2013 - 2014

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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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Table of Contents

Executive Summary

The following report is a comprehensive proposed thesis that will not only investigate the structural implications of a redesigned gravity system for the James W. & Frances G. McGlothlin Medical Education Center, but will also explore the impacts made on architectural plans and construction management with said redesign. 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 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. The VCU SOM (School of Medicine) had a vision for both this new building and its reinvented curriculum: open, honest collaboration.

To answer all building functions and program requirements, a rational design alternative of a non-composite system with bar joists and steel girders will be explored in the spring semester of 2014. All gravity members will be redesigned using both hand calculations and computer modeling, while lateral force resisting members will remain the same. The redesigned gravity system will then be properly vetted to determine if it is an economical solution.

The redesigned gravity system will have impacts on numerous systems throughout the project; two of these impacts deemed significant will also be explored during the spring semester. First, the redesign to the gravity system will greatly affect the architectural plans and "flow" on each floor. The change in steel horizontal framing members will allow for increased bay sizes, providing an opportunity for a more open concept layout. Each floor's layout will be reevaluated and altered to ensure that VCU SOM's vision of collaboration will be achieved.

The second breadth will focus on increases/decreases to both the cost and the schedule for the VCU SOM project. A detailed cost analysis will be completed for the new system and compared to the original. Even though both systems, the original and the redesign, are composed of steel, the possibility exists that the schedule could be reduced with the new system. Results from both analyses will be compared with the original system to evaluate which steel gravity system is more economical.

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 explained below.

Foundation System

All site investigation and tests drillings, six borings total, were completed by Geotech Inc.; their professional recommendations were then reported in April of 2009. Of the four schemes suggested, an arrangement using three differently sized piers extending 54' below the sub-basement level was applied. The different drilled piers used were intended to account for three variations of loadings: those loads considered "small" (≤ 450 kips), "medium" (730 to 1640 kips), and "heavy" (1640 up to roughly 3300 kips). To support all "small" loads, straight shaft drilled piers ranging in diameter from 3' to 8' were used. When loads were considered "medium", single-belled drilled piers with shaft diameters from 3' to 6' were used, under the condition that the bell diameters were not to exceed 3 times the shaft diameters. For all "heavy" loads, double-belled drilled piers were utilized, with shaft diameters between 3' and 6' and bell diameters between 9' and 13.5'.

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 existing piers, a caisson and grade beam system was used where conflicts existed. 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 – 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.

Floor System

The typical slab-on-deck found on floors 2 through 12 is a composite concrete/steel system. Most floors utilize 3", 20 gauge composite galvanized steel decking with a 3 ½" lightweight concrete topping. ½" diameter steel rebars placed at 12" on center provide reinforcement for the concrete. Shear studs, placed along the beams and girders, provide for composite behavior between the members and floor system.

Framing System

The VCU SOM framing system is composed of steel members: columns, beams, and girders.

Since a variety of loads are applied, 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.

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. There are two bay sizes that make up the majority of these floors: a 30’x20’ bay and a 30’x40’ bay. A typical floor plan showing the 30’x20’ size bay can be seen in Figure 2 below. To allow for open classroom space on several floors, the 30’x40’ bay is necessary, explaining the variant bay sizes.

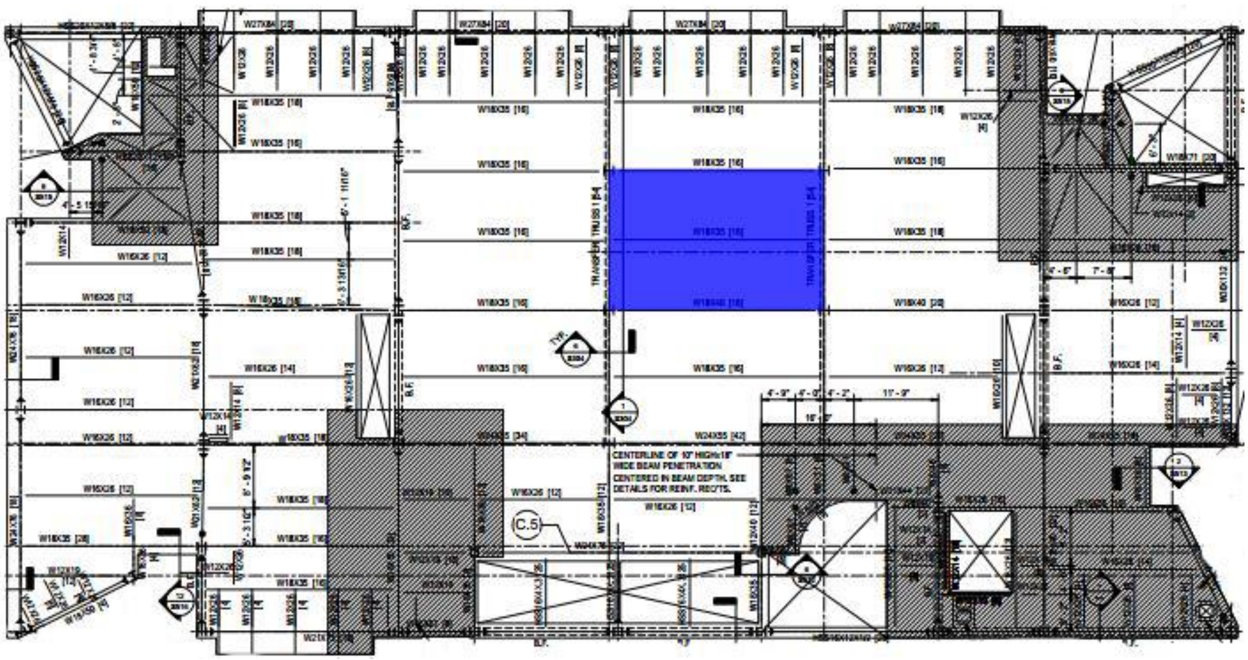


Figure 2 – Typical Floor Plan with Smaller Bay Size Emphasized

Lateral Force 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 3. 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 A. A basic description of the applied lateral loads can be found below.

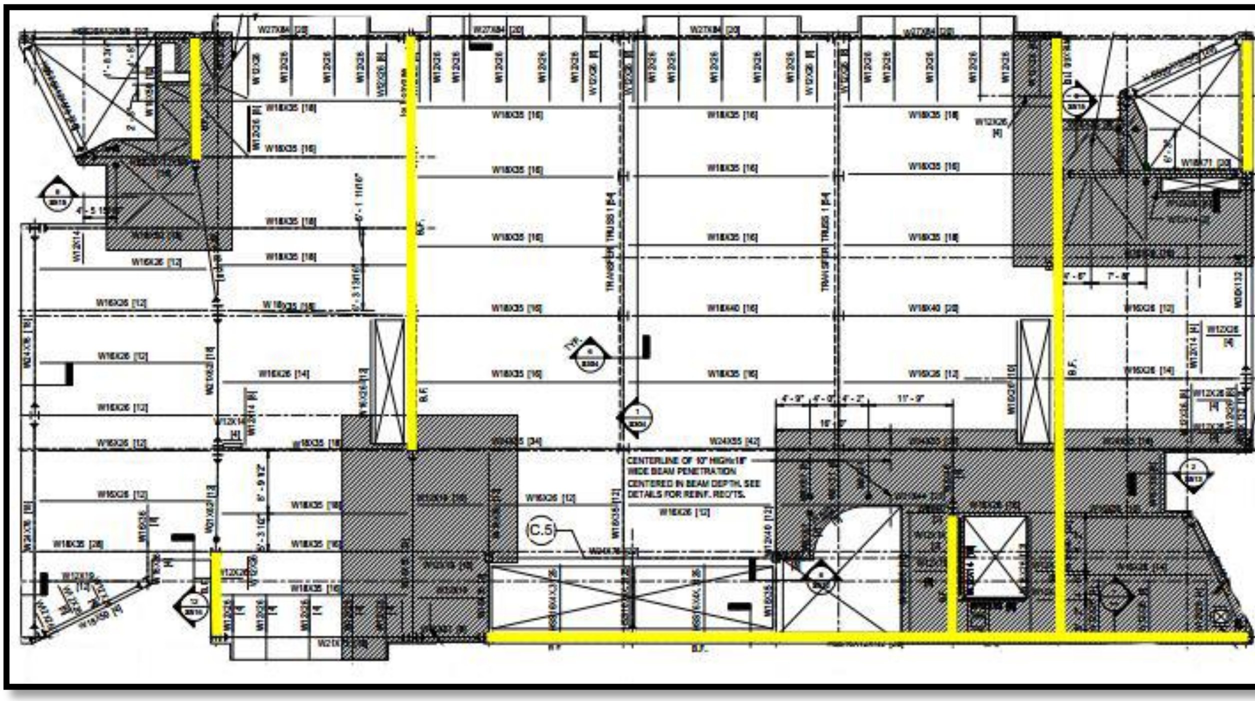


Figure 3 – Framing Typical to Floors 4th thru 12th with Braced Frames Highlighted

As seen in Figure 3, 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 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.

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 4 below. 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).

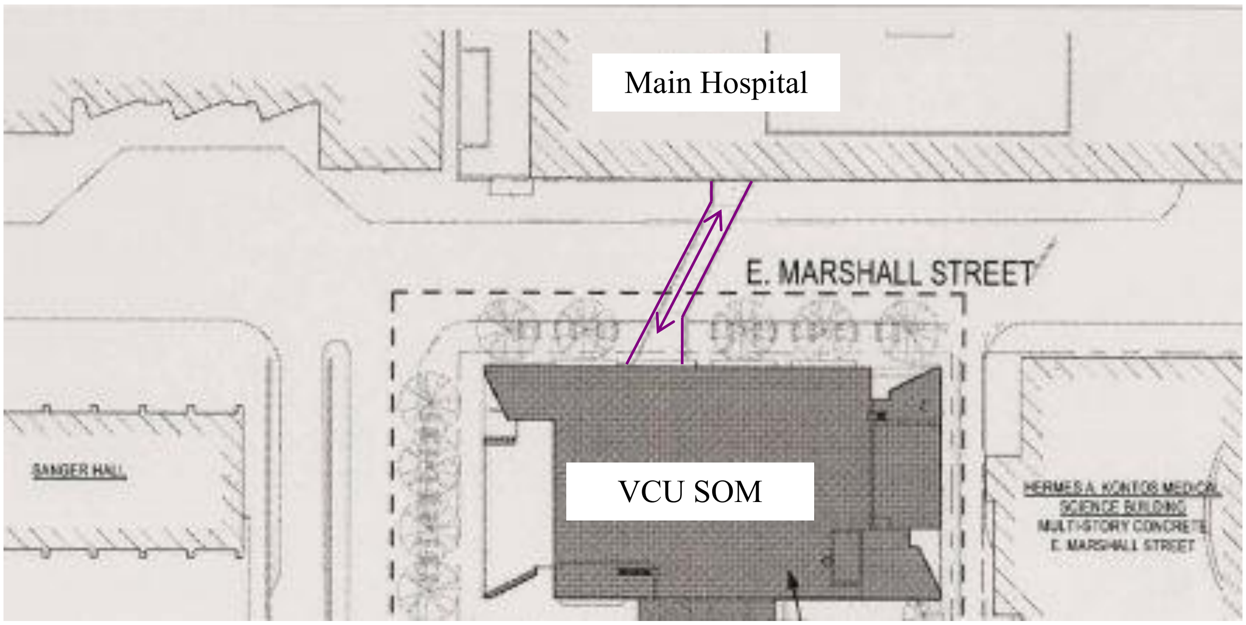


Figure 4 – Bridge Connecting VCU SOM to Main Hospital

Structural Design Alternative

Problem Statement

As mentioned in the Structural System Overview, the VCU SOM building is composed of steel structural members, a composite concrete/steel floor system, and steel concentrically braced frames. While investigating alternate systems in Structural Technical Report III, it was determined that steel was the most economical option for the gravity system. Steel is moderately easy to construct, reasonably priced, and lightweight. While a composite deck and beam/girder system is used in the project, the possibility exists that using alternative steel systems could help reduce costs, decrease the schedule, and allow for larger spans and bay sizes.

The Virginia Commonwealth University School of Medicine also underwent a curriculum redesign in conjunction with construction of the project. The new program focuses on collaboration – open learning environments, multidisciplinary studies, and hand-on experiences. The current structural system allows for some open spaces, but the opportunity is available to increase bay sizes to ensure students and faculty are able to use floor layouts to their full potential.

Proposed Solution

In order to achieve the most efficient gravity system possible, an alternative steel system will be designed and compared to the original. From Structural Technical Report III, it was determined that a gravity system consisting of non-composite decking with K-series bar joists and steel girders could be feasible. Not only does this system have the potential for a decreased schedule, the added strength from the joists in the system also allows for increased spans throughout the floors. The lateral load resisting system will not be significantly altered, and therefore will remain steel concentrically braced frames that travel through the entire height of the structure.

Solution Method

The redesign of the steel gravity system will be completed with the assistance of the AISC Steel Construction Manual 14th Edition, Vulcraft Steel Roof and Floor Deck Catalog, and Catalog of Standard Specifications and Load and Weight Tables for Steel Joists and Joist Girders. Non-composite flooring, steel floor framing members, and columns will be designed by hand. Once typical trial member sizes are found, a model will be created in the computer program RAM. The computer model and known gravity loadings will then be used to analyze the validity of the redesigned system.

Breadth Topic 1 – Architectural Considerations

As mentioned in the Problem Statement found above, the VCU School of Medicine altered its curriculum in hopes of producing well-rounded leaders in the medical field capable of cooperation. The VCU SOM project was intended to create an environment conducive to this curriculum – open floor plans that provide spaces for team meetings, faculty consultations, and large group classes. The original design achieved this open layout on only a couple floors, with most floors having smaller bay sizes. With the redesign of the gravity system, K-series joists could easily span 40', allowing for a larger bay size to be utilized throughout the floors. The larger bay sizes will have significant impact on the layouts for each floor. Each floor's layout will be reevaluated and altered to ensure that VCU SOM's vision of collaboration will be achieved. Other architectural implications (impact of altered wall configurations, increased ceiling height, possibility of open ceilings with exposed steel, acoustical impacts) caused by redesigned gravity system will also be investigated to ensure the integrity of the original design is not compromised.

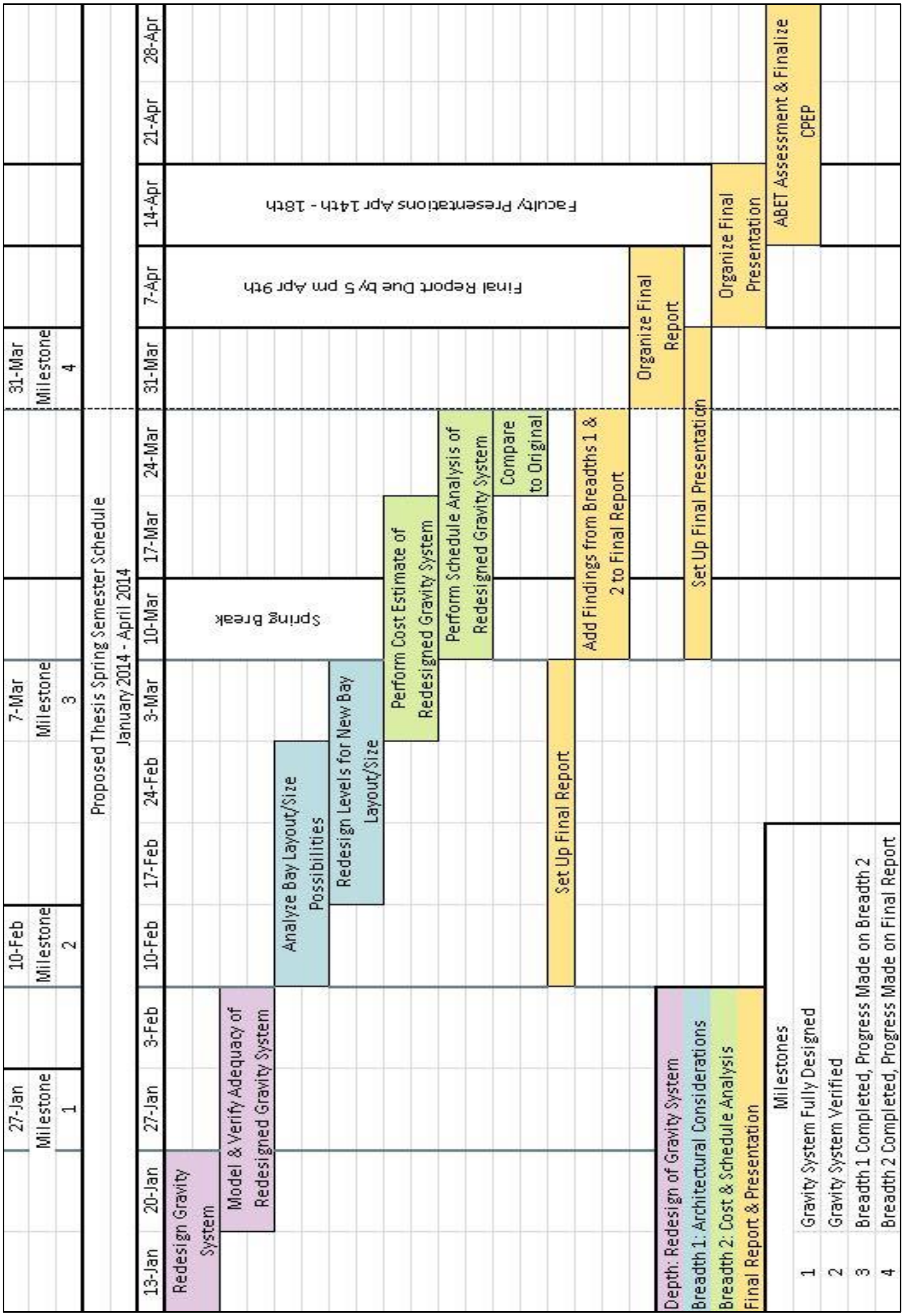
Breadth Topic 2 – Cost & Schedule Analysis

While the redesigned structure will remain steel construction, both the cost and schedule could be greatly affected by the change to non-composite decking and K-series bar joists. An in-depth cost analysis will be completed for the new system – this cost will then be compared with the original system to see which is more economical. A comprehensive schedule analysis will also be completed since lead times and installation will vary from the original system. The schedule and feasibility of erecting the redesigned structure will then be compared with the original design. Considering both cost and schedule, the two systems will be evaluated to find which is ultimately more economical.

Tasks

1) Redesign Gravity System
    a) Design non-composite flooring
    b) Design horizontal steel framing members (K-series joists & girders)
    c) Design vertical steel framing members (columns)
    d) Model redesigned gravity system in RAM
    e) Verify adequacy of redesigned gravity system (both computer & hand calculations)
2) Research Architectural Possibilities due to Redesign
    a) Adjust horizontal members to achieve larger bay sizes on all floors
    b) Adjust, as necessary, vertical steel framing members to accommodate larger bay sizes
    c) Verify adequacy of members using RAM model
    d) Restructure floor plan layouts for larger bay sizes
    e) Explore additional implications from increased bay size
3) Perform Cost & Schedule Analysis
    a) Using RSMeans, complete detailed cost analysis of redesigned gravity system
    b) Compare cost with original system
    c) Alter schedule to reflect redesigned gravity system
    d) Compare schedule with original system
4) Final Report & Presentation
    a) Set up final report
    b) Set up final presentation
    c) Add to final report & presentation as progress is made
    d) Finalize final report & submit
    e) Finalize final presentation & practice
    f) Present findings for evaluation

Schedule

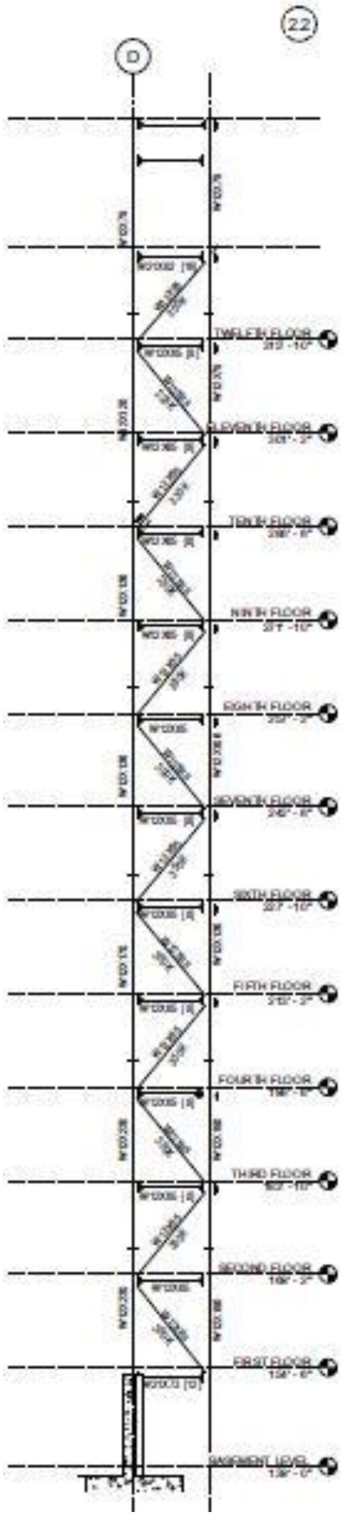

Proposed Thesis Spring Semester Schedule
January 2014 - April 2014
27-Jan Milestone 1
10-Feb Milestone 2
7-Mar Milestone 3
31-Mar Milestone 4
13-Jan
20-Jan
27-Jan
3-Feb
10-Feb
17-Feb
24-Feb
3-Mar
10-Mar
17-Mar
24-Mar
31-Mar
7-Apr
14-Apr
21-Apr
28-Apr
Redesign Gravity System
Model & Verify Adequacy of Redesigned Gravity System
Analyze Bay Layout/Size Possibilities
Redesign Levels for New Bay Layout/Size
Perform Cost Estimate of Redesigned Gravity System
Perform Schedule Analysis of Redesigned Gravity System
Compare to Original
Set Up Final Report
Add Findings from Breadths 1 & 2 to Final Report
Organize Final Report
Set Up Final Presentation
Organize Final Presentation
ABET Assessment & Finalize CPEP
Spring Break
Final Report Due by 5 pm Apr 9th
Faculty Presentations Apr 14th - 18th
Depth: Redesign of Gravity System
Breadth 1: Architectural Considerations
Breadth 2: Cost & Schedule Analysis
Final Report & Presentation
Milestones
1 Gravity System Fully Designed
2 Gravity System Verified
3 Breadth 1 Completed, Progress Made on Breadth 2
4 Breadth 2 Completed, Progress Made on Final Report

Closing

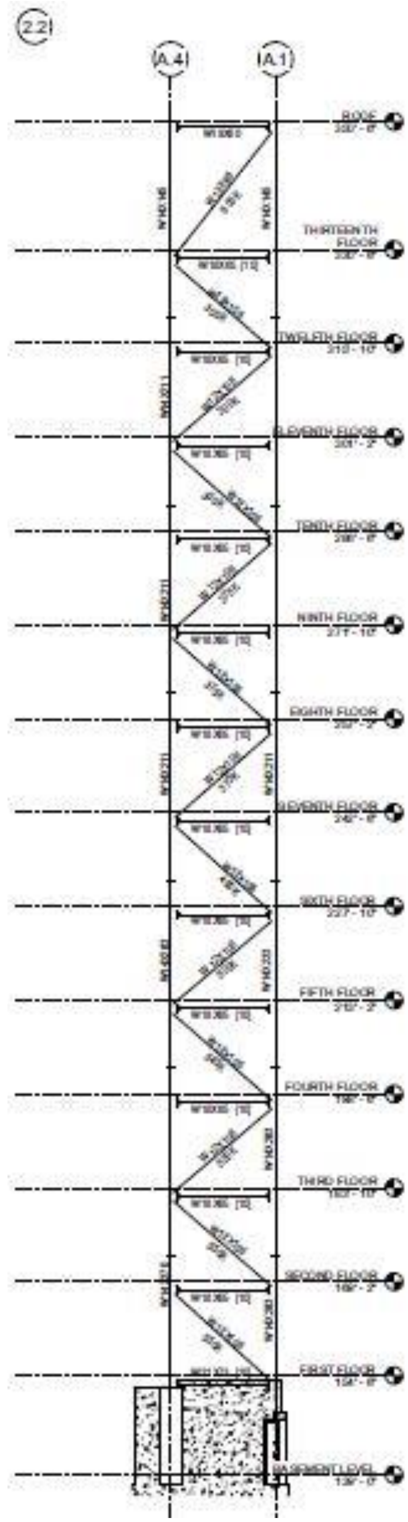
As mentioned prior to this report and demonstrated throughout the text, a rational alternative exists for the gravity system found in the James W. & Frances G. McGlothlin Medical Education Center. While the original composite steel/concrete system meets all requirements, a non-composite system with bar joists and steel girders could provide additional strength along with a reduction to the project's duration. To prove the validity of this redesign, both hand calculations and computer modeling will be completed during the spring semester.

The changes to the gravity system will not only affect the structure of the building – there will also be significant impacts on the floor layout, cost, and schedule for the VCU SOM project. The first breadth of this proposed thesis will explore the architectural impacts caused by the redesign. New floor plans and flow of the layouts will be evaluated to ensure VCU SOM's mission of collaboration is achieved. The second breath will focus on the cost and schedule for the redesigned gravity system. Both areas will be analyzed in-depth and compared to the original system – this comparison will also serve to validate if the redesign is the more economical option.

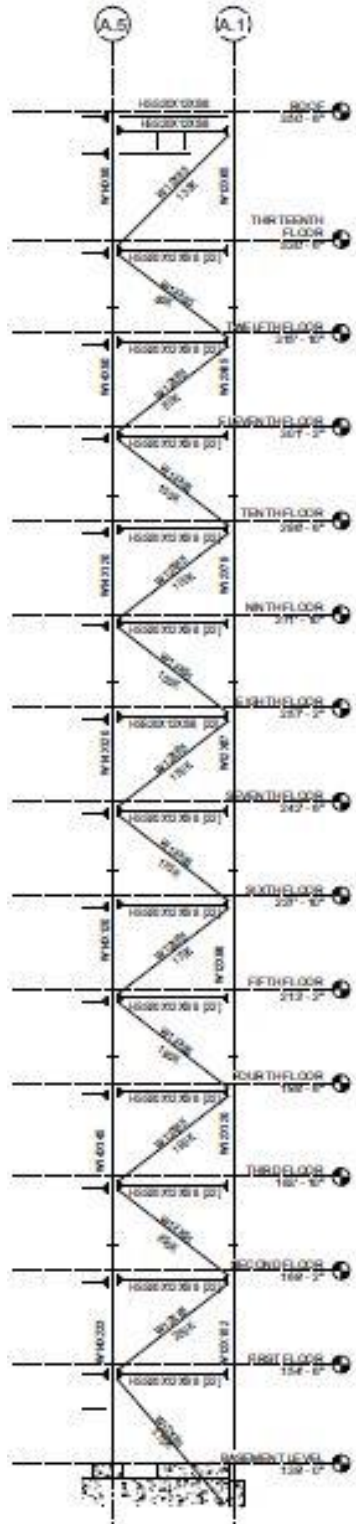
Appendix A – Braced Frame Supplemental Drawings



Braced Frame – Line 2.1

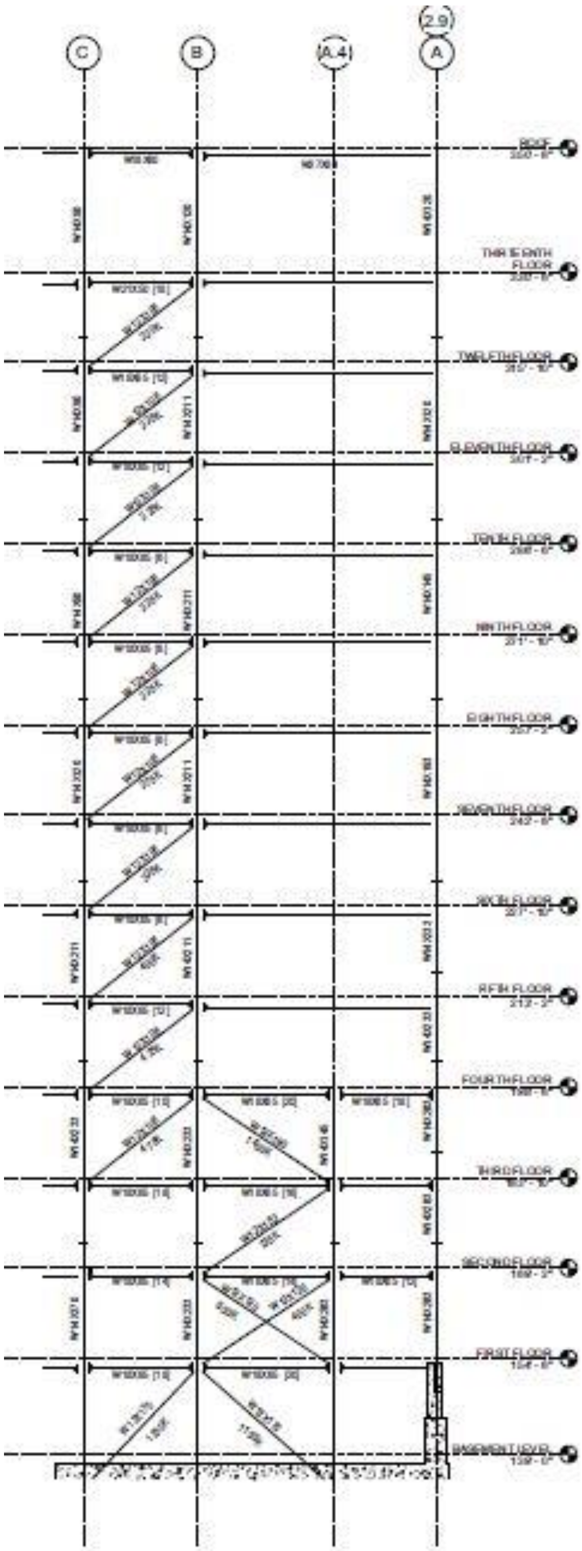


Braced Frame – Line 2

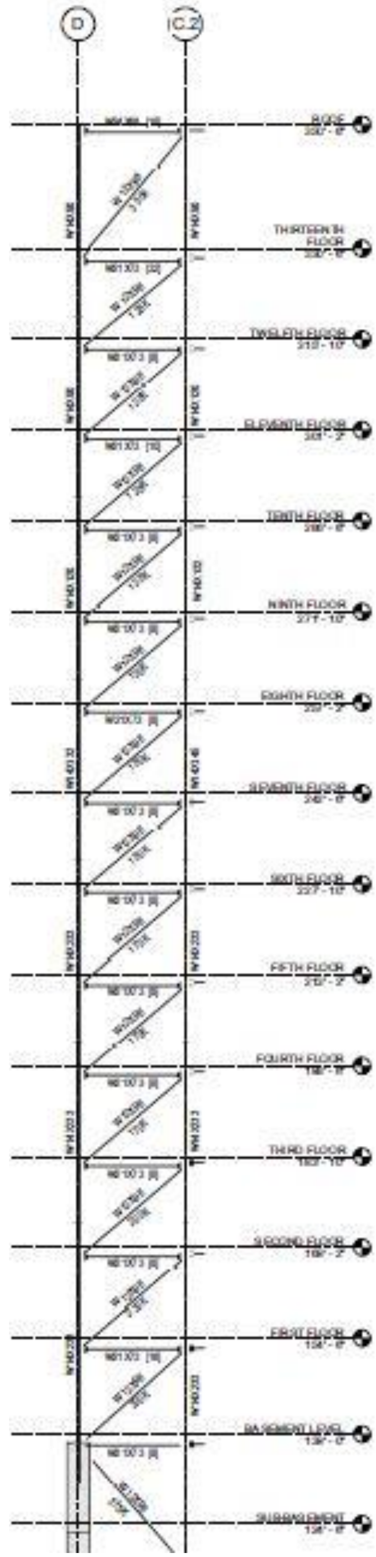


Braced Frame – Line 7

Appendix A – Braced Frame Supplemental Drawings

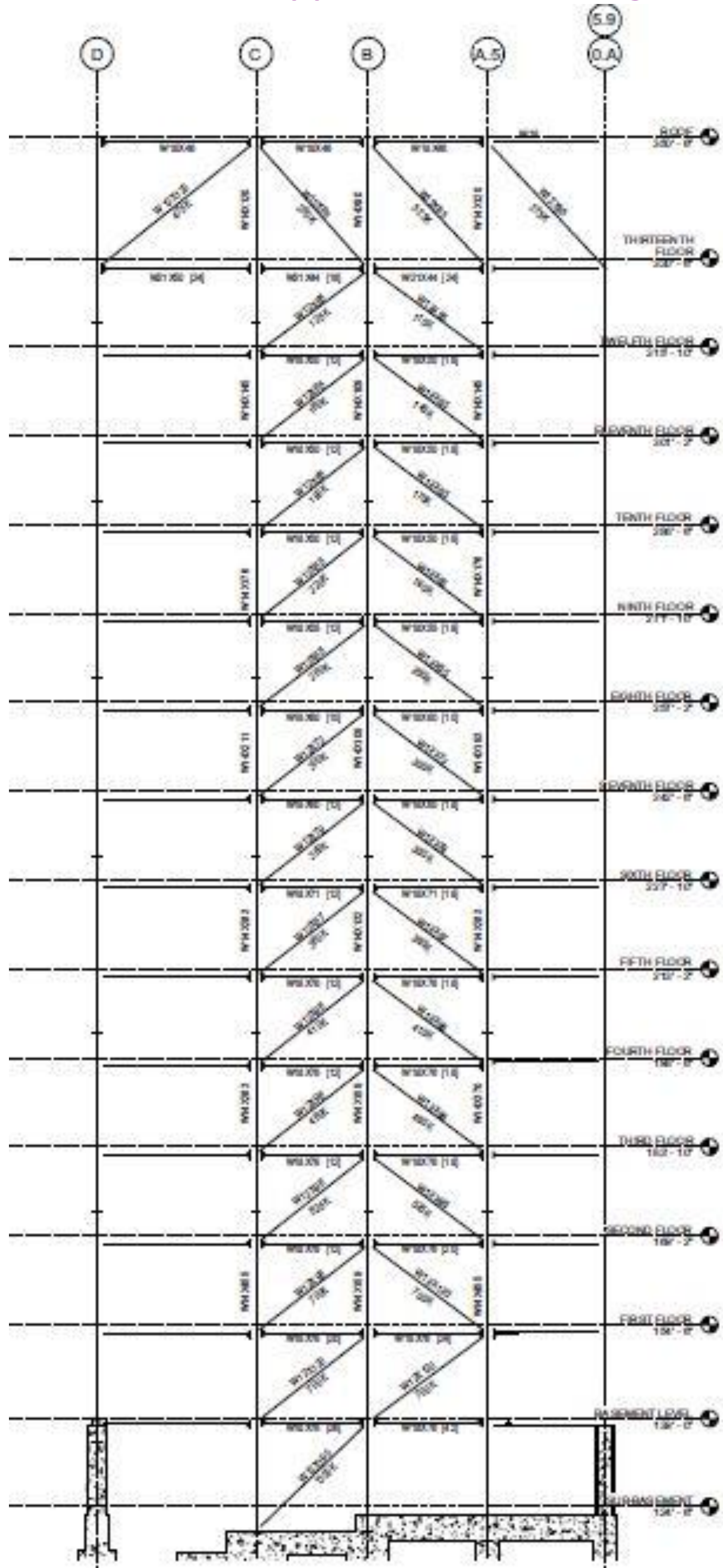


Braced Frame – Line 3



Braced Frame – Line 5.7

Appendix A – Braced Frame Supplemental Drawings



Braced Frame – Line 6

Appendix A – Braced Frame Supplemental Drawings

Braced Frame – Line D
(S202)