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{Structural Option}
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James W. & Frances G. McGlothlin Medical Education Center
Virginia Commonwealth University School of Medicine
Richmond, Virginia

Structural Thesis Proposal

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Executive Summary

The following technical report is a thorough overview of the existing conditions of the structural system found in the newly constructed James W. & Frances G. McGlothlin Medical Education Center. Located in Richmond, Virginia, the new Virginia Commonwealth University School of Medicine building rests on the previous site of the A.D. William's Building. The foundation system incorporates multiple, differing drilled piers and drilled pier-grade beam combinations to support the 13-story above ground structure. The framing system is all steel on composite steel/concrete decking. Lateral loads (mostly contributed from wind) are resisted by steel concentrically braced frames, seven total in the building. A 65'-0" pedestrian bridge connects the new structure to the Main Hospital across East Marshall Street. The exterior façade was designed by internationally acclaimed architecture firm Pei Cobb Freed & Partners and is mainly glass and concrete panels.

To provide background information, floor plans, bays, columns, and other elements from the structure are referenced throughout the report and can be found in the appendices for further examination. State and national codes used in the design of the structure are also cited in the following report; these codes, more specifically loading values, will be utilized in further research and subsequent technical reports.

Building Introduction

The James W. & Frances G. McGlothlin Medical Education Center, also known as the new Virginia Commonwealth University School of Medicine Education Center, is located in Richmond, Virginia. The 13 story, 220,000 square foot building was completed in early 2013. The project was constructed following the demolition of the A.D. Williams Building, which previously housed the VCU School of Medicine faculty offices, outpatient clinics, and laboratories. The new construction, as shown in Figure 1, encompasses all of these program requirements, along with various collaborative spaces, classrooms, and a 300-seat auditorium accessible via the second and third floors.

The building rests atop approximately 60 drilled piers of varying capacities and a 10" thick slab-on-grade. As the building progresses skyward, the structural lateral load resisting system is composed of steel concentrically braced frames, structural steel members, and composite concrete slabs on metal decking. The exterior of the building, designed by internationally acclaimed architecture firm Pei Cobb Freed & Partners, does not contribute to the structural strength of the building, but is intended for aesthetic and environmental purposes. The project is currently under review by the U.S. Green Building Council in hopes of achieving a LEED (Leadership in Energy & Environmental Design) Silver status.

Figure 1 – James W. & Frances G. McGlothlin Medical Education Center when approaching on E. Marshall Street

Structural System Overview

The James W. & Frances G. McGlothlin Medical Education Center, known as the Virginia Commonwealth University School of Medicine (VCU SOM) project during development and construction, is a 13-story building that has both a basement and small sub-basement located below ground level, which is at an elevation of 153 feet. Since the VCU SOM project was constructed following the demolition of the A.D. Williams Building, the foundation system is designed to accommodate existing conditions. The superstructure of the building is composed of a composite concrete/steel deck with steel members and steel concentrically braced frames . Both the 13th Floor and the rooftop house mechanical equipment, requiring added strength. All of these systems are further analyzed on the following pages.

Foundation System

Geotechnical Investigation

All test drillings, site investigation, and subsurface explorations were completed by Geotech, Inc.; findings and recommendations were then reported in April of 2009. At the time of the report, only five of the six borings had been completed – the last boring was scheduled to follow the demolition of the existing building on the site. The six boring sites, those completed prior to demolition in purple and the final boring site in blue, are highlighted in Figure 2. Using these findings and their previous experience on VCU campus, Geotech, Inc. was able to recommend four differing schemes for consideration by Ballinger, the A/E for the project.

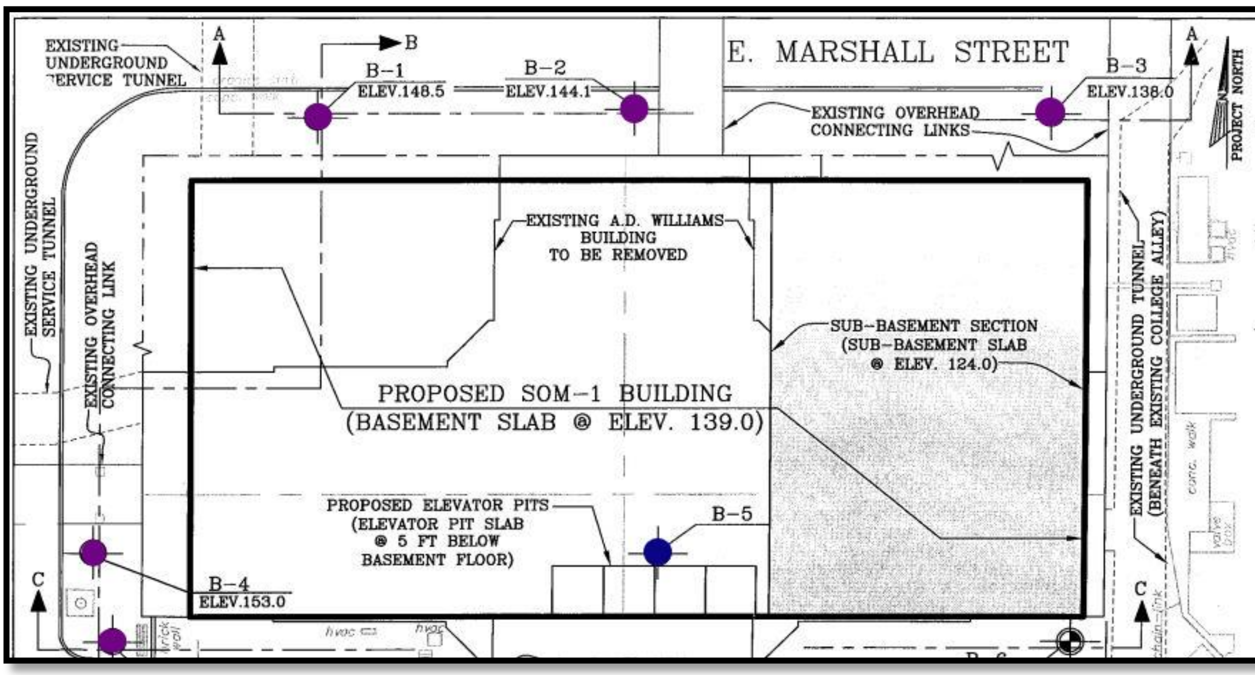


Figure 2 – Test boring sites, highlighted in color, established in the field by Geotech, Inc.

Foundation Scheme – Drilled Piers

Due to the varying nature of the loads applied across the building foundation, a scheme of three different piers was applied. The piers extend 54 feet below the sub-basement level, providing sufficient foundation support for the tall structure. The three different drilled piersused were intended to account for three variations of loadings: those loads considered "small", "medium", or "heavy". To support all "small" loads (≤ 450 kips), straight shaft drilled piers ranging in diameter from 3' to 8' were used. When loads were calculated in the range from 730 to 1,640 kips, or "medium" loads, single-belled drilled piers were installed. The shaft diameters for these piers range from 3' to 6', with the bell diameters not to exceed 3 times the shaft diameter. For all "heavy" loads (1640 kips up to roughly 3,300 kips), double-belled drilled piers were utilized, with shaft diameters between 3' and 6' and bell diameters between 9' and 13.5'. Highlighted drawings of the drilled pier layout for both the sub-basement and basement levels are available for reference in Figures 3 and 5.Straight shaft drilled piers are colored purple, single-belled drilled piers are in blue, and double-belled drilled piers are highlighted in red. All columns for both the sub-basement and basement levels can be found marked in Figures 4 and 6, respectively, for comparison.

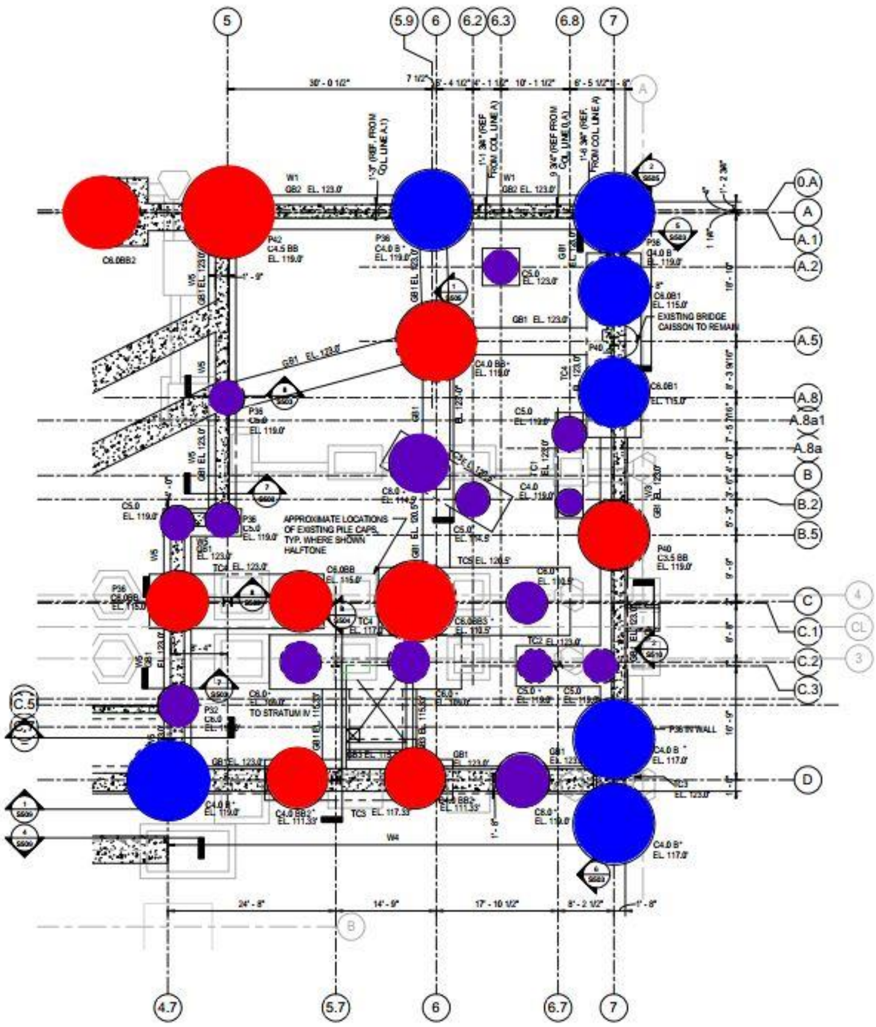


Figure 3 – Drilled Pier Scheme for the Sub-Basement Level –
Straight Shaft = Purple
Single-Belled = Blue
Double-Belled = Red

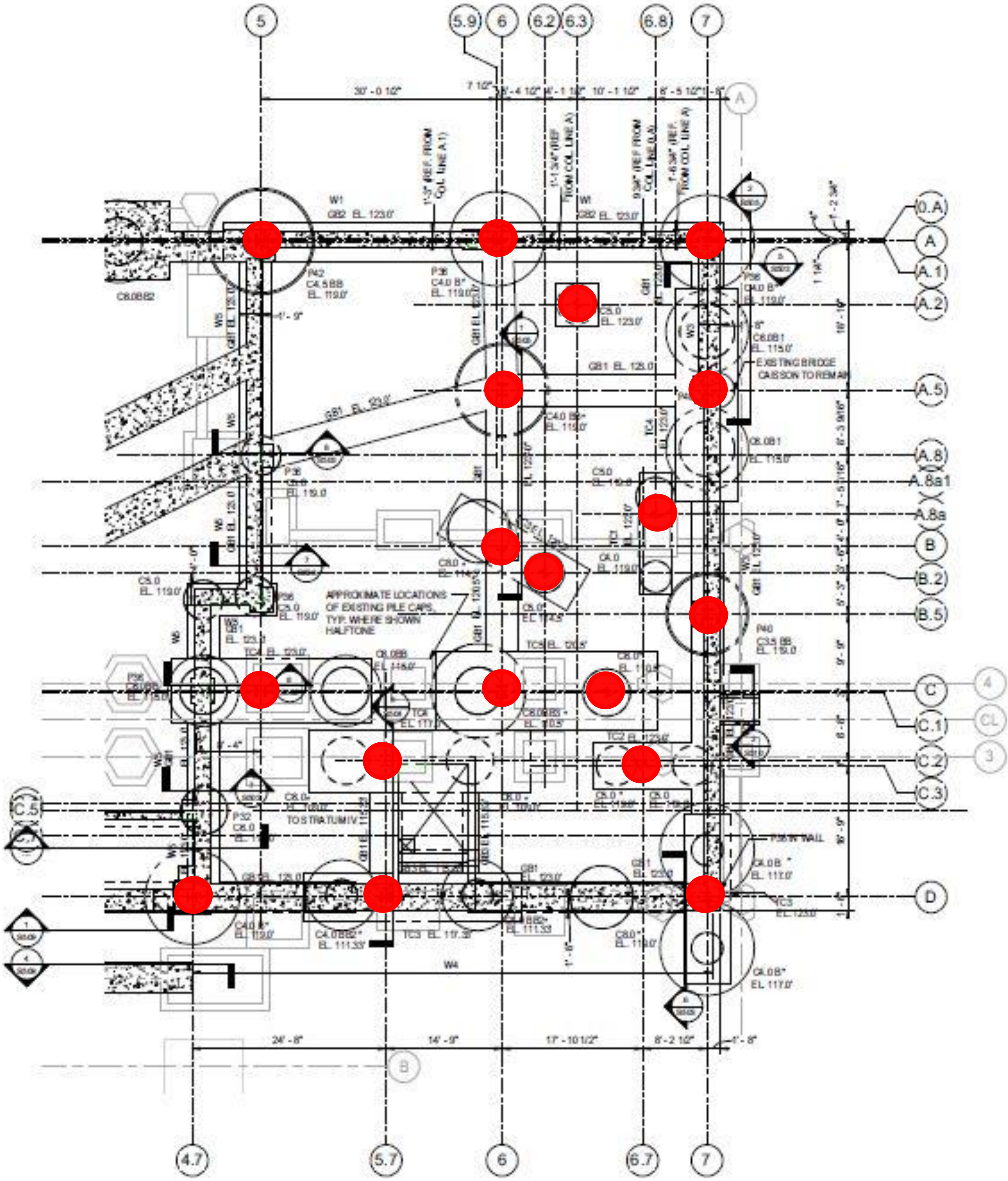


Figure 4 – Column Layout (Highlighted in Red) for the Sub-Basement Level

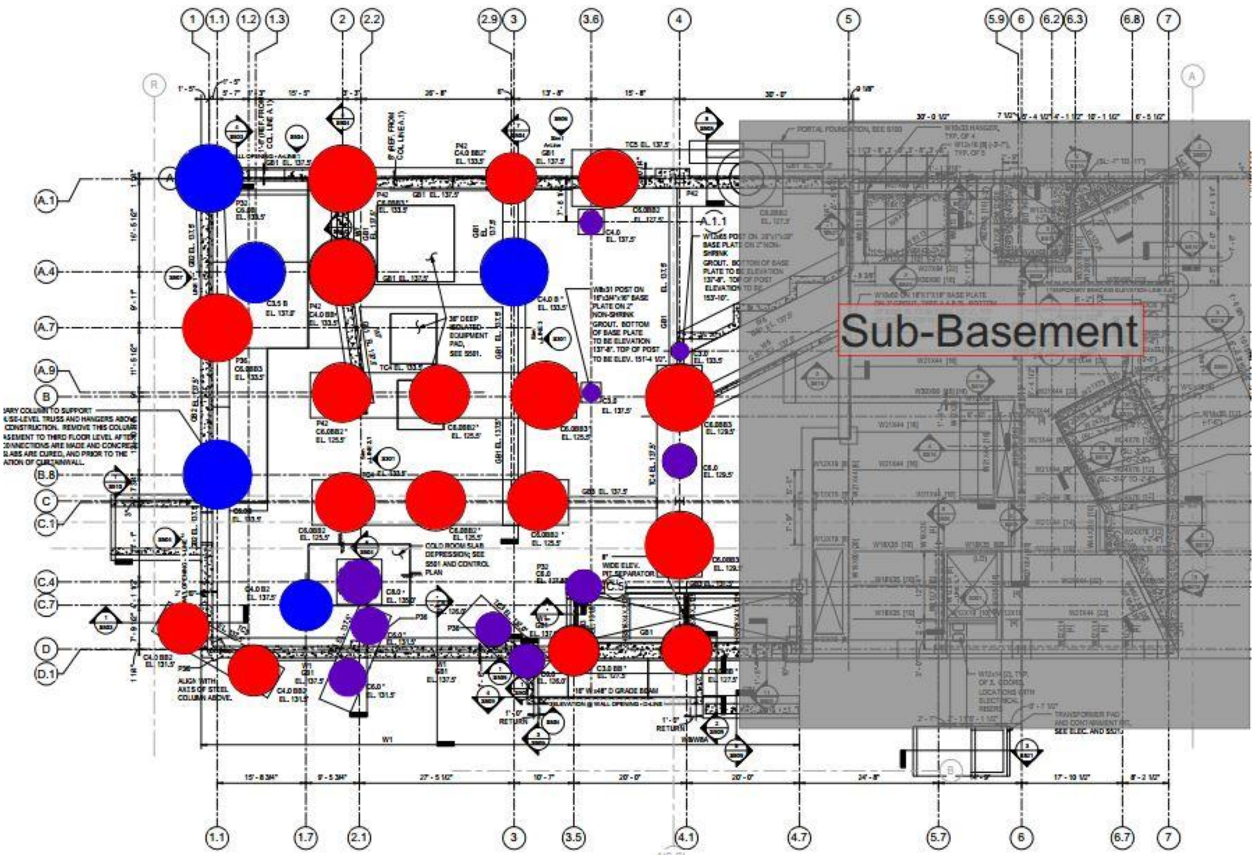


Figure 5 – Drilled Pier Scheme for the Basement Level –
Straight Shaft = Purple
Single-Belled = Blue
Double-Belled = Red

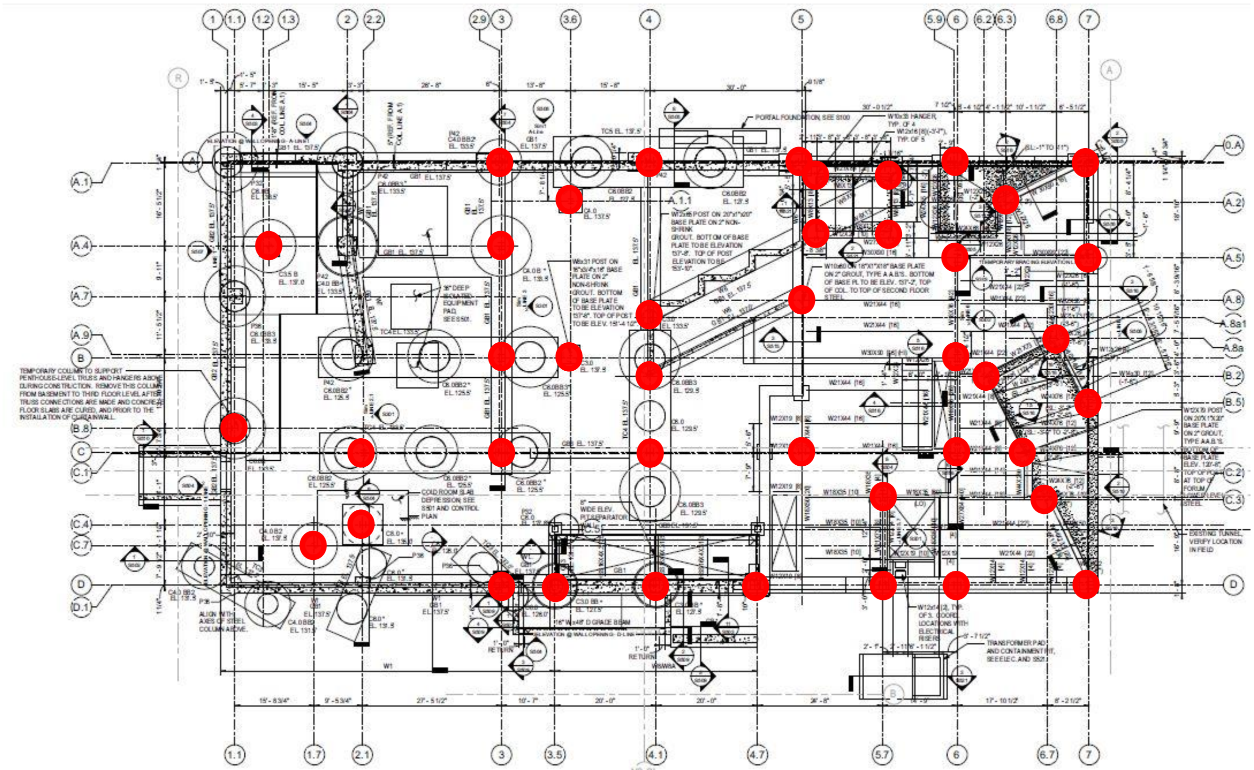


Figure 6 – Column Layout (Highlighted in Red) for the Basement Level

The three differently sized pier scheme accounts for all loads applied from the new construction; however, it does not address the existing piers previously used to support the A.D. Williams Building. During Geotech, Inc.'s thorough site investigation, it was concluded that some existing piers would in fact conflict with piers necessary for support of columns in the new construction. To avoid removal of the existing piers, a caisson and grade beam system was used. In any area where an existing pier interrupted the strength of the foundation, two caissons were placed on either side of the existing pile cap and a grade beam was used to connect the two new piers, providing the necessary support for the column line. The foundation plans for both the sub-basement and basement level can be found above for further examination of the drilled caissons and grade beam system. The grade beams used in this configuration are all 48” deep and range in width, from 24” to 60”. The sub-basement floor and portions of the basement floor are slab-on-grade, while all floors above grade and portions of the basement floor (i.e. loading dock) are slab on composite deck. There are two different slab-on-grades, but the differences are only minor. The slab-on-grade located at the sub-basement level is 6” concrete slab on 4” crushed stone and the slab-on-grade located at the basement level is 5” concrete slab on 5” crushed stone – both result in a 10” thick system.

Framing System

The VCU SOM framing system is composed of steel columns, with 9 of the 46 columns originating at the foundation of the sub-basement at an elevation of 124' 6”. About 75% of the columns extend almost the entirety of the structure, typically from the basement level (139' elevation) to the roof (350' 6” elevation). The other 25% of the columns support the following unique areas of the building: main entrance level, auditorium, public spaces above the auditorium, and the mechanical equipment heavy 13th floor. The columns range anywhere in size from W10x88 to W14x455, with the majority of the columns closer in size to W14x145. Beams and girders throughout the structure are also composite steel construction; the beams are typically W18x35 and the girders are typically W24x76, excluding areas where extra strength is required. Typical bays and slab-on-deck floor systems are further explored in the following section.

Floor System

Due to the irregularity of the structure's shape, a single typical bay is not common throughout the entire building. However, the 4th thru 13th Floors are closer in design and function, and therefore are more ordered. The bay sizes common throughout the core of the building are highlighted in Figure 7 These bays are typical throughout Floors 4 to 13; beam and girder sizes found in these bays are regular throughout Floors 4-12 and are shown in more detail in Figures 8 and 9. The 13th Floor is composed of beams and girders of increased size and capacity due to the heavy loads applied from the mechanical equipment housed there. The slab-on-decks for each floor are described in Table 1. All of the slab-on-decks were designed and constructed without the usage of temporary shoring.

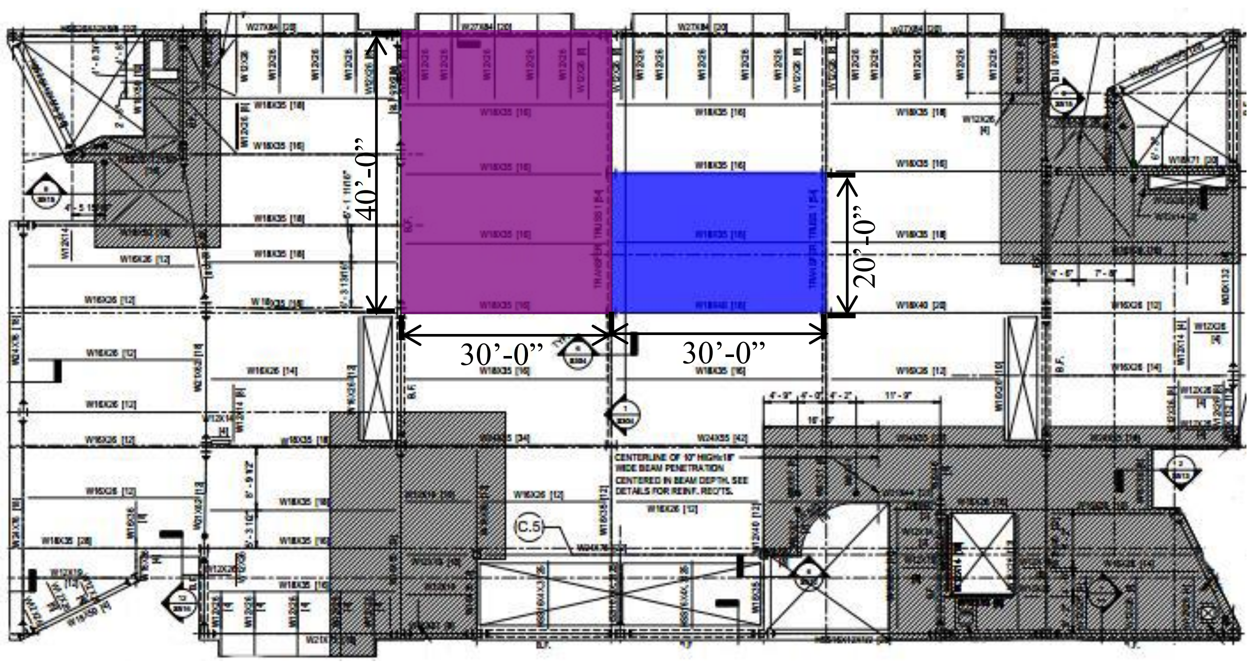


Figure 7 – Typical Floor Plan with Typical Bay Sizes Emphasized

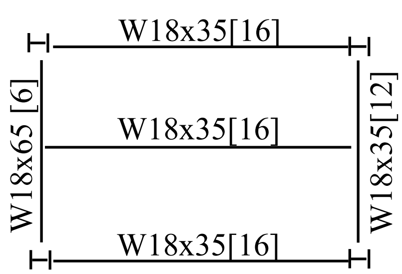


Figure 8 – Detailed Drawing of "Smaller" Bay

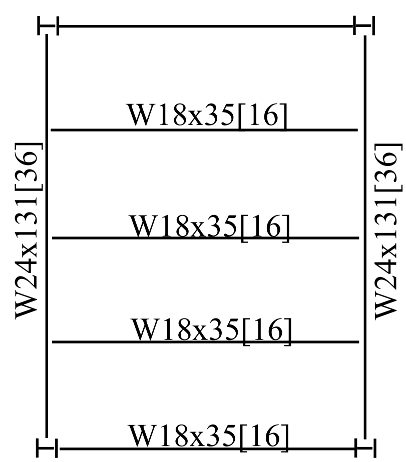


Figure 9 – Detailed Drawing of "Larger" Bay

Building Floor	Concrete	Steel Decking (Thickness/Type)	Reinforcement
1st	5” LW	3”, 16 Gage Composite Galvanized	#4@12” o.c. e.w. – 1½” from top of slab
2nd	3½” LW	3”, 16 Gage Composite Galvanized	#4@12” o.c. e.w. – 1½” from top of slab
3rd	3½” LW	3”, 20 Gage Composite Galvanized	#4@12” o.c. e.w. – 1½” from top of slab
4th	3½” LW	3”, 20 Gage Composite Galvanized	#4@12” o.c. x 8’-0” over beams & girders on column lines
5th – 12th	3½” LW	3”, 20 Gage Composite Galvanized	#4@12” o.c. x 8’-0” over beams & girders on column lines
13th	8” NW	3”, 16 Gage Composite Galvanized	#4@12” o.c. – 2” from top of slab

Table 1 – Slab-On-Deck Components by Building Floor

Lateral Load Resisting System

The VCU SOM's main lateral resisting system is a combination of braced frames and moment connections throughout the structure. There are seven steel concentrically braced frames, six traveling in one direction, with one frame contributing to the strength in the other path. The braced frames can be found highlighted in Figure 8. The layout of the braced frames accounts for lateral loads that could be applied from any of the possible directions. All of the frames are concentric, but each frame differs in size and levels included. Detailed drawings of the seven braced frames can be found in the supplemental drawings in Appendix B. A detailed calculation of applicable loadings is to be completed in future reports. For the time being, a basic description of the applied lateral loads can be found below.

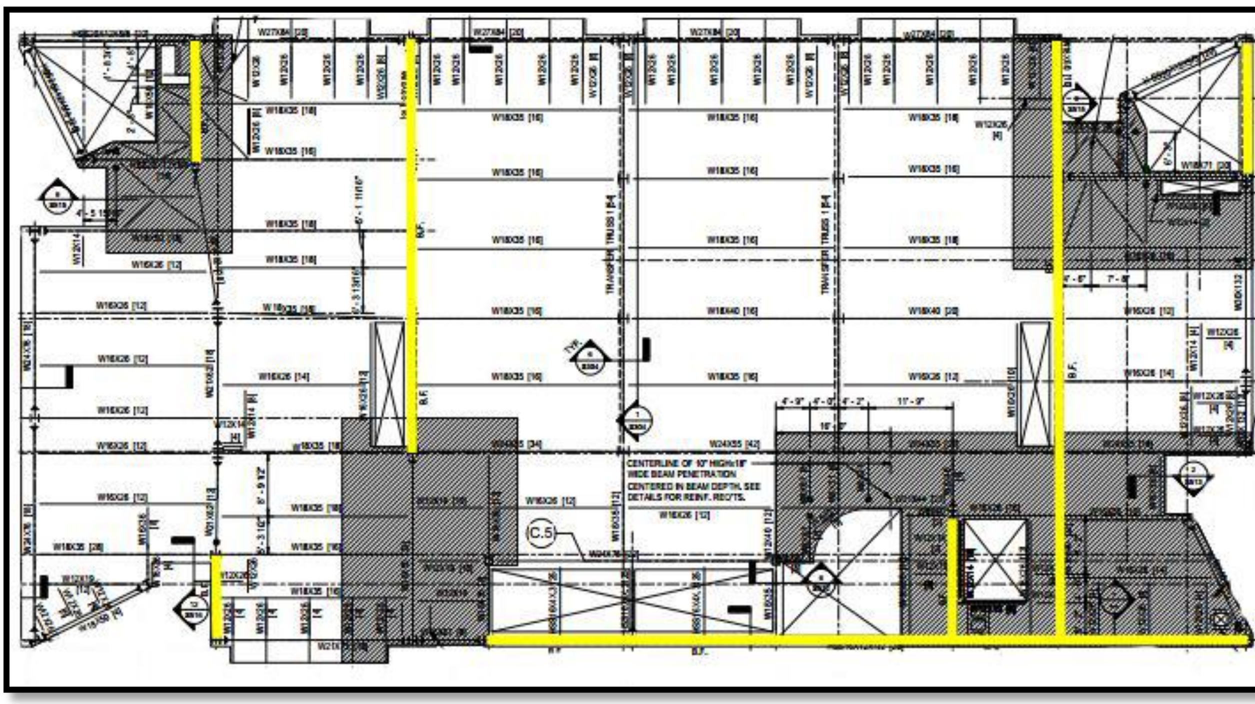


Figure 8 – Framing Typical to Floors 4th thru 12th with Braced Frames Highlighted

As seen in Figure 8, the braced frames throughout the structure span both directions, with the majority of the strength running North to South. Due to the positioning of the building, the anticipated loads are difficult to determine without a full investigation. The VCU SOM project is surrounded by equally tall buildings, but the wind tunnel effect cannot be discounted. The basic idea behind the lateral resisting system used in this project is that all "roads" will lead to the braced frames. Lateral loads hitting the building from any direction with traverse perpendicularly from their original direction across the floor through the beam and girder system. These loads will then be applied to the braced frames, which have been designed to withstand these pressures.

Roof System

The roofing system found in the VCU SOM project consists of 1 1/2”, 18 gage wide-rib steel roof deck covered with a rubber roofing membrane (EPDM). This Ethylene-Propylene-Diene-Monomor (EPDM) rubber roofing is fully adhered on top of tapered insulation. Often referred to as white roofing for its coloring, EPDM installed in this building was required to have a specific solar reflectance to contribute to LEED certification. The elevator machine room does require a small area of concrete slab-on-deck on the roof (as shown in red in Figure 9); this system is 5” normal weight concrete on 3” deep, 16 gage steel roof deck. The roof deck is supported from below by W16x26 beams spaced at 5’-0” and W27x84 girders every 30’-0”. Some steel roof bridging is required mid-span between girders for additional deflection control.

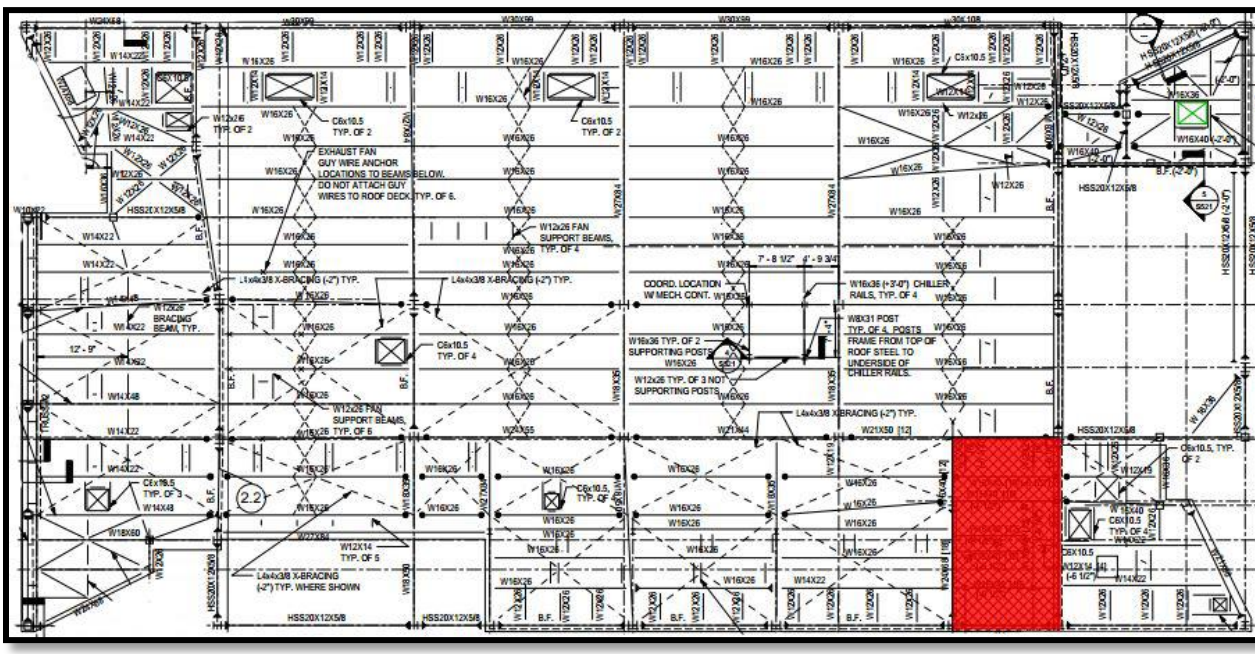


Figure 9 – Roof Framing Plan with Added Concrete Slab-On-Deck Highlighted

Bridge to Main Hospital

One of the most complicated structural elements found in the VCU SOM project is the bridge that connects the 2nd Floor to the existing Main Hospital 1st Floor, crossing E. Marshall Street. Approximately 65 ' in length, the bridge exits the VCU SOM building at an angle and travels on a diagonal towards the Main Hospital, as shown in Figure 10 below.

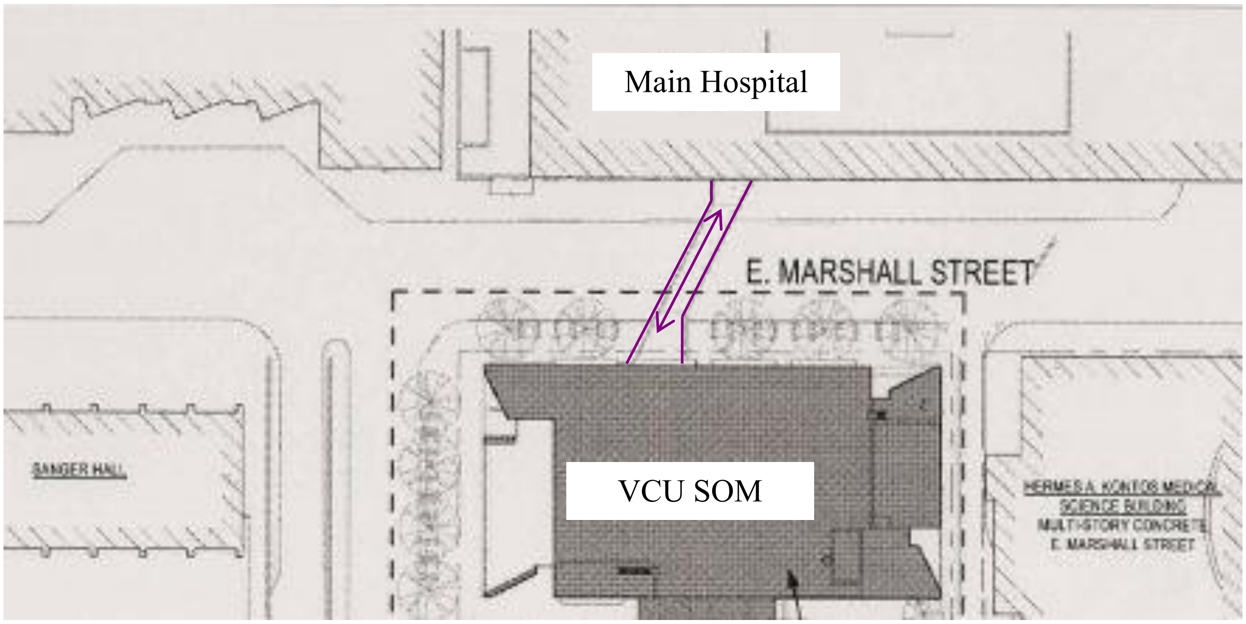


Figure 10 – Bridge Connecting VCU SOM to Main Hospital

The bridge also slopes 2” towards the Main Hospital, starting at an elevation of 169'-2” and ending at an elevation of 169'-0”. The bridge has a height of roughly 14'-6” from the surface of the bridge floor to the bottom of the roof deck (at the intersection with VCU SOM project). An elevation of the bridge connection with the Main Hospital can be seen in Figure 11. The multiple components of the bridge are further described in the sections below. Plan and elevation views of the bridge are available in Appendix C for further inspection.

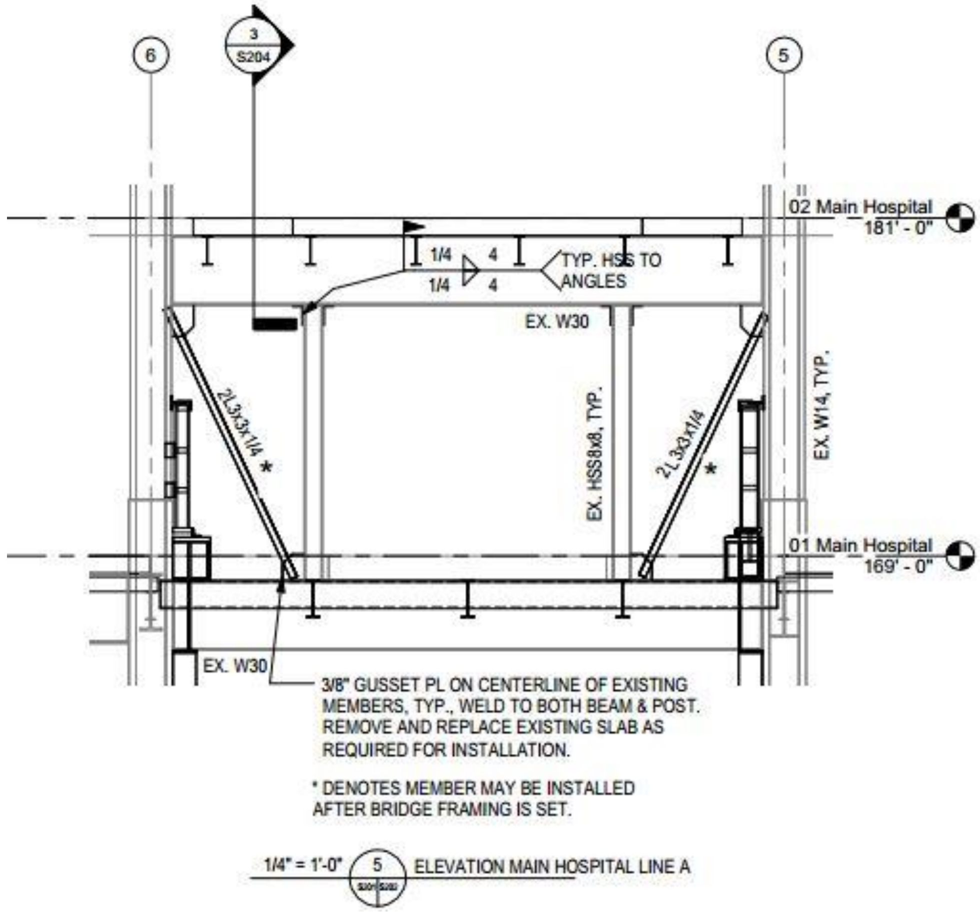


Figure 11 – Elevation of Bridge Connection with Main Hospital

Floor System

The floor of the bridge is slab-on-deck construction – 3" lightweight concrete on 2", 18 gage steel deck with #4@8 o.c. reinforcement continuous throughout the entire length. Due to the addition of the bridge, some slab-on-deck infill was required at the connection to the VCU SOM building. This new slab-on-deck infill is 3" lightweight concrete on 3" deep, 16 gage steel deck with reinforcement typical to the slab on that level. HSS (Hollow Structural Sections) steel members in the floor framing are typically either HSS8x6x5/8 or HSS9x7x5/8 and are oriented with their long direction horizontal.

Framing

Like the floor framing, all of the steel members used are HSS. The vertical components of the framing are HSS8x8x5/8 throughout the length of the bridge, with heftier HSS12x8x5/8 members at the intersections with the VCU SOM building and the Main Hospital. Diagonal bracing across the bridge varies in direction with each bay; these members are HSS8x8x5/8. Additional bracing is applied to existing members at the connection to the Main Hospital to ensure necessary strength is achieved. At about 3'-6" below the bridge roof, bracing

(HSS8x6x5/8) traverses the width of the bridge with eccentrically placed members (HSS6x6x3/8) contributing to additional strength capacity; this detail can be seen in Figure 12.

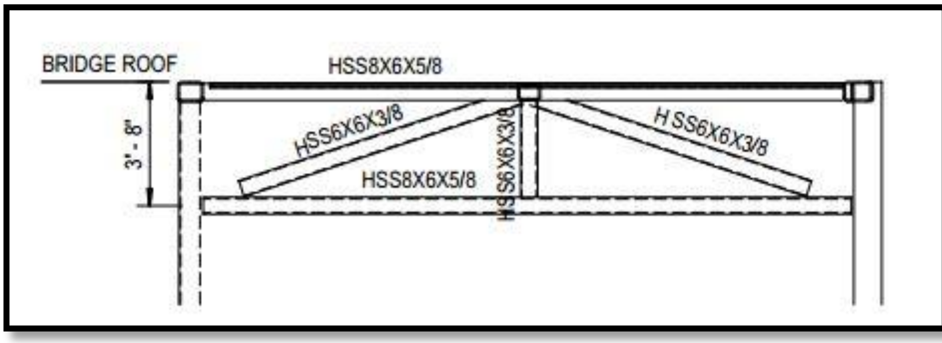


Figure 12 – Bridge Framing Detail at North Elevation

Roof System

The bridge roof framing consists of steel roof deck and HSS steel members. The roof deck is 1 1/2" wide-rib, 18 gage steel decking and spans across the width of the bridge. The steel members used are the same as the floor framing, typically either HSS8x6x5/8 or HSS9x7x5/8.

Design Codes & Loadings

A major factor in the design and construction of the VCU SOM project was the relevant design codes and loadings applied, based on both national and state standards. A comprehensive list of all applicable Codes and the areas of the building affected can be found in Table 2. The loadings used in the design of the structural system originated from American Society of Civil Engineers (ASCE) 7-2005, International Building Code (IBC) 2006, and the 2006 Virginia Uniform Statewide Building Code (USBC) for Restrained Construction. A brief description of typical loads applied during design of the project can be seen in Table 3. ASCE 7 has been identified as the document used for determination of the loadsBeyond the loadings found in Figure 11, no significance was placed on other special loadings due to the nature of the VCU SOM project.

Design Code	Area Affected	Specific Components in Area
International Building Code (IBC), 2006	Entire Project	Minimum Regulations for ALL Building Systems
2006 Virginia Uniform Statewide Building Code (USBC), Restrained Construction	Construction	Design Criteria for all systems, Permits, Inspections, Certificates of Occupancy
American Institute of Steel Construction (AISC), 2005	Structural Steel	Design Criteria for all structural steel, Fabrication, Erection, Shop/Erection Drawings
American Concrete Institute (ACI) 318	Reinforced Concrete	Design Criteria for all structural concrete, Quality, Strength, Inspections
American Society of Civil Engineers (ASCE) 7	Loadings	Live, Dead, Snow, Wind, Seismic

Table 2 – Applicable Design Codes and Affected Areas of the VCU SOM Project

Loading Group	Loads	Description	Source
SNOW	Ground Snow Load, Pg	Historical data of loads experienced by area	ASCE 7
	Flat-Roof Snow Load, Pf	Load applicable to roofs with a slope ≤5°	ASCE 7 Pf=0.7CeCtIPg
	Snow Exposure Factor, Ce	Based on terrain category, exposure by type of area	ASCE 7, Table 7-2
	Thermal Factor, Ct	Factor centered on heating of structure	ASCE 7, Table 7-3
	Snow Load Importance Factor (I)	Factor assigned by nature of occupancy of structure	ASCE 7
WIND	Basic Wind Speed	Contour map of average wind speeds in U.S.	ASCE &, Figure 6-1
	Wind Importance Factor (I)	Similar to Snow Loads, assigned by nature of occupancy of structure	ASCE 7
	Wind Exposure	Determined by mean roof height & ground surface roughness	ASCE 7
	Internal Pressure Coefficient	Based on building enclosure categorizations	ASCE 7
SEISMIC	Occupancy Category	Designation based on building occupancy level & nature of use	ASCE 7
	Seismic Importance Factor (I)	Similar to Snow & Wind, assigned by nature of occupancy of structure	ASCE 7
	Spectral Response Coefficient, Ss	Response of material, by area, to seismic conditions during short periods	ASCE 7
	Spectral Response Coefficient, S1	Response of material, by area, to seismic conditions at a period of 1s	ASCE 7
	Site Class	Based on site soil properties	ASCE 7
	Response Modification Factor	Determined by ductility of the intended structure	ASCE 7
	Seismic Design Category	Based on risk associated with predicted spectral response in area	ASCE 7

Table 3– Structural Design Criteria – Typical Loadings & Their Source for Determination

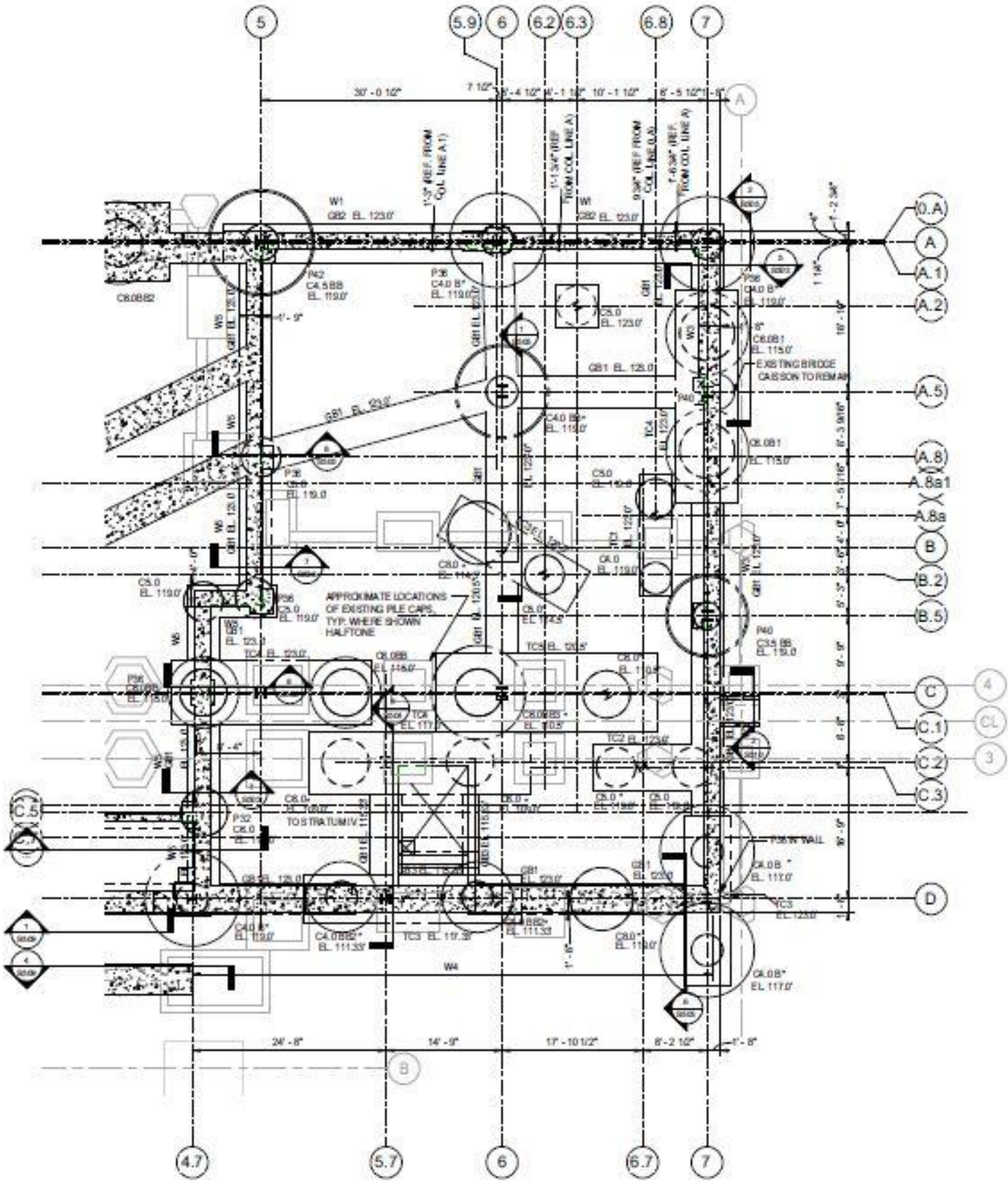
Closing

As mentioned prior to this technical report and demonstrated throughout the text, the James W. & Frances G. McGlothlin Medical Education Center is a complicated structure composed of countless parts that must work in harmony. Starting at the bottom, the site itself posed many issues before construction even started. Not only was the foundation system required to support 13 stories above ground and 2 below, but it also had to account for the existing piers left behind from the demolished A.D. Williams Building. The VCU SOM building itself is an intricate framework, traveling almost 200 feet skyward from street level. The framing and floor systems throughout the building diversify based on the function of the levels, requiring different bay, column, beam, girder, and slab-on-deck sizes and strengths. In addition to the already elaborate structural systems in this building, a bridge exiting the building at the 2nd Level to connect to an existing structure across a main street adds further complexity.

All of these elements, mentioned above and thru the entirety of the report, will most certainly impact future analysis of the structure in subsequent technical reports. However, even though the building may be complex, a thorough understanding of the existing conditions has been reached. With this strong base of knowledge and significant project documentation, analysis of loadings, examination of conditions, and design of alternate methods appears attainable.

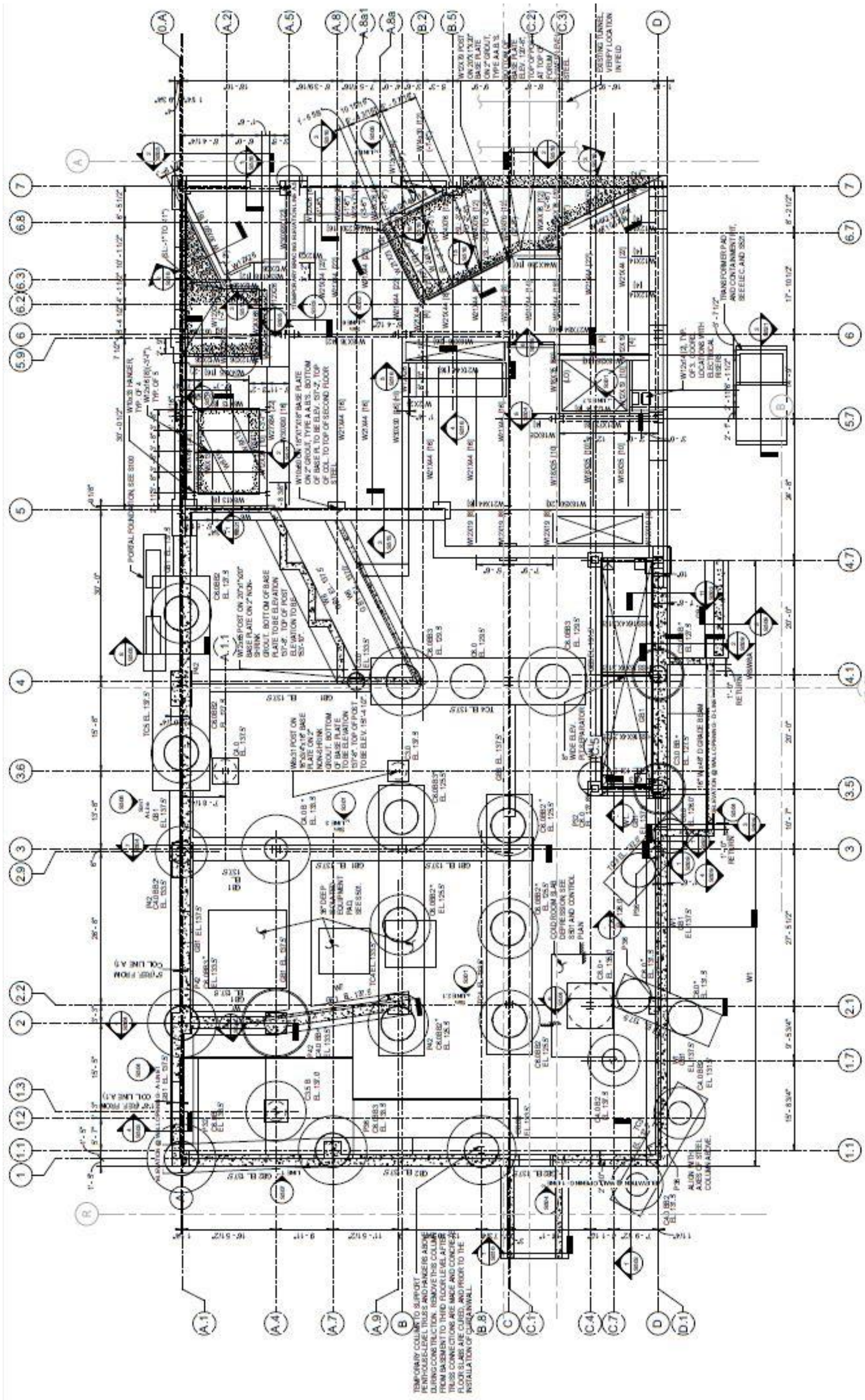
Appendices

Appendix A – Foundation Plans



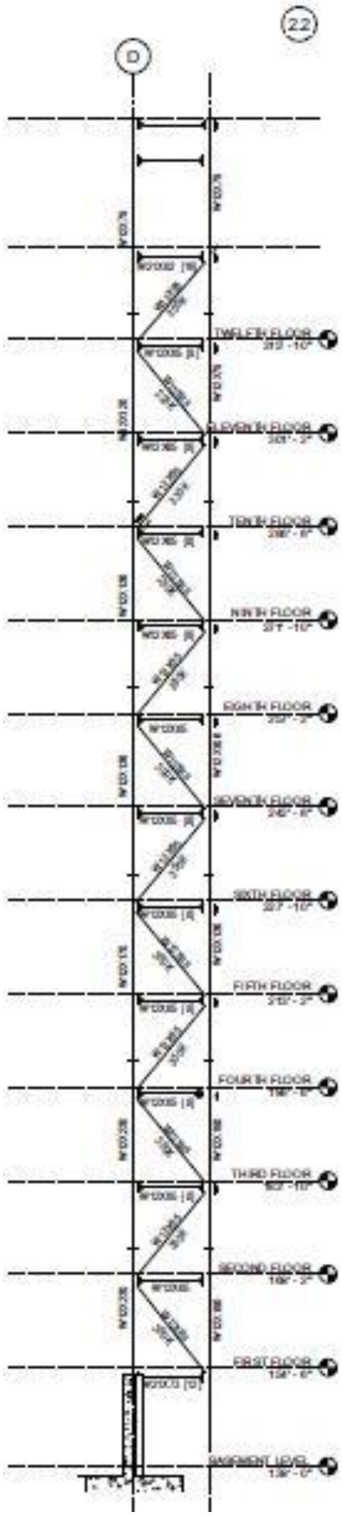
Sub-Basement Floor Plan (S099)

Appendix A – Foundation Plans

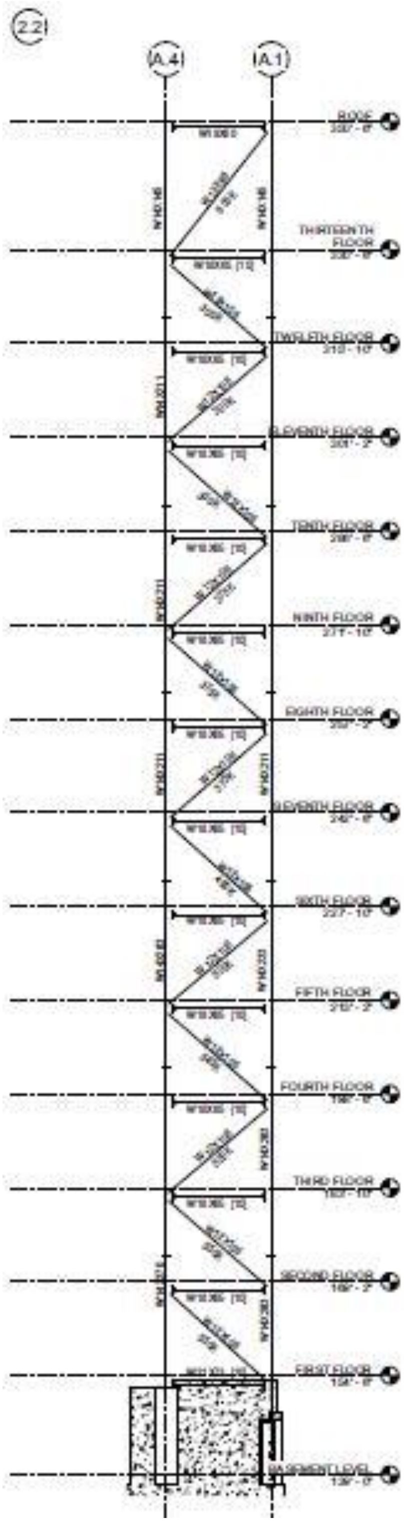


Basement Floor Plan (S100)

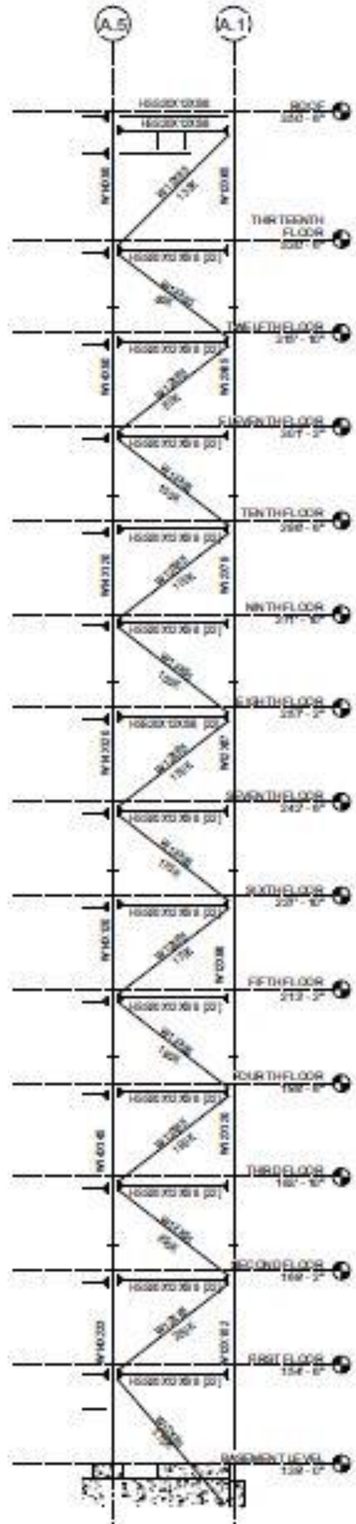
Appendix B – Braced Frame Supplemental Drawings



Braced Frame – Line 2.1

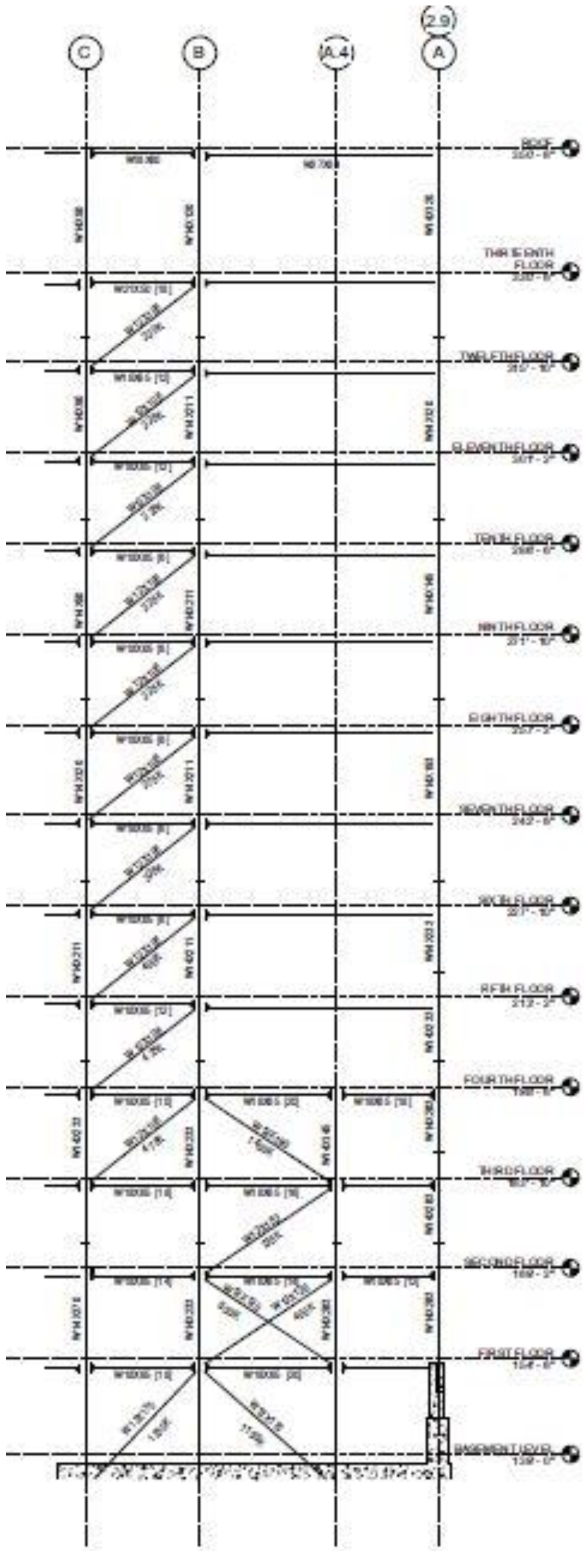


Braced Frame – Line 2

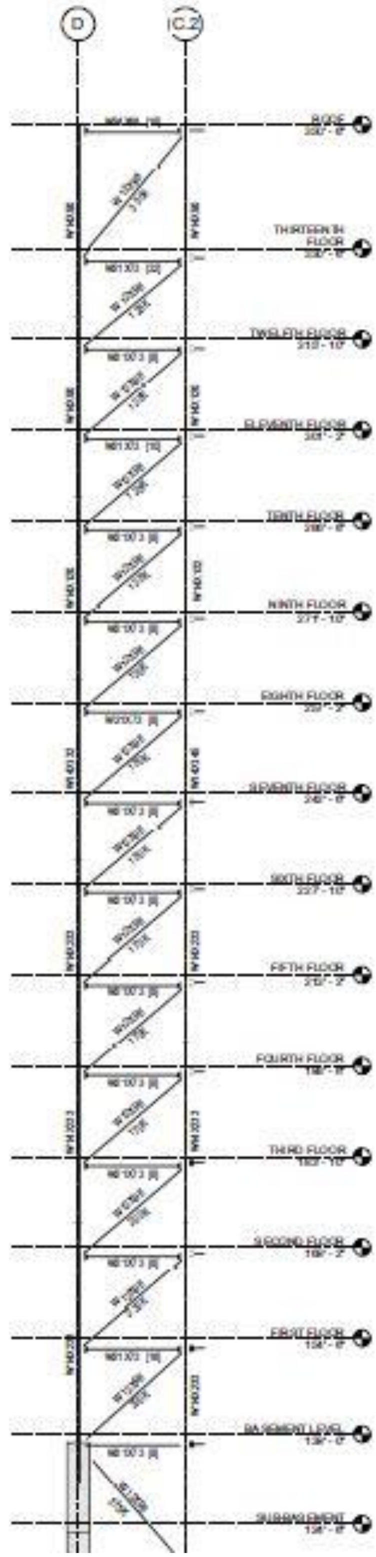


Braced Frame – Line 7

Appendix B – Braced Frame Supplemental Drawings

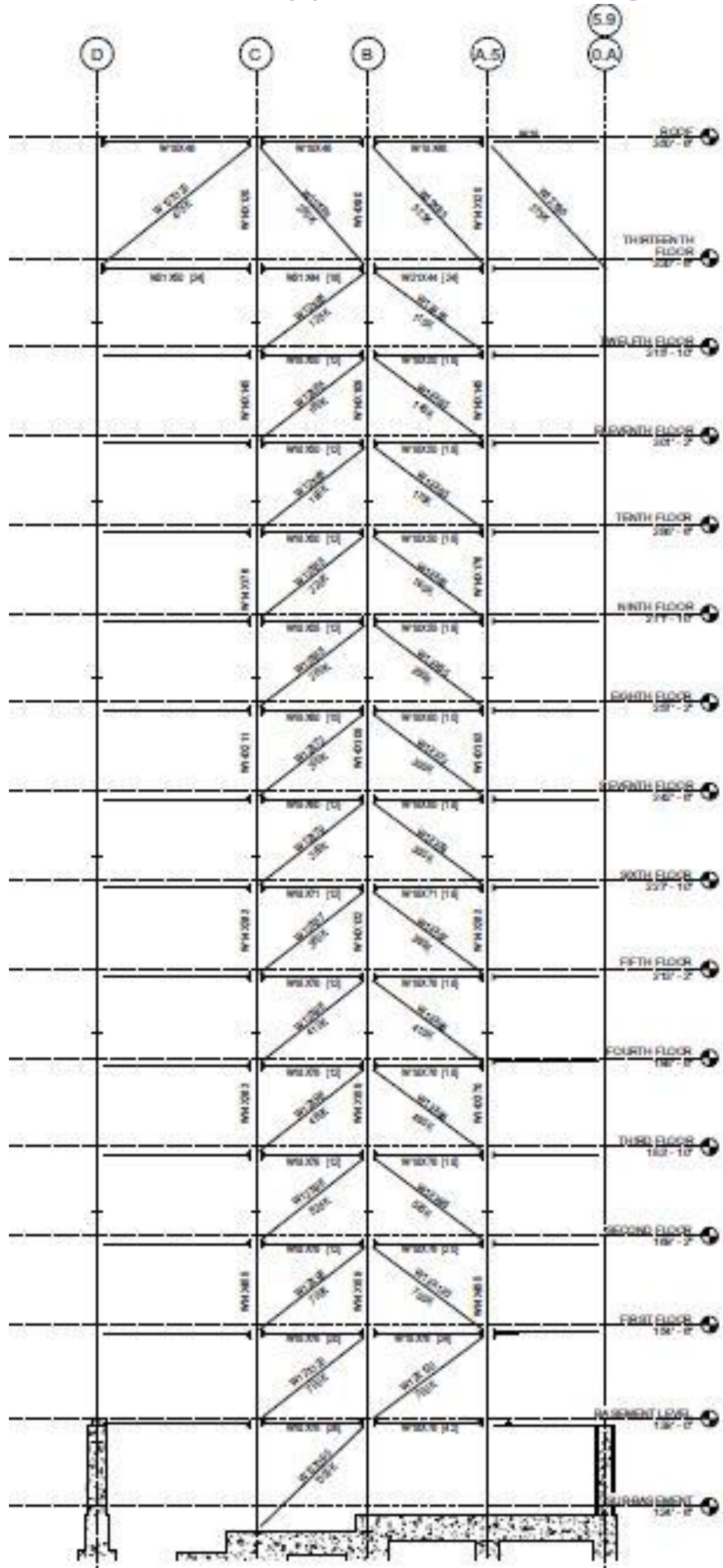


Braced Frame – Line 3



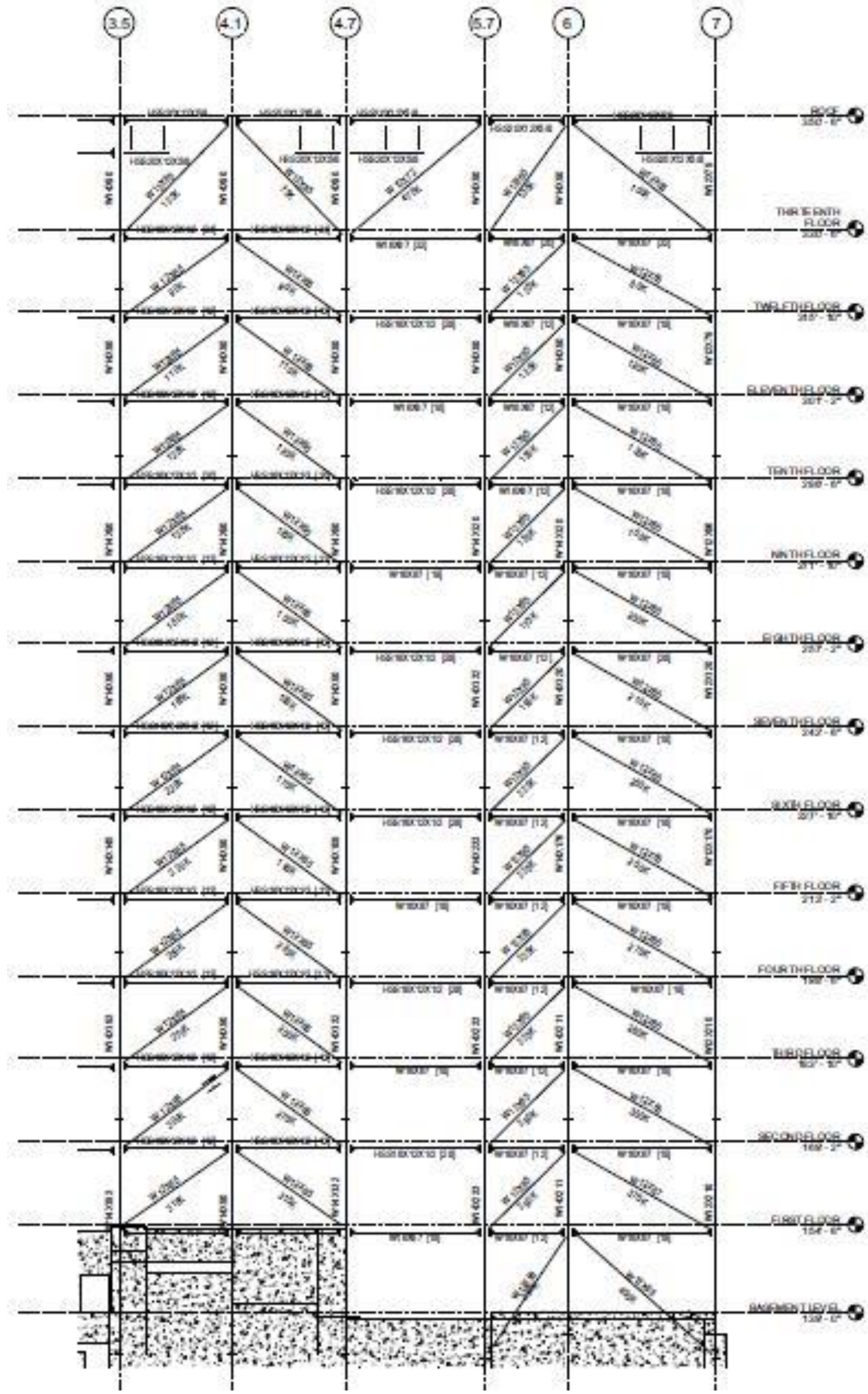
Braced Frame – Line 5.7

Appendix B – Braced Frame Supplemental Drawings



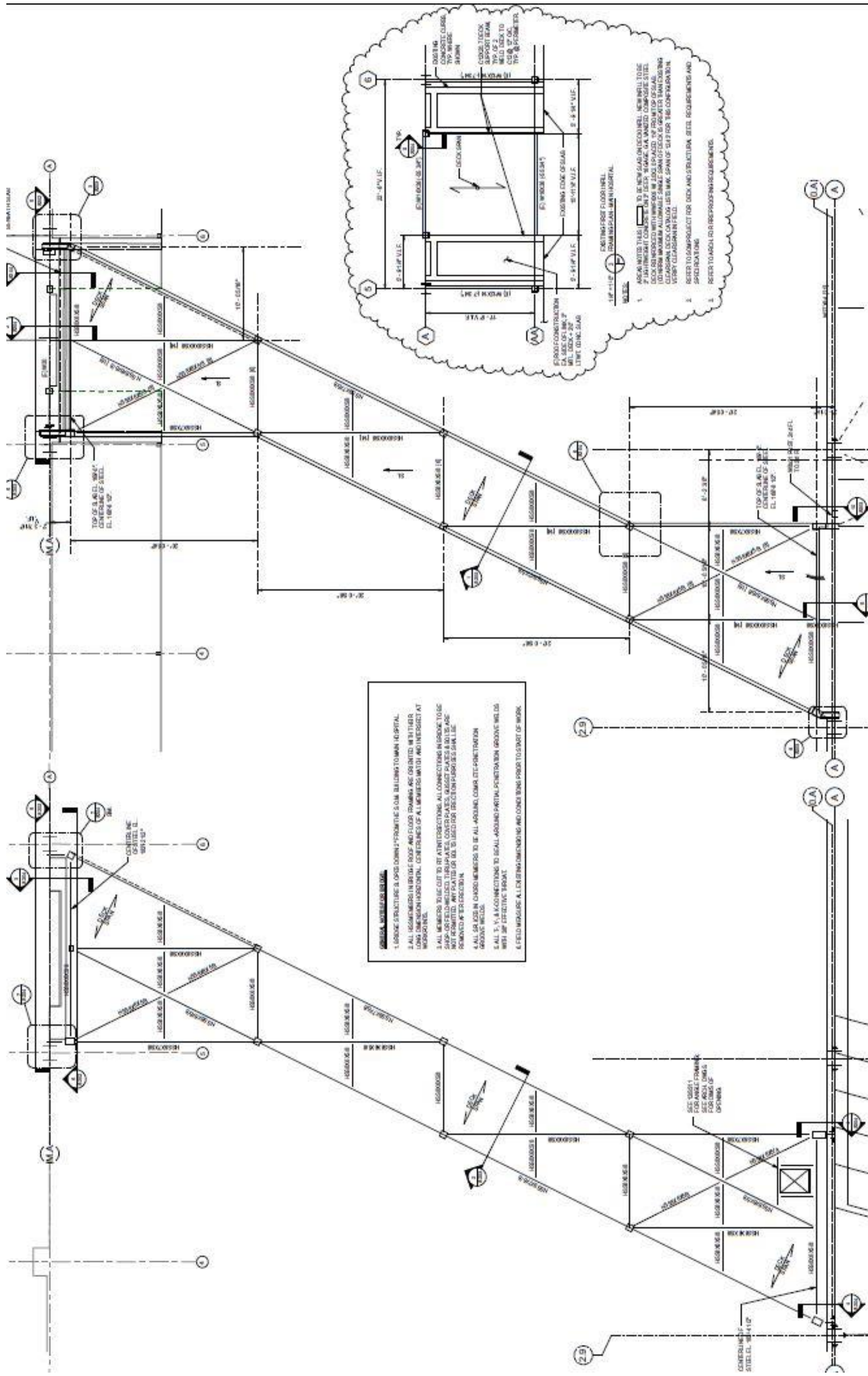
Braced Frame – Line 6

Appendix B – Braced Frame Supplemental Drawings



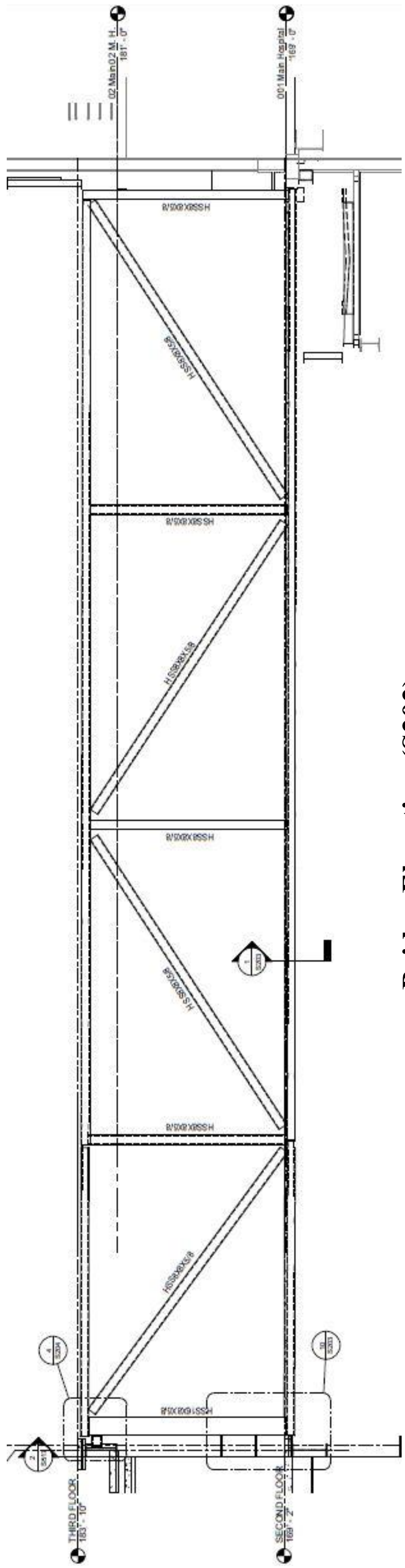
Braced Frame – Line D

Appendix C – Bridge Plans



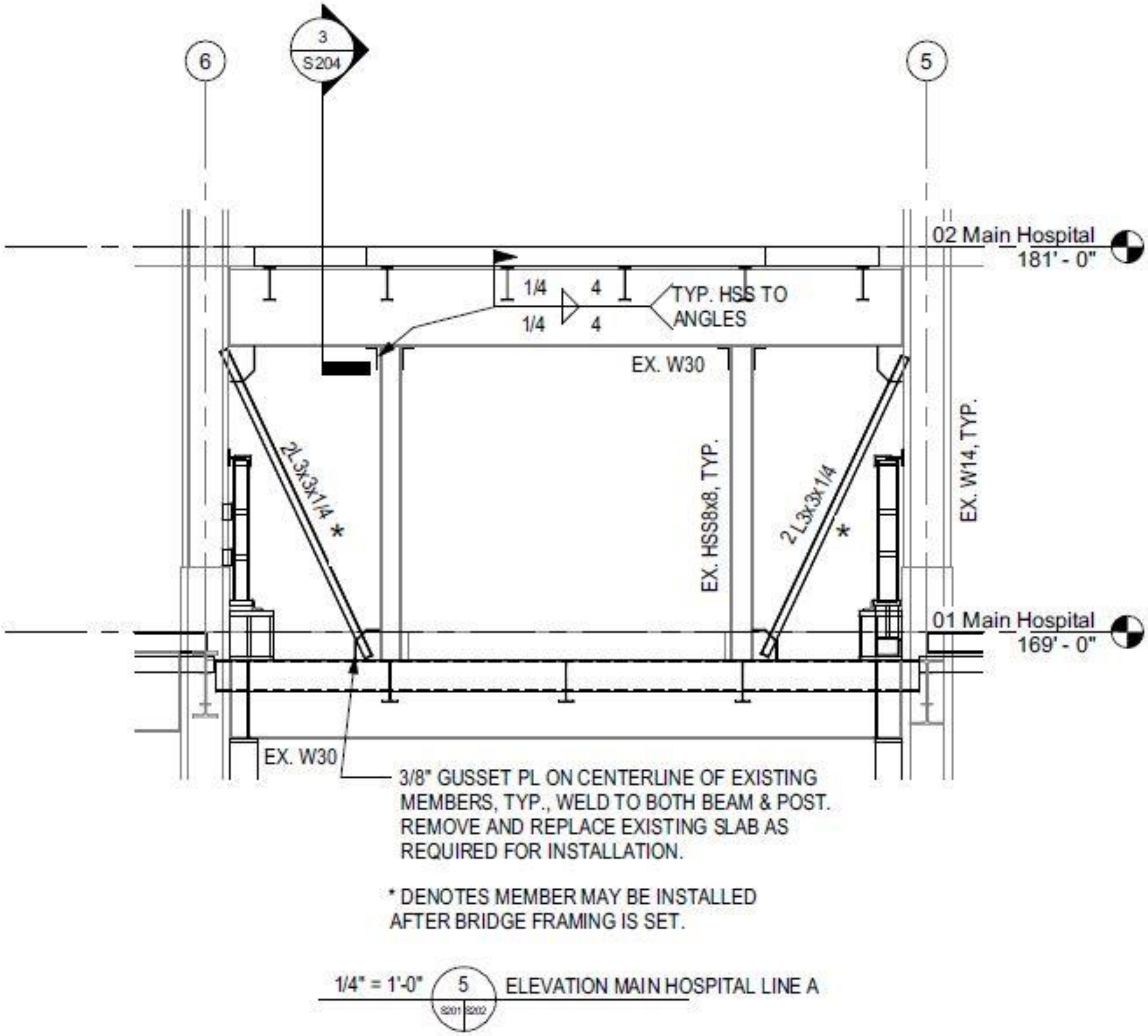
Bridge Plan (S201)

Appendix C – Bridge Plans



Bridge Elevation (S202)

Appendix C – Bridge Plans



Bridge Detailed Elevation at Connection to Main Hospital (S202)