Franklin Square Hospital Center Patient Tower

Baltimore, MD

Thesis Proposal

Thomas Weaver

Structural Option

AE 481W Senior Thesis

Consultant: Professor M. Kevin Parfitt
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Executive Summary

The Franklin Square Hospital Center Patient Tower is a 7 story 356,000 square foot hospital addition that serves the existing Franklin Square Hospital campus while adding 291 private inpatient rooms, an expanded emergency department, a dedicated pediatric emergency department and inpatient suites, four new medical and surgical units, and an expanded 50 bed critical care unit.

The current structural system consists a of two-way mildly reinforced concrete flat plate floor system and reinforced concrete moment frames. The proposed thesis focuses on lateral design and optimization by relocating the building to Berkeley California which requires changes to both the gravity and lateral systems. A redesign of the entire floor system with a post-tensioned flat plate will be utilized to lower building self weight and the existing moment frames will be supplemented with interior concrete shear walls to resist lateral loads.

Berkeley California was chosen as the new building site for its seismic history. For the purpose of this thesis, an intense lateral redesign was chosen which requires intense lateral loading. Located less than half a mile from the Hayward Fault, Berkeley Ca was a logical choice. Hayward Fault is considered by some to be the most dangerous fault in America at this time with a 63% chance of a magnitude 6.7 or greater earthquake within the next 30 years. The past five large earthquakes of this fault have occurred on average about 140 years apart and the last occurred 142 years ago, October 21, 1868.

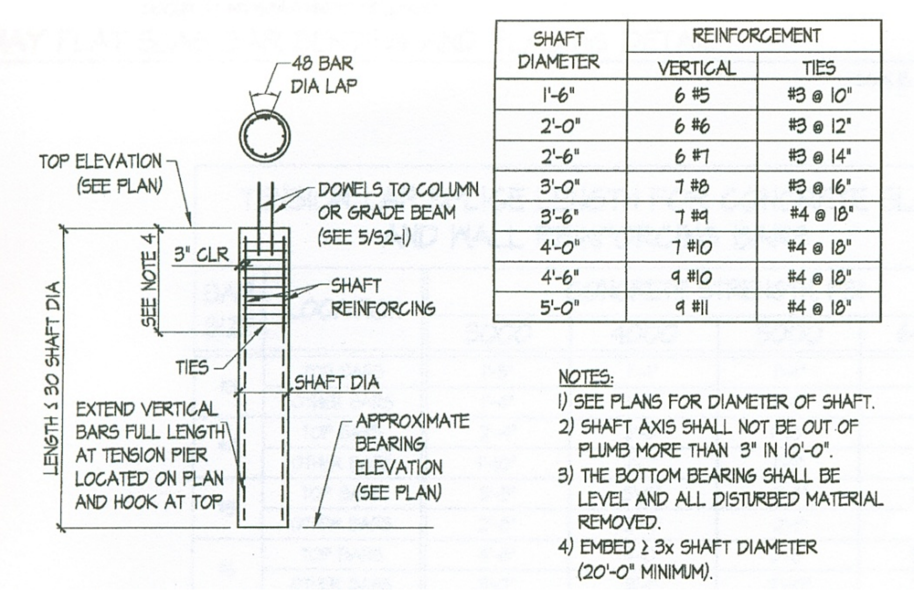
Additional breadth topics proposed in this report focus on other architectural engineering disciplines such as construction management and architecture. One of these studies will focus on a cost and scheduling comparison to determine adjustment to the construction schedule necessitated by the change from a mildly reinforced two way flat plate to a post-tensioned two way flat plate. The associated costs with a changed schedule will also be investigated. The second study involves an architectural redesign of support spaces, nurse's stations and hallways to function around the addition of structural shear walls.

The MAE requirements for the project will be fulfilled through the rigorous seismic analysis and design taught in AE 538. Additionally, an improved and comprehensive computer model will be constructed and modeled in ETABS according to the material learned in AE 597A.

Structural Systems

Foundation System

The foundation system of the Franklin Square Hospital Patient Tower consists of drilled piers or caissons 4 feet in diameter and centered under columns or slightly offset under perimeter grade beams. The piers range in size from 1.5 feet in diameter to 5 feet in diameter. They are embedded a minimum of 20 feet into bedrock. The total typical depth of the piers is around 42 feet below grade pending geotechnical engineer inspection. See Figure 1, "Drilled Pier Reinforcing."

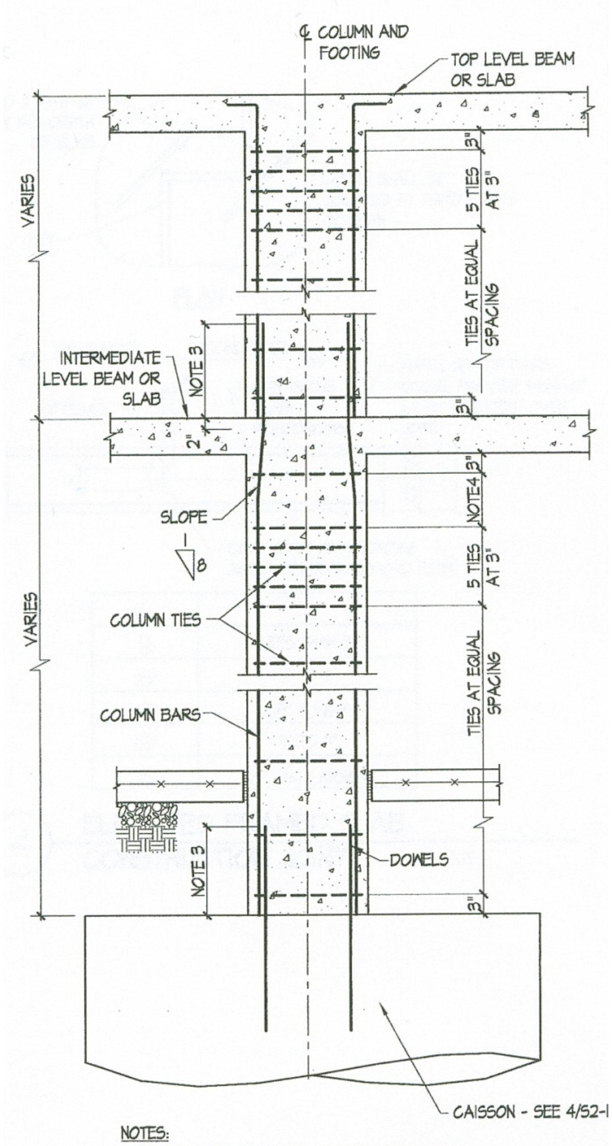


SHAFT DIAMETER	REINFORCEMENT	
	VERTICAL	TIES
1'-6"	6 #5	#3 @ 10"
2'-0"	6 #6	#3 @ 12"
2'-6"	6 #7	#3 @ 14"
3'-0"	7 #8	#3 @ 16"
3'-6"	7 #9	#4 @ 18"
4'-0"	7 #10	#4 @ 18"
4'-6"	9 #10	#4 @ 18"
5'-0"	9 #11	#4 @ 18"

NOTES:
1) SEE PLANS FOR DIAMETER OF SHAFT.
2) SHAFT AXIS SHALL NOT BE OUT OF PLUMB MORE THAN 3" IN 10'-0".
3) THE BOTTOM BEARING SHALL BE LEVEL AND ALL DISTURBED MATERIAL REMOVED.
4) EMBED ≥ 3x SHAFT DIAMETER (20'-0" MINIMUM).

Figure 1: Drilled Pier Reinforcing

The piers are required to be a normal weight concrete with a concrete compressive strength (f'_c) of 3000 psi. As previously mention, the piers directly support interior columns. See Figure 2, "Column Caisson Connection and Column Reinforcing."



NOTES:
1) SEE COLUMN SCHEDULE FOR DIMENSIONS AND REINFORCEMENT.
2) SEE GENERAL NOTES FOR MINIMUM CONCRETE COVER TO PRIMARY REINFORCING.
3) SEE 3/S2-1 FOR SPLICE LENGTHS OF VERTICAL BARS.
4) WHEN DIMENSION OF STIRRUP TO VERT BAR BEND EXCEEDS 6", PROVIDE ADDITIONAL TIE.

Figure 2: Typical Column Caisson Connection and Column Reinforcing

The piers also directly support perimeter grade beams. The typical grade beam is 24"x24" with some that are 36"x24". See Figure 3, "Typical Grade Beam Caisson Connection."

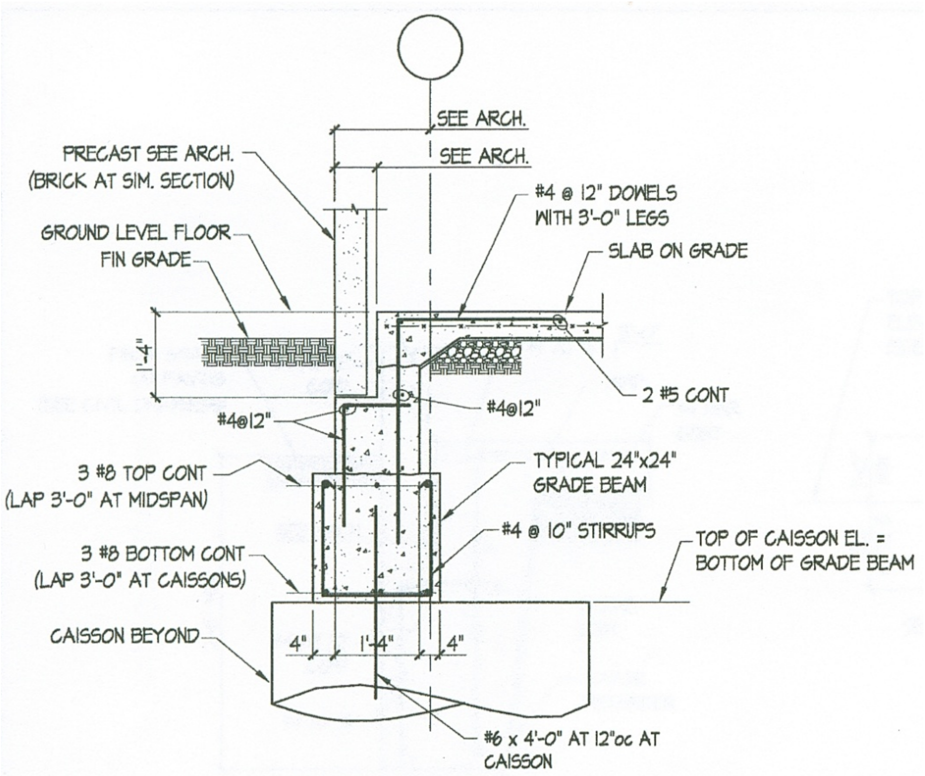


Figure 3: Typical Grade Beam Caisson Connection

While there are no sub grade levels in the structure, the west side of the ground floor can be considered below grade because the ground has been filled to provide on grade access to the first floor lobby. The existing hospital ground floor also resides on the level corresponding to the patient tower's first floor. Lateral soil pressures from the foundation of the existing building are resisted by a 16" thick foundation wall in these areas. See Figure 4, "Typical Foundation Wall Section."

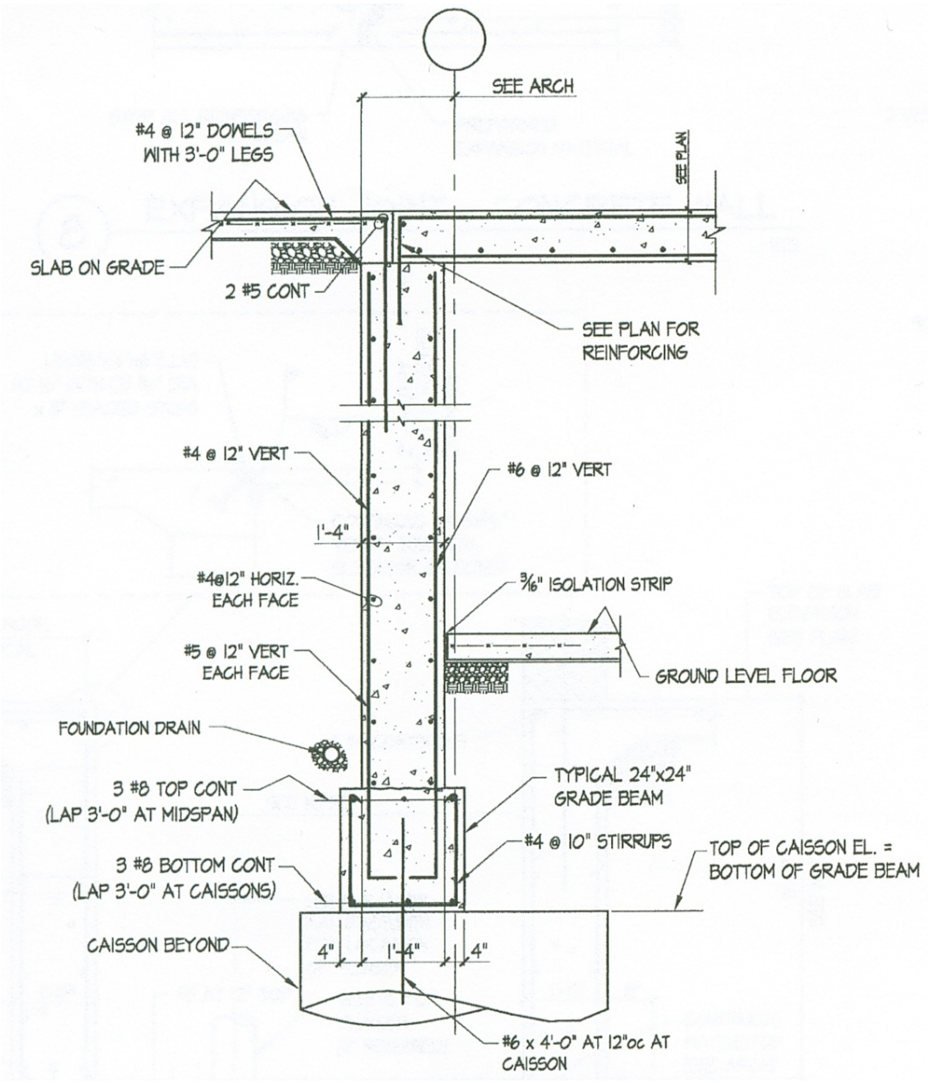


Figure 4: Typical Foundation Wall Section

The rest of the foundation consists of a 5 inch ground floor slab on grade of compressive strength equal to 3000 psi. The slab on grade is reinforced with 6x6-W2.9xW2.9 welded wire fabric over a 4 inch layer of clean, well-graded gravel or crushed stone.

Floor System

The buildings typical floor system is a 10" reinforced two way slab, or flat plate, spanning a typical 30'x30' bay. The reinforcing varies a great deal depending on location and span but for the most part there is a continuous bottom mat of #5 or #6 bars at 12" each way with continuous top reinforcing within the column strips with mostly #6 or #8 bars. See Appendix A for Floor Plans and Figure 5, "Slab Reinforcing Detail."

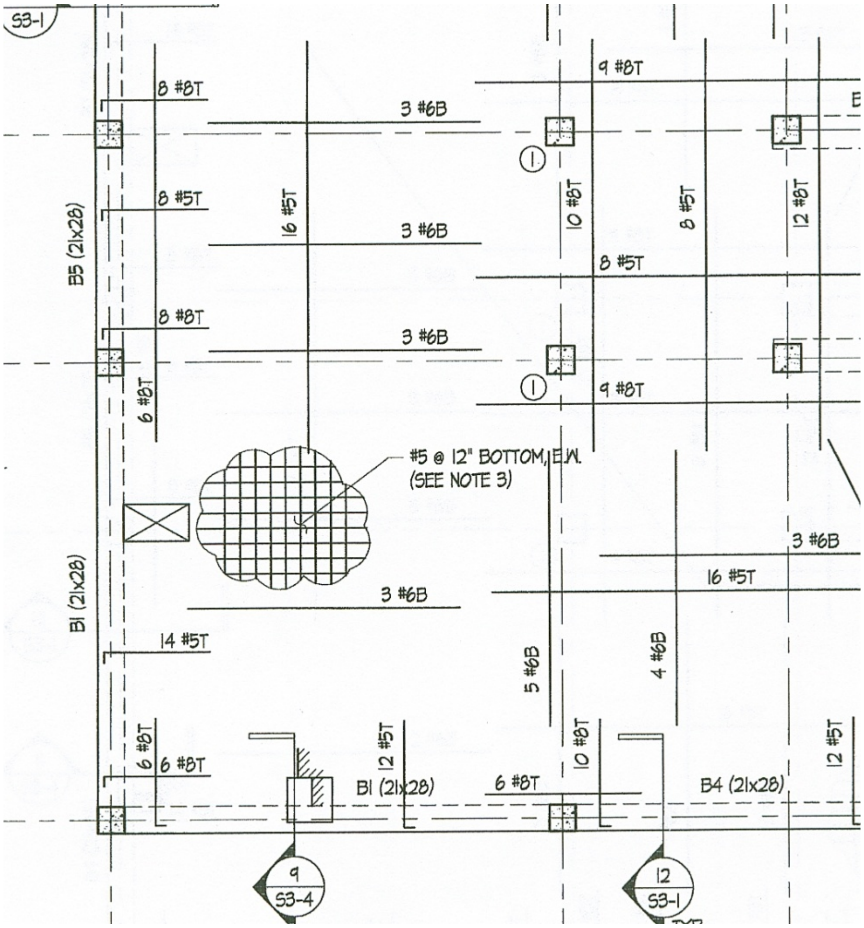


Figure 5: Slab Reinforcing Detail

The floor system also consists of edge beams that wrap the perimeter of the slab and surround openings such as stairs, elevators, and mechanical shafts. The typical edge beam is 21"x28" reinforced with #9 bars top and bottom. See Figure 6, "Portion of Concrete Beam Schedule."

CONCRETE BEAM SCHEDULE

MARK	SIZE		REINFORCING				STIRRUPS				REMARKS
	W (INCHES)	D (INCHES)	BOTTOM BARS	TOP BARS LE	TOP BARS FL	TOP BARS RE	SIZE	TYPE	SPACING (INCHES)	END	
B1	21	28	3#9	-	2#9	-	#4	S2	1@2, 12@12, R@18	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B2	12	28	3 #9	-	3#9	-	#4	S2	1@2, R@10	EE	
B3	10	28	3 #8	-	3#8	-	#4	S2	1@2, R@12	EE	
B4	26	20	3 #9	-	3#9	-	#4	S3	1@2, R@8 CANT. 1@2, R@8	EE	
B5	21	28	2#9	-	2#9	-	#4	S2	1@2, R@12	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B6	21	28	4#9	-	3#9	-	#4	S2	1@2, R@8	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B7	21	28	3#9	1#9	2#9	1#9	#4	S2	1@2, 18@8, R@12	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B8	21	28	3#9	-	2#9	3#9	#4	S2	1@2, 16@12, R@18	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B9	26	20	3#9	3#9	2#9	3#9	#4	S3	1@2, 20@8, R@18	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B10	22	20	4#9	5#10	2#10	5#10	#4	S3	1@2, 12@4, R@6	EE	
B11	26	20	3#9	3#9	2#9	3#9	#4	S3	1@2, 20@8, R@18	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B12	21	28	3#9	2#9	2#9	2#9	#4	S2	1@2, 14@12, R@18	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B13	26	20	5#9	5#9	-	7#10	#4	S3	1@2, 12@4, R@8	EE	
B14	20	20	3#9	6#9	-	6#9	#4	S3	1@2, R@6	EE	
B15	12	28	3#9	1#9	2#9	1#9	#4	S2	1@2, 6@8, R@12 CANT. 1@2, R@8	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B16	20	20	2#9	-	2#9	-	#4	S2	1@2, 6@8, R@12	EE	
B17	12	20	2#9	3#9	-	3#9	#4	S2	1@2, 16@6, R@12	EE	
B18	22	24	4#9	1#9	2#9	1#9	#4	S2	1@2, 15@10, R@18	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B19	22	24	4#9	-	2#9	-	#4	S2	1@2, 15@10, R@18	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B20	22	24	3#9	-	2#9	-	#4	S2	1@2, 5@10, R@18	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B21	21	28	3#9	1#9	2#9	1#9	#4	S2	1@2, 12@12, R@18	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B22	21	28	5#9	-	2#9	-	#4	S2	1@2, R@10	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B23	21	16	2#9	-	2#9	1#9	#4	S2	1@2, 16@6, R@12	EE	
B24	21	28	5#9	2#9	2#9	2#9	#4	S2	1@2, R@12	EE	
B25	30	28	3#9	4#9	4#9	-	#4	S3	1@2, 12@12, R@18 CANT. 1@2, R@12	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B26	21	28	5#9	2#9	2#9	-	#4	S2	1@2, 10@6, R@8	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B27	21	28	3#9	2#9	2#9	-	#4	S2	1@2, 10@6, R@12	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B28	21	28	2#9	-	2#9	2#9	#4	S2	1@2, R@8	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B29	21	28	5#9	1#9	2#9	1#9	#4	S2	1@2, 12@6, R@10	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B30	21	28	3#9	5#9	2#9	-	#4	S2	1@2, 16@4, R@12	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B31	21	28	3#9	-	2#9	5#9	#4	S2	1@2, 16@4, R@12	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B32	21	28	5#9	2#9	2#9	2#9	#4	S2	1@2, 10@6, R@12	EE	PROVIDE 2 #9 WEB BARS AT MID-DEPTH
B33	26	22	2#9	3#9	-	3#9	#3	S2	1@2, R@6	EE	

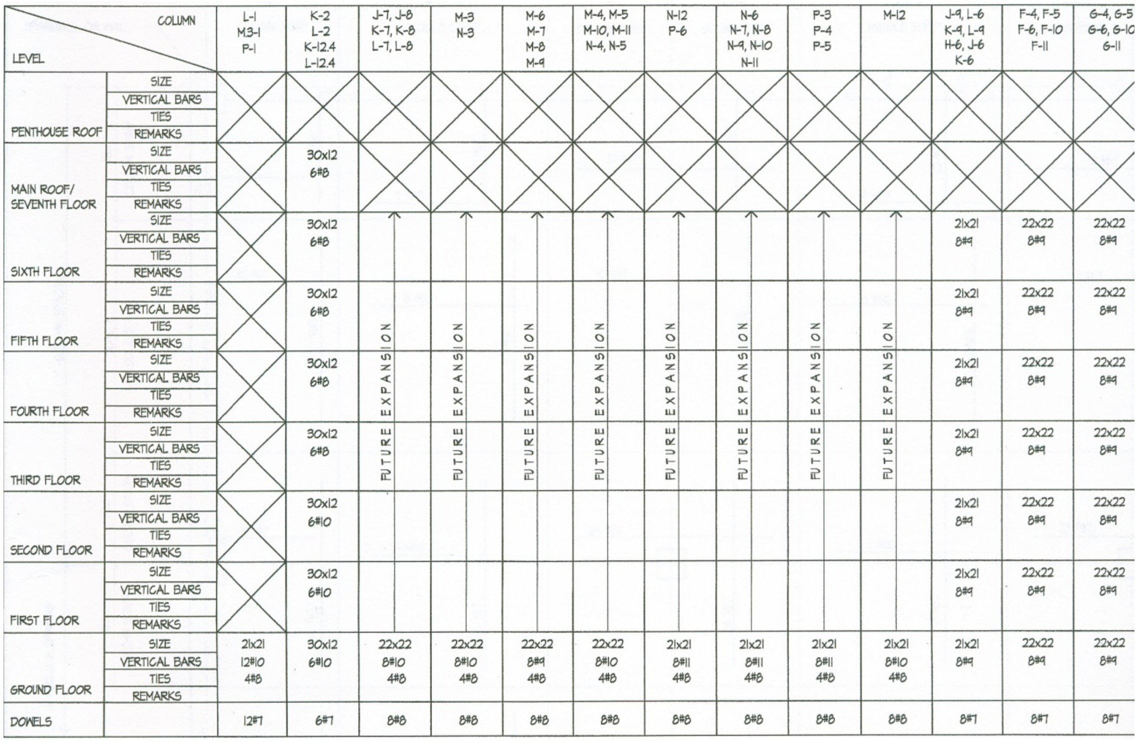
Figure 6: Portion of Concrete Beam Schedule

Columns

The columns are for the most part 21"x21" and 22"x22 with (8) #9 bars. Instead of changing column sizes as the building rises, the engineers specified different concrete compressive strengths for different levels and reduced the reinforcing to (8) #8's in spots. The ground to 3rd floor columns have a 28 day compressive strength of 7000 psi and the columns from the 3rd floor to the roof have a 28 day compressive strength of 5000 psi.

Portions of the penthouse are supported by steel columns. For continuity and moment resisting strength, these steel columns are embedded in the full length of the concrete columns from the floor below. This results in steel columns that are 2 levels tall and fully integrated in the moment frame of the rest of the building.

The portion of the tower that does not rise past the ground floor has oversized columns designed for future expansion. The Franklin Square Hospital Center Patient Tower was realized because the existing hospital had no capacity left for additional floors. Desperately needing space, the hospital commissioned the Patient Tower and supporting spaces. In the future when such a situation arises, the new Patient tower will be able to grow with the needs of the hospital. See Figure 2, "Typical Column Caisson Connection and Column Reinforcing" and see Figure 7, "Portion of Concrete Column Schedule."



LEVEL	COLUMN	L-1 M3-1 P-1	K-2 L-2 K-12.4 L-12.4	J-7, J-8 K-7, K-8 L-7, L-8	M-3 N-3	M-6 M-7 M-8 M-9	M-4, M-5 M-10, M-11 N-4, N-5	N-12 P-6	N-6 N-7, N-8 N-9, N-10 N-11	P-3 P-4 P-5	M-12	J-9, L-6 K-9, L-9 H-6, J-6 K-6	F-4, F-5 F-6, F-10 F-11	G-4, G-5 G-6, G-10 G-11
PENTHOUSE ROOF	SIZE													
	VERTICAL BARS													
	TIES													
	REMARKS													
MAIN ROOF/ SEVENTH FLOOR	SIZE		30x12											
	VERTICAL BARS		6#8											
	TIES													
	REMARKS													
SIXTH FLOOR	SIZE		30x12									21x21	22x22	22x22
	VERTICAL BARS		6#8									8#9	8#9	8#9
	TIES													
	REMARKS													
FIFTH FLOOR	SIZE		30x12	FUTURE EXPANSION	FUTURE EXPANSION	FUTURE EXPANSION	FUTURE EXPANSION	FUTURE EXPANSION	FUTURE EXPANSION	FUTURE EXPANSION	FUTURE EXPANSION	21x21	22x22	22x22
	VERTICAL BARS		6#8									8#9	8#9	8#9
	TIES													
	REMARKS													
FOURTH FLOOR	SIZE		30x12									21x21	22x22	22x22
	VERTICAL BARS		6#8									8#9	8#9	8#9
	TIES													
	REMARKS													
THIRD FLOOR	SIZE		30x12									21x21	22x22	22x22
	VERTICAL BARS		6#8									8#9	8#9	8#9
	TIES													
	REMARKS													
SECOND FLOOR	SIZE		30x12									21x21	22x22	22x22
	VERTICAL BARS		6#10									8#9	8#9	8#9
	TIES													
	REMARKS													
FIRST FLOOR	SIZE		30x12									21x21	22x22	22x22
	VERTICAL BARS		6#10									8#9	8#9	8#9
	TIES													
	REMARKS													
GROUND FLOOR	SIZE	21x21	30x12	22x22	22x22	22x22	22x22	21x21	21x21	21x21	21x21	21x21	22x22	22x22
	VERTICAL BARS	12#10	6#10	8#10	8#10	8#9	8#10	8#11	8#11	8#11	8#10	8#9	8#9	8#9
	TIES	4#8		4#8	4#8	4#8	4#8	4#8	4#8	4#8	4#8			
	REMARKS													
DOWELS		12#7	6#7	8#8	8#8	8#8	8#8	8#8	8#8	8#8	8#8	8#7	8#7	8#7

Figure 7: Portion of Concrete Column Schedule

Roof System

The main roof system consists of cambered steel beams ranging from W12x14 to W21x73 and 1.5" deep, wide rib, 20 gauge galvanized metal deck with 3 ¼" lightweight concrete. Many of these beams are moment connected to the steel columns supporting them. A center portion of the roof contains a 10" reinforced concrete slab with concrete columns extending 2' above the surface for future placement of the helipad deck. See Appendix A for "Roof Framing Plan."

Wall System

The exterior façade is for the most part 7" precast concrete panels. Loads bearing connections occur at each level, with two per panel. The connections permit horizontal movement parallel to the panel except for a single non-load bearing connection which is fixed. Precast panel loads are supported only by the columns.

Lateral System

The Franklin Square Hospital Center Patient Tower utilizes the entire structure to resist lateral forces. Every column, slab and beam acts as an ordinary reinforced concrete moment frame resisting forces in both the North-South direction and the East-West direction. The large moments are carried down the building through the columns and directly into the drilled piers. The piers, with depths of 42 feet, are quite substantial and help greatly to give the building a rigid, fixed base.

In the case of wind, the force exerted on the precast panels is directly transferred to the columns and not the floor diaphragm. Once this occurs, the force is carried down the column and across the floor diaphragm to the remaining columns. The columns are expected to resist the lateral force through their moment capacity. The perimeter edge beams are stiffer than the diaphragm and function as more efficient moment frames. There are a total of 13 moment frames acting in each direction for a total of 26 moment frames in the structure. Some are very rigid and take much of the load while others are very flexible and do little in terms of lateral force resistance. The frames that reside on the perimeter of the building have beam elements consisting of substantial 21"x28" edge beams. These are the frames that take the majority of the lateral loads compared to the rest of the frames that have beam elements consisting of the slab cross-section. Figure 9, "Moment Frames Level 4" shows the typical floor and moment frame layout. The layout of the frames changes slightly on lower floors when the plan extents expand as shown in Figure 8, “Moment Frames Ground Level”. The frame designations 1 through 12.4 and A through P are referred to heavily throughout this report and are visually identifiable on Figures 8 and 9 below. For full elevation views of each moment frame, see Appendix B.

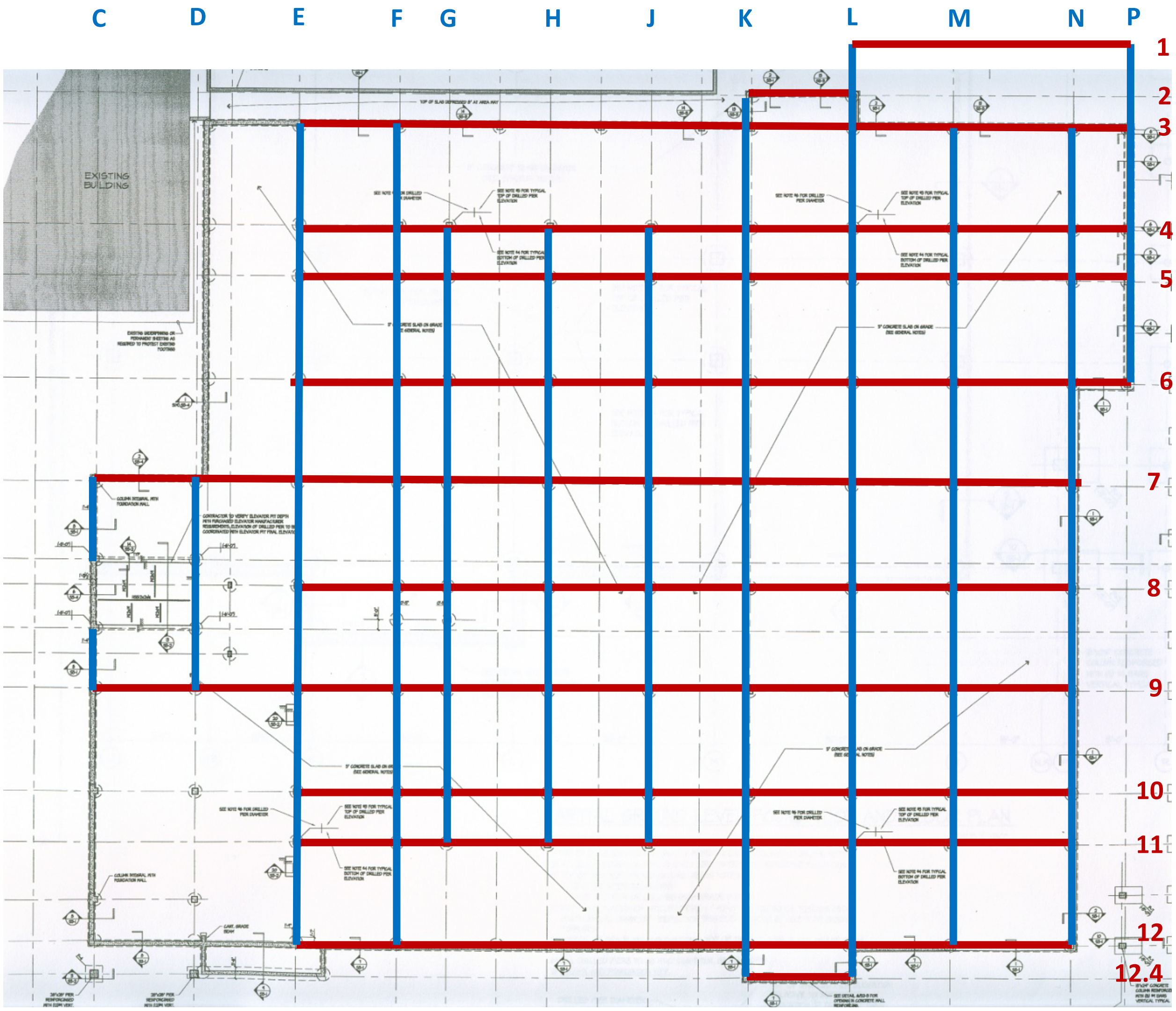


Figure 8: Moment Frames Ground Level

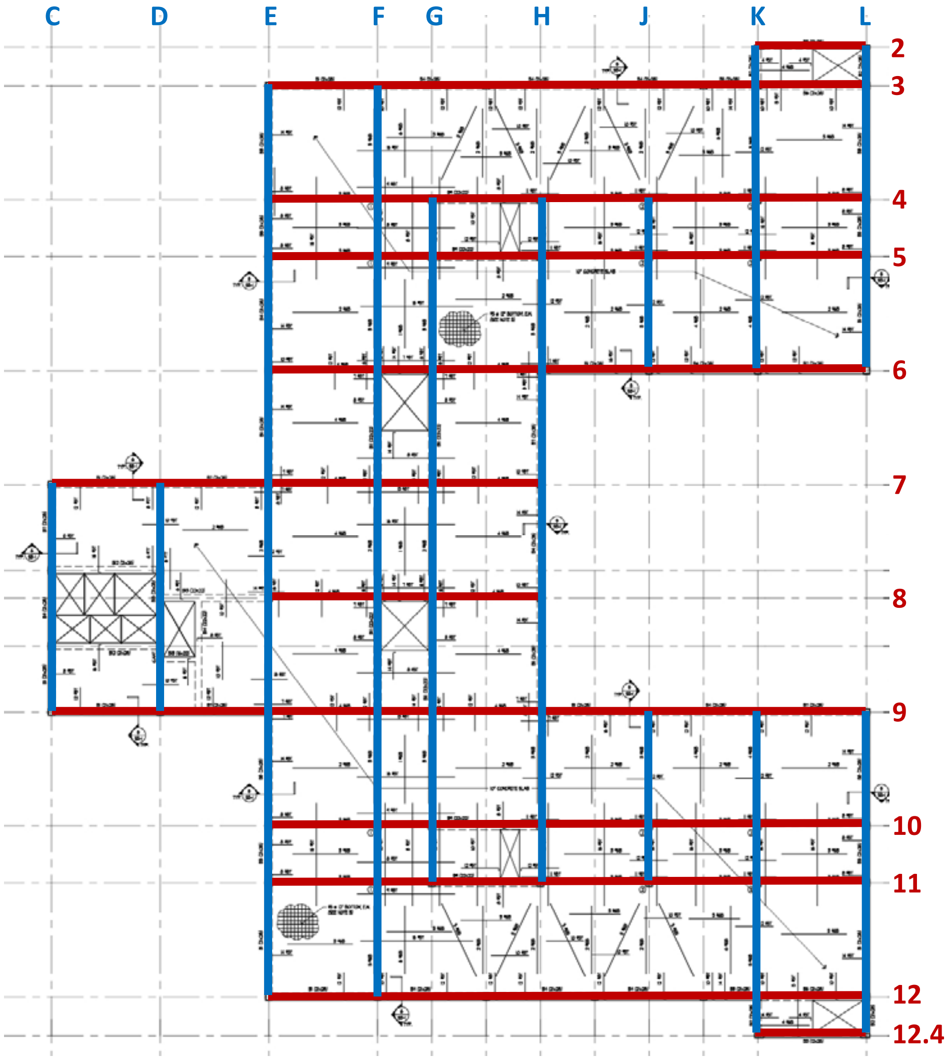


Figure 9: Moment Frames Level 4

Problem Statement

Project Goal: To design a gravity floor system that effectively reduces the self weight of the structure in an attempt to study and design a more efficient lateral system for higher seismic requirements by relocation of the building.

In its current design, Franklin Square Hospital Center Patient's Tower structural floor system is a flat plate regularly reinforced slab with perimeter edge beams while the lateral system consists of concrete moment frames with concrete columns, perimeter edge beams, and the 10" flat plate floor system. Located in Baltimore the seismic requirements are very low, but given the extremely large weight of the structure and the majority of that weight coming from slab self weight, seismic loading controls the design of the lateral system. With a lighter structural floor system, the self weight of the structure would decrease dramatically reducing the imposed seismic loads

In addition, for the purpose of studying lateral system design in seismic prone areas, the building could be studied as if it was built in a dangerous seismic area with high seismic requirements. Such a building relocation would necessitate the redesign of the existing lateral system and possibly changing the lateral system to a different type or dual system.

Proposed Solution

Proposal: To redesign the Franklin Square Hospital Center Patient Tower using a post-tensioned floor system while also investigating higher seismic loading from building relocation to Berkeley California for the redesign of the existing perimeter moment frames and the addition of shear walls.

Based on the results of Technical Report #2, the slab thickness could be reduced by 20% if a post-tensioned system were to be utilized. This, in turn, would significantly decrease the weight of the building benefiting the design of the lateral system. Unlike other lightweight floor systems such as composite beams or composite joist, the change to a post-tensioned floor system will not require column layout changes as the post-tensioned tendons can be placed in such a way to provide strength and support for portions of slab that have awkward placement of supporting columns. Additionally, the post-tensioned floor system would decrease the magnitude of creep deformations while also more effectively controlling deflection and still providing a flat ceiling for easier placement and installation of mechanical and electrical systems.

For the purposes of lateral system study and design, Berkeley California was chosen as the new location for the Franklin Square Hospital Center Patient Tower due to its proximity to the dangerous Hayward Fault. See Figure 10, "Proposed Building Relocation Site." Located just over half a mile from the newly proposed building site, the Hayward Fault is considered by some to be the most dangerous fault in America at this time with a 63% chance of a magnitude 6.7 or greater earthquake within the next 30 years. These extreme seismic requirements will require the redesign of the existing perimeter moment frame system and the addition of interior shear walls to effectively resist seismic induced loading.

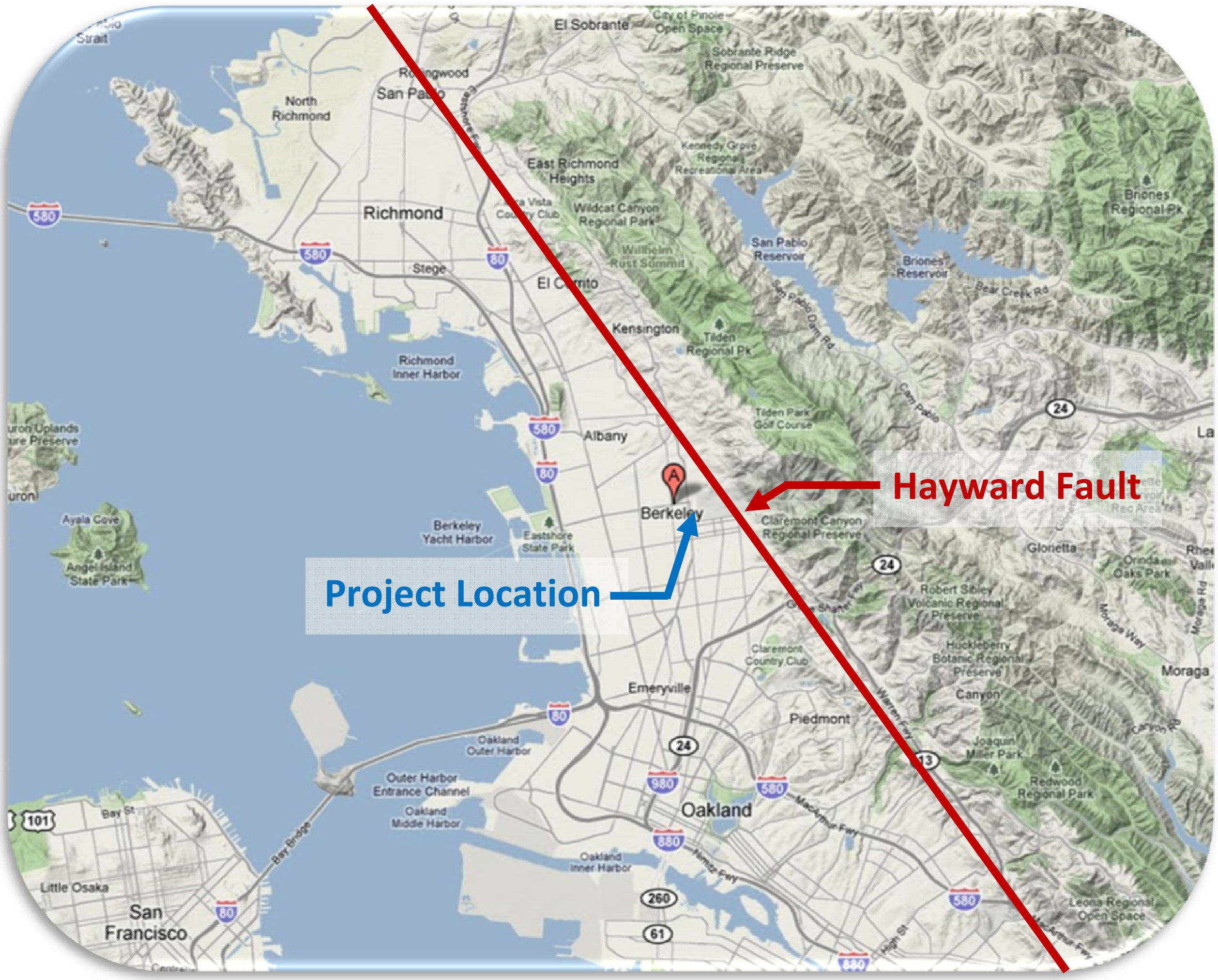


Figure 10: Proposed Building Relocation Site

Solution Method

The redesign of the Franklin Square Hospital Center Patient Tower will be implemented using ASCE 7-05, ACI 318-08, and PCI along with appropriate computer programs. The post-tensioned floor system will be designed based on the existing column grid and live loads from previous technical assignments. Design of the post-tensioning will be conducted using RAM Concept and supplemental hand calculations. ETABS will be used to model the lateral system and design the perimeter moment frames and interior shear walls while hand calculations will be used to check the ETABS design. Additionally, PCA Column will be utilized for design and checking of all gravity and moment resisting columns.

Breadth Topics

Construction: In-Depth Schedule and Cost Analysis in regard to the change to a Post-Tensioned Floor System

The first breadth topic will involve a scheduling and cost study of the existing floor system compared to the newly proposed floor system by determining the effect of the structural changes to the length of construction and the associated cost differences with the altered construction length. With the change to a post tensioned floor system, the construction schedule can be expected to lengthen resulting in a more expenses.

Architecture: Interior Architectural Layout Changes from addition of Shear Walls

The second breadth topic involves the changes architecturally to the building involved with the addition of shear walls. With interior shear walls, the outward appearance of the building will remain the same but the interior layout will require changes including relocation of support spaces, nurse's stations, and hallways while still providing the necessary function and ease of use needed in a hospital environment.

MAE Course Related Study:

The MAE requirements for the project will be fulfilled through the rigorous seismic analysis and design taught in AE 538. Additionally, an improved and comprehensive computer model will be constructed and modeled in ETABS according to the material learned in AE 597A.

Tasks and Tools

Depth

1. Design of Post-Tensioned Floor system
    a. Create RAM Concept model
    b. Determine required slab thickness
    c. Design post-tensioned tendon layout
    d. Evaluate deflections, shear and moment capacities
2. Design Concrete Gravity Columns
    a. Determine loads from new floor system
    b. Determine sizing and reinforcing with PCA Column
3. Design of Lateral Moment Frames and Shear Walls
    a. Recalculate overall building weight with change of floor system
    b. Recalculate seismic loads for Berkeley Ca using ASCE 7-05
    c. Modify ETABS model with new seismic loads and additional shear walls
    d. Experiment with various concrete strengths and wall locations/sizes
    e. Verify ETABS design through spot checks and reiterate design
    f. Check deflections
4. Evaluate Foundation System
    a. Check caissons for applied loads from columns and shear walls

Breadth

Construction:

5. Obtain schedule and cost information for the building as currently constructed
6. Create schedule and cost information for the structural redesign and compare

Architectural:

7. Determine possible locations for shear walls with least impact on existing layout
8. Relocate spaces and hallways to accommodate shear wall additions

Presentation

9. Prepare Presentation
    a. Organize and format Final Report
    b. Prepare Power Point Presentation
    c. Update CPEP site with final information

Time Table

Task	Week 1 Jan. 11-17	Week 2 Jan. 18-24	Week 3 Jan. 25-31	Week 4 Fed. 1-7	Week 5 Feb. 8-14	Week 6 Feb. 15-21	Week 7 Feb. 22-28	Week 8 Mar. 1-7	Week 9 Mar. 8-14
1	🟥	🟥	🟥						Spring Break - No Classes
2		🟥	🟥	🟥					
3			🟥	🟥	🟥	🟥	🟥		
4							🟥	🟥	
5	🟨	🟨							
6							🟨	🟨	
7	🟩	🟩							
8			🟩	🟩					
9									

Task	Week 10 Mar. 15-21	Week 11 Mar 22-28	Week 12 Mar. 29-Apr. 3	Week 13 Apr. 5-10	Week 14 Apr. 12-17	Week 15 Apr. 19-25	Week 16 Apr. 26-May 2	Week 17 May 3-7
1					Present to Faculty Jury			Final Exams
2								
3								
4								
5								
6								
7								
8								
9	🟦	🟦	🟦	🟦		🟦	🟦	

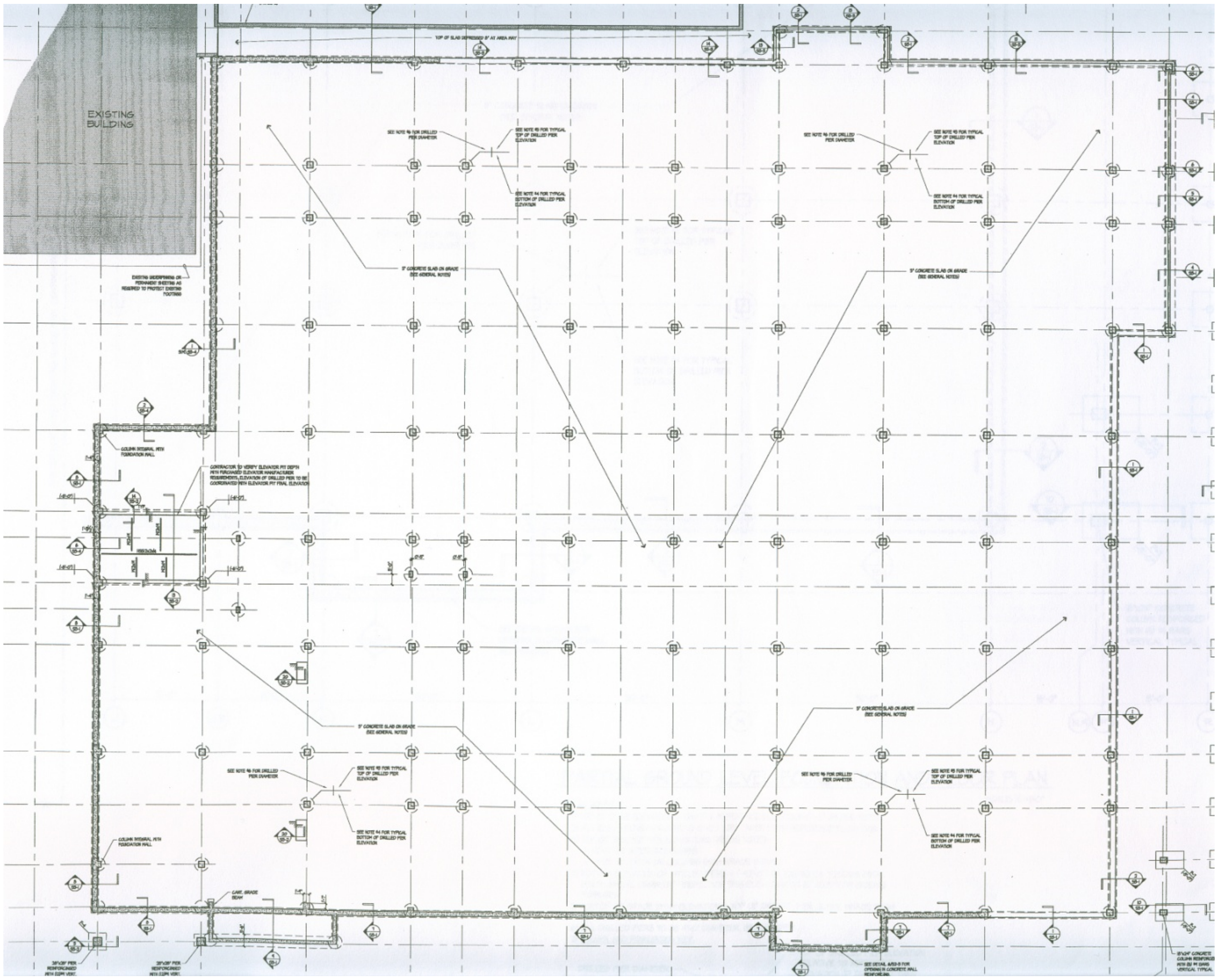
Conclusion

The main problem being addressed through this proposal is the building's self weight and its impact of the lateral system of the structure in addition to the redesign of the lateral system due to higher seismic loading. The design of a gravity floor system that effectively reduces the self weight of the structure in an attempt to study and design a more efficient lateral system was chosen as the best option. A post-tensioned floor system is an excellent way to retain the advantages of a conventionally reinforced concrete slab such as noise and vibration suppression while offering a shallower structural depth and greatly reduced self weight. The buildings transplant to Berkeley California allows much higher lateral loads to be studied and the effectiveness of dual system moment frames and shear walls in such a structure can be analyzed. With the aid of RAM Concept and ETABS both of these systems will be rigorously analyzed and designed.

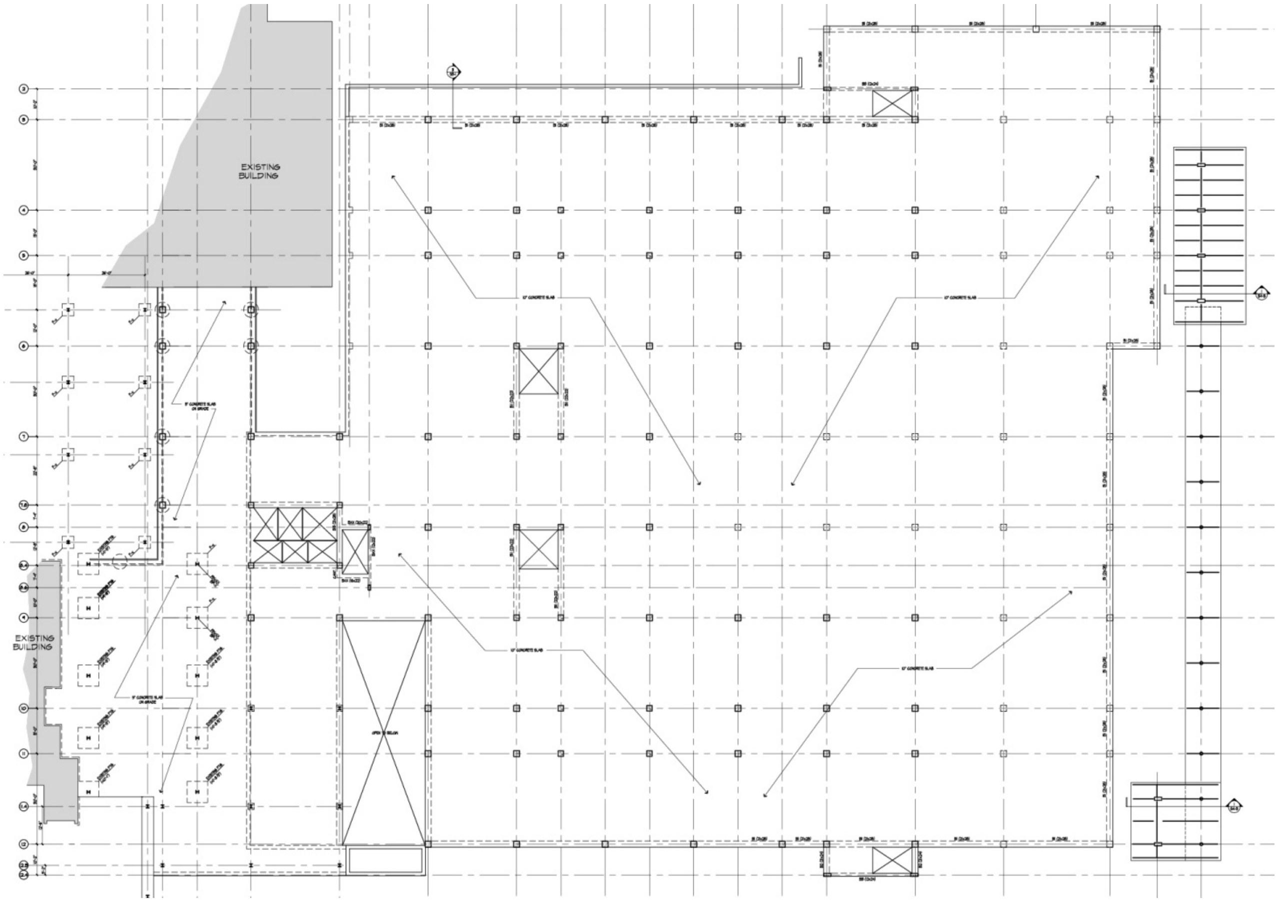
Closely correlating to the depth of the thesis proposal, the breadth studies focus on a determination of scheduling and costs associated with the structural redesign of the floor system while accompanying an architectural study of the implementation of shear walls into the congested layout of a hospital.

Appendix

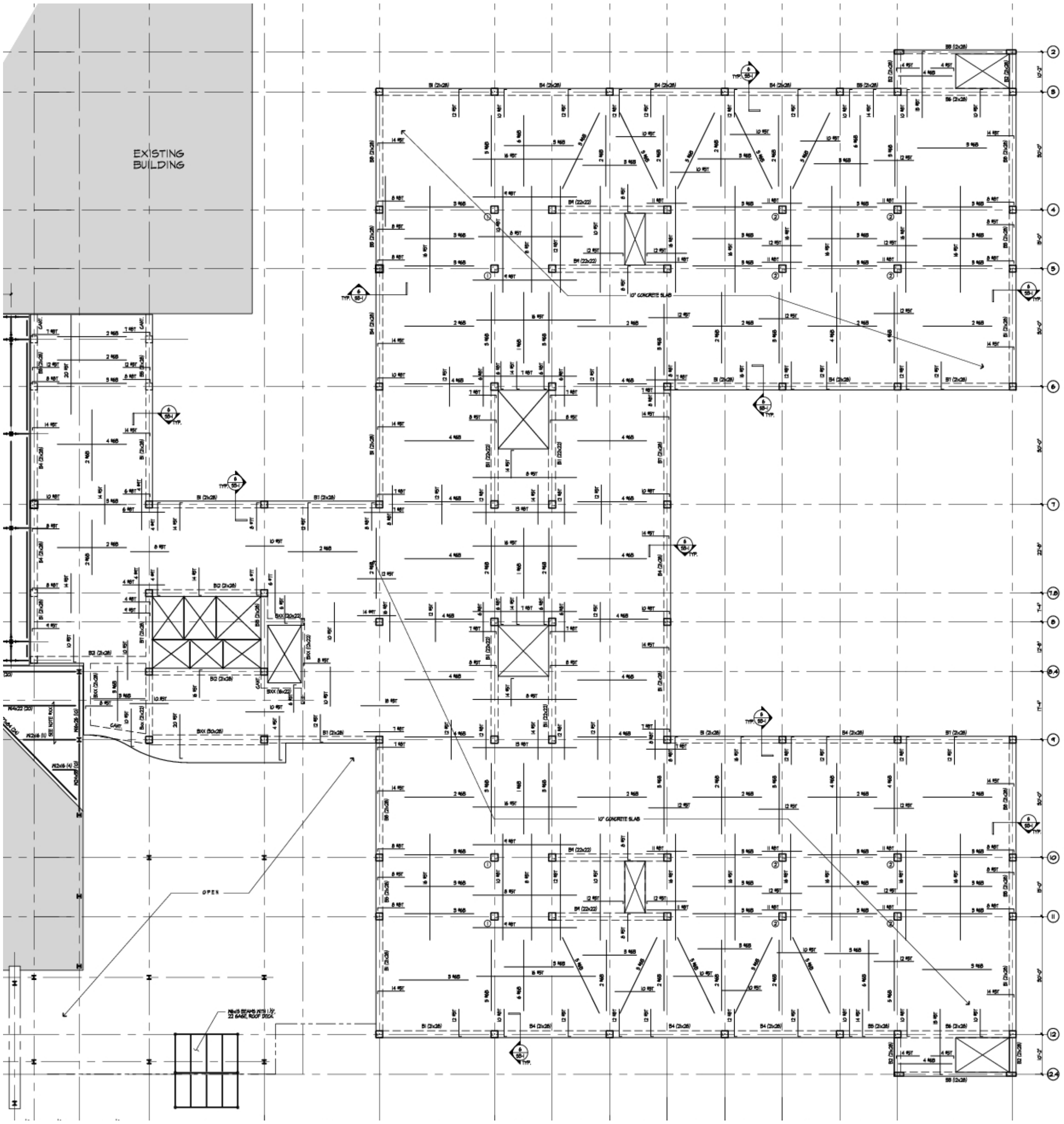
Appendix A: Typical Floor Plans



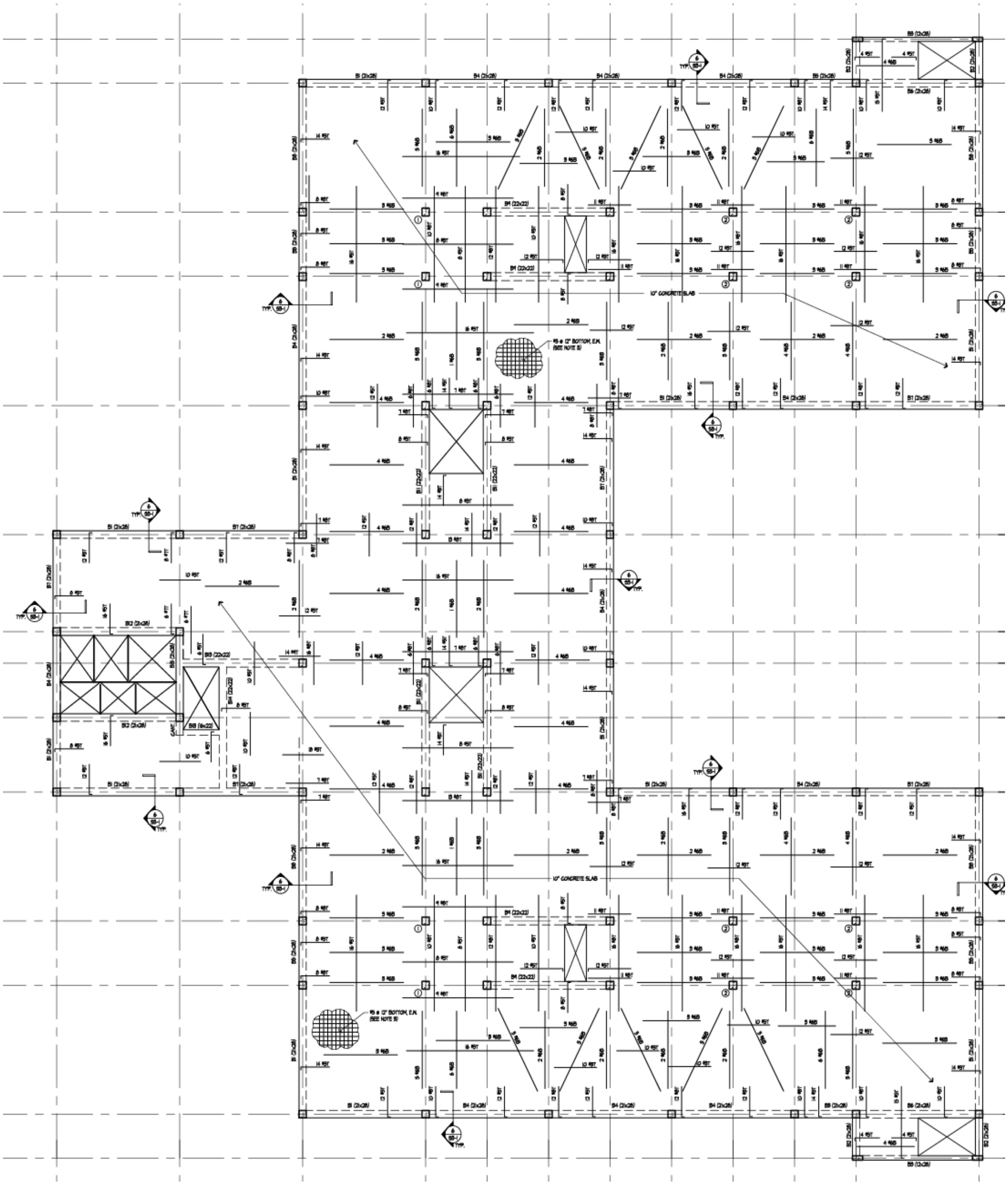
Ground Level



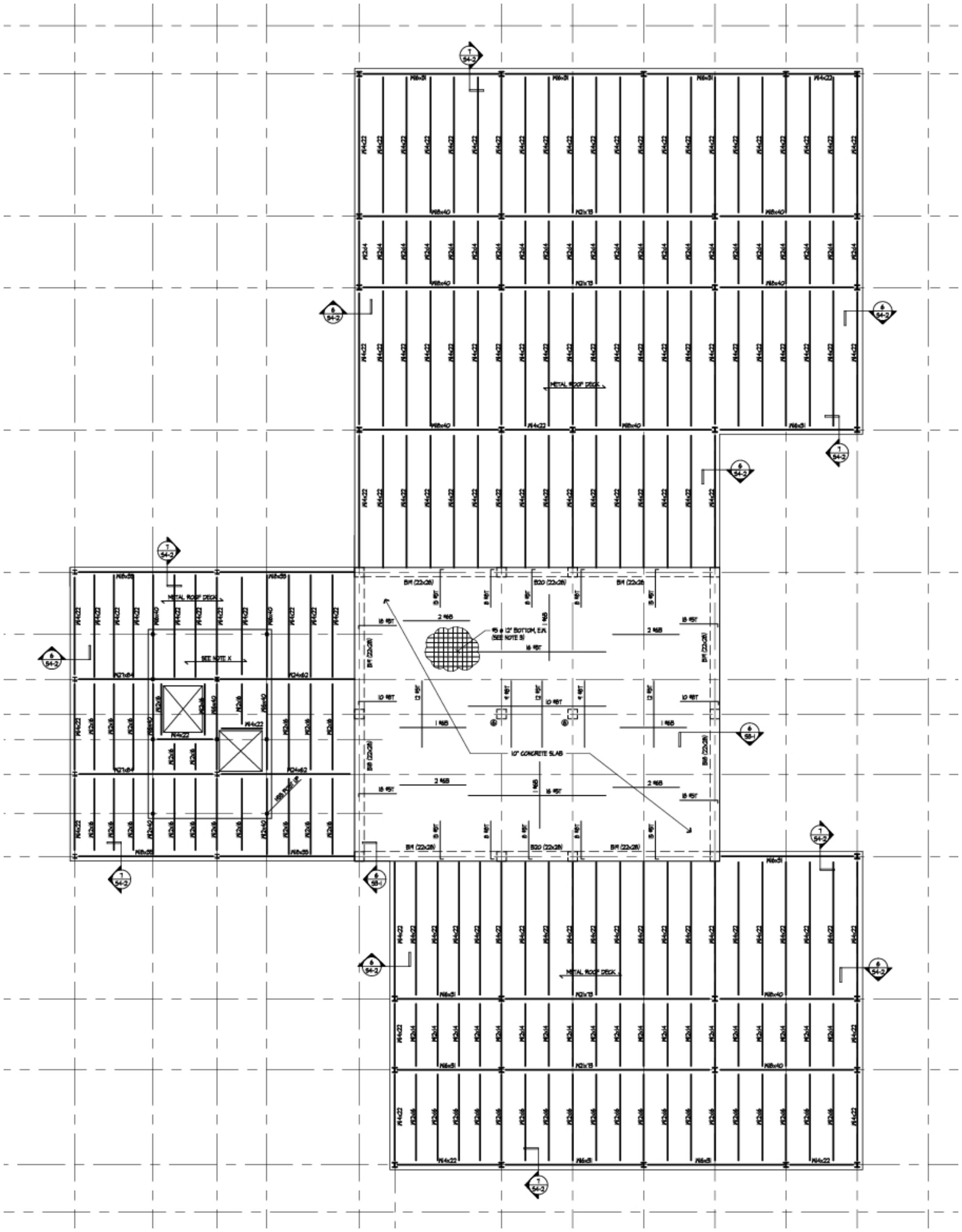
Level 1



Level 2 (Level 3 similar)



Level 4-7 (all similar)



Roof Level