University of North Carolina's

Imaging Research Building

Thesis Proposal

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Structural Option

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Executive Summary

The Imaging Research Building, also known as IRB, is located on the University of North Carolina's Chapel Hill campus on Mason Farm road. It has an "L" shaped floor plan containing a re-entrant corner, with the long face dimensions of 282'-4" by 247'-3". It has an overall height of 180'-0" from Basement 2 (second floor subgrade) to the roof, with a 20' setback at the mechanical mezzanine level. The building's usage will be a combination of research space, laboratories, and office space for UNC.

After reviewing the existing conditions, examining alternate framing systems and verifying the current lateral system, it is necessary to propose certain changes to be UNC IRB that will develop into a study for the remainder of thesis coursework. The framing of structure above grade will be changed from concrete to steel, and a composite steel floor system will be used. By making this change, several benefits are produced. First the structural depth can be reduced for other trades. Second, the overall building weight can be reduced and hopefully shallower and more economical foundations can be designed. Third, more usable floor space will become available. The structural study will consist of making the proposed change and analyzing its effect on these three assets. Also, a new lateral system and foundation system will be designed, if study of costs indicated it is necessary.

Two non-structural breadths will also be considered. A look into the impact of switching the superstructure of steel on the construction management will be conducted, and fire protection will also be addressed. The construction management concerns will look at cost, schedule, constructability and other location defined problems. Fire protection will be researched and case studies will be conducted before a method is chosen. It's cost will then be compared to the existing system and details will be drawn.

Architectural Design Concepts

The Imaging Research Building at UNC Chapel Hill was designed by the architecture firm Perkins + Will. Its primary usage is the driving force behind many of the structural decisions for the project. Once it is open, it will contain the most advanced imaging equipment in any one spot in the world. First, the two subgrade floors house several heavy pieces of imaging research equipment that have large Gaussian fields. Because of this, foundations, walls, and slabs were made thicker than usual, which will result in the use of mass concrete pouring techniques to be required when constructed. For example, the foundation where a 1.5GHZ NMR machine will sit required a 6' thick mat footing.

Above grade you will find typical bays sizes of 21'-4" by 21'-4", and 21'-4" by 31'-4" driven by the laboratory space requirements on every floor. A bridge also connects the new imaging research facility to existing Lineberger Cancer Center on the second floor. At the eighth floor, a large area houses all of the mechanical equipment with a partial mezzanine at the floor above, which services all of the imaging and laboratory equipment below. These architectural and usage restraints have a generous effect on the structural system as noted below, and hopefully in future technical reports.

Structural System

Foundation

The geotechnical engineering study was performed by Tai and Associates on November 12, 2008. The study indicates that the subsurface materials on the site consist of pavement and topsoil, fill, residual soil, weathered rock, and rock and boulders. Based on this composition, Tai and Associates were gave Mulkey a net allowable bearing pressure of 6000 pounds per square foot to use in their foundation calculations.

Because of this allowable bearing pressure, Mulkey had to be creative with their foundation design. The result is a mixture of spread footings under the columns, and a combination of spread and mat footings under the large imaging research equipment and shear walls. The walls below grade range from 18" to 36" in thickness¸ and in one location a 36" wall spans both subgrade floors to the first floor unbraced. An example of a typical mat footing can be seen in Figure 1.1. As with the other mat footings, this one is combined and sits under two pieces of large imaging equipment. It is 6'-0" thick and also services a shear wall that steps 6' in elevation. Another area of note in the foundation design is a 6'-0" thick concrete footing which will service a cyclotron, another heavy piece of imaging equipment.

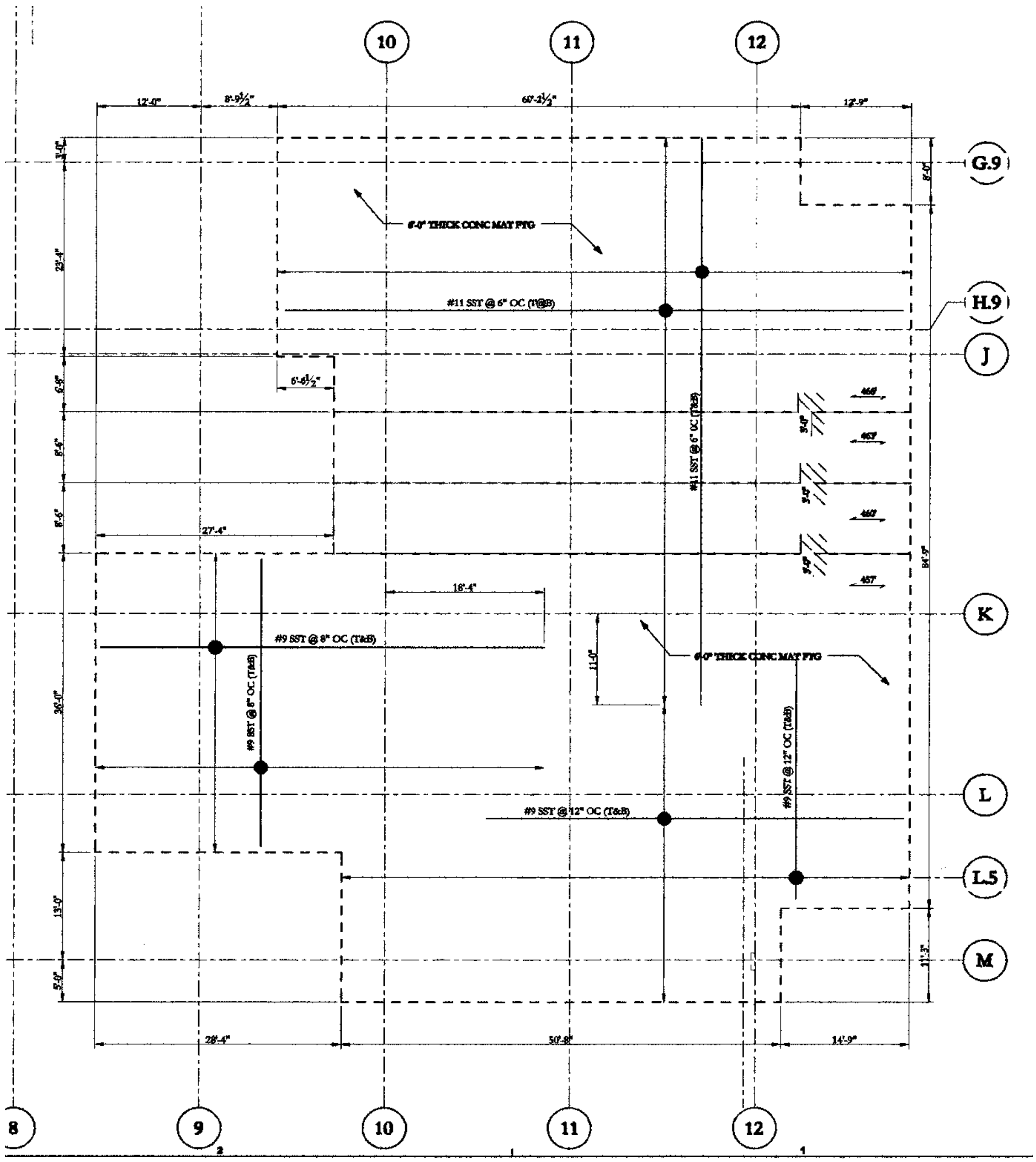

Figure 1.1 – Typical Mat Foundation under Imaging Equipment

Superstructure

The first floor and the floors above to the eighth floor is a 6" one-way cast-in-place slab (NWC) with a compressive strength (f'c) of 5 ksi. The beams on these levels are mostly 18"x20" T-Beams, which change directions at the re-entrant corner where the building changes directions. The girder dimensions vary, but are typically 28"x30".

Most of the columns in the Imaging Research Building are 20"x20" square columns with #3 ties above the first floor, and 24"x24" below grade, with all them having a compressive strength of 7 ksi. The typical frame consists of four bays with three of them being approximately twenty feet in width and the other being thirty feet in width to accommodate the laboratories that occupy these spaces on almost every floor of the building.

For more detail on the superstructure a section of the third floor framing is provided in figure 2.1 for reference.

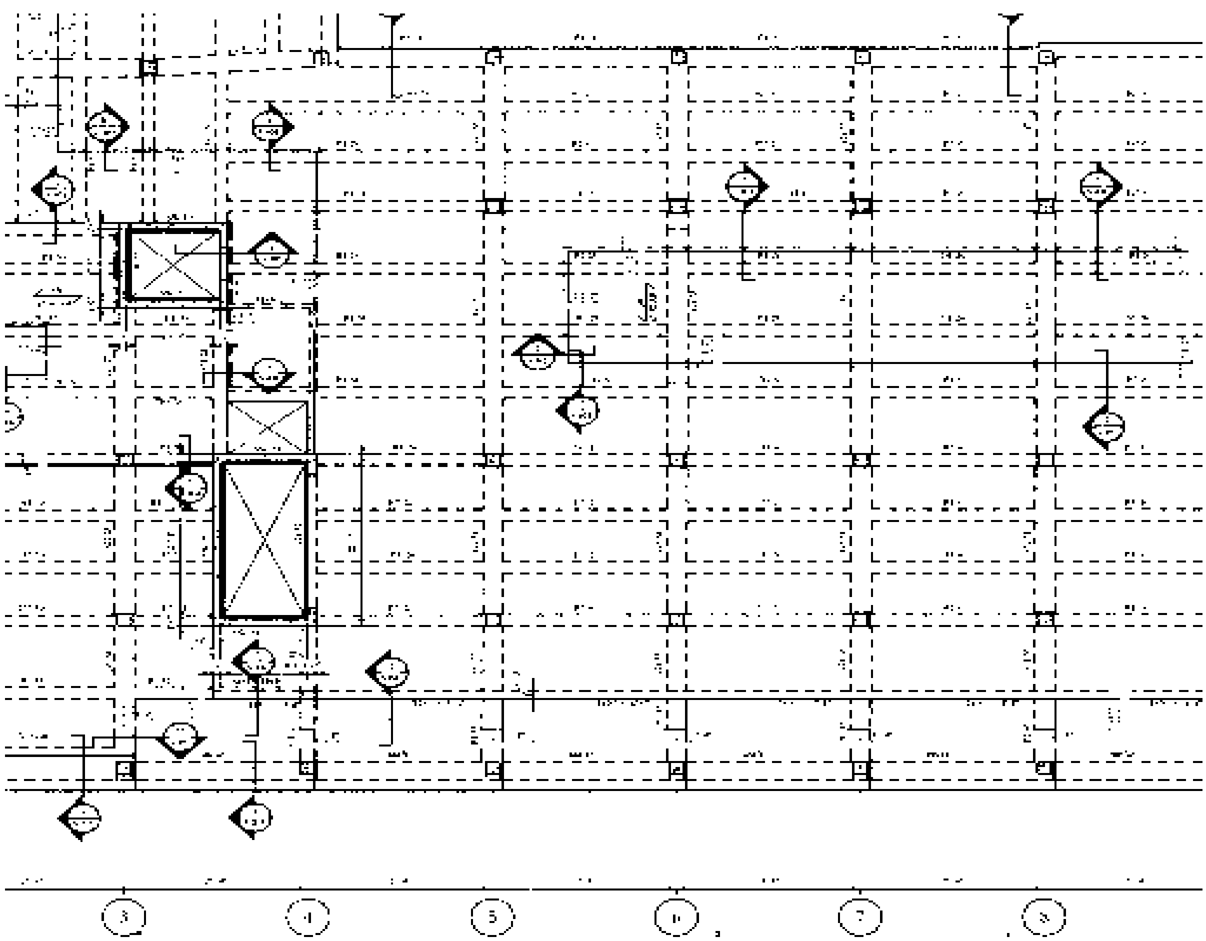

Figure 1.2 - Third Floor Framing

Lateral System

Ordinary reinforced concrete shearwalls are used as the main lateral force resisting system in the UNC Imaging Research Building. The largest ones wrap around the main elevator and stairwell cores while the other ones encase mechanical closets. Most of the shearwalls run from the foundation to the mechanical mezzanine with only half of them continuing to the roof level. In total, there are thirty-three shearwalls either 12" or 16" thick. Figure 1.3 shows an example of the shearwalls around the main stair and elevator core.

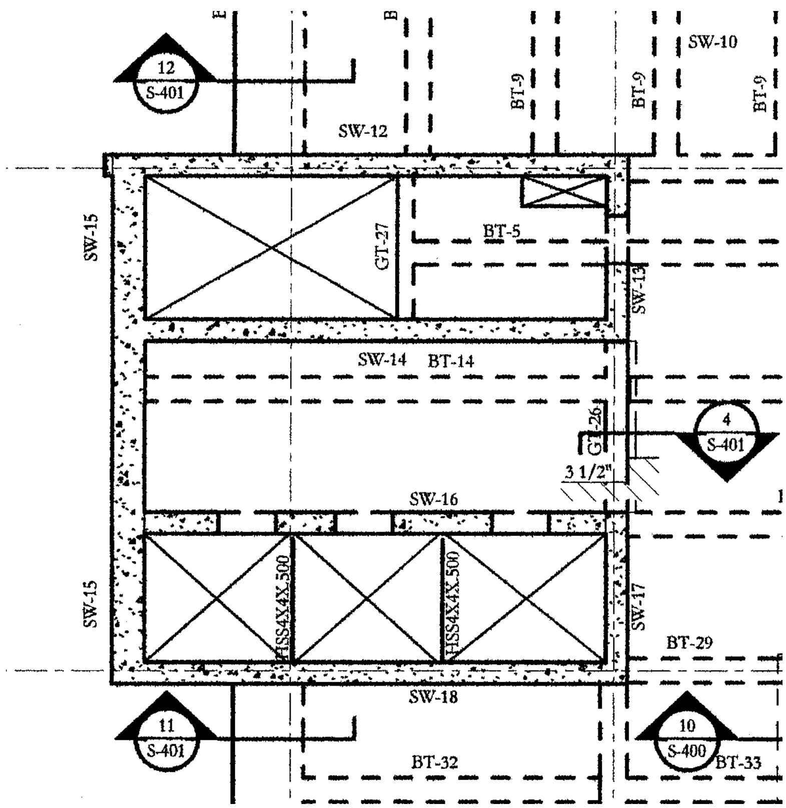

Figure 1.3 - Shearwalls around Elevator Core

In addition, the lateral system uses 7000 psi concrete in the shearwalls from the basement to the 6th floor and 5000 psi concrete from the 6th floor and above. The location of the shearwalls can be seen in figure 1.4, created for the reader's reference.

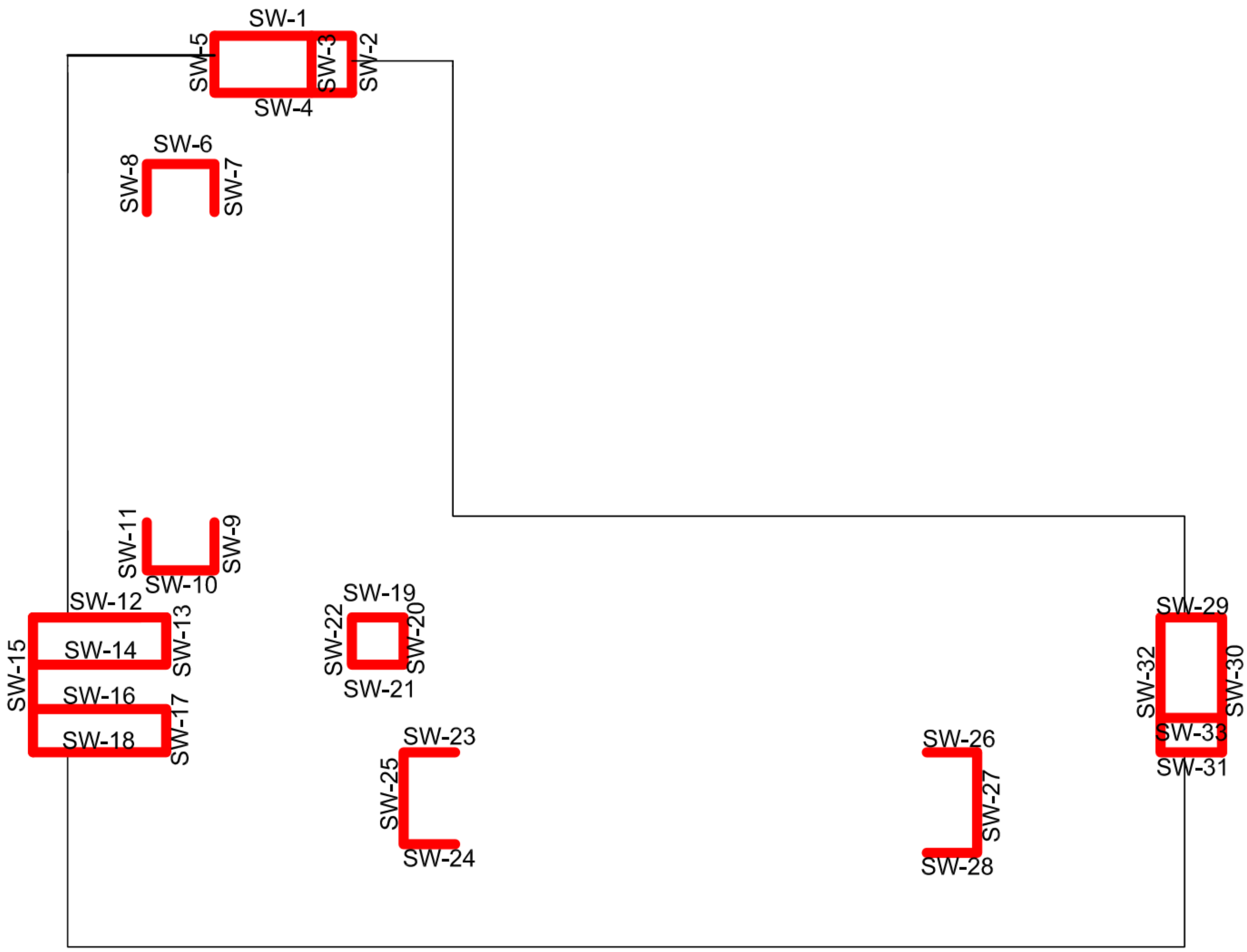

Figure 1-4 – UNC IRB Shearwall Plan

Problem Statement

Currently, UNC IRB is designed as a complete concrete structure. The main reason for this is because of the existence of the highly magnetic imaging equipment in the two subgrade floors of the building. There are also a couple pieces of equipment on the first floor as well, but after that there is no other magnetic equipment that would determine a need for a concrete column, beam and floor system.

The reason that concrete was chosen as the remainder of the above grade framing can be ascertained though. As far as the lateral system is concerned, shearwalls are regarded as the cheapest method for resisting lateral loads. There is also no problem connecting the system into the rest of the concrete superstructure. Not only that, but the one-way cast-in-place slab is a simple floor system to design and construct. Therefore, it is relatively inexpensive both in design and construction. Also, it works for heavier live loads as in the Imaging Research Building because there is very little deflection when used in combination with beams. But more importantly, penetrations in the slab cause few structural problems because there is not a lot of large rebar or tendons running through the slab, and it is easy to reinforce around them after they have been created. This is very important on a job like the Imaging Research Building where there are a number of mechanical systems and equipment lines for the imaging laboratory equipment penetrating through the floors.

However, the concrete superstructure is very bulky and heavy. The 20”x20” columns reduce the usable floor space and the 30” deep girders for the floor system take up a lot of critical room for the mechanical and other trades could use. Also, the cast-in-place beam and slab system requires a lot of formwork that will be time consuming and costly. This results in a longer construction schedule which will delay the opening of the building.

Another disadvantage is the quality of concrete work that can be expected. It is common judgment that the quality of concrete placement in the south is inferior to that above the Mason-Dixon Line. While obviously not a make or break factor, it is one that must be considered none-the-less.

After reviewing this information, the goal is to reduce the overall weight of the building, increase usable floor space, and increase vertical trade space, while not incurring much of a cost increase, if any at all. While further studied is needed, it is already determined in technical report two that the composite steel floor system in combination with steel framing would be the most likely candidate for replacing the existing floor system and framing to meet these goals.

There are some problems that will need to be addressed in the proposed solution. For one, the serviceability (mainly vibration) of the new system will have to be investigated. Also, the lateral system will have to be changed, unless a solution can be generated to tie the new steel framing to the shearwalls. Finally, the issue with the highly sensitive imaging equipment will also have to be addressed.

Proposed Solution

To meet the goals outlined in the problem statement, the superstructure of the building will be changed from concrete to steel **only** above grade. Hence, the new structure of the building will be a concrete base for the two basement levels, with steel above. The new floor system will preliminarily be composite steel and composite deck unless further study suggest otherwise. From the study done in technical report two, the implication of a composite steel framing system should decrease the overall depth of the floor system, allowing more space to be freed for other trades. The member sizes for a typical bay generated from an analysis run in RAM Structural system can be seen in figure 2.

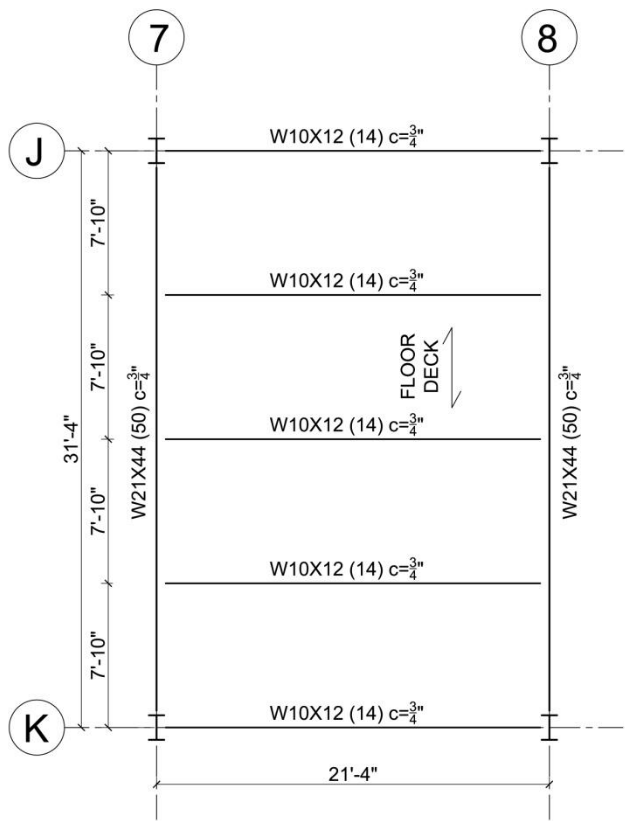

Figure 2 - Typical Composite Floor Framing

While columns weren't addressed in technical report two, the steel columns should be smaller than the existing 20"x20" concrete columns. In turn, more usable floor space will open up unless further study indicates that the need for increased fire protection negates the smaller depths.

Also an analysis will be done on both the impact of the steel structure on the lateral system and the foundations. For the lateral system, it will also be changed to either brace framed or moment frames unless enough evidence suggests a cost effective shearwall connection can be employed. Since cost drives most projects, if it is determined that a new lateral system is economical, it will be designed and summarized. Finally, an analysis will be done to determine the impact of the steel structure on the foundation. Since it was preliminarily determined in technical report two that steel framing will reduce the overall weight of the structure, the foundations should be redesigned to be shallower, and therefore less expensive.

Solution Method

A computer model of the structure will be created using RAM Structural System. The gravity loads will be defined according to ASCE 7-05 and applied to the overall structure. Once the model is determined to be satisfactory, the sizes of the new steel gravity members will be determined from RAM. Time permitting, the new members will be spot checked by hand.

After the gravity framing as been determined, research will be conducted to determine the type of connections available and the cost of the connections for steel framing into shearwalls. The cost of braced frames and moment connections will also be surveyed. The method that is most cost effective will chosen and designed in either RAM or ETABS for a new lateral system, or by hand for the steel to concrete connection.

Finally, with the new overall building weight, the new impact on the foundations will be analyzed with hand calculated spot checks. RAM foundation will be used to redesign the foundations if it is warranted.

Breadth Topics

In addition to the structural proposal, two non-structural aspects of UNC IRB will also be investigated. It expected that the redesign of the gravity system, and possible lateral and foundation systems, will effect significant changes to the construction and architecture of the project.

Breadth Topic 1 – Construction Management Study

In order to evaluate how a steel superstructure will affect the project, cost and schedule will be considered. By completely changing from concrete to steel for the above grade floors, the entire construction process will be different. For this breath, research will be conducted and an interview will be done with the project manager to obtain pertinent information regarding labor cost, material cost and availability, constructability, and any other critical information that is unique to construction in that area. Scheduling software such as Microsoft project and Navis Works will be used to create a 4D phasing model if time permits. The results of the new cost and schedule will be analyzed and compared to the existing costs and schedule.

Breadth Topic 2 – Fire Protection Study

Since the laboratory spaces within UNC IRB are subject to flammable equipment, steel framing is being introduced; fire protection will need to be addressed. Research will be conducted into possible fire protection methods and previous case studies will be examined. Then, a solution will be chosen and typical detail will be drawn to show the changes. The cost of the changes will be examined and compared, but hopefully, the cost savings elsewhere by switching to steel framing will offset these costs.

Tasks and Tools

Primary Study – Structural

1. Design a steel superstructure on concrete base
    a. Create RAM structural model
        i. Design composite floor system
        ii. Design beams and columns
    b. Hand calculations and spot checks for comparison
        i. Check flexure
        ii. Check shear
        iii. Check deflections
    c. Consider special structural locations
2. Design of shearwall to steel connections or new lateral system
    a. If shearwall to steel connections – hand calculations
        i. Draw details of connections
    b. If new lateral system –design using RAM or ETABS
        i. Determine loads
        ii. Analyze loads on new system
            1. Compare output with hand calculations where necessary
3. Design of new foundation system if warranted
    a. Analyze new building in RAM foundation
    b. If new foundations determined then redesign
        i. Use RAM foundation
        ii. Spot check with hand calculations

Breadth 1: Construction Management Study

1. Acquire schedule, cost, and other construction information for existing building
    a. Research and interviews
2. Create new schedule for building
    a. Microsoft Project
    b. Navis Works
    c. Research
3. Research location factors
4. Compare to existing building
    a. Cost (materials and labor)
    b. Schedule and time constraints
    c. Material and laborer availability
    d. Constructability

Breadth 2: Fire Protection Study

1. Research different fire protection methods for steel buildings
2. Review and analyze case studies of fire protection methods and failures
3. Choose solution and create details
    a. AutoCAD to create details
4. Generate new costs of fire protection
    a. Compare costs to existing costs
    b. Show where the fire protection costs can be offset by other savings

TASKS	Jan 11 - 15	Jan 18 - 22	Jan 25 - 29	Feb 1 -5	Feb 8 - 12	Feb 15 - 19	Feb 22 - 26
Create RAM Model	■	■					
Hand calcs			■	■			
Consider Special Structural Locations				■	■		
Research cost of shearwall to steel connections or new lateral system				■			
Design connections or new lateral system					■	■	
Draw details of connectials or compare new lateral system						■	
Analyze new loads on foundation						■	
Desing the new foundations system if warranted						■	■
Construct model in RAM Foundation						■	■
Compare Results							■
Begin Construction Mangagement Study							■
	Mar 1 - 5	Mar 8 - 12	Mar 15 - 19	Mar 22 - 26	Mar 29 -Apr 2	Apr 5 - 9	Apr 12 - 16
Acquire schedule cost and other construction information	■						
Research and interviews	■	■					
Create schedule in Microsoft Project	■	■					
Navisworks 4d model		■					
Compare new schedule and costs to existing			■				
Fire Protection Research		■					
Review Case Studies		■	■				
Choose solution and create details			■				
Compare costs of fire protection				■			
Create reports and charts demonstrating benefits of steel structure				■	■		
Create Final Report and Presentation					■	■	
THESIS PRESENTATION							■