The Commonwealth Medical College

Scranton, PA

Thesis Proposal

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Structural Option

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Executive Summary

The Commonwealth Medical College, TCMC, is a four story building located in Scranton, PA. It was completed in April 2011. The structure of TCMC is composed of a composite steel system and utilizes moment frames for the lateral system.

TCMC was not designed to resist heavy wind and weather loads. Therefore, if a powerful storm were to hit the Scranton area, heavy structural damage will occur to TCMC. Because of this, this structural depth proposal is to investigate the increase in wind and weather loads in a design process by theoretically relocating TCMC to Miami, FL, a hurricane prone region. Higher design wind loads, from hurricane winds, and impact from debris will be considered.

The codes that will be used to design TCMC in Miami are the Florida Building Code 2010, and ASCE 7-10. Two main systems will be designed and compared in this proposal; moment frames and laterally braced frames. Moment frames are the original system for TCMC. It will be designed to withstand a larger wind load since it is now in Miami. This frame will be compared to a lateral braced frame system, which is the second system proposed. Both systems will stay with the original gravity system of structural steel. A new foundation will be designed to account for the different soil condition in Miami Florida. Also, the foundations for the two proposed system will be different due to the different lateral systems. The intent of the new designs is to show the difference in the amount of structural impact and cost between the new one and the original one.

In addition to the structural depth proposal, three breadths are also proposed. The first breadth is on façade design, concentrating on impact resistance due to debris in a storm. In addition, with a different climate, the proposed façade design will incorporate heat transfer as well as waterproofing considerations.

The second breath is on solar panel design. It is easy to see the great opportunities for solar energy in Florida, so a new photovoltaic system will be very beneficial. TCMC can use the readily available abundant amounts of solar energy and convert it to electricity that can be used. This will make TCMC more energy efficient and will potentially increase its LEED rating.

And the last breath is on MEP changes. The weather conditions in Miami are very different compared to Scranton. Because of this, the mechanical systems need to be analyzed. Most heating units will be replaced by cooling units for the warmer climate. The addition of solar panels will impact electrical wiring. The electrical system will be wired so that it can use electricity more efficiently. Lastly, a more powerful emergency backup power will be needed in case of a powerful storm.

MAE coursework will be incorporated into the new design of TCMC. This includes building modeling techniques and many other graduate courses. Tasks and schedule are set forth in this proposal and will be presented in later sections.

Building Introduction

The Commonwealth Medical College (TCMC), also known as The Medical Sciences Building (MSB), is a medical school located in the heart of Scranton, PA. Costing over $120 million, this four story building, with an additional penthouse on the roof, was completed in April, 2011. The architecture was intended to complement the existing schools and hospitals in the surrounding area. Shown in Figure 1 is the building footprint of TCMC, highlighted in yellow, and the surrounding site.

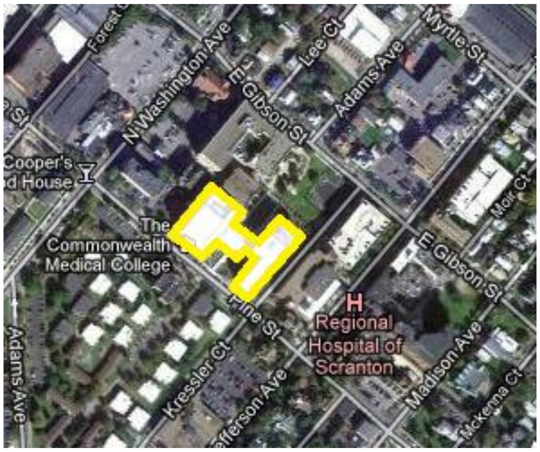


Figure 1 Aerial map from Google.com showing the location of the building site

TCMC is clad in brick, stone, and glass curtain wall. The building is separated into two individual wings, west wing and east wing. The link is the lobby area that connects the two wings and it is clad largely in insulated glass units to let natural sunlight in. An additional feature is the tower which is also clad largely in glass, as shown in Figure 2. The tower, located in the East wing, is considered the main focal point of the building. The interior space of the tower is mainly corridors and small meeting rooms so the students can enjoy the view.

Figure 2 Picture of the exterior showing the glass and brick facade on the TCMC. The Tower is shown, made will all glass walls. http://www.hok.com

TCMC is a multi-use building, using all modern technology. It has a library where students go for information, Clinical Skills and Simulation Center where students learn from beyond classrooms, lecture halls that can seat up to 160 students, classrooms with Wi-Fi connections, small group meeting rooms where a team of students can work together, and a luxurious student lounge for study or relaxation. Figure 3 shows the interior lobby of TCMC. TCMC also has a garden around the link that allows the occupants to enjoy the nice green views that the city cannot offer. The building is 93 feet tall, 185,000 square feet of space, and is a composite steel framed building that utilizes moment frames for its lateral system.

Figure 3 Interior picture of the TCMC lobby. http://www.hok.com

Structural Overview

Design Codes

According to Sheet LS100, the building was designed to comply with:

Building Code	2006 International Building Code (IBC)
Mechanical	2006 International Mechanical Code
Electrical	2005 NFPA 70/ Nation Electrical Code
Plumbing	2006 International Plumbing Code
	2006 International Fuel Gas Code
Fire Protection	2006 International fire Code

All concrete work conforms to the requirements of the American Concrete Institute ACI-318-05.

Additional Code Reference from American Concrete Institute:

- ACI-211
- ACI-301
- ACI-302
- ACI-304
- ACI-305
- ACI-306
- ACI-315
- ACI-347

Regulatory Guidelines and Standards

Accessibility	ICC/ANSI A117.1 1998

Material Properties

Concrete		
Usage	Weight	Strength (psi)
MAT Slab	Normal	4000psi
Columns	Normal	4000psi
Slab on Grade	Normal	3000psi
Caisson	Normal	4000psi
Wall	Normal	4000psi
Grade Beam	Normal	4000psi
Floor Slab	Normal	4000psi
Floor Slab	Lightweight	3500psi
Floor Slab	Normal	3500psi
Lean Concrete Fill	Normal	2000psi

Steel		
Type	Standard	Grade
Reinforcing Bars	ASTM A615	60
Composite Floor Deck	ASTM A992	20 gauge
Roof Deck	ASTM A992	B
Galvanized Plate	ASTM A992	50
W shape Steel	ASTM A992	50
Angles	ASTM A992	50
Bolts	ASTM A325	N/A
Anchor Rods	ASTM F1554	N/A
HSS	ASTM A992	50
Welded Wire Fabric	ASTM A185	70,000psi

Masonry		
Type	Standard	Strength (psi)
Grout	ASTM C476	5000psi
Concrete Masonry Units	ASTM C90	2100psi
Mortar	ASTM C270	N/A

Miscellaneous	
Type	Strength (psi)
Non-Shrink Grout	10,000psi

Figure 4 Tables showing materials that are used in the TCMC project

Foundations

The West wing of the TCMC is built with a mat slab foundation that is 4’-0” thick. The mat slab is designed for a soil bearing pressure of 3000psf. It is on top of a 2’-0” thick structural fill and a 4” mud slab. Figure 5 shows a typical section of the mat slab. After the mat slab, over 4’ of compacted AASHTO # 57 stone typical was placed in followed by a 5” slab on grade. Due to the confidentially of the geotechnical report, the actual bearing capacity of the soil and the recommended type of foundations were never released.

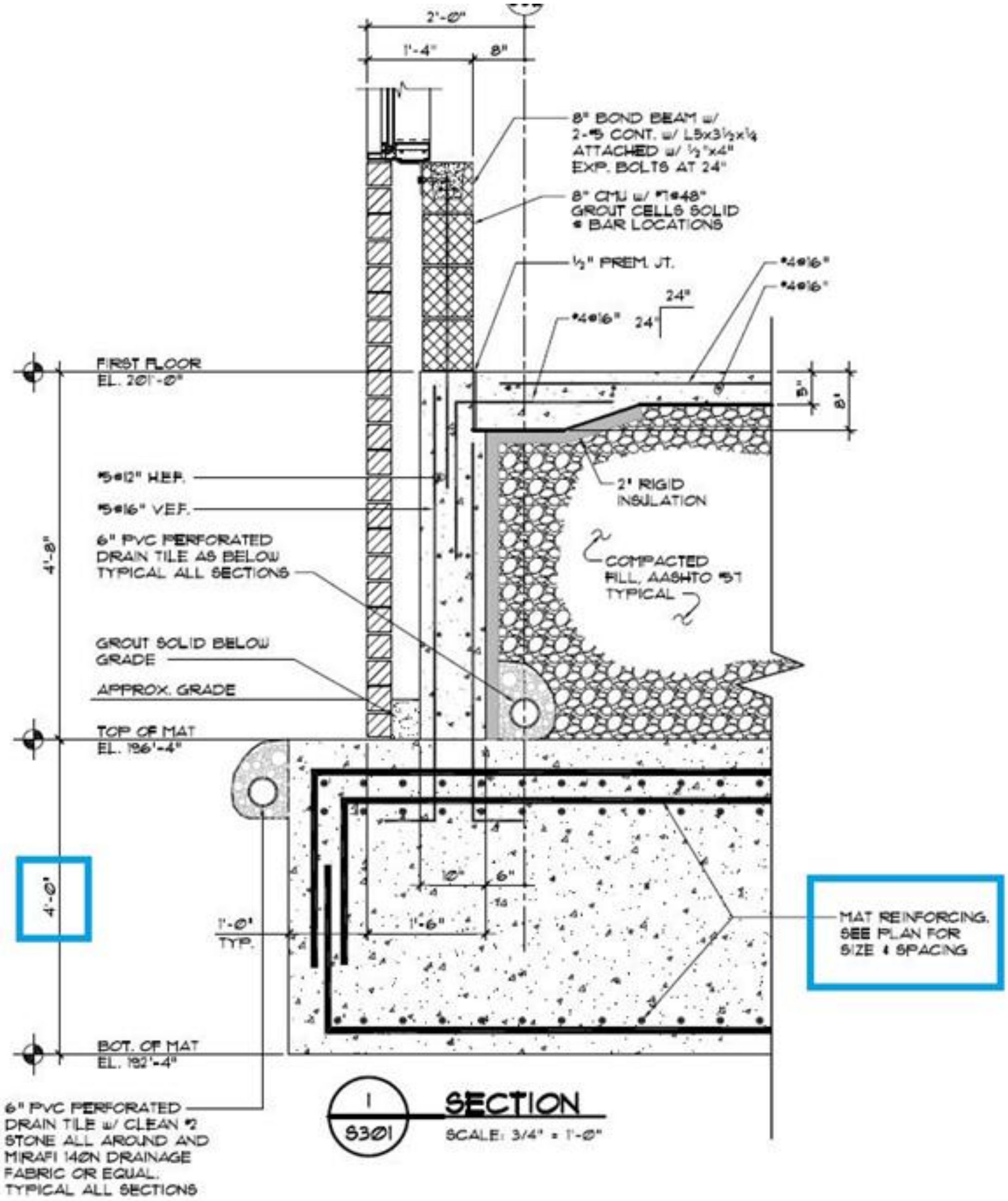


Figure 5 A typical Section cut showing the mat slab foundation. Courtesy of Highland Associates

The East wing of the TCMC has drilled caissons ranging from 36” to 60” in diameter and is used to carry loads from grade beams to bedrock below. The typical floor slab in the east wing is 7.5” and it’s also on top of compacted AASHTO material. This can all be visualized by looking at a typical section cut from Figure 6 below.

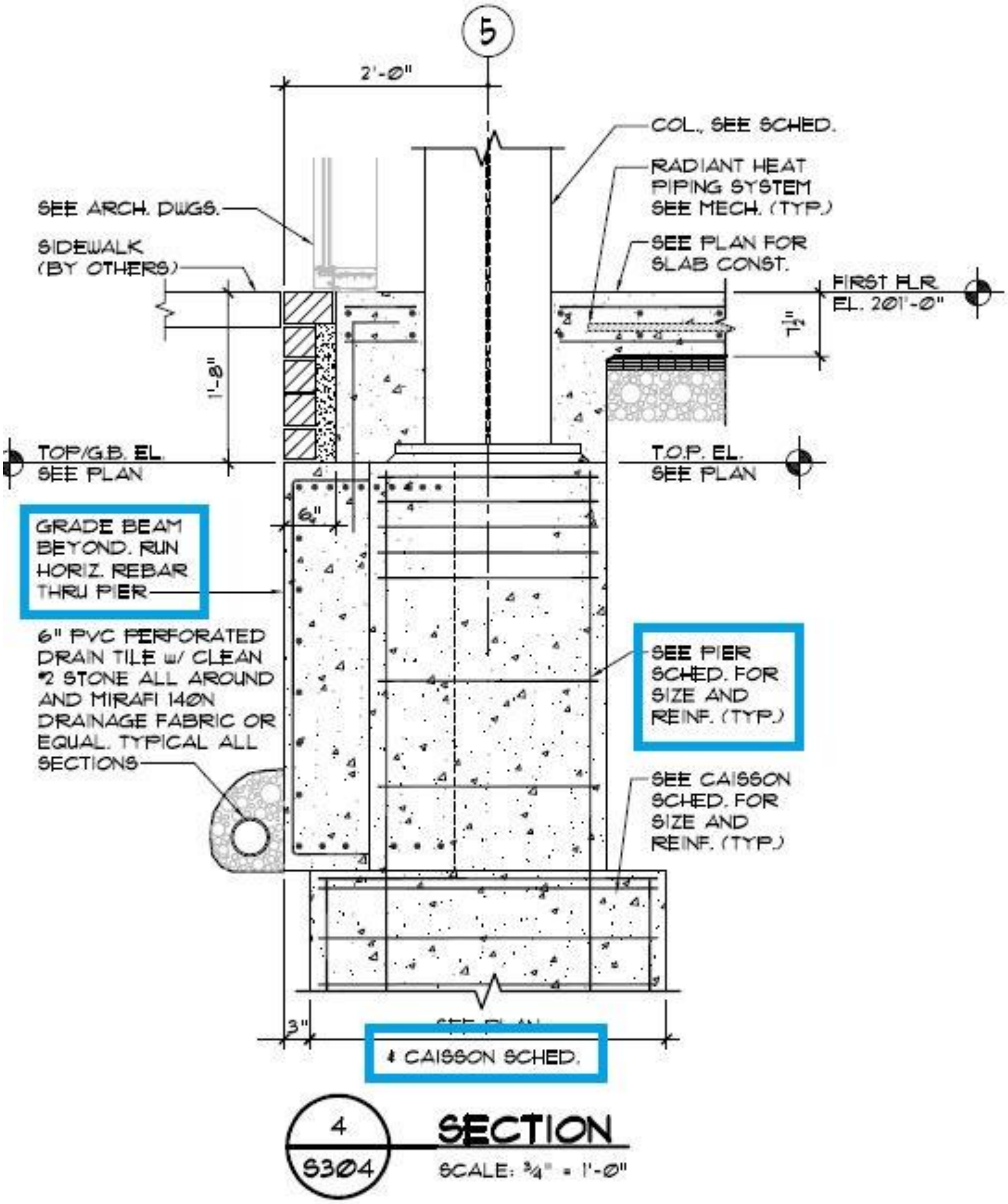


Figure 6 A section cut of a drilled caisson foundation. Courtesy of Highland Associates

Floor Systems

The existing floor system of the TCMC is held up by W-shaped steel columns and composite steel beams. Figure 7 shows the floor plan with different bay sizes in different colors. Bay sizes are shown along with the figure, with the span required for the slab first and the span required for the girder next, match with their colors. Small bays sizes are not shown in Figure 7.

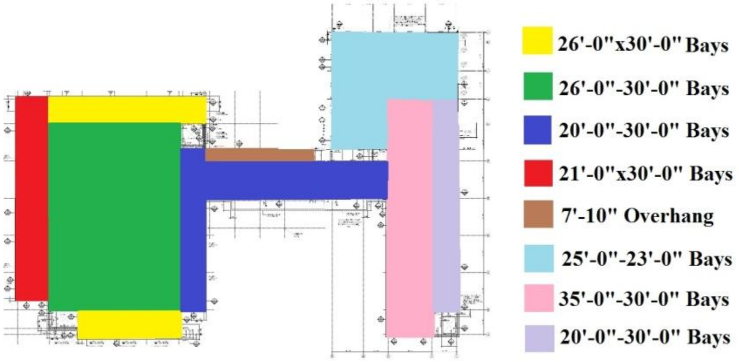


Figure 7 Different Bay sizes respective to their color

The floor is composite steel deck with concrete topping. The typical floor plan in the west wing is shown in Figure 8 along with two section cuts, Figures 9 and 10. It is a 4.5" normal weight concrete topping on a 3" lok-floor 20 gauge galvanized composite floor deck, giving it a total slab construction of 7.5". The east wing, and the link, has different slab thickness than the west wing. They are 3.25" lightweight concrete topping on U.S.D. 2" lok-floor 20 gauge galvanized composite floor deck, making the total thickness of 5.25".

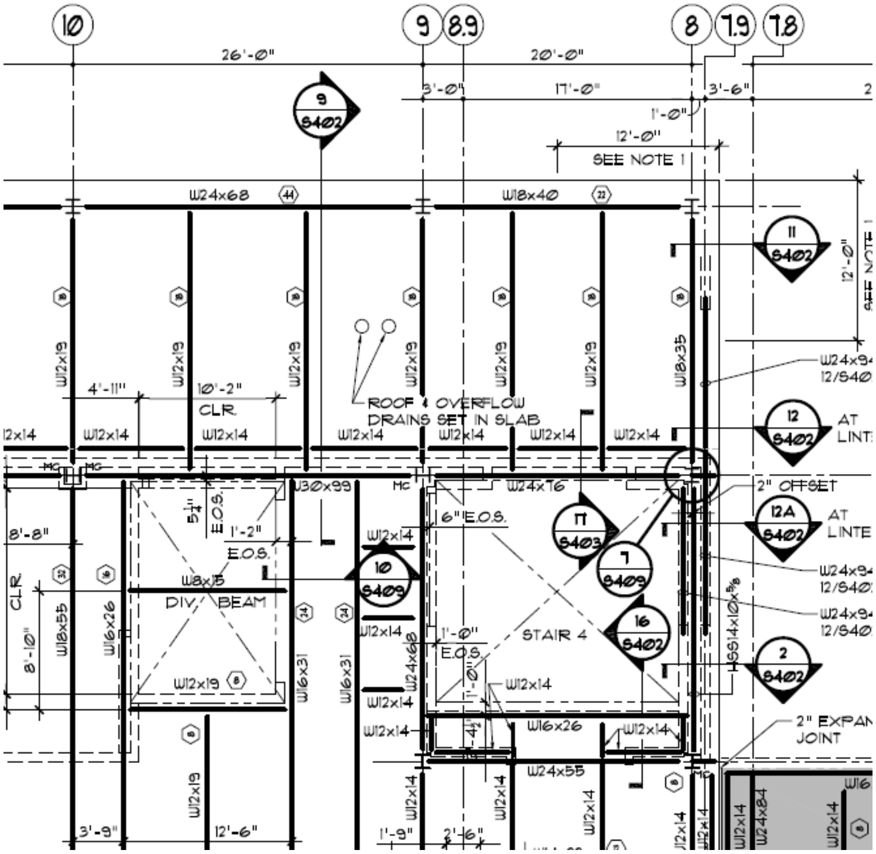


Figure 8 Partial plan showing the second floor, northeast corner of the west wing

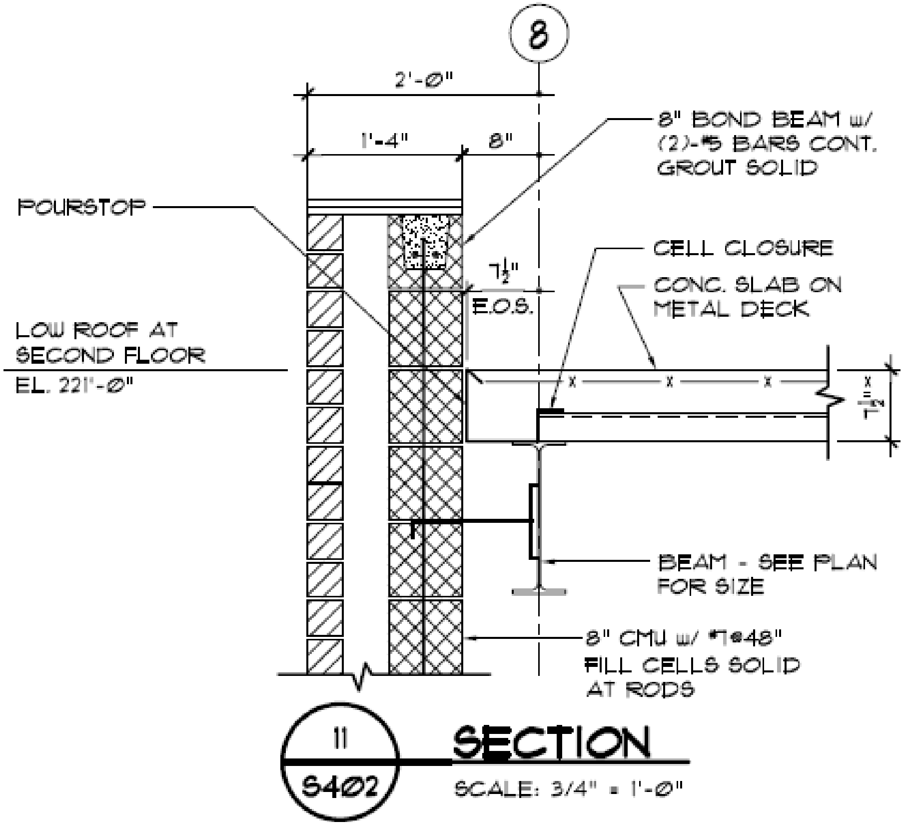


Figure 9 Section cut 11 from Figure 8

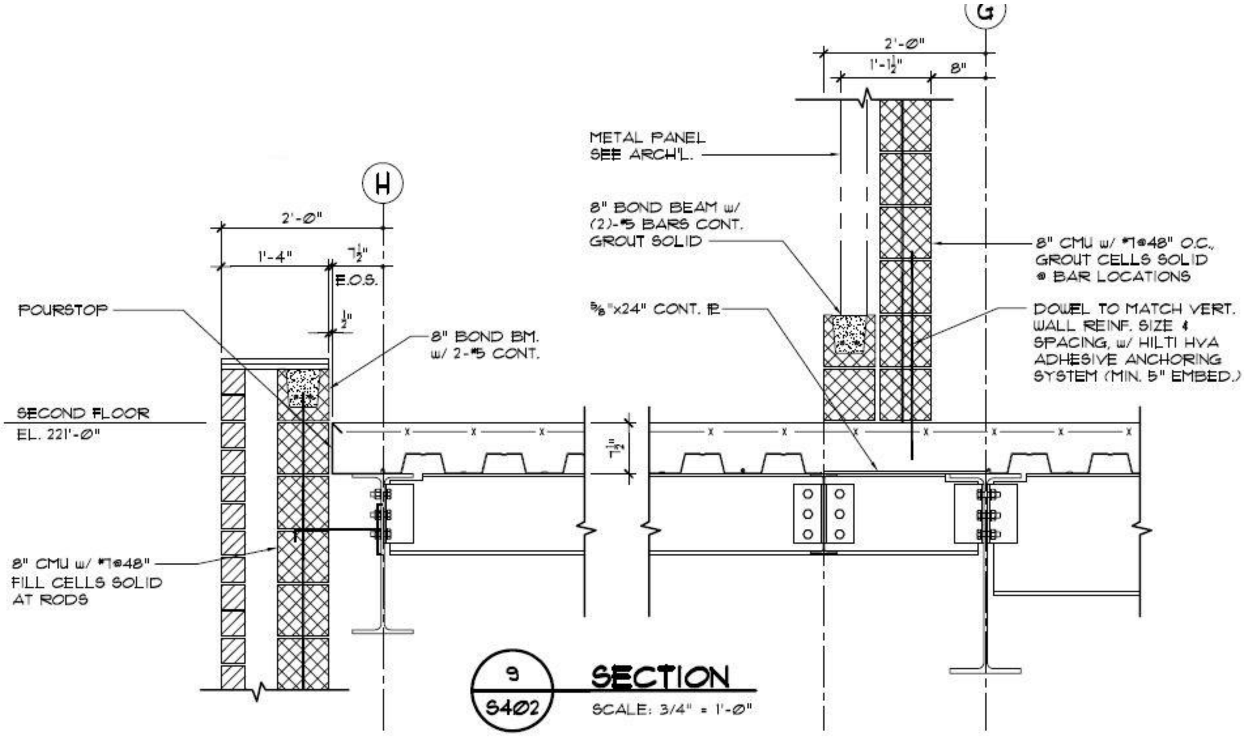


Figure 10 Section cut 9 from Figure 8

Roof Systems

TCMC has over 9 different roof heights, as shown in Figure 11, with the ground referenced at 0’-0”. The link between two wings has an average roof height of 36’. The west wing goes up to 92’. The Tower, shaded in red, in the east wing goes up to 89’-4”. The rest of the east wing goes up to 81’-4” while the east wing penthouse goes up to 102’.

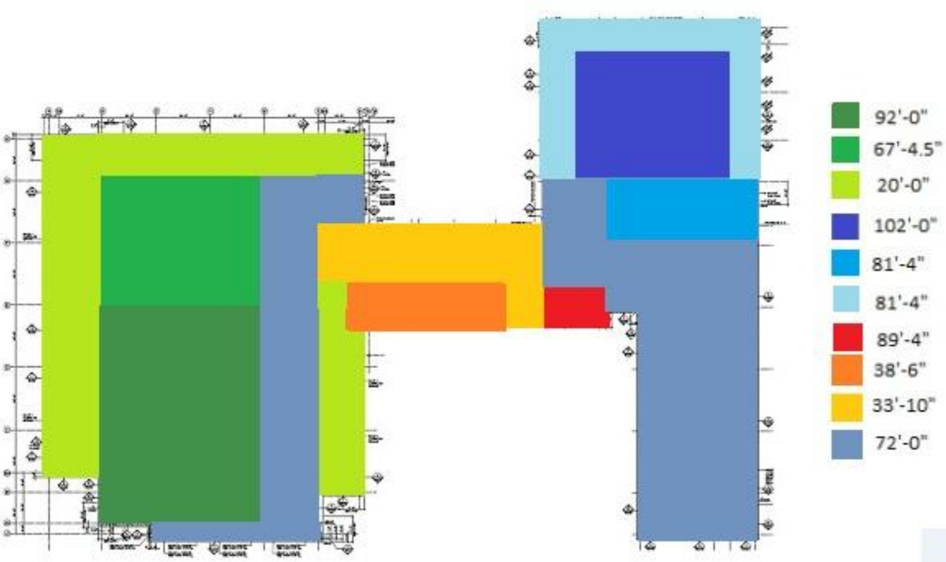


Figure 11 Plan showing the different roof heights; the darker, the higher.

The main roof is constructed of 1.5” type B wide rib, 22 gauge, painted roof deck supported by W-shape framing. A typical roof section cut is shown on Figure 12. The typical roofing system has two layers of 2” rigid roof insulation. The walls around the roof extend 4’ higher than the steel deck so that it can be used as railings.

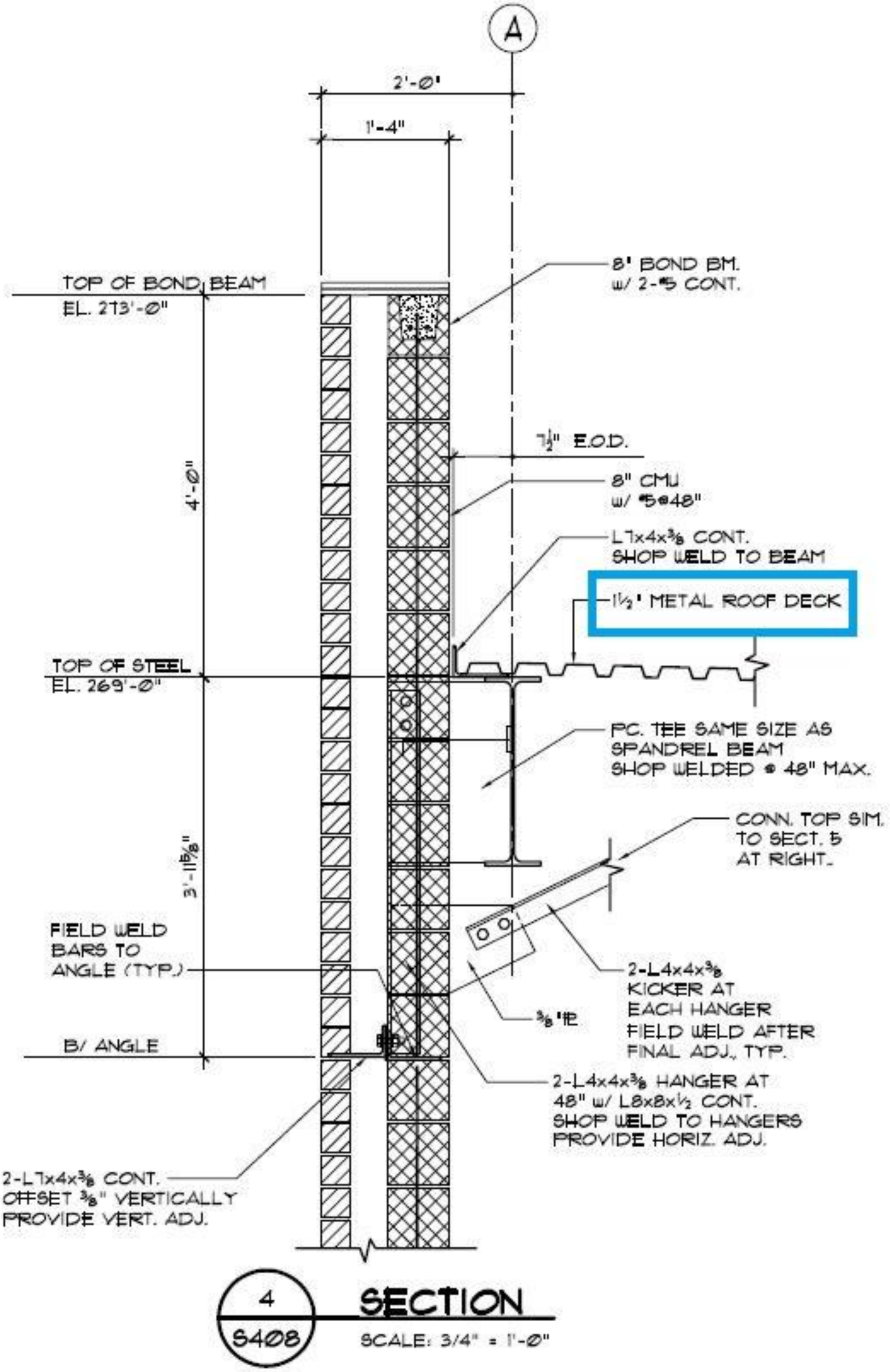


Figure 12 Typical roof section cut showing the roof deck. Courtesy of Highland Associates

Framing System

TCMC has a composite steel framed system. The sizes of the beams and columns ranged from W8x24, being the lightest, to W14x257, being the heaviest. The longest column is 44’-7” and it stopped between the third and fourth floor. An additional 48’-0” of lighter steel column is connected to this column, extending it all the way up to the penthouse.

Lateral System

The main lateral system used in TCMC consists of multiple moment frames. They are present in the west wing, east wing, and also in the link, as shown in Figure 13.1. Most frames are near the exterior wall to maximize the lateral force it can resist. The moment frames span across the entire building, from north to south and from east to west. This provides lateral resistance in each direction. The frames in the link begin on the first floor and extend to the roof, the third floor. The frames in the two wings begin on the first floor and extend to the floor of the penthouse. Figure 13.2 shows the only four frames that extend to the roof of the penthouse.

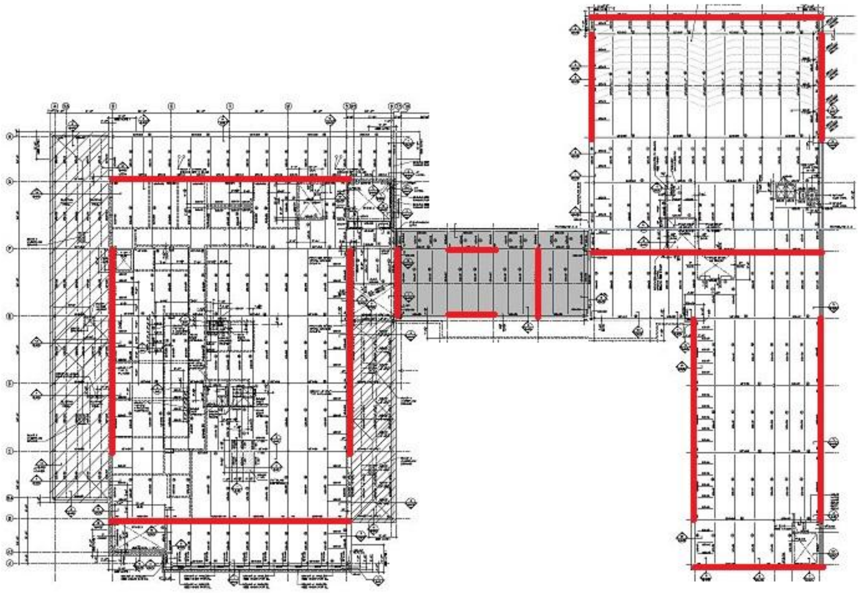


Figure 13.1 Locations of Moment Frames at TCMC. Courtesy of Highland Associates, edited by Xiao Zheng

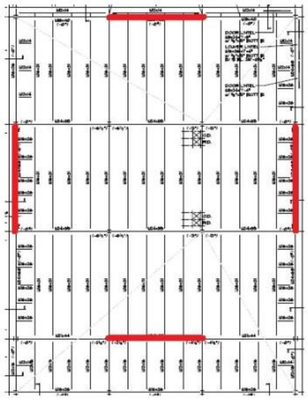


Figure 13.2 Locations of Moment Frames at the Penthouse of TCMC. Courtesy of Highland Associates, edited by Xiao Zheng

Gravity Loads

The dead, live, and snow loads were calculated under this section for TCMC using IBC 2006, ASCE 7-05, and estimation.

Dead and Live Loads

For the dead load calculations, the materials that have the most impact on the dead weight of the building were found and then calculated. The west wing primarily uses composite 3” steel deck with concrete slab that weighs 75 psf according to Vulcraft Steel Deck catalog. The east wing and the hallway use 2” steel deck, lightweight concrete, so it only weights 42 psf. Then W-shape Steel Beams and Columns are assumed as 15 psf that covers that whole entire building. The heaviest exterior wall is chosen and is assumed throughout the building at 1000plf. Then these weights are multiplied by the area or the length that they occupied in to get the weight in pounds. A sample of this calculation is shown for the 2nd floor of the TCMC in Figure 14 below. Doing this for every level, a weight in psf and lbs are both obtained. Then the total dead weight is found to be around 22,378 kips and will be used later in seismic calculations. A breakdown of the weight per Level is shown in Figure 15.

Weight for 2nd Floor			
Material	Weight (psf)	Area or Length	Total Weight (lb)
Normal Weight Conc Slab with Deck	75 (psf)	20408 sf	1,530,600
Light Weight Conc Slab with Deck	42 (psf)	24952 sf	1,047,984
W-Shape Steel	15 (psf)	45360 sf	680,400
Exterior Walls	1000 (plf)	1418 lf	1,418,000
Total Weight			4,676,984
Total Weight per sf (close to design average dead load of 93 psf)			103.11

Figure 14 Total Weight per square foot of TCMC

Weight Per Level			
Level	Area (ft^2)	Weight (psf)	Weight (k)
1st	51,348.00	99.3	5099
2nd	45,360.00	103.1	4677
3rd	40,425.00	106.0	4286
4th	40,422.00	106.0	4286
Penthouse	10,337.00	209.2	2163
Roof (all level)	40,455.00	46.0	1867
Total	228,347.00		22378

Figure 15 Total Weights per Level of TCMC

The design live load for the TCMC can be found in the drawings on sheet S201A and S201B. A comparison of it to the minimum live load requirement from ASCE 7-05 can be seen on Figure 16. Notice that most design load are the same as the minimum required live load. However, some design live loads for several locations are higher because more live loads are expected.

Design Live Loads for West Wing			
Location	Design Live Load (psf)	ASCE 7-05 Live Load (psf)	Notes
Offices	50	50	
Lobbies/ Corridors	100	100	
Corridors above 1st	80	80	
Stairs	100	100	
Classrooms	40	40	
Laboratories	100	60	Larger equipment needed in TCMC Labs
Storage Rooms	125	125	Light warehouse
Restrooms	60	N/A	
Mechanical Room	150	N/A	
Mechanical Roof	30	N/A	
Roof	20	20	ordinary flat
Partitions	15	15	

Design Live Loads for Rest of Building			
Location	Design Live Load (psf)	ASCE 7-05 Live Load (psf)	Notes
Offices above 1st	65	50	Partitions and some heavier office equipment
Lobbies/ Corridors	100	100	
Corridors above 1st	80	80	
Stairs	100	100	
Classrooms	50	40	
Sorage above 1st	125	125	
Restrooms above 1st	75	N/A	
Auditorium	100	100	if seats are fixed, then only 60psf
Bookstore	150	N/A	
Lecture Halls	60	N/A	
Mechanical Room	150	N/A	
Library	75	N/A	
1st floor offices	65	50	
1st floor restrooms	75	N/A	
Roof	30	20	
Mechanical Roof	30	N/A	
1st floor storage	125	100	

Figure 16 Design live load is compared to ASCE 7-05, required live load

Snow Loads

The variables needed for snow load calculations are found on sheet S201B of the drawings. Figure 17 shows all the loads and variables that are from Sheet S201B of the structural drawing. Also, because of the many different roof heights, snow drifts can happen in over 10 different areas of the building. One of these areas is calculated and shown under Appendix A, snow load calculations. The result of that area is that the snow acuminated in the corner reached over 73 psf, more than double the amount compared to the regular flat roof amount of 30 psf. Snow drift is an important factor when designing TCMC.

Flat Roof Snow Load Calculations	
Variable	Value
Ground Snow Load (P_G)	35 psf
Flat Roof Snow Load (P_F)	30 psf
Snow Exposure Factor (C_E)	1.0
Importance Factor (I_S)	1.1
Thermal Factor (C_T)	1.0

Figure 17 Variable for snow load obtained from S201B

Proposal

Structural Depth

The Commonwealth Medical College is currently being used as a medical college in the middle of a city and was designed for such use. It was designed for the expected wind, seismic and weather loads in Scranton area. Therefore, if a powerful storm were to hit the building, it may not be able to resist that load. For the purpose of this thesis, TCMC will be assumed to be a medical college designed to be built in Miami, Florida, a hurricane prone region. Higher design wind loads and impact from debris loadings will be considered.

Weather patterns or the force of nature can never be accurately predicted. Just recently, Hurricane Sandy hit the east coast of the United States, causing many building failures. If a storm more powerful than Hurricane Sandy goes by Scranton, which is unlikely but not impossible, TCMC may not survive. To lessen structural damage, the members will be designed to resist heavier wind loads, which will be discuss further later on. Using larger loads is the reason why TCMC will be assumed to be in located in Miami. As stated before, the existing structure is composed of composite steel framing system. Steel will be used again in this redesign.

Not only the weather is different, but the site is also different in Miami and Scranton. The site in Scranton has a much higher bearing capacity, while the site is Miami has a lot less bearing capacity due to its sandy nature. Therefore, a different foundation will be designed.

Proposed Solutions

To meet the new requirements of design for TCMC in Miami, FL, the lateral system will be redesigned along with a new foundation design. The codes that will be used to redesign TCMC in Miami are the Florida Building Code 2010, and ASCE 7-10. Two main systems will be designed and compared in this thesis:

- Moment Frames
- Laterally Braced Frames

Moment frames are the original system for TCMC. It will be designed to withstand a larger wind load since it is now in Miami. This frame will be compared to a lateral braced frame system, which is the second system proposed. Both systems will stay with the original gravity system of structural steel. The rest of the gravity system, such as the floor system, will also be changed a little to fit the appropriate new design.

A new foundation will be designed to account for the different soil condition in Miami Florida. To accomplish this, a geotechnical research will be done on a typical site in Miami. Also, the foundations for the two proposed system will be different due to their difference in lateral systems.

Breadth One: Façade Design

By relocating TCMC to Miami Florida, hurricanes and tornadoes caused by hurricanes are prevalent. The flying debris during the storm will cause damage to the façade of the structure. To protect TCMC from such impacts, the façade will be designed to withstand it. In addition, with a different climate, the proposed façade design will incorporate heat transfer as well as waterproofing considerations. Breadth 1 focuses on the design of TCMC resistance to impacts, heat transfer, and waterproofing.

Breadth Two: Solar Panel Design

Being a LEED silver certified building, adding solar panels to TCMC will increase its efficiency of energy usage and possibly increase its LEED rating. Research will be done to confirm this. The climate in Florida will make the photovoltaic system very beneficial because more sunlight can be converted into energy. Solar panel design will be investigated along with batteries to provide enough energy for lighting and other usage in the entire building. This may potentially remove TCMC of the electric grid.

Breadth Three: MEP Changes

And the last breath design is on MEP changes. The weather conditions in Miami are very different compared to Scranton. Because of this, new mechanical systems need to be analyzed. Most heating units will be replaced by cooling units. The addition of solar panels will impact electrical wirings. The electrical system will be wired so that it can use electricity more efficiently. Lastly, a more powerful emergency backup power will be needed in case of a powerful storm, which is unlikely to happen in Scranton; therefore it is not currently designed for it.

MAE Material Incorporation

The information learned in AE 534, Steel Connections, will be utilized to design a typical braced frame connection and a typical moment frame connection for TCMC. In addition, information learned in AE 537, Building Performance Failures and Forensic Techniques, and AE 542, Building Enclosures, will be used to redesign and detail the façade for impact and pressure resistance, waterproofing, and heat transfer. Lastly, information learned in AE 530, Computer Modeling, will be used to model the appropriate moment frame system and braced frame system.

Tasks and Tools

Structural Depth: Wind Study in Hurricane Prone Region

I) Determine lateral loads

- Research Florida Building Code 2010 and ASCE 7-10 to determine the following:
  - Wind loads
  - Hurricane-prone region wind loads
  - Seismic loads
  - Small and large debris impact loads

II) Redesign the lateral system for the West Wing, East Wing, and the Link

- Moment Frames
- Lateral Braced Frames

III) Design the rest of the gravity system

- Design the new floor system using Vulcraft Ecospan Composite Floor System for required loads, depth requirements, and serviceability
- Design beams, girders, columns, and bracing using AISC 14th edition for required loads, depth requirements, and serviceability.
- Use structural design software to fully define the layout.

IV) Foundation design

- Research if mat slab and drilled caissons foundations can still be used
- Design a new foundation when TCMC has moment frames
- Design a new foundation when TCMC has braced frames

V) Cost Analysis

- Use RS Means to find the cost for the two new proposed systems

VI) Comparison

- Compare the difference between TCMC built in Scranton, TCMC if build in Miami, and TCMC with braced frame build in Miami

Breadth One: Façade Design

I) AE 542, Building Enclosures

- Use the information learned from Building Enclosures class to design a new façade

II) Research small and large debris impact resistant design

- Use Florida Building Code 2010
- Use sources that were touched on in AE 542

III) Design the façade in detailed drawing

IV) Determine the cost difference between new and original façade designs

Breadth Two: Solar Panel Design

I) Research Solar Panels and determine sunlight data in Miami

II) Determine standards applicable to photovoltaic design

III) Determine other buildings in Miami usage of solar panels

IV) Determine the use of solar panels in TCMC

- Find the electrical load requirements of TCMC
- Calculate the size of batteries require to store the energy
- Determine cost savings and pay off period

V) Structural Check

- Check that solar panels weight less than the snow load in Scranton or if the roof needs to be resize to support the panels

Breadth Three: MEP Changes

I) Electrical Changes

- Draw a wiring diagram that will use the energy from solar panels
- Determined the new backup emergency system: find out how much energy is needed

II) Change the Cooling and Heating Systems

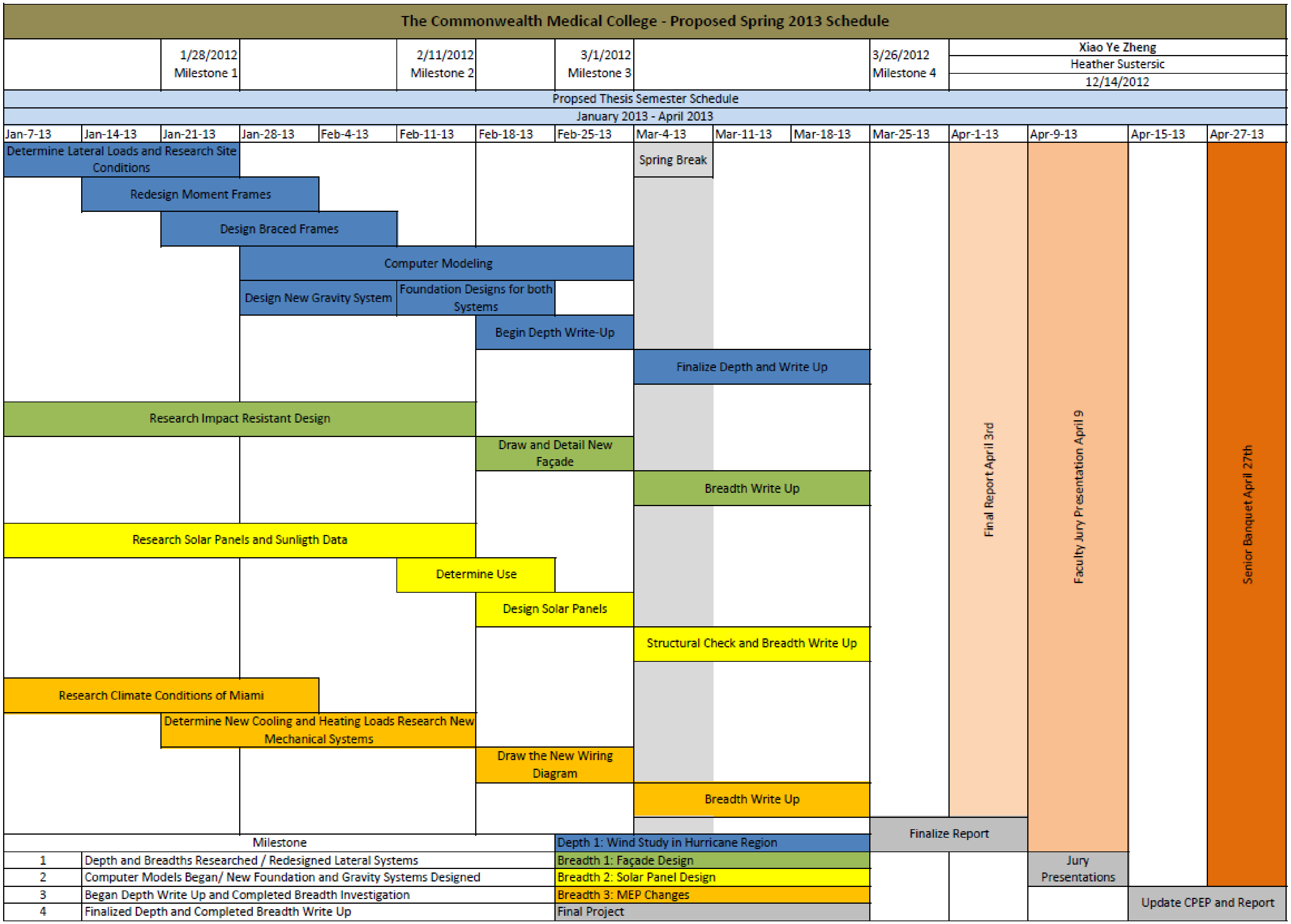
- Calculate the new loads required for cooling and heating
- Determine how many heating systems should be removed and how many cooling systems should be added.

III) Research Cooling Systems

- Determine which cooling systems is more popular for large buildings in Miami and why it is popular

IV) Compare cost between new and original MEP changes

Proposed Schedule



Milestone	
1	Depth and Breadths Researched / Redesigned Lateral Systems
2	Computer Models Began/ New Foundation and Gravity Systems Designed
3	Began Depth Write Up and Completed Breadth Investigation
4	Finalized Depth and Completed Breadth Write Up

Conclusion

The structural depth for this thesis begins with code research of Miami, Florida. New load has to be determined, along with site conditions and many other. The codes that will be used are the Florida Building Code 2010, and ASCE 7-10. After loads are determined, two new lateral systems will be designed and compared. The first system that will be looked at is the used of moment frames. This is the existing design of TCMC but will be redesigned to meet the new load requirements in Miami. The second system that will be looked at is the steel braced frames. Both situations will implement the original steel gravity system. This redesign will include the change of the composite floor system, beams, girders, and columns. More importantly, the foundation will have to be redesigned to support the change of lateral systems and the different soil condition.

Three breadth topics will also be included in this thesis. The first breath consists of a new façade design concentrating on impact resistance due to debris in a hurricane or tornado. The second breath is on solar panel design that could make TCMC more energy efficient by taking advantage of Miami’s sunlight. The last breath in on new MEP design because the climate is very different between Scranton and Miami.