Trump Taj Mahal Hotel

Atlantic City, New Jersey

Technical Report Number Three

Lateral System Analysis and Confirmation Design

Prepared By: Stephen Reichwein, Structural Option

Faculty Advisor: Dr. Andres Lepage

The Pennsylvania State University

Department of Architectural Engineering

Date: December 3, 2007

Executive Summary

The purpose of this report is to determine through analytical methods the response of the lateral force resisting system of the Trump Taj Mahal Hotel in Atlantic City, New Jersey, to effects of wind and seismic loads.

In order to effectively determine the forces acting on the shear wall, a simplified ETABS model was constructed. The model was analyzed under the effects of wind loads provided by a wind tunnel test performed by DFA. The building modes and periods, center of rigidities, displacements, wall forces, and frame forces were determined directly from ETABS. Pier forces were input into PCA column along with the current design of the pier under investigation. An interaction diagram was than developed to determine whether or not the strength of the pier was adequate to handle the forces. Shear strength was checked by hand per requirements of ACI 318 -05.

Most of the design criteria were met or exceeded, with the exception of a few shear wall piers that failed either because of excessive tensile forces or shear forces. However, these failures are generally within 10%. Lateral displacements meet the requirements of H/400 and the story drift limit of 0.5”, as specified by the New Jersey State Uniform Construction Code. In fact, the lateral displacements calculated in ETABS are well below these limits. This may be something to consider later in the semester with a shear wall reduction depth study.

Table of Contents

Introduction

Atlantic City is known as the "Las Vegas" of the east coast. It is home to some of the largest and finest hotels, resorts, and casinos, as well as one of the largest boardwalks in the world. Donald Trump came to Atlantic City with a vision to create one of the world's finest casinos along with Atlantic City's most luxurious hotels. At the 900 block of the Atlantic City boardwalk in 1990, Trump unveiled the first Taj Mahal Hotel, unprecedented in craftsmanship and opulence. Its stern use of iconic architecture, rich with lights and signage, matches that of the rest of Atlantic City.

The Trump Taj Mahal Hotel Tower at 1000 Boardwalk resembles a powerful type of iconic architecture, signifying the power and wealth of Donald Trump along with the luxury you can expect from such a hotel. Such iconic characteristics that are clearly expressed on the building include large, bold signage (Both the Taj Mahal running down the east and west sides of the building and Trump across the top of the building.), a unique and pure geometric plan that rivals its neighboring predecessor, and it's overwhelming height as compared to the neighboring buildings along the ocean front skyline. The facade of the building is constructed with mostly modern materials, comprised of a reflective glass curtain wall, metal panels, and architectural pre-cast concrete panels.

The new Taj Mahal Hotel will serve as an expansion to its older and neighboring hotel tower that was built in the early 1990s. It will provide an additional 786 guest suites, ranging from spacious single rooms to deluxe 3 bay super suites. The tower will have 732,000 square feet of usable space and will soar 435 feet, 40 stories, into the air, making it an icon in the view of the Atlantic City skyline.

The current gravity floor system of the Trump Taj Mahal is a filigree flat plate system. This system utilizes pre-cast thin plates as its base and for formwork. Typical floors were designed for a 10" voided slab, where foam voids are cast into the top of the plank. These voids result in approximately a 30% reduction in dead weight as compared to a traditional flat plate system.

The main components of the lateral force resisting system of the Trump Taj Mahal are ordinary reinforced concrete shear walls. These walls are typically 16" thick with varying concrete compressive strengths (anywhere from 9000psi at the base to 5000psi at the top). The walls have multiple openings and are connected to each other via link beams. These link beams provide added stiffness to the overall structure.

Existing Structural Systems

The proceeding section contains detailed descriptions of the various structural systems that have been designed by the engineer of record for the Trump Taj Mahal Hotel. Descriptions of the foundation system, columns, floor systems, and lateral system are provided, in that respective order. Figure 1 provides an illustration of the framing plan of a typical level of the tower.

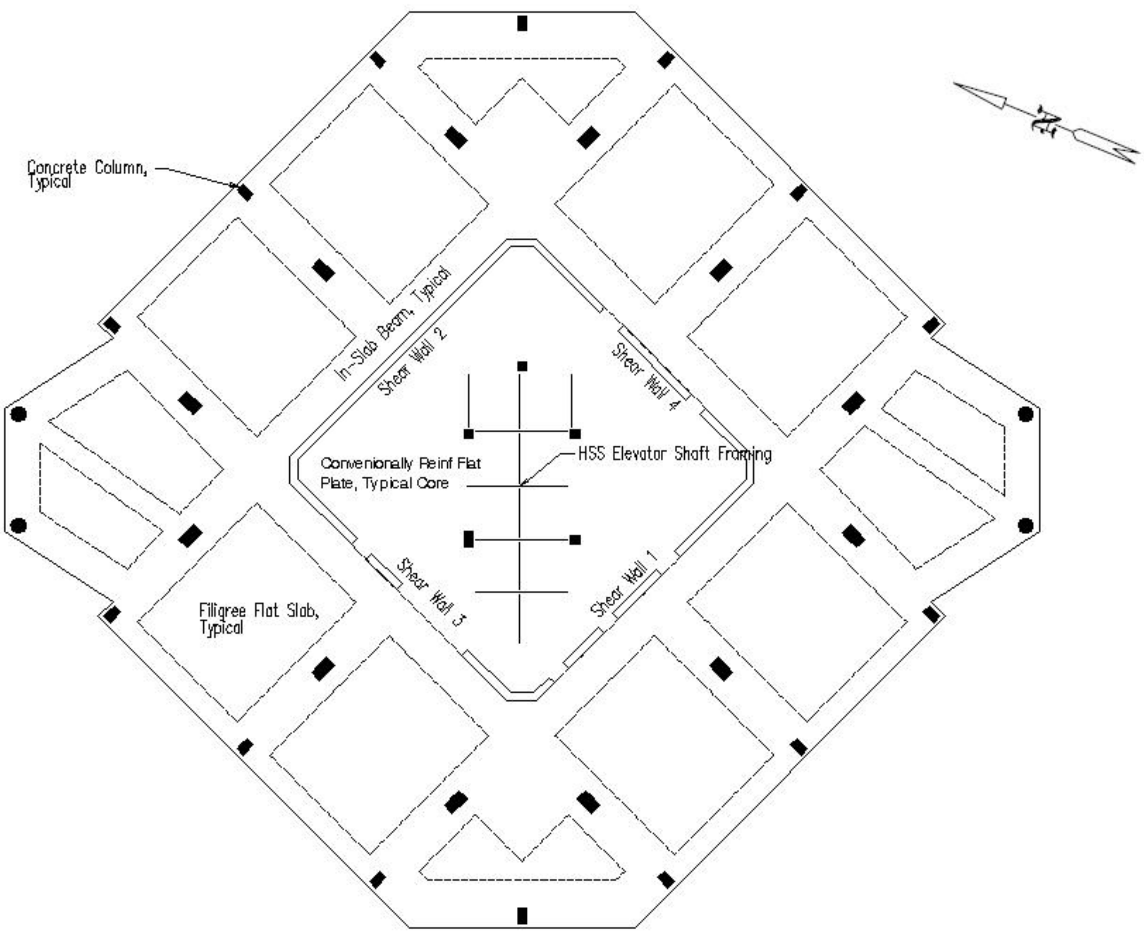


Figure 1: Typical Framing Plan

Foundation System

The foundation system of the Trump Taj Mahal Hotel is comprised of a mat foundation, as recommended by the geotechnical report. The perimeter of the mat foundation is 6'-0" thick, the center 9'-0" thick. #11 bars at 10" each way, top and bottom are provided for the

9'-0" section and #11 at 15" each way, top and bottom are provided for the 6'-0" section. Additional reinforcing is provided around openings and columns. The mat foundation acts as the floor system of level one, no topping slab provided.

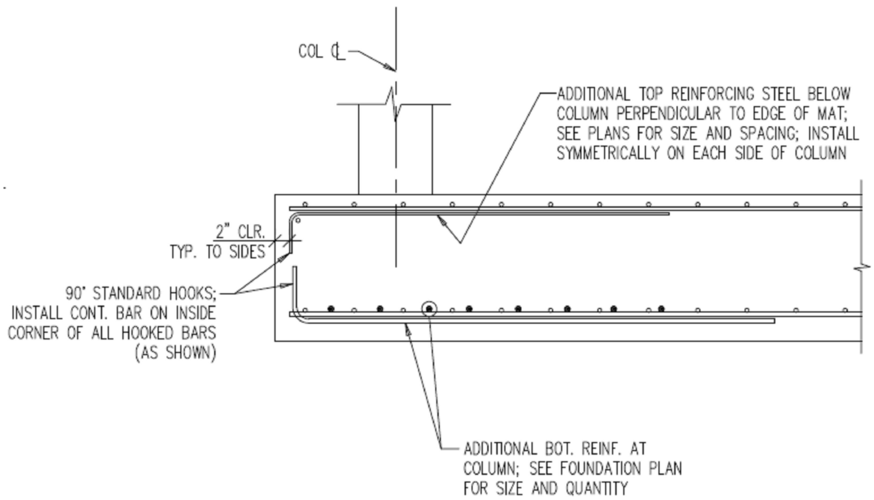


Figure 2: Typical Section at Mat Foundation

Columns

Square, rectangular, and round reinforced concrete columns are used throughout the hotel tower, with a wide range of sizes and reinforcing arrangements. Figure 3 provides a typical detail that illustrates the tie arrangements, vertical reinforcing steel arrangements, and dimensions of the columns that are found throughout the tower. Specified compressive strength of concrete used for the columns varies by level, generally higher at lower levels. See Section III (Material Strengths) for details.

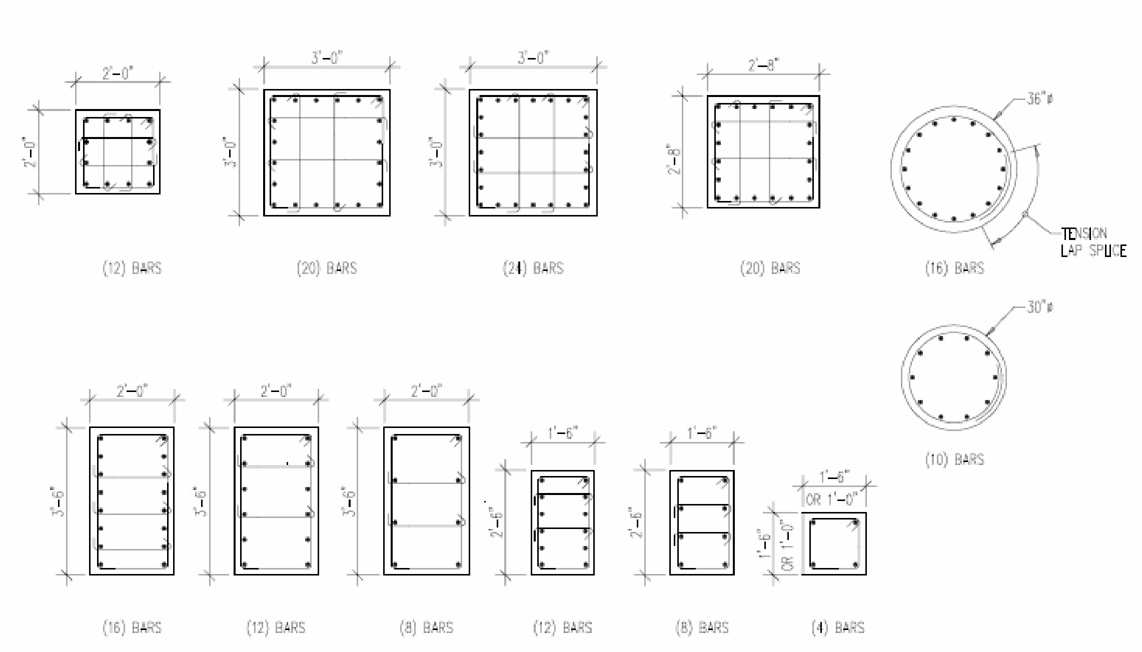


Figure 3: Detail of Typical Column Types

Floor Systems

Two types of floor systems are used on a typical level of the hotel tower. A one-way pre-stressed filigree flat plate system is utilized in the areas outside of the central elevator core. Inside of the core, a conventionally reinforced flat plate system is utilized. 5000psi is the specified compressive strength of both systems.

A filigree flat plate floor slab acts as a composite system, utilizing both pre-cast and cast-in-place components. 8'-0" wide 2 ¼" thick pre-stressed planks form the base of the system. Foam voids are cast on top of the planks, lowering the dead weight of the system. However, some floors of the tower with higher loads may have solid slabs instead of voided slabs. A layer of concrete is poured on top of the planks and 2 ¼" on top of the voids, if present. 10x10 W4xW4 Welded Wire Fabric is used as temperature reinforcing for the cast –in-place concrete.

The loads of the filigree flat slab are transferred to the columns via 8'-0" wide conventionally reinforced in-slab beams that run 32'-0" x 16'-0" bays, typically. The filigree flat slabs are connected to the in-slab beams by reinforcing dowels, typically #7 bars on the top layer. The base of the beams are formed using the filigree planks, however the pre-stressed tendons are not utilized in the design strength of the beam.

Please note, because this particular type of filigree system is proprietary to Mid-State Filigree, construction documents issued by the structural engineering consultant only indicate design moments.

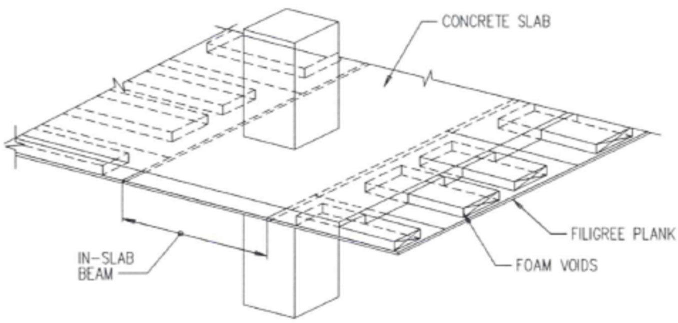


Figure 4: Filigree Flat Plate System

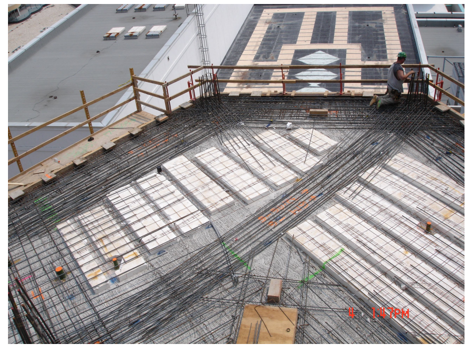


Figure 5: Filigree Construction Photo

Filigree Flat Slab System (Non-Core)

The proceeding diagram describes the various filigree flat slabs, by level number.

Level Number	Solid or Voided	Total Depth (inches)
2, 3	Voided	12
4	Solid	10
5 thru 39	Voided	10
40	Solid	12
41	Solid	10

Conventionally Reinforced Flat Plate System (Core)

The proceeding diagram describes the various conventionally reinforced flat plate slabs, by level number.

Level	Reinforcing	Thickness (inches)
2, 3	#6 @ 12” Bottom, Each Way	12
4	#7 @ 12” Bottom, Each Way	10
5 thru 39	#6 @ 12” Bottom, Each Way	10
40	#6 @ 12” Bottom, Each Way	12
41	#7 @ 12” Bottom, Each Way	10

Lateral Force Resisting System

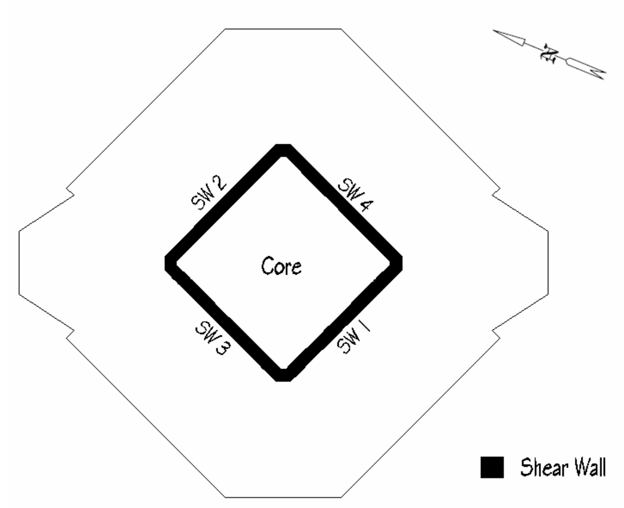


Figure 6: Location of Shear Walls

The primary lateral force resisting system of the hotel tower is comprised of four shear walls, encompassing the elevator core at the geometric center of the tower's plan. A series of braced frames are used to stiffen the sign support structure at the top of the tower.

Ordinary Reinforced Concrete Shear Walls

Four shear walls, spanning to level 41, are the primary lateral force resisting system of the Trump Taj Mahal Hotel. Two 60' long walls resist the forces in the east/west direction, as well as the north/south direction. These four walls form the elevator core that lies in the geometric center of the tower. Because of the symmetry of both the plan of the building and the shear wall core, it is highly unlikely that torsion will control the design of the shear walls.

The shear walls decrease in thickness, 24" from levels 1 through 4 and 16" from levels 4 through 41. Because numerous openings exist, link (coupling) beams provide load transfer across the openings. Specified compressive strength of the concrete used for the shear walls varies by level (See Material Strengths Section). Detailed elevations of each shear wall are provided in Appendix A.

Braced Frames

Because the framing system supporting the large sign at the top of the tower is long and narrow, lateral bracing is needed to stiffen the system against strong wind forces. In the short (north/south) direction, seven X braced frames with single angle diagonals and one single strut braced frame with double angle diagonals. The long (east/west) direction does not require much lateral stiffening because of its depth. Only two X braced frames with single angle diagonals are provided.

The loads of these braced frames are transferred to the concrete floor system on the 41st level below. The concrete floor system acts as a rigid diaphragm, transferring the loads to the concrete shear walls.

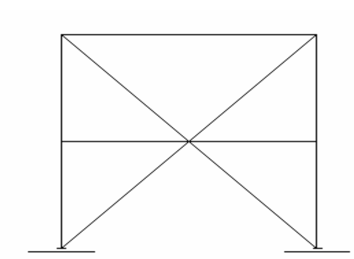


Figure 7: Braced Frame 1

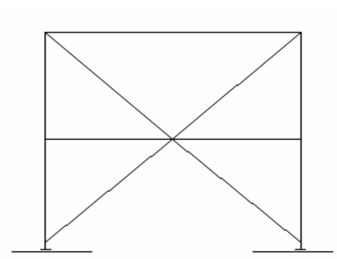


Figure 8: Braced Frame 2

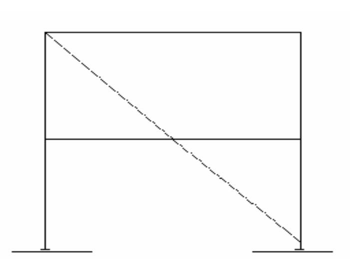


Figure 9: Braced Frame 3

Lateral System Design Criteria

A general list of relevant structural criteria will be discussed to clarify all design assumptions of the lateral force resisting system. The criteria include codes and standards, deflection limitations, material strengths, gravity loads, wind loads, and earthquake loads.

Codes and Standards

Building Code:

New Jersey State Uniform Construction Code (IBC 2000)

Loads:

Minimum Design Loads for Buildings and Other Structures, ASCE 7-02
American Society of Civil Engineers
Comment: Standards of ASCE 7-02/7-05 are referenced by IBC

Structural Concrete:

ACI 318-02
American Concrete Institute

Manual of Standard Practice, 27th Edition, March 2002
Concrete Reinforcing Steel Institute

Structural Steel:

Steel Construction Manual, 13th Edition
American Institute of Steel Construction

Detailing for Steel Construction
American Institute of Steel Construction

Welding:

Structural Welding Code – Steel, AWS D1.1-2002
Structural Welding Code – Reinforcing Steel, AWS D1.4-1998

Metal Decking:

Design Manual for Floor Decks and Roof Decks
Steel Deck Institute

Deflection Limitations

Because the Trump Taj Mahal falls under residential construction defined by the New Jersey State Uniform Construction Code, lateral deflection limits are H/400 total drift or a story drift of 0.5”, whichever controls. This translates to a total allowable lateral drift of 13” at roof level.

Material Strengths

The following tables list the design strengths and properties of various building materials, as specified by the structural engineer of record.

Concrete Compressive Strengths

Location		f'c @ 28 Days (PSI)	Unit Wt. (PCF)
Shear Walls:	Below Level 12	9000*	145
	Levels 12 to 23	7000*	145
	Above Level 23	5000	145

* Indicates 56 – Day Strength

Reinforcing Steel

Deformed Reinforcing Bars	
#10 and Smaller	ASTM A615, Grade 60
#11 and Larger	ASTM A615, Grade 75
Weldable Deformed Reinf Bars	ASTM A706
Welded Wire Fabric (WWF)	ASTM A185
Seven-Wire Stress Relieved Prestressing Strands	ASTM A416, Grade 270
Epoxy Coated Reinf Bars	ASTM A775
Reinforcing Steel Mechanical Splice Couplers	Lenton Splice Couplers or Approved Equal
Doweling Adhesive for Anchoring Reinf Bars into Existing Concrete	Hilti System or Powers Acrylic 100 System

Gravity Loads

The dead weight of non-core areas will be taken as 88psf, the weight of a typical 10" voided filigree slab, plus an additional 15psf. The self weight of the core areas will be taken as 125psf, the weight of a 10" flat plate system, plus an additional 15psf. Both core and non-core areas will have an additional 40psf live load. All loads are per the engineer of record's drawings and conform to ASCE 7.

Wind Loads

Wind loads for the Trump Taj Mahal were computed using a wind tunnel test performed by DFA; 100 year recurrent wind speeds were used. Results of the wind tunnel test can be found in Appendix B. Base shears for the north/south and east west directions are 3445kips and 2500kips, respectively. Figure 10 lists the load cases that were issued by DFA. These load cases were used in the confirmation analysis of the lateral system and were factored as ultimate loads in accordance with ASCE 7 (See ETABS Analysis Section).

Table 4: Load Combinations In Orthogonal Directions

Load Case	Y-Axis (%)	X-Axis (%)	Z-Axis (%)
1	+100	+50	+50
2	+100	+50	-50
3	+100	-50	+50
4	+100	-50	-50
5	-100	+50	+50
6	-100	+50	-50
7	-100	-50	+50
8	-100	-50	-50
9	+65	+100	+60
10	+65	+100	-60
11	-65	+100	+60
12	-65	+100	-60
13	+65	-100	+60
14	+65	-100	-60
15	-65	-100	+60
16	-65	-100	-60
17	+65	+50	+60
18	+65	-50	+60
19	-65	+50	-60
20	-65	-50	-60

Figure 10: Load Cases to be used with the Wind Tunnel Test Results

The proceeding table contains the story forces and overturning moments at the base of the tower (obtained from the wind tunnel test report).

Level	Height (ft)	Force N/S, Y Direction (kips)	Overturning Moment (ft-kips)	Force E/W, X Direction (kips)	Overturning Moment (ft-kips)
1	0.00				
2	16.00	8.80	140.80	6.40	102.40
3	26.00	12.60	468.40	9.20	341.60
4	62.00	41.10	3016.60	29.80	2189.20
5	71.58	25.60	4849.13	18.60	3520.65
6	81.17	29.10	7211.08	21.10	5233.27
7	90.75	32.50	10160.46	23.60	7374.97
8	100.33	35.80	13752.39	26.00	9983.63
9	109.92	39.20	18061.13	28.50	13116.26
10	119.50	42.60	23151.83	31.00	16820.76
11	129.08	46.10	29102.57	33.40	21132.14
12	138.67	49.50	35966.57	35.90	26110.28
13	148.25	53.00	43823.82	38.40	31803.08
14	157.83	56.40	52725.62	40.90	38258.46
15	167.42	59.80	62737.13	43.40	45524.34
16	177.00	63.30	73941.23	45.90	53648.64
17	186.58	66.70	86386.34	48.40	62679.28
18	196.17	70.10	100137.63	50.90	72664.16
19	205.75	73.40	115239.68	53.30	83630.63
20	215.33	76.90	131798.81	55.80	95646.23
21	224.92	80.30	149859.62	58.30	108758.88
22	234.50	83.70	169487.27	60.80	123016.48
23	244.08	87.20	190771.33	63.30	138466.95
24	253.67	90.60	213753.53	65.80	155158.22
25	263.25	96.00	239025.53	69.70	173506.74
26	272.83	99.60	266199.73	72.30	193232.59
27	282.42	103.10	295316.89	74.80	214357.36
28	292.00	106.60	326444.09	77.40	236958.16
29	301.58	110.10	359648.42	79.90	261054.67
30	311.17	113.40	394934.72	82.30	286663.68
31	320.75	116.90	432430.39	84.90	313895.36
32	330.33	120.50	472235.56	87.40	342766.49
33	339.92	124.00	514385.23	90.00	373358.99
34	349.50	127.50	558946.48	92.50	405687.74
35	359.08	131.00	605986.39	95.10	439836.57
36	368.67	134.50	655572.06	97.60	475818.43
37	378.25	138.00	707770.56	100.20	513719.08
38	387.83	132.70	759236.04	96.30	551067.43
39	397.42	142.10	815708.95	103.20	592080.83
40	407.00	233.30	910662.05	169.30	660985.93
Roof	434.83	191.40	993889.15	139.00	721427.77
		3445.00	**10844935.18**	**2500.60**	**7871598.32**

Seismic Loads

Seismic loads for the Trump Taj Mahal were calculated using ASCE 7-05, Equivalent Lateral Force Procedure. The calculations and parameters can be found in a spreadsheet referenced in Appendix C of this report. The base shear for both directions was calculated to be approximately 1086kips.

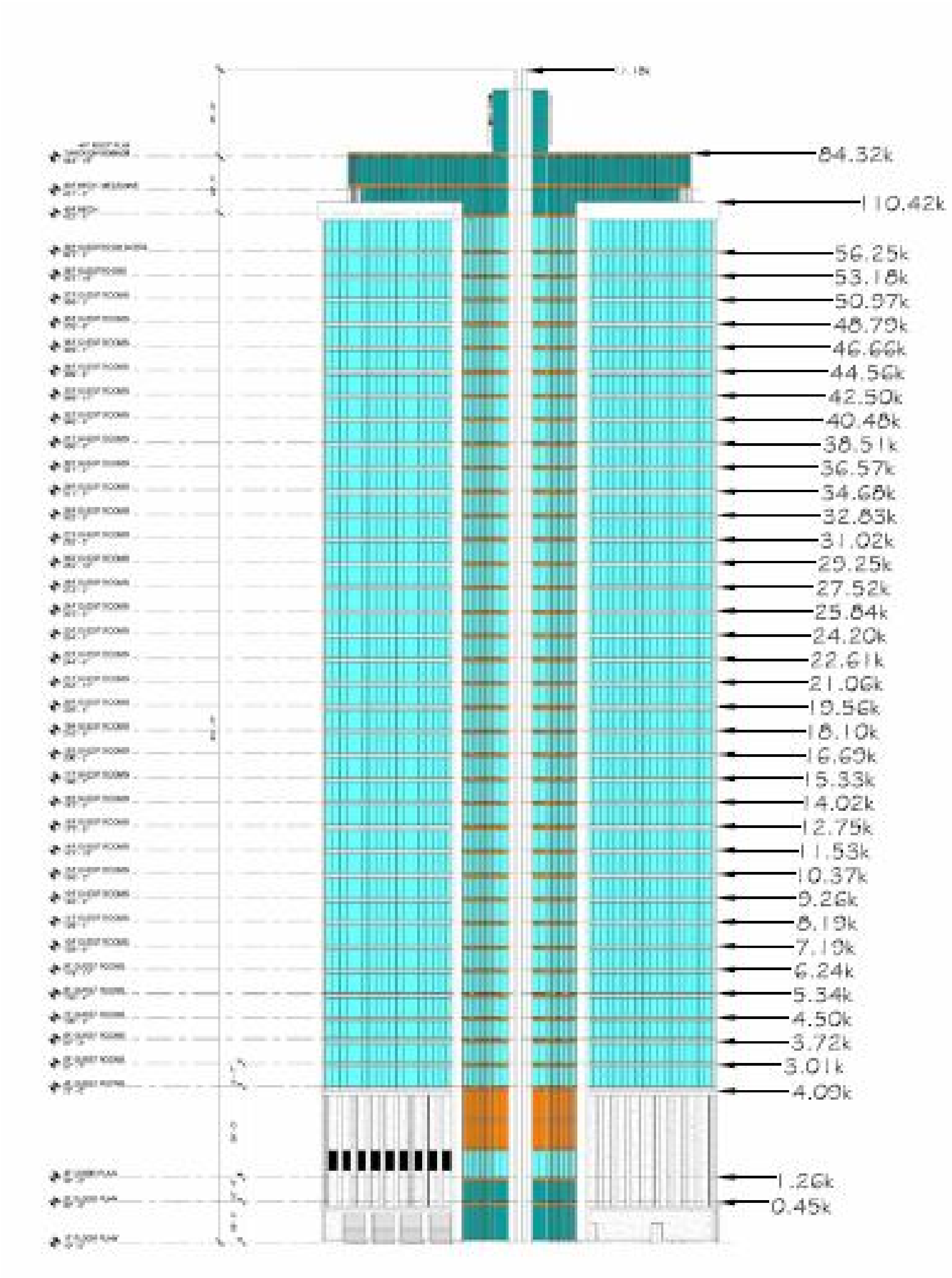
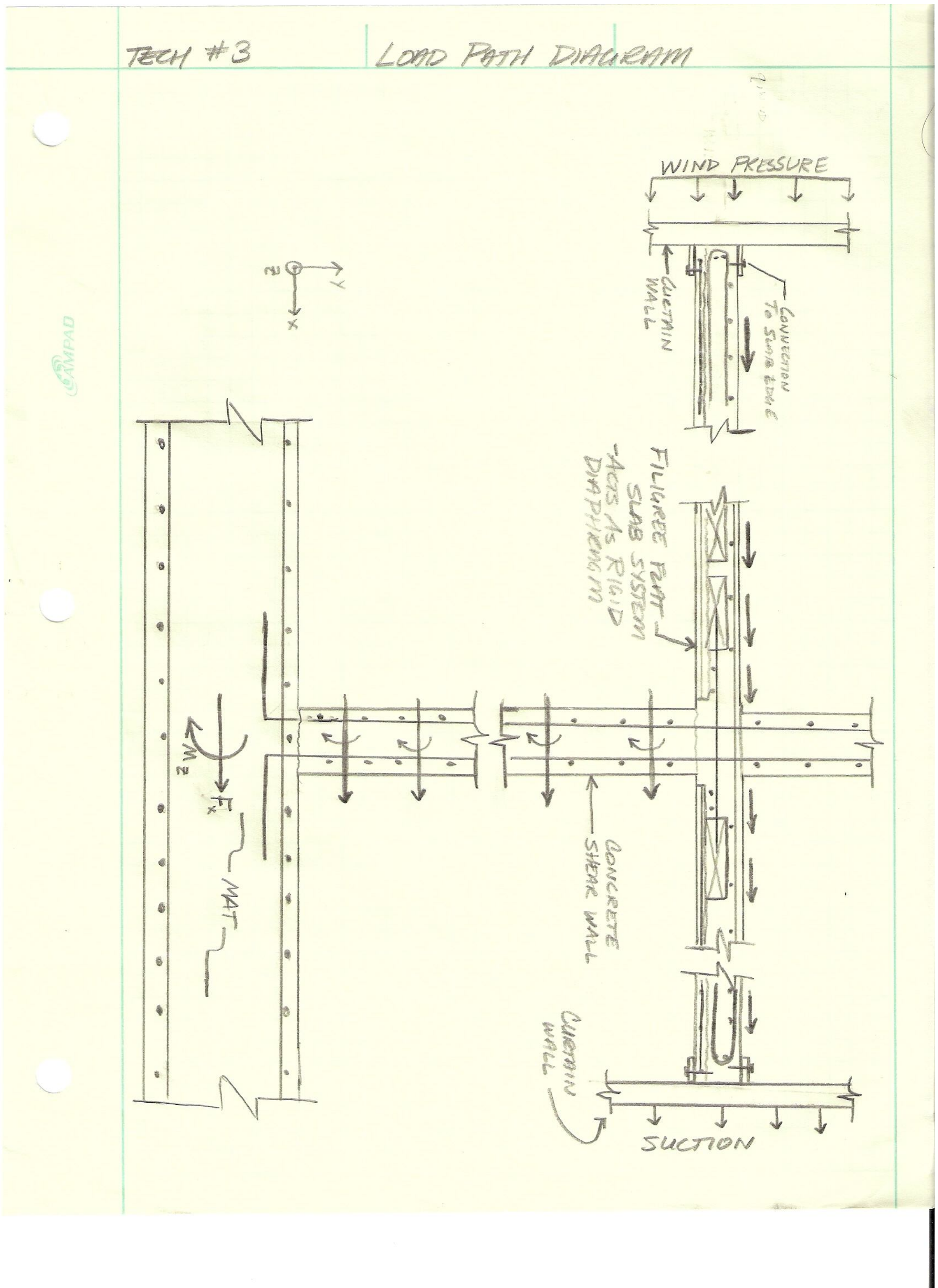


Figure 12: Seismic Force Distribution, Either Direction

Load Path



Note: Out of plane shear forces shown for simplicity of diagram

ETABS Analysis

A simplified ETABS model was constructed to distribute the lateral loads of the tower. The piers of the shear wall were modeled using shell elements, out of plane forces considered, with the respective properties of the wall. The link beams were modeled as frame elements. The wall was meshed using square elements with a maximum dimension of 24". All elements were connected with a rigid diaphragm applied at each floor. A mass equivalent to that of the floor system was applied to that diaphragm.

The engineer of record indicated that the tower was controlled by the 100 year wind forces of the DFA wind tunnel test. Because of this, seismic loads were overlooked in order to further investigate the effects of wind. Wind loads were manually applied to the model at the center of mass of each story. Each of the 20 different load cases provided by DFA was investigated.

Because a 100 year wind velocity was used, property modifiers were applied to the wall and coupling beams to account for cracking over time. 0.7 was applied to f22 for the walls and 0.35 was applied to Ig33 for the coupling beams. P-delta effects were considered; two iterations were performed.

Figure 15 contains the modal analysis of the shear wall core. The first mode occurred in the Y-direction (north/south) at 3.128s. The second mode occurred in the X-direction (east/west) at 2.752s. The third mode occurred in the Z-direction (torsion) at 1.77s.

M O D A L   P E R I O D S   A N D   F R E Q U E N C I E S

MODE NUMBER	PERIOD (TIME)	FREQUENCY (CYCLES/TIME)	CIRCULAR FREQ (RADIANS/TIME)
Mode 1	3.12786	0.31971	2.00878
Mode 2	2.75207	0.36336	2.28307
Mode 3	1.77037	0.56485	3.54909
Mode 4	0.91585	1.09189	6.86053
Mode 5	0.73908	1.35303	8.50132
Mode 6	0.48434	2.06468	12.97275
Mode 7	0.42598	2.34752	14.74991
Mode 8	0.35805	2.79294	17.54853
Mode 9	0.29224	3.42181	21.49984
Mode 10	0.27818	3.59478	22.58666
Mode 11	0.26301	3.80208	23.88915
Mode 12	0.25698	3.89141	24.45047

ETABS v9.1.1 File:SHEAR WALL MODEL CURRENT SHELL Units:Kip-in December 2, 2007 18:02 PAGE 8

M O D A L   P A R T I C I P A T I N G   M A S S   R A T I O S

MODE NUMBER	X-TRANS %MASS <SUM>	Y-TRANS %MASS <SUM>	Z-TRANS %MASS <SUM>	RX-ROTN %MASS <SUM>	RY-ROTN %MASS <SUM>	RZ-ROTN %MASS <SUM>
Mode 1	6.27 < 6>	59.30 < 59>	0.00 < 0>	81.70 < 82>	9.04 < 9>	6.75 < 7>
Mode 2	51.03 < 57>	9.73 < 69>	0.00 < 0>	13.90 < 96>	77.65 < 87>	3.81 < 11>
Mode 3	5.47 < 63>	1.86 < 71>	0.00 < 0>	3.57 < 99>	9.51 < 96>	66.10 < 77>
Mode 4	3.63 < 66>	8.57 < 79>	0.00 < 0>	0.20 < 99>	0.85 < 97>	0.45 < 77>
Mode 5	7.44 < 74>	6.67 < 86>	0.00 < 0>	0.34 <100>	1.34 < 98>	3.13 < 80>
Mode 6	8.52 < 82>	0.17 < 86>	0.00 < 0>	0.01 <100>	1.02 < 99>	7.65 < 88>
Mode 7	1.71 < 84>	2.96 < 89>	0.00 < 0>	0.11 <100>	0.11 <100>	0.99 < 89>
Mode 8	2.39 < 86>	1.76 < 91>	0.00 < 0>	0.07 <100>	0.16 <100>	0.87 < 90>
Mode 9	0.00 < 86>	0.71 < 92>	0.00 < 0>	0.02 <100>	0.00 <100>	0.76 < 91>
Mode 10	0.01 < 86>	0.03 < 92>	0.00 < 0>	0.00 <100>	0.00 <100>	0.16 < 91>
Mode 11	0.02 < 86>	0.02 < 92>	0.00 < 0>	0.00 <100>	0.00 <100>	0.61 < 91>
Mode 12	0.00 < 86>	0.01 < 92>	0.00 < 0>	0.00 <100>	0.00 <100>	0.54 < 92>

Figure 15: ETABS Modal Analysis Results

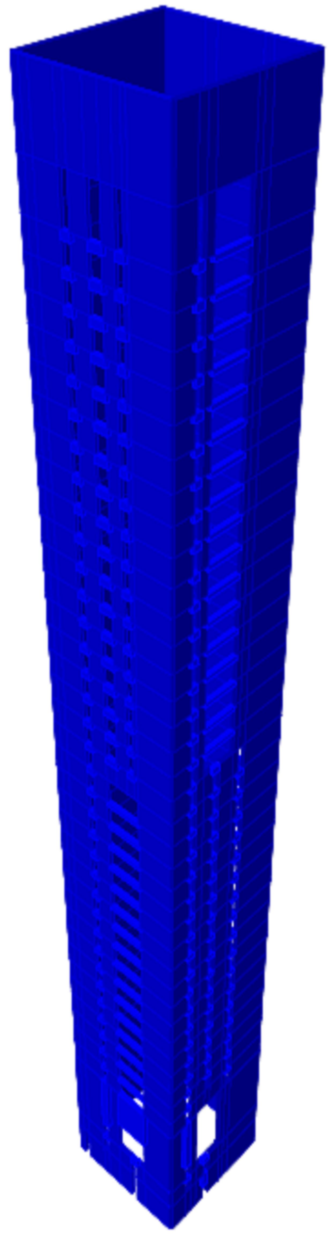


Figure 14: ETABS Shear Wall Model

Figure 16 provides the ETABS calculated centers of rigidity of the structure. The center of rigidity favors the northeast corner of the shear wall core. These results make sense because the calculated points are closest to the stiffest elements of the shear wall core.

C E N T E R S   O F   C U M U L A T I V E   M A S S   &   C E N T E R S   O F   R I G I D I T Y

STORY LEVEL	DIAPHRAGM NAME	CENTER OF MASS: MASS	CENTER OF MASS: ORDINATE-X	CENTER OF MASS: ORDINATE-Y	CENTER OF RIGIDITY: ORDINATE-X	CENTER OF RIGIDITY: ORDINATE-Y
STORY40	D1	4.154E+00	347.557	347.650	522.942	639.105
STORY39	D1	8.323E+00	347.409	347.554	524.114	641.698
STORY38	D1	1.253E+01	347.069	347.032	526.255	638.781
STORY37	D1	1.674E+01	346.898	346.771	527.916	635.776
STORY36	D1	2.096E+01	346.796	346.616	529.771	631.839
STORY35	D1	2.517E+01	346.728	346.512	531.827	627.102
STORY34	D1	2.938E+01	346.680	346.438	534.115	621.689
STORY33	D1	3.359E+01	346.643	346.383	536.669	615.714
STORY32	D1	3.780E+01	346.615	346.339	539.525	609.293
STORY31	D1	4.201E+01	346.593	346.305	542.723	602.555
STORY30	D1	4.622E+01	346.574	346.277	546.302	595.644
STORY29	D1	5.043E+01	346.559	346.253	550.307	588.728
STORY28	D1	5.464E+01	346.546	346.234	554.783	582.002
STORY27	D1	5.886E+01	346.535	346.217	559.775	575.685
STORY26	D1	6.307E+01	346.525	346.202	565.331	570.018
STORY25	D1	6.728E+01	346.517	346.189	571.496	565.259
STORY24	D1	7.149E+01	346.509	346.178	578.318	561.667
STORY23	D1	7.570E+01	346.503	346.167	585.854	559.486
STORY22	D1	7.991E+01	346.497	346.158	594.245	559.219
STORY21	D1	8.411E+01	346.490	346.187	602.958	560.487
STORY20	D1	8.831E+01	346.541	346.199	619.626	556.963
STORY19	D1	9.252E+01	346.544	346.203	624.212	557.900
STORY18	D1	9.672E+01	346.548	346.207	625.686	558.392
STORY17	D1	1.009E+02	346.551	346.210	624.658	558.516
STORY16	D1	1.051E+02	346.553	346.213	621.521	558.387
STORY15	D1	1.093E+02	346.556	346.215	616.575	558.026
STORY14	D1	1.135E+02	346.558	346.218	610.011	557.411
STORY13	D1	1.178E+02	346.560	346.220	601.938	556.480
STORY12	D1	1.220E+02	346.562	346.222	592.387	555.155
STORY11	D1	1.262E+02	346.564	346.224	581.590	553.740
STORY10	D1	1.304E+02	346.566	346.226	568.618	551.562
STORY9	D1	1.346E+02	346.568	346.228	554.052	548.198
STORY8	D1	1.388E+02	346.569	346.230	538.003	543.790
STORY7	D1	1.430E+02	346.571	346.231	520.390	538.106
STORY6	D1	1.472E+02	346.572	346.233	501.080	530.753
STORY5	D1	1.514E+02	346.573	346.234	479.809	521.182
STORY4	D1	1.556E+02	346.576	346.244	456.043	513.001
STORY3	D1	1.604E+02	346.183	346.076	432.302	528.800
STORY2	D1	1.646E+02	346.200	346.074	318.061	359.991
STORY1	D1	1.689E+02	346.321	346.043	321.108	290.454

Figure 16: ETABS Calculated Center of Masses and Center of Rigidities

Figure 17 provides the ETABS calculated displacements and story drifts of the shear walls. These deflections are well below the limits of H/400 (13") total drift and 0.5" story drift.

Level	Total Deflection	Story Drift	Level	Total Deflection	Story Drift
41	7.7651	0.3391	21	3.8812	0.1857
40	7.426	0.2411	20	3.6955	0.199
39	7.1849	0.1626	19	3.4965	0.2079
38	7.0223	0.1677	18	3.2886	0.2148
37	6.8546	0.1727	17	3.0738	0.2195
36	6.6819	0.1772	16	2.8543	0.2221
35	6.5047	0.1815	15	2.6322	0.2228
34	6.3232	0.1854	14	2.4094	0.2218
33	6.1378	0.1887	13	2.1876	0.2188
32	5.9491	0.1916	12	1.9688	0.2127
31	5.7575	0.194	11	1.7561	0.2073
30	5.5635	0.1958	10	1.5488	0.2008
29	5.3677	0.1968	9	1.348	0.1929
28	5.1709	0.197	8	1.1551	0.1835
27	4.9739	0.1963	7	0.9716	0.1723
26	4.7776	0.1943	6	0.7993	0.1593
25	4.5833	0.1908	5	0.64	0.1409
24	4.3925	0.1858	4	0.4991	0.4111
23	4.2067	0.1766	3	0.088	0.0498
22	4.0301	0.1489	2	0.0382	0.0382

Figure 17: ETABS Calculated Lateral Displacements

Lateral System Strength Spot Checks

Spot checks were performed on various components of the shear wall core. Shear wall piers were checked on levels 5 and 20. Forces for each of the 20 load cases were extracted from ETABS and placed into a spreadsheet, where the largest moments, shears, and axial loads were found. Additional axial loads from live and dead loads were also taken into account based on the tributary area of the pier (See Appendix D). Shear strength was checked by hand following guidelines set forth in ACI 318-05; calculations and results can be found in Appendix E. Moment and axial strengths of individual piers were checked using PCA column. Calculations and results for each pier can be found in Appendix F.

The following load combinations provided by ASCE 7-02 were used to determine the design forces:

1. 1.4 DL
2. 1.2 DL + 1.4 LL
3. 1.2 DL + 1.6 W + 1.0 LL
4. 1.2 DL – 1.6 W + 1.0 LL
5. 0.9 DL + 1.6 W
6. 0.9 DL – 1.6 W

As seen by the interaction diagrams in Appendix F, most of the design loads are less than the ultimate capacity of the wall piers. The only piers that did not pass the spot checks were at the 20th level of shear wall 3. Piers 23, 24, and 25 had at least four load combinations that had fallen outside the interaction diagram on the tension side. Simplifications in the ETABS model developed by Stephen Reichwein may have caused these small discrepancies. The actual shear wall core was designed with chamfers on the corners. These chamfers were omitted from the ETABS model referenced in this report.

The shear check verifies the design of the lateral force resisting system. Most of the shear strengths of the piers exceeded the ultimate shear load. A few have fallen short, but are within 10%. Again, these small discrepancies are possibly a result of simplifications.

Conclusion

In order to effectively determine the forces acting on the shear wall, a simplified ETABS model was constructed. The model was analyzed under the effects of wind loads provided by a wind tunnel test performed by DFA. The building modes and periods, center of rigidities, displacements, pier forces, and frame forces were determined directly from ETABS. Pier forces were input into PCA column along with the current design of the pier under investigation. An interaction diagram was than developed to determine whether or not the strength of the pier was adequate to handle the forces. Shear strength was checked by hand per requirements of ACI 31805

Most of the design criteria were met or exceeded, with the exception of a few shear wall piers that failed either because of excessive tensile forces or shear forces. Simplifications taken by Stephen Reichwein in the development of his ETABS model may be the cause of some discrepancies.

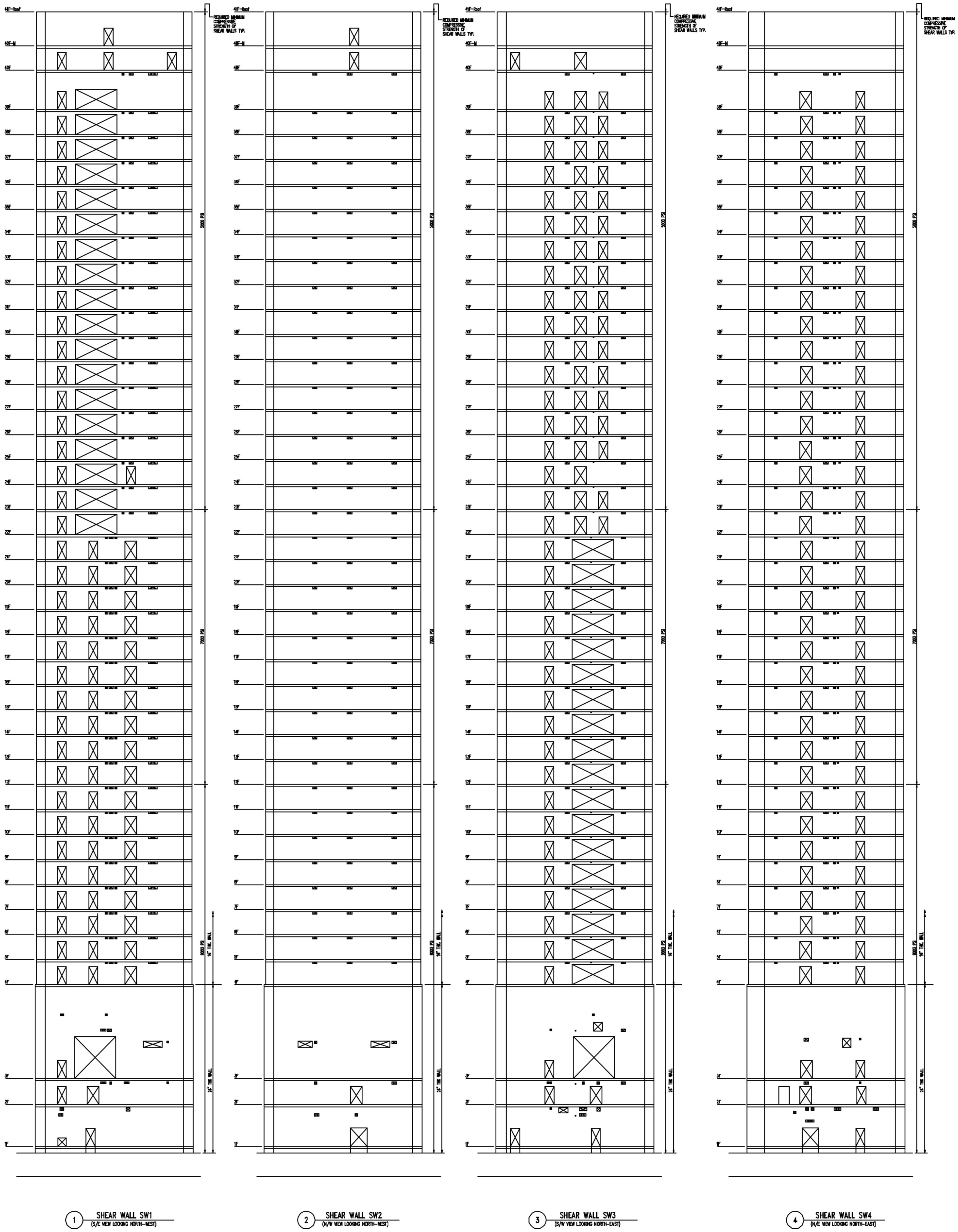
Lateral displacements meet the New Jersey State Uniform Construction Code requirements of H/400, as well as a story drift limit of 0.5”. In fact, the lateral displacements calculated by ETABS are well below these limits. This may be something to consider later in the semester as a structural depth study.

The first building period calculated by ETABS was 3.128s. As a rule of thumb, approximate building periods are calculated by the equation Tapprox = 0.10 x (Number of Stories), where the story height is 12’ typically. Adjusting this equation for the building height of 9’-7” for the Trump Taj Mahal Hotel, Tapprox is equal to 3.2s, very close to 3.128s calculated by the ETABS model. This small spot check confirms the ETABS model used for Technical Report Three.

Appendix

Section	**Page**

Appendix A – Shear Wall Elevations



Appendix B – Wind Tunnel Report Performed by DFA

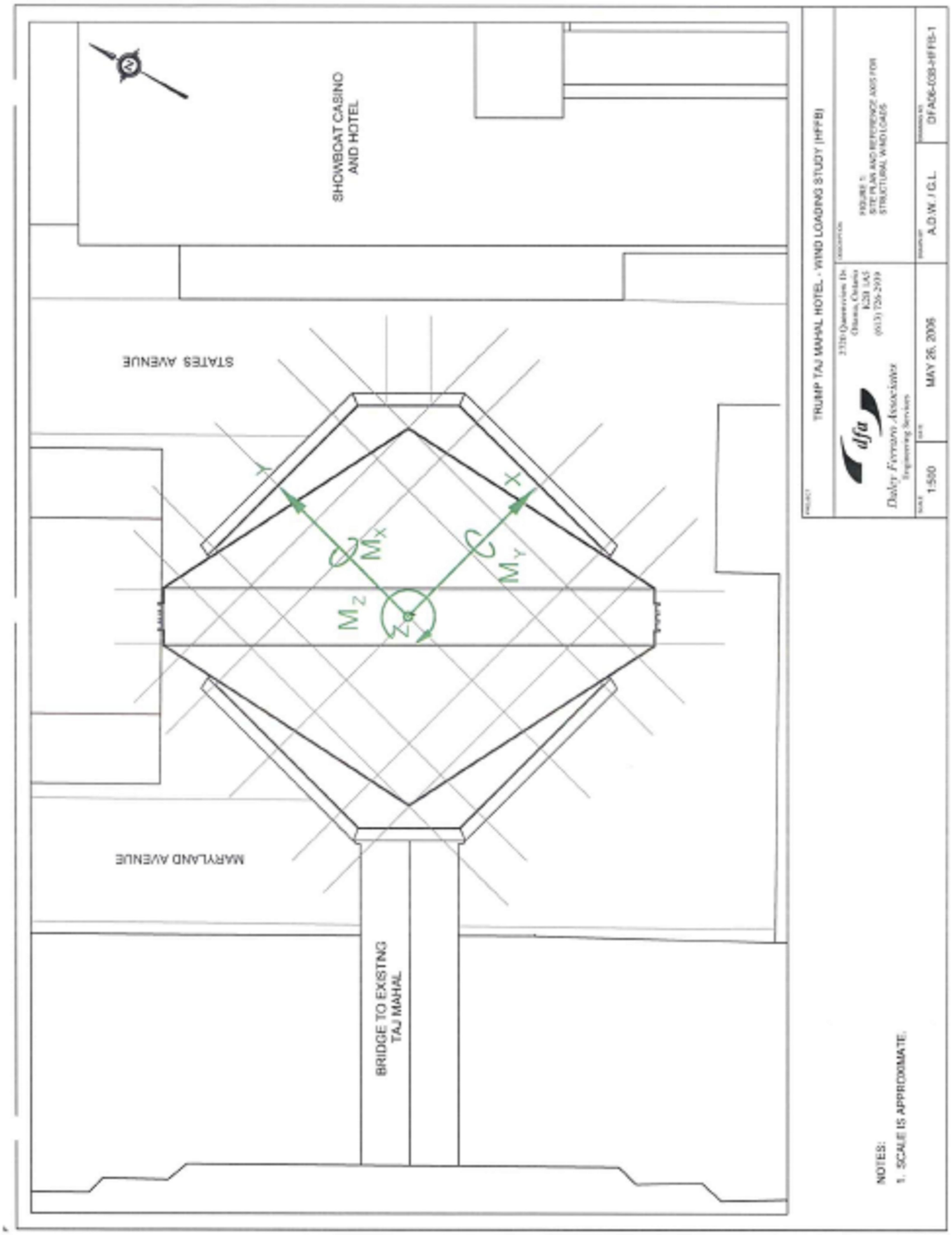
dfa

Table 3a: Effective Static Wind Loads At Each Floor Level Corresponding To 50 Year Base Moments (With Phase II Present) (Continued)
Structural Damping of 0.020
fx = 0.326 Hz, fy = 0.302 Hz, fz = 0.517 Hz
(Based on Hurricane Wind Data)

Floor	Height ft	Fx kip	Fy kip	Mz kip-ft x10³
21	224.86	58.3	80.3	0.99
20	215.28	55.8	76.9	0.95
19	205.70	53.3	73.4	0.91
18	196.12	50.9	70.1	0.87
17	186.54	48.4	66.7	0.82
16	176.96	45.9	63.3	0.78
15	167.38	43.4	59.8	0.74
14	157.80	40.9	56.4	0.70
13	148.22	38.4	53.0	0.65
12	138.64	35.9	49.5	0.61
11	129.06	33.4	46.1	0.57
10	119.48	31.0	42.6	0.53
9	109.90	28.5	39.2	0.48
8	100.32	26.0	35.8	0.44
7	90.74	23.6	32.5	0.40
6	81.16	21.1	29.1	0.36
5	71.58	18.6	25.6	0.32
4	62.00	29.8	41.1	0.39
3	26.00	9.2	12.6	0.15
2	16.00	6.4	8.8	0.10
Σ		2500.7	3444.9	41.0

Table 3a: Effective Static Wind Loads At Each Floor Level Corresponding To 50 Year Base Moments (With Phase II Present)
Structural Damping of 0.020
fx = 0.326 Hz, fy = 0.302 Hz, fz = 0.517 Hz
(Based on Hurricane Wind Data)

Floor	Height ft	Fx kip	Fy kip	Mz kip-ft x10^3
Roof	437.22	139.0	191.4	1.71
40	414.72	169.3	233.3	2.66
39	399.72	103.2	142.1	1.66
38	387.72	96.3	132.7	1.58
37	378.14	100.2	138.0	1.67
36	368.56	97.6	134.5	1.63
35	358.98	95.1	131.0	1.59
34	349.40	92.5	127.5	1.54
33	339.82	90.0	124.0	1.50
32	330.24	87.4	120.5	1.46
31	320.66	84.9	116.9	1.42
30	311.08	82.3	113.4	1.37
29	301.50	79.9	110.1	1.33
28	291.92	77.4	106.6	1.29
27	282.34	74.8	103.1	1.25
26	272.76	72.3	99.6	1.21
25	263.18	69.7	96.0	1.16
24	253.60	65.8	90.6	1.12
23	244.02	63.3	87.2	1.08
22	234.44	60.8	83.7	1.03



Axes Designation for Wind Tunnel Report

Appendix C – Seismic Loads per ASCE 7 Equivalent Lateral Force Procedure

Project Trump Taj Mahal - AE 481W
Engineer Stephen Reichwein
Date 10/2/2007

Seismic Loads Per ASCE 7-05 Standard

Input

Occupancy Category	I	
Importance Factor	1.00	
Soil Site Class	D	
Seismic Design Category	B	
F_a	1.600	
F_v	2.400	
S_s	0.191	
S_1	0.061	
S_{DS}	0.204	
S_{D1}	0.0976	
R	5.0	
Ω	2.5	
C_d	4.5	
T_s	0.319	
h_n	434.830	
x	0.750	
C_t	0.020	
T_a	1.904	
T_L	6.0	
C_s	0.0102	
k	1.7	
Base Shear (V_b)	**1085.8**	kips

$T_a = C_t \times h_n^x$

$T \le T_L$ min
$C_s = S_{D1} / (T (R / I))$ 0.0102
$C_s = S_{DS} / (R / I)$ 0.0408

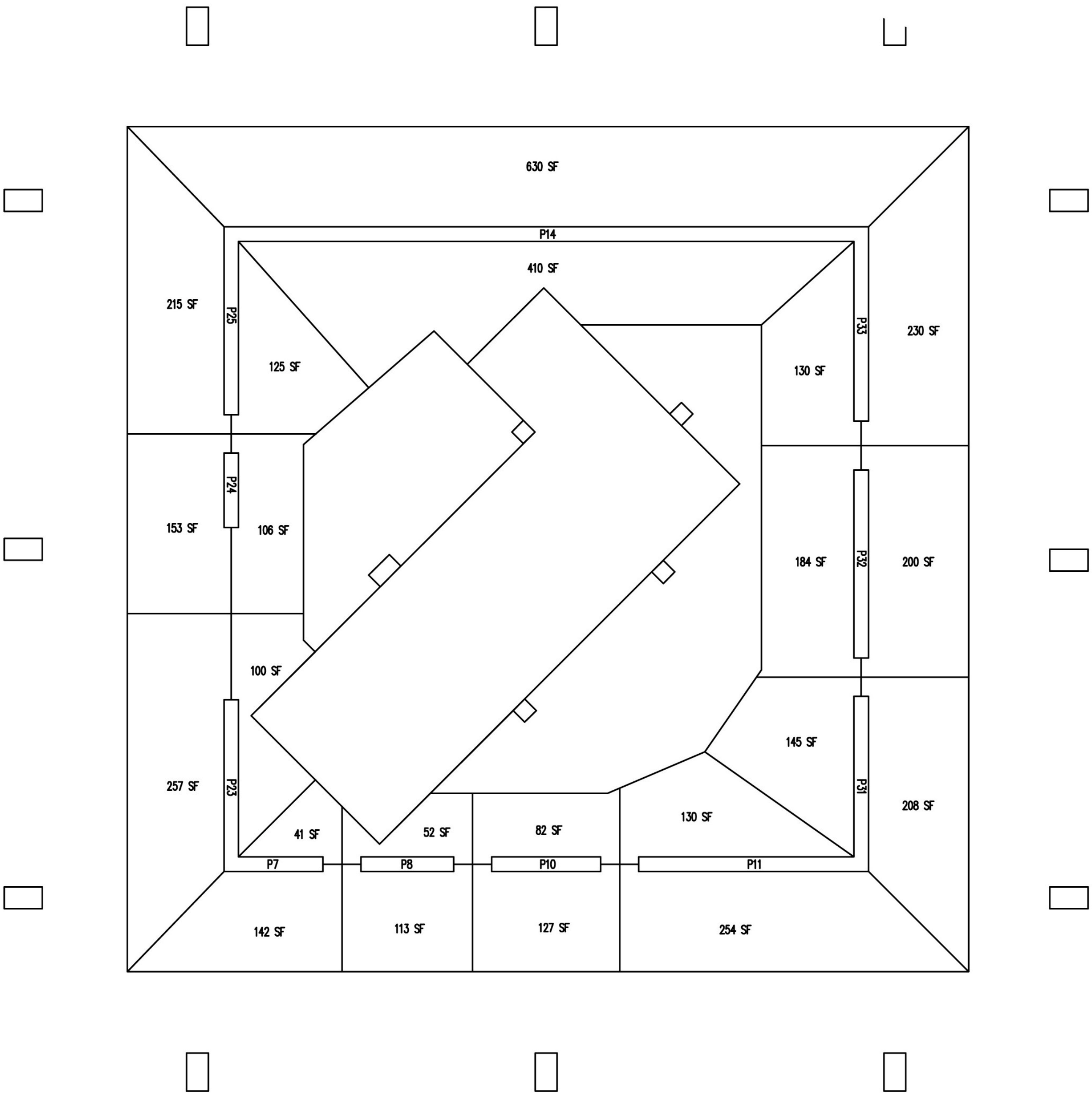
$T > T_L$ min
$C_s = S_{D1} \times T_L / (T^2 (R / I))$
$C_s = S_{DS} / (R / I)$

$C_{smin} = .01$

Level	Area Non Core (sf)	Area Core (sf)	Tributary Height of Level (ft)	Perimeter (ft)	Façade Wt. (psf)	Self Weight Core (psf)	Self Weight Non Core (psf)	Shear Wall and Column Self Weight (kips)	Super-Imposed DL Core (psf)	Super-Imposed DL Non Core (psf)	Weight of Level (kips)	Elevation Height (feet)	$w_x h_x^k$	$(w_x h_x^k/\sum w_x h_x^k) x V_b$ Shear Per Floor (kips)
Sign	N/A	N/A	36.00	400	20	N/A	0	70	0	0	358	470.83	12524409.81	11.18
Roof	13800	N/A	13.92	465	15	N/A	120	925	N/A	30	3092	434.83	94492632.96	84.32
40	14400	3500	18.71	565	15	145	145	1240	30	30	4531	407.00	123739868.4	110.42
39	14400	3500	9.58	565	15	120	90	303	25	15	2404	397.42	63037935.43	56.25
38	14400	3500	9.58	565	15	120	90	303	15	15	2369	387.83	59595054.84	53.18
37	14400	3500	9.58	565	15	120	90	303	15	15	2369	378.25	57113357.31	50.97
36	14400	3500	9.58	565	15	120	90	303	15	15	2369	368.67	54675288.16	48.79
35	14400	3500	9.58	565	15	120	90	303	15	15	2369	359.08	52281184.61	46.66
34	14400	3500	9.58	565	15	120	90	303	15	15	2369	349.50	49931395.49	44.56
33	14400	3500	9.58	565	15	120	90	303	15	15	2369	339.92	47626281.94	42.50
32	14400	3500	9.58	565	15	120	90	303	15	15	2369	330.33	45366218.21	40.48
31	14400	3500	9.58	565	15	120	90	303	15	15	2369	320.75	43151592.55	38.51
30	14400	3500	9.58	565	15	120	90	303	15	15	2369	311.17	40982808.12	36.57
29	14400	3500	9.58	565	15	120	90	303	15	15	2369	301.58	38860284.05	34.68
28	14400	3500	9.58	565	15	120	90	303	15	15	2369	292.00	36784456.64	32.83
27	14400	3500	9.58	565	15	120	90	303	15	15	2369	282.42	34755780.56	31.02
26	14400	3500	9.58	565	15	120	90	303	15	15	2369	272.83	32774730.34	29.25
25	14400	3500	9.58	565	15	120	90	303	15	15	2369	263.25	30841801.92	27.52
24	14400	3500	9.58	565	15	120	90	303	15	15	2369	253.67	28957514.42	25.84
23	14400	3500	9.58	565	15	120	90	303	15	15	2369	244.08	27122412.16	24.20
22	14400	3500	9.58	565	15	120	90	303	15	15	2369	234.50	25337066.88	22.61
21	14400	3500	9.58	565	15	120	90	303	15	15	2369	224.92	23602080.28	21.06
20	14400	3500	9.58	565	15	120	90	303	15	15	2369	215.33	21918086.94	19.56
19	14400	3500	9.58	565	15	120	90	303	15	15	2369	205.75	20285757.63	18.10
18	14400	3500	9.58	565	15	120	90	303	15	15	2369	196.17	18705803.12	16.69
17	14400	3500	9.58	565	15	120	90	303	15	15	2369	186.58	17178978.6	15.33
16	14400	3500	9.58	565	15	120	90	303	15	15	2369	177.00	15706088.87	14.02
15	14400	3500	9.58	565	15	120	90	303	15	15	2369	167.42	14287994.42	12.75
14	14400	3500	9.58	565	15	120	90	303	15	15	2369	157.83	12925618.59	11.53
13	14400	3500	9.58	565	15	120	90	303	15	15	2369	148.25	11619956.21	10.37
12	14400	3500	9.58	565	15	120	90	303	15	15	2369	138.67	10372084.04	9.26
11	14400	3500	9.58	565	15	120	90	303	15	15	2369	129.08	9183173.502	8.19
10	14400	3500	9.58	565	15	120	90	303	15	15	2369	119.50	8054506.508	7.19
9	14400	3500	9.58	565	15	120	90	303	15	15	2369	109.92	6987495.351	6.24
8	14400	3500	9.58	565	15	120	90	303	15	15	2369	100.33	5983708.208	5.34
7	14400	3500	9.58	565	15	120	90	303	15	15	2369	90.75	5044902.475	4.50
6	14400	3500	9.58	565	15	120	90	303	15	15	2369	81.17	4173069.39	3.72
5	14400	3500	9.58	565	15	120	90	303	15	15	2369	71.58	3370495.55	3.01
4	14400	3500	22.79	565	25.11	120	120	1923	30	30	4931	62.00	5495872.279	4.90
3	14400	3500	23.00	565	63	170	110	2027	30	30	5562	26.00	1414689.335	1.26
2	14400	3500	21.00	565	63	145	110	1145	30	30	4521	16.00	503776.6072	0.45
										∑	**105935**		**1216734482**	**1085.83**

Appendix D – Shear Wall Load Takedown

This Page Left Intentionally Blank



Pier Designations and Tributary Areas

Load Takedown

Project Tech 3
Engr SMR
Date 12/21/07

Shear Wall Load Takeoffs

	Core	Non-Core
Dead Load	140	102
Live Load	40	40

5th Level

Pier Label	Self Weight		
	Axial (kips)	*V (kips)*	*M (kip-feet)*
P7	736	40	145
P8	551	14	86
P10	667	25	126
P11	1665	43	199
P14	4474	12	2314
P23	1371	15	63
P24	580	0	9
P25	1334	10	62
P31	1210	18	120
P32	1292	5	88
P33	1272	12	61

Pier Label	Additional Axial Force From Superimposed Dead and Live Loads				
	Core Trib Area (sf)	*Hotel Trib Area (sf)*	*Levels Above*	*Dead Load (kips)*	*Live Load (kips)*
P7	41	142	36	728	264
P8	52	113	36	677	238
P10	82	127	36	880	301
P11	130	254	36	1588	553
P14	410	630	36	4380	1498
P23	100	257	36	1448	514
P24	106	153	36	1096	373
P25	125	215	36	1419	490
P31	145	208	36	1495	508
P32	184	200	36	1662	553
P33	130	230	36	1500	518

Pier Label	Wind Loads		
	Axial (kips)	*V (kips)*	*M (kip-feet)*
P7	2262	362	1881
P8	1545	462	3112
P10	1583	529	4005
P11	5667	435	8340
P14	11599	1719	102729
P23	3318	366	5641
P24	2085	185	1150
P25	3048	827	8350
P31	4370	753	5934
P32	2451	1008	9641
P33	4230	860	7144

Load Takedown

Project Tech 3
Engr SMR
Date 12/21/07

Shear Wall Load Takedowns

	Core	Non-Core
Dead Load	140	102
Live Load	40	40

20th Level

Pier Label	Self Weight		
	Axial (kips)	*V (kips)*	*M (kip-feet)*
P7	464	25	81
P8	361	14	75
P10	419	8	46
P11	1009	31	135
P14	2853	1	1350
P23	878	35	161
P24	393	7	42
P25	835	28	111
P31	750	11	24
P32	821	0	2
P33	800	11	22

Pier Label	Additional Axial Force From Superimposed Dead and Live Loads				
	Core Trib Area (sf)	*Hotel Trib Area (sf)*	*Levels Above*	*Dead Load (kips)*	*Live Load (kips)*
P7	41	142	21	425	154
P8	52	113	21	395	139
P10	82	127	21	513	176
P11	130	254	21	926	323
P14	410	630	21	2555	874
P23	100	257	21	844	300
P24	106	153	21	639	218
P25	125	215	21	828	286
P31	145	208	21	872	297
P32	184	200	21	969	323
P33	130	230	21	875	302

Pier Label	Wind Loads		
	Axial (kips)	*V (kips)*	*M (kip-feet)*
P7	1188	345	1273
P8	810	377	1844
P10	1189	365	2026
P11	1639	432	5858
P14	3330	1113	47913
P23	4127	580	5691
P24	2310	162	914
P25	2975	739	6110
P31	1185	508	2552
P32	1221	622	3952
P33	1684	599	3188

Appendix E – Shear Wall Shear Check

This Page Left Intentionally Blank

Shear Check

Project Tech 3
Engr SMR
Date 12/21/07

Shear Wall Shear Check – Level 5

Controlling Load Combination: 0.9 DL + 1.6 W
f_c' (psi) 9000
f_y (psi) 60000

A(#7)	A(#6)	SP1	SP2
0.6	0.44	12	18

$$\textit{Nominal Shear Capacity}: \Phi V_n = \phi A_{cv}[\alpha_c \sqrt{(f'_c)} + \rho_t f_y]$$

	Pier Label	V_U (kips)	Vert. Reinf.	L (in)	h (in)	A_{cv} (in^2)	α_c	ρ_t	ΦV_N (kips)	
	P7	615	(2)#7 @ 12”	102	16	1632	2	0.63%	691	Ok
	P8	751	(2)#7 @ 12”	102	16	1632	2	0.63%	691	**NG**
	P10	869	(2)#7 @ 12”	120	16	1920	2	0.63%	813	**NG**
	P11	734	(2)#7 @ 12”	246	16	3936	2	0.63%	1667	Ok
SW 1	**SUM**	**2969**							**3863**	Ok
	P14	2761	(2)#7 @ 12”	696	16	11136	2	0.63%	4717	Ok
SW2	**SUM**	**2761**							**4717**	Ok
	P23	599	(2)#6 @ 18”	182	16	2912	2	0.31%	815	Ok
	P24	295	(2)#6 @ 18”	82	16	1312	2	0.31%	367	Ok
	P25	1333	(2)#6 @ 18”	196	16	3136	2	0.31%	877	**NG**
SW3	**SUM**	**2228**							**2059**	**NG**
	P31	1221	(2)#7 @ 12”	186	16	2976	2	0.63%	1260	Ok
	P32	1617	(2)#7 @ 12”	207	16	3312	2	0.63%	1403	**NG**
	P33	1387	(2)#7 @ 12”	207	16	3312	2	0.63%	1403	Ok
SW4	**SUM**	**4225**							**4066**	**NG**

Shear Check

Project Tech 3
Engr SMR
Date 12/21/07

Shear Wall Shear Check – Level 20

Controlling Load Combination: 0.9 DL + 1.6 W
f_c' (psi) 9000
f_y (psi) 60000

A(#7)	A(#6)	SP1	SP2
0.6	0.44	12	18

Nominal Shear Capacity : $\Phi V_n = \phi A_{cv} [\alpha_c \sqrt{(f'_c)} + \rho_t f_y]$

	Pier Label	V_U (kips)	Vert. Reinf.	L (in)	h (in)	A_{cv} (in^2)	α_c	ρ_t	ΦV_N (kips)	
	P7	574	(2)#7 @ 12"	102	16	1632	2	0.63%	691	Ok
	P8	615	(2)#7 @ 12"	102	16	1632	2	0.63%	691	Ok
	P10	591	(2)#7 @ 12"	120	16	1920	2	0.63%	813	Ok
	P11	719	(2)#7 @ 12"	246	16	3936	2	0.63%	1667	Ok
SW 1	**SUM**	**2499**							**3863**	Ok
	P14	1783	(2)#6 @ 18"	696	16	11136	2	0.31%	3116	Ok
SW2	**SUM**	**1783**							**3116**	Ok
	P23	960	(2)#6 @ 18"	182	16	2912	2	0.31%	815	**NG**
	P24	265	(2)#6 @ 18"	82	16	1312	2	0.31%	367	Ok
	P25	1208	(2)#6 @ 18"	196	16	3136	2	0.31%	877	**NG**
SW3	**SUM**	**2433**							**2059**	**NG**
	P31	823	(2)#6 @ 18"	186	16	2976	2	0.31%	833	Ok
	P32	995	(2)#6 @ 18"	207	16	3312	2	0.31%	927	**NG**
	P33	968	(2)#6 @ 18"	207	16	3312	2	0.31%	927	**NG**
SW4	**SUM**	**2785**							**2686**	**NG**

Appendix F – PCA Column Calculations and Results

This Page Left Intentionally Blank

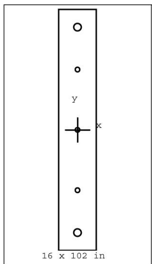
5th Level

Pier	Quantity, Each End	Bar Size	L (in)	As (in^2)	d (in)
P7	6	11	102	9.36	91.94
P8	10	11	102	15.6	87.94
P10	10	11	120	15.6	105.94
P11	16	11	246	24.96	225.94
P14	16	11	696	24.96	675.94
P23	4	11	182	6.24	173.94
P24	8	11	82	12.48	69.94
P25	8	11	196	12.48	183.94
P31	6	11	186	9.36	175.94
P32	6	11	207	9.36	196.94
P33	8	11	207	12.48	194.94

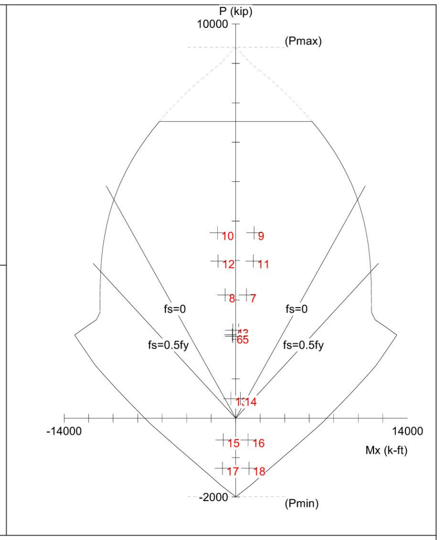
20th Level

Pier	Quantity, Each End	Bar Size	L (in)	As (in^2)	d (in)
P7	4	11	102	6.24	93.94
P8	4	11	102	6.24	93.94
P10	6	11	120	9.36	109.94
P11	8	11	246	12.48	233.94
P14	10	11	696	15.6	681.94
P23	4	11	182	6.24	173.94
P24	4	11	82	6.24	73.94
P25	6	11	196	9.36	185.94
P31	4	11	186	6.24	177.94
P32	4	11	207	6.24	198.94
P33	4	11	207	6.24	198.94

Pier End Reinforcement Takedown



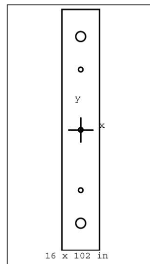
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:32:58



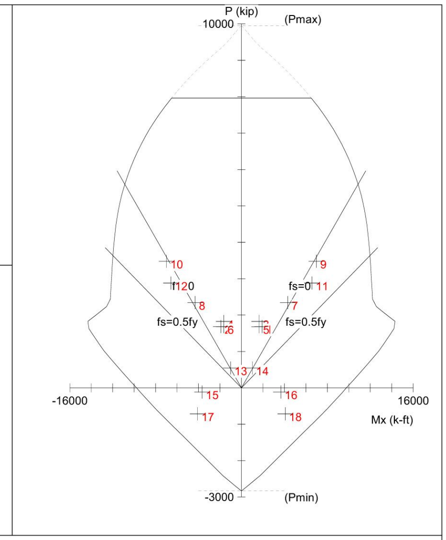
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P7 - 5.col
Project: Tech 3
Column: P7 — Engineer: SMR

f'c = 9 ksi	fy = 75 ksi	Ag = 1632 in^2	5 bars
Ec = 5408 ksi	Es = 29000 ksi	As = 29.52 in^2	Rho = 1.81%
fc = 7.65 ksi	fc = 7.65 ksi	Xo = 0.00 in	Ix = 1.41494e+006 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 34816 in^4
Beta1 = 0.65		Clear spacing = 15.20 in	Clear cover = 5.77 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



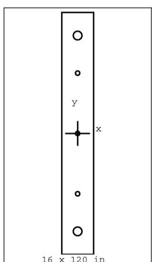
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:33:39



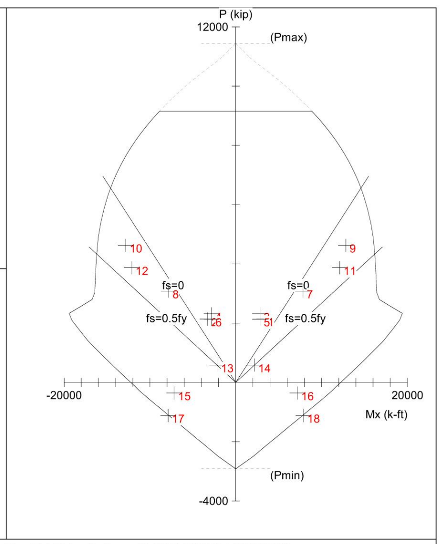
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P8 - 5.col
Project: Tech 3
Column: P7 — Engineer: SMR

f'c = 9 ksi	fy = 75 ksi	Ag = 1632 in^2	5 bars
Ec = 5408 ksi	Es = 29000 ksi	As = 42.00 in^2	Rho = 2.57%
fc = 7.65 ksi	fc = 7.65 ksi	Xo = 0.00 in	Ix = 1.41494e+006 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 34816 in^4
Beta1 = 0.65		Clear spacing = 10.70 in	Clear cover = 5.77 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



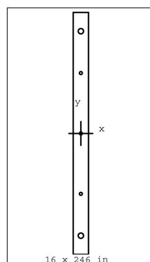
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:34:18



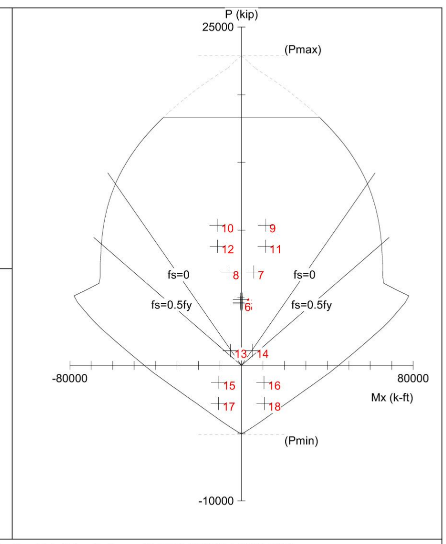
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P10 - 5.col
Project: Tech 3
Column: P7 — Engineer: SMR

f'c = 9 ksi	fy = 75 ksi	Ag = 1920 in^2	5 bars
Ec = 5408 ksi	Es = 29000 ksi	As = 43.20 in^2	Rho = 2.25%
fc = 7.65 ksi	fc = 7.65 ksi	Xo = 0.00 in	Ix = 2.304e+006 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 40960 in^4
Beta1 = 0.65		Clear spacing = 15.14 in	Clear cover = 5.77 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:34:53

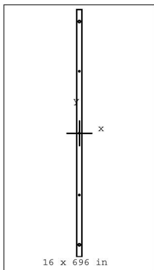


pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

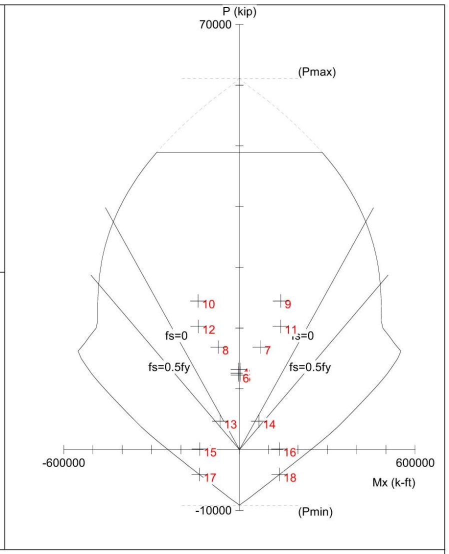
File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P11 - 5.col
Project: Tech 3
Column: P7 — Engineer: SMR

f'c = 9 ksi	fy = 75 ksi	Ag = 3936 in^2	5 bars
Ec = 5408 ksi	Es = 29000 ksi	As = 75.20 in^2	Rho = 1.91%
fc = 7.65 ksi	fc = 7.65 ksi	Xo = 0.00 in	Ix = 1.98492e+007 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 83968 in^4
Beta1 = 0.65		Clear spacing = 38.04 in	Clear cover = 5.18 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

Level 5, Page 1



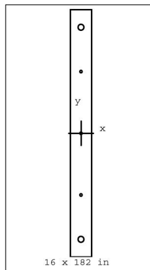
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/01/07
Time: 21:44:10



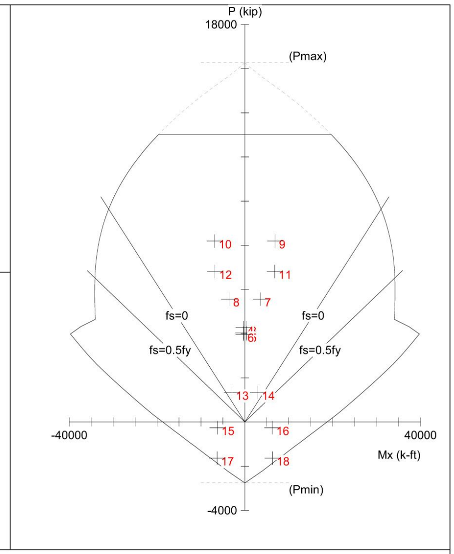
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P14 - 5.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 9 ksi	fy = 60 ksi	Ag = 11136 in^2	5 bars
Ec = 5408 ksi	Es = 29000 ksi	As = 169.44 in^2	Rho = 1.52%
fc = 7.65 ksi	fc = 7.65 ksi	Xo = 0.00 in	Ix = 4.49538e+008 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 237568 in^4
Beta1 = 0.65		Clear spacing = 133.30 in	Clear cover = 4.01 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



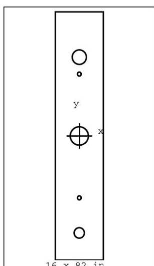
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:36:38



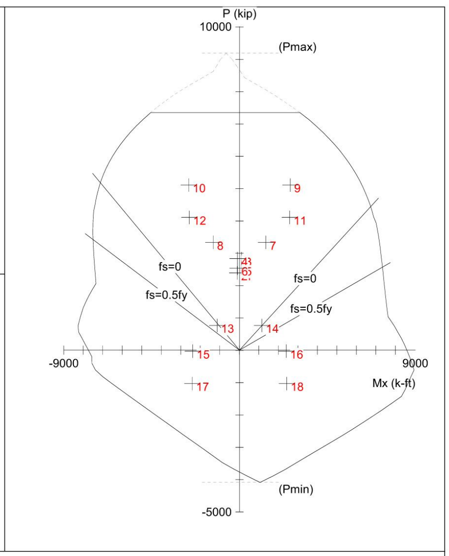
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P23 - 5.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 9 ksi	fy = 75 ksi	Ag = 2912 in^2	5 bars
Ec = 5408 ksi	Es = 29000 ksi	As = 40.89 in^2	Rho = 1.40%
fc = 7.65 ksi	fc = 7.65 ksi	Xo = 0.00 in	Ix = 8.03809e+006 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 62122.7 in^4
Beta1 = 0.65		Clear spacing = 29.26 in	Clear cover = 5.77 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



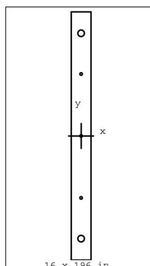
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:37:16



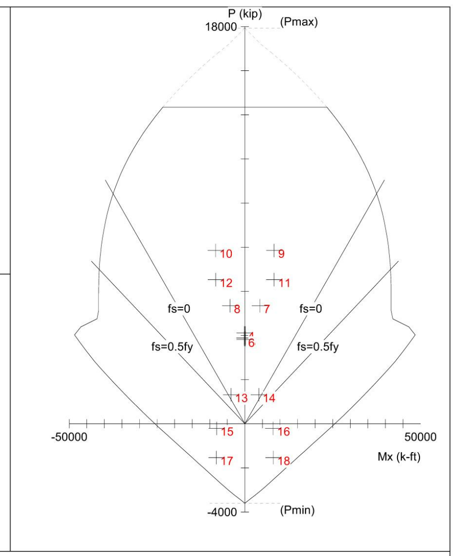
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P24 - 5.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 9 ksi	fy = 75 ksi	Ag = 1312 in^2	5 bars
Ec = 5408 ksi	Es = 29000 ksi	As = 60.57 in^2	Rho = 4.62%
fc = 7.65 ksi	fc = 7.65 ksi	Xo = 0.00 in	Ix = 735157 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27989.3 in^4
Beta1 = 0.65		Clear spacing = 2.37 in	Clear cover = 4.93 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:37:52

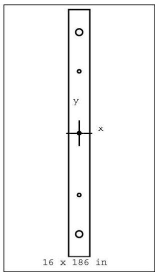


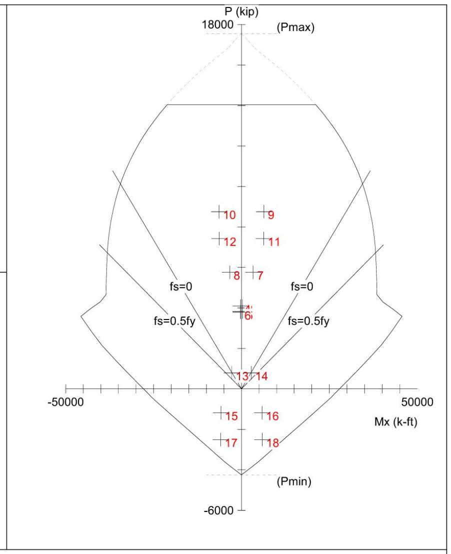
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P25 - 5.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 9 ksi	fy = 75 ksi	Ag = 3136 in^2	5 bars
Ec = 5408 ksi	Es = 29000 ksi	As = 53.37 in^2	Rho = 1.70%
fc = 7.65 ksi	fc = 7.65 ksi	Xo = 0.00 in	Ix = 1.00394e+007 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 66901.3 in^4
Beta1 = 0.65		Clear spacing = 28.35 in	Clear cover = 5.36 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

Level 5, Page 2



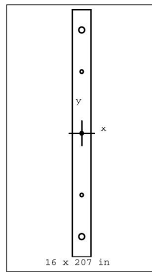


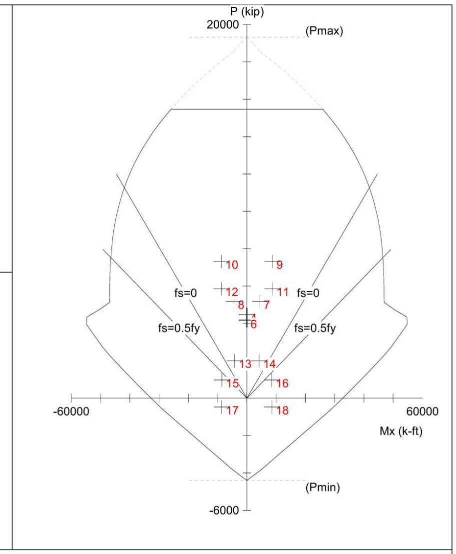
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:38:29

pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P31 - 5.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 9 ksi	fy = 75 ksi	Ag = 2976 in^2	5 bars
Ec = 5408 ksi	Es = 29000 ksi	As = 62.88 in^2	Rho = 2.11%
fc = 7.65 ksi	fc = 7.65 ksi	Xo = 0.00 in	Ix = 8.57981e+006 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 63488 in^4
Beta1 = 0.65		Clear spacing = 25.44 in	Clear cover = 5.36 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



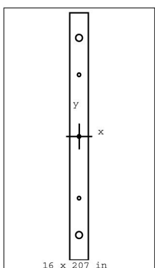


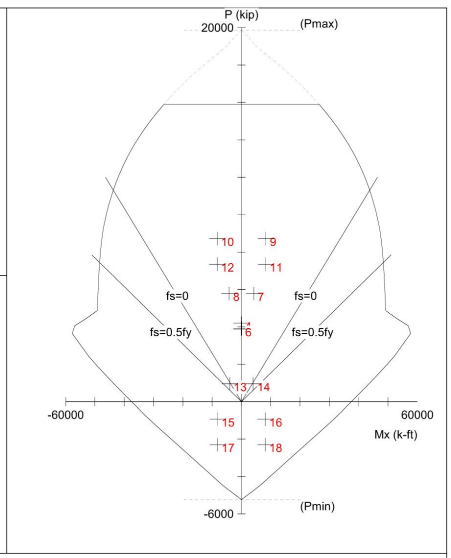
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:39:04

pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P32 - 5.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 9 ksi	fy = 75 ksi	Ag = 3312 in^2	5 bars
Ec = 5408 ksi	Es = 29000 ksi	As = 65.28 in^2	Rho = 1.97%
fc = 7.65 ksi	fc = 7.65 ksi	Xo = 0.00 in	Ix = 1.18263e+007 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 70656 in^4
Beta1 = 0.65		Clear spacing = 30.60 in	Clear cover = 5.36 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		





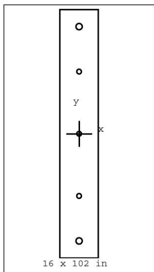
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:39:40

pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

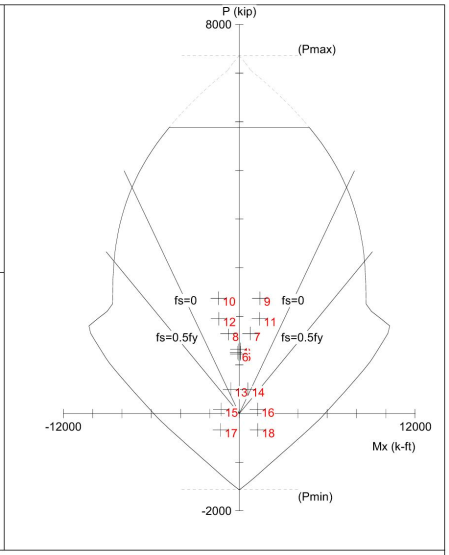
File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P33 - 5.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 9 ksi	fy = 75 ksi	Ag = 3312 in^2	5 bars
Ec = 5408 ksi	Es = 29000 ksi	As = 77.60 in^2	Rho = 2.34%
fc = 7.65 ksi	fc = 7.65 ksi	Xo = 0.00 in	Ix = 1.18263e+007 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 70656 in^4
Beta1 = 0.65		Clear spacing = 26.25 in	Clear cover = 5.01 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

Level 5, Page 3



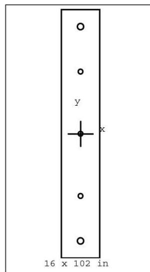
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:33:21



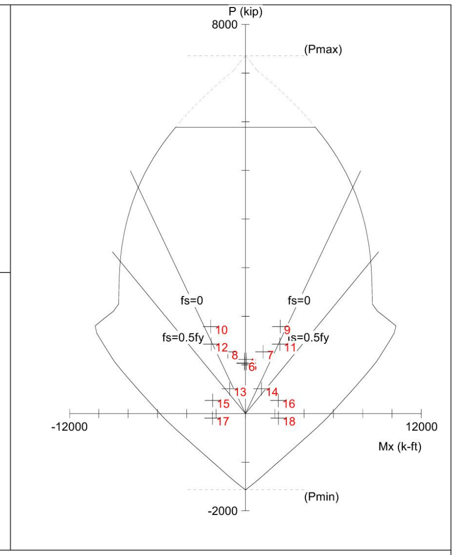
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P7 - 20.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 7 ksi	fy = 75 ksi	Ag = 1632 in^2	5 bars
Ec = 4769 ksi	Es = 29000 ksi	As = 23.28 in^2	Rho = 1.43%
fc = 5.95 ksi	fc = 5.95 ksi	Xo = 0.00 in	Ix = 1.41494e+006 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 34816 in^4
Beta1 = 0.7		Clear spacing = 16.02 in	Clear cover = 5.59 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



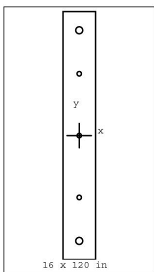
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:34:01



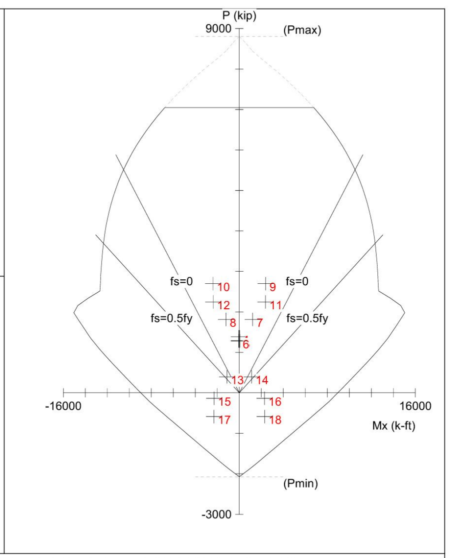
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P8 - 20.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 7 ksi	fy = 75 ksi	Ag = 1632 in^2	5 bars
Ec = 4769 ksi	Es = 29000 ksi	As = 23.28 in^2	Rho = 1.43%
fc = 5.95 ksi	fc = 5.95 ksi	Xo = 0.00 in	Ix = 1.41494e+006 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 34816 in^4
Beta1 = 0.7		Clear spacing = 16.02 in	Clear cover = 5.59 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



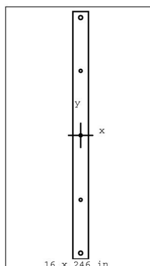
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:34:35



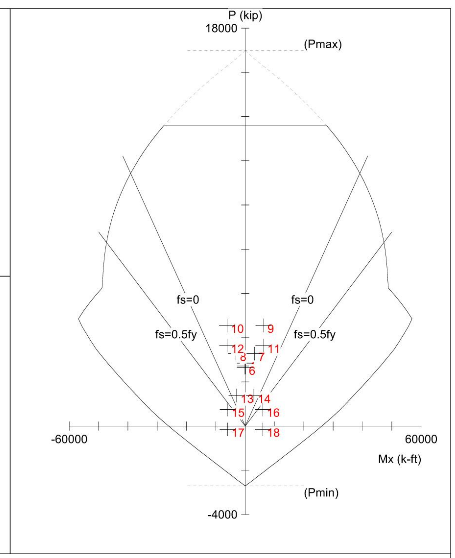
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P10 - 20.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 7 ksi	fy = 75 ksi	Ag = 1920 in^2	5 bars
Ec = 4769 ksi	Es = 29000 ksi	As = 30.72 in^2	Rho = 1.60%
fc = 5.95 ksi	fc = 5.95 ksi	Xo = 0.00 in	Ix = 2.304e+006 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 40960 in^4
Beta1 = 0.7		Clear spacing = 18.15 in	Clear cover = 6.27 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:35:09

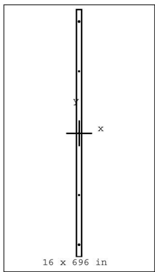


pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

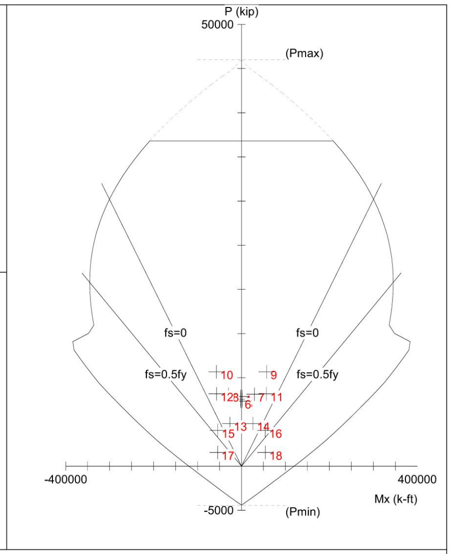
File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P11 - 20.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 7 ksi	fy = 60 ksi	Ag = 3936 in^2	5 bars
Ec = 4769 ksi	Es = 29000 ksi	As = 50.16 in^2	Rho = 1.27%
fc = 5.95 ksi	fc = 5.95 ksi	Xo = 0.00 in	Ix = 1.98492e+007 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 83968 in^4
Beta1 = 0.7		Clear spacing = 49.37 in	Clear cover = 4.01 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

Level 20, Page 1



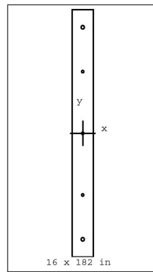
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:35:57



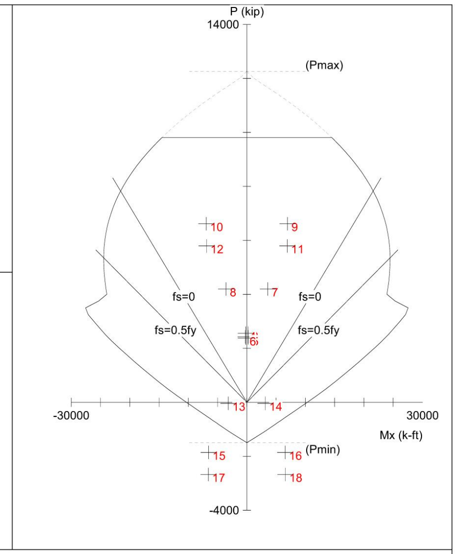
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P14 - 20.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 7 ksi	fy = 75 ksi	Ag = 11136 in^2	5 bars
Ec = 4769 ksi	Es = 29000 ksi	As = 65.52 in^2	Rho = 0.59%
fc = 5.95 ksi	fc = 5.95 ksi	Xo = 0.00 in	Ix = 4.49538e+008 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 237568 in^4
Beta1 = 0.7		Clear spacing = 135.86 in	Clear cover = 5.77 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



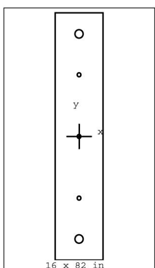
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:36:56



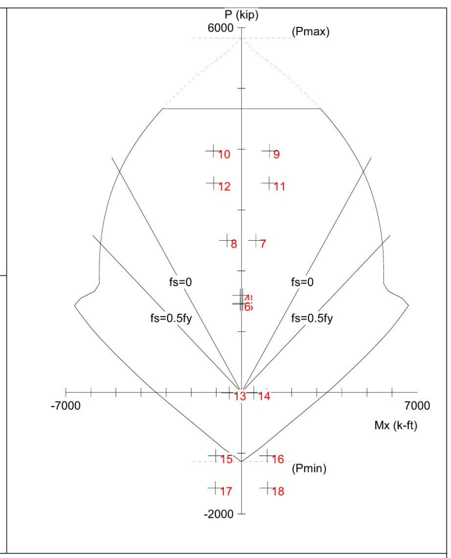
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P23 - 20.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 7 ksi	fy = 75 ksi	Ag = 2912 in^2	5 bars
Ec = 4769 ksi	Es = 29000 ksi	As = 22.17 in^2	Rho = 0.76%
fc = 5.95 ksi	fc = 5.95 ksi	Xo = 0.00 in	Ix = 8.03809e+006 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 62122.7 in^4
Beta1 = 0.7		Clear spacing = 30.08 in	Clear cover = 6.59 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



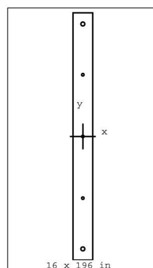
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:37:32



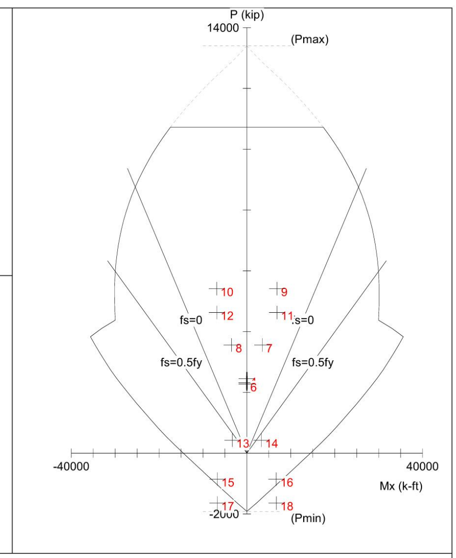
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P24 - 20.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 7 ksi	fy = 75 ksi	Ag = 1312 in^2	5 bars
Ec = 4769 ksi	Es = 29000 ksi	As = 16.89 in^2	Rho = 1.29%
fc = 5.95 ksi	fc = 5.95 ksi	Xo = 0.00 in	Ix = 735157 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27989.3 in^4
Beta1 = 0.7		Clear spacing = 11.41 in	Clear cover = 5.59 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:38:11

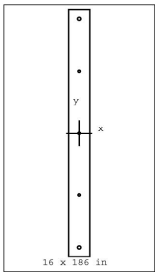


pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

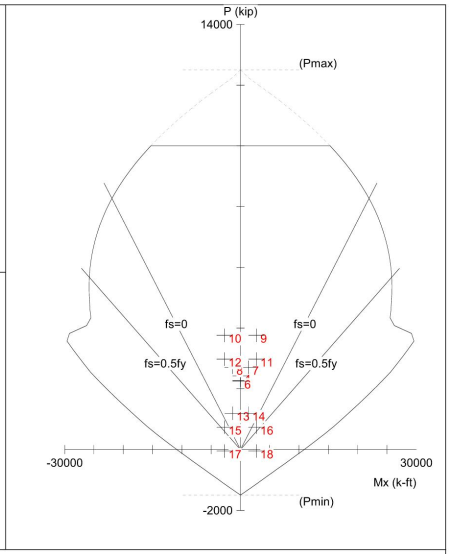
File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P25 - 20.col
Project: Tech 3
Column: P7 Engineer: SMR

f'c = 7 ksi	fy = 75 ksi	Ag = 3136 in^2	5 bars
Ec = 4769 ksi	Es = 29000 ksi	As = 28.41 in^2	Rho = 0.91%
fc = 5.95 ksi	fc = 5.95 ksi	Xo = 0.00 in	Ix = 1.00394e+007 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 66901.3 in^4
Beta1 = 0.7		Clear spacing = 37.26 in	Clear cover = 6.27 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

Level 20, Page 2



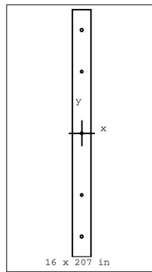
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:38:47



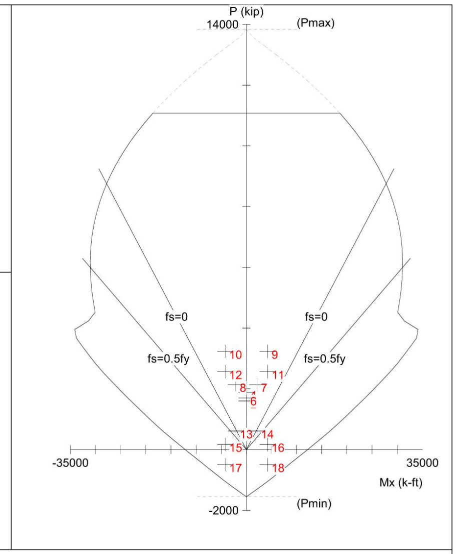
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P31 - 20.col
Project: Tech 3

Column: P7		Engineer: SMR	
f'c = 7 ksi	fy = 75 ksi	Ag = 2976 in^2	5 bars
Ec = 4769 ksi	Es = 29000 ksi	As = 22.16 in^2	Rho = 0.74%
fc = 5.95 ksi	fc = 5.95 ksi	Xo = 0.00 in	Ix = 8.57981e+006 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 63488 in^4
Beta1 = 0.7		Clear spacing = 37.08 in	Clear cover = 5.59 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



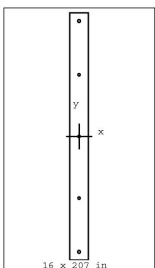
Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:39:22



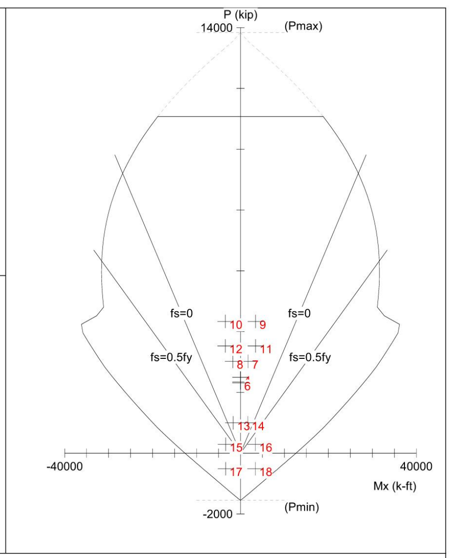
pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P32 - 20.col
Project: Tech 3

Column: P7		Engineer: SMR	
f'c = 7 ksi	fy = 75 ksi	Ag = 3312 in^2	5 bars
Ec = 4769 ksi	Es = 29000 ksi	As = 23.04 in^2	Rho = 0.70%
fc = 5.95 ksi	fc = 5.95 ksi	Xo = 0.00 in	Ix = 1.18263e+007 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 70656 in^4
Beta1 = 0.7		Clear spacing = 32.28 in	Clear cover = 6.59 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		



Code: ACI 318-02
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 12/02/07
Time: 17:39:54



pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-26188

File: C:\Users\Steve\Desktop\Thesis - Taj Mahal\Tech 3\PCA Column\P33 - 20.col
Project: Tech 3

Column: P7		Engineer: SMR	
f'c = 7 ksi	fy = 75 ksi	Ag = 3312 in^2	5 bars
Ec = 4769 ksi	Es = 29000 ksi	As = 23.04 in^2	Rho = 0.70%
fc = 5.95 ksi	fc = 5.95 ksi	Xo = 0.00 in	Ix = 1.18263e+007 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 70656 in^4
Beta1 = 0.7		Clear spacing = 42.28 in	Clear cover = 5.59 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

Level 20, Page 3