Thesis Proposal

Advisor: Boothby
12-12-2005

Executive Summary

The Christina Landing Apartment Tower is a 22 story apartment building located just outside center city Wilmington, DE. The tower provides 250,000 square feet of floor space. The structure is a predominately cast-in-place concrete building. Its floors are supported by a two way flat slab system. The typical floor system also incorporates small areas of reinforced concrete and post-tensioned beams to aid the lateral force resisting system. The floors are supported by square and round concrete columns. Lateral forces induced on the building are resisted by a box of four shear walls. All columns and shear walls rest on a foundation system of H-piles and pile caps. Typical floor loads are 130psf dead load and 40psf live load.

The proposed thesis will include an investigation of two alternate structural systems as well as two breadth studies for the apartment building. The first structural redesign will be changing an 8” reinforced concrete slab framing system to a 7” post-tensioned slab. The goal of this redesign will be to decrease material cost. The second redesign proposed will involve eliminating the structure’s concrete moment frames and replacing them with shear walls on the east face of the building. The goal of this redesign will be to reduce material and labor costs, as well as decrease the total building deflection. The two breadth studies that will be undertaken will be a cost comparison between systems, and an acoustical redesign.

Thesis Background

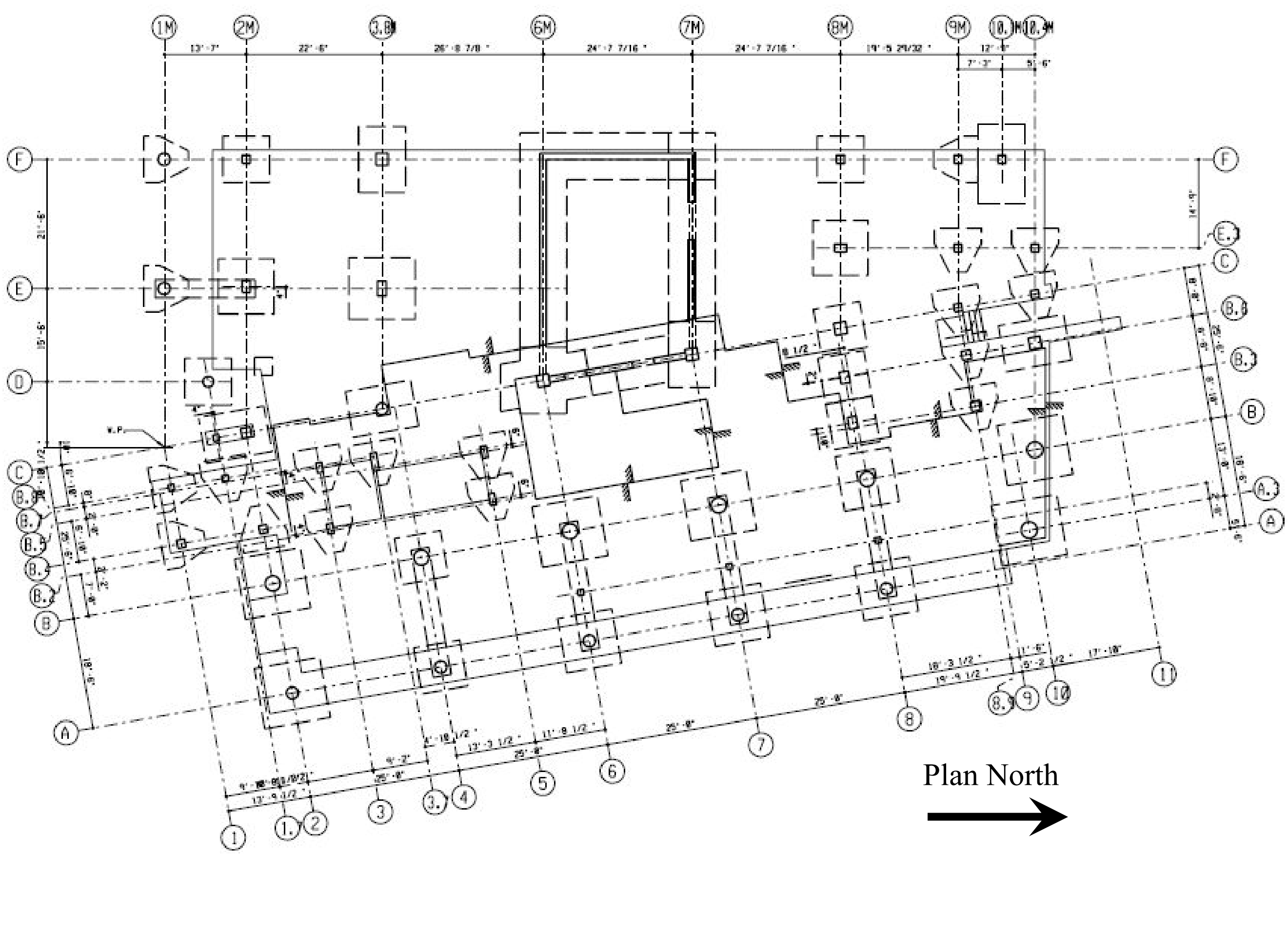
Building Introduction

The Christina Landing Apartment Tower is a 22 story apartment building located just outside center city Wilmington, DE. The tower provides 250,000 square feet of floor space and its footprint covers approximately 12,000 square feet. The typical floor to floor height (floors 3-20) is 10 feet, while the common spaces on the first and second floors and the penthouses on the 21^{st} and 22^{nd} floor have 12 foot floor heights. The total building height is 230'. The structure is a predominately cast-in-place concrete building. Its floors are supported by a two way flat slab system. Spans between columns are on average approximately 20 to 25 feet. Other than the bays that contain slab openings, the typical panel ratios range from 1:1 to 1:1.5 (see page 5 for framing plan). The typical floor system also incorporates small areas of reinforced concrete beams and post-tensioned beams in the plan-northeast and southeast corners to aid the lateral force resisting system. The floors are supported by square and round concrete columns. Column sizes for typical bays are 2' square or 2' round columns. For columns that surround slab openings and support smaller spans, sizes range down to 12"*12". Column sizes seldom vary from floor to floor although reinforcement frequently changes. Lateral forces induced on the building are resisted by a box of four shear walls located in the center of the west wall. Because of the large torsional force created by the eccentricity of the center of rigidity, the regions of post-tensioned concrete moment frames are used to provide extra stiffness. All columns and shear walls rest on a foundation system of H-piles and pile caps. Concrete strengths differ throughout the structure, ranging from 4000 psi to 8000 psi (see page 4 for concrete strength schedule.)

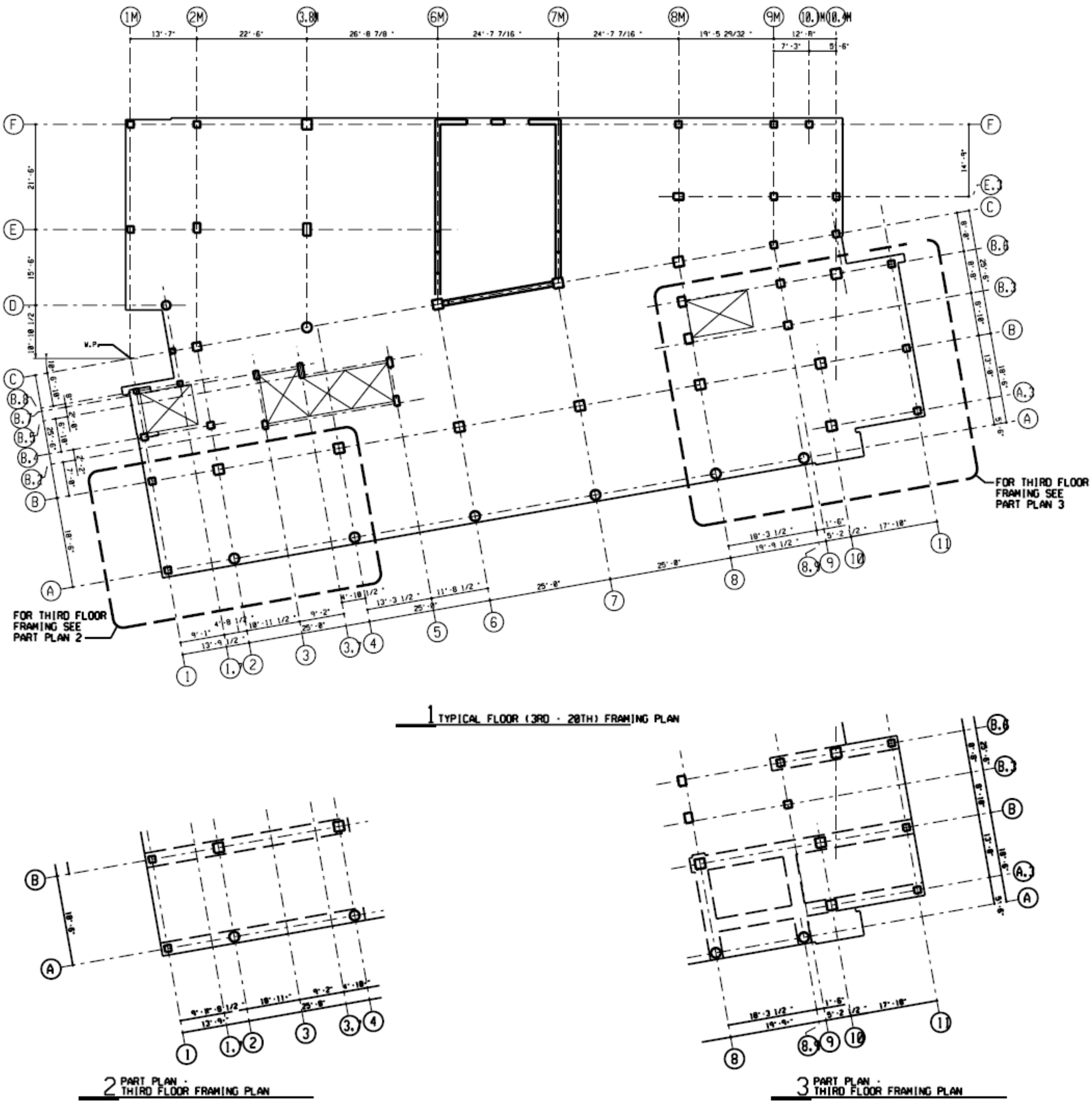
<u>This report will cover, in order, the following areas</u>:
Thesis Background
Problem Statement
Proposed Solution
Solution Method
Tasks and Tools
Timetable

Concrete Strength Schedule	
Element	28 Day Cylinder Strength (psi)
Pile Caps	4,000
Slabs 5th Floor and Above	4,500
Slabs Below 5th Floor	5,600
Columns 5th Floor and Above	5,000
Columns Below 5th Floor	8,000
Exterior Slabs and Paving	5,000
Shear Walls	5,000
Topping Fills	4,000

1st Floor Framing Plan

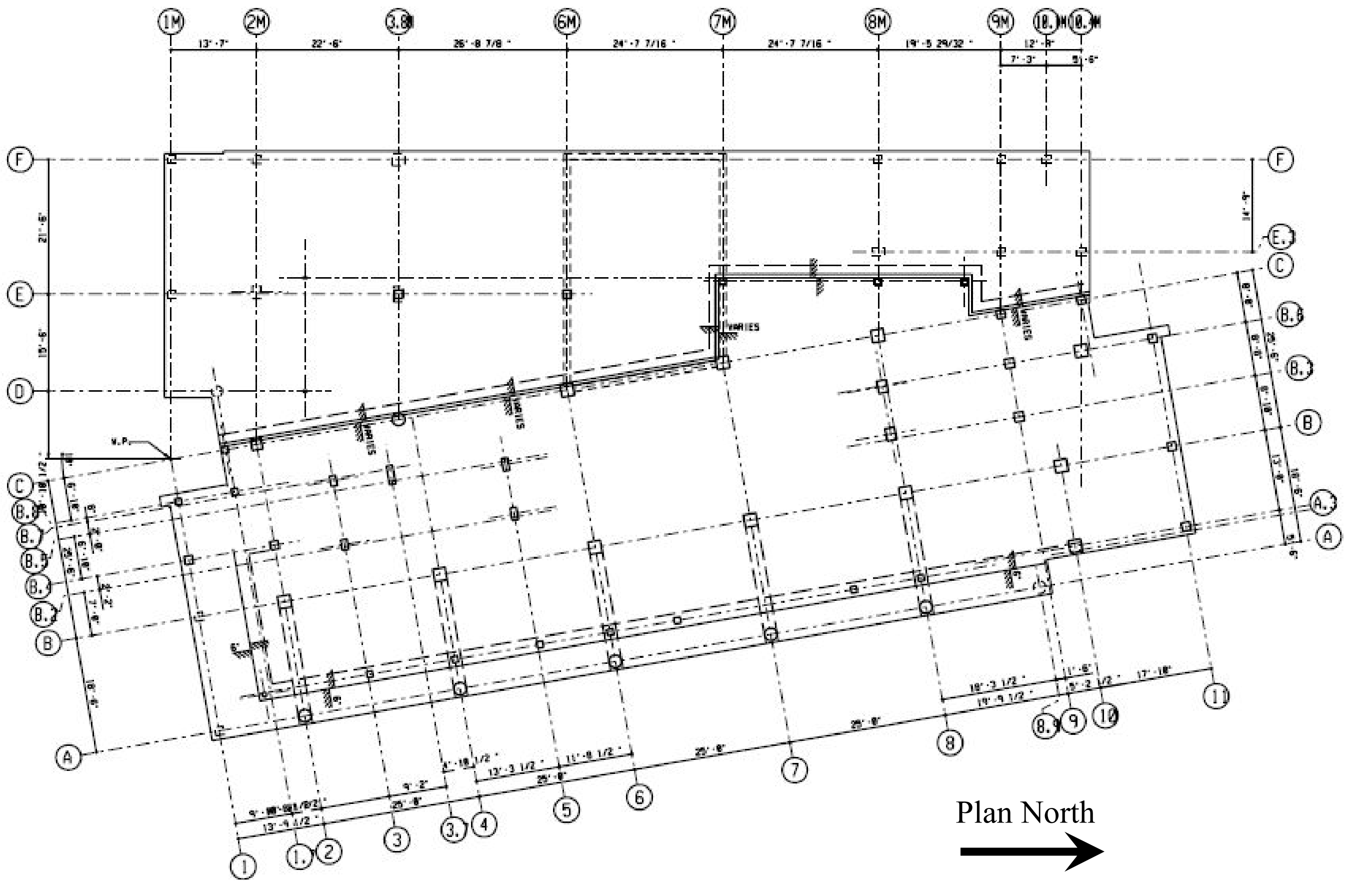


Typical Framing Plan



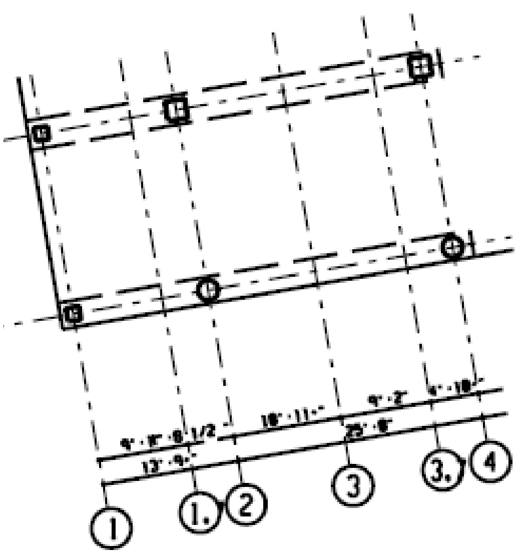
Plan North

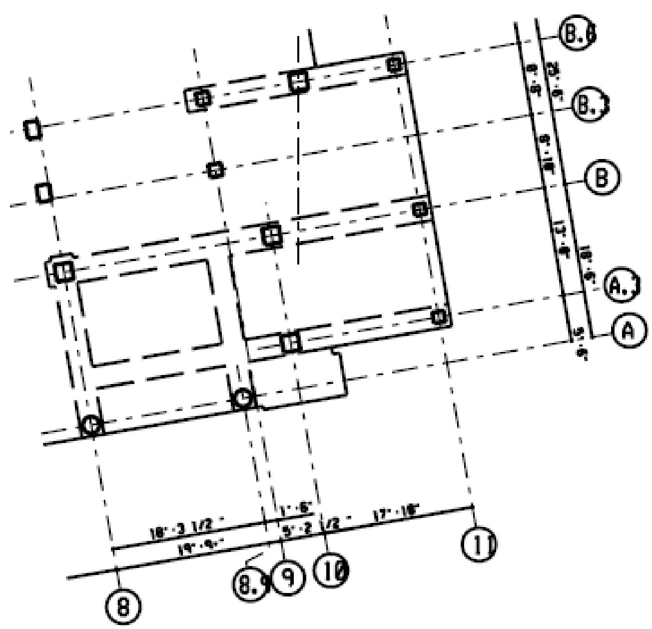
21st Floor Framing Plan



Existing Slab and Framing System

All the floors in the building have the same two way flat slab system, including the roof and the ground floor. Spans between columns are on average approximately 20 to 25 feet. Other than the bays that contain slab openings the typical panel ratios range from 1:1 to 1:1.5 (see page 4 for framing plan). The typical floor system also incorporates small areas of reinforced concrete beams and post-tensioned beams in the plan-northeast and southeast corners to aid the lateral force resisting system. The slab its self is an 8” slab with #6 bars at 10” on center, each way in the top and #4 bars at 10” on center, each way in the bottom. The strength of the concrete in the floor system is 5,600psi from the ground floor to the fifth floor and 4,500psi above the fifth floor. The post-tensioned members in the corners of the floors are 36”x 60” and vary in tensioning force. The members in the north-south direction have a higher force for the fact that they are longer spans and this is the principal direction in which the lateral force resisting system needs extra stiffness (see diagram below for clarification).

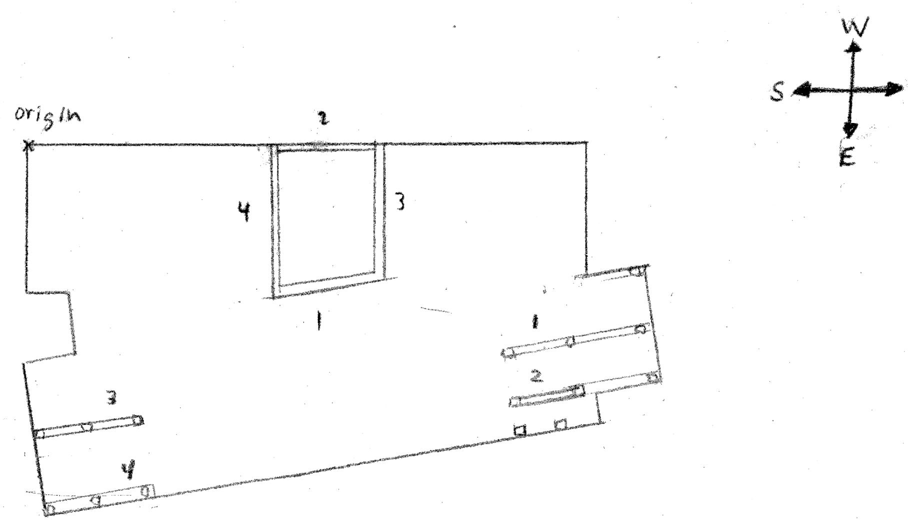


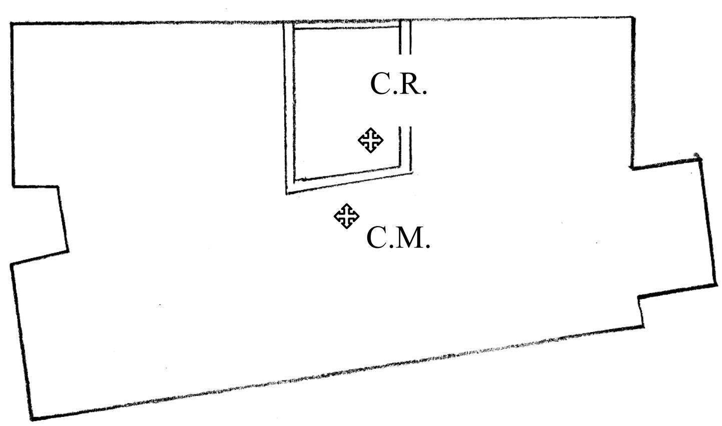


Plan North

Introduction of Lateral System

The lateral system of this building consists of both shear walls and concrete moment frames. There are four shear walls in the tower arranged in a box at the center of the west wall. The walls are connected at the corners and act in unison to allow for shear flow. For ease of analysis it was assumed that all four walls are perpendicular to each other by conservatively adjusting their lengths. All of the walls are 12" thick with #4 bars at 12" on center each way in each face. Two of the walls are 32' and two of the walls are 24'. The building has 7 concrete moment frames. The lateral analysis included the 4 frames that have the most significant affect on curbing the large torsional force produced by a north-south wind. The frames are located in the north-east and south-east corners of the tower. Although the bay sizes vary, each of the 4 frames include 3 columns: 2-24" square, and 1-16" square. The columns are connected by 36"x60" post-tensioned beams.





Problem Statement

To this point in the thesis research the existing conditions of the Christina Landing Apartment Tower have been analyzed, and have shown that both the existing framing and lateral systems are highly successful systems for the building type and location. In technical assignment 2 the existing 8" flat slab was found to be the thinnest possible slab for that type of system. In technical assignment 3 it was shown that the lateral system had a deflection of L/350. The goal of the remainder of this thesis will be to attempt to make both the framing and the lateral systems more efficient by redesigning them. The goal of any structural engineer is to find the most economical design while keeping serviceability requirements in mind. Any change made to the existing structure will impact labor cost, material cost, and job schedule. It is important for engineers to remember these are the issues that should influence their design. The focus of this redesign will be to attempt to find alternate floor and lateral systems that improve the balance between cost, schedule, and serviceability.

Proposed Solutions

Floor System Redesign:

Technical assignment 2 investigated the possibility of using a post-tensioned slab for the building. Using a span/depth ratio of 45 it was found that the minimum slab depth to be approximately 7”. It seems that according to prior calculations total reinforcement tonnage will also be saved for the job. While this solution saves material cost it may be found to increase labor cost as well as schedule. One goal of the semester ahead will be to investigate the potential savings versus costs for this system.

Lateral System Redesign:

Technical assignment 3 found the deflection of the building to be approximately 8” which is a large deflection for the height of 230’. It may be possible that this large deflection can be reduced by eliminating the large torsional shear force due to a north-south wind load. In order to eliminate these forces one option would be to remove the concrete moment frames from the building and replace them with shear walls on the east face. The walls size and position will be determined by making their resultant center of rigidity as close as possible to the center of mass.

Solution Method

Floor System Redesign:

The slab will be designed according to post-tensioning guidelines set in ACI 3-18 2005. The initial post-tension slab calculation will be done for a typical group of bays. After establishing an initial slab thickness the post-tensioning and standard reinforcing will be designed for. Finally, if available the calculations will be checked using a structural design software. Please see Tasks and Tools for a more detailed description of this process.

Lateral System Redesign:

The shear walls will be designed according to shear wall guidelines set in ACI 3-18 2005. It will first be necessary to find all story shears on the wall in question. After this is calculated the story forces will be entered into a structural design software to find the wall's total drift. Please see Tasks and Tools for a more detailed description of this process.

Tasks and Tools

1. Floor System Redesign
   a) Assume slab thickness based on design guide
   b) Find allowable stresses in the extreme tension and compression areas of the slab
   c) Find maximum moment in slab and maximum eccentricity of strands
   d) Find optimal prestressing force
   e) Determine the number of strands needed
   f) Determine the amount of standard reinforcing needed for flexural strength requirements
   g) Detail slab
   h) If available check solution in computer program

2. Lateral System Redesign
   a) Determine size and location of the new shear wall resulting in a center of rigidity which matches the center of mass
   b) Find the stiffness of the new shear wall using an Excel spreadsheet
   c) Redistribute the lateral forces per floor based on stiffnesses of the shear walls per floor
   d) Find the story shears on each shear wall
   e) Use RAM Advanse or similar software to enter story forces and find building deflection

3. Cost Comparison of Systems
   a) Using present day material costs, determine material savings between systems
   b) Using Means Building Construction Cost Data, determine labor cost between systems
   c) Research both the current and new systems for constructability data to determine schedule impacts
   d) Compare all findings and suggest whether the new system is worth while

4. Acoustic Analysis
   a) Determine key areas of acoustic concern
      -Walls between apartments

-Floor between gym and apartments

b) Research wall systems that decrease sound penetration

c) Complete acoustic calculations for existing barriers as well as several alternate systems

d) Suggest viable alternatives to existing design

Breadth Studies

Construction Management:

For my first breadth study I will investigate the differences in cost between the existing and proposed structural systems. I plan to compute the total volume of concrete and reinforcing saved by the new systems. I will then research the current market price for these materials and find the cost savings. While it is my belief that the new systems will save significant material cost I am uncertain what affect they will have on labor cost, and the project schedule. In order to determine labor cost I will use Means Building Construction Cost Data. I plan to look at the balance between material cost, labor cost, and schedule for each of my structural redesigns. After weighing the advantages and disadvantages of each system I will suggest whether or not the redesign is worth while for cost savings.

Acoustics Study:

The acoustic properties of walls and floors are very important in residential high rises. In order for the design to be successful and tenants to be happy, engineers have to take into consideration that 2 people of very different lifestyles might be sharing a wall. For this study I will concentrate to two different areas where the effects of sound damping would be most significant. First I will investigate a wall shared between two apartment units where loud music could disturb one of the tenants. Second I will analyze the floor slab between the gym and the apartment above where the noise of music, banging weights, and people might disturb tenants.

Time Table

Week #	Dates	Tasks
1	1/09-1/15	Research Post-Tensioned Concrete
2	1/16-1/22	Design Post-Tensioned Slab
3	1/23-1/29	Determine Size and Location of New Shear Walls
4	1/30-2/05	Find Forces on Shear Walls
5	2/06-2/12	Find Deflections of Shear Walls
6	2/13-2/19	Start Cost Comparison of Systems
7	2/20-2/26	Finish Cost Comparison
8	2/27-3/05	Start Acoustic Analysis of Apartments
9	3/06-3/12	Spring Break
10	3/13-3/19	Finish Acoustic Analysis of Apartments
11	3/20-3/26	Start Final Report
12	3/27-4/02	Complete Final Report
13	4/03-4/09	Final Report Due Wednesday 4/15
14	4/10-4/16	Thesis Presentation Week
15	4/17-4/23	- - - - - - - - - - - - - - - - - - -
16	4/24-4/30	- - - - - - - - - - - - - - - - - - -
17	5/01-5/06	Finals Week