Fall 2009

Hunter College school of Social Work

Thesis Proposal

To analyze how energy efficiency can be implemented using facade and green roof redesign. It ties structural engineering concepts with existing enclosure installation methods to provide a secure barrier against water and the temperature of the outside world.

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Executive Summary

Hunter College School of Social Work is located on Third Avenue between 118th and 119th street. It is designed to be both a college and university space. The structure is comprised of a composite steel floor system that utilizes steel braced and moment frames to resist lateral forces. Drilled caissons and spread footings make up the foundation system. The cellar floor is a reinforced slab on a mat foundation. The total height is 133ft above ground level.

The focus of this thesis is energy efficiency and how it can be implemented using facade and green roof redesign. It ties structural engineering concepts with existing enclosure installation methods to provide a secure barrier against water and the temperature of the outside world.

The façade is composed of various building materials which increases the potential for water infiltration. Water is the number one damaging agent to building materials. It rusts metals and fosters mold growth, making it an unhealthy breathing environment for its occupants.

All of this has to be achieved while maintaining an inviting and transparent appearance to the community so that they can feel welcome. The building's design responds to the School of Social Work's mission by providing an open and engaging face to the neighborhood and opportunities for community use of parts of the facility. The entrance lobby, conceived as an interior street, is glazed from floor to ceiling along 119th Street to provide a transparent and welcoming appearance from the exterior and to link the interior of the building to its neighborhood surroundings.

Enclosure design is important to ensure the life of a structure in addition to continual building maintenance. Simple and inexpensive measures can be taken to significantly improve the buildings energy efficiency. This thesis topic was inspired by the School of Social Work building's current goal of achieving LEED certification.

Introduction

The building's design responds to the School of Social Work's mission by providing an open and engaging face to the neighborhood and opportunities for community use of parts of the facility. The entrance lobby, conceived as an interior street, is glazed from floor to ceiling along 119th Street to provide a transparent and welcoming appearance from the exterior and to link the interior of the building to its neighborhood surroundings. Classrooms and lecture halls occupy the lower levels with academic departments and offices on upper floors. An auditorium on the second floor is expressed on the facade, with a glazed wall allowing

Keyplan

The structure of Hunter College School of Social Work is comprised of a composite steel floor system that utilizes steel braced and moment frames to resist lateral forces. Drilled caissons and spread footings make up the foundation system. The cellar floor is a reinforced slab on a mat foundation. The total height is 133ft

Structural Systems

Foundation System

There is one below-grade level in the Hunter College School of Social Work. This level known as the cellar contains a parking garage for the residential building adjacent, a library, computer labs, large kitchen areas, and mechanical rooms.

Slab thickness varies throughout the cellar level. It can be 30", 33", or 40". Steel reinforcement varies according to the slab thickness. For a 30" slab #7@11 are required top and bottom (T&B) each way, for a 33" slab #8@13 top and bottom, and for a 40" slab #9@13 top and bottom each way. The mat foundation will have a 2" mud slab above 12" of ¾ crushed stone to facilitate installation of waterproofing membrane. The subgrade is composed of undisturbed soil or compacted back fill with a required bearing capacity of 1.5 tons.

The soil is not considered susceptible to liquefaction for a Magnitude 6 earthquake and a peak ground acceleration of 0.16g. It is expected to encounter ground water during erection of the cellar level. Excavation depths are anticipated to vary from about 12ft to 20ft below existing ground surface grades. Footings shall bear on sound rock with a bearing capacity of 20 ton per square foot or on decomposed rock with a bearing capacity of 8 ton per square foot or on sand with a bearing capacity of 3 ton per square foot.

Foundation walls are designed to resist lateral pressures resulting from static earth, groundwater, adjacent foundations, and sidewalk surcharge loads. These walls will extend 14ft below existing ground surface grades. Concrete for foundations and site work shall be air-entrained normal weight stone concrete with a minimum compressive strength of 4000psi at 28 days and a maximum water to cement ratio of 0.45 by weight.

In the western portion of the six story faculty housing building footprint, it is recommended to excavate rock 12" below bottom of foundation in order to limit differential settlement between sections of the mat foundation bearing on rock and that bearing on soil.

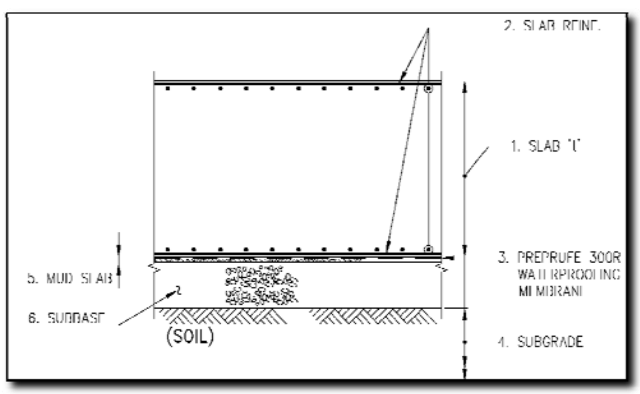


Figure 1: Mat Foudation Detail

Gravity System

Columns in the basement are 4000psi air-entrained concrete and vary in size from 32x48 to 36x60. The bay sizes vary from 30'x28', 30'x 28'2", 30'x31'5" and 30'x36' from north to south respectively.

All columns in the superstructure are W14s. Due to setbacks and varying story footprint, service loads carried by the columns at the ground level vary ranging from 137 to 1154kips. Because the service loads vary greatly throughout the floor, the column sizes vary as well; for example, on the ground floor column sizes range from w14x68 to w14x730. In the levels above the cellar, the bay sizes do not change.

There are non-composite beams as well as composite beams (with studs). Non-composite beams are found where beam to beam, and beam to column connections are designed to transfer the reaction for a simply supported, uniformly loaded beam. For composite beams, connections are designed to have 160% capacity of the reaction for a simply supported, uniformly loaded beam of the same size, span, fy, and allowable unit stress. For framed beam connections, including single plate connections, the minimum number of horizontal bolt rows should be provided based on 3" center-to-center.

Roof System

The roof is typically composed of 3 1/2 "light weight concrete over 3"-18 gage metal deck reinforced with 6x6-2.9x2.9 WWF. In a 200 square foot section the slab is 8" lightweight concrete slab reinforced with #4@12 top and bottom E.W. Columns are placed where needed and don't necessarily follow a typical framing layout. To provide additional vibration control, 4" concrete pads are located below mechanical equipment. Curbs on the roof are of CMU and concrete.

Floor System*- Composite steel beam and deck floor system*

The slab thickness for all floors is 3 ¼" thick 3500psi lightweight concrete placed over 3" deep 18 gage composite galvanized metal deck reinforced with 6x6- W2.9xW2.9 welded-wire-fabric. Exceptions on the ground floor are on the outdoor court, entry vestibules, and loading area; here 3" lightweight concrete is placed over 16 gage metal deck is used and instead of WWF, reinforcement is #4@12" o.c. top bars each way and 1-#5 bottom bars each rib. The exception for the second floor is the roof terrace where there is 5" of lightweight concrete over 3"-16 gage metal deck. On the roof level, the floor slab for the electrical control room is 8" lightweight concrete formed slab reinforced with to#4@12"o.c. top and bottom each way.

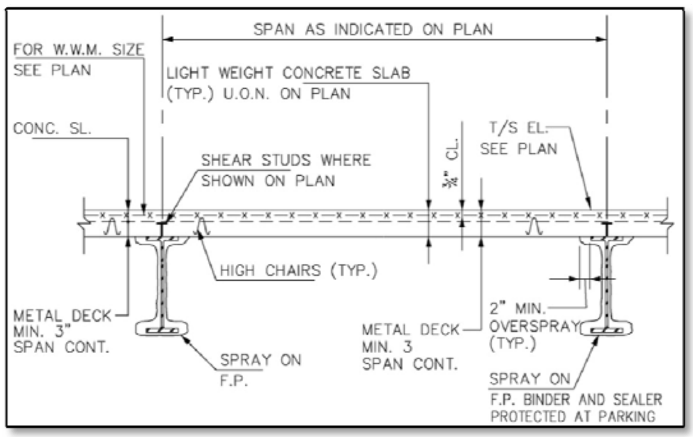


Figure 2. Typical Floor Construction, Metal Deck Perpendicular to Floor Beams on Girders

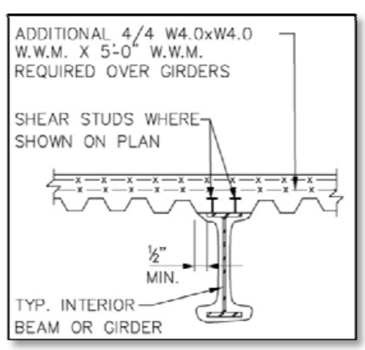


Figure 3. Typical Floor Construction, Metal Deck Parallel to Beams or Girders

Lateral System

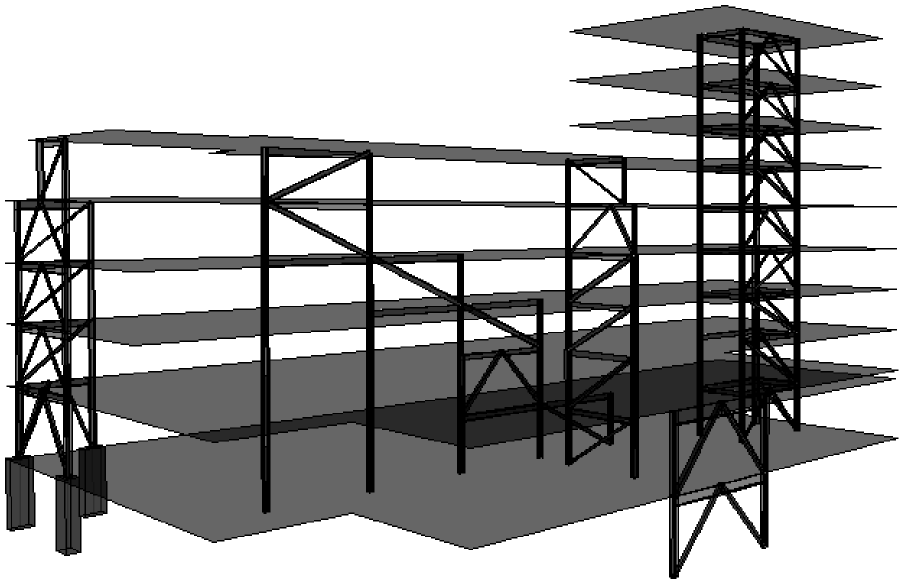


Figure 4. ETABS model of the Lateral Force Resisting System

The lateral system is made up of braced frames and moment frames. Braced frames with column splices at four feet above floor level with vertical members attached using moment connections make up the lateral system. Locations of these frames are represented on figure 2 in red; they run all the way up to the top of the building. The only exception to this is the braced frame represented on figure 2 as blue since it changes as you go up in elevation. An elevation view of this truss is shown as figure 3. Braced frames were chosen to resist lateral forces because they are more efficient than moment frames in both cost and erection time. The exceptions are the two moment frames used to surround the storm water detention tank. Moment frames provide unobstructed access to the tank that would not be possible if it was a braced frame. The other two frames surrounding the tank are in fact braced frames.

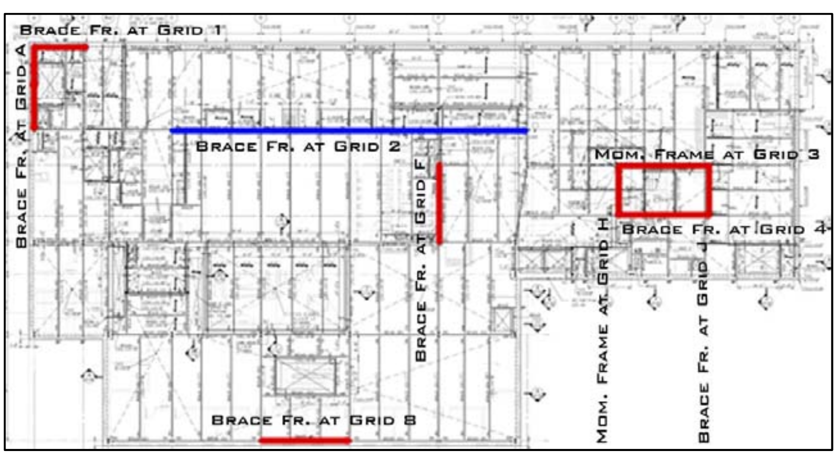


Figure 5. Location of Lateral Force Resisting Systems (Braced Frames)

Problem Statement

Problem 1: the vertical core is made up of a combination of braced and moment frames.
Moment frames are more costly than braced frames. This is because they are many times field welded, making it riskier and more time consuming than braced connections.

Problem 2: building façade is susceptible to water and air infiltration
The façade is composed of various building materials which increases the potential for water and air infiltration. Water is the number one damaging agent to building materials. It rusts metals and fosters mold growth, making it an unhealthy breathing environment for its occupants.

As seen on the North elevation (below) the bottom band is 8″x 2 ½″ two-aided curtain wall with custom cap with both transparent panels and spandrel shadow boxes. The left side of the middle band is architectural precast concrete while the right side is brick-faced precast panel in stack bond pattern with false jointing. The top band is 6 ¾″ x 3″ four-sided structurally glazed curtain wall with both transparent panels and spandrel shadow boxes. Above the main top band there is a vertical protrusion whose façade is 1″stucco on cmu substrate. Similarly the South elevation has this same pattern of horizontal bands of varying material.

Unlike the North and South elevations, the East and West elevations don't present the horizontal banding clearly, instead it transitions into more vertical bands of varying material. From left to right these materials are 6″ nominal cmu, 1″ stucco, 6″nominal cmu again, brick-faced precast panel, and 1″ stucco again. This vertical pattern applies up to the fifth floor, above that, the horizontal bands of stucco and glass curtain wall persist.

Figure 6.North Elevation of Hunter College School of Social Work

Proposed Solutions

Problem 1: the vertical core is made up of a combination of braced and moment frames.
Solution 1: revise all moment frames to braced frames

The new vertical core which is a large part of the lateral load resisting system, should with stand gravity, seismic, and wind loads. The vertical core will be revised so that it is made up of braced frames only instead of a combination of braced frames and moment frames.

Problem 2: building façade is susceptible to water and air infiltration
Solution 2: redesign of façade for improved waterproofing and incorporating thermal dampers

To ensure that the building is sealed tight against water penetration and that the outside temperature doesn't greatly affect the interior environment, there will be thermal dampers on exterior structural members. A redesign of the façade will be conducted for improved waterproofing and incorporation of the thermal dampers. Along with the redesign of the façade, the perimeter structural framing will be changed to better incorporate the new façade.

Graduate Course Integration

Steel Connections will also be addressed in the redesign of façade connections to the structural steel. The connections will be analyzed for applicable failure modes. These include shear, bearing, tear-out, etc. The building enclosures class is expected to be heavily integrated with this thesis. Building façade connectivity to structural members will also be analyzed for ease of installation.

Following the main structural depth study, a minimum of two breath studies will also be performed for this proposal. These include a cost analysis including savings due to shorter erection time. The second breath will be a redesign of the green roof and building façade to increase energy efficiency.

Breadth I. Construction Impact and Cost Analysis

Changing the moment frames to braced frames is expected to have an impact on erection time, the savings associated with this will be analyzed. In addition, the new façade with thermal dampers will also have an effect on the erection time, it may either increase or decrease the construction schedule, however it is expected that the energy savings will supplant the added initial cost.

Breadth II. Redesign of green roof and façade for energy efficiency.

The building is currently going for LEED certification.
Green roof filtration systems will be looked at in more detail and façade connectivity to structural members will be analyzed as well. A green roof redesign will be performed as well since they currently cover two roof levels. The water retention tank capacity may increase or decrease accordingly.
The viability of the new green roof and water retention tank will be analyzed against cost, time of placement, and complexity of labor.

Solution Methods

Solution 1: revise all moment frames to braced frames

An etabs model of the existing lateral load resisting system will be created. A new model incorporating the changes of the vertical core will be compared to it. Changes in story drift, story shears, and relative stiffness of lateral elements will be analyzed along with lateral member spot checks.

Solution 2: redesign of façade for improved waterproofing and incorporating thermal dampers

An analysis of the enclosure will be done to determine possible areas of improvement. Areas of weakness are expected to be wherever there is a transition of building material. Since this occurs often on the building façade, it is expected that there will be many areas in need of improvement.

Alternative materials through manufacturers' catalogs; which have been preapproved to be used in accordance with the LEED rating system, will be chosen if they better improve the building's performance with respect to energy efficiency. The effect of the alternative materials will be analyzed. These include the impact on the structural system, cost, and time.

Tasks and Tools

I. Revise all moment frames to braced frames
   a. Find the required capacity of the current tower
   b. Develop ETABS models of the old and redesigned tower
   c. Report on the advantages of braced frames vs. moment frames

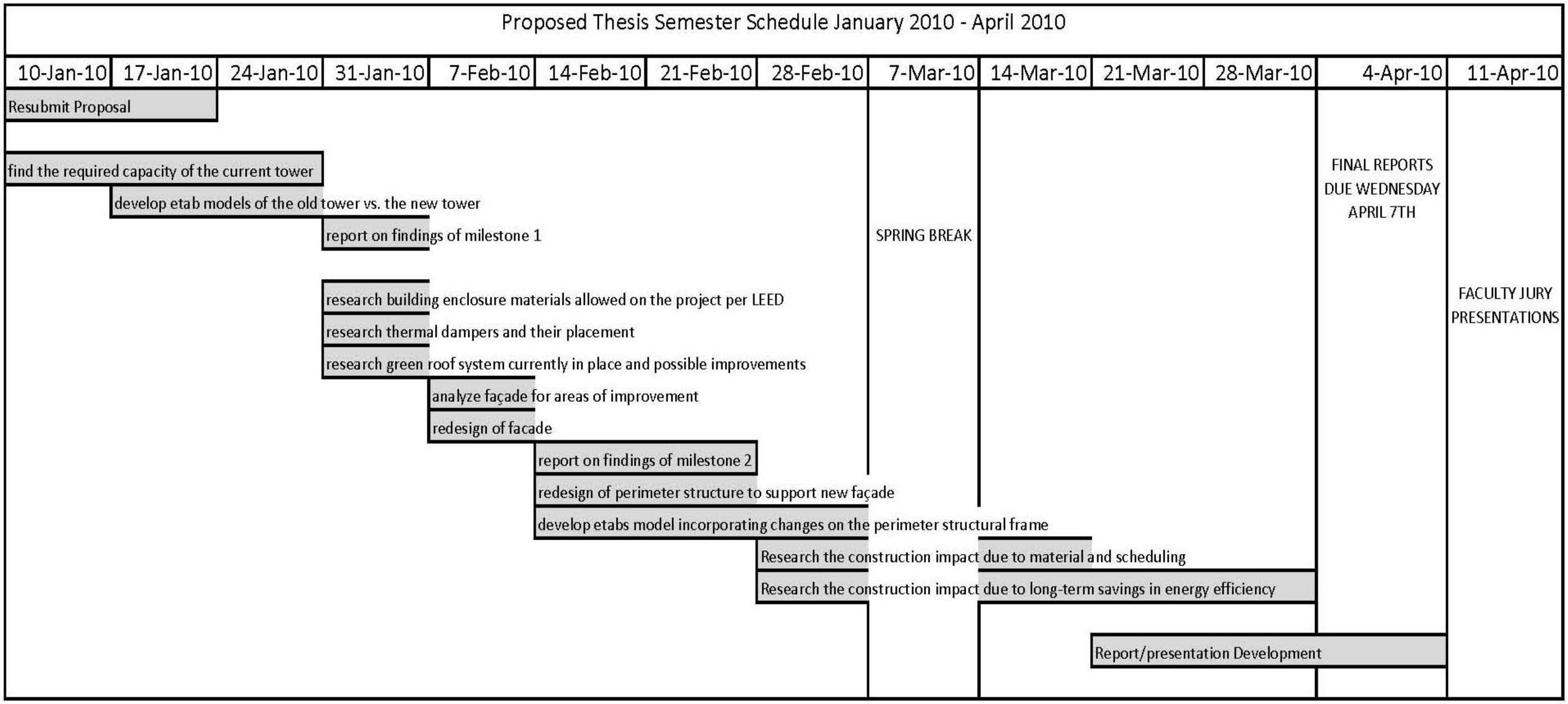
II. Research enclosure materials and façade redesign
   a. Building facade
      1. R-value
      2. Thermal dampers available
      3. LEED compliance.
   b. Green roofs
      4. Planting medium,
      5. Vegetation used
      6. Water filtration system
      7. Total weight of green roof
   c. redesign perimeter structure to support new façade
   d. if necessary redesign support structure for green roofs

III. Construction impact and cost analysis
   a. Material Cost
   b. Labor Cost
   c. Scheduling Cost
   d. System savings
      1. Immediate savings
      2. Long-term savings based on increased energy efficiency

IV. Structural Analysis
   a. Core redesign
      1. Lateral system
      2. Gravity system
   b. Roof members redesign
      1. Lateral system
      2. Gravity system

V. Compose Final Presentation and Report

Schedule



Milestone Activity List

1 revision of all moment frames to braced frames completed
2 energy efficiency improvements have been made
3 construction impact and cost analysis has begun
4 Report materials gathered

Analysis #1: revise all moment frames to braced frames
Analysis #2: redesign of façade for improved waterproofing and incorporating thermal dampers
Analysis #3: construction impact and cost analysis
Analysis #4: redesign of green roof and façade for energy efficiency

Figure 7. Schedule for Thesis work Spring 2010

Conclusions

The focus of my thesis is energy efficiency and how it can be implemented using facade ad green roof redesign. It ties structural engineering concepts with existing enclosure installation methods to provide a secure barrier against water and the temperature of the outside world. It will also provide sound isolation from street noise to foster a more comfortable learning environment for students.

All of this has to be achieved while maintaining an inviting and transparent appearance to the community so that they can feel welcome. This may cause limitations in the window glazing chosen and its corresponding R-value. This in-depth analysis could not be achieved without the redesign of the structural system and its impact on cost.

Enclosure design is important to ensure the life of a structure in addition to continual building maintenance. Simple and inexpensive measures can be taken to significantly improve the buildings energy efficiency. This thesis topic was inspired by the building's current goal of achieving LEED certification.

Appendix - Loading Diagrams

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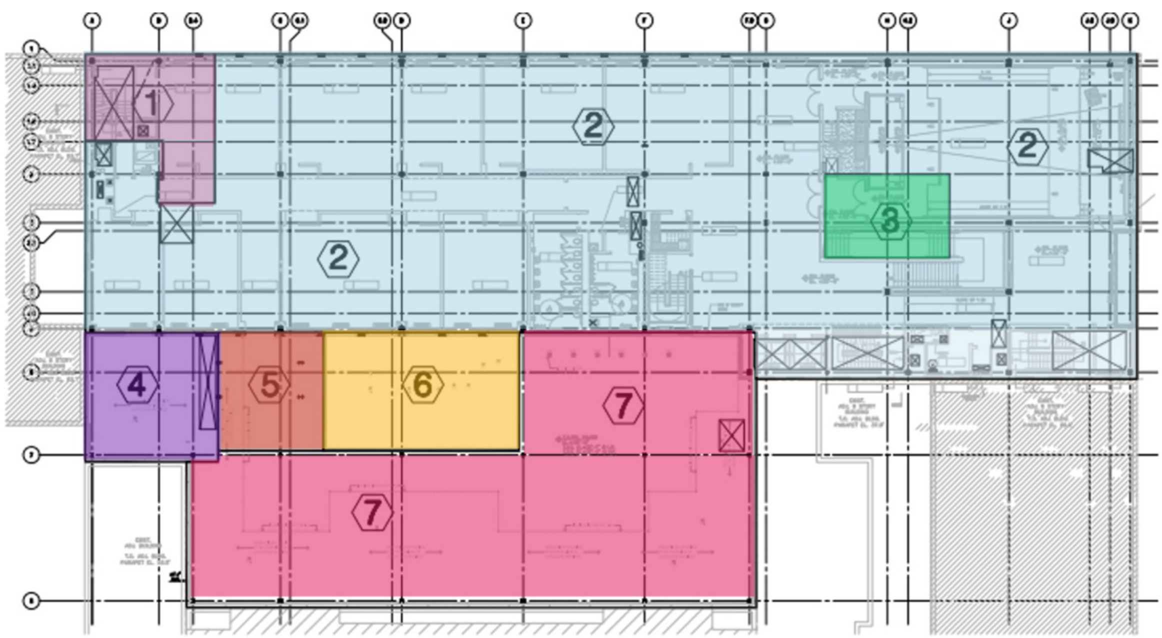
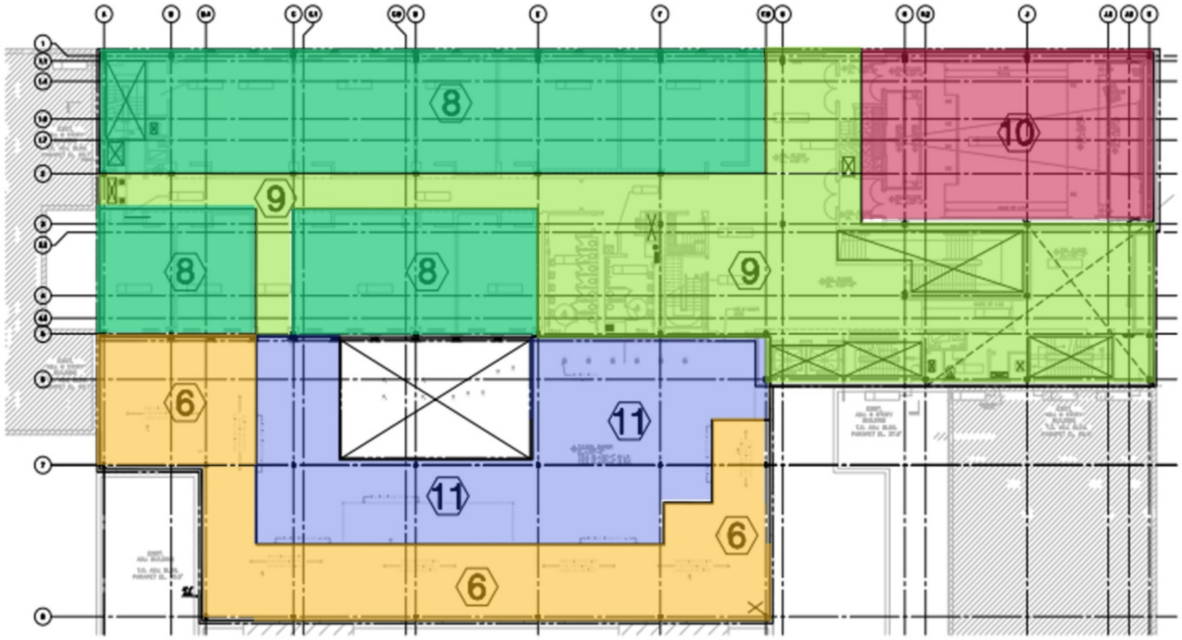
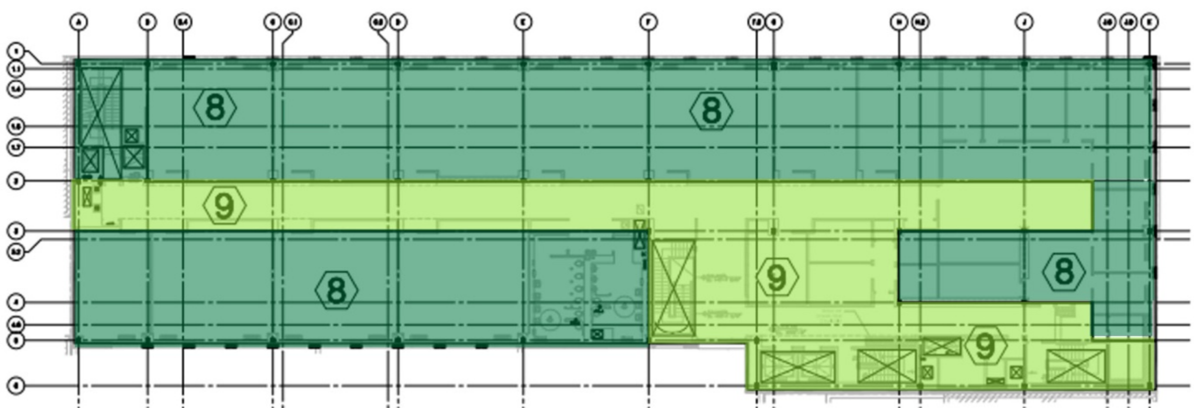
LOADING SCHEDULE		
ID	DL psf	LL psf
1. LOADING DOCK	150.0	600.0
2. 1ST FLOOR	130.0	100.0
3. PODIUM	200.0	100.0
4. ARCHIVE	75.0	350.0
5. OFFICES	71.0	50.0
6. ROOF WITH GARDEN	365.0	100.0
7. LIBRARY STACKS	71.0	100.0
8. CLASSROOMS	71.0	40.0
9. CORRIDOR	71.0	100.0
10. AUDITORIUM	85.0	60.0
11. ROOF WITH PAVERS ON 2	150.0	100.0
12. ROOF	90.0	45.0
13. ROOF WITH DRIFT	85.0	60.0
14. MECHANICAL	120.0	100.0



1 1ST FLOOR LOADING DIAGRAM
SCALE: 1/8" = 1'-0"



2ND FLOOR LOADING DIAGRAM
SCALE: 1/8"=1'-0"



3RD FLOOR LOADING DIAGRAM
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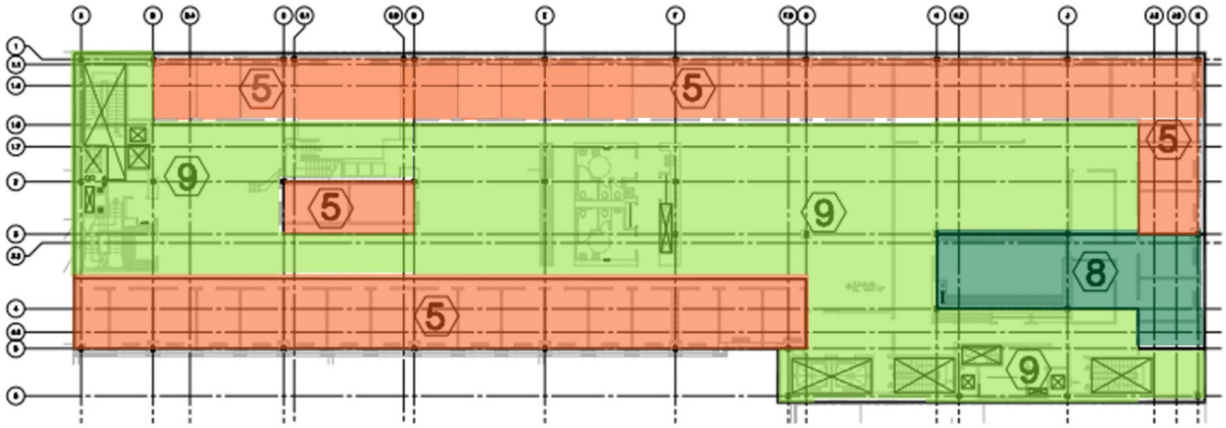
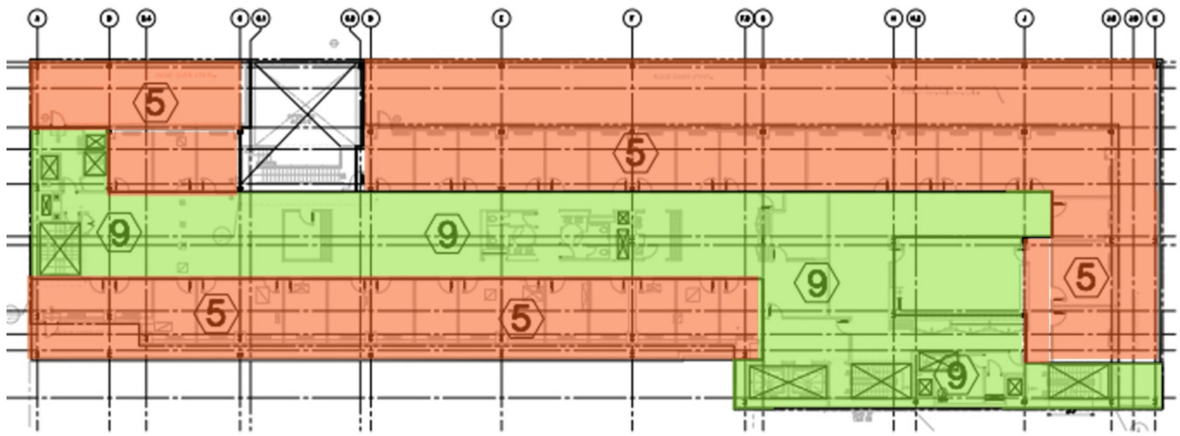
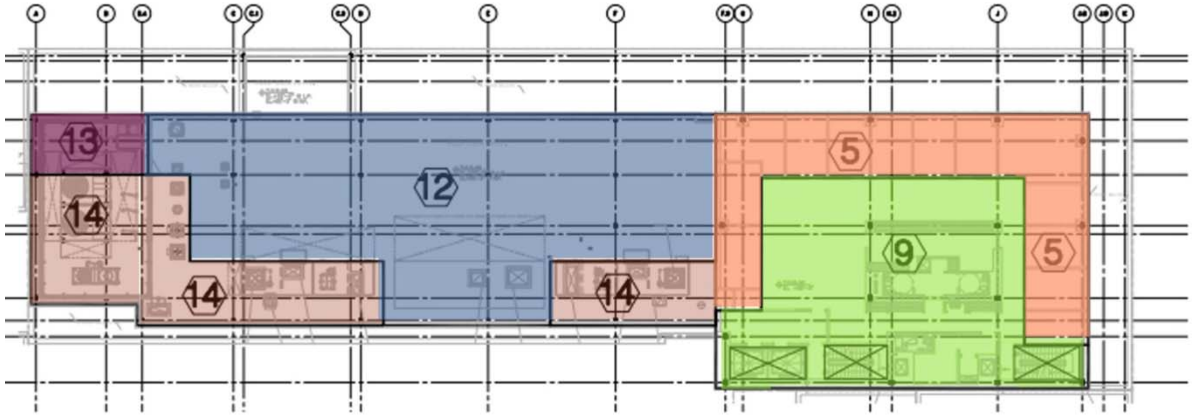


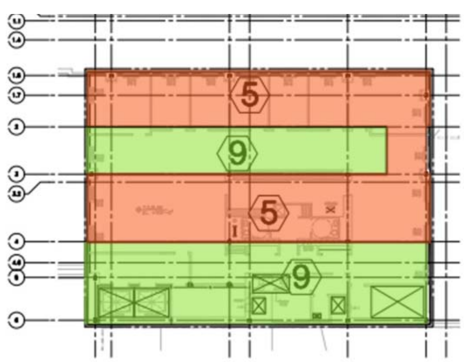
4 4TH FLOOR LOADING DIAGRAM
SCALE: ⅛"=1'-0"



5 5TH FLOOR LOADING DIAGRAM
SCALE: ⅛"=1'-0"

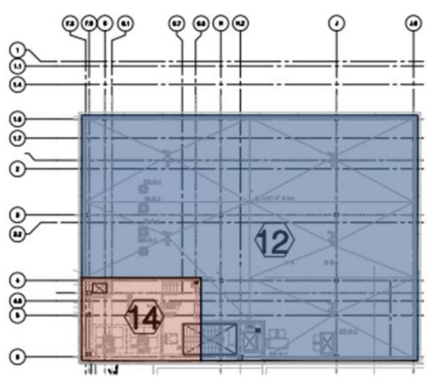


6TH FLOOR LOADING DIAGRAM

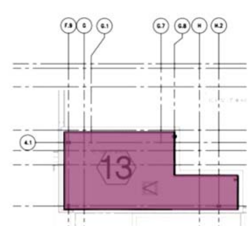


7TH FLOOR LOADING DIAGRAM

8TH FLOOR LOADING DIAGRAM



ROOF LOADING DIAGRAM



PENTHOUSE LOADING DIAGRAM