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Structural Option

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1100 Broadway

Oakland, CA

Revised Senior Thesis Proposal

http://www.engr.psu.edu/ae/thesis/portfolios/2009/sgh132/

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Executive Summary

1100 Broadway is a 20-story office building located in the Bay Area of Oakland, California. It contains 310,000 square feet of office space and 10,000 square feet of retail space at the ground level. The project is currently in the design development phase and construction is scheduled to begin in June of 2010. The gravity system is composite metal deck supported by composite steel beams and the lateral system is composed of steel moment and concentric braced frames.

A depth study will be performed that focuses on the structural system of 1100 Broadway. The current composite floor system is 30.25" in depth and supporting composite member sizes are controlled by deflections. The impact of a one-way mild steel reinforced concrete slab with post-tensioned concrete beams is proposed for study in place of the current composite metal deck and supporting composite steel beam gravity system. Advantages of the proposed system include better economy, reduced floor depth, and reduced deflections. The change of system will in turn require a change of lateral systems. Concrete shear walls will be chosen and designed for the new lateral system.

The proposed system will be designed using a combination of computer modeling programs and hand calculations to supplement and check the models. Software to be utilized includes RAM Concrete, RAM Concept, and RAM Frame. This portion of the study is an extension of AE 597A, Building Modeling, and is intended to fill the MAE requirement.

In addition to a depth study focusing on the structural system, two breath topics outside the field of structures will be proposed for study. The breadth studies will focus on the green roof on the Key System portion of the building. An architectural breadth will be performed to research the sustainable benefits of installing a green roof on a building and also to provide a landscape design for the green roof. Additionally, a building enclosure breadth will be performed to research the thermal and waterproofing issues associated with the green roof and the integration of the system with the building. Drawing details of the building envelope/waterproofing aspect of the green roof design will be provided.

Background

Building Overview

1100 Broadway is a 20-story tower primarily used for offices but also provides shopping and entertainment at the ground level. Its architecture combines a new high-rise tower with the adaptive re-use of the Key System Building facade which houses a smaller portion of the building. The Key System Building is a 37,000 square foot historic office building which was damaged in the 1989 Loma Prieta earthquake and has remained vacant ever since. It is now a National Historic Landmark and its facade is incorporated into the design of the first eight floors of 1100 Broadway. Sustainability was a primary concern in the design of 1100 Broadway. It aims to achieve a LEED Gold rating by incorporating many green features into its design. It takes advantage of the opportunity to utilize Transit Oriented Development (TOD) due to its location directly above the 12th Street/City Center BART public transportation station. It features photovoltaic solar panels on the tower roof, a green roof on the Key System Building portion, and a rainwater collection, filtration and reuse system. The building envelope is comprised of high performance glass from floor to roof with large curtain walls on two of the four elevations. The high performance glass is "tuned" depending on which side of the building it's on: At the south and west facades, which receive more direct sun, the glass is slightly darker, at the north and east facades the glass is slightly clearer.

Structural System

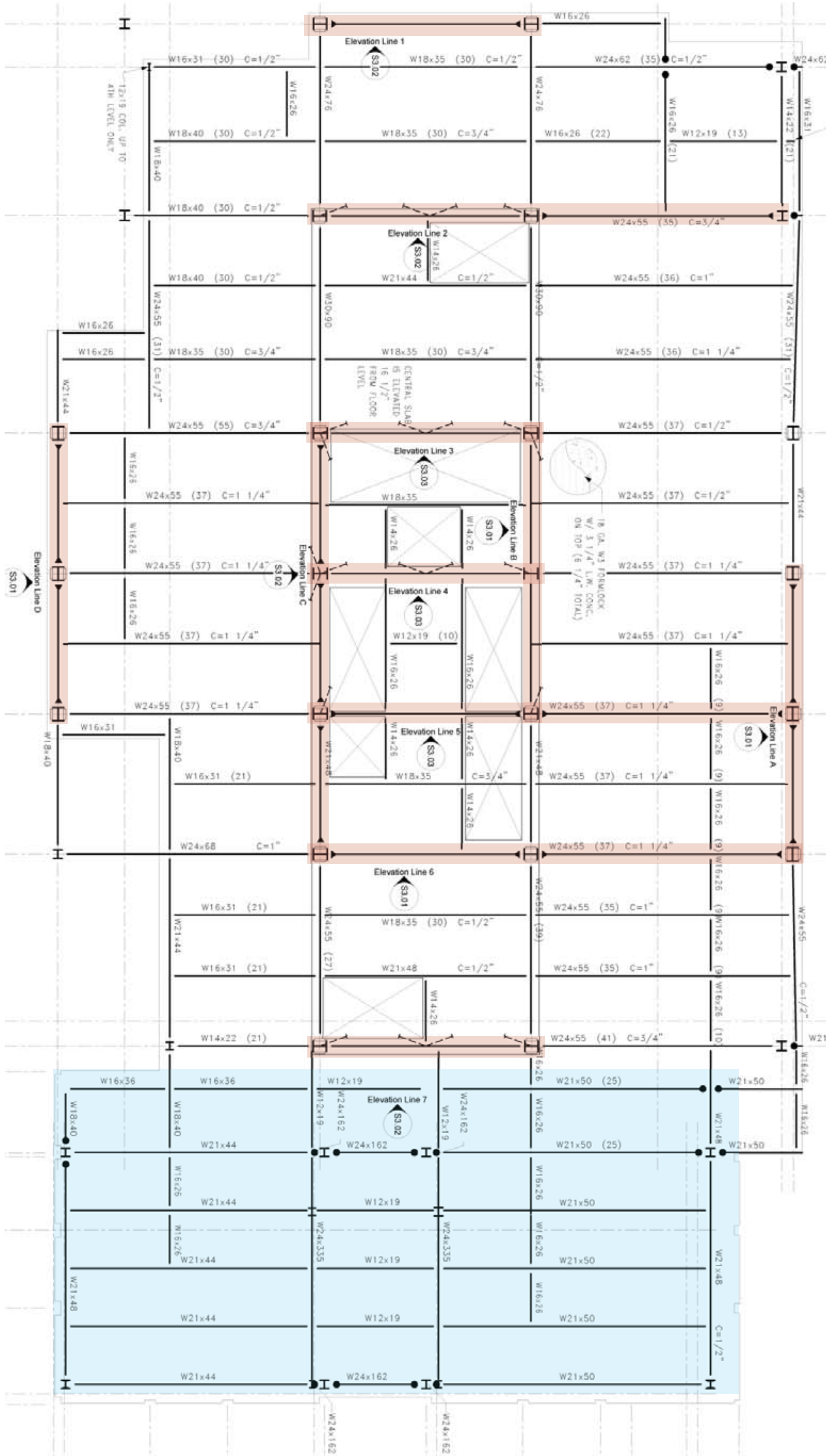
Typical office floors are 3¼″ light weight concrete fill on a 3″ 18 gage Verco W3 Formlock composite steel deck for a total thickness of 6¼″. Composite steel beams support the deck. Columns supporting the composite deck are standard structural steel wide flange sections. Mechanical areas are similar to the typical office floors with the exception of normal weight concrete fill in place of the lightweight fill on composite metal deck. The roof system on the tower portion of the structure consists of the same composite steel deck system as the typical office floors.

Wind and earthquake forces are resisted by a dual system composed of Steel Special Concentric Braced Frames located around and across the building core and Special Moment Resisting Frames (SMRF) at the building perimeter. Braces are wide flange members with welded connections. Diagonal bracing member sizes range from W12x96 to W14x132. Member sizes of the moment resisting frames range from W24x94 to W24x207. Lateral forces are distributed to the SMRF at the perimeter of the building and the loads are distributed to surrounding members based on their relative stiffnesses with a higher percentage of the load being distributed to the stiffer members.

The main tower of the building is supported by 110 ton, 14″-square, driven prestressed precast concrete piles beneath a reinforced concrete mat foundation. The structure utilizes 117 existing 14″ square piles and requires 334 new 70′-0″ long prestressed concrete piles. The concrete mat slab is 5′-9″ thick with #11 bars spaced at 12″ O.C. each way on both faces. The remaining portion of the foundation is a 9″ thick reinforced concrete slab with #5 bars spaced at 12″ O.C. Framing within Key System portion of the structure is supported by 6′-0″ square spread footings. See Figures 1 and 2 for typical framing plans.

Typical Framing Plans

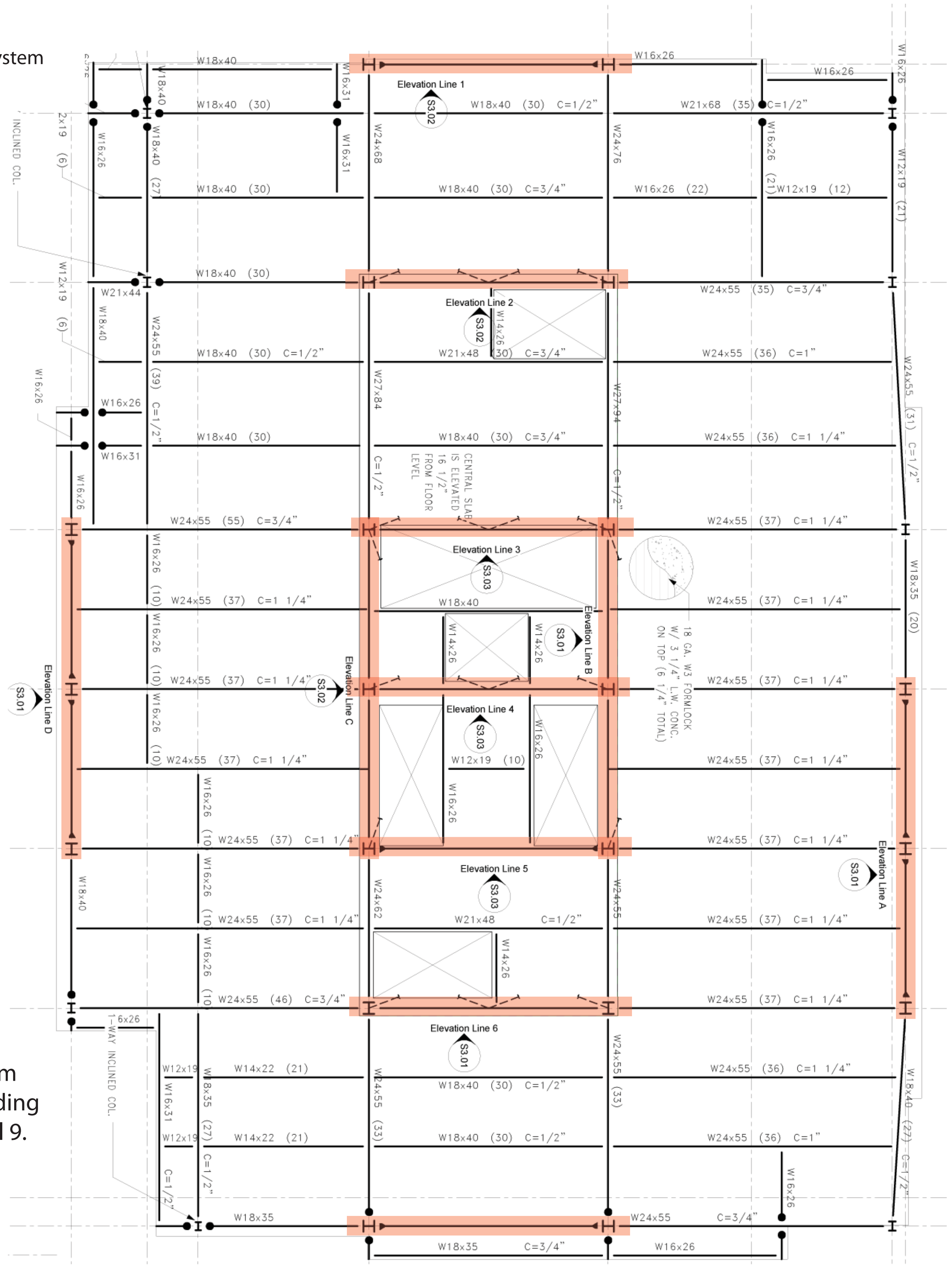
Figure 1:
Typical Levels 3 - 9
Members of the lateral system are indicated in red



The breadth studies will focus on the historic Key System portion of 1100 Broadway which is highlighted in blue.

Typical Framing Plans

Figure 2:
Typical Levels 10 - Roof
Members of the lateral system are indicated in red



Note the Key System portion of the building terminated at Level 9.

Depth Study

Problem Statement

1100 Broadway's current floor system is composite metal deck supported by composite steel beams. The assembly consists of a 3", 18 gage, W3 Verco Formlok deck with 3 ¼" lightweight concrete topping for a total slab depth of 6 ¼". The controlling parameter for the design of gravity members supporting the composite deck is deflection due to total load as determined in Technical Report 2. Member capacity is significantly higher than the gravity load demands. The total depth of the composite metal deck system and supporting composite steel beams and girders amounts to 30.25".

Solution

Technical Report 2 provided an alternative system study of a 2-way post-tensioned concrete slab. The analysis yielded a 9" total system depth, reducing the current floor depth by approximately one-third. Another advantage of post-tensioned systems is very limited deflections due to the upward force exerted by the post-tensioning tendons. With closer observation, the rectangular geometry of most bays will result in a one-way behavior. Therefore, a one-way mild steel reinforced concrete slab with post-tensioned concrete beams will be proposed for study next semester. Concrete gravity columns will be designed in place of the current steel columns.

A post-tensioned slab will not be considered for study. A post-tensioned slab system would be very costly especially due to 1100 Broadway's 20-story building and therefore it is more economical to post-tension only the beams and have a mild steel reinforced slab. Another disadvantage of a post-tensioned slab is opening locations are critical, limiting the placement of openings throughout the entire structure. Openings locations for a mild steel reinforced slab are not nearly as critical and can accommodate most plans.

The one-way slab and post-tensioned beam system will most likely be deeper than the 2-way post-tensioned slab previously studied, but the depth of the floor system should still be significantly reduced. Although the floor system depth will be reduced, concrete systems are usually heavier than steel systems and the impact of the proposed system on the foundations will need to be investigated.

The current lateral system of steel moment and braced frames is no longer a viable system for the proposed concrete slab and post-tensioned beams. A change of lateral system will be necessary. Concrete shear walls make for the best alternative lateral system due to the 20-story height of the building. The post-tensioned beams will not be part of the lateral system.

Depth Study

Solution Method

ACI 318-08 will be referenced for the design of the proposed concrete system. RAM software will be used to design the gravity and lateral systems. It will be necessary to learn RAM Concrete and RAM Concept which can be done through tutorials and handbooks on the topics. The concrete system will be modeled in RAM Concrete and individual floors will be imported to RAM Concept to design the post-tensioned beams. Hand checks will also be performed to supplement and confirm designs by the modeling programs. This portion of the study will be an extension of AE 597A, Computer Modeling, and is intended to fill the MAE requirement.

Breadth Studies

In addition to an in depth study of 1100 Broadway's structural system, two additional studies will be conducted in fields of study outside of structures. Both breadth topics will focus on the Key System portion of the building.

The Key System Building is a 37,000 square foot historic office building which was damaged in the 1989 Loma Prieta earthquake and has remained vacant ever since. It is now a National Historic Landmark and its facade is incorporated into the design of the first eight floors of 1100 Broadway.

At Level 9 a large set back occurs where the Key System Building portion terminates. There are intentions to create a green roof at this level which will contribute to the sustainable goals of the building. Since the project is only in design development phase there are no drawings related to the green roof available.

Breadth 1:
To provide an architectural breadth to research the sustainable benefits of installing a green roof on a building and also provide a landscape design for the green roof.

Breadth 2:
To provide a building envelope breadth to research thermal, drainage, and waterproofing issues and integration of the system with the building. Drawing details of the building envelope/waterproofing aspect of the green roof design will be provided.

Background: Key System Building

A supplemental plan and renderings of 1100 Broadway are provided below to help the reader understand the layout and context of the Key System portion of the building which the breadth studies will focus on. See Figures 3 through 6 below.

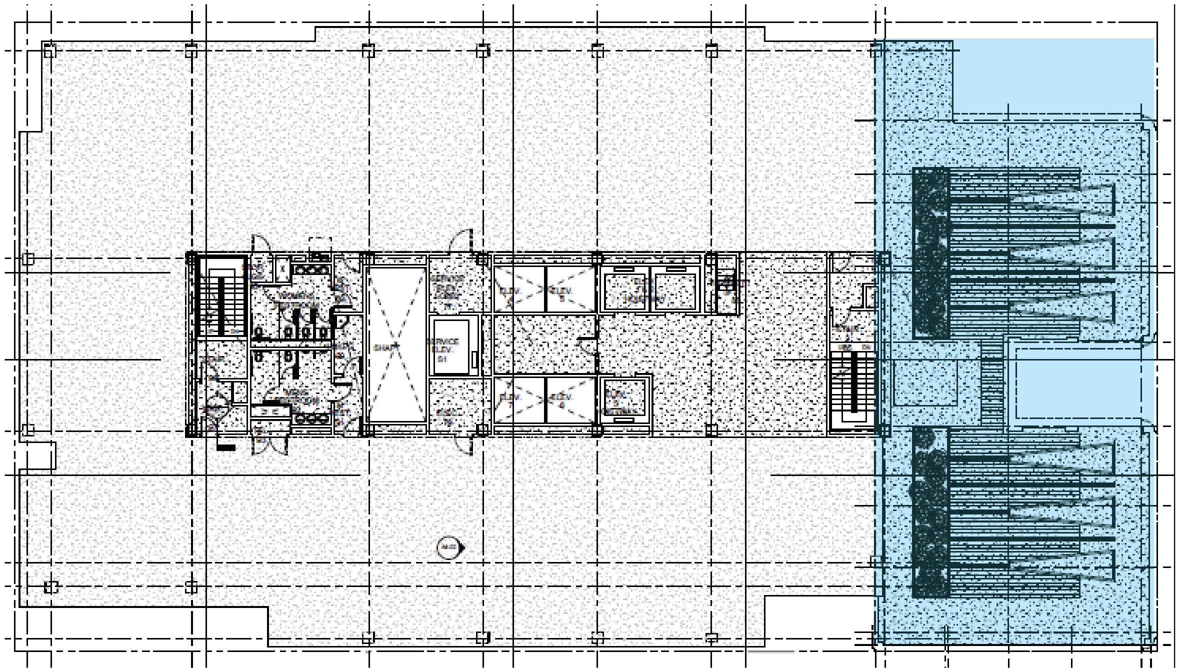


Figure 3:
Architectural floor plan of Level 9. Key System portion is highlighted in blue.

Figures 4-6:
Renderings of 1100 Broadway showing the Key System portion of the building.

Tasks to Accomplish

Depth Study: Structures

A task outline of the proposed depth study is listed below. For a schedule of the tasks for the spring semester see Table 1.

Task: Design Gravity System

1. Learn RAM Concrete and RAM Concept (Milestone 1: January 26)
2. Determine member trial sizes
3. Model system in RAM Concrete (Milestone 2: February 9)
4. Import floors to RAM Concept and design post-tensioned beams
5. Compare concrete gravity system with existing steel composite system (Milestone 3: February 23)

Task: Design Lateral System

1. Determine new weight of building and impact on the seismic loads referencing ASCE 7-05
2. Determine changes in floor to floor height and overall building height and calculate wind loads referencing ASCE 7-05
3. Learn RAM Frame
4. Model concrete shear walls in RAM Frame (Milestone 4: March 16)

Task: Study impact of proposed concrete system on foundations

Task: Compare and contrast the proposed concrete system with existing steel system

1. Develop conclusions

Task: Finalize Report

Task: Prepare Presentation

Task: Completion of Senior Thesis Work!

Tasks to Accomplish

Breadth Studies

A task outline of the proposed breadth topics is listed below. For a schedule of the breadth tasks see Table 1.

Green Roof

Breadth 1 - Architectural:

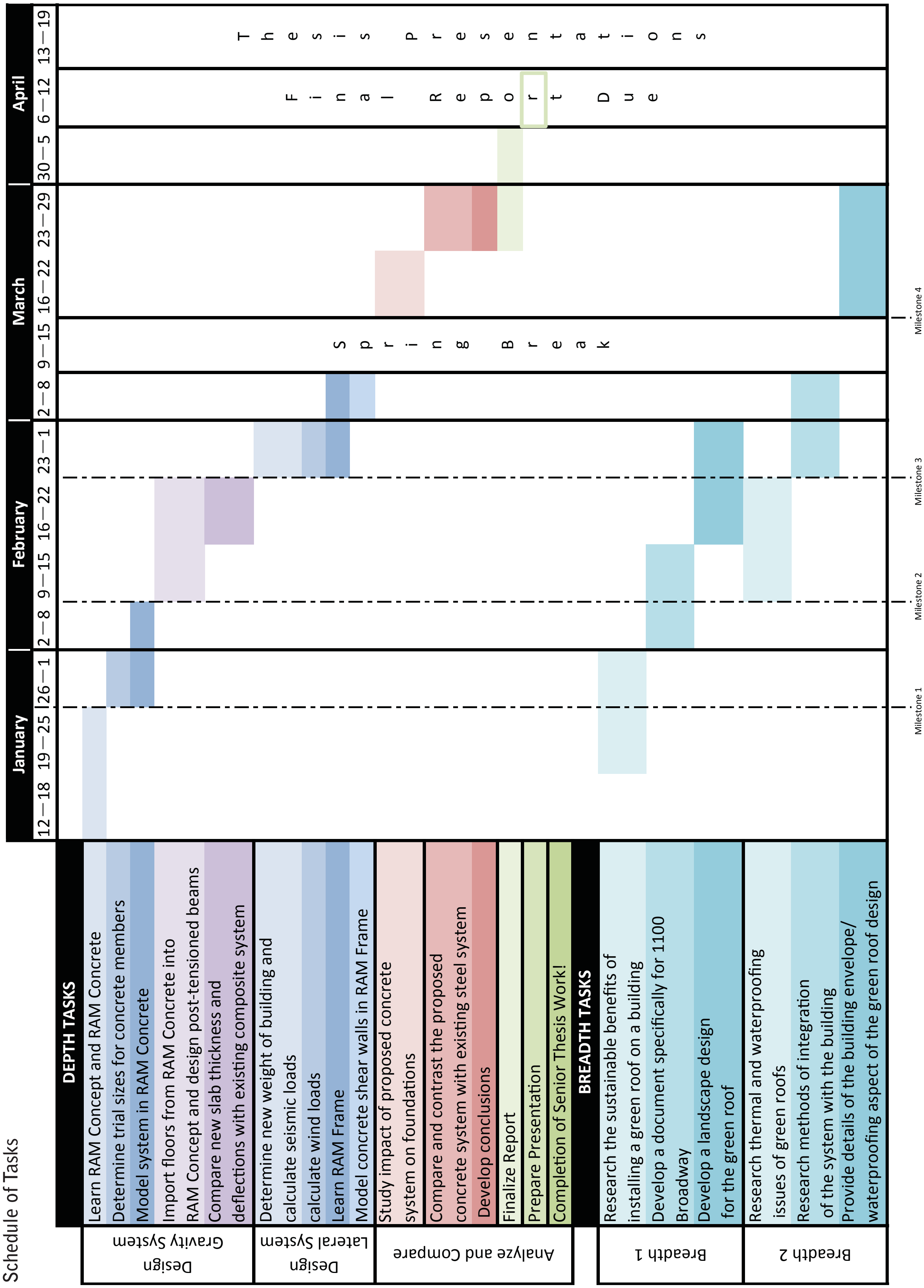
1. Research the sustainable benefits of installing a green roof on a building
2. Develop a document detailing the sustainable benefits and advantages of a green roof specifically for 1100 Broadway
3. Develop a landscape design for the green roof

Breadth 2 - Building Enclosure:

1. Research thermal, drainage, and waterproofing issues of green roofs
2. Research methods of integration of the system with the structure
3. Provide details of the building envelope/waterproofing aspect of the green roof design

Schedule

Table 1:
Schedule of Tasks



Conclusion

The purpose of the proposal is to provide a plan of study in the structures option for Senior Thesis in the spring semester of 2009. An in-depth study focused on changing the gravity system from a composite metal deck system with composite steel beams to a one-way concrete slab with post-tensioned concrete beams will be performed. Changing the gravity system will require a change of lateral system as well. Concrete shear walls will be selected and designed for the new lateral system. The proposed gravity system and lateral systems will also impact the foundations and those changes will be studied. The concrete system will be designed using a combination of computer software and hand calculations. The final design will be compared with the existing system to determine the best option for 1100 Broadway. An architectural breadth and building enclosure breadth will be performed which focus on the green roof of the historic Key System portion of the building.