UNIVERSITY OF ROCHESTER
BME / OPTICS BUILDING

Thesis Proposal

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AE 481W – Senior Thesis
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University of Rochester
BME / Optics Building

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Executive Summary

Building Description
The University of Rochester BME / Optics Building provides laboratory, research facility, office, classroom, and lecture spaces for the acclaimed Institute of Optics and emerging Biomedical Engineering Department. It is a 100,000 sq. ft. facility, standing five stories with an additional mechanical penthouse and partial basement.

The structure of the BME / Optics Building consists of composite steel beams and girders on W12 steel columns. The column layout of the building is based on the irregular footprint and the spatial uses of the building. As a result, the layout consists of square bays with relatively short spans. For lateral stability, concentrically braced frames in the short, east-west direction and moment frames in the long, north-south direction are used.

Proposal
The current structural system of the building was found in previous reports to be well-designed and well-suited to meet all of the unique demands of this building. However, exploring an alternative, concrete structural system in depth will help develop an understanding of what type of advantages can be gained. This report proposes a thesis project involving structural redesign.

Depth Topics
First, the layout and geometry of the steel system will be considered, since composite beams tend to be inefficient in short spans. Then, a complete structural redesign using concrete is being proposed. The new floor system will be a cast-in-place concrete flat slab, using drop panels and edge beams. The lateral system will utilize the edge beams as a moment frame in one direction, but will also use a number of shear walls to resist lateral load. Detailed floor vibration analysis will be performed for laboratory spaces.

Breadth Topics
1. Cost and Scheduling Impact – to determine the effects the new system will have on meeting or exceeding budget and time constraints
2. LEED Rating (Option) – to design one or more specific ways, unique to this building, that will make it more environmentally friendly
3. Atrium Space Analysis (Option) – acoustics, lighting, or innovative mechanical system

Introduction / Scope

Through three technical reports, the steel-framed structure of the University of Rochester BME / Optics Building was determined to be well-designed, meeting all the spatial, architectural, and functional challenges in an effective manner. The purpose of this report is to propose a thesis project that will explore an alternative structural system in order to determine what advantages, if any, can be gained. The effects of the alternative system on the various different aspects of the building will also be explored in the proposed thesis.

Background

The Institute of Optics at the University of Rochester was founded in 1929 as the first optics education program in the United States. Almost 80 years later, it remains a cutting edge program and one of the finest educational and research institutions in the country. The Institute of Optics, along with the Biomedical Engineering Department, are currently obtaining a new facility to cater to the increasing needs of these highly regarded programs. The new facility, currently known as the BME/Optics Building, began construction in January of 2005, with a scheduled completion of December 2006.

Architecture

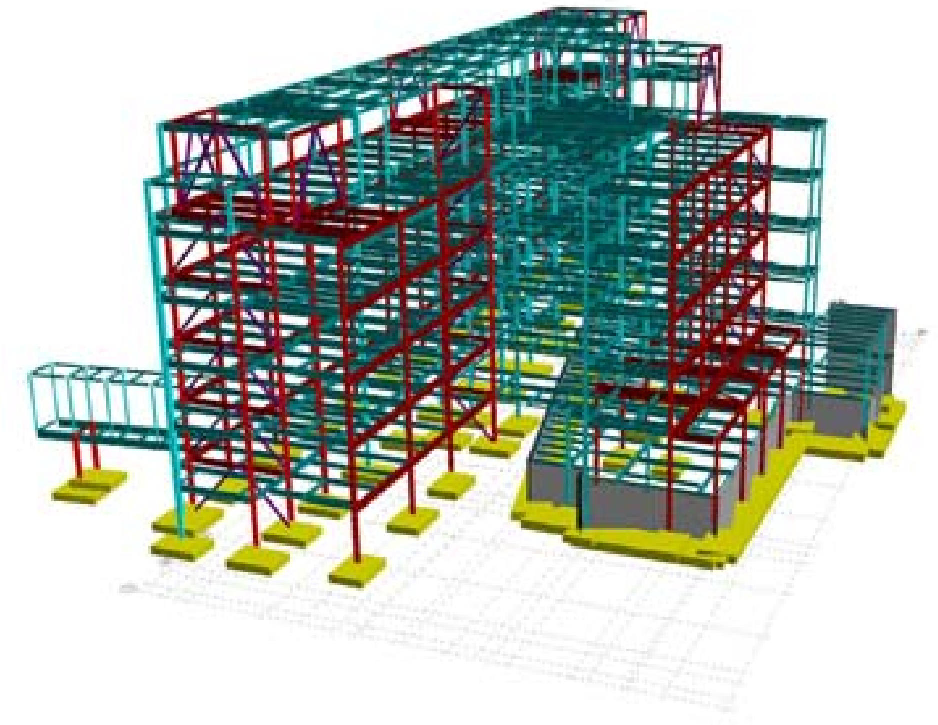
The BME/Optics Building is strategically located on the south end of the U of R River Campus, across the street from the Medical Center. It is built adjacent on two sides (with pedestrian access on two floors) to the current Biomedical and Optics facility, the Wilmot Building. Also, a second floor pedestrian bridge connects the new BME/O Building to the nearby CSB Building to provide access to computer lab and library services.

The façade of the building is primarily clay brick with limestone at the first floor level. Key architectural features of the building include channel glass façade at stairwells and an 80’ atrium inside the main entrance to be lit by skylights. The 100,000 square foot structure is 5 stories above grade plus a mechanical penthouse and partial basement, and consists of laboratory, classroom, and office space.

Structure

The foundation system used in this building consists of concrete pile caps supported by 50 ksi steel H-piles bearing on bedrock. There are several different pile configurations, but each has a design lateral load capacity of 4 kips. The foundation system also uses concrete grade beams at different sections of the building. These include support of the exterior façade and framing around an existing steam/utility tunnel running under the footprint of the building. Since this tunnel supplies several buildings on this section of campus, its complete functionality throughout construction of BME/O was an important design consideration.

The typical floor system consists of 4 ½" concrete slabs on 3" composite metal deck. The load is distributed from the slab to composite steel beams and girders, and finally down to steel columns and the foundation. Figure 1 shows the column layout of a typical floor. Although the loads are relatively constant throughout the building, the steel shapes vary in size due to varying spans. This is because of the variation in size of the building's bays, designed to meet architectural and spatial challenges. The only "typical bay" redundancy occurs at the west end of the building, shaded in Figure 1 on the following page.



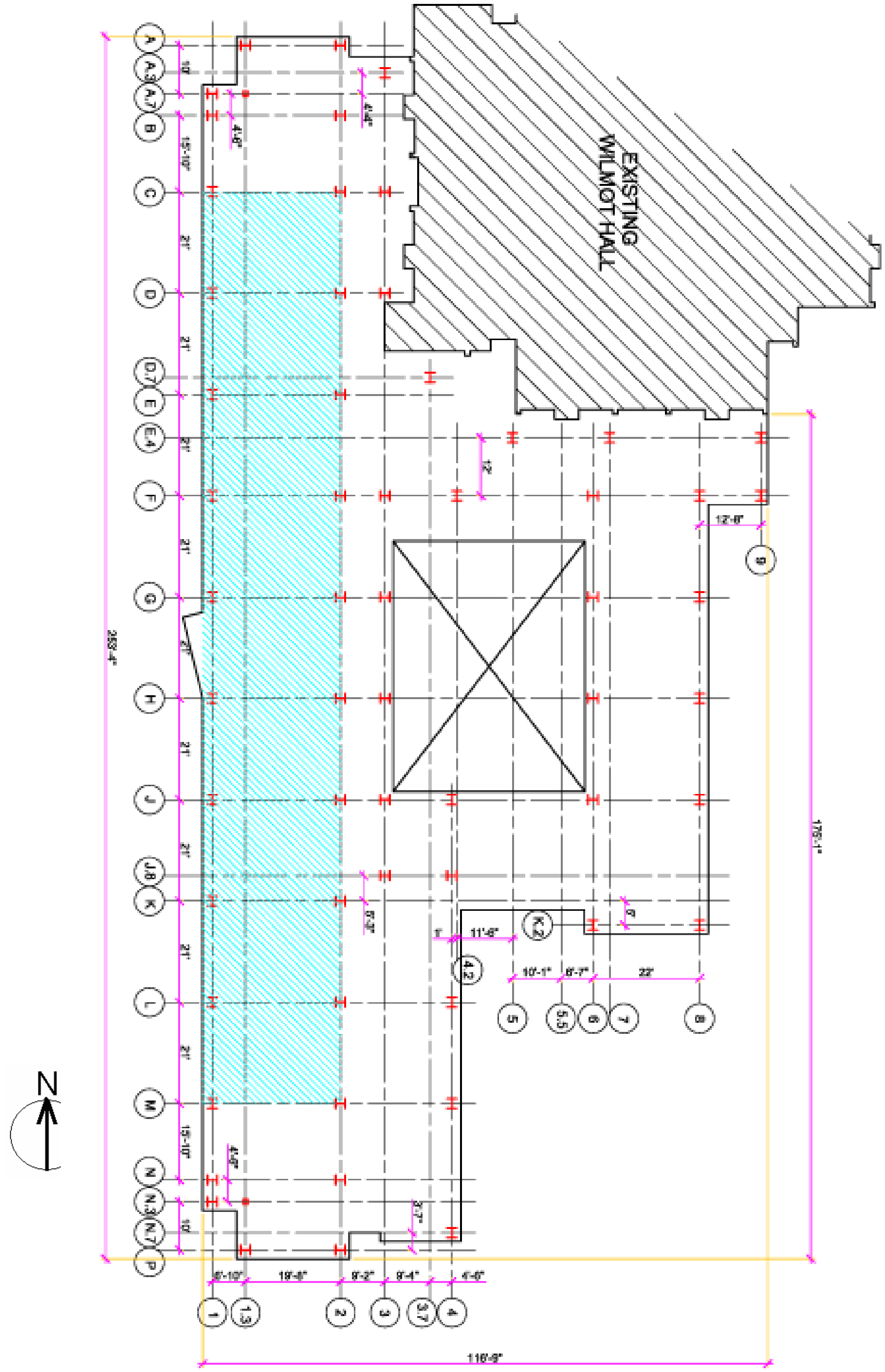


Figure 1 – Typical Column Layout, Floors 2-5, Critical Bays Shaded

Lateral forces due to wind and seismic loading were important design considerations for the BME/Optics Building. Since it was built adjacent to the existing Wilmot Hall on two sides, the lateral deflection was especially important. At these locations, the steel framing cantilevers out from the columns to form building isolation joints that increase in size from the first floor to the roof. Accuracy in lateral calculations was necessary to determine proper clearance.

The lateral system uses concentric braced frames in the short (E-W) direction, and ordinary moment frames in the long (N-S) direction. The four concentric braced frames use HSS 7x7x1/2 bracing members in a chevron configuration. Elevations are shown in Figure 2. The moment frames occur at the outer faces of the building. The moment frame at the east face is unique because the columns are not continuous to the ground. Transfer beams at the second level transfer gravity load around the lecture hall to different columns. To transfer lateral force, a horizontal truss is used at the roof of the lecture hall. This can be seen at the right side of the 3-dimensional framing model on page 3.

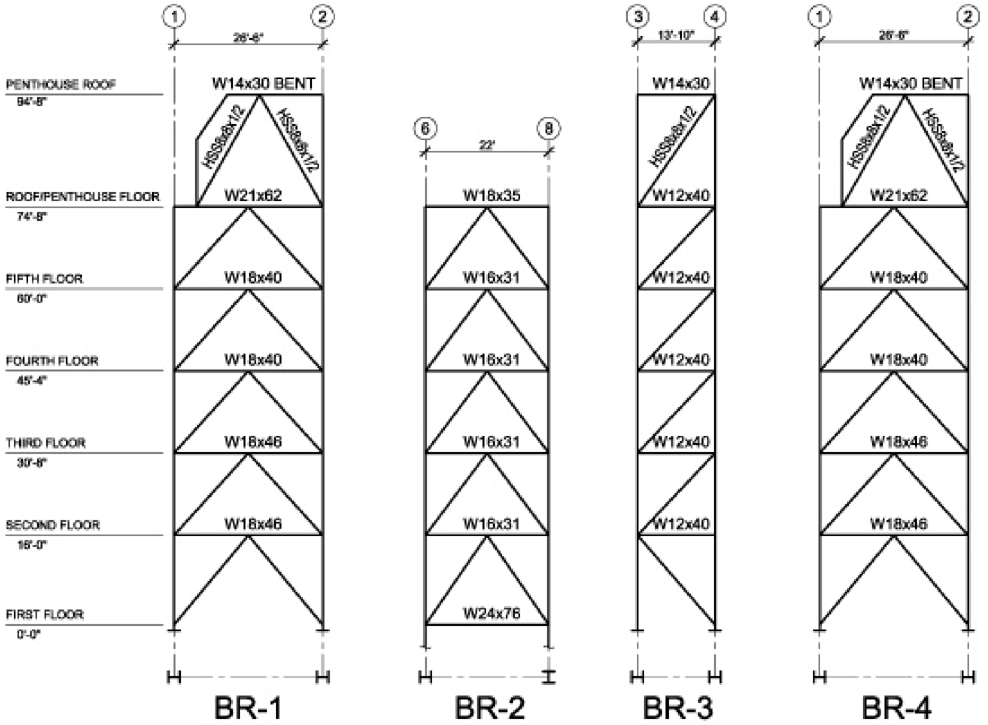


Figure 2: Braced Frame Elevations

Problem Statement

The existing structural system for the University of Rochester BME / Optics Building was determined, in previous technical reports, to be well-designed and uniquely suited to the building's architectural and functional demands. Steel is a familiar material for buildings in this area, and a sufficient labor force was available to complete the project and meet the required deadlines.

However, the deadlines for the completion of the project and the needs of the owner dictated an expedited design process. Although the current design works extremely well and was most effective at the time of construction, there is a possibility that alternative design options could prove to be more efficient and economical, had there not been a time constraint limiting consideration of alternative solutions. Use of composite steel in relatively short spans is often inefficient. The steel system used will be further analyzed to determine if gains can be made, and a concrete redesign of the structural system will be optimized to be used in comparison with the current design. Economy and scheduling impact will be the main criteria for comparison.

In redesign of the structure, several important considerations must be made. For one, there is a walking vibration criterion in laboratory spaces that may limit longer steel spans. Also, the functionality of the building must be considered. The location of columns and varying dimensions of the bays coincide with the architectural layout of the building. Changing the bay sizes or layouts significantly would probably require dramatic architectural changes, which is beyond the scope of this project. Also, the functional relationship with the adjacent Wilmot Hall limits floor-to-floor height changes.

Problem Solution #1 – Steel Optimization

The existing composite steel system will be further analyzed to determine if any gains can be made. These include a possible doubling of bays along the west face of the building, removal of columns in some instances to increase spans and reduce the number of members, and other geometric changes. An important change may involve one of the moment frames in which the columns are not continuous to the foundation. Transfer girders and a horizontal truss carry gravity and lateral loads to nearby columns to create a column-free space in the lecture hall at the first floor. Further analysis will be needed to determine if this can be avoided while still meeting the architectural goals of the building. As stated earlier, vibration criteria will need to be considered, which may be a concern when lengthening steel beam spans.

This steel optimization will be primarily as a basis for comparison to the concrete redesign.

Problem Solution #2 – Redesign in Concrete

The main focus of my proposed thesis is a structural redesign in concrete. Based on the relatively small, square bays, a flat slab cast-in-place concrete system seems to be ideal. In a previous technical report, a flat slab concrete system for this building was estimated, using CRSI Manual charts, to be an 8.5” thick with additional 7” drop panels and edge beams at the critical bays at the west end of the building (See Appendix A). At other sections of the building where bay size is smaller, drop panels may not be necessary.

Although the layout and geometries of the bays seem to dictate flat slab construction at this point, alternative concrete systems may be considered in an effort to optimize the switch to concrete. Shearheads, column size and spacing, and concrete strength will also be investigated to optimize the concrete redesign.

The switch to a concrete structural system also necessitates a redesign of the lateral system. The concrete system will require the design of shear walls for lateral stability. In the long direction, however, the edge beams and columns, which are poured together, form a natural moment frame. This will be considered as part of the lateral system, and the determination will be made as to how much additional lateral support, if any, will be needed in this direction.

In designing the concrete system, it will be necessary to determine the impact on the foundation and increase in seismic load due to added weight of the structure.

As another main focus of the proposed thesis, I will research and perform a detailed floor vibration analysis. The allowable vibration limit is 2000 micro inches per second for laboratory space, based on moderate walking speed vibrations alone. The mechanical equipment for the building is isolated from laboratory space in the mechanical penthouse. No other specific vibration from equipment has been specified at this stage of the project, although allowable “capacity” for what type of vibrations could occur in the concrete system will be determined, both for future considerations and to compare with the steel system.

Solution Method

Although the Building Code of New York State, used to design this building, references IBC 2000 and ASCE 7-98, upgrades to IBC 2003 and ASCE 7-05 will be used in this thesis project.

For the preliminary steel assessment, the current 3-dimensional RAM building model used in Technical Assignment #3 will be modified. This model uses LRFD steel design with design loads consistent with current codes.

In designing the flat slab system, a 3-dimensional computer model using ETABS (v.8) will be used, which provides detailed analysis using ACI 318-99. Various live load patterns and load combinations will be considered. Hand calculations and spot checks will use ACI 318-05 as an upgrade and basis for comparison.

Vibration analysis will also use the ETABS model, along with research and consultation with faculty.

Breadth Topics

Breadth Topic #1 – Cost and Scheduling Analysis

The new concrete structural design will be evaluated in terms of cost, constructability, and scheduling impacts. This study will involve a detailed cost estimate and preliminary schedule for a comparison with the current design. Important considerations will be availability of materials, equipment and an adequate labor force, cold weather issues, formwork design, lead time on rebar in comparison with steel members, and general feasibility.

Breadth Topic #2 (Option) – LEED Rating

As the tendency of the building industry has moving steadily towards green building technology in recent years, there has been an increasing demand for buildings to achieve a LEED rating. Especially in a collegiate atmosphere that strives to be at the cutting edge, there is a strong desire to be more economically friendly. Despite some concern, the BME/Optics Building did not achieve a LEED rating. This study will not merely involve a generic list of ways to achieve points towards a rating, but will instead involve research and design of one or more in-depth methods of making this building more environmentally friendly. It will involve a cost estimate and a return period if applicable.

Breadth Topic #3 (Option) – Analysis of Atrium Space

The atrium space inside the main entrance is one of this building's main highlights. This breadth option will involve one or more of the following studies:

- Natural lighting analysis in combination with conventional lighting methods
- Acoustic analysis and areas for improvement
- Innovative methods of heating/cooling, either supplementary or as an alternative

While Breadth Topic #1 is straightforward, options #2 and #3 are a bit generalized and vague at this point. After further research and investigation, it will be possible to narrow down the second breadth choice (between options #2 and #3) to come up with a more specific, focused idea. It may be possible to combine these into one, such as environmentally friendly HVAC system for the atrium space and how it contributes to LEED rating. Time has been allotted in the schedule to research the possibilities for a specific breadth.

Tasks

1. Further Evaluation of Steel Structural System

1.1. Investigation of where improvements can be made
1.2. Consultation with faculty
1.3. Adjustments to RAM model to determine new member sizes
1.4. Comparison with existing system to determine benefits

2. Concrete Flat Slab Design

2.1. Research applicable codes, design guides and methods
2.2. Set up building model in ETABS
2.3. Determine most effective design
2.4. Spot-check design using the direct design method
2.5. Evaluate unique conditions such as cantilevered stairs, penetrations, etc.
2.6. Recalculate building weight based on new dead load
2.7. Determine new column loads and design using PCA Col
2.8. Calculate impact on foundation
2.9. Research & analyze floor vibrations
2.10. Compare damping of concrete system with steel system

3. Lateral System Redesign

3.1. Recalculate lateral loads based on new building weight
3.2. Determine preliminary locations for shear walls and how many to use
3.3. Distribute lateral loads, evaluate initial shear wall layout (iterative process)
3.4. Design concrete moment frame and determine effectiveness
3.5. Finalize layout of lateral elements
3.6. Design shear wall reinforcement
3.7. Calculate torsional effects and building drift

4. Breadth #1: Cost & Scheduling

4.1. Perform detailed cost analysis of existing steel structure using CostWorks or MC2, using actual data obtained from GC, if available
4.2. Perform detailed cost analysis of new concrete design in a similar manner
4.3. Create a mock schedule of existing system using Primavera or actual scheduling information from the GC, if available
4.4. Create a mock schedule of the new concrete system using Primavera
4.5. Compare cost and scheduling, along with feasibility and overall impact of redesign

5. Breadth #2: TBD (LEED Rating / Analysis of Atrium Space)

5.1. Research and begin to investigate the additional breadth options described above
5.2. Determine a specific study that is most relevant, reasonable, and meaningful
5.3. Allow sufficient time to perform an in-depth study

Preliminary Schedule

TASK	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
	1/16-1/19	1/22-1/26	1/29-2/2	2/5-2/19	2/12-2/16	2/19-2/23	2/26-3/2	3/5-3/9	3/12-3/16	3/19-3/23	3/26-3/30	4/2-4/6	4/9-4/13
Revise proposal & Clean up remaining issues from AE 481	▨	▨							**SPRING BREAK**				
Concrete system design (ETABS)			▨	▨	▨								
Vibration Research & Analysis					▨	▨							
Recalculate Lateral Loads, Lateral System Design							▨	▨					
Preliminary ideas for steel optimization						▨							
Optimize steel system for comparison							▨	▨					
Research and finalize proposed breadth ideas			▨	▨	▨								
#1 – Cost / Scheduling / Feasibility										▨	▨		
#2 – LEED / Atrium Space											▨	▨	
Written report *(Due APRIL 9)*							▨	▨		▨	▨	▨	
Prepare / practice presentation *(APRIL 16)*													▨