THE CROSSROADS AT WESTFIELDS - BUILDING II

CHANTILLY, VA

THE DEPARTMENT OF ARCHITECTURAL ENGINEERING

THE PENNSYLVANIA STATE UNIVERSITY

SENIOR THESIS 2009

PRESENTATION OUTLINE

- BUILDING INTRODUCTION
- PROPOSED GOALS
- STRUCTURAL DEPTH
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    - OPTIONS BREAKDOWN
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    - FINAL DESIGN
    - COST COMPARISON
- ARCHITECTURAL BREADTH
  - INTRODUCTION
  - DESIGN
  - ADDITIONAL COSTS
- COMPARISONS & CONCLUSIONS
- QUESTIONS

BUILDING INTRODUCTION

- LOCATION: CHANTILLY, VA (WESTFIELDS CORPORATE CENTER)
- TYPE: 5-STORY OFFICE BUILDING (68 FT)
- BUILDING AREA :155,692 GSF
- COST: $14.5 MILLION
- PROJECT TEAM
  - OWNER: THE ALTER GROUP
  - STRUCTURAL DESIGN: STRUCTURA
  - ARCHITECT: HICKOK COLE

➢ NEVER CONSTRUCTED, PROJECT CURRENTLY ON HOLD

➢ AT CROSSROADS OF LEE RD. AND STONECROFT BLVD, HENCE THE NAME

➢ 41 FT BAYS CREATE AN OPEN FLOOR PLAN FOR TENANT FLEXIBILITY

CROSSROADS AT WESTFIELDS

SITE PLAN

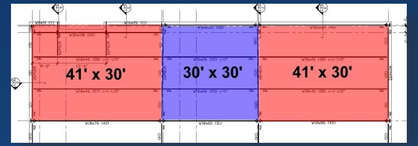
FLOOR PLAN

EXISTING SITE

ELEVATION

BUILDING INTRODUCTION

- FOUNDATION SYSTEM
  - REINFORCED CAST-IN-PLACE CONCRETE FOOTINGS (3-6 KSI)
  - 4” SLAB ON GRADE
- FLOOR SYSTEM
  - 3” COMPOSITE STEEL DECK WITH 3 ¼” LW CONC. SLAB
  - EXTERIOR BAYS ARE 41’ x 30’ & INTERIOR BAYS ARE 30’x30’

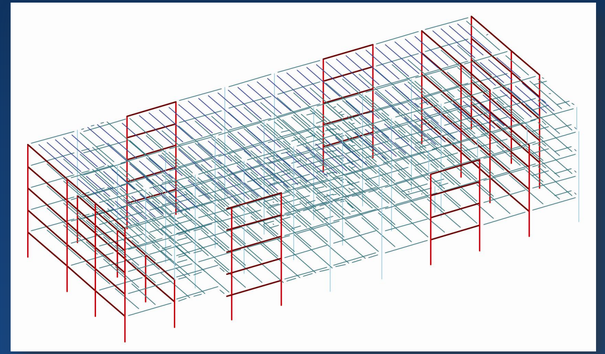


- ROOF SYSTEM
  - ROOF FRAMING CONSISTS OF K-SERIES JOISTS
  - SCREEN WALL CONSTRUCTED OF LIGHTGAGE FRAMING

EXISTING STRUCTURE

EXISITNG LATERAL SYSTEM

- 4 MOMENT FRAMES IN EACH DIRECTION



PROPOSED PROBLEMS

STRUCTURAL ISSUES

• EXISTING LATERAL SYSTEM CONSISTS OF 8 MOMENT FRAMES WHICH ADDS A LOT OF EXTRA WEIGHT TO THE BUILDING

HYPOTHETICAL SITUATION

• WITH THE CLOSE PROXIMITY TO OUR NATION CAPITAL AND ITS LOCATION IN A CORPORATE CENTER, BUILDING II WILL BE CONSIDERED A ‘HIGH-PROFILE’ BUILDING FOR THIS REPORT.

PROPOSED SOLUTION AND GOALS

• REDESIGN THE EXISTING LATERAL SYSTEM TO BE MORE COST EFFICIENT

• REDESIGN THE STRUCTURE TO MITIGATE THE RISK OF PROGRESSIVE COLLAPSE USING TWO DIFFERENT THREAT LEVELS

• ACHIEVE BOTH P.C. DESIGNS USING THE NEW LATERAL SYSTEM AND STILL PRODUCE A MORE COST EFFICIENT STRUCTURE THAN ORIGINAL

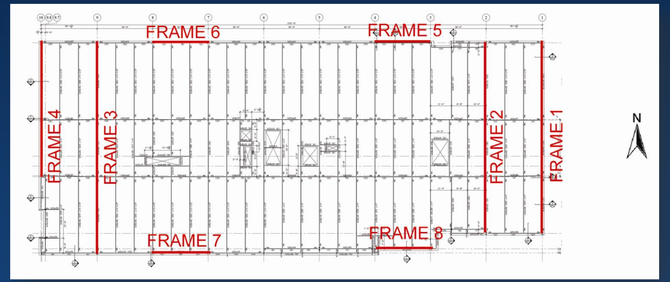
• REDESIGN THE SITE AND HARDEN THE FAÇADE TO PROTECT THE BUILDING FROM A POTENTIAL ATTACK

- ✓PRESENTATION OUTLINE
- ✓ BUILDING INTRO
- ✓ PROPOSED GOALS
- ✓ **STRUCTURAL DEPTH**
- ✓ **LATERAL REDESIGN**
- • PROGRESSIVE COLLAPSE DESIGN
- • ARCHITECTURE BREADTH
- • COMPARISONS & CONCLUSIONS
- • THANK YOU
- • QUESTIONS

STRUCTURAL DEPTH

LATERAL REDESIGN

ORIGINAL (R=3)



Design Base Shears - Original		
Lateral Force	**North-South**	**East-West**
	R=3	R=3
Wind	342 K	144 K
Seismic	210 K	210 K

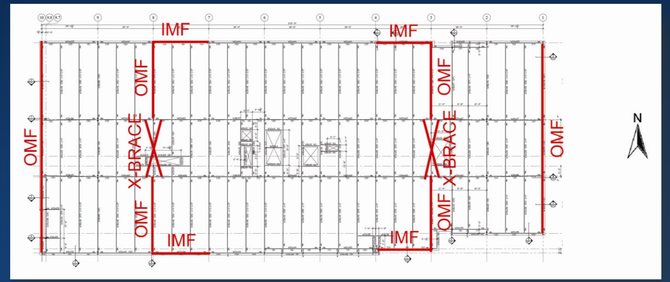
OPTION A-1 (R=8)

Design Base Shears - Option A-1		
Lateral Force	**North-South**	**East-West**
	R=8	R=8
Wind	342 K	144 K
Seismic	124 K	124 K

STRUCTURAL DEPTH

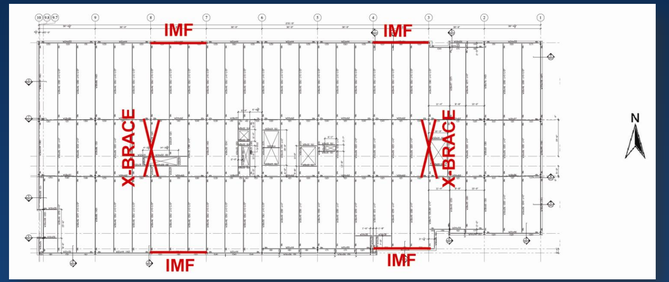
LATERAL REDESIGN

OPTION B-1 (R= 6 N-S, R =4.5 E-W)



Design Base Shears - Option B-1		
Lateral Force	**North-South**	**East-West**
	R=6	R=4.5
Wind	315 K	144 K
Seismic	123 K	142 K

OPTION B-2 (R= 3 N-S, R=4.5 E-W)

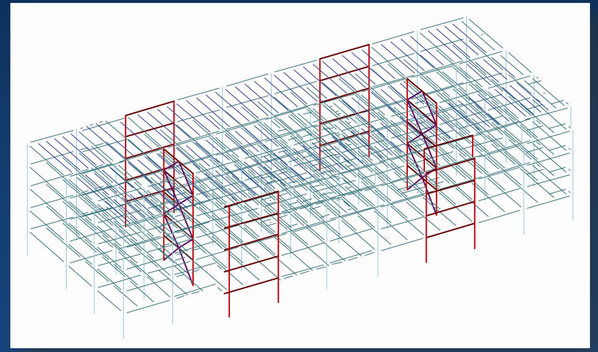


Design Base Shears - Option B-2		
Lateral Force	**North-South**	**East-West**
	R=3	R=4.5
Wind	315 K	144 K
Seismic	208 K	141 K

STRUCTURAL DEPTH

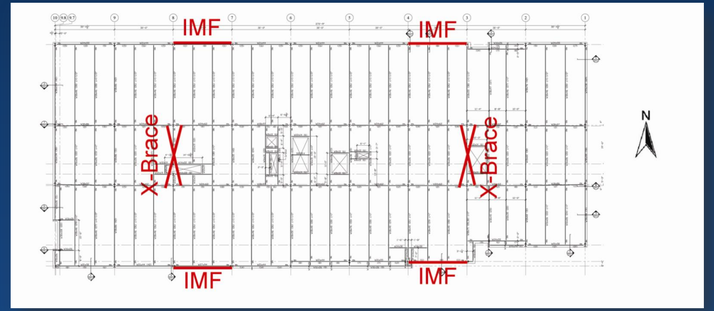
LATERAL REDESIGN

FINALIZED LATERAL DESIGN



N-S BRACED FRAMES (R= 3)

E-W IMF (R=4.5)



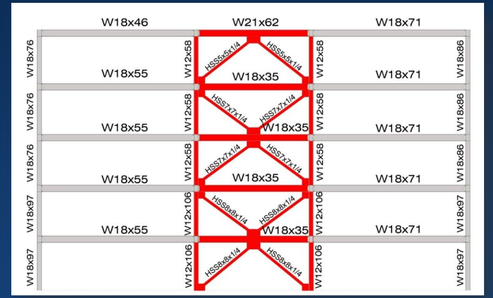
STRUCTURAL DEPTH

LATERAL REDESIGN

ORIGINAL (R=3) TYPICAL MOMENT FRAME

Original Design Takeoff						
	Beams	**Columns**	**Joists**	**Braces**		
Gravity members (lbs)	813,457	88,509	58,000	0	480.0	tons
Lateral members (lbs)	210,003	173,127	-	0	191.6	tons
Total Weight (lbs)	1,023,460	261,636	58,000	0		
Tons of Steel	511.7	130.8	29.0	0.0	671.5	tons

REDESIGN (R= 3 N-S, R=4.5 E-W) BRACED FRAME



Lateral Redesign Takeoff						
	Beams	**Columns**	**Joists**	**Braces**		
Gravity members (lbs)	831,534	123,582	58,000		506.6	tons
Lateral members (lbs)	129,539	65,588		8,686	101.9	tons
Total Weight (lbs)	961,073	189,170	58,000	8,686		
Tons of Steel	480.5	94.6	29.0	4.3	608.5	tons

STRUCTURAL DEPTH

PROGRESSIVE COLLAPSE DESIGN

IN THE PAST 15 YEARS THERE HAVE BEEN ATTACKS ON US BUILDINGS CAUSING PORTIONS TO COLLAPSE AND RESULTING IN CAUSUALTIES. THE ATTACKS HAVE TARGETED HIGHER PROFILE AND GOVERNMENT BUILDINGS:

- MURRAH FEDERAL BUIDLING* (OKLAHOMA CITY)
- WORLD TRADE CENTER (NEW YORK CITY)

WITH THE CLOSE PROXIMITY TO OUR NATION'S CAPTIAL AND ITS LOCATION IN A CORPORATE CENTER, ***BUILDING II WILL BE CONSIDERED A 'HIGH-PROFILE' BUILDING FOR THIS REPORT***.

*MURRAH FEDERAL BUILDING – PORTION OF BUILDING COLLAPSED AFTER BEING BOMBED ON APRIL 19TH, 1995

STRUCTURAL DEPTH

PROGRESSIVE COLLAPSE DESIGN

ASCE 7-05 - GENERAL COMMENTARY

C1.4 STRUCTURAL INTEGRITY:

"…Except for specially designed protective systems, it is usually impractical for a structure to be designed to resist general collapse caused by gross misuse of a large part of the system or severe abnormal loads acting directly on a large portion of it. However, precautions can be taken in the design of structures to limit the effects of local collapse to prevent or minimize progressive collapse…."

DEPARTMENT OF DEFENSE (DoD)

- UNIFIED FACILITIES CRITERIA (UFC, 2005)

GENERAL SERVICES ADMINISTRATION (GSA)

- PROGRESSIVE COLLPASE ANALYSIS AND DESIGN GUIDELINES (2003)

STRUCTURAL DEPTH

PROGRESSIVE COLLAPSE DESIGN

SITUATION 1: DOD GUIDELINES

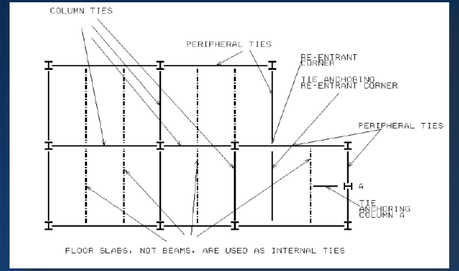
THREAT LEVEL: **LOW LEVEL OF PROTECTION** (LLOP)

Indirect Design Approach – provide resistance to progressive collapse "implicitly through the provision of minimum levels of strength, continuity, and strength."

- Plan layout
- Integrated system of ties
- Redundancy
- Ductile detailing
- Reinforcement for blast and load reversal

FINAL DESIGN

➢ ALL TIE FORCE MET AND MOMENT CONNECTIONS (R=3) ADDED AROUND PERIMETER TO ADD DUCTILITY TO STRUCTURE.



EXAMPLES OF TIES IN STEEL FRAMED BUILDING

Tie Force	Force Required	Connection Capacity	
Internal Tie Force	42.2 K	48.1 K	ok
Peripheral Tie Force	42.2 K	51.0 K	ok
Horizontal Tie Force	42.2 K	51.0 K	ok
Vertical Tie Force	113.9 K	Continuous	ok

STRUCTURAL DEPTH

PROGRESSIVE COLLAPSE DESIGN

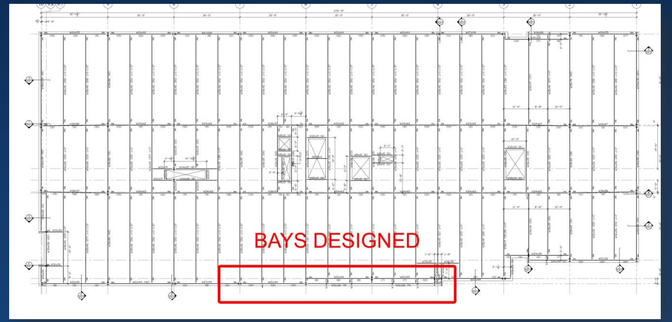
SITUATION 2: GSA GUIDELINES

THREAT LEVEL: **HIGH LEVEL OF PROTECTION**

Direct Design Approach – provide "explicit consideration of resistance to progressive collapse during the design process"

- Alternate Path – structure must be capable of bridging over a missing structural element, localizing damage.

- Specific Local Resistance – which requires a part of the building to sufficient strength to resist the load or blast



STRUCTURAL DEPTH

PROGRESSIVE COLLAPSE DESIGN

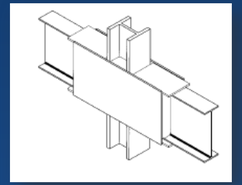
FINAL DESIGN

➢PLASTIC ANALYSIS USING VIRTUAL WORK TO MEET ALL REQUIRED DEMAND CAPACITY RATIOS (DCR) FOR RESPECTIVE MEMBERS

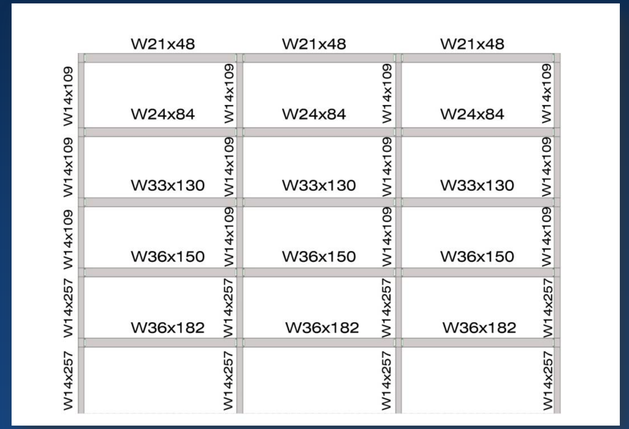
$$DCR = \frac{Q_{UD}}{Q_{CE}}$$

Q_{UD} – DEMAND FORCE
Q_{CE} – UN-FACTORED CAPACITY

➢SIDE PLATE CONNECTIONS



• SIDE PLATE CONNECTIONS MEET ALL GSA TESTING REQUIREMENTS



FINAL 3-BAY DESIGN

STRUCTURAL DEPTH

COST COMPARISONS

ORIGINAL DESIGN (R=3)

Tons of Steel	Total Cost of Structure
671.5	$1,925,672

LATERAL REDESIGN (N-S R=3, E-W R=4.5)

Tons of Steel	Total Cost of Structure	+/- Costs	+/- %	Total Project +/-%
608.5	$1,578,115	-$347,557	-18.05%	-2.39%

LATERAL REDESIGN + PROGRESSIVE COLLAPSE (DIRECT)

Tons of Steel	Total Cost of Structure	+/- Costs	+/- %	Total Project +/-%
647	$1,710,159	-$215,513	-11.19%	-1.48%

LATERAL REDESIGN + PROGRESSIVE COLLAPSE (INDIRECT)

Tons of Steel	Total Cost of Structure	+/- Costs	+/- %	Total Project +/-%
608.5	$1,616,789	-$308,883	-16.04%	-2.12%

ARCHITECTURE BREADTH INTRODUCTION

SITUATION 3: GSA'S SITE SECURITY DESIGN CRITERIA

THREAT LEVEL: **HIGH LEVEL OF PROTECTION**

EXPLOSIVE WEIGHT: 500 LB EQUIVALENT TNT

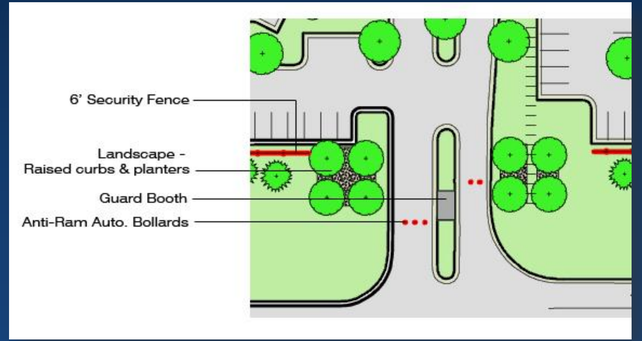
SITE DESIGN SOLUTION:

- ➢ SECURE THE PERIMETER
  - • BOLLARDS
  - • FENCES
  - • GUARD BOOTHS
- ➢ HARDEN FAÇADE
  - • BLAST RESISTANT GLAZING
  - • PRECAST CONNECTIONS

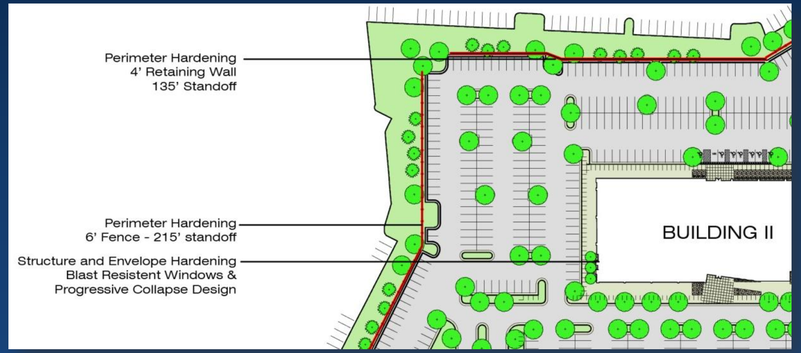
OVERALL SITE DESIGN

ARCHITECTURE BREADTH

SITE REDESIGN



SECURED ACCESS POINTS



PERIMETER HARDENING

ARCHITECTURE BREADTH

GLAZING DESIGN:

CRITICAL STANDOFF = 230 FT

EXPLOSIVE WEIGHT = 500LB

TYPICAL 30 SF WINDOW OPENING

FROM ASTM CHARTS:

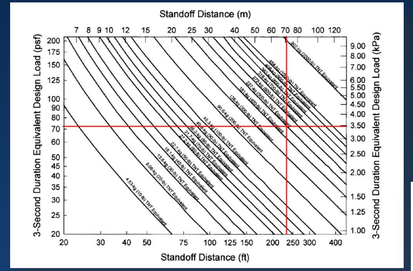
➔ 71 PSF (3-SECOND DURATION DESIGN LOAD)

➔ ½" ANNEALED MONOLITHIC OR ¼" HEAT STRENGTHENED (LAMINATED GLASS)

FINAL DESIGN

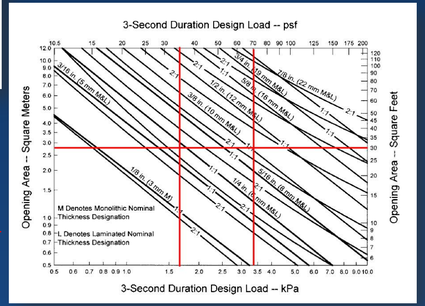
- ¼" HS-LG ((2) 1/8" HS PLIES WITH .03" PVB LAYER)
- MEETS DOD REQUIREMENTS AS WELL
- COSTS TWICE AS MUCH AS ORIGINAL GLAZING!

FAÇADE HARDENING – GLAZING DESIGN



← STANDOFF DISTANCE VS. 3 SEC. DESIGN BLAST LOAD (ASTM 2248-03)

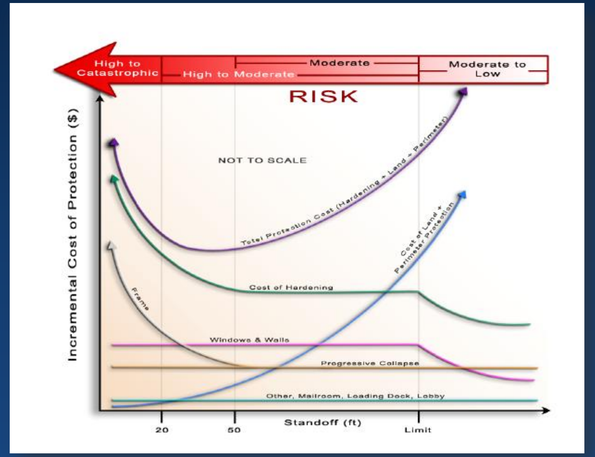
FENESTRATION OPENING VS. 3 SEC. DESIGN BLAST LOAD →



ARCHITECTURE BREADTH

SITE REDESIGN

Additional Site Costs					
	quantity	**unit**	**unit price**	**amount**	
Bollards	12.0	Ea	$600	$7,200	Redesign
Guard Booth	3.0	booth	$25,000	$75,000	
Security Fence	1926.0	LF	$130	$250,380	
Additional site Costs	---------->			$332,580	
Additional facade Costs	---------->			$2,113,275	
Original Total	---------->			$8,199,546	Original
New Total	---------->			$10,645,401	
				29.83%	



COST VS. RISK
(ISC PERFORMANCE BASED DESIGN GUIDE)

- ✓PRESENTATION OUTLINE
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COMPARISONS

Summary of Cost Analysis				
	Total Cost of Structure	**+/- Costs**	**+/- %**	**Total Project +/-%**
Original Design	$1,925,672	-	-	
Lateral Redesign	$1,578,115	-$347,557	-18.05%	-2.39%
Direct Method PC*	$1,710,159	-$215,513	-11.19%	-1.48%
Indirect Method PC	$1,616,789	-$308,883	-16.04%	-2.12%

* Specific Load Path in lieu of Alternative Load Path

CONCLUSIONS

✓ REDESIGN THE EXISTING LATERAL SYSTEM TO BE MORE COST EFFICIENT

✓ REDESIGN THE STRUCTURE TO MITIGATE THE RISK PROGRESSIVE COLLAPSE USING TWO DIFFERENT THREAT LEVELS

✓ ACHIEVE BOTH PC MITIGATION DESIGNS USING THE NEW LATERAL SYSTEM AND STILL PRODUCE A MORE COST EFFICIENT STRUCTURE THAN ORIGINAL

✓ REDESIGN THE SITE AND HARDEN THE FAÇADE TO PROTECT THE BUILDING FROM A POTENTIAL ATTACK

ACKNOWLEDGEMENTS

My family for all the support they've provided over the past five years while I've attended Penn State University

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Dr. Andres Lepage, Assistant Professor of Architectural Engineering
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Prof. Robert Holland, Associate Professor of AE and Arch.

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- All of my professors in the Architectural Engineering Department from the past five years

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- Charlie Angelilli of Structura, Inc.
- Eric Inman, R.A. of Hickok Cole Architects
- David Morse, P.E., PhD

The Alter Group and Structura, Inc. for providing me permission and the drawings for The Crossroads at Westfields Building II as my thesis project.

My roommates Jamison Morse and David Sivin

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QUESTIONS?