# Belmont Executive Center; Building A

## Ashburn, VA

**Thesis Proposal**
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# Executive Summary

Currently the gravity system of Building A consists of lightweight concrete on metal deck. Composite action is achieved through the use of shear studs attached to the supporting beams. The floor slab is supported by W-shape members, which are supported by W-shape steel columns. This floor system spans over three bays in the short direction of the building and eight in the long direction. In the short direction, the outer two bays are roughly 40' x 30' and the middle bay is 26' x 30'. Lateral forces are resisted by braced frames, located in the core of the building. Overall, the structure works well to transfer the factored loads across these large spans.

The proposed thesis will include a complete redesign of the building using concrete as the primary structural material. The floor will be supported by either normal reinforced concrete girders or post tensioned girders, which in turn will be supported by concrete columns. The large spans in the short direction of the building will be decreased with the creation of a different column layout. Instead of three spans, the outer two bays will be decreased, and an extra column will be introduced at the midpoint of the building. Between the girders an optimal one-way floor system will be implemented. All columns will be redesigned using concrete, and will replace the existing steel columns. This particular design alternative is being proposed to gain a better understanding of concrete design, and it also could potentially have a floor depth either equal to or less than the existing. A minimal floor depth is desired because of height restrictions in the Ashburn, VA area. A significant increase in building weight will result from changing the building structure, and as a result the foundation will be engineered to support the heavier dead load. The lateral force resisting elements will be switched from braced frames to concrete moment frames because it will be more difficult to implement shear walls if the column layout is changed.

The breadth proposal will include a study of the cost and schedule impact, created by constructing the building with concrete. Comparisons will be drawn between the original costs/schedule and the new costs and schedule. Cost and schedule impacts are not necessarily being conducted because a concrete structure is believed to be less expensive or quicker to build, but is primarily being done to gain a better understanding of the differences between building with the two different materials.

The second breadth study will focus on architectural impacts of the proposed column layout. Great care will be taken to place the columns in locations that have the least impact on the open floor space. In the core of the building, some spaces will need to be restructured, and a functional alternative layout will be created. A typical office layout will be superimposed onto the new column layout to make sure the column locations do not conflict with office plan.

## Introduction

The Belmont Executive Center; Building A is located in the Belmont Executive Center, which will include office, retail, restaurant, daycare, and hotel spaces. Residents of the Dulles North area will be offered daily shopping, specialty shopping, and dining choices.

Building A is a 125,000 SF, 5-story office building designed to accommodate multiple tenants. The façade of the building is constructed primarily of face brick supported by C-channel steel members. Steel angle is welded to the C-channel members to support the brick on each level. Lateral support of the C-channels is provided by a connection to the exterior beams.

Vertical brick columns are spaced around the perimeter façade, some of which enclose structural columns, others which do not support any load. A large glass curtain wall system distinguishes the entrance of the building, and the corners of the building also have a curtain wall system. The structural system of the building is constructed of steel framing with light weight concrete on composite deck as the floor system. Lateral bracing is provided by four concentrically braced frames.

Each floor provides unobstructed open space on both sides of the core, and a floor to ceiling height of 9’. Lateral forces are resisted by three braced frames in the north-south direction of the building, and one braced frame in the east-west direction.

## Structural System

### Foundation System

A geotechnical investigation concluded that the site conditions provide an allowable soil bearing capacity of 2.5 ksf. The geotechnical engineers suggested the foundation system be designed as shallow spread footings. Therefore, the foundation system is made up of spread footings located at the base of the steel columns, and range from 19’-6” square to 10’-6” square, depending on the location. Larger footings are located in the center right part of the building, to support a mechanical room and the restrooms. Smaller foundations are located at the exterior columns. All larger foundations are shown in yellow in the Figure 1 below. The perimeter footings are connected by a stepped continuous strip footing that supports the masonry facade. A change in elevation of the strip footing is located just to the left of the entrance to allow a connection to the sanitary line. There is also a step in the strip footing on the right side of the building for the domestic water line and fire service line connection. The ground floor is a 5” thick concrete slab on grade reinforced with #3 rebar @ 15”o.c. running both directions. A 6” slab on grade is located to the right side of the building to support a 30 yard trash compactor, and is highlighted in purple in Figure 1. It is reinforced with #3 rebar @ 12”o.c. each way. The slabs are supported by 4” granular material, on top of compacted soil.

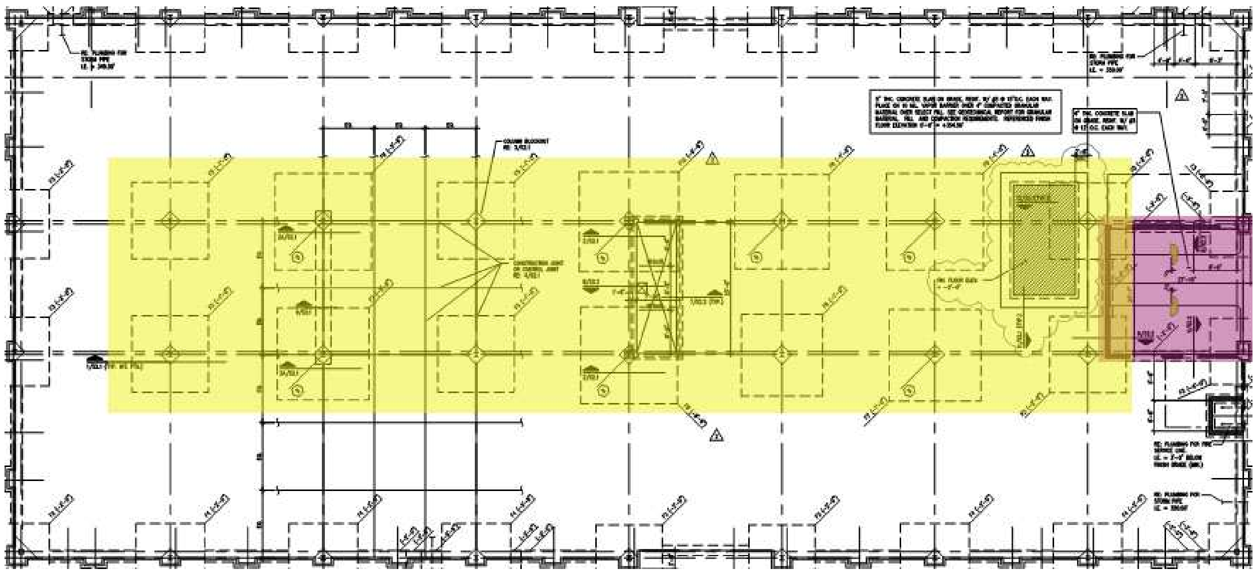


**Figure 1: Foundation Layout**

## Column System

The floor and roof system are supported by three column lines in the north-south direction and nine rows of columns in the east-west direction. Because the exterior column spacing is dictated by the architecture of the building, the columns on the left and right side of the building are offset from those in the interior. At the corners of the building they are offset by 1'-3" and the interior columns are offset by 7 ¼". This offset creates a slight skew in the beams spanning from the exterior to the interior. Figure 3 shows the column offset. Most of the columns are W shape steel beams, and a few are HSS columns. Hollow structural steel columns are located at the front left and right corners of the building. They are also used in the left rear and right rear corners, on floors three to five, and to provide intermediate bracing below the exterior terrace on the fifth floor. The typical bay sizes for each floor is 38'x 30' and 26'x30'. Figure 3 shows the typical column layout.

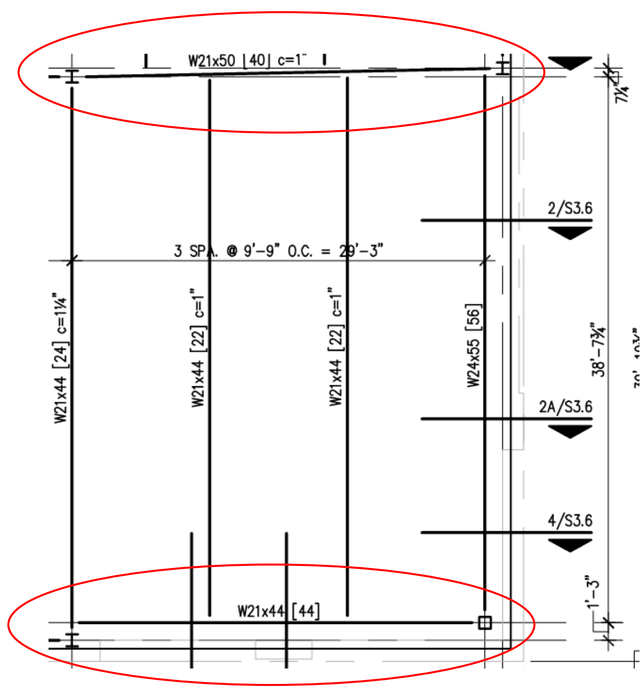



**Figure 2: Column Offset**

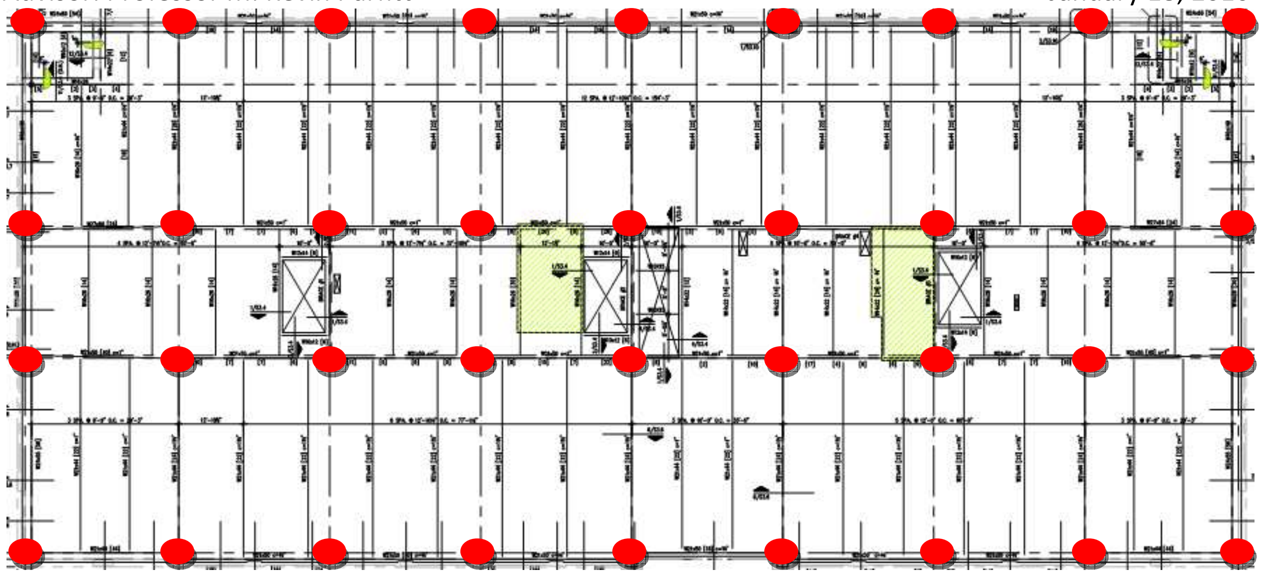


**Figure 3: Column Layout**

## Floor System

Floors 2-4 are constructed of 3-1/4" light weight concrete, on 3" composite metal deck. The deck is reinforced by 6 x6 - W1.4 x W1.4 welded wire fabric, and supported by W-shape steel beams. There are three bays in the north-south direction, and ten in the east-west direction of the building. For reference, the outer lying bays are highlighted in red, and the middle bay is highlighted in green, see Figure 4. Typically, there are W21x44 beams spaced 12'-10 ¼" to 9'-9", on floors 2 through 5, in the two outside bays. In the middle bay the beams are typically W16x26. Between the elevators and stairwell three, the steel beams are W14x22. Composite action is provided shear studs, and most beams also have upward camber ranging from ¾" to 1" to compensate for service and live load deflections. W 21x50 girders support the load reactions from the beams. On the second floor there is no framing at the main entrance, because this area is open to the ground floor. Floors 3-5 are framed similarly. On the fifth floor the exterior terrace floor is supported by W10x12 steel beams.

The mechanical equipment in the penthouse is supported by a typical concrete floor, constructed of lightweight concrete on composite metal deck. This is the only concrete slab on the roof level. W16x26 beams span across the bay to support the floor.

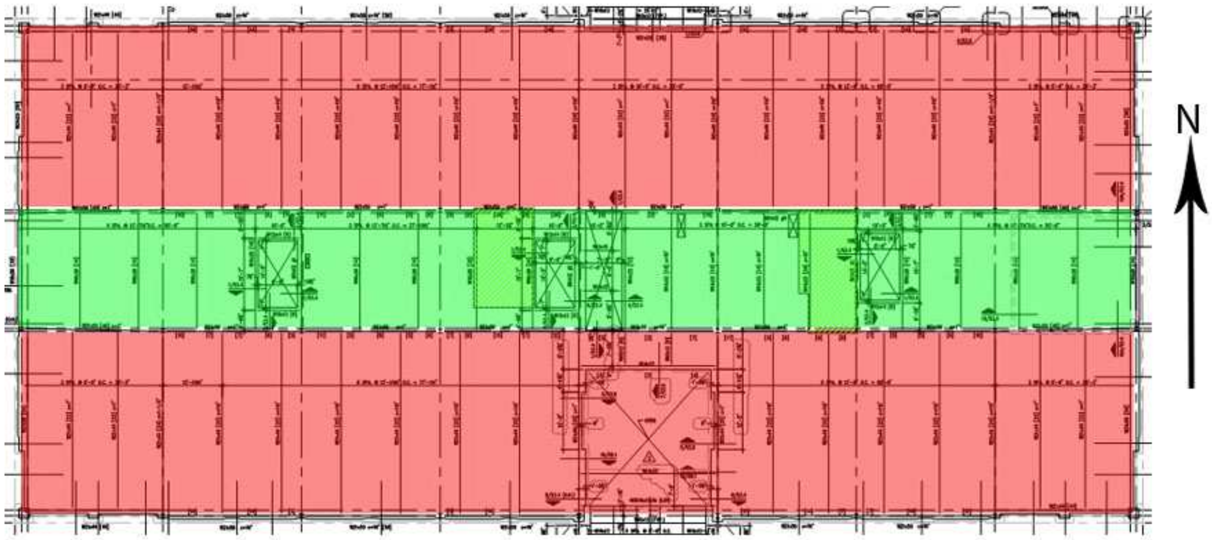



**Figure 4: Typical Beam Size and Spacing**

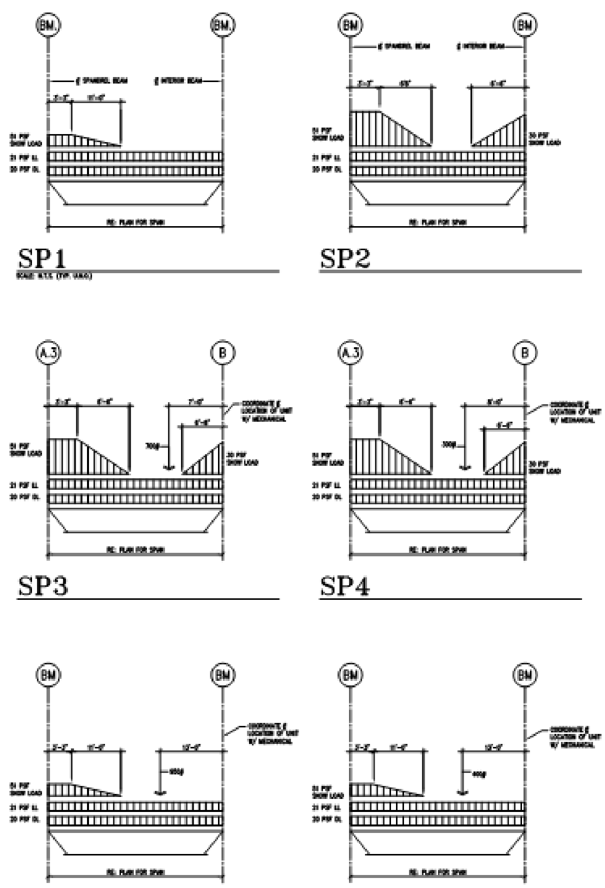



**Figure 5: Special Loading Conditions**

## Roof System

The roof system is supported by K-series joist, spanning across the three bays in the north-south direction. All the joists in the outside two bays are spaced at 6’-0” on center. Joists in the front and rear bays were designed for specifically by the joist manufacturer for snow drifting, because this can be a critical load failure for open web joists. All joists that were specially designed are denoted by SP, and there are 6 different loading conditions. Each loading condition is shown in Figure 5. Three rows of bracing are provided in the rear bay, to prevent lateral torsional buckling. Regular K series joists ranging from 22K5 to 18K3 support the roof in the middle bay. The penthouse roof is supported by 20K3 spaced at 6’-0”, with 3 rows of bridging.

The standing seam metal roof screen that shields the penthouse from view is supported by a combination of K Series joists and W shape beams. At roughly every 30’ W shaped steel beams are angled at 45 degrees, and are supported by steel posts. Between the beams, four K series joists run parallel to the building perimeter. L 2 x 2 x1/8" angle provides bracing at 6', between the joists. Figure 6 shows the angled beams, highlighted in yellow, and the joists can be seen spanning between them. Figure 7 shows a typical cross section of the roof screen.

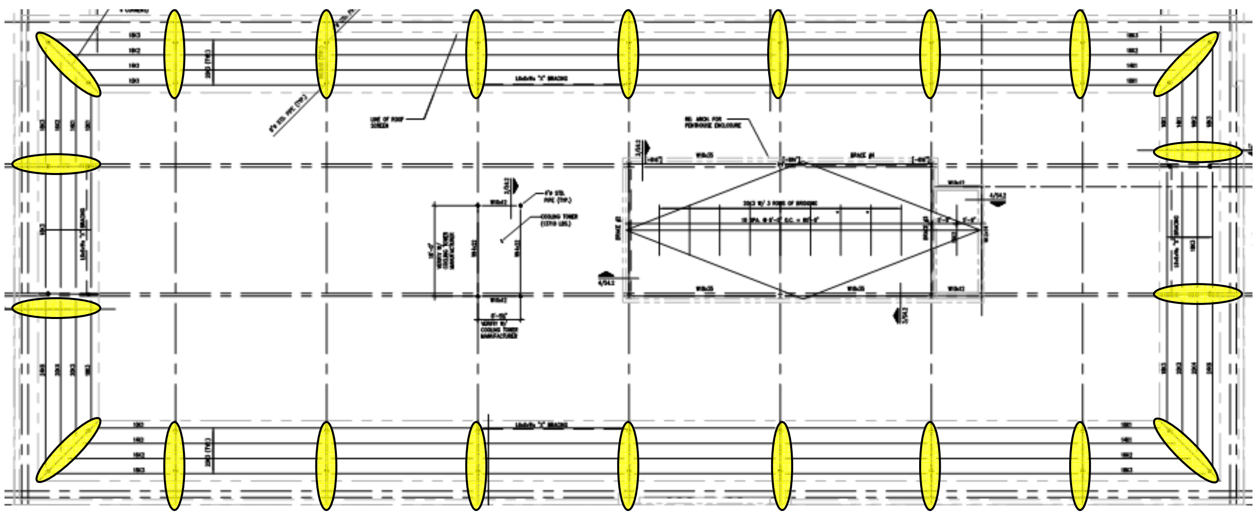


**Figure 6: Angled W Shape Beams**

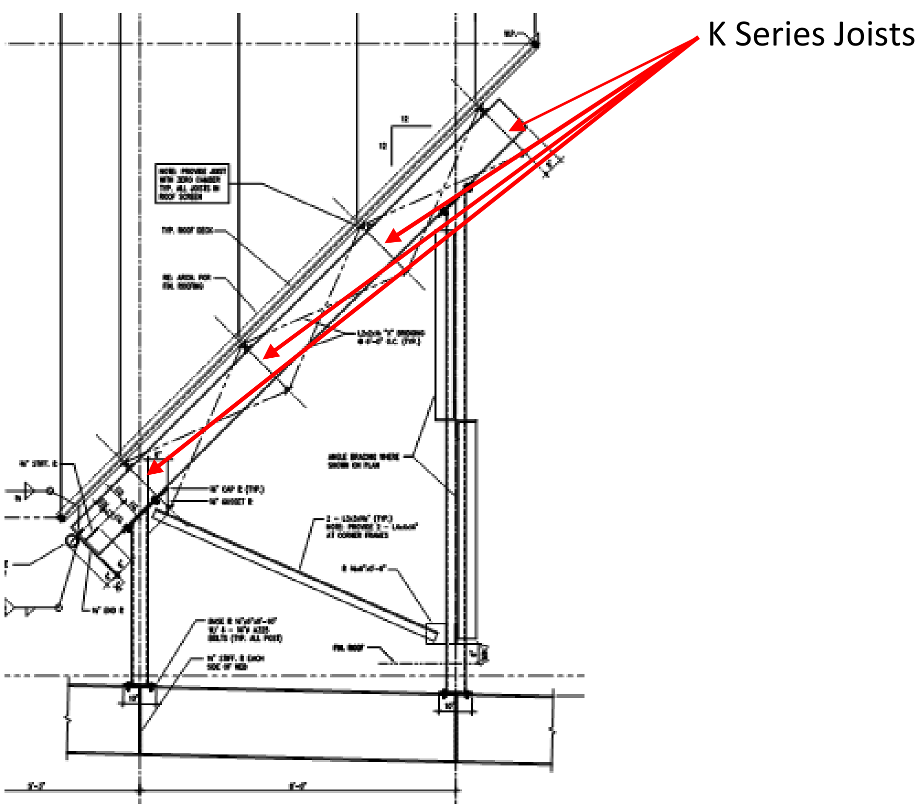



**Figure 7: Roof Screen Support**

## Lateral System

Lateral loads on the building are supported by four concentrically braced frames. Three of the frames are located in the north-south direction to support higher wind loads from the broad side of the building, and one frame is located in the east-west direction. The three frames in the north-south direction are located on the column lines, adjacent to stairwell one and two. The other is located to the left of stairwell three. In the east-west direction the frame is located between columns B6 and B7. All frames are braced with hollow structural steel ranging in size 8 x 8 x ¼ at the first floor to 4 x 4 x ¼ on the fifth floor. Figure 8 shows the elevations of each braced frame, and Figure 9 shows the location of each frame.

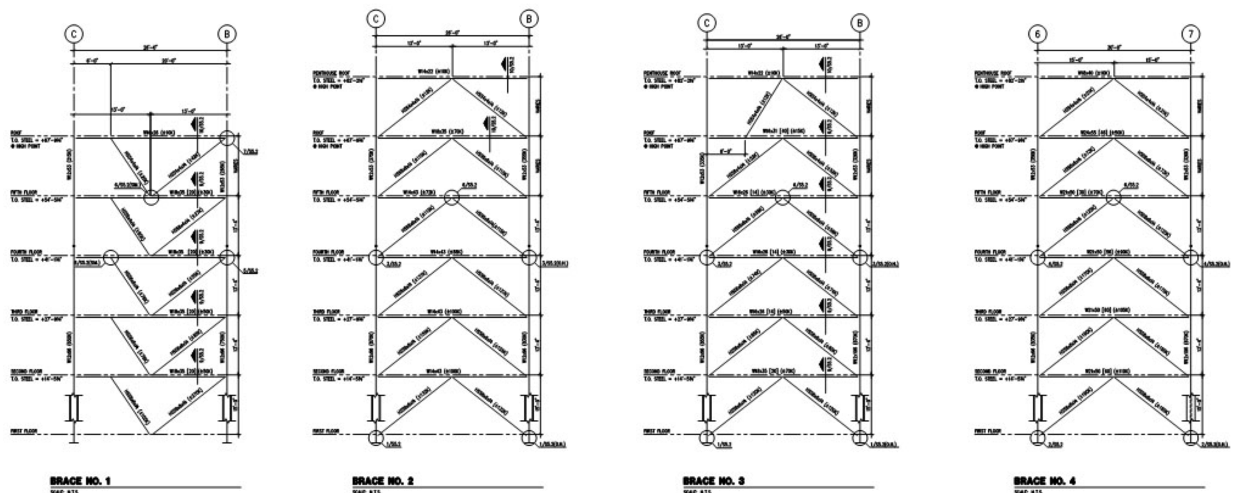



**Figure 8: Braced Frame Elevations**

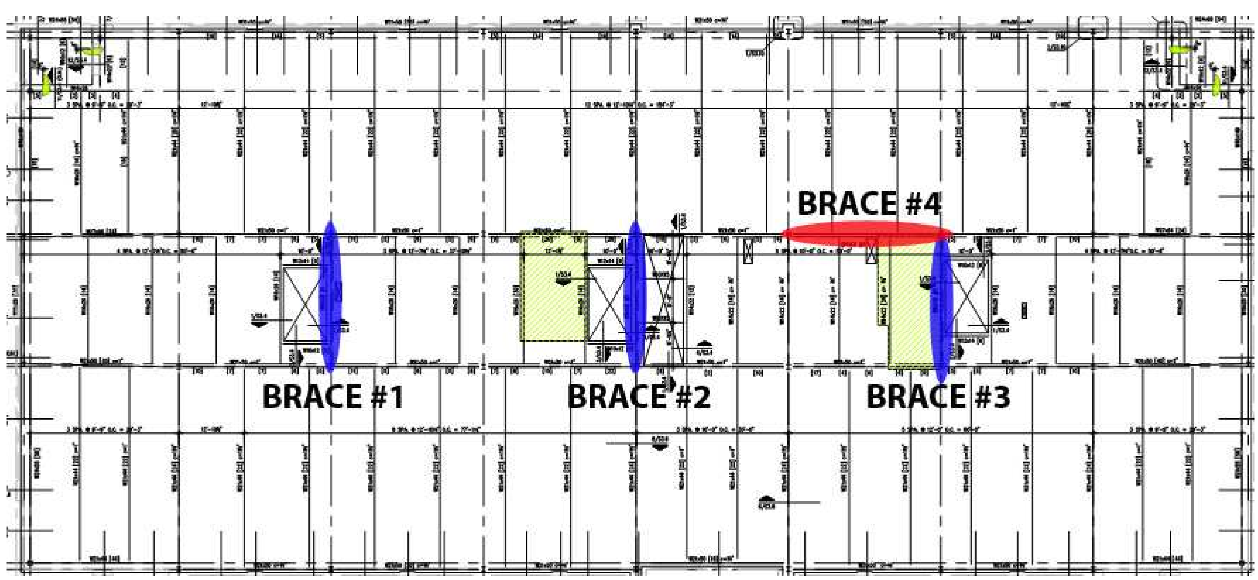



**Figure 9: Location of Braced Frames**

## Problem Statement

The existing structural system in Building A consists of light weight concrete slab supported by steel framing. All floors are composite construction and are very efficient at supporting factored loads over large spans. Steel columns support the floor, and the current columns are spaced relatively far apart. The location of the columns can be reviewed in Figure 3. Lateral drifts are resisted by steel braced frames and limit total deflections to acceptable standards. The building location is near the D.C. metro area, where concrete construction is, but not exclusively, the primary building method. Concrete will be used to design a structure, equivalent in performance and floor depth, compared to the existing steel superstructure.

## Proposed Solution

Extensive research into alternative floor systems in Technical Report 2 did not provide a clear candidate to warrant a change of the existing structure. It was required that all floor systems be capable of supporting loads across large spans in order to maintain flexible office space. Concurrently, the existing floor depth had to be maintained or decreased because of height limitations. The existing column layout was not modified in Technical Report 2 making it difficult to design a concrete floor suitable for the long spans.

A main reason why such large spans exist in the short direction of the building is because of the need to hide the braced frames from public view. Currently the braced frames are located inside the mechanical rooms and adjacent to stairwells. The switch to concrete will eliminate the use of braced frames and instead of using concrete shear walls, the concrete frame will be designed to resist the lateral loads. Doing this allows for a more flexible column layout, which will decrease the span distances. Figure 10 shows a conceptual idea of the proposed column layout.

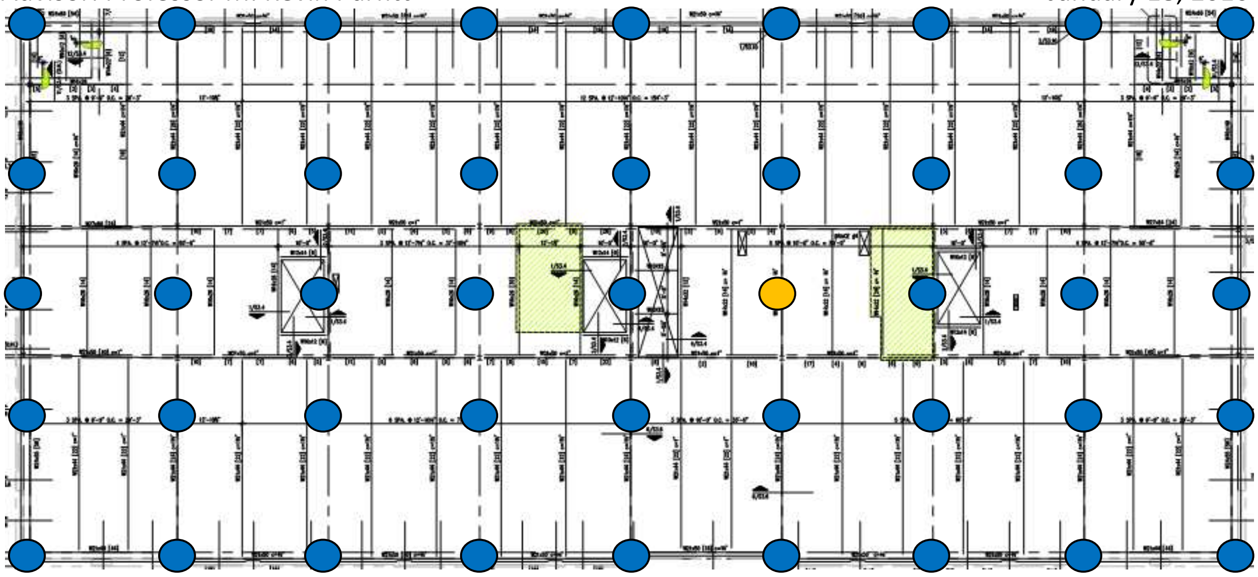


**Figure 10: Conceptual Column Layout**

With the spans decreased, either normal reinforced concrete girders or post-tensioned girders will be designed to span between the columns. Between these girders an optimal one-way floor system will then be engineered. A post-tensioned one-way slab, normal reinforced one-way slab, and a one-way slab with ribs will be considered, as well as others.

A result of changing the gravity system to concrete will be a significant increase in building weight. It is unlikely the existing foundations will be capable of supporting this increase in load. Therefore all foundations will be redesigned as larger spread footings. The braced frames will be eliminated and the concrete frame moment capacity will be used to resist lateral loads.

## Solution Method

Firstly, the architectural plans will be reviewed to determine the best locations for the columns. The mechanical room and the men and women's restroom will have to be rearranged to accommodate the middle column. Figure 10 shows the problematic column location highlighted in yellow. Once the column layout is finalized the optimal girder system will be designed, followed by the design of an optimal floor system. Both will be designed using the computer program ADAPT. A 3-D model will then be created in ETABS, and dead and live load will then be applied to determine the load on the columns. All column sizes and reinforcement will then be designed using PCA column. Once all floors and supporting members are designed, the foundation loads will be computed and foundation design will be completed. Following the completion of the foundations, lateral loads determined by using ASCE 7-05 will be applied to the ETABS model, and the lateral analysis will be performed to further the design of the concrete moment frames.

# Breadth Topics

## Breadth 1

Altering the current column locations will create issues with the layout and flow of the office spaces. An office fit out plan will be superimposed onto the floor plan to see if the columns conflict with the plan. If there is a conflict, an alternative office layout will be developed.

To accommodate an interior column at the midpoint of the building, the mechanical room and restrooms will have to be rearranged. An alternative, functional design will be created for the new layout.

## Breadth 2

Not only will the building architecture be impacted by using a concrete structure, but also the project costs and schedule will change. A structural costs estimate will be performed for the concrete design, and a construction schedule will be created. The costs and schedule associated with the proposed design will then be compared to the existing costs and schedule.

# Tasks and Tools

## Depth

1. Determine and Design Optimal Girder System
    a. Design girders using normal reinforced concrete using ADAPT. If girders are too deep design them as post-tensioned.
2. Design Optimal One-Way Slab System
    a. Determine optimal slab system, and design using ADAPT.
3. Design Concrete Columns
    a. Create 3-D ETABS model and apply new dead loads and live loads
    b. Determine column loads at corresponding levels
    c. Size columns and reinforcement using PCA Column
4. Design Foundation System
    a. Determine total building weight and foundation loads
    b. Check strength capacity of current foundation system
    c. Redesign spread footings or implement new system
5. Design of Moment Frames
    a. Develop lateral loads using ASCE 7-05
    b. Apply lateral loads to ETABS model
    c. Design Moment Frames using ETABS.
    d. Check Deflections

## Breadth

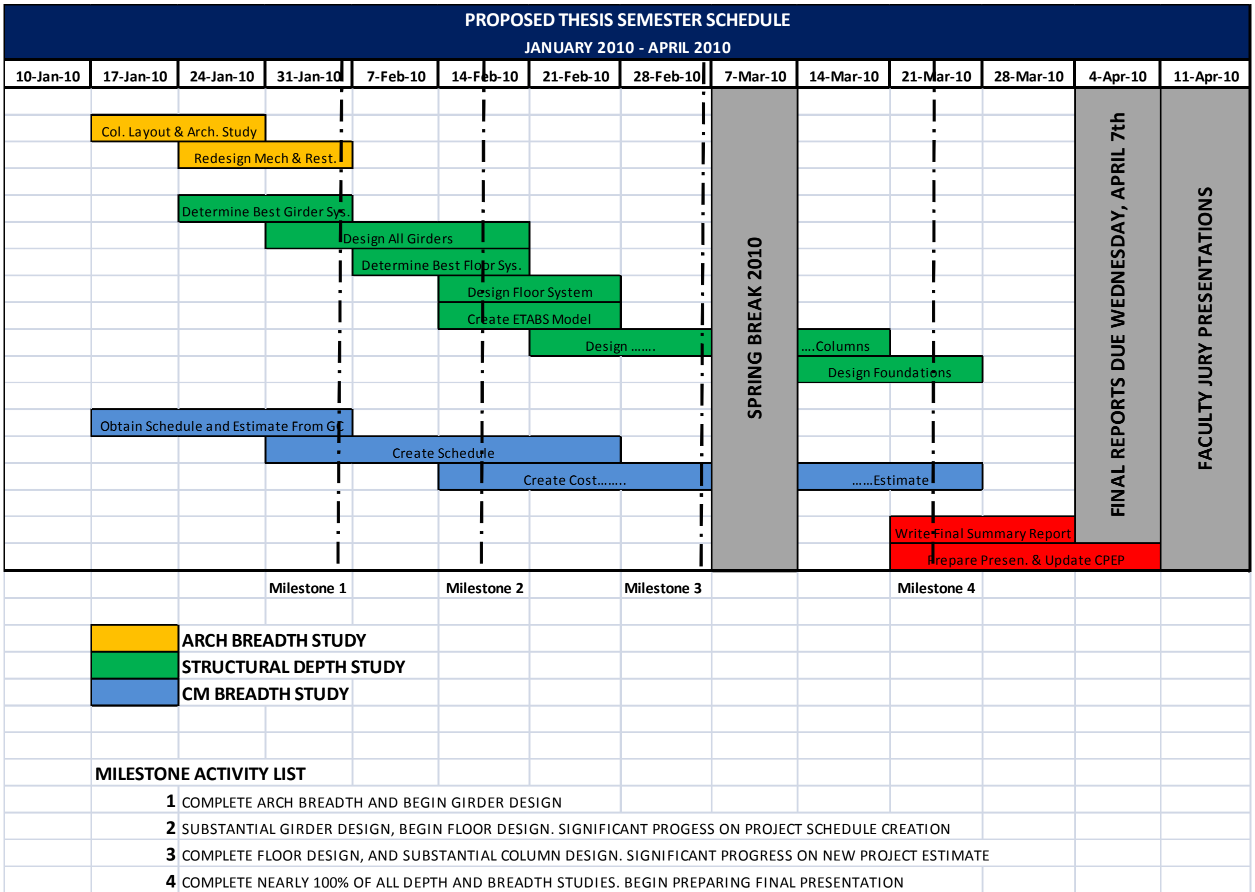
### Architecture

1. Review architectural plan and determine best column locations
2. Redesign the support spaces located to the right of the main lobby (Electronic architectural plans currently not available to show exact location)

### Construction

1. Obtain project estimate and project schedule
2. Create new project estimate and schedule
3. Compare the proposed schedule and costs to the existing

## Schedule




## Conclusion

Throughout next semester the entire gravity system of the building will be redesigned using concrete. All design will be done by various hand calculations and through the use of computer programs. The driving factor of the design is to maintain the large open floor plan and to minimize the floor depth. Breadth topics include the study of costs and schedule impact associated with a concrete structure, and the architectural impact the concrete columns will have on the architectural plans.