Thesis Proposal

Roberts Pavilion
Camden, NJ

Andrew Voorhees | Structural

Revised Senior Thesis Proposal
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Faculty Advisor: Dr. Linda Hanagan

Executive Summary

The Roberts Pavilion is a patient care center located in Camden, NJ. It is part of the Cooper University Hospital and serves a large range of patient needs. Standing 10 stories above grade, it is a noticeable landmark when entering Camden. The pavilion was built between two existing hospital buildings and now serves to connect them. During construction, renovations updated the façades on the adjacent buildings to give a sense of uniformity to the complex. Aluminum and glass panels make up the main façade and give patients excellent views to the outside. Structurally, the building is framed in steel, with composite deck flooring. Lateral loads are resisted by four ordinary steel concentrically braced frames in each direction of the building.

Purpose and Scope

The purpose of this proposal is to put forth an outline of the work that will be done in the spring semester of 2013. Several major components of the Robert's Pavilion will be redesigned. As was shown in previous technical reports, a steel structure may not be the most economical solution. Therefore, the building will be redesigned out of reinforced concrete. This will include the gravity system as well as the lateral system. Three different concrete floor systems will be studied before picking the most effective to use in the final design.

The first breadth will address acoustics. Changing to a concrete structure should result in better acoustical performance. An acoustical analysis of the concrete system will be compared to the existing steel structure's acoustical performance. Particular attention will be given to the mechanical space on the roof and the sound transmission to the floor below. A typical patient room will also be studied to determine the best way to control noise transmission.

Changing from a steel structure to a concrete structure will result in a cost difference as well as a longer length of construction. Therefore, a breadth in construction cost and scheduling will be completed. A cost estimate will be used to compare the new structure to the existing. Additionally, the schedule will be modified to account for the change to concrete. Results will be compared to those of the existing steel structure in order to determine which design is the most economical.

MAE coursework will be implemented into this design particularly from courses AE 530 and CE 543. Advanced computer modeling from programs learned in 530 will be used to study the building's reactions to applied loading. CE 543 addresses prestressed concrete. This will be studied as a solution to roof spans in the lobby which are too large for normal concrete beams to span.

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Building Introduction

The Roberts Pavilion, as shown in red in Figure 1, is a recently constructed patient care center at the Cooper University Hospital in Camden, New Jersey. Completed in December 2008, the project cost about $220 million. The pavilion is approximately 320,000 GSF and occupies 10 stories above grade as well as one basement level. Additionally, during construction, the adjacent Kelemen and Dorrance Buildings, shown in Figure 1 in blue and purple respectively, underwent 51,000 GSF of renovations.

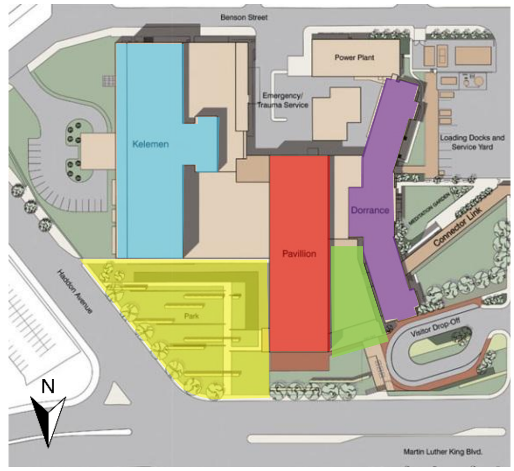


Figure 1 : Site plan (Courtesy of EwingCole)

Cooper has been a leading medical institution in southern New Jersey for many years. The Roberts Pavilion establishes Cooper's presence in Camden and upon entering the city, it is easily visible. Architecture and engineering systems were designed by EwingCole. They designed the façade, as shown in Figure 2, to be composed mostly of glass and aluminum panels. During renovations, façades of the adjacent buildings were updated to give the complex a sense of uniformity. The master plan also called for the demolition of the parking garage on the corner of Haddon Avenue and Martin Luther King Boulevard, as shown in yellow in Figure 1, and for the space to be turned into a park to improve the surrounding landscape.

Figure 2 : Roberts Pavilion (Courtesy of Halkin photography, LLC)

The lobby, shown in green in Figures 1 and 3, is a grand, open space with an abundance of natural light and warm colors. It also acts as a link between the new pavilion and the existing Dorrance Building which is shown in purple in Figure 1. Bamboo plantings and natural materials give the space a garden-like feel. Cooper wanted the pavilion to feel like a "healing garden" where patients experience a calm and peaceful atmosphere seemingly distant from the city outside. This idea is evident in the design from the lobby to the upper floors.

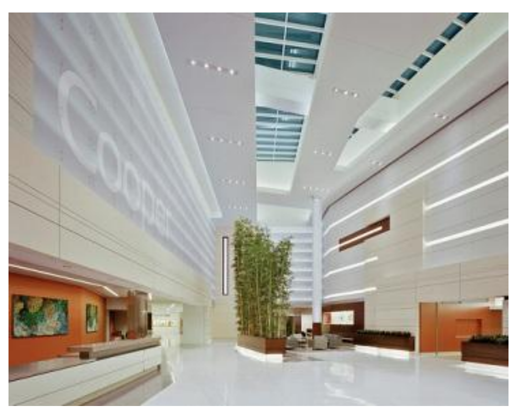


Figure 3 : Lobby (Courtesy of Eduard Hueber/Arch Photo, Inc.)

Each floor maintains a different function. The second floor houses clinical cardiology, while the third floor houses surgical suites, and the fourth and fifth floors hold the intensive care units. Typical patient rooms are located on floors six through ten.

Structural Overview

Foundation

URS Corporation investigated the Roberts Pavilion site conditions by performing nine test borings. The top layer of soil in most of the drillings consisted of silty sand with some gravel and fragments of brick and concrete. This fill layer was classified as poorly to well-graded sand (SP-SW). Soil under the fill layer was classified as loose to dense silty sand with layers of clay becoming more firm with depth. 16" diameter reinforced piles were cast with a depth of -68' below the basement slab to reach firm soil. A minimum compressive strength of 4000 PSI concrete was used along with ASTM A615 Grade 60 reinforcement. Pile caps required concrete with minimum compressive strength of 5000 PSI and range in thickness from 3'-6" to 6'-0". The stratum layer under the footings was compacted to reach a bearing capacity of 4000 PSF.

The main basement will have an elevation of +8' above sea level (being about 5' above the water table), but elevator pits and mechanical space will be about +2' (1' below the water table). This means that the lower slab and walls will require waterproofing. Additionally these areas should be designed for hydrostatic uplift pressures. A permanent pump-operated subsurface drainage system was added to control the water level.

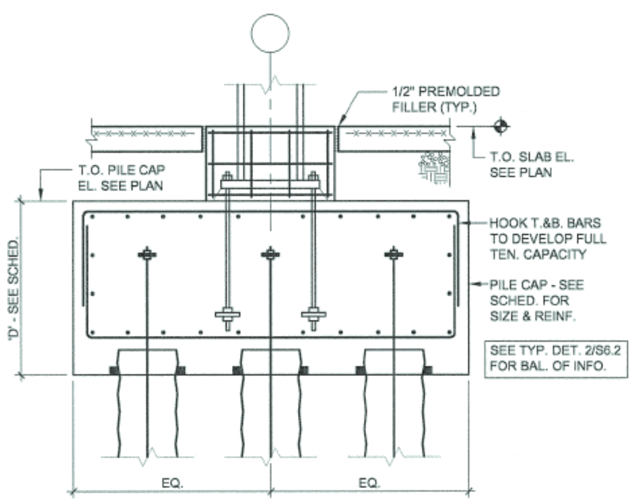


Figure 4 : Typical pile cap without pedestal

The main basement level is a 5" concrete slab, with a 16" slab poured in the north end under the mechanical room. Structural fill was placed for support under the foundations and used as backfill for the walls and footings. Soil pressures will need to be calculated when designing foundation walls.

Floor System

Typical floor framing in the pavilion consists of a composite system. It incorporates a 2", 18-gauge steel deck with a 3¼" lightweight concrete topping reinforced with WWF (welded-wire-fabric). The Decking runs perpendicular to the beams and shear studs transfer the load to the beam to allow for composite behavior.

Framing System

All steel wide flange members in the building are A992 grade 50. Columns are typically spaced 30' on center in the North-South direction. In the East-West direction there are typically three bays; the interior span being 23', and the two exterior spans being 29'-6". Column spacing is shown in Figure 5 Column weights vary; with the heaviest being a W14x426. However, all columns have a 14" web.

Beams on floors 4 - 10 are typically wide flange members W16x26 and W14x22 spaced at 10' (See Figure 6). Floors 1 (ground) - 3 have larger beams, being that they are supporting heavier equipment. The 3rd floor holds the operating suites and part of the trauma unit thus it supports larger dead and live loads than most of the floors. It uses mostly W21x44 beams spaced at 7'-6".

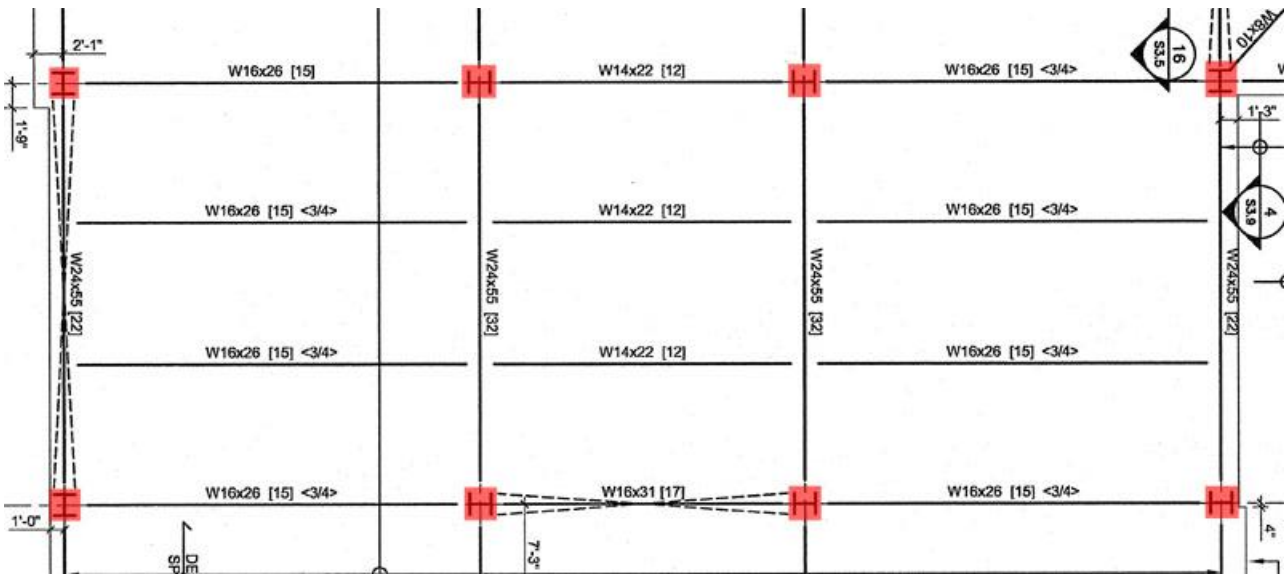


Figure 5: Typical bay (See Appendix A for full framing plan)

Roof System

The roof of the pavilion supports mechanical equipment; specifically three cooling towers, an air cooled chiller, and three air handling units. It has two different levels, where the center level rises 3' above the main level to support the AHU's. Composite steel decking is also used on the roof, with the exception of the elevator core roof which is a poured slab. Wide flange members in the raised level are spaced at 6'-6" maximum to support the load from the mechanical units. In the south-west corner of the roof there is a small mechanical room with the roofing material being 1½", 20 gauge roof galvanized metal roof decking. All the mechanical systems on the roof are hidden by a 19' parapet.

Lateral System

The lateral resisting system in the pavilion consists of ordinary steel concentrically braced frames (OSCBF). There are four frames in each direction of the building as shown in Figure 6. Each frame extends through one full bay and through the full height of the building. Two typical frames are shown below in Figure 8. They consist of a variety of square HSS members with the most common being HSS10x10x1/2.

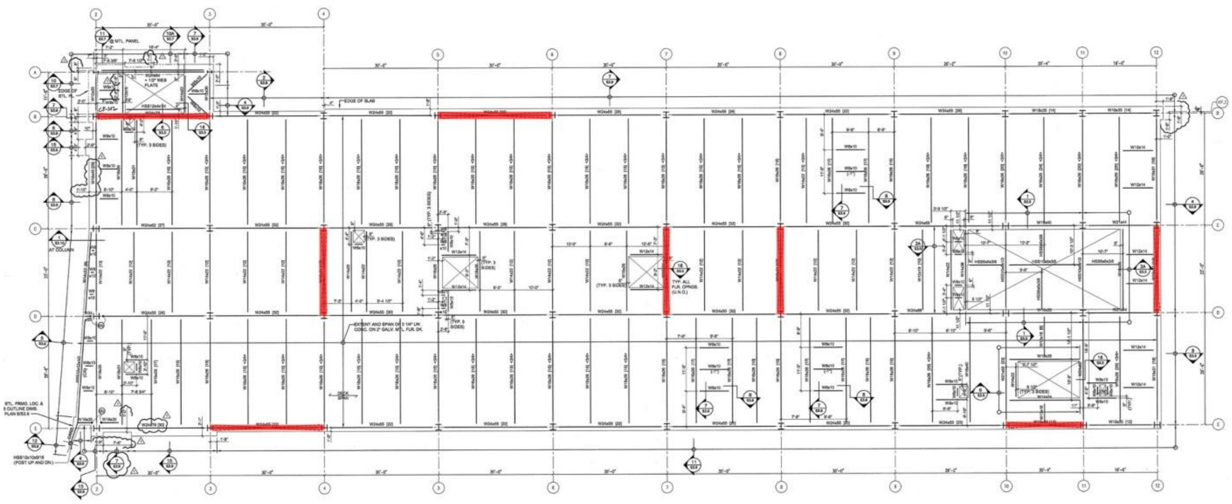


Figure 6: Braced frame locations

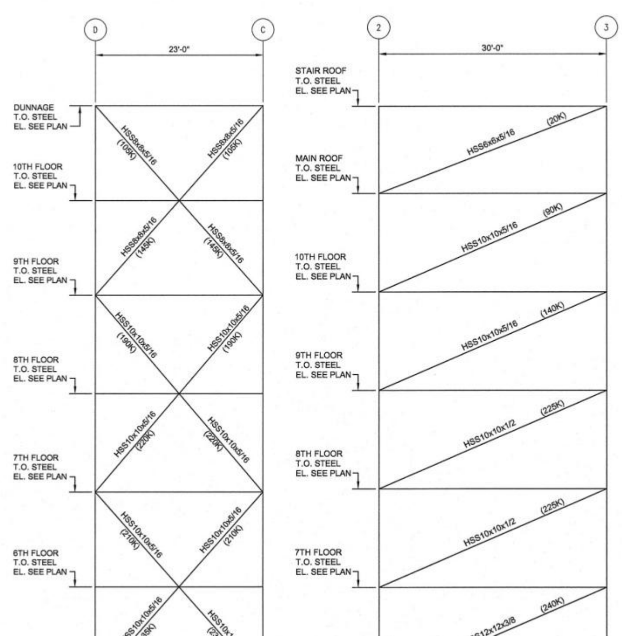


Figure 7: Two typical braced frames (OSCBF)

Problem Statement

As previously discussed, the Robert's Pavilion is a steel framed building with composite deck flooring. This is a good system being lightweight and capable of supporting large spans. However, as was shown in Technical Report II, a concrete system may be more economical. Reinforced concrete, while it is heavier, allows for lower floor-to-floor heights, and consequently decreases building cost. The increased mass of a concrete system is also beneficial when considering vibration and noise control; two issues that are critical in a hospital.

Technical Report III addressed an additional issue with the steel structure. The Robert's Pavilion was designed under the 2002 ASCE code. However, the loads determined via ASCE 7-05 in Technical Report III were larger, and thus it was shown that there were issues with drift. The current lateral force resisting system is concentrically braced steel frames. Designing the lateral force resisting system to incorporate concrete shear walls, particularly in the East-West direction, would likely stiffen the building and solve any drift issues.

Proposed Solution

With the intention of designing the most cost-efficient building, three concrete systems will be considered. In order to find the most economical design, the systems discussed in Technical Report II will be studied in relation to feasibility and cost. The two most practical designs were determined to be a one-way slab with beams and a two-way flat plate slab with shear caps or drop panels as necessary. A study will also be done to determine the feasibility of a waffle slab system. The most practical of these three systems will be chosen to use in the design. Each floor of the building will then be designed and detailed for the given loads. Columns will also be sized and designed to be placed on existing column lines in order to avoid changing the architecture in any major way.

The lateral system will also be redesigned to incorporate shear walls and concrete moment frames. Placement of the walls will coincide with the location of the current braced frames acting in the East-West direction. Current braced frames in the North-South direction are located at the exterior of the building, and placing a shear wall in the same location would result in the loss of windows in patient rooms or a major façade redesign. Therefore, the lateral system in the North-South direction will be redesigned to incorporate concrete moment frames. Beams will be added at the edges of the slab as well as along the two interior spans. In the event that these beams are not sufficient to resist lateral loads, return walls will be added in the core of the building to resist loads in the North-South direction. Shear walls in the center of the building may conflict with the architecture in ways such as wall thickness and placement of doors. These issues will be addressed as necessary and shear walls will be designed to include openings where required.

Floor systems, columns, and the lateral system will be designed by hand. Then a detailed model will be created in ETABS using the final design. Through the program, members will be checked for their required gravity loads and an analysis of the lateral systems will be completed as well.

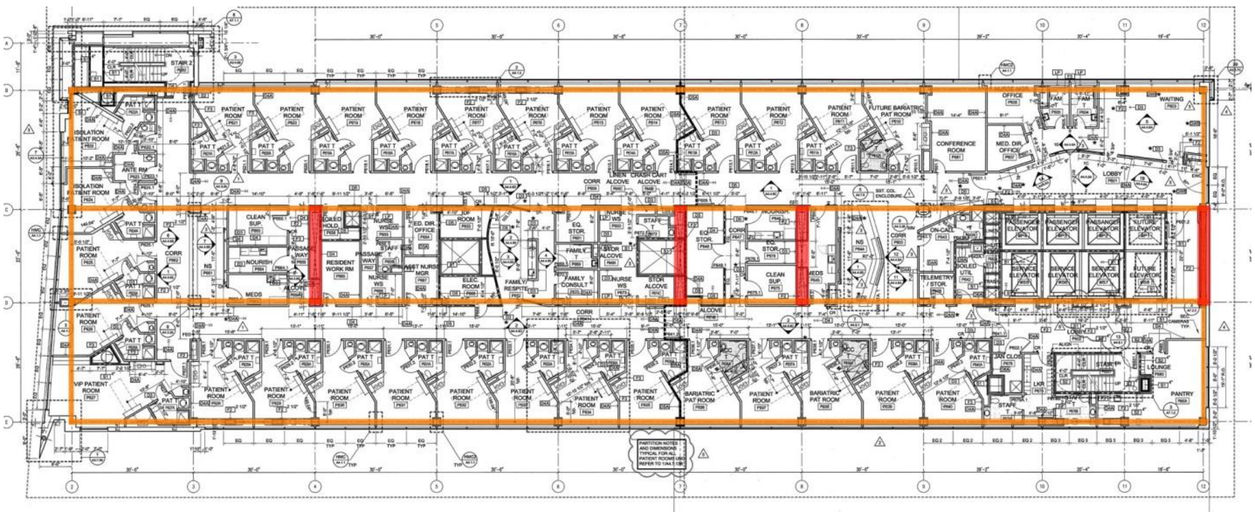


Figure 8: Proposed Lateral System Layout

The figure above shows the proposed layout for the new lateral system. Shown in red are shear walls. These will be input at the same location of the current braced frames. It is possible that not all four shear walls will be required to resist lateral loads, in which case two or three will be used instead. Shown in orange is the proposed location for beams that will create moment frames in the North-South direction, as well as edge beams in the East-West direction that will work along with the shear walls.

Breadth Topic 1 – Acoustics Analysis

Changing the structure of the building from steel to concrete should result in better acoustical performance. A study of the sound transmission of the concrete structure will be compared to that of the steel structure. Particular attention will be given to the roof level. Mechanical equipment on the roof is located on a raised level of the current roof, shown in red below, to control vibration and noise transmission to the floor below. Changing to a concrete slab may result in a raised platform being unnecessary. HVAC noise transmission will be modeled using computer programs and each structural system will be compared. A typical patient room will also be modeled to observe acoustical performance for each structural system.

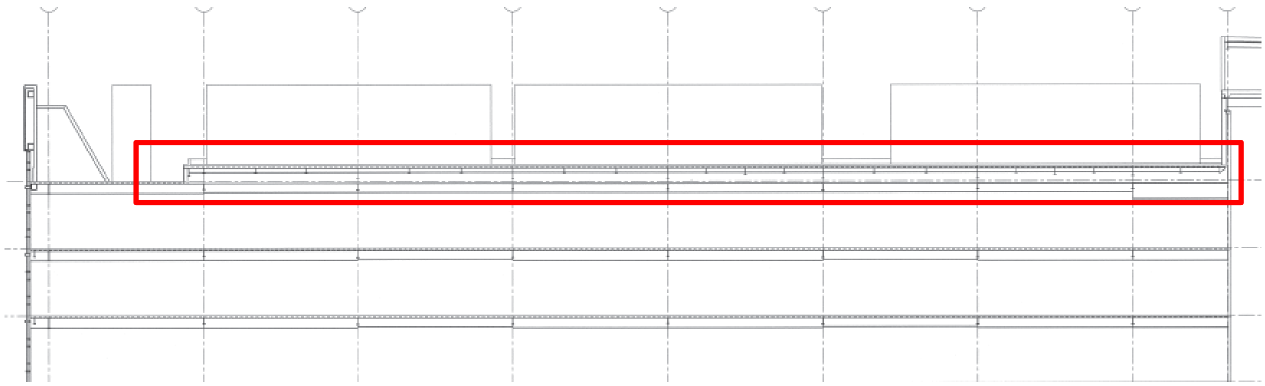


Figure 9: Raised Roof Mechanical Equipment Platform

Breadth Topic 2 – Cost and Schedule Analysis

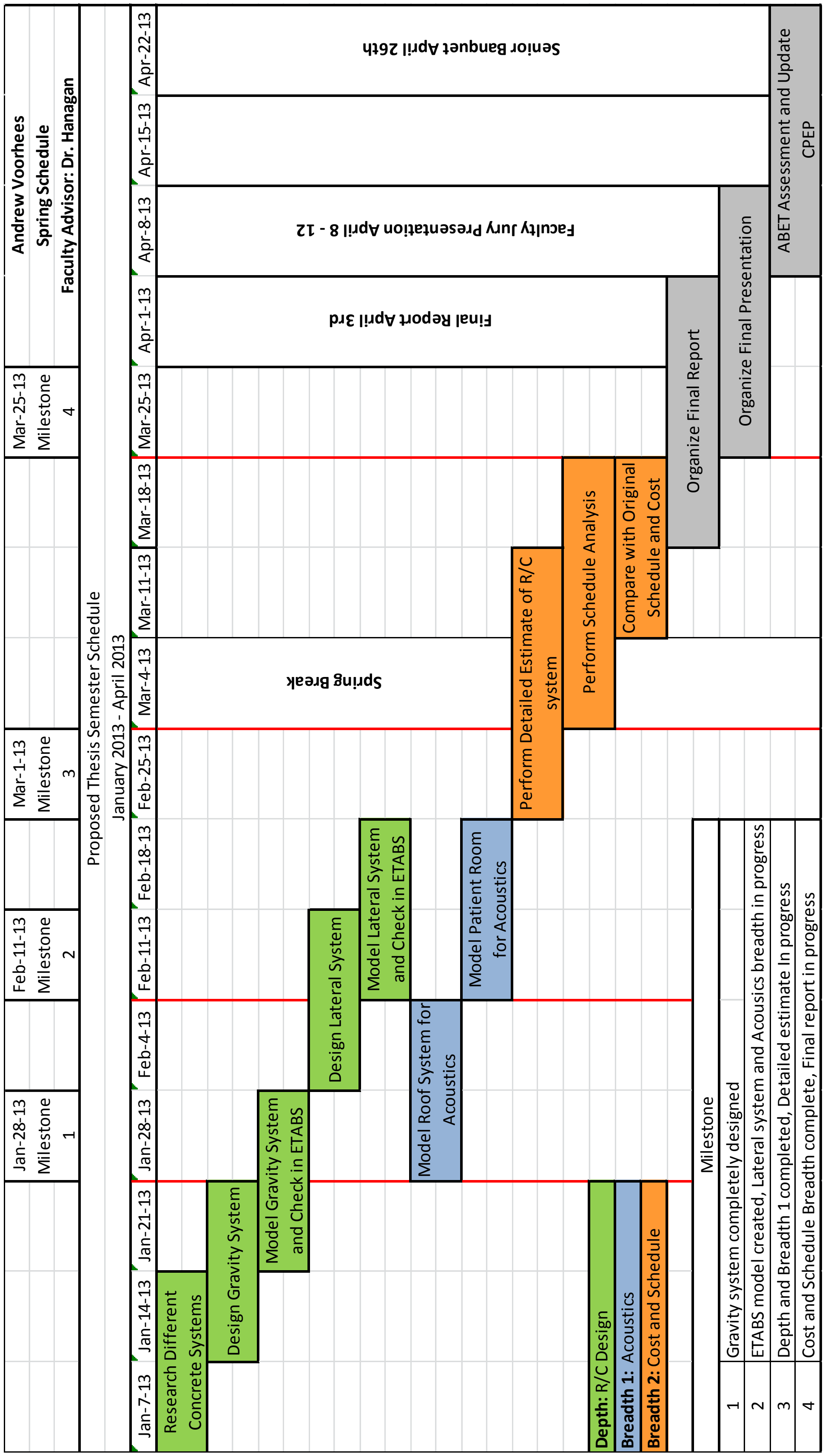
A cost estimate of the concrete system will be completed. Using the estimate, the cost of the concrete system will be compared to that of the existing steel system to determine the feasibility of each. In addition, the impact on the construction schedule will be studied. Changing the structure to concrete will impact the critical path and length of construction. These effects will be studied and compared to the steel structure. It can then be determined which system is more economical.

MAE Requirements

Graduate level work will be incorporated into this design work particularly from AE 530: Advanced Computer Modeling. The ETABS model will be very important for determining the building's reaction to both gravity and lateral loads. Additional work from CE 543: Prestressed Concrete, will be considered as well. Spans in the lobby are too large for regular concrete beams to span, therefore prestressing will be considered as an alternative to maintaining a steel structure.

Tasks

1. Research and compare the three different concrete systems
    a. Research existing hospital structural systems
    b. Compare feasibility and practicality of each system
    c. Pick the best design to go forward with
2. Design the new concrete system
    a. Design gravity system
        i. Design each floor system (slab, beams, etc)
        ii. Design columns
        iii. Check members in ETABS model
    b. Design lateral system
        i. Determine wind and seismic loads based on ASCE 7-10
        ii. Determine shear wall placement
        iii. Design shear walls
        iv. Check strength and serviceability requirements in ETABS model
3. Acoustics
    a. Determine critical noise control areas
    b. Determine sound isolating materials to be used (slab, insulation, etc)
    c. Model roof level for noise control, steel and concrete structure
    d. Model typical patient room, steel and concrete structure
    e. Compare results
4. Perform cost and schedule analysis
    a. Cost analysis
        i. Complete detailed estimate of concrete system
        ii. Compare cost with that of steel system
    b. Schedule analysis
        i. Adjust schedule to account for concrete system
        ii. Compare construction time and feasibility with steel system
5. Final Report and Presentation
    a. Outline final report
    b. Outline final presentation
    c. Finalize report
    d. Prepare final presentation
    e. Practice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Spring Schedule
Faculty Advisor: Dr. Hanagan
Jan-28-13 Milestone 1
Feb-11-13 Milestone 2
Mar-1-13 Milestone 3
Mar-25-13 Milestone 4
Proposed Thesis Semester Schedule
January 2013 - April 2013
Jan-7-13
Jan-14-13
Jan-21-13
Jan-28-13
Feb-4-13
Feb-11-13
Feb-18-13
Feb-25-13
Mar-4-13
Mar-11-13
Mar-18-13
Mar-25-13
Apr-1-13
Apr-8-13
Apr-15-13
Apr-22-13
Research Different Concrete Systems
Design Gravity System
Model Gravity System and Check in ETABS
Design Lateral System
Model Lateral System and Check in ETABS
Model Roof System for Acoustics
Model Patient Room for Acoustics
Perform Detailed Estimate of R/C system
Perform Schedule Analysis
Compare with Original Schedule and Cost
Organize Final Report
Organize Final Presentation
ABET Assessment and Update CPEP
Spring Break
Final Report April 3rd
Faculty Jury Presentation April 8 - 12
Senior Banquet April 26th
Depth: R/C Design
Breadth 1: Acoustics
Breadth 2: Cost and Schedule
Milestone
1 Gravity system completely designed
2 ETABS model created, Lateral system and Acousics breadth in progress
3 Depth and Breadth 1 completed, Detailed estimate In progress
4 Cost and Schedule Breadth complete, Final report in progress

Conclusion

The steel structure of the Robert's Pavilion works well for the given loading and spans. However, it has been proposed that a concrete structure should be designed and compared to the existing structure. A reinforced concrete structure will decrease the floor-to-floor height and is more cost effective based on labor and material cost. In order to judge the feasibility of a concrete structure, the gravity system and the lateral system will be redesigned in reinforced concrete. A computer model will aid with member checks and lateral resisting capabilities. Shear walls and moment frames will be incorporated to provide a stiffer structure. They will be placed in the locations where they have the least architectural impact.

Acoustical performance of a hospital is paramount. Therefore, each structural system will be analyzed for noise transmission. The roof level holds large mechanical equipment, and will be considered along with a typical patient room on a lower floor. Noise transmission from the HVAC equipment will be modeled in a computer program and the results will be compared.

The second breadth will cover an analysis of the cost and schedule of the new design. The design in concrete will be used to create an estimate in order to compare to the cost of the steel structure. After cost is considered, the effect on the schedule will be taken into account. Length of construction will be increased, and will also be studied to determine the effect on the critical path. Effects on the cost and scheduled combined will be taken into account when determining the overall practicality of the structure.

MAE requirements will be satisfied by work from the courses AE 530 and CE 543, advanced computer modeling and prestressed concrete design respectively. Utilizing skills learned from 530, an ETABS model will be created to study building behavior. Material from CE 543 will be considered when determining the appropriate structure for the lobby, as spans there are too large for normal concrete beams.