Thesis Proposal

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Structural Option

Professor Behr

Hospital Patient Tower

Virginia, U.S.A.

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Executive Summary

The following is a proposed in-depth study for the redesign of a structural system for the Patient tower. The Patient Tower is part of the 2015 Capital Improvement Project, of which the Tower Expansion is one of the earlier phases. The new Patient Tower will connect with an existing patient tower by a bank of elevators. The Tower will also await the connection of a women's health facility that is one of the next phases of the Capital Improvement Project.

The existing structural system is a two – way reinforced concrete slab supported by concrete columns with reinforced concrete shear walls to resist the lateral loads that are applied to the tower.

The proposed structural change for the Patient tower is changing the gravity system of the tower from two-way concrete to a steel frame with hollow concrete plank will help with the weight of the system and the construction duration. The lateral system for the tower will remain the same for the existing system.

Breath studies will explore constructability and serviceability impacts. The Change in the gravity resisting system from a two – way flat plate reinforced concrete slab to a steel frame with precast concrete plank decking will produce a change in the Construction management of the project. With the change in system there will be a decrease the weight of the tower which would decrease the need for such a bearing ability of the foundations elements. With the faster erection time for steel shortening the length of construction should yield a lower cost of the structure.

With the change for a concrete gravity system to a steel system there are a few serviceability criteria that will need to be checked. In a hospital vibration, acoustics and floor deflection will all be very important criteria that will need to be kept with in close tolerances to not affect the patients. The existing concrete system has inherit properties that will handle these criteria where the new system may need the addition of other materials to help it satisfy the criteria.

Figure 1: Rendering by Wilmot Sanz

Introduction

The Patient Tower is part of the 2015 Capital Improvement Project, of which the Tower Expansion is one of the earlier phases. The new Patient Tower will connect with an existing patient tower by a bank of elevators separated into two sections, one for visitors and the other for patients at every floor. The Tower will also await the connection of a women's health facility that is one of the next phases of the Capital Improvement Project. The Façade of the Patient Tower will blend in with the existing buildings by keeping some of the red brick on the exterior, but also by taking on a more modern look by incorporating an aluminum curtain wall and precast concrete panels. The new tower consists of 12 stories above grade with one level below grade. The patient tower is 216,000 square feet with 174 patient rooms, an operation area and a mechanical level. The contract for this tower was awarded to Turner Construction, the general contractor, in a Design-Bid-Build method with a contact value of $161 million.

One of the main design considerations is individual patient rooms. Based on the hospital's goals for care the individual patient rooms were a large factor in the design of the floor plan. During the design phases the project team requested input from the physicians, nurses and staff to help make the design as efficient as possible. Medical/surgical patients aging 65 years and older were the focus of this tower, with a special emphasis on their safety and a good healing environment. With the hospital team input the placements for monitoring stations were optimized to ensure patient privacy as well as enhancing the monitoring capabilities.

One of the hospital's goals, along with excellent patient care, is also to lower the hospital's impact on the environment. The hospital's plan for this new tower included green features such as living roofs, low flow water fixtures, and rain gardens. The design also calls for no/low VOC building materials to be used in construction of the tower. The tower design has been submitted for a LEED Silver certification.

Figure 2: Sketch by Wilmot Sanz

Structural Systems

Foundations

The geotechnical report was prepared by Schnabel Engineering, LLC, on March 25, 2010. The foundation of the patient tower is set on piles, with pile caps and grade beams. Each column location has a range of 4 to 12 piles. The slab on grade for the tower is 5" with integrated slab pile caps in locations of high stress, such as the elevator shaft and stair well. During the excavation for the new tower the existing basement and caissons supporting the connecting structure were exposed. The existing 66" caissons will support a small portion of the tower connection while the rest will be supported by new piles. In a few locations where there is no basement piles were drilled to reach up to the ground floor level to support irregular building features.

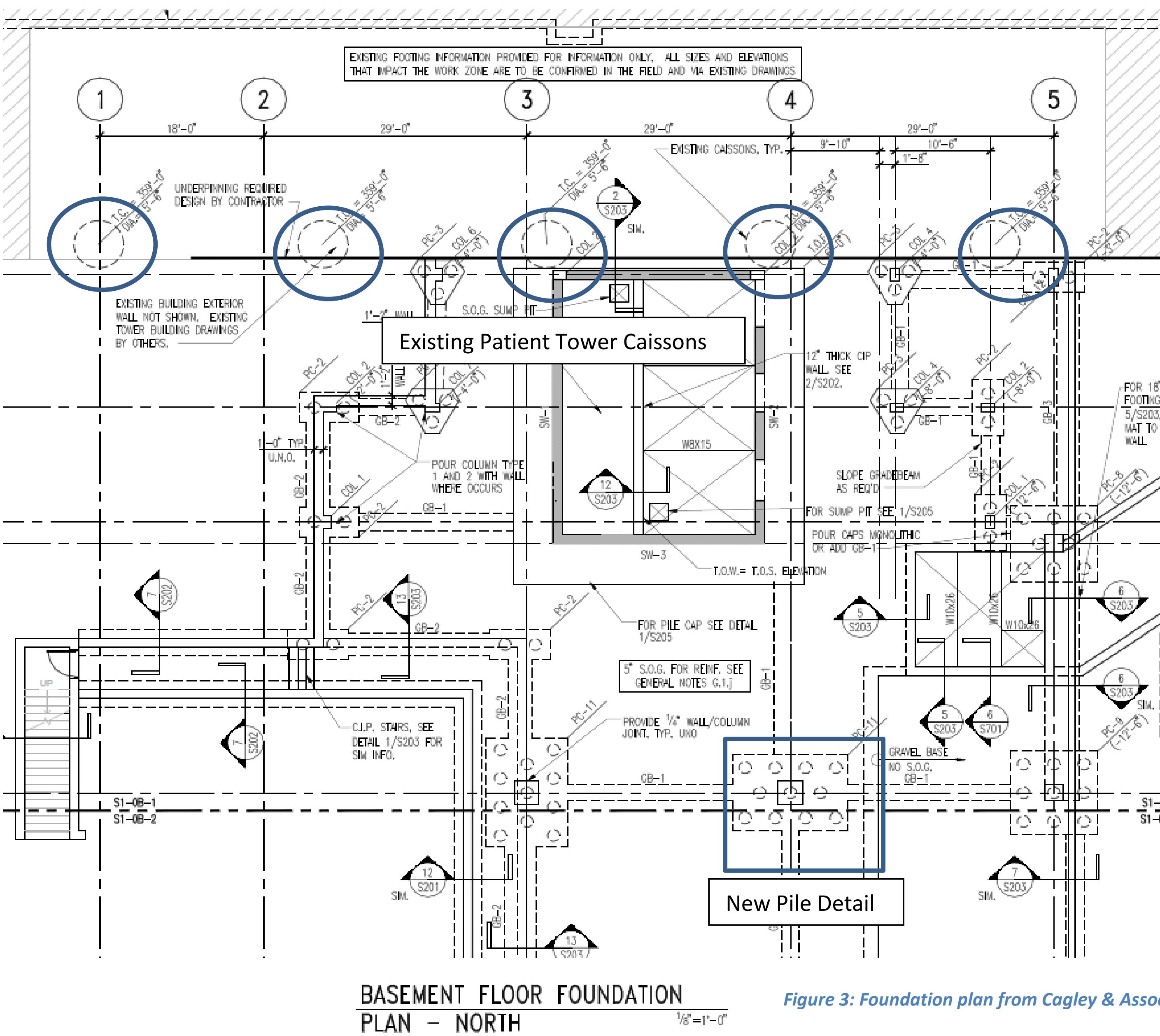


Figure 3: Foundation plan from Cagley & Associates

Columns

The column layout of the patient tower is very regular with a few variations on the 1st through 3rd floors. The bay spacing in the patient tower is mostly square 29' x 29' with a few exceptions as see in Figure 6. The columns are reinforced concrete ranging in size from 30" x 30" to 12" x 18". The typical column size is 24" x 24" with vertical reinforcing of #11 bars numbering from 4 bars to 12 bars as they move through the structure. The vertical reinforcing is tied together with #4 bars placed every 18". The columns on the basement level up through the 4th floor are poured with 7,000 psi concrete and from the 5th floor up they are 5,000 psi concrete. The structural system of the Patient Tower utilizes column capitals to resist punching shear within the slab. The typical capital in the tower is 10' x 10' x 6" depth, making the slab thickness at the capitals 15 ½".

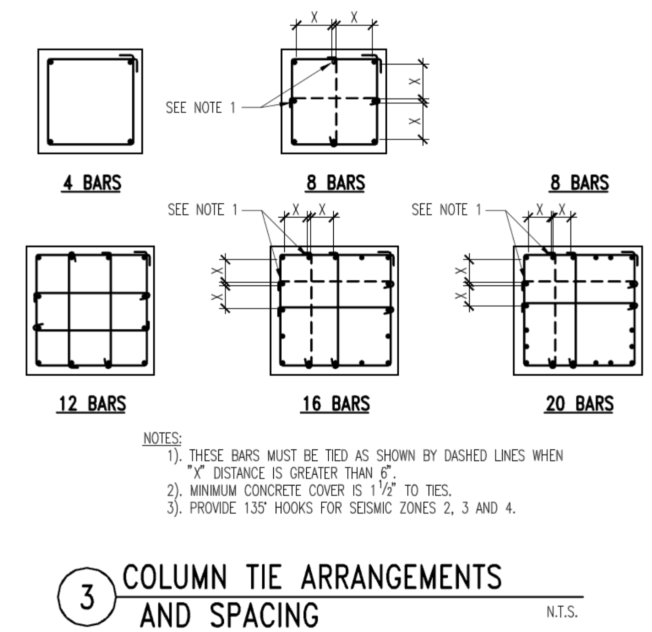


Figure 4: Column Reinforcing Detail from Cagley & Associates

MECH ROOM FLOOR						
MAIN ROOF						
ELEVENTH FLOOR		24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24 4#11 #4@18
TENTH FLOOR		24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24 4#11 #4@18
NINTH FLOOR		24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24 4#11 #4@18
EIGHTH FLOOR		24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24 4#11 #4@18
SEVENTH FLOOR		24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 8#11 #4@18"	24"x24 4#11 #4@18
SIXTH FLOOR		24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 8#11 #4@18"	24"x24 4#11 #4@18
FIFTH FLOOR		24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 12#11 #4@18"	24"x24 4#11 #4@18
FOURTH FLOOR		24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 12#11 #4@18"	24"x24 4#11 #4@18
THIRD FLOOR		24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 12#11 #4@18"	24"x24 8#11 #4@18
SECOND FLOOR	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 4#11 #4@18"	24"x24" 8#11 #4@18"	26"x26" 16#11 #4@18"	24"x24 8#11 #4@18
FIRST FLOOR	24"x24" 4#11 #4@18"	24"x24" 8#11 #4@18"	24"x24" 8#11 #4@18"	24"x24" 8#11 #4@18"	26"x26" 16#11 #4@18"	24"x24 12#11 #4@18
GROUND FLOOR	24"x24" 4#11 #4@18"	24"x24" 8#11 #4@18"	24"x24" 8#11 #4@18"	24"x24" 12#11 #4@18"	28"x28" 20#11 #4@18"	24"x24 12#11 #4@18
BASEMENT FLOOR TOP OF FOUNDATION			24"x24" 12#11 #4@18"		30"x30" 20#11 #4@18"	26"x26 16#11 #4@18

Figure 5: Partial Column Schedule from Cagley & Associates

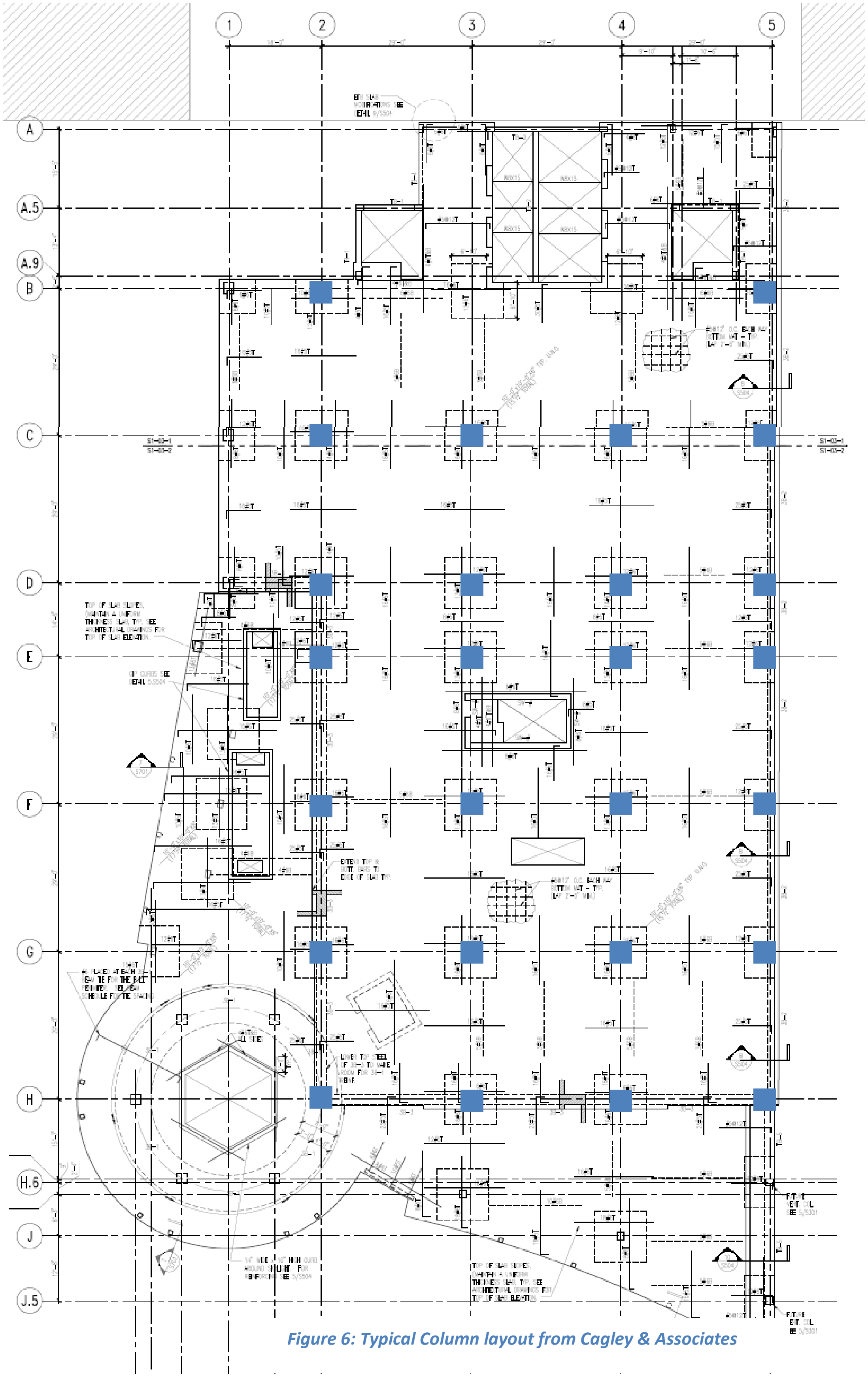


Figure 6: Typical Column layout from Cagley & Associates

Floor System

The floor system for this patient tower is a 9.5" 2-way flat plate. For the ground floor through the 4th floor the slab is 5000 psi concrete with the remaining floors at 4000 psi concrete. The largest span for this flat plate is 29' in each direction with square bays. The flat plate system has both top and bottom steel reinforcing. The top steel placed at regions of negative moment is typical notated with a number of #5 bars. The bottom reinforcing is a 2-way mat of #5 bars at 12" on center. In the end bays of the slab there are extra bottom bars added to handle the carry over moments for the interior span. On the 5th floor of the tower is the mechanical level, which increases the loading on the slab giving it a 10.5" concrete slab. See figure 7 below for details.

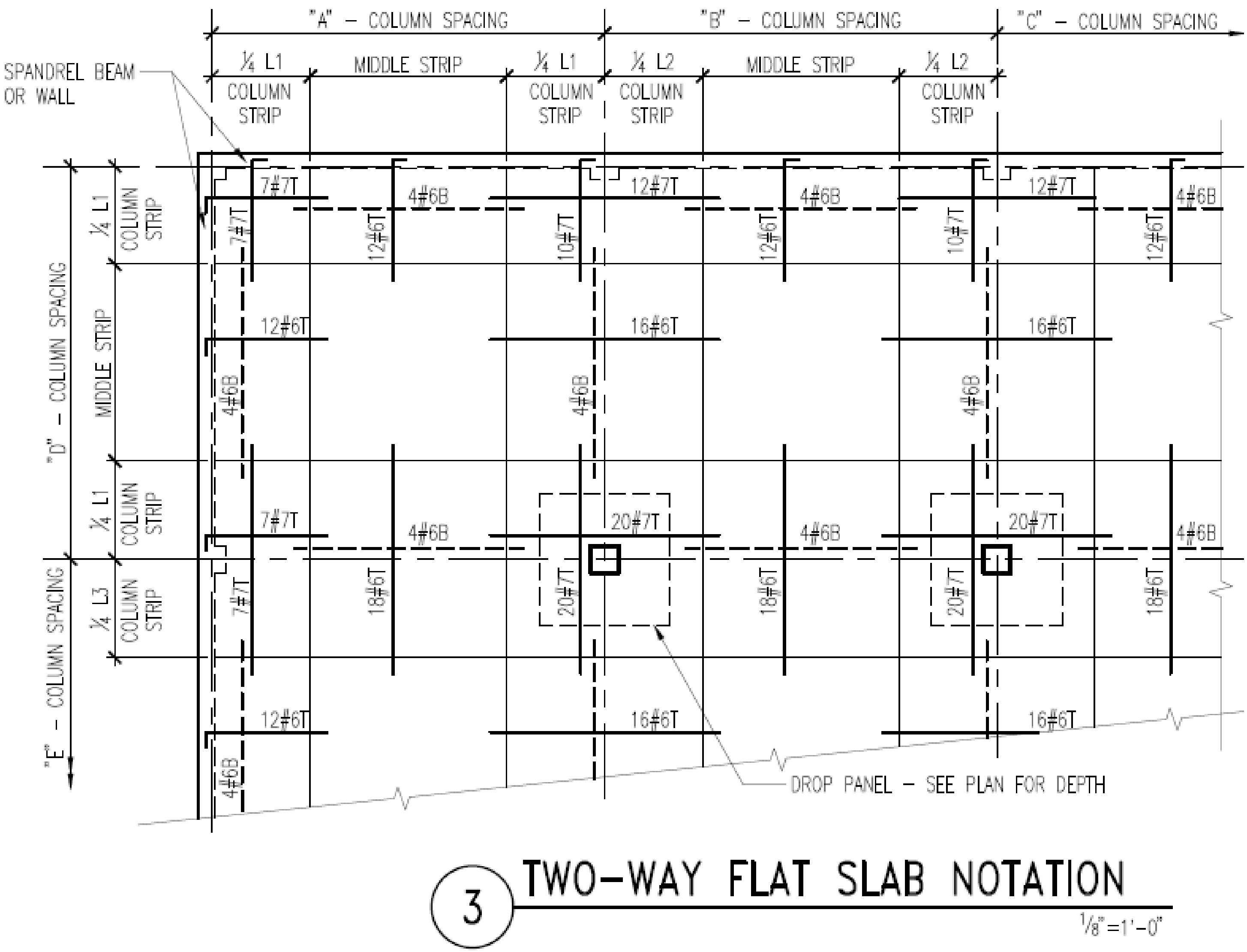


Figure 7: Two-way Flat Slab Detail from Cagley & Associates

Roof System

The roof system for the patient tower is designed with the same conditions at a typical floor, a 9.5” Two-way flat plate with mat and bar reinforcing detailed in the above section. The roof does have a few variations from a typical floor; the roof area that will support the mechanical penthouse has been increased to a 14” slab to support the extra weight of the equipment and there were supports added to the main slab to support the new helipad (Figure 8) for the tower.

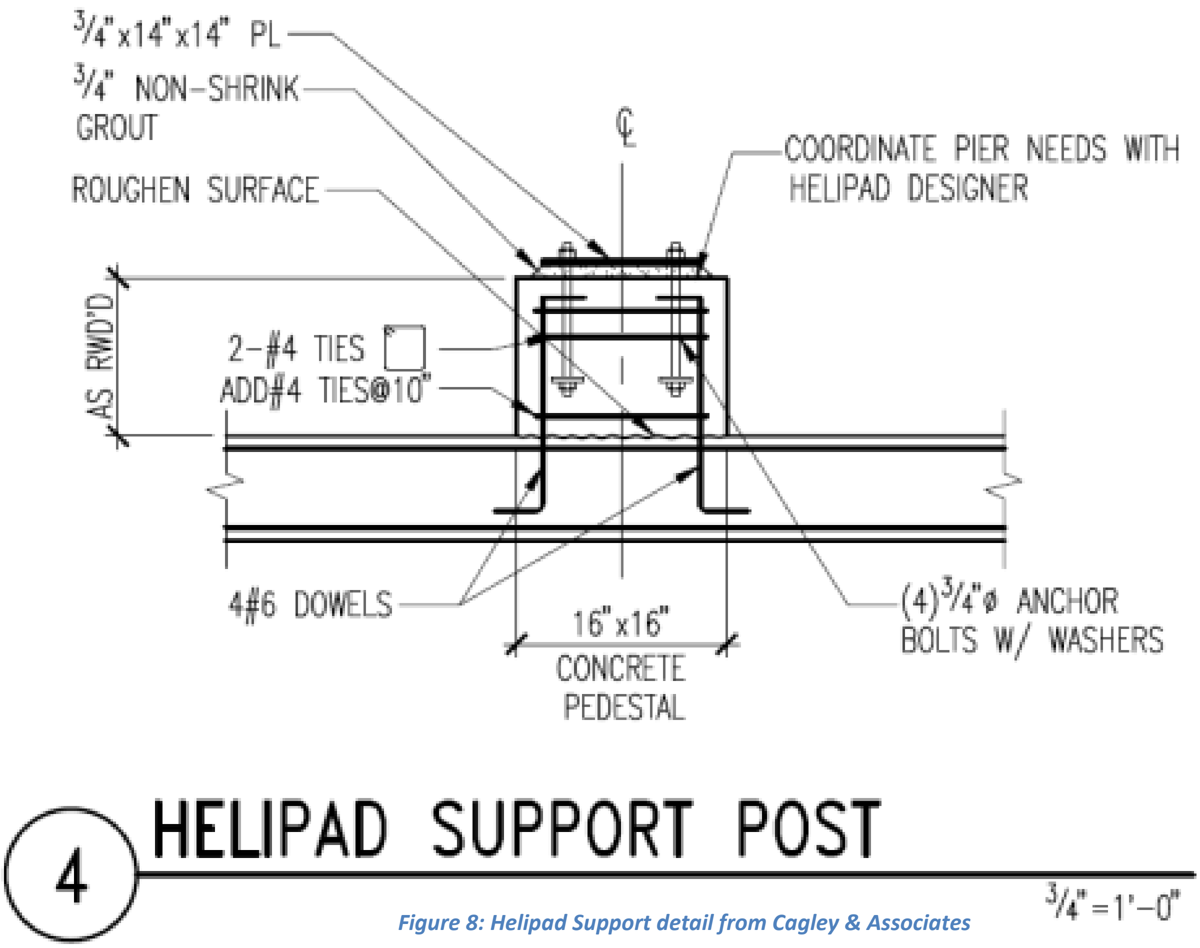


Figure 8: Helipad Support detail from Cagley & Associates

Lateral System

The lateral system in the new patient tower consists of seven 12" reinforced concrete shear walls. These walls are located in different locations throughout the building depicted to the right. The shear walls consists of 5000 psi concrete and were run continuously through the tower from the foundations up to the roof with the northern core extending through the penthouse. This system of two shear wall cores resists lateral loads in both the north-south and east-west direction based on the orientation of the wall. The towers main structural system is a concrete two-way flat plate. This system will also act a concrete moment frame which will also resist lateral forces. Between this two system all of the lateral forces applied to this tower can be resisted.

Design & Code Review

Design Codes and References

- International Building Code – 2006 "International Code Council".
- ASCE 7 – 05 "Minimum Design loads for Buildings and Other Structures" American Society of Civil Engineers.
- ACI 318-05 "Building Code Requirements for Structural Concrete" American Concrete Institute.
- ACI Manual of Concrete Practice.
- AISC "Manual of Steel Construction – Allowable Stress Design".

Thesis Codes and References

- International Building Code – 2006 "International Code Council".
- ASCE 7 – 10 "Minimum Design loads for Buildings and Other Structures" American Society of Civil Engineers.
- ACI 318-08 "Building Code Requirements for Structural Concrete" American Concrete Institute.

Deflection Criteria

Floor Deflection Criteria

Typical Live load Deflection limited to L/360

Typical Total load Deflection limited to L/240

Material Specifications

Materials	Grade	Strength
Concrete		
• Piles	-	f'_c = 4,000 psi
• Foundations	-	f'_c = 3,000 psi
• Slab-on-grade	-	f'_c = 3,500 psi
• Shear Walls	-	f'_c = 5,000 psi
• Columns	-	f'_c = 5,000/7,000 psi
• Floor Slabs	-	f'_c = 4,000/5,000 psi
W Flange Shapes	ASTM A992	F_y = 65,000 psi
HSS Round	ASTM A53 grade B	F_y = 35,000 psi
HSS Rectangular	ASTM A500 grade B	F_y = 46,000 psi
Reinforcing bars	ASTM 615 grade 60	F_y = 60,000 psi
Steel Decking	ASRM A653 SS Grade 33	F_y = 33,000 psi

Table 1: Material Specifications

Problem Statement

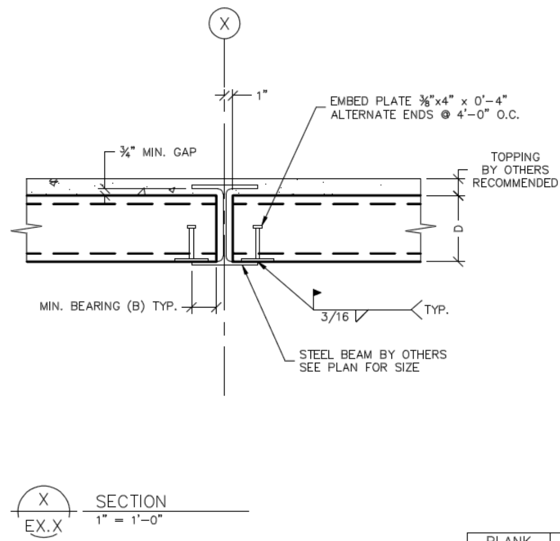
The Patient tower is currently a two – way flat plate reinforced concrete slab supported by reinforced concrete columns. This system is the main gravity load bearing system that transfers each floor load to the foundation of slab on grade and drilled piles. The towers current lateral system is reinforced concrete shear walls cores. There are two cores located around the central stair case and the elevator shaft. The strength of concrete used in the shear walls is 5000psi with the gravity system using both 5000 and 7000 psi concrete.

The Patient tower is an addition to an existing hospital campus to provide updated equipment and facilities for care while being integrally connected to the existing patient tower. The goal of this thesis is to decrease the overall cost of the tower, decrease the construction time while maintaining the functionality of the tower.

Problem Solution

In order to decrease the overall cost of the tower, decreasing the construction time and the overall building weight are the two main ways that this problem confronted. Changing the gravity system of the tower from two-way concrete to a steel frame with hollow concrete plank will help with the weight of the system and the construction duration.

The new proposed floor system would be hollow core concrete plank ranging from 8” to 12” supported with W-shape steel beams. These planks would be placed in the beam as shown in the figure and not placed on top of them as is traditionally done. Since the plank and beams will be place in conjunction with each other the floor system will be low in depth allowing for the patient tower to maintain its floor to floor heights so that it will be able to make the connection to the existing tower. The current floor system depth is 9.5” giving the tower enough space in the ceiling cavity for all of the mechanical system so if the proposed new system is designed with this in mind there should not be many issues with ceiling cavity space.



PLANK THICKNESS (D)	MIN. BEARING (B)
8"	2½"
10"	2½"
12"	2½"
16"	4"

With this changing in floor system the columns for the tower would also have to be redesigned to account for the change in material and loading of the floor system. ASCE7-10 will be used to determine the correct floor loads for the tower as evaluated in Tech Report #2.

The lateral resisting system will remain the same from the original design with the two shear wall cores surrounding the stairway and the elevator shaft. With the changes to the building weight it maybe found that the lateral system is over designed for with the new gravity system but will be maintained during this assignment. If it is found that the shear walls are found to be insufficient in the new design they will be redesigned to carry the higher loads.

Breadth Issues

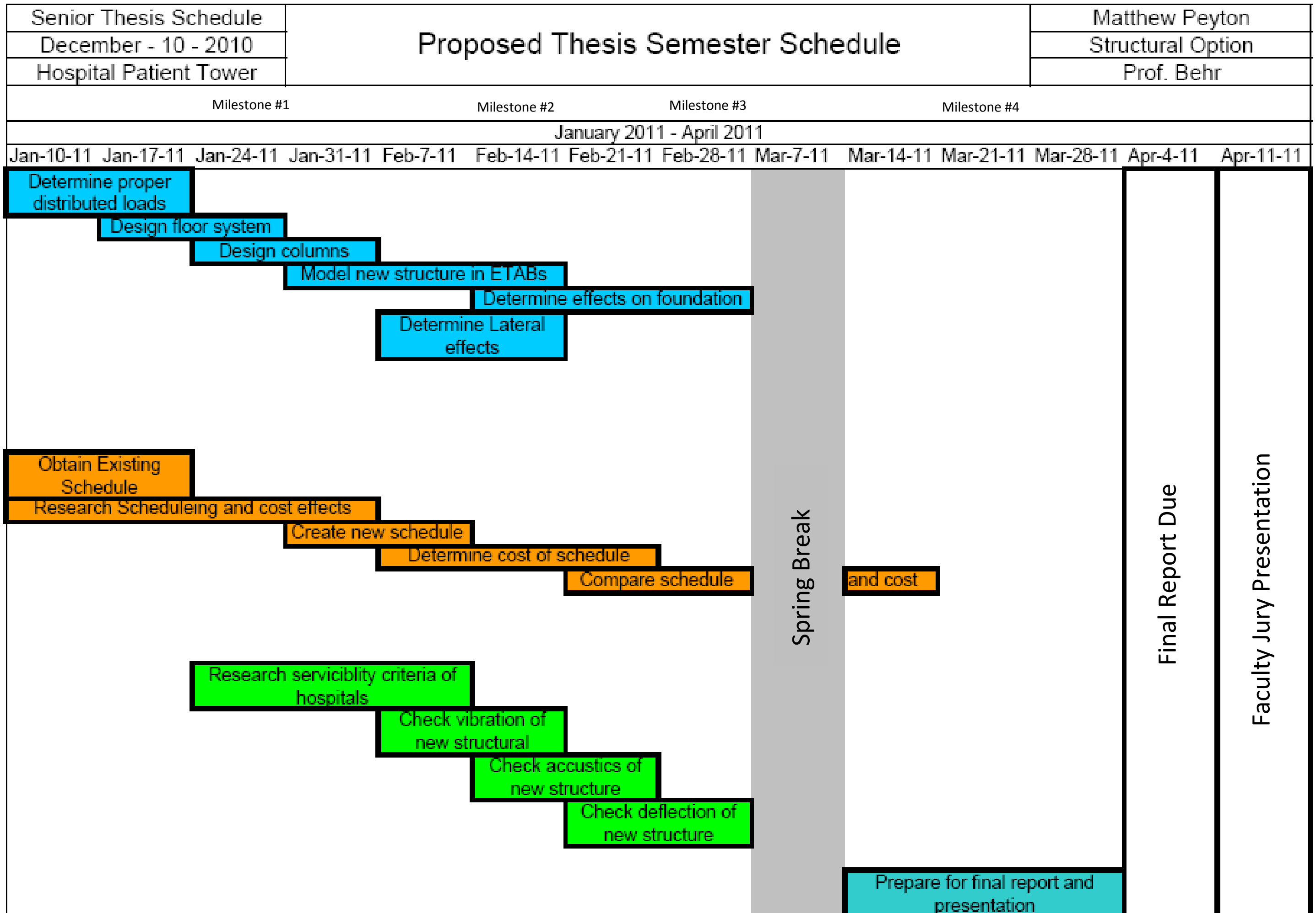
The Change in the gravity resisting system from a two – way flat plate reinforced concrete slab to a steel frame with precast concrete plank decking will produce a change in the Construction management of the project. While steel structural elements are prefabricated and have a longer lead time we are trying to decrease the weight of the tower which would decrease the need for such a bearing ability of the foundations elements. With the faster erection time for steel shortening the length of construction should yield a lower cost of the structure.

With the change for a concrete gravity system to a steel system there are a few serviceability criteria that will need to be checked. In a hospital vibration, acoustics and floor deflection will all be very important criteria that will need to be kept with in close tolerances to not affect the patients. With a concrete system these criteria are satisfied by the mass and rigidity of the system but with a steel system all of these criteria will need to be checked.

Task and Tools

1) Evaluate all gravity loads
   a) Dead loads
   b) Live loads
   c) Snow loads
2) Redesign the gravity system
   a) Choose appropriate slab
   b) Design girder system
   c) Design steel column
3) Revaluate lateral system
   a) Wind loads
   b) Seismic
4) Construction management Investigation
   a) Cost of the new system
   b) Construction time
5) Serviceability Checks
   a) Vibration
   b) Acoustics
6) Final Presentation Preparation
   a) Organize, format and finalize presentation
   b) Prepare for final presentation

Proposed Schedule

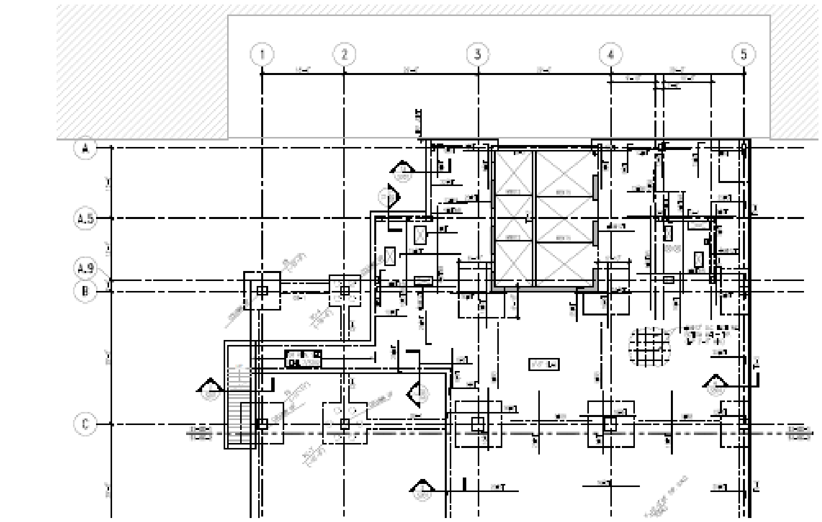


	Mildstones	Complete?
1	Finish new floor slab design	
2	Finish ETABs model of new system	
3	Finish new structural shedule	
4	Finalize final report and presentation	

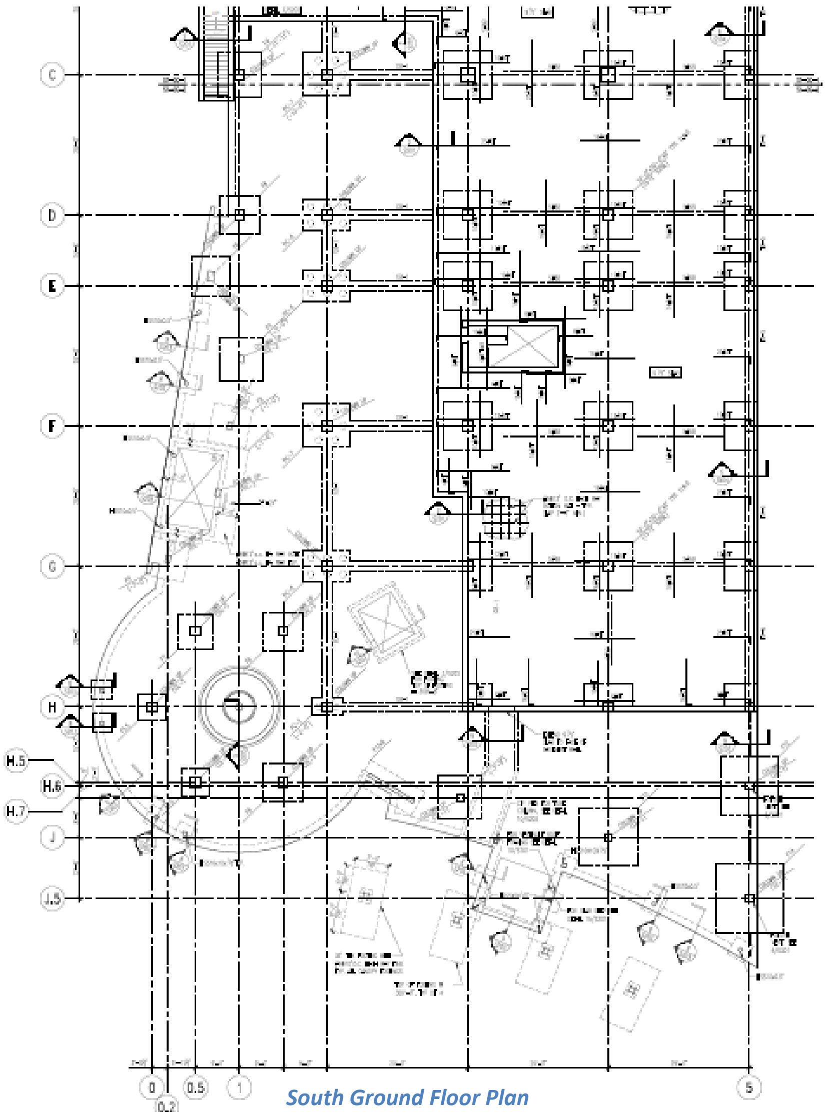
Structural Depth Topic	(blue)
Breath Topic 1 - CM	(orange)
Breath Topic 2 - Serviceability	(green)

Appendix I

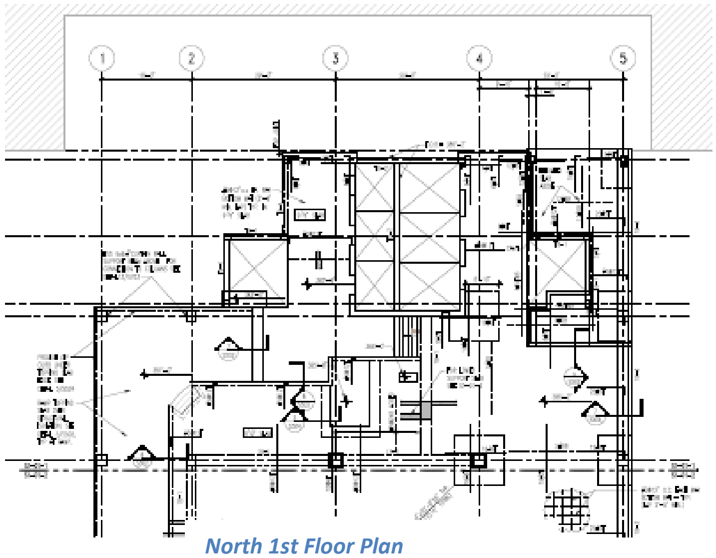
This section is where the supplementary information for the layout and design for the Hospital Patient Tower can be found.



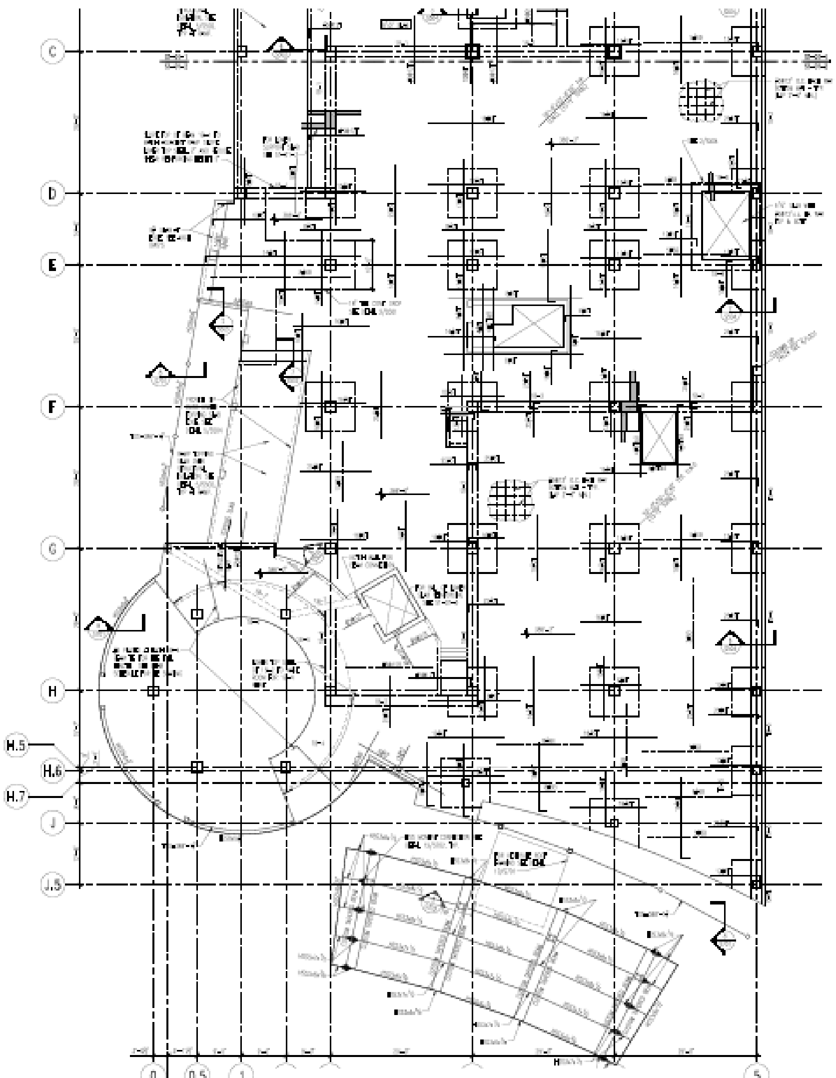
North Ground Floor Plan



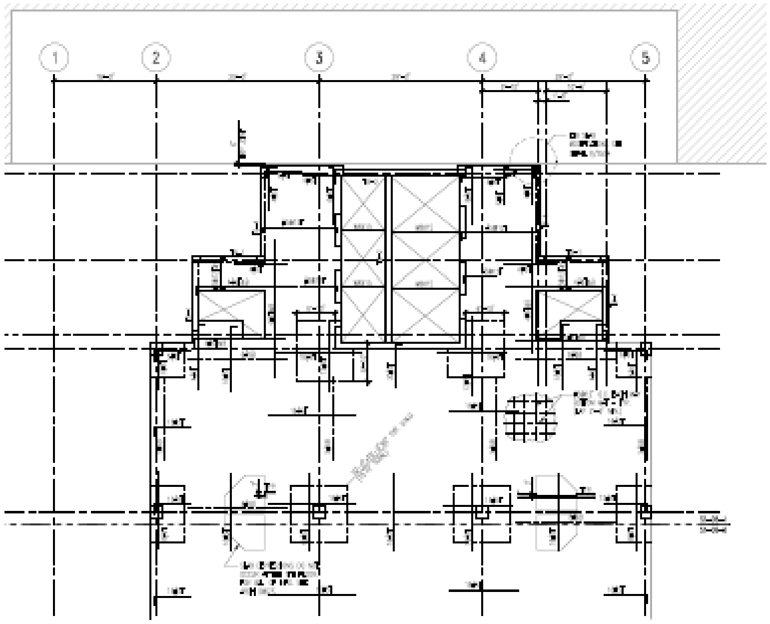
South Ground Floor Plan



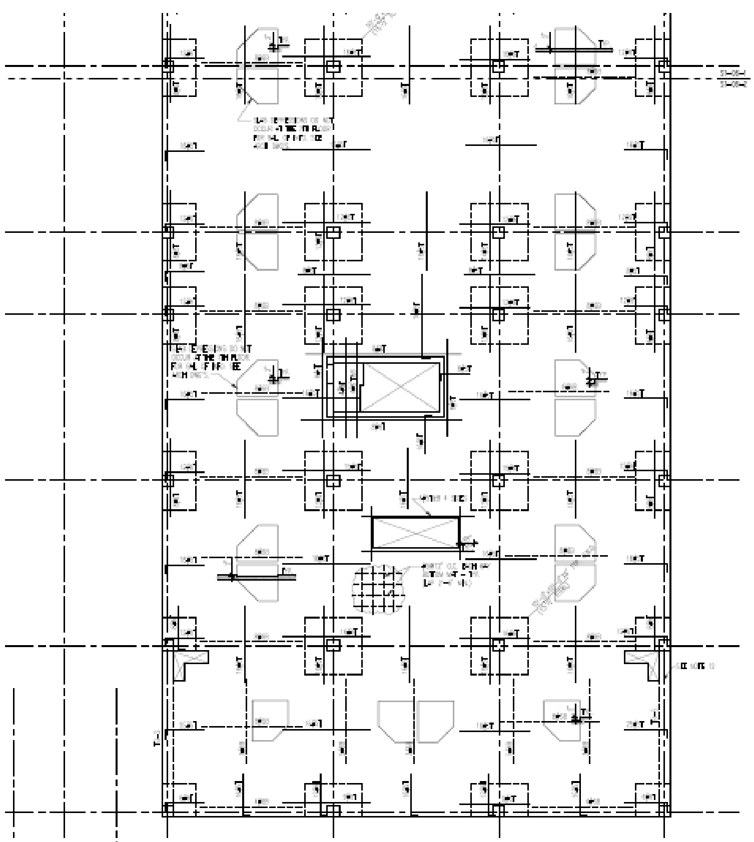
North 1st Floor Plan



South 1st Floor Plan



North Typical Floor Plan



South Typical Floor Plan