Senior Thesis Final Report

"Penn State AE Senior Capstone Project"

Columbia University Northwest Science Building

Broadway & 120th Street, New York, NY

Jonathan R. Torch

Pennsylvania State University

Architectural Engineering

Structural Option

Adviser: Ali M. Memari

April 7, 2010

Columbia University
Northwest Science Building

Broadway & 120th St. New York, NY

ARCHITECTURE:

- *Building, when completed in October 2010, will house classrooms, faculty offices, and research facilities for chemistry, biology, engineering, and physics.*
- *The facade is aluminum-cladded. The structural system also serves as a key architectural facade design. See the structure section below.*
- *Street entrance on corner of Broadway and West 120th Street allows for easy pedestrain access and provides a link to upper campus.*
- *Cafe, which has exterior glazing, is located above the lobby entrance and provides great views of Manhattan city life.*

STRUCTURE:

Framing system:
- *Steel bay framing system used (W shapes).*
- *Building has a 126-foot clear span over an existing structure, the Dodge Physical Fitness Center. Three giant heavy-duty trusses are used for the span. Trusses use diagonal members ranging from W14x90 up to W14x550.*

Lateral system:
- *Diagonal wind bracing can be seen up and down the building facade. Composite floor system helps transfer lateral loads.*

Floor system:
- *Composite (shear studs, concrete slab, steel decking) floor system used. Diagonal members used on level 4 and below to increase diaphragm stiffness.*

Foundation:
- *Concrete piers near building perimeter, column spread footings (minumum bearing capacity of 20 tons/ft), and grade beams used to resist lateral column base movement.*

M.E.P. SYSTEMS:

Mechanical:
- *Four 46,000 CFM air handling units to be installed on the penthouse, serving laboratories.*
- *33,200 CFM air handling unit to be installed on level 6, serving the library.*
- *12,500 CFM air handling unit to be installed on level 4, serving the cafeteria.*

Electrical:
- *3 Phase, 3 Wire 265Y/460V; 3 Phase, 4 Wire 265Y/460V; 3 Phase, 4 Wire 120Y/208V electrical systems all used.*

Lighting:
- *12 different emergency lighting fixtures used throughout the building's stair wells, mechanical rooms, electrical rooms, exterior, elevators, and roof.*
- *32 different architectural lighting fixtures used throughout the building's laboratories, lecture halls, cafe, library, lobby, etc.*

Sprinklers:
- *Automatic wet fire suppression system used.*

GENERAL BUILDING DATA:

Size:	*188,000 Square Feet*
Height:	*14 Stories above Grade* *Max Height 226' 0"*
Occupancy:	*Educational*
Cost:	*$250,000,000* *Total Construction Cost*

PROJECT TEAM:

Owner	*Columbia University Facilities*
Lead Design Architect	*Rafael Moneo Arquitecto*
Project Design Architect	*Moneo Brock Studio*
Architect of Record	*Davis Brody Bond*
General Contractor	*Turner Construction*
Structural/MEP/Fire Engineers	*Ove Arup & Partners Consulting Engineers*

Jonathan Torch - Penn State Architectural Engineering, Structural Option

Web Address: www.engr.psu.edu/ae/thesis/portfolios/2010/jrt5027/index.html

All Images and Renderings of the Columbia Northwest Science Building were generously provided by Turner Construction.

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~Special thanks to all friends, colleagues, family, and peers of the author.~

The following thesis is dedicated to the author's parents, Robert & Anne Torch. Thank you for all the life lessons learned, patience, and love given to me for the past twenty-three plus years.

Executive Summary:

This final thesis report contains a main structural depth study along with two breadth studies. These studies are the resultant of a thesis proposal that dealt with the relocation of the Northwest Science Building from New York, NY to Miami, FL. This relocation causes several design concerns for the author. These concerns are addressed in the main depth and breadth studies of this final thesis report. Below is a brief description of the main structural depth study, and two breadth studies. Along with each description is a brief summary of the design changes needed due to the relocation of the building.

Structural Depth Study – Lateral System Redesign:

The main goal of this thesis is to produce a lateral system redesign due to the relocation of the Northwest Science Building to Miami, FL. This relocation will cause more severe wind forces acting upon the lateral system due to Miami, FL being in a hurricane prone region.

Upon analysis of the lateral system the author determined that an additional amount of stiffness was needed in the East-West direction frames of the structure to limit drifts and story drifts. The exterior braced frames in this direction were redesign completely. They now provide continuous diagonal bracing over the full height of the structure. These exterior grids did not provide all the additional stiffness needed, therefore, another interior braced frame was designed. This braced frame consists of chevron bracing over the full height of the structure to provide architectural accessibility. Along with the increased stiffness of the structure, lateral strength requirements were checked and redesign where needed. The increased overturning moment was determined not to be a design concern.

Breadth Topic One - Building Enclosure:

The relocation of the building to Miami, FL causes water condensation and heat transmission concerns. An analysis of the current building enclosure will be performed and modified accordingly for Miami, FL. This breadth will consist of R-value, air leakage, and condensation analyses. ASHRAE recommendations based on climate data will also be researched and discussed.

Upon analysis of the building enclosure it was determined that a reduction in the insulation layer was achievable. The 4 inch foam glass insulation layer was able to be reduced to 2.5 inches. A bare material cost analysis of this reduction was performed, and a savings of $185,900 was concluded.

Breadth Topic Two - Architecture:

The relocation of the building to Miami, FL also causes exterior architectural concerns. The author wants the exterior appearance of the building to be representative of Miami architecture. Therefore, research will be performed and discussed concerning the history of Miami's architecture. The building's architecture will be modified based on this research.

Research of Miami, FL architecture included Streamline Modern, Art Deco, and Mediterranean Revival styles. These three styles are prevalent within the area. The author was able to produce an exterior architecture redesign, blending these three styles and the redesigned lateral system.

Masters of Architectural Engineering (MAE) Course-Related Studies:

AE 542 (Building Enclosure Science and Design) and AE 597A (Computer Modeling of Framed Structures) are graduate level courses that will be used within this senior thesis study. The Building Enclosure Breadth Study will utilize learned material of AE 542. An analysis of the curtain wall system will take place. This study will involve an R-value, condensation, and air leakage analyses. These analyses were all learned during AE 542 class work and studies. The main structural depth will utilize AE 597A by incorporating an ETABS model and analysis of the building's lateral system.

This Senior Thesis Final Report will accomplish the following goals:

Goals (Based on Relocation of Building to Miami, FL):

- Redesign building's lateral system to meet code requirements.
- Provide analysis of lateral system through means of ETABS and hand calculations.
- Research, analyze, and modify building enclosure appropriately for water condensation and heat transmission concerns.
- Redesign exterior architecture of building for Miami, FL.

Introduction & Background:

The following thesis report is based upon the Columbia University Northwest Science Building. The building is located at the intersection of Broadway and 120th Street in New York City. This building will provide Columbia University with science research facility space. It is approximately 188,000 square feet in size with 14 stories above grade.

This building design had to overcome an existing spatial concern. In order to use the site to its full capacity, the building design called for a 126 foot clear span over an existing gymnasium structure. Diagonal bracing is utilized throughout the structure not only for lateral forces, but to transfer gravity loads for the 126 foot clear span. Also, the diagonal members serve as a key architectural feature. The diagonal members create braced frames in each direction of the building, which serve as the building's lateral system.

Below is a brief description of the buildings lateral system. This final thesis report deals greatly with the building's lateral system design.

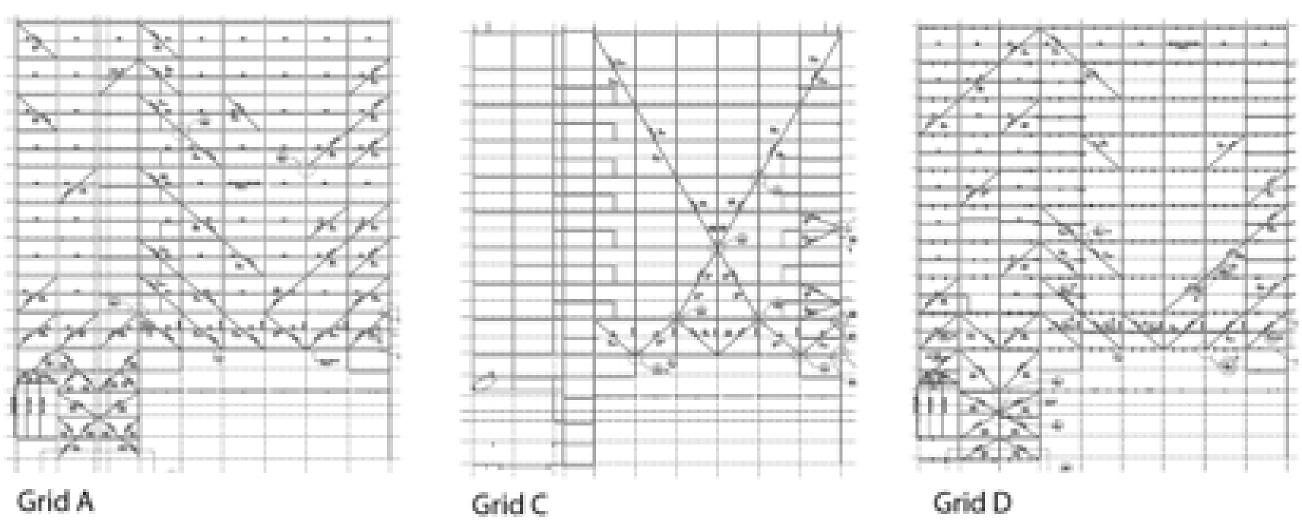
Lateral System:

The lateral system utilizes diagonal wind bracing, wind girts, a composite floor system, and wide flange beams and columns.

The diagonal wind bracing elements are made up of W14 members and the wind girts are HSS shaped members. A typical HSS member size used is a 9x3x1/2. The wind girts allow wind to be distributed into the structure at the mezzanine levels, which are in between each main level. The lateral load is first distributed into the building by beams, wind girt members, and the composite floor system. It is then distributed downwards into diagonal bracing and columns until it reaches the foundation of the structure.

Below are images of the main lateral resisting frames (North-South Direction) of the structure.

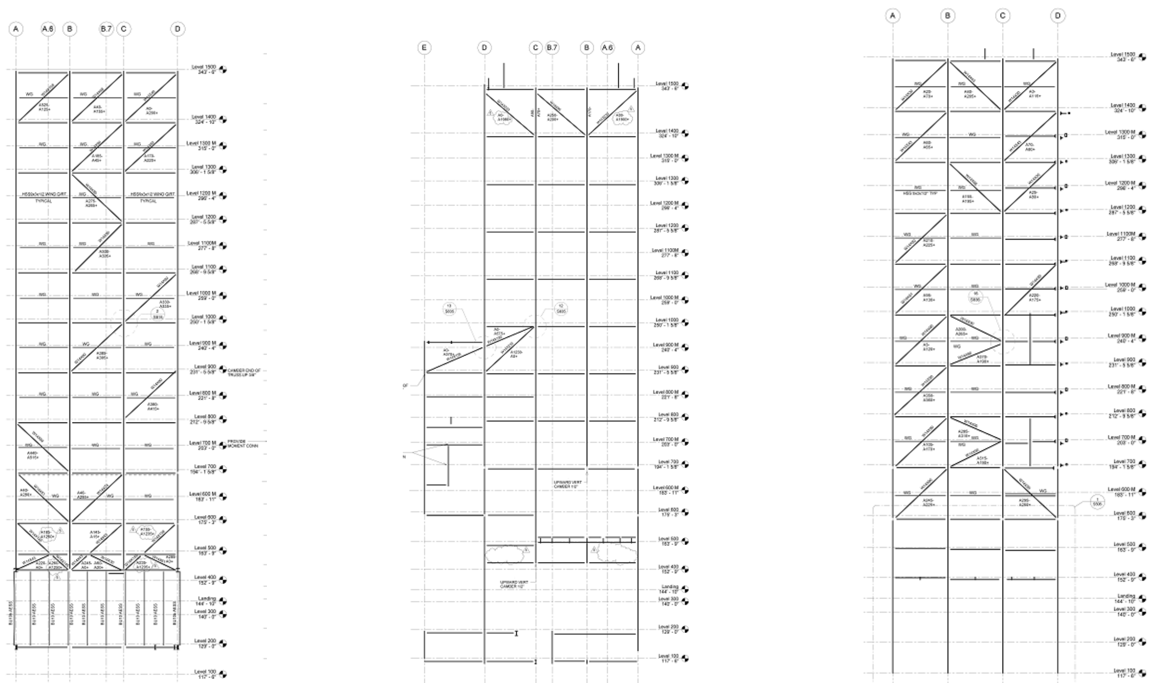
Figure 1: North-South Lateral Resisting Frames



The diagonal bracing in the North-South direction is utilized for both lateral force resisting and gravity loads of the 126-foot clear span at level 5 of the building.

Below are images of the main lateral resisting frames (East-West Direction) of the structure.

Figure 2: East-West Lateral Resisting Frames



GRID 1 **GRIDS 2-4** **GRID 10**

The lateral bracing of these grids above are solely designed for lateral force resisting.

Below is a typical floor plan of the structure of the Columbia University Northwest Science Building. For an enlarged image of this floor plan see Appendix Section B at the end of this thesis report.

Figure 3: East-West Lateral Resisting Frames

Notice the longer spans of this floor system. These spans use castellated beams for the large laboratory spaces.

Additional Building Statistics:

General Building Data:

- Building Name: Northwest Science Building
- Location & Site: Broadway & 120th Street, New York, NY
- Building Occupant Name: Columbia University
- Function Type: Educational
- Size: 188,000 Square Feet
- Number of Stories: 14 Stories Above Grade
- Height: 239' 4"
- Construction Dates: March 2007 – October 2010
- Cost: $250,000,000 (Total Construction Cost)
- Project Delivery Method: Design-Bid-Build

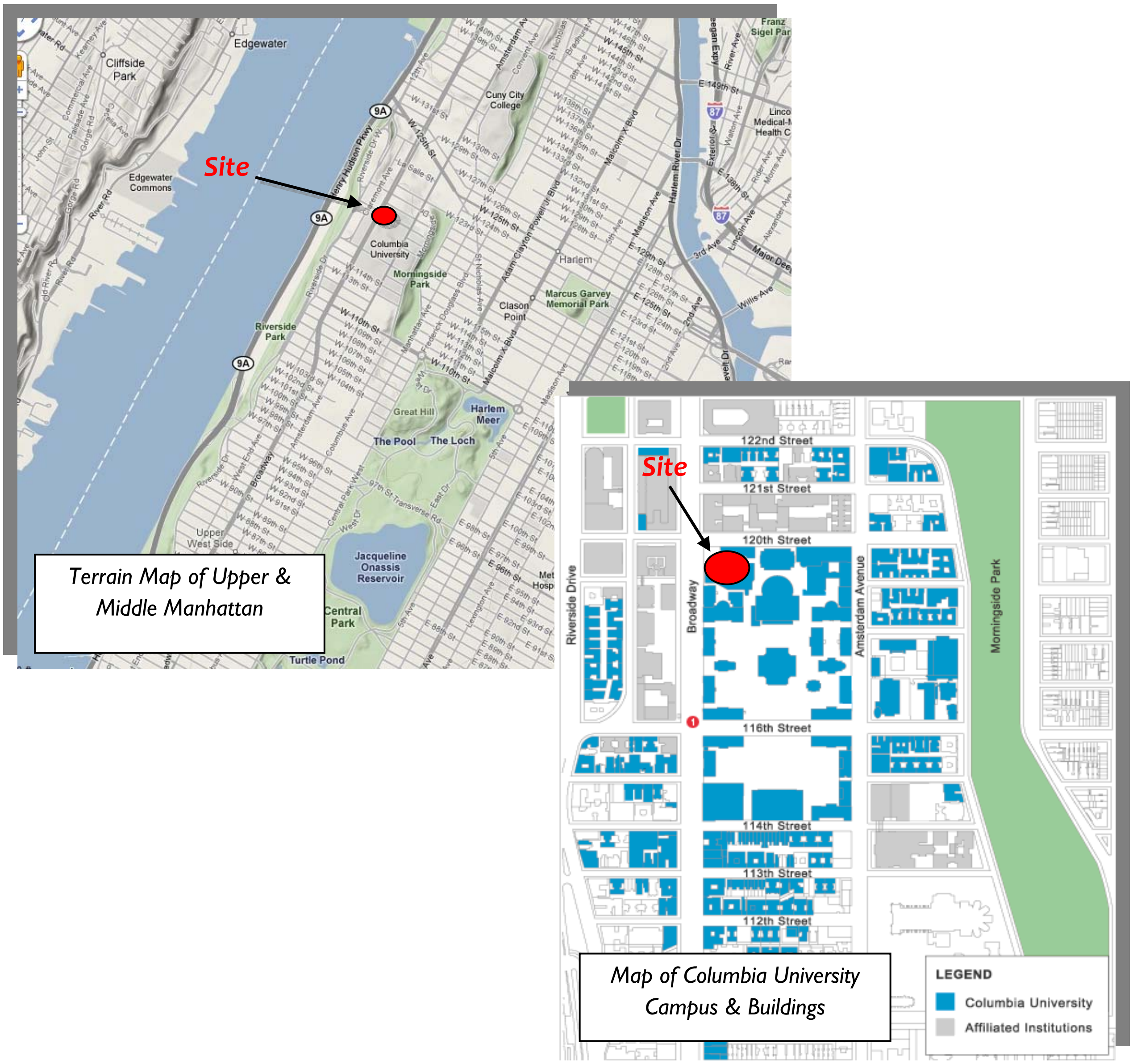
Project Team:

Role	Location	Web Page
Owner: Columbia University Facilities	*410 West 118th Street* *New York, NY 10027*	http://www.facilities.columbia.edu/
Lead Design Architect: Rafael Moneo Arquitecto	*Calle Cinca 5* *28002 Madrid, Spain*	*Web Page Not Available*
Project Design Architect: Moneo Brock Studio	*c/ Francisco de Asis Mendez* *Casariego 7, bajo* *28002 Madrid, Spain*	http://www,moneobrock.com
Architect of Record: Davis Brody Bond	*315 Hudson Street* *New York, NY 10013*	http://www,davisbrody.com/
General Contractor: Turner Construction	*375 Hudson Street* *New York, NY 10014*	http://www.turnerconstruction.com/
Structural/MEP/Fire Engineers: Ove Arup & Partners Consulting Engineers	*155 Avenue of the Americas* *New York, NY 10012*	http://www.arup.com/

Architecture:

The Northwest Science Building is located at the corner of Broadway and West 120th Street, New York, NY. It is located on a 13,000 square foot lot size that is adjacent to Columbia University's Chandler Hall and Pupin Physics Laboratories. The building, when completed, will house classrooms, faculty offices, and research facilities for chemistry, biology, engineering, and physics.

Figure 4: Site Location of Northwest Science Building



This 14 story interdisciplinary science building has a 126-foot clear span over an existing structure, the Dodge Physical Fitness Center. Three giant, heavy-duty steel trusses are used for the span and are supported by four super columns. These structural components also serve as key architectural components.

Another key architectural design is the street entrance located on the corner of Broadway and West 120th Street. This science building will be one of the few buildings on Columbia's campus that can be entered from street level. There is a café above the lobby entrance that gives outside views of Manhattan city life.

Figure 5: Main Entrance/Main Lobby Renderings of Northwest Science Building

Interior Rending of Main Lobby
(Stairwell Shown Provides Access to Café)

Exterior Rendering of Main Entrance from Street
(Café Located Above Main Lobby Entrance)

Zoning:

The Columbia University Northwest Science Building is located in Upper Manhattan and is in New York City's zoning district R8. R8 is a general residence district consisting of a broad range of housing types. It also includes community facilities. This zoning district is a mixed use district. The entire Columbia University Campus is located within this zoning district.

Applicable Codes:

- International Building Code 2006
- National Electric Code 2006
- New York City Building Code & Regulations
- New York City Construction Code

Building Enclosure:

The building enclosure has a very modern appearance. Clear anodized aluminum panels clad the exterior bays with the diagonal structural elements. The panels express the diagonal structural element lines with extruded aluminum fins. The bays that are clear of structural diagonal elements are equipped with fenestrations. These fenestrations are clear glass panels. Larger glass curtain walls can be found between the 2nd and 4th levels, exposing the café, and between the 13th and 15th levels, exposing laboratories and support spaces. Also, a large area of the East building elevation, plaza façade, is covered in glass curtain wall, which encloses office space.

Structural Depth Study:

The following is a description of the main structural depth study proposed by the author for Penn State Architectural Engineering Senior Thesis, Spring 2010.

The Columbia University Northwest Science Building's lateral system was determined to be governed by wind forces in Technical Report 3. This is due to the large 110 MPH wind design speed of New York City. It is also due to the fact that the building is rectangular shaped with the long side measuring 193 feet by 226 feet in height. These large East and West areas of the building act as a wind sail. This creates a large amount of wind force acting upon the East-West lateral system. The lateral design of the building provides large diagonal braced frames and wind girts at mezzanine levels. This lateral system design clearly indicates the large wind forces it resists.

To further study wind effects upon the building and its lateral system, it is proposed by the author to move the building site from New York City, NY (110 MPH design wind speed) to Miami, FL where there is an increase in design wind speed to 150 MPH. This increase is due to Miami, FL being in a more hurricane prone area. It is also in the author's interest to research different lateral bracing systems (chevron, eccentric, and k bracing) and propose one of them in the redesign.

The relocation of the building to Miami, FL will affect the lateral system design. This in turn should affect the diagonal brace member sizes and locations.

This structural breadth study will consist of the following three tasks.

- Calculation of Wind Forces for Miami, FL
- Analyze Existing Lateral System for Miami, FL
- Redesign and Analyze Lateral System

Figure 6: Relocation of Building to Miami, FL (Wind Force Study)

Structural Depth Study
Task One – Calculation of Wind Forces (Miami, FL)

Description:

Task one was completed to determine wind forces for the relocation of the Columbia University Northwest Science building to Miami, FL. These calculations will be used throughout this thesis for determining a lateral system redesign. A basic wind speed of 150 MPH was determined for Miami, FL. The following tables, graphs, figures, and conclusions provide a detailed description and documentation of these wind forces.

Tables, Graphs, and Figures:

Below is a bulleted list explaining the tables, graphs, and figures to follow, regarding wind calculations and diagrams.

- Table 1: Basic Wind Pressure Parameters
  - Provides basic wind factors based upon location of site, topography of site, and additional building properties.
- Table 2: Gust Factor Parameters
  - Provides factors needed in finding the gust effect on the structure.
- Table 3: C_p, Gust Factor, GC_{pi} Factors
  - Summarizes the gust factors found for the leeward and windward sides of the building. Also provides the external pressure coefficient (C_p), and internal pressure coefficient (GC_{pi}) values.
- Figure 7: Wind North-South Direction Diagram
  - Provides a visual of the wind forces (windward and leeward) on the structure in PSF.
- Figure 8: Wind East-West Direction Diagram
  - Provides a visual of the wind forces (windward and leeward) on the structure in PSF.
- Graph 1: Comparison of Base Shears (NYC vs. Miami)
  - Provides a numerical and visual comparison of the base shears of each city.
- Tables 4A & 4B: Wind North-South Direction *(found in Structural Depth Appendix A)*
  - Provides the excel spreadsheet wind analysis that was used in finding the wind forces acting on the structure. Also, provides the final base shear and overturning moment for the structure caused by wind.
- Tables 5A & 5B: Wind East-West Direction *(found in Structural Depth Appendix A)*
  - Provides the excel spreadsheet wind analysis that was used in finding the wind forces acting on the structure. Also, provides the final base shear and overturning moment for the structure caused by wind.
- Table 6: Unfactored Story Forces for ETABS Deflection Analysis *(found in Structural Depth Appendix A)*
  - Provides the story forces that will be entered into ETABS for lateral wind analysis.

Conclusions:

A 1400 kips base shear was calculated for the building in the North-South direction, while 5490 kips base shear was calculated for the East-West direction. These values were suspected to rise due to an increase in basic wind speed of 150 MPH compared to New York City's 110 MPH. The values did rise considerably. A 192% increase in base shear for both the North-South and East-West base shear took place.

Table 1: Basic Wind Pressure Parameters

Basic Wind Speed (V)	150 MPH
Wind Exposure Category	C
Building Category	III
Importance Factor	1.15
Wind Directionality Factor (K_d)	0.85
Topographic Factor (K_{zt})	1.0

Number of Stories	14
Building Height (Feet)	226'-0"
N-S Building Length (Feet)	196.75'
E-W Building Length (Feet)	60.5'
L/B in N-S Direction	3.252
L/B in E-W Direction	0.307

Table 2: Gust Factor Parameters

Gust Factor		
Variable	**Wind Direction**	
	N-S	**E-W**
Stiffness	**Flexible (n_1<1)**	**Flexible (n_1<1)**
n_1	0.4425	0.4425
B (Feet)	60.5196	196.75
L (Feet)	196.75	60.5
h (Feet)	226	226
I_z	0.158	0.158
L_z (Feet)	663.31	663.31
Q	0.854	0.824
g_r	3.99	3.99
g_Q & g_v	3.4	3.4
V_z	177.73	177.73
α	1/6.5	1/6.5
b	0.65	0.65
N_1	1.651	1.651
R_n	0.0997	0.0997
R_h	0.312	0.312
R_B	0.662	0.346
R_L	0.124	0.339
R	0.660	0.517
G_f	0.992	0.935

Table 3: C_p, Gust Factor, GC_{pi} Factors

Wind Direction	**C_p (Windward)**	**C_p (Leeward)**	**Gust Factor (Windward)**	**Gust Factor (Leeward)**	**GC_{pi}**
N-S Direction	0.8	-0.225	0.992	0.935	±0.18
E-W Direction	0.8	-0.5	0.992	0.935	±0.18

Figure 7: Wind North-South Direction Diagram

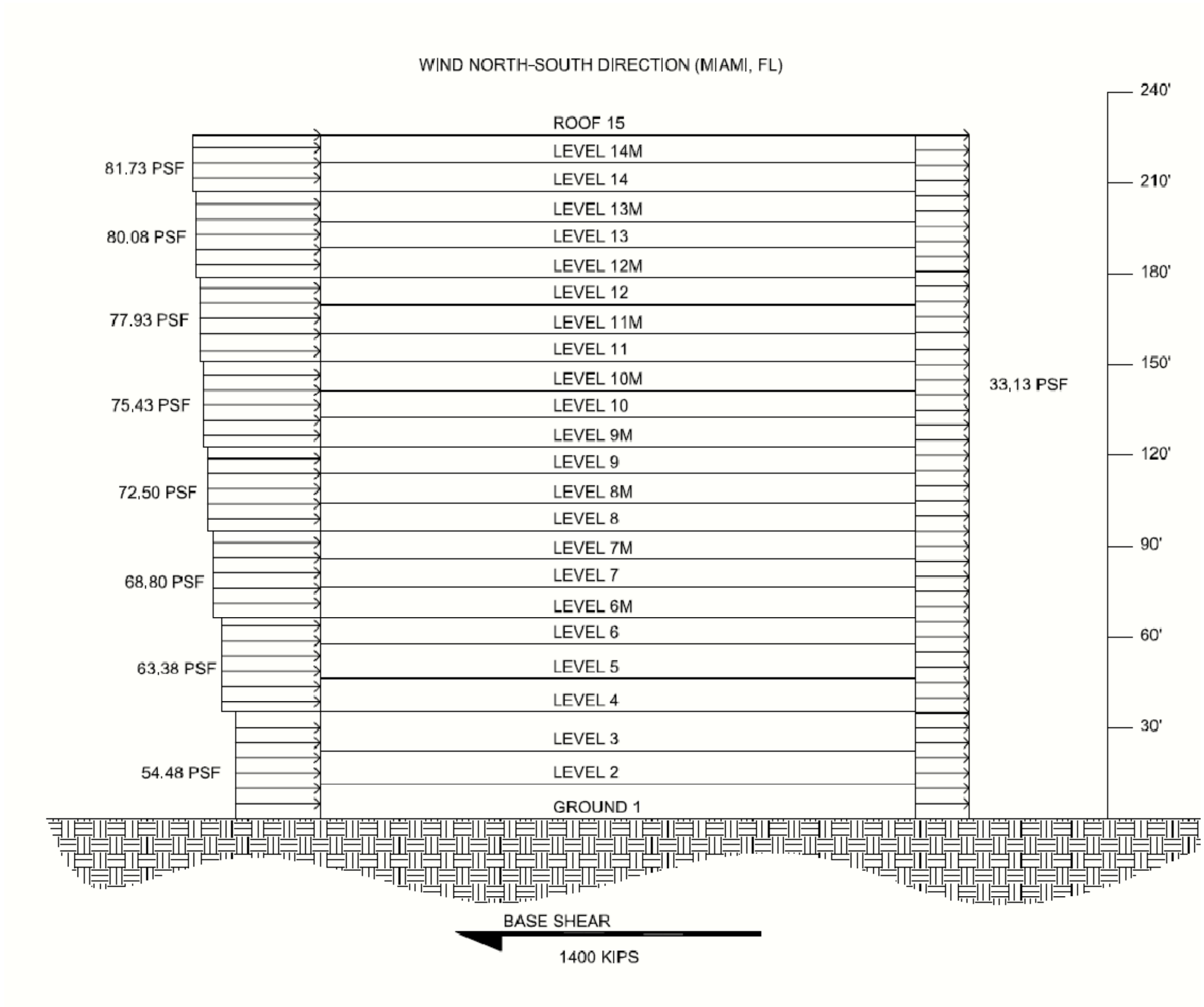
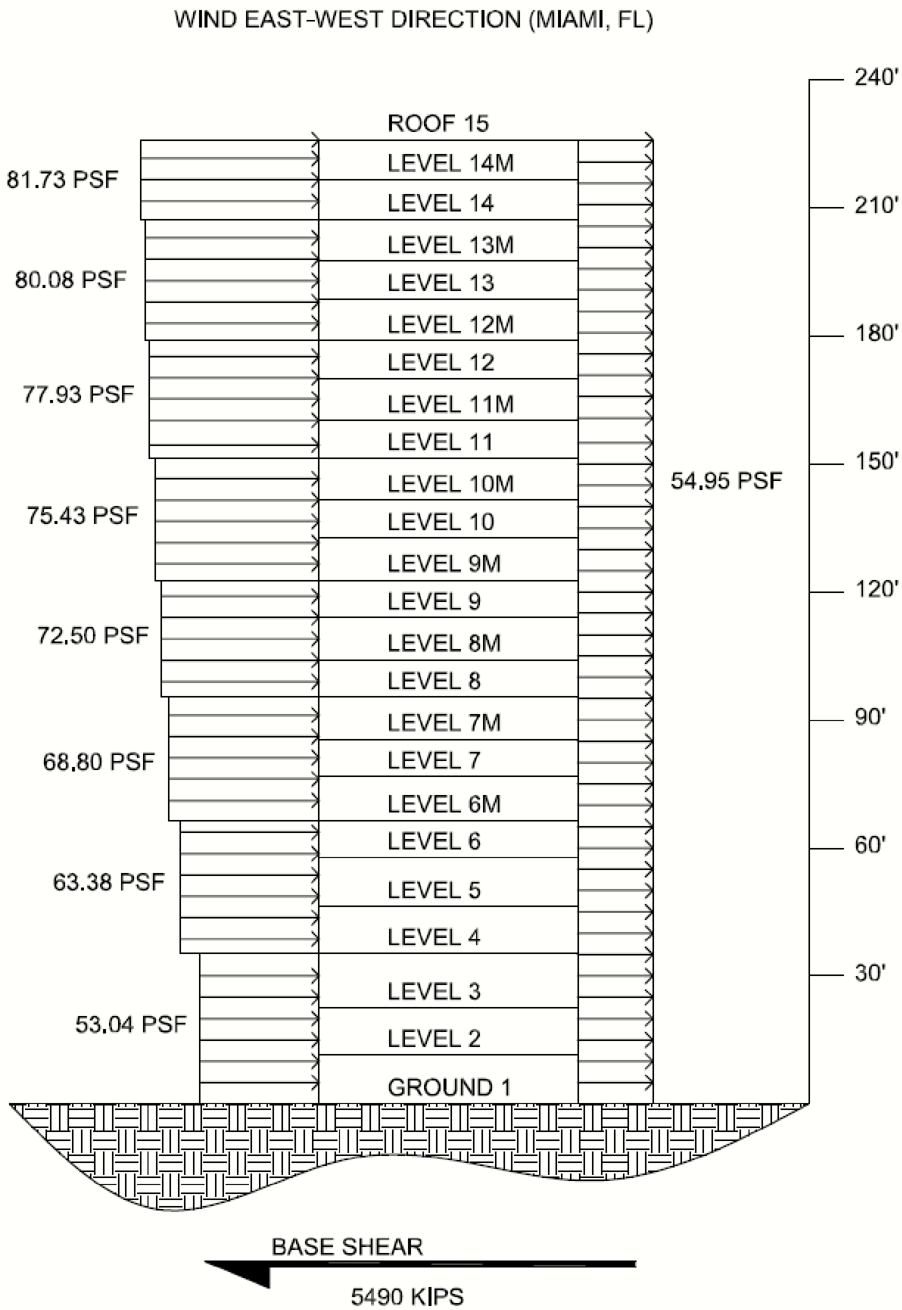
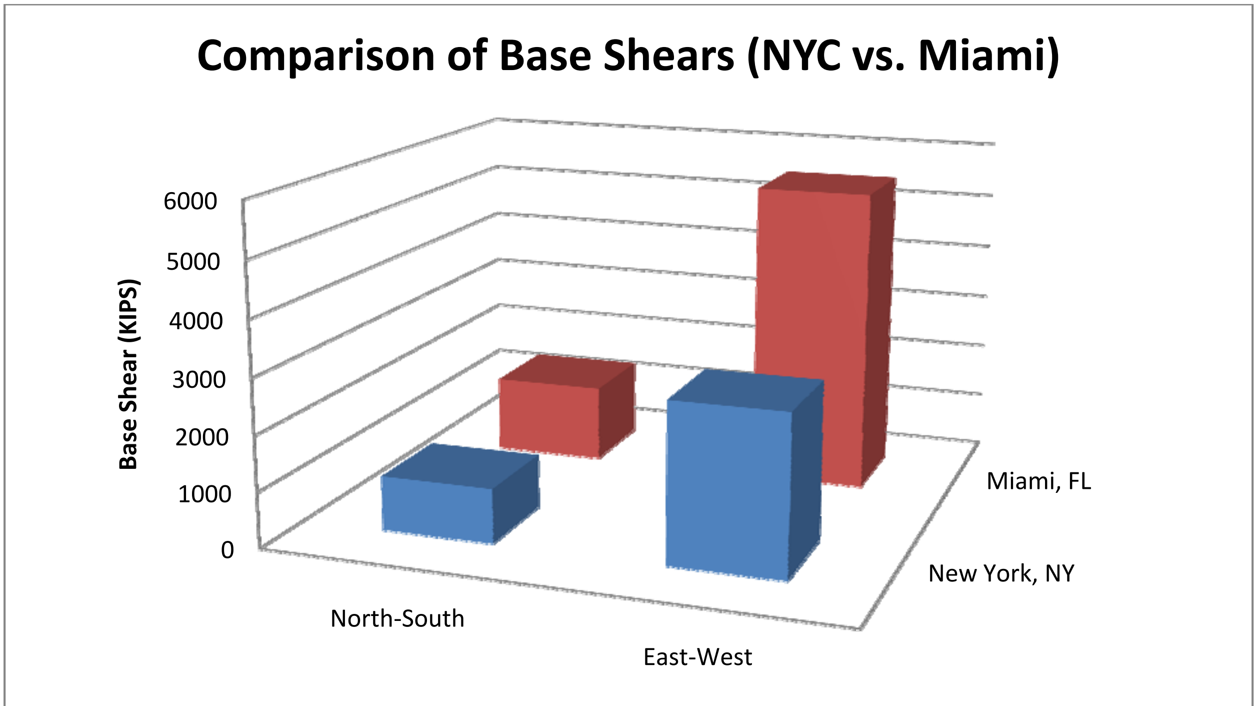


Figure 8: Wind East-West Direction Diagram



Graph 1: Comparison of Base Shears (NYC vs. Miami)



	North-South	East-West
New York, NY	982	2860
Miami, FL	1400	5490

<u>Discussion of Graph 1:</u>

As you can see above in the graph, there is a substantial difference in base shear forces from New York, NY to Miami, FL. The relocation of the building to Miami, as shown above, will cause a great increase in wind forces in both the North-South and East-West directions. A substantial part of this thesis will be providing a redesign of the building's lateral system to meet these new wind force requirements.

Structural Depth Study

<u>Task Two – Analyze Existing Lateral System (Miami, FL)</u>

<u>Description:</u>

Task two was completed to determine if the existing lateral system could withstand Miami, FL wind forces. Task one's wind calculations were used along with an ETABS model to determine if the existing lateral design is still satisfactory for Miami, FL.

The author suspects that the lateral system will be unsatisfactory due to the increase in wind load with the building's relocation. The following calculations and analysis will take place:

- Recording/checking wind drifts and story drifts.
- Comparing drifts and story drifts to Technical Report 3 results.
- Providing checks of overturning and strength.

<u>Tables, Graphs, and Figures:</u>

Below is a bulleted list explaining the tables, graphs, and figures to follow, regarding the existing lateral system's wind analysis for Miami, FL.

- Figures 9 & 10: ETABS Model Images 1 & 2
    - Images of ETABS model used.
- Table 7: Wind Case Summary
    - Provides the forces each grid must resist for Miami, FL wind forces.
- Graph 2: Maximum Grid Force Summary - Wind
    - Compares each grid's maximum shear resisting forces in bar graph format.
- Table 8: Overturning Moment Calculations
    - Provides a spreadsheet of all the calculations made for overturning moment checks.
- Table 9: East-West Direction – Wind Serviceability Checks *(found in Structural Depth Appendix A)*
    - Provides the drift and story drifts for each grid of the East-West lateral system.
- Table 10: North-South Direction – Wind Serviceability Checks *(found in Structural Depth Appendix A)*
    - Provides the drift and story drifts for each grid of the North-South lateral system.
- Table 11: Wind Serviceability Checks - Summary
    - Provides a summary of the met and unmet drift and story drifts of the existing lateral system.
- Graph 3: Wind Drift Comparison – NYC vs. Miami
    - Compares the max wind drifts of the building located in NYC vs. Miami.

<u>Conclusions:</u>

From this existing lateral system analysis for Miami, FL the author found that the East-West lateral system needed a substantial redesign. This system failed drift, story drift, and strength requirements. The North-South lateral system seems to meet most requirements. However, the author does suspect strength concerns in this direction as well. The following pages discuss the results of Structural Depth Study, Task 2.

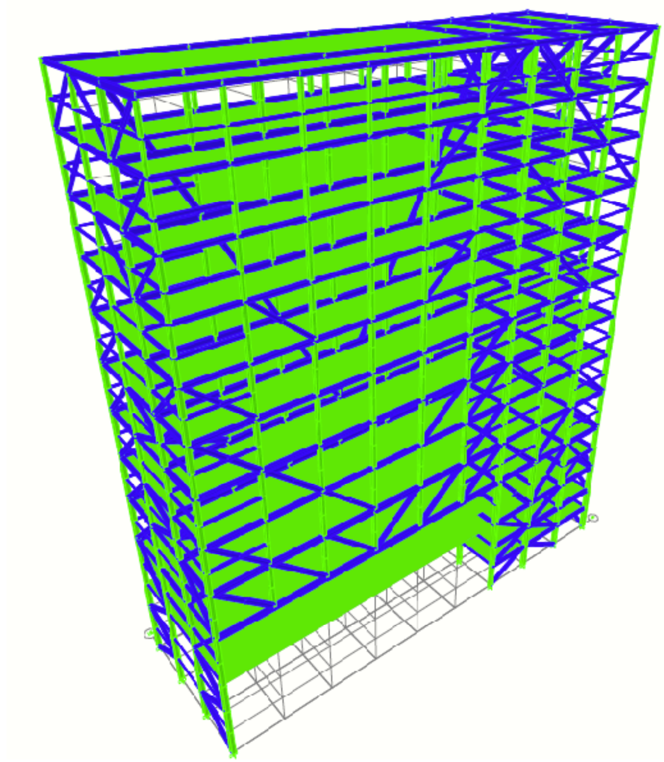


Figure 9: ETABS Model – Image 1

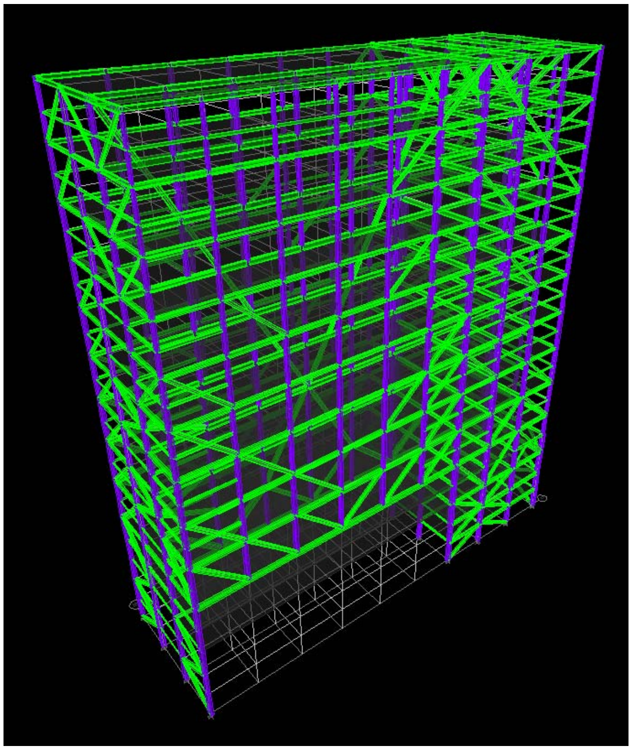


Figure 10: ETABS Model – Image 2

ETABS Model:

The ETABS model seen on the previous page was used in assisting the existing lateral system analysis for Miami, FL hurricane wind loads. This model was created to match, to the best ability, the structural drawings of ARUP (structural design engineering firm).

All members of the lateral system were inputted with their proper material properties and connection requirements. All of the beams within the structure were moment released on both ends. This is due to the fact that the entire lateral system contains only braced frames, and no moment frames.

Load Combinations Used:

The author is only focusing on a wind analysis of the existing lateral system for Miami, FL. The relocation of the building to a hurricane prone area causes the author to strongly believe wind will control the lateral design. Therefore the following load combinations will be used:

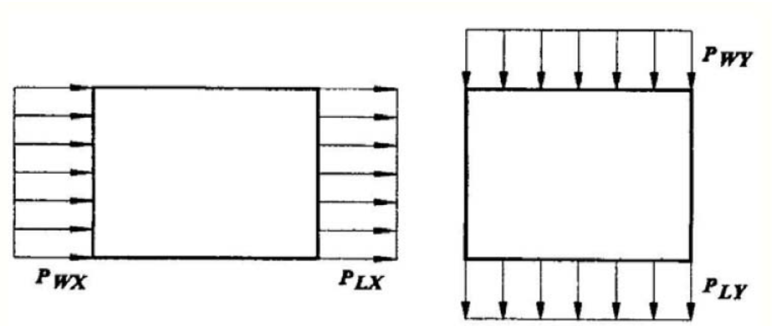
- 1.2(Dead) + 1.6(Roof Live) + 0.8(Wind)
- 1.2(Dead) + 1.6(Wind) + 1.0(Live) + 0..5(Roof Live)
- 0.9(Dead) + 1.6(Wind)

Wind Cases:

Following is a description of each wind case to be considered. Each wind case will provide an image of the wind forces and the tabulation of results.

Wind Case 1:

Wind Case 1 considers the full wind pressures acting perpendicular to the building structure. The pressures are considered separately in each direction as shown below.

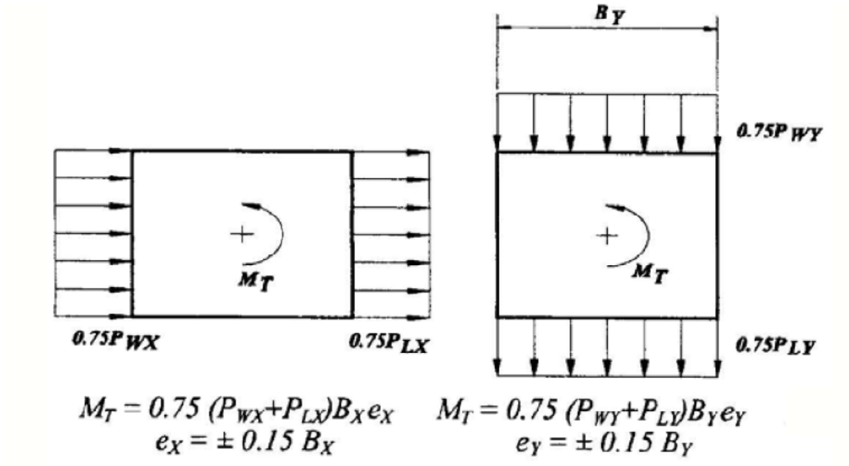


	Grid A	Grid C	Grid D	Grid 1	Grid 2	Grid 3	Grid 4	Grid 10
Wind Case 1	566	125	573	2180	298	412	156	2444

*All values shown above are in kips and un-factored.

Wind Case 2:

Wind Case 2 considers three quarters of the design wind pressure acting perpendicular to the building structure. Also a torsional moment is considered for each principal axis.

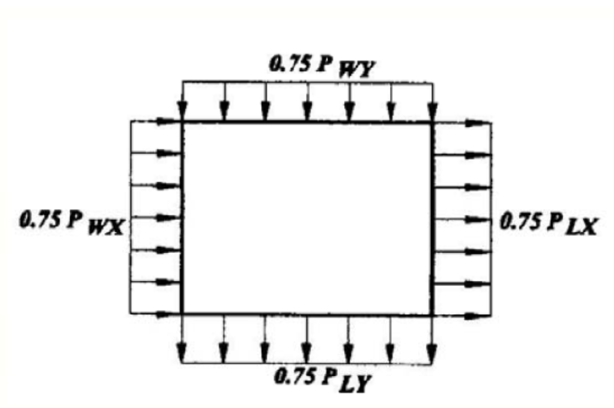


	Grid A	Grid C	Grid D	Grid 1	Grid 2	Grid 3	Grid 4	Grid 10
Wind Case 2 (+M)	351	92	470	1400	194	280	434	1940
Wind Case 2 (-M)	461	86	351	1697	223	290	101	1617

*All values shown above are in kips and un-factored.

Wind Case 3:

Wind Case 3 considers three quarters of the design wind pressure acting perpendicular to the building structure in both directions simultaneously.

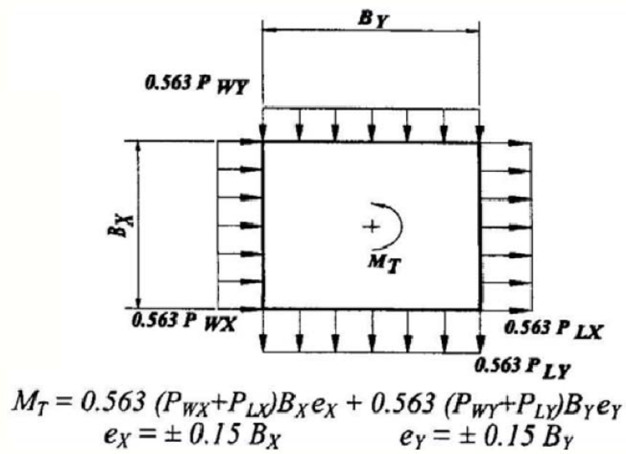


	Grid A	Grid C	Grid D	Grid 1	Grid 2	Grid 3	Grid 4	Grid 10
Wind Case 3	485	80	315	1600	208	278	99	1783

*All values shown above are in kips and un-factored.

Wind Case 4:

Wind Case 4 considers loading similar to Wind Case 2, however the wind is acting simultaneously. Moment and wind forces are factored according to the image below.



	Grid A	Grid C	Grid D	Grid 1	Grid 2	Grid 3	Grid 4	Grid 10
Wind Case 4 (+M)	85	82	566	617	109	212	112	2043
Wind Case 4 (-M)	672	45	66	1857	227	241	51	716

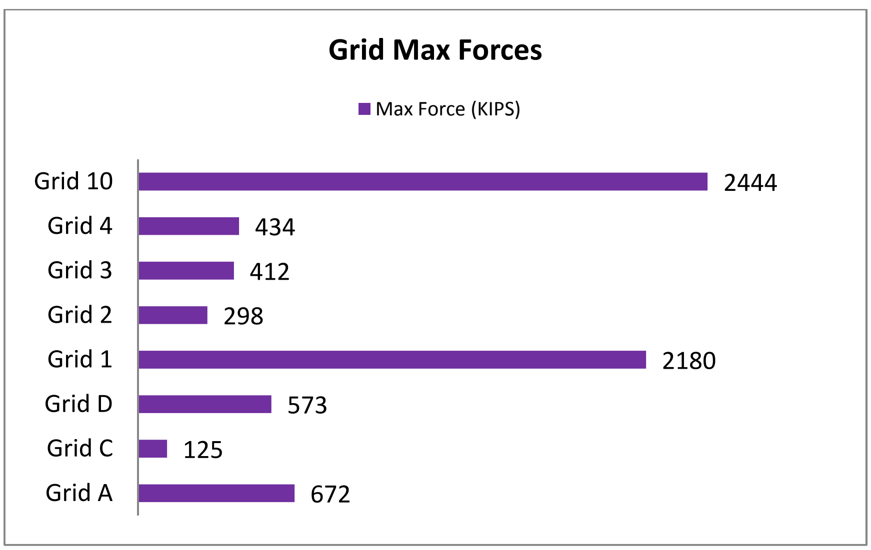
*All values shown above are in kips and un-factored.

Wind Cases 1-4 Summary:

Table 7: Wind Case Summary

	Grid A	Grid C	Grid D	Grid 1	Grid 2	Grid 3	Grid 4	Grid 10
Wind Case 1	566	125	573	2180	298	412	156	2444
Wind Case 2 (+M)	351	92	470	1400	194	280	434	1940
Wind Case 2 (-M)	461	86	351	1697	223	290	101	1617
Wind Case 3	485	80	315	1600	208	278	99	1783
Wind Case 4 (+M)	85	82	566	617	109	212	112	2043
Wind Case 4 (-M)	672	45	66	1857	227	241	51	716
	Grid A	Grid C	Grid D	Grid 1	Grid 2	Grid 3	Grid 4	Grid 10
Max Force (KIPS)	672	125	573	2180	298	412	434	2444

Graph 2: Maximum Grid Force Summary - Wind



As seen from the chart and graph comparison above, Grids 1 & 10 are required to withstand the largest wind forces from Wind Cases 1-4 analysis. Grids 1 & 10 are both resisting forces in the East-West Direction. The East-West direction is a large concern of the author and will be discussed in-depthly throughout this thesis report.

Overturning Checks:

Table 8: Overturning Moment Calculations

Overturning Moment due to 1.6Wind										Overturning Moment (K-FT)	
N-S	PSF*1.6 (N-S)	Height of Level (FT)	Width	Force (K)	E-W	PSF*1.6 (E-W)	Height of Level (FT)	Width	Force (K)	N-S	E-W
14	183.28	18.67	80.66	276.00	14	218.19	18.67	193	786.21	59236	168739
13M	182.20	9.83	80.66	144.46	13M	217.11	9.83	193	411.91	28947	82536
13	181.19	8.83	80.66	129.05	13	216.10	8.83	193	368.28	24654	70359
12M	180.03	7.83	80.66	113.70	12M	214.95	7.83	193	324.82	20775	59350
12	178.94	8.83	80.66	127.45	12	213.85	8.83	193	364.45	22225	63554
11M	177.68	9.83	80.66	140.88	11M	212.59	9.83	193	403.33	23253	66572
11	176.48	8.83	80.66	125.70	11	211.40	8.83	193	360.26	19574	56102
10M	175.10	9.83	80.66	138.83	10M	210.01	9.83	193	398.43	20324	58329
10	173.78	8.83	80.66	123.77	10	208.69	8.83	193	355.65	16964	48747
9M	172.23	9.83	80.66	136.56	9M	207.15	9.83	193	393.00	17444	50199
9	170.75	8.83	80.66	121.61	9	205.66	8.83	193	350.49	14400	41500
8M	169.00	9.83	80.66	134.00	8M	203.91	9.83	193	386.87	14616	42197
8	167.30	8.83	80.66	119.16	8	202.22	8.83	193	344.61	11885	34374
7M	165.27	9.83	80.66	131.04	7M	200.19	9.83	193	379.79	11848	34339
7	163.27	8.83	80.66	116.29	7	198.19	8.83	193	337.75	9429	27386
6M	160.72	10.25	80.66	132.88	6M	195.64	10.25	193	387.02	9507	27690
6	158.31	8.67	80.66	110.71	6	193.22	8.67	193	323.32	6873	20073
5	154.62	11.5	80.66	143.42	5	189.53	11.5	193	420.66	7458	21874
4	150.33	11	80.66	133.38	4	185.24	11	193	393.27	5435	16026
3	143.75	12.75	80.66	147.84	3	178.67	12.75	193	439.66	4269	12695
2	138.33	11	80.66	122.73	2	169.93	11	193	360.77	2086	6133
1	138.41	11.5	80.66	128.39	1	169.74	11.5	193	376.73	738	2166
									Totals	351941	1010941

Overturning Moment/0.5Length		Weight of Building	Weight of Building/2
N-S	E-W		
911.76	6266.68	21724	10862
Overturning Issue			
N-S	E-W		
No	No		

To check if an overturning issue is present in the existing lateral design for the relocation of the building to Miami, FL, an overturning moment was calculated for a wind factor of 1.6. This moment was then divided by 0.5 x Length. This length is the length of the building the overturning moment is acting upon. This value was compared to both the total building weight, and half the total building weight. The overturning moment for Miami, FL increased almost 2 times the overturning moment calculated for New York City wind forces. However, this increase as shown in the calculations is still not enough to cause in overturning moment issue. With no overturning moment issue for Miami, FL the author suspects minimal foundation design changes.

Strength Check:

A strength check has been performed by the author for the relocation of the building to Miami, FL. This strength check focuses on the lateral system wind analysis forces.

Strength Check – Grid 10 – Wind Case 1

A strength check for Grid 10 – Wind Case 1 was performed by the author. The analysis of Wind Case 1 resulted in a maximum lateral force of 2444 kips resistance provided by Grid 10. This extreme case needed to be checked by the author for further analysis and conclusions.

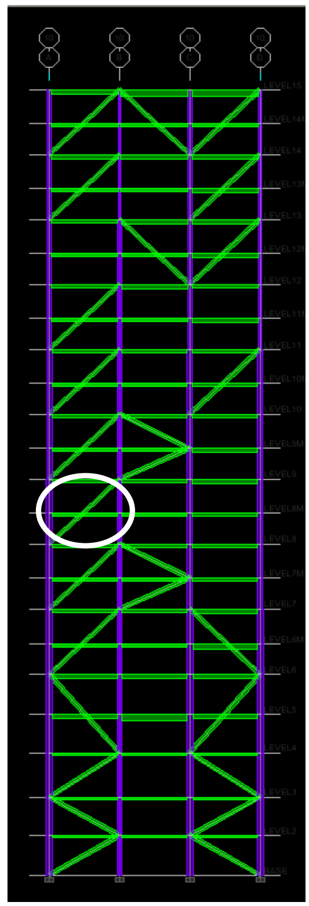


Figure 11: Grid 10 Elevation

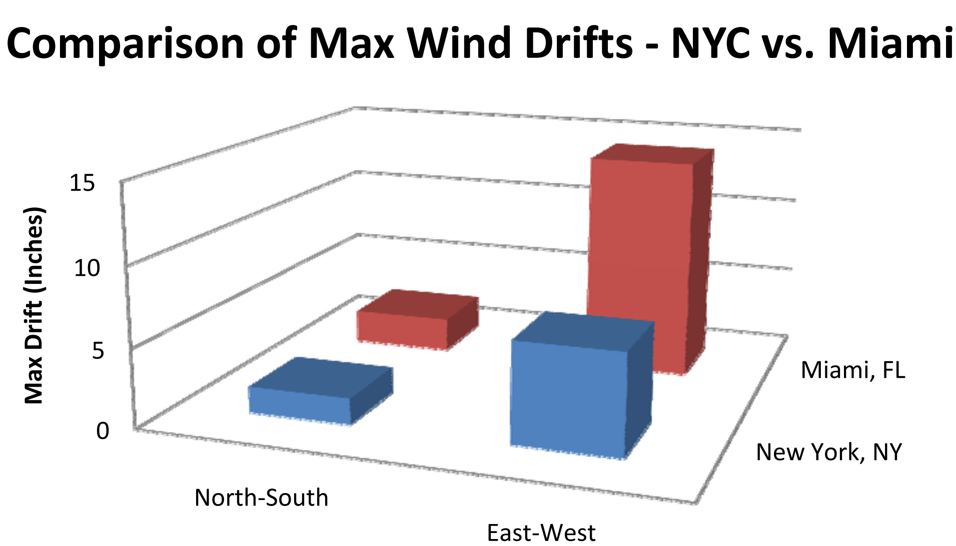
An axial capacity strength check was performed for the circled diagonal member above on Grid 10. This existing member is a W14x90. The strength check concluded that the member does not meet strength requirements. The author suspects many braced frames in the East-West lateral system to fail strength requirements. This issue will be considered during the redesign for Miami, FL. Please see Appendix Section A at the end of this report for supportive calculations.

Table 11: Wind Serviceability Checks - Summary

Wind – Serviceability Checks - Drift		Maximum Allowable Drift: 6.78 inches (H/400)
North-South – Max Drift	**East-West – Max Drift**	
2.16 Inches	14.09 Inches	
Okay	**Not Okay**	

Wind – Serviceability Checks – Story Drift		Maximum Allowable Story Drift: 0.32 inches ($0.020h_{sx}$)
North-South – Max Story Drift	**East-West – Max Story Drift**	
0.18 Inches	0.96 Inches	
Okay	**Not Okay**	

Graph 3: Wind Drift Comparison – NYC vs. Miami



	North-South	East-West
New York, NY	1.65	6.3
Miami, FL	2.16	14.09

Discussion of Serviceability Checks:

As seen on the previous page the East-West direction is not fulfilling drift and story drift requirements. Therefore, the East-West direction will need to have an increase in overall stiffness upon redesign. The author will propose additional braced frames, and larger members to fulfill stiffness requirements to reduce drift and story drifts seen previously.

Structural Depth Study

Task Three – Redesign and Analyze Lateral System (Miami, FL)

Description:

The completion of task two concluded that a redesign of the Northwest Science Building's lateral system was necessary due to the increase wind forces of Miami, FL. The lateral system must be made stiffer in the East-West direction. Instead of just increasing the cross sectional sizes of the diagonal bracing members, it is proposed to do a complete lateral redesign of the structure. Chevron bracing has been researched and is seen as a viable system based on economical concerns. Using this bracing type, the lateral system has been redesigned. The redesign process and analysis can be found on the following pages.

Upon the selection of the chevron bracing system, the following steps have been completed in the following order for task three.

- Provide initial frame sketches and stiffness calculations believed to withstand Miami, FL wind forces.
- Create ETABS model of redesigned lateral system.
- Analyze model with obtained wind forces. (Miami, FL)
- Record drifts and story drifts.
- Compare drifts and story drifts to Task 2 results.
- Provide checks of overturning and strength.
- Note any impact on foundations and design accordingly.

Tables and Figures:

Below is a bulleted list explaining the tables and figures to follow, regarding the redesign of the lateral system for Miami, FL.

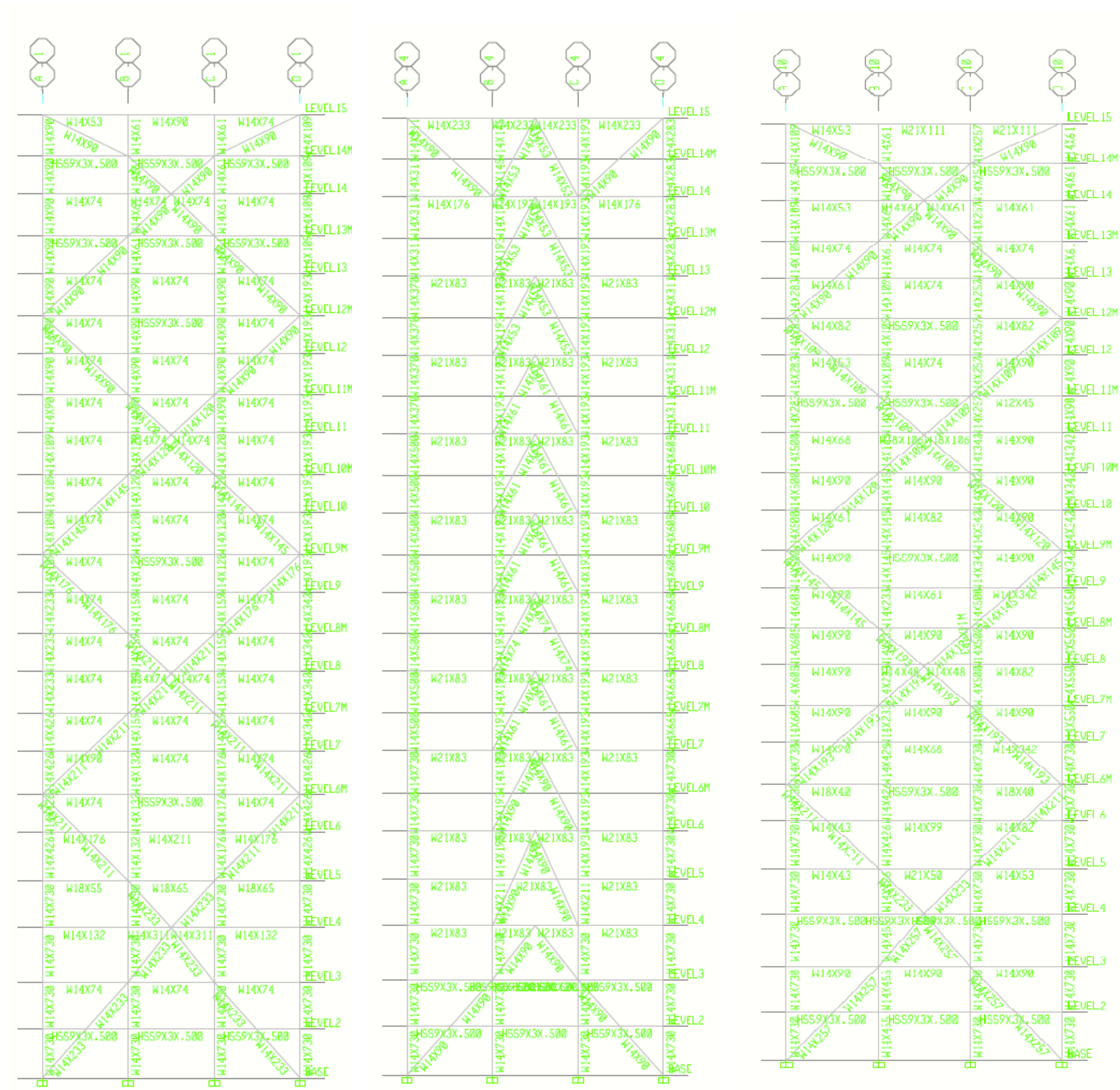
- Figure 13: Lateral Bracing Systems
    - Images of the four bracing systems to be considered as a redesign component.
- Table 12: Lateral Bracing Systems – Advantages/Disadvantages
    - Discusses the positives & negatives to be aware of for each system.
- Figure 15: Braced Frame Sketch (Grids 1 & 10)
    - Proposed additional braced framing by author.
- Figure 16: Preliminary Braced Frame Sizes (Grids 1 & 10)
    - Proposed section sizes of members based on axial and tension loads.
- Table 13: Wind Case Summary
    - Provides the maximum base shear forces on each grid. This information is used by the author to determine the governing wind force on each grid.
- Table 14: East-West Direction – Wind Serviceability Checks *(found in Structural Depth Appendix A)*
    - Story drift and drift checks of redesigned lateral system in East-West direction.
- Table 15: North-South Direction – Wind Serviceability Checks *(found in Structural Depth Appendix A)*
    - Story drift and drift checks of redesigned lateral system in North-South direction.
- Table 16: Wind Serviceability Checks – Summary
    - Provides conclusions on story drift and drift checks of redesigned lateral system in North-South direction.
- Graph 5: Wind Drift Comparison – Existing vs. Redesign

Conclusions:

The redesign of the lateral system consisted mainly of redesigning grids 1, 4, & 10 of the East-West direction. Large chevron continuous bracing was implemented for the exterior grids 1 & 10, while one bay chevron bracing was used for interior grid 4. This redesign provided acceptable story drifts, drifts, and strength requirements for the structure's relocation to Miami, FL. The North-South direction still met most load and serviceability requirements with the structure's relocation. Therefore, strength checks were implemented in this direction. The members that did not meet strength requirements were redesigned appropriately.

Below are images of redesigned grids 1, 4, & 10 respectively. These grids provide additional stiffness to reduce the deflections determined in Task 2. For larger images of these grids please see Appendix Section A at the end of this report.

Figure 12: Lateral Bracing Grids



Types of Lateral Bracing Systems:

Below is am image of four lateral bracing systems to be considered for the Northwest Science Building's redesign in Miami, FL.

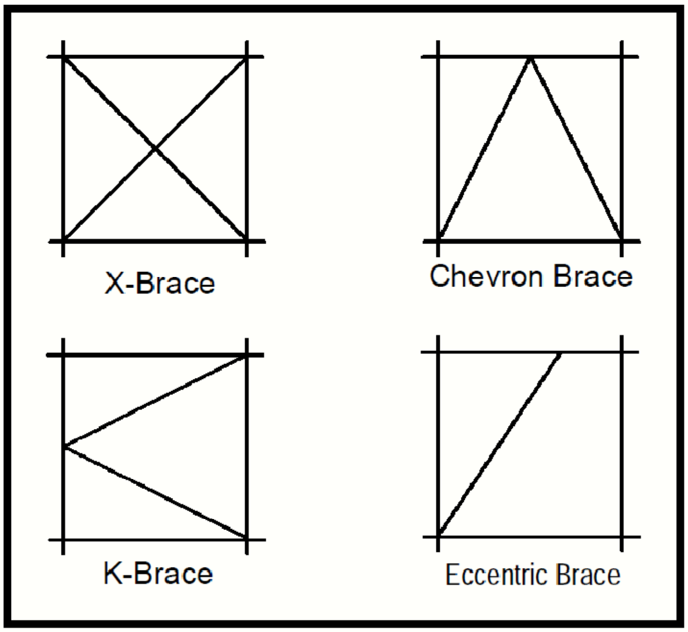
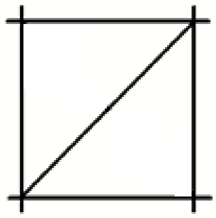
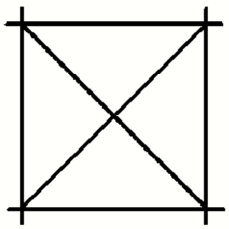
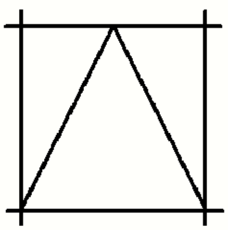
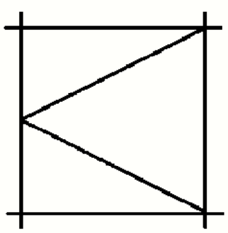
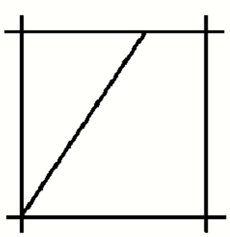


Figure 13: Lateral Bracing Systems

The advantages and disadvantages of each bracing system (along with the existing bracing system) are discussed on the following page.

Table 12: Lateral Bracing Systems – Advantages/Disadvantages

Lateral Bracing System	Advantages	Disadvantages
 Diagonal Brace (Existing System)	• Designed as both a compression and tension member • Less connection labor • Economical Design	• Larger members/sections required • Blocks circulation within building, must be coordinated with architect
 X-Brace	• Smaller members/sections used • Geometrically stable/braced in all four corners	• More connections required • Connection labor expensive • Blocks circulation within building, must be coordinated with architect
 Chevron Brace	• Smaller members/sections used • Allow circulation within building	• Design must considered shear transfer at midpoint of beam
 K-Brace	• Smaller members/sections used	• Blocks circulation within building, must be coordinated with architect • Design must considered shear transfer at midpoint of column
 Eccentric Brace	• Flexible design - can provide plenty coordination with architect's requests	• Design must considered eccentric force effects

Discussion of Lateral Bracing Systems:

The previous page explains many advantages/disadvantages a designer should be aware of when choosing a lateral bracing frame system. After studying each system, the author believes implementing the Chevron Brace into this thesis redesign is the best alternative. The following paragraph describes the reasons why the chevron bracing system was chosen.

Task 2's Existing Lateral System Analysis confirmed that the lateral system needs a substantial increase in the stiffness of the East-West lateral system. A great amount of stiffness in this direction comes from the two exterior frames of the structure. The author believes more interior frame bracing will be needed for the East-West direction. Chevron bracing will allow for minimal circulation concerns with the addition of these braced interior frames. The design will require more connection design and labor than the existing system; however, the increase in connections is not substantial compared to the three other proposed systems.

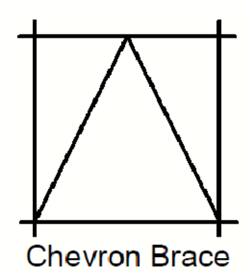


Figure 14: Chevron Brace – Chosen Lateral Bracing System

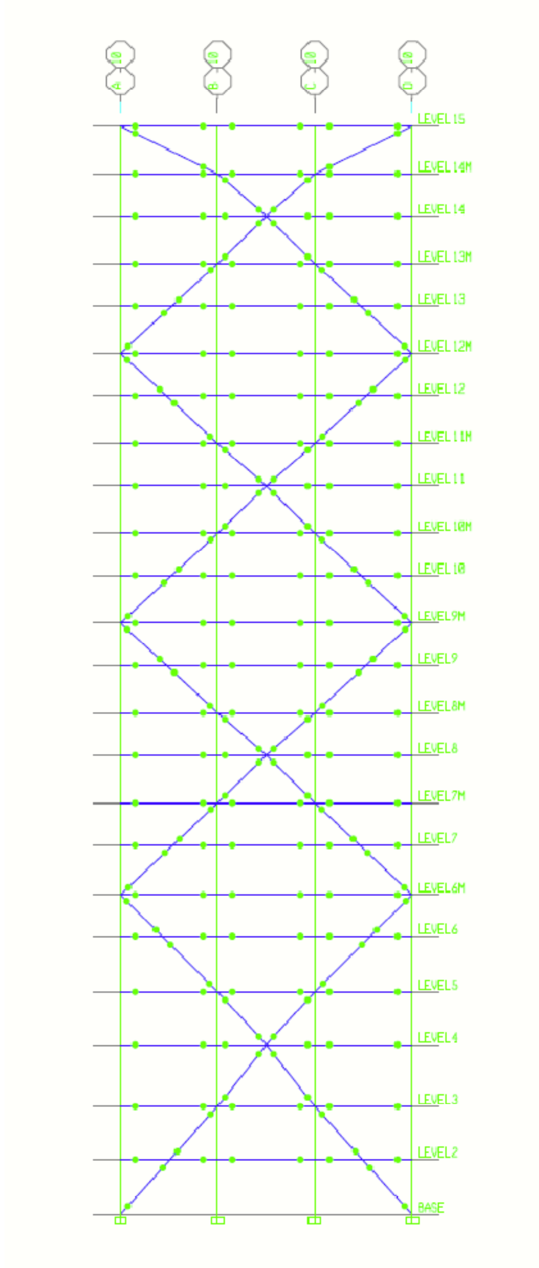
Preliminary Redesign:

The East-West lateral system as discussed in Task 2 needs to be redesigned to meet drift, story drift, and strength requirements. The redesign of the East-West lateral system is of more concern to the author and therefore will be redesigned, analyzed, and discussed more than the North-South system. The North-South redesign will be limited, due to the existing design fulfilling drift and story drift requirements and most strength requirements.

The preliminary design addressed the two exterior braced frames in the East-West direction. These frames currently provide most of the lateral resistance. The existing design, however, does not provide a continuous bracing path from the top to the bottom of the structure. This existing design was effective and cost efficient for New York City. With the relocation of the building to Miami, FL the author believes that these two braced frames will need to provide continuous bracing. Larger member sizes are also expected to be utilized.

The author chose the use of chevron bracing. After a few hand sketches, a schematic braced frame design was chosen. The following page provides the braced frame sketch.

Figure 15: Braced Frame Sketch (Grids 1 & 10)



This sketch provides continuous bracing from the top to bottom of the structure. This continuous bracing is expected to increase the stiffness of the East-West lateral system. This design is also seen to be more geometrically pleasing to the eye. These grids are exterior and will be seen. The use of architectural materials along with the brace framed system will be studied in the Architectural Breadth Study later in this report.

Once the braced frame geometry was chosen and sketched a design analysis was ready to take place. In order to get the members to reasonably accurate sizes, an ETABS model was used to find axial forces within the braced frame members. Braced frame sections were chosen based on the following two assumptions.

- The controlling wind cases for each grid were the same as the existing lateral system analysis. (See Task 2)
- Due to concentric connections the braced members were analyzed as axial members.

With these assumptions braced frame members could be chosen. Their unbraced length along with axial forces found will determine the member size. This process had to be reiterated several times until axial load forces remained fairly constant. The following preliminary design was determined.

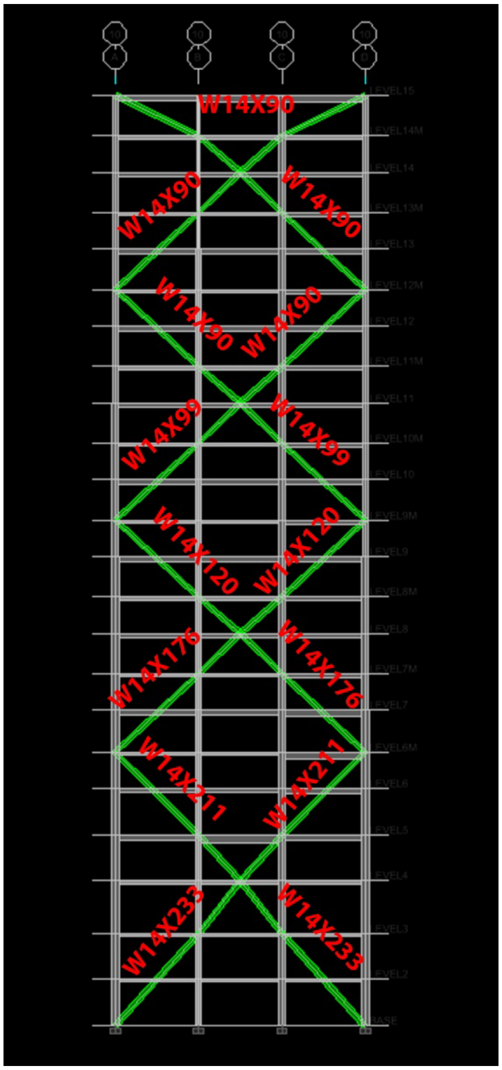


Figure 16: Preliminary Braced Frame Sizes (Grid 1 & 10)

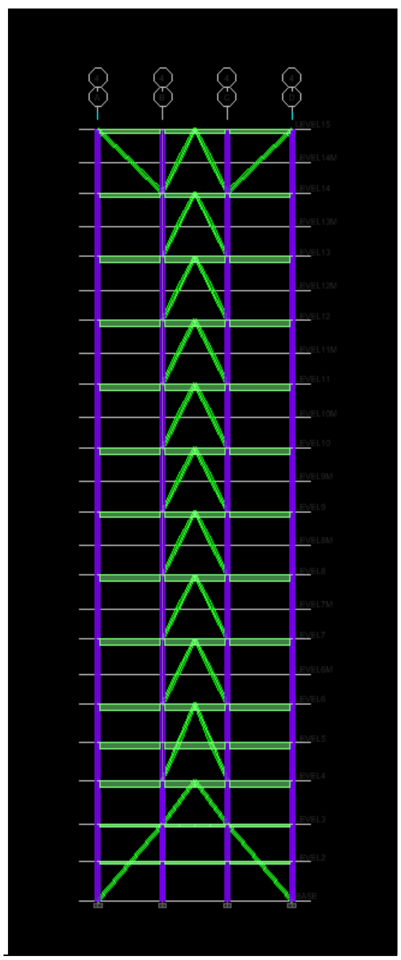
Finalized Redesign:

To finalize the redesign the following steps needed to be made:

- Provide additional stiffness to East-West lateral system to limit drift to an allowable drift of 6.78 inches. Currently preliminary design is drifting 7.62" at roof level.
- Once preliminary design is finalized, recheck strength requirements of braces.
- Check the strength requirements of the columns participating in the lateral system and redesign accordingly.
- Check the North-South lateral system for strength requirements.

Additional stiffness was provided within Grid 4 of the East-West lateral system. Chevron bracing was utilized throughout this grid because it is an interior frame. Chevron bracing allows for minimal interior space interference. The chevron bracing seen below is adjacent to an elevator shaft. This placement of bracing was seen by the author to be both architecturally and structurally acceptable.

Figure 17: Grid 4 – Chevron Bracing



The additional stiffness provided by Grid 4 reduced the overall deflection to 6.77 inches which meets serviceability requirements.

The braces strength requirements where checked based on pure axial and tension requirements. All of the braces provided are assumed to be concentric, therefore pure axial and tension will be governing design factors. LRFD compression and tension tables were used to check each member's capacity.

Summary of Strength Requirements Checked for Bracing:

- Available Compressive Strength ($\Phi_c P_n$)
- Local Buckling
- Effective Length and Column Slenderness
- Available Strength in Axial Tension ($\Phi_t P_n$)

All of the bracing for the East-West lateral system was checked and modified if needed for the above design checks. All concentric braces were assumed to transfer only wind loads. Therefore a 1.6 Wind Load factor and combination was used. For finalized member framing sizes see the Appendix Section A at the end of this report.

North-South direction design checks were focused upon the truss bracing at the 126 foot clear span level. These members are critical due to the fact that they support both gravity and lateral loads. Most of the members were acceptable with increased loading. The author believes the factor of safety these members were designed with was higher than first expected. A higher factor of safety could be due to the fact that this structure is very unique (has a 125 foot clear span) and therefore additional safety measures were implemented. A few of the members were not acceptable and were modified accordingly for the increase in loads.

Summary of Strength Requirements Checked for Columns:

- Available Compressive Strength ($\Phi_c P_n$)
- Local Buckling
- Effective Length and Column Slenderness
- Available Strength in Axial Tension ($\Phi_t P_n$)

Columns in the East-West direction were strength checked similarly to the brace members. The difference is that the columns will be carrying dead and live loads in addition to the wind loads. The following load combinations were assumed to control by inspection.

- 1.2(Dead) + 1.6(Wind) + 1.0(Live)
- 0.9(Dead) + 1.6(Wind)

Several columns needed to be redesigned due to increased wind loads and additional brace frame load transfer. These columns were modified appropriately. For finalized member framing sizes see Appendix Section A at the end of this report.

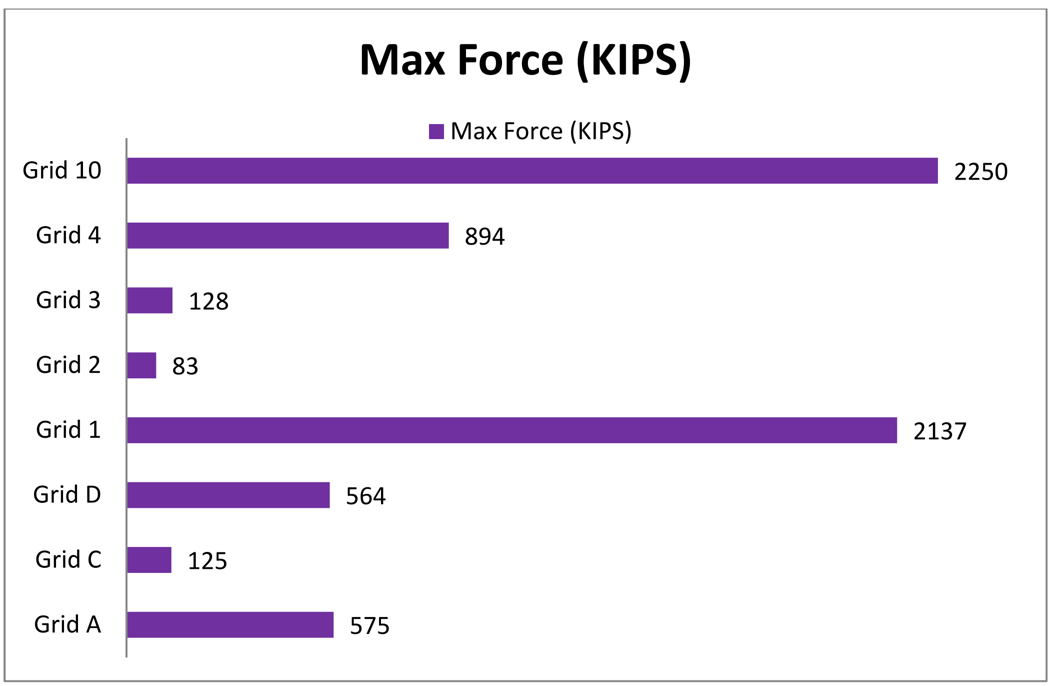
North-South direction columns were checked with the increase loads on the structure. Most columns met their strength criteria. This again is assumed by the author to be due to factor of safety in the initial design. W14x730 column members provide most of the column support towards the bottom of the structure. These members are massive in section and are sufficient for the increased loads.

Table 13 and Graph 4 on the following page summarize the participation of each lateral braced frame for the redesign of the structure. Grids 1 & 10, as seen, provide a great amount of stiffness in the East-West direction and therefore participate greatly in the lateral system.

Table 13: Wind Case Summary

	Grid A	Grid C	Grid D	Grid 1	Grid 2	Grid 3	Grid 4	Grid 10
Wind Case 1	575	125	564	2137	83	128	894	2250
Wind Case 2 (+M)	386	90	432	1352	50	84	627	1814
Wind Case 2 (-M)	438	87	375	1686	57	78	640	1465
Wind Case 3	416	89	395	1523	56	75	630	1644
Wind Case 4 (+M)	181	80	470	507	31	81	485	1988
Wind Case 4 (-M)	470	62	155	1905	66	53	515	553
	Grid A	Grid C	Grid D	Grid 1	Grid 2	Grid 3	Grid 4	Grid 10
Max Force (KIPS)	575	125	564	2137	83	128	894	2250

Graph 4: Maximum Grid Force Summary - Wind



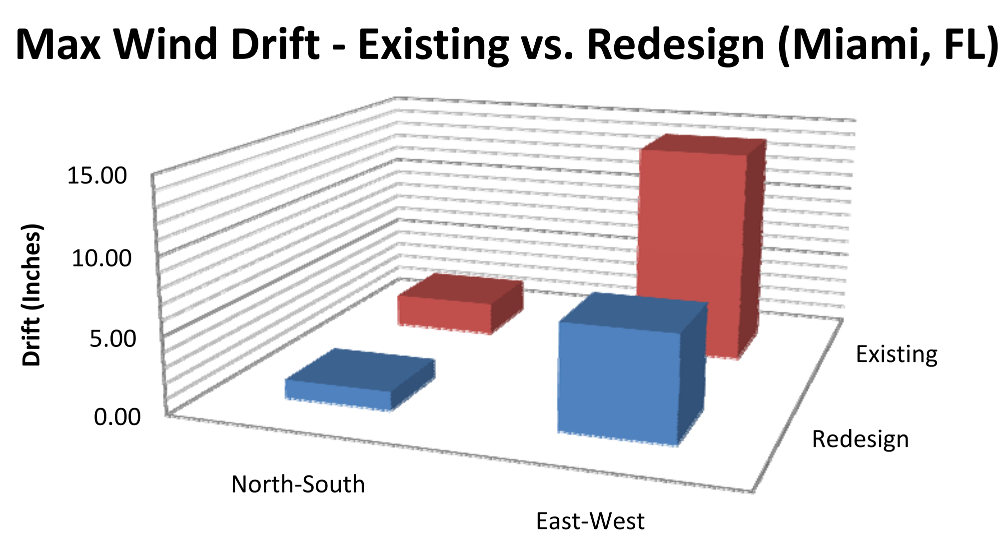
Redesigned Drifts & Story Drifts:

Table 16: Wind Serviceability Checks – Summary

Wind – Serviceability Checks - Drift		Maximum Allowable Drift: 6.78 inches (H/400)
North-South – Max Drift	**East-West – Max Drift**	
1.20	6.77 Inches	
Okay	Okay	

Wind – Serviceability Checks – Story Drift		Maximum Allowable Story Drift: 0.32 inches ($0.020h_{sx}$)
North-South – Max Story Drift	**East-West – Max Story Drift**	
0.17 Inches	0.45 Inches	
Okay	Okay (Close Enough)	

Graph 5: Wind Drift Comparison – Existing vs. Redesign



	North-South	East-West
Redesign	1.20	6.77
Existing	2.16	14.09

Discussion of Serviceability Checks for Redesign:

The redesigned lateral system is acceptable for story drift and drift requirements as shown on the previous page. With added stiffness in the East-West direction (Grids 1, 4, & 10), the overall drift was reduced by 50% (from 14.09 to 6.77 inches). Serviceability requirements have been meet by the author for the relocation of the building to Miami, FL.

Overturning and Strength Concerns of Redesign:

The existing lateral system was analyzed in Miami, FL for overturning acceptability. The existing system did not have any overturning concerns. This is based on the assumption that the site soils are fairly similar to those of the current site (NYC). The redesigned lateral system contains additional stiffness and therefore weighs more than the existing system. With increased weight there is even less of a concern of overturning issues. Therefore, it is assumed by the author that overturning is not a concern for the building. With no overturning concerns, the foundation of the building is seen to be acceptable for strength requirements. Strength checks of the foundation system are not included in the scope of this thesis project. The author suspects the foundation to increase in size slightly due to the increased weight of the redesigned structure.

As previously analyzed and discussed, strength requirements were checked for all lateral system members. After all checks and modifications have been made, strength requirements of the entire lateral system are now seen by the author to be acceptable.

Building Enclosure Breadth Study

Description:

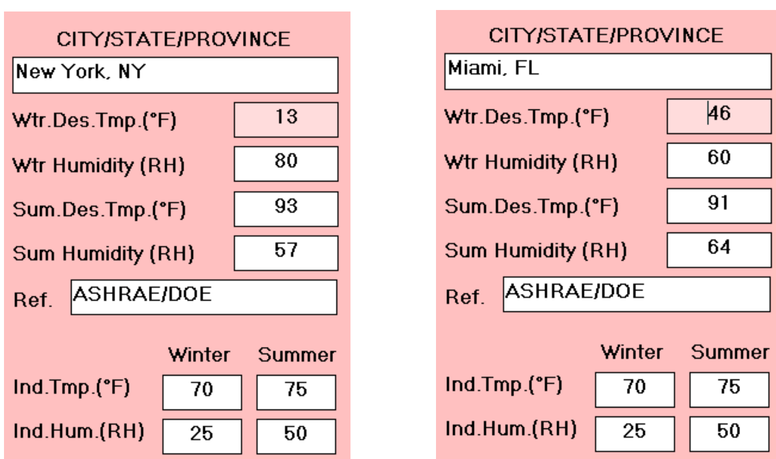
The existing building enclosure of the Northwest Science Building is described below. A brief understanding of the makeup of the building enclosure is vital to this Building Enclosure Breadth Study.

Building Enclosure:

The building enclosure has a very modern appearance. Clear anodized aluminum panels clad the exterior bays with diagonal structural elements. The panels express the diagonal structural element lines with extruded aluminum fins. The bays that are clear of structural diagonal elements are equipped with fenestrations. These fenestrations are clear glass panels. Larger glass curtain walls can be found between the 2nd and 4th levels, exposing the cafe, and between the 13th and 15th levels, exposing laboratories and support spaces. Also, a large area of the East building elevation, plaza facade, is covered in glass curtain wall, which encloses office space.

The author is concerned with the building enclosure elements due to the relocation of the Northwest Science Building to Miami, FL. The hot climate of Miami, FL is a concern the author believes will have a great impact on the building's enclosure system.

Below is an image comparing design temperatures and relative humidity used for both New York, NY and Miami, FL. This noticeable difference will be addressed.



CITY/STATE/PROVINCE	New York, NY	
Wtr.Des.Tmp.(°F)	13	
Wtr Humidity (RH)	80	
Sum.Des.Tmp.(°F)	93	
Sum Humidity (RH)	57	
Ref.	ASHRAE/DOE	
	Winter	Summer
Ind.Tmp.(°F)	70	75
Ind.Hum.(RH)	25	50

CITY/STATE/PROVINCE	Miami, FL	
Wtr.Des.Tmp.(°F)	46	
Wtr Humidity (RH)	60	
Sum.Des.Tmp.(°F)	91	
Sum Humidity (RH)	64	
Ref.	ASHRAE/DOE	
	Winter	Summer
Ind.Tmp.(°F)	70	75
Ind.Hum.(RH)	25	50

Figure 18: New York, NY vs. Miami, FL – Design Temperatures/Relative Humidity

The current building enclosure consists of the elements, described below.

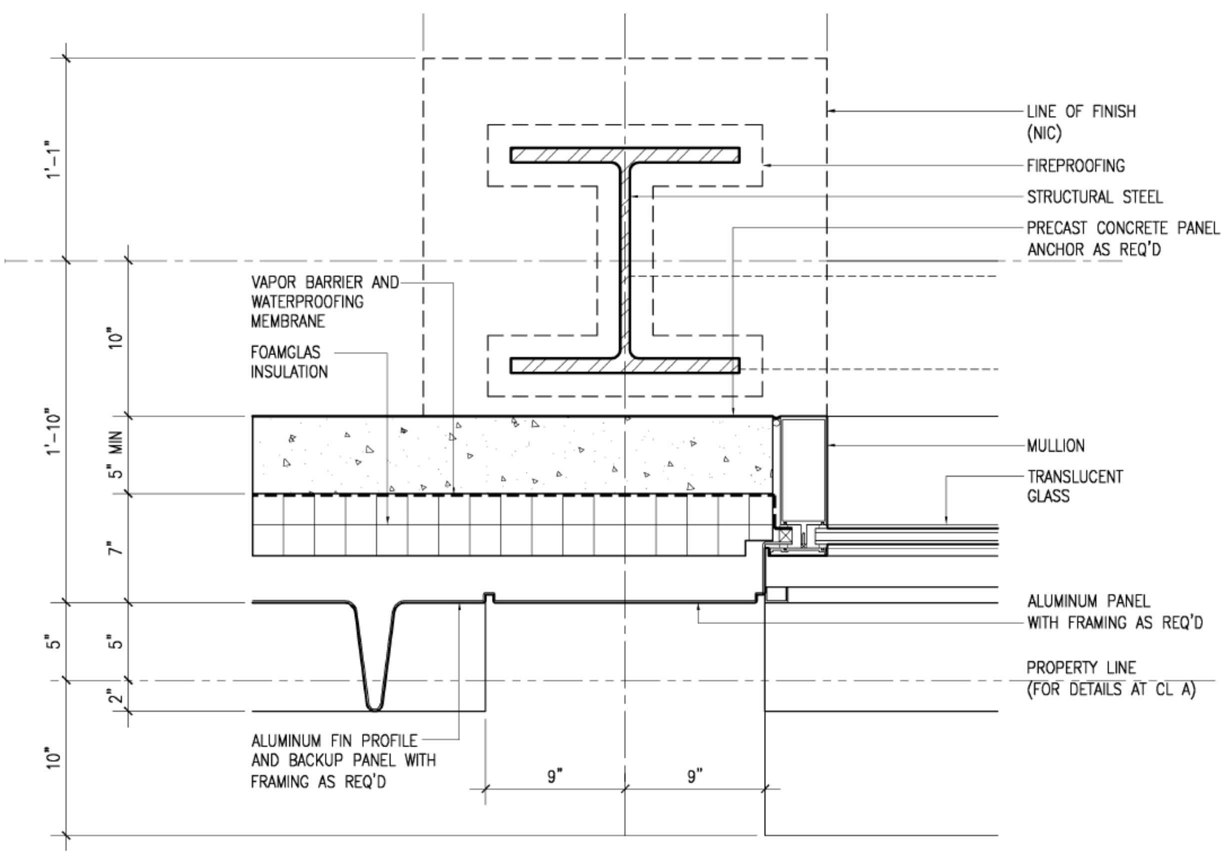
<u>Unitized Curtain Wall System:</u>

- Aluminum Panels (1/8")
  - Provides the surface seen on the exterior of the building.
  - This aluminum is anodize, which increases its resistance to corrosion.
  - At fenestrations and panel intersections aluminum mullions are used.
- 5" Precast Concrete Panels (Backup Structure)
  - Durable and wind support layer of wall system
- Foam Glass Insulation
  - The main thermal resistance layer of the curtain wall system.
- Vapor Barrier and Waterproofing Membrane
  - Located in between foam glass insulation and precast panel layers.
  - Used for vapor/air flow resistance.

<u>Note:</u> Described above is the widely used building enclosure system seen throughout the building envelope. Variations of this system do take place due to structural member intersections and coordination concerns. The system described above will be the building enclosure system researched and analyzed for this thesis project.

Below is a typical section detail of the building enclosure system.

Figure 19: Building Enclosure System Detail - Typical



This Building Enclosure Breadth will include the following steps.

- Research and document existing building materials of curtain wall system.
- Perform R-value, condensation, and air leakage analyses of curtain wall system.
- Research ASHRAE climate data and enclosure recommendations.
- Modify curtain wall system appropriately for Miami, FL.
- Perform cost analysis of existing enclosure versus redesign for Miami, FL.

Figures & Graphs:

Below is a bulleted list explaining the figures and graphs to follow, regarding this building enclosure study.

- Figure 20: R-Value Analysis – New York City
  - Depicts the existing wall system's thermal insulation analysis for NYC.
- Figures 21 & 22: Condensation Analysis – New York City
  - Depicts the existing wall system's water resistance analysis for NYC for both summer and winter seasons.
- Figures 23 & 24: Air Leakage Analysis – New York City
  - Depicts the existing wall system's energy loss due to air leakage through the building envelope for both summer and winter seasons.
- Figure 25: R-Value Analysis – Miami, FL
  - Depicts the redesigned wall system's thermal insulation analysis for Miami, FL.
- Figures 26 & 27: Condensation Analysis – Miami, FL
  - Depicts the redesigned wall system's water resistance analysis for Miami, FL for both summer and winter seasons.
- Figures 28 & 29: Air Leakage Analysis – Miami, FL
  - Depicts the redesigned wall system's energy loss due to air leakage through the building envelope for both summer and winter seasons.
- Graph 6: Air Leakage Analysis Comparison – Miami vs. NYC
  - Shows the differences in energy loss for Miami and NYC. Conclusions are made from this data.

Conclusions:

This building enclosure study revealed that less insulation will be needed for the building's relocation from New York City to Miami, FL. Four inches of foam glass insulation was used for the existing design (New York City). An R-value analysis (R-value of curtain wall system is 21.2), condensation analysis, and air leakage analysis on this curtain wall system yielded that it was sufficient for its New England climate. An R-value analysis (R-value of redesigned curtain wall system is 13.5), condensation analysis, and air leakage analysis of the redesigned was performed. These studies concluded that a 2.5 inch insulation layer was sufficient for Miami, FL. ASHRAE thermal insulations recommendations based on climate data also supported this analysis and research.

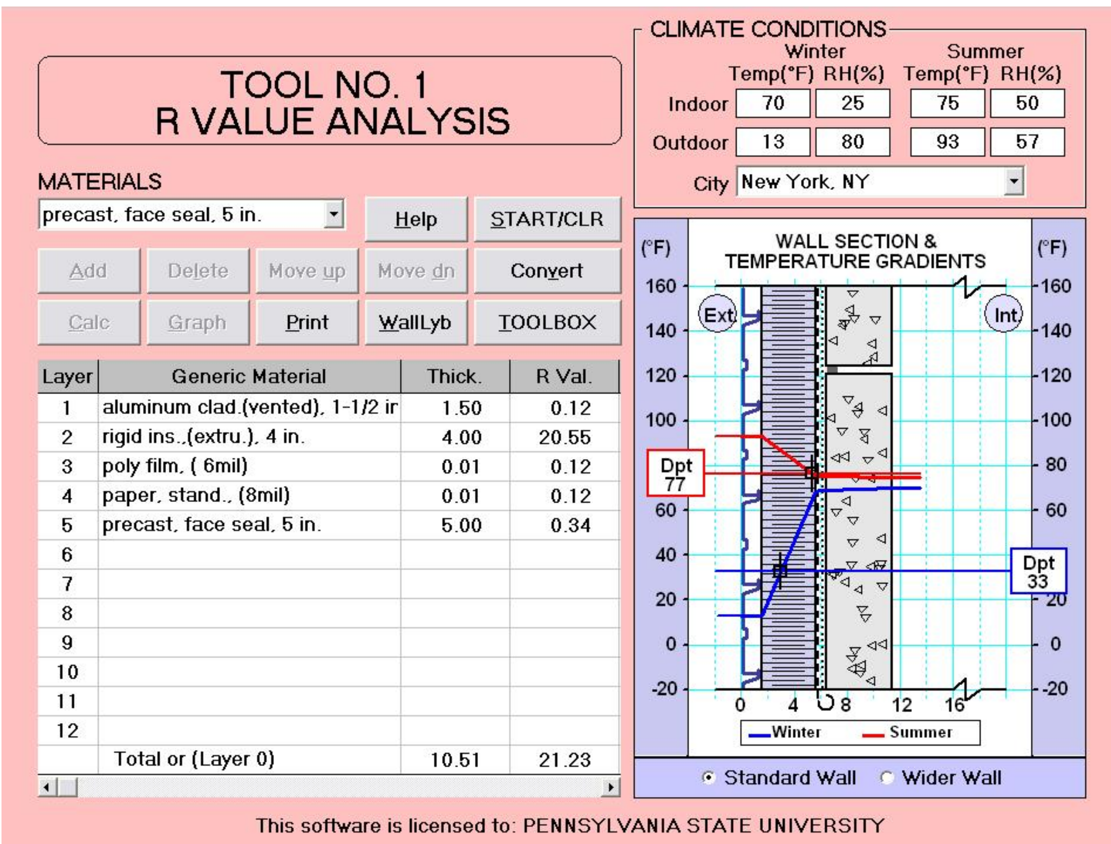
Summary of Existing Building Enclosure:

- Metal Panel Cladding with Infill Windows
    - Consists of 1/8" aluminum panels mounted onto a precast back-up structure. This system forms a rain screen cladding. The panel joints are unsealed, which allows for air ventilation.
    - Aluminum panels consist of extruded aluminum blades, which express the diagonal bracing of the structural system.
    - All glass is fully tempered or heat-strengthened as required.
    - The finish of all aluminum is clear anodized.
    - Between metal panel and precast layer non-combustible foam glass insulation of 4 inches is used.

R-Value Analysis – New York City:

An R-Value analysis of the existing building enclosure for New York City was performed. Below is an image of the R-Value analysis. H.A.M (Heat. Air. Moisture) Toolbox was the software program used for this analysis and several other analyses to follow.

Figure 20: R-Value Analysis – Existing Enclosure System – New York City



As shown above the dew point temperatures (for winter and summer) occur both on the exterior portion of the wall enclosure system, within the rigid insulation layer. This allows for water to condensate towards the exterior portion of the system, and be weeped to the exterior of the building, causing no interior condensation concerns.

Condensation Analysis – New York City:

Below is a condensation analysis, conveying that there are no condensation concerns for this existing enclosure system for New York City.

Figure 21: Condensation Analysis Winter – Existing Enclosure System – New York City

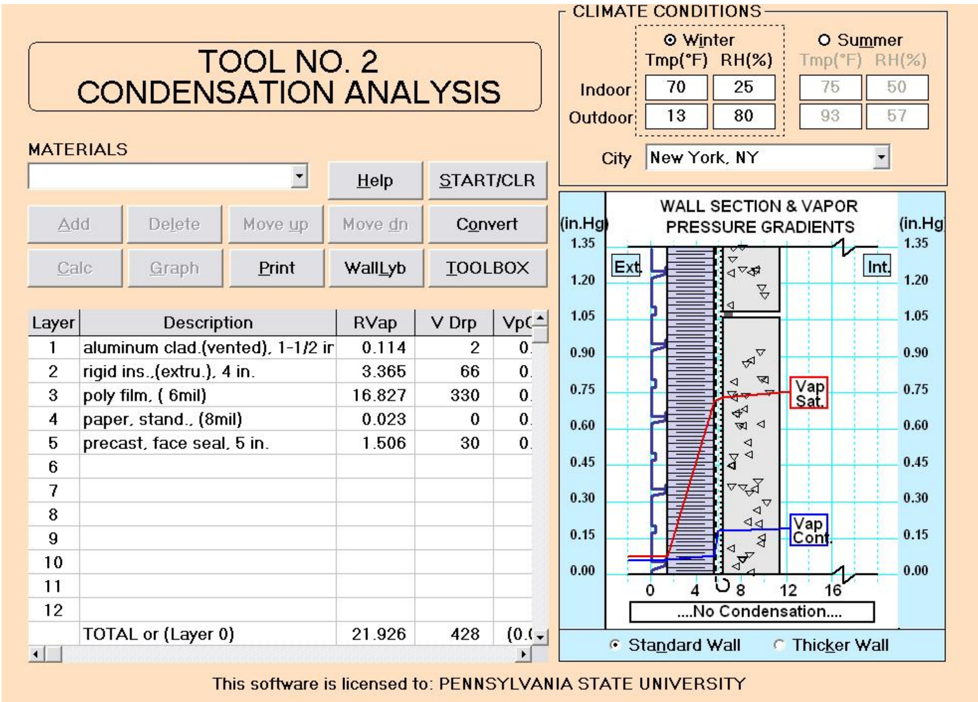
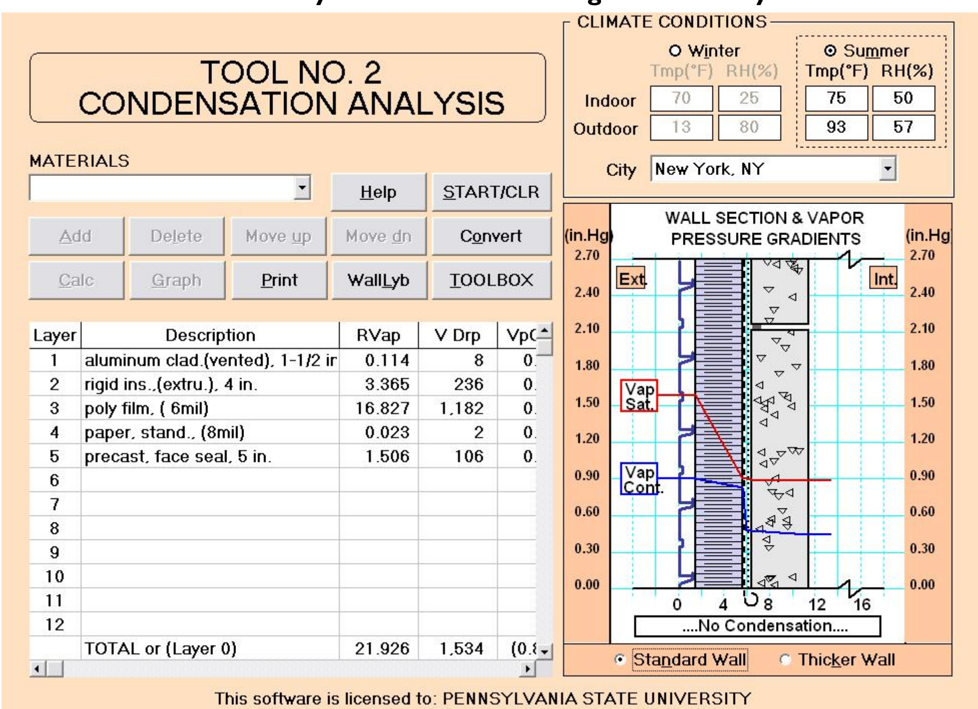


Figure 22: Condensation Analysis Summer – Existing Enclosure System – New York City



<u>Air Leakage Analysis – New York City:</u>

Below is an air leakage analysis for the building in New York City. This analysis estimates the energy loss for the whole building due to building enclosure air leakage during the summer and winter seasons.

Figure 23: Air Leakage Analysis Winter – Enclosure System – New York City

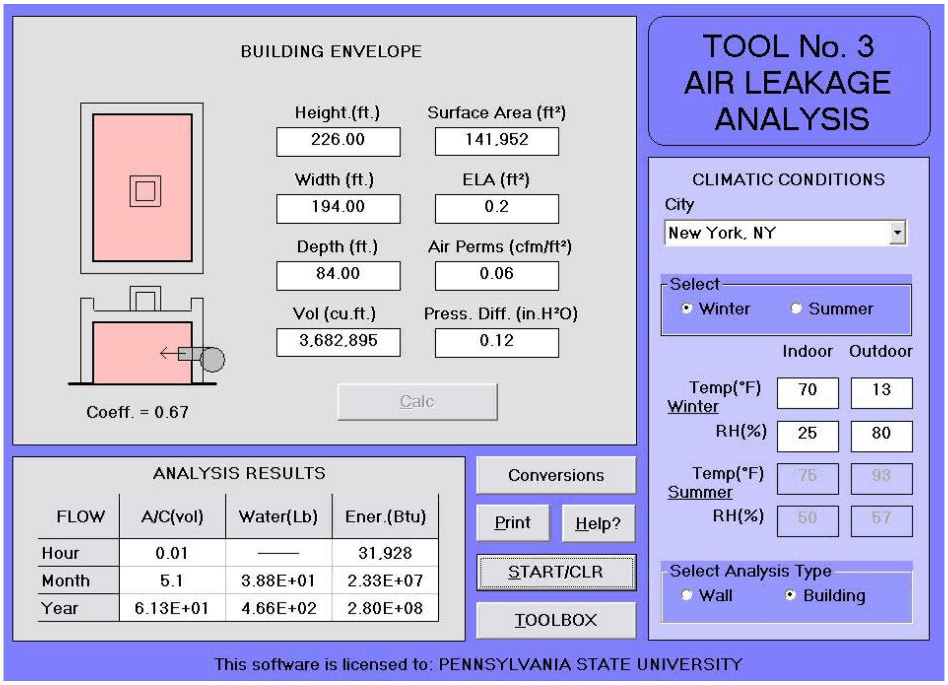
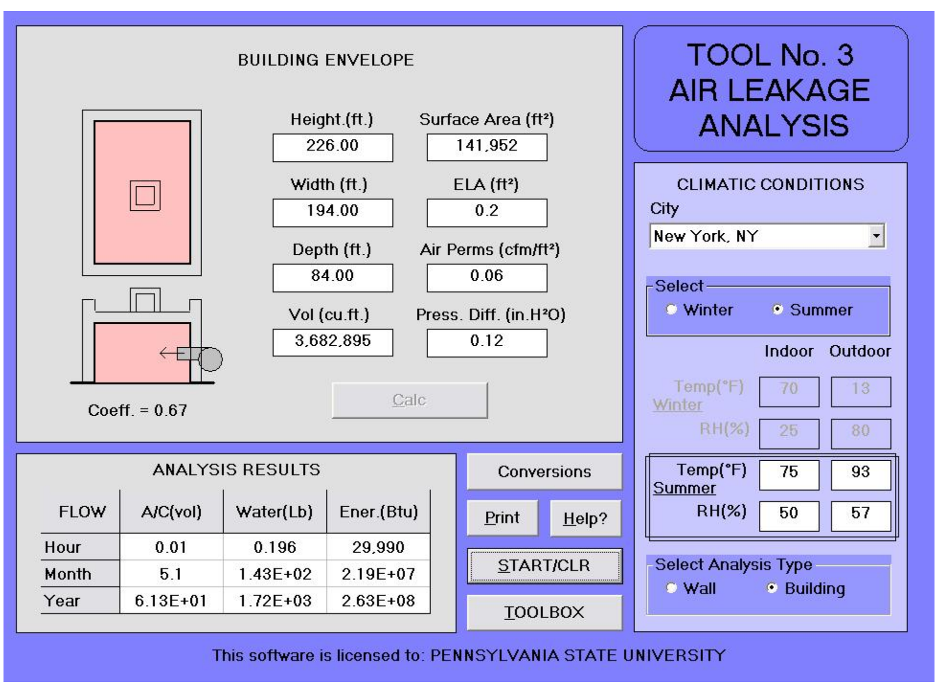


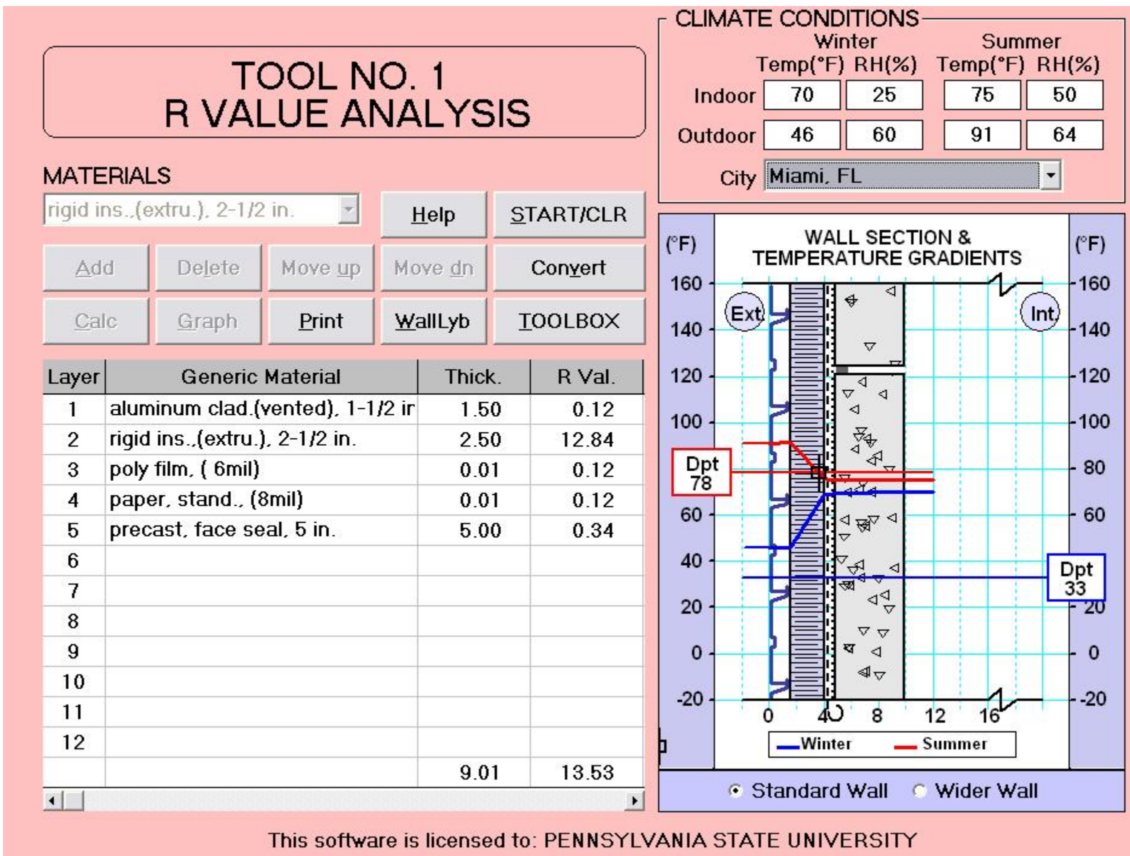
Figure 24: Air Leakage Analysis Summer – Enclosure System – New York City



R-Value Analysis – Miami, FL:

An R-Value analysis of the building enclosure system for Miami, FL was performed. Below is an image of the R-Value analysis. Notice that the existing wall closure was modified slightly for the relocation. A 2.5 inch insulation layer is used for Miami, FL (4 in. was used for New York City). This decrease in insulation was made possible due to Miami's warmer climate.

Figure 25: R-Value Analysis – Redesigned Enclosure System – Miami, FL



Condensation Analysis – Miami, FL:

Below is a condensation analysis, conveying that there are no condensation concerns for the enclosure system in Miami, FL. Notice again, that the existing wall closure was modified slightly for the relocation. A 2.5 inch insulation layer is used for Miami, FL (4 in. was used for New York City).

Figure 26: Condensation Analysis Summer – Redesigned Enclosure System – Miami, FL

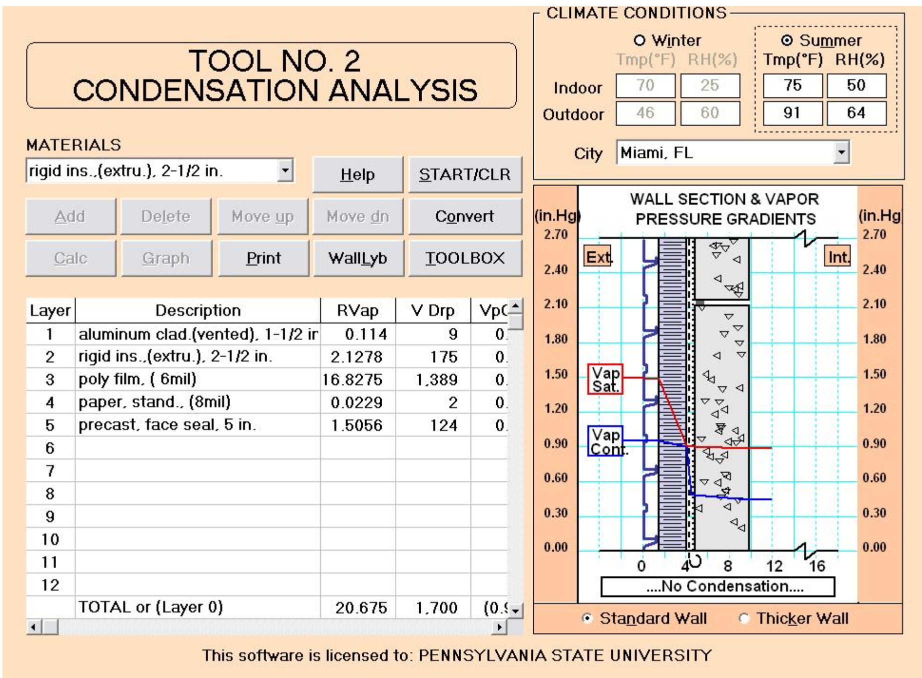
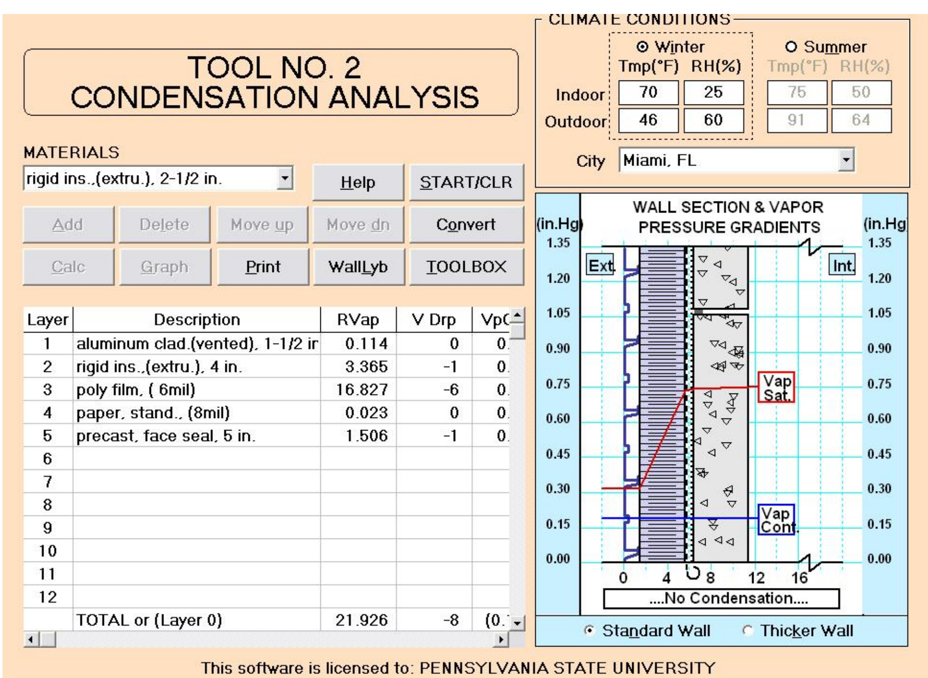


Figure 27: Condensation Analysis Winter – Redesigned Enclosure System – Miami, FL



Air Leakage Analysis – Miami, FL:

Below is an air leakage analysis for the building in Miami, FL. This analysis estimates the energy loss for the whole building due to building enclosure air leakage during the summer and winter seasons.

Figure 28: Air Leakage Analysis Winter – Enclosure System – Miami, FL

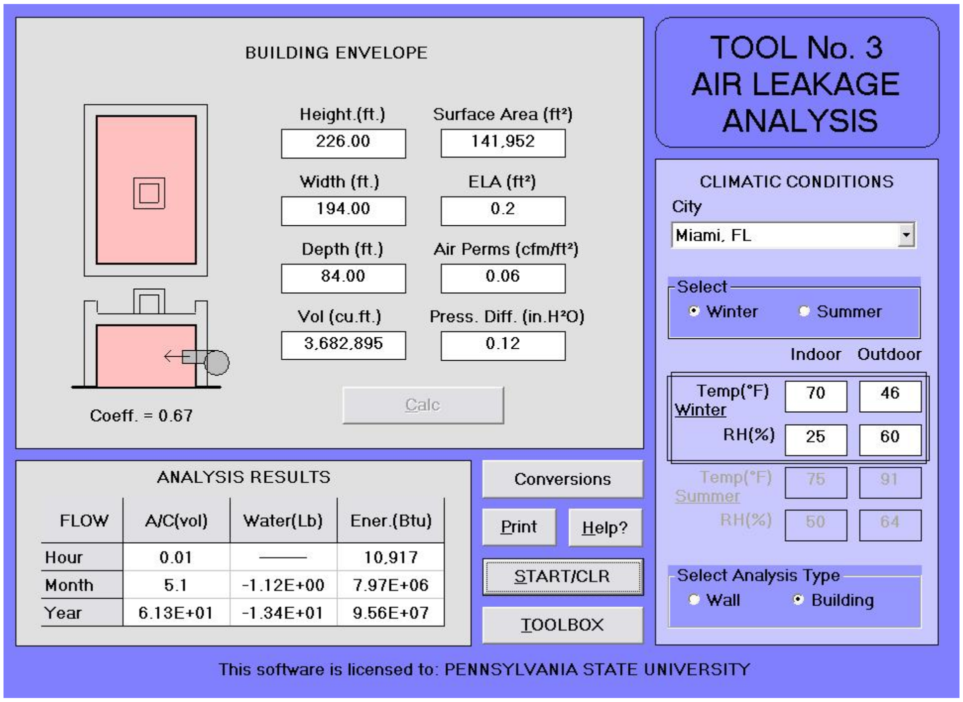
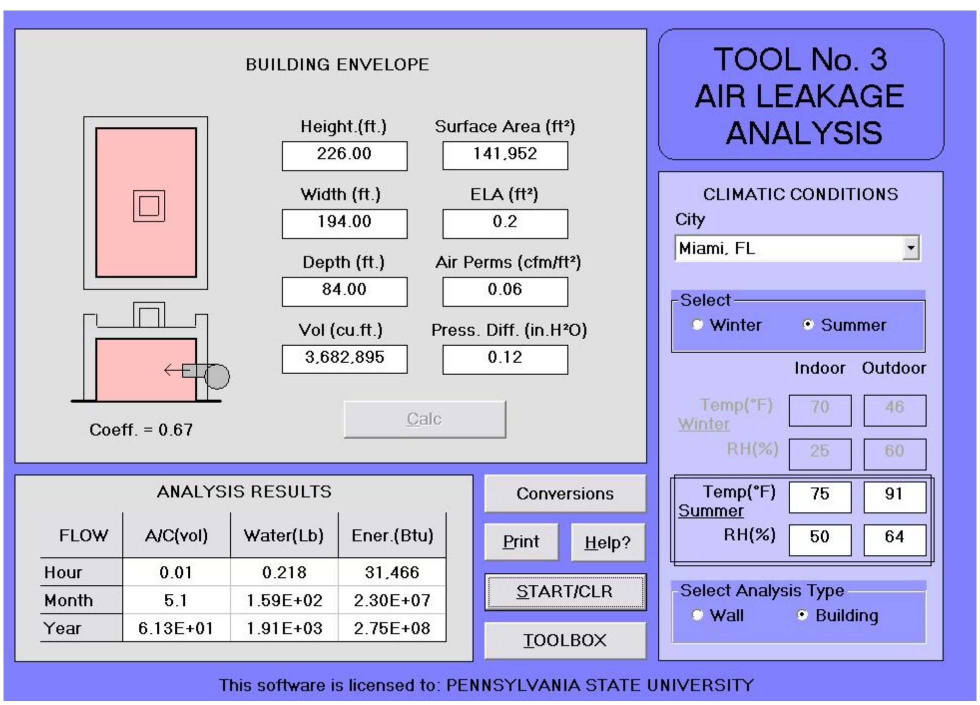
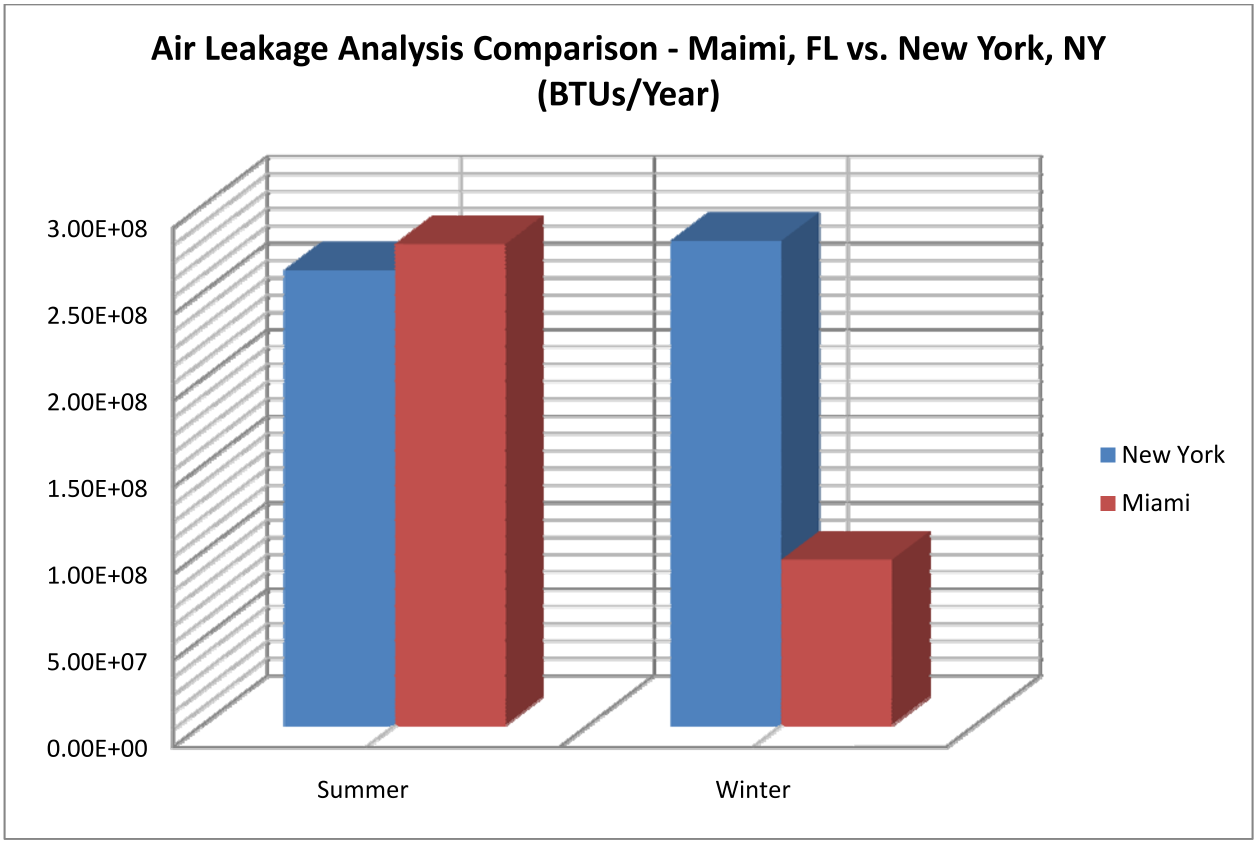


Figure 29: Air Leakage Analysis Summer –Enclosure System – Miami, FL



Air Leakage Analysis Comparison – Miami, FL vs. New York, NY



Graph 6: Air Leakage Analysis Comparison – Miami, FL vs. New York, NY

Air Leakage Analysis Comparison - Miami, FL vs. New York, NY		
All Values in BTUs per Year		
	Summer	**Winter**
New York	2.63E+08	2.80E+08
Miami	2.78E+08	9.56E+07
Difference	1.50E+07	**1.84E+08**

The comparison above shows that there is a small difference in energy loss due to air leakage during the summer season between New York, NY and Miami, FL. On the other hand, there is a large difference in energy loss during the winter season of 1.84E+08 BTUs/Year. This is equivalent to burning about 200,000 gallons of natural gas. This establishes that the building in New York City experiences an overall greater energy loss due to air leakage.

The R-value analysis, condensation analysis, and the air leakage analysis all support the building enclosure modification of the insulation layer from originally 4 inches thick (NYC) to a 2.5 inches thick for Miami, FL. ASHRAE recommended R-Values based on climate also support the redesign of this insulation layer. The following pages provide ASHRAE data and discussion.

ASHRAE Climate Zone - Roof, Walls, and Vertical Glazing Material Recommendations

Figure 30: Climate Zone 1 – Miami, FL

Climate Zone 1 Recommendation Table

	Item	Component	Recommendation	How-To's in Chapter 4
Envelope	Roof	Insulation entirely above deck	R-15 c.i.	EN1-2, 17, 20-21
		Metal building	R-19	EN1, 3, 17, 20-21
		Attic and other	R-30	EN4, 17-18, 20-21
		Single rafter	R-30	EN5, 17, 20-21
		Surface reflectance/emittance	0.65 initial/0.86	EN1
	Walls	Mass (HC > 7 Btu/ft^2)	No recommendation	EN6, 17, 20-21
		Metal building	R-13	EN7, 17, 20-21
		Steel framed	R-13	EN8, 17, 20-21
		Wood framed and other	R-13	EN9, 17, 20-21
		Below-grade walls	No recommendation	EN10, 17, 20-21
	Floors	Mass	R-4.2 c.i.	EN11, 17, 20-21
		Steel framed	R-19	EN12, 17, 20-21
		Wood framed and other	R-19	EN12, 17, 20-21
	Slabs	Unheated	No recommendation	EN17, 19-21
		Heated	No recommendation	EN17, 19-21
	Doors	Swinging	U-0.70	EN15, 20-21
		Non-swinging	U-1.45	EN16, 20-21
	Vertical Glazing	Window to wall ratio (WWR)	20% to 40% maximum	EN23, 36-37
		Thermal transmittance	U-0.56	EN25
		Solar heat gain coefficient (SHGC)	N, S, E, W - 0.35 / N only - 0.49	EN27-28
		Window orientation	$(A_N * SHGC_N + A_S * SHGC_S) > (A_E * SHGC_E + A_W * SHGC_W)$	A_x–Window area for orientation x EN26-32
		Exterior sun control (S, E, W only)	Projection factor 0.5	EN24, 28, 30, 36, 40, 42 DL5-6

Figure 31: Climate Zone 4 – New York, NY

Climate Zone 4 Recommendation Table

	Item	Component	Recommendation	How-To's in Chapter 4
Envelope	Roof	Insulation entirely above deck	R-20 c.i.	EN2, 17, 20-21
		Metal building	R-13 + R-19	EN3, 17, 20-21
		Attic and other	R-38	EN4, 17-18, 20-21
		Single rafter	R-38	EN5, 17, 20-21
		Surface reflectance/emittance	No recommendation	
	Walls	Mass (HC > 7 Btu/ft^2)	R-11.4 c.i.	EN6, 17, 20-21
		Metal building	R-13	EN7, 17, 20-21
		Steel framed	R-13 + R-7.5 c.i.	EN8, 17, 20-21
		Wood framed and other	R-13	EN9, 17, 20-21
		Below-grade walls	No recommendation	EN10, 17, 20-21
	Floors	Mass	R-8.3 c.i.	EN11, 17, 20-21
		Steel framed	R-30	EN12, 17, 20-21
		Wood framed and other	R-30	EN12, 17, 20-21
	Slabs	Unheated	No recommendation	EN17, 19-21
		Heated	R-7.5 for 24 in.	EN14, 17, 19-21
	Doors	Swinging	U-0.70	EN15, 20-21
		Non-swinging	U-0.50	EN16, 20-21
	Vertical Glazing	Window to wall ratio (WWR)	20% to 40% maximum	EN23, 36-37
		Thermal transmittance	U-0.42	EN25
		Solar heat gain coefficient (SHGC)	N, S, E, W - 0.46 / N only - 0.46	EN27-28
		Window orientation	$(A_N * SHGC_N + A_S * SHGC_S) > (A_E * SHGC_E + A_W * SHGC_W)$	A_x–Window area for orientation x EN26-32
		Exterior sun control (S, E, W only)	Projection factor 0.5	EN24, 28, 30, 36, 40, 42 DL5-6

Summary of Recommendations Provided by ASHRAE:

Walls:

- An R-value of 13 is recommended for Miami, FL
- An R-value of 13 + 7.5 of continuous insulation (total of 20.5) is recommended for New York City.

Roof:

- An R-value of 19 is recommended for Miami, FL
- An R-value of 13 + 19 (total of 32) is recommended for New York City.

Comparison of R-Values Provided - Existing vs. Redesign Enclosure:

- Miami, Fl: R-Value of Walls Provided = **13.5** (13 is recommended)
- New York, NY: R-Value of Walls Provided = **21.2** (20.5 is recommended)

The comparison above shows that the existing curtain wall design and the redesign curtain wall for Miami, FL both meet R-Value requirements. This also supports the reduction in the rigid insulation layer as previously discussed.

Note: Roof R-value recommendations of ASHRAE also suggest that a redesign of the roofing could be analyzed and redesign. This analysis was not included within the scope of this breadth. The author believes a redesign of the roofing will reduce material insulation. Construction costs are believed to decrease along with the redesign of the curtain wall system.

Building Envelope – RS Means – Cost Estimation Analysis:

Figure 32: Insulation Cost Data – Cost Works

0721 Thermal Insulation — Lines 1 - 50 of 201

Line Number		Description	Unit	Crew	Daily Output	Labor Hours	Bare Material	Bare Labor	Bare Equipment	Bare Total
072113100520	G	Foil faced,...	S.F.	1 C...	1000.00	0.008	0.92	0.32		1.24
072113100540	G	1-1/2" t...	S.F.	1 C...	1000.00	0.008	1.36	0.32		1.68
072113100560	G	2" thick,...	S.F.	1 C...	890.00	0.009	1.71	0.36		2.07
072113100580	G	2-1/2" t...	S.F.	1 C...	800.00	0.010	2.02	0.40		2.42
072113100600	G	3" thick,...	S.F.	1 C...	800.00	0.010	2.19	0.40		2.59
072113100670	G	6#/CF, unface...	S.F.	1 C...	1000.00	0.008	0.98	0.32		1.30
072113100690	G	1-1/2" t...	S.F.	1 C...	890.00	0.009	1.50	0.36		1.86
072113100700	G	2" thick,...	S.F.	1 C...	800.00	0.010	2.12	0.40		2.52
072113100721	G	2-1/2" t...	S.F.	1 C...	800.00	0.010	2.32	0.40		2.72
072113100741	G	3" thick,...	S.F.	1 C...	730.00	0.011	2.78	0.44		3.22
072113100821	G	Foil faced,...	S.F.	1 C...	1000.00	0.008	1.38	0.32		1.70
072113100840	G	1-1/2" t...	S.F.	1 C...	890.00	0.009	1.98	0.36		2.34
072113100850	G	2" thick,...	S.F.	1 C...	800.00	0.010	2.59	0.40		2.99
072113100880	G	2-1/2" t...	S.F.	1 C...	800.00	0.010	3.11	0.40		3.51
072113100900	G	3" thick,...	S.F.	1 C...	730.00	0.011	3.72	0.44		4.16
072113101500	G	Foamglass, 1-1/2...	S.F.	1 C...	800.00	0.010	1.37	0.40		1.77
072113101530	G	2" thick,...	S.F.	1 C...	765.00	0.010	1.94	0.42		2.36
072113101550	G	3" thick,...	S.F.	1 C...	730.00	0.011	3.29	0.44		3.73

A bare material cost analysis was performed for the foam glass rigid insulation layer.

The following table represents the data calculated.

RS MEANS RESULTS	Bare Material Cost
Miami, FL (2.5" Foamglass)	$344,250
New York, NY (4.0" Foamglass)	$530,150

This bare material cost analysis shows that a bare material savings of $185,900 can be obtained from using 1.5 inches less of foam glass insulation.

Architectural Breadth Study (Miami, FL)

Description:

The relocation of the building to Miami, FL causes architectural concerns. The author wants the building to be representative of Miami, FL architecture. The author believes the exterior building architecture should include elements seen throughout Miami, FL. However, the building should also have a unique blend of exterior elements to produce an eye-pleasing design. This study will first include an architectural historical timeline of Miami, FL. Miami's architectural styles will be discussed in detail. The author will propose a new architectural appearance of the building exterior. The architecture chosen is intended to embody Miami architecture's past and present.

Images:

Below is a bulleted list explaining the images to follow, regarding this Miami, FL Architectural Breadth Study.

- Image 1: Freedom Tower – Miami, FL
    - Mediterranean Revival Style example of Miami, FL.
- Image 2: Park Central Hotel – Miami, FL
    - Art Deco Style example of Miami, FL..
- Image 3: US Bacardi Headquarter – Miami, FL
    - Streamline Modern Style example of Miami, FL.
- Images 4 & 5: Proposed North & South Architectural Facades
    - Redesign of exterior architecture of North and South facades along with author's discussion.
- Images 6 & 7: Proposed East & West Architectural Facades
    - Redesign of exterior architecture of East and West facades along with author's discussion.
- Images 8 & 9: 3-D Architecture Renderings
    - 3-D images of redesign of architectural appearance along with author's discussion.

Conclusions:

The architecture redesign implemented by the author provides a modern feel to the building, while still incorporating historical and currently seen Miami styles. The styles implemented into this redesign are Art Deco, Mediterranean Revival, and Streamline Modern. The following literature provides how the author developed the architectural image seen to the right.

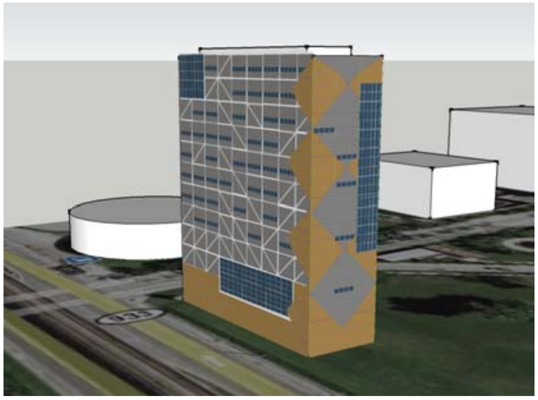


Image 8: South-West Architectural Rendering

Miami, FL Architectural Styles:

Three of Miami, FL architectural styles will be discussed below. These three styles are the most influential of Miami, FL and therefore can be seen throughout the city.

1. **Mediterranean Revival Style of the 1910's - 1930's**

   This style was used greatly during Miami's Ocean Beach boom period. It is representative of Mediterranean resort architecture. Therefore, it is seen to contain Italian, Northern Africa, and Spanish themes. This style can be seen applied to hotels, apartment buildings, and commercial structures. Some of the main architectural elements include stucco walls, terra cotta roofs, and arches. The freedom tower shown below is a good representation of this architectural style.

Image 1: Freedom Tower – Miami, FL

Image supplied by www.historicpreservationmiami.com

This building was originally named the Miami Daily News Tower. It is one of the most impressive landmarks of Miami's skyline. It was renamed the Freedom Tower in the 1960's when it served as the Cuban Refugee Emergency Center. Take notice of the stucco color walls cladding the building. Arches and a terra cotta roof are not seen on this building. This is one of the few high rise structures in Miami to be a Mediterranean style. Low rise construction of Mediterranean style is seen to include arches, terra cotta roofs, along with stucco walls. The freedom tower is similar in height the Northwest Science Building, and therefore was seen as a more appropriate comparison.

2. Art Deco Style of the 1920's - 1930's

This style originated from the 1925 Paris Exposition des Arts Decoratifs et Industriels Modernes. This was a design fair that celebrated the union of decorative arts and advancements in technology and industry.

Buildings expressing Art Deco Style are angular and clean, have stepped back facades, have symmetrical or asymmetrical massing, and also have strong vertical expressions. The architecture can be seen to include geometric patterns, natural forms, and industrial symbols. In Miami, natural themes of tropical flowers, palm trees, and flamingoes can be seen. Materials used to achieve these designs were stucco, etched glass, different metals, and cast concrete. Below is an image representation of an Art Deco style building.

Image 2: Park Central Hotel – Miami, FL

Image supplied by www.travelmuse.com

The type of architecture displayed in the above image of the Park Central Hotel dominates the Miami shoreline. The building image above contains vertical expressive blue stucco strips, vertical stacked windows, and octagonal shaped windows which are all significant to the Art Deco Style.

3. Streamline Modern Style of the 1930's-1950 (MiMo)

This style followed the Art Deco period and started as modern transportation and industrial design began to have a great impact on building construction. It is referred to as Miami Modern Style, also known as MiMo. The sleek character of automobiles, airplanes, trains, and buses motivated powerful horizontal design components. These horizontal displays are accented by prominent vertical features. Some examples include continuous stripe banding, radio tower-like spires, and deck railings. Smooth rounded corners also can be seen in this style. Below is an image of a Miami Modern Style building.

Image 3: US Bacardi Headquarters – Miami, FL

Image supplied by www.wikimedia.org

The US Bacardi Headquarters building depicted above is a great example of Miami's Modern Style Architecture blended with Art Deco Style. Notice the dominant vertical mullions on the large façade of the building (Streamline Modern Style), while the smaller area façade contains a natural theme of leaves (Art Deco). This building was chosen as an architectural example because it is very proportionally similar in dimensions (length, width, and height) to the Northwest Science Building.

Miami, FL Architectural Styles Applied to Northwest Science Building:

Several characteristics of the previously discussed architectural styles will be implemented into the redesign of the Northwest Science Building's exterior appearance. The following characteristics were seen by the author to be both representative to Miami architecture and a possible complement to the existing Northwest Science Building.

- Geometric Patterns (Art Deco Style)
- Imitate Stucco Colored Walls (Mediterranean Revival Style)
- Powerful Horizontal and Vertical Components (MiMo Style)

These three characteristics will be used in the redesign of the exterior architecture of the Northwest Science Building for Miami, FL

Following are sketches for the exterior architectural appearance of the building. These sketches have brief descriptions. The images will progress from 2-D to 3-D views, showing how each façade is blended into one another.

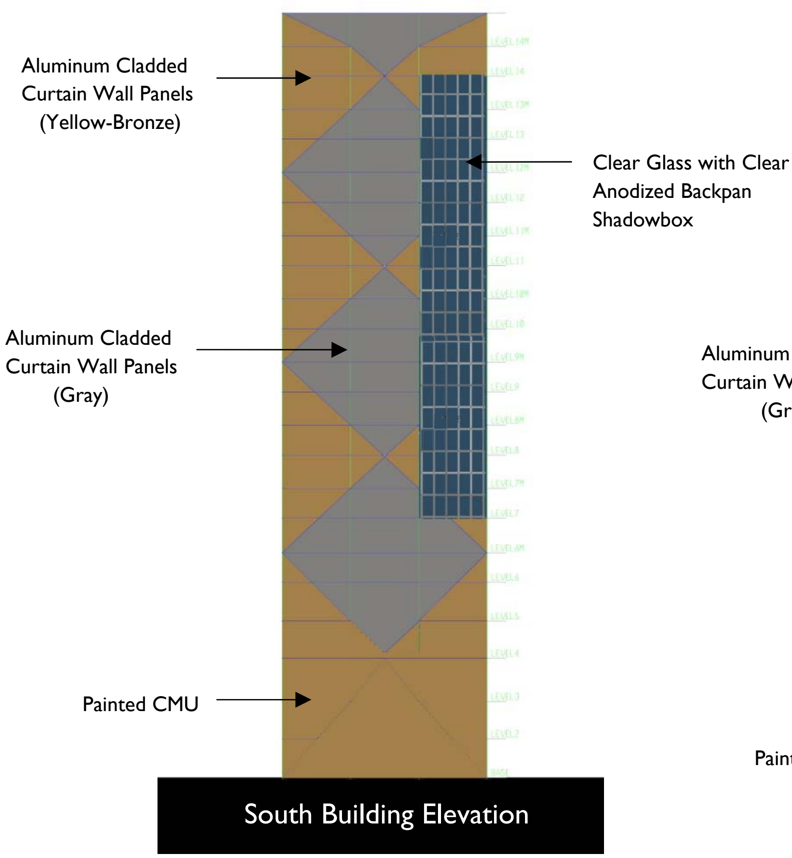


Image 4: Proposed South Façade

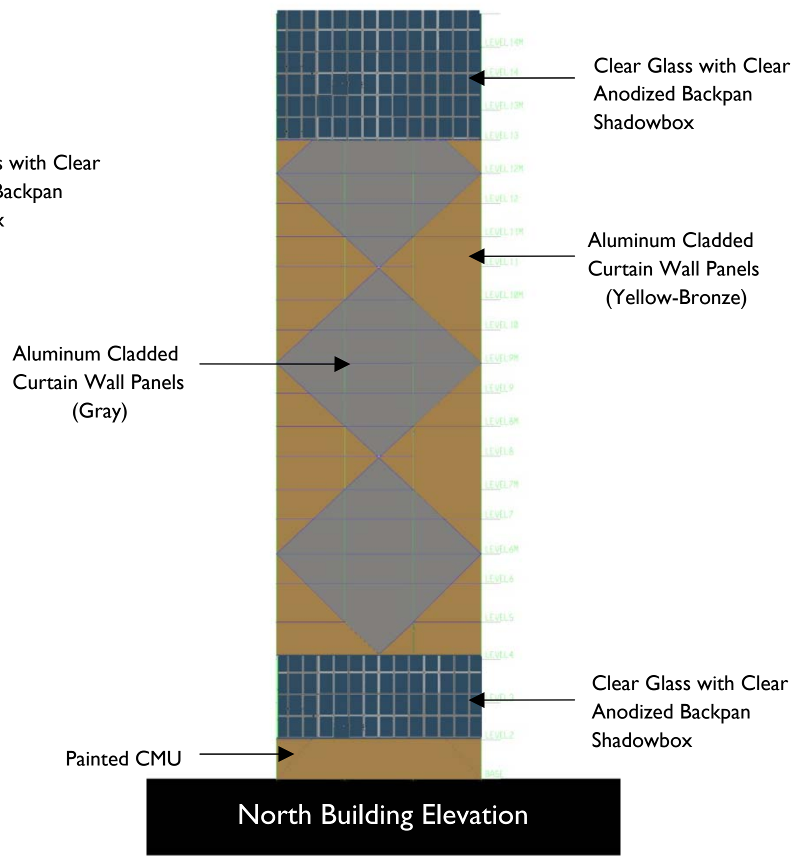


Image 5: Proposed North Facade

The proposed North and South facades on the previous page incorporate both gray and yellow-bronze colored aluminum cladding. This aluminum coloring provides three functions. These functions are listed below.

- The color cladding is a representative of the Mediterranean Revival Style stucco colored walls.
- The diamond shaped pattern exemplifies the lateral exterior frame structure.
- The diamond pattern also is representative of the Art Deco Style.

Below is an image of the proposed East façade, followed by the West façade on the following page.

Image 6: Proposed East Facade

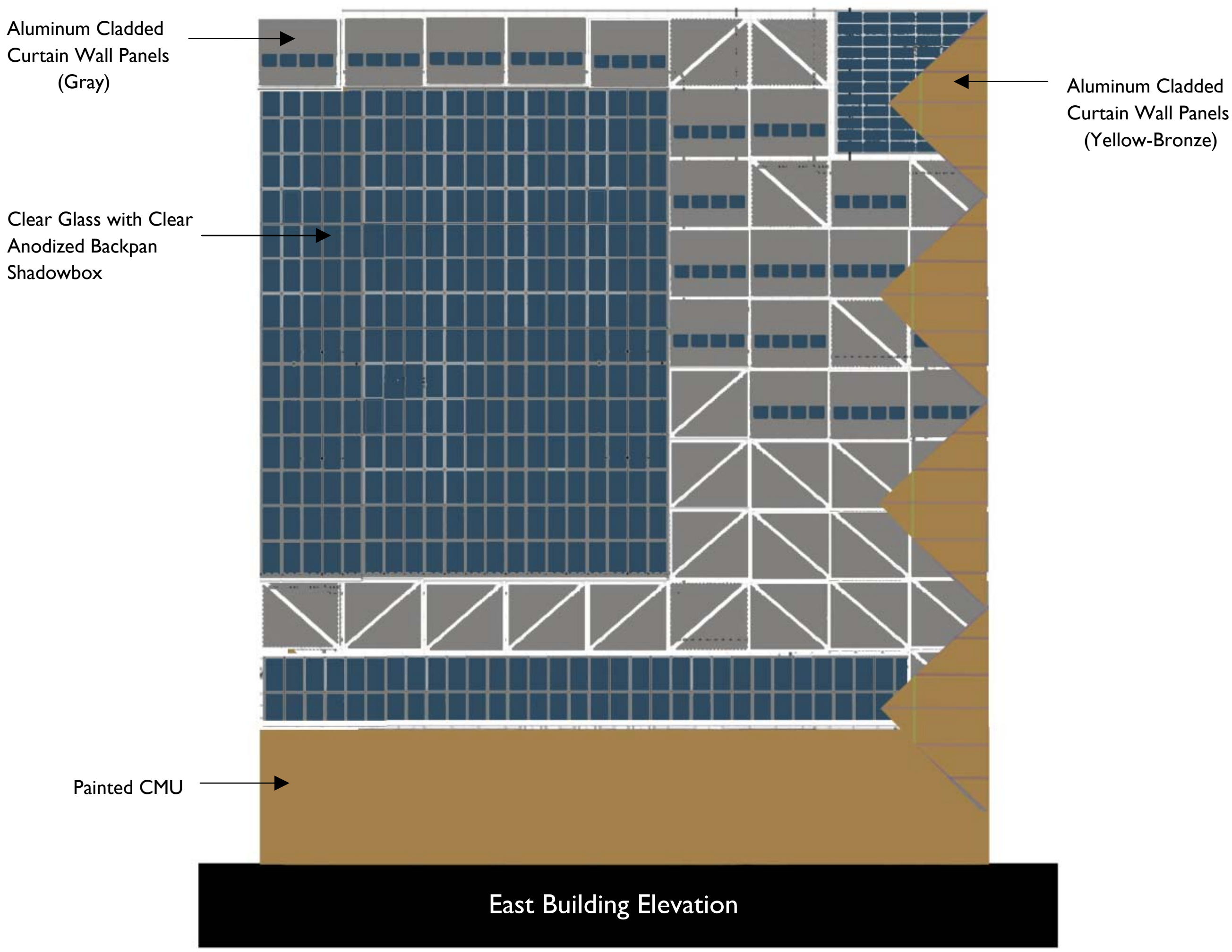
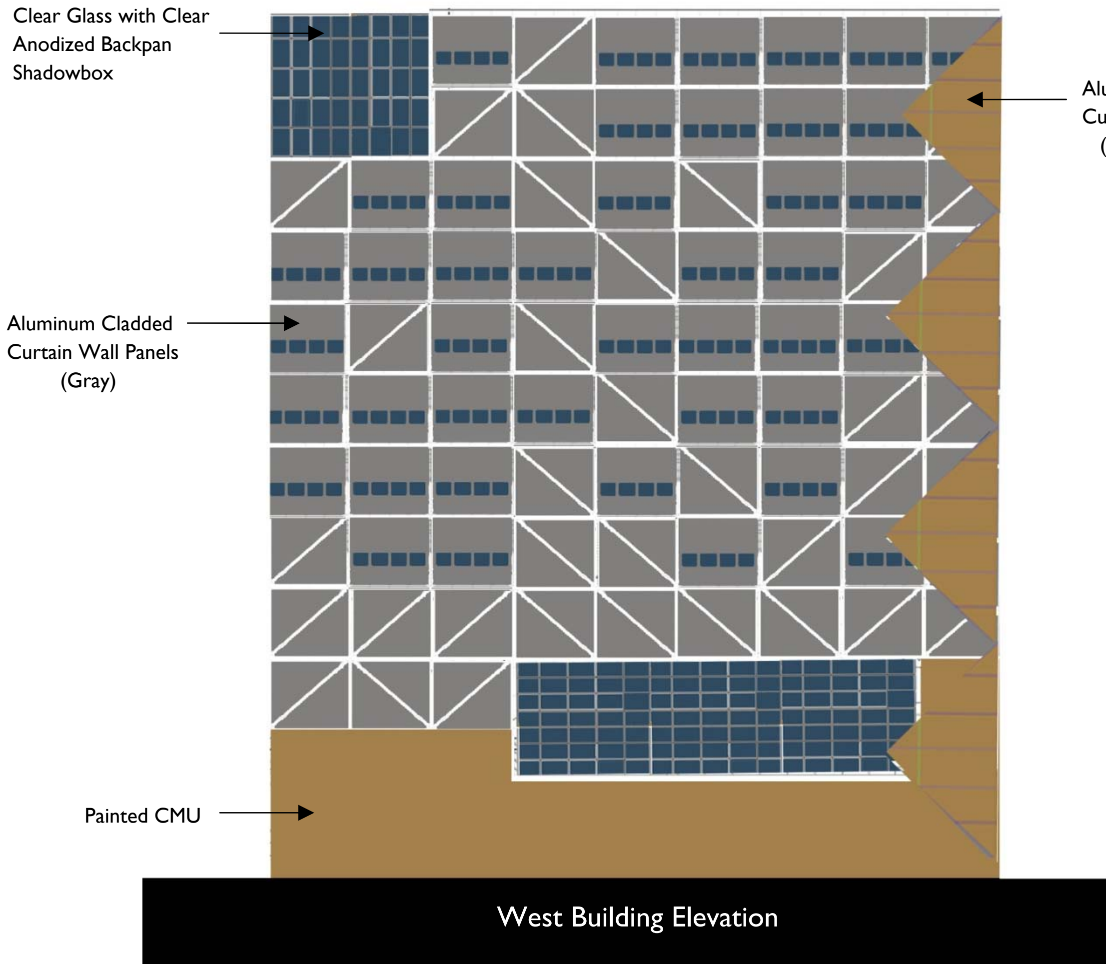


Image 7: Proposed West Facade

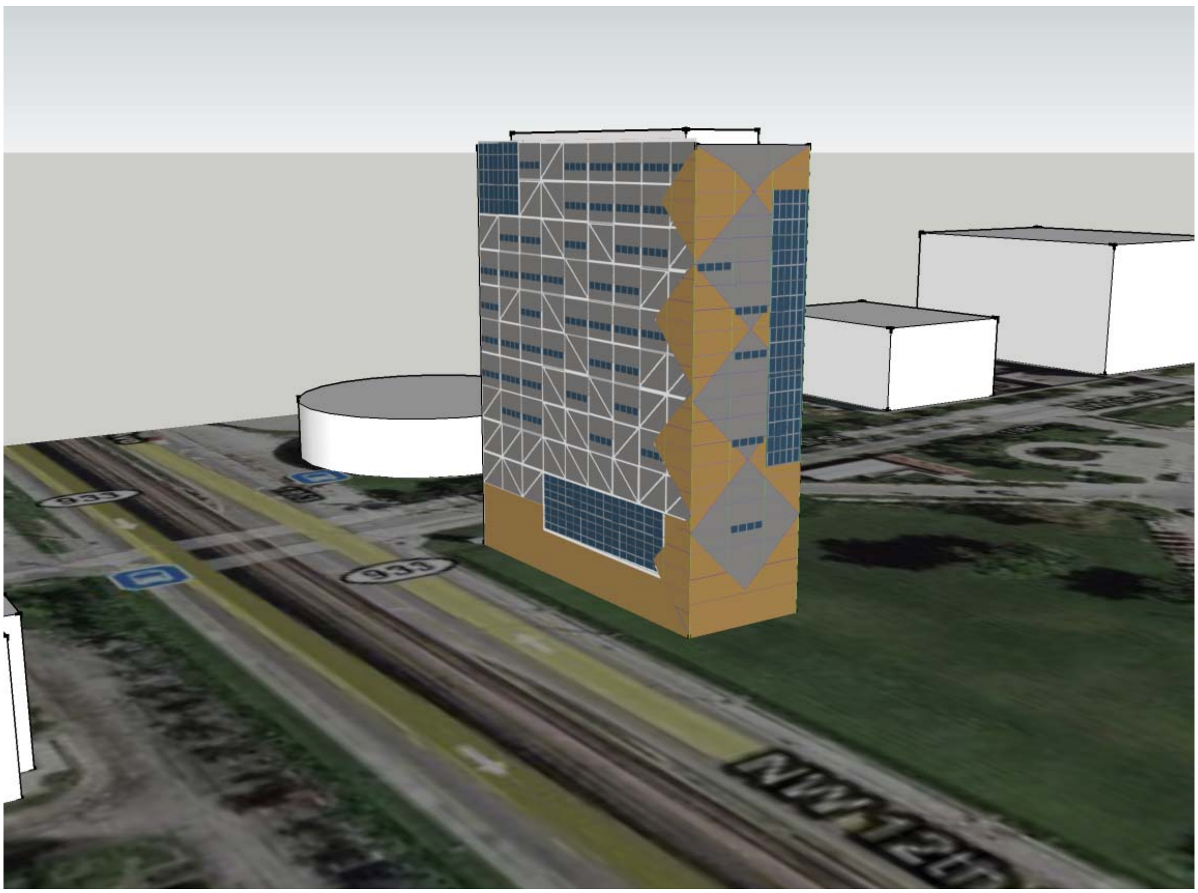


The structure of the East and West facades did not change the architectural aesthetics as seen with the North and South façade architectural changes. However, the author wanted to blend the architecture of the North and South facades in some way into the East and West facades. Therefore, the yellow-bronze aluminum cladding was "wrapped" around the corner of the building, as shown above. This architectural design serves two functions, which are listed below.

- The "wrapping" provides a blending technique, connecting each façade's architecture.
- The East and West facades now symbolize a sailboat appearance, which is representative to Miami, FL culture.

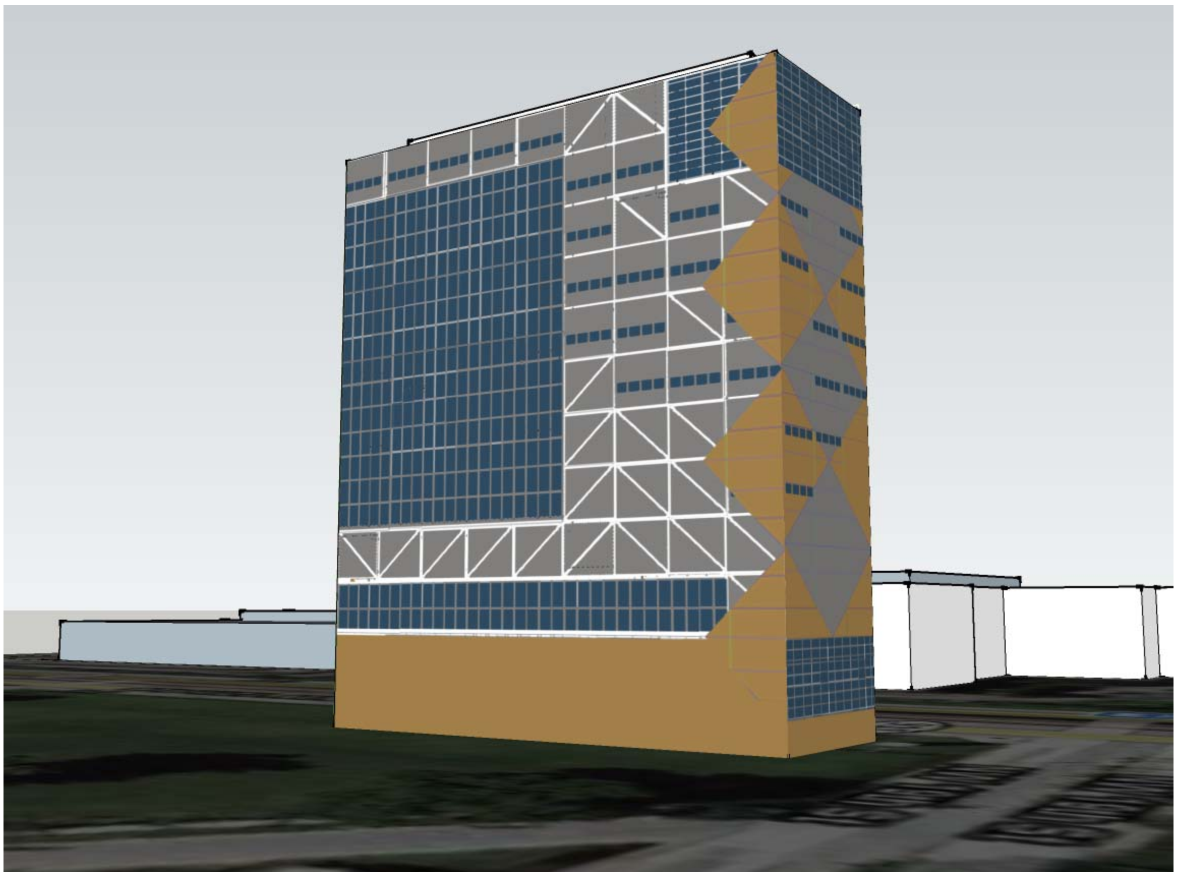
Below is an image of the proposed building architectural envelope redesign. Please take note that this is a color rendering and textures are not shown. This rendering depicts the "wrapping technique" discussed previously by the author. The building was placed on a site within Miami, FL near several other University of Miami buildings. Since the building is academic, it was placed on campus on an empty lot at the corner of NW 12th Avenue and NW 19th Street of Miami, FL.

Image 8: South-West Architectural Rendering



Below is another image of the proposed building architectural envelope redesign. Please take note that this is a color rendering and textures are not shown.

Image 9: North-West Architectural Rendering



Final Comparisons

Description:

This final comparisons study is intended to compare the changes of the Northwest Science Building from its existing form in New York City, to its redesigned form in Miami, FL. This comparison will involve the following studies and conclude if the redesigned building is feasible for construction in Miami, FL.

Comparison Studies:

- Member Size Differences
- Overall Structural Cost Concerns/Differences
- Building Enclosure Material Changes
- Overall Building Cost Concerns/Differences

Tables, Figures, and Graphs:

Below is a bulleted list explaining the tables, figures, and graphs to follow, regarding this Final Comparisons Study.

- Figure 33: Grid 1 – Existing Design
- Figure 34: Grid 1 – Redesign
    - Visually compare the difference in the amount of diagonal bracing used and the size of the members used.
- Table 17: East-West Lateral System Steel Bracing Poundage
    - Shows the amount of pounds in steel bracing used for each grid.
- Table 18: East-West Lateral System Steel Bracing Bare Material Cost
    - Cost analysis of lateral bracing changes from existing to redesign.
- Graph 7: Steel Poundage Comparison
    - Provides a comparison of steel bracing poundage for existing versus redesigned lateral system.
- Graph 8: Bare Material Cost Comparison
    - Provides a comparison of steel bracing bare material cost for existing versus redesigned lateral system.

Conclusions:

From this Final Comparisons Analysis, the increase in structural bare material cost and architectural aesthetic cost (shown and described on the following pages) is believed to be fairly small in comparison to the total building construction cost.

For further conclusions and discussion on the overall building cost concerns and differences, see page 66 of this thesis report.

Lateral Member Size Differences:

The increased wind forces of Miami, FL had a substantial impact on the East-West lateral system redesign of the structure. This direction experienced a greater amount of wind forces and therefore needed an increased stiffness in each of its main brace resisting frames. To increase stiffness, larger wide flange sections were used. In Grid 1 sections consisted of W14x90's (smallest) up to W14x233's (largest). The East-West direction (Grid 1) existing design consisted of W14x48's (smallest) up to W14x159's (largest). As described, there is a substantial increase in area sections used in Miami, FL design compared to the New York, NY existing design. This increase in section area provides a greater amount of stiffness in each grid. The greater stiffness provides for greater wind force resisting and overall less deflection. Grids 4 & 10 in the East-West direction also provide an increase in stiffness.

For further evidence and justification of the increase in steel bracing used in the East-West direction see the following section "Structural Cost Differences/Concerns."

Figure 33: Grid 1 – Existing Design

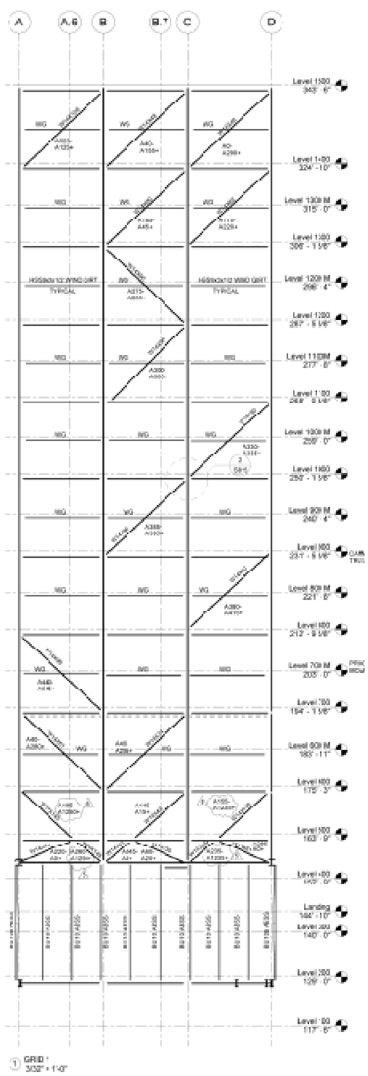
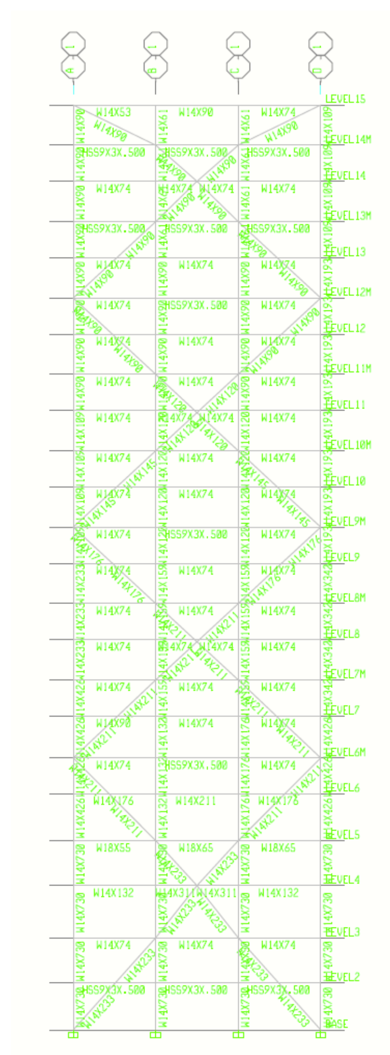


Figure 34: Grid 1 – Redesign



In the figures above notice the increase in section area and the increase in the amount of bracing used.

Structural Cost Concerns/Differences:

Due to the East-West Direction having an extensive redesign, the author proposes a material cost analysis of this lateral system direction. The North-South direction had minor changes due to minor overall deflection concerns. This lateral system direction had minor changes in steel sections, and therefore there is small concern in cost and material differences.

The following table lists a summary of steel poundage of lateral bracing for each grid in the East-West direction for the existing New York, NY design and the redesigned Miami, FL system.

Table 17: East-West Lateral System Steel Bracing Poundage

	GRID 1	GRID 4	GRID 10
Existing Lateral Bracing (LBS)	42405	21698	36658
Redesign Lateral Bracing (LBS)	104500	38934	101200

Below is a bare material steel poundage cost analysis of the existing lateral bracing versus the redesign lateral bracing.

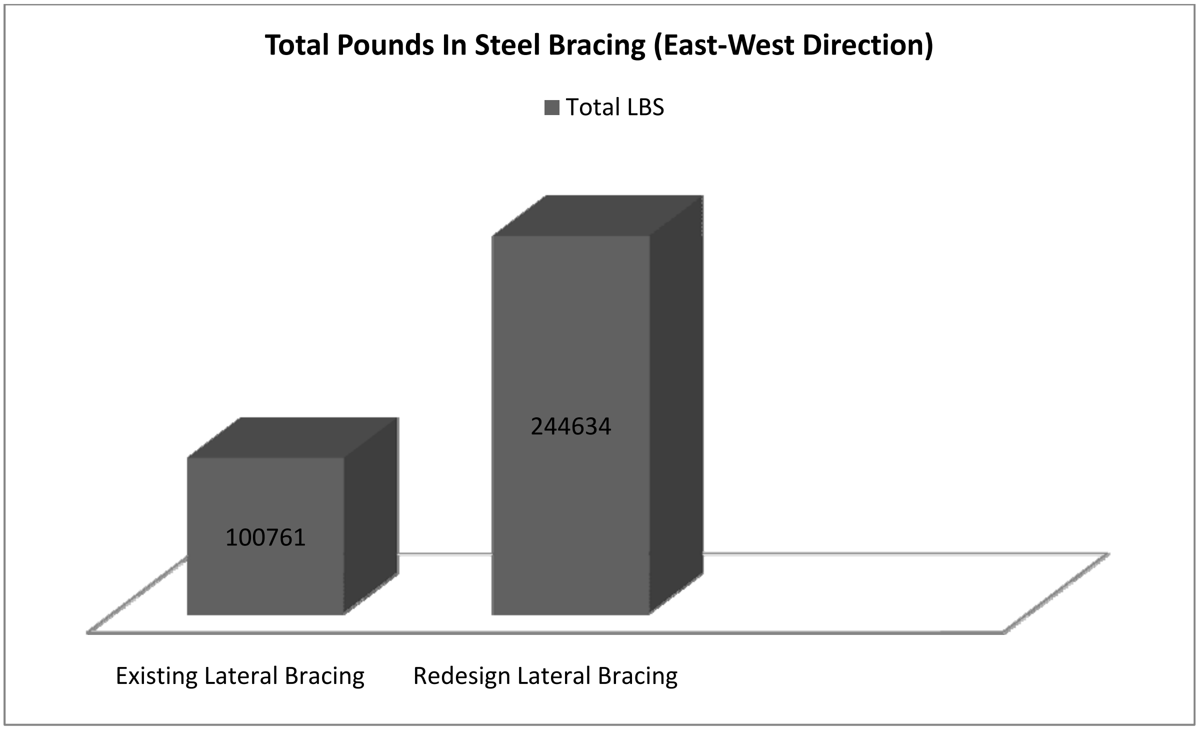
Table 18: East-West Lateral System Steel Bracing Bare Material Cost

	Total LBS	Total Tons	RS MEANS COSTWORKS *Bare Material Cost*	Total Bare Material Cost
Existing Lateral Bracing (LBS)	100761	50.38	$3234.38/Ton (New York, NY)	**$163,000**
Redesign Lateral Bracing (LBS)	244634	122.32	$3009.38/Ton (Miami, FL)	**$368,000**
Difference In Bare Material Cost = **$205,000**				

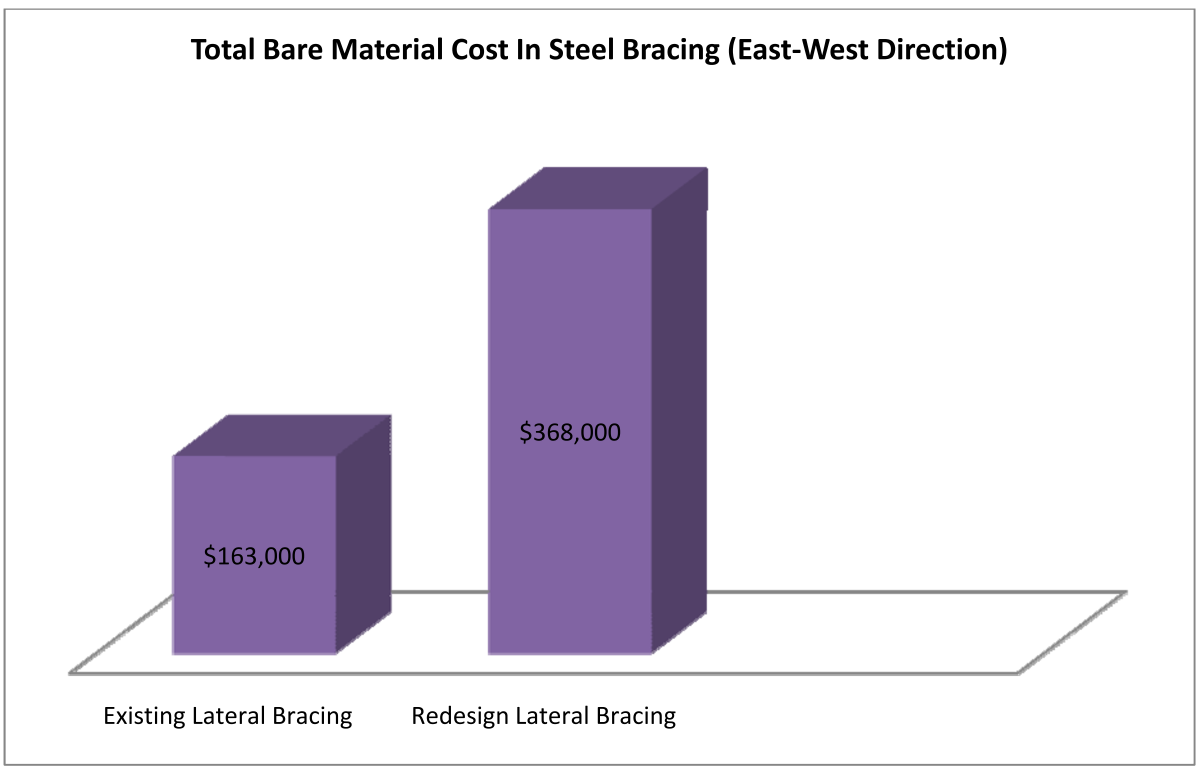
The author also would like to note that the redesign of the East-West lateral system contains a greater amount of heavy bracing connections. These extensive connections along with the increase in steel bracing are expected to increase the structural system cost significantly.

The following page depicts graphs comparing total pounds in steel bracing used and bare material costs for existing vs. redesigned systems.

Graph 7: Steel Poundage Comparison



Graph 8: Bare Material Cost Comparison



Building Enclosure Material Changes:

The building enclosure breadth yielded a reduction in the rigid insulation layer of the curtain wall system from 4 inches (New York, NY) to 2 ½ inches (Miami, FL). This reduction is estimated to save a total of $185,900 in bare material cost. This cost savings is expected to mitigate the increase cost of the exterior architectural design. Due to the changing of material usage on the exterior, and an increase in demand for coordination of construction, the author foresees an overall increase in architectural cost for the project.

Overall Building Cost Concerns/Differences - Summary:

The author believes that the feasibility of relocation of the building to Miami, FL relies solely on the connection cost and labor. The increase in structural bare material cost and architectural aesthetic cost is believed to be small in comparison to connection material and labor cost.

Therefore the author believes that the building would be feasible for construction upon the owner's acceptance on connection labor and cost of the structure.

Summary & Conclusions:

The author established the following goals for this final thesis study on the Northwest Science Building. These goals are listed below along with a discussion and conclusion for each goal.

Goals (Based on Relocation of Building to Miami, FL):

✓ Redesign building's lateral system to meet code requirements.

The lateral system was successfully redesigned for increased lateral forces of Miami, FL wind. The East-West direction lateral system needed a substantial redesign, consisting of a new layout of diagonal bracing, which included 72 additional tons of steel. This additional 72 tons provided the increase in stiffness needed to reduce drifts and story drifts. The additional steel also provided proper strength capacities to prevent failure. The North-South direction did not need an extensive redesign like the East-West direction. However, a small occurrence in lateral system member sizes was seen to increase, providing adequate strengths to prevent failure.

✓ Provide analysis of lateral system through means of ETABS and hand calculations.

An ETABS model and hand calculation checks provided additional understanding and insight of the redesign process, changes, and overall function of the building's lateral system.

✓ Research, analyze, and modify building enclosure appropriately for water condensation and heat transmission concerns.

The building's curtain wall system was successfully modified for Miami, FL climate. This modification included a reduction in the foam glass insulation layer (4" to 2.5"). This reduction provided a savings of $185,900 in bare material cost. This building enclosure breadth was made possible through R-Value, Condensation, and Air Leakage analyses.

✓ Redesign exterior architecture of building for Miami, FL.

The building's exterior architecture appearance was successfully modified to fit Miami, FL culture. The building's architecture now includes elements of Mediterranean Revival, Art Deco, and Streamline Modern Style architecture. These three architectural styles are commonly seen in Miami, FL.

Works Cited:

The following software programs were used to assist the author with design and analysis calculations.

- H.A.M (Heat, Air, & Moisture) Building Science ToolBox – Copyright © 1999 Rick Quirouette
- ETABS – Extended 3D Analysis of Building Systems – Copyright © 1984-2008 Computers & Structures, Inc.
- Google SketchUp – Copyright © Google Inc. 2008
- RSMeans CostWorks – Copyright © 2010 RSMeans

The following design aids were used to assist the author with design and analysis calculations.

- "ASCE 7-05 Minimum Design Loads for Buildings and Other Structures" – American Society of Civil Engineers
- "International Building Code 2006" – International Code Council
- "ACI 318-05 Manual of Concrete Practice" – American Concrete Institute
- "Manual of Steel Construction 9th Edition" – American Institute of Steel Construction, Inc.

The following firm/companies would like to be cited by the author due to the use of Northwest Science Building design documents.

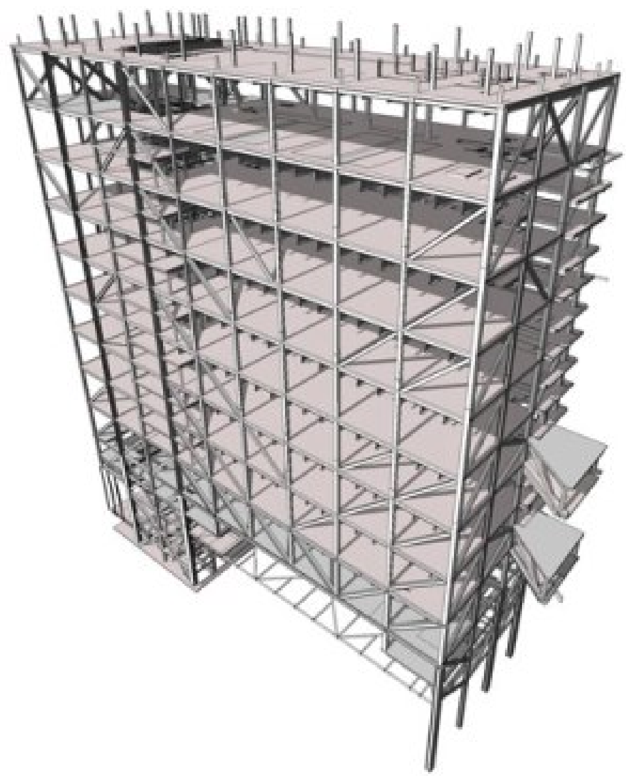
- Davis Brody Bond, LLP – Architects & Planners – 315 Hudson Street, New York, NY 10013
- Rafael Moneo Valles Arquitecto – Design Architect – Madrid Spain, 28002
- Moneo Brock Studio – Design Project Architect – Madrid Spain, 28002
- Ove Arup & Partners – Consulting Engineers – 155 Avenue of Americas, New York, NY 10013

The following works citied were used to assist the author for additional research purposes.

- "Building Safety and Earthquakes." *Built to Resist Earthquakes* 1. 1-2. Web. 30 Mar 2010. <http://www.atcouncil.org/pdfs/bp1c.pdf>.
- "Historical Preservation." *Miami Architectural Styles*. Historic and Environmental Preservation Board (HEPB), n.d. Web. 30 Mar 2010. <http://www.historicpreservationmiami.com/>.

Appendix A

Structural Depth Appendix
(with Commentary)



Columbia University Northwest Science Building

Broadway & 120th Street, New York, NY

This Structural Depth Appendix Section will provide commentary along with some of the tables, graphs, images, and figures. The commentary is intended to give the reader a better understanding of the process in which the lateral system was analyzed and redesigned.

1/19/10 1

WIND CALCS: (MIAMI, FL)

- IS THE BUILDING ENCLOSED? — YES
- IS THE BLD. LOW-RISE? — NO
  - $n_1 = 100/226 = 0.4425 < 1$ (FLEXIBLE)
  - BASIC WIND SPEED (V) FOR MIAMI, FL. 150 MPH

- $K_d = 0.85$
- $I = 1.15$
- $K_{zt} = 1.0$
- EXPOSURE CATEGORY C
- $G = 0.85$

- FOR ALL OTHER CALCULATIONS ON WIND
  ↳ SEE WIND SPREADSHEETS, TABLES, + FIGURES

The following tables provide excel spreadsheet calculations for determining the wind forces acting upon the building in Miami, FL. These calculations conclude with story forces, story shear, and overturning moment values.

Table 4A: Wind North-South Direction

Level	Height (Feet)	Tributary Area (Feet)	K_z	$q_z = 0.00256K_zK_{zt}K_dV^2I$	K_h	$q_h = 0.00256K_hK_{zt}K_dV^2I$
Roof (15)	226.00	4.67	1.50	84.87	1.50	84.87
14M	216.67	9.34	1.49	84.12	1.50	84.87
14	207.33	9.59	1.48	83.34	1.50	84.87
13M	197.50	9.36	1.46	82.49	1.50	84.87
13	188.63	9.34	1.45	81.70	1.50	84.87
12M	178.83	9.33	1.43	80.79	1.50	84.87
12	169.97	9.33	1.42	79.93	1.50	84.87
11M	160.17	9.34	1.40	78.93	1.50	84.87
11	151.30	9.34	1.38	77.99	1.50	84.87
10M	141.50	9.84	1.36	76.90	1.50	84.87
10	132.63	9.84	1.34	75.86	1.50	84.87
9M	122.83	9.33	1.32	74.64	1.50	84.87
9	113.97	8.83	1.30	73.48	1.50	84.87
8M	104.17	8.84	1.28	72.10	1.50	84.87
8	95.30	9.34	1.25	70.76	1.50	84.87
7M	85.50	9.33	1.22	69.16	1.50	84.87
7	76.64	9.54	1.20	67.59	1.50	84.87
6M	66.42	9.45	1.16	65.58	1.50	84.87
6	57.75	10.09	1.13	63.68	1.50	84.87
5	46.25	11.25	1.08	60.77	1.50	84.87
4	35.25	11.88	1.02	57.39	1.50	84.87
3	22.50	11.88	0.92	52.22	1.50	84.87
2	11.50	11.25	0.85	47.94	1.50	84.87
Ground (1)	0.00	0	0.85	48.01	1.50	84.87

Table 4B: Wind North-South Direction Continued

Level	Windward (psf)	Leeward (psf)	Total (psf)	Story Force (kips)	Story Shear (kips)	Overturning Moment (ft-kips)
Roof (15)	82.63	33.13	115.76	32.71	32.71	0.00
14M	82.03	33.13	115.16	65.08	97.78	305.15
14	81.42	33.13	114.55	66.46	164.24	1218.42
13M	80.74	33.13	113.87	64.48	228.73	2832.91
13	80.11	33.13	113.24	63.99	292.72	4861.70
12M	79.39	33.13	112.52	63.51	356.23	7730.32
12	78.71	33.13	111.84	63.13	419.36	10886.51
11M	77.92	33.13	111.05	62.75	482.11	14996.21
11	77.17	33.13	110.30	62.33	544.44	19272.51
10M	76.31	33.13	109.44	65.15	609.59	24607.99
10	75.48	33.13	108.61	64.66	674.24	30015.02
9M	74.51	33.13	107.64	60.76	735.01	36622.61
9	73.59	33.13	106.72	57.01	792.02	43134.76
8M	72.49	33.13	105.63	56.49	848.51	50896.52
8	71.43	33.13	104.56	59.09	907.59	58422.77
7M	70.16	33.13	103.29	58.31	965.90	67317.17
7	68.91	33.13	102.04	58.90	1024.80	75875.03
6M	67.32	33.13	100.45	57.43	1082.23	86348.44
6	65.81	33.13	98.94	60.40	1142.63	95731.34
5	63.50	33.13	96.63	65.77	1208.40	108871.54
4	60.82	33.13	93.95	67.53	1275.93	122163.92
3	56.72	33.13	89.85	64.58	1340.50	138431.98
2	53.33	33.13	86.46	58.84	1399.35	153177.51
Ground (1)	53.38	33.13	86.51	0.00	**1399.35**	**169270.00**

Table 5A: Wind East-West Direction

Level	Height (Feet)	Tributary Area (Feet)	K_z	$q_z = 0.00256K_zK_{zt}K_dV^2I$	K_h	$q_h = 0.00256K_hK_{zt}K_dV^2I$
Roof (15)	226.00	4.67	1.50	84.87	1.50	84.87
14M	216.67	9.34	1.49	84.12	1.50	84.87
14	207.33	9.59	1.48	83.34	1.50	84.87
13M	197.50	9.36	1.46	82.49	1.50	84.87
13	188.63	9.34	1.45	81.70	1.50	84.87
12M	178.83	9.33	1.43	80.79	1.50	84.87
12	169.97	9.33	1.42	79.93	1.50	84.87
11M	160.17	9.34	1.40	78.93	1.50	84.87
11	151.30	9.34	1.38	77.99	1.50	84.87
10M	141.50	9.84	1.36	76.90	1.50	84.87
10	132.63	9.84	1.34	75.86	1.50	84.87
9M	122.83	9.33	1.32	74.64	1.50	84.87
9	113.97	8.83	1.30	73.48	1.50	84.87
8M	104.17	8.84	1.28	72.10	1.50	84.87
8	95.30	9.34	1.25	70.76	1.50	84.87
7M	85.50	9.33	1.22	69.16	1.50	84.87
7	76.64	9.54	1.20	67.59	1.50	84.87
6M	66.42	9.45	1.16	65.58	1.50	84.87
6	57.75	10.09	1.13	63.68	1.50	84.87
5	46.25	11.25	1.08	60.77	1.50	84.87
4	35.25	11.88	1.02	57.39	1.50	84.87
3	22.50	11.88	0.92	52.22	1.50	84.87
2	11.50	11.25	0.80	45.34	1.50	84.87
Ground (1)	0.00	0	0.80	45.18	1.50	84.87

Table 5B: Wind East-West Direction Continued

Windward (psf)	Leeward (psf)	Total (psf)	Story Force (kips)	Story Shear (kips)	Overturning Moment (ft-kips)
82.63	54.95	137.58	126.41	126.41	0.00
82.03	54.95	136.99	251.73	378.14	1179.42
81.42	54.95	136.37	257.30	635.45	4711.27
80.74	54.95	135.70	249.89	885.34	10957.71
80.11	54.95	135.07	248.20	1133.54	18810.69
79.39	54.95	134.34	246.61	1380.15	29919.42
78.71	54.95	133.66	245.36	1625.51	42147.56
77.92	54.95	132.87	244.17	1869.68	58077.53
77.17	54.95	132.12	242.80	2112.47	74661.56
76.31	54.95	131.26	254.12	2366.59	95363.80
75.48	54.95	130.43	252.52	2619.11	116355.47
74.51	54.95	129.47	237.66	2856.77	142022.75
73.59	54.95	128.54	223.31	3080.08	167333.72
72.49	54.95	127.45	221.66	3301.75	197518.52
71.43	54.95	126.38	232.25	3534.00	226805.01
70.16	54.95	125.12	229.67	3763.67	261438.18
68.91	54.95	123.87	232.50	3996.17	294784.30
67.32	54.95	122.27	227.34	4223.51	335625.14
65.81	54.95	120.76	239.74	4463.25	372242.98
63.50	54.95	118.46	262.20	4725.45	423570.41
60.82	54.95	115.78	270.61	4996.06	475550.35
56.72	54.95	111.67	261.01	5257.08	539250.17
51.26	54.95	106.21	235.08	5492.16	597078.00
51.13	54.95	106.09	0.00	**5492.16**	**660237.85**

Table 6: Un-factored Story Forces for ETABS Deflection Wind Analysis

X-Direction Story Forces (kips)			Y-Direction Story Forces (kips)		
Level			**Level**		
Roof (15)	126.41	252.28	**Roof (15)**	32.71	65.24
14M	251.73		**14M**	65.08	
14	257.30	508.12	**14**	66.46	131.24
13M	249.89		**13M**	64.48	
13	248.20	496.45	**13**	63.99	127.99
12M	246.61		**12M**	63.51	
12	245.36	490.74	**12**	63.13	126.26
11M	244.17		**11M**	62.75	
11	242.80	491.94	**11**	62.33	126.28
10M	254.12		**10M**	65.15	
10	252.52	498.41	**10**	64.66	127.61
9M	237.66		**9M**	60.76	
9	223.31	452.97	**9**	57.01	115.64
8M	221.66		**8M**	56.49	
8	232.25	457.92	**8**	59.09	116.48
7M	229.67		**7M**	58.31	
7	232.50	461.01	**7**	58.90	116.77
6M	227.34		**6M**	57.43	
6	239.74	353.41	**6**	60.40	89.11
5	262.20	262.20	**5**	65.77	65.77
4	270.61	270.61	**4**	67.53	67.53
3	261.01	261.01	**3**	64.58	64.58
2	235.08	235.08	**2**	58.84	58.84

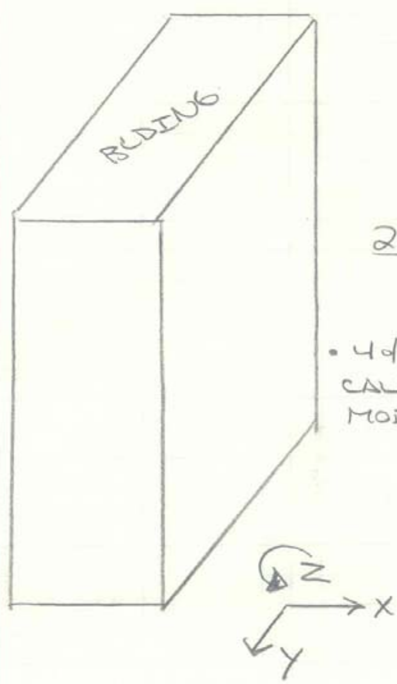
Before the calculated wind forces are inputted into ETABS and analyzed, the author wanted to make sure the structure's lateral system was modeled accurately using ETABS software. An accurate modeled structure will consist of the proper connections, mass, member sizes, member properties, and geometric inputs. The structure is very complex, and it is suspected by the author that it will not be modeled 100% accurate. However, to confirm the validity of the model, the main period of the building will be checked. Below shows the comparison of an estimated code calculation yielding 1.75 seconds, and the ETABS analysis yielding 2.11 seconds. These values are relatively close to one another, ensuring the author that the ETABS model inputs are accurate enough for this thesis study.

1/24/10

CALCULATION OF PERIOD FOR BLD: (EX. LAT)

$T_a = C_t h_n^x = (0.03)226^{0.75} = 1.75\ sec$

COMPARE TO ETABS MODEL:



$T_x = 2.11\ sec$

$T_y = 1.25\ sec$

$T_z = 1.06\ sec$

$\frac{2.11 + 1.25}{2} = 1.68\ sec$

• 4% DIFFERENCE BETWEEN CALCULATED PERIOD + ETABS MODEL

∴ OKAY!

– NEEDED TO GET ACCURATE + PRECISE PERIODS SO ETABS MODEL IS CORRECT FOR WIND ANALYSIS (FOR FUTURE DISTRIBUTION OF LATERAL FORCES.

Table 9: East-West Direction – Wind Serviceability Checks (Existing Design)

Grid 1 Wind (Servicability Checks)

STORY	DISP-X (IN)	STORY DRIFT (IN)
LEVEL 15	14.09	
LEVEL 14M	14.06	0.16
LEVEL 14	13.93	
LEVEL 13M	13.58	0.49
LEVEL 13	13.09	
LEVEL 12M	12.41	0.69
LEVEL 12	11.72	
LEVEL 11M	10.88	0.80
LEVEL 11	10.08	
LEVEL 10M	9.19	0.59
LEVEL 10	8.61	
LEVEL 9M	8.33	0.37
LEVEL 9	7.96	
LEVEL 8M	7.08	0.94
LEVEL 8	6.14	
LEVEL 7M	5.12	0.84
LEVEL 7	4.28	
LEVEL 6M	3.46	0.61
LEVEL 6	2.84	
LEVEL 5	2.15	0.37
LEVEL 4	1.78	
LEVEL 3	1.08	0.65
LEVEL 2	0.43	

Grid 2 Wind (Servicability Checks)

STORY	DISP-X (IN)	STORY DRIFT (IN)
LEVEL 15	14.04	
LEVEL 14M	14.01	0.18
LEVEL 14	13.86	
LEVEL 13M	13.49	0.48
LEVEL 13	13.01	
LEVEL 12M	12.37	0.67
LEVEL 12	11.70	
LEVEL 11M	10.87	0.80
LEVEL 11	10.07	
LEVEL 10M	9.20	0.57
LEVEL 10	8.63	
LEVEL 9M	8.32	0.36
LEVEL 9	7.96	
LEVEL 8M	7.12	0.96
LEVEL 8	6.16	
LEVEL 7M	5.16	0.79
LEVEL 7	4.37	
LEVEL 6M	3.57	0.62
LEVEL 6	2.95	
LEVEL 5	2.24	0.43
LEVEL 4	1.81	
LEVEL 3	1.08	0.67
LEVEL 2	0.41	

Grid 3 Wind (Servicability Checks)

STORY	DISP-X (IN)	STORY DRIFT (IN)
LEVEL 15	14.00	
LEVEL 14M	13.95	0.20
LEVEL 14	13.80	
LEVEL 13M	13.42	0.48
LEVEL 13	12.94	
LEVEL 12M	12.32	0.65
LEVEL 12	11.67	
LEVEL 11M	10.84	0.78
LEVEL 11	10.06	
LEVEL 10M	9.22	0.56
LEVEL 10	8.66	
LEVEL 9M	8.34	0.37
LEVEL 9	7.97	
LEVEL 8M	7.12	0.93
LEVEL 8	6.19	
LEVEL 7M	5.23	0.76
LEVEL 7	4.47	
LEVEL 6M	3.68	0.62
LEVEL 6	3.06	
LEVEL 5	2.33	0.49
LEVEL 4	1.84	
LEVEL 3	1.09	0.69
LEVEL 2	0.40	

Grid 4 Wind (Servicability Checks)

STORY	DISP-X (IN)	STORY DRIFT (IN)
LEVEL 15	13.96	
LEVEL 14M	13.89	0.23
LEVEL 14	13.73	
LEVEL 13M	13.34	0.48
LEVEL 13	12.86	
LEVEL 12M	12.27	0.62
LEVEL 12	11.65	
LEVEL 11M	10.83	0.78
LEVEL 11	10.05	
LEVEL 10M	9.23	0.55
LEVEL 10	8.68	
LEVEL 9M	8.36	0.38
LEVEL 9	7.98	
LEVEL 8M	7.13	0.92
LEVEL 8	6.21	
LEVEL 7M	5.29	0.73
LEVEL 7	4.56	
LEVEL 6M	3.79	0.62
LEVEL 6	3.17	
LEVEL 5	2.42	0.55
LEVEL 4	1.87	
LEVEL 3	1.09	0.71
LEVEL 2	0.38	

Grid 10 Wind (Servicability Checks)

STORY	DISP-X (IN)	STORY DRIFT (IN)
LEVEL 15	13.68	
LEVEL 14M	13.54	0.37
LEVEL 14	13.31	
LEVEL 13M	12.85	0.45
LEVEL 13	12.40	
LEVEL 12M	11.98	0.46
LEVEL 12	11.52	
LEVEL 11M	10.73	0.74
LEVEL 11	9.99	
LEVEL 10M	9.32	0.47
LEVEL 10	8.85	
LEVEL 9M	8.46	0.44
LEVEL 9	8.02	
LEVEL 8M	7.16	0.80
LEVEL 8	6.36	
LEVEL 7M	5.70	0.54
LEVEL 7	5.16	
LEVEL 6M	4.46	0.62
LEVEL 6	3.84	
LEVEL 5	2.96	0.90
LEVEL 4	2.06	
LEVEL 3	1.18	0.75
LEVEL 2	0.43	

Above is ETABS analysis output data for drift and story drift checks. This output data was obtained by loading the lateral system in the East-West direction using unfactored loads (for serviceability checks). As shown above the existing design is deflecting a great amount due to the increase wind loads of Miami, FL. This occurrence is similar to the North-South direction existing analysis. (Table can be found on the following page.)

Table 10: North-South Direction – Wind Serviceability Checks (Existing Design)

Grid A Wind (Servicability Checks)		
STORY	DISP-Y (IN)	STORY DRIFT (IN)
LEVEL 15	2.16	0.03
LEVEL 14M	2.14	
LEVEL 14	2.13	
LEVEL 13M	2.25	0.17
LEVEL 13	2.08	
LEVEL 12M	1.94	0.16
LEVEL 12	1.78	
LEVEL 11M	1.61	0.11
LEVEL 11	1.50	
LEVEL 10M	1.37	0.14
LEVEL 10	1.23	
LEVEL 9M	1.14	0.07
LEVEL 9	1.07	
LEVEL 8M	0.95	0.09
LEVEL 8	0.86	
LEVEL 7M	0.73	0.11
LEVEL 7	0.62	
LEVEL 6M	0.59	0.03
LEVEL 6	0.56	
LEVEL 5	0.49	0.02
LEVEL 4	0.47	
LEVEL 3	0.31	0.14
LEVEL 2	0.17	

Grid C Wind (Servicability Checks)		
STORY	DISP-Y (IN)	STORY DRIFT (IN)
LEVEL 15	1.99	0.05
LEVEL 14M	2.04	
LEVEL 14	2.04	
LEVEL 13M	1.99	0.14
LEVEL 13	1.85	
LEVEL 12M	1.79	0.07
LEVEL 12	1.72	
LEVEL 11M	1.61	0.15
LEVEL 11	1.46	
LEVEL 10M	1.40	0.04
LEVEL 10	1.36	
LEVEL 9M	1.25	-0.02
LEVEL 9	1.27	
LEVEL 8M	1.08	0.08
LEVEL 8	1.00	
LEVEL 7M	0.92	0.05
LEVEL 7	0.87	
LEVEL 6M	0.86	0.03
LEVEL 6	0.83	
LEVEL 5	0.72	0.17
LEVEL 4	0.55	
LEVEL 3	0.33	0.18
LEVEL 2	0.15	

Grid D Wind (Servicability Checks)		
STORY	DISP-Y (IN)	STORY DRIFT (IN)
LEVEL 15	1.92	0.01
LEVEL 14M	1.96	
LEVEL 14	1.93	
LEVEL 13M	1.86	0.12
LEVEL 13	1.74	
LEVEL 12M	1.70	0.08
LEVEL 12	1.62	
LEVEL 11M	1.52	0.07
LEVEL 11	1.45	
LEVEL 10M	1.34	0.06
LEVEL 10	1.28	
LEVEL 9M	1.16	0.13
LEVEL 9	1.03	
LEVEL 8M	0.98	0.03
LEVEL 8	0.95	
LEVEL 7M	0.96	0.01
LEVEL 7	0.95	
LEVEL 6M	0.94	0.02
LEVEL 6	0.92	
LEVEL 5	0.82	0.22
LEVEL 4	0.60	
LEVEL 3	0.34	0.18
LEVEL 2	0.16	

Table 14: East-West Direction – Wind Serviceability Checks (Redesign System)

Grid 1 Wind (Servicability Checks)		
STORY	DISP-X (IN)	STORY DRIFT (IN)
LEVEL 15	6.76	0.16
LEVEL 14M	6.61	
LEVEL 14	6.60	
LEVEL 13M	6.47	0.28
LEVEL 13	6.19	
LEVEL 12M	5.78	0.14
LEVEL 12	5.64	
LEVEL 11M	5.10	0.33
LEVEL 11	4.77	
LEVEL 10M	4.42	0.45
LEVEL 10	3.97	
LEVEL 9M	3.65	0.14
LEVEL 9	3.51	
LEVEL 8M	2.93	0.37
LEVEL 8	2.56	
LEVEL 7M	2.26	0.31
LEVEL 7	1.95	
LEVEL 6M	1.59	0.32
LEVEL 6	1.27	
LEVEL 5	0.87	0.24
LEVEL 4	0.63	
LEVEL 3	0.38	0.25
LEVEL 2	0.13	

Grid 2 Wind (Servicability Checks)		
STORY	DISP-X (IN)	STORY DRIFT (IN)
LEVEL 15	6.75	0.14
LEVEL 14M	6.72	
LEVEL 14	6.61	
LEVEL 13M	6.43	0.23
LEVEL 13	6.20	
LEVEL 12M	5.91	0.29
LEVEL 12	5.62	
LEVEL 11M	5.22	0.36
LEVEL 11	4.86	
LEVEL 10M	4.36	0.36
LEVEL 10	4.00	
LEVEL 9M	3.74	0.24
LEVEL 9	3.50	
LEVEL 8M	3.05	0.46
LEVEL 8	2.59	
LEVEL 7M	2.26	0.29
LEVEL 7	1.97	
LEVEL 6M	1.63	0.35
LEVEL 6	1.28	
LEVEL 5	0.89	0.23
LEVEL 4	0.66	
LEVEL 3	0.36	0.22
LEVEL 2	0.14	

Grid 3 Wind (Servicability Checks)		
STORY	DISP-X (IN)	STORY DRIFT (IN)
LEVEL 15	6.77	0.15
LEVEL 14M	6.71	
LEVEL 14	6.62	
LEVEL 13M	6.44	0.23
LEVEL 13	6.21	
LEVEL 12M	5.90	0.32
LEVEL 12	5.58	
LEVEL 11M	5.18	0.37
LEVEL 11	4.81	
LEVEL 10M	4.33	0.34
LEVEL 10	3.99	
LEVEL 9M	3.74	0.26
LEVEL 9	3.48	
LEVEL 8M	3.06	0.43
LEVEL 8	2.63	
LEVEL 7M	2.25	0.27
LEVEL 7	1.98	
LEVEL 6M	1.60	0.28
LEVEL 6	1.32	
LEVEL 5	0.92	0.28
LEVEL 4	0.64	
LEVEL 3	0.35	0.21
LEVEL 2	0.14	

Grid 4 Wind (Servicability Checks)		
STORY	DISP-X (IN)	STORY DRIFT (IN)
LEVEL 15	6.76	0.13
LEVEL 14M	6.71	
LEVEL 14	6.63	
LEVEL 13M	6.46	0.24
LEVEL 13	6.22	
LEVEL 12M	5.91	0.33
LEVEL 12	5.58	
LEVEL 11M	5.13	0.40
LEVEL 11	4.73	
LEVEL 10M	4.30	0.32
LEVEL 10	3.98	
LEVEL 9M	3.70	0.28
LEVEL 9	3.42	
LEVEL 8M	2.97	0.41
LEVEL 8	2.56	
LEVEL 7M	2.24	0.27
LEVEL 7	1.97	
LEVEL 6M	1.61	0.31
LEVEL 6	1.30	
LEVEL 5	0.90	0.26
LEVEL 4	0.64	
LEVEL 3	0.35	0.21
LEVEL 2	0.14	

Grid 10 Wind (Servicability Checks)		
STORY	DISP-X (IN)	STORY DRIFT (IN)
LEVEL 15	6.77	0.18
LEVEL 14M	6.75	
LEVEL 14	6.59	
LEVEL 13M	6.47	0.21
LEVEL 13	6.26	
LEVEL 12M	5.71	0.35
LEVEL 12	5.36	
LEVEL 11M	4.89	0.23
LEVEL 11	4.66	
LEVEL 10M	4.34	0.32
LEVEL 10	4.02	
LEVEL 9M	3.61	0.30
LEVEL 9	3.31	
LEVEL 8M	2.86	0.30
LEVEL 8	2.56	
LEVEL 7M	2.26	0.28
LEVEL 7	1.98	
LEVEL 6M	1.63	0.29
LEVEL 6	1.34	
LEVEL 5	0.95	0.27
LEVEL 4	0.68	
LEVEL 3	0.36	0.21
LEVEL 2	0.15	

Above is ETABS analysis output data for drift and story drift checks. This output data was obtained by loading the lateral system in the East-West direction using unfactored loads (for serviceability checks). As shown above the redesign lateral system now meets serviceability requirements under Miami, FL wind loading. This holds true for the North-South direction redesigned system analysis. (Table can be found on following page.)

Table 15: North-South Direction – Wind Serviceability Checks (Redesigned System)

Grid A Wind (Servicability Checks)		
STORY	DISP-Y (IN)	STORY DRIFT (IN)
LEVEL 15	1.20	0.04
LEVEL 14M	1.18	
LEVEL 14	1.16	
LEVEL 13M	1.14	0.02
LEVEL 13	1.12	
LEVEL 12M	1.09	0.02
LEVEL 12	1.07	
LEVEL 11M	1.01	0.05
LEVEL 11	0.96	
LEVEL 10M	0.91	0.05
LEVEL 10	0.86	
LEVEL 9M	0.80	0.04
LEVEL 9	0.76	
LEVEL 8M	0.71	0.03
LEVEL 8	0.68	
LEVEL 7M	0.64	0.03
LEVEL 7	0.61	
LEVEL 6M	0.60	0.02
LEVEL 6	0.58	
LEVEL 5	0.47	0.06
LEVEL 4	0.41	
LEVEL 3	0.25	0.14
LEVEL 2	0.11	

Grid C Wind (Servicability Checks)		
STORY	DISP-Y (IN)	STORY DRIFT (IN)
LEVEL 15	1.18	0.03
LEVEL 14M	1.16	
LEVEL 14	1.15	
LEVEL 13M	1.12	0.02
LEVEL 13	1.10	
LEVEL 12M	1.07	0.02
LEVEL 12	1.05	
LEVEL 11M	0.99	0.05
LEVEL 11	0.94	
LEVEL 10M	0.89	0.05
LEVEL 10	0.84	
LEVEL 9M	0.79	0.05
LEVEL 9	0.74	
LEVEL 8M	0.70	0.03
LEVEL 8	0.67	
LEVEL 7M	0.63	0.02
LEVEL 7	0.61	
LEVEL 6M	0.60	0.02
LEVEL 6	0.58	
LEVEL 5	0.49	0.11
LEVEL 4	0.38	
LEVEL 3	0.28	0.17
LEVEL 2	0.11	

Grid D Wind (Servicability Checks)		
STORY	DISP-Y (IN)	STORY DRIFT (IN)
LEVEL 15	1.18	0.04
LEVEL 14M	1.16	
LEVEL 14	1.14	
LEVEL 13M	1.11	0.10
LEVEL 13	1.01	
LEVEL 12M	0.99	0.01
LEVEL 12	0.98	
LEVEL 11M	0.97	0.04
LEVEL 11	0.93	
LEVEL 10M	0.88	0.05
LEVEL 10	0.83	
LEVEL 9M	0.78	0.04
LEVEL 9	0.74	
LEVEL 8M	0.69	0.02
LEVEL 8	0.67	
LEVEL 7M	0.63	0.03
LEVEL 7	0.60	
LEVEL 6M	0.58	0.07
LEVEL 6	0.51	
LEVEL 5	0.43	0.10
LEVEL 4	0.33	
LEVEL 3	0.25	0.14
LEVEL 2	0.11	

A strength check of the existing structure for Miami, FL wind forces is provided below. This strength check yields a failed member. This failure is one example of several occurrences throughout the existing lateral system.

1/30/10

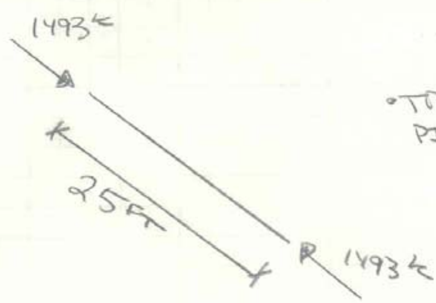
STRENGTH CHECK

• EXISTING LATERAL SYSTEM – MAIMI, FL

BRACED FRAME BETWEEN LEVELS 8 & 9.

→ ETABS CALCULATED AXIAL FORCE FOR MEMBER (W14x90) → 1493^k

CHECK AXIAL CAPACITY OF THIS W14x90 MEMBER:



• $P_u = 1493^k$

• TREAT BRACE AS PIN-PIN COLUMN

$P_u = 1493^k$

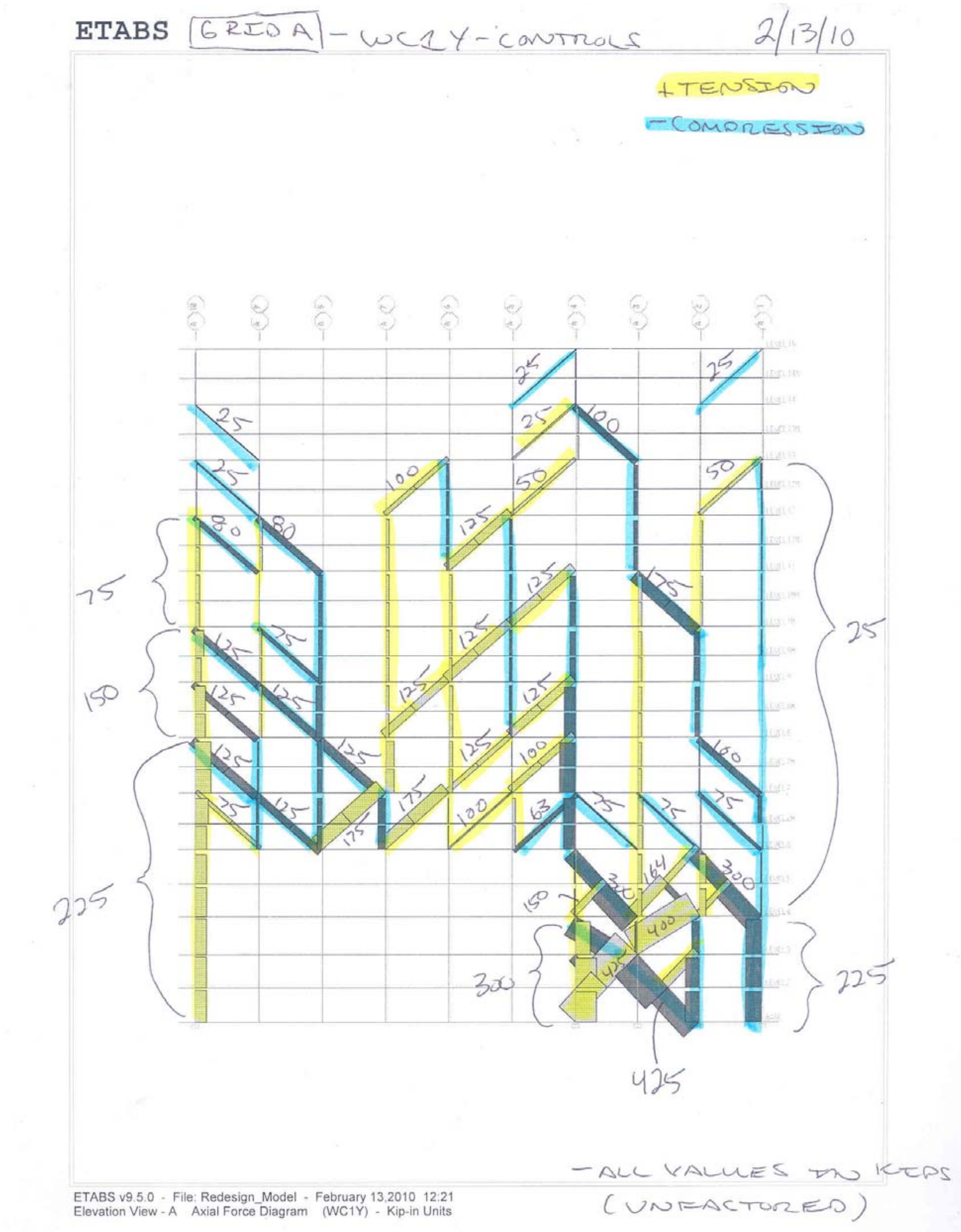
$\phi P_n = 765^k$ (24 FT)
$\phi P_n = 708^k$ (26 FT)

BOTH < 1493^k

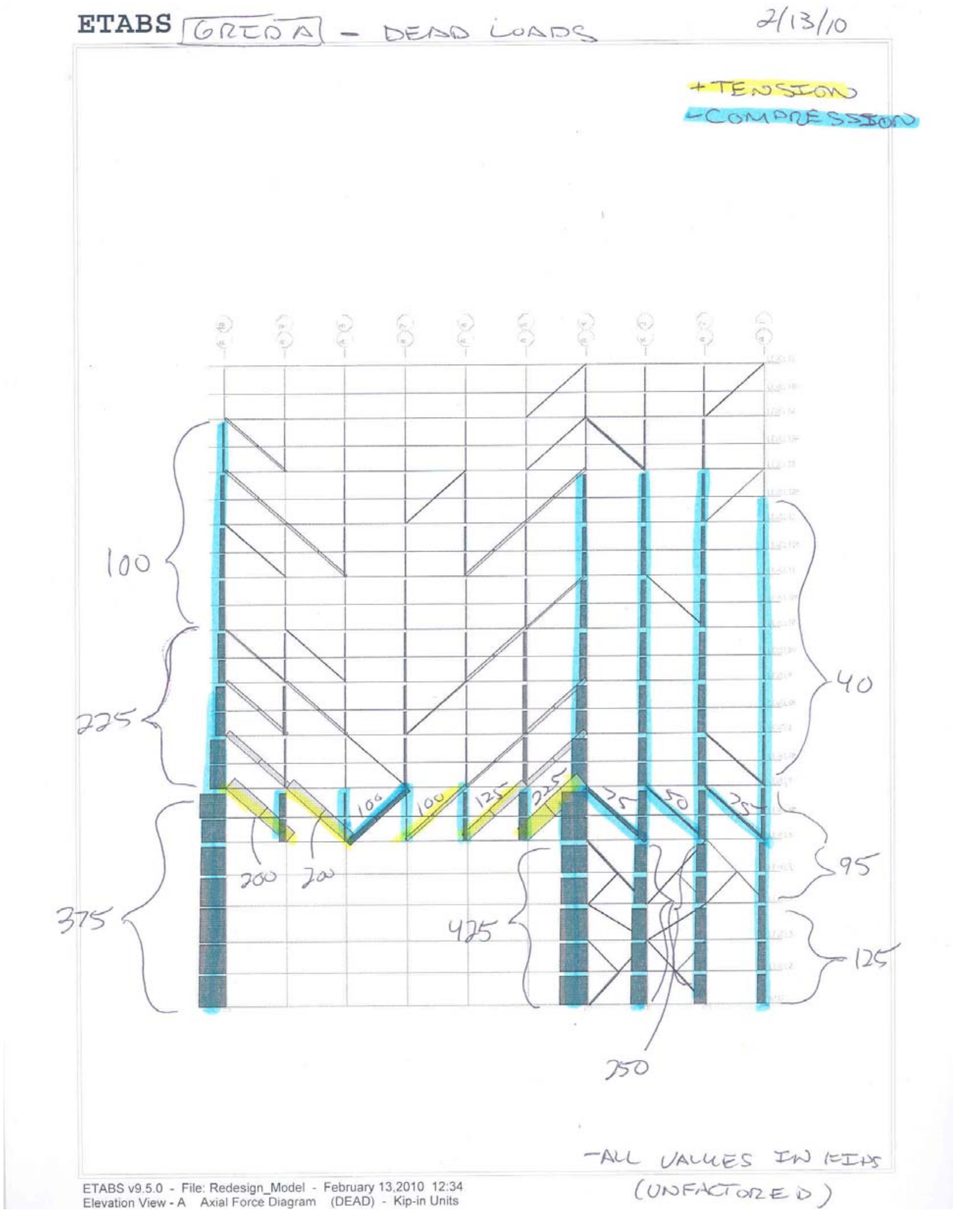
∴ W14x90 BRACE MEMBER IS NO GOOD FOR STRENGTH REQUIREMENT.

– NOTE: AUTHOR SUSPECTS MANY BRACED MEMBERS IN EAST-WEST LAT. SYSTEM TO FAIL STRENGTH REQ. → WILL BE CONSIDERED DURING REDESIGN.

Below is an ETABS printout of axial forces in Grid A for its controlling wind force case. These members were checked by the author and redesign appropriately if a larger section was needed for tension or compression requirements.



Below is an ETABS printout of mainly compressive forces in Grid A. Grid A is in the North-South direction of the lateral system. Grids A, C, & D have lateral members that are loaded under both wind and dead load forces. Combinations of these forces are analyzed to check the design of column and brace frame members.



Below is example hand calculation checks performed for Grid A.

GRID CHECKS | GRID A | 2/13/10

CHECK TRUSS BRACING:

COMBO 1.2D+1.6W+1.0L:

CHECK BRACE BETWEEN 5-4 / LEVEL 6.

$1.2[225] + 1.6[175] + 1.0[225] = 800^k$ COMP.

W14x550 — $\phi_c P_n = 4560^k$
LENGTH → 30FT

(OKAY)

CHECK COLUMNS:

LINE 4 – LEVEL 2

$1.2(425) + 1.0(425) + 300(1.6) = 1415^k$

24 FT LONG
W14x730 → (OKAY!)

CHECK BRACE: LEVEL 1-3 (BETWEEN LINES 4-5)

$1.6(425) + 1.2(75) + 1.0(75) = 900^k$

W14x90 — $\phi_c P_n = 596^k$
LENGTH 30FT

NEED LARGER SECTION.

(W14x145) → OKAY

MODIFY OTHER BRACING ACCORDINGLY.

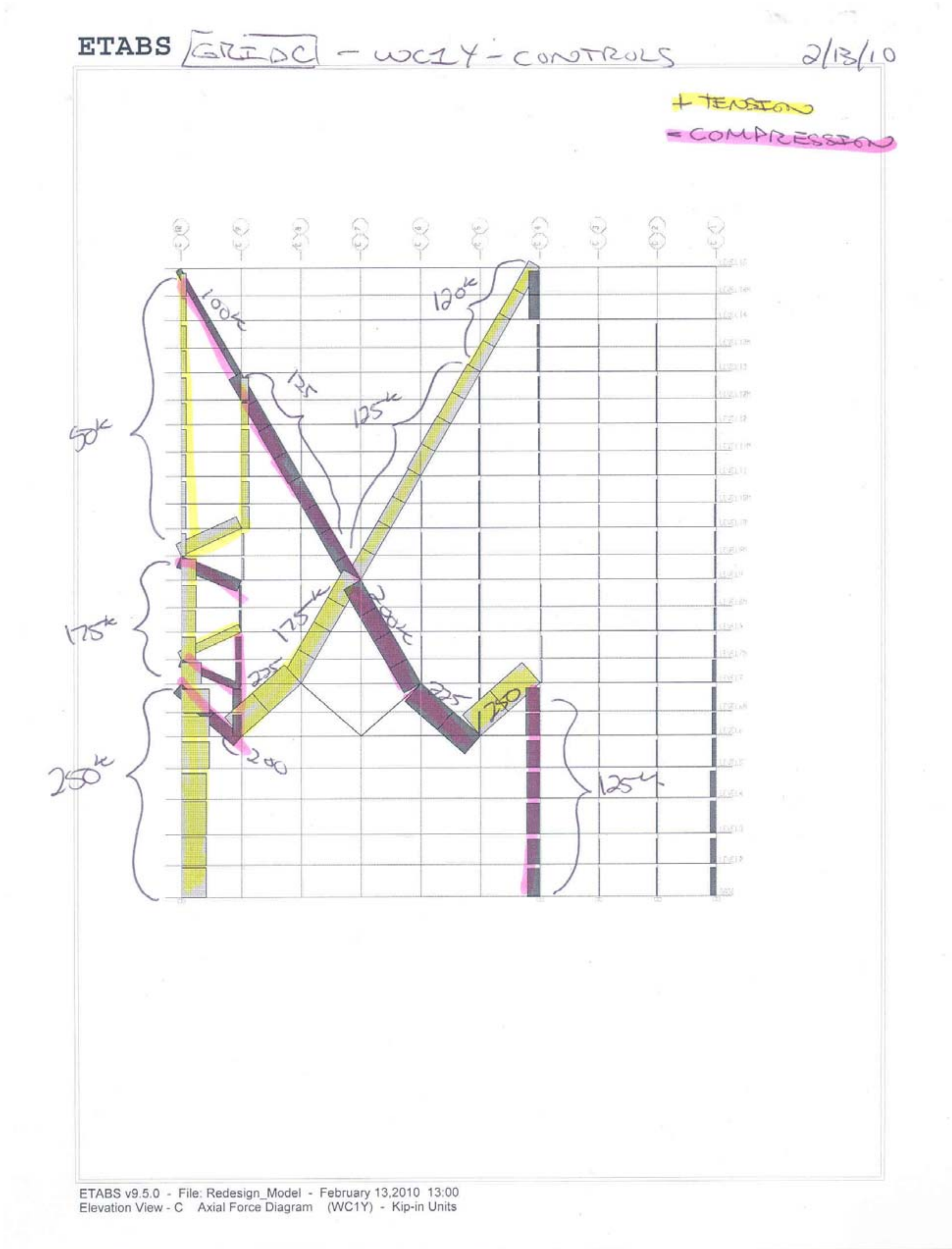
CHECK LONG EXT. COLUMN

W14x730 (LENGTH = 56FT) — $\phi_c P_n = 2970^k$

$1.2(375) + 1.0(375) + 225(1.6) = 1100^k$

(FOS > 2 → OKAY)

Analysis and preliminary design of Grid C followed the same process as shown previously for Grid A.



GRID CHECKS | GRID C | 2/13/10

CHECK LONG EXTERIOR COLUMN:

SOFT LONG
W14x730 $\phi_c P_n = 2970^k$

$1.6(250) + 1.2(450) + 1.0(450) = 1400^k$

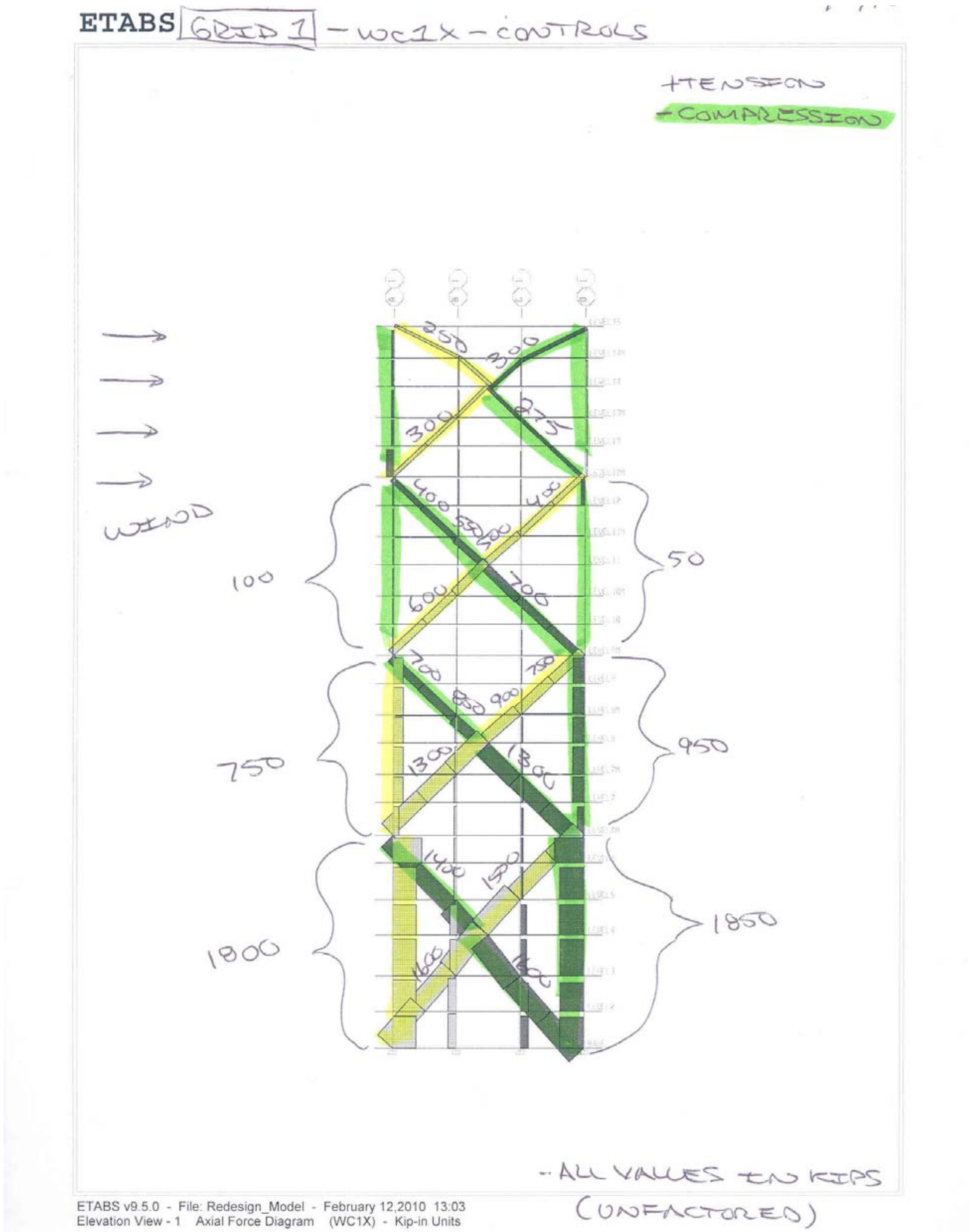
$FOS = \frac{2970}{1400} = 2 \rightarrow$ (OKAY)

CHECK TRUSS BRACING:

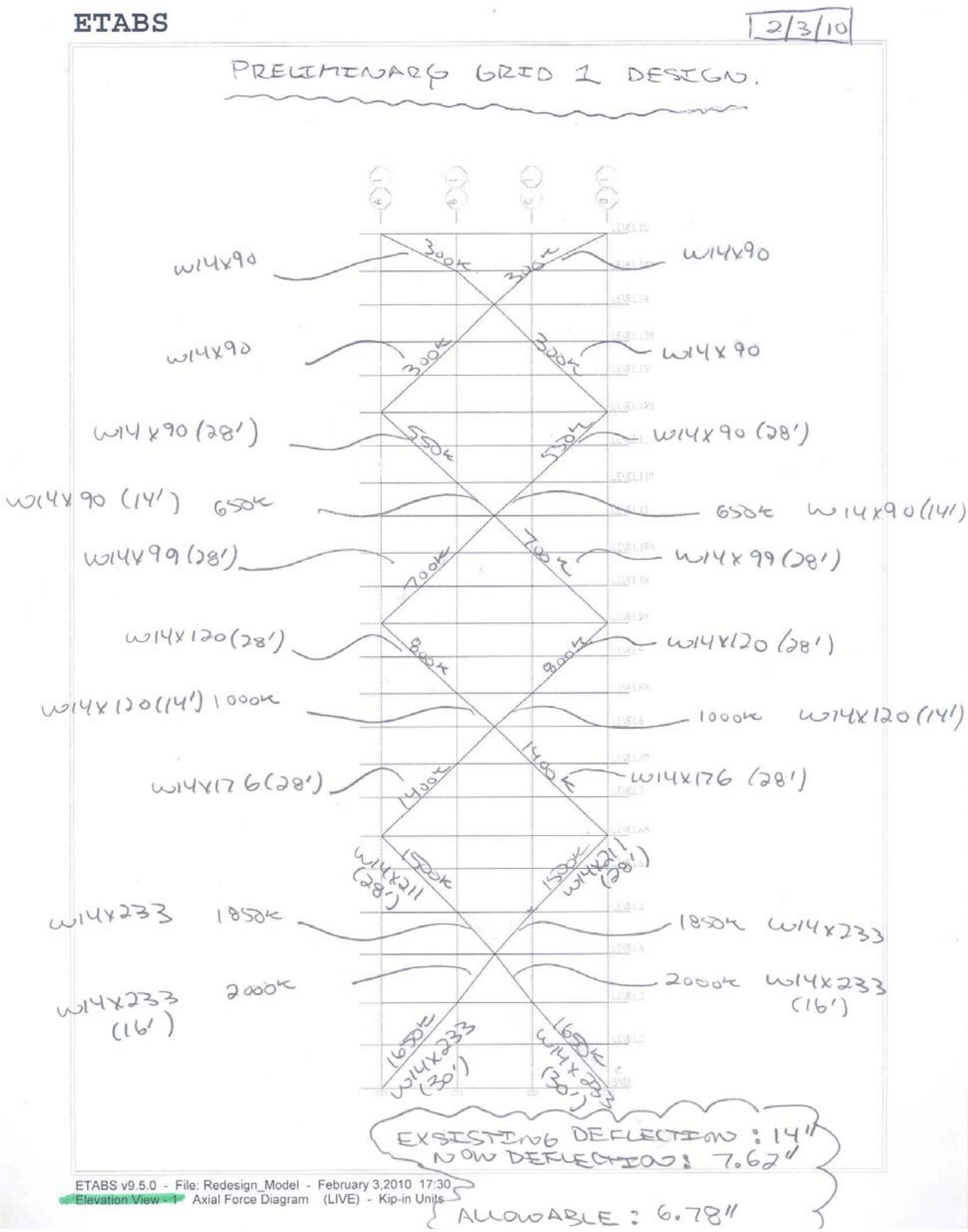
$1.6(250) + 1.2(300) + 1.0(300) = 1100^k$

W14x730^k → (OKAY!)

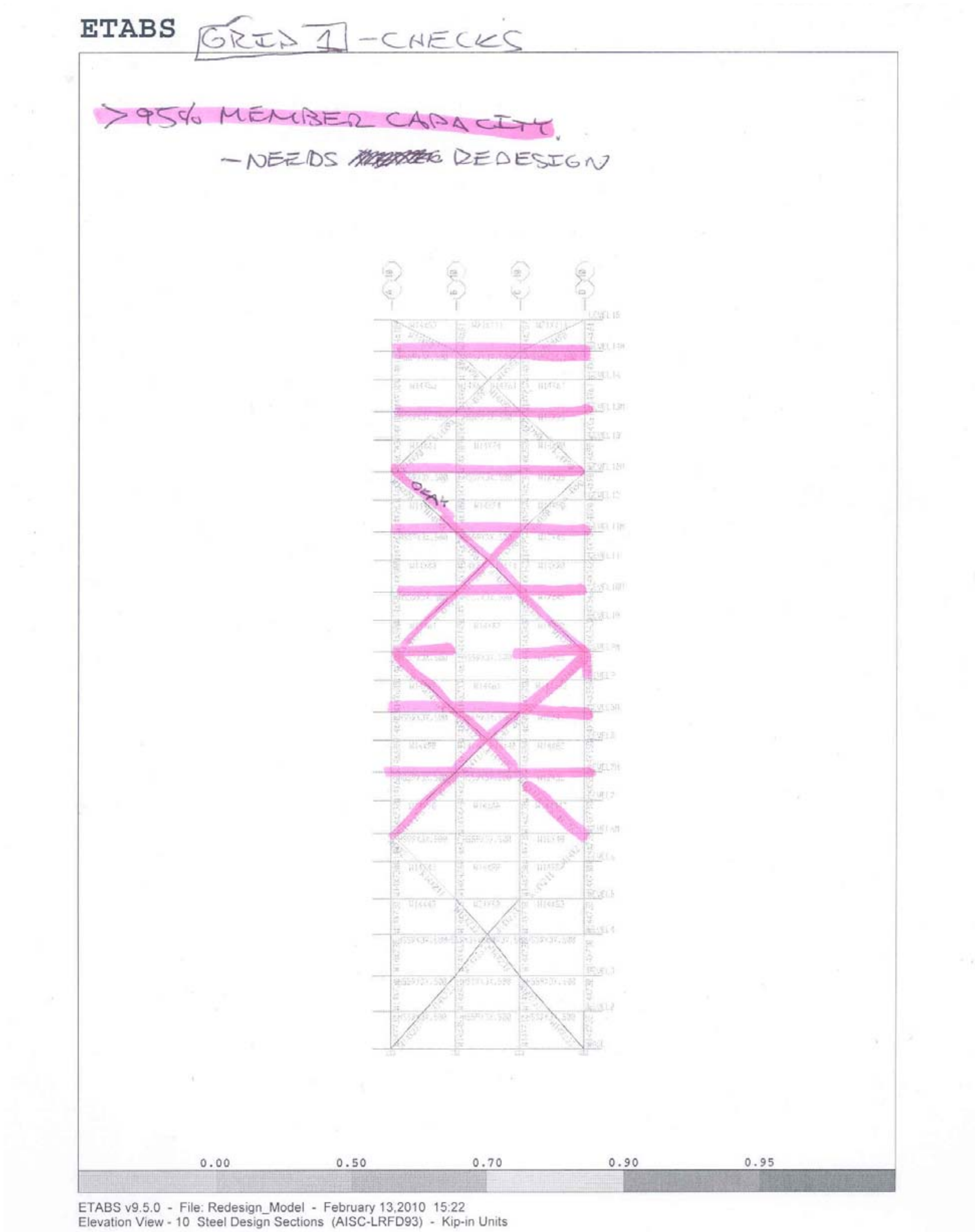
The East-West direction preliminary design came next. This redesign was extensive and did not just involve checking existing member's sizes, which was performed in the North-South direction grids.



Below is a preliminary design of Grid 1 bracing members. The members were treated as concentric (axial loaded) members. Member sizes were chosen appropriately using the LRFD (Load & Resistance Factor Design) manual.



After member changes were performed, the ETABS model was analyzed, once again. Members that did not meet capacity demands were noted and redesign appropriately. This process continued until a sufficient design was attainable.



Additional hand calculated checks (Grid 1) were performed to provide validity of the ETABS analysis.

GRID CHECKS | GRID 1 | 2/11/10 | 2

CHECK 1.2D + 1.6W + 1.0L COLUMNS:

LEVEL 5 EXTERIOR COLUMNS:

$1.2(200^k) + 1.6(1850) + 1.0(200) = 3400^k$

$3400 \leq \phi_c P_n$ (2120) COLUMN [W14x176] LENGTH 12FT

↳ NO GOOD BUMP UP TO W14x426 ($\phi P_n = 5190^k$)

↓ MODIFY COLUMNS ACCORDINGLY.

FACTOR OF SAFETY:

$\frac{4510}{3400} = 1.52 > 1.5$ (OKAY)

CHECK 0.9D + 1.6L:

LEVEL 5 COLUMN

$1.6(1800) - 0.9(200) = 2700^k$ (TENSION)

↑ TENSION

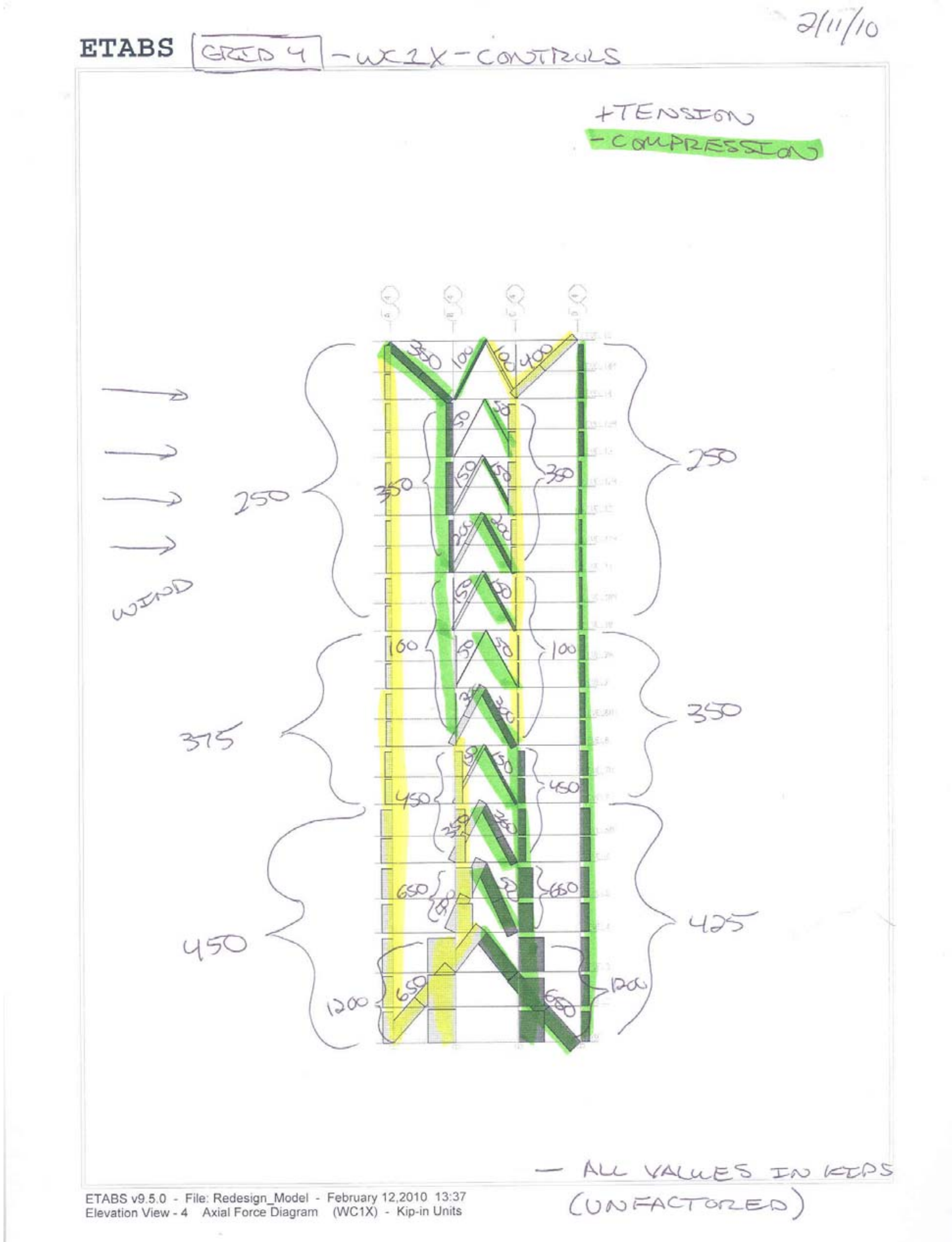
$\phi_c P_n = 5630^k$ [W14x426]

$2700 \leq \phi_t P_n$ → (OKAY)

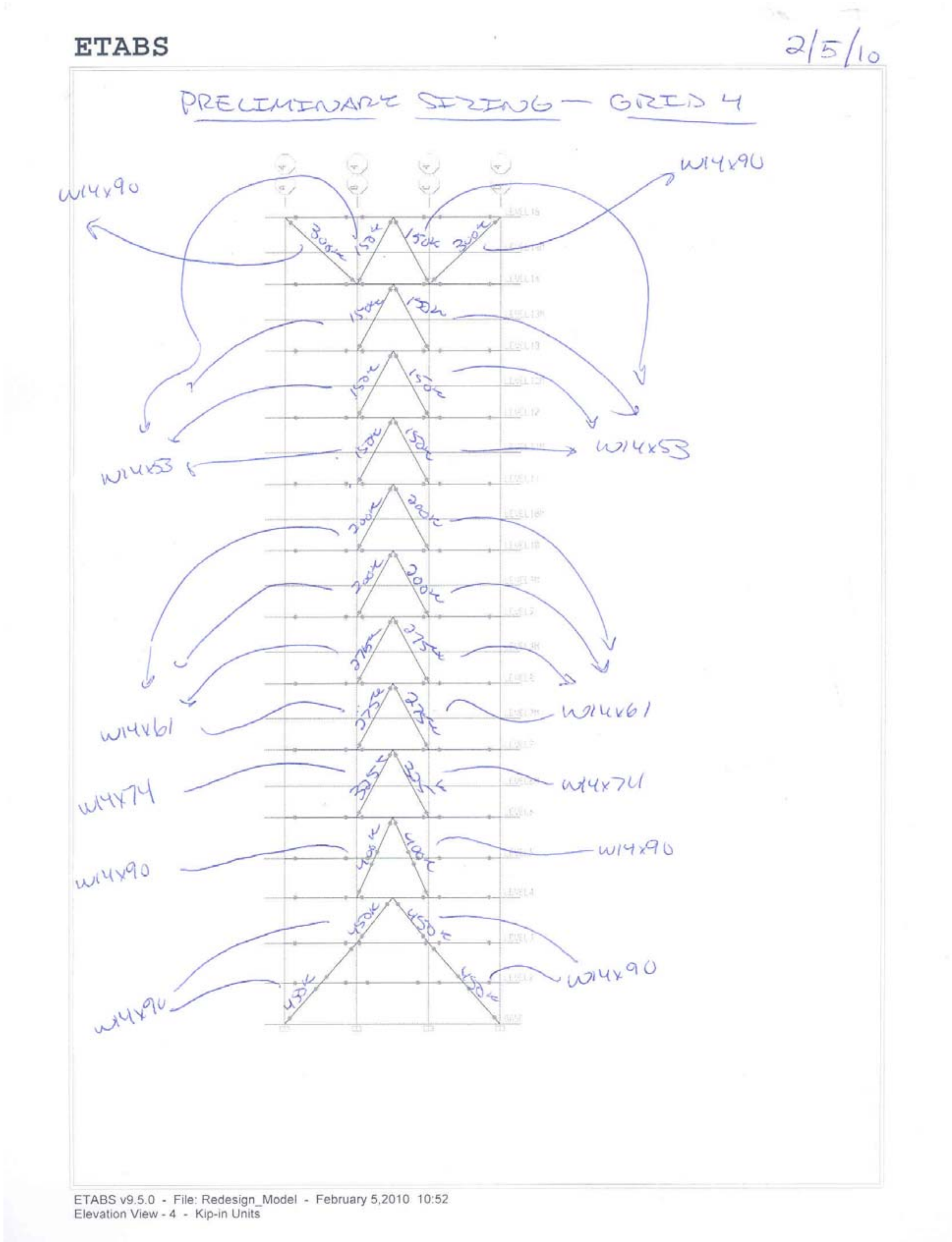
FACTOR OF SAFETY:

$\frac{5630}{2700} = 2.1$ → (OKAY)

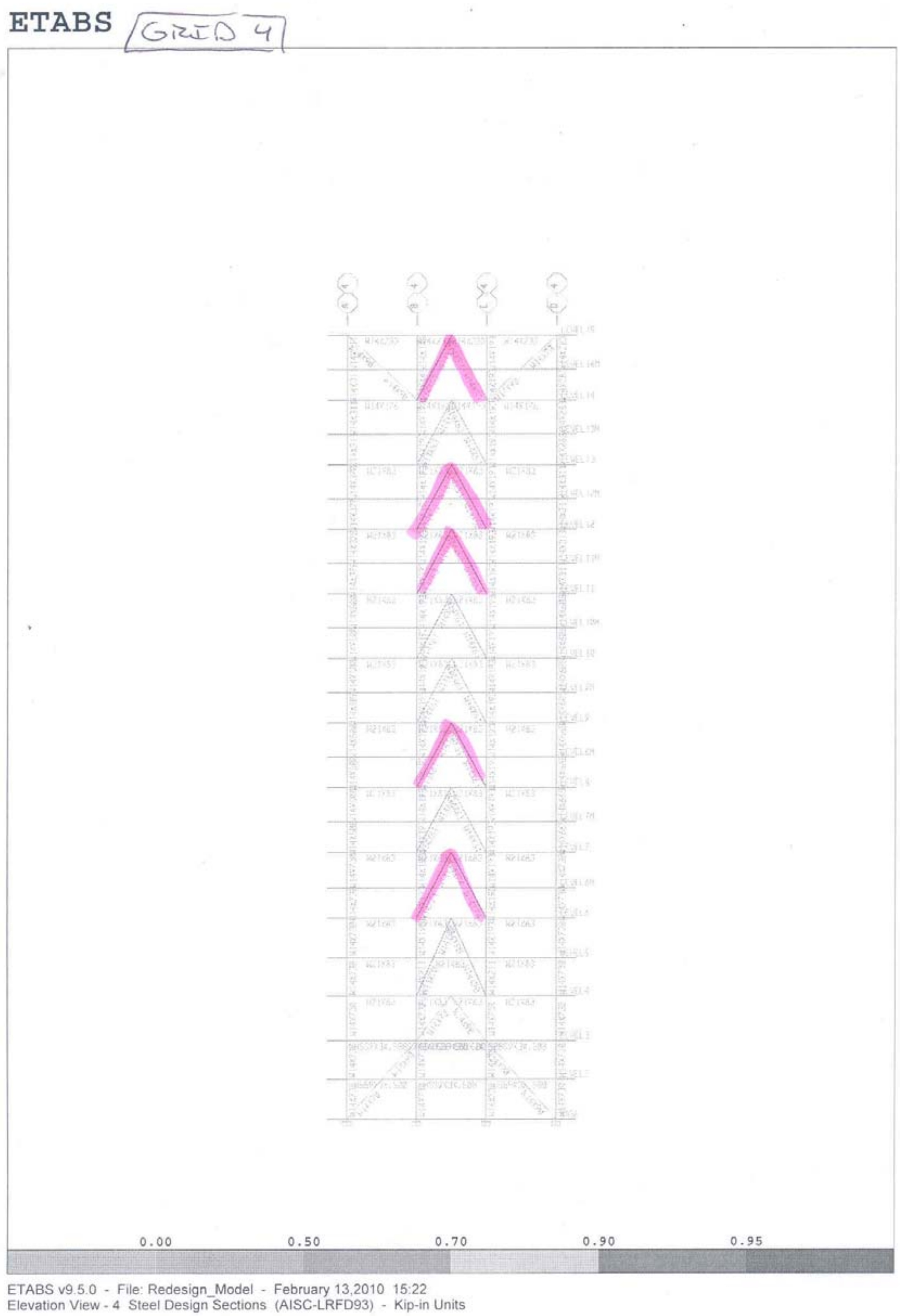
Analysis and redesign of Grid 4 followed similarly to Grid 1. Take notice that Grid 4 is an interior grid and therefore contains one bay chevron bracing to fulfill architectural spatial needs.



Preliminary sizing of Grid 4 members is shown below.



Capacity check of Grid 4 is shown below. Highlighted members did not meet capacity demands and were redesigned once again.



Hand calculated checks of Grid 4 redesign is shown below and on the following page.

GRID CHECKS | GRID 4 - INT | 2/11/10

CHECK 1.2D + 1.6W + 1.0L COLUMNS:

INTERIOR COLUMNS

LEVEL 5

$1.2(225) + 1.6(650) + 1.0(225) = 1535^k$

$\phi_c P_n = 2120^k$ [W14x176] LENGTH 12FT

$1535^k \leq 2120^k$

OKAY → BUMP UP SO FOS ≥ 1.5

• USE W14x193 ($\phi_c P_n = 2330$) → ADJUST OTHER COLUMNS ACCORDINGLY.

FOS = 1.52 > 1.5 (OKAY)

LEVEL 5 - INTERIOR COLUMN:

CHECK 0.9D + 1.6W:

$-0.9(225) + 1.6(650) = 850^k$ (TENS)

W14x193 → $\phi_t P_n = 2560^k$ → (OKAY.)

FOS > 1.5 → (OKAY)

GRID CHECKS | GRID 4 - EXT | 2/11/10

CHECK 1.2D + 1.6W + 1.0L COLUMNS:

EXT. COL - LEVEL 5

$1.2(400) + 1.6(425) + 1.0(400) = 1560^K$

W14x730
LENGTH 12FT → $\phi_c P_n = 9030^k$ → OKAY!

FOS > 1.5 → OKAY

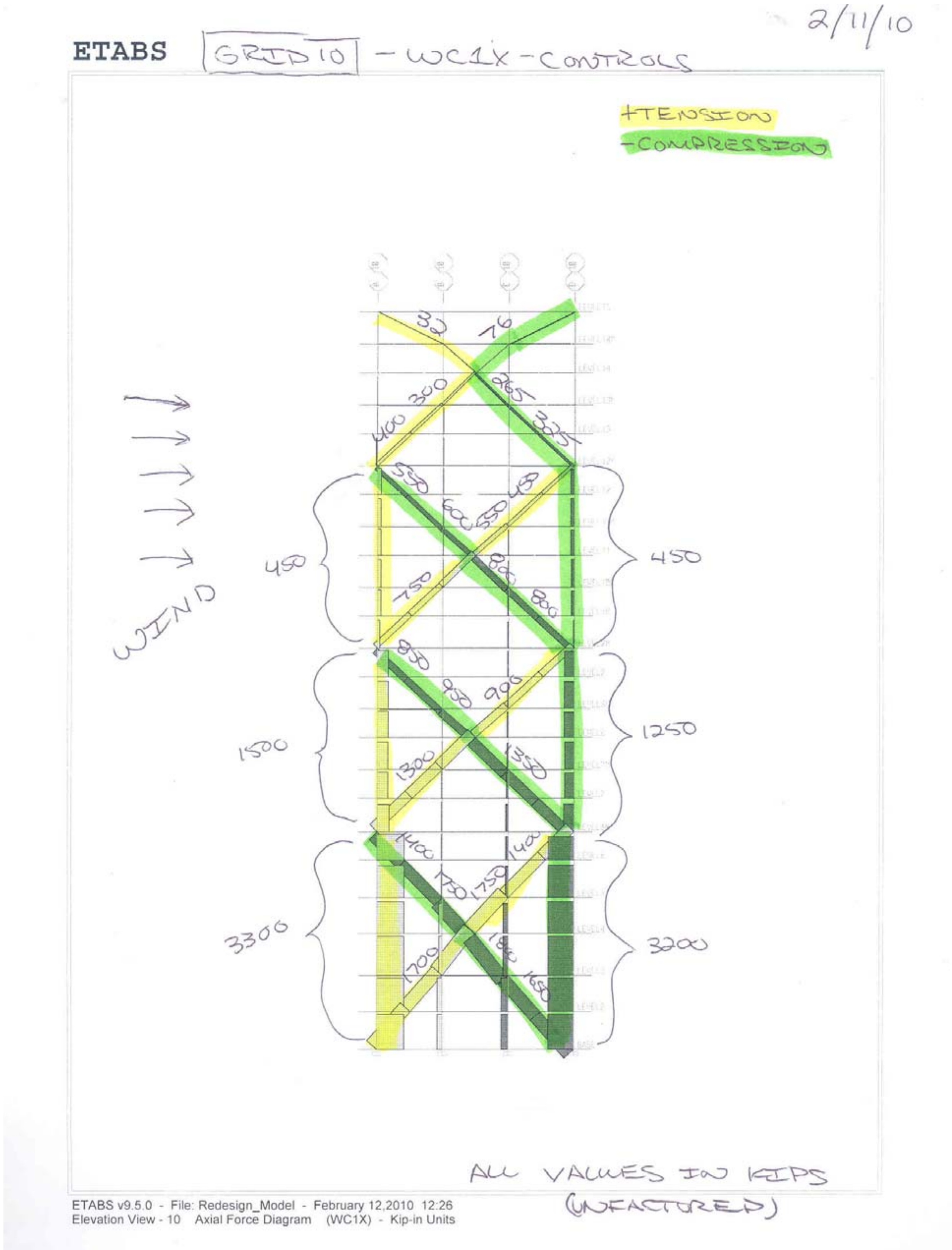
EXT COL - LEVEL 5

CHECK 0.9D + 1.6W

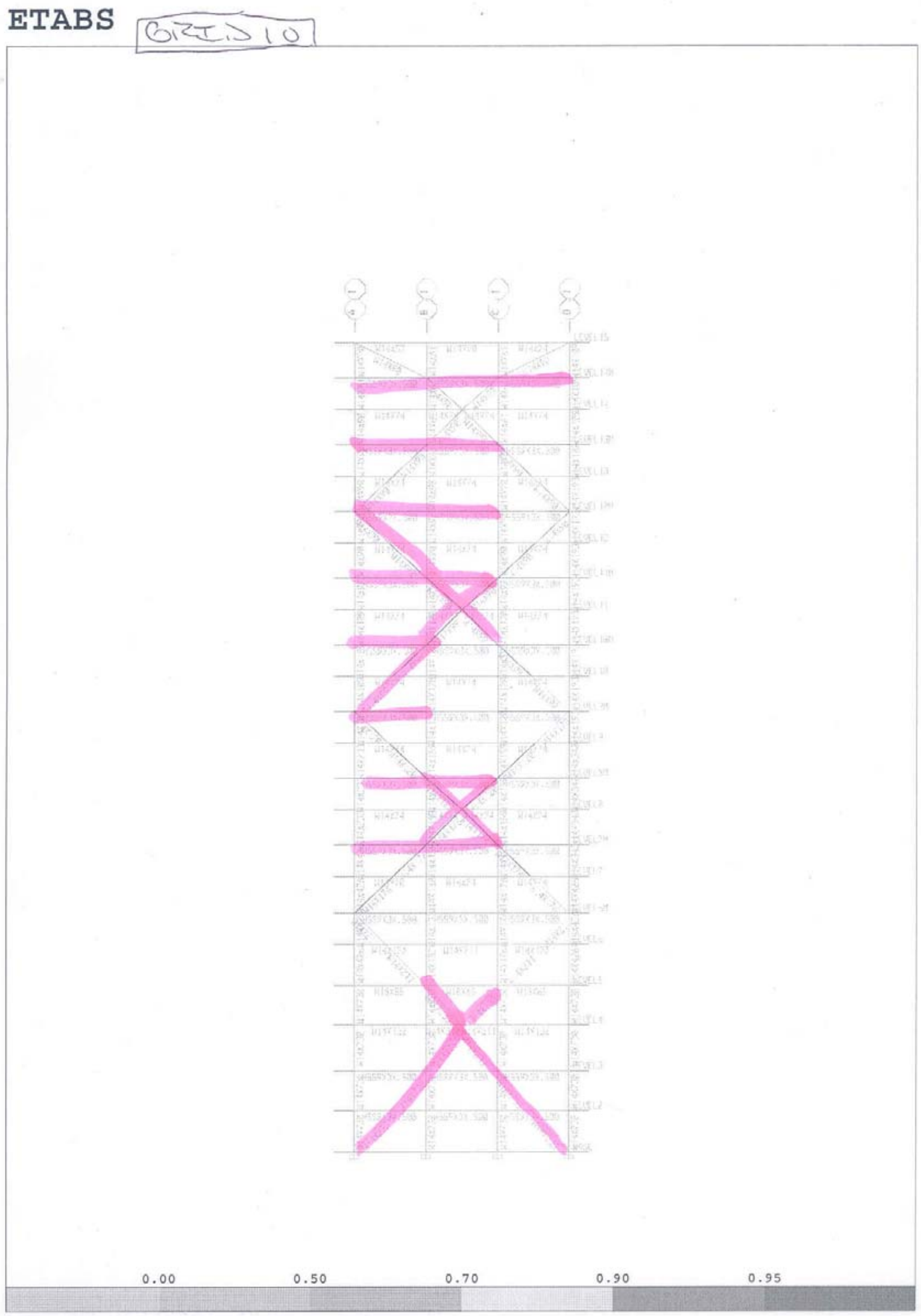
$-0.9(350) + 1.6(450) = 405^k \leq \phi_t P_n$ → OKAY

FOS ≥ 1.5 → OKAY

Analysis and redesign of Grid 10 followed similarly to Grids 1 & 4.



Capacity check of Grid 10 is shown below. Highlighted members did not meet capacity demands and were redesigned once again.



ETABS v9.5.0 - File: Redesign_Model - February 13,2010 15:22
Elevation View - 1 Steel Design Sections (AISC-LRFD93) - Kip-in Units

Hand calculated checks of Grid 10 redesign is shown below.

GRID CHECKS | GRID 10 | 2/11/10 | 1

CHECK 1.2D+1.6W+1.0L COLUMNS:

LEVEL 5 EXTERIOR COLUMN:

$1.2(350^k) + 1.6(3200^k) + 1.0(350^k) = 5900^k$

- ASSUME LIVE LOAD IS EQUAL TO DL ON COLUMN

$5900 \leq \phi_c P_n$ COLUMN IS W14x730
LENGTH 12^{FT}

$\phi_c P_n = 9030^k \rightarrow$ (OKAY!)

FACTOR OF SAFETY:

$\frac{9030}{5900} = 1.53 > 1.5$ (OKAY)

CHECK 0.9D+1.6L

LEVEL 5 COLUMN

$1.6(3300^k) - 0.9(350) = 4965^k$ (TENSION)

↑ TENSION

$\phi_t P_n = 9680$ W14x730

$4965 \leq \phi_t P_n \rightarrow$ (OKAY!)

FACTOR OF SAFETY:

9685/4965 = 1.95 > 1.5 (OKAY)

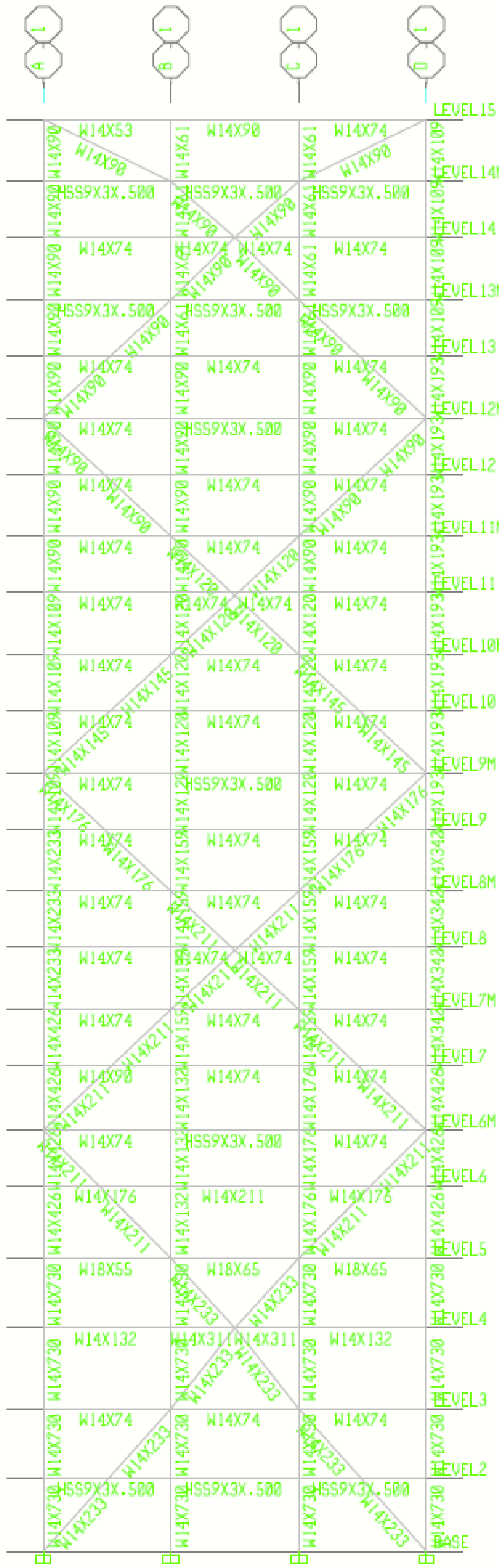
Finalized Member Sizes:

The following pages provide images of all the participating grids of the redesigned lateral system. These images provide finalized member sizes for each grid. Please note that these member sizes were determined through a repetitive analysis process, which is explained in the following paragraph.

This process utilized ETABS software to analyze each grid under its governing wind case. Forces and stresses were found using the calculated wind forces and ETABS analysis. From these forces and stresses, member sizes could be chosen appropriately. When several member sizes were designed, the stiffness of a participating grid would change relative to the entire lateral system. This would cause a redistribution of lateral forces to each grid. This is why the lateral system was designed using a repetitive process, until distribution of lateral forces to grids remained relatively constant.

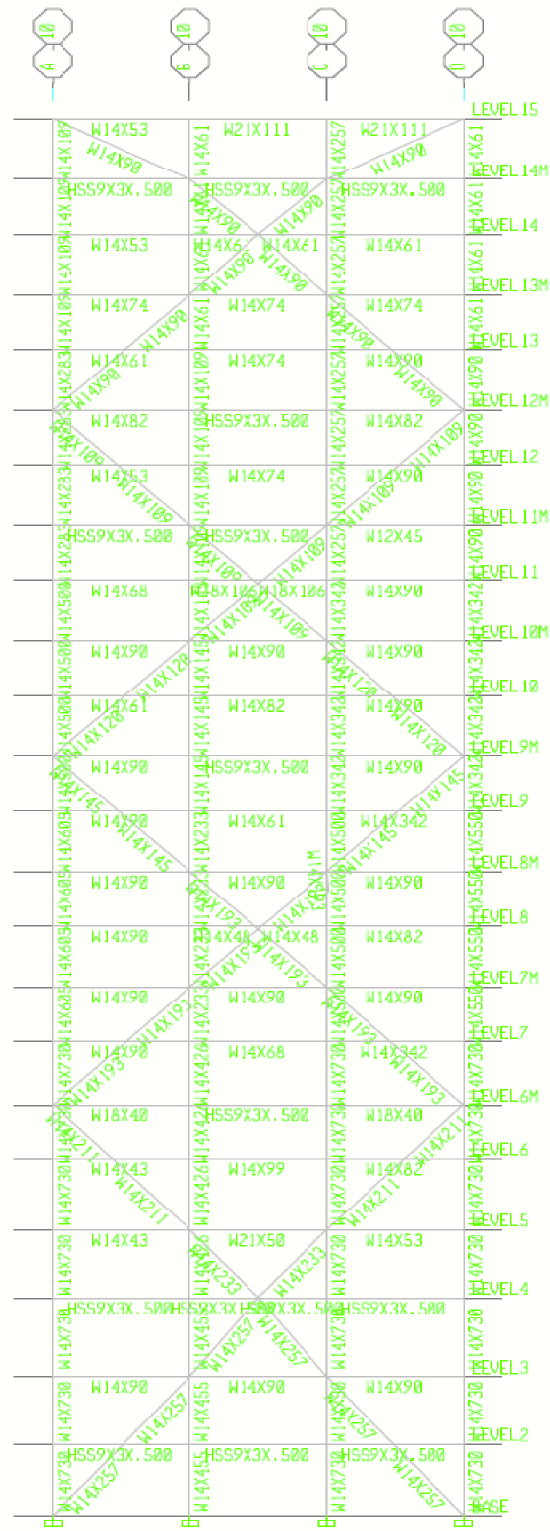
The finalized grid designs of the lateral system were obtained only after each passed drift, story drift, and strength requirements.

Grid 1 – Finalized Member Sizes

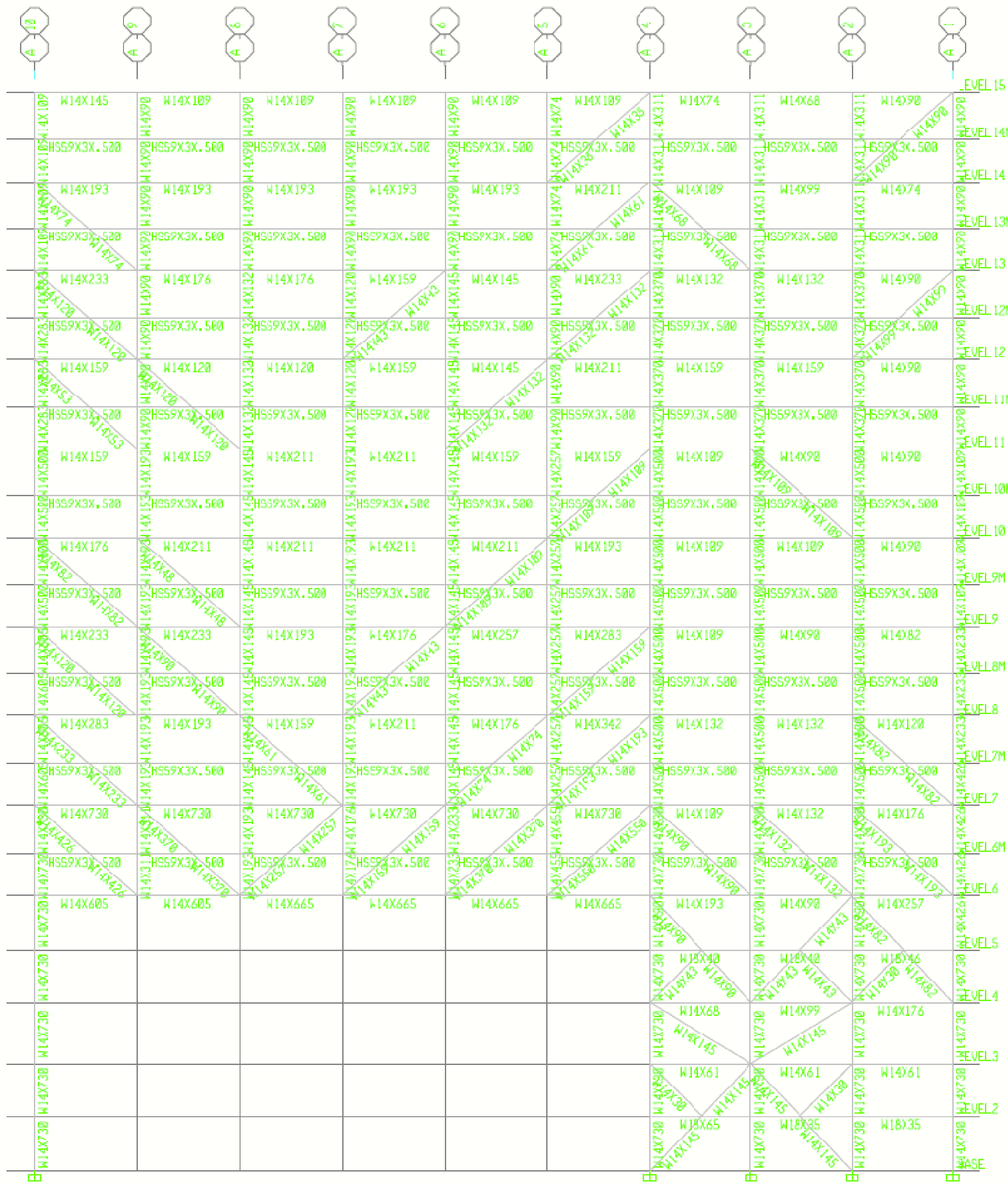


Grid 4 – Finalized Member Sizes

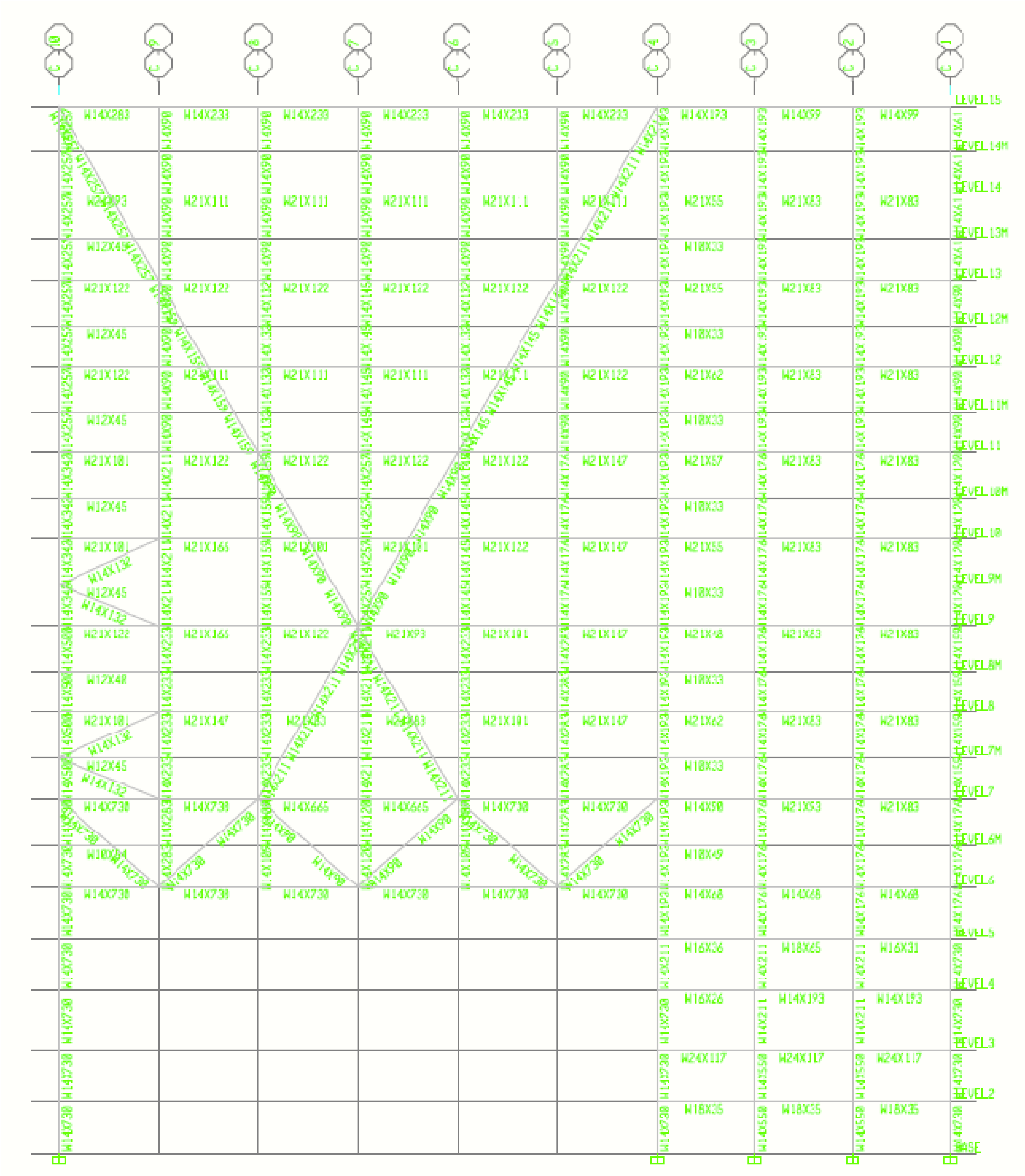
Grid 10 – Finalized Member Sizes



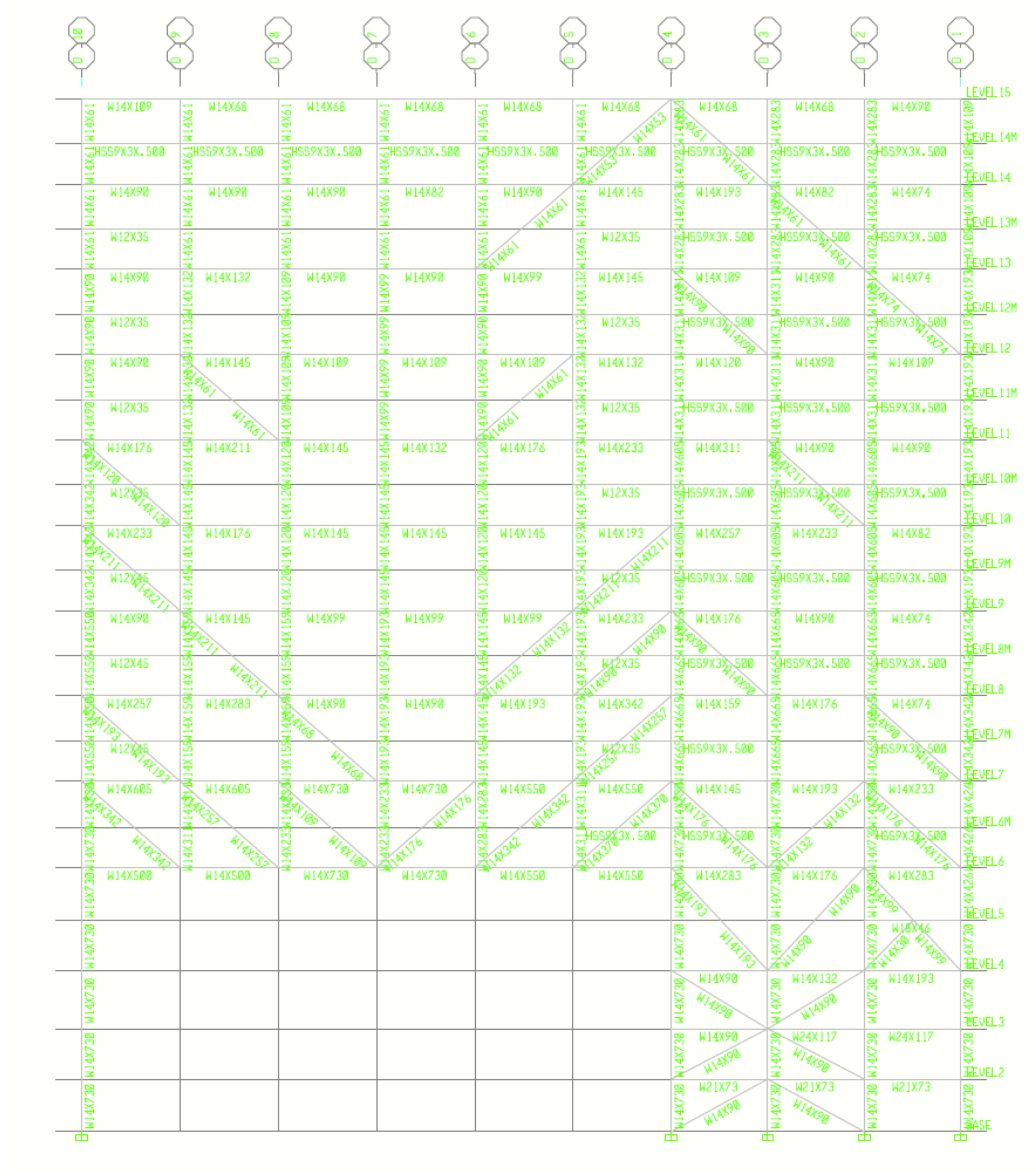
Grid A – Finalized Member Sizes



Grid C – Finalized Member Sizes



Grid D – Finalized Member Sizes



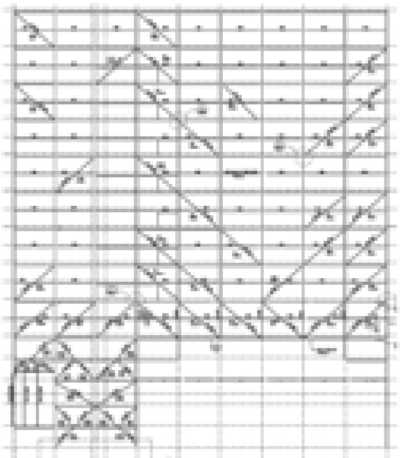
Appendix B

Existing Plans, Elevations, & Sections

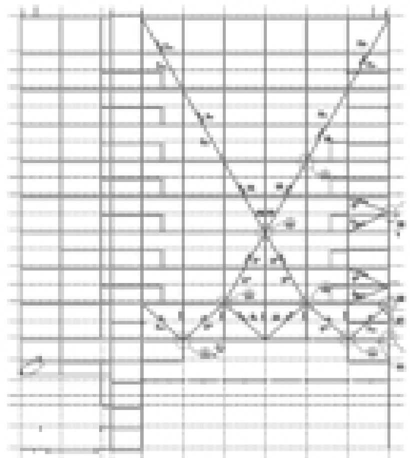
Columbia University Northwest Science Building

Broadway & 120th Street, New York, NY

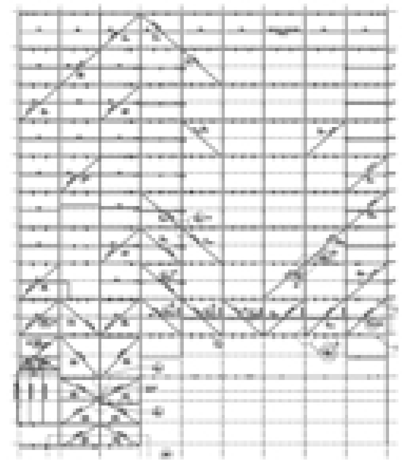
Lateral System Frame Elevations



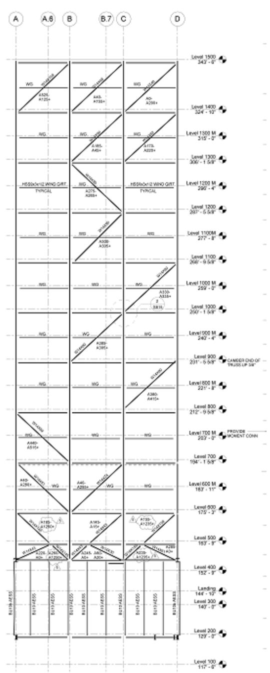
Grid A



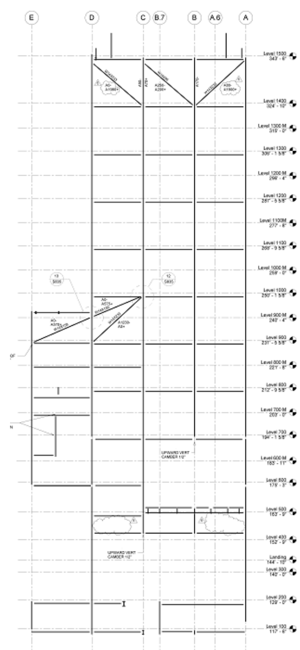
Grid C



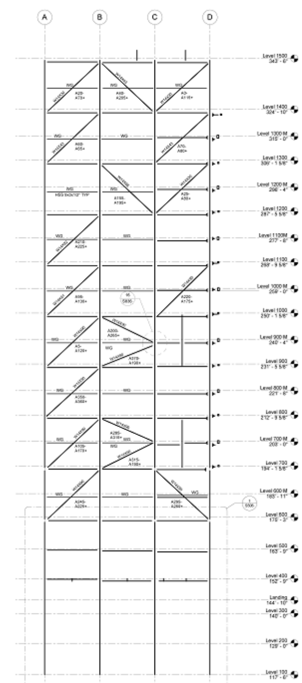
Grid D



GRID 1

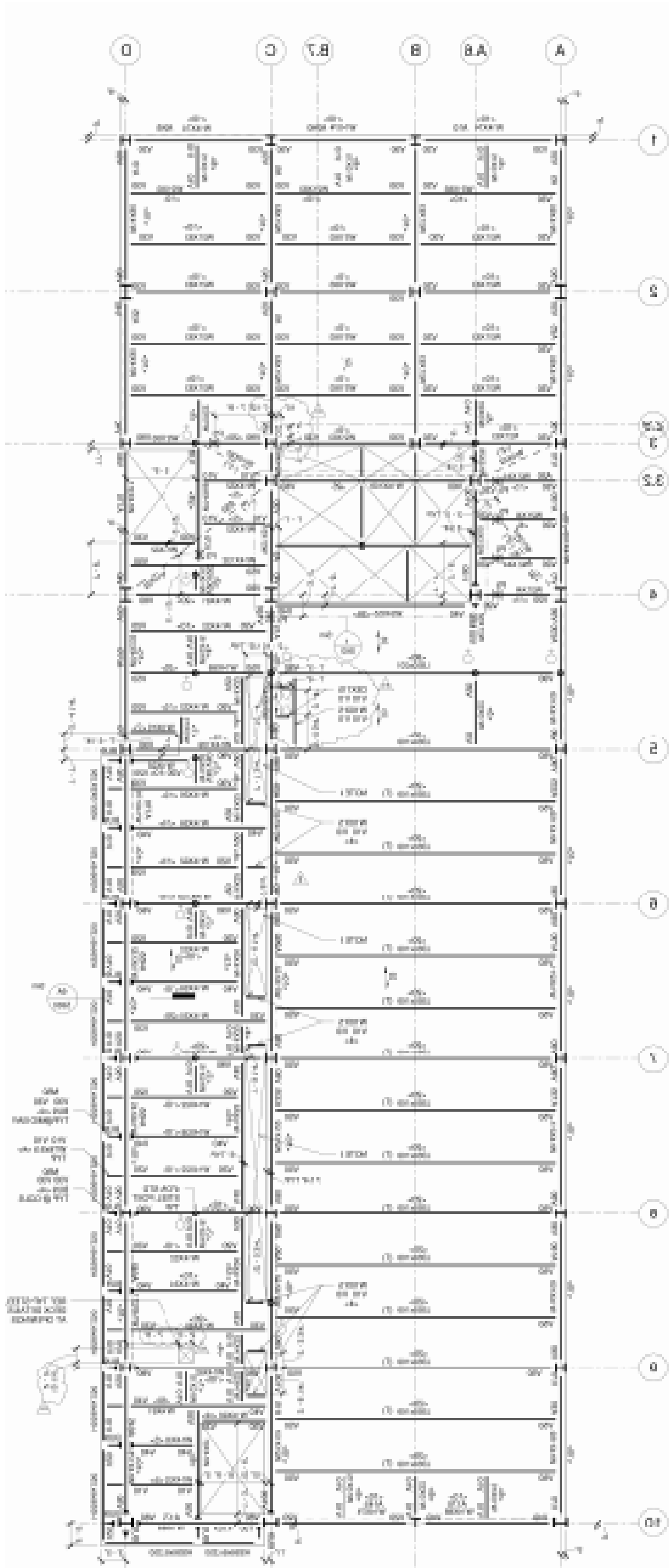


GRIDS 2-4

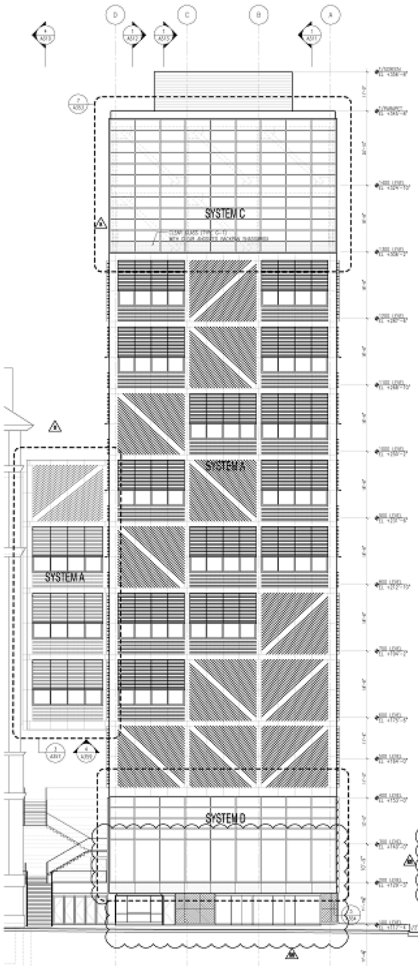


GRID 10

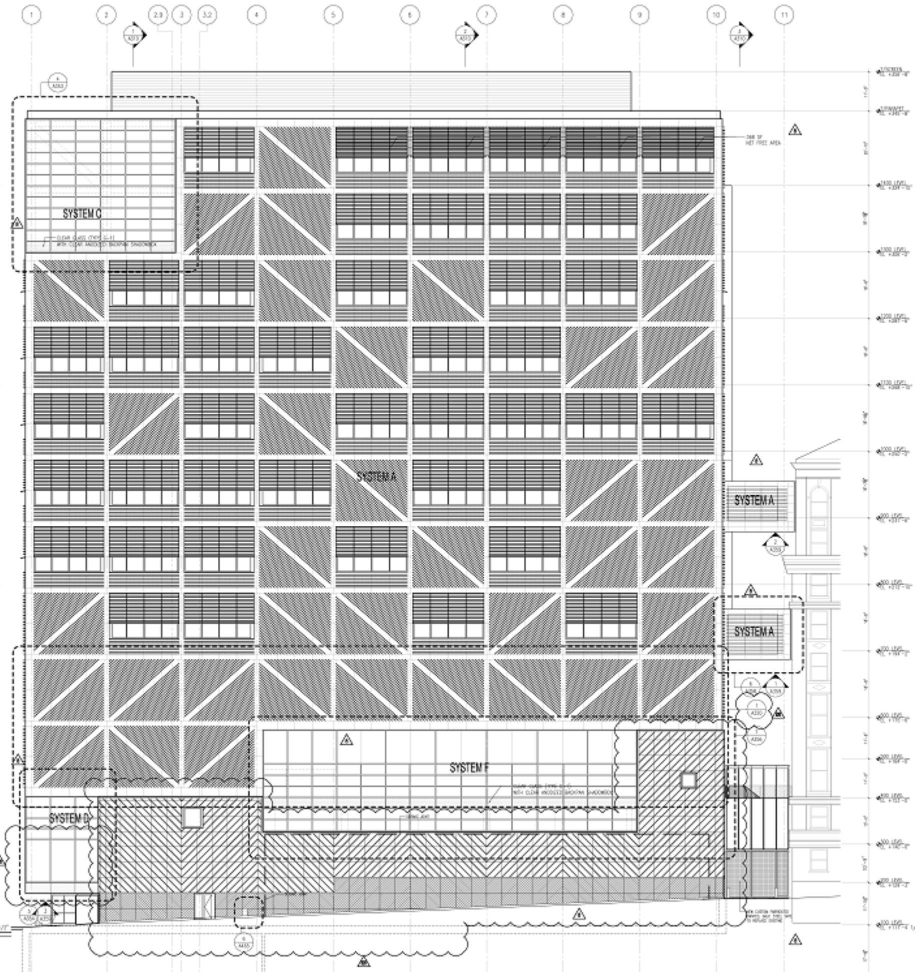
Typical Floor Plan



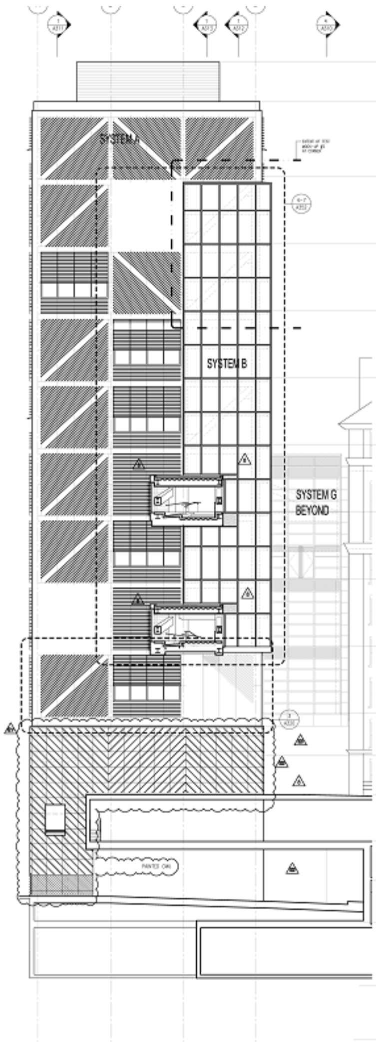
North Building Elevation



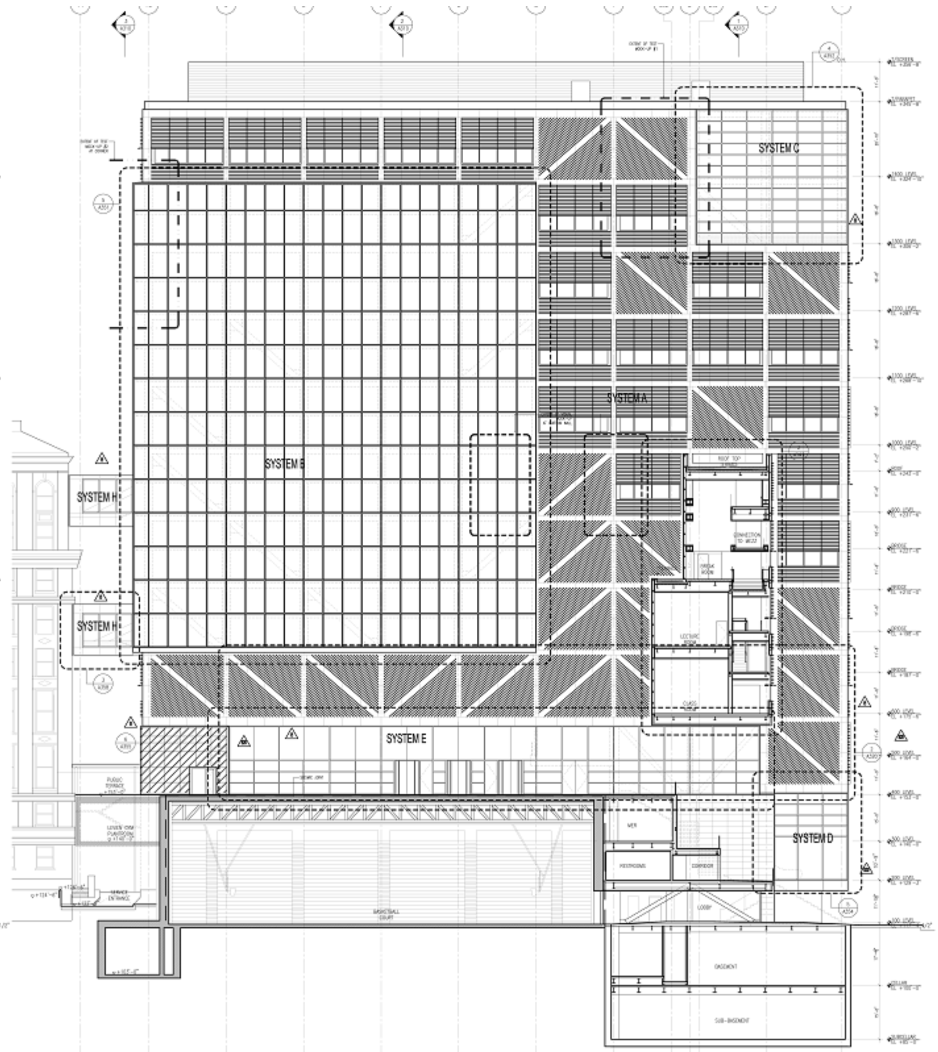
West Building Elevation



South ***Building Elevation***



East Building Elevation



Appendix C

Cost Analyses Calculations & Data

Columbia University Northwest Science Building

Broadway & 120th Street, New York, NY

The following two pages provide a cost analysis for the Building Enclosure Breadth's Study. This study was able to reduce the insulation layer of the building enclosure from 4" to 2.5".

RS MEANS 1

NEW YORK, NY

INSULATION → 4" FOAM GLASS

BARE MATERIAL → $0.50 FOR 4" / PER SF

SQUARE FT OF CURTAIN WALL ON BLD:

- WEST ELEVATION:
  - GROSS → 194 x 226 = 43,844 FT²
  - GLAZING → 30(40) + (20)(100) = 3,200 FT²
  - A_NET = 40,600 FT²
- NORTH ELEVATION:
  - GROSS → 226 x 84 = 18984 FT²
  - GLAZING → 60(45) + 60(30) = 4,500 FT²
  - A_NET = 14,400 FT²
- SOUTH ELEVATION:
  - GROSS = 18984 FT²
  - GLAZING → 23(105) = 2415 FT²
  - A_NET = 16,500 FT²
- EAST ELEVATION:
  - GROSS = 43,844 FT²
  - GLAZING → 105(105) = 11,025 FT²
  - A_NET = 32,800 FT²

A_TOTAL CURTAIN WALL = 104,300 FT²

RS MEANS 2

NEW YORK, NY

4" FOAMGLASS INSUL. $ \$3.88 / SQ FT \cdot 104{,}300 SQ FT / 1 $

$ = \$404{,}684 \rightarrow \$404{,}700 $ BARE MATERIAL

NYC LOCATION FACTOR
↓
$(1.31)(404{,}700) = \$530{,}150$ (BASE BARE MATERIAL COST)

MIAMI, FL

2.5" FOAMGLASS INSUL. $ \$2.62 / SQ FT \cdot 104{,}300 SQ FT / 1 $

$ = \$273{,}300 $ BARE MATERIAL

MIAMI LOCATION FACTOR.
↓
$(1.26)(273{,}200) = \$344{,}250$ (BASE BARE MATERIAL COST)

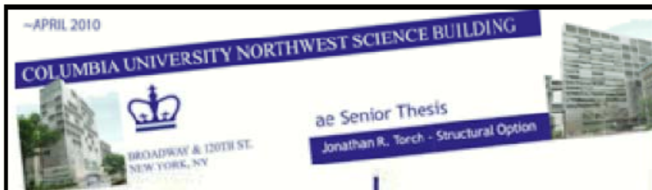
Appendix D

Thesis Presentation Slides

Columbia University Northwest Science Building

Broadway & 120th Street, New York, NY

~APRIL 2010



Special Thanks To: Turner

- **EXISTING**
- THESIS PROPOSAL
- GOALS
- EXISTING LATERAL
- LATERAL REDESIGN
- BUILDING ENCLOSURE
- ARCHITECTURE
- CONCLUSION

PSU AE — THE PENNSYLVANIA STATE UNIVERISTY

Columbia University Northwest Science Building

New York, NY

Jonathan R. Torch
Structural Option
B.A.E/M.A.E Candidate
Faculty Advisor: Dr. Ali Memari

Northwest Science Building – Location

- Located at the Corner of Broadway & West 120th Street, New York, NY
- 13,000 square foot lot size
- Adjacent to Columbia University's Chandler Hall and Pupin Physics Laboratories.
- Building contains a 126-foot clear span over an existing structure, the Dodge Physical Fitness Center.

Upper Manhattan

Columbia University Campus

Slide 2

Northwest Science Building – Statistics

• Location & Site:	Broadway & 120th Street, New York, NY
• Building Occupant Name:	Columbia University
• Function Type:	Educational
• Size:	188,000 Square Feet
• Number of Stories:	14 Stories Above Grade
• Height:	239' 4"
• Construction Dates:	March 2007 – October 2010
• Cost:	$250,000,000 (Total Construction Cost)
• Project Delivery Method:	Design-Bid-Build

Role	Location	Web Page
General Contractor: Turner Construction	375 Hudson Street New York, NY 10014	http://www.turnerconstruction.com/
Structural/MEP/Fire Engineers: Ove Arup & Partners Consulting Engineers	155 Avenue of the Americas New York, NY 10012	http://www.arup.com/

Thesis Abstract

- Located in Engr. Unit A (across from Room 104)
- Copies Also Upfront

Slide 3

Northwest Science Building – Statistics

Architecture
- Building when completed in October 2010 will house:
  - Classrooms
  - Faculty Offices
  - Research Facilities for Chemistry, Biology, Engineering, and Physics

Structure
- Composite Steel Frame Design
  - Concrete Slab & Metal Decking Shear Studded to Beam Members
- All Columns are W14's
- Castellated Beams (Cellular Beams) are used for Larger Clear Spans of Laboratory Spaces.
- Lateral System Contains the following:
  - Horizontal HSS Shaped Girt Members
  - Concentric Braced Frames (Wide Flanges)

Thesis Abstract
- *Located in Engr. Unit A (across from Room 104)*
- *Copies Also Upfront*

Slide 4

Thesis Proposal

Structural Depth
- Calculation of Wind Forces for Miami, FL
- Analyze Existing Lateral System for Miami, FL
- Redesign and Analyze Lateral System

Building Enclosure Breadth
- Perform R-value, Condensation, and Air Leakage Analyses
- Modify Curtain Wall for Miami, FL

Architectural Breadth
- Research Miami, FL Architecture
- Redesign Exterior Architecture for Miami, FL

***Relocation of Building** – New York, NY to Miami, FL*

Slide 5

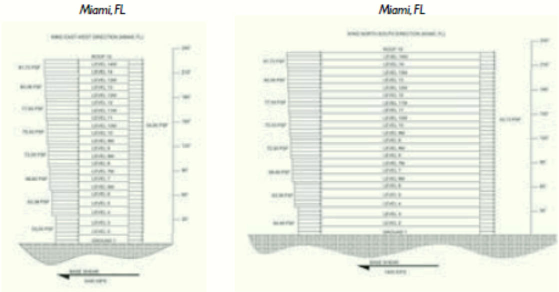
Thesis – Goals

Goals – Based on Relocation of Building to Miami, FL

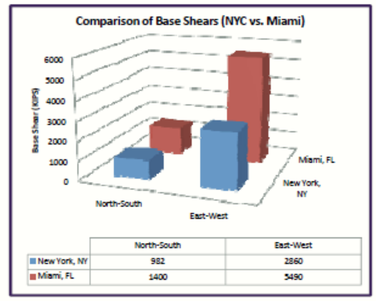
- Redesign building's lateral system to meet code requirements.
- Provide analysis of lateral system through means of ETABS and hand calculations.
- Research, analyze, and modify building enclosure appropriately for water condensation and heat transmission concerns.
- Redesign exterior architecture of building.

Slide 6

Determination of Wind Forces for Miami, FL



- Wind force determination using ASCE 7-05 Method 2 – Analytical Procedure.
- Base Shear Increased by **2600 kips** (East-West Direction)
- Base Shear Increased by **418 kips** (North-South Direction)

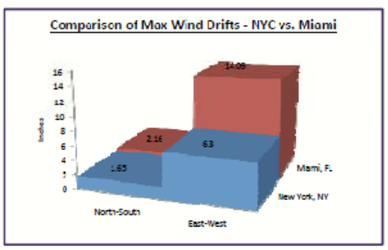


	North-South	East-West
New York, NY	982	2860
Miami, FL	1400	5490

Slide 7

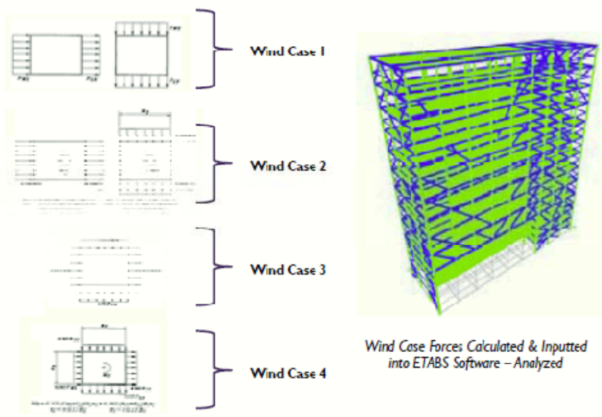
Existing Lateral Analysis for Miami, FL

- Main Wind Force Resisting System – Method 2 – Design Wind Load Cases Used
- Governing Wind Case Determined for Each Frame



Allowable Drift
*H/400 = **6.78 in.***

- *Existing Lateral System Failed Most Drift, Story Drift, & Strength Checks*
- *System Acceptable for Overturning Moment Calculations*



Wind Case Forces Calculated & Inputted into ETABS Software – Analyzed

Slide 8

My Lateral Redesign for Miami, FL

Strength Requirements Checked for Bracing & Columns:

- Available Compressive Strength ($\Phi_c P_n$)
- Local Buckling
- Effective Length and Bracing Slenderness
- Available Strength in Axial Tension ($\Phi_t P_n$)

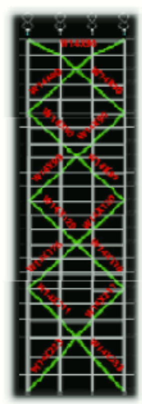
Strength Requirements Checked for Participating Beam Members:

- Available Compressive Strength ($\Phi_c P_n$)
- Available Strength in Axial Tension ($\Phi_t P_n$)
- Shear Capacity/Transfer at Joints

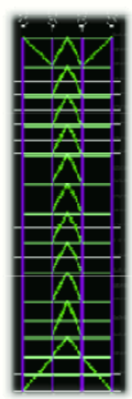
Load Combinations Critical for Design of Members:

- 1.2(Dead) + 1.6(Wind) + 1.0(Live)
- 0.9(Dead) + 1.6(Wind)

East-West Direction Lateral Redesign - Critical



Preliminary Exterior Braced Frame Design
Grids 1 & 10



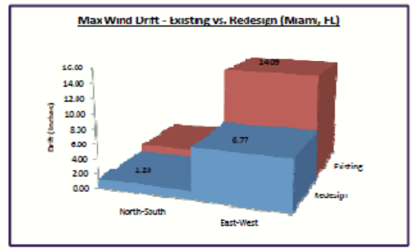
Interior Grid 4
Chevron Bracing

Slide 9

My Lateral Redesign for Miami, FL

- Existing Building Drift (Miami, FL) – **14.09 Inches** *(East West Direction)*
- Redesigned Building Drift (Miami, FL) – **6.77 Inches** *(East-West Direction)*
- Existing Building Drift (Miami, FL) – **2.16 Inches** *(North-South Direction)*
- Redesigned Building Drift (Miami, FL) – **1.20 Inches** *(North-South Direction)*
- North-South Direction Lateral System Redesign
  - Not as critical as East-West Direction
  - Larger member sections provided where needed. (small occurrence)

- ***Redesigned Lateral System Meets Drift, Story Drift, & Strength Requirements***
- ***Redesign Acceptable for Overturning Moment Calculations***



Allowable Drift
*H/400 = **6.78 in.***

Slide 10

My Lateral Redesign for Miami, FL

Lateral Steel Tonage:

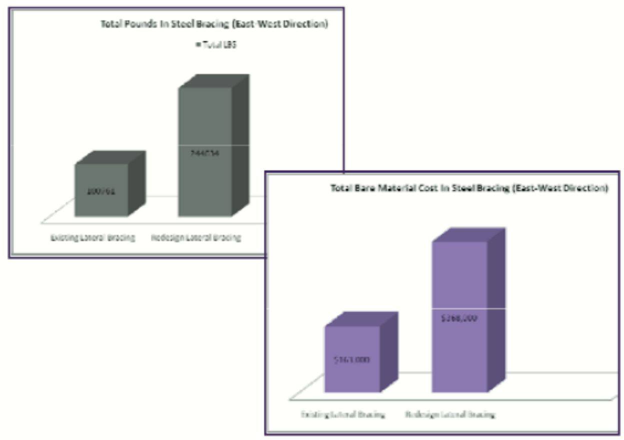
- Existing Lateral Bracing – **50.38 Tons** *(East-West Direction)*
- Redesigned Lateral Bracing– **122.32 Tons** *(East-West Direction)*

Increase of 72 Tons

Bare Material Costs:

- Existing Lateral Bracing – **$163,000** *(East-West Direction)*
- Redesigned Lateral Bracing– **$368,000** *(East-West Direction)*

Increase of $205,000



Slide 11

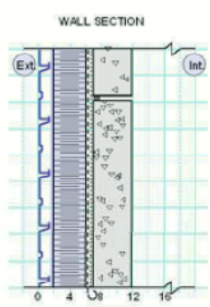
Building Enclosure Breadth

Building Enclosure Breadth Goals

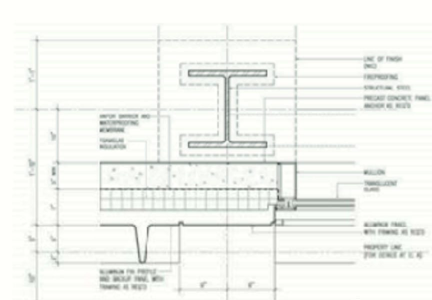
- Perform R-value, condensation, and air leakage analyses of curtain wall system for Miami, FL.
- Design for ASHRAE climate recommendations.
- Perform bare material cost analysis

Wall Section

- Aluminum Cladding
- Cavity (1/2")
- Foamglass Insulation
- Vapor & Air Barriers
- 5 Inch Precast Face Seal



Existing Building Enclosure System - Detail



Slide 12

Building Enclosure Breadth

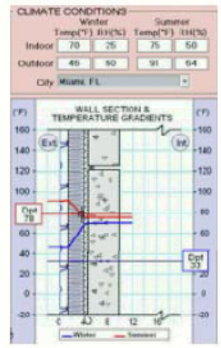
R-Value Analysis

- Decrease in insulation layer (due to Miami's warmer climate)
- R-Value of Existing Wall System (21.23)
- R Value of Redesign Wall System (**13.53**)

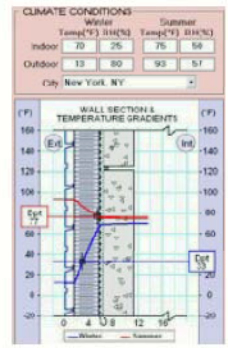
Condensation Analysis

- Decrease in insulation layer checked for condensation concerns.
- Dew points occur on outside of water vapor barrier – ***ACCEPTABLE***

Redesign Wall Section
2.5" Rigid Insulation



Existing Wall Section
4" Rigid Insulation



Building Enclosure Analysis and Images above made possible with H.A.M. Toolbox Software

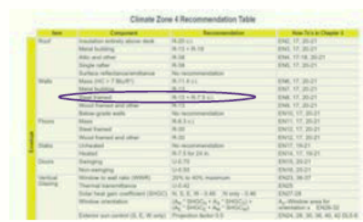
Slide 13

Building Enclosure Breadth

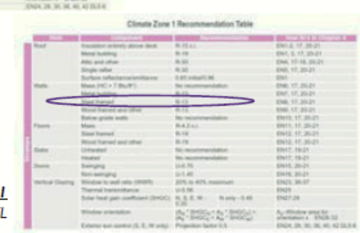
ASHRAE R-Value Recommendations

- Climate Zone 4 (New York, NY)
  - Walls R-Value of 22.5
- Climate Zone 1 (Miami, FL)
  - Walls R-Value of 13.5

- R-Value Provided in Wall Redesign is 13.53 - ***ACCEPTABLE***



ASHRAE Climate Zone 4
New York, NY



ASHRAE Climate Zone 1
Miami, FL

Slide 14

Building Enclosure Breadth

Air Leakage Analysis – *(New York, NY versus Miami, FL)*

- Small difference in energy loss due to air leakage during the summer.
- Large difference in energy loss due to air leakage during the winter.
- 184,000,000 BTUs/Year Difference (New York, NY Greater Energy Loss)
- Equivalent too burning approximately 200,000 gallons of natural gas.
- Analysis supports reduction in insulation layer for Miami, FL.

Bare Material Cost Analysis – *(RS Means)*

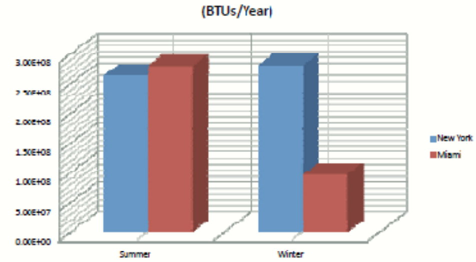
- **$185,900** bare material cost **savings** due to reduction in insulation layer.

Building Enclosure Breadth Conclusions:

- The existing wall system with a modification in the insulation layer (4" to 2.5" thick) will be acceptable for Miami, FL.

Air Leakage Analysis Comparison - Miami, FL vs. New York, NY		
	All Values in BTUs per Year	
	Summer	Winter
New York	2.63E+08	2.80E+08
Miami	2.78E+08	9.56E+07
Difference	1.50E+07	1.84E+08

Air Leakage Analysis Comparison Miami, FL vs. New York, NY (BTUs/Year)

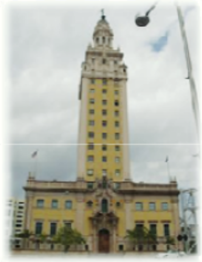


Slide 15

Architectural Breadth

Architectural Breadth Goal

- Redesign building exterior appearance to be representative of Miami architectural culture.
  - Mediterranean Revival Style
  - Art Deco Style
  - Streamline Modern Style



Freedom Tower – Miami, FL
Mediterranean Revival Style

Park Central Hotel – Miami, FL
Art Deco Style

US Bacardi Headquarters – Miami, FL
Streamline Modern Style

Slide 16

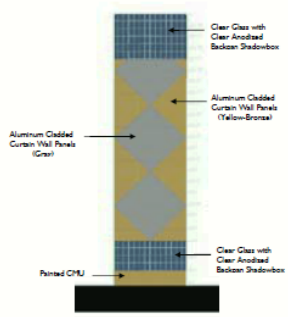
Architectural Breadth

Proposed Architecture – North Façade

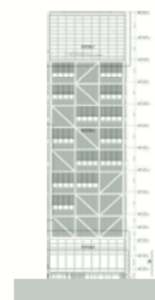
- Aluminum Cladding Coloring (Yellow-Bronze & Gray)
  - Diamond Color Pattern Exemplifies Lateral Exterior Frame
  - Color Cladding Represents Art Deco Style Architecture

Park Central Hotel – Miami, FL
Art Deco Style

North Façade Redesign



Existing North Facade



Slide 17

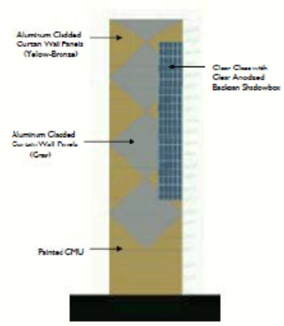
Architectural Breadth

Proposed Architecture – South Façade

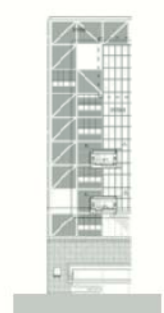
- Aluminum Cladding Coloring (Yellow-Bronze & Gray)
  - Diamond Color Pattern Exemplifies Lateral Exterior Frame
  - Color Cladding Represents Art Deco Style Architecture

Park Central Hotel – Miami, FL
Art Deco Style

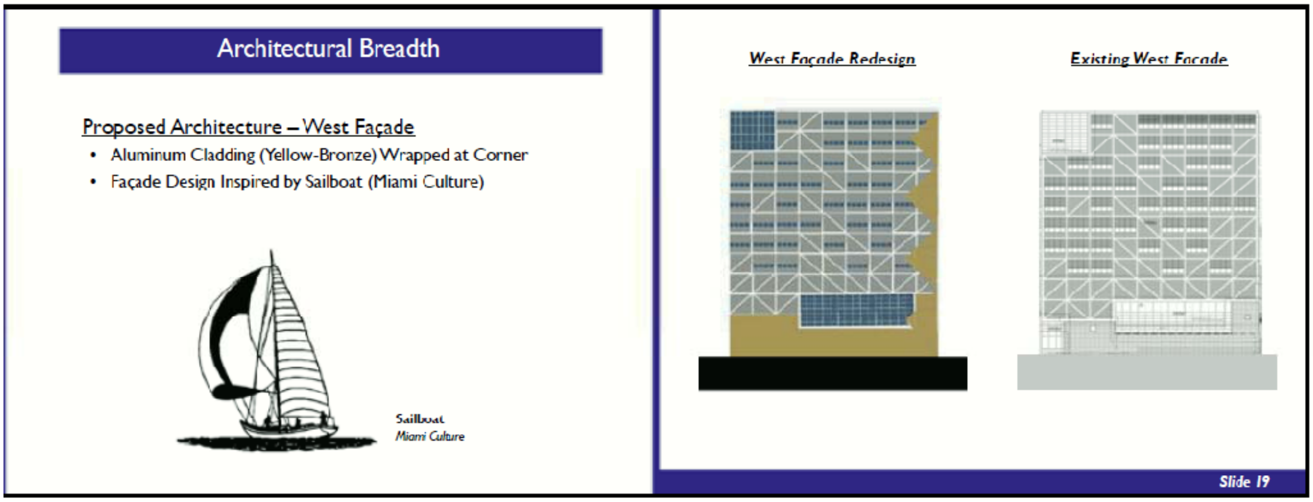
South Façade Redesign

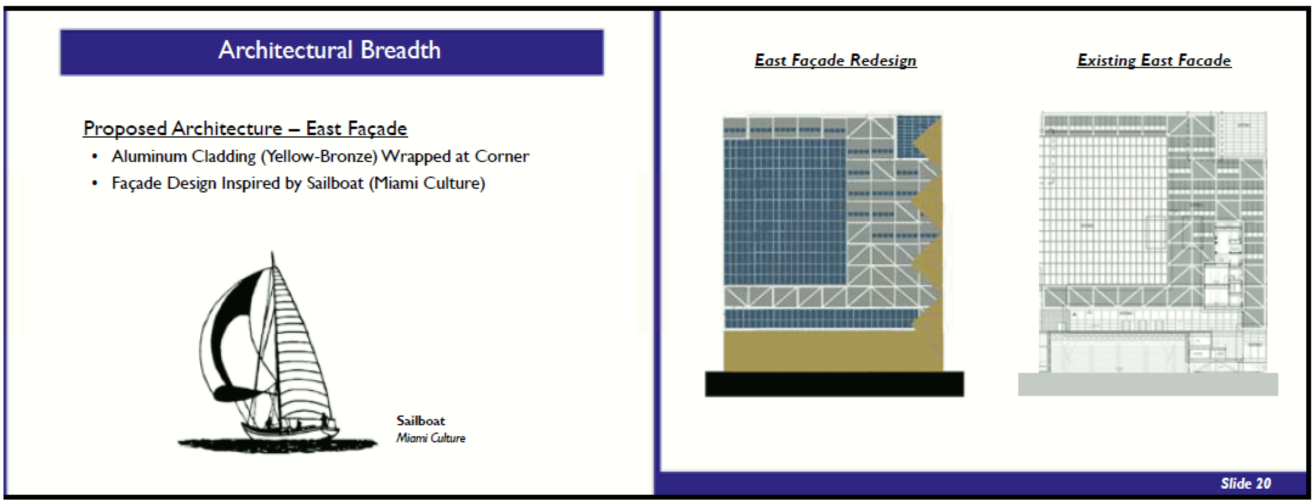


Existing South Facade

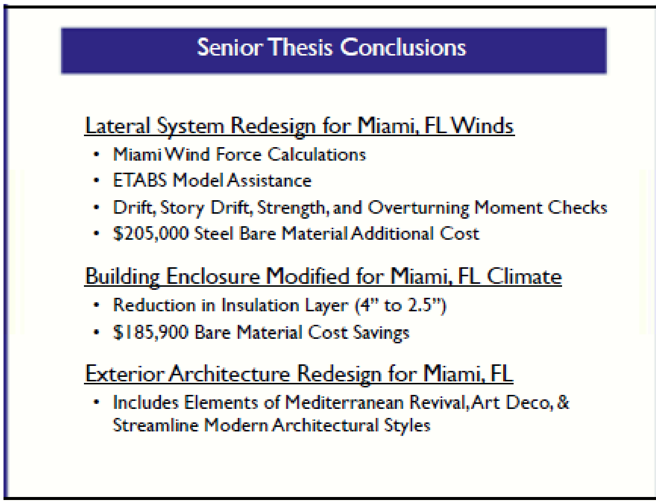


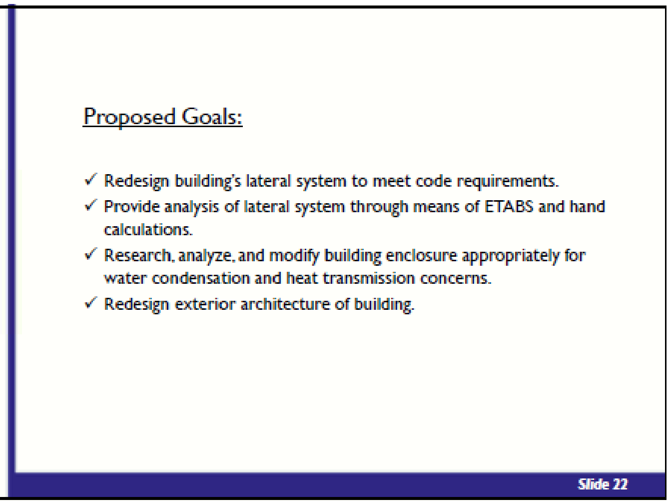
Slide 18


Architectural Breadth
Proposed Architecture – West Façade
• Aluminum Cladding (Yellow-Bronze) Wrapped at Corner
• Façade Design Inspired by Sailboat (Miami Culture)
Sailboat
Miami Culture
West Façade Redesign
Existing West Facade
Slide 19

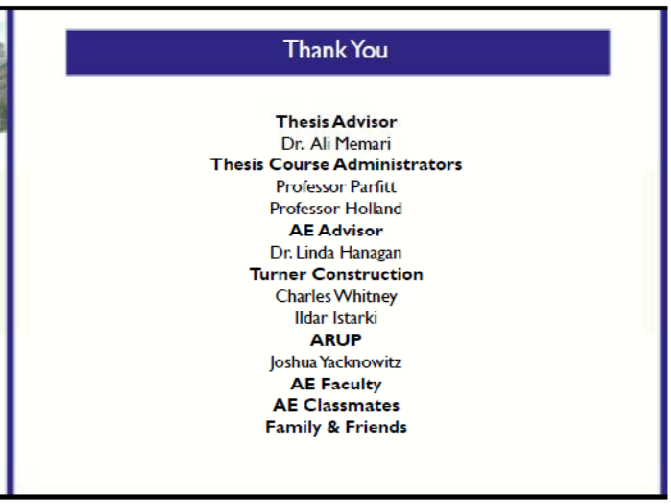

Architectural Breadth
Proposed Architecture – East Façade
• Aluminum Cladding (Yellow-Bronze) Wrapped at Corner
• Façade Design Inspired by Sailboat (Miami Culture)
Sailboat
Miami Culture
East Façade Redesign
Existing East Facade
Slide 20

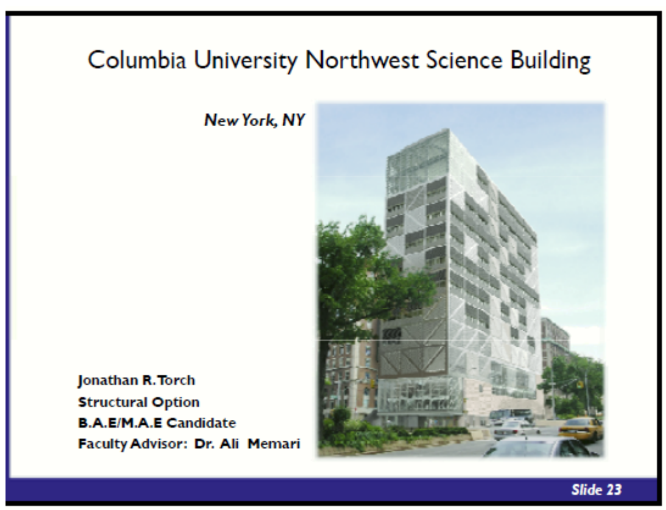

Architectural Breadth
Architectural Breadth Conclusions
• Design Incorporates Mix of Miami Modern Architectural Styles
○ Mediterranean Revival
○ Art Deco
○ Streamline Modern
3D North-East Image
3D South-West Image
Slide 21


Senior Thesis Conclusions
Lateral System Redesign for Miami, FL Winds
• Miami Wind Force Calculations
• ETABS Model Assistance
• Drift, Story Drift, Strength, and Overturning Moment Checks
• $205,000 Steel Bare Material Additional Cost
Building Enclosure Modified for Miami, FL Climate
• Reduction in Insulation Layer (4" to 2.5")
• $185,900 Bare Material Cost Savings
Exterior Architecture Redesign for Miami, FL
• Includes Elements of Mediterranean Revival, Art Deco, & Streamline Modern Architectural Styles


Proposed Goals:
✓ Redesign building's lateral system to meet code requirements.
✓ Provide analysis of lateral system through means of ETABS and hand calculations.
✓ Research, analyze, and modify building enclosure appropriately for water condensation and heat transmission concerns.
✓ Redesign exterior architecture of building.
Slide 22


~APRIL 2010
COLUMBIA UNIVERSITY NORTHWEST SCIENCE BUILDING
BROADWAY & 120TH ST.
NEW YORK, NY
ae Senior Thesis
Jonathan R. Torch - Structural Option
Special Thanks To:
Turner
✓ EXISTING
✓ THESIS PROPOSAL
✓ GOALS
✓ EXISTING LATERAL
✓ LATERAL REDESIGN
✓ BUILDING ENCLOSURE
✓ ARCHITECTURE
• CONCLUSION
PSU AE
THE PENNSYLVANIA STATE UNIVERISTY


Thank You
Thesis Advisor
Dr. Ali Memari
Thesis Course Administrators
Professor Parfitt
Professor Holland
AE Advisor
Dr. Linda Hanagan
Turner Construction
Charles Whitney
Ildar Istarki
ARUP
Joshua Yacknowitz
AE Faculty
AE Classmates
Family & Friends


Columbia University Northwest Science Building
New York, NY
Jonathan R. Torch
Structural Option
B.A.E/M.A.E Candidate
Faculty Advisor: Dr. Ali Memari
Slide 23