AASHTO T-3 TRIAL DESIGN BRIDGE DESCRIPTION

State: *Illinois*

Trial Design Designation: *IL-3*

Bridge Name: ______________________________

Superstructure Type: *Simply supported steel plate girder composite with a concrete deck*

Span Length(s): *134.5 ft. – 167.3 ft. – 134.5 ft. (total 436.3 ft.)*

Substructure Type: *Tapered concrete pier wall supported on a pile cap at the bents*

Foundation: *Steel piles at abutments and bents*

Abutments: *Seat type supported on steel piles*

Seismic Design Category (SDC): *"C"*

Seismic Design Strategy (Type 1, 2 or 3): *Type 1*

Design Spectral Acceleration at 1-second Period (S_{D1}): *0.487g*

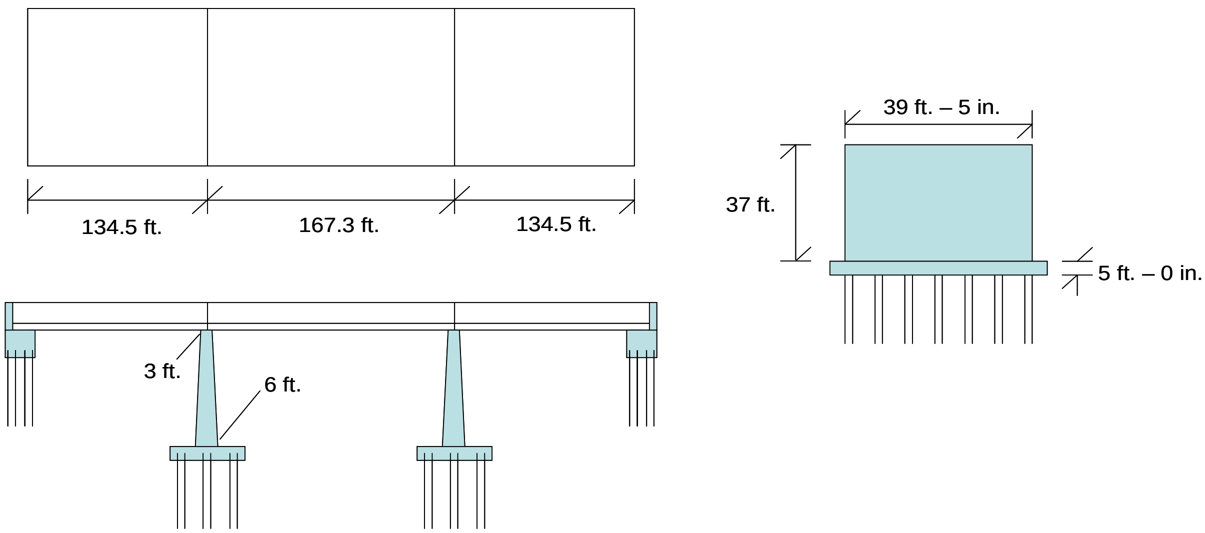
Additional Description (Optional): ______________________________

Bridge No.: 3 Transverse Seismic Calculations

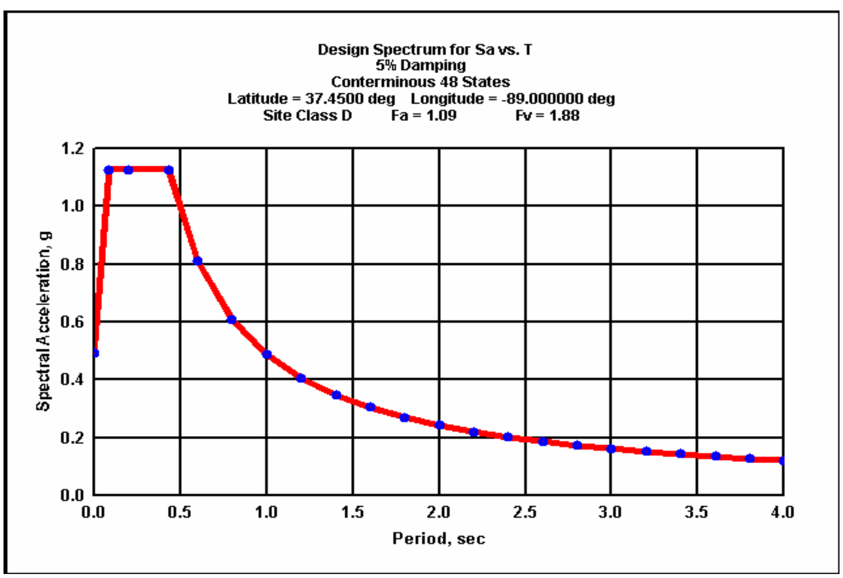
Description: 3-Span Plate Girder with Solid Wall Piers and Steel Piles at Piers and Abutments

(Skew Simplified to 0 degrees)

(Pile Design Method Similar for Imbsen and LRFD, therefore not shown - See Bridge No. 2)



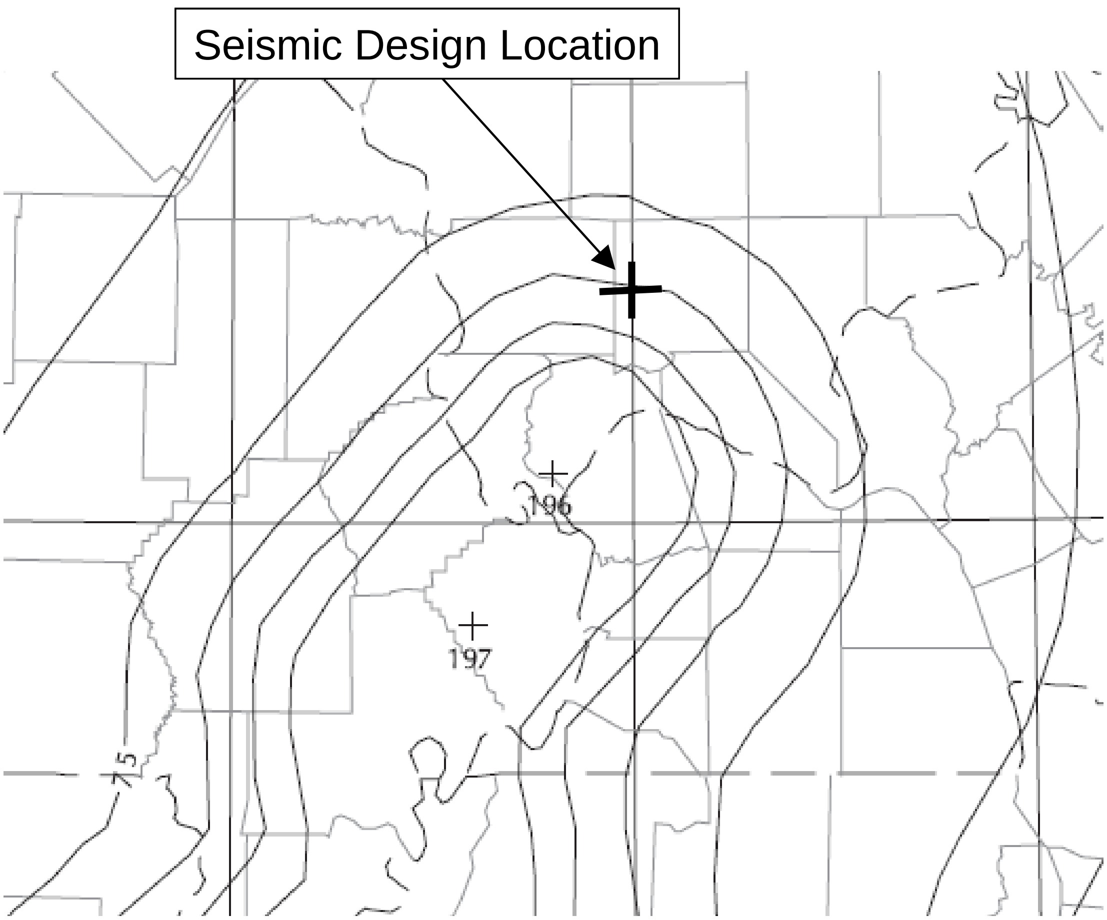
Design Response Specturm



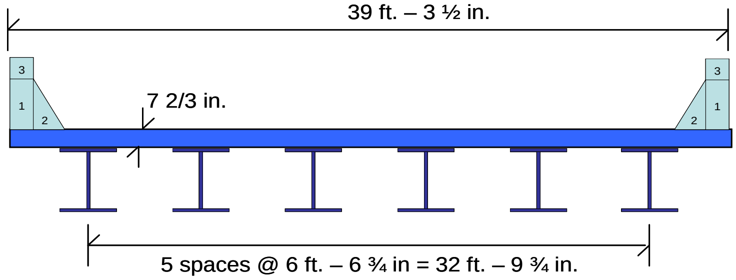
SDC and Other Pertinent Design Spectrum Information

S_{D1} =	0.487 g	Seismic Design Category C		
S_{DS} =	1.128 g	0.3g <=	0.487g	< 0.5 g
End Plateau	0.432 Seconds	(Imbsen Table 3.5-1)		

Chosen Location for Bridge Study and 0.2 Second 1000 year Accleration Map (2006 Map)



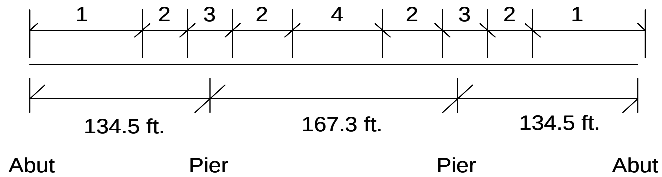
Simple Cross Section of Deck



Weight of Super and Sub Structure for Seismic Calculations

Beams	Plate Girder	
No. Beams	6.00	
Beam Spacing	6.56	ft.

Girder Section



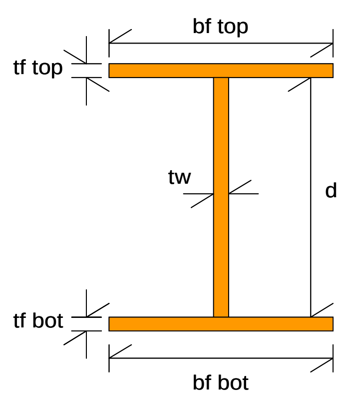
4 Plate Girder Sections Along 3 Spans

Girder Section	1	
bf top	11.81	in
tf top	0.79	in
bf bot	11.81	in
tf bot	0.98	in
d	56.10	in
tw	0.43	in
Area	45.22	in^2
1 Bm. Weight	0.15	k/ft
6 Bm. Weight	0.92	k/ft

Girder Section Lengths

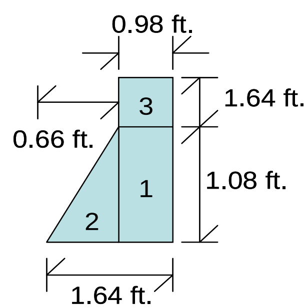
1: 105 ft. (Spans 1 and 3)
2: 19.7 ft. (Spans 1 and 3)
3: 19.6 ft. (Spans 1-2, and Spans 2-3 Over Piers
2: 27.9 ft. (Span 2)
4: 91.9 ft. (Span 2)

Girder Section	2	
bf top	11.81	in
tf top	1.57	in
bf bot	11.81	in
tf bot	1.57	in
d	56.10	in
tw	0.55	in
Area	68.12	in^2
1 Bm. Weight	0.23	k/ft
6 Bm. Weight	1.39	k/ft



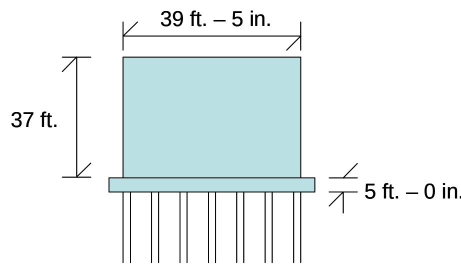
Weight of Super and Sub Structure for Seismic Calculations (Cont.)

Girder Section	3	
bf top	11.81	in
tf top	2.76	in
bf bot	11.81	in
tf bot	2.76	in
d	56.10	in
tw	0.55	in
Area	96.02	in^2
1 Bm. Weight	0.33	k/ft
6 Bm. Weight	1.96	k/ft
Girder Section	4	
bf top	11.81	in
tf top	0.79	in
bf bot	11.81	in
tf bot	0.79	in
d	56.10	in
tw	0.43	in
Area	42.90	in^2
1 Bm. Weight	0.15	k/ft
6 Bm. Weight	0.88	k/ft
Total Weight of Beams		
Tot. Len. Sec. 1	210	ft
Tot. Len. Sec. 2	95.2	ft
Tot. Len. Sec. 3	39.2	ft
Tot. Len. Sec. 4	91.9	ft
Tot. Weight	484	kips
Th. of Slab	7.68	in.
Th. of Surface	0.00	in.
Width	39.30	ft.
Wt. of Slab	3.77	k/ft.
Parapet		
Area 1	1.06	ft^2
Area 2	0.36	ft^2
Area 3	1.61	ft^2
Total Area	3.02	ft^2
Wt. of Parapet	0.45	k/ft.
Cross Frames And Bracing (est. as 5%	5.00	%
of Steel)	24.18	kips
Steel Parapet Rail (est. as 0%	0.00	%
of Steel)	0.00	k/ft



Weight of Super and Sub Structure for Seismic Calculations (Cont.)

Cap Beam		
Length	0.00	ft.
Width	0.00	ft.
Height	0.00	ft.
Wt. of 1 Beam	0.00	kips
Wt. of 2 Beams	0.00	kips
1/2 of Walls		
Avg. Width	3.80	ft.
Height	18.50	ft.
Length	39.42	ft.
Wt. of 1 Wall	415.68	kips
No. of Walls	2	
Wt. of 2 Walls	831.37	kips
Total Wt. for Seismic Calculations		
Super Length	436.3	ft.
Total Weight	3380	kips



Transverse Period Calculation

Pier Piles Stiffness (Wall is Rigid)

$$k_p = \frac{12 \times E_s \times I_s}{h_c^3}$$

Pile Type	HP 14 X 102	
E_s	29000	ksi
I_s	380	in^4
No. Piles	39	
h_c	100.8	inches (depth of fixity)
k_p	129	k/in
k_{pier}	5036	k/in

I of Superstructure Transverse

$$Area_{Steel\ Beam} = \frac{n \times Area}{2}$$

Transf. Area with 50% Shear Lag

E_s	29000	ksi
f'_c	3500	psi
E_c	3372	ksi
n (mod. Ratio)	8.6	
I_{slab}	67125719.38	in^4
$Area_{Parapet}$	435.2	in^2
Area 1 Beam	54.3	in^2 (A weighted average based upon length in Bridge)
$Area_{Steel\ Bm}$	233.5	in^2 (Transformed)

Transverse Period Calculation (Cont.)

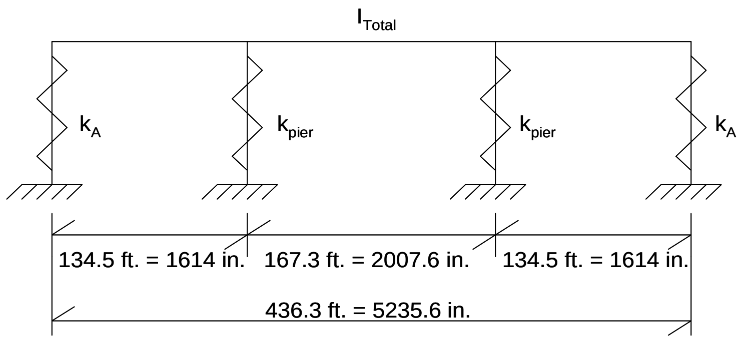
Momen of Inertia of Superstructure Table

	No.	I_0 (In^4)	A (in^2)	x bar (in)	A (x bar)^2 (in^4)	I (in^4)
Parapet	2	----	435.168	228	22621773.31	45243546.6
Slab	1	67125719.38	----	----	67125719.38	67125719.4
Steel 1	2	----	233.5	39.4	362405.769	724811.538
Steel 2	2	----	233.5	118.1	3256135.386	6512270.77
Steel 3	2	----	233.5	196.9	9050948.443	18101896.9

I_{Total} 1.377E+08 in^4

A_{Total} 5892 in^2

Model the Bridge Transversely with I_{total} of the Superstr. and Springs for the Abutment Piles and Pier Piles



Estimate the Abutment Pile Transverse Stiffness

k_A 1750 k/in

Solve for the Displacement from Simple Model Above as Outlined Below for a 1 k/in Uniform Load

Find the Deflection at the Center of the Bridge Assuming No Piers and Infinitely Stiff Abutments

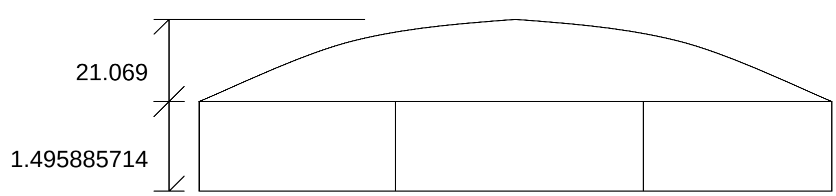
w	1	k/in
L	5235.6	in
E_c	3372	ksi
I_{Total}	1.377E+08	in^4
δ_c	21.069	in

$$\delta_C = \frac{5 \times w \times L^4}{384 \times E_c \times I_{Total}}$$

Find the Deflection Along the Bridge Assuming an Infinitely Stiff Superstr., No Piers, and Abut. Springs

w	1	k/in
L	5235.6	in
k_A	1750	k/in
δ_e	1.495885714	in

$$\delta_e = \frac{\frac{w \times L}{2}}{k_A}$$

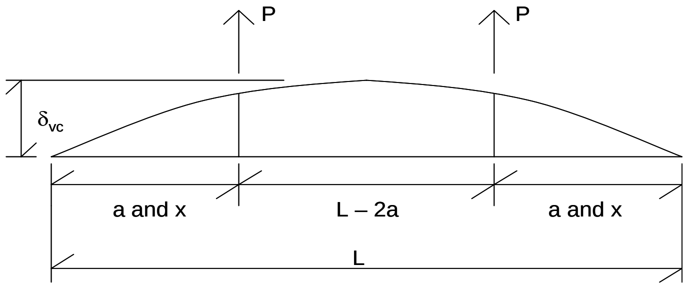


Transverse Period Calculation (Cont.)

Find the Total Estimated Displacement Without the Piers

$\delta_T = \delta_c + \delta_e$ 22.564 in

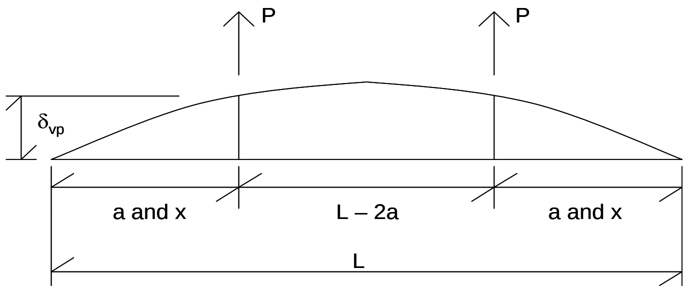
Find the Estimated Deflection at the Center of the Bridge for a Two Point Load at Piers with Infinitely Stiff Abuts.
In Terms of an Applied Load "P".



L	5235.6	in
x	1614	in
a	1614	in
E_c	3372	ksi
I_{Total}	1.377E+08	in^4
δ_{vc}	0.0104001	P

$$\delta_{vc} = \frac{P \times a}{24 \times E_c \times I_{Total}}\left(3 \times L^2 - 4 \times a^2\right)$$

Find the Estimated Deflection at the Pier of the Bridge for a Two Point Load at Piers with Infinitely Stiff Abuts.
In Terms of an Applied Load "P".

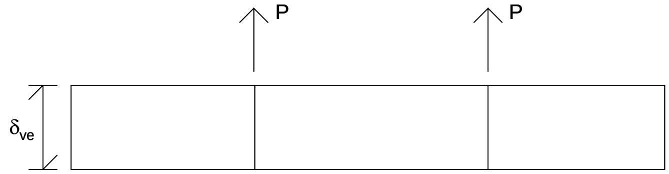


L	5235.6	in
x	1614	in
a	1614	in
E_c	3372	ksi
I_{Total}	1.377E+08	in^4
δ_{vp}	0.0086490	P

$$\delta_{vp} = \frac{P \times x}{6 \times E_c \times I_{Total}}\left(3 \times L \times a - 3 \times a^2 - x^2\right)$$

Transverse Period Calculation (Cont.)

Find the Estimated Uniform Deflection for a Two Point Load at Piers with Springs at Abuts.
In Terms of an Applied Load "P".



k_A	1750	k/in
δ_{ve}	0.000571429	P

$$\delta_{ve} = P / k_A$$

Find the Fraction of the Estimated Pier Deflection at the Piers Versus that at Center Span

δ_{vc}	0.0104001	P
δ_{vp}	0.0086490	P
δ_{ve}	0.000571429	P
fr	0.840	

$$fr = \frac{\delta_{ve} + \delta_{vp}}{\delta_{ve} + \delta_{vc}}$$

Find the Pier Reactions (V_0) in Terms of δ_{max}, the Actual Estimated Deflection of the Bridge

fr	0.840	
k_{pier}	5036	k/in
V_0	4231.9	δ_{max}

$$V_0 = fr \times \delta_{max} \times k_{pier}$$

Solve for δ_{max}:

$\delta_{ve} + \delta_{vc}$ = 0.010971 P

Set:
$P = V_0$ = 4231.9 δ_{max}

Therefore:
$\delta_{ve} + \delta_{vc}$ = 0.010971 x 4231.9 x δ_{max}
$\delta_{ve} + \delta_{vc}$ = 46.429854 δ_{max}

And:

The Actual Estimated Delfection of the Bridge is the Deflection Without Piers Minus the Contribution with the Piers

δ_{max} = δ_T - 46.429854 δ_{max}
δ_{max} = 22.564 / 47.429854
δ_{max} = 0.476 in

Solve for the "Equivalent Stiffness" of the Bridge in the Transverse Direction

w	1	k/in
L	5235.6	in
δ_{max}	0.476	in
k_{Bridge}	11005	k/in

$$k_{Bridge} = \frac{w \times L}{\delta_{max}}$$

Solve for the Period T

Tot. Weight (W)	3380	kips
g	386.4	in/sec^2
k_{Bridge}	11005.067	k/in
T	0.18	seconds

$$T = 2\pi\sqrt{\frac{W}{g \times k_{Bridge}}}$$

Transverse Seismic Force On Superstructure (Base Shear)

0.18 < 0.432 seconds

Therefore: 112.8% of the Mass is "Effective" and the Total Seismic Load in the Transverse Direction is:

1.128 x 3380 = 3813 kips (Base Shear)

or:
3813 / 5235.6 = 0.73 k/in (Base Shear)

Transverse Seismic Force on Pier (Base Shear)

$V_{Base\ Shear\ P}$ = 0.73 / 1 x 0.476 x 4231.9

$V_{Base\ Shear\ P}$ = 1466 kips

Transverse Seismic Force on Abutments (Base Shear)

$V_{Base\ Shear\ A}$ = 3813 / 2 - 1466

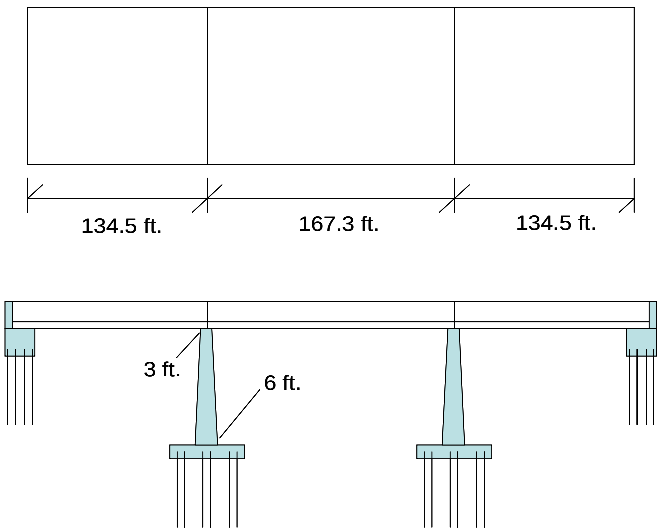
$V_{Base\ Shear\ A}$ = 440 kips

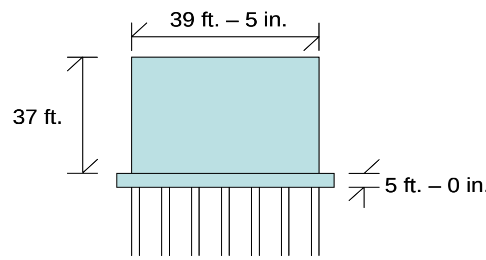
Transverse Seismic Displacement of Pier

δ_{PierT} = 1466 / 5036 = 0.29 in.

Bridge No.: 3 **Longitudinal Seismic Calculations**

Description: 3-Span Plate Girder with Solid Wall Piers and Steel Piles at Piers and Abutments (Skew Simplified to 0 degrees)





Weight of Superstructure

Total Weight: 3380 kips

Longitudinal Period Calculation

Pier Stiffness Longitudinal Direction

$$k_c = \frac{3 \times E_c \times I_c}{h_c^3} \qquad E_c = \frac{57000\sqrt{f_c'}}{1000} \qquad \theta_{TC} = \frac{P \times h_c^2}{2 \times E_c \times I_c}$$

Contribution from Wall

f'_c	3500	psi
E_c	3372	ksi
Width	39.42	ft
I_c	8514000	in^4
$I_c/2$	4257000	in^4 Half Cracked Section
No. Walls	1	
$1 \times I_c/2$	4257000	in^4 Half Cracked Section
h_c	444	inches (clear column height)
k_c	492	k/in
k_{pier}	492	k/in

Eq. Thickness for Stiffness Calc. 5 ft.

Contribution from Cap Beam (Stiffness is infinite but it deflects as a rigid body and contributes to pier stiffness)

Find the estimated deflection at the top of column for a load "P"

δ_{TC} = P / 492 in

Find the estimated rotation at the top of column for a load "P"

θ_{TC} = P / 145638.6 radians

Cap height 0.000001 in

Find the added estimated deflection at the top of the pier

δ_A = Cap hght x θ_{TC} = P / 1.5E+11 in

Find the total estimated delfection at the top of the pier

δ_{TD} = δ_A + δ_{TC} = P / 492.0 in

So, the stiffness of a pier is:

k_{pier} = 492 k/in

Find the Mass of the Superstructure

M = 3380 / 386.4 = 8.75 k-sec^2/in

Find the period T:

$$T = 2\pi\sqrt{\frac{M}{2 \times k_{pier}}}$$

T = 0.59 sec.

Longitudinal Seismic Force On Superstructure (Base Shear)

0.59 > 0.432 Seconds

Therefore: 82% of the Mass is "Effective" and the Total Seismic Load in the Longitudinal Direction is:

0.82 x 3380 = 2779 kips (Base Shear)

Longitudinal Seismic Force On Each Pier assuming the abutments don't contribute (Base Shear)

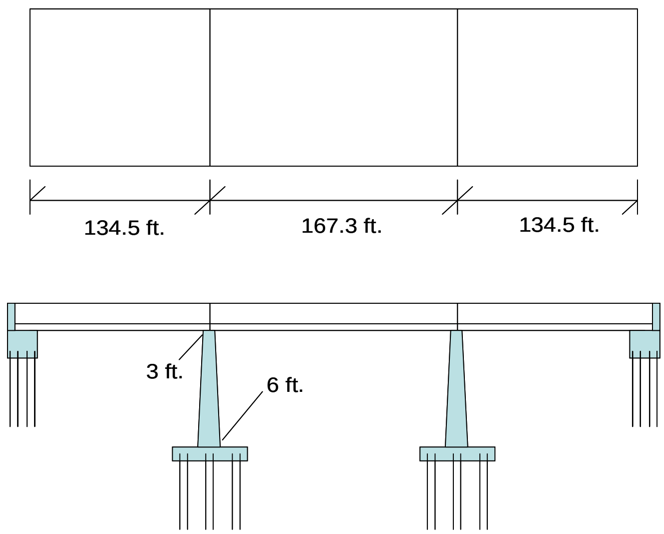
2779	/	2	=	1389	kips (Base Shear)

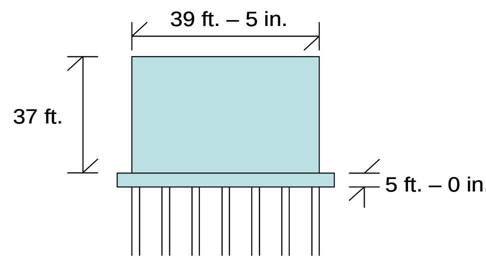
Longitudinal Seismic Displacement of Pier

δ_{PierL} =	1389	/	492.0	=	2.82	in.

Bridge No.: 3 **Force Based Wall Design and Displacement Check**

Description 3-Span Plate Girder with Solid Wall Piers and Steel Piles at Piers and Abutments
(Skew Simplified to 0 degrees)





Wall Forces

Dead

Dead Load Total	3380	kips
Bridge Length	436.3	ft.
Dead Load per ft.	7.75	k/ft
Dead Load per pier	1299.4	kips
No. of Walls	1	
Dead Ld. Per Wall	1299.4	kips
Plus 1/2 Wall	574.0	kips
Design Dead	1873.4	kips

$$\text{DL per pier} = w \times \left(\frac{5}{8} L_{OuterSpan} + \frac{1}{2} L_{CenterSpan} \right)$$

$$w = \text{Dead Load per ft.}$$

Transverse Shear and Moment (Simple Cantilever/Shear Wall Statics)

S_P (Pier Base Shear)	1466	kips
Col arm (h)	37.00	ft.
$M_{WallBot}$	54252.0	k-ft.

Longitudinal Shear and Moment (Simple Cantilever Statics)

S_L (Pier Base Shear)	1389	kips
Col arm (h)	37.00	ft.
$M_{WallBot}$	51407.9	k-ft.

Orthogonally Combined Load Cases

Transverse Dominant - Load Case 1

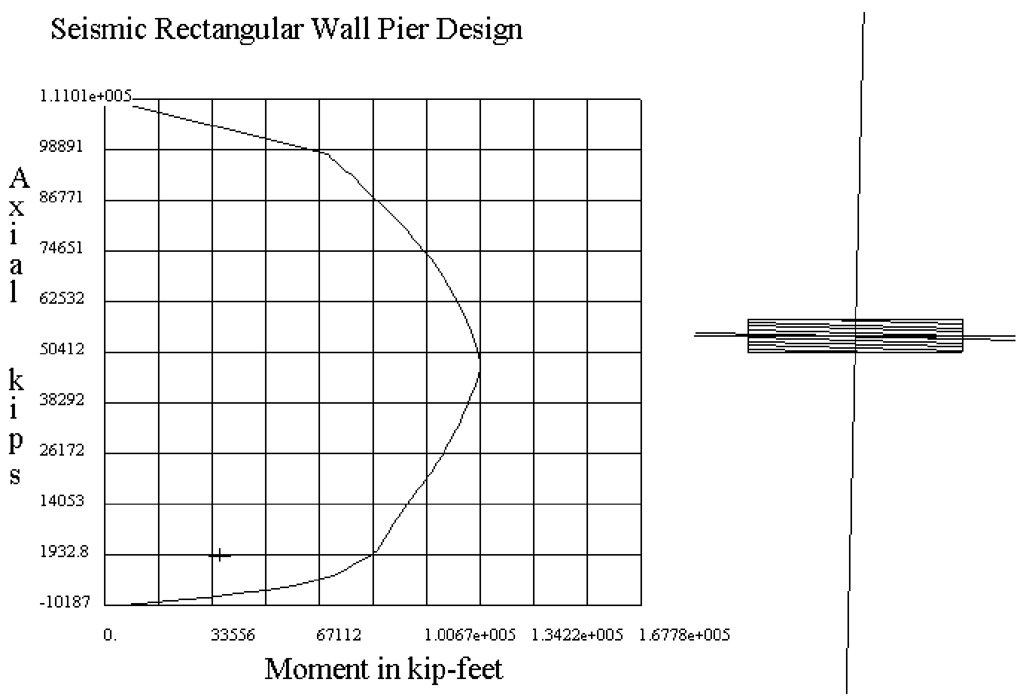
P =	1873.4	kips						
M_T =	54252.0	/	1.5 (R-factor)			=	36168	k-ft
M_L =	51407.9	/	1.5 (R-factor)	x	0.3	=	10282	k-ft
$M_{Combined}$ =							37601	k-ft
λ =	$\tan^{-1}(M_T/M_L)$					=	74.1	degrees

Longitudinal Dominant - Load Case 2 - Governs the Design

P =	1873.4	kips						
M_T =	54252.0	/	1.5 (R-factor)	x	0.3	=	10850	k-ft
M_L =	51407.9	/	1.5 (R-factor)			=	34272	k-ft
$M_{Combined}$ =							35949	k-ft
λ =	$\tan^{-1}(M_T/M_L)$						17.6	degrees
$\theta \cong$							0.5 - 1.5	degrees

Wall Vertical Reinforcement Design - "Nominal Provided"

Pier is Adequate with or without R-Factors Applied (i.e. "not as a ductile or seismic column")



Vertical Reinforcement

Bars:	#9
No.	170
No. Transverse Faces	75
No. Longitudial Faces	10
ρ_v	0.0053 > 0.0025 (LRFD 5.10.11.4.2 and Imbsen 8.17 - Provisions are Identical)

Displacement Check

We interpret this as a way to check deflections for walls. Imbsen provsions are either somewhat incomplete or unclear on this.

Scratch Calculation Table

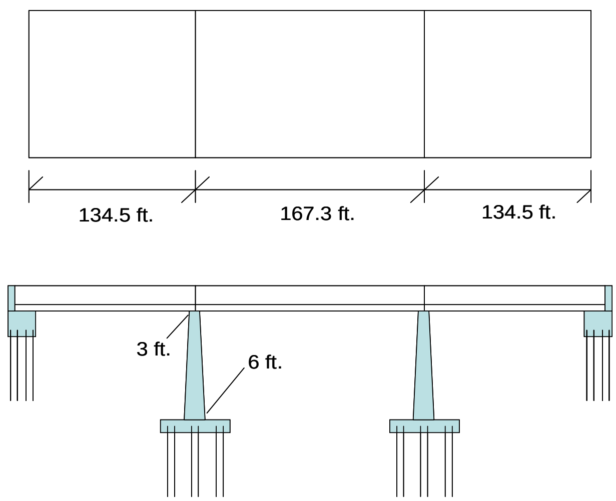
Imbsen Section 4.8					
Wall Height (ft)	Wall Width (ft)	H/100 (in)	x Fixed-Pinned	Delta Calc. Fixed - Pinned (in)	Delta Allow. Fixed - Pinned (in)
37	5.00	4.44	0.14	15.20	15.20

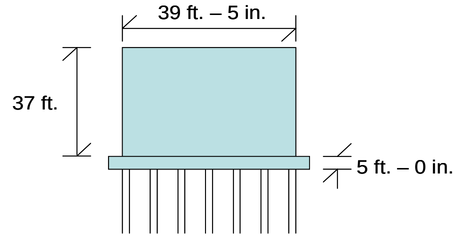
Longitudinal Direction

	Imbsen Fig. 5.4				
Wall Height (ft.)	Steel Ratio (Ast/Ag)	Fraction of Ig	Long. Period (Sec.)	Long. Deflection (in)	Long. Allowable Deflection (in)
37	0.005	?	0.59	2.82	15.20

Bridge No. 3 **Design for Shear**

Descriptior 3-Span Plate Girder with Solid Wall Piers and Steel Piles at Piers and Abutments
(Skew Simplified to 0 degrees)





Transverse Shear

S_P (Pier Base Shear) 1466 kips

Longitudinal Shear

S_L (Pier Base Shear) 1389 kips

Orthogonally Combined Load Cases (Elastic)

Transverse Dominant - Load Case 1

$S_{Combined}$ = 1524 kips

Longitudinal Dominant - Load Case 2

$S_{Combined}$ = 1457 kips

Shear Strength

LRFD 5.10.11.4.2 and Imbsen 8.8.3 are Identical
Check to see that Minimum Shear Reinforcement is Adequate

Take the Lesser of:

$V_r = 0.253\sqrt{f_c'}bd =$ 13291 kips

or

$V_r = 0.9\left[0.063\sqrt{f_c'} + \rho_h f_y\right]bd =$ 6769 kips

Minimum reinforcement is Adequate.

ρ_h set to:	minimun of 0.0025	
b set to	60	in
d set to	468	in
f'c	3.5	ksi
fy	60	ksi

A "short" spacing of bars may be used near the base of wall
if confinement or plastic hinging is a potential concern in the
longitudinal direction.

Bridge No.: 3 Seat Width Requirements

Descriptior 3-Span Plate Girder with Solid Wall Piers and Steel Piles at Piers and Abutments
(Skew Simplified to 0 degrees)

Seat Width Requirements

Compare Imbsen with NCHRP 12-49 and the Current LRFD Code
LRFD calibrated for 500 years and 12-49 calibrated to 1.0 Sec. Accel. with improved Soil Coef.
so it is "return period independent".

NCHRP 12-49

$$N = \left[0.10 + 0.0017L + 0.007H + 0.05\sqrt{H}\sqrt{1 + \left(2\frac{B}{L}\right)^2}\right](1 + 1.25F_v S_1) \quad \text{(metric)}$$

L =	436.3	ft	or	132.98	meters
FvS1 =				0.487	g
H =	37	ft	or	11.28	meters
B =	39.29	ft	or	11.98	meters

Imbsen 4.12.2

$$N = (4 + \Delta_{ot} + 1.65\Delta_{eq}) \geq 12$$

Δot =	0.01L =	4.363	inches
Δeq =		2.82	inches

LRFD 4.7.4.4

$$N = 8 + 0.02L + 0.08H$$

L =	436.3	ft	%N for Cat. C = 150
H =	37	ft	

Summary of Seat Width Requirements (NCHRP 12-49, Imbsen and LRFD) for 16 Cases

	Imbsen Fig. 5.4						
Wall Height (ft.)	Steel Ratio (Ast/Ag)	Fraction of Ig	Long. Deflection (in)	Imbsen 4.12.2 Calc. Seat (in)	Imbsen 4.12.2 Req. Seat (in)	NCHRP 12-49 Req. Seat (in)	Current LRFD Req. Seat (in)
37	0.005	?	2.82	10.7	12.0	36.5	29.5