Image Provided By DCS Design

Kingstowne Section 36A

Office Building with Parking Garage

Fairfax County, VA

PSU AE Senior Thesis

April 8, 2013

James Chavanic

Structural

Image Provided By DCS Design

Image Provided By DCS Design

Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Image Provided By DCS Design

Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Project Information

BUILDING OVERVIEW

- 200,000 SF
- 8 Stories (4 Parking, 4 Office)
- Height = 101’-2” (86’-11” from Avg. Grade)
- $ 19 Million
- Construction: February 2012 – May 2013

PROJECT TEAM

Owner: Halle Companies

Architect:	Davis, Carter, Scott Ltd. (DCS Design)
GC:	L.F. Jennings Inc.
Civil Eng.:	Tri-Tek Engineering
Mech. Eng.:	Jordan & Skala Engineers
Struct. Eng.:	Cagley & Associates

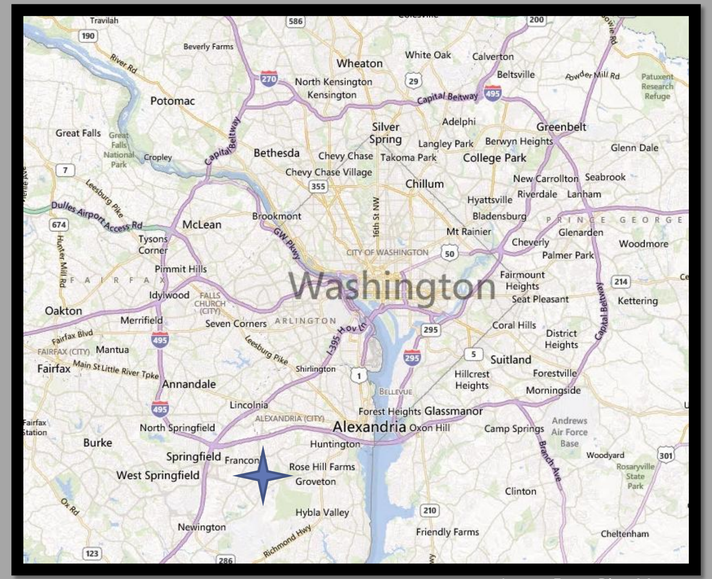
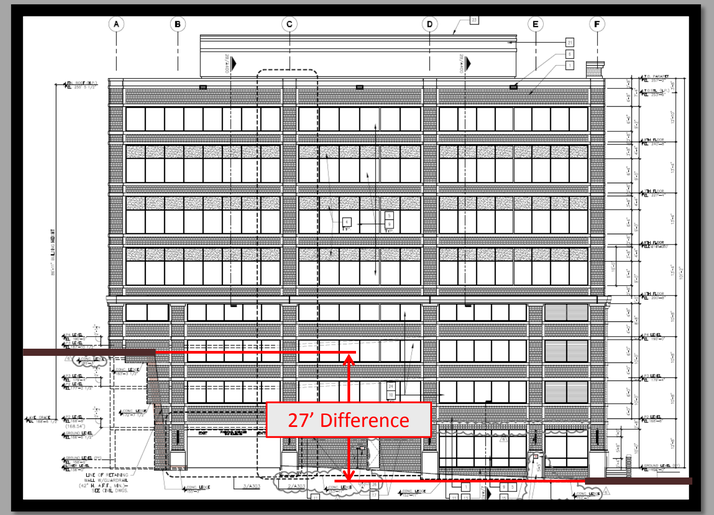


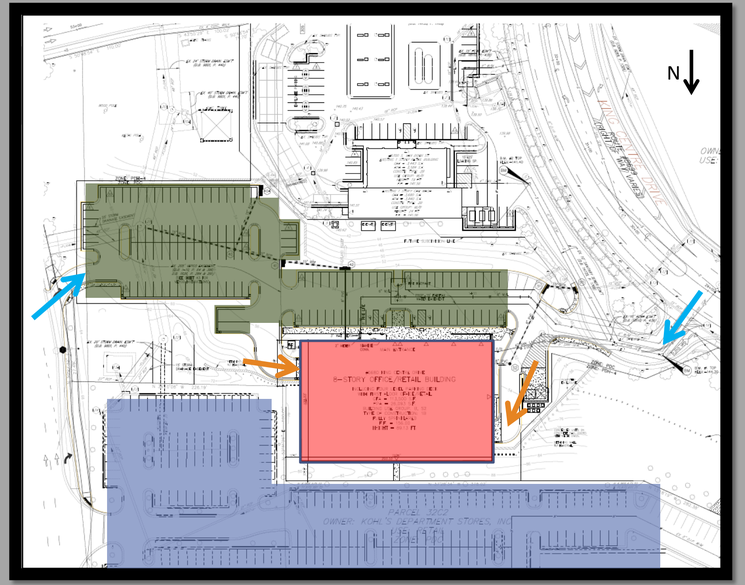
Image From Bing Maps

Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Site Relationship





Original Images: DCS Design

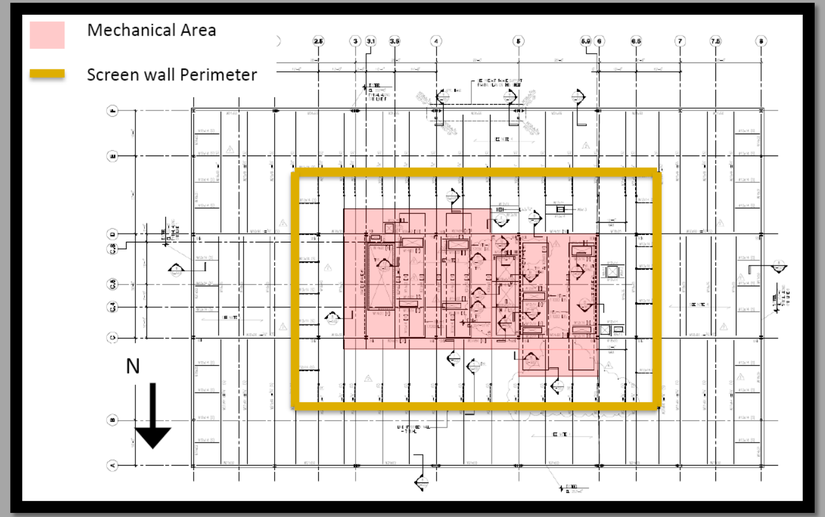
Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Existing Structure

ROOF

- 3.25” LW Concrete on 2” 18 GA Composite Deck (Mech. Areas)
- 3” x 20 GA Type N Roof Deck (Remaining Areas)
- Spans
  - A-C 45’-0” , C-D 36’-6” , D-F 43’-6”
  - East West Direction 28’-6”
- Composite action in mechanical areas
- (4) 17,000 lb. Roof-top Mechanical Units



Original Image: Cagley & Associates

Presentation Outline

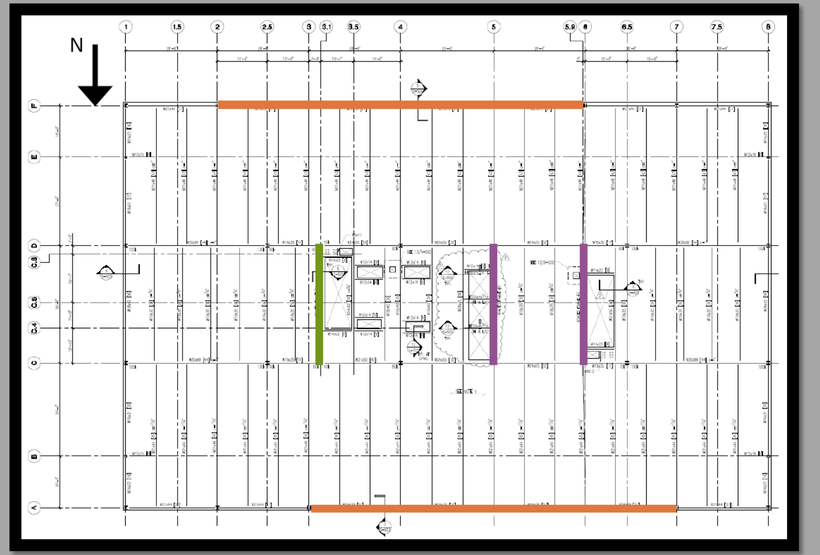
- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Existing Structure

OFFICE LEVELS 2 THROUGH 4

- 2” x 18 GA Composite Deck
- 3.25” LW Concrete Topping (3000 psi)
- Spans
  - A-C 45’-0” , C-D 36’-6” , D-F 43’-6”
  - East West Direction 28’-6”
- Composite action beams and girders
- 13’-4” Floor to floor height

- Lateral System
  - Moment Frames
  - Concentrically Braced Frames
  - Eccentrically Braced Frames



Original Image: Cagley & Associates

Presentation Outline

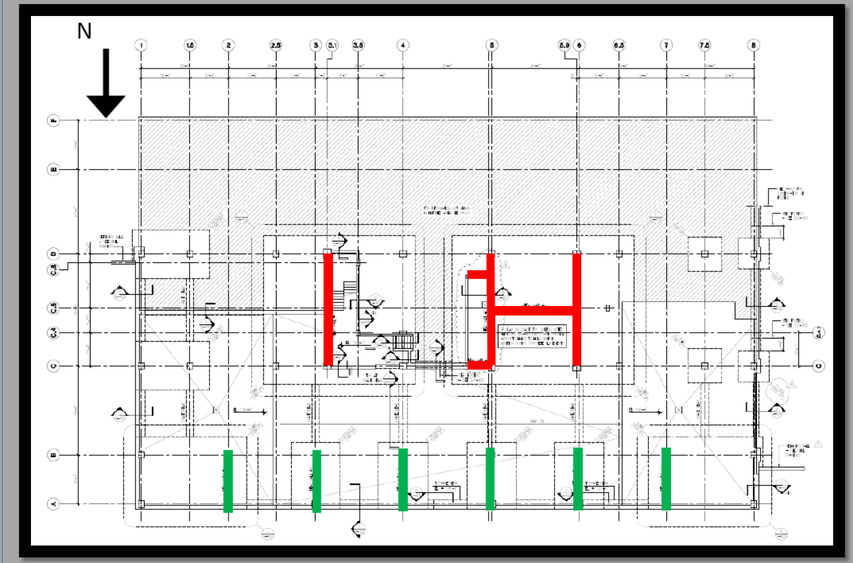
- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Existing Structure

PARKING LEVELS AND OL1

- 8” Thick concrete flat slab
  - #4 @ 12” O.C. Bottom Mat
- f'_c = 5000 psi
- Typical bay is 28’-6” x 29’-0”
- 24” x 24” Typical columns
- 10-8” Floor to floor height

- Lateral System
  - 12 Shear walls
  - 12” Thick
  - f'_c = 5000 psi
  - #5 @ 12” O.C. Typical E.F.



Original Image: Cagley & Associates

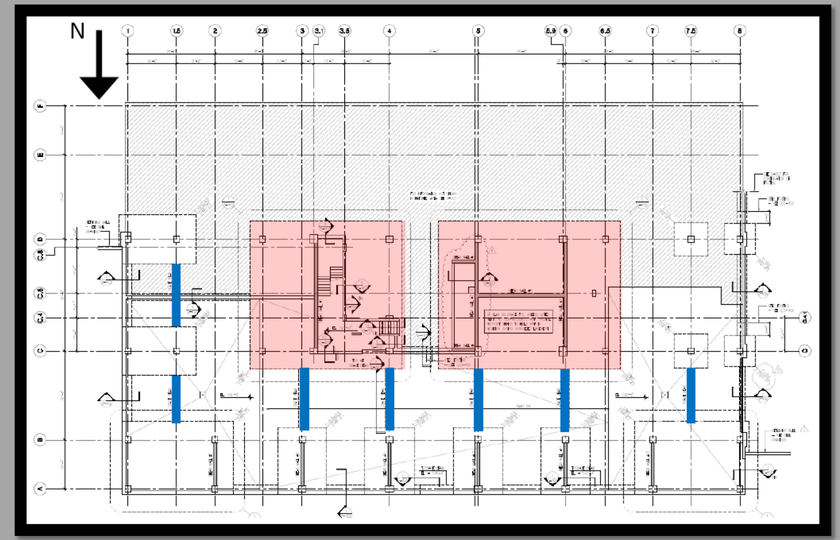
Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Existing Structure

FOUNDATION

- All Concrete f'c = 3000 psi
- 48" Thick concrete mat foundations
- Spread Footings
  - 7000 psi bearing capacity
  - 8' x 8' to 16' x 24'
- Strip Footings
  - 2500 psi bearing capacity
- Geopiers (Rammed Aggregate Piers)
  - 30" Dia. 16' deep
  - 100 k capacity each



Original Image: Cagley & Associates

Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Proposed Work

SETTING THE STAGE

- Currently, no tenant selected
- Police / Emergency services for Fairfax County, VA
- Risk Category IV (Originally Category II)
- U.S. Department of Defense Standards

www.defense.gov

www.gsa.gov

www.asce.org

Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Proposed Work

STRUCTURAL DEPTH

- Reinforced concrete
- Maintain flat slab system
- Gravity Design
  - Use designed OL1 for OL2 - OL4
  - Design edge beams
  - Design roof structure
- Lateral Design
  - Ordinarily reinforced concrete shear walls
- Progressive Collapse Design
  - Satisfy requirements adopted by the U.S. Dept. of Defense
- Goals
  - Reduce cost of structural system
  - Simplify construction

BREADTH 1: SITE REDESIGN

- Assess potential security issues
- Goal
  - Reduce risks to human occupants

BREADTH 2: FACADE REDESIGN

- Design glazing for worst scenario from site redesign
- Goals
  - Protect occupants of the building
  - Maintain thermal performance

MAE REQUIREMENTS

- AE 530 – Computer Modeling of Building Structures
- AE 538 – Earthquake Engineering
- AE 542 – Building Enclosure Science and Design

Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Gravity Design

GRAVITY SYSTEM

- 2 – way flat slab
  - Office levels
  - Significantly cheaper than existing steel system
  - Reduces floor-to-floor height
- Perimeter edge beams
  - Creates moment frames
  - Depth constrained to allowed structure plenum
- All columns continued from parking levels through office levels
  - 2 additional column lines
- Check strength of existing column designs
  - Higher loads

DESIGN CONSIDERATIONS

- Risk Category IV
  - I_{snow} = 1.2
- All Concrete f'_c = 5000 psi
- Façade Load
  - Assume 100 psf
- Floor to floor height
  - 9’-0” Floor to ceiling
  - 17” Clear space in existing Office structure
  - Provide 24” below flat slab
  - 8” slab system
  - Result = 11’-8”
  - Reduce overall by 7’-8”

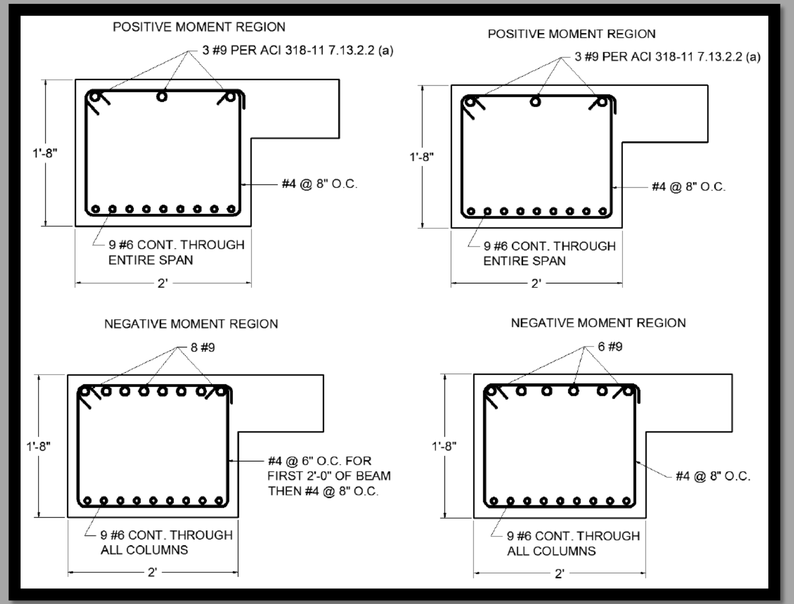
Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Gravity Design

DESIGN OF EDGE BEAMS

- GSA Design Guide Appendix B.3
  - 2(DL + 0.5L)
- 9’-0” Tributary Width
- 20” Trial Depth (2.5*h)
  - Gives sufficient beam/slab ratio
- ACI Moment Coefficients
  - East – West direction
- Frame Analysis
  - North – South direction
  - Pattern Loading



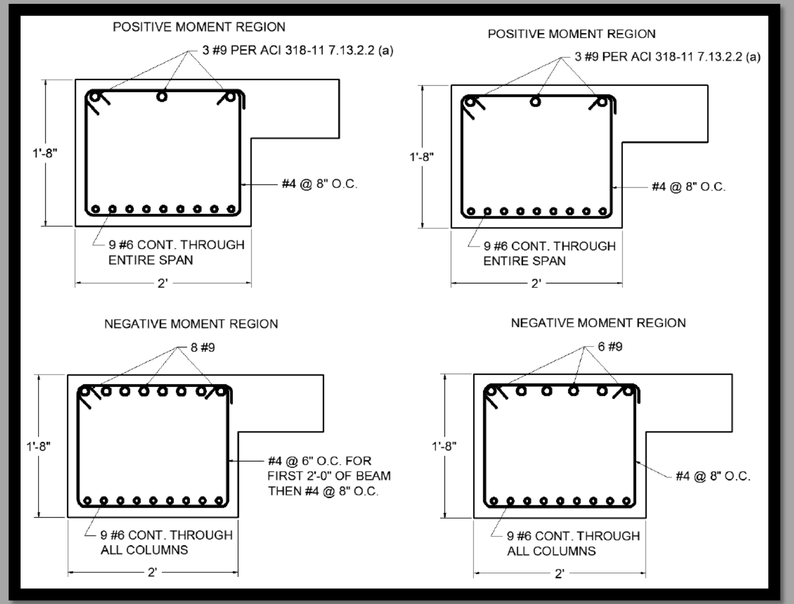
Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Gravity Design

DESIGN/CHECK OF COLUMNS

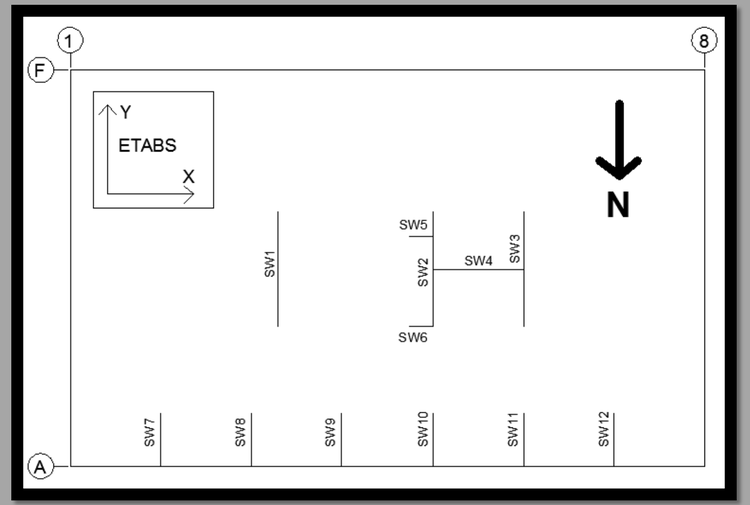
- GSA Design Guide Appendix B.3
  - 2(DL + 0.5L)
- Live load reduction considered
- Spliced at OL1
  - “Check” below
  - “Design” above
- Unbalanced moment from slabs
- Spreadsheet
  - Typical columns
  - Highest load columns
- Typically 129% of Original A_s



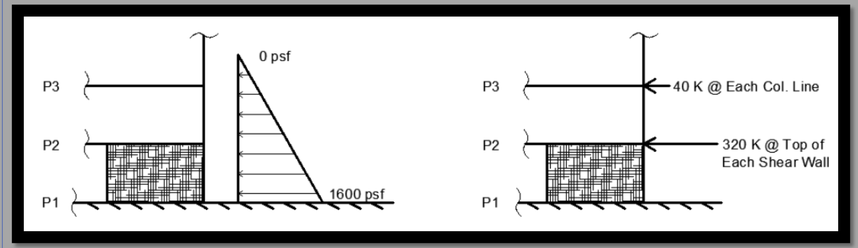
Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Lateral Design



SOIL LOAD



WIND LOAD

- 120 MPH (Cat. IV)
- Exposure B
- GC_{pi}
  - Office = 0.18
  - Parking = 0.55
- Cont. Base Shear
  - 765 k
  - North Blowing

SEISMIC LOAD

- Site Class = D
- $I_{seismic}$ = 1.5
- SDC = C
- R = 5 (ORC Walls)
- C_s = 0.0249
- Weight = 39,017 k
- Base Shear
  - 972 k

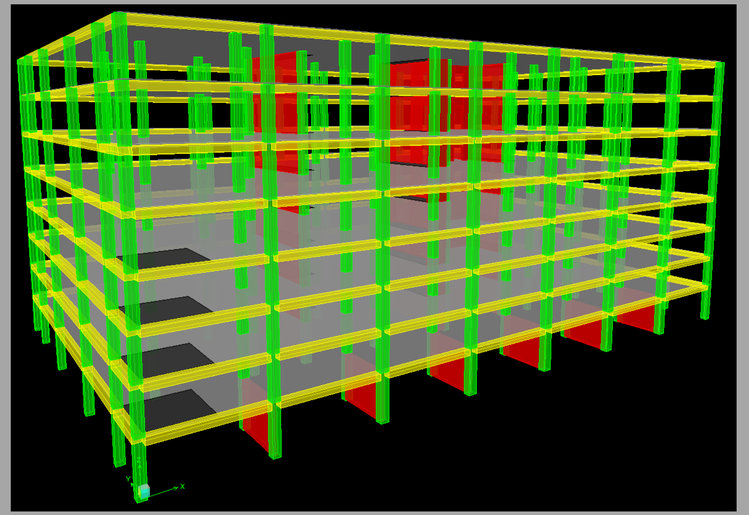
Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Lateral Design

ETABS MODEL

- All elements modeled
- Idealize parking levels
- Total height = 91’-4”
- Effects of cracked sections
- Rigid diaphragms
- Columns in-line with walls
- Walls
  - Membrane elements
  - 18” x 18” maximum mesh
- Seismic loads control
  - Extreme torsional irregularity N-S direction



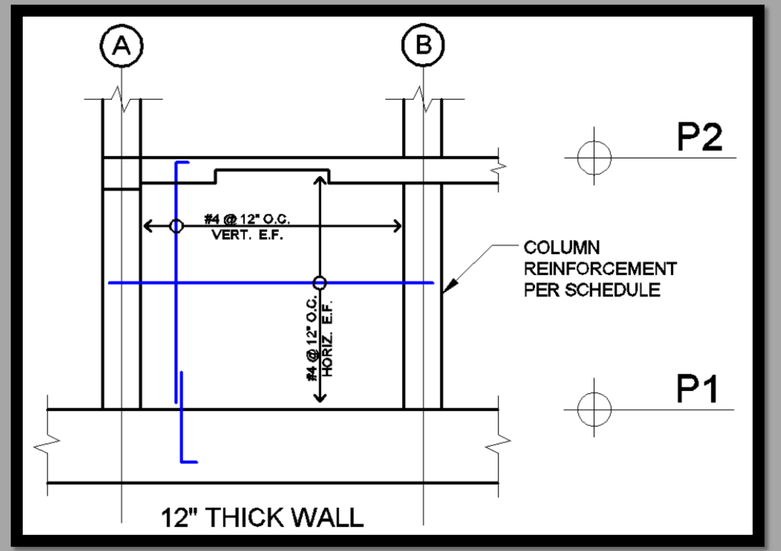
Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Lateral Design

SHEAR WALL DESIGN

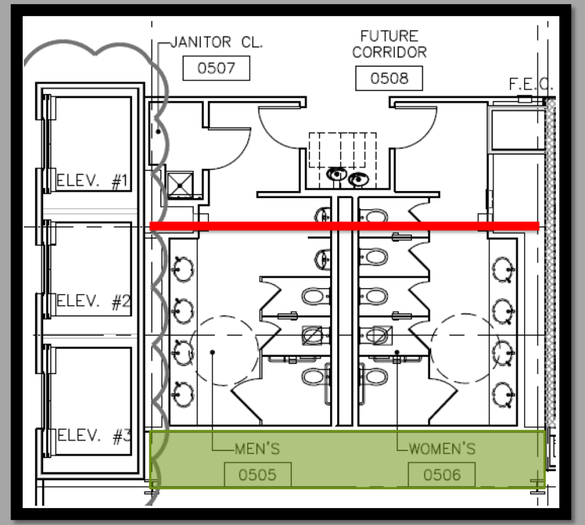
- SW7 – SW12 (Same Design)
  - SW7 Worst Case
  - Seismic N-S Controls
  - Primarily Soil Load
- SW1 – SW3 (Same Design)
  - SW1 Worst Case
  - Seismic N-S Controls
- SW5, SW6
  - Not in scope
- SW4
  - Architectural interference
  - Seismic E-W Controls

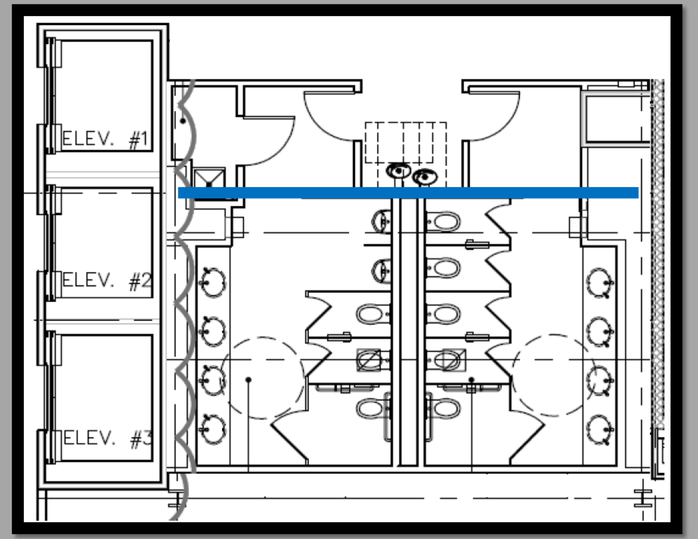


Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Lateral Design (SW4)





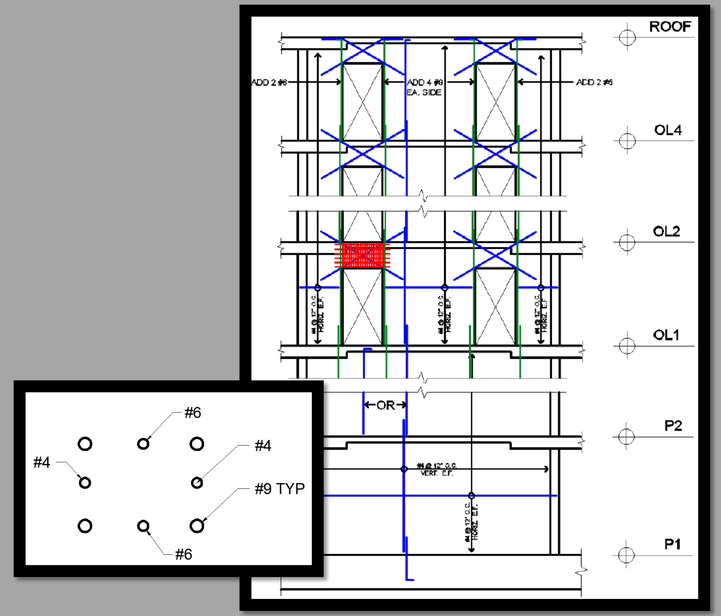
Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Lateral Design (SW4)

SHEAR WALL DESIGN

- Openings
  - 105” Tall
  - 54” Wide
  - Increased Reinforcement
- Coupling Beams
  - 35” Deep
  - ACI 318-11 21.9.7
  - Diagonal Reinforcement
  - Transverse Reinforcement
    - Tight Curtain
- Increase Boundary Reinforcement
  - Intersection w/ SW2 and SW3



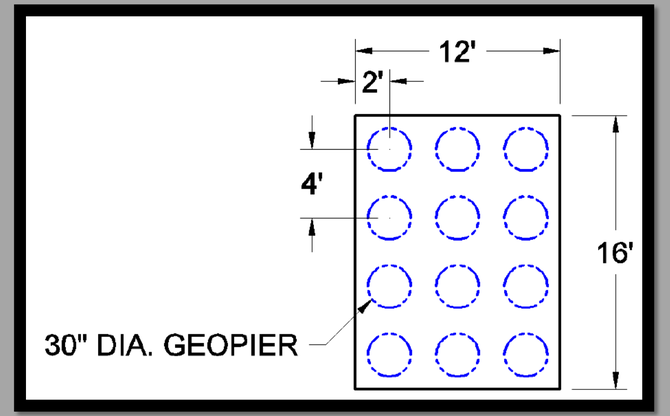
Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Foundation Impact

CHECK ON TYPICAL SPREAD FOOTING

- Gravity and Lateral Considered
  - Free Columns
    - Negligible Lateral Influence
  - Boundary Columns
    - High Lateral Influence
- Footing at C-1.5 Checked
  - ASD Combo (D + 0.75L + 0.75S) = 1165 k
  - 11’-0” x 11’-0”
  - Assuming 9 Geopiers
- Results
  - 12’-0” x 16’-0” (58% Inc.)
  - 12 Geopiers (33% Inc.)



Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

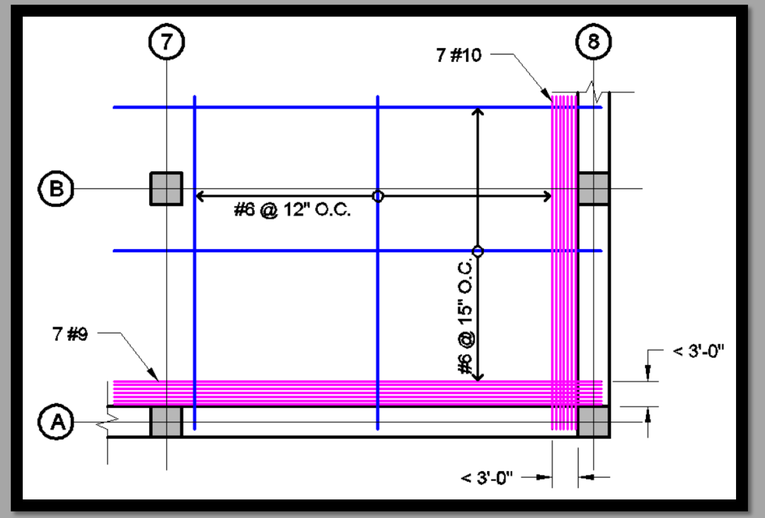
Propressive Collapse Design

REQUIREMENTS

- UFC 4-023-03
  - Occupancy Category IV
    - Tie Force Method
    - Alternative Path Method
    - Enhanced Local Resistance

TIE-FORCE METHOD

- $\phi R_n = \phi \Omega A_s F_y$
- Load Combo $W_f = 1.2D + 0.5L$
  - Internal Ties ($3W_f L_i$)
  - Peripheral Ties ($6W_f L_i L_p$)
  - Vertical Ties ($A_T W_f$)



Presentation Outline

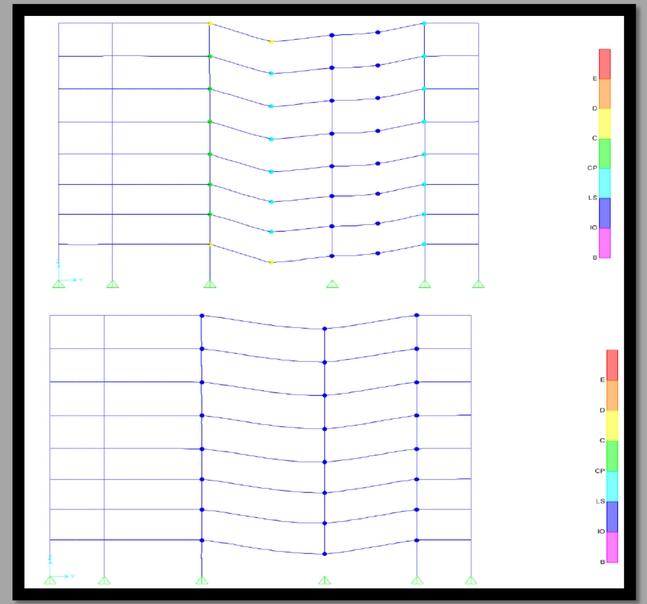
- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Propressive Collapse Design

ALTERNATE PATH METHOD

- Load Combo [(0.9 or 1.2)D + (0.5L or 0.2S)]
  - Increase at “Collapse” Bays (x 1.83)
  - Notional Lateral Load
    - 0.2% of Floor DL

- SAP 2000 Model
  - Hinge Properties Calculated
    - 0.03 Radians (LS)
  - Cracked Section Properties
  - Pinned Base Restraints



Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

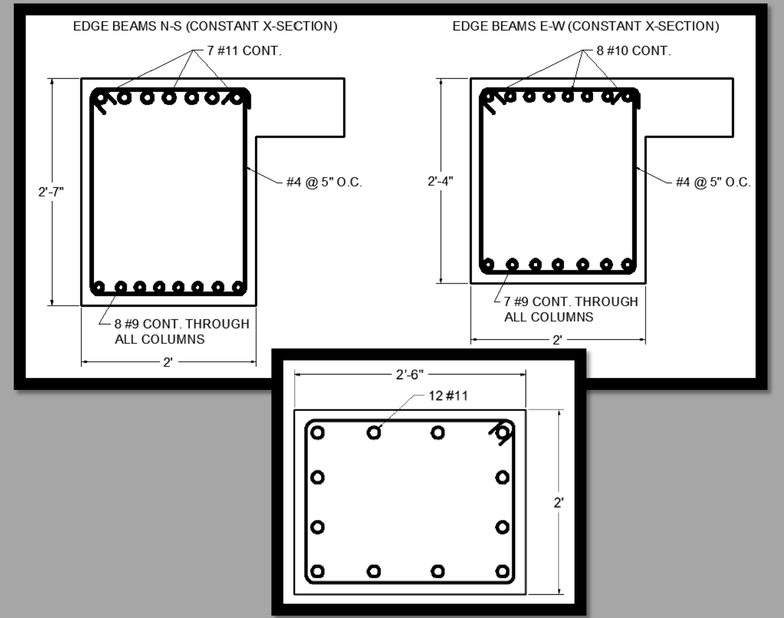
Propressive Collapse Design

ENHANCED LOCAL RESISTANCE

- Occupancy Category IV
  - First 2 Stories Above Grade
- Double Moment Capacity

RESULTING DESIGN

- 31” Deep Beams N – S Direction
- 28” Deep Beams E – W Direction
- Limit Aggregate Size



Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Structural Design Summary

SLABS

- 8” Thick Concrete
- Typical Bottom Mat
  - #6 @ 12” O.C. N – S
  - #6 @ 15” O.C. E – W

EDGE BEAMS

- Longitudinal Reinforcement
  - Varies #9, #10, #11
- Transverse Reinforcement
  - #4 @ 5” O.C.
- 24” Wide
- 28” – 31” Deep

COLUMNS

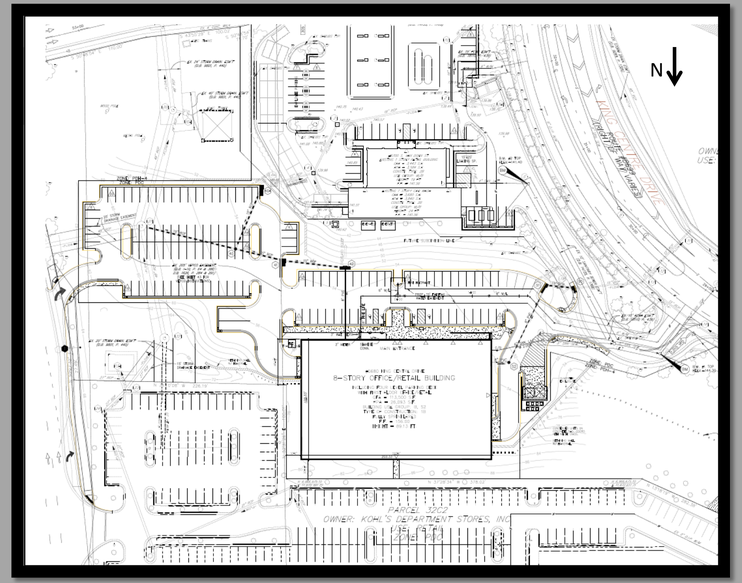
- 24” x 30” Exterior (12 #11 Bars)
- Interior Reinforcement Increases

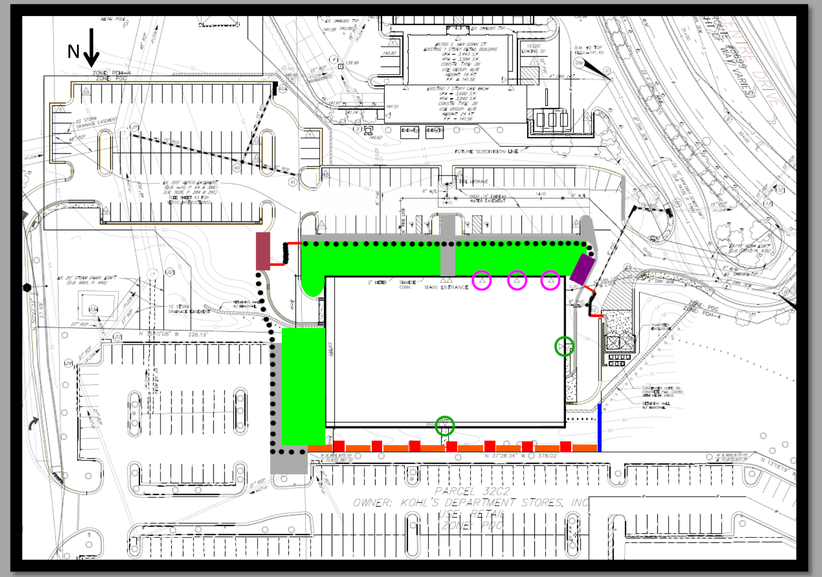
COST COMPARISON

- Existing Structure
  - $4,127,161
- All Concrete Structure
  - $4,541,898
- Difference
  - $414,737
- 8% Increase
  - Progressive collapse design
  - Edge beams
  - Result = $448,000 Additional Structure Cost

Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS





Presentation Outline

- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

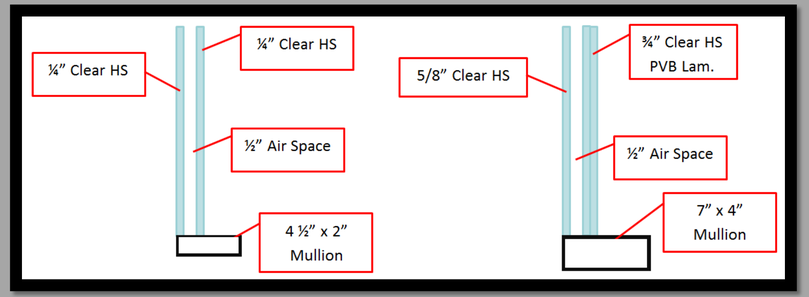
Glazing Design

DESIGN PARAMETERS

- 35’ Standoff Distance
- Small Car Bomb
  - 80 lb. TNT Equivalent

DESIGN GUIDES

- ASTM F2248-12
  - Equivalent 3s Blast Load
- E1300-12a
  - Glazing Design Tables



RESULTS

- All glass heat strengthened
- Occupants Protected
- Thermal Performance Not Achieved
  - More heat gain in summer
  - More heat gain in winter

Presentation Outline

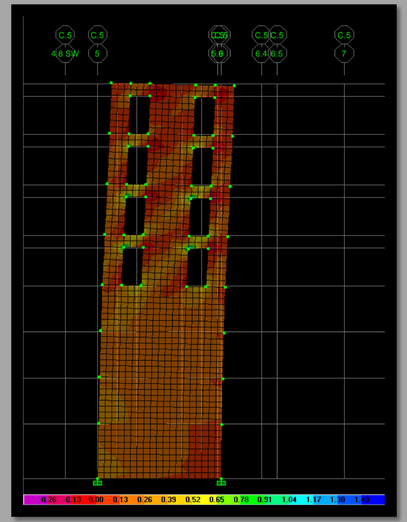
- BUILDING INTRODUCTION
- EXISTING STRUCTURE
- THESIS PROPOSAL
- STRUCTURAL DEPTH
- BREADTH 1: SITE REDESIGN
- BREADTH 2: FAÇADE REDESIGN (GLAZING)
- RESULTS
- QUESTIONS

Conclusion

- Successful design of structure using reinforced concrete
  - However, costs $448,000 more
- Meets requirements for OC IV Building
- Meets requirements of Department of Defense for progressive collapse
- Site safety increased, however not ideal
- Occupant safety increased
  - Lost thermal performance

Image Provided By DCS Design

QUESTIONS



ACKNOWLEDGEMENTS

- AE Faculty
  - Dr. Boothby
  - Dr. Lepage
  - Professor Parfitt
- AE Graduate Students
  - David Tran
  - Ryan Solnosky
- Cagley & Associates
  - Frank Malits
  - Nehemias Iglesias
- Halle Companies
  - Rich Rounds
- DCS Design
  - Carmencita Calong
- My family, fiancée, and friends