



Thesis Proposal

University Hospitals
Case Medical Center
Cancer Hospital

11100 Euclid Avenue Cleveland, Ohio

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Structural Option
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<http://www.engr.psu.edu/ae/thesis/portfolios/2009/dcm234>

Executive Summary

The University Hospitals Case Medical Center Cancer Hospital is a 9 story research and patient care facility located in Cleveland, Ohio. Its infrastructure consists of steel and steel composite members which have been carefully arranged in order to conform to the modular architectural design system known as the *Universal Grid*, allowing full optimization of available space for varying use. Sloped curtain walls envelope the Cancer Hospital, consisting of exterior glazing and curved steel. The new Cancer Hospital will serve as an addition to the adjacent Case Medical Center which will integrate medical services once spread through 7 different buildings.

The Cancer Hospital has been evaluated in 3 previous technical assignments involving a study of the overall structure, various slab systems, and the existing lateral frames. Through information obtained from these reports, areas of concern were developed for research and investigation. These areas primarily involve the serviceability of the structure in respect to vibration, drift, and torsion. Improvement in these areas will result in an increase in efficiency for the sensitive areas of the Cancer Hospital including rooms used for surgery, advanced research, and medical imaging.

This proposal establishes the distinct concerns mentioned and presents a method of research and evaluation for each. In addition to research conducted on the structure of the Cancer Center, two breadths are presented for study. These breadths include a construction management evaluation which will determine the impact of the proposed revisions on the cost and schedule of the project as well as a building envelope study which will present any additional areas of concern.

Tasks have been presented which are necessary to obtain sufficient information needed to propose a revised design. This design will improve the serviceability of the Cancer Hospital and thereby improve the efficiency of its sensitive areas.

A schedule has been developed and presented in order to more accurately depict the progress of research and design over the course of spring semester 2009.



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Introduction



The University Hospitals Case Medical Center Cancer Hospital will integrate patient care and cancer research in a new and innovative way. Architecturally, the Cancer Hospital will reflect this cutting edge link by joining adjacent buildings together while serving as a primary gateway to the UHCMC campus located in Cleveland, Ohio.

The Cancer Hospital design fulfills the wishes of former facility cancer patients in creating an appealing and comfortable environment as opposed to the sterile feel of the past. This is accomplished through use of strong architectural accents including the Cancer Hospital's

most dominating feature, its curved facade. A universal grid system consisting of 31'-6" modular bays has been incorporated into design to optimize floor space for varying uses. Clinical pods have been designed for treatment of specific patient populations.

Medical services which were previously distributed among seven facilities will now be performed under one roof to optimize cancer research, education, and patient care while providing an architecturally appealing exterior as well as a warm and inviting natural interior.

The Cancer Hospital has been evaluated previously in 3 technical reports including an overall structural study, a slab evaluation, and a lateral system analysis. Through information obtained from these reports, certain key areas of concern were developed. These distinct areas primarily involve serviceability in respect to vibration, drift, and torsion. Improvement in these areas will increase the efficiency of the vital sensitive spaces in the Cancer Hospital including the surgery, imaging, and research areas. In addition to the structural research to be performed, two breadths are presented for study. These breadths include a construction management study which will determine the cost and schedule effect the proposed revisions will cause, as well as a building envelope evaluation to determine any additional areas for concern.

This proposal will present the intended tasks necessary to obtain sufficient information needed to ultimately propose a revised design which will improve the serviceability of the Cancer Hospital, and thereby improve efficiency of its sensitive areas.

A schedule has been developed in order to more accurately depict the progress of research and design over the course of the spring semester of 2009.

Existing Structural Systems

Foundation

The Cancer Hospital consists of drilled piers transferring load to caissons for the gravity columns with the combined use of grade beams for the lateral force resisting frames. The drilled gravity piers/caissons range 30" to 60" in diameter depending on location. The drilled piers/caissons receiving lateral load are typically 66" in diameter. Along the south side, 36" thick spread footings, typically 48" by 72", have been used to carry gravity load along the existing adjacent Case Medical Center Hospital. The grade beams which carry the lateral load to the drilled piers/caissons are typically 24" by 24" and consist of Grade 60, #7 reinforcement bars. All foundations are made from concrete having a compressive strength of 4000psi with the exception of the caissons and spread footings, which have a strength of 3000psi.

The soil on site has been classified as hard shale (see Figure 1). Thus, giving the caissons used in the foundation an end bearing capacity of 50kpf with a skin friction capacity of 10psi below the first 5' of shale. The typical minimum penetration depth for the gravity piers/caissons is 3'-0" and for the lateral, 16'-6".

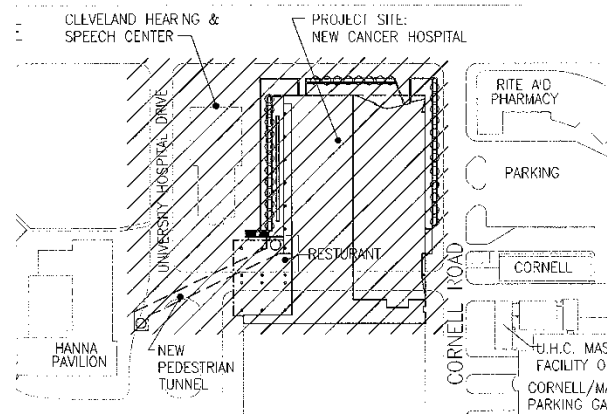


Figure 1

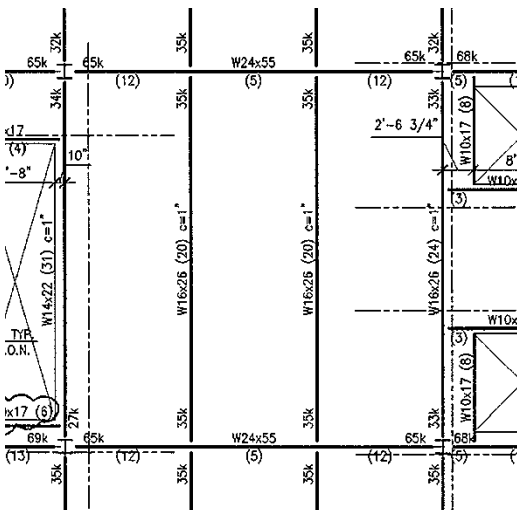


Figure 2

Floor System

Being a primarily steel structure, the Cancer Hospital has a fairly typical composite steel beam and girder framing system. The typical composite floor slab is 5-1/4" thick using 3000psi lightweight composite concrete, an 18 gauge 2" galvanized steel deck, and 3-1/2" metal studs. This composite floor slab is used on all but the 2nd and 8th floors. The second floor requiring a thicker slab with normal weight concrete due the vibration requirements of the surgery and imaging rooms and the 8th due to the increased load from the mechanical system. The slab used on these floors consists of 6-1/2" thick 3000psi normal weight concrete, an 18 gauge 2" galvanized steel deck, and 3-1/2" metal studs. Both decks are reinforced with 6x6 Welded Wire Fabric; W4.5xW4.5 for the first floor, W3.5xW3.5 for the second and eighth floors, and W2.1x2.1 for the remaining floors.

Framing

Bay sizes conform to the universal grid, having a typical size of 31'-6" by 31'-6". Infill beams are typically W16x26 around the interior and W14x22 around the exterior framing into W24x68 girders (see Figure 2). For the larger breaks in the slab, such as the elevator shafts, HSS 8x4x1/4 tubes have been used. On the 4th and roof level, moment connections are utilized in conjunction with cantilevered beams in order to support the curved exterior façade. Smaller breaks used for mechanical, plumbing, etc., consist typically of W10x17. Columns consist of a typical W14 member decreasing in size with elevation and spliced every other floor starting with the second. All steel members conform to ASTM A-992, Grade 50 unless otherwise noted.

Ground Level

At the ground level, a 6" thick slab-on-grade is used with Grade 60 #5 reinforcement bars spaced @ 18" oc EW. The slab rests on a 10 mils min. vapor barrier on compacted granular material over a 2000psi mud slab. In the northeastern and southeastern section of the building special research equipment has been placed requiring a 12" thick slab-on-grade with Grade 60 #5 reinforcement bars placed @ 12" oc EW.

Machine Room

A 31'-0" by 63'-0" machine room is located on the 8th floor. Framing is similar to the rest of the structure however with shorter spans and larger members to account for the additional weight. Beams range from W21 beams to W40 beams depending on specific equipment.

Roof System

The roof of the Cancer Center is a sloped deck with a 63'-0' by 63'-0" elevator penthouse perched at the southern corner. The roof slopes downward along the east and west sides of the building and allows drainage to the center third. The roof system consists of a 3"x20ga type 'N' galvanized steel deck. The roof deck rests typically rests on W14x22 beams framing into W21x44 girders with W18x35 beams being used to support mechanical equipment spaced uniformly across the building's center. Roof decks lower than the top of the 8th level consist of 1.5"x20ga. type 'B' galvanized steel deck (see Figure 3).

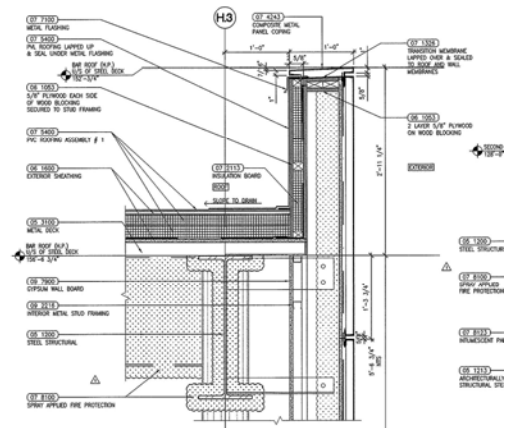


Figure 3

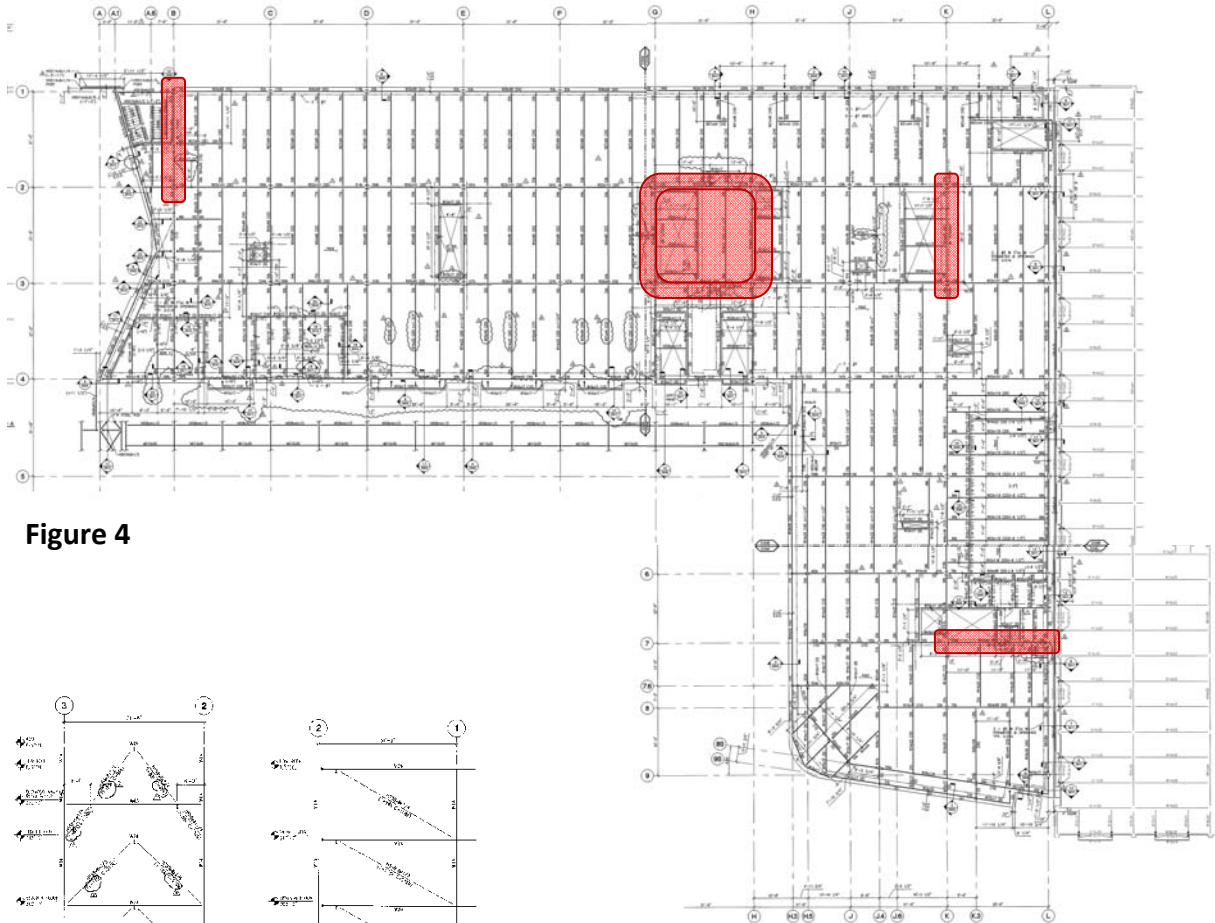


Figure 4

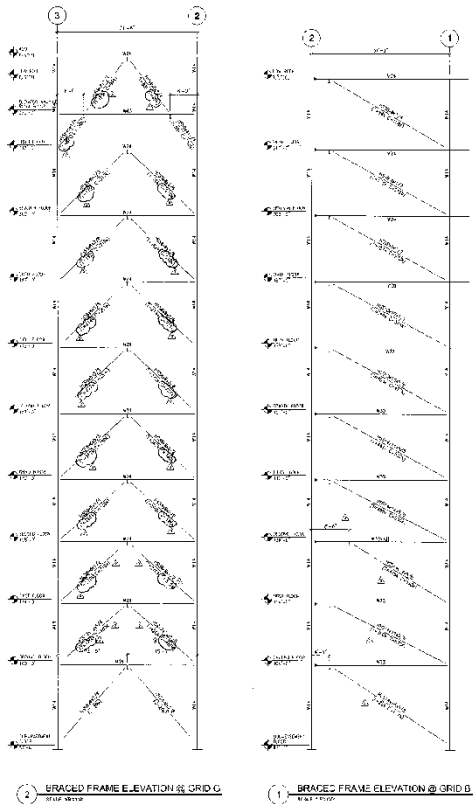


Figure 5

Lateral System

Lateral forces are resisted by a series of concentrically braced frames located at the center of the building near the main elevator core and along isolated points of the exterior bays (see Figure 4). This system consists of four chevron braces and two diagonal braces, which are used both in the north/south direction as well as the east/ west direction. Each brace typically consists of a 31'-6" wide W24 beam, a 15'-0' tall W14 column, and two HSS8 size diagonal members (see Figure 5). Structural brace members beyond the 8th floor increase in size due to increased lateral loads.

Background

Through the analysis of the University Hospitals Case Medical Center Cancer Hospital in 3 different Technical Reports involving the overall structure, various slab proposals, and a lateral system evaluation, certain key areas of concern were developed. These areas are based on the strict movement limitations required due to the certain uses of the Cancer Hospital.

The current Cancer Hospital design has located imaging and surgery rooms throughout the 3rd level, imaging rooms on the 3rd and ground levels, and advanced research equipment on the ground and sub-ground levels (see Figure 6). The location of these uses requires an abnormal restriction of movement when compared to typical buildings. This movement must be limited in respect to vibration, drift, and torsion.

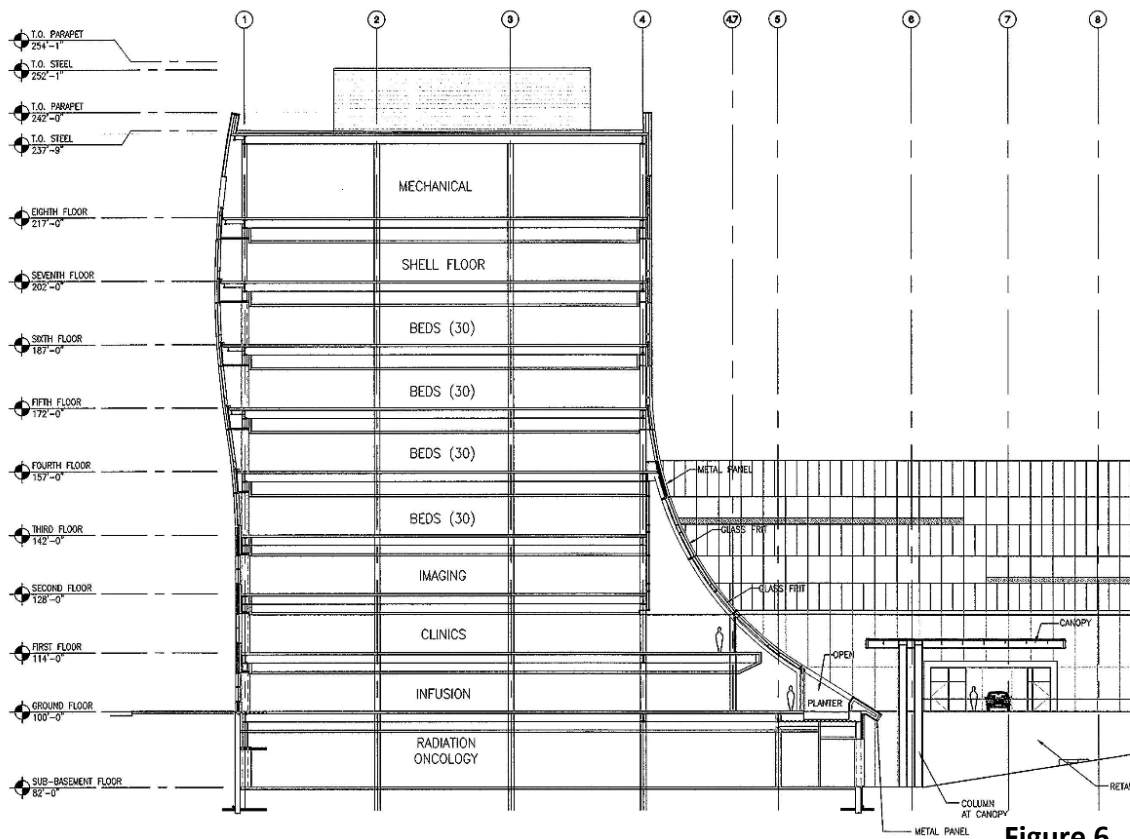


Figure 6

Problem Statement

The existing Cancer Hospital design is been found to adhere to all drift limits and strength requirements as per all applicable codes. However, due to the Cancer Hospital's sensitivity to movement caused by the location of advanced research equipment, surgical rooms, and imaging, a further investigation into the reduction of vibration, drift and, torsion in the building is required.

Solution

Vibration

An in-depth investigation of the stringent vibration requirements necessary for peak performance in regard to imaging, research equipment, and surgical rooms will be conducted. An adequate understanding of the effect of vibration on these subjects will be obtained and improvements to the current structural system will be evaluated. In conjunction with data obtained from *Technical Report 2*, this additional information will be used to propose the most efficient method of reducing vibration to a level which does not compromise surgery, imaging, or research.

Drift

From the results of *Technical Report 3*, it was found that a maximum drift of 3.156" occurred in the north/south direction due to wind which amounts to a drift ratio of approximately $h/500$. When compared to the $h/400$ allowable drift ratio, it can be seen that a sizeable amount of drift occurs. In order to reduce this value, an evaluation of the effect of the use of different lateral systems will be conducted. Systems which will be evaluated include Moment Frame, Dual Braced Frame-Concrete Shear Wall Core, and Steel Truss. Once data from these systems has been obtained, the most efficient solution will be proposed and determined to be feasible based on the effect of the required change.

Torsion

The current design of the lateral frames in the Cancer Hospital were found in *Technical Report 3* to be adequate in carrying the combined force from direct shear and torsion. However, the loads on each frame did not appear to be evenly distributed over the structure as a whole. Atypical configurations and irregularities in frames were found to cause stress reversals and contribute to the uneven distribution of forces. In order to address this concern, investigation will be conducted to determine the cause and effect of these abnormal frame sections. In conjunction with the research of different lateral systems in order to reduce drift, the movement of these systems to more optimal positions in order to reduce torsion will be evaluated.

Breadth Options

Construction Management

Upon final selection of the optimal structural system to reduce vibration, drift, and torsion, a cost comparison will be conducted to evaluate the cost and feasibility of the existing Cancer Hospital design and the proposed design change. In addition to cost, scheduling of project phases and tasks will be performed for the revised system and will be compared to that of the existing design.

Building Envelope

Due to the atypical curved facade of the Cancer Hospital, an investigation into the construction, efficiency, and cost of the current building envelope will be conducted. Material used, methods of installation, and serviceability in conjunction with the affiliated cost will be researched and evaluated based on specifications to determine any areas of concern. In the event that any issues are identified, solutions will be proposed and investigated for feasibility.

Codes and References

Codes

IBC 2006 International Building Code

ASCE-7-05 Design Code for Minimum Design Loads

LRFD Specifications for Structural Steel Design – Unified Version, 2005

References

CRSI Handbook

United Steel Deck Manual

RS Means Building Construction Cost Data (2009)

ETABS V9.2.0

RAM Structural Systems

PCA Slab

PCI Design Handbook/6th Edition

Tasks

Vibration Research

- Investigate the effect of vibration on the basic structural elements of a building through consultation of AE Faculty, coursework, code, and applicable design aids.
- Apply vibration information obtained to the structure and environment of the Cancer Hospital.
- Establish limits and recommended values to be used in the evaluation of solutions to lower the vibration in the Cancer Hospital.
- Select and evaluate proposed solution using applicable software based on material configuration.

Drift Reduction

- Gather necessary information on the design of the 3 lateral systems to be tested; Moment Frame, Dual Braced Frame-Concrete Shear Wall Core, and Steel Truss.
- Create a Model of each system in *ETABS* and check for accuracy using design aids, hand calculations, and applicable codes.
- Evaluate results through a comparison between systems and select most efficient to be used in the redesign of the lateral structure of the Cancer Hospital.

Torsion Reduction

- Investigate bracing irregularities and determine cause for use.
- Using the created *ETABS* models, evaluate the effect of the location changes of each system in effort to reduce torsion throughout the building.
- Propose a solution which will more evenly distribute forces throughout out the frames or walls in the Cancer Hospital.

Construction Management Breadth

- Compare added cost of proposed lateral changes and revisions for vibration reduction using *RS Means* .
- Create a schedule which has been revised based on the proposed changes and compare with existing schedule.
- Configure the impact that the proposed changes make on the project and prepare for presentation.

Building Envelope Breadth

- Research and analyze existing building envelope using provided specifications and design documents.
- Make note of any areas of concern to be evaluated in effort to reduce chance of a failure.
- If deemed necessary, propose a solution and evaluate affect of the construction cost and revised schedule.

PROPOSED SCHEDULE

| | | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 | Week 8 |
|-------------------|--|-----------|-----------|-----------|---------|----------|-----------|-----------|---------|
| Task | | Jan 12-16 | Jan 19-23 | Jan 26-30 | Feb 2-6 | Feb 9-13 | Feb 16-20 | Feb 23-27 | Mar 2-6 |
| Vibration | Investigate Vibration | █ | █ | | | | | | |
| | Apply Research to Cancer Hospital | | █ | | | | | | |
| | Establish Limits and Value for Reduction | | █ | █ | | | | | |
| | Propose Solution and Evaluate Using | | | █ | █ | | | | |
| Drift | Gather Information on Proposed Lateral | | | █ | █ | | | | |
| | Model Each System and Check for Accuracy | | | | █ | █ | | | |
| | Evaluate Results and Compare Systems | | | | █ | █ | | | |
| Torsion | Investigate Bracing Irregularities | | | | | █ | █ | | |
| | Model Location Changes and Evaluate | | | | | | █ | | |
| | Propose Solution for Even Distribution | | | | | | █ | █ | |
| CM | Compare Cost of Proposed Changes | | | | | | | █ | |
| | Create Schedule | | | | | | | █ | █ |
| Building Envelope | Compare Cost and Schedule to Existing | | | | | | | | █ |
| | Research Existing Envelope | | | | | | | | |
| | Evaluate Areas of Concern | | | | | | | | |
| | Propose Solution if Necessary | | | | | | | | |

PROPOSED SCHEDULE

| | | Week 9 | Week 10 | Week 11 | Week 12 | Week 13 | Week 14 | Week 15 | Week 16 | Week 17 |
|-------------------|--|----------|-----------|-----------|-----------|----------|-----------|-----------|----------|---------|
| Task | | Mar 9-13 | Mar 16-20 | Mar 23-27 | Mar 30 -3 | Apr 6-10 | Apr 13-17 | Apr 20-24 | Apr 27-1 | May 4-8 |
| Vibration | Investigate Vibration | | | | | | | | | |
| | Apply Research to Cancer Hospital | | | | | | | | | |
| | Establish Limits and Value for Reduction | | | | | | | | | |
| | Propose Solution and Evaluate Using | | | | | | | | | |
| Drift | Gather Information on Proposed Lateral | | | | | | | | | |
| | Model Each System and Check for Accuracy | S | | | | | P | | | F |
| | Evaluate Results and Compare Systems | p | | | | | r | | | i |
| Torsion | Investigate Bracing Irregularities | n | | | | | e | | | n |
| | Model Location Changes and Evaluate | g | | | | | s | | | a |
| | Propose Solution for Even Distribution | B | | | | | t | | | i |
| CM | Compare Cost of Proposed Changes | a | | | | | a | | | e |
| | Create Schedule | k | | | | | t | | | x |
| | Compare Cost and Schedule to Existing | | | | | | i | | | a |
| Building Envelope | Research Existing Envelope | | | | | | n | | | m |
| | Evaluate Areas of Concern | | | | | | | | | s |
| | Propose Solution if Necessary | | | | | | | | | |

Conclusion

Through vibration research, a drift analysis analyzing three distinct lateral systems, and a torsion reduction study, a proposed revision to the existing design of the University Hospitals Case Medical Center will be established. This revision will allow for increased efficiency in the sensitive areas of the Cancer Hospital including surgery rooms, imaging rooms, and research labs. This efficiency will be obtained by decreasing the movement caused by vibration, drift, and torsion.

Upon completion of the design proposal, a final report will be prepared and subsequently presented members of the structural engineering profession during end of spring semester 2009.

