\text{ft}^2$
$I_y$	Moment of inertia about local Y-axis	740.9 $\text{ft}^4$
$I_z$	Moment of inertia about local Z-axis	388.8 $\text{ft}^4$
$I_x$	Torsional moment of inertia (St. Venant) = $I_x \text{GROSS}/3 = 5079/3$	1693 $\text{ft}^4$
$y_M$	Distance from centerline of bridge to center of gravity along Y-axis	12.59 ft
$z_M$	Distance from soffit to center of gravity along Z-axis	6.33 ft

Longitudinal Interior Member at Face of Bent Cap:

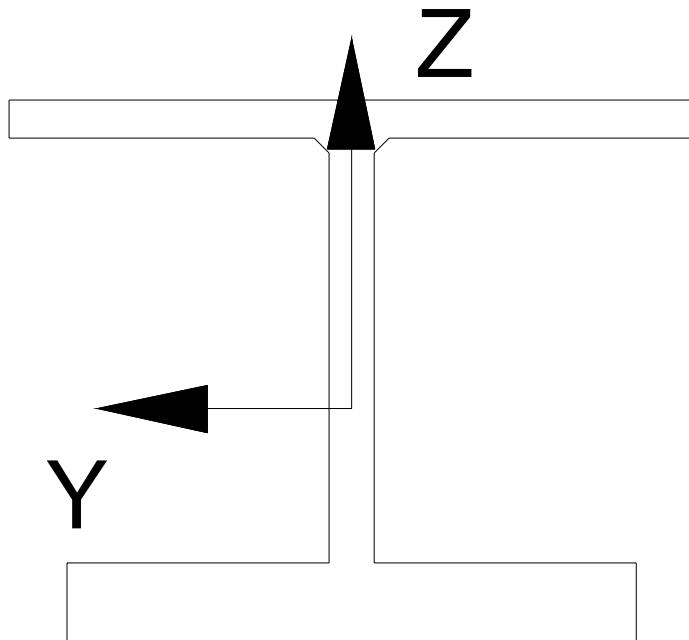


Figure B-23 – Section Properties for Grillage Model  
 Longitudinal Interior Member at Face of Bent Cap  
 Overall dimensions 15.17 x 12.0 ft

$A_x$	Sectional area	$44.38 \text{ ft}^2$
$A_{v,z}$	Conventional shearing area along Z-axis	$12.00 \text{ ft}^2$
$A_{v,y}$	Conventional shearing area along Y-axis	$34.97 \text{ ft}^2$
$I_y$	Moment of inertia about local Y-axis	$1028 \text{ ft}^4$
$I_z$	Moment of inertia about local Z-axis	$538.7 \text{ ft}^4$
$I_x$	Torsional moment of inertia (St. Venant) = $I_x \text{ GROSS}/3 = 5079/3$	$1693 \text{ ft}^4$
$y_M$	Distance from centerline of bridge to center of gravity along Y-axis	0 ft
$z_M$	Distance from soffit to center of gravity along Z-axis	5.17 ft

Typical Transverse Member (See Appendix C for Grillage Analysis Guidelines for transverse member property requirements):

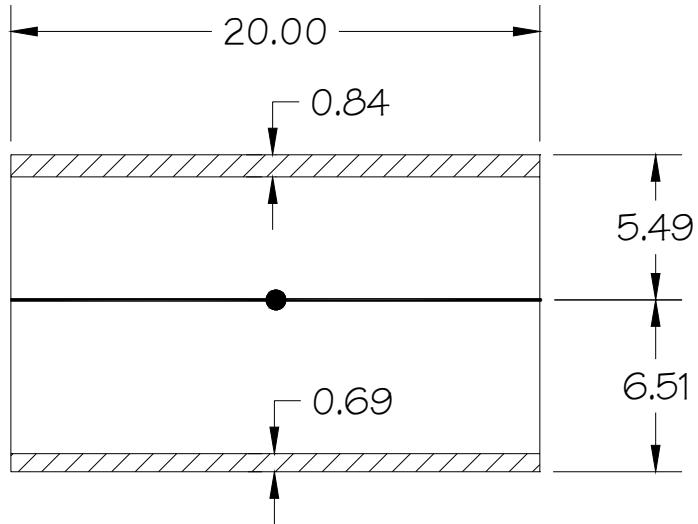


Figure B-24 – Section at Typical Transverse Grillage Member

$$A_x = b(t_t + t_b) = 20(0.84 + 0.69) = 30.60 \text{ ft}^2$$

$$A_{yy} = A_x = 30.60 \text{ ft}^2$$

$$A_{zz} = [(t_t^3 + t_b^3)/I_{member}] \cdot \left[ \frac{t_w^3}{I_{member} \cdot t_w^3 + (t_t^3 + t_b^3) \cdot d} \right] \cdot \frac{E}{G} \cdot b$$

$$= [(0.84^3 + 0.69^3)/13.34] \cdot \left[ \frac{1.0^3}{13.34 \cdot (1.0)^3 + (0.84^3 + 0.69^3) \cdot 12} \right] \cdot 2.34 \cdot 20$$

$$= 0.0691 \cdot 0.041 \cdot 2.34 \cdot 20 = 0.1325 \text{ ft}^2$$

$$I_x = b \cdot [2d^2 t_t t_b / (t_t + t_b)] = 20 \cdot [2(12)^2 \cdot 0.84 \cdot 0.69 / (0.84 + 0.69)] = 2182 \text{ ft}^4$$

$$I_y = b \frac{t_t^3 + t_b^3}{12} + b[t_t y_t^2 + t_b y_b^2] = 20 \cdot \frac{0.84^3 + 0.69^3}{12} + 20[0.84(5.49)^2 + 0.69(6.51)^2]$$

$$= 1.54 + 1091.2 = 1093 \text{ ft}^4$$

$$I_z = b^3 (t_t + t_b) / 12 = 20^3 (0.84 + 0.69) / 12 = 1020 \text{ ft}^4$$

Transverse Member Adjacent to Bent Cap (See Appendix C):

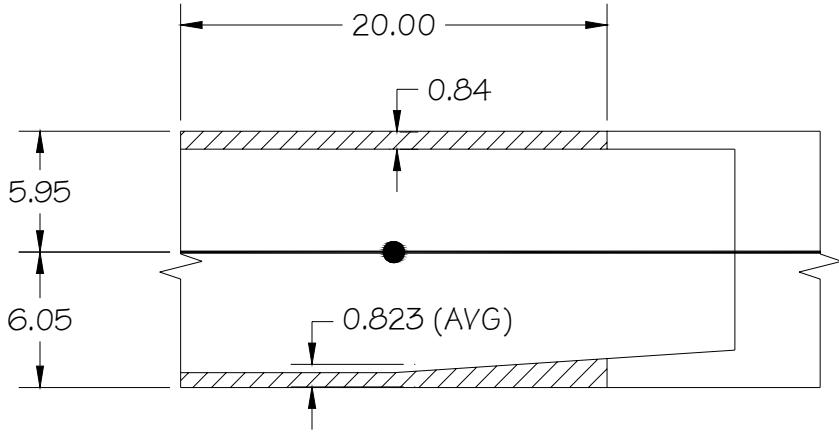


Figure B-25 – Transverse Member Adjacent to Bent Cap

$$A_x = b(t_t + t_b) = 20(.84 + .823) = 33.26 \text{ ft}^2$$

$$A_{yy} = A_x = 33.26 \text{ ft}^2$$

$$\begin{aligned} A_{zz} &= [(t_t^3 + t_b^3)/I_{member}] \cdot \left[ \frac{t_w^3}{I_{member} \cdot t_w^3 + (t_t^3 + t_b^3) \cdot d} \right] \cdot \frac{E}{G} \cdot b \\ &= [(0.84^3 + 0.823^3)/13.34] \cdot \left[ \frac{1.0^3}{13.34 \cdot (1.0)^3 + (0.84^3 + 0.823^3) \cdot 12} \right] \cdot 2.34 \cdot 20 \\ &= 0.08622 \cdot 0.03684 \cdot 2.34 \cdot 20 = 0.149 \text{ ft}^2 \end{aligned}$$

$$I_x = b \cdot [2d^2 t_t t_b / (t_t + t_b)] = 20 \cdot [2(12)^2 \cdot 0.84 \cdot 0.823 / (0.84 + 0.823)] = 2394 \text{ ft}^4$$

$$\begin{aligned} I_y &= b \frac{t_t^3 + t_b^3}{12} + b[t_t y_t^2 + t_b y_b^2] = 20 \cdot \frac{0.84^3 + 0.823^3}{12} + 20[0.84(5.95)^2 + 0.823(6.05)^2] \\ &= 1.9 + 11197.2 = 11199 \text{ ft}^4 \end{aligned}$$

$$I_z = b^3 (t_t + t_b) / 12 = 20^3 (0.84 + 0.823) / 12 = 1199 \text{ ft}^4$$

Bent Cap Section Properties (From STAAD Section Wizard except as noted)

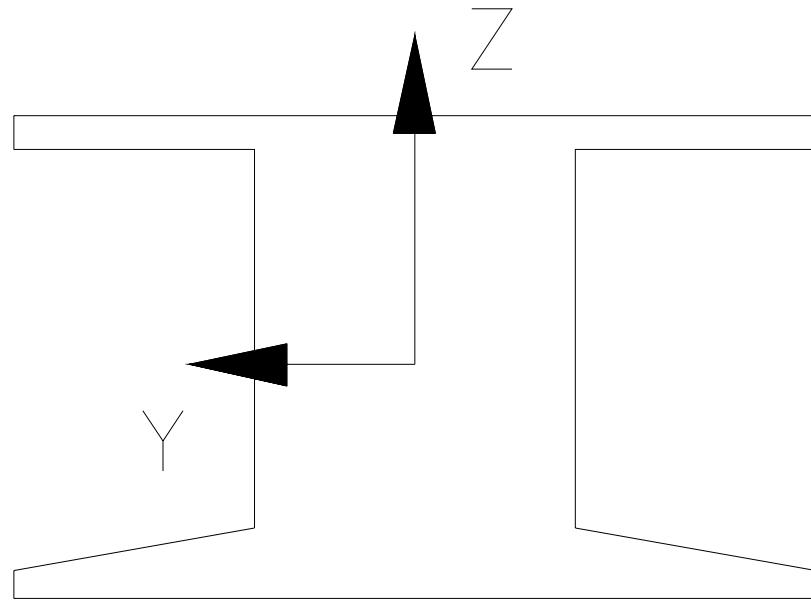
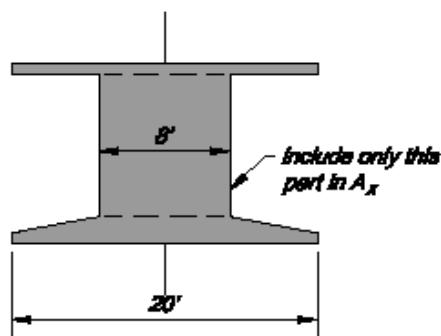


Figure B-26 – Section Properties for Grillage Model  
Bent Cap  
Overall dimensions 20.0 x 12.0 ft

$A_x$	Reduced sectional area – $A_x = 8(12 - 1.75 - .84)$	75.28 $\text{ft}^2$
$A_{v,y}$	Conventional shearing area along Y-axis	75.28 $\text{ft}^2$
$A_{v,z}$	Conventional shearing area along Z-axis	75.28 $\text{ft}^2$
$I_y$	Moment of inertia about Y-axis	1884 $\text{ft}^4$
$I_z$	Moment of inertia about Z-axis	1213 $\text{ft}^4$
$I_x$	Torsional moment of inertia (St. Venant)	1708 $\text{ft}^4$
$Z_M$	Distance from soffit to center of gravity along Z-axis	5.817 ft



Abutment Diaphragm (From STAAD Section Wizard except as noted):

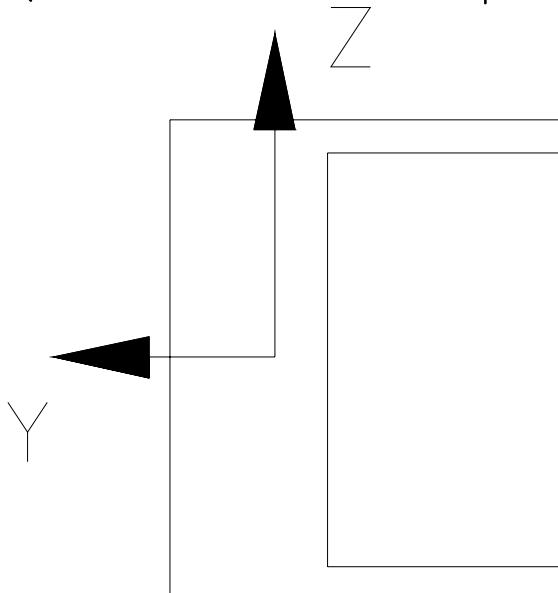
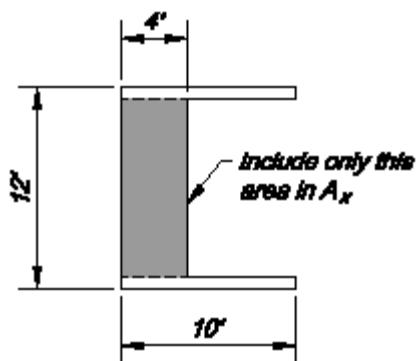


Figure B-27 – Section Properties for Grillage Model

Abutment Diaphragm

Overall dimensions 10.0 x 12.0 ft

$A_x$	Sectional area - $A_x = 4(12-.84-.69)$	41.88 $\text{ft}^2$
$A_{v,y}$	Conventional shearing area along Y-axis	41.88 $\text{ft}^2$
$A_{v,z}$	Conventional shearing area along Z-axis	41.88 $\text{ft}^2$
$I_y$	Moment of Inertia about Y-axis	865.4 $\text{ft}^4$
$I_z$	Moment of inertia about Z-axis	284.2 $\text{ft}^4$
$I_x$	Torsional moment of inertia (St. Venant)	198.6 $\text{ft}^4$
$Z_M$	Distance from soffit to center of gravity along Z-axis	6.082 ft



Loads:

DW:

Outside Webs:

$$w_z = \sigma_{\text{overlay}} (W_{\text{bridge}} - W_{\text{interior}}) \div 2 + w_{\text{rail}} = 0.035(43.0 - 15.17) \div 2 + .500 = .987 \text{ kips/ft}$$

$$\begin{aligned} m_x &= w_{\text{overlay}} e_{\text{overlay}} + w_{\text{rail}} e_{\text{rail}} = .487(21.5 - 6.96 - 13.34) + .500(21.5 - .5(1.75) - 13.34) \\ &= .584 + 3.643 = 4.23 \text{ ft-kips/ft} \end{aligned}$$

Inside Web

$$w_z = \sigma_{\text{overlay}} W_{\text{interior}} = 0.035(15.17) = .53 \text{ kips/ft}$$

LL

Eccentric Live Load Position:

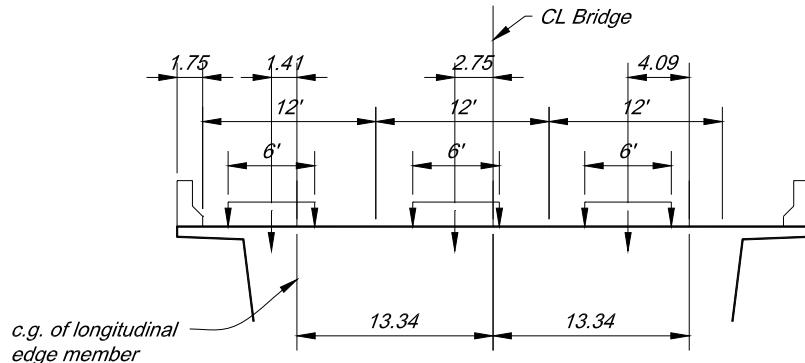


Figure B-28 – Position of Eccentric Lanes

Web 1:

$$N_L = 1.0$$

$$e_y = 1.41 \text{ ft}$$

Web 2:

$$N_L = 1.0$$

$$e_y = 2.75 \text{ ft}$$

Web 3:

$$N_L = 1.0$$

$$e_y = 4.09 \text{ ft}$$

Note: It is assumed that the above is the critical load case for maximum member forces, but in order to perform a rigorous check, a two lane loading with maximum eccentricity should also be checked in that it may produce greater torsion forces in the section even though it is likely to produce less flexural shear.

Concentric Live Load Position:

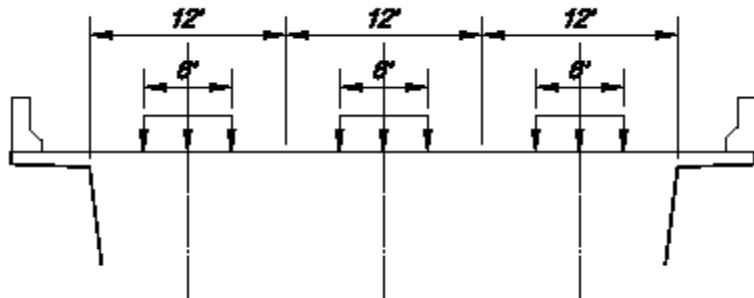


Figure B-29 – Position of Concentric Lanes

Web 1:

$$N_L = 1.0$$

$$e_y = 1.34 \text{ ft}$$

Web 2:

$$N_L = 1.0$$

$$e_y = 0$$

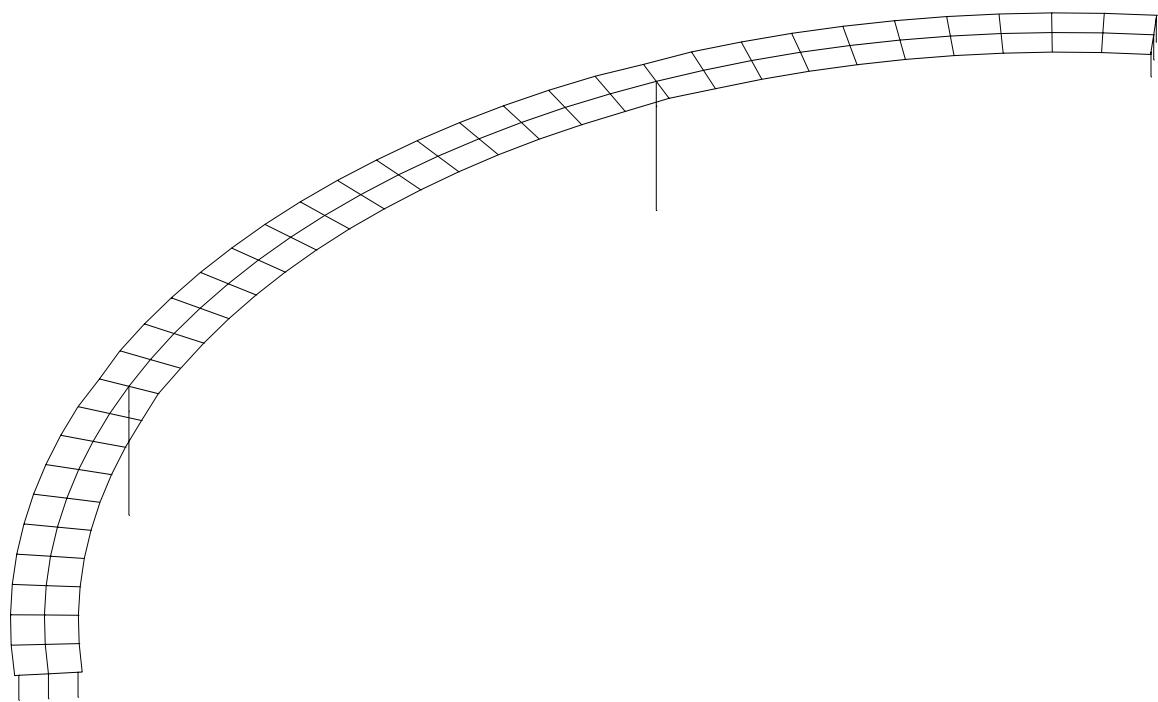
Web 3:

$$N_L = 1.0$$

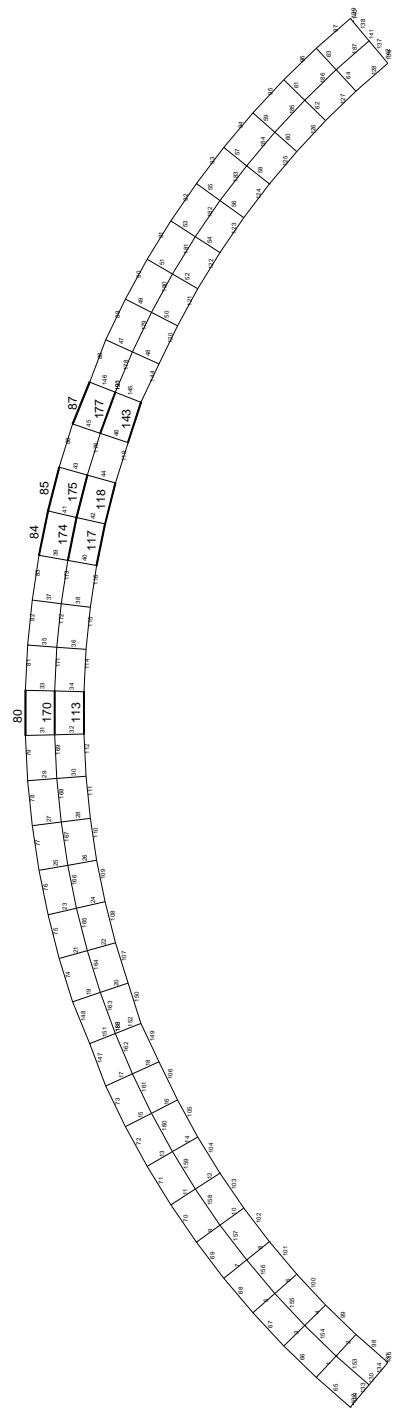
$$e_y = -1.34 \text{ ft}$$



Grillage Analysis Input and Results  
Selected LARSA Output



LARSA Model for Grillage Analysis



Critical Members for Grillage Analysis

## LARSA Properties for Grillage Analysis

### INPUT : Material Properties

Name	Modulus of Elasticity (lb/in <sup>2</sup> )	Poisson Ratio	Shear Modulus (lb/in <sup>2</sup> )	Unit Weight (lb/in <sup>3</sup> )	Thermal Expansion (1/ °F *10 <sup>-6</sup> )	Assigned
Fc_5	4031000	0.17	1722000	0.087	5.5	Yes
WEIGHTLESS	4031000	0.17	1722000	0	5.5	Yes
PSS	28500000	0.29	11046512	0.278	5.5	Yes

### INPUT : Sections

Name	Section Area (ft <sup>2</sup> )	Shear Area in yy (ft <sup>2</sup> )	Shear Area in zz (ft <sup>2</sup> )	Torsion Constant (ft <sup>4</sup> )	Inertia Izz (ft <sup>4</sup> )	Inertia Iyy (ft <sup>4</sup> )
Longside	27.12	16.65	12	1389	289.8	554.1
Longmid	31.85	21.38	12	1389	353.6	751.9
Transverse	30.6	30.6	0.13	2182	1093	1020
Bentcap	75.28	75.28	75.28	1213	1884	1708
Abutdiaphragm	41.88	41.88	41.88	198.6	284.2	865.4
Column	108	108	108	1296	2916	324
Rigid	108	108	108	10000	10000	10000
LongsideBent	31.85	22.44	12	1693	388.8	740.9
LongmidBent	44.38	34.97	12	1693	538.7	1028
TransverseBent	33.26	33.26	0.15	1197	1199	1109

## LARSA Joint Data

### INPUT : Joints

ID	X (ft)	Y (ft)	Z (ft)	Translation DOF	Rotation DOF	Displacement UCS	Assignment
1	636.43	-1478.45	0	all free	all free	Global	Yes
2	617.1	-1478.45	0	all free	all free	Global	Yes
3	655.74	-1479.42	0	all free	all free	Global	Yes
4	597.79	-1479.42	0	all free	all free	Global	Yes
5	636.77	-1465.11	0	all free	all free	Global	Yes
6	616.77	-1465.11	0	all free	all free	Global	Yes
7	656.74	-1466.11	0	all free	all free	Global	Yes
8	596.79	-1466.11	0	all free	all free	Global	Yes
9	674.97	-1481.35	0	all free	all free	Global	Yes
10	578.56	-1481.35	0	all free	all free	Global	Yes
11	637.1	-1451.78	0	all free	all free	Global	Yes
12	616.43	-1451.78	0	all free	all free	Global	Yes
13	676.64	-1468.11	0	all free	all free	Global	Yes
14	576.9	-1468.11	0	all free	all free	Global	Yes
15	657.74	-1452.81	0	all free	all free	Global	Yes
16	595.79	-1452.81	0	all free	all free	Global	Yes
17	694.09	-1484.23	0	all free	all free	Global	Yes
18	559.45	-1484.23	0	all free	all free	Global	Yes
19	678.3	-1454.87	0	all free	all free	Global	Yes
20	575.23	-1454.87	0	all free	all free	Global	Yes
21	696.41	-1471.1	0	all free	all free	Global	Yes
22	557.12	-1471.1	0	all free	all free	Global	Yes
23	713.03	-1488.07	0	all free	all free	Global	Yes
24	540.5	-1488.07	0	all free	all free	Global	Yes
25	698.73	-1457.96	0	all free	all free	Global	Yes
26	554.8	-1457.96	0	all free	all free	Global	Yes
27	716.01	-1475.07	0	all free	all free	Global	Yes
28	537.52	-1475.07	0	all free	all free	Global	Yes
29	731.76	-1492.86	0	all free	all free	Global	Yes
30	521.77	-1492.86	0	all free	all free	Global	Yes
31	718.99	-1462.07	0	all free	all free	Global	Yes
32	534.55	-1462.07	0	all free	all free	Global	Yes
33	735.39	-1480.02	0	all free	all free	Global	Yes
34	518.15	-1480.02	0	all free	all free	Global	Yes
35	739.01	-1467.18	0	all free	all free	Global	Yes
36	514.53	-1467.18	0	all free	all free	Global	Yes
37	750.23	-1498.57	0	all free	all free	Global	Yes
38	503.3	-1498.57	0	all free	all free	Global	Yes
39	754.49	-1485.93	0	all free	all free	Global	Yes
40	499.04	-1485.93	0	all free	all free	Global	Yes
41	758.75	-1473.29	0	all free	all free	Global	Yes
42	494.78	-1473.29	0	all free	all free	Global	Yes
43	484.87	-1504.5	0	all free	all free	Global	Yes
44	768.66	-1504.5	0	all free	all free	Global	Yes

45	773.28	-1492.79	0	all free	all free	Global	Yes
46	480.26	-1492.79	0	all free	all free	Global	Yes
47	773.28	-1492.79	-12	all free	all free	Global	Yes
48	480.26	-1492.79	-12	all free	all free	Global	Yes
49	475.65	-1481.07	0	all free	all free	Global	Yes
50	777.89	-1481.07	0	all free	all free	Global	Yes
51	786.19	-1512.73	0	all free	all free	Global	Yes
52	467.34	-1512.73	0	all free	all free	Global	Yes
53	773.28	-1492.79	-62	all fixed	all fixed	Global	Yes
54	480.26	-1492.79	-62	all fixed	all fixed	Global	Yes
55	791.69	-1500.57	0	all free	all free	Global	Yes
56	461.84	-1500.57	0	all free	all free	Global	Yes
57	797.19	-1488.42	0	all free	all free	Global	Yes
58	456.34	-1488.42	0	all free	all free	Global	Yes
59	803.6	-1521.13	0	all free	all free	Global	Yes
60	449.93	-1521.13	0	all free	all free	Global	Yes
61	809.7	-1509.27	0	all free	all free	Global	Yes
62	443.83	-1509.27	0	all free	all free	Global	Yes
63	815.8	-1497.41	0	all free	all free	Global	Yes
64	437.73	-1497.41	0	all free	all free	Global	Yes
65	820.57	-1530.4	0	all free	all free	Global	Yes
66	432.97	-1530.4	0	all free	all free	Global	Yes
67	827.25	-1518.86	0	all free	all free	Global	Yes
68	426.28	-1518.86	0	all free	all free	Global	Yes
69	833.94	-1507.32	0	all free	all free	Global	Yes
70	419.59	-1507.32	0	all free	all free	Global	Yes
71	837.05	-1540.51	0	all free	all free	Global	Yes
72	416.49	-1540.51	0	all free	all free	Global	Yes
73	844.3	-1529.31	0	all free	all free	Global	Yes
74	409.23	-1529.31	0	all free	all free	Global	Yes
75	851.55	-1518.12	0	all free	all free	Global	Yes
76	401.98	-1518.12	0	all free	all free	Global	Yes
77	853	-1551.42	0	all free	all free	Global	Yes
78	400.53	-1551.42	0	all free	all free	Global	Yes
79	860.81	-1540.6	0	all free	all free	Global	Yes
80	392.73	-1540.6	0	all free	all free	Global	Yes
81	868.61	-1529.78	0	all free	all free	Global	Yes
82	384.92	-1529.78	0	all free	all free	Global	Yes
83	868.39	-1563.12	0	all free	all free	Global	Yes
84	385.14	-1563.12	0	all free	all free	Global	Yes
85	876.73	-1552.71	0	all free	all free	Global	Yes
86	376.81	-1552.71	0	all free	all free	Global	Yes
87	885.06	-1542.29	0	all free	all free	Global	Yes
88	368.47	-1542.29	0	all free	all free	Global	Yes
89	883.17	-1575.57	0	all free	all free	Global	Yes
90	370.36	-1575.57	0	all free	all free	Global	Yes
91	892.02	-1565.59	0	all free	all free	Global	Yes
92	361.51	-1565.59	0	all free	all free	Global	Yes
93	900.87	-1555.6	0	all free	all free	Global	Yes
94	352.67	-1555.6	0	all free	all free	Global	Yes

95	897.32	-1588.75	0	all free	all free	Global	Yes
96	356.21	-1588.75	0	all free	all free	Global	Yes
97	906.65	-1579.22	0	all free	all free	Global	Yes
98	346.88	-1579.22	0	all free	all free	Global	Yes
99	915.99	-1569.69	0	all free	all free	Global	Yes
100	337.55	-1569.69	0	all free	all free	Global	Yes
101	910.79	-1602.62	0	all free	all free	Global	Yes
102	342.75	-1602.62	0	all free	all free	Global	Yes
103	920.59	-1593.57	0	all free	all free	Global	Yes
104	332.95	-1593.57	0	all free	all free	Global	Yes
105	930.38	-1584.51	0	all free	all free	Global	Yes
106	323.15	-1584.51	0	all free	all free	Global	Yes
107	923.54	-1617.14	0	all free	all free	Global	Yes
108	329.99	-1617.14	0	all free	all free	Global	Yes
109	924.83	-1616.07	0	all free	all free	Global	Yes
110	328.71	-1616.07	0	all free	all free	Global	Yes
111	924.83	-1616.07	-12	z fixed	all free	Global	Yes
112	328.71	-1616.07	-12	z fixed	all free	Global	Yes
113	933.78	-1608.59	0	all free	all free	Global	Yes
114	319.75	-1608.59	0	all free	all free	Global	Yes
115	933.78	-1608.59	-12	z fixed	all free	Global	Yes
116	319.75	-1608.59	-12	z fixed	all free	Global	Yes
117	942.74	-1601.11	0	all free	all free	Global	Yes
118	310.79	-1601.11	0	all free	all free	Global	Yes
119	942.74	-1601.11	-12	z fixed	all free	Global	Yes
120	310.79	-1601.11	-12	z fixed	all free	Global	Yes
121	944.02	-1600.04	0	all free	all free	Global	Yes
122	309.51	-1600.04	0	all free	all free	Global	Yes

### LARSA Member Data for Grillage Analysis

#### INPUT : Members

ID	I-Joint	J-Joint	Type	Section at Start	Section at End	Material	Length (ft)
1	106	104	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
2	104	102	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
3	100	98	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
4	98	96	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
5	94	92	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
6	92	90	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
7	88	86	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
8	86	84	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
9	82	80	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
10	80	78	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
11	76	74	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
12	74	72	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
13	70	68	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
14	68	66	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
15	64	62	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
16	62	60	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
17	58	56	Beam	TransverseBent	(same as start)	Fc_5	13.34
18	56	52	Beam	TransverseBent	(same as start)	Fc_5	13.34
19	42	40	Beam	TransverseBent	(same as start)	Fc_5	13.34
20	40	38	Beam	TransverseBent	(same as start)	Fc_5	13.34
21	36	34	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
22	34	30	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
23	32	28	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
24	28	24	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
25	26	22	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
26	22	18	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
27	20	14	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
28	14	10	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
29	16	8	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
30	8	4	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
31	12	6	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
32	6	2	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
33	11	5	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
34	5	1	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
35	15	7	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
36	7	3	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
37	19	13	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
38	13	9	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
39	25	21	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
40	21	17	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
41	31	27	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
42	27	23	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
43	35	33	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
44	33	29	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
45	41	39	Beam	TransverseBent	(same as start)	WEIGHTLESS	13.34
46	39	37	Beam	TransverseBent	(same as start)	WEIGHTLESS	13.34
47	57	55	Beam	TransverseBent	(same as start)	WEIGHTLESS	13.34
48	55	51	Beam	TransverseBent	(same as start)	WEIGHTLESS	13.34
49	63	61	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
50	61	59	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
51	69	67	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
52	67	65	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
53	75	73	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
54	73	71	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
55	81	79	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
56	79	77	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
57	87	85	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
58	85	83	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
59	93	91	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
60	91	89	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
61	99	97	Beam	Transverse	(same as start)	WEIGHTLESS	13.34

62	97	95	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
63	105	103	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
64	103	101	Beam	Transverse	(same as start)	WEIGHTLESS	13.34
65	122	106	Beam	Longside	(same as start)	Fc_5	20.6648
66	106	100	Beam	Longside	(same as start)	Fc_5	20.6648
67	100	94	Beam	Longside	(same as start)	Fc_5	20.6648
68	94	88	Beam	Longside	(same as start)	Fc_5	20.6648
69	88	82	Beam	Longside	(same as start)	Fc_5	20.6648
70	82	76	Beam	Longside	(same as start)	Fc_5	20.6648
71	76	70	Beam	Longside	(same as start)	Fc_5	20.6648
72	70	64	Beam	Longside	(same as start)	Fc_5	20.6648
73	64	58	Beam	Longside	(same as start)	Fc_5	20.6648
74	42	36	Beam	Longside	(same as start)	Fc_5	20.6648
75	36	32	Beam	Longside	(same as start)	Fc_5	20.6648
76	32	26	Beam	Longside	(same as start)	Fc_5	20.6648
77	26	20	Beam	Longside	(same as start)	Fc_5	20.6648
78	20	16	Beam	Longside	(same as start)	Fc_5	20.6648
79	16	12	Beam	Longside	(same as start)	Fc_5	20.6648
80	12	11	Beam	Longside	(same as start)	Fc_5	20.6648
81	11	15	Beam	Longside	(same as start)	Fc_5	20.6648
82	15	19	Beam	Longside	(same as start)	Fc_5	20.6648
83	19	25	Beam	Longside	(same as start)	Fc_5	20.6648
84	25	31	Beam	Longside	(same as start)	Fc_5	20.6648
85	31	35	Beam	Longside	(same as start)	Fc_5	20.6648
86	35	41	Beam	Longside	(same as start)	Fc_5	20.6648
87	41	50	Beam	Longside	LongsideBent	Fc_5	20.6895
88	50	57	Beam	LongsideBent	Longside	Fc_5	20.6895
89	57	63	Beam	Longside	(same as start)	Fc_5	20.6648
90	63	69	Beam	Longside	(same as start)	Fc_5	20.6648
91	69	75	Beam	Longside	(same as start)	Fc_5	20.6648
92	75	81	Beam	Longside	(same as start)	Fc_5	20.6648
93	81	87	Beam	Longside	(same as start)	Fc_5	20.6648
94	87	93	Beam	Longside	(same as start)	Fc_5	20.6648
95	93	99	Beam	Longside	(same as start)	Fc_5	20.6648
96	99	105	Beam	Longside	(same as start)	Fc_5	20.6648
97	105	121	Beam	Longside	(same as start)	Fc_5	20.6648
98	108	102	Beam	Longside	(same as start)	Fc_5	19.331
99	102	96	Beam	Longside	(same as start)	Fc_5	19.331
100	96	90	Beam	Longside	(same as start)	Fc_5	19.331
101	90	84	Beam	Longside	(same as start)	Fc_5	19.331
102	84	78	Beam	Longside	(same as start)	Fc_5	19.331
103	78	72	Beam	Longside	(same as start)	Fc_5	19.331
104	72	66	Beam	Longside	(same as start)	Fc_5	19.331
105	66	60	Beam	Longside	(same as start)	Fc_5	19.331
106	60	52	Beam	Longside	(same as start)	Fc_5	19.331
107	38	30	Beam	Longside	(same as start)	Fc_5	19.331
108	30	24	Beam	Longside	(same as start)	Fc_5	19.331
109	24	18	Beam	Longside	(same as start)	Fc_5	19.331
110	18	10	Beam	Longside	(same as start)	Fc_5	19.331
111	10	4	Beam	Longside	(same as start)	Fc_5	19.331
112	4	2	Beam	Longside	(same as start)	Fc_5	19.331
113	2	1	Beam	Longside	(same as start)	Fc_5	19.331
114	1	3	Beam	Longside	(same as start)	Fc_5	19.331
115	3	9	Beam	Longside	(same as start)	Fc_5	19.331
116	9	17	Beam	Longside	(same as start)	Fc_5	19.331
117	17	23	Beam	Longside	(same as start)	Fc_5	19.331
118	23	29	Beam	Longside	(same as start)	Fc_5	19.331
119	29	37	Beam	Longside	(same as start)	Fc_5	19.331
120	51	59	Beam	Longside	(same as start)	Fc_5	19.331
121	59	65	Beam	Longside	(same as start)	Fc_5	19.331
122	65	71	Beam	Longside	(same as start)	Fc_5	19.331
123	71	77	Beam	Longside	(same as start)	Fc_5	19.331
124	77	83	Beam	Longside	(same as start)	Fc_5	19.331
125	83	89	Beam	Longside	(same as start)	Fc_5	19.331
126	89	95	Beam	Longside	(same as start)	Fc_5	19.331
127	95	101	Beam	Longside	(same as start)	Fc_5	19.331

128	101	107	Beam	Longside	(same as start)	Fc_5	19.331
129	118	120	Beam	Rigid	(same as start)	WEIGHTLESS	12
130	114	116	Beam	Rigid	(same as start)	WEIGHTLESS	12
131	110	112	Beam	Rigid	(same as start)	WEIGHTLESS	12
132	122	118	Beam	Abutdiaphragm	(same as start)	Fc_5	1.67
133	118	114	Beam	Abutdiaphragm	(same as start)	Fc_5	11.67
134	114	110	Beam	Abutdiaphragm	(same as start)	Fc_5	11.67
135	110	108	Beam	Abutdiaphragm	(same as start)	Fc_5	1.67
136	107	109	Beam	Abutdiaphragm	(same as start)	Fc_5	1.67
137	109	113	Beam	Abutdiaphragm	(same as start)	Fc_5	11.67
138	113	117	Beam	Abutdiaphragm	(same as start)	Fc_5	11.67
139	117	121	Beam	Abutdiaphragm	(same as start)	Fc_5	1.67
140	117	119	Beam	Rigid	(same as start)	WEIGHTLESS	12
141	113	115	Beam	Rigid	(same as start)	WEIGHTLESS	12
142	109	111	Beam	Rigid	(same as start)	WEIGHTLESS	12
143	37	44	Beam	Longside	LongsideBent	Fc_5	19.396
144	44	51	Beam	LongsideBent	Longside	Fc_5	19.396
145	45	44	Beam	Bentcap	(same as start)	Fc_5	12.59
146	45	50	Beam	Bentcap	(same as start)	Fc_5	12.59
147	58	49	Beam	Longside	LongsideBent	Fc_5	20.6895
148	49	42	Beam	LongsideBent	Longside	Fc_5	20.6895
149	52	43	Beam	Longside	LongsideBent	Fc_5	19.396
150	43	38	Beam	LongsideBent	Longside	Fc_5	19.396
151	46	49	Beam	Bentcap	(same as start)	Fc_5	12.59
152	46	43	Beam	Bentcap	(same as start)	Fc_5	12.59
153	114	104	Beam	Longmid	(same as start)	Fc_5	19.9979
154	104	98	Beam	Longmid	(same as start)	Fc_5	19.9979
155	98	92	Beam	Longmid	(same as start)	Fc_5	19.9979
156	92	86	Beam	Longmid	(same as start)	Fc_5	19.9979
157	86	80	Beam	Longmid	(same as start)	Fc_5	19.9979
158	80	74	Beam	Longmid	(same as start)	Fc_5	19.9979
159	74	68	Beam	Longmid	(same as start)	Fc_5	19.9979
160	68	62	Beam	Longmid	(same as start)	Fc_5	19.9979
161	62	56	Beam	Longmid	(same as start)	Fc_5	19.9979
162	56	46	Beam	Longmid	LongmidBent	Fc_5	20.0587
163	46	40	Beam	LongmidBent	Longmid	Fc_5	20.0587
164	40	34	Beam	Longmid	(same as start)	Fc_5	19.9979
165	34	28	Beam	Longmid	(same as start)	Fc_5	19.9979
166	28	22	Beam	Longmid	(same as start)	Fc_5	19.9979
167	22	14	Beam	Longmid	(same as start)	Fc_5	19.9979
168	14	8	Beam	Longmid	(same as start)	Fc_5	19.9979
169	8	6	Beam	Longmid	(same as start)	Fc_5	19.9979
170	6	5	Beam	Longmid	(same as start)	Fc_5	19.9979
171	5	7	Beam	Longmid	(same as start)	Fc_5	19.9979
172	7	13	Beam	Longmid	(same as start)	Fc_5	19.9979
173	13	21	Beam	Longmid	(same as start)	Fc_5	19.9979
174	21	27	Beam	Longmid	(same as start)	Fc_5	19.9979
175	27	33	Beam	Longmid	(same as start)	Fc_5	19.9979
176	33	39	Beam	Longmid	(same as start)	Fc_5	19.9979
177	39	45	Beam	Longmid	LongmidBent	Fc_5	20.0587
178	45	55	Beam	LongmidBent	Longmid	Fc_5	20.0587
179	55	61	Beam	Longmid	(same as start)	Fc_5	19.9979
180	61	67	Beam	Longmid	(same as start)	Fc_5	19.9979
181	67	73	Beam	Longmid	(same as start)	Fc_5	19.9979
182	73	79	Beam	Longmid	(same as start)	Fc_5	19.9979
183	79	85	Beam	Longmid	(same as start)	Fc_5	19.9979
184	85	91	Beam	Longmid	(same as start)	Fc_5	19.9979
185	91	97	Beam	Longmid	(same as start)	Fc_5	19.9979
186	97	103	Beam	Longmid	(same as start)	Fc_5	19.9979
187	103	113	Beam	Longmid	(same as start)	Fc_5	19.9979
188	46	48	Beam	Rigid	(same as start)	WEIGHTLESS	12
189	48	54	Beam	Column	(same as start)	Fc_5	50
190	45	47	Beam	Rigid	(same as start)	WEIGHTLESS	12
191	47	53	Beam	Column	(same as start)	Fc_5	50

## LARSA Member Offsets

### INPUT : Member End Offsets

ID	I-Offset X (ft)	I-Offset Y (ft)	I-Offset Z (ft)	J-Offset X (ft)	J-Offset Y (ft)	J-Offset Z (ft)
1	0	0	-5.49	0	0	-5.49
2	0	0	-5.49	0	0	-5.49
3	0	0	-5.49	0	0	-5.49
4	0	0	-5.49	0	0	-5.49
5	0	0	-5.49	0	0	-5.49
6	0	0	-5.49	0	0	-5.49
7	0	0	-5.49	0	0	-5.49
8	0	0	-5.49	0	0	-5.49
9	0	0	-5.49	0	0	-5.49
10	0	0	-5.49	0	0	-5.49
11	0	0	-5.49	0	0	-5.49
12	0	0	-5.49	0	0	-5.49
13	0	0	-5.49	0	0	-5.49
14	0	0	-5.49	0	0	-5.49
15	0	0	-5.49	0	0	-5.49
16	0	0	-5.49	0	0	-5.49
17	0	0	-5.95	0	0	-5.95
18	0	0	-5.95	0	0	-5.95
19	0	0	-5.95	0	0	-5.95
20	0	0	-5.95	0	0	-5.95
21	0	0	-5.49	0	0	-5.49
22	0	0	-5.49	0	0	-5.49
23	0	0	-5.49	0	0	-5.49
24	0	0	-5.49	0	0	-5.49
25	0	0	-5.49	0	0	-5.49
26	0	0	-5.49	0	0	-5.49
27	0	0	-5.49	0	0	-5.49
28	0	0	-5.49	0	0	-5.49
29	0	0	-5.49	0	0	-5.49
30	0	0	-5.49	0	0	-5.49
31	0	0	-5.49	0	0	-5.49
32	0	0	-5.49	0	0	-5.49
33	0	0	-5.49	0	0	-5.49
34	0	0	-5.49	0	0	-5.49
35	0	0	-5.49	0	0	-5.49
36	0	0	-5.49	0	0	-5.49
37	0	0	-5.49	0	0	-5.49
38	0	0	-5.49	0	0	-5.49
39	0	0	-5.49	0	0	-5.49
40	0	0	-5.49	0	0	-5.49
41	0	0	-5.49	0	0	-5.49
42	0	0	-5.49	0	0	-5.49
43	0	0	-5.49	0	0	-5.49
44	0	0	-5.49	0	0	-5.49
45	0	0	-5.95	0	0	-5.95
46	0	0	-5.95	0	0	-5.95
47	0	0	-5.95	0	0	-5.95
48	0	0	-5.95	0	0	-5.95
49	0	0	-5.49	0	0	-5.49
50	0	0	-5.49	0	0	-5.49
51	0	0	-5.49	0	0	-5.49
52	0	0	-5.49	0	0	-5.49
53	0	0	-5.49	0	0	-5.49
54	0	0	-5.49	0	0	-5.49
55	0	0	-5.49	0	0	-5.49
56	0	0	-5.49	0	0	-5.49
57	0	0	-5.49	0	0	-5.49
58	0	0	-5.49	0	0	-5.49
59	0	0	-5.49	0	0	-5.49
60	0	0	-5.49	0	0	-5.49

61	0	0	-5.49	0	0	-5.49
62	0	0	-5.49	0	0	-5.49
63	0	0	-5.49	0	0	-5.49
64	0	0	-5.49	0	0	-5.49
65	0	0	-4.566	0	0	-4.566
66	0	0	-4.566	0	0	-4.566
67	0	0	-4.566	0	0	-4.566
68	0	0	-4.566	0	0	-4.566
69	0	0	-4.566	0	0	-4.566
70	0	0	-4.566	0	0	-4.566
71	0	0	-4.566	0	0	-4.566
72	0	0	-4.566	0	0	-4.566
73	0	0	-4.566	0	0	-4.566
74	0	0	-4.566	0	0	-4.566
75	0	0	-4.566	0	0	-4.566
76	0	0	-4.566	0	0	-4.566
77	0	0	-4.566	0	0	-4.566
78	0	0	-4.566	0	0	-4.566
79	0	0	-4.566	0	0	-4.566
80	0	0	-4.566	0	0	-4.566
81	0	0	-4.566	0	0	-4.566
82	0	0	-4.566	0	0	-4.566
83	0	0	-4.566	0	0	-4.566
84	0	0	-4.566	0	0	-4.566
85	0	0	-4.566	0	0	-4.566
86	0	0	-4.566	0	0	-4.566
87	0	0	-4.566	0	0	-5.675
88	0	0	-5.675	0	0	-4.566
89	0	0	-4.566	0	0	-4.566
90	0	0	-4.566	0	0	-4.566
91	0	0	-4.566	0	0	-4.566
92	0	0	-4.566	0	0	-4.566
93	0	0	-4.566	0	0	-4.566
94	0	0	-4.566	0	0	-4.566
95	0	0	-4.566	0	0	-4.566
96	0	0	-4.566	0	0	-4.566
97	0	0	-4.566	0	0	-4.566
98	0	0	-4.566	0	0	-4.566
99	0	0	-4.566	0	0	-4.566
100	0	0	-4.566	0	0	-4.566
101	0	0	-4.566	0	0	-4.566
102	0	0	-4.566	0	0	-4.566
103	0	0	-4.566	0	0	-4.566
104	0	0	-4.566	0	0	-4.566
105	0	0	-4.566	0	0	-4.566
106	0	0	-4.566	0	0	-4.566
107	0	0	-4.566	0	0	-4.566
108	0	0	-4.566	0	0	-4.566
109	0	0	-4.566	0	0	-4.566
110	0	0	-4.566	0	0	-4.566
111	0	0	-4.566	0	0	-4.566
112	0	0	-4.566	0	0	-4.566
113	0	0	-4.566	0	0	-4.566
114	0	0	-4.566	0	0	-4.566
115	0	0	-4.566	0	0	-4.566
116	0	0	-4.566	0	0	-4.566
117	0	0	-4.566	0	0	-4.566
118	0	0	-4.566	0	0	-4.566
119	0	0	-4.566	0	0	-4.566
120	0	0	-4.566	0	0	-4.566
121	0	0	-4.566	0	0	-4.566
122	0	0	-4.566	0	0	-4.566
123	0	0	-4.566	0	0	-4.566
124	0	0	-4.566	0	0	-4.566
125	0	0	-4.566	0	0	-4.566
126	0	0	-4.566	0	0	-4.566

127	0	0	-4.566	0	0	-4.566
128	0	0	-4.566	0	0	-4.566
129	0	0	0	0	0	0
130	0	0	0	0	0	0
131	0	0	0	0	0	0
132	0	0	-5.918	0	0	-5.918
133	0	0	-5.918	0	0	-5.918
134	0	0	-5.918	0	0	-5.918
135	0	0	-5.918	0	0	-5.918
136	0	0	-5.918	0	0	-5.918
137	0	0	-5.918	0	0	-5.918
138	0	0	-5.918	0	0	-5.918
139	0	0	-5.918	0	0	-5.918
140	0	0	0	0	0	0
141	0	0	0	0	0	0
142	0	0	0	0	0	0
143	0	0	-4.566	0	0	-5.675
144	0	0	-5.675	0	0	-4.566
145	0	0	-6.151	0	0	-6.151
146	0	0	-6.151	0	0	-6.151
147	0	0	-4.566	0	0	-5.675
148	0	0	-5.675	0	0	-4.566
149	0	0	-4.566	0	0	-5.675
150	0	0	-5.675	0	0	-4.566
151	0	0	-6.151	0	0	-6.151
152	0	0	-6.151	0	0	-6.151
153	0	0	-5.27	0	0	-5.27
154	0	0	-5.27	0	0	-5.27
155	0	0	-5.27	0	0	-5.27
156	0	0	-5.27	0	0	-5.27
157	0	0	-5.27	0	0	-5.27
158	0	0	-5.27	0	0	-5.27
159	0	0	-5.27	0	0	-5.27
160	0	0	-5.27	0	0	-5.27
161	0	0	-5.27	0	0	-5.27
162	0	0	-5.27	0	0	-6.83
163	0	0	-6.83	0	0	-5.27
164	0	0	-5.27	0	0	-5.27
165	0	0	-5.27	0	0	-5.27
166	0	0	-5.27	0	0	-5.27
167	0	0	-5.27	0	0	-5.27
168	0	0	-5.27	0	0	-5.27
169	0	0	-5.27	0	0	-5.27
170	0	0	-5.27	0	0	-5.27
171	0	0	-5.27	0	0	-5.27
172	0	0	-5.27	0	0	-5.27
173	0	0	-5.27	0	0	-5.27
174	0	0	-5.27	0	0	-5.27
175	0	0	-5.27	0	0	-5.27
176	0	0	-5.27	0	0	-5.27
177	0	0	-5.27	0	0	-6.83
178	0	0	-6.83	0	0	-5.27
179	0	0	-5.27	0	0	-5.27
180	0	0	-5.27	0	0	-5.27
181	0	0	-5.27	0	0	-5.27
182	0	0	-5.27	0	0	-5.27
183	0	0	-5.27	0	0	-5.27
184	0	0	-5.27	0	0	-5.27
185	0	0	-5.27	0	0	-5.27
186	0	0	-5.27	0	0	-5.27
187	0	0	-5.27	0	0	-5.27
188	0	0	0	0	0	0
189	0	0	0	0	0	0
190	0	0	0	0	0	0
191	0	0	0	0	0	0

## LARSA Prestress Tendon Input

### INPUT : Tendons

Tendon Name	Material	Exposure	Strand Area (per strand) (ft <sup>2</sup> )	# of Strands	Proposed Jacking Force (kips)	Jacking End	Anchor Set (ft)	Wobble Coefficient (per ft)	Curvature Friction Coefficient	Elongation After Pull 1	Elongation After Pull 2
TMIDF	PSS	Internal	0.0015	124	4912	Start, then End	0.0328	0.0002	0.15	3.6191	0.4152
TOUTF	PSS	Internal	0.0015	124	4912	Start, then End	0.0328	0.0002	0.15	3.7115	0.4427
TINF	PSS	Internal	0.0015	124	4912	Start, then End	0.0328	0.0002	0.15	3.4945	0.4044

### TENDON TMIDF

Point Type	Reference Object Type	Reference Object or Range	Offset X (ft)	Offset Y (ft)	Offset Z (ft)	X Reference	Y Reference	Z Reference	Curvature Type
geometry	member	153	0	0	-6	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	154	0	0	-7.53	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	155	0	0	-8.63	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	156	0	0	-9.28	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	157	0	0	-9.5	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	158	0	0	-9.24	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	159	0	0	-8.466	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	160	0	0	-7.174	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	161	0	0	-5.366	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	162	0	0	-3.04	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	163	0	0	-1.75	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	164	0	0	-2.513	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	165	0	0	-4.4814	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	166	0	0	-6.2685	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	167	0	0	-7.7306	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	168	0	0	-8.8678	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	169	0	0	-9.68	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	170	0	0	-10.168	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	170	10	0	-10.33	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	171	0	0	-10.168	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	172	0	0	-9.68	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	173	0	0	-8.8678	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	174	0	0	-7.7306	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	175	0	0	-6.285	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	176	0	0	-4.4814	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	177	0	0	-2.513	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	178	0	0	-1.75	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	179	0	0	-3.04	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	180	0	0	-5.366	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	181	0	0	-7.174	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	182	0	0	-8.466	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	183	0	0	-9.24	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	184	0	0	-9.5	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	185	0	0	-9.28	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	186	0	0	-8.63	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	187	0	0	-7.73	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	187	0	0	-6	End	Reference Line	+Z1 Local Edge	No Curve

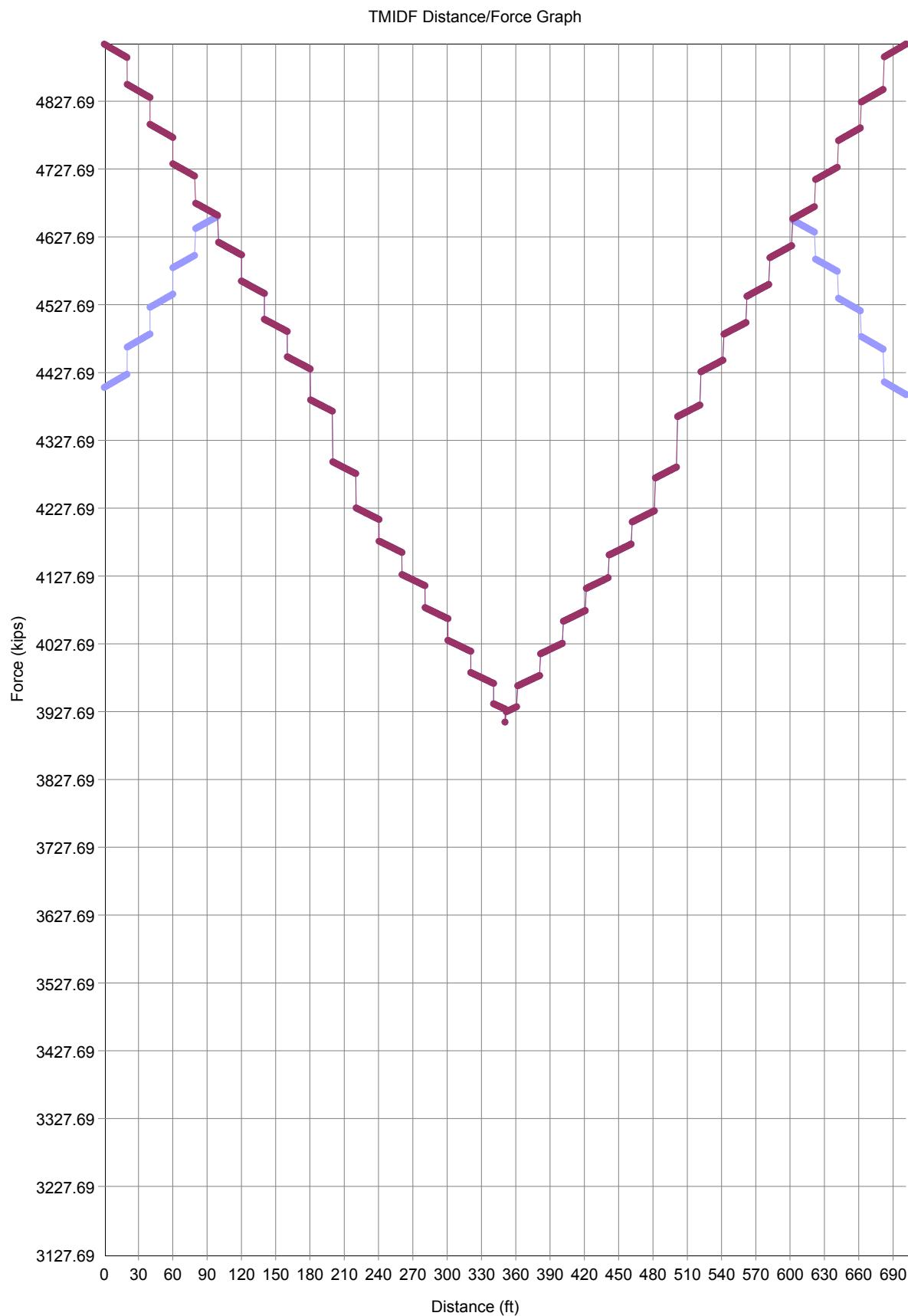
**TENDON TOUTF**

Point Type	Reference Object Type	Reference Object or Range	Offset X (ft)	Offset Y (ft)	Offset Z (ft)	X Reference	Y Reference	Z Reference	Curvature Type
geometry	member	65	0	0	-6	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	66	0	0	-7.53	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	67	0	0	-8.63	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	68	0	0	-9.28	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	69	0	0	-9.5	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	70	0	0	-9.24	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	71	0	0	-8.466	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	72	0	0	-7.174	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	73	0	0	-5.366	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	147	0	0	-3.04	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	148	0	0	-1.75	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	74	0	0	-2.513	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	75	0	0	-4.4814	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	76	0	0	-6.2685	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	77	0	0	-7.7306	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	78	0	0	-8.8678	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	79	0	0	-9.68	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	80	0	0	-10.168	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	80	10	0	-10.33	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	81	0	0	-10.168	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	82	0	0	-9.68	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	83	0	0	-8.8678	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	84	0	0	-7.7306	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	85	0	0	-6.285	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	86	0	0	-4.4814	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	87	0	0	-2.513	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	88	0	0	-1.75	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	89	0	0	-3.04	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	90	0	0	-5.366	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	91	0	0	-7.174	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	92	0	0	-8.466	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	93	0	0	-9.24	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	94	0	0	-9.5	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	95	0	0	-9.28	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	96	0	0	-8.63	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	97	0	0	-7.73	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	97	0	0	-6	End	Reference Line	+Z1 Local Edge	No Curve

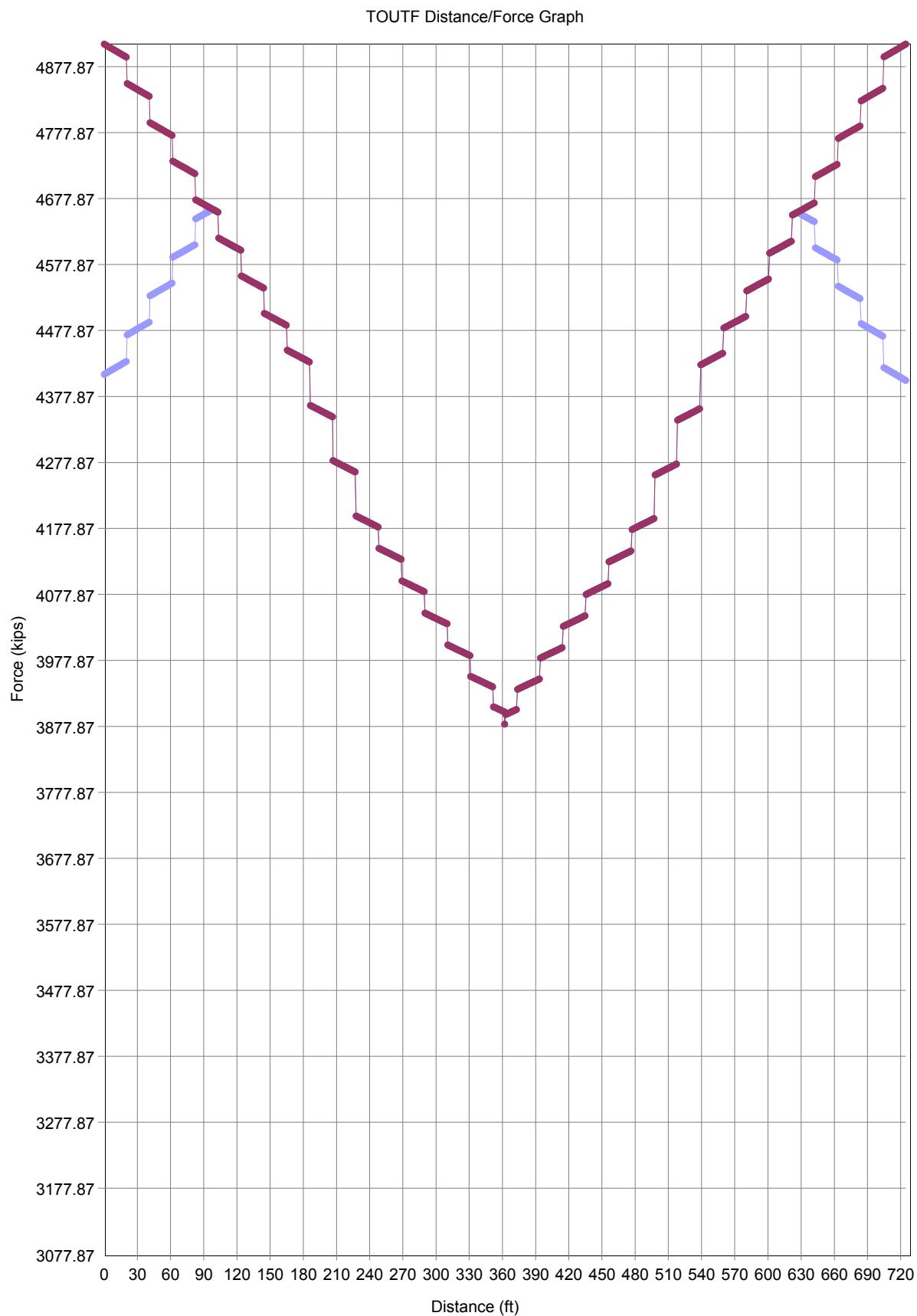
**TENDON TINF**

Point Type	Reference Object Type	Reference Object or Range	Offset X (ft)	Offset Y (ft)	Offset Z (ft)	X Reference	Y Reference	Z Reference	Curvature Type
geometry	member	98	0	0	-6	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	99	0	0	-7.53	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	100	0	0	-8.63	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	101	0	0	-9.28	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	102	0	0	-9.5	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	103	0	0	-9.24	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	104	0	0	-8.466	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	105	0	0	-7.174	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	106	0	0	-5.366	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	149	0	0	-3.04	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	150	0	0	-1.75	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	107	0	0	-2.513	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	108	0	0	-4.4814	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	109	0	0	-6.2685	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	110	0	0	-7.7306	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	111	0	0	-8.8678	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	112	0	0	-9.68	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	113	0	0	-10.168	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	113	10	0	-10.33	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	114	0	0	-10.168	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	115	0	0	-9.68	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	116	0	0	-8.8678	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	117	0	0	-7.7306	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	118	0	0	-6.285	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	119	0	0	-4.4814	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	143	0	0	-2.513	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	144	0	0	-1.75	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	120	0	0	-3.04	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	121	0	0	-5.366	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	122	0	0	-7.174	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	123	0	0	-8.466	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	124	0	0	-9.24	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	125	0	0	-9.5	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	126	0	0	-9.28	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	127	0	0	-8.63	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	128	0	0	-7.73	Start	Reference Line	+Z1 Local Edge	No Curve
geometry	member	128	0	0	-6	End	Reference Line	+Z1 Local Edge	No Curve

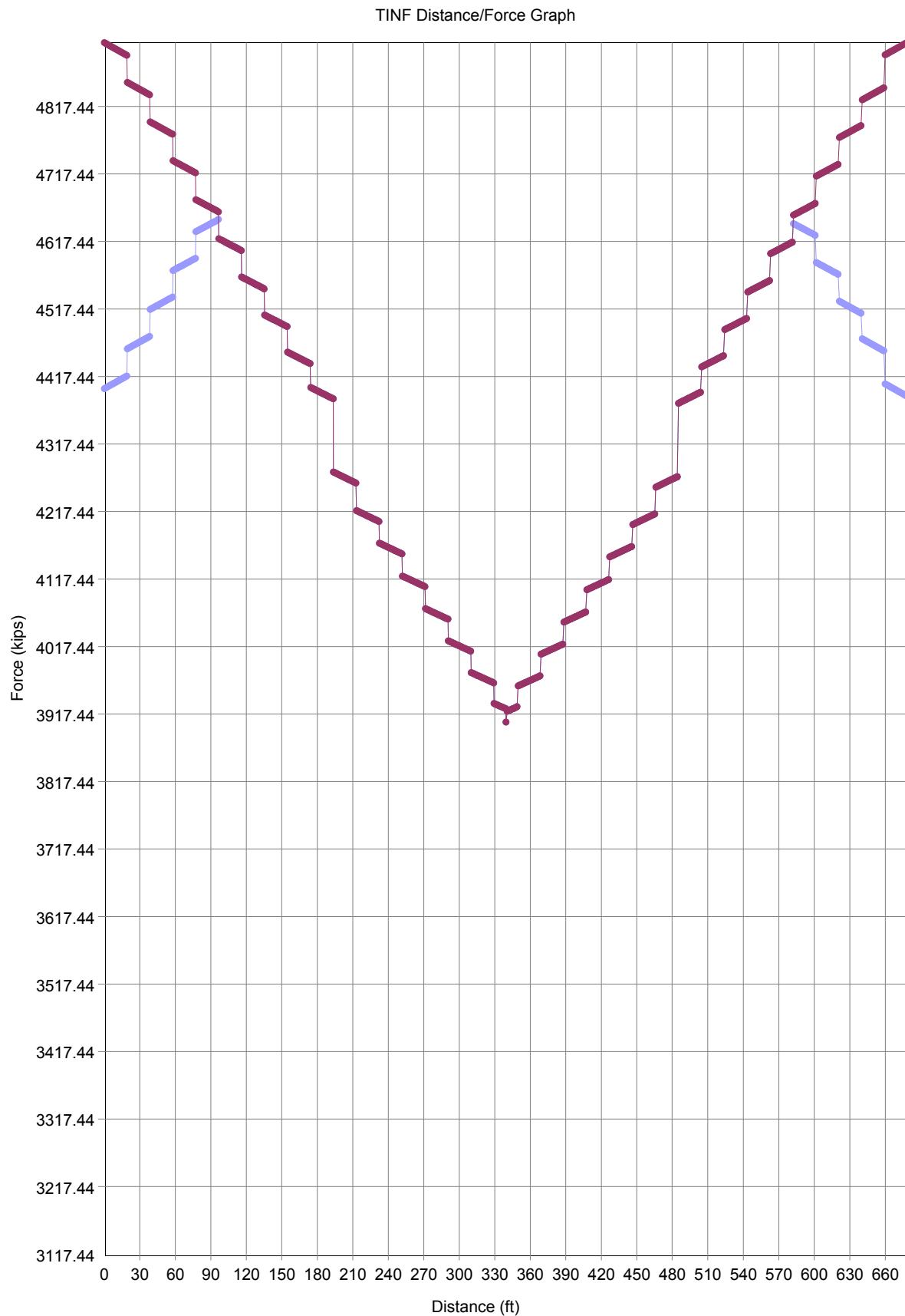
## TENDON TMIDF, Graph



## TENDON TOUTF, Graph



## TENDON TINF, Graph



### LARSA Selected Tendon Force Results

#### RESULT : Total Tendon force @ Member Ends

Member	Location	Force in Tendon (kips)	Fx (kips)	Fy (kips)	Fz (kips)	Primary Mx (kips-ft)	Primary My (kips-ft)	Primary Mz (kips-ft)	Secondary Mx (kips- ft)	Secondary My (kips- ft)	Secondary Mz (kips- ft)
84	End	4127	4106	-205	359	-353	-7058	0	-1412	9311	-243
85	Start	4127	4106	-205	359	-353	-7058	0	-1412	9311	-243
117	End	4150	4127	-207	386	-355	-7094	0	-1524	8748	-481
118	Start	4150	4127	-207	386	-355	-7094	0	-1524	8748	-481
174	End	4158	4141	0	374	0	-4204	0	-1592	8006	-544
175	Start	4158	4141	0	374	0	-4204	0	-1592	8006	-544

## LARSA Abutment 4 Reactions

### RESULT : Reactions

Joint	Result Case	Force X/R (kips)	Force Y/Theta/Phi (kips)	Force Z/Theta (kips)	Moment X/R (kips-ft)	Moment Y/Theta/Phi (kips-ft)	Moment Z/Theta (kips-ft)
111	DC	0	0	204	0	0	0
111	DW	0	0	1	0	0	0
111	PSFINAL	0	0	-75	0	0	0
115	DC	0	0	365	0	0	0
115	DW	0	0	32	0	0	0
115	PSFINAL	0	0	-1	0	0	0
119	DC	0	0	490	0	0	0
119	DW	0	0	106	0	0	0
119	PSFINAL	0	0	183	0	0	0

### RESULT ENVELOPE :Reactions @ Force Z (kips)

Joint	Result Case	Force X/R (kips)	Force Y/Theta/Phi (kips)	Force Z/Theta (kips)	Moment X/R (kips-ft)	Moment Y/Theta/Phi (kips-ft)	Moment Z/Theta (kips-ft)
111	ULLOut5	0	0	-27	0	0	0
111	ULLOut2	0	0	21	0	0	0
115	ULLOut2	0	0	-9	0	0	0
115	ULLOut5	0	0	50	0	0	0
119	ULLOut2	0	0	-40	0	0	0
119	ULLOut5	0	0	137	0	0	0

### RESULT ENVELOPE :Reactions @ Force Z (kips)

Joint	Result Case	Force X/R (kips)	Force Y/Theta/Phi (kips)	Force Z/Theta (kips)	Moment X/R (kips-ft)	Moment Y/Theta/Phi (kips-ft)	Moment Z/Theta (kips-ft)
111	ULLMid5	0	0	-1	0	0	0
111	ULLMid2	0	0	28	0	0	0
115	ULLMid2	0	0	-9	0	0	0
115	ULLMid5	0	0	50	0	0	0
119	ULLMid2	0	0	-46	0	0	0
119	ULLMid5	0	0	112	0	0	0

### RESULT ENVELOPE :Reactions @ Force Z (kips)

Joint	Result Case	Force X/R (kips)	Force Y/Theta/Phi (kips)	Force Z/Theta (kips)	Moment X/R (kips-ft)	Moment Y/Theta/Phi (kips-ft)	Moment Z/Theta (kips-ft)
111	ULLIn3	0	0	3	0	0	0
111	ULLIn1	0	0	57	0	0	0
115	ULLIn4	0	0	-9	0	0	0
115	ULLIn5	0	0	50	0	0	0
119	ULLIn2	0	0	-51	0	0	0
119	ULLIn5	0	0	86	0	0	0

### RESULT ENVELOPE :Reactions @ Force Z (kips)

Joint	Result Case	Force X/R (kips)	Force Y/Theta/Phi (kips)	Force Z/Theta (kips)	Moment X/R (kips-ft)	Moment Y/Theta/Phi (kips-ft)	Moment Z/Theta (kips-ft)
111	Dist: 615.00	0	0	-28	0	0	0
111	Dist: 420.00	0	0	16	0	0	0
115	Dist: 420.00	0	0	-6	0	0	0
115	Dist: 695.00	0	0	58	0	0	0
119	Dist: 415.00	0	0	-28	0	0	0
119	Dist: 675.00	0	0	104	0	0	0

**RESULT ENVELOPE :Reactions @ Force Z (kips)**

Joint	Result Case	Force X/R (kips)	Force Y/Theta/Phi (kips)	Force Z/Theta (kips)	Moment X/R (kips-ft)	Moment Y/Theta/Phi (kips-ft)	Moment Z/Theta (kips-ft)
111	Dist: 600.00	0	0	-14	0	0	0
111	Dist: 690.00	0	0	31	0	0	0
115	Dist: 415.00	0	0	-6	0	0	0
115	Dist: 700.00	0	0	57	0	0	0
119	Dist: 415.00	0	0	-31	0	0	0
119	Dist: 670.00	0	0	85	0	0	0

**RESULT ENVELOPE :Reactions @ Force Z (kips)**

Joint	Result Case	Force X/R (kips)	Force Y/Theta/Phi (kips)	Force Z/Theta (kips)	Moment X/R (kips-ft)	Moment Y/Theta/Phi (kips-ft)	Moment Z/Theta (kips-ft)
111	Dist: 710.00	0	0	-3	0	0	0
111	Dist: 685.00	0	0	53	0	0	0
115	Dist: 415.00	0	0	-6	0	0	0
115	Dist: 695.00	0	0	55	0	0	0
119	Dist: 420.00	0	0	-33	0	0	0
119	Dist: 660.00	0	0	66	0	0	0

**LARSA Member Forces Results for Grillage Analysis**

**RESULT : Member End Forces (Local)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	DC	-4	0	42	-4	14846	257
80	11	DC	4	0	42	4	-14839	-258
84	25	DC	-72	9	-309	-2226	6281	281
84	31	DC	72	-9	393	2226	965	-87
85	31	DC	-109	11	-390	-2143	338	255
85	35	DC	109	-11	474	2143	8588	-27
87	41	DC	-204	9	-557	952	-15775	1
87	50	DC	199	-9	648	-952	28237	189
113	2	DC	593	0	39	-4	15642	252
113	1	DC	-593	0	40	4	-15638	-252
117	17	DC	336	39	-245	-2459	5453	548
117	23	DC	-336	-39	324	2459	47	198
118	23	DC	193	47	-319	-2472	-1047	588
118	29	DC	-193	-47	398	2472	7979	323
143	37	DC	-165	61	-478	-2835	-17112	492
143	44	DC	160	-61	563	2835	27205	683
170	6	DC	-241	0	47	-4	20668	303
170	5	DC	241	0	49	4	-20649	-303
174	21	DC	77	21	-352	-2355	7637	427
174	27	DC	-77	-21	447	2355	349	-3
175	27	DC	253	28	-455	-2325	-876	445
175	33	DC	-253	-28	550	2325	10920	114
177	39	DC	804	49	-607	-926	-25711	341
177	45	DC	-813	-49	722	926	39038	634

**RESULT : Member End Forces (Local)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	DW	-1	0	10	46	2869	50
80	11	DW	1	0	10	42	-2874	-50
84	25	DW	-14	2	-62	-396	1279	56
84	31	DW	14	-2	83	483	217	-16
85	31	DW	-20	2	-80	-383	152	51
85	35	DW	20	-2	100	470	1708	-3
87	41	DW	-35	2	-117	215	-2968	4
87	50	DW	34	-2	138	-128	5608	38
113	2	DW	116	0	10	-39	3027	49
113	1	DW	-116	0	9	-43	-3031	-49
117	17	DW	66	7	-49	-525	1113	106
117	23	DW	-66	-7	68	443	26	38
118	23	DW	39	9	-65	-530	-125	114
118	29	DW	-39	-9	84	448	1573	61
143	37	DW	-27	12	-101	-606	-3217	91
143	44	DW	26	-12	120	524	5357	134
170	6	DW	-47	0	6	2	4010	59
170	5	DW	47	0	5	-2	-4014	-59
174	21	DW	14	4	-63	-466	1419	83
174	27	DW	-14	-4	74	466	-51	-1
175	27	DW	47	5	-80	-464	-266	87
175	33	DW	-47	-5	90	464	1963	22
177	39	DW	146	9	-99	-205	-5080	64
177	45	DW	-147	-9	110	205	7179	125

**RESULT : Member End Forces (Local)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	PSFINAL	3696	0	-63	0	-10333	-268
80	11	PSFINAL	-3702	196	-92	1097	10368	268
84	25	PSFINAL	3873	198	180	-754	-2557	-257
84	31	PSFINAL	-3923	4	-244	1393	-2322	172
85	31	PSFINAL	3941	198	237	-1413	2305	-242
85	35	PSFINAL	-3990	6	-311	1764	-8651	108
87	41	PSFINAL	4024	363	556	-3503	15503	-89
87	50	PSFINAL	-4200	-102	95	3147	-22559	211
113	2	PSFINAL	3289	0	-64	0	-11180	-266
113	1	PSFINAL	-3295	197	-100	1104	11208	265
117	17	PSFINAL	3634	-25	335	-1501	-3459	-460
117	23	PSFINAL	-3671	231	-415	1854	-2961	-30
118	23	PSFINAL	3784	-30	421	-1877	1676	-479
118	29	PSFINAL	-3816	30	-424	1877	-9812	-102
143	37	PSFINAL	4044	-1	702	-1921	16170	-524
143	44	PSFINAL	-4172	596	-1	-313	-25089	-528
170	6	PSFINAL	4515	0	-64	0	-14593	-325
170	5	PSFINAL	-4520	197	-96	966	14620	325
174	21	PSFINAL	4410	-26	307	-1424	-3256	-519
174	27	PSFINAL	-4448	232	-383	1634	-2836	5
175	27	PSFINAL	4325	-32	385	-1800	3797	-543
175	33	PSFINAL	-4358	32	-388	1800	-11514	-99
177	39	PSFINAL	4115	156	740	-3654	21892	-677
177	45	PSFINAL	-4280	267	-73	1997	-32303	-445

**RESULT ENVELOPE :Member End Forces (Local) @ Force Z (kips)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	ULLOut5	49	0	0	1	-547	-74
80	12	ULLOut2	-22	0	10	-5	2399	72
80	11	ULLOut3	-24	0	-4	15	237	39
80	11	ULLOut1	-3	0	7	9	-2162	-34
84	25	ULLOut4	-31	7	-49	-526	1459	147
84	25	ULLOut3	16	-3	4	-7	115	-52
84	31	ULLOut3	-16	3	-4	7	-188	-2
84	31	ULLOut4	31	-7	63	544	-300	-4
85	31	ULLOut4	-22	9	-62	-568	578	145
85	31	ULLOut3	10	-3	3	-19	222	-53
85	35	ULLOut3	-10	3	-3	19	-290	-15
85	35	ULLOut4	22	-9	75	587	844	31
87	41	ULLOut1	-31	1	-88	-13	-2387	-6
87	41	ULLOut3	-5	-4	2	-69	350	-34
87	50	ULLOut3	5	4	-2	69	-398	-45
87	50	ULLOut1	30	-1	101	32	4340	31
113	2	ULLOut5	-131	0	0	1	-572	-80
113	2	ULLOut2	144	0	15	8	2471	69
113	1	ULLOut3	65	0	-8	18	204	37
113	1	ULLOut1	-79	0	6	25	-2267	-32
117	17	ULLOut1	43	5	-34	-450	730	75
117	17	ULLOut3	-45	-4	7	-8	93	-62
117	23	ULLOut3	45	4	-7	8	-234	-7
117	23	ULLOut1	-43	-5	47	501	53	30
118	23	ULLOut1	23	7	-45	-481	-243	81
118	23	ULLOut3	-35	-4	7	-20	205	-62
118	29	ULLOut3	35	4	-7	20	-342	-22
118	29	ULLOut1	-23	-7	58	531	1236	47
143	37	ULLOut1	-28	9	-69	-573	-2625	64
143	37	ULLOut3	-11	-6	6	-34	354	-44
143	44	ULLOut3	11	6	-6	34	-468	-67
143	44	ULLOut1	27	-9	82	624	4088	101
170	6	ULLOut5	-22	0	0	1	-761	-93
170	6	ULLOut2	-26	0	13	2	3319	84
170	5	ULLOut3	11	0	-7	16	315	45
170	5	ULLOut1	37	0	6	18	-3004	-39
174	21	ULLOut4	33	11	-54	-545	1815	197
174	21	ULLOut3	-22	-4	8	-7	134	-75
174	27	ULLOut3	22	4	-8	7	-290	-11
174	27	ULLOut4	-33	-11	67	580	-609	14
175	27	ULLOut4	59	13	-70	-597	529	203
175	27	ULLOut3	-25	-5	8	-19	280	-77
175	33	ULLOut3	25	5	-8	19	-445	-30
175	33	ULLOut4	-59	-13	82	632	991	64
177	39	ULLOut4	142	20	-91	-553	-3619	131
177	39	ULLOut3	-34	-8	7	-68	725	-69
177	45	ULLOut3	34	8	-7	68	-864	-95
177	45	ULLOut4	-143	-20	104	588	5580	279

**RESULT ENVELOPE :Member End Forces (Local) @ Moment X (kips-ft)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	ULLOut3	24	0	4	-15	-310	-35
80	12	ULLOut1	3	0	7	9	2162	34
80	11	ULLOut5	-49	0	0	-1	546	73
80	11	ULLOut2	22	0	3	24	-2472	-68
84	25	ULLOut2	-15	4	-46	-532	1575	94
84	25	ULLOut5	21	-6	1	104	-545	-111
84	31	ULLOut5	-21	6	-1	-104	527	-9
84	31	ULLOut2	15	-4	59	551	-488	-5
85	31	ULLOut2	-12	5	-59	-587	800	92
85	31	ULLOut5	6	-7	1	132	-544	-113
85	35	ULLOut5	-6	7	-1	-132	528	-36
85	35	ULLOut2	12	-5	72	605	554	16
87	41	ULLOut2	-6	6	-84	-362	-1318	32
87	41	ULLOut5	-30	-9	-2	281	-720	-72
87	50	ULLOut5	30	9	2	-281	757	-111
87	50	ULLOut2	5	-6	97	381	3185	97
113	2	ULLOut3	-65	0	8	-18	-368	-42
113	2	ULLOut1	79	0	6	25	2267	32
113	1	ULLOut5	131	0	0	-1	573	79
113	1	ULLOut2	-144	0	-2	43	-2635	-74
117	17	ULLOut2	99	9	-24	-570	1353	133
117	17	ULLOut5	-101	-7	-3	113	-530	-120
117	23	ULLOut5	101	7	3	-113	595	-10
117	23	ULLOut2	-99	-9	36	620	-775	33
118	23	ULLOut2	72	11	-34	-638	480	141
118	23	ULLOut5	-85	-8	-4	139	-517	-123
118	29	ULLOut5	85	8	4	-139	599	-39
118	29	ULLOut2	-72	-11	46	689	295	64
143	37	ULLOut2	4	14	-55	-718	-1561	99
143	37	ULLOut5	-43	-11	-8	112	-710	-79
143	44	ULLOut5	43	11	8	-112	871	-143
143	44	ULLOut2	-5	-14	67	768	2750	177
170	6	ULLOut3	-11	0	7	-16	-447	-46
170	6	ULLOut1	-37	0	6	18	3004	39
170	5	ULLOut5	22	0	0	-1	761	92
170	5	ULLOut2	26	0	0	33	-3451	-85
174	21	ULLOut2	10	6	-46	-552	1949	122
174	21	ULLOut5	-22	-8	2	108	-772	-147
174	27	ULLOut5	22	8	-2	-108	723	-19
174	27	ULLOut2	-10	-6	59	587	-899	3
175	27	ULLOut2	34	8	-61	-616	809	126
175	27	ULLOut5	-22	-10	3	136	-765	-151
175	33	ULLOut5	22	10	-3	-136	697	-55
175	33	ULLOut2	-34	-8	74	651	545	34
177	39	ULLOut2	108	12	-84	-621	-2894	62
177	39	ULLOut5	-25	-15	4	203	-340	-108
177	45	ULLOut5	25	15	-4	-203	259	-193
177	45	ULLOut2	-109	-12	97	656	4716	184

**RESULT ENVELOPE :Member End Forces (Local) @ Moment Y (kips-ft)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	ULLOut5	49	0	0	1	-547	-74
80	12	ULLOut4	-46	0	7	9	2709	107
80	11	ULLOut4	46	0	7	9	-2709	-107
80	11	ULLOut5	-49	0	0	-1	546	73
84	25	ULLOut5	21	-6	1	104	-545	-111
84	25	ULLOut2	-15	4	-46	-532	1575	94
84	31	ULLOut2	15	-4	59	551	-488	-5
84	31	ULLOut5	-21	6	-1	-104	527	-9
85	31	ULLOut5	6	-7	1	132	-544	-113
85	31	ULLOut2	-12	5	-59	-587	800	92
85	35	ULLOut3	-10	3	-3	19	-290	-15
85	35	ULLOut1	16	-1	75	456	1372	-5
87	41	ULLOut1	-31	1	-88	-13	-2387	-6
87	41	ULLOut3	-5	-4	2	-69	350	-34
87	50	ULLOut3	5	4	-2	69	-398	-45
87	50	ULLOut1	30	-1	101	32	4340	31
113	2	ULLOut5	-131	0	0	1	-572	-80
113	2	ULLOut4	210	0	6	25	2840	111
113	1	ULLOut4	-210	0	6	25	-2840	-111
113	1	ULLOut5	131	0	0	-1	573	79
117	17	ULLOut5	-101	-7	-3	113	-530	-120
117	17	ULLOut2	99	9	-24	-570	1353	133
117	23	ULLOut2	-99	-9	36	620	-775	33
117	23	ULLOut5	101	7	3	-113	595	-10
118	23	ULLOut5	-85	-8	-4	139	-517	-123
118	23	ULLOut2	72	11	-34	-638	480	141
118	29	ULLOut3	35	4	-7	20	-342	-22
118	29	ULLOut1	-23	-7	58	531	1236	47
143	37	ULLOut1	-28	9	-69	-573	-2625	64
143	37	ULLOut3	-11	-6	6	-34	354	-44
143	44	ULLOut3	11	6	-6	34	-468	-67
143	44	ULLOut1	27	-9	82	624	4088	101
170	6	ULLOut5	-22	0	0	1	-761	-93
170	6	ULLOut4	-15	0	6	18	3766	131
170	5	ULLOut4	15	0	6	18	-3766	-131
170	5	ULLOut5	22	0	0	-1	761	92
174	21	ULLOut5	-22	-8	2	108	-772	-147
174	21	ULLOut2	10	6	-46	-552	1949	122
174	27	ULLOut2	-10	-6	59	587	-899	3
174	27	ULLOut5	22	8	-2	-108	723	-19
175	27	ULLOut5	-22	-10	3	136	-765	-151
175	27	ULLOut2	34	8	-61	-616	809	126
175	33	ULLOut3	25	5	-8	19	-445	-30
175	33	ULLOut1	-36	-3	79	497	1687	9
177	39	ULLOut1	116	5	-87	-352	-3958	23
177	39	ULLOut3	-34	-8	7	-68	725	-69
177	45	ULLOut3	34	8	-7	68	-864	-95
177	45	ULLOut1	-117	-5	100	387	5837	87

**RESULT ENVELOPE :Member End Forces (Local) @ Force Z (kips)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	ULLMid5	47	0	0	0	-525	-71
80	12	ULLMid2	-24	0	11	-10	2423	75
80	11	ULLMid3	-23	0	-4	1	222	37
80	11	ULLMid1	1	0	7	-9	-2202	-38
84	25	ULLMid4	-31	7	-47	-437	1464	148
84	25	ULLMid3	15	-3	4	6	110	-51
84	31	ULLMid3	-15	3	-4	-6	-190	-2
84	31	ULLMid4	31	-7	60	419	-356	-5
85	31	ULLMid4	-22	9	-59	-451	584	146
85	31	ULLMid3	9	-3	4	-6	213	-51
85	35	ULLMid3	-9	3	-4	6	-289	-15
85	35	ULLMid4	22	-9	73	434	778	30
87	41	ULLMid1	-29	1	-84	132	-2330	1
87	41	ULLMid3	-5	-4	3	-55	340	-32
87	50	ULLMid3	5	4	-3	55	-396	-44
87	50	ULLMid1	29	-1	98	-150	4213	28
113	2	ULLMid5	-126	0	0	0	-549	-76
113	2	ULLMid2	151	0	14	5	2521	72
113	1	ULLMid3	63	0	-8	3	201	35
113	1	ULLMid1	-88	0	6	8	-2320	-37
117	17	ULLMid1	50	6	-37	-355	818	81
117	17	ULLMid3	-43	-3	6	6	99	-59
117	23	ULLMid3	43	3	-6	-6	-224	-7
117	23	ULLMid1	-50	-6	49	372	14	29
118	23	ULLMid1	29	7	-48	-357	-143	87
118	23	ULLMid3	-33	-4	6	-5	208	-60
118	29	ULLMid3	33	4	-6	5	-329	-21
118	29	ULLMid1	-29	-7	61	374	1194	47
143	37	ULLMid1	-24	9	-73	-409	-2530	72
143	37	ULLMid3	-10	-6	5	-20	349	-42
143	44	ULLMid3	10	6	-5	20	-449	-65
143	44	ULLMid1	23	-9	85	425	4058	101
170	6	ULLMid5	-21	0	0	0	-731	-89
170	6	ULLMid2	-25	0	13	-2	3369	88
170	5	ULLMid3	11	0	-6	2	302	44
170	5	ULLMid1	36	0	6	0	-3066	-45
174	21	ULLMid4	33	11	-54	-451	1861	204
174	21	ULLMid3	-21	-4	8	6	134	-72
174	27	ULLMid3	21	4	-8	-6	-285	-11
174	27	ULLMid4	-33	-11	67	451	-659	17
175	27	ULLMid4	58	14	-69	-473	584	210
175	27	ULLMid3	-24	-5	8	-5	276	-74
175	33	ULLMid3	24	5	-8	5	-435	-29
175	33	ULLMid4	-58	-14	82	473	931	69
177	39	ULLMid4	141	22	-91	-346	-3528	154
177	39	ULLMid3	-33	-8	7	-51	707	-65
177	45	ULLMid3	33	8	-7	51	-841	-93
177	45	ULLMid4	-142	-22	104	346	5482	279

**RESULT ENVELOPE :Member End Forces (Local) @ Moment X (kips-ft)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	ULLMid2	-24	0	11	-10	2423	75
80	12	ULLMid5	47	0	0	0	-525	-71
80	11	ULLMid1	1	0	7	-9	-2202	-38
80	11	ULLMid3	-23	0	-4	1	222	37
84	25	ULLMid4	-31	7	-47	-437	1464	148
84	25	ULLMid5	21	-6	1	99	-523	-106
84	31	ULLMid5	-21	6	-1	-99	506	-8
84	31	ULLMid4	31	-7	60	419	-356	-5
85	31	ULLMid2	-13	5	-56	-457	798	95
85	31	ULLMid5	6	-7	1	126	-521	-108
85	35	ULLMid5	-6	7	-1	-126	507	-34
85	35	ULLMid2	13	-5	69	439	489	16
87	41	ULLMid2	-5	6	-80	-186	-1295	38
87	41	ULLMid5	-29	-8	-2	263	-695	-69
87	50	ULLMid5	29	8	2	-263	732	-106
87	50	ULLMid2	4	-6	93	169	3084	90
113	2	ULLMid3	-63	0	8	-3	-349	-40
113	2	ULLMid1	88	0	6	8	2320	37
113	1	ULLMid5	126	0	0	0	550	76
113	1	ULLMid2	-151	0	-1	11	-2668	-78
117	17	ULLMid4	147	12	-34	-462	1326	196
117	17	ULLMid5	-97	-6	-3	107	-508	-115
117	23	ULLMid5	97	6	3	-107	571	-9
117	23	ULLMid4	-147	-12	46	479	-557	38
118	23	ULLMid2	77	11	-38	-494	561	144
118	23	ULLMid5	-81	-8	-4	132	-496	-117
118	29	ULLMid5	81	8	4	-132	575	-37
118	29	ULLMid2	-77	-11	50	511	290	64
143	37	ULLMid2	7	14	-59	-523	-1492	106
143	37	ULLMid5	-41	-11	-8	94	-689	-76
143	44	ULLMid5	41	11	8	-94	846	-136
143	44	ULLMid2	-8	-14	72	540	2763	171
170	6	ULLMid2	-25	0	13	-2	3369	88
170	6	ULLMid5	-21	0	0	0	-731	-89
170	5	ULLMid5	21	0	0	0	731	88
170	5	ULLMid2	25	0	0	2	-3496	-89
174	21	ULLMid4	33	11	-54	-451	1861	204
174	21	ULLMid5	-21	-8	2	102	-741	-141
174	27	ULLMid5	21	8	-2	-102	692	-18
174	27	ULLMid4	-33	-11	67	451	-659	17
175	27	ULLMid2	34	9	-61	-479	860	136
175	27	ULLMid5	-21	-10	3	130	-735	-145
175	33	ULLMid5	21	10	-3	-130	667	-53
175	33	ULLMid2	-34	-9	74	479	496	41
177	39	ULLMid2	108	14	-84	-397	-2821	89
177	39	ULLMid5	-24	-14	4	211	-313	-104
177	45	ULLMid5	24	14	-4	-211	230	-185
177	45	ULLMid2	-109	-14	97	397	4641	186

**RESULT ENVELOPE :Member End Forces (Local) @ Moment Y (kips-ft)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	ULLMid5	47	0	0	0	-525	-71
80	12	ULLMid4	-47	0	7	-9	2727	109
80	11	ULLMid4	47	0	7	-9	-2727	-109
80	11	ULLMid5	-47	0	0	0	525	71
84	25	ULLMid5	21	-6	1	99	-523	-106
84	25	ULLMid2	-16	4	-43	-431	1574	97
84	31	ULLMid2	16	-4	56	413	-546	-7
84	31	ULLMid5	-21	6	-1	-99	506	-8
85	31	ULLMid5	6	-7	1	126	-521	-108
85	31	ULLMid2	-13	5	-56	-457	798	95
85	35	ULLMid3	-9	3	-4	6	-289	-15
85	35	ULLMid1	16	-2	72	308	1285	-4
87	41	ULLMid1	-29	1	-84	132	-2330	1
87	41	ULLMid3	-5	-4	3	-55	340	-32
87	50	ULLMid3	5	4	-3	55	-396	-44
87	50	ULLMid1	29	-1	98	-150	4213	28
113	2	ULLMid5	-126	0	0	0	-549	-76
113	2	ULLMid4	213	0	6	8	2869	113
113	1	ULLMid4	-213	0	6	8	-2869	-113
113	1	ULLMid5	126	0	0	0	550	76
117	17	ULLMid5	-97	-6	-3	107	-508	-115
117	17	ULLMid2	104	9	-27	-456	1425	137
117	23	ULLMid2	-104	-9	39	473	-781	31
117	23	ULLMid5	97	6	3	-107	571	-9
118	23	ULLMid5	-81	-8	-4	132	-496	-117
118	23	ULLMid2	77	11	-38	-494	561	144
118	29	ULLMid3	33	4	-6	5	-329	-21
118	29	ULLMid1	-29	-7	61	374	1194	47
143	37	ULLMid1	-24	9	-73	-409	-2530	72
143	37	ULLMid3	-10	-6	5	-20	349	-42
143	44	ULLMid3	10	6	-5	20	-449	-65
143	44	ULLMid1	23	-9	85	425	4058	101
170	6	ULLMid5	-21	0	0	0	-731	-89
170	6	ULLMid4	-15	0	6	0	3798	133
170	5	ULLMid4	15	0	6	0	-3798	-133
170	5	ULLMid5	21	0	0	0	731	88
174	21	ULLMid5	-21	-8	2	102	-741	-141
174	21	ULLMid2	11	7	-46	-445	1996	132
174	27	ULLMid2	-11	-7	59	445	-943	7
174	27	ULLMid5	21	8	-2	-102	692	-18
175	27	ULLMid5	-21	-10	3	130	-735	-145
175	27	ULLMid2	34	9	-61	-479	860	136
175	33	ULLMid3	24	5	-8	5	-435	-29
175	33	ULLMid1	-37	-4	79	344	1598	17
177	39	ULLMid1	117	7	-87	-136	-3840	50
177	39	ULLMid3	-33	-8	7	-51	707	-65
177	45	ULLMid3	33	8	-7	51	-841	-93
177	45	ULLMid1	-118	-7	100	136	5711	94

RESULT ENVELOPE :Member End Forces (Local) @ Force Z (kips)								
Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	ULLIn5	45	0	0	0	-503	-67
80	12	ULLIn2	-26	0	11	-15	2448	78
80	11	ULLIn3	-22	0	-4	-12	207	35
80	11	ULLIn1	4	0	7	-27	-2241	-43
84	25	ULLIn4	-31	7	-45	-347	1469	149
84	25	ULLIn3	15	-2	4	18	104	-49
84	31	ULLIn3	-15	2	-4	-18	-192	-2
84	31	ULLIn4	31	-7	58	293	-411	-6
85	31	ULLIn4	-22	9	-56	-335	591	147
85	31	ULLIn3	9	-3	4	7	204	-49
85	35	ULLIn3	-9	3	-4	-7	-288	-15
85	35	ULLIn4	22	-9	70	281	712	30
87	41	ULLIn1	-28	2	-81	277	-2273	7
87	41	ULLIn3	-4	-4	3	-42	330	-30
87	50	ULLIn3	4	4	-3	42	-394	-43
87	50	ULLIn1	27	-2	94	-331	4086	25
113	2	ULLIn5	-120	0	0	0	-527	-72
113	2	ULLIn2	157	0	13	3	2570	76
113	1	ULLIn3	60	0	-7	-12	198	33
113	1	ULLIn1	-97	0	6	-9	-2373	-42
117	17	ULLIn1	57	6	-39	-260	907	87
117	17	ULLIn3	-41	-3	6	20	104	-57
117	23	ULLIn3	41	3	-6	-20	-214	-7
117	23	ULLIn1	-57	-6	52	243	-25	28
118	23	ULLIn1	35	7	-51	-233	-44	92
118	23	ULLIn3	-32	-4	5	9	210	-58
118	29	ULLIn3	32	4	-5	-9	-317	-21
118	29	ULLIn1	-35	-7	64	216	1153	48
143	37	ULLIn1	-20	9	-76	-244	-2435	80
143	37	ULLIn3	-10	-5	4	-7	345	-40
143	44	ULLIn3	10	5	-4	7	-431	-63
143	44	ULLIn1	19	-9	88	227	4028	100
170	6	ULLIn5	-20	0	0	0	-701	-84
170	6	ULLIn2	-25	0	13	-5	3418	93
170	5	ULLIn3	10	0	-6	-12	289	42
170	5	ULLIn1	35	0	6	-18	-3129	-51
174	21	ULLIn4	32	12	-54	-357	1908	210
174	21	ULLIn3	-21	-4	7	19	134	-68
174	27	ULLIn3	21	4	-7	-19	-279	-10
174	27	ULLIn4	-32	-12	66	321	-709	21
175	27	ULLIn4	58	15	-69	-350	639	218
175	27	ULLIn3	-23	-5	8	8	272	-71
175	33	ULLIn3	23	5	-8	-8	-425	-28
175	33	ULLIn4	-58	-15	82	315	871	75
177	39	ULLIn4	141	23	-91	-138	-3437	177
177	39	ULLIn3	-32	-8	6	-35	689	-61
177	45	ULLIn3	32	8	-6	35	-818	-90
177	45	ULLIn4	-142	-23	104	103	5385	279

**RESULT ENVELOPE :Member End Forces (Local) @ Moment X (kips-ft)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	ULLIn1	-4	0	7	-27	2241	43
80	12	ULLIn3	22	0	4	12	-296	-32
80	11	ULLIn2	26	0	2	-39	-2537	-75
80	11	ULLIn5	-45	0	0	0	503	68
84	25	ULLIn4	-31	7	-45	-347	1469	149
84	25	ULLIn5	20	-5	1	94	-500	-102
84	31	ULLIn5	-20	5	-1	-94	485	-7
84	31	ULLIn4	31	-7	58	293	-411	-6
85	31	ULLIn4	-22	9	-56	-335	591	147
85	31	ULLIn5	6	-7	1	120	-498	-104
85	35	ULLIn5	-6	7	-1	-120	486	-33
85	35	ULLIn4	22	-9	70	281	712	30
87	41	ULLIn3	-4	-4	3	-42	330	-30
87	41	ULLIn1	-28	2	-81	277	-2273	7
87	50	ULLIn1	27	-2	94	-331	4086	25
87	50	ULLIn3	4	4	-3	42	-394	-43
113	2	ULLIn1	97	0	6	-9	2373	42
113	2	ULLIn3	-60	0	7	12	-329	-39
113	1	ULLIn2	-157	0	-1	-21	-2701	-81
113	1	ULLIn5	120	0	0	0	527	73
117	17	ULLIn4	150	12	-36	-362	1393	197
117	17	ULLIn5	-93	-6	-3	102	-486	-110
117	23	ULLIn5	93	6	3	-102	547	-8
117	23	ULLIn4	-150	-12	49	345	-573	37
118	23	ULLIn4	113	15	-47	-359	431	205
118	23	ULLIn5	-78	-8	-4	125	-475	-112
118	29	ULLIn5	78	8	4	-125	552	-35
118	29	ULLIn4	-113	-15	60	342	601	84
143	37	ULLIn2	10	14	-64	-328	-1422	112
143	37	ULLIn5	-40	-10	-8	77	-668	-73
143	44	ULLIn5	40	10	8	-77	821	-128
143	44	ULLIn2	-11	-14	76	311	2776	166
170	6	ULLIn1	-35	0	6	-18	3129	51
170	6	ULLIn3	-10	0	6	12	-411	-43
170	5	ULLIn2	25	0	0	-30	-3540	-93
170	5	ULLIn5	20	0	0	0	701	85
174	21	ULLIn4	32	12	-54	-357	1908	210
174	21	ULLIn5	-20	-8	2	97	-711	-134
174	27	ULLIn5	20	8	-2	-97	662	-17
174	27	ULLIn4	-32	-12	66	321	-709	21
175	27	ULLIn4	58	15	-69	-350	639	218
175	27	ULLIn5	-20	-9	3	123	-705	-138
175	33	ULLIn5	20	9	-3	-123	637	-50
175	33	ULLIn4	-58	-15	82	315	871	75
177	39	ULLIn2	109	15	-84	-173	-2748	116
177	39	ULLIn5	-23	-14	4	218	-285	-99
177	45	ULLIn5	23	14	-4	-218	201	-178
177	45	ULLIn2	-110	-15	97	138	4566	189

**RESULT ENVELOPE :Member End Forces (Local) @ Moment Y (kips-ft)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	ULLIn5	45	0	0	0	-503	-67
80	12	ULLIn4	-48	0	7	-27	2744	110
80	11	ULLIn4	48	0	7	-27	-2744	-110
80	11	ULLIn5	-45	0	0	0	503	68
84	25	ULLIn5	20	-5	1	94	-500	-102
84	25	ULLIn2	-17	4	-40	-329	1573	100
84	31	ULLIn2	17	-4	54	275	-603	-8
84	31	ULLIn5	-20	5	-1	-94	485	-7
85	31	ULLIn5	6	-7	1	120	-498	-104
85	31	ULLIn2	-13	5	-52	-327	795	98
85	35	ULLIn3	-9	3	-4	-7	-288	-15
85	35	ULLIn1	16	-2	69	160	1198	-3
87	41	ULLIn1	-28	2	-81	277	-2273	7
87	41	ULLIn3	-4	-4	3	-42	330	-30
87	50	ULLIn3	4	4	-3	42	-394	-43
87	50	ULLIn1	27	-2	94	-331	4086	25
113	2	ULLIn5	-120	0	0	0	-527	-72
113	2	ULLIn4	217	0	6	-9	2899	115
113	1	ULLIn4	-217	0	6	-9	-2899	-115
113	1	ULLIn5	120	0	0	0	527	73
117	17	ULLIn5	-93	-6	-3	102	-486	-110
117	17	ULLIn2	109	9	-31	-342	1497	140
117	23	ULLIn2	-109	-9	43	325	-787	30
117	23	ULLIn5	93	6	3	-102	547	-8
118	23	ULLIn5	-78	-8	-4	125	-475	-112
118	23	ULLIn2	81	11	-42	-350	642	147
118	29	ULLIn3	32	4	-5	-9	-317	-21
118	29	ULLIn1	-35	-7	64	216	1153	48
143	37	ULLIn1	-20	9	-76	-244	-2435	80
143	37	ULLIn3	-10	-5	4	-7	345	-40
143	44	ULLIn3	10	5	-4	7	-431	-63
143	44	ULLIn1	19	-9	88	227	4028	100
170	6	ULLIn5	-20	0	0	0	-701	-84
170	6	ULLIn4	-14	0	6	-18	3829	135
170	5	ULLIn4	14	0	6	-18	-3829	-135
170	5	ULLIn5	20	0	0	0	701	85
174	21	ULLIn5	-20	-8	2	97	-711	-134
174	21	ULLIn2	12	8	-46	-337	2042	142
174	27	ULLIn2	-12	-8	59	302	-988	10
174	27	ULLIn5	20	8	-2	-97	662	-17
175	27	ULLIn5	-20	-9	3	123	-705	-138
175	27	ULLIn2	35	10	-61	-342	911	147
175	33	ULLIn3	23	5	-8	-8	-425	-28
175	33	ULLIn1	-38	-5	79	191	1509	24
177	39	ULLIn1	118	9	-87	81	-3722	78
177	39	ULLIn3	-32	-8	6	-35	689	-61
177	45	ULLIn3	32	8	-6	35	-818	-90
177	45	ULLIn1	-119	-9	99	-116	5586	101

**RESULT ENVELOPE :Member End Forces (Local) @ Force Z (kips)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	LLOut: Dist: 350.00	-20	0	-27	-106	2313	55
80	12	LLOut: Dist: 385.00	-19	0	36	110	2167	67
80	11	LLOut: Dist: 405.00	21	0	-29	-123	-2123	-55
80	11	LLOut: Dist: 370.00	18	0	32	38	-2119	-63
84	25	LLOut: Dist: 435.00	-6	3	-52	-348	1695	65
84	25	LLOut: Dist: 465.00	-1	2	14	-109	1438	56
84	31	LLOut: Dist: 485.00	1	-2	-11	66	-908	-1
84	31	LLOut: Dist: 455.00	2	-3	56	251	-866	-4
85	31	LLOut: Dist: 455.00	-1	3	-56	-350	1225	52
85	31	LLOut: Dist: 485.00	3	2	12	-99	1041	38
85	35	LLOut: Dist: 505.00	-2	-1	-9	43	-508	0
85	35	LLOut: Dist: 475.00	-2	-2	59	245	-347	5
87	41	LLOut: Dist: 495.00	2	1	-60	-184	156	1
87	41	LLOut: Dist: 530.00	-3	-1	5	117	65	1
87	50	LLOut: Dist: 130.00	4	3	-2	54	-342	-39
87	50	LLOut: Dist: 515.00	-3	0	62	70	687	0
113	2	LLOut: Dist: 330.00	113	1	-26	-158	1950	67
113	2	LLOut: Dist: 365.00	128	0	34	74	2349	63
113	1	LLOut: Dist: 380.00	-127	0	-29	-81	-2673	-67
113	1	LLOut: Dist: 350.00	-124	-1	33	191	-2019	-52
117	17	LLOut: Dist: 410.00	80	7	-42	-461	1215	110
117	17	LLOut: Dist: 440.00	74	6	19	-205	1499	88
117	23	LLOut: Dist: 460.00	-62	-4	-12	179	-1388	12
117	23	LLOut: Dist: 425.00	-78	-7	47	477	-739	29
118	23	LLOut: Dist: 425.00	56	8	-45	-476	595	108
118	23	LLOut: Dist: 460.00	48	6	13	-215	1008	76
118	29	LLOut: Dist: 480.00	-36	-4	-6	178	-832	23
118	29	LLOut: Dist: 445.00	-53	-7	53	491	-153	47
143	37	LLOut: Dist: 465.00	7	8	-57	-472	-429	54
143	37	LLOut: Dist: 135.00	-9	-5	5	-25	304	-38
143	44	LLOut: Dist: 135.00	9	5	-5	25	-397	-57
143	44	LLOut: Dist: 485.00	-7	-6	66	471	1054	81
170	6	LLOut: Dist: 340.00	-17	0	-27	-142	2822	66
170	6	LLOut: Dist: 375.00	-25	0	35	101	3139	76
170	5	LLOut: Dist: 395.00	20	0	-29	-115	-3099	-72
170	5	LLOut: Dist: 360.00	24	0	32	117	-2921	-75
174	21	LLOut: Dist: 420.00	5	5	-55	-423	1847	93
174	21	LLOut: Dist: 455.00	-7	4	8	-146	1965	76
174	27	LLOut: Dist: 135.00	19	4	-7	2	-248	-10
174	27	LLOut: Dist: 440.00	4	-4	60	377	-1243	5
175	27	LLOut: Dist: 440.00	14	5	-62	-435	1182	83
175	27	LLOut: Dist: 135.00	-21	-5	7	-12	240	-66
175	33	LLOut: Dist: 135.00	21	5	-7	12	-381	-26
175	33	LLOut: Dist: 460.00	-4	-4	66	379	-474	21
177	39	LLOut: Dist: 480.00	40	4	-68	-381	-605	9
177	39	LLOut: Dist: 135.00	-29	-7	6	-53	619	-58
177	45	LLOut: Dist: 135.00	29	7	-6	53	-736	-81
177	45	LLOut: Dist: 500.00	-25	-2	71	313	1202	42

**RESULT ENVELOPE :Member End Forces (Local) @ Moment X (kips-ft)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	LLOut: Dist: 325.00	-22	0	-20	-131	1677	49
80	12	LLOut: Dist: 405.00	-21	0	29	123	1513	64
80	11	LLOut: Dist: 405.00	21	0	-29	-123	-2123	-55
80	11	LLOut: Dist: 325.00	22	0	20	131	-1256	-59
84	25	LLOut: Dist: 405.00	-14	3	-46	-405	1122	74
84	25	LLOut: Dist: 605.00	5	-3	-2	92	-550	-49
84	31	LLOut: Dist: 605.00	-5	3	2	-92	600	-6
84	31	LLOut: Dist: 405.00	14	-3	46	405	-170	-5
85	31	LLOut: Dist: 420.00	-9	4	-50	-420	569	69
85	31	LLOut: Dist: 605.00	-3	-3	-2	125	-639	-50
85	35	LLOut: Dist: 605.00	3	3	2	-125	688	-17
85	35	LLOut: Dist: 420.00	9	-4	50	420	464	12
87	41	LLOut: Dist: 455.00	-1	3	-56	-249	-637	13
87	41	LLOut: Dist: 600.00	-21	-4	-4	284	-906	-32
87	50	LLOut: Dist: 600.00	21	4	4	-284	983	-53
87	50	LLOut: Dist: 455.00	1	-3	56	249	1795	57
113	2	LLOut: Dist: 330.00	113	1	-26	-158	1950	67
113	2	LLOut: Dist: 415.00	111	-1	20	125	1399	50
113	1	LLOut: Dist: 415.00	-111	1	-20	-125	-1782	-67
113	1	LLOut: Dist: 350.00	-124	-1	33	191	-2019	-52
117	17	LLOut: Dist: 410.00	80	7	-42	-461	1215	110
117	17	LLOut: Dist: 605.00	-47	-3	-9	100	-522	-49
117	23	LLOut: Dist: 605.00	47	3	9	-100	691	-2
117	23	LLOut: Dist: 425.00	-78	-7	47	477	-739	29
118	23	LLOut: Dist: 425.00	56	8	-45	-476	595	108
118	23	LLOut: Dist: 610.00	-42	-3	-9	133	-606	-50
118	29	LLOut: Dist: 610.00	42	3	9	-133	785	-14
118	29	LLOut: Dist: 445.00	-53	-7	53	491	-153	47
143	37	LLOut: Dist: 455.00	6	9	-54	-475	-661	60
143	37	LLOut: Dist: 615.00	-26	-5	-12	134	-868	-30
143	44	LLOut: Dist: 615.00	26	5	12	-134	1095	-63
143	44	LLOut: Dist: 455.00	-6	-9	54	475	1699	111
170	6	LLOut: Dist: 330.00	-13	0	-24	-144	2461	64
170	6	LLOut: Dist: 410.00	-13	0	24	125	2048	74
170	5	LLOut: Dist: 410.00	13	0	-24	-125	-2536	-67
170	5	LLOut: Dist: 330.00	13	0	24	144	-1977	-72
174	21	LLOut: Dist: 410.00	10	5	-53	-431	1565	99
174	21	LLOut: Dist: 605.00	0	-3	-4	95	-758	-60
174	27	LLOut: Dist: 605.00	0	3	4	-95	846	-6
174	27	LLOut: Dist: 410.00	-10	-5	53	431	-508	4
175	27	LLOut: Dist: 425.00	23	6	-58	-448	766	95
175	27	LLOut: Dist: 610.00	2	-4	-4	129	-877	-62
175	33	LLOut: Dist: 610.00	-2	4	4	-129	955	-21
175	33	LLOut: Dist: 425.00	-23	-6	58	448	402	27
177	39	LLOut: Dist: 455.00	60	7	-64	-406	-1454	31
177	39	LLOut: Dist: 610.00	8	-6	-2	228	-895	-34
177	45	LLOut: Dist: 610.00	-8	6	2	-228	939	-80
177	45	LLOut: Dist: 455.00	-60	-7	64	406	2735	109

**RESULT ENVELOPE :Member End Forces (Local) @ Moment Y (kips-ft)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	LLOut: Dist: 135.00	21	0	3	-8	-265	-30
80	12	LLOut: Dist: 365.00	-18	0	-23	-43	2569	62
80	11	LLOut: Dist: 390.00	19	0	-2	-72	-2322	-60
80	11	LLOut: Dist: 610.00	-20	0	3	-12	260	29
84	25	LLOut: Dist: 610.00	5	-3	-2	91	-551	-49
84	25	LLOut: Dist: 450.00	-3	3	-15	-220	1807	62
84	31	LLOut: Dist: 470.00	1	-2	51	186	-1029	-4
84	31	LLOut: Dist: 610.00	-5	3	2	-91	601	-6
85	31	LLOut: Dist: 610.00	-3	-3	-2	125	-640	-50
85	31	LLOut: Dist: 470.00	2	3	-50	-261	1367	47
85	35	LLOut: Dist: 490.00	-3	-2	53	173	-545	1
85	35	LLOut: Dist: 360.00	17	-5	34	323	844	20
87	41	LLOut: Dist: 380.00	-4	6	-39	-153	-1218	40
87	41	LLOut: Dist: 510.00	3	1	-53	-92	382	5
87	50	LLOut: Dist: 135.00	4	3	-2	55	-342	-39
87	50	LLOut: Dist: 405.00	4	-5	46	196	2112	79
113	2	LLOut: Dist: 135.00	-55	0	7	-10	-311	-36
113	2	LLOut: Dist: 360.00	127	0	4	-44	2448	65
113	1	LLOut: Dist: 380.00	-127	0	-29	-81	-2673	-67
113	1	LLOut: Dist: 610.00	55	0	7	-14	308	35
117	17	LLOut: Dist: 610.00	-47	-3	-9	100	-523	-49
117	17	LLOut: Dist: 425.00	78	7	-7	-313	1520	101
117	23	LLOut: Dist: 455.00	-66	-5	19	325	-1409	15
117	23	LLOut: Dist: 610.00	47	3	9	-100	693	-2
118	23	LLOut: Dist: 610.00	-42	-3	-9	133	-606	-50
118	23	LLOut: Dist: 455.00	50	6	-17	-342	1032	82
118	29	LLOut: Dist: 475.00	-40	-4	24	329	-856	27
118	29	LLOut: Dist: 355.00	-56	-8	24	340	791	46
143	37	LLOut: Dist: 385.00	6	11	-30	-377	-1339	79
143	37	LLOut: Dist: 135.00	-9	-5	5	-25	304	-38
143	44	LLOut: Dist: 135.00	9	5	-5	25	-397	-57
143	44	LLOut: Dist: 410.00	-5	-11	37	433	1975	132
170	6	LLOut: Dist: 135.00	-9	0	6	-9	-378	-39
170	6	LLOut: Dist: 360.00	-24	0	8	-7	3314	70
170	5	LLOut: Dist: 380.00	24	0	-2	-18	-3319	-74
170	5	LLOut: Dist: 610.00	9	0	5	-13	374	39
174	21	LLOut: Dist: 610.00	0	-3	-4	95	-759	-60
174	21	LLOut: Dist: 440.00	-4	4	-20	-267	2208	82
174	27	LLOut: Dist: 460.00	8	-4	24	226	-1587	3
174	27	LLOut: Dist: 610.00	0	3	4	-95	847	-6
175	27	LLOut: Dist: 610.00	2	-4	-4	129	-877	-62
175	27	LLOut: Dist: 460.00	4	4	-26	-269	1558	67
175	33	LLOut: Dist: 480.00	1	-3	29	222	-882	13
175	33	LLOut: Dist: 355.00	-43	-8	37	326	1102	37
177	39	LLOut: Dist: 385.00	84	12	-44	-299	-2385	76
177	39	LLOut: Dist: 135.00	-29	-7	6	-53	619	-58
177	45	LLOut: Dist: 135.00	29	7	-6	53	-736	-81
177	45	LLOut: Dist: 405.00	-83	-11	50	345	3332	150

**RESULT ENVELOPE :Member End Forces (Local) @ Force Z (kips)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	LLMid: Dist: 350.00	-20	0	-27	-36	2365	56
80	12	LLMid: Dist: 380.00	-19	0	36	-28	2281	67
80	11	LLMid: Dist: 400.00	21	-1	-30	-37	-2200	-54
80	11	LLMid: Dist: 370.00	18	0	33	-29	-2156	-64
84	25	LLMid: Dist: 430.00	-7	3	-51	-264	1651	65
84	25	LLMid: Dist: 465.00	-1	2	14	-197	1304	55
84	31	LLMid: Dist: 485.00	1	-2	-10	108	-830	1
84	31	LLMid: Dist: 450.00	2	-3	55	182	-853	-5
85	31	LLMid: Dist: 450.00	-1	3	-55	-258	1187	52
85	31	LLMid: Dist: 485.00	3	2	12	-177	908	37
85	35	LLMid: Dist: 505.00	-2	-1	-8	73	-435	2
85	35	LLMid: Dist: 470.00	-2	-2	58	168	-336	5
87	41	LLMid: Dist: 490.00	3	1	-59	-80	134	3
87	41	LLMid: Dist: 525.00	-2	-1	5	28	140	0
87	50	LLMid: Dist: 135.00	4	3	-2	46	-340	-38
87	50	LLMid: Dist: 515.00	-4	0	63	-51	609	-8
113	2	LLMid: Dist: 325.00	112	1	-26	-78	1882	66
113	2	LLMid: Dist: 360.00	128	0	35	17	2409	64
113	1	LLMid: Dist: 380.00	-127	0	-29	-30	-2631	-67
113	1	LLMid: Dist: 345.00	-123	-1	32	80	-1930	-53
117	17	LLMid: Dist: 405.00	81	7	-43	-346	1189	110
117	17	LLMid: Dist: 440.00	73	6	17	-228	1457	85
117	23	LLMid: Dist: 455.00	-64	-4	-12	198	-1443	14
117	23	LLMid: Dist: 425.00	-79	-6	50	339	-827	27
118	23	LLMid: Dist: 425.00	57	8	-48	-356	701	105
118	23	LLMid: Dist: 455.00	50	6	13	-231	1079	78
118	29	LLMid: Dist: 475.00	-39	-4	-6	186	-884	25
118	29	LLMid: Dist: 445.00	-53	-7	55	340	-253	45
143	37	LLMid: Dist: 465.00	8	8	-60	-333	-313	54
143	37	LLMid: Dist: 130.00	-9	-5	4	-16	300	-36
143	44	LLMid: Dist: 130.00	9	5	-4	16	-384	-55
143	44	LLMid: Dist: 485.00	-8	-5	68	297	928	70
170	6	LLMid: Dist: 340.00	-18	0	-27	-64	2912	68
170	6	LLMid: Dist: 370.00	-25	0	36	1	3231	75
170	5	LLMid: Dist: 390.00	20	0	-30	-37	-3195	-75
170	5	LLMid: Dist: 360.00	24	0	33	24	-2996	-74
174	21	LLMid: Dist: 420.00	3	5	-56	-312	1946	96
174	21	LLMid: Dist: 450.00	-7	4	9	-215	2057	79
174	27	LLMid: Dist: 130.00	18	4	-6	-7	-244	-9
174	27	LLMid: Dist: 440.00	5	-5	61	251	-1332	7
175	27	LLMid: Dist: 440.00	13	6	-62	-313	1292	85
175	27	LLMid: Dist: 130.00	-21	-4	7	-3	237	-63
175	33	LLMid: Dist: 130.00	21	4	-7	3	-373	-25
175	33	LLMid: Dist: 460.00	-3	-5	66	243	-579	23
177	39	LLMid: Dist: 480.00	37	5	-69	-221	-435	21
177	39	LLMid: Dist: 130.00	-28	-7	6	-42	605	-55
177	45	LLMid: Dist: 130.00	28	7	-6	42	-720	-79
177	45	LLMid: Dist: 500.00	-22	-2	72	137	1027	33

**RESULT ENVELOPE :Member End Forces (Local) @ Moment X (kips-ft)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	LLMid: Dist: 320.00	-23	-1	-19	-67	1603	48
80	12	LLMid: Dist: 420.00	-23	1	23	52	1126	59
80	11	LLMid: Dist: 395.00	20	-1	1	-68	-2250	-56
80	11	LLMid: Dist: 320.00	23	1	19	67	-1209	-59
84	25	LLMid: Dist: 395.00	-16	3	-43	-311	984	76
84	25	LLMid: Dist: 610.00	4	-3	-3	81	-531	-47
84	31	LLMid: Dist: 610.00	-4	3	3	-81	586	-5
84	31	LLMid: Dist: 395.00	16	-3	43	311	-101	-6
85	31	LLMid: Dist: 410.00	-11	4	-46	-320	447	71
85	31	LLMid: Dist: 605.00	-3	-3	-3	113	-618	-48
85	35	LLMid: Dist: 605.00	3	3	3	-113	672	-17
85	35	LLMid: Dist: 410.00	11	-4	46	320	514	13
87	41	LLMid: Dist: 440.00	-2	4	-52	-140	-801	21
87	41	LLMid: Dist: 600.00	-20	-4	-4	263	-884	-31
87	50	LLMid: Dist: 600.00	20	4	4	-263	967	-51
87	50	LLMid: Dist: 440.00	2	-4	52	140	1886	60
113	2	LLMid: Dist: 325.00	112	1	-26	-78	1882	66
113	2	LLMid: Dist: 420.00	106	-1	19	59	1245	49
113	1	LLMid: Dist: 420.00	-106	1	-19	-59	-1607	-65
113	1	LLMid: Dist: 340.00	-121	-1	31	80	-1772	-52
117	17	LLMid: Dist: 405.00	81	7	-43	-346	1189	110
117	17	LLMid: Dist: 610.00	-46	-3	-8	88	-510	-47
117	23	LLMid: Dist: 610.00	46	3	8	-88	668	-2
117	23	LLMid: Dist: 405.00	-81	-7	43	346	-363	28
118	23	LLMid: Dist: 415.00	58	8	-45	-358	479	110
118	23	LLMid: Dist: 610.00	-40	-3	-9	120	-590	-48
118	29	LLMid: Dist: 610.00	40	3	9	-120	759	-14
118	29	LLMid: Dist: 415.00	-58	-8	45	358	384	50
143	37	LLMid: Dist: 435.00	7	10	-49	-358	-923	71
143	37	LLMid: Dist: 615.00	-26	-5	-11	115	-846	-28
143	44	LLMid: Dist: 615.00	26	5	11	-115	1060	-59
143	44	LLMid: Dist: 435.00	-7	-10	49	358	1866	117
170	6	LLMid: Dist: 325.00	-11	0	-23	-73	2367	65
170	6	LLMid: Dist: 420.00	-8	0	21	57	1685	68
170	5	LLMid: Dist: 420.00	8	0	-21	-57	-2109	-64
170	5	LLMid: Dist: 325.00	11	0	23	73	-1898	-70
174	21	LLMid: Dist: 400.00	13	6	-50	-330	1383	106
174	21	LLMid: Dist: 610.00	0	-3	-4	84	-737	-58
174	27	LLMid: Dist: 610.00	0	3	4	-84	821	-6
174	27	LLMid: Dist: 400.00	-13	-6	50	330	-376	7
175	27	LLMid: Dist: 415.00	26	7	-56	-341	607	103
175	27	LLMid: Dist: 605.00	2	-4	-4	116	-852	-60
175	33	LLMid: Dist: 605.00	-2	4	4	-116	928	-20
175	33	LLMid: Dist: 415.00	-26	-7	56	341	512	32
177	39	LLMid: Dist: 440.00	68	9	-61	-273	-1713	54
177	39	LLMid: Dist: 605.00	8	-6	-2	222	-864	-33
177	45	LLMid: Dist: 605.00	-8	6	2	-222	904	-78
177	45	LLMid: Dist: 440.00	-68	-9	61	273	2931	122

**RESULT ENVELOPE :Member End Forces (Local) @ Moment Y (kips-ft)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	LLMid: Dist: 130.00	20	0	3	1	-259	-29
80	12	LLMid: Dist: 365.00	-19	0	9	-46	2570	62
80	11	LLMid: Dist: 385.00	19	0	-3	-38	-2348	-60
80	11	LLMid: Dist: 605.00	-20	0	3	-3	255	28
84	25	LLMid: Dist: 605.00	4	-3	-3	81	-532	-47
84	25	LLMid: Dist: 445.00	-3	3	-46	-217	1806	61
84	31	LLMid: Dist: 470.00	1	-2	19	128	-1006	-2
84	31	LLMid: Dist: 605.00	-4	3	3	-81	587	-5
85	31	LLMid: Dist: 605.00	-3	-3	-3	113	-618	-48
85	31	LLMid: Dist: 465.00	1	3	-49	-204	1354	47
85	35	LLMid: Dist: 490.00	-3	-2	21	105	-555	2
85	35	LLMid: Dist: 355.00	17	-5	31	245	808	19
87	41	LLMid: Dist: 380.00	-3	6	-38	-85	-1201	40
87	41	LLMid: Dist: 510.00	2	0	-22	-40	394	4
87	50	LLMid: Dist: 130.00	4	3	-2	46	-340	-38
87	50	LLMid: Dist: 405.00	4	-5	44	116	2052	74
113	2	LLMid: Dist: 130.00	-54	0	7	-1	-297	-35
113	2	LLMid: Dist: 355.00	127	0	4	-27	2434	65
113	1	LLMid: Dist: 375.00	-128	0	2	18	-2665	-65
113	1	LLMid: Dist: 605.00	53	0	6	-5	294	34
117	17	LLMid: Dist: 605.00	-46	-3	-8	88	-511	-47
117	17	LLMid: Dist: 435.00	76	6	-13	-276	1559	89
117	23	LLMid: Dist: 455.00	-64	-4	-12	198	-1443	14
117	23	LLMid: Dist: 605.00	46	3	8	-88	670	-2
118	23	LLMid: Dist: 605.00	-40	-3	-9	120	-592	-48
118	23	LLMid: Dist: 455.00	50	6	13	-231	1079	78
118	29	LLMid: Dist: 475.00	-39	-4	-6	186	-884	25
118	29	LLMid: Dist: 350.00	-56	-8	25	258	785	45
143	37	LLMid: Dist: 380.00	7	11	-31	-289	-1299	81
143	37	LLMid: Dist: 130.00	-9	-5	4	-16	300	-36
143	44	LLMid: Dist: 130.00	9	5	-4	16	-384	-55
143	44	LLMid: Dist: 405.00	-7	-11	38	334	1969	129
170	6	LLMid: Dist: 130.00	-9	0	5	0	-366	-38
170	6	LLMid: Dist: 355.00	-23	0	8	-38	3321	71
170	5	LLMid: Dist: 375.00	24	0	-2	-14	-3335	-75
170	5	LLMid: Dist: 605.00	9	0	5	-4	361	38
174	21	LLMid: Dist: 605.00	0	-3	-4	84	-738	-58
174	21	LLMid: Dist: 435.00	-3	5	-19	-271	2241	87
174	27	LLMid: Dist: 455.00	8	-4	24	195	-1617	4
174	27	LLMid: Dist: 605.00	0	3	4	-84	822	-6
175	27	LLMid: Dist: 605.00	2	-4	-4	116	-852	-60
175	27	LLMid: Dist: 455.00	5	5	-25	-266	1593	73
175	33	LLMid: Dist: 475.00	1	-4	28	181	-909	16
175	33	LLMid: Dist: 350.00	-42	-8	36	248	1073	39
177	39	LLMid: Dist: 380.00	84	12	-43	-201	-2335	85
177	39	LLMid: Dist: 130.00	-28	-7	6	-42	605	-55
177	45	LLMid: Dist: 130.00	28	7	-6	42	-720	-79
177	45	LLMid: Dist: 400.00	-82	-11	49	238	3274	151

**RESULT ENVELOPE :Member End Forces (Local) @ Force Z (kips)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	LLIn: Dist: 345.00	-20	-1	-26	23	2290	54
80	12	LLIn: Dist: 380.00	-19	0	35	-143	2179	68
80	11	LLIn: Dist: 400.00	21	-1	-29	43	-2117	-52
80	11	LLIn: Dist: 365.00	19	0	32	-74	-2108	-65
84	25	LLIn: Dist: 425.00	-7	3	-49	-178	1606	65
84	25	LLIn: Dist: 460.00	-1	3	15	-311	1404	56
84	31	LLIn: Dist: 480.00	1	-2	-11	163	-899	2
84	31	LLIn: Dist: 450.00	2	-3	55	84	-902	-5
85	31	LLIn: Dist: 450.00	0	3	-54	-149	1243	51
85	31	LLIn: Dist: 480.00	3	2	12	-283	1006	39
85	35	LLIn: Dist: 500.00	-2	-1	-8	120	-497	3
85	35	LLIn: Dist: 470.00	-3	-2	58	62	-396	4
87	41	LLIn: Dist: 490.00	3	1	-59	40	221	4
87	41	LLIn: Dist: 520.00	-1	0	6	-72	218	-4
87	50	LLIn: Dist: 140.00	4	3	-3	36	-335	-37
87	50	LLIn: Dist: 510.00	-5	0	63	-135	628	-10
113	2	LLIn: Dist: 325.00	114	1	-27	0	1961	66
113	2	LLIn: Dist: 360.00	129	0	34	-41	2368	63
113	1	LLIn: Dist: 375.00	-128	0	-30	27	-2693	-65
113	1	LLIn: Dist: 345.00	-125	-1	33	-29	-2010	-54
117	17	LLIn: Dist: 400.00	82	7	-43	-236	1167	110
117	17	LLIn: Dist: 435.00	75	6	17	-253	1526	86
117	23	LLIn: Dist: 455.00	-63	-4	-11	203	-1393	14
117	23	LLIn: Dist: 420.00	-80	-6	50	200	-769	26
118	23	LLIn: Dist: 420.00	58	8	-49	-238	688	105
118	23	LLIn: Dist: 455.00	49	6	11	-236	1039	75
118	29	LLIn: Dist: 475.00	-37	-4	-5	178	-843	24
118	29	LLIn: Dist: 440.00	-54	-7	55	191	-201	45
143	37	LLIn: Dist: 460.00	9	8	-60	-200	-330	58
143	37	LLIn: Dist: 130.00	-8	-5	4	-7	296	-35
143	44	LLIn: Dist: 130.00	8	5	-4	7	-371	-54
143	44	LLIn: Dist: 480.00	-9	-6	68	127	975	66
170	6	LLIn: Dist: 335.00	-16	0	-27	7	2812	70
170	6	LLIn: Dist: 370.00	-24	0	35	-87	3153	76
170	5	LLIn: Dist: 390.00	20	0	-29	36	-3113	-76
170	5	LLIn: Dist: 355.00	23	0	32	-53	-2913	-73
174	21	LLIn: Dist: 415.00	4	6	-55	-208	1895	101
174	21	LLIn: Dist: 450.00	-7	4	9	-261	1960	79
174	27	LLIn: Dist: 130.00	18	3	-6	-15	-240	-9
174	27	LLIn: Dist: 435.00	4	-5	60	145	-1296	10
175	27	LLIn: Dist: 435.00	14	6	-61	-202	1250	91
175	27	LLIn: Dist: 130.00	-20	-4	7	5	233	-61
175	33	LLIn: Dist: 130.00	20	4	-7	-5	-366	-24
175	33	LLIn: Dist: 455.00	-4	-5	65	129	-549	27
177	39	LLIn: Dist: 475.00	39	6	-68	-75	-466	37
177	39	LLIn: Dist: 130.00	-27	-6	6	-32	592	-53
177	45	LLIn: Dist: 130.00	27	6	-6	32	-703	-77
177	45	LLIn: Dist: 495.00	-24	-3	71	-14	1056	34

**RESULT ENVELOPE :Member End Forces (Local) @ Moment X (kips-ft)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	LLIn: Dist: 380.00	-19	0	35	-143	2179	68
80	12	LLIn: Dist: 345.00	-20	-1	-26	23	2290	54
80	11	LLIn: Dist: 380.00	19	0	29	-119	-2298	-61
80	11	LLIn: Dist: 400.00	21	-1	-29	43	-2117	-52
84	25	LLIn: Dist: 460.00	-1	3	15	-311	1404	56
84	25	LLIn: Dist: 605.00	4	-2	-3	70	-512	-45
84	31	LLIn: Dist: 605.00	-4	2	3	-70	572	-5
84	31	LLIn: Dist: 385.00	17	-3	39	220	-45	-6
85	31	LLIn: Dist: 480.00	3	2	12	-283	1006	39
85	31	LLIn: Dist: 605.00	-3	-3	-3	101	-596	-47
85	35	LLIn: Dist: 605.00	3	3	3	-101	655	-16
85	35	LLIn: Dist: 400.00	12	-4	43	224	554	13
87	41	LLIn: Dist: 520.00	-1	0	6	-72	218	-4
87	41	LLIn: Dist: 600.00	-20	-4	-4	243	-860	-31
87	50	LLIn: Dist: 525.00	-1	1	60	-247	372	-23
87	50	LLIn: Dist: 425.00	3	-4	48	39	1924	61
113	2	LLIn: Dist: 360.00	129	0	34	-41	2368	63
113	2	LLIn: Dist: 235.00	25	0	-5	21	201	16
113	1	LLIn: Dist: 360.00	-129	0	30	-50	-2522	-58
113	1	LLIn: Dist: 385.00	-126	0	-28	30	-2466	-68
117	17	LLIn: Dist: 420.00	80	6	-10	-257	1566	98
117	17	LLIn: Dist: 605.00	-44	-2	-8	76	-498	-45
117	23	LLIn: Dist: 605.00	44	2	8	-76	646	-1
117	23	LLIn: Dist: 385.00	-82	-7	39	240	-105	25
118	23	LLIn: Dist: 400.00	59	8	-42	-250	290	114
118	23	LLIn: Dist: 605.00	-39	-3	-8	107	-577	-47
118	29	LLIn: Dist: 605.00	39	3	8	-107	735	-13
118	29	LLIn: Dist: 400.00	-59	-8	42	250	524	49
143	37	LLIn: Dist: 420.00	7	10	-46	-248	-1038	77
143	37	LLIn: Dist: 620.00	-24	-4	-10	97	-807	-27
143	44	LLIn: Dist: 620.00	24	4	10	-97	1006	-55
143	44	LLIn: Dist: 420.00	-7	-10	46	248	1928	118
170	6	LLIn: Dist: 370.00	-24	0	35	-87	3153	76
170	6	LLIn: Dist: 235.00	3	0	-3	19	225	18
170	5	LLIn: Dist: 370.00	24	0	29	-89	-3293	-76
170	5	LLIn: Dist: 390.00	20	0	-29	36	-3113	-76
174	21	LLIn: Dist: 450.00	-7	4	9	-261	1960	79
174	21	LLIn: Dist: 605.00	0	-3	-4	73	-716	-56
174	27	LLIn: Dist: 605.00	0	3	4	-73	797	-6
174	27	LLIn: Dist: 390.00	-16	-6	48	232	-257	10
175	27	LLIn: Dist: 400.00	31	8	-53	-240	364	113
175	27	LLIn: Dist: 605.00	2	-4	-4	104	-827	-58
175	33	LLIn: Dist: 605.00	-2	4	4	-104	899	-19
175	33	LLIn: Dist: 400.00	-31	-8	53	240	687	38
177	39	LLIn: Dist: 425.00	74	10	-57	-149	-1905	73
177	39	LLIn: Dist: 600.00	8	-5	-2	216	-832	-32
177	45	LLIn: Dist: 600.00	-8	5	2	-216	868	-75
177	45	LLIn: Dist: 425.00	-74	-10	57	149	3056	132

**RESULT ENVELOPE :Member End Forces (Local) @ Moment Y (kips-ft)**

Member	Joint	Result Case	Force X (kips)	Force Y (kips)	Force Z (kips)	Moment X (kips-ft)	Moment Y (kips-ft)	Moment Z (kips-ft)
80	12	LLIn: Dist: 130.00	19	0	4	9	-254	-28
80	12	LLIn: Dist: 360.00	-19	0	-22	20	2555	60
80	11	LLIn: Dist: 385.00	20	-1	-2	-18	-2312	-58
80	11	LLIn: Dist: 600.00	-19	0	4	5	250	27
84	25	LLIn: Dist: 605.00	4	-2	-3	70	-512	-45
84	25	LLIn: Dist: 440.00	-4	3	-45	-167	1788	61
84	31	LLIn: Dist: 465.00	1	-3	18	137	-1042	-2
84	31	LLIn: Dist: 600.00	-4	2	3	-69	572	-5
85	31	LLIn: Dist: 605.00	-3	-3	-3	101	-596	-47
85	31	LLIn: Dist: 465.00	2	2	-17	-256	1355	45
85	35	LLIn: Dist: 485.00	-3	-2	20	106	-587	4
85	35	LLIn: Dist: 355.00	17	-5	30	180	770	18
87	41	LLIn: Dist: 375.00	-3	6	-35	-10	-1183	42
87	41	LLIn: Dist: 505.00	4	0	-53	64	435	5
87	50	LLIn: Dist: 130.00	4	3	-3	38	-338	-37
87	50	LLIn: Dist: 400.00	4	-5	42	30	1992	71
113	2	LLIn: Dist: 130.00	-52	0	6	9	-284	-34
113	2	LLIn: Dist: 355.00	128	0	3	-8	2460	64
113	1	LLIn: Dist: 375.00	-128	0	-30	27	-2693	-65
113	1	LLIn: Dist: 605.00	51	0	6	4	281	33
117	17	LLIn: Dist: 600.00	-44	-2	-8	76	-498	-45
117	17	LLIn: Dist: 430.00	77	6	-14	-225	1570	91
117	23	LLIn: Dist: 450.00	-67	-5	20	169	-1436	17
117	23	LLIn: Dist: 605.00	44	2	8	-76	646	-1
118	23	LLIn: Dist: 600.00	-39	-3	-8	106	-577	-46
118	23	LLIn: Dist: 450.00	51	6	-19	-211	1095	80
118	29	LLIn: Dist: 470.00	-41	-5	26	146	-898	28
118	29	LLIn: Dist: 350.00	-57	-8	28	189	779	45
143	37	LLIn: Dist: 375.00	8	11	-32	-203	-1258	82
143	37	LLIn: Dist: 130.00	-8	-5	4	-7	296	-35
143	44	LLIn: Dist: 130.00	8	5	-4	7	-371	-54
143	44	LLIn: Dist: 405.00	-7	-11	41	242	1964	124
170	6	LLIn: Dist: 130.00	-9	0	5	9	-354	-37
170	6	LLIn: Dist: 355.00	-23	0	8	-57	3317	73
170	5	LLIn: Dist: 375.00	24	0	-2	-21	-3323	-77
170	5	LLIn: Dist: 605.00	9	0	5	5	349	36
174	21	LLIn: Dist: 605.00	0	-3	-4	73	-716	-56
174	21	LLIn: Dist: 430.00	-3	5	-51	-191	2238	92
174	27	LLIn: Dist: 455.00	8	-4	24	146	-1613	4
174	27	LLIn: Dist: 605.00	0	3	4	-73	797	-6
175	27	LLIn: Dist: 605.00	2	-4	-4	104	-827	-58
175	27	LLIn: Dist: 450.00	6	5	-56	-177	1598	78
175	33	LLIn: Dist: 475.00	1	-4	29	119	-922	15
175	33	LLIn: Dist: 345.00	-42	-8	35	172	1044	42
177	39	LLIn: Dist: 380.00	83	12	-44	-114	-2285	93
177	39	LLIn: Dist: 130.00	-27	-6	6	-32	592	-53
177	45	LLIn: Dist: 130.00	27	6	-6	32	-703	-77
177	45	LLIn: Dist: 400.00	-81	-12	50	138	3216	149

Longitudinal Stresses:

@ Midpoint of Span 2:

Table B-9 - Longitudinal Member Forces – Inside of Curve (LARSA Member 113)

Load	P <sub>x</sub> (kips)	M <sub>y</sub> (ft.-kips)	M <sub>z</sub> (ft.-kips)
DC	593	15,642	252
DW	116	3,027	49
PS <sub>FINAL</sub>	3,289	-11,180	-266
LL <sub>TRUCK</sub> + IM	128	2,460	64
LL <sub>LANE</sub>	217	2,897	115
DC+DW+PS <sub>FINAL</sub>	3,998	7,489	35
DC+DW+PS <sub>FINAL</sub> +LL+IM	4,343	12,846	214

Table B-10 - Longitudinal Member Forces – Outside of Curve (LARSA Member 80)

Load	P <sub>x</sub> (kips)	M <sub>y</sub> (ft.-kips)	M <sub>z</sub> (ft.-kips)
DC	-4	14,846	257
DW	-1	2,869	50
PS <sub>FINAL</sub>	3,696	-10,333	-268
LL <sub>TRUCK</sub> + IM	-19	2,570	62
LL <sub>LANE</sub>	-48	2,744	110
DC+DW+PS <sub>FINAL</sub>	3,691	7,382	39
DC+DW+PS <sub>FINAL</sub> +LL+IM	3,624	12,696	211

Live Loads adjusted by multiple presence factor and live load dynamic effect.

Stress Calculation:

$$A_x = 27.12$$

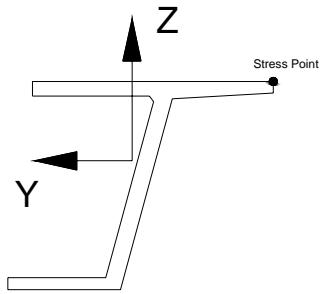
$$S_{ZTOP} = \frac{I_y}{y_t} = \frac{554.1}{4.566} = 121.35$$

$$S_{ZBOTTOM} = \frac{I_y}{y_b} = \frac{554.1}{7.434} = 74.54$$

$$S_{YOUT} = \frac{I_z}{x_{outside}} = \frac{289.8}{8.16} = 35.51 \quad \text{where } x_{outside} = 43/2 - 13.34 = 8.16$$

$$S_{YSOFFIT} = \frac{I_z}{x_{soffit}} = \frac{289.8}{-0.67} = -289.13 \quad \text{where } x_{soffit} = 43/2 - 8.83 - 13.34 = -0.67$$

Maximum Compression – Longitudinal Member – Inside of Curve:



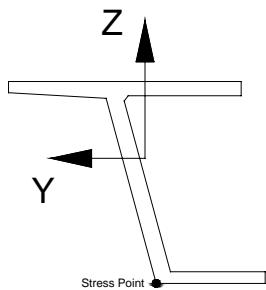
DC+DW+PS<sub>FINAL</sub>:

$$\sigma_c = \frac{P_x}{A_x} + \frac{M_y}{S_y} + \frac{M_z}{S_z} = \frac{3998}{27.12} + \frac{7489}{121.35} + \frac{35}{35.51} = 147.4 + 61.7 + 1.0 = 210.1 \text{ ksf} > 1459 \text{ psi}$$

DC+DW+PSFINAL+LL+IM

$$\sigma_c = \frac{4343}{27.12} + \frac{12,846}{121.35} + \frac{214}{35.51} = 160.1 + 105.9 + 6.0 = 272.0 \text{ ksf} > 1889 \text{ psi}$$

Maximum Tension – Longitudinal Member – Outside of Curve:



DC+DW+PS<sub>FINAL</sub>:

$$\sigma_t = \frac{3691}{27.12} - \frac{7382}{74.54} - \frac{39}{289.13} = 136.1 - 99.0 - 0.1 = 37.0 \text{ ksf} > 257 \text{ psi (C)}$$

DC+DW+PSFINAL+LL+IM

$$\sigma_t = \frac{3624}{27.12} - \frac{12,696}{74.54} - \frac{211}{289.13} = 133.6 - 170.3 - 0.7 = -37.4 \text{ ksf} > -260 \text{ psi}$$

@ Bent 3 - Span 2:

Table B-11 - Longitudinal Member – Outside of Curve (LARSA Member 87)

Load	$P_x$ (kips)	$M_y$ (ft.-kips)	$M_z$ (ft.-kips)
DC	-199	-28,237	189
DW	-34	-5608	38
$PS_{FINAL}$	4,200	22,559	-211
$LL_{TRUCK} + IM$	-4	-2,112	-79
$LL_{LANE}$	-30	-4,340	-31
$DC+DW+PS_{FINAL}$	3,967	-11,286	438
$DC+DW+PS_{FINAL}+LL+IM$	3,933	-17,738	328

Table B-12 - Longitudinal Member – Inside of Curve (LARSA Member 143)

Load	$P_x$ (kips)	$M_y$ (ft.-kips)	$M_z$ (ft.-kips)
DC	-160	-27,205	-683
DW	-26	-5,357	-134
$PS_{FINAL}$	4,172	25,089	528
$LL_{TRUCK} + IM$	5	-1,975	-132
$LL_{LANE}$	-27	-4,088	-101
$DC+DW+PS_{FINAL}$	3,986	-7,473	-289
$DC+DW+PS_{FINAL}+LL+IM$	3,964	-13,536	-522

Live Loads adjusted by multiple presence factor and live load dynamic effect.

Stress Calculation:

$$A_x = 33.03$$

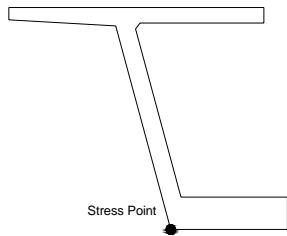
$$S_{ZTOP} = \frac{I_y}{y_t} = \frac{740.9}{5.675} = 130.56$$

$$S_{ZBOTTOM} = \frac{I_y}{y_b} = \frac{740.9}{6.325} = 117.14$$

$$S_{YOUT} = \frac{I_z}{x_{outside}} = \frac{388.8}{8.91} = 43.64 \quad \text{where } x_{outside} = 43/2 - 12.59 = 8.91$$

$$S_{YSOFFIT} = \frac{I_z}{x_{soffit}} = \frac{289.8}{0.08} = 3623 \quad \text{where } x_{soffit} = 43/2 - 8.83 - 12.59 = 0.08$$

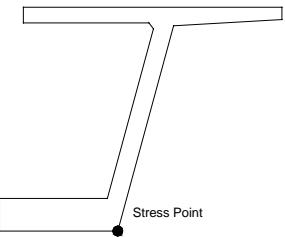
Maximum Compression – Longitudinal Member – Outside of Curve:



DC+DW+PS<sub>FINAL</sub>:

$$\sigma_c = \frac{P_x}{A_x} + \frac{M_y}{S_y} + \frac{M_z}{S_z} = \frac{3967}{33.03} + \frac{11,286}{117.14} + \frac{438}{3623} = 120.1 + 96.3 + 0.1 = 216.5 \text{ ksf} > 1503 \text{ psi}$$

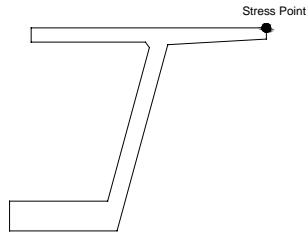
Maximum Compression – Longitudinal Member – Inside of Curve:



DC+DW+PS<sub>FINAL</sub>+LL+IM

$$\sigma_c = \frac{3933}{33.03} + \frac{17,738}{117.14} - \frac{328}{3623} = 119.1 + 151.4 - 0.1 = 270.4 \text{ ksf} > 1878 \text{ psi}$$

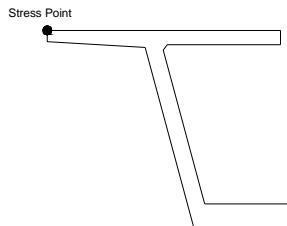
Maximum Tension – Longitudinal Member – Inside of Curve:



DC+DW+PS<sub>FINAL</sub>:

$$\sigma_t = \frac{3967}{33.03} - \frac{11,286}{130.56} - \frac{438}{3623} = 120.1 - 86.4 - 0.1 = 33.6 \text{ ksf} > 223 \text{ psi (C)}$$

Maximum Tension – Longitudinal Member – Outside of Curve:



DC+DW+PSFINAL+LL+IM

$$\sigma_t = \frac{3964}{33.03} - \frac{13536}{130.56} + \frac{522}{3623} = 120.0 - 103.7 + 0.1 = 16.4 \text{ ksf} > 114 \text{ psi}$$

Comparison of Longitudinal Stresses:

Table B-13 – Comparison of Spine and Grillage Model Stresses

Section	Load	Compression (psi)		Tension (psi)	
		Spine	Grillage	Spine	Grillage
Midspan	DC+DW+PS <sub>F</sub>	1556	1459	203	257
	DC+DW+PS <sub>F</sub> +LL+IM	1953	1889	-403	-260
Bent 3	DC+DW+PS <sub>F</sub>	1262	1503	399	223
	DC+DW+PS <sub>F</sub> +LL+IM	1863	1878	-218	114

- Responses for the live load for whole-width design are reported for the spine beam analysis. The results for the worst-case live loading are reported for the grillage analysis.

### Shear @ 0.8 Pt of Span 2:

Shear in the webs at this location is checked for comparison with the results from the spine beam analysis. This requires a correction of the shear carried by the longitudinal grillage members to account for residual torsion that is generated as an artifact of the grillage model. This residual torsion is carried in the individual longitudinal members. These member torsions must be added together and reapplied to the total section of the bridge, which results in a shear flow about the perimeter of the section and increases the shear in one exterior web and decreases it in the other. This torsional component of shear in a box section is included in AASHTO LRFD Equation 5.8.2.1-6 and is given below as follows

$$V_{\text{correction}} = \frac{\sum T_u d_s}{2A_0} = 0.0188 \sum T_u$$

For example, consider DC+DW+ES in Table B-14:

$$V_{\text{correction}} = 0.188 \cdot (1383 + 1107 + 1403) = 0.0188 \cdot 3893 = 73.2 \text{ kips}$$

Table B-14 – Residual Torsions and Shear Correction

Load	Residual Torsion from LARSA - $M_x$			Unfactored $V_{\text{correction}}$	Factored $V_{\text{correction}}$
	Outside	Interior	Inside		
DC	2185	2340	2466	131	164
DW	433	465	486	26	39
EL	-1412	-1592	-1524	-72	-72
LLTRUCK+IM <sup>(1)</sup>	407	486	262	22	38
LLLANE <sup>(2)</sup>	392	416	214	19	34
DC+DW+ES	1206	1213	1428	85	131
DC+DW+ES+LL+IM	2005	2115	1904	113	198

1. Adjust LARSA results by 1.33 for impact plus 0.9 for multiple presence – CF = 1.197
2. Adjust LARSA results by 0.90 for multiple presence
3. EL is  $M_x$  for Secondary Prestress

4. Shear @ 0.8 Pt. Of Span 2:

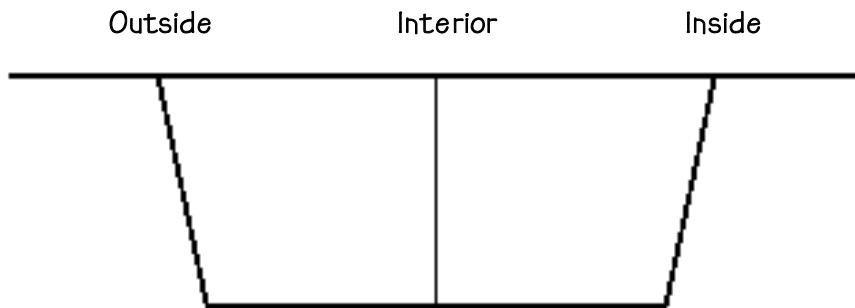


Figure B-30 – Web Locations

Table B-15 – LARSA Web Shears ± Torsion Correction

Load	Outside	Interior	Inside
DC	653	564	192
DW	141	96	62
EL	46	-43	74
LL <sub>TRUCK+IM</sub> <sup>(1)</sup>	147	128	74
LL <sub>LANE</sub> <sup>(2)</sup>	131	107	44
DC+DW+EL	840	617	328
DC+DW+EL+LL+IM	1118	852	446

1. Adjust LARSA results by 1.33 for impact plus 0.9 for multiple presence – CF = 1.197
2. Adjust LARSA results by 0.90 for multiple presence
3. EL is the difference between PS<sub>FINAL</sub> and the Primary Prestress Force as calculated on the previous page.

Table B-16 - Comparison of Factored Web Shears from Spine and Grillage Models

Model	Outside	Interior	Inside
Spine	1290	907	524
Grillage	1118	852	446

Spine results are for Case 2 for maximum shear and does not include the minimum shear on the inside web. Grillage results reflect the worst-case loading and more accurately reflect the minimum shear on the inside web.

Bearing Forces at Abutment 4 (Allowable Stress Design):

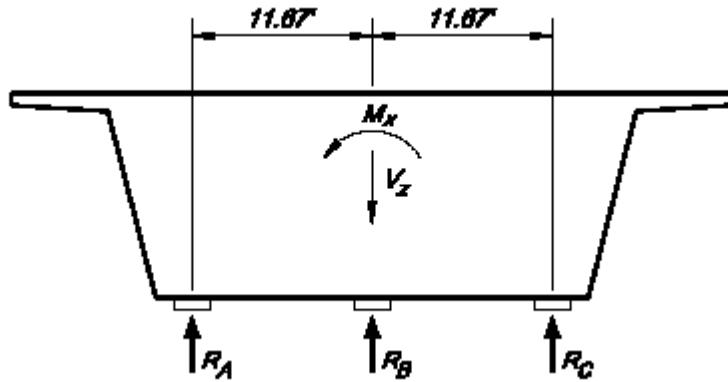


Figure B-31 – Abutment Bearing Reactions

Table B-17 – Abutment Bearing Reactions from Grillage Analysis (Unfactored)

Load	RA	RB	RC
DC	490	365	204
DW	106	32	0
PSFINAL	183	-1	-75
LLTRUCK+IM (Max)	124	69	63
LLLANE (Max)	123	45	51
LLTRUCK+IM (Min)	-40	-7	-34
LLLANE (Min)	-46	-8	-24
DC+DW+PS	779	396	129
DC+DW+PS+LL+IM (Max)	1026	510	243
DC+DW+PS+LL+IM (Min)	693	381	71

Table B-18 – Comparison of Bearing Reactions from Spine and Grillage Models

Load	Model	RA	RB	RC
DC+DW+PS	Spine	747	442	137
	Grillage	779	396	129
DC+DW+PS+LL+IM	Spine	920	532	144
	Grillage (Max)	1026	510	243
	Grillage (Min)	693	381	71

Spine beam results for live load are for the maximum torsion case. This corresponds most closely to the maximum results for the grillage analysis.

## EXAMPLE B-2 - TENDON CONFINEMENT EVALUATION

### Introduction

The primary purpose of the following numerical example is to demonstrate the recommended approach to evaluate a web without web and duct ties for tendon pull out and for tensile stresses on the cover concrete.

This example also presents the application of a 2-d frame analysis of the box girder to determine the regional moments due to lateral prestress forces. Note that a frame analysis is not required by the specifications. The designer has the option of applying equation 5.10.4.3.1-6 to calculate a more conservative estimate of the regional moments.

### Construction Method

The example problem assumes a continuous cast-in-place box girder constructed on falsework.

### Concrete Strength

The example assumes a concrete strength of 3.5 ksi at transfer. In practice, the required strength will be dictated by design and local requirements.

### Post-tensioning System

The prestress force, post-tensioning supplier, and the tendon arrangement were assumed for the purpose of demonstrating the procedure. In practice, the designer needs to consider permissible variations in prestress force between girders and a variety of tendon arrangements to determine the critical condition.

### Comments

The following should be noted:

- The box girder is a fairly deep section (10'-6").
- The jacking force is relatively high (over 3400 kips per web).
- The radius is relatively large (3000-feet) and the resulting  $F_{u-in}$  of 1.4 k/ft is relatively small.
- The shear force exerted on the cover concrete is well below its capacity.
- The tensile stresses in the cover concrete due to combined local and regional bending are fairly high even though the radius is relatively large. This is due to the combination of the large number of bundled ducts and the large height of the webs. Transverse moments due to dead and live loads and the effects of construction tolerances, which can be significant, were ignored for this example.
- Note that the regional moments in the exterior webs are 9% higher than the interior web even though the interior web has a 4% higher prestress force.

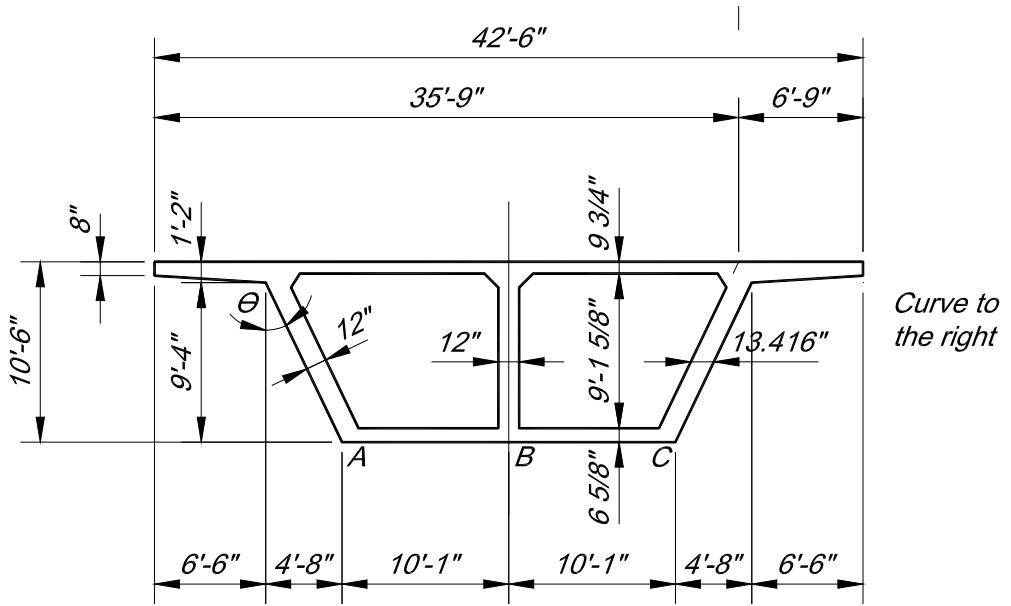


Figure B-32 - Typical Section (Looking Upstation)

CONCRETE:  $f_{ci} = 3.5 \text{ ksi}$

STIRRUPS: #6 Grade 60  
2-1/2" Cover to stirrups  
3-1/4" Cover to ducts

PRESTRESSING:  $f_{pu} = 270 \text{ ksi}$   
Jacking stress =  $0.75f_{pu}$

0.6" diameter strands  
 $A_{ps} = 0.217 \text{ in}^2 \text{ per strand}$

Jacking Force =  $P_j = 10,400 \text{ kips}$

Assumed Tendon Arrangement:

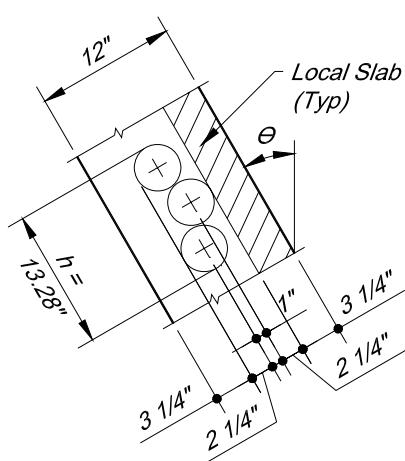
Required number of strands =  $10,400 / (0.75 \times 270 \times 0.217) = 237$  strands

Assume (3) 26 - 0.6" tendons @ A & C - (4-1/2" duct)

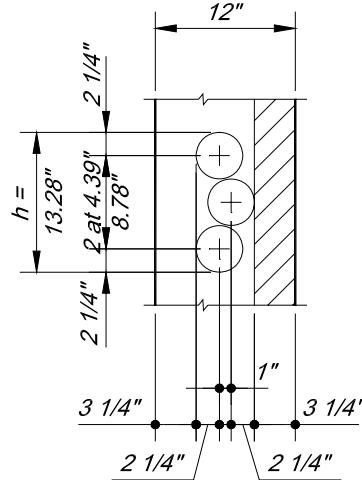
Assume (3) 27 - 0.6" tendons @ B - (4-1/2" duct)

$$A \text{ or } C \quad P_j = 3 \times 26 \times 0.217 \times 0.75 \times 270 = 3428 \text{ kips}$$

$$B \quad P_j = 3 \times 27 \times 0.217 \times 0.75 \times 270 = 3559 \text{ kips}$$



Web A (C similar)



Web B

Figure B-33 – Tendon Geometry at Webs

Table B-19 – Web Transverse Prestress Forces

Web	$P_j$	R	$P_j/R$	$\theta$	$P_j \cos \theta / R$	$P_j \cos \theta / R h_{ds}$
	kips	ft	kips/ft	degrees	kips/ft	kips/in/ft
A	3428	3026.65	1.133	26.6	1.013	0.0763
B	3559	3014.5	1.181	0	1.181	0.0889
C	3428	3002.35	1.142	26.6	1.021	0.0769

Where:

$P_j$  = Unfactored jacking force in web

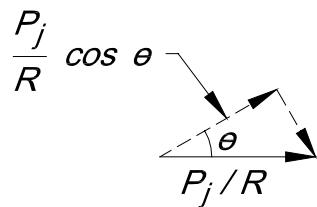
$R$  = Horizontal radius of web

$\theta$  = Slope of web from vertical

$h_{ds}$  = Height of duct bundle

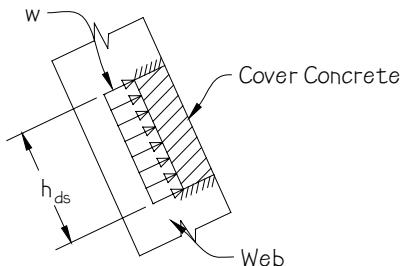
The lateral prestress force normal to the web is given by:

$$F = \frac{P_j \cos \theta}{R}$$



The resulting load acting on the cover concrete is approximated as a uniform load:

$$w = \frac{F}{h_{ds}} = \frac{P_j \cos \theta}{R h_{ds}}$$



Check Shear on Local Slab (LRFD 5.10.4.3.1a):

$$d_{\text{eff}} = \text{Cover to duct} + \text{duct dia.}/4 = 3.25 + 4.5/4 = 4.38 \text{ in}$$

$$V_n = 0.125 d_{\text{eff}} \sqrt{f_{ci}'} = 0.125 \cdot 4.38 \sqrt{3.5} = 1.02 \text{ kips/in} > 12.3 \text{ kips/ft}$$

$$V_r = \phi V_n = 0.9 \cdot 12.3 = 11.0 \text{ kips/ft}$$

$$F_{u-in} = 1.2 P_j / R \cos \theta = 1.2 \cdot 1.181 = 1.4 \text{ kips/ft} \text{ (Web B controls)}$$

$$F_{u-in} \ll V_r \quad \text{OK}$$

Shear capacity is adequate to resist tendon pullout.

Stresses Due to Prestressing (Unfactored):

Check point on tendon path that causes largest regional moment (i.e. cgs is at mid-clear height of web).

Section Properties:

$A = 11041 \text{ in}^2$	$A \text{ of top slab} = 5158 \text{ in}^2$
$I_y = 23.955 \times 10^6 \text{ in}^4$	$A \text{ of webs} = 4257 \text{ in}^2$
$y_t = 45.34 \text{ in}$	$A \text{ of bottom slab} = 1625 \text{ in}^2$
$y_b = 80.66 \text{ in}$	

Note: Calculations for section properties not included for brevity.

$$f = \frac{P}{A} \pm \frac{Pec}{I_y}$$

where:

$$P = P_j = 10,400 \text{ kips}$$

$$e = 80.66'' - 61.44'' = 19.22''$$

c = Distance from cgc

Table B-20 – Longitudinal stresses due to prestressing

Location	c	f (ksi)
CG of top slab	40.22"	0.606
Top of web	35.59	0.645
Bottom of web	74.04"	1.560
CG of bottom slab	77.28"	1.587

Check Resultant Forces:

$$\begin{aligned}
 \text{Top slab} & 0.606 \times 5158 & = 3126 \text{ kips} \\
 \text{Webs} & \frac{1}{2} (0.645 + 1.560) \times 4257 & = 4693 \text{ kips} \\
 \text{Bottom slab} & 1.587 \times 1625 & = \underline{2579 \text{ kips}} \\
 \text{Total} & & = 10,390 \sim P_j \text{ OK}
 \end{aligned}$$

#### Horizontal Forces (Unfactored):

Radial components of concrete compressive stresses due to  $P_j$  acting on a 1' strip.

Top slab:

$$C/R = 3126/3014.5 = 1.037 \text{ kips/ft}$$

Left web:

$$\text{Top: } f_{b_w}/R = 0.645 \times 13.42 \times 12/3026.65 = 0.0343 \text{ kips/ft}$$

$$\text{Bot: } f_{b_w}/R = 1.560 \times 13.42 \times 12/3026.65 = 0.0830 \text{ kips/ft}$$

Center web:

$$\text{Top: } f_{b_w}/R = 0.645 \times 12 \times 12/3014.50 = 0.0308 \text{ kips/ft}$$

$$\text{Bot: } f_{b_w}/R = 1.560 \times 12 \times 12/3014.50 = 0.0745 \text{ kips/ft}$$

Right web:

$$\text{Top: } f_{b_w}/R = 0.645 \times 13.42 \times 12/3002.35 = 0.0346 \text{ kips/ft}$$

$$\text{Bot: } f_{b_w}/R = 1.560 \times 13.42 \times 12/3026.65 = 0.0837 \text{ kips/ft}$$

For lateral forces at tendons ( $P_j/R$ ), see Table B-19

Regional Bending of Webs:

Analysis of 1' strip

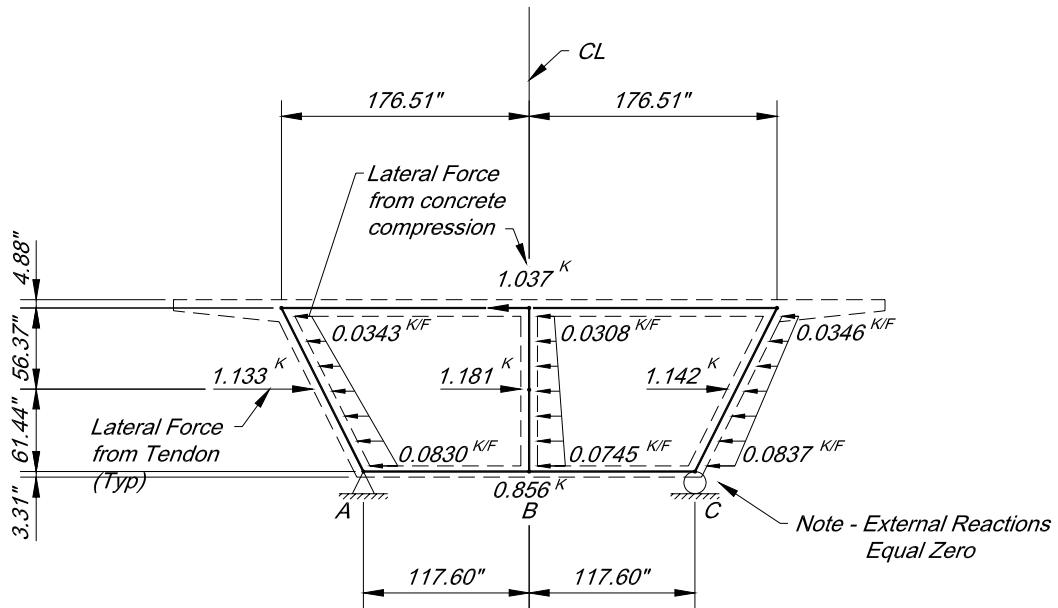


Figure B-34 – Unfactored Loads and Analysis Model

For applied forces refer to Table B – 19 and the previous page.

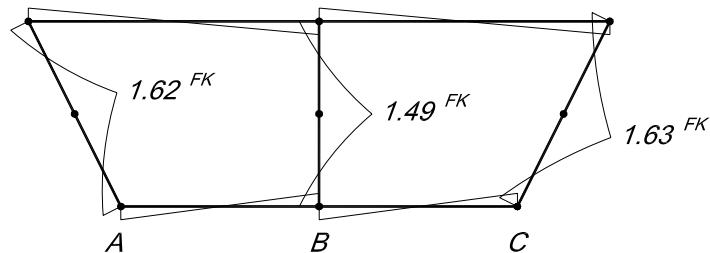
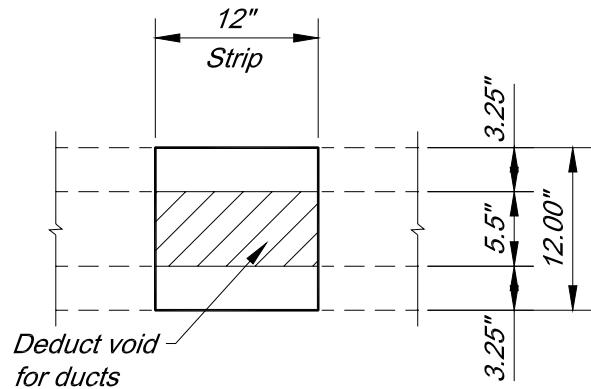


Figure B-35 – Unfactored Moments from Frame Analysis

Note: Input and output of frame analysis not provided for brevity.

Web Section for Regional Bending:



$$I = \frac{12}{12} 12^3 - \frac{12}{12} \cdot 5.5^3 = 1562 \text{ in}^4$$

$$S_w = I/c = 1562/6 = 260 \text{ in}^3$$

Section Modulus of Local Slab (1' Strip):

$$S = 12 \cdot 3.25^2 / 6 = 21.1 \text{ in}^3/\text{ft}$$

Center Web – Combined Stresses (Factored)

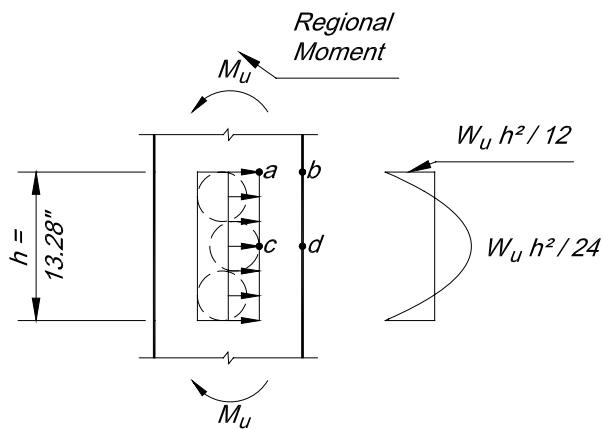


Figure B-36 – Local Stress Points

*Regional Moment :*

$$M_u = 1.2 \cdot 1.49 = 1.79 \text{ ft-kips} = 21.5 \text{ in-kips}$$

*Local Moments*

$$w_u = 1.2 \cdot 0.0889 = 0.11 \text{ kips/in}$$

$$M_l = w_u h_{ds}^2 / 12 = 0.11 \cdot 13.28^2 / 12 = 1.62 \text{ in-kips} @ a \& b$$

$$M_l = w_u h_{ds}^2 / 24 = 0.11 \cdot 13.28^2 / 24 = 0.81 \text{ in-kips} @ c \& d$$

**Check Combined Regional and Local Bending Stresses:**

**Point a:**

$$f_{cu} = \frac{M_u}{S_w} - \frac{M_l}{S_c} = -21.5 \cdot 2.75 / 1562 - 1.62 / 21.1 = -0.038 - 0.077 = -0.115 \text{ ksi Tension}$$

**Point b**

$$f_{cu} = \frac{M_u}{S_w} + \frac{M_l}{S_c} = -21.5 / 260 + 1.62 / 21.1 = -0.083 + 0.077 = -0.006 \text{ ksi Tension}$$

**Point c**

$$f_{cu} = \frac{M_u}{S_w} + \frac{M_l}{S_c} = -21.5 \cdot 2.75 / 1562 + 0.81 / 21.1 = -0.038 + 0.038 = 0 \text{ ksi}$$

**Point d**

$$f_{cu} = \frac{M_u}{S_w} - \frac{M_l}{S_c} = -21.5 / 260 - 0.81 / 21.1 = -0.083 - 0.038 = -0.121 \text{ ksi Tension}$$

**Limiting Stress (Eqn. 5.10.4.3.1-6)**

$$\sigma_{cr} = \phi \sigma_n = 0.55 \cdot 0.16 \sqrt{3.5} = 0.164 \text{ ksi} > f_u = 0.121 \text{ ksi} \quad \text{OK}$$

Tension stresses are less than permitted, so no special web and duct ties are required. However, in sizing stirrups, the effect of regional bending should be added to the effect of flexural and torsion shear as illustrated in Example B-1.



## EXAMPLE B-3 - TENDON CONFINEMENT DESIGN

### Introduction

The primary purpose of the following numerical example is to demonstrate the recommended approach to design reinforcement for a web with web and duct ties.

Calculations are provided for the required steel area of the duct ties, web ties, and vertical stirrup leg on the inside of the curve. Local and regional effects were considered. Transverse moments due to dead and live loads and the effects of construction tolerances were ignored for this example. Global shear and torsion was not considered in the example but must be considered in actual designs.

Equation 5.10.4.3.1-6 was used to determine the regional web moment due to the lateral prestress forces. A 2-d frame analysis of the box girder would have resulted in smaller web moments as demonstrated in Example C-1

### Construction Method

The example problem assumes a continuous cast-in-place box girder constructed on falsework.

### Concrete Strength

The example assumes a concrete strength of 3.5 ksi at transfer and 4.0 ksi at 28 days. In practice, the required strength will be dictated by design and local requirements.

### Post-tensioning System

The prestress force, post-tensioning supplier, and the tendon arrangement were assumed for the purpose of demonstrating the procedure. In practice, the designer needs to consider permissible variations in prestress force between girders and a variety of tendon arrangements to determine the critical condition.

### Comments

The following should be noted:

- The box girder is a fairly deep section (9'-0").
- The jacking force is moderate (approximately 2700 kips per web).
- The radius is relatively small (650-feet) and the resulting  $F_u$ -in of 5.1 kips/ft per web is moderate.
- It is assumed that web and duct ties are required for the purpose of this example. Refer to Example C-1 for the recommended procedure to evaluate the need for web and duct ties.

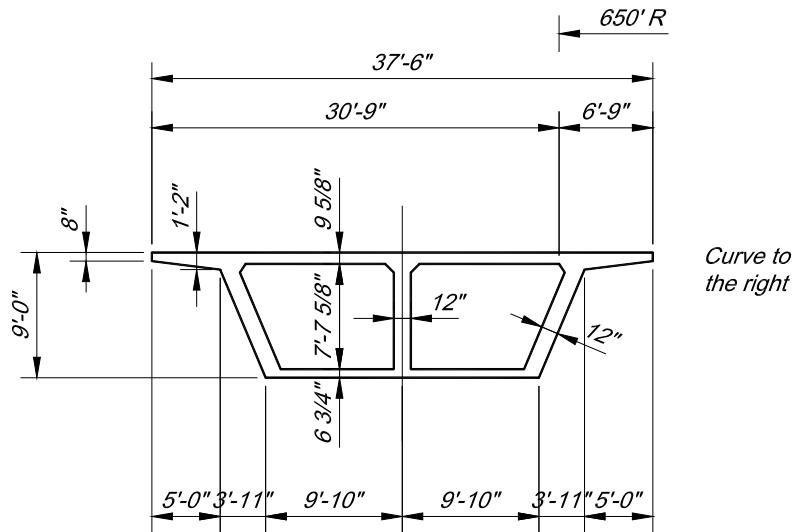


Figure B-37 – Typical Section (Looking Upstation)

CONCRETE:  $f_{ci}' = 3.5 \text{ ksi}$

$f_c' = 4.0 \text{ ksi}$

STIRRUPS: #5 Grade 60

See Figure B-38 for clearances

PRESTRESSING:  $f_{pu} = 270 \text{ ksi}$

Jacking stress =  $0.75f_{pu}$

0.5" diameter strands

$A_{ps} = 0.153 \text{ in}^2$  per strand

Jacking Force =  $P_j = 6,920 \text{ kips}$

### Determine Critical Tendon Arrangement:

Assumptions:

Max Tendon Size = 31 - 0.5"  
Distribution of  $P_j$  = 3:2 ratio max per Caltrans Standard Specifications  
Force Variation = 725 kips maximum

Note: Caltrans requirements are assumed for this example, but designer should use local requirements

Option 1 – Max  $P_j$  at exterior webs

Exterior Web  $P_j$  = 2548 kips  
Interior Web  $P_j$  = 1824 kips  
Force Variation = 724 kips OK  
Force Distribution = 1.4:1 < 3:2 OK

Option 2 – Max  $P_j$  at interior webs

Exterior Web  $P_j$  = 2065 kips  
Interior Web  $P_j$  = 2790 kips  
Force Variation = 725 kips OK  
Force Distribution = 1.35:1 < 3:2 OK

### Check Interior Web Shear for Option 2:

$$P_j = 2790 \text{ kips (max)}$$

$$\text{Number of Strands} = 2790 / (0.75 \times 270 \times 0.153) = 30.05$$

Assume 3 – 30 Strand Tendons

$$P_j = 3 \times 30 \times 0.153 \times 0.75 \times 270 = 2788 \text{ kips}$$

Duct Diameter = 4.13 inches

Centerline Radius = 662'

$$P_j/R = 2788/662 = 4.21 \text{ kips/ft (3 Tendons)} \\ = 1.40 \text{ kips/ft (per Tendon)}$$

Web Reinforcement:

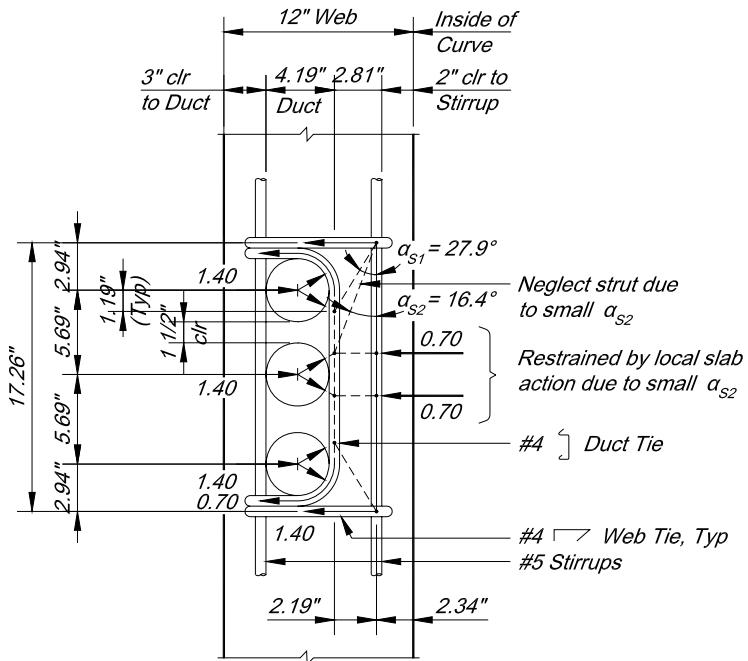


Figure B-38 – Web and Duct Tie Details

Lateral Force at Tendon (Unfactored):

$$\frac{P_j}{R} = 1.40^K \quad \left. \begin{array}{l} \text{Resultant force acting} \\ \text{on web concrete} \end{array} \right\}$$

Figure B-39 - Resultant Force on Web Concrete

Confinement Reinforcement (Article 5.10.4.3):

$$f_s = 0.6f_y = 36 \text{ ksi} @ \text{Service Limit State}$$

Maximum spacing = 24" or 3 duct diameters

$$3 \times 4.19 = 12.6 \text{ inches} \quad \text{Use 12" spacing (typical)}$$

Duct Ties:

$T = 0.70 \text{ kips/ft}$  Unfactored

$$A_s = T/f_s = 0.70/36 = 0.02 \text{ in}^2/\text{ft}$$

#4 @ 12" OK ( $A_s = 0.20 \text{ in}^2/\text{ft}$ )

Web Ties:

$T = 1.40 \text{ kips/ft}$  Unfactored

$$A_s = T/f_s = 1.40/36 = 0.04 \text{ in}^2/\text{ft}$$

#4 @ 12" OK ( $A_s = 0.20 \text{ in}^2/\text{ft}$ )

Stirrup Leg on Inside of Curve

Tension Tie:

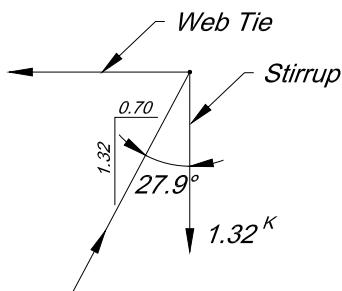


Figure B-40 – Free Body Diagram

$T = 1.32 \text{ kips Unfactored}$

$$T_u = 1.2 \cdot 1.32 = 1.58 \text{ kips/ft}$$

$$A_s = T_u / (\phi f_y) = 1.58 / (0.9 \cdot 60) = 0.03 \text{ in}^2/\text{ft}$$

### Local Bending of Cover Slab:

$$M_{End} \approx 1.2(2 \cdot 0.70) \cdot 1.44 / 8 = 0.30 \text{ ft-kips/ft (Factored)}$$

$$A_{s2} \approx M_{End} / 4d = 0.30 / 4 \cdot 2.34 = 0.03 \text{ in}^2/\text{ft - Approximate formula}$$

$$f_r = 0.37 \sqrt{f_c} = 0.37 \sqrt{4} = 0.740 \text{ ksi}$$

$$S_c = 12 \cdot 4.81^2 / 6 = 46.3 \text{ in}^3$$

$$1.2M_{cr} = 1.2f_r S_c = 1.2 \cdot 0.740 \cdot 46.3 / 12 = 3.43 \text{ ft-kips/ft}$$

$$1.2M_{cr} > M_u, \text{ Use } 1.33A_{s2} = 0.04 \text{ in}^2/\text{ft}$$

### Regional Bending

$$F_{u-in} = 1.2P_j / R = 1.2 \cdot 4.21 \text{ kips/ft} = 5.05 \text{ ft-kips/ft Factored}$$

Use simplified method for determining regional moment (Eqn. 5.10.4.3.1-6)

$$M_u \approx \psi F_{u-in} h / 4 = 0.6 \cdot 5.05 \cdot 7.64 / 4 = 5.79 \text{ ft-kips/ft}$$

$$A_{s3} \approx M_u / (4d) = 5.79 / (4 \cdot 9.66) = 0.15 \text{ in}^2/\text{ft}$$

$$S_c = 12 \cdot 12^2 / 6 = 288 \text{ in}^3$$

$$1.2M_{cr} = 1.2f_r S_c = 1.2 \cdot 0.740 \cdot 288 / 12 = 21.3 \text{ ft-kips/ft}$$

$$\text{Use } 1.33A_{s3} = 0.20 \text{ in}^2/\text{ft}$$

Total area of one stirrup leg (tendon confinement & bending)

Tension tie	= 0.03
Local bending	= 0.04
Regional bending	= <u>0.20</u>
Subtotal	= 0.27 in <sup>2</sup> /ft

The above reinforcement does not include reinforcement for global shear and torsion. Refer to Article 5.8.1.5 for the reinforcement for combined effects.

## EXAMPLE B-4

### MODIFIED CHRISTIAN MENN METHOD OF COMBINING SHEAR, TORSION AND REGIONAL BENDING

#### Introduction

The primary purpose of the following numerical example is to demonstrate the use of the modified Christian Menn method for combining the shear, torsion and regional bending from the comprehensive example problem (Problem B-1).

Calculations are provided that consider the interaction of shear (both flexural and torsional) and transverse regional bending. The procedure used is based on "Prestress Concrete Bridges," by Christian Menn, 1990. The procedure has been extended to include the presence of the ducts and to include a portion of the concrete contribution,  $V_c$ . While this extended procedure is rational, further experimental validation of this approach is required. The required transverse web reinforcement is similar to that obtained by the 100% combination method used in Problem B-1.

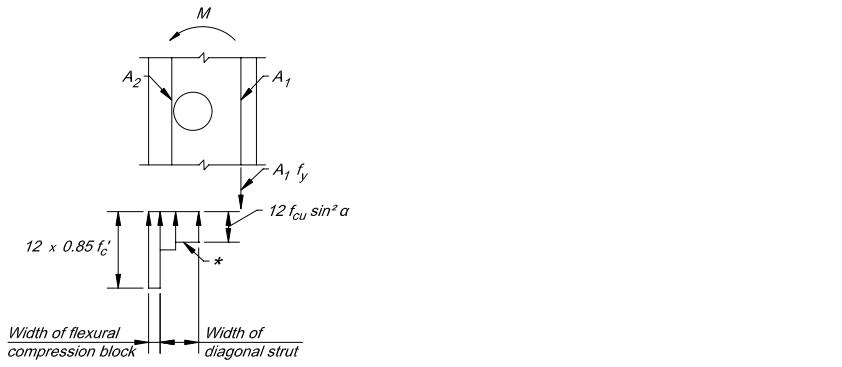
#### Intermediate Points – Free Body Diagrams: (1' wide strip)

Shear Predominates - Vertical Component of Diagonal Compression Strut  $\geq A_{sf} f_y$



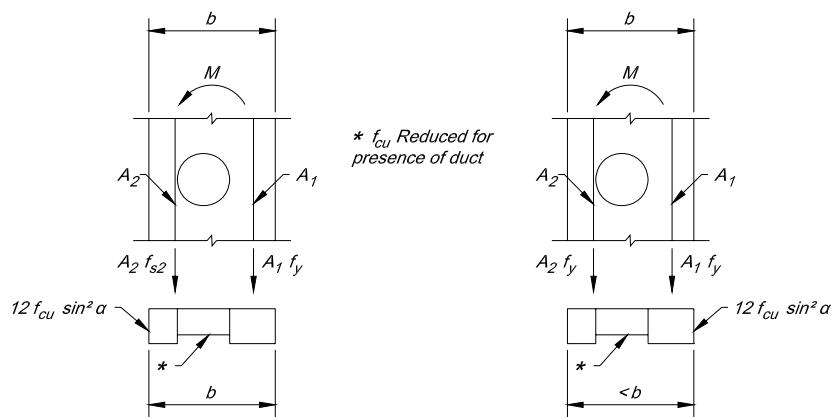
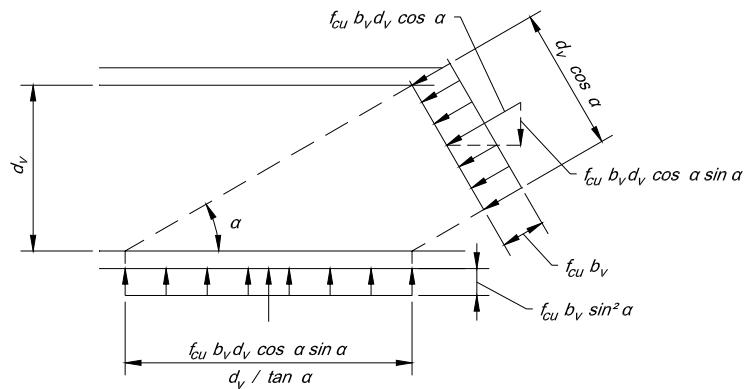
\* Indicates  $f_{cu}$  reduced for presence of ducts

Bending Predominates – Vertical Component of Diagonal Compression Strut  $< A_{sf} f_y$



\*\* Equals zero for pure bending

## Maximum Shear



Controlled by Strut

Controlled by Stirrups

Figure B-41 - Web Section (1' Wide Stirrups)

### Vertical Shear & Transverse Bending Interaction

Consider 0.2 pt. from centerline of Bent within Span 2 of exterior web on outside of curve

$$\phi_f = 0.9 \quad \phi_v = 0.9 \quad \text{LRFD 5.5.4.2.1}$$

$$f_s = 60.0 \text{ ksi} \quad E_s = 29,000 \text{ ksi}$$

$$f_c' = 5.0 \text{ ksi} \quad \beta_f = 0.8 \quad \alpha_s = 27.2^\circ$$

### Web Dimensions

$$d_v = 103.7 \text{ inches}$$

$$t_w = 12.0 \text{ inches}$$

$$\phi_{duct} = 4.75 \text{ inches}$$

$$d_c = 3.0 \text{ inches}$$

$$c_{duct} = 0.75 \text{ inches}$$

### Reinforcement

Stirrups: #6 @ 4.25"

$$d = 9.56 \text{ inches}$$

$$d' = 2.56 \text{ inches}$$

### Points on Shear – Bending Interaction Diagram:

#### **Point 1 – Maximum Shear:**

##### Maximum shear based on web crushing

$$b_v = 10.81 \text{ inches} \quad \text{LRFD 5.8.2.9}$$

$$V_{nmax} = 0.25 f_c' b_v d_v = 0.25 \cdot 5.0 \cdot 10.81 \cdot 103.7 = 1401 \text{ kips} \quad \text{LRFD 5.8.3.3-1}$$

$$V_{nmax} = f_{cu} b_v d_v \sin\alpha_s \cos\alpha_s$$

$$\therefore f_{cu} = V_{nmax} / b_v d_v \sin\alpha_s \cos\alpha_s = 1401 / 10.81 \cdot 103.7 \cdot 0.457 \cdot 0.889 = 3.075 \text{ ksi}$$

Maximum shear based on stirrups yielding

$$V_{s\max} = (A_1 + A_2)f_y d_v \cot \alpha_s = (1.24 + 1.24) \cdot 60.0 \cdot \frac{103.7}{12} \cdot 1.9458 = 2506 \text{ kips}$$

Controlling Case

$V_n = 1401 \text{ kips}$  Minimum of  $V_{n\max}$  and  $V_{s\max}$

$$V_n / (d_v \cot \alpha_s) = 1401 / (103.7 \div 12) \cdot 1.9458 = 83.4 \text{ kips/foot}$$

Calculate Net Moment Capacity of Section Based on Concrete Compression and Steel Tension (See Figure B-40)

Force Component	Width - in	Force - kips	Moment Arm - in	F * Arm in-kips	Steel $f_s$ (ksi)
Cover on Compression Side of Tendon	3.00	23.1	1.50	34.7	
Tendon	4.75	27.5	5.38	147.6	
Cover on tension side of tendon	4.25	32.8	9.87	323.5	
$\Sigma$		<b>83.4</b>		<b>505.8</b>	
Steel on tension face		74.5	9.56	712.6	60.0
Steel on compression face		8.8	2.56	22.6	7.1
$\Sigma$		<b>83.4</b>		<b>735.2</b>	

Interaction Points:

$$M_n = (735.2 - 505.8)/12 = 19.12 \text{ ft-kips/foot}$$

$V_n = 1401 \text{ kips}$

Point 2 – Assumed Compression Block + Strut Width = Web Width Minus One-Half Tension Side Cover – Tension Face Steel Yields:

Maximum force based on strut capacity

Assumed compression block + strut width = 9.88 inches

$$b_{eff} = 8.69 \text{ inches}$$

$$V_{n\max} = 12 b_{eff} f_{cu} \sin^2 \alpha_s = 12 \cdot 8.69 \cdot 3.075 \cdot 0.457 \cdot 0.457 = 67.0 \text{ kips/ft}$$

Maximum force based on stirrups yielding

$$V_{s\max} = (A_1 + A_2)f_y = (1.24 + 1.24) \cdot 60.0 = 149.1 \text{ kips/ft}$$

Controlling Case

$$V_n = 67.0 \text{ kips} \quad \text{Minimum of } V_{n\max} \text{ and } V_{s\max}$$

Calculate Net Moment Capacity of Section Based on Concrete Compression and Steel Tension (See Figure B-41)

Force Component	Width - in	Force - kips	Moment Arm - in	F * Arm in-kips	Steel $f_s$ (ksi)
Cover on Compression Side of Tendon	3.00	23.1	1.50	34.7	
Tendon	4.75	27.5	5.38	147.6	
Cover on tension side of tendon	2.13	16.4	8.81	144.4	
$\Sigma C$		<b>67.0</b>		<b>326.7</b>	
"Net" Flexural Compression = $\Sigma T - \Sigma C$	$a = 0.17^*$	<b>7.6</b>	0.09	0.7	
Steel on tension face		74.5	9.56	712.6	60.0
Steel on compression face		0.0	2.56	0.0	0.0
$\Sigma T$		<b>74.5</b>		<b>712.6</b>	

$$* a = 7.6 / (0.85 f_c' - f_{cu} \sin^2 \alpha_s) \bullet 12$$

Interaction Points:

$$M_n = (712.6 - 0.7 - 326.7) / 12 = \mathbf{32.10 \text{ ft-kips/foot}}$$

$$\text{Total flexural compression resultant} = a \bullet (0.85 f_c') \bullet 12 = 8.9 \text{ kips/ft}$$

$$V_{n\text{net}} = \text{Net vertical component of compression strut} = \Sigma T - 8.9 = 65.6 \text{ kips/ft}$$

$$V_n = V_{n\text{net}} \bullet d_v \bullet \cot \alpha / 12 = 65.6 \bullet 103.7 \bullet 1.9458 / 12 = \mathbf{1103 \text{ kips}}$$

**Point 3 – Assumed Compression Block + Strut Width = Compression Side Cover Plus Tendon Diameter – Tension Face Steel Yields:**

Maximum force based on strut capacity

Assumed compression block + strut width = 7.75 inches

$$b_{eff} = 6.56 \text{ inches}$$

$$V_{n\max} = 12 b_{eff} f_{cu} \sin^2 \alpha_s = 12 \cdot 6.56 \cdot 3.075 \cdot 0.457 \cdot 0.457 = 50.6 \text{ kips/ft}$$

Maximum force based on stirrups yielding

$$V_{s\max} = (A_1 + A_2) f_y = (1.24 + 1.24) \cdot 60.0 = 149.1 \text{ kips/ft}$$

Controlling Case

$$V_n = 50.6 \text{ kips} \quad \text{Minimum of } V_{n\max} \text{ and } V_{s\max}$$

Calculate Net Moment Capacity of Section Based on Concrete Compression and Steel Tension (See Figure B-41)

Force Component	Width - in	Force - kips	Moment Arm - in	F * Arm in-kips	Steel $f_s$ (ksi)
Cover on Compression Side of Tendon	3.00	23.1	1.50	34.7	
Tendon	4.75	27.5	5.38	147.6	
Cover on tension side of tendon	0.00	0.00	7.75	0.00	
$\Sigma C$		<b>50.6</b>		<b>182.3</b>	
"Net" Flexural Compression = $\Sigma T - \Sigma C$	0.55*	<b>23.9</b>	0.28	6.6	
Steel on tension face		74.5	9.56	712.6	60.0
Steel on compression face		0.0	2.56	0.0	0.0
$\Sigma T$		<b>74.5</b>		<b>712.6</b>	

Interaction Points:

$$M_n = (712.6 - 6.6 - 182.3)/12 = \mathbf{43.64 \text{ ft-kips/foot}}$$

$$\text{Total flexural compression resultant} = a \bullet (0.85f_c) \bullet 12 = 28.2 \text{ kips/ft}$$

$$V_{nnet} = \text{Net vertical component of compression strut} = \Sigma T - 28.2 = 46.3 \text{ kips/ft}$$

$$V_n = V_{nnet} \bullet d_v \bullet \cot \alpha / 12 = 46.3 \bullet 103.7 \bullet 1.9458 / 12 = \mathbf{779 \text{ kips}}$$

**Point 4 – Compression Block + Strut Width = Compression Side Cover - Tension Face Steel Yields:**

Maximum force based on strut capacity

Assumed compression block + strut width = 3.00 inches

$$b_{eff} = 3.00 \text{ inches}$$

$$V_{nmax} = 12b_{eff}f_{cu} \sin^2 \alpha_s = 12 \cdot 3.00 \cdot 3.075 \cdot 0.457 \cdot 0.457 = 23.1 \text{ kips/ft}$$

Maximum force based on stirrups yielding

$$V_{smax} = (A_1 + A_2)f_y = (1.24 + 1.24) \cdot 60.0 = 149.1 \text{ kips/ft}$$

Controlling Case

$$V_n = 23.1 \text{ kips} \quad \text{Minimum of } V_{nmax} \text{ and } V_{smax}$$

Calculate Net Moment Capacity of Section Based on Concrete Compression and Steel Tension (See Figure B-41)

Force Component	Width - in	Force - kips	Moment Arm - in	F * Arm in-kips	Steel $f_s$ (ksi)
Cover on Compression Side of Tendon	3.00	23.1	1.50	34.7	
Tendon	0.00	0.00	3.00	0.0	
Cover on tension side of tendon	0.00	0.00	3.00	0.0	
$\Sigma C$		<b>23.1</b>		<b>34.7</b>	
"Net" Flexural Compression = $\Sigma T - \Sigma C$	1.19	<b>51.4</b>	0.59	30.5	
Steel on tension face		74.5	9.56	712.6	60.0
Steel on compression face		0.0	2.56	0.0	0.0
$\Sigma T$		<b>74.5</b>		<b>712.6</b>	

Interaction Points:

$$M_n = (712.6 - 30.5 - 34.7)/12 = 53.95 \text{ ft-kips/foot}$$

$$\text{Total flexural compression resultant} = a \bullet (0.85f_c') \bullet 12 = 60.0 \text{ kips/ft}$$

$$V_{nnet} = \text{Net vertical component of compression strut} = \Sigma T - 60.0 = 14.0 \text{ kips/ft}$$

$$V_n = V_{nnet} \bullet d_v \bullet \cot \alpha / 12 = 14.0 \bullet 103.7 \bullet 1.9458 / 12 = 235 \text{ kips}$$

**Point 5 – Pure Bending:**

$M_n$  using tension face reinforcement only:

$$T_u = A_s f_y = 74.5 \text{ kips/ft}$$

$$a = T_u / (0.85f_c' b) = 1.46 \text{ inches}$$

$$M_n = T_u (d - a/2) = 54.84 \text{ ft-kips/ft}$$

$M_n$  using all reinforcement & strain compatibility (Trial & Error to Converge on Solution):

$$\text{Depth of neutral axis} = a/\beta_1 = 1.91 \text{ inches}$$

Calculate Net Moment Capacity of Section Based on Concrete Compression and Steel Tension (See Figure B-41)

Force Component	Width - in	Force - kips	Moment Arm - in	F * Arm in-kips	Steel $f_s$ (ksi)	Strain
Flexural Compression	1.53	77.9	0.76	59.4		
Steel on tension face		74.5	9.56	712.6	60	
Steel on compression face		7.9	2.56	20.2	6.4	0.00022
$\Sigma$ Steel		82.4		732.8		

Check equilibrium:

$$T_u/C_u = 82.4/77.9 = 1.059 \text{ say OK}$$

$$\text{Net moment on web} - M_n = (732.8 - 59.4)/12 = 56.12 \text{ ft-kips/foot}$$

**Interaction Diagram:**

Nominal Shear Resistance of Concrete –  $V_c = 192$  kips  
(neglecting effects of regional bending)

$$b_v = 10.81 \text{ inches}$$

Vertical component of effective prestress force –  $V_p = 325$  kips

<b>INTERACTION DIAGRAM</b>								
$M_n$	$\phi M_n$	$V_s$	$\phi V_s$	$b_{eff}$	$k =$	$k V_c$	$V_c + V_s$	$\phi V_n$
ft-kips/ft	ft-kips/ft	kips	kips	inches	$b_{eff} / b_v$	kips	kips	kips
0	0.00	1401	1261	10.81	1.00	192	1401	1554
19.12	17.20	1401	1261	10.81	1.00	192	1401	1554
32.10	28.89	1103	993	8.69	0.80	154	1258	1424
43.64	39.27	779	701	6.56	0.61	117	895	1098
53.95	48.55	235	211	3.00	0.28	53	288	552
56.12	50.51	0	0	0.00	0.00	0	0	293

Note -  $\phi V_n = \phi(kV_c + V_n + V_p)$  where  $k = b_{eff}/d_v$ . The factor  $k$  reduces  $V_c$  by the ratio  $b_{eff}/d_v$  to account for the reduced width of the diagonal compression strut due to regional bending of the web.

**Controlling Load Case:**

Minimum flexural reinforcement requirements:

$$1.2M_{cr} = 1.2 \left( 0.37 \sqrt{f_c} \cdot b \cdot T^2 \div 6 \right) = 23.83 \text{ ft-kips/ft} \quad \text{LRFD 5.4.2.6 & 5.7.3.3.2}$$

Factored design loads:

Vertical component of flexural shear = 929 kips

Torsional shear along inclined centerline of web = 618 kips

Angle of inclined web from vertical -  $\alpha = 15.26$  degrees

Vertical component of torsional shear = 596 kips

Length of shear flow path along centerline of web -  $d_s = 139.7$  inches

Vertical component of  $d_s = 134.8$  inches

$d_s/d_s^*$  vertical component of torsional shear = 459 kips – See note below

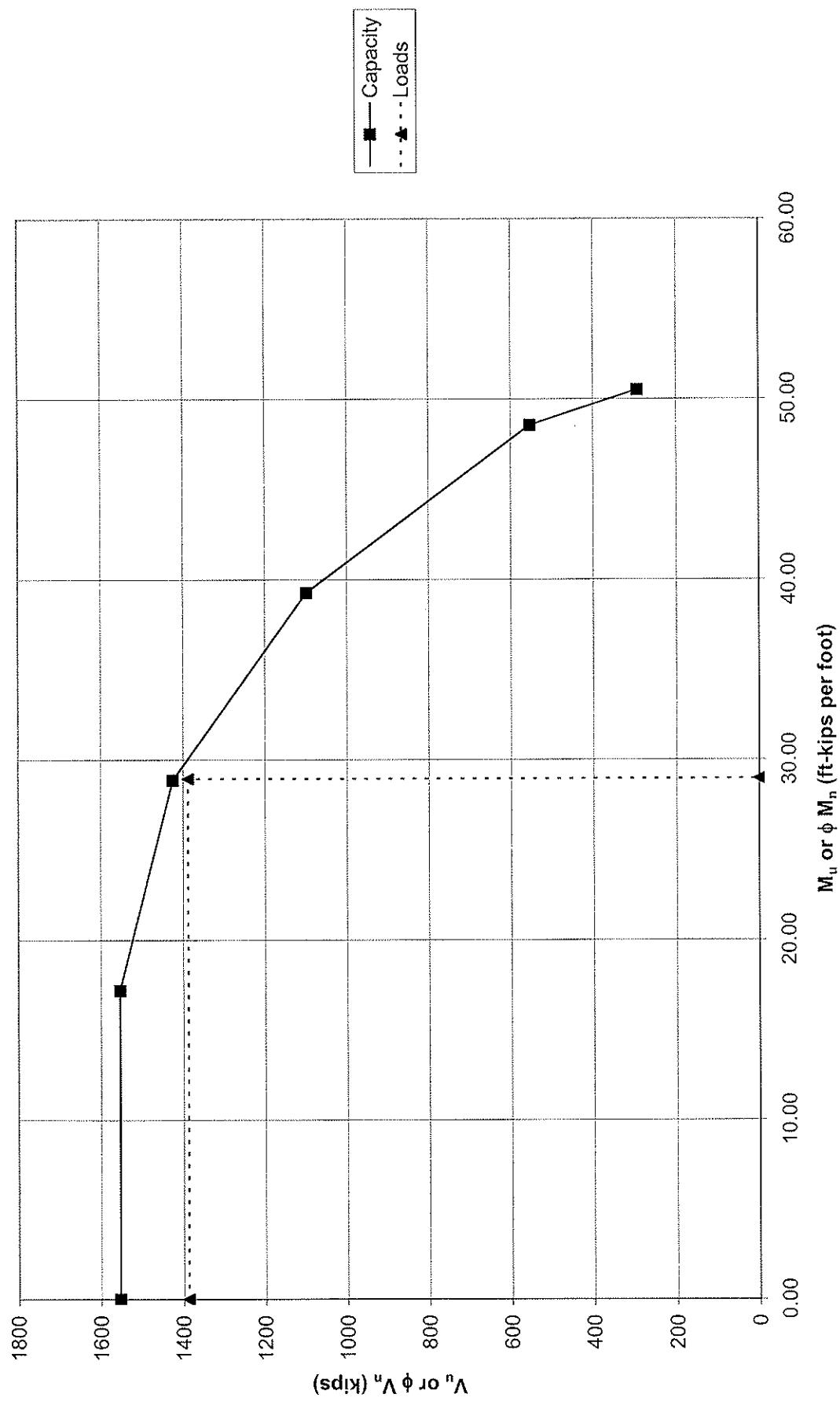
Combined Shear -  $V_u = 1388$  kips

$M_u = 28.95$  ft-kips/foot >  $1.2M_{cr}$

Design  $M_u = 28.95$  ft-kips/foot

Note: The capacity is determined as if the shear force is due to flexural shear only (which is resisted over  $d_s$ ). Therefore the inclined torsional shear along the web centerline (which is resisted over a length  $d_s$ ) is converted to an equivalent vertical flexural shear force resisted over  $d_s$ .

## INTERACTION DIAGRAM



EXAMPLE B-5  
PODOLNY-MULLER COMBINATION OF SHEAR AND TRANSVERSE BENDING

Independent Stirrup Requirements from Example B-1

For shear and torsion of the longitudinal member

$$A_s = 0.79 \text{ in}^2/\text{ft} \text{ for 2 legs} = 0.40 \text{ in}^2/\text{ft} \text{ for one leg}$$

Regional bending

$$A_s = 0.63 \text{ in}^2/\text{ft} \text{ for one leg}$$

The minimum area for a single stirrup leg should be the maximum of the following:

$$A_s = 0.40 + \frac{1}{2} \bullet 0.63 = 0.715 \text{ in}^2/\text{ft}$$

$$A_s = \frac{1}{2} \bullet 0.40 + 0.63 = 0.83 \text{ in}^2/\text{ft}$$

$$A_s = 0.7(0.40 + 0.63) = 0.721 \text{ in}^2/\text{ft}$$

Therefore, use  $A_s = 0.83 \text{ in}^2/\text{ft}$

Use #6 @ 6"



EXAMPLE B-6  
 DEVIATION SADDLE DESIGN FOR PRECAST CURVED SPAN  
 (After Beaupre, et. al., 1988)

Provide full bottom flange width deviation saddle for small radius curved span

Tendon 2 – 19-0.6”ø 270 ksi strands –  $A_{ps}=4.09 \text{ in}^2$  (Closest to web wall)

Tendon 1 – 19-0.6”ø 270 ksi strands –  $A_{ps}=4.09 \text{ in}^2$

$f_c' = 6000 \text{ psi}$  Grade 60 reinforcement

Maximum Allowable Jacking Force =  $0.8f_{ps} \cdot A_{ps}$

Tendon 2 =  $(0.8)(270)(4.09) = 883.4 \text{ kips}$

Tendon 1 =  $(0.8)(270)(4.09) = 883.4 \text{ kips}$

Tendon	Horiz. Dev.	Vert. Dev.	Horiz. Force	Vert. Force
2	$\pm 4.0^\circ$	$+ 8.0^\circ$	$\pm 61.8 \text{ kips}$	$+ 122.9 \text{ kips}$
1	$\pm 4.0^\circ$	$+ 6.0^\circ$	$\pm 61.8 \text{ kips}$	$+ 92.3 \text{ kips}$
Total			$\pm 123.6 \text{ kips}$	$+ 215.2 \text{ kips}$

Load Factor = 1.7

$\phi = 0.9$  (Tension)

$\phi = 0.85$  (Shear)

Design tendon loops based on 122.9 kips

$$F_u = \phi(A_s)(f_y)$$

$$A_s = F_u / (\phi f_y) = (122.9) \cdot 1.7 / (0.90)(60.0) = 3.87 \text{ in}^2$$

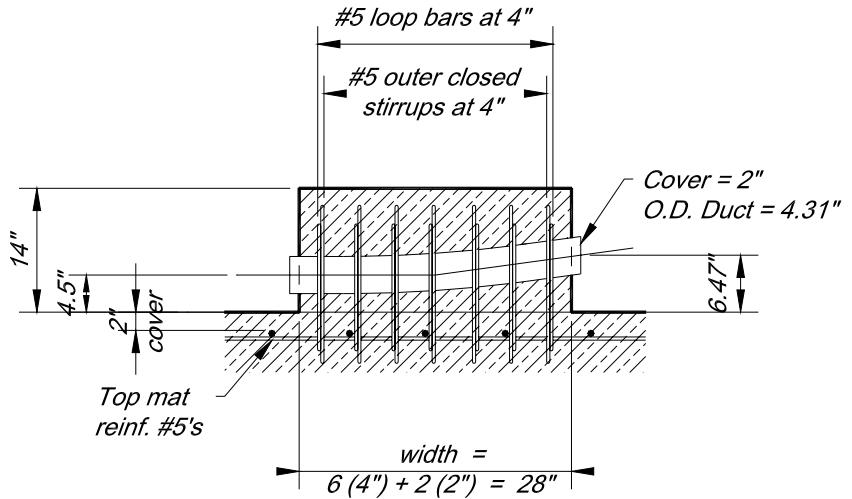
Assume #5 bars  $A_s = 0.31 \text{ in}^2$

Number of loops =  $3.87 \text{ in}^2 / 2(0.31) = 6.2$  use 7 - #5 loops each tendon

Use 7 - #5 closed outer stirrups

No shear friction check required since full bottom flange deviation saddle provided

See Figure B-32 for dimensioning of reinforcement and concrete

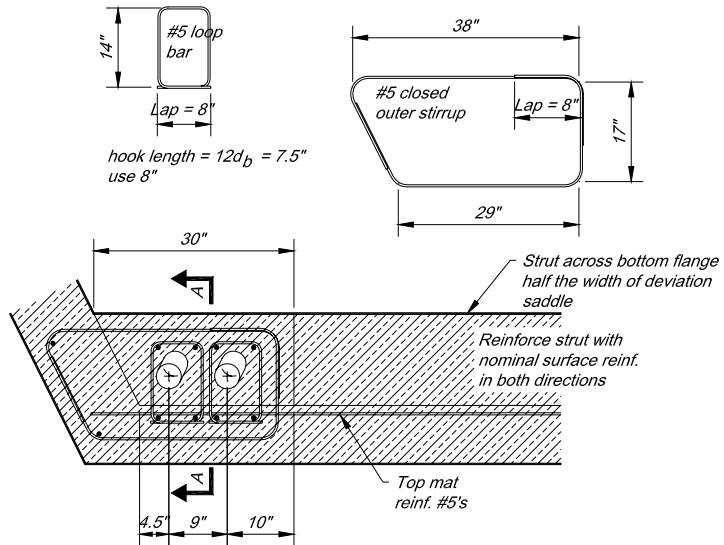


Section A-A Maximum Deviated Tendon

Link bar vertical dimension =  $4.5" + 4.31"/2 + (12\text{")}(\tan 8.0^\circ) + 2" + 2(5/8") + 1" + 2(5/8") = 13.8"$   
 (out-to-out dimension) – use 14"

Link bar horizontal dimension =  $4.31" + (12\text{")}(\tan 4.0^\circ) + 1" + 2(5/8") = 7.4"$   
 (out-to-out dimension) – use 8"

Outer stirrup vertical dimension (out-to-out) =  $14" + 3" = 17"$



Deviation Saddle Elevation

Figure B-42 Design Example for Curved Span