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110 Third Avenue
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12/9/05

Thesis Proposal

Investigation and Summary of Future Research and Activity

1.1 Executive Summary

110 Third Avenue is a residential mid-rise tower that sits in the heart of Manhattan between Gramercy and East Village. Standing at 210' to the bulkhead slab, it offers 21 stories of mid-sized apartments totaling approximately 107,000 square feet of inhabitable space. The structural system of 110 Third Avenue is predominantly cast-in-place concrete. Most floors have 8" CIP slab, but beginning with floor 15 the slab increases to as much as 24" to support cantilevered portions of the building and mechanical equipment on the roof.

The proposed thesis analysis is two-fold. First, the advantages and disadvantages of the existing floor system will be compared to a Post Tensioned alternate system. Manhattan is a unique environment for concrete buildings due to height restrictions and high occupancy level per volume of space. Owners desire the thinnest, easiest-to-construct floor system possible. A post tensioned two-way slab will likely allow an increase in spans without increasing the depth of the floor, but columns and the lateral system will subsequently need to be adjusted. Construction in Manhattan has almost always used a flat plate system for a mid-rise residential structure such as 110 Third Avenue. Knowing the bounds of this system, however, will allow designers to properly evaluate which system is best and economical for a given set of conditions.

Second, lateral analysis in Tech 3 demonstrated that designers used a combination system, not just shear walls, in the design of the lateral force resisting system. This system was previously only analyzed by taking into account shear walls. In future research, the combination system will be analyzed and compared to the shear wall system. Finally, the redone analysis of the lateral system will be compared to the modified lateral system created by using a two-way post tensioned floor system.

1.2 Introduction

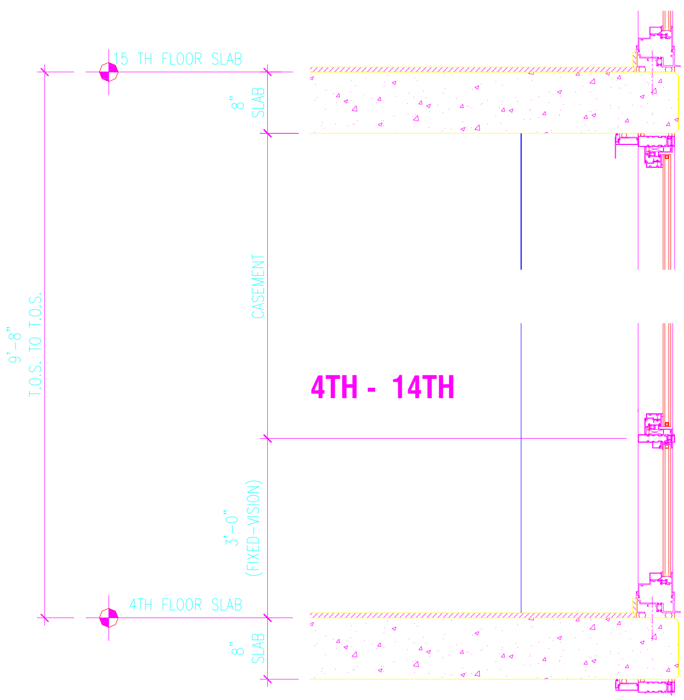
110 Third Avenue is a residential mid-rise tower that sits in the heart of Manhattan between Gramercy and East Village. Standing at 210' to the bulkhead slab, it offers 21 stories of mid-sized apartments totaling approximately 107,000 square feet of inhabitable space. The structural system of 110 Third Avenue is predominantly cast-in-place concrete. Most floors have 8" CIP slab, but beginning with floor 15 the slab increases to as much as 24" to support cantilevered portions of the building and mechanical equipment on the roof. All slabs and columns have f'_c= 5000 psi. Loads are carried from the two-way slab system to concrete columns ranging from 12x12 to 40x12. The columns are continuous throughout the height of the building except for a few columns that terminate at floor 16 due to a setback in the building perimeter, and a few columns that originate on the drawings at floor 11 due to the reduction of the elevator core to column-sized portions. Footings range from 4'6" square up to 15' x 9'6". The only beams present in the structure are in the basement level and are grade beams extending from perimeter East-face and West-Face footings to the outside wall. Shear walls extend throughout the height of the building and are located mostly on the North and South sides of the building. The roof is a flat slab system that is drained by roof drains nested under pavers. Supporting columns are recessed from the façade on average 10", and therefore allow the designer to use non-bearing prefabricated panels.

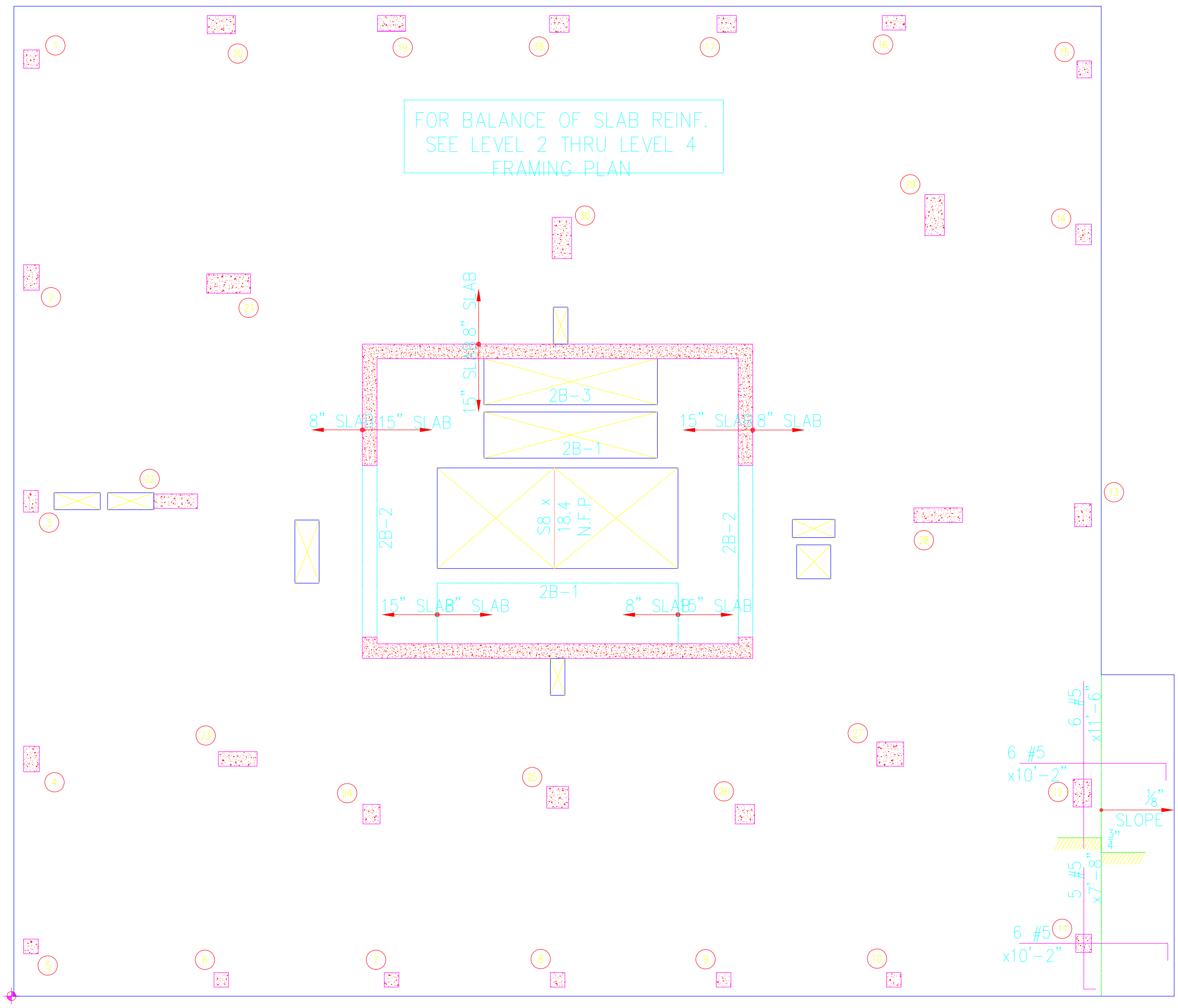
Loading conditions on the vast majority of the building are relatively light due to their use as residential space. A table below provides a complete description of loads according to drawing S.001 provided by Axis Design Group. When factored according to ASCE-07, loading throughout the apartments is only 94 psf. Low loading consequently makes the existing system, the 8" flat plate system, a very good choice in order to maximize space. Most other systems aren't competitive simply because they cannot maintain a depth of only 8".

Floor	Partition	Ceiling & Mech.	Floor Finish	Live	Total Imposed
Lobby	-	5	40	100	145
Apartment	12	-	5	40	65
Roof	-	5	25	30	60
Retail	-	5	15	100	120
Storage	-	5	-	100	105
Stairs	-	-	-	100	100
Private Roof Terrace	-	-	65	60	200
Public Roof Terrace	-	-	65	100	200
Mechanical	-	25	40	150	215
Gym	-	5	15	100	215
Courtyard	-	-	65	60	215

1.3 Existing Structural Floor System

110 Third Avenue is completely a flat plate system with columns roughly sorted into a 7x5 element bay. The building extends 68’ in the North-South direction (5 columns) and 75’ in the East-West direction (7 columns). A flat plate system supports the loads placed on the building and directly transfers the loading to the columns. No drop panels assist in the distribution of weight or add to the building’s resistance to punching shear. A central shear wall system centered around the elevator core provides lateral stability and resistance to wind and seismic loading.





Typical Floor Plan for Floors 5 through 10, other floors are very similar

Design weight of floor framing is 8" thick concrete flat plate slab at 100 PSF (S-001) A typical flat plate slab system serves the entirety of 110 Third Avenue, with a typical slab thickness of 8". Slab size increases around the elevator core to 15", and increases to 24" near the elevator core on the roof level to support mechanical equipment. Slabs are continued, in portions of each floor, past the perimeter to form balconies. The balconies have a ¾" step down from the 8" slab that makes up the entire interior space, and are therefore 7 ¼ in. thick. The flat plate slab is a great approach to a mid-rise residential tower because it saves on formwork and labor costs. All slabs are 5000 psi concrete.

2.1 Problem Statement

Designers of 110 Third Avenue faced a very simple design problem: create an efficient design suitable for residential construction with a height limit by putting the most floors in as possible while making sure to avoid interference with architectural design. Several interesting solutions were incorporated into the design of the structural system and can be examined further. First, the floor system is a two-way flat plate, but this simple system might not be the best solution with regard to ease of installation and economy. The maximum height limitation for 110 Third Avenue is 210'-0", and the reasonable maximum number of stories for such a restriction is twenty one. In order to maximize occupiable volume per floor, the floor system must remain slim and not exceed 8". There exists no room for a plenum space for mechanical equipment, and any slab system exceeding 8" would not have nearly as many advantages as a flat plate system. The criteria for an improved floor system design are as follows:

1) Equal to or less than 8" thick
2) Maintain strength of system without compromising span length
3) Must keep costs equal to or lower than a flat plate system
4) Ease of construction/installation

Second, as seen in Tech Report 3, a major difference in lateral force resisting system analysis was discovered and should be reevaluated. Designers assumed use of slabs and columns to resist lateral forces, not just shear walls. Until a few years ago, there were no computer programs that could easily analyze a structure in this manner, but tools are now available that will allow this analysis to be performed. Both shear walls and the use of slabs and columns as a moment frame acted together to drastically reduce the drift with minimal force in the slab. The columns have no additional size or reinforcement and the slab simply includes a few additional top bars at the columns for the wind moment. Due to time constraints during the completion of Technical Report 3, a completely new model could not be created in time for this report.

The drift should be further analyzed in the future using revised load cases (without factors) and the combined system previously specified. If these two adjustments are made to the computer model, it should produce perfectly reasonable drifts. Finally, the Excel file, although seemingly off in its forces, also uses reasonable values for base shear and weight of the building (242.8 k base shear and 7838.8 k weight). The wind forces applied to both the ETABS and Excel model are identical except for the 1.6 factor, indicating they should be off by a multiplier of 1.6, not 3. The report shows that the lateral system was competently designed, although using ETABS did not necessarily demonstrate exact loading and resisting conditions. The difference in results using computer models is clearly explained from the different approach a combination system takes. The use of the combined frame and shear wall reduces lateral movement for a given size and reinforcing of shear walls.

2.2 Proposed Solutions

2.2.1 Floor System Redesign

Although a flat plate system seems well suited to conditions present in 110 Third Avenue, such as height restriction and desire for high occupancy, other alternate floor systems may be equally as viable if not more advantageous. The most viable option is a post-tensioned two-way slab that will allow for greater spans, but subsequent redesign of columns and the lateral system must be performed.

2.2.1.1 Post Tensioned Two-Way Slab

The use of PT presents many benefits that are conducive to the requirements presented by 110 Third Avenue. PT slabs are typically thinner than an ordinary reinforced concrete slab. A thinner slab could quite possibly mean the incorporation of an extra story into the design (although this may be overly ambitious). According to http://www.concretecentre.com, "the amount of prestress can be adjusted to control deflection, thus enabling the minimum depth of slab to be used. Deflection calculation can also be simpler than for reinforced concrete because the section is uncracked."

The presence of irregular grids in 110 Third Avenue offers a severe challenge to any system that can't readily adapt to differing bay sizes and shapes. A PT slab is an especially exciting prospect since it has the same flexibility to accommodate irregular design that a normal slab does. Post Tensioned slabs are also easily erected and could possibly save on construction time and erection costs such as formwork.

A possible downside to the use of PT is most sources claim a PT slab won't become economical until spans reach around 20'. Spans in 110 Third Avenue are approximately around this 20' mark in the long direction, so the floor layout as it is may not be best suited for a PT slab. However, if necessary, the floors could be redesigned to have fewer columns.

A redesign of these columns will be performed in a manner that will avoid interference with the architecture already present in the designs of 110 Third Avenue. Of course, the redesign of the columns will influence the lateral system since it relies on a combined system of shear walls and a moment frame consisting of the floor slab and columns. The procedure for redesigning 110 Third Avenue using post-tensioning will consist of:

1) Design the floor slab assuming a larger bay size to make the system economical
2) Reduce number of columns to accommodate the larger bay size
3) Resize the columns
4) Analyze the lateral system using the new column layout and adjust the shear walls and columns as necessary

2.2.2 Combination Lateral System Analysis

A new lateral analysis will be performed using ETabs that will incorporate the use of a combined lateral force resisting system. The old model, which did not incorporate actual column and bay sizes, will have to be completely redone with accurate column sizes spaced irregularly to provide the proper degree of accuracy. In addition, the new ETabs model will place slab-beams running between columns to approximate the moment frame. Finally, the factored loads input into the model will be changed to unfactored loads and compared to hand analysis once again to verify the design. Adjusting the analysis in this way will allow the combination system to be evaluated and compared to the previously analyzed shear-wall-only system.

3.1 Solution Method

The post tensioned system will be checked at initial and service conditions for the given loading. Also, the strands much be checked to make sure they are within the acceptable range for placement of PT reinforcement. Capacity is evaluated at initial condition, after jacking, and after losses. Shear stresses will be checked as well. Needless to say, more research will need to be done to ensure proper design of a PT slab, and most of the knowledge of PT systems currently comes from CE 543. Also, RAM Concept could possibly aid in the design of a PT system.

Once design and analysis of the floor system is complete, the columns can be resized based on the new weights and loadings from the new bay sizes. After they have been resized for vertical loading, a lateral analysis will insure they will be sufficient for wind and seismic loadings in combination with the existing shear walls. It may be necessary, if the combination system fails with regard to story drift, to increase the size of the shear walls.

The current floor system will be analyzed for punching shear and then the addition of stud rails will determine whether the floor system can be reduced in thickness.

Lateral analysis will be performed using ETabs, as stated before, and will use a completely new and separate model from Tech 3. The new model will not modify column placement and size, but rather will maintain true-to-life column sizing and spacing to make sure an accurate end analysis is obtained. In this manner, shear walls and the moment frame created by the slabs and the columns will be analyzed as a combination system. Also, the new system will be compared to the shear wall system previously analyzed using the output found in Tech 3.

4.1 Tasks and Tools

1. Two-way Slab Post Tensioned Floor System Alternative

   Task 1: Determine loading
   Task 2: Design slab
   a) determine minimum thickness
   b) find applied moments
   c) check capacity of slab
   d) check deflections

2. Redesign of columns

   Task 1: Determine vertical loading based on the loading criteria listed on page 3
   Task 2: Size the columns using the analysis learned in AE431

3. Perform a Lateral Analysis of the New System

   Task 1: Input model into ETabs
   Task 2: Analyze model for drifts and member forces
   Task 3: Compare drifts to serviceability criterion
   Task 4: Conclude whether the system is sufficient in all aspects of design

4. Combination Lateral Force Resisting System Analysis

   Task 1: Input model into ETabs
   Task 2: Analyze model for drifts and member forces
   Task 3: Compare drifts to serviceability criterion
   Task 4: Compare conclusions to actual design of lateral system and previous system.

5.1 Breadth Work

5.1.1 Construction Management

The redesign of the floor system must be evaluated in comparison to the existing system. To do this, issues such as cost, constructability, and labor must be addressed. The post tensioned system will be examined and compared to the current system. After a comparison of each system has been constructed, a final determination will be made of which system is best.

Also, the construction process will be examined first hand in New York City in February. Any issues that have arisen or could potentially arise will be examined in-depth.

Installation of the floor system will also be examined in detail to provide a firm basis of comparison for other systems.

5.1.2 Building Technology

The exterior walls of 110 Third Ave. consist of a “window wall” system. This system is fixed window units fabricated with flush aluminum panels finished to match the window wall that rests on the slab. Surrounding the windows are glazed aluminum window wall framing. The window units themselves consist of a 1/4” thick nominal aluminum composite panel affixed to the exterior face window-wall unit with conceded fasteners and/or adhesives finished to match the window-wall. Also present is an insulating spandrel panel. The roof is concrete slab supporting mechanical equipment, but it also hosts several private terraces and a common terrace for occupants. The roof itself is composed of a layer of fluid applied roofing membrane, drainage panels, 4” polystyrene, adjustable paver pedestals, topped with a layer of precast concrete pavers. Surrounding the living spaces is a 4’-0” high perimeter parapet planter all around the roof.

These key features of the building envelope must perform as intended, otherwise water penetration could pose a significant threat to the health of the building and the satisfaction of tenants. Each part of the building envelope will be examined for adequacy, and potential issues that could arise during construction will be listed. The construction process is key to ensuring proper performance of the window wall system.

6.1 Timetable

1-9 Classes begin
3-6 to 3-10 Spring Break
4-5 Paper completed
4-28 Classes End

Item	Week 1 1/9 to 1/16	Week 2 1/16 to 1/23	Week 3 1/23 to 1/30	Week 4 1/30 to 2/6	Week 5 2/6 to 2/13	Week 6 2/13 to 2/20	Week 7 2/20 to 2/27	Week 8 2/27 to 3/6
1. Post Tensioning Research	X	X						
2. Design of PT Floor System		X	X					
3. Design of new Columns			X	X				
4. Design of new lateral system					X	X		
5. Breadth 1- Compare Floor systems						X	X	
6. Develop ETabs model								X
7. Find drifts and evaluate								
8. Breadth 2- Build. Tech.								
9. Present								
10. Review								

Item	Week 9 3/6 to 3/13	Week 10 3/13 to 3/20	Week 11 3/20 to 3/27	Week 12 3/27 to 4/3	Week 13 4/3 to 4/10	Week 14 4/10 to 4/17	Week 15 4/17 to 4/24	Week 16 4/24 to 4/28
1. Post Tensioning Research	Break							
2. Design of PT Floor System	Break							
3. Design of new Columns	Break							
4. Design of new lateral system	Break							
5. Breadth 1- Compare Floor systems	Break							
6. Develop ETabs model	Break	X	X					
7. Find drifts and evaluate	Break		X					
8. Breadth 2- Build. Tech.	Break			X				
9. Submit	Break				X			
10. Present and Review	Break					X	X	X