Kaleida Health – Global Heart and Vascular Institute
University at Buffalo – CTRC/Incubator

Buffalo, New York

Revised Thesis Proposal

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Structural Option
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Executive Summary

The following document is the proposal for senior thesis and includes information regarding the Kaleida Health and University at Buffalo, Global Heart and Vascular Institute. This project will be referred to throughout this report simply as GHVI. This report includes the proposed structural depth and two breadth topics that will be investigated in the Spring Semester of 2011.

GHVI is a ten story medical facility in the city of Buffalo, NY. The building is square in shape with a length and width of 221 feet, and a height of 185 feet. The foundation is made of grade beams and steel helical piles that are driven 82 to 87 feet deep. Floor construction entails composite metal deck resting on steel superstructure. A standard bay size of 31'-6" by 31'-6" is used throughout the building, utilizing W14 columns of varying weight to make up the gravity system. The lateral system is comprised of braced frames which are located near the perimeter of the building.

The proposed thesis includes an investigation into the replacement of the existing steel structure with a reinforced concrete structure, in the hopes of reducing the overall cost of the building. The three alternative floor systems that were studied in Technical Report 2 will be examined in further detail, and the best solution will be selected. A reinforced concrete building will be designed, including a new gravity and lateral system. Finally, a vibration study will be performed to determine if the building sufficiently meets the current vibrational velocity requirements for a healthcare facility.

The change of the structure is intended to decrease the overall cost of the building. To check if this is in fact true, an in-depth cost analysis will be performed and compared to the original pricing estimation. A new schedule will also be developed to ensure that the new design is feasible and able to be completed in the time allowed for the original building. In an attempt to create a more sustainable facility, changes will be made to the façade and building envelope of GHVI. The goal of these changes will be to design a more efficient glazing system with respect to both thermal and lighting considerations.

Introduction

GHVI is a state-of-the-art medical facility and a fundamental component in a joint undertaking between Kaleida Health Systems and the University at Buffalo School of Medicine. The building spans ten levels and includes exam rooms, classrooms, offices, a café, a wellness center and library, and a research facility. It is intended to bring patients, surgeons, and researchers together to collaborate in an unprecedented way.

Key themes considered throughout the design were collaboration, flexibility, and comfort. Kaleida Health Systems sought a structure that would link clinical and research work and combine all vascular disciplines. A spirit of collaboration was the driving force behind bringing both Kaleida and the University at Buffalo together in a single structure. Keeping this in mind, the design team developed the facility with a "collaborative core" which enables interaction among those working within the facility. This collaborative learning environment brings together research, ideas, and solutions and results in better patient care.

A universal grid design increases the flexibility of space and achieves measurable advantage in initial capital cost, speed to market, operating economy, and future adaptability. The universal grid is comprised of three 10'-6" building modules and forms a 31'-6" x 31'-6" structural grid capable of integrating the building's diverse functions. When combined with an 18' floor-to-floor height, the flexible grid creates an open plan capable of adapting to present and future healthcare needs. The building will be able to incorporate unknown, but rapidly changing technological developments within the industry, also giving it longevity through its adaptability.

With patient comfort in mind, a separate "hotel" level was designed on the second floor and separated from the procedural floors. Functionally, the "hotel" is comprised of private patient rooms and a small lounge area. Other family lounges are also provided and the perimeter of the building is shaped to bring in as much natural daylight as possible. The vision of GHVI is to create an atmosphere that is more than a simple hospital, but instead a facility for world-class treatment and state-of-the-art technology.

Structural System Overview

Foundation

Based on the recommendations of the October 2008 Geotechnical Report by Empire Geo-Services, Inc., the foundation of GHVI consists of grade beams and pile caps placed on top of steel helical piles.

The helical piles are HP12x74 sections with an allowable axial capacity of 342 kips (171 tons) which are driven to absolute refusal on limestone bedrock 82 to 87 feet below the sub-basement finish level. Grade beams and pile caps have a concrete strength of 4000 psi, and it should be noted that the width of the grade beams equals that of the pile caps at the foundations of the braced frames. The grade beams provide resistance to lateral column base movement, and the pile caps link the steel helical piles and the structural steel columns of the superstructure.

Spanning the grade beams is the sub-basement floor, a 5" slab-on-grade. Due to the slope of the site, part of this sub-basement is below grade, and therefore a one foot thick foundation wall slopes along the west elevation of the sub-basement.

Floor System

The floors of GHVI consist of 3" composite metal deck with a total slab thickness ranging from 4" to 7½". The metal deck is 18-gage galvanized steel sheets resting on various different beam and girder sizes. These sizes change throughout the structure because of the various functions of the spaces. The bay sizes through the building are mostly 31'-6" by 31'-6", with beams spaced at 10'-6". As was discussed in the introduction, this universal grid design increases the future flexibility of the space. A slight variation in the floor can be seen on Levels 6-8. On these levels, part of the floor structure is left open to provide for the collaborative atrium that was designed to bring the various disciplines together.

Gravity System

Steel columns are used throughout the building to transmit the gravity load to the foundation. All of the columns in the building are W14s, but they range in weight from 68 lb/ft to 370 lb/ft, and they are typically spliced every 36 feet. These columns provide an 18' floor-to-floor height, which also contributes to the universal grid and future flexibility of the space.

Lateral System

The lateral system of GHVI utilizes braced frames located near the perimeter of the building, all of which are HSS sections. A braced frame system is ideal in steel buildings because of its low cost compared to moment connection frames. There are moment connections in some parts of this structure, but they are used to support the small amount of slab overhang that is cantilevered. These moment connections may actually add some stiffness to the lateral system, but they cannot be included in the lateral system design. Figure A depicts the location of the braced frames on the outer part of the structure, and an elevation of each frame is shown on the following two pages.

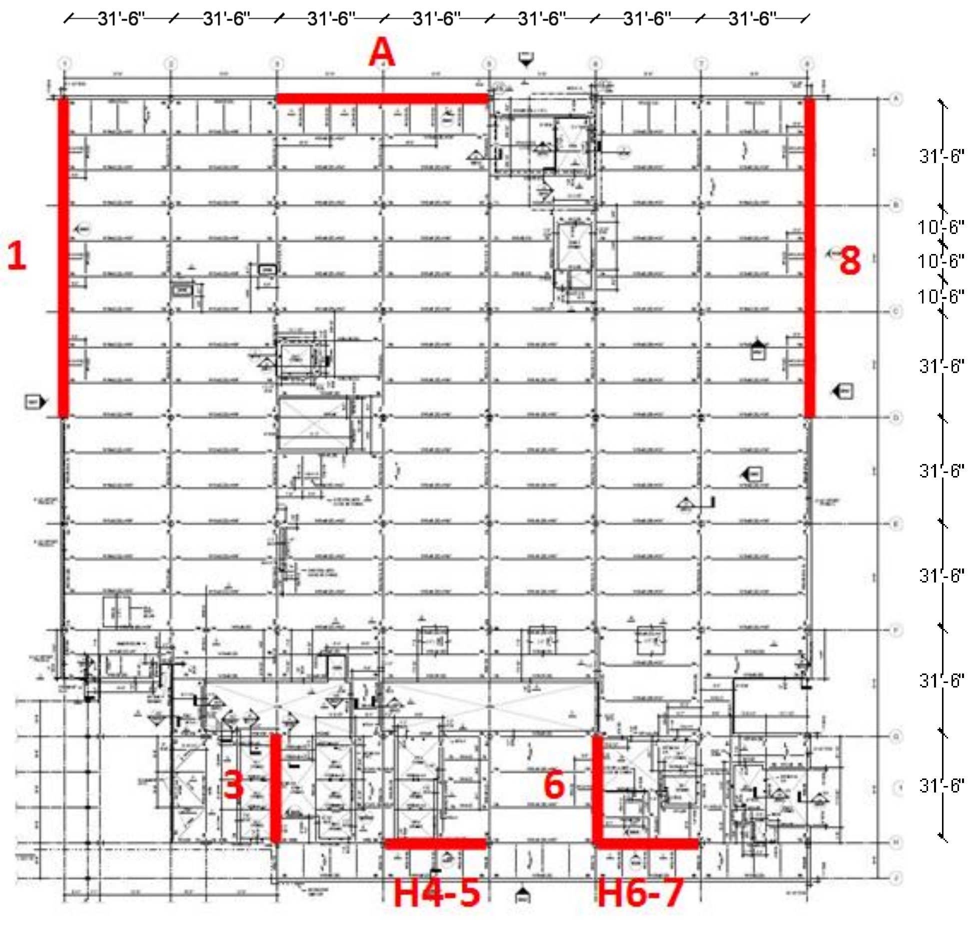

Figure A – Level Two Framing Plan with Braced Frames Highlighted (Cannon Design)

Problem Statement

The current design of GHVI utilizes a steel superstructure which rests on steel helical piles driven to bedrock. The superstructure is made up of W14 shapes for columns, a composite metal deck flooring system, and braced frames on the perimeter of the building. A universal grid was designed with 31’-6” by 31’-6” bays and beams spaced at 10’-6”. The structure is built using a 3” composite metal deck with a total slab thickness ranging from 4” to 7½”, depending on the level and its live load requirements. The metal deck is 18-gage galvanized steel and rests on beams and girders of various sizes. Shear studs are used on the beams and girders in order to create composite action with the slab. A section of a typical composite deck can be seen in Figure B.

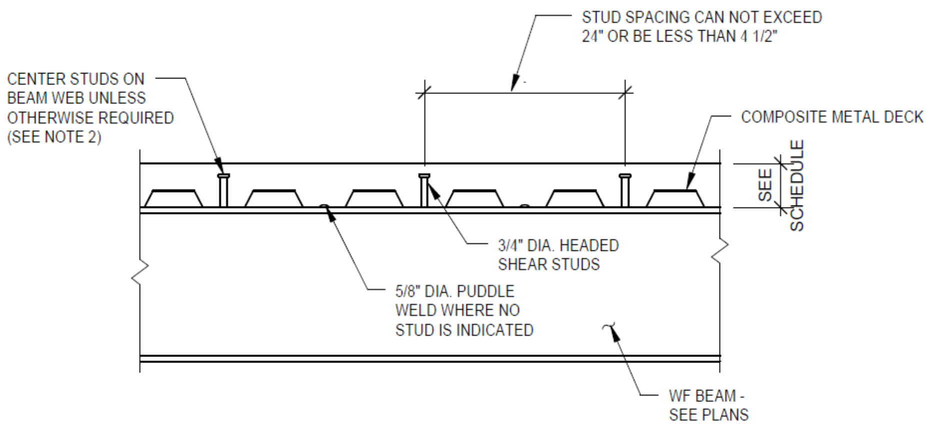

Figure B – Typical Composite Steel Construction (Cannon Design)

A composite deck system is good for long spans and heavy loads. It results in a structure with a reduced weight that is easy to design and quick to construct. However, as was reported in Technical Report 2, steel construction may be the more costly method. Using RSMeans Building Construction Cost Data, the steel system was found to be more expensive than the three concrete alternatives that were explored. The assembly of a steel structure requires high labor costs, especially when it comes to assembling connections. Steel also requires spray on fireproofing, which is not required by concrete systems. A redesign to a concrete structure may result in a project with a lower cost.

Because GHVI is a hospital and a research laboratory, there are many areas of the building that will house vibration sensitive equipment. The current design calls for some of these areas to meet specific maximum vibrational velocities. Investigation must be conducted to determine how the floors were designed to meet these vibration requirements, and if there was an additional cost associated in construction. Concrete floor systems have inherent vibration resistance, and may be more efficient than a steel system at preventing vibrations. This efficiency may result in a lower cost of design and construction.

Proposed Solutions

In an attempt to reduce the current cost of GHVI, the building will be redesigned using one of the three reinforced concrete systems explored in Technical Report 2. In that report, it was concluded that a flat slab system with drop panels was most likely the most efficient and cost effective option to replace the current system. This design would require a slab thickness of 10" to meet ACI 9.5.3.2, and would employ 6¼" drop panels to resist the large live loads of GHVI. A flat slab system would not result in a change to the current bay size, and would allow for a relatively flat ceiling.

The second alternative system is a one-way pan joist and beam system. This will be considered because it is normally adequate for long spans and heavy live loads. A 4½" slab will be used to meet a two hour fire rating. A 72" pan joist module will be implemented, consisting of 66" pans and 6" ribs as prescribed by ACI requirements. The ribs will be 16" deep, making the total structure thickness 20½". Although this system can carry heavy live loads, it would require an adjustment to the current bay size and column grid, and would entail the use of complex formwork.

The final system to be considered is a pre-cast hollow core plank design. Because the pre-cast planks come in 4' sections, the standard bay size of the building would be altered from 31'-6" by 31'-6" to 32' by 32'. This change is minimal, would be easy to implement, and would have a lower cost than ordering specially designed pre-cast planks. Using the PCI Design Handbook, it was found that 4'-0" by 10" planks with 2" of topping would be sufficient. It may also be necessary to design this system using post-tensioned strands.

After these systems are compared and the best is chosen, it will be necessary to redesign the columns and the lateral force system. First, the column grid layout will be revised, and then columns throughout the structure will be redesigned. It must also be investigated whether or not the inherent moment connections of the reinforced concrete structures will be enough to resist the lateral load. If this is not true, shear walls will need to be placed throughout the structure. This must be carefully planned so as to not disrupt the flow of the current structure. A vibration study will be conducted to assure that the new design meets the standards of the current building. If the floors are not sufficient with respect to vibration, they will be redesigned to provide an adequate vibration-controlled structure. Finally, the increased weight of the structure will also necessitate an examination of the current foundation design. If the foundation is not sufficient, it will require further design.

Breadth Topic 1 – Cost and Schedule Analysis

An in-depth cost and schedule analysis will be conducted on the redesigned reinforced concrete system. Although RSMeans can provide a satisfactory initial estimate, further research will be conducted on how to properly cost-analyze this building. Using industry information and practices, a detailed cost and schedule breakdown will be performed. This breakdown will then be compared to the original cost and schedule information to determine if the proposed structural redesign is in fact feasible.

Breadth Topic 2 – Building Envelope and Façade Study

A mechanical breadth into the building envelope and façade will also be performed as a part of this thesis. The current curtain wall designs will be obtained from Cannon Design, and research will be conducted to determine a more efficient type of glazing, with the intent of creating a more sustainable facility. Thermal calculations will be performed for a room on each of the four facades, and the effects on the lighting of the building will also be considered.

MAE Requirements

MAE Requirements for this thesis will be met using methods from both AE 597A, Computer Modeling of Building Structures, and AE 542, Building Enclosure Science and Design. By building a detailed computer model in ETABS, material taught in AE 597A will be applied to this thesis. The building envelope and façade breadth will also implement material that is covered in AE 542, including glass type and thickness, as well as thermal, lighting, and acoustic considerations.

Solution Methods

The three proposed alternative concrete systems will be designed using methodology contained in ACI 318-08, Building Code Requirements for Structural Concrete. The PCI Handbook will also be referenced when considering the pre-cast hollow core plank design. Dead loads will need to be recalculated, and live loads will be double checked using ASCE 7-10.

Further research must be conducted to determine how the vibration design will be performed. Faculty will be consulted to find pertinent design guides, such as AISC Design Guide 11. Information must also be obtained from Cannon Design in reference to the current vibration design.

A computer model will be created in ETABS to analyze the gravity and lateral system of the newly designed concrete building. Wind and lateral loading will be obtained from ASCE 7-10. Other programs such as spColumn, spBeam, spSlab will also be used as aids throughout the design.

Finally, all cost and schedule data must be obtained from Cannon Design. Microsoft Excel will be used to create detailed breakdowns, and Microsoft Project will be used to create a project schedule. The CPEP forum will also be consulted to determine current practices for pricing and scheduling from people in industry.

Tasks and Tools

1. Determine most advantageous alternative floor system
    a. Further investigate three systems chosen in Technical Report 2
    b. Develop more efficient method of comparison
    c. Choose the best system
2. Design new concrete system
    a. Redesign gravity system
        i. Determine column floor plan layout
        ii. Confirm dead and live loads
        iii. Design slab/drop panels/beams (etc.)
        iv. Design columns
        v. Confirm using computer programs (ETABS, sp Beam, etc.)
    b. Redesign lateral system
        i. Determine lateral force resisting system and placement
        ii. Confirm lateral loads from ASCE 7-10
        iii. Further develop computer model using ETABS
        iv. Check torsion, drift, and overturning
3. Perform vibration analysis
    a. Investigate current vibration design
    b. Research differences between steel and concrete vibration design
    c. Evaluate effectiveness of newly designed concrete system
    d. Compare steel and concrete systems by hand and computer
4. Perform in-depth cost and schedule analysis
    a. Request current cost and schedule information from Cannon
    b. Research methods of detailed analysis
    c. Perform analysis on redesigned concrete structure, including vibration design
        i. Material cost
        ii. Labor cost
        iii. Scheduling
    d. Compare to existing design
5. Complete building envelope/facade redesign
    a. Obtain current curtain wall designs from Cannon
    b. Research and investigate optimal performance designs
    c. Redesign as necessary
        i. Glass type and thicknesses
        ii. Thermal, lighting, and acoustic considerations
6. Final Report and Presentation
    a. Organize and complete final report
    b. Create presentation outline
    c. Format presentation texts and style
    d. Organize and complete presentation
    e. Practice

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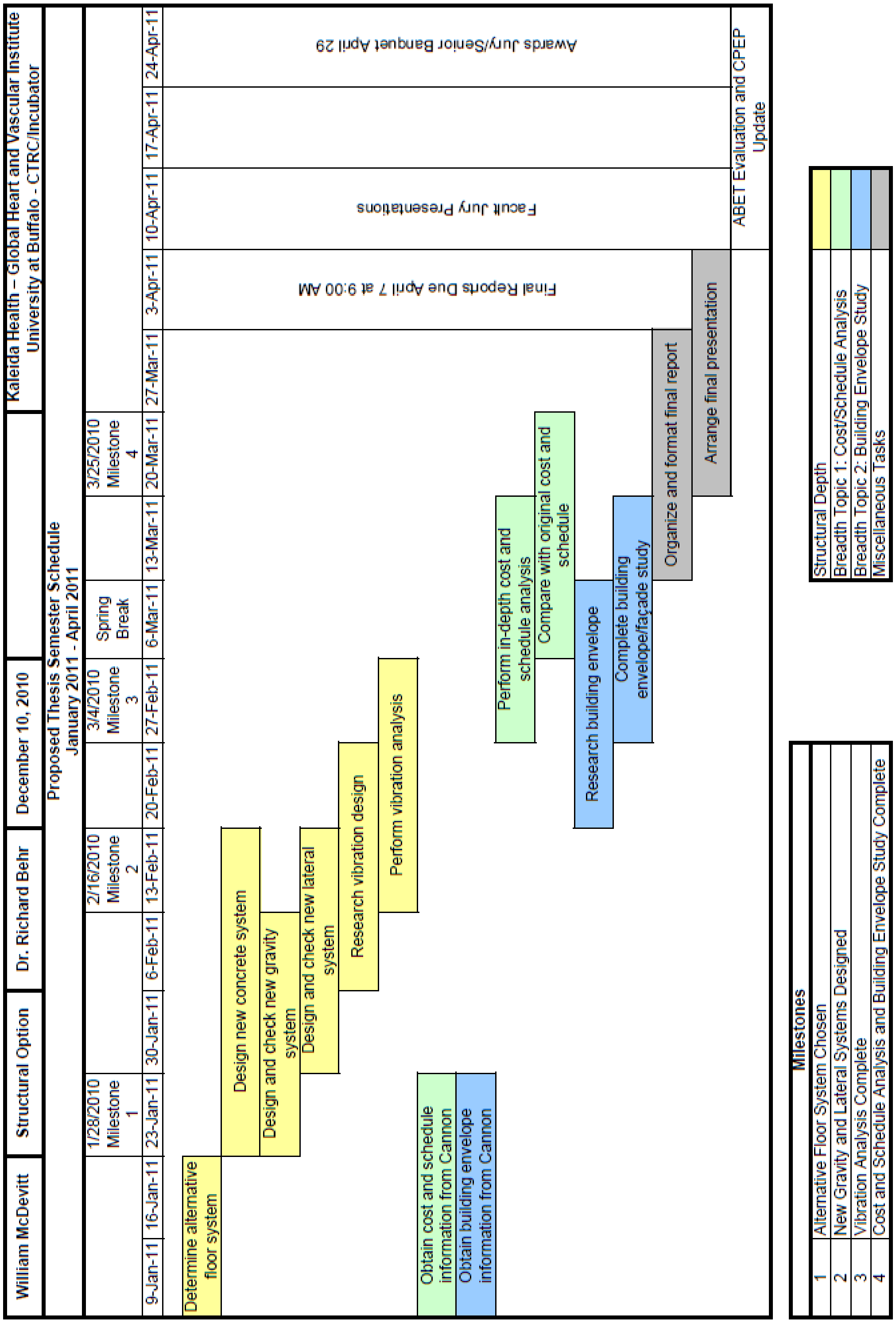
Schedule



Conclusion

For the Spring Semester, GHVI will be redesigned as a reinforced concrete structure. The intent of replacing the steel structure is to reduce the overall cost of the building. The three alternative floor systems that were studied in Technical Report 2 will be further examined, and the best solution will be selected. A new gravity and lateral system will be designed, and a vibration study will be conducted. One breadth study will focus on comparing the new cost and schedule with the originals provided by Cannon Design. The other breadth will attempt to create a more sustainable facility by changing the glazing of GHVI.

Appendix

Appendix A: Typical Floor Plans and Elevations

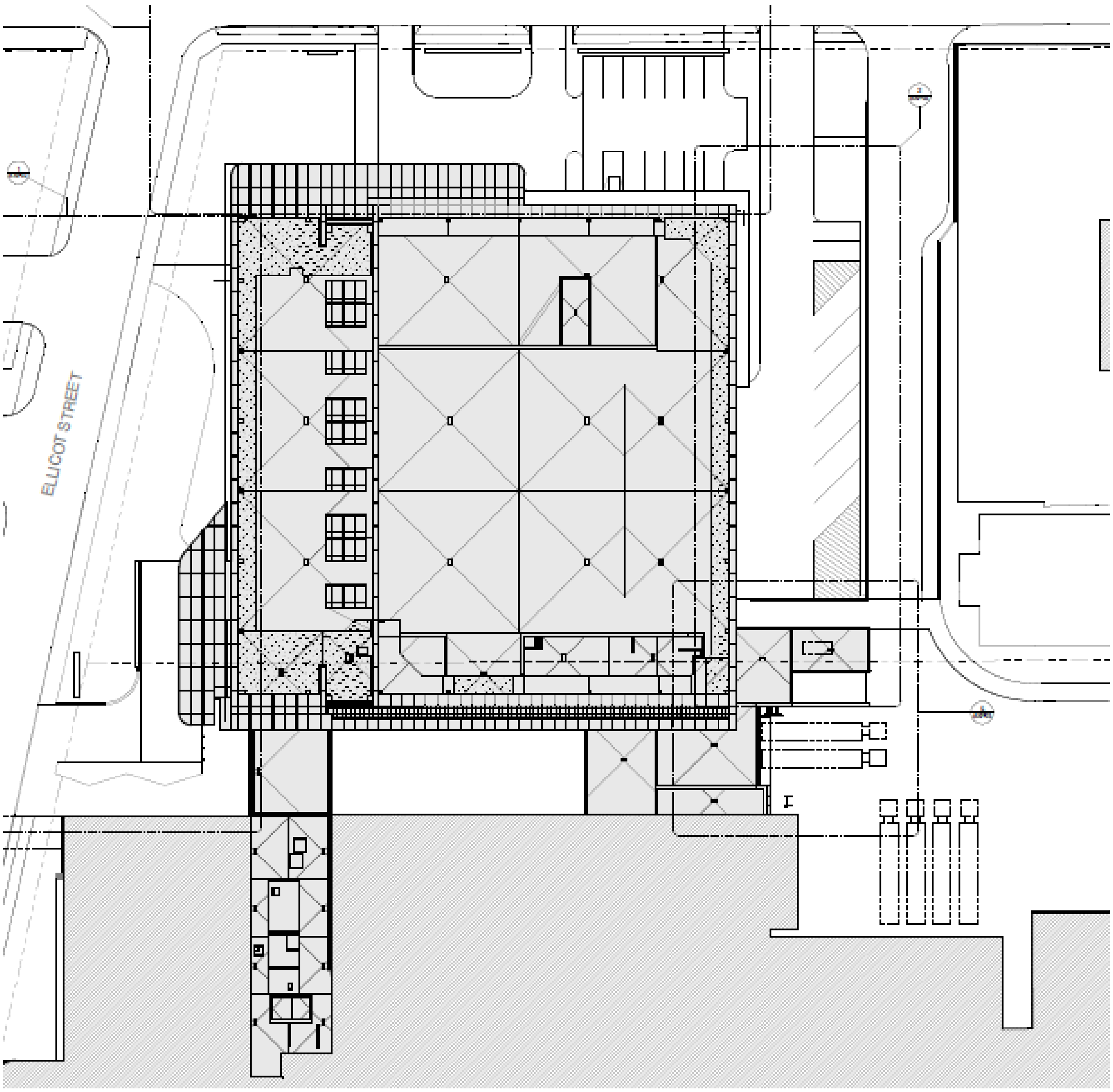


Figure C – Site Plan (Cannon Design)

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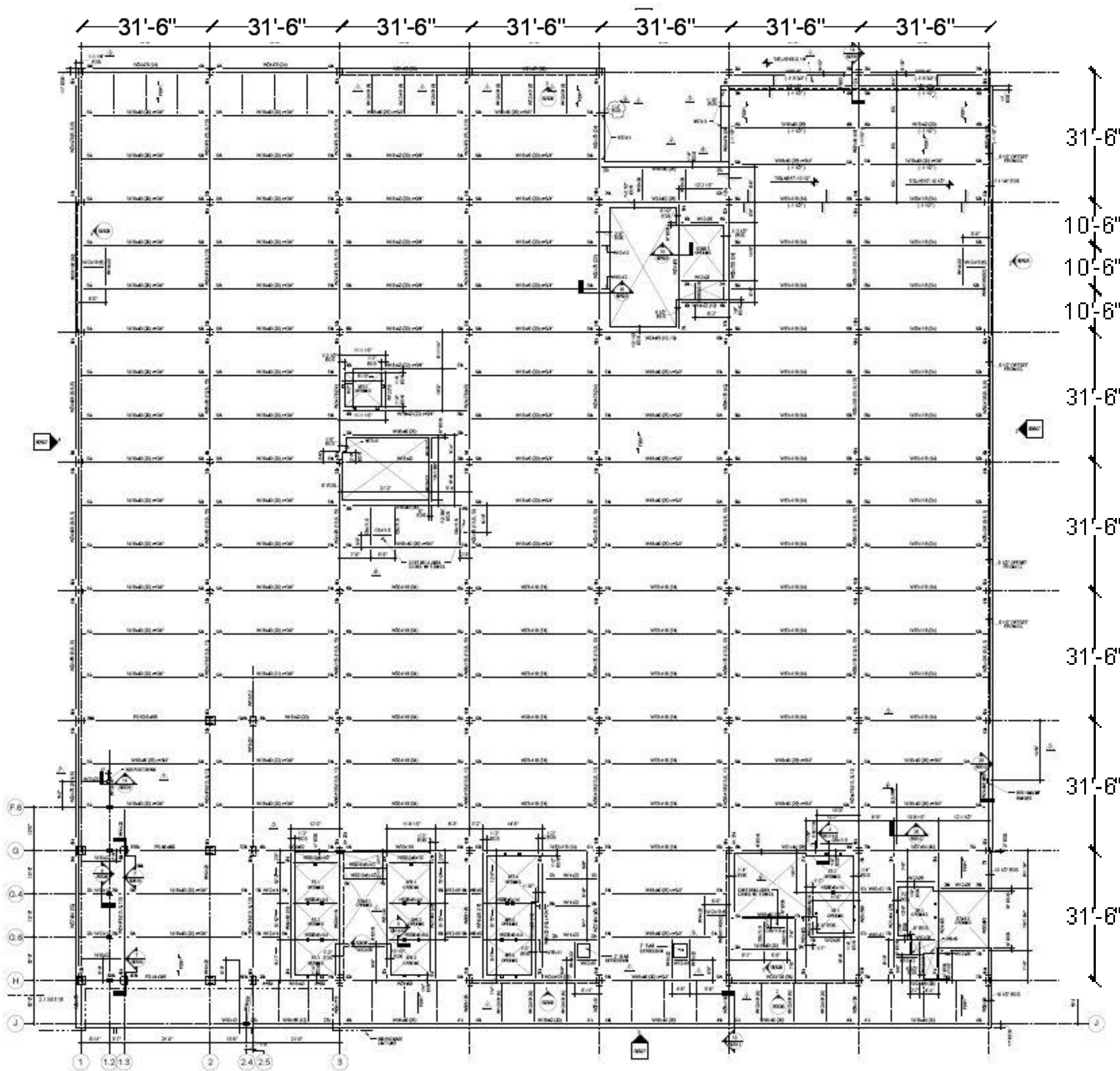

Figure D – Typical floor framing plan (Cannon Design)

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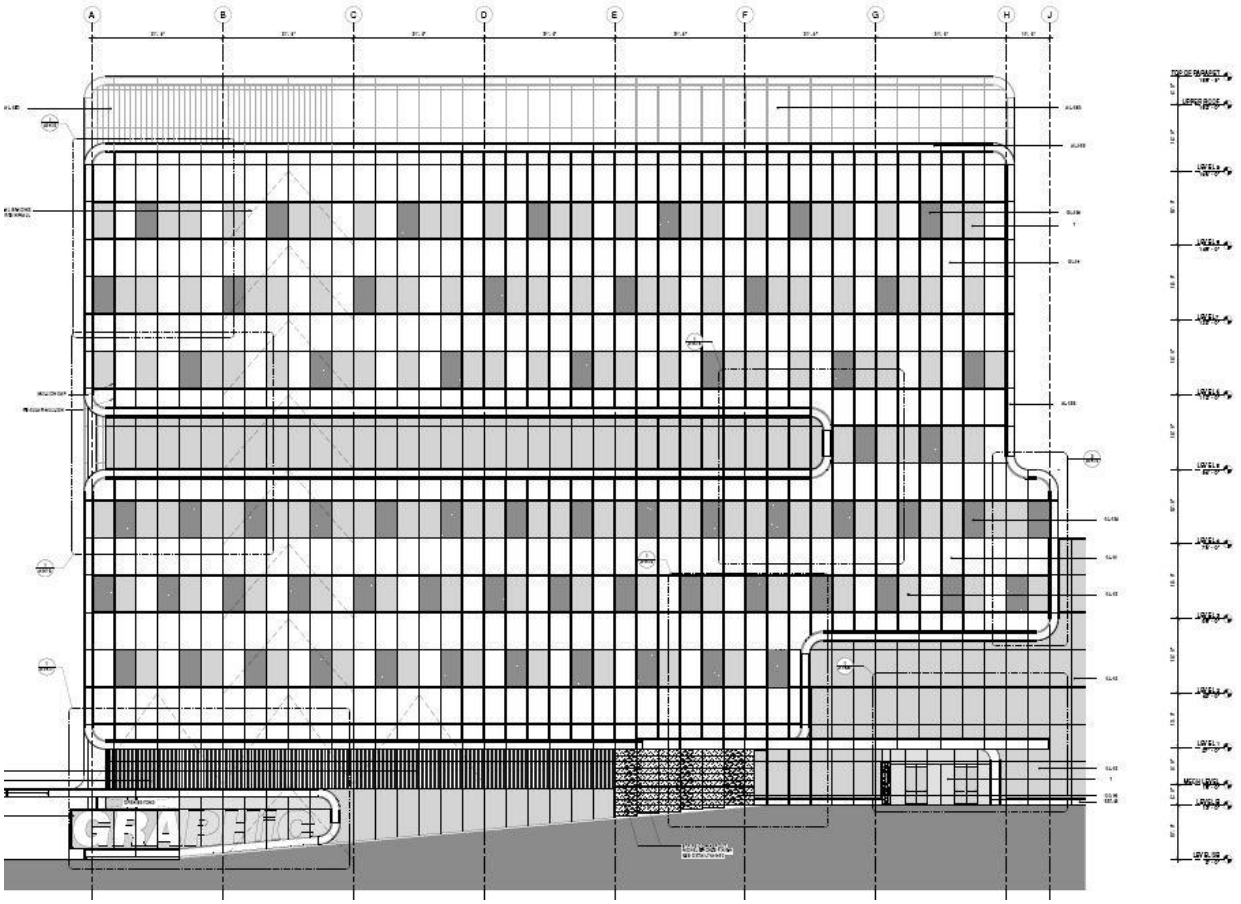

Figure E – West Elevation (Cannon Design)