Rutgers University Law School

Building Addition and Renovation

Camden, NJ

Thesis Proposal

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Structural Option
AE 481W Senior Thesis
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Executive Summary

Building Description:

The Rutgers University Law School Building and Renovation consists of an east building addition, west building renovation and addition, and the development of a connecting bridge which is used to create a student lounge. The building structure is created through the use of steel moment resisting frames used for both gravity as well as lateral forces on the building.

Proposal:

The lateral force resisting system of the building, moment resisting frames, are very expensive and labor intensive. It is proposed that this system be eliminated and replaced with a braced frame or shear wall system—actual system to be determined through research. This proposal will convert the gravity framing system to one of composite steel joists while utilizing bracing or concrete shear walls as the lateral support.

Solution:

The proposal will be accomplished through an initial study of the alternative lateral systems, followed by a design and analysis of the new framing system. Through hand calculations and computer models, the project will be analyzed for effectiveness in areas such as cost and overall schedule impact. This study will attempt to maintain the current exterior building configuration while adding additional elements which were not programmed for in the design process.

Breadth Topics:

As a result of the structural proposal, there is a need to analyze the impact of a new lateral system on the architectural floor plan of the building. Therefore, an architectural breadth is proposed to incorporate the new system into the architectural program. A second breadth study has been proposed to examine the construction schedule, as well as overall cost, of the project, related to the change in framing system. This study will reflect information regarding the overall effectiveness of the system as understood/expected by the building owner.

Introduction

The Rutgers University Law School Building and Renovation consists of an east building addition, west building renovation and addition, and the development of a connecting bridge which is used to create a student lounge. As the west building additions are minimal, I will concentrate my efforts primarily on the east building addition and bridge components of this project.

The east building consists of two major sections, the primary classroom section, which will be referred to as the primary east addition (4 floors, with basement and penthouse, 75’-0” height) and a student law clinic, which will be referred to as the secondary east addition (2 floors, with basement, 36’-4” height). Connected to the west edge of the primary east addition is the bridge support system.

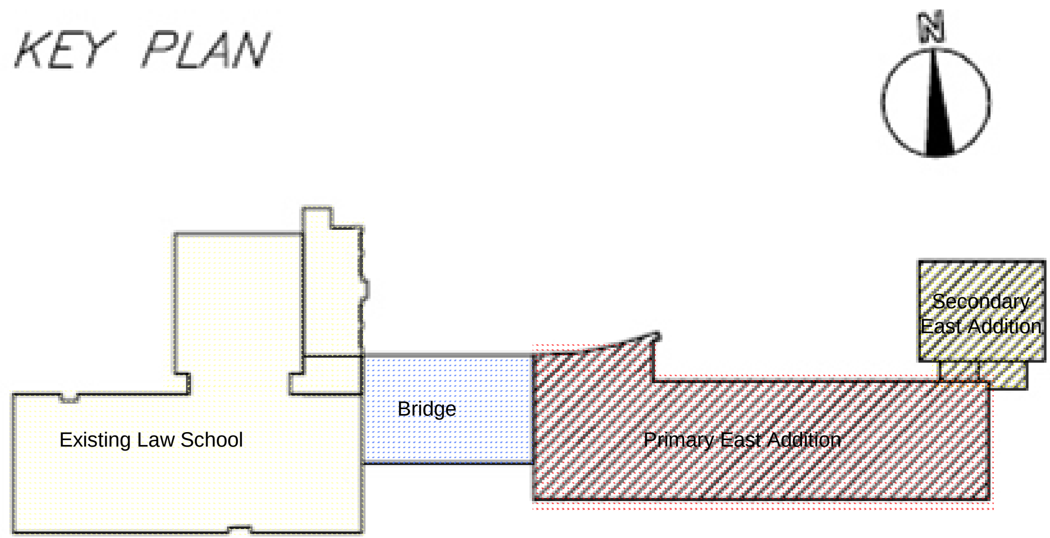


Figure 1: Plan illustrating different building components referenced in this report

Structural System

The following sections will describe the structural elements incorporated in the design of the Rutgers University Law School Building.

Foundation System

The foundation system utilized to support the east building addition incorporates moment-resisting spread foundations, concrete pad foundations, and typical wall footing foundations. The foundation system supporting the bridge designed to cross Fifth Street includes drilled piles with pile caps along with a typical wall footing. These foundations have been sized to support the lateral loads associated with the moment frame construction.

Columns

The typical framing system used in the Rutgers University Law School is steel moment frame construction. Typical columns are attached to form a fixed connection to the foundations are A992 Grade 50 W14X159 for the primary east addition creating typical bays of 20'-0" by 46'-8", and A992 Grade 50 W14X82 for the secondary east addition which create 41'0" by 22'8" typical bays. Optional column splices have been located above the third floor for value engineering options.

Floor Systems

There are several different types of floor systems used throughout the Law School Building. Each system incorporates a composite floor slab (3/4" X 5" shear studs) with typical A992 Grade 50 steel framing systems.

The floor system used in the primary east addition consist of W21X68 wide flange beams spanning 46'-8", with intermediate beams consisting of W8X18 members spanning the 10'-0" spacing between the beams, which frame into W24X55 girders spanning 20'-0". The typical floor slab consists of 4-1/2" normal weight concrete (f^1_c = 4000 psi), reinforced with 6X6 W2.9 X W2.9 WWF, on 3"-16ga metal floor decking which spans 10'-0". This floor system is used, with slight variations of beam sizes for all levels of the primary east addition, as well as for the secondary east addition.

In the bridge section of the building, rolled wide flange beams, W21X62, span 43'-0" to W40X235 girders spanning the 67'4" across Fifth Street. The floor slab consists of 4-1/2" normal weight concrete (f^1_c = 5000 psi) reinforced with 6X6 W2.9 X W2.9 WWF on 3"-16ga metal floor decking spanning 11'-2" to the W21X62 beams.

Lateral Force Resisting System

The lateral support for the entire east building addition is developed through the use of moment-resisting frames, as an open plan was critical in the architectural design of the building. There are (8) frames spaced at 20'-0" on center for the primary east addition, and (4) frames spaced at 11'-4" on center for the secondary east addition. For the bridge addition, (2) lateral wind resisting frames are required to withstand the load, these frames are spaced at 67'-4" on center. Each of the lateral support frames are created through beam-column moment connections.

Roof Framing System

The roof framing system designed for the entire east building addition and bridge section of the Rutgers University Law School consists of W18 beams spaced at 10'-0" or less on center framing into W18 girders with 3"-18ga galvanized roof decking.

Typical Floor Framing Plan

Figure 2: Typical Framing Plan (Lateral Elements Shown in Red)

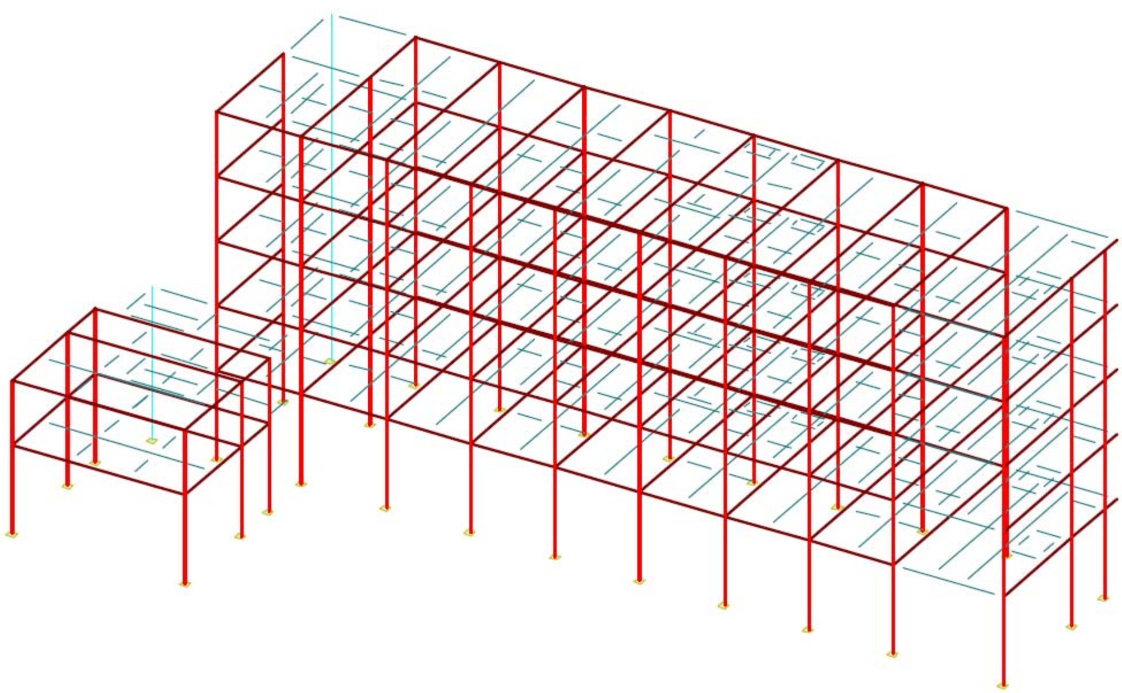


Figure 3: Model of Rutgers University Law School Addition showing Moment-Resisting Frames in Red

Problem Statement

The architectural features and layout of the Rutgers University Law School Building Addition require an open plan. In addition, the height limitation of 85'-0" has eliminated several other alternative framing systems. These requirements have led the structure to consist of steel moment frame construction, a very expensive and timely procedure.

Following an analysis of this structure, it has been determined that the framing system utilized has been sized for serviceability criteria due to wind drift. The models generated by RAM Structural System and STAAD Pro 2006 have verified the drift requirements and sizes chosen in the design; however, these members are loaded to approximately 50 percent of their available capacity.

As a result of this excess capacity, and in an attempt to save on the construction schedule and labor costs associated with creating moment connections at all beam and column connections, it is proposed that these connections be removed and replaced with shear connections. This will eliminate the existing lateral force resisting system of the building—requiring the addition of either braced frames or shear walls. Each of these lateral systems will be researched and analyzed in connection with a new gravity framing system of composite steel joists. While the implementation of open web steel joists will increase the overall depth of the floor system, the large floor to ceiling heights will permit this change without a major impact to the overall architectural experience. This system would be able to be erected much faster and potentially less costly. This new framing system will be evaluated using ASCE 7-05, IBC 2006, SJI, AISC and ACI code techniques, as well as computer modeling techniques.

Proposed Solution

The Rutgers University Law School Building Addition requires large clear spans, 47'-0". Keeping with this architectural feature, the alternative floor framing system of composite steel joists will be studied for its economy and ease of installation. The steel joist framing will be supported by wide-flange beams. This solution will generate pinned connections at all joints, removing lateral stability of each frame. Unfortunately, the use of steel joists creates a potential vibration issue; therefore, in addition to strength requirements, all serviceability criteria will be analyzed with this system: live load deflection, total load deflection, fire protection, and vibrations (evaluated using techniques found in the AISC Design Guide 11).

As the existing lateral system has been eliminated, the use of shear walls will be analyzed and compared to the installation of braced frames. Because the existing system does not utilize either method of lateral resistance, both of these methods will be compared and evaluated for feasibility on this project. This modification to the lateral system may greatly reduce the required foundation sizes; the current configuration requires moment support from the spread footings while this method would only require gravity resistance. After a lateral system has been chosen, the system will be designed within the existing framing bays, to reduce the impact on the architectural requirements without creating unnecessary scheduling or constructability issues.

The proposed system consists of two parts, a gravity load composite steel joist system with a separate lateral force resisting system—braced frames or shear walls.

Solution Method

The composite steel joist system will be designed following the First Edition of the Standard Specification for Composite Joists Code of Standard Practice. While this specification is currently in publication, I have acquired a copy from Drew Potts, Engineering Manager of CMC Joist and Deck. As Mr. Potts worked with the committee developing the specification, I have an excellent resource to investigate this system. Unfortunately, as this system is relatively new, the entire design for the gravity system strength and serviceability will be preformed through hand calculations.

The lateral framing system analysis will be preformed using computer modeling procedures. If a braced frame system is chosen as the most efficient method of resisting the lateral loads, the model generated for Technical Assignment 3 developed in RAM Structural System will be enhanced and modified to determine the building response. A model will be generated in ETABS to represent concrete shear walls, if shear walls are determined to be a more feasible solution. In either case, additional hand calculations will be provided to spot check the computer simulations. Both of the systems will be compared on a cost basis as well as serviceability and constructability stand point.

Following analysis, the proposed solution of composite steel joists with additional required lateral resistance will be compared with the existing moment frame construction. These methods will be analyzed based on cost and scheduling to determine if the new composite joist system proves beneficial.

Breadth Options

In connection with the proposed structural study of the Rutgers University Law School Addition framing system, two additional breadth studies will be conducted. As modification to the free plan generated by the moment frame construction, an architectural breadth to investigate impacts of shear wall or braced frame placement will be performed. The second study will incorporate the schedule and cost implications associated with the revised floor plan and structural system to be installed.

The first breadth study, an architectural study will include a review of the building program, in connection with the additional lateral framing system generated from the structural study. As the structural study will ultimately impact the architecture of the building, an architectural breadth must be investigated to determine the complete impact of the new design. Following analysis, the floor plan of the Law School Building will be revised to accommodate the new structure if necessary. Each floor will be reworked to generate benefits from the structural design. Another architectural study will include incorporation of cross bracing into the exterior façade. This alternative will be explored if cross braces can be utilized exclusively on exterior spans. The architectural study will include floor plan modifications if necessary or façade alternatives, or possibly a combination of both options.

The second breadth study is a direct correlation to the structural system redesign. The changes from the existing moment frame connections to shear connections required for the composite joist system is expected to significantly reduce overall building cost—and possibly permit earlier occupancy. The overall building schedule will be reviewed to analyze the time required to complete the field welding associated with the moment frame connections. The complete system design will be examined for its cost implications (floor system and column sizes); however, the schedule impact is anticipated to be negligible as the construction practices will be very similar for composite beam compared to composite joist construction.

Tasks and Materials

Structural Investigation

Task 1. Research Composite Steel Joist Design
Review composite joist material and investigate vibration effects.
Investigate fire-proofing required with system.

Task 2. Research Lateral Force Resisting Systems
Compare benefits associated with shear walls and braced frames.
Choose most feasible system for this project.

Task 3. Design Composite Steel Joist Floor System
Analyze joists for strength, deflection, and vibration capacity.
Design required wide-flange beams for joist bearing.

Task 4. Design Lateral Force Resisting System
Determine trial member sizes and locations.
Generate computer model of lateral building elements.
Design lateral resisting members and elements.

Task 5. Compare and Contrast Framing Systems
Analyze cost associated with each framing system.
Evaluate schedule impact of new framing system.

Architectural Breadth Study

Task 6. Review Building Program Requirements
Determine required spaces and sizes.

Evaluate potential modifications to plan.

Task 7. Create Revised Floor Plan Based on Structural Design
Investigate location of shear walls or braced frames.
Revise floor plans to accommodate lateral system.

Task 8. Compare Existing Plan to Revised Plan
Evaluate plans based on required building program.

Construction Management Breadth Study

Task 9. Evaluate Cost Information
Determine cost of current construction.
Determine cost related to new construction.

Task 10. Review Scheduling Issues
Examine required amounts of time for construction.
Focus on connection requirements.
Generate new schedule for alternate construction process.

Task 11. Compare Existing System with the Proposed System
Compare cost of both systems.
Compare scheduling times required for construction.

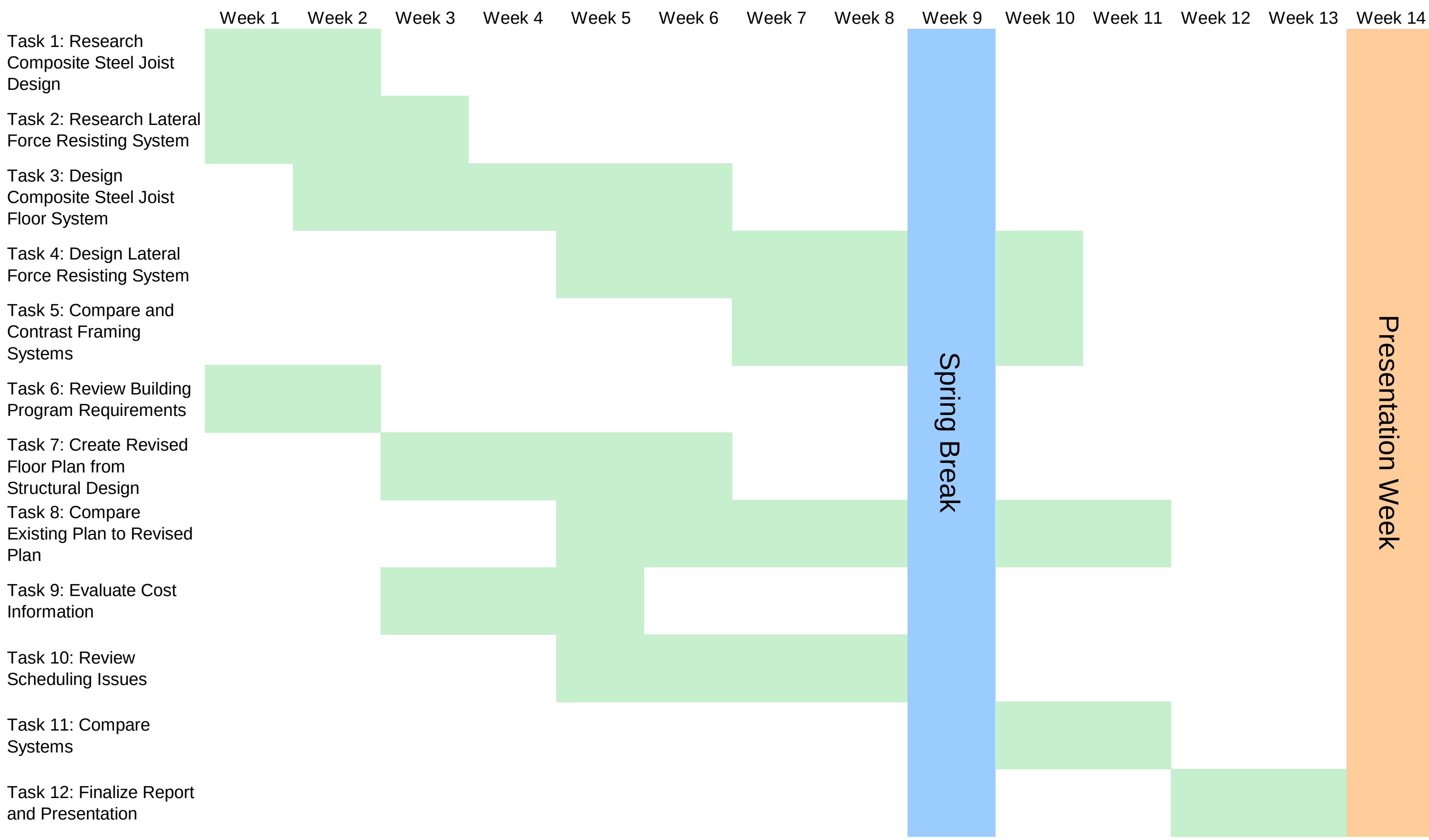
Conclusion

The Rutgers University Law School Building Addition has been examined through Technical Reports 1 through 3. As a result of these studies, it has been proposed to modify the existing lateral force resisting system by creating braced frames or shear walls to resist the loads, rather than moment frames.

As these moment frames are expensive and labor intensive, it is proposed that an alternative framing system consisting of composite steel joists with braced frames or shear walls be implemented. This change to the structural system of the building will require investigation into the architectural layout and program for the space—creating one breadth study.

The second breadth study will evaluate the cost savings associated with a new system and determine schedule modifications which will result. These systems will be evaluated on completion time as well as overall building cost.

Schedule


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
Week 14
Task 1: Research Composite Steel Joist Design
Task 2: Research Lateral Force Resisting System
Task 3: Design Composite Steel Joist Floor System
Task 4: Design Lateral Force Resisting System
Task 5: Compare and Contrast Framing Systems
Task 6: Review Building Program Requirements
Task 7: Create Revised Floor Plan from Structural Design
Task 8: Compare Existing Plan to Revised Plan
Task 9: Evaluate Cost Information
Task 10: Review Scheduling Issues
Task 11: Compare Systems
Task 12: Finalize Report and Presentation
Spring Break
Presentation Week