OFFICE BUILDING-G

Eastern United States

Thesis Proposal

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Structural Option

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Executive Summary

The purpose of this Thesis Proposal is to outline the work that will be performed to satisfy the required coursework of the Architectural Engineering Senior Capstone Project. This report provides a necessary amount of information to familiarize the reader with the existing structural system of Office Building-G. A problem with the current structural design is then identified and the context of the problem is explained. A proposed structural redesign is introduced along with breadth studies on the effect the solution will have on the design and construction of Office Building-G.

The internal shear walls and perimeter columns of Office Building-G are critical members to the existing structure. However, these elements reduce the amount of rentable space and restrict the designs for the tenant fit outs. Removing these structural components would resolve this problem but it would require an entirely new structural system. A variety of external structural designs will be compared in an effort to find the most efficient design for the criteria presented by Office Building-G.

In an effort to create an open floor plan, the existing shear wall core will not be used to resist any of the lateral forces which Office Building-G will experience. This requires the use of an external lateral system. In order to choose the most efficient structure, multiple designs will be compared to each other on a basis of period of vibration, maximum deflection, foundation impacts, and structural weight. A variety of different braced frame geometries will be compared.

Introducing an external structure to a building has a large impact on the façade aesthetics and construction of Office Building-G. Breadth studies will be performed to determine the extent of the structures impact. These topics will be considered in the final comparison between the existing structure and the proposed alternative.

This report gives a complete description of the tasks which need to be performed and outlines the order in which they must be performed. A tentative schedule has been created which summarizes the time allotted to the given tasks in order to complete the project in a timely matter.

Introduction

Due to owner restrictions, the building name, location and tenant of Office Building-G cannot be disclosed. Neighboring an existing metro station, this 14 story building will become one the tallest of the modest skyline. Beneath the superstructure is a below grade, 4-story parking garage with space for 662 cars. On the first two floors of the building, a larger floor plan is used to accommodate for rentable space for retail, a restaurant, a bank and a loading dock. Typical floors have a square footage of 25,376 sf with a floor to floor height of 12'-3". The roof of the mechanical penthouse is 195 ft above grade and the gross square footage of the superstructure and garage combined is 649,461 sf. Figure 1 is a rendering of Office Building-G.

Figure 1

Gravity System

Gravity loads are carried down the building through a combination of interior and perimeter concrete columns and a shear wall core. The typical floor system is a cast-in-place concrete one-way slab. Thickness changes based on loading conditions but the typical floor is a 7", 5000 psi normal weight concrete slab. On the first floor, there is a 12" concrete slab designed for fire separation between the parking garage and superstructure. The slab system carries the loads to post-tensioned concrete beams with spans between 41'-5" and 45'-1 1/4".

The post tensioned beams range in width from 18" to 48" and have a maximum depth of 24". In Office Building-G, the typical girder is 18" deep by 48" wide. These beams collect the floor loads from the slab and distribute their reactions to the columns supporting them.

Rectangular and round concrete columns then transfer the loads down the strictly followed grid. Typical floors have columns sizes of 24" x 24", 24" x 30", and 30" diameter. Smaller columns are used in the mechanical penthouse due to the much lower loads they are carrying. On above grade floors, higher strength concrete is placed below columns and shear walls in the slab to accommodate for any possibility of punching shear. In the parking garage, 8" drop panels are used instead of the different concrete strengths. The typical floor plan, shown in Figure 2 below, highlights the post-tensioned beams in yellow, the reinforced beams in purple, shear walls in green and blue, and the columns in red.

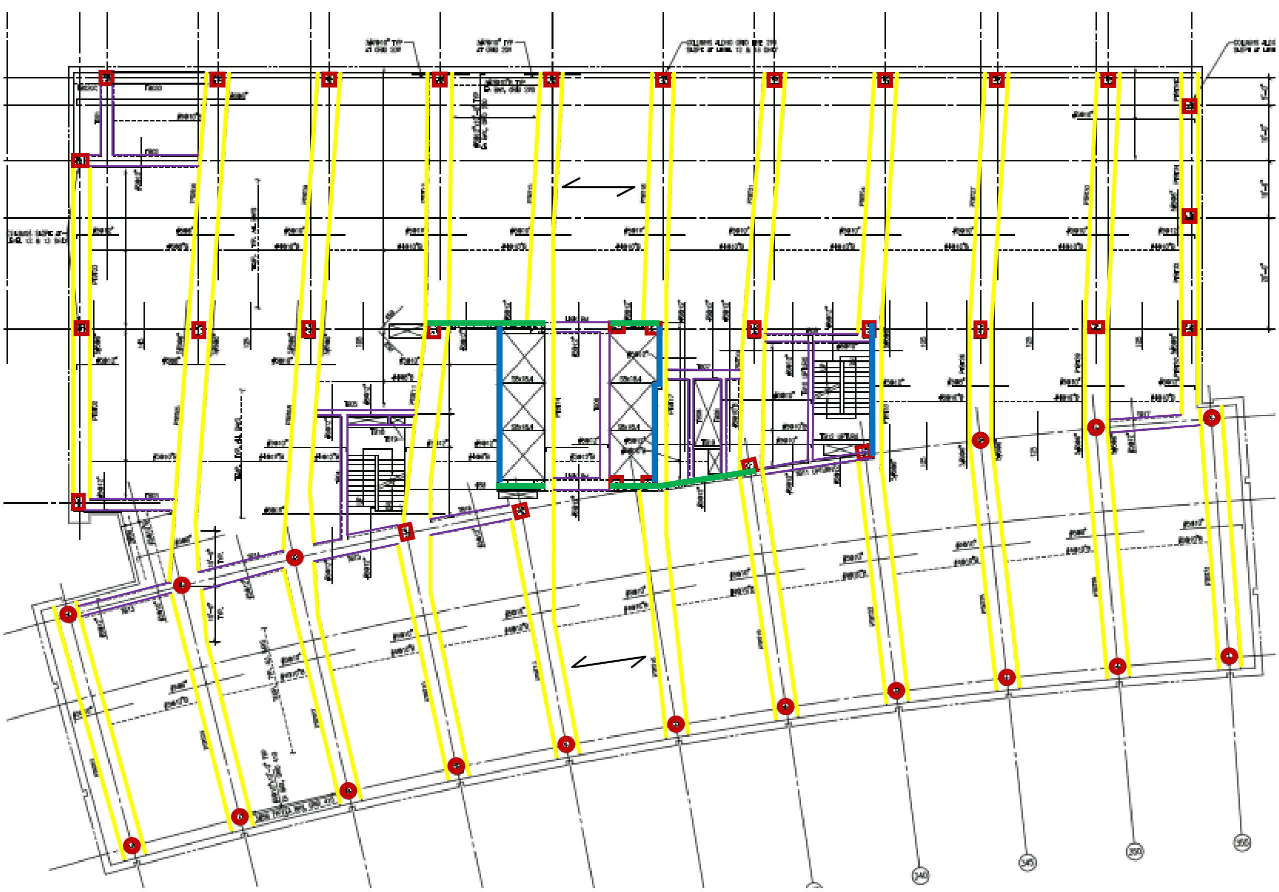


Figure 2

Lateral System:

Wind and seismic forces are resisted by an internal shear wall core. The core is made of reinforced concrete walls which have a consistent floor plan from the bottom floor of the parking garage up to the slab of the roof. Basement shear walls were designed with f'c = 10,000 psi, levels 1-4 use f'c = 8,000 psi, and levels 5-14 use f'c = 5,000 psi. Precast concrete beams attached to concrete columns using precast lateral connections provide the required resistance for the mechanical penthouse and elevator machine room.

Lateral forces are engaged by the shear walls through the use of floor diaphragms. The building façade collects wind forces that are then transferred to the respective floor diaphragm. Forces then travel through the diaphragm until the shear walls are engaged, at which point the forces are distributed based on the relative stiffness of the walls.

Foundation System:

The geotechnical engineering on the project performed a geotechnical study for the location of Office Building-G which determined the possible foundation systems as spread footings, caissons or geopiers. The structural engineers decided to use a system of spread footings under the columns, shear walls and along the perimeter concrete bearing wall. Square footage and depth of the footings are based on the load carrying capability of the soil and the vertical load on the column.

Service loads on the columns ranged greatly depending on whether or not the column extended up into the superstructure of the building. Based on the structure above the foundation, the load capacity of soil was determined to support a range of 3,000 psf to 10,000 psf. Loads on the footings varied between 60 kips to 3075 kips, once again depending on which part of Office Building-G they are supporting.

Problem Statement

Office Building-G currently relies on reinforced concrete members to resist the vertical and horizontal forces applied to the building. An internal shear wall core is responsible for resisting all of the lateral forces applied to the building. Perimeter columns and shear walls resist the gravity forces the building experiences. Gravity loads are distributed to the columns and shear walls through the use of post-tensioned girders giving the building a structural depth of 18".

Office Building-G consists of 14 stories of rentable office space. An increase in rentable floor space would offer the owner an opportunity to see larger profits. If the majority of the columns were removed, the open floor plan would be appealing to potential tenants, also resulting in additional profits for the owner. The goal of this thesis is to maximize the profits available to Office Building-G through the removal of the internal shear wall core, all perimeter columns and as many interior columns as possible.

Proposed Solution

The application of an external structure to Office Building-G will allow for the removal of the interior columns and shear walls, resulting in a greater square footage of rentable space. Additionally, an external structure will allow the open floor plan to be more flexible for tenant fit outs. The proposed structure will be designed with the assumption that the typical floor plan is consistent for every story of Office Building-G. The new structure will resist the all of the lateral loads as well as any necessary gravity loads. The feasibility of keeping the existing structural depth of 18" through the evaluation of different floor systems will also be considered. Due to the visibility of the external structure, the aesthetics of the structure will influence the choice of the final design.

Introduction

Steel was chosen as the structural material which lends itself the best to the requirements of the proposed solution. Steel allows for a variety of geometries to be explored for the lateral force resisting elements which will be visible in the façade of the building. Braced frames were chosen for the new lateral system of Office Building-G because they are more efficient than moment frames. Braced frames can be designed in multiple different ways, allowing for different façade geometries to be explored. The choice to use steel frames requires a new floor system because the post-tensioned concrete beams can no longer be applied. Without increasing the existing ceiling cavity space, a new floor system capable of distributing the gravity loads between the columns while leaving space for the other building components like mechanical ductwork must be designed. The following sections describe how the structural system will be designed and the effects it will have on the other building elements.

Braced Frames

Capable of resisting both wind and seismic forces, braced frames are a common lateral system in steel buildings. Lateral loads enter the frame through the floor diaphragm and are then transferred down the frame into the foundation system. Braced frames can be designed in a variety of different geometries and these will be explored for their aesthetic qualities.

Once the geometry of the frames is chosen, they will be applied in different locations of the building. Again, aesthetics will influence the final layout of the frames but the structural performance of the different frame locations will be compared. This comparison will be made through the use of computer modeling. Each layout will be modeled in the computer program ETABS and the building loads will be applied. The layouts will be compared based on the period of vibration, maximum deflection, total weight, and their influence on the foundation.

After the frame geometry and layout has been decided, the frames will be designed for structural economy. This will require applying a variety of load combinations to the structure to define the controlling load case for each element. The distribution of lateral loads will be performed by ETABS and confirmed through hand calculations. Economical elements will be chosen based on the lightest element capable resisting the applied loads.

Columns

The majority of the columns will be located along the perimeter of Office Building-G as part of the façade. Columns which are used as part of the braced frames must be designed for the combination of both lateral and gravity loads. Columns which are not part of a frame will be designed based on the controlling gravity load combination.

Due to the large floor plan of Office Building-G, there must be interior columns to reduce the span of the floor system. These interior columns will be placed in locations which will not influence the architecture. The interior columns will be located around the stair wells and elevator shafts in order to have the smallest impact of the available floor space.

Columns will be designed economically based on weight as well as depth to ensure simple splice connections. RAM Structural System will be used to determine the loads applied to the columns. These values will be hand checked by following the load path of the gravity loads.

Castellated Beams

Castellated beams are created by cutting a typical W-Flange section in half in a method as shown below in figure 10. The beam is then offset and welded to create a deeper section as shown in Figure 10. New section properties can be calculated based on the new beam geometry. The size of the openings designed will be determined by the amount of space needed for the mechanical equipment in the cavity space.

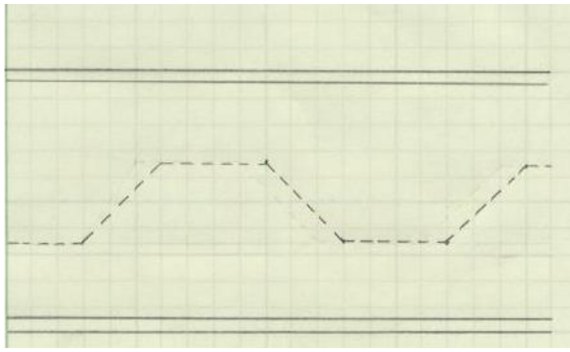


Figure 3

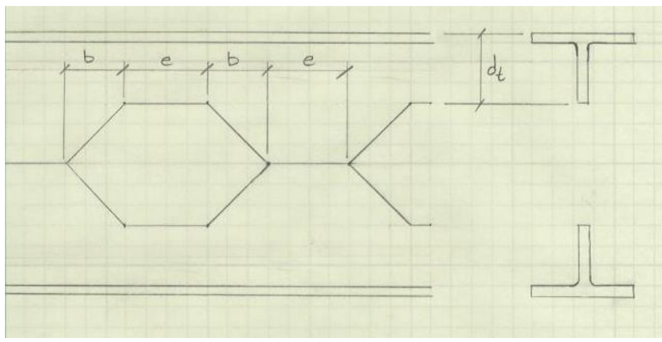


Figure 4

Castellated beams will be designed by the controlling forces of Vierendeel Bending. Vierendeel bending occurs when the global bending moment causes a localized compression or tension force in the top or bottom of the member known as a primary force. When the primary forces pass through the opening in the beam, localized bending moments are created, known as the secondary forces. These forces change at every opening in the beam so it is necessary to check each opening to examine the interaction of shear and moment.   To check Vierendeel bending one must: calculate the net shear and moment at each hole, calculate the axial and moment capacity of the top and bottom tees, and check the interaction of the axial and flexural forces.

Breadth Topics

Two breadth study topics were chosen based on the other aspects of Office Building-G's design which would be directly altered if the proposed solution was going to be implemented into an actual building.

Architectural

Implementing an external structure to the existing façade of Office Building-G will greatly change the appearance of the building. As mentioned previously, aesthetics and structural efficiency will influence the design and location of the external structure. External renderings of Office Building-G displaying the proposed final façade will be created to show difference from the original design.

Architectural changes are not limited to the exterior of the building. Minor but significant changes to the typical floor plan of Office Building-G will result from an external structure. The columns and shear wall core do not take up a large amount of square footage of the floor but the appeal of an open floor plan and additional rentable square footage offer the owner an opportunity to charge a larger cost per square foot. The potential gain in income will be analyzed as part of this breadth study.

Mechanical

Office Building-G has large duct work in the cavity space between the floors. The original structural depth of 18" allowed for these large ducts to pass under the framing plan. A steel structure is a much deeper solution so without increasing the cavity space, the duct work must pass through the castellated beams. However, the existing duct is 48" wide by 12" deep, too large to pass through a castellated beam.

New duct work will be sized which will be able to pass through the castellated beams. Without changing the mechanical requirements, these smaller ducts will need to provide the space with the same volume of air per minute. The CFM requirements of the space will likely result in a larger fan design for the smaller ducts.

MAE Requirements

MAE requirements of the thesis proposal will be met through the creation and analysis of ETABS computer models. The coursework taught in AE 597A provide the necessary knowledge to create a computer model. Results of the computer model will be used to evaluate the building under lateral and gravity loads. As part of the construction breadth, the nodal connection will be designed and analyzed using the methods taught in AE 534.

Solution Method

The redesign of Office Building-G will be performed using the following codes and resources: IBC 2006, ASCE 7-10, AISC Design Guides, metal deck catalogs, ETABS, RAM Structural System, and Revit Architecture. The alternative floor system will be designed with the aid Metal Deck Catalogs, AISC design guides, and The Design of Welded Structures, The lateral system and the majority of the gravity system will be designed with the aid of ETABS and RAM Structural System. Based on the results of the ETABS analysis, additional models may need to be created to determine alternative, more efficient designs. Throughout the redesign process, the effects of the new structural system on the mechanical system and architecture of Office Building-G will be considered.

Tasks

1. Determine Loads

a. Determine wind loads based on steel structure
b. Calculate seismic loads with an estimation of new floor loads
c. Estimate weight of structure
d. Determine controlling load cases

2. Design Floor System

a. Research castellated beams and alternative floor systems
b. Determine necessity for interior gravity columns
c. Consider systems capable of distributing lateral loads to structure
d. Choose system structural depth, span length and size of openings.

3. Consider Frame Geometries

a. Draw geometries in AutoCAD
b. Create ETABS models
c. Compare systems on period of vibration, deflection, weight, and uplift
d. Choose final design

4. Design Castellated Beams

a. Design preliminary size based on strength and deflection requirements
b. Adjust beam and opening size based new ducts
c. Chose final design

5. Finalize Design

a. Create complete building model in ETABS
b. Analyze elements for applicable load combinations
c. Consider impact of design on entire building

6. Render Architectural Images

a. Create Revit Architectural model
b. Insert the external structure elements on façade
c. Render images to show departure from original design

7. Analyze Connections

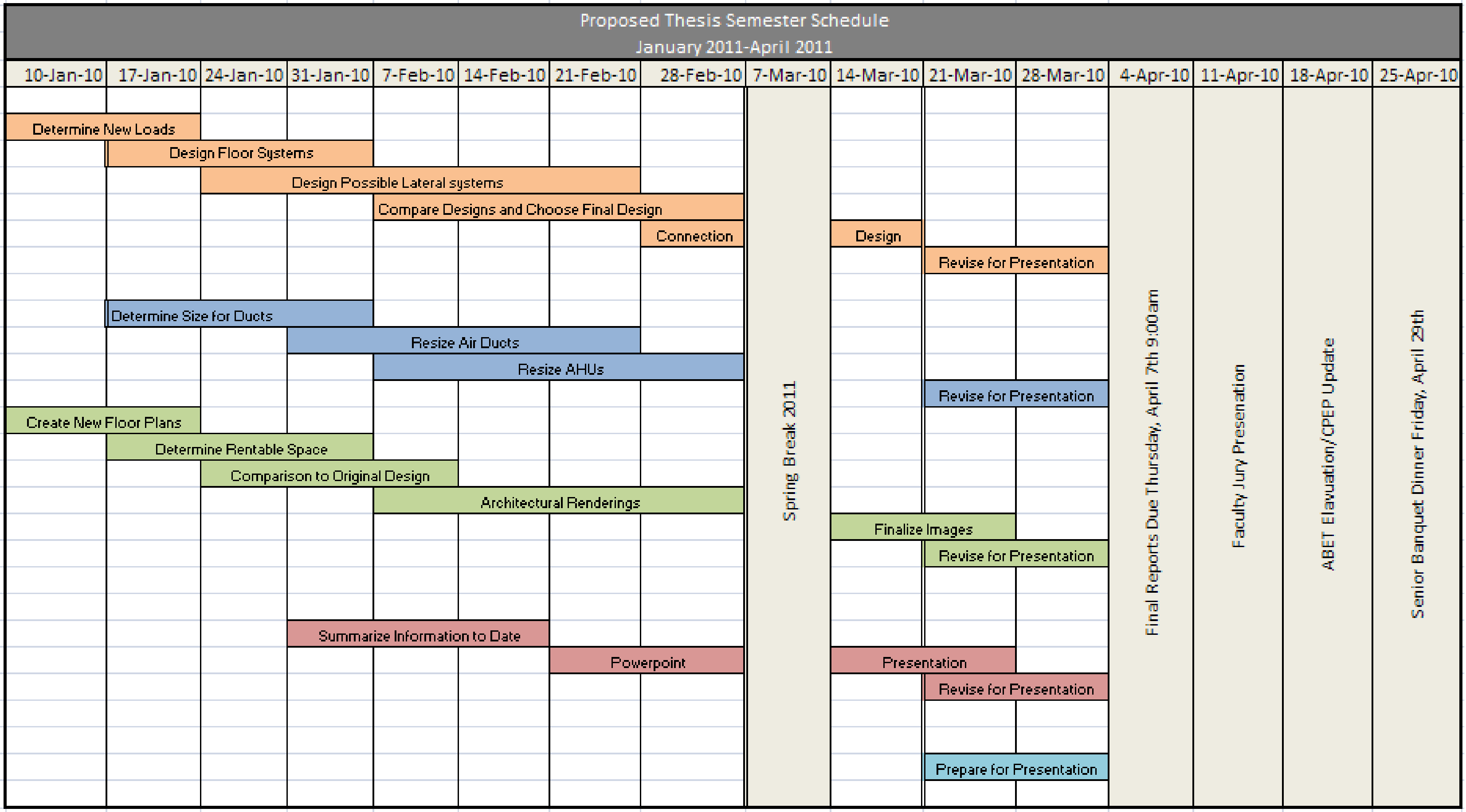
a. Design typical connection between diagonal and horizontal elements
b. Create connection designs based on constructability

8. Final Presentation Preparation

a. Organize, format and finalize presentation
b. Prepare for final presentation

Schedule

SENIOR THESIS FINAL PROPOSAL	OFFICE BUILDING-G	CARL HUBBEN
12/10/2010		Consultatnt: Ali Memari
		STRUCTURAL



Milestone:	January 10th 2010:	DETERMINE LOADS	Analysis 1: Structural Redesign
Milestone:	February 14th 2010:	DESIGN FLOOR SYSTEMS, ANALYZE POSSIBLE DIAGRID USES	Analysis 2: Construction Breadth
Milestone:	March 7th 2010:	RENDER ARCHITECTURAL IMAGES	Analysis 3: Architectural Breadth
Milestone:	March 28th 2010:	CONTENT COMPLETE AND READY FOR FORMATTING	Analysis 4: Final Presentation