Ingleside at King Farm

Thesis Proposal

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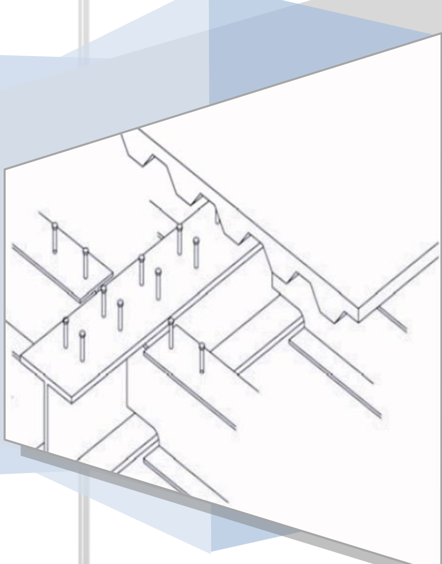

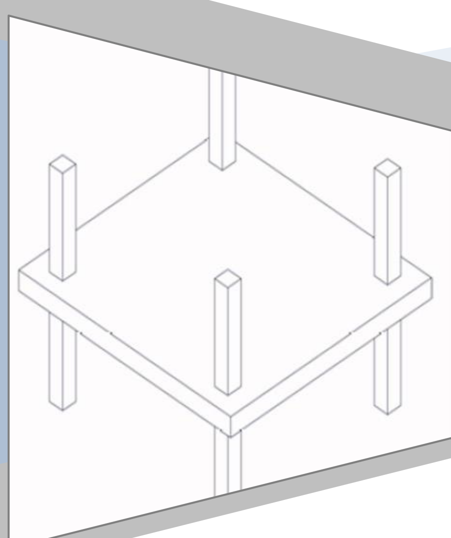

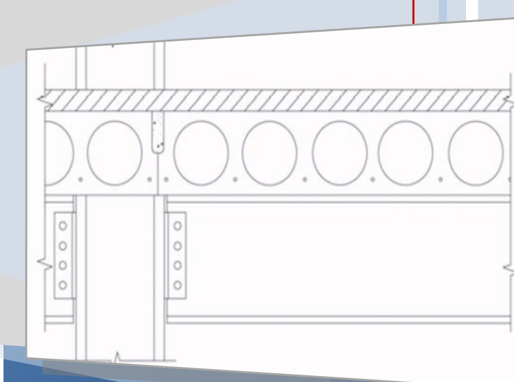

The Pennsylvania State University
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EXECUTIVE SUMMARY

Ingleside at King Farm is a 5 to 7-story building that serves as a continuous care retirement center located in a planned development zone. The building is a mixed-use building containing independent living units, assisted living units, and nursing units, and many public servicing areas. Construction of the 103 feet and 790,000 square footage post-tension concrete building began on November 1, 2006. It is expected to end on January 15, 2009.

The proposed thesis will include a refinement of the existing post tension system with shear walls as its only lateral resisting elements. Proposed changes include the study of alternative tendon layouts to achieve an optimum load balance and the increase of deflection control, re-alignment of offset columns, the utilization of Welded Reinforcement Grids in shear walls and columns, to establishing a concrete shear wall core only system, the relocation of expansion joints to a more rational distance along the building, and to utilize restraint-free slab and non-load bearing wall connections to reduce concrete shortening issues.

The two-way flat plate post-tension building will be modeled in SAP2000. The redesign of the Shear wall elements and tendon layouts will be analyzed in separate models. Investigations will be made to determine changes such as self weight, story drift and total drift cause by lateral forces, overturning moments, base shear, torsion, deflection and bending moments in slabs. The main goal is to determine the most optimum combination.

An additional architectural and construction Breadth study will also be conducted. The breadth studies and structural study will integrate with one another. The architectural breadth will consist of the redesign of the exterior veneer facade with custom designed precast panels to reduce labor cost and construction time. Due to the resizing of structural elements and relocation of columns, there will be a need to resize or relocate rooms. Case studies will also be conducted on a convenient developed architectural plan for the different occupants. The construction breadth study will focus on value engineering techniques to reduce construction time and cost. There will also be an emphasis on sustainable features as the owner is seeking LEEDs certification for the building. This will include the study on how the building can utilize the surrounding resources, such as the artificial pond and existing green roofs.

Individual tasks for each study were developed as check points and mild stones for the process of completing a successful thesis. They are organized in a gaunt chart for correlation. The schedule may change depending on the difficulty of the task, delay, and further investigations. A self imposed mile stone for the completion of the thesis was considered one week ahead of the actual due date to give extra time if any problem should arise. Contacts with the thesis consultant and Turner representatives are not mentioned in the schedule, but will likely to happen.

INTRODUCTION

This report includes proposed solutions to remedy or improve upon the imperfections associated with the existing structural system of Ingleside at King Farm. Each proposed solution will include an explanation on the methods, tasks, and tools necessary for achievement. In addition, an architectural and construction breadth study will be proposed, which will integrate with the proposed structural studies. Finally, a schedule of tasks and mile stones will be discussed to bring about the completion of the thesis project.

BUILDING GENERAL INFORMATION

Statistics

Ingleside at King Farm is owned by the Ingleside Presbyterian Retirement Community and was designed by Cochran, Stephenson & Donkervoet, Inc. (CSD). The building is being constructed under a guaranteed max price of $97 million, which covers construction only with a CM contract by general contractor Turner Construction Company of Baltimore, MD and construction manager Turner-Konover of Rockville, MD. Morabito Consultants, Inc. is serving as the engineering firm. Construction of the 103 feet, seven- story and 790,000 square footage post-tension concrete building began on November 1, 2006. It is expected to end on January 15, 2009.

Location

The building site is located between a residential and commercial zone. The building itself is a mixed-use continuous care retirement center designed with several roof gardens, independent living units, assisted living units, and nursing units for the top seven floors. In addition, the first floor consist of many public servicing areas including but not limited to a theater, Olympic size swimming pool and a market place is the first floor. All the floor plans are identical with the exception of the first floor having an extended floor area for the swimming pool and market place.

Due to the building site's proximately of 0.30 miles from King Farm Farmstead Park Historic District, the architectural design is rather conservative (by choice) and is designed in context with the existing buildings in the community. There is no unique style to describe its architecture. Although it resembles the Victorian style it follows the Architectural Design Guidelines for the Exterior Rehabilitation of Buildings in Rockville's Historic Districts adopted in 1977.

Aesthetics

The base of the building consist of cast stones, which gives it a more solid and rustic appearance than the rest of the building. The mid-portion of the building consists of brick veneer from the 2nd to 5th floor, and light-beige stucco for the 6th floor. The 7th floor consists of a mansard roof construction with metal shingles that gives it a well defined soffit line.

There is rhythm and harmony in the proportioning of the building's geometry and the facades. The appearance complements the surround residential buildings. Windows are all proportional and are evenly spaced apart. Keystones, dormers, lintels and wrought iron shutters are used to give dept to windows and doors.

Building Envelope

The building envelope consists of three primary wall assemblies. The exterior façade at the base consist of 16x24 cast stones. It is followed by an air space, ½" sheathing, masonry veneer ties at 16" O.C., 6" steel studs at 16" O.C., 6" batt insulation at an R value of 19 and 5/8" foil face gypsum board.

The mid section of the building (2nd to 5th floor) is similar to the base section except that masonry brick is used in place of the cast stones. On the 6th floor, the exterior veneer brick is replaced by a light-beige stucco with a reinforcing mesh behind it. The 7th floor building envelope consist of a sloped roof assemble (mansard roof style) characterized by dark colored metal shingles on plywood roof sheathing and 4" metal stud framing.

The roof membrane is a 3" rigid insulation on 1 ½" x 20 gauge galvanized metal deck supported by either 26 k12 or 28 k12 joists depending on the roof loads. There are also a low roof areas (mainly for the roof gardens and penthouse) with an assembly consisting of 8" post tension slab with a membrane roof water proofing system.

Construction

The developer Penrose Group hired Turner Construction and Konover in a joint venture contract to deliver the Ingleside at King Farm project with a CM Agent delivery method. The goal of the project was to deliver affordable living to senior citizens in Rockville. Penrose Group had helped finance this project. Construction of the 790,000 square foot complex began in November 2006. The complex is a mixed use building: Type I construction. It will consist of living units, office spaces, a multi use theater space, Olympic size swimming pool (under a different contract), a market place, and several of public spaces for the seniors.

There are four true expansion joints built into the building. The primary reason for these expansion joints is to reduce pre-stress losses in the tendons due to the shortening of the concrete slab caused by shrinkage or cooling, which will induce cracks around restraining boundaries (such as walls and beams).

Figure 1: Building Sections (Expansion Joints indicated by red lines)

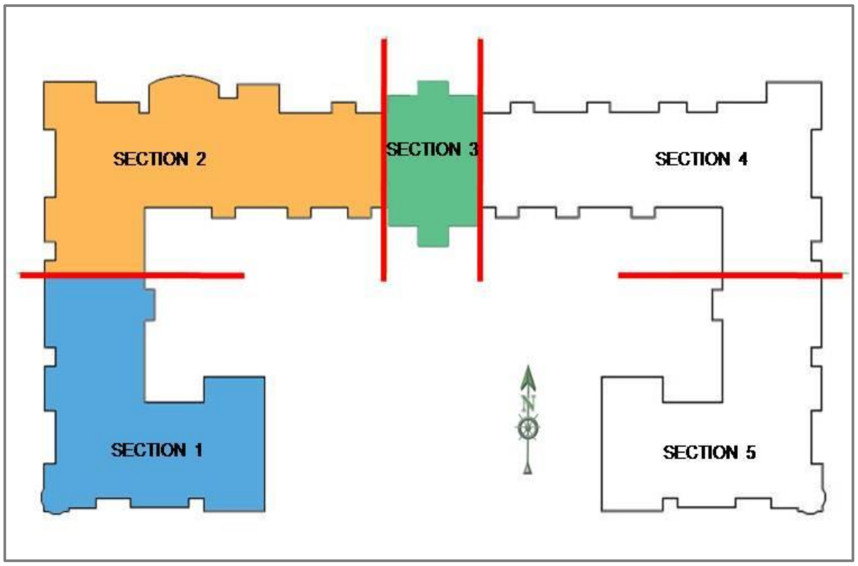
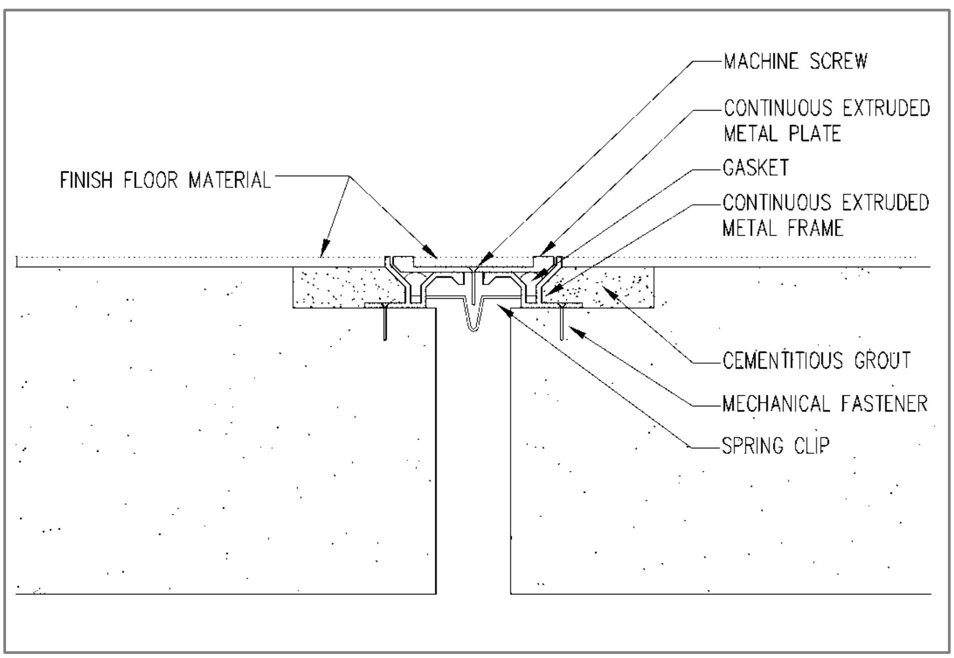


Figure 2: (2”) Expansion Joint Detail



EXISTING STRUCTURAL SYSTEM

Foundation

The sub level of the building is mainly used as a parking garage and contains most of the building's mechanical rooms. The loads from above are transferred down by 30" x 18" reinforced concrete columns with 10 #8 bars to spread footings. Beneath the spread footings is 3 feet of compact fill and then soil with a bearing capacity of 50 ksf. The 30" x 18" reinforced columns extends all the way to either the 6th or 7th floor. The structural slab in the foundation and sub level parking garage is a 5" concrete slab on grade reinforced with 6" x 6" W2.9 / W2.9 welded wire fabric over a vapor barrier and a 4" porous fill. It utilizes standard weight concrete with a 28 day minimum compressive strength of 4000 psi.

Typical Floor Frame

Ingleside at King Farm's primary structural system is a two-way flat plate post-tension concrete (normal weight) structure with 270 ksi unbounded ½ diameter 7 wire tendons. The post-tension concrete slabs are 8 inches thick for typical floors with a compressive strength of 4500 psi. The only drop panels in the building are found on the sub level columns holding up the 12 inch thick slab (f'c=6000 psi) that is supporting the weight of the court yard, and the 6th floor columns supporting the 7th floor loads due to the offset W 8 x 31 wide flange columns found on the 7th floor. All the drop panels are 5' x 5' x 10". Due to the irregular column gird of the building, bays range from 15 feet to 29.5 feet.

Lateral System

Ingleside at King Farm has eleven shear walls to resist lateral loads from the sub level up to the 7th floor. Seven of the walls are ordinary reinforced concrete shear walls located at stairwells and elevator shafts with #4 horizontal reinforcing bars and #8 vertical reinforcing bars. Typical spacing of these bars is 12 inches. All these walls have a compressive strength of 5000 psi. The remaining four reinforced concrete shear walls have boundary elements and are 15 feet in length; two in east/west direction and two in north/south direction. Spacing of vertical and horizontal reinforcements is 30 inches and 12 inches respectively. Typical clear cover is 1 ½ inches for the reinforcements.

On the 7th floor, in addition to the shear walls, there are also moment connections to resist the lateral loads. Based on lateral load analysis in technical report one, it was discovered that the loads were largest at the 7th floor roof line. Thus, these moment connections (framed seated beam connection) justify the high wind loads that were calculated in technical report one.

Columns

The building contains over 140 reinforced columns, which are either 18" x 30" or 12" x 30". Due to the building's irregular column grid, some columns are miss-counted for in the column schedule. These reinforced concrete columns extend from the sub level to the 6th floor.

All 7th floor columns are W 8 x 31 steel rolled. There are approximately 152 of these steel columns and 33 of them are offset from the concrete reinforced concrete columns below. Thus, 5' x 5' x 10" drop panels are present on the 6th floor to aid with the load transfer and punching shear resistance for the offset columns.

The column schedule also does not account for the 6" x 6" x 3/8" steel tubular columns that are located in section two of the building where a majority of the public areas are found. These HSS columns support the gravity loads of areas whose roof line is at the first floor and second floor level.

PROBLEM STATEMENT

After a comparative study with alternative floor systems in Technical Report 2, the existing two-way post-tension flat plate was deemed to be the most optimum floor system. The lateral system consisting of shear walls was analyzed in Technical Report 3 and was concluded to be adequate for resisting the lateral loads. Since Ingleside at King Farm is located within the proximity of Washington D.C. where concrete construction is the major practice, it is logical to keep the existing concrete system and improve upon it.

The existing post-tension system offers numerous advantages, such as reduction of structural depth, long span length, deduction of floor weight and material consumption, flexibility in layout of services, and improved cracking and deflection control due to the load-balancing effect of draped tendons. However, there is the issue of low punching shear capacity, and pre-stress losses due to cracking caused by concrete shortening and restraining boundaries. To mitigate these problems, the existing system includes the usage of expensive expansion joints and expensive formwork for drop panels for certain areas of the building.

PROPOSED SOLUTION

To reduce further pre-stress losses, restraining boundaries such as walls can be reduced. This can be made possible by establishing a concrete shear wall core only system, and do away with unfavorable arrangement of independent shear walls. Additional coupling beams connecting the shear walls of the core will be designed to yield, while the wall portion of the core will remain elastic. There is a possibility that the thickness of the core will need to be increased to resist additional seismic loads if the response modification factor value is reduced.

Expansion joints are typically placed between 150 feet to 200 feet of the slab's length. There are two expansion joints that are approximately 64 feet apart (the two joints creating section 3 of the building - see Figure 1). These joints can be relocated to a more rational adjacent distance from each other. Another solution is to utilize restraint-free slab and non-load bearing wall connections.

In order to regain the deflection control reduced by pre-stress losses, the pre-stressing tendons can be rearranged to provide a more optimized load-balance. An additional change will be to relocate offset columns so that the column grid will be more aligned. This column realignment will result in the reduction of curved tendon paths and a more efficient tendon layout. In addition it may be possible to eliminate the drop panels carrying the loads from the 7^{th} floor due to the offset steel columns on the 7^{th} floor. The shifting of the 7^{th} floor steel columns may lead to the redesign of the roof framing system, mainly the spans of the truss members.

SOLUTION METHOD

To reduce the seismic loads, the weight of the building can be reduced by utilizing light weight concrete, and reducing the amount of reinforcements. The reduction of reinforcements without reducing the effectiveness of the shear cores and ductile performance can be made possible with Welded Reinforcements Grids (WRG). The WRG will also reduce rebar congestion, improve constructability, construction time, and labor cost up to 75%. Tests had shown that a safe structure can be designed with 50% less vertical reinforcements required by present code used in boundary elements. The modified concrete core will be designed in accordance with ASCE 7-05 and UCSD test data. The reduction of building weight will result in a less base shear.

The construction documents specifically cross section details will be analyzed to see if restraint-free slab and non-load bearing wall connections is possible. Several expansion joint constructions will also be analyzed for its effectiveness and cost.

Figure 2: Restraint-Free Connections

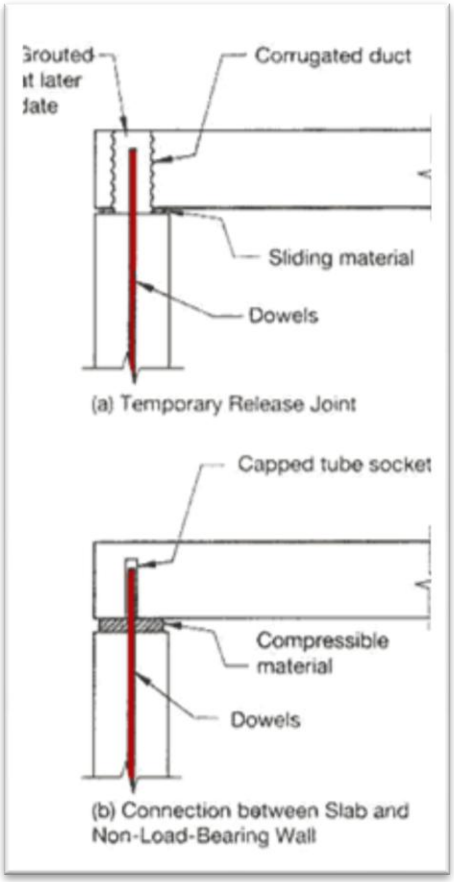
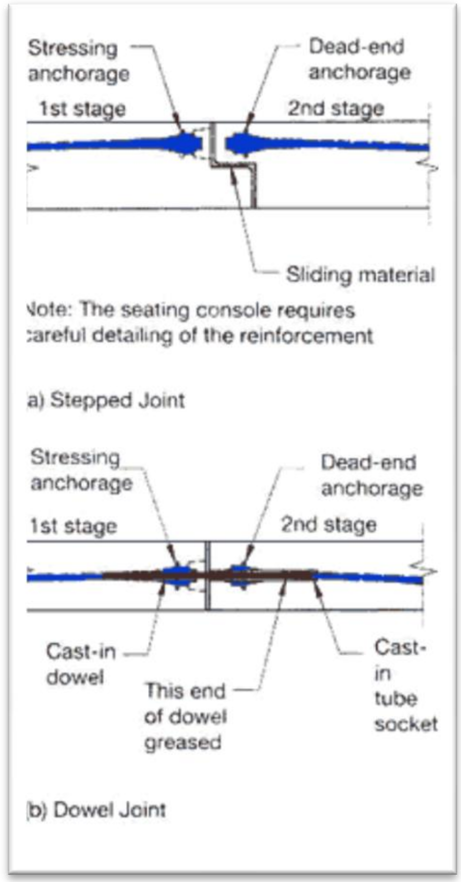
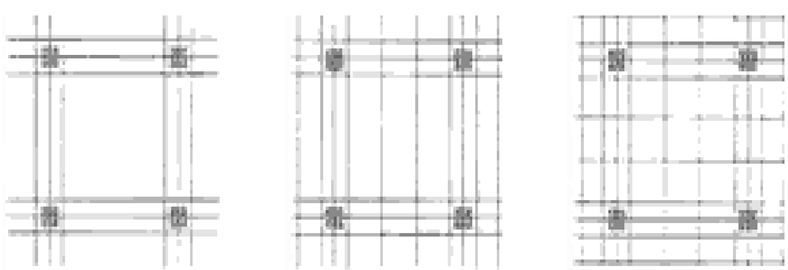


Figure 2: Different Expansion Joints



As for the rearrangement of pre-stressing tendons to provide a more optimized load-balance, an SAP2000 computer model will be used in the study of slab's moments and deflections due to several typical tendons layouts. The re-alignment of columns will result in a required analysis of the load paths from the roof and 7th floor.

Figure 3: Typical Tendon Layout



BREADTH STUDY I (Architectural)

Facade Study

The existing facade contains a large portion of brick veneer. An alternative solution is to use precast architectural panels (manufacture not decided yet), which can be customized to resemble the existing veneer appearance. The exterior wall will then be stiffer. The use of precast panels can reduce labor cost and construction time of the exterior facade. A study on the thermal performance of the exterior wall system will also be studied and compared with the existing one for energy cost and savings.

Retirement Home Case Study

An investigation will be conduction on elderly housing, typically on the arrangement of spaces and its practical locations. Since the building is also a multi use building with plenty of public or social spaces, privacy is a considerable issue. The existing first floor plan consists of 50% housing units and 50% public spaces. There is also a need to study whether the transportation system (elevators) is adequately provided. All of the assisting living, nursing units, and dementia areas are located on the 7^{th} floor. This could pose an issue if an emergency arises where an ambulance is required to transport a patient as elevators may be inadequately provided.

Floor Plan Arrangement

Due to the rearrangement of columns and the increase of the shear core, the architectural plans will require modification; mainly due to floor area. Depending on the case study of retirement home communities, public and health service areas may need to be relocated to the ground floor for convenience.

BREADTH STUDY II (Construction)

LEEDs Certification and Value Engineering

Value engineering was never considered in the construction of Ingleside at King Farm as design documents were not completed before the construction began. The bid documents were not even completed then. Turner-Konover stepped in to act as the designer of record to complete the design of the building systems. Due to this reason, LEEDs certification was not an idea developed during the design process, but was pursued during the construction process. If it was implemented in the early design stages, more money could have been saved.

Through the usage of Welded Reinforcements Grids (WRG), a reduction of steel reinforcements is possible. Results include improved constructability, reduced construction time, and labor cost of up to 75%. The realignment of the columns on the 7^{th} floor and the reduction of drop panels will also produce savings.

The utilization of the artificial pond besides the building into the mechanical system can aid in the LEEDs certification, and become a cost effective cooling system for the building similar to how the cooling of solar panels work. The movement of cool water through duct work in the building will help with mitigating unwanted latent heat from the building during the summer months. Other green/sustainable usage and methods will be researched as well.

In addition, a cost analysis and schedule acceleration scenarios will also be studied, integrating both the structural depth and architectural breadth study.

TASKS

Structural Study

1. Model existing building in SAP 2000
   a. Analyze lateral resisting system - shear walls
   b. Check shear strength, overturning moment, drift, story drift due to wind and seismic
   c. Analyze moments and deflections for typical bays

2. Determine relocation of expansion joints (PTI Handbook)

3. Remodel building in SAP 2002 with modifications starting with the redesign of a center shear core for each building section (if additional shear walls are needed, then location of additional walls must be arranged to lessen shortening of slab).

4. Modify shear walls using Welded Reinforcement Grids (WRG)

5. Re-align Columns to create a more regular column grid
   a. Modify Columns using Welded Reinforcement Grids (WRG)

6. Perform trial locations of shear cores in building

7. Check shear strength, overturning moment, drifts due to wind and seismic
   a. Re-design of foundation below building core if necessary

8. Once the most optimized shear resisting system is redesigned, proceed with duplicated computer models in SAP2000 to analyze slab system for maximum efficiency with optimized load-balancing for the tendons arrangements (starting with typical known tendons layouts).

Breadth Study I (Architectural)

9. Calculate performance efficiency of building's existing

10. Redesign exterior wall system (find manufacturer)
    a. Calculate performance efficiency of building's existing and new envelope.
    b. Compare cost and construction time.

11. Research retirement homes/assisted living units and service requirements
    a. Analyze existing floor plans for improvements
    b. Redesign areas/relocation of spaces if necessary

12. Re-range walls to account for the re-alignment of columns

Breadth Study II (Construction)

13. Research LEEDs certification

14. Research value engineering techniques
    a. Find possible changes that will help increase LEED points

15. Analyze existing mechanical system (for heating and cooling)

16. Estimate savings and construction time due to existing building system

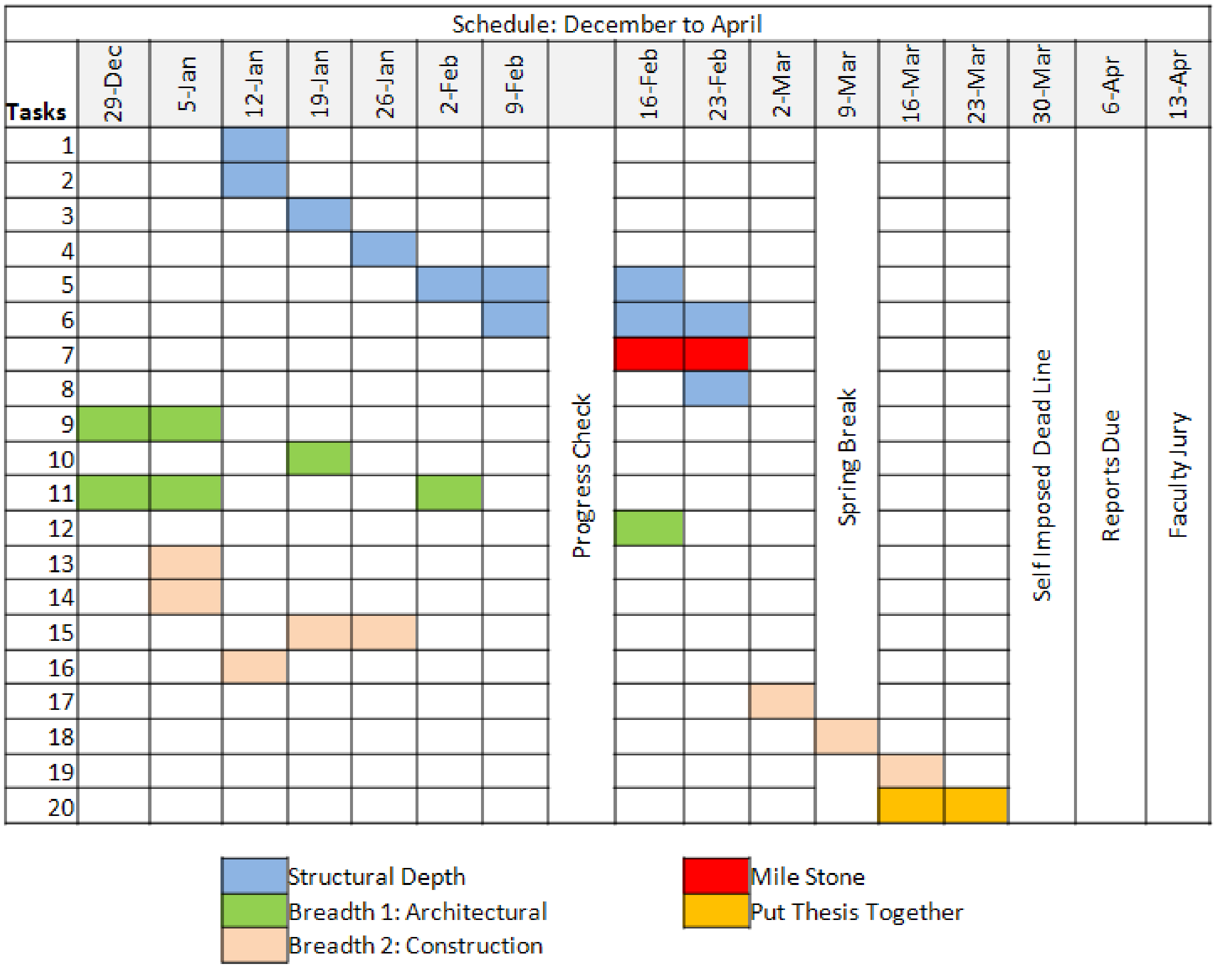
17. Calculate savings and construction time due to structural changes, breadth architectural study, and changes made in construction breadth study

18. Model schedule acceleration scenarios based on construction sequences

19. Compare and contrast results of changes

20. Put together report and presentation

TIME TABLE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Tasks
29-Dec
5-Jan
12-Jan
19-Jan
26-Jan
2-Feb
9-Feb
16-Feb
23-Feb
2-Mar
9-Mar
16-Mar
23-Mar
30-Mar
6-Apr
13-Apr
1
2
3
4
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11
12
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14
15
16
17
18
19
20
Progress Check
Spring Break
Self Imposed Dead Line
Reports Due
Faculty Jury
Structural Depth
Breadth 1: Architectural
Breadth 2: Construction
Mile Stone
Put Thesis Together

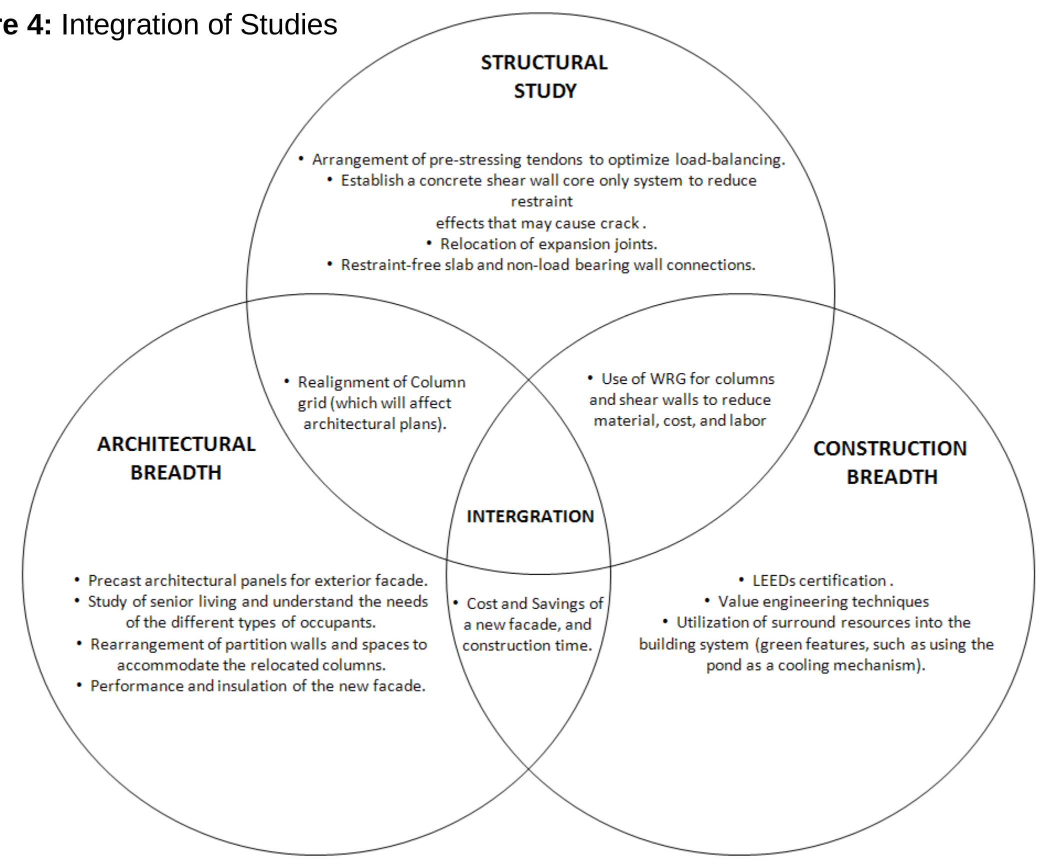
CONCLUSION: INTEGRATION OF PROPOSAL AND BREADTH STUDIES

The proposed thesis will include a redesign of the Shear wall elements and tendon layouts will be analyzed in separate models. Investigations will be made determine changes such as self weight, story drift and total drift cause by lateral forces, overturning moments, base shear, torsion, deflection and bending moments in slabs. The main goal is to determine the most optimum combination.

The breadth studies and structural study will integrate with one another. The architectural breadth will consist of the redesign of the facade system, but will still maintain the same appearance. Due to the resizing of structural elements and relocation of columns, there will be a need to resize or relocate rooms. Case studies will also be conducted on a convenient developed architectural plan for the different occupants.

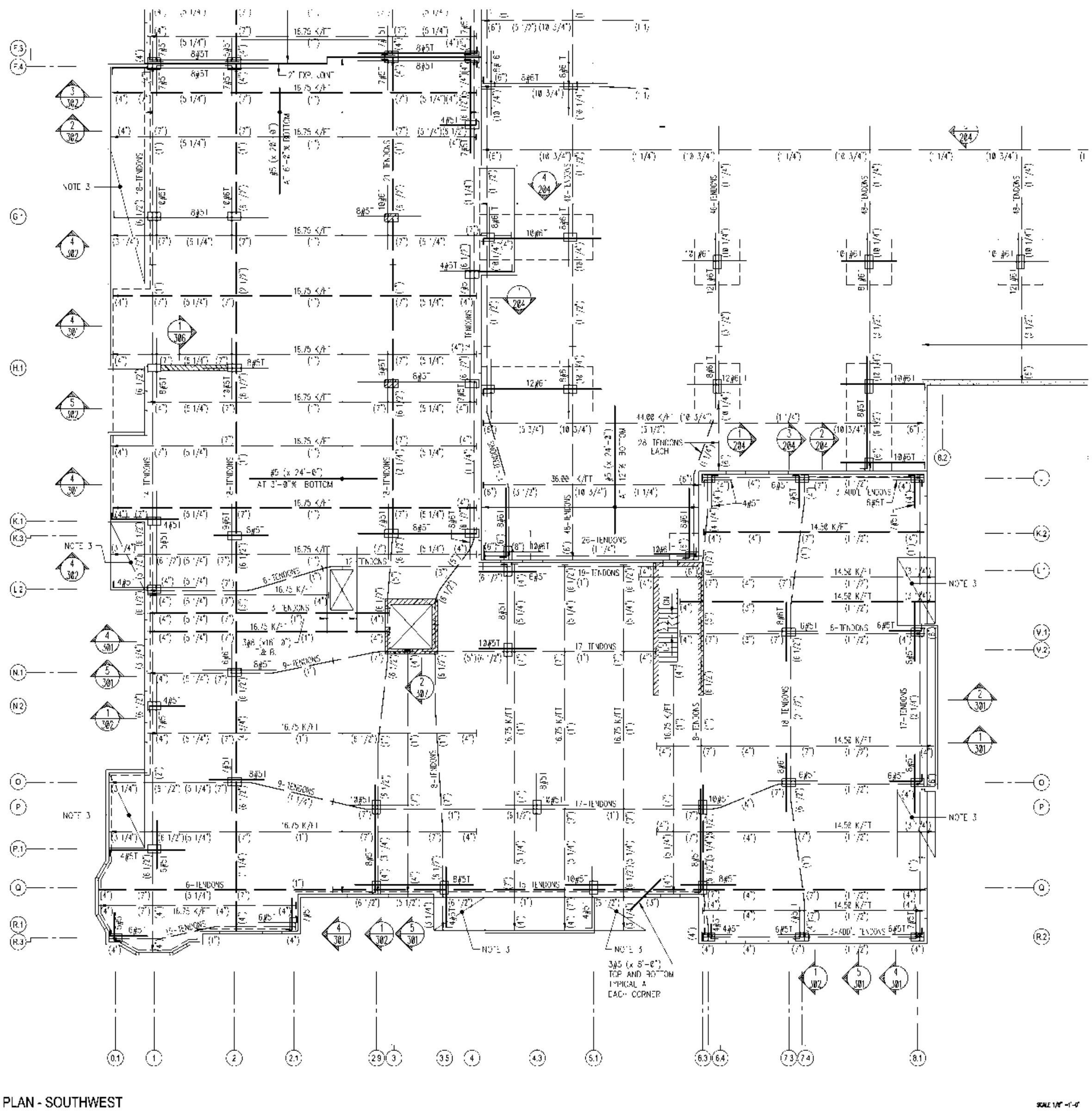
The construction breadth study will focus on value engineering techniques to reduce construction time and cost. There will also be an emphasis on sustainable features as the owner is seeking LEEDs certification for the building. This will include the study on how the building can utilize the surrounding resources, such as the artificial pond and existing green roofs. Tasks for each study were organized in a gaunt chart for correlation. The entire thesis is modeled to integrate the structural study and the breadth studies as seen with Figure 4.

Figure 4: Integration of Studies

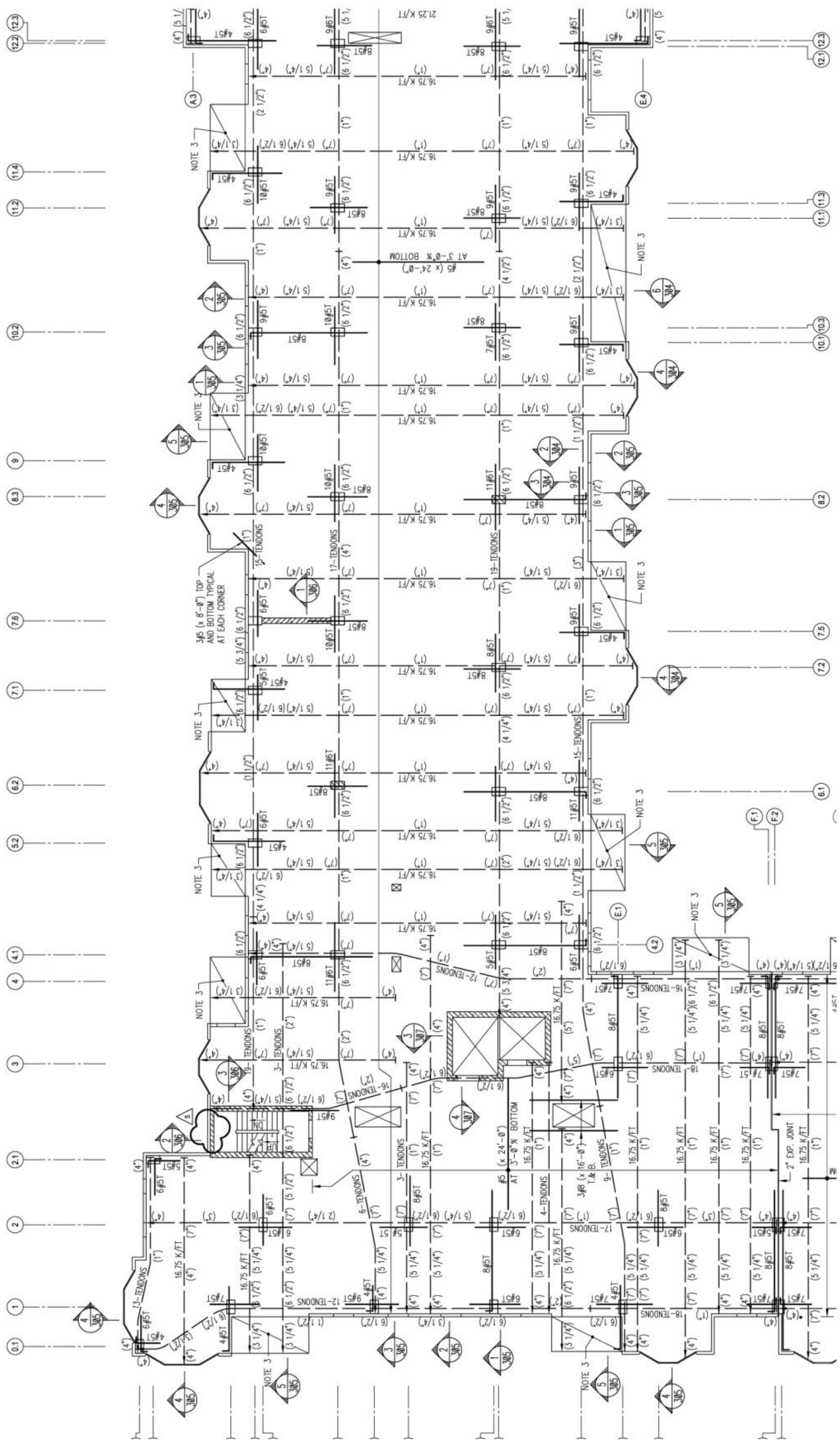


Appendix A – Floor Plans

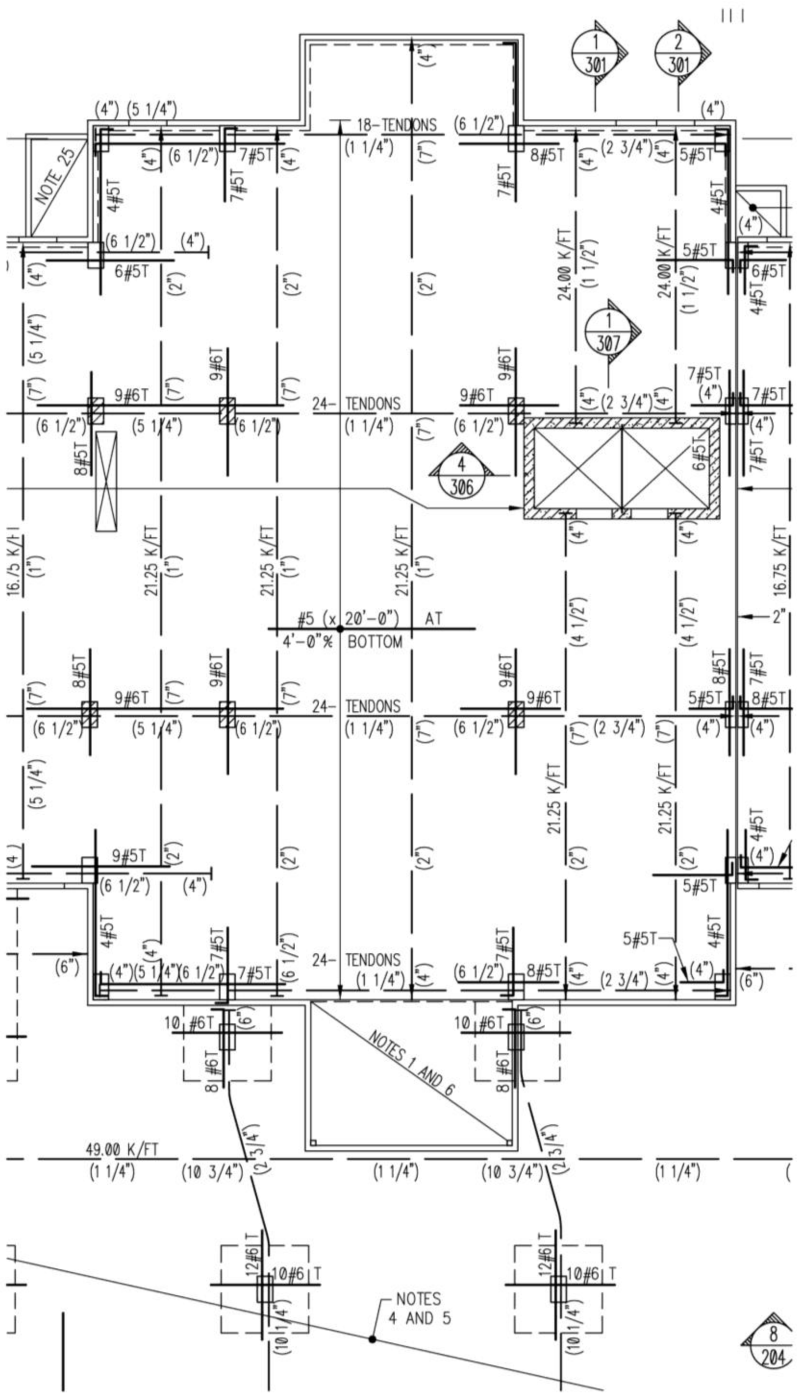
Building Section 1



Building Section 2



Building Section 3



FLOOR PLAN-CENTER