Proposal

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AE 481W-Senior Thesis
The Pennsylvania State University

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Executive Summary

Building Description:

The Washingtonian Center is an eight story office building located in Gaithersburg Maryland. The building is an envelope and core design to allow for the tenants to tailor their spaces to their particular needs and tastes. To accomplish maximum flexibility of the architectural plan, a structural steel framing system was used so that no columns would need to be placed in the tenant spaces. The lateral force resisting system in the building uses concentrically braced chevron frames located around the mechanical core of the building. The façade is a glass curtain wall combined with pre-cast concrete panels.

Proposal:

Owing to the fact that the primary design goal of the structure was to provide open leasable space, it is proposed that this can be adequately achieved while offering many benefits by altering the column grid and converting the building to a concrete structure. This proposal will utilize a concrete post-tensioned floor system and concrete shear walls as the lateral system. This will drastically reduce the floor to floor heights and potentially allow for an additional floor to be added to the building while maintaining the same overall height of the structure.

Solution:

To accomplish this proposal, the entire structure of the building will need to be redesigned. This includes the lateral system, which will become concrete shear wall. Additionally an entirely new floor system will need to be designed. The design will use a post-tensioned two-way flat plate system to hopefully limit the slab thickness to eight or nine inches. The columns will also need to be designed in concrete to support the newly calculated loads. Finally the footings of the building will need to be redesigned to ensure adequate stability of the structure.

Breadth Topics:

To complete the scope of the proposal, an architectural investigation will be done to show that the impact of the additional columns that will be required can be minimal to the flexibility of the leasable space. Additionally a study on the scheduling impact and cost of the new design will be conducted.

Introduction

The Washingtonian Center is phase one of a three phase development of the site located in Gaithersburg Maryland. The other two phases consist of a pre-cast concrete parking garage structure and a second office building. The building is an eight story office tower supported on a structural steel frame. The over arching goal of the project was to create an office environment that provided maximum comfort to its occupants along with allowing the tenants to layout, design and finish their spaces as they see fit. To achieve this idea, an envelope and core design was utilized. The façade consists of expansive glass curtain walls intermixed with concrete pre-cast panels to break up the glass and add visual interest. The building was designed using the IBC 2003 with reference to ASCE 7-02. For the purposes of this proposal, ASCE 7-05 will be used.

Background

Foundation:

The foundations for the Washingtonian Center consist of spread footings for the gravity columns with a combined mat footing for the lateral force resisting frames. Typically the exterior gravity columns are supported on 9' x 9' square footings that are 30" thick and have bottom reinforcing of #6 bars at eight inches in each direction. Interior gravity columns have a typical footing size of 11' x 11', 30" thick and reinforced with #8 at twelve inches on center. The lateral force resisting frames sit on a combined mat footing that is 40' x 36' and 4.5 feet thick. The mat footing has a base bottom reinforcing mat of #11 bars at nine inches in the long direction and #7 at twelve in the short direction. Additional steel is added around each column to take the increased moments. The top reinforcement consists of #7 at twelve inches in both directions with addition bars added around the columns. All the foundations are made from concrete having a compressive strength of 3000 psi.

Columns:

The columns in the building are spliced at the fourth floor and the seventh. All gravity columns in the building are either a W10 or W12 with sizes below the first splice point ranging from W10x49 to W12x96. Above the first splice location (floors 4,5 and 6) the columns range in size from W10x39 to W12x65. On the upper levels (floors 7, 8, the roof and mechanical penthouse) the columns range in size from W10x33 to W12x53. The un-braced length of the columns is the floor to floor height of 13'-4".

Floor System:

The general floor system used is 3" 20 gage composite steel floor deck with 3.25" inch topping of light weight concrete with a compressive strength of 4000 psi. The floor is reinforced with 6" x 6"-W2.1 x W2.1 welded wire fabric placed 1" below the top of the concrete. This system is utilized for the 2nd – 8th floors. The ground floor is a slab on grade that is 5" thick and reinforced with 6" x 6"-W2.1 x W2.1 welded wire fabric. The slab on grade is poured on a 6" granular base. The steel deck floor system is supported on W21x44 beams spaced every 10' and spanning a distance of 45' on the exterior bays. The interior bays are supported by W14x22 spaced every 10' and spanning a distance of 20'. The girders supporting these beams are typically W14x22 spanning 20'.

Lateral System:

The lateral force resisting system implemented in the Washingtonian Center is a series of concentrically braced chevron frames around the elevator cores need the center of the building. The frames span in both directions for a distance of 20'. The columns in the frames are spliced at the fourth and seventh levels and are W12x210 at the bottom, W12x106 at the middle levels and 12x65 at the upper floors. The beams in the frame are W18x50 and the chevron braces are W10x77.

Problem Statement

The main reason to redesign the Washingtonian Center in concrete is to eliminate the depth of the floor system. The Current steel design has a floor depth of twenty eight inches. By adding addition rows of columns along grid lines two and five, a post-tensioned concrete floor will be possible, potentially reducing the floor slab down to eight inches. This will result in a savings of twenty inches per floor, and when accumulated over the entire height of the building will save enough space to add a ninth floor on top. This will increase leasable space and provide additional revenue for the property management company.

ETABS will be used to model and analyze the structure, as well as design the lateral systems. The floors will be designed in RAM Concept and the columns and footings will be done with programs produced by PCA.

Problem Solution

To limit the floor depth of the structure a post-tensioned concrete flat plate will be used. Base on common practice and rules of thumb it has been determined that an eight inch concrete slab with 5000 psi concrete will be able to provide the required strength and adequate serviceability. Drop panels will not be used if at all possible, instead shear reinforcing along with stud rails will be used in locations where shear presents itself as a problem. The tendons will consist of standard seven wire strand un-bonded extruded tendons.

With structural conversion from steel to concrete, the lateral system will need to be redesigned as well. To control drift of the building shear walls are proposed to be located where the current chevron braced frames are. This will place the walls around the mechanical core of the building, allowing for the floor plan to remain unobstructed and the exterior façade to remain entirely glass curtain wall. Based on the shear strength of concrete, it has been roughly calculated that shears on the proposed locations that are eight inches thick and made from 5000psi concrete will be adequate to resisting the current governing wind loads. It should be noted that seismic forces will need to be recalculated based on the new weight of the structure, however these are unlikely to govern over wind.

The columns will be design as well using 5000 psi concrete. For the preliminary purposed of this report, it is thought that 30” x 30” square columns at the ground level will be strong enough to support the gravity loads. These column sizes will be reduced to appropriate sizes at the third and seventh levels.

Solution Method

Lateral Design and Analysis:

Etabs will be used to do a dynamic analysis of the building and then used to also design the concrete shear walls. The process will include two separate models of the structure. One will be a serviceability model and will utilize the load combinations specified by ASCE 7-05 for serviceability conditions. These loads will be used to size the shear walls to adequately limit the drift of the structure. Once the required wall sizes have been determined, a separate model will be made using the same structure but with the load combinations specified for strength. This model will be used to design the reinforcement for the shear walls. Both Etabs models will be done using cracked section properties were appropriate. Additionally the floor slab will be modeled as a rigid diaphragm because there is no basement or other condition in which shear reversals are expected and need to be minimized.

Post-Tensioned Concrete Floor System:

RAM Concept will be used to design the floor systems. Columns will be placed along grid lines two and five to make this type of floor system a possibility. A two-way flat plate design will be the ideal way to minimize floor depth, and will be used as a starting point in the design. Banded tendons are proposed to run parallel to the numbered grid lines (similar to the girders in the current design) The distributed tendons will be laid out along the lettered gridlines (similar to the beams in the current design). The design process will use the goal of balancing 70% of the dead load in each span in each direction. A target pre-compression of 150 psi will be used to estimate the number of tendons and the spacing at which they are required. The tendon profiles will be maximized over the supports with the center span depth altered to provide the proper balancing. All tendons will be anchored at the center of the slab.

Concrete Columns:

The columns in the new design will be done in a program produced by PCA. To keep the concrete strength consistent throughout the project 5000 psi concrete will be used. This will also help to keep the required sizes lower. The columns will be modeled as pinned-pinned with an un-braced length equal to the new floor to floor height of the building.

Breadth Options

To compliment the scope of the redesign, the breadth studies will focus on two main factors playing into the validity of idea. The first will be an architectural study in which the impact the new columns will have on the tenant space will be evaluated. The goal of this breadth study will be to show that the leasable space in the building will not be greatly impacted by the additional columns that will need to be added. The second bread study will focus on the cost difference between the new concrete design of the building and the current steel design. Hopefully it will be shown that the additional space that the redesign yields (in the form of an additional floor) can be justified based on a cost analysis of the two designs.

The focus of the architectural study will be spacial arrangement. Several potential layouts will be developed to show that even though there will be columns within the space, it can still remain open and flexible. Revit will be used to develop virtual tours of the layouts and to help show the different possibilities.

The cost analysis will feature a detailed take-off on the different designs including scheduling. RS Means will be referenced to help develop these numbers, in addition to the current cost estimates of the steel structure. Hopefully the this analysis will show that the concrete option is a very viable option.

Tasks

Task 1: Determine Loads

This includes calculating the wind and seismic loads for the new structure in addition to the live finding the live loads from ASCE 7-05.

Task 2: Design the Concrete Columns

The loads on each column on each floor need to be calculated, including live load reductions where possible. Then the columns need to be designed in PCA column. The columns will change sizes on the third and seventh level with every column on the individual floors the same. Therefore only three columns will need to be designed, the worst case column on ground level, third level and seventh level.

Task 3: Design the Post Tensioned Concrete Floor

This involves doing the actual design in Ram Concept and determining the slab thickness and shear reinforcement detailing.

Task 4: Build the Service Model in Etabs

This model will be used to size the shear walls. It will involve building the actual model, inputting the loads, and load combinations and analyzing the results.

Task 5: Build the Strength Model in Etabs

This will be the same as the service model except the load combinations will be different. This model will be used to design the shears walls for strength.

Task 6: Design the Concrete Footings

The column loads at the base of the structure will be taken from Etabs (including axial and moments). PCA Mats will be used to design the spread footing foundations. A mat footing was required for the lateral frame in the steel design but hopefully the shear wall foundations can be designed as spread footings.

Task 7: Create Architectural Layouts in Revit

This will involve learning how to use Revit and then creating the virtual tours of the different layouts.

Task 8: Do Cost Analysis

This will be done with the help of RS Means.

Task 9: Create Report and Presentation

Timetable

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9
Task 1: Determine Loads									
Task 2: Design Concrete Column									
Task 3: Design PT Floor									
Task 4: Build Etabs Service Model									
Task 5: Build Etabs Strength Model									
Task 6: Design Concrete Footings									
Task 7: Create Revit Arch. Layouts									
Task 8: Do Cost Analysis									
Task 9: Create Report									

	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17
Task 1: Determine Loads								
Task 2: Design Concrete Column								
Task 3: Design PT Floor								
Task 4: Build Etabs Service Model								
Task 5: Build Etabs Strength Model								
Task 6: Design Concrete Footings								
Task 7: Create Revit Arch. Layouts								
Task 8: Do Cost Analysis								
Task 9: Create Report								

Appendix

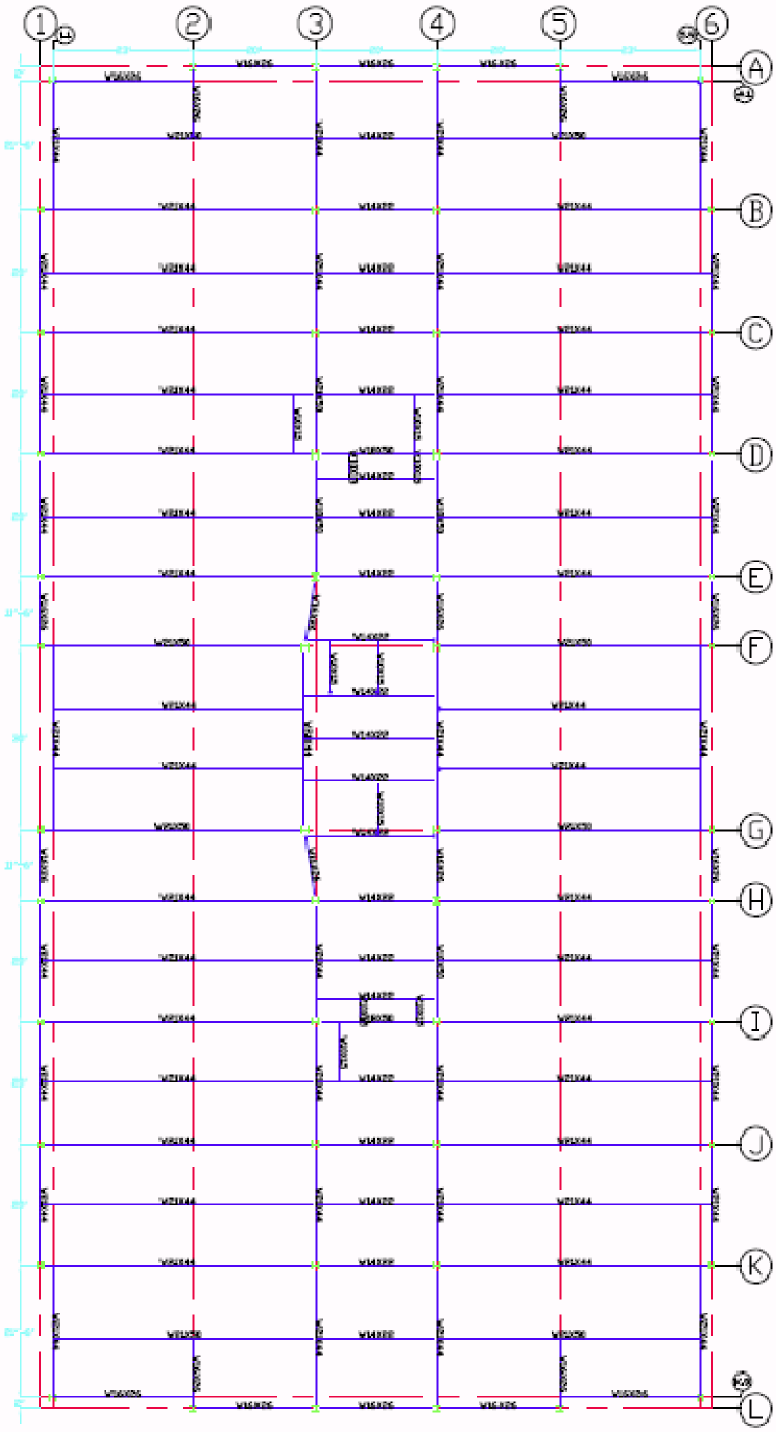

Figure 1: Current Steel Framing

Figure 2: Steel Column Layout

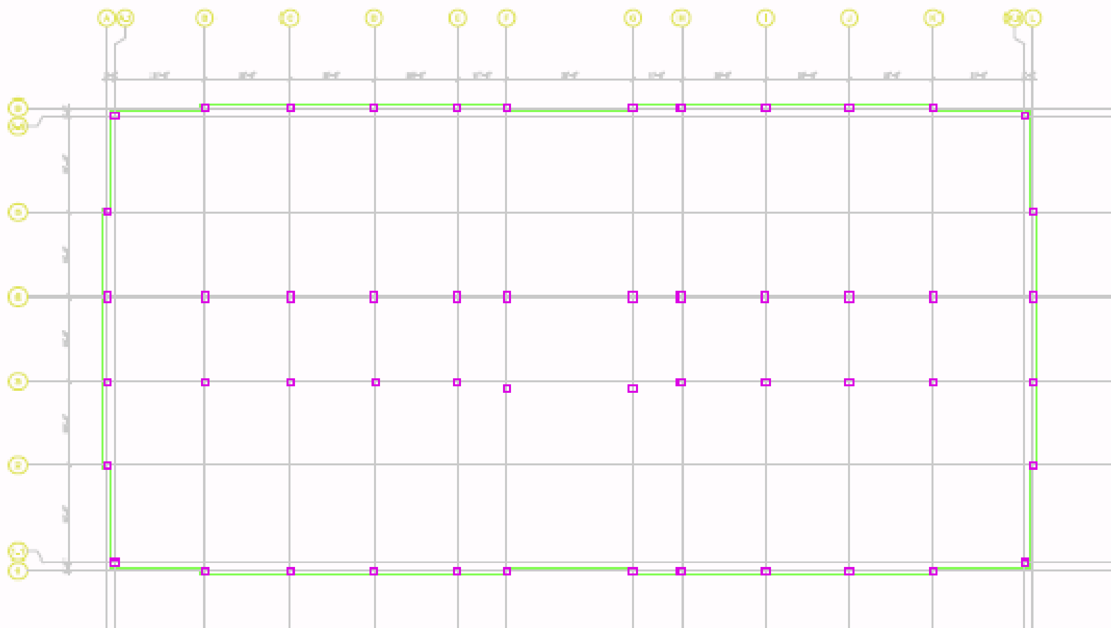

Figure 3: Concrete Column Layout