Thesis Proposal

Falls Church Tower

Falls Church, VA

Nathan Eck

Structural Option

Consultant: Dr. Memari

January 14, 2011

Table of Contents

Executive Summary

Falls Church Tower is a fairly complex building. This is mainly due to its long, curved midsection which connected to shorter section s at either end that run almost perpendicular to the midsection. Add to this the fact that the floor area decreases as the building's height increases. For these reasons the engineers developed a complex layout for gravity and lateral load resisting systems. The gravity system consists of a flat plate system with post tensioned strands running in the North-South direction. The lateral system consists of an irregular array of columns with a variety of sizes .

Due to this complexity the building was modeled in ETABS in order to determine such factors as shear, bending, and drift. The analysis of the building showed that the story drift of the mechanical roof was too large. Additionally there are a set of 12”x48” that need to be re-evaluated for strength.

The purpose of this thesis will be to redesign the lateral force resisting system using shear walls around the elevators and stairwells. This will change the loads in the columns which can then be resized accordingly. With this change in column sizes comes a change in overall building cost. Additionally the column layout will change which will have an effect on the floor plans.

Introduction

The Falls Church Tower is a luxury apartment building located in Falls Church, Virginia. The high rise apartment building stand eleven stories tall with penthouse on the main roof. Three and a half levels of parking are offered beneath the building and private pool sits adjacent to the plaza. The building encloses 364,000 square feet of gross floor area which excludes mechanical rooms, underground rooms, and garage space. The first floor contains the lobby, a residential gym, and a lounge as well as some living space with the remaining floors serving as strictly residential space. Overall the building contains 213 residential units with a wide view of the surrounding area courtesy of the building's curved facade. The structural system of the building is primarily concrete consisting of retaining walls, columns, post-tensioned slabs, and beams. The lateral system is composed of the aforementioned columns and slabs which form and ordinary concrete moment frame.

Foundation

The foundation system of Falls Church Tower was designed in accordance with the geotechnical report provided by Whitlock, Dairymple, Poston and Associates. The report indicated a soil bearing pressure of 4 ksf along the southern face of the tower and a bearing pressure of 10 ksf for the remainder of the structure.

The foundation system from levels B3 Ext. through B1 consist of retaining walls, spread footings, and a precast slab on grade. The retaining wall runs the full perimeter of the building with a thickness of 1'-4"on the B3 Ext. level and 1'-0" for B3 through B1. The footings under the retaining walls have a width ranging from 2' to 3'. The 2' width is used for sections of the buildings where the B1 retaining wall is offset towards the interior of the building by 3'-6". A section of a typical retaining wall can be seen in Figure 1-2 and Figure 1-3.

The column footings have a range of 6'x6' to 12'x12' throughout the structure. The larger footings (10'x10' to 12'x12') being located in the basement parking section beneath the plaza. A typical footing detail can be seen in Figure 1-1. The slab on grade is 5 ksi, normal weight concrete that is 5" thick with 6x6-W2.0xW2.0 welded wire fabric placed on a vapor barrier on top of 6" of #57 washed crushed stone.

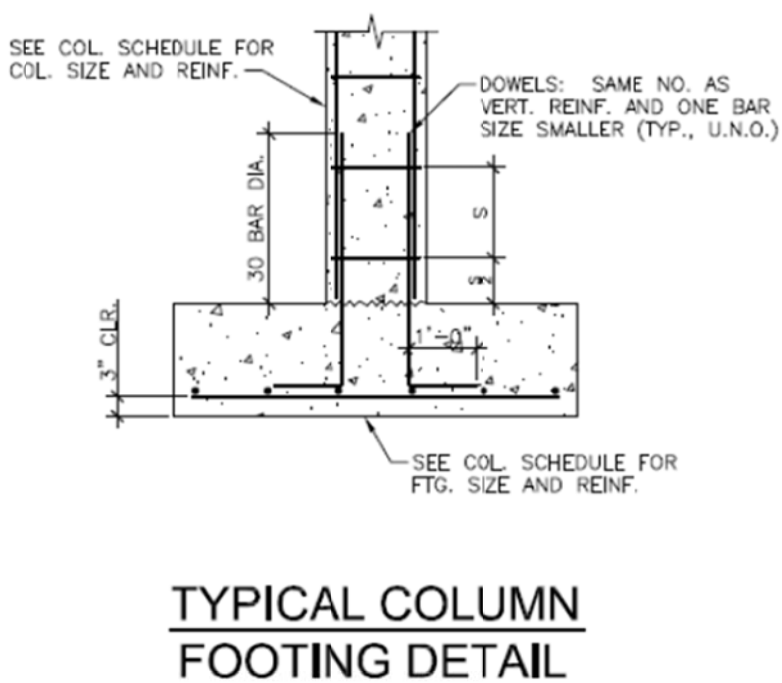


Figure 1-1

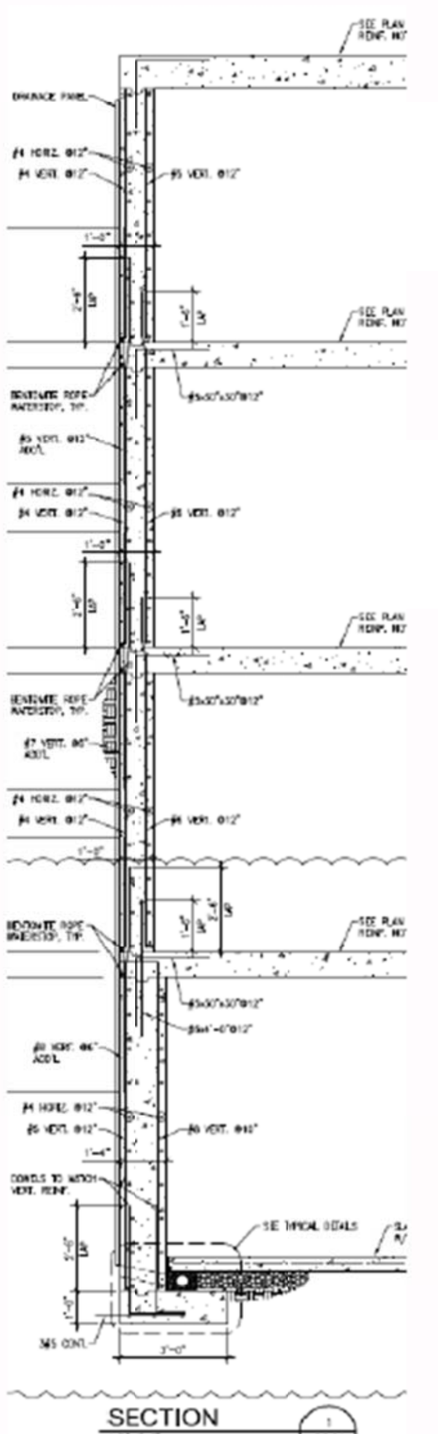


Figure 1-2

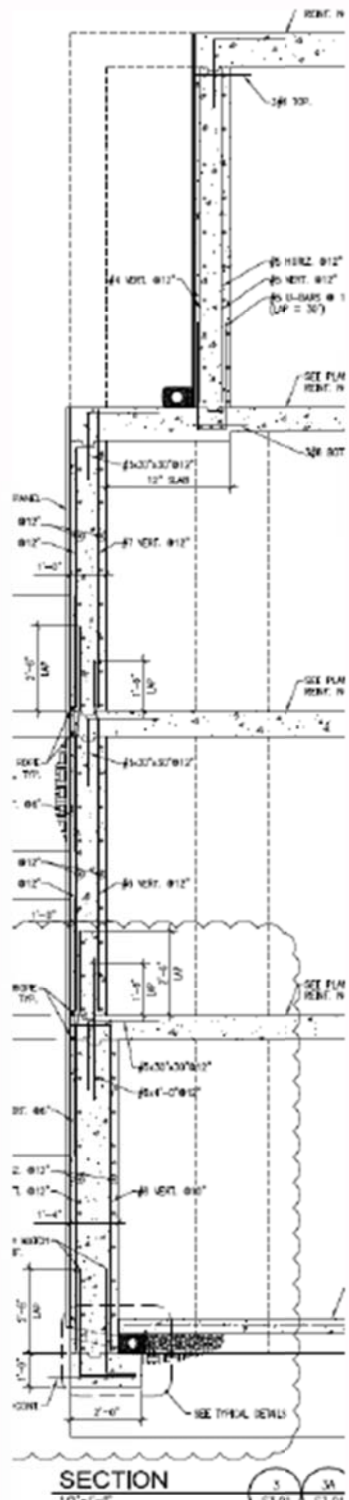


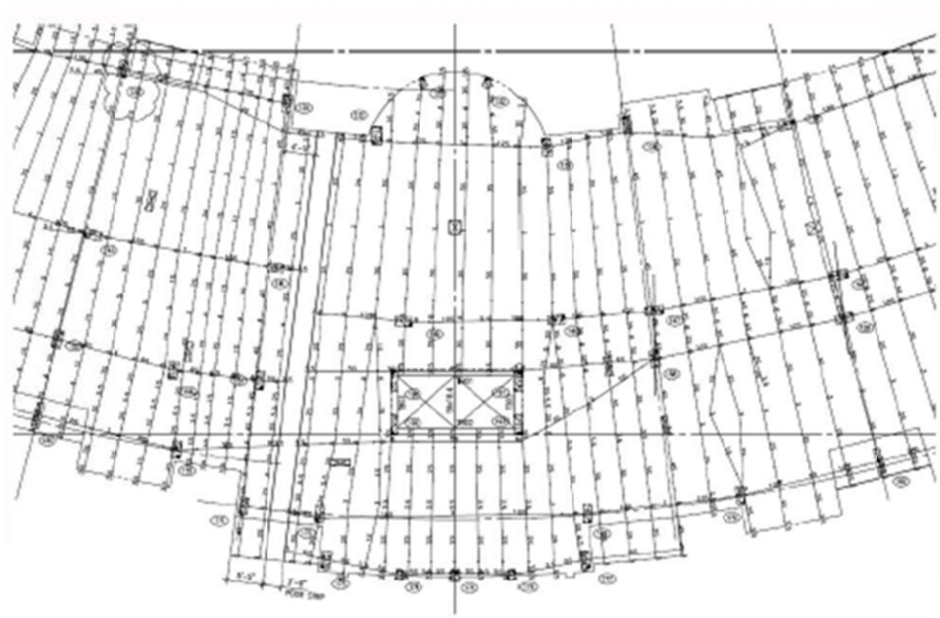
Figure 1-3

Gravity Load System

The main gravity load resisting system is composed of a flat plate supported by an intricate array of columns. Levels B3 Ext. through B1 plate systems are typically a 5 ksi, 9” thick, normal weight slab with a two way mat of #4 bottom bars at 12” on center except for slabs on grade which are 5 kis, 5” thick normal weight concrete. The penthouse roof and the elevator machine room roof use a 6” thick, one-way slab with the same properties and is support by a system of concrete beams. The plate systems from level 1 through the main roof utilize a 7” thick post tensioned slab. The typical tendons are two to three strands thick and spaced 5' on center. For a typical post tension layout plan refer to Figure 1-4.

The tower columns don't necessarily have a standard bay size due to the building's curved shape and the stair cases in both the east and west wings which interrupt any attempt at a rectilinear layout. The most typical bay size established throughout the building would be the 28'x24' bays located in the western half of the building's curved section. A standard column layout can be seen in Figure 1-5

In addition to the flat plate system the structural engineers also incorporated concrete beams into the design where necessary. As previously mentioned a system of beams is used to support the penthouse and mechanical room roofs. There are also strap (grade) beams used in the west section of B3 Ext. foundation and the east edge of B3 foundation which can be seen in Figure 1-6. Lastly, beams are used to frame all stairs and elevator shafts.



FOURTH FLOOR POST TENSION LAYOUT PLAN

Figure 1-4

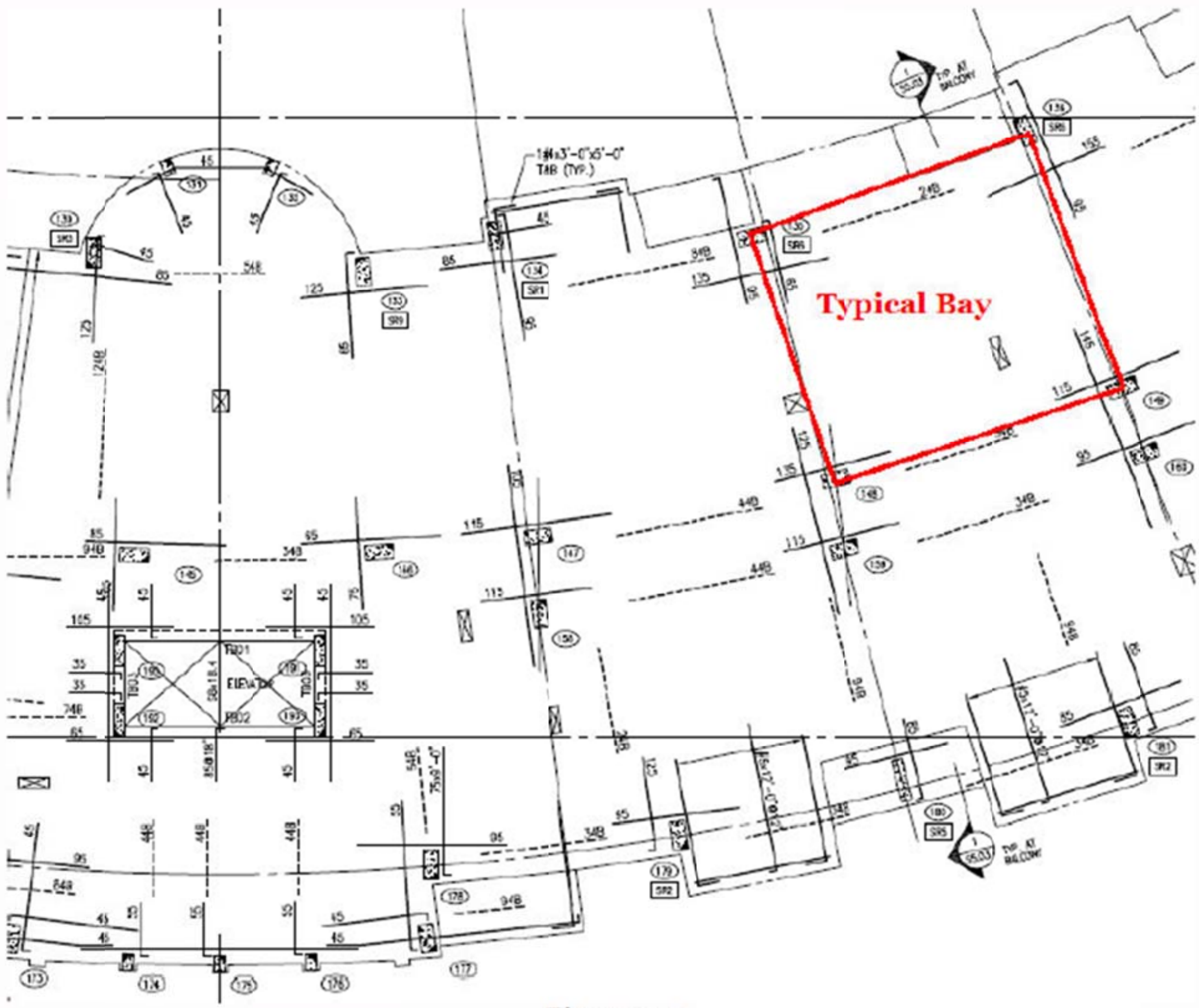


Figure 1-5

Lateral Load System

The lateral system of the building is an ordinary concrete moment frame. The tower columns' dimensions range from 12” to 24” on the short face and 12” to 48” on the long face. The two most typical columns that occur throughout the building are 16”x32” and 12”x36”. The 16”x32” dimension is common for most of the interior columns whereas the 12”x36” columns are used to frame the stairs and elevator shafts. The irregular layout of the columns is shown in Figure 1-6.

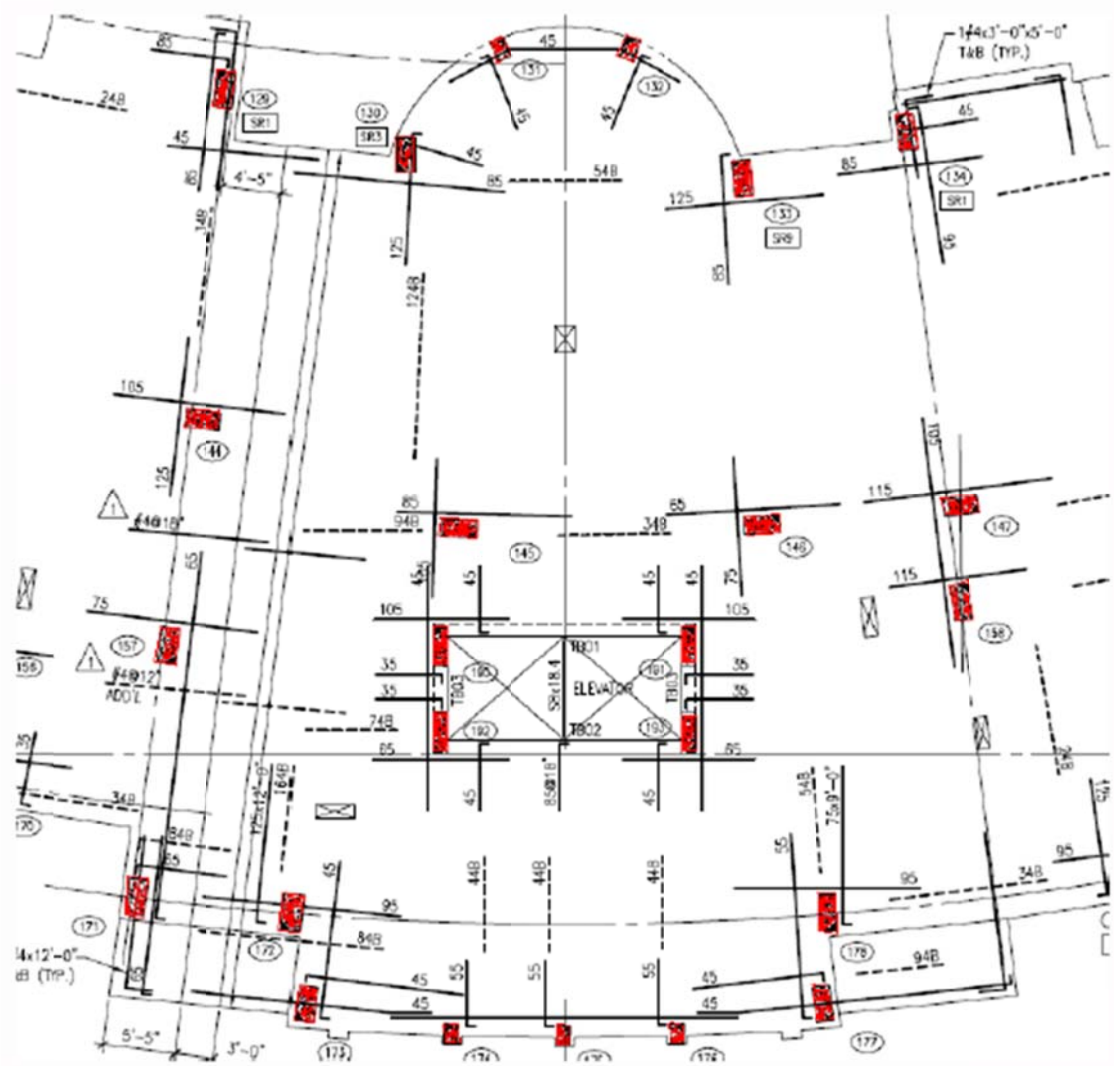


Figure 1-6 : Column Layout

Problem Statement

As determined in technical report three, some serviceability and strength issues exist within the building. Starting with serviceability, the mechanical roof system experienced a total story drift of 0.196” resulting from wind loads in the North-South direction. This exceeded the allowable story drift of 0.17”. This drift was the result of ETABS considering the separate mechanical roofs as a single diaphragm. The western roof is supported by 12”x36” columns with the larger dimension running in the North-South direction which gives them sufficient stiffness to resist lateral loads in that direction. The Eastern mechanical roof is supported by the same columns but these column are arranged with the larger dimension running in the East-West direction. This provides less stiffness and thus less strength to resist lateral loads in the North-South direction.

From technical report three it was found that a 12”x48” column on the first floor lacked the strength needed to support both axial loads and bending forces. It is still unclear as whether or not an error occurred in the analysis of that column. However, if there is no error then it needs to be redesigned along with other columns of the same type.

Proposed Solution

In order to solve both of the aforementioned problems the lateral force resisting system should be reevaluated. By incorporating shear walls around the central elevators, the east and west stairwells, and other keys points throughout the building the moment frame could be eliminated or at the very least reduced. Shear walls around the stairwells would provide ample stiffness in both directions, thus reducing the story drift of the mechanical roof. In addition, the shear walls would carry a majority of the lateral forces thus reducing the moments in the 12”x48” columns.

The assessment ans re-evaluation of the building lateral force resisting system will be conducted using ETABS. Multiple shear wall layouts will be examined and the layout that performs most efficiently will be used. After choosing the shear wall layouts the breadth topics will be addressed.

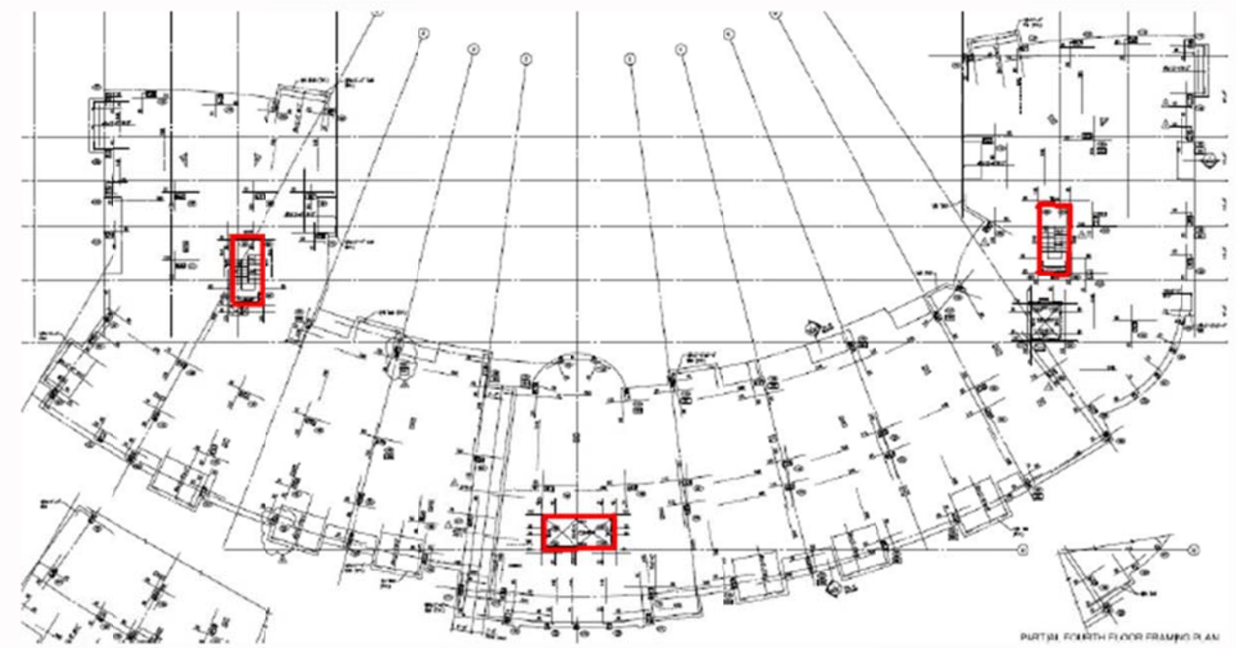


Figure 2-1 : Shear Wall Placement

Breadth Topics

Effect on Construction

Incorporating shear walls as the main lateral force resisting system will necessitate the redesign of the columns and even the column layout. The following topics will be researched and analyzed during the spring semester.

- The change in the amount of labor hours
- Type of laborers needed
- The amount of money saved by reducing column sizes
- The effect of shear wall installation on other systems and sequences of Installation

The substitution of shear walls as the primary means of resisting lateral forces adds another element to the construction schedule of the building. With these shear walls one must consider the number of crews needed to complete the shear wall installation so as not to increase the duration of the building's original construction phase. The cost in labors hours of the crews will be based upon the number of crews needed and amount of time it takes to complete the task.

In additions to the labor cost one must also take into account the material cost of the shear walls, the formwork, and any support required. Add to this the material cost of the resized columns and the factors associated with them and the overall cost of the building will show substantial change.

Finally the installation of shear walls may affect the construction schedule. The construction of shear walls may take more time than the construction of standard columns. If this is the case then research must be done to determine whether or not this process can be expedited by the addition of laborers and/or a change in materials (i.e. quick drying concrete). Furthermore the incorporation of shear walls may affect the delivery date of other systems such as floors and HVAC.

A majority of the material needed to cover the construction breadth was taught in AE 372 but further research and additional resources will be required to complete the analysis.

Effects on Architecture

By implementing shear walls the overall column layout will be subject to change. A more organized pattern will be incorporated based on the curved shape of the building's midsection. As the building is currently laid out, the columns have no grid to which they conform and the irregular placement and orientation of the columns suggests a "guess-and-check" method of structural design. Shear walls will reduce the need for rectangular columns and allow a more uniform layout. This layout would include moving columns to the exterior to break up the horizontal continuity of the facade. This creates the illusion that the building is smaller than it seems thus making more of an impression on occupants when they enter the building.

The redesign of the column layout will mean altering the apartment modules based on the new location of the columns. Apartments may have to be lengthened, widened, or merely shifted to accommodate the new layout. This would also have an effect of the location of balconies and windows.

Tasks and Tools

I. Design Shear Wall Layout
- A. Develop multiple layouts
- B. Model in ETABS
- C. Choose the most efficient layout
- D. Redesign columns and layout

II. Construction time line and cost analysis
- A. Material cost
- B. Labor hours
- C. Labor cost
- D. Scheduling change

III. Architectural systems
- A. Alter floor plan
- B. Alter fenestration

IV. Compose Final Report and Presentation