FDA OC/ORA Office Building

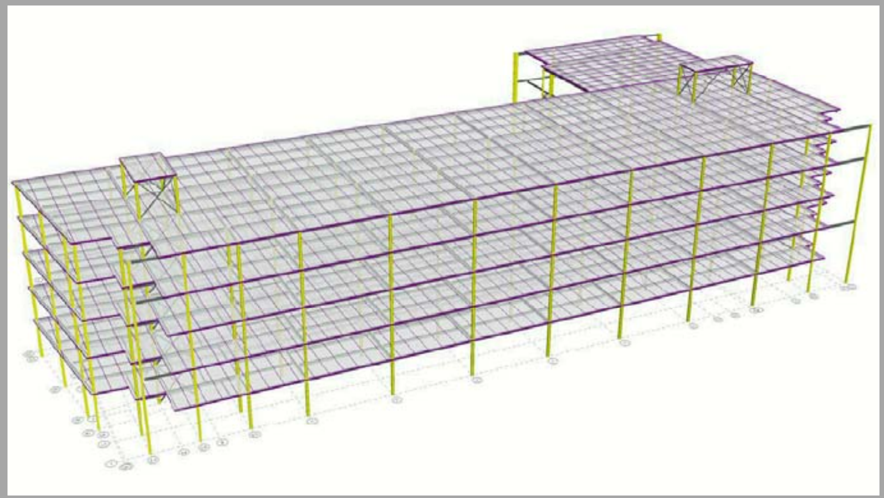
Silver Spring, MD

Adam Love

Structural

Senior Thesis Presentation 2010

The Pennsylvania State University



Presentation Outline

- **Introduction**
- Structural Redesign
- Progressive Collapse
- Mechanical Considerations
- Conclusions
- Questions

Presentation Outline

- **Introduction**
  - Presentation Outline
  - Existing Conditions
  - Goals and Objectives
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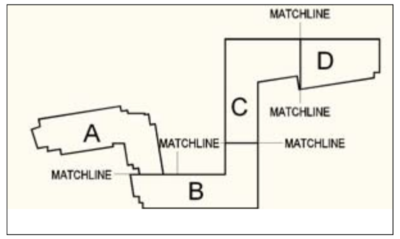
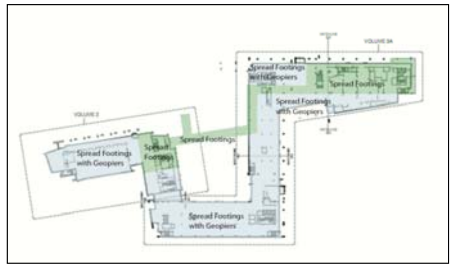
Existing Conditions



•Architecture: Divided into four wings
Façade is a Brick Veneer
Curtain Wall Structure

•Structure: Reinforced Concrete Columns
supported with spread footings
on GeoPiers
Reinforced Concrete Two-Way Flat Slab

•Building Name: FDA OC/ORA Office Building
•Location and Site: Silver Spring, MD
•Function: Office Building with Mixed Use
•Size: 500,000 S.F.
•Number of Stories: Building 31: 4 Stories
Building 32: 5 Stories
•Final Contract Cost: $110 Million
•Delivery Method: Lump Sum Project



Existing Conditions

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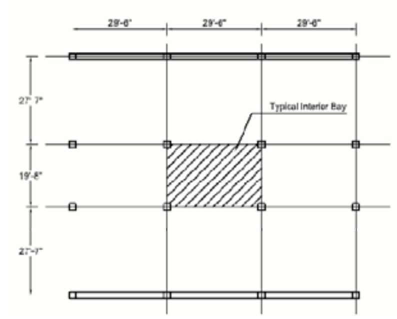

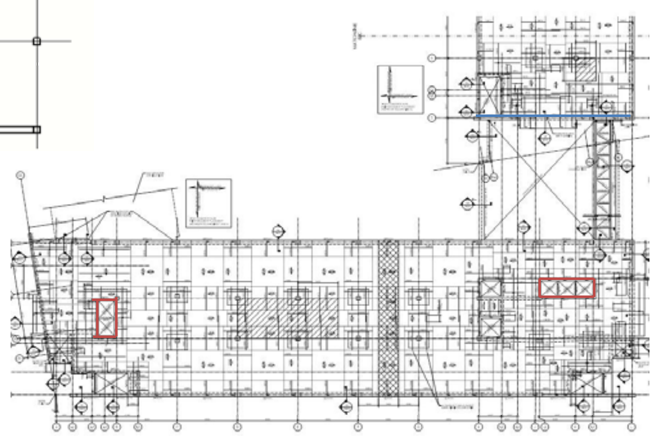

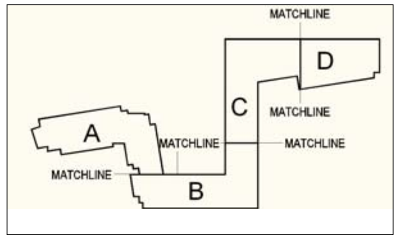

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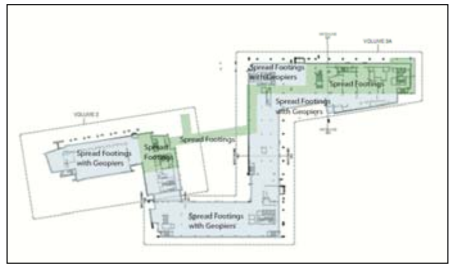

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Goals and Objectives

•Structural Redesign
- • Design a lateral resisting system to decrease the eccentric effects of Wing B.

•Connection Design
- • Design typical connections throughout the structure to support the required loading

•Progressive Collapse Design
- •Study the design of structures to resist progressive collapse.

•Impacts on New Design
- •Look at the cost and Schedule impacts for the new structural design.
- •Revaluate the mechanical system for the new structural system.

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  - Lateral Framing
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Structural Redesign

•Gravity Loads

Live Loads					
	Design		GSA 05	ASCE 7-05	
Location	kPa	psf	psf	psf	
Office	3.8	79.36	80	50	
Typical Roof	1.5	31.33		20	
Public Lobbies	4.8	100.25		100	
Mech Room	7.3	152.46		150	(Assumed)
Telecom Room	12	250.63	250	150	
Redestrian Bridge	4.8	100.25		60	
Balconies	4.8	100.25		100	
High Density Filing	12	250.63		250	(Assumed)
Green Roof	1.5	31.33		100	

Dead Loads		
	psf	
Superimposed Dead Load (MEP, Ceiling)	15	(Assumed)
Roofing System	40	(Assumed)
Mechanical Unit	150	(Assumed)
Exteior Curtain Wall	30	(Assumed)
Atrium Cutrain Wall	20	(Assumed)
Mechanical Pentouse Walls	20	(Assumed)

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Structural Redesign

•Lateral Loads

Design Wind Loads in N-S Direction				
	External Windward Load (kips)	External Leeward Loads (kips)	Base Shear (kips)	
			1.0W	1.6W
Level 1	0	0		
Level 2	31.771	16.907	**48.678**	**77.884**
Level 3	33.480	15.398	**48.878**	**78.205**
Level 4	36.700	15.398	**52.098**	**83.356**
level 5	39.327	15.398	**54.725**	**87.560**
Roof	25.274	9.578	**34.851**	**55.762**
Parapet	5.010	1.879	**6.889**	**11.022**
Base Shear			**246.119**	**393.790**

Design Wind Loads in E-W Direction				
	External Windward Load (kips)	External Leeward Loads (kips)	Base Shear (kips)	
			1.0W	1.6W
Level 1	0	0		
Level 2	14.675	7.809	**22.484**	**35.974**
Level 3	15.464	7.112	**22.576**	**36.122**
Level 4	16.951	7.112	**24.064**	**38.502**
level 5	18.165	7.112	**25.277**	**40.443**
Roof	11.674	4.424	**16.098**	**25.756**
Parapet	2.314	0.868	**3.182**	**5.091**
Base Shear			**113.680**	**181.888**

Seismic Loads					
Level	Story Weight w_x (kips)	Height h_x (ft)	Lateral Force F_x (Kips)	Base Shear (kips)	
2	1711.82	15.82	17.12		
3	1696.03	28.31	16.96		
4	1696.03	41.2	16.96		
5	1696.03	54.09	16.96		
Roof	2680.3	66.98	26.80		
			$\Sigma F_x = V_x =$	95	**kips**

•Gravity Loads

Live Loads					
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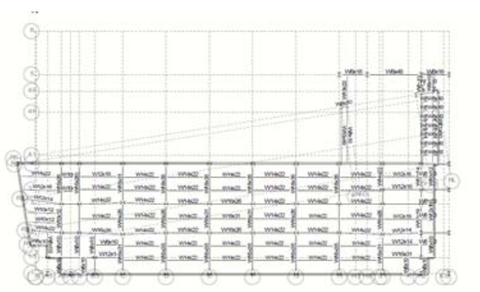
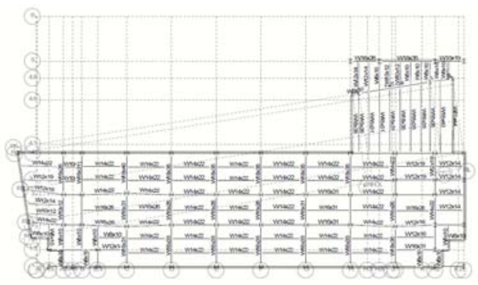
Structural Redesign

•Steel Framing



Second Floor Framing



Roof Floor Framing

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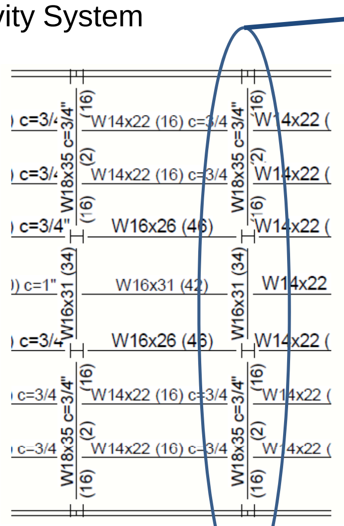
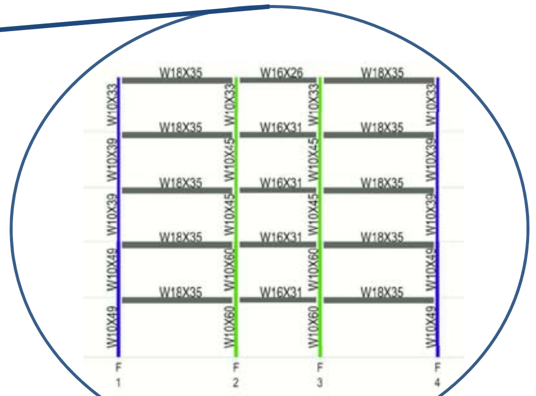
Structural Redesign

•Gravity System

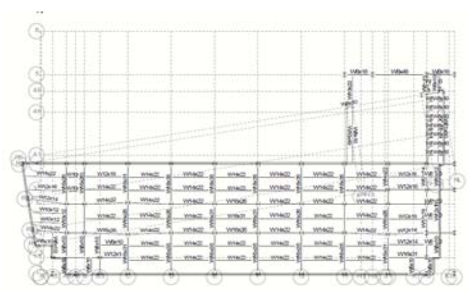


Beam Design



Column Design

•Steel Framing



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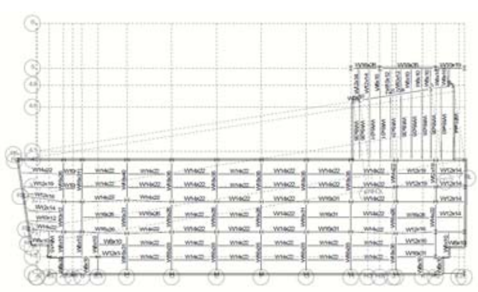

Roof Floor Framing

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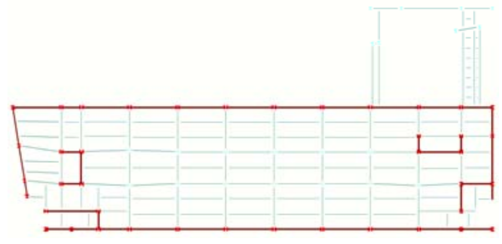
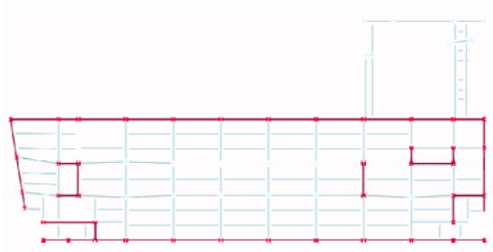
Structural Redesign

•Lateral Analysis



RAM Model 1



RAM Model 2

Center of Rigidity Compariosn for RAM Models						
	RAM Model 1		RAM Model 2		COM of Both Models	
	X (ft)	Y (ft)	X (ft)	Y (ft)	X (ft)	Y(ft)
Roof	85.26	41.25	128.47	41.35	154.33	49.98
Floor 5	91.23	41.02	131.95	41.09	142.63	41.12
Floor 4	104.65	41.025	140.67	41.13	142.64	41.12
Floor 3	126.14	40386	153.38	40.86	142.65	41.11
Floor 2	158.01	40.42	171.24	40.32	138.75	40.98
* RAM Model 2 adds Brace at Grid H						

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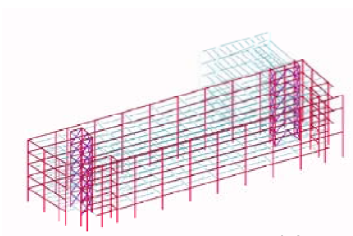
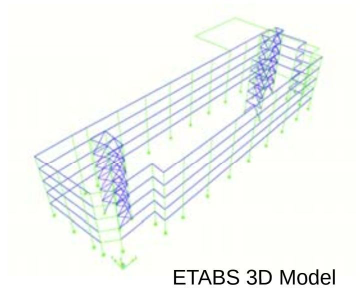


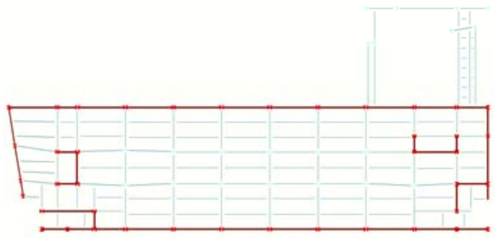
RAM 3D Model



ETABS 3D Model

3D Model Period Comaprisons										
RAM Model 1				RAM Model 2				ETABS Model		
	Direction	Period (s)			Direction	Period (s)			Direction	Period (s)
Mode 1	2.145	Z		Mode 1	1.4798	Z		Mode 1	1.1971	Z
Mode 2	1.2959	X		Mode 2	1.3521	X		Mode 2	1.0513	X
Mode 3	1.1244	Z		Mode 3	1.1173	Z		Mode 3	0.8627	Z
*Braced Frames at Core				*Additional Brace				*Same as RAM Model 2		
*Exterior Moment Frames										

•Lateral Analysis



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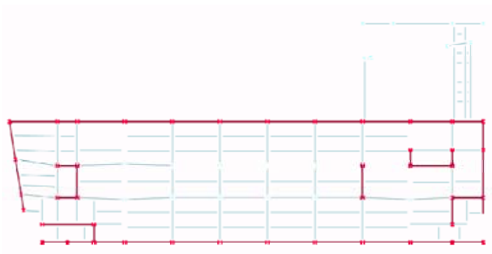

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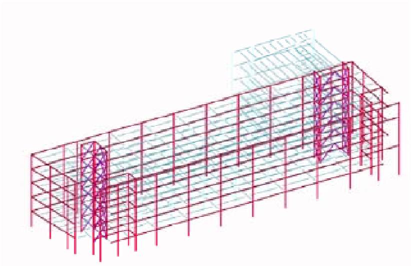
Structural Redesign

- Lateral Framing



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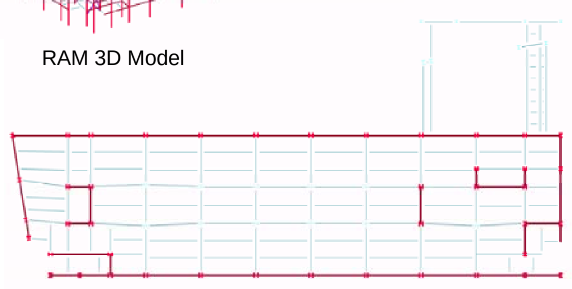
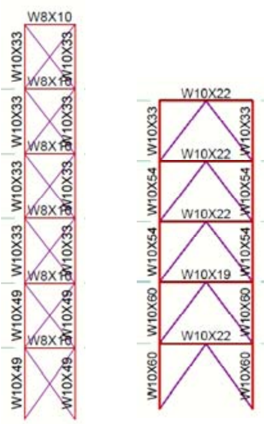


Lateral Framing Plan



Braced Frame Design

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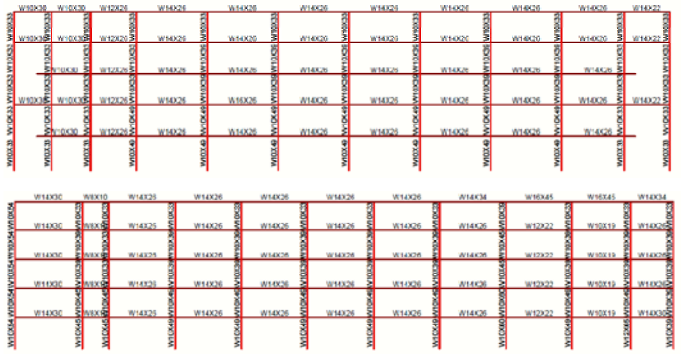
Structural Redesign

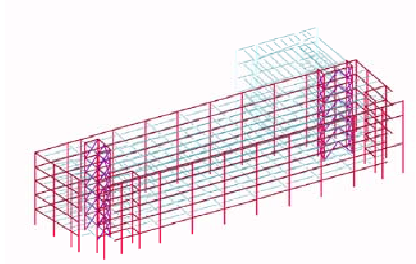
•Lateral Framing



Moment Frame Design

Drift Study from RAM							
		Displacements			Drift		
	hx	Displ X	Displ Y	Allow.	Drift X	Drift Y	Allow.
Roof	12.89	0.3611	1.1775	1.9716	0.0543	0.2794	0.3867
5th	12.89	0.3068	0.8981	1.5849	0.0747	0.29	0.3867
4th	12.89	0.2321	0.6081	1.1982	0.0878	0.271	0.3867
3rd	12.89	0.1443	0.3371	0.8115	0.1443	0.3371	0.3867
2nd	14.16	0.0596	0.135	0.4248	0.0596	0.135	0.4248

•Lateral Framing



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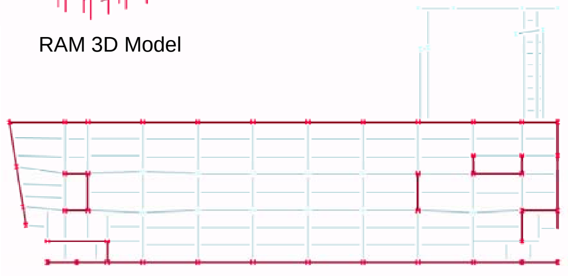
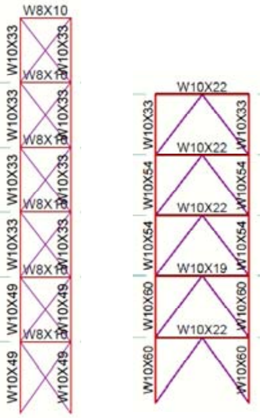


Lateral Framing Plan



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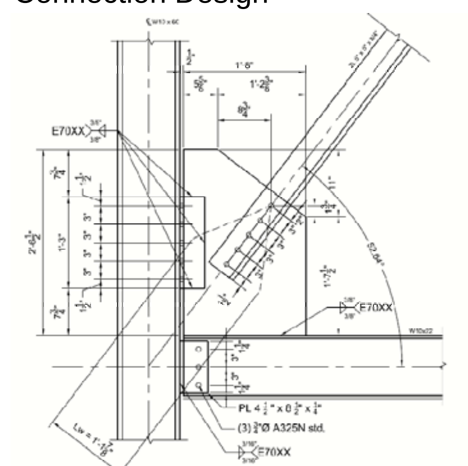
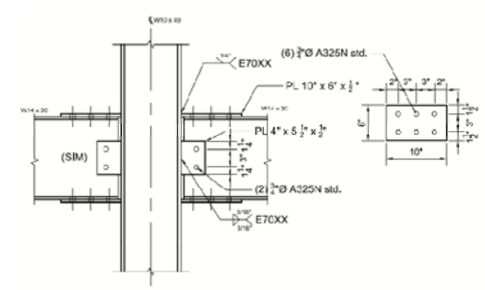
•Connection Design



Typical Braced Connection



Typical Moment Connection
(Lateral Beam to Column Flange)

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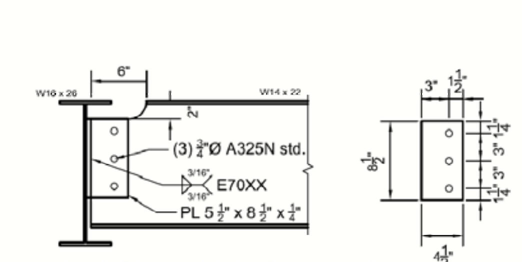
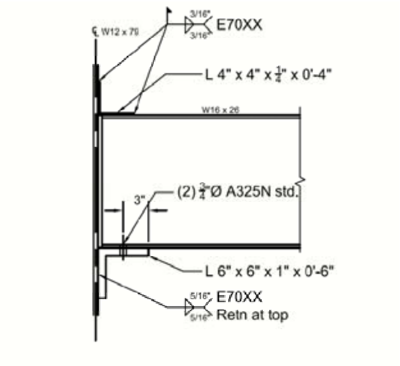
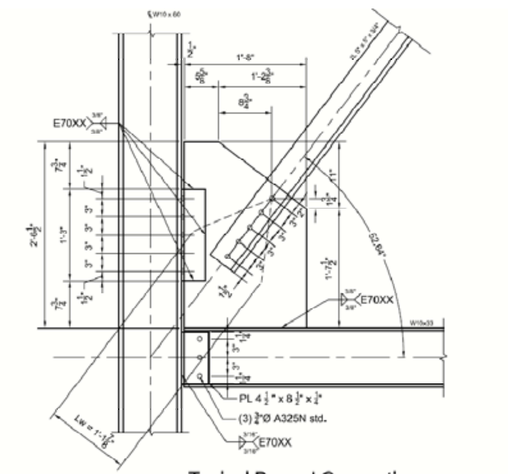
•Connection Design



Typical Shear Tab Connection
(Beam to Girder Connection)



Typical Seated Connection
(Girder to Column Web Connection)



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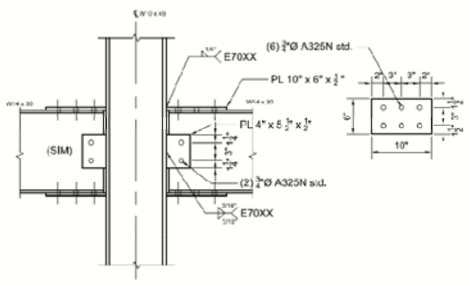

Typical Moment Connection
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- **Progressive Collapse**
  - Basic Concepts
  - GSA Standards
  - DOD Standards
  - Design (GSA Method)
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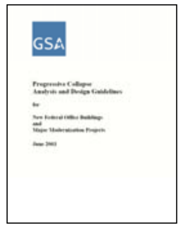
Progressive Collapse

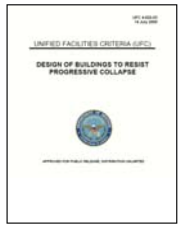
•Basic Concepts

• What is Progressive Collapse and How is it designed for?
  •Collapse or Disproportionate Collapse
  •Connection Design, Redundancy

• Other methods to protect buildings against unforeseeable events.
  •Standoff Distance, and Blast Resistant Design

• Methods of Design
  •U.S. General Services Administration Standards (GSA)
  •Department of Defense Standards (DOD)





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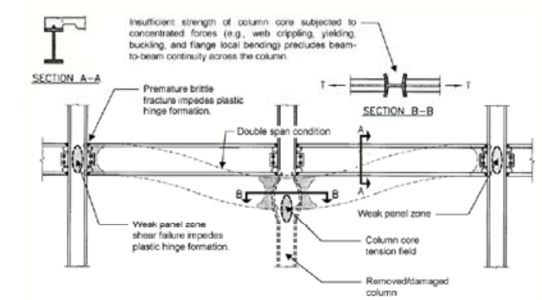
Progressive Collapse

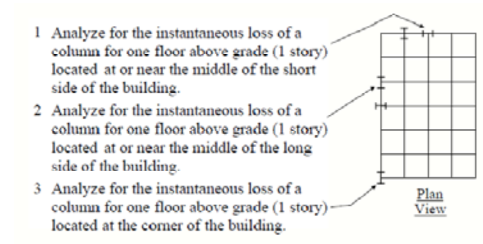
- Progressive Collapse Analysis and Design Guideline

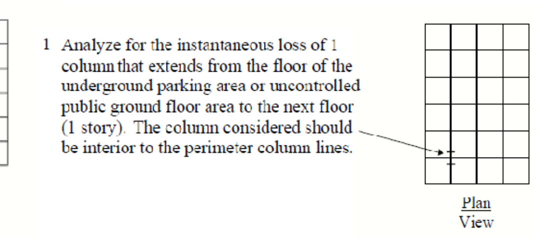
  - Design Guidance
    - Provide discrete beam-to-beam continuity
    - Connection Resilience, Redundancy, and Rotation

  - Analysis Procedure
    - Linear Elastic Static Analysis Approach
      - Use of non linear analysis is acceptable
    - Recommends use of 3D Modeling.
      - 2D Modeling is more conservative
    - Exterior and Interior Considerations
      - Load = 2(DL + .25LL)

  Acceptance Criteria
    - Demand Capacity Ratios: DCR = Q_{UD} / Q_{CE}







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Progressive Collapse

•Analysis Methods for Alternate Path Method

• Linear Static Method
  • Limited to structures that are considered Regular.
    •If irregularity exist, linear static can be used of DCR is less than 2.0.
  • Demand forces are compared to the acceptance criteria.

• Nonlinear Static Method
  • No DCR or regularity limitations
  • Demand forces are compared to the acceptance criteria.

• Nonlinear Dynamic Method
  •Gravity and lateral loads are applied to the structure

Linear Static Analysis	
$G_{LD} = \Omega_{LD}[(.9 \text{ or } 1.2)D + (.5L \text{ Or } .2S)]$	$\Phi m Q_{CE} \geq Q_{UD}$
$G_{LF} = \Omega_{LF}[(.9 \text{ or } 1.2)D + (.5L \text{ Or } .2S)]$	$\Phi Q_{CL} \geq Q_{UF}$
$G = [(.9 \text{ or } 1.2)D + (.5L \text{ Or } .2S)]$	
$L_{LAT} = .002\Sigma P$	

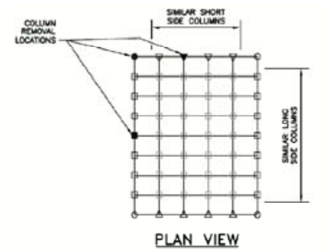
Nonlinear Static Analysis	
$G_N = \Omega_N[(.9 \text{ or } 1.2)D + (.5L \text{ Or } .2S)]$	$\Phi Q_{CL} \geq Q_{UF}$
$G = [(.9 \text{ or } 1.2)D + (.5L \text{ Or } .2S)]$	
$L_{LAT} = .002\Sigma P$	

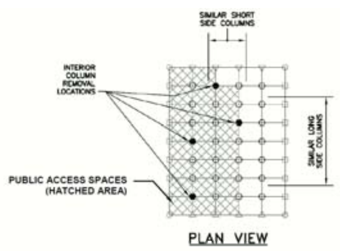
Nonlinear Dynamic Analysis	
$G_{ND} = \Omega_{ND}[(.9 \text{ or } 1.2)D + (.5L \text{ Or } .2S)]$	$\Phi Q_{CL} \geq Q_{UF}$
$L_{LAT} = .002\Sigma P$	

• Unified Facilities Criteria: Design of Buildings to Resist Progressive Collapse

• Three Methods of Design and Analysis
  •Tie Force Method, Alternate Path Method, and Enhanced Local Resistance

•Alternate Path Method Analysis Procedures
  • Linear Static, Nonlinear Static, and Nonlinear Dynamic
  • Primary and Secondary Elements
  • Stories to Analyze





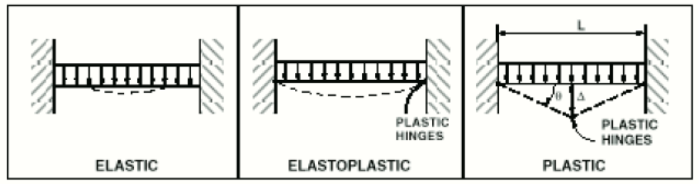
Presentation Outline

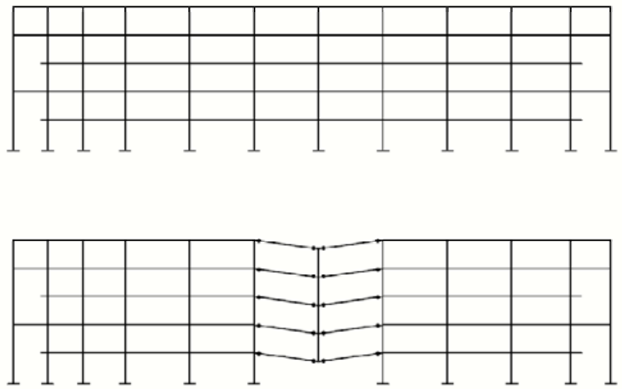
Progressive Collapse

- Progressive Collapse Design
  - Using the GSA Method, and Nonlinear Analysis
    - Exterior moment frame along Grid 1 chosen for analysis
  - Application of Load and Collapse Area
    - RL = 326 kips FL = 277.1 kips
    - Area of collapse = 1627 S.F.
  - Progressive Collapse Design

Progressive Collapse Design Summary

	Original Design	Applied Load (Kips)	Total Load (Kips)	Required Mp (ft-kips)	DCR	New Design
Roof	W14x22	326	326	1604.5	3	W21x62
5th	W14x22	277.1	603.1	2968.3	2	W33x118
4th	W14x22	277.1	880.2	4332.1	3	W24x146
3rd	W14x22	277.1	1157.3	5695.8	3	W33x141
2nd	W14x22	277.1	1434.4	7059.6	3	W33x169





Presentation Outline

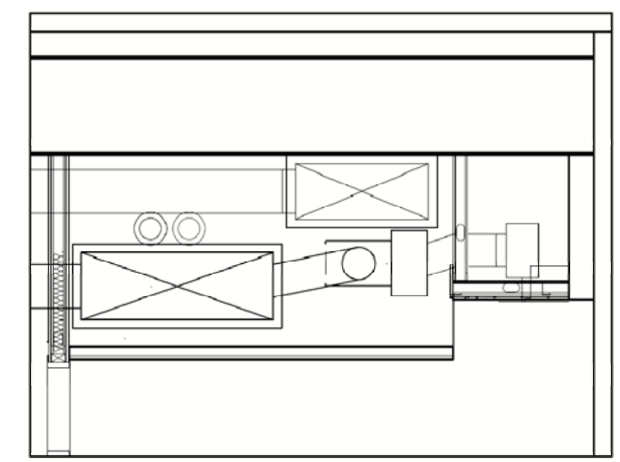
- Introduction
- Structural Redesign
- Progressive Collapse
- **Mechanical Considerations**
  - Feasibility Study
  - Supply Duct Design
- Conclusions
- Questions

Mechanical Coordination

- Mechanical Coordination and Design
  - Feasibility Study
    - Original Design
  - Airflow Assumptions
    - Existing airflow
    - Assumed airflow velocity
  - New Mechanical Design

Mechanical Design			
	cfm	v (ft/s)	A (ft^2)
Duct 1	3385.97	20	2.82
Duct 2	2101.93	20	1.75

Mechanical Design Summary			
		Width	Heigth
Original Design	Duct 1	29.53"	15.75"
	Duct 2	25.59"	11.81"
New Design	Duct 1	35.5"	12"
	Duct 2	24"	11"



Presentation Outline

- Introduction
- Structural Redesign
- Progressive Collapse
- Mechanical Considerations
- **Conclusions**
  - Conclusions/ Lessons Learned
  - Ideas to Build On
- Questions

Conclusion

- Conclusions
  - Structural redesign
    - A lighter structure
    - Minimum impact on architecture
    - Lateral System effective for deflection, Torsion still a problem,
  - Progressive Collapse
    - GSA Standards vs. DOD Standards
  - Cost and Schedule Analysis
    - Decrease cost
    - Faster schedule
    - Local Market Considerations
  - Mechanical Coordination
    - Acceptable redesign

Presentation Outline

- Introduction
- Structural Redesign
- Progressive Collapse
- Mechanical Considerations
- **Conclusions**
  - Conclusions/ Lessons Learned
  - Ideas to Build On
- Questions

Conclusion

- Ideas to Build on/ Lessons learned
  - Gravity System
    - The gravity design is much lighter, vibration and acoustical issues should be considered
    - Connections designed were very effective, with minor constructability issues.
  - Lateral System
    - The current design could be improved to better minimize eccentric effects
  - Progressive Collapse
    - A 3D Model should be developed to further study progressive collapse.
    - Current moment connections are not efficient

- Conclusions
  - Structural redesign
    - A lighter structure
    - Minimum impact on architecture
    - Lateral System effective for deflection, Torsion still a problem,
  - Progressive Collapse
    - GSA Standard are more conservative for progressive collapse.
    - DOD Standard is more specialized for each building
  - Cost and Schedule Analysis
    - Initial results conclude a decrease cost and faster schedule for the new structural system.
    - However, local market favors Two-way Flat Slab Construction.
  - Mechanical Coordination
    - The mechanical ducts could be effectively resized to fit under the new structural floor system.

Presentation Outline

- Introduction
- Structural Redesign
- Progressive Collapse
- Mechanical Considerations
- Conclusions
- **Questions**
  - **Questions**
  - **Acknowledgements**

Questions

Thesis Research

Course Materials:

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- Acknowledgements
  - Turner Construction (For Providing the building documentation and support)
    - Mike Stigliano
  - Tompkins Builders
    - Jeremy Wong
  - The Pennsylvania State University
    - Dr. Linda Hanagan
    - Dr. Louis Geschwindner
    - Dr. Ali Memari
    - Professor Parfitt
    - Gaby Issa-El-Khoury