



**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

Approved **Approved As Noted**
 Rejected

This review is only for general conformance with the design concept and the information given in the Construction Documents. Corrections or comments made on the shop drawings during the review do not relieve the Contractor from compliance with the requirements of the Plans and Specifications. Review of a specific item shall not include review of an assembly of which an item is a component. The Contractor is responsible for dimensions to be confirmed and corrected at the job site; information that pertains solely to the fabrication process or to the means, methods, techniques, sequences and procedures of construction; coordination of the Work with that of other trades and performing all Work in a safe and satisfactory manner.

Date 6/6/2014

 **McFarland Johnson**

By T. Traver



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	2.35	1.15	---	---	---	---	---
POSTING	---	---	---	---	---	---	---
OPERATING	3.12	1.49	3.12	2.02	2.02	2.59	2.91

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.

Deck 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

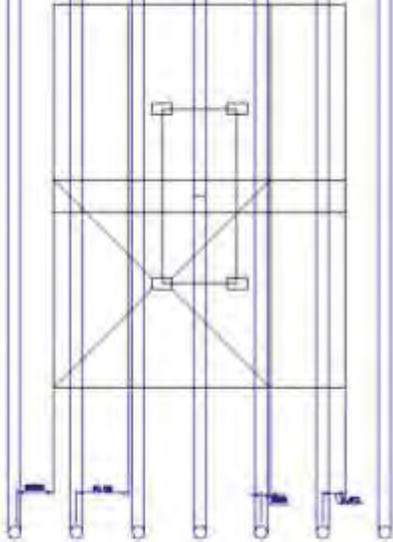
The deck needed to be analyzed for the following cases resulting in a possible combination of eight cases.

Load Rating Case	Inventory	Operating
Cover	Deep	Shallow
Lanes	One	Two

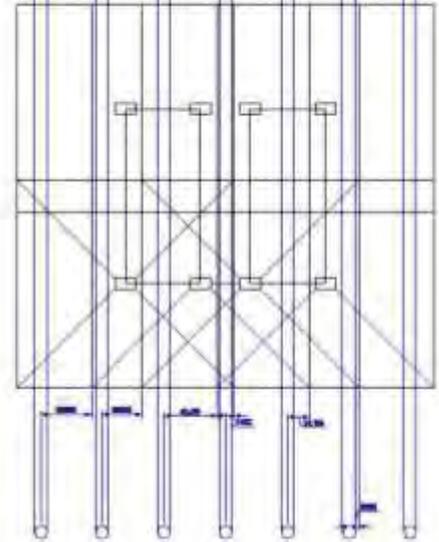
This analysis was simplified by eliminating some cases by inspection.

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 DEEP BURY ONE LANE



H20 DEEP BURY TWO LANES



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
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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



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]

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

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, ϕM_n	841.8	in*kip
Moment Capacity, Unreinforced Region, ϕM_n	522.7	in*kip
Development Length of End Reinforcing Bars	28.0	in
Length of Bars above TOF (excluding Id)	0.0	in
Shear Capacity, Reinforced Region, ϕV_n	112.4	kip
Shear Capacity, Unreinforced Region, ϕV_n	54	kip

Vehicle Description H20

Results:

ARCHES

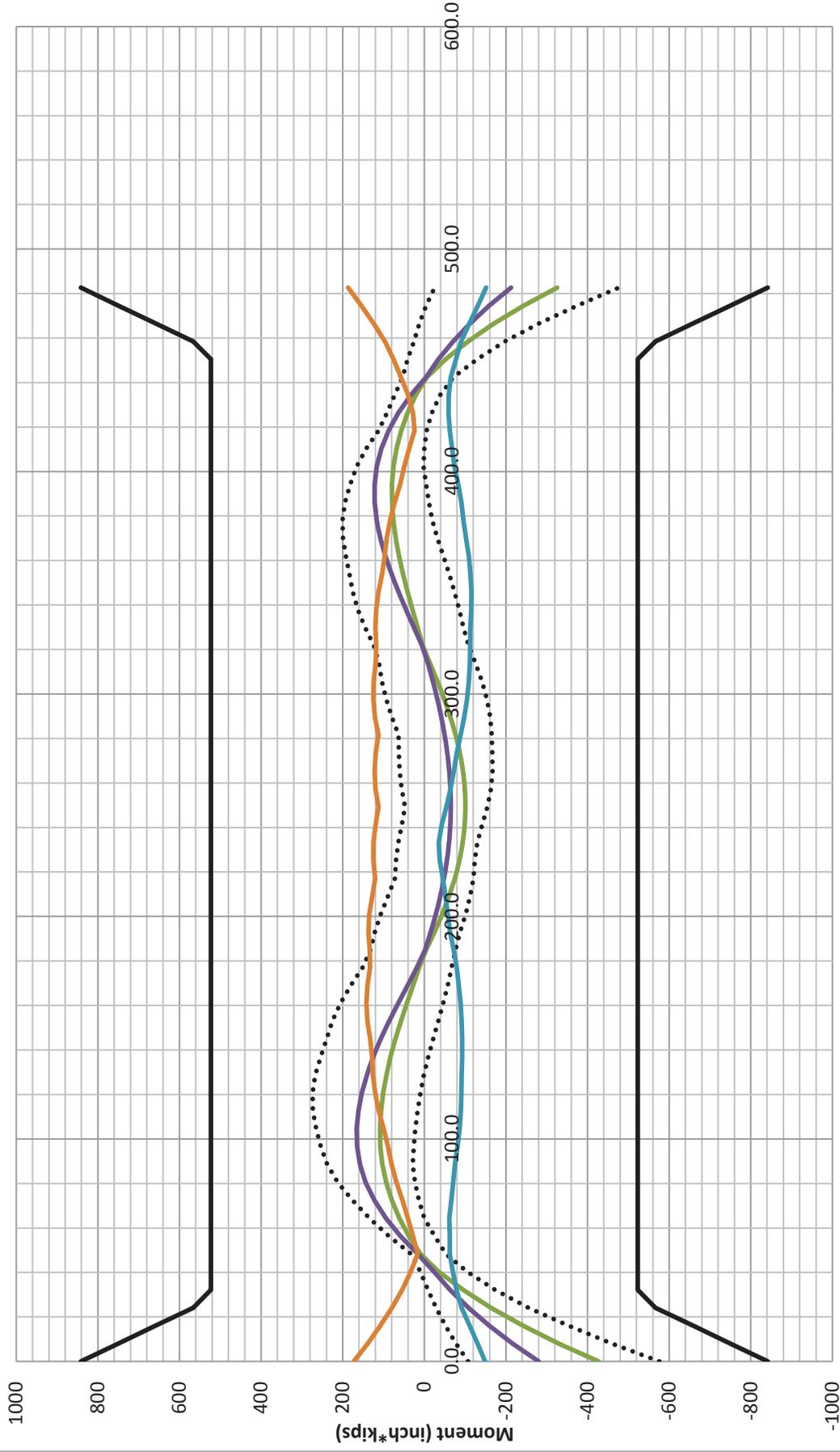
	Operating	Inventory
Moment Rating Factor	3.60	2.78
Shear Rating Factor	16.22	12.51

DECKING

Rating Factor 3.12 2.35

Overall Rating Factor 3.12 2.35

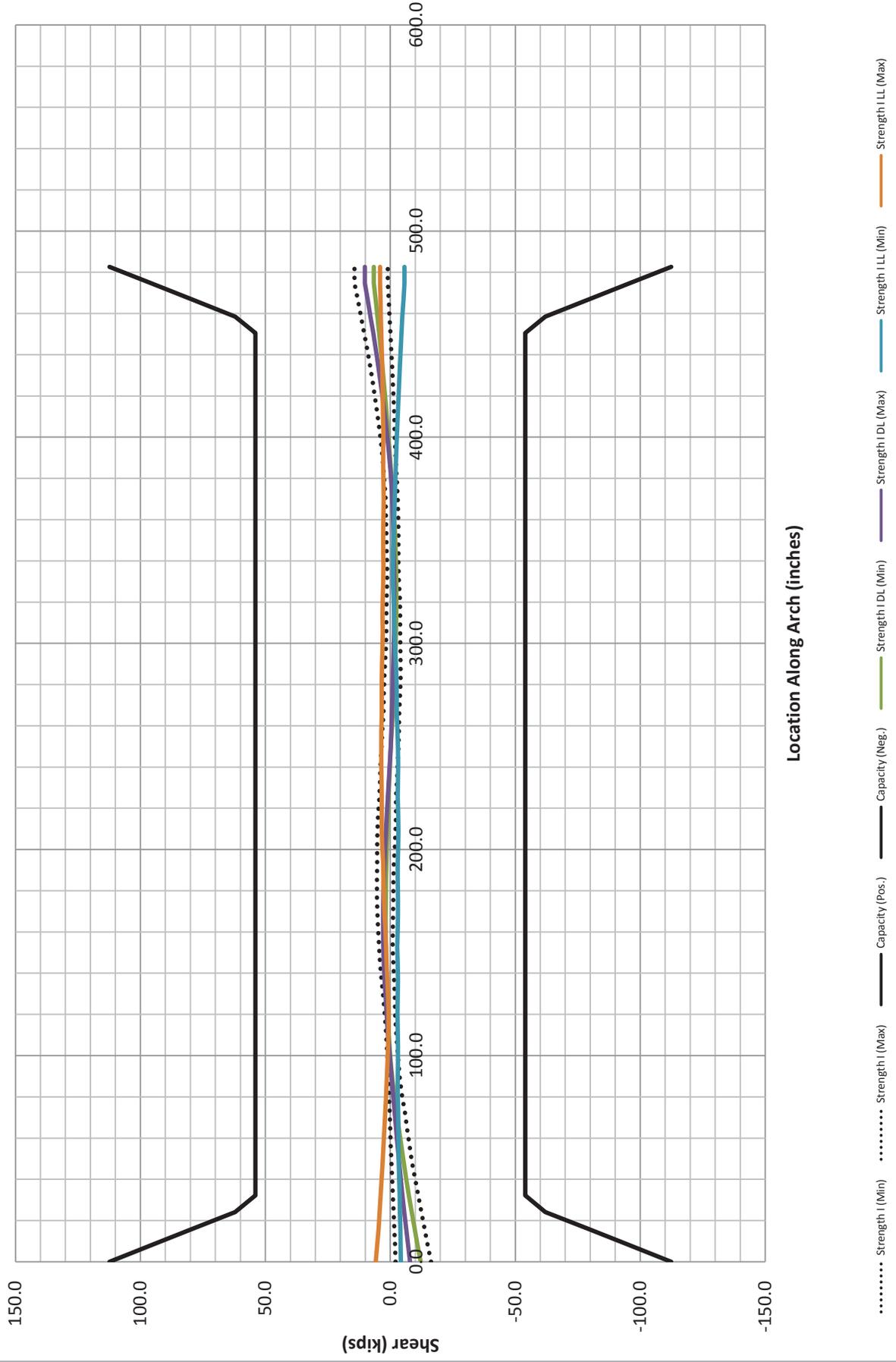
Moment Envelopes and Capacities



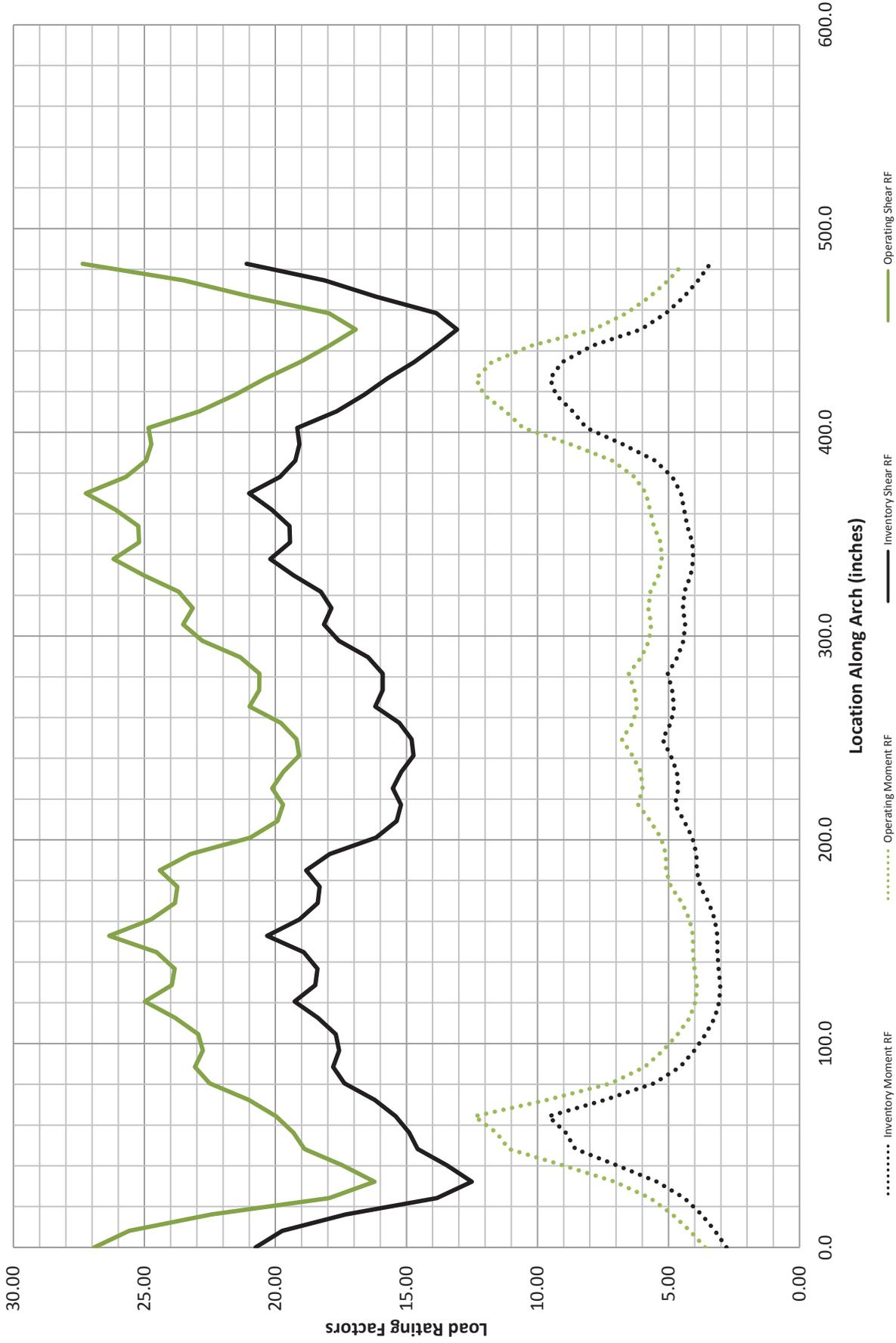
Location Along Arch (inches)

..... 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



Load Rating Factors Along Arch





H2O DEEP TWO LANES

INVENTORY

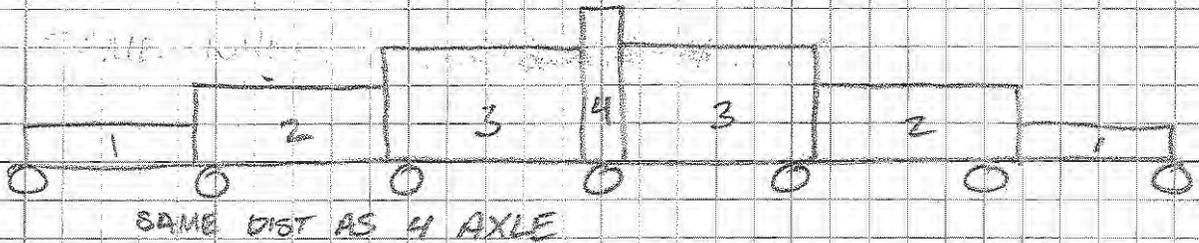
$D = 1.472 \text{ k/ft}$
 $L_4 = 0.014 \text{ k/ft/wheel}$
 $L_{16} = 0.057 \text{ k/ft/wheel}$

- 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) $D + 4L_4 + 4L_{16} = 1.756^*$

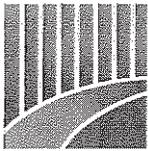
OPERATING

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

- 1.521
- 1.570
- 1.619
- 1.668



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



H2O SHALLOW 2 LANES

INVENTORY

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

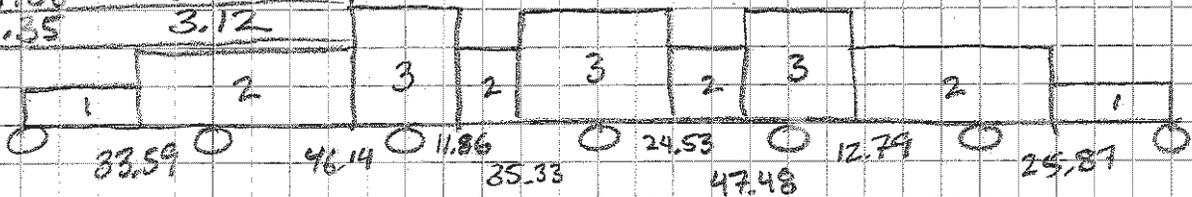
	INV
1) D	0.827
2) D+L	1.253
3) D+2L	1.679

OPERATING

DL = 0.827
 $L_{16} = 0.329$

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

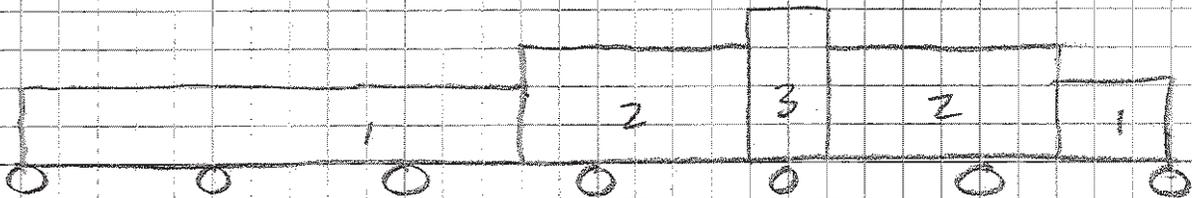
RISA	INV	OP
Loc	NODE#	NODE#
R	7.98	7.127
M	39.988	35.028
RF	2.35	3.12



H2O SHALLOW 1 LANE INVENTORY

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

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



RISA	
NODES	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 $sp := 59.3\text{in}$

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

Depth of soil above lowest panel: $d := 13.7\text{ft}$

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: $\rho := 135 \frac{\text{lbf}}{\text{ft}^3}$

Horizontal projection of decking: $H_p := 1\text{ft}$

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

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

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

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

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

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

Factored dead load pressure perpendicular to the deck panel: $\text{DL_Press} := \frac{\text{Total_Force}}{\sqrt{H_p^2 + V_p^2}} = 12.58 \cdot \text{psi}$

RISA Input Dead Load Distributed Load	$RISA_DL := DL_Press \cdot 9.75 \text{ in} = 1.47 \cdot \frac{\text{kip}}{\text{ft}}$	
Reaction Due to Dead Load only	$R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 8.26 \cdot \text{kip}$	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	$W1 := 10 \text{ in} + d \cdot 1.15 = 16.59 \cdot \text{ft}$	
Wheel Distribution Across Arch	$W2 := 20 \text{ in} + d \cdot 1.15 = 17.42 \cdot \text{ft}$	
Area of Wheel Load Patch at Depth of Interest	$Load_Patch := W1 \cdot W2 = 289 \cdot \text{ft}^2$	
Average Wheel Pressure	$Wheel_Vert_Press := \frac{Wheel_load \cdot MPF}{Load_Patch}$	
Vertical pressure along horizontal projection:	$Vert_{LL} := \gamma_{LL} \cdot Wheel_Vert_Press \cdot H_p = 24.22 \cdot \frac{\text{lbf}}{\text{ft}}$	
Horizontal pressure along vertical projection:	$Horiz_{LL} := \gamma_{LL} \cdot Wheel_Vert_Press \cdot K_o \cdot V_p = 11.79 \cdot \frac{\text{lbf}}{\text{ft}}$	
Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure:	$C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 16.83 \cdot \frac{\text{lbf}}{\text{ft}}$	
Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure:	$C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 8.48 \cdot \frac{\text{lbf}}{\text{ft}}$	
Total resultant force perpendicular to the deck panel:	$Total_Force_{LL} := C_{vLL} + C_{hLL} = 25.31 \cdot \frac{\text{lbf}}{\text{ft}}$	
Factored LL pressure perpendicular to the deck panel per wheel:	$LL_Press := \frac{Total_Force_{LL}}{\sqrt{H_p^2 + V_p^2}} = 0.12 \cdot \text{psi}$	
RISA Input Live Load Distributed Load	$RISA_LL := LL_Press \cdot 9.75 \text{ in} = 0.014 \cdot \frac{\text{kip}}{\text{ft}}$	per wheel
Load from one wheel	Wheel_load := 16kip	
Wheel Distribution Along Arch	$W1 := 10 \text{ in} + d \cdot 1.15 = 16.59 \cdot \text{ft}$	
Wheel Distribution Across Arch	$W2 := 20 \text{ in} + d \cdot 1.15 = 17.42 \cdot \text{ft}$	
Area of Wheel Load Patch at Depth of Interest	$Load_Patch := W1 \cdot W2 = 289 \cdot \text{ft}^2$	
Average Wheel Pressure	$Wheel_Vert_Press := \frac{Wheel_load \cdot MPF}{Load_Patch}$	
Vertical pressure along horizontal projection:	$Vert_{LL} := \gamma_{LL} \cdot Wheel_Vert_Press \cdot H_p = 96.89 \cdot \frac{\text{lbf}}{\text{ft}}$	

Horizontal pressure along vertical projection:

$$\text{Horiz}_{LL} := \gamma_{LL} \cdot \text{Wheel_Vert_Press} \cdot K_o \cdot V_p = 47.15 \cdot \frac{\text{lbf}}{\text{ft}}$$

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

$$C_{vLL} := \cos(\theta) \cdot \text{Vert}_{LL} = 67.3 \cdot \frac{\text{lbf}}{\text{ft}}$$

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

$$C_{hLL} := \sin(\theta) \cdot \text{Horiz}_{LL} = 33.92 \cdot \frac{\text{lbf}}{\text{ft}}$$

Total resultant force perpendicular to the deck panel:

$$\text{Total_Force}_{LL} := C_{vLL} + C_{hLL} = 101.22 \cdot \frac{\text{lbf}}{\text{ft}}$$

Factored LL pressure perpendicular to the deck panel per wheel:

$$\text{LL_Press} := \frac{\text{Total_Force}_{LL}}{\sqrt{H_p^2 + V_p^2}} = 0.49 \cdot \text{psi}$$

RISA Input Live Load Distributed Load

$$\text{RISA_LL} := \text{LL_Press} \cdot 9.75 \text{ in} = 0.057 \cdot \frac{\text{kip}}{\text{ft}} \text{ per wheel}$$

RISA Analysis Results:

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

Reaction from RISA

$$R_u := 9.026 \text{ kip}$$

From RISA Analysis of six span beam - Node 2

Moment from RISA

$$M_u := 49.392 \text{ in} \cdot \text{kip}$$

Moment:Reaction from RISA Analysis

$$\text{MR} := \frac{M_u}{R_u} = 5.47 \cdot \text{in}$$

Deck Panel Capacity:

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

Characterisitic Reaction Value 18" bend tests

$$R_{n18} := 21574 \text{ lbf}$$

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.

Characteristic Reaction Value 24" bend tests

$$R_{n24} := 14745 \text{ lbf}$$

Moment:Reaction for 18" Tests

$$\text{MR}_{18} := 4.5 \text{ in}$$

Moment:Reaction for 24" Tests

$$\text{MR}_{24} := 6 \text{ in}$$

Interpolated Characteristic Value

$$R_n := \frac{\text{MR}_{24} - \text{MR}}{\text{MR}_{24} - \text{MR}_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 17.15 \cdot \text{kip}$$

Compression Resistance Factor

$$\Phi_c := 0.7$$

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

Moisture Reduction Factor	$C_m := 0.9$	Design of Pultruded Fiber Reinforced Polymer Structures
Design Reaction Value	$\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.8 \cdot \text{kip}$	
Rating Factor	$RF_{inv1} := \frac{\Phi R_n - R_{u_DL_only}}{(R_u - R_{u_DL_only})} = 3.31$	
Pressure at Deep Cover - Two Lanes - Operating		
Inputs:		
Arch Spacing	$sp := 59.3 \text{ in}$	
Angle of panel at base of arch:	$\theta := 46 \text{ deg}$	
Depth of soil above lowest panel:	$d := 13.7 \text{ ft}$	
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:	$\rho := 135 \frac{\text{lbf}}{\text{ft}^3}$	
Horizontal projection of decking:	$H_p := 1 \text{ ft}$	
Vertical projection of decking:	$V_p := H_p \cdot \tan(\theta) = 1.04 \cdot \text{ft}$	
Vertical pressure along horizontal projection:	$\text{Vert} := \gamma_e \cdot \rho \cdot d \cdot H_p = 2496.83 \cdot \frac{\text{lbf}}{\text{ft}}$	
Horizontal pressure along vertical projection:	$\text{Horiz} := \gamma_e \cdot \rho \cdot d \cdot K_o \cdot V_p = 1215.2 \cdot \frac{\text{lbf}}{\text{ft}}$	
Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure:	$C_v := \cos(\theta) \cdot \text{Vert} = 1734.44 \cdot \frac{\text{lbf}}{\text{ft}}$	
Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure:	$C_h := \sin(\theta) \cdot \text{Horiz} = 874.14 \cdot \frac{\text{lbf}}{\text{ft}}$	
Total resultant force perpendicular to the deck panel:	$\text{Total_Force} := C_v + C_h = 2608.58 \cdot \frac{\text{lbf}}{\text{ft}}$	
Factored dead load pressure perpendicular to the deck panel:	$DL_Press := \frac{\text{Total_Force}}{\sqrt{H_p^2 + V_p^2}} = 12.58 \cdot \text{psi}$	
RISA Input Dead Load Distributed Load	$RISA_DL := DL_Press \cdot 9.75 \text{ in} = 1.47 \cdot \frac{\text{kip}}{\text{ft}}$	

Reaction Due to Dead Load only

$$R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 8.26 \cdot \text{kip}$$

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

Live Load:

Load from one wheel

$$\text{Wheel_load} := 4 \text{kip}$$

Wheel Distribution Along Arch

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

Wheel Distribution Across Arch

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

Area of Wheel Load Patch at Depth of Interest

$$\text{Load_Patch} := W1 \cdot W2 = 289 \cdot \text{ft}^2$$

Average Wheel Pressure

$$\text{Wheel_Vert_Press} := \frac{\text{Wheel_load} \cdot \text{MPF}}{\text{Load_Patch}}$$

Vertical pressure along horizontal projection:

$$\text{Vert}_{LL} := \gamma_{LL} \cdot \text{Wheel_Vert_Press} \cdot H_p = 18.69 \cdot \frac{\text{lbf}}{\text{ft}}$$

Horizontal pressure along vertical projection:

$$\text{Horiz}_{LL} := \gamma_{LL} \cdot \text{Wheel_Vert_Press} \cdot K_o \cdot V_p = 9.09 \cdot \frac{\text{lbf}}{\text{ft}}$$

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

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

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

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

Total resultant force perpendicular to the deck panel:

$$\text{Total_Force}_{LL} := C_{vLL} + C_{hLL} = 19.52 \cdot \frac{\text{lbf}}{\text{ft}}$$

Factored LL pressure perpendicular to the deck panel per wheel:

$$LL_Press := \frac{\text{Total_Force}_{LL}}{\sqrt{H_p^2 + V_p^2}} = 0.09 \cdot \text{psi}$$

RISA Input Live Load Distributed Load

$$RISA_LL := LL_Press \cdot 9.75 \text{in} = 0.011 \cdot \frac{\text{kip}}{\text{ft}} \text{ per wheel}$$

Load from one wheel

$$\text{Wheel_load} := 16 \text{kip}$$

Wheel Distribution Along Arch

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

Wheel Distribution Across Arch

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

Area of Wheel Load Patch at Depth of Interest

$$\text{Load_Patch} := W1 \cdot W2 = 289 \cdot \text{ft}^2$$

Average Wheel Pressure

$$\text{Wheel_Vert_Press} := \frac{\text{Wheel_load} \cdot \text{MPF}}{\text{Load_Patch}}$$

Vertical pressure along horizontal projection:

$$\text{Vert}_{LL} := \gamma_{LL} \cdot \text{Wheel_Vert_Press} \cdot H_p = 74.74 \cdot \frac{\text{lbf}}{\text{ft}}$$

Horizontal pressure along vertical projection:

$$\text{Horiz}_{LL} := \gamma_{LL} \cdot \text{Wheel_Vert_Press} \cdot K_o \cdot V_p = 36.38 \cdot \frac{\text{lbf}}{\text{ft}}$$

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

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

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

$$C_{hLL} := \sin(\theta) \cdot \text{Horiz}_{LL} = 26.17 \cdot \frac{\text{lbf}}{\text{ft}}$$

Total resultant force perpendicular to the deck panel:

$$\text{Total_Force}_{LL} := C_{vLL} + C_{hLL} = 78.09 \cdot \frac{\text{lbf}}{\text{ft}}$$

Factored LL pressure perpendicular to the deck panel per wheel:

$$\text{LL_Press} := \frac{\text{Total_Force}_{LL}}{\sqrt{H_p^2 + V_p^2}} = 0.38 \cdot \text{psi}$$

RISA Input Live Load Distributed Load

$$\text{RISA_LL} := \text{LL_Press} \cdot 9.75 \text{ in} = 0.044 \cdot \frac{\text{kip}}{\text{ft}} \text{ per wheel}$$

RISA Analysis Results:

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

Reaction from RISA

$$R_u := 8.825 \text{ kip}$$

From RISA Analysis of six span beam - Node 2

Moment from RISA

$$M_u := 48.384 \text{ in} \cdot \text{kip}$$

Moment: Reaction from RISA Analysis

$$\text{MR} := \frac{M_u}{R_u} = 5.48 \cdot \text{in}$$

Deck Panel Capacity:

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

Characterisitic Reaction Value 18" bend tests

$$R_{n18} := 21574 \text{ lbf}$$

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.

Characteristic Reaction Value 24" bend tests

$$R_{n24} := 14745 \text{ lbf}$$

Moment: Reaction for 18" Tests

$$\text{MR}_{18} := 4.5 \text{ in}$$

Moment: Reaction for 24" Tests

$$\text{MR}_{24} := 6 \text{ in}$$

Interpolated Characteristic Value

$$R_n := \frac{\text{MR}_{24} - \text{MR}}{\text{MR}_{24} - \text{MR}_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 17.1 \cdot \text{kip}$$

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 $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.77 \cdot \text{kip}$

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

$$DL_Press := cover \cdot \rho \cdot \gamma_e = 7.07 \cdot \text{psi}$$

RISA Input Dead Load Distributed Load

$$RISA_DL := DL_Press \cdot 9.75 \text{in} = 0.83 \cdot \frac{\text{kip}}{\text{ft}}$$

Reaction Due to Dead Load only

$$R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 4.64 \cdot \text{kip}$$

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

$$W1 := 10 \text{in} + cover \cdot 1.15 = 7.25 \cdot \text{ft}$$

Wheel Distribution Across Arch

$$W2 := 20 \text{in} + cover \cdot 1.15 = 8.09 \cdot \text{ft}$$

Load Patch Area

$$Load_Patch := W1 \cdot W2 = 58.67 \cdot \text{ft}^2$$

Impact Factor

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

Factored Wheel Load

$$P_u := P \cdot \gamma_{LL} \cdot MPF \cdot IM = 30.79 \cdot \text{kip}$$

Factored Live Load Pressure

$$PRL_u := \frac{P_u}{Load_Patch} = 3.64 \cdot \text{psi}$$

Factored Live Load Distributed Load

$$w_L := PRL_u \cdot 9.75 \text{in} = 0.426 \cdot \frac{\text{kip}}{\text{ft}} \quad \text{per wheel}$$

RISA Analysis:

Reaction from RISA

$R_u := 7.98 \text{kip}$

Moment from RISA

$M_u := 38.988 \text{in} \cdot \text{kip}$

From RISA Analysis of six span beam - Node 2

Moment:Reaction from RISA Analysis

$$MR := \frac{M_u}{R_u} = 4.89 \cdot \text{in}$$

Deck Panel Capacity:

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

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

$$\text{Compression Resistance Factor } \Phi_c := 0.7$$

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

$$\text{Moisture Reduction Factor } C_m := 0.9$$

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

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

$$\text{Soil Cover } \text{cover} := 67\text{in}$$

Measured from bottom of deck corrugation to road surface

Dead Load:

$$\text{Factored Soil Pressure } DL_Press := \text{cover} \cdot \rho \cdot \gamma_e = 7.07 \cdot \text{psi}$$

$$\text{RISA Input Dead Load Distributed Load } RISA_DL := DL_Press \cdot 9.75\text{in} = 0.83 \cdot \frac{\text{kip}}{\text{ft}}$$

$$\text{Reaction Due to Dead Load only } R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 4.64 \cdot \text{kip}$$

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

Live Load:

$$\text{Maximum Wheel Load } P := 16\text{kip}$$

$$\text{Multiple Presence Factor } MPF := 1.0$$

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

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

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

$$\text{Load Patch Area } Load_Patch := W1 \cdot W2 = 58.67 \cdot \text{ft}^2$$

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

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

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

Factored Live Load Distributed Load	$w_L := PRL_u \cdot 9.75 \text{ in} = 0.329 \cdot \frac{\text{kip}}{\text{ft}}$	per wheel
RISA Analysis:		
Reaction from RISA	$R_u := 7.127 \text{ kip}$	
Moment from RISA	$M_u := 35.028 \text{ in} \cdot \text{kip}$	From RISA Analysis of six span beam - Node 2
Moment: Reaction from RISA Analysis	$MR := \frac{M_u}{R_u} = 4.91 \cdot \text{in}$	
Deck Panel Capacity:		
Interpolate Characteristic Reaction Value between 18in tests and 24in tests		
Interpolated Characteristic Value	$R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 19.69 \cdot \text{kip}$	
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	$\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 12.4 \cdot \text{kip}$	
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	$\text{cover} := 67 \text{ in}$	Measured from bottom of deck corrugation to road surface
Dead Load:		
Factored Soil Pressure	$DL_Press := \text{cover} \cdot \rho \cdot \gamma_e = 7.07 \cdot \text{psi}$	
RISA Input Dead Load Distributed Load	$RISA_DL := DL_Press \cdot 9.75 \text{ in} = 0.83 \cdot \frac{\text{kip}}{\text{ft}}$	
Reaction Due to Dead Load only	$R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 4.64 \cdot \text{kip}$	Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table
Live Load:		
Maximum Wheel Load	$P := 16 \text{ kip}$	
Multiple Presence Factor	$MPF := 1.2$	
Load Factor for LL	$\gamma_{LL} := 1.75$	
Wheel Distribution Along Arch	$W1 := 10 \text{ in} + \text{cover} \cdot 1.15 = 7.25 \cdot \text{ft}$	

Wheel Distribution Across Arch	$W2 := 20\text{in} + \text{cover} \cdot 1.15 = 8.09 \cdot \text{ft}$	
Load Patch Area	$\text{Load_Patch} := W1 \cdot W2 = 58.67 \cdot \text{ft}^2$	
Impact Factor	$\text{IM} := 1 + 0.33 \left(1.0 - 0.125 \frac{\text{cover}}{12\text{in}} \right) = 1.100$	
Factored Wheel Load	$P_u := P \cdot \gamma_{LL} \cdot \text{MPF} \cdot \text{IM} = 36.95 \cdot \text{kip}$	
Factored Live Load Pressure	$\text{PRL}_u := \frac{P_u}{\text{Load_Patch}} = 4.37 \cdot \text{psi}$	
Factored Live Load Distributed Load	$w_L := \text{PRL}_u \cdot 9.75\text{in} = 0.512 \cdot \frac{\text{kip}}{\text{ft}}$	per wheel

RISA Analysis:

Reaction from RISA	$R_u := 7.848\text{kip}$	
Moment from RISA	$M_u := 37.02\text{in} \cdot \text{kip}$	From RISA Analysis of six span beam - Node 5
Moment: Reaction from RISA Analysis	$\text{MR} := \frac{M_u}{R_u} = 4.72 \cdot \text{in}$	

Deck Panel Capacity:

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

Interpolated Characteristic Value	$R_n := \frac{\text{MR}_{24} - \text{MR}}{\text{MR}_{24} - \text{MR}_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 20.59 \cdot \text{kip}$	
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	$\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 12.97 \cdot \text{kip}$	
Rating Factor	$\text{RF}_{\text{inv}3} := \frac{\Phi R_n - R_{u_DL_only}}{(R_u - R_{u_DL_only})} = 2.59$	

Summary Inventory and Operating Load Rating Factors for Deck

Inventory Rating Factor	$\text{RF}_{\text{inv}} := \min(\text{RF}_{\text{inv}1}, \text{RF}_{\text{inv}2}, \text{RF}_{\text{inv}3}) = 2.35$
Operating Rating Factor	$\text{RF}_{\text{op}} := \min(\text{RF}_{\text{op}1}, \text{RF}_{\text{op}2}) = 3.12$



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]

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

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, ϕM_n	522.7	in*kip
Development Length of End Reinforcing Bars	28.0	in
Length of Bars above TOF (excluding Id)	0.0	in
Shear Capacity, Reinforced Region, ϕV_n	112.4	kip
Shear Capacity, Unreinforced Region, ϕV_n	54	kip

Vehicle Description	HL-93
---------------------	-------

Results:

ARCHES

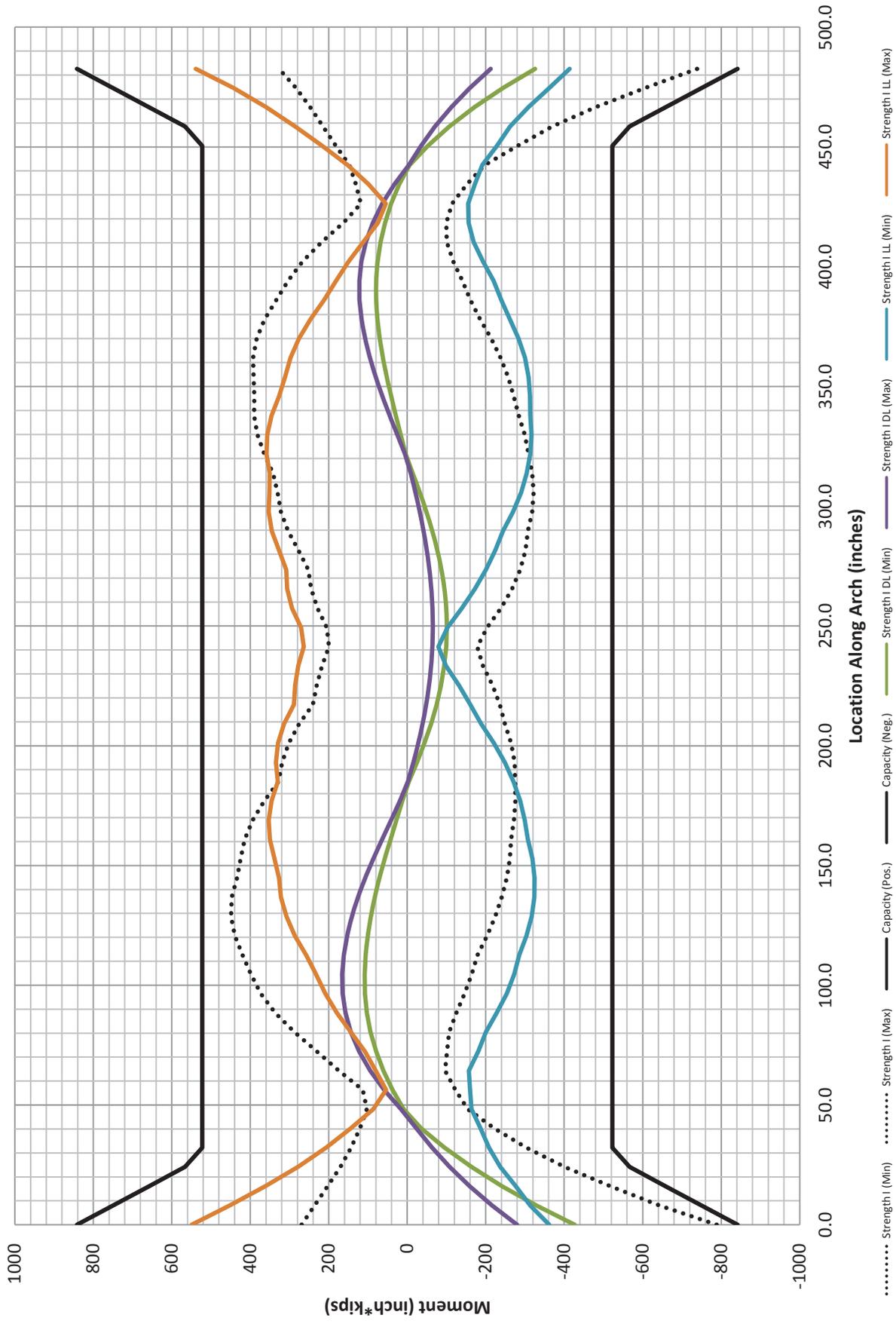
	Operating	Inventory
Moment Rating Factor	1.49	1.15
Shear Rating Factor	6.08	4.69

DECKING

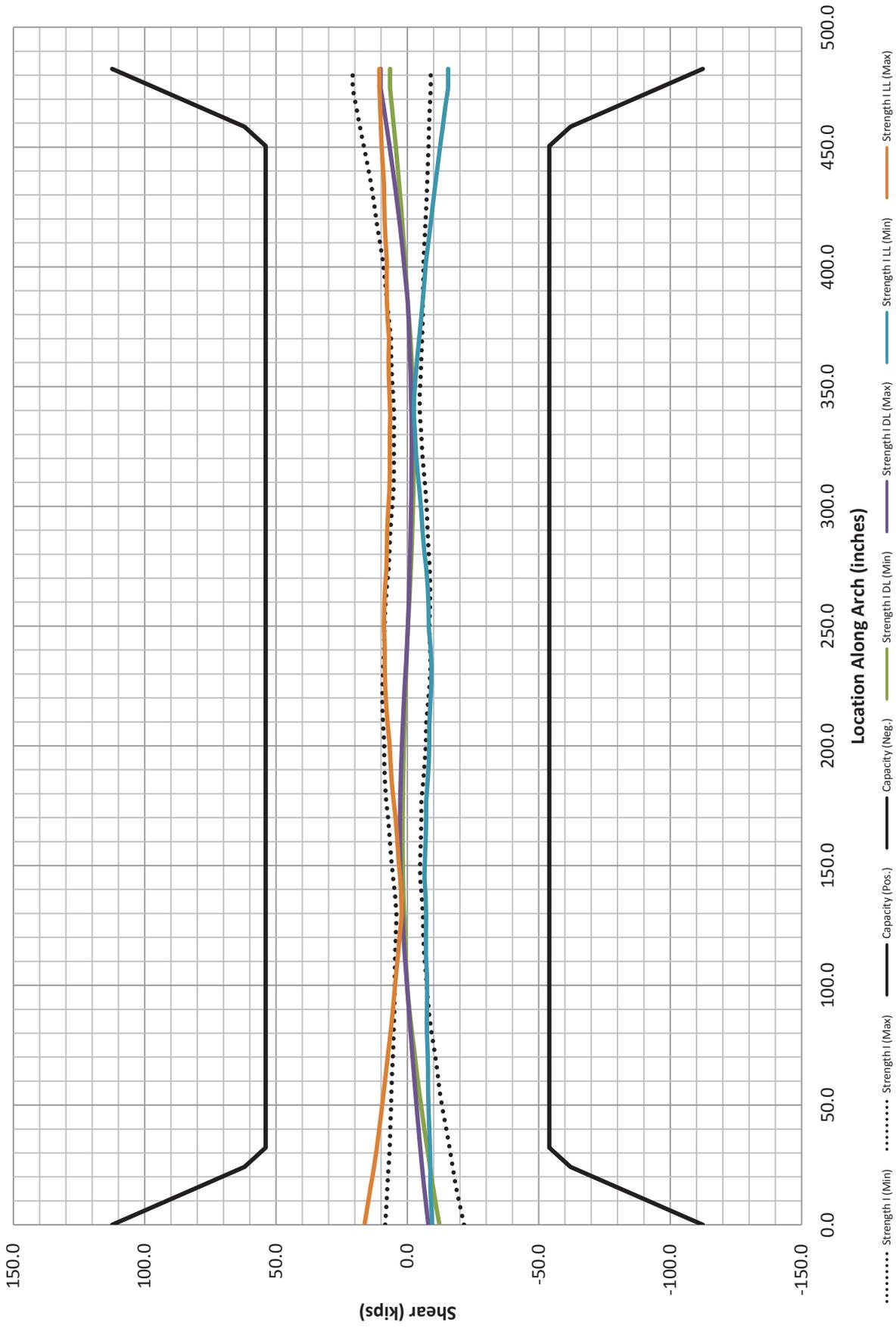
Tandem Rating Factor	1.96	1.48
Truck Rating Factor	2.23	1.79

Overall RF	1.49	1.15
------------	------	------

Moment Envelopes and Capacities



Shear Envelopes and Capacities



Load Rating Factors Along Arch



HL93 Truck 2 Lane Deep INV & OP

INVENTORY

DL = 1.472 k/ft
 LL₁₆ = 0.057 k/ft/wheel
 LL_{Ln} = 0.043 k/ft/laner

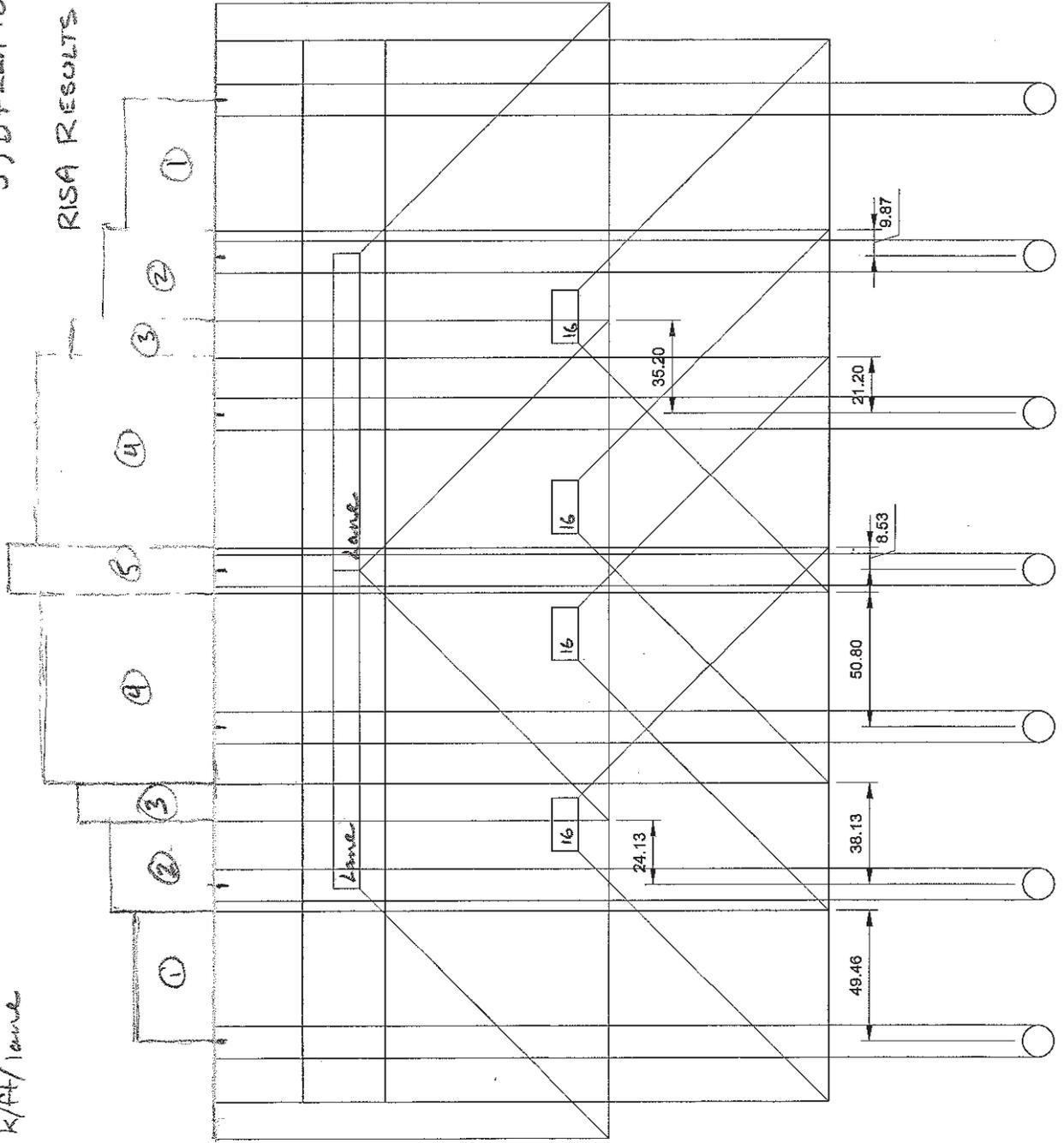
OPERATING

DL = 1.472 k/ft
 LL₁₆ = 0.044 k/ft/wheel
 LL_{Ln} = 0.034 k/ft/laner

	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		
RF	1.79	2.23



HL93 Tandem Shallow 1 Lane

INVENTORY

$$DL = 0.827 \text{ k/ft}$$

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

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

OPERATING

$$DL = 0.827 \text{ k/ft}$$

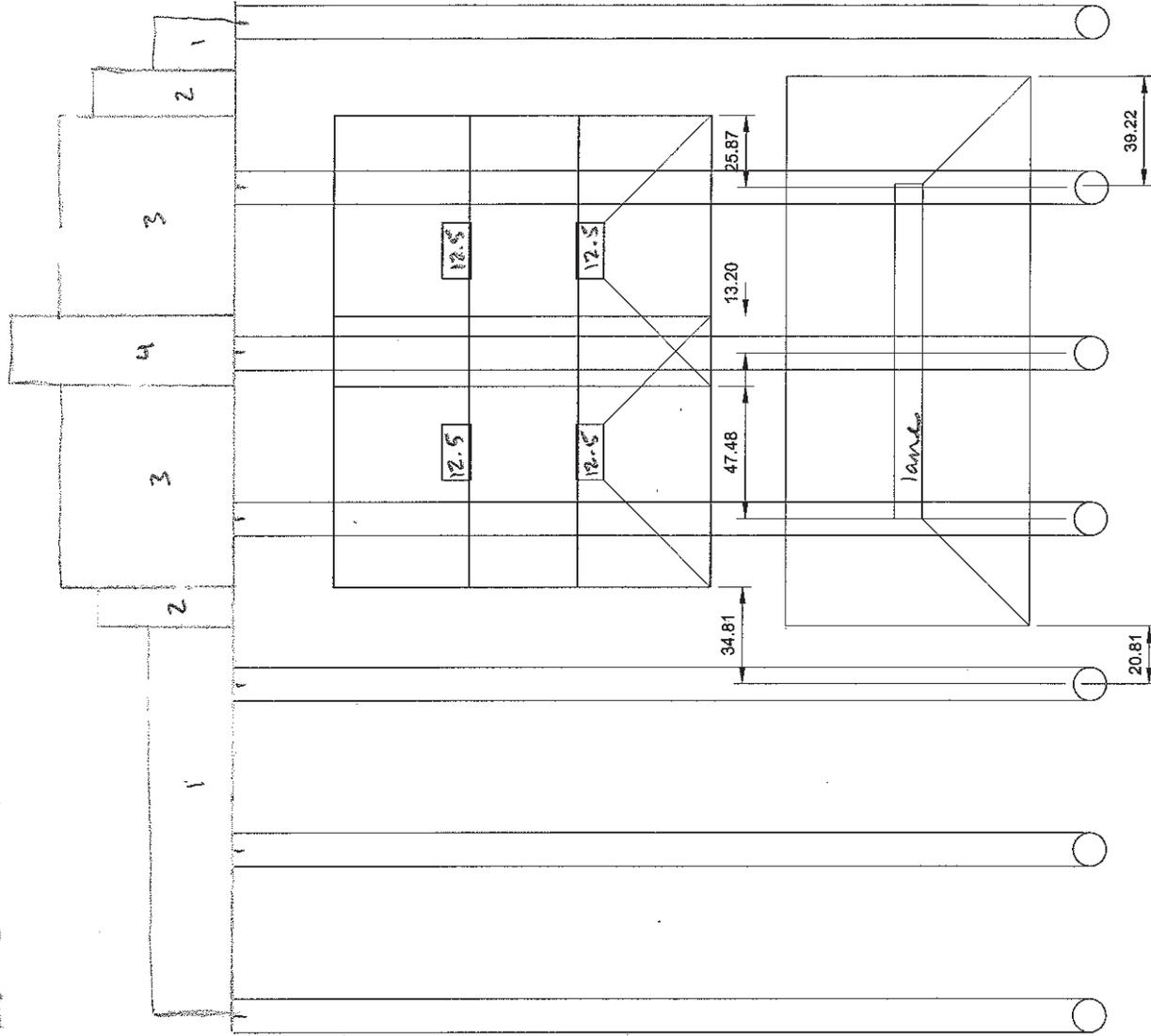
$$LL_{12.5} = 0.308 \text{ k/ft/wheel}$$

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

	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
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 $sp := 59.3\text{in}$

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

Depth of soil above lowest panel: $d := 13.7\text{ft}$

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: $\rho := 135 \frac{\text{lbf}}{\text{ft}^3}$

Horizontal projection of decking: $H_p := 1\text{ft}$

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

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

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

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

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

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

Factored dead load pressure perpendicular to the deck panel: $\text{DL_Press} := \frac{\text{Total_Force}}{\sqrt{H_p^2 + V_p^2}} = 12.584 \cdot \text{psi}$

RISA Input Dead Load Distributed Load	$RISA_DL := DL_Press \cdot 9.75 \text{ in} = 1.472 \cdot \frac{\text{kip}}{\text{ft}}$	
Reaction Due to Dead Load only	$R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 8.255 \cdot \text{kip}$	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	$W1 := 10 \text{ in} + d \cdot 1.15 = 16.588 \cdot \text{ft}$	
Wheel Distribution Across Arch	$W2 := 20 \text{ in} + d \cdot 1.15 = 17.422 \cdot \text{ft}$	
Area of Wheel Load Patch at Depth of Interest	$Load_Patch := W1 \cdot W2 = 289 \cdot \text{ft}^2$	
Average Wheel Pressure	$Wheel_Vert_Press := \frac{Wheel_load \cdot MPF \cdot \gamma_{LL}}{Load_Patch}$	
Vertical pressure along horizontal projection:	$Vert_{LL} := Wheel_Vert_Press \cdot H_p = 96.887 \cdot \frac{\text{lbf}}{\text{ft}}$	
Horizontal pressure along vertical projection:	$Horiz_{LL} := Wheel_Vert_Press \cdot K_o \cdot V_p = 47.155 \cdot \frac{\text{lbf}}{\text{ft}}$	
Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure:	$C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 67.303 \cdot \frac{\text{lbf}}{\text{ft}}$	
Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure:	$C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 33.92 \cdot \frac{\text{lbf}}{\text{ft}}$	
Total resultant force perpendicular to the deck panel:	$Total_Force_{LL} := C_{vLL} + C_{hLL} = 101.224 \cdot \frac{\text{lbf}}{\text{ft}}$	
Factored LL pressure perpendicular to the deck panel per wheel:	$LL_Press := \frac{Total_Force_{LL}}{\sqrt{H_p^2 + V_p^2}} = 0.488 \cdot \text{psi}$	
RISA Input Live Load Distributed Load	$RISA_LL := LL_Press \cdot 9.75 \text{ in} = 0.057 \cdot \frac{\text{kip}}{\text{ft}}$ per wheel	
Lane Load	$w_{lane} := \gamma_{LL} \cdot 640 \text{ lbf} = 1.12 \cdot \text{kip}$ per foot of lane along arch	
Lane Width at Deck Depth	$Width_{lane} := 10 \text{ ft} + d \cdot 1.15 = 25.755 \cdot \text{ft}$	
RISA Input Lane Load	$RISA_Lane := \frac{w_{lane}}{Width_{lane}} = 0.043 \cdot \frac{\text{kip}}{\text{ft}}$	

RISA Analysis Results:

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

Reaction from RISA $R_u := 9.692\text{kip}$ From RISA Analysis of six span beam - Node 2
 Moment from RISA $M_u := 52.96\text{in}\cdot\text{kip}$

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

Deck Panel Capacity:

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

Characterisitic Reaction Value 18" bend tests $R_{n18} := 21574\text{lbf}$ 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.
 Characteristic Reaction Value 24" bend tests $R_{n24} := 14745\text{lbf}$

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

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

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

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 $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.826\cdot\text{kip}$

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 $RISA_DL := DL_Press \cdot 9.75\text{in} = 1.472 \cdot \frac{\text{kip}}{\text{ft}}$

Reaction Due to Dead Load only $R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 8.255\cdot\text{kip}$

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

Live Load:

Load from one wheel

$$\text{Wheel_load} := 16\text{kip}$$

Wheel Distribution Along Arch

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

Wheel Distribution Across Arch

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

Area of Wheel Load Patch at Depth of Interest

$$\text{Load_Patch} := W1 \cdot W2 = 289 \cdot \text{ft}^2$$

Average Wheel Pressure

$$\text{Wheel_Vert_Press} := \frac{\text{Wheel_load} \cdot \text{MPF} \cdot \gamma_{\text{LL}}}{\text{Load_Patch}}$$

Vertical pressure along horizontal projection:

$$\text{Vert}_{\text{LL}} := \text{Wheel_Vert_Press} \cdot H_p = 74.741 \cdot \frac{\text{lb}}{\text{ft}}$$

Horizontal pressure along vertical projection:

$$\text{Horiz}_{\text{LL}} := \text{Wheel_Vert_Press} \cdot K_o \cdot V_p = 36.377 \cdot \frac{\text{lb}}{\text{ft}}$$

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

$$C_{\text{vLL}} := \cos(\theta) \cdot \text{Vert}_{\text{LL}} = 51.92 \cdot \frac{\text{lb}}{\text{ft}}$$

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

$$C_{\text{hLL}} := \sin(\theta) \cdot \text{Horiz}_{\text{LL}} = 26.167 \cdot \frac{\text{lb}}{\text{ft}}$$

Total resultant force perpendicular to the deck panel:

$$\text{Total_Force}_{\text{LL}} := C_{\text{vLL}} + C_{\text{hLL}} = 78.087 \cdot \frac{\text{lb}}{\text{ft}}$$

Factored LL pressure perpendicular to the deck panel per wheel:

$$\text{LL_Press} := \frac{\text{Total_Force}_{\text{LL}}}{\sqrt{H_p^2 + V_p^2}} = 0.377 \cdot \text{psi}$$

RISA Input Live Load Distributed Load

$$\text{RISA_LL} := \text{LL_Press} \cdot 9.75\text{in} = 0.044 \cdot \frac{\text{kip}}{\text{ft}} \text{ per wheel}$$

Lane Load

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

Lane Width at Deck Depth

$$\text{Width}_{\text{lane}} := 10\text{ft} + d \cdot 1.15 = 25.755 \cdot \text{ft}$$

RISA Input Lane Load

$$\text{RISA_Lane} := \frac{w_{\text{lane}}}{\text{Width}_{\text{lane}}} = 0.034 \cdot \frac{\text{kip}}{\text{ft}}$$

RISA Analysis Results:

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

Reaction from RISA

$$R_u := 9.398\text{kip}$$

From RISA Analysis of six span beam - Node 2

Moment from RISA

$$M_u := 51.43\text{in} \cdot \text{kip}$$

Moment:Reaction from RISA Analysis

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

Deck Panel Capacity:

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

Characterisitic Reaction Value 18" bend tests $R_{n18} := 21574\text{ lbf}$ 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.

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

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

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

Interpolated Characteristic Value $R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 17.147 \cdot \text{kip}$

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 $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.802 \cdot \text{kip}$

Rating Factor $RF_{op1} := \frac{\Phi R_n - R_{u_DL_only}}{(R_u - R_{u_DL_only})} = 2.229$

Pressure at Shallow Cover One Lane - Tandem - Inventory

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

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

Dead Load:

Factored Soil Pressure $DL_Press := cover \cdot \rho \cdot \gamma_e = 7.066 \cdot \text{psi}$

RISA Input Dead Load Distributed Load $RISA_DL := DL_Press \cdot 9.75\text{ in} = 0.827 \cdot \frac{\text{kip}}{\text{ft}}$

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

Live Load:

Maximum Wheel Load $P := 12.5\text{ kip}$

Multiple Presence Factor $MPF := 1.2$

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

Wheel Distribution Across Arch	$W_2 := 20\text{in} + \text{cover} \cdot 1.15 = 8.087 \cdot \text{ft}$	
Load Patch Area	$\text{Load_Patch} := W_1 \cdot W_2 = 58.668 \cdot \text{ft}^2$	
Impact Factor	$\text{IM} := 1 + 0.33 \left(1.0 - 0.125 \frac{\text{cover}}{12\text{in}} \right) = 1.100$	
Factored Wheel Load	$P_u := P \cdot \gamma_{LL} \cdot \text{MPF} \cdot \text{IM} = 28.867 \cdot \text{kip}$	
Factored Live Load Pressure	$\text{PRL}_u := \frac{P_u}{\text{Load_Patch}} = 3.417 \cdot \text{psi}$	
Factored Live Load Distributed Load	$w_L := \text{PRL}_u \cdot 9.75\text{in} = 0.400 \cdot \frac{\text{kip}}{\text{ft}}$	per wheel
Lane Load	$w_{\text{lane}} := \gamma_{LL} \cdot 640\text{lb} = 1.12 \cdot \text{kip}$	per foot of lane along arch
Lane Width at Deck Depth	$\text{Width}_{\text{lane}} := 10\text{ft} + \text{cover} \cdot 1.15 = 16.421 \cdot \text{ft}$	
RISA Input Lane Load	$\text{RISA_Lane} := \frac{w_{\text{lane}}}{\text{Width}_{\text{lane}}} = 0.068 \cdot \frac{\text{kip}}{\text{ft}}$	
RISA Analysis:		
Reaction from RISA	$R_u := 10.34\text{kip}$	
Moment from RISA	$M_u := 48.36\text{in} \cdot \text{kip}$	From RISA Analysis of six span beam - Node 5
Moment: Reaction from RISA Analysis	$\text{MR} := \frac{M_u}{R_u} = 4.677 \cdot \text{in}$	
Deck Panel Capacity:		
Interpolate Characteristic Reaction Value between 18in tests and 24in tests		
Interpolated Characteristic Value	$R_n := \frac{\text{MR}_{24} - \text{MR}}{\text{MR}_{24} - \text{MR}_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 20.768 \cdot \text{kip}$	
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	$\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 13.084 \cdot \text{kip}$	
Rating Factor	$\text{RF}_{\text{inv}2} := \frac{\Phi R_n - R_{u_DL_only}}{(R_u - R_{u_DL_only})} = 1.481$	

Pressure at Shallow Cover One Lane - Tandem - Operating

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

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

Dead Load:

Factored Soil Pressure $DL_Press := \text{cover} \cdot \rho \cdot \gamma_e = 7.066\text{ psi}$

RISA Input Dead Load Distributed Load $RISA_DL := DL_Press \cdot 9.75\text{in} = 0.827 \cdot \frac{\text{kip}}{\text{ft}}$

Reaction Due to Dead Load only $R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 4.636\text{ kip}$

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

Live Load:

Maximum Wheel Load $P := 12.5\text{kip}$

Multiple Presence Factor $MPF := 1.2$

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

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

Load Patch Area $Load_Patch := W1 \cdot W2 = 58.668 \cdot \text{ft}^2$

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

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

Factored Live Load Pressure $PRL_u := \frac{P_u}{Load_Patch} = 2.636\text{ psi}$

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

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

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

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

RISA Analysis:

Reaction from RISA $R_u := 8.9\text{kip}$

Moment from RISA $M_u := 41.86\text{in} \cdot \text{kip}$

From RISA Analysis of six span beam - Node 5

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

Deck Panel Capacity:

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

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

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 $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 13.008 \cdot \text{kip}$

Rating Factor $RF_{op2} := \frac{\Phi R_n - R_{u_DL_only}}{(R_u - R_{u_DL_only})} = 1.963$

Summary Inventory and Operating Load Rating Factors for Deck

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

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



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]

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

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, ϕM_n	522.7	in*kip
Development Length of End Reinforcing Bars	28.0	in
Length of Bars above TOF (excluding Id)	0.0	in
Shear Capacity, Reinforced Region, ϕV_n	112.4	kip
Shear Capacity, Unreinforced Region, ϕV_n	54	kip

Vehicle Description 3S2

Results:

ARCHES

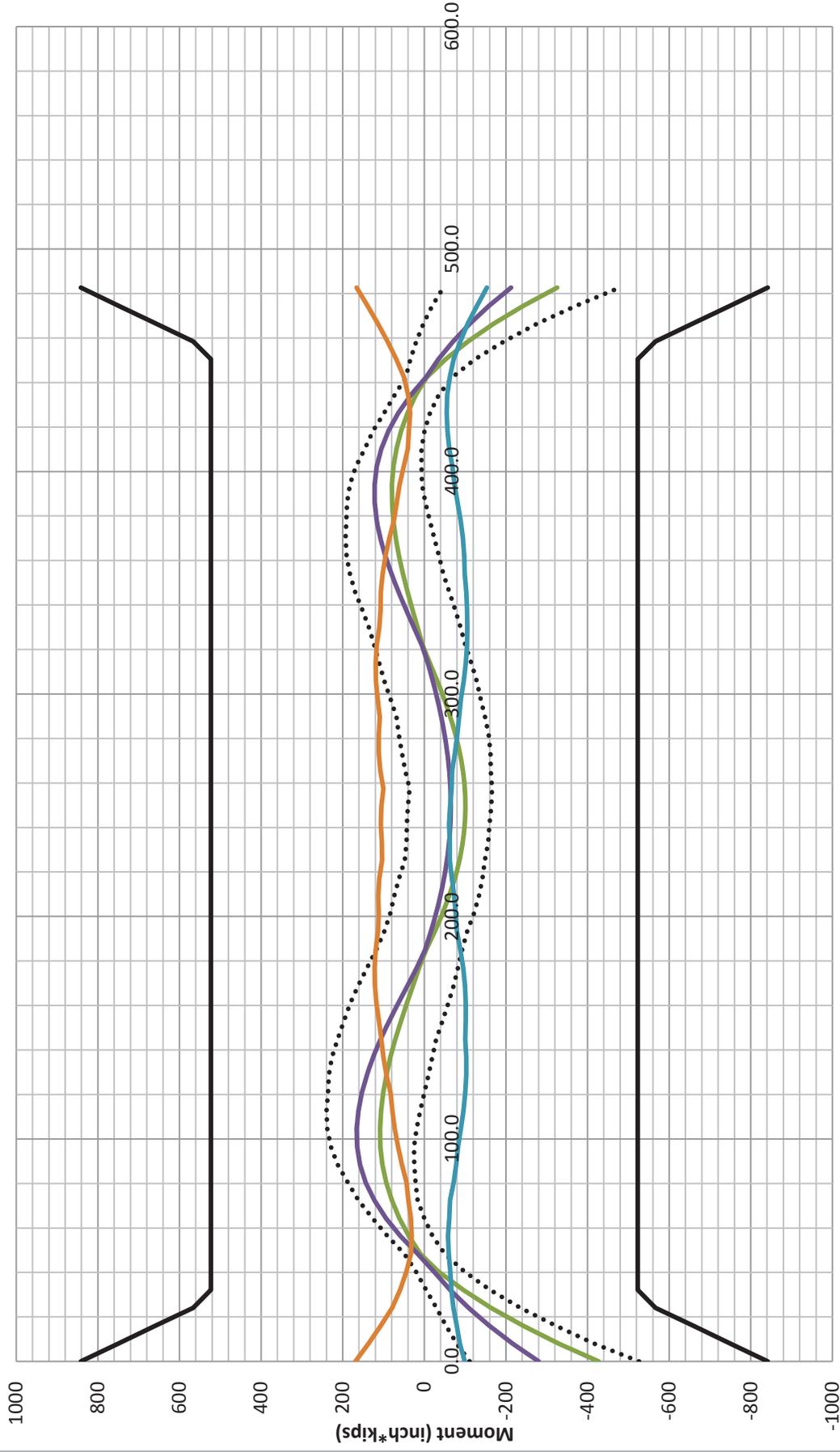
	Operating
Moment RF	4.36
Shear RF	17.34

DECKING

Shallow Cover Rating Factor	3.12
Deep Cover Rating Factor	4.04

Overall RF 3.12

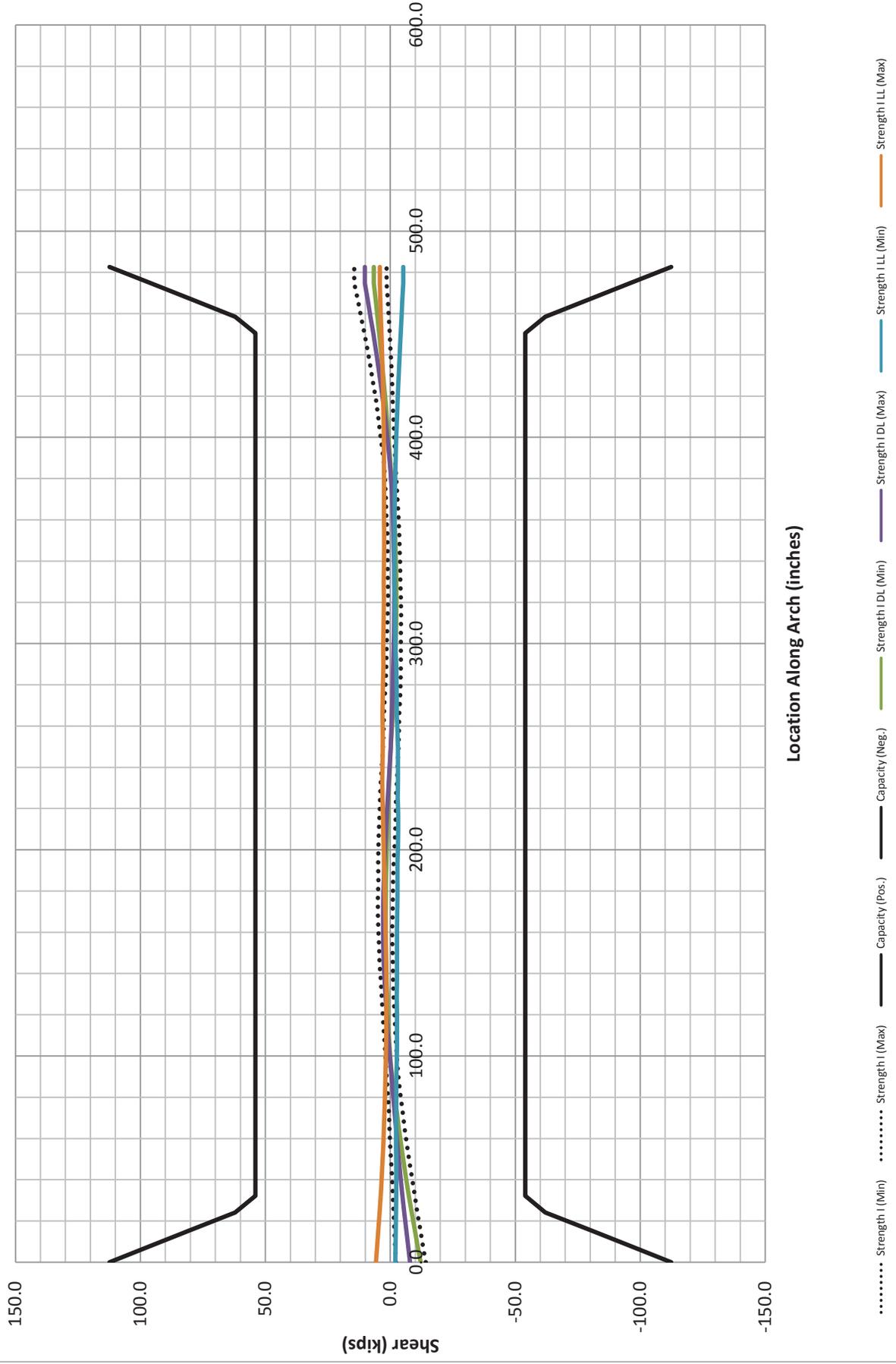
Moment Envelopes and Capacities



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



Load Rating Factors Along Arch





382 2 LANES DEEP OPERATING

SAME WHEEL CONFIGURATION AS 5 AXLE SEMI

$$D = 1.472 \text{ k/ft}$$

$$L_4 = 0.011 \text{ k/ft/wheel}$$

$$L_8 = 0.022 \text{ k/ft/wheel}$$

$$1) D + L_4 + 2L_8 \text{ --- } 1.527$$

$$2) D + 2L_4 + 4L_8 \text{ --- } 1.582$$

$$3) D + 3L_4 + 6L_8 \text{ --- } 1.637$$

$$4) D + 4L_4 + 8L_8 \text{ --- } 1.692$$

RISA NODE 2

$$R = 8.88$$

$$M = 48.66$$

$$RF = 4.04$$

382 1 LANE SHALLOW OPERATING

$$D = 0.827 \text{ k/ft}$$

$$L_2 = 0.197 \text{ k/ft/wheel}$$

$$1) D \text{ --- } 0.827$$

$$2) D + 2L \text{ --- } 1.221$$

$$3) D + 4L \text{ --- } 1.615$$

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 $sp := 59.3\text{in}$

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

Depth of soil above lowest panel: $d := 13.7\text{ft}$

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: $\rho := 135 \frac{\text{lbf}}{\text{ft}^3}$

Horizontal projection of decking: $H_p := 1\text{ft}$

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

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

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

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

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

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

Factored dead load pressure perpendicular to the deck panel: $\text{DL_Press} := \frac{\text{Total_Force}}{\sqrt{H_p^2 + V_p^2}} = 12.584 \cdot \text{psi}$

RISA Input Dead Load Distributed Load	$RISA_DL := DL_Press \cdot 9.75 \text{ in} = 1.472 \cdot \frac{\text{kip}}{\text{ft}}$	Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table
Reaction Due to Dead Load only	$R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 8.255 \cdot \text{kip}$	
Live Load:		
Load from one wheel	Wheel_load := 4kip	
Wheel Distribution Along Arch	$W1 := 10 \text{ in} + d \cdot 1.15 = 16.588 \cdot \text{ft}$	
Wheel Distribution Across Arch	$W2 := 20 \text{ in} + d \cdot 1.15 = 17.422 \cdot \text{ft}$	
Area of Wheel Load Patch at Depth of Interest	$Load_Patch := W1 \cdot W2 = 289 \cdot \text{ft}^2$	
Average Wheel Pressure	$Wheel_Vert_Press := \frac{Wheel_load \cdot MPF \cdot \gamma_{LL}}{Load_Patch}$	
Vertical pressure along horizontal projection:	$Vert_{LL} := Wheel_Vert_Press \cdot H_p = 18.685 \cdot \frac{\text{lbf}}{\text{ft}}$	
Horizontal pressure along vertical projection:	$Horiz_{LL} := Wheel_Vert_Press \cdot K_o \cdot V_p = 9.094 \cdot \frac{\text{lbf}}{\text{ft}}$	
Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure:	$C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 12.98 \cdot \frac{\text{lbf}}{\text{ft}}$	
Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure:	$C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 6.542 \cdot \frac{\text{lbf}}{\text{ft}}$	
Total resultant force perpendicular to the deck panel:	$Total_Force_{LL} := C_{vLL} + C_{hLL} = 19.522 \cdot \frac{\text{lbf}}{\text{ft}}$	
Factored LL pressure perpendicular to the deck panel per wheel:	$LL_Press := \frac{Total_Force_{LL}}{\sqrt{H_p^2 + V_p^2}} = 0.094 \cdot \text{psi}$	
RISA Input Live Load Distributed Load	$RISA_LL_4 := LL_Press \cdot 9.75 \text{ in} = 0.011 \cdot \frac{\text{kip}}{\text{ft}}$ per wheel	
Load from one wheel	Wheel_load := 8 · kip	
Wheel Distribution Along Arch	$W1 := 10 \text{ in} + d \cdot 1.15 = 16.588 \cdot \text{ft}$	
Wheel Distribution Across Arch	$W2 := 20 \text{ in} + d \cdot 1.15 = 17.422 \cdot \text{ft}$	
Area of Wheel Load Patch at Depth of Interest	$Load_Patch := W1 \cdot W2 = 289 \cdot \text{ft}^2$	
Average Wheel Pressure	$Wheel_Vert_Press := \frac{Wheel_load \cdot MPF \cdot \gamma_{LL}}{Load_Patch}$	

Vertical pressure along horizontal projection:

$$\text{Vert}_{LL} := \text{Wheel_Vert_Press} \cdot H_p = 37.371 \cdot \frac{\text{lbf}}{\text{ft}}$$

Horizontal pressure along vertical projection:

$$\text{Horiz}_{LL} := \text{Wheel_Vert_Press} \cdot K_o \cdot V_p = 18.188 \cdot \frac{\text{lbf}}{\text{ft}}$$

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

$$C_{vLL} := \cos(\theta) \cdot \text{Vert}_{LL} = 25.96 \cdot \frac{\text{lbf}}{\text{ft}}$$

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

$$C_{hLL} := \sin(\theta) \cdot \text{Horiz}_{LL} = 13.084 \cdot \frac{\text{lbf}}{\text{ft}}$$

Total resultant force perpendicular to the deck panel:

$$\text{Total_Force}_{LL} := C_{vLL} + C_{hLL} = 39.043 \cdot \frac{\text{lbf}}{\text{ft}}$$

Factored LL pressure perpendicular to the deck panel per wheel:

$$\text{LL_Press} := \frac{\text{Total_Force}_{LL}}{\sqrt{H_p^2 + V_p^2}} = 0.188 \cdot \text{psi}$$

RISA Input Live Load Distributed Load

$$\text{RISA_LL}_{8_5} := \text{LL_Press} \cdot 9.75 \text{ in} = 0.022 \cdot \frac{\text{kip}}{\text{ft}} \text{ per wheel}$$

RISA Analysis Results:

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

Reaction from RISA

$$R_u := 8.88 \text{ kip}$$

From RISA Analysis of six span beam - Node 2

Moment from RISA

$$M_u := 48.66 \text{ in} \cdot \text{kip}$$

Moment: Reaction from RISA Analysis

$$MR := \frac{M_u}{R_u} = 5.48 \cdot \text{in}$$

Deck Panel Capacity:

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

Characterisitic Reaction Value 18" bend tests

$$R_{n18} := 21574 \text{ lbf}$$

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.

Characteristic Reaction Value 24" bend tests

$$R_{n24} := 14745 \text{ lbf}$$

Moment: Reaction for 18" Tests

$$MR_{18} := 4.5 \text{ in}$$

Moment: Reaction for 24" Tests

$$MR_{24} := 6 \text{ in}$$

Interpolated Characteristic Value

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

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	$\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.782 \cdot \text{kip}$	

Rating Factor

$$RF_{op1} := \frac{\Phi R_n - R_{u_DL_only}}{(R_u - R_{u_DL_only})} = 4.043$$

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

$$DL_Press := cover \cdot \rho \cdot \gamma_e = 7.066 \cdot \text{psi}$$

RISA Input Dead Load Distributed Load

$$RISA_DL := DL_Press \cdot 9.75 \text{ in} = 0.827 \cdot \frac{\text{kip}}{\text{ft}}$$

Reaction Due to Dead Load only

$$R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 4.636 \cdot \text{kip}$$

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

Live Load:

Maximum Wheel Load

$$P := 8 \text{ kip}$$

Multiple Presence Factor

$$MPF := 1.2$$

Wheel Distribution Along Arch

$$W1 := 10 \text{ in} + cover \cdot 1.15 = 7.254 \cdot \text{ft}$$

Wheel Distribution Across Arch

$$W2 := 20 \text{ in} + cover \cdot 1.15 = 8.087 \cdot \text{ft}$$

Load Patch Area

$$Load_Patch := W1 \cdot W2 = 58.668 \cdot \text{ft}^2$$

Impact Factor

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

Factored Wheel Load

$$P_u := P \cdot \gamma_{LL} \cdot MPF \cdot IM = 14.252 \cdot \text{kip}$$

Factored Live Load Pressure

$$PRL_u := \frac{P_u}{Load_Patch} = 1.687 \cdot \text{psi}$$

Factored Live Load Distributed Load

$$w_L := PRL_u \cdot 9.75 \text{ in} = 0.197 \cdot \frac{\text{kip}}{\text{ft}} \quad \text{per wheel}$$

RISA Analysis:

Reaction from RISA

$$R_u := 7.181 \text{ kip}$$

Moment from RISA

$$M_u := 34.848 \text{ in} \cdot \text{kip}$$

From RISA Analysis of six span beam - Node 5

Moment: Reaction from RISA Analysis

$$MR := \frac{M_u}{R_u} = 4.853 \cdot \text{in}$$

Deck Panel Capacity:

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

Interpolated Characteristic Value

$$R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 19.968 \cdot \text{kip}$$

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

$$\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 12.58 \cdot \text{kip}$$

Rating Factor

$$RF_{op2} := \frac{\Phi R_n - R_{u_DL_only}}{(R_u - R_{u_DL_only})} = 3.121$$

Summary Load Rating Factors for Deck

Operating Rating Factor

$$RF_{op} := \min(RF_{op1}, RF_{op2}) = 3.121$$



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]

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

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, ϕM_n	522.7	in*kip
Development Length of End Reinforcing Bars	28.0	in
Length of Bars above TOF (excluding l_d)	0.0	in
Shear Capacity, Reinforced Region, ϕV_n	112.4	kip
Shear Capacity, Unreinforced Region, ϕV_n	54	kip

Vehicle Description 6 Axle Trailer

Results:

ARCHES

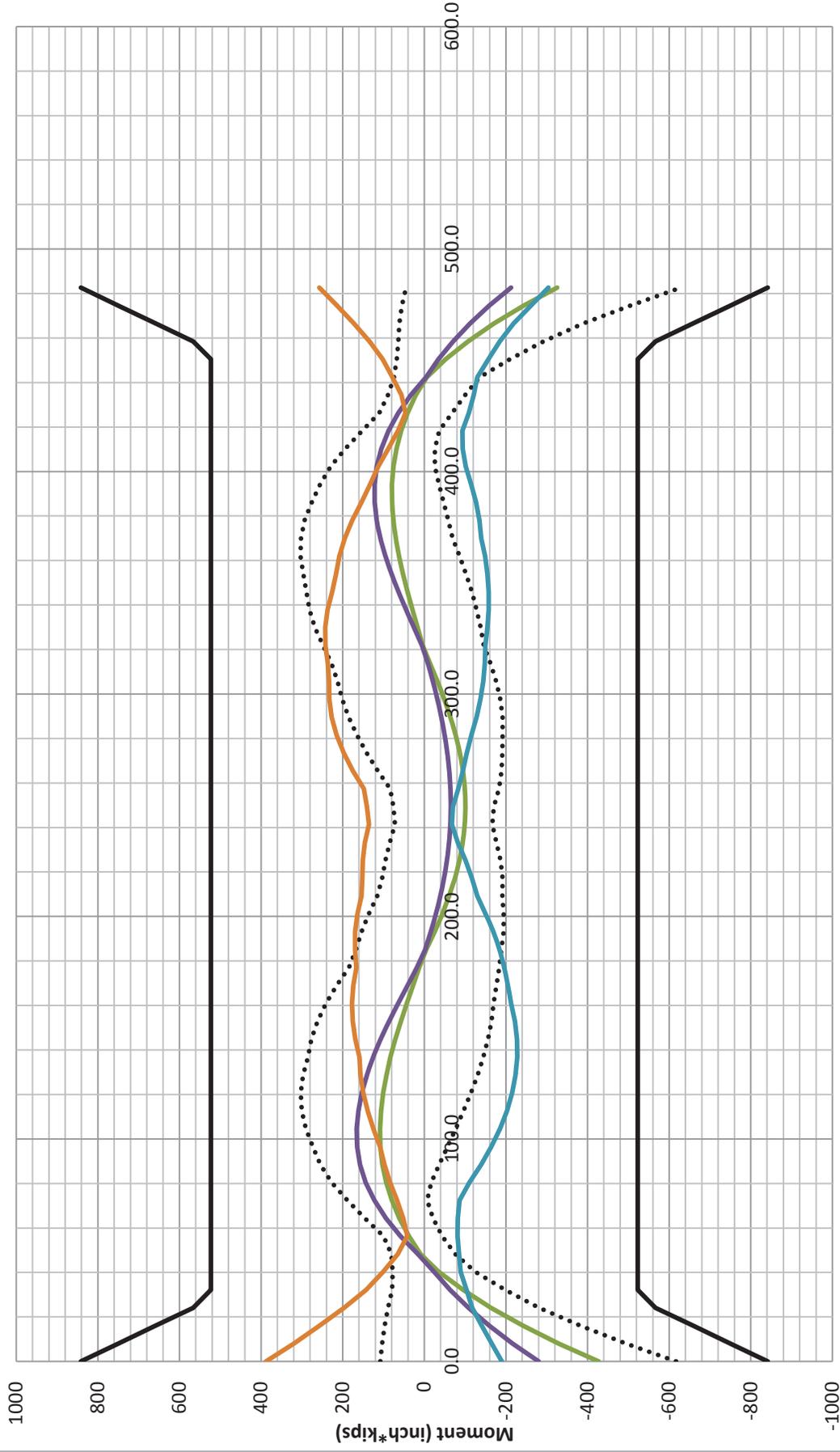
	Operating
Moment RF	2.20
Shear RF	8.44

DECKING

Shallow Cover Rating Factor	2.02
Deep Cover Rating Factor	2.51

Overall RF **2.02**

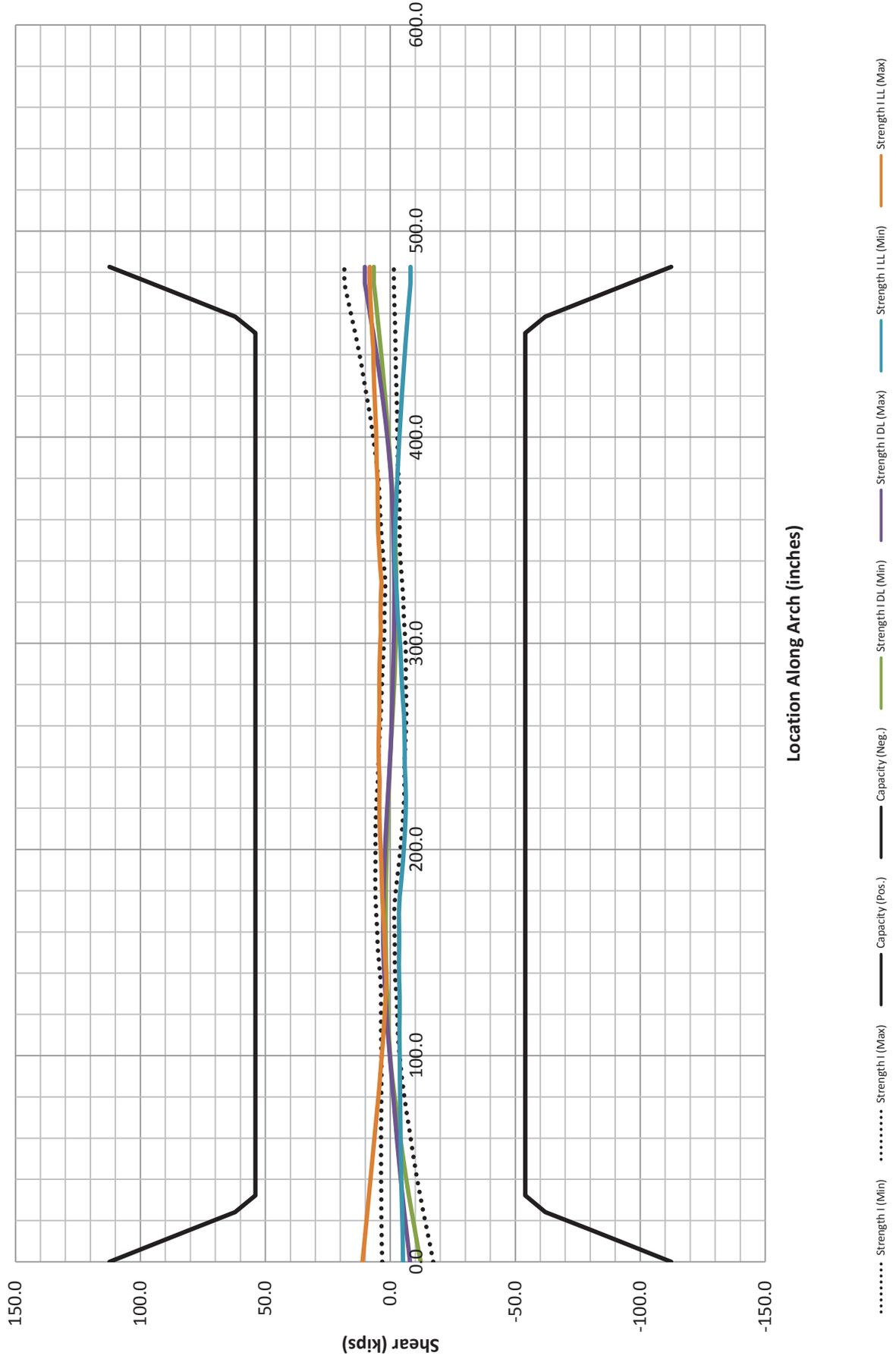
Moment Envelopes and Capacities



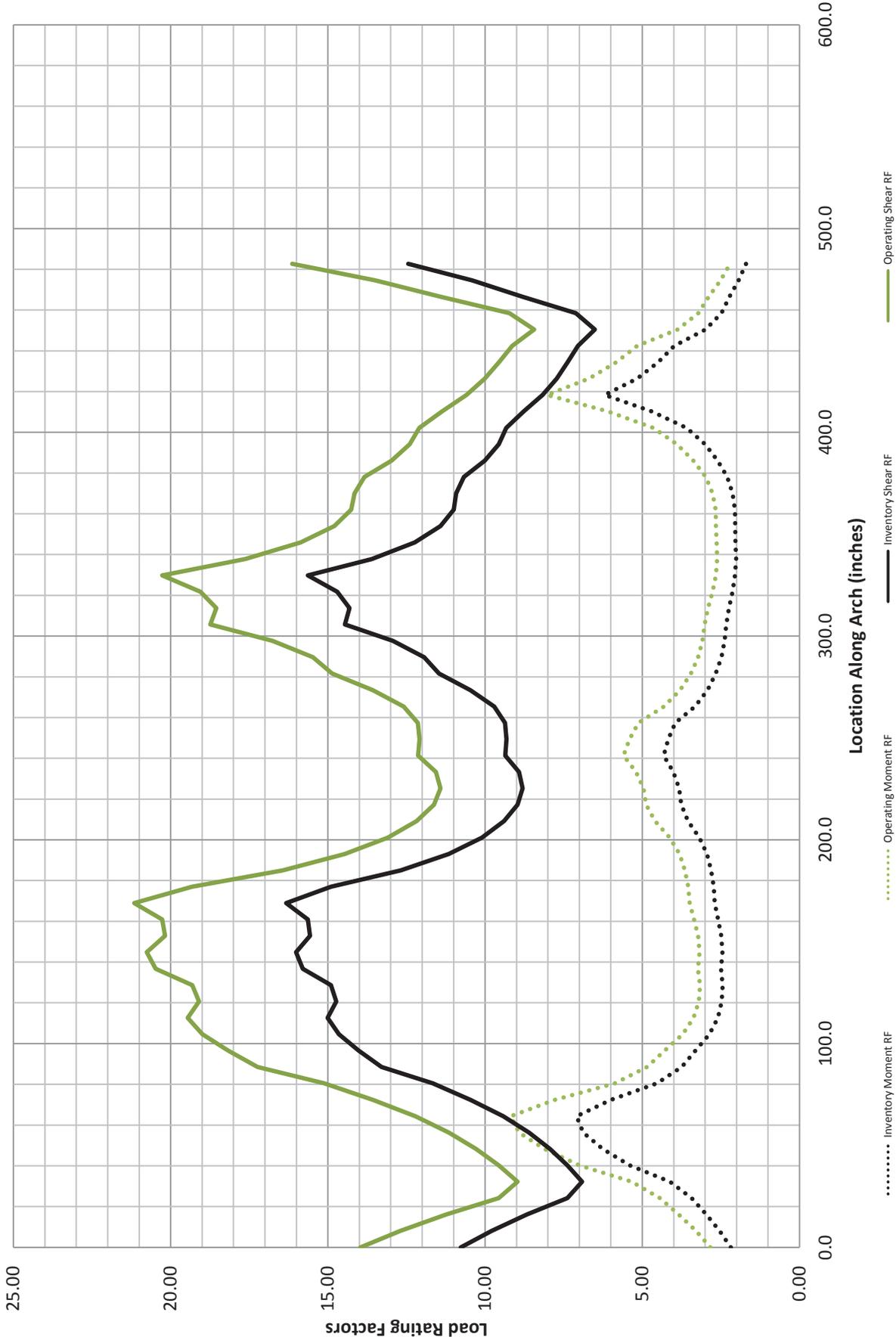
Location Along Arch (inches)

..... 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



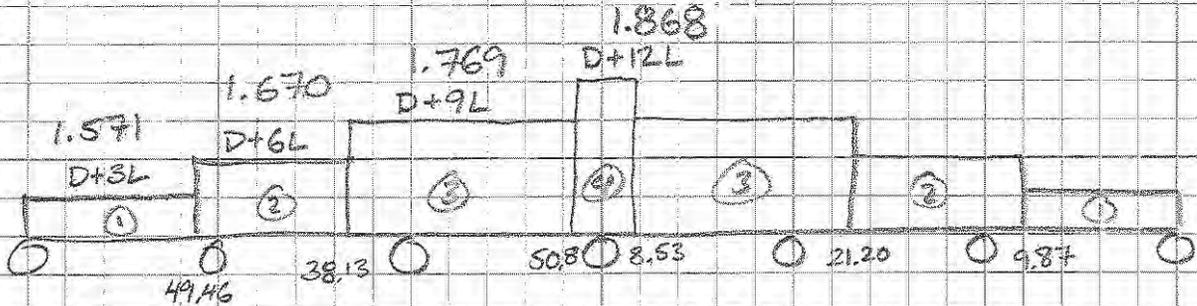
Load Rating Factors Along Arch





6 AXLE TRAILER DEEP BURY TWO LANES OPERATING

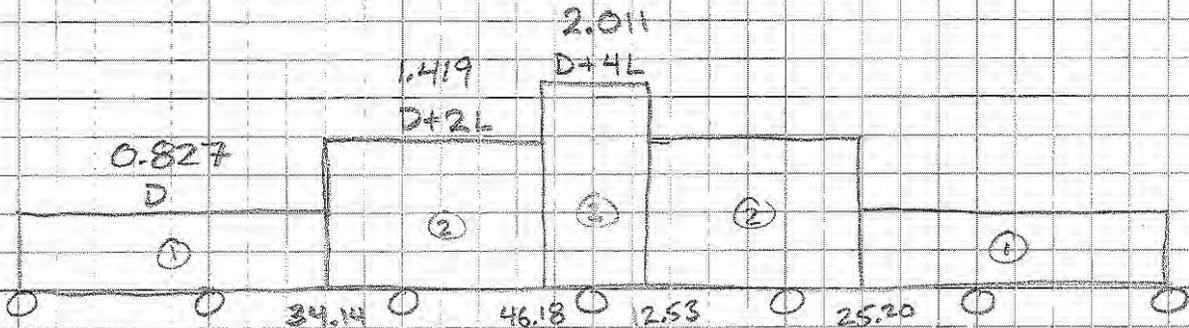
$DL = 1.472$ k/ft
 $LL_{12} = 0.033$ k/ft per wheel



	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	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 6 Axle Trailer Loading

Pressure at Deep Cover Two Lanes - Operating

Inputs:

Arch Spacing $sp := 59.3\text{in}$

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

Depth of soil above lowest panel: $d := 13.7\text{ft}$

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: $\rho := 135 \frac{\text{lbf}}{\text{ft}^3}$

Horizontal projection of decking: $H_p := 1\text{ft}$

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

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

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

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

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

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

Factored dead load pressure perpendicular to the deck panel: $\text{DL_Press} := \frac{\text{Total_Force}}{\sqrt{H_p^2 + V_p^2}} = 12.584 \cdot \text{psi}$

RISA Input Dead Load Distributed Load $RISA_DL := DL_Press \cdot 9.75 \text{ in} = 1.472 \cdot \frac{\text{kip}}{\text{ft}}$

Reaction Due to Dead Load only $R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 8.255 \cdot \text{kip}$

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

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

Area of Wheel Load Patch at Depth of Interest $Load_Patch := W1 \cdot W2 = 289 \cdot \text{ft}^2$

Average Wheel Pressure $Wheel_Vert_Press := \frac{Wheel_load \cdot MPF \cdot \gamma_{LL}}{Load_Patch}$

Vertical pressure along horizontal projection: $Vert_{LL} := Wheel_Vert_Press \cdot H_p = 56.056 \cdot \frac{\text{lbf}}{\text{ft}}$

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

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

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

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

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

RISA Input Live Load Distributed Load $RISA_LL := LL_Press \cdot 9.75 \text{ in} = 0.033 \cdot \frac{\text{kip}}{\text{ft}}$ per wheel

RISA Analysis Results:

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

Reaction from RISA **$R_u := 9.281 \text{ kip}$** From RISA Analysis of six span beam - Node 2

Moment from RISA **$M_u := 50.688 \text{ in} \cdot \text{kip}$**

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

Deck Panel Capacity:

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

Characterisitic Reaction Value
18" bend tests $R_{n18} := 21574\text{ lbf}$ 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.

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

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

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

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

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 $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.834 \cdot \text{kip}$

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 $\text{cover} := 67\text{ in}$ Measured from bottom of deck corrugation to road surface

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

Dead Load:

Factored Soil Pressure $DL_Press := \text{cover} \cdot \rho \cdot \gamma_e = 7.066 \cdot \text{psi}$

RISA Input Dead Load Distributed Load $RISA_DL := DL_Press \cdot 9.75\text{ in} = 0.827 \cdot \frac{\text{kip}}{\text{ft}}$

Reaction Due to Dead Load only $R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 4.636 \cdot \text{kip}$

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

Live Load:

Maximum Wheel Load $P := 12\text{ kip}$

Multiple Presence Factor $MPF := 1.2$

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

Wheel Distribution Across Arch

$$W2 := 20\text{in} + \text{cover} \cdot 1.15 = 8.087 \cdot \text{ft}$$

Load Patch Area

$$\text{Load_Patch} := W1 \cdot W2 = 58.668 \cdot \text{ft}^2$$

Impact Factor

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

Factored Wheel Load

$$P_u := P \cdot \gamma_{LL} \cdot \text{MPF} \cdot \text{IM} = 21.378 \cdot \text{kip}$$

Factored Live Load Pressure

$$\text{PRL}_u := \frac{P_u}{\text{Load_Patch}} = 2.53 \cdot \text{psi}$$

Factored Live Load Distributed Load

$$w_L := \text{PRL}_u \cdot 9.75\text{in} = 0.296 \cdot \frac{\text{kip}}{\text{ft}} \quad \text{per wheel}$$

RISA Analysis:

Reaction from RISA

$$R_u := 8.662 \text{kip}$$

Moment from RISA

$$M_u := 41.496 \text{in} \cdot \text{kip}$$

From RISA Analysis of six span beam - Node 5

Moment: Reaction from RISA Analysis

$$\text{MR} := \frac{M_u}{R_u} = 4.791 \cdot \text{in}$$

Deck Panel Capacity:

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

Interpolated Characteristic Value

$$R_n := \frac{\text{MR}_{24} - \text{MR}}{\text{MR}_{24} - \text{MR}_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 20.251 \cdot \text{kip}$$

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

$$\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 12.758 \cdot \text{kip}$$

Rating Factor

$$\text{RF}_{\text{op2}} := \frac{\Phi R_n - R_{u_DL_only}}{(R_u - R_{u_DL_only})} = 2.017$$

Summary Load Rating Factors for Deck

Operating Rating Factor

$$\text{RF}_{\text{op}} := \min(\text{RF}_{\text{op1}}, \text{RF}_{\text{op2}}) = 2.017$$



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]

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

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, ϕM_n	522.7	in*kip
Development Length of End Reinforcing Bars	28.0	in
Length of Bars above TOF (excluding Id)	0.0	in
Shear Capacity, Reinforced Region, ϕV_n	112.4	kip
Shear Capacity, Unreinforced Region, ϕV_n	54	kip

Vehicle Description: 3 Axle Straight

Results:

ARCHES

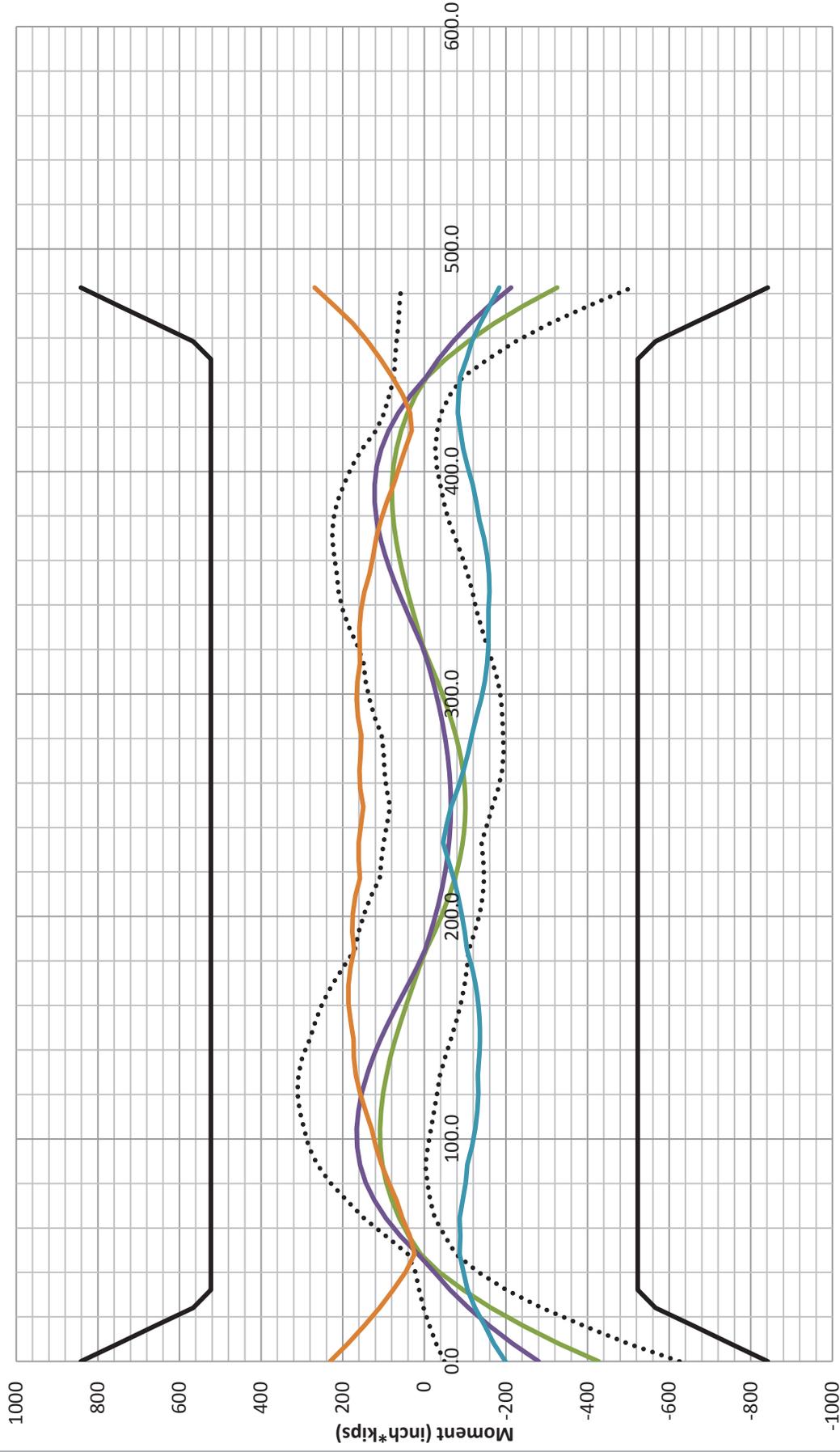
Moment RF	Operating	2.71
Shear RF		11.55

DECKING

Shallow Cover Rating Factor	2.02
Deep Cover Rating Factor	3.51

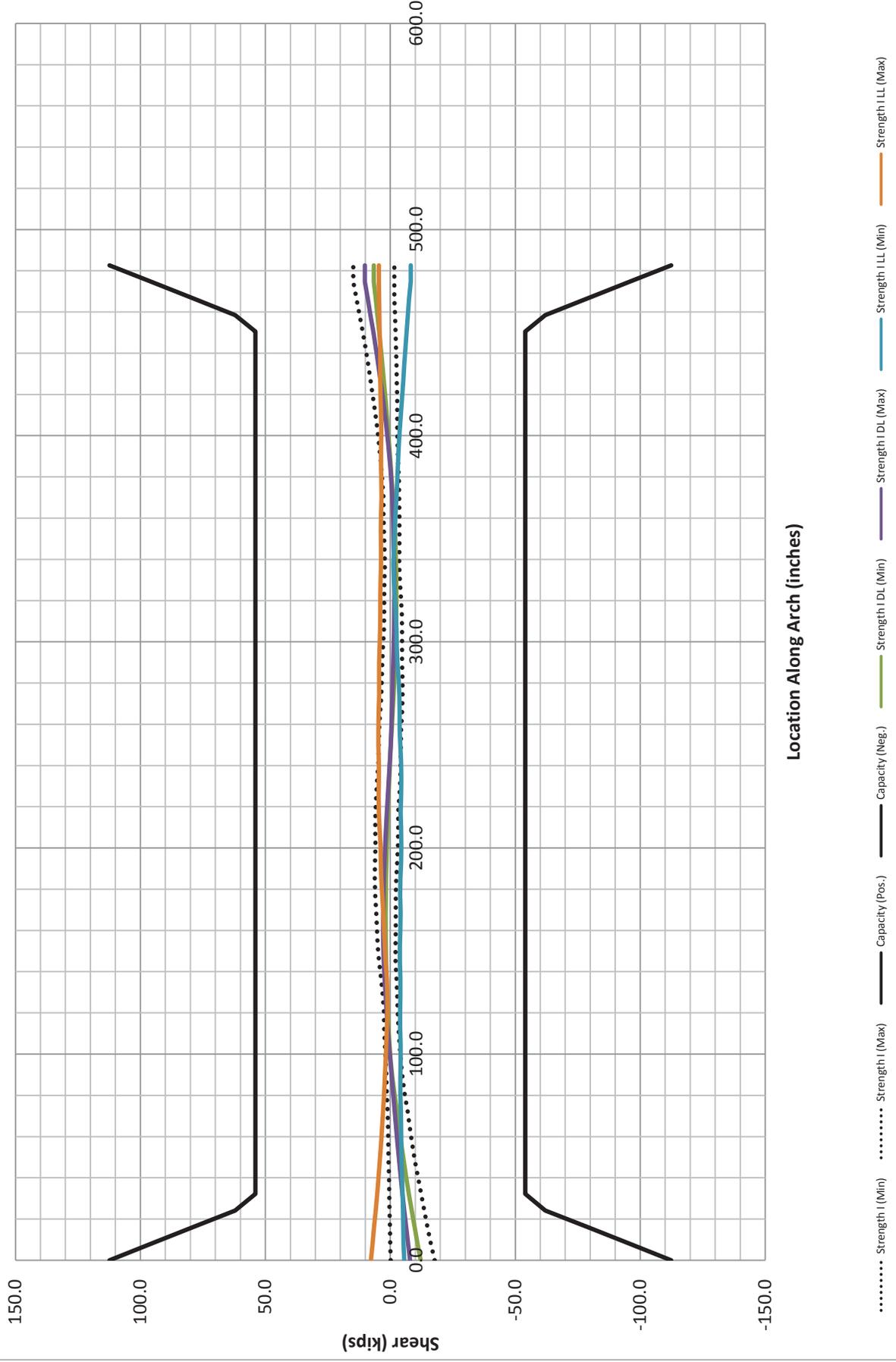
Overall RF: 2.02

Moment Envelopes and Capacities

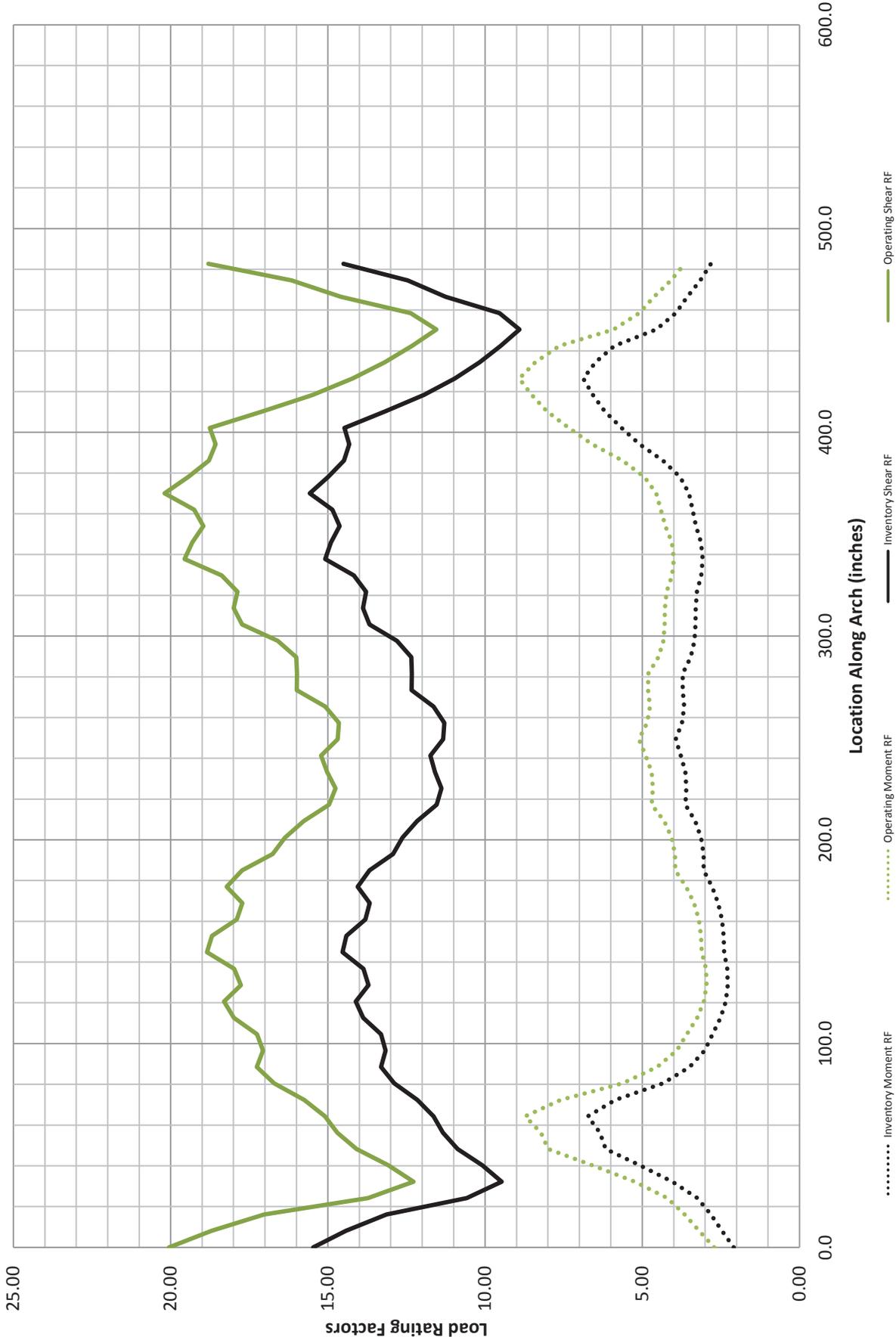


Location Along Arch (inches)

Shear Envelopes and Capacities



Load Rating Factors Along Arch





3 AXLE 2 LANES DEEP OPERATING

$D = 1.472 \text{ k/ft}$

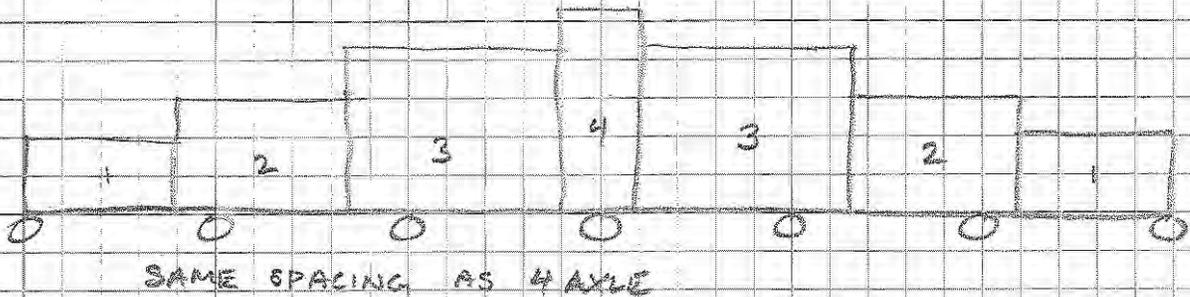
$L_{12} = 0.033 \text{ k/ft/wheel}$

1) $D + 2L = 1.538$

2) $D + 4L = 1.604$

3) $D + 6L = 1.670$

4) $D + 8L = 1.736$



RISA
NODE 2

$R = 8.98$

$M = 49.164$

$RF = 3.51$

3 AXLE 1 LANE SHALLOW OPERATING

$D = 0.827 \text{ k/ft}$

$LL_{12} = 0.296 \text{ k/ft/wheel}$

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 $sp := 59.3\text{in}$

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

Depth of soil above lowest panel: $d := 13.7\text{ft}$

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: $\rho := 135 \frac{\text{lbf}}{\text{ft}^3}$

Horizontal projection of decking: $H_p := 1\text{ft}$

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

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

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

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

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

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

Factored dead load pressure perpendicular to the deck panel: $\text{DL_Press} := \frac{\text{Total_Force}}{\sqrt{H_p^2 + V_p^2}} = 12.584 \cdot \text{psi}$

RISA Input Dead Load Distributed Load $RISA_DL := DL_Press \cdot 9.75 \text{ in} = 1.472 \cdot \frac{\text{kip}}{\text{ft}}$

Reaction Due to Dead Load only $R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 8.255 \cdot \text{kip}$

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

Live Load:

Load from one wheel $Wheel_load := 12 \text{ kip}$

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

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

Area of Wheel Load Patch at Depth of Interest $Load_Patch := W1 \cdot W2 = 289 \cdot \text{ft}^2$

Average Wheel Pressure $Wheel_Vert_Press := \frac{Wheel_load \cdot MPF \cdot \gamma_{LL}}{Load_Patch}$

Vertical pressure along horizontal projection: $Vert_{LL} := Wheel_Vert_Press \cdot H_p = 56.056 \cdot \frac{\text{lb}}{\text{ft}}$

Horizontal pressure along vertical projection: $Horiz_{LL} := Wheel_Vert_Press \cdot K_o \cdot V_p = 27.282 \cdot \frac{\text{lb}}{\text{ft}}$

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

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

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

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

RISA Input Live Load Distributed Load $RISA_LL_4 := LL_Press \cdot 9.75 \text{ in} = 0.033 \cdot \frac{\text{kip}}{\text{ft}}$ per wheel

RISA Analysis Results:

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

Reaction from RISA $R_u := 8.98 \text{ kip}$ From RISA Analysis of six span beam - Node 2

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

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

Deck Panel Capacity:

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

Characterisitic Reaction Value 18" bend tests $R_{n18} := 21574\text{ lbf}$ 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.

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

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

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

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

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 $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.796 \cdot \text{kip}$

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 $cover := 67\text{ in}$ Measured from bottom of deck corrugation to road surface

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

Dead Load:

Factored Soil Pressure $DL_Press := cover \cdot \rho \cdot \gamma_e = 7.066 \cdot \text{psi}$

RISA Input Dead Load Distributed Load $RISA_DL := DL_Press \cdot 9.75\text{ in} = 0.827 \cdot \frac{\text{kip}}{\text{ft}}$

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

Live Load:

Maximum Wheel Load $P := 12\text{ kip}$

Multiple Presence Factor $MPF := 1.2$

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

Wheel Distribution Across Arch	$W2 := 20\text{in} + \text{cover} \cdot 1.15 = 8.087 \cdot \text{ft}$	
Load Patch Area	$\text{Load_Patch} := W1 \cdot W2 = 58.668 \cdot \text{ft}^2$	
Impact Factor	$\text{IM} := 1 + 0.33 \left(1.0 - 0.125 \frac{\text{cover}}{12\text{in}} \right) = 1.100$	
Factored Wheel Load	$P_u := P \cdot \gamma_{LL} \cdot \text{MPF} \cdot \text{IM} = 21.378 \cdot \text{kip}$	
Factored Live Load Pressure	$\text{PRL}_u := \frac{P_u}{\text{Load_Patch}} = 2.53 \cdot \text{psi}$	
Factored Live Load Distributed Load	$w_L := \text{PRL}_u \cdot 9.75\text{in} = 0.296 \cdot \frac{\text{kip}}{\text{ft}}$	per wheel

RISA Analysis:

Reaction from RISA	$R_u := 8.662\text{kip}$	
Moment from RISA	$M_u := 41.496\text{in} \cdot \text{kip}$	From RISA Analysis of six span beam - Node 5
Moment: Reaction from RISA Analysis	$\text{MR} := \frac{M_u}{R_u} = 4.791 \cdot \text{in}$	

Deck Panel Capacity:

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

Interpolated Characteristic Value

$$R_n := \frac{\text{MR}_{24} - \text{MR}}{\text{MR}_{24} - \text{MR}_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 20.251 \cdot \text{kip}$$

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	$\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 12.758 \cdot \text{kip}$	

Rating Factor

$$\text{RF}_{\text{op2}} := \frac{\Phi R_n - R_{u_DL_only}}{(R_u - R_{u_DL_only})} = 2.017$$

Summary Load Rating Factors for Deck

Operating Rating Factor

$$\text{RF}_{\text{op}} := \min(\text{RF}_{\text{op1}}, \text{RF}_{\text{op2}}) = 2.017$$



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]

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

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, ϕM_n	522.7	in*kip
Development Length of End Reinforcing Bars	28.0	in
Length of Bars above TOF (excluding Id)	0.0	in
Shear Capacity, Reinforced Region, ϕV_n	112.4	kip
Shear Capacity, Unreinforced Region, ϕV_n	54	kip

Vehicle Description 4 Axle Straight

Results:

ARCHES

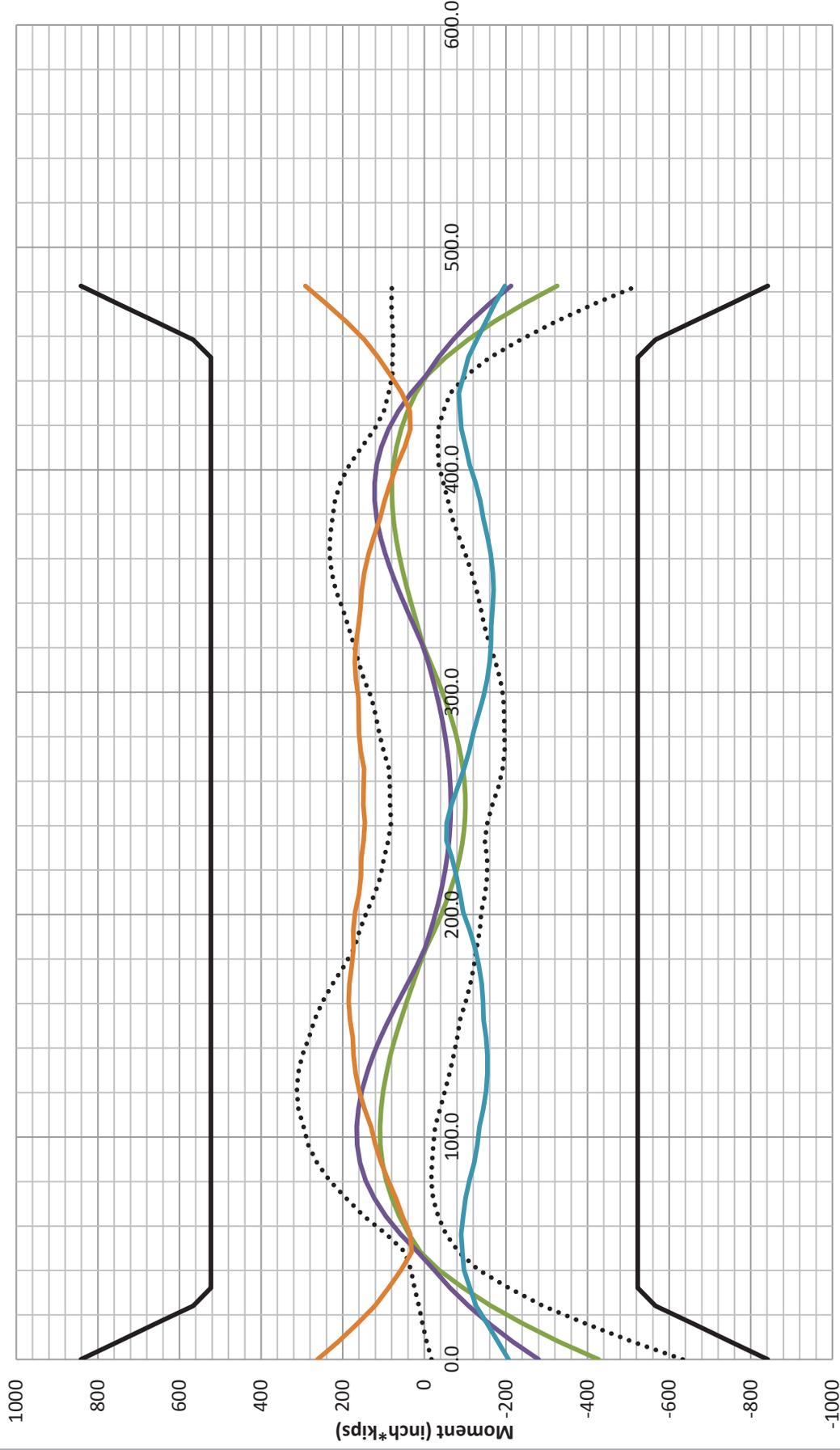
	Operating
Moment RF	2.61
Shear RF	10.70

DECKING

Shallow Cover Rating Factor	2.59
Deep Cover Rating Factor	3.06

Overall RF 2.59

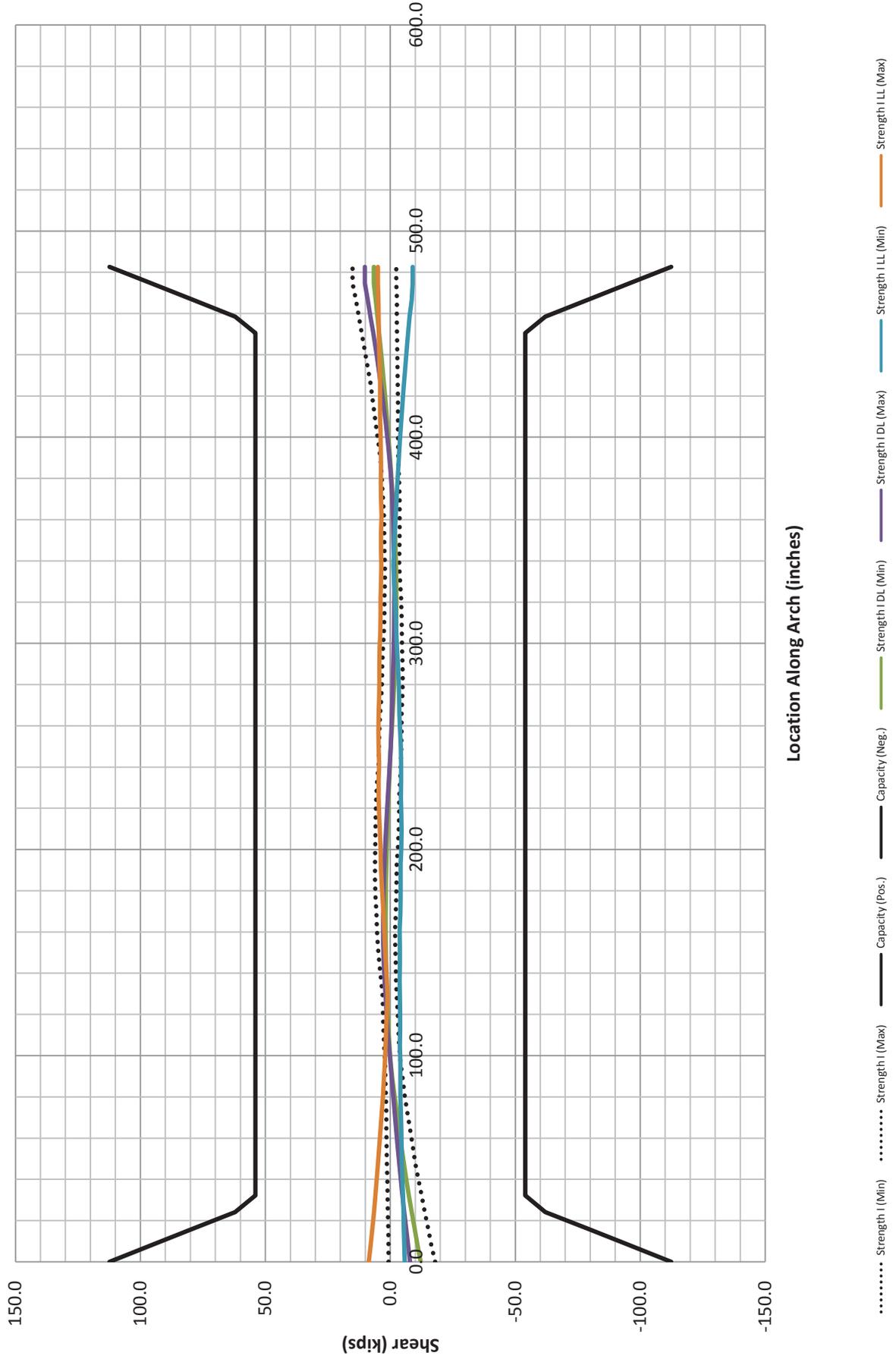
Moment Envelopes and Capacities



Location Along Arch (inches)

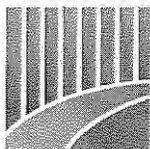
..... Strength I (Min) Strength I (Max) Capacity (Pos.) Capacity (Neg.) Strength I DL (Min) Strength I DL (Max) Strength I LL (Min) Strength I LL (Max)

Shear Envelopes and Capacities



Load Rating Factors Along Arch





4 AXLE STRAIGHT 2 LANES DEEP OPERATING

$D = 1.472 \text{ k/ft}$

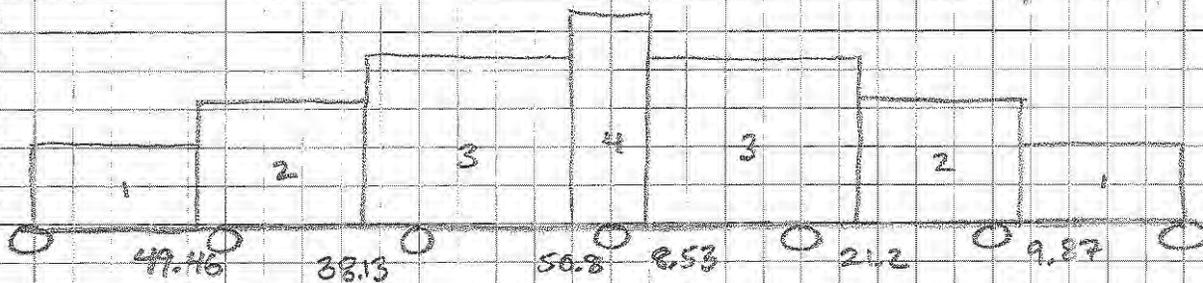
$L_{9.5} = 0.026 \text{ k/ft/wheel}$

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

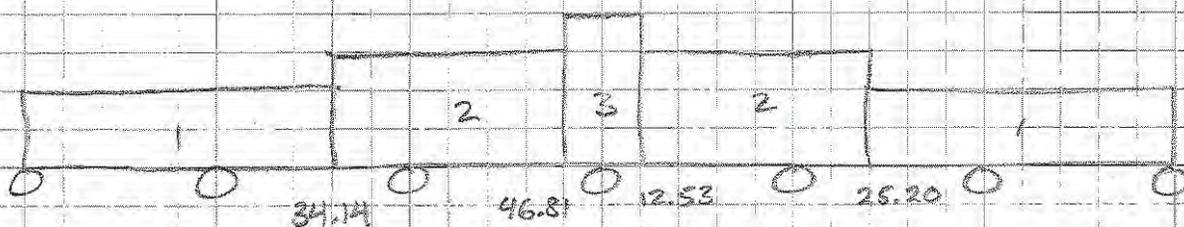
$D = 0.827 \text{ k/ft}$

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

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 $sp := 59.3\text{in}$

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

Depth of soil above lowest panel: $d := 13.7\text{ft}$

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: $\rho := 135 \frac{\text{lbf}}{\text{ft}^3}$

Horizontal projection of decking: $H_p := 1\text{ft}$

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

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

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

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

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

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

Factored dead load pressure perpendicular to the deck panel: $\text{DL_Press} := \frac{\text{Total_Force}}{\sqrt{H_p^2 + V_p^2}} = 12.584 \cdot \text{psi}$

RISA Input Dead Load Distributed Load $RISA_DL := DL_Press \cdot 9.75 \text{ in} = 1.472 \cdot \frac{\text{kip}}{\text{ft}}$

Reaction Due to Dead Load only $R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 8.255 \cdot \text{kip}$

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

Live Load:

Load from one wheel $Wheel_load := 9.5 \text{ kip}$

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

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

Area of Wheel Load Patch at Depth of Interest $Load_Patch := W1 \cdot W2 = 289 \cdot \text{ft}^2$

Average Wheel Pressure $Wheel_Vert_Press := \frac{Wheel_load \cdot MPF \cdot \gamma_{LL}}{Load_Patch}$

Vertical pressure along horizontal projection: $Vert_{LL} := Wheel_Vert_Press \cdot H_p = 44.378 \cdot \frac{\text{lbf}}{\text{ft}}$

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

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

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

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

Factored LL pressure perpendicular to the deck panel per wheel: $LL_Press := \frac{Total_Force_{LL}}{\sqrt{H_p^2 + V_p^2}} = 0.224 \cdot \text{psi}$

RISA Input Live Load Distributed Load $RISA_LL_4 := LL_Press \cdot 9.75 \text{ in} = 0.026 \cdot \frac{\text{kip}}{\text{ft}}$ per wheel

RISA Analysis Results:

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

Reaction from RISA $R_u := 9.09 \text{ kip}$ From RISA Analysis of six span beam - Node 2

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

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

Deck Panel Capacity:

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

Characterisitic Reaction Value 18" bend tests $R_{n18} := 21574\text{ lbf}$ 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.

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

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

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

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

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 $\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.811 \cdot \text{kip}$

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 $cover := 67\text{ in}$ Measured from bottom of deck corrugation to road surface

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

Dead Load:

Factored Soil Pressure $DL_Press := cover \cdot \rho \cdot \gamma_e = 7.066 \cdot \text{psi}$

RISA Input Dead Load Distributed Load $RISA_DL := DL_Press \cdot 9.75\text{ in} = 0.827 \cdot \frac{\text{kip}}{\text{ft}}$

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

Live Load:

Maximum Wheel Load $P := 9.5\text{ kip}$

Multiple Presence Factor $MPF := 1.2$

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

Wheel Distribution Across Arch	$W2 := 20\text{in} + \text{cover} \cdot 1.15 = 8.087 \cdot \text{ft}$	
Load Patch Area	$\text{Load_Patch} := W1 \cdot W2 = 58.668 \cdot \text{ft}^2$	
Impact Factor	$\text{IM} := 1 + 0.33 \left(1.0 - 0.125 \frac{\text{cover}}{12\text{in}} \right) = 1.100$	
Factored Wheel Load	$P_u := P \cdot \gamma_{LL} \cdot \text{MPF} \cdot \text{IM} = 16.924 \cdot \text{kip}$	
Factored Live Load Pressure	$\text{PRL}_u := \frac{P_u}{\text{Load_Patch}} = 2.003 \cdot \text{psi}$	
Factored Live Load Distributed Load	$w_L := \text{PRL}_u \cdot 9.75\text{in} = 0.234 \cdot \frac{\text{kip}}{\text{ft}}$	per wheel

RISA Analysis:

Reaction from RISA	$R_u := 7.735\text{kip}$	
Moment from RISA	$M_u := 37.332\text{in} \cdot \text{kip}$	From RISA Analysis of six span beam - Node 5
Moment: Reaction from RISA Analysis	$M_R := \frac{M_u}{R_u} = 4.826 \cdot \text{in}$	

Deck Panel Capacity:

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

Interpolated Characteristic Value	$R_n := \frac{MR_{24} - MR}{MR_{24} - MR_{18}} \cdot (R_{n18} - R_{n24}) + R_{n24} = 20.088 \cdot \text{kip}$
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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	$\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 12.656 \cdot \text{kip}$	

Rating Factor	$\text{RF}_{op2} := \frac{\Phi R_n - R_{u_DL_only}}{(R_u - R_{u_DL_only})} = 2.588$
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Summary Load Rating Factors for Deck

Operating Rating Factor	$\text{RF}_{op} := \min(\text{RF}_{op1}, \text{RF}_{op2}) = 2.588$
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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]

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

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, ϕM_n	522.7	in*kip
Development Length of End Reinforcing Bars	28.0	in
Length of Bars above TOF (excluding Id)	0.0	in
Shear Capacity, Reinforced Region, ϕV_n	112.4	kip
Shear Capacity, Unreinforced Region, ϕV_n	54	kip

Vehicle Description: 5 Axle Semi

Results:

ARCHES

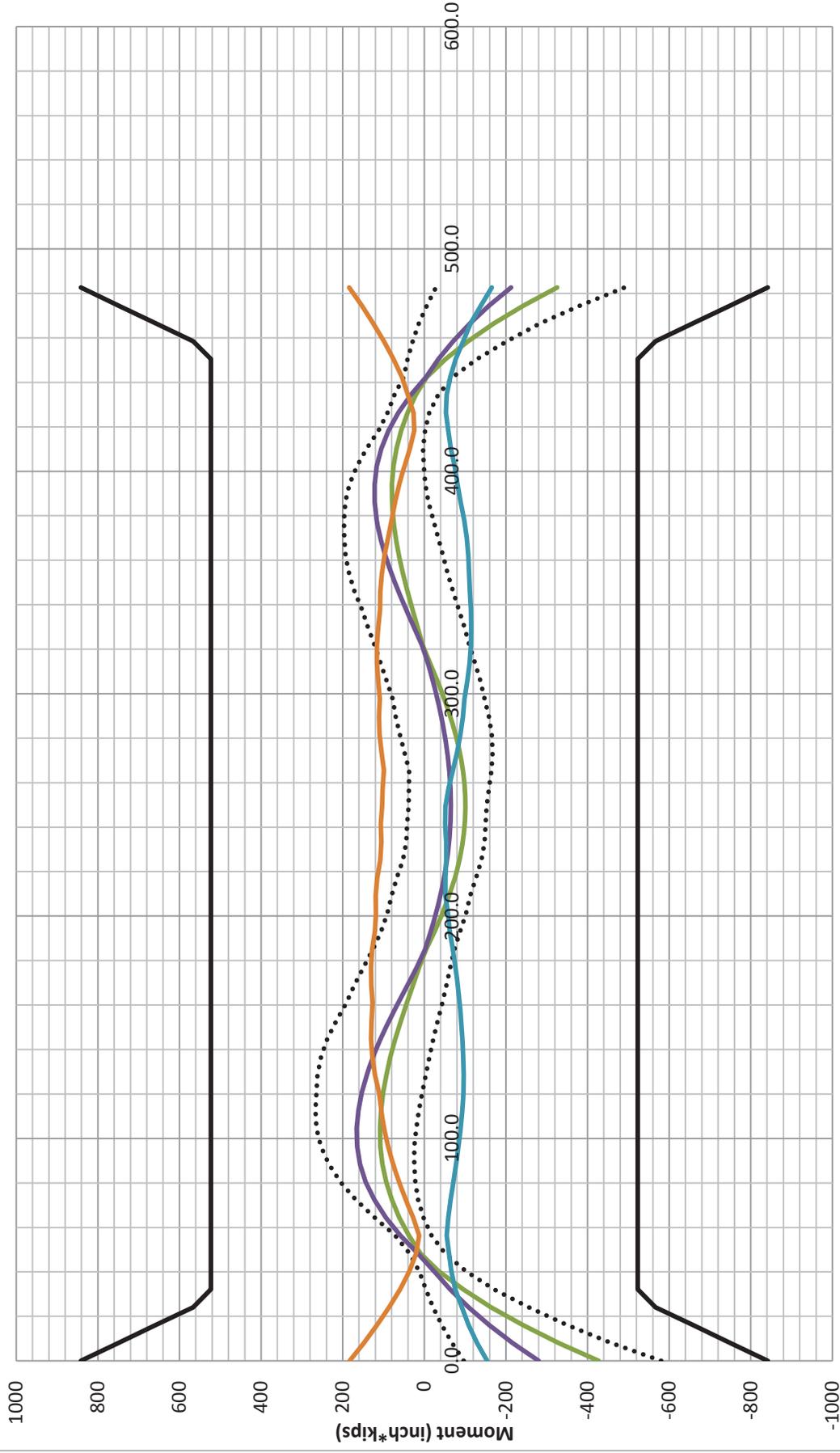
Moment RF	3.50
Shear RF	16.27

DECKING

Shallow Cover Rating Factor	2.91
Deep Cover Rating Factor	3.93

Overall RF: 2.91

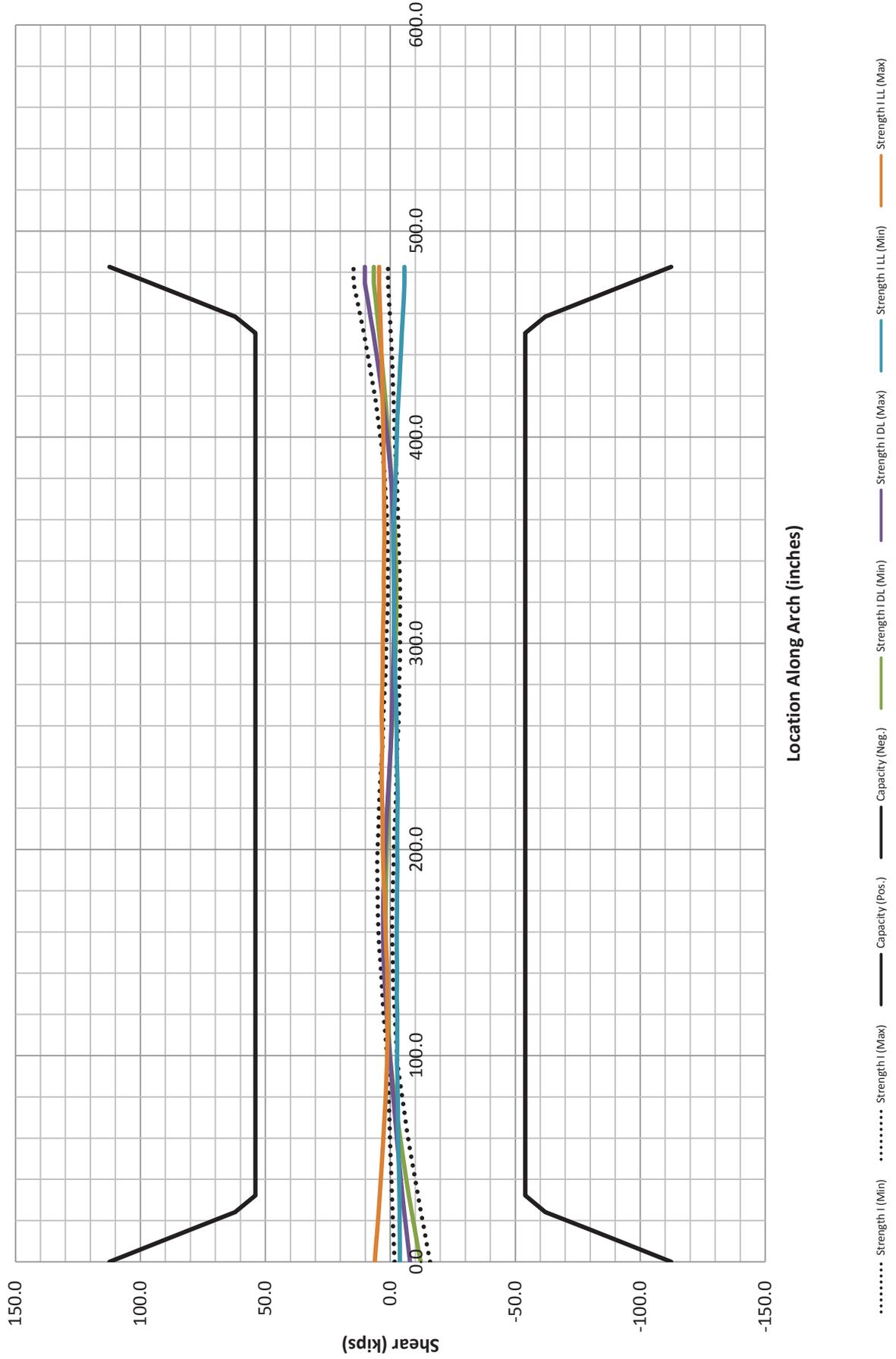
Moment Envelopes and Capacities



Location Along Arch (inches)

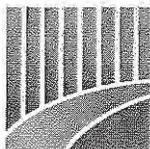
..... Strength I (Min) Strength I (Max) Capacity (Pos.) Capacity (Neg.) Strength I DL (Min) Strength I DL (Max) Strength I LL (Min) Strength I LL (Max)

Shear Envelopes and Capacities



Load Rating Factors Along Arch





5 AXLE SEMI SHALLOW 1 LANE OPERATING

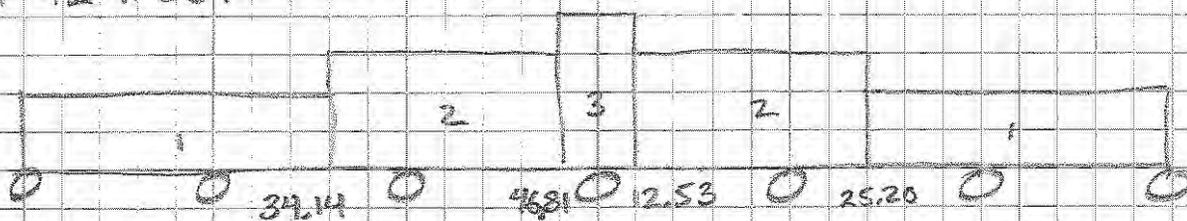
$$D = 0.827 \text{ k/ft}$$

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

1) $D = 0.827$

2) $D + 2L = 1.247$

3) $D + 4L = 1.667$



RISA NODE 4

$$R = 7.376$$

$$M = 35.724$$

$$RF = 2.91$$

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 $sp := 59.3\text{in}$

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

Depth of soil above lowest panel: $d := 13.7\text{ft}$

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: $\rho := 135 \frac{\text{lbf}}{\text{ft}^3}$

Horizontal projection of decking: $H_p := 1\text{ft}$

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

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

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

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

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

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

Factored dead load pressure perpendicular to the deck panel: $\text{DL_Press} := \frac{\text{Total_Force}}{\sqrt{H_p^2 + V_p^2}} = 12.584 \cdot \text{psi}$

RISA Input Dead Load Distributed Load	$RISA_DL := DL_Press \cdot 9.75 \text{ in} = 1.472 \cdot \frac{\text{kip}}{\text{ft}}$	Based on reaction at first support of six span continuous uniformly loaded beam AISC Load Table
Reaction Due to Dead Load only	$R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 8.255 \cdot \text{kip}$	
Live Load:		
Load from one wheel	Wheel_load := 4kip	
Wheel Distribution Along Arch	$W1 := 10 \text{ in} + d \cdot 1.15 = 16.588 \cdot \text{ft}$	
Wheel Distribution Across Arch	$W2 := 20 \text{ in} + d \cdot 1.15 = 17.422 \cdot \text{ft}$	
Area of Wheel Load Patch at Depth of Interest	$Load_Patch := W1 \cdot W2 = 289 \cdot \text{ft}^2$	
Average Wheel Pressure	$Wheel_Vert_Press := \frac{Wheel_load \cdot MPF \cdot \gamma_{LL}}{Load_Patch}$	
Vertical pressure along horizontal projection:	$Vert_{LL} := Wheel_Vert_Press \cdot H_p = 18.685 \cdot \frac{\text{lbf}}{\text{ft}}$	
Horizontal pressure along vertical projection:	$Horiz_{LL} := Wheel_Vert_Press \cdot K_o \cdot V_p = 9.094 \cdot \frac{\text{lbf}}{\text{ft}}$	
Portion of the pressure perpendicular to the deck panel contributed by the vertical pressure:	$C_{vLL} := \cos(\theta) \cdot Vert_{LL} = 12.98 \cdot \frac{\text{lbf}}{\text{ft}}$	
Portion of the pressure perpendicular to the deck panel contributed by the horizontal pressure:	$C_{hLL} := \sin(\theta) \cdot Horiz_{LL} = 6.542 \cdot \frac{\text{lbf}}{\text{ft}}$	
Total resultant force perpendicular to the deck panel:	$Total_Force_{LL} := C_{vLL} + C_{hLL} = 19.522 \cdot \frac{\text{lbf}}{\text{ft}}$	
Factored LL pressure perpendicular to the deck panel per wheel:	$LL_Press := \frac{Total_Force_{LL}}{\sqrt{H_p^2 + V_p^2}} = 0.094 \cdot \text{psi}$	
RISA Input Live Load Distributed Load	$RISA_LL_4 := LL_Press \cdot 9.75 \text{ in} = 0.011 \cdot \frac{\text{kip}}{\text{ft}}$ per wheel	
Load from one wheel	Wheel_load := 8.5kip	
Wheel Distribution Along Arch	$W1 := 10 \text{ in} + d \cdot 1.15 = 16.588 \cdot \text{ft}$	
Wheel Distribution Across Arch	$W2 := 20 \text{ in} + d \cdot 1.15 = 17.422 \cdot \text{ft}$	
Area of Wheel Load Patch at Depth of Interest	$Load_Patch := W1 \cdot W2 = 289 \cdot \text{ft}^2$	
Average Wheel Pressure	$Wheel_Vert_Press := \frac{Wheel_load \cdot MPF \cdot \gamma_{LL}}{Load_Patch}$	

Vertical pressure along horizontal projection:

$$\text{Vert}_{LL} := \text{Wheel_Vert_Press} \cdot H_p = 39.706 \cdot \frac{\text{lbf}}{\text{ft}}$$

Horizontal pressure along vertical projection:

$$\text{Horiz}_{LL} := \text{Wheel_Vert_Press} \cdot K_o \cdot V_p = 19.325 \cdot \frac{\text{lbf}}{\text{ft}}$$

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

$$C_{vLL} := \cos(\theta) \cdot \text{Vert}_{LL} = 27.582 \cdot \frac{\text{lbf}}{\text{ft}}$$

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

$$C_{hLL} := \sin(\theta) \cdot \text{Horiz}_{LL} = 13.901 \cdot \frac{\text{lbf}}{\text{ft}}$$

Total resultant force perpendicular to the deck panel:

$$\text{Total_Force}_{LL} := C_{vLL} + C_{hLL} = 41.484 \cdot \frac{\text{lbf}}{\text{ft}}$$

Factored LL pressure perpendicular to the deck panel per wheel:

$$\text{LL_Press} := \frac{\text{Total_Force}_{LL}}{\sqrt{H_p^2 + V_p^2}} = 0.2 \cdot \text{psi}$$

RISA Input Live Load Distributed Load

$$\text{RISA_LL}_{8_5} := \text{LL_Press} \cdot 9.75 \text{ in} = 0.023 \cdot \frac{\text{kip}}{\text{ft}} \text{ per wheel}$$

RISA Analysis Results:

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

Reaction from RISA

$$R_u := 8.898 \text{ kip}$$

From RISA Analysis of six span beam - Node 2

Moment from RISA

$$M_u := 48.756 \text{ in} \cdot \text{kip}$$

Moment: Reaction from RISA Analysis

$$MR := \frac{M_u}{R_u} = 5.479 \cdot \text{in}$$

Deck Panel Capacity:

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

Characterisitic Reaction Value 18" bend tests

$$R_{n18} := 21574 \text{ lbf}$$

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.

Characteristic Reaction Value 24" bend tests

$$R_{n24} := 14745 \text{ lbf}$$

Moment: Reaction for 18" Tests

$$MR_{18} := 4.5 \text{ in}$$

Moment: Reaction for 24" Tests

$$MR_{24} := 6 \text{ in}$$

Interpolated Characteristic Value

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

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	$\Phi R_n := \Phi_c \cdot C_m \cdot R_n = 10.782 \cdot \text{kip}$	

Rating Factor

$$RF_{op1} := \frac{\Phi R_n - R_{u_DL_only}}{(R_u - R_{u_DL_only})} = 3.931$$

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

$$DL_Press := cover \cdot \rho \cdot \gamma_e = 7.066 \cdot \text{psi}$$

RISA Input Dead Load Distributed Load

$$RISA_DL := DL_Press \cdot 9.75 \text{ in} = 0.827 \cdot \frac{\text{kip}}{\text{ft}}$$

Reaction Due to Dead Load only

$$R_{u_DL_only} := RISA_DL \cdot sp \cdot \frac{118}{104} = 4.636 \cdot \text{kip}$$

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

Live Load:

Maximum Wheel Load

$$P := 8.5 \text{ kip}$$

Multiple Presence Factor

$$MPF := 1.2$$

Wheel Distribution Along Arch

$$W1 := 10 \text{ in} + cover \cdot 1.15 = 7.254 \cdot \text{ft}$$

Wheel Distribution Across Arch

$$W2 := 20 \text{ in} + cover \cdot 1.15 = 8.087 \cdot \text{ft}$$

Load Patch Area

$$Load_Patch := W1 \cdot W2 = 58.668 \cdot \text{ft}^2$$

Impact Factor

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

Factored Wheel Load

$$P_u := P \cdot \gamma_{LL} \cdot MPF \cdot IM = 15.143 \cdot \text{kip}$$

Factored Live Load Pressure

$$PRL_u := \frac{P_u}{Load_Patch} = 1.792 \cdot \text{psi}$$

Factored Live Load Distributed Load

$$w_L := PRL_u \cdot 9.75 \text{ in} = 0.210 \cdot \frac{\text{kip}}{\text{ft}} \quad \text{per wheel}$$

RISA Analysis:

Reaction from RISA

$$R_u := 7.376 \text{ kip}$$

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

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

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

$$RF_{op2} := \frac{\Phi R_n - R_{u_DL_only}}{(R_u - R_{u_DL_only})} = 2.909$$

Summary Load Rating Factors for Deck

Operating Rating Factor

$$RF_{op} := \min(RF_{op1}, RF_{op2}) = 2.909$$