Best Buy Corporate Building D (4)
Richfield, MN

Final Report

Jon Aberts
Structural Option
Professor Boothby

April 7th, 2009

Best Buy Campus

Building D

Richfield, MN

Project Team

Owner :

Besy Buy Inc.

Architects:

Opus Architects & Engineers, Inc.

Perkins & Will

Constructor:

Opus Northwest, LLC

Building Statistics

Size:

6 stories

304,610 sq. ft.

Delivery Method:

Design-Build

Construction Dates:

Aug 2001 - Feb 2003

Cost:

Overall - $250 million

Electrical System

Generator Set

400KW-277/480-3ø-4W

Panelboards

277/480-3ø-4W

Switchboards

3000A-277/480-3ø-4W

Mechanical System

12 Air Handling Units

2 per floor

460/3/60

2 Make-up Air Units

located on roof

460/3/60

Structural System

Exterior:

Architectural precast curtain wall

Structure

Slab on grade construction

Braced frame system

Wide flange steel columns supported by concrete piers

Jonathan Aberts - Structural Option

http://www.arche.psu.edu/thesis/eportfolio/2007/portfolios/JEA169/

Table of Contents

Executive Summary

The requirements for the engineers of Best Buy Corporate Building D are basic in that they meet the needs of economy and the future occupants of the building. This report consists of a new design of the structural system and concludes, independently of existing conditions, an alternate system for the site and conditions impacting the corporate campus.

The new structural system removes columns throughout the building thus opening the floor plan while resisting the same loadings. Increasing the bay sizes to adapt the floor plan impacted all other structural systems in the building, while having little impact on mechanical and lighting systems. Larger bays lent the design of the new building to a post-tensioned system, because PT does not become cost effective until bays reach spans of twenty or more feet. The post-tensioned cast-in-place floor slab can support the larger bay sizes without dramatically increasing the overall depth of the slab. The effectiveness of post-tensioning is judged based on the advantages it provides for the building against the costs of both the old and new system.

The lateral system was also redesigned using shear walls. The positions of the existing lateral force resisting system were considered for the placement of the new shear walls. The building currently has two cores holding stairwells, elevator shafts, and mechanical shafts. The curtain wall system with ribbon windows had to be kept intact to preserve the original look of the building. As a result, the best location for the new lateral system was clearly around the cores.

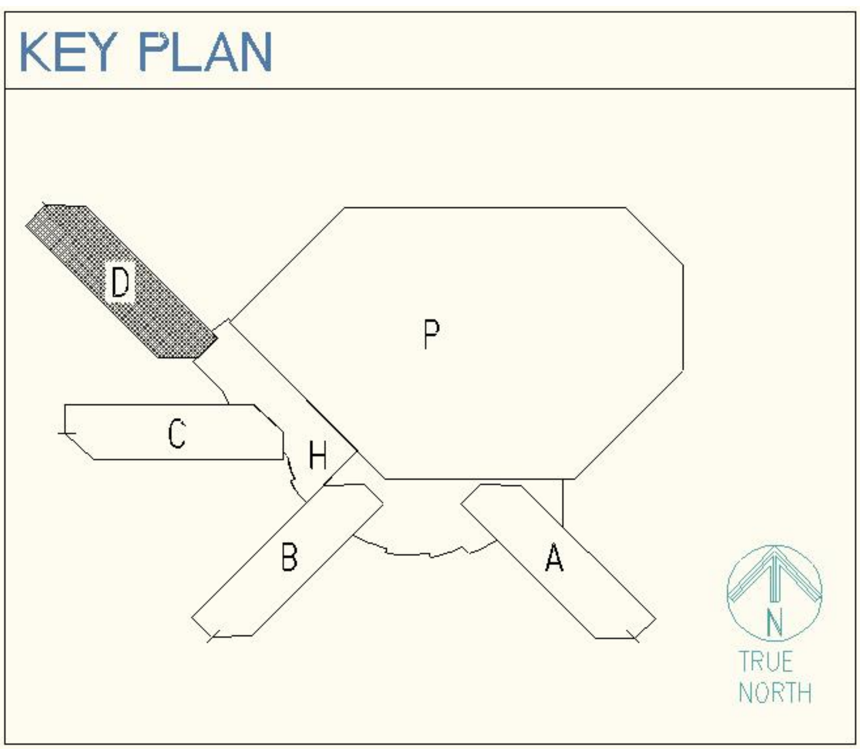
Cost analysis of the new concrete system, proved, unfortunately, that the old system was about 8% cheaper than the new. However, removal of roughly 30% of the original internal columns increased office space. The increased time to construct the new structural system also increases the cost of the project. In the end, both systems are comparable, but the original steel structure is a better solution in Richfield, MN because of the low availability of PT contractors in the area.

Introduction

The Best Buy corporate campus consists of four buildings connected by a central hub. This report focuses on building number four (also dubbed building D), which is a six story braced frame, steel system. The 304,610 square foot building consists of slab on grade construction with wide flange steel columns supported on concrete piers. Lateral loads are supported by a braced frame system. The exterior of the building consists of an architectural precast curtain wall with integrated ribbon windows. Considering the large amounts of integrated technologies required by Best Buy, there are no other major dead or live loads other than those listed in the provided drawings. The occupancy of the building, as expected, is primarily for office use. There are a few open spaces on the first level for future tenants, but the bulk of the building has open space for office partitions.

This report focuses on a new design of corporate building D that features a new column layout that will open usable office space by reducing the number of internal columns and increasing the bay sizes. A new floor slab system designed as a one-way post-tensioned cast-in-place flat plate slab replaces the current deck and cast-in-place concrete. A new lateral system that utilizes the new column layout is evaluated for drift requirements and compared to the old system. In addition, the impact of the new structural system on the architecture, mechanical, and electrical layouts was examined. Finally, a cost comparison of the new and old structural systems give a basis for deciding which system is more suited to the requirements of the site that face the owner, designers, and contractors.

Included are appendices to assist the reader in following thought processes and supports conclusions reached in the body of the report. Please note this report is intended for educational purposes only and does not substitute for the original design.



Building Description

Project Information

Building Name:
- Best Buy Main Corporate Building

Location:
- Richfield, MN

Occupants:
- Best Buy corporate employees

Function:
- Office building

Size:
- 1.5 million square feet

Number of Stories:
- 6

Project Team:
- Owner:
  - Best Buy Corp. (www.bestbuy.com)
- Architects:
  - Perkins & Will (www.perkinswill.com) - Minneapolis, MN
- Engineers:
  - Opus Northwest (www.opuscorp.com) - Minnetonka, MN
- CM:
  - Chris Johnson

Construction Dates:
- August 2001 - February 2003

Overall Cost:
- $250 million+

Delivery Method:
- Design Build

System Descriptions

Architectural Description:

Building D, also referred to as Building 4, of the Best Buy corporate campus consists of a steel structure enclosed in an architectural precast curtain wall. The building has an open floor plan to allow for partitioned spaces to be easily changed. The structure was built slab on grade, and uses a braced frame system and wide flange steel columns supported by concrete piers. One of the building's key features noticed from the exterior is the outward sloped wall on the northwest end.

Design Codes:

Minnesota State Building Code – 1998
Uniform Building Code – 1997
Minnesota Plumbing Code – 1998
Minnesota Accessibility Code – 1999
Minnesota Uniform Fire Code – 1998
National Electric Code – 1999
Minnesota Energy Code – 1999
Uniform Mechanical Code – 1991
ANSI Elevator and Escalator – 1996
NFPA Chapter 13 Sprinkler Systems – 1996

Zoning:

City zoned general commercial: C-2

Historical Requirements:

No historical requirements were noted and the location does not fall within the city's historical district.

Building Envelope and Roof Description:

As previously mentioned the exterior consists of a precast curtain wall and ribbon windows. Best Buy employed a flat roof with a B.U.R. system over a composite deck. The composite deck is largely made up of 3" 20 gauge roof decking with 3¼" of light weight concrete. The curtain wall consists of 6" architectural precast panels tied into the steel structure. A prefinished aluminum closure panel holds the ribbon of windows on each floor.

Electrical/Lighting:

The electrical system used in the building is 480/277 volt, 3 phase, 3 wire setup. There is also a secondary 120/208 volt, 3 phase, 4 wire system, which is used by most of the transformers on site. Most of the main lighting is provided by fluorescent fixtures with only a few locations using incandescent bulbs.

Mechanical:

The Best Buy Corporate Building D has a mechanical room located on the roof of the building. This building is cooled by 12 AHUs, 2 on each floor. There are also 2 MUA's on the roof of the building. Each AHU has a fan power of 25,000 CFM and is powered by 480V 3-phase power. A large system of duct work and multiple VAV's and diffusers are positioned throughout the building to move the air.

Structural:

Building D consists of a conventional structural steel system with composite beam floor framing and a braced frame system for lateral support. For each interior bay, the typical beam sizes are W16x26 and most girders sizes are W21x50. The exterior typically uses W18x40 beams and W18x35 girders. Columns vary in size but the typical column sizes W12xXX and W14xXX. The interior bay columns are spaced to create 30'x30' bays and the exterior bays are 42'6"x30'. The foundation for this structure consists of slab on grade with concrete piers for columns. Wind forces are resisted in this structure by the use of braced steel frames.

Fire Protection:

Aside from the standard pull box switches, Best Buy comes complete with a sprinkler fire suppressant. Smoke detectors are placed in all major areas including hallways, elevator shafts, and ducts. The pipes that regulate water throughout the building are located in the stairwells that have a 3-hour fire rating. Spray-on fireproofing is also present on the beams and girders located in the stairwells.

Telecommunications:

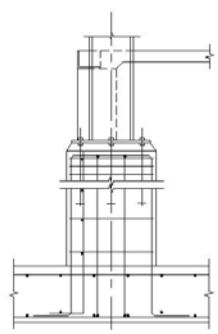
Best Buy has 2 data rooms on each floor that house the telecommunications support. Wires are run from the data rooms outward to each room and work area, allowing people both phone and internet access.

Structural System Information

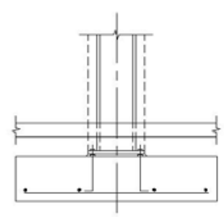
The Best Buy corporate campus consists of four buildings connected by a central hub. This report focuses on building number four, which is a six story braced frame, steel system. The 304,610 square foot building consists of slab on grade construction with wide flange steel columns supported on concrete piers. Lateral loads are supported by a braced frame system. The exterior of the building consists of an architectural precast curtain wall with integrated ribbon windows. Considering the large amounts of integrated technologies required by Best Buy, there are no other major dead or live loads other than those listed in the provided drawings. The occupancy of the building, as expected, is primarily for office use. There are a few open spaces on the first level for future tenants, but the bulk of the building has open space for office partitions.

Foundation:

The foundation for this structure uses a combination of spread footings and piers for the interior and strip footings on the exterior. The concrete slab on grade is unreinforced with a 4" minimum depth with the basement slab on grade having a 6" minimum. Footings are placed under the columns and braced from system. Step footings were used where needed for extra support. All exterior footings must extend 4' below the finished grade to protect from frost with open air foundations having a minimum of 5'. Spread and strip footings were designed for a net soil bearing pressure of 10,000 psf.



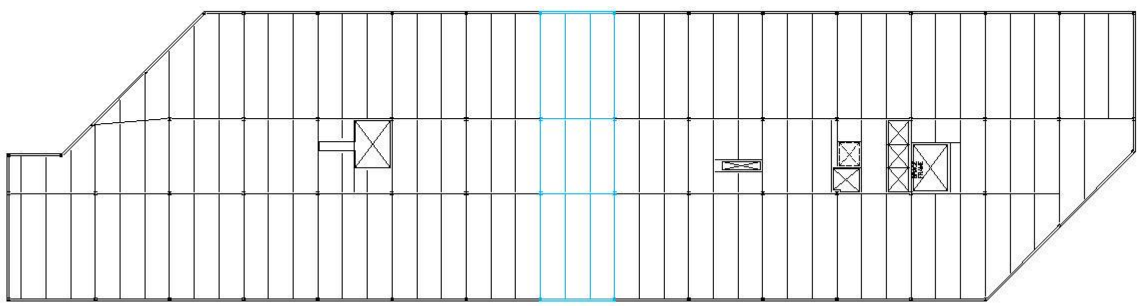
SECTION
PIER DETAIL

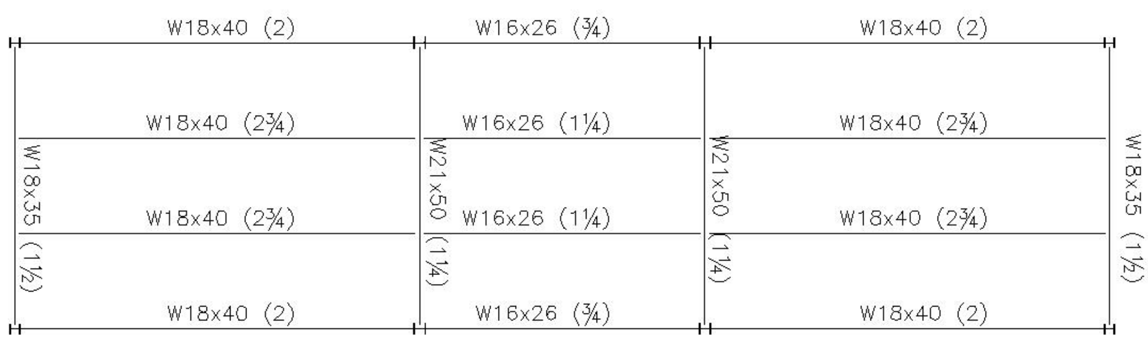


SECTION
TYP. INTERIOR COL. FOOTING

Floor System:

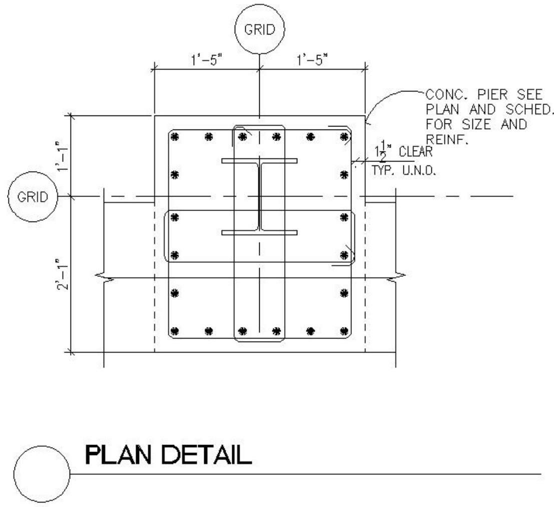
The floor system Building D utilizes a composite beam floor framing system. The overall slab is 6¼" using 3" 20 gauge composite deck and 3¼" lightweight concrete covering. The first floor uses #4 rebar at 18" on center for concrete reinforcing while the remaining floors use 6x6-W2.1xW2.1 welded wire frame. Each internal bay has a typical size of 30'x30' and external bays are typically 30'x42'8". The internal beams are typically W16x26 while the typical external beam is W18x40. Finally, the typical internal girder size is W21x50 and external is W18x35. Material strength is given as 3500 psi for the concrete and A992 50 ksi steel for the beams and girders. Spray on fireproofing was used to meet the fire rating required for the building. The floor framing system along with a typical interior bay is shown below.





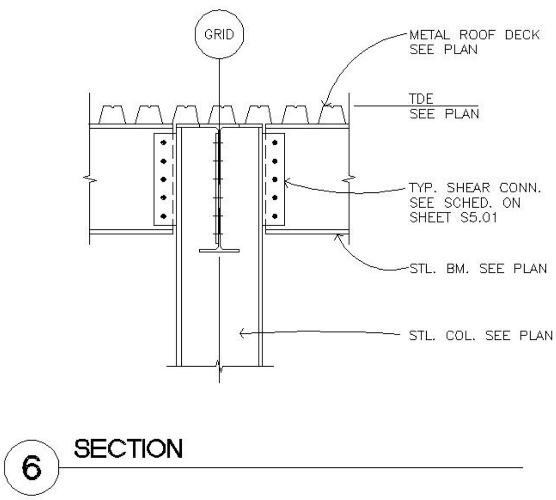
Columns:

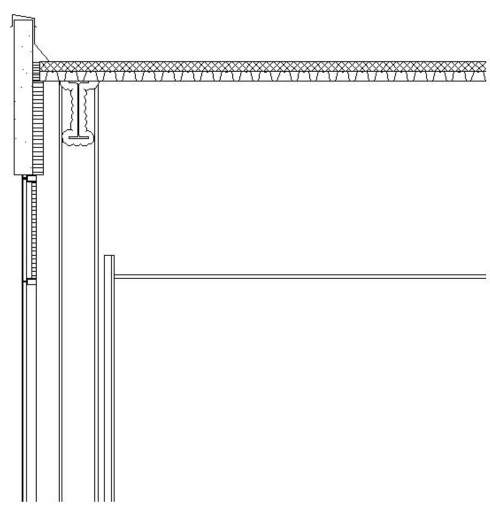
While columns for the building vary in size and weight, the typical column depth is 14". The columns are spaced according to the bay size mentioned previously. Below is a typical column cross section showing overall column size and reinforcement.



Roof:

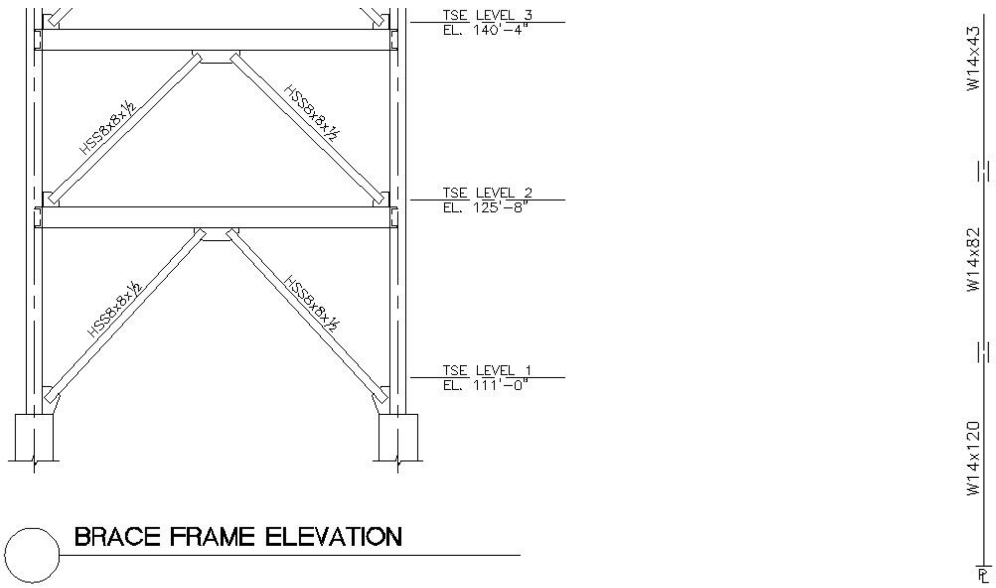
As with the floor system, the roof consists of a composite deck using 3" 20 gauge roof decking with 3 ½" lightweight concrete. This system is covered by a rigid insulation and B.U.R. system. Girder size did not need to increase for the interior; however the exterior girders were increased to W24x55. There is a penthouse located on the roof that houses all the major mechanical components for the entire building.





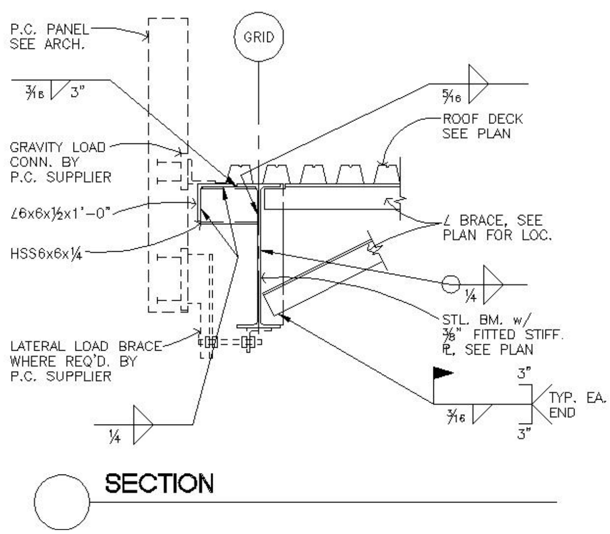
Lateral System:

For the lateral system, this building utilizes a composite floor system and braced framing. The vertical members of the braced frame consist of 3 W14 columns spliced together at the 3rd and 5th floors. The beams between these columns are heavier, W16x57. As shown below, there are 2 diagonal HSS members to provide further support.



Envelope:

The building has an angled wall on the end furthest from the central hub. The façade is 6" architectural precast concrete separated by ribbon windows on each level. The precast components were cast with gravity load connections and lateral load bracing where required by the precast supplier. A detail of the precast connection to the building frame is shown below. This is at the roof level, however it is typical throughout.



Gravity Loads

All gravity load calculations found in the existing building used Uniform Building Code 1997 as their design standard. For simplicity and current accurate standards, I will use ASCE 7-05 to find, factor, and calculate all gravity loads in the building. If uniform differences in sizes occur, it may be a result of this change.

Live Loads:

Roof:		40 psf + Snow loads
Floor:	Level 1:	100 psf
	Levels 2-6:	80 psf
Stairs, Corridors and Lobbies:		100 psf
Mechanical Rooms:		125 psf

Dead Loads:

Roof:	(Design)	25 psf
Floor:	(Superimposed)	5 psf
	(Finishes @ Level 1)	25 psf
	(Partitions @ Levels 2-6)	20 psf
Total:		75 psf

Snow Loads:

Use the equation	$p_f = 0.7 * C_e * C_t * I * p_g$
From Table 7-2, Exposure Factor, C_e =	0.9
From Table 7-3, Thermal Factor, C_t =	1.0
From Table 7-4, Importance Factor, I =	1.1
From Figure 7-1, Ground Snow Load, p_g =	50 psf
Total Snow Load =	34.65 psf

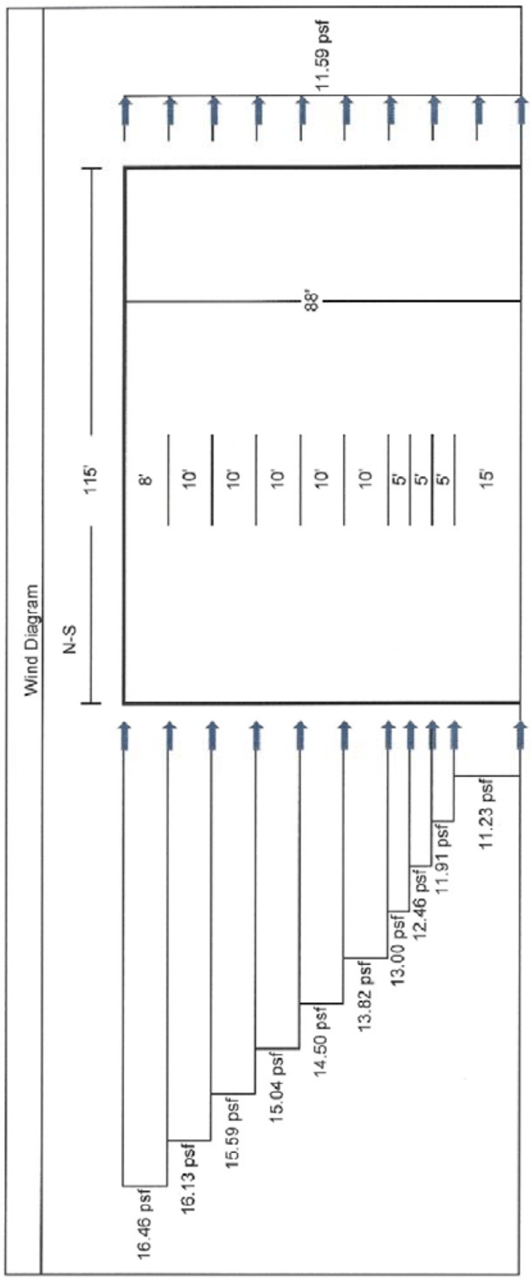
Lateral Loads

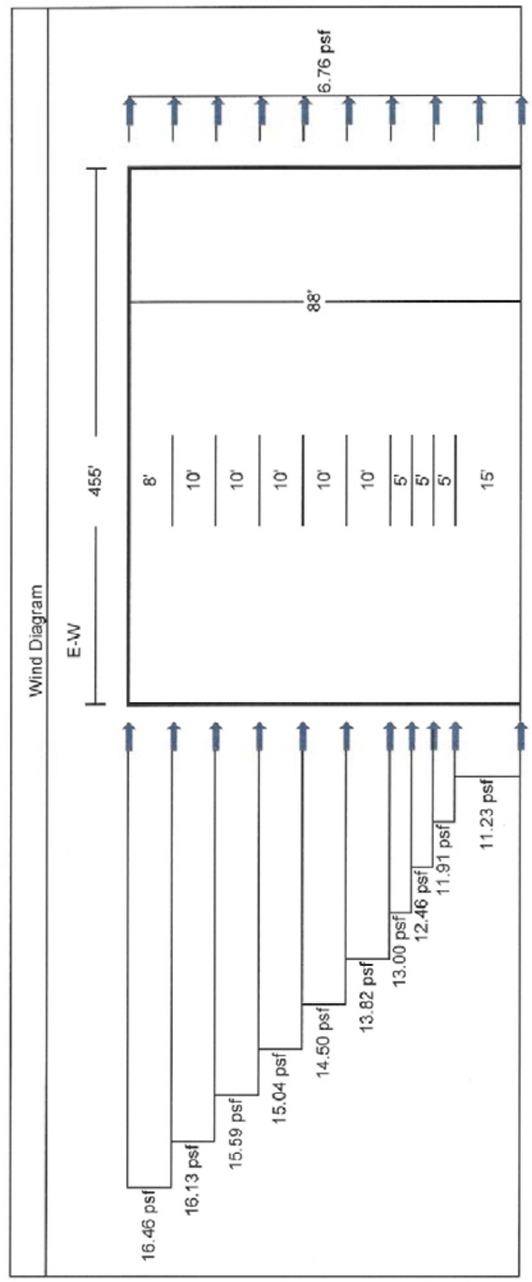
Wind Loads:

The charts below summarize the results found from my wind calculation analysis. Specific calculations of wind forces are located in the Appendix in Excel form. Wind loading diagrams also follow.

	Windward		Leeward		Max (psf) N-S	Max (psf) E-W
Z(ft)	N-S	E-W	N-S	E-W		
0-15	11.23	11.23	-11.59	-6.76	22.82	17.99
20	11.91	11.91	-11.59	-6.76	23.50	18.67
25	12.46	12.46	-11.59	-6.76	24.05	19.22
30	13.00	13.00	-11.59	-6.76	24.59	19.76
40	13.82	13.82	-11.59	-6.76	25.41	20.58
50	14.50	14.50	-11.59	-6.76	26.09	21.26
60	15.04	15.04	-11.59	-6.76	26.63	21.80
70	15.59	15.59	-11.59	-6.76	27.18	22.35
80	16.13	16.13	-11.59	-6.76	27.72	22.89
90	16.54	16.54	-11.59	-6.76	28.13	23.30
88	16.46	16.46	-11.59	-6.76	28.05	23.22

	N-S	E-W
Shear @ 6	185.97	38.87
Shear @ 5	181.91	37.83
Shear @ 4	176.29	36.41
Shear @ 3	170.60	34.97
Shear @ 2	156.75	31.65
Shear @ 1	3.43	0.68
Shear @ Ground	152.35	30.36
Base Shear	1,027.29	210.76
Overturning Moment	52,210.43	10,808.69


Wind Diagram
N-S
115'
88'
11.59 psf
8'
10'
10'
10'
10'
10'
5'
5'
5'
15'
16.46 psf
16.13 psf
15.59 psf
15.04 psf
14.50 psf
13.82 psf
13.00 psf
12.46 psf
11.91 psf
11.23 psf


Wind Diagram
E-W
455'
88'
6.76 psf
8'
10'
10'
10'
10'
10'
5'
5'
5'
15'
16.46 psf
16.13 psf
15.59 psf
15.04 psf
14.50 psf
13.82 psf
13.00 psf
12.46 psf
11.91 psf
11.23 psf

Seismic Loads:

The charts below summarize the results found from my seismic calculation analysis. Specific calculations of seismic forces are located in the Appendix in Excel form.

Summary N-S						
Level	w_x	h_x	$w_x h_x^k$	C_{vx}	F_x (kips)	M_x (ft-kips)
6	1,796.14	88.00	2,376,777.04	0.25556	82.45	7,255.79
5	2,867.05	73.35	2,832,213.68	0.30454	98.25	7,206.76
4	2,867.05	58.68	1,979,465.13	0.21284	68.67	4,029.51
3	2,867.05	44.01	1,247,305.17	0.13412	43.27	1,904.31
2	2,867.05	29.34	650,545.91	0.06995	22.57	662.14
1	2,867.05	14.67	213,800.17	0.02299	7.42	108.81
Σ	16,131.39		9,300,107.09	1.00	322.63	21,167.32

Summary E-W						
Level	w_x	h_x	$w_x h_x^k$	C_{vx}	F_x (kips)	M_x (ft-kips)
6	1,796.14	88.00	2,376,777.04	0.25556	82.45	7,255.79
5	2,867.05	73.35	2,832,213.68	0.30454	98.25	7,206.76
4	2,867.05	58.68	1,979,465.13	0.21284	68.67	4,029.51
3	2,867.05	44.01	1,247,305.17	0.13412	43.27	1,904.31
2	2,867.05	29.34	650,545.91	0.06995	22.57	662.14
1	2,867.05	14.67	213,800.17	0.02299	7.42	108.81
Σ	16,131.39		9,300,107.09	1.00	322.63	21,167.32

Problem Statement

After extensive studies of the building systems found in Best Buy Corporate Building D, the current system has been determined to be effective. All of the building loads and forces are sufficiently resisted by the building in accordance with ASCE 7-05. The problem that will be addressed is to redesign the building using concrete instead of steel. The floor system will consist of a post-tensioned slab with beams. All of the steel columns will also be replaced by concrete columns. These changes will have a large architectural affect on the building along with scheduling and cost changes. The aim of these changes is to reduce the number of columns in the short direction of the building. The post-tensioned slab should also allow for shallower floor depths and the elimination of fireproofing.

Proposed Solution

The proposal is to redesign Best Buy Corporate Building D as a full concrete system. The floor system will be redesigned using a 15.5" post-tensioned slab with beams and the columns will also be redesigned into concrete. This change to post-tension allows for a larger bay size in the short direction of the building. Also as a result of the move away from steel, the lateral bracing system will have to be redesigned to utilize shear walls instead of the current braced frame. All of the building loads will be computed using ASCE 7-05. Research from the spring semester regarding gravity and lateral loading will be used to aid in the redesign of the structure. Special attention will also be given to the change in schedule and overall costs of the project. The impact of the change in architecture on the tenant and rentable area, such as removing a column row, will be investigated as well.

Solution Method

The design of the post-tensioned system will be based on ACI 318-05 Building Code Requirements for Structural Concrete, chapter 18. After completing the redesign of the building, ADAPT-PT will be used to verify the design can withstand the gravity and lateral loads calculated. Based on preliminary findings in technical report 2, the design will start with a slab thickness of 15.5", using 68 strands tensioned at 35 kips, and an eccentricity of at least 6.75". A cost analysis of the structure will be determined using the most recent version of RS Means Building Construction Cost Data available in the engineering library and a schedule analysis will also be considered. Basic floor area calculations will be performed to compare the change in usable floor area and research into the required mechanical and electrical systems changes will be considered.

Tasks & Tools:

Task 1: Redesign the building using concrete

i. Design post-tensioned floor system
ii. Design beams and girders
iii. Design columns
iv. Design and place shear walls
v. Double check design of system in RAM Concept

Task 2: Breadth analysis: Construction management

i. Obtain cost information on current system
ii. Obtain cost information on proposed new system
iii. Comparative cost analysis
iv. Obtain schedule information for current system
v. Obtain schedule information on proposed new system
vi. Comparative schedule analysis

Task 3: Breadth analysis: Architecture

i. Check existing usable floor area
ii. Calculate proposed new usable floor area
iii. Compare usable areas
iv. Compare changes in mechanical and lighting systems

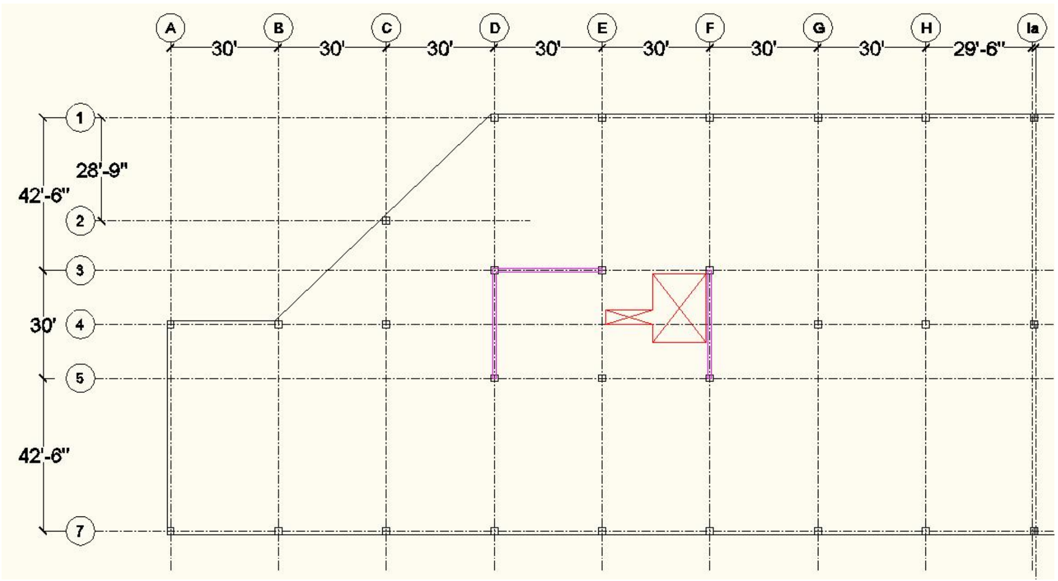
Task 4: Overall comparison of existing system to proposed new system

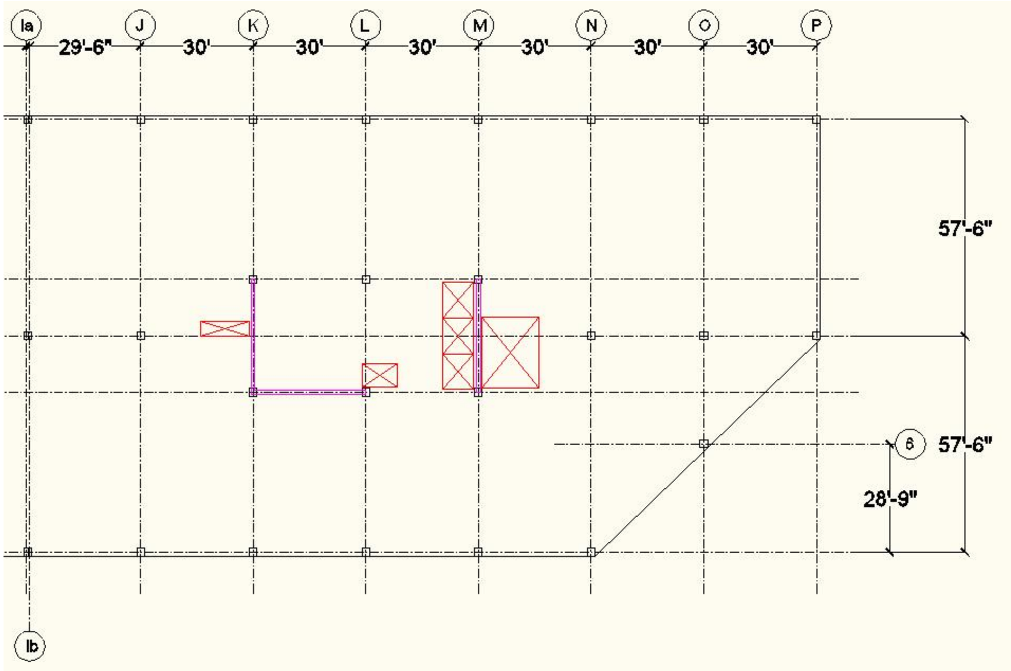
i. Summary of findings
ii. Cost comparison
iii. Schedule comparison
iv. Advantages of proposed new system
v. Disadvantages of proposed new system

Design Work

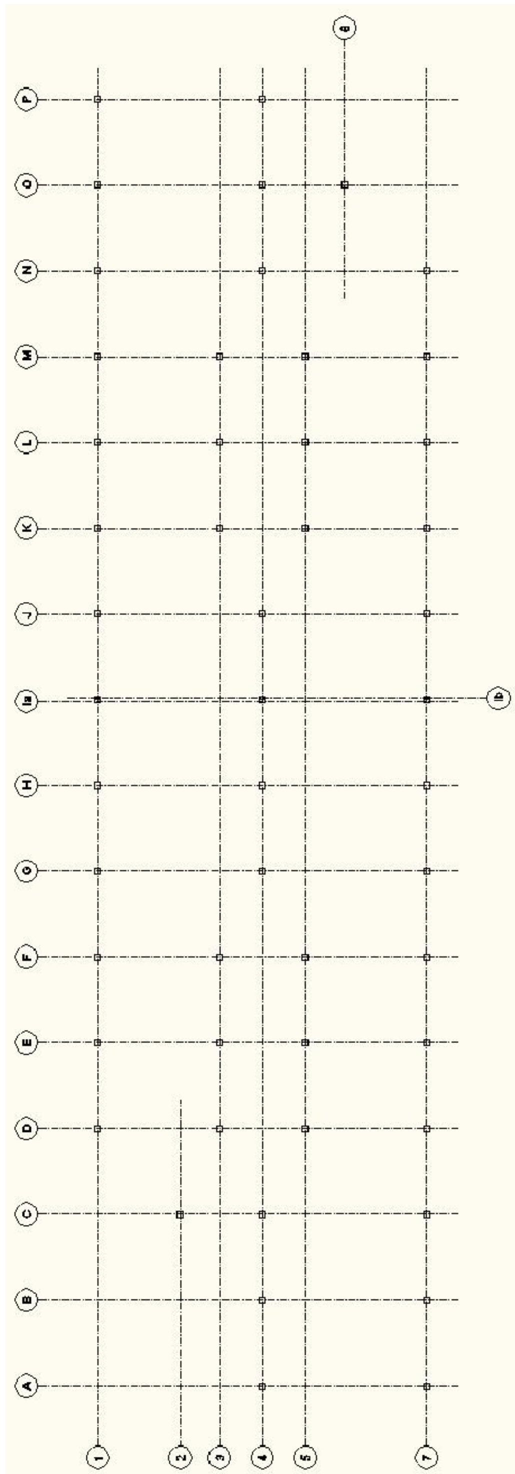
Column Design

The first step in designing the new column layout that would be implemented in Building D was to consider the architectural ramifications of removing columns. The goal of removing some of the columns is to open the floor plan to allow more freedom to the occupants when positioning partition walls. Columns surrounding the mechanical rooms, bathrooms, stairs, and elevator shafts will not be removed. These columns are currently hidden in the walls and do not create a large impact on the open floor plan. Areas in the center of the building as well as bays outside the previously mentioned rooms will be reduced to one interior column.

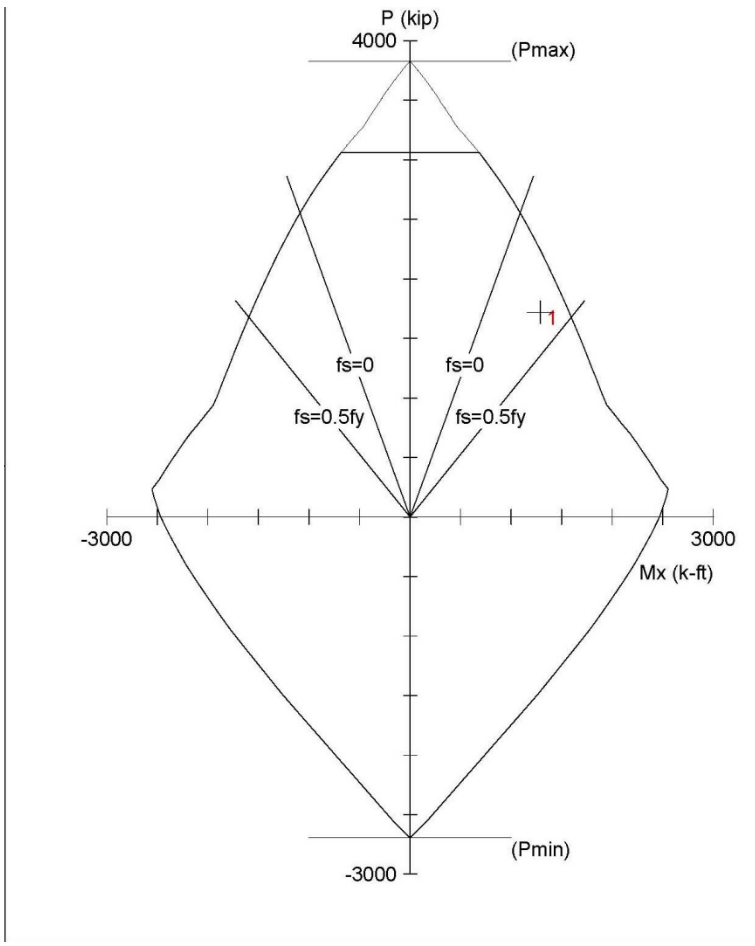




The first step in the design was to decide how the new columns would be placed. The new plan has only twenty interior columns, which is a 23% decrease from the existing steel system. Four of the removed columns are between the two cores. Ten of the columns are between shear walls.



The second step in creating a column layout was to define how these columns were to be designed. To begin, an excel spreadsheet was created to assist in determining the floor loads and initial axial loading. Hand calculations were then performed to determine what size columns to begin with. PCA Column was then used to verify the reinforcement required for each column and corresponding loading. Once initial sizes of the columns were found, there were no changes considered until the design of the lateral. Each column and its reinforcing were governed largely by gravity loads. Further design in ETABS used these columns to reduce story drifts and assumed an increased moment loading on each.



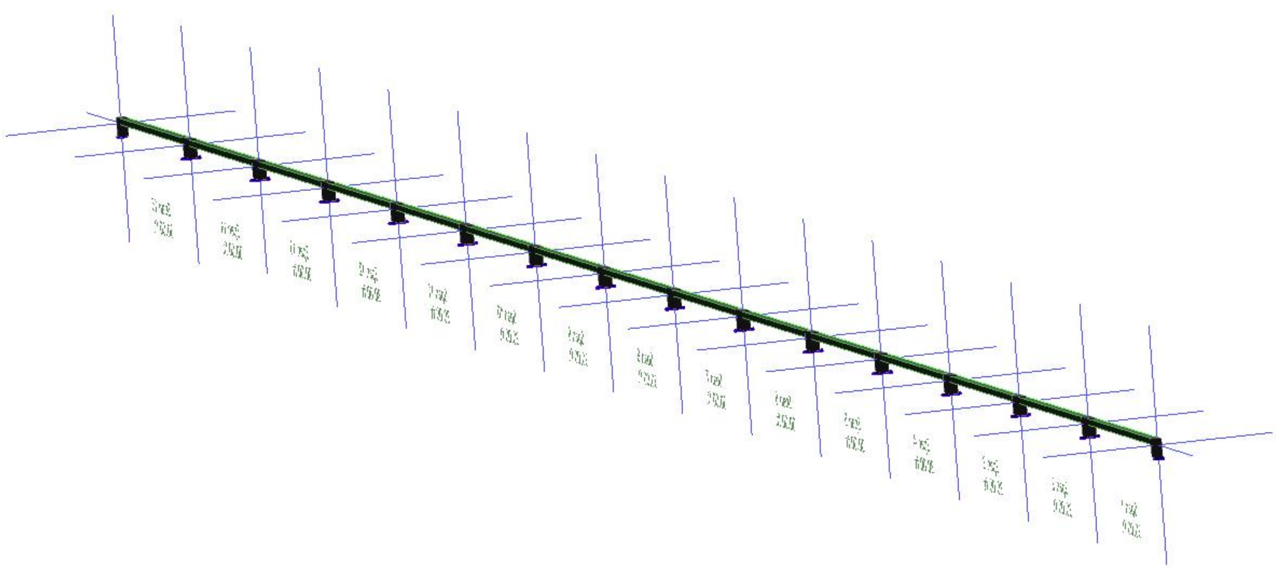
This diagram is the PCA Column result for one of the 30x30 columns. The excel spreadsheet and other PCA Column results are located in Appendix A.

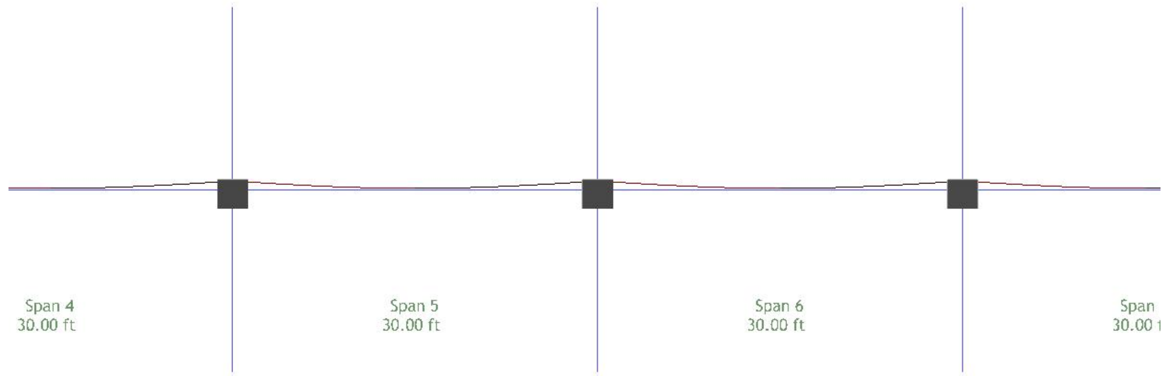
After the lateral system design was completed, a second inspection of the columns showed the reinforcing of each column had to be reexamined. ETABS was then used to assist in the design of the columns based on the moments the program generated. PCA Column was once again utilized to design reinforcement. The design output from ETABS indicated all column sizes were sufficient. To check these results the columns were tested once again in PCA Column with the new moments and forces. The columns did in fact check out and a final column schedule was developed with little trouble. It was found that the larger 3 column spans required a 30"x30" column along the entire row and 24"x24" columns along the 4 column spans.

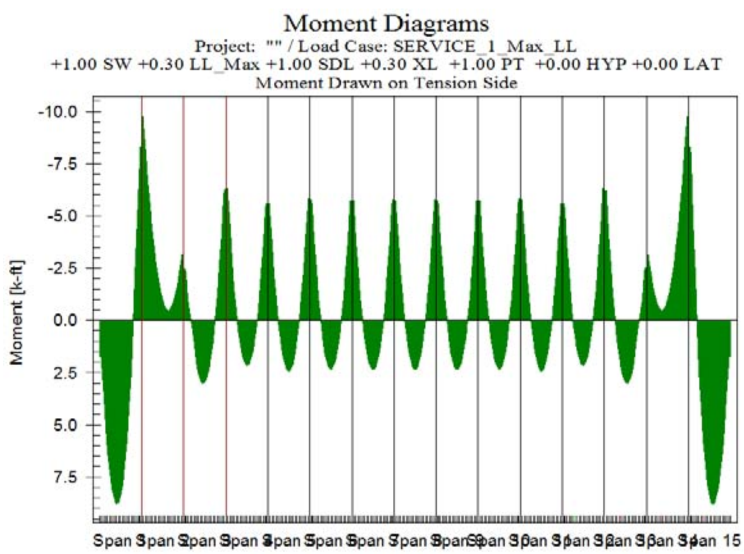
Post Tension Floor Slab Design

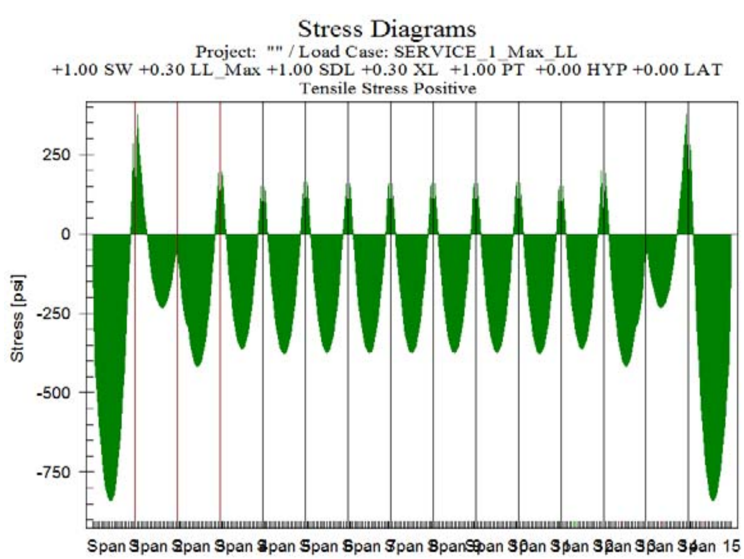
A post-tensioned one-way floor slab system poses several advantages over a regularly reinforced system. After the building was redesigned using these larger bay sizes, it became clear that post-tensioning would be a reasonable alternate floor system. Initially, the redesign called for the beams to run along the long axis of the building and the one-way slab to run along the short distance. However, upon further inspection, in order to keep the depth of the floor slab reasonable, it was decided to run the beams in the short direction and the slab along the long axis. Based on the recommended span/depth ratio alone this reduced the slab from a very large 15.5” to a more realistic 9.5”. Because the slab is being supported on beams, punching shear will not be a controlling factor.

The majority of post-tensioned analysis was performed using ADAPT-PT. This program is new to the AE computer labs and presented many challenges as students learned to navigate their way through the finer points of their models. The result of modeling a new floor system for Building D however, was easier than expected. ADAPT-PT produced a design that agrees with the expected layout for a basically rectangular floor plan. In the model, banding of tendons runs in the east-west direction, while a regular spacing of tendons runs in the north-south direction along column lines. ADAPT also provided a better analysis than could be achieved by hand calculation. ADAPT-PT use design strips, and then analyzing it using conventional analysis techniques. Complete output information can be found in Appendix B.



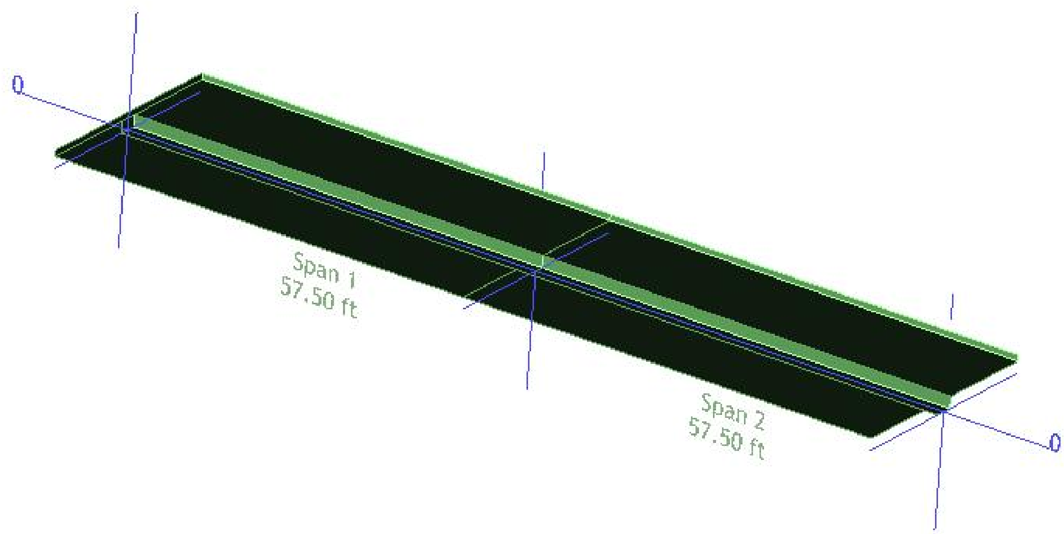

Span 4
30.00 ft
Span 5
30.00 ft
Span 6
30.00 ft

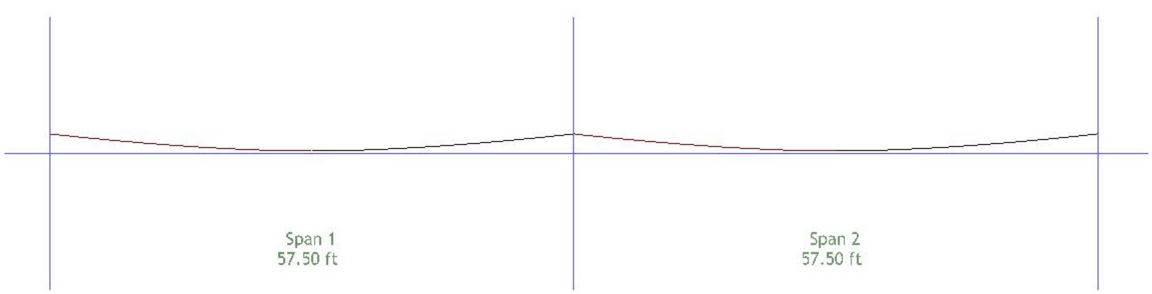

Moment Diagrams
Project: "" / Load Case: SERVICE_1_Max_LL
+1.00 SW +0.30 LL_Max +1.00 SDL +0.30 XL +1.00 PT +0.00 HYP +0.00 LAT
Moment Drawn on Tension Side
Moment [k-ft]

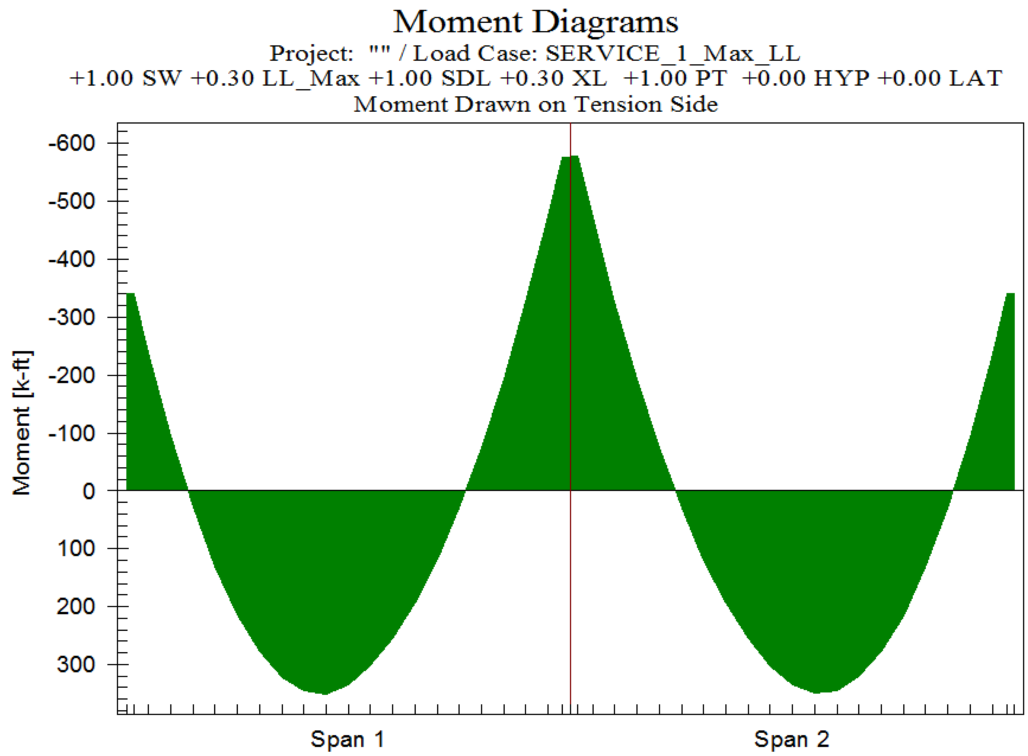

Stress Diagrams
Project: "" / Load Case: SERVICE_1_Max_LL
+1.00 SW +0.30 LL_Max +1.00 SDL +0.30 XL +1.00 PT +0.00 HYP +0.00 LAT
Tensile Stress Positive
Stress [psi]

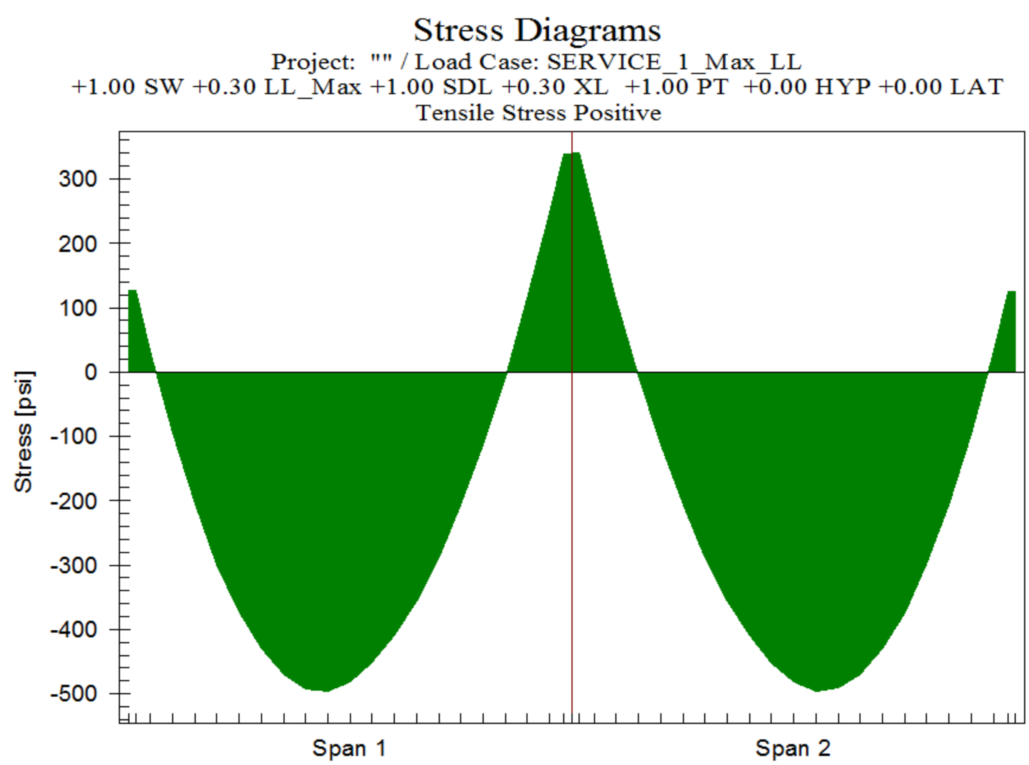
Post Tension Beam Design

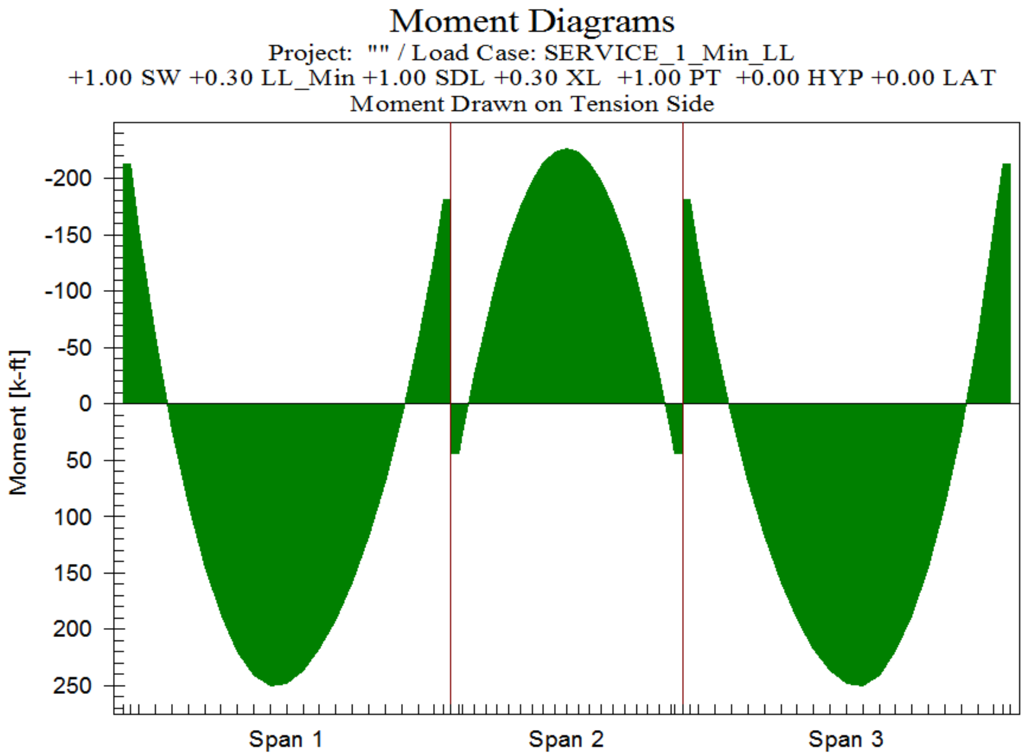
A post-tensioned beam was also implemented due to the larger spans created along the column lines. The larger bay sizes created by eliminating columns are more conducive to PT. Similar to the PT slab design, ADAPT-PT was utilized to aid in the design of the PT beams. An initial span/depth ratio was taken to begin the beam design. The process had to be completed twice, once for the two equal span distances of 57'6" and again for the three span 42'6", 30', 42'6" column line. The dimensions of the longer span was used for both designs in order to keep the building uniform, the only thing that changed was the required number of post-tensioning strands. The final design consisted of 28"x30" beams. The tendons possessed a 270ksi ultimate strength and effective long term stress of 175ksi. The 3 span beams required 19 tendons while the 2 span beams required 27 tendons. Some output information can be found in Appendix C but due to the length of the output, separate PDF documents can be found on the thesis website under final report.

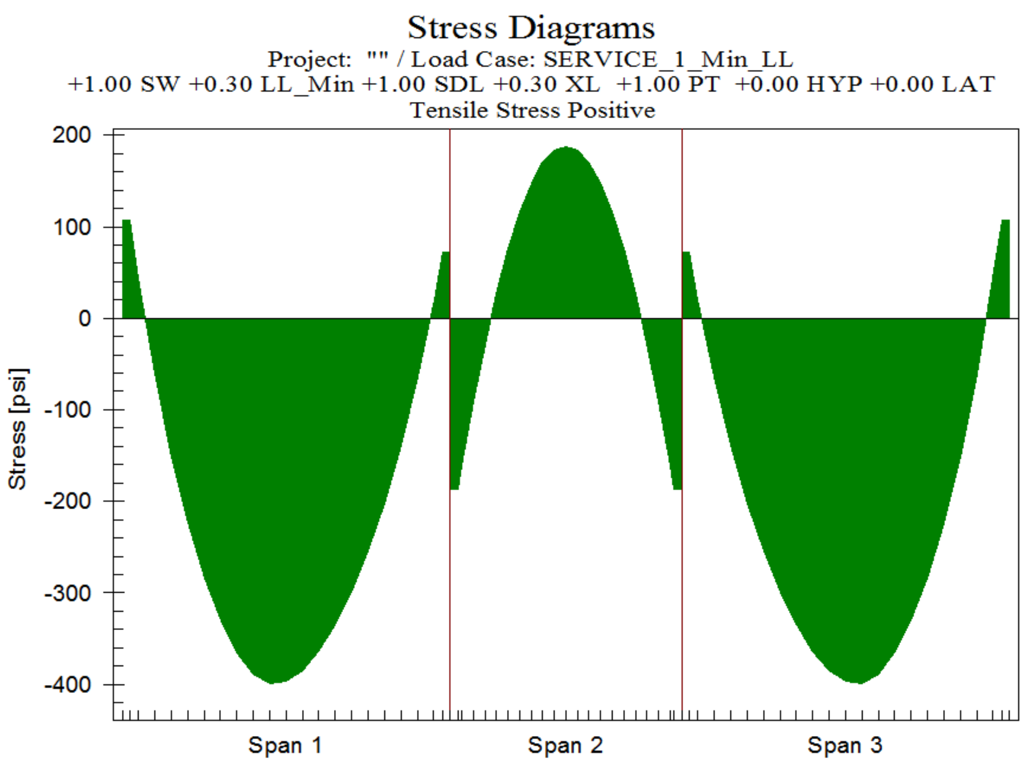





Moment Diagrams
Project: "" / Load Case: SERVICE_1_Max_LL
+1.00 SW +0.30 LL_Max +1.00 SDL +0.30 XL +1.00 PT +0.00 HYP +0.00 LAT
Moment Drawn on Tension Side
Moment [k-ft]
-600
-500
-400
-300
-200
-100
0
100
200
300
Span 1
Span 2


Stress Diagrams
Project: "" / Load Case: SERVICE_1_Max_LL
+1.00 SW +0.30 LL_Max +1.00 SDL +0.30 XL +1.00 PT +0.00 HYP +0.00 LAT
Tensile Stress Positive
Stress [psi]
300
200
100
0
-100
-200
-300
-400
-500
Span 1
Span 2


Moment Diagrams
Project: "" / Load Case: SERVICE_1_Min_LL
+1.00 SW +0.30 LL_Min +1.00 SDL +0.30 XL +1.00 PT +0.00 HYP +0.00 LAT
Moment Drawn on Tension Side
Moment [k-ft]
-200
-150
-100
-50
0
50
100
150
200
250
Span 1
Span 2
Span 3


Stress Diagrams
Project: "" / Load Case: SERVICE_1_Min_LL
+1.00 SW +0.30 LL_Min +1.00 SDL +0.30 XL +1.00 PT +0.00 HYP +0.00 LAT
Tensile Stress Positive
Stress [psi]
200
100
0
-100
-200
-300
-400
Span 1
Span 2
Span 3

Lateral System Design

Initial Design

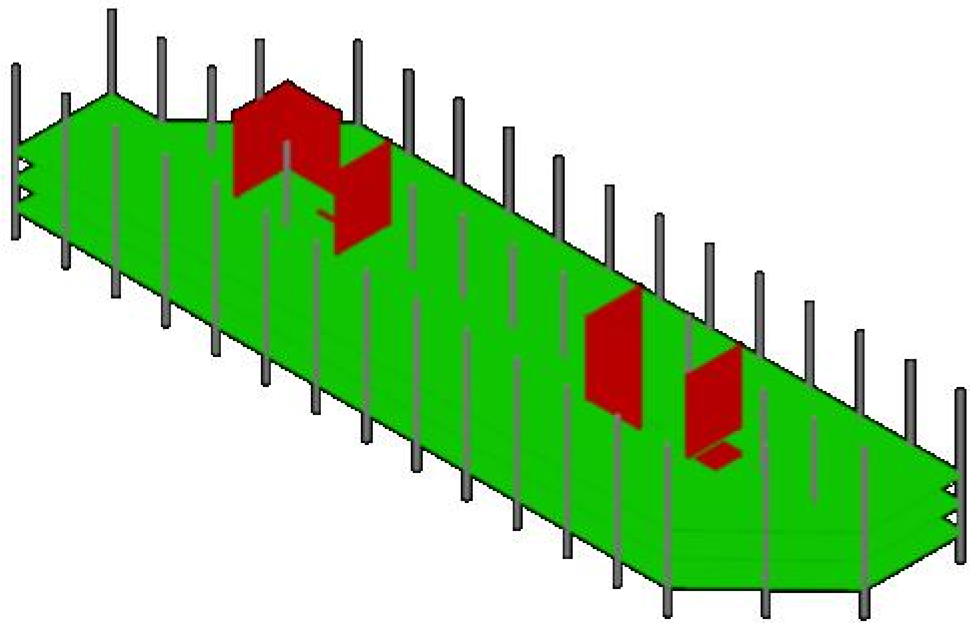
A computer model using ETABS was generated to assist in the lateral analysis of Best Buy Corporate Building D. The shear walls act as vertical cantilever beams which transfer lateral forces from the superstructure to the foundation. In the first ETABS analysis, each floor is assumed to act as a rigid diaphragm for loads in the plane of the floor. As a result, the shear walls alone are assumed to resist all lateral forces. Excel calculated loads and those generated by ETABS were used in the analysis. Using this simplified model made its construction in ETABS more efficient, and should not have posed any problem to analyzing the structure. From a practical standpoint, the structure should not drift more than H/400 to prevent serviceability issues from arising.

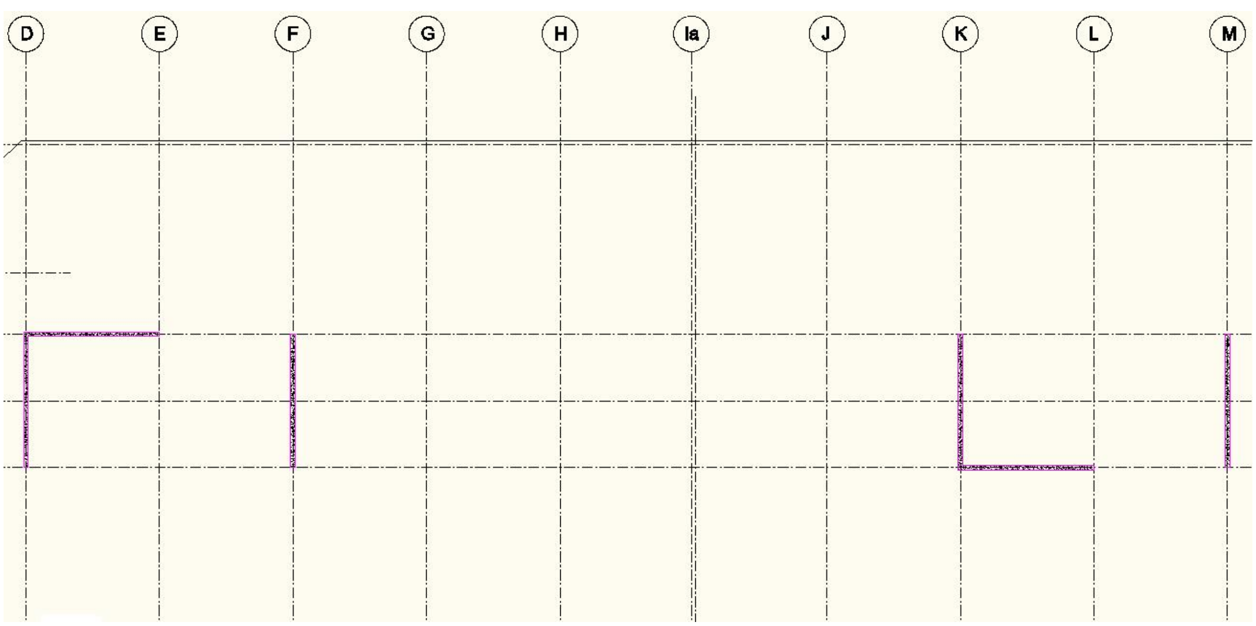
The design of the lateral system was simple in that it relied on shear walls as the sole resisting elements in the building. A lateral system that consisted only of shear walls was intended to be fast, simple, and offer an amount of redundancy. If a shear wall were to fail, the columns would still be able to handle the increased moment placed on them. From the PCA Column program, most columns are well below their ΦM_n.

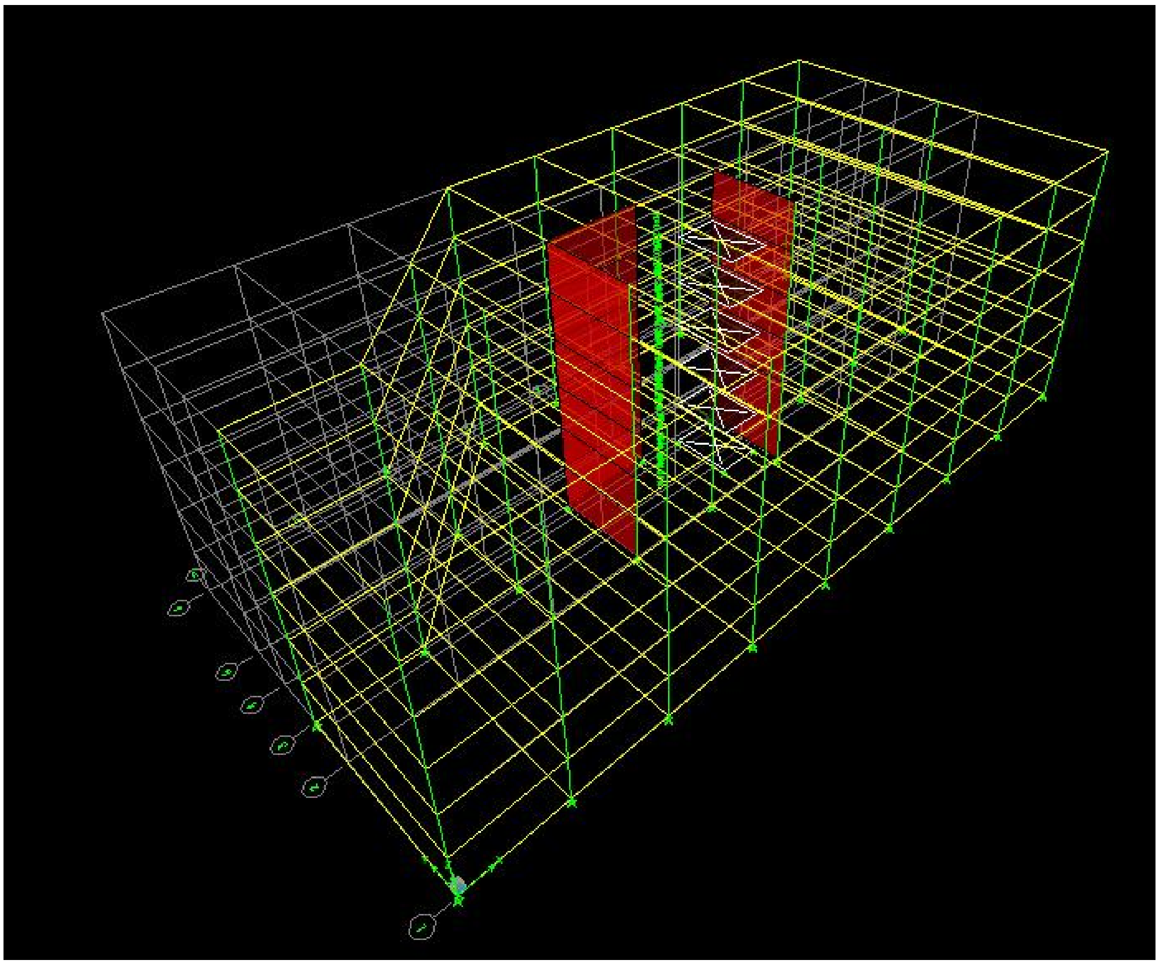
Final Design

Initial design of the lateral system was conducted assuming only the shear walls would resist lateral forces. After a thorough analysis using ETABS, it was determined that such a system would be disadvantageous in a number of ways. A 12" wall system was analyzed. Fortunately the architecture allowed for the walls to be located for enough apart that excessively large walls were not required.

Reinforcement design for the shear walls surrounding the elevator core was based on ACI Chapter 11 and 21, an example from The Seismic Design Handbook and another example from Design of Concrete Structures. The interesting setup that places columns at the ends of the shear walls posed a dilemma for designing the boundary elements in the wall. The increased load at the ends of the wall due to resolving the moment on the wall into a force couple placed an added burden on whatever element was considered to be the end of the wall. Instead of placing an extra axial load on the column, a boundary element could be designed at the end of the shear wall leading up to the column. Interestingly enough, designs proved that a boundary element could be confined to a 12" x 12" area easily concealed within all shear walls since all of them are 12" thick. In all cases, the boundary element can be confined 12" x 12", the standard shear wall size. This route of design was advantageous over placing an added burden on the columns and having to subsequently upsize them.




D
E
F
G
H
Ia
J
K
L
M



Foundation

Although the foundation was not redesigned for the alternate concrete system, it should be noted that the foundation would need to be redesigned. Concrete buildings are generally heavier than steel structures, which results in an overall increased building dead load. The increased dead load was seen when performing seismic calculations. Increasing the foundation strength capacity could be done by increasing the concrete strength from 4000psi to 5000psi or by increasing the dimensions of the piers and slabs. Both of these foundation design options could be explored independently at critical locations or in combination to increase foundation performance.

Breadth Topic I: Construction Management

Cost Analysis

Possibly the most important part of any structural design, the cost of systems must be compared to each other to determine which one is a better option for contractors and developers to construct in a given area. Below is the estimated cost per floor using a steel structure and composite floor system.

Floor System	
Total Cost per Floor	$407,256.83
Total Building Cost	$2,443,540.96

Beams and Girders	
Total Cost per Floor	$494,074.20
Total Building Cost	$2,964,445.20

Columns
Total Length per Floor
924.21
Total Building Cost
$909,422.64

The costs for a concrete structure are expected to be more for this location, the breakdown of structural components and cost are below.

Slab

Total (c.y.)
1431.75

Cast in Place

Cost per Floor
$873,367.50

Placing Concrete

Cost per Floor
$65,860.50

Columns

Total (c.y.)
139.78

Cast In Place

Cost per Floor
$192,194.44

Placing Concrete

Cost per Floor
$10,203.78

Beams

Total (c.y.)
321.66

Cast In Place

Cost per Floor
$385,991.11

Placing Concrete

Cost per Floor
$36,347.50

The final tally shows that the cost to build a post-tension concrete structure in this location far exceeds the costs of the existing steel building.

	Beam	Columns	Floor System	Total
Steel	$2,964,445.20	$909,422.64	$2,443,540.96	$6,317,408.80
Concrete	$2,534,031.64	$777,209.17	$5,635,368.00	$8,946,608.82

Raw cost data is only a part of how one system compares to another. Availability of contractors to perform the work in a timely fashion also highly influences what type of construction is prevalent in a given area. For example, post tensioning is much more common in Washington D.C. than in Richfield, MN because there are many more contractors who can perform the work in the areas surrounding Washington. Looking at the rest of the area, steel is the preferred method of construction in the area.

Breadth Topic II: Architectural

Best Buy Corporate Building D from the exterior has no visible changes. The existing curtain wall can be attached to the building with little change. Precast companies provide hangers for both steel and concrete structures. Inside however, the steel is no longer covered with fireproofing and there is a clean concrete face on all surfaces. The removal of a column from the center of the floor plan has also opened space for larger conference rooms. The original composite steel structure has 30'x30' bays down the center and 4.'6"x30' bays outside of them. The post-tension concrete redesign has 57'6"'x30' in the core of the structure. The original goal of removing columns in the steel system is desirable as to increase useable floor area and traffic flow.

The mechanical was able to stay where it is currently located due to designing shear walls and columns around them. As a result the only thing that would need to change in the mechanical system is possibly their output, as the concrete can be designed to better insulate the floors. The reduced heat transfer will work with the system. Mechanical rooms are located on the east and west ends of the structure by the stairwells.

The existing steel columns are exposed to office space and public areas on the lower levels. The new interior cast in place concrete columns measure 30"x30" in most of the open areas. While this is a significant increase from the original W14x there are fewer of them for the tenant to work around. The following images depict how the tenant is currently forced to work around the columns on the open floor plan.

Notice how the conference rooms have been placed at angles as to hide the existing columns. With the new central column, two conference rooms can be placed where only one stood before.

Summary

Designing Best Buy Corporate Building D started with the simple principle of finding a comparable structural system to the one already in place and possibly providing the advantage of reduced cost and architectural benefits. To do this, the column layout was rearranged. Over 26% of preexisting columns were removed and the remaining columns were upsized in order to allow for more usable space throughout each floor. The result was a more open layout that can be adjusted by architects to suit the increased space available. With the assistance of PCA Column, columns reinforcement was designed to meet the needs of axial loading as well as lateral loads.

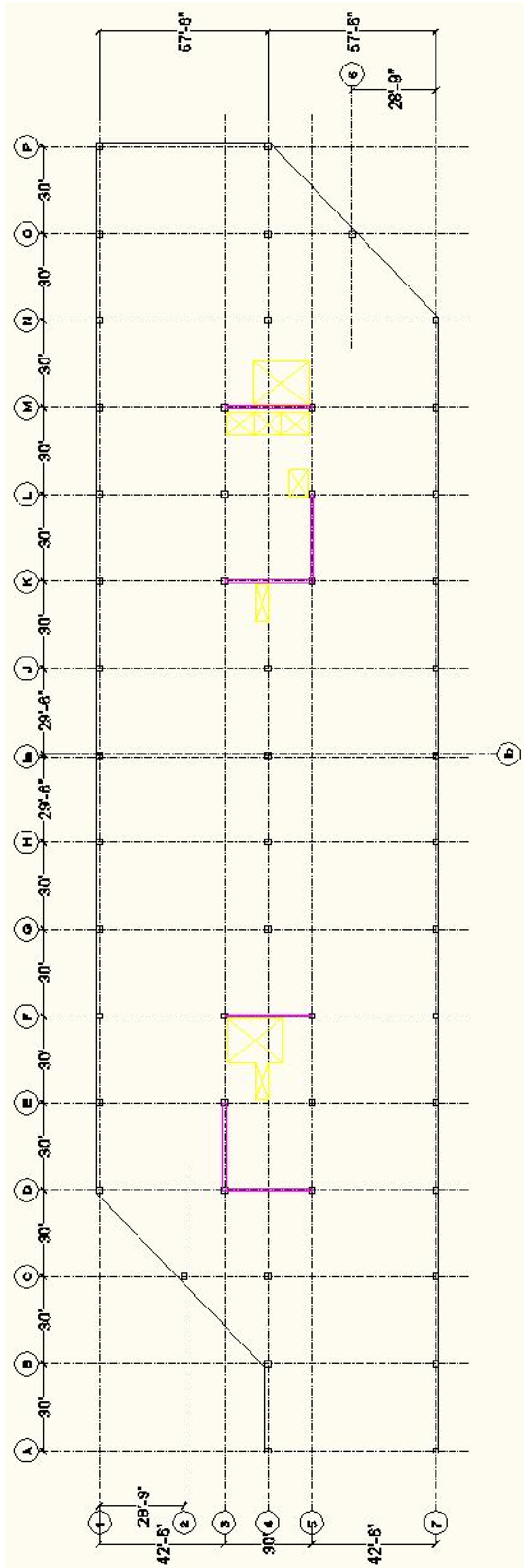
After designing the columns, a floor slab model was developed using ADAPT-PT. The floor slab is 9.5" thick, vastly increasing its thickness from the original designs. Post-tensioning is used throughout the floor with banding around the columns. Post-tension beams were also design with the aid of ADAPT-PT. it was found that the beams needed to be 28" deep. This was comparable to the original ceiling to floor depth 27". This mean the design met at least one of the goals of increasing usable space without sacrificing floor to ceiling height. The floor meets all deflection criteria. The floor slab, as well as the columns and shear walls, are 4000 psi concrete.

The lateral system developed was a shear wall system. Hand calculations were used to determine initial sizing and ETABS was used to complete a model. After examining the columns and the moments on them in ETABS, they were reevaluated in PCA Column for new reinforcement plans. All of the columns could stay the same size, according to ETABS, and PCA Column

In addition, an analysis was performed evaluating the costs of each floor system. A post-tensioned floor system was about 8% more expensive than the existing steel structure. Also, the low availability of PT contractors in Richfield, MN adversely affects the price and ability to erect a PT floor system.

Finally the electrical, mechanical and architectural impact of the new design was investigated. Due to the ability to keep the beams comparable to the existing design, the existing electrical and mechanical systems layout was able to be unaffected. The removal of columns however, did open the floor plan and will allow the customer to use the partitioned space more effectively. The concrete also increases the aesthetics of the building by removing the need for fireproofing.

The following page contains the final layout of the columns and shear walls.


67'-6"
57'-6"
28'-9"
30'
29'-6"
42'-6"

Conclusions

The new design for Best Buy Corporate Building D functions well within the bounds of code requirements and can be considered a valid design for the future. The column layout has a definite advantage over the previous layout because it frees valuable work space.

The post-tensioned slab in combination with the post-tensioned beam makes the expanded floor plan possible. However, an increased cost comes with the new system, and contractors in the Richfield do not usually perform PT construction. The lateral system, a shear wall system is definitely the best system.

In the end, the original system was the best design for the location due to availability and the great increase in costs.

Acknowledgements

I would sincerely like to thank everyone who helped contribute to the development of my thesis throughout the months. Without their help, none of my research would have been possible. It's through the generosity of contributors, professional and personal, who give young students the ability to succeed and rise to the challenge that's been set before us.

The following people deserve many thanks for helping me see the project to completion:

Thesis Advisors:
Dr. Thomas E. Boothby

Industry Contacts:
Gary R. Strand, P.E. - Simpson Gumpertz & Heger
David B. Smith, P.E. - Holbert Apple Associates
Richard Apple, P.E. - Holbert Apple Associates

Other Mentors:
Professor M. Kevin Parfitt
Professor Moses Ling

References

American Concrete Institute, Building Code Requirements for Structural Concrete ACI 318-05, Farmington Hills, MI: American Concrete Institute, 2005

American Institute of Steel Construction, Steel Construction Manual: 13th Edition, Chicago: American Institute of Steel Construction, 2001

Nilson et al. Design of Concrete Structures, Boston: McGraw Hill, 2004

West, Harry and Louis Geschwindner, Fundamentals of Structural Analysis, New York: John Wiley and Sons, Inc., 2002

Appendix A: Column Design

Column ID		Trib. Area
A	4	431.25
A	7	431.25
B	4	970.31
B	7	862.50
C	2	431.25
C	4	1293.75
C	7	862.50
D	1	529.69
D	3	1087.50
D	5	1087.50
D	7	637.50
E	1	637.50
E	3	1087.50
E	5	1087.50
E	7	637.50
F	1	637.50
F	3	1087.50
F	5	1087.50
F	7	637.50
G	1	806.25
G	4	1837.50
G	7	806.25
H	1	862.50
H	4	1725.00
H	7	862.50
Ia	1	431.25
Ib	1	431.25
Ia	4	862.50
Ib	4	862.50
Ia	7	431.25
Ib	7	431.25

Column ID		Trib. Area
J	1	806.25
J	4	1837.50
J	7	806.25
K	1	637.50
K	3	1087.50
K	5	1087.50
K	7	637.50
L	1	637.50
L	3	1087.50
L	5	1087.50
L	7	637.50
M	1	637.50
M	3	1087.50
M	5	1087.50
M	7	637.50
N	1	806.25
N	4	1837.50
N	7	698.44
O	1	862.50
O	4	1293.75
O	6	431.25
P	1	431.25
P	4	646.88

Column Design (G4)							
Column Below Level	Tributary Area (ft^2)	Live Load Influence Area (ft^2)	Live Load Reduction Factor	Dead Load (kips)	Roof Live Load (kips)	Floor Live Load (kips)	Column Load 1.2D+1.6L+.5RL (kips)
1	1837.5	0	1.00	45.9	55.125		143
2	3675	7350	0.42	220.5		78.1	417
3	5512.5	14700	0.40	395.1		147.0	737
4	7350	22050	0.40	569.6		220.5	1064
5	9187.5	29400	0.40	744.2		294.0	1391
6	11025	36750	0.40	918.8		367.5	1718

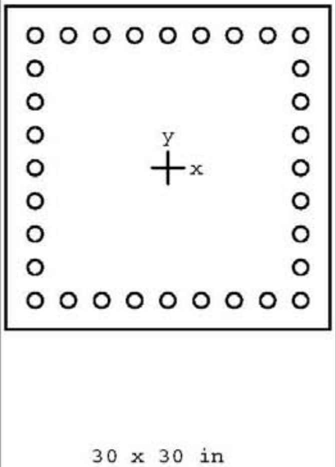
Concrete	
P_u (k)	1718
M_u (ft-k)	1289
F'_c (ksi)	4
F_y (ksi)	60
e	9.00
h	30
# of Faces	4
e/h	0.30
γ	0.8
$\rho_{(Test)}$	0.03
$k_{n(Estimated)}$	0.63
A_g	1048.8
$h_{(Calculated)}$	32.4
$h_{(Test)}$	30

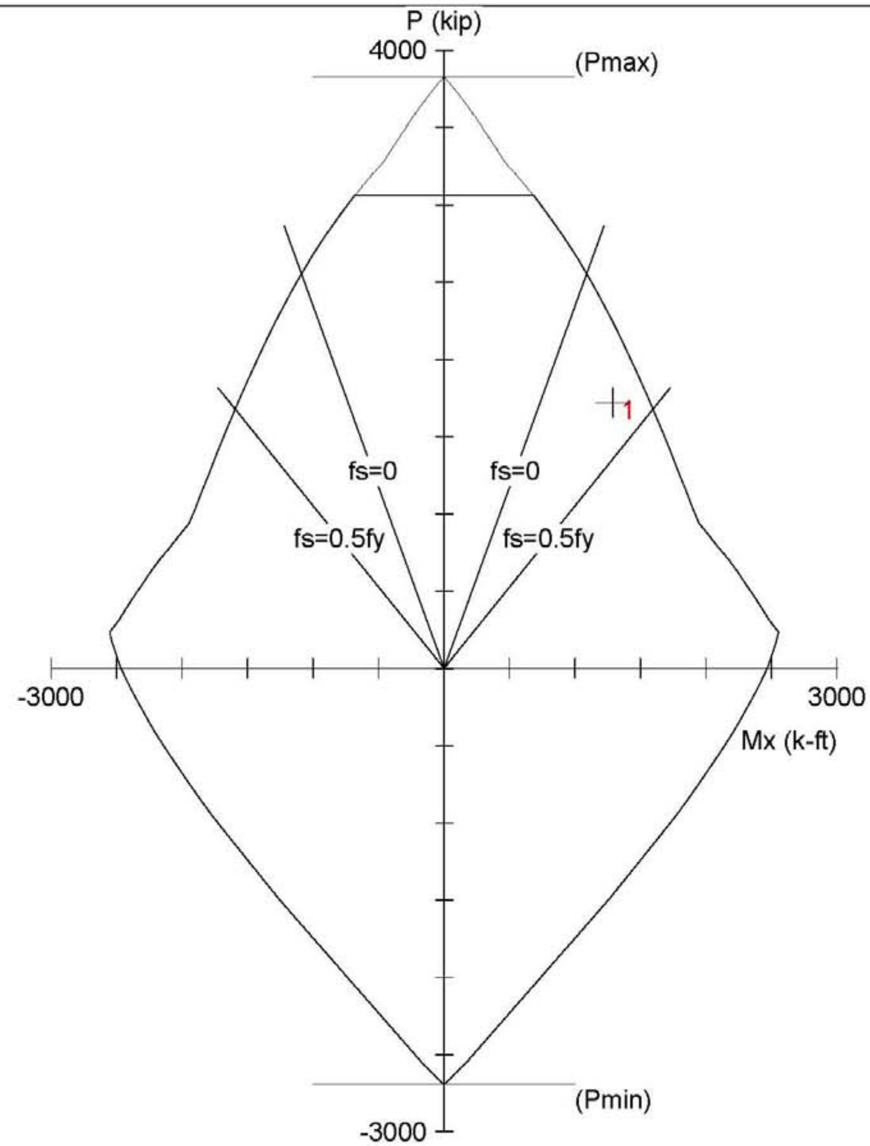
Steel	
$k_{n(Calculated)}$	0.73
$R_{n(Calculated)}$	0.22
ρ	0.042
A_{smin}	37.80
# of Bars	32
A_s	1.181
Rebar Size	11

Final Column Size										
30	"	x	30	"	w/	0	-	#	11	in each face

Use Graphs A.5 - A.12 in Appendix A of Design of Concrete Structures, 13th Edition.

```
pcaColumn v3.64 © Portland Cement Association                                  Page   2
Licensed to: Penn State University. License ID: 52411-1010265-4-22545-224F4   04/08/09
untitled.col                                                                   05:56 PM


  General Information:
  ====================
     File Name: untitled.col
     Project:
     Column:                               Engineer:
     Code:     ACI 318-02                  Units: English

     Run Option: Investigation             Slenderness: Not considered
     Run Axis:   X-axis                    Column Type: Structural

  Material Properties:
  ====================
     f'c   = 4 ksi                         fy   = 60 ksi
     Ec    = 3605 ksi                      Es   = 29000 ksi
     Ultimate strain = 0.003 in/in
     Beta1 = 0.85

  Section:
  ========
     Rectangular: Width = 30 in            Depth = 30 in

     Gross section area, Ag =  900 in^2
     Ix =  67500 in^4                      Iy =  67500 in^4
     Xo =  0 in                            Yo =  0 in

  Reinforcement:
  ==============
     Rebar Database: ASTM A615
     Size Diam (in) Area (in^2)   Size Diam (in) Area (in^2)   Size Diam (in) Area (in^2)
     ---- --------- -----------   ---- --------- -----------   ---- --------- -----------
     #  3      0.38        0.11   #  4      0.50        0.20   #  5      0.63        0.31
     #  6      0.75        0.44   #  7      0.88        0.60   #  8      1.00        0.79
     #  9      1.13        1.00   # 10      1.27        1.27   # 11      1.41        1.56
     # 14      1.69        2.25   # 18      2.26        4.00

     Confinement: Tied; #3 ties with #10 bars,  #4 with larger bars.
     phi(a) = 0.8,  phi(b) = 0.9,  phi(c) = 0.65

     Layout: Rectangular
     Pattern: All Sides Equal  (Cover to transverse reinforcement)
     Total steel area, As = 49.92 in^2 at 5.55%
     32 #11   Cover = 1.5 in

  Factored Loads and Moments with Corresponding Capacities: (see user's manual for notation)
  ========================================================
                    Pu          Mux          fMnx
     No.           kip         k-ft          k-ft   fMn/Mu
     --- ------------ ------------ ------------ --------
       1       1718.0       1289.0       1574.1    1.221

     *** Program completed as requested! ***
```





Code: ACI 318-02

Units: English

Run axis: About X-axis

Run option: Investigation

Slenderness: Not considered

Column type: Structural

Bars: ASTM A615

Date: 04/08/09

Time: 18:26:40

pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-224F4

File: untitled.col

Project:

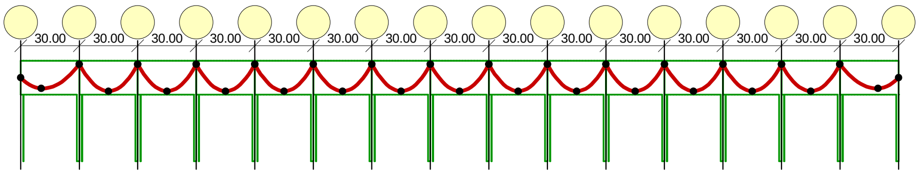
Column:		Engineer:	
f'c = 4 ksi	fy = 60 ksi	Ag = 900 in^2	32 #11 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 49.92 in^2	Rho = 5.55%
fc = 3.4 ksi	fc = 3.4 ksi	Xo = 0.00 in	Ix = 67500 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 67500 in^4
Beta1 = 0.85		Clear spacing = 1.66 in	Clear cover = 2.00 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

Appendix B: PT Floor Slab Design

ADAPT - STRUCTURAL CONCRETE SOFTWARE SYSTEM
ADAPT-PT Version "8.00" Date: "04 - 06 - 2009" Time: "16:57" File: BestBuySlab

1 - PROJECT TITLE: ""
1.1 Design Strip:
1.2 Load Case: SERVICE_1_Max_LL +1.00 SW +0.30 LL_Max +1.00 SDL +0.30 XL +1.00 PT +0.00 HYP +0.00 LAT

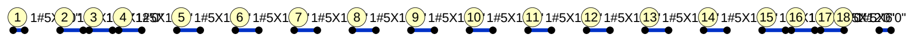
2 - MEMBER ELEVATION
[ft]



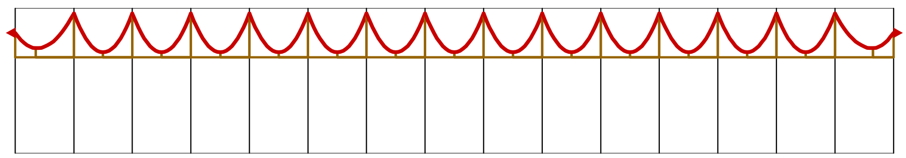
3 - TOP REBAR

3.1 ADAPT selected

3.2 ADAPT selected



4 - TENDON PROFILE



4.1 Datum Line

4.2 CGS Distance A[in]
4.3 Force A

4.75 1.76 8.50 1.00 8.50 1.00 8.50 1.00 8.50 1.00 8.50 1.00 8.50 1.00 8.50 1.00 8.50 1.00 8.50 1.00 8.50 1.00 8.50 1.00 8.50 1.00 8.50 1.00 8.50 1.00 8.50 1.76 4.75
[30 kips] [30 kips] [25 kips] [25 kips] [25 kips] [25 kips] [25 kips] [25 kips] [25 kips] [25 kips] [25 kips] [25 kips] [25 kips] [30 kips] [30 kips]

4.6 CGS Distance B[in]
4.7 Force B

4.10 CGS Distance C[in]
4.11 Force C

5 - BOTTOM REBAR

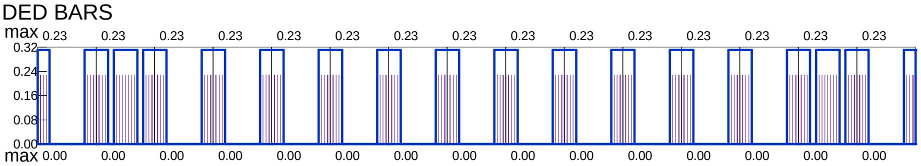
5.1 ADAPT selected

5.2 ADAPT selected

6 - REQUIRED & PROVIDED BARS

6.1 Top Bars
[in^2]
required
provided

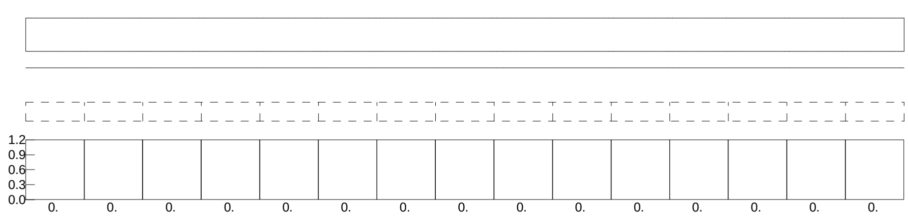
6.2 Bottom Bars



7 - SHEAR STIRRUPS
7.1 ADAPT selected.
Bar Size # 5 Legs: 2
Spacing [in]

7.2 User-selected
Bar Size # Legs:

7.3 Required area
[in^2/ft]



8 - LEGEND Stressing End Dead End

9 - DESIGN PARAMETERS
9.1 Code: ACI05 f'_c = 4000 psi f_y = 60 ksi (longitudinal) f_y = 60 ksi (shear) f_{pu} = 270 ksi
9.2 Rebar Cover: Top = 1 in Bottom = 1 in Rebar Table:

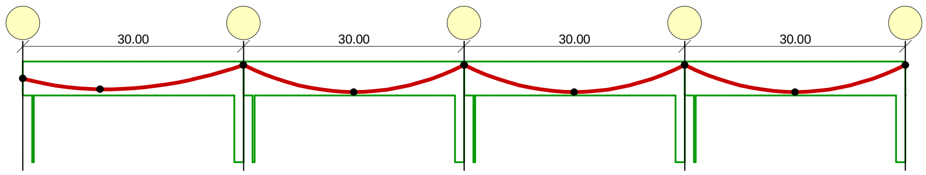
10 - DESIGNER'S NOTES

ADAPT - STRUCTURAL CONCRETE SOFTWARE SYSTEM

ADAPT-PT Version "8.00" Date: "04 - 06 - 2009" Time: "16:57" File: BestBuySlab

1 - PROJECT TITLE: ""
1.1 Design Strip:
1.2 Load Case: SERVICE_1_Max_LL +1.00 SW +0.30 LL_Max +1.00 SDL +0.30 XL +1.00 PT +0.00 HYP +0.00 LAT

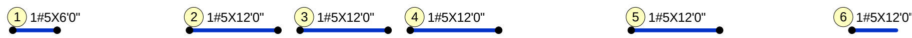
2 - MEMBER ELEVATION
[ft]



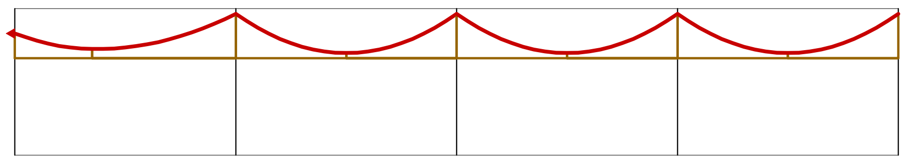
3 - TOP REBAR

3.1 ADAPT selected

3.2 ADAPT selected



4 - TENDON PROFILE



4.1 Datum Line

4.2 CGS Distance A[in]	4.75	1.76	8.50	1.00	8.50	1.00	8.50	1.00	8.50
4.3 Force A		[30 kips]		[30 kips]		[25 kips]		[25 kips]	

4.6 CGS Distance B[in]
4.7 Force B

4.10 CGS Distance C[in]
4.11 Force C

5 - BOTTOM REBAR

5.1 ADAPT selected

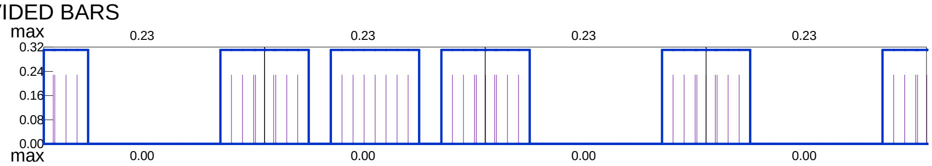
5.2 ADAPT selected

6 - REQUIRED & PROVIDED BARS

6.1 Top Bars

[in^2]
required
provided

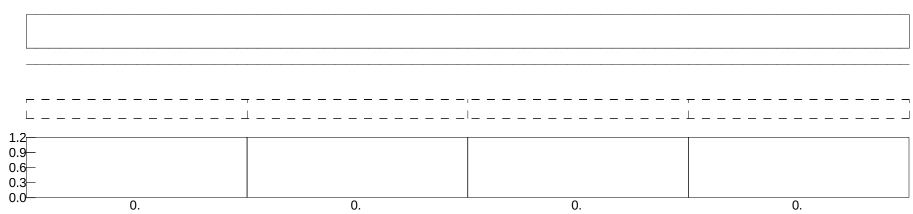
6.2 Bottom Bars



7 - SHEAR STIRRUPS
7.1 ADAPT selected.
Bar Size # 5 Legs: 2
Spacing [in]

7.2 User-selected
Bar Size # Legs:

7.3 Required area
[in^2/ft]



8 - LEGEND Stressing End Dead End

9 - DESIGN PARAMETERS

9.1 Code: ACI05 f'_c = 4000 psi f_y = 60 ksi (longitudinal) f_y = 60 ksi (shear) f_{pu} = 270 ksi

9.2 Rebar Cover: Top = 1 in Bottom = 1 in Rebar Table:

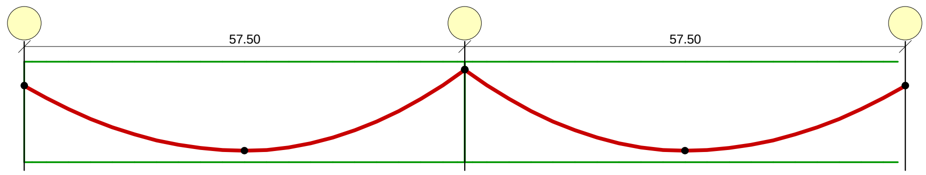
10 - DESIGNER'S NOTES

Appendix C: PT Beam Design

ADAPT - STRUCTURAL CONCRETE SOFTWARE SYSTEM
ADAPT-PT Version "8.00" Date: "04 - 06 - 2009" Time: "17:55" File: BestBuyBeam

1 - PROJECT TITLE: ""
1.1 Design Strip:
1.2 Load Case: SERVICE_1_Max_LL +1.00 SW +0.30 LL_Max +1.00 SDL +0.30 XL +1.00 PT +0.00 HYP +0.00 LAT

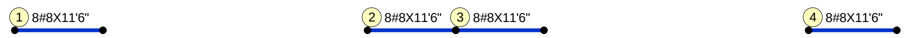
2 - MEMBER ELEVATION
[ft]



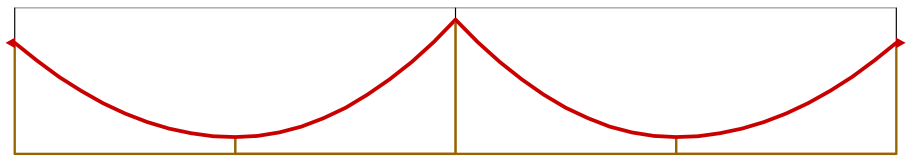
3 - TOP REBAR

3.1 ADAPT selected

3.2 ADAPT selected



4 - TENDON PROFILE



4.1 Datum Line

4.2 CGS Distance A[in] 21.30 3.25 25.75 3.25 21.30
4.3 Force A [716.101 kips] [716.101 kips]

4.6 CGS Distance B[in]
4.7 Force B

4.10 CGS Distance C[in]
4.11 Force C

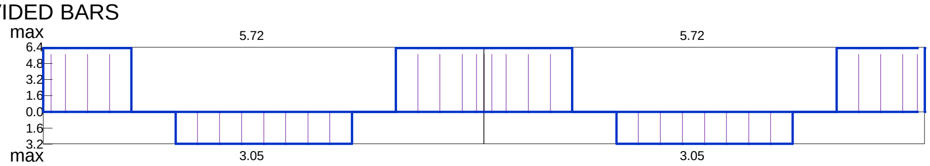
5 - BOTTOM REBAR

5.1 ADAPT selected

5.2 ADAPT selected

6 - REQUIRED & PROVIDED BARS
6.1 Top Bars
[in^2]
required
provided

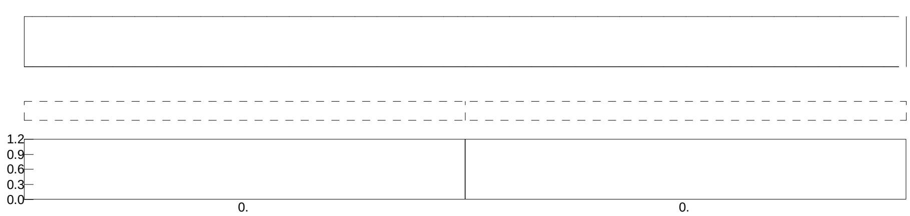
6.2 Bottom Bars



7 - SHEAR STIRRUPS
7.1 ADAPT selected.
Bar Size # 4 Legs: 2
Spacing [in]

7.2 User-selected
Bar Size # Legs:

7.3 Required area
[in^2/ft]



8 - LEGEND Stressing End Dead End

9 - DESIGN PARAMETERS
9.1 Code: ACI05 f'_c = 4000 psi f_y = 60 ksi (longitudinal) f_y = 60 ksi (shear) f_{pu} = 270 ksi
9.2 Rebar Cover: Top = 2 in Bottom = 3 in Rebar Table:

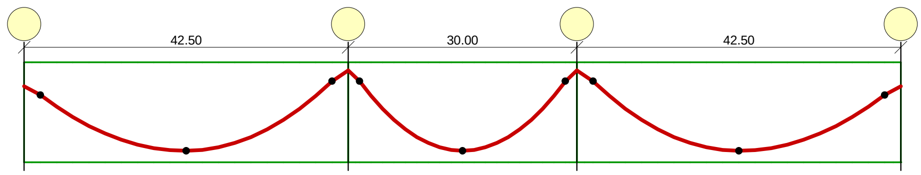
10 - DESIGNER'S NOTES

ADAPT - STRUCTURAL CONCRETE SOFTWARE SYSTEM

ADAPT-PT Version "8.00" Date: "04 - 06 - 2009" Time: "18:30" File: BBY Beam2

1 - PROJECT TITLE: ""
1.1 Design Strip:
1.2 Load Case: SERVICE_1_Min_LL +1.00 SW +0.30 LL_Min +1.00 SDL +0.30 XL +1.00 PT +0.00 HYP +0.00 LAT

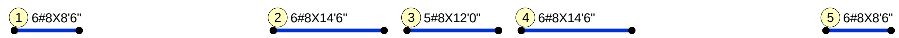
2 - MEMBER ELEVATION
[ft]



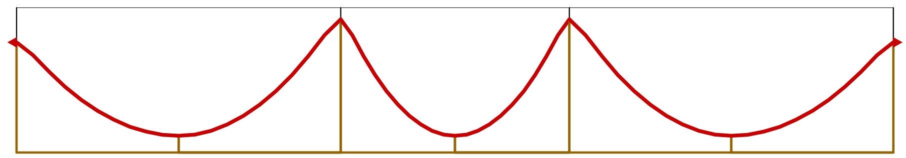
3 - TOP REBAR

3.1 ADAPT selected

3.2 ADAPT selected



4 - TENDON PROFILE



4.1 Datum Line

4.2 CGS Distance A[in]	21.30	3.25	25.75	3.25	25.75	3.25	21.30
4.3 Force A		[500 kips]		[500 kips]		[500 kips]	

4.6 CGS Distance B[in]
4.7 Force B

4.10 CGS Distance C[in]
4.11 Force C

5 - BOTTOM REBAR

5.1 ADAPT selected

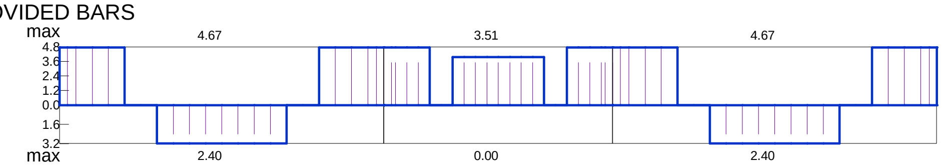
5.2 ADAPT selected

6 - REQUIRED & PROVIDED BARS

6.1 Top Bars

[in²]
required
provided

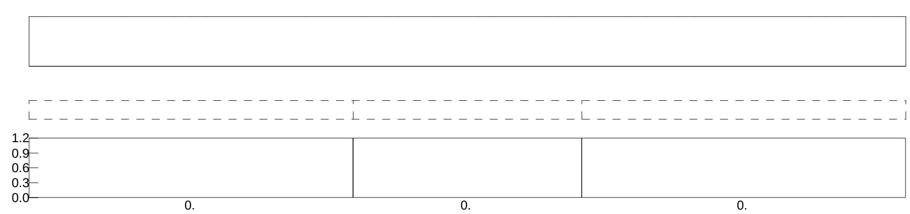
6.2 Bottom Bars



7 - SHEAR STIRRUPS
7.1 ADAPT selected.
Bar Size # 5 Legs: 2
Spacing [in]

7.2 User-selected
Bar Size # Legs:

7.3 Required area
[in²/ft]



8 - LEGEND Stressing End Dead End

9 - DESIGN PARAMETERS
9.1 Code: ACI05 f'_c = 4000 psi f_y = 60 ksi (longitudinal) f_y = 60 ksi (shear) f_{pu} = 270 ksi
9.2 Rebar Cover: Top = 2 in Bottom = 3 in Rebar Table:

10 - DESIGNER'S NOTES

Appendix D: Breadth Topics

Slab		Columns			Beams		
Depth	Area	# of	Height	Area	# of	Length	Area
0.83	46575	51	11.84	4	16	115	4.72
Total (c.y.)		Total (c.y.)			Total (c.y.)		
1431.75		89.46			321.66		

Cast-in-Place Concrete		
Cost per c.y.	Cost per c.y.	Cost per c.y.
610	1375	1200
Cost per Floor	Cost per Floor	Cost per Floor
$873,367.50	$123,004.44	$385,991.11
CIP Costs per Floor		
$1,382,363.06		
Total Building CIP Costs		
$8,294,178.33		

Placing Concrete		
Cost per c.y.	Cost per c.y.	Cost per c.y.
46	73	113
Cost per Floor	Cost per Floor	Cost per Floor
$65,860.50	$6,530.42	$36,347.50
CIP Costs per Floor		
$108,738.41		
Total Building CIP Costs		
$652,430.48		

Total Concrete Frame Costs
$8,946,608.82

Floor System	
Floor Area (ft^2)	
46863	
Concrete Cost per ft^2	Total per Floor
$3.68	$172,455.84
Concrete Placing per CY	Total per Floor
$53.50	$48,286.25
Deck Cost per ft^2	Total per Floor
$3.98	$186,514.74
Total Cost per Floor	$407,256.83
Total Building Cost	$2,443,540.96

Beams and Girders				
Size	Quantity	Average Length	Cost per ft	Cost per Floor
W8x15	3	10	$37.00	$1,110.00
W12x14	8	10	$36.00	$2,880.00
W12x19	5	15	$36.00	$2,700.00
W14x22	2	13	$47.00	$1,222.00
W16x26	42	30	$53.00	$66,780.00
W16x31	1	30	$63.50	$1,905.00
W16x57	4	30	$98.50	$11,820.00
W18x35	25	30	$81.00	$60,750.00
W18x40	81	42.5	$72.00	$247,860.00
W21x44	1	34	$87.50	$2,975.00
W21x50	27	30	$98.50	$79,785.00
W24x55	3	33.2	$107.00	$10,657.20
W24x62	1	30	$121.00	$3,630.00
		Total Cost per Floor		$494,074.20
		Total Building Cost		$2,964,445.20

Columns		
# per Floor	Length per Floor	Total Length per Floor
63	14.67	924.21
Cost per ft	Cost per Floor	Total Building Cost
$164.00	$151,570.44	$909,422.64