

35 WEST 21ST STREET NEW YORK, NY



THESIS PROPOSAL

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EXECUTIVE SUMMARY

35 West 21st Street is a cast in place concrete residential building with the first level consisting of two retail areas. The building is composed of two towers that are initially connected at the ground and second floor levels, but then set back to form two separate towers. The southern tower is 15 stories and has a roof height of 150 feet. The northern tower is 8 stories and has a roof height of 80 feet. The lateral system consists of reinforced concrete shear walls while the gravity system is two-way flat plate concrete reinforced with mild steel.

The goal of this thesis is to ultimately design the addition of a level of residential space without increasing the overall height of the building. In doing so, an alternate column grid, and lateral system will be designed. The intent is to reduce drift and optimize the size of the shear walls that comprise the lateral system. The second main study will be to design a two-way post-tensioned concrete floor system in order to decrease the floor-to-floor heights in the building. The study will involve a complete lateral system redesign, as well as a complete floor system redesign. The breadth topics will focus on the mechanical systems employed as well as the effects of a new column grid layout on the architectural plan and facade. The combination of these studies will allow for a cost and feasibility analysis as well as recommendations.

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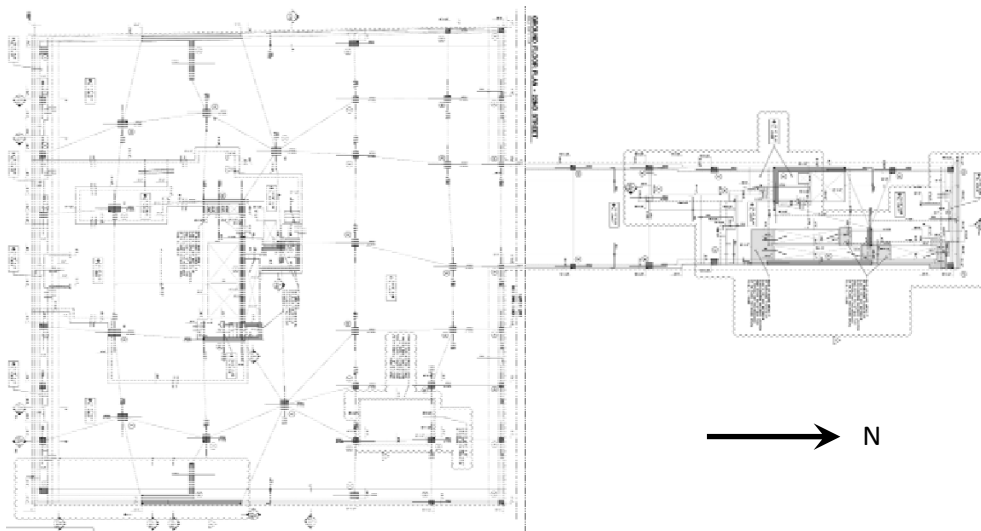
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INTRODUCTION

35 West 21st Street is shaped by the surrounding buildings and its site. With adjacent 4-12 story buildings, the plan takes on a T-shape to maximize the footprint. The stem of the T-shape is an eight story residential tower facing the north, while the top of the T-shape is a fifteen story residential tower facing the south with retail space at grade. Over 162,000 sq. feet of residential and retail space are provided.

35 West 21st Street is located in the Flatiron District within the Ladies' Mile Historic District. The area is zoned as C6-4A which allows for commercial, light manufacturing, and residential construction. The predominant historical requirements of Ladies' Mile consist of street walls a minimum of 60 feet tall that are in character with the surrounding area. Therefore, the building has a classic stone facade with infill glass windows.

The columns of the superstructure are continuous from the foundation to the top of the building with no transfers throughout the building. The columns are arranged in a semi regular pattern where most bays are rectangular in plan. The arrangement of columns allows for open residential and retail floor plans while a two way flat plate concrete floor system allows for 8' high ceilings while maintaining a typical 9'-8" floor to floor height. The residential units in the upper floors have large personal balconies which overlook the surrounding city and allow for a spacious outdoor room in crowded New York City.



Plan showing relationship of the two towers.

STRUCTURAL SYSTEMS OVERVIEW

Floor System

35 West 21st Street is a typical reinforced concrete residential structure. The floor system is a two way flat plate slab without drop panels or beams. Typical residential floors are 8 inches thick. The bottom is typically reinforced with #5 deformed bars at 12 inches on center each way. Middle strips are typically reinforced with #5 deformed bars at 12 inches on center at the top of the slab, while column strip top bars vary according to span lengths which range from 13' to 18'. In areas of high shear, slab supports also have studrails to help prevent punch through shear. Typical columns are gravity only, and run the entire height of the building without transfers. On the fifteenth floor, columns lining the exterior balconies are transferred to the 14" slab and then transferred to nearby columns that go down to the foundations. Typical columns are 16"x18" with 8-#7 longitudinal bars and #3 ties at 12 inches on center. Minimum concrete compressive strength is 5 ksi for slabs above ground, and 5.95 ksi for columns. The slab also provides a two hour fire rating.

Basement

The basement floor is a slab on grade reinforced with 6" WWF 6x6 – W2.0xW2.0. Typical slab on grade thickness is 6".

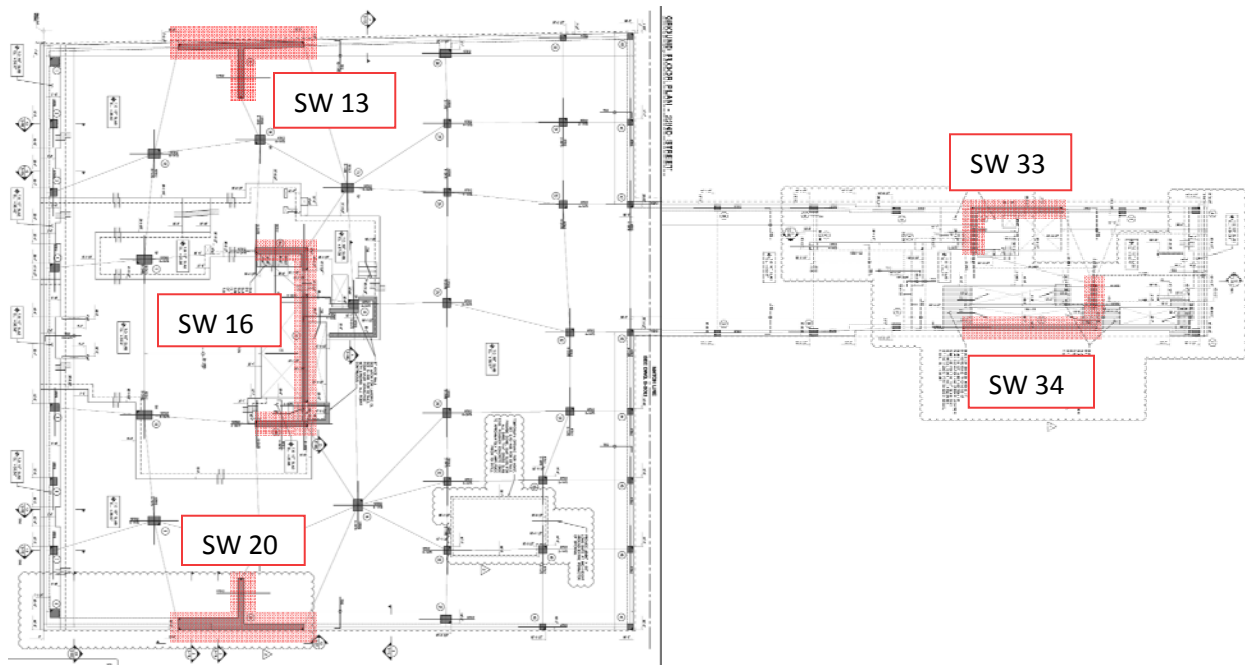
Roof system

The roof slab is 12 inches thick with typical reinforcing like that on all the residential floors. Cooling towers bear on dunnage that consists of 16"x16" concrete piers and galvanized W10x33 steel beams. The remaining mechanical equipment including elevator machines are housed in the bulkhead, which consists of shear wall 16 and three transfer columns. The loads from the concrete piers and columns are transferred through the 12" slab and into columns below that continue to the foundation.

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Lateral System

The lateral system of 35 West 21st Street is comprised of shear walls in both the North-South and East-West directions of the building. The two towers of the building are built integrally with each other through the two way slab at the basement, ground and second floor. However, at the second floor, the 15 story south tower steps back to allow for an outdoor courtyard, thus breaking the connection between the two towers. Because the connection of the two towers only exists on the first two floors, the towers' lateral systems were designed separately from each other. It is assumed that the two buildings act separately, and thus do not transfer any torsional moment between the two lateral systems. Typical shear walls are 1'-0" wide and longitudinal reinforcement ranges from #10 at 12" on center at the base of the shear walls to #4 at 12" on center at the top of the building. Horizontal shear reinforcement typically consists of #4 at 12" on center closed loop bars.



Foundation

The foundation system consists of spread footings for typical concrete columns and large mat foundations for shear walls. On the east side of the building, 240 ton caissons spread loads from the footings to the bedrock below. The caissons are at a minimum drilled 9'-0" into bedrock and are typically 12 inches in diameter.

PROBLEM STATEMENT

The current design of 35 West 21st Street utilizes a flat-plate mild steel reinforced concrete floor system and a reinforced concrete shear wall lateral system. Because it was more important for the building owner to have the building occupied than to optimize the design, the structural engineer had very little time to design both the lateral and gravity systems of the building. Consequently, the typical floor thickness of 8 inches is greater than needed as shown in Technical Report 2. Shear walls, as well, were also overdesigned. The drift of the building is about half of the allowable drift by code and engineering standards, according to Technical Report 3. As presented in Technical Report 1, the columns are spaced close together and in an irregular pattern. Although the overdesign and irregularity is not a strength or serviceability problem, it is a problem for the owner in terms of revenue and construction costs.

The oversized floor thickness increases the floor-to-floor height of the building. Although an extra 2 inches of floor thickness seems insignificant for a single floor, over the full 15 stories of the building it yields an extra 30 inches of wasted vertical space. The typical ceiling cavity is 12 inches due to HVAC ducts that feed the individual apartments. The ceiling cavity adds up to 15 feet of vertical space over the height of the building that could be used for an extra floor of rentable residential space.

In order to allow complete freedom of the architectural plan, columns are spaced at 15 to 18 feet apart on an irregular grid. The oversized columns interfere with the floor plan and use excessive material over the height of the building. If the columns were placed at a larger spacing, placed on a more regular column grid, and shear walls were optimally designed, floor plan freedom along with optimized constructability and material usage could be achieved. This could help decrease construction time and cost.

PROPOSED SOLUTION

Optimization of floor-to-floor height presents an opportunity to greatly improve the amount of residential space by adding at least one floor to the building without exceeding zoning height limitations. A completely new floor system will be implemented in order to achieve a more reasonable floor thickness. The system will include designing and placing columns on a more regular column grid and at a larger spacing to improve constructability and create a more open floor plan. A two-way post-tensioned flat plate concrete slab system will then be designed in order to decrease the floor thickness. The existing floor system and proposed floor system will then be compared and analyzed based on cost, constructability, and possible revenue generated. However, decreasing the floor thickness alone will not allow for another story without increasing the overall building height. As a result, a breadth study on the mechanical system and possible redesign will be conducted. In order to completely eliminate the ceiling cavity, individual air-to-air heat pumps for each apartment, like that in a hotel, will be studied. It is anticipated that the individual units will be able to handle the heating, cooling and ventilation loads of the building.

Lateral system efficiency will be addressed next. In order to create more freedom with the architectural floor plan and use less material, shear wall lengths will be studied and optimized. The effects of an extra floor on the lateral system will also be studied. The existing and proposed lateral system will then be compared and analyzed based on cost, constructability, and floor plan optimization. As a second breadth study, a redesign of the architectural floor plan and façade will be incorporated in order to integrate structure and architecture. It is expected that the redesign of the key structural, mechanical, and architectural elements will decrease overall costs of the building while still allowing for a functioning floor plan.

SOLUTION METHODS

The proposed two-way post-tensioned concrete floor system will be designed per Chapter 18 of ACI 318-05 *Building Code Requirements for Structural Concrete*. A computer analysis for gravity loads will be completed using the program RAM Advance. Approximate hand calculations will be conducted to check the output of the computer. With the redesign of the slab and column layout, columns will be redesigned based on a new column load take down and the requirements of Chapter 10 of ACI 318-05. A computer analysis will be conducted using the program PCA Column, and hand calculations will be used to check the computer output.

The proposed lateral system will be redesigned using seismic loads, wind loads, and allowable drift determined using ASCE 7-05 *Minimum Design Loads for Buildings and Other Structures*. A full three-dimensional model of the lateral system will be constructed using the computer program ETABS. This model will be used to determine the actual building period and drift due to wind and seismic loads. A hand calculation of the distribution of story forces to shear walls will be conducted to determine if the program is distributing loads properly. The reinforcement for the shear walls will be designed based on the requirements of chapters 11, 14, and 21 of ACI 318-05. The computer program SAP will be used to design the reinforcement in the shear walls while hand calculations will be conducted to check the computer output.

In order to design a new HVAC system for each individual apartment, cooling, heating, and ventilation loads will have to be determined using the ASHRAE handbook. Research into the type of unit required to meet those design loads will then be conducted and certain typical unit will be recommended.

TASKS AND TOOLS

I) Gravity System Optimization

- i) *Task 1: Redesign column layout*
 - a) Establish column layout to maximize floor space and minimize irregularities
 - b) Integrate Architectural Plan and facade with column layout
- ii) *Task 2: Design of two-way post-tensioned concrete floor system*
 - a) Establish loads based on ASCE 7-05
 - b) Create computer model using RAM Advance
 - c) Check computer output using hand calculations based on ACI 318-05
- iii) *Task 3: Design of gravity columns*
 - a) Perform load take down for columns
 - b) Design column using PCA Column
 - c) Check computer output using hand calculations based on ACI 318-05
- iiii) *Task 4: Gravity framing Comparison*
 - a) Determine cost savings
 - b) Determine pros and cons of existing and proposed system

II) Mechanical System Optimization

- i) *Task 1: Determine loads*
 - a) Determine heating, cooling, and ventilation loads based on ASHRAE
- ii) *Task 2: Research HVAC units*
 - a) Research HVAC Units to handle loads
 - b) Implement a typical unit that can be integrated with facade

III) Lateral System Optimization

- i) *Task 1: Design efficient shear walls*
 - a) Establish lateral loads based on ASCE 7-05
 - b) Establish possible shear wall schemes
 - c) Establish Trial shear wall sizes
- ii) *Task 2: Analyze new lateral system*
 - a) Create ETABS model for new framing
 - b) Analyze pros and cons of different shear wall schemes
 - c) Determine most efficient scheme
 - d) Check computer output by hand
- iii) *Task 3: Design of shear wall reinforcement*
 - a) Design shear wall reinforcement based on ACI 318-05

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- iv) *Task 4: Lateral system comparison*
 - a) Compare ETABS model with existing design
 - b) Determine cost savings
 - c) Implementation of lateral system to architecture of building

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SCHEDULE

Tasks	1/12 - 1/18	1/19 - 1/25	1/26 - 2/1	2/2 - 2/8	2/9 - 2/15	2/16 - 2/22	2/23 - 3/1	3/2 - 3/8	Spring Break	3/16 - 3/22	3/23 - 3/29	3/30 - 4/5	4/6 - 4/8	4/13 - 4/17
1	Determine Mechanical System Loads													
2	Research HVAC units													
3		Redesign Column layout												
4		Redesign Architectural floor plans and facade												
5				Design post-tensioned slab										
6							Design Gravity Columns							
7							Gravity Framing Comparison							
8								Design efficient shear walls						
9								Design Shear Wall Reinforcement						
10										Analyze new lateral System				
11												Lateral System Comparison		
12													Prepare Final Report	
														Final Reports due
														Final presentations

CONCLUSION

For the spring semester, an alternate lateral framing system and gravity framing system will be designed and compared to the existing building. It is expected that an optimized structural system will yield a lower cost. On top of the structural redesign, two breadth redesigns will also be incorporated to integrate the architecture and mechanical systems with the structural systems. The underlying theme of the thesis is to increase the number of stories in the building without increasing the overall height. It is expected that the increase in stories will offset the increase in initial cost by increasing the square footage and consequently increasing revenue.