Crossroads at Westfields
Building II

Chantilly, Va

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Structural option

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Thesis Proposal

EXECUTIVE SUMMARY

On completion of the Technical Reports, the overall design of the building complied with all of the applicable codes however it was concluded that it may not be the most economical solution. After modeling the building, it was found that the moment frames were oversized in the original design and can be optimized to a smaller member if the lateral design is altered. To approach this, gravity loads will be analyzed alone to get initial members, then lateral loads will be added according to code. By adding simple moment connections around the entire perimeter and making the building more rigid, the original member sizes of the moment frames will decrease. By optimizing the original design the goal of a more economical structure will be obtained.

For the purpose of this thesis the building will occupy a hypothetical client of government or 'high profile' stature. With the building now being considered 'performance based' or high profile it could be subject to abnormal loading from an explosion or blast from a terrorist attack. Following recommendations from the GSA, the building will be analyzed and designed structurally to mitigate progressive collapse and architecturally to prevent and/or withstand a blast from a terrorist attack. A cost analysis will then be conducted to compare the original design to the optimized design and the design for an attack.

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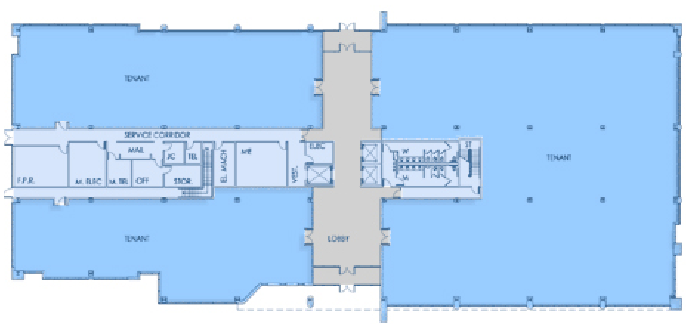
BACKGROUND

The Crossroads at Westfields are two identical office buildings mirroring each other on site. Although the project is currently on hold, these two buildings will offer over 300,000 GSF of office space to future tenants. Located in the Westfields Corporate Center in Chantilly, Virginia, the site is located at the crossing of the Stonecroft Blvd. and Lee Rd., hence the name.

SITE PLAN

Building II, identical to Building I, is a 5-story office building with floor plans that offer spans of over 41 feet. The long spans in the exterior bays create a large open floor allowing the tenant to easily adapt the space to their needs. The structure consists of composite steel beam framing on each floor and is combined with ordinary moment frames to resist lateral loading. The roof is supported by joists and steel decking that will support future mechanical units.



TYPICAL FLOOR PLAN

In prior Technical Reports, the existing design for Building II was analyzed to check the the building's structural systems to see if they met applicable codes and requirements. This included an analysis of gravity design loads and lateral forces in compliance with ASCE 7-05, an assessment of multiple floor systems comparing cost and ease of constructability, and finally a complete analysis of the buildings lateral system. On completion of these reports, the overall design complied with all of the applicable codes however it was found that it may not be the most economical solution. The following proposal will attempt to find the most economical structural solution as well as investigate other related topics.

EXISTING STRUCTURAL SYSTEMS

FOUNDATION SYSTEMS

The Foundation system consists of reinforced cast-in-place concrete spread footings. According to the Geotechnical report recommendations prepared by ECS, Ltd the allowable soil bearing values vary throughout the site. Foundations bearing on the natural 'weathered rock' soil classification will be designed with an allowable soil bearing of 6000 psf while foundations bearing on engineered fill will be designed for soil bearing of 3000 psf. The concrete strength shall be 3000 psi.

According to recommendations in the Geotechnical Report, the Slab on Grade will bear on the natural soil. The slab is a 4" thick cast-in-place concrete with 6x6–10/10 welded wire mesh (WWM), laid on a 6-mil fiberglass reinforced polyethylene vapor barrier and 4" of washed gravel. Interior SOG will have a compressive strength of 3000 psi, while exterior SOG will have a strength of 4500 psi.

FLOOR SYSTEMS

A typical floor in the Building II consists of 3" 20 gauge composite steel deck with 3-1/4" lightweight concrete slab totaling a total slab thickness of 6-1/4". The slab shall be reinforced with 6X6-10/10 WWM and have a compressive strength of 3000 psi. The floor is supported by A992 wide flange beams with studs dimensioned at ¾" in diameter and 5 ¼" in length. The beams are spaced at 10' o/c and span 41'-8" in a typical exterior bay and 30'-0" in a typical interior bay, as you can see in Figure 2 below. Depending on the floor, the beams will be cambered from an 1" to 1½" and will vary in size and weight. Typical interior girders are W24-62 spanning 30'-0", while typical exterior girders vary in size and also span 30'-0".

ROOF SYSTEM

As seen in Figure 3, the roof system is comprised of 1-1/2" 22 gauge Type B wide rib galvanized roof deck, on K series bar joists and steel girders. Light-gage framing makes up the 4' parapet and the screen wall encompassing the roof. Precast panels frame into each floor including the roof.

Rooftop Mechanical pads for future tenant equipment shall be constructed similar to the typical floor system consisting of 3" 20 gauge composite steel deck with 3-1/4" lightweight concrete slab totaling a total slab thickness of 6-1/4". The slab shall be reinforced with 6X6-10/10 WWM and have a compressive strength of 3000 psi.

COLUMN SYSTEM

Having a very uniform design layout the column system consists of typical exterior bays of 30'-0" x 41'-8" and interior bays of 30'-0" x 30'-0". All of the columns consist of either a gravity resisting member or a combined lateral and gravity resisting member. Each columns is spliced at 4 feet past the third floor, regardless of its resisting system. All columns vary in size depending on location and load resistance capabilities.

LATERAL SYSTEM

The lateral resisting system for wind and seismic loads consists of a number of structural steel moment frames running in both directions. Lateral loading is transferred from precast panels (connected at each floor) to each individual floor. Once transferred into the floor system, the load is transferred into composite beams which make up the framing and then into the columns. The columns and beams are connected by a moment connection seen in Figure 1. the columns transfer the rest of the load into the foundation.

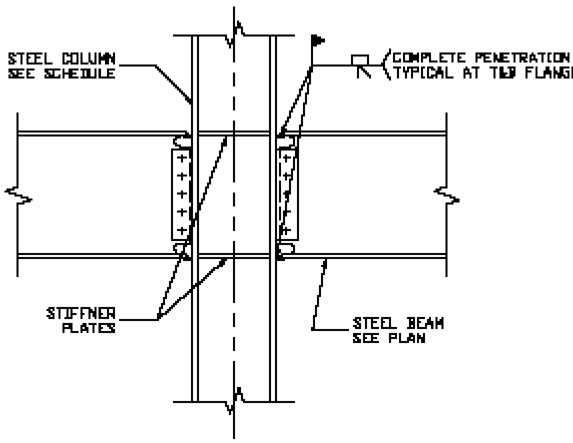


FIGURE 1 – Typical Beam to Column Moment connection

Figure 2 clearly shows the four moment frames positioned in each direction, North-South and East-West, supporting the building laterally. In both directions the moment frames are positioned symmetrically about the center axis. The North-South (Frames 1-4) lateral system is 2 sets of parallel moment frames anchoring each end bay. The East-West (Frames 5-8) lateral system is a set of 2 moment frames on each exterior side of the building. The beam sizes vary.

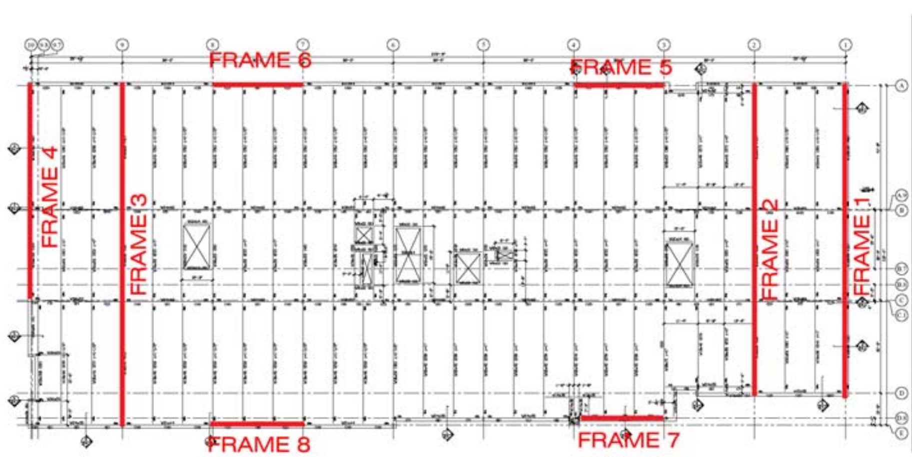


FIGURE 2 – Typical Floor plan with moment frames

PROBLEM STATEMENT

On completion of the Technical Reports, the overall design complied with all of the applicable codes however it was found that the original design was not the most economical solution. The existing structure includes four moment frames positioned in each direction to resist lateral loads from wind and seismic forces. After modeling the building, it was found that these frames were oversized and can be optimized to a more economical member if the building is constructed differently.

Currently, the building has no tenants and is on hold therefore a hypothetical situation will be used for this thesis project. The building will be occupied by a 'high profile' government agency and the building will be considered 'performance based'. Although there are no code requirements, the General Services Administration (GSA) highly recommends that performance based buildings are designed for blast loads and mitigating the risk of progressive collapse.

PROPOSED SOLUTION AND METHODS

After modeling the building, it was found that the members of the lateral frames were oversized and can be optimized to a more economical member if the lateral design is changed. First the members will be optimized for gravity loads and reduced to minimum code requirements. After they have been designed, the lateral loads will be applied and members will be designed according to ASCE 7-05. Due to the building's location in a low seismic region, simple moment connections can be used for the frames. The current design transfers lateral load from the rigid diaphragm at each floor into the moment frames. By adding simple moment connections around the entire perimeter and making the building more rigid, the original member sizes of the moment frames will decrease. By optimizing the original design the goal of a more economical structure should be obtained.

Now a 'high profile' government building, Building II could be subject to a terrorist attack and must be designed for such an event. Structurally, the building must be designed to reduce the risk of progressive collapse. The analysis will consist of the removal of an individual structural element at certain locations around the perimeter and designing alternate load paths for the remaining structure. Designing alternate load paths usually results in adding redundancy to the remaining structure. To obtain the most economical building it will be important to integrate the lateral system with the design for collapse to minimize the amount steel.

ARCHITECTURE BREADTH

In addition to re-analyzing the structure of the building, there are several architectural design features that can be analyzed to reduce the risk of a terrorist attack and damage from a resulting blast. This breadth will investigate site elements that can possibly prevent an attack from happening. There are many things that can be done such as setbacks, bollards and retaining walls to prevent a blast load from reaching the building. Also, a façade study will be conducted to test certain materials to see if they can help the building retain its integrity after a blast. Blast resistant materials will used in lieu of the existing precast panels and windows.

CONSTRUCTION MANAGEMENT BREADTH

This breadth will conduct cost analyses comparing the original design to the optimization of the structural design. The analysis will also include the schedule impact of adding moment connections around the perimeter. The added time and labor will be weighed against the amount of steel saved. A full analysis of the progressive collapse design will also be conducted. The added redundancy to resist collapse will certainly add to the costs but the goal is to see how it compares to the original design.

TASKS

I) Member Optimization

Task 1: Design of Framing System for Gravity Loads
- a) Establish dead and live loads
- b) Optimize members in RAM Model
- c) Establish trial member sizes

Task 2: Design of Lateral Framing Systems
- a) Establish Lateral Loads from Code
- b) Add moment connections to perimeter of RAM Model
- c) Determine controlling member sizes
- d) Design Simple Moment connection

Task 3: Lateral Framing Comparisons
- a) Determine cost savings
- b) Determine added time to schedule for extra connections
- c) Compare original design to optimized design

II) High Profile Design

Task 4: Analyze Structure for Progressive Collapse
- a) Research techniques for analysis
- b) Determine local members to be removed
- c) Model and analyze remaining structural members

Task 5: Progressive Collapse Design
- a) Determine possible redundancy techniques
- b) Determine member sizes
- c) Determine connection types

Task 6: Integrate Lateral System with Collapse Design
- a) Analyze the lateral loads with new framing
- b) Add necessary changes for lateral system
- c) Determine additional costs
- d) Determine extra schedule time
- e) Compare to original design

III) Breadth Studies

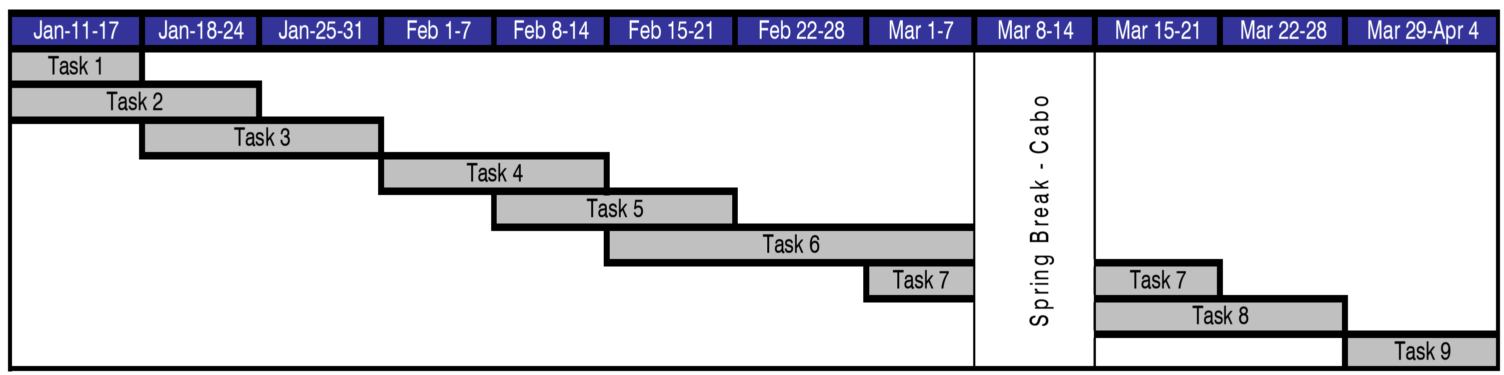
Task 7: Façade Investigation and Site Design
- a) Research Site Features to prevent attacks
- b) Research blast load cases
- c) Research resistant material for façade
- c) Design Site to prevent attacks
- d) Design Façade to resist blast and retain integrity

Task 8: Cost Analysis Comparisons
- a) Analyze comparison of original and optimized design
- b) Analyze comparison of original and progressive collapse design

IV) Presentation

Task 9: Presentation Development

PROPOSED SCHEDULE



APPENDIX

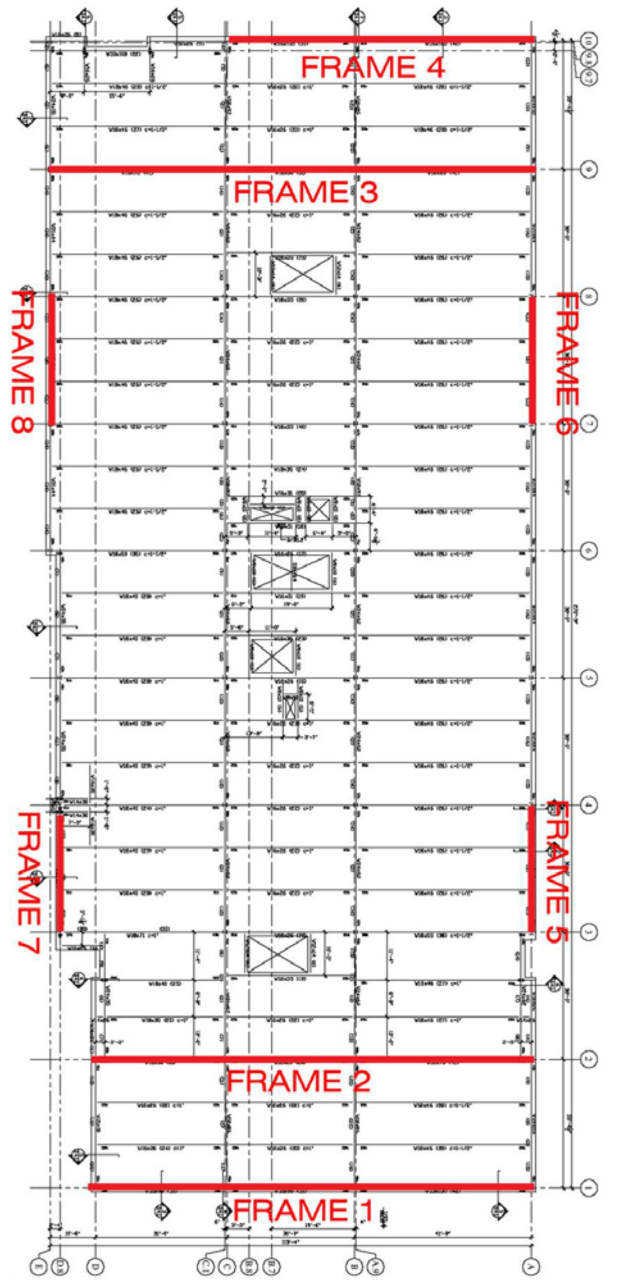


FIGURE 3 – Typical floor plan with lateral frames

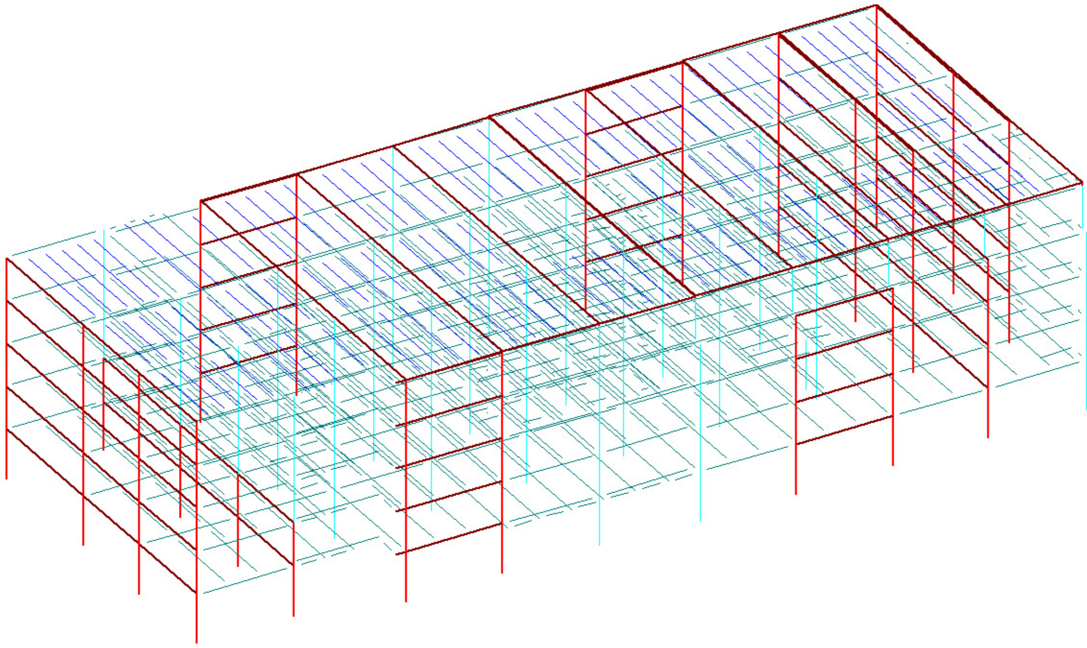


FIGURE 4 – Overall 3D RAM Model with highlighted moment frames