THESIS PROPOSAL

Penn State Hershey Medical Center Children's Hospital

Hershey, Pennsylvania

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The Pennsylvania State University

Architectural Engineering

Structural Option

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Executive Summary

The Hershey Medical Center Children's Hospital is located at 500 University Drive in Hershey, Pennsylvania. The existing structure consists of a composite steel deck floor system utilizing steel moment frames and concentric braced frames. Pile caps comprised of several micropiles provide foundation support for the superstructure. The overall building dimensions are 359.1 feet by 124.25 feet with a total height of 85.5 feet above grade.

The existing structure was determined through previous reports to provide adequate support under the subjected loading. It was determined in Technical Report 2 that there was potential to redesign the structure using reinforced concrete. There are numerous advantages associated with switching to a concrete structure. One of these advantages is that the floor heights at each level can be decreased significantly reducing building costs. This can be accomplished by using wider beams that are shallower in depth to transfer loads to the columns. Another benefit is that concrete has built-in fireproofing inherent in the material while the structural steel must be sprayed with fire retardant.

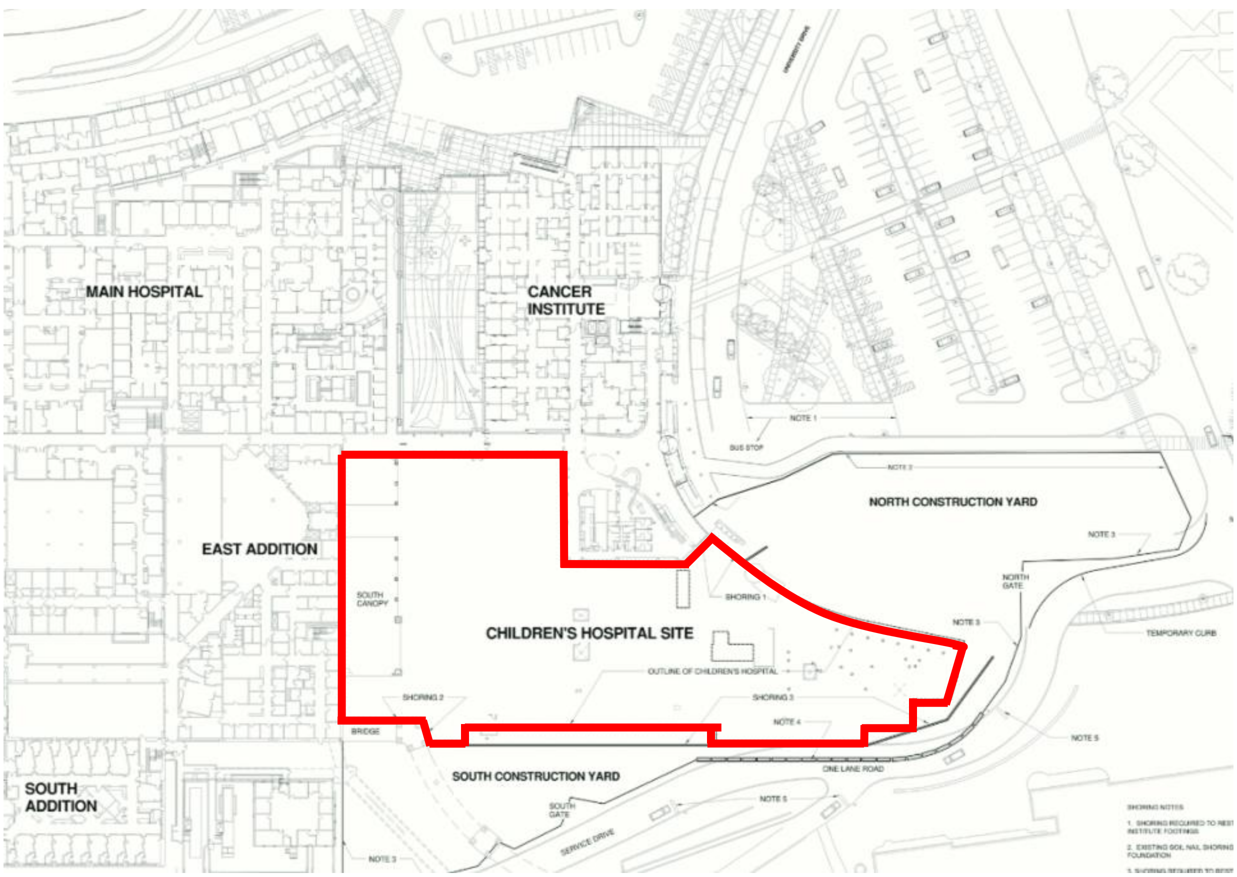
The proposed redesign of the structure should have a significant impact on the construction costs and schedule as compared with the original design. The cost for constructing the building using reinforced concrete and tasks associated with this change will be compared with the original design. For the schedule, more time must be allowed for construction teams to set up formwork, place the concrete, and allow the concrete to cure for all floors. It will be researched as to whether these changes will have a significant impact on the time frame as compared with the current design.

Changes to the structure from steel to concrete will impact how the façade attaches to the building. In lieu of this, an alternative façade design will be researched. Research for the new façade will focus on using materials to increase the energy efficiency of the building envelope and the occupants comfort. The design of the Children's Hospital is proposed to be LEED certified upon completion. For this purpose, a green roof system will be looked at for the roof of the building enclosure. The benefit of a green roof will be to prevent water runoff caused by the building footprint on the existing site. It is the overall goal of this proposal to determine if these changes will create a more efficient and effective building design in accordance with the owner's requirements.

Building Overview

The new Penn State Hershey Medical Center Children's Hospital is located at 500 University Drive in Hershey, Pennsylvania. The Children's Hospital is an expansion project on the existing Cancer Institute and Main Hospital. The overall project plan calls for a five story, 263,556 square-foot addition which will contain a number of operating rooms, offices, and patient rooms specializing in pediatric care. The exterior of the building utilizes vision glass and an aluminum curtain wall system. The main curve of the façade helps to tie the building into the existing curve along the Cancer Institute. A vegetated roof garden will be situated on the third level above the existing Cancer Institute. See Figure 1 for a site plan of the Children's Hospital.

The dates of construction for the Children's Hospital are scheduled for March 2010 to August 2012. The drawing specifications for the Children's Hospital note that an additional two floors of occupancy are intended for a later date. The range of this thesis project will be limited to the structural analysis of the Children's Hospital.



(Courtesy of: Payette Architects)

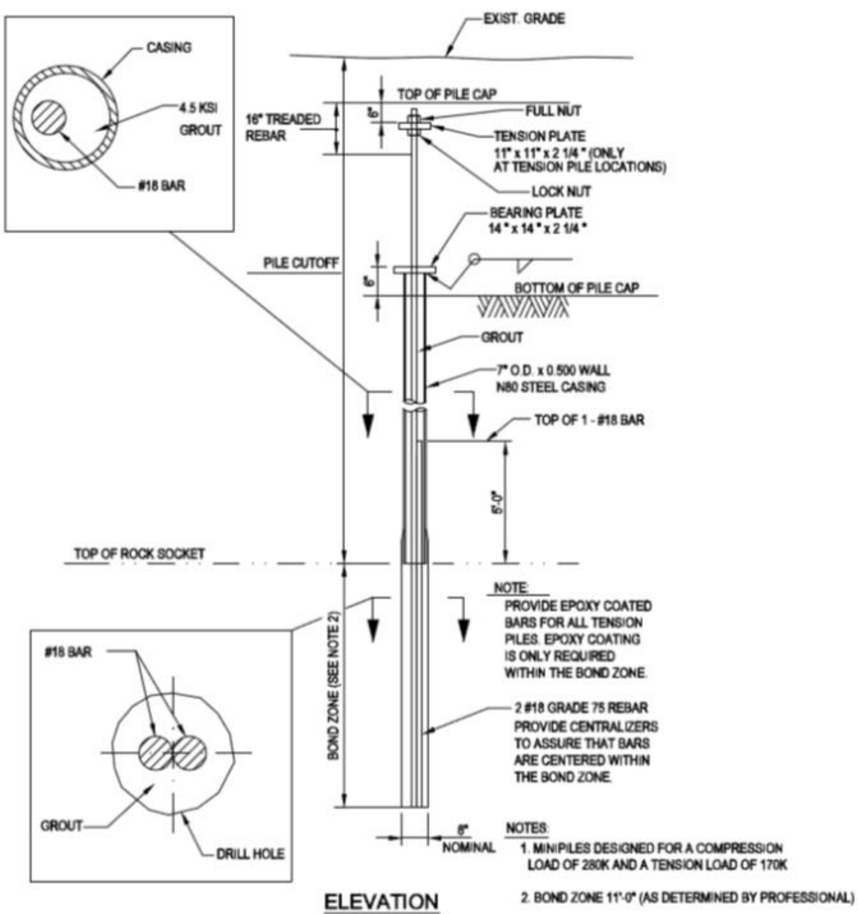
Figure 1 – Site Plan

Introduction to Structural System

The primary structural system comprises of structural steel framing integrated with a composite floor system. The composite floor consists of metal decking with normal weight concrete topping. Shear studs are welded to the supporting beam and embedded into the slab allowing interaction between the two elements. Transfer girders help to transmit the gravity loads from the beams to the columns. All of the columns consist of W14 members which allows for easier constructability. The lateral force resisting system consists of moment connected frames along the East-West direction while diagonal bracing members assist in North-South bracing.

Foundation

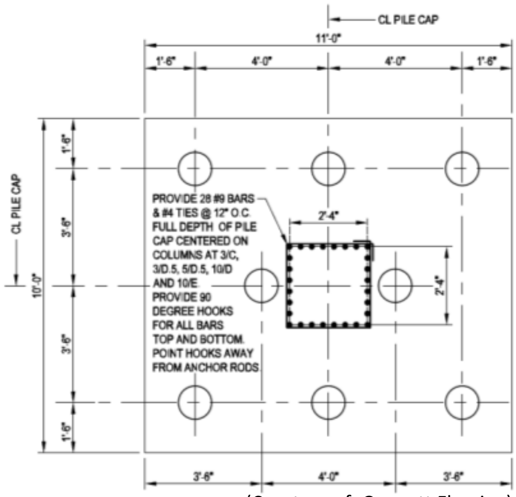
Due to the potential for excessive settlement, micropiles were utilized as recommended in the Geotechnical Report provided by CMT Laboratories. Micropiles consist of a casing that is injected with grout to create a friction bond within the bond zone. The piles that are used in the design are specified for a compression load of 280kips and a tension capacity of 170 kips. There are over 600 micropiles that were used in the foundation of the structure. See Figure 2 for a detail section of a typical micropile.



(Courtesy of: Gannett Fleming)

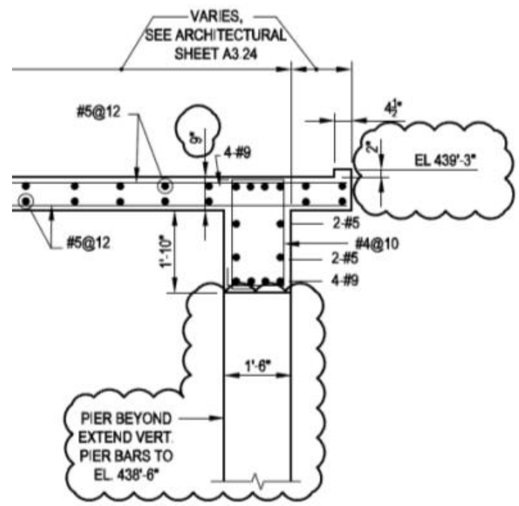
Figure 2 - Micropile Detail

The micropiles are grouped into various sizes of pile caps ranging from 3'0" x 3'0" to 10'0" x 15'0" with a depth ranging from 3' 6" to 6' 0". An example of a typical pile cap can be seen in Figure 4. Typical strut beams of 1' 6" wide by 2' 8" deep span between all pile caps to provide resistance to lateral column base movement. See "Figure 3 – Typ. Strut Beam" below.



(Courtesy of: Gannett Fleming)

Figure 4 - P8 Pile Cap Plan



(Courtesy of: Gannett Fleming)

Figure 3 - Typ. Strut Beam

The floor at the ground level is a 5" concrete slab while in heavier load areas such as elevator pits and mechanical rooms a slab thickness of 6" is used. Below is an overview of the West End foundation plan.

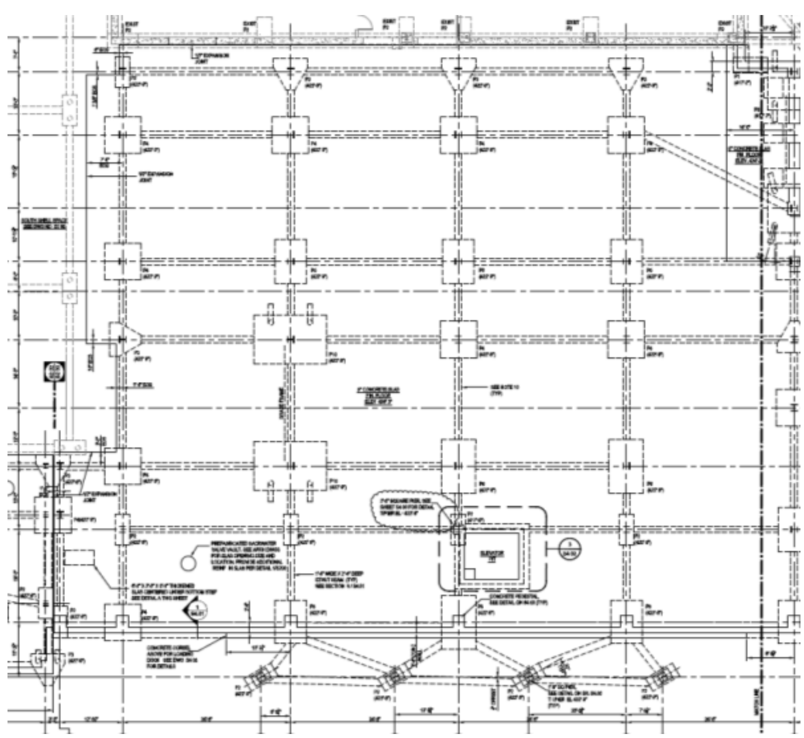


Figure 5 - West End Foundation Plan (Courtesy of: Gannett Fleming)

Floor System

The typical floor slab throughout all five stories consists of a composite floor system denoted on structural drawings as S1 TYP. This slab type is comprised of a 2" deep, 20-gage composite metal deck with a 4 ½" topping thickness. The reinforcement within the slab is 6x6 W2.1xW2.1 Welded Wire Fabric. The only change in slab thickness occurs at an area on Level 2 marked as having a slab type of S2 TYP (see Figure 6). Here, a 6" concrete slab sits on a 2" deep, 20 gage composite deck with 6x6 W2.9xW2.9 Welded Wire Fabric. The main reason behind increasing the slab thickness in this area is to account for a future MRI space where the live load is considered to be 215 PSF. All floor slabs are connected to wide flange beams using ¾" diameter shear studs where the number of studs is listed on each beam in the framing plans. The typical span for a wide flange beam is 34' 6".

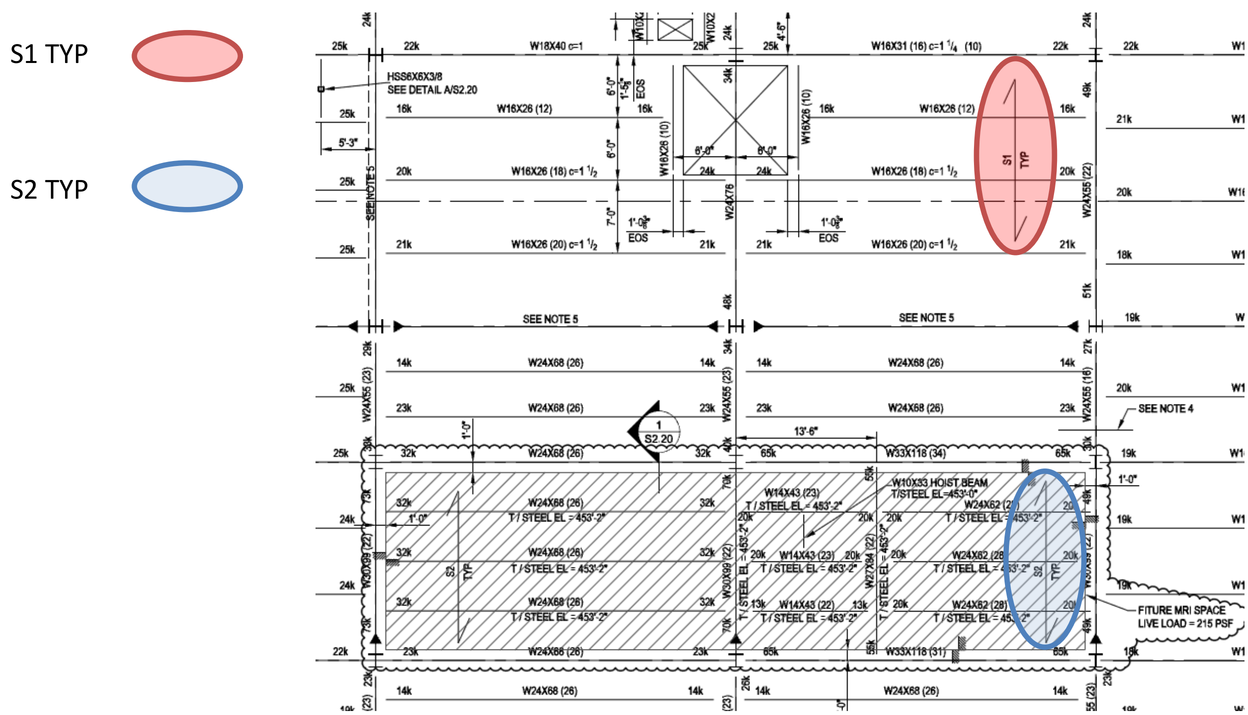
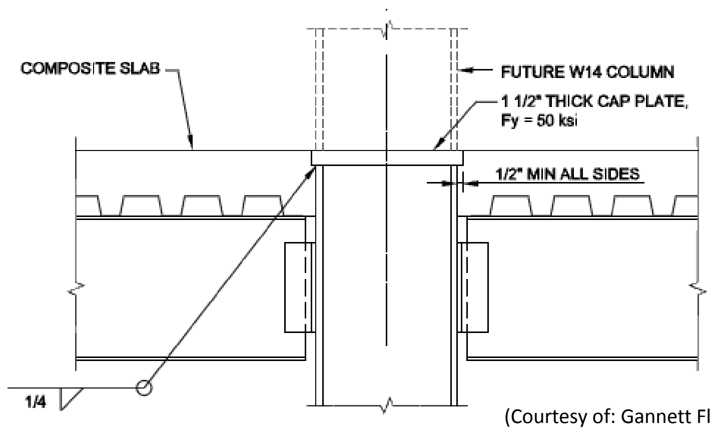


Figure 6 - Level 2 Framing Plan (Courtesy of: Gannett Fleming)

Roof System

The roof system for the Children's Hospital utilizes the same construction as the S1 TYP floor designation. Future plans call for an additional two stories of occupiable space to be constructed above the current roof level. Figure 7 shows how the columns for the future sixth floor are to be attached to the existing columns. The roofing material consists of a multiple-ply built-up roofing membrane on top of insulation. Surrounding the roof is an 8" thick parapet wall that rises 1' 4" above the top of the composite slab.



(Courtesy of: Gannett Fleming)

Figure 7 - Top of Column at Future Sixth Floor

Lateral System

The main lateral force resisting system is composed of several moment frames located at the interior of the floor plan. These moment frames run in the East-West direction along the floor plan and are represented in Figure 8 with red. The purpose in placing the moment frames in these locations is to allow for a consistent and open floor space which is important for the functionality of a hospital. Running perpendicular to the moment frames are diagonally braced frames which are represented with blue in Figure 8. The locations of these braced frames are set in locations where space requirements are not as significant such as partitions to the elevator banks.

The main lateral members used in the moment frame system are wide flange sections, primarily W24x229 and W24x176 while the columns are W14x342 and W14x283. The braced frames used in the structure are comprised of W10x112 and W10x88 bracing members.

Conclusions on Structural System

The structural system for the Children's Hospital allows for optimal use of space and provides room for future expansion when the need arises. The importance of using a composite floor system is that it allows for smaller framing members to be used. By using shallower members, the floor to floor height can be decreased, saving significant costs with respect to the structural system. Another benefit of using a composite floor system is that it assists in providing additional lateral resistance by creating a stiffer structure. This, along with the moment frames, allows for more free space which is necessary for daily operations of the Children's Hospital.

Figure 8 – Framing Plan (Courtesy of: Gannett Fleming)

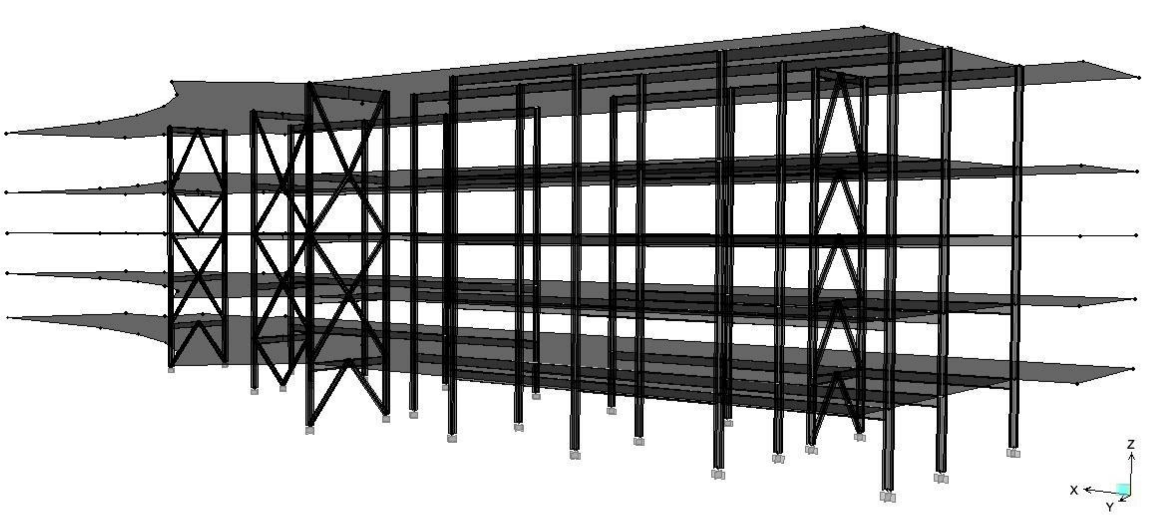


Figure 9 – ETABS model of Lateral Force Resisting System

Problem Statement

Problem 1: Structural redesign of existing structure

The existing structure is composed of a composite floor system with structural steel framing members. From the preliminary technical reports, the structure was determined to have been designed adequately to resist the required lateral and gravity loads. Despite this, there are a few disadvantages to designing the structure using steel. The depth of the wide flanges supporting the floor can become fairly deep in certain areas depending on the applied loads. This increase in depth takes away from the floor to ceiling heights within the building. Since the existing system is structural steel all exposed members will require fire retardant spray which adds to the overall building cost. From Technical Report 2, it was determined that there were some advantages to using an alternative structural design using a reinforced concrete system.

Problem 2: Future expansion of Children's Hospital

The design for the Children's Hospital includes plans for a future expansion of the existing structure. By adding more floors to the structure, this would allow for more patient rooms, operating rooms and more office space for hospital staff. This addition would affect the existing design by increasing the lateral and gravity loads seen by the existing structural design. One of the goals will be to analyze and design the vertical expansion of the hospital in the proposed revisions.

Proposed Solutions

Problem 1 Solution

During the analysis of "Technical Report 2: Structural Study of Alternate Floor Systems", it was determined that the existing structure has potential to be designed more efficiently. From Technical Report 2, it was determined that the structure could be made more efficient by switching to a reinforced concrete. As a result the overall structure height could be reduced allowing for a reduction in building cost and project scheduling. Another advantage for a concrete structure is the inherent fireproofing. This will save cost for fire retardant spray needed for the existing structure. Although formwork and lead times will adjust the costs and schedule of the project, it is estimated that these changes will make the structure more efficient.

Problem 2 Solution

The owners of the Children's Hospital would like to have flexibility for future expansion. With this in mind, additional floors will be designed for the proposed structure. The effects due to wind and seismic loads will increase due to the change in overall building height. Along with the solution to problem one, the loads due to the expansion will be analyzed to size members adequately.

Graduate Course Integration

The redesign of the structural system for the Children's Hospital will be modeled using AE 597A (Computer Modeling). An ETABS model for the concrete design will be used to determine member forces. AE 542 (Building Enclosure Science and Design) will be referenced in the design of the proposed curtain wall design. A heat transfer analysis will be used to determine the heat flow rate through both the existing and proposed systems.

Breadth I: Construction Impact and Cost Analysis

The redesign of the structure using reinforced concrete instead of structural steel will have significant impact on the cost and schedule for the project. Direct costs associated with the redesign will include items such as base material cost, additional labor teams, and formwork. An alternative schedule will be necessary to account for the new construction process. An accurate detailed analysis of these changes in cost and project schedule will be necessary to determine the effects of the proposed changes compared with the existing design.

Breadth II: Building Enclosure

Due to the large amount of north facing glass on the façade of the Children's Hospital, a heat transfer analysis will be performed to analyze the efficiency of the existing curtain wall system. Based on the analysis, an alternative configuration will be proposed to decrease heat loss due to the exposed glass curtain wall. Comparisons will be made with the existing curtain wall system to quantify the energy savings of the proposed system.

Tasks and Tools

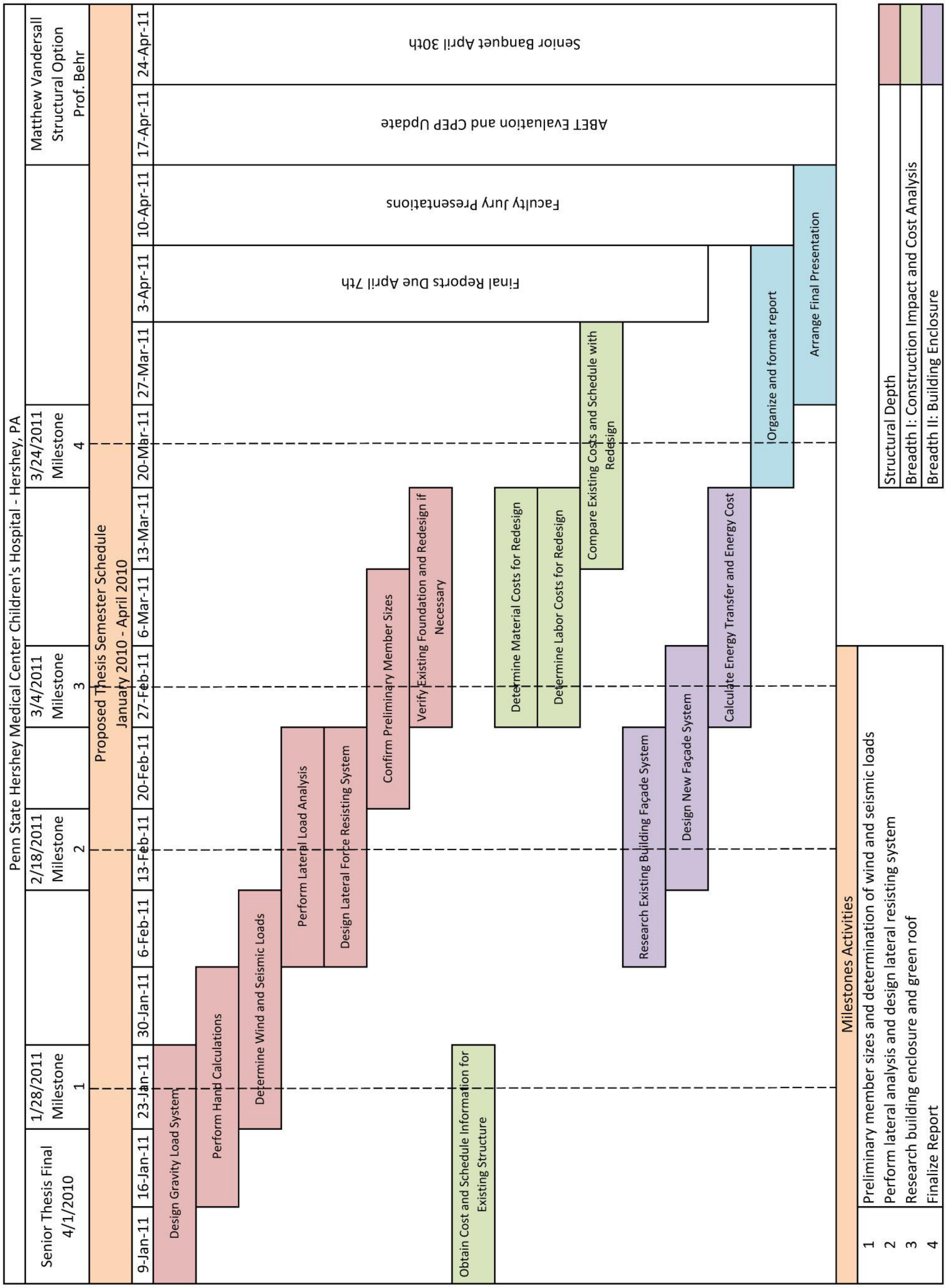
I. Structural Depth
   a. Design gravity load system
   b. Perform hand calculations
   c. Determine wind and seismic loads
   d. Perform lateral analysis
   e. Design lateral force resisting system
   f. Confirm preliminary member sizes
   g. Verify existing foundation and redesign if necessary

II. Breadth I: Construction Impact and Cost Analysis
   a. Obtain cost and schedule information for existing structure
   b. Determine material costs for redesign
   c. Determine labor costs for redesign
   d. Compare the existing costs and schedule with the redesign

III. Breadth II: Building Enclosure
   a. Research existing building façade system
   b. Design new façade system based on increased efficiency

IV. Organize final presentation and report

Schedule


Penn State Hershey Medical Center Children's Hospital - Hershey, PA
Senior Thesis Final 4/1/2010
1/28/2011 Milestone 1
2/18/2011 Milestone 2
3/4/2011 Milestone 3
3/24/2011 Milestone 4
Matthew Vandersall Structural Option Prof. Behr
Proposed Thesis Semester Schedule January 2010 - April 2010
9-Jan-11
16-Jan-11
23-Jan-11
30-Jan-11
6-Feb-11
13-Feb-11
20-Feb-11
27-Feb-11
6-Mar-11
13-Mar-11
20-Mar-11
27-Mar-11
3-Apr-11
10-Apr-11
17-Apr-11
24-Apr-11
Design Gravity Load System
Perform Hand Calculations
Determine Wind and Seismic Loads
Perform Lateral Load Analysis
Design Lateral Force Resisting System
Confirm Preliminary Member Sizes
Verify Existing Foundation and Redesign if Necessary
Obtain Cost and Schedule Information for Existing Structure
Determine Material Costs for Redesign
Determine Labor Costs for Redesign
Compare Existing Costs and Schedule with Redesign
Research Existing Building Façade System
Design New Façade System
Calculate Energy Transfer and Energy Cost
Organize and format report
Arrange Final Presentation
Final Reports Due April 7th
Faculty Jury Presentations
ABET Evaluation and CPEP Update
Senior Banquet April 30th
Milestones Activities
1 Preliminary member sizes and determination of wind and seismic loads
2 Perform lateral analysis and design lateral resisting system
3 Research building enclosure and green roof
4 Finalize Report
Structural Depth
Breadth I: Construction Impact and Cost Analysis
Breadth II: Building Enclosure

Conclusion

This proposal focuses on the structural redesign of the Children's Hospital. To satisfy owner requirements for the project, two additional floors will be designed above the current roof level. This will increase both gravity and lateral loads on the structural system. In addition, the structure will be redesigned using a reinforced concrete system. The goal through researching these proposals is to see if the structure will be more cost efficient while still satisfying the owner's needs. A cost analysis will be made between the existing plans and the redesign. While redesigning the structure, the building enclosure will be looked at in terms of building performance. Supporting research will determine how these modifications compare with the existing design while satisfying the needs of the owner.