

## Thesis Proposal



Columbia University Northwest Science Building

*Broadway & 120<sup>th</sup> Street, New York, NY*

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Architectural Engineering

Structural Option

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### **Executive Summary:**

The following thesis proposal is based upon the Columbia University Northwest Science Building. The building is located at the intersection of Broadway and 120<sup>th</sup> 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.

The past three technical reports completed on the Northwest Science Building has given the author great insight into its structural system. The author now proposes a more focused research and design of the building's lateral system. In order to study a redesign of the lateral system, the author chose to relocate the building to Miami, FL where hurricane wind forces will provide a dominating lateral design concern. Along with the redesign of the lateral system a typical braced frame connection will be proposed, designed, and detailed. (***MAE Integrated - Steel Connections Study***)

The following is a description of two additional breadth studies to be accomplished within this thesis.

The relocation of the building also causes concerns with the water infiltration, along with heat and light transmission. These concerns will be addressed through building enclosure design. (***Building Enclosure Breadth Study***) The exterior architecture will also be redesigned. (***Architectural Breath Study***)

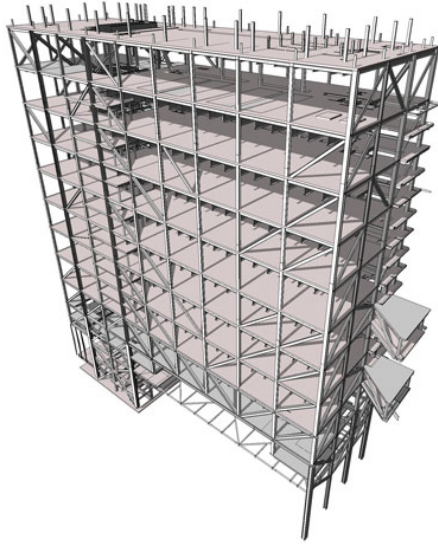
This proposal first introduces the existing structural system of Columbia University Northwest Science Building. A proposal statement is then addressed. Following this statement is a solution on how the author intends to go about solving the proposal. Detailed tasks and a schedule are provided for further understanding of the steps to be taken to reach the ultimate goals of this thesis. These goals are listed below.

#### **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.
- Design a typical braced frame connection of the lateral system.
- Research and choose proper building enclosure materials.
- Redesign exterior architecture of building.

\*Special thanks to Turner Construction Company for providing the necessary documents, information, and images necessary for this Architectural Engineering Senior Thesis Proposal.

## **Existing Structural System**



**Figure 1: Structure Rendering**

### **I. Foundation**

The foundation consists of concrete piers, footings, column spread footings, and grade beams.

The concrete piers coincide with the sub-cellar and cellar foundation walls. These piers range in cross sectional size from 2'-0" x 3'-0" up to 5'-0" x 8'-0". These piers are required to be normal weight concrete with a concrete compressive strength ( $f'_c$ ) of 6000 PSI.

The footings support the exterior foundation walls. These footings span the distance between the concrete piers. The column spread footings support mainly interior columns and a few exterior columns. The spread footings vary in size. A large spread footing for this project is considered a 9'-0" x 9'-0" with a 5'-6" depth, while a smaller spread footing is 4'-6" x 4'-6" with a 2'-6" depth.

Two grade beams are used in the foundation of the building. These grade beams are used to provide a resistance to lateral column base movement. One of the grade beams used is 80'-6" long and has a cross section of 3'-0" x 3'-6". The other is smaller in cross section and length and spans in the opposite direction.

### **2. Floor System**

The building's floor system changes dramatically from level 500 to level 600. This is due to the buildings 126 foot clear span. The building spans over an existing structure, the Dodge Physical Fitness Center. This clear span allows for the continued use of the center, with minimum demolition to its existing structure. Due to this dramatic change in floor area from level 500 to level 600, two floor plans of the structure will be discussed. These floor plans will be discussed as Typical Floor Plan 1 and Typical Floor Plan 2.

#### **A. Typical Floor Plan 1 (Levels 100 to 500)**

This floor system is a composite steel structure. The beam spanning consists of wide flange shapes. Spanning across from beam to beam is corrugated steel decking with concrete topping, both shear studded to the wide

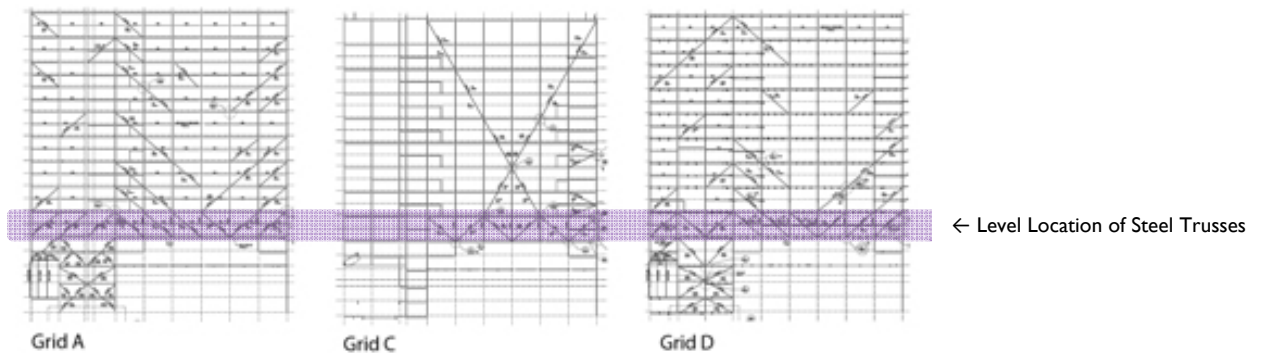
flanges. The concrete slabs are designated a concrete compressive strength of 4000 PSI. Slab thickness and the use of normal and lightweight concrete vary throughout the structure.

#### B. Typical Floor Plan 2 (Levels 600 to 1400)

This floor system is also a composite steel structure and also uses wide flange shape spanning. However, another spanning member is introduced because of longer clear spans needed for large laboratory spaces. These members are castellated beams, also known as cellular beams. They are typically about five foot deep and allow for 40 feet clear spans in the labs.

### 3. Gravity System

As mentioned, the building structure has a clear span of 126 feet occurring at level 5. The structure uses three wide-flange made steel trusses. These trusses are located on the three main longitudinal frames of the structure. See Figure 2, “Longitudinal Frame Elevations”, below.



**Figure 2: Longitudinal Frame Elevations**

Grid A and Grid D are the exterior frames, while Grid C is the middle longitudinal frame. As shown, each frame has a single story truss (purple shaded). These trusses can be comparable in size to most civil, steel-bridge structures. Grid C frame has continuous diagonal members over the full height of the structure. These diagonal tension members, bring the gravity load diagonally up and over to the far edge columns.

### 4. Lateral System

The lateral system utilizes diagonal wind bracing, wind girts, a composite floor system, moment connections, 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, moment connections and columns, until it reaches the foundation of the structure.

## **I. Problem Statement:**

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 connections.

## **II. Proposed Solution:**

The existing lateral design has been confirmed in Technical Report 3 to be acceptable regarding drift, story drift, overturning, and strength requirements. However, the relocation of the building to Miami, FL will cause greater wind forces. This thesis will require calculating these wind forces. The calculation of these wind forces will be interpreted from “ASCE7-05, Minimum Design Loads for Buildings and Other Structures.”

Once the wind forces are obtained, the original lateral system will be analyzed through distribution of lateral forces to each framing grid of the structure. This distribution will be determined through relative stiffness calculations. An ETABS model will also be implemented for further analyzing and verification. Also overturning, drift, story drift, and strength checks will be performed. From this initial analysis, it is suspected that the lateral system in the East-West direction will not be sufficient. The North-South lateral system may also fail code requirements.

The lateral system will be redesigned to withstand the severe wind forces of Miami, FL. This redesign will contain a different braced framing system (chevron, eccentric, or k bracing). This redesign will be analyzed similarly to the original lateral system. Overturning, drift, story drift, and strength checks will also take place.

Relocation of the building to Miami, FL also causes additional water, heat, and light infiltration concerns. Different building enclosure materials, sealant, and constructability issues will be researched and implemented into this thesis. If there is a substantial difference in exterior enclosure material used, the author also proposes a redesign of the building’s exterior architectural appearance.

### **III. Solution Method:**

#### **I. Structural Analysis**

With the relocation of the building to Miami, FL the lateral system will need to be redesigned. Greater wind forces will cause the lateral system to have larger members. Also, additional braced frames may have to be implemented. This redesign will be modeled in ETABS and compared to the original lateral system. The design will focus on limiting the story drift and drift of the building. Impact on foundations, overturning, and strength requirements will also be verified.

#### **2. MAE Integrated Study (Steel Connections)**

In addition to the redesign of the building's lateral system, the author will investigate different types of brace frame connections. Connections containing bolts, welds, and plates will all be considered. The most efficient connection will be chosen balancing cost and construction difficulty. Once the connection is chosen it will be designed and detailed.

#### **3. Building Enclosure Breadth**

Due to relocation of the building to Miami, FL, different enclosure materials and sealants will be researched. A design will be chosen to limit water penetration, while also balancing heat and light transmission. Constructability will also be a concern along with material cost. All of these variables will be investigated and building enclosure materials and sealants will be chosen.

#### **4. Architectural Breadth**

If the building enclosure breadth comes to a conclusion of changing the exterior building materials, the author also will propose a redesign of the building's exterior appearance. This will involve coordination of materials, building openings and spaces. Finalized building exterior renderings of each façade will be proposed.



#### **IV. Tasks:**

##### **1. Task One – Calculation of Wind Forces (Miami, FL)**

- a) Perform wind calculations based on ASCE-07.
- b) Compare base shears caused by Miami wind to New York City wind.
- c) Sketch wind diagrams in North-South and East-West Directions

##### **2. Task Two – Analyze Existing Lateral System (Miami, FL)**

- a) Create ETABS lateral system model.
- b) Analyze model with obtained wind forces (Miami, FL).
- c) Record drifts and story drifts.
- d) Compare drifts and story drifts to Technical Report 3 results.
- e) Provide checks of overturning and strength.
- f) Note any impact on foundations.
- g) Conclude on any code requirements that are unmet.

##### **3. Task Three – Redesign and Analyze Lateral System (Miami, FL)**

- a) Research positive and negatives of different lateral bracing systems.
- b) Choose a bracing system.
- c) Create ETABS model of redesigned lateral system.
- d) Analyze model with obtained wind forces (Miami, FL).
- e) Record drifts and story drifts.
- f) Compare drifts and story drifts to Task 2 results.
- g) Provide checks of overturning and strength.
- h) Note any impact on foundations and design accordingly.

##### **4. Task Four – Building Enclosure Breadth Study**

- a) Research existing building materials and sealant properties.
- b) Choose building materials and sealants based on constructability, heat and light transmission, and water penetration for Miami, FL.
- c) Compare existing material to newly chosen material cost, heat and light transmission, and water penetration characteristics.
- d) Conclude with final chosen exterior materials.
- e) Provide a typical flashing detail.

##### **5. Task Five – Architectural Breadth Study**

- a) Note changes in exterior building façade due to newly chosen exterior materials and redesigned lateral system.
- b) Propose modifications/changes to exterior architecture where needed.
- c) Provide renderings of the exterior architectural changes.

##### **6. Task Six – MAE Integrated Study (Steel Connections)**

- a) Research different types of brace frame connections.
- b) Rate each connection depending on its cost and construction difficulty.
- c) Choose a connection.
- d) Design and detail the typical chosen connection.

## **7. Task Seven – Final Comparisons**

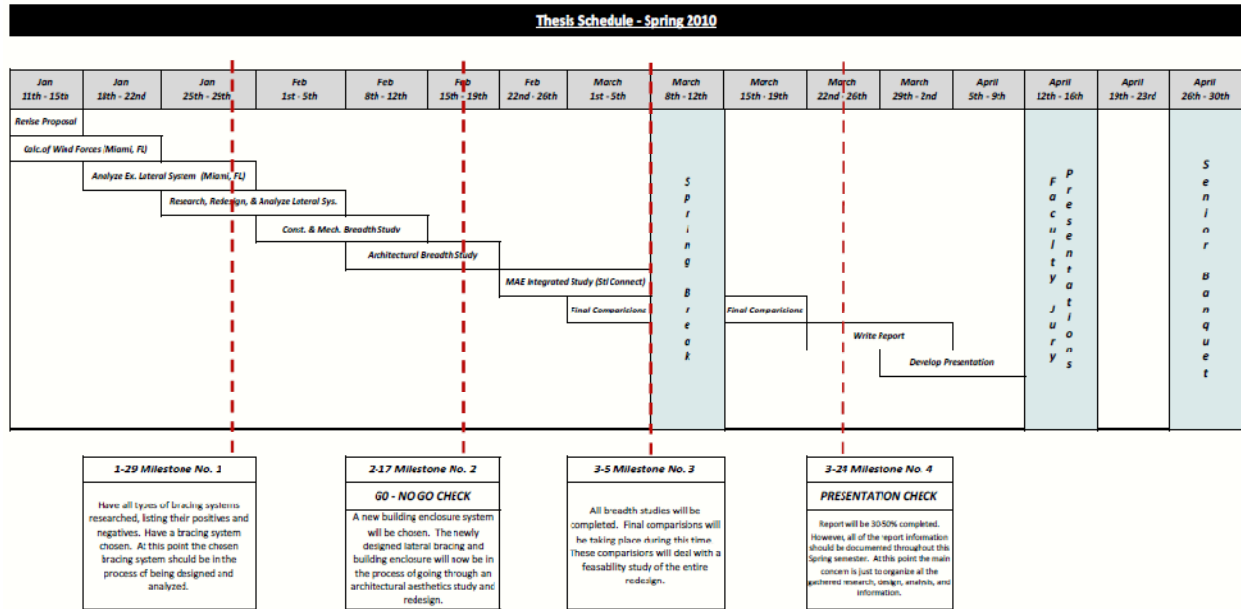
- a) Summarize the main differences from the existing to the redesigned lateral and building enclosure systems.
  - i. Member Size Differences
  - ii. Connection Changes
  - iii. Overall Structural Cost Concerns/Differences
  - iv. Building Enclosure Material Changes
  - v. Material Property Differences
  - vi. Overall Material Cost Concerns/Differences
- b) Compare the above differences/changes and conclude if redesigned systems are feasible for construction in Miami, FL.

## **8. Task Eight – Write Report**

## **9. Task Nine – Develop Presentation**

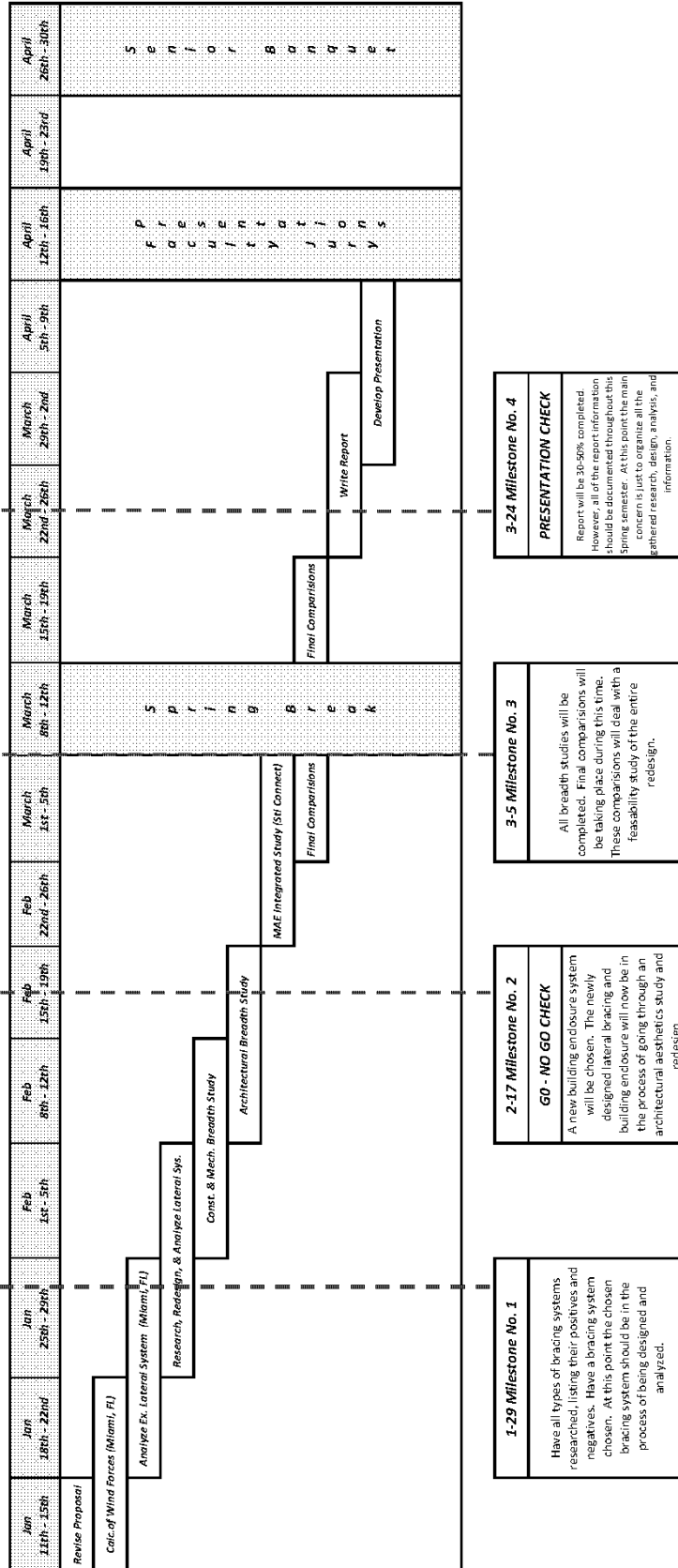
**V. Schedule:**

Below is the proposed schedule for Senior Thesis Spring 2010. Each task was given an estimated amount of time by the author. The schedule may change due to approximate times.



A larger image of the schedule above can be found on the following page.

Thesis Schedule - Spring 2010



**1-29 Milestone No. 1**

Have all types of bracing systems researched, listing their positives and negatives. Have a bracing system chosen. At this point the chosen bracing system should be in the process of being designed and analyzed.

**2-17 Milestone No. 2**

**GO - NO GO CHECK**

A new building enclosure system will be chosen. The newly designed lateral bracing and building enclosure will now be in the process of going through an architectural aesthetics study and redesign.

**3-5 Milestone No. 3**

All breadth studies will be completed. Final comparisons will be taking place during this time. These comparisons will deal with a feasibility study of the entire redesign.

**3-24 Milestone No. 4**

**PRESENTATION CHECK**

Report will be 30-50% completed. However, all of the report information should be documented throughout this Spring semester. At this point the main concern is just to organize all the gathered research, design, analysis, and information.

**Conclusions:**

By the end of spring 2010 semester, a new lateral system for the Columbia University Northwest Science Building will be designed for the relocation to Miami, FL. Also, a typical diagonal brace connection will be chosen based on cost and construction difficulty concerns. A typical connection will also be designed.

Building enclosure and architectural breadth studies will also take place for further understanding of Architectural Engineering and trade coordination.

Below is a summary of the ultimate goals involved with this spring 2010 Penn State Architectural Engineering Senior Thesis.

**Goals:**

- Redesign building's lateral system to meet code requirements.
- Provide analysis of lateral system through means of ETABS and hand calculations.
- Design a typical braced frame connection of the lateral system.
- Research and choose proper building enclosure materials.
- Redesign exterior architecture of building.

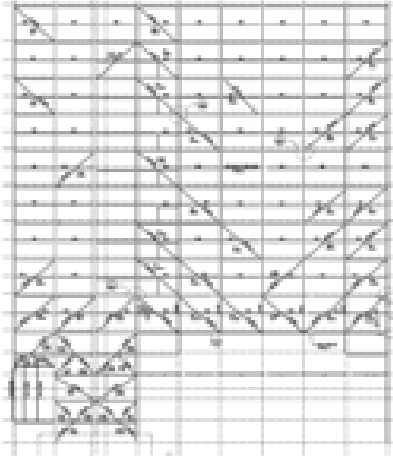
## **Appendix:**



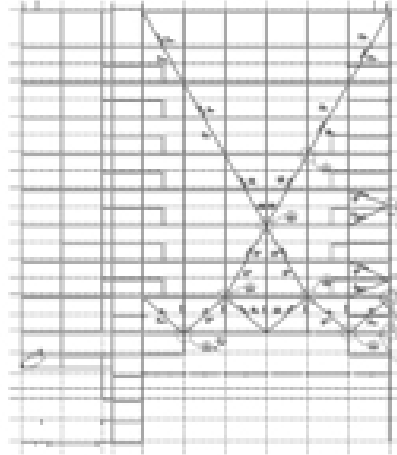
(Building Plans, Elevations, & Sections)

**Appendix A: (Plans, Elevations, & Sections)**

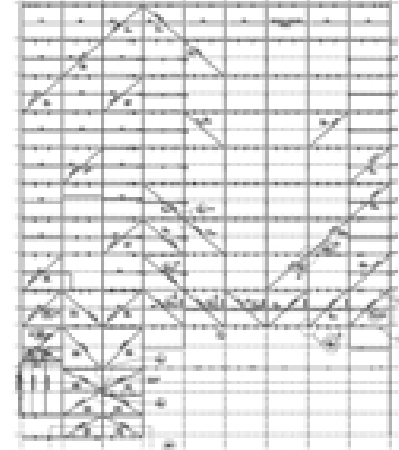
**Lateral System Frame Elevations**



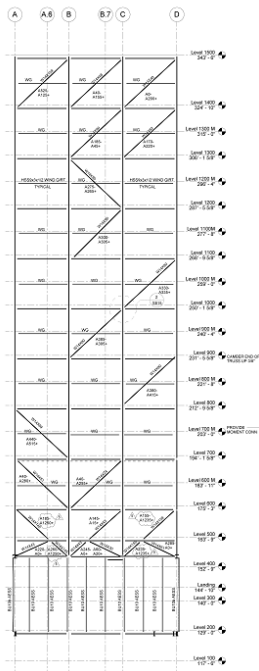
**Grid A**



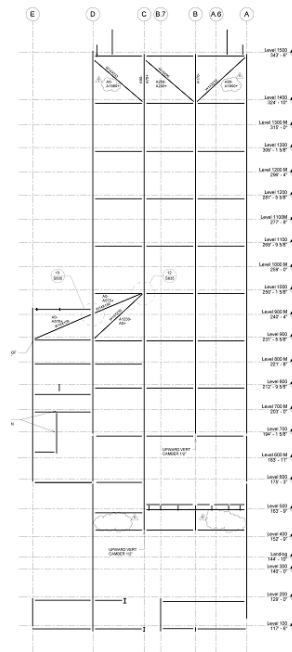
**Grid C**



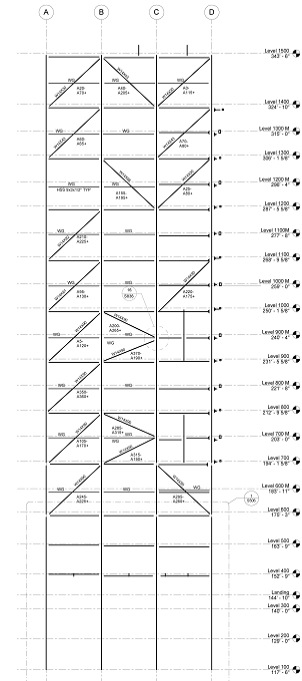
**Grid D**



**GRID I**

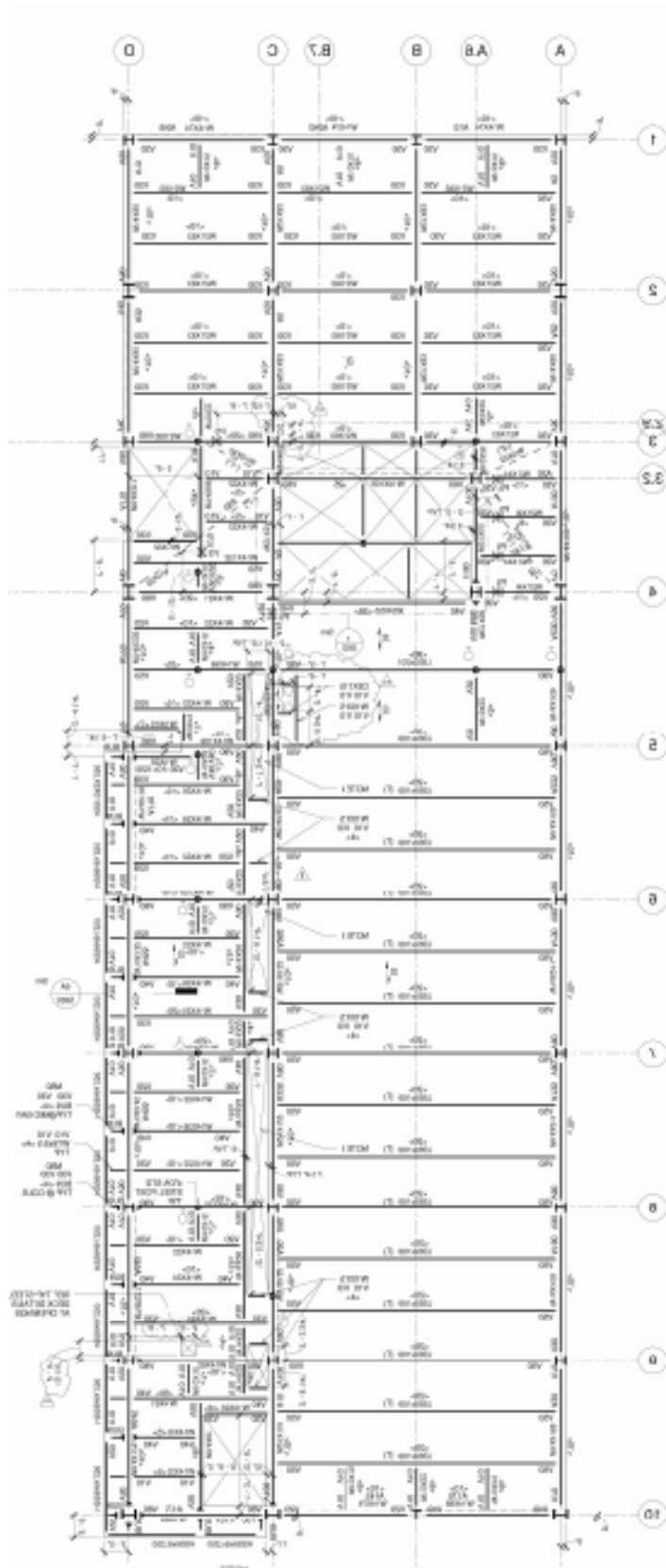


**GRIDS 2-4**



**GRID 10**

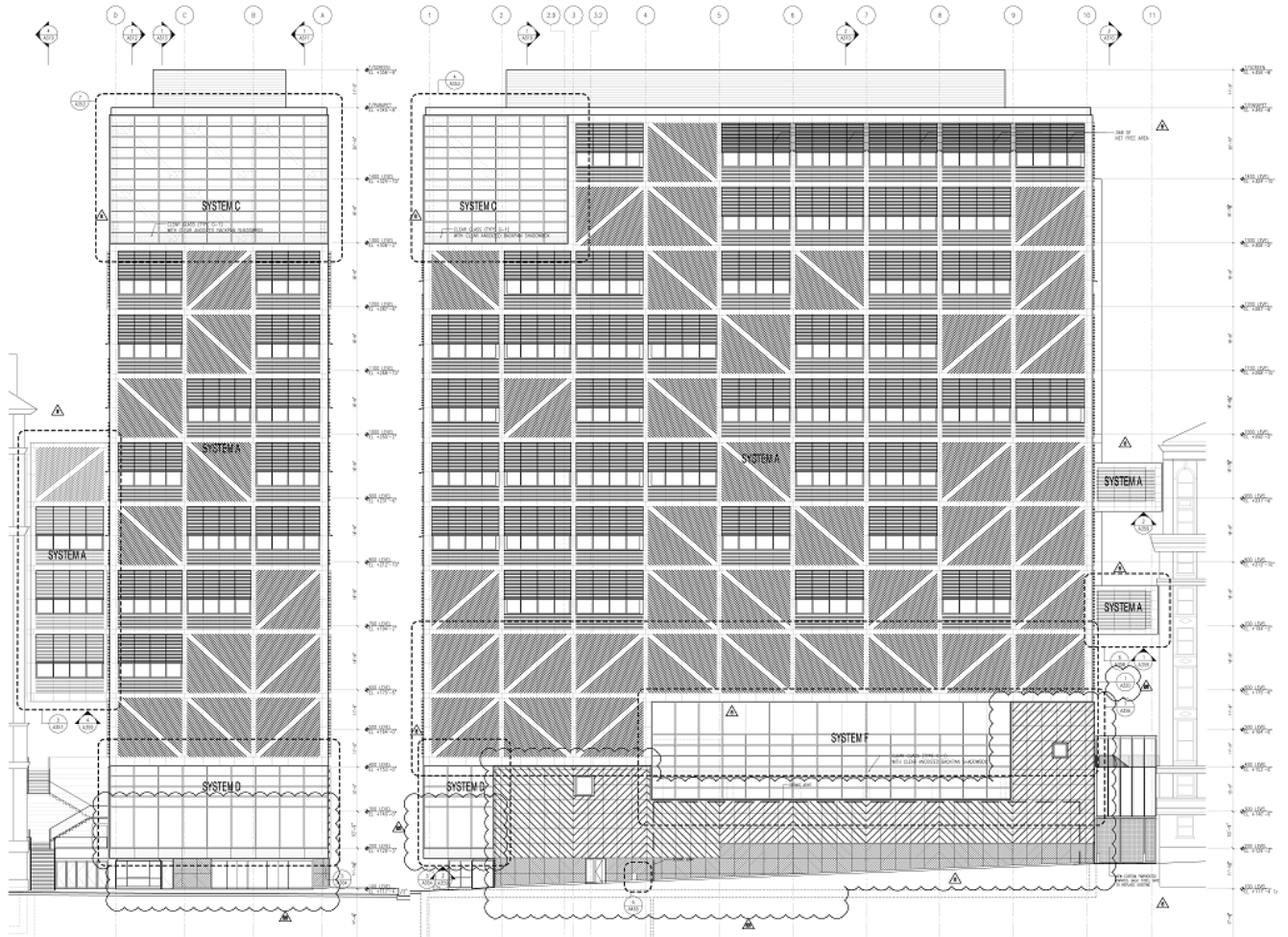
Typical Floor Plan





North Building Elevation

West Building Elevation



**South Building Elevation**

**East Building Elevation**

