STRUCTURAL CALCULATIONS

for

SOUTH RIVER ROAD OVER ALBEE BROOK
BRIDGE NO. C-05-027 (0ET)
CHARLEMONT, MASSACHUSETTS

Prepared for:

TOWN OF CHARLEMONT

STRUCTURAL CALCULATIONS
NOVEMBER 2024

Prepared by:

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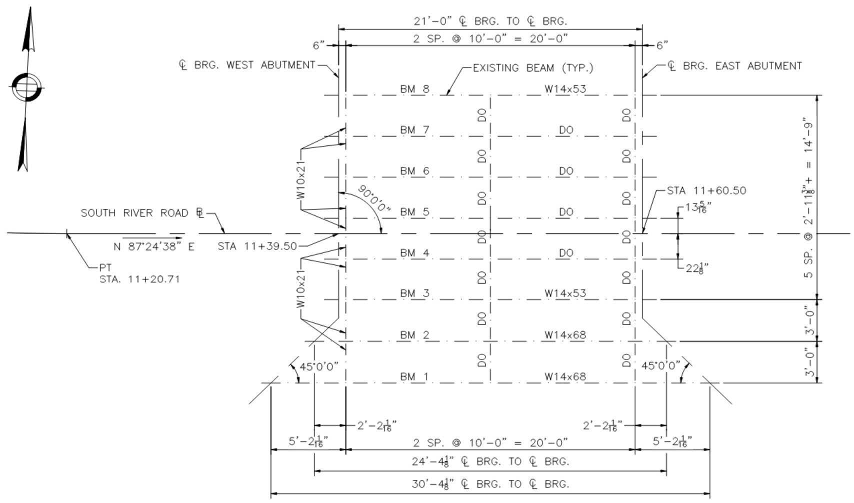
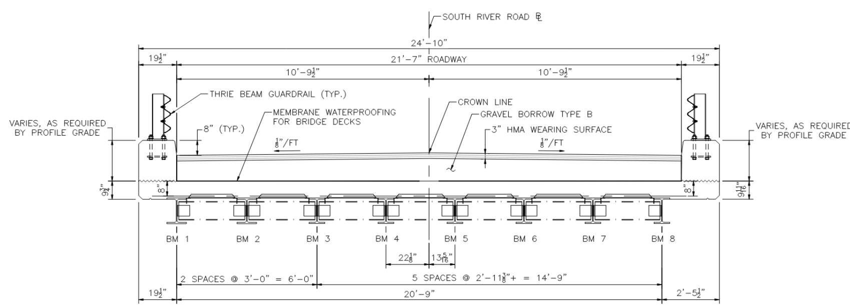
INDEX TO CALCULATIONS

Plans

Load Rating - Plans C-05-027



FRAMING PLAN
SCALE: ¼" = 1'-0"



PROPOSED CROSS SECTION
SCALE: ½" = 1'-0"

NOTE:
SECTIONS TAKEN LOOKING WEST.

General Information

Load Rating - General Information C-05-027

References:
1) AASHTO Standard Specifications, 17th Edition, 2002
2) MassDOT Bridge Manual 2024
3) 1995 Mass Highway Bridge Manual
4) AISC Steel Construction Manual, 15th Edition, 2017
5) AASHTO LRFD Bridge Design, 9th Edition, 2020 with 2021 Errata
6) AASHTO Manual for Bridge Evaluation, 3rd Edition, 2018 thru 2022 Interim

Bridge Geometry

Beam 1 Span =	30.34 ft	
Beam 2 Span =	24.34 ft	
Beams 3-8 Span =	21.0 ft	
Beam 1-2 Shape =	W14x68	
Beam 3-8 Shape =	W14x53	
W14x68 t_f =	0.060 ft =	0.720 in
W14x53 t_f =	0.055 ft =	0.660 in
W14x68 w_{tf} =	10.00 in	
W14x53 w_{tf} =	8.06 in	
W14x68 t_w =	0.415 in	
W14x53 t_w =	0.370 in	
W14x68 A =	20.0 in²	
W14x53 A =	15.6 in²	

No. of Beams =	8
Beam 1-2 Spacing =	3.00 ft
Beam 3 Spacing =	2.97 ft
Beam 4-8 Spacing =	2.95 ft
Beam 1 Overhang =	1.63 ft
Beam 8 Overhang =	2.46 ft
Beam 1 Overhang Thickness=	0.813 ft
Beam 8 Overhang Thickness=	0.807 ft
Add'l. Deck Depth at Overhang =	0.083 ft

Load Rating - General Information C-05-027

Roadway Width =	21.6 ft
Safety Curb Width =	1.63 ft
Wearing Surface Depth =	0.250 ft
Deck Thickness =	0.667 ft
Haunch Height =	1.00 in
Diaphragm Shape =	W10x21
Diaphragm Cut Length =	0.042 ft

*Assuming Diaphragms are cut 0.5" before reaching beam web allowing space for connection

Railing Type =	Thrie Beam Guardrail
No. of Rail Posts South =	6
Railing Length South =	31.3 ft
Post Height =	2.00 ft

Curb Width =	1.63 ft
Height of Curb above WS =	0.667 ft
West Crown Depth =	1.15 ft
West Curb Depth =	1.03 ft
East Crown Depth =	1.02 ft
East Curb Depth =	0.91 ft
WS Depth =	0.250 ft

Beam 1 d_e = -0.017 ft = 1.63 ft - 1.63 ft - 0.017 ft

Beam 8 d_e = 0.818 ft = 2.46 ft - 1.63 ft - 0.015 ft

Load Rating - General Information C-05-027

Material Properties

Unit Weights

Concrete =	0.150 kcf	(1) 3.3.6
Wearing Surface =	0.150 kcf	(1) 3.3.6
Gravel Borrow =	0.120 kcf	(1) 3.3.6
Steel =	0.490 kcf	(1) 3.3.6

Steel Member Weights

W14x53 =	0.053 klf	(4) 1-25
W14x68 =	0.068 klf	(4) 1-25
W10x21 =	0.021 klf	

Material Properties

$f'_{c,deck}$ =	5.00 ksi	(6) 6B.5.2.1-1
n =	6.76	
E_B =	29,000 ksi	(5) 6.4.1
E_D =	4291 ksi	(5) C5.4.2.4-2
$F_{y,1960\ steel}$ =	33 ksi	(6) 6B.5.2.1-1

Dead Loads

Load Rating - Dead Loads C-05-027

References:
1) AASHTO Standard Specifications, 17th Edition, 2002
2) MassDOT Bridge Manual 2024
3) 1995 Mass Highway Bridge Manual
4) AISC Steel Construction Manual, 15th Edition, 2017
5) AASHTO LRFD Bridge Design, 9th Edition, 2020 with 2021 Errata

Narrative:
Calculate proposed dead loads. Dead loads distributed per (2) 3.5.3 and 3.5.4.

Summary:

Beam	DC1	DC2	DW	BRR DC1
1	0.429 klf	0.573 klf	0.101 klf	0.048 klf
2	0.384 klf	0.452 klf	0.101 klf	0.016 klf
3	0.365 klf	0.452 klf	0.101 klf	0.015 klf
4	0.363 klf	0.452 klf	0.101 klf	0.015 klf
5	0.363 klf	0.452 klf	0.101 klf	0.015 klf
6	0.363 klf	0.452 klf	0.101 klf	0.015 klf
7	0.363 klf	0.452 klf	0.101 klf	0.015 klf
8	0.511 klf	0.583 klf	0.101 klf	0.064 klf

Bridge Geometry

No. of Beams = 8
Beam 1-3 Spacing = 3.00 ft
Beam 3-8 Spacing = 2.95 ft

Beam 1 Span = 30.3 ft
Beam 2 Span = 24.3 ft
Beams 3-8 Span = 21.0 ft

Beam 1 Trib. Width = 3.13 ft = 1.63 ft + 1.50 ft
Beam 2 Trib. Width = 3.00 ft = 3.00 ft
Beam 3 Trib. Width = 2.97 ft = 1.50 ft + 1.47 ft
Beam 4-7 Trib. Width = 2.95 ft = 2.95 ft
Beam 8 Trib. Width = 3.93 ft = 1.47 ft + 2.46 ft

Load Rating - Dead Loads C-05-027

Calculate DC1 (Non-Composite DL) Loads

Concrete Deck

Unit Weight = 0.150 kcf
Depth = 0.667 ft
Load = 0.100 ksf

Haunch

Beam 1

Unit Weight =	0.150 kcf			
W14x68 w_{tf} =	10.00 in			
Haunch Width =	11.00 in		*assuming add an inch on inside	
Haunch Height =	1.00 in		to account for haunch shape	
Haunch Area =	0.076 ft² =	(11.00 in x	1.00 in)/	144
Load =	0.011 klf =	0.076 ft² x	0.150 kcf	

Beam 8

Unit Weight =	0.150 kcf			
W14x53 w_{tf} =	8.06 in			
Haunch Width =	9.06 in		*assuming add an inch on inside	
Haunch Height =	1.00 in		to account for haunch shape	
Haunch Area =	0.063 ft² =	(9.06 in x	1.00 in)/	144
Load =	0.009 klf =	0.063 ft² x	0.150 kcf	

Beam 2

Unit Weight =	0.150 kcf			
W14x68 w_{tf} =	10.00 in			
Haunch Width =	12.00 in		*assuming add an inch on each side	
Haunch Height =	1.00 in		to account for haunch shape	
Haunch Area =	0.083 ft² =	(12.00 in x	1.00 in)/	144
Load =	0.013 klf =	0.083 ft² x	0.150 kcf	

Beam 3-7

Unit Weight =	0.150 kcf			
W14x53 w_{tf} =	8.06 in			
Haunch Width =	10.06 in		*assuming add an inch on each side	
Haunch Height =	1.00 in		to account for haunch shape	
Haunch Area =	0.070 ft² =	(10.06 in x	1.00 in)/	144
Load =	0.010 klf =	0.070 ft² x	0.150 kcf	

Load Rating - Dead Loads C-05-027

Overhang

Beam 1

Overhang Length =	1.63 ft				
Depth of Addt. Conc. =	0.146 ft =	0.813 ft -	0.667 ft		
Unit Weight =	0.150 kcf				
Load =	0.036 klf				

Beam 8

Overhang Length =	2.46 ft				
Depth of Addt. Conc. =	0.141 ft =	0.807 ft -	0.667 ft		
Unit Weight =	0.150 kcf				
Load =	0.052 klf				

Girder Self Weight

Beam 1-2 =	0.068 klf
Beam 3-8 =	0.053 klf

Diaphragm Self Weight

W10x21 =	0.021 klf				
Cut Length Int. Beams =	0.083 ft =	2 x	0.042 ft		
Cut Length Ext. Beams =	0.042 ft				
Beam 1 Diaphragm Length =	1.46 ft =	3.13 ft -	1.63 ft -	0.042 ft	
Beam 2 Diaphragm Length =	2.92 ft =	3.00 ft -	0.083 ft		
Beam 3 Diaphragm Length =	2.89 ft =	2.97 ft -	0.083 ft		
Beam 4-7 Diaphragm Length =	2.86 ft =	2.95 ft -	0.083 ft		
Beam 8 Diaphragm Length =	1.43 ft =	3.93 ft -	2.46 ft -	0.042 ft	
No. of Diaphragms =	3				
Beam 1 Diaphragm Load =	0.031 k =	1.46 ft x	0.021 klf		
Beam 2 Diaphragm Load =	0.061 k =	2.92 ft x	0.021 klf		
Beam 3 Diaphragm Load =	0.061 k =	2.89 ft x	0.021 klf		
Beam 4-7 Diaphragm Load =	0.060 k =	2.86 ft x	0.021 klf		
Beam 8 Diaphragm Load =	0.030 k =	1.43 ft x	0.021 klf		
Angles Qty. =	4.00				
L6x4x3/8 Weight =	12.30 plf				
Angle Length =	0.500 ft				
Angle Weight =	0.025 k =	0.50 ft x	12.30 plf x	4.00/	1,000

Load Rating - Dead Loads C-05-027

*Add 5% to total weight for connections exterior diaphragms only have 2 angles

Beam 1 Diaphragm Tot.Load =	0.045 k =	(0.031 k +	0.012 k) x	1.050
Beam 2 Diaphragm Tot Load =	0.090 k =	(0.061 k +	0.025 k) x	1.050
Beam 3 Diaphragm Tot. Load =	0.090 k =	(0.061 k +	0.025 k) x	1.050
Beam 4-7 Diaphragm Tot. Load =	0.089 k =	(0.060 k +	0.025 k) x	1.050
Beam 8 Diaphragm Tot. Load =	0.044 k =	(0.030 k +	0.012 k) x	1.050

Table showing breakdown of each beams DC1 loading. Load units in klf

Beam #	1	2	3	4
Trib Width	3.13 ft	3.00 ft	2.97 ft	2.95 ft
Span Length	30.3 ft	24.3 ft	21.0 ft	21.0 ft
Deck	0.313 klf	0.300 klf	0.297 klf	0.295 klf
Haunch	0.011 klf	0.013 klf	0.010 klf	0.010 klf
Overhang	0.036 klf	n/a	n/a	n/a
Girder Weight	0.068 klf	0.068 klf	0.053 klf	0.053 klf
Diaphragm Weight	0.001 klf	0.004 klf	0.004 klf	0.004 klf
DC1 =	0.429 klf	0.384 klf	0.365 klf	0.363 klf

Beam #	5	6	7	8
Trib Width	2.95 ft	2.95 ft	2.95 ft	3.93 ft
Span Length	21.0 ft	21.0 ft	21.0 ft	21.0 ft
Deck	0.295 klf	0.295 klf	0.295 klf	0.393 klf
Haunch	0.010 klf	0.010 klf	0.010 klf	0.010 klf
Overhang	n/a	n/a	n/a	0.052 klf
Girder Weight	0.053 klf	0.053 klf	0.053 klf	0.053 klf
Diaphragm Weight	0.004 klf	0.004 klf	0.004 klf	0.002 klf
DC1 =	0.363 klf	0.363 klf	0.363 klf	0.511 klf

Calculate DC2 (Superimposed Load) Loads

Railing

Railing =	Thrie Beam Guardrail			
No. of Rail Posts South =	6.00			
Railing Length South =	31.3 ft			
Post Height =	2.00 ft			
Post Unit Weight =	0.015 klf			
Total Post Weight =	0.180 k =	0.015 klf x	2.00 ft x	6.00
Post Linear Weight =	0.006 klf =	0.180 k/	31.3 ft	
Thrie Beam Weight =	0.011 klf			
Railing Weight =	0.017 klf =	0.011 klf +	0.006	
15% Additional Weight for Connection =	0.003 klf =	0.017 klf x	0.150	
Total Railing Weight =	0.019 klf =	0.003 klf +	0.017 klf	

Safety Curb

Safety Curb assumed to be rectangle with dimensions using the average height of the curb through the span

Avg. Gravel Depth at Curb =	0.97 ft =	(1.03 ft +	0.91 ft)/	2.00
Avg. Curb Height =	1.89 ft =	0.67 ft +	0.25 ft +	0.97 ft
Unit Weight =	0.150 kcf			
Curb Width =	1.63 ft			
Load =	0.460 klf =	1.89 ft x	1.63 ft x	0.150 kcf

Gravel Borrow Type B

No. of Beams =	8			
Unit Weight =	0.120 kcf			
West Crown Depth =	1.15 ft			
West Curb Depth =	1.03 ft			
East Crown Depth =	1.02 ft			
East Curb Deth =	0.91 ft			
Avg. Crown Depth =	1.08 ft =	(1.15 ft +	1.02 ft)/	2.00
Avg. Curb Depth =	0.97 ft =	(1.03 ft +	0.91 ft)/	2.00
Avg. Depth =	1.03 ft =	1.08 ft +	0.97 ft/	2.00
Rdwy Width =	21.6 ft			
Gravel Load =	2.66 klf =	1.03 ft x	21.6 ft x	0.120 kcf

*Interior beams have load from both railings and curbs

Beam #	Railing Load	Curb Load	Gravel Load	Total DC2 Load
Beam 1	0.019 klf	0.460 klf	2.66 klf	3.140 klf
Beam 2	0.039 klf	0.920 klf	2.66 klf	3.619 klf
Beam 3	0.039 klf	0.920 klf	2.66 klf	3.619 klf
Beam 4-7	0.039 klf	0.920 klf	2.66 klf	3.619 klf
Beam 8	0.019 klf	0.460 klf	2.66 klf	3.140 klf

Load Rating - Dead Loads C-05-027

Calculate and Distribute DW Loads

Wearing Surface

No. of Beams = 8
WS Unit Wt. = 0.150 kcf

Rdwy Width = 21.6 ft
WS Depth = 0.250 ft

WS Load = 0.101 klf = 0.150 kcf x 21.58 ft x 0.25 ft x 0.125

DW Load = 0.101 klf

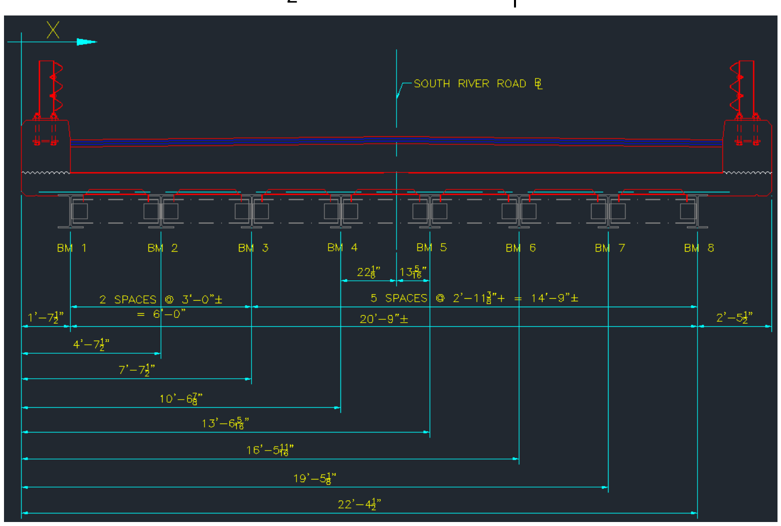
Distribute DC2 Loads

Per (2) distribute DC2 loads to beams using the pile cap method to exterior stems.
DC2 loads shall be distributed to interior stems equally.
Stems will be treated as individual beams, where their sums will equal the load applied to the NEXTD beams for design.

$$CG = \frac{\Sigma xA}{\Sigma A}$$

x= horizontal distance from left edge of bridge deck
A= Area of girder section

Beam	x	A	x*A
Beam 1	1.625	1.000	1.625
Beam 2	4.625	1.000	4.625
Beam 3	7.625	1.000	7.625
Beam 4	10.575	1.000	10.58
Beam 5	13.525	1.000	13.53
Beam 6	16.475	1.000	16.48
Beam 7	19.425	1.000	19.43
Beam 8	22.375	1.000	22.38
	∑ =	8.000	96.250



CG = 12.03 ft *from the left edge of bridge deck

$$\frac{1}{N_b} + \frac{X_{ext}\sum e}{\sum x^2}$$

N_b = number of beams
e = eccentricity of load from C.G.
x = horizontal distance from C.G. of pattern of beams to each beam
X_{ext} = horizontal dist from C.G. of pattern of beams to exterior beam

CG =	12.03 ft	*from the left edge of bridge deck
Beam 1 Overhang =	1.63 ft	
Beam 8 Overhang =	2.46 ft	
Out to Out Dist.	24.83 ft	
x_{Beam1} =	10.41 ft	(CL Beam 1 to CG Beam Group)
x_{Beam2} =	7.41 ft	(CL Beam 2 to CG Beam Group)
x_{Beam3} =	4.41 ft	(CL Beam 3 to CG Beam Group)
x_{Beam4} =	1.46 ft	(CL Beam 4 to CG Beam Group)
x_{Beam5} =	-1.49 ft	(CL Beam 5 to CG Beam Group)
x_{Beam6} =	-4.44 ft	(CL Beam 6 to CG Beam Group)
x_{Beam7} =	-7.39 ft	(CL Beam 7 to CG Beam Group)
x_{Beam8} =	-10.34 ft	(CL Beam 8 to CG Beam Group)

Load Rating - Dead Loads C-05-027

x^2_{Beam1} =	108.29	x_{Beam1} =	10.41
x^2_{Beam2} =	54.85	x_{Beam2} =	7.41
x^2_{Beam3} =	19.42	x_{Beam3} =	4.41
x^2_{Beam4} =	2.12	x_{Beam4} =	1.46
x^2_{Beam5} =	2.23	x_{Beam5} =	-1.49
x^2_{Beam6} =	19.75	x_{Beam6} =	-4.44
x^2_{Beam7} =	54.67	x_{Beam7} =	-7.39
x^2_{Beam8} =	106.99	x_{Beam8} =	-10.34
$\sum x^2$ =	368.32		

$x_{Beam1} / \sum x^2$ = 0.0283
$x_{Beam8} / \sum x^2$ = 0.0281

South Railing e = 11.22 ft
North Railing e = 11.99 ft

*Assuming Railing CG @ Center of Curb

South Curb e = 11.22 ft
North Curb e = 11.99 ft

$$\frac{1}{N_b} + \frac{X_{ext}\sum e}{\sum x^2}$$

Gravel e = 0.385 ft

Beam 1 South Railing DF = 0.442
Beam 8 North Railing DF = 0.462
Beam 2-7 Railing DF = 0.125

Beam 1 South Curb DF = 0.442
Beam 8 North Curb DF = 0.462
Beam 2-7 Curb DF = 0.125

Beam 1 Gravel DF = 0.136
Beam 8 Gravel DF = 0.136
Beam 2-7 Gravel DF = 0.125

Beam #	Railing Load	DF	Factored DC2 Load
DC2 Beam 1	0.019 klf	0.442	0.009 klf
DC2 Beam 2-7	0.039 klf	0.125	0.005 klf
DC2 Beam 8	0.019 klf	0.462	0.009 klf

Beam #	Curb Load	DF	Factored DC2 Load
DC2 Beam 1	0.460 klf	0.442	0.203 klf
DC2 Beam 2-7	0.920 klf	0.125	0.115 klf
DC2 Beam 8	0.460 klf	0.462	0.212 klf

Beam #	Gravel Load	DF	Factored DC2 Load
DC2 Beam 1	2.660 klf	0.136	0.361 klf
DC2 Beam 2-7	2.660 klf	0.125	0.333 klf
DC2 Beam 8	2.660 klf	0.136	0.361 klf

Live Load Distribution Factors

Load Rating - Live Load Distribution Factors C-05-027

References:
1) AASHTO Standard Specifications, 17th Edition, 2002
2) MassDOT Bridge Manual 2024
3) 1995 Mass Highway Bridge Manual
4) AISC Steel Construction Manual, 15th Edition, 2017
5) AASHTO LRFD Bridge Design, 9th Edition, 2020 with 2021 Errata

Narrative:
Calculate live load distribution factors per (2) and (5) Section 3.5.4.

Summary:

Beam	LLDF M	LLDF V	LLDF M FAT.	LLDF V FAT.	LLDF DEFLECTION
1	0.333	0.333	0.278	0.278	0.250
2	0.346	0.480	0.248	0.400	0.250
3	0.349	0.479	0.253	0.399	0.250
4	0.347	0.478	0.252	0.398	0.250
5	0.347	0.478	0.252	0.398	0.250
6	0.347	0.478	0.252	0.398	0.250
7	0.347	0.478	0.252	0.398	0.250
8	0.365	0.365	0.304	0.304	0.250

Geometry:

Spacing, S Beam 1-2 = 3.00 ft
Spacing, S Beam 3 = 2.97 ft
Spacing, S Beam 4-8 = 2.95 ft
t_s = 0.67 ft
Span Length, L Beam 1 = 30.3 ft
Span Length, L Beam 2 = 24.3 ft
Span Length, L Beam 3-8 = 21.0 ft
N_b = 8

Roadway Width = 21.6 ft
Number of Lanes = 1

Load Rating - Live Load Distribution Factors C-05-027

Beam Geometry:

Beam 1-2 Type =	W14x68	
Beam 1-2 A =	20.0	in^2
Beam 1-2 Depth =	14.0	in
Beam 1-2 Y_t =	7.00	in
Beam 1-2 I_x =	722	in^4
Beam 3-8 Type =	W14x53	
Beam 3-8 A =	15.6	in^2
Beam 3-8 Depth =	13.9	in
Beam 3-8 Y_t =	6.95	in
Beam 3-8 I_x =	541	in^4

Calculate K_g:

Beam 1-2 e_g =	11.0 in	(8.00 in x	0.5) +	7.00 in
Beam 3 e_g =	11.0 in	(8.00 in x	0.5) +	6.95 in
Beam 4-8 e_g =	11.0 in	(8.00 in x	0.5) +	6.95 in
n =	6.76	29000 ksi/	4291 ksi	(5) 4.6.2.2.1-2
Beam 1-2 K_g =	21,234 in^4			(5) 4.6.2.2.1-1
Beam 3-8 K_g =	16,297 in^4			(5) 4.6.2.2.1-1

Load Rating - Live Load Distribution Factors C-05-027

Moment for Interior Beams:

Per (2) - Section 3.5.3.8&9, Distribution of live load to interior beams shall be calculated using (5) - Section 4.6.2.2.2

Applicability

$3.5 \leq S \leq 16.0$
$4.5 \leq t_s \leq 12.0$
$20 \leq L \leq 240$
$N_b \geq 4$
$10{,}000 \leq K_g \leq 7{,}000{,}000$

(5) Table 4.6.2.2.2b-1

	Beam 2	Beam 2 Check
S =	3.00 ft	NO GOOD
t_s =	8.00 in	OKAY
L =	24.34 ft	OKAY
N_b =	8	OKAY
K_g =	21,234 in⁴	OKAY

	Beam 3	Beam 3-7 Check
S =	2.97 ft	NO GOOD
t_s =	8.00 in	OKAY
L =	21.0 ft	OKAY
N_b =	8	OKAY
K_g =	16,297 in⁴	OKAY

	Beam 4-7	Beam 3-7 Check
S =	2.95 ft	NO GOOD
t_s =	8.00 in	OKAY
L =	21.0 ft	OKAY
N_b =	8	OKAY
K_g =	16,297 in⁴	OKAY

The existing beam spacing is below the minimum beam spacing specified in the Range of Applicability for live load distribution factors (LLDFs) for shear and moment of interior beams, as given in Tables 4.6.2.2.2b-1 and 4.6.2.2.3a-1. Consequently, an alternate analysis is performed further on by theoretically increasing the beam spacing to the minimum value specified in these tables. By demonstrating that the beams are adequate at this larger spacing, which falls within the range of applicability, it is shown that they will be adequate for the actual smaller spacing. This is because the distribution factors would be lower in the real conditions at the smaller spacing. The interior beams were checked to rate above statutory with the alternate distribution factors. The results presented use the distribution factors from the actual beam spacing.

Load Rating - Live Load Distribution Factors C-05-027

(4) Table 4.6.2.2.2b-1

Concrete Deck or Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-Beams, T- and Double T-Sections	a, e, k and also i, j if sufficiently connected to act as a unit	One Design Lane Loaded: $0.06+\left(\frac{S}{14}\right)^{0.4}\left(\frac{S}{L}\right)^{0.3}\left(\frac{K_g}{12.0Lt_s^3}\right)^{0.1}$ Two or More Design Lanes Loaded: $0.075+\left(\frac{S}{9.5}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}\left(\frac{K_g}{12.0Lt_s^3}\right)^{0.1}$	$3.5 \le S \le 16.0$ $4.5 \le t_s \le 12.0$ $20 \le L \le 240$ $N_b \ge 4$ $10{,}000 \le K_g \le 7{,}000{,}000$
		use lesser of the values obtained from the equation above with $N_b = 3$ or the lever rule	$N_b = 3$

Beam 2

One Lane Loaded

$$DF_{Mom.Beam2} = 0.297 \qquad 0.06 + \left(\frac{3.00\text{ ft}}{14}\right)^{0.4}\left(\frac{3.00\text{ ft}}{24.34\text{ ft}}\right)^{0.3} \times \left(\frac{21{,}234\text{ in}^4}{12.0 \times 24.34\text{ ft} \times (8.00\text{ in})^3}\right)^{0.1}$$

Two or More Lanes Loaded

$$DF_{Mom.Beam2} = 0.346 \qquad 0.075 + \left(\frac{3.00\text{ ft}}{9.5}\right)^{0.6}\left(\frac{3.00\text{ ft}}{24.34\text{ ft}}\right)^{0.2} \times \left(\frac{21{,}234\text{ in}^4}{12.0 \times 24.34\text{ ft} \times (8.00\text{ in})^3}\right)^{0.}$$

One Lane Loaded

$DF_{Mom.Beam2} =$ 0.297

Two or More Lanes Loaded

$DF_{Mom.Beam2} =$ 0.346

Critical Factor

$DF_{Mom.Beam2} =$ 0.346

Beam 3

One Lane Loaded

$$DF_{Mom.Beam3} = 0.303 = 0.06 + \left(\frac{2.97\text{ ft}}{14}\right)^{0.4}\left(\frac{2.97\text{ ft}}{21.00\text{ ft}}\right)^{0.3} \times \left(\frac{16{,}297\text{ in}^4}{12.0 \times 21.00\text{ ft} \times (8.00\text{ in})^3}\right)^{0.1}$$

Two or More Lanes Loaded

$$DF_{Mom.Beam3} = 0.349 = 0.075 + \left(\frac{2.97\text{ ft}}{9.5}\right)^{0.6}\left(\frac{2.97\text{ ft}}{21.00\text{ ft}}\right)^{0.2} \times \left(\frac{16{,}297\text{ in}^4}{12.0 \times 21.00\text{ ft} \times (8.00\text{ in})^3}\right)^{0.1}$$

One Lane Loaded

$DF_{Mom.Beam3} =$ 0.303

Two or More Lanes Loaded

$DF_{Mom.Beam3} =$ 0.349

Critical Factor

$DF_{Mom.Beam3} =$ **0.349**

Beam 4-7

One Lane Loaded

$$DF_{Mom.Beam4\text{-}7} = 0.302 = 0.06 + \left(\frac{2.95\text{ ft}}{14}\right)^{0.4}\left(\frac{2.95\text{ ft}}{21.00\text{ ft}}\right)^{0.3} \times \left(\frac{16{,}297\text{ in}^4}{12.0 \times 21.00\text{ ft} \times (8.00\text{ in})^3}\right)^{0.1}$$

Two or More Lanes Loaded

$$DF_{Mom.Beam4\text{-}7} = 0.347 = 0.075 + \left(\frac{2.95\text{ ft}}{9.5}\right)^{0.6}\left(\frac{2.95\text{ ft}}{21.00\text{ ft}}\right)^{0.2} \times \left(\frac{16{,}297\text{ in}^4}{12.0 \times 21.00\text{ ft} \times (8.00\text{ in})^3}\right)^{0.1}$$

One Lane Loaded

$DF_{Mom.Beam4\text{-}7} =$ 0.302

Two or More Lanes Loaded

$DF_{Mom.Beam4\text{-}7} =$ 0.347

Critical Factor

$DF_{Mom.Beam4\text{-}7} =$ **0.347**

Load Rating - Live Load Distribution Factors C-05-027

Shear for Interior Beams:

Per (2) - Section 3.5.3.8&9, Distribution of live load to interior beams shall be calculated using (5) - Section 4.6.2.2.2

Applicability (5) Table 4.6.2.2.3a-1

$$3.5 \le S \le 16.0$$
$$20 \le L \le 240$$
$$4.5 \le t_s \le 12.0$$
$$N_b \ge 4$$

	Beam 2	Beam 2 Check
S =	3.00 ft	NO GOOD
t_s =	8.00 ft	OKAY
L =	24.34 ft	OKAY
N_b =	8.00 ft	OKAY

	Beam 3	Beam 3-7 Check
S =	2.97 ft	NO GOOD
t_s =	8.00 ft	OKAY
L =	21.00 ft	OKAY
N_b =	8.00 ft	OKAY

	Beam 3-7	Beam 3-7 Check
S =	2.95 ft	NO GOOD
t_s =	8.00 ft	OKAY
L =	21.00 ft	OKAY
N_b =	8.00 ft	OKAY

(5) Table 4.6.2.2.3a-1

Concrete Deck or Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-Beams, T- and Double T-Sections	a, e, k and also i, j if sufficiently connected to act as a unit	$0.36+\frac{S}{25.0}$	$0.2+\frac{S}{12}-\left(\frac{S}{35}\right)^{2.0}$	$3.5 \le S \le 16.0$ $20 \le L \le 240$ $4.5 \le t_s \le 12.0$ $N_b \ge 4$
		Lever Rule	Lever Rule	$N_b = 3$

Beam 2

One Lane Loaded

$DF_{Shear,Beam2} = 0.480 \quad 0.36 + \left(\frac{3.00\ ft}{25}\right)$

Two or More Lanes Loaded

$DF_{Shear,Beam2} = 0.443 \quad 0.2 + \left(\frac{3.00\ ft}{12}\right) - \left(\frac{3.00\ ft}{35}\right)^{2.0}$

One Lane Loaded

$DF_{Shear,Beam2} = 0.480$

Two or More Lanes Loaded

$DF_{Shear,Beam2} = 0.443$

Critical Factor

$DF_{Shear,Beam2} = $ **0.480**

Beam 3

One Lane Loaded

$DF_{Shear,Beam3} = 0.479 \quad 0.36 + \left(\frac{2.97\ ft}{25}\right)$

Two or More Lanes Loaded

$DF_{Shear,Beam3} = 0.441 \quad 0.2 + \left(\frac{2.97\ ft}{12}\right) - \left(\frac{2.97\ ft}{35}\right)^{2.0}$

One Lane Loaded

$DF_{Shear,Beam3} = 0.479$

Two or More Lanes Loaded

$DF_{Shear,Beam3} = 0.441$

Critical Factor

$DF_{Shear,Beam3} = $ **0.479**

Beam 4-7

One Lane Loaded

$DF_{Shear,Beam4\text{-}7}$ = 0.478 $0.36 + \left(\frac{2.95\ ft}{25}\right)$

Two or More Lanes Loaded

$DF_{Shear,Beam4\text{-}7}$ = 0.439 $0.2 + \left(\frac{2.95\ ft}{12}\right) - \left(\frac{2.95\ ft}{35}\right)^{2.0}$

One Lane Loaded

$DF_{Shear,Beam4\text{-}7}$ = 0.478

Two or More Lanes Loaded

$DF_{Shear,Beam4\text{-}7}$ = 0.439

Critical Factor

$DF_{Shear,Beam4\text{-}7}$ = 0.478

Moment for Exterior Beams:

Per (2) - Section 3.5.3.10, Distribution of live load to exterior beams under safety curb or barrier shall be calculated using (4) - Section 4.6.2.2.2

Per (4) - Section 4.6.2.2.2d - Exterior beam distribution factors shall be taken as the larger of those calculated using Table 4.6.2.2.2d-1, or the pile cap analogy as outlined in C4.6.2.2.2d

Applicability

$$-1.0 \le d_e \le 5.5$$

Beam 1 d_e =	-0.017 ft	OKAY
Beam 4 d_e =	0.818 ft	OKAY

(5) Table 4.6.2.2.2d-1

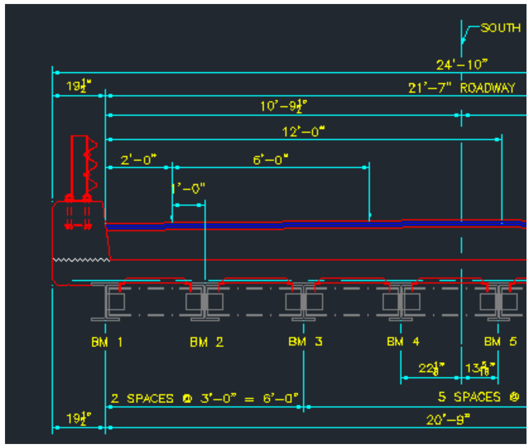
Concrete Deck or Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-Beams, T- and Double T-Sections	a, e, k and also i, j if sufficiently connected to act as a unit	Lever Rule	$g = e\ g_{interior}$ $e = 0.77 + \frac{d_e}{9.1}$	$-1.0 \le d_e \le 5.5$
			use lesser of the values obtained from the equation above with $N_b = 3$ or the lever rule	$N_b = 3$

Load Rating - Live Load Distribution Factors C-05-027

Beam 1

One Lane Loaded

Lever Rule



0.5

D1 = 2.00 ft
S = 3.00 ft

$DF_{Mom.Beam\,1}$ = 0.167 = (1 - (2.00 ft/ 3.00 ft)) x

Two or More Lanes Loaded

Beam 1 d_e = -0.017 ft
e = 0.768 ft = 0.77 + -(0.017 ft/ 9.1)
g,interior = 0.346
$DF_{Mom.Beam\,1}$ = 0.266 = 0.768 ft x 0.346

"Rigid Superstructure" Pile Cap Analogy

$$CG = \frac{\Sigma xA}{\Sigma A}$$

x= horizontal distance from left edge of bridge deck
A= Area of girder section

Beam	x	A	x*A
Beam 1	1.625	0.139	0.226
Beam 2	4.625	0.139	0.642
Beam 3	7.625	0.139	1.059
Beam 4	10.575	0.139	1.47
Beam 5	13.525	0.139	1.88
Beam 6	16.475	0.139	2.29
Beam 7	19.425	0.139	2.70
Beam 8	22.375	0.139	3.11
	∑ =	1.111	13.368

CG = 12.03 ft *from the left edge of bridge deck

Load Rating - Live Load Distribution Factors C-05-027

$$\frac{1}{N_b} + \frac{X_{ext} \sum e}{\sum x^2}$$

N_b = number of beams
e = eccentricity of load from C.G.
x = horizontal distance from C.G. of pattern of beams to each beam
X_{ext} = horizontal dist from C.G. of pattern of beams to exterior beam

CG =	12.03 ft	*from the left edge of bridge deck
Beam 1 Overhang =	1.63 ft	
Beam 8 Overhang =	2.46 ft	
Out to Out Dist.	24.83 ft	
x_{Beam1} =	10.41 ft	(CL Beam 1 to CG Beam Group)
x_{Beam2} =	7.41 ft	(CL Beam 2 to CG Beam Group)
x_{Beam3} =	4.41 ft	(CL Beam 3 to CG Beam Group)
x_{Beam4} =	1.46 ft	(CL Beam 4 to CG Beam Group)
x_{Beam5} =	-1.49 ft	(CL Beam 5 to CG Beam Group)
x_{Beam6} =	-4.44 ft	(CL Beam 6 to CG Beam Group)
x_{Beam7} =	-7.39 ft	(CL Beam 7 to CG Beam Group)
x_{Beam8} =	-10.34 ft	(CL Beam 8 to CG Beam Group)

x^2_{Beam1} =	108.29	x_{Beam1} =	10.41
x^2_{Beam2} =	54.85	x_{Beam2} =	7.41
x^2_{Beam3} =	19.42	x_{Beam3} =	4.41
x^2_{Beam4} =	2.12	x_{Beam4} =	1.46
x^2_{Beam5} =	2.23	x_{Beam5} =	-1.49
x^2_{Beam6} =	19.75	x_{Beam6} =	-4.44
x^2_{Beam7} =	54.67	x_{Beam7} =	-7.39
x^2_{Beam8} =	106.99	x_{Beam8} =	-10.34
$\sum x^2$ =	368.32		

$x_{Beam1} / \sum x^2 =$ 0.0283
$x_{Beam8} / \sum x^2 =$ 0.0281

$$R = \frac{N_L}{N_b} + \frac{X_{ext}\sum^{N_L} e}{\sum^{N_b} x^2}$$

e = Eccentricity of a design truck or a design lane load from the C.O.G. of the pattern of girders (ft)

x = Horizontal distance from the C.O.G. of the pattern of girders to each girder (ft)

N_L = Number of loaded lanes under consideration

X_{ext} = Horizontal distance from the C.O.G. of the pattern of girders to the exterior girder (ft)

e_1 = 5.41 ft = 10.41 ft - 2.00 ft - 3.00 ft

e_2 = -5.39 ft = 10.41 ft - 2.00 ft - 13.79 ft

R_1 = 0.278 = $\frac{1}{8}$ + (0.0283 x 5.41 ft)

R_2 = 0.251 = $\frac{2}{8}$ + (0.0283 x (5.41 ft +

One Lane Loaded (Lever Rule)
$DF_{Mom.Beam1}$ = 0.200 = 0.167 x 1.20
One Lane Loaded (Pile Cap)
$DF_{Mom.Beam1}$ = 0.333 = 0.278 x 1.20

Two or More Lanes Loaded (Formula)
$DF_{Mom.Beam1}$ = 0.266 0.266
Two or More Lanes Loaded (Pile Cap)
$DF_{Mom.Beam1}$ = 0.251 = 0.251 x 1.00

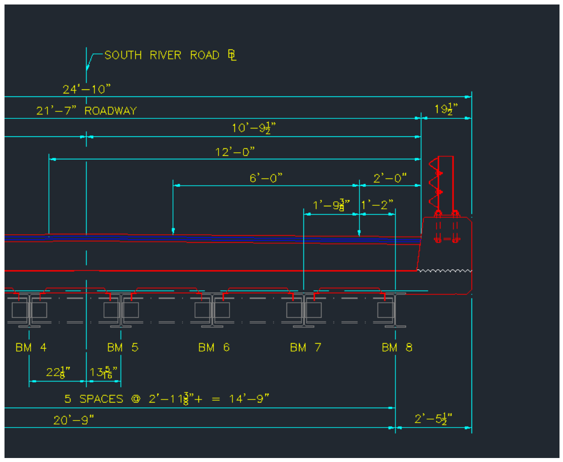
Critical Factor
$DF_{Mom.Beam1}$ = 0.333

Load Rating - Live Load Distribution Factors C-05-027

Beam 8

One Lane Loaded

Lever Rule



0.5

D1 = 1.17 ft
S = 2.95 ft

$DF_{Mom.Beam8}$ = 0.302 = (1 - (1.17 ft/ 2.95 ft)) x

Two or More Lanes Loaded

Beam 8 d_e = 0.818 ft
e = 0.860 ft = 0.77 + (0.818 ft/ 9.1)
g,interior = 0.347
$DF_{Mom.Beam8}$ = 0.298 = 0.860 ft x 0.347

Load Rating - Live Load Distribution Factors C-05-027

"Rigid Superstructure" Pile Cap Analogy

$$CG = \frac{\Sigma xA}{\Sigma A}$$

x= horizontal distance from left edge of bridge deck
A= Area of girder section

Beam	x	A	x*A
Beam 1	1.625	0.139	0.226
Beam 2	4.625	0.139	0.642
Beam 3	7.625	0.108	0.826
Beam 4	10.575	0.108	1.15
Beam 5	13.525	0.108	1.47
Beam 6	16.475	0.108	1.78
Beam 7	19.425	0.108	2.10
Beam 8	22.375	0.108	2.42
	∑ =	0.928	10.618

CG = 11.44 ft *from the left edge of bridge deck

$$R = \frac{N_L}{N_b} + \frac{X_{ext}\sum^{N_L} e}{\sum^{N_b} x^2}$$

N_b = number of beams
e = eccentricity of load from C.G.
x = horizontal distance from C.G. of pattern of beams to each beam
X_{ext} = horizontal dist from C.G. of pattern of beams to exterior beam

CG = 11.44 ft *from the left edge of bridge deck
Beam 1 Overhang = 1.63 ft
Beam 8 Overhang = 0.00 ft
Out to Out Dist. 24.83 ft

x_{Beam1} = 9.82 ft (CL Beam 1 to CG Beam Group)
x_{Beam2} = 7.41 ft (CL Beam 2 to CG Beam Group)
x_{Beam3} = 4.41 ft (CL Beam 3 to CG Beam Group)
x_{Beam4} = 1.46 ft (CL Beam 4 to CG Beam Group)
x_{Beam5} = -1.49 ft (CL Beam 5 to CG Beam Group)
x_{Beam6} = -4.44 ft (CL Beam 6 to CG Beam Group)
x_{Beam7} = -7.39 ft (CL Beam 7 to CG Beam Group)
x_{Beam8} = -10.34 ft (CL Beam 8 to CG Beam Group)

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Load Rating - Live Load Distribution Factors C-05-027

x^2_{Beam1} =	96.42	x_{Beam1} =	9.82
x^2_{Beam2} =	54.85	x_{Beam2} =	7.41
x^2_{Beam3} =	19.42	x_{Beam3} =	4.41
x^2_{Beam4} =	2.12	x_{Beam4} =	1.46
x^2_{Beam5} =	2.23	x_{Beam5} =	-1.49
x^2_{Beam6} =	19.75	x_{Beam6} =	-4.44
x^2_{Beam7} =	54.67	x_{Beam7} =	-7.39
x^2_{Beam8} =	106.99	x_{Beam8} =	-10.34
$\sum x^2$ =	356.45		

$x_{Beam1} / \sum x^2$ = 0.0275

$x_{Beam8} / \sum x^2$ = 0.0290

$$R = \frac{N_L}{N_b} + \frac{X_{ext}\sum^{N_L} e}{\sum^{N_b} x^2}$$

e = Eccentricity of a design truck or a design lane load from the C.O.G. of the pattern of girders (ft)

x = Horizontal distance from the C.O.G. of the pattern of girders to each girder (ft)

N_L = Number of loaded lanes under consideration

X_{ext} = Horizontal distance from the C.O.G. of the pattern of girders to the exterior girder (ft)

e_1 =	6.18 ft =	10.34 ft -	1.17 ft -	3.00 ft
e_2 =	-4.61 ft =	10.34 ft -	1.17 ft -	13.79 ft

R_1 = 0.304 = $\frac{1}{8}$ + (0.0290 x 6.18 ft)

R_2 = 0.295 = $\frac{2}{8}$ + (0.0290 x (6.18 ft + -4.61 ft))

One Lane Loaded (Lever Rule)

$DF_{Mom.Beam8}$ = 0.363 = 0.302 x 1.20

One Lane Loaded (Pile Cap)

$DF_{Mom.Beam8}$ = 0.365 = 0.304 x 1.20

Two or More Lanes Loaded (Formula)

$DF_{Mom.Beam8}$ = 0.298 = 0.298

Two or More Lanes Loaded (Pile Cap)

$DF_{Mom.Beam8}$ = 0.295 = 0.295 x 1.00

Critical Factor

$DF_{Mom.Beam8}$ = 0.365

Load Rating - Live Load Distribution Factors C-05-027

Shear for Exterior Beams:

Per (2) - Section 3.5.3.10, Distribution of live load to exterior beams under safety curb or barrier shall be calculated using (4) - Section 4.6.2.2.2

Applicability

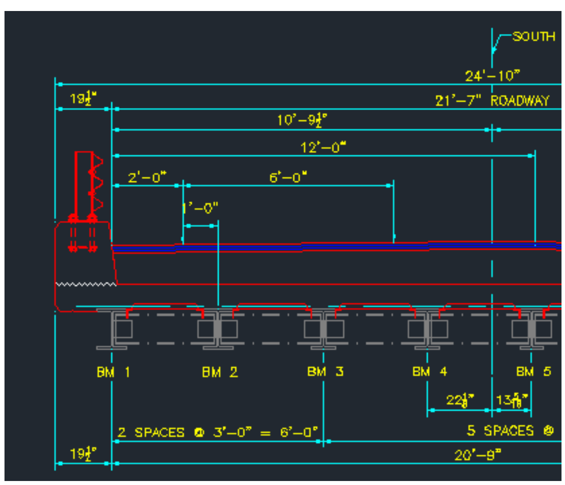
$$-1.0 \le d_e \le 5.5$$ (5) 4.6.2.2.3b-1

Beam 1 d_e =	-0.017 ft	OKAY
Beam 8 d_e =	0.818 ft	OKAY

Concrete Deck or Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-Beams, T- and Double T-Beams	a, e, k and also i, j if sufficiently connected to act as a unit	Lever Rule	$g = e\, g_{interior}$ $e = 0.6 + \frac{d_e}{10}$	$-1.0 \le d_e \le 5.5$
			Lever Rule	$N_b = 3$

Beam 1

One Lane Loaded



0.5

Load Rating - Live Load Distribution Factors C-05-027

Lever Rule

Beam 1 D=	2.00 ft				
Beam 1 S =	3.00 ft				
$DF_{Shear,Beam 1}$ =	0.167 =	(1 -	(2.00 ft/	3.00 ft)) x	

Two or More Lanes Loaded

Beam 1 d_e =	-0.017 =			
e =	0.598 =	0.60 +	-(0.017 ft/	10.0)
g,interior =	0.443			
$DF_{Shear,Beam 1}$ =	0.265 =	0.598 ft x	0.443	

One Lane Loaded (Lever Rule)

$DF_{Shear,Beam 1}$ = 0.200 = 0.167 x 1.20

One Lane Loaded (Pile Cap) *See Moment Calculation

$DF_{Shear,Beam 1}$ = 0.333 = 0.278 x 1.20

Two or More Lanes Loaded

$DF_{Shear,Beam 1}$ = 0.265 = 0.265

Two or More Lanes Loaded (Pile Cap) *See Moment Calculation

$DF_{Shear,Beam 1}$ = 0.251 = 0.251 x 1.00

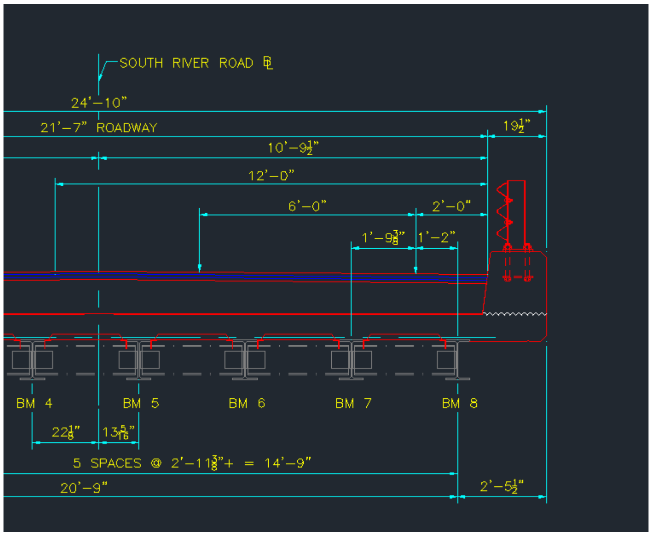
Critical Factor

$DF_{Shear,Beam 1}$ = 0.333

Load Rating - Live Load Distribution Factors C-05-027

Beam 8

One Lane Loaded



0.5

Lever Rule

Beam 1 D=	1.17 ft
Beam 1 S =	2.95 ft

$DF_{Shear,Beam8}$ = 0.302 = (1 - (1.17 ft/ 2.95 ft)) x

Load Rating - Live Load Distribution Factors C-05-027

Two or More Lanes Loaded

Beam 8 d_e =	0.818 =			
e =	0.682 =	0.60 +	(0.818 ft/	10.0)
g,interior =	0.439			
$DF_{Shear.Beam8}$ =	0.299 =	0.682 ft x	0.439	

One Lane Loaded (Lever Rule)

$DF_{Shear.Beam8}$ = 0.363 = 0.302 x 1.20

One Lane Loaded (Pile Cap) *See Moment Calculation

$DF_{Shear.Beam8}$ = 0.365 = 0.304 x 1.20

Two or More Lanes Loaded

$DF_{Shear.Beam8}$ = 0.299 = 0.299 x 1.00

Two or More Lanes Loaded (Pile Cap) *See Moment Calculation

$DF_{Shear.Beam8}$ = 0.295 = 0.295 x 1.00

Critical Factor

$DF_{Shear.Beam8}$ = 0.365

Deflection for All Beams

C2.5.2.6.2

These provisions permit, but do not encourage, the use of past practice for deflection control. Designers were permitted to exceed these limits at their discretion in the past. Calculated deflections of structures have often been found to be difficult to verify in the field due to numerous sources of stiffness not accounted for in calculations. Despite this, many Owners and designers have found comfort in the past requirements to limit the overall stiffness of bridges. The desire for continued availability of some guidance in this area, often stated during the development of these Specifications, has resulted in the retention of optional criteria, except for orthotropic decks, for which the criteria are required. Deflection criteria are also mandatory for lightweight decks comprised of metal and concrete, such as filled and partially filled grid decks, and unfilled grid decks composite with reinforced concrete slabs, as provided in Article 9.5.2.

Additional guidance regarding deflection of steel bridges can be found in Wright and Walker (1971).

Additional considerations and recommendations for deflection in timber bridge components are discussed in more detail in Chapters 7, 8, and 9 in Ritter (1990).

For a straight girder system bridge, this is equivalent to saying that the distribution factor for deflection is equal to the number of lanes divided by the number of beams.

g = 2
No. of Beams = 8

DF = 0.250 = 2/ 8

Alternate Live Load Distribution Factors

Load Rating - Alternate Live Load Distribution Factors C-05-027

References:
1) AASHTO Standard Specifications, 17th Edition, 2002
2) MassDOT Bridge Manual 2024
3) 1995 Mass Highway Bridge Manual
4) AISC Steel Construction Manual, 15th Edition, 2017
5) AASHTO LRFD Bridge Design, 9th Edition, 2020 with 2021 Errata

Narrative:
Calculate live load distribution factors per (2) and (5) Section 3.5.4.

Summary:

Beam	LLDF M	LLDF V	LLDF M FAT.	LLDF V FAT.	LLDF DEFLECTION
1	x	x	x	x	x
2	0.382	0.500	0.382	0.417	0.250
3	0.387	0.500	0.387	0.417	0.250
4	0.387	0.500	0.387	0.417	0.250
5	0.387	0.500	0.387	0.417	0.250
6	0.387	0.500	0.387	0.417	0.250
7	0.387	0.500	0.387	0.417	0.250
8	x	x	x	x	x

The existing beam spacing is below the minimum beam spacing specified in the Range of Applicability for live load distribution factors (LLDFs) for shear and moment of interior beams, as given in Tables 4.6.2.2.2b-1 and 4.6.2.2.3a-1. Consequently, an alternate analysis is performed by theoretically increasing the beam spacing to the minimum value specified in these tables. By demonstrating that the beams are adequate at this larger spacing, which falls within the range of applicability, it is shown that they will be adequate for the actual smaller spacing. This is because the distribution factors would be lower in the real conditions at the smaller spacing. The interior beams were checked to rate above statutory with the distribution factors. The results presented use the distribution factors from the actual beam spacing.

Geometry:

Spacing, S Beam =	3.50 ft
t_s =	0.67 ft
Span Length, L Beam 1 =	30.3 ft
Span Length, L Beam 2 =	24.3 ft
Span Length, L Beam 3-8 =	21.0 ft
N_b =	8
Roadway Width =	21.6 ft
Number of Lanes =	1

Load Rating - Alternate Live Load Distribution Factors — C-05-027

Beam Geometry:

Beam 1-2 Type =	W14x68
Beam 1-2 A =	20.0 in²
Beam 1-2 Depth =	14.0 in
Beam 1-2 Y_t =	7.00 in
Beam 1-2 I_x =	722 in⁴
Beam 3-8 Type =	W14x53
Beam 3-8 A =	15.6 in²
Beam 3-8 Depth =	13.9 in
Beam 3-8 Y_t =	6.95 in
Beam 3-8 I_x =	541 in⁴

Calculate K_g:

Beam 1-2 e_g =	11.0 in	(8.00 in x	0.5) +	7.00 in	
Beam 3-8 e_g =	11.0 in	(8.00 in x	0.5) +	6.95 in	
n =	6.76	29000 ksi/	4291 ksi		(5) 4.6.2.2.1-2
Beam 1-2 K_g =	21,234 in⁴				(5) 4.6.2.2.1-1
Beam 3-8 K_g =	16,297 in⁴				(5) 4.6.2.2.1-1

Moment for Interior Beams:

Per (2) - Section 3.5.3.8&9, Distribution of live load to interior beams shall be calculated using (5) - Section 4.6.2.2.2

Applicability

$3.5 \leq S \leq 16.0$
$4.5 \leq t_s \leq 12.0$
$20 \leq L \leq 240$
$N_b \geq 4$
$10{,}000 \leq K_g \leq 7{,}000{,}000$

(5) Table 4.6.2.2.2b-1

	Beam 2	Beam 2 Check
S =	3.50 ft	OKAY
t_s =	8.00 in	OKAY
L =	24.34 ft	OKAY
N_b =	8	OKAY
K_g =	21,234 in⁴	OKAY

	Beam 3-7	Beam 3-7 Check
S =	3.50 ft	OKAY
t_s =	8.00 in	OKAY
L =	21.0 ft	OKAY
N_b =	8	OKAY
K_g =	16,297 in⁴	OKAY

(4) Table 4.6.2.2.2b-1

Concrete Deck or Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-Beams, T- and Double T-Sections	a, e, k and also i, j if sufficiently connected to act as a unit	One Design Lane Loaded: $0.06+\left(\frac{S}{14}\right)^{0.4}\left(\frac{S}{L}\right)^{0.3}\left(\frac{K_g}{12.0Lt_s^3}\right)^{0.1}$ Two or More Design Lanes Loaded: $0.075+\left(\frac{S}{9.5}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}\left(\frac{K_g}{12.0\,Lt_s^3}\right)^{0.1}$	$3.5 \leq S \leq 16.0$ $4.5 \leq t_s \leq 12.0$ $20 \leq L \leq 240$ $N_b \geq 4$ $10{,}000 \leq K_g \leq 7{,}000{,}000$
		use lesser of the values obtained from the equation above with $N_b = 3$ or the lever rule	$N_b = 3$

Beam 2

One Lane Loaded

$DF_{Mom.Beam2} =$ 0.324 $= 0.06 + \left(\frac{3.50\ ft}{14}\right)^{0.4} \left(\frac{3.50\ ft}{24.34\ ft}\right)^{0.3} \times \left(\frac{21{,}234\ in^4}{12.0 \times 24.34\ ft \times (8.00\ in)^3}\right)^{0.1}$

Two or More Lanes Loaded

$DF_{Mom.Beam2} =$ 0.382 $= 0.075 + \left(\frac{3.50\ ft}{9.5}\right)^{0.6} \left(\frac{3.50\ ft}{24.34\ ft}\right)^{0.2} \times \left(\frac{21{,}234\ in^4}{12.0 \times 24.34\ ft \times (8.00\ in)^3}\right)^{0.1}$

One Lane Loaded

$DF_{Mom.Beam2} =$ 0.324

Two or More Lanes Loaded

$DF_{Mom.Beam2} =$ 0.382

Critical Factor

$DF_{Mom.Beam2} =$ **0.382**

Beam 3-7

One Lane Loaded

$DF_{Mom.Beam3\text{-}7} =$ 0.333 $= 0.06 + \left(\frac{3.50\ ft}{14}\right)^{0.4} \left(\frac{3.50\ ft}{21.00\ ft}\right)^{0.3} \times \left(\frac{16{,}297\ in^4}{12.0 \times 21.00\ ft \times (8.00\ in)^3}\right)^{0.1}$

Two or More Lanes Loaded

$DF_{Mom.Beam3\text{-}7} =$ 0.387 $= 0.075 + \left(\frac{3.50\ ft}{9.5}\right)^{0.6} \left(\frac{3.50\ ft}{21.00\ ft}\right)^{0.2} \times \left(\frac{16{,}297\ in^4}{12.0 \times 21.00\ ft \times (8.00\ in)^3}\right)^{0.1}$

One Lane Loaded

$DF_{Mom.Beam3\text{-}7} =$ 0.333

Two or More Lanes Loaded

$DF_{Mom.Beam3\text{-}7} =$ 0.387

Critical Factor

$DF_{Mom.Beam3\text{-}7} =$ **0.387**

Shear for Interior Beams:

Per (2) - Section 3.5.3.8&9, Distribution of live load to interior beams shall be calculated using (5) - Section 4.6.2.2.2

Applicability (5) Table 4.6.2.2.3a-1

$$3.5 \le S \le 16.0$$
$$20 \le L \le 240$$
$$4.5 \le t_s \le 12.0$$
$$N_b \ge 4$$

	Beam 2	Beam 2 Check
S =	3.50 ft	OKAY
t_s =	8.00 ft	OKAY
L =	24.34 ft	OKAY
N_b =	8.00 ft	OKAY

	Beam 3-7	Beam 3-7 Check
S =	3.50 ft	OKAY
t_s =	8.00 ft	OKAY
L =	21.00 ft	OKAY
N_b =	8.00 ft	OKAY

(5) Table 4.6.2.2.3a-1

Concrete Deck or Filled Grid, Partially Filled Grid, or Unfilled Grid Deck Composite with Reinforced Concrete Slab on Steel or Concrete Beams; Concrete T-Beams, T- and Double T-Sections	a, e, k and also i, j if sufficiently connected to act as a unit	$0.36 + \frac{S}{25.0}$	$0.2 + \frac{S}{12} - \left(\frac{S}{35}\right)^{2.0}$	$3.5 \le S \le 16.0$ $20 \le L \le 240$ $4.5 \le t_s \le 12.0$ $N_b \ge 4$
		Lever Rule	Lever Rule	$N_b = 3$

Load Rating - Alternate Live Load Distribution Factors C-05-027

Beam 2

One Lane Loaded

$DF_{Shear,Beam2} = 0.500 \quad 0.36 + \left(\frac{3.50\ ft}{25}\right)$

Two or More Lanes Loaded

$DF_{Shear,Beam2} = 0.482 \quad 0.2 + \left(\frac{3.50\ ft}{12}\right) - \left(\frac{3.50\ ft}{35}\right)^{2.0}$

One Lane Loaded

$DF_{Shear,Beam2} = 0.500$

Two or More Lanes Loaded

$DF_{Shear,Beam2} = 0.482$

Critical Factor

$DF_{Shear,Beam2} = $ **0.500**

Beam 3-7

One Lane Loaded

$DF_{Shear,Beam3-7} = 0.500 \quad 0.36 + \left(\frac{3.50\ ft}{25}\right)$

Two or More Lanes Loaded

$DF_{Shear,Beam3-7} = 0.482 \quad 0.2 + \left(\frac{3.50\ ft}{12}\right) - \left(\frac{3.50\ ft}{35}\right)^{2.0}$

One Lane Loaded

$DF_{Shear,Beam3-7} = 0.500$

Two or More Lanes Loaded

$DF_{Shear,Beam3-7} = 0.482$

Critical Factor

$DF_{Shear,Beam3-7} = $ **0.500**

Deterioration

Load Rating - Deterioration C-05-027

References:
1) AASHTO Standard Specifications, 17th Edition, 2002
2) MassDOT Bridge Manual 2024
3) 1995 Mass Highway Bridge Manual
4) AISC Steel Construction Manual, 15th Edition, 2017
5) AASHTO LRFD Bridge Design, 9th Edition, 2020 with 2021 Errata
6) AASHTO Manual for Bridge Evaluation, 3rd Edition, 2018 thru 2022 Interim

Bottom Flange Deterioration

Top flange deterioration was estimated to be a 1/4" loss of thickness to the top flange along the entire span of each beam.

BM #	Shape	Top Flange Thickness	Remaining Thickness	Percent Loss
BM 1-2	W14x68	0.72	0.47	34.72
BM 3-8	W14x53	0.66	0.41	37.88

Section Properties

SECTION PROPERTIES C-05-027

COMPOSITE SECTION PROPERTIES

GIRDER DESCRIPTION Beam 1
GIRDER NUMBER BM1
GIRDER LOCATION EXTERIOR

WELDED PLATE GIRDER
GROSS SECTION PROPERTIES

ELEMENTS						PROPERTIES				
COMPOSITE	n value	width	y	WIDTH	DEPTH	A	Y	AY	AY^2	I_O
DECK	n= 6.76	37.50	4.00	5.55	8.00	44.38	18.00	798.8	14378.7	236.7
Cover Plate			0.000	0	0	0.00	14.00	0.0	0.0	0.0
Flange Plate			0.360	10.00	0.72	7.20	13.64	98.2	1339.6	0.3
Web Plate			6.280	0.42	12.56	5.21	7.00	36.5	255.4	68.5
Flange Plate			0.360	10.00	0.72	7.20	0.36	2.6	0.9	0.3
Cover Plate			0.000	0	0	0.00	0.00	0.0	0.0	0.0
		SUMS			22.00	64.0	-	936.1	15974.6	305.8

$I_Z = \Sigma I_O + \Sigma AY^2$ 16280 in^4

$I_{GROSS} = I_Z - (\Sigma A)(Y')^2$ 2586.499 in^4

$Y' = \frac{\Sigma AY}{\Sigma A}$ 14.63 in

DEPTH (Incl Deck) 22.00 in
$C_{TOP\ DECK}$ 7.37 in
$S_{DECK\ TRANS}$ 2372.0 in^3

MEMBER AREA 19.6 in^2
WEB AREA 5.8 in^2

MEMBER DEPTH (Less Deck) 14.00 in
$C_{TOP\ ST}$ -0.63 in
$S_{TOP\ ST}$ -4114.4 in^3
C_{BOTTOM} 14.63 in
S_{BOTTOM} 176.8 in^3

STATICAL MOMENT OF INERTIA OF TOP AND BOTTOM FLANGES - $Q = \Sigma Ad$

where: A is the area of each flange component & d is the distance from the N.A. of the section the C.G. of the area

Q - DECK A = 44.38 in^2 d = Y-Y' 3.37 in Q DECK = 149.6 in^3

Q - TOP FLANGE cover plates + deck

deck	A = 44.38 in^2	d = Y-Y' 3.37 in	Q= 149.6 in^3
cover plate	A = 0.00 in^2	d = Y-Y' -0.63 in	Q= 0.0 in^3
flange plate	A = 7.20 in^2	d = Y-Y' -0.99 in	Q= -7.1 in^3

Q TOP FLANGE = Σ 142.5 in^3

Q - BOTTOM FLANGE cover plates

flange plate	A = 7.20 in^2	d = Y-Y' 14.27 in	Q= 102.7 in^3
cover plate	A = 0.00 in^2	d = Y-Y' 14.63 in	Q= 0.0 in^3

Q BOTTOM FLANGE = Σ 102.7 in^3

SECTION PROPERTIES C-05-027

COMPOSITE SECTION PROPERTIES

GIRDER DESCRIPTION Beam 2
GIRDER NUMBER BM2
GIRDER LOCATION INTERIOR

WELDED PLATE GIRDER
GROSS SECTION PROPERTIES

ELEMENTS						PROPERTIES				
COMPOSITE	n value	width	y	WIDTH	DEPTH	A	Y	AY	AY^2	I_O
DECK	n= 6.76	36.00	4.00	5.33	8.00	42.60	18.00	766.9	13803.6	227.2
Cover Plate			0.000	0	0	0.00	14.00	0.0	0.0	0.0
Flange Plate			0.360	10.00	0.72	7.20	13.64	98.2	1339.6	0.3
Web Plate			6.280	0.42	12.56	5.21	7.00	36.5	255.4	68.5
Flange Plate			0.360	10.00	0.72	7.20	0.36	2.6	0.9	0.3
Cover Plate			0.000	0	0	0.00	0.00	0.0	0.0	0.0
		SUMS			22.00	62.2	-	904.2	15399.4	296.4

$I_Z = \Sigma I_O + \Sigma AY^2$ 15696 in^4

$I_{GROSS} = I_Z - (\Sigma A)(Y')^2$ 2556.280 in^4

$Y' = \dfrac{\Sigma AY}{\Sigma A}$ 14.53 in

DEPTH (Incl Deck) 22.00 in
$C_{TOP\ DECK}$ 7.47 in
$S_{DECK\ TRANS}$ 2314.1 in^3

MEMBER AREA 19.6 in^2
WEB AREA 5.8 in^2

MEMBER DEPTH (Less Deck) 14.00 in
$C_{TOP\ ST}$ -0.53 in
$S_{TOP\ ST}$ -4800.9 in^3
C_{BOTTOM} 14.53 in
S_{BOTTOM} 175.9 in^3

STATICAL MOMENT OF INERTIA OF TOP AND BOTTOM FLANGES - $Q = \Sigma Ad$

where: A is the area of each flange component & d is the distance from the N.A. of the section the C.G. of the area

Q - DECK A = 42.60 in^2 d = Y-Y' 3.47 in Q DECK = 147.7 in^3

Q - TOP FLANGE cover plates + deck

	A	d = Y-Y'	Q
deck	42.60 in^2	3.47 in	147.7 in^3
cover plate	0.00 in^2	-0.53 in	0.0 in^3
flange plate	7.20 in^2	-0.89 in	-6.4 in^3

Q TOP FLANGE = Σ 141.3 in^3

Q - BOTTOM FLANGE cover plates

	A	d = Y'-Y	Q
flange plate	7.20 in^2	14.17 in	102.0 in^3
cover plate	0.00 in^2	14.53 in	0.0 in^3

Q BOTTOM FLANGE = Σ 102.0 in^3

SECTION PROPERTIES C-05-027

COMPOSITE SECTION PROPERTIES

GIRDER DESCRIPTION Beam 3-7
GIRDER NUMBER BM3-7
GIRDER LOCATION INTERIOR

WELDED PLATE GIRDER
GROSS SECTION PROPERTIES

ELEMENTS						PROPERTIES				
COMPOSITE	n value	width	y	WIDTH	DEPTH	A	Y	AY	AY^2	I_O
DECK	n= 6.76	35.38	4.00	5.23	8.00	41.86	17.90	749.4	13413.6	223.3
Cover Plate			0.000	0	0	0.00	13.90	0.0	0.0	0.0
Flange Plate			0.330	8.06	0.66	5.32	13.57	72.2	979.6	0.2
Web Plate			6.290	0.37	12.58	4.65	6.95	32.3	224.8	61.4
Flange Plate			0.330	8.06	0.66	5.32	0.33	1.8	0.6	0.2
Cover Plate			0.000	0	0	0.00	0.00	0.0	0.0	0.0
		SUMS			21.90	57.2	-	855.7	14618.6	285.0

$I_Z = \Sigma I_O + \Sigma AY^2$ 14904 in^4

$I_{GROSS} = I_Z - (\Sigma A)(Y')^2$ 2094.403 in^4

$Y' = \frac{\Sigma AY}{\Sigma A}$ 14.97 in

DEPTH (Incl Deck) 21.90 in
$C_{TOP\ DECK}$ 6.93 in
$S_{DECK\ TRANS}$ 2043.1 in^3

MEMBER AREA 15.3 in^2
WEB AREA 5.1 in^2

MEMBER DEPTH (Less Deck) 13.90 in
$C_{TOP\ ST}$ -1.07 in
$S_{TOP\ ST}$ -1957.2 in^3
C_{BOTTOM} 14.97 in
S_{BOTTOM} 139.9 in^3

STATICAL MOMENT OF INERTIA OF TOP AND BOTTOM FLANGES - $Q = \Sigma Ad$

where: A is the area of each flange component & d is the distance from the N.A. of the section the C.G. of the area

Q - DECK A = 41.86 in^2 d = Y-Y' 2.93 in Q DECK = 122.7 in^3

Q - TOP FLANGE cover plates + deck

deck	A = 41.86 in^2	d = Y-Y' 2.93 in	Q= 122.7 in^3
cover plate	A = 0.00 in^2	d = Y-Y' -1.07 in	Q= 0.0 in^3
flange plate	A = 5.32 in^2	d = Y-Y' -1.40 in	Q= -7.4 in^3
			Q TOP FLANGE = Σ 115.2 in^3

Q - BOTTOM FLANGE cover plates

flange plate	A = 5.32 in^2	d = Y'-Y 14.64 in	Q= 77.9 in^3
cover plate	A = 0.00 in^2	d = Y'-Y 14.97 in	Q= 0.0 in^3
			Q BOTTOM FLANGE = Σ 77.9 in^3

SECTION PROPERTIES C-05-027

COMPOSITE SECTION PROPERTIES

GIRDER DESCRIPTION Beam 8
GIRDER NUMBER BM8
GIRDER LOCATION EXTERIOR

WELDED PLATE GIRDER
GROSS SECTION PROPERTIES

ELEMENTS						PROPERTIES				
COMPOSITE	n value	width	y	WIDTH	DEPTH	A	Y	AY	AY^2	I_O
DECK	n= 6.76	47.19	4.00	6.98	8.00	55.84	17.90	999.6	17892.7	297.8
Cover Plate			0.000	0	0	0.00	13.90	0.0	0.0	0.0
Flange Plate			0.330	8.06	0.66	5.32	13.57	72.2	979.6	0.2
Web Plate			6.290	0.37	12.58	4.65	6.95	32.3	224.8	61.4
Flange Plate			0.330	8.06	0.66	5.32	0.33	1.8	0.6	0.2
Cover Plate			0.000	0	0	0.00	0.00	0.0	0.0	0.0
		SUMS			21.90	71.1	-	1105.9	19097.7	359.6

$I_Z = \Sigma I_O + \Sigma AY^2$ 19457 in^4

$I_{GROSS} = I_Z - (\Sigma A)(Y')^2$ 2265.380 in^4

$Y' = \frac{\Sigma AY}{\Sigma A}$ 15.55 in

DEPTH (Incl Deck) 21.90 in
$C_{TOP\ DECK}$ 6.35 in
$S_{DECK\ TRANS}$ 2410.1 in^3

MEMBER AREA 15.3 in^2
WEB AREA 5.1 in^2

MEMBER DEPTH (Less Deck) 13.90 in
$C_{TOP\ ST}$ -1.65 in C_{BOTTOM} 15.55 in
$S_{TOP\ ST}$ -1376.4 in^3 S_{BOTTOM} 145.7 in^3

STATICAL MOMENT OF INERTIA OF TOP AND BOTTOM FLANGES - $Q = \Sigma Ad$

where: A is the area of each flange component & d is the distance from the N.A. of the section the C.G. of the area

Q - DECK A = 55.84 in^2 d = Y-Y' 2.35 in Q DECK = 131.5 in^3

Q - TOP FLANGE cover plates + deck

deck	A = 55.84 in^2	d = Y-Y' 2.35 in	Q= 131.5 in^3
cover plate	A = 0.00 in^2	d = Y-Y' -1.65 in	Q= 0.0 in^3
flange plate	A = 5.32 in^2	d = Y-Y' -1.98 in	Q= -10.5 in^3

Q TOP FLANGE = Σ 121.0 in^3

Q - BOTTOM FLANGE cover plates

flange plate	A = 5.32 in^2	d = Y-Y 15.22 in	Q= 80.9 in^3
cover plate	A = 0.00 in^2	d = Y-Y 15.55 in	Q= 0.0 in^3

Q BOTTOM FLANGE = Σ 80.9 in^3

SHEAR CONNECTORS

SHEAR STUDS C-05-027

References:
1. MassDOT LRFD Bridge Manual, 2024 Part II
2. AASHTO LRFD Bridge Design Specifications, 9th Edition, 2020 with 2021 Errata

Per Ref (2) 6.3.7 Shear studs shall be designed for the controlling fatigue limit state, then checked with the controlling strength limit state.

Material Properties:

Shear Connector Diameter, d =	0.750 in	(Ref 1 - Dwg. 8.4.2)
Shear Connector Area, A_{sc} =	0.44 in	
Shear Connector Height, h =	6.00 in	
Number of Studs in a Line, n =	2	
Minimum Edge Clear Distance, e =	1.00 in	(Ref 2 - 6.10.10.1.3)
Deck f'c =	5 ksi	
Deck Ec =	4287 ksi	
Shear Connector Fu =	60 ksi	(Ref 2 - 6.4.4)
Girder Web F_y =	33 ksi	
Girder Flange F_y =	33 ksi	
Beam 1-2 Top Flange Width, bf =	10.00 in	
Beam 3-8 Top Flange Width, bf =	8.06 in	
Deck Thickness, t_d =	8.00 in	
Haunch Thickness, t_h =	1.00 in	
Load Factor Fatigue I =	1.75	(Ref 2 - Table 3.4.1-1)
Load Factor Fatigue II =	0.80	(Ref 2 - Table 3.4.1-1)

SHEAR STUDS C-05-027

Geometry Checks:

Ref 2 - 6.10.10.1.1, ratio of the height to the diameter of a stud shear connector shall not be less than 4.0.

$$\frac{h}{d} = \frac{6.00 \text{ in}}{0.75 \text{ in}} = 8.00$$ OK

Ref 2 - 6.10.10.1.2, The center-to-center pitch of shear connectors shall also not be less than six stud diameters.

Min. Pitch =	10.00 in	>	4.50 in	OK

Ref 2 - 6.10.10.1.3, stud shear connectors shall not be closer than 4.0 stud diameters center-to-center transverse to the longitudinal axis of the supporting member.

Beam 1-2:				
$S_{provided}$ =	7.25 in	>	3.00 in	OK
Edge Dist. =	1.38 in	>	1.00 in	OK
Beam 3-8:				
$S_{provided}$ =	5.31 in	>	3.00 in	OK
Edge Dist. =	1.38 in	>	1.00 in	OK

Ref 2 - 6.10.10.1.4, the clear depth of concrete cover over the tops of the shear connectors should not be less than 2.0 in. Shear connectors should penetrate at least 2.0 in. into the concrete deck.

Cover Top =	9.00" -	6.00"	=	3.00"	OK
Pen. Bot =	6.00" -	1.00"	=	5.00"	OK

SHEAR STUDS C-05-027

Traffic Information:

ADT = 154
ADTT = 9.24
p = 0.85 (Ref 2 - Table 3.6.1.4.2-1)

$ADTT_{SL}$ = p x ADTT (Ref 2 - Eq. 3.6.1.4.2-1)
$ADTT_{SL}$ = 0.85 x 9 = 7.854
n = 1.00 (Ref 2 - Table 6.6.1.2.5-2, L > 40ft, simple span)

$N = (365)(75)n(ADTT)_{SL}$ (Ref 2 - Eq. 6.6.1.2.5-3)
N = 365 x 75 x 1 x 7.85 = 215003.25

Age and Service

(27) Year Built			1938
(106) Year Reconstructed			1960
(42) Type of Service: On -	Highway		
Under - Waterway		Code	15
(28) Lanes: On Structure	02	Under structure	00
(29) Average Daily Traffic			000154
(30) Year of ADT	2018	(109) Truck ADT	06 %
(19) Bypass, detour length			016 KM

From Routine & Special Member Inspection Report dated November 1, 2022

Shear Connector Fatigue Resistance:

Ref 2 - 6.10.10.2:

If $(ADTT)_{SL}$ >= 1090, use Fatigue I load combination and the fatigue shear resistance for infinite life shall be taken as:

$Zr = 5.5d^2 =$ 3.1 k

Otherwise, the Fatigue II load combination shall be used and the fatigue shear resistance for finite life shall be taken as:

$Zr = \alpha d^2 =$ 6.6 k

where $\alpha = 34.5 - 4.28 \log N$

$\alpha =$ 34.5 - 4.28 x 5.33 = 11.68

$ADTT_{SL} =$ 7.854 <1090

Therefore $Zr =$ 6.57 k

SHEAR STUDS C-05-027

Required Pitch:

Ref 2 - 6.10.10.1.2, The pitch, p, of shear connectors shall satisfy:

$$p \leq \frac{n \times Z_r}{V_{sr}}$$ (Ref 2 - Eq. 6.10.10.1.2-1)

Where $V_{sr} = [(V_{fat})^2 + (F_{fat})^2]^{1/2}$ (Ref 2 - Eq. 6.10.10.1.2-2)

Ref 2 - 6.10.10.1.2, for straight spans or segments, the radial fatigue shear range from Eq. 6.10.10.1.2-4 may be taken equal to zero.

Ref 2 - 6.10.10.1.2, the center-to-center pitch of shear connectors shall not exceed 24.0 in. and shall not be less than six stud diameters.

Calculate V_{sr} and required p for each beam:

*Fatigue Shear Loads taken from BrR

Beam 1:

Span =	30.34	
I (in^4) =	2586	(See Section Properties Calc)
Q (in^3) =	150	(See Section Properties Calc)

Point	Distance	V_f	$V_{sr}=V_{fat}=V_fQ/I$	$p = nZ_r/V_{sr}$
0	0	11.59 k	0.67 k	19.59
0.1	3.034	11.33 k	0.66 k	20.04
0.2	6.068	11.07 k	0.64 k	20.52
0.3	9.102	10.82 k	0.63 k	20.99
0.4	12.136	10.56 k	0.61 k	21.51
0.5	15.17	10.41 k	0.60 k	21.82
0.6	18.204	10.56 k	0.61 k	21.51
0.7	21.238	10.82 k	0.63 k	20.99
0.8	24.272	11.07 k	0.64 k	20.52
0.9	27.306	11.33 k	0.66 k	20.04
1	30.34	11.59 k	0.67 k	19.59

Actual: Spacing		Min: Spacing	
10.00 in	<	19.59	ok

SHEAR STUDS C-05-027

Beam 2:

Span =	24.34	
I (in^4) =	2556	(See Section Properties Calc)
Q (in^3) =	148	(See Section Properties Calc)

Point	Distance	V_f	$V_{sr}=V_{fat}=V_fQ/I$	$p = nZ_r/V_{sr}$
0	0	16.28 k	0.94 k	13.96
0.1	2.434	15.91 k	0.92 k	14.29
0.2	4.868	15.54 k	0.90 k	14.63
0.3	7.302	15.18 k	0.88 k	14.97
0.4	9.736	14.81 k	0.86 k	15.35
0.5	12.17	14.72 k	0.85 k	15.44
0.6	14.604	14.81 k	0.86 k	15.35
0.7	17.038	15.18 k	0.88 k	14.97
0.8	19.472	15.54 k	0.90 k	14.63
0.9	21.906	15.91 k	0.92 k	14.29
1	24.34	16.28 k	0.94 k	13.96

Actual: Spacing		Min: Spacing	
10.00 in	<	13.96	ok

Beam 3-7:

Span =	21	
I (in^4) =	2094	(See Section Properties Calc)
Q (in^3) =	123	(See Section Properties Calc)

*To be conservative, using the fatigue DF from Beam 3 as it is slightly higher than Beams 4-7

Point	Distance	V_f	$V_{sr}=V_{fat}=V_fQ/I$	$p = nZ_r/V_{sr}$
0	0	15.91 k	0.93 k	14.10
0.1	2.1	15.55 k	0.91 k	14.43
0.2	4.2	15.18 k	0.89 k	14.78
0.3	6.3	14.81 k	0.87 k	15.15
0.4	8.4	14.69 k	0.86 k	15.27
0.5	10.5	14.68 k	0.86 k	15.28
0.6	12.6	14.69 k	0.86 k	15.27
0.7	14.7	14.81 k	0.87 k	15.15
0.8	16.8	15.18 k	0.89 k	14.78
0.9	18.9	15.55 k	0.91 k	14.43
1	21	15.91 k	0.93 k	14.10

Actual: Spacing		Min: Spacing	
10.00 in	<	14.10	ok

SHEAR STUDS C-05-027

Beam 8:

Span =	21	
I (in^4) =	2265	(See Section Properties Calc)
Q (in^3) =	131	(See Section Properties Calc)

Point	Distance	V_f	$V_{sr}=V_{fat}=V_fQ/I$	$p = nZ_r/V_{sr}$
0	0	12.13 k	0.71 k	18.49
0.1	2.1	11.85 k	0.69 k	18.93
0.2	4.2	11.57 k	0.68 k	19.39
0.3	6.3	11.29 k	0.66 k	19.87
0.4	8.4	11.20 k	0.66 k	20.03
0.5	10.5	11.20 k	0.66 k	20.03
0.6	12.6	11.20 k	0.66 k	20.03
0.7	14.7	11.29 k	0.66 k	19.87
0.8	16.8	11.57 k	0.68 k	19.39
0.9	18.9	11.85 k	0.69 k	18.93
1	21	12.13 k	0.71 k	18.49

Actual: Spacing		Min: Spacing	
10.00 in	<	18.49	ok

Shear Connector Strength Resistance:

Calculate shear resistance of single shear stud:

$Q_r = \phi_{sc} Q_n$ (Ref 2 - Eq. 6.10.10.4.1-1)

ϕ_{sc} = 0.85 (Ref 2 - 6.5.4.2)

$$Q_n = 0.5 A_{sc}\sqrt{f'_c E_c} \leq A_{sc} F_u$$ (Ref 2 - Eq. 6.10.10.4.3-1)

Q_n = 0.50 x x 0.44 in2 [5 ksi x 4287 ksi]$^{0.5}$ = 32.340 k

$A_{sc}F_u$ = 0.44 in2 x 60.00 ksi = 26.507 k

Q_r = 26.51 k x 0.85 = 22.5 k

SHEAR STUDS C-05-027

Calculate nominal shear force:

Ref 2 - 6.10.10.4.2, for simple spans and for continuous spans that are noncomposite for negative flexure in the final condition, the total nominal shear force, P, between the point of maximum positive design live load plus impact moment and each adjacent point of zero moment shall be taken as:

$$P = [P_p^2 + F_p^2]^{1/2} \quad \text{(Ref 2 - Eq. 6.10.10.4.2-1)}$$

In which: P_p is the lesser of

$$P_{1p} = 0.85f'_c b_s t_s \quad \text{or} \quad P_{2p} = F_{yw}Dt_w + F_{yt}b_{ft}t_{ft} + F_{yc}b_{fc}t_{fc}$$

Per Ref 2 - 6.10.10.4.2, For straight spans or segments, Fp may be taken equal to zero.

	Beam 1	Beam 2	Beam 3-7	Beam 8
b_s	37.50 in	36.00 in	35.38 in	47.19 in
t_s	8.00 in	8.00 in	8.00 in	8.00 in
D	12.56 in	12.56 in	12.58 in	12.58 in
t_w	0.42 in	0.42 in	0.37 in	0.37 in
b_{ft}	10.00 in	10.00 in	8.06 in	8.06 in
t_{ft}	0.72 in	0.72 in	0.66 in	0.66 in
b_{fc}	10.00 in	10.00 in	8.06 in	8.06 in
t_{fc}	0.72 in	0.72 in	0.66 in	0.66 in
P_{1p}	1275.0 k	1224.0 k	1202.8 k	1604.4 k
P_{2p}	647.2 k	647.2 k	504.7 k	504.7 k
P_p = P	647.2 k	647.2 k	504.7 k	504.7 k

Calculate number of shear studs required:

Ref 2 - 6.10.10.4.1, at the strength limit state, the minimum number of shear connectors, n, over the region under consideration shall be taken as:

$$n = \frac{P}{Q_r}$$

$$n_{Beam1} = \frac{P}{Q_r} = \frac{647.2\text{ k}}{22.5\text{ k}} = 29$$

$$n_{Beam2} = \frac{P}{Q_r} = \frac{647.2\text{ k}}{22.5\text{ k}} = 29$$

$$n_{Beam3\text{-}7} = \frac{P}{Q_r} = \frac{504.7\text{ k}}{22.5\text{ k}} = 23$$

$$n_{Beam8} = \frac{P}{Q_r} = \frac{504.7\text{ k}}{22.5\text{ k}} = 23$$

The above number of shear studs need to be provided between tenth points 0 and 5 and between 5 and 10 in order to meet the strength limit state.

SHEAR STUDS C-05-027

Check Strength Requirement:
Check the number of studs for the full length of the girder to the full length number of shear studs required

Beam 1

# Provided =	74 =	37 x	2
74	>	58	ok

Beam 2

# Provided =	62 =	31 x	2
62	>	58	ok

Beam 3-7

# Provided =	54 =	27 x	2
54	>	46	ok

Beam 8

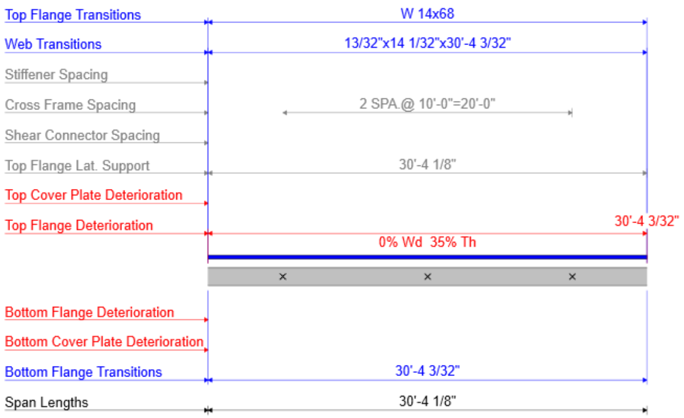
# Provided =	54 =	27 x	2
54	>	46	ok

Rating Results Summary Report

Name: Charlemont
Bridge ID: C-05-027 (LRFD)
NBI: C-05-027
Struct-Def: C-05-027
Member: Member 1
Member alt: Beam 1 Alt.

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HL-93 (US)	Truck + Lane	LRFR	Inventory	52.26	1.452	12.14	1 - (40.0)	SERVICE-II Steel Fle...	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	67.94	1.887	12.14	1 - (40.0)	SERVICE-II Steel Fle...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	45.03	1.251	15.17	1 - (50.0)	SERVICE-II Steel Fle...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	58.54	1.626	15.17	1 - (50.0)	SERVICE-II Steel Fle...	As Requested	As Requested

C-05-027 (LRFD)
Charlemont - C-05-027 - Member 1
South River Road / Albee Brook
11/7/2024



Notes:
* All flange length dimensions are horiz. (length along flange may differ).
* Transverse stiffener pairs shown in red.
* Single transverse stiffener shown in blue.
* Bearing stiffeners shown in green.
* Dimensioning starts and ends at CL bearings.
* X denotes cross frame locations.

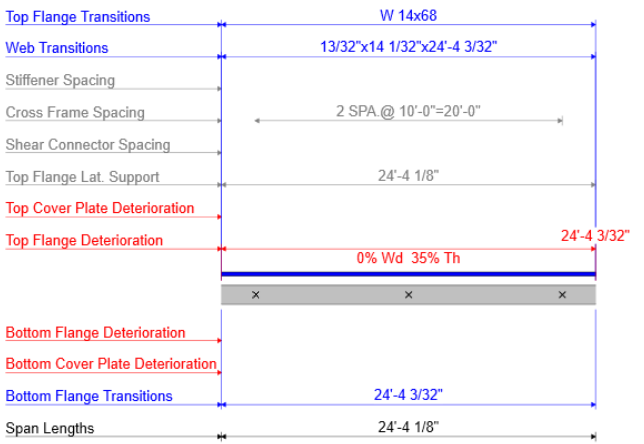
AASHTO LRFR Engine Version 7.5.1.3001
Analysis preference setting: None
Analysis time: 11/2/2024 12:05:26 PM
Print time: 11/2/2024 12:05:42 PM
Analyzed by: BrR

Rating Results Summary Report

Name: Charlemont | Bridge ID: C-05-027 (LRFD) | NBI: C-05-027
Struct-Def: C-05-027 | Member: Member 2 | Member alt: Beam 2 Alt.

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HL-93 (US)	Truck + Lane	LRFR	Inventory	53.56	1.488	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	69.44	1.929	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	53.26	1.479	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	69.03	1.918	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested

C-05-027 (LRFD)
Charlemont - C-05-027 - Member 2
South River Road / Albee Brook
11/7/2024



Notes:
* All flange length dimensions are horiz. (length along flange may differ).
* Transverse stiffener pairs shown in red.
* Single transverse stiffener shown in blue.
* Bearing stiffeners shown in green.
* Dimensioning starts and ends at CL bearings.
* X denotes cross frame locations.

AASHTO LRFR Engine Version 7.5.1.3001
Analysis preference setting: None
Analysis time: 11/2/2024 12:06:21 PM
Print time: 11/2/2024 12:06:33 PM

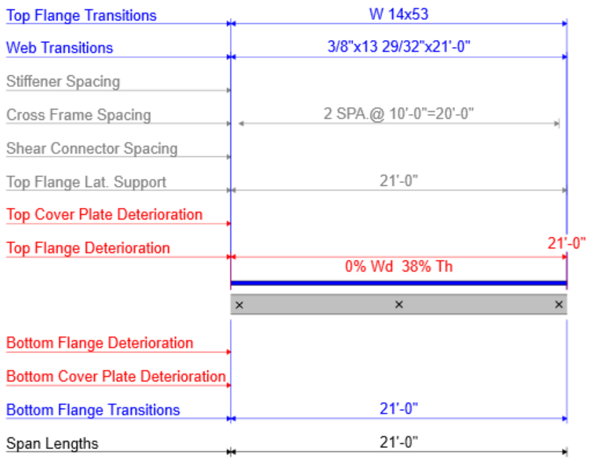
Analyzed by: BrR

Rating Results Summary Report

Name: Charlemont
Bridge ID: C-05-027 (LRFD)
NBI: C-05-027
Struct-Def: C-05-027
Member: Member 3
Member alt: Beam 3 Alt.

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HL-93 (US)	Truck + Lane	LRFR	Inventory	52.04	1.446	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	67.46	1.874	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	49.38	1.372	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	64.01	1.778	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested

C-05-027 (LRFD)
Charlemont - C-05-027 - Member 3
South River Road / Albee Brook
11/7/2024



Notes:
* All flange length dimensions are horiz. (length along flange may differ).
* Transverse stiffener pairs shown in red.
* Single transverse stiffener shown in blue.
* Bearing stiffeners shown in green.
* Dimensioning starts and ends at CL bearings.
* X denotes cross frame locations.

AASHTO LRFR Engine Version 7.5.1.3001
Analysis preference setting: None
Analysis time: 11/2/2024 12:07:04 PM
Print time: 11/2/2024 12:07:23 PM
Analyzed by: BrR

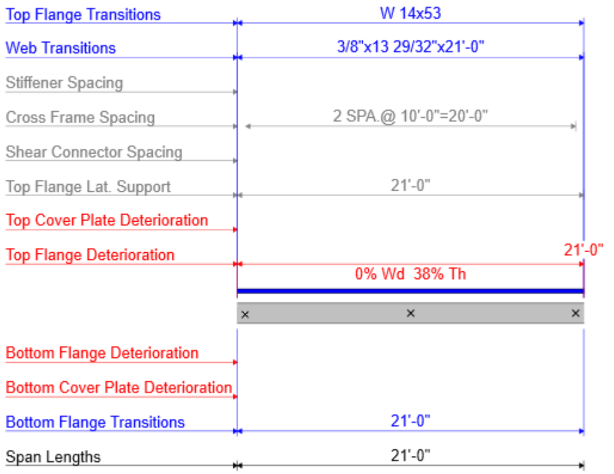
Rating Results Summary Report

Name: Charlemont | Bridge ID: C-05-027 (LRFD) | NBI: C-05-027

Struct-Def: C-05-027 | Member: Member 4-7 | Member alt: Beam 4-7 Alt.

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HL-93 (US)	Truck + Lane	LRFR	Inventory	52.18	1.449	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	67.64	1.879	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	49.51	1.375	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	64.18	1.783	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested

C-05-027 (LRFD)
Charlemont - C-05-027 - Member 4-7
South River Road / Albee Brook
11/7/2024



Notes:
* All flange length dimensions are horiz. (length along flange may differ).
* Transverse stiffener pairs shown in red.
* Single transverse stiffener shown in blue.
* Bearing stiffeners shown in green.
* Dimensioning starts and ends at CL bearings.
* X denotes cross frame locations.

AASHTO LRFR Engine Version 7.5.1.3001
Analysis preference setting: None
Analysis time: 11/2/2024 12:07:49 PM
Print time: 11/2/2024 12:08:03 PM

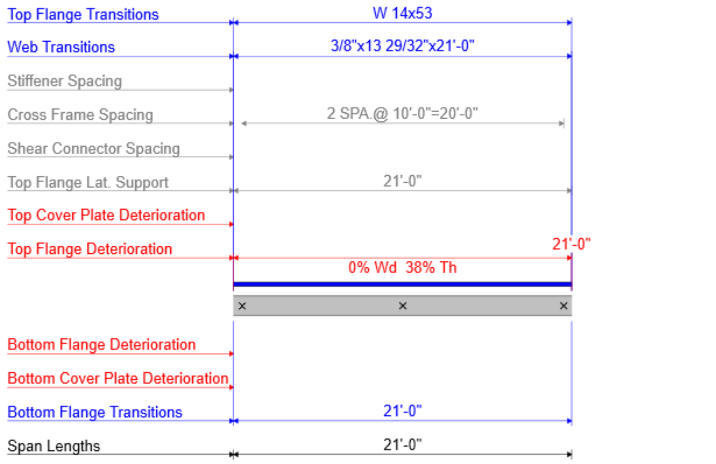
Analyzed by: BrR

Rating Results Summary Report

Name: Charlemont
Bridge ID: C-05-027 (LRFD)
NBI: C-05-027
Struct-Def: C-05-027
Member: Member 8
Member alt: Beam 8 Alt.

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HL-93 (US)	Truck + Lane	LRFR	Inventory	65.08	1.808	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	84.37	2.344	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	61.76	1.715	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	80.05	2.224	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested

C-05-027 (LRFD)
Charlemont - C-05-027 - Member 8
South River Road / Albee Brook
11/7/2024



Notes:
* All flange length dimensions are horiz. (length along flange may differ).
* Transverse stiffener pairs shown in red.
* Single transverse stiffener shown in blue.
* Bearing stiffeners shown in green.
* Dimensioning starts and ends at CL bearings.
* X denotes cross frame locations.

AASHTO LRFR Engine Version 7.5.1.3001
Analysis preference setting: None
Analysis time: 11/2/2024 12:08:34 PM
Print time: 11/2/2024 12:08:45 PM
Analyzed by: BrR

Alternate Load Path Analysis

Rating Results Summary Report

Name: Charlemont | Bridge ID: C-05-027 (LRFD) | NBI: C-05-027

Struct-Def: C-05-027 | Member: Member 2 | Member alt: Beam 2 Alt. S=3.5 LLDF

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HL-93 (US)	Truck + Lane	LRFR	Inventory	51.42	1.428	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	66.66	1.852	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	51.12	1.420	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	66.27	1.841	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested

AASHTO LRFR Engine Version 7.5.1.3001
Analysis preference setting: None
Analysis time: 11/2/2024 12:09:13 PM
Print time: 11/2/2024 12:09:27 PM

Analyzed by: BrR

Alternate Load Path Analysis

Rating Results Summary Report

Name: Charlemont
Bridge ID: C-05-027 (LRFD)
NBI: C-05-027
Struct-Def: C-05-027
Member: Member 3
Member alt: Beam 3 Alt. S=3.5 LLDF

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HL-93 (US)	Truck + Lane	LRFR	Inventory	49.86	1.385	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	64.63	1.795	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	47.31	1.314	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	61.33	1.704	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested

AASHTO LRFR Engine Version 7.5.1.3001
Analysis preference setting: None
Analysis time: 11/2/2024 12:09:57 PM
Print time: 11/2/2024 12:10:09 PM

Analyzed by: BrR

Alternate Load Path Analysis

Rating Results Summary Report

Name: Charlemont | Bridge ID: C-05-027 (LRFD) | NBI: C-05-027

Struct-Def: C-05-027 | Member: Member 4-7 | Member alt: Beam 4-7 Alt. S=3.5 LLDF

Live Load	Live Load Type	Rating Method	Rating Level	Load Rating (Ton)	Rating Factor	Location (ft)	Location Span-(%)	Limit State	Impact	Lane
HL-93 (US)	Truck + Lane	LRFR	Inventory	49.88	1.386	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Truck + Lane	LRFR	Operating	64.66	1.796	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Inventory	47.33	1.315	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested
HL-93 (US)	Tandem + Lane	LRFR	Operating	61.35	1.704	0.00	1 - (0.0)	STRENGTH-I Steel S...	As Requested	As Requested

AASHTO LRFR Engine Version 7.5.1.3001
Analysis preference setting: None
Analysis time: 11/2/2024 12:10:34 PM
Print time: 11/2/2024 12:10:46 PM

Analyzed by: BrR