Final Report

Virginia Advanced Shipbuilding & Carrier Integration Center
Newport News, VA

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Structural Option
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April 7, 2011

Advanced Shipbuilding & Carrier Integration Center

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Structural

Building Statistics

- Function Type: Office/Research/Shipbuilding Facility
- Size: 241,000 Square Feet
- Dates of Construction: Dec. 1999—Feb. 2002
- Project Delivery: Design - Bid - Build
- Project Cost: $58 million

Architecture

The office building is 8 stories enclosed by a curtain wall, curved into the shape of a bow, giving it the appearance of a large ship looming over the James

MEP

- 480V - 208y/120V power distribution system
- 100KW and 28.5 tons required air cooling
- 125 KW and 125 GPM required for water cooling

Project Team

All Architecture/Landscape Architecture and Engineering were completed by Clark Nexsen

Structure

- Bulkheads were designed as an anchored bulkhead which consisted of a protective coating on hot-rolled Z-shaped steel sheet piles with continuous, reinforced cast-in-place concrete cap.
- 12"x12" precast, prestressed concrete piles
- K braced frame with columns ranging from W14x82 to W14x159 with diagonal bracing ranging from H SS8x8x1/4 to HSS 12x12x1/2
- Steel girders range from W 12x14 to W 24x55
- 8" precast wall panels and 6" slab on grade with w/ 6x6 w2.9xw2.9 WWF used in laboratory wing

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Executive Summary

The Virginia Advanced Shipbuilding & Carrier Integration Center (VASCIC) is home to Northrop Grumman, a leading global security company and is used as the company's base for designing and testing ships. The thesis study performed includes the complete structural redesign of the office building and analysis of the advantages and disadvantages of this redesign. The office building originally used steel wide flange columns and beams and a composite steel deck to support gravity loads and two steel member k-braced frames to resist lateral loads. The thesis redesign will be a design using two-way reinforced concrete slabs with drop panels as well as reinforced concrete columns to resist gravity loads and reinforced concrete shear walls to resist lateral loads.

A complete redesign of the column layout was done as well. The original layout of the columns led to many irregularly shaped bays. The new column layout made use of a standard grid system in order to obtain more rectangular bays. Rectangular bays are easier to work with, design, and construct and an attempt to keep as many bays as possible in a rectangular shape was made.

The effect this redesign had on the architecture of the building was considered as well. The redesign of the column layout had a large effect on the architecture. More columns needed to be created due to the new grid layout in order to keep the bays at a reasonable size. The VASCIC looked light and open architecturally and used steel to easily satisfy the look. This was taken into consideration when redesigning the building using concrete. Column sizes would potentially be increased and take up more space within the floor plan. To make sure the large concrete columns did not dominate the building they were placed in open areas that would ultimately make the columns look small in comparison. The redesign of the floor system allowed for a reduction in height by 5 feet. The original floor-to-floor heights were kept unchanged to keep the architecture in this aspect intact.

The second breadth conducted was a cost analysis of the structural systems. A cost analysis was done for the existing steel structure as well as the new concrete redesign. Both were compared to see which design was cheaper. After completing the cost analysis, the costs of each design was analyzed and different factors as to why one was chosen over the other were considered.

A further depth topic of flood control was considered as well. The VASCIC is located on the shore of the James River. Flood loads were taken into consideration and a flood-retention system was created. A levee system was designed using slurry walls to prevent seepage.

Throughout the rest of the report, the existing system and building will be referred to as the "current" or "existing" system or building. The thesis redesign will be referred to as the "redesign" system or building.

Acknowledgements

I would like to thank the following individuals for their support on this project:

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Dr. Richard Behr

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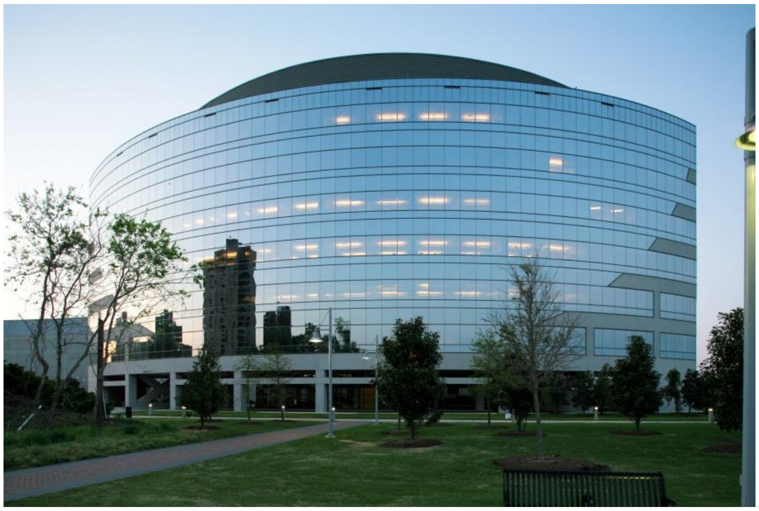
I would also like to thank my parents, John and Diana for their relentless support throughout this semester.

Introduction

The Virginia Advanced Shipbuilding and Carrier Integration Center was designed by Clark Nexsen. The project consists of two main buildings: the office building and the lab wing complete with lab parking and a parking deck. The office building is a typical composite steel frame design. The steel frame grid consists of wide flange beams and columns that range from W12x14 to W18x40. The Lab wing consists of concrete slab with concrete columns and precast concrete walls.

The office building is elevated on piles of concrete made of concrete piles surrounding wide flange steel columns.



Source: Clark Nexsen

The first floor consists of a 5” reinforced concrete slab in the main office area, an 8” reinforced concrete slab at the front of the building and a 6” reinforced concrete slab in the stairwells. The rest of the floors consist of a grid of wide flange steel columns and beams that is shaped into the unique curved design of the Virginia Advanced Shipbuilding and Carrier Integration Center. The composite steel deck and slab is 4.5” in total thickness and consists of lightweight concrete placed on a 2” deep, .038” thick galvanized steel deck.

The lab wing consists of 24”x24” precast concrete columns, 8” precast lightweight concrete walls, and 4” reinforced concrete slabs. The roof of the lab wing consists of gable trusses with steel deck.

Throughout this thesis analysis, the existing conditions of both the lab wing and office building will be analyzed. However, due to height restraints, only the office building will be investigated further.

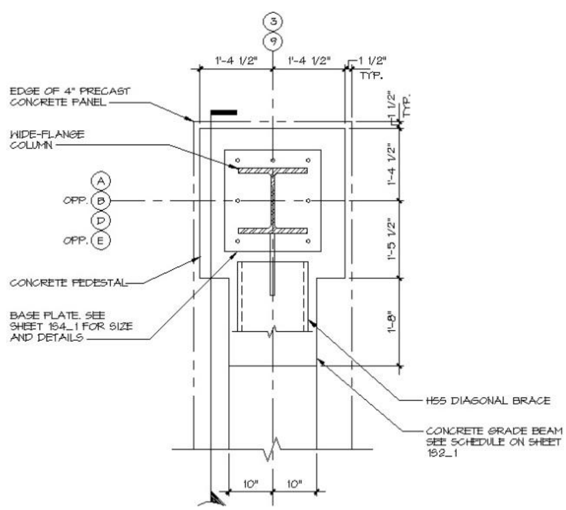
Structural Systems Overview

1. Foundation

A. Office Building

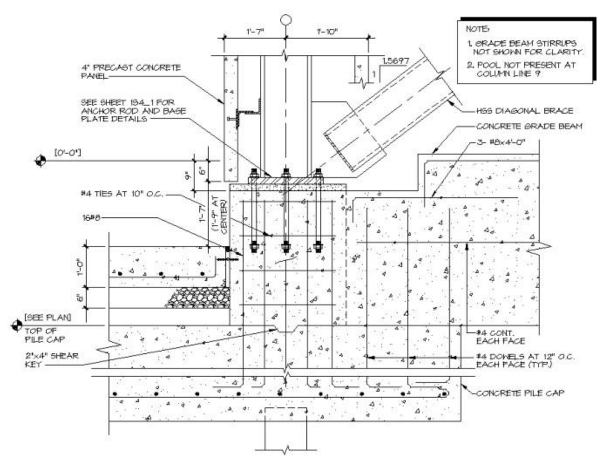
The foundation of the office building consists of a wide-flange steel column on a concrete pedestal. These concrete pedestal/steel column arrangements are placed around the perimeter of the office building in a shape that resembles a football. The soil condition on the site consists of unstable soil do to the waterfront location of the building. This shape is repeated for interior columns as well. *Figure 1* shows the plan view of the concrete pedestal/steel column arrangement and *Figure 2* shows the section view.

FIGURE 1 –CONC. PEDESTAL PLAN



Source: Clark-Nexsen

FIGURE 2 – CONC.PEDESTAL SECTION



Source: Clark-Nexsen

The concrete used in these arrangements is 3000 psi concrete. It is reinforced by #4 ties at 10"O.C, a 2"x4" shear key, and 16 #8 steel rebar. These concrete piles support the wide flange columns that are placed on them and connected with steel plates and anchor rods.

Two grade beams are used in the foundation of the office building. These grade beams are used to resist lateral column base movement as well as distribute the weight of the building over the soil. These grade beams are important due to the unstable soil condition on the site. Lateral column base movement is important in this project as it is on the coast of the James River. A bulkhead of steel sheet pile had to be constructed to resist the water pressure of the river as well as to provide slope stability and increase bearing capacity for the building foundation. They also serve to increase the bearing capacity for the building foundation. The grade beams are used to further this insurance that the building will not be affected by the river. *Table 1* shows the width, depth and reinforcing of these grade bars.

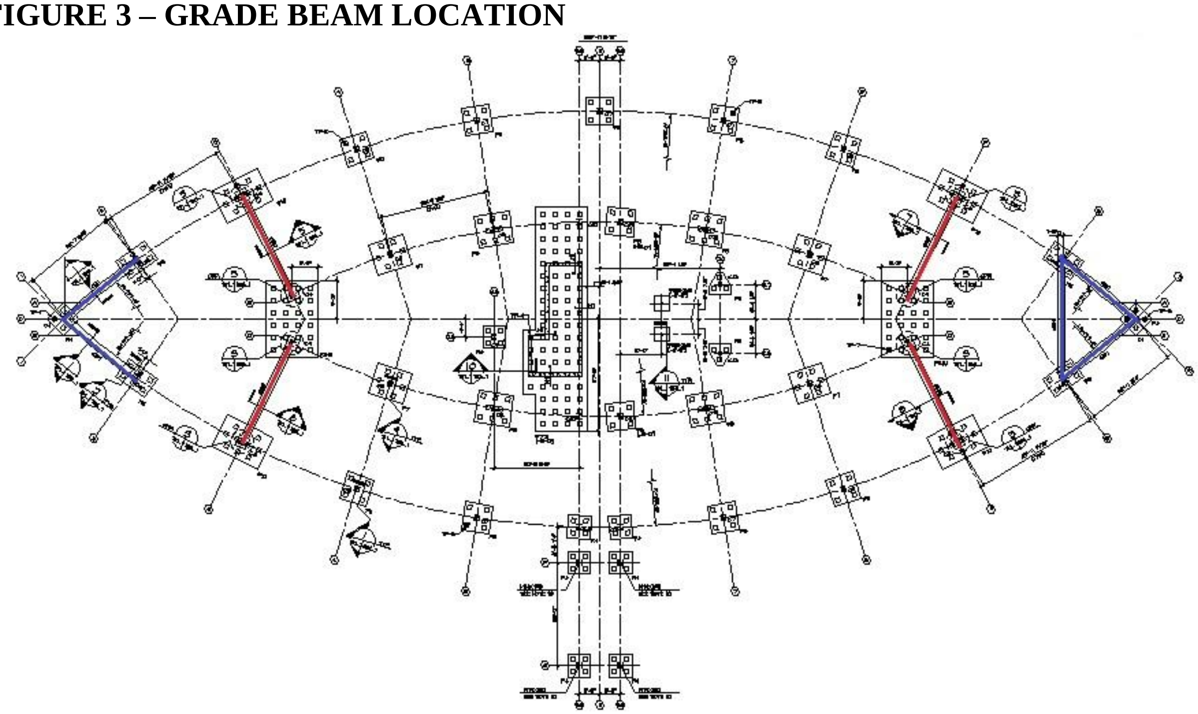
TABLE 1: GRADE BEAM SCHEDULE

GRADE BEAM SCHEDULE						
MARK	WIDTH	DEPTH	TOP BARS	BOTTOM BARS	STIRRUPS	
					SIZE	SPACING
GB1	22"	46"	4 - #8	4 - #8	#4	12" O.C.
GB2	20"	50"	4 - #7	4 - #7	#4	12" O.C.

Source: Clark-Nexsen

Figure 3 shows the locations of the grade beams. GB1 is indicated in blue and GB 3 is indicated in red.

FIGURE 3 – GRADE BEAM LOCATION

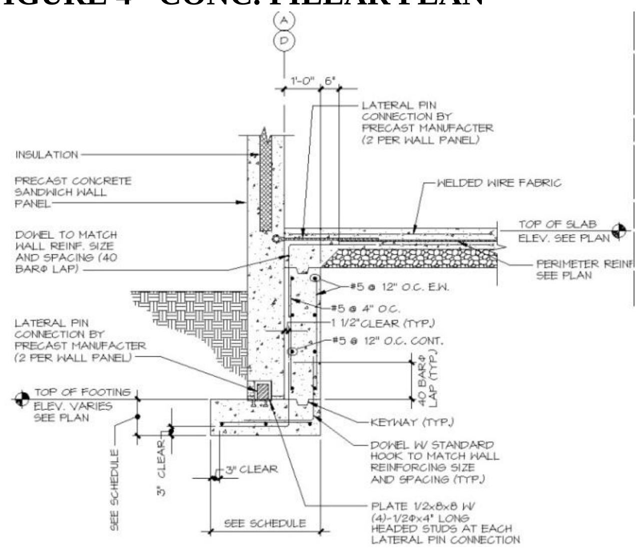


Source: Clark-Nexsen

B. <u>Lab Wing</u>

The lab wing foundation consists of concrete pillars attached to concrete footing. The pillars, which are continuous in length, contain #5 rebar at 12" O.C. and are attached to the footing by a lateral pin. *Figure 4* shows the plan view of the concrete pillars.

FIGURE 4 - CONC. PILLAR PLAN



Source: Clark-Nexsen

The concrete used in the pillars for the lab wing are 3000psi concrete. They support precast concrete walls. The footings that support these walls are continuous in length. They range from 2'-0" wide by 1'-0" thick to 7'-0" by 1'-0". *Table 2* shows the footing schedule. The "A" bars indicate reinforcing in concrete deposited against the ground. The "B" bars indicate reinforcing in the concrete exposed to earth or weather.

TABLE 2: FOOTING SCHEDULE

FOOTING SCHEDULE						
MARK	DIMENSIONS			REINFORCEMENT		NOTES
	W	L	T	'A' BARS	'B' BARS	
CF2.0	2'-0"	CONT.	1'-0"	(2) #5's CONT.	#5's @ 4'-0" O/C	1
CF3.0	3'-0"	CONT.	1'-0"	(3) #5's CONT.	#5's @ 4'-0" O/C	1
CF4.0	4'-0"	CONT.	1'-0"	(4) #5's CONT.	#5's @ 6' O/C	1 2
CF7.0	7'-0"	CONT.	1'-0"	(6) #5's CONT.	#5's @ 6' O/C	1 2
F4.0x4.0	4'-0"	4'-0"	1'-0"	(6) #4's	(6) #4's	1
F8.5x8.5	8'-6"	8'-6"	1'-8"	(7) #7's	(7) #7's	1

Source: Clark Nexsen

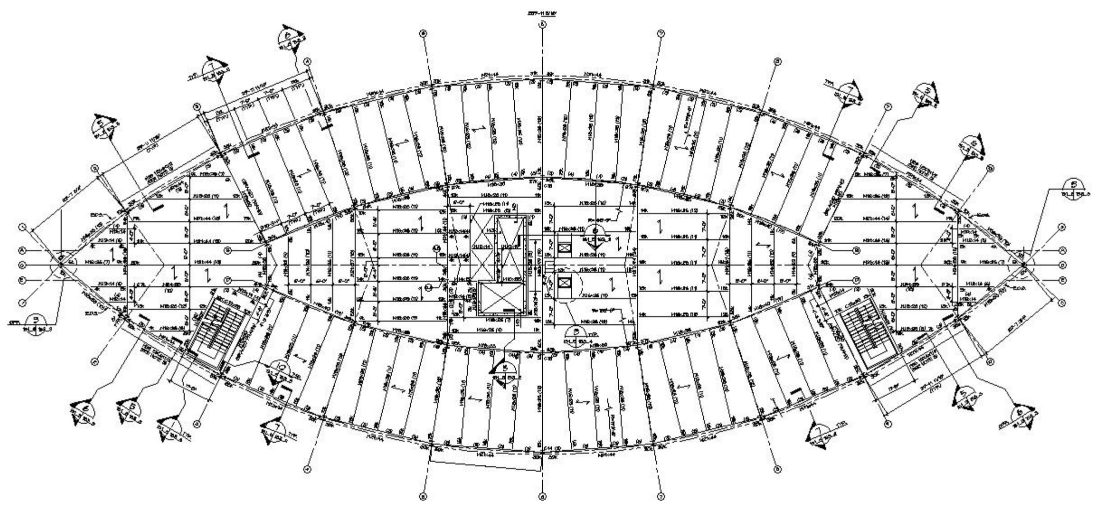
The lab wing also contains a 23"wide by 30" deep grade beam, GB1 along vertical grid line 1.5.

2. Floor System

A. Office Building

The floor system of the office building is consistent from the second floor to the seventh floor. These floors contain 4.5" total thickness composite steel deck and slab. This slab consists of lightweight concrete placed on a 2" deep, .038" thick galvanized steel deck. The steel deck conforms to ASTM A653-94 specifications and has a minimum yield strength of 33ksi. The beams are wide flange steel beams arranged in various grids that form together to fit the curved shape of the building. *Figure 5* shows the floor plan from floor 2 to floor 7.

FIGURE 5 – FLOOR PLAN: FLOOR 2-7

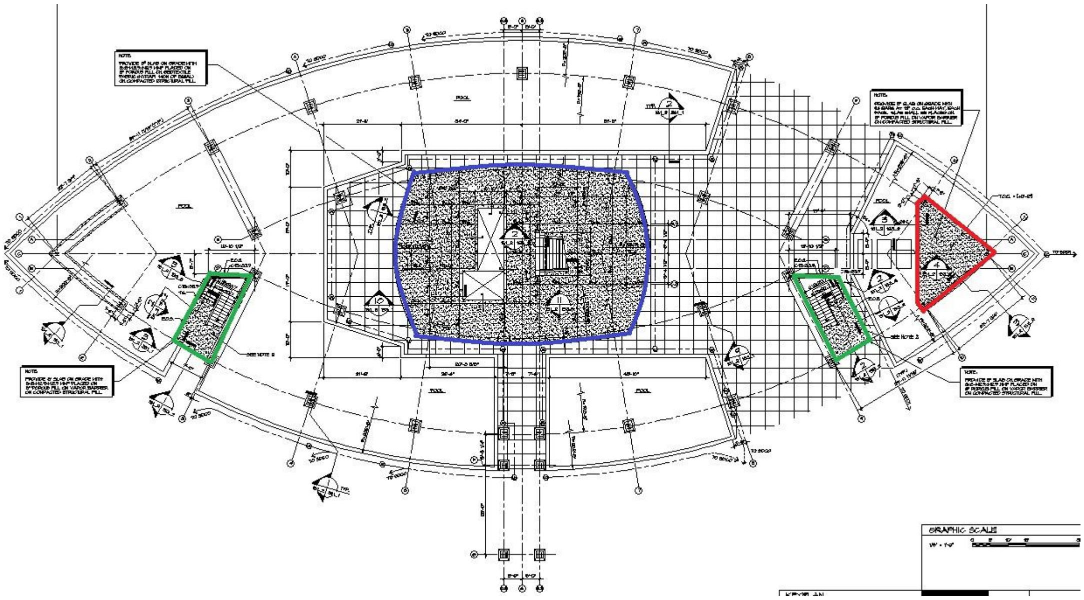


Source: Clark-Nexsen

The first floor of the office building contains three separate load-bearing reinforced concrete slabs. The first slab is at the center of the building. It consists of a 5" slab on grade with 6x6-W2.9xW2.9 WWF placed on 6" porous fill.

There is also a triangular slab in the back of the building. This slab is 8" slab on grade with #4 bars at 12" O.C. Finally, there is a slab on the floor of the stairwells. These slabs are a 6" slab on grade with 6x6-W2.9xW2.9 WWF. *Figure 6* shows the first floor plan. The 5" slab is outlined in blue, the 8" inch slab is outlined in red, and 6" slab is outlined in green.

FIGURE 6 – FIRST FLOOR PLAN



Source: Clark-Nexsen

B. Lab Wing

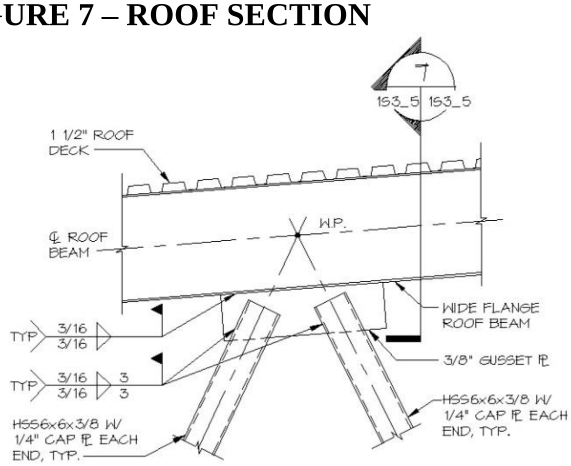
The lab wing consists of a 4" reinforced concrete slab. The slab is reinforced with 6x6 W2.0xW2.0 WWF. This concrete used in the slab is 4000psi.

3. Roof System

A. Office Building

The roof structure of the office building is 1 ½" corrugated composite steel deck. The deck sits on wide flange steel roof beams. *Figure 7* shows the section view of the roof.

FIGURE 7 – ROOF SECTION

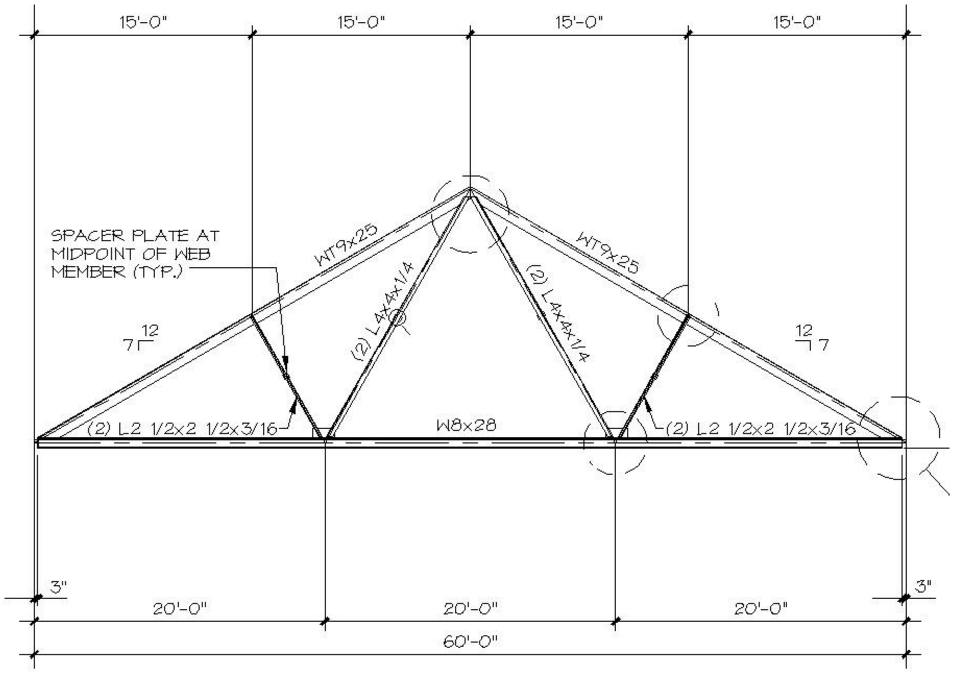


Source: Clark-Nexsen

B. Lab Wing

The roof of the lab wing involves gable trusses, spanning between concrete columns. The gable trusses are constructed using WT9x25, L2 1/2x2 1/2x3/16, and W8x28 steel members. On the gable trusses is a 20GA 1 ½" deep wide rib roof deck. *Figure 8* shows a section view of the gable trusses.

FIGURE 8 – GABLE TRUSSES



Source: Clark-Nexsen

There is also a special truss located along column line 2.5. For these trusses, bottom chord members are W8x31 and the top chord members are WT9x27.5.

4. <u>Columns</u>

A. Office Building

The office building contains steel wide flange columns. 42 columns are arranged to fit the curved shape of the building. The columns used are W8, W10, W12, and W14 steel members. These wide flange columns are encased by concrete piles on the foundation to provide extra structural stability. This is important on the foundation because, as previously stated, the building is raised off the ground to provide protection against flooding. The number of piles used for each column varies from 2 to 9.

These columns on floors 1 to 7 direct gravity loads to the foundation where the columns and concrete piles direct the loads to the earth's foundation.

B. Lab Wing

The lab wing uses concrete columns. These columns vary in size, with the most common size being 24"x24" precast concrete. The columns are accompanied by concrete piles at the foundation in order to provide extra strength at the foundation of the building.

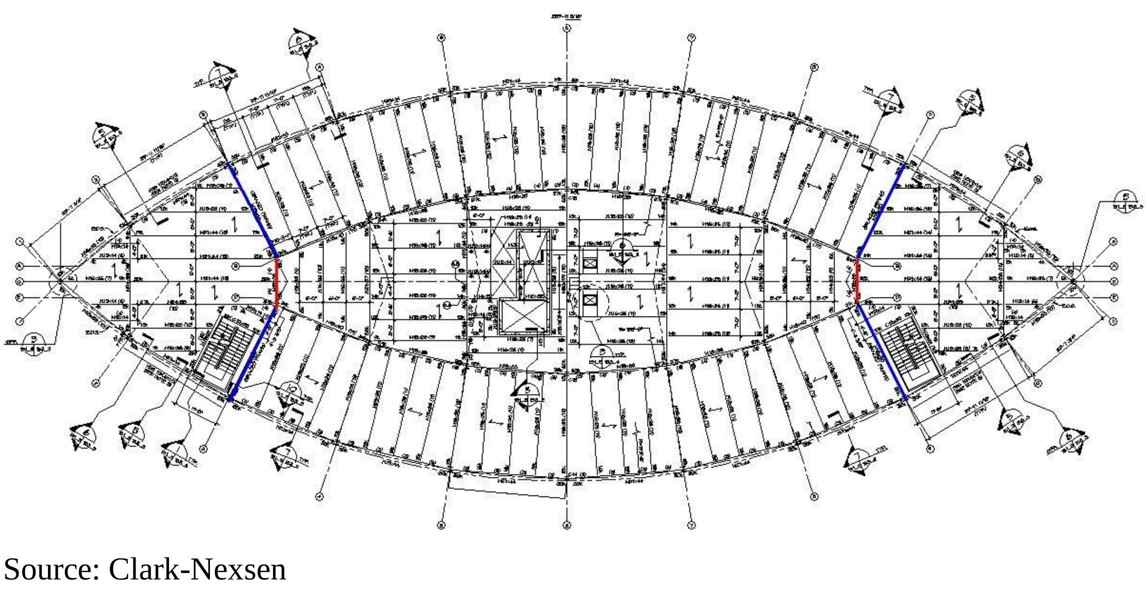
5. Lateral System

A. Office Building

The lateral system of the office building consists of a "K" braced frame. This braced frame occurs at column lines 3 and 9. The frame consists of wide-flange steel members as well as HSS steel members. The wide-flange members are used as columns. The HSS members are used as diagonal bracing. The wide-flange members are W14 and range from W14x82 at the top, W14x90 in the middle, and W14x159 at the bottom. The HSS members range from HSS 8x8 at the top to HSS 10x10 in the middle, and finally HSS 12x12 at the bottom.

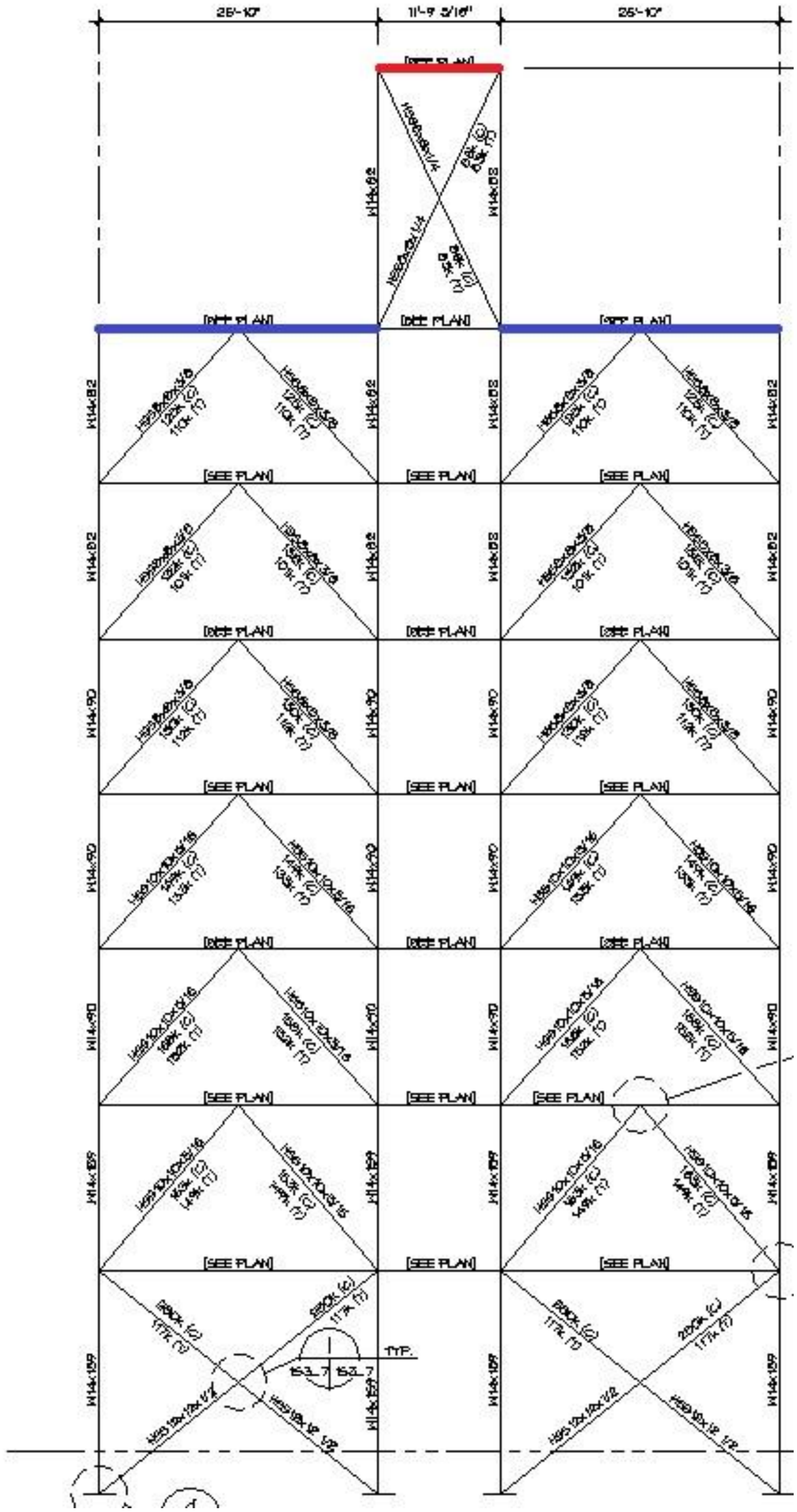
"X" bracing is used in three bays of this structure: the outer bays on the bottom level as well as the middle bay in the penthouse level. "X" bracing is used on these floor as added bracing because of the loads on the floors. As discussed later in the "Wind Load" section, the penthouse sees the highest load in psf from wind. The penthouse also lacks the outer bays to help deflect the load like the floors below it have. The bays on the bottom level have the added weight of the floors above to take into consideration. The "X" bracing allows one diagonal brace to be in tension and one to be in compression. *Figure 9* shows the location of the "K" braced frame and *Figure 10* shows the "K" braced frame in elevation.

FIGURE 9 – K-BRACE FRAME LOCATIONS



Source: Clark-Nexsen

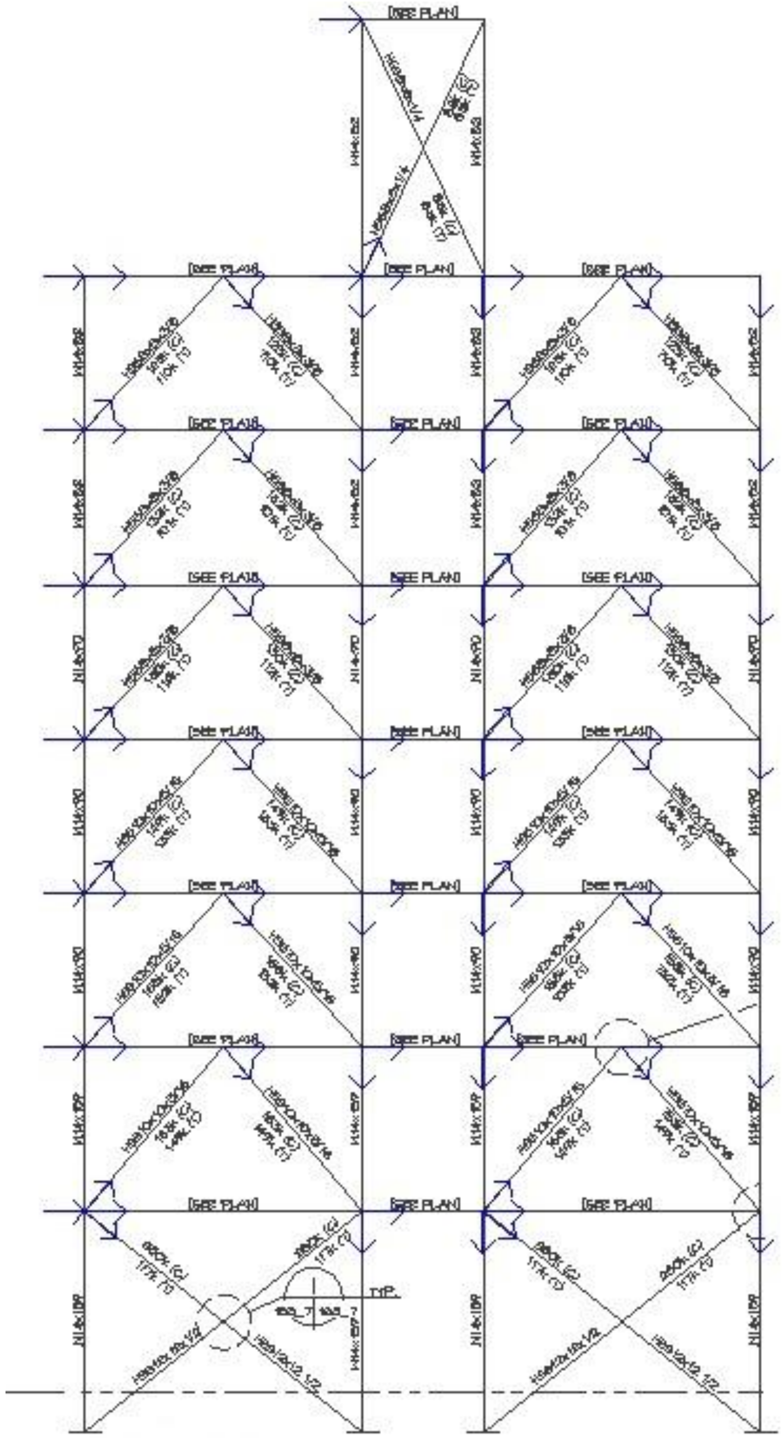
FIGURE 10 – K-BRACED FRAME: ELEVATION



Source: Clark-Nexsen

The unique design of the building caters to the shape of the frame. The outer bays are perpendicular to the load and transfer the load to the middle bays as well as down through the cross bracing. *Figure 11* shows the load path of the frame.

FIGURE 11 – Source: K_BRACED FRAME: LOAD PATH



B. Lab Wing

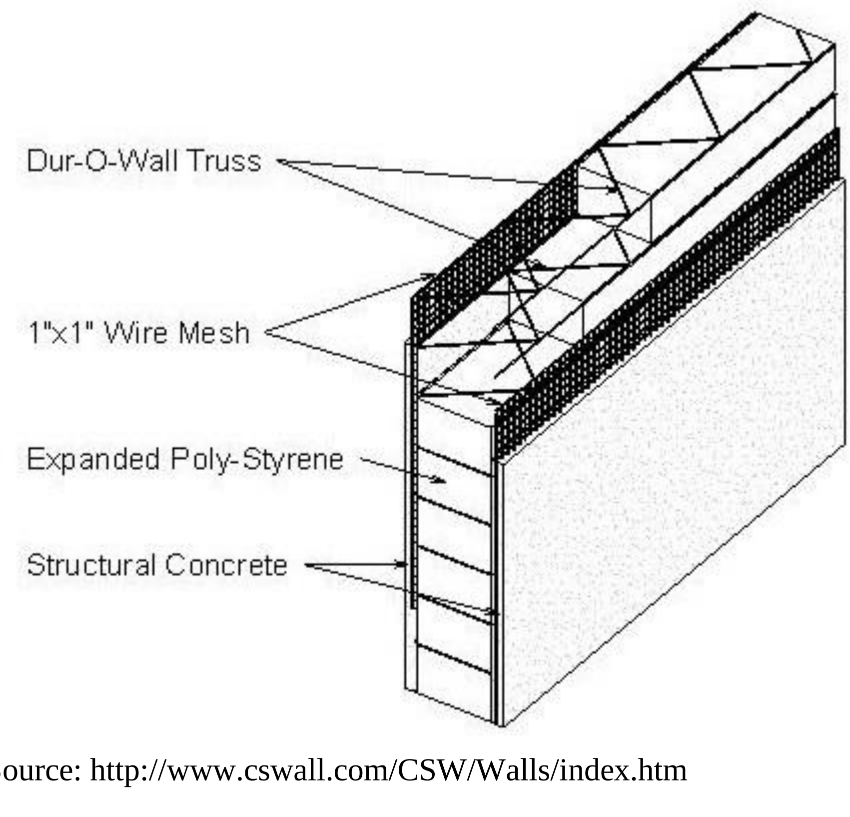
The lateral support for the lab wing is provided by shear walls. 8" precast lightweight concrete walls are used as sheer walls throughout the lab wing of the building. These walls combine with the concrete slabs to provide lateral support for the building.

6. Structural Details

A. Sandwich Wall

The lab wing makes use of concrete sandwich walls. Sandwich walls are resistant to many important forces of nature including, earthquakes, hurricanes, heat, cold, and flooding. Flooding is the most important natural force in the situation of the Virginia Advanced Shipbuilding & Carrier Integration Center. As stated earlier, the office building is raised with thick concrete piles to avoid problems caused by the flooding of the James River. The lab wall instead makes use of the sandwich wall in order to defend against flooding. *Figure 12* shows the sandwich wall in section.

FIGURE 12 – SANDWICH WALL: SECTION

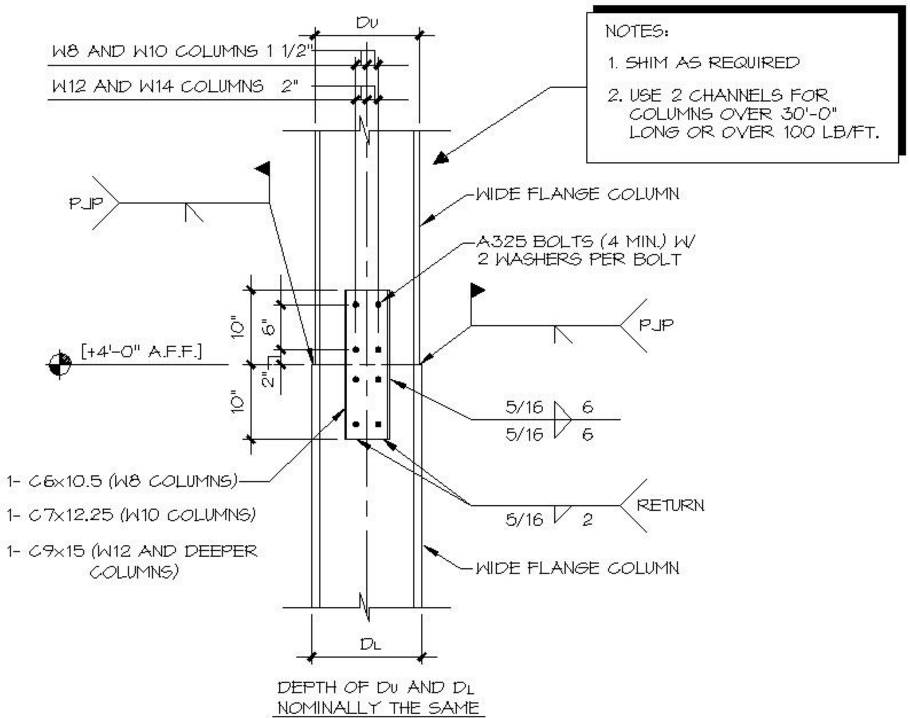


Source: http://www.cswall.com/CSW/Walls/index.htm

B. Column Splice Connections

The height of the office building makes it necessary for column splice connections to be used. *Figure 13* shows the typical column splice details.

FIGURE 13 – TYPICAL COLUMN SPLICE DETAILS



Source: Clark-Nexsen

It is important to note the variance of the connections from the W8 to the W14 columns. A325 bolts are used. Also, 2 channels are used for columns over 30'-0" long or over 100lb/ft.

7. Conclusions on Structural System

The first thing that was noticed when looking at the structural drawings is the vast difference between the office building and the lab wing. The office building makes use of steel columns and beams as well as diagonal steel bracing. The lab wing, however, makes use of concrete slabs and concrete columns as well as shear walls and sandwich walls.

Flooding is an important natural force that had to be accounted for in the structural design of the building. The building had to be designed to withstand flood loads. The use of large concrete areas on the ground floor are designed to resist these loads. The ground floor does not contain offices or any rooms. Instead, the offices are located above flood levels in the floors above the ground floor. This allowed the ground floor to keep an open feel to it even with the large areas of concrete. The office building makes use of stilts and thick concrete piles to remain above flood level. The Lab wing, however, makes use of sandwich walls.

The use of steel in the office building is most likely due to the architect wanting to keep the office building more open and spacious and not have to worry about large, cramping concrete columns. The steel columns and beams are complimented by the curtain wall that engulfs the building. This provides a light, spacious, and well-lit office building.

The lab wing, on the other hand, is designed as a seemingly heavier, less spacious building. Most business will be taking place in the office building and it is clear that the designer wanted the office building to feel more welcoming. The parking deck makes use of concrete because it is most likely cheaper to design a parking deck out of concrete. Also, while the laboratories will be operated during the day, they make more use of artificial lighting and rely less on natural light.

Design Codes and Standards

The design of the Virginia Advanced Shipbuilding & Carrier Integration Center followed the following codes:

The BOCA National Building Code – 1996
AISC Manual of Steel Construction, Load and Resistance Factor Design, Second Edition
ACI 318-95 Building Code Requirements for Structural Concrete

This report will make use of the following codes and standards

ASCE/SEI 7-05 – Minimum Design Loads for Buildings and Other Structures
This text will be referred to as *ASCE 7-05* from now within the report. ASCE 7-05 was used to determine appropriate Live Loads, Wind Loads, Snow Loads, Seismic Loads, Flood Loads, as well as Load Factoring and Live Load Reduction.

AISC Steel Construction Manual Thirteenth Edition
This text well be referred to as AISC from now on within the report. AISC was used to determine loads as well as sizes of steel beams and columns. LRFD was used in the calculation and determination of these loads and steel member sizes.

ACI 318-08 Building Code Requirements for Structural Concrete
This text will be referred to as ACI 318-08 from now within the report. ACE 318-08 was used to determine loads as well as sizes of concrete structural aspects including slabs and load bearing precast concrete walls as well as concrete columns.

Material Properties

Reinforced Concrete

TYPE	F'c	Aggregate
Slab on Grade	4000psi	Normal Weight
Walls	4000psi	Light Weight
Grade Beams	3000psi	Normal Weight
Pile Caps	3000psi	Normal Weight
Composite Deck Fill	3000psi	Lightweight
All Other Concrete	3000psi	Normal Weight

Structural Steel

Shape	Fy (KSI)
Wide Flanges	50
Rectangular HSS members	46
WT members	50
Channels	50
Connectors – Angles	36
Connectors – Angles	36

Gravity and Lateral Loads

1. Live Loads

Live Loads for the project were in accordance with the following. Live loads were determined using ASCE 7-05 S4.

A. Office Building

OCCUPANCY	DESIGN LOAD (psf)	THESIS LOAD (psf)
Penthouse Roof	20	20
Low Roof	80	60
Penthouse Floor	125	125
Offices	80	50
Conference Rooms	100	100
Corridors	100	80
Stairs	100	100
Toilets	75	75

B. Lab Wing

OCCUPANCY	DESIGN LOAD (psf)	THESIS LOAD (psf)
Antenna Tower Roof	100	100
Antenna Tower Room Floor	125	125
Auditorium	60	60
Cafeteria	100	100
Catwalks/Elevated Walkways	60	60
Corridors (1st floor)	100	100
Corridors (above 1st floor)	100	80
Exterior Service Yard	300	300
Garages	50	40
Laboratory (Elevated Floor)	300	300
Laboratory (Floor on Grade)	600	600
Laboratory (Storage Area on 2nd floor)	250	250
Mechanical/Electrical Equipment Rooms	125	125
Patio	100	100
Patio Planters (Dead Load)	400	400
Roof (UON)	20	20
Stairs & Exits	100	100
Concrete Load	2000lbs on 2 ½ SF	2000 lbs on 2 ½ SF

2. Dead Loads

LOAD TYPE	LOAD
Normal Weight Concrete	150 pcf
Lightweight Concrete	120pcf
MEP	10psf
Partitions	20psf
Finishes	10psf
Curtain Wall	15psf

Source: Clark Nexsen

3. Wind Loads

BOCA 1996 was used as the resource for wind calculations for the existing design. My analysis, however, will make use of ASCE 7-05 chapter 6. Section 6.5 (Method 2 – Analytical Procedure), specifically section 6.5.3 (Design procedure), was used as a guide for the calculation of wind load.

Basic Wind Data

- Location: Newport News, VA
- Exposure: D (Building at Shoreline)
- Occupancy: III

Design Procedure

- Basic Wind Speed (V) = 90 mph from Fig. 6-1
- Importance factor (I) = 1.0 from fig 6-1
- Exposure Category = D from Section 6.5.6.3
- Directionality Factor (K_d) = .85 from table 6-4
- Topographic Factor (K_{zt}) = 1.0 from section 6.5.7
- Gust Effect Factor (G) E/W = 1.003 from section 6.5.8 (see appendices for calculation)
- Internal Pressure Coefficient (GC_{pi}) = $\pm$ .18 from figure 6-5
- Velocity Pressure (q_z) = 25.204 @ 6th floor from section 6.5.10 (see appendices for calculation)
- Velocity Pressure (q_z) = 26.421 @ mean roof height from section 6.5.10 (see appendices for calculation)

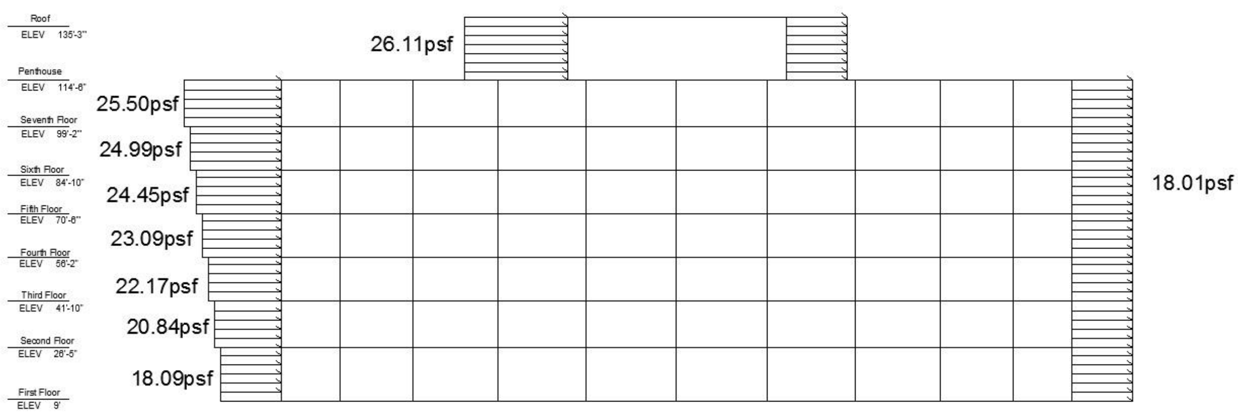
TABLE 3: Wind Loads

	Height	Kz	qz	P	Height Difference	F
First	9	0.943	16.62	18.09	0	0.00
Second	26.5	1.137	20.05	20.84	17.5	91.60
Third	41.83	1.231	21.70	22.17	15.33	87.19
Fourth	56.16	1.296	22.85	23.09	14.33	87.43
Fifth	70.5	1.348	23.77	23.83	14.34	89.97
Sixth	84.83	1.393	24.54	24.45	14.33	92.11
Seventh	99.16	1.431	25.22	24.99	14.33	97.42
Penthouse	114.5	1.467	25.86	25.50	15.34	121.17
Roof	135.21	1.510	26.62	26.11	20.71	70.30

TABLE 4: Wind Forces

	Force (k)	Shear (k)	Moment (ft-k)
Ground	0	179	0
First	92	175	1603
Second	87	177	2863
Third	87	182	4123
Fourth	90	190	5533
Fifth	92	219	6984
Sixth	97	191	8783
Penthouse	121	70	12783
Roof	70	0	8873

FIGURE 14 – E/W WIND LOAD DIAGRAM



4. Seismic Load

My seismic analysis for the Virginia Advanced Shipbuilding & Carrier Integration Center was done using ASCE 7-05. Newport News, Virginia is not a seismic zone, however it is important to analyze the seismic loads to determine their impact on the structure of the building. The building cost enough and is important enough to the community that, if a freak earthquake were to occur, it is necessary to make sure the building would remain intact.

ASCE 7-05, sections 11, 12, and 22 were of use during the seismic analysis. Calculations for the following values can be found in the appendices. *Table 5* shows the seismic forces for each floor.

Basic Seismic Information

- Location: Newport News, VA
- Site Class: D
- Importance Factor: 1

Design Procedure

- S_s = .123 from USGS website
- S_1 = .049 from USGS website
- F_a = 1.6 from table 11.4-4
- F_v = 2.4 from table 11.4-2
- S_{MS} = .1968
- S_{M1} = .1176
- S_{DS} = .1312
- S_{D1} = .0784
- C_t = .028 from table 12.8-2
- x = .8 from table 12.8-2
- T_a = 1.419
- T_s = .598
- R = 8 from table 12.2-1
- C_u = 1.7 from table 12.8-1
- Cs = .0069
- V = 90.37
- K = 1.46 from section 12.8.3

TABLE 5: SEISMIC FORCES

Floor	Wx (k)	Hx (ft)	Hx^k	WxHx^k	ΣWxHx^k	Cvx	Fx
First	1019	9	25	25186	25186	0.005	0.4
Second	606	26.5	120	72486	97672	0.742	67.1
Third	1809	41.83	233	421601	519273	0.812	73.4
Fourth	1809	56.16	358	648176	1167449	0.555	50.2
Fifth	1809	70.5	499	903412	2070861	0.436	39.4
Sixth	1809	84.83	654	1183619	3254479	0.364	32.9
Seventh	1809	99.16	822	1486555	4741034	0.314	28.3
Penthouse	598	113.5	1001	597939	5338973	0.112	10.1
			Total	5338973			

Problem Statement

As discussed throughout the first three technical reports, the architecture and shape of the building are extremely important to the Virginia Advanced Shipbuilding & Carrier Integration Center. The building's unique shape, however, leads to confusing column layouts, which in turn leads to even more confusing beam and joist layouts. Some beams seemed to span great distances while other beams spanned only a few feet. This creates a great difference in floor depth throughout the bays as many different sizes of wide flange members are used. One way to fix this problem is to use reinforced concrete columns and slabs as opposed to steel members.

Unfortunately, if a concrete slab is designed for gravity loads, a new lateral resisting system will need to be designed. The existing K-braced frame is not compatible with a concrete floor system as it makes use of steel wide flange and hollow steel section members. Lateral resistance can be accomplished with the use of concrete sheer walls.

Problem Solution

In order to solve this problem, a new column layout will be investigated. This new column layout will allow for a uniform slab thickness throughout the building. A uniform slab thickness will cut down on construction cost. More importantly, the new column layout will achieve a lower floor thickness. As stated in Technical Report II, the reason concrete was not used for the VASCIC was due to the fact that the office building looked to achieve a light, open feel. The concrete may take away from this idea slightly, however the reduced floor thickness may actually contribute to the look.

Sheer walls will have to be designed in order to create a lateral resistance system that is compatible with the new concrete slab. The symmetrical shape of the building will make this redesign simpler. It will not be difficult to place sheer walls strategically throughout the building in order to achieve minimal to no torsional effect.

Architectural Breadth

Throughout the redesign of the building, analysis of the impacts on the architecture will be done. The Virginia Advanced Shipbuilding & Carrier Integration Center is a very architecturally sound building and the key aspects of its architectural appeal were considered when the redesign was being done. The first step in the architectural analysis was consideration of location of the concrete columns during the column layout redesign. Next, the effect of the lower floor thickness was considered. The light, open feel of the building had to be focused on when redesigning the columns and shear walls. Further architectural analysis of each aspect will follow the redesigns in the "Reinforced Concrete Redesign" section.

Reinforced Concrete Redesign

1. Column Layout Redesign

The first step of the concrete redesign includes redesigning the column layout. The original column layout contained irregularly shaped bays which are difficult to work with. For the redesign, a column grid was created. This allowed the bays to be mostly rectangular. Due to the shape of the building, the bays along the outside of the floor plan are triangular. These bays will make the slab and drop panels easier to design as they are more linear and will create a solid grid throughout the building. *Figure 15* shows the current column layout, with the purple squares indicating the location of the columns. *Figure 16* shows the new column layout.

FIGURE 15 – CURRENT COLUMN LAYOUT

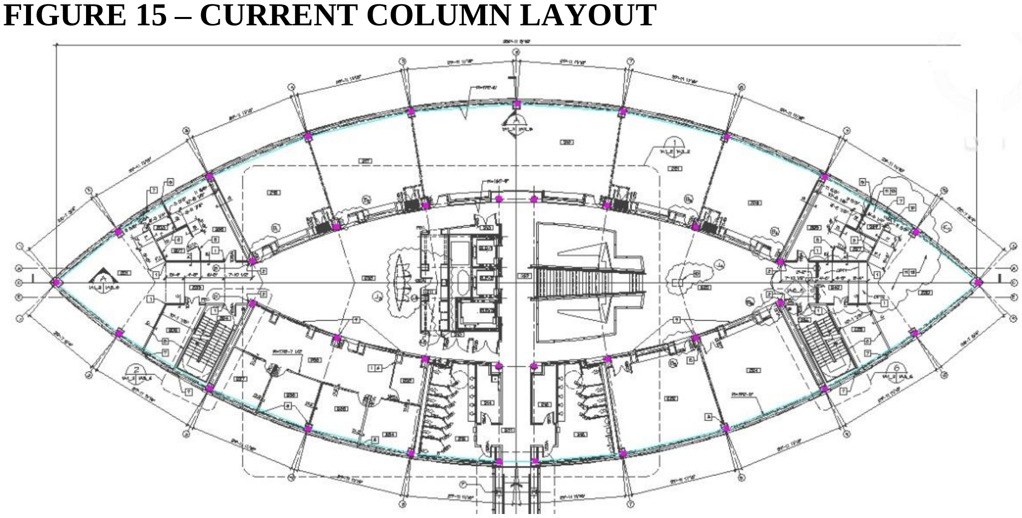


FIGURE 16 – NEW COLUMN LAYOUT

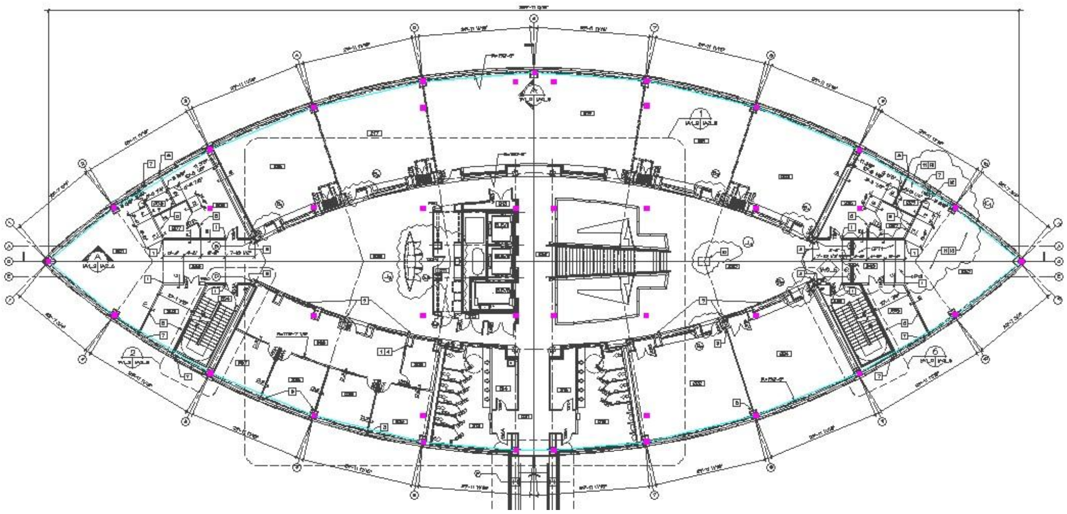


FIGURE 17 – CURRENT COLUMN LAYOUT W/O FLOOR PLAN

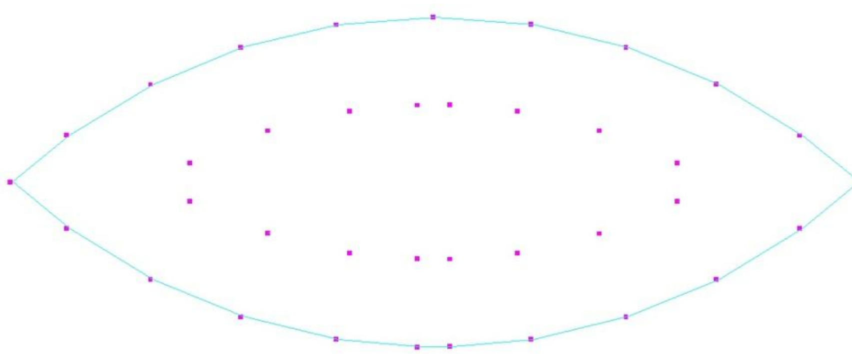
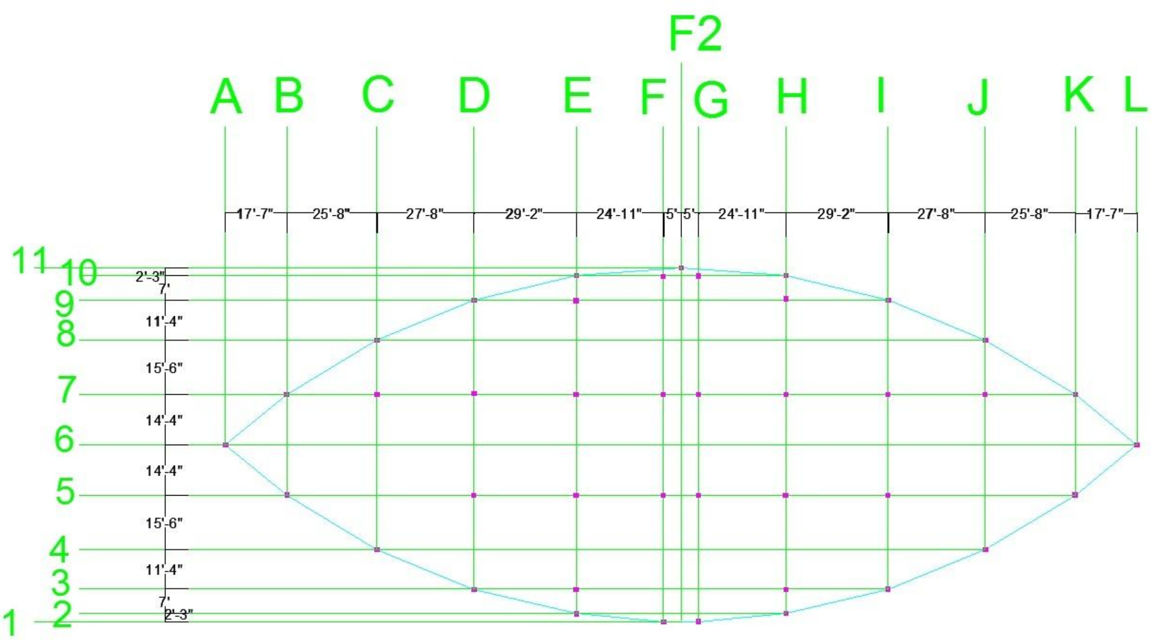


FIGURE 18 – NEW COLUMN LAYOUT W/O FLOOR PLAN



Bays vary in size in the new design. The smallest bay is a 24' 11" x 2' 3" triangular bay at the top of the building. The largest bay is 29' 11" x 33' x 10". Since the redesign included more columns, it was easy for the floor plan to become clustered with columns. Large distances between the columns were used in order to keep the more open feel to the spaces. The column layout is vertically symmetrical about the center of the building; however, horizontally there is a slight difference between the top and bottom of the floor plan. This is due to the fact that the original outer column layout was used in the redesign. The original column layout fits well with the outer shape of the building and was used as the basis for the grid-lines.
Columns were placed with little-to-no interference with the current floor plan. The interference could be fixed easily, by either moving the wall as little as 6" in some spots or moving a door as little as a foot along a wall. This could easily be done as the original room layout hinged greatly on the location of the existing columns. With the new column layout there would be more freedom to make slight changes to make the walls more compatible with the layout.

2. Two Way Flat Slab

The existing floor system is a composite steel deck with concrete topping. The redesign will be a two-way reinforced concrete flat slab using 4,000 psi concrete. Two-way flat plates are commonly used in multi-story construction such as hotels, hospitals, offices, and apartment buildings. They tend to have easy formwork, simple bar placements, and minimize floor to floor heights. This is a good system to analyze because the minimal slab thickness will hopefully allow the office building to keep the light, open look it seeks and accomplished with the composite steel system.

The main advantage of the slab is a severe reduction in floor thickness. The existing system has a total floor thickness of 22.5 inches. The redesign allowed for a max slab thickness of 12 inches with 3 inch drop panels, totaling 15 inches. This is a nearly 8 inch reduction in floor thickness, which could reduce the building height by about 5 feet. *Figure 19* shows the slab thickness with drop panels of floors 1-7. *Figure 20* shows the slab thickness with drop panels of the penthouse floor.

FIGURE 19 – SLAB THICKNESS WITH DROP PANELS FLOORS 1-7

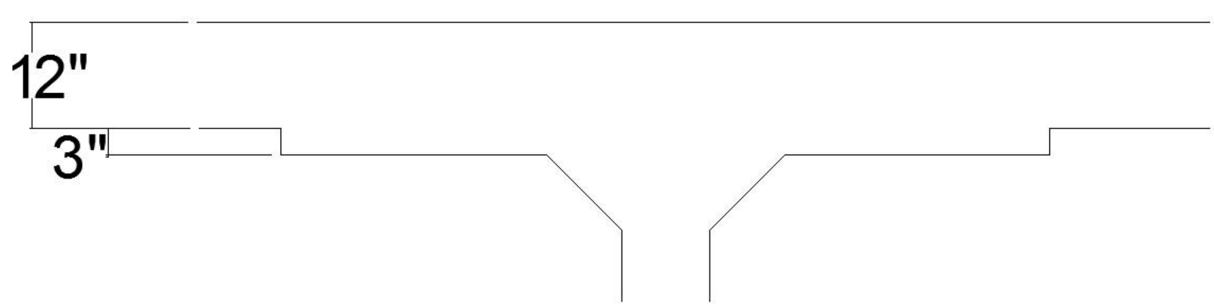
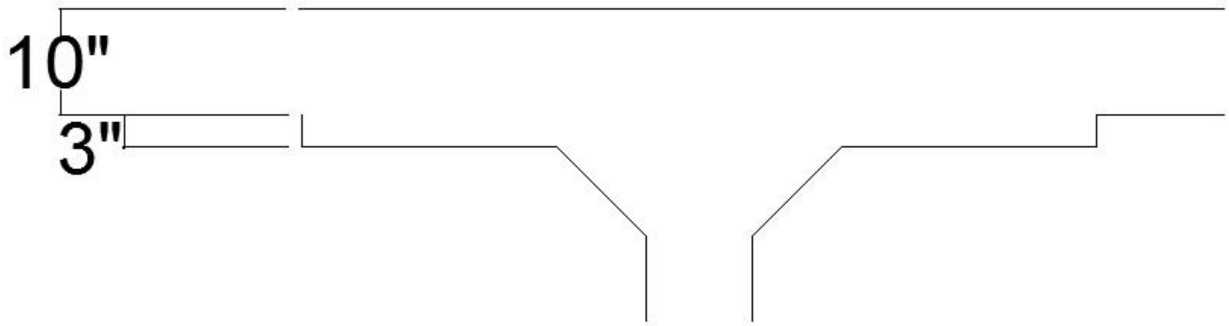


FIGURE 20 – SLAB THICKNESS WITH DROP PANELS PENTHOUSE



It was found that a 10" slab with 3" drop panels would be required to sustain the loads of the building on the penthouse level.

#5 bars were used to design the majority of the column strips in the concrete slab. Some smaller bays used #4 or #3 bars. The largest column strip was column strip 9E-H and 3E-H which spanned 59'-10" and had a tributary width of 9'-2". This strip required 74-#5bars on the second floor, 66-#5 bars on the third and fourth floors 74 and 66-#5 bars respectively for the fifth floor, and 74-#5 bars for the sixth and seventh floor. The average number of bars for the rest of the building was between 16 and 36. The column strip designs, tables, and calculations are summed in the Appendices. *Table 6* shows the height differential between the current building and the redesigned building.

TABLE 6: HEIGHT DIFFERENTIALS

FLOOR	HEIGHT (CURRENT BUILDING)	HEIGHT (REDESIGN)
1st	0'-0"	0'-0"
2nd	17'-6"	17'-6"
3rd	32'-10"	32'-2"
4th	47'-2"	45'-10"
5th	61'-6"	59'-6"
6th	75'-10"	73'-2"
7th	90'-2"	86'-10"
Penthouse	104'-6"	99'-8"
Roof	126'-3"	122'-1"

3. Column Design

The current column design uses wide-flange steel members. The redesign will use square concrete columns with steel rebar. In order to keep the light, spacious feel to the building, an attempt to keep the columns as small as possible was be made.

In order to complete the column design a RAM model was created. The dead load of each floor was found to be 80psf. After carefully placing the live loads, the RAM model analyzed the building and designed the columns. *Figure 21* shows the isometric view of the RAM model. *Figure 22* shows the front view.

FIGURE 21 – RAM MODEL

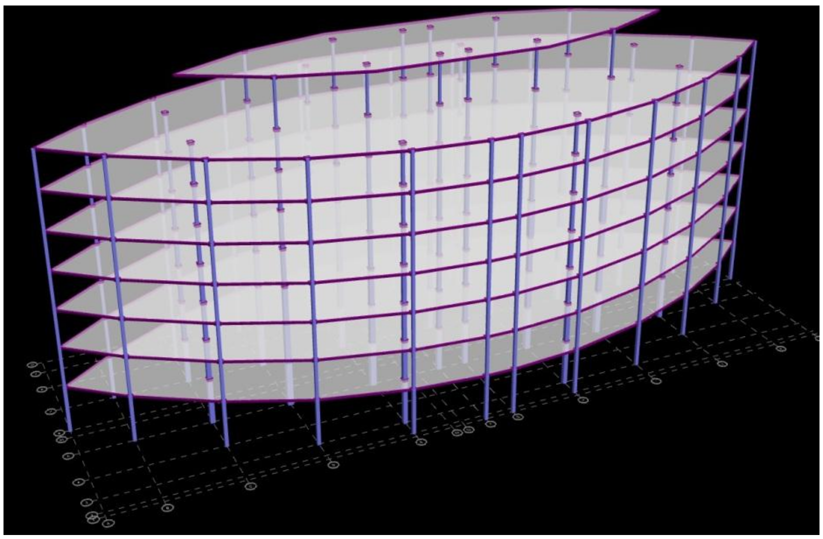
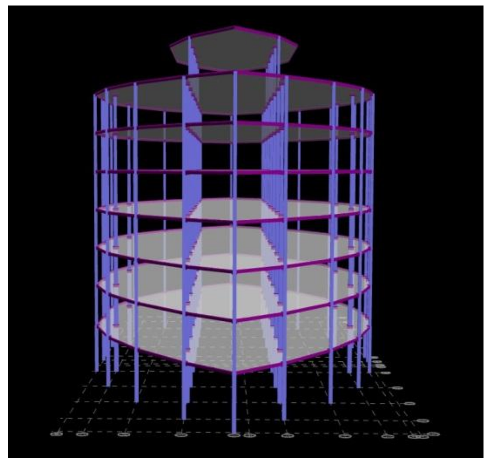


FIGURE 22 – FRONT VIEW



A number of different bar configurations were used in order to find the one that produces the least steel area. The columns holding the largest tributary area were columns D5, D7, I5, and I7 which all held an estimated tributary area of 847 ft^2. These columns were the largest in all but the penthouse floor. Lowering the area of steel is important as, the lower the steel area, the lower the cost. The number of bars per column ranges from 8 to 16.

Columns ranged from 10”x10” in the penthouse to 24”x24” at the bottom level. Though some columns are larger than anticipated, the larger columns are located in more open, spacious areas that will ultimately make them look smaller than if they were placed in a tighter area.

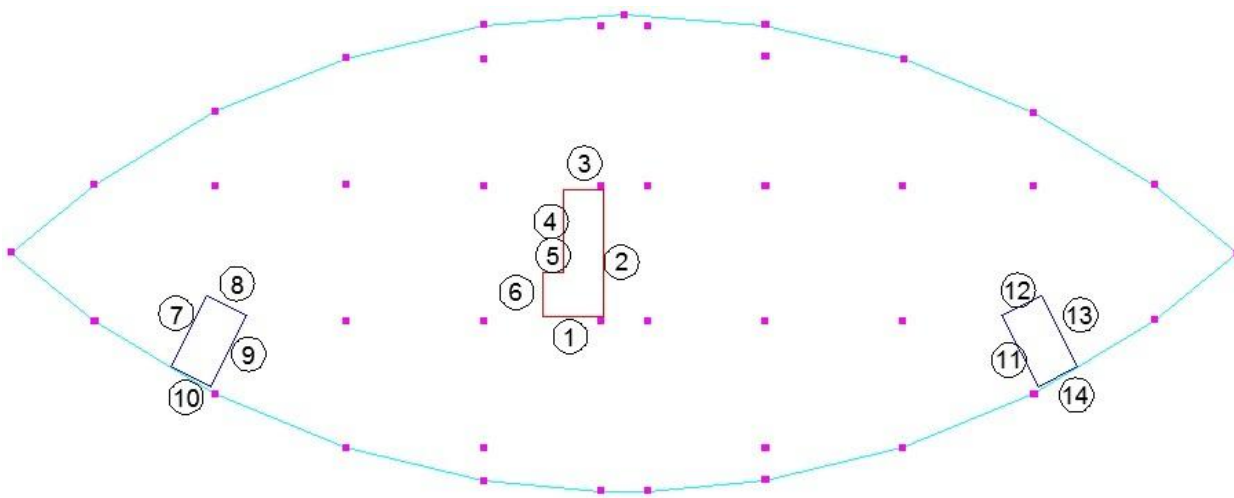
Full column design information can be found in the Appendices.

4. Shear Wall

The current building uses a steel K-braced frame along existing column lines 3 and 9. Due to the use of steel beams and columns, the frame is not compatible with the redesigned slab and column system. The system also is integrated into the existing column layout and is not compatible with the column layout redesign.

A new system of shear walls was designed in order to resist lateral loads. The shear walls are reinforced concrete. As with the other elements of the redesign, the architectural integrity of the structure was considered. Concrete tends to make the building look heavy which contrasts the lightness of the existing building. 10" walls with heavier reinforcement were used to avoid thick walls that would take up more space. Existing concrete walls in the stairwell, elevator shaft, and mechanical area were used so more concrete walls did not need to be added. *Figure 23* shows the layout of the shear walls. The dark blue walls indicate the stairwells. The red walls indicate the elevator and mechanical areas.

FIGURE 23 – SHEAR WALL LAYOUT



New wind calculations had to be made due to the height differential between the existing building and redesigned building. *Table 7* shows the newly calculated wind loads. *Table 8* shows the wind forces acting on the redesigned building. *Figure 24* shows the new wind diagram.

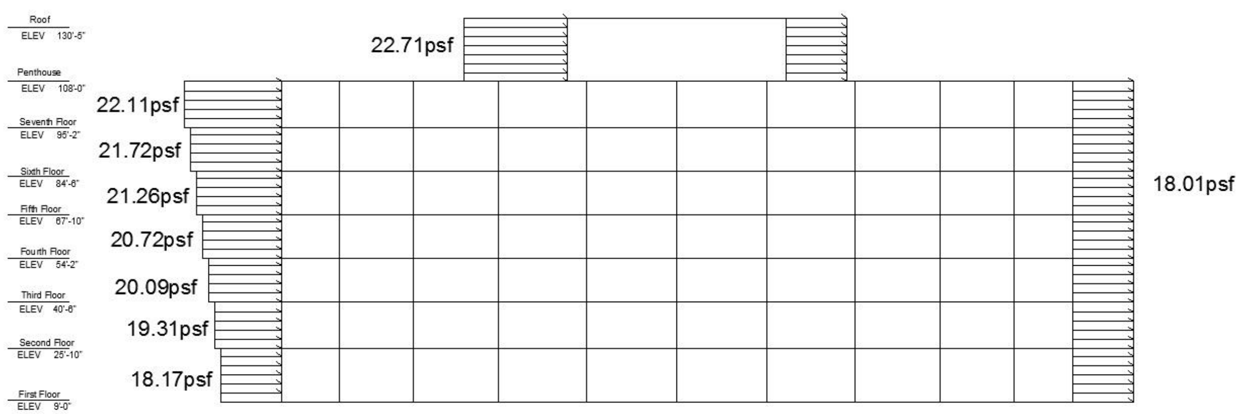
TABLE 7: NEW WIND LOADS

	Height	Kz	qz	P(lb/ft^2)	Height Difference	F(lb/ft)	F(k)
First	9	0.943	16.62	15.83	0	0	0.0
Second	25.83	1.132	19.96	18.17	16.83	295	76.6
Third	40.5	1.225	21.58	19.31	14.67	279	72.5
Fourth	54.16	1.288	22.70	20.09	13.66	279	72.5
Fifth	67.83	1.339	23.61	20.72	13.67	287	74.6
Sixth	81.5	1.383	24.37	21.26	13.67	294	76.4
Seventh	95.16	1.421	25.04	21.72	13.66	290	75.5
Penthouse	108	1.452	25.60	22.11	12.84	397	103.1
Roof	130.42	1.501	26.45	22.71	22.42	255	66.2

TABLE 8: NEW WIND FORCES

	Force (k)	Shear (k)	Moment (ft-k)
First	0	149.1	0
Second	76.6	145.0	1289
Third	72.5	147.1	2284
Fourth	72.5	151.0	3274
Fifth	74.6	151.8	4389
Sixth	76.4	178.6	5536
Seventh	75.5	169.3	6504
Penthouse	103.1	66.2	10207
Roof	66.2	0.0	8036

FIGURE 24: NEW WING DIAGRAM



At first, the building was analyzed using only the elevator and mechanical space walls as shear walls and ignoring the stairwells. This was done because the stairwells are not perpendicular to the wind load and would provide complications when calculated and designed. Unfortunately the shear walls were found to be too large and would have taken away from the architectural integrity of the inner spaces of the building, making them more crowded and heavy aesthetically.

The stair walls were then used in the design process and broken down into x and y components to incorporate the magnitude at which they effect the perpendicular wind force. *Table 9* breaks down the lengths and distance from the origin of the walls in the x direction. *Table 10* does the same for the y direction walls.

TABLE 9: LENGTHS & DISTANCES OF X DIRECTION WALLS

Wall			XL
W2	L	25.42	317.75
	X	12.5	
W4	L	16.83	1969.11
	X	117	
W6	L	7.67	97.7925
	X	12.75	
W7	L	13.59	511.854
	X	37.67	
W8	L	4.28	197.0656
	X	46.08	
W9	L	13.59	626.1278
	X	46.08	
W10	L	4.28	162.5107
	X	38	
W11	L	13.59	2906.711
	X	213.92	
W12	L	4.28	104.0496
	X	24.33	
W13	L	13.59	3016.501
	X	222	
W14	L	4.28	949.4048
	X	222	

$\Sigma L = 121.38$
$\Sigma XL = 10858.88$
$\Sigma XL/\Sigma L = 89.5$
$e_x = 40.54$

TABLE 10: LENGTHS & DISTANCES OF Y DIRECTION WALLS

Y-Direction			YL
W1	L	12.75	470.73
	Y	36.92	
W3	L	8.5	544
	Y	64	
W5	L	3.33	154.01
	Y	46.25	
W7	L	6.92	234.84
	Y	33.92	
W8	L	8.39	330.10
	Y	39.33	
W9	L	6.92	205.42
	Y	29.67	
W10	L	8.39	203.54
	Y	24.25	
W11	L	6.92	205.42
	Y	29.67	
W12	L	8.39	330.11
	Y	39.33	
W13	L	6.92	234.84
	Y	33.92	
W14	L	8.39	203.54
	Y	24.25	

$\Sigma L = 85.85$
$\Sigma YL = 3116.55$
$\Sigma YL/\Sigma L = 36.3$
$e_y = 14.2$

TABLE 11: J-VALUES

Floor	ΣKX^2	ΣKY^2	J
1st	336,396	110,153	446,549
2nd	486,015	160,457	646,472
3rd-Penthouse	585,073	197,580	782,653

The breakdown of stiffness calculations as well as the design calculations for shear walls can be found in the Appendices.

TABLE 12: SHEAR WALL DESIGN

Wall	Reinforcement (bars)	Spacing (inches)
2	#7	16
4	#6	18
6	#2	18
7	#5	16
8	#3	18
9	#5	16
10	#3	18
11	#5	16
12	#3	18
13	#5	16
14	#3	18

Construction Management Breadth: Cost Analysis

The concrete redesign was chosen due to the possibilities of creating a cheaper solution while keeping the architectural integrity of the building. The lower floor thickness due to the two-way flat slab redesign allowed for a reduction in building height. The use of shear walls would incorporate existing concrete walls into the lateral resisting structural system instead of building an entire new system like the k-braced frame used in the existing building. The existing column layout led to many irregular bays. Beams had to span large distances and were laid out in odd arrangements. The new column layout was created to keep the bays in a rectangular fashion. The bays would cut down on large spans in bays which would cut down on the depth of the slab and amount of reinforcement needed which would ultimately cut down on the cost.

In order to test this theory, an RS Means cost estimate was done for the existing steel structure and the concrete redesign. Only the components that were redesigned were taken into account when doing the RS Means estimate.

The concrete redesign was found to cost less than the original steel design. The original design was estimated to cost $1,411,217. The redesign was estimated to cost $1,285,191. The original design was found to take 171 days to construct. The concrete redesign was estimated to take 143 days.

The redesign would have theoretically saved $126,026 and 28 days. These estimates are so close in value that it is easy to see why the steel design was used. The concrete redesign looked to achieve enough of an advantage in cost that the architectural aspects sacrificed using the design could be overlooked. Instead, when trying to achieve a specific look and style, it is easy to choose the option that is slightly more expensive in order to achieve that look and style as closely as possible. In the end, the $100,000 and one month saved from using a concrete design is not enough to overlook the architectural impact of the design.

The concrete slab was the most expensive aspect of the redesign, costing an estimated $555,297.96 (43%). Including the reinforcing steel, the slab cost $730,960 (57%). A more detailed breakdown on the cost and schedule analysis can be found in the Appendices.

Flood Analysis

One of the most important aspects of design for the VASCIC is the consideration of flooding of the James River. The building is currently elevated in order to account for the flooding of the river. Because of this aspect, a further analysis of flood-resisting structures was done. A levee design was considered the most effective and aesthetically pleasing as it makes use of existing soil and backfill to make a more natural looking flood-resisting structure.

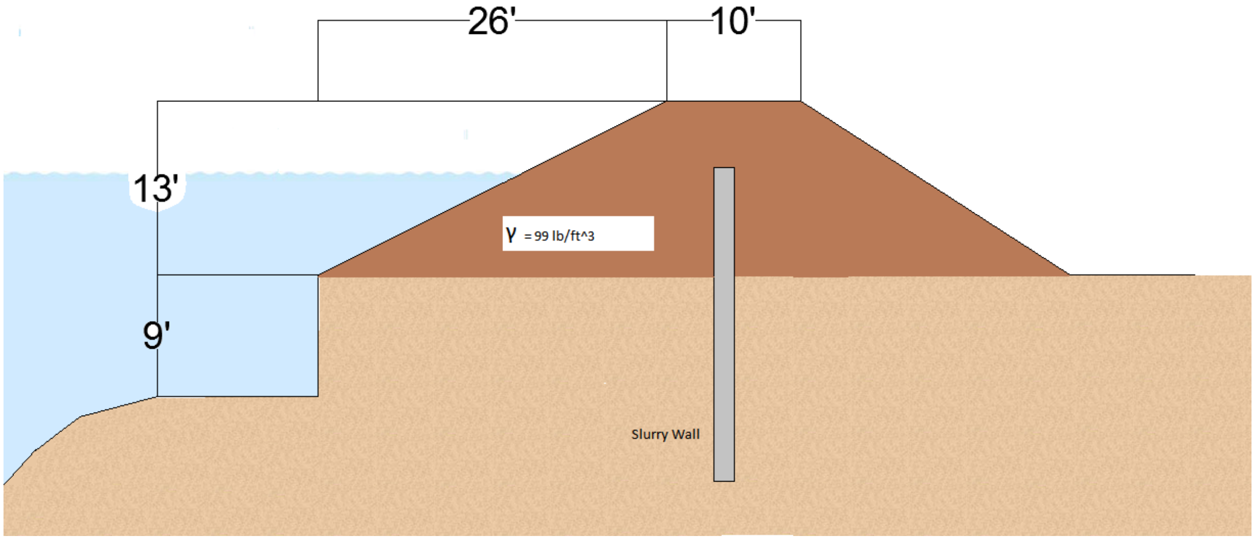
The highest point above sea level the James River has ever reached is 22 ft. The Virginia Advanced Shipbuilding & Carrier Integration Center is 9 ft. above sea level. This means the levee will have to be 13 ft. tall. The force acting on the levee due to the water is 811 ft/sf. It was assumed that the soil used for the levee would be sand, dense and well graded. This soil is aesthetically pleasing, can resist the force of the water easily, and will also resist seepage well.

Due to the location of the building in respect to the river, seepage is an important factor. In order to resist seepage completely in a flood situation, a slurry wall using soil-cement bentonite will be used in the levee. The slurry wall will be over 13 ft. deep in order to resist seepage from the flooding.

The advantages of soil-cement bentonite slurry walls are as follows:

Low Cost
- High productivity
- Verifiable Continuity and Depth
- Excellent resistance to contaminated groundwater
- Ability to easily flex with ground movements
- Cementuous materials added to the backfill increase the strength of the backfill
- Greater trench stability is possible because the backfill creates a shorter backfill slope
- Often preferred in levees for its resistant to erosion and burrowing animals

FIGURE 25 – LEVEE DESIGN



APPENDIX:

APPENDIX A: EXISTING BUILDING WIND CALCS

Gust Factor Calculation (ACI 6.5.8)

ACE 6.5.8.1
z = .6(135.2) = 81.2

c = .15 (Table 6-2)

$I_z = .15(\frac{33}{81.12})^{1/6} = .129$

$Lz = 650(\frac{81.12}{33})^{1/8} = 727.3$

H = 129.5ft
B = 260ft

$$Q = \sqrt{\frac{1}{1+\left(\frac{260+129.5}{727.3}\right)^{.63}}} = .838$$

ACI 6.5.8.2
$g_Q = g_r = 3.4$

$n_1 = \frac{100}{135.2} = .74$

$$g_R = \sqrt{2\ln(3600(.74))} + \frac{.577}{\sqrt{2\ln(3600(.74))}} = 4.18$$

$V_z = .8(\frac{81.12}{33})^{1/9} 90(\frac{88}{60}) = 116.7$

$N_1 = \frac{.74(727.3)}{116.7} = 4.61$

$$R_n = \frac{7.47(4.61)}{(1+10.3(4.61))^{5/3}} = .053$$

$4.6n_1EB/V_z = 7.58$

$RB = \frac{1}{7.58} - \frac{1}{2(7.58^2)}(1- e^{-2(7.58)}) = .123$

$\frac{15.4n1L}{Vz}$ = 25.39

$R_L = \frac{1}{25.39} - \frac{1}{2(25.39^2)}(1 - e^{-2(25.39)}) = .0386$

β = .004 for steel

$R = \sqrt{\frac{1}{.004}(.053)(.230)(.123)(.53 + .47(.0386))} = .453$

$G = .925\frac{1+1.7(.129)\sqrt{(3.4^2)(.838^2)+(4.18^2)(.453^2)}}{1+1.7(3.4).129} = 1.003$

Velocity Pressure ACI 6.5.10

$q_z = .00256K_zK_{zt}K_dV^2I$

$K_z = 2.01(\frac{99.161}{700})^{2/11.5} = 1.43$ @ 6^{th} floor

$q_z = .00256(1.43)(1)(.85)(90^2)(1) = 26.421$

Pressure ACI 6.5.12

$p = qG_fC_p - q_i(GC_{pi})$

C_p = .8 winward
.5 leeward

Winward: $p = q_z(1.003)(.8) - 26.421(-.18) = .0824q_z + 4.7558$
Leeward: $p = 26.421(1.003)(-.5) - 26.421(18) = -18.06$

Force of Winward Pressure

@ 5^{th} floor

$K_z = 2.01(\frac{84.83}{700})^{2/11.5} = 1.39$

$q_z = .00256(1.39)(1)(.85)(90^2)(1) = 24.50$

$P_{5th\ floor} = .8024(24.5) + 4.7558 = 24.415$

$P_{6th\ floor} = .8024(25.204) + 4.7558 = 24.979$

$F = \frac{260}{1000}(24.415(\frac{14.33}{2}) + 24.979(\frac{14.33}{2})) = 92k$

APPENDIX B: EXISTING BUILDING SEISMIC CALCS

S_s = .123
S_1 = .049

Site Class: D
Importance Factor: 1

F_a = 1.6
F_v = 2.4

S_{MS} = 1.6(.123) = .1968
S_{M1} = 2.4(.049) = .1176

$S_{DS} = \frac{2}{3}(.1968) = .1312$
$D_{D1} = \frac{2}{3}(.1176) = .0784$

C_T = .028
x = .8

$T_a = .028(135.21)^{.8} = 1.419$
$T_s = \frac{.0784}{.1312} = .598$

R = 8

C_v = 1.7

$C_s = \frac{.1312}{8} = .0164$
$C_s = \frac{.0784}{1.419(8)} = .00691$

Use Min => C_s = .0069

V = .00691(13078.09) = 90.37

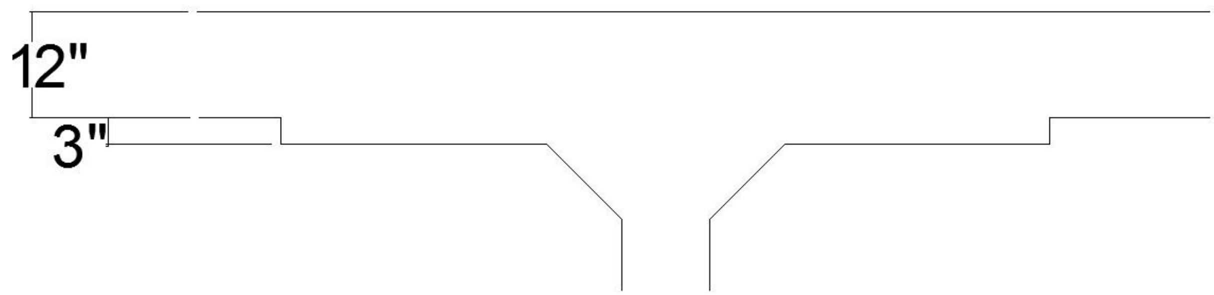
K =

$Fx = \frac{WxHx^{1.46}}{\sum Wihi^{1.46}}$

APPENDIX C: SLAB THICKNESS
w/ drop panels

$T_{min} = \frac{Ln}{36} = \frac{(33+\left(\frac{10}{12}\right))(12)-24}{36}$ = 10.61" => 12" (Table 9.5(c))

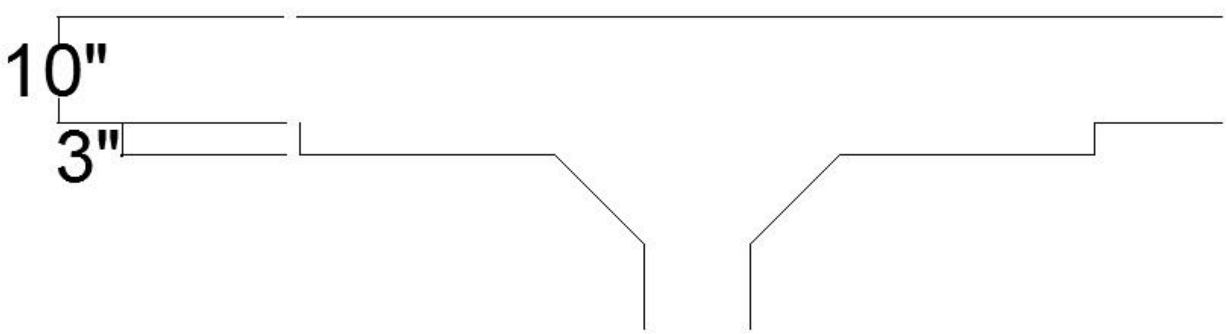
Drop Panel



Avg span = $.2(29 + \frac{11}{12})$ = 5.98"
a = $5- \frac{5.98}{2}$ = 2.01"

thickness = $\frac{12}{4}$ = 3"

Penthouse:
$T_{min} = \frac{Ln}{36} = \frac{(28+\left(\frac{8}{12}\right))(12)-10}{36}$ = 9.28" => 10" (Table 9.5(c))



Avg span = $.2(24 + \frac{11}{12})$ = 4.98"
a = $5- \frac{4.98}{2}$ = 2.5" => use 3"

APPENDIX D: COLUMN STRIPS

Column Strip D:
Assume: #5 bars (A_s = .31)

DL = 180 psf
LL = 80 (corridors)

W_u = 1.2(180) + 1.6(80) = 344 psf

Moments

$$M = \frac{344\left(\frac{29'-2"}{2}\right)\left(28+\frac{8}{12}-\frac{15}{12}\right)^2}{8} = 471 \text{ ft-k}$$

	M- (ft-k)	M+ (ft-k)
Total Moment	.26(471) = 122	.52(471) = 245
Column Moment	122	.6(245) = 147
Middle Strip		.4(245) = 98

$b = \frac{29'-2"}{2}(12) = 175"$
$d = 10 - \frac{3}{4} - \frac{1}{2}(.625) = 8.9$

M-	M+
$Mn = \frac{122}{.9} = 136$	$Mn = \frac{147}{.9} = 163$
$R = \frac{136(12)(1000)}{175(8.9^2)} = 118$	$R = \frac{163(12)(1000)}{175(8.9^2)} = 141$
$\rho = .002$	$\rho = .0024$
$As_{min} = .002(175)(8.9) = 3.13$	$As_{min} = .0024(175)(8.9) = 3.75$
$N = \frac{3.13}{.31} = 10.1$ => use 12	$N = \frac{3.75}{.31} = 12.1$ => use 14
12-#5 Bars (As = 3.72)	14-#5 Bars (As = 4.34)

ρ interpolation

$$\rho = .0033 - \left(\frac{.0034-.0033}{197.9-192.2}\right)(192.2 - 117) = .00198$$

APPENDIX E: COLUMN STRIP SCHEDULE

1st Floor

Column Line	# of Bars (M-)	Bar Size (M-)	# of Bars (M-)	Bar Size (M+)
D7-5	12	5	14	5
E3-5	16	5	20	5
E7-5	36	5	16	5
E7-9	16	5	20	5
F7-5	24	5	10	5
G7-5	26	5	12	5
H3-5	18	5	20	5
H7-5	36	5	18	5
H7-9	18	5	20	5
I3-5	18	5	22	5
I7-5	38	5	16	5
I7-9	18	5	20	5
J7-5	36	5	16	5
J7-9	6	5	6	5
K7-5	16	5	20	5
F5-1	6	5	8	5
G5-1	6	5	8	5

5D-E	20	5	24	5
5E-F	28	5	12	5
5F-G	4	4	2	4
5G-H	30	5	14	5
5H-I	40	5	18	5
5I-J	28	5	12	5
5J-K	14	5	16	5
7D-E	22	5	26	5
7E-F	28	5	12	5
7F-G	4	4	2	4
7G-H	30	5	14	5
7H-I	40	5	18	5
7I-J	28	5	12	5
7J-K	14	5	16	5

2nd Floor

Column Line	Column Line	# of Bars (M-)	Bar Size (M-)	# of Bars (M-)	Bar Size (M+)
B5-7	J5-7	16	5	20	5
C4-5	K4-5	22	5	26	5
C5-7	K5-7	32	5	14	5
C7-8	K7-8	22	5	26	5
D3-5	I3-5	20	5	24	5
D5-7	I5-7	38	5	16	5
D7-9	I7-9	20	5	24	5
E2-3		2	3	2	3
E3-5		30	5	14	5
E5-7		36	5	16	5
E7-9		34	5	16	5
E9-10		2	3	2	3
F1-5		20	5	26	5
F5-7		24	5	10	5
F7-10		20	5	24	5
G1-5		20	5	26	5
G5-7		26	5	12	5
G7-10		20	5	24	5
H2-3		2	3	2	3
H3-5		34	5	16	5
H5-7		40	5	18	5
H7-9		34	5	16	5
H9-10		2	3	2	3

7B-C	5B-C	12	5	14	5
7C-D	5C-D	38	5	18	5
7D-E	5D-E	42	5	20	5
7E-F	5E-F	30	5	14	5
7F-G	5F-G	4	5	2	5
7G-H	5G-H	30	5	14	5
7H-I	5H-I	42	5	20	5
7I-J	5I-J	38	5	18	5
7J-K	5J-K	12	5	14	5
9D-E	3D-E	8	5	10	5
9E-H	3E-H	74	5	28	5
9H-I	3H-I	8	5	10	5
10E-F	1E-F	4	5	4	5
10F-G	1F-G	2	3	2	3
10G-H	1G-H	4	5	4	5

3rd Floor

Column Line	Column Line	# of Bars (M-)	Bar Size (M-)	# of Bars (M-)	Bar Size (M+)
B5-7	J5-7	16	5	20	5
C4-5	K4-5	22	5	26	5
C5-7	K5-7	32	5	14	5
C7-8	K7-8	22	5	26	5
D3-5		18	5	22	5
D5-7		42	5	18	5
D7-9		18	5	22	5
E2-3		2	3	2	3
E3-5		32	5	14	5
E5-7		40	5	18	5
E7-9		32	5	14	5
E9-10		2	3	2	3
F1-5		20	5	26	5
F5-7		24	5	10	5
F7-10		20	5	24	5
G1-5		20	5	26	5
G5-7		24	5	10	5
G7-10		18	5	22	5
H2-3		2	3	2	3
H3-5		32	5	14	5
H5-7		36	5	16	5
H7-9		34	5	16	5
H9-10		2	3	2	3
I3-5		18	5	22	5
I5-7		38	5	16	5
I7-9		20	5	24	5

5B-C		12	5	14	5
5C-D		34	5	16	5
5D-E		42	5	20	5
5E-F		28	5	12	5
5F-G		4	5	2	5
5G-H		28	5	12	5
5H-I		40	5	18	5
5I-J		34	5	16	5
5J-K		12	5	14	5
7B-C		12	5	14	5
7C-D		34	5	16	5
7D-E		42	5	20	5
7E-F		28	5	12	5
7F-G		4	5	2	5
7G-H		28	5	12	5

7H-I		42	5	20	5
7I-J		38	5	18	5
7J-K		12	5	14	5
9D-E	3D-E	8	5	8	5
9E-H	3E-H	66	5	28	5
9H-I	3H-I	8	5	10	5
10E-F	1E-F	4	5	4	5
10F-G	1F-G	2	3	2	3
10G-H	1G-H	4	5	4	5

4th Floor

Column Line	Column Line	# of Bars (M-)	Bar Size (M-)	# of Bars (M-)	Bar Size (M+)
B5-7	J5-7	16	5	20	5
C4-5	K4-5	22	5	26	5
C5-7	K5-7	32	5	14	5
C7-8	K7-5	22	5	26	5
D3-5		18	5	22	5
D5-7		42	5	18	5
D7-9		18	5	22	5
E2-3		2	3	2	3
E3-5		32	5	14	5
E5-7		40	5	18	5
E7-9		32	5	14	5
E9-10		2	3	2	3
F1-5		20	5	26	5
F5-7		24	5	10	5
F7-10		20	5	24	5
G1-5		20	5	26	5
G5-7		24	5	10	5
G7-10		18	5	22	5
H2-3		2	3	2	3
H3-5		32	5	14	5
H5-7		36	5	16	5
H7-9		34	5	16	5
H9-10		2	3	2	3
I3-5		18	5	22	5
I5-7		38	5	16	5
I7-9		20	5	24	5

5B-C		12	5	14	5
5C-D		34	5	16	5
5D-E		42	5	20	5
5E-F		28	5	12	5
5F-G		4	5	2	5
5G-H		28	5	12	5
5H-I		40	5	18	5
5I-J		34	5	16	5
5J-K		12	5	14	5
7B-C		12	5	14	5
7C-D		34	5	16	5
7D-E		42	5	20	5
7E-F		28	5	12	5
7F-G		4	5	2	5
7G-H		28	5	12	5
7H-I		42	5	20	5
7I-J		38	5	18	5
7J-K		12	5	14	5
9D-E	3D-E	8	5	8	5
9E-H	3E-H	66	5	28	5
9H-I	3H-I	8	5	10	5
10E-F	1E-F	4	5	4	5
10F-G	1F-G	2	3	2	3
10G-H	1G-H	4	5	4	5

5th Floor

Column Line	Column Line	# of Bars (M-)	Bar Size (M-)	# of Bars (M-)	Bar Size (M+)
B5-7	J5-7	16	5	20	5
C4-5	K4-5	20	5	24	5
C5-7	K5-7	32	5	14	5
C7-8	K7-8	22	5	26	5
D3-5	I3-5	18	5	22	5
D5-7	I5-7	38	5	6	5
D7-9	I7-9	20	5	24	5
E2-3		2	3	2	3
E3-5		32	5	14	5
E5-7		36	5	16	5
E7-9		32	5	14	5
E9-10		2	3	2	3
F7-10		18	5	22	5
F5-7		24	5	10	5
F1-5		20	5	26	5
G1-5		20	5	26	5

G5-7		24	5	10	5
G7-10		18	5	24	5
H2-3		2	3	2	3
H3-5		32	5	14	5
H5-7		40	5	16	5
H7-9		34	5	32	5
H9-10		32	5	32	5

1E-F		4	5	4	5
1F-G		2	3	2	3
1G-H		4	5	4	5
3D-E		8	5	8	5
3E-H		66	5	26	5
3H-I		8	5	8	5
7B-C	5B-C	12	5	14	5
7C-D	5C-D	38	5	18	5
7D-E	5D-E	40	5	18	5
7E-F	5E-F	28	5	12	5
7F-G	5F-G	4	4	2	4
7G-H	5G-H	32	5	26	5
7H-I	5H-I	40	5	18	5
7I-J	5I-J	34	5	16	5
7J-K	5J-K	12	5	14	5
9D-E		8	5	10	5
9E-H		74	5	28	5
9H-I		8	5	10	5
10E-F		4	5	4	5
10F-G		2	3	2	3
10G-H		6	5	6	5

6th Floor

Column Line	Column Line	# of Bars (M-)	Bar Size (M-)	# of Bars (M-)	Bar Size (M+)
B-5-7	J5-7	16	5	20	5
C4-5	K4-5	22	5	26	5
C5-7	K5-7	32	5	14	5
C7-8	K7-8	22	5	26	5
D3-5	I3-5	20	5	24	5
D5-7	I5-7	38	5	16	5
D7-9	I7-9	20	5	24	5
E2-3		2	3	2	3
E3-5		32	5	14	5
E5-7		36	5	16	5
E7-9		32	5	14	5
E9-10		2	3	2	3
F1-5		20	5	26	5
F5-7		24	5	10	5
F7-10		18	5	22	5
G1-5		20	5	26	5
G5-7		24	5	10	5
G7-10		18	5	24	5
H2-3		2	3	2	3
H3-5		34	5	14	5
H5-7		40	5	16	5
H7-9		34	5	14	5
H9-10		2	3	2	3

7B-C	5B-C	12	5	14	5
7C-D	5C-D	38	5	18	5
7D-E	5D-E	40	5	18	5
7E-F	5E-F	28	5	12	5
7F-G	5F-G	4	5	2	5
7G-H	5G-H	28	5	12	5
7H-I	5H-I	40	5	18	5
7I-J	5I-J	34	5	16	5
7J-K	5J-K	12	5	14	5
9D-E	3D-E	8	5	10	5
9E-H	3E-H	74	5	28	5
9H-I	3H-I	8	5	10	5
10E-F	1E-F	4	5	4	5
10F-G	1F-G	2	3	2	3
10G-H	1G-H	4	5	4	5

7[Th] Floor

Column Line	Column Line	# of Bars (M-)	Bar Size (M-)	# of Bars (M-)	Bar Size (M+)
B-5-7	J5-7	16	5	20	5
C4-5	K4-5	22	5	26	5
C5-7	K5-7	32	5	14	5
C7-8	K7-8	22	5	26	5
D3-5	I3-5	20	5	24	5
D5-7	I5-7	38	5	16	5
D7-9	I7-9	20	5	24	5
E2-3		2	3	2	3
E3-5		32	5	14	5
E5-7		36	5	16	5
E7-9		32	5	14	5
E9-10		2	3	2	3
F1-5		20	5	26	5
F5-7		24	5	10	5
F7-10		18	5	22	5
G1-5		20	5	26	5
G5-7		24	5	10	5
G7-10		18	5	24	5
H2-3		2	3	2	3
H3-5		34	5	14	5
H5-7		40	5	16	5
H7-9		34	5	14	5
H9-10		2	3	2	3

7B-C	5B-C	12	5	14	5
7C-D	5C-D	38	5	18	5
7D-E	5D-E	40	5	18	5
7E-F	5E-F	28	5	12	5
7F-G	5F-G	4	5	2	5
7G-H	5G-H	28	5	12	5
7H-I	5H-I	40	5	18	5
7I-J	5I-J	34	5	16	5
7J-K	5J-K	12	5	14	5
9D-E	3D-E	8	5	10	5
9E-H	3E-H	74	5	28	5
9H-I	3H-I	8	5	10	5
10E-F	1E-F	4	5	4	5
10F-G	1F-G	2	3	2	3
10G-H	1G-H	4	5	4	5

Penthouse

Column Line	# of Bars (M-)	Bar Size (M-)	# of Bars (M-)	Bar Size (M+)
D7-5	14	5	16	5
E7-5	44	5	20	5
E7-9	20	5	26	5
F7-5	30	5	12	5
G7-5	30	5	14	5
H7-5	44	5	20	5
H7-9	20	5	26	5
I7-5	38	5	20	5

APPENDIX F: COLUMN CHECK

Column D-7, Level 3

$At = 847\ ft^2$

DL = 180 psf
LL = 80 psf

$W_u = 1.2(180) + 1.6(80) = 344$ psf

$P_{u\ 3rd\ floor} = \frac{344(8437)}{1000} = 291.37$ k

$P_{u\ above\ floors} = 1268.25$ k

$P_u = 291.37 + 1268.25 = 1559.2$ k

$M_{uT} = 36.12$ ft-k

$M_{uB} = -22.08$ ft-k

H = 13.33 ft

$F_y = 60$ ksi

$F'_c = 4$ ksi

14 #10 bars

$\Phi P_n = .8\Phi[.85f'_c(A_g - A_{st}) + fy(A_{st})]$

$\Phi(1559.2) = .8\Phi[.85(4)(20(20) - 14(1.27)) + 60(14)(14)(1.27)]$

1559.2 < 1893.1 => ok

APPENDIX G: COLUMN REINFORCEMENT SCHEDULE

1st Floor

Column Line	Column Line	size	# of bars	bar size
A	6	14x14	8	5
B	5	14x14	8	5
B	7	14x14	8	5
C	4	14x14	8	5
C	5	20x20	12	8
C	7	20x20	12	8
C	8	14x14	8	5
D	3	14x14	8	6
D	5	24x24	14	10
D	7	24x24	14	10
D	9	14x14	14	5
E	2	14x14	8	5
E	3	18x18	14	10
E	5	24x24	16	6
E	7	24x24	16	7
E	9	18x18	14	9
E	10	14x14	8	5
F	1	14x14	8	5
F	5	20x20	12	6
F	7	20x20	12	6
F	10	14x14	12	4
G	1	14x14	8	5
G	5	20x20	12	9
G	7	20x20	12	8
G	10	14x14	8	5
H	2	14x14	8	5
H	3	18x18	14	10
H	5	24x24	16	10
H	7	24x24	16	10
H	9	18x18	14	10
H	10	14x14	8	5
I	3	14x14	8	7
I	5	24x24	16	10
I	7	24x24	16	10
I	9	14x14	8	6
J	4	14x14	8	5

J	5	20x20	14	8
J	7	20x20	14	8
J	8	14x14	8	5
K	5	14x14	8	5
K	7	14x14	8	5
L	6	14x14	8	5

2nd Floor

Column Line	Column Line	size	# of bars	bar size
A	6	12x12	8	4
B	5	12x12	8	8
B	7	12x12	8	8
C	4	12x12	8	4
C	5	18x18	12	10
C	7	18x18	12	10
C	8	12x12	8	4
D	3	12x12	8	8
D	5	22x22	14	10
D	7	22x22	14	10
D	9	12x12	8	8
E	2	12x12	8	4
E	3	18x18	14	9
E	5	22x22	16	5
E	7	22x22	16	7
E	9	18x18	14	8
E	10	12x12	8	5
F	1	12x12	8	6
F	5	18x18	12	5
F	7	18x8	12	5
F	10	12x12	12	5
G	1	12x12	8	7
G	5	18x18	12	10
G	7	18x18	12	9
G	10	12x12	8	7
H	2	12x12	8	5
H	3	18x18	14	9
H	5	22x22	16	10
H	7	22x22	16	10
H	9	18x18	14	9
H	10	12x12	8	5

I	3	12x12	8	8
I	5	22x22	16	10
I	7	22x22	16	10
I	9	12x12	8	8
J	4	12x12	8	4
J	5	18x18	14	9
J	7	18x18	14	9
J	8	12x12	8	4
K	5	12x12	8	8
K	7	12x12	8	4
L	6	12x12	8	8

3rd Floor

Column Line	Column Line	size	# of bars	bar size
A	6	12x12	8	4
B	5	12x13	8	7
B	7	12x14	8	7
C	4	12x12	8	4
C	5	16x16	12	9
C	7	16x16	12	9
C	8	12x12	8	4
D	3	12x12	8	7
D	5	20x20	14	10
D	7	20x21	14	10
D	9	16x16	14	4
E	2	12x12	8	4
E	3	16x16	14	9
E	5	20x20	16	5
E	7	20x20	16	7
E	9	16x16	14	8
E	10	12x12	8	4
F	1	12x12	8	5
F	5	16x16	12	5
F	7	16x17	12	5
F	10	16x18	12	4
G	1	12x12	8	6
G	5	16x16	12	10
G	7	16x16	12	9
G	10	12x12	8	6
H	2	12x12	8	5

H	3	16x16	14	9
H	5	20x20	16	9
H	7	20x20	16	9
H	9	20x20	14	8
H	10	12x12	8	5
I	3	16x16	8	6
I	5	20x20	16	9
I	7	20x20	16	9
I	9	12x12	8	7
J	4	12x12	8	4
J	5	16x16	14	9
J	7	16x17	14	9
J	8	12x12	8	4
K	5	12x12	8	7
K	7	12x12	8	7
L	6	12x12	8	4

4th Floor

Column Line	Column Line	size	# of bars	bar size
A	6	12x12	8	4
B	5	12x12	8	7
B	7	12x12	8	7
C	4	12x12	8	4
C	5	16x16	12	8
C	7	16x16	12	8
C	8	12x12	8	4
D	3	12x12	8	7
D	5	16x16	14	10
D	7	16x16	14	10
D	9	12x12	14	5
E	2	12x12	8	4
E	3	16x16	14	8
E	5	16x16	16	8
E	7	16x16	16	9
E	9	16x16	14	7
E	10	12x12	8	4
F	1	12x12	8	6
F	5	16x16	12	5
F	7	16x17	12	5
F	10	12x12	12	4

G	1	12x12	8	6
G	5	16x16	12	9
G	7	16x16	12	8
G	10	12x12	8	5
H	2	12x12	8	5
H	3	16x16	14	8
H	5	24x24	16	6
H	7	24x24	16	6
H	9	16x16	14	7
H	10	12x12	8	5
I	3	12x12	8	6
I	5	24x24	16	6
I	7	24x24	16	6
I	9	12x12	8	6
J	4	12x12	8	4
J	5	18x18	14	5
J	7	18x18	14	5
J	8	12x12	8	4
K	5	12x12	8	7
K	7	12x12	8	7
L	6	12x12	8	4

5th Floor

Column Line	Column Line	size	# of bars	bar size
A	6	12x12	8	4
B	5	12x12	8	7
B	7	12x12	8	7
C	4	12x12	8	4
C	5	14x14	12	8
C	7	14x14	12	8
C	8	12x12	8	4
D	3	12x12	8	7
D	5	16x16	14	10
D	7	16x16	14	10
D	9	12x12	14	5
E	2	12x12	4	8
E	3	14x14	14	8
E	5	16x16	16	8
E	7	16x16	16	8
E	9	14x14	14	7

E	10	12x12	8	4
F	1	12x12	8	6
F	5	16x16	12	5
F	7	16x16	12	5
F	10	12x12	12	4
G	1	12x12	8	7
G	5	16x16	12	8
G	7	16x16	12	7
G	10	12x12	8	5
H	2	12x12	8	4
H	3	14x14	14	8
H	5	16x16	16	10
H	7	16x16	16	10
H	9	14x14	14	7
H	10	12x12	8	4
I	3	12x12	8	6
I	5	16x16	16	10
I	7	16x16	16	10
I	9	12x12	8	5
J	4	12x12	8	4
J	5	14x14	14	8
J	7	14x14	14	8
J	8	12x12	8	4
K	5	12x12	8	7
K	7	12x12	8	7
L	6	12x12	8	4

6th Floor

Column Line	Column Line	size	# of bars	bar size
A	6	12x12	8	4
B	5	12x12	8	5
B	7	12x12	8	5
C	4	12x12	8	4
C	5	12x12	12	7
C	7	12x12	12	7
C	8	12x12	8	4
D	3	12x12	8	5
D	5	14x14	14	8
D	7	14x14	14	8
D	9	12x12	14	4

E	2	12x12	8	4
E	3	12x12	14	6
E	5	14x14	16	5
E	7	14x14	16	6
E	9	12x12	14	6
E	10	12x12	8	4
F	1	12x12	8	6
F	5	14x14	12	6
F	7	14x14	12	6
F	10	12x12	8	5
G	1	12x12	8	6
G	5	14x14	12	6
G	7	14x14	12	6
G	10	12x12	8	5
H	2	12x12	8	4
H	3	12x12	14	6
H	5	14x14	16	7
H	7	14x14	16	7
H	9	12x12	14	6
H	10	12x12	8	4
I	3	12x12	8	4
I	5	14x14	16	7
I	7	14x14	16	7
I	9	12x12	8	4
J	4	12x12	8	4
J	5	12x12	14	6
J	7	12x12	14	6
J	8	12x12	8	4
K	5	12x12	8	5
K	7	12x12	8	5
L	6	12x12	8	4

7th Floor

Column Line	Column Line	size	# of bars	bar size
A	6	12x12	8	4
B	5	12x12	8	7
B	7	12x12	8	7
C	4	12x12	8	4
C	5	12x12	12	4
C	7	12x12	12	4

C	8	12x12	8	4
D	3	12x12	8	5
D	5	12x12	14	6
D	7	12x12	14	6
D	9	12x12	14	4
E	2	12x12	8	4
E	3	12x12	14	3
E	5	12x12	16	4
E	7	12x12	16	4
E	9	12x12	14	3
E	10	12x12	8	4
F	1	12x12	8	6
F	5	12x12	12	4
F	7	12x12	12	4
F	10	12x12	12	4
G	1	12x12	8	7
G	5	12x12	12	4
G	7	12x12	12	4
G	10	12x12	8	6
H	2	12x12	8	4
H	3	12x12	14	3
H	5	12x12	16	6
H	7	12x12	16	6
H	9	12x12	14	3
H	10	12x12	8	4
I	3	12x12	8	4
I	5	12x12	16	5
I	7	12x12	16	5
I	9	12x12	8	4
J	4	12x12	8	4
J	5	12x12	14	3
J	7	12x12	14	3
J	8	12x12	8	4
K	5	12x12	8	6
K	7	12x12	8	6
L	6	12x12	8	4

Penthouse

Column Line	Column Line	size	# of bars	bar size
D	5	10x10	14	4

D	7	10x10	14	4
E	5	10x10	16	3
E	7	10x10	16	3
F	5	10x10	12	3
F	7	10x10	12	3
G	5	10x10	12	3
G	7	10x10	12	3
H	5	10x10	16	3
H	7	10x10	16	3
I	5	10x10	16	4
I	7	10x10	16	4

APPENDIX H: NEW WIND CALCS

Exposure: D
Occupancy: II

Basic Wind Speed: V = 90mph
I = 1.0

Gust Factor Calculation

c = .15

Z_{min} = .6(126.06) = 75.64

$I_z = .15\left(\frac{33}{75.64}\right)^{1/6} = .131$

$L_z = 650\left(\frac{75.64}{33}\right)^{1/8} = 721$

h = 116.3 ft
B = 260 ft

$Q = \frac{1}{1+.63\left(\frac{260+116.3}{721}\right)^{.63}} = .705$

g_q = gr = 3.4

$n_1 = \frac{100}{126.06} = .79$

$g_r = \sqrt{2\ln(3600(.79))} + \frac{.577}{\sqrt{2\ln(3600(.79))}} = 4.13$

$V_z = .8\left(\frac{75.64}{33}\right)^{1/9}(90)\left(\frac{88}{60}\right) = 115.8$

$N_1 = \frac{.79(721)}{115.8} = 4.92$

$R_n = \frac{7.47(4.92)}{(1+10.3(4.92))^{\frac{5}{3}}} = .051$

$\frac{4.61(.79)(1)(260)}{115.8} = 8.18$

$R_b = \frac{1}{8.18} - \frac{1}{2(8.18^2)}(1-e^{-2(8.18)}) = .115$

$\frac{15.4(.79)(260)}{115.8} = 27.32$

$R_L = \frac{1}{27.32} - \frac{1}{2(27.32^2)}(1\text{-}e^{-2(27.32)}) = .0359$

β = .013 for reinforced concrete

$\frac{4.6(.79)(116.3)}{115.8} = 3.65$

$R_h = \frac{1}{3.65} - \frac{1}{2(3.65^2)}(1\text{-}e^{-2(3.65)}) = .236$

$R = \sqrt{\frac{1}{.013}(.051)(.236)(.115)(.53 + .47(.0359))} = .058$

$G = .925\left(\frac{1 + .17(.131)\sqrt{3.4^2(.705^2) + 4.13^2(.058^2)}}{1 + .17(3.4)(.131)}\right) = .874$

<u>Velocity Pressure @ 4th Floor</u>

$q_z = .00256 K_Z K_{ZT} K_d V^2 I$

$K_Z = 2.01\left(\frac{66.49}{700}\right)^{2/11.5} = 1.33$

$q_z = .00256(1.33)(1)(.85)(90^2)(1) = 23.44$

<u>Pressure</u>

$P = qG_F G_P - q_i(GC_{pi})$

Cp = .85 winward
.5 leeward

Winward: p = q (.874)(.8)-23.44(-.18) = .699q + 4.22
Leeward: p = 23.44(.874)(-.5) – 23.44(.18) = -14.46

<u>Force of Winward Pressure</u> @ 3rd floor

$Kz = 2.01\left(\frac{53.16}{700}\right)^{2/11.5} = 1.28$

$qz = .00256(1.28)(1)(.85)(90^2)(1) = 22.56$

P5th = .699(23.44) + 4.22 = 20.6

P6th = .699(22.56) + 4.22 = 19.99

APPENDIX I: SHEAR WALL CALCS

Stiffness

Wall 1, floor 1

L: 12.75'
h: 15.5'
b: 10"

G: 3000000
E: 3600000

$I = \frac{L^3 b}{12} = \frac{12.75^3(\frac{10}{12})}{12} = 144 \text{ ft}^4$
$A = 12.75(\frac{10}{12}) = 10.625 \text{ ft}^2$

$K_f = \frac{3EI}{h^5} = \frac{3(3600000)(144)}{15.5^3} = 417443$

$1/K_f = .00000240$

$K_s = \frac{GA}{h} = \frac{3000000(10.625)}{15.5} = 2056452$

$1/K_s = .000000486$

$K = \frac{1}{\frac{1}{Kf}+\frac{1}{Ks}} = \frac{1}{\frac{1}{.0000024}+\frac{1}{.000000486}} = 347004$

First Floor

X-direction			X^2	KX^2
W2	K	1831		66062.48
	X	36.08	1301.766	
W4	K	709		19554.22
	X	27.58	760.6564	
W6	K	85		1983.05
	X	23.33	544.2889	
W7	K	554		28713.82
	X	51.83	2393.553	
W8	K	152		6662.16
	X	43.83	872.1486	
W9	K	554		23866.32
	X	43.08	1653.606	
W10	K	152		7815.84
	X	51.42	1200.361	
W11	K	554		68973
	X	124.5	13810.82	
W12	K	152		18987.84
	X	124.92	7084.538	
W13	K	554		73637.68
	X	132.92	15742.05	
W14	K	152		20140
	X	132.5	7970.385	

Y-Direction			Y^2	KY^2
W1	K	347		12811.24
	Y	36.92	1363.086	
W3	K	113		7232
	Y	64	4096	
W5	K	7		323.75
	Y	46.25	2139.063	
W7	K	554		18791.68
	Y	33.92	522.3472	
W8	K	152		5978.16
	Y	39.33	1378.252	
W9	K	554		16437.18
	Y	29.67	399.6526	
W10	K	152		3686
	Y	24.25	523.9673	
W11	K	554		16437.18
	Y	29.67	399.6526	
W12	K	152		5978.16
	Y	39.33	1378.252	
W13	K	554		18791.68
	Y	33.92	522.3472	
W14	K	152		3686
	Y	24.25	523.9673	

Second Floor

X-direction			X^2	KX^2
W2	K	2487		89730.96
	X	36.08	1301.766	
W4	K	1021		28159.18
	X	27.58	760.6564	
W6	K	130		3032.9
	X	23.33	544.2889	
W7	K	806		41774.98
	X	51.83	2393.553	
W8	K	230		10080.9
	X	43.83	872.1486	
W9	K	806		34722.48
	X	43.08	1653.606	
W10	K	230		11826.6
	X	51.42	1200.361	
W11	K	806		100347
	X	124.5	13810.82	
W12	K	230		28731.6
	X	124.92	7084.538	
W13	K	806		107133.5
	X	132.92	15742.05	
W14	K	230		30475
	X	132.5	7970.385	

Y-Direction			Y^2	KY^2
W1	K	515		19013.8
	Y	36.92	1363.086	
W3	K	173		11072
	Y	64	4096	
W5	K	11		508.75
	Y	46.25	2139.063	
W7	K	806		27339.52
	Y	33.92	522.3472	
W8	K	230		9045.9
	Y	39.33	1378.252	
W9	K	806		23914.02
	Y	29.67	399.6526	
W10	K	230		5577.5
	Y	24.25	523.9673	
W11	K	806		23914.02
	Y	29.67	399.6526	
W12	K	230		9045.9
	Y	39.33	1378.252	
W13	K	806		27339.52
	Y	33.92	522.3472	
W14	K	152		3686
	Y	24.25	523.9673	

Third-Penthouse Floor

X-direction			X^2	KX^2	Y-Direction			Y^2	KY^2
W2	K	2889		104235.1	W1	K	628		23185.76
	X	36.08	1301.766			Y	36.92	1363.086	
W4	K	1223		33730.34	W3	K	215		13760
	X	27.58	760.6564			Y	64	4096	
W6	K	162		3779.46	W5	K	14		647.5
	X	23.33	544.2889			Y	46.25	2139.063	
W7	K	973		50430.59	W7	K	973		33004.16
	X	51.83	2393.553			Y	33.92	522.3472	
W8	K	285		12491.55	W8	K	285		11209.05
	X	43.83	872.1486			Y	39.33	1378.252	
W9	K	973		41916.84	W9	K	973		28868.91
	X	43.08	1653.606			Y	29.67	399.6526	
W10	K	285		14654.7	W10	K	285		6911.25
	X	51.42	1200.361			Y	24.25	523.9673	
W11	K	973		121138.5	W11	K	973		28868.91
	X	124.5	13810.82			Y	29.67	399.6526	
W12	K	285		35602.2	W12	K	285		11209.05
	X	124.92	7084.538			Y	39.33	1378.252	
W13	K	973		129331.2	W13	K	973		33004.16
	X	132.92	15742.05			Y	33.92	522.3472	
W14	K	285		37762.5	W14	K	285		6911.25
	X	132.5	7970.385			Y	24.25	523.9673	

<u>Forces</u>

Wall 2, First Floor

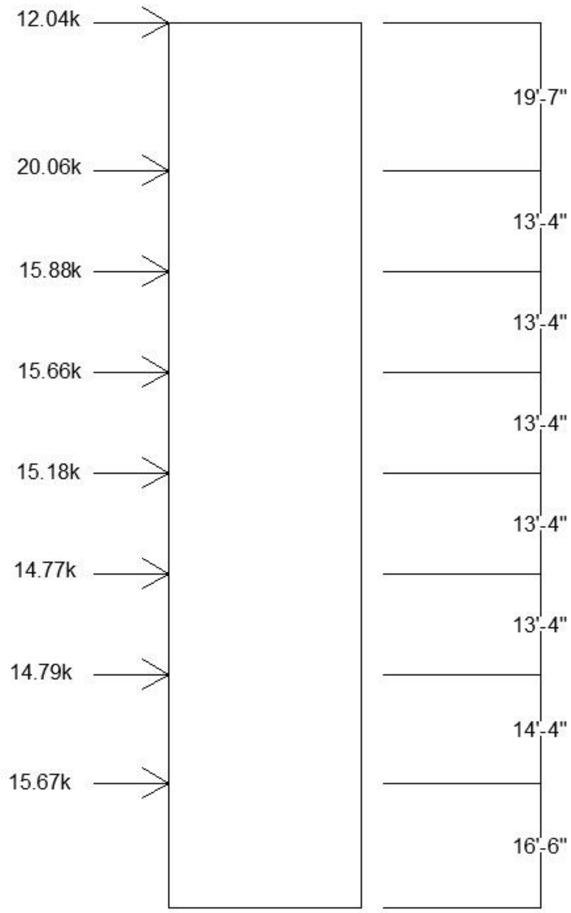
K = 1831
x = 36.08
p = 74.8
e = 40.5
J = 446549

$F = \frac{kxpe}{J}$ = 448 k

L = 25.42 ft
$L/\Sigma L = \frac{25.42}{121.4}$ = .209

V = 74.8(.209) = 15.665 k

Wall 2



L = 12(25.42) = 305.04 in

h = 10 in

s_{max} = min (
$\frac{L}{5} = \frac{305.04}{5}$ = 61 in
(3h = 30 in
(18 in

⇨ Use 18 in

Assume: #7 bars

<u>Moment Strength</u>

M = 15.67(1635) + 14.79(30.83) + 14.77(44.16) + 15.18(57.6) + 15.66(70.83) + 15.88(84.16) + 20.06(97.5) + 12.04(117.08)
= 8051 ft-k

M_u = 1.6(8051) = 12882 ft-k

$\rho_L = \frac{2(.6)}{10(18)} = .0067$

$\omega = .0067(\frac{60}{4}) = .101$

$\alpha = 0$

$c = \frac{.101}{.85(.85)+2(.101)}(305.04) = 33.3$

d = .8(305.04) = 244

$Ast = 2(.6)(\frac{305.04}{18}) = 20.34$

$T = 20.34(60)(\frac{305.04-33.3}{305.04}) = 1087$

$Mn = 1087(\frac{305.04}{2(12)}) = 13816$ ft-k

ΦMn = (.9)13816 = 12434 ft-k

12882 > 12434 => not ok

try s = 16 in

138387 > 12882 => ok

APPENDIX J: COST AND SCHEDULE ANALYSIS

Concrete Slab: 033105350300
Normal Weight Concrete, Ready Mix
Extended Total: $120.10/CY
Extended Total O&P: $131.76/CY
Total Cubic Yards: **3,023**
Daily output: 180 (over 10" slabs)
Days: **26 days**

Slab Form
15-20ft ceiling
Total P&P: 5.28
Total SF: **567.67**
Daily Output: 495
Days: **1.15 days**

Slab Reinforcement
Elevated slabs: 032110600400
Total O&P: $1616.67/ton
Total Weight: **135.93 tons**
Daily Output: 2.90
Days: **47 days**

Concrete Column: 033105350300
Normal Weight Concrete, Ready Mix
Extended Total: $120.10/CY
Extended Total O&P: $131.76/CY
Total Cubic Yards: **2235.59**
Daily Output: 60
Days: **37 days**

Column Reinforcement
Columns #3-#7: 032110600200
Total O&P: $2413.68/ton
Total Weight: **19.52 tons**
Columns #8-#18: 032110600250
Total O&P: $1721.63/ton
Total Weight: **28.73 tons**
Daily Output: 1.5
Days: **19.2 days**

Column Form:
12x12: 031113255650 (4 use)
Number: 12
14x14
Number: 8
Daily Output: 180
16x16: 031113256000
Number: 6
18x18
Number: 4
20x20
Number: 9
22x22
Number: 8
24x24
Number: 4
Days: 9

Shear Walls: 033105350300
Normal Weight Concrete, Ready Mix
Extended Total: $120.10/CY
Extended Total O&P: $131.76/CY
Total Cubic Yards: **488.67**
Daily Output: 60
Days: 8.1 days

Wall Form: 031113852400
8-16ft: $9.90/sf
Total SF: **261**
Daily Output: 280
Days: **.93 days**
16+ft: $11.10/sf
Total SF: **261**
Daily Output: 235
Days: **1.11 days**

EXISTING BUILDING STEEL

Offices hopitals 7-15 stories: 051223770900
Total O&P: $3155.76/ton
Total weight: **455.34 tons**
Labor Hours: 9.014/ton
Total Hours: 4104.43 hours = 171 days

Schedule:

First Floor:

- Column Form: 1
- Columns: 9 days
- Slab Form: 1
- Slab reinforcement: 6
- Slab: 1
- Shear Wall w/ reinforcement: 1
- Total: 19 days

Second Floor – Seventh Floor

- Column Form: 1
- Columns: 6 days
- Slab Form: 1
- Slab reinforcement: 6
- Slab: 4
- Shear Wall w/ reinforcement: 1
- Total: 19days

Penthouse

- Column Form: 1
- Columns: 1 days
- Slab reinforcement: 6
- Slab: 1
- Shear Wall w/ reinforcement: 1
- Total: 10 days

Total Days: 143

Concrete Slab			
	SF	CF	CY
1st	3266	2721.667	100.8024691
2-7th	17862	14885	551.2962963
Penthouse	5374	4478.333	165.8641975
TOTAL	97950	81625	3023.148148

Columns							
	Size	Area (SF)	Height (ft)	CF	CY	#	Total CY
1st Floor	14x14	1.36	17.5	23.82	7.94	22	174.68
	18x18	2.25	17.5	39.38	13.13	4	52.50
	20x20	2.78	17.5	48.61	16.20	8	129.63
	24x24	4.00	17.5	70.00	23.33	8	186.67
2nd Floor	12x12	1.00	14.67	14.67	4.89	22	107.58
	18x18	2.25	14.67	33.01	11.00	12	132.03
	22x22	3.36	14.67	49.29	16.43	8	131.44
3rd Floor	12x12x	1.00	13.67	13.67	4.56	19	86.58
	16x16	1.78	13.67	24.30	8.10	14	113.41
	20x20	2.78	13.67	37.97	12.66	9	113.92
4th Floor	12x12	1.00	13.67	13.67	4.56	22	100.25
	16x16	1.78	13.67	24.30	8.10	14	113.41
	18x18	2.25	13.67	30.76	10.25	2	20.51
	24x24	4	13.67	54.68	18.23	4	72.91
5th Floor	12x12	1.00	13.67	13.67	4.56	22	100.25
	14x14	1.36	13.67	18.61	6.20	8	49.62
	16x16	1.78	13.67	24.30	8.10	12	97.21
6th Floor	12x12	1.00	13.67	13.67	4.56	30	136.70
	14x14	1.36	13.67	18.61	6.20	12	74.43
7th Floor	12x12	1.00	12.83	12.83	4.28	42	179.62
Penthouse	10x10	0.69	22.42	15.57	5.19	12	62.28
						TOTAL	2235.59

Columns Formwork						
First Floor	SF	DO/Crew	Crews	Days	Total O&P	Total Cost
14x14	1797	235	8	1	6.50	$11,678.33
18x18	420	238	2	1	6.52	$2,738.40
20x20	933	238	4	1	6.52	$6,085.33
24x24	1120	238	5	1	6.52	$7,302.40
Second Floor						
12x12	1291	225	6	1	6.74	$8,701.07
18x18	1056	238	4	1	6.50	$6,865.56
22x22	861	238	4	1	6.50	$5,594.16
Third Floor						
12x12	1039	225	5	1	6.74	$7,002.32

16x16	1021	235	4	1	6.50	$6,634.51
20x20	820	238	3	1	6.52	$5,347.70
Fourth Floor						
12x12	1203	225	5	1	6.74	$8,107.95
16x16	1021	235	4	1	6.50	$6,634.51
18x18	164	238	1	1	6.52	$1,069.54
24x24	437	238	2	1	6.52	$2,852.11
Fifth Floor						
12x12	1203	225	5	1	6.74	$8,107.95
14x14	510	235	2	1	6.50	$3,317.25
16x16	875	235	4	1	6.50	$5,686.72
Sixth Floor						
12x12	1640	225	7	1	6.74	$11,056.30
14x14	766	235	3	1	6.50	$4,975.88
Seventh Floor						
10x10	897	225	4	1	6.74	$6,044.43

Shear Walls				
Wall	Length	CY		Perimeter
2	25.42	2586.06		52.51
4	16.83	1712.17		35.33
6	7.67	780.29		17.01
7	13.59	1382.56		28.85
8	4.28	435.42		10.23
9	13.59	1382.56		28.85
10	4.28	435.42		10.23
11	13.59	1382.56		28.85
12	4.28	435.42		10.23
13	13.59	1382.56		28.85
14	4.28	435.42		10.23
	TOTAL	12350.43		261.13