Image Courtesy RTKL

CORPORATE HEADQUARTERS

Great Lakes Region, U.S.A.

THESIS PROPOSAL

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STRUCTURAL OPTION
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Contents

Executive Summary

The Corporate Headquarters, located in the Great Lakes Region of the United States, is a new 5 story office and retail space designed to serve as new home base for an established and successful US based company. The building will serve as a focal point for the south entrance of an existing retail park.

The building's architecture was designed to mirror its surrounding buildings, namely, the newer retail area situated directly to the north of the building. It aims to mirror those buildings through its façade, which changes materials in order to break up the large building. In keeping with that architectural style, the Corporate Headquarters features a façade of glass and face brick.

The building's structural system is composed of W-shape steel beams, girders, and columns. The composite beams and girders, along with the concrete on metal floor deck, make up the building's gravity system. The Corporate Headquarters relies on eight braced frames as its lateral force resisting system. Within the building lies an open air courtyard that can be accessed on the third floor. The courtyard features an intensive green roof system that will be examined in future reports.

Purpose and Scope

The purpose of this proposal is to provide an overview of the work that will be completed in Spring 2015. A new structural design solution will be presented, as will additional information detailing how this solution is a reasonable response to the building's current requirements. A task list, and schedule are provided in this report to show how the work will be effectively accomplished throughout the upcoming semester. Background information about the building will be provided to help with building context and requirements.

This proposal includes three major sections: the structural redesign, and two breadth topics. The structural redesign will change the gravity system from a composite floor system with w-shapes to a steel joist system. The lateral system of the building will be changed from braced frames to concrete cast in place shear walls.

The two breadths will focus on the building's interior open air courtyard. Both the architecture and the waterproofing methods of the space will be examined. First, the geometry of the courtyard will change. The courtyard will move from a trapezoidal shape to a rectangular shape. This change will affect the planting pattern within the space, so a new pattern will be created, along with new paths to move throughout the courtyard. Next, the waterproofing will be examined. The change in the courtyard's shape and angle require a change in waterproofing. The waterproofing membrane, as well as the application method, will be changed.

Building Introduction

The Corporate Headquarters will be constructed at the South end of an existing retail park in the Great Lakes Region of the Midwestern United States. It is a five story office a retail space designed to serve as the new headquarters for an established and successful US based company. The new 659,000 SF building's architecture was designed to blend in with the style of the surrounding buildings in the retail park. Designed in the contemporary "Americana" style, serving as the last component of the planned retail are. Ground broke in August 2014 and the project is anticipated to reach substantial completion in Spring 2016.

The building features an interior open courtyard with entry access on the third floor and many large view windows, allowing workers within the offices to bring the atmosphere of the outside in. This courtyard is meant to help enrich the sense of creativity and community within employees. The courtyard features an intensive greenroof with a variety of plantings and walking paths. To achieve this courtyard, the structural engineer chose laterally braced the building with braced frames, which are tied at the base by grade beams at the foundation.

The Corporate Headquarters serves as the south port of entry into a retail park and will incorporate retail space on its ground floor. The upper levels are dedicated to larger open office spaces that allow for spatial flexibility and mobility. Pending acquisition of land adjacent to the site, a proposed bridge will connect the upper two floors of the Corporate Headquarters with a parking structure, as is commonplace in the rest of the retail park. The proposed face brick and curtain wall façade mimics the "Main Street America" feel of the retail park but speaks to how the company has evolved throughout the generations to stay classic, but feel current.

Structural Overview

The Corporate Headquarters is supported on a foundation comprised of spread footings, column piers, and grade beams. Floors 2-5 of the building are framed with a composite system of wide flange members and metal deck. Eight braced frames near the core of the building are the lateral force resisting system and the roof is concrete on metal deck.

Building Materials

The tables below lists the building materials and specifications used in the design of the Corporate Headquarters.

Structural Steel	
Member	**Grade**
Wide Flange Shapes & WT Shapes	ASTM A992,UNO
Channels	ASTM A36, UNO
Angles	ASTM A36, UNO
Rectangular and Square Hollow Structural Sections	ASTM A500 GRADE B, UNO
Round Hollow Structural Sections	ASTM A500 GRADE B, UNO
Steel Pipe	ASTM A53 GRADE B
Steel Plates	ASTM A36, UNO
High Strength Bolts	ASTM A325 OR A490
Anchor Bolts	ASTM F1554, GRADE 36 AND GRADE 105
Standard Fasteners	ASTM A307

*UNO= unless nothed otherwise in drawings

TABLE 1: STURCTURAL STEEL SPECIFICATIONS

Concrete		
Application	Strength (psi)	Weight (pcf)
Spread Footings	3500	150
Walls, Piers, Grade Beams	4000	150
Slab on Grade	3500	150
Mud Mat	2000	150

TABLE 2: CONCRETE SPECIFICATIONS

Reinforcement	
Application	Grade
Deformed Bars	ASTM A615, Grade 60
Deformed Bars (Weldable)	ASTM A706
Welded Wire Fabric	ASTM A185

TABLE 3: REINFORCING SPECIFICATIONS

Foundation System

A geotechnical report of the future site of the Corporate Headquarters was written by in February 2012 by Geo-Sci, Inc. Following the completion of the report, the geotechnical engineer determined that the original soil bearing capacity of 4ksf would not be sufficient to support the weight of the building. In order to increase the soil bearing capacity, aggregate pier soil reinforcement system was recommended. These piers are to be placed below each column footing. Aggregate pier sizing varies with column footing size, with an average diameter of approximately 18".

The geotechnical report required that all footings, both column and wall, be excavated and poured on the same day. If this cannot be achieved, a 3" concrete mud mat must be poured over all of the excavated soil. The foundation is comprised of spread footings, wall footings, column piers, and grade beams.

The foundation of the Corporate Headquarters required the use of grade beams in order to resolve the large dead load of the courtyard trees into the site soil below. This is evident due to the placement of the grade beams near the areas with courtyard access, namely, the southwestern corner of the courtyard and the northwestern corner. The grade beams take the load from the large columns located near the building core.

The typical spread footings (Figure 1) are centered under the base of the steel columns and are placed directly above the aggregate piers used for soil reinforcement. Since there are no moment frames within the structure of the building, it can be reasonably assumed that the connections are pinned. For columns that sit on both a spread footing and concrete pier (Figure 2), the connection can also be assumed to be pinned. All spread footings in this building are supported by aggregate piers due to the poor soil quality on the site.

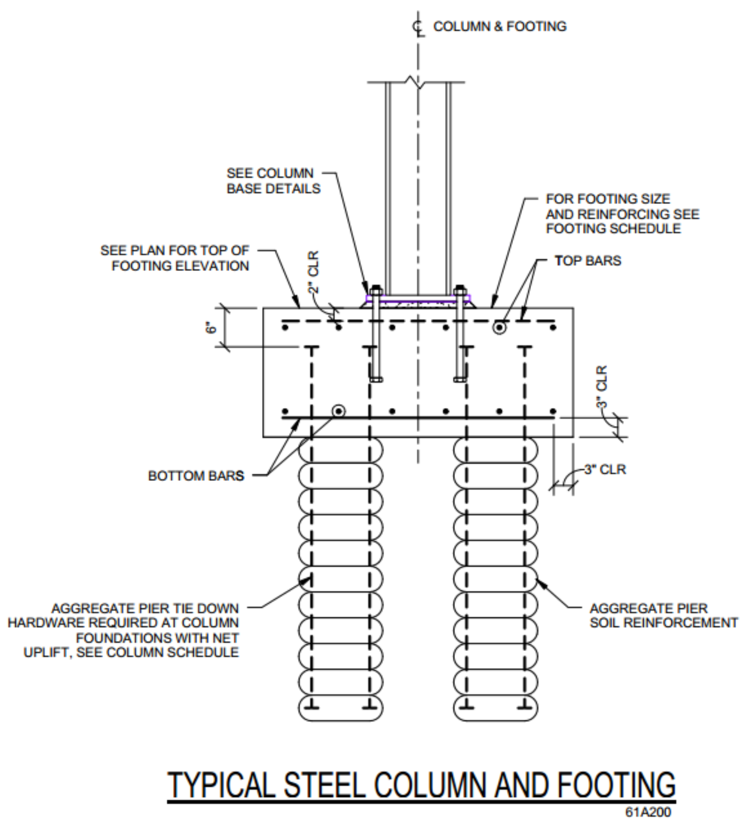


FIGURE 1- TYPICAL STEEL COLUMN AND FOOTING

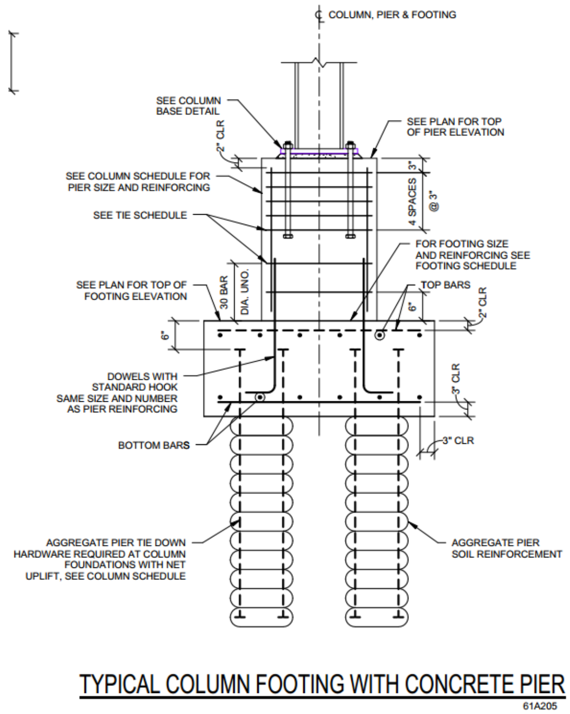


FIGURE 2- TYPICAL COLUMN FOOTING WITH CONCRETE PIER

Wall footings are used at all exterior cavity wall locations along the perimeter of the building, and the building rests on two different types of slab on grade. The larger slab depth (Type S-2 in) is used throughout the northern half of the building since it is slightly below grade and carries larger dead loads. Slab Type S-1 is used primarily near the center of the building, near the area of the courtyard, and is typical slab on grade construction. Both slab types can be seen in Figure 3.

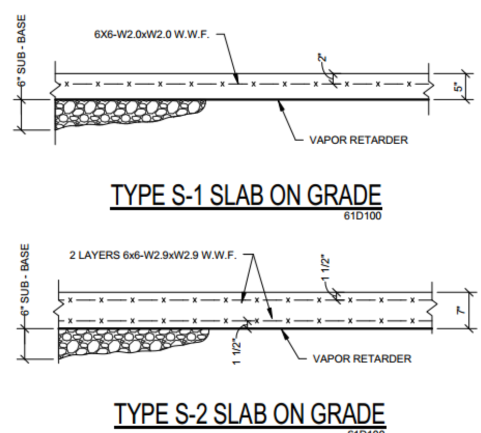


FIGURE 3- SLAB ON GRADE DETAILS

Floor System

The Corporate Headquarter features two different construction assemblies for the floor system. The first assembly (F-1) features 3 ¼" lightweight concrete with 6x6-W1.4xW1.4 welded wire fabric reinforcement on top of a 2" 18 gage composite metal deck. Assembly F-2 has 4 ¼" of lightweight concrete reinforced with 6x6-W2.0xW2.0 draped welded wire fabric on 3" 16 gage composite metal deck. The decking runs perpendicular to the wide flange beams.

Typical Floor Bay

Many of the bays in the Corporate Headquarters are rectangular, and shapes only differ near the edges of the building and the interior courtyard area. A typical bay is 38'x40'. Two typical member sizes used in all levels of floor framing are W21x44 and W24x55, with slight variation in depth (+/- 3") and weight (+/- 13 psf) when spans differ. In smaller span areas, such as around stair and elevator openings and the courtyard, W18 shapes and W21 shapes are common. Typical interior girders for a standard bay are W24x68, and in areas with smaller bays are typically W21 shapes or lighter W24 shapes. Figure 4 below shows a typical 38' bay and W24x55 beams.

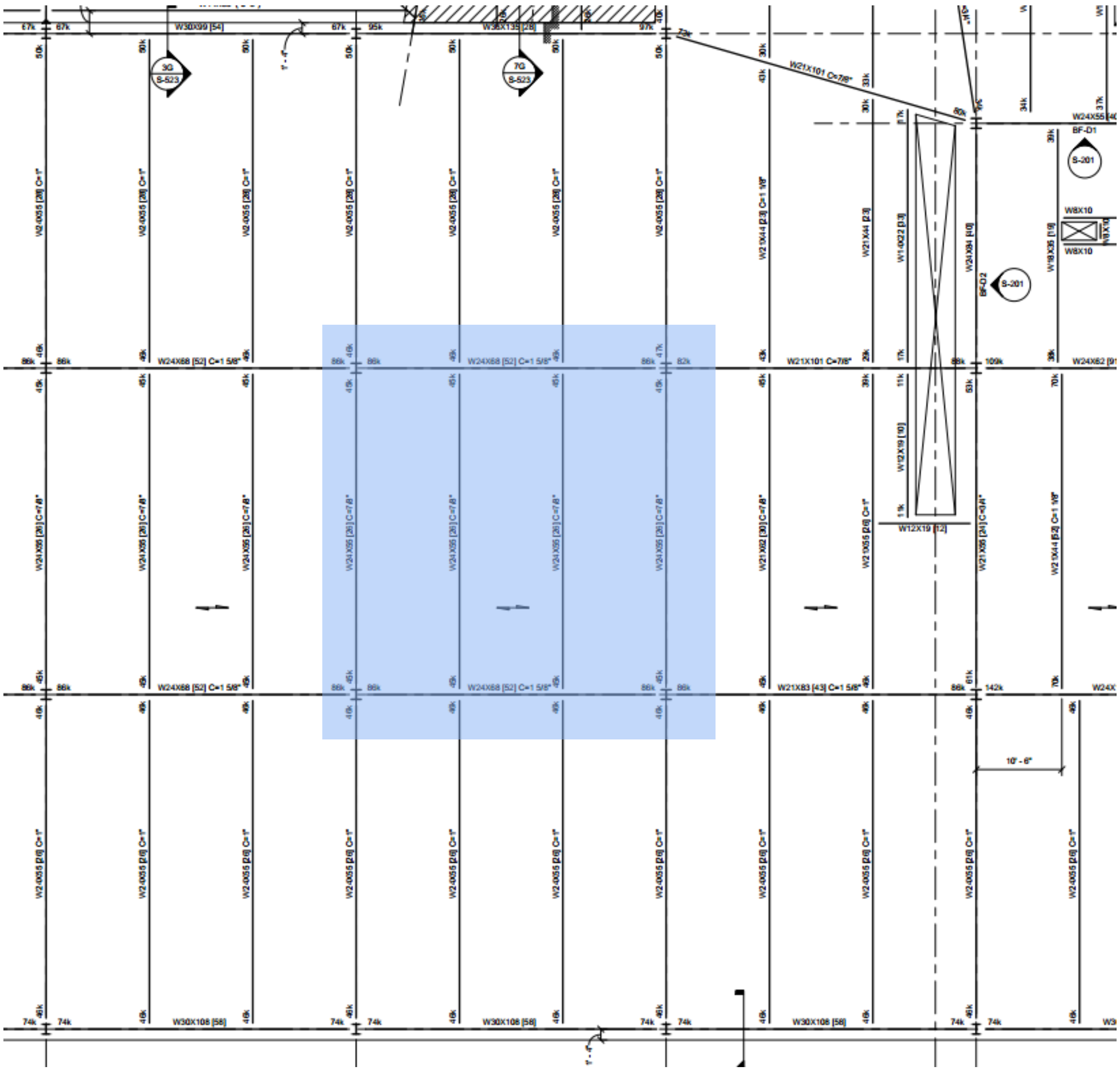
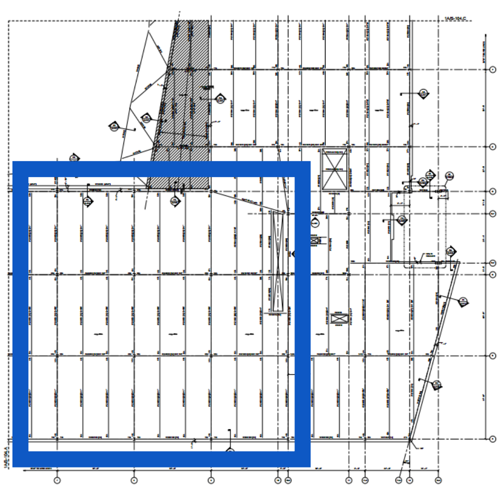


FIGURE 4: LEVEL 4 FRAMING PLAN SHOWING TYPICAL BAY (S104.D)



Framing System

The gravity framing of the building is composed of steel wide flange columns. All columns are W14 or W12, with the majority of weights between 61 and 170. One exception to this is a column that extends from the first floor to the roof. Nearly every column in the building has a column splice, all of which have larger shapes on the bottom than the top. Every combination of column splices varies slightly in size, with no predominant size majority. The columns are typically spliced between level 2 and level 3, and eleven columns in the building have tension spices. The columns are tension spliced because they are part of braced frames and carry a large axial load.

COLUMN SCHEDULE

LOCATION \ COLUMN	L-11	L-12	L-4-D1	L-4-D2	L-8-D1.2	M-D2	M-4	M-5	M-6	M-7	M-8	M-8.3
PENTHOUSE ROOF / EL. = 794'-6"												
MAIN ROOF / EL. = 781'-3"												
5TH FLOOR (EL. = 766'-7") – 3RD FLOOR	W14x61	W14x48	W14x43	W14x53	HSS8x8x3/8	W14x43	W14x48	W14x61	W14x61	W14x61	W14x53	W14x43
3RD FLOOR (EL. = 735'-3") – 1ST FLOOR	W14x90	W14x90	W14x82	W14x90	HSS8x8x3/8	W14x61	W14x90	W14x90	W14x90	W14x90	W14x90	W14x48
BASE PLATE/ ANCHOR BOLTS (EL. = 697'-1")	21"x1 1/2"x1'-9" (4) 3/4" Ø BOLTS 1HS-T23	21"x1 1/4"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 1/2"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 1/4"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	14"x3/4"x1'-2" (4) 3/4"Ø BOLTS 9HS-T23	20"x1"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 1/4"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 1/2"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 1/2"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 1/2"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 1/4"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	20"x1"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23
PIER												
FOUNDATION DESIGN LOADS (KIPS)	559	318	270	358	66	143	333	478	475	474	384	120

LOCATION \ COLUMN	M-9	M-10.2	M-11.3	DA.8-D0.8	DA-D1	DA-D2	DA-D3	DA-D3.7	DB-D1	DB-D2	DB-D3	DB-D4
PENTHOUSE ROOF / EL. = 794'-6"												
MAIN ROOF / EL. = 781'-3"												
5TH FLOOR (EL. = 766'-7") – 3RD FLOOR	W14x61	W14x61	W14x48		W12x40	W14x53	W14x53	W14x43	W14x53	W14x61	W14x61	W14x61
3RD FLOOR (EL. = 735'-3") – 1ST FLOOR	W14x90	W14x90	W14x90	W8x31	W12x53	W14x90	W14x90	W14x90	W14x90	W14x90	W14x90	W14x120
BASE PLATE/ ANCHOR BOLTS (EL. = 697'-1")	21"x1 1/4"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 1/2"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 1/4"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	10"x3/4"x1'-2" (4) 3/4"Ø BOLTS 1HS-T23	19"x1 1/2"x1'-7" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 1/2"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 1/4"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 1/4"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 3/4"x1'-9" (4) 7/8"Ø BOLTS 1HS-T23	21"x1 1/2"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 1/2"x1'-9" (4) 3/4"Ø BOLTS 1HS-T23	21"x1 3/4"x1'-9" (4) 7/8"Ø BOLTS 1HS-T23
PIER				12"x12" (4)#8		30"x30" (8)#10	30"x30" (8)#10	30"x30" (8)#10		30"x30" (8)#10	30"x30" (8)#10	30"x30" (8)#10
FOUNDATION DESIGN LOADS (KIPS)	416	461	408	20	286	432	357	365	356	450	585	757

FIGURE 5- COLUMN SCHEDULE

Lateral System

The lateral system of the Corporate Headquarters is made up of eight braced frames near the core of the building. In six locations braced frames extend from the first floor to the roof, and in two locations the braced member begins on the second floor level. These two frames do not have braced members on level one to accommodate a future retail shaft. The load of these frames is transferred using heavier columns than those used in the other six braced frames. The columns in turn transfer the load to the grade beams in the foundation system.

The braced members are made of Hollow Structural Sections varying from HSS8x8x1/4 to HSS 16x16x5/8. In two locations, the bottom member of the brace is made of a W14 shape. The braces take a diagonal shape in five locations, a chevron shape in one location, and an inverted chevron shape in two locations.

The braced frames were chosen as the lateral force resistance system due to their strength and stiffness properties. Additionally, braced frames use less material than moment resisting frames and don't require formwork, as concrete shear walls do.

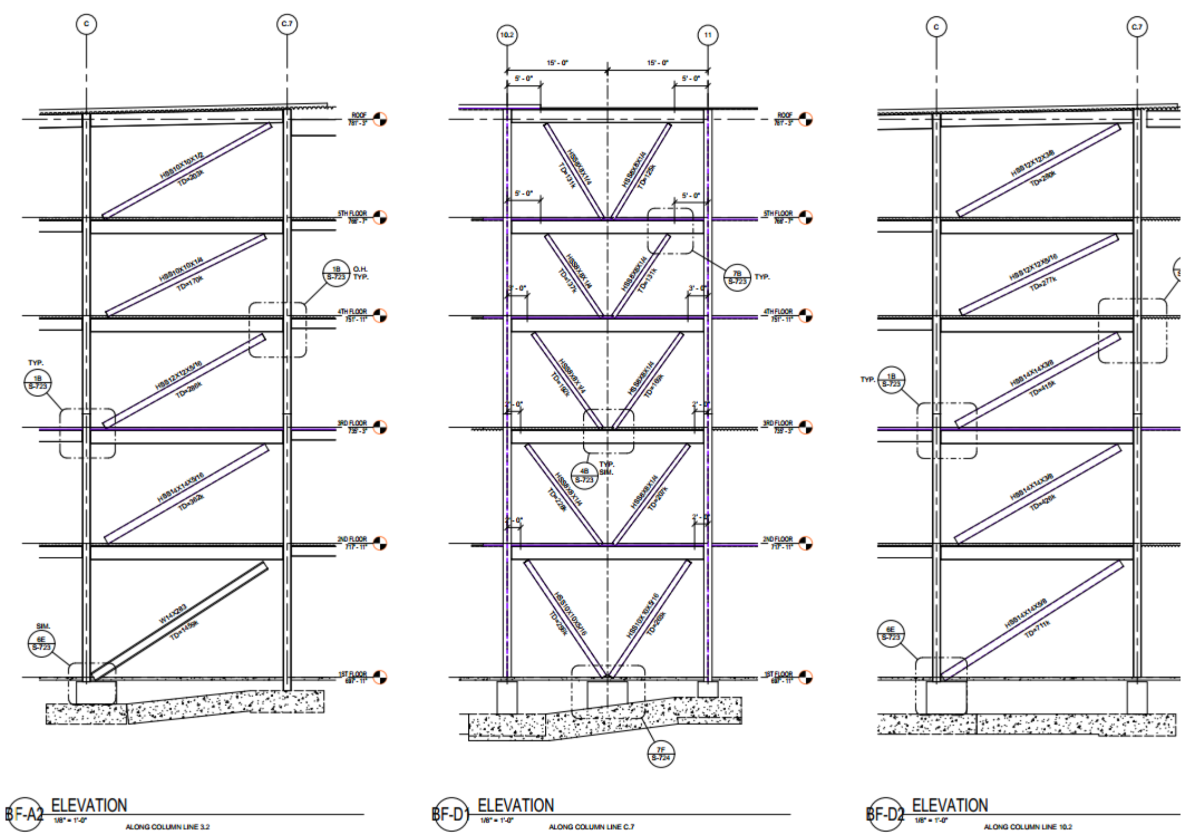


FIGURE 6- SAMPLE BRACED FRAME ELEVATIONS

Problem Statement

The current design of the Corporate Headquarters meets all strength and serviceability requirements, as was determined in technical report four. Though the design works, a scenario has created in which the building owner would like to make the building lighter and stiffer to assist in seismic performance, as the building is controlled by seismic loads. Though the current structural design could be varied in order to meet the needs of the client, another change was proposed. The owner would like also like to gain extra office space on the upper three floors of the building, and aims to do so by changing the geometry of the courtyard. The change in geometry will greatly affect the atmosphere of the courtyard, so the owner would like the planting pattern to be redesigned in order to maintain the feel of the original space.

Proposed Solution

To achieve the owner's request to make the building lighter and stiffer for seismic performance, the buildings gravity system will change to steel floor joists, while w-shapes will be maintained for the columns. The lateral system within the building will change from eight steel braced frames to eight cast in place reinforced concrete shear walls. To accommodate the owners request for more office space, the shape of the courtyard will change from a trapezoid to a rectangle. This change in geometry will alter the parameters of the watertight barrier, so that system will be investigated further in order to prevent any future water infiltration.

Though a steel joist system was not studied as an alternate system in technical report 3, it was determined to be the best fit for the Corporate Headquarters. The other systems studied included non-composite beams, one way concrete slab, and two way flat plate slab. The chosen solution limits the weight of the building and does not greatly impact the current floor to floor height. The proposed maximum height of each steel joist is 24", which is the average depth of the composite beams currently specified.

The system is a good fit for the building because the current steel framing system performed well under gravity and lateral loads. The change is also directly related to the change in geometry of the courtyard. Changing the shape of the courtyard into a rectangular shape will eliminate some of the load of the green roof, impacting the overall weight of the building. This decreased load will be easily handled by the steel joist system.

The proposed steel joist system will be designed with LRFD to keep with the factored loads used in technical report two.

Breadth Studies

Architectural Breadth- Courtyard

The shape of the interior courtyard must be altered, which leads to an architectural breadth. This change in shape will significantly alter the current planting pattern and design of the entire space. Due to this, a new planting pattern will be proposed. The current garden areas will be reshaped in order to change the layout of the paths. The garden redesigns will include shapes that are significant to the building occupant. Additionally, plants native to the building's location will be chosen, as a nod to the occupant's history within the local community.

The decision to change the change the courtyard into a rectangle rather than a different shape, such as an oval, was done in order to regularize the bays surrounding the courtyard. In the northwest corner of the building, there are angled column lines, some of which can be made parallel to other column lines by this architectural change.

Waterproofing Breadth- Courtyard and Roof

Changing the geometry of the courtyard greatly affects the waterproofing membrane. Upturn locations in the material will have to change due to the new exterior angles of the space, and new path locations may change the drainage locations. Additionally, different types of plants may require more water, so there may be opportunities to use excess water runoff to feed the plants. This concept of excess runoff and drainage locations will also be explored on the main roof level. To reduce building costs, the roofing membrane and installation methods used in the courtyard will also be used on the main roof.

Changes will be made to both the type of roofing membrane and the method of application. To ensure that the building is water tight, a series of tests will be presented to the client, with detailed instructions on how to conduct each one. On the main roof level, a flood test will be conducted, in which the drains are temporarily plugged and water is ponded on the roof. On the courtyard level, simple hose tests will be conducted, targeting areas where seams in the waterproofing membrane are visible.

Methods and Research

The first step toward reaching the proposed solution is to achieve a fully functioning building model. The first couple weeks of the semester will be spent trouble shooting an existing model and reporting the analyzed load cases applied to the existing braced frames. Once the loads are verified, work can begin on the proposed solution.

After the model is correct and the loads are verified, the geometry of the courtyard must be redesigned. This new shape affects adjacent bays and overall building loading, so it must be considered before anything else. Hand sketches of a proposed shape will be overlaid on top of the existing floor plan, and a new floor plan will be created for levels 3, 4, and 5. Images of surrounding buildings and similar courtyards will be considered before a final decision is made regarding the courtyard's shape.

Once the new floor plan has been created, the structural depth may begin. First, the gravity system will be designed. To begin, loads will be calculated using loading information from IBC 2009, ASCE 7-05, and the original design criteria. Following determination of loads, the gravity system design will be developed using the Steel Joist Institute Standard Specifications Design Manual, K-series joists as well as the Steel Construction Manual. Each load case will be input into a new gravity system model and representative floor joists will be hand checked for member strength. A variety of live load patterns, including full live load on all spans, 75% full load on all spans, and no load on adjacent spans will be investigated.

Following the gravity system redesign, the lateral system redesign will begin. In an effort to maximize floor space, the shears walls will be placed at the location of the current braced frames. Wind and seismic loading conditions will be taken from IBC 2009 and ASCE 7-05. The stiffness of the new gravity system aims to reduce seismic load, so using these parameters, the reinforced cast in place shear walls will be designed and input into the model. The model results will check distribution of forces, strength, center of rigidity, and center of mass. These results will be verified using hand calculations.

After completion of the structural depth, the remainder of the architectural breadth may be considered. Garden design, path locations, and types of plants will be investigated. Planting experts will be consulted in order to aid in proper selection, and landscape architects will be consulted to aid with proper location of gardens and paths. After these consultations, a final design will be prepared, using both hand drawings and computer renderings.

The final portion of the project is the waterproofing breadth. This breadth will be done concurrently with the courtyard redesign. The new waterproofing membrane for the courtyard will be selected, and application processes will be researched. This same type of membrane will be used on the main roof. Following this step, types of water tests will be researched and presented, focusing particularly on flood test and hose tests. This material will be summarized, with a final recommendation highlighted in a future report.

At the end of each segment of the project, a write-up will be completed to add to the final report. At the end of the semester, the report will be finalized and a presentation will be prepared. Lastly, the report will be submitted, and the project will be presented to the structural jury.

Tasks and Tools

I. Task 1: Fix Model
   a. Trouble shoot problems
   b. Analyze lateral load cases
II. Task 2: Redesign Courtyard Geometry
   a. Review appearance of surrounding buildings
   b. Research similar interior courtyard shapes
   c. Do preliminary hand sketches of possible solutions
      i. Create a variety of solutions
      ii. Aim to maximize adjacent office space
   d. Create new floor plans using final geometry
III. Task 3: Structural Redesign
   a. Determine new loads
      i. Reference new floor plans to recalculate courtyard load and office space load
   b. Design gravity system
      i. Size gravity columns and floor joists
      ii. Create new gravity system model
      iii. Analyze model output
      iv. Complete member spot checks
      v. Write-up gravity system summary for final report
   c. Design lateral system
      i. Verify wind and seismic loading
      ii. Design shear walls
      iii. Model shear walls
      iv. Analyze model output
      v. Evaluate shear wall strength
      vi. Write up lateral system summary for final report

IV. Task 4: Complete Architectural Breadth
    a. Redesign placement of gardens and walking paths
        i. Consult with landscape architect
    b. Select planting pattern
        i. Consult with planting experts
    c. Complete architectural breadth write-up for final report

V. Task 5: Waterproofing Breadth
    a. Select new waterproofing material
        i. Research membrane manufacturers
        ii. Complete cost comparison
        iii. Compare application methods
    b. Check drainage locations
    c. Select appropriate water test method
        i. Research different water tests
            1. Concentrate on flood tests and simple hose tests
        ii. Create a comparison chart
            1. costs
            2. time to conduct test
            3. feasibility of test
        iii. Select most appropriate method
    d. Create waterproofing write-up for final report

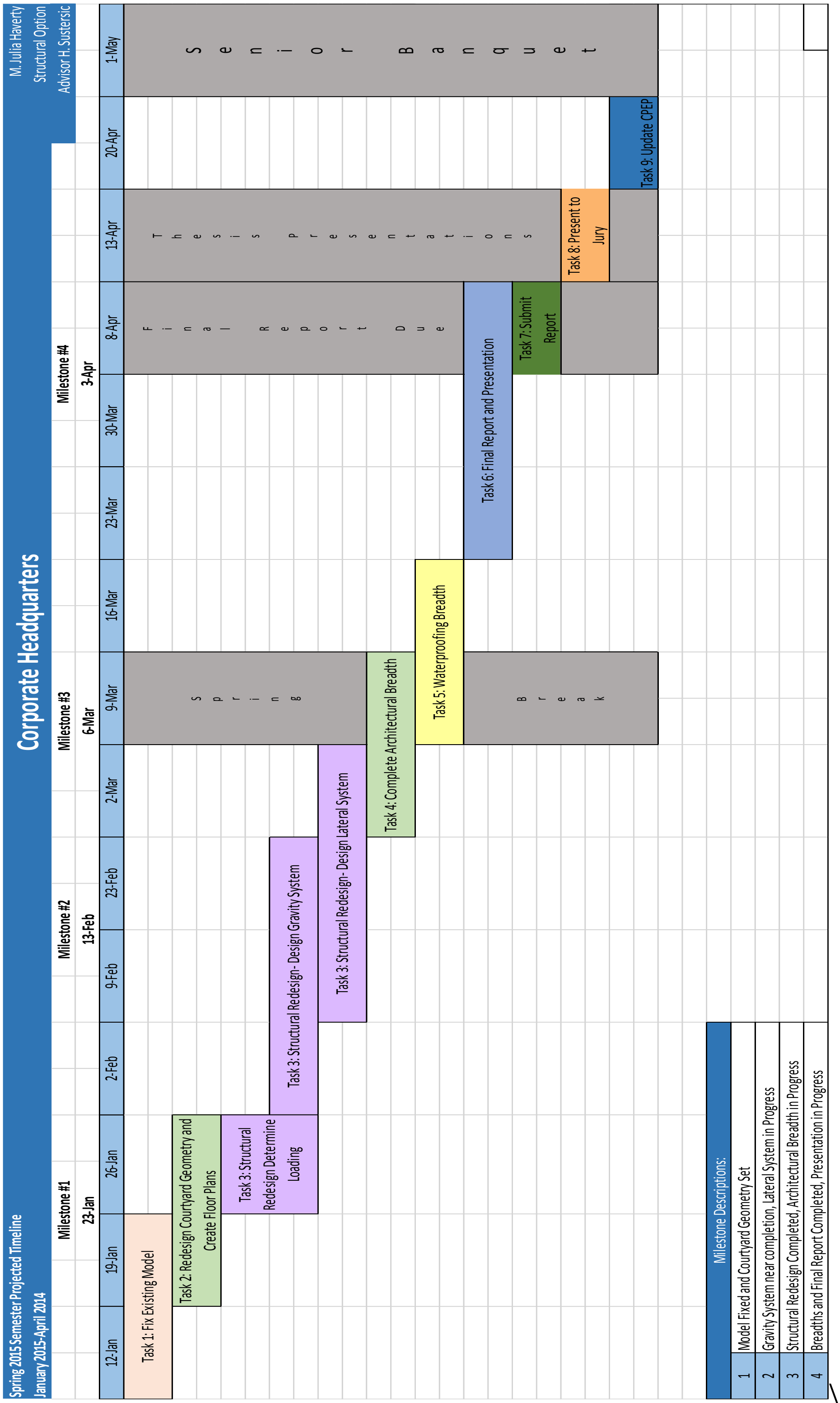
VI. Task 6: Final Report and Presentation
    a. Outline final report
    b. Finalize report
    c. Prepare presentation

VII. Task 7: Submit Report

VIII. Task 8: Present to jury

IX. Task 9: Update CPEP

Schedule


Spring 2015 Semester Projected Timeline
January 2015-April 2014
Corporate Headquarters
M. Julia Haverty
Structural Option
Advisor H. Sustersic
Milestone #1
23-Jan
Milestone #2
13-Feb
Milestone #3
6-Mar
Milestone #4
3-Apr
12-Jan
19-Jan
26-Jan
2-Feb
9-Feb
23-Feb
2-Mar
9-Mar
16-Mar
23-Mar
30-Mar
8-Apr
13-Apr
20-Apr
1-May
Task 1: Fix Existing Model
Task 2: Redesign Courtyard Geometry and Create Floor Plans
Task 3: Structural Redesign Determine Loading
Task 3: Structural Redesign- Design Gravity System
Task 3: Structural Redesign- Design Lateral System
Task 4: Complete Architectural Breadth
Task 5: Waterproofing Breadth
Task 6: Final Report and Presentation
Task 7: Submit Report
Task 8: Present to Jury
Task 9: Update CPEP
Spring
Break
Final Report Due
Thesis presentations
Senior Banquet
Milestone Descriptions:
1 Model Fixed and Courtyard Geometry Set
2 Gravity System near completion, Lateral System in Progress
3 Structural Redesign Completed, Architectural Breadth in Progress
4 Breadths and Final Report Completed, Presentation in Progress

Conclusion

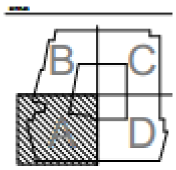
Though the existing structural system of the Corporate Headquarters is adequate to meet the current needs of the building, the owner's requests indicate that a change must be made. In order to meet the owner's demands of additional office space, the geometry of the interior courtyard must be changed. This change will affect the weight of the building, bays adjacent to the courtyard, and the courtyard waterproofing system. Additionally, for the building to perform better in seismic, the gravity and lateral systems must be changed.

First, the geometry of the courtyard will be changed to become more rectangular. Following that change, the structure will be redesigned to reflect the change in loads and the building's new seismic performance requirements. Next, the court yard's appearance will be changed by redesigning garden, changing planting patterns, and altering walking paths. Finally, the waterproofing of the courtyard and the main roof will be reconsidered in order to prevent water infiltration.

Appendices

Appendix A: Typical Building Floor Plans

Building Key Plan



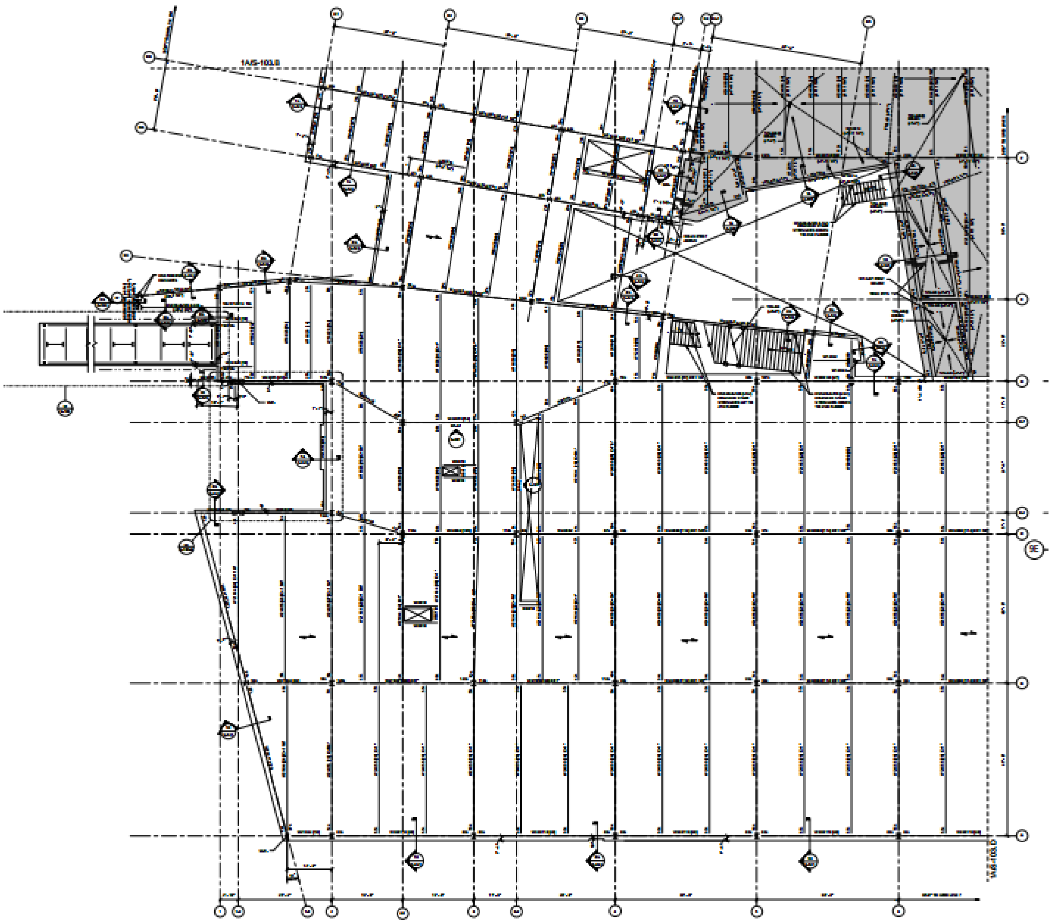


FIGURE 7- TYPICAL SEGMENT A FLOOR FRAMING PLAN

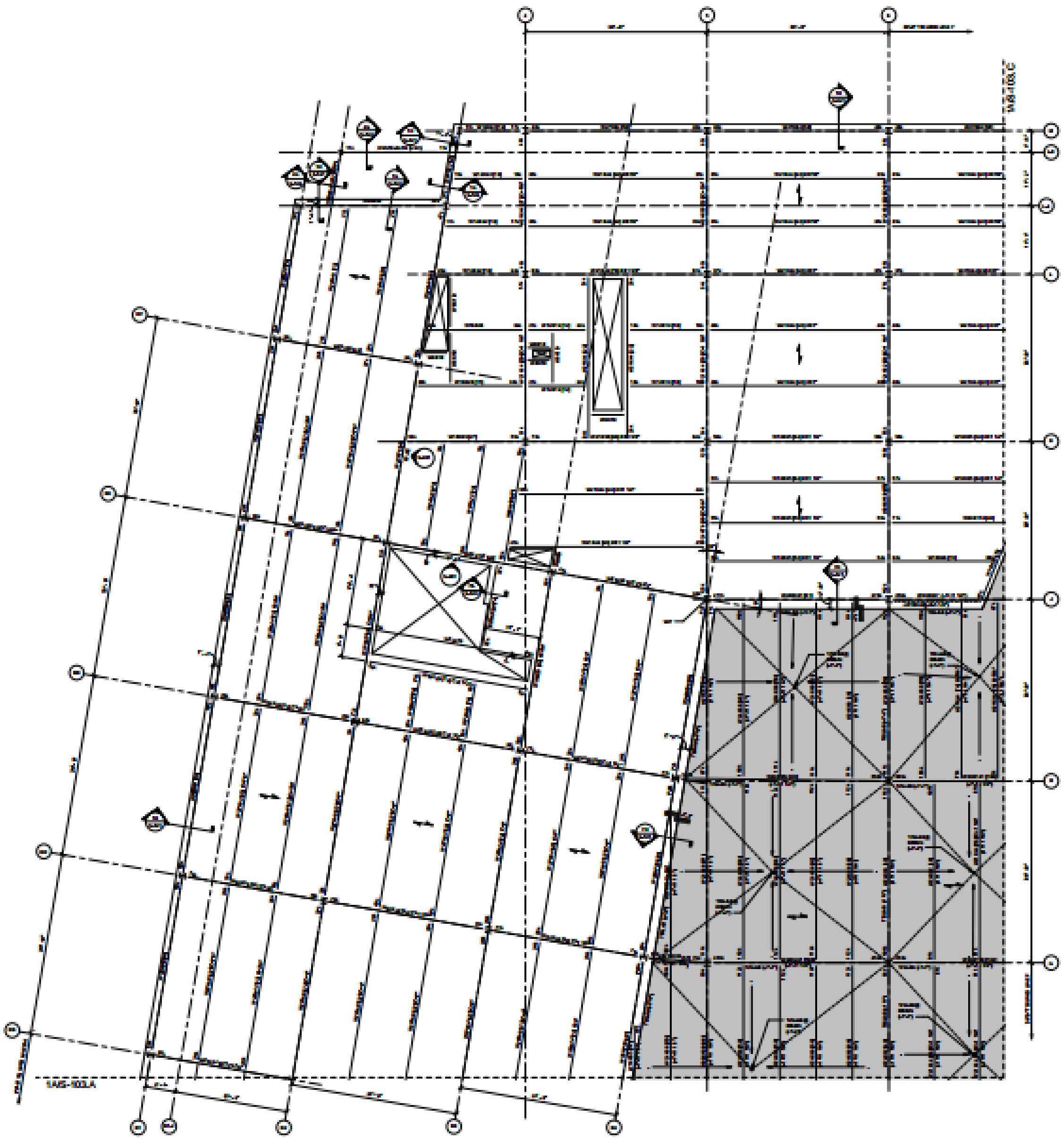


FIGURE 8- TYPICAL SEGMENT B FLOOR FRAMING PLAN

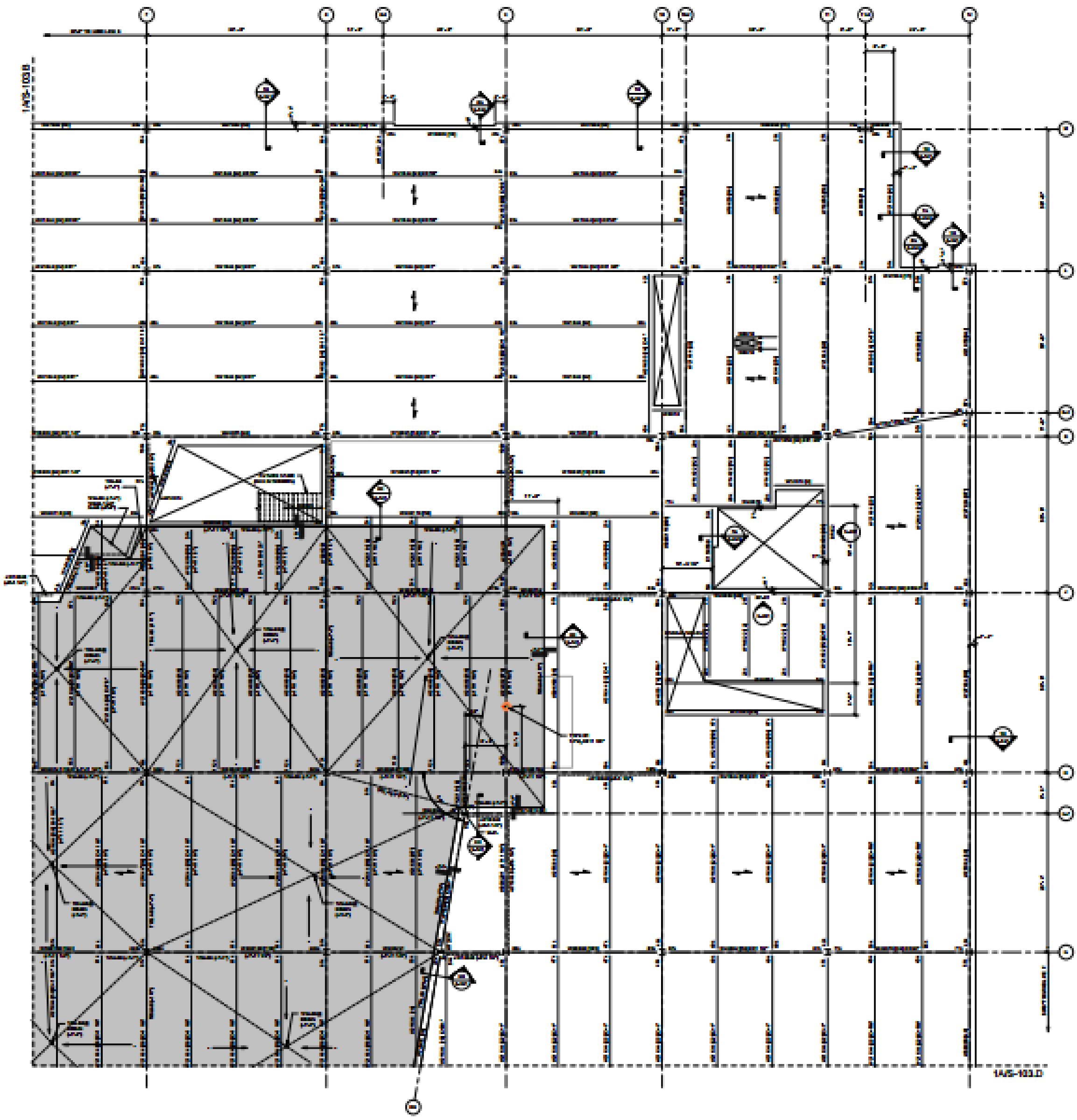


FIGURE 9-TYPICAL SEGMENT C FLOOR FRAMING PLAN

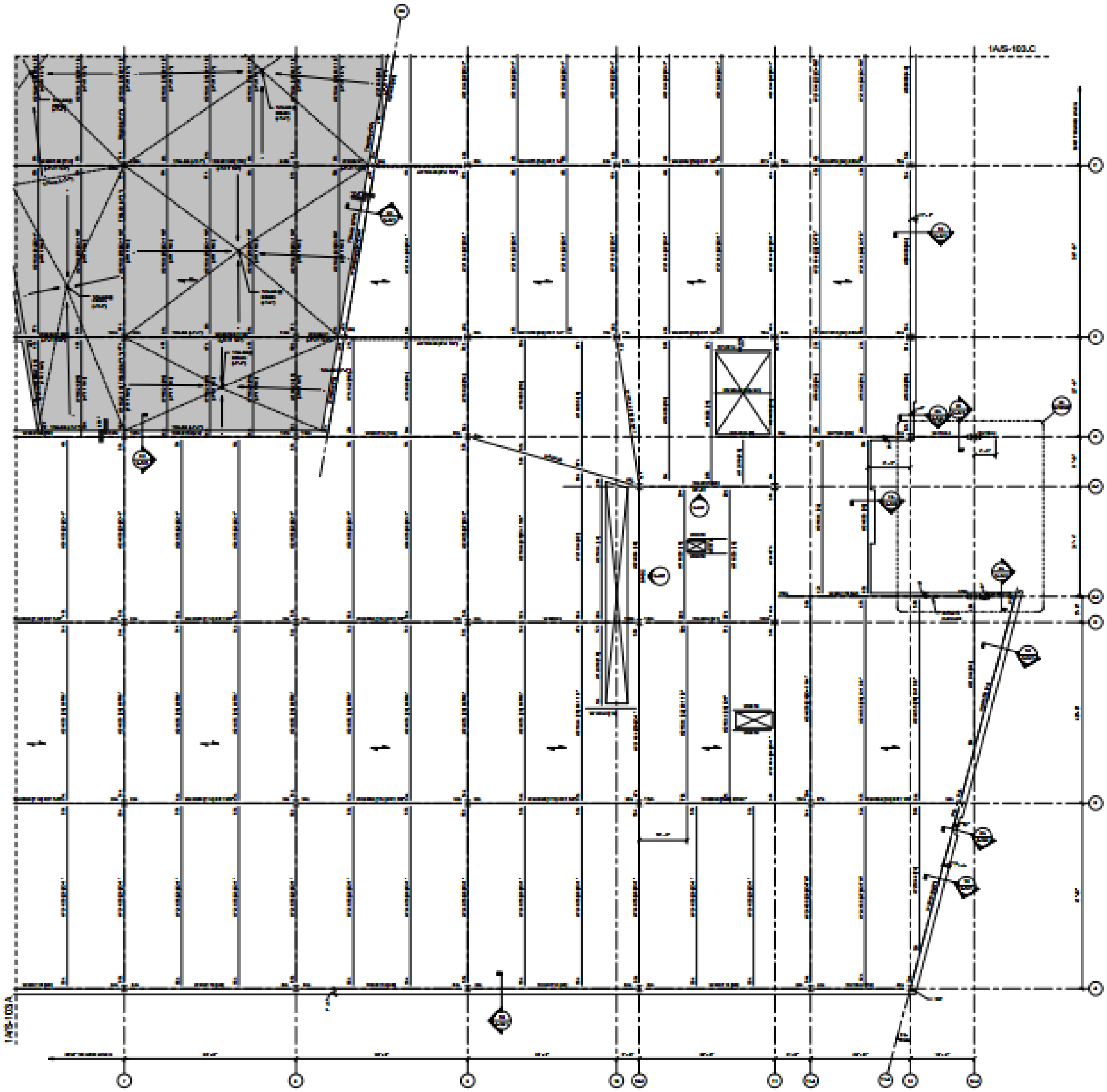


FIGURE 10-TYPICAL SEGMENT D FLOOR FRAMING PLAN

Appendix B: Building Elevations

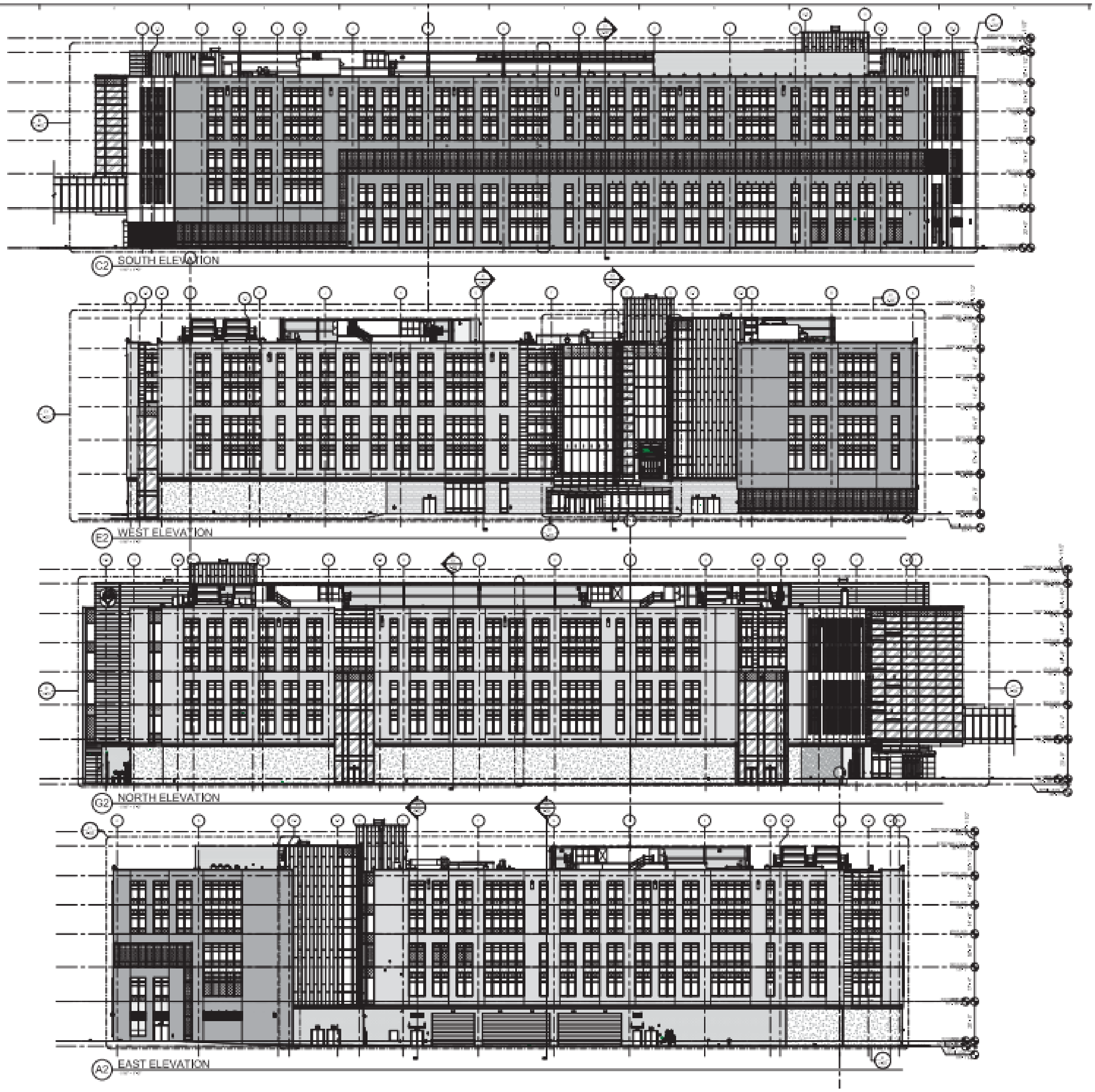


Figure 11- building elevations, From Top Down: south, West, North, East