ADVANCED INFRASTRUCTURE TECHNOLOGIES

Load Rating Calculations Package

for

Wanzer Road Bridge No. 48 BRO 1448(38)

Fairfield, Franklin County, Vermont

May 29, 2014

Complied By:

Jonathan Kenerson, EI

Summary of Load Rating Analysis

LRFR LOAD RATING FACTORS							
LOADING LEVELS	TRUCK						
	H-20	HL-93	3S2	6 AXLE	3A. STR.	4A. STR.	6A. SEMI
TONNAGE	20	36	36	66	30	34.5	38
INVENTORY			---	---	---	---	---
POSTING	---	---	---	---	---	---	---
OPERATING							

Description of Load Rating Analysis

For each truck the arches and decking were analyzed to determine which controlled the rating factor. Analyzing the arches required modifying the FEA Analysis Code to accept the reconfigured axle loads and spacing. For all but the HL-93 Load Case the lane load was removed. Outputs were analyzed to determine which elements were controlling the design and whether these elements were moment or shear controlled.

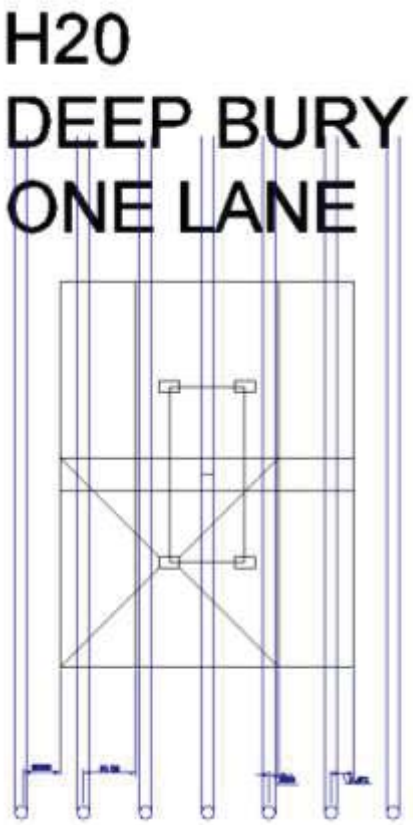
Dec k analysis required more extensive checks using AutoCAD to determine wheel interactions at the decking depth, MathCad to calculate soil and live load pressures at these depths, and RISA to model continuous beam elements with these loads applied to them. The reaction and moment from the RISA analysis were then entered into the MathCAD sheet to calculate deck capacity (which depends on the Moment to Reaction ratio) and ultimately the Rating Factor.

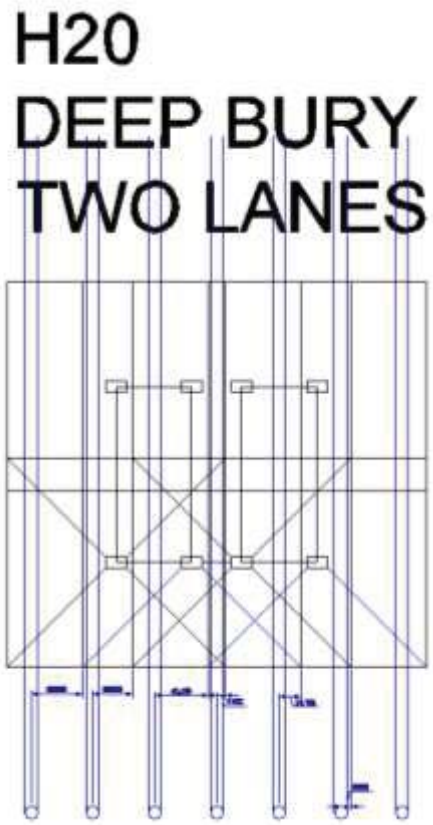
HL-20 Loading

The deck needed to be analyzed for the following cases resulting in a possible combination of eight cases.

Load Rating Case	Inventory	Operating
Cover	Deep	Shallow
Lanes	One	Two

This analysis was simplified by eliminating some cases by inspection. The Inventory and Operating Cases for the Deep cover 1 lane case were eliminated based on the load patch area of the wheel interaction. The increase of the multiple presence factor would not outweigh the effects of a second vehicle acting on the same load patch area. After performing the Inventory analysis Shallow cover for one and two lanes resulted in the 2 lane case controlling, the Operating Shallow 1 lane case was eliminated because this is the same as the inventory analysis only with altered magnitudes. This resulted in five analyses.





H20 Configuration	Deck Rating Factor
H20 Inventory Deep 2 Lanes	3.31
H20 Operating Deep 2 Lanes	4.42
H20 Inventory Deep 1 Lane	Eliminated by Inspection
H20 Operating Deep 1 Lane	Eliminated by Inspection
H20 Inventory Shallow 1 Lane	2.59
H20 Operating Shallow 1 Lane	Eliminated by Inspection
H20 Inventory Shallow 2 Lanes	2.35
H20 Operating Shallow 2 Lanes	3.12

HL-93 Loading

The deck needed to be analyzed for the following cases resulting in a possible combination of sixteen cases.

Load Rating Case	Inventory	Operating
Vehicle	Truck	Tandem
Cover	Deep	Shallow
Lanes	One	Two

This analysis was simplified by eliminating some cases by inspection.

In the case of the Deep cover analyses it was observed that 2 lanes would always control over 1 lane due to the wheel interactions at that depth. This eliminated four analyses.

For the Deep cover case the truck was determined to control over the tandem because both the 32 kip axles interacted at the depth for a total load on the load patch of 64 kips vs. the 50 kips from the tandem. This eliminated two more analyses.

For the shallow cover cases the tandem was determined to control over the truck because all the truck wheels did not interact at this shallow depth whereas the tandem's wheels did. This eliminated four analyses.

For the shallow Tandem case one lane was determined to control over two lanes. This eliminated two more analyses. This resulted in four analyses.

HL-93 Configuration	Deck Rating Factor

HL93 Truck Inventory Deep 2 Lanes	1.79
HL93 Truck Operating Deep 2 Lanes	2.23
HL93 Truck Inventory Deep 1 Lane	Eliminated by Inspection
HL93 Truck Operating Deep 1 Lane	Eliminated by Inspection
HL93 Truck Inventory Shallow 1 Lane	Eliminated by Inspection
HL93 Truck Operating Shallow 1 Lane	Eliminated by Inspection
HL93 Truck Inventory Shallow 2 Lanes	Eliminated by Inspection
HL93 Truck Operating Shallow 2 Lanes	Eliminated by Inspection
HL93 Tandem Inventory Deep 2 Lanes	Eliminated by Inspection
HL93 Tandem Operating Deep 2 Lanes	Eliminated by Inspection
HL93 Tandem Inventory Deep 1 Lane	Eliminated by Inspection
HL93 Tandem Operating Deep 1 Lane	Eliminated by Inspection
HL93 Tandem Inventory Shallow 1 Lane	1.48
HL93 Tandem Operating Shallow 1 Lane	1.96
HL93 Tandem Inventory Shallow 2 Lanes	Eliminated by Inspection
HL93 Tandem Operating Shallow 2 Lanes	Eliminated by Inspection

Vermont Standard Load Rating Trucks

The remainder of the trucks were analyzed for Operating Rating Factors only. For each truck the deck needed to be analyzed for the following cases resulting in a possible combination of four cases. However it was found that the Deep case was always controlled by two lanes and the shallow case was always controlled by one lane. Therefore there were only two cases per Truck for these cases.

Cover	Deep	Shallow
Lanes	One	Two

Advanced Infrastructure Technologies
20 Godfrey Drive, Orono, ME 04473
Telephone: 207-866-6526
Fax: 207-866-6501

Project Name:	Fairfield Vt Bridge	Name:	J. Kenerson
Project Number:	12018	Date:	5/27/2014
Location:	Fairfield, Vt	Checked By:	Z.Uzman
Client:	VDOT	Date:	5/28/2014

AIT Load Rating Analysis Sheet

General LRFR, design level load rating equation:
[Ref. AASHTO Manual for Bridge Evaluation]

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_{LL})(LL + IM)}$$

For use in this load rating spreadsheet this equation is simplified to:

$$RF = \frac{C - D}{LL}$$

Where the variables are as follows:

C = Capacity (Moment or Shear, and positive or negative depending on the condition being checked)
D = Total envelope dead load effect, includes DC, EV, EH, DW, with all appropriate STRENGTH I load factors
LL = Total envelope live load effect, includes IM, and worst design vehicle, 1&2 lanes loaded with MPF

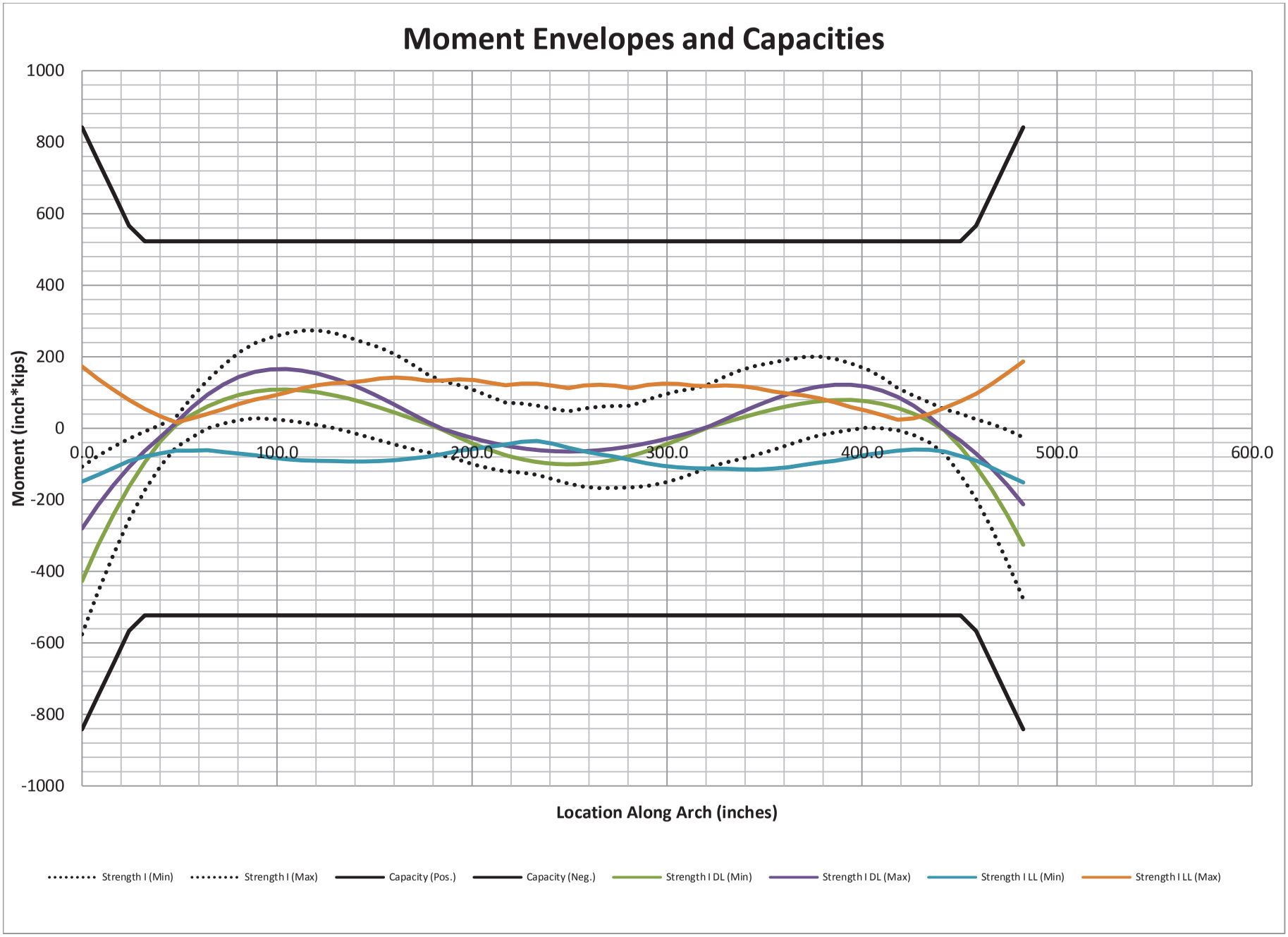
Inputs:

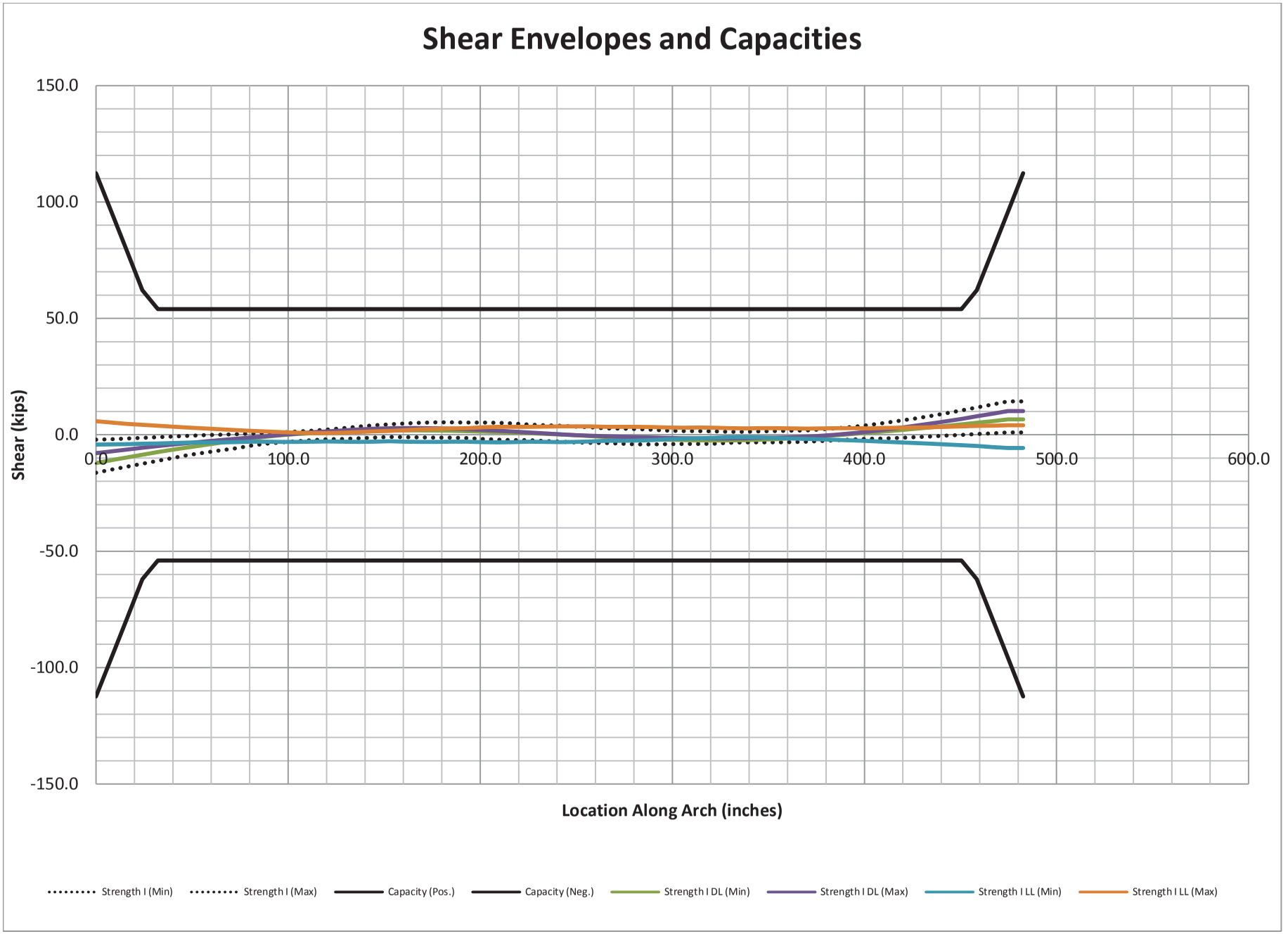
ARCHES

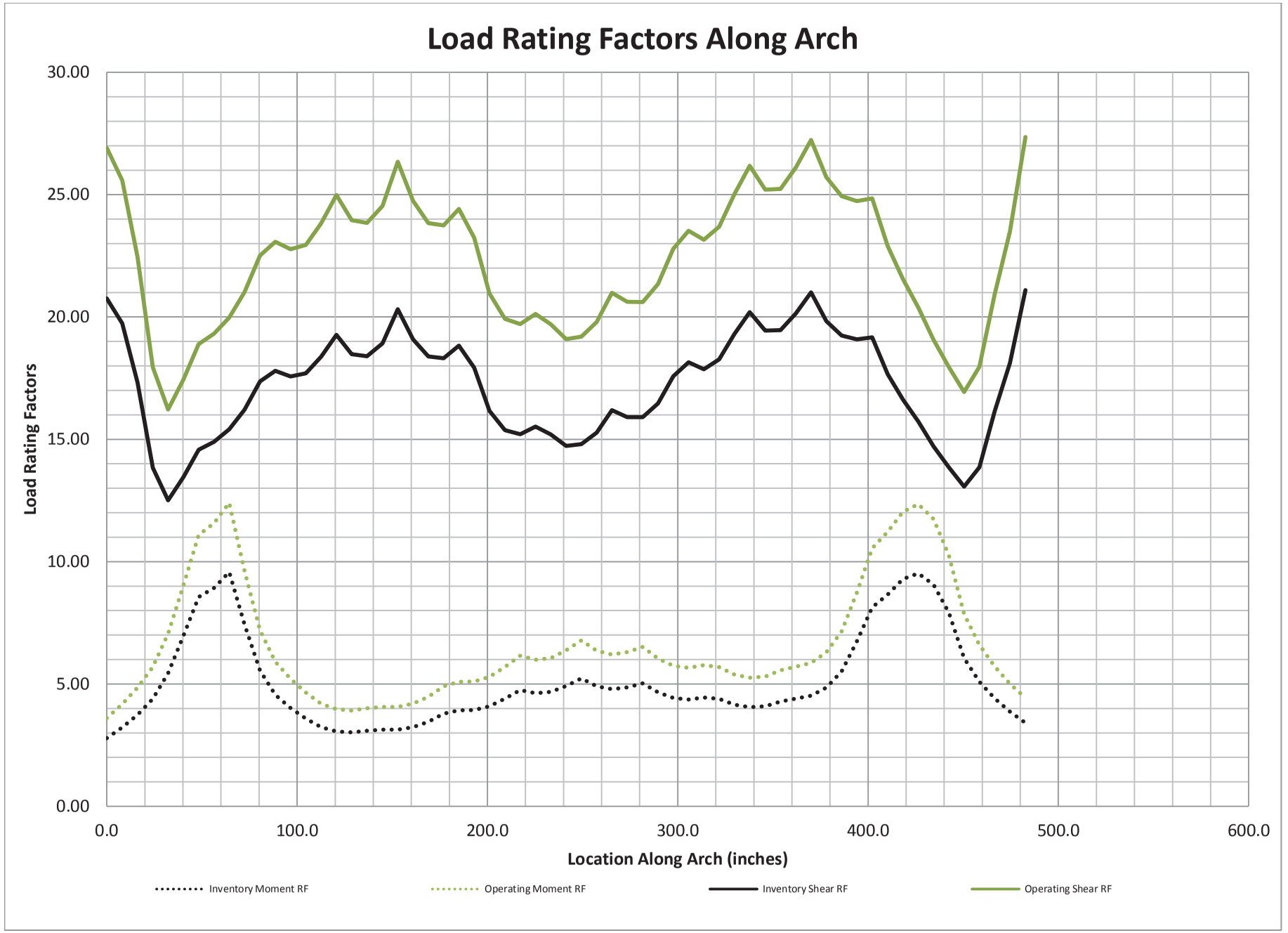
Moment Capacity, Reinforced Region, ϕ_{Mn}	841.8	in*kip
Moment Capacity, Unreinforced Region, ϕMn	522.7	in*kip
Development Length of End Reinforcing Bars	28.0	in
Length of Bars above TOF (excluding ld)	0.0	in
Shear Capacity, Reinforced Region, ϕVn	112.4	kip
Shear Capacity, Unreinforced Region, ϕVn	54	kip
Vehicle Description	H20	

Results:

	Operating	Inventory
ARCHES		
Moment Rating Factor	3.60	2.78
Shear Rating Factor	16.22	12.51
DECKING		
Rating Factor	3.12	2.35
Overall Rating Factor	**3.12**	**2.35**


Moment Envelopes and Capacities
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
Moment (inch*kips)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Strength I (Min)
Strength I (Max)
Capacity (Pos.)
Capacity (Neg.)
Strength I DL (Min)
Strength I DL (Max)
Strength I LL (Min)
Strength I LL (Max)


Shear Envelopes and Capacities
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
Shear (kips)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Strength I (Min)
Strength I (Max)
Capacity (Pos.)
Capacity (Neg.)
Strength I DL (Min)
Strength I DL (Max)
Strength I LL (Min)
Strength I LL (Max)


Load Rating Factors Along Arch
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Load Rating Factors
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Inventory Moment RF
Operating Moment RF
Inventory Shear RF
Operating Shear RF

ADVANCED INFRASTRUCTURE TECHNOLOGIES

Job
Sheet No. of
Calculated By Date
Checked By Date

H20 DEEP TWO LANES

INVENTORY

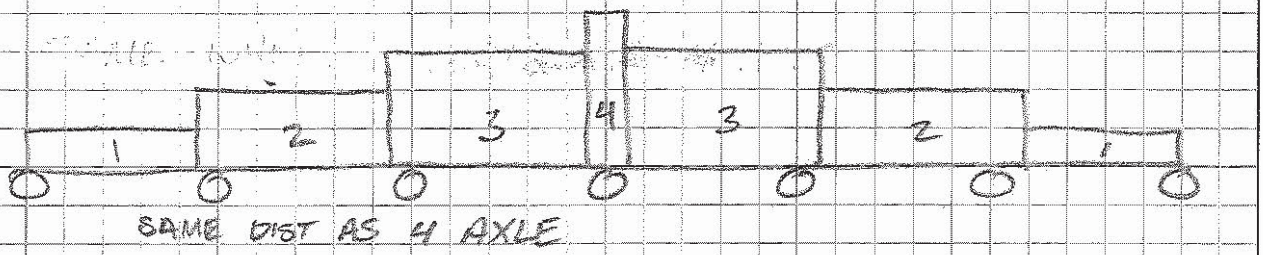
$D = 1.472$ k/ft
$L_4 = 0.014$ k/ft/wheel
$L_{16} = 0.057$ k/ft/wheel

1) $D + L_4 + L_{16} = 1.543$
2) $D + 2L_4 + 2L_{16} = 1.614$
3) $D + 3L_4 + 3L_{16} = 1.685$
4) $D + 4L_4 + 4L_{16} = 1.756$

OPERATING

$D = 1.472$ k/ft
$L_4 = 0.011$ k/ft/wheel
$L_{16} = 0.038$ k/ft/wheel

1) 1.521
2) 1.570
3) 1.619
4) 1.668



SAME DIST AS 4 AXLE

RISA	INV	OP
LOCATION	NODE 2	NODE 2
R	9.026	8.825
M	49.392	48.384
RF	3.31	4.42

ADVANCED INFRASTRUCTURE TECHNOLOGIES

Job
Sheet No. of
Calculated By Date
Checked By Date

H20 SHALLOW 2 LANES

INVENTORY

DL = 0.827 k/ft
L_{16} = 0.426 k/ft/wheel

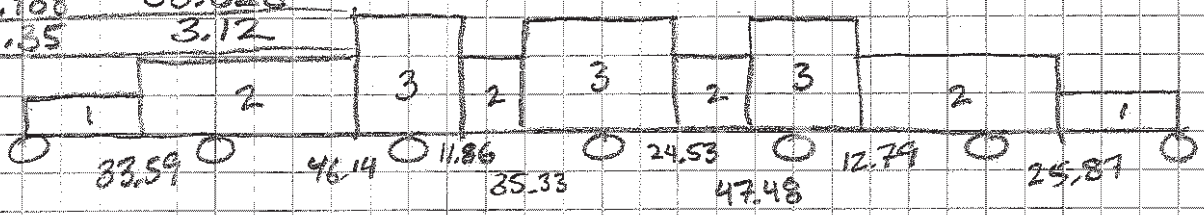
		INV
1)	D	0.827
2)	D+L	1.253
3)	D+2L	1.679

OPERATING

DL = 0.827
L_{16} = 0.329

		OP
1)	D	0.827
2)	D+L	1.156
3)	D+2L	1.485

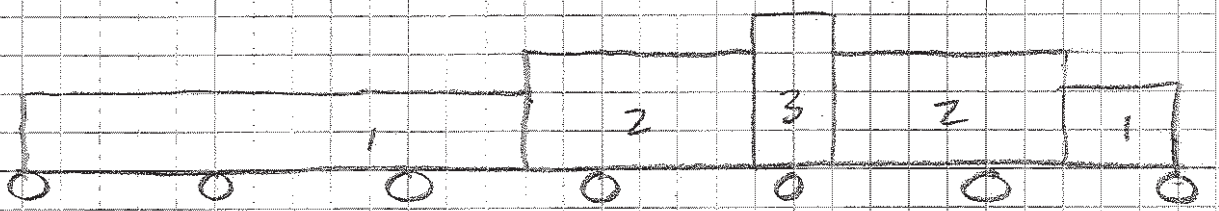
RISA	INV	OP
LOC	NODE 4	NODE 4
R	7.98	7.127
M	39.988	35.028
RF	2.35	3.12



H20 SHALLOW 1 LANE INVENTORY

DL = 0.827 k/ft
L_{16} = 0.512 k/ft/wheel

1)	D	0.827
2)	D+L	1.339
3)	D+2L	1.851



RISA NODE 5
R = 7.848
M = 37.02
RF = 2.59

Advanced Infrastructure Technologies

20 Godfrey Drive
Orono, Maine 04473
Telephone: (207) 866-6526
Fax: (207) 866-6501
www.aitbridges.com

Project: Fairfield, VT BRO 1448(38)

Task: Calculate Decking Rating Factors for H20 Loading

Pressure at Deep Cover - Two Lanes - Inventory

Inputs:

Arch Spacing $sp := 59.3in$

Angle of panel at base of arch: $\theta := 46deg$

Depth of soil above lowest panel: $d := 13.7ft$

Load factor for vertical earth: $\gamma_e := 1.35$

Load Factor for LL $\gamma_{LL} := 1.75$

Multiple Presence Factor $MPF := 1.0$

Dead Load:

At-rest earth pressure coefficient: $K_o := 0.47$

Density of backfill: $\rho := 135\frac{lbf}{ft^3}$

Horizontal projection of decking: $H_p := 1ft$

Vertical projection of decking: $V_p := H_p \cdot \tan(\theta) = 1.04 \cdot ft$

Vertical pressure along horizontal projection: $Vert := \gamma_e \cdot \rho \cdot d \cdot H_p = 2496.83 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz := \gamma_e \cdot \rho \cdot d \cdot K_o \cdot V_p = 1215.2 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_v := \cos(\theta) \cdot Vert = 1734.44 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_h := \sin(\theta) \cdot Horiz = 874.14 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force := C_v + C_h = 2608.58 \cdot \frac{lbf}{ft}$

Factored dead load pressure perpendicular to the deck panel: $DL\_Press := \frac{Total\_Force}{\sqrt{H_p^2 + V_p^2}} = 12.58 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 1.47 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 8.26 \cdot kip$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Load from one wheel $Wheel\_load := 4kip$

Wheel Distribution Along Arch $W1 := 10in + d \cdot 1.15 = 16.59 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + d \cdot 1.15 = 17.42 \cdot ft$

Area of Wheel Load Patch at Depth of Interest $Load\_Patch := W1 \cdot W2 = 289 \cdot ft^2$

Average Wheel Pressure $Wheel\_Vert\_Press := \frac{Wheel\_load \cdot MPF}{Load\_Patch}$

Vertical pressure along horizontal projection: $Vert_{LL} := \gamma_{LL} \cdot Wheel\_Vert\_Press \cdot H_p = 24.22 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz_{LL} := \gamma_{LL} \cdot Wheel\_Vert\_Press \cdot K_o \cdot V_p = 11.79 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 16.83 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 8.48 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force_{LL} := C_{vLL} + C_{hLL} = 25.31 \cdot \frac{lbf}{ft}$

Factored LL pressure perpendicular to the deck panel per wheel: $LL\_Press := \frac{Total\_Force_{LL}}{\sqrt{H_p^{\,2} + V_p^{\,2}}} = 0.12 \cdot psi$

RISA Input Live Load Distributed Load $RISA\_LL := LL\_Press \cdot 9.75in = 0.014 \cdot \frac{kip}{ft}$ per wheel

Load from one wheel $Wheel\_load := 16kip$

Wheel Distribution Along Arch $W1 := 10in + d \cdot 1.15 = 16.59 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + d \cdot 1.15 = 17.42 \cdot ft$

Area of Wheel Load Patch at Depth of Interest $Load\_Patch := W1 \cdot W2 = 289 \cdot ft^2$

Average Wheel Pressure $Wheel\_Vert\_Press := \frac{Wheel\_load \cdot MPF}{Load\_Patch}$

Vertical pressure along horizontal projection: $Vert_{LL} := \gamma_{LL} \cdot Wheel\_Vert\_Press \cdot H_p = 96.89 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz_{LL} := \gamma_{LL} \cdot Wheel\_Vert\_Press \cdot K_o \cdot V_p = 47.15 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 67.3 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 33.92 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force_{LL} := C_{vLL} + C_{hLL} = 101.22 \cdot \frac{lbf}{ft}$

Factored LL pressure perpendicular to the deck panel per wheel: $LL\_Press := \frac{Total\_Force_{LL}}{\sqrt{H_p^{\,2} + V_p^{\,2}}} = 0.49 \cdot psi$

RISA Input Live Load Distributed Load $RISA\_LL := LL\_Press \cdot 9.75in = 0.057 \cdot \frac{kip}{ft}$ per wheel

RISA Analaysis Results:

Run RISA Analysis using appropriate number of wheels for given spans to determine Moment and Reaction

Reaction from RISA $R_u := 9.026kip$ From RISA Analysis of six span beam - Node 2

Moment from RISA $M_u := 49.392in \cdot kip$

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 5.47 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Characterisitc Reaction Value 18" bend tests $R_{n18} := 21574lbf$

Characteristic Reaction Value 24" bend tests $R_{n24} := 14745lbf$

18" and 24" span bending tests performed on decking simulated the reaction of the arch on decking. This value is mean -3sigma from three tests.

Moment:Reaction for 18" Tests $MR_{18} := 4.5in$

Moment:Reaction for 24" Tests $MR_{24} := 6in$

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 17.15 \cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor

Moisture Reduction Factor $C_m := 0.9$ Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.8 \cdot kip$

Rating Factor $RF_{inv1} := \frac{\Phi R_n - R_{u\_DL\_only}}{\left(R_u - R_{u\_DL\_only}\right)} = 3.31$

Pressure at Deep Cover - Two Lanes - Operating

Inputs:

Arch Spacing $sp := 59.3in$

Angle of panel at base of arch: $\theta := 46deg$

Depth of soil above lowest panel: $d := 13.7ft$

Load factor for vertical earth: $\gamma_e := 1.35$

Load Factor for LL $\gamma_{LL} := 1.35$

Multiple Presence Factor $MPF := 1.0$

Dead Load:

At-rest earth pressure coefficient: $K_o := 0.47$

Density of backfill: $\rho := 135 \frac{lbf}{ft^3}$

Horizontal projection of decking: $H_p := 1ft$

Vertical projection of decking: $V_p := H_p \cdot \tan(\theta) = 1.04 \cdot ft$

Vertical pressure along horizontal projection: $Vert := \gamma_e \cdot \rho \cdot d \cdot H_p = 2496.83 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz := \gamma_e \cdot \rho \cdot d \cdot K_o \cdot V_p = 1215.2 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_v := \cos(\theta) \cdot Vert = 1734.44 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_h := \sin(\theta) \cdot Horiz = 874.14 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force := C_v + C_h = 2608.58 \cdot \frac{lbf}{ft}$

Factored dead load pressure perpendicular to the deck panel: $DL\_Press := \frac{Total\_Force}{\sqrt{H_p^2 + V_p^2}} = 12.58 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 1.47 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only

$$R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 8.26 \cdot kip$$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Load from one wheel

$$Wheel\_load := 4kip$$

Wheel Distribution Along Arch

$$W1 := 10in + d \cdot 1.15 = 16.59 \cdot ft$$

Wheel Distribution Across Arch

$$W2 := 20in + d \cdot 1.15 = 17.42 \cdot ft$$

Area of Wheel Load Patch at Depth of Interest

$$Load\_Patch := W1 \cdot W2 = 289 \cdot ft^2$$

Average Wheel Pressure

$$Wheel\_Vert\_Press := \frac{Wheel\_load \cdot MPF}{Load\_Patch}$$

Vertical pressure along horizontal projection:

$$Vert_{LL} := \gamma_{LL} \cdot Wheel\_Vert\_Press \cdot H_p = 18.69 \cdot \frac{lbf}{ft}$$

Horizontal pressure along vertical projection:

$$Horiz_{LL} := \gamma_{LL} \cdot Wheel\_Vert\_Press \cdot K_o \cdot V_p = 9.09 \cdot \frac{lbf}{ft}$$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure:

$$C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 12.98 \cdot \frac{lbf}{ft}$$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure:

$$C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 6.54 \cdot \frac{lbf}{ft}$$

Total resultant force perpendicular to the deck panel:

$$Total\_Force_{LL} := C_{vLL} + C_{hLL} = 19.52 \cdot \frac{lbf}{ft}$$

Factored LL pressure perpendicular to the deck panel per wheel:

$$LL\_Press := \frac{Total\_Force_{LL}}{\sqrt{H_p^{\,2} + V_p^{\,2}}} = 0.09 \cdot psi$$

RISA Input Live Load Distributed Load

$$RISA\_LL := LL\_Press \cdot 9.75in = 0.011 \cdot \frac{kip}{ft}$$ per wheel

Load from one wheel

$$Wheel\_load := 16kip$$

Wheel Distribution Along Arch

$$W1 := 10in + d \cdot 1.15 = 16.59 \cdot ft$$

Wheel Distribution Across Arch

$$W2 := 20in + d \cdot 1.15 = 17.42 \cdot ft$$

Area of Wheel Load Patch at Depth of Interest

$$Load\_Patch := W1 \cdot W2 = 289 \cdot ft^2$$

Average Wheel Pressure

$$Wheel\_Vert\_Press := \frac{Wheel\_load \cdot MPF}{Load\_Patch}$$

Vertical pressure along horizontal projection:

$$Vert_{LL} := \gamma_{LL} \cdot Wheel\_Vert\_Press \cdot H_p = 74.74 \cdot \frac{lbf}{ft}$$

Horizontal pressure along vertical projection: $Horiz_{LL} := \gamma_{LL} \cdot Wheel\_Vert\_Press \cdot K_o \cdot V_p = 36.38 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 51.92 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 26.17 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force_{LL} := C_{vLL} + C_{hLL} = 78.09 \cdot \frac{lbf}{ft}$

Factored LL pressure perpendicular to the deck panel per wheel: $LL\_Press := \frac{Total\_Force_{LL}}{\sqrt{H_p^{\,2} + V_p^{\,2}}} = 0.38 \cdot psi$

RISA Input Live Load Distributed Load $RISA\_LL := LL\_Press \cdot 9.75in = 0.044 \cdot \frac{kip}{ft}$ per wheel

RISA Analaysis Results:

Run RISA Analysis using appropriate number of wheels for given spans to determine Moment and Reaction

Reaction from RISA $R_u := 8.825kip$ From RISA Analysis of six span beam - Node 2

Moment from RISA $M_u := 48.384in \cdot kip$

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 5.48 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Characterisitc Reaction Value 18" bend tests $R_{n18} := 21574lbf$

Characteristic Reaction Value 24" bend tests $R_{n24} := 14745lbf$

18" and 24" span bending tests performed on decking simulated the reaction of the arch on decking. This value is mean -3sigma from three tests.

Moment:Reaction for 18" Tests $MR_{18} := 4.5in$

Moment:Reaction for 24" Tests $MR_{24} := 6in$

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot \left(R_{n18} - R_{n24}\right) + R_{n24} = 17.1 \cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$

Moisture Reduction Factor $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.77 \cdot kip$

Rating Factor $RF_{op1} := \frac{\Phi R_n - R_{u\_DL\_only}}{(R_u - R_{u\_DL\_only})} = 4.42$

Pressure at Shallow Cover - Two Lanes - Inventory

Soil Cover $cover := 67in$ Measured from bottom of deck corrugation to road surface

Dead Load:

Factored Soil Pressure $DL\_Press := cover \cdot \rho \cdot \gamma_e = 7.07 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 0.83 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 4.64 \cdot kip$ Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Maximum Wheel Load $P := 16kip$

Multiple Presence Factor $MPF := 1.0$

Load Factor for LL $\gamma_{LL} := 1.75$

Wheel Distribution Along Arch $W1 := 10in + cover \cdot 1.15 = 7.25 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + cover \cdot 1.15 = 8.09 \cdot ft$

Load Patch Area $Load\_Patch := W1 \cdot W2 = 58.67 \cdot ft^2$

Impact Factor $IM := 1 + 0.33\left(1.0 - 0.125\frac{cover}{12in}\right) = 1.100$

Factored Wheel Load $P_u := P \cdot \gamma_{LL} \cdot MPF \cdot IM = 30.79 \cdot kip$

Factored Live Load Pressure $PRL_u := \frac{P_u}{Load\_Patch} = 3.64 \cdot psi$

Factored Live Load Distributed Load $w_L := PRL_u \cdot 9.75in = 0.426 \cdot \frac{kip}{ft}$ per wheel

RISA Analysis:

Reaction from RISA $R_u := 7.98kip$

Moment from RISA $M_u := 38.988in \cdot kip$ From RISA Analysis of six span beam - Node 2

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 4.89 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 19.82 \cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$

Moisture Reduction Factor $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 12.49 \cdot kip$

Rating Factor $RF_{inv2} := \frac{\Phi R_n - R_{u\_DL\_only}}{(R_u - R_{u\_DL\_only})} = 2.35$

Pressure at Shallow Cover - Two Lanes - Operating

Soil Cover $cover := 67in$

Measured from bottom of deck corrugation to road surface

Dead Load:

Factored Soil Pressure $DL\_Press := cover \cdot \rho \cdot \gamma_e = 7.07 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 0.83 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 4.64 \cdot kip$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Maximum Wheel Load $P := 16kip$

Multiple Presence Factor $MPF := 1.0$

Load Factor for LL $\gamma_{LL} := 1.35$

Wheel Distribution Along Arch $W1 := 10in + cover \cdot 1.15 = 7.25 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + cover \cdot 1.15 = 8.09 \cdot ft$

Load Patch Area $Load\_Patch := W1 \cdot W2 = 58.67 \cdot ft^2$

Impact Factor $IM := 1 + 0.33\left(1.0 - 0.125\frac{cover}{12in}\right) = 1.100$

Factored Wheel Load $P_u := P \cdot \gamma_{LL} \cdot MPF \cdot IM = 23.75 \cdot kip$

Factored Live Load Pressure $PRL_u := \frac{P_u}{Load\_Patch} = 2.81 \cdot psi$

Factored Live Load Distributed Load $w_L := PRL_u \cdot 9.75in = 0.329 \cdot \frac{kip}{ft}$ per wheel

RISA Analysis:

Reaction from RISA $R_u := 7.127kip$

Moment from RISA $M_u := 35.028in \cdot kip$ From RISA Analysis of six span beam - Node 2

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 4.91 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 19.69 \cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$ Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Moisture Reduction Factor $C_m := 0.9$

Design Reaction Value $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 12.4 \cdot kip$

Rating Factor $RF_{op2} := \frac{\Phi R_n - R_{u\_DL\_only}}{(R_u - R_{u\_DL\_only})} = 3.12$

Pressure at Shallow Cover - One Lane - Inventory

Soil Cover $cover := 67in$ Measured from bottom of deck corrugation to road surface

Dead Load:

Factored Soil Pressure $DL\_Press := cover \cdot \rho \cdot \gamma_e = 7.07 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 0.83 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 4.64 \cdot kip$ Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Maximum Wheel Load $P := 16kip$

Multiple Presence Factor $MPF := 1.2$

Load Factor for LL $\gamma_{LL} := 1.75$

Wheel Distribution Along Arch $W1 := 10in + cover \cdot 1.15 = 7.25 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + cover \cdot 1.15 = 8.09 \cdot ft$

Load Patch Area $Load\_Patch := W1 \cdot W2 = 58.67 \cdot ft^2$

Impact Factor $IM := 1 + 0.33\left(1.0 - 0.125\frac{cover}{12in}\right) = 1.100$

Factored Wheel Load $P_u := P \cdot \gamma_{LL} \cdot MPF \cdot IM = 36.95 \cdot kip$

Factored Live Load Pressure $PRL_u := \frac{P_u}{Load\_Patch} = 4.37 \cdot psi$

Factored Live Load Distributed Load $w_L := PRL_u \cdot 9.75in = 0.512 \cdot \frac{kip}{ft}$ per wheel

RISA Analysis:

Reaction from RISA $R_u := 7.848kip$

Moment from RISA $M_u := 37.02in \cdot kip$ From RISA Analysis of six span beam - Node 5

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 4.72 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot \left(R_{n18} - R_{n24}\right) + R_{n24} = 20.59 \cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$

Moisture Reduction Factor $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 12.97 \cdot kip$

Rating Factor $RF_{inv3} := \frac{\Phi R_n - R_{u\_DL\_only}}{\left(R_u - R_{u\_DL\_only}\right)} = 2.59$

Summary Inventory and Operating Load Rating Factors for Deck

Inventory Rating Factor $RF_{inv} := \min\left(RF_{inv1}, RF_{inv2}, RF_{inv3}\right) = 2.35$

Operating Rating Factor $RF_{op} := \min\left(RF_{op1}, RF_{op2}\right) = 3.12$

Advanced Infrastructure Technologies
20 Godfrey Drive, Orono, ME 04473
Telephone: 207-866-6526
Fax: 207-866-6501

Project Name:	Fairfield Vt Bridge	Name:	J. Kenerson
Project Number:	12018	Date:	5/29/2014
Location:	Fairfield, Vt	Checked By:	
Client:	VDOT	Date:	

AIT Load Rating Analysis Sheet

General LRFR, design level load rating equation:
[Ref. AASHTO Manual for Bridge Evaluation]

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_{LL})(LL + IM)}$$

For use in this load rating spreadsheet this equation is simplified to:

$$RF = \frac{C - D}{LL}$$

Where the variables are as follows:

C = Capacity (Moment or Shear, and positive or negative depending on the condition being checked)
D = Total envelope dead load effect, includes DC, EV, EH, DW, with all appropriate STRENGTH I load factors
LL = Total envelope live load effect, includes IM, and worst design vehicle, 1&2 lanes loaded with MPF
Michigan Overload Class A Results

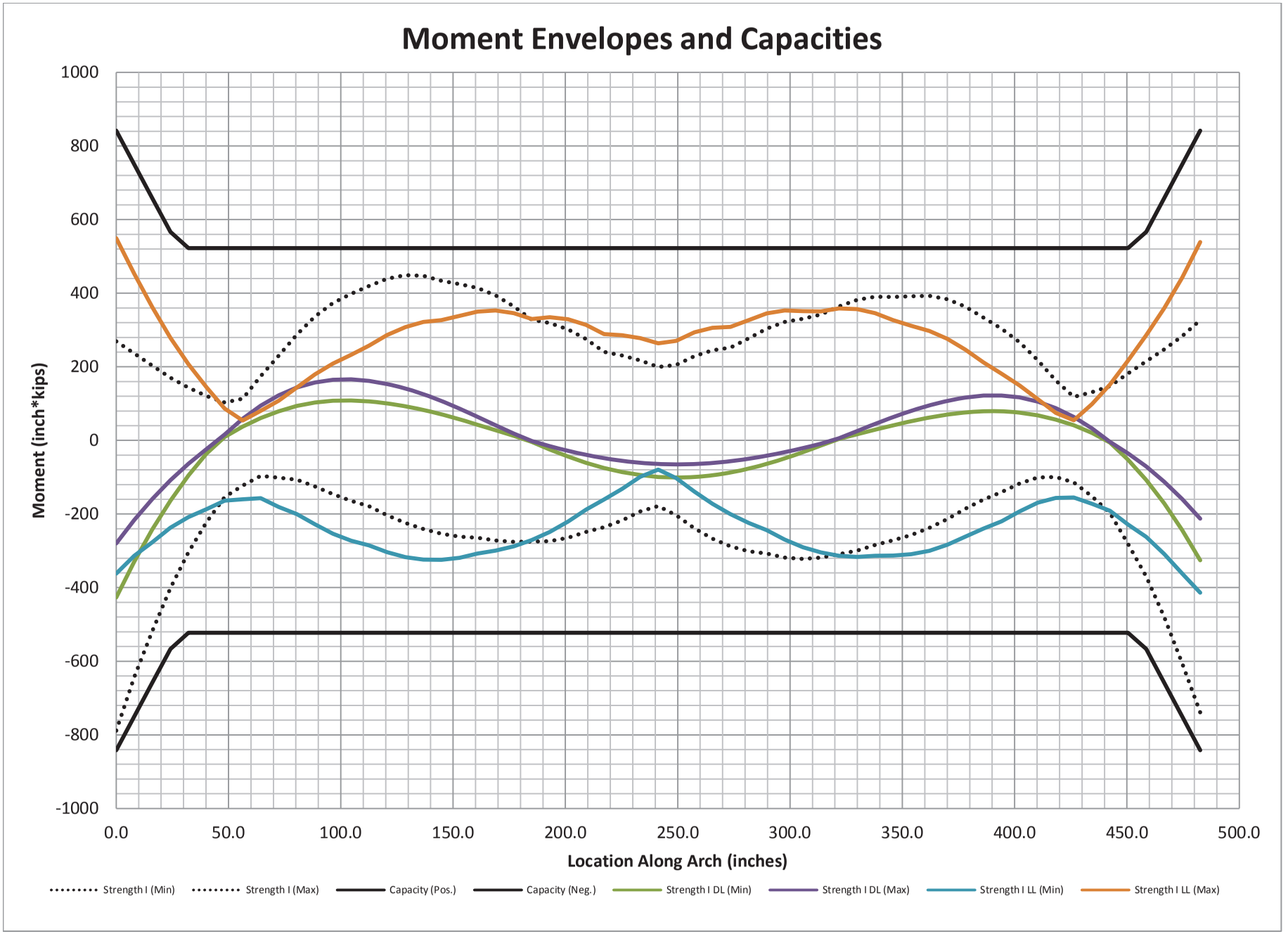
Inputs:

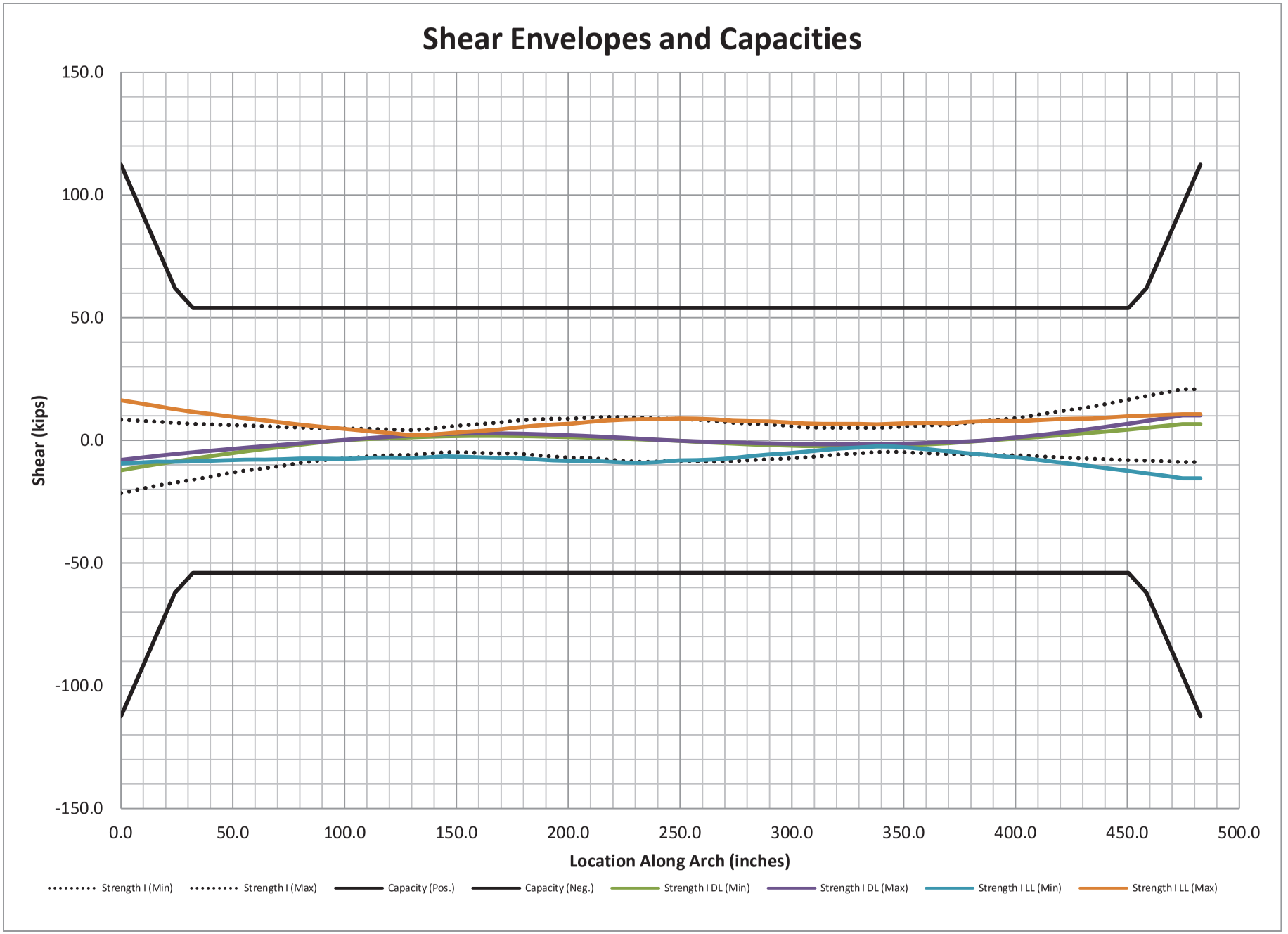
ARCHES

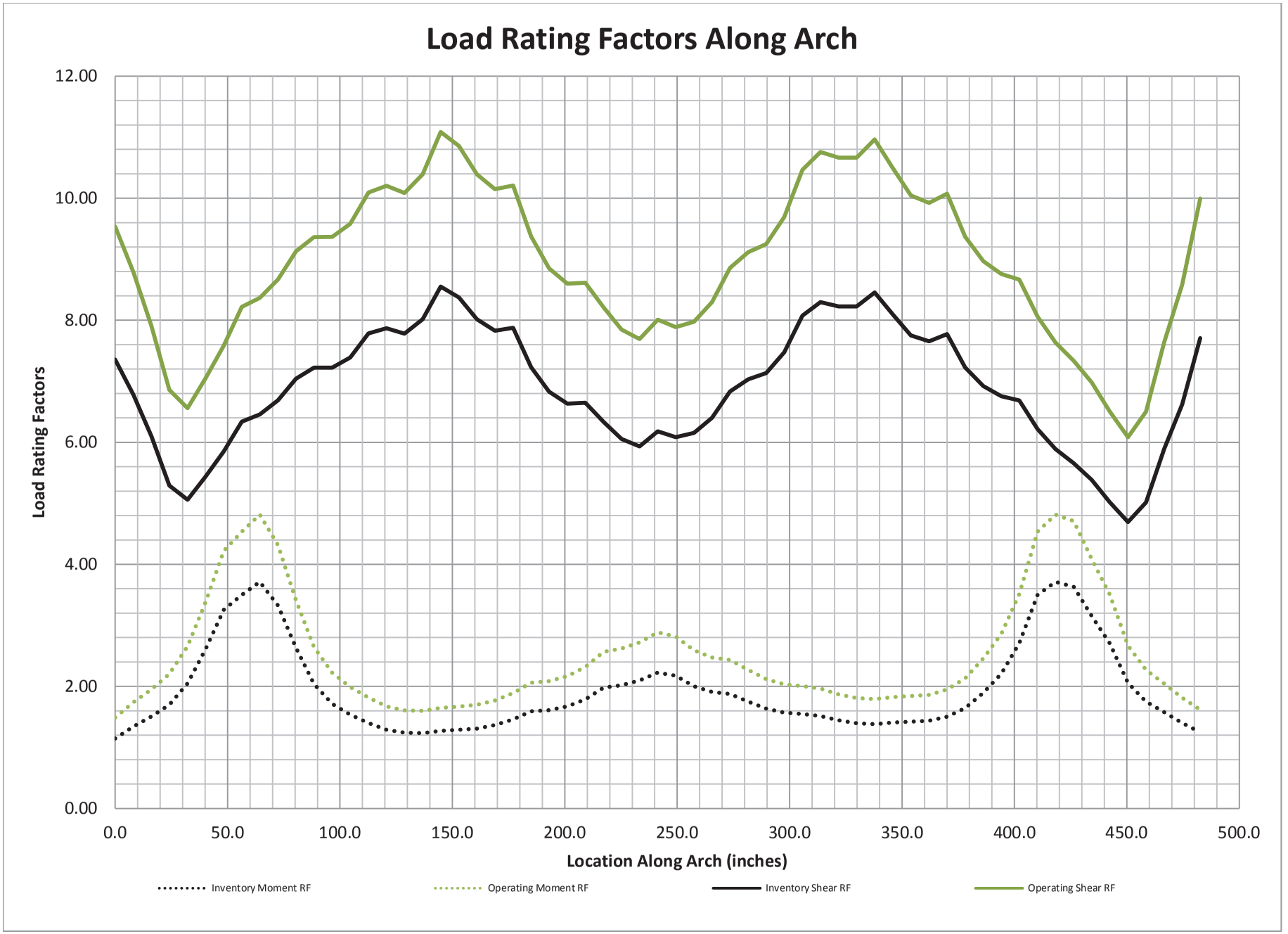
Moment Capacity, Reinforced Region, ϕM_n	841.8	in*kip
Moment Capacity, Unreinforced Region, ϕMn	522.7	in*kip
Development Length of End Reinforcing Bars	28.0	in
Length of Bars above TOF (excluding ld)	0.0	in
Shear Capacity, Reinforced Region, ϕVn	112.4	kip
Shear Capacity, Unreinforced Region, ϕVn	54	kip
Vehicle Description	HL-93	

Results:

	Operating	Inventory
ARCHES		
Moment Rating Factor	1.49	1.15
Shear Rating Factor	6.08	4.69
DECKING		
Tandem Rating Factor	1.96	1.48
Truck Rating Factor	2.23	1.79
Overall RF	**1.49**	**1.15**


Moment Envelopes and Capacities
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
Moment (inch*kips)
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
500.0
Location Along Arch (inches)
Strength I (Min)
Strength I (Max)
Capacity (Pos.)
Capacity (Neg.)
Strength I DL (Min)
Strength I DL (Max)
Strength I LL (Min)
Strength I LL (Max)


Shear Envelopes and Capacities
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
Shear (kips)
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
500.0
Location Along Arch (inches)
Strength I (Min)
Strength I (Max)
Capacity (Pos.)
Capacity (Neg.)
Strength I DL (Min)
Strength I DL (Max)
Strength I LL (Min)
Strength I LL (Max)


Load Rating Factors Along Arch
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Load Rating Factors
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
450.0
500.0
Location Along Arch (inches)
Inventory Moment RF
Operating Moment RF
Inventory Shear RF
Operating Shear RF

HL93 Truck 2 Lane Deep INV & OP

INVENTORY

DL = 1.472 k/ft

LL_{16} = 0.057 k/ft/wheel

LL_{Ln} = 0.043 k/ft/lane

OPERATING

DL = 1.472 k/ft

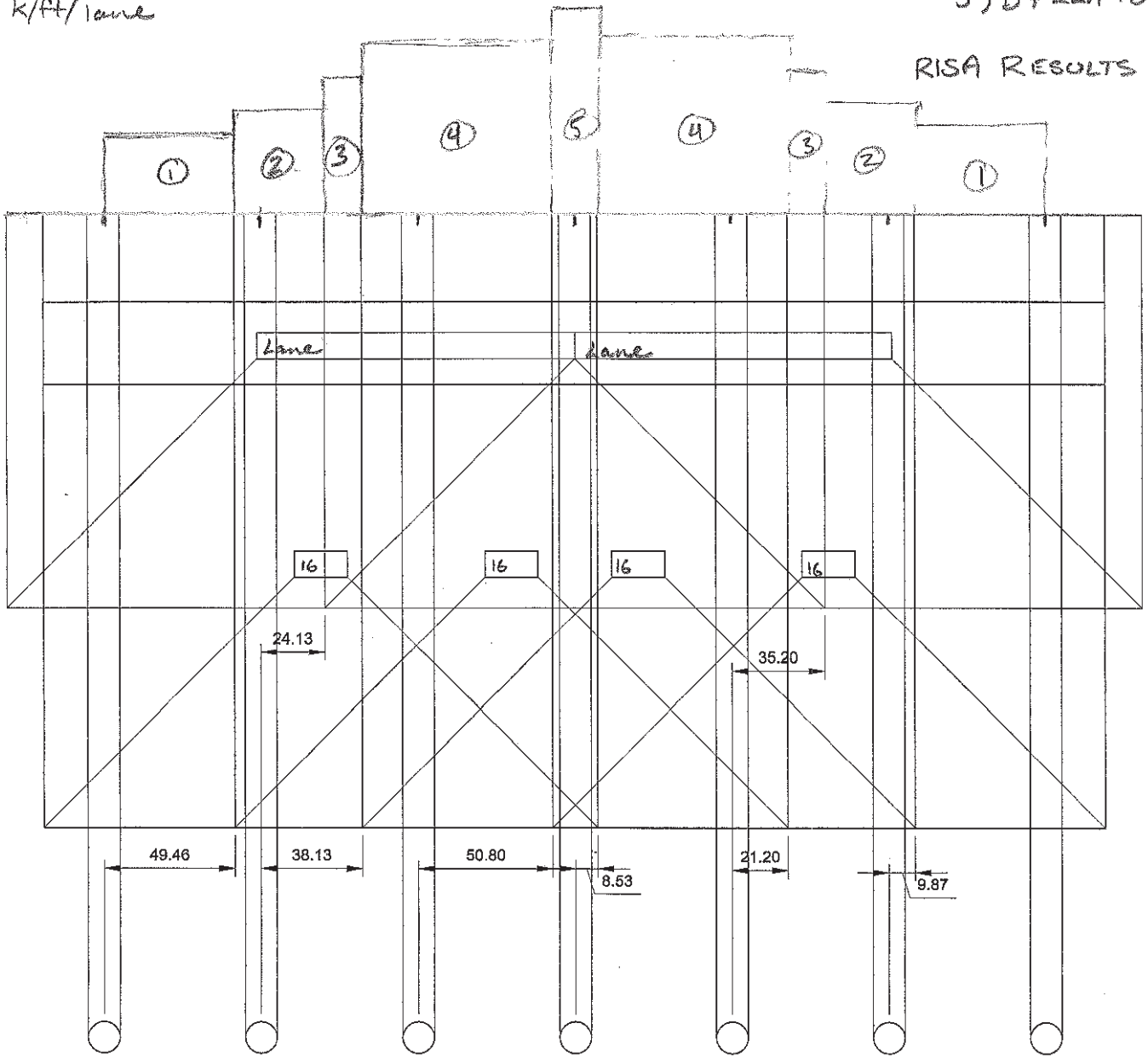
LL_{16} = 0.044 k/ft/wheel

LL_{Ln} = 0.034 k/ft/lane

	INV	OP
1) D + Ln + 2L	1.629	1.594
2) D + Ln + 4L	1.743	1.682
3) D + 2Ln + 4L	1.786	1.716
4) D + 2Ln + 6L	1.900	1.804
5) D + 2Ln + 8L	2.014	1.892

RISA RESULTS

	INV	OP
R	9.692	9.398
M	52.96	51.43
	Node 2	Node 2
RF	1.79	2.23



HL93 Tandem Shallow 1 Lane

INVENTORY

$DL = 0.827$ k/ft

$LL_{12.5} = 0.400$ k/ft/wheel

$LL_{Ln} = 0.068$ k/ft/lane

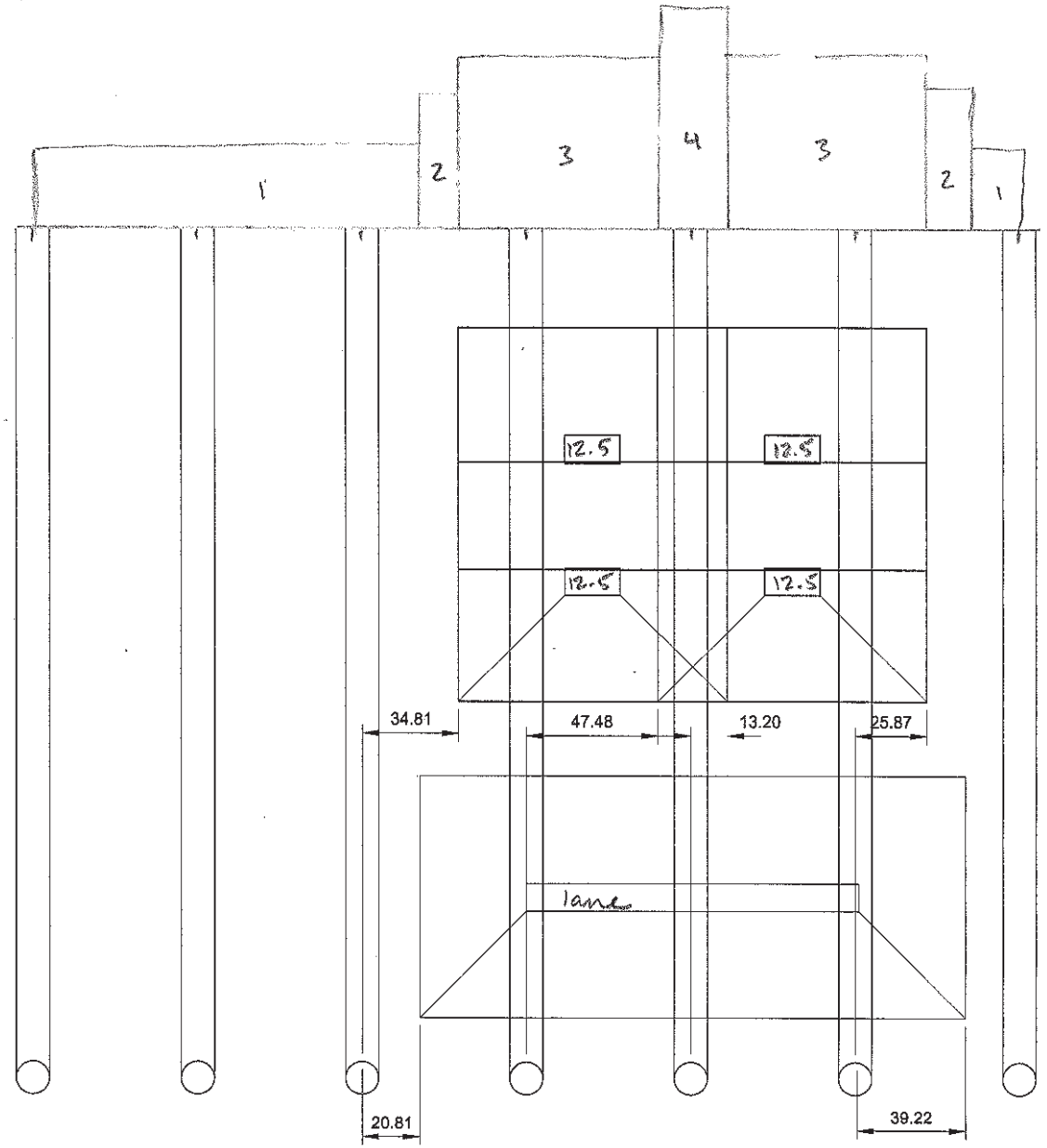
OPERATING

$DL = 0.827$ k/ft

$LL_{12.5} = 0.308$ k/ft/wheel

$LL_{Ln} = 0.053$ k/ft/lane

	INV	OP
1) D	0.827	0.827
2) D+Ln	0.895	0.880
3) D+Ln+2L	1.695	1.496
4) L+Ln+4L	2.495	2.112



RISA RESULTS

	INV	OP
R	10.34	8.90
M	48.36	41.86
	Node 5	Node 5
RF	1.48	1.96

Advanced Infrastructure Technologies

20 Godfrey Drive
Orono, Maine 04473
Telephone: (207) 866-6526
Fax: (207) 866-6501
www.aitbridges.com

Project: Fairfield, VT BRO 1448(38)

Task: Calculate Decking Rating Factors for HL93 Loading

Pressure at Deep Cover Two Lanes - Inventory - Truck

Inputs:

Arch Spacing $sp := 59.3in$

Angle of panel at base of arch: $\theta := 46deg$

Depth of soil above lowest panel: $d := 13.7ft$

Load factor for vertical earth: $\gamma_e := 1.35$

Load Factor for LL $\gamma_{LL} := 1.75$

Multiple Presence Factor $MPF := 1.0$

Dead Load:

At-rest earth pressure coefficient: $K_o := 0.47$

Density of backfill: $\rho := 135\frac{lbf}{ft^3}$

Horizontal projection of decking: $H_p := 1ft$

Vertical projection of decking: $V_p := H_p \cdot \tan(\theta) = 1.036 \cdot ft$

Vertical pressure along horizontal projection: $Vert := \gamma_e \cdot \rho \cdot d \cdot H_p = 2496.825 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz := \gamma_e \cdot \rho \cdot d \cdot K_o \cdot V_p = 1215.203 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_v := \cos(\theta) \cdot Vert = 1734.44 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_h := \sin(\theta) \cdot Horiz = 874.144 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force := C_v + C_h = 2608.584 \cdot \frac{lbf}{ft}$

Factored dead load pressure perpendicular to the deck panel: $DL\_Press := \frac{Total\_Force}{\sqrt{H_p^2 + V_p^2}} = 12.584 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 1.472 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 8.255 \cdot kip$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Load from one wheel $Wheel\_load := 16kip$

Wheel Distribution Along Arch $W1 := 10in + d \cdot 1.15 = 16.588 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + d \cdot 1.15 = 17.422 \cdot ft$

Area of Wheel Load Patch at Depth of Interest $Load\_Patch := W1 \cdot W2 = 289 \cdot ft^2$

Average Wheel Pressure $Wheel\_Vert\_Press := \frac{Wheel\_load \cdot MPF \cdot \gamma_{LL}}{Load\_Patch}$

Vertical pressure along horizontal projection: $Vert_{LL} := Wheel\_Vert\_Press \cdot H_p = 96.887 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz_{LL} := Wheel\_Vert\_Press \cdot K_o \cdot V_p = 47.155 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 67.303 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 33.92 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force_{LL} := C_{vLL} + C_{hLL} = 101.224 \cdot \frac{lbf}{ft}$

Factored LL pressure perpendicular to the deck panel per wheel: $LL\_Press := \frac{Total\_Force_{LL}}{\sqrt{H_p^{\,2} + V_p^{\,2}}} = 0.488 \cdot psi$

RISA Input Live Load Distributed Load $RISA\_LL := LL\_Press \cdot 9.75in = 0.057 \cdot \frac{kip}{ft}$ per wheel

Lane Load $w_{lane} := \gamma_{LL} \cdot 640lbf = 1.12 \cdot kip$ per foot of lane along arch

Lane Width at Deck Depth $Width_{lane} := 10ft + d \cdot 1.15 = 25.755 \cdot ft$

RISA Input Lane Load $RISA\_Lane := \frac{w_{lane}}{Width_{lane}} = 0.043 \cdot \frac{kip}{ft}$

RISA Analaysis Results:

Run RISA Analysis using appropriate number of wheels for given spans to determine Moment and Reaction

Reaction from RISA $R_u := 9.692kip$ From RISA Analysis of six span beam - Node 2

Moment from RISA $M_u := 52.96in \cdot kip$

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 5.464 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Characterisitc Reaction Value 18" bend tests $R_{n18} := 21574lbf$

Characteristic Reaction Value 24" bend tests $R_{n24} := 14745lbf$

18" and 24" span bending tests performed on decking simulated the reaction of the arch on decking. This value is mean -3sigma from three tests.

Moment:Reaction for 18" Tests $MR_{18} := 4.5in$

Moment:Reaction for 24" Tests $MR_{24} := 6in$

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 17.184 \cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$

Moisture Reduction Factor $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.826 \cdot kip$

Rating Factor $RF_{inv1} := \frac{\Phi R_n - R_{u\_DL\_only}}{(R_u - R_{u\_DL\_only})} = 1.789$

Pressure at Deep Cover Two Lanes - Operating - Truck

Inputs:

Load Factor for LL $\gamma_{LL} := 1.35$

Multiple Presence Factor $MPF := 1.0$

Dead Load:

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 1.472 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 8.255 \cdot kip$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Load from one wheel

$Wheel\_load := 16kip$

Wheel Distribution Along Arch

$W1 := 10in + d \cdot 1.15 = 16.588 \cdot ft$

Wheel Distribution Across Arch

$W2 := 20in + d \cdot 1.15 = 17.422 \cdot ft$

Area of Wheel Load Patch at Depth of Interest

$Load\_Patch := W1 \cdot W2 = 289 \cdot ft^2$

Average Wheel Pressure

$$Wheel\_Vert\_Press := \frac{Wheel\_load \cdot MPF \cdot \gamma_{LL}}{Load\_Patch}$$

Vertical pressure along horizontal projection:

$$Vert_{LL} := Wheel\_Vert\_Press \cdot H_p = 74.741 \cdot \frac{lbf}{ft}$$

Horizontal pressure along vertical projection:

$$Horiz_{LL} := Wheel\_Vert\_Press \cdot K_o \cdot V_p = 36.377 \cdot \frac{lbf}{ft}$$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure:

$$C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 51.92 \cdot \frac{lbf}{ft}$$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure:

$$C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 26.167 \cdot \frac{lbf}{ft}$$

Total resultant force perpendicular to the deck panel:

$$Total\_Force_{LL} := C_{vLL} + C_{hLL} = 78.087 \cdot \frac{lbf}{ft}$$

Factored LL pressure perpendicular to the deck panel per wheel:

$$LL\_Press := \frac{Total\_Force_{LL}}{\sqrt{H_p^2 + V_p^2}} = 0.377 \cdot psi$$

RISA Input Live Load Distributed Load

$$RISA\_LL := LL\_Press \cdot 9.75in = 0.044 \cdot \frac{kip}{ft}$$ per wheel

Lane Load

$w_{lane} := \gamma_{LL} \cdot 640lbf = 0.864 \cdot kip$ per foot of lane along arch

Lane Width at Deck Depth

$Width_{lane} := 10ft + d \cdot 1.15 = 25.755 \cdot ft$

RISA Input Lane Load

$$RISA\_Lane := \frac{w_{lane}}{Width_{lane}} = 0.034 \cdot \frac{kip}{ft}$$

RISA Analaysis Results:

Run RISA Analysis using appropriate number of wheels for given spans to determine Moment and Reaction

Reaction from RISA

$R_u := 9.398kip$ From RISA Analysis of six span beam - Node 2

Moment from RISA

$M_u := 51.43in \cdot kip$

Moment:Reaction from RISA Analysis

$$MR := \frac{M_u}{R_u} = 5.472 \cdot in$$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Characterisitc Reaction Value 18" bend tests: $R_{n18} := 21574lbf$

Characteristic Reaction Value 24" bend tests: $R_{n24} := 14745lbf$

18" and 24" span bending tests performed on decking simulated the reaction of the arch on decking. This value is mean -3sigma from three tests.

Moment:Reaction for 18" Tests: $MR_{18} := 4.5in$

Moment:Reaction for 24" Tests: $MR_{24} := 6in$

Interpolated Characteristic Value:

$$R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot \left(R_{n18} - R_{n24}\right) + R_{n24} = 17.147 \cdot kip$$

Compression Resistance Factor: $\Phi_c := 0.7$

Moisture Reduction Factor: $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value: $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.802 \cdot kip$

Rating Factor:

$$RF_{op1} := \frac{\Phi R_n - R_{u\_DL\_only}}{\left(R_u - R_{u\_DL\_only}\right)} = 2.229$$

Pressure at Shallow Cover One Lane - Tandem - Inventory

Soil Cover: $cover := 67in$ Measured from bottom of deck corrugation to road surface

Load Factor for LL: $\gamma_{LL} := 1.75$

Dead Load:

Factored Soil Pressure: $DL\_Press := cover \cdot \rho \cdot \gamma_e = 7.066 \cdot psi$

RISA Input Dead Load Distributed Load:

$$RISA\_DL := DL\_Press \cdot 9.75in = 0.827 \cdot \frac{kip}{ft}$$

Reaction Due to Dead Load only:

$$R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 4.636 \cdot kip$$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Maximum Wheel Load: $P := 12.5kip$

Multiple Presence Factor: $MPF := 1.2$

Wheel Distribution Along Arch: $W1 := 10in + cover \cdot 1.15 = 7.254 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + cover \cdot 1.15 = 8.087 \cdot ft$

Load Patch Area $Load\_Patch := W1 \cdot W2 = 58.668 \cdot ft^2$

Impact Factor $IM := 1 + 0.33\left(1.0 - 0.125\frac{cover}{12in}\right) = 1.100$

Factored Wheel Load $P_u := P \cdot \gamma_{LL} \cdot MPF \cdot IM = 28.867 \cdot kip$

Factored Live Load Pressure $PRL_u := \frac{P_u}{Load\_Patch} = 3.417 \cdot psi$

Factored Live Load Distributed Load $w_L := PRL_u \cdot 9.75in = 0.400 \cdot \frac{kip}{ft}$ per wheel

Lane Load $w_{lane} := \gamma_{LL} \cdot 640lbf = 1.12 \cdot kip$ per foot of lane along arch

Lane Width at Deck Depth $Width_{lane} := 10ft + cover \cdot 1.15 = 16.421 \cdot ft$

RISA Input Lane Load $RISA\_Lane := \frac{w_{lane}}{Width_{lane}} = 0.068 \cdot \frac{kip}{ft}$

RISA Analysis:

Reaction from RISA $R_u := 10.34kip$

Moment from RISA $M_u := 48.36in \cdot kip$ From RISA Analysis of six span beam - Node 5

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 4.677 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot \left(R_{n18} - R_{n24}\right) + R_{n24} = 20.768 \cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$

Moisture Reduction Factor $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 13.084 \cdot kip$

Rating Factor $RF_{inv2} := \frac{\Phi R_n - R_{u\_DL\_only}}{\left(R_u - R_{u\_DL\_only}\right)} = 1.481$

Pressure at Shallow Cover One Lane - Tandem - Operating

Soil Cover $cover := 67in$ Measured from bottom of deck corrugation to road surface

Load Factor for LL $\gamma_{LL} := 1.35$

Dead Load:

Factored Soil Pressure $DL\_Press := cover \cdot \rho \cdot \gamma_e = 7.066 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 0.827 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 4.636 \cdot kip$ Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Maximum Wheel Load $P := 12.5kip$

Multiple Presence Factor $MPF := 1.2$

Wheel Distribution Along Arch $W1 := 10in + cover \cdot 1.15 = 7.254 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + cover \cdot 1.15 = 8.087 \cdot ft$

Load Patch Area $Load\_Patch := W1 \cdot W2 = 58.668 \cdot ft^2$

Impact Factor $IM := 1 + 0.33\left(1.0 - 0.125\frac{cover}{12in}\right) = 1.100$

Factored Wheel Load $P_u := P \cdot \gamma_{LL} \cdot MPF \cdot IM = 22.269 \cdot kip$

Factored Live Load Pressure $PRL_u := \frac{P_u}{Load\_Patch} = 2.636 \cdot psi$

Factored Live Load Distributed Load $w_L := PRL_u \cdot 9.75in = 0.308 \cdot \frac{kip}{ft}$ per wheel

Lane Load $w_{lane} := \gamma_{LL} \cdot 640lbf = 0.864 \cdot kip$ per foot of lane along arch

Lane Width at Deck Depth $Width_{lane} := 10ft + cover \cdot 1.15 = 16.421 \cdot ft$

RISA Input Lane Load $RISA\_Lane := \frac{w_{lane}}{Width_{lane}} = 0.053 \cdot \frac{kip}{ft}$

RISA Analysis:

Reaction from RISA $R_u := 8.9kip$

Moment from RISA $M_u := 41.86in \cdot kip$ From RISA Analysis of six span beam - Node 5

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 4.703 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot \left(R_{n18} - R_{n24}\right) + R_{n24} = 20.648 \cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$

Moisture Reduction Factor $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 13.008 \cdot kip$

Rating Factor $RF_{op2} := \frac{\Phi R_n - R_{u\_DL\_only}}{\left(R_u - R_{u\_DL\_only}\right)} = 1.963$

Summary Inventory and Operating Load Rating Factors for Deck

Inventory Rating Factor $RF_{inv} := \min\left(RF_{inv1}, RF_{inv2}\right) = 1.481$

Operating Rating Factor $RF_{op} := \min\left(RF_{op1}, RF_{op2}\right) = 1.963$

Advanced Infrastructure Technologies
20 Godfrey Drive, Orono, ME 04473
Telephone: 207-866-6526
Fax: 207-866-6501

Project Name:	Fairfield Vt Bridge	Name:	J. Kenerson
Project Number:	12018	Date:	5/28/2014
Location:	Fairfield, Vt	Checked By:	Z.Uzman
Client:	VDOT	Date:	5/28/2014

AIT Load Rating Analysis Sheet

General LRFR, design level load rating equation:
[Ref. AASHTO Manual for Bridge Evaluation]

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_{LL})(LL + IM)}$$

For use in this load rating spreadsheet this equation is simplified to:

$$RF = \frac{C - D}{LL}$$

Where the variables are as follows:

C = Capacity (Moment or Shear, and positive or negative depending on the condition being checked)
D = Total envelope dead load effect, includes DC, EV, EH, DW, with all appropriate STRENGTH I load factors
LL = Total envelope live load effect, includes IM, and worst design vehicle, 1&2 lanes loaded with MPF
Michigan Overload Class A Results

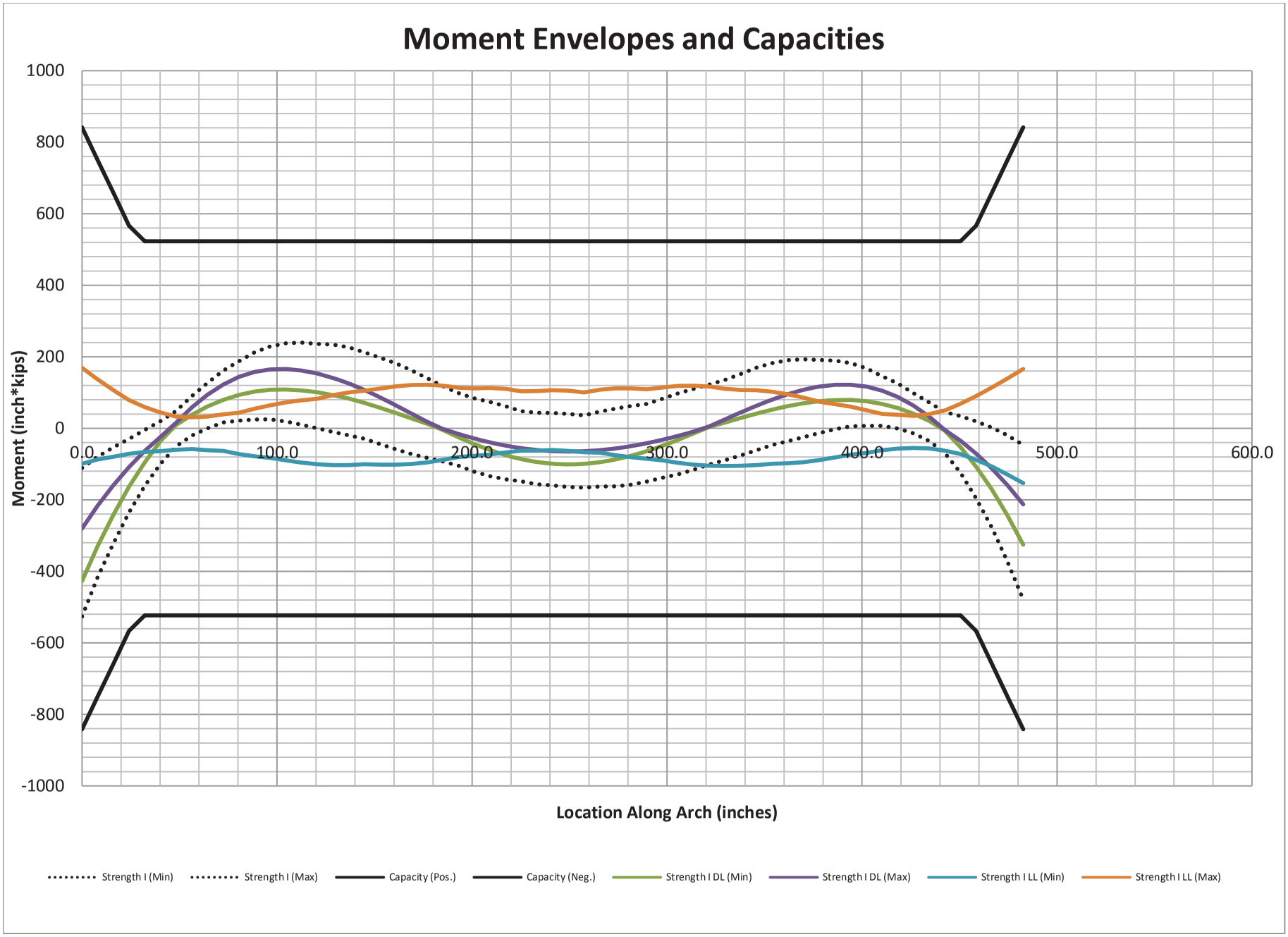
Inputs:

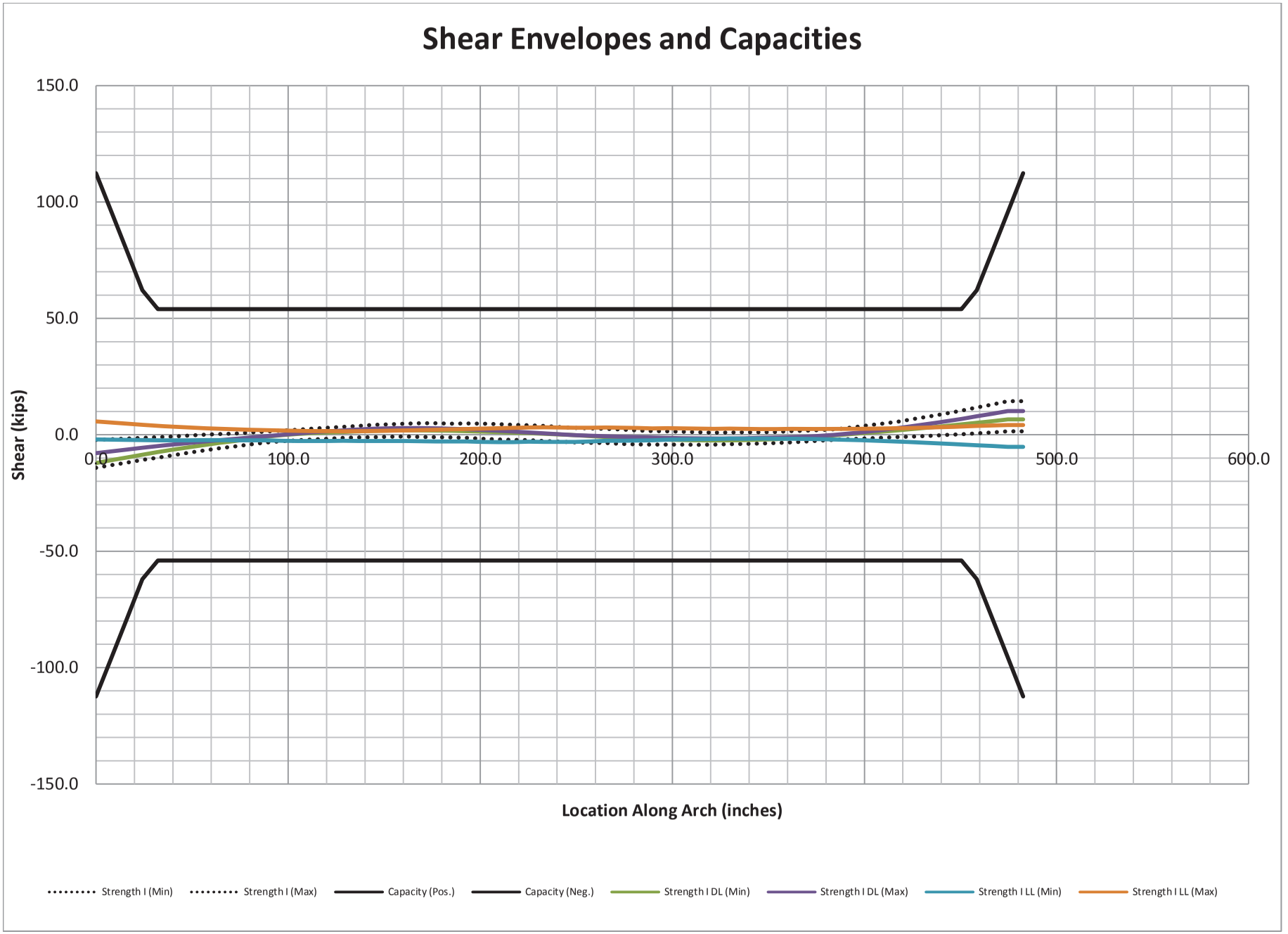
ARCHES

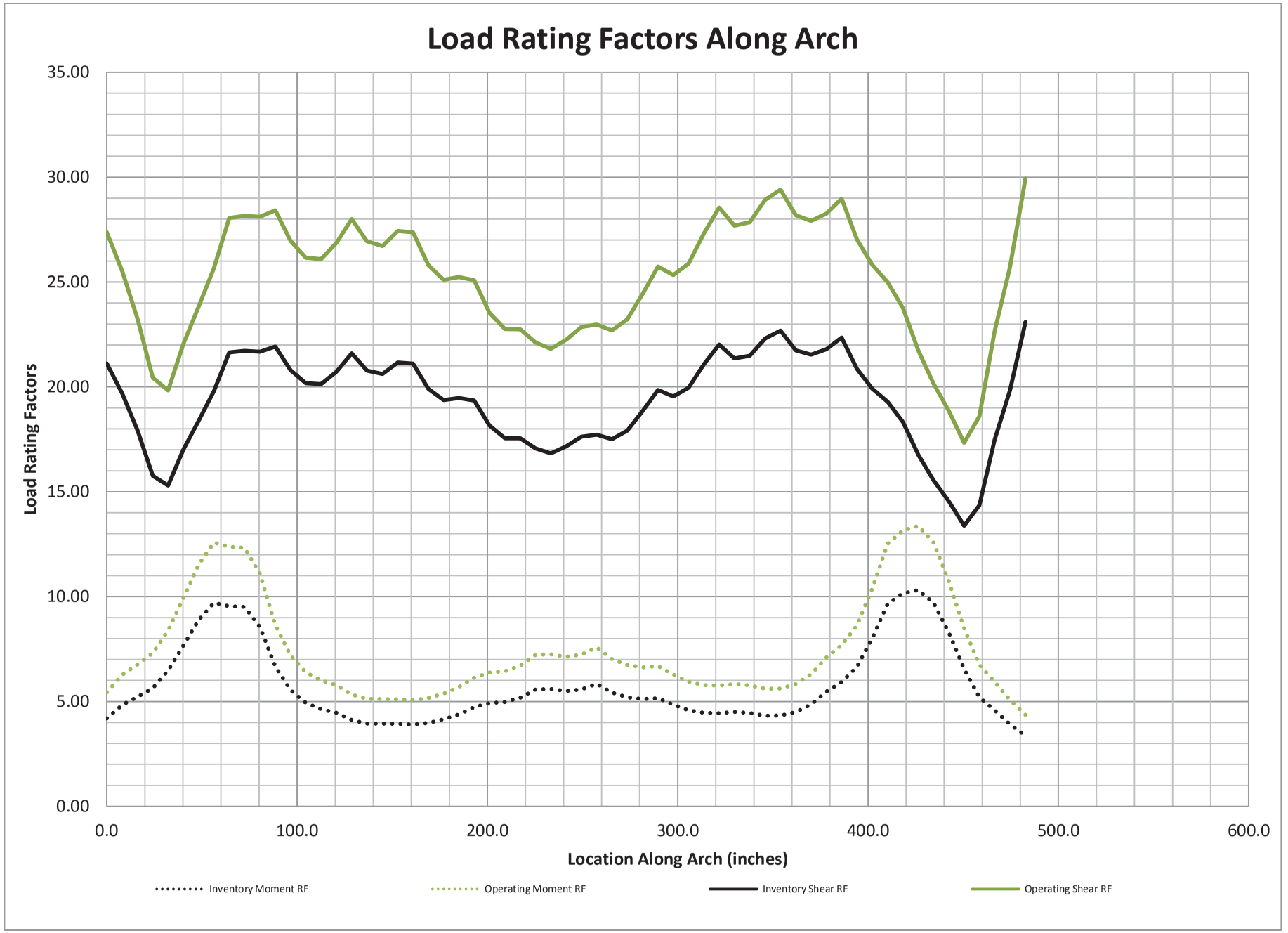
Moment Capacity, Reinforced Region, ϕM_n	841.8	in*kip
Moment Capacity, Unreinforced Region, ϕMn	522.7	in*kip
Development Length of End Reinforcing Bars	28.0	in
Length of Bars above TOF (excluding ld)	0.0	in
Shear Capacity, Reinforced Region, ϕVn	112.4	kip
Shear Capacity, Unreinforced Region, ϕVn	54	kip
Vehicle Description	3S2	

Results:

	Operating
ARCHES	
Moment RF	4.36
Shear RF	17.34
DECKING	
Shallow Cover Rating Factor	3.12
Deep Cover Rating Factor	4.04
Overall RF	**3.12**


Moment Envelopes and Capacities
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
Moment (inch*kips)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Strength I (Min)
Strength I (Max)
Capacity (Pos.)
Capacity (Neg.)
Strength I DL (Min)
Strength I DL (Max)
Strength I LL (Min)
Strength I LL (Max)


Shear Envelopes and Capacities
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
Shear (kips)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Strength I (Min)
Strength I (Max)
Capacity (Pos.)
Capacity (Neg.)
Strength I DL (Min)
Strength I DL (Max)
Strength I LL (Min)
Strength I LL (Max)


Load Rating Factors Along Arch
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Load Rating Factors
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Inventory Moment RF
Operating Moment RF
Inventory Shear RF
Operating Shear RF

ADVANCED INFRASTRUCTURE TECHNOLOGIES

Job
Sheet No. of
Calculated By Date
Checked By Date

3S2 2 LANES DEEP OPERATING

SAME WHEEL CONFIGURATION AS 5 AXLE SEMI

$D = 1.472$ K/ft
$L_4 = 0.044$ K/ft/wheel
$L_8 = 0.022$ K/ft/wheel

1) $D + L_4 + 2L_8$ — 1.527
2) $D + 2L_4 + 4L_8$ — 1.582
3) $D + 3L_4 + 6L_8$ — 1.637
4) $D + 4L_4 + 8L_8$ — 1.692

RISA NODE 2

$R = 8.88$
$M = 48.66$

$RF = 4.04$

3S2 1 LANE SHALLOW OPERATING

$D = 0.827$ K/ft
$L_8 = 0.197$ K/ft/wheel

1) D — 0.827
2) $D + 2L$ — 1.221
3) $D + 4L$ — 1.615

RISA NODE 4

$R = 7.181$
$M = 34.848$

$RF = 3.12$

Advanced Infrastructure Technologies

20 Godfrey Drive
Orono, Maine 04473
Telephone: (207) 866-6526
Fax: (207) 866-6501
www.aitbridges.com

Project: Fairfield, VT BRO 1448(38)

Task: Calculate Decking Rating Factors for 3S2 Loading

Pressure at Deep Cover Two Lanes - Operating

Inputs:

Arch Spacing $sp := 59.3in$

Angle of panel at base of arch: $\theta := 46deg$

Depth of soil above lowest panel: $d := 13.7ft$

Load factor for vertical earth: $\gamma_e := 1.35$

Load Factor for LL $\gamma_{LL} := 1.35$

Multiple Presence Factor $MPF := 1.0$

Dead Load:

At-rest earth pressure coefficient: $K_o := 0.47$

Density of backfill: $\rho := 135 \frac{lbf}{ft^3}$

Horizontal projection of decking: $H_p := 1ft$

Vertical projection of decking: $V_p := H_p \cdot \tan(\theta) = 1.036 \cdot ft$

Vertical pressure along horizontal projection: $Vert := \gamma_e \cdot \rho \cdot d \cdot H_p = 2496.825 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz := \gamma_e \cdot \rho \cdot d \cdot K_o \cdot V_p = 1215.203 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_v := \cos(\theta) \cdot Vert = 1734.44 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_h := \sin(\theta) \cdot Horiz = 874.144 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force := C_v + C_h = 2608.584 \cdot \frac{lbf}{ft}$

Factored dead load pressure perpendicular to the deck panel: $DL\_Press := \frac{Total\_Force}{\sqrt{H_p^2 + V_p^2}} = 12.584 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 1.472 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 8.255 \cdot kip$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Load from one wheel $Wheel\_load := 4kip$

Wheel Distribution Along Arch $W1 := 10in + d \cdot 1.15 = 16.588 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + d \cdot 1.15 = 17.422 \cdot ft$

Area of Wheel Load Patch at Depth of Interest $Load\_Patch := W1 \cdot W2 = 289 \cdot ft^2$

Average Wheel Pressure $Wheel\_Vert\_Press := \frac{Wheel\_load \cdot MPF \cdot \gamma_{LL}}{Load\_Patch}$

Vertical pressure along horizontal projection: $Vert_{LL} := Wheel\_Vert\_Press \cdot H_p = 18.685 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz_{LL} := Wheel\_Vert\_Press \cdot K_o \cdot V_p = 9.094 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 12.98 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 6.542 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force_{LL} := C_{vLL} + C_{hLL} = 19.522 \cdot \frac{lbf}{ft}$

Factored LL pressure perpendicular to the deck panel per wheel: $LL\_Press := \frac{Total\_Force_{LL}}{\sqrt{H_p^{\,2} + V_p^{\,2}}} = 0.094 \cdot psi$

RISA Input Live Load Distributed Load $RISA\_LL_4 := LL\_Press \cdot 9.75in = 0.011 \cdot \frac{kip}{ft}$ per wheel

Load from one wheel $Wheel\_load := 8 \cdot kip$

Wheel Distribution Along Arch $W1 := 10in + d \cdot 1.15 = 16.588 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + d \cdot 1.15 = 17.422 \cdot ft$

Area of Wheel Load Patch at Depth of Interest $Load\_Patch := W1 \cdot W2 = 289 \cdot ft^2$

Average Wheel Pressure $Wheel\_Vert\_Press := \frac{Wheel\_load \cdot MPF \cdot \gamma_{LL}}{Load\_Patch}$

Vertical pressure along horizontal projection: $Vert_{LL} := Wheel\_Vert\_Press \cdot H_p = 37.371 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz_{LL} := Wheel\_Vert\_Press \cdot K_o \cdot V_p = 18.188 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 25.96 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 13.084 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force_{LL} := C_{vLL} + C_{hLL} = 39.043 \cdot \frac{lbf}{ft}$

Factored LL pressure perpendicular to the deck panel per wheel: $LL\_Press := \frac{Total\_Force_{LL}}{\sqrt{H_p^{\,2} + V_p^{\,2}}} = 0.188 \cdot psi$

RISA Input Live Load Distributed Load $RISA\_LL_{8\_5} := LL\_Press \cdot 9.75in = 0.022 \cdot \frac{kip}{ft}$ per wheel

RISA Analaysis Results:

Run RISA Analysis using appropriate number of wheels for given spans to determine Moment and Reaction

Reaction from RISA $R_u := 8.88kip$

Moment from RISA $M_u := 48.66in \cdot kip$

From RISA Analysis of six span beam - Node 2

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 5.48 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Characterisitc Reaction Value 18" bend tests $R_{n18} := 21574lbf$

Characteristic Reaction Value 24" bend tests $R_{n24} := 14745lbf$

18" and 24" span bending tests performed on decking simulated the reaction of the arch on decking. This value is mean -3sigma from three tests.

Moment:Reaction for 18" Tests $MR_{18} := 4.5in$

Moment:Reaction for 24" Tests $MR_{24} := 6in$

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 17.114 \cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$

Moisture Reduction Factor $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.782 \cdot kip$

Rating Factor $RF_{op1} := \frac{\Phi R_n - R_{u\_DL\_only}}{\left(R_u - R_{u\_DL\_only}\right)} = 4.043$

Pressure at Shallow Cover One Lane - Operating

Soil Cover $cover := 67in$ Measured from bottom of deck corrugation to road surface

Load Factor for LL $\gamma_{LL} := 1.35$

Dead Load:

Factored Soil Pressure $DL\_Press := cover \cdot \rho \cdot \gamma_e = 7.066 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 0.827 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 4.636 \cdot kip$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Maximum Wheel Load $P := 8kip$

Multiple Presence Factor $MPF := 1.2$

Wheel Distribution Along Arch $W1 := 10in + cover \cdot 1.15 = 7.254 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + cover \cdot 1.15 = 8.087 \cdot ft$

Load Patch Area $Load\_Patch := W1 \cdot W2 = 58.668 \cdot ft^2$

Impact Factor $IM := 1 + 0.33\left(1.0 - 0.125\frac{cover}{12in}\right) = 1.100$

Factored Wheel Load $P_u := P \cdot \gamma_{LL} \cdot MPF \cdot IM = 14.252 \cdot kip$

Factored Live Load Pressure $PRL_u := \frac{P_u}{Load\_Patch} = 1.687 \cdot psi$

Factored Live Load Distributed Load $w_L := PRL_u \cdot 9.75in = 0.197 \cdot \frac{kip}{ft}$ per wheel

RISA Analysis:

Reaction from RISA $R_u := 7.181kip$

Moment from RISA $M_u := 34.848\,in\cdot kip$ From RISA Analysis of six span beam - Node 5

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 4.853\cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}}\cdot\left(R_{n18} - R_{n24}\right) + R_{n24} = 19.968\cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Moisture Reduction Factor $C_m := 0.9$

Design Reaction Value $\Phi R_n := \Phi_c\cdot C_m\cdot R_n = 12.58\cdot kip$

Rating Factor $RF_{op2} := \frac{\Phi R_n - R_{u\_DL\_only}}{\left(R_u - R_{u\_DL\_only}\right)} = 3.121$

Summary Load Rating Factors for Deck

Operating Rating Factor $RF_{op} := \min\left(RF_{op1}, RF_{op2}\right) = 3.121$

Advanced Infrastructure Technologies
20 Godfrey Drive, Orono, ME 04473
Telephone: 207-866-6526
Fax: 207-866-6501

Project Name:	Fairfield Vt Bridge	Name:	J. Kenerson
Project Number:	12018	Date:	5/28/2014
Location:	Fairfield, Vt	Checked By:	Z.Uzman
Client:	VDOT	Date:	5/28/2014

AIT Load Rating Analysis Sheet

General LRFR, design level load rating equation:
[Ref. AASHTO Manual for Bridge Evaluation]

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_{LL})(LL + IM)}$$

For use in this load rating spreadsheet this equation is simplified to:

$$RF = \frac{C - D}{LL}$$

Where the variables are as follows:

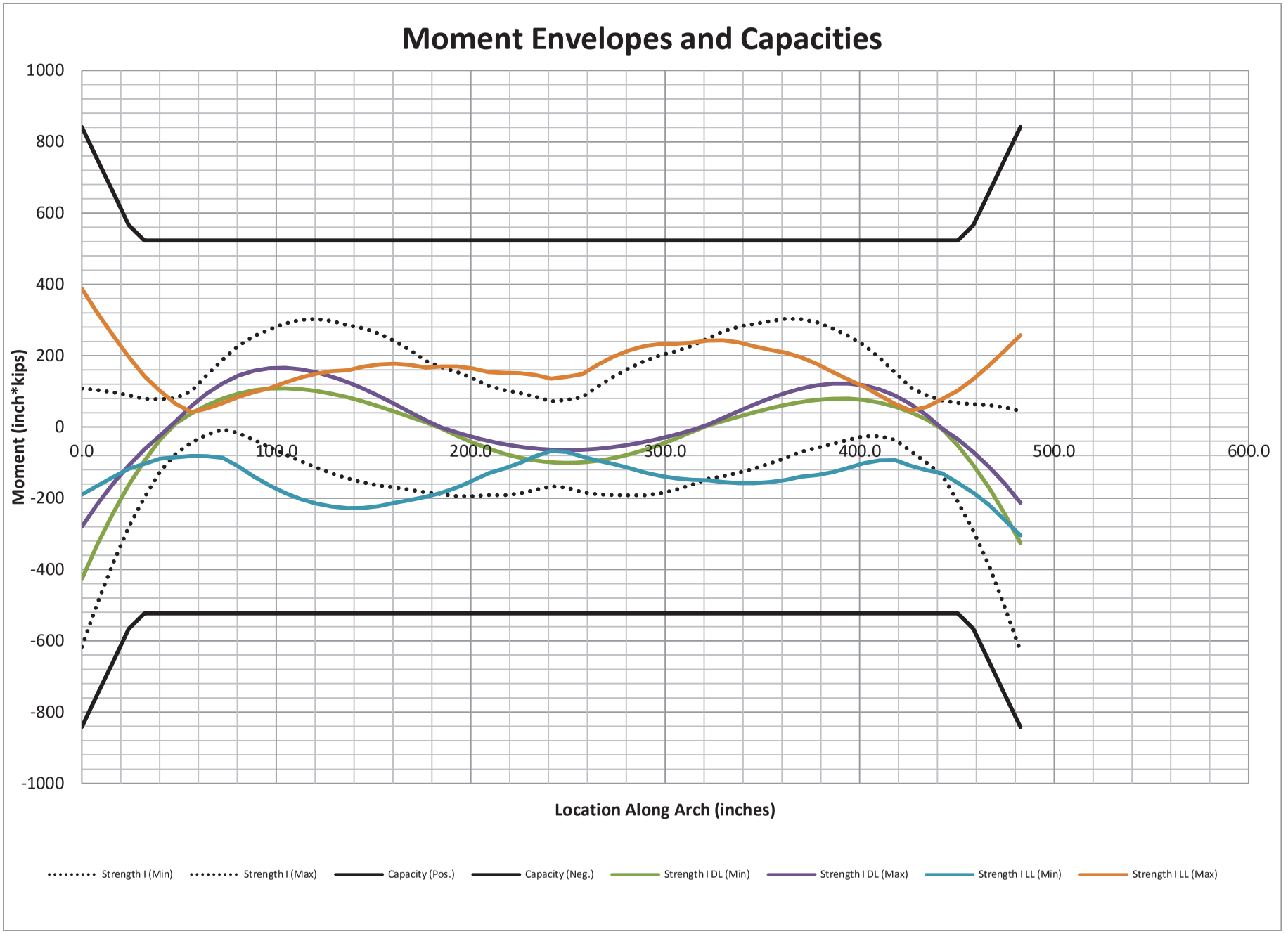
C = Capacity (Moment or Shear, and positive or negative depending on the condition being checked)
D = Total envelope dead load effect, includes DC, EV, EH, DW, with all appropriate STRENGTH I load factors
LL = Total envelope live load effect, includes IM, and worst design vehicle, 1&2 lanes loaded with MPF
Michigan Overload Class A Results

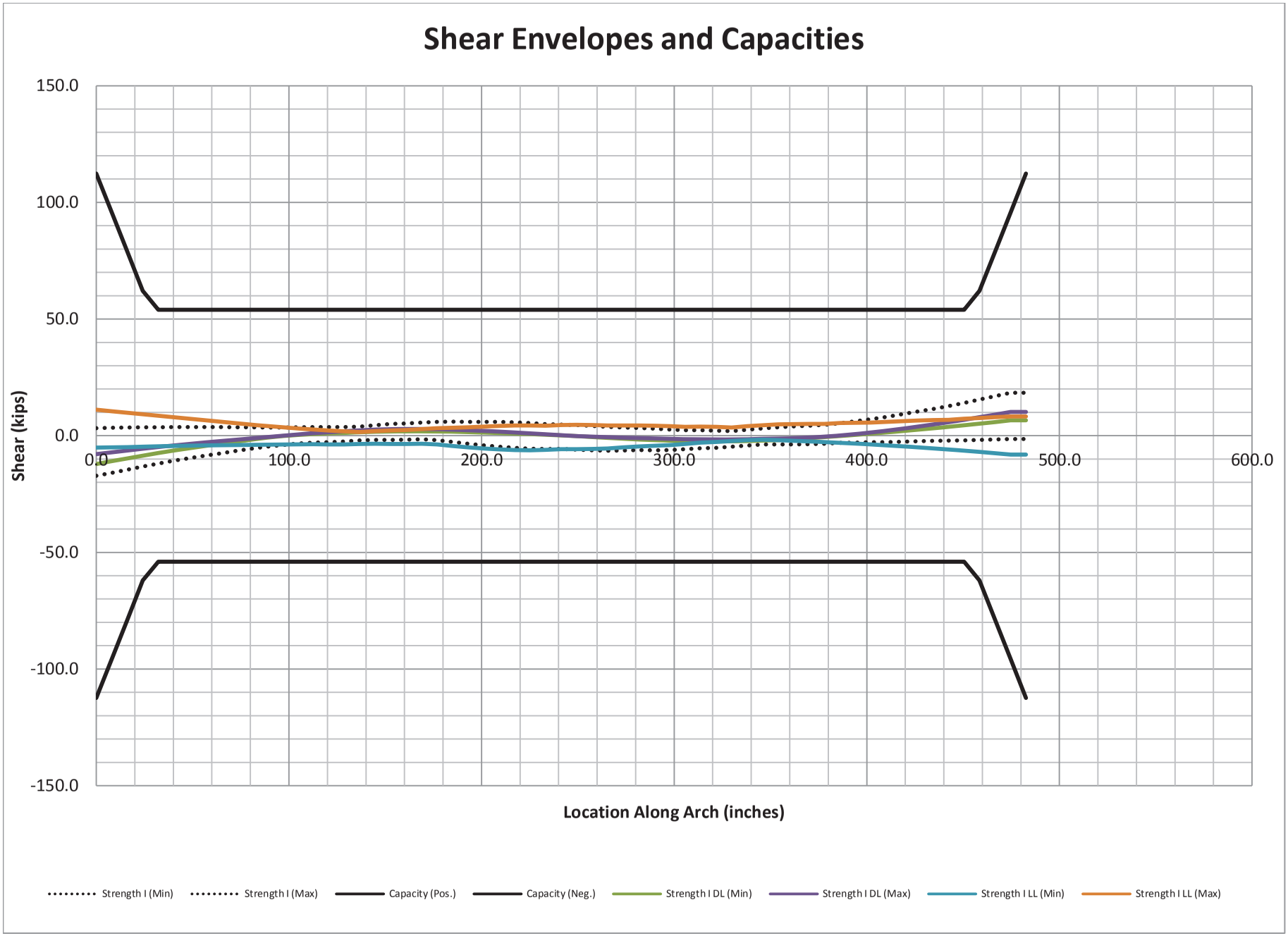
Inputs:

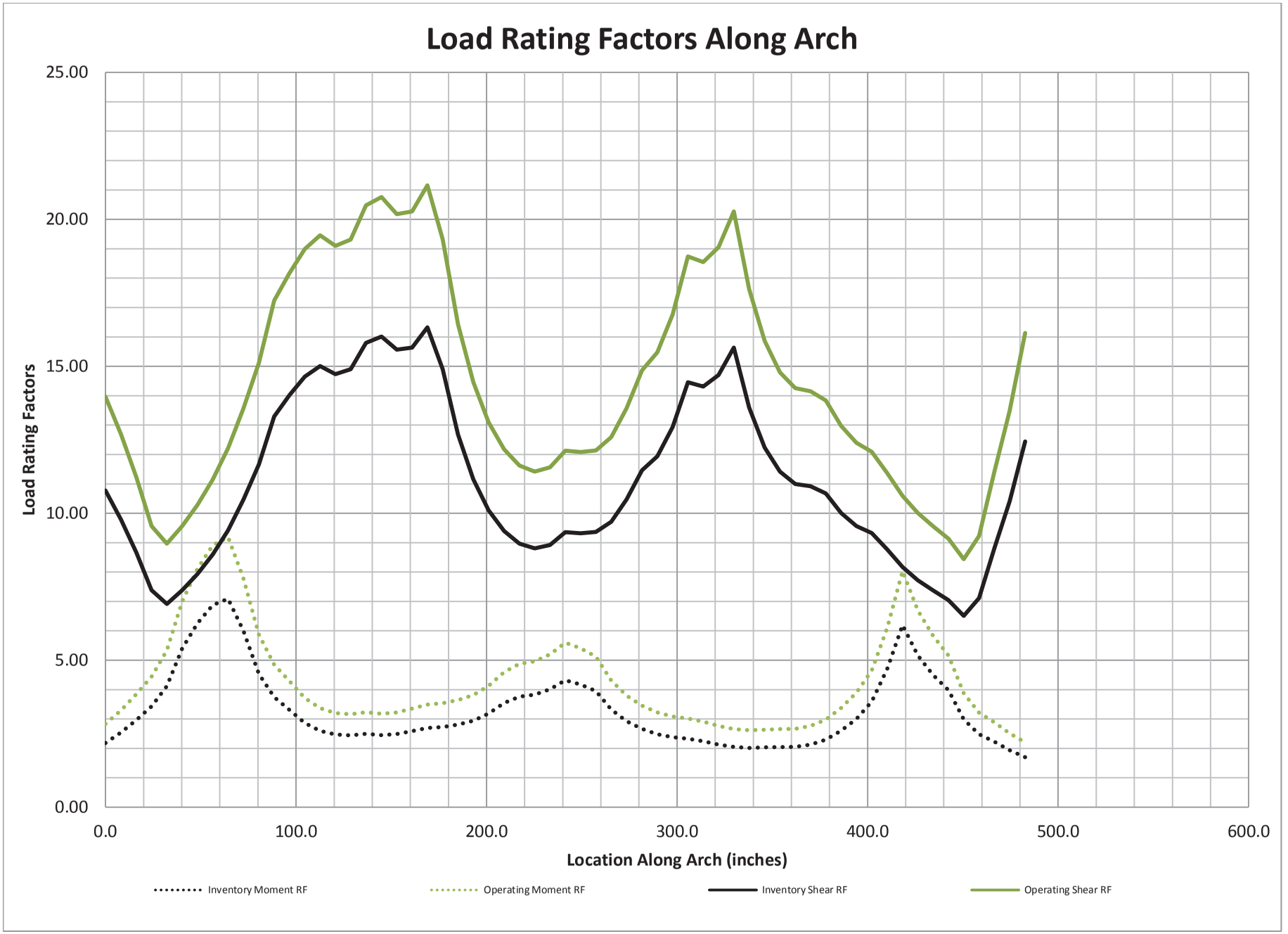
ARCHES		
Moment Capacity, Reinforced Region, ϕM_n	841.8	in*kip
Moment Capacity, Unreinforced Region, ϕMn	522.7	in*kip
Development Length of End Reinforcing Bars	28.0	in
Length of Bars above TOF (excluding ld)	0.0	in
Shear Capacity, Reinforced Region, ϕVn	112.4	kip
Shear Capacity, Unreinforced Region, ϕVn	54	kip
Vehicle Description	6 Axle Trailer	

Results:

	Operating
ARCHES	
Moment RF	2.20
Shear RF	8.44
DECKING	
Shallow Cover Rating Factor	2.02
Deep Cover Rating Factor	2.51
Overall RF	**2.02**


Moment Envelopes and Capacities
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
Moment (inch*kips)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Strength I (Min)
Strength I (Max)
Capacity (Pos.)
Capacity (Neg.)
Strength I DL (Min)
Strength I DL (Max)
Strength I LL (Min)
Strength I LL (Max)


Shear Envelopes and Capacities
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
Shear (kips)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Strength I (Min)
Strength I (Max)
Capacity (Pos.)
Capacity (Neg.)
Strength I DL (Min)
Strength I DL (Max)
Strength I LL (Min)
Strength I LL (Max)

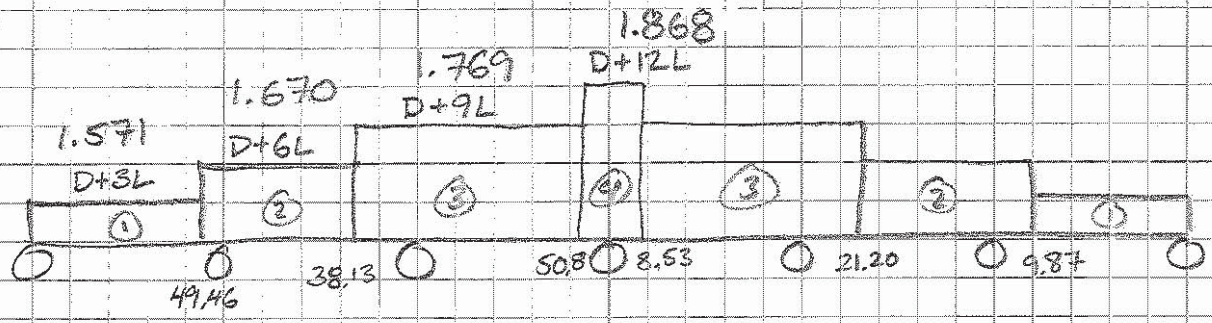

Load Rating Factors Along Arch
25.00
20.00
15.00
10.00
5.00
0.00
Load Rating Factors
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Inventory Moment RF
Operating Moment RF
Inventory Shear RF
Operating Shear RF

ADVANCED INFRASTRUCTURE TECHNOLOGIES

Job FAIRFIELD, VT LOAD RATING
Sheet No. _____ of _____
Calculated By _____ Date _____
Checked By _____ Date _____

6 AXLE TRAILER DEEP BURY TWO LANES OPERATING

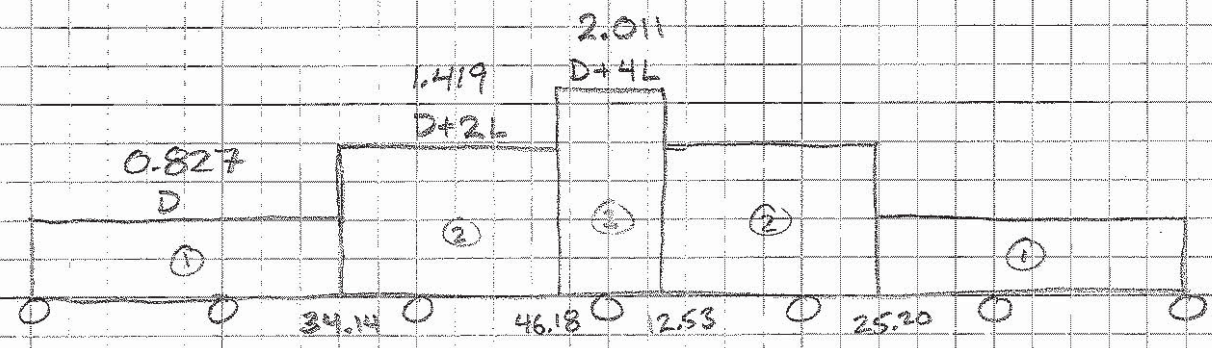
DL = 1.472 k/ft
LL_{12} = 0.033 k/ft per wheel



	NODE 2
R	9.281
M	50.688
RF	2.51

6 AXLE TRAILER SHALLOW BURY ONE LANE OPERATING

DL = 0.827 k/ft
LL_{12} = 0.296 k/ft/wheel



	NODE 4
R	8.662
M	411.496
RF	2.02

Advanced Infrastructure Technologies

20 Godfrey Drive
Orono, Maine 04473
Telephone: (207) 866-6526
Fax: (207) 866-6501
www.aitbridges.com

Project: Fairfield, VT BRO 1448(38)

Task: Calculate Decking Rating Factors for 6 Axle Trailer Loading

Pressure at Deep Cover Two Lanes - Operating

Inputs:

Arch Spacing $sp := 59.3in$

Angle of panel at base of arch: $\theta := 46deg$

Depth of soil above lowest panel: $d := 13.7ft$

Load factor for vertical earth: $\gamma_e := 1.35$

Load Factor for LL $\gamma_{LL} := 1.35$

Multiple Presence Factor $MPF := 1.0$

Dead Load:

At-rest earth pressure coefficient: $K_o := 0.47$

Density of backfill: $\rho := 135\frac{lbf}{ft^3}$

Horizontal projection of decking: $H_p := 1ft$

Vertical projection of decking: $V_p := H_p \cdot \tan(\theta) = 1.036 \cdot ft$

Vertical pressure along horizontal projection: $Vert := \gamma_e \cdot \rho \cdot d \cdot H_p = 2496.825 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz := \gamma_e \cdot \rho \cdot d \cdot K_o \cdot V_p = 1215.203 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_v := \cos(\theta) \cdot Vert = 1734.44 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_h := \sin(\theta) \cdot Horiz = 874.144 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force := C_v + C_h = 2608.584 \cdot \frac{lbf}{ft}$

Factored dead load pressure perpendicular to the deck panel: $DL\_Press := \frac{Total\_Force}{\sqrt{H_p^2 + V_p^2}} = 12.584 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 1.472 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 8.255 \cdot kip$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Load from one wheel $Wheel\_load := 12kip$

Wheel Distribution Along Arch $W1 := 10in + d \cdot 1.15 = 16.588 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + d \cdot 1.15 = 17.422 \cdot ft$

Area of Wheel Load Patch at Depth of Interest $Load\_Patch := W1 \cdot W2 = 289 \cdot ft^2$

Average Wheel Pressure $Wheel\_Vert\_Press := \frac{Wheel\_load \cdot MPF \cdot \gamma_{LL}}{Load\_Patch}$

Vertical pressure along horizontal projection: $Vert_{LL} := Wheel\_Vert\_Press \cdot H_p = 56.056 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz_{LL} := Wheel\_Vert\_Press \cdot K_o \cdot V_p = 27.282 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 38.94 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 19.625 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force_{LL} := C_{vLL} + C_{hLL} = 58.565 \cdot \frac{lbf}{ft}$

Factored LL pressure perpendicular to the deck panel per wheel: $LL\_Press := \frac{Total\_Force_{LL}}{\sqrt{H_p^2 + V_p^2}} = 0.283 \cdot psi$

RISA Input Live Load Distributed Load $RISA\_LL := LL\_Press \cdot 9.75in = 0.033 \cdot \frac{kip}{ft}$ per wheel

RISA Analaysis Results:

Run RISA Analysis using appropriate number of wheels for given spans to determine Moment and Reaction

Reaction from RISA $R_u := 9.281kip$ From RISA Analysis of six span beam - Node 2

Moment from RISA $M_u := 50.688in \cdot kip$

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 5.461 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Characterisitc Reaction Value 18" bend tests: $R_{n18} := 21574lbf$

Characteristic Reaction Value 24" bend tests: $R_{n24} := 14745lbf$

18" and 24" span bending tests performed on decking simulated the reaction of the arch on decking. This value is mean -3sigma from three tests.

Moment:Reaction for 18" Tests: $MR_{18} := 4.5in$

Moment:Reaction for 24" Tests: $MR_{24} := 6in$

Interpolated Characteristic Value: $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 17.197 \cdot kip$

Compression Resistance Factor: $\Phi_c := 0.7$

Moisture Reduction Factor: $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value: $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.834 \cdot kip$

Rating Factor: $RF_{op1} := \frac{\Phi R_n - R_{u\_DL\_only}}{(R_u - R_{u\_DL\_only})} = 2.514$

Pressure at Shallow Cover One Lane - Operating

Soil Cover: $cover := 67in$ Measured from bottom of deck corrugation to road surface

Load Factor for LL: $\gamma_{LL} := 1.35$

Dead Load:

Factored Soil Pressure: $DL\_Press := cover \cdot \rho \cdot \gamma_e = 7.066 \cdot psi$

RISA Input Dead Load Distributed Load: $RISA\_DL := DL\_Press \cdot 9.75in = 0.827 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only: $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 4.636 \cdot kip$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Maximum Wheel Load: $P := 12kip$

Multiple Presence Factor: $MPF := 1.2$

Wheel Distribution Along Arch: $W1 := 10in + cover \cdot 1.15 = 7.254 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + cover \cdot 1.15 = 8.087 \cdot ft$

Load Patch Area $Load\_Patch := W1 \cdot W2 = 58.668 \cdot ft^2$

Impact Factor $IM := 1 + 0.33\left(1.0 - 0.125\frac{cover}{12in}\right) = 1.100$

Factored Wheel Load $P_u := P \cdot \gamma_{LL} \cdot MPF \cdot IM = 21.378 \cdot kip$

Factored Live Load Pressure $PRL_u := \frac{P_u}{Load\_Patch} = 2.53 \cdot psi$

Factored Live Load Distributed Load $w_L := PRL_u \cdot 9.75in = 0.296 \cdot \frac{kip}{ft}$ per wheel

RISA Analysis:

Reaction from RISA $R_u := 8.662kip$

Moment from RISA $M_u := 41.496in \cdot kip$ From RISA Analysis of six span beam - Node 5

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 4.791 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot \left(R_{n18} - R_{n24}\right) + R_{n24} = 20.251 \cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$

Moisture Reduction Factor $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 12.758 \cdot kip$

Rating Factor $RF_{op2} := \frac{\Phi R_n - R_{u\_DL\_only}}{\left(R_u - R_{u\_DL\_only}\right)} = 2.017$

Summary Load Rating Factors for Deck

Operating Rating Factor $RF_{op} := \min\left(RF_{op1}, RF_{op2}\right) = 2.017$

Advanced Infrastructure Technologies
20 Godfrey Drive, Orono, ME 04473
Telephone: 207-866-6526
Fax: 207-866-6501

Project Name:	Fairfield Vt Bridge	Name:	J. Kenerson
Project Number:	12018	Date:	5/28/2014
Location:	Fairfield, Vt	Checked By:	Z.Uzman
Client:	VDOT	Date:	5/28/2014

AIT Load Rating Analysis Sheet

General LRFR, design level load rating equation:
[Ref. AASHTO Manual for Bridge Evaluation]

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_{LL})(LL + IM)}$$

For use in this load rating spreadsheet this equation is simplified to:

$$RF = \frac{C - D}{LL}$$

Where the variables are as follows:

C = Capacity (Moment or Shear, and positive or negative depending on the condition being checked)
D = Total envelope dead load effect, includes DC, EV, EH, DW, with all appropriate STRENGTH I load factors
LL = Total envelope live load effect, includes IM, and worst design vehicle, 1&2 lanes loaded with MPF
Michigan Overload Class A Results

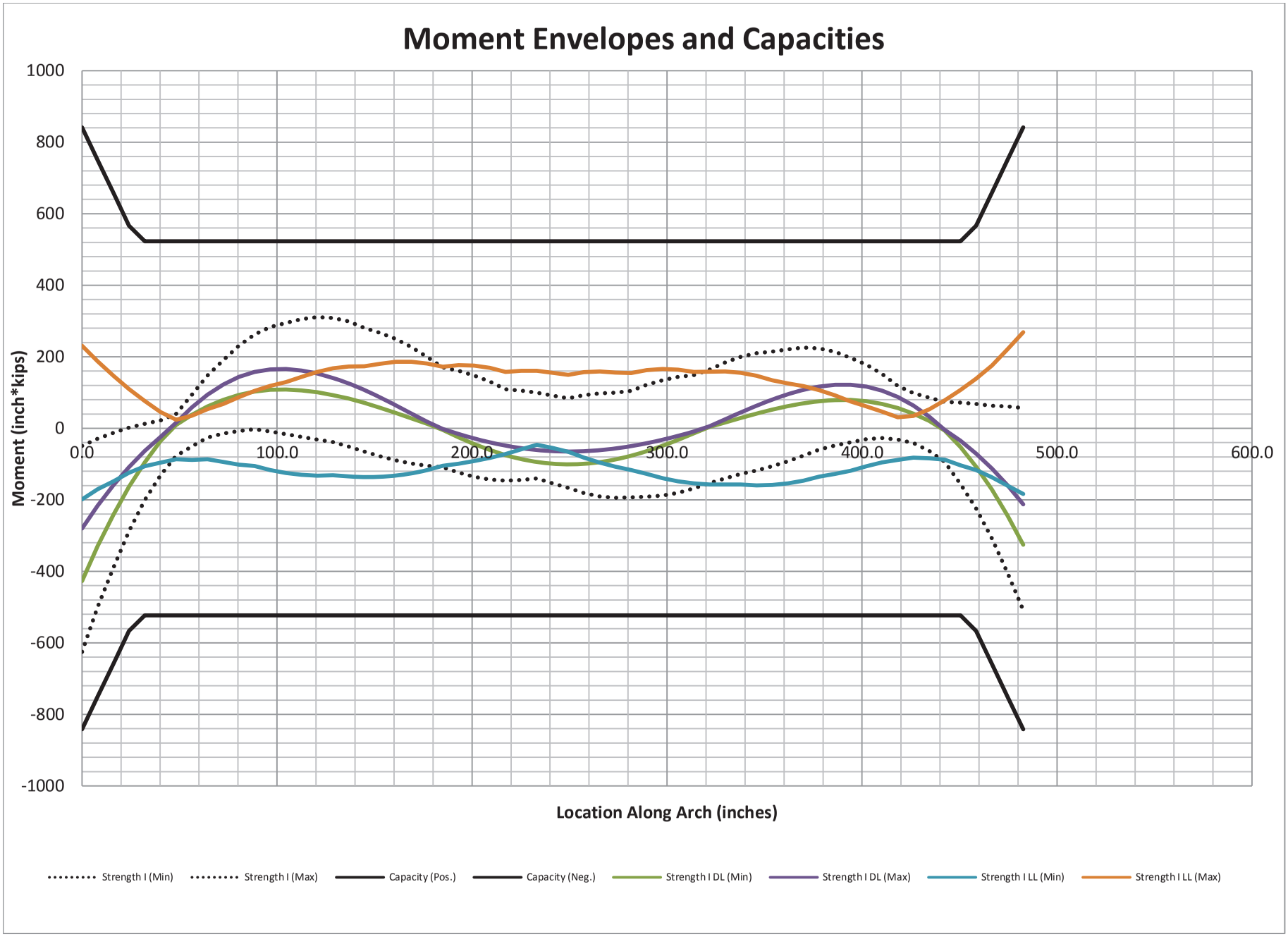
Inputs:

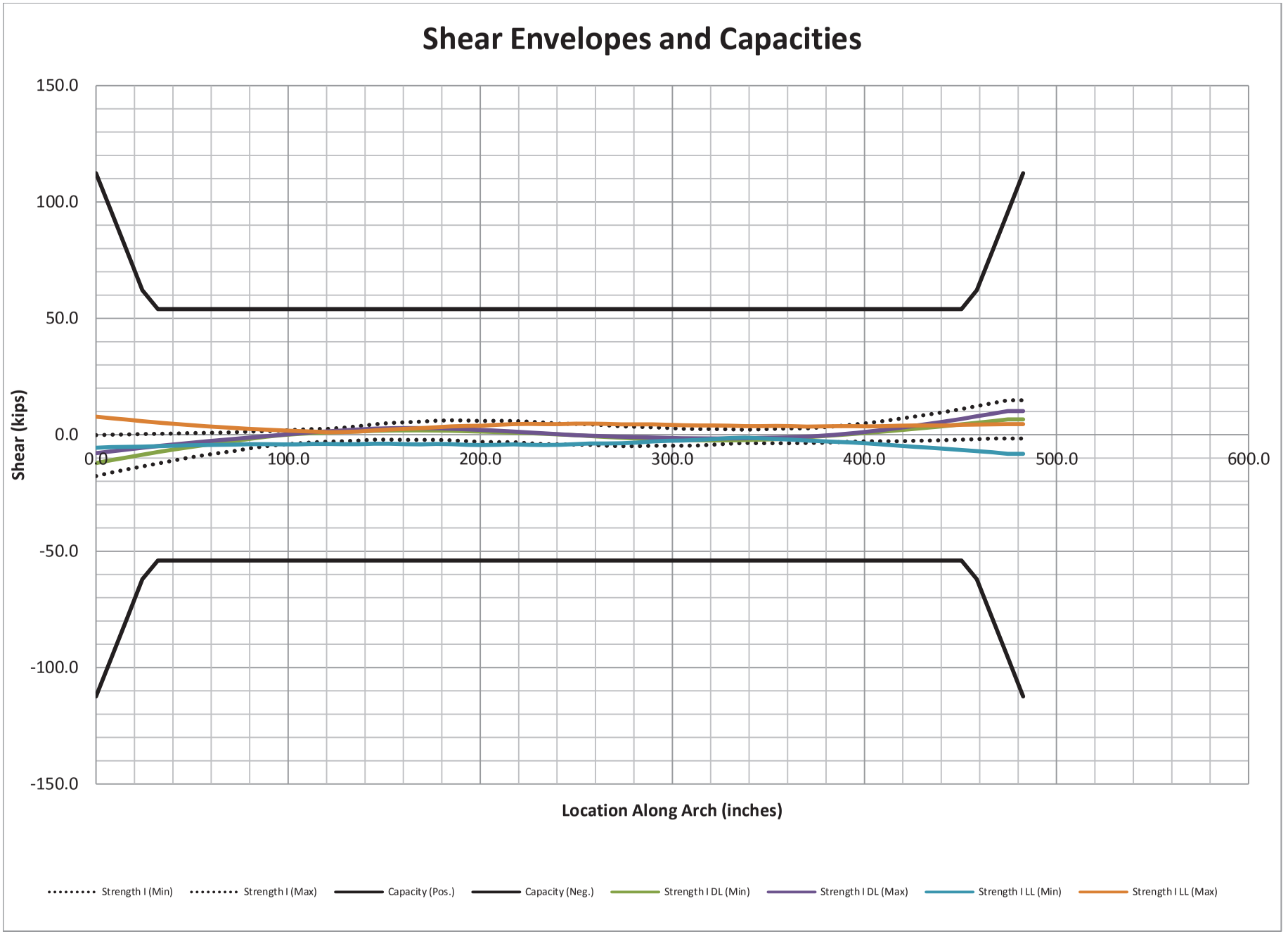
ARCHES

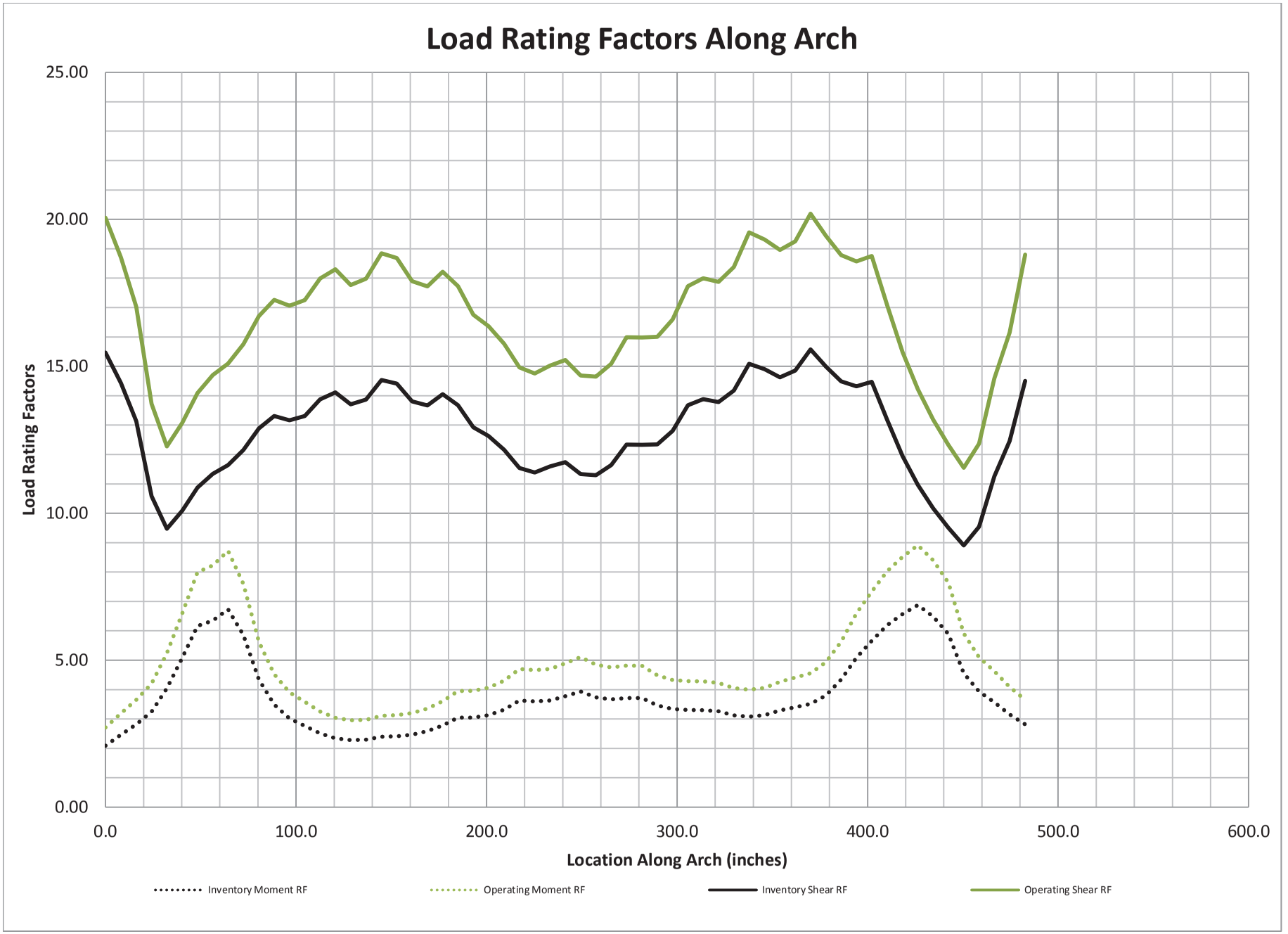
Moment Capacity, Reinforced Region, ϕ_{Mn}	841.8	in*kip
Moment Capacity, Unreinforced Region, ϕMn	522.7	in*kip
Development Length of End Reinforcing Bars	28.0	in
Length of Bars above TOF (excluding ld)	0.0	in
Shear Capacity, Reinforced Region, ϕVn	112.4	kip
Shear Capacity, Unreinforced Region, ϕVn	54	kip
Vehicle Description	3 Axle Straight	

Results:

	Operating
ARCHES	
Moment RF	2.71
Shear RF	11.55
DECKING	
Shallow Cover Rating Factor	2.02
Deep Cover Rating Factor	3.51
Overall RF	**2.02**


Moment Envelopes and Capacities
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
Moment (inch*kips)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Strength I (Min)
Strength I (Max)
Capacity (Pos.)
Capacity (Neg.)
Strength I DL (Min)
Strength I DL (Max)
Strength I LL (Min)
Strength I LL (Max)


Shear Envelopes and Capacities
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
Shear (kips)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Strength I (Min)
Strength I (Max)
Capacity (Pos.)
Capacity (Neg.)
Strength I DL (Min)
Strength I DL (Max)
Strength I LL (Min)
Strength I LL (Max)


Load Rating Factors Along Arch
25.00
20.00
15.00
10.00
5.00
0.00
Load Rating Factors
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Inventory Moment RF
Operating Moment RF
Inventory Shear RF
Operating Shear RF

ADVANCED INFRASTRUCTURE TECHNOLOGIES

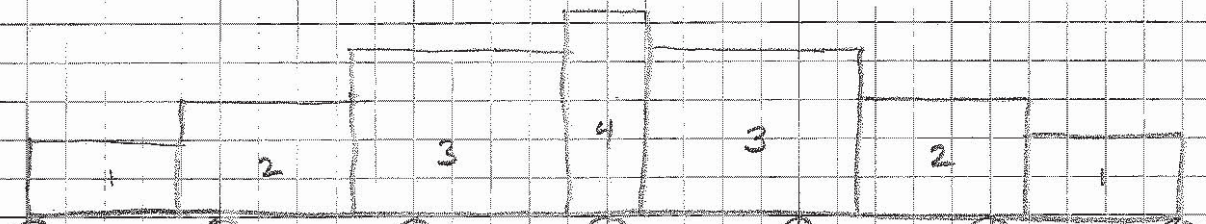
Job
Sheet No. of
Calculated By Date
Checked By Date

3 AXLE 2 LANES DEEP OPERATING

D = 1.472 k/ft

L_{L2} = 0.033 k/ft/wheel

1) D+2L — 1.538
2) D+4L — 1.604
3) D+6L — 1.670
4) D+8L — 1.736



SAME SPACING AS 4 AXLE

RISA NODE 2

K = 8.98

M = 49.164

RF = 3.51

3 AXLE 1 LANE SHALLOW OPERATING

D = 0.827 k/ft

LL_{12} = 0.296 k/ft/wheel

1) D — 0.827
2) D+2L — 1.419
3) D+4L — 2.011

SAME WHEEL CONFIGURATION AS 5 AXLE

RISA NODE 4

R = 8.662

M = 41.496

RF = 2.02

Advanced Infrastructure Technologies

20 Godfrey Drive
Orono, Maine 04473
Telephone: (207) 866-6526
Fax: (207) 866-6501
www.aitbridges.com

Project: Fairfield, VT BRO 1448(38)

Task: Calculate Decking Rating Factors for 3 Axle Straight Loading

Pressure at Deep Cover Two Lanes - Operating

Inputs:

Arch Spacing $sp := 59.3in$

Angle of panel at base of arch: $\theta := 46deg$

Depth of soil above lowest panel: $d := 13.7ft$

Load factor for vertical earth: $\gamma_e := 1.35$

Load Factor for LL $\gamma_{LL} := 1.35$

Multiple Presence Factor $MPF := 1.0$

Dead Load:

At-rest earth pressure coefficient: $K_o := 0.47$

Density of backfill: $\rho := 135 \frac{lbf}{ft^3}$

Horizontal projection of decking: $H_p := 1ft$

Vertical projection of decking: $V_p := H_p \cdot \tan(\theta) = 1.036 \cdot ft$

Vertical pressure along horizontal projection: $Vert := \gamma_e \cdot \rho \cdot d \cdot H_p = 2496.825 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz := \gamma_e \cdot \rho \cdot d \cdot K_o \cdot V_p = 1215.203 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_v := \cos(\theta) \cdot Vert = 1734.44 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_h := \sin(\theta) \cdot Horiz = 874.144 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force := C_v + C_h = 2608.584 \cdot \frac{lbf}{ft}$

Factored dead load pressure perpendicular to the deck panel: $DL\_Press := \frac{Total\_Force}{\sqrt{H_p^2 + V_p^2}} = 12.584 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 1.472 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 8.255 \cdot kip$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Load from one wheel $Wheel\_load := 12kip$

Wheel Distribution Along Arch $W1 := 10in + d \cdot 1.15 = 16.588 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + d \cdot 1.15 = 17.422 \cdot ft$

Area of Wheel Load Patch at Depth of Interest $Load\_Patch := W1 \cdot W2 = 289 \cdot ft^2$

Average Wheel Pressure $Wheel\_Vert\_Press := \frac{Wheel\_load \cdot MPF \cdot \gamma_{LL}}{Load\_Patch}$

Vertical pressure along horizontal projection: $Vert_{LL} := Wheel\_Vert\_Press \cdot H_p = 56.056 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz_{LL} := Wheel\_Vert\_Press \cdot K_o \cdot V_p = 27.282 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 38.94 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 19.625 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force_{LL} := C_{vLL} + C_{hLL} = 58.565 \cdot \frac{lbf}{ft}$

Factored LL pressure perpendicular to the deck panel per wheel: $LL\_Press := \frac{Total\_Force_{LL}}{\sqrt{H_p^2 + V_p^2}} = 0.283 \cdot psi$

RISA Input Live Load Distributed Load $RISA\_LL_4 := LL\_Press \cdot 9.75in = 0.033 \cdot \frac{kip}{ft}$ per wheel

RISA Analaysis Results:

Run RISA Analysis using appropriate number of wheels for given spans to determine Moment and Reaction

Reaction from RISA $R_u := 8.98kip$

Moment from RISA $M_u := 49.164in \cdot kip$

From RISA Analysis of six span beam - Node 2

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 5.475 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Characterisitc Reaction Value 18" bend tests $R_{n18} := 21574lbf$

Characteristic Reaction Value 24" bend tests $R_{n24} := 14745lbf$

18" and 24" span bending tests performed on decking simulated the reaction of the arch on decking. This value is mean -3sigma from three tests.

Moment:Reaction for 18" Tests $MR_{18} := 4.5in$

Moment:Reaction for 24" Tests $MR_{24} := 6in$

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 17.136 \cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$

Moisture Reduction Factor $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.796 \cdot kip$

Rating Factor $RF_{op1} := \frac{\Phi R_n - R_{u\_DL\_only}}{(R_u - R_{u\_DL\_only})} = 3.505$

Pressure at Shallow Cover One Lane - Operating

Soil Cover $cover := 67in$ Measured from bottom of deck corrugation to road surface

Load Factor for LL $\gamma_{LL} := 1.35$

Dead Load:

Factored Soil Pressure $DL\_Press := cover \cdot \rho \cdot \gamma_e = 7.066 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 0.827 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 4.636 \cdot kip$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Maximum Wheel Load $P := 12kip$

Multiple Presence Factor $MPF := 1.2$

Wheel Distribution Along Arch $W1 := 10in + cover \cdot 1.15 = 7.254 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + cover \cdot 1.15 = 8.087 \cdot ft$

Load Patch Area $Load\_Patch := W1 \cdot W2 = 58.668 \cdot ft^2$

Impact Factor $IM := 1 + 0.33\left(1.0 - 0.125\frac{cover}{12in}\right) = 1.100$

Factored Wheel Load $P_u := P \cdot \gamma_{LL} \cdot MPF \cdot IM = 21.378 \cdot kip$

Factored Live Load Pressure $PRL_u := \frac{P_u}{Load\_Patch} = 2.53 \cdot psi$

Factored Live Load Distributed Load $w_L := PRL_u \cdot 9.75in = 0.296 \cdot \frac{kip}{ft}$ per wheel

RISA Analysis:

Reaction from RISA $R_u := 8.662kip$

Moment from RISA $M_u := 41.496in \cdot kip$ From RISA Analysis of six span beam - Node 5

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 4.791 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot \left(R_{n18} - R_{n24}\right) + R_{n24} = 20.251 \cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$

Moisture Reduction Factor $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 12.758 \cdot kip$

Rating Factor $RF_{op2} := \frac{\Phi R_n - R_{u\_DL\_only}}{\left(R_u - R_{u\_DL\_only}\right)} = 2.017$

Summary Load Rating Factors for Deck

Operating Rating Factor $RF_{op} := \min\left(RF_{op1}, RF_{op2}\right) = 2.017$

Advanced Infrastructure Technologies
20 Godfrey Drive, Orono, ME 04473
Telephone: 207-866-6526
Fax: 207-866-6501

Project Name:	Fairfield Vt Bridge	Name:	J. Kenerson
Project Number:	12018	Date:	5/28/2014
Location:	Fairfield, Vt	Checked By:	Z.Uzman
Client:	VDOT	Date:	5/28/2014

AIT Load Rating Analysis Sheet

General LRFR, design level load rating equation:
[Ref. AASHTO Manual for Bridge Evaluation]

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_{LL})(LL + IM)}$$

For use in this load rating spreadsheet this equation is simplified to:

$$RF = \frac{C - D}{LL}$$

Where the variables are as follows:

C = Capacity (Moment or Shear, and positive or negative depending on the condition being checked)
D = Total envelope dead load effect, includes DC, EV, EH, DW, with all appropriate STRENGTH I load factors
LL = Total envelope live load effect, includes IM, and worst design vehicle, 1&2 lanes loaded with MPF Michigan Overload Class A Results

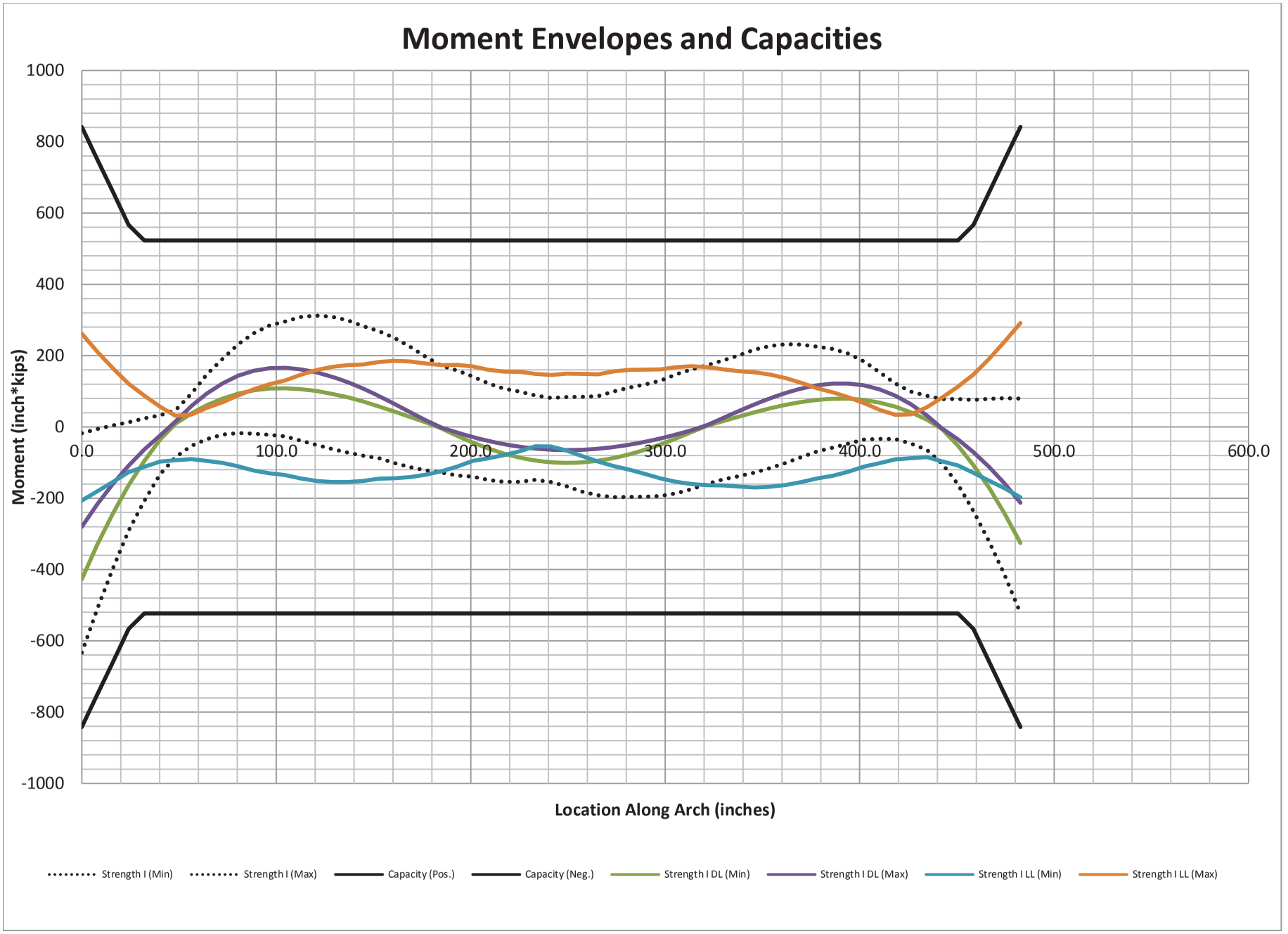
Inputs:

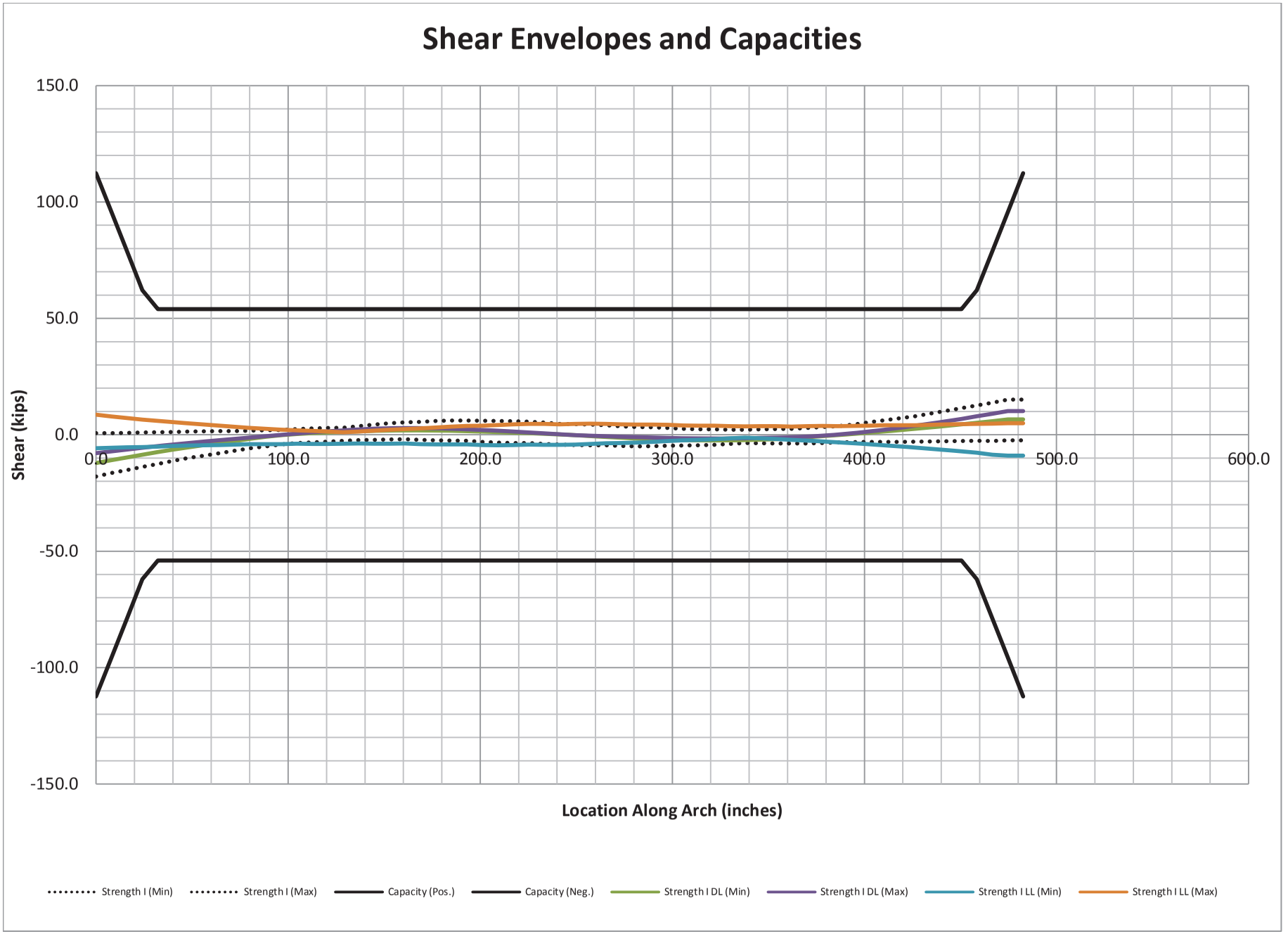
ARCHES

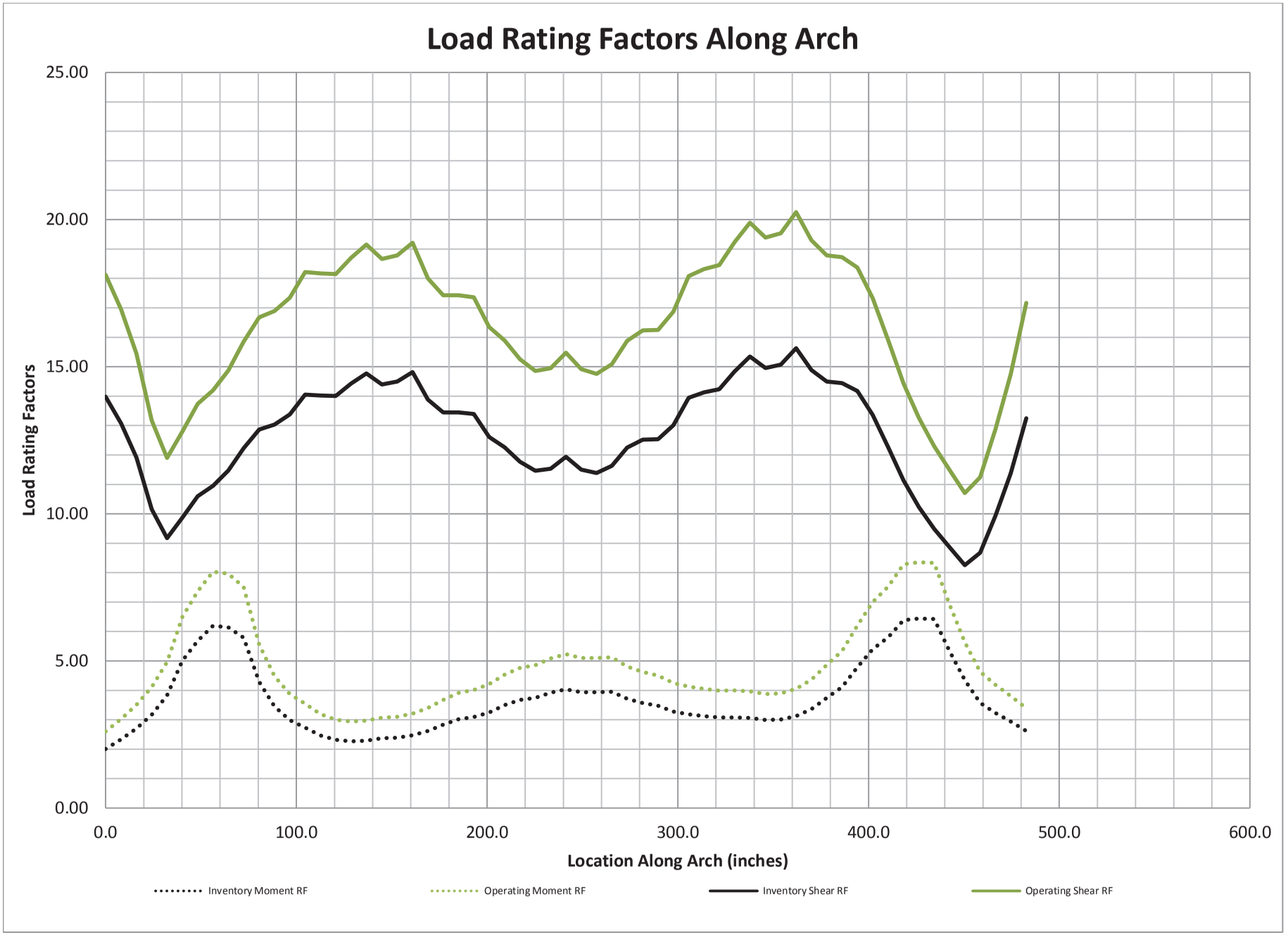
Moment Capacity, Reinforced Region, ϕ_{Mn}	841.8	in*kip
Moment Capacity, Unreinforced Region, ϕMn	522.7	in*kip
Development Length of End Reinforcing Bars	28.0	in
Length of Bars above TOF (excluding ld)	0.0	in
Shear Capacity, Reinforced Region, ϕVn	112.4	kip
Shear Capacity, Unreinforced Region, ϕVn	54	kip
Vehicle Description	4 Axle Straight	

Results:

	Operating
ARCHES	
Moment RF	2.61
Shear RF	10.70
DECKING	
Shallow Cover Rating Factor	2.59
Deep Cover Rating Factor	3.06
Overall RF	**2.59**


Moment Envelopes and Capacities
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
Moment (inch*kips)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Strength I (Min)
Strength I (Max)
Capacity (Pos.)
Capacity (Neg.)
Strength I DL (Min)
Strength I DL (Max)
Strength I LL (Min)
Strength I LL (Max)


Shear Envelopes and Capacities
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
Shear (kips)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Strength I (Min)
Strength I (Max)
Capacity (Pos.)
Capacity (Neg.)
Strength I DL (Min)
Strength I DL (Max)
Strength I LL (Min)
Strength I LL (Max)


Load Rating Factors Along Arch
25.00
20.00
15.00
10.00
5.00
0.00
Load Rating Factors
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Inventory Moment RF
Operating Moment RF
Inventory Shear RF
Operating Shear RF

ADVANCED INFRASTRUCTURE TECHNOLOGIES

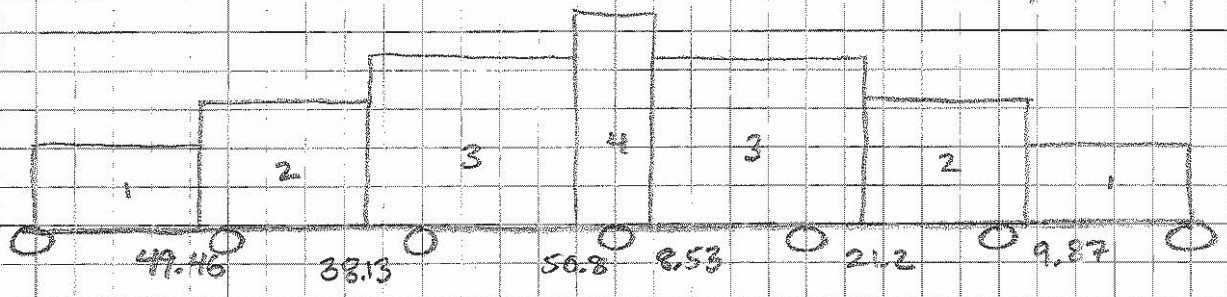
Job _____
Sheet No. _____ of _____
Calculated By _____ Date _____
Checked By _____ Date _____

4 AXLE STRAIGHT 2 LANES DEEP OPERATING

D = 1.472 k/ft

$L_{9.5}$ = 0.026 k/ft/wheel

1) D + 3L — 1.550
2) D + 6L — 1.628
3) D + 9L — 1.706
4) D + 12L — 1.784



RISA NODE 2

R = 9.090
M = 49.716

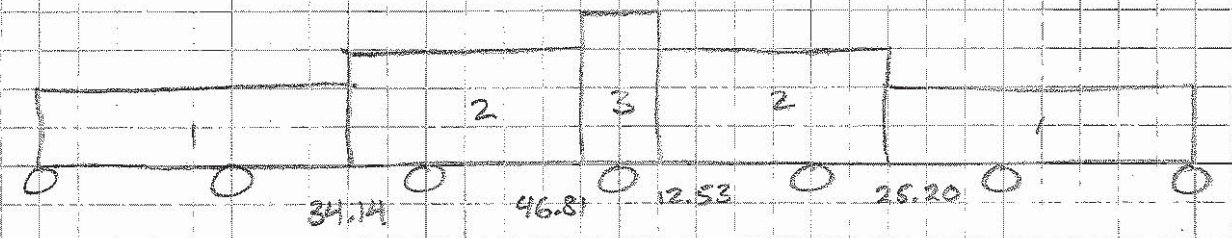
RF = 3.06

4 AXLE STRAIGHT 1 LANE SHALLOW OPERATING

D = 0.827 k/ft

$L_{9.5}$ = 0.234 k/ft/wheel

1) D — 0.827
2) D + 2L — 1.295
3) D + 4L — 1.763



RISA NODE 4

R = 7.735
M = 37.332

RF = 2.59

Advanced Infrastructure Technologies

20 Godfrey Drive
Orono, Maine 04473
Telephone: (207) 866-6526
Fax: (207) 866-6501
www.aitbridges.com

Project: Fairfield, VT BRO 1448(38)

Task: Calculate Decking Rating Factors for 4 Axle Straight Loading

Pressure at Deep Cover Two Lanes - Operating

Inputs:

Arch Spacing $sp := 59.3in$

Angle of panel at base of arch: $\theta := 46deg$

Depth of soil above lowest panel: $d := 13.7ft$

Load factor for vertical earth: $\gamma_e := 1.35$

Load Factor for LL $\gamma_{LL} := 1.35$

Multiple Presence Factor $MPF := 1.0$

Dead Load:

At-rest earth pressure coefficient: $K_o := 0.47$

Density of backfill: $\rho := 135 \frac{lbf}{ft^3}$

Horizontal projection of decking: $H_p := 1ft$

Vertical projection of decking: $V_p := H_p \cdot \tan(\theta) = 1.036 \cdot ft$

Vertical pressure along horizontal projection: $Vert := \gamma_e \cdot \rho \cdot d \cdot H_p = 2496.825 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz := \gamma_e \cdot \rho \cdot d \cdot K_o \cdot V_p = 1215.203 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_v := \cos(\theta) \cdot Vert = 1734.44 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_h := \sin(\theta) \cdot Horiz = 874.144 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force := C_v + C_h = 2608.584 \cdot \frac{lbf}{ft}$

Factored dead load pressure perpendicular to the deck panel: $DL\_Press := \frac{Total\_Force}{\sqrt{H_p^2 + V_p^2}} = 12.584 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 1.472 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 8.255 \cdot kip$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Load from one wheel $Wheel\_load := 9.5kip$

Wheel Distribution Along Arch $W1 := 10in + d \cdot 1.15 = 16.588 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + d \cdot 1.15 = 17.422 \cdot ft$

Area of Wheel Load Patch at Depth of Interest $Load\_Patch := W1 \cdot W2 = 289 \cdot ft^2$

Average Wheel Pressure $Wheel\_Vert\_Press := \frac{Wheel\_load \cdot MPF \cdot \gamma_{LL}}{Load\_Patch}$

Vertical pressure along horizontal projection: $Vert_{LL} := Wheel\_Vert\_Press \cdot H_p = 44.378 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz_{LL} := Wheel\_Vert\_Press \cdot K_o \cdot V_p = 21.599 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 30.827 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 15.537 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force_{LL} := C_{vLL} + C_{hLL} = 46.364 \cdot \frac{lbf}{ft}$

Factored LL pressure perpendicular to the deck panel per wheel: $LL\_Press := \frac{Total\_Force_{LL}}{\sqrt{H_p^{\,2} + V_p^{\,2}}} = 0.224 \cdot psi$

RISA Input Live Load Distributed Load $RISA\_LL_4 := LL\_Press \cdot 9.75in = 0.026 \cdot \frac{kip}{ft}$ per wheel

RISA Analaysis Results:

Run RISA Analysis using appropriate number of wheels for given spans to determine Moment and Reaction

Reaction from RISA $R_u := 9.09kip$

Moment from RISA $M_u := 49.716in \cdot kip$

From RISA Analysis of six span beam - Node 2

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 5.469 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Characterisitc Reaction Value 18" bend tests: $R_{n18} := 21574lbf$

Characteristic Reaction Value 24" bend tests: $R_{n24} := 14745lbf$

18" and 24" span bending tests performed on decking simulated the reaction of the arch on decking. This value is mean -3sigma from three tests.

Moment:Reaction for 18" Tests: $MR_{18} := 4.5in$

Moment:Reaction for 24" Tests: $MR_{24} := 6in$

Interpolated Characteristic Value: $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 17.161 \cdot kip$

Compression Resistance Factor: $\Phi_c := 0.7$

Moisture Reduction Factor: $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value: $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.811 \cdot kip$

Rating Factor: $RF_{op1} := \frac{\Phi R_n - R_{u\_DL\_only}}{(R_u - R_{u\_DL\_only})} = 3.062$

Pressure at Shallow Cover One Lane - Operating

Soil Cover: $cover := 67in$ Measured from bottom of deck corrugation to road surface

Load Factor for LL: $\gamma_{LL} := 1.35$

Dead Load:

Factored Soil Pressure: $DL\_Press := cover \cdot \rho \cdot \gamma_e = 7.066 \cdot psi$

RISA Input Dead Load Distributed Load: $RISA\_DL := DL\_Press \cdot 9.75in = 0.827 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only: $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 4.636 \cdot kip$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Maximum Wheel Load: $P := 9.5kip$

Multiple Presence Factor: $MPF := 1.2$

Wheel Distribution Along Arch: $W1 := 10in + cover \cdot 1.15 = 7.254 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + cover \cdot 1.15 = 8.087 \cdot ft$

Load Patch Area $Load\_Patch := W1 \cdot W2 = 58.668 \cdot ft^2$

Impact Factor $IM := 1 + 0.33\left(1.0 - 0.125\frac{cover}{12in}\right) = 1.100$

Factored Wheel Load $P_u := P \cdot \gamma_{LL} \cdot MPF \cdot IM = 16.924 \cdot kip$

Factored Live Load Pressure $PRL_u := \frac{P_u}{Load\_Patch} = 2.003 \cdot psi$

Factored Live Load Distributed Load $w_L := PRL_u \cdot 9.75in = 0.234 \cdot \frac{kip}{ft}$ per wheel

RISA Analysis:

Reaction from RISA $R_u := 7.735kip$

Moment from RISA $M_u := 37.332in \cdot kip$ From RISA Analysis of six span beam - Node 5

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 4.826 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot \left(R_{n18} - R_{n24}\right) + R_{n24} = 20.088 \cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$

Moisture Reduction Factor $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 12.656 \cdot kip$

Rating Factor $RF_{op2} := \frac{\Phi R_n - R_{u\_DL\_only}}{\left(R_u - R_{u\_DL\_only}\right)} = 2.588$

Summary Load Rating Factors for Deck

Operating Rating Factor $RF_{op} := \min\left(RF_{op1}, RF_{op2}\right) = 2.588$

Advanced Infrastructure Technologies
20 Godfrey Drive, Orono, ME 04473
Telephone: 207-866-6526
Fax: 207-866-6501

Project Name:	Fairfield Vt Bridge	Name:	J. Kenerson
Project Number:	12018	Date:	5/28/2014
Location:	Fairfield, Vt	Checked By:	Z.Uzman
Client:	VDOT	Date:	5/28/2014

AIT Load Rating Analysis Sheet

General LRFR, design level load rating equation:
[Ref. AASHTO Manual for Bridge Evaluation]

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_{LL})(LL + IM)}$$

For use in this load rating spreadsheet this equation is simplified to:

$$RF = \frac{C - D}{LL}$$

Where the variables are as follows:

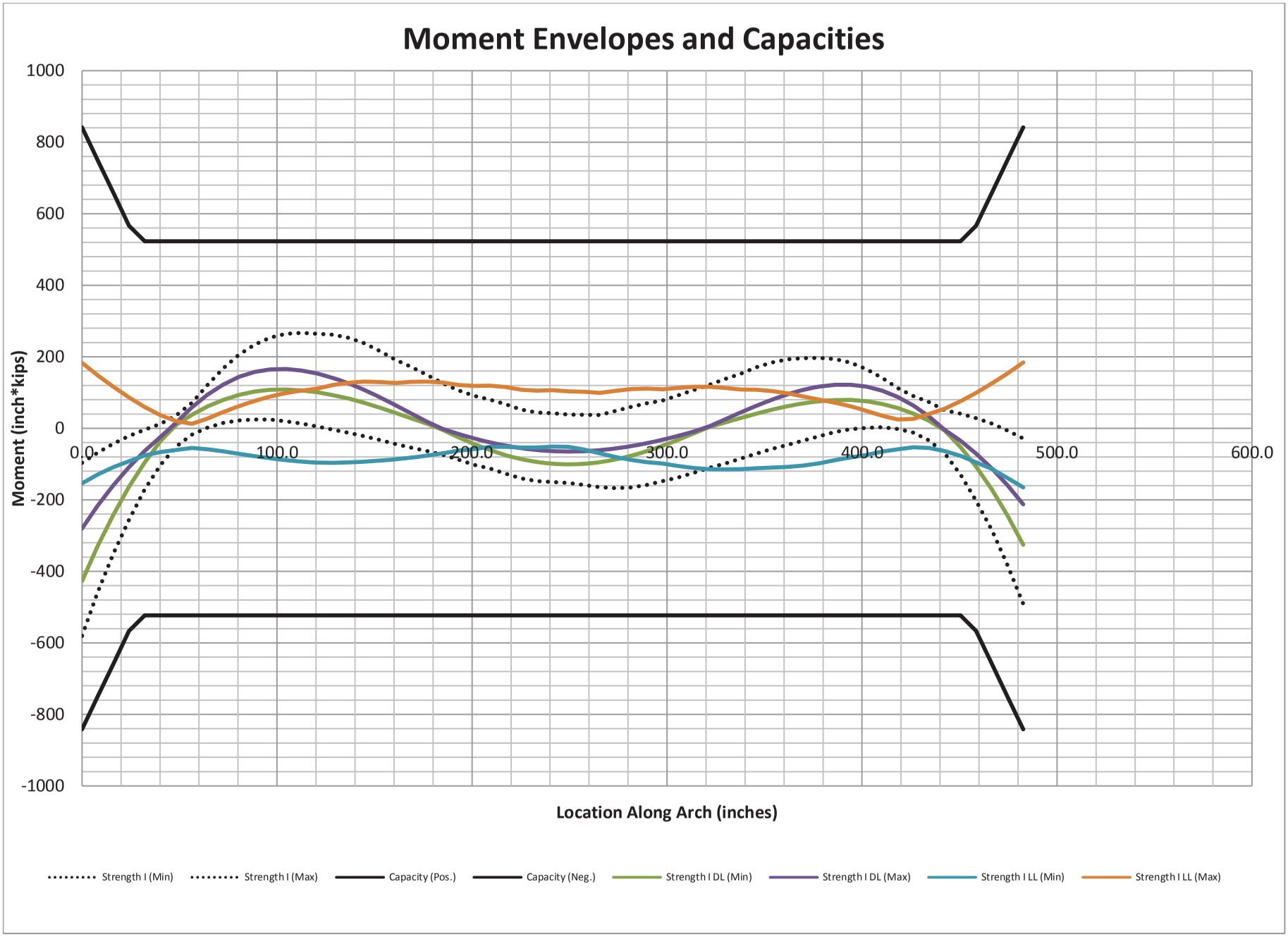
C = Capacity (Moment or Shear, and positive or negative depending on the condition being checked)
D = Total envelope dead load effect, includes DC, EV, EH, DW, with all appropriate STRENGTH I load factors
LL = Total envelope live load effect, includes IM, and worst design vehicle, 1&2 lanes loaded with MPF
Michigan Overload Class A Results

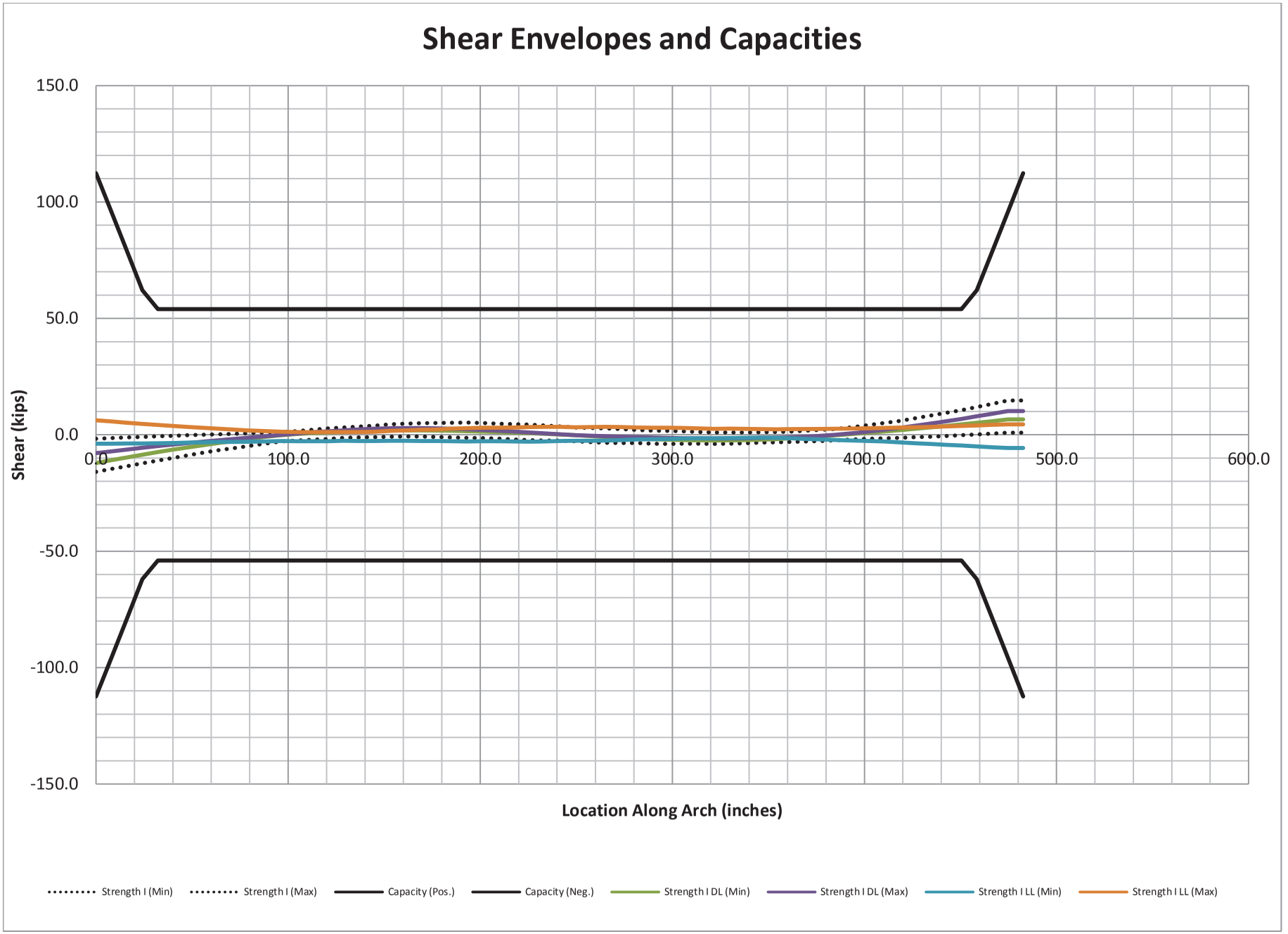
Inputs:

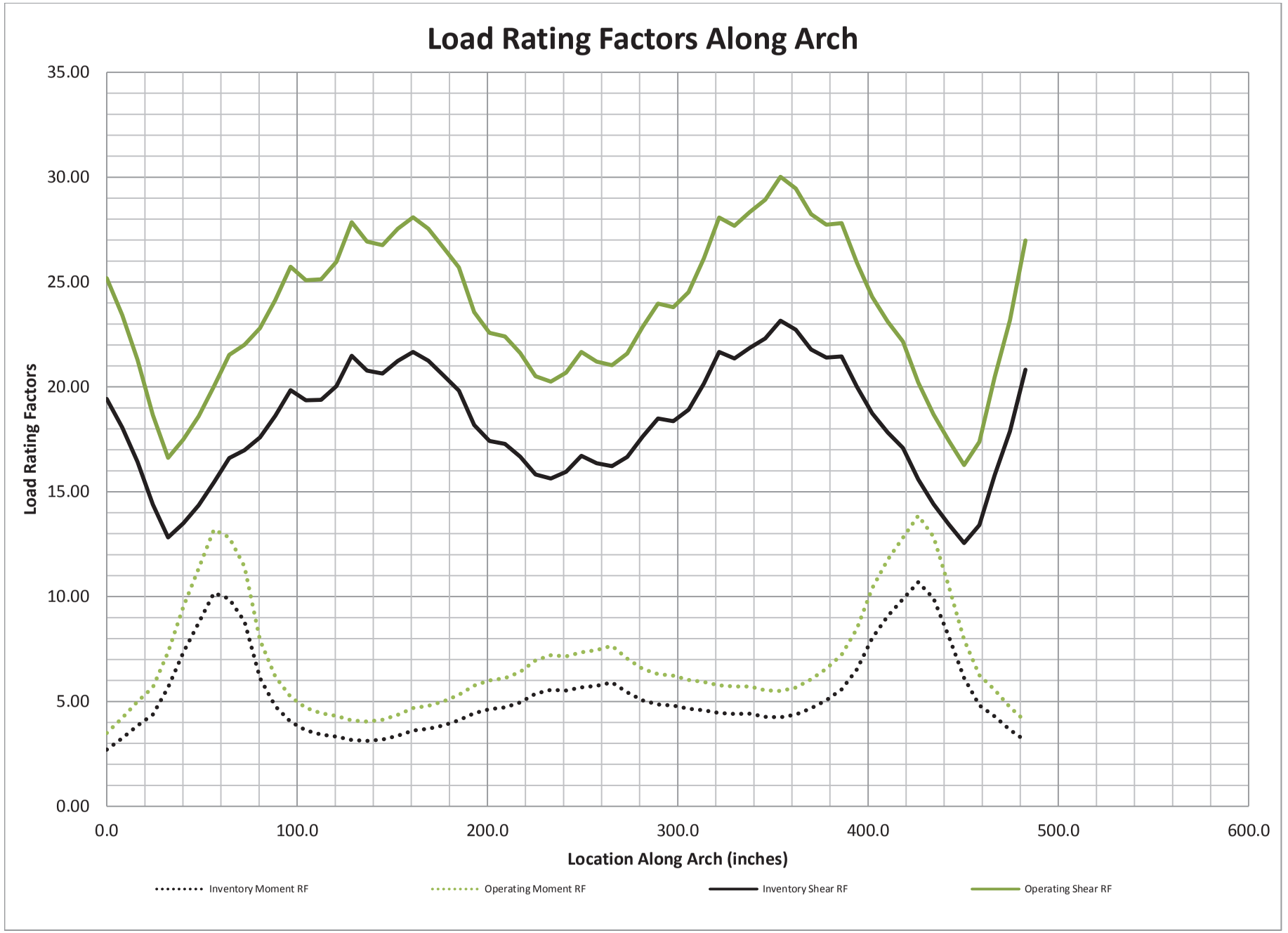
ARCHES		
Moment Capacity, Reinforced Region, ϕM_n	841.8	in*kip
Moment Capacity, Unreinforced Region, ϕMn	522.7	in*kip
Development Length of End Reinforcing Bars	28.0	in
Length of Bars above TOF (excluding ld)	0.0	in
Shear Capacity, Reinforced Region, ϕVn	112.4	kip
Shear Capacity, Unreinforced Region, ϕVn	54	kip
Vehicle Description	5 Axle Semi	

Results:

	Operating
ARCHES	
Moment RF	3.50
Shear RF	16.27
DECKING	
Shallow Cover Rating Factor	2.91
Deep Cover Rating Factor	3.93
Overall RF	**2.91**


Moment Envelopes and Capacities
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
Moment (inch*kips)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Strength I (Min)
Strength I (Max)
Capacity (Pos.)
Capacity (Neg.)
Strength I DL (Min)
Strength I DL (Max)
Strength I LL (Min)
Strength I LL (Max)


Shear Envelopes and Capacities
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
Shear (kips)
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Strength I (Min)
Strength I (Max)
Capacity (Pos.)
Capacity (Neg.)
Strength I DL (Min)
Strength I DL (Max)
Strength I LL (Min)
Strength I LL (Max)


Load Rating Factors Along Arch
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Load Rating Factors
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Location Along Arch (inches)
Inventory Moment RF
Operating Moment RF
Inventory Shear RF
Operating Shear RF

ADVANCED INFRASTRUCTURE TECHNOLOGIES

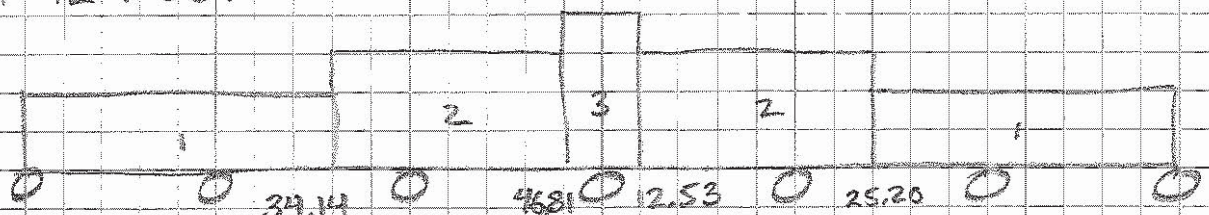
Job
Sheet No. of
Calculated By Date
Checked By Date

5 AXLE SEMI SHALLOW 1 LANE OPERATING

D = 0.827 k/ft

$L_{8.5}$ = 0.210 k/ft/wheel

1) D 0.827
2) D+2L 1.247
3) D+4L 1.667



RISA NODE 4

R = 7.376

M = 35.724

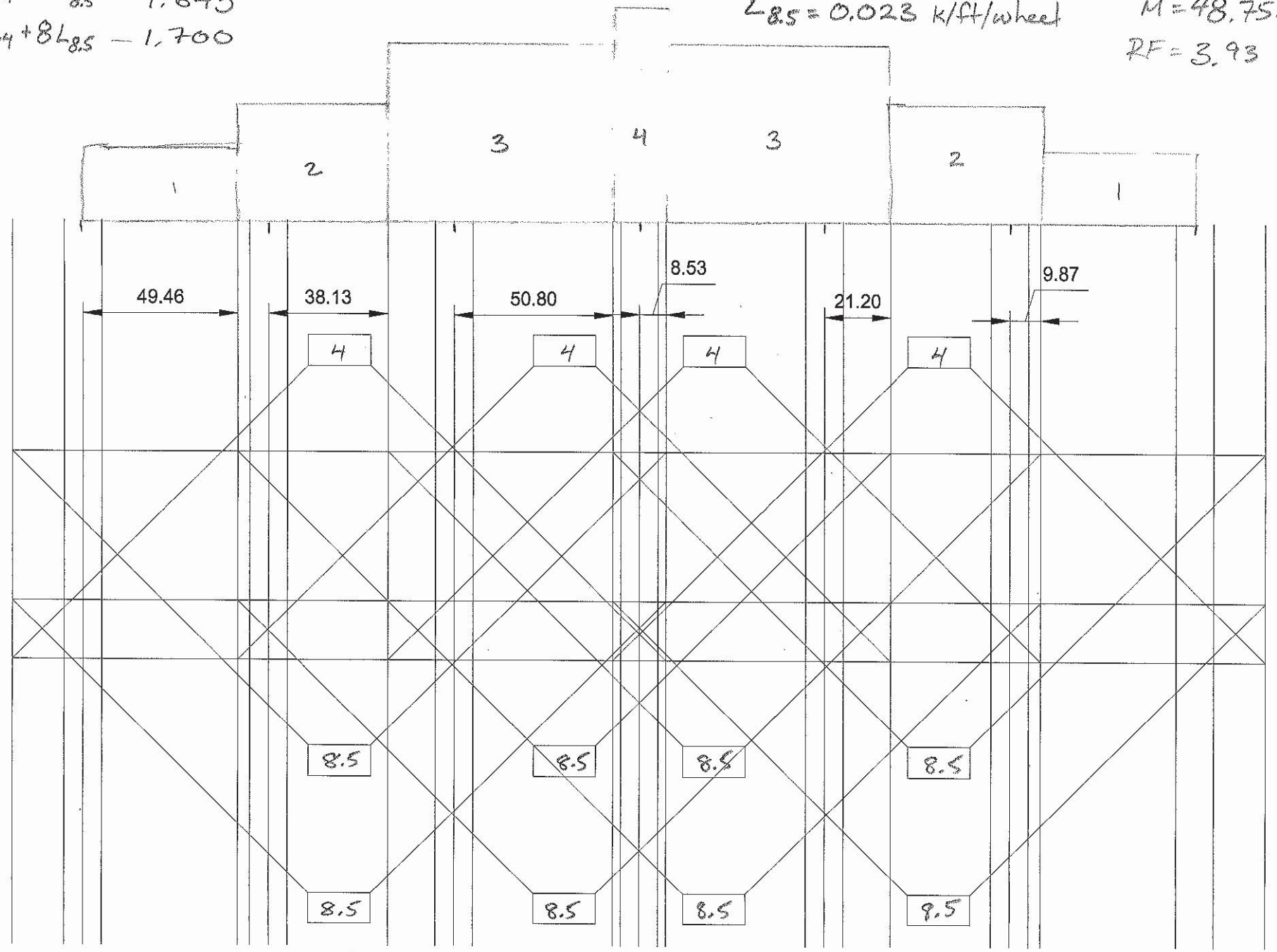
RF = 2.91

5 AXLE SEMI 2 LANE DEEP OPERATING

1) $D + L_4 + 2L_{8.5}$ — 1,529
2) $D + 2L_4 + 4L_{8.5}$ — 1,586
3) $D + 3L_4 + 6L_{8.5}$ — 1,643
4) $D + 4L_4 + 8L_{8.5}$ — 1,700

$D = 1.472$ k/ft
$L_4 = 0.011$ k/ft/wheel
$L_{8.5} = 0.023$ k/ft/wheel

RISA NODE2
R = 8.898
M = 48.756
RF = 3.93



Advanced Infrastructure Technologies

20 Godfrey Drive
Orono, Maine 04473
Telephone: (207) 866-6526
Fax: (207) 866-6501
www.aitbridges.com

Project: Fairfield, VT BRO 1448(38)

Task: Calculate Decking Rating Factors for 5 Axle Semi Loading

Pressure at Deep Cover Two Lanes - Operating

Inputs:

Arch Spacing $sp := 59.3in$

Angle of panel at base of arch: $\theta := 46deg$

Depth of soil above lowest panel: $d := 13.7ft$

Load factor for vertical earth: $\gamma_e := 1.35$

Load Factor for LL $\gamma_{LL} := 1.35$

Multiple Presence Factor $MPF := 1.0$

Dead Load:

At-rest earth pressure coefficient: $K_o := 0.47$

Density of backfill: $\rho := 135\frac{lbf}{ft^3}$

Horizontal projection of decking: $H_p := 1ft$

Vertical projection of decking: $V_p := H_p \cdot \tan(\theta) = 1.036 \cdot ft$

Vertical pressure along horizontal projection: $Vert := \gamma_e \cdot \rho \cdot d \cdot H_p = 2496.825 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz := \gamma_e \cdot \rho \cdot d \cdot K_o \cdot V_p = 1215.203 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_v := \cos(\theta) \cdot Vert = 1734.44 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_h := \sin(\theta) \cdot Horiz = 874.144 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force := C_v + C_h = 2608.584 \cdot \frac{lbf}{ft}$

Factored dead load pressure perpendicular to the deck panel: $DL\_Press := \frac{Total\_Force}{\sqrt{H_p^2 + V_p^2}} = 12.584 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 1.472 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 8.255 \cdot kip$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Load from one wheel $Wheel\_load := 4kip$

Wheel Distribution Along Arch $W1 := 10in + d \cdot 1.15 = 16.588 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + d \cdot 1.15 = 17.422 \cdot ft$

Area of Wheel Load Patch at Depth of Interest $Load\_Patch := W1 \cdot W2 = 289 \cdot ft^2$

Average Wheel Pressure $Wheel\_Vert\_Press := \frac{Wheel\_load \cdot MPF \cdot \gamma_{LL}}{Load\_Patch}$

Vertical pressure along horizontal projection: $Vert_{LL} := Wheel\_Vert\_Press \cdot H_p = 18.685 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz_{LL} := Wheel\_Vert\_Press \cdot K_o \cdot V_p = 9.094 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 12.98 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 6.542 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force_{LL} := C_{vLL} + C_{hLL} = 19.522 \cdot \frac{lbf}{ft}$

Factored LL pressure perpendicular to the deck panel per wheel: $LL\_Press := \frac{Total\_Force_{LL}}{\sqrt{H_p^{\,2} + V_p^{\,2}}} = 0.094 \cdot psi$

RISA Input Live Load Distributed Load $RISA\_LL_4 := LL\_Press \cdot 9.75in = 0.011 \cdot \frac{kip}{ft}$ per wheel

Load from one wheel $Wheel\_load := 8.5kip$

Wheel Distribution Along Arch $W1 := 10in + d \cdot 1.15 = 16.588 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + d \cdot 1.15 = 17.422 \cdot ft$

Area of Wheel Load Patch at Depth of Interest $Load\_Patch := W1 \cdot W2 = 289 \cdot ft^2$

Average Wheel Pressure $Wheel\_Vert\_Press := \frac{Wheel\_load \cdot MPF \cdot \gamma_{LL}}{Load\_Patch}$

Vertical pressure along horizontal projection: $Vert_{LL} := Wheel\_Vert\_Press \cdot H_p = 39.706 \cdot \frac{lbf}{ft}$

Horizontal pressure along vertical projection: $Horiz_{LL} := Wheel\_Vert\_Press \cdot K_o \cdot V_p = 19.325 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure: $C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 27.582 \cdot \frac{lbf}{ft}$

Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure: $C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 13.901 \cdot \frac{lbf}{ft}$

Total resultant force perpendicular to the deck panel: $Total\_Force_{LL} := C_{vLL} + C_{hLL} = 41.484 \cdot \frac{lbf}{ft}$

Factored LL pressure perpendicular to the deck panel per wheel: $LL\_Press := \frac{Total\_Force_{LL}}{\sqrt{H_p^{\,2} + V_p^{\,2}}} = 0.2 \cdot psi$

RISA Input Live Load Distributed Load $RISA\_LL_{8\_5} := LL\_Press \cdot 9.75in = 0.023 \cdot \frac{kip}{ft}$ per wheel

RISA Analaysis Results:

Run RISA Analysis using appropriate number of wheels for given spans to determine Moment and Reaction

Reaction from RISA $R_u := 8.898kip$ From RISA Analysis of six span beam - Node 2

Moment from RISA $M_u := 48.756in \cdot kip$

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 5.479 \cdot in$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Characterisitc Reaction Value 18" bend tests $R_{n18} := 21574lbf$

Characteristic Reaction Value 24" bend tests $R_{n24} := 14745lbf$

18" and 24" span bending tests performed on decking simulated the reaction of the arch on decking. This value is mean -3sigma from three tests.

Moment:Reaction for 18" Tests $MR_{18} := 4.5in$

Moment:Reaction for 24" Tests $MR_{24} := 6in$

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 17.115 \cdot kip$

Compression Resistance Factor $\Phi_c := 0.7$

Moisture Reduction Factor $C_m := 0.9$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Design Reaction Value $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.782 \cdot kip$

Rating Factor $RF_{op1} := \frac{\Phi R_n - R_{u\_DL\_only}}{\left(R_u - R_{u\_DL\_only}\right)} = 3.931$

Pressure at Shallow Cover One Lane - Operating

Soil Cover $cover := 67in$ Measured from bottom of deck corrugation to road surface

Load Factor for LL $\gamma_{LL} := 1.35$

Dead Load:

Factored Soil Pressure $DL\_Press := cover \cdot \rho \cdot \gamma_e = 7.066 \cdot psi$

RISA Input Dead Load Distributed Load $RISA\_DL := DL\_Press \cdot 9.75in = 0.827 \cdot \frac{kip}{ft}$

Reaction Due to Dead Load only $R_{u\_DL\_only} := RISA\_DL \cdot sp \cdot \frac{118}{104} = 4.636 \cdot kip$

Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table

Live Load:

Maximum Wheel Load $P := 8.5kip$

Multiple Presence Factor $MPF := 1.2$

Wheel Distribution Along Arch $W1 := 10in + cover \cdot 1.15 = 7.254 \cdot ft$

Wheel Distribution Across Arch $W2 := 20in + cover \cdot 1.15 = 8.087 \cdot ft$

Load Patch Area $Load\_Patch := W1 \cdot W2 = 58.668 \cdot ft^2$

Impact Factor $IM := 1 + 0.33\left(1.0 - 0.125\frac{cover}{12in}\right) = 1.100$

Factored Wheel Load $P_u := P \cdot \gamma_{LL} \cdot MPF \cdot IM = 15.143 \cdot kip$

Factored Live Load Pressure $PRL_u := \frac{P_u}{Load\_Patch} = 1.792 \cdot psi$

Factored Live Load Distributed Load $w_L := PRL_u \cdot 9.75in = 0.210 \cdot \frac{kip}{ft}$ per wheel

RISA Analysis:

Reaction from RISA $R_u := 7.376kip$

Moment from RISA $M_u := 35.724\text{in}\cdot\text{kip}$ From RISA Analysis of six span beam - Node 5

Moment:Reaction from RISA Analysis $MR := \frac{M_u}{R_u} = 4.843\cdot\text{in}$

Deck Panel Capacity:

Interpolate Characteristic Reaction Value between 18in tests and 24in tests

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}}\cdot\left(R_{n18} - R_{n24}\right) + R_{n24} = 20.011\cdot\text{kip}$

Compression Resistance Factor $\Phi_c := 0.7$

Resistance factor and moisture reduction factor are from ASCE Pre-standard for Load and Resistance Factor Design of Pultruded Fiber Reinforced Polymer Structures

Moisture Reduction Factor $C_m := 0.9$

Design Reaction Value $\Phi R_n := \Phi_c\cdot C_m\cdot R_n = 12.607\cdot\text{kip}$

Rating Factor $RF_{op2} := \frac{\Phi R_n - R_{u\_DL\_only}}{\left(R_u - R_{u\_DL\_only}\right)} = 2.909$

Summary Load Rating Factors for Deck

Operating Rating Factor $RF_{op} := \min\left(RF_{op1}, RF_{op2}\right) = 2.909$