Exterior Girder (G5) Load Rating

Bridge Information:

Built Approx. :	1965
Span Length, L :	147 ft
Girder Spacing, S :	8 ft
Slab Thickness, t_s :	9.5 in
Skew Angle, ϴ :	49 degrees
Asphalt Thickness :	2 in

Steel Properties:

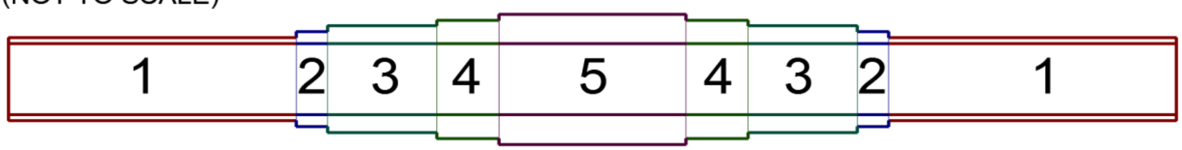
A36 Steel	
F_y :	36 ksi
f'_c :	3 ksi
E :	29000 ksi
rebar cover :	1 in
rebar dia :	0.625 in

Sidewalk Information:

Width	5.25 ft
Height	1 ft

	Location of Each Section	
1	0	36.5
2	36.5	38
3	38	49.5
4	49.5	52
5	52	95
4	95	97.5
3	97.5	109
2	109	110.5
1	110.5	147

Different Section Properties
(NOT TO SCALE)



Calculate Non-Composite Section Properties

Section Property 1	Width (b) in	Height (h) in	I in^4	Area (A) in^2	y of plate in	A*y in^3	d in	I+A*d^2 in^4
Top Plate	20	0.875	1.11653646	17.5	61.4375	1075.1563	-32.6688508	18678.058
Web	0.375	60	6750	22.5	31	697.5	-2.23135081	6862.0258
Bottom Plate	22	1	1.83333333	22	0.5	11	28.2686492	17582.397
			Σ A =	*62*	**Σ A*y =**	*1783.656*	**I =**	***43122.481***
					Neutral Axis, y =	***28.76865***		

Section Property 2	Width (b) in	Height (h) in	I in^4	Area (A) in^2	y of plate in	A*y in^3	d in	I+A*d^2 in^4
Top Plate	20	0.875	1.11653646	17.5	62.3125	1090.4688	-39.5884615	27427.927
Web	0.375	60	6750	22.5	31.875	717.1875	-9.15096154	8634.1522
Bottom Plate	22	1.875	12.0849609	41.25	0.9375	38.671875	21.7865385	19591.532
			Σ A =	*81.25*	**Σ A*y =**	*1846.328*	**I =**	***55653.611***
					Neutral Axis, y =	***22.72404***		

Section Property 3	Width (b) in	Height (h) in	I in^4	Area (A) in^2	y of plate in	A*y in^3	d in	I+A*d^2 in^4
Top Plate	20	1.75	8.93229167	35	62.75	2196.25	-32.8552215	37790.228
Web	0.375	60	6750	22.5	31.875	717.1875	-1.98022152	6838.2287
Bottom Plate	22	1.875	12.0849609	41.25	0.9375	38.671875	28.9572785	34601.199
			Σ A =	*98.75*	**Σ A*y =**	*2952.109*	**I =**	***79229.655***
				Neutral Axis, y =		***29.89478***		

Section Property 4	Width (b) in	Height (h) in	I in^4	Area (A) in^2	y of plate in	A*y in^3	d in	I+A*d^2 in^4
Top Plate	20	1.75	8.93229167	35	63.75	2231.25	-38.3929865	51599.682
Web	0.375	60	6750	22.5	32.875	739.6875	-7.51798654	8021.7027
Bottom Plate	22	2.875	43.5667318	63.25	1.4375	90.921875	23.9195135	36231.619
			Σ A =	*120.75*	**Σ A*y =**	*3061.859*	**I =**	***95853.004***
				Neutral Axis, y =		***25.35701***		

Section Property 5	Width (b) in	Height (h) in	I in^4	Area (A) in^2	y of plate in	A*y in^3	d in	I+A*d^2 in^4
Top Plate	20	2.625	30.1464844	52.5	64.5625	3389.5313	-35.5260239	66290.311
Web	0.375	60	6750	22.5	33.25	748.125	-4.21352389	7149.4601
Bottom Plate	22	3.25	62.9348958	71.5	1.625	116.1875	27.4114761	53787.25
			Σ A =	*146.5*	**Σ A*y =**	*4253.844*	**I =**	***127227.02***
				Neutral Axis, y =		***29.03648***		

Summary of Non-Composite Section Properties

Section Property	Length, x ft	A in^2	I in^4	y in	Depth in	Stop in^3	Sbot in^3
1	36.5	62	43122.481	28.7686492	61.875	1302.5441	1498.94007
2	1.5	81.25	55653.6106	22.7240385	62.75	1390.4378	2449.10739
3	11.5	98.75	79229.6554	29.8947785	63.625	2348.9219	2650.28408
4	2.5	120.75	95853.0039	25.3570135	64.625	2440.9961	3780.13775
5	43	146.5	127227.021	29.0364761	65.875	3453.6406	4381.62747

Calculate Composite Section Properties

Effective Flange Width, 1/2*Interior b_{eff} + : Interior b_{eff} : 96 in

Minimum of:

(i) 1/8*L			220.5	in
(ii) $6t_s$ + greater of:			62	in
	$1/2*t_w$	0.1875		
	$1/4*b_{ftop}$	*5*		
(iii) Overhang :	5'-3"		63	in
		b_{eff} =	***96***	in

Modular Ratio, n :

For $2.9 < f'_c < 3.6$: f'c : 3 ksi

n = ***9***

Short-Term Composite, (n) :

$b_e = b_{eff}/n$: ***10.66666667*** in

$I_{concrete} = (b_e t_s\text{^}3)/12$

762.1111111 in^4

$A_{concrete} = b_e * t_s$

101.3333333 in^2

Section Property	y for concrete	y in	Beam d in	Beam I+Ad^2 in^4	Concrete d in	Concrete I+Ad^2 in^4	$I_{ST\text{-}Comp}$ in^4	S_{top} in^3	S_{bot} in^3
1	66.625	*52.25503827*	23.4863891	77322.3303	-14.3699617	21687.019	*99009.3492*	*10292.073*	*1894.73307*
2	67.5	*47.57459493*	24.8505565	105829.561	-19.9254051	40993.65	*146823.211*	*9675.0769*	*3086.16839*
3	68.375	*49.38330383*	19.4885254	116735.164	-18.9916962	37311.476	*154046.64*	*10816.594*	*3119.40734*
4	69.375	*45.44176829*	20.0847548	144563.237	-23.9332317	58805.802	*203369.039*	*10601.396*	*4475.37688*
5	70.625	*46.04106422*	17.0045881	169588.378	-24.5839358	62004.927	*231593.305*	*11676.619*	*5030.14665*

Summary of Short Term Composite Section Properties

Section Property	y in	$I_{ST\text{-}Comp}$ in^4	S_{top} in^3	S_{bot} in^3
1	52.2550383	99009.34915	10292.0731	1894.73307
2	47.5745949	146823.211	9675.0769	3086.16839
3	49.3833038	154046.6403	10816.5936	3119.40734
4	45.4417683	203369.039	10601.3962	4475.37688
5	46.0410642	231593.3052	11676.6187	5030.14665

Long-Term Composite, (3n) :

$b_e = b_{eff}/n$: ***3.555555556*** in

$I_{concrete} = (b_e t_s$^3)/12

254.037037 in^4

$A_{concrete} = b_e * t_s$

33.77777778 in^2

Section Property	y for concrete	y in	Beam d in	Beam I+Ad^2 in^4	Concrete d in	Concrete I+Ad^2 in^4	$I_{ST\text{-}Comp}$ in^4	S_{top} in^3	S_{bot} in^3
1	66.625	*42.1193808*	13.3507316	54173.4872	-24.5056192	20538.45	*74711.9368*	*3781.8069*	*1773.81375*
2	67.5	*35.87244929*	13.1484108	69700.1681	-31.6275507	34042.014	*103742.183*	*3859.8079*	*2891.97377*
3	68.375	*39.70235538*	9.8075769	88728.2761	-28.6726446	28023.442	*116751.718*	*4880.3851*	*2940.67486*
4	69.375	*34.97877719*	9.62176373	107031.838	-34.3962228	40216.531	*147248.369*	*4966.8509*	*4209.64884*
5	70.625	*36.82871726*	7.79224115	136122.358	-33.7962827	38834.634	*174956.992*	*6023.3867*	*4750.55894*

Summary of Long Term Composite Section Properties

Section Property	y in	$I_{ST\text{-}Comp}$ in^4	S_{top} in^3	S_{bot} in^3
1	42.1193808	74711.93679	3781.80689	1773.81375
2	35.8724493	103742.1826	3859.8079	2891.97377
3	39.7023554	116751.7184	4880.3851	2940.67486
4	34.9787772	147248.3689	4966.85092	4209.64884
5	36.8287173	174956.992	6023.38666	4750.55894

Dead Load Analysis:

Unit Weight Concrete:	0.15	k/ft^3
Unit Weight Steel:	0.49	k/ft^3
Weight per Diaphragm:	0.308	k/ft^3
Number of Diaphragms:	6	

Note: Increase Steel and Diaphragms by : 0.06 %
to account for connections

DC1 - Non-Composite Dead Loads

Section Property	Deck k/ft	Stringer k/ft	Diaphragm k/ft	Total Per Stringer Per Section		Sum of Section Loads
1	1.0984375	0.223630556	0.00666286	***1.328730913***	k/ft	96.997357
2	1.0984375	0.293064236	0.00666286	***1.398164593***	k/ft	4.1944938
3	1.0984375	0.356185764	0.00666286	***1.461286121***	k/ft	33.609581
4	1.0984375	0.435538542	0.00666286	***1.540638899***	k/ft	7.7031945
5	1.0984375	0.528417361	0.00666286	***1.633517718***	k/ft	70.241262

1.4472509 k/ft

Note:
Use as input for QuickBridge to apply load to bridge and calculate Moment and Shear Demand Envelopes.
See 'Raw Demand Loads' tab for results.

DC2 - Composite Dead Loads

Sidewalk :	0.7875	k/ft
Railing :	0.1	k/ft
DC2 =	***0.8875***	***k/ft***

Note:
Use as input for QuickBridge to apply load to bridge and calculate Moment and Shear Demand Envelopes. See 'Raw Demand Loads' tab for results.

DW - Wearing Surface Loads

DW is the same for each section property.

Unit Weight Asphalt:	0.14	k/ft^3
DW Per Stringer:	***0.09333333***	***k/ft***

Note:
Use as input for QuickBridge to apply load to bridge and calculate Moment and Shear Demand Envelopes. See 'Raw Demand Loads' tab for results.

Live Load Analysis:

Moment:

One Lane Loaded - Lever Rule

For one lane loaded the multiple presence factor, m = 1.2 de = -1 ft

$g_{m1} = m*((S-d_e-2)/(2*S)) =$ 0.375

Two or More Lanes Loaded

$e = 0.77+d_e/9.1 =$ 0.66010989 $g_{mInt} =$ 0.56299311

$g_{m2} = eg_{mint} =$ 0.371637318

Shear:

One Lane Loaded - Lever Rule

$g_{v1} = g_{m1} =$ 0.375

Two or More Lanes Loaded

$e = 0.6+d_e/10 =$ 0.5 $g_{vInt} =$ 0.81442177

$g_{v2} = eg_{int} =$ 0.407210885

Special Analysis for Exterior Girders with Diaphragms:

$R = (N_L/N_b)+(X_{ext}*sum(e))/sum(x)^2$ $g_{s1} = m*R$ m = 1.2

Note : See Last Page of hand calculations for the Special Analysis of the exterior Girder.

R1 =	0.417	$g_{special\ 1}$ =	0.5004
R2 =	0.619	$g_{special\ 2}$ =	0.7428
R3 =	0.607	$g_{special\ 3}$ =	0.7284

Summary of Distribution Factors

	Moment	Shear
One Lane Loaded, g_{m1} :	0.375	0.375
Two or More Lanes Loaded, g_{m2} :	0.37163732	0.4072109
Special Analysis (1 Lane Loaded), g_{s1} :	0.5004	0.5004
Special Analysis (Max. 2 Lanes Loaded), g_{s2} :	0.7428	0.7428
Special Analysis (3 Lanes Loaded), g_{s3} :	0.7284	0.7284
Maximum g =	***0.7428***	***0.7428***

Skew Correction Factor

Use Kg from section at midspan to be consevative

$K_g = n(I+Ae_g\verb|^|2)$ n = 9 eg = 41.588524

Kg = 3425527.8

Reduction of Load Distribution Factors for moment in longitudinal beams on skewed supports.

$M_{SCF} = 1-c_1(\tan\Theta)\verb|^|1.5$ 0.91172068

$c_1 = 0.25*(K_g/(12*L*t_s\verb|^|3))\verb|^|0.25*(S/L)\verb|^|0.5 =$ 0.07154691

gm = 0.677226118

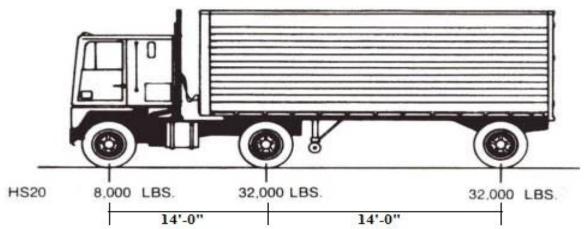
Use maximum g_m to be conservative, g_m = 0.677

Use maximum g_v to be conservative, g_v = 0.743

Compute Live Load Effects:

Maximum moment effects are estimated to occur with the design live load centered on the span.

Design Lane Load =	***0.64***	***k/ft***
Design Truck Load =		



Note:

Use as input for QuickBridge to apply load to bridge and calculate Moment and Shear Demand Envelopes. See 'Raw Demand Loads' tab for results.

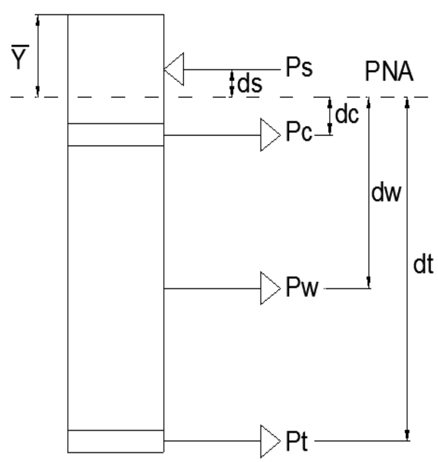
Note:

From hand calculations and Quick Bridge the Tandem Axles Moment did not control.

Apply Distribution Factors and Impact Factor

Distribution factors and impact factors are applied to moment and shear demand envelopes on 'Strength I Limit State' tab.

Compute Nominal Resistance of Sections:



$P_s = 0.85f'_c b_{eff} t_s =$ 2325.6 k

c_{rb} = distance from top of slab to center of bottom layer of longitudinal reinforcing steel.

crb = 8.8125

crb/ts = 0.92763158

Nominal Flexural Resistance, Mn:

PNA lies in Web :

$\bar{Y} = (D/2)[(P_t-P_c-P_s)/P_{w+1}]$

$M_p = (P_w/2D)*(\bar{Y}^2+(D-\bar{Y})^2)+[P_sd_s+P_cd_c+P_td_t]$

PNA lies in Top Flange :

$\bar{Y} = (tc/2)[(Pw+P_t-P_s)/Pc_{+1}]$

$M_p = (Pc/2tc)*(\bar{Y}^2+(tc-\bar{Y})^2)+[P_sd_s+P_wd_w+P_td_t]$

PNA lies in Concrete Deck :

$\bar{Y} = (t_s)[(P_c+P_w+P_t)/P_s]$

$M_p = (\bar{Y}^2*Ps/2t_s)+[P_cd_c+P_wd_w+P_td_t]$

If Dp < 0.1 Dt, then Mn = Mp

Otherwise, Mn = Mp(1.07-0.7*(Dp/Dt))

				If Pt+Pw>Pc+Ps PNA in Web		If Pt+Pw+Pc>Ps PNA in Top Flange		If Pc+Pw+Pt>(crb/ts)*Ps PNA in Deck	
Section Property	Pc = FyAc	Pw = FyAw	Pt = FyAt	Pt+Pw	Pc+Ps	Pc+Pw+Pt	Ps	Pc+Pw+Pt	(c_{rb}/t_s)*Ps
	k	k	k	k	k	k	k	k	k
1	630	810	792	1602	2955.6	2232	2325.6	2232	2157.3
2	630	810	1485	2295	2955.6	2925	2325.6	-	-
3	1260	810	1485	2295	3585.6	3555	2325.6	-	-
4	1260	810	2277	3087	3585.6	4347	2325.6	-	-
5	1890	810	2574	3384	4215.6	5274	2325.6	-	-

Section Property	Ȳ	dc	dw	dt	ds	*Mp*	Dp = Ȳ	$0.1D_t$ =	*Mn*
	in	in	in	in	in	*k-ft*	in	$0.1D_{comp}$	*k-ft*
1	9.11764706	0.819852941	31.2573529	61.7573529	-	*7076.84*	9.11764706	7.1375	*6939.4078*
2	0.41625	0.02125	30.45875	61.39625	5.16625	*10666.48*	0.41625	7.225	*10666.4823*
3	0.85375	0.02125	30.89625	61.83375	5.60375	*10869.39*	0.85375	7.3125	*10869.3948*
4	1.40375	-0.52875	30.34625	61.78375	6.15375	*15027.15*	1.40375	7.4125	*15027.1473*
5	2.0475	-0.735	30.5775	62.2025	6.7975	*16859.55*	2.0475	7.5375	*16859.5459*

Nominal Flexural Resistance with Repair Plate, Mn:

Plate Geometry	b	h	A
	21	0.75	15.75

New Section Property	At	y	Pc = FyAc	Pw = FyAw	Pt = FyAt	Pt+Pw	Pc+Ps	Pc+Pw+Pt	Ps
	in	in	k	k	k	k	k	k	k
1 w/ pl	37.75	0.875	630	810	1359	2169	630	2799	2325.6
2 w/ pl	57	1.3125	630	810	2052	2862	630	3492	2325.6
3 w/ pl	57	1.3125	1260	810	2052	2862	1260	4122	2325.6

New Section Property	Ȳ	dc	dw	dt	ds	*Mp*	Dp = Ȳ	0.1Dt =	*Mn*
	in	in	in	in	in	*k-ft*	in	0.1Dcomp	*k-ft*
1 w/ pl	1.94375	-1.50625	28.93125	59.43125	6.69375	*9024.86*	1.94375	7.1375	*9024.86016*
2 w/ pl	2.425	-1.9875	28.45	59.3875	7.175	*12517.93*	2.425	7.225	*12517.9313*
3 w/ pl	2.8625	-1.9875	28.8875	59.825	7.6125	*12656.73*	2.8625	7.3125	*12656.7281*

Nominal Shear Resistance, Vn:

Interior Panels:

Vn = Vp[C+(0.87(1-C)/sqrt(1+(do/D)^2)]

Vp = 0.58FyDtw = *469.8 k*

do = transverse stiffener spacing = 60 in

C = ratio of Shear Buckling to Shear Yield Strength

Section Property	Is $(2Dt_w)/(b_{fc}t_{fc}+b_{ft}t_{ft})<2.5$:	
1	1.13924051	
2	0.76595745	
3	0.59016393	< 2.5
4	0.45801527	
5	0.36290323	

C = 1.0	if D/tw < 1.12sqrt(E*k/Fyw) :	100.523076
C = (1.12/(D/tw))*sqrt(E*k/Fyw)	if D/tw < 1.40sqrt(E*k/Fyw) :	125.653845
C = (1.57/(D/tw)^2)*(E*k/Fyw)	if D/tw > 1.40sqrt(E*k/Fyw) :	125.653845

K = 5+5/(do/D)^2 = 10

D/tw = 160 Therefore: C = 0.4940321

Vn = 378.32755 k

Exterior Panels:

Vn = Vcr = CVp		C = ratio of Shear Buckling to Shear Yield Strength			
Vp =	469.8 k	C = 1.0	if D/tw < 1.12sqrt(E*k/Fyw) :	158.940939
do =	30 in	C = (1.12/(D/tw))*sqrt(E*k/Fyw)	if D/tw < 1.40sqrt(E*k/Fyw) :	198.676174
K =	25	C = (1.57/(D/tw)^2)*(E*k/Fyw)	if D/tw > 1.40sqrt(E*k/Fyw) :	198.676174

Therefore, C = 0.9933809

Vn = 466.69033 k

Moment

Section Property	Location ft	MDC k-ft	MDW k-ft	MLL+IM k-ft	Capacity k-ft
1	36.5	4714.86925	187.546125	3696.09429	6939.4078
2	38	4841.998	192.603	3792.61714	10666.4823
3	49.5	5641.88625	224.420625	4387.39714	10869.3948
4	52	5774.86	229.71	4482.69714	15027.1473
5	73.5	6315.23025	251.204625	4875.5	16859.5459

Shear

Location of Stiffener Change	VDC k	VDW k	VLL+IM k	Capacity k
End Panel (0 - 5'-0")	171.843	6.8355	47.04	466.690333
Interior Panel	163.868	6.324	129.617143	378.327547

General Load Rating Equation

RF = $(\varphi\varphi_c\varphi_s R_n - \gamma_{DC}DC - \gamma_{DW}DW)/(\gamma_L(LL+IM))$

Strength I Limit State

Inventory		Operating		Distribution Factors		Impact Factor	
γ_{DC}	1.25	γ_{DC}	1.25	g_m	0.677	IM	1.33
γ_{DW}	1.5	γ_{DW}	1.5	g_v	0.743		
γ_{LL}	1.75	γ_{LL}	1.35				

Note: See 'Strength I Limit State' tab for plots

Rating Factors

Section Property	Moment	
	Inventory	Operating
1	0.17	0.23
2	0.69	1.25
3	0.13	0.87
4	2.76	1.82
5	2.85	1.93
Section Property	**Shear**	
	Inventory	Operating
End Panel	3.95	5.12
Interior Panel	0.97	1.26

Service II Limit State

Inventory		Operating		Distribution Factors		Impact Factor	
γ_{DC}	1	γ_{DC}	1	g_m	0.677	IM	1.33
γ_{LL}	1.3	γ_{LL}	1	g_v	0.743		

$f_R = 0.95R_hF_{yf}$ = 34.2 ksi

Rh : 1 for homogenuous sections

Factored Live Load and Dead Load Stresses

Section Property	Inventory		Operating	
	$\gamma_{DC} f_D$	$\gamma_{LL} f_{LL+IM}$	$\gamma_{DC} f_D$	$\gamma_{LL} f_{LL+IM}$
1	36.712	22.014	36.712	16.934
2	23.086	13.625	23.086	10.481
3	25.451	15.762	25.451	12.125
4	18.505	16.105	18.505	12.388
5	17.385	10.843	17.385	8.340

Rating Factors

Section Property	Moment	
	Inventory	Operating
1	-0.114	-0.148
2	0.816	1.060
3	0.555	0.722
4	0.975	1.267
5	1.551	2.016

Summary of Rating Factor for Exterior Girders

Moment

Section Property	**Strength I Limit State**		**Service II Limit State**	
	Inventory	**Operating**	**Inventory**	**Operating**
1	***0.17***	***0.23***	***0.00***	***0.00***
2	***0.69***	***1.25***	***0.82***	***1.06***
3	***0.13***	***0.87***	***0.56***	***0.72***
4	***2.76***	***1.82***	***0.97***	***1.27***
5	***2.85***	***1.93***	***1.55***	***2.02***

Shear

Location	**Inventory**	**Operating**
End Panels	***3.95***	***5.12***
Interior Panels	***0.97***	***1.26***

Exterior Girder (G6)	**Strength I Limit State**		**Service II Limit State**	
	Inventory	Operating	Inventory	Operating
Moment RF	***0.13***	***0.23***	***0.00***	***0.00***
Shear RF	***0.97***	***1.26***	-	-