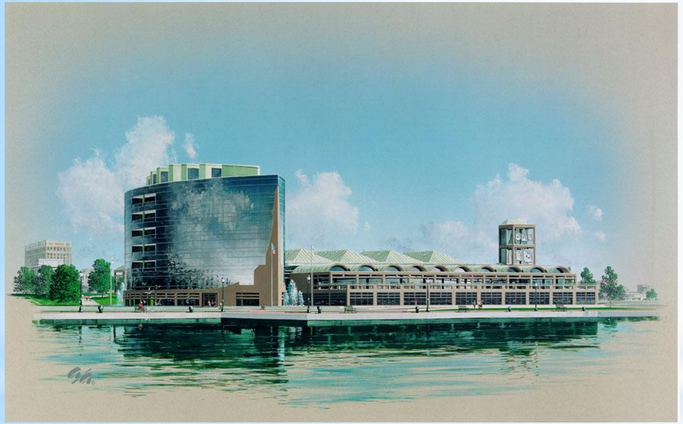
VIRGINIA ADVANCED SHIPBUILDING & CARRIER INTEGRATION CENTER

NEWPORT NEWS, VA

John Boyle
Structural Option
Thesis Advisor – Dr. Behr



Source: Clark-Nexsen

Source: Clark-Nexsen

ACKNOWLEDGEMENTS

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

Professor M. Kevin Parfitt
Professor Robert Holland
Dr. Behr

Kurt J. Clemente

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

- **Introduction**
  - **Building Statistics**
  - Architecture
- Existing Structural System
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- Column Redesign
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Building Statistics

- Building Occupancy Name: Northrop Grunman Newport News
- Occupancy Type: Office / Research / Shipbuilding Facility
- Size: 241,000 sf
- Number of Stories: 8
- Date of Construction: December 1999-February 2002
- Actual cost: $58 million
- Project Delivery: Design-Bid-Build

Project Team

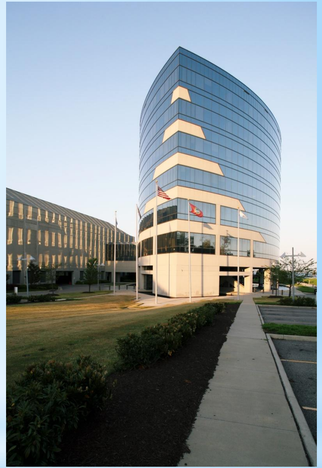
Clark-Nexsen Architecture & Engineering

Source: Clark-Nexsen

- **Introduction**
  - Building Statistics
  - **Architecture**
- Existing Structural System
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- Column Redesign
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Architecture

- Achieves light, open feel
  - Uses steel wide-flange members
  - Enclosed in reflective curtain wall
- Curve shape
  - Gives appearance of a tall, glass ship looking over the James River
- Concrete “figurehead”



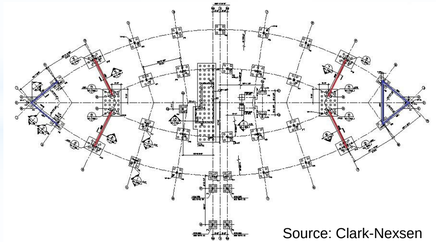
Source: Clark-Nexsen

- Introduction
- **Existing Structural System**
  - **Foundation**
  - Gravity
  - Lateral
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- Column Redesign
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Existing Structural System

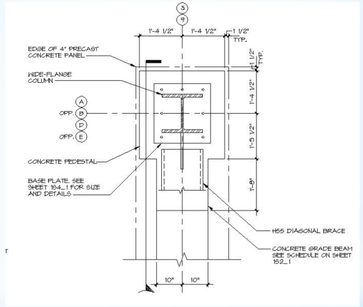
FOUNDATION

- Wide-flange steel column on a concrete pedestal
  - Placed around perimeter of the building
- Soil Condition: Unstable soil
- Grade beams: 20” & 22”
  - Resist lateral column base movement
  - Distribute weight of the building over soil



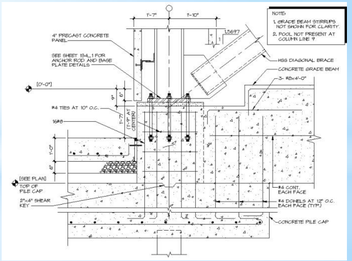
Source: Clark-Nexsen

CONC. PEDESTAL PLAN



Source: Clark-Nexsen

CONC. PEDESTAL SECTION



Source: Clark-Nexsen

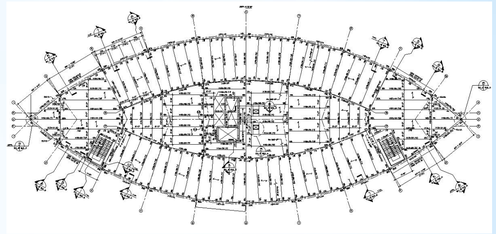
- Introduction
- **Existing Structural System**
  - Foundation
  - **Gravity**
  - Lateral
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- Column Redesign
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Existing Structural system

GRAVITY

- FLOOR
  - 4.5” total thickness composite steel deck and slab
    - Lightweight concrete placed 2” deep, .038” thick galvanized steel deck
    - Yield Strength: 33 ksi
- BEAMS / COLUMNS
  - Steel wide-wide flange members
  - W12x14 – W18x40 used for beams
  - W8, W10, W12, W14 used for columns

- 1st Floor
  - 5” slab on grade w/ 6x6 W2.9xW2.9 WWF (blue)
  - 8” slab on grade- #4 bars @ 12” o.c. (red)
  - 6” slab on grade w/ 6x6 W2.9xW2.9 WWF (green)

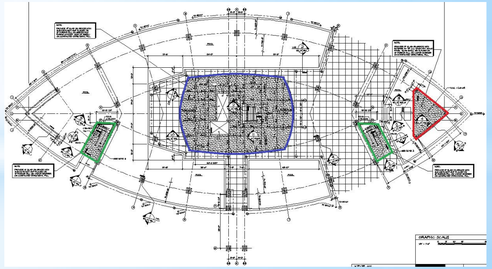


Floors 2-7
Structural Floorplan

Source: Clark-Nexsen

First Floor
Structural Floorplan

Source: Clark-Nexsen



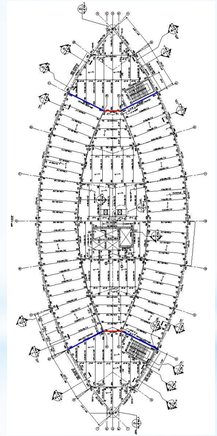
- Introduction
- **Existing Structural System**
  - Foundation
  - Gravity
  - **Lateral**
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- Column Redesign
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Existing Structural System

LATERAL

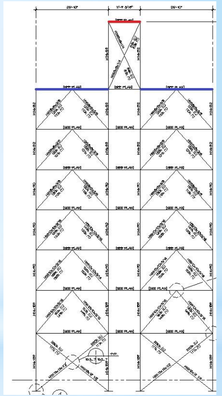
- K-Braced Frame
  - Wide-flange members used for vertical members
    - W14x82 – W14x90 – W14x159
  - HSS members used for cross-bracing
- X-Bracing used in 3 bays
  - Penthouse resists largest wind force
  - Bays on bottom level have added weight of floors above
  - X-bracing allows one member to be in tension and one to be in compression
- Caters well to the shape of the building
- Allows lateral loads to be distributed throughout the unique shape of the building

K-Braced Frame Location



Source: Clark-Nexsen

K-Braced Frame Section



Source: Clark-Nexsen

- Introduction
- Existing Structural System
- **Problem Statement**
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- Column Redesign
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Problem Statement

- Curved shape leads to confusing column layouts
- Current column layout leads to confusing beam and joist layouts
- Creates great differences in floor depth

- Introduction
- Existing Structural System
- Problem Statement
- **Proposed Solution**
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- Column Redesign
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Problem Solution

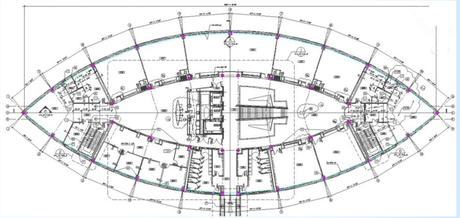
- Investigate new column layouts
- Redesign structural system using reinforced concrete
  - Composite Steel Deck / Wide flange steel beams
    - => Two-way flat slabs
  - Wide flange steel columns
    - => Reinforced concrete columns
  - K-Braced lateral resisting frame
    - => Shear walls
- Reduces floor thickness which will allow building to keep a light, open feel and may reduce cost

- Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- **Architectural Breadth: Column Layout Redesign**
- Slab Redesign
- Loads
- Column Redesign
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Architectural Breadth: Column Layout Redesign

- Original column layout:
  - Contains irregularly shaped bays
  - Crafted to shape of building

- Redesign
  - Created grid using existing perimeter columns
  - Created moderately sized, rectangular bays
  - Will make designing column strips and drop panels easier
  - Smallest Bay: 24’-11” x 2’-3”
  - Largest Bay: 29’-11” x 33’-10”
  - Columns are placed with little-to-no interference with the current floor plan

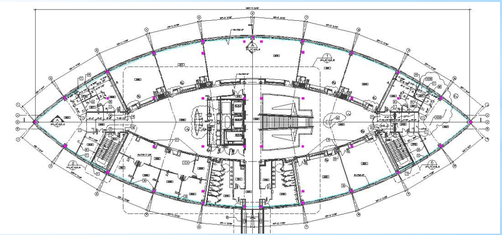


Current Column Layout

Source: Clark-Nexsen

Redesigned Column Layout

Source: Clark-Nexsen

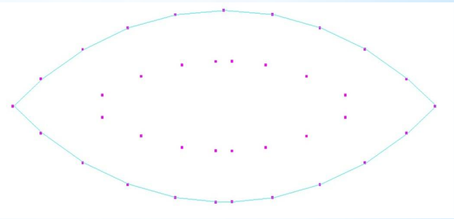


- Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- **Architectural Breadth: Column Layout Redesign**
- Slab Redesign
- Loads
- Column Redesign
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Architectural Breadth: Column Layout Redesign

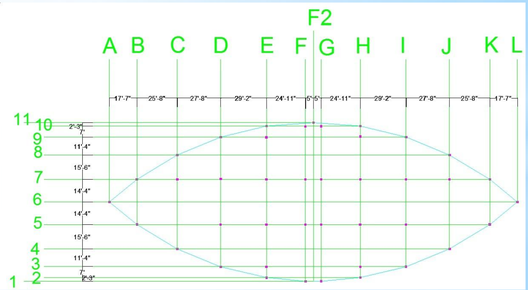
- Original column layout:
  - Contains irregularly shaped bays
  - Crafted to shape of building

- Redesign
  - Created grid using existing perimeter columns
  - Created moderately sized, rectangular bays
  - Will make designing column strips and drop panels easier
  - Smallest Bay: 24’-11” x 2’-3”
  - Largest Bay: 29’-11” x 33’-10”
  - Columns are placed with little-to-no interference with the current floor plan



Current Column Layout

Redesigned Column Layout



- Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- **Slab Redesign**
  - **Results**
  - Architectural Impact
- Loads
- Column Redesign
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

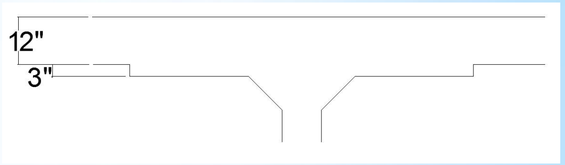
Slab Redesign

- Original floor system
  - Composite steel deck
  - Wide-flange steel beams
  - Floor thickness: 22.5”

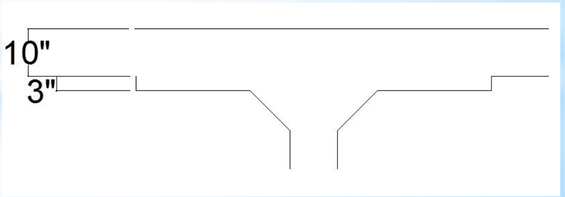
- Redesign
  - Two-way flat slab: 4,000 psi concrete
  - Advantages
    - Easy formwork
    - Simple bar placements
    - Minimize floor-to-floor heights

- Results
  - 12” thickness w/ 3” drop panels
  - Penthouse:
    - 10” thickness w/ 3” drop panels
  - Nearly 8”/floor reduction

SLAB THICKNESS FLOORS 1-7



SLAB THICKNESS PENTHOUSE



- Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- **Slab Redesign**
  - Results
  - **Architectural Impact**
- Loads
- Column Redesign
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Slab Redesign

- Architectural Impact
  - 8” reduction in floor thickness
  - Reduces total floor height by nearly 5 feet

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”

- Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- **Loads**
  - **Gravity**
  - Wind
- Column Redesign
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Loads

GRAVITY

- Live loads

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

Source: Clark-Nexsen

- 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

- Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- **Loads**
  - Gravity
  - **Wind**
- Column Redesign
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Loads

WIND

- Location: Newport News, VA
- Exposure: D (Building @ Shoreline)
- Occupancy: III
- Basic Wind Speed (V): 90 mph

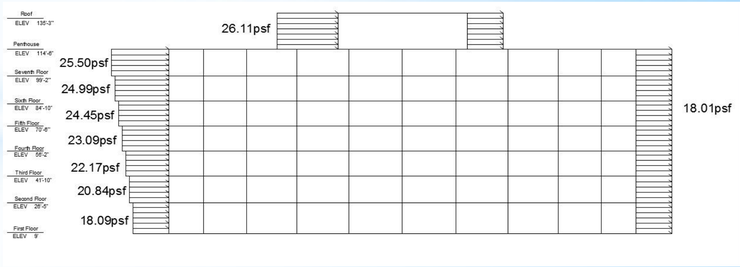
Wind Loads

	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

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

Wind Diagram



- Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- **Column Redesign**
  - **Design Criteria**
  - RAM Model
  - Results / Architectural Impact
  - Checks
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Column Redesign

DESIGN CRITERIA

- Original column design
  - Steel wide-flange members

- Redesign
  - Reinforced concrete columns w/ steel rebar
  - Columns kept as small as possible to retain the light, open feel of the current design

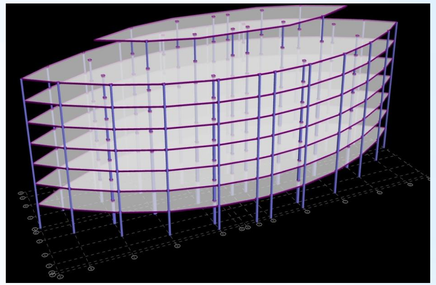
- Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- **Column Redesign**
  - Design Criteria
  - **RAM Model**
  - Results / Architectural Impact
  - Checks
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Column Redesign

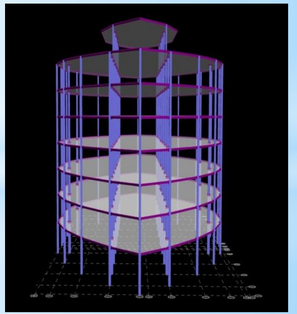
RAM MODEL

- DL: 80 psf
- LL carefully placed with floor plan
- Bar configurations:
  - # of bars range from 8-16

RAM Model



Front View



- Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- **Column Redesign**
  - Design Criteria
  - RAM Model
  - **Results / Architectural Impact**
  - Checks
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Column Redesign

RESULTS
- 10”x10” in penthouse
- 24x24” in first floor

ARCHITECTURAL IMPACT
- Columns larger than anticipated
- Larger columns located in more open, spacious areas

- Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- **Column Redesign**
  - Design Criteria
  - RAM Model
  - Results / Architectural Impact
  - **Checks**
- Lateral System Redesign
- CM Breadth: Cost Analysis
- Flood Analysis

Column Redesign

Checks

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

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

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

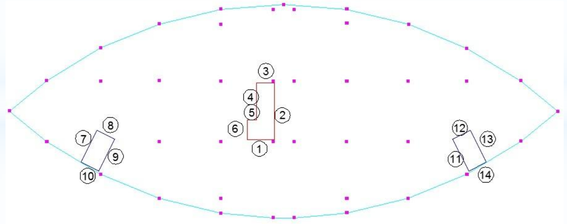
1559.2 < 1893.1 => ok

- Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- Column Redesign
- **Lateral System Redesign**
  - **Design Criteria**
  - Results
- CM Breadth: Cost Analysis
- Flood Analysis

Lateral System Redesign

- Original Lateral System
  - K-Braced Frame with steel wide-flange and HSS members

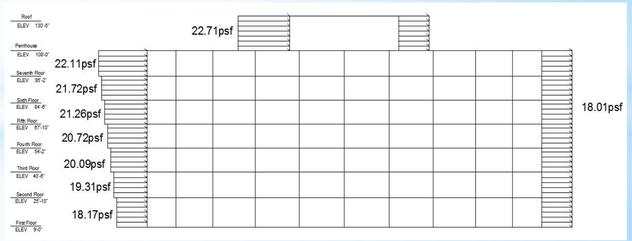
- Redesign
  - Reinforced concrete shear walls
  - Existing concrete walls used
    - Stair wells (blue)
    - Elevator shaft / mechanical space (red)



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

New Wind Diagram



- Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- Column Redesign
- **Lateral System Redesign**
  - Design Criteria
  - **Results**
- CM Breadth: Cost Analysis
- Flood Analysis

Lateral System Redesign

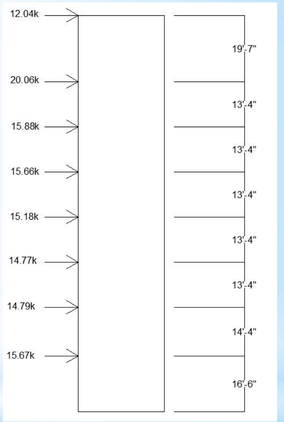
- Results
  - Both stairwell and elevator / mechanical space walls needed
  - 10” walls

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

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



- Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- Column Redesign
- Lateral System Redesign
- **CM Breadth: Cost Analysis**
- Flood Analysis

Construction Management Breadth: Cost Analysis

- Original Steel Design: $1,411,217

- Concrete Redesign: $1,285, 191
  - Slab: $831,960
  - Columns: $383,363
  - Shear Walls: $69,868

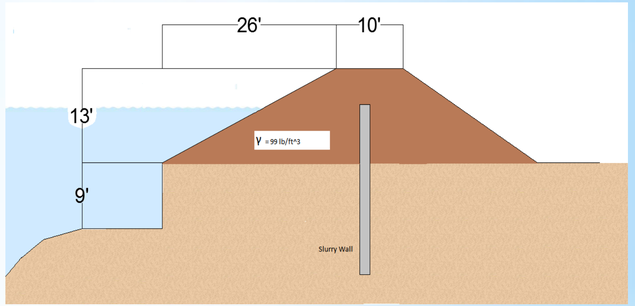
- Introduction
- Existing Structural System
- Problem Statement
- Proposed Solution
- Architectural Breadth: Column Layout Redesign
- Slab Redesign
- Loads
- Column Redesign
- Lateral System Redesign
- CM Breadth: Cost Analysis
- **Flood Analysis**

Flood Analysis

- Highest flood level of James River: 22 ft
- VASCIC 9 ft above sea level

- Levee Design
  - Soil: sand, dense and well graded
    - Aesthetically pleasing
    - Resists 811 lb/sf force acting on levee
    - Resists seepage
  - Slurry Wall: Soil-cement bentonite
    - High productivity
    - Verifiable continuity and depth
    - Excellent resistance to contaminated water
    - Ability to easily flex with ground movements
    - Greater trench stability possible
    - Resistant to erosion and burrowing animals

Levee Design



Thank You For Your Time