THE ODYSSEY
ARLINGTON, VA

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Structural Technical Report I

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Structural Concepts / Structural Existing Conditions Report

Executive Summary:

The Odyssey is a 475,650 SF luxury residential complex located in Arlington, Virginia. It features 2- 3 story townhouses adjacent to 3 levels of underground parking and towers clad with glass curtain walls and brick. There are 16 stories of apartments with suites located on the top floors and retail space on the ground floors. In this first technical report the existing structural conditions of the Odyssey are introduced through detailed descriptions of the foundation, floor, column, and lateral systems. A preliminary analysis of design loads and lateral forces are spot checked on a typical column and shear wall for discrepancies in design criteria. The analyses provide better understanding into loading and code assumptions made through ASCE7-02 provisions.

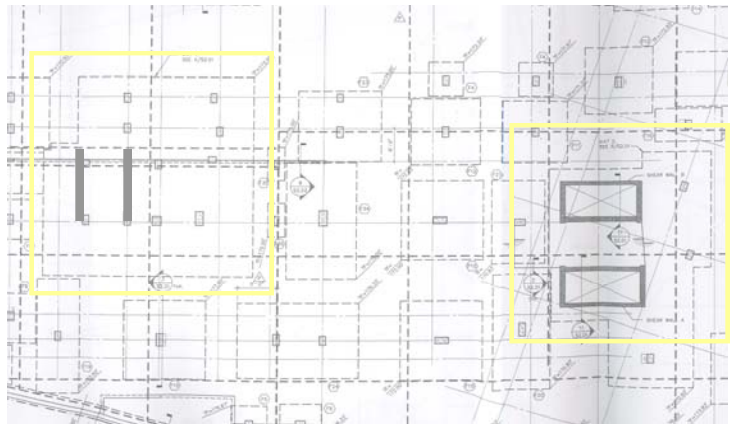
The wind analysis was carried out under ASCE7-02 section 6 with general building assumptions including disregarded façade curvature and overall rectangular dimensions. The preliminary analysis resulted in an unbalanced leeward to windward wind ratio which may be a result of the preliminary assumptions. A further detailed analysis is required to obtain a specific controlling wind direction and resulting loading envelope. A seismic analysis was carried out under the equivalent lateral force procedure specified in section 9 of ASCE7-02. All seismic factors were chosen through design parameters based upon the building characteristics and location. As a result of the analysis the controlling seismic direction is E-W with a base shear of 2045k.

Design checks upon both gravity and lateral systems were carried out to verify the accuracy of loading assumptions made through code provisions. The 2-way post-tensioned flat slab system was determined acceptable to resist slab moments from typical floor live and dead loads on a typical residential level of the Odyssey. Through the preliminary analysis the slab stresses resulting from post-tensioning maintained values within the ultimate stresses. A column located on the 1st level was spot checked to ensure the design reinforcement was adequate to resist accumulated gravity loads over the remaining levels. The loading on the column corresponded closely to given design column load of 2180k and the 12 -#11 bar reinforcement was found adequate up to 2340k. An analysis of the lateral systems will be addressed in the Lateral Systems Analysis and Confirmation Design report. Analysis calculations and observations are found in Appendices A - E as well as descriptive figures of preliminary structural design components and a typical floor plan.

Structural Systems:

Foundation

The primary foundation structures of the Odyssey are concrete footings of various rectangular sizes, depths, and reinforcement throughout the lower garage level footprint. Individual column footings are typical; however 54"deep mat footings distribute larger gravity loads and resist overturning from several integrated shear walls. The primary mat foundation spans over numerous columns which support shear walls beginning on the 1st floor of the building. A second mat footing resists the lateral overturning through core shear walls located around the central elevator shafts depicted in a partial foundation plan shown to the right. Continuous strip footings typically sized at 2'-0" x 1'-4" and support a perimeter bearing wall surrounding the lower garage levels.



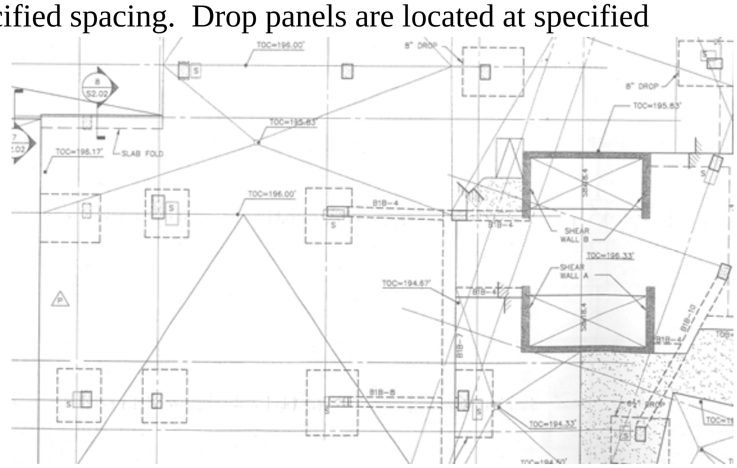
Floor Systems

The floor systems found throughout the Odyssey seemingly vary as much as the space usage in the building. Three distinct systems are noted in the following sections due to size, loading, and use of the supported space:

<u>Sub-Level Garage:</u>

The lower garage level (B3) is composed of 4" concrete slab (f'c=5ksi) on grade and reinforced with 6x6 – w1.4 x w1.4 wire mesh on 6mil vapor barrier over 6" compacted gravel with a capacity of 5,500psf.

The remaining lower garage levels through the first floor are primarily 8.5" conventionally reinforced 2-way concrete flat slabs with bottom reinforcement of #4 bars @ 13" o.c. Additional top and bottom reinforcement is specified as needed throughout the floor with varying bar sizes at specified spacing. Drop panels are located at specified columns and typically extend 4-1/2" below slab with several panels up to 6-1/4" to 8" below the slab. Also found on these floors are reinforced edge beams around larger spans for loading docks, mechanical spaces/shafts, and retail space located on both the upper garage and 1st floors. Typical bays sizes for the reinforced 2-way slab system are 25'x25' and 17'x25'.



<u>Tower:</u>

2nd – 15th

The Odyssey tower is primarily an 8" 2-way post tensioned flat concrete slab (f'c=5ksi) with continuous bottom reinforcement of #4 bars @ 24" o.c in each direction. Negative moment reinforcement of the slab at column junctions is typically #4 bars expanding $.33l_n$ in both span directions. Added reinforcement at slab openings in the long direction of specified bays is also typically #4 bars. Post tensioning tendons are 7 wire strands spanning columns and mid spans on a typical frame. Floor bays vary in size but 25'x 22' and 25'x 28' are typical with a variation on the 14th floor that has post tensioned beams integrated into the 2-way slab to support the rooftop swimming pool. *(See Appendix A for a typical floor plan of the 2nd – 15th levels of the Odyssey)*

16th & Roof

The roof and upper floor system of the western portion of the Odyssey's tower is similar to that of the lower floors, however reinforced concrete edge beams and interior post tensioned beams were included to properly support excess loads from mechanical equipment. Sizes and reinforcement vary between beams and post tension loading varies depending on span and location in the system. The east tower on the 16th level support the pool terrace and is a 11" 2-way post tensioned flat slab(f'c=5ksi) with #5 bars @ 24" o.c. each way and specified areas with added bottom reinforcement typically #5 and #6 bars. Typical floor bay sizes vary with 25'x 22' and 25'x 28' most common throughout these levels.

Townhouses

Townhouses which span the length of the site on the east are built integrally with the lower garage levels but do not share the same floor system. The system is 8.5" one-way concrete slab conventionally reinforced with #4 bar @ 13" o.c. and built-in reinforced edge beams typically 24"x18" and 26"x16" with #6 and #11 reinforcement. Two floor bay sizes are split between the townhouses with 23'x 30' and 19'x 30' spanning the edge beams. The townhouse roof system is also split over the row with the typical one-way concrete slab or cantilevered 12" metal C-joists @ 24" o.c. with metal soffit.

Columns:

Structural columns of the Odyssey are primarily a simple concrete structure with varied sizes, shapes, and reinforcement dependent on level and location throughout the building. The columns found in the tower of the Odyssey, levels 1-16, support the floor systems and are typically sized at 18"x 26" with #11 bar reinforcement. Round columns are found at the corners of the tower with primarily architectural design influences to not detract from symmetric corner windows with conventional rectangular columns integrated into apartment walls.

The columns located in the lower garage through 1st levels, and partially on 2nd and 3rd levels, serve a dual purpose in the structural design of the Odyssey. Rotated columns are oriented differently at floor slabs, typically rotating 90° from underside to the top side of the floor slab. These columns support the floor systems and are an architectural design to better fit apartment spaces.

Sloping columns are oriented differently from face to face of the slab on the same level. The purpose of these sloping columns is to effectively transmit lateral loads from shear walls and the building edge into the foundation. A further look into the integrated functioning of sloping column and foundation in regard to lateral distribution and moment may provide better analysis of the structures behavior. Both types of columns vary in size with a range in sizes from 18"x 26" to 26" x 42" with #11 bar reinforcement.

Column concrete strengths vary by level to resist accumulated gravity loads:

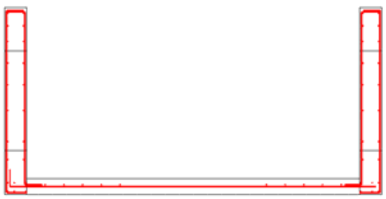
Levels B3-B1	: f'c = 6000psi	Levels 1-4	: f'c = 8000psi
Levels 5	: f'c = 6000psi	Levels 6-16	: f'c = 5000psi

Lateral System:

The lateral resisting systems of the Odyssey are groupings of shear walls placed throughout the floor plan integrated with slab frames. Locations on the exterior wings provide single lateral direction bracing while those at the core provide resistance in both primary directions. The shear walls are depicted below in simplified plans with a generalized description of each wall. *(See Appendix-A for a typical floor plan and shear wall distribution)*

Shear wall A:

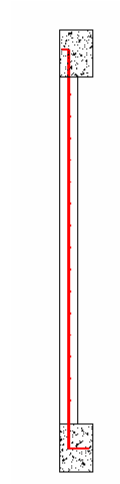
Resists both lateral load directions: North-South & East-West.
Location: Surrounds 2 central-north elevator shafts
Range: B3 - 4th level
Size: North-South walls - 1'-2" x 10'
Integrated into columns - 14"x 28"
Column Reinforcement – 6 #9 bars
East-West wall – 10"x17'-10"
Wall Reinforcement: #5 & #6 bars @ 12"



Shear wall B:

Resists both lateral load directions: North-South & East-West.
Location: Surrounds 2 central-south elevator shafts
Range: B3 - 4th level
Size: North-South walls - 1'-2" x 10'
Integrated into columns - 14"x 28"
Column Reinforcement – 6 #9 bars
East-West wall – 10"x17'-0"
Wall Reinforcement: #5 & #6 bars @ 12"

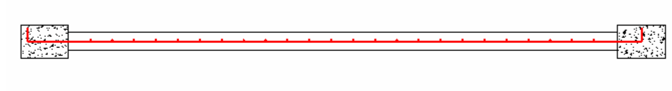
Shear wall C , C1:



Resists lateral load directions: North-South
Location: Surrounding West stair tower.
Range: 1st - 16th level
C1 terminates at 10th level
Size: North-South walls - 10"x 13'-10.5"
Ends attached to columns – 18"x 26" and 24"x 24"
Column Reinforcement – (varies) #11 bars
Wall Reinforcement: #5 & #6 bars @ 12"

Shear wall E:

Resists lateral load directions: North West-South East
Location: Column line X4 - North side of East tower
Range: 1st - 14th level
Size: North-South walls - 10"x 29'-5"
Ends attached to columns – 18"x 26"
Column Reinforcement – (varies) #11 bars
Wall Reinforcement: #5 & #6 bars @ 12"



Codes and Requirements:

The Odyssey is designed under:
The 1996 BOCA National Building Code
The 1996 Virginia Uniform Statewide Building Code with 2000 Amendments
Concrete construction in accordance with:
American Concrete Institute 318 – "Reinforced Concrete Design"
American Concrete Institute 301 – "Specification for Structural Concrete"
Building Officials and Code Administrators (BOCA) – Latest Edition
Steel construction in accordance with:
Building Officials and Code Administrators (BOCA)
American Institute of Steel Construction Manual – Allowable stress design (ASD)
Masonry construction in accordance with:
Building Officials and Code Administrators (BOCA)
"Building Code Requirements for Masonry Structures and Specifications for Masonry Structures" – ACI-530 / ACI-530.1
Material strength and details in accordance with:
ASTM Standards – Properties of Building Materials

Gravity and Lateral Loads:

The gravity and lateral loads for structural analysis were determined in accordance with ASCE7-02. General assumptions for several dead loads were made with interpretation of details and structural component averages. Load factors and adjustments are used when appropriate according to provisions of ASCE7-02 for the analysis of structural components and systems. A list of relevant gravity loads follow:

Gravity: (psf)

Floor Live:	
Residential Units & Corridors	40
Public Areas	100
Mech. Room	150
Pool Terrace	100
Parking Garage	50
Stairs and Exits	100
Roof Live:	
Min. Roof Live Load	30
Roof Snow:	
Roof Snow Load	21
Floor Dead:	
Concrete Slab	100 –150 (varied thickness 8”-12”)
Partitions	8
Flooring	4
Ceiling	5
Mechanical	10
Beams/Columns	(* varies)

Lateral:

A summary of lateral loads calculated in accordance with ASCE7-02 design provisions are presented in the following sections. Refer to Appendices B & C for further detailed procedure and analysis of calculations including generalized assumptions.

Wind: ASCE7-02 Section 6

Wind loads were determined for the Odyssey under the analytical procedure of Section 6, ASCE7-02. General assumptions for the preliminary analysis include simplifying the Odyssey’s irregular shape into a general rectangular dimension for accordance of shape limitations set forth by the analytical procedure. Analysis factors were determined through ASCE7-02 references and are detailed in the analysis located in Appendix-B. The factors are dependent on building location, characteristics, and predetermined factors outlined on the structural prints. Building rigidity of both wind loading directions were found to be rigid through generalized and detailed analysis of the fundamental period. *(The fundamental period calculation is found in Seismic Analysis section: Appendix C)*

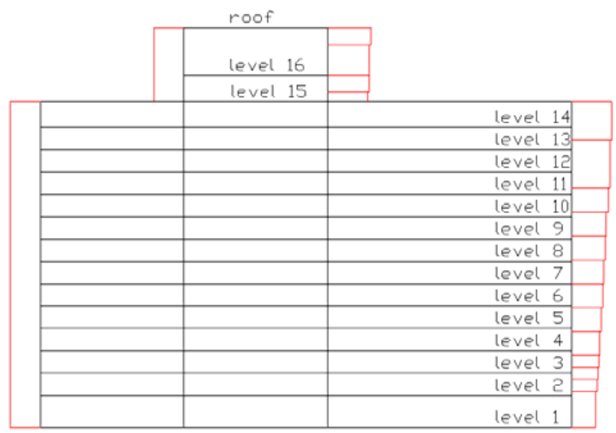
The windward pressures found through the analytical procedure are low by a comparison ratio to the leeward pressure. Discrepancies in procedure or calculation errors were unable to be found upon review of the analysis. Further investigation into wind loading will be dealt with in a later technical report regarding lateral design. The wind loading was determined not to control the lateral design of the Odyssey.

Wind Pressure Envelope

	Windward		Leeward		Total MWFRS	
Z(ft)	N-S	E-W	N-S	E-W	N-S	E-W
0-15	5.18	5.18	-6.50	-6.47	11.68	11.65
20	5.63	5.63	-6.50	-6.47	12.13	12.11
25	6.00	6.00	-6.50	-6.47	12.50	12.47
30	6.36	6.36	-6.50	-6.47	12.86	12.84
40	6.91	6.91	-6.50	-6.47	13.40	13.38
50	7.36	7.36	-6.50	-6.47	13.86	13.84
60	7.72	7.72	-6.50	-6.47	14.22	14.20
70	8.09	8.09	-6.50	-6.47	14.59	14.56
80	8.45	8.45	-6.50	-6.47	14.95	14.93
90	8.72	8.72	-6.50	-6.47	15.22	15.20
100	9.00	9.00	-6.50	-6.47	15.49	15.47
120	9.45	9.45	-6.50	-6.47	15.95	15.93
140	9.91	9.91	-6.50	-6.47	16.40	16.38
160	10.27	10.27	-6.50	-6.47	16.77	16.74
180	10.63	10.63	-6.50	-6.47	17.13	17.11
167	10.40	10.40	-6.50	-6.47	16.89	16.87

N-S Distribution

(Controlling direction)



Seismic: ASCE7-02 Section 9

Seismic loads were determined through the equivalent lateral force procedure outlined in Section 9 of ASCE7-02. All relevant factors and accelerations were found in figures and tables of section 9, which are outlined in the seismic analysis section located in Appendix C. Building and floor weights are based on assumptions of design dead loads according to load provisions of ASCE7-02.

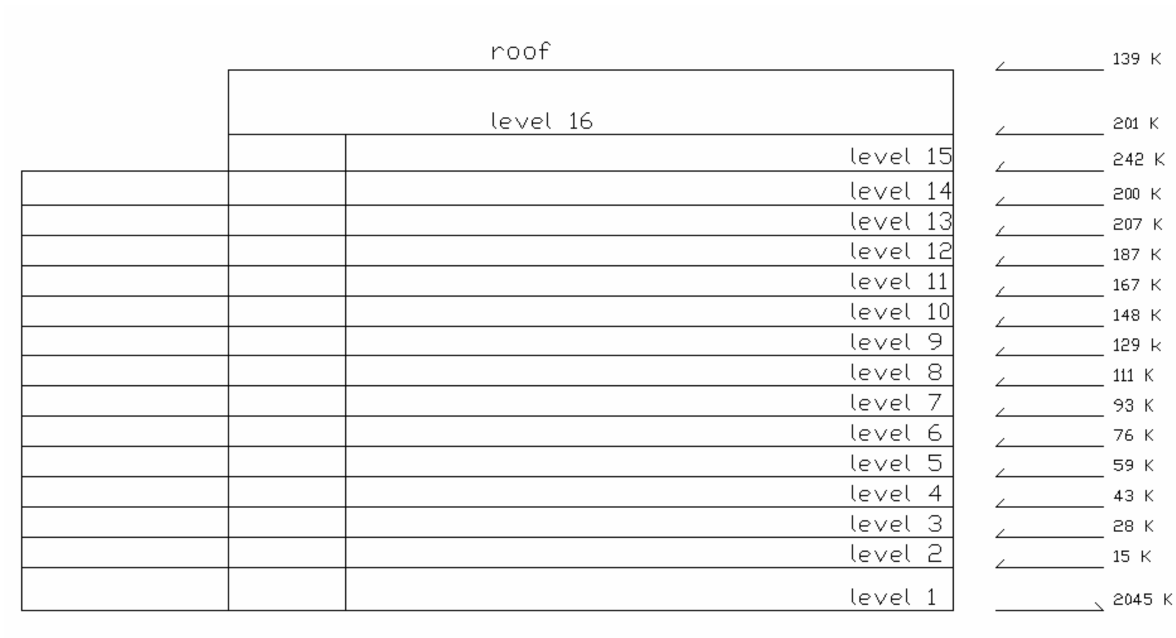
The base shear was 2045 kips in both loading directions with an overturning moment of 215347 ft-k. The base shear to building weight ratio is approximately 4%. The analysis results can be considered acceptable for a low seismic region.

Vertical Distribution of Seismic

(E-W)

					Load	Shear	Moment
E-W	w_x	h_x	$w_x h_x^k$	C_{vx}	F_x	V_x	M_x
Level, x	(kips)	(ft)			(kips)	(kips)	(ft-kips)
Roof	1507	163	732,728	0.068	139		22,730
16	2460	147.1	1,055,881	0.098	201	139	29,559
15	3253	136.1	1,270,351	0.118	242	340	32,904
14	2978	125.3	1,051,948	0.098	200	582	25,085
13	3379	116	1,086,958	0.101	207	782	23,996
12	3379	106.63	981,264	0.091	187	989	19,913
11	3379	97.3	877,986	0.082	167	1,176	16,258
10	3379	88	777,134	0.072	148	1,343	13,015
9	3379	78.64	677,920	0.063	129	1,491	10,146
8	3379	69.31	581,518	0.054	111	1,620	7,670
7	3379	60	488,065	0.045	93	1,731	5,573
6	3379	50.65	397,302	0.037	76	1,824	3,830
5	3379	41.32	310,263	0.029	59	1,899	2,440
4	3379	32	227,459	0.021	43	1,958	1,385
3	3379	22.66	149,573	0.014	28	2,001	645
2	3379	13.33	78,520	0.007	15	2,030	199
1						2,045	
	Σ = 50748		Σ = 10744870	Σ = 1.000	Σ = 2045		Σ = 215347

E-W Distribution



Preliminary Analysis / Spot Check Summary:

Gravity

Post-Tensioned 2-way Concrete Slab:

A preliminary structural analysis of a 8" 2-way post-tensioned concrete flat slab was carried out under generalized assumptions to better understand the design effects of post-tensioning reinforcement. A typical floor bay was determined to be 25'x 22' excluding the edge panel balcony sections. Slab moments were resolved for residential and corridor live loads with standard dead loads for typical residential levels. Slab moments and calculations can be referenced in Appendix D. Standard top and bottom slab reinforcement of #4 bars was analyzed for resisting the slab moments and was inadequate in mid span and support strips. As a result, post tensioning is required through the slab to maintain an 8" depth with minimal #4 bar reinforcement. The designed 7 wire strand reinforcing tendons are tensioned to 509k in the long frame direction over columns, and 1300k in the short direction through the mid span. The post tensioning analysis was carried out by calculating the slab stresses at both service and initial loading stages and then compared to the ultimate slab stresses. The post tensioning design was adequate to resist the slab moments with resulting stress calculations maintained within initial and service stresses. *(Details of calculations and findings of the post tensioned slab analysis are found in Appendix E)*

Column:

The structural spot check was carried out with a typical 18"x26" column on the 1st level of the Odyssey. The column has a tributary area of 625 S.F. and is located at the intersection of column lines F & 7.5. Gravity loads of the remaining levels were calculated to the column including typical floor and roof loads. The axial load resolved on the column was 2162k, which is reasonable for design assumptions of building loads compared to the actual 2180k on the column. The CRSI Design Handbook was used to reference the adequate column reinforcement for a 18"x26" column with design strength of f'c = 8ksi. The given reinforcement of 12 - #11 bars is capable of carrying a design load of 2340k. The typical reinforcement design size in columns throughout the building is determined adequate by spot check requirements for loading assumptions and provisions of ASCE7-02.

Lateral

Shear Wall:

Due to the complexity of the lateral systems, the analysis and spot check of the shear walls will be addressed in the Lateral Systems Analysis and Confirmation Design report.

Conclusions/Summary:

The Odyssey is a multifaceted building including underground parking, retail stores, and 15 levels of residential apartments/condominiums. The existing gravity structural system is 2-way post tensioned flat slab for residential levels and 2-way flat slab with drop panels for the parking levels. The lateral systems are shear walls located at the building core and on the exterior wings integrated with slab frames composed of the concrete columns and 2-way flat slab floor system. Lateral loads were determined in accordance with provisions and design procedures of ASCE7-02 and it was found that seismic loads control the Odyssey's lateral design.

Design checks upon both gravity and lateral systems were carried out to verify the accuracy of loading assumptions made through code provisions. The 2-way post-tensioned flat slab system was determined acceptable to resist slab moments from typical floor live and dead loads on a typical residential level of the Odyssey. Through the preliminary analysis the slab stresses resulting from post-tensioning maintained values within the ultimate stresses. A column located on the 1st level was spot checked to ensure the design reinforcement was adequate to resist accumulated gravity loads over the remaining levels. The loading on the column corresponded closely to given design column load of 2180k and the 12 -#11 bar reinforcement was found adequate up to 2340k. An analysis of the lateral systems will be addressed in the Lateral Systems Analysis and Confirmation Design report. Analysis calculations and observations are found in Appendices A - E as well as descriptive figures of preliminary structural design components and a typical floor plan.

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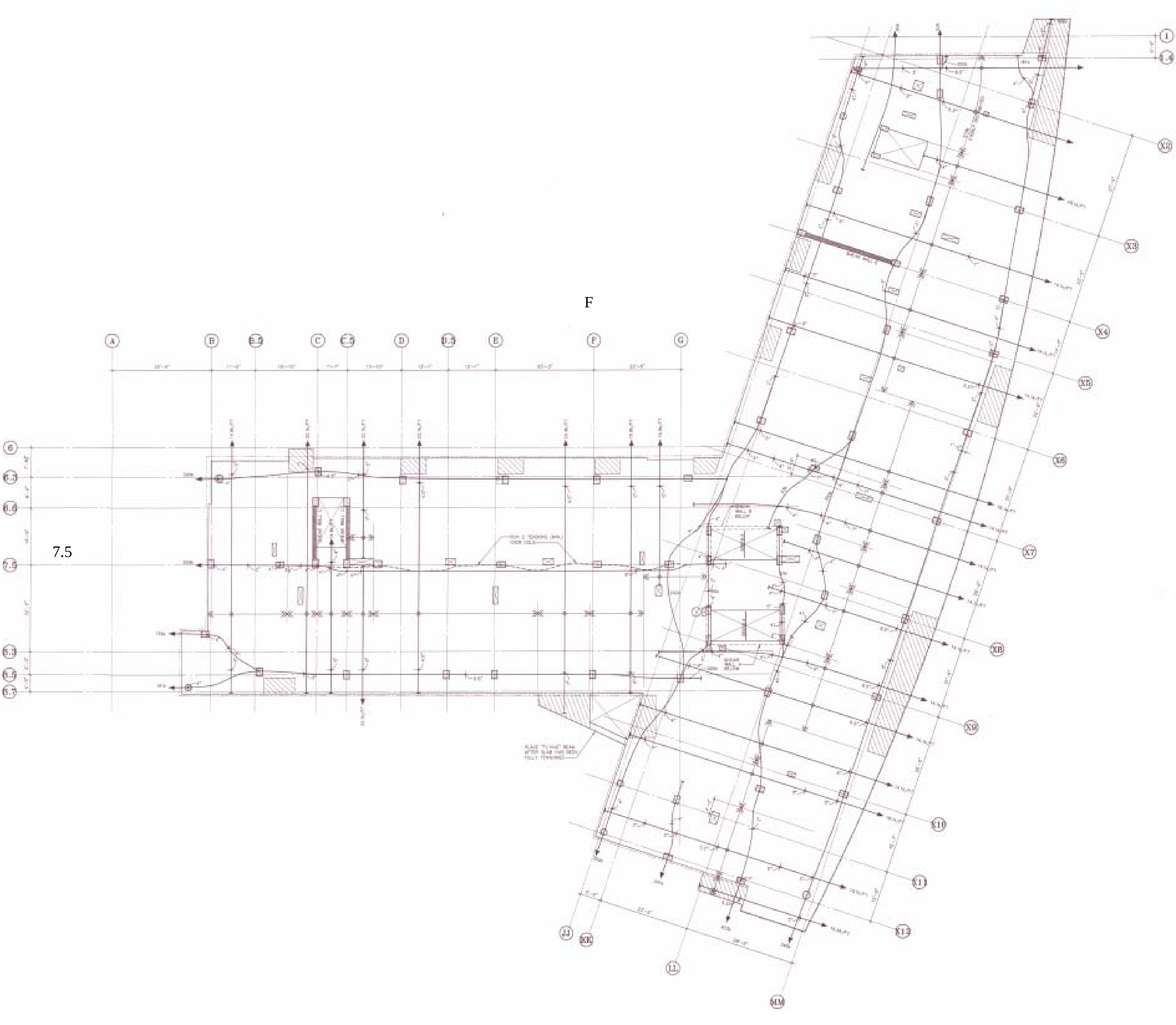
Appendix

References:

CRSI Design Handbook 2002

ASCE7-02 Design Code

Appendix – A FLOOR PLAN



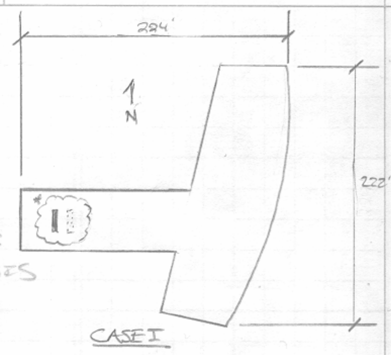
Appendix – B WIND ANALYSIS

* NOTE: WIND LOADING CASE I ASSUMED FOR PRELIMINARY ANALYSIS OF SHEARWALLS (C)

BUILDING DESCRIPTION:

LOCATION: ARLINGTON, VA.
MWFRS: N-S : SHEARWALLS
E-W : SHEARWALLS
OCCUPANCY: CATEGORY II

* PRELIMINARY DESIGN ANALYSIS ASSUMPTIONS:
  - ASSUME GENERAL SHAPE FOR ANALYSIS
  - DISREGARD CURVED FACADE.



BUILDING DESIGN PROPERTIES:

BASIC WIND SPEED: V = 80 MPH — 6.5.4

WIND DIRECTIONALITY FACTOR: $K_d = 0.85$ — 6.5.4.4
- BUILDINGS; MAIN WIND FORCE RESISTING SYSTEM — TABLE 6-4

IMPORTANCE FACTOR: I = 1.0 — 6.5.5
- CONSTRUCTION SET SPECS.

EXPOSURE CATEGORY: EXPOSURE B — 6.5.6
- URBAN AND SUBURBAN AREAS (SURFACE ROUGHNESS) — 6.5.6.2
- UPWIND CONDITION UNCHANGED (EXPOSURE CATS) — 6.5.6.3

VELOCITY PRESSURE EXPOSURE COEFFICIENT K_z, K_h — 6.5.6.6
EXPOSURE B
- a) ALL MWFRS IN BUILDINGS — CASE 2: IGNORE TORSION — TABLE 6-3
- b) ALL MWFRS IN OTHER SYSTEMS

K_z, K_h

EXPOSURE: B	
$H_{t}(z)$	CASE 2
0-15	0.57
20	0.62
25	0.66
30	0.70
40	0.76
50	0.81
60	0.85
70	0.89
80	0.93
90	0.96
100	0.99
120	1.04
140	1.09
160	1.13
180	1.17

TERRAIN EXPOSURE CONSTANTS — 6.5.6, TABLE 6-2

EXPOSURE	α	z_g	$\hat{a}$	$\hat{b}$	$\bar{\alpha}$	c	ℓ	$\bar{\epsilon}$	z_{min} *
B	7.0	1200	1/7	0.84	1/4.0	0.30	320	1/3.0	100.2

* $z_{min} = 0.6h > z_{min} = 30'$

TOPOGRAPHIC FACTOR: $K_{zt} = 1.0$ — 6.7.7.2
- ASSUME FLAT: SLOPE INSIGNIFICANT → 6.5.7.1

$K_{zt} = (1 + K_1 K_2 K_3)^2$ — FIG 6-4

GUST EFFECT FACTOR — 6.5.8
* RIGID STRUCTURES $n_1 \geq 1.0$ — 6.5.8.1

B = 224' h = 167'

$L_{\bar{z}} = \ell(\bar{z}/33)^{\bar{\epsilon}} = 463.38$ — EQ. 6-7

$$Q = \left[\frac{1}{1 + 0.63\left(\frac{B+h}{L_{\bar{z}}}\right)^{0.63}}\right]^{1/2} = 0.8$$ — EQ. 6-6

$I_{\bar{z}} = c(33/\bar{z})^{1/6} = 0.25$ — EQ. 6-5

$$G_f = 0.925\left[\frac{(1 + 1.7 g_Q I_{\bar{z}} Q)}{1 + 1.7 g_v I_{\bar{z}}}\right] = 0.8157$$ — EQ 6-4

OR

$\rightarrow g_v, g_Q = 3.4$ $= 0.85$

* RIGIDITY
$C_t = 0.02$
$h = 167'$
$x = 0.75$
$T_a = [C_t h^x]^{-1}$
$f_n = 1.07 \geq 1.0$

* SEE SHEARWALL RIGIDITY
$f_n \geq 1.0$

ENCLOSURE CLASSIFICATION → ENCLOSED — 6.5.9

VELOCITY PRESSURE $q_z = 13.9264 K_z$

$q_z = 0.00256 K_z K_{zt} K_d V^2 I$ (lb/ft²) Eq-6-15

$q_h = \left(\frac{167-160}{180-160}\right)(1.17-1.13)(13.9264) + 13.9264(1.13) = 15.932$

Ht (z)	q_z (lb/ft²)
0-15	7.94
20	8.63
25	9.19
30	9.75
40	10.58
50	11.28
60	11.84
70	12.39
80	12.59
90	13.37
100	13.79
120	14.48
140	15.18
160	15.74
180	16.29

ENCLOSURE CLASSIFICATION GCp: 6.5.11.1

ENCLOSED BUILDING +0.18 FIG 6-5
-0.18

EXTERNAL PRESSURE COEFFICIENTS 6.5.11.2

WINDWARD → (L/B) = ALL VALUES TABLE 6-6
$C_p = 0.8$

LEEWARD → (L/B) = 1.0
$C_p = -0.5$

DESIGN WIND LOAD 6.5.12.2

MAIN WIND FORCE-RESISTING SYSTEMS

- RIGID BUILDINGS 6.5.12.2.1

$P_z = qGC_p -$ ~~$q_i(GC_{pi})$~~ (lb/ft²) Eq. 6-17

WINDWARD

$P_w = q_z G C_p$

LEEWARD

$P_l = q_h G C_p$

	Windward		Leeward		Total MWFRS	
Z(ft)	N-S	E-W	N-S	E-W	N-S	E-W
0-15	5.18	5.18	-6.50	-6.47	11.68	11.65
20	5.63	5.63	-6.50	-6.47	12.13	12.11
25	6.00	6.00	-6.50	-6.47	12.50	12.47
30	6.36	6.36	-6.50	-6.47	12.86	12.84
40	6.91	6.91	-6.50	-6.47	13.40	13.38
50	7.36	7.36	-6.50	-6.47	13.86	13.84
60	7.72	7.72	-6.50	-6.47	14.22	14.20
70	8.09	8.09	-6.50	-6.47	14.59	14.56
80	8.45	8.45	-6.50	-6.47	14.95	14.93
90	8.72	8.72	-6.50	-6.47	15.22	15.20
100	9.00	9.00	-6.50	-6.47	15.49	15.47
120	9.45	9.45	-6.50	-6.47	15.95	15.93
140	9.91	9.91	-6.50	-6.47	16.40	16.38
160	10.27	10.27	-6.50	-6.47	16.77	16.74
180	10.63	10.63	-6.50	-6.47	17.13	17.11
167	10.40	10.40	-6.50	-6.47	16.89	16.87

WIND SHEAR ON LEVEL

NOTE: SIMPLIFIED ASSUMPTIONS TAKEN FOR DISTRIBUTION OVER EACH LEVEL.
- LEVEL HEIGHTS TAKEN AS TRIBUTARY HT/LEVEL
- WIND LOAD DISTRIBUTION TAKEN AS AVERAGE OVER LEVEL.

Vertical Distribution of Wind Forces

Wind Loading (N-S)

Level	Story Height (ft.)	Elevation (ft.)	Tributary Height (ft.)	Tributary Width (ft.)	Tributary Area (ft²)	Wind Load (psf)	Wind Load (k)	Shear (k)	Moment (ft - k)
Roof	4	162.95	12	183	2196	16.8	37	37	-
16	16	146.95	13.5	183	2471	16.5	41	78	590.3
15	11	135.95	10.83	183	1982	16.3	32	110	1444.5
14	10.66	125.29	9.995	224	2239	16	36	146	2616.7
13	9.33	115.96	9.33	224	2090	15.5	32	178	3976.8
12	9.33	106.63	9.33	224	2090	15.5	32	211	5639.2
11	9.33	97.30	9.33	224	2090	15.4	32	243	7603.8
10	9.33	87.97	9.33	224	2090	15.2	32	275	9868.8
9	9.33	78.64	9.33	224	2090	14.9	31	306	12430.0
8	9.33	69.31	9.33	224	2090	14.6	31	336	15281.9
7	9.33	59.98	9.33	224	2090	14.2	30	366	18418.4
6	9.33	50.65	9.33	224	2090	13.9	29	395	21831.8
5	9.33	41.32	9.33	224	2090	13.6	28	423	25516.2
4	9.33	31.99	9.33	224	2090	13	27	450	29465.8
3	9.33	22.66	9.33	224	2090	12.5	26	477	33668.9
2	9.33	13.33	11.33	224	2538	11.7	30	506	38115.8
1	13.33	0.00	6.665	224	1493	-	-	-	44864.9

Vertical Distribution of Wind Forces

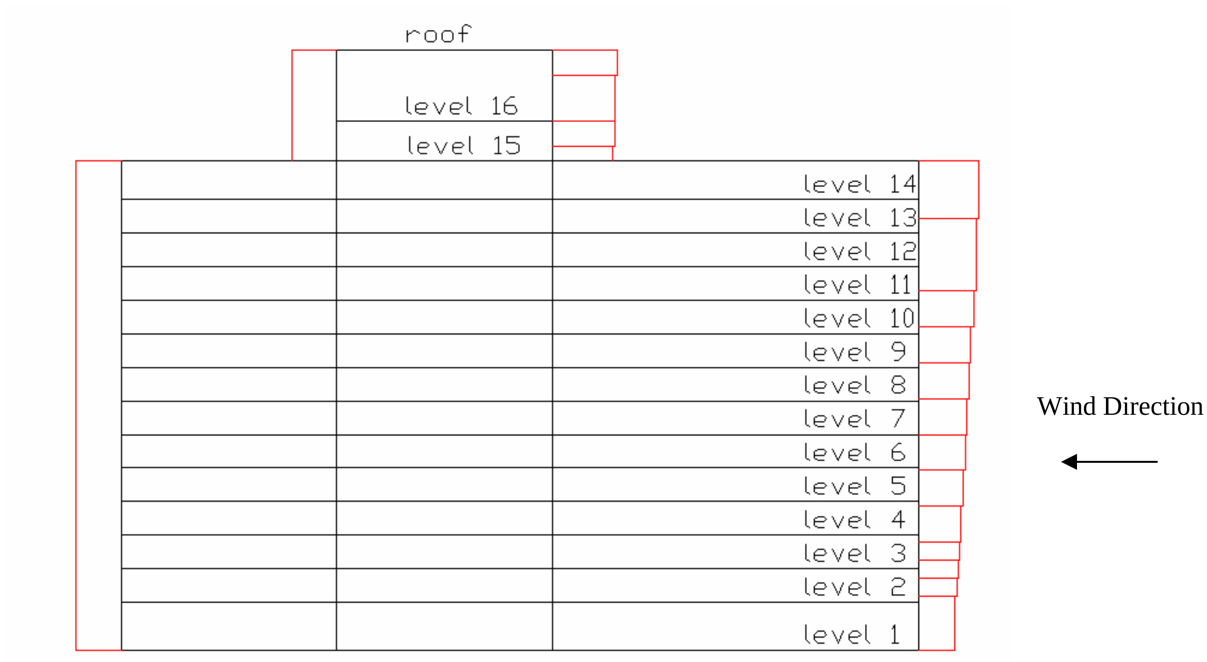
N-S Level, x	Wind Load Fx (k)	Shear Vx (k)	Moment Mx (ft - k)
Roof	37	37	-
16	41	78	590
15	32	110	1445
14	36	146	2617
13	32	178	3977
12	32	211	5639
11	32	243	7604
10	32	275	9869
9	31	306	12430
8	31	336	15282
7	30	366	18418
6	29	395	21832
5	28	423	25516
4	27	450	29466
3	26	477	33669
2	30	506	38116
1	-	-	44865
			Σ = 271333.8

Wind Loading (E-W)

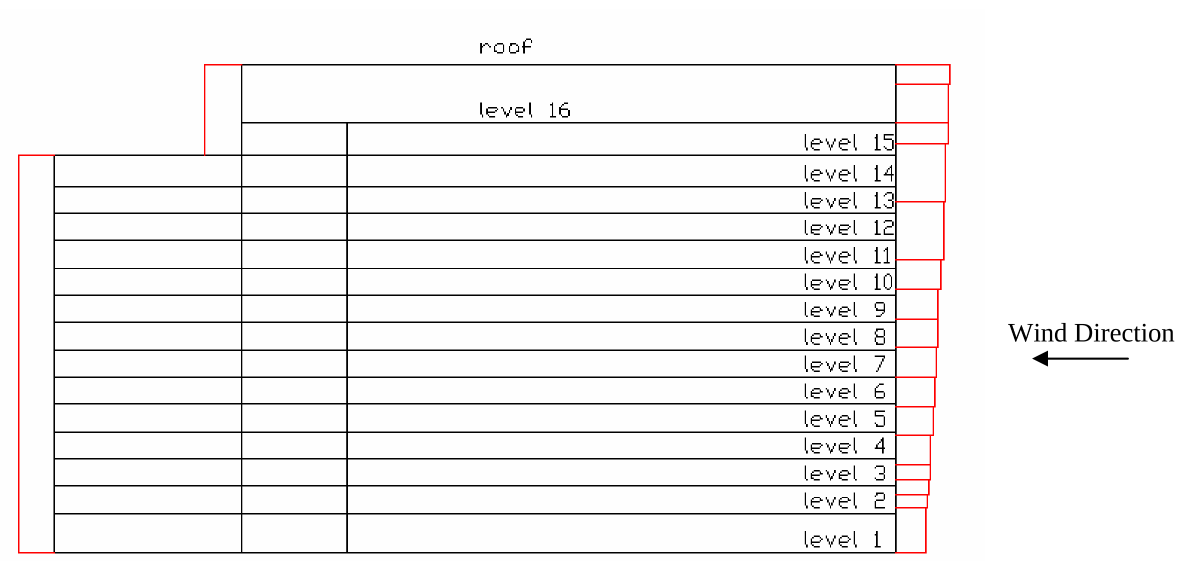
Level	Story Height (ft.)	Elevation (ft.)	Tributary Height (ft.)	Tributary Width (ft.)	Tributary Area (ft²)	Wind Load (psf)	Wind Load (k)	Shear (k)	Moment (ft - k)
Roof	4	162.95	12	62	744	16.5	12	12	-
16	16	146.95	13.5	62	837	16.3	14	26	196.4
15	11	135.95	10.83	62	671	16.1	11	37	481.5
14	10.66	125.29	9.995	222	2219	15.8	35	72	873.1
13	9.33	115.96	9.33	222	2071	15.3	32	103	1542.8
12	9.33	106.63	9.33	222	2071	15.2	31	135	2508.3
11	9.33	97.30	9.33	222	2071	15.1	31	166	3767.5
10	9.33	87.97	9.33	222	2071	14.9	31	197	5318.5
9	9.33	78.64	9.33	222	2071	14.7	30	228	7157.4
8	9.33	69.31	9.33	222	2071	14.3	30	257	9280.4
7	9.33	59.98	9.33	222	2071	14	29	286	11679.8
6	9.33	50.65	9.33	222	2071	13.7	28	315	14349.7
5	9.33	41.32	9.33	222	2071	13.3	28	342	17284.4
4	9.33	31.99	9.33	222	2071	12.8	27	369	20476.0
3	9.33	22.66	9.33	222	2071	12.3	25	394	23915.1
2	9.33	13.33	11.33	222	2515	11.4	29	423	27591.8
1	13.33	0.00	6.665	222	1480	-	-	-	33227.1

E-W Level, x	Wind Load Fx (k)	Shear Vx (k)	Moment Mx (ft - k)
Roof	12	12	-
16	14	26	196
15	11	37	482
14	35	72	873
13	32	103	1543
12	31	135	2508
11	31	166	3767
10	31	197	5318
9	30	228	7157
8	30	257	9280
7	29	286	11680
6	28	315	14350
5	28	342	17284
4	27	369	20476
3	25	394	23915
2	29	423	27592
1	-	-	33227
			Σ = 179649.8

N-S Distribution



E-W Distribution



Appendix – C SEISMIC ANALYSIS

EQUIVALENT LATERAL FORCE PROCEDURE — ASCE7-02 SECT. 9

SEISMIC DESIGN PARAMETERS

LOCATION:	ARLINGTON, VA.	
# OF STORIES:	$N = 16$	
INTER STORY Ht:	h_s = VARIES → 9'-4" (TYP)	
BUILDING Ht:	$h_n = 167'$	
SEISMIC USE GROUP:	I	TABLE 9.1.3
OCCUPANCY IMPORTANCE:	1.0	TABLE 9.1.4
SITE CLASSIFICATION:	A	9.4.1.2
ACCELERATIONS:		
0.2s →	$S_s = 0.19$ g-s	FIG. 9.4.1.1(a)
1.0s →	$S_1 = 0.06$ g-s	FIG. 9.4.1.1(b)
SITE CLASS FACTOR:	$F_a = 0.80$	TABLE 9.4.1.2a
SITE CLASS FACTOR:	$F_v = 0.80$	TABLE 9.4.1.2b
ADJUSTED ACCELERATIONS: (MAXIMUM)	$S_{MS} = F_a S_s$ → 0.148 g-s	9.4.1.2.4-1
	$S_{M1} = F_v S_1$ → 0.050 g-s	9.4.1.2.4-2
DESIGN SPECTRAL RESPONSE ACCELERATIONS	$S_{DS} = \frac{2}{3} S_{MS}$ → 0.099 g-s	9.4.1.2.5-1
	$S_{D1} = \frac{2}{3} S_{D1}$ → 0.033 g-s	9.4.1.2.5-2
SEISMIC DESIGN CATEGORY	A	9.4.2.1a/b
RESPONSE MODIFICATION	$R = 3$	TABLE 9.5.2.2
DEFLECTION MODIFICATION	$C_d = 5$	
ALLOWABLE STORY DRIFT	$\Delta_a = 0.02 h_{sx}$	TABLE 9.5.2.8
FUNDAMENTAL PERIOD		9.5.5.3.2
SHEAR WALLS		EQ 9.5.5.3.2-2
		EQ 9.5.5.3.2-3

$$T_a = \frac{0.0019}{\sqrt{C_W}} h_n$$

$$C_W = \frac{100}{A_B} \sum_{i=1}^{n} \left(\frac{h_n}{h_i}\right)^2 \frac{A_i}{\left[1 + 0.83\left(\frac{h_i}{D_i}\right)^2\right]}$$

VERTICAL DISTRIBUTION OF SEISMIC FORCES

$$F_x = C_{vx} V \quad \text{EQ. 9.5.5.4-1}$$

$$C_{vx} = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k} \quad \text{EQ 9.5.5.4-2}$$

OVERTURNING

$$M_x = \sum_{i=1}^{n} F_i (h_i - h_x) \quad \text{EQ 9.5.5.6}$$

Design Parameters

Location:	Arlington, Virginia			
Number of Stories:	N =	16		
Inner Story Height:	hs =	varies - 9'4" typ.		
Building Height:	hn =	167		
Seismic Use Group:	1		Table:	9.1.3
Occupancy Importance:	I =	1.0	Table:	9.1.4
Site Classification:	A			9.4.1.2
Accelerations:				
0.2 s	Ss =	0.19	Figure:	9.4.1.1(a)
1.0 s	S1 =	0.06	Figure:	9.4.1.1(b)
Site Class Factor:	Fa =	0.8	Table:	9.4.1.2(a)
	Fv =	0.8	Table:	9.4.1.2(b)
Adjusted Accelerations:	Sms =	0.152		9.4.1.2.4-1
(max.)	Sm1 =	0.048		9.4.1.2.4-2
Design Spectral Response	S_{DS} =	0.101		9.4.1.2.5-1
Accelerations:	S_{D1} =	0.032		9.4.1.2.5-2
Seismic Design Category:		A		9.4.2.1(a/b)
Response Modification:	R =	3	Table:	9.5.2.2
Deflection Modification:	Cd =	5		

Fundamental Period

	A_B	22000
11	hn	167.000

N-S

Shearwalls	A	B	C	E
t	1.167	1.167	0.833	-
Di	10.000	10.000	13.875	-
A_i	11.670	11.670	11.563	-
h	32.000	32.000	147.000	-
$\Sigma_{9.5.5.3.2\text{-}3}$	66.919	66.919	0.158	-

Cw	0.609
Ta	0.407

E-W

Shearwalls	A	B	C	E
t	0.800	0.800	-	0.800
Di	20.167	19.330	-	29.417
A_i	16.134	15.464	-	23.533
h	32.000	32.000	-	125.300
$\Sigma_{9.5.5.3.2\text{-}3}$	142.213	128.615	-	2.603

Cw	1.243
Ta	0.285

ROOF: MAIN ROOF   AREA: 6100 SF (ROUGH TAKE OFF)
DEAD: PERIMETER: 502 FT (ROUGH TAKE OFF)

GRAVEL : 12 PSF
RIGID INSULATION: 0.75 PSF
MEMBRANE : 1 PSF
CONCRETE : 100 PSF (BASED ON 8" CONCRETE SLAB)
CONCRETE BEAMS: 63 PSF (ASSUMED AVG. SIZE: $W_{AVG.} = 1^{KLF}$
* PSF BASED OFF CUM. LENGTH OF BEAMS OVER AVG. FLOOR AREA.)
1/2" GYP. CEILING: 5 PSF
MEP : 10 PSF
TOTAL q roof : 191.75 PSF

ROOF: 15th LEVEL - POOL TERRACE   AREA: 10000 SF (EXCLUDING POOL)
DEAD   PERIMETER: 515 FT

TILE PAVERS: 15 PSF
MEMBRANE : 1 PSF
CONCRETE : 112.5 PSF (BASED ON AVG.(t) [VARIES FROM 8" & 11"])
1/2" GYP CEILING: 5 PSF
MEP : 10 PSF
TOTAL q'roof : 143.5 PSF

FLOOR: 16th LEVEL   AREA 9700 SF (ROUGH TAKE OFF)
DEAD   PERIMETER: 502 ft (ROUGH TAKE OFF)

FLOORING: 4 PSF
MECH YARD/PARTITIONS: 8 PSF
CONCRETE SLAB: 150 PSF (BASED ON 12" CONCRETE SLAB)
CONCRETE BEAMS : 30 PSF
1/2" GYP CEILING: 5 PSF
MEP 10 PSF

LIVE:
PUBLIC AREA: 100 PSF (STRUCTURAL SET)
TOTAL q 16th 307 psf

FLOOR: 15th LEVEL   AREA: 9700 SF (ROUGH TAKE-OFF)
DEAD: PERIMETER: 502 FT (ROUGH TAKE-OFF)

FLOORING: 4 PSF
PARTITIONS: 8 PSF
CONCRETE SLAB: 112.5 (BASED ON AVG(t) [VARIES FROM 8" & 11"])
1/2" GYP CEILING: 5 PSF
MEP 10 PSF

LIVE:
APARTMENT & CORRIDOR: 40 PSF
TOTAL q 15th 179.5 psf

REMAINING FLOORS: (1-14) LEVELS   AREA: 22,000 PSF *(AVG.)
PERIMETER: 850 FT. *(ROUGH TAKEOFF)

DEAD:

FLOORING: 4 PSF
CONCRETE SLAB: 100 PSF (BASED ON 8"(4 SLAB)
PARTITIONS: 8 PSF
1/2 GYP CEILING: 5 PSF
MEP: 10 PSF

LIVE:

APT & CORRIDOR: 40 psf (STRUCTURAL SET)
TOTAL q_{floor} 167 psf

PERIMETER WALL:

DEAD:

EXTERIOR WALL: q_{wall}: 56.0 psf (STUD/BRICK VENEER/WINDOW SYSTEM)

SNOW LOAD:

SNOW: q_{snow}: 4.2 psf (20% OF FLAT ROOF LOAD)

Weight of Floor (w_x) and Total Weight (W)

	Area (SF)	Perimeter (ft)	Total q (PSF)	Weight (w_x) (Kips)	
Main Roof	6100	502	191.75	1507.019	
Roof: Level 15	10000	515	143.5	1588.7172	
Floor: Level 16	9711	502	207	2459.969	
Floor: Level 15	9711	502	139.5	1663.9165	
Level 14	19453	850	127	2977.947	w/floor 2-13
Levels 2-13	23111	850	127	35665.272	3379.205
Level 1	18476	850	127	-	
			W = Σ w =	45862.8407	

q_{wall} (PSF)
56

exp. K
k; .5 ≤ Ta ≤ 2.5
1.21

E-W

Base Shear (Kips)	Cs (Ta, E-W)
V = Cs * W	0.037
2044.871	
	Cs
	0.034

N-S

Base Shear (Kips)	Cs (Ta, N-S)
V = Cs * W	0.026
2044.871	

Level	hs (ft)
1	13.33
2 - 13	9.33
14	10.66
15	11
16	16
Roof	4

Cs (Min.)	Cs (Ta -.02)	Ta - (.02)
0.045	0.036	0.93

Vertical Distribution of Seismic Forces

N-S	w_x	h_x	$w_x h_x^k$	C_{vx}	Load F_x	Shear V_x	Moment M_x
Level, x	(kips)	(ft)			(kips)	(kips)	(ft-kips)
Roof	1507	163	732,728	0.068	139		22,730
16	2460	147.1	1,055,881	0.098	201	139	29,559
15	3253	136.1	1,270,351	0.118	242	340	32,904
14	2978	125.3	1,051,948	0.098	200	582	25,085
13	3379	116	1,086,958	0.101	207	782	23,996
12	3379	106.63	981,264	0.091	187	989	19,913
11	3379	97.3	877,986	0.082	167	1,176	16,258
10	3379	88	777,134	0.072	148	1,343	13,015
9	3379	78.64	677,920	0.063	129	1,491	10,146
8	3379	69.31	581,518	0.054	111	1,620	7,670
7	3379	60	488,065	0.045	93	1,731	5,573
6	3379	50.65	397,302	0.037	76	1,824	3,830
5	3379	41.32	310,263	0.029	59	1,899	2,440
4	3379	32	227,459	0.021	43	1,958	1,385
3	3379	22.66	149,573	0.014	28	2,001	645
2	3379	13.33	78,520	0.007	15	2,030	199
1						2,045	
	Σ = 50748		Σ = 10744870	Σ = 1.000	Σ = 2045		Σ = 215347

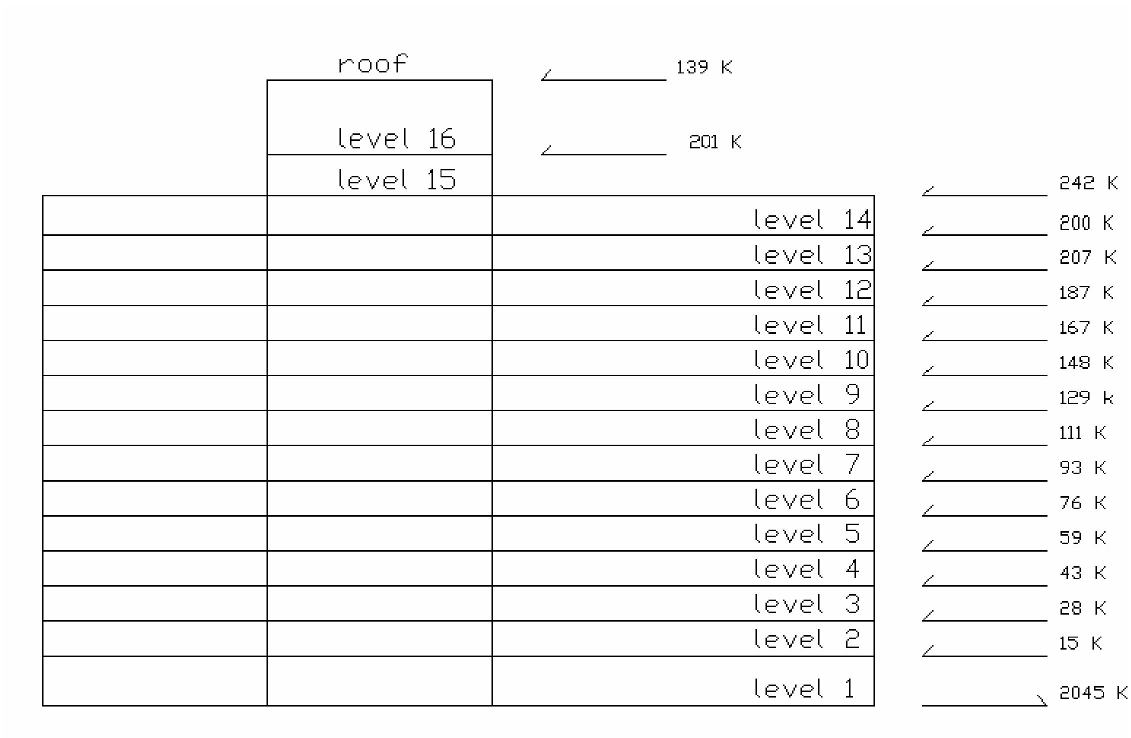
Vertical Distribution of Seismic Forces

N-S	Load Fx	Shear Vx	Moment Mx
Level, x	(kips)	(kips)	(ft-kips)
Roof	139	0	22,730
16	201	139	29,559
15	242	340	32,904
14	200	582	25,085
13	207	782	23,996
12	187	989	19,913
11	167	1176	16,258
10	148	1343	13,015
9	129	1491	10,146
8	111	1620	7,670
7	93	1731	5,573
6	76	1824	3,830
5	59	1899	2,440
4	43	1958	1,385
3	28	2001	645
2	15	2030	199
1	-	2045	-
			Σ = 215347

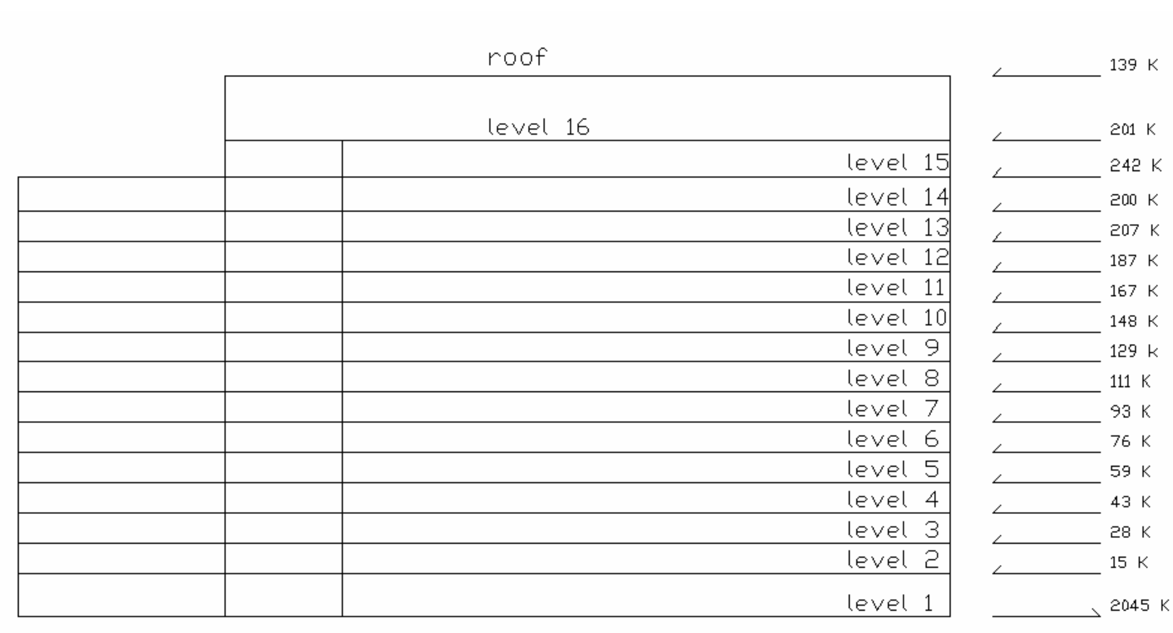
E-W	w_x	h_x	$w_x h_x^k$	C_{vx}	Load F_x	Shear V_x	Moment M_x
Level, x	(kips)	(ft)			(kips)	(kips)	(ft-kips)
Roof	1507	163	732,728	0.068	139		22,730
16	2460	147.1	1,055,881	0.098	201	139	29,559
15	3253	136.1	1,270,351	0.118	242	340	32,904
14	2978	125.3	1,051,948	0.098	200	582	25,085
13	3379	116	1,086,958	0.101	207	782	23,996
12	3379	106.63	981,264	0.091	187	989	19,913
11	3379	97.3	877,986	0.082	167	1,176	16,258
10	3379	88	777,134	0.072	148	1,343	13,015
9	3379	78.64	677,920	0.063	129	1,491	10,146
8	3379	69.31	581,518	0.054	111	1,620	7,670
7	3379	60	488,065	0.045	93	1,731	5,573
6	3379	50.65	397,302	0.037	76	1,824	3,830
5	3379	41.32	310,263	0.029	59	1,899	2,440
4	3379	32	227,459	0.021	43	1,958	1,385
3	3379	22.66	149,573	0.014	28	2,001	645
2	3379	13.33	78,520	0.007	15	2,030	199
1						2,045	
	Σ = 50748		Σ = 10744870	Σ = 1.000	Σ = 2045		Σ = 215347

E-W	Load Fx	Shear Vx	Moment Mx
Level, x	(kips)	(kips)	(ft-kips)
Roof	139	0	22,730
16	201	139	29,559
15	242	340	32,904
14	200	582	25,085
13	207	782	23,996
12	187	989	19,913
11	167	1176	16,258
10	148	1343	13,015
9	129	1491	10,146
8	111	1620	7,670
7	93	1731	5,573
6	76	1824	3,830
5	59	1899	2,440
4	43	1958	1,385
3	28	2001	645
2	15	2030	199
1	-	2045	-
			Σ = 215347

N-S Distribution



E-W Distribution



Appendix – D SNOW LOAD

ASCE7-02
SECT 7

ROOF SNOW LOAD

GROUND SNOW LOAD:	$P_g = 30$ PSF	7.2
THERMAL FACTOR:	$C_t = 1.0$	7.3.2
SNOW EXPOSURE FACTOR:	$C_e = 0.7$	7.3.1
IMPORTANCE FACTOR: * CATEGORY: II	$I = 1.00$	7.3.3
FLAT ROOF SNOW LOADS: $P_f = 0.7 C_e C_t I p_g$	$P_f = 14.7$ psf	7.3

* STRUCTURAL SET DESIGNED: $P_f = 21$ psf

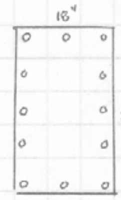
* ASSUME DESIGN ANALYSIS ASCE7-02 DIFFERS FROM CODE ANALYSIS PER BOCA 1996

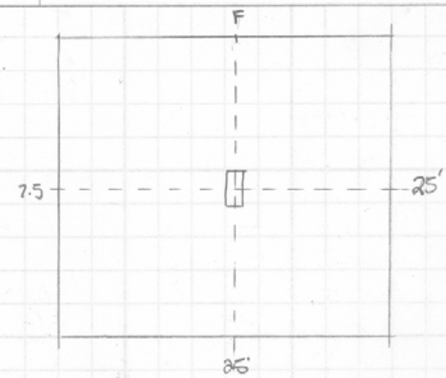
* USE $P_f = 21$ PSF FOR ACCURATE STRUCTURAL ANALYSIS.

Appendix – E GRAVITY LOAD CHECK

COLUMN:

LOCATION: 1ST LEVEL (F/7.5)
SIZE: 18" x 26"
f'_c: 8 KSI
REBAR: 12 #11
f_y: 60 KSI
P: 2180K





LOADS:

ROOF LEVEL: DEAD

DEAD		LIVE	
8" CONC SLAB	100	ROOF	30
BEAMS	25	MECH	150
COVER	5		180
MEP	10		
	140		

16th LEVEL: DEAD

DEAD		LIVE	
12" CONC SLAB	150	PUBLIC	100
PARTITIONS	8	CORRIDOR	40
CLG/FLR	9		140
MEP	10		
(16') COLUMN	15		
	192		

15th LEVEL: DEAD

DEAD		LIVE	
8" CONC SLAB	100	CORRIDOR	40
PARTITIONS	8		40
CLG/FLR	9		
MEP	10		
(11') COLUMN	10		
	137		

2ND – 14th LEVEL: DEAD

DEAD		LIVE	
8" CONC. SLAB	100	CORRIDOR	40
PARTITIONS	8		40
CLG/FLR	9		
MEP	10		
(9') COLUMN	7		
	134		

COLUMN LOAD:

$W_n = 1.2D + 1.6L = 3460$ PSF

$P_n = W_n \times A_T = 3460 \text{ PSF} \times (25' \times 25')$

$P_n = 2162^K \rightarrow 2180^K$ (ACTUAL) OK

CRSI DESIGN HANDBOOK 2002

RECTANGULAR COLUMNS: 18" x 26"
12 - #11 REINFORCEMENT
$\phi P = 2340^K > P_n$ OK

RECTANGULAR TIED COLUMNS 18″ × 26″

Short columns – no sidesway

Bending on major or minor axis

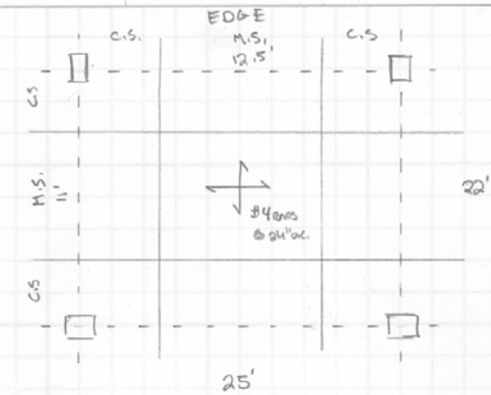
MI / MA

f'_c = 8,000 psi f_y = 60,000 psi

ϕM in inch-kips ϕP in kips

BARS	RHO	AXIS	Max Cap		0% fy		25% fy		50% fy		100% fy		$.1f'_c$ Ag		Zero Axial Load
			ϕM	ϕP	ϕM	ϕP	ϕM	ϕP	ϕM	ϕP	ϕM	ϕP	ϕM	ϕP	ϕM
10-#11	3.33	MA	5714	2247	9436	1599	10307	1339	10852	1113	11632	749	10082	374	9068
3L - 4S		MI	3793	2247	6133	1546	6499	1278	6684	1065	6931	708	6131	374	5771
10-#10	2.71	MA	5448	2160	8627	1576	9294	1314	9626	1102	10006	776	8601	374	7512
4L - 3S		MI	3743	2160	6169	1488	6576	1248	6791	1043	7052	716	5902	374	4936
10-#11	3.33	MA	5610	2247	8979	1625	9714	1348	10124	1121	10684	767	9507	374	8953
4L - 3S		MI	3840	2247	6420	1526	6871	1275	7140	1056	7524	700	6441	374	5876
10-#14	4.81	MA	6018	2452	9811	1760	10756	1446	11383	1181	12411	759	11522	374	11987
4L - 3S		MI	4095	2452	7030	1644	7634	1364	8064	1108	8755	674	7800	374	8115
10-#10	2.71	MA	5299	2160	8311	1586	8873	1323	9099	1121	9227	780	8028	374	7170
5L - 2S		MI	3844	2160	6476	1463	6969	1233	7271	1030	7706	707	6196	374	4914
10-#11	3.33	MA	5432	2247	8595	1636	9203	1372	9486	1143	9740	771	8765	374	8426
5L - 2S		MI	3958	2247	6786	1521	7340	1258	7712	1042	8302	691	6849	374	5853
10-#14	4.81	MA	5768	2452	9263	1775	10027	1480	10473	1212	11065	762	10520	374	11363
5L - 2S		MI	4257	2452	7546	1638	8295	1341	8870	1089	9846	663	8509	374	8109
12-#10	3.26	MA	5753	2236	9600	1602	10420	1328	11003	1115	11845	754	10190	374	8974
3L - 5S		MI	3740	2236	6034	1558	6390	1301	6554	1078	6715	716	5980	374	5607
12-#10	3.26	MA	5664	2236	9123	1623	9930	1348	10402	1122	11062	770	9694	374	8937
4E		MI	3828	2236	6237	1553	6659	1285	6890	1065	7210	719	6336	374	5825
12-#11	4.00	MA	5868	2340	9577	1683	10481	1390	11059	1146	11956	760	10824	374	10599
4E		MI	3944	2340	6498	1604	6968	1319	7256	1081	7709	701	6899	374	6761
12-#10	3.26	MA	5517	2236	8807	1633	9509	1356	9875	1141	10283	774	9114	374	8558
5L - 3S		MI	3871	2236	6476	1535	6969	1282	7271	1064	7706	710	6561	374	5835
12-#11	4.00	MA	5693	2340	9193	1694	9970	1414	10421	1168	11013	763	10072	374	10102
5L - 3S		MI	3991	2340	6786	1584	7340	1317	7712	1081	8302	692	7221	374	6943
12-#14	5.77	MA	6136	2587	10114	1859	11117	1540	11803	1248	12875	752	12374	374	13716
5L - 3S		MI	4306	2587	7546	1728	8295	1424	8870	1144	9846	662	8899	374	9598
12-#10	3.26	MA	5410	2236	8491	1639	9090	1377	9354	1148	9582	790	8584	374	8306
6L - 2S		MI	3970	2236	6783	1530	7363	1267	7751	1050	8359	701	6875	374	5818
12-#11	4.00	MA	5565	2340	8819	1702	9462	1423	9789	1175	10163	781	9380	374	9628
6L - 2S		MI	4107	2340	7152	1579	7808	1300	8284	1067	9080	684	7657	374	6926
14-#10	3.80	MA	5879	2312	9619	1671	10666	1382	11178	1143	12117	764	10787	374	10361
4L - 5S		MI	3868	2312	6340	1606	6783	1335	7034	1098	7369	710	6642	374	6460
14-#10	3.80	MA	5734	2312	9303	1680	10145	1390	10651	1162	11338	768	10199	374	9950
5L - 4S		MI	3956	2312	6544	1600	7053	1319	7370	1085	7864	713	6988	374	6662
14-#11	4.67	MA	5951	2433	9792	1752	10737	1456	11356	1193	12286	756	11379	374	11783
5L - 4S		MI	4094	2433	6864	1662	7437	1361	7828	1106	8487	693	7670	374	7760
14-#10	3.80	MA	5630	2312	8987	1686	9726	1411	10130	1169	10637	784	9663	374	9703
6L - 3S		MI	3998	2312	6783	1583	7363	1316	7751	1084	8359	704	7221	374	6729
14-#11	4.67	MA	5828	2433	9417	1760	10228	1465	10724	1201	11436	774	10679	374	11288
6L - 3S		MI	4141	2433	7152	1642	7808	1359	8284	1107	9080	685	8005	374	8004
14-#10	3.80	MA	5522	2312	8631	1703	9318	1417	9632	1188	9954	800	9093	374	9224
7L - 2S		MI	4096	2312	7090	1577	7756	1301	8231	1071	9012	695	7553	374	6717
16-#10	4.34	MA	5949	2388	9799	1728	10781	1424	11427	1182	12394	762	11284	374	11346
5E		MI	3996	2388	6647	1653	7177	1368	7514	1119	8022	704	7305	374	7316
16-#10	4.34	MA	5847	2388	9463	1734	10362	1445	10906	1189	11693	778	10743	374	11062
6L - 4S		MI	4083	2388	6851	1647	7446	1353	7850	1108	8517	707	7642	374	7504
16-#11	5.33	MA	6088	2526	10015	1818	10995	1506	11659	1226	12709	767	11979	374	12953
6L - 4S		MI	4245	2526	7230	1721	7906	1403	8400	1131	9265	686	8444	374	8765
16-#10	4.34	MA	5741	2388	9127	1751	9954	1451	10407	1208	11010	794	10168	374	10618
7L - 3S		MI	4125	2388	7090	1630	7756	1350	8231	1105	9012	698	7884	374	7622
18-#10	4.88	MA	6064	2463	9980	1781	10998	1479	11681	1210	12749	772	11822	374	12465
6L - 5S		MI	4124	2463	6954	1700	7570	1402	7994	1140	8675	698	7970	374	8175
18-#10	4.88	MA	5958	2463	9623	1798	10590	1485	11183	1229	12065	788	11242	374	12015
7L - 4S		MI	4210	2463	7158	1695	7840	1387	8330	1126	9170	701	8297	374	8350
20-#10	5.43	MA	6174	2539	10119	1845	11226	1519	11959	1250	13121	782	12316	374	13415
7L - 5S		MI	4251	2539	7261	1747	7964	1436	8474	1160	9328	692	8637	374	9037

CONCRETE SLAB:



DESCRIPTION:

SLAB: 2-WAY $t_s = 8''$

$f'_c = 5^{ksi}$

REINFORCMENT: #4 @ 24" o.c (BOTH WAYS)

10-#4 @ COLUMNS

$f_y = 60^{ksi}$

COLUMN: 18"x20"

$f'_c = 5^{ksi}$

LOADING:

DEAD: (PSF)		LIVE: (PSF)	
SLAB	100	CORRIDOR & RESIDENTIAL	40
PARTITION	8		
CLG/FLR	9		
MEP	10		
	127		

$W_U = 1.2D + 1.6L$

$= 1.2(127) + 1.6(40)$

$W_U = 216.4$ PSF

MINIMUM REINFORCMENT: $A_{min} = 0.0018 A_g$ @ 2'-0"

$A = 0.0018 \times (24''/1) \times (8'') = 0.3456 \text{ in}^2$

#4 @ 24" o.c. BOTH WAYS $\rightarrow A_s = 0.4 \text{ in}^2$

INTERIOR PANEL

STATIC MOMENT:

$$M_0 = \frac{W_U l_2 l_n^2}{8} = \frac{(216.4)(22')(22.833)^2}{8} = 310.3 \text{ ft-k}$$

LOCATION	STRIP	TOTAL M_U	STRIP WIDTH	M_U/ft OF WIDTH
SUPPORT	C.S. 75%	151.3 ft-k	11'	13.75 ft-k/ft
0.65 M_U	M.S. 25%	50.4 ft-k	11'	4.6 ft-k/ft
MIDSPAN	C.S. 60%	65.2 ft-k	11'	6 ft-k/ft
0.35 M_0	M.S. 40%	43.4 ft-k	11'	4 ft-k/ft

BOTTOM: #4 @ 40" o.c

MIDSPAN: CHECK REINFORCMENT #4 @ 24" o.c. A_s .15 in²/ft

$a = \frac{A_s f_y}{0.85 f'_c b'} = \frac{(0.15)(60)}{0.85(5)(12''/1)} = 0.1765''$ $d = 8'' - 0.75 - .5 - .25 = 6.5''$

$\phi M_n = \phi A_s f_y (d - a/2) = 0.9(0.15)(60)(6.5 - \frac{0.1765}{2})(1/12'') = 4.3 \frac{ft\text{-}k}{ft} < 6$

TOP:

SUPPORT: CHECK REINFORCMENT #4 @ 24" o.c $A_s = .1$ in²/ft

$a = \frac{(0.1)(60)}{0.85(5)(12)} = 0.11765''$

$\phi M_n = 0.9(0.1)(60)(6.5 - \frac{.11765}{2})(1/12) = 2.9 \frac{k\text{-}ft}{ft} <$

POST TENSIONING REQ'D IN SLAB.

EXTERIOR PANEL

STATIC MOMENT

$$M_o = \frac{(216.4)(25)(20.5)^2}{8} = 284.2^{ft\text{-}k}$$

LOCATION	STRIP	TOTAL M_o	STRIP WIDTH	M_u/ft OF WIDTH
INT SUPPORT	C.S. 70%	139.3	12.5'	11.1
0.70 M_o	M.S 30%	59.7	12.5'	4.8
MIDSPAN	C.S 60%	88.7	12.5'	7.1
0.52 M_o	M.S 40%	59.1	12.5'	4.73
EXT SUPPORT	C.S. 100%	73.9	12.5'	5.9
0.26 M_o	M.S. 0%	0	12.5'	0

MIDSPAN: CHECK REINFORCEMENT #4@24" O.C. $A_s = .1$, $d = 6.5''$

$$a = \frac{(0.1)(60)}{0.85(5)(12'')} = 0.11765$$

$$\phi M_n = 0.9(0.1)(60)(6.5 - \frac{.11765}{2})(1/12) = 2.9 \frac{ft\text{-}k}{ft}$$

EXT SUPPORT: CHECK REINFORCEMENT #4 @ 36" O.C. $A_s = .067$, $d = 6.5''$

$$a = \frac{(0.067)(60)}{0.85(5)(12'')} = .078$$

$$\phi M_n = 0.9(0.067)(60)(6.5 - \frac{.078}{2})(1/12) = 1.95 \frac{ft\text{-}k}{ft}$$

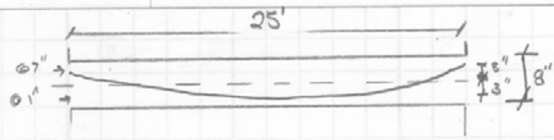
INT SUPPORT: CHECK REINFORCEMENT #4@24" O.C $A_s = .1$, $d = 6.5$

$$a = \frac{(0.1)(60)}{0.85(5)(12)} = 0.11705$$

$$\phi M_n = 0.9(0.1)(60)(6.5 - \frac{.11705}{2})(1/12) = 2.9 \frac{k\text{-}ft}{ft}$$

POST-TENSIONING REQUIRED IN SLAB.

INTERIOR PANEL: (C.S.)
POST TENSIONING.



LOADING: MAX SERVICE $W_U = 167^{PSF}$ INITIAL $W_U = 100$ PSF

MOMENTS:

$M_0 = \frac{W_U l_2 l_n^2}{8} =$ MAX SERVICE: $239.4^{ft\text{-}k}$ INITIAL: $143.4^{ft\text{-}k}$

		MAX	INITIAL
SUPPORT C.S.	$M_U = (0.65)(0.75)M_0$	$1400.5^{in\text{-}k}$	$839^{in\text{-}k}$
MIDSPAN C.S.	$M_U = (0.35)(0.60)M_0$	$603.3^{in\text{-}k}$	$361.4^{in\text{-}k}$

COMPRESSION: $P_i = 509^K$ $\eta = .85$
$P_{ci} = 432.6^K$

SECTION PROPERTIES:
$S = \frac{bd^2}{6} = \frac{(11' \times 12")(8")^2}{6} = 1408\ in^3$
$A = 1056\ in^2$

STRESSES $f'_c = 5^{ksi}$ $f'_{ci} = 3^{ksi}$

$\bar{\sigma}_{cs} = .6f'_c = 3^{ksi}$ $\bar{\sigma}_{ts} = -7.5\sqrt{f'_c} = -.53^{ksi}$ $\bar{\sigma}_{ci} = .6f'_{ci} = 1.8^{ksi}$

$\bar{\sigma}_{ti} = -3\sqrt{f'_{ci}} = -.16^{ksi}$

STRESS CHECK

SUPPORT C.S. - SERVICE

$\sigma_{TOP} = -\frac{432.6^K}{1056\ in^2} + \frac{(432.6^K)(3")}{1408\ in^3} - \frac{1400^{in\text{-}k}}{1408\ in^3} = -.48^{ksi} > \bar{\sigma}_{ts}$ ok

$\bar{\sigma}_{BOT} = -\frac{432.6^K}{1056\ in^2} - \frac{(432.6^K)(3")}{1408\ in^3} + \frac{1400^{in\text{-}k}}{1408\ in^3} = -.33^{ksi} < \bar{\sigma}_{cs}$ ok

MIDSPAN C.S. SERVICE.

$\sigma_{TOP} = \frac{432.6^K}{1056\ in^2} - \frac{(432.6^K)(3")}{1408\ in^3} + \frac{603.6^{in\text{-}k}}{1408\ in^3} = -.08^{ksi} < \bar{\sigma}_{cs}$ ok

$\bar{\sigma}_{BOT} = \frac{432.6^K}{1056\ in^2} + \frac{(432.0^K)(3")}{1408\ in^3} - \frac{603.6^{in\text{-}k}}{1408\ in^3} = .9^{ksi} > \bar{\sigma}_{ts}$ ok

SUPPORT C.S. - INITIAL

$\sigma_{TOP} = -\frac{509^K}{1056\ in^2} + \frac{(509^K)(3")}{1408\ in^3} - \frac{839^{in\text{-}k}}{1408\ in^3} = .006^{ksi} > \bar{\sigma}_{ti}$ ok

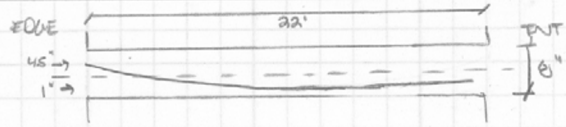
$\sigma_{BOT} = -\frac{509^K}{1056\ in^2} - \frac{(509^K)(3")}{1408\ in^3} + \frac{839^{in\text{-}k}}{1408\ in^3} = -.97^{ksi} < \bar{\sigma}_{ci}$ OK

MIDSPAN C.S. - INITIAL

$\sigma_{TOP} = \frac{509^K}{1056\ in^2} - \frac{(509^K)(3")}{1408\ in^3} + \frac{361.4^{in\text{-}k}}{1408\ in^3} = -.346^{ksi} < \bar{\sigma}_{ci}$ OK

$\sigma_{BOT} = \frac{509^K}{1056\ in^3} + \frac{(509^K)(3")}{1408\ in^3} - \frac{361.4^{in\text{-}k}}{1408\ in^3} = 1.3^{ksi} > \sigma_{ti}$ ok

EXTERIOR PANEL (M.S)
POST TENSIONING



LOADING: MAX SERVICE $w_u = 167$ psf   INITIAL $w_u = 100$ psf

MOMENTS:

$M_o = \frac{w_u l_2 l_n^2}{8}$ MAX $243^{ft\text{-}k}$ INITIAL $131.3^{ft\text{-}k}$

INT. SUPPORT (M.S) $(.7)(.3)M_o$ $552.6^{''\text{-}k}$ $331^{''\text{-}k}$

MIDSPAN (M.S) $(.52)(.4)M_o$ $547.3^{''\text{-}k}$ $327.7^{''\text{-}k}$

EXT SUPPORT (M.S) $(0\%)M_o$ –   –

COMPRESSION: $P_e = 1300^k$ $\eta = .85$ SECTION: $S = \frac{bd^2}{6} = 1600\,in^3$

$P_{ei} = 1105^k$ $A = 1200\,in^2$

STRESSES: $f'_c = 5^{ksi}$ $f'_{ci} = 3^{ksi}$

$\bar{\sigma}_{cs} = .6f'_c = 3^{ksi}$ $\bar{\sigma}_{ts} = -7.5\sqrt{f'_c} = -.53^{ksi}$ $\bar{\sigma}_{ci} = .6f'_{ci} = 1.8^{ksi}$ $\bar{\sigma}_{ti} = -3\sqrt{f'_{ci}}$

STRESS CHECK:

INT SUPPORT (M.S) - SERVICE

$$\sigma_{TOP} = -\frac{1105^k}{1200\,in^2} + \frac{(1105^k)(3")}{1600\,in^3} - \frac{552.6^{''\text{-}k}}{1600\,in^3} = .8^{ksi} > \bar{\sigma}_{ts}$$

$$\sigma_{BOT} = \frac{-1105^k}{1200\,in^2} - \frac{(1105^k)(3")}{1600\,in^3} + \frac{552.6^{''\text{-}k}}{1600\,in^3} = -2.6^{ksi} < \bar{\sigma}_{cs}$$

MIDSPAN (M.S) - SERVICE

$$\sigma_{TOP} = \frac{1105^k}{1200\,in^2} - \frac{(1105^k)(3")}{1600\,in^3} + \frac{547.3^{''\text{-}k}}{1600\,in^3} = -.81^{ksi} < \bar{\sigma}_{cs}$$

$$\sigma_{BOT} = \frac{1105^k}{1200\,in^2} + \frac{(1105^k)(3")}{1600\,in^3} - \frac{547.3^{''\text{-}k}}{1600\,in^3} = 2.65^{ksi} > \bar{\sigma}_{ts}$$

INT SUPPORT (M.S) - INITIAL

$$\sigma_{TOP} = -\frac{1300^k}{1200\,in^2} + \frac{(1300^k)(3")}{1600\,in^3} - \frac{552.6^{''\text{-}k}}{1600\,in^3} = 1.0^{ksi} > \bar{\sigma}_{ts}$$

$$\sigma_{BOT} = -\frac{1300^k}{1200\,in^2} - \frac{(1300^k)(3")}{1600\,in^3} + \frac{552.6^{''\text{-}k}}{1600\,in^3} = -3.17^{ksi} < \bar{\sigma}_{cs}$$

MIDSPAN (M.S) - INITIAL

$$\sigma_{TOP} = \frac{1300^k}{1200\,in^2} - \frac{(1300^k)(3")}{1600\,in^3} + \frac{547.3^{''\text{-}k}}{1600\,in^3} = -1.0^{ksi} < \bar{\sigma}_{cs}$$

$$\sigma_{BOT} = \frac{1300^k}{1200\,in^2} + \frac{(1300^k)(3")}{1600\,in^3} - \frac{547.3^{''\text{-}k}}{1600\,in^3} = 3.17^{ksi} > \bar{\sigma}_{ts}$$