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. First, a look into the impact on construction management as a result of switching the superstructure to steel will be conducted. Second, the existing building's façade will be analyzed and redesigned for blast loading. The construction management concerns will look at cost, schedule, constructability and other location defined problems. The building façade breadth will include not only the redesign for blast loading, but lighting, acoustical, and thermal issues will also be addressed. Finally, the façade connections to the proposed steel system will be investigated and designed.

Architectural Design Concepts

The Imaging Research Building at UNC Chapel Hill was designed by the architecture firm Perkins + Will. The primary usage of the building is the driving force behind many of the structural decisions for the project. Once the building 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 placement 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 are typical bays sizes of 21'-4" by 21'-4", and 21'-4" by 31'-4" where size is dictated 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.

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 recommended a net allowable bearing pressure of 6000 pounds per square foot for use in the foundation calculations.

Because of this allowable bearing pressure, Mulkey developed a mixed foundations system 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 supports two pieces of large imaging equipment. The mat 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 supports a cyclotron, another heavy piece of imaging equipment.

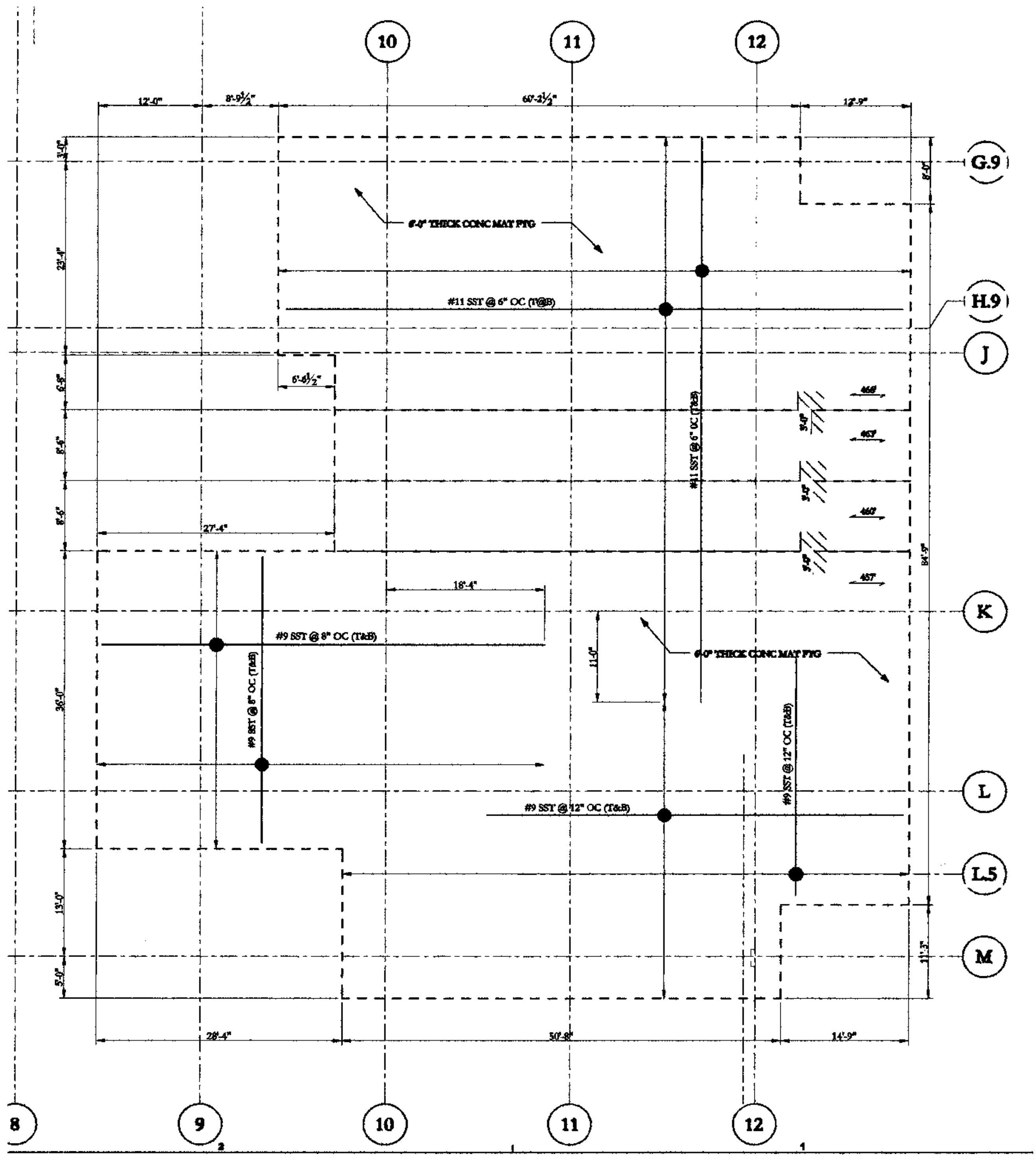

Figure 1.1 – Typical Mat Foundation under Imaging Equipment

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" by 20" T-Beams, which change directions at the re-entrant corner where the building changes directions. The girder dimensions vary, but are typically 28" by 30".

Most of the columns in the Imaging Research Building are 20" by 20" square columns with #3 ties above the first floor, and 24" by24" 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 1.2 for reference.

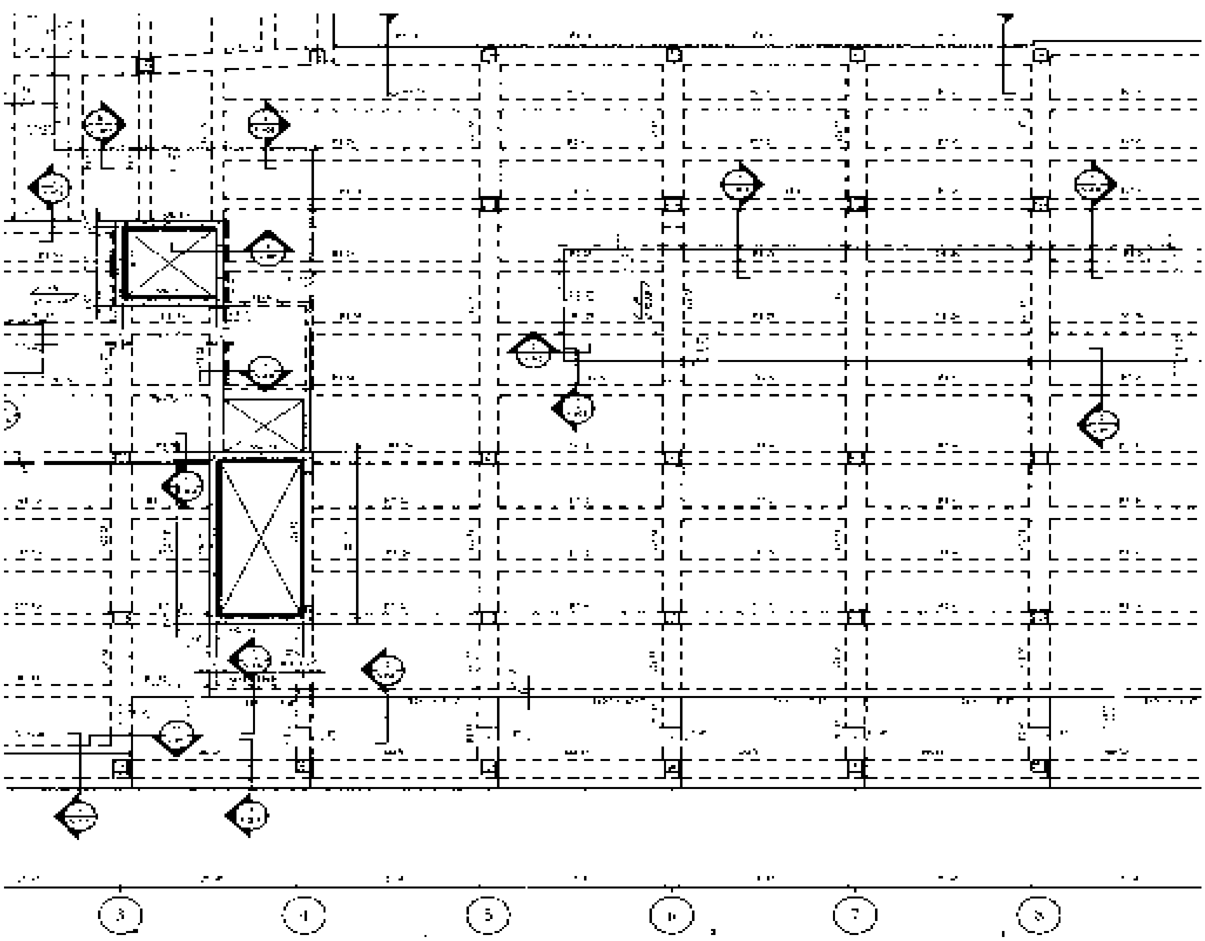

Figure 1.2 - Third Floor Framing

Lateral System

Ordinary reinforced concrete shearwalls are used as the main lateral force resisting system in the UNC Imaging Research Building. The largest ones enclose 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.

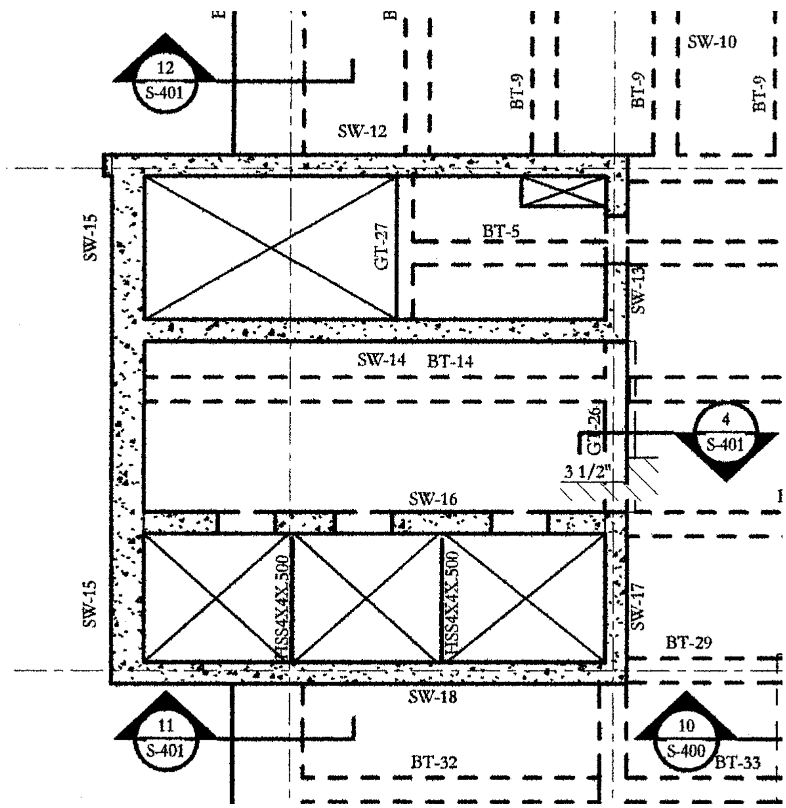

Figure 1.3 - Shearwalls around Elevator Core

In addition, the lateral system uses 7000 psi concrete in the shearwalls from the basement to the 6^{th} floor and 5000 psi concrete from the 6^{th} floor and above. The location of the shearwalls can be seen in figure 1.4.

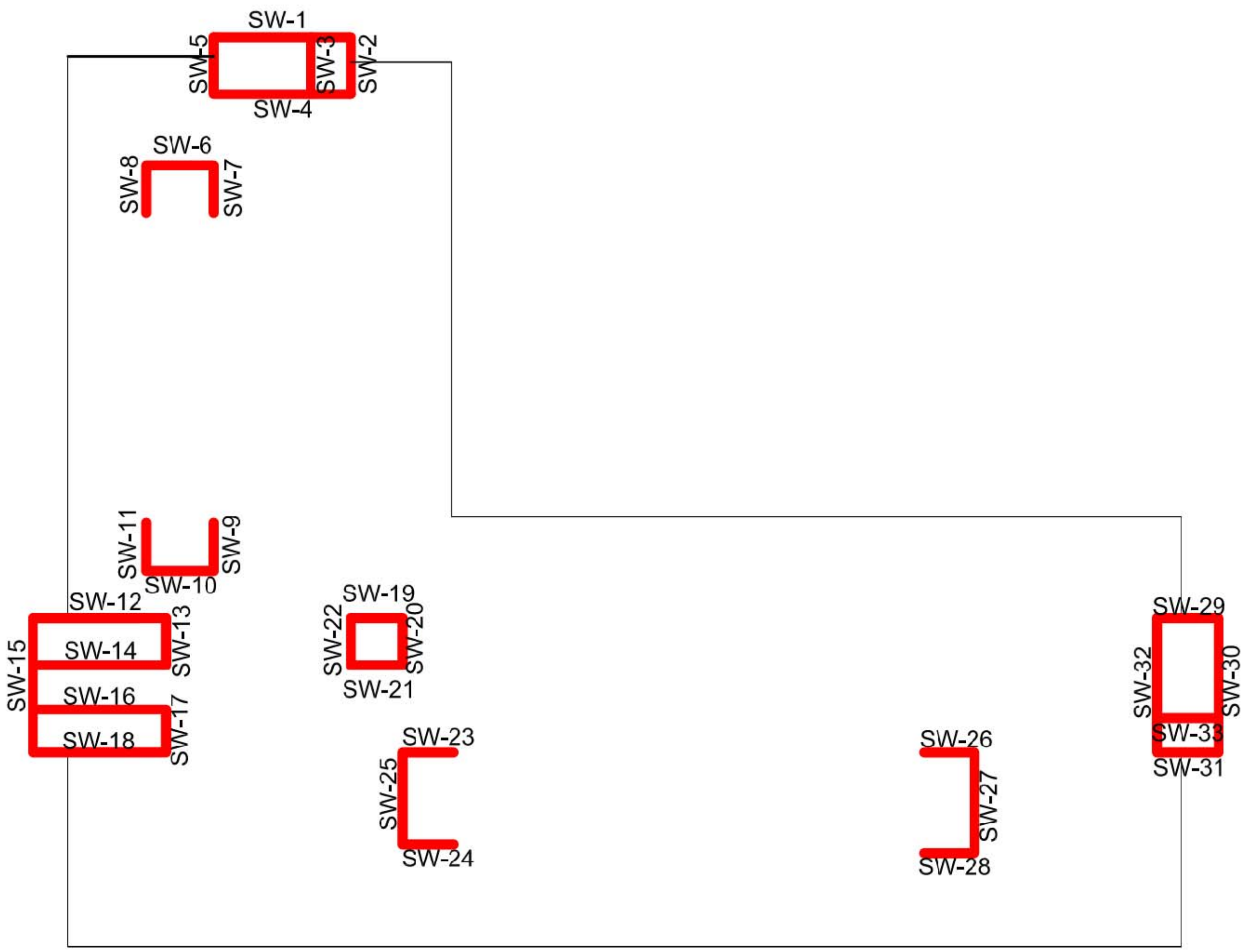

Figure 1-4 – UNC IRB Shearwall Plan

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 is apparent. 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 lateral 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 project 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.

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.

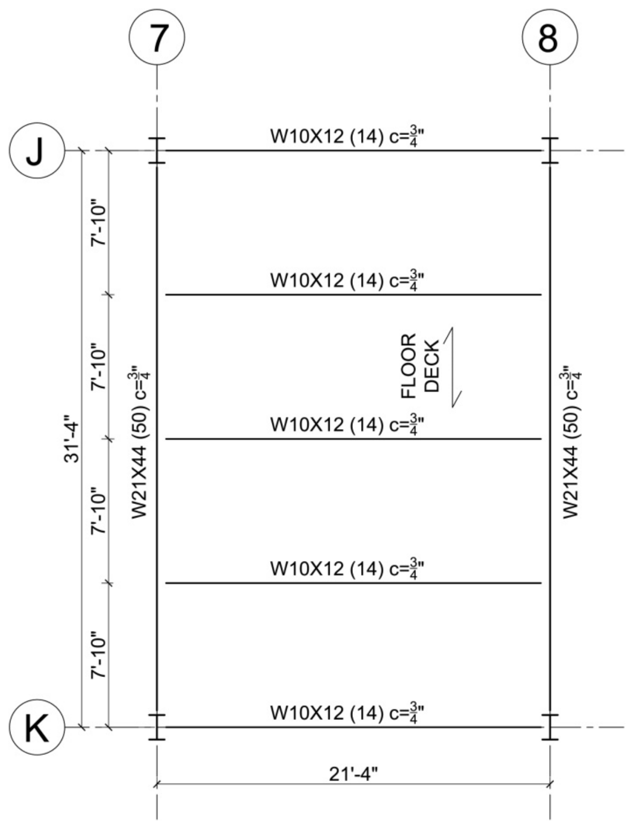

Figure 2 - Typical Composite Floor Framing

While columns weren't addressed in technical report two, the steel columns should be smaller than the existing 20" by 20" 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

The design of the steel framing will be based on the 13th edition of the AISC steel manual. Analysis for gravity and lateral loads will be done with a model created in RAM Structural System based on LRFD. Input for the model will consist of loads as determined from ASCE 7-05 and trial sizes of the members. Live load reduction will be considered and load combinations from ASCE 7-05 will be set up and run to determine the required sizes of the members for the steel framing. 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

By changing the building from concrete to steel for the above grade floors, the entire construction process will be different. Cost, schedule, material delivery, crane coverage and other site logistics will be considered. To do this, 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.

Besides cost and schedule, the material delivery, crane coverage and other site logistics will be investigated. Research on delivery will be conducted by interviewing the project manager. Once crane coverage and other site logistics are determined a new site plan will be developed and compared to the existing one.

Breadth Topic 2 – Façade Analysis

The second breadth topic will be an analysis of the existing façade and a design proposal for a new blast resistant façade. The design of the blast resistant façade will be performed by hand. Factors that will also be study include the thermal, lighting, and acoustic characteristics of the new system. Finally, the connections of the new façade to the proposed steel framing will also be designed by hand.

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: Façade analysis

1. Analyze existing facade
2. Design new façade based on blast loading
3. Design of façade connections
4. Generate new costs blast resistant facade
    a. Compare costs to existing costs