Thesis Proposal

2011-2012 AE Senior Thesis

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Executive Summary

The UPMC Hamot Women's Hospital is a 5 story, 92 foot tall, healthcare facility located on the bay of Lake Erie. The steel framing system supports the lightweight concrete composite floor system and the lateral loads from wind and seismic forces are resisted by moment connected steel frames in the E-W plan direction and both a moment connected steel frame and a braced frame in the N-S plan direction.

This thesis proposal is intended to outline a course of learning for the Spring 2012 semester. This will be done through several investigations, with the depth concentration of the work being related to the buildings structure and then two breadths with how that structure affects other components of the building.

The structural depth for this thesis will be split up into three distinct investigations. An investigation on the new building code with a comparison to the previous edition and how it affects the structural weight and performance will be done. An investigation into the possibility of effectively utilizing braced frames rather than moment frames will be completed. Finally, an investigation into a complete building redesign without using the existing structure or grid will be done to determine if the correct decision was made by the construction team.

As these elements are completed two breadth studies will be undertaken. An architectural breadth will be done to analyze the impact on the architecture that the braced frame system has on the building. A construction management breadth will also be done to analyze the impact of not using the existing structure and grid to build from.

Introduction

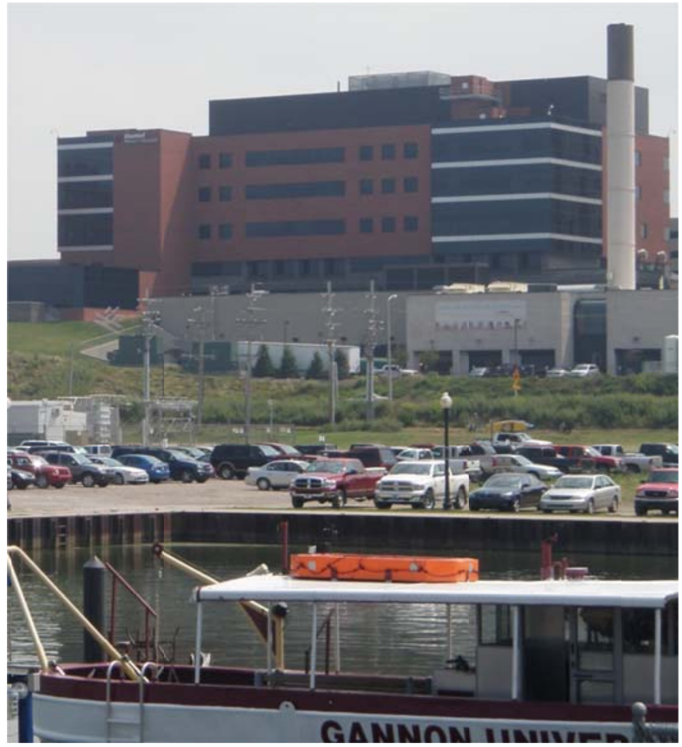

Figure 1: North Façade, Showing 2-D Escarpment

Located on the shoreline of Lake Erie, 201 State Street, which will be referred to as UPMC Hamot Women's Hospital, is a 5 story, steel framed healthcare and hospital facility. This site is centrally located on the UPMC Hamot campus, directly between the UPMC Hamot Main Hospital and the UPMC Hamot Heart Institute.

The 163,616 sq. ft. Women's Hospital was completed in early January of 2011. This structure has a very unique history; originally the hospital wanted a four story building, but only had the financing for two levels. Thus the structure was designed for four stories, but only the first two were constructed. Then the hospital decided that a five story structure more suited their needs, so the building was stripped down to the shell (structural steel and floor slabs), the current roof slab was then removed, with the columns being truncated 4'-0" above the second story slab. The decision was made to reinforce the columns and beams below this point, as needed, and to build to the desired five stories above.

The city of Erie zoned the UPMC Hamot campus as Waterfront Commercial 2 (W-C2), which permits residential, commercial, recreational, and historical uses. This zoning is similar to Waterfront Commercial (W-C), except that this area permits Group Care Facilities. The maximum building height in this zoning district is 100 ft, with a building footprint not greater than 65% of the lot; the exterior lighting of the building must prevent glare to adjoining properties; the lot is required to have 1 parking space per 4 beds.

The five stories of the UPMC Hamot Women's Hospital are topped with a mechanical penthouse that does not cover the entire building footprint. This penthouse houses three air handling units that supply conditioned air to all areas of the building. This is achieved via a large mechanical opening in each floor; this opening is located on the west side of the building and measures approximately 27'-0"± by 30'-0"±.

Figure 2: Interior Water Wall

The UPMC Hamot Women's Hospital was designed to match the Architectural style of the other buildings on the Hamot Medical Center campus. This includes a brick and glass façade that is intended to allow sufficient amounts of natural light into the building without being uncomfortable to the patients. The interior of the building was constructed to a very luxurious standard. The owner of the building was not primarily concerned about cost, but rather wanted the building to put the patients at ease by making them feel as if they were at home. This is primarily achieved through earth tone colors throughout the interior the water wall located in the lobby and the cabinets in every room to hide the hoses and cables that are typical of a hospital, moreover, each room is equipped with a Jacuzzi and a very luxurious bathroom, again to achieve a relaxing environment for the patients.

UPMC Hamot Women's Hospital has an exterior façade of 4" nominal face brick, a 3" air space, 1" of rigid insulation, on 6" nominal metal studs with R-19 batt insulation filing the wall core. The wall is then closed with 5/8" gypsum wall board. Where applicable the wall system is double pane insulated glass windows. The roof system is EPDM roofing on protection board on polyisocyanurate insulation.

Figure 3: Exterior Building Façade

Structural System

• Foundation

The foundation is unique in that many of the existing foundations also had to increase in size when the building increased in height. The foundation system utilizes both strip and spread footings. The strip footings are typically 2'-0" wide and 1'-0" deep; reinforcement consists of 3-#5 longitudinally and #5 x 1'-6" @ 12" O.C. transverse. The modifications to the spread footings are unique because many of the existing spread footings had to be increased in length, width, and depth. The minimum height of the footings below grade is 3'-6". The typical foundation overbuild details can be found on sheet S403.

Figure 4: Foundation Excavion during Construction

• Floor Construction

The beams are typically W shapes that tend to be framed with the girders spanning the short direction and the beams framing the long direction of the bay. The beams are typically W14x22 composite beams, where concrete slab on deck exists. In the shorter spans (12'-4") the beams become W8x10, and when the tributary spacing is decreased, W12x19 composite beams are likely to be used. Elsewhere the beams are non-composite. The girders are also composite where applicable.

The elevated floor slabs have a total thickness of 6", consisting of 4" of lightweight 4000 psi concrete on a 2" – 20 GA composite metal deck. These slabs are reinforced with 6x6 – W1.4xW1.4 welded wire fabric.

• Lateral System

The lateral system in the N-S direction consists of a 5 story (6 with penthouse), 49' long braced frame along column line N. This is the only full height braced frame in the building. The N-S direction also has a full height 42'-8" long moment frame along column line B. In the E-W direction full height moment frames are utilized along column line 1 and 17, which are 161' and 173'-4" long, respectively. The columns are spliced 4'-0" above the second floor, where the existing shell remained and was reinforced below. The columns are also spliced at above the 4th floor, at the same 4'-0" elevation. The unique construction sequence has led to the need to reinforce the base of these columns dramatically, especially in the moment frames. The details of these reinforcements can be seen on sheet S400. The column sizes vary from W8 sizes to W14 sizes. The lateral system of the mechanical penthouse is entirely braced frames.

Design Codes & Standards

2006 International Building Code (IBC 2006) with Local Amendments

2006 International Mechanical Code (IMC 2006) with Local Amendments

2006 International Electrical Code (IEC 2006) with Local Amendments

2006 International Fire Code (IFC 2006) with Local Amendments

Minimum Design Loads for Buildings and Other Structures (ASCE 7-05)

Building Code Requirements for Structural Concrete (ACI 318-08)

Building Code Requirements for Masonry Structures (ACI 530)

AISC Manual of Steel Construction, Allowable Stress Design (ASD- 9th Edition)

Structural Materials

Structural Steel		
Type	**Standard**	**Grade**
W-Shape Structural Steel	**ASTM A572**	**50**
Hollow Structural Sections (HSS)	**ASTM A500**	**C**
Bars, Plates and Angles	**ASTM A36**	**N/A**
Bolts, Washers, and Nuts	**ASTM A325**	**N/A**

Concrete		
Usage	**Weight**	**Strength**
Footings	**Normal**	**3000 psi**
Slab-on-Grade	**Normal**	**4000 psi**
Concrete on Steel Deck	**Lightweight**	**4000 psi**

Building Loads

Part of this technical report will incorporate the calculation of both gravity and lateral loads. The gravity loads will consist of dead, live, and snow loads. The lateral loads will be analyzed through wind and seismic loading. The intent of this aspect of the report is to lay the groundwork for remainder of this thesis project, as well as begin to determine how conservative the primary designer may or may not have been.

- ## Dead Load

Dead loads were calculated using the most recent data available through the Vulcraft Corporation. Typical floor weight was found to be 59 psf, although to allow for some unknowns a superimposed dead load was decided to be used, which is conservative; thus leaving a typical floor dead load of 69 psf. The roof dead load was also calculated using the Vulcraft Corporation manuals, and the roof dead load was determined to be 15 psf. To be conservative a roof dead load of 20 psf will be used, allowing for future roof coverings to be laid on the initial roof. Appendix A includes the appropriate figures from the Vulcraft Manuals used, as well as detailed calculations for the typical floor and roof dead load.

- ## Live Load

Live Loads were calculated in accordance with IBC 2006 using ASCE 7-05 (Minimum Design Loads for Buildings and Other Structures). The relevant loads derived are tabulated in Table 1 and in Appendix A.

ASCE 7-05 Live Loads	
Space	Load (psf)
Lobbies	100
First Floor Corridors	100
Offices	50 + 20 (partitions)
Stairs	100
Mechanical	150
Roof	20
Hospitals	
Operating Rooms/Labs	60
Patient Rooms	40
Corridors, above First Floor	80

Table 1: ASCE 7-05 Live Loads

- ## Snow Load

Snow loads were calculated using the procedure outlined in ASCE 7-05 Chapter 7. The city of Erie, PA falls into an area requiring a Case Study (CS) of the ground snow load. A call to the Erie Building Code Official yielded a local requirement for designers to use a ground snow load of 40 psf. The Snow Load Calculations are summarized in Table 2 and detailed calculations are available in Appendix B. Several locations were determined to be potential drift locations, located around the Mechanical Penthouse and the Stair Pop-out. The Mechanical Penthouse yielded a peak drift load of 106.2 psf with a width of 17'-0". The Stair Pop-Out yielded a peak drift load of 58.2 psf with a width of 7'-0". A roof plan with mark-ups of the applicable snow drift areas is available in Appendix B.

ASCE 7-05 Snow Loads	
Variable	**Value**
Ground Snow Load, p_g (psf)	**40**
Temperature Factor, C_t	**1.0**
Exposure Factor, C_e	**0.8**
Importance Factor, I_s	**1.1**
Flat Roof Snow Load, p_f (psf)	**24.64**

Table 2: ASCE 7-05 Snow Loads

- ## Wind Load

Wind loads were calculated in accordance with Chapter 6 of ASCE 7-05, Method 2 Main Wind Force Resisting System (MWFRS). In order to use this procedure a few minor simplifications had to be made, such as reducing the five different building heights to three. This was done by taking two of the minor pop-outs (< 5 ft) and simplifying them into the main roof.

The wind loading for this building is also unusual and interesting. The building sits on the peak of a 60 ft tall 2-D escarpment, as described in ASCE 7-05. This produces an atypical wind loading pattern in the North-South Direction. This problem is compounded by the building being located on the bay of Lake Erie, this flat open body of water allows for wind velocities to increase rapidly. This leads to a very large wind load at the base of the North wall of the building due to the exposure factors and 2-D escarpment.

Wind loads on the building are collected by the exterior façade and distributed to the slab, at which point the slab will distribute the forces to the MWFRS, based on the stiffness and location of the various structural elements.

The user should note that the internal pressures are not added to the external windward and leeward pressures. This is due to the fact that the internal pressures effectively cancel themselves out. This has been done in this report as is standard practice in structural engineering.

The wind pressures that engage the North-South lateral system was analyzed as a wind coming from the North. This is due to the large 2-D escarpment located on that side of the building. The wind pressures engage the East-West lateral system was analyzed as a wind coming from the East, although the wind coming from the West would be identical.

Details pertaining to the wind calculations can be found in Appendix C, while a summary of the final wind pressures can be found in Table 3 and Table 4, for a pictorial view of how these pressures are applied to the building see Figure 5 and Figure 6.

ASCE 7-05 Wind Pressures – N-S Direction		
Type	**Height**	**Wind Pressure (psf)**
Windward Walls	0'-15'	59.51
	15'-20'	39.39
	20'-25'	36.35
	25'-30'	34.03
	30'-40'	32.76
	40'-50'	29.87
	50'-60'	28.13
	60'-70'	26.98
	70'-80'	26.40
	80'-90'	26.03
	90'-92'	25.71
Leeward Walls	Full Height	-15.55

Table 3: ASCE 7-05 Wind Pressures in N-S Direction

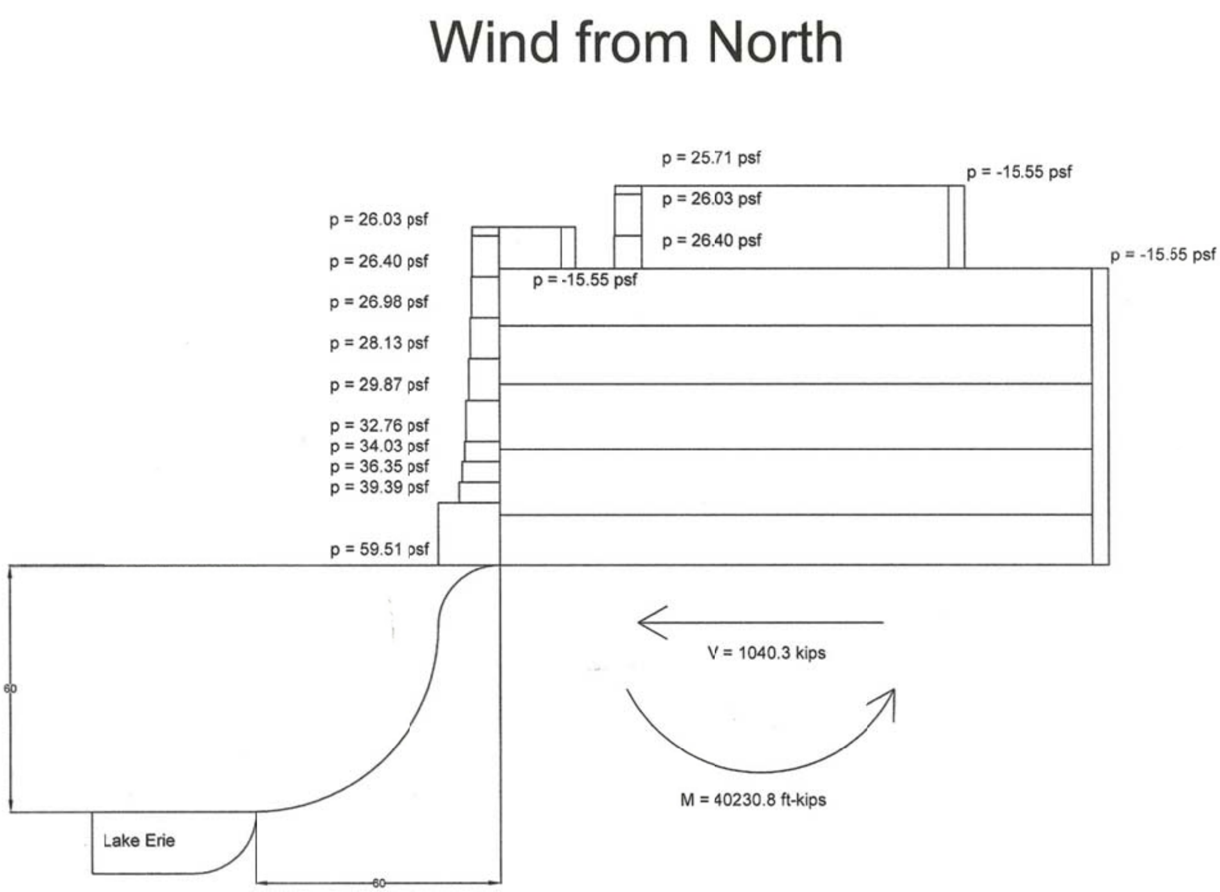

Figure 5: Wind Pressures in N-S Direction, showing 2-D Escarpment

ASCE 7-05 Wind Pressures –E-W Direction		
Type	**Height**	**Wind Pressure (psf)**
Windward Walls	0'-15'	19.20
	15'-20'	19.88
	20'-25'	20.43
	25'-30'	20.99
	30'-40'	21.82
	40'-50'	22.50
	50'-60'	23.05
	60'-70'	23.47
	70'-80'	24.16
	80'-90'	24.44
	90'-92'	24.58
Leeward Walls	Full Height	-14.13

Table 4: ASCE 7-05 Wind Pressures in E-W Direction

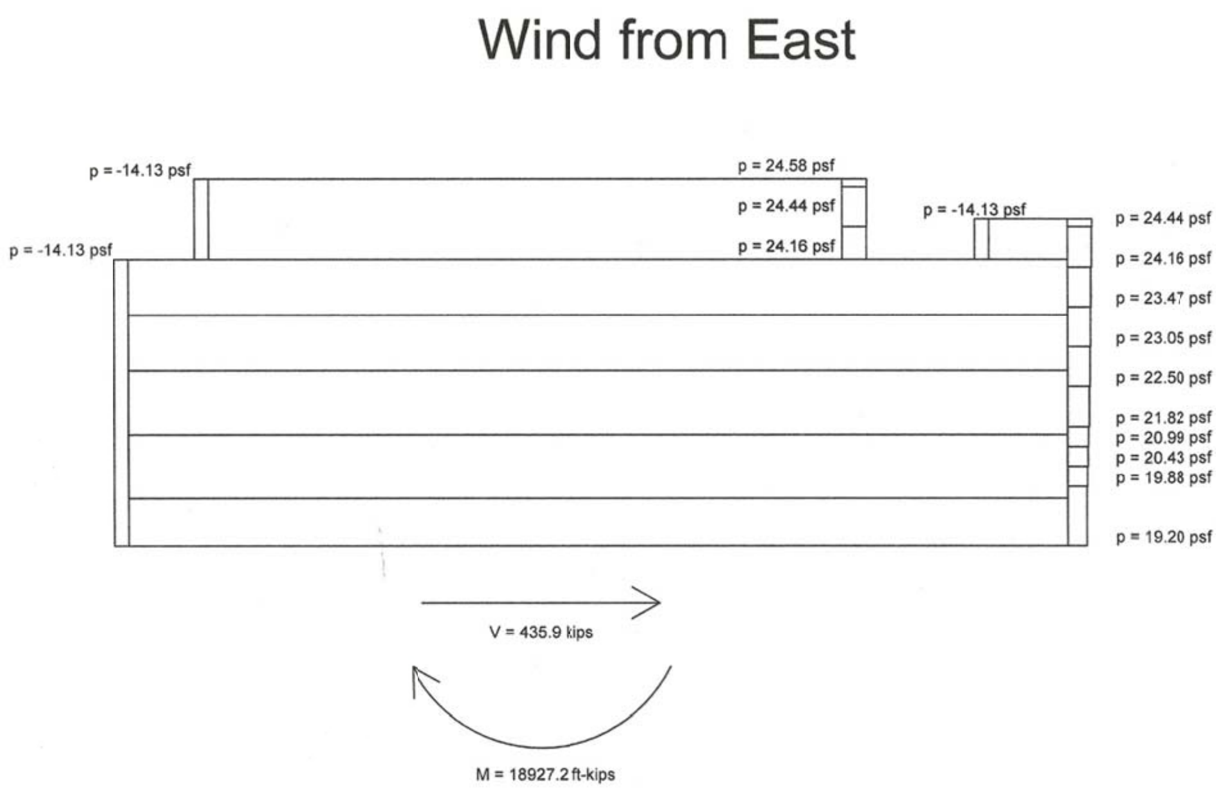

Figure 6: Wind Pressures in E-W Direction

- **Seismic Load**

Seismic loads were calculated as required by ASCE 7-05, Chapter 11 and 12. This section requires the use of the Equivalent Lateral Force Procedure. For this analysis an R-Factor of 3 was chosen, meaning the building is "not specifically detailed for seismic loads".

Seismic loads tend to be very complicated in nature, due to the fact that no two earthquakes are ever the same. This leads to many engineering simplifications within the code to allow us to analyze the structure quickly and efficiently. Wind loads are easier to quantify because it acts as a pressure on the building. Earthquake loads are more difficult to quantify because the loading comes through the motion of the ground. ASCE 7-05 assists the structural engineer by providing a procedure that allows for the complicated loading to be turned into forces applied at the various levels. The overall base shear of the building is controlled by many factors, although the inertial mass of the building can be singled out as one of the most important factors. The mass and height of each level leads to how much of the overall base shear we can apply to that respective level.

Several assumptions had to be made in order to use the Equivalent Force Method in ASCE 7-05. The first assumption is that the mass of each story is lumped at that story level. This is an acceptable assumption because the majority of a stories mass is located in the slab and beams attributed to that story. The mass associated with columns spanning between levels were divided to the stories above and below based on tributary height between the levels, giving half of the columns mass to the level above and half to the level below. The other major assumption is that the building utilizes a rigid diaphragm. This is a reasonable assumption due to the relative rigidity of the slab compared to that of the lateral system. This is also reasonable due to the absence of shear walls, if shear walls were present as a lateral system in this structure the interaction between the slab and the walls would have to be carefully analyzed and detailed to transfer the large loads that the shear walls would take.

Details pertaining to the seismic calculations can be found in Appendix D, while a summary of the final seismic forces can be found in Table 5, for a pictorial view of the forces being applied at the various story levels see Figure 7.

ASCE 7-05 Seismic Calculations			
Level	**Level Weight (kips)**	**Level Height**	**EQ Force (kips)**
Penthouse	315.4	92'-0"	17.24
Stair Roof	74.3	82'-0"	3.41
Roof	1616.0	72'-0"	60.77
5th Floor	2282.7	58'-0"	61.71
4th Floor	2348.6	44'-0"	41.64
3rd Floor	2401.9	28'-0"	21.36
2nd Floor	2567.1	12'-0"	6.26
Ground Floor	N/A	0'-0"	0

Table 5: ASCE 7-05 Seismic Calculations

Earthquake Forces

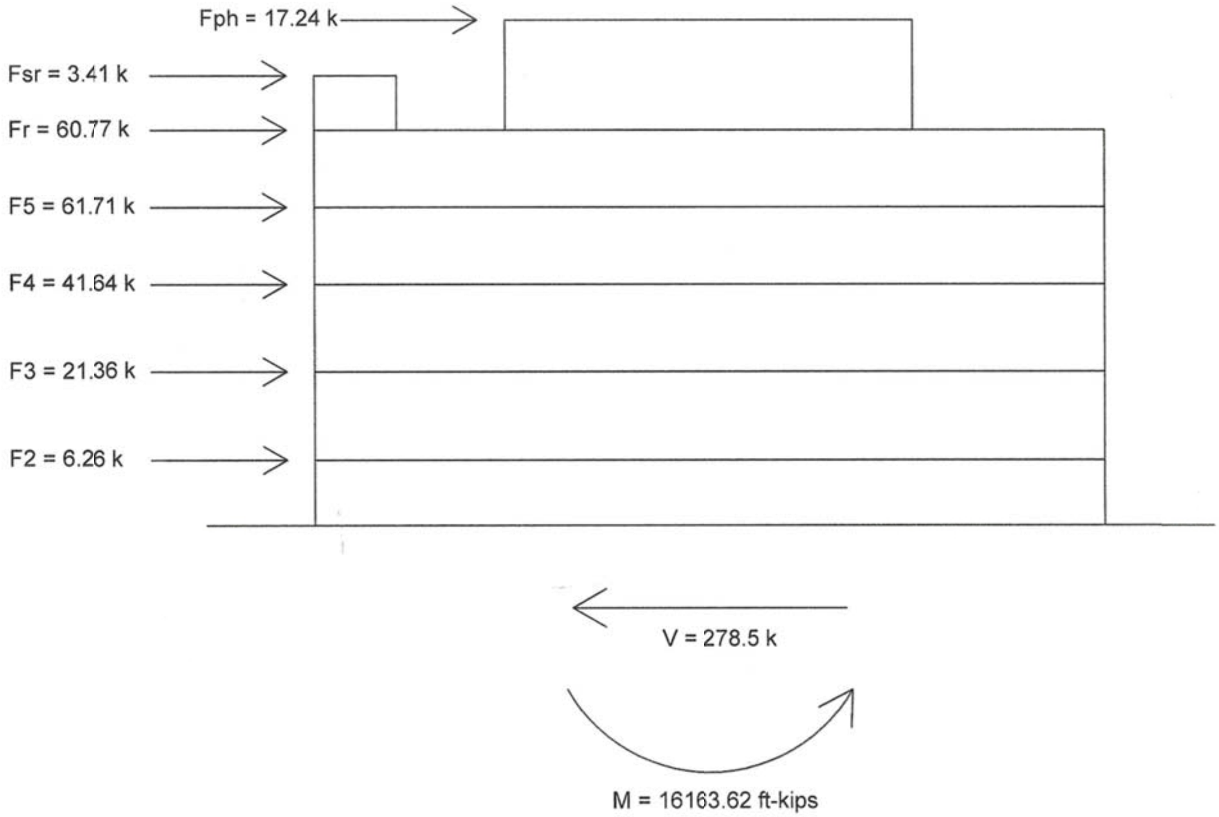

Figure 7: Earthquake Forces at Various Levels

Problem Statement

Technical Reports I, II, and III proved that the gravity and lateral systems utilized in the UPMC Hamot Women's Hospital are adequate for both strength and serviceability requirements. The major question throughout this project was based on the lateral system choice and the construction methods chosen with respect to tearing down the existing structure and starting over, or to do as the design team did and use the lower floors of the existing structure while reinforcing as needed. The decisions made for these issues were driven by various factors, primarily the architecture and building cost. The architect requested an open floor plan and was clear that the use of braced frames could not work with his visions for the spaces. Thus the use of very long moment frames was used; these connections are expensive and time consuming to produce. The construction team deemed that the use of the existing building floor plan would lead to the most cost effective building, although this would require almost all of the existing columns and beams to be reinforced, as well as several of the footings needing to be excavated and reinforced. A detailed cost analysis of this was never actually done, but the recommendation of the construction team was taken. The use of the existing system is also not desirable because many of the spans were deemed to not be as efficient, through using long-long-short spans. Designing a system that can incorporate with the architecture as well as be a more cost effective alternative is what is desired.

Problem Solution

Through the discoveries of these various Technical Reports and background knowledge of the building history various aspects of this project shall be analyzed. First a comparison of building codes (ASCE 7-05 vs. ASCE 7-10) will be done with special care being taken to analyze how the changes to the wind loading sections of the code affect this and other structures. Secondly the existing moment frames will be redesigned as braced frames, with special care being taken to incorporate them with the current architectural theme, or hide them within the structure as needed. This will be done using the loads determined through the use of ASCE 7-05 to allow for an equivalent comparison to the lateral system that is being utilized in the existing building. Then an analysis will be done to examine how starting from 'scratch' could have affected the structure. This will be accomplished through finding new locations for columns (not using the existing grid), hopefully being able to find a more efficient layout. Constraints will be imposed to maintain the same building footprint and room areas, etc. This will allow for fewer construction cost variable and a more accurate final assessment. Obviously these alterations will affect other aspects of the building. For example placing braced frames inside of a wall will require a wider wall system and possible relocation of doors. These issues will be dealt with through various breadth topics discussed below.

Breadth Study I

The redesign of the buildings lateral system will undoubtedly have an impact on the buildings architecture. The architect was adamant about not having braces disrupt the floor plan of the hospital. Hiding the frames inside of the wall will maintain the open rooms, but may require the relocation of some of the doors within the building. Thus an architectural breadth will be required to analyze how these changes influence the architectural appearance of the UPMC Hamot Women's Hospital.

Breadth Study II

When redesigning the building as a 'new' structure and thus ignoring the existing column grid and starting from scratch poses a very interesting question. Will it cost more? This is unknown but was speculated by the construction team to be the case. A more in-depth study of this should be done before any conclusion can be drawn. Thus a construction management breadth will be done to analyze the cost and schedule differences associated with this alternative.

MAE Course Related Study

Utilizing the knowledge gained through taking AE 534, Steel Connections, several typical connections will be analyzed for both the existing moment connections and the alternative braced connections.

Information gained through taking AE 597A, Computer Modeling of Building Structures, will also be utilized but adapted to this project. RAM Structural Systems will be the primary method of computer analysis. This platform was not explicitly taught as part of this course, but through teaching myself this platform and not blindly trusting the computer solution, the coursework becomes applicable.

Tasks and Tools

ASCE Load Comparison

- Comparing ASCE 7-05 and ASCE 7-10 Loads
    - Gravity Load Comparison
    - Lateral Load Comparison
        - Wind and Seismic
- Determine impact that the new code would have on this structure
    - Increase or decrease member sizes?
        - Columns Only
        - Beams Only
        - Both Columns and Beams
    - Increase or decrease in load results in heavier or lighter building?
- Discuss and compare results

Braced Frame Analysis and Design

- Locate potential places within the existing structure where a braced frame could be hidden from the building occupants (Sketch Elevations)
    - Using RAM Steel determine the required member sizes to support both gravity and lateral loads for both strength and serviceability
    - Analyze the structural impacts of changing the lateral system
    - Analyze the architectural impacts of changing the lateral system
- Design connection for the existing moment frame
- Design connections for the typical braced frame
- Discuss and compare results

New Building Analysis and Design

- Determine a feasible alternative column grid within the existing structure
- Use RAM Steel to design the gravity and lateral system for the new column grid
    - Compare the alternative structure to the existing structure based on structural weight and performance characteristics
- Determine cost comparisons between the as built and alternative building
- Determine schedule comparisons between the as built and alternative building
- Discuss and compare results

Thesis Schedule

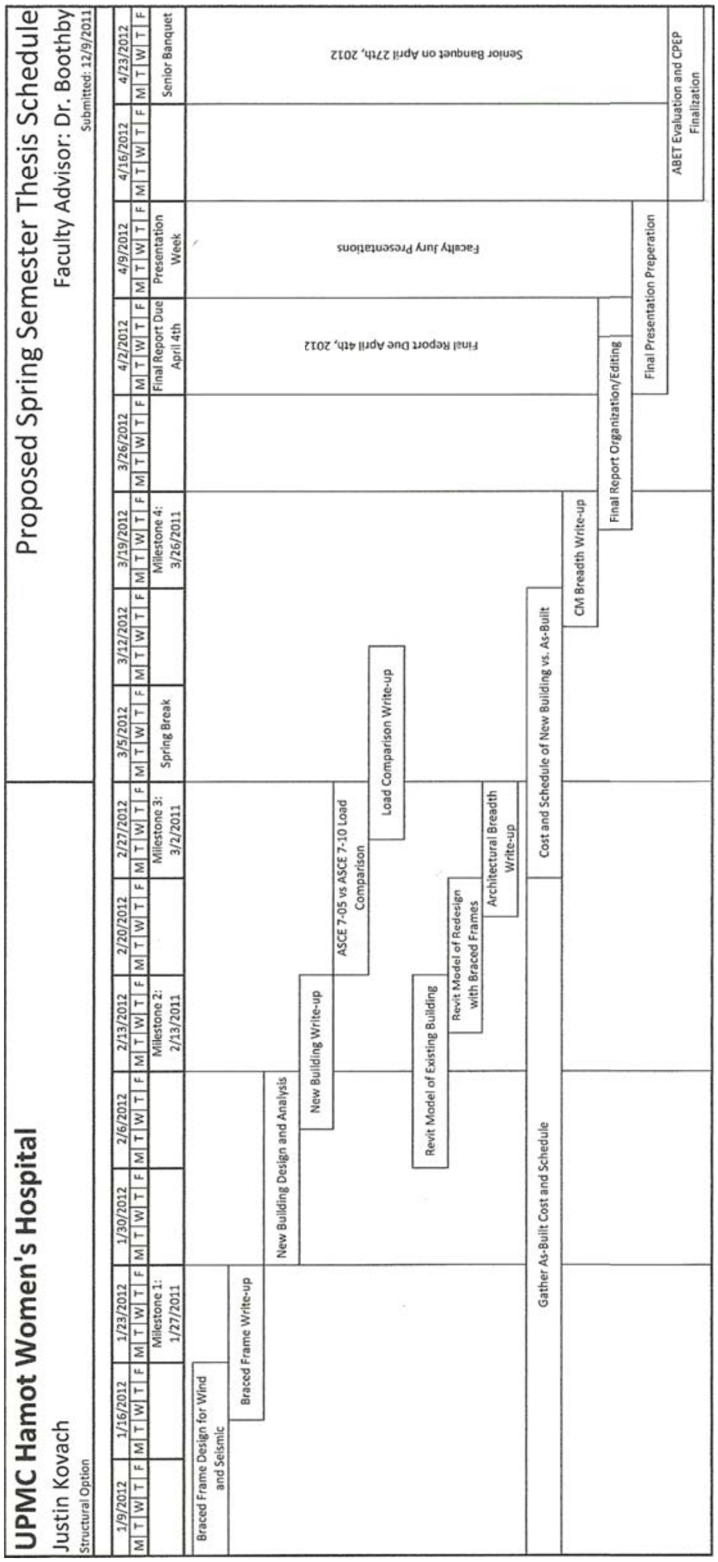

Figure 8: Proposed Thesis Schedule

Conclusion

The structural depth for this thesis will be split up into three distinct investigations. An investigation on the new building code with a comparison to the previous edition and how it affects the structural weight and performance will be done. An investigation into the possibility of effectively utilizing braced frames rather than moment frames will be completed. Finally, an investigation into a complete building redesign without using the existing structure or grid will be done to determine if the correct decision was made by the construction team.

As these elements are completed two breadth studies will be undertaken. An architectural breadth will be done to analyze the impact on the architecture that the braced frame system has on the building. A construction management breadth will also be done to analyze the impact of not using the existing structure and grid to build from.

Results from all of these studies will be summarized in a final report on or before April 4th, 2012.