Appendix 4

Strut Sectional Checks

3	B6.3	18.03	22.60	37	8.03	0.25	458	492
4	B6.4	61.81	22.60	36	7.81	0.25	1570	492
5	B5.1	-52.83	28.19	36	7.81	0.43	-1342	634
6	B5.2	-24.49	28.19	37	8.03	0.43	-622	634
7	B5.3	16.77	28.19	37	8.03	0.43	426	634
8	B5.4	60.55	28.19	36	7.81	0.43	1538	634
9	B4.1	-53.46	35.59	37	8.03	0.48	-1358	822
10	B4.2	-25.12	35.59	37	8.03	0.48	-638	822
11	B4.3	17.40	35.59	37	8.03	0.48	442	822
12	B4.4	61.18	35.59	37	8.03	0.48	1554	822
13	T3.1	-54.09	206.02	36	7.81	0.21	-1374	5175
14	T3.2	-25.75	206.02	37	8.03	0.21	-654	5175
15	T3.3	3.86	206.02	37	8.03	0.21	98	5175
16	T3.4	63.11	206.02	36	7.81	0.21	1603	5175
17	T2.1	-39.29	211.61	37	8.03	0.12	-998	5317
18	T2.2	-10.94	211.61	37	8.03	0.12	-278	5317
19	T2.3	17.40	211.61	37	8.03	0.12	442	5317
20	T2.4	45.75	211.61	37	8.03	0.12	1162	5317
21	T1.1	-52.83	211.61	36	7.81	0.00	-1342	5317
22	T1.2	-24.49	211.61	37	8.03	0.00	-622	5317
23	T1.3	2.60	211.61	37	8.03	0.00	66	5317
24	T1.4	61.85	211.61	36	7.81	0.00	1571	5317
					190.96	0.25		
	Centroids =	-0.58	119.29	in				
	Eccentricity =	-0.58	1.18	in				

- *Longitudinal reinforcement locations:*

**from bottom of gross section

No.	Name	db (in)	y**(in)	Qty	Area (in2)	db (mm)	y (mm)
1	B1	2.24	6.44	16	63.28	57	164
2	B2	2.24	12.31	14	55.37	57	313
3	B3	2.24	18.19	14	55.37	57	462
4	B4	2.24	24.07	6	23.73	57	611
5	B5	2.24	29.95	6	23.73	57	761
6	B6	2.24	35.82	6	23.73	57	910
7	B7	2.24	41.70	6	23.73	57	1059
8	B8	2.24	47.58	14	55.37	57	1209
9	B9	2.24	53.46	14	55.37	57	1358
10	B10	2.24	59.33	14	55.37	57	1507
11	B11	2.24	65.21	14	55.37	57	1656
12	M1	1.69	71.09	6	13.51	43	1806
13	M2	1.69	76.97	6	13.51	43	1955
14	M3	1.69	82.85	6	13.51	43	2104
15	M4	1.69	88.72	6	13.51	43	2254
16	M5	1.69	94.60	6	13.51	43	2403
17	M6	1.69	100.48	6	13.51	43	2552
18	M7	1.69	106.36	6	13.51	43	2701
19	M8	1.69	112.23	6	13.51	43	2851
20	M9	1.69	118.11	6	13.51	43	3000
21	M10	1.69	123.99	6	13.51	43	3149
22	M11	1.69	129.87	6	13.51	43	3299
23	M12	1.69	135.74	6	13.51	43	3448
24	M13	1.69	141.62	6	13.51	43	3597
25	M14	1.69	147.50	6	13.51	43	3746
26	M15	1.69	153.38	6	13.51	43	3896
27	M16	1.69	159.25	6	13.51	43	4045
28	T1	2.24	165.13	13	51.42	57	4194
29	T2	2.24	171.01	5	19.78	57	4344
30	M17	1.69	176.89	6	13.51	43	4493
31	M18	1.69	182.76	6	13.51	43	4642
32	M19	1.69	188.64	6	13.51	43	4791
33	M20	1.69	194.52	6	13.51	43	4941
34	M21	1.69	200.40	6	13.51	43	5090
35	M22	1.69	206.27	6	13.51	43	5239
36	T3	2.24	212.15	20	79.10	57	5389

0 Specifications: AASHTO LRFD Design Specs. 2012

1 Material properties:

				Metric	
- Concrete density:	Wc =	0.15	kcf	24	KN/m3
- Concrete 28-day compressive strength:	f'c =	8	ksi	55	MPa
- Reinforcement strength:	fy =	60	ksi	414	MPa
- Prestressing steel strand:	Diameter =	0.60	in	15	mm
Strand cross-sectional area:	A =	0.217	in2	140	mm2
Modulus of Elasticity:	Ep =	28478	ksi	196500	MPa
Ultimate tensile strength:	Fpu =	58.43	kips	260	KN
	fpu =	269	ksi	1858	MPa
Minimum yield strength:	Fpy =	52.58	kips	234	KN
	fpy =	90%	fpu		
Maximum stressing force per strand:	Fp max =	43.82	kips	195	KN
	fp jacking =	75%	fpu		
% prestressing stress after transfer with Max losses:	fpt =	67%	fpu		
% Effective prestressing stress considering Max losses:	fpe =	63%	fpu		
Effective prestressing strain considering Max losses:	ε_{po} =	0.00592			
Wedge seating:	Δ =	0.39	in	10	mm
Friction coefficient:	μ =	0.15	/rad	0.15	/rad
Wobble coefficient:	k =	0.000201	/ft	0.00066	/m
- Tendons:					
Duct diameter:	OD =	5.51	in	140	mm
Location of tendon CG with respect to duct CG	Z =	0.47	in	12	mm

2 Bearing location:

- Eccentricity between shaft and top of pier cap:	e1 =	39.17	in	995	mm

3 Loads:

- Case	Maximum	Bearing: Mux max			
		PT + EQ + DL		PT + EQ + DL	
- *Loading effects at the section of maximum effect:*					
Axial (if <0 → Tension)	Pu =	37045	kips	165	MN
In-plane shear	Vuy =	15649	kips	70	MN
Out-of-plane shear	Vux =	0	kips	0	MN
In-plane-bending moment: (if >0 → Top fiber in tension)	Mux =	692959	kip-ft	941	MN-m
Out-of-plane bending moment	Muy =	2014	kip-ft	3	MN-m
Torsion	Tu =	0	kip-ft	0	MN-m

4 Pier cap section properties:

- Section No.		1			
	Location =	Bearing			
- *Dimensions:*					
Location from cap end	x =	16.59	ft	5058	mm
Width	B =	175.3	167 in	4453	mm
Depth	H =	236.2	228 in	6000	mm
Concrete cover:	Top =	4.33	in	110	mm
	Bottom =	4.33	in	110	mm
	Lateral =	4.33	in	110	mm

- *Section properties:*		Gross	Eff at ε_{pu}	
Area	A =	41414	37924	in2
Centroid (with respect to left bottom corner)	yc =	118.110	114	in
	xc =	88	83	in
Moment of inertia	Ix =	192573235	163652090	in4
	Iy =	106074258	87775676	in4
Section modulus	Sx =	1630453	1438326	in3
	Sy =	1210084	1053377	in3

- *Longitudinal tendon locations:*

*from section centerline
**from bottom of gross section

No.	Name	x* (in)	y**(in)	Strands	Area (in2)	α (rad)	x (mm)	y (mm)
1	B6.1	-54.09	22.60	36	7.81	0.25	-1374	492
2	B6.2	-25.75	22.60	37	8.03	0.25	-654	492

8	B5.4	23.86	0.00324	92.13	720	-90	-5393
9	B4.1	31.26	0.00364	103.71	833	-83	-5726
10	B4.2	31.26	0.00364	103.71	833	-83	-5726
11	B4.3	31.26	0.00364	103.71	833	-83	-5726
12	B4.4	31.26	0.00364	103.71	833	-83	-5726
13	T3.1	201.69	0.01301	262.59	2051	88	15028
14	T3.2	201.69	0.01301	262.59	2108	88	15446
15	T3.3	201.69	0.01301	262.59	2108	88	15446
16	T3.4	201.69	0.01301	262.59	2051	88	15028
17	T2.1	207.28	0.01331	262.91	2111	94	16448
18	T2.2	207.28	0.01331	262.91	2111	94	16448
19	T2.3	207.28	0.01331	262.91	2111	94	16448
20	T2.4	207.28	0.01331	262.91	2111	94	16448
21	T1.1	207.28	0.01331	262.91	2054	94	16004
22	T1.2	207.28	0.01331	262.91	2111	94	16448
23	T1.3	207.28	0.01331	262.91	2111	94	16448
24	T1.4	207.28	0.01331	262.91	2054	94	16004
					33984		125840

Reinforcement forces:

No.	Name	yeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B1	2.11	-0.00388	-60.00	-3797	-112	35335
2	B2	7.98	-0.00356	-60.00	-3322	-106	29291
3	B3	13.86	-0.00324	-60.00	-3322	-100	27664
4	B4	19.74	-0.00292	-60.00	-1424	-94	11159
5	B5	25.62	-0.00259	-60.00	-1424	-88	10461
6	B6	31.49	-0.00227	-60.00	-1424	-82	9764
7	B7	37.37	-0.00195	-56.46	-1340	-76	8531
8	B8	43.25	-0.00162	-47.09	-2608	-71	15327
9	B9	49.13	-0.00130	-37.73	-2089	-65	11256
10	B10	55.00	-0.00098	-28.36	-1571	-59	7693
11	B11	60.88	-0.00066	-19.00	-1052	-53	4637
12	M1	66.76	-0.00033	-9.63	-130	-47	510
13	M2	72.64	-0.00001	-0.27	-4	-41	12
14	M3	78.51	0.00031	9.09	123	-35	-361
15	M4	84.39	0.00064	18.46	249	-29	-611
16	M5	90.27	0.00096	27.82	376	-24	-736
17	M6	96.15	0.00128	37.19	502	-18	-738
18	M7	102.02	0.00161	46.55	629	-12	-616
19	M8	107.90	0.00193	55.92	755	-6	-370
20	M9	113.78	0.00225	60.00	810	0	0
21	M10	119.66	0.00257	60.00	810	6	397
22	M11	125.53	0.00290	60.00	810	12	794
23	M12	131.41	0.00322	60.00	810	18	1191
24	M13	137.29	0.00354	60.00	810	24	1588
25	M14	143.17	0.00387	60.00	810	29	1984
26	M15	149.04	0.00419	60.00	810	35	2381
27	M16	154.92	0.00451	60.00	810	41	2778
28	T1	160.80	0.00483	60.00	3085	47	12088
29	T2	166.68	0.00516	60.00	1187	53	5231
30	M17	172.55	0.00548	60.00	810	59	3969
31	M18	178.43	0.00580	60.00	810	65	4366
32	M19	184.31	0.00613	60.00	810	71	4763
33	M20	190.19	0.00645	60.00	810	76	5160
34	M21	196.07	0.00677	60.00	810	82	5557
35	M22	201.94	0.00709	60.00	810	88	5953
36	T3	207.82	0.00742	60.00	4746	94	37195
37	T4	213.70	0.00774	60.00	4746	100	39520
38	T5	219.58	0.00806	60.00	4509	106	39752
39	T6	225.45	0.00839	60.00	4509	112	41961
					13254		384836

37	T4	2.24	218.03	20	79.10	57	5538
38	T5	2.24	223.91	19	75.15	57	5687
39	T6	2.24	229.78	19	75.15	57	5837
					1167.27		

5 Check for axial and flexural force effects:

- *Resistance factor:* A.5.10.11.4.1b ϕ_n = 0.90

- *Loading effects:*

1 Prestressing loading effects:

Pu =	32218	kips	143	MN
Mux =	-3171	kip-ft	-4	MN-m
Muy =	-1551	kip-ft	-2	MN-m

2 Net loading effects:

Pu =	4827	kips	21	MN
Mux =	689788	kip-ft	936	MN-m
Muy =	463	kip-ft	1	MN-m

3 Total loading stresses:

Pu/A =	0.895	ksi	6.2	MPa
Mux/Sx =	5.100	ksi	35.2	MPa
Muy/Sy =	0.020	ksi	0.1	MPa
Max =	6.015	ksi	41.5	MPa
	75%	f'c	75%	
Min =	-4.226	ksi	-29.2	MPa
	53%	f'c	53%	

- *Analysis approach:* *Strain compatibility*

- *Concrete behavior assumptions:* *Unconfined*

Stress distribution: A.5.7.2.2 *Rectangular*

α_1 = 0.85

β_1 = 0.65

Compressive strength: f'c = 8 ksi

Ultimate compression strain: ε_{cu} = 0.004 *

* Seismic Design of Reinforced Concrete and Masonry Buildings, Paulay and Priestly, pag. 98

Ignore concrete cover for calculations at this strain level

Modulus of Elasticity: A.5.4.2.4-1 E = 5422 ksi

Effective section properties: b = 167 in 4233 mm

h = 228 in 5780 mm

- *Major-axis bending resistance: Pnx, Mnx*

Eccentricity: ey = 1714.90 in

Neutral axis depth: c = 72.81 in

a = 47.32 in

Concrete forces: Pc = 53630 kips

Mc = 402752 kip-ft

Tendon forces:

Effective initial prestressing strain: ε_{po} = 0.00592

No.	Name	yeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B6.1	18.27	0.00293	83.39	651	-96	-5185
2	B6.2	18.27	0.00293	83.39	670	-96	-5329
3	B6.3	18.27	0.00293	83.39	670	-96	-5329
4	B6.4	18.27	0.00293	83.39	651	-96	-5185
5	B5.1	23.86	0.00324	92.13	720	-90	-5393
6	B5.2	23.86	0.00324	92.13	740	-90	-5543
7	B5.3	23.86	0.00324	92.13	740	-90	-5543

Load Contour Method:

Mux/Mrx =	0.84		
Muy/Mry =	0.02		
IE =	**0.86**	**OK!**	**0.86**

6 Check for shear and torsional force effects:

- *Resistance factor:* A.5.5.4.2 ϕ = 0.90

- *Torsional effects:*

Total area enclosed by outside perimeter of concrete:	Acp =	41414	in2		
Outside perimeter of the concrete section:	pc =	823	in		
Diameter of exterior stirrups:	d =	0.98	in	25	mm
Spacing of exterior stirrups:	s =	5.91	in	150	mm
Area enclosed by the shear path:	Ao =	37537	in2		
Perimeter of centerline of exterior stirrups:	ph =	784	in		
Torsional cracking moment:	Tcr =	109830	kip-ft	149	MN-m
	0.25ϕTcr=	24712	kip-ft	34	MN-m
	Tu =	0	kip-ft	0	MN-m

Torsional effects DO NOT need to be considered for shear checking

Torsional resistance:	ϕTn=	60191	kip-ft	82	MN-m
	Tu/ϕTn =	**0.00**	**OK!**	**0.00**	

- *In-plane shear:*

Factored load:	Vuy =	15649	Kips	70	MN
Prestressing force in direction of Vu:	Vp =	2405	Kips	11	MN
In-plane concrete shear resistance approach:	Method =	2	A.5.8.4.3.2		
Effective width	bv =	175	in		
Minimum Shear depth:	dv =	189	in		
Net tensile Strains:	$\varepsilon_{average}$ =	0.00196			
Crack angle:	θ =	35.9			
Parameter β assuming min. transverse reinforcement:	β=	1.941			
In-plane concrete shear resistance:	Vc =	5743	Kips	26	MN
In-plane steel shear resistance:	Vs =	16145	Kips	72	MN
Inclination of reinforcement:	α=	90	deg		
Diameter of stirrups:	d =	0.98	in		
Spacing of stirrups:	s =	5.91	in		
No. of reinforcement legs:	n =	8			
	ϕVn =	19699	Kips	88	MN
	Vu/ϕVn =	**0.79**	**OK!**	**0.79**	

- *Out-of-plane shear:*

Factored load:	Vux =	0	Kips	0	MN
Prestressing force in direction of Vu:	Vp =	0	Kips	0	MN
In-plane concrete shear resistance approach:	Method =	2	A.5.8.4.3.2		
Effective width	bv =	236	in		
Minimum Shear depth:	dv =	126	in		
Net tensile Strains:	$\varepsilon_{average}$ =	0.00000			
Parameter β assuming min. transverse reinforcement:	β=	4.800			
In-plane concrete shear resistance:	Vc =	12792	Kips	57	MN
	ϕVc =	11513	Kips	51	MN
	Vu/ϕVc =	**0.00**	**OK!**	**0.00**	

Resultant forces:

Pnx =	6392	kips	28	MN
Mnx =	913429	kip-ft	1239	MN-m
ey =	1714.95	in		
ey req/ ey res =	1.00		1.00	

- *Minor-axis bending resistance: Pny, Mny*

Eccentricity:	ex = 1.15	in
Neutral axis depth:	c = 254.97	in
	a = 165.73	in
Concrete forces:	Pc = 256452	kips
	Mc = 9887	kip-ft

Tendon forces:

Effective initial prestressing strain: ε_{so}= 0.00592

No.	Name	xeff in	ε_{si}	fsi ksi	Tsi kips	di in	Msi kip-ft
1	B6.1	137.42	0.00408	116.20	908	54	4092
2	B6.2	109.08	0.00364	103.54	831	26	1784
3	B6.3	65.30	0.00295	83.98	674	-18	-1013
4	B6.4	21.52	0.00226	64.42	503	-62	-2592
5	B5.1	136.16	0.00406	115.64	903	53	3977
6	B5.2	107.82	0.00362	102.97	827	24	1687
7	B5.3	66.56	0.00297	84.54	679	-17	-949
8	B5.4	22.78	0.00228	64.98	508	-61	-2561
9	B4.1	136.79	0.00407	115.92	931	53	4147
10	B4.2	108.45	0.00363	103.25	829	25	1735
11	B4.3	65.93	0.00296	84.26	677	-17	-981
12	B4.4	22.15	0.00227	64.70	519	-61	-2648
13	T3.1	137.42	0.00408	116.20	908	54	4092
14	T3.2	109.08	0.00364	103.54	831	26	1784
15	T3.3	79.47	0.00317	90.31	725	-4	-233
16	T3.4	20.22	0.00224	63.84	499	-63	-2623
17	T2.1	122.62	0.00385	109.59	880	39	2881
18	T2.2	94.27	0.00340	96.92	778	11	710
19	T2.3	65.93	0.00296	84.26	677	-17	-981
20	T2.4	37.58	0.00251	71.59	575	-46	-2191
21	T1.1	136.16	0.00406	115.64	903	53	3977
22	T1.2	107.82	0.00362	102.97	827	24	1687
23	T1.3	80.73	0.00319	90.87	730	-3	-158
24	T1.4	21.48	0.00226	64.40	503	-62	-2593
					17624		13029

Resultant forces:

Pny =	238828	kips	1063	MN
Mny =	22917	kip-ft	31	MN-m
ex =	1.15	in		
ex req/ ex res =	1.00		1.00	

- *Biaxial flexure check:* A.5.7.4.5

Minimum axial load to be considered as a column:	0.1ϕf'cAg =	29818	kips	133	MN
Factored axial load:	Pu =	4827	kips	21	MN
Nominal axial resistance:	Po =	246120	kips	1095	MN

Method to check biaxial flexure: Load Contour Method

Reciprocal Load Method:	Pr =	NA	Kips
	Pu/Pr =	**NA**	**NA**

5	B5.1	-52.83	28.19	36	7.81	0.43	-1342	634
6	B5.2	-24.49	28.19	37	8.03	0.43	-622	634
7	B5.3	16.77	28.19	37	8.03	0.43	426	634
8	B5.4	60.55	28.19	36	7.81	0.43	1538	634
9	B4.1	-53.46	35.59	37	8.03	0.48	-1358	822
10	B4.2	-25.12	35.59	37	8.03	0.48	-638	822
11	B4.3	17.40	35.59	37	8.03	0.48	442	822
12	B4.4	61.18	35.59	37	8.03	0.48	1554	822
13	T3.1	-54.09	206.02	36	7.81	0.21	-1374	5175
14	T3.2	-25.75	206.02	37	8.03	0.21	-654	5175
15	T3.3	3.86	206.02	37	8.03	0.21	98	5175
16	T3.4	63.11	206.02	36	7.81	0.21	1603	5175
17	T2.1	-39.29	211.61	37	8.03	0.12	-998	5317
18	T2.2	-10.94	211.61	37	8.03	0.12	-278	5317
19	T2.3	17.40	211.61	37	8.03	0.12	442	5317
20	T2.4	45.75	211.61	37	8.03	0.12	1162	5317
21	T1.1	-52.83	211.61	36	7.81	0.00	-1342	5317
22	T1.2	-24.49	211.61	37	8.03	0.00	-622	5317
23	T1.3	2.60	211.61	37	8.03	0.00	66	5317
24	T1.4	61.85	211.61	36	7.81	0.00	1571	5317
					190.96	0.25		
	Centroids =	-0.58	119.29	in				
	Eccentricity =	-0.58	1.18	in				

- *Longitudinal reinforcement locations:*

**from bottom of gross section

No.	Name	db (in)	y**(in)	Qty	Area (in2)	db (mm)	y (mm)
1	B1	2.24	6.44	16	63.28	57	164
2	B2	2.24	12.31	14	55.37	57	313
3	B3	2.24	18.19	14	55.37	57	462
4	B4	2.24	24.07	6	23.73	57	611
5	B5	2.24	29.95	6	23.73	57	761
6	B6	2.24	35.82	6	23.73	57	910
7	B7	2.24	41.70	6	23.73	57	1059
8	B8	2.24	47.58	14	55.37	57	1209
9	B9	2.24	53.46	14	55.37	57	1358
10	B10	2.24	59.33	14	55.37	57	1507
11	B11	2.24	65.21	14	55.37	57	1656
12	M1	1.69	71.09	6	13.51	43	1806
13	M2	1.69	76.97	6	13.51	43	1955
14	M3	1.69	82.85	6	13.51	43	2104
15	M4	1.69	88.72	6	13.51	43	2254
16	M5	1.69	94.60	6	13.51	43	2403
17	M6	1.69	100.48	6	13.51	43	2552
18	M7	1.69	106.36	6	13.51	43	2701
19	M8	1.69	112.23	6	13.51	43	2851
20	M9	1.69	118.11	6	13.51	43	3000
21	M10	1.69	123.99	6	13.51	43	3149
22	M11	1.69	129.87	6	13.51	43	3299
23	M12	1.69	135.74	6	13.51	43	3448
24	M13	1.69	141.62	6	13.51	43	3597
25	M14	1.69	147.50	6	13.51	43	3746
26	M15	1.69	153.38	6	13.51	43	3896
27	M16	1.69	159.25	6	13.51	43	4045
28	T1	2.24	165.13	13	51.42	57	4194
29	T2	2.24	171.01	5	19.78	57	4344
30	M17	1.69	176.89	6	13.51	43	4493
31	M18	1.69	182.76	6	13.51	43	4642
32	M19	1.69	188.64	6	13.51	43	4791
33	M20	1.69	194.52	6	13.51	43	4941
34	M21	1.69	200.40	6	13.51	43	5090
35	M22	1.69	206.27	6	13.51	43	5239
36	T3	2.24	212.15	20	79.10	57	5389
37	T4	2.24	218.03	20	79.10	57	5538
38	T5	2.24	223.91	19	75.15	57	5687
39	T6	2.24	229.78	19	75.15	57	5837
					1167.27		

0 Specifications: AASHTO LRFD Design Specs. 2012

1 Material properties:

				Metric	
- Concrete density:	Wc =	0.15	kcf	24	KN/m3
- Concrete 28-day compressive strength:	f'c =	8	ksi	55	MPa
- Reinforcement strength:	fy =	60	ksi	414	MPa
- Prestressing steel strand:	Diameter =	0.60	in	15	mm
Strand cross-sectional area:	A =	0.217	in2	140	mm2
Modulus of Elasticity:	Ep =	28478	ksi	196500	MPa
Ultimate tensile strength:	Fpu =	58.43	kips	260	KN
	fpu =	269	ksi	1858	MPa
Minimum yield strength:	Fpy =	52.58	kips	234	KN
	fpy =	90%	fpu		
Maximum stressing force per strand:	Fp max =	43.82	kips	195	KN
	fp jacking =	75%	fpu		
% prestressing stress after transfer with Max losses:	fpt =	67%	fpu		
% Effective prestressing stress considering Max losses:	fpe =	63%	fpu		
Effective prestressing strain considering Max losses:	ε_{po} =	0.00592			
Wedge seating:	A =	0.39	in	10	mm
Friction coefficient:	μ =	0.15	/rad	0.15	/rad
Wobble coefficient:	k =	0.000201	/ft	0.00066	/m
- Tendons:					
Duct diameter:	OD =	5.51	in	140	mm
Location of tendon CG with respect to duct CG	Z =	0.47	in	12	mm

2 Bearing location:

- Eccentricity between shaft and top of pier cap:	e1 =	39.17	in	995	mm

3 Loads:

- Case	Maximum Bearing: Mux min				
	PT + EQ + DL			PT + EQ + DL	
- *Loading effects at the section of maximum effect:*					
Axial (if <0 → Tension)	Pu =	27908	kips	124	MN
In-plane shear	Vuy =	11341	kips	50	MN
Out-of-plane shear	Vux =	0	kips	0	MN
In-plane-bending moment: (if >0 → Top fiber in tension)	Mux =	-671357	kip-ft	-912	MN-m
Out-of-plane bending moment	Muy =	2014	kip-ft	3	MN-m
Torsion	Tu =	0	kip-ft	0	MN-m

4 Pier cap section properties:

- Section No.		1			
	Location =	Bearing			
- *Dimensions:*					
Location from cap end	x =	16.59	ft	5058	mm
Width	B =	175.3	167 in	4453	mm
Depth	H =	236.2	228 in	6000	mm
Concrete cover:	Top =	4.33	in	110	mm
	Bottom =	4.33	in	110	mm
	Lateral =	4.33	in	110	mm

- *Section properties:*		Gross	Eff at ε_{cu}	
Area	A =	41414	37924	in2
Centroid (with respect to left bottom corner)	yc =	118.110	114	in
	xc =	88	83	in
Moment of inertia	Ix =	192573235	163652090	in4
	Iy =	106074258	87775676	in4
Section modulus	Sx =	1630453	1438326	in3
	Sy =	1210084	1053377	in3

- *Longitudinal tendon locations:*

*from section centerline
**from bottom of gross section

No.	Name	x* (in)	y**(in)	Strands	Area (in2)	α (rad)	x (mm)	y (mm)
1	B6.1	-54.09	22.60	36	7.81	0.25	-1374	492
2	B6.2	-25.75	22.60	37	8.03	0.25	-654	492
3	B6.3	18.03	22.60	37	8.03	0.25	458	492
4	B6.4	61.81	22.60	36	7.81	0.25	1570	492

14	T3.2	201.69	0.00330	93.90	754	-88	-5524
15	T3.3	201.69	0.00330	93.90	754	-88	-5524
16	T3.4	201.69	0.00330	93.90	734	-88	-5374
17	T2.1	207.28	0.00300	85.45	686	-94	-5346
18	T2.2	207.28	0.00300	85.45	686	-94	-5346
19	T2.3	207.28	0.00300	85.45	686	-94	-5346
20	T2.4	207.28	0.00300	85.45	686	-94	-5346
21	T1.1	207.28	0.00300	85.45	668	-94	-5202
22	T1.2	207.28	0.00300	85.45	686	-94	-5346
23	T1.3	207.28	0.00300	85.45	686	-94	-5346
24	T1.4	207.28	0.00300	85.45	668	-94	-5202
					33463		122025

Reinforcement forces:

No.	Name	yeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B1	2.11	0.00797	60.00	3797	112	35335
2	B2	7.98	0.00766	60.00	3322	106	29291
3	B3	13.86	0.00734	60.00	3322	100	27664
4	B4	19.74	0.00703	60.00	1424	94	11159
5	B5	25.62	0.00672	60.00	1424	88	10461
6	B6	31.49	0.00641	60.00	1424	82	9764
7	B7	37.37	0.00610	60.00	1424	76	9066
8	B8	43.25	0.00578	60.00	3322	71	19528
9	B9	49.13	0.00547	60.00	3322	65	17900
10	B10	55.00	0.00516	60.00	3322	59	16273
11	B11	60.88	0.00485	60.00	3322	53	14646
12	M1	66.76	0.00454	60.00	810	47	3175
13	M2	72.64	0.00422	60.00	810	41	2778
14	M3	78.51	0.00391	60.00	810	35	2381
15	M4	84.39	0.00360	60.00	810	29	1984
16	M5	90.27	0.00329	60.00	810	24	1588
17	M6	96.15	0.00298	60.00	810	18	1191
18	M7	102.02	0.00266	60.00	810	12	794
19	M8	107.90	0.00235	60.00	810	6	397
20	M9	113.78	0.00204	59.15	799	0	0
21	M10	119.66	0.00173	50.10	677	-6	-331
22	M11	125.53	0.00142	41.05	554	-12	-543
23	M12	131.41	0.00110	32.00	432	-18	-635
24	M13	137.29	0.00079	22.96	310	-24	-607
25	M14	143.17	0.00048	13.91	188	-29	-460
26	M15	149.04	0.00017	4.86	66	-35	-193
27	M16	154.92	-0.00014	-4.19	-57	-41	194
28	T1	160.80	-0.00046	-13.23	-680	-47	2666
29	T2	166.68	-0.00077	-22.28	-441	-53	1942
30	M17	172.55	-0.00108	-31.33	-423	-59	2072
31	M18	178.43	-0.00139	-40.38	-545	-65	2938
32	M19	184.31	-0.00170	-49.42	-667	-71	3923
33	M20	190.19	-0.00202	-58.47	-790	-76	5028
34	M21	196.07	-0.00233	-60.00	-810	-82	5557
35	M22	201.94	-0.00264	-60.00	-810	-88	5953
36	T3	207.82	-0.00295	-60.00	-4746	-94	37195
37	T4	213.70	-0.00326	-60.00	-4746	-100	39520
38	T5	219.58	-0.00358	-60.00	-4509	-106	39752
39	T6	225.45	-0.00389	-60.00	-4509	-112	41961
					15201		401308

Resultant forces:

Pnx =	39063	kips	174	MN
Mnx =	939529	kip-ft	1274	MN-m
ey =	-288.62	in		
ey req/ ey res =	1.00		1.00	

5 Check for axial and flexural force effects:

- *Resistance factor:* A.5.10.11.4.1b ϕ = 0.90

- *Loading effects:*

1 Prestressing loading effects:

Pu =	32218	kips	143	MN
Mux =	-3171	kip-ft	-4	MN-m
Muy =	-1551	kip-ft	-2	MN-m

2 Net loading effects:

Pu =	27908	kips	124	MN
Mux =	-671357	kip-ft	-911	MN-m
Muy =	2014	kip-ft	3	MN-m

3 Total loading stresses:

Pu/A =	0.674	ksi	4.6	MPa
Mux/Sx =	-4.941	ksi	-34.1	MPa
Muy/Sy =	0.020	ksi	0.1	MPa
Max =	-4.247	ksi	-29.3	MPa
	-53%	f'c	-53%	
Min =	5.595	ksi	38.6	MPa
	70%	f'c	70%	

- *Analysis approach:* *Strain compatibility*

- *Concrete behavior assumptions:* *Unconfined*

Stress distribution: A.5.7.2.2 *Rectangular*

α_1 = 0.85

β_1 = 0.65

Compressive strength: f'c = 8 ksi

Ultimate compression strain: ε_{cu} = 0.004 *

* Seismic Design of Reinforced Concrete and Masonry Buildings, Paulay and Priestly, pag. 98

Ignore concrete cover for calculations at this strain level

Modulus of Elasticity: A.5.4.2.4-1 E = 5422 ksi

Effective section properties: b = 167 in 4233 mm

h = 228 in 5780 mm

- *Major-axis bending resistance: Pnx, Mnx*

Eccentricity: ey = -288.68 in

Neutral axis depth: c = 75.36 in

a = 48.98 in

Concrete forces: Pc = 55509 kips

Mc = 413025 kip-ft

Tendon forces:

Effective initial prestressing strain: ε_{po} = 0.00592

No.	Name	yeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B6.1	18.27	0.01303	262.62	2052	96	16329
2	B6.2	18.27	0.01303	262.62	2109	96	16783
3	B6.3	18.27	0.01303	262.62	2109	96	16783
4	B6.4	18.27	0.01303	262.62	2052	96	16329
5	B5.1	23.86	0.01274	262.28	2049	90	15353
6	B5.2	23.86	0.01274	262.28	2106	90	15780
7	B5.3	23.86	0.01274	262.28	2106	90	15780
8	B5.4	23.86	0.01274	262.28	2049	90	15353
9	B4.1	31.26	0.01234	261.76	2102	83	14453
10	B4.2	31.26	0.01234	261.76	2102	83	14453
11	B4.3	31.26	0.01234	261.76	2102	83	14453
12	B4.4	31.26	0.01234	261.76	2102	83	14453
13	T3.1	201.69	0.00330	93.90	734	-88	-5374

6 Check for shear and torsional force effects:

- *Resistance factor:* A.5.5.4.2 ϕ = 0.90

- *Torsional effects:*

Total area enclosed by outside perimeter of concrete:	Acp =	41414	in2		
Outside perimeter of the concrete section:	pc =	823	in		
Diameter of exterior stirrups:	d =	0.98	in	25	mm
Spacing of exterior stirrups:	s =	5.91	in	150	mm
Area enclosed by the shear path:	Ao =	37537	in2		
Perimeter of centerline of exterior stirrups:	ph =	784	in		
Torsional cracking moment:	Tcr =	109830	kip-ft	149	MN-m
	0.25ϕTcr=	24712	kip-ft	34	MN-m
	Tu =	0	kip-ft	0	MN-m

Torsional effects DO NOT need to be considered for shear checking

Torsional resistance:	ϕTn=	60279	kip-ft	82	MN-m
	Tu/ϕTn =	**0.00**	**OK!**	**0.00**	

- *In-plane shear:*

Factored load:	Vuy =	11341	Kips	50	MN
Prestressing force in direction of Vu:	Vp =	2405	Kips	11	MN
In-plane concrete shear resistance approach:	Method =	2	A.5.8.4.3.2		
Effective width	bv =	175	in		
Minimum Shear depth:	dv =	187	in		
Net tensile Strains:	$\varepsilon_{average}$ =	0.00195			
Crack angle:	θ =	35.8			
Parameter β assuming min. transverse reinforcement:	β=	1.948			
In-plane concrete shear resistance:	Vc =	5698	Kips	25	MN
In-plane steel shear resistance:	Vs =	15986	Kips	71	MN
Inclination of reinforcement:	α=	90	deg		
Diameter of stirrups:	d =	0.98	in		
Spacing of stirrups:	s =	5.91	in		
No. of reinforcement legs:	n =	8			
	ϕVn =	19516	Kips	87	MN
	Vu/ϕVn =	**0.58**	**OK!**	**0.58**	

- *Out-of-plane shear:*

Factored load:	Vux =	0	Kips	0	MN
Prestressing force in direction of Vu:	Vp =	0	Kips	0	MN
In-plane concrete shear resistance approach:	Method =	2	A.5.8.4.3.2		
Effective width	bv =	236	in		
Minimum Shear depth:	dv =	126	in		
Net tensile Strains:	$\varepsilon_{average}$ =	0.00000			
Parameter β assuming min. transverse reinforcement:	β=	4.800			
In-plane concrete shear resistance:	Vc =	12792	Kips	57	MN
	ϕVc =	11513	Kips	51	MN
	Vu/ϕVc =	**0.00**	**OK!**	**0.00**	

- *Minor-axis bending resistance: Pny, Mny*

Eccentricity:	ex =	0.87	in
Neutral axis depth:	c =	255.67	in
	a =	166.18	in
Concrete forces:	Pc =	257151	kips
	Mc =	5069	kip-ft

Tendon forces:

Effective initial prestressing strain: ε_{so}= 0.00592

No.	Name	xeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B6.1	137.42	0.00407	116.03	906	54	4086
2	B6.2	109.08	0.00363	103.40	830	26	1781
3	B6.3	65.30	0.00295	83.90	674	-18	-1012
4	B6.4	21.52	0.00226	64.39	503	-62	-2591
5	B5.1	136.16	0.00405	115.47	902	53	3972
6	B5.2	107.82	0.00361	102.84	826	24	1685
7	B5.3	66.56	0.00297	84.46	678	-17	-948
8	B5.4	22.78	0.00228	64.95	507	-61	-2560
9	B4.1	136.79	0.00406	115.75	929	53	4141
10	B4.2	108.45	0.00362	103.12	828	25	1733
11	B4.3	65.93	0.00296	84.18	676	-17	-980
12	B4.4	22.15	0.00227	64.67	519	-61	-2647
13	T3.1	137.42	0.00407	116.03	906	54	4086
14	T3.2	109.08	0.00363	103.40	830	26	1781
15	T3.3	79.47	0.00317	90.21	724	-4	-233
16	T3.4	20.22	0.00224	63.81	498	-63	-2622
17	T2.1	122.62	0.00384	109.44	879	39	2877
18	T2.2	94.27	0.00340	96.81	777	11	709
19	T2.3	65.93	0.00296	84.18	676	-17	-980
20	T2.4	37.58	0.00251	71.55	574	-46	-2190
21	T1.1	136.16	0.00405	115.47	902	53	3972
22	T1.2	107.82	0.00361	102.84	826	24	1685
23	T1.3	80.73	0.00319	90.77	729	-3	-158
24	T1.4	21.48	0.00226	64.37	503	-62	-2592
					17604		12995

Resultant forces:	Pny =	271765	kips	1209	MN
	Mny =	19615	kip-ft	27	MN-m
	ex =	0.87	in		
	ex req/ ex res =	1.00		1.00	

- *Biaxial flexure check:* A.5.7.4.5

Minimum axial load to be considered as a column:	0.1ϕf'cAg =	29818	kips	133	MN
Factored axial load:	Pu =	27908	kips	124	MN
Nominal axial resistance:	Po =	267050	kips	1188	MN
Method to check biaxial flexure:		Load Contour Method			
Reciprocal Load Method:	Pr =	NA	Kips		
	Pu/Pr =	**NA**	**NA**	**NA**	
Load Contour Method:	Mux/Mrx =	0.79			
	Muy/Mry =	0.11			
	IE =	**0.91**	**OK!**	**0.91**	

5	B5.1	-52.83	28.19	36	7.81	0.43	-1342	634
6	B5.2	-24.49	28.19	37	8.03	0.43	-622	634
7	B5.3	16.77	28.19	37	8.03	0.43	426	634
8	B5.4	60.55	28.19	36	7.81	0.43	1538	634
9	B4.1	-53.46	35.59	37	8.03	0.48	-1358	822
10	B4.2	-25.12	35.59	37	8.03	0.48	-638	822
11	B4.3	17.40	35.59	37	8.03	0.48	442	822
12	B4.4	61.18	35.59	37	8.03	0.48	1554	822
13	T3.1	-54.09	206.02	36	7.81	0.21	-1374	5175
14	T3.2	-25.75	206.02	37	8.03	0.21	-654	5175
15	T3.3	3.86	206.02	37	8.03	0.21	98	5175
16	T3.4	63.11	206.02	36	7.81	0.21	1603	5175
17	T2.1	-39.29	211.61	37	8.03	0.12	-998	5317
18	T2.2	-10.94	211.61	37	8.03	0.12	-278	5317
19	T2.3	17.40	211.61	37	8.03	0.12	442	5317
20	T2.4	45.75	211.61	37	8.03	0.12	1162	5317
21	T1.1	-52.83	211.61	36	7.81	0.00	-1342	5317
22	T1.2	-24.49	211.61	37	8.03	0.00	-622	5317
23	T1.3	2.60	211.61	37	8.03	0.00	66	5317
24	T1.4	61.85	211.61	36	7.81	0.00	1571	5317
					190.96	0.25		

Centroids = -0.58 119.29 in
Eccentricity = -0.58 1.18 in

- *Longitudinal reinforcement locations:*

**from bottom of gross section

No.	Name	db (in)	y**(in)	Qty	Area (in2)	db (mm)	y (mm)
1	B1	2.24	6.44	16	63.28	57	164
2	B2	2.24	12.31	14	55.37	57	313
3	B3	2.24	18.19	14	55.37	57	462
4	B4	2.24	24.07	6	23.73	57	611
5	B5	2.24	29.95	6	23.73	57	761
6	B6	2.24	35.82	6	23.73	57	910
7	B7	2.24	41.70	6	23.73	57	1059
8	B8	2.24	47.58	14	55.37	57	1209
9	B9	2.24	53.46	14	55.37	57	1358
10	B10	2.24	59.33	14	55.37	57	1507
11	B11	2.24	65.21	14	55.37	57	1656
12	M1	1.69	71.09	6	13.51	43	1806
13	M2	1.69	76.97	6	13.51	43	1955
14	M3	1.69	82.85	6	13.51	43	2104
15	M4	1.69	88.72	6	13.51	43	2254
16	M5	1.69	94.60	6	13.51	43	2403
17	M6	1.69	100.48	6	13.51	43	2552
18	M7	1.69	106.36	6	13.51	43	2701
19	M8	1.69	112.23	6	13.51	43	2851
20	M9	1.69	118.11	6	13.51	43	3000
21	M10	1.69	123.99	6	13.51	43	3149
22	M11	1.69	129.87	6	13.51	43	3299
23	M12	1.69	135.74	6	13.51	43	3448
24	M13	1.69	141.62	6	13.51	43	3597
25	M14	1.69	147.50	6	13.51	43	3746
26	M15	1.69	153.38	6	13.51	43	3896
27	M16	1.69	159.25	6	13.51	43	4045
28	T1	2.24	165.13	13	51.42	57	4194
29	T2	2.24	171.01	5	19.78	57	4344
30	M17	1.69	176.89	6	13.51	43	4493
31	M18	1.69	182.76	6	13.51	43	4642
32	M19	1.69	188.64	6	13.51	43	4791
33	M20	1.69	194.52	6	13.51	43	4941
34	M21	1.69	200.40	6	13.51	43	5090
35	M22	1.69	206.27	6	13.51	43	5239
36	T3	2.24	212.15	20	79.10	57	5389
37	T4	2.24	218.03	20	79.10	57	5538
38	T5	2.24	223.91	19	75.15	57	5687
39	T6	2.24	229.78	19	75.15	57	5837
					1167.27		

0 Specifications: AASHTO LRFD Design Specs. 2012

1 Material properties:

				Metric	
- Concrete density:	Wc =	0.15	kcf	24	KN/m3
- Concrete 28-day compressive strength:	f'c =	8	ksi	55	MPa
- Reinforcement strength:	fy =	60	ksi	414	MPa
- Prestressing steel strand:	Diameter =	0.60	in	15	mm
Strand cross-sectional area:	A =	0.217	in2	140	mm2
Modulus of Elasticity:	Ep =	28478	ksi	196500	MPa
Ultimate tensile strength:	Fpu =	58.43	kips	260	KN
	fpu =	269	ksi	1858	MPa
Minimum yield strength:	Fpy =	52.58	kips	234	KN
	fpy =	90%	fpu		
Maximum stressing force per strand:	Fp max =	43.82	kips	195	KN
	fp jacking =	75%	fpu		
% prestressing stress after transfer with Max losses:	fpt =	67%	fpu		
% Effective prestressing stress considering Max losses:	fpe =	63%	fpu		
Effective prestressing strain considering Max losses:	ε_{po} =	0.00592			
Wedge seating:	Δ =	0.39	in	10	mm
Friction coefficient:	μ =	0.15	/rad	0.15	/rad
Wobble coefficient:	k =	0.000201	/ft	0.00066	/m
- Tendons:					
Duct diameter:	OD =	5.51	in	140	mm
Location of tendon CG with respect to duct CG	Z =	0.47	in	12	mm

2 Bearing location:

- Eccentricity between shaft and top of pier cap:	e1 =	39.17	in	995	mm

3 Loads:

- Case	Maximum Bearing: Pu min				
	PT + EQ + DL			PT + EQ + DL	
- *Loading effects at the section of maximum effect:*					
Axial (if <0 → Tension)	Pu =	46182	kips	206	MN
In-plane shear	Vuy =	15932	kips	71	MN
Out-of-plane shear	Vux =	0	kips	0	MN
In-plane-bending moment: (if >0 → Top fiber in tension)	Mux =	588677	kip-ft	799	MN-m
Out-of-plane bending moment	Muy =	2014	kip-ft	3	MN-m
Torsion	Tu =	0	kip-ft	0	MN-m

4 Pier cap section properties:

- Section No.		1			
	Location =	Bearing			
- *Dimensions:*					
Location from cap end	x =	16.59	ft	5058	mm
Width	B =	175.3	167 in	4453	mm
Depth	H =	236.2	228 in	6000	mm
Concrete cover:	Top =	4.33	in	110	mm
	Bottom =	4.33	in	110	mm
	Lateral =	4.33	in	110	mm

- *Section properties:*		Gross	Eff at ε_{cu}	
Area	A =	41414	37924	in2
Centroid (with respect to left bottom corner)	yc =	118.110	114	in
	xc =	88	83	in
Moment of inertia	Ix =	192573235	163652090	in4
	Iy =	106074258	87775676	in4
Section modulus	Sx =	1630453	1438326	in3
	Sy =	1210084	1053377	in3

- *Longitudinal tendon locations:*

*from section centerline
**from bottom of gross section

No.	Name	x* (in)	y**(in)	Strands	Area (in2)	α (rad)	x (mm)	y (mm)
1	B6.1	-54.09	22.60	36	7.81	0.25	-1374	492
2	B6.2	-25.75	22.60	37	8.03	0.25	-654	492
3	B6.3	18.03	22.60	37	8.03	0.25	458	492
4	B6.4	61.81	22.60	36	7.81	0.25	1570	492

14	T3.2	201.69	0.01123	259.79	2086	88	15281
15	T3.3	201.69	0.01123	259.79	2086	88	15281
16	T3.4	201.69	0.01123	259.79	2029	88	14868
17	T2.1	207.28	0.01149	260.33	2090	94	16287
18	T2.2	207.28	0.01149	260.33	2090	94	16287
19	T2.3	207.28	0.01149	260.33	2090	94	16287
20	T2.4	207.28	0.01149	260.33	2090	94	16287
21	T1.1	207.28	0.01149	260.33	2034	94	15847
22	T1.2	207.28	0.01149	260.33	2090	94	16287
23	T1.3	207.28	0.01149	260.33	2090	94	16287
24	T1.4	207.28	0.01149	260.33	2034	94	15847
					33144		128218

Reinforcement forces:

No.	Name	yeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B1	2.11	-0.00390	-60.00	-3797	-112	35335
2	B2	7.98	-0.00363	-60.00	-3322	-106	29291
3	B3	13.86	-0.00336	-60.00	-3322	-100	27664
4	B4	19.74	-0.00309	-60.00	-1424	-94	11159
5	B5	25.62	-0.00282	-60.00	-1424	-88	10461
6	B6	31.49	-0.00255	-60.00	-1424	-82	9764
7	B7	37.37	-0.00228	-60.00	-1424	-76	9066
8	B8	43.25	-0.00200	-58.14	-3219	-71	18923
9	B9	49.13	-0.00173	-50.28	-2784	-65	15000
10	B10	55.00	-0.00146	-42.42	-2349	-59	11504
11	B11	60.88	-0.00119	-34.55	-1913	-53	8434
12	M1	66.76	-0.00092	-26.69	-360	-47	1412
13	M2	72.64	-0.00065	-18.83	-254	-41	872
14	M3	78.51	-0.00038	-10.96	-148	-35	435
15	M4	84.39	-0.00011	-3.10	-42	-29	103
16	M5	90.27	0.00016	4.76	64	-24	-126
17	M6	96.15	0.00044	12.63	171	-18	-251
18	M7	102.02	0.00071	20.49	277	-12	-271
19	M8	107.90	0.00098	28.35	383	-6	-188
20	M9	113.78	0.00125	36.22	489	0	0
21	M10	119.66	0.00152	44.08	595	6	292
22	M11	125.53	0.00179	51.94	701	12	687
23	M12	131.41	0.00206	59.80	808	18	1187
24	M13	137.29	0.00233	60.00	810	24	1588
25	M14	143.17	0.00260	60.00	810	29	1984
26	M15	149.04	0.00288	60.00	810	35	2381
27	M16	154.92	0.00315	60.00	810	41	2778
28	T1	160.80	0.00342	60.00	3085	47	12088
29	T2	166.68	0.00369	60.00	1187	53	5231
30	M17	172.55	0.00396	60.00	810	59	3969
31	M18	178.43	0.00423	60.00	810	65	4366
32	M19	184.31	0.00450	60.00	810	71	4763
33	M20	190.19	0.00477	60.00	810	76	5160
34	M21	196.07	0.00504	60.00	810	82	5557
35	M22	201.94	0.00532	60.00	810	88	5953
36	T3	207.82	0.00559	60.00	4746	94	37195
37	T4	213.70	0.00586	60.00	4746	100	39520
38	T5	219.58	0.00613	60.00	4509	106	39752
39	T6	225.45	0.00640	60.00	4509	112	41961
					7166		404999

Resultant forces:

Pnx =	23561	kips	105	MN
Mnx =	988829	kip-ft	1341	MN-m
ey =	503.62	in		
ey req/ ey res =	1.00		1.00	

5 Check for axial and flexural force effects:

- *Resistance factor:* A.5.10.11.4.1b ϕ = 0.90

- *Loading effects:*

1 Prestressing loading effects:

Pu =	32218	kips	143	MN
Mux =	-3171	kip-ft	-4	MN-m
Muy =	-1551	kip-ft	-2	MN-m

2 Net loading effects:

Pu =	13964	kips	62	MN
Mux =	585506	kip-ft	794	MN-m
Muy =	463	kip-ft	1	MN-m

3 Total loading stresses:

Pu/A =	1.115	ksi	7.7	MPa
Mux/Sx =	4.333	ksi	29.9	MPa
Muy/Sy =	0.020	ksi	0.1	MPa
Max =	5.468	ksi	37.7	MPa
	68%	f'c	68%	
Min =	-3.237	ksi	-22.3	MPa
	40%	f'c	40%	

- *Analysis approach:* *Strain compatibility*

- *Concrete behavior assumptions:* *Unconfined*

Stress distribution: A.5.7.2.2 *Rectangular*

α_1 = 0.85

β_1 = 0.65

Compressive strength: f'c = 8 ksi

Ultimate compression strain: ε_{cu} = 0.004 *

* Seismic Design of Reinforced Concrete and Masonry Buildings, Paulay and Priestly, pag. 98

Ignore concrete cover for calculations at this strain level

Modulus of Elasticity: A.5.4.2.4-1 E = 5422 ksi

Effective section properties: b = 167 in 4233 mm

h = 228 in 5780 mm

- *Major-axis bending resistance: Pnx, Mnx*

Eccentricity: ey = 503.15 in

Neutral axis depth: c = 86.71 in

a = 56.36 in

Concrete forces: Pc = 63872 kips

Mc = 455612 kip-ft

Tendon forces:

Effective initial prestressing strain: ε_{po} = 0.00592

No.	Name	yeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B6.1	18.27	0.00277	78.80	616	-96	-4900
2	B6.2	18.27	0.00277	78.80	633	-96	-5036
3	B6.3	18.27	0.00277	78.80	633	-96	-5036
4	B6.4	18.27	0.00277	78.80	616	-96	-4900
5	B5.1	23.86	0.00303	86.15	673	-90	-5043
6	B5.2	23.86	0.00303	86.15	692	-90	-5183
7	B5.3	23.86	0.00303	86.15	692	-90	-5183
8	B5.4	23.86	0.00303	86.15	673	-90	-5043
9	B4.1	31.26	0.00337	95.87	770	-83	-5293
10	B4.2	31.26	0.00337	95.87	770	-83	-5293
11	B4.3	31.26	0.00337	95.87	770	-83	-5293
12	B4.4	31.26	0.00337	95.87	770	-83	-5293
13	T3.1	201.69	0.01123	259.79	2029	88	14868

6 Check for shear and torsional force effects:

- *Resistance factor:* A.5.5.4.2 ϕ = 0.90

- *Torsional effects:*

Total area enclosed by outside perimeter of concrete:	Acp =	41414	in2		
Outside perimeter of the concrete section:	pc =	823	in		
Diameter of exterior stirrups:	d =	0.98	in	25	mm
Spacing of exterior stirrups:	s =	5.91	in	150	mm
Area enclosed by the shear path:	Ao =	37537	in2		
Perimeter of centerline of exterior stirrups:	ph =	784	in		
Torsional cracking moment:	Tcr =	109830	kip-ft	149	MN-m
	0.25ϕTcr=	24712	kip-ft	34	MN-m
	Tu =	0	kip-ft	0	MN-m

Torsional effects DO NOT need to be considered for shear checking

Torsional resistance:	ϕTn=	64708	kip-ft	88	MN-m
	Tu/ϕTn =	**0.00**	**OK!**	**0.00**	

- *In-plane shear:*

Factored load:	Vuy =	15932	Kips	71	MN
Prestressing force in direction of Vu:	Vp =	2405	Kips	11	MN
In-plane concrete shear resistance approach:	Method =	2	A.5.8.4.3.2		
Effective width	bv =	175	in		
Minimum Shear depth:	dv =	189	in		
Net tensile Strains:	$\varepsilon_{average}$ =	0.00141			
Crack angle:	θ =	33.9			
Parameter β assuming min. transverse reinforcement:	β=	2.335			
In-plane concrete shear resistance:	Vc =	6907	Kips	31	MN
In-plane steel shear resistance:	Vs =	17356	Kips	77	MN
Inclination of reinforcement:	α=	90	deg		
Diameter of stirrups:	d =	0.98	in		
Spacing of stirrups:	s =	5.91	in		
No. of reinforcement legs:	n =	8			
	ϕVn =	21837	Kips	97	MN
	Vu/ϕVn =	**0.73**	**OK!**	**0.73**	

- *Out-of-plane shear:*

Factored load:	Vux =	0	Kips	0	MN
Prestressing force in direction of Vu:	Vp =	0	Kips	0	MN
In-plane concrete shear resistance approach:	Method =	2	A.5.8.4.3.2		
Effective width	bv =	236	in		
Minimum Shear depth:	dv =	126	in		
Net tensile Strains:	$\varepsilon_{average}$ =	0.00000			
Parameter β assuming min. transverse reinforcement:	β=	4.800			
In-plane concrete shear resistance:	Vc =	12792	Kips	57	MN
	ϕVc =	11513	Kips	51	MN
	Vu/ϕVc =	**0.00**	**OK!**	**0.00**	

- *Minor-axis bending resistance: Pny, Mny*

Eccentricity:	ex =	0.40	in
Neutral axis depth:	c =	422.49	in
	a =	166.66	in
Concrete forces:	Pc =	257883	kips
	Mc =	0	kip-ft

Tendon forces:

Effective initial prestressing strain: ε_{so}= 0.00592

No.	Name	xeff in	ε_{si}	fsi ksi	Tsi kips	di in	Msi kip-ft
1	B6.1	137.42	0.00323	91.86	718	54	3235
2	B6.2	109.08	0.00296	84.21	676	26	1451
3	B6.3	65.30	0.00254	72.41	581	-18	-874
4	B6.4	21.52	0.00213	60.60	473	-62	-2439
5	B5.1	136.16	0.00321	91.52	715	53	3148
6	B5.2	107.82	0.00295	83.87	673	24	1374
7	B5.3	66.56	0.00255	72.75	584	-17	-816
8	B5.4	22.78	0.00214	60.94	476	-61	-2402
9	B4.1	136.79	0.00322	91.69	736	53	3280
10	B4.2	108.45	0.00295	84.04	675	25	1412
11	B4.3	65.93	0.00255	72.58	583	-17	-845
12	B4.4	22.15	0.00213	60.77	488	-61	-2488
13	T3.1	137.42	0.00323	91.86	718	54	3235
14	T3.2	109.08	0.00296	84.21	676	26	1451
15	T3.3	79.47	0.00268	76.23	612	-4	-197
16	T3.4	20.22	0.00212	60.25	471	-63	-2476
17	T2.1	122.62	0.00309	87.86	705	39	2310
18	T2.2	94.27	0.00282	80.22	644	11	587
19	T2.3	65.93	0.00255	72.58	583	-17	-845
20	T2.4	37.58	0.00228	64.94	521	-46	-1988
21	T1.1	136.16	0.00321	91.52	715	53	3148
22	T1.2	107.82	0.00295	83.87	673	24	1374
23	T1.3	80.73	0.00269	76.57	615	-3	-133
24	T1.4	21.48	0.00213	60.59	473	-62	-2440
					14785		8063

Resultant forces:	Pny =	243098	kips	1082	MN
	Mny =	8063	kip-ft	11	MN-m
	ex =	0.40	in		
	ex req/ ex res =	1.00		1.00	

- *Biaxial flexure check:* A.5.7.4.5

Minimum axial load to be considered as a column:	0.1ϕf'cAg =	29818	kips	133	MN
Factored axial load:	Pu =	13964	kips	62	MN
Nominal axial resistance:	Po =	246120	kips	1095	MN
Method to check biaxial flexure:		Load Contour Method			
Reciprocal Load Method:	Pr =	NA	Kips		
	Pu/Pr =	**NA**	**NA**	**NA**	
Load Contour Method:	Mux/Mrx =	0.66			
	Muy/Mry =	0.06			
	IE =	**0.72**	**OK!**	**0.72**	

5	B5.1	-52.83	28.19	36	7.81	0.43	-1342	634
6	B5.2	-24.49	28.19	37	8.03	0.43	-622	634
7	B5.3	16.77	28.19	37	8.03	0.43	426	634
8	B5.4	60.55	28.19	36	7.81	0.43	1538	634
9	B4.1	-53.46	35.59	37	8.03	0.48	-1358	822
10	B4.2	-25.12	35.59	37	8.03	0.48	-638	822
11	B4.3	17.40	35.59	37	8.03	0.48	442	822
12	B4.4	61.18	35.59	37	8.03	0.48	1554	822
13	T3.1	-54.09	206.02	36	7.81	0.21	-1374	5175
14	T3.2	-25.75	206.02	37	8.03	0.21	-654	5175
15	T3.3	3.86	206.02	37	8.03	0.21	98	5175
16	T3.4	63.11	206.02	36	7.81	0.21	1603	5175
17	T2.1	-39.29	211.61	37	8.03	0.12	-998	5317
18	T2.2	-10.94	211.61	37	8.03	0.12	-278	5317
19	T2.3	17.40	211.61	37	8.03	0.12	442	5317
20	T2.4	45.75	211.61	37	8.03	0.12	1162	5317
21	T1.1	-52.83	211.61	36	7.81	0.00	-1342	5317
22	T1.2	-24.49	211.61	37	8.03	0.00	-622	5317
23	T1.3	2.60	211.61	37	8.03	0.00	66	5317
24	T1.4	61.85	211.61	36	7.81	0.00	1571	5317
					190.96	0.25		
	Centroids =	-0.58	119.29	in				
	Eccentricity =	-0.58	1.18	in				

- *Longitudinal reinforcement locations:*

**from bottom of gross section

No.	Name	db (in)	y**(in)	Qty	Area (in2)	db (mm)	y (mm)
1	B1	2.24	6.44	16	63.28	57	164
2	B2	2.24	12.31	14	55.37	57	313
3	B3	2.24	18.19	14	55.37	57	462
4	B4	2.24	24.07	6	23.73	57	611
5	B5	2.24	29.95	6	23.73	57	761
6	B6	2.24	35.82	6	23.73	57	910
7	B7	2.24	41.70	6	23.73	57	1059
8	B8	2.24	47.58	14	55.37	57	1209
9	B9	2.24	53.46	14	55.37	57	1358
10	B10	2.24	59.33	14	55.37	57	1507
11	B11	2.24	65.21	14	55.37	57	1656
12	M1	1.69	71.09	6	13.51	43	1806
13	M2	1.69	76.97	6	13.51	43	1955
14	M3	1.69	82.85	6	13.51	43	2104
15	M4	1.69	88.72	6	13.51	43	2254
16	M5	1.69	94.60	6	13.51	43	2403
17	M6	1.69	100.48	6	13.51	43	2552
18	M7	1.69	106.36	6	13.51	43	2701
19	M8	1.69	112.23	6	13.51	43	2851
20	M9	1.69	118.11	6	13.51	43	3000
21	M10	1.69	123.99	6	13.51	43	3149
22	M11	1.69	129.87	6	13.51	43	3299
23	M12	1.69	135.74	6	13.51	43	3448
24	M13	1.69	141.62	6	13.51	43	3597
25	M14	1.69	147.50	6	13.51	43	3746
26	M15	1.69	153.38	6	13.51	43	3896
27	M16	1.69	159.25	6	13.51	43	4045
28	T1	2.24	165.13	13	51.42	57	4194
29	T2	2.24	171.01	5	19.78	57	4344
30	M17	1.69	176.89	6	13.51	43	4493
31	M18	1.69	182.76	6	13.51	43	4642
32	M19	1.69	188.64	6	13.51	43	4791
33	M20	1.69	194.52	6	13.51	43	4941
34	M21	1.69	200.40	6	13.51	43	5090
35	M22	1.69	206.27	6	13.51	43	5239
36	T3	2.24	212.15	20	79.10	57	5389
37	T4	2.24	218.03	20	79.10	57	5538
38	T5	2.24	223.91	19	75.15	57	5687
39	T6	2.24	229.78	19	75.15	57	5837
					1167.27		

0 Specifications: AASHTO LRFD Design Specs. 2012

1 Material properties:

				Metric	
- Concrete density:	Wc =	0.15	kcf	24	KN/m3
- Concrete 28-day compressive strength:	f'c =	8	ksi	55	MPa
- Reinforcement strength:	fy =	60	ksi	414	MPa
- Prestressing steel strand:	Diameter =	0.60	in	15	mm
Strand cross-sectional area:	A =	0.217	in2	140	mm2
Modulus of Elasticity:	Ep =	28478	ksi	196500	MPa
Ultimate tensile strength:	Fpu =	58.43	kips	260	KN
	fpu =	269	ksi	1858	MPa
Minimum yield strength:	Fpy =	52.58	kips	234	KN
	fpy =	90%	fpu		
Maximum stressing force per strand:	Fp max =	43.82	kips	195	KN
	fp jacking =	75%	fpu		
% prestressing stress after transfer with Max losses:	fpt =	67%	fpu		
% Effective prestressing stress considering Max losses:	fpe =	63%	fpu		
Effective prestressing strain considering Max losses:	ε_{po} =	0.00592			
Wedge seating:	Δ =	0.39	in	10	mm
Friction coefficient:	μ =	0.15	/rad	0.15	/rad
Wobble coefficient:	k =	0.000201	/ft	0.00066	/m
- Tendons:					
Duct diameter:	OD =	5.51	in	140	mm
Location of tendon CG with respect to duct CG	Z =	0.47	in	12	mm

2 Bearing location:

- Eccentricity between shaft and top of pier cap:	e1 =	39.17	in	995	mm

3 Loads:

- Case	Maximum Bearing: Vuy max				
	PT + EQ + DL			PT + EQ + DL	
- *Loading effects at the section of maximum effect:*					
Axial (if <0 → Tension)	Pu =	35624	kips	159	MN
In-plane shear	Vuy =	19951	kips	89	MN
Out-of-plane shear	Vux =	1072	kips	5	MN
In-plane-bending moment: (if >0 → Top fiber in tension)	Mux =	224034	kip-ft	304	MN-m
Out-of-plane bending moment	Muy =	1819	kip-ft	2	MN-m
Torsion	Tu =	14051	kip-ft	19	MN-m

4 Pier cap section properties:

- Section No.		1			
	Location =	Bearing			
- *Dimensions:*					
Location from cap end	x =	16.59	ft	5058	mm
Width	B =	175.3	167 in	4453	mm
Depth	H =	236.2	228 in	6000	mm
Concrete cover:	Top =	4.33	in	110	mm
	Bottom =	4.33	in	110	mm
	Lateral =	4.33	in	110	mm

- *Section properties:*		Gross	Eff at ε_{cu}	
Area	A =	41414	37924	in2
Centroid (with respect to left bottom corner)	yc =	118.110	114	in
	xc =	88	83	in
Moment of inertia	Ix =	192573235	163652090	in4
	Iy =	106074258	87775676	in4
Section modulus	Sx =	1630453	1438326	in3
	Sy =	1210084	1053377	in3

- *Longitudinal tendon locations:*

*from section centerline
**from bottom of gross section

No.	Name	x* (in)	y**(in)	Strands	Area (in2)	α (rad)	x (mm)	y (mm)
1	B6.1	-54.09	22.60	36	7.81	0.25	-1374	492
2	B6.2	-25.75	22.60	37	8.03	0.25	-654	492
3	B6.3	18.03	22.60	37	8.03	0.25	458	492
4	B6.4	61.81	22.60	36	7.81	0.25	1570	492

14	T3.2	201.69	0.01208	261.38	2099	88	15375
15	T3.3	201.69	0.01208	261.38	2099	88	15375
16	T3.4	201.69	0.01208	261.38	2042	88	14959
17	T2.1	207.28	0.01237	261.79	2102	94	16378
18	T2.2	207.28	0.01237	261.79	2102	94	16378
19	T2.3	207.28	0.01237	261.79	2102	94	16378
20	T2.4	207.28	0.01237	261.79	2102	94	16378
21	T1.1	207.28	0.01237	261.79	2045	94	15936
22	T1.2	207.28	0.01237	261.79	2102	94	16378
23	T1.3	207.28	0.01237	261.79	2102	94	16378
24	T1.4	207.28	0.01237	261.79	2045	94	15936
					33571		127238

Reinforcement forces:

No.	Name	yeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B1	2.11	-0.00389	-60.00	-3797	-112	35335
2	B2	7.98	-0.00360	-60.00	-3322	-106	29291
3	B3	13.86	-0.00330	-60.00	-3322	-100	27664
4	B4	19.74	-0.00301	-60.00	-1424	-94	11159
5	B5	25.62	-0.00271	-60.00	-1424	-88	10461
6	B6	31.49	-0.00241	-60.00	-1424	-82	9764
7	B7	37.37	-0.00212	-60.00	-1424	-76	9066
8	B8	43.25	-0.00182	-52.82	-2925	-71	17191
9	B9	49.13	-0.00153	-44.23	-2449	-65	13196
10	B10	55.00	-0.00123	-35.65	-1974	-59	9668
11	B11	60.88	-0.00093	-27.06	-1498	-53	6605
12	M1	66.76	-0.00064	-18.47	-250	-47	978
13	M2	72.64	-0.00034	-9.89	-134	-41	458
14	M3	78.51	-0.00004	-1.30	-18	-35	52
15	M4	84.39	0.00025	7.28	98	-29	-241
16	M5	90.27	0.00055	15.87	214	-24	-420
17	M6	96.15	0.00084	24.46	330	-18	-485
18	M7	102.02	0.00114	33.04	446	-12	-437
19	M8	107.90	0.00144	41.63	562	-6	-275
20	M9	113.78	0.00173	50.22	678	0	0
21	M10	119.66	0.00203	58.80	794	6	389
22	M11	125.53	0.00232	60.00	810	12	794
23	M12	131.41	0.00262	60.00	810	18	1191
24	M13	137.29	0.00292	60.00	810	24	1588
25	M14	143.17	0.00321	60.00	810	29	1984
26	M15	149.04	0.00351	60.00	810	35	2381
27	M16	154.92	0.00380	60.00	810	41	2778
28	T1	160.80	0.00410	60.00	3085	47	12088
29	T2	166.68	0.00440	60.00	1187	53	5231
30	M17	172.55	0.00469	60.00	810	59	3969
31	M18	178.43	0.00499	60.00	810	65	4366
32	M19	184.31	0.00528	60.00	810	71	4763
33	M20	190.19	0.00558	60.00	810	76	5160
34	M21	196.07	0.00588	60.00	810	82	5557
35	M22	201.94	0.00617	60.00	810	88	5953
36	T3	207.82	0.00647	60.00	4746	94	37195
37	T4	213.70	0.00676	60.00	4746	100	39520
38	T5	219.58	0.00706	60.00	4509	106	39752
39	T6	225.45	0.00736	60.00	4509	112	41961
					10246		395649

Resultant forces:

Pnx =	14675	kips	65	MN
Mnx =	951693	kip-ft	1291	MN-m
ey =	778.19	in		
ey req/ ey res =	1.00		1.00	

5 Check for axial and flexural force effects:

- *Resistance factor:* A.5.10.11.4.1b ϕ = 0.90

- *Loading effects:*

1 Prestressing loading effects:

Pu =	32218	kips	143	MN
Mux =	-3171	kip-ft	-4	MN-m
Muy =	-1551	kip-ft	-2	MN-m

2 Net loading effects:

Pu =	3406	kips	15	MN
Mux =	220863	kip-ft	300	MN-m
Muy =	268	kip-ft	0	MN-m

3 Total loading stresses:

Pu/A =	0.860	ksi	5.9	MPa
Mux/Sx =	1.649	ksi	11.4	MPa
Muy/Sy =	0.018	ksi	0.1	MPa
Max =	2.527	ksi	17.4	MPa
	32%	f'c	32%	
Min =	-0.807	ksi	-5.6	MPa
	10%	f'c	10%	

- *Analysis approach:* *Strain compatibility*

- *Concrete behavior assumptions:* *Unconfined*

Stress distribution: A.5.7.2.2 *Rectangular*

α_1 = 0.85

β_1 = 0.65

Compressive strength: f'c = 8 ksi

Ultimate compression strain: ε_{cu} = 0.004 *

* Seismic Design of Reinforced Concrete and Masonry Buildings, Paulay and Priestly, pag. 98

Ignore concrete cover for calculations at this strain level

Modulus of Elasticity: A.5.4.2.4-1 E = 5422 ksi

Effective section properties: b = 167 in 4233 mm

h = 228 in 5780 mm

- *Major-axis bending resistance: Pnx, Mnx*

Eccentricity: ey = 778.19 in

Neutral axis depth: c = 79.41 in

a = 51.61 in

Concrete forces: Pc = 58492 kips

Mc = 428805 kip-ft

Tendon forces:

Effective initial prestressing strain: ε_{si} = 0.00592

No.	Name	yeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B6.1	18.27	0.00284	81.01	633	-96	-5037
2	B6.2	18.27	0.00284	81.01	650	-96	-5177
3	B6.3	18.27	0.00284	81.01	650	-96	-5177
4	B6.4	18.27	0.00284	81.01	633	-96	-5037
5	B5.1	23.86	0.00313	89.03	696	-90	-5212
6	B5.2	23.86	0.00313	89.03	715	-90	-5356
7	B5.3	23.86	0.00313	89.03	715	-90	-5356
8	B5.4	23.86	0.00313	89.03	696	-90	-5212
9	B4.1	31.26	0.00350	99.65	800	-83	-5502
10	B4.2	31.26	0.00350	99.65	800	-83	-5502
11	B4.3	31.26	0.00350	99.65	800	-83	-5502
12	B4.4	31.26	0.00350	99.65	800	-83	-5502
13	T3.1	201.69	0.01208	261.38	2042	88	14959

- *Minor-axis bending resistance: Pny, Mny*

Eccentricity:	ex =	0.94	in
Neutral axis depth:	c =	255.56	in
	a =	166.11	in
Concrete forces:	Pc =	257042	kips
	Mc =	5825	kip-ft

Tendon forces:

Effective initial prestressing strain: ε_{so} = 0.00592

No.	Name	xeff in	ε_{si}	fsi ksi	Tsi kips	di in	Msi kip-ft
1	B6.1	137.42	0.00408	116.06	907	54	4087
2	B6.2	109.08	0.00363	103.42	830	26	1782
3	B6.3	65.30	0.00295	83.91	674	-18	-1012
4	B6.4	21.52	0.00226	64.39	503	-62	-2591
5	B5.1	136.16	0.00406	115.50	902	53	3973
6	B5.2	107.82	0.00361	102.86	826	24	1685
7	B5.3	66.56	0.00297	84.47	678	-17	-948
8	B5.4	22.78	0.00228	64.96	507	-61	-2560
9	B4.1	136.79	0.00407	115.78	930	53	4142
10	B4.2	108.45	0.00362	103.14	828	25	1733
11	B4.3	65.93	0.00296	84.19	676	-17	-980
12	B4.4	22.15	0.00227	64.68	519	-61	-2648
13	T3.1	137.42	0.00408	116.06	907	54	4087
14	T3.2	109.08	0.00363	103.42	830	26	1782
15	T3.3	79.47	0.00317	90.23	724	-4	-233
16	T3.4	20.22	0.00224	63.82	499	-63	-2622
17	T2.1	122.62	0.00384	109.46	879	39	2878
18	T2.2	94.27	0.00340	96.82	777	11	709
19	T2.3	65.93	0.00296	84.19	676	-17	-980
20	T2.4	37.58	0.00251	71.55	575	-46	-2190
21	T1.1	136.16	0.00406	115.50	902	53	3973
22	T1.2	107.82	0.00361	102.86	826	24	1685
23	T1.3	80.73	0.00319	90.79	729	-3	-158
24	T1.4	21.48	0.00226	64.38	503	-62	-2592
					17607		13000

Resultant forces:	Pny =	239435	kips	1065 MN
	Mny =	18826	kip-ft	26 MN-m
	ex =	0.94	in	
	ex req/ ex res =	1.00		1.00

- *Biaxial flexure check:* A.5.7.4.5

Minimum axial load to be considered as a column:	$0.1\phi_c f'_c A_g$ =	29818	kips	133 MN
Factored axial load:	Pu =	3406	kips	15 MN
Nominal axial resistance:	Po =	246120	kips	1095 MN
Method to check biaxial flexure:		Load Contour Method		
Reciprocal Load Method:	Pr =	NA	Kips	
	Pu/Pr =	**NA**	**NA**	**NA**
Load Contour Method:	Mux/Mrx =	0.26		
	Muy/Mry =	0.02		
	IE =	**0.27**	**OK!**	**0.27**

6 Check for shear and torsional force effects:

- *Resistance factor:* A.5.5.4.2 ϕ = 0.90

- *Torsional effects:*

Total area enclosed by outside perimeter of concrete:	Acp =	41414	in2		
Outside perimeter of the concrete section:	pc =	823	in		
Diameter of exterior stirrups:	d =	0.98	in	25	mm
Spacing of exterior stirrups:	s =	5.91	in	150	mm
Area enclosed by the shear path:	Ao =	37537	in2		
Perimeter of centerline of exterior stirrups:	ph =	784	in		
Torsional cracking moment:	Tcr =	109830	kip-ft	149	MN-m
	$0.25\phi_T$Tcr=	24712	kip-ft	34	MN-m
	Tu =	14051	kip-ft	19	MN-m

Torsional effects DO NOT need to be considered for shear checking

Torsional resistance:	ϕ_TTn=	69443	kip-ft	94	MN-m
	Tu/ϕ_TTn =	**0.20**	**OK!**	**0.20**	

- *In-plane shear:*

Factored load:	Vuy =	19951	Kips	89	MN
Prestressing force in direction of Vu:	Vp =	2405	Kips	11	MN
In-plane concrete shear resistance approach:	Method =	2	A.5.8.4.3.2		
Effective width	bv =	175	in		
Minimum Shear depth:	dv =	189	in		
Net tensile Strains:	$\varepsilon_{average}$ =	0.00088			
Crack angle:	θ =	32.1			
Parameter β assuming min. transverse reinforcement:	β=	2.892			
In-plane concrete shear resistance:	Vc =	8555	Kips	38	MN
In-plane steel shear resistance:	Vs =	18626	Kips	83	MN
Inclination of reinforcement:	α=	90	deg		
Diameter of stirrups:	d =	0.98	in		
Spacing of stirrups:	s =	5.91	in		
No. of reinforcement legs:	n =	8			
	ϕ_VVn =	24463	Kips	109	MN
	Vu/ϕ_VVn =	**0.82**	**OK!**	**0.82**	

- *Out-of-plane shear:*

Factored load:	Vux =	1072	Kips	5	MN
Prestressing force in direction of Vu:	Vp =	0	Kips	0	MN
In-plane concrete shear resistance approach:	Method =	2	A.5.8.4.3.2		
Effective width	bv =	236	in		
Minimum Shear depth:	dv =	126	in		
Net tensile Strains:	$\varepsilon_{average}$ =	0.00000			
Parameter β assuming min. transverse reinforcement:	β=	4.800			
In-plane concrete shear resistance:	Vc =	12792	Kips	57	MN
	ϕ_VVc =	11513	Kips	51	MN
	Vu/ϕ_VVc =	**0.08**	**OK!**	**0.08**	

5	B5.1	-52.83	28.19	36	7.81	0.43	-1342	634
6	B5.2	-24.49	28.19	37	8.03	0.43	-622	634
7	B5.3	16.77	28.19	37	8.03	0.43	426	634
8	B5.4	60.55	28.19	36	7.81	0.43	1538	634
9	B4.1	-53.46	35.59	37	8.03	0.48	-1358	822
10	B4.2	-25.12	35.59	37	8.03	0.48	-638	822
11	B4.3	17.40	35.59	37	8.03	0.48	442	822
12	B4.4	61.18	35.59	37	8.03	0.48	1554	822
13	T3.1	-54.09	206.02	36	7.81	0.21	-1374	5175
14	T3.2	-25.75	206.02	37	8.03	0.21	-654	5175
15	T3.3	3.86	206.02	37	8.03	0.21	98	5175
16	T3.4	63.11	206.02	36	7.81	0.21	1603	5175
17	T2.1	-39.29	211.61	37	8.03	0.12	-998	5317
18	T2.2	-10.94	211.61	37	8.03	0.12	-278	5317
19	T2.3	17.40	211.61	37	8.03	0.12	442	5317
20	T2.4	45.75	211.61	37	8.03	0.12	1162	5317
21	T1.1	-52.83	211.61	36	7.81	0.00	-1342	5317
22	T1.2	-24.49	211.61	37	8.03	0.00	-622	5317
23	T1.3	2.60	211.61	37	8.03	0.00	66	5317
24	T1.4	61.85	211.61	36	7.81	0.00	1571	5317
					190.96	0.25		
		Centroids =	-0.58	119.29	in			
		Eccentricity =	-0.58	1.18	in			

- *Longitudinal reinforcement locations:*

**from bottom of gross section

No.	Name	db (in)	y**(in)	Qty	Area (in2)	db (mm)	y (mm)
1	B1	2.24	6.44	20	79.10	57	164
2	B2	2.24	12.31	20	79.10	57	313
3	B3	2.24	18.19	20	79.10	57	462
4	B4	2.24	24.07	12	47.46	57	611
5	B5	2.24	29.95	12	47.46	57	761
6	B6	2.24	35.82	12	47.46	57	910
7	B7	2.24	41.70	12	47.46	57	1059
8	B8	2.24	47.58	14	55.37	57	1209
9	B9	2.24	53.46	14	55.37	57	1358
10	B10	2.24	59.33	14	55.37	57	1507
11	B11	2.24	65.21	14	55.37	57	1656
12	M1	1.69	71.09	6	13.51	43	1806
13	M2	1.69	76.97	6	13.51	43	1955
14	M3	1.69	82.85	6	13.51	43	2104
15	M4	1.69	88.72	6	13.51	43	2254
16	M5	1.69	94.60	6	13.51	43	2403
17	M6	1.69	100.48	6	13.51	43	2552
18	M7	1.69	106.36	6	13.51	43	2701
19	M8	1.69	112.23	6	13.51	43	2851
20	M9	1.69	118.11	6	13.51	43	3000
21	M10	1.69	123.99	6	13.51	43	3149
22	M11	1.69	129.87	6	13.51	43	3299
23	M12	1.69	135.74	6	13.51	43	3448
24	M13	1.69	141.62	6	13.51	43	3597
25	M14	1.69	147.50	6	13.51	43	3746
26	M15	1.69	153.38	6	13.51	43	3896
27	M16	1.69	159.25	6	13.51	43	4045
28	T1	2.24	165.13	13	51.42	57	4194
29	T2	2.24	171.01	5	19.78	57	4344
30	M17	1.69	176.89	6	13.51	43	4493
31	M18	1.69	182.76	6	13.51	43	4642
32	M19	1.69	188.64	6	13.51	43	4791
33	M20	1.69	194.52	6	13.51	43	4941
34	M21	1.69	200.40	6	13.51	43	5090
35	M22	1.69	206.27	6	13.51	43	5239
36	T3	2.24	212.15	36	142.39	57	5389
37	T4	2.24	218.03	28	110.75	57	5538
38	T5	2.24	223.91	27	106.79	57	5687
39	T6	2.24	229.78	27	106.79	57	5837
					1483.69		

0 Specifications: AASHTO LRFD Design Specs. 2012

1 Material properties:

				Metric	
- Concrete density:	Wc =	0.15	kcf	24	KN/m3
- Concrete 28-day compressive strength:	f'c =	8	ksi	55	MPa
- Reinforcement strength:	fy =	60	ksi	414	MPa
- Prestressing steel strand:	Diameter =	0.60	in	15	mm
Strand cross-sectional area:	A =	0.217	in2	140	mm2
Modulus of Elasticity:	Ep =	28478	ksi	196500	MPa
Ultimate tensile strength:	Fpu =	58.43	kips	260	KN
	fpu =	269	ksi	1858	MPa
Minimum yield strength:	Fpy =	52.58	kips	234	KN
	fpy =	90%	fpu		
Maximum stressing force per strand:	Fp max =	43.82	kips	195	KN
	fp jacking =	75%	fpu		
% prestressing stress after transfer with Max losses:	fpt =	67%	fpu		
% Effective prestressing stress considering Max losses:	fpe =	63%	fpu		
Effective prestressing strain considering Max losses:	ε_{po} =	0.00592			
Wedge seating:	Δ =	0.39	in	10	mm
Friction coefficient:	μ =	0.15	/rad	0.15	/rad
Wobble coefficient:	k =	0.000201	/ft	0.00066	/m
- Tendons:					
Duct diameter:	OD =	5.51	in	140	mm
Location of tendon CG with respect to duct CG	Z =	0.47	in	12	mm

2 Bearing location:

- Eccentricity between shaft and top of pier cap:	e1 =	39.17	in	995	mm

3 Loads:

- Case	Maximum Shear Key: Mux max				
	PT + EQ + DL			PT + EQ + DL	
- *Loading effects at the section of maximum effect:*					
Axial (if <0 → Tension)	Pu =	41614	kips	185	MN
In-plane shear	Vuy =	20054	kips	89	MN
Out-of-plane shear	Vux =	1840	kips	8	MN
In-plane-bending moment: (if >0 → Top fiber in tension)	Mux =	906959	kip-ft	1232	MN-m
Out-of-plane bending moment	Muy =	23576	kip-ft	32	MN-m
Torsion	Tu =	24111	kip-ft	33	MN-m

4 Pier cap section properties:

- Section No.		1			
	Location =	SK			
- *Dimensions:*					
Location from cap end	x =	30.51	ft	9298	mm
Width	B =	216.5	208 in	5500	mm
Depth	H =	236.2	228 in	6000	mm
Concrete cover:	Top =	4.33	in	110	mm
	Bottom =	4.33	in	110	mm
	Lateral =	4.33	in	110	mm

- *Section properties:*		Gross	Eff at ε_{cu}	
Area	A =	51150	47304	in2
Centroid (with respect to left bottom corner)	yc =	118.110	114	in
	xc =	108	104	in
Moment of inertia	Ix =	237848451	204127410	in4
	Iy =	199858768	170338765	in4
Section modulus	Sx =	2013784	1794061	in3
	Sy =	1845968	1638865	in3

- *Longitudinal tendon locations:*

*from section centerline
**from bottom of gross section

No.	Name	x* (in)	y**(in)	Strands	Area (in2)	α (rad)	x (mm)	y (mm)
1	B6.1	-54.09	22.60	36	7.81	0.25	-1374	492
2	B6.2	-25.75	22.60	37	8.03	0.25	-654	492
3	B6.3	18.03	22.60	37	8.03	0.25	458	492
4	B6.4	61.81	22.60	36	7.81	0.25	1570	492

14	T3.2	201.69	0.01387	263.42	2115	88	15495
15	T3.3	201.69	0.01387	263.42	2115	88	15495
16	T3.4	201.69	0.01387	263.42	2058	88	15076
17	T2.1	207.28	0.01420	263.69	2117	94	16497
18	T2.2	207.28	0.01420	263.69	2117	94	16497
19	T2.3	207.28	0.01420	263.69	2117	94	16497
20	T2.4	207.28	0.01420	263.69	2117	94	16497
21	T1.1	207.28	0.01420	263.69	2060	94	16051
22	T1.2	207.28	0.01420	263.69	2117	94	16497
23	T1.3	207.28	0.01420	263.69	2117	94	16497
24	T1.4	207.28	0.01420	263.69	2060	94	16051
					34344		124336

Reinforcement forces:

No.	Name	yeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B1	2.11	-0.00388	-60.00	-4746	-112	44169
2	B2	7.98	-0.00353	-60.00	-4746	-106	41845
3	B3	13.86	-0.00318	-60.00	-4746	-100	39520
4	B4	19.74	-0.00283	-60.00	-2848	-94	22317
5	B5	25.62	-0.00248	-60.00	-2848	-88	20922
6	B6	31.49	-0.00214	-60.00	-2848	-82	19528
7	B7	37.37	-0.00179	-51.84	-2460	-76	15666
8	B8	43.25	-0.00144	-41.75	-2312	-71	13587
9	B9	49.13	-0.00109	-31.66	-1753	-65	9444
10	B10	55.00	-0.00074	-21.56	-1194	-59	5849
11	B11	60.88	-0.00040	-11.47	-635	-53	2801
12	M1	66.76	-0.00005	-1.38	-19	-47	73
13	M2	72.64	0.00030	8.71	118	-41	-403
14	M3	78.51	0.00065	18.80	254	-35	-746
15	M4	84.39	0.00100	28.89	390	-29	-956
16	M5	90.27	0.00134	38.98	526	-24	-1031
17	M6	96.15	0.00169	49.07	663	-18	-974
18	M7	102.02	0.00204	59.16	799	-12	-783
19	M8	107.90	0.00239	60.00	810	-6	-397
20	M9	113.78	0.00274	60.00	810	0	0
21	M10	119.66	0.00308	60.00	810	6	397
22	M11	125.53	0.00343	60.00	810	12	794
23	M12	131.41	0.00378	60.00	810	18	1191
24	M13	137.29	0.00413	60.00	810	24	1588
25	M14	143.17	0.00448	60.00	810	29	1984
26	M15	149.04	0.00482	60.00	810	35	2381
27	M16	154.92	0.00517	60.00	810	41	2778
28	T1	160.80	0.00552	60.00	3085	47	12088
29	T2	166.68	0.00587	60.00	1187	53	5231
30	M17	172.55	0.00622	60.00	810	59	3969
31	M18	178.43	0.00656	60.00	810	65	4366
32	M19	184.31	0.00691	60.00	810	71	4763
33	M20	190.19	0.00726	60.00	810	76	5160
34	M21	196.07	0.00761	60.00	810	82	5557
35	M22	201.94	0.00796	60.00	810	88	5953
36	T3	207.82	0.00830	60.00	8543	94	66951
37	T4	213.70	0.00865	60.00	6645	100	55328
38	T5	219.58	0.00900	60.00	6407	106	56490
39	T6	225.45	0.00935	60.00	6407	112	59629
					16025		527027

Resultant forces:

Pnx =	11709	kips	52	MN
Mnx =	1126371	kip-ft	1528	MN-m
ey =	1154.32	in		
ey req/ ey res =	1.00		1.00	

5 Check for axial and flexural force effects:

- *Resistance factor:* A.5.10.11.4.1b ϕ = 0.90

- *Loading effects:*

1 Prestressing loading effects:

Pu =	32218	kips	143	MN
Mux =	-3171	kip-ft	-4	MN-m
Muy =	-1551	kip-ft	-2	MN-m

2 Net loading effects:

Pu =	9395	kips	42	MN
Mux =	903788	kip-ft	1226	MN-m
Muy =	22025	kip-ft	30	MN-m

3 Total loading stresses:

Pu/A =	0.814	ksi	5.6	MPa
Mux/Sx =	5.405	ksi	37.3	MPa
Muy/Sy =	0.153	ksi	1.1	MPa
Max =	6.371	ksi	44.0	MPa
	80%	f'c	80%	
Min =	-4.744	ksi	-32.7	MPa
	59%	f'c	59%	

- *Analysis approach:* *Strain compatibility*

- *Concrete behavior assumptions:* *Unconfined*

Stress distribution: A.5.7.2.2 *Rectangular*

α_1 = 0.85

β_1 = 0.65

Compressive strength: f'c = 8 ksi

Ultimate compression strain: ε_{cu} = 0.004 *

* Seismic Design of Reinforced Concrete and Masonry Buildings, Paulay and Priestly, pag. 98

Ignore concrete cover for calculations at this strain level

Modulus of Elasticity: A.5.4.2.4-1 E = 5422 ksi

Effective section properties: b = 208 in 5280 mm

h = 228 in 5780 mm

- *Major-axis bending resistance: Pnx, Mnx*

Eccentricity: ey = 1154.32 in

Neutral axis depth: c = 67.56 in

a = 43.92 in

Concrete forces: Pc = 62078 kips

Mc = 475008 kip-ft

Tendon forces:

Effective initial prestressing strain: ε_{po} = 0.00592

No.	Name	yeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B6.1	18.27	0.00301	85.60	669	-96	-5323
2	B6.2	18.27	0.00301	85.60	687	-96	-5470
3	B6.3	18.27	0.00301	85.60	687	-96	-5470
4	B6.4	18.27	0.00301	85.60	669	-96	-5323
5	B5.1	23.86	0.00334	95.03	742	-90	-5563
6	B5.2	23.86	0.00334	95.03	763	-90	-5717
7	B5.3	23.86	0.00334	95.03	763	-90	-5717
8	B5.4	23.86	0.00334	95.03	742	-90	-5563
9	B4.1	31.26	0.00378	107.51	863	-83	-5936
10	B4.2	31.26	0.00378	107.51	863	-83	-5936
11	B4.3	31.26	0.00378	107.51	863	-83	-5936
12	B4.4	31.26	0.00378	107.51	863	-83	-5936
13	T3.1	201.69	0.01387	263.42	2058	88	15076

6 Check for shear and torsional force effects:

- *Resistance factor:* A.5.5.4.2 ϕ = 0.90

- *Torsional effects:*

Total area enclosed by outside perimeter of concrete:	Acp =	51150	in2		
Outside perimeter of the concrete section:	pc =	906	in		
Diameter of exterior stirrups:	d =	0.98	in	25	mm
Spacing of exterior stirrups:	s =	12.60	in	320	mm
Area enclosed by the shear path:	Ao =	46876	in2		
Perimeter of centerline of exterior stirrups:	ph =	867	in		
Torsional cracking moment:	Tcr =	141976	kip-ft	193	MN-m
	0.25ϕTcr=	31945	kip-ft	43	MN-m
	Tu =	24111	kip-ft	33	MN-m

Torsional effects DO NOT need to be considered for shear checking

Torsional resistance:	ϕTn=	34007	kip-ft	46	MN-m
	Tu/ϕTn =	**0.71**	**OK!**	**0.71**	

- *In-plane shear:*

Factored load:	Vuy =	20054	Kips	89	MN
Prestressing force in direction of Vu:	Vp =	2405	Kips	11	MN
In-plane concrete shear resistance approach:	Method =	2	A.5.8.4.3.2		
Effective width	bv =	217	in		
Minimum Shear depth:	dv =	189	in		
Net tensile Strains:	$\varepsilon_{average}$ =	0.00224			
Crack angle:	θ =	36.8			
Parameter β assuming min. transverse reinforcement:	β=	1.791			
In-plane concrete shear resistance:	Vc =	6543	Kips	29	MN
In-plane steel shear resistance:	Vs =	27211	Kips	121	MN
Inclination of reinforcement:	α=	90	deg		
Diameter of stirrups:	d =	1.69	in	43	mm
Spacing of stirrups:	s =	10.00	in	254	mm
No. of reinforcement legs:	n =	8			
	ϕVn =	30379	Kips	135	MN
	Vu/ϕVn =	**0.66**	**OK!**	**0.66**	

- *Out-of-plane shear:*

Factored load:	Vux =	1840	Kips	8	MN
Prestressing force in direction of Vu:	Vp =	0	Kips	0	MN
In-plane concrete shear resistance approach:	Method =	2	A.5.8.4.3.2		
Effective width	bv =	236	in		
Minimum Shear depth:	dv =	156	in		
Net tensile Strains:	$\varepsilon_{average}$ =	0.00000			
Parameter β assuming min. transverse reinforcement:	β=	4.800			
In-plane concrete shear resistance:	Vc =	15800	Kips	70	MN
	ϕVc =	14220	Kips	63	MN
	Vu/ϕVc =	**0.12**	**OK!**	**0.12**	

- *Minor-axis bending resistance: Pny, Mny*

Eccentricity:	ex =	28.13	in
Neutral axis depth:	c =	242.39	in
	a =	157.55	in
Concrete forces:	Pc =	243794	kips
	Mc =	511190	kip-ft

Tendon forces:

Effective initial prestressing strain: ε_{so}= 0.00592

No.	Name	xeff in	ε_{si}	fsi ksi	Tsi kips	di in	Msi kip-ft
1	B6.1	158.03	0.00453	129.07	1008	54	4545
2	B6.2	129.69	0.00406	115.75	929	26	1994
3	B6.3	85.91	0.00334	95.18	764	-18	-1148
4	B6.4	42.13	0.00262	74.60	583	-62	-3002
5	B5.1	156.77	0.00451	128.48	1004	53	4419
6	B5.2	128.43	0.00404	115.16	925	24	1887
7	B5.3	87.17	0.00336	95.77	769	-17	-1075
8	B5.4	43.39	0.00264	75.19	587	-61	-2964
9	B4.1	157.40	0.00452	128.78	1034	53	4607
10	B4.2	129.06	0.00405	115.45	927	25	1940
11	B4.3	86.54	0.00335	95.47	767	-17	-1112
12	B4.4	42.76	0.00263	74.90	601	-61	-3066
13	T3.1	158.03	0.00453	129.07	1008	54	4545
14	T3.2	129.69	0.00406	115.75	929	26	1994
15	T3.3	100.08	0.00358	101.84	818	-4	-263
16	T3.4	40.83	0.00260	73.99	578	-63	-3040
17	T2.1	143.23	0.00429	122.12	980	39	3210
18	T2.2	114.88	0.00382	108.79	874	11	797
19	T2.3	86.54	0.00335	95.47	767	-17	-1112
20	T2.4	58.19	0.00288	82.15	660	-46	-2515
21	T1.1	156.77	0.00451	128.48	1004	53	4419
22	T1.2	128.43	0.00404	115.16	925	24	1887
23	T1.3	101.34	0.00360	102.43	822	-3	-178
24	T1.4	42.09	0.00262	74.58	583	-62	-3003
					19845		13769

Resultant forces:	Pny =	223949	kips	997	MN
	Mny =	524959	kip-ft	712	MN-m
	ex =	28.13	in		
	ex req/ ex res =	1.00		1.00	

- *Biaxial flexure check:* A.5.7.4.5

Minimum axial load to be considered as a column:	0.1ϕf'cAg =	36828	kips	164	MN
Factored axial load:	Pu =	9395	kips	42	MN
Nominal axial resistance:	Po =	309901	kips	1379	MN
Method to check biaxial flexure:		Load Contour Method			
Reciprocal Load Method:	Pr =	NA	Kips		
	Pu/Pr =	**NA**	**NA**	**NA**	
Load Contour Method:	Mux/Mrx =	0.89			
	Muy/Mry =	0.05			
	IE =	**0.94**	**OK!**	**0.94**	

5	B5.1	-52.83	28.19	36	7.81	0.43	-1342	634
6	B5.2	-24.49	28.19	37	8.03	0.43	-622	634
7	B5.3	16.77	28.19	37	8.03	0.43	426	634
8	B5.4	60.55	28.19	36	7.81	0.43	1538	634
9	B4.1	-53.46	35.59	37	8.03	0.48	-1358	822
10	B4.2	-25.12	35.59	37	8.03	0.48	-638	822
11	B4.3	17.40	35.59	37	8.03	0.48	442	822
12	B4.4	61.18	35.59	37	8.03	0.48	1554	822
13	T3.1	-54.09	206.02	36	7.81	0.21	-1374	5175
14	T3.2	-25.75	206.02	37	8.03	0.21	-654	5175
15	T3.3	3.86	206.02	37	8.03	0.21	98	5175
16	T3.4	63.11	206.02	36	7.81	0.21	1603	5175
17	T2.1	-39.29	211.61	37	8.03	0.12	-998	5317
18	T2.2	-10.94	211.61	37	8.03	0.12	-278	5317
19	T2.3	17.40	211.61	37	8.03	0.12	442	5317
20	T2.4	45.75	211.61	37	8.03	0.12	1162	5317
21	T1.1	-52.83	211.61	36	7.81	0.00	-1342	5317
22	T1.2	-24.49	211.61	37	8.03	0.00	-622	5317
23	T1.3	2.60	211.61	37	8.03	0.00	66	5317
24	T1.4	61.85	211.61	36	7.81	0.00	1571	5317
					190.96	0.25		
	Centroids =	-0.58	119.29	in				
	Eccentricity =	-0.58	1.18	in				

- *Longitudinal reinforcement locations:*

**from bottom of gross section

No.	Name	db (in)	y**(in)	Qty	Area (in2)	db (mm)	y (mm)
1	B1	2.24	6.44	20	79.10	57	164
2	B2	2.24	12.31	20	79.10	57	313
3	B3	2.24	18.19	20	79.10	57	462
4	B4	2.24	24.07	12	47.46	57	611
5	B5	2.24	29.95	12	47.46	57	761
6	B6	2.24	35.82	12	47.46	57	910
7	B7	2.24	41.70	12	47.46	57	1059
8	B8	2.24	47.58	14	55.37	57	1209
9	B9	2.24	53.46	14	55.37	57	1358
10	B10	2.24	59.33	14	55.37	57	1507
11	B11	2.24	65.21	14	55.37	57	1656
12	M1	1.69	71.09	6	13.51	43	1806
13	M2	1.69	76.97	6	13.51	43	1955
14	M3	1.69	82.85	6	13.51	43	2104
15	M4	1.69	88.72	6	13.51	43	2254
16	M5	1.69	94.60	6	13.51	43	2403
17	M6	1.69	100.48	6	13.51	43	2552
18	M7	1.69	106.36	6	13.51	43	2701
19	M8	1.69	112.23	6	13.51	43	2851
20	M9	1.69	118.11	6	13.51	43	3000
21	M10	1.69	123.99	6	13.51	43	3149
22	M11	1.69	129.87	6	13.51	43	3299
23	M12	1.69	135.74	6	13.51	43	3448
24	M13	1.69	141.62	6	13.51	43	3597
25	M14	1.69	147.50	6	13.51	43	3746
26	M15	1.69	153.38	6	13.51	43	3896
27	M16	1.69	159.25	6	13.51	43	4045
28	T1	2.24	165.13	13	51.42	57	4194
29	T2	2.24	171.01	5	19.78	57	4344
30	M17	1.69	176.89	6	13.51	43	4493
31	M18	1.69	182.76	6	13.51	43	4642
32	M19	1.69	188.64	6	13.51	43	4791
33	M20	1.69	194.52	6	13.51	43	4941
34	M21	1.69	200.40	6	13.51	43	5090
35	M22	1.69	206.27	6	13.51	43	5239
36	T3	2.24	212.15	36	142.39	57	5389
37	T4	2.24	218.03	28	110.75	57	5538
38	T5	2.24	223.91	27	106.79	57	5687
39	T6	2.24	229.78	27	106.79	57	5837
					1483.69		

0 Specifications: AASHTO LRFD Design Specs. 2012

1 Material properties:

				Metric	
- Concrete density:	Wc =	0.15	kcf	24	KN/m3
- Concrete 28-day compressive strength:	f'c =	8	ksi	55	MPa
- Reinforcement strength:	fy =	60	ksi	414	MPa
- Prestressing steel strand:	Diameter =	0.60	in	15	mm
Strand cross-sectional area:	A =	0.217	in2	140	mm2
Modulus of Elasticity:	Ep =	28478	ksi	196500	MPa
Ultimate tensile strength:	Fpu =	58.43	kips	260	KN
	fpu =	269	ksi	1858	MPa
Minimum yield strength:	Fpy =	52.58	kips	234	KN
	fpy =	90%	fpu		
Maximum stressing force per strand:	Fp max =	43.82	kips	195	KN
	fp jacking =	75%	fpu		
% prestressing stress after transfer with Max losses:	fpt =	67%	fpu		
% Effective prestressing stress considering Max losses:	fpe =	63%	fpu		
Effective prestressing strain considering Max losses:	ε_{po} =	0.00592			
Wedge seating:	Δ =	0.39	in	10	mm
Friction coefficient:	μ =	0.15	/rad	0.15	/rad
Wobble coefficient:	k =	0.000201	/ft	0.00066	/m
- Tendons:					
Duct diameter:	OD =	5.51	in	140	mm
Location of tendon CG with respect to duct CG	Z =	0.47	in	12	mm

2 Bearing location:

- Eccentricity between shaft and top of pier cap:	e1 =	39.17	in	995	mm

3 Loads:

- Case	Maximum Shear Key: Vuy max				
	PT + EQ + DL			PT + EQ + DL	
- *Loading effects at the section of maximum effect:*					
Axial (if <0 → Tension)	Pu =	35624	kips	159	MN
In-plane shear	Vuy =	20662	kips	92	MN
Out-of-plane shear	Vux =	1072	kips	5	MN
In-plane-bending moment: (if >0 → Top fiber in tension)	Mux =	506353	kip-ft	688	MN-m
Out-of-plane bending moment	Muy =	13092	kip-ft	18	MN-m
Torsion	Tu =	14049	kip-ft	19	MN-m

4 Pier cap section properties:

- Section No.		1			
	Location =	SK			
- *Dimensions:*					
Location from cap end	x =	30.51	ft	9298	mm
Width	B =	216.5	208 in	5500	mm
Depth	H =	236.2	228 in	6000	mm
Concrete cover:	Top =	4.33	in	110	mm
	Bottom =	4.33	in	110	mm
	Lateral =	4.33	in	110	mm

- *Section properties:*		Gross	Eff at ε_{cu}	
Area	A =	51150	47304	in2
Centroid (with respect to left bottom corner)	yc =	118.110	114	in
	xc =	108	104	in
Moment of inertia	Ix =	237848451	204127410	in4
	Iy =	199858768	170338765	in4
Section modulus	Sx =	2013784	1794061	in3
	Sy =	1845968	1638865	in3

- *Longitudinal tendon locations:*

*from section centerline
**from bottom of gross section

No.	Name	x* (in)	y**(in)	Strands	Area (in2)	α (rad)	x (mm)	y (mm)
1	B6.1	-54.09	22.60	36	7.81	0.25	-1374	492
2	B6.2	-25.75	22.60	37	8.03	0.25	-654	492
3	B6.3	18.03	22.60	37	8.03	0.25	458	492
4	B6.4	61.81	22.60	36	7.81	0.25	1570	492

14	T3.2	201.69	0.01437	263.82	2118	88	15519
15	T3.3	201.69	0.01437	263.82	2118	88	15519
16	T3.4	201.69	0.01437	263.82	2061	88	15099
17	T2.1	207.28	0.01472	264.07	2120	94	16521
18	T2.2	207.28	0.01472	264.07	2120	94	16521
19	T2.3	207.28	0.01472	264.07	2120	94	16521
20	T2.4	207.28	0.01472	264.07	2120	94	16521
21	T1.1	207.28	0.01472	264.07	2063	94	16074
22	T1.2	207.28	0.01472	264.07	2120	94	16521
23	T1.3	207.28	0.01472	264.07	2120	94	16521
24	T1.4	207.28	0.01472	264.07	2063	94	16074
					34549		123382

Reinforcement forces:

No.	Name	yeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B1	2.11	-0.00387	-60.00	-4746	-112	44169
2	B2	7.98	-0.00351	-60.00	-4746	-106	41845
3	B3	13.86	-0.00314	-60.00	-4746	-100	39520
4	B4	19.74	-0.00278	-60.00	-2848	-94	22317
5	B5	25.62	-0.00242	-60.00	-2848	-88	20922
6	B6	31.49	-0.00206	-59.62	-2830	-82	19404
7	B7	37.37	-0.00169	-49.10	-2330	-76	14839
8	B8	43.25	-0.00133	-38.58	-2136	-71	12556
9	B9	49.13	-0.00097	-28.06	-1554	-65	8370
10	B10	55.00	-0.00060	-17.53	-971	-59	4756
11	B11	60.88	-0.00024	-7.01	-388	-53	1712
12	M1	66.76	0.00012	3.51	47	-47	-186
13	M2	72.64	0.00048	14.03	189	-41	-650
14	M3	78.51	0.00085	24.55	332	-35	-974
15	M4	84.39	0.00121	35.07	474	-29	-1160
16	M5	90.27	0.00157	45.59	616	-24	-1206
17	M6	96.15	0.00194	56.12	758	-18	-1114
18	M7	102.02	0.00230	60.00	810	-12	-794
19	M8	107.90	0.00266	60.00	810	-6	-397
20	M9	113.78	0.00302	60.00	810	0	0
21	M10	119.66	0.00339	60.00	810	6	397
22	M11	125.53	0.00375	60.00	810	12	794
23	M12	131.41	0.00411	60.00	810	18	1191
24	M13	137.29	0.00447	60.00	810	24	1588
25	M14	143.17	0.00484	60.00	810	29	1984
26	M15	149.04	0.00520	60.00	810	35	2381
27	M16	154.92	0.00556	60.00	810	41	2778
28	T1	160.80	0.00593	60.00	3085	47	12088
29	T2	166.68	0.00629	60.00	1187	53	5231
30	M17	172.55	0.00665	60.00	810	59	3969
31	M18	178.43	0.00701	60.00	810	65	4366
32	M19	184.31	0.00738	60.00	810	71	4763
33	M20	190.19	0.00774	60.00	810	76	5160
34	M21	196.07	0.00810	60.00	810	82	5557
35	M22	201.94	0.00847	60.00	810	88	5953
36	T3	207.82	0.00883	60.00	8543	94	66951
37	T4	213.70	0.00919	60.00	6645	100	55328
38	T5	219.58	0.00955	60.00	6407	106	56490
39	T6	225.45	0.00992	60.00	6407	112	59629
					17512		520527

Resultant forces:

Pnx =	7477	kips	33	MN
Mnx =	1103937	kip-ft	1497	MN-m
ey =	1771.80	in		
ey req/ ey res =	1.00		1.00	

5 Check for axial and flexural force effects:

- *Resistance factor:* A.5.10.11.4.1b ϕ = 0.90

- *Loading effects:*

1 Prestressing loading effects:

Pu =	32218	kips	143	MN
Mux =	-3171	kip-ft	-4	MN-m
Muy =	-1551	kip-ft	-2	MN-m

2 Net loading effects:

Pu =	3406	kips	15	MN
Mux =	503182	kip-ft	682	MN-m
Muy =	11541	kip-ft	16	MN-m

3 Total loading stresses:

Pu/A =	0.696	ksi	4.8	MPa
Mux/Sx =	3.017	ksi	20.8	MPa
Muy/Sy =	0.085	ksi	0.6	MPa
Max =	3.799	ksi	26.2	MPa
	47%	f'c	47%	
Min =	-2.406	ksi	-16.6	MPa
	30%	f'c	30%	

- *Analysis approach:* *Strain compatibility*

- *Concrete behavior assumptions:* *Unconfined*

Stress distribution: A.5.7.2.2 *Rectangular*

α_1 = 0.85

β_1 = 0.65

Compressive strength: f'c = 8 ksi

Ultimate compression strain: ε_{cu} = 0.004 *

* Seismic Design of Reinforced Concrete and Masonry Buildings, Paulay and Priestly, pag. 98

Ignore concrete cover for calculations at this strain level

Modulus of Elasticity: A.5.4.2.4-1 E = 5422 ksi

Effective section properties: b = 208 in 5280 mm

h = 228 in 5780 mm

- *Major-axis bending resistance: Pnx, Mnx*

Eccentricity: ey = 1772.91 in

Neutral axis depth: c = 64.80 in

a = 42.12 in

Concrete forces: Pc = 59538 kips

Mc = 460028 kip-ft

Tendon forces:

Effective initial prestressing strain: ε_{po} = 0.00592

No.	Name	yeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B6.1	18.27	0.00305	86.92	679	-96	-5404
2	B6.2	18.27	0.00305	86.92	698	-96	-5554
3	B6.3	18.27	0.00305	86.92	698	-96	-5554
4	B6.4	18.27	0.00305	86.92	679	-96	-5404
5	B5.1	23.86	0.00340	96.74	756	-90	-5663
6	B5.2	23.86	0.00340	96.74	777	-90	-5821
7	B5.3	23.86	0.00340	96.74	777	-90	-5821
8	B5.4	23.86	0.00340	96.74	756	-90	-5663
9	B4.1	31.26	0.00385	109.76	881	-83	-6060
10	B4.2	31.26	0.00385	109.76	881	-83	-6060
11	B4.3	31.26	0.00385	109.76	881	-83	-6060
12	B4.4	31.26	0.00385	109.76	881	-83	-6060
13	T3.1	201.69	0.01437	263.82	2061	88	15099

6 Check for shear and torsional force effects:

- *Resistance factor:* A.5.5.4.2 ϕ = 0.90

- *Torsional effects:*

Total area enclosed by outside perimeter of concrete:	Acp =	51150	in2		
Outside perimeter of the concrete section:	pc =	906	in		
Diameter of exterior stirrups:	d =	0.98	in	25	mm
Spacing of exterior stirrups:	s =	12.60	in	320	mm
Area enclosed by the shear path:	Ao =	46876	in2		
Perimeter of centerline of exterior stirrups:	ph =	867	in		
Torsional cracking moment:	Tcr =	141976	kip-ft	193	MN-m
	0.25ϕTcr=	31945	kip-ft	43	MN-m
	Tu =	14049	kip-ft	19	MN-m

Torsional effects DO NOT need to be considered for shear checking

Torsional resistance:	ϕTn=	38227	kip-ft	52	MN-m
	Tu/ϕTn =	**0.37**	**OK!**	**0.37**	

- *In-plane shear:*

Factored load:	Vuy =	20662	Kips	92	MN
Prestressing force in direction of Vu:	Vp =	2405	Kips	11	MN
In-plane concrete shear resistance approach:	Method =	2	A.5.8.4.3.2		
Effective width	bv =	217	in		
Minimum Shear depth:	dv =	189	in		
Net tensile Strains:	$\varepsilon_{average}$ =	0.00134			
Crack angle:	θ =	33.7			
Parameter β assuming min. transverse reinforcement:	β=	2.396			
In-plane concrete shear resistance:	Vc =	8753	Kips	39	MN
In-plane steel shear resistance:	Vs =	30588	Kips	136	MN
Inclination of reinforcement:	α=	90	deg		
Diameter of stirrups:	d =	1.69	in	43	mm
Spacing of stirrups:	s =	10.00	in	254	mm
No. of reinforcement legs:	n =	8			
	ϕVn =	35407	Kips	158	MN
	Vu/ϕVn =	**0.58**	**OK!**	**0.58**	

- *Out-of-plane shear:*

Factored load:	Vux =	1072	Kips	5	MN
Prestressing force in direction of Vu:	Vp =	0	Kips	0	MN
In-plane concrete shear resistance approach:	Method =	2	A.5.8.4.3.2		
Effective width	bv =	236	in		
Minimum Shear depth:	dv =	156	in		
Net tensile Strains:	$\varepsilon_{average}$ =	0.00000			
Parameter β assuming min. transverse reinforcement:	β=	4.800			
In-plane concrete shear resistance:	Vc =	15800	Kips	70	MN
	ϕVc =	14220	Kips	63	MN
	Vu/ϕVc =	**0.07**	**OK!**	**0.07**	

- *Minor-axis bending resistance: Pny, Mny*

Eccentricity:	ex =	40.66	in
Neutral axis depth:	c =	210.06	in
	a =	136.54	in
Concrete forces:	Pc =	211279	kips
	Mc =	627992	kip-ft

Tendon forces:

Effective initial prestressing strain: ε_{so}= 0.00592

No.	Name	xeff in	ε_{si}	fsi ksi	Tsi kips	di in	Msi kip-ft
1	B6.1	158.03	0.00493	140.50	1098	54	4948
2	B6.2	129.69	0.00439	125.13	1005	26	2156
3	B6.3	85.91	0.00356	101.39	814	-18	-1223
4	B6.4	42.13	0.00273	77.65	607	-62	-3124
5	B5.1	156.77	0.00491	139.82	1092	53	4809
6	B5.2	128.43	0.00437	124.45	999	24	2039
7	B5.3	87.17	0.00358	102.07	820	-17	-1145
8	B5.4	43.39	0.00275	78.33	612	-61	-3088
9	B4.1	157.40	0.00492	140.16	1125	53	5014
10	B4.2	129.06	0.00438	124.79	1002	25	2097
11	B4.3	86.54	0.00357	101.73	817	-17	-1184
12	B4.4	42.76	0.00274	77.99	626	-61	-3193
13	T3.1	158.03	0.00493	140.50	1098	54	4948
14	T3.2	129.69	0.00439	125.13	1005	26	2156
15	T3.3	100.08	0.00383	109.08	876	-4	-282
16	T3.4	40.83	0.00270	76.94	601	-63	-3161
17	T2.1	143.23	0.00465	132.48	1064	39	3483
18	T2.2	114.88	0.00411	117.10	940	11	858
19	T2.3	86.54	0.00357	101.73	817	-17	-1184
20	T2.4	58.19	0.00303	86.36	693	-46	-2643
21	T1.1	156.77	0.00491	139.82	1092	53	4809
22	T1.2	128.43	0.00437	124.45	999	24	2039
23	T1.3	101.34	0.00385	109.76	881	-3	-191
24	T1.4	42.09	0.00273	77.63	606	-62	-3126
					21288		15810

Resultant forces:	Pny =	189991	kips	845	MN
	Mny =	643802	kip-ft	873	MN-m
	ex =	40.66	in		
	ex req/ ex res =	1.00		1.00	

- *Biaxial flexure check:* A.5.7.4.5

Minimum axial load to be considered as a column:	0.1ϕf'cAg =	36828	kips	164	MN
Factored axial load:	Pu =	3406	kips	15	MN
Nominal axial resistance:	Po =	309901	kips	1379	MN
Method to check biaxial flexure:		Load Contour Method			
Reciprocal Load Method:	Pr =	NA	Kips		
	Pu/Pr =	**NA**	**NA**	**NA**	
Load Contour Method:	Mux/Mrx =	0.51			
	Muy/Mry =	0.02			
	IE =	**0.53**	**OK!**	**0.53**	

5	B5.1	-52.83	28.19	36	7.81	0.43	-1342	634
6	B5.2	-24.49	28.19	37	8.03	0.43	-622	634
7	B5.3	16.77	28.19	37	8.03	0.43	426	634
8	B5.4	60.55	28.19	36	7.81	0.43	1538	634
9	B4.1	-53.46	35.59	37	8.03	0.48	-1358	822
10	B4.2	-25.12	35.59	37	8.03	0.48	-638	822
11	B4.3	17.40	35.59	37	8.03	0.48	442	822
12	B4.4	61.18	35.59	37	8.03	0.48	1554	822
13	T3.1	-54.09	206.02	36	7.81	0.21	-1374	5175
14	T3.2	-25.75	206.02	37	8.03	0.21	-654	5175
15	T3.3	3.86	206.02	37	8.03	0.21	98	5175
16	T3.4	63.11	206.02	36	7.81	0.21	1603	5175
17	T2.1	-39.29	211.61	37	8.03	0.12	-998	5317
18	T2.2	-10.94	211.61	37	8.03	0.12	-278	5317
19	T2.3	17.40	211.61	37	8.03	0.12	442	5317
20	T2.4	45.75	211.61	37	8.03	0.12	1162	5317
21	T1.1	-52.83	211.61	36	7.81	0.00	-1342	5317
22	T1.2	-24.49	211.61	37	8.03	0.00	-622	5317
23	T1.3	2.60	211.61	37	8.03	0.00	66	5317
24	T1.4	61.85	211.61	36	7.81	0.00	1571	5317
					190.96	0.25		
	Centroids =	-0.58	119.29	in				
	Eccentricity =	-0.58	1.18	in				

- *Longitudinal reinforcement locations:*

**from bottom of gross section

No.	Name	db (in)	y**(in)	Qty	Area (in2)	db (mm)	y (mm)
1	B1	2.24	6.44	20	79.10	57	164
2	B2	2.24	12.31	20	79.10	57	313
3	B3	2.24	18.19	20	79.10	57	462
4	B4	2.24	24.07	12	47.46	57	611
5	B5	2.24	29.95	12	47.46	57	761
6	B6	2.24	35.82	12	47.46	57	910
7	B7	2.24	41.70	12	47.46	57	1059
8	B8	2.24	47.58	14	55.37	57	1209
9	B9	2.24	53.46	14	55.37	57	1358
10	B10	2.24	59.33	14	55.37	57	1507
11	B11	2.24	65.21	14	55.37	57	1656
12	M1	1.69	71.09	6	13.51	43	1806
13	M2	1.69	76.97	6	13.51	43	1955
14	M3	1.69	82.85	6	13.51	43	2104
15	M4	1.69	88.72	6	13.51	43	2254
16	M5	1.69	94.60	6	13.51	43	2403
17	M6	1.69	100.48	6	13.51	43	2552
18	M7	1.69	106.36	6	13.51	43	2701
19	M8	1.69	112.23	6	13.51	43	2851
20	M9	1.69	118.11	6	13.51	43	3000
21	M10	1.69	123.99	6	13.51	43	3149
22	M11	1.69	129.87	6	13.51	43	3299
23	M12	1.69	135.74	6	13.51	43	3448
24	M13	1.69	141.62	6	13.51	43	3597
25	M14	1.69	147.50	6	13.51	43	3746
26	M15	1.69	153.38	6	13.51	43	3896
27	M16	1.69	159.25	6	13.51	43	4045
28	T1	2.24	165.13	13	51.42	57	4194
29	T2	2.24	171.01	5	19.78	57	4344
30	M17	1.69	176.89	6	13.51	43	4493
31	M18	1.69	182.76	6	13.51	43	4642
32	M19	1.69	188.64	6	13.51	43	4791
33	M20	1.69	194.52	6	13.51	43	4941
34	M21	1.69	200.40	6	13.51	43	5090
35	M22	1.69	206.27	6	13.51	43	5239
36	T3	2.24	212.15	36	142.39	57	5389
37	T4	2.24	218.03	28	110.75	57	5538
38	T5	2.24	223.91	27	106.79	57	5687
39	T6	2.24	229.78	27	106.79	57	5837
					1483.69		

0 Specifications: AASHTO LRFD Design Specs. 2012

1 Material properties:

				Metric	
- Concrete density:	Wc =	0.15	kcf	24	KN/m3
- Concrete 28-day compressive strength:	f'c =	8	ksi	55	MPa
- Reinforcement strength:	fy =	60	ksi	414	MPa
- Prestressing steel strand:	Diameter =	0.60	in	15	mm
Strand cross-sectional area:	A =	0.217	in2	140	mm2
Modulus of Elasticity:	Ep =	28478	ksi	196500	MPa
Ultimate tensile strength:	Fpu =	58.43	kips	260	KN
	fpu =	269	ksi	1858	MPa
Minimum yield strength:	Fpy =	52.58	kips	234	KN
	fpy =	90%	fpu		
Maximum stressing force per strand:	Fp max =	43.82	kips	195	KN
	fp jacking =	75%	fpu		
% prestressing stress after transfer with Max losses:	fpt =	67%	fpu		
% Effective prestressing stress considering Max losses:	fpe =	63%	fpu		
Effective prestressing strain considering Max losses:	ε_{so} =	0.00592			
Wedge seating:	A =	0.39	in	10	mm
Friction coefficient:	μ =	0.15	/rad	0.15	/rad
Wobble coefficient:	k =	0.000201	/ft	0.00066	/m
- Tendons:					
Duct diameter:	OD =	5.51	in	140	mm
Location of tendon CG with respect to duct CG	Z =	0.47	in	12	mm

2 Bearing location:

- Eccentricity between shaft and top of pier cap:	e1 =	39.17	in	995	mm

3 Loads:

- Case	Maximum Shear Key: Pu min				
	PT + EQ + DL			PT + EQ + DL	
- *Loading effects at the section of maximum effect:*					
Axial (if <0 → Tension)	Pu =	46182	kips	206	MN
In-plane shear	Vuy =	20336	kips	90	MN
Out-of-plane shear	Vux =	1840	kips	8	MN
In-plane-bending moment: (if >0 → Top fiber in tension)	Mux =	866517	kip-ft	1177	MN-m
Out-of-plane bending moment	Muy =	23576	kip-ft	32	MN-m
Torsion	Tu =	24111	kip-ft	33	MN-m

4 Pier cap section properties:

- Section No.		1			
	Location =	SK			
- *Dimensions:*					
Location from cap end	x =	30.51	ft	9298	mm
Width	B =	216.5	208 in	5500	mm
Depth	H =	236.2	228 in	6000	mm
Concrete cover:	Top =	4.33	in	110	mm
	Bottom =	4.33	in	110	mm
	Lateral =	4.33	in	110	mm

- *Section properties:*		Gross	Eff at ε_{cu}	
Area	A =	51150	47304	in2
Centroid (with respect to left bottom corner)	yc =	118.110	114	in
	xc =	108	104	in
Moment of inertia	Ix =	237848451	204127410	in4
	Iy =	199858768	170338765	in4
Section modulus	Sx =	2013784	1794061	in3
	Sy =	1845968	1638865	in3

- *Longitudinal tendon locations:*

*from section centerline
**from bottom of gross section

No.	Name	x* (in)	y**(in)	Strands	Area (in2)	α (rad)	x (mm)	y (mm)
1	B6.1	-54.09	22.60	36	7.81	0.25	-1374	492
2	B6.2	-25.75	22.60	37	8.03	0.25	-654	492
3	B6.3	18.03	22.60	37	8.03	0.25	458	492
4	B6.4	61.81	22.60	36	7.81	0.25	1570	492

14	T3.2	201.69	0.01309	262.67	2109	88	15451
15	T3.3	201.69	0.01309	262.67	2109	88	15451
16	T3.4	201.69	0.01309	262.67	2052	88	15033
17	T2.1	207.28	0.01339	262.99	2112	94	16453
18	T2.2	207.28	0.01339	262.99	2112	94	16453
19	T2.3	207.28	0.01339	262.99	2112	94	16453
20	T2.4	207.28	0.01339	262.99	2112	94	16453
21	T1.1	207.28	0.01339	262.99	2055	94	16009
22	T1.2	207.28	0.01339	262.99	2112	94	16453
23	T1.3	207.28	0.01339	262.99	2112	94	16453
24	T1.4	207.28	0.01339	262.99	2055	94	16009
					34018		125708

Reinforcement forces:

No.	Name	yeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B1	2.11	-0.00388	-60.00	-4746	-112	44169
2	B2	7.98	-0.00356	-60.00	-4746	-106	41845
3	B3	13.86	-0.00323	-60.00	-4746	-100	39520
4	B4	19.74	-0.00291	-60.00	-2848	-94	22317
5	B5	25.62	-0.00258	-60.00	-2848	-88	20922
6	B6	31.49	-0.00226	-60.00	-2848	-82	19528
7	B7	37.37	-0.00193	-56.03	-2659	-76	16933
8	B8	43.25	-0.00161	-46.60	-2580	-71	15166
9	B9	49.13	-0.00128	-37.17	-2058	-65	11088
10	B10	55.00	-0.00096	-27.73	-1536	-59	7522
11	B11	60.88	-0.00063	-18.30	-1013	-53	4468
12	M1	66.76	-0.00031	-8.87	-120	-47	469
13	M2	72.64	0.00002	0.56	8	-41	-26
14	M3	78.51	0.00034	9.99	135	-35	-397
15	M4	84.39	0.00067	19.42	262	-29	-642
16	M5	90.27	0.00100	28.86	390	-24	-764
17	M6	96.15	0.00132	38.29	517	-18	-760
18	M7	102.02	0.00165	47.72	644	-12	-631
19	M8	107.90	0.00197	57.15	772	-6	-378
20	M9	113.78	0.00230	60.00	810	0	0
21	M10	119.66	0.00262	60.00	810	6	397
22	M11	125.53	0.00295	60.00	810	12	794
23	M12	131.41	0.00327	60.00	810	18	1191
24	M13	137.29	0.00360	60.00	810	24	1588
25	M14	143.17	0.00392	60.00	810	29	1984
26	M15	149.04	0.00425	60.00	810	35	2381
27	M16	154.92	0.00457	60.00	810	41	2778
28	T1	160.80	0.00490	60.00	3085	47	12088
29	T2	166.68	0.00522	60.00	1187	53	5231
30	M17	172.55	0.00555	60.00	810	59	3969
31	M18	178.43	0.00587	60.00	810	65	4366
32	M19	184.31	0.00620	60.00	810	71	4763
33	M20	190.19	0.00652	60.00	810	76	5160
34	M21	196.07	0.00685	60.00	810	82	5557
35	M22	201.94	0.00717	60.00	810	88	5953
36	T3	207.82	0.00750	60.00	8543	94	66951
37	T4	213.70	0.00782	60.00	6645	100	55328
38	T5	219.58	0.00815	60.00	6407	106	56490
39	T6	225.45	0.00848	60.00	6407	112	59629
					13599		536946

Resultant forces:

Pnx =	18801	kips	84	MN
Mnx =	1162370	kip-ft	1577	MN-m
ey =	741.92	in		
ey req/ ey res =	1.00		1.00	

5 Check for axial and flexural force effects:

- *Resistance factor:* A.5.10.11.4.1b ϕ = 0.90

- *Loading effects:*

1 Prestressing loading effects:

Pu =	32218	kips	143	MN
Mux =	-3171	kip-ft	-4	MN-m
Muy =	-1551	kip-ft	-2	MN-m

2 Net loading effects:

Pu =	13964	kips	62	MN
Mux =	863346	kip-ft	1171	MN-m
Muy =	22025	kip-ft	30	MN-m

3 Total loading stresses:

Pu/A =	0.903	ksi	6.2	MPa
Mux/Sx =	5.164	ksi	35.6	MPa
Muy/Sy =	0.153	ksi	1.1	MPa
Max =	6.220	ksi	42.9	MPa
	78%	f'c	78%	
Min =	-4.414	ksi	-30.5	MPa
	55%	f'c	55%	

- *Analysis approach:* *Strain compatibility*

- *Concrete behavior assumptions:* *Unconfined*

Stress distribution: A.5.7.2.2 *Rectangular*

α_1 = 0.85

β_1 = 0.65

Compressive strength: f'c = 8 ksi

Ultimate compression strain: ε_{cu} = 0.004 *

* Seismic Design of Reinforced Concrete and Masonry Buildings, Paulay and Priestly, pag. 98

Ignore concrete cover for calculations at this strain level

Modulus of Elasticity: A.5.4.2.4-1 E = 5422 ksi

Effective section properties: b = 208 in 5280 mm

h = 228 in 5780 mm

- *Major-axis bending resistance: Pnx, Mnx*

Eccentricity: ey = 741.91 in

Neutral axis depth: c = 72.29 in

a = 46.99 in

Concrete forces: Pc = 66418 kips

Mc = 499716 kip-ft

Tendon forces:

Effective initial prestressing strain: ε_{po} = 0.00592

No.	Name	yeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B6.1	18.27	0.00294	83.59	653	-96	-5198
2	B6.2	18.27	0.00294	83.59	671	-96	-5342
3	B6.3	18.27	0.00294	83.59	671	-96	-5342
4	B6.4	18.27	0.00294	83.59	653	-96	-5198
5	B5.1	23.86	0.00324	92.40	722	-90	-5409
6	B5.2	23.86	0.00324	92.40	742	-90	-5559
7	B5.3	23.86	0.00324	92.40	742	-90	-5559
8	B5.4	23.86	0.00324	92.40	722	-90	-5409
9	B4.1	31.26	0.00365	104.06	836	-83	-5746
10	B4.2	31.26	0.00365	104.06	836	-83	-5746
11	B4.3	31.26	0.00365	104.06	836	-83	-5746
12	B4.4	31.26	0.00365	104.06	836	-83	-5746
13	T3.1	201.69	0.01309	262.67	2052	88	15033

6 Check for shear and torsional force effects:

- *Resistance factor:* A.5.5.4.2 ϕ = 0.90

- *Torsional effects:*

Total area enclosed by outside perimeter of concrete:	Acp =	51150	in2		
Outside perimeter of the concrete section:	pc =	906	in		
Diameter of exterior stirrups:	d =	0.98	in	25	mm
Spacing of exterior stirrups:	s =	12.60	in	320	mm
Area enclosed by the shear path:	Ao =	46876	in2		
Perimeter of centerline of exterior stirrups:	ph =	867	in		
Torsional cracking moment:	Tcr =	141976	kip-ft	193	MN-m
	0.25ϕTcr=	31945	kip-ft	43	MN-m
	Tu =	24111	kip-ft	33	MN-m
Torsional effects DO NOT need to be considered for shear checking					
Torsional resistance:	ϕTn=	34837	kip-ft	47	MN-m
	Tu/ϕTn =	**0.69**	**OK!**	**0.69**	

- *In-plane shear:*

Factored load:	Vuy =	20336	Kips	90	MN
Prestressing force in direction of Vu:	Vp =	2405	Kips	11	MN
In-plane concrete shear resistance approach:	Method =	2	A.5.8.4.3.2		
Effective width	bv =	217	in		
Minimum Shear depth:	dv =	189	in		
Net tensile Strains:	$\varepsilon_{average}$ =	0.00205			
Crack angle:	θ =	36.2			
Parameter β assuming min. transverse reinforcement:	β=	1.891			
In-plane concrete shear resistance:	Vc =	6908	Kips	31	MN
In-plane steel shear resistance:	Vs =	27875	Kips	124	MN
Inclination of reinforcement:	α=	90	deg		
Diameter of stirrups:	d =	1.69	in	43	mm
Spacing of stirrups:	s =	10.00	in	254	mm
No. of reinforcement legs:	n =	8			
	ϕVn =	31305	Kips	139	MN
	Vu/ϕVn =	**0.65**	**OK!**	**0.65**	

- *Out-of-plane shear:*

Factored load:	Vux =	1840	Kips	8	MN
Prestressing force in direction of Vu:	Vp =	0	Kips	0	MN
In-plane concrete shear resistance approach:	Method =	2	A.5.8.4.3.2		
Effective width	bv =	236	in		
Minimum Shear depth:	dv =	156	in		
Net tensile Strains:	$\varepsilon_{average}$ =	0.00000			
Parameter β assuming min. transverse reinforcement:	β=	4.800			
In-plane concrete shear resistance:	Vc =	15800	Kips	70	MN
	ϕVc =	14220	Kips	63	MN
	Vu/ϕVc =	**0.12**	**OK!**	**0.12**	

- *Minor-axis bending resistance: Pny, Mny*

Eccentricity:	ex =	18.93	in
Neutral axis depth:	c =	267.40	in
	a =	173.81	in
Concrete forces:	Pc =	268949	kips
	Mc =	381763	kip-ft

Tendon forces:

Effective initial prestressing strain: ε_{so}= 0.00592

No.	Name	xeff	ε_{si}	fsi	Tsi	di	Msi
		in		ksi	kips	in	kip-ft
1	B6.1	158.03	0.00429	122.13	954	54	4301
2	B6.2	129.69	0.00386	110.05	884	26	1896
3	B6.3	85.91	0.00321	91.40	734	-18	-1103
4	B6.4	42.13	0.00255	72.75	568	-62	-2927
5	B5.1	156.77	0.00427	121.59	950	53	4182
6	B5.2	128.43	0.00385	109.51	879	24	1794
7	B5.3	87.17	0.00323	91.94	738	-17	-1032
8	B5.4	43.39	0.00257	73.29	573	-61	-2889
9	B4.1	157.40	0.00428	121.86	978	53	4359
10	B4.2	129.06	0.00385	109.78	881	25	1845
11	B4.3	86.54	0.00322	91.67	736	-17	-1067
12	B4.4	42.76	0.00256	73.02	586	-61	-2989
13	T3.1	158.03	0.00429	122.13	954	54	4301
14	T3.2	129.69	0.00386	110.05	884	26	1896
15	T3.3	100.08	0.00342	97.44	782	-4	-252
16	T3.4	40.83	0.00254	72.20	564	-63	-2966
17	T2.1	143.23	0.00407	115.82	930	39	3045
18	T2.2	114.88	0.00364	103.74	833	11	760
19	T2.3	86.54	0.00322	91.67	736	-17	-1067
20	T2.4	58.19	0.00279	79.59	639	-46	-2436
21	T1.1	156.77	0.00427	121.59	950	53	4182
22	T1.2	128.43	0.00385	109.51	879	24	1794
23	T1.3	101.34	0.00344	97.97	787	-3	-170
24	T1.4	42.09	0.00255	72.73	568	-62	-2929
					18968		12528

Resultant forces:	Pny =	249982	kips	1112	MN
	Mny =	394291	kip-ft	535	MN-m
	ex =	18.93	in		
	ex req/ ex res =	1.00		1.00	

- *Biaxial flexure check:* A.5.7.4.5

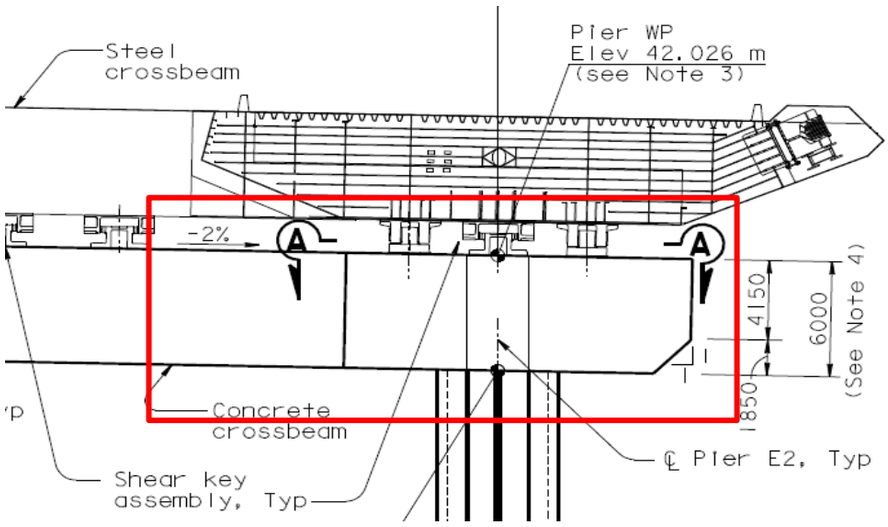
Minimum axial load to be considered as a column:	0.1ϕf'cAg =	36828	kips	164	MN
Factored axial load:	Pu =	13964	kips	62	MN
Nominal axial resistance:	Po =	309901	kips	1379	MN
Method to check biaxial flexure:		Load Contour Method			
Reciprocal Load Method:	Pr =	NA	Kips		
	Pu/Pr =	**NA**	**NA**	**NA**	
Load Contour Method:	Mux/Mrx =	0.83			
	Muy/Mry =	0.06			
	IE =	**0.89**	**OK!**	**0.89**	

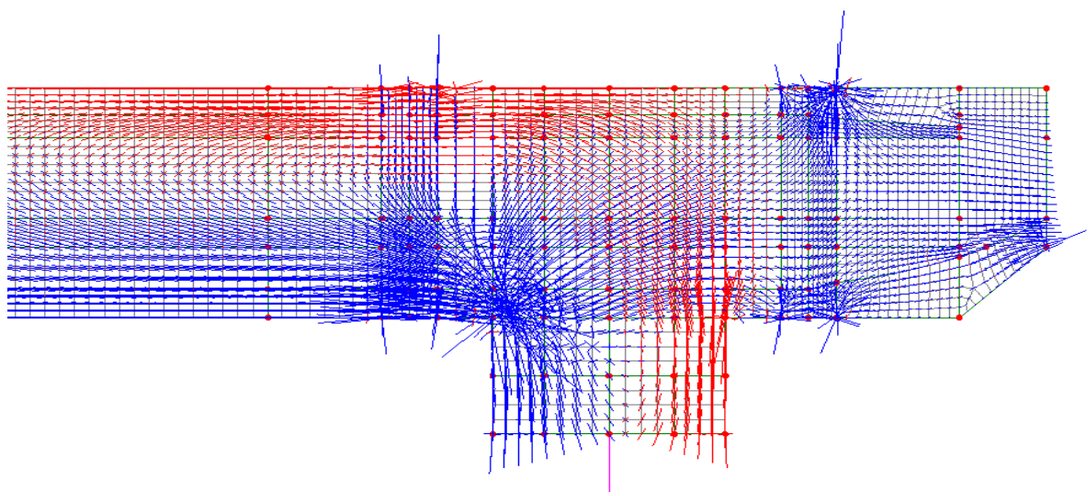
Appendix 5

Strut-and-Tie Model Calculations

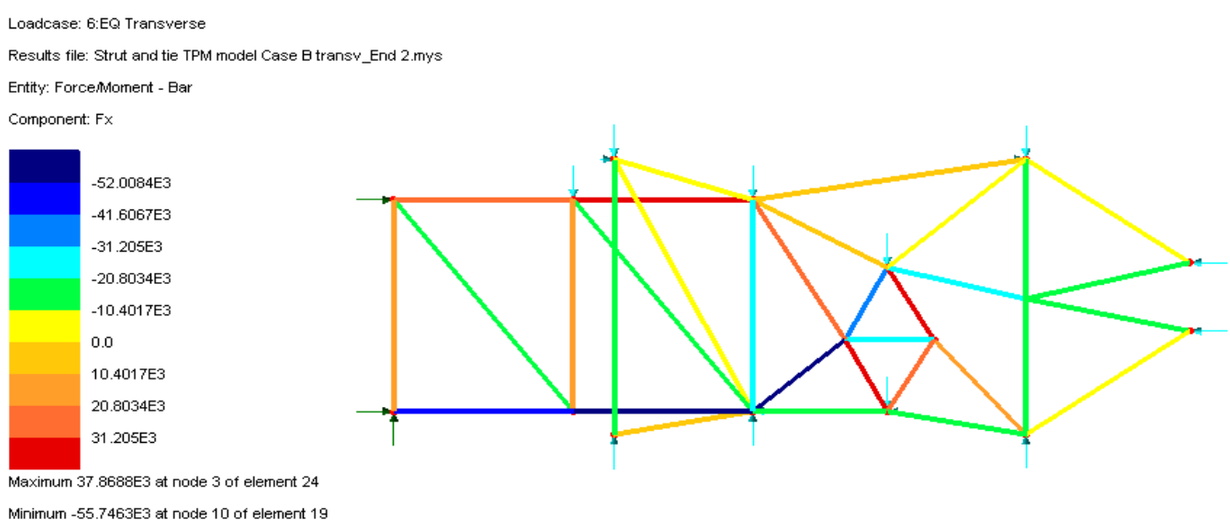
0 Specifications: AASHTO LRFD Design Specs. 2012

1 Principal Stress Directions from FEM





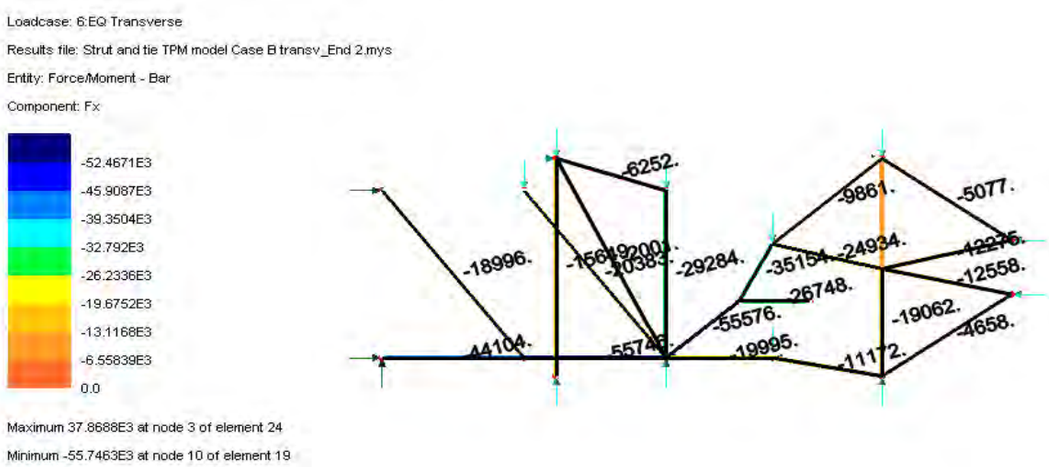
2 Strut-tie Model:

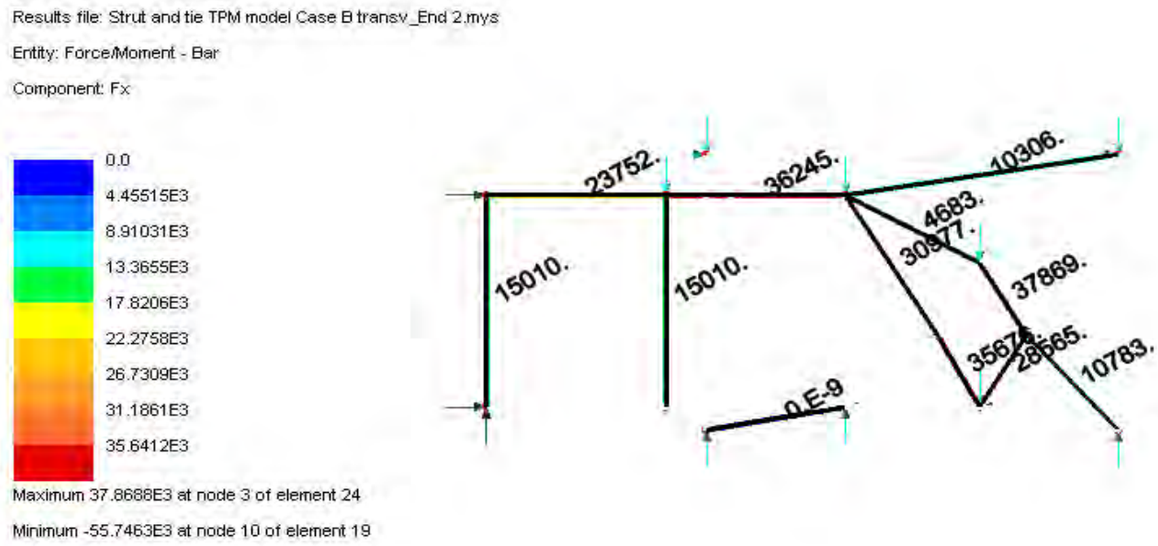


3 Boundary forces:

			US		Metric	
- Column:	Moment:		641000	kip-ft	870	MN-m
	Axial force:		25145	kips	112	MN
	Distance between resultant internal forces:		9.088	ft		
	Shear force:		13483	kips	60	MN
	Effective compression:		83105	kips	370	MN
	Effective Tension:		-57960	kips	-258	MN
- Longitudinal Post-tensioning forces:						
	Total postensiong force at service:		32121	kips	143	MN
	No. of points where the load is applied:		2			
	Force at points of application:		16061	kips	71	MN
- Bearing forces including PT forces:	Top	Hor. =	6853	kips	30	MN
		Vert. =	-19344	kips	-86	MN
	Bottom	Vert. =	15649	kips	70	MN

4 Model forces:





5 Checks:

- *Compressive struts:*

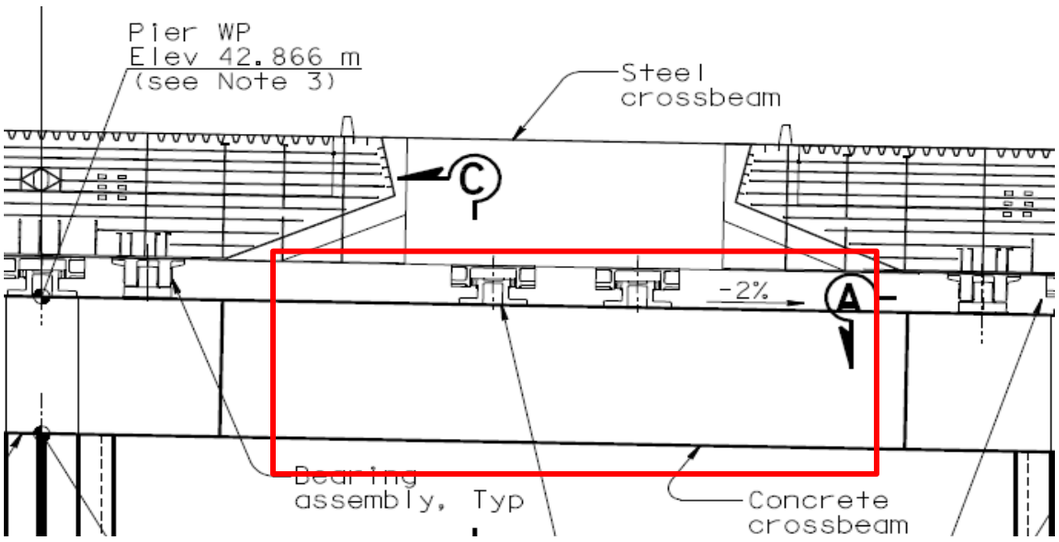
Effective cross sectional area of critical strut:	Acs =	13387.86	in2		
Diameter of the reinforcement that anchors the strut:	db =	2.24	in	57	mm
Distance between longitudinal bars in the column resisting compression:	s =	78.74	in	2000	mm
Horizontal projection of Width of strut:	la =	105.67	in	2684	mm
Inclination of strut:	θs =	40.29	deg		
Width of strut:	b1 =	68.33	in		
Depth of strut:					
Assume an average width of cap beam between column and bearings	d =	195.93	in	4976.5	mm
Limiting compressive stress in the strut:	fcu =	6.80	ksi		
Compressive concrete strength:	f'c =	8	ksi		
Angle between strut and adjoining tie:	α =	79.71	deg		
Tensile strain in the concrete in the direction of tie:					
Assume prestressing compression has not been exceeded	εs=	0.0000			
	εl=	6.59E-05			
Resistance Factor:	ϕ =	0.70			
Strut compressive resistance:	ϕPn =	63726	Kips	284	MN
Critical Compression:	Pu =	55576	Kips	247	MN
	D/C =	**0.87**	OK!		

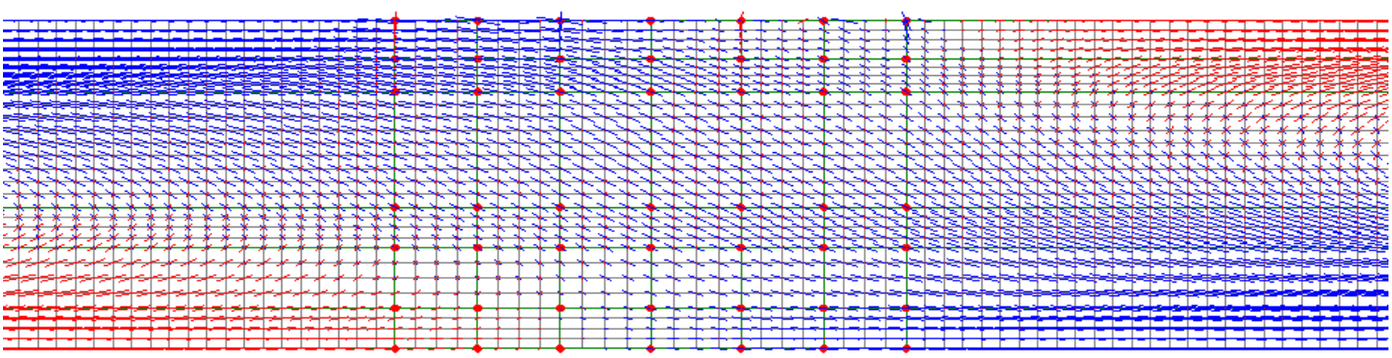
- *Tension ties:*

Area of longitudinal steel reinforcement in tie:		Ast =	852.90	in2	If uncut	
			677.97	in3	If all cut	
Column vertical reinforcement:	M bars:	db =	2.24	in	57	mm
		n =	96		If uncut	
			66		If all cut	
		db =	1.69	in	43	mm
		n =	72		If uncut	
			51		If all cut	
	N bars:	db =	1.69	in	43	mm
		n =	20		If uncut	
			16		If all cut	
Cap beam stirrups and bars:		db =	1.69	in	43	mm
		n =	102			
		db =	0.98	in	25	
		n =	48			
Yield strength of reinforcement:		fy =	60	ksi		
Resistance Factor:		ϕ =	0.90			
Tie tensile resistance:		ϕPn =	46057	Kips	205	MN
			36610	Kips	163	MN
Critical Tension:		Pu =	55634	Kips	248	MN
		D/C =	1.21	NG	If uncut	
		D/C =	1.52	NG	If all cut	

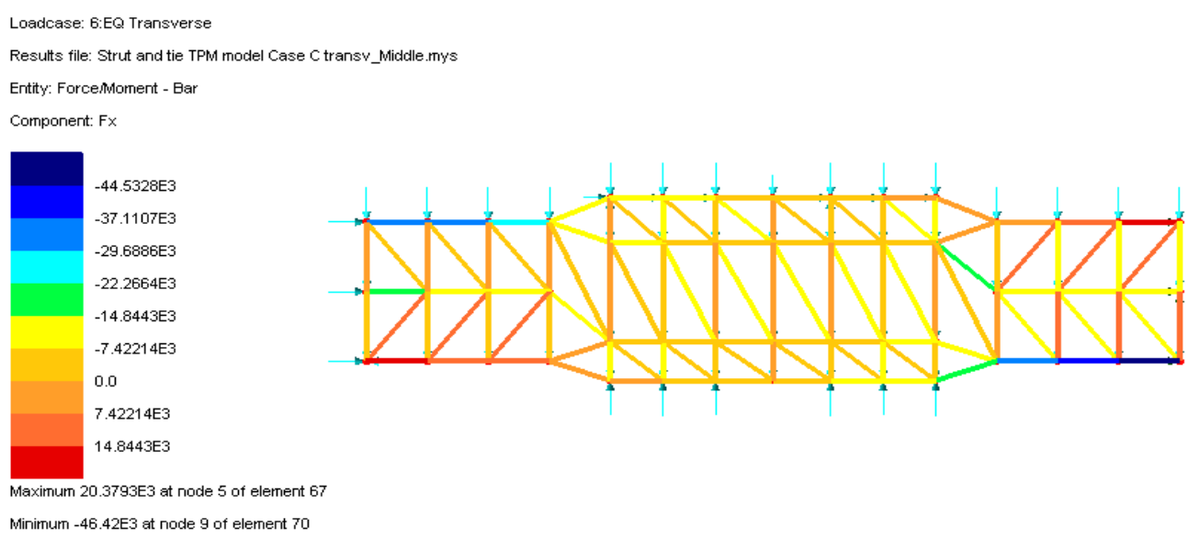
0 Specifications: AASHTO LRFD Design Specs. 2012

1 Principal Stress Directions from FEM





2 Strut-tie Model:



				US		Metric	
3 Boundary forces:							
- Column:	Moment:			322754	kip-ft	438	MN-m
	Axial force:			13351	kips	59	MN
	Distance between resultant internal forces:			13.15	ft		
	Shear force:			12424.3	kips	55	MN
	Effective compression:	top		17868.5	kips	80	MN
	Effective Tension:	bottom		-31219.5	kips	-139	MN
- Longitudinal Post-tensioning forces:							
	Total postensiong force at service:			32121	kips	143	MN
	No. of points where the load is applied:			3			
	Midpoint:			16061	kips	71	MN
	End points:			8030	kips	36	MN
- Shear key forces including PT forces:		Midpoint:	Hor. =	2284	kips	10	MN
			Vert. =	0	kips	0	MN
		Lateral point a:	Hor. =	1142	kips	5	MN
			Vert. =	1641	kips	7	MN
		Lateral point b:	Hor. =	1142	kips	5	MN
			Vert. =	-1641	kips	-7	MN
- Shear key forces PT forces:			P/2 =	13538	kips	60	MN
			P/4 =	6769	kips	30	MN

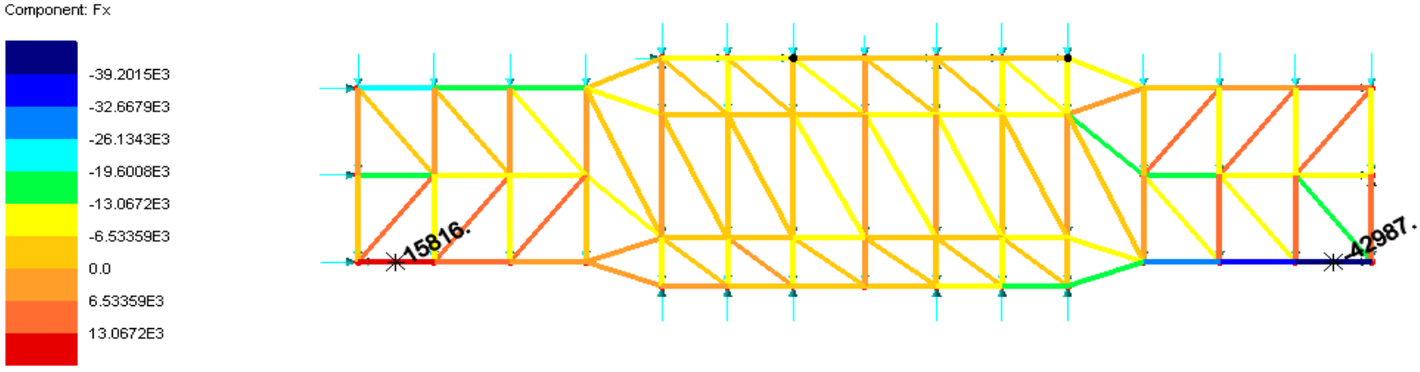
4 Maximum Model Forces:

Loadcase: 6:EQ Transverse

Results file: Strut and tie TPM model Case D transv_Middle.mys

Entity: Force/Moment - Bar

Component: Fx



Maximum 15.8155E3 at node 5 of element 67

Minimum -42.9867E3 at node 9 of element 70

5 Checks:

- *Compressive struts:*

Critical Compression:	Pu =	42987	Kips	191	MN
Limiting compressive stress in the strut:	fcu =	6.80	ksi		
Compressive concrete strength:	f'c =	8	ksi		
Angle between strut and adjoining tie:	α =	90.00	deg		
Tensile strain in the concrete in the direction of tie:	εl=	7.5E-36			
Assume prestressing compression has not been exceeded	εs=	0.0000			
Resistance Factor:	ϕ =	0.70			
Reinforcement in direction of strut:	Ts =	17087	Kips		
	db =	2.24	in	57	mm
	N =	72			
	fy =	60.00	ksi		
Required cross sectional area of critical strut:	Acs =	5800.22	in2		
Depth of strut:	d =	154.72	in	3930	mm
Required width of strut:	b1 =	37.49	in	952	mm

Required width is similar to the distance over which the reinforcement is distributed ∴ OK!

- *Tension ties:*

Area of longitudinal steel reinforcement in tie:	Ast =	314.96	in2		
	db =	2.24	in	57	mm
	n =	72			
	db =	1.69	in	43	mm
	n =	8			
	db =	0.98	in	25	
	n =	16			
Yield strength of reinforcement:	fy =	60	ksi		
Area of prestressing steel in tie:	Aps =	95.48	in2		
Effective prestressing stress:	fpe =	169.47	ksi		
Resistance Factor:	ϕ =	0.90			
Tie tensile resistance:	ϕPn =	36727	Kips	163	MN
Critical Tension:	Pu =	15816	Kips	70	MN
	D/C =	**0.43**	OK!		