SENIOR THESIS PROPOSAL

STRUCTURAL ANALYSIS and EFFICIENCY OF MATERIALS

Duquesne University Multipurpose/ Athletic Facility

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December 15, 2006
Senior Thesis Proposal

Executive Summary

Duquesne University's new multipurpose building, scheduled to be completed in January 2008, is a 125,000 square foot structure meant to house a multitude of facilities. In previous Technical Assignments, each structural system was studied and scrutinized. This proposal will delve deeper into several issues brought about by the previous tasks.

The upper floors of the building are used for athletic and large group activities. These areas are framed with long spanning steel members. When these areas are in use, serviceability issues, mainly vibration, are a concern. In my first study, I will look more closely at vibration and its effects on the structure.

In Technical Assignment 3, torsion related issues were found to be problematic. While torsion will be a topic, the lateral resisting system will be the main point of focus in several ways. Along with torsion studies, I will determine whether or not it is beneficial to use alternative braced framing configurations or alternate locations for the frames themselves.

Overall, the study will look at optimizing the overall structure and its many components. Material, cost, and schedule savings will be considered in all aspects of my study. In addition, other systems that can be modified (architecture, construction, acoustics, etc…) will be taken into account after all else has been completed.

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Introduction/Background

Duquesne University, located in the city of Pittsburgh, is in the process of expanding its campus. The land being developed is situated along Forbes Avenue, adjacent to the A.J. Palumbo Center, and "will be used for commercial and educational purposes, improving both the entrance to campus and the Forbes Avenue corridor." The first phase of the project, a multipurpose athletic facility, is currently under construction, and should be ready for use in January 2008. The building itself will be home to a variety of spaces including retail outlets, fitness and recreation facilities, athletic offices, and a ballroom/conference center.

The building is supported by a steel superstructure, including a composite steel floor system. Each of the first three floors are framed in rectangular bays, ranging in size from 20'x20' to 21'x34'. The upper athletic and ballroom floors are also composite steel, but are framed with longer spans (79'6") due to the open plan of the gymnasiums below.

Lateral resistance is provided by a system of concentrically braced frames located on all four faces of the structure. On the South face of the building, frames are constructed around both elevator shafts and a stair tower. The same is true on the North and West faces of the building where bracing is positioned at stair towers. The typical columns used in each of bracing elements are W14's ranging from W14x53 to W14x132. Each floor to floor section makes use of a series of cross braced HSS members ranging in size from HSS6x4's to HSS8x4's, 1/4" to 5/8" thick.

During the process of researching this structure in previous Technical Assignments, several issues have been discovered, and will be further researched.

- Framing Design
- Vibration control
- Material optimization
- Lateral stability/Torsion
- Lateral system design
- Design efficiency

Under construction 11/20/06

Design Considerations

Like any other structure, the Duquesne Multipurpose Facility was engineered to meet IBC and ASCE strength and serviceability code requirements. In the coming months, I will investigate the ability to redesign and optimize structural framing and lateral resisting elements of the building.

Design Efficiency

Within all of the following research topics is the subject of optimizing each individual structural system. Therefore, the overall goal of my research will be to create a more cost effective and structurally efficient building. This general thought will not be limited to the subsequent topics, but will be applied in any sense that seems appropriate.

Framing Design/Vibration

The lower levels of the Duquesne Multipurpose Facility are framed in rectangular bays, typically 31’4”x 21’0”. The first floor contains retail space, including a bookstore and coffee shop. The second and third floors are mainly comprised of aerobic, fitness, and weight training areas, as well as classroom and office facilities. The third floor also contains the first of two basketball courts. Along with the static loading conditions present, there are many dynamic and rhythmic activities taking place. It would stand to reason that vibration concerns would be taken into consideration during design.

The upper levels, floors 4 and 5, are framed out with 79’6” spans (Figure 1.1) and are the most susceptible to vibration driven design. The fourth floor is made up of the second of two basketball courts and two racquetball courts. A ballroom and lounge occupy the fifth floor. Since personal comfort and serviceability requirements will be most relevant here, these floors will be the most scrutinized during this structural investigation.

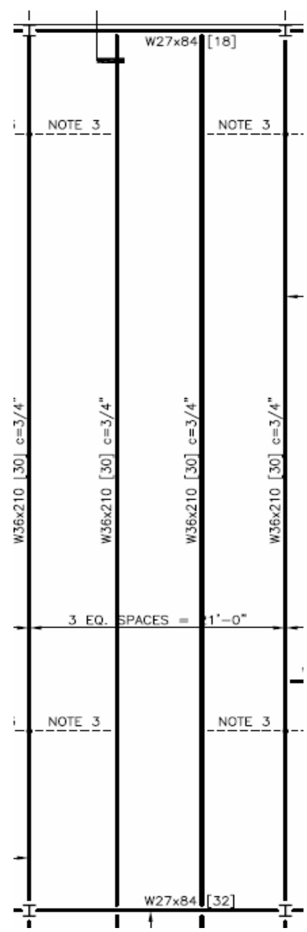


Figure 1.1 – 5th floor gymnasium

Material Efficiency

While researching vibration response characteristics in the framing, reducing member sizes and optimizing the framing system throughout the building is a goal.

When looking at the overall floor framing system, there are several aspects that have the potential for change. First, the floor slab 4.5" of concrete on 2" composite metal deck (Figure 1.2). The average deck spans 7'0". The combination of span and loading conditions leads me to believe that the floor slab can be reduced, and if so, the framing members may be reduced as well.

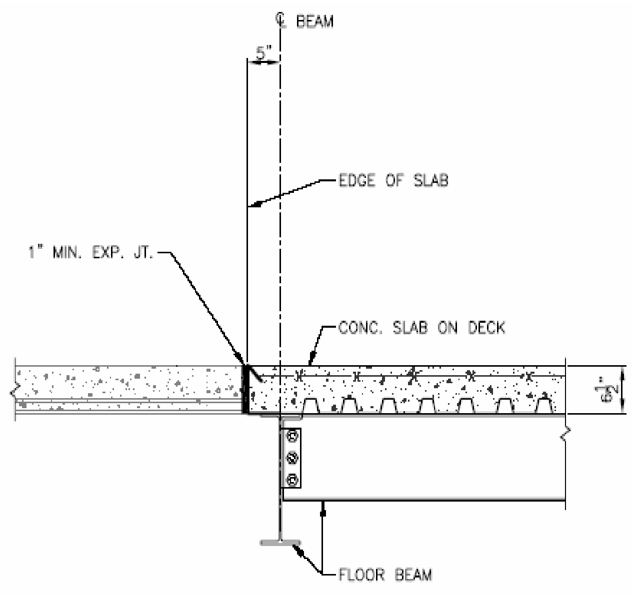
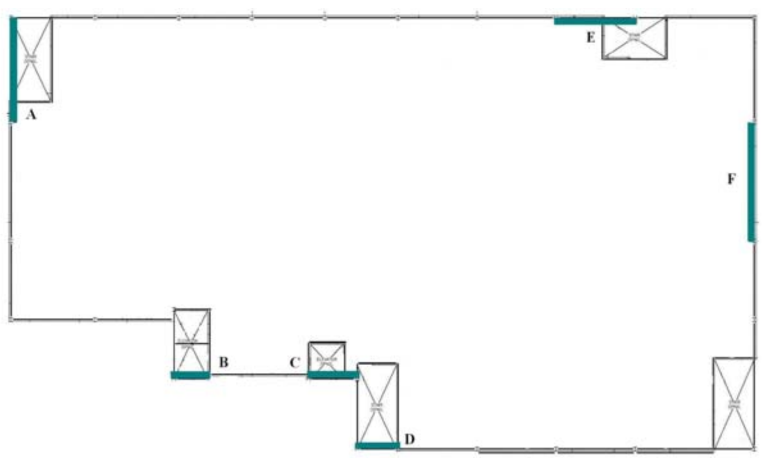


Figure 1.2 - Floor framing assembly

This study into using the structural materials efficiently will be extended into the lateral system analysis as well.

Lateral System Design

The existing lateral resisting system in the Duquesne Multipurpose Facility is a series of concentrically braced frames. There are 6 frames located around the perimeter of the building as shown in Figure 1.3. In Technical Assignment 3, the frames were checked based on the assumption that the diagonal braces were designed to take the full lateral force in tension. If the frames were designed under this assumption, then it is possible that the diagonal braces are significantly over designed. If this is true, then a redesign of the lateral system could result in lighter, more efficient structure.



Proposed Investigations

Vibration Control

Vibrations in floor systems are caused by many common activities and devices found within buildings. Simply walking on a floor causes the material under ones feet to respond in one manner or another. Vibration control is not new, and it, as well as deflection characteristics, can be the driving influence in designing structural framing members. In the Duquesne Multipurpose Facility, there are two particular areas that are prime candidates for further investigation into vibratory activity. First, two gymnasiums, resting on floors three and four, house relatively volatile activities as compared to the rest of the structure. These facilities will be used for athletic competition and will be investigated so not to disturb the game being played. The courts also have the distinction of resting on two very different composite steel framing configurations: One on fairly common rectangular bays and the other over long spanning members.

The next area to be studied is the fifth floor ballroom. Like the second gymnasium, it too rests on long spanning members of almost 80’. This area will be looked at much like the gymnasiums, and checked for human comfort. With the expectation that more people will use the ballroom floor simultaneously, I expect to have more extensive restrictions at this particular level.

Lateral Design and Torsion

Research from Technical Assignment 3 yielded high torsional forces acting on the upper stories of the structure. After verifying my calculations, I will investigate possible solutions to reducing these torsion forces. Also, analysis results from RAM Frame software will be further scrutinized as a further confirmation of my calculations. Currently, I am in the process of obtaining more information about the system from the structural engineer of record. The information will help confirm the exact amount of strain on the building due to torsion.

Along with torsion analysis, I will look at alternative bracing schemes. The goal of this assessment will be to determine if the existing X-bracing is indeed the most efficient bracing scheme. Alternative systems will include K-bracing, Chevron bracing, and alternate locations of the frames themselves.

Research Methods and Criteria

Vibration Control

Initial sizes for the framing members will be taken from the AISC Steel Manual, 13th edition (LRFD). These sizes will later be compared to findings from vibration specific analysis. The primary information regarding design procedures and specifications will come directly from AISC's Steel Design Guide 11, Floor Vibrations Due to Human Activity. Consultation with faculty and design professionals will also aid my progress throughout this study. The results of my study will be compared to the existing framing, and hopefully made to be more structurally able and efficient.

Lateral Design and Torsion

When an issue with torsion was first discovered, hand calculations were the primary alarm. Afterwards, a RAM model was consulted to look further into these effects. At this time, I am obtaining more information from the structural design professionals as to the role that overall torsion forces played in their design process. I anticipate using further hand calculations based on ASCE 7-05 lateral loading and torsional force methods and standards.

A redesign of the braced frames with alternative schemes will be completed in RAM, and checked or optimized (if possible) further with RAM Advanse and hand calculations. Using the existing and alternative bracing schemes, I will also check alternative locations for the braces to attempt to minimize the effects of torsion.

Design Efficiencies

Overall, efforts in structural and general efficiency will be studied throughout the building. I will explore the possibility of a reduced floor slab, lighter framing members, lighter lateral bracing members, faster construction methods, a more appropriate architectural layout, etc. Most of this focus will be dealt with during the above stated design issues. RAM software will be used in creating alternative models to aid in design modification. Also, new and improved hand calculations will be done to ensure a complete and correct attempt is made to amend the structural system. If alternative are deemed to be an acceptable change to the structure, the changes associated with directly effected systems (i.e. architectural, MEP, etc.) will be taken into account.

Breadth Topics

In addition to my structural emphasis, I will also study the following topics:

- Construction Cost and Scheduling
- Acoustical Improvement

Since my structural emphasis will directly impact the size of members and the amount of material (steel and concrete) used, I will attempt to minimize cost of the structural system as compared to the existing structure. Along with cost analysis, scheduling or construction sequencing is another area of that I feel will be able to be improved upon. More specifically, the erection time associated with a more efficient lateral system and the use of thinner floor slabs should speed up construction.

The mixed use design of the building lends itself to having several different activities going on in a relatively small area. Some parts of the building are home to offices and classrooms as well as aerobic and weight training rooms. This close proximity can lead to unwanted noises and disturbances at inopportune times. Improving upon the existing acoustic qualities throughout the structure will benefit everyone inside.

Construction as of November 2006

Tasks and Tools

Vibration Control

1. Determine proper floor loadings from IBC 2003 and ASCE 7-05
2. Analyze composite floor system using AISC Design Guide 11
3. Reduce floor slab thickness and resize members
4. Reanalyze composite floor system using AISC Design Guide 11
5. Change framing (both typical bays and long spans) from composite steel wide flange sections to composite steel joists
6. Analyze composite joist system for vibration using AISC Design Guide 11

Lateral Analysis

1. Confirm assumptions made by structural engineer for existing lateral design
2. Research and analyze lateral system for effects of torsion
    a. Hand calculations based on ASCE 7-05
    b. RAM Frame modeling
3. Reanalyze existing lateral system under reformed loading conditions
4. Revise braced framing configuration
5. Alter the locations of the braced frames in an attempt to minimize torsion

Design Efficiencies and Construction Management

1. Collect existing cost and scheduling data from contractors
2. Gather cost and scheduling data for above noted studies
3. Analyze optimizations from all revised sections
    a. Structural material and space within building
    b. Overall Weight of structure
    c. Cost of materials
    d. Construction sequencing
4. Analyze construction scheduling and compare with existing

Acoustical Considerations

1. Gather existing acoustic data and/or material make-up of interior spaces
2. Calculate acoustical quality of existing structure
3. Revise acoustical materials as needed after vibration analysis
    a. Integrated floors
    b. Athletic/Ballroom floors

Timetable – Spring 2007

Week	Tasks
January	
16	Research vibration design principles and calculate loads
22	Analyze vibration characteristics of existing floor system Reduce floor slab and resize members Analyze vibration characteristics of resized floor system
29	Insert composite joist framing system Analyze joists against composite steel members Compile cost comparison for existing system vs. alterations
February	
5	Confirm assumptions used in designing existing lateral system Research effects of torsion/calculate torsion loading
12	Analyze existing system based on new assumptions/loads Decide on new bracing configurations
19	Revise bracing configurations and analyze Propose alternate locations for braced frames
26	Study the effects of moving locations of braced frames Compare existing conditions and alternate framing Gather cost comparison for different configurations
March	
5	CM: Collect scheduling data for existing conditions CM: Create schedule for improved/changed systems
12	Spring Break - Week Off
19	Acoustics: Compile existing data and revise
26	Finalize comparison data for all previous items Look into façade/architectural changes due to redesign Study effects of structural alterations on other building systems
April	
2	Prepare presentation
9	Finalize presentation
16	Present Thesis Work