Washington Park Condominiums

Mt. Lebanon, Pennsylvania

Thesis Proposal Revised

Architectural Engineering
2008-2009 Senior Thesis

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January 19, 2009

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Executive Summary:

Washington Park Condominiums is an 8-story multi-use retail and residential building located in Mt. Lebanon, Pennsylvania. The primary structural system employed within the building is a proprietary composite steel joist system, supported by a steel moment frame system. These systems are adequate in carrying the gravity and lateral loads of the building. The past three technical reports have taken a detailed look at the current structural system of the building as well as exploring various other floor systems that could possibly be used as an alternative to the current design. These same technical reports have brought to light the fact that the current structural system may not be the most efficient or cost effective solution available for design. Because of this a depth study and two coinciding breadth studies will be completed as a means of research and analysis.

Depth Study: Structural System Redesign

First, thorough research will be conducted on different high rise condominium buildings throughout the Mid-Atlantic region to see how the structural systems for those buildings were implemented. The focus of the research will be centered on concrete structural systems and how they perform under given gravity and lateral loading conditions. Next, the new structural design that will be studied is a two way flat plate concrete slab system with cast in place concrete columns. The design will take into account the fact that the slab thickness needs to be minimized within the design so the ceiling height within the apartments can be maximized. Moreover, this system should be able to use the same column grid as the steel structure with possibly a few changes near the elevator shafts and stairways. The foundation for the building will also need to be redesigned to handle the additional load on the building. Moreover, concrete shear walls will be designed to carry the lateral loads on the building. These shear walls can be placed around the elevator shafts and staircases located within the interior of the building causing minimal interference with the architectural aspects of the floor plan.

Breadth Study 1: Structural System Acoustical Performance

The different spaces that are included in the building lead to the possibility of sound transmission between floors caused by the close proximity of busy retail spaces and the private condominiums. Also, the amount of unwanted vibration experienced by tenants caused by HVAC equipment as well as the elevator equipment is a concern. This particular concern was expressed by the owner of the building during a meeting with him before the beginning of the project. This study will be conducted using the current structural steel system as well as the new flat plate concrete system. The two systems, along with a typical living space, will be acoustically analyzed using decibel levels as well as STC and sound transmission values so that the results can be compared and presented to the owner. Ultimately, a modification of the wall and/or ceiling cavities may need to be done to suffice the acoustical requirements of the owner and the tenants.

Breadth Study 2: Architectural Detailing and MEP Distribution

As a result of the structural system of Washington Park Condominiums being changed from a composite steel joist system to a flat plate concrete slab system, the architectural details will also need to be modified. More specifically, electrical, mechanical and plumbing systems will need to be modified so that they will fit in with the new ceiling cavity and the new structural system. The modification of the structural system may lead to a redesign of duct sizes and placement throughout the ceiling cavity. These systems are the most important systems to the patrons of the building and will need to be adapted in a way that doesn't impact the individual living spaces. A comparison between the details provided by the architect and the details produced for this study will then be compared for ease of construction, impact of living space and ultimately cost.

Introduction:

Washington Park Condominiums is a multi-use retail and residential building located at the intersection of Bower Hill Road and Washington Road in Mt. Lebanon, Pennsylvania. Site work and excavation has begun at the site and construction should begin sometime before the end of the Fall 2008, with the project lasting until fall 2010. Washington Park Condominiums is the first of two buildings proposed to be built on the site. Building One is a nine-story, 148,000 ft^2 structure which is owned by Zamagias Properties of Pittsburgh, PA. The building was architecturally designed by Indovina Associates Architects and is being constructed by PJ Dick, Inc. for a price of $23,418,000. The building's primary use is residential and it contains 7 stories of condominiums on the 2nd through 8th floors. The first floor of the building is used for retail space and as a location for extra amenities for the residents of Washington Park. The building also contains two below grade levels of parking. The enclosed parking garage contains 78 parking spaces that can be used by the residents. Two elevators and two stairs serve the parking areas that also contain resident storage, a wine room and trash collection along with mechanical and electrical rooms. The ground floor serves primarily as retail space with four separate areas available for possible tenants. Also contained on the floor are a resident exercise room and a private entrance and lobby for the residents.

As the building moves to the second floor, the function changes from primarily retail to one of solely residential with six upscale condominiums located on the floor. These condominiums each have different floor plans and layouts with overall areas ranging from 1523 ft^2 to 2288 ft^2. Each unit contains two or three bedrooms and bathrooms depending on size, along with a living room, dining room, kitchen, study, laundry, entry and in some cases a balcony. This floor layout continues throughout the next four floors, with a total of 30 units on floors 2 through 6. The 7th and 8th floors of the building are the penthouse level. This floor contains five condominiums that range from 1732 ft^2 to 2453 ft^2. These units contain the same amenities and spaces as the units on the below floors do. All of the condominiums floors are served by two elevators and two stairways that are connected by a hallway that runs through the center of the building in the long direction. Finally, the roof contains mechanical spaces that are accessed by using the northern most stairway or elevator.

The typical exterior wall system of the building consists mainly of 4" brick veneer backed by a 2" airspace and 2" of rigid XPS insulation, then containing another 2" layer of rigid spray-foam insulation that is followed by an airspace and then 5/8" gypsum board. This exterior wall system is typical for the first 6 floors of the building. The 7th and 8th floors of the building consist of a similar wall construction except for the exterior façade which is a 5/16" layer of painted fiber-cement siding.

Existing Composite Joist and Precast Concrete Plank System:

Foundations

The foundation system can be best described as a spread footing system with attached concrete piers. The sizes for the spread footings range from the smallest, a 4'-0" x 4'-0" x 2'-0" footing with #8 @ 12" each way, to a 14'-0" x 14-0" x 3'-6" footing with #8 @ 6" each way with the deepest of the footings will be 25'-0" below grade. In addition to the spread footings, interior and exterior wall footings were used and are either 2'-0" or 3'-0" wide by 1'-4" deep. The steel reinforcing in these wall footings are (3) #5 continuous bars and #5 x 1'-8" @ 16".

The slab on grade in this system consist of either a 6" or 8" normal weight concrete slab reinforced with 6x6-W2.9xW2.9 welded wire fabric or 6x6-W4xW4 welded wire fabric. The slab on grade is also thickened to a minimum if 1'-0" at non-load bearing walls and (2) #4 bars are added for tensile strength. Connecting the columns to the slab on grade and the footings are column piers that range from 16" x 16" with (4) #7 of vertical reinforcement to 40" x 40" w/ (12) #7 of vertical reinforcement and f'_c = 4000 psi concrete is used for the entire system.

Floor Systems

Two separate floors systems are typical within the structure of Washington Park. The first is a precast concrete plank system that is used in the parking areas as well as the first and second floor framing. The precast concrete plank is 8" thick and also contains a 2" thick structural topping. The reinforcing in the structural topping is 6x6-W1.4xW1.4 welded wire fabric. The precast concrete plank system bears on W shapes which then carry the load to the columns. This system was used in the parking areas because of the systems diaphragm capacity (ability to transfer horizontal loading) and because of its durability and strength.

The second primary floor system in the building is the VESCOM composite joist floor system. The composite joist system interlocks the top chord of a joist with the concrete producing less deflection, less vibration and greater stiffness. The floor construction consists of a 2 11/16" reduced weight concrete slab that is poured on top of the 1 5/16", 22 Gage galvanized floor decking. The bottom chord acts as the main tension member, and in the composite stage the embedded top chord serves as a continuous shear connection. The concrete is also reinforced with welded wire fabric and compressive strength of the concrete is f'_c = 3500 psi. Finally, the system was used as an architectural element since the ceiling could be installed directly to the joist bottom chord and the mechanical systems (HVAC, plumbing, fire protection, electrical and telecommunications) could be installed with the joist system, saving space and allowing for higher ceilings and floor to floor height within the apartments. A section of the VESCOM Composite floor system can be found in figure 2 below.

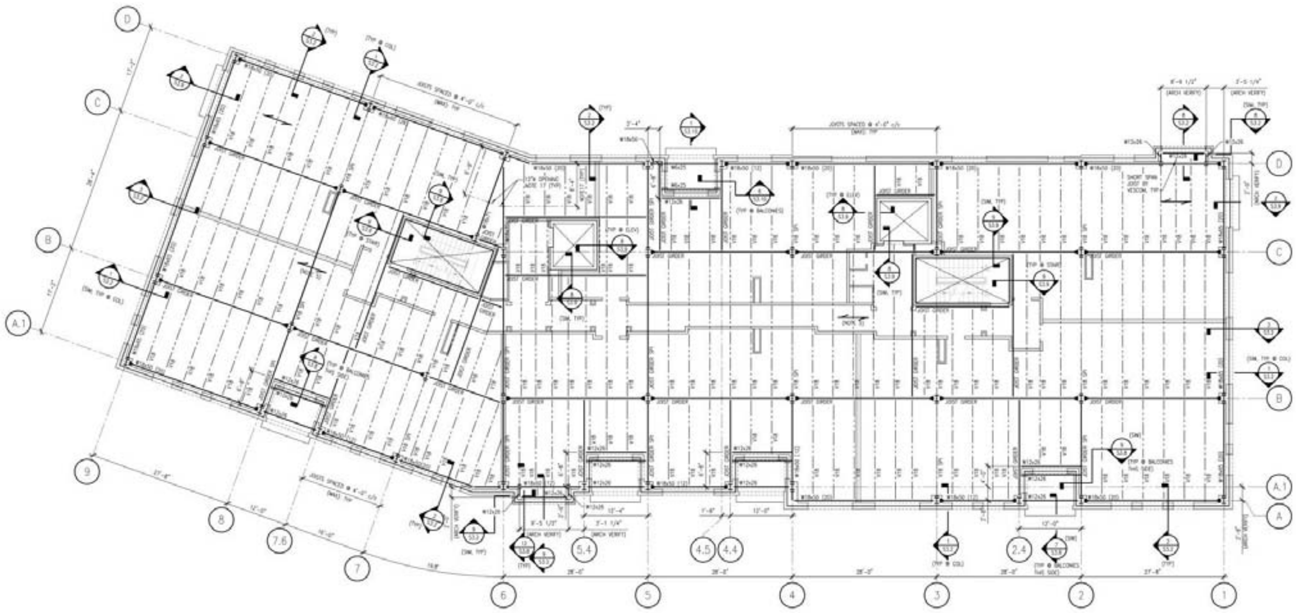

Figure 1: Typical Floor Layout

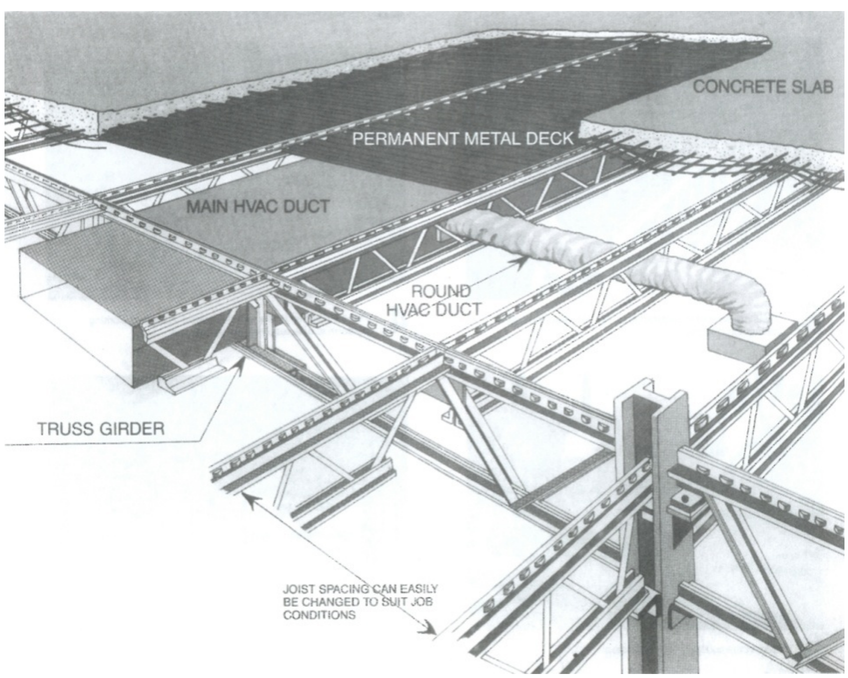

Figure 2: Composite Joist Floor System Section

Lateral System

The lateral resisting system within the building is mainly moment resisting steel frames made up of wide flange beams. These frames begin on the second floor and continue up through the top of the building. These frames run in the north-south direction and run along column lines A, B, C and D. Rigid connections also occur on these floors along column lines 1 through 9. Figure 3 shows the four different types of moment frames that exist within the building. These four frames take on the lateral load and transfer it into the rigid floor diaphragm. Since the VESCOM floor system is being used as a diaphragm to transfer shear loading, the load path begins at the exterior beams and then continues on through the floor system to joist girders which are to be designed and manufactured by the joist manufacturer. The load is then transferred into the large W14 columns, and finally to the brace frames and the foundations. There are a total of eleven braced frames located in the basement and sub-basement levels running along column lines 1 through 11 from column lines A.1 to B. The brace frames are 17'-2" in length and they begin at the sub-basement level and connect into the framing for the ground floor. The bracing in the frames consists of HSS 8x8x1/2 up to the basement level, and HSS 6x6x3/8 from the basement level to the ground floor. This plan detail and the detail of the brace frames can be found in Figures 4 and 5.

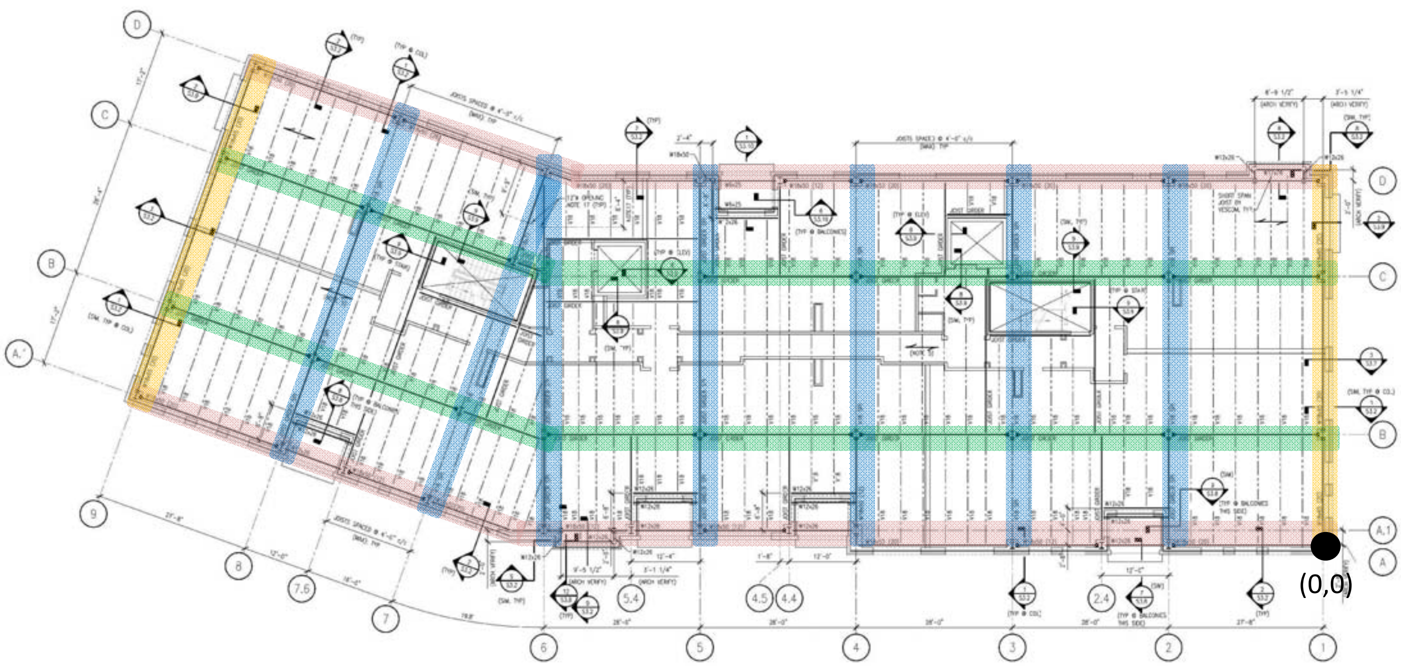

Figure 3: Moment Frame Diagram

North – South Frames (A & D)

East – West Frames (F thru L)

North – South Frames (B & C)

East – West Frames (E & M)

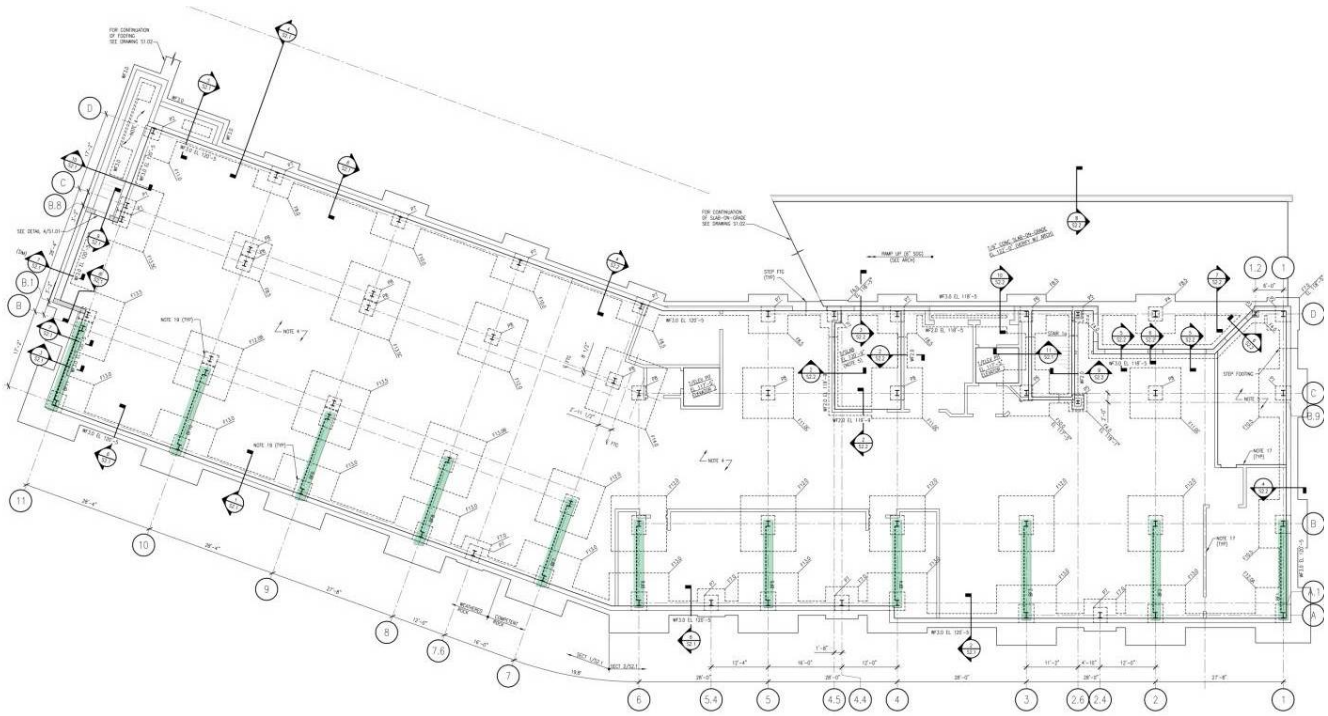

Figure 4: Braced Frame Location Diagram

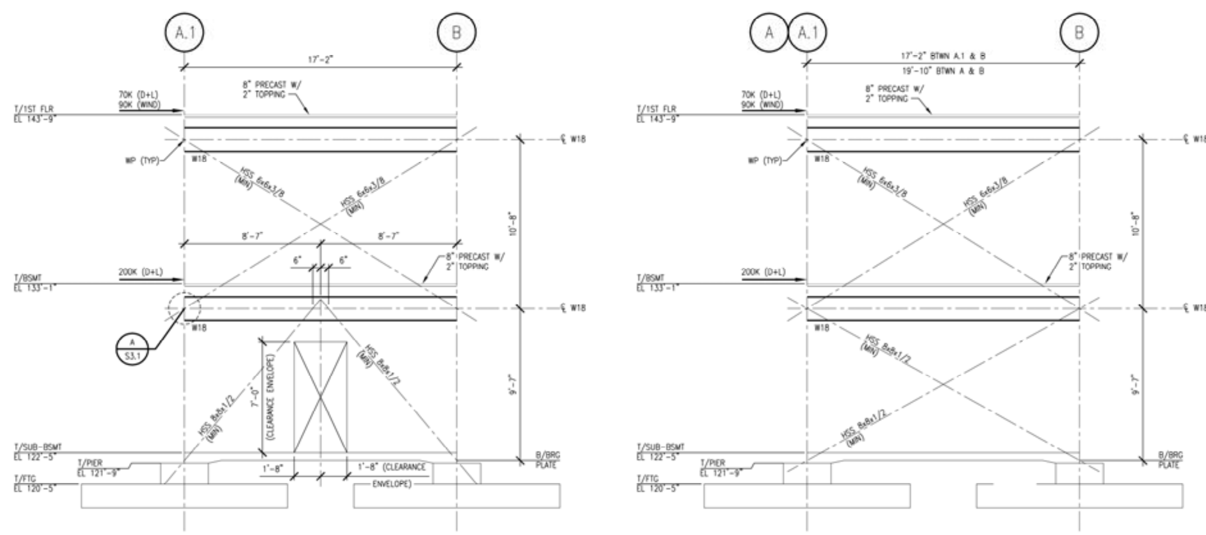

Figure 5: Braced Frames Elevation

Problem Statement

The current design of Washington Park Condominiums implements a composite joist floor system for the resistance of gravity loads and steel moment frames for the resistance of the lateral loads found on the site. These systems are sufficient in carrying the loading on the structure and also accomplish the architectural requirements. Although, the composite joist floor system is optimized for residential applications, it creates a few major problems for engineers. Since the system is used less than typical steel construction, many engineers and construction managers are not fully familiar with the system. This causes issues and delays in design and construction of the structure and ultimately costs the owner of the building precious time and money. These issues add to the notion that the current system used for the resistance of gravity loads within the structure is not the most efficient or cost effective solution.

In conjunction with the gravity load resisting system, steel moment frames are used for the resistance of the lateral loads. There are thirteen primary moment frames that can be found on floors 1 thru 8. Four of the frames run in the entire length of the building in the north-south direction while the other nine frames run the length of the building in the east-west direction. These thirteen frames use the majority of the columns, girders and beams within the frames to resist the lateral load on the building. Since most of the structure is moment frames, most of the connection between girders or beams and columns are moment connections. The connections between in the frames running in the north-south direction are primarily semi-rigid moment connections whereas the connections in the frames in the east-west direction are rigid moment connections. Both of these types of moment connections are more expensive than conventional gravity connections between beams and columns. Because of the need for so many moment frames, and therefore so many moment connections, it is likely that there is a better and more efficient structural solution available that can be used to resist the lateral loads found on the building.

Proposed Solution

Washington Park Condominiums utilizes a composite joist floor system for the resistance of gravity loads and a steel moment frames for the resistance of the lateral loads found on the site. Although these systems are sufficient to resist the loads of the site, it seems that they are not the most efficient and cost effective solutions. Because of the shortcomings that were detailed in the problem statement above a completely new structural system will be designed and implemented for Washington Park Condominiums. Before the system is designed, thorough research will be conducted on different high rise condominium buildings throughout the Mid-Atlantic region to see how the structural systems for those buildings were implemented. The focus of the research will be centered on concrete structural systems and how they perform under given gravity and lateral loading conditions. The research will also be used to determine any benefits in cost and scheduling effectiveness.

The new structural design will be a two way flat plate concrete slab system or a two way flat slab system, both utilizing cast in place concrete columns. The design will take into account the fact that the slab thickness needs to be optimized within the design so the ceiling height within the apartments can be maximized. Moreover, this system should be able to use the same column grid as the steel structure with possibly a few changes near the elevator shafts and stairways. The foundation for the building will also need to be redesigned to handle the additional load on the building. Depending on the total weight of the building the foundations could possibly remain spread footings or could be changed to a cast in place pile foundation system. Concrete shear walls will be designed to carry the lateral loads on the building. These shear walls can be placed around the elevator shafts and staircases located within the interior of the building causing minimal interference with the architectural aspects of the floor plan. One issue that will need to be studied is whether or not the placement of the shear walls will develop an eccentricity problem within the structure. If this is the case, some of the shear walls may have to be moved, or additional shear walls may be added to decrease the amount of eccentricity in the building. The concrete structural system is a possible design alternative because one of the major advantages concrete construction for high-rise buildings is the material's inherent properties of heaviness and mass, which create lateral stiffness, or resistance to horizontal movement. Occupants of concrete towers are less able to perceive building motion than occupants of comparable tall buildings with non-concrete structural systems. The ability to perceive less building motion is also important in the case of vibration caused by lateral loads, mechanical equipment and elevators.

Solution Methods

The redesign of Washington Park Condominiums will aim to utilize as many of the parameters and restraints from the original design which are determined to apply as possible. Furthermore, ASCE 7-05, and ACI 318-08 will be used as the basis for the new design. The flat plate or flat slab concrete floor system will be designed using the existing column grid as a way to minimize the architectural impact on the building's layout. A computer model using ETABS will then be generated for both the existing structural steel system and the new concrete system. The output from ETABS will also be backed up by hand calculations, just as was done in Technical Reports 1 thru 3. Through the assessment of the two models a difference in vibrations, deflections and story drift can be determined so that a comparison can be completed in order to discern the most efficient structural system.

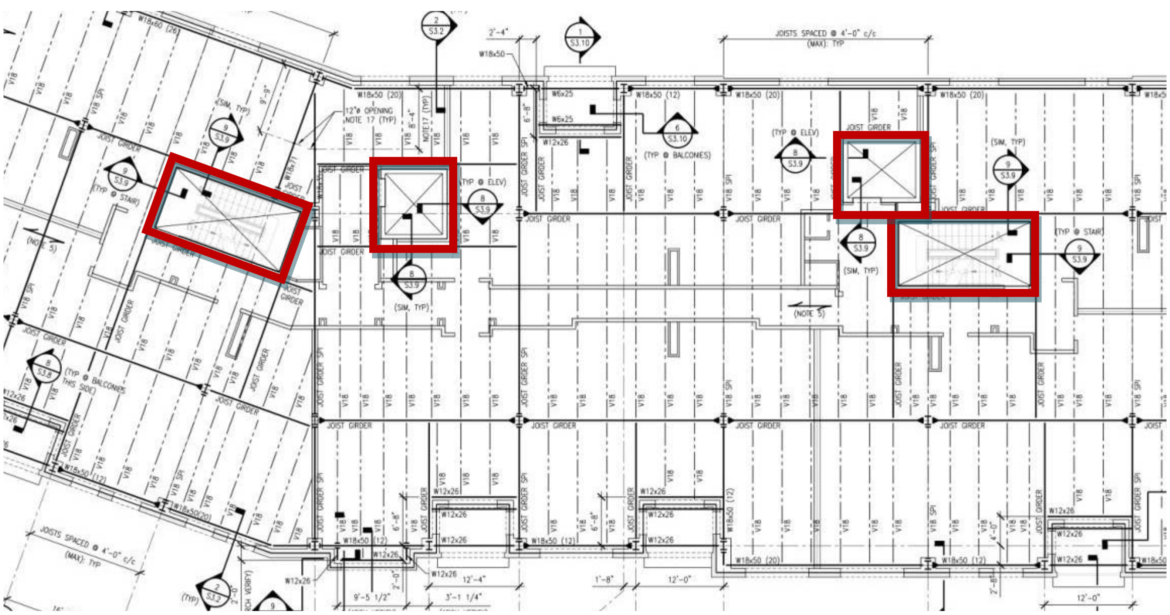

Figure 6: Possible Shear Wall Locations

After the results of the gravity and lateral system redesigns are completed, a redesign of the foundation system will also be necessary to meet the requirements of the additional structure weight and shear walls added. Most likely the current spread footing foundation system will have to be changed to a cast in place pile system, with thickened slabs and possible strip footings to support the shear walls. Finally, a cost breakdown and comparison will be completed using information provided by past thesis projects with the same structural system and comparing them to the cost figures determined earlier in Technical Report #2.

Breadth Options

Breadth Study 1: Structural System Acoustical Performance

The different spaces that are included in the building lead to the possibility of sound transmission between floors caused by the close proximity of busy retail spaces and the private condominiums. Also, the amount of unwanted vibration experienced by tenants caused by HVAC equipment as well as the elevator equipment is a concern. This particular concern was expressed by the owner of the building during a meeting with him before the beginning of the project. This study will be conducted using the current structural steel system as well as the new flat plate concrete system. The two systems, along with a typical living space, will be acoustically analyzed using decibel levels as well as STC and sound transmission values so that the results can be compared and presented to the owner. Ultimately, a modification of the wall and/or ceiling cavities may need to be done to suffice the acoustical requirements of the owner and the tenants.

Breadth Study 2: Architectural Detailing and MEP Distribution

As a result of the structural system of Washington Park Condominiums being changed from a composite steel joist system to a flat plate concrete slab system, the architectural details will also need to be modified. More specifically, electrical, mechanical and plumbing systems will need to be modified so that they will fit in with the new ceiling cavity and the new structural system. The modification of the structural system may lead to a redesign of duct sizes and placement throughout the ceiling cavity. These systems are the most important systems to the patrons of the building and will need to be adapted in a way that doesn't impact the individual living spaces. A comparison between the details provided by the architect and the details produced for this study will then be compared for ease of construction, impact of living space and ultimately cost.

Tasks and Tools

I. Redesign of Structural System

Task 1: Confirm all gravity and lateral loads on the structure, using ASCE 7-05

a. Revise loads for concrete structure modifying seismic, wind and gravity loads
b. Discuss results with thesis consultant

Task 2: Preliminary Gravity Load Design

a. Establish preliminary slab thickness and exterior beam sizes using PCA Slab
b. Establish preliminary column sizes using the CRSI Handbook

Task 3: Preliminary Lateral Frame Design

a. Establish preliminary shear wall Locations
b. Locate openings in shear walls
c. Establish preliminary shear wall sizes using hand calculations

Task 4: Analyze gravity and lateral systems

a. Create ETABS model for new concrete structure.
b. Analyze and check: slab thickness, slab and beam strength, and deflections for gravity loads
c. Analyze and check: shear strength, overturning moment, drift, story drift, fundamental period and design of shear walls for lateral loading
d. Compare new design to results found from existing structural system

Task 5: Other Redesign Considerations

a. Complete spot checks on typical bays for controlling load cases
b. Redesign foundations based on new system weight and loads
c. Determine impacts of redesign on cost and scheduling

II. Breadth Studies

Task 6: Structural System Acoustical Performance

a. Calculate reverberation time and decibel levels for existing steel system
b. Calculate sound transmission class (STC) of existing steel system
c. Calculate reverberation time and decibel levels for new concrete system
d. Calculate sound transmission class (STC) for new concrete system
e. Identify problem areas and redesign wall/ceiling cavity
f. Compare systems and determine any cost implications

Task 7: Architectural Detailing

a. Research architectural details for both structural systems
b. Research how HVAC systems integrate with varying structural systems in high rise condominium structures
c. Develop new details for wall and ceiling cavities for the concrete system
d. Identify possible problems with new details and existing details provided.

e. Determine impacts of details on overall design and construction.

III. Report and Presentation Development

Task 8: Develop and write Depth and Breadth reports

Task 9: Create Presentation on PowerPoint

Task 10: Present research to faculty board

Timetable

Task	Weekly Schedule: January and February						
	1/12 - 1/16	1/19 - 1/23	1/26- 1/30	2/2 - 2/6	2/9 - 2/13	2/16 - 2/20	2/23- 2/27
1							
2							
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10							

Task	Weekly Schedule: March and April						
	3/2 - 3/6	3/9 - 3/13	3/16- 3/20	3/23 - 3/27	3/30 - 4/3	4/6 - 4/10	4/13- 4/17
1							
2							
3							
4							
5							Present to Faculty Board
6		Spring Break					
7							
8							
9							
10							

Task 1: Confirm all gravity and lateral loads
Task 2: Preliminary Gravity Load Design
Task 3: Preliminary Lateral Frame Design
Task 4: Analyze gravity and lateral systems
Task 5: Other Redesign Considerations
Task 6: Structural System Acoustical Performance
Task 7: Architectural Detailing
Task 8: Develop and write Depth and Breadth reports
Task 9: Create Presentation on PowerPoint
Task 10: Present research to faculty board

Conclusion

The purpose of the thesis research for the spring semester is to determine how the structure can be changed to create a better overall building. Completely changing the gravity and lateral framing systems in the building from steel to concrete is a drastic change which is warranted through research of other similar projects and issues that were encountered during the analysis of the original structure. This complete redesign of the structure leads to the breadth studies which will be completed. The acoustical study was not only requested by the building's owner but also is relevant due to the known acoustic issues inherently encountered in steel buildings. Finally, the architectural details breadth was born out of the changing structure as a means to research and discuss the modifications necessary in the various systems when the structure is changed from steel to concrete. Ultimately, the goal of this research is to determine why the structural engineer made the choices that led to the use of a certain structure and to make our own design choices based on knowledge that has been gained within the classes offered in the Architectural Engineering curriculum. In the end, these are all beneficial aspects that play a major role in the maturation of young structural engineers making the transition from college to the workforce.