Westinghouse Electric Company Corporate Headquarters

Cranberry, PA

Final Report

Spring 2009
B.A.E.

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Structural Option
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Westinghouse Electric Company Corporate Headquarters Building One Cranberry, PA

Building Information

Occupancy:	Office
Size:	434,800 SQ FT
Height:	5 Levels, 87'-6" Tall
Build Time:	Feb 2008-May 2009
Cost:	$80 Million
Delivery:	Design-Bid-Build

Project Team

Owner:	Wells Real Estate Funds
Architect:	IKM, Inc.
Structural/mech:	LLI Engineering
Civil:	Civil & Environmental Consultants, Inc.
Construction:	Turner Construction Company

Structural

Structural Steel Framing With 2" Composite Steel Deck And 2-1/2" Concrete Slab

Typical Bay Size Is 45'-0"

Moment Connections Resist Wind Forces

Slab On Grade, Grade Beams, And Cassion Foundation System

Mechanical/Electrical/Lighting

Two Gas Fired Boilers Serve To Heat The Building With Capacities Of 1265 CFM And 960 CFM.

Six AHU's With Varying Capacity Serve The Building And VAV Units.

480/277V, 3 Phase, 3 Wire Primary, 208/120V 3 Phase 4 Wire Secondary Delta-Wye Dry Type Transformers.

Mainly Flourescent Lighting To Contribute To Leed Certification.

Generator Protection On Campus For All Controls.

Architecture

Site Is On 83 Acres In Cranberry, PA

LEED Certification Goal

Bio-retention Parking Lot

Brick Façade Is Textured To Create Vertical Element While Polished Concrete Block Emphasizes Imporantance.

Powerful Entrance Makes Use Of Two-Story Atrium

Floor-To-Floor Height Of 14'-0", Entrance Level Is 18'-0".

Roof System Consists Of An EDPM System With A Membrane Over 1/2" Protection Board Over Tapered Insulation Over 5/8" GWB On The Roof Decking.

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www.engr.psu.edu/ae/thesis/portfolios/2009/jll5004/

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Executive Summary

The Westinghouse Electric Company Corporate Headquarters will be a three-building campus with site features which include asphalt walking paths and volleyball courts on eighty-three acres in Cranberry, PA. For the purpose of the project, only Building One will be analyzed as the other two are considered a separate project by all parties involved. The truncated V-shape building has been given a look of importance with polished concrete block merging into brick stepped-out columns to accentuate the verticality of the five-story 74'-6" tall structure.

The purpose of this report is to redesign the structural system of the Westinghouse Electric Company Corporate Headquarters Building One using reinforced cast-in-place concrete and a one-way slab with beams floor system. The building was analyzed in concrete by hand and in the RAM Structural System program. The success of this part of the report relies on the implementation of the code effectively and correctly to determine if the proposed modifications could be implemented.

For this report, a detailed analysis of the alternative structural system was performed. In order for this method to be correct, all structural members were designed according to ACI 318-08 and ASCE 7-05 for gravity loads, lateral loads, and torsion. Hand calculations were done for spot checked members in addition to a RAM Structural System model and analysis. The new structural system consists of typical square columns 24"x24" and beams typically 24"x34" with a 10" thick one-way slab. The spread footings and caissons were also spot checked and updated as necessary for the new structural dead load. Uplift and overturning moment were considered and checked for this report, but due to the weight of the building, neither was determined to be an issue.

Since the building material was changed, it is necessary to compare the new building cost estimate and schedule to the as-built structure's cost budget and schedule. The new building was determined to be $30.60/SF without a green roof and $33.28/SF with a green roof, while the original design cost is $30.90/SF. Also, it takes two months longer for the new concrete structure to be erected compared to the original steel structure. Despite the fact that the lead time for steel is much longer than concrete, most of the steel will be on site by the time the foundations are complete, so the lead time did not affect the schedule. While the goal of the project was to obtain a cost and schedule for the new building so a comparison could be made, it can clearly be see that the concrete structure is not the best alternative for this building.

The sustainable architecture study was an attempt to make the corporate headquarters stand out among headquarters buildings by being incorporated into the environment. A green roof was added, and the extra load of the soils and supporting structure was determined and evaluated with the entire building. The green roof was designed for the third floor area above what will be the employee cafeteria. This part of the building also conveniently faces the south, which is the optimum direction for a successful green roof. The area will be extremely beneficial to the company by its multiple purposes, whether it is as a lunch area, a break room, or an informal meeting location. The waterproofing, drainage system including pipe sizes, detail of the materials, specification of materials and plants acceptable for the green roof were all determined. A LEED analysis was performed for the new building also, since one of the goals of the owners was to have a LEED certified building. It was determined that it is possible for the building to be LEED silver rated, but would require further information and investigation to be rated higher.

Overall, the project was a success, even though it was not erected cheaper or faster than the original steel building. It is feasible to build the building in concrete, but it is not an effective alternative. It is recommended to add a green roof to the structure to emphasize the corporate headquarters aspect of the building and to incorporate it into the environment.

ACKNOWLEDGEMENTS

I would like to thank:

- Turner Construction Company for their assistance and support in completing my project and providing supplies for this project. Special thanks to Bob Hennessey for his time and efforts to help me with my questions throughout the year, providing the schedule and estimate, and also taking the time to show me the site.

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- The Pennsylvania State University Architectural Engineering Department and Staff for teaching us the skills necessary to become the best engineers possible and their advice and help throughout the past five years. In particular, Dr. Linda Hanagan, my thesis advisor, for her assistance and feedback throughout the year, and Prof. Kevin Parfitt and Prof. Robert Holland for teaching the class.

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INTRODUCTION

WESTINGHOUSE ELECTRIC COMPANY CORPORATE HEADQUARTERS BUILDING ONE

The Corporate Headquarters building for the Westinghouse Electric Company is located in Cranberry, Pennsylvania. Just north of the city in Butler County, the site is on 83 acres in an office park easily accessible by I-79 and PA-228. With five above grade floors and a full 17' high basement, Building One will be the main building on this campus. Complete with cafeteria, gym, locker rooms, offices, and executive conference rooms, the flagship building comes well equipped and diverse. At 434,800 square feet, the building makes quite an architectural statement.

The main building utilizes a powerful entrance with a two-story atrium to express its importance. The first floor also has a height of 18'-0" to emphasize a larger space while floors two through four have floor-to-floor heights of 14'-0". The fifth floor has a height of 14'-6". Building One has a 74'-6" above grade with an 18' penthouse, making the final height 92'-6". Aluminum and glass curtain walls add light and make the building feel more open while polished concrete at the base of the brick façade accentuate the height. The foundation system consists of caissons in addition to some spread footings and grade beams. A typical bay is 45'-0" by 24'-0", and uses a steel system with composite beams and deck. In most of the building, the girders are not composite, but the beams framing into the girders have some composite action. The floor system is a 2" 22 gage steel deck with 2-1/2" of lightweight concrete topping. The Westinghouse Electric Company Corporate Headquarters Building One has two expansion joints present, thus creating essentially three structural buildings inside of one. The expansion joints create the East, Center, and West parts of the building. These joints can be seen along column lines 7.9 and 8 between the east and center portions, and column lines 21 and 21.1 between the center and west parts of the building.

A successful redesign of this building will be completed and checked using a computer program, such as RAM Structural System, following the design procedure laid out by ACI 318-08 and ASCE 7-05, and will be constructible. The design will consist of gravity design of member, wind load calculations, seismic load calculation, torsion member checks, resizing of foundations, and uplift and overturning moment. Any changes will be evaluated in terms of cost and schedule implications and be compared to original values for both obtained from the Turner Construction Company. The construction management portion will compare these values. Ideally, the building will be built faster or less expensively than the original, but this is not a main point in the success or failure of this portion. Finally, the redesign will be a success if the building can be further integrated into the environment while providing details and specifications.

SITE PLAN

Figure 1: Site boxed in red and the road leading up to the site highlighted in red

Third floor plan- East with portal analysis Frame 2 and spot checked columns highlighted.

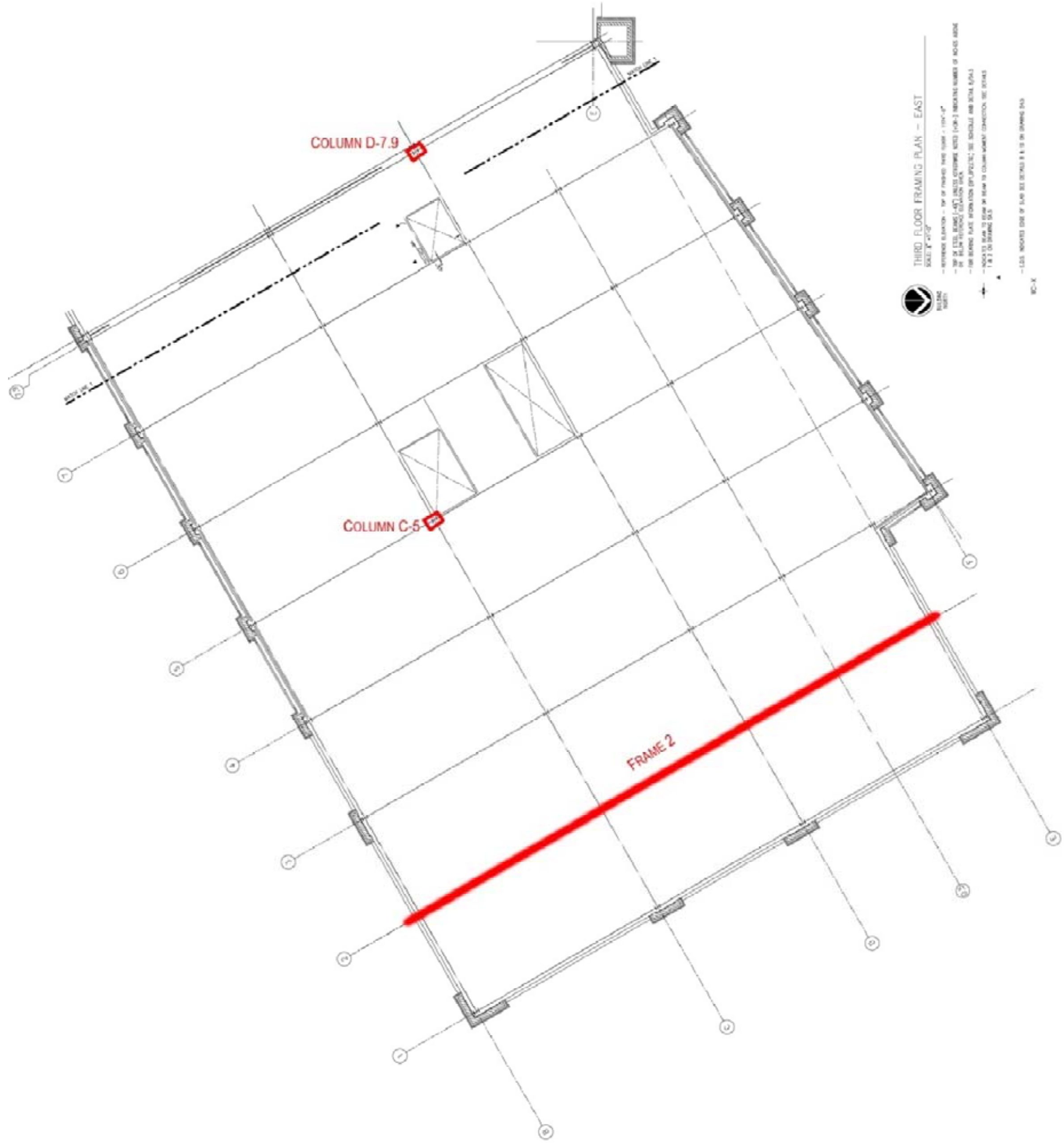


Figure 2: Third Floor Plan East

Third Floor Plan Center with portal analysis Frame 13, interior beam designed, lateral member C.2-D.2- 13 checked, and spot checked columns B-15 and A-15 highlighted

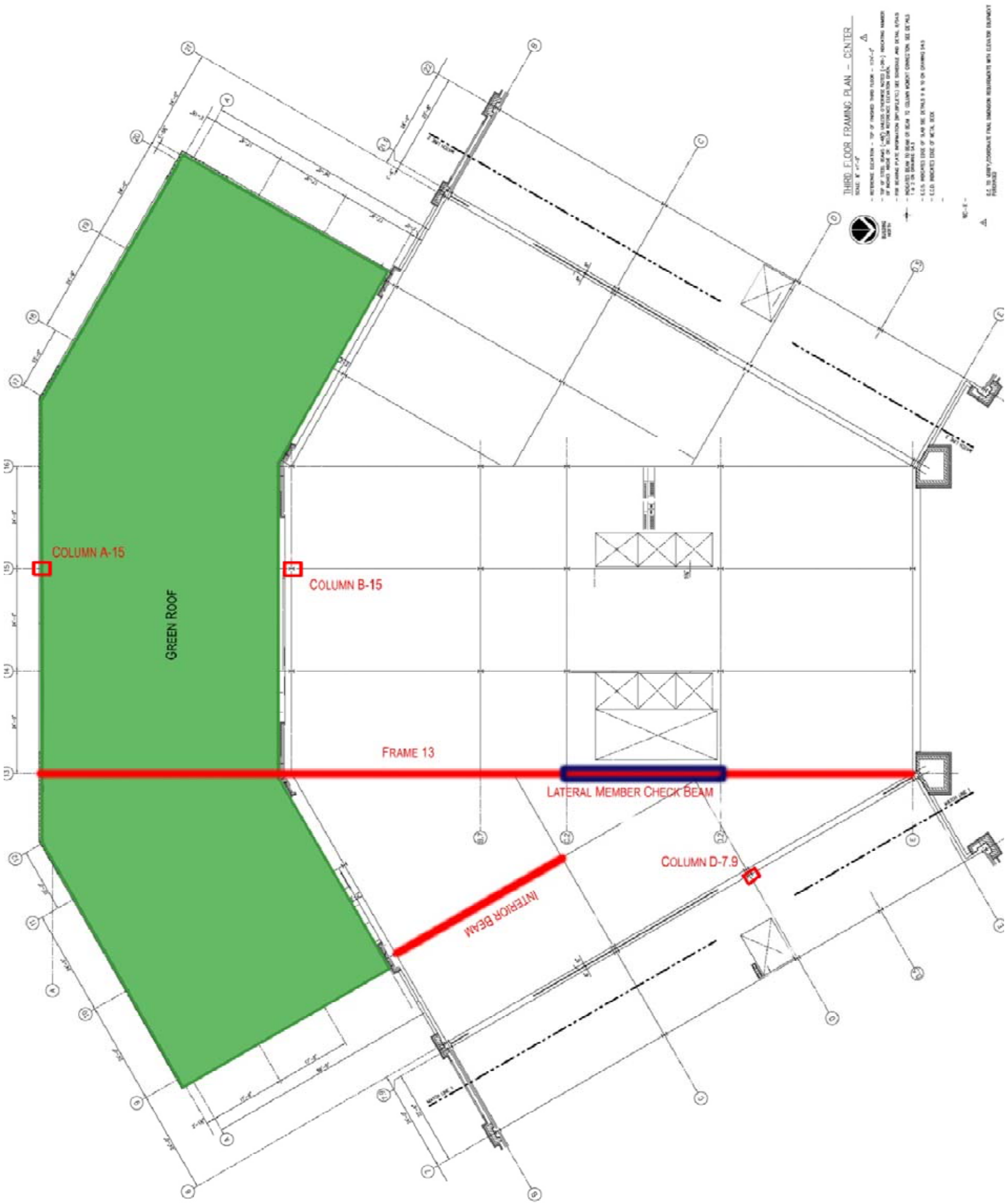


Figure 3: Third Floor Plan Center

Second Floor Plan Center of as-built design with frames indicated

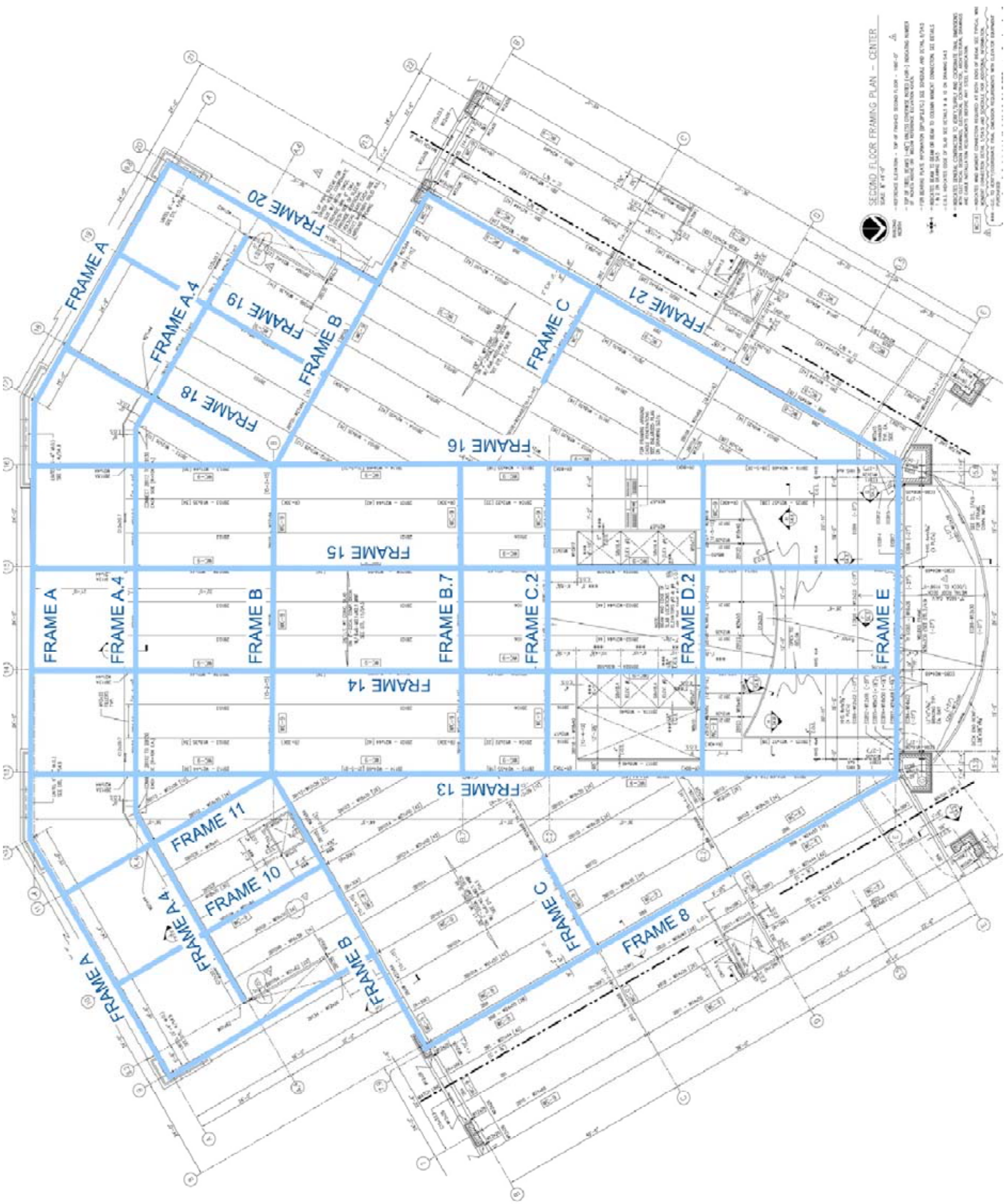


Figure 4: Second Floor Plan Center As-Built

EXISTING STRUCTURAL SYSTEMS

FOUNDATIONS

Sixty-one caissons are the main elements in the foundation system. Each was designed to carry 8,000 psf. The caissons range from 36" to 84" in diameter and from 8'-0" to 30'-8" in height. On top of each caisson, there is a 2'-6" cap with #6 @8" each way on the top and the bottom as well as base plates for the columns. The 5" slab on grade in the basement bears directly on the soil and the thickened slabs under the non-load bearing walls. On the south side and the east portion of the building, where caissons are not present, there are spread footings or grade beams. The sub-grade walls in the basement (referred to as grade beams in the drawings) range from 1'-4" to 1'-8" wide and are 14'-4" deep. The bottom reinforcement in the grade beams is mainly (3) #6, but varies from #6 to #9 and in number. Top reinforcement also varies from #6 to #9 and from two bars to four bars. All end reinforcing bars are #6, but vary from two bars to four bars.

FLOOR AND ROOF SYSTEM

The floor system for the corporate headquarters main building consists of 2" 22 gage metal deck with 2 ½" lightweight concrete topping, for a total slab depth of 4 ½". The typical bay size of this composite steel system is 24'-0" by 45'-0". W21 beams (W21x44 typ.) spaced 24'-0" on center and W18x35 beams spaced 8'-0" on center support the deck and transfer the load to the W24 girders (W24x55 typ.). The girders then continue to transfer the load to the columns. The 5" thick slab-on-grade in the basement of the headquarters is the exception to the typical floors. The roof uses a different system consisting of 1 ½" 20 gage roof deck, steel beams and steel K series joists. However, the penthouse system uses 2" 20 gage metal deck with a 2 ½" lightweight concrete topping. Where the penthouse is absent, roof uses a fully adhered EPDM roofing system including the membrane over ½" protection board over tapered insulation over 5/8" type X GWB over the roof decking.

LATERAL SYSTEM

The Westinghouse Corporate Headquarters Building One uses moment connections at every column to resist lateral loads from wind and seismic forces and torsion forces. Wind moment connections with angles and bolts are provided at all members in the lateral system of the building.

COLUMNS

The columns used in the headquarters are typical for a mid-rise building. The large columns in the basement and first floor of the building are W36x230 at the largest, but typically are W14x90. The W36x230 columns are larger because the entire front façade of the building is bearing on a W36x230 beam and the two columns. On the roof, any columns that do not continue up from the fifth floor are W10x49 or W10x33. The rest of the building is generally the same size, of course with some smaller sizes of columns, such as W10's on the fifth and roof levels. The base plates have four possible layouts and range in thickness from 1 ¾" to 3".

Problem Statement

Based on the analysis performed on the Westinghouse Electric Company Corporate Headquarters Building, it can be concluded that the original composite deck and beam system is well suited for time and space considerations. In depth calculations and comparisons can be seen in Technical Report 2. However, with wind moment connections at every column, the lateral system could be explored further for efficiency. The size of the typical bays is fairly large and leads to larger beam sizes to keep the deflection reasonable. A one-way reinforced cast-in-place concrete slab with beams would be the best way to approach the 2:1 bays.

The building owners have decided to make the new corporate headquarters a LEED certified building. A study on the feasibility of making the building Silver Rated instead would be desirable and beneficial to the project. With a building and campus so large, integrating the site into the building is a must.

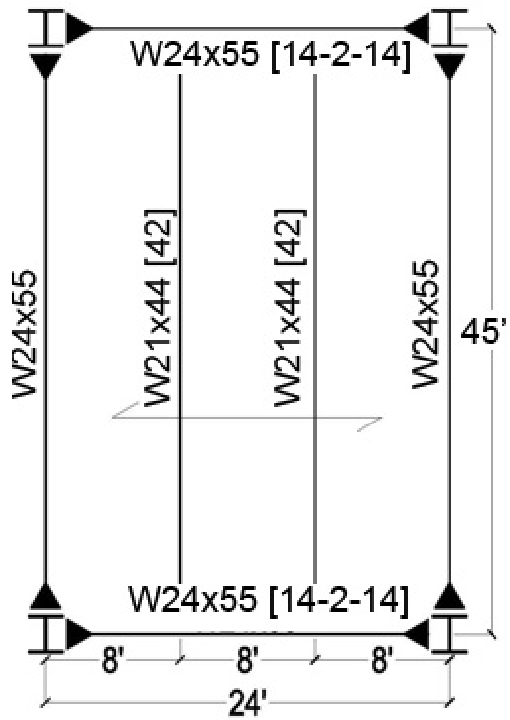


Figure 5: As-Built Typical Bay Framing

With so many changes in regard o the structure of the building, it would be beneficial to the project to perform a cost estimate for the new design and to generate a schedule. These were done in an effort to compare and evaluate the as-built design and the new redesign on a more even level.

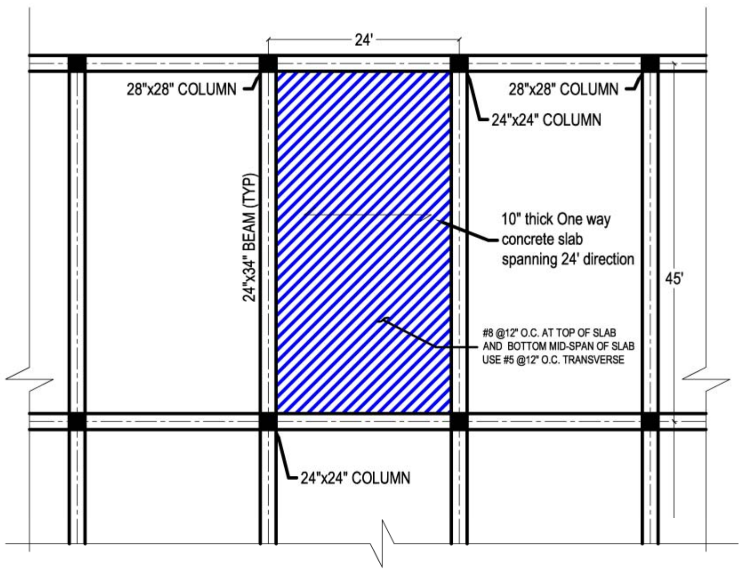


Figure 6: New Design Concrete Typical Framing

SOLUTION METHOD

The building will be redesigned for concrete with one-way reinforced concrete floors with beams. With the current column layout, the one-way slab has been shown to be more efficient than the two-way slab. Concrete moment resisting frames will be considered for the lateral system. Shear walls would have been an option, but without tenant fit-out drawings and a request for an open plan, they could not be the main system. In addition to changing the building to a concrete system, a green roof will be added to bring the building closer to the campus and its surroundings. Since the building is changed to concrete, the foundations will have to be re-examined and resized for the new loads. The building will be designed using a combination of hand calculations with ACI 318-08, IBC 2006, and a RAM model for verification of design. The project will be considered a success if it physically can be built and uses a design following all applicable codes. Also, it will be a success if the number of moment frames can be reduced.

In order to fully gauge which system is more effective overall, the steel and concrete buildings must be compared. Since the material is changing, there will be cost implications that need to be considered. Also, the difference in materials means there is a difference in erection time as well. To be able to make an assessment of the redesigned concrete system, a cost estimate and a schedule will be generated. The estimate will be compared to Turner Construction Company's budget for the building in steel, and the generated schedule will be compared to their actual schedule also. The building is currently under construction, but the structure was finished according to the schedule. Since the building owner wants it to be LEED certified, a LEED analysis of the new structure is required. A green roof was added to the building to integrate it into the surrounding land and to make the building unique as a corporate headquarters in Pittsburgh. The green roof also has structural implications which need to be addressed as well as cost and schedule impact. The potential plant inhabitants, waterproofing, and drainage system including pipes required to drain the water from the roof need to be evaluated. Achieving a LEED Silver Rating would be ideal, but ensuring the building still is capable of being rated would be acceptable. This portion of the project will be considered a success if a green roof can and is properly integrated into the building with proper drainage and detailing, and if a cost estimate can be calculated and a projected schedule can be generated. Ideally, the ultimate goal would be if the project could be completed faster or less expensively than the original steel building. However, the success of this project does not hinge entirely on obtaining the ideal goal.

CODE AND DESIGN REQUIREMENTS

These are the design standards, codes, and design criteria used by the design professional and in the calculations for this report.

APPLICABLE DESIGN STANDARDS

THE 2006 INTERNATIONAL BUILDING CODE

ACI 318-05 (REINFORCED CONCRETE DESIGN)

AISC STEEL CONSTRUCTION MANUAL, 13^{TH} EDITION

ACI 530 (MASONRY STRUCTURES)

ASCE 7-05 (MINIMUM DESIGN LOADS FOR BUILDINGS AND OTHER STRUCTURES)

DEFLECTION CRITERIA

FLOOR DEFLECTION CRITERIA

L/240 TOTAL LOAD

L/360 LIVE LOAD

L/600 CURTAIN WALL LOAD

LATERAL DEFLECTION CRITERIA

H/400 TOTAL ALLOWABLE WIND DRIFT

H/400 STORY WIND DRIFT

H/50 TOTAL ALLOWABLE SEISMIC DRIFT (Δ=0.02H_{SX} FROM TABLE 12.12-1 ASCE 7-05)

Materials

The materials used in the Westinghouse Electric Company Corporate Headquarters as listed on the general notes page of the structural drawing set are as follows and were used in design and analysis as appropriate.

Concrete

Freezing Temperature Exposure	Air entrained (6% ±1%)
Slab-on-grade	4,000 PSI
Slab-on-deck	4,000 PSI
Caissons	3,000 PSI
Footings and Caisson Caps	3,000 PSI
Walls and Piers	4,000 PSI
Over excavation fill	2,000 PSI

Reinforcing Steel

Reinforcing Bar	ASTM A-615
Welded Wire Fabric	ASTM A-185

Structural Steel

W-Shapes	ASTM A-992
C-Shapes	ASTM A-36
Steel Pipe	ASTM A-501
Tubes	ASTM A-500 Grade B

Metal Deck

Bolts	ASTM A-325, ¾" diameter
Deck	ASTM A611 Grade C or D
Studs	¾"x 3 ½" headed stud

Masonry

CMU	ASTM C-90
Concrete Brick	ASTM C-55 type N-1
Mortar	ASTM C-270
Grout	ASTM C-476

Gravity and Lateral Loads

The loads on the building are applied as such based on the design professional's specification on the drawings. It is understood the values for the original building are conservative since the live load of 80 PSF was used everywhere on the upper floors and a partition load is also used. The loading on the new redesigned concrete building is a 50 PSF live load and a 20 PSF partition load everywhere on the upper floors. Load combinations from IBC 2006 were taken into consideration and the highlighted combinations were used for the lateral analysis of the frames in the building.

- Loads for the Original Steel Building
  - Dead Loads

Concrete	115 PCF
Steel	490 PCF
Partitions	10 PSF
M.E.P.	5 PSF
Finishes	3 PSF

  - Live Loads

Public Areas	100 PSF
Lobbies	100 PSF
Corridors above 1st	80 PSF
Office	50 PSF
Mechanical	150 PSF
Stairs	100 PSF

- Differences in Loads for New Concrete Building
  - Dead Loads

Concrete	145 PCF

  - Live Loads

Partitions	20 PSF

From IBC 2006:
1605.2.1 Basic Load Combinations
(As applied to this Report)

1.4 D	Eq 16-1
1.2D + 1.6L	Eq 16-2
1.2D+1.0L	Eq 16-3
1.2D+0.8W	Eq 16-3
1.2D+1.0L+1.6W	Eq 16-4
1.2D+1.0E+1.0L	Eq 16-5
0.9D+1.6W	Eq 16-6
0.9D+1.0E	Eq 16-7

WIND DESIGN

Wind loads were determined using Section 6.5 of ASCE 7-05. The building was analyzed using a Main Wind Force Resisting System. Typically, wind would be the controlling design factor for a building in Pennsylvania, and wind was for the original building. However, once the building was redesigned in concrete, the increase in weight was enough to cause the seismic load to control the lateral system. All the coefficients were determined, and the windward and leeward pressures were determined according to ASCE 7-05. A RAM Structural System analysis was performed to confirm the validity of the hand calculations. The RAM values are comparable to the hand checks, but are slightly different. This may be due to a computer program's ability to quickly perform a finite element analysis. More in depth calculations can be seen in Appendix C of the report.

Table 1: Wind Design Properties

Basic Wind Speed (V) mph	90
Exposure Category	B
Importance Factor (I)	1
Wind Directionality Factor (Kd)	0.85
Topographic Factor (Kzt)	1

Table 2: Wind Pressure with Respect to Height

Floor Heights	Level	Total Height	K_Z	q_Z	Wind Pressures (psf)					
					N-S Windward	N-S Leeward	N-S Side Wall	E-W Windward	E-W Leeward	E-W Sidewall
18	Penthouse	92.5	0.9675	14.354	11.54	-8.21	-10.43	12.20	-4.91	-10.49
14.5	Roof	74.5	0.908	13.471	10.99	-8.21	-10.43	11.61	-4.91	-10.49
14	5	60	0.85	12.611	10.46	-8.21	-10.43	11.43	-4.91	-10.49
14	4	46	0.79	11.720	9.91	-8.21	-10.43	11.04	-4.91	-10.49
14	3	32	0.712	10.563	9.20	-8.21	-10.43	10.65	-4.91	-10.49
18	2	18	0.59	8.902	7.90	-8.21	-10.43	10.45	-4.91	-10.49

Table 3: Wind Story Forces, Shears, and Moments

Level	Wind Design					
	Load (kips)		Shear (kips)		Moment (ft-k)	
	N-S	E-W	N-S	E-W	N-S	E-W
Pent	193.4	38.8	0	0	3481.3	698.2
Roof	151.5	30.2	193.4	38.8	2196.7	437.6
5	144.8	29.3	344.9	69.0	2026.7	410.7
4	138.0	28.1	489.7	98.3	1932.5	393.8
3	132.6	27.4	627.7	126.4	1856.3	384.1
2	140.2	31.0	760.3	153.9	2523.7	557.2
Total	900.5	184.8	900.5	184.8	10535.9	2183.4

Note: Total Base Shear includes load from Windward and Leeward pressures

The wind story forces are summarized in these pictures of each side of the building. The story forces are on the left and the story shears are on the right side of the pictures.

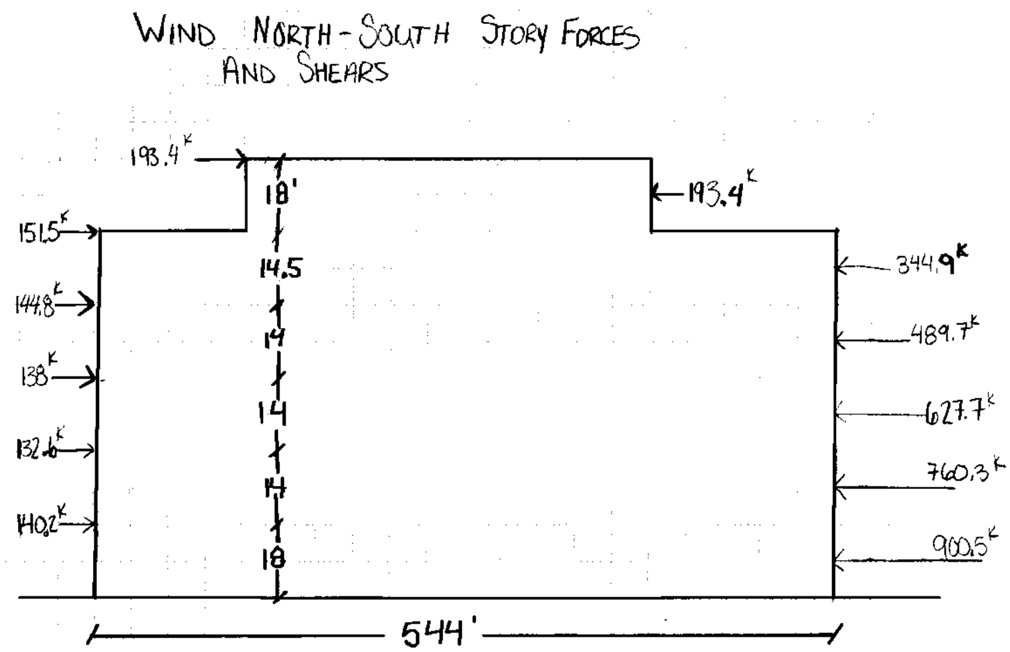


Figure 7: Wind North-South Story Force and Shear Diagram

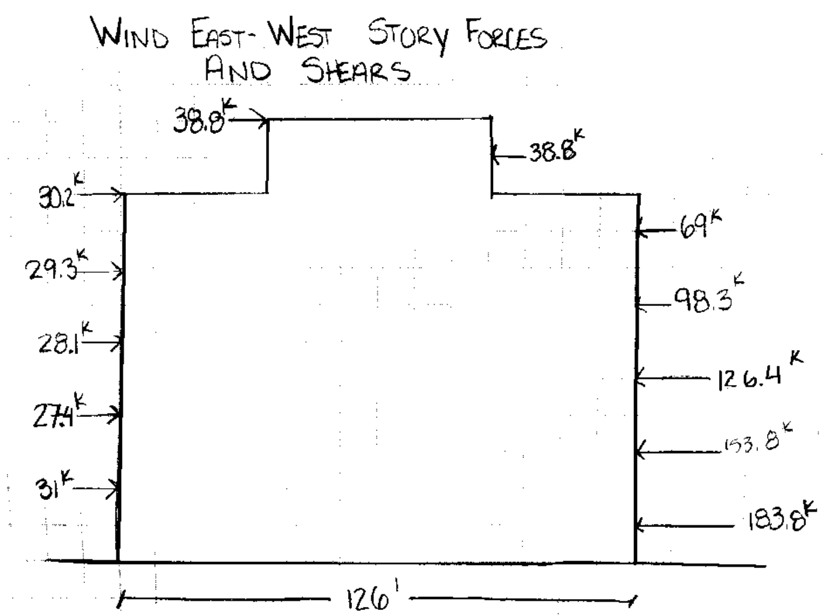


Figure 8: Wind East-West Story Force and Shear Diagram

These values are not extraordinary. The RAM checked values are different from the calculated ones from the point where q_z values come into the picture. They may be different because RAM actually calculated the values using finite element analysis instead of using Table 6-3 in ASCE 7-05.

Table 4: Hand calculation and RAM values Comparison by Height

From Table 6-3

H (ft)	K_z	q_z
92.5	0.9675	14.354
74.5	0.908	13.471
60	0.85	12.611
46	0.79	11.720
32	0.712	10.563
18	0.59	8.902
0	0.57	8.456

From RAM

H (ft)	K_z	q_z
92.5	0.966	14.331
74.5	0.909	13.486
60	0.854	12.670
46	0.792	11.750
32	0.714	10.593
18	0.605	8.976
0	0.575	8.531

Since the wind pressures do not start with the same value, they cannot be expected to be equal at any point. However the values are similar to each other, confirming the accuracy of the hand calculated values.

Seismic Design and Analysis

Typically in Pennsylvania, wind controls the design of the building's lateral system. As previously stated, this is not the case for this particular redesigned concrete building. The weight of the concrete makes the building heavy enough to cause the seismic loads to increase dramatically. The seismic loads were calculated according to ASCE 7-05, Chapters 11 and 12. The loads were determined based on a response modification factor of 3. The structure fits into the "Concrete Moment-Resisting Frame" category of ASCE 7-05's Table 12.8-2 and the C_T and X values for the period calculations were found according to those values. Further calculations can be seen in Appendix D.

Table 5: Seismic Design Values and ASCE 7-05 References

Seismic Design Values, ASCE 7-05		
Occupancy	II	Table 1-1
Importance Factor	I= 1	Table 11.5-1
Site Class	D	Table 20.3-1
Spectral Response Acceleration, short	S_S= 0.12	Figure 22-1
Spectral Response Acceleration, 1 sec	S_1= 0.046	Figure 22-2
Site Coefficient F_a	F_a= 1.6	Table 11.4-1
Site Coefficient F_V	F_V= 2.4	Table 11.4-2
MCE Spectral Response Acceleration, short	S_{MS}= 0.192	Eq. 11.4-1
MCE Spectral Response Acceleration, 1 sec	S_{M1}= 0.1104	Eq. 11.4-2
Design Spectral Acceleration, short	S_{DS}= 0.128	Eq. 11.4-3
Design Spectral Acceleration, 1 sec	S_{D1}= 0.0736	Eq. 11.4-4
Seismic Design Category	B	Table 11.6-1

Table 6: Seismic Design Values and ASCE 7-05 References

Seismic Design Values, ASCE 7-05		
Response Modification Coefficient	R= 3	Table 12.2-1
Coefficient	C_U= 1.7	Table 12.8-1
Fundamental Period	T= 1.600	Sec. 12.8.2
Seismic Response Coefficient	C_S= 0.015	Eq. 12.8-3
Building Height (above grade)	h= 92.5	

The weight of the building in concrete is over three and a half times as much as the weight of the original building in steel. The values in concrete are not even comparable to steel. The concrete loads are significantly larger, in every category. The values were checked in RAM and found to be similar. The different response modification coefficients yield different story forces, story shears, and moments as seen on the next page.

Table 7: Story Shears, Forces, and Moments for R=3.0 in concrete new design

Floor	w_x (k)	h_x (ft)	h_x^k (ft)	$w_x h_x^k$	C_{vx}	Story Force F_x (k)	Story Shear V_x (k)	Moment at Floor (ft-k)
Penthouse	6481.1	92.5	1115.41	7229044	0.179	293.33	0	27133.348
Roof	18245.1	74.5	797.56	14551503	0.361	590.46	293.33	43989.083
5	14162.0	60	570.24	8075727	0.200	327.69	883.79	19661.364
4	13922.9	46	377.75	5259370	0.130	213.41	1211.48	9816.8534
3	16960.3	32	215.24	3650482	0.091	148.13	1424.89	4740.0283
2	17785.3	18	88.23	1569200	0.039	63.67	1573.02	1146.1239
1	19178.2						1636.69	
Sum	106734.9	92.5	3164.42	40335326	1.000	1636.69	1636.69	106486.8

Table 8: Story shears, Forces, and Moments for R=3.0 in steel as-built design

Floor	w_x (k)	h_x (ft)	h_x^k (ft)	$w_x h_x^k$	C_{vx}	Story Force F_x (k)	Story Shear V_x (k)	Moment at Floor (ft-k)
Penthouse	4213	92.5	884.38	3725874	0.330	154.13	0	14256.981
Roof	4240.5	74.5	639.41	2711449	0.240	112.17	154.13	8356.3249
5	4713.6	60	462.27	2178985	0.193	90.14	266.29	5408.3285
4	4726.5	46	310.43	1467216	0.130	60.69	356.43	2791.9616
3	4724.0	32	180.20	851252	0.075	35.21	417.13	1126.8496
2	4653.4	18	76.08	354028	0.031	14.65	452.34	263.61354
1	5444.4						466.99	
Sum	28502.4	74.5	1668.39	11288804	1.000	312.86	466.99	17947.078

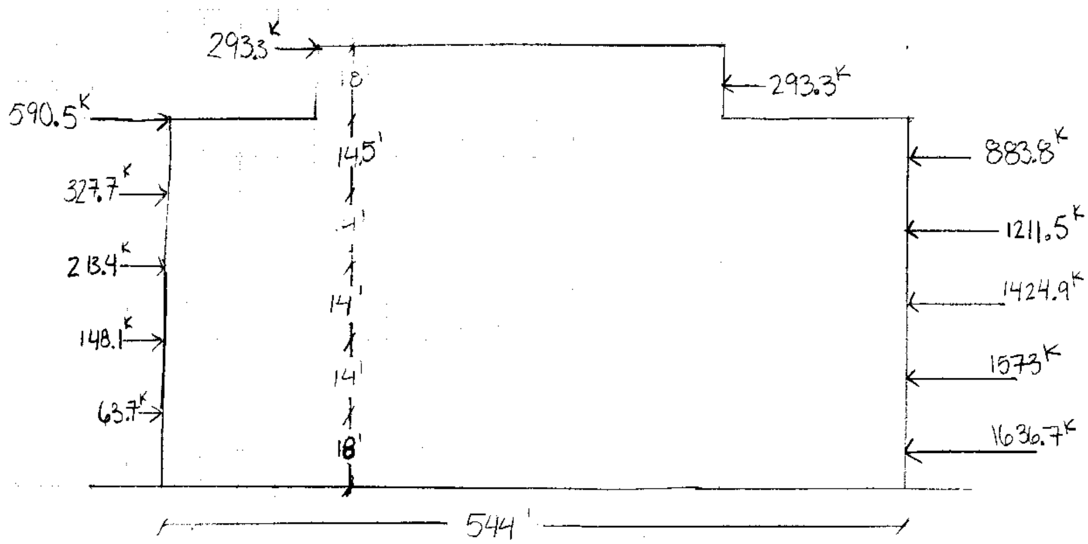


Figure 9: Seismic Forces and Story Shears

MEMBER DESIGN

To determine the members to be used in the RAM Structural System model, hand calculations were performed. The loading used for the building was 70 PSF live load (50 PSF office and 20 PSF partition load) everywhere. An 80 PSF corridor live load could also have been used, but would have been excessive since corridors do not exist everywhere on the floor.

The one-way concrete slab was designed for the 45'x24' bay. Since after the beams are removed from the length, it is a 45'x22' bay, the $L_1>2L_2$ requirement is met for a one-way slab. The slab was determined to be 10" thick with #8 @ 12" O.C. in the top of the slab and also in the bottom at mid-span of the slab. The 10" thickness was determined based on the ACI 318 deflection criteria table and was designed by hand and checked in RAM. The minimum transverse reinforcement for shrinkage and temperature is #5@12" O.C. This design is also appropriate for both green roof areas. The calculation can be viewed in Appendix E. Even though the deflection table was used, the deflections were also checked by hand and found to be within the allowable limits of L/360 for live load and L/240 for total loading. Since the new system used is a one-way slab with beams, there is no punching shear requirement for the slab.

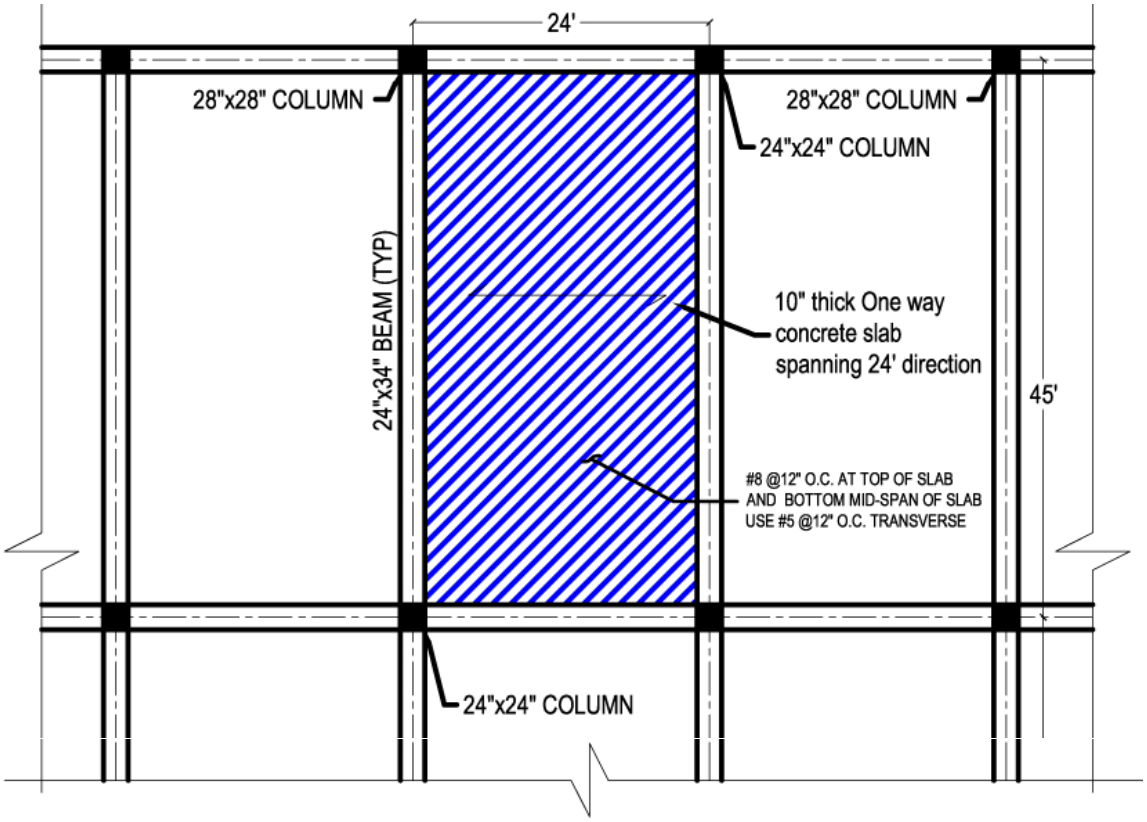


Figure 10: Redesigned Concrete Layout

After the preliminary design was done, the RAM model was built using RAM structural System and the Concrete module of the program. The lateral system was determined to be concrete moment resisting frames and spaced according to the picture below. The blue members are the gravity members and take no lateral forces. They are spaced every other frame on the plan.

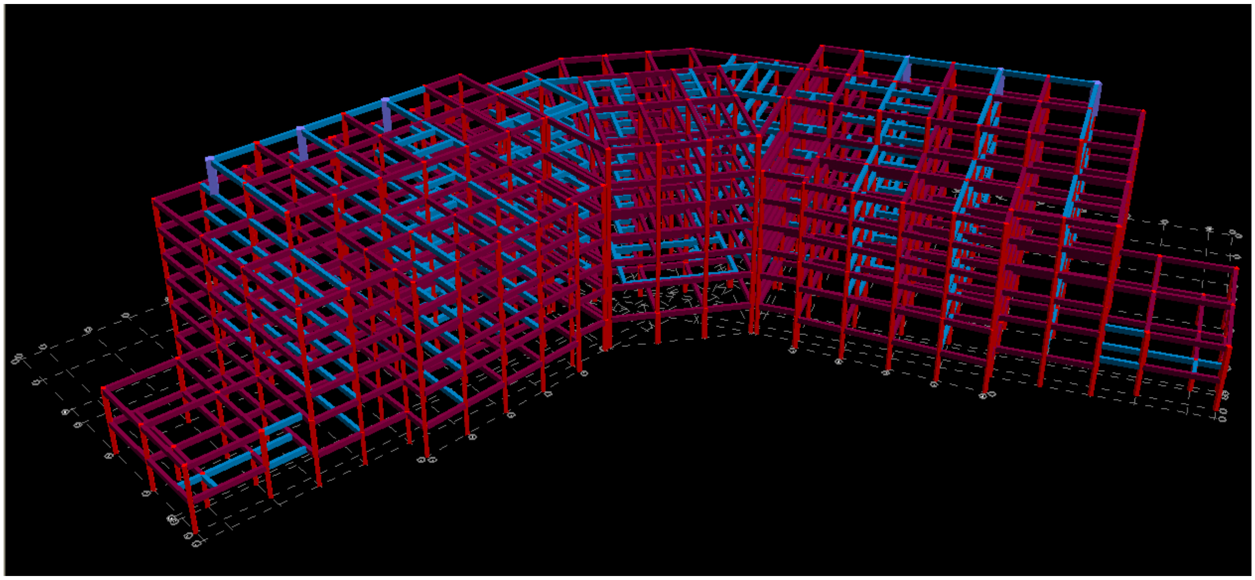


Figure 11: Whole building framing

The beams sizes were calculated also for a 45' length and a 24' distribution along the entire length of the beam. The slab weight was taken into account as well as the weight of the beam. The beams are 24"x34" and for the particular one designed two rows of (6) #8 bars were sufficient. Shear reinforcement for the interior beam was also designed and found to need (3) #3 stirrups @5" at the ends of the beam and another section of the beam was found to require (3) #3 stirrups @12". The calculation can be seen in Appendix E of this report.

The beam design was checked in RAM and the beams were updated as necessary. The green indicates the members were ok as originally designed and needed by RAM no updating to make the members meet code. The blue members needed updating of beam size, rebar size and or placement, or stirrup placement in order to meet all the code requirements. Any red members would indicate a failure to meet one of the code requirements. As seen in the picture below, all beams meet the code requirements.

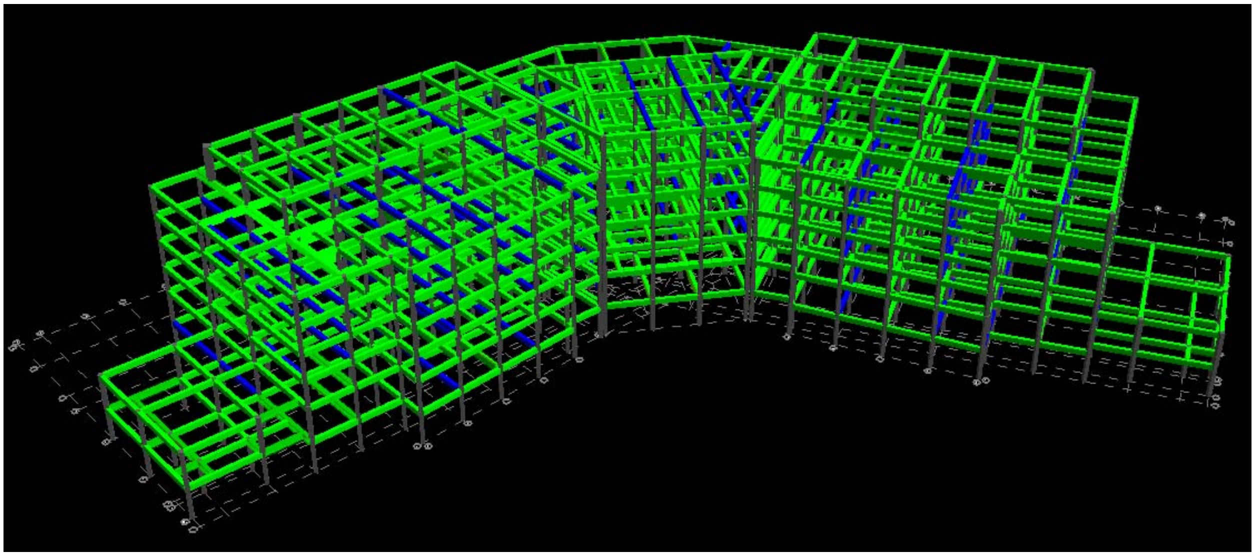


Figure 12: Beam Framing for Whole Building

The columns were originally designed in PCA column for a few members. Once placed in RAM, they were evaluated for strength, slenderness, and torsion. The columns were also updated as required. The different colors represent the percent strength required vs. the available strength of the member. The closer to the color red the column is, the higher the ratio. Blue is the lowest ratio color. As is visible, all the columns also meet the code requirements after updating. Some needed to be resized, the rebar changed, and or the transverse reinforcing altered. The columns were also spot checked after design with PCA column and the loads taken from RAM. The typical column size is 24"x24" but there is also a significant number of 28"x28" columns, mainly in the lateral system. Most of the rebar layouts have 12 bars in them, but a few have 16 bars. The typical rebar size is #10's. The PCA spot checks for select columns can be seen in Appendix E.

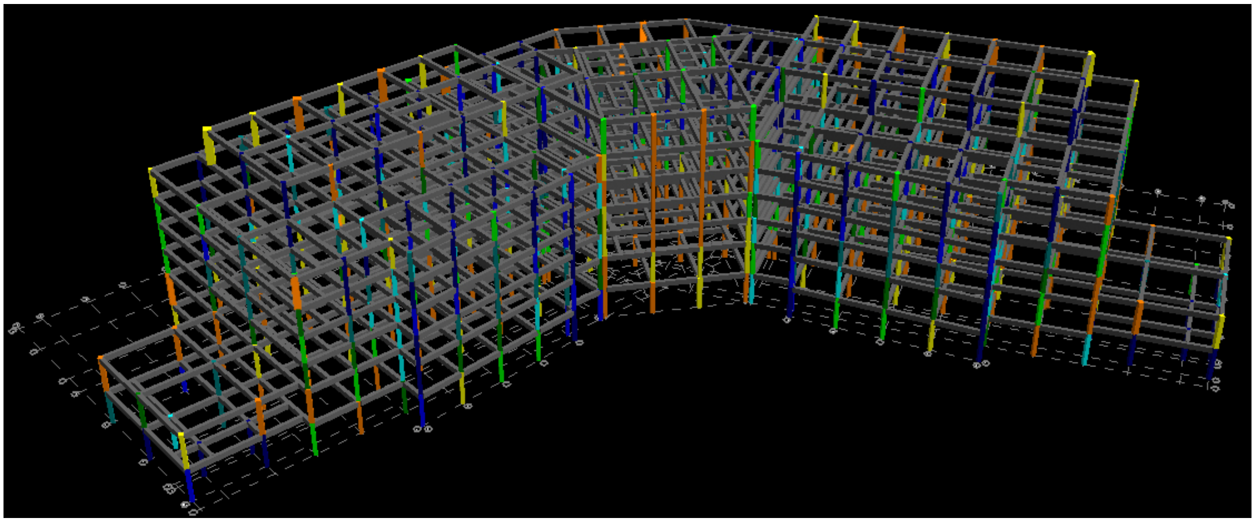


Figure 13: Column Framing for Whole Building

The lateral system is more clearly shown here with the third floor plan. The blue frames are gravity only and the red are lateral members.

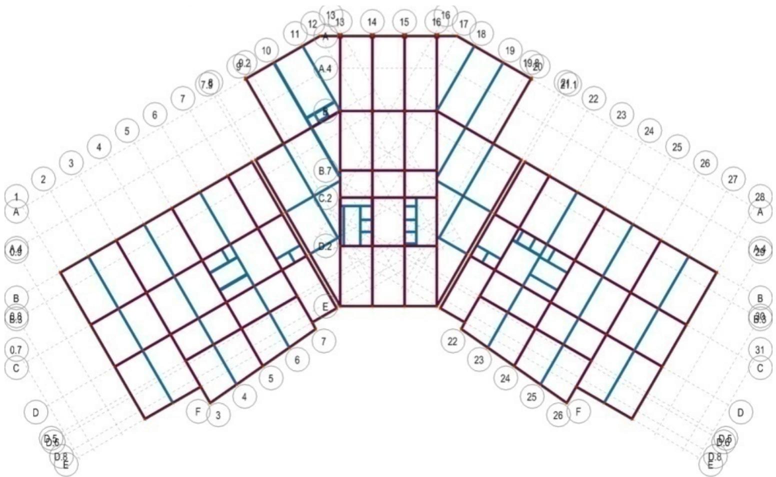


Figure 14: Whole building plan

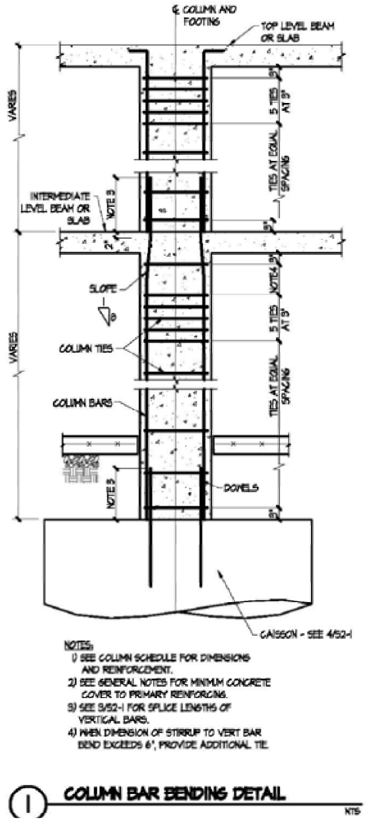


Figure 15: CMRF detail

Concrete moment resisting frames are the main lateral system. A typical detail can be seen on the right. CMRF's are more in the concept phase now. They work by assuming a concrete frame is forced to work a certain way. The rebar proceeds through the slab at an angle and continues up into the above column. The rest of the reinforcing remains the same as is designed for gravity and lateral loading. Because the rebar extends through the slab, it is possible to transfer the moment through the frames easier than in typical concrete columns.

Foundation Impact Of New Structure

The redesigned building is much heavier than the as-built steel structure. Since the original spread footings and deep foundation caissons were designed for a lighter dead load, they must be resized and updated. The difference was taken into account in the schedule and cost. A sample of the spread footings and caissons were taken and the original capacity was determined. For the spread footings, a simple Capacity= Area/ Soil Bearing Pressure calculation was performed. The bearing pressure is 8000 PSF for the site in Pittsburgh, according to the current drawings and foundation notes. The required force was determined by comparing all possible combinations and taking the most critical. The area of the spread footing foundation was calculated by using the same equation, with a slight alteration, Area= Capacity/Bearing Pressure. The required height of the new spread footing involved checking punching shear and overturning moment.

The three equations used to check punching shear are:

$$V_C \leq \begin{cases} \phi(2+4\beta_C)\sqrt{(f'c)}b_O d \\ \phi 4\sqrt{(f'c)}b_O d \\ \phi(\alpha_s d/b_o+2)\sqrt{(f'c)}b_o d \end{cases}$$

After punching shear was determined, the required height on the footing could be calculated using

$$d^2\ (4V_C+q) + (2V_C+q)\ w = q\ (BL-w^2)$$

The caisson calculation was more difficult. The depth was kept the same for both the old and new caissons. This calculation consisted of finding the axial capacity of the caisson (uplift was considered, but is resisted based on 0.9*Building Weight). The calculation performed was taking the area of the caisson and multiplying it by the allowable rock bearing pressure (which in this case is 30 KSF) and then subtracting the weight of the caisson. The size for the caissons listed in the next table is the diameter.

$$\pi D/4*\text{Bearing}-\pi D/4*H*145= \text{Capacity}$$

The equation was entered into Excel to allow for ease of comparison of sizes and to allow for easier evaluation.

The new foundation sizes for the selected columns can be seen in the following table. The table was later used to determine the difference in the amount of concrete required for the foundations and to estimate the cost and labor required for the larger foundation system.

Table 9: Foundation size comparison

Size	Column	Type of Foundation	Size (ft)	Height (in)	Capacity (k)	Required (k)	Required Size	Required Height (in)	New Size (ft)	New Capacity (k)	Final Height (in)	RAM Size (ft)	RAM Height (in)
28	0.7-C	spread footing	5	18	200	384.844	6.936	18.273	7	392	22	8	24
24	1-B	spread footing	9.5	28	722	978.696	11.061	39.397	11.5	1058	44	11	36
24	1-C	spread footing	12	36	1152	1471.816	13.564	49.499	14	1568	54	13	42
24	1-D	spread footing	11	34	968	1606.032	14.169	51.518	14.5	1682	56	14	42
28	2-D	spread footing	12	36	1152	2179.108	16.504	56.044	17	2312	60	16	48
24	4-B	spread footing	10	32	800	1417.268	13.310	47.480	13.5	1458	52	13	42
30	1-E	caisson #48	5.5	146	712.749	957.832		146	7.00	1084.30	150		
28	6-B	spread footing	10	32	800	1454.464	13.484	42.858	13.5	1458	48	13	36
24	7.9-C	spread footing	13	40	1352	1342.364	12.954	45.460	13	1352	50	12	36
28	8-B	spread footing	11	34	968	922.328	10.737	33.426	11	968	38	11	30
24	8-C	spread footing	13	40	1352	1330.536	12.896	45.460	13	1352	50	12	36
48	13-A	spread footing	8	32	512	570.728	8.446	14.111	9	648	18	9	24
24	14-A.4	spread footing	8	32	512	418.416	7.232	25.211	8	512	30	7	18
24	15-B.7	spread footing	12	36	1152	1782.08	14.925	53.536	15	1800	58	14	48
28	16-E	caisson #53	4	306	376.991	1316.164		306	8.25	1399.22	310		

TORSION

Torsion must be accounted for in lateral systems due to the possibility for twisting and portions of the building being loaded in a non-uniform manner. The expansions joints allow the building to be treated structurally as three separate buildings based on the locations of the joints. To find the torsion, relative stiffness needs to be taken into account. Relative stiffness is a measure of stiffness as compared to other members in the frame. These relative stiffness values for each frame are distributed throughout the building by frames using distribution factors. The distribution factors are calculated by finding the total value of the stiffness for all the frames in a particular direction, and then finding what percent of the total each frame makes up. The stiffness is used as a basis to distribute the lateral loading through the building frames. Once both are found, the lateral loads can be distributed throughout the building. The center of mass of each section is shown in red on the following picture.

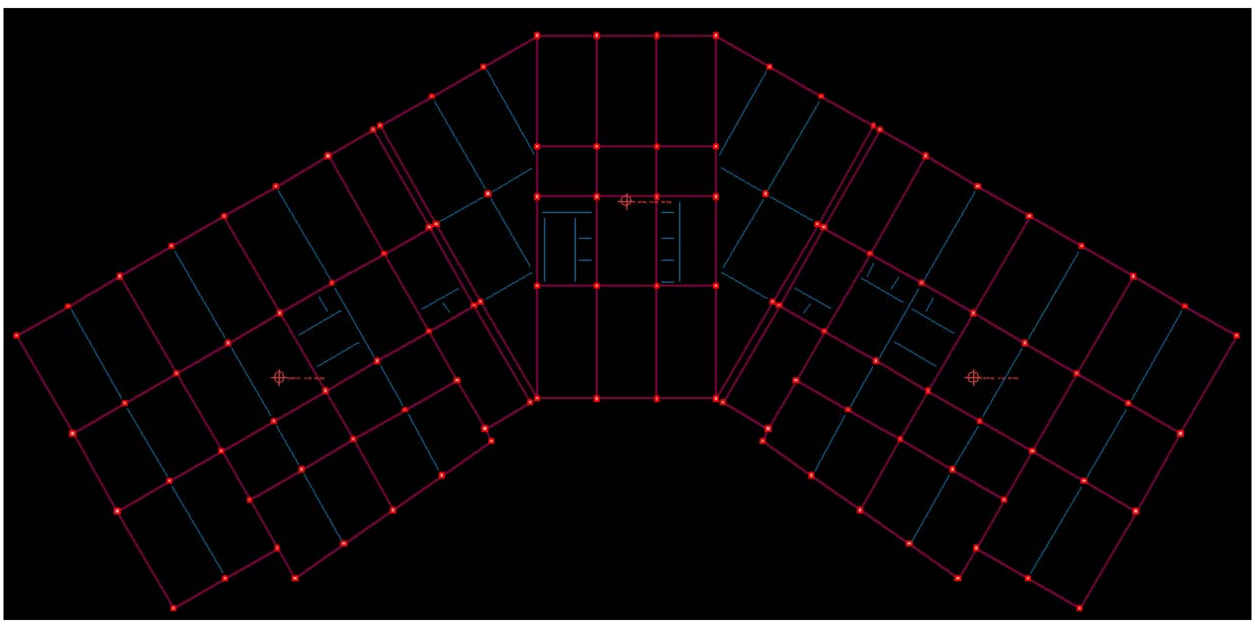


Figure 16: Center of Mass of concrete new design

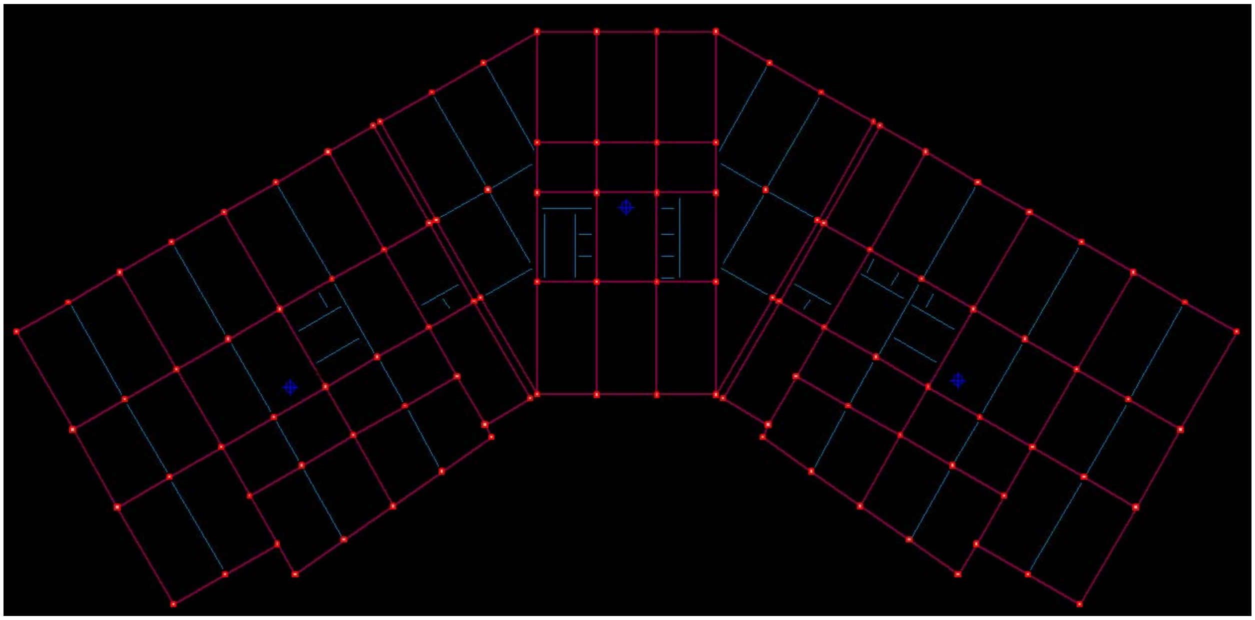


Figure 17: Centers of Rigidity of new concrete design

Torsion was not an issue with the redesigned building in concrete. However, the concepts were taken into consideration accordingly. The RAM model checked for extra torsional requirements of the lateral members and found the concrete and the stirrups were enough to resist the accidental torsion= 5% and inherent torsional loading. The lateral members clearly incurred more torsion that the gravity members in the same direction. The story shears of the lateral system frames are higher than those of the gravity system frames, as they should be. Also, frames further away from the centers of rigidity and mass are more susceptible to torsion, and as such, have higher story shears, which are reflected in the RAM output in Appendix B.

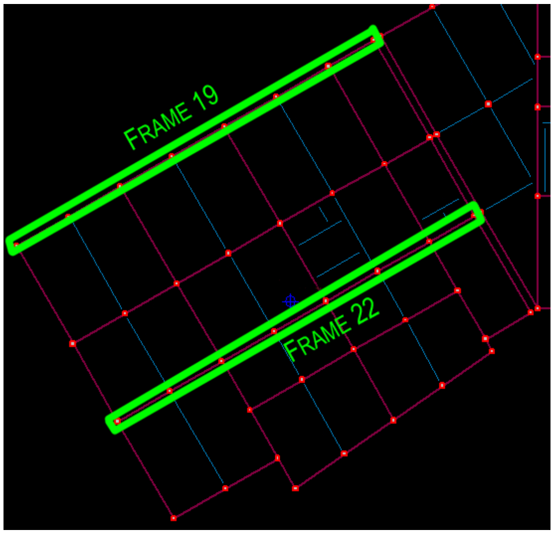


Figure 18: Center of Rigidity and Frames for Comparison

PORTAL METHOD

A portal method analysis was performed to find the moments and shear forces in the members of two frames (one from each the East-Frame 2 and Center- Frame 13 portions). This analysis was performed using the controlling seismic force on the individual frame as determined through the analysis and a RAM confirmation.

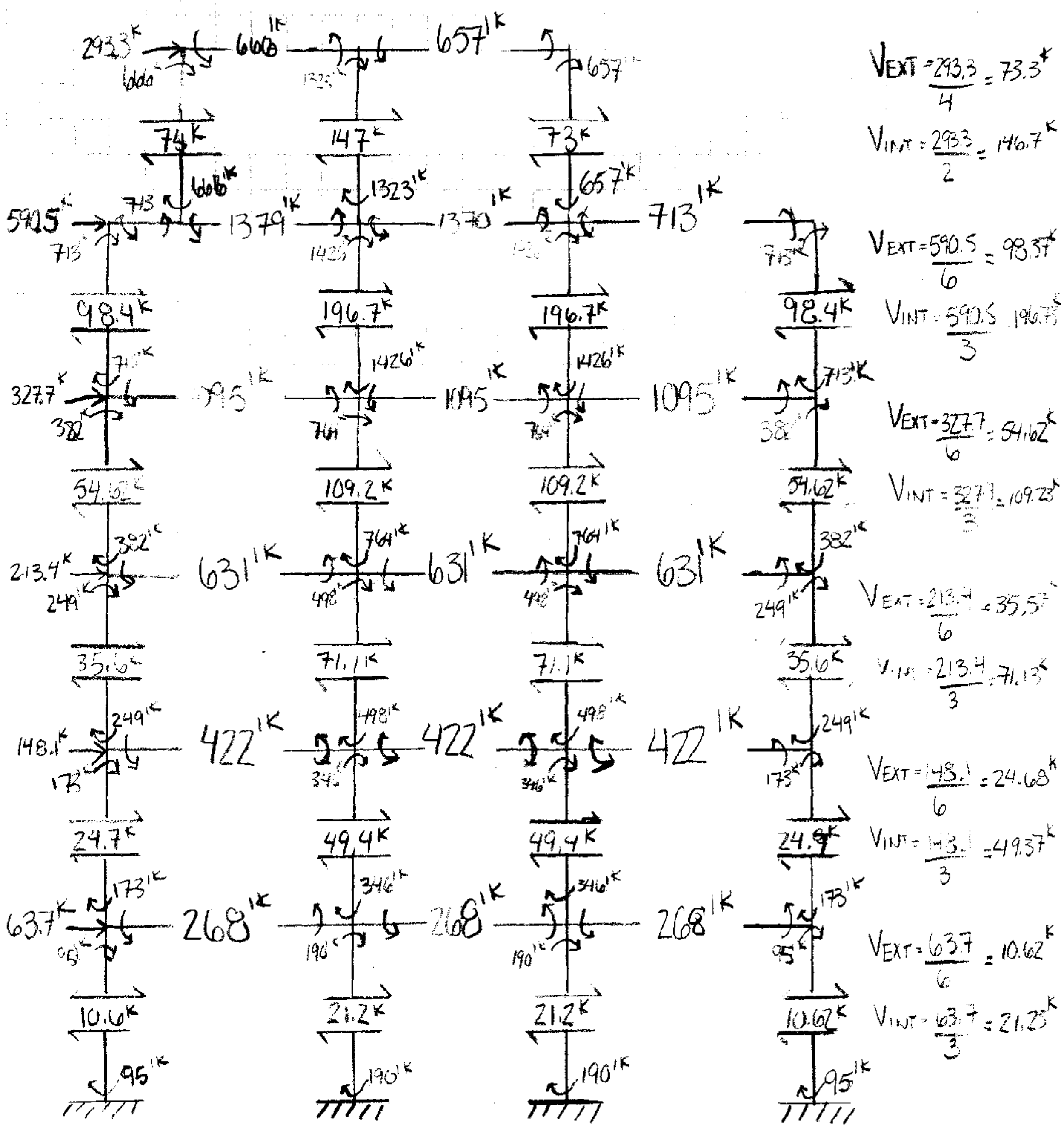


Figure 19: Portal Analysis of Frame 2 East Building with Seismic Loads Applied

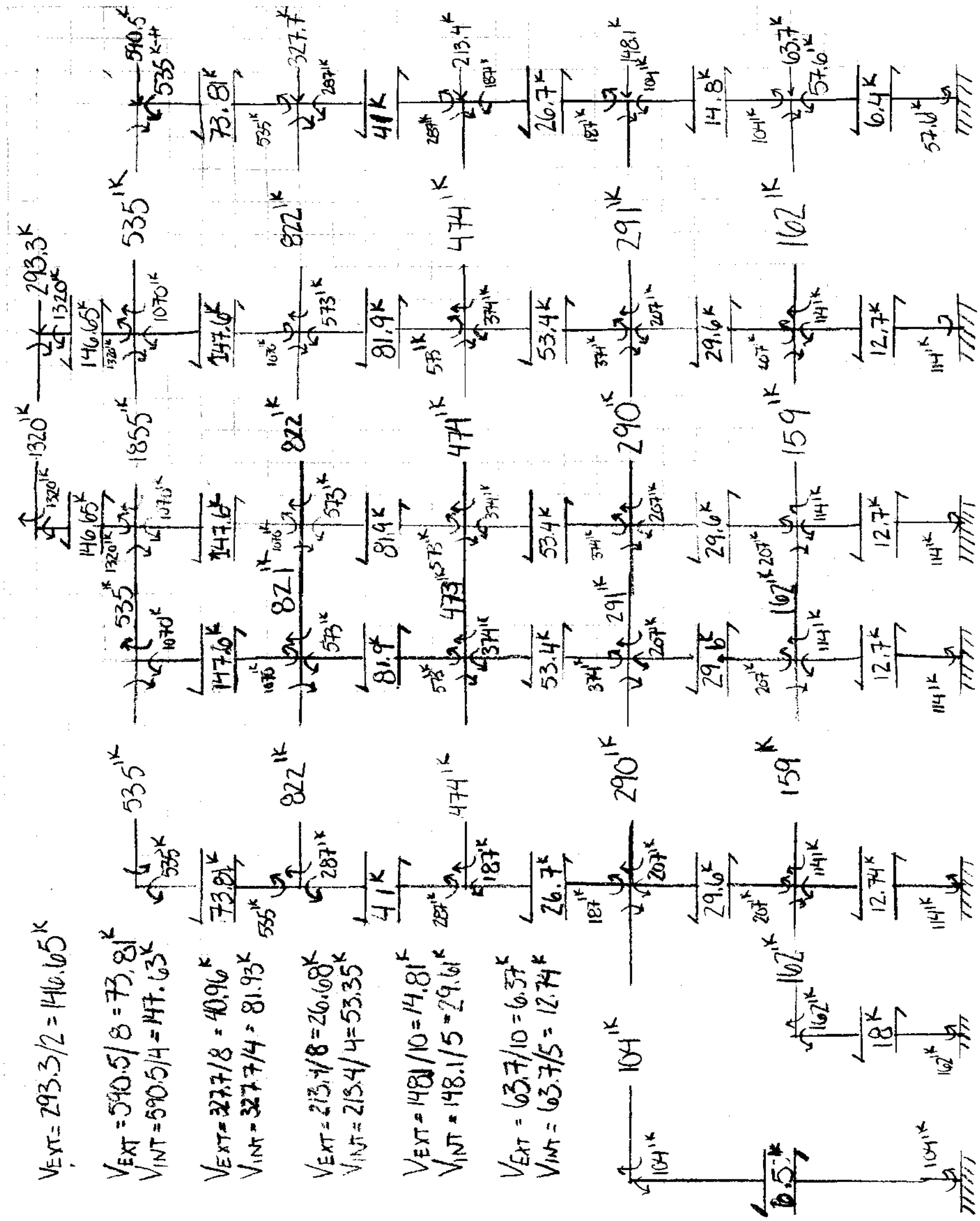


Figure 20: Portal Analysis of Frame 13 in the Center Building with Seismic Loads Applied

MEMBER CHECKS

For the new design of the building, before sizes could be checked in RAM Structural system, preliminary sizes needed to be determined. The preliminary beam checks can be seen in Appendix E. A live load of 70 PSF (50 PSF office loading and 20 PSF partition load) was used to determine the sizes. A live load of 80 could have been used, but the load of 80 PSF is for a corridor, and although there are no tenant fit-out drawings, there will not be corridors everywhere in an office building and it is acceptable to use the current loading. The preliminary design indicated the initial sizes of beams and columns for the building model. Once the sizes were assigned in the RAM Concrete design module, a full analysis was performed to check for the feasibility of all the members in the building and the lateral system's integrity. After the building gravity and lateral loads were determined by hand, they were then checked by RAM and their validity was confirmed. The columns were checked by using PCA column and can also be seen in Appendix E. An example column check is shown on the next page. A lateral beam check was performed after the moments determined through the portal analysis were applied to a specific member. The lateral beam check confirmed the beam is adequate for all load combinations in ASCE 7-05. The lateral beam check can also be seen in the Member Design Appendix.

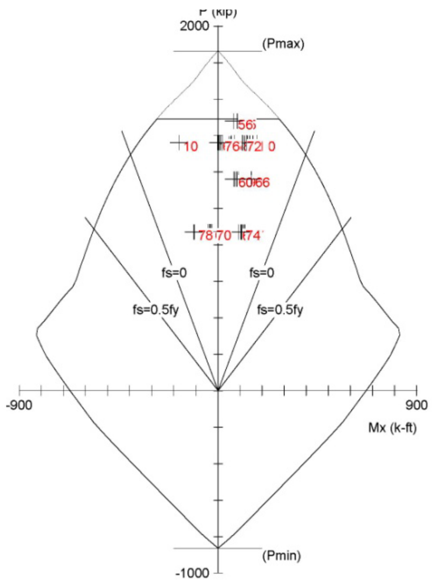


Figure 21: PCA Column Output of Column 5-C 3rd Floor

For the column check, column 5-C was chosen. This column is also on the third floor of the building. The seismic building response controls the design of the building in concrete.

DRIFT

ASCE 7-05 was used to determine the appropriate allowable drifts for wind and seismic effects. Due to drift involving serviceability rather than strength, ASCE 7-05 requires in section CC.1.2 the drift be less than H/400 on a wall or frame. The story drift was determined through RAM Analysis and checked against the ASCE 7-05 requirements. The wind was checked for all three portions of the building for each controlling load combination. The maximum story drift for each of the three portions was checked against the allowable drift according to ASCE 7-05 and the worst case scenario drift is seen below and is compared to the original steel building drift.

Table 10: Wind Drift of Concrete Redesign

Controlling Wind										
Story	Story height (ft)	Story Drift (in)	Allowable Story Drift (in) Δ_{Wind}= H/400			Total Drift (in)	Allowable Total Drift (in) Δ_{Wind}=H/400		
Penthouse	92.5	0.045	<	0.54	Acceptable	0.38814	<	2.775	Acceptable
Roof	74.5	0.033	<	0.435	Acceptable	0.34359	<	2.235	Acceptable
5	60.0	0.050	<	0.42	Acceptable	0.31057	<	1.8	Acceptable
4	46.0	0.068	<	0.42	Acceptable	0.2606	<	1.38	Acceptable
3	32.0	0.088	<	0.42	Acceptable	0.19286	<	0.96	Acceptable
2	18.0	0.105	<	0.54	Acceptable	0.10536	<	0.54	Acceptable

Table 11: Wind Drift of Original Steel Design

Controlling Wind									
Story	Story height (ft)	Story Drift (in)	Allowable Story Drift (in) Δ_{Wind}= H/400			Total Drift (in)	Allowable Total Drift (in) Δ_{Wind}=H/400		
Roof	74.5	0.127	<	0.435	Acceptable	1.02425	<	2.235	Acceptable
5	60.0	0.187	<	0.42	Acceptable	0.89767	<	1.8	Acceptable
4	46.0	0.247	<	0.42	Acceptable	0.71044	<	1.38	Acceptable
3	32.0	0.257	<	0.42	Acceptable	0.46336	<	0.96	Acceptable
2	18.0	0.207	<	0.54	Acceptable	0.20662	<	0.54	Acceptable

For seismic drift, table 12.12-1 was used to find the maximum drift of $0.02h_{sx}$, since the structure falls into the "All other structures" category of the table. This was then converted into an elastic drift ratio using equation 12.8-15 as follows so the values could be compared to RAM output, which is available upon request.

$\delta_x = C_d * \delta_{xe} / I$

$0.02h_{sx} = (3*\delta_{xe})/1.0 =$ 0.06

drift ratio= $\delta_{xe}/h_{sx} = 0.02*1.0/3 =$ 0.0066667

Table 12: Seismic Drift of Concrete Redesign

Controlling Seismic				
Story	Story height (ft)	Acutal Drift Ratio	Allowable Total Drift Ratio δ_{xe}/h_{sx}=0.02*1.0/3	
Pent	92.5	0.0004	<	0.006667
Roof	74.5	0.0005	<	0.006667
5	60.0	0.0008	<	0.006667
4	46.0	0.0009	<	0.006667
3	32.0	0.001	<	0.006667
2	18.0	0.0009	<	0.006667

Table 13: Seismic Drift of Steel Design

Controlling Seismic				
Story	Story height (ft)	Acutal Drift Ratio	Allowable Total Drift Ratio δ_{xe}/h_{sx}=0.02*1.0/3	
Roof	74.5	0.0011	<	0.006667
5	60.0	0.0013	<	0.006667
4	46.0	0.0014	<	0.006667
3	32.0	0.0012	<	0.006667
2	18.0	0.0006	<	0.006667

Comparing the drift ratios for wind and seismic forces to the allowable drift, it can be concluded that drift is not an issue for either load. It can also reasonably be confirmed that the concrete structure is less susceptible to drift than the steel building.

Overturning Moment

Overturning moment is a design issue that needs to be taken into consideration for steel building, but in general concrete buildings resist the overturning moment purely by the weight of the building. The calculation below is just to show how little the overturning moment impacts the design for this concrete building.

M_{WN-S}= 1.6*Moment from Wind Design=	81566	k-ft
$M_E = \Sigma H(ft)$*Earthquake Design Load(k)=	106487	k-ft
P_{Uplift}=M/L=	647.3497	k
P_{DBldg}=	87557	kips
Load on Opposite Columns= $0.9P_D$=	78800.99	kips
$M_{Resisting}$= P*Trib Area=	4964462	k-ft

$M_{Resisting} > M_E > M_W$

Clearly the overturning moment is insignificant when compared to the weight of the building.

Depth Study Overview

The intent of this study was to practice concrete design and design a building capable of being built according to all applicable codes. Lateral analysis determined both the wind and seismic loads, and also determined the building to be seismically controlled as opposed to the original steel building being controlled by wind load. Lateral frames were eliminated from every frame, to every other frame, which is definitely a success in the design. Torsion was checked for this building, and found to be as expected. As also would be expected, the lateral members are a bit larger than the gravity only members, though not significantly. The addition of the green roof had some structural implications with the sizing of columns and beams supporting such a massive load, but did not cause any serious issues in the design.

Breadth Study 1- Construction Management Analysis

Cost Analysis

Before a final response to the proposed changes can be evaluated, cost and schedule implications must be considered. The building in concrete is completely structurally different from a steel building. A budget for the as-built building was obtained from Turner Construction Company and was compared to the redesigned concrete building cost. An estimate for the redesign was calculated using RSMeans and the new structure volume of concrete and weight of steel rebar. Cost estimates for the building structure with and without the green roofs were developed. It was necessary to develop a schedule and estimate without a green roof so it could be more accurately compared to the existing steel building, which does not have a green roof.

Table 14: Cost Estimate for Redesigned Building without Green Roofs

Detailed Cost Analysis of the Structure-No Green Roof									
Level	Description	Amount	Material Price	Material Cost	Labor Price	Labor Cost	Equipment Price	Equipment Cost	Total Cost
Reinforcement	Foundation	58 Ton	$935.00	$54,230	$430.00	$24,940	$30.35	$1,760	$80,930
	Columns	156Ton	$935.00	$147,263	$430.00	$430.00	$30.35	$4,780	$152,473
	Beam/Slabs	504 Ton	$935.00	$470,642	$430.00	$216,445	$30.35	$15,277	$702,363
	SUB-TOTAL	719	$935.00	$672,134	$430.00	$241,815	$30.35	$21,817	$935,766
Cast in Place Concrete	Foundations	6100 CY	$109.00	$664,900	$14.90	$90,890	$5.55	$33,855	$789,645
	Columns	1443 CY	$109.00	$157,189	$34.00	$49,031	$16.95	$24,444	$230,664
	Slabs	14192 CY	$109.00	$1,546,928	$18.20	$258,294	$9.15	$129,857	$1,935,079
	Beams	6477 CY	$109.00	$706,026	$26.50	$171,648	$1,320.00	$8,550,036	$9,427,710
	SUB-TOTAL	28211	$109.00	$3,075,043	$20.20	$569,864	$1,352	$8,738,191	$12,383,098
Location Factor: 98.9%	Total Structure Estimate:			$13,173,000			Total Labor Cost:	$812,000	
	Total Material Cost:			$3,748,000			Total Equipment Cost:	$8,761,000	

Table 15: Turner's Budgets

Turner Construction Company Budgets	
Deep foundations (caissons)	$215,000
Concrete (Spread ftgs, slabs)	$5,199,000
Structural Steel	$7,892,000
Total Structure	$13,306,000
Whole Building	$55,878,000

Turner's whole building budget was $55,878,000. Their entire structure budget was $13,306,000, which is approximately equal to the concrete redesign estimate. The cost per square foot for the as-built building is $30.90/SF while the new building in concrete is $30.60/SF. Some reasons for the cost of the building being so much greater for concrete than for the steel could be Turner's budget came directly from subcontractors and there was competition for the work or also that their estimates were real numbers and are therefore more accurate than an RSMeans estimate.

Schedule Analysis

A schedule analysis was also necessary to evaluate the two structures. Microsoft Project was used to generate a schedule for the redesigned concrete building. To develop the duration times of each slab, the building was split into columns. The beams were formed first, then the slab right after. The two were reinforced together, but the beams were placed before the slab. After the slab had accrued three-day strength, the columns on that floor were formed. The columns went through the same process with the beams above being formed after the columns had accrued the same three-day strength. Both structures were started on the same day, March 3, 2008. Turner's schedule has the concrete on the penthouse done being placed on October 10, 2008. The schedule produced for the redesigned concrete building estimates the penthouse slab finished on December 9, 2008. The entire schedule calendar can be seen in Appendix F. A Gantt chart is available upon request but was not included due to its length but a condensed Gantt chart is included. The condensed Gantt chart shows the first few tasks, and the method is repeated for each section on each floor throughout the building.

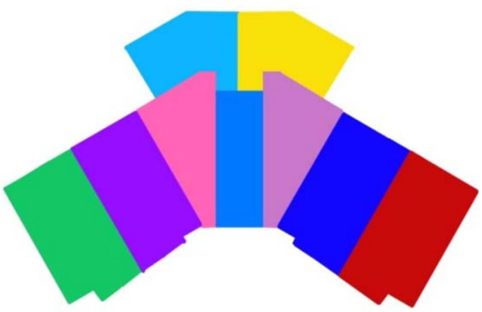


Figure 22: Sample Floor Plan Divided (3rd Floor)

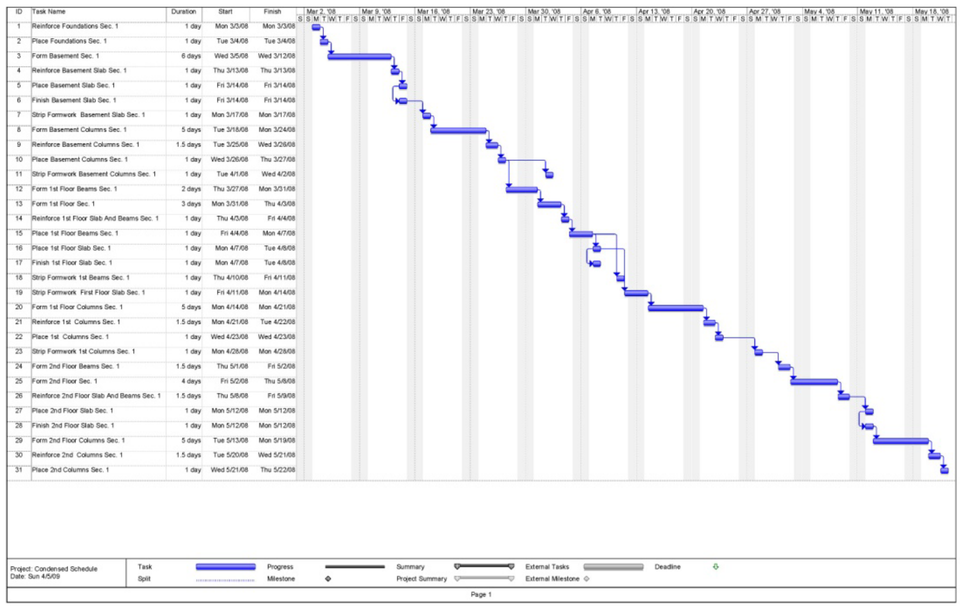


Figure 23: Condensed Gantt chart

Breadth Study 1 Overview

The goals for the construction management breadth study of calculating a cost estimate and generating a schedule were certainly met. Also, a cost estimate and schedule were generated and compared with the addition of the green roof and to Turner Construction Company's original estimate and schedule. It was determined that Turner Construction Company managed to erect the building much faster and cheaper in steel than the design would have been in concrete. Concrete generally does take longer to erect than steel due to the curing time and placing and stripping of the formwork. This breadth portion of the project was a success even though it was not the most efficient - in time or money- way to build this building.

BREADTH STUDY 2- SUSTAINABLE ARCHITECTURE

Since one of the owner's goals was to have a LEED certified building, adding another green feature seemed to be a realistic option. The way the Westinghouse Electric Company Corporate Headquarters Building One is situated, with a large portion of the building facing south, a green roof would be just one more way to make the building "green". Green roofs help to integrate their buildings into the natural surroundings and can be used for various activities for the office. These areas can be used as patios, lunch areas, or meeting areas.

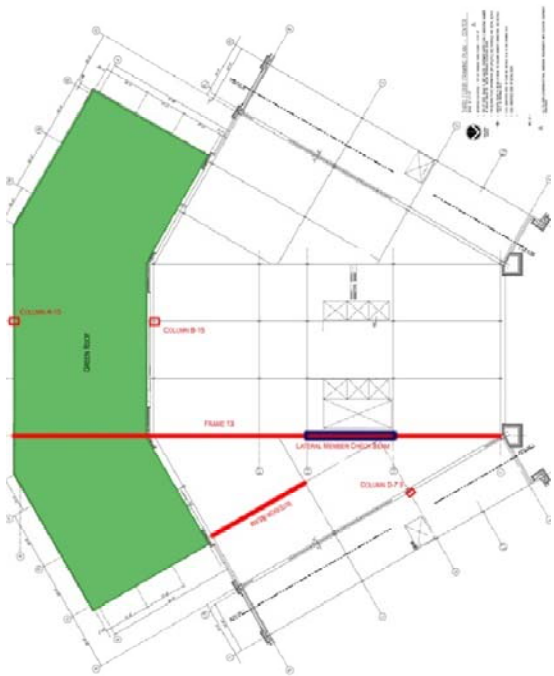


Figure 24: 3rd Floor Plan Center with Green Roof

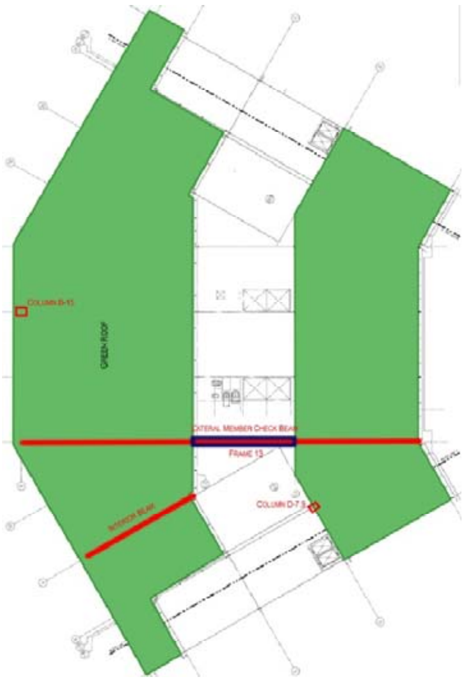


Figure 25: Roof Plan Center with Green Roof

A LEED credit analysis was also performed to check to see the viability of making the redesigned concrete building a LEED Certified building as well as the as-built one. The redesigned building was able to achieve 28 credits, with the requirement for certification at 26. The actual checklist can be seen in Appendix G. The benefits of a green roof are extensive. They make the recycled water content quality better, and provide a clean way to collect it as well as limiting the heat island effects.

The green roof materials selected are modular, meaning the sod and plants come in rectangular sections capable of being moved around if the owner decides to change the layout of the walkways and the soil. Native Pennsylvania plants will be used on the green roof patio. The green roof on the third floor will be available for use as an outdoor patio, and was treated as such with loading.

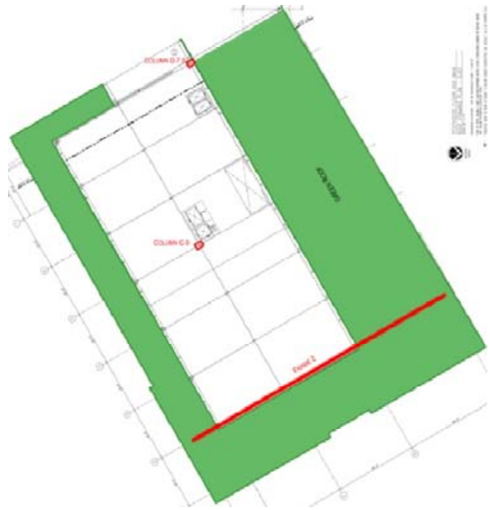


Figure 26: Roof Plan East with Green Roof Areas in Green

However, the green roof on the top of the building will not be accessible except for service conditions.

Green roofs typically consist of soil and vegetation, a filter of some sort of fabric, a drainage system, a moisture barrier, insulation, a root barrier, a protection layer, and a waterproofing membrane.

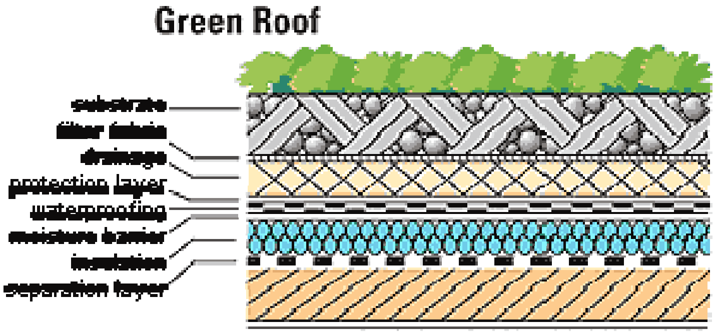


Figure 27: Green Roof Detail courtesy of www.deq.state.mi.us/documents/deq-ess-p2-p2week-greenroofreources.doc

Carlisle Coatings and Waterproofing has a green roof waterproofing system that fits exactly what this building requires. CCW is located in Carlisle, PA, which is approximately 205 miles away from the site. They specify for an extensive green roof a CCS 500R Hot applied waterproofing membrane system, CCW Protection Board HS, a CCW Root Barrier consisting of 40-mil non-reinforced Geomembrane, a CCW MiraDRAIN 9800 Drainage Board, insulation as required, MiraDRAIN GR 9200, and CCW 300HV Water Retention Mat, all underneath the soil. The full specification can be found at www.carlisle-ccw.com/Doco/spec07555613CCW500RGreenRoofWaterproofingSystem.pdf.

Also, for this study, since the green roof will be retaining water, pipes were spaced and sized for water flow. The green roof on the third floor was separated into three parts- two 6,131 SF sections and one 6,419 SF section. The green roof on the roof level of the building was split into six equal 6,434 SF sections. For all the sections used, two 3" pipes were found to meet the code requirements. The Portal Plus Roof Drain Calculator was used to help size the drains and pipes (located at www.portalplus.com/drain_calc.htm). The calculation is performed based on the 100-year storm. This calculation takes each local code and translates it based on the area of the roof area.

Table 16: Cost Estimate with green roof

Detailed Cost Analysis of the Structure									
Level	Description	Amount	Material Price	Material Cost	Labor Price	Labor Cost	Equipment Price	Equipment Cost	Total Cost
Reinforcement	Foundation	58 Ton	$935.00	$54,230	$430.00	$24,940	$30.35	$1,760	$80,930
	Columns	175 Ton	$935.00	$163,625	$430.00	$430.00	$30.35	$5,311	$169,366
	Beam/Slabs	572 Ton	$935.00	$534,820	$430.00	$245,960	$30.35	$17,360	$798,140
	SUB-TOTAL	805	$935.00	$752,675	$430.00	$346,150.00	$30.35	$24,432	$1,123,257
Cast in Place Concrete	Foundations	6100 CY	$109.00	$664,900	$14.90	$90,890	$5.55	$33,855	$789,645
	Columns	1518 CY	$109.00	$165,462	$34.00	$51,612	$16.95	$25,730	$242,804
	Slabs	14192 CY	$109.00	$1,546,928	$18.20	$258,294	$9.15	$129,857	$1,935,079
	Beams	7197 CY	$109.00	$784,473	$26.50	$190,721	$1,320.00	$9,500,040	$10,475,234
	SUB-TOTAL	29007	$109.00	$3,161,763	$23.40	$271,330	$1,352	$9,689,482	$13,122,575
Location Factor: 98.9%	Total Structure Estimate:		$14,332,000			Total Labor Cost:		$863,000	
	Total Material Cost:		$3,915,000			Total Equipment Cost:		$9,714,000	

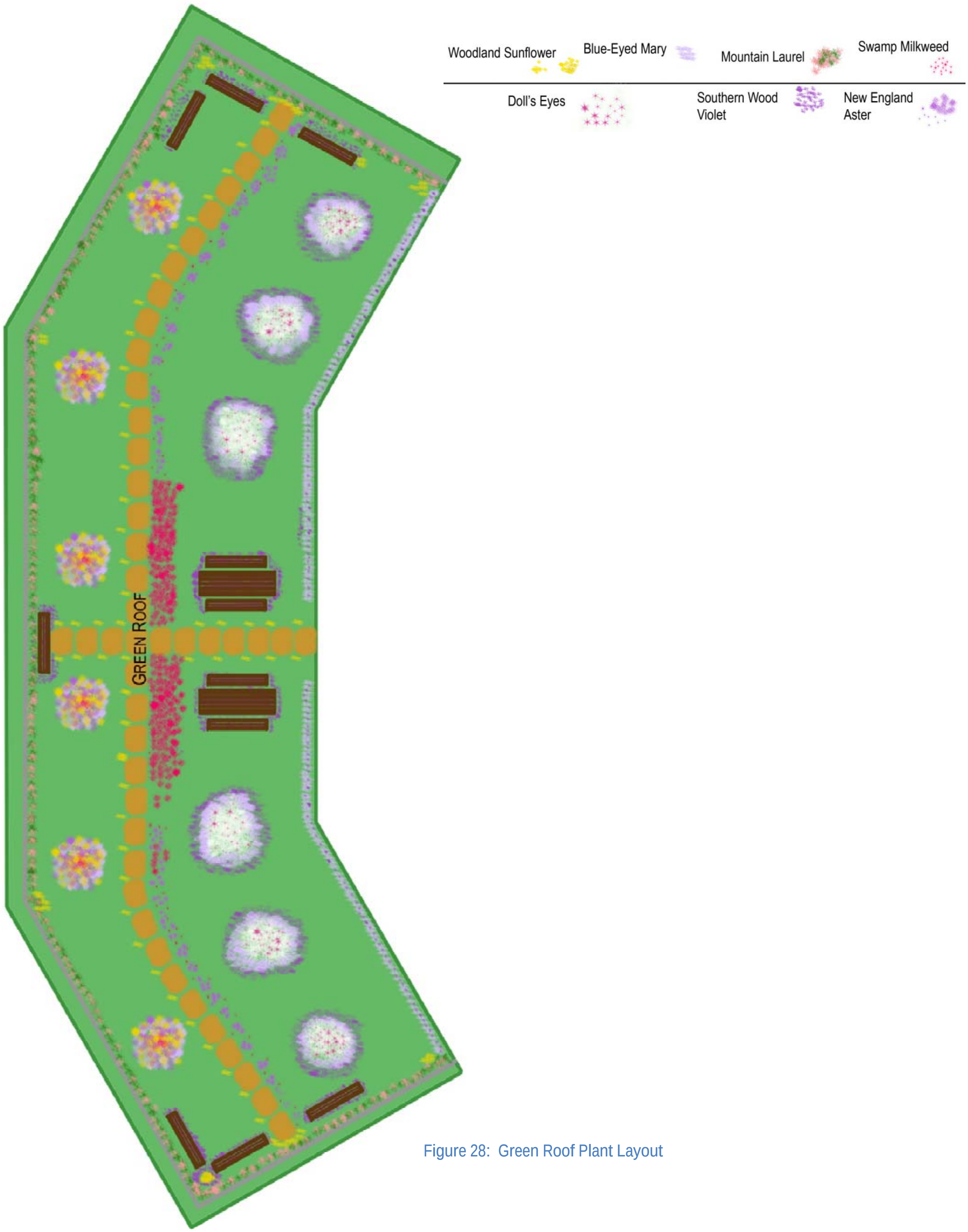


Figure 28: Green Roof Plant Layout

Some of the plants native to Pennsylvania able to be planted on the roof material are:

Figure 29: Doll's Eyes

Figure 30: Swamp Milkweed

Figure 31: Blue-eyed Mary

Figure 32: New England Aster

Figure 33: Woodland Sunflower

Figure 34: Southern Wood Violet

All the plants and figures are from the Audubon Society of Western Pennsylvania, Audubon Center for Native Plants webpage located at: http://www.aswp.org/acnp_culture_and_use_guide.html. Also, all the plants are smaller plants, which will mesh nicely into the green roof environment or rain garden environment and can be moved around and resituated easily. The plants also bloom at different points of the season, so from May until mid-winter there will be plants blooming on the roof. The Blue-eyed Mary emerges in the fall and stays green through the winter. The smallest plants tend to be shrubby, spread easily, and require little maintenance, which will keep costs down. Instead of grass for a base on the roof, the main plant is sedum, which is hardier than grass and is a preferred plant on such surfaces.

Breadth Study 2 Overview

The green roof has a weight much larger than a typical roof and since one of the green roofs is going to be used as a patio, the live load also increases. These differences impact the size of the structural members, which also impact the cost of the structure and the schedule. The columns require an additional 19 tons more reinforcing and the beams and slabs require an additional 68 tons. The volume of concrete required for the structure to be able to support the green roof is: 75 CY for columns and 750 CY for the beams. These differences translate into $1,159,000 which is equivalent to $2.68/SF, more to add a green roof onto this redesigned concrete structure. As far as schedule is concerned, the building could be completed one week earlier without a green roof.

After all these items are considered, it can be concluded that adding a green roof is certainly a viable option for this building. The green roof portion of this report was a success. It met all the goals set for it such as proper integration of a green roof system into the building, detailing, specifying native plants and laying them out, and sizing of a pipe for water flow from the roof for drainage. The system also had a cost estimate and a schedule generated for it so the green roof could be compared to the new concrete design system. The difference in cost from the new system with a green roof and without a green roof was able to be calculated and compared and found to be not considerably higher when compared to the total cost of the building.

CONCLUSIONS AND RECOMMENDATIONS

The study and redesign of the Westinghouse Electric Company Corporate Headquarters Building One has been an overall success. Instead of using the same 80 PSF live load everywhere used in the previous technical reports, a live load of 70 PSF (50 PSF office load and 20 PSF partition load) was used uniformly throughout the upper floors of the building. The redesigned concrete building was able to be compared to the original steel building in terms of construction cost, schedule impact, and overall effectiveness. The redesigned building also had a green roof added to the building in order to integrate it into the environment and make a statement as a corporate headquarters.

The building was successfully redesigned with a concrete cast-in-place one-way slab with beams system using concrete moment resisting frames as the lateral system. Shear walls were considered for this design, but could not be used effectively due to the necessity of an open plan for tenant fit-out requirements. The slab, beams, columns, and foundations were all designed or resized according to ACI 318-08 and ASCE 7-05 and the applicable sections. Once a preliminary design was established, the building was modeled in RAM Structural System and checked for validity and uniformity of members and reinforcement and torsion.

Since the building material was changed to concrete, the weight of the building significantly increased, causing the seismic loads to change. In the original steel design, wind was the controlling lateral load in one of the directions and seismic controlled the other direction. However, in the concrete redesign seismic load controls the lateral system. The lateral loads were checked in RAM as well. Drift ratios and drift were determined in RAM and checked to the allowable values for serviceability from ASCE 7-05 and found to be acceptable. A hand check was performed on a lateral beam to ensure the validity of the structural design. Uplift is not an issue because the pure weight of the building will hold the building down. The foundations were resized according to the required strength for both the spread footings and the caissons. All the goals for the structural part of this project were met, making it a success.

After all analyses were performed for the design of the concrete building, the building was compared to the original steel building. It can be reasonably concluded steel is a more efficient system than concrete in this particular application. The cost estimate was compared to Turner's budget, and found to be significantly higher. The schedule for the new building was generated and also compared to Turner's and was found to be two months longer. While the project was a success in terms of the goals, it was not ideal since the proposed modifications extended the schedule and increased the cost.

As far as the sustainable architecture breadth is concerned, the project was also a success. The green roof was detailed, materials specified, drainage pipes sized based on local code requirements, and plants specified for the area. Additionally, the green roof impacts the structure and causes the columns and beams to be larger. The green roof increases the structural cost $1,159,000 ($2.68/SF) and increases the schedule by one week.

All parts of this analysis considered, it is not recommended to make the building structure concrete instead of steel. The building can be built at a better value and has a much faster erection time in steel. However, it is recommended to use more sustainable architecture in the form of a green roof. The total cost of the building does not change comparatively when it is added, and it increases the value of the building with respect to LEED certification and incorporation into the environment.

Further calculations can be found in the appendices. Additional calculations for wind and seismic loading and the RAM Model are available upon request.

APPENDIX A: TYPICAL FLOOR LAYOUT

Figure 35: Second Floor Layout of As-Built Building

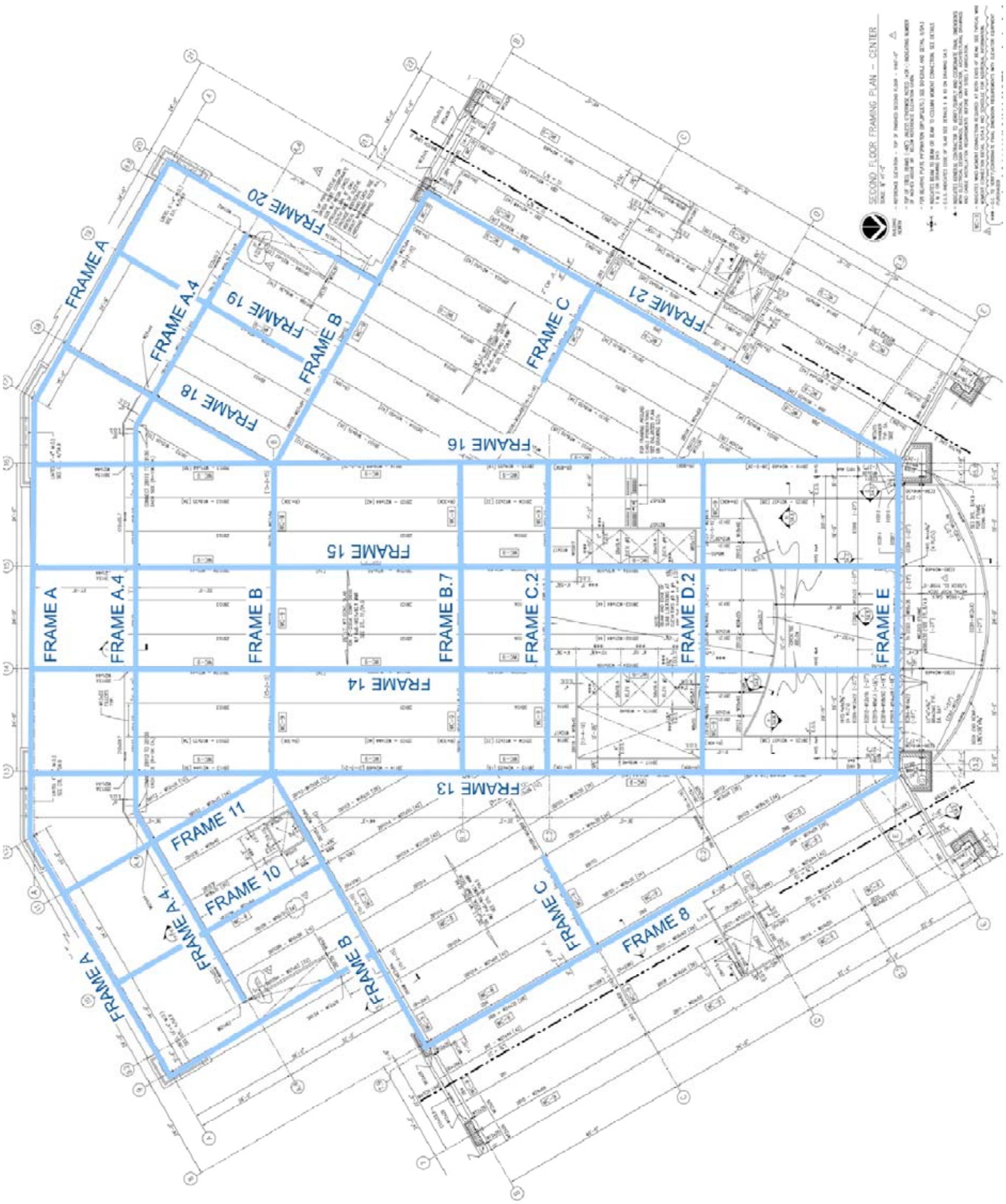


Figure 36: Second Floor Layout of Center or As-Built building

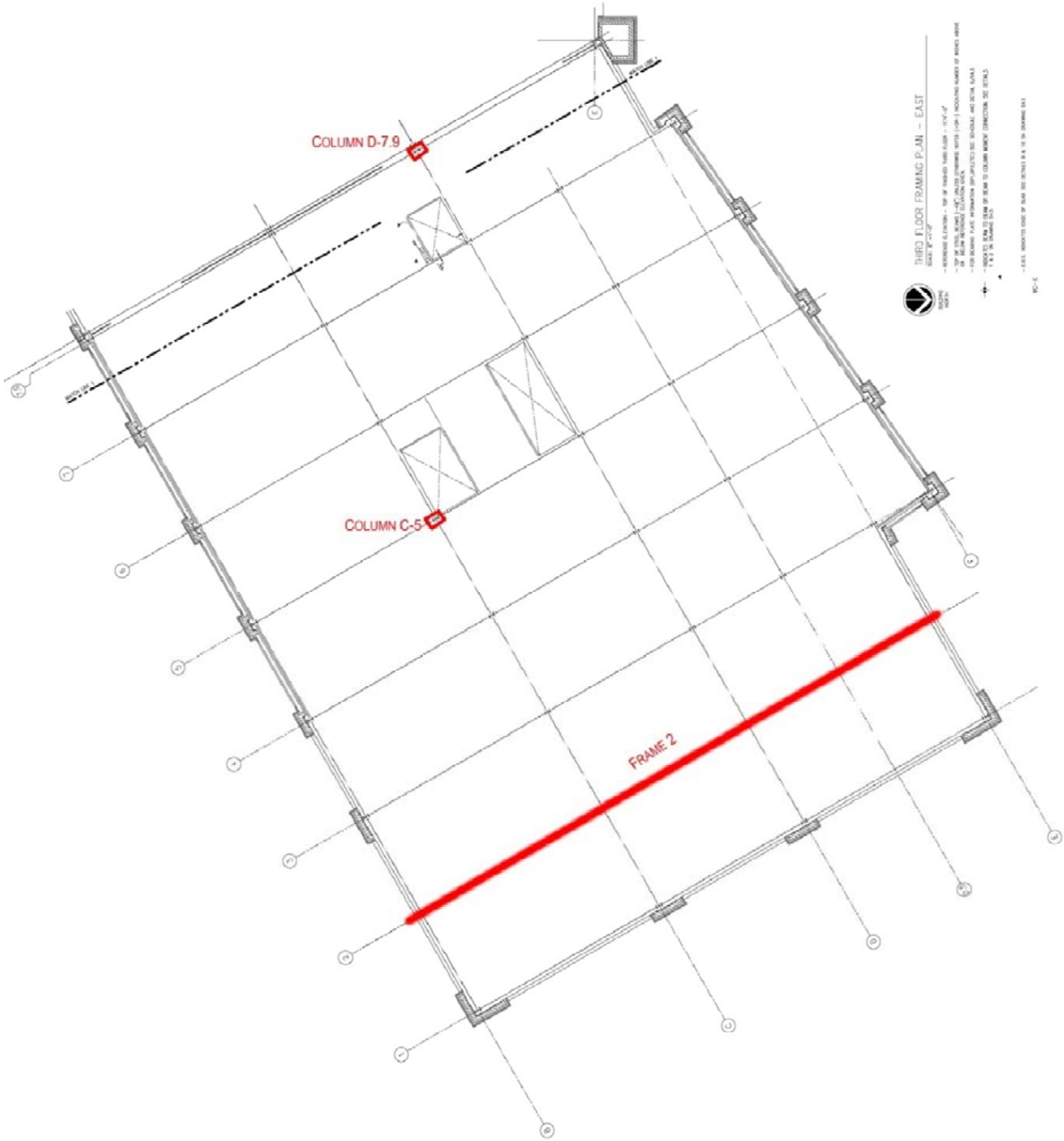


Figure 37: Third Floor East of Redesigned Concrete Building with Portal Analysis Frame Indicated and Columns for Column Checks Indicated

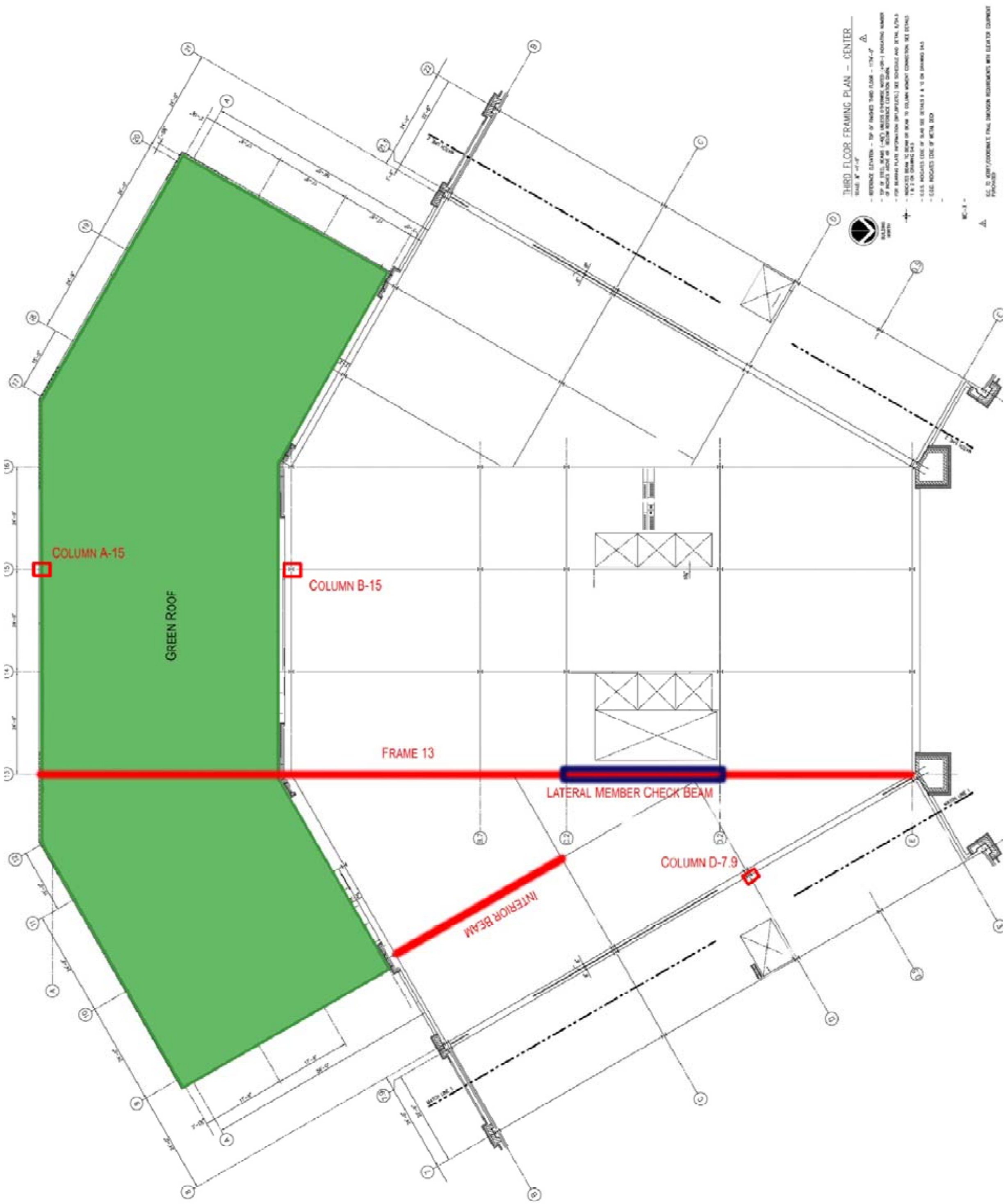


Figure 38: Third Floor Center of Redesigned Concrete Building with Portal Analysis Frame Indicated and Columns for Column Checks Indicated

Figure 39: Green Roof Plan East of Redesigned Building with Portal Frame Analysis and Spot Checked Columns Indicated

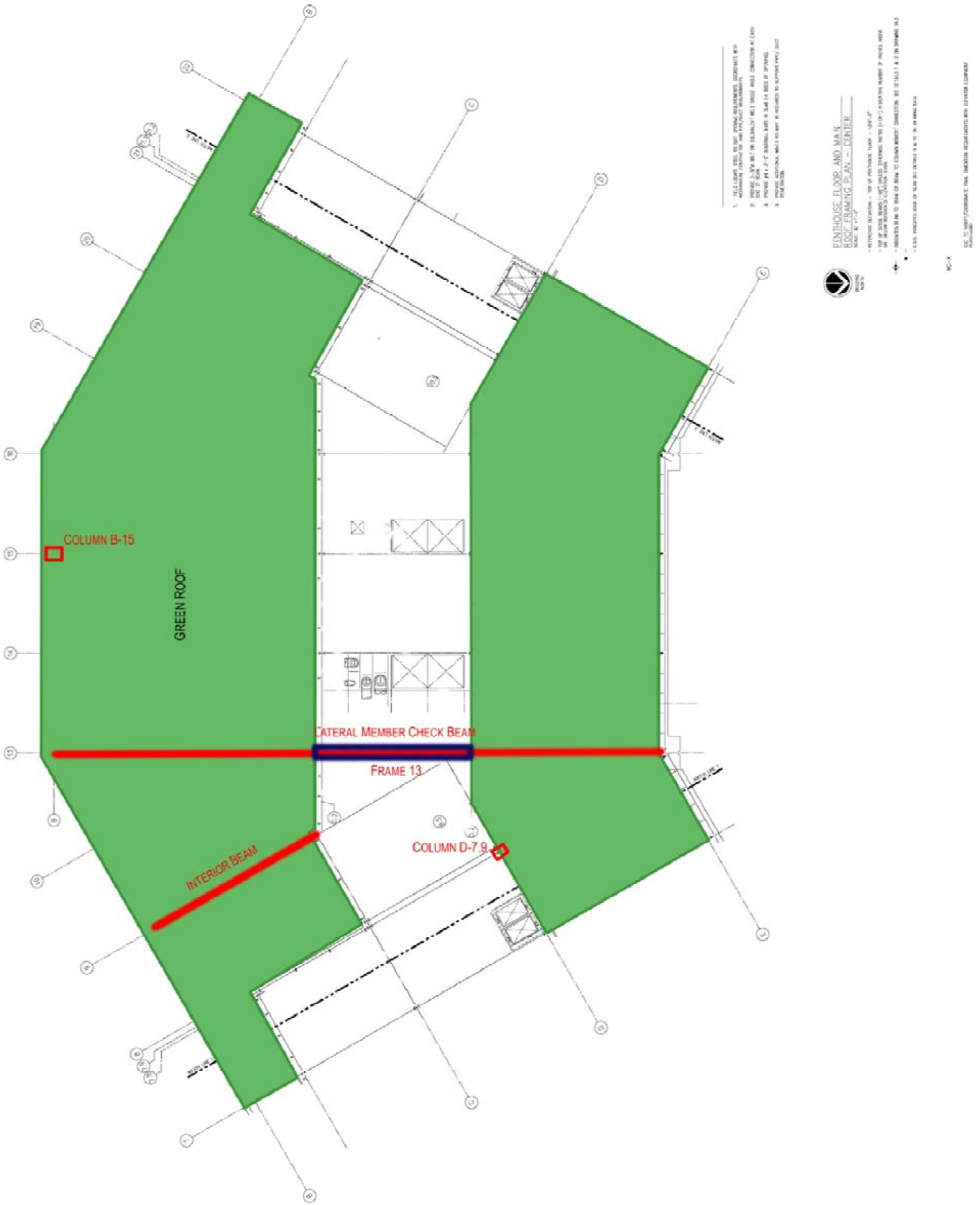


Figure 40: Green Roof Plan Center of Redesigned Building with Portal frame Analysis, lateral Beam Check, Interior Beam Check, and Spot Checked Columns Indicated

Appendix B: Torsion Effects Calculations

The centers of rigidity for each direction were determined by taking the sum of the stiffness in one direction multiplied by the distance from the perpendicular distance from the origin (distance from the opposite origin) all divided by the sum of the stiffness for each frame used in the calculation. For example, the center of rigidity in the Y direction was calculated by taking the K in the X direction and multiplying it by the distance from the Y origin, and finding the sum of all the values divided by the sum of the K's in the X direction (Kix*dix/ΣKix). The Ix was calculated by taking the sum of the K's in the X direction multiplied by the distance from the Y origin squared ($\Sigma kix*yi^2$). The Iy was calculated using the same method.

$$\text{Center of Rigidity in Y} = Kix*dix/\Sigma kix$$
$$\text{Center of Rigidity in X} = Kiy*dix/\Sigma kiy$$
$$Ix = \Sigma kix*yi^2$$
$$Iy = \Sigma kiy*xi^2$$

After the K values were determined, the K in the direction of the force was divided by the sum of the K's in the same direction and multiplied by the force in the specific direction. The torsion induced moment in each direction was determined differently for wind and for seismic.

For seismic forces, the torsion induced moment was calculated by taking the force at the specified story multiplied by the center of rigidity subtracted from center of mass in the direction perpendicular to the force.

Torsion Induced Moment X= (Force)*(Center of Mass in Y direction- Center of Rigidity in X direction)

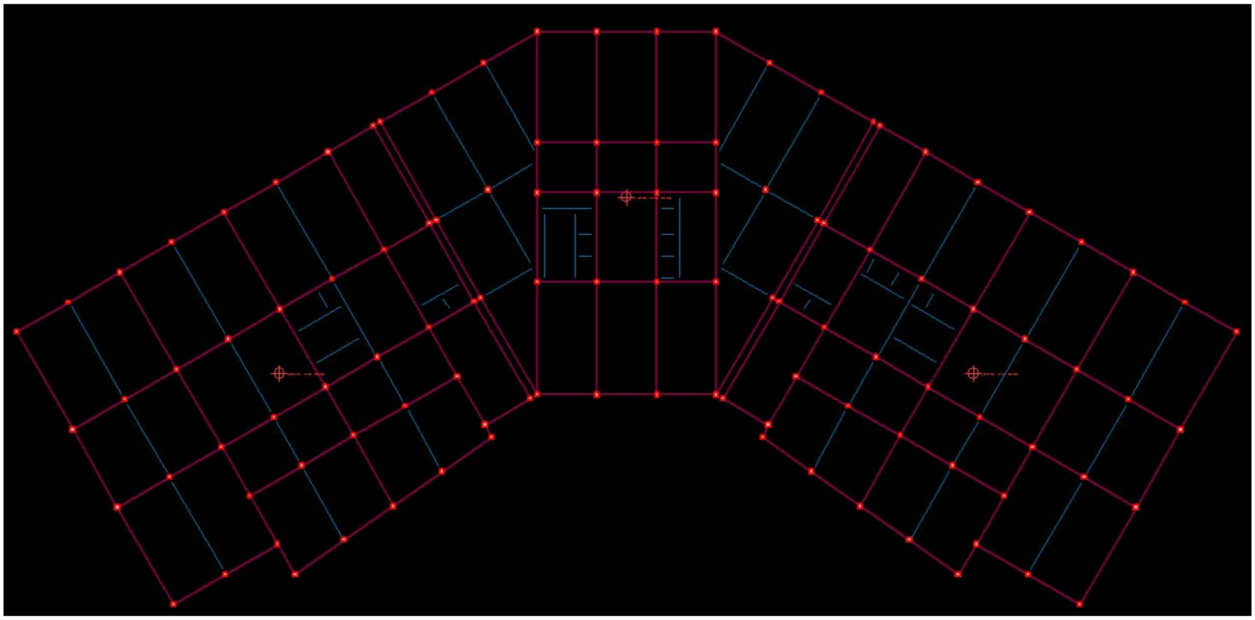


Figure 41: Centers of Mass for New Building

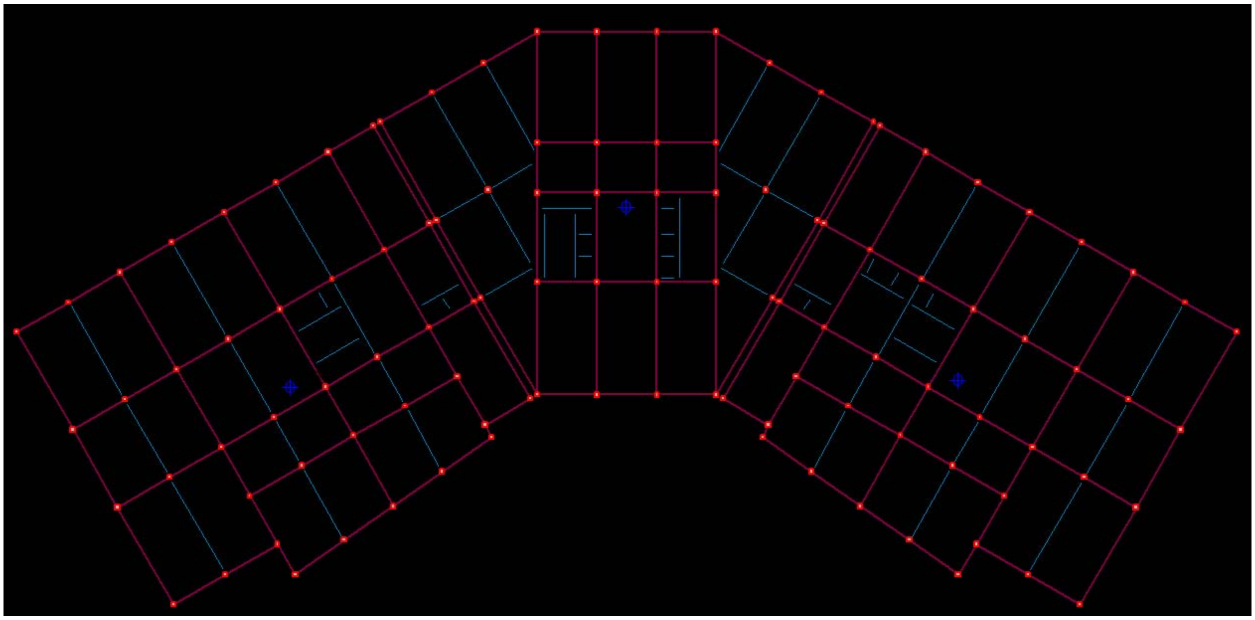


Figure 42: Centers of Rigidity for New Building

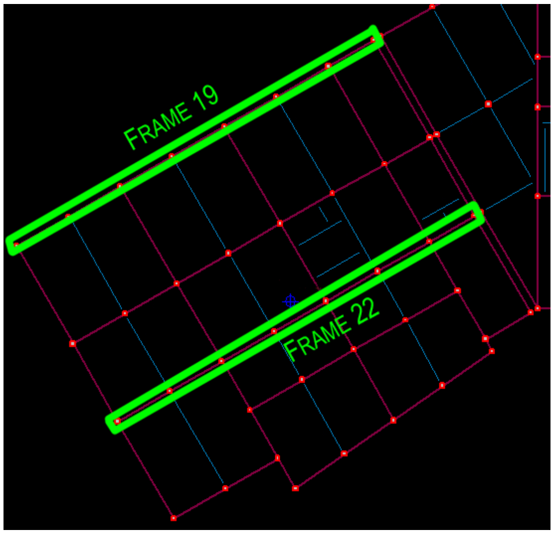


Figure 43: Center of Rigidity and Frames for Comparison

As is seen in the following figures of the wind shears from frames 19 and 22, the further away from the center of rigidity the frame is located, the more torsion and shear the frame takes. The concept of torsion is evident in these frames.

Load Case: W9 Wind Wind_IBC06_4_X+Y_CW

Level	Shear-X kips	Change-X kips	Shear-Y kips	Change-Y kips
Roof	24.27	24.27	17.43	17.43
Fifth	29.05	4.78	20.97	3.54
Fourth	43.42	14.37	31.90	10.93
Third	51.17	7.75	38.22	6.32
Second	46.66	-4.51	33.40	-4.82
First	-9.04	-55.70	-11.12	-44.52

Figure 44: Wind Shears Frame 19

Load Case: W9 Wind Wind_IBC06_4_X+Y_CW

Level	Shear-X kips	Change-X kips	Shear-Y kips	Change-Y kips
Penthouse	3.26	3.26	3.47	3.47
Roof	3.71	0.45	7.56	4.10
Fifth	9.77	6.06	15.69	8.12
Fourth	12.68	2.91	20.61	4.92
Third	18.67	5.99	27.52	6.92
Second	19.37	0.70	35.57	8.05
First	-3.24	-22.62	-10.30	-45.87

Figure 45: Wind Shears Frame 22

Load Case: E1 Seismic EQ_IBC06_X_+E_F

Level	Shear-X kips	Change-X kips	Shear-Y kips	Change-Y kips
Roof	50.00	50.00	15.85	15.85
Fifth	49.63	-0.37	14.53	-1.33
Fourth	64.72	15.09	19.06	4.54
Third	66.40	1.68	20.10	1.04
Second	73.12	6.72	15.00	-5.10
First	-23.19	-96.31	7.26	-7.74

Figure 46: Seismic Shears Frame 19

Load Case: E1 Seismic EQ_IBC06_X_+E_F

Level	Shear-X kips	Change-X kips	Shear-Y kips	Change-Y kips
Penthouse	20.03	20.03	6.15	6.15
Roof	26.35	6.32	-6.05	-12.20
Fifth	47.99	21.64	-4.00	2.05
Fourth	56.10	8.12	-5.38	-1.38
Third	65.66	9.56	-5.03	0.35
Second	60.39	-5.28	-4.42	0.61
First	-17.19	-77.57	6.33	10.75

Figure 47: Seismic Shears Frame 22

APPENDIX C: WIND LOAD CALCULATIONS

MAIN WIND-FORCE RESISTING SYSTEM (ASCE 7-05)

Table 18: Wind Calculation Conditions

Basic Wind Speed (V) mph	90
Exposure Category	B
Importance Factor (I)	1
Wind Directionality Factor (Kd)	0.85
Topographic Factor (Kzt)	1

BUILDING L/B AND VALUES

Table 19: Windward, Leeward, and Sidewall constants

		L/B	C_p
East-West Direction			
	Windward	4.317	0.8
	Leeward	4.317	-0.2
	Sidewall	4.317	-0.7
North-South Direction			
	Windward	0.232	0.8
	Leeward	0.232	-0.5
	Sidewall	0.232	-0.7

Table 17: Wind Calculation Constants

	Wind Direction	
Variable	N-S	E-W
Stiffness	Flex	Flex
B	544	126
L	126	544
h	92.5	92.5
z	30'	30'
ℓ	320	320
ϵ	0.333	0.333
α	0.25	0.25
β	0.05	0.05
V	90	90
V_z	67.644	67.644
L_z	380.55	380.55
n_1	1.163	1.163
N_1	6.54	6.54
R_n	0.043	0.043
R_h	0.127	0.127
R_b	0.023	0.095
R_L	0.030	0.007
b	0.45	0.45
R	0.037	0.074
I_z	0.275	0.275
g_R	0.000	0.000
q_p	14.836	14.836
g_V	3.4	3.4
Q	0.731	0.832
G_f	0.772	0.830

WIND CALCULATIONS CONTINUED:

$q_p =$ $0.00256\ K_hK_{zt}K_dV^2I=$ 14.836

GCpn= 1.5 -1

$Pp = q_pGCpn =$ 22.254 -14.836

$n_1 = \dfrac{43.5}{H^{0.9}}$ 1.163 eq (C6-15)

$n_1 > 1$ therefore Rigid structure

$g_Q =$ $g_V =$ 3.4
G= 0.85

z= 0.6h = 55.5

$z_{min} =$ 30'

$I_z = c(33/z)^{1/6} =$ 0.275

$L_z = l(z/33)^{\epsilon} =$ 380.55

$Q_{N\text{-}S} =$ $\sqrt{(1/(1+0.63(\ B+h/L_z)^{0.63}))} =$ 0.731

$Q_{E\text{-}W} =$ $\sqrt{(1/(1+0.63(\ B+h/L_z)^{0.63}))} =$ 0.832

$G_{f\ N\text{-}S} =$ $0.925\ [(1+1.7I_zg_QQ)/(1+1.7g_vI_z)] =$ 0.772274

$G_{f\ E\text{-}W} =$ $0.925\ [(1+1.7I_zg_QQ)/(1+1.7g_vI_z)] =$ 0.829674

WIND CALCULATIONS CONTINUED:

Table 20: Design Wind Pressure in N-S

Design Wind Pressures p in N-S Direction (Table 5.41)						
Location	Height above Ground Level z (ft)	q(psf)	External Pressure qGC_p (psf)	Internal Pressure q_hGC_{pi}	Net Pressure p (psf)	
					+Gcpi	-Gcpi
Windward	92.5	14.354	8.87	2.67	6.20	11.54
	74.5	13.47	8.32	2.67	5.65	10.99
	70	13.20	8.16	2.67	5.49	10.83
	60	12.61	7.79	2.67	5.12	10.46
	50	12.02	7.42	2.67	4.75	10.09
	46	11.72	7.24	2.67	4.57	9.91
	40	11.28	6.97	2.67	4.30	9.64
	32	10.56	6.53	2.67	3.86	9.20
	30	9.79	6.05	2.67	3.38	8.72
	25	9.20	5.68	2.67	3.01	8.35
	20	8.46	5.22	2.67	2.55	7.90
	18	8.46	5.22	2.67	2.55	7.90
	15	8.46	5.22	2.67	2.55	7.90
Leeward	All	14.35	-5.54	2.67	-8.21	-2.87
Side	All	14.35	-7.76	2.67	-10.43	-5.09

Table 21: Design Wind Pressure in E-W

Design Wind Pressures p in E-W Direction (Table 5.41)						
Location	Height above Ground Level z (ft)	q(psf)	External Pressure qGC_p (psf)	Internal Pressure q_hGC_{pi}	Net Pressure p (psf)	
					+Gcpi	-Gcpi
Windward	92.5	14.35	9.53	2.67	6.86	12.20
	74.5	13.47	8.94	2.67	6.27	11.61
	70	13.20	8.76	2.67	6.09	11.43
	60	12.61	8.37	2.67	5.70	11.04
	50	12.02	7.98	2.67	5.31	10.65
	46	11.72	7.78	2.67	5.11	10.45
	40	11.28	7.48	2.67	4.81	10.15
	32	10.56	7.01	2.67	4.34	9.68
	30	10.39	6.89	2.67	4.22	9.56
	25	9.79	6.50	2.67	3.83	9.17
	20	9.20	6.11	2.67	3.43	8.78
	18	8.90	5.91	2.67	3.24	8.58
	15	8.46	5.61	2.67	2.94	8.28
Leeward	All	13.47	-2.24	2.67	-4.91	0.44
Side	All	13.47	-7.82	2.67	-10.49	-5.15

WIND CALCULATIONS CONTINUED:

Table 22: Total Wind pressures by Height

Floor Heights	Level	Total Height	K_Z	q_Z	Wind Pressures (psf)					
					N-S Windward	N-S Leeward	N-S Side Wall	E-W Windward	E-W Leeward	E-W Sidewall
18	Penthouse	92.5	0.9675	14.354	11.54	-8.21	-10.43	12.20	-4.91	-10.49
14.5	Roof	74.5	0.908	13.471	10.99	-8.21	-10.43	11.61	-4.91	-10.49
14	5	60	0.85	12.611	10.46	-8.21	-10.43	11.43	-4.91	-10.49
14	4	46	0.79	11.720	9.91	-8.21	-10.43	11.04	-4.91	-10.49
14	3	32	0.712	10.563	9.20	-8.21	-10.43	10.65	-4.91	-10.49
18	2	18	0.59	8.902	7.90	-8.21	-10.43	10.45	-4.91	-10.49

Table 23: Wind Forces, Shears, and Moment

Level	Wind Design					
	Load (kips)		Shear (kips)		Moment (ft-k)	
	N-S	E-W	N-S	E-W	N-S	E-W
Pent	193.4	38.8	0	0	3481.3	698.2
Roof	151.5	30.2	193.4	38.8	2196.7	437.6
5	144.8	29.3	344.9	69.0	2026.7	410.7
4	138.0	28.1	489.7	98.3	1932.5	393.8
3	132.6	27.4	627.7	126.4	1856.3	384.1
2	140.2	31.0	760.3	153.9	2523.7	557.2
Total	900.5	184.8	900.5	184.8	10535.9	2183.4

Note: Total Base Shear includes load from Windward and Leeward pressures

Wind Calculations Continued:

RAM Comparison

As these tables show, RAM values are around the same change from floor to floor as the hand calculations.

RAM values were compared further to the hand calculation method results used throughout the report and used in previous technical reports. The main differences have already been addressed, such as the possibility of a finite element analysis. The wind design table below is the final story force and story shears for the east portion of the building.

RAM Calculated Values

Table 24: RAM Calculated Wind Values

Floor Heights	Level	Total Height	K_Z	q_Z	RAM Wind Pressures (psf)					
					N-S Windward	N-S Leeward	N-S Side Wall	E-W Windward	E-W Leeward	E-W Sidewall
18	Penthouse	92.5	0.966	14.331	11.57	-8.23	-10.46	11.57	-5.98	-8.23
14.5	Roof	74.5	0.909	13.486	11.05	-8.23	-10.46	11.05	-5.98	-8.23
14	5	60	0.854	12.670	10.54	-8.23	-10.46	10.54	-5.98	-8.23
14	4	46	0.792	11.750	9.97	-8.23	-10.46	9.97	-5.98	-8.23
14	3	32	0.714	10.593	9.25	-8.23	-10.46	9.25	-5.98	-8.23
18	2	18	0.605	8.976	8.25	-8.23	-10.46	8.25	-5.98	-8.23

Table 25: RAM Wind Forces, Shears, and Moments

Level	Wind Design					
	Load (kips)		Shear (kips)		Moment (ft-k)	
	N-S	E-W	N-S	E-W	N-S	E-W
Pent	193.9	39.8	0	0	3491.0	716.6
Roof	152.1	31.1	193.9	39.8	2205.3	451.1
5	143.0	29.7	346.0	70.9	2001.8	415.3
4	138.6	28.1	489.0	100.6	1940.9	393.9
3	133.2	26.9	627.7	128.7	1864.2	376.2
2	161.4	28.7	760.8	155.6	2904.7	516.3
Total	922.2	184.3	922.2	184.3	10916.9	2152.9

Note: Total Base Shear includes load from Windward and Leeward pressures

Appendix D: Seismic Load Calculations

Table 26: Seismic Design Values

Seismic Design Values, ASCE 7-05			
Response Modification Coefficient	R= 3	R= 3.5	Table 12.2-1
Coefficient	C_U= 1.7	C_U= 1.7	Table 12.8-1
Fundamental Period	T= 1.497	T= 1.497	Sec. 12.8.2
Seismic Response Coefficient	C_S= 0.016	C_S= 0.014	Eq. 12.8-3
Building Height (above grade)	h= 74.5	h= 74.5	

Table 27: Seismic Design Values continued

Seismic Design Values, ASCE 7-05		
Occupancy	II	Table 1-1
Importance Factor	I= 1	Table 11.5-1
Site Class	D	Table 20.3-1
Spectral Response Acceleration, short	S_S= 0.12	Figure 22-1
Spectral Response Acceleration, 1 sec	S_1= 0.046	Figure 22-2
Site Coefficient F_a	F_a= 1.6	Table 11.4-1
Site Coefficient F_V	F_V= 2.4	Table 11.4-2
MCE Spectral Response Acceleration, short	S_{MS}= 0.192	Eq. 11.4-1
MCE Spectral Response Acceleration, 1 sec	S_{M1}= 0.1104	Eq. 11.4-2
Design Spectral Acceleration, short	S_{DS}= 0.128	Eq. 11.4-3
Design Spectral Acceleration, 1 sec	S_{D1}= 0.0736	Eq. 11.4-4
Seismic Design Category	B	Table 11.6-1

Table 28: Fv Values

F_V Values (Table 11.4-2 ASCE 7-05)					
	S_1≤0.1	S_1=0.3	S_1=0.3	S_1=0.4	S_1≥0.5
D	2.4	2	1.8	1.6	1.5

Table 29: Fa Values

F_a Values (Table 11.4-1 ASCE 7-05)					
	S_S≤0.25	S_S=0.5	S_S=0.75	S_S=1.0	S_S≥1.25
D	1.6	1.4	1.2	1.2	1

SEISMIC CALCULATIONS CONTINUED:

The values for all the seismic coefficients were determined using ASCE 7-05 equations and tables. The building was first confirmed as Seismic design category B by using Table 11.6-2 of ASCE 7-05. Once the design category had been confirmed, the approximate period was calculated by using equation 12.8-7 and table 12.8-2. Since ASCE 7-05 section 11.6 requires where an S_1 value is less than 0.75 the Seismic Design Category can be determined solely on table11.6-1 and 11.6-2 when $T_a > 0.8T_S$, the period used to calculate drift is less than T_S, equation 12.8-2 is used to find C_S, and rigid diaphragms are present.

Table 30: Seismic Response Value Comparison

Calculated Values		USGS Website Values
S_S= 0.12	(From Figure 22-1)	S_S= 0.125
S_1= 0.046	(From Figure 22-2)	S_1= 0.048
$S_{MS}= F_a*S_S =$ 0.192		S_{MS}= 0.2
$S_{M1}= F_V*S_1 =$ 0.1104		S_{M1}= 0.116
$S_{DS}= 2S_{MS}/3=$ 0.128	A (Table 11.6-1)	S_{DS}= 0.133
$S_{D1}= 2S_{M1}/3=$ 0.0736	B (Table 11.6-2)	S_{D1}= 0.077

C_T = 0.016 (From Table 12.8-2)
X = 0.9 (From Table 12.8-2)

$T_a = C_t h_n^x =$ 0.9411255
$T_s = S_{D1}/S_{DS} =$ 0.575
$0.8T_s =$ 0.46 $<T_a$ therefore must use Table 11.6-1,2

T_L= 12 (From Fig. 22-15 p. 228 ASCE 7-05)

C_S values were calculated according to Section 12.8.1.1 equations 12.8-2, 12.8-3, and 12.8-4 and checked against the minimum requirement from EQ 12.8-5 of $C_S \geq 0.01$. Equation 12.8-3 is a maximum for this structure, and equation 12.8-4 does not apply since equation 12.8-3 does. The values were then compared based on R and what the professional calculated.

R=3

C_S= MAX for $T>T_L$

$S_{DS}/(R/I)$ = 0.0427

$S_{D1}/(T^*R/I)$ = 0.0153

$S_{D1}T_L/(T^2R/I)$ = 0.3324

≥ 0.01

C_S= 0.0153

T= $C_U{}^*T_a$ = 1.5999134

k= 1.550

W= 106734.9

V= $C_s{}^*W$= 1636.69

The floor weights used for the seismic calculations were calculated using a 10" NWC slab over the entire area, added to the column weights. Also, the superimposed loads were added and a bracing allowance to account for beams as part of the floor system.

Table 31: Beams on 4th floor with total beam weight

Beams:			
Shape	Unit Weight (lb/ft)	Beam Length (ft)	Total Weight
32x34	1095.56	0	0.0 kips
30x34	1027.08	0	0.0 kips
34x34	1164.03	48	55.9 kips
24x34	821.667	5443.9	4473.1 kips
Total Weight=	4528.9 kips		

Table 32: Fourth Floor weight calculation

Floor # 4

Approx. Area: 64231.7 ft^2 Floor to Floor Height: 14

Slab:

NWC	145	PCF
Thickness=	10	inches
unit weight=	120.8333	psf
total weight=	**7761**	**kips**

Columns:

Shape	Quantity	Unit Weight (lb/ft)	Column Height (ft)	Total Weight	
24x24	102	580	14	828.2	kips
28x28	3	789.44444	14	33.2	kips
30x30	6	906.25	14	76.1	kips
32x32	0	1031.1111	14	0.0	kips
34x34	0	1164.0278	14	0.0	kips
36x36	0	1305	14	0.0	kips
48x48	0	2320	14	0.0	kips

Column Reinf =	22.35	Kips
X-verse Reinf=	2.77	kips
Total Weight=	**962.6**	**kips**
Beam =	4528.9	kips
Reinforcement=	156.177	kips
Total Weight=	**4685.1**	**kips**

Super Imposed:

MEP=	5	psf
Finishes=	3	psf
Total Weight=	513.9	kips

TOTAL FLOOR WEIGHT: 13922.9 kips or 216.8 psf

The values in this portion of the report were calculated using the method described in the Seismic design portion of this report and the same method used in Technical Report One.

Table 33: Seismic Forces, Shears and Moments for As- Built with R=3

R=3

Floor	w_x (k)	h_x (ft)	h_x^k (ft)	$w_x h_x^k$	C_{vx}	Story Force F_x (k)	Story Shear V_x (k)	Moment at Floor (ft-k)
Roof	4240.5	74.5	639.41	2711449	0.359	167.42	0	12473.065
5	4713.6	60	462.27	2178985	0.288	134.55	167.42	8072.7394
4	4726.5	46	310.43	1467216	0.194	90.60	301.97	4167.4204
3	4724.0	32	180.20	851252	0.113	52.56	392.57	1681.9916
2	4653.4	18	76.08	354028	0.047	21.86	445.13	393.48265
1	5444.4						466.99	
Sum	28502.4	74.5	1668.39	7562930	1.000	466.99	466.99	26788.699

Table 34: Seismic Forces, Shears, and Moments for As-Built with R=3.5

R=3.5

Floor	w_x (k)	h_x (ft)	h_x^k (ft)	$w_x h_x^k$	C_{vx}	Story Force F_x (k)	Story Shear V_x (k)	Moment at Floor (ft-k)
Roof	4240.5	74.5	639.41	2711449	0.359	143.51	0	10691.199
5	4713.6	60	462.27	2178985	0.288	115.32	143.51	6919.4909
4	4726.5	46	310.43	1467216	0.194	77.65	258.83	3572.0746
3	4724.0	32	180.20	851252	0.113	45.05	336.48	1441.7071
2	4653.4	18	76.08	354028	0.047	18.74	381.54	337.27085
1	5444.4						400.28	
Sum	28502.4	74.5	1668.39	7562930	1.000	400.28	400.28	22961.742

Table 35: Seismic Forces, Shears, and Moments for Redesigned with R=3

Floor	w_x (k)	h_x (ft)	h_x^k (ft)	$w_x h_x^k$	C_{vx}	Story Force F_x (k)	Story Shear V_x (k)	Moment at Floor (ft-k)
Penthouse	6481.1	92.5	1115.41	7229044	0.179	293.33	0	27133.348
Roof	18245.1	74.5	797.56	14551503	0.361	590.46	293.33	43989.083
5	14162.0	60	570.24	8075727	0.200	327.69	883.79	19661.364
4	13922.9	46	377.75	5259370	0.130	213.41	1211.48	9816.8534
3	16960.3	32	215.24	3650482	0.091	148.13	1424.89	4740.0283
2	17785.3	18	88.23	1569200	0.039	63.67	1573.02	1146.1239
1	19178.2						1636.69	
Sum	106734.9	92.5	3164.42	40335326	1.000	1636.69	1636.69	106486.8

APPENDIX E: MEMBER DESIGNS AND CHECKS

Interior 45' span beam Design

GIRDER DESIGN - INTERIOR - FLOOR

LOADING: DEAD: 125 PSF + 8 PSF + GIRDER WT
LIVE: 50 PSF + 20 PSF

*NO LIVE LOAD REDUCTION TO BE CONSERVATIVE SINCE TENANT FIT-OUT DWG'S UNAVAILABLE

$W_u = 1.2(125+8) + 1.6(50+20) = 272$ PSF

$\boxed{W_u = 272 \text{ PSF}}$

MAXIMUM MOMENT DETERMINATION

M_{MAX} @ ENDS $= \frac{wl^2}{12} = \frac{(0.272 \text{ KSF})(24')(45')^2}{12} = 1101.6$ k-ft

M_{MAX} @ MID $= \frac{wl^2}{24} = \frac{(0.272 \text{ KSF})(24')(45')^2}{24} = 550.8$ k-ft

GIRDER SIZE

$bd^2 = 20 M_u$

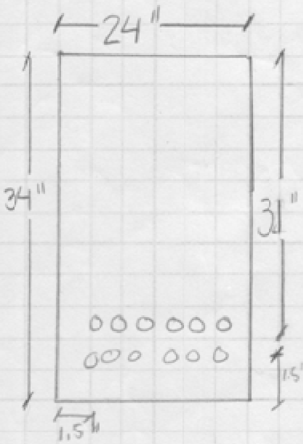
$24(d)^2 = 20(1102)$

$d = 30.3''$ TRY #8'S

$h = d + 1.5 + d_b/2 = 30.3 + 1.5 + 1/2 = 32.3$

$\boxed{h = 34''}$ $d = h - 1.5 - 3d_b/2 = 34 - 1.5 - 3/2 = 31$

$A_s = \frac{M_u}{4d} = \frac{1102}{4(31)} = 8.89 \text{ in}^2$



- TRY 12 # 8'S IN 2 ROWS, $A_s = 9.48 \text{ in}^2$
- ASSUME $f_s > f_y$

$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{(9.48)(60)}{0.85(4)(24")} = 6.97''$

$c = a/\beta_1 = 6.97/0.85 = 8.2''$

- CHECK $f_s > f_y$

$f_s = \varepsilon_u / c (d-c) = 0.003/8.2(31-8.2) = 0.0083 > 0.005$ ∴ OK $\phi = 0.9$

$\phi M_n = \phi A_s f_y (d - a/2) = 0.9(9.48)(60)(31 - 6.97/2) = 14085.5$ k-in

$\boxed{\phi M_n = 1173.8 \text{ k-ft} > M_u = 1102 \text{ k-ft} \therefore OK}$

MEMBER DESIGN CONTINUED:

· CHECK SHEAR

$V_n = V_c + V_s$ $\phi V_n \geq V_u$

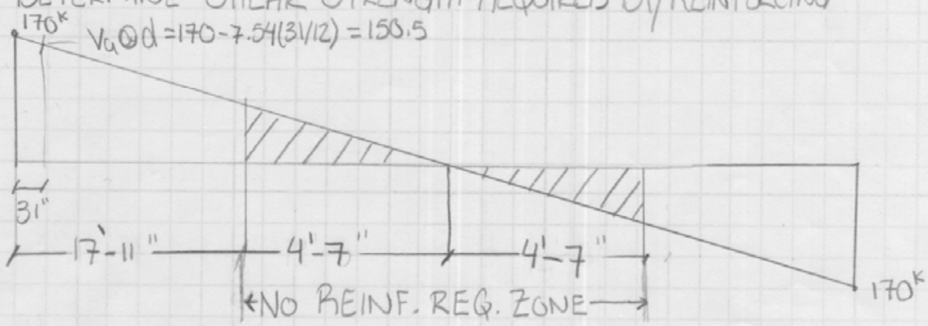
· SHEAR STRENGTH OF CONC. BM w/o STIRRUPS

$V_c = 2\lambda\sqrt{f'c}\, b w d$

$= 2(1)\sqrt{4000}(24)(31) = 94.1^K$

$\phi V_n = 0.5\, \phi V_c = 0.5(0.75)(94.1) = 35.3^K$

· DETERMINE SHEAR STRENGTH REQUIRED BY REINFORCING



$W_u = [(125+8) \times 24' + (34/12 \cdot 24/12 \cdot 150)]\, 1.2 + (1.6)(24')(70) = 7.54$ klf

$V_s = \frac{V_u}{\phi} - V_c = \frac{150.5}{0.75} - 94.1 = 106.6^K$

$V_s \leq 8\sqrt{f'c}\, b w d = 8\sqrt{4000}(24)(31)/1000 = 376.4^K$

$106.6^K < 376.4^K$ ∴ OK

· DETERMINE MAXIMUM SPACING OF SHEAR REINF.

IF $V_s \leq 4\sqrt{f'c}\, b w d = 188.2^K$ THEN $S_{MAX} = \text{MIN} \begin{cases} d/2 = 31/2 = 15.5" \\ 24" \end{cases}$

$V_s = 106.6^K < 188.2$

ELSE $S_{MAX} = \text{MIN} \begin{cases} d/4 \\ 12" \end{cases}$

$\boxed{S = 15"}$

MEMBER DESIGN CONTINUED:

- DETERMINE MINIMUM SHEAR REINF.

$$A_{v,MIN} = MAX \begin{cases} 0.75\sqrt{f'c}\,b_w S/f_{yt} = 0.75\sqrt{4000}\,(24)(15)/60\,000 = 0.285\,IN^2 \\ 50\,b_w S/f_{yt} = 50(24)(15)/60\,000 = 0.3\,IN^2 \end{cases}$$

$A_{v,MIN} = 0.3\,IN^2$

USE #3 STIRRUPS @ 15" AS MINIMUM SHEAR REINF.
(3 LEGS = 3(0.11 IN²) = 0.33 IN² > 0.3 IN² ✓OK

- DESIGN SHEAR REINF

$V_s = A_v f_{yt} d/s$

$$s = \frac{A_v f_{yt} d}{V_s} = \frac{0.33(60)(31)}{106.6} = 5.76''$$

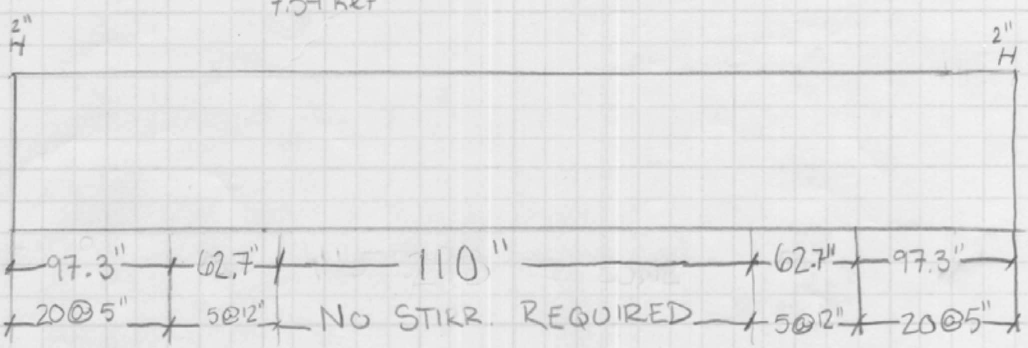
USE (3)#3 @ 5" AT MEMBER ENDS, STARTING 2" FROM FACE OF SUPPORT

- FIND WHERE (3)#3 @ 12" WORKS

$$\phi V_n = \phi V_c + \phi V_s = 0.75\left(94.1 + \frac{0.33(60)(31)}{12}\right) = 108.9375^k$$

DISTANCE WHERE $V_u = 108.9375^k$

$$l_v = \frac{(170 - 108.9)(12''/ft)}{7.54\ klf} = 97.25'' = 8'-1\tfrac{1}{4}''$$



MEMBER DESIGN CONTINUED:

Interior slab thickness design

INTERIOR DESIGN

LOADING:
50 OFFICE LOAD - LIVE
20 PARTITION LOAD - LIVE
8 SUPERIMPOSED DEAD (FOR MEP, ETC)
+ ? CONC SLAB

$W_u = 1.2(8\text{ PSF}) + 1.6(70) = 121.6\text{ PSF}$

MATERIALS:
$f'_c = 4000\text{ PSI}$
$f_y = 60\text{ KSI}$

MINIMUM SLAB THICKNESS:

· ASSUME COLUMNS ARE 24"X24"

$l_n = 24' - 2' = 22'$

· FROM ACI 318-08, TABLE 9.5 $h \geq l_n/28$

$h \geq (22 \times 12)/28$

$h \geq 9.43" \rightarrow \boxed{h = 10"}$

SLAB CONTRIBUTION TO DEAD LOAD

$\text{SLAB WEIGHT} = 150\text{ PCF} \times \frac{10"}{12"/\text{ft}} = 125\text{ PSF}$

$W_{SLAB} = 1.2(125\text{ PSF}) = 150\text{ PSF}$

TOTAL LOAD:

$W_u = 121.6\text{ PSF} + 150\text{ PSF} = 271.6\text{ PSF}$

$\boxed{W_u = 272\text{ PSF}}$

MOMENT VALUES USING ACI COEFFICIENTS

· AT INTERIOR SUPPORTS: $-M = \left(\frac{1}{10}\right) w_u l_n^2 = \left(\frac{1}{10}\right)(272)(22)^2 = 13.165\text{ k-ft}$

· AT MIDSPAN: $+M = \left(\frac{1}{16}\right) w_u l_n^2 = \left(\frac{1}{16}\right)(272)(22)^2 = 8.228\text{ k-ft}$

· UNFACTORED: $M_u = \frac{wl^2}{8} = \frac{(70+8+125)(22)^2}{8} = 12.282\text{ k-ft}$

MEMBER DESIGN CONTINUED:

REQUIRED REINFORCEMENT

- $\rho_{MAX} = 0.85\beta(f'c/fy)\left[\frac{\varepsilon_s}{\varepsilon_s+\varepsilon_t}\right]$

$$\rho_{MAX} = 0.85(0.85)\left(\frac{4}{60}\right)\left[\frac{0.003}{0.003+0.004}\right] = 0.0206$$

- EFFECTIVE DEPTH:

$$bd^2 = 20M_u$$

$$(12'')(d^2) = 20(13.165\ \text{K-ft})$$

$$\boxed{d = 4.68''}$$

- AREA OF STEEL REQUIRED PER FOOT IN TOP OF SLAB:

$$A_s = \frac{M_u}{4d}$$

$$A_s = \frac{13.165}{4 \times 4.68} = 0.703\ \text{in}^2$$

$$\boxed{\text{USE \#8 @ 12'' } (A_s = 0.79\ \text{in}^2)}$$

- AREA OF STEEL REQUIRED PER FOOT @ MIDSPAN:

$$A_s = \frac{M_u}{4d}$$

$$A_s = \frac{8.228}{4 \times 4.68} = 0.4395\ \text{in}^2$$

$$\boxed{\text{USE \#8 @ 12'' } (A_s = 0.79\ \text{in}^2)}$$ (FOR EASE OF CONSTRUCTION)

- MINIMUM STEEL FOR SHRINKAGE + TEMPERATURE

$$A_{s\,MIN} = 0.0018(12'')(10'') = 0.216\ \text{in}^2$$

$$A_{s\,MIN} = 0.216\ \text{in}^2 < A_s = 0.31\ \text{in}^2 \ \therefore \text{OK}$$

$$\boxed{\text{USE \#5 @ 12'' O.C.}}$$

MEMBER DESIGN CONTINUED:

- CHECK SHEAR
  - SHEAR IN END MEMBERS @ FIRST INTERIOR SUPPORT

$$V_u = \frac{1.15 w_u l_n}{2} = \frac{1.15(0.272)(22)}{2} = 3.44\ K$$

  - SHEAR AT OTHER SUPPORTS

$$V_u = \frac{W_u l_n}{2} = \frac{(0.272)(22)}{2} = 2.99^{K}$$

- ALLOWABLE SHEAR

$$\phi V_n = 0.75(2)\sqrt{f'c}\ bd$$

$$\phi V_n = 0.75(2)\sqrt{4000}(12)(4.68)$$

$$\phi V_n = 4.97^{K}$$

$$\boxed{V_u < \phi V_n \quad \therefore OK}$$

- DEFLECTION CHECK (TABLE 9.5 CONFIRMATION)

$$\Delta = \frac{5 w l^4}{384\ EI}$$

$$I = \frac{(24' \times 12''/1')(12'')^3}{12} = 41472\ \text{IN}^4$$

$$E = 57000\sqrt{4000} = 3605\ \text{KSI}$$

$$\Delta = \frac{5(0.272\ \text{KSF})(45')(24')^4(1728)}{384(3605\ \text{KSI})(41472\ \text{IN}^4)} = 0.611''$$

$$\Delta_{MAX} = \frac{l}{240} = \frac{24 \times 12}{240} = 1.2''$$

$$\boxed{\Delta_{MAX} > \Delta \quad \therefore OK}$$

MEMBER DESIGN CONTINUED: Third Floor Green Roof Slab Design

LOADING: 50 PSF DEAD
100 PSF LIVE
+ SELF

$W_u = 1.2(50) + 1.6(100) = 220 \text{ PSF}$

MATERIALS: $f'c = 4000 \text{ PSI}$
$f_y = 60 \text{ KSI}$

MINIMUM SLAB THICKNESS

- ASSUME COLUMNS ARE 24"x24"

$l_n = 24' - 2' = 22'$

- FROM ACI 318-08, TABLE 9.5 $h \geq l_n/28$

$h \geq (22 \times 12)/28$

$h \geq 9.43" \rightarrow h = 10"$

SLAB CONTRIBUTION TO DEADLOAD

$\text{SLAB WT} = 150 \text{ PCF} \times \frac{10"}{12"/\text{ft}} = 125 \text{ PSF}$

$W_{SLAB} = 1.2(125) = 150 \text{ PSF}$

TOTAL LOAD:

$W_u = 220 \text{ PSF} + 150 \text{ PSF} = 370 \text{ PSF}$

$\boxed{W_u = 370 \text{ PSF}}$

MOMENT VALUES USING ACI COEFFCIENTS

- AT INTERIOR SUPPORTS: $-M = \left(\frac{1}{10}\right) W_u l_n^2 = \frac{1}{10}(370)(22)^2 = 17.91 \text{ K-ft}$
- AT MIDSPAN: $+M = \frac{1}{16} W_u l_n^2 = \frac{1}{16}(370)(22)^2 = 11.19 \text{ K-ft}$
- UNFACTORED: $M_a = \frac{w l^2}{8} = \frac{(50+100+125)(22)^2}{8} = 16.64 \text{ K-ft}$

MEMBER DESIGN CONTINUED:

REQUIRED REINFORCEMENT

- $\rho_{MAX} = 0.85\beta(f'c/fy)\left[\frac{\varepsilon_s}{\varepsilon_s + \varepsilon_t}\right]$

$$\rho_{MAX} = 0.85(0.85)(4/60)\left[\frac{0.003}{0.003+0.004}\right] = 0.0206$$

- EFFECTIVE DEPTH:

$$bd^2 = 20Mu$$

$$(12'')(d^2) = 20(16.64 \text{ k-ft})$$

$$\boxed{d = 5.27''}$$

- AREA OF STEEL REQUIRED PER FOOT IN TOP OF SLAB:

$$As = \frac{Mu}{4d} = \frac{16.64}{4 \times 5.27} = 0.789 \text{ IN}^2$$

$$\boxed{\text{USE \#8 @ 12'' } (As = 0.79 \text{ IN}^2)}$$

- AREA OF STEEL REQUIRED PER FOOT @ MIDSPAN:

$$As = \frac{Mu}{4d} = \frac{11.19}{4 \cdot 5.27} = 0.531 \text{ IN}^2$$

$$\boxed{\text{USE \#8 @ 12'' } (As = 0.79 \text{ IN}^2)}$$

- MINIMUM STEEL FOR SHRINKAGE + TEMPERATURE:

$$As_{MIN} = 0.0018(12'')(10'') = 0.216 \text{ IN}^2$$

$$As_{MIN} = 0.216 \text{ IN}^2 < As = 0.31 \text{ IN}^2 \quad \therefore \text{OK}$$

$$\boxed{\text{USE \#5 @ 12'' O.C.}}$$

MEMBER DESIGN CONTINUED:

- CHECK SHEAR
  - SHEAR IN END MEMBERS @ FIRST INTERIOR SUPPORT

$$V_u = \frac{1.15 w_u l_n}{2} = \frac{1.15(0.37)(22)}{2} = 4.68\text{ k}$$

  - SHEAR AT OTHER SUPPORTS

$$V_u = \frac{w_u l_n}{2} = \frac{(0.37)(22)}{2} = 4.07\text{k}$$

  - ALLOWABLE SHEAR

$$\phi V_n = 0.75(2)\sqrt{f'c}\,bd$$

$$\phi V_n = 0.75(2)\sqrt{4000}\,(12)(5.27)$$

$$\phi V_n = 6^k$$

$$\boxed{\phi V_n = 6^k > V_u = 4.68^k \therefore OK}$$

MEMBER DESIGN CONTINUED: TOP FLOOR GREEN ROOF SLAB DESIGN

LOADING: 8 PSF DEAD
100 PSF LIVE
+SELF

$W_u = 1.2(8) + 1.6(100) = 169.6\text{ PSF}$

MATERIALS: $f'c = 4000\text{ PSI}$
$f_y = 60\text{ KSI}$

MINIMUM SLAB THICKNESS

- ASSUME 24"x24" COLUMNS

$\ell_n = 24' - 2' = 22'$

- FROM ACI 318-08, TABLE 9.5 $h \geq \ell_n/28$

$h \geq (22 \times 12)/28$

$h \geq 9.43'' \rightarrow h = 10''$

SLAB CONTRIBUTION TO DEADLOAD

SLAB WT $= 150\text{ PCF} \times \frac{10''}{12''/ft} = 125\text{ PSF}$

$W_{SLAB} = 1.2(125) = 150\text{ PSF}$

TOTAL LOAD:

$W_u = 170\text{ PSF} + 150\text{ PSF} = 320\text{ PSF}$

$\boxed{W_u = 320\text{ PSF}}$

MOMENT VALUES USING ACI COEFFCIENTS:

- AT INTERIOR SUPPORTS: $-M = \left(\frac{1}{10}\right) W_u \ell_n^2 = \frac{1}{10}(0.32)(22)^2 = 15.49\text{ k-ft}$
- AT MIDSPAN: $+M = \frac{1}{16} W_u \ell_n^2 = \frac{1}{16}(0.32)(22)^2 = 9.68\text{ k-ft}$
- UNFACTORED: $M_u = \frac{w\ell^2}{8} = \frac{(100+8+125)(22)^2}{8} = 14.1\text{ k-ft}$

MEMBER DESIGN CONTINUED:

REQUIRED REINFORCEMENT

- $\rho_{MAX} = 0.85(0.85)(4/60)\left[\frac{0.03}{0.03+0.07}\right] = 0.0206$

- EFFECTIVE DEPTH:

  $bd^2 = 20M_u$

  $12d^2 = 20(14.1) \rightarrow \boxed{d = 4.85''}$

- AREA OF STEEL REQUIRED PER FOOT IN TOP OF SLAB:

  $A_s = \frac{M_u}{4d} = \frac{14.1}{4 \times 4.85} = 0.727\ IN^2$

  $\boxed{\text{USE \#8 @ 12'' } (A_s = 0.79\ IN^2)}$

- AREA OF STEEL REQUIRED PER FOOT @ MIDSPAN:

  $A_s = \frac{M_u}{4d} = \frac{9.68}{4 \times 4.85} = 0.50\ IN^2$

  $\boxed{\text{USE \#8 @ 12'' } (A_s = 0.79\ IN^2)}$

- MINIMUM STEEL REQ'D FOR SHRINKAGE + TEMPERATURE:

  $A_{S_{MIN}} = 0.0018(12'')(10'') = 0.216\ IN^2$

  $A_{S_{MIN}} = 0.216\ IN^2 < A_s = 0.31\ IN^2 \therefore OK$ $\boxed{\text{USE \#5 @ 12'' O.C.}}$

- CHECK SHEAR

- SHEAR IN END MEMBER @ FIRST INT. SUPPORT

  $V_u = \frac{1.15 w_u l_n}{2} = \frac{1.15(0.32)22}{2} = 4.048\ K$

- SHEAR @ OTHER SUPPORTS

  $V_u = \frac{w_u l_n}{2} = \frac{0.32(22)}{2} = 3.52\ K$

- ALLOWABLE SHEAR

  $\phi V_n = 0.75(2)\sqrt{4000}(12)(4.85) = 5.52^K$

  $\boxed{\phi V_n = 5.52^K > V_u = 4.05^K \therefore OK}$

MEMBER CHECK CONTINUED: LATERAL BEAM GIRDER CHECK

GIRDER CHECK

LATERAL END MOMENT = 290^{1K} [EQ LOAD]

LOADING : DEAD = 125 PSF + 8 PSF + 850 PLF

LIVE = 50 PSF + 20 PSF

$$W_u = 1.2(125+8)(12)+1.2(850)+1.6(50+20)(12)$$

$$W_u = 4279.2\ \text{PLF}$$

MAXIMUM MOMENT DETERMINATION

GRAVITY

$$M_{MAX@ENDS} = \frac{wl^2}{12} = \frac{(4.28\ \text{KLF})(36')^2}{12} = 462.2\ \text{K-ft}$$

$$M_{MAX@MID} = \frac{wl^2}{24} = \frac{(4.28\ \text{KLF})(36')^2}{24} = 231.1\ \text{K-ft}$$

GRAVITY + LATERAL [1.2D+1.6L+1.0E]

$$M_{MAX@ENDS} = 462.2\ \text{K-ft} + 290\ \text{K-ft} = 752.2\ \text{K-ft}$$

$$M_{MAX@MID} = 231.1\ \text{K-ft} + 290\ \text{K-ft} = 521.1\ \text{K-ft}$$

BM HAS (8) #8's IN 2 ROWS

$\therefore d = 31''$

$A_s = 8(0.79\ \text{IN}^2) = 6.32\ \text{IN}^2$

$$\phi M_n = \phi A_s f_y(d - a/2) \rightarrow a = \frac{A_s f_y}{0.85 f'_c b} = \frac{(6.32)(60)}{0.85(4)(24)} = 4.647''$$

$$\phi M_n = 0.9(6.32\ \text{IN}^2)(60\ \text{KSI})(31'' - 4.647''/2)$$

$$\phi M_n = 9787\ \text{K-IN} = 815.6\ \text{K-ft} > M_u = 752.2\ \text{K-ft} \checkmark \text{OK}$$

MEMBER CHECK CONTINUED:

CHECK SHEAR

$V_n = V_c + V_s$ $\qquad \phi V_n \geq V_u$

STRENGTH OF CONC

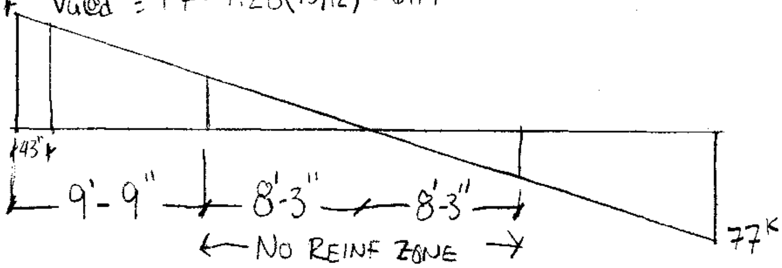
$V_c = 2\lambda\sqrt{f'c}\, b_w \cdot d$

$= 2\sqrt{4000}\,(24)(31) = 94.1^K$

$\phi V_n = 0.5\phi V_c = 0.5(0.75)(94.1) = 35.29^K$

• DETERMINE SHEAR STRENGTH REQ'D BY REINFORCING

77^K $\quad V_u@d = 77 - 4.28(43/12) = 61.7^K$



$V_s = \dfrac{V_u}{\phi} - V_c = \dfrac{61.7}{0.75} - 94.1 = -11.88^K \quad \therefore$ MIN

$V_s \leq 8\sqrt{f'c}\, b_w d = 8\sqrt{4000}(24)(31)/1000 = 376.4^K$ ✓OK

. DETERMINE MAX SPACING

If $V_s \leq 4\sqrt{f'c}\, b_w d = 188.2$ ✓OK THEN $S_{MAX} = \begin{cases} 15.5" \\ 24" \end{cases}$

ELSE $S_{MAX} = \text{MIN}\begin{cases} d/4 \\ 12" \end{cases}$

$\underline{S = 15"}$

MEMBER CHECK CONTINUED:

DETERMINE MIN. SHEAR REINF.

$$A_{V\,MIN} = MAX \begin{cases} 0.75\sqrt{f'_c}\, b_w S/f_{yt} = 0.75\sqrt{4000}(24)(15)/60000 = 0.285\ IN^2 \\ 50 b_w S/f_{yt} = 50(24)(15)/60000 = 0.3\ IN^2 \end{cases}$$

$A_{V\,MIN} = 0.3\ IN^2$

• BM HAS (3)#3 STIRRUPS, $A_s = 0.33\ IN^2 > A_{V\,MIN} = 0.3\ IN^2$ ∴ OK

• CHECK SPACING

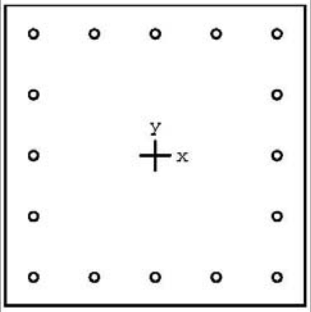
$V_S = A_V f_{yt}\, d/s$

$V_S = -11.9''$ ∴ USE MAX SPACING

$S_{MAX} = 15''$

SPACING ON BM $= 9''$ ∴ OK

MEMBER CHECK CONTINUED: COLUMN C-5 PENTHOUSE LEVEL



24 x 24 in

Code: ACI 318-02

Units: English

Run axis: About X-axis

Run option: Investigation

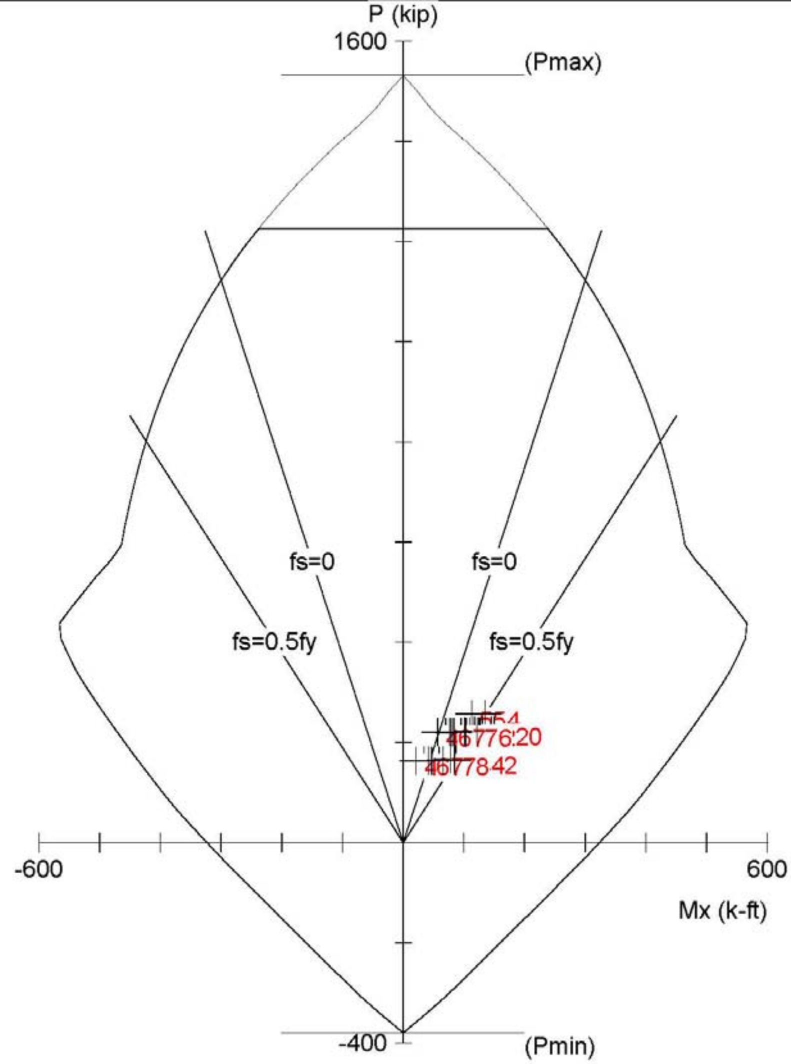
Slenderness: Considered

Column type: Structural

Bars: ASTM A615

Date: 02/28/09

Time: 16:16:48



pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-28F4D

File: G:\thesis stuff\FINAL\PCA\column5-C 6.col

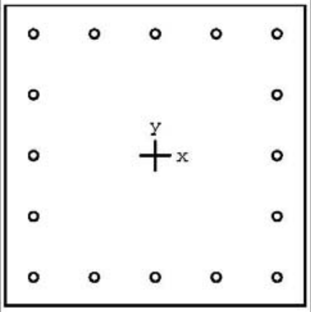
Project:

Column:		Engineer:	
f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	16 #6 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 7.04 in^2	Rho = 1.22%
fc = 3.4 ksi	fc = 3.4 ksi	Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Clear spacing = 4.13 in	Clear cover = 1.88 in

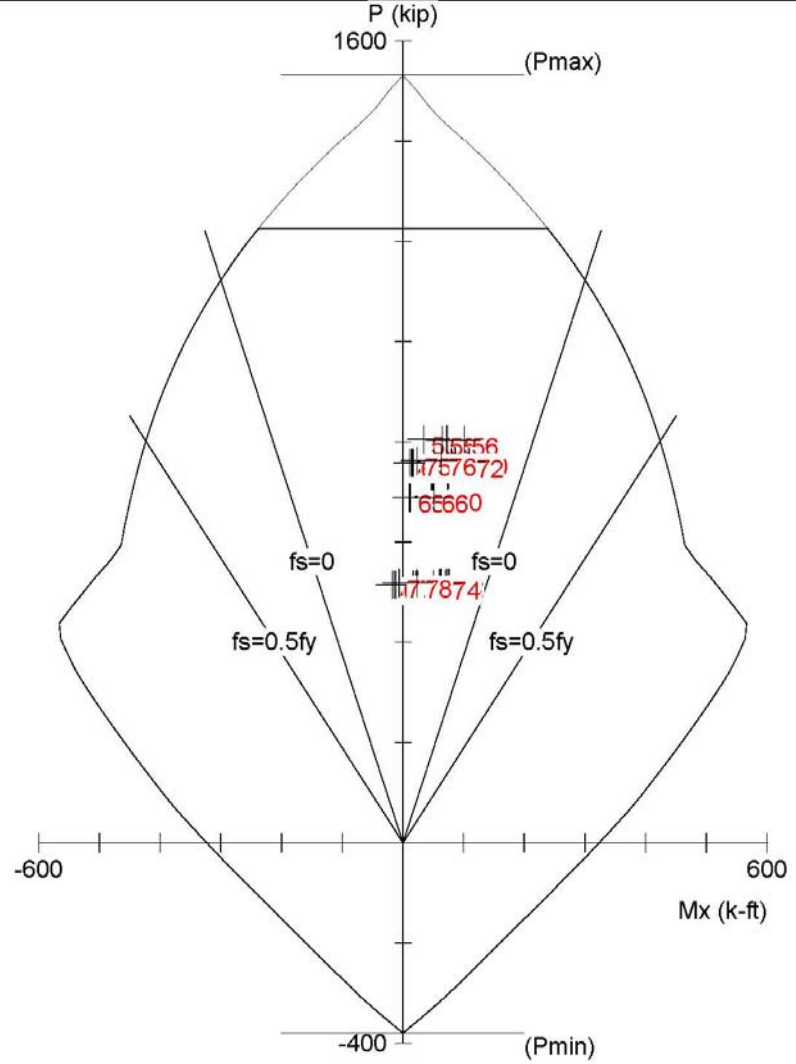
Confinement: Tied phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65

kx(braced) = 0.893474, kx(sway) = N/A

MEMBER CHECK CONTINUED: COLUMN C-5 FIFTH FLOOR



24 x 24 in



Code: ACI 318-02

Units: English

Run axis: About X-axis

Run option: Investigation

Slenderness: Considered

Column type: Structural

Bars: ASTM A615

Date: 02/28/09

Time: 16:11:45

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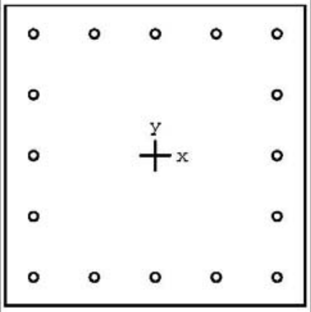
File: G:\thesis stuff\FINAL\PCA\column5-C 5.col

Project:

Column:		Engineer:	
f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	16 #6 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 7.04 in^2	Rho = 1.22%
fc = 3.4 ksi	fc = 3.4 ksi	Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Clear spacing = 4.13 in	Clear cover = 1.88 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

kx(braced) = 0.963329, kx(sway) = N/A

MEMBER CHECK CONTINUED: COLUMN C-5 FOURTH FLOOR



24 x 24 in

Code: ACI 318-02

Units: English

Run axis: About X-axis

Run option: Investigation

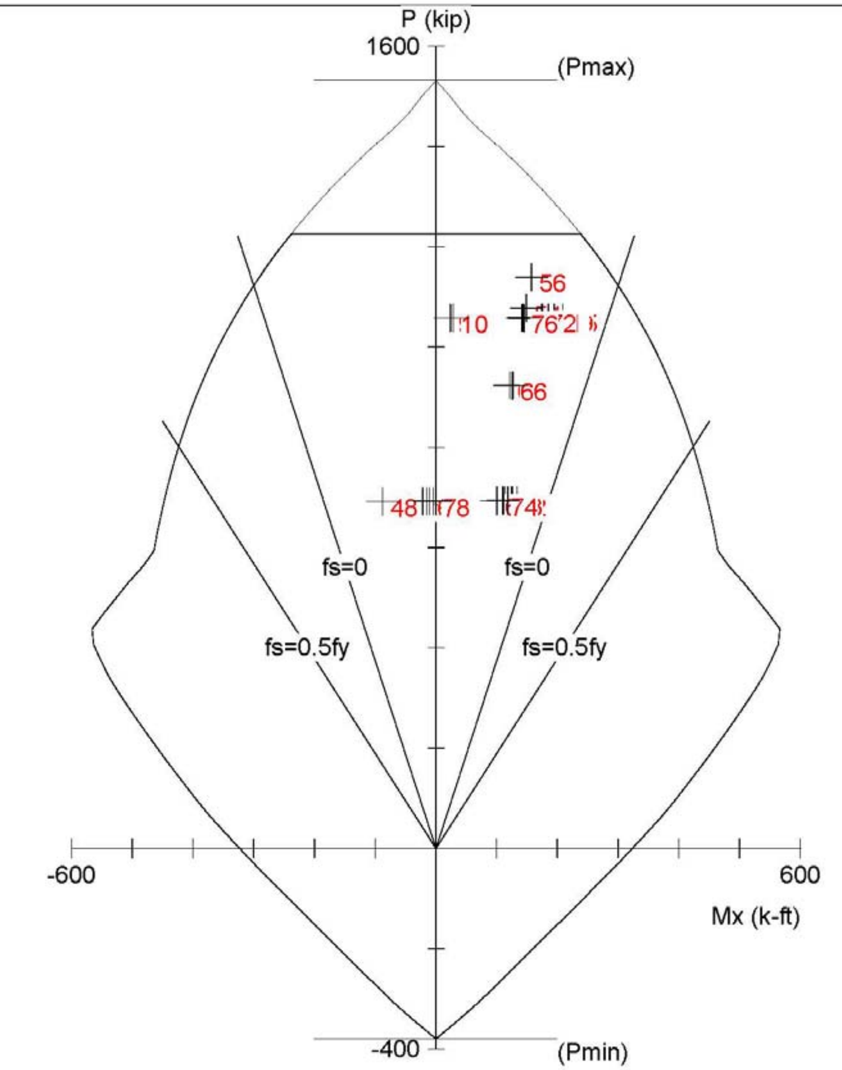
Slenderness: Considered

Column type: Structural

Bars: ASTM A615

Date: 02/28/09

Time: 16:02:02



pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-28F4D

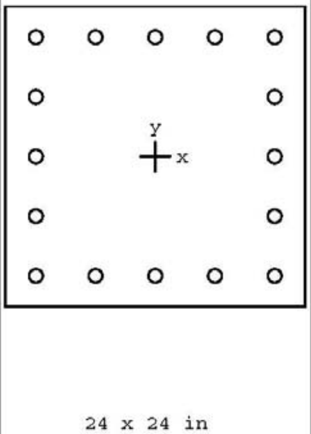
File: G:\thesis stuff\FINAL\PCA\column5-C 4.col

Project:

Column:		Engineer:	
f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	16 #6 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 7.04 in^2	Rho = 1.22%
fc = 3.4 ksi	fc = 3.4 ksi	Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Clear spacing = 4.13 in	Clear cover = 1.88 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

kx(braced) = 0.965049, kx(sway) = N/A

MEMBER CHECK CONTINUED: COLUMN C-5 THIRD FLOOR



Code: ACI 318-02

Units: English

Run axis: About X-axis

Run option: Investigation

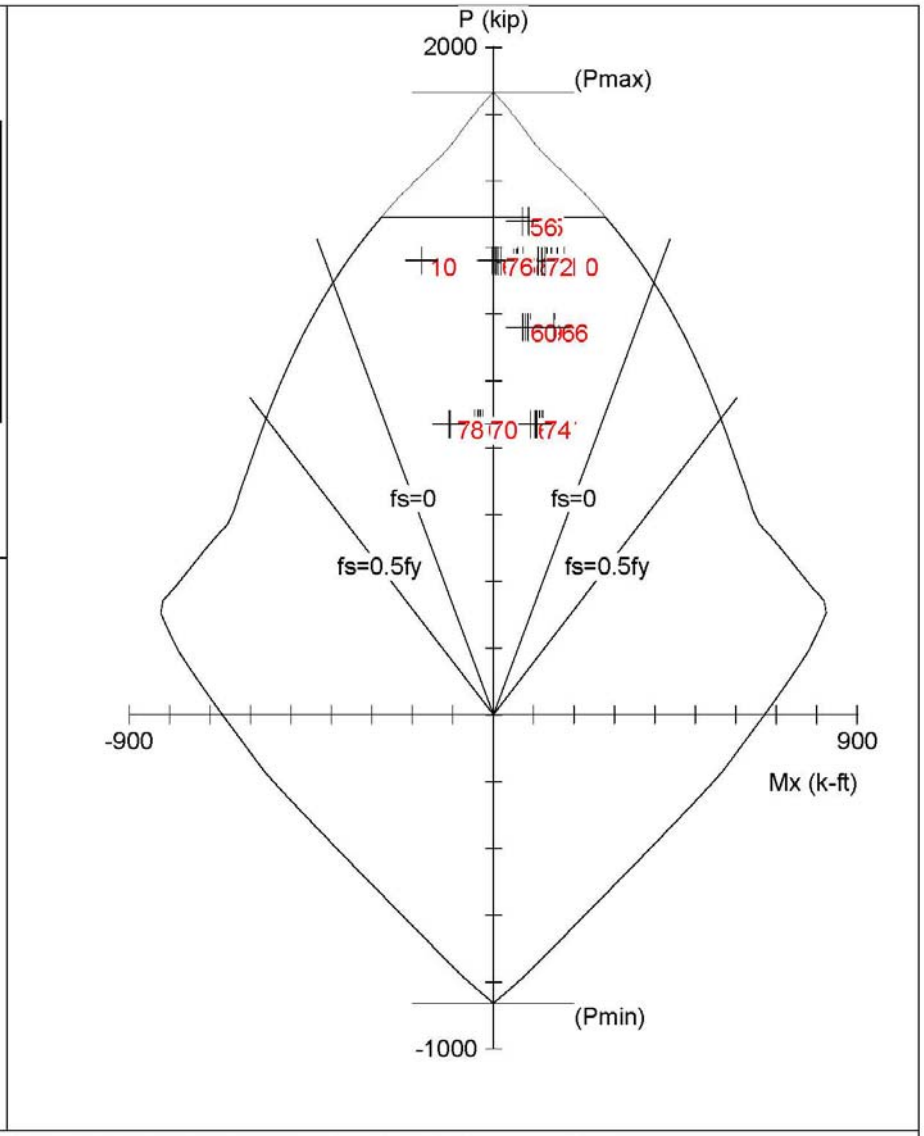
Slenderness: Considered

Column type: Structural

Bars: ASTM A615

Date: 02/28/09

Time: 15:37:36



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File: G:\thesis stuff\FINAL\PCA\column5-C 3.col

Project:

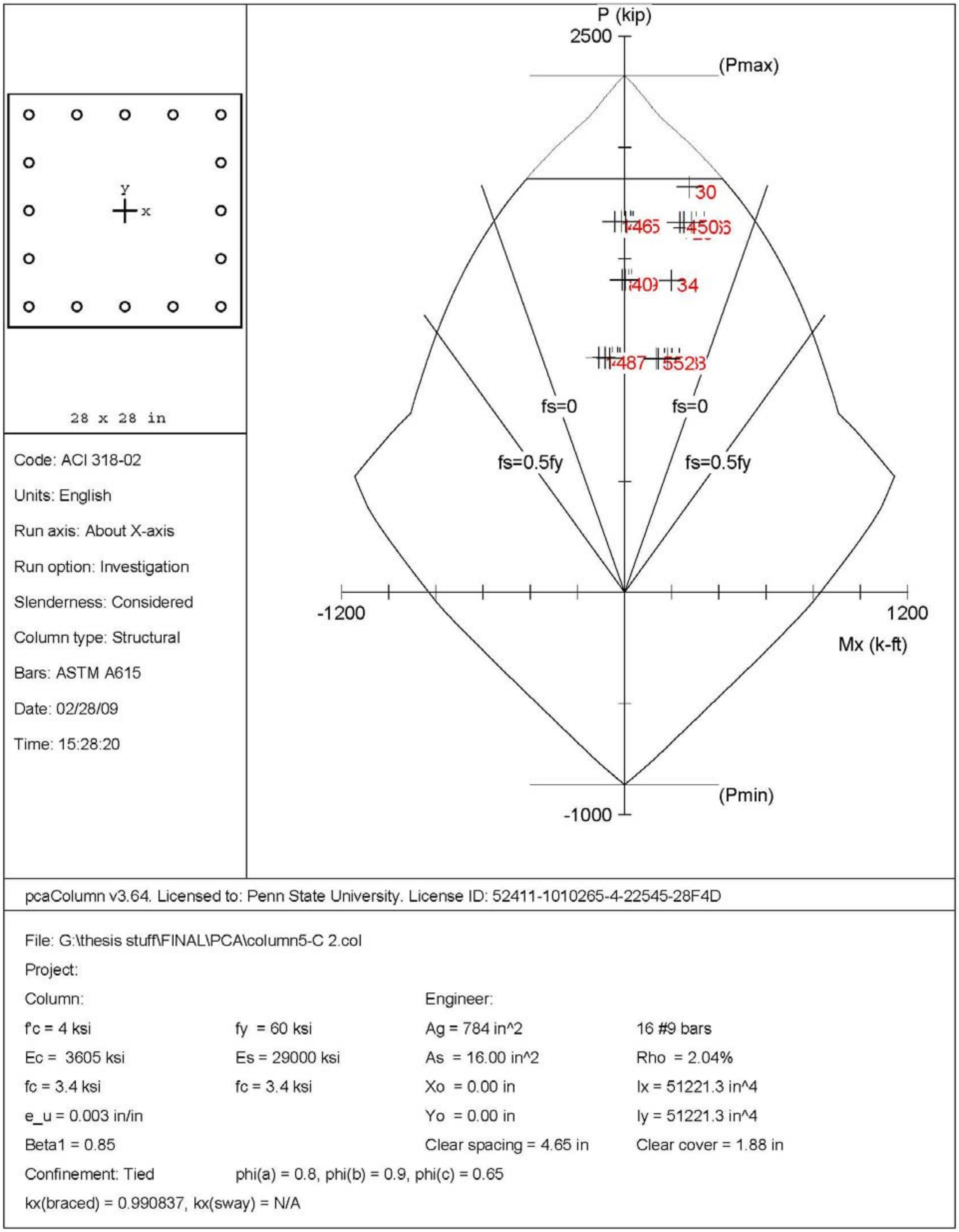
Column: Engineer:

f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	16 #9 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 16.00 in^2	Rho = 2.78%
fc = 3.4 ksi	fc = 3.4 ksi	Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Clear spacing = 3.65 in	Clear cover = 1.88 in

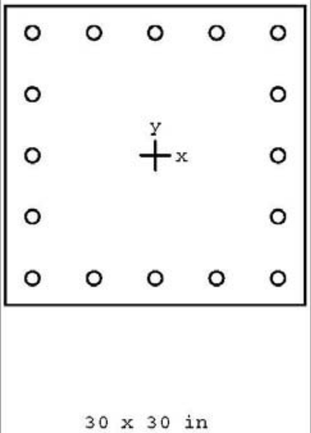
Confinement: Tied phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65

kx(braced) = 0.965049, kx(sway) = N/A

Member Check Continued: Column C-5 Second Floor



MEMBER CHECK CONTINUED: COLUMN C-5 FIRST FLOOR



Code: ACI 318-02

Units: English

Run axis: About X-axis

Run option: Investigation

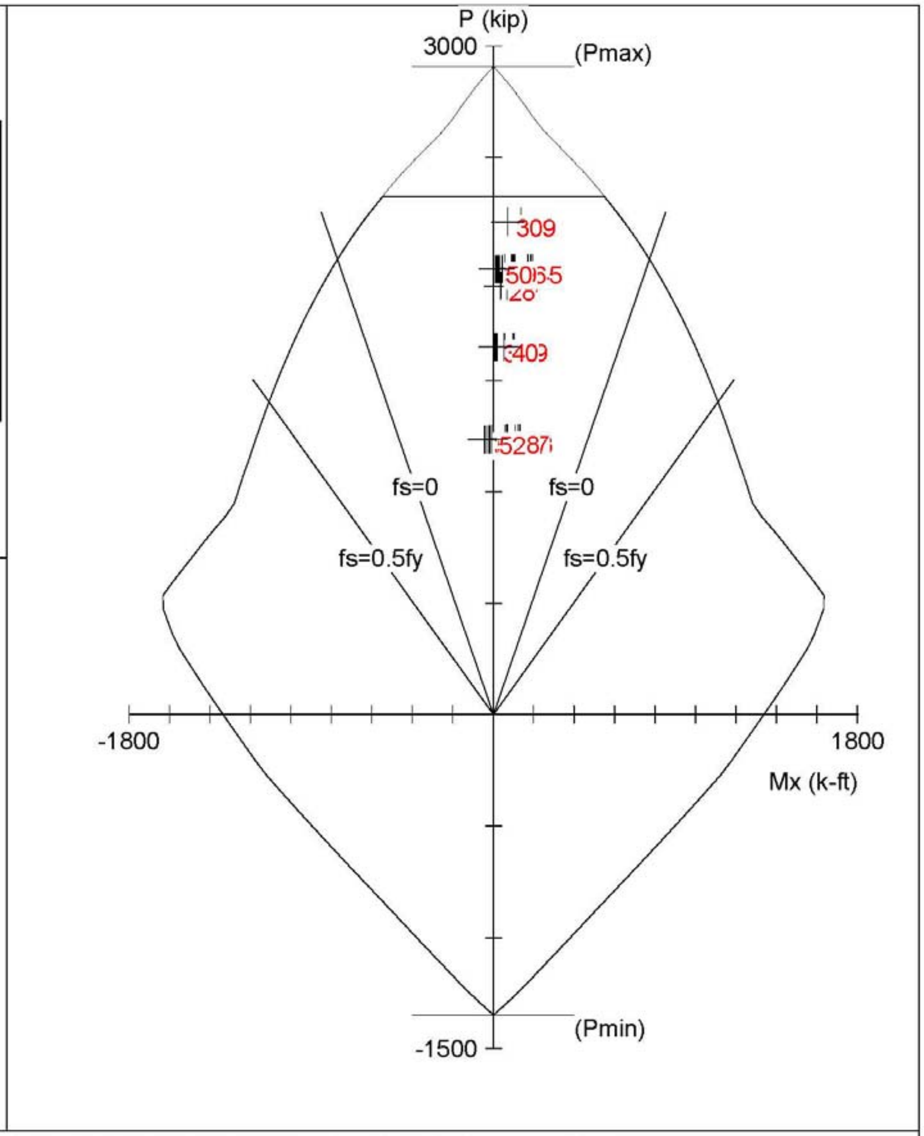
Slenderness: Considered

Column type: Structural

Bars: ASTM A615

Date: 02/28/09

Time: 15:23:33



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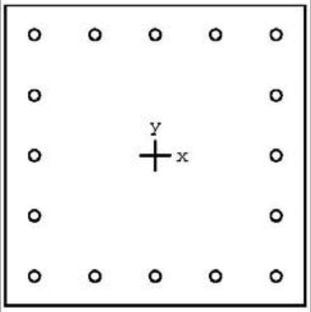
File: G:\thesis stuff\FINAL\PCA\column5-C 1.col

Project:

Column:		Engineer:	
f'c = 4 ksi	fy = 60 ksi	Ag = 900 in^2	16 #11 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 24.96 in^2	Rho = 2.77%
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 = 4.74 in	Clear cover = 2.00 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

kx(braced) = 1, kx(sway) = N/A

MEMBER CHECK CONTINUED: COLUMN D-7.9 PENTHOUSE FLOOR



24 x 24 in

Code: ACI 318-02

Units: English

Run axis: About X-axis

Run option: Investigation

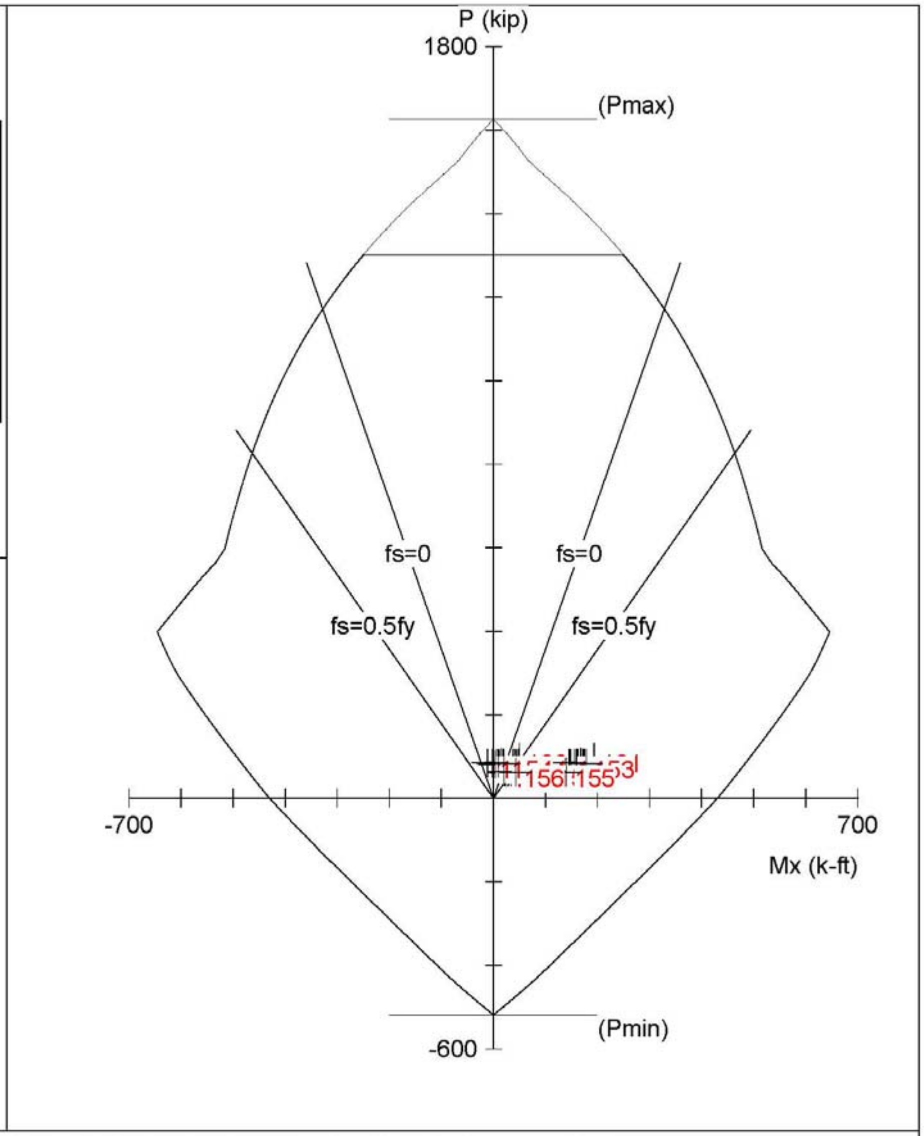
Slenderness: Considered

Column type: Structural

Bars: ASTM A615

Date: 02/28/09

Time: 17:59:57



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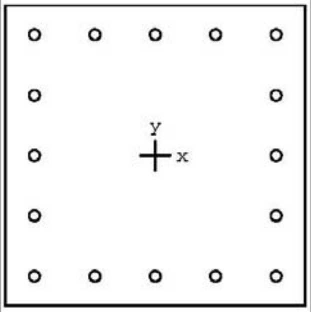
File: G:\thesis stuff\FINAL\PCA\column7.9-D 7.col

Project:

Column: 7.9-D 1		Engineer:	
f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	16 #7 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 9.60 in^2	Rho = 1.67%
fc = 3.4 ksi	fc = 3.4 ksi	Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Clear spacing = 3.97 in	Clear cover = 1.88 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

kx(braced) = 0.893474, kx(sway) = N/A

MEMBER CHECK CONTINUED: COLUMN D-7.9 FIFTH FLOOR



24 x 24 in

Code: ACI 318-02

Units: English

Run axis: About X-axis

Run option: Investigation

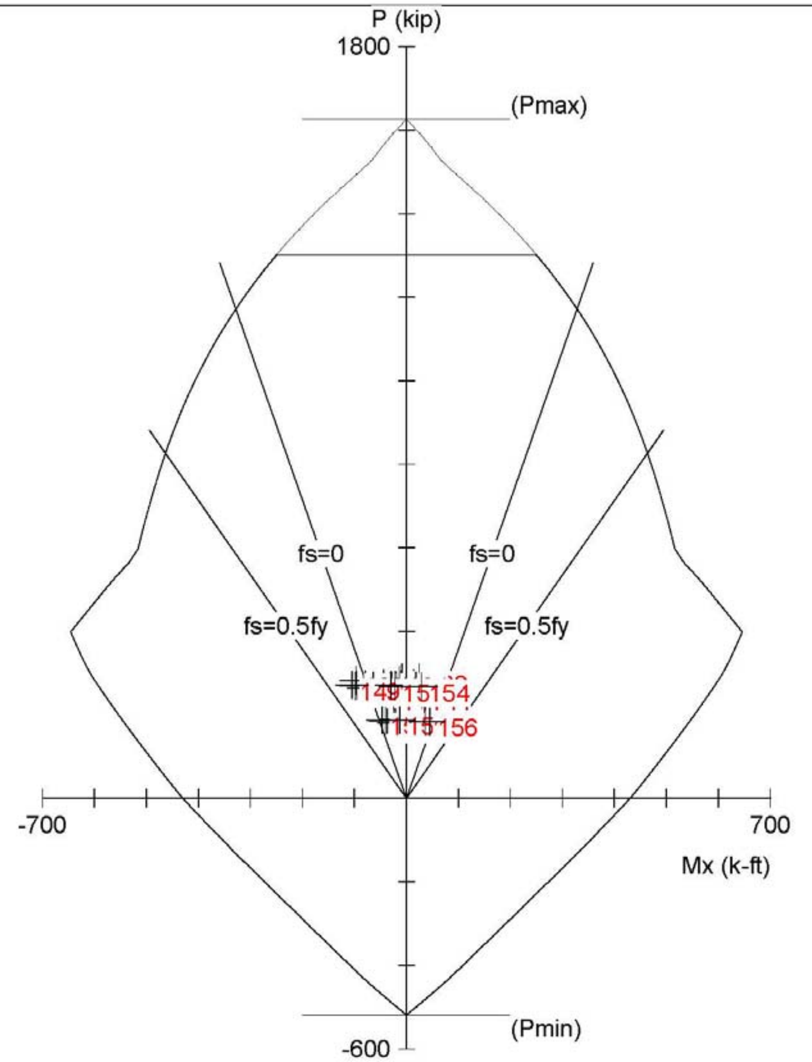
Slenderness: Considered

Column type: Structural

Bars: ASTM A615

Date: 02/28/09

Time: 17:54:00



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File: G:\thesis stuff\FINAL\PCA\column7.9-D 6.col

Project:

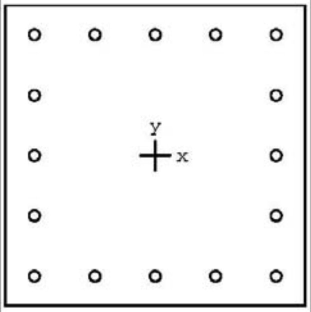
Column: 7.9-D 1 Engineer:

f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	16 #7 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 9.60 in^2	Rho = 1.67%
fc = 3.4 ksi	fc = 3.4 ksi	Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Clear spacing = 3.97 in	Clear cover = 1.88 in

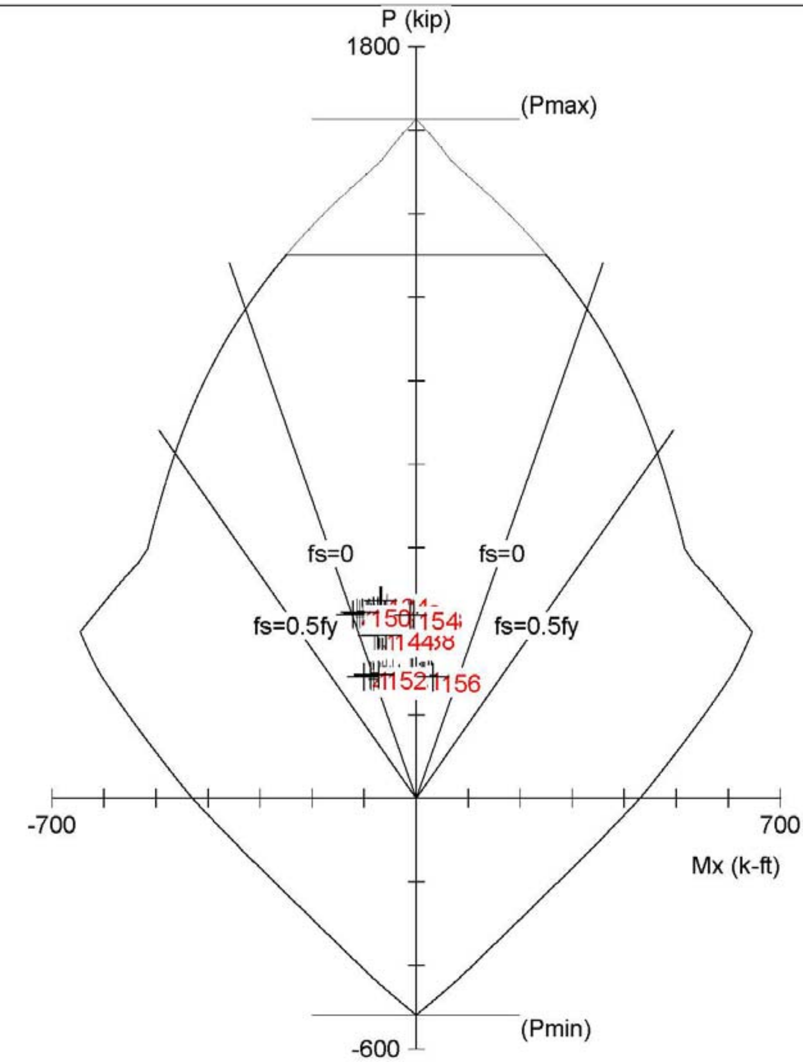
Confinement: Tied phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65

kx(braced) = 0.94993, kx(sway) = N/A

MEMBER CHECK CONTINUED: COLUMN D-7.9 FOURTH FLOOR



24 x 24 in



Code: ACI 318-02

Units: English

Run axis: About X-axis

Run option: Investigation

Slenderness: Considered

Column type: Structural

Bars: ASTM A615

Date: 02/28/09

Time: 17:10:29

pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-28F4D

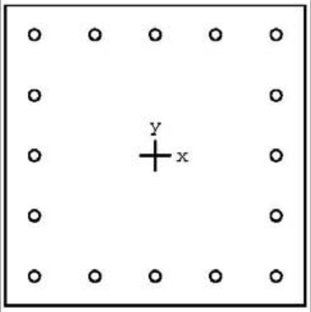
File: G:\thesis stuff\FINAL\PCA\column7.9-D 5.col

Project:

Column: 7.9-D 1		Engineer:	
f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	16 #7 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 9.60 in^2	Rho = 1.67%
fc = 3.4 ksi	fc = 3.4 ksi	Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Clear spacing = 3.97 in	Clear cover = 1.88 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

kx(braced) = 0.96297, kx(sway) = N/A

MEMBER CHECK CONTINUED: COLUMN D-7.9 THIRD FLOOR



24 x 24 in

Code: ACI 318-02

Units: English

Run axis: About X-axis

Run option: Investigation

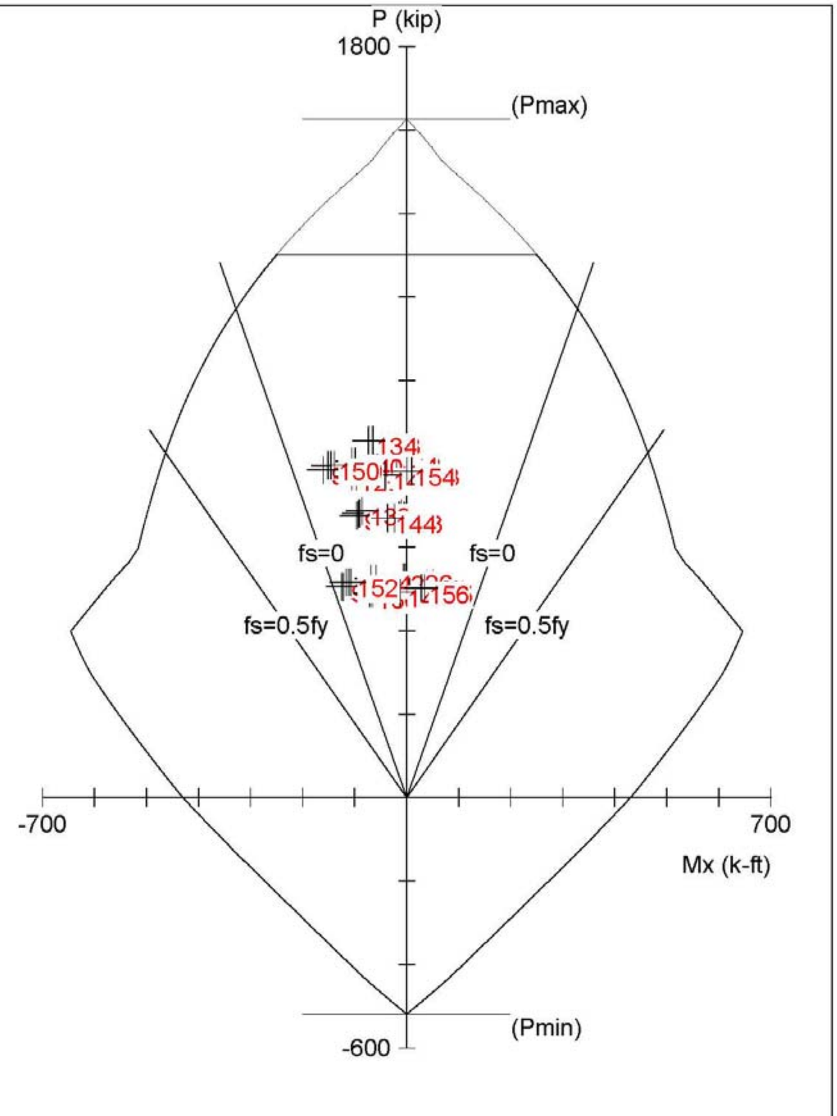
Slenderness: Considered

Column type: Structural

Bars: ASTM A615

Date: 02/28/09

Time: 16:45:24



pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-28F4D

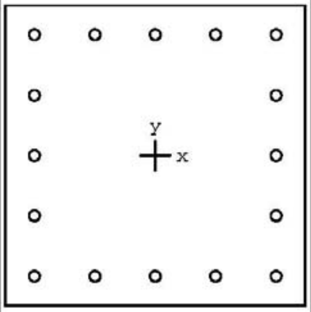
File: G:\thesis stuff\FINAL\PCA\column7.9-D 3.col

Project:

Column: 7.9-D 1		Engineer:	
f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	16 #7 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 9.60 in^2	Rho = 1.67%
fc = 3.4 ksi	fc = 3.4 ksi	Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Clear spacing = 3.97 in	Clear cover = 1.88 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

kx(braced) = 0.95165, kx(sway) = N/A

MEMBER CHECK CONTINUED: COLUMN D-7.9 SECOND FLOOR



24 x 24 in

Code: ACI 318-02

Units: English

Run axis: About X-axis

Run option: Investigation

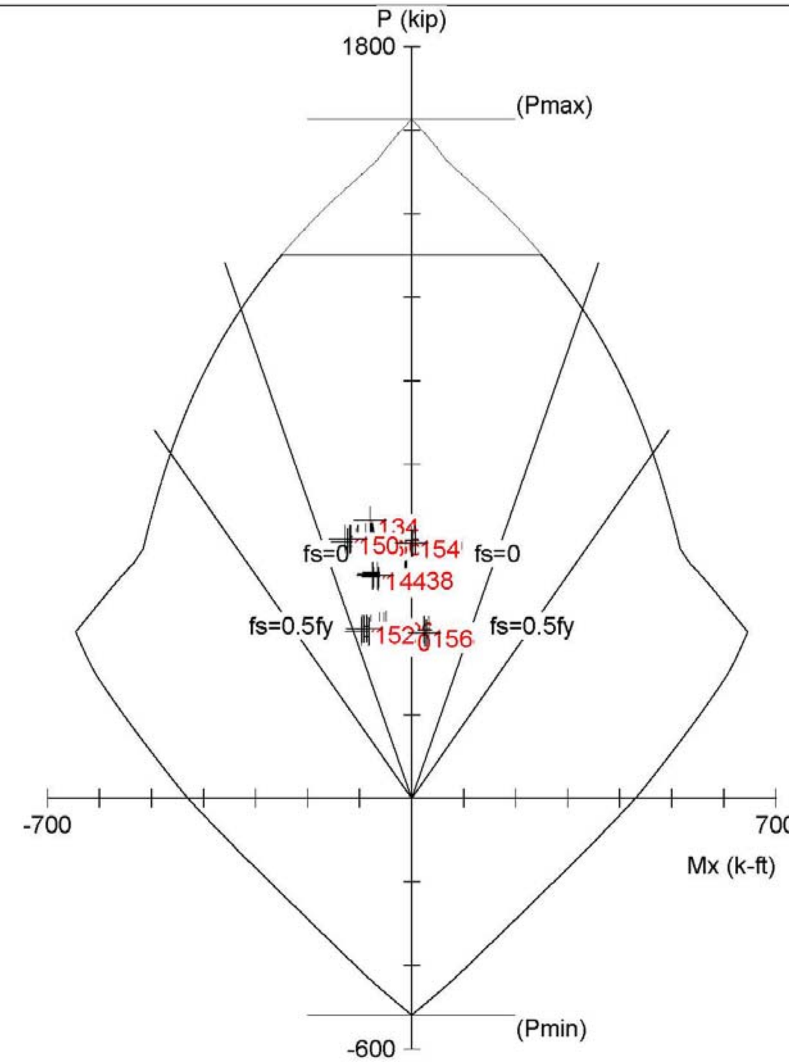
Slenderness: Considered

Column type: Structural

Bars: ASTM A615

Date: 02/28/09

Time: 16:52:51



pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-28F4D

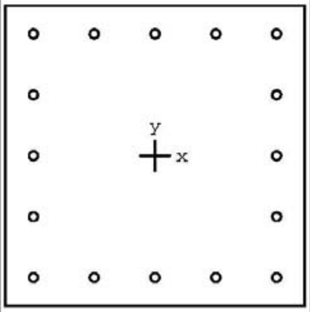
File: G:\thesis stuff\FINAL\PCA\column7.9-D 4.col

Project:

Column: 7.9-D 1		Engineer:	
f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	16 #7 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 9.60 in^2	Rho = 1.67%
fc = 3.4 ksi	fc = 3.4 ksi	Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Clear spacing = 3.97 in	Clear cover = 1.88 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

kx(braced) = 0.965049, kx(sway) = N/A

Member Check Continued: Column D-7.9 First Floor



24 x 24 in

Code: ACI 318-02

Units: English

Run axis: About X-axis

Run option: Investigation

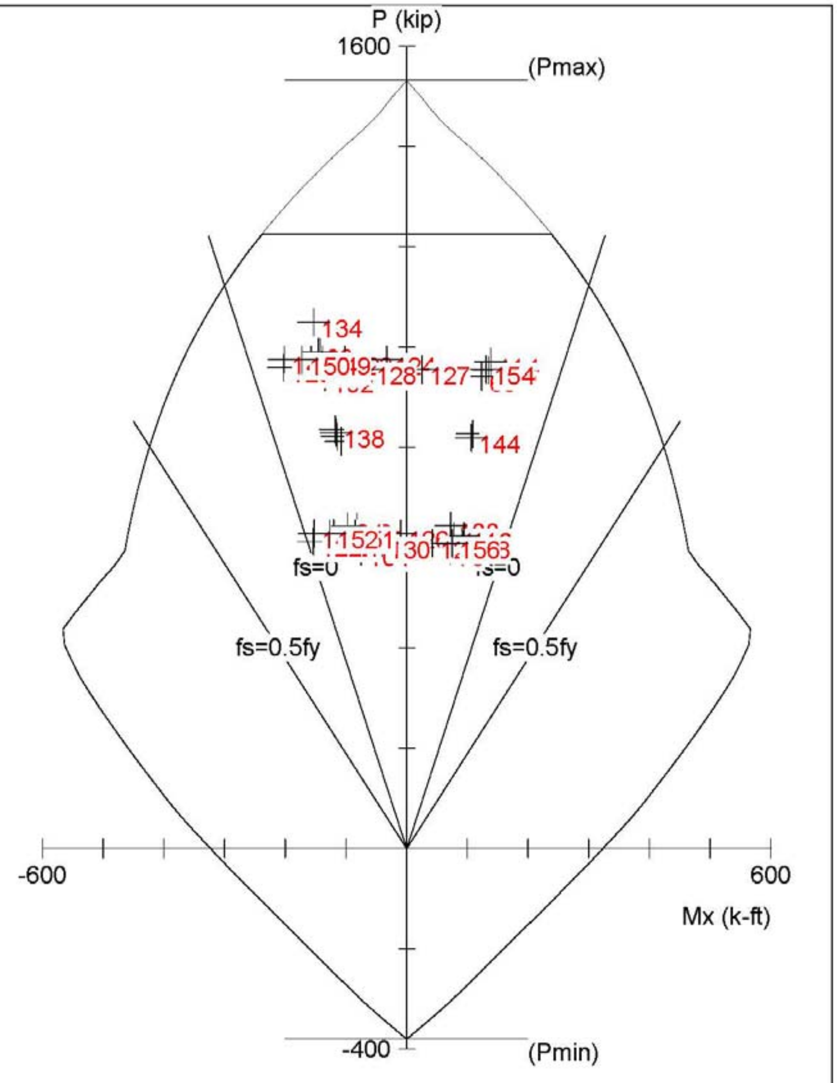
Slenderness: Considered

Column type: Structural

Bars: ASTM A615

Date: 02/28/09

Time: 16:37:43



pcaColumn v3.64. Licensed to: Penn State University. License ID: 52411-1010265-4-22545-28F4D

File: G:\thesis stuff\FINAL\PCA\column7.9-D 2.col

Project:

Column: 7.9-D 1		Engineer:	
f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	16 #6 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 7.04 in^2	Rho = 1.22%
fc = 3.4 ksi	fc = 3.4 ksi	Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Clear spacing = 4.13 in	Clear cover = 1.88 in
Confinement: Tied	phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65		

kx(braced) = 0.94037, kx(sway) = N/A

APPENDIX F: CONSTRUCTION MANAGEMENT BREADTH STUDY

Table 36: Cost Analysis Estimate for Concrete Structure with Green Roof

Detailed Cost Analysis of the Structure									
Level	Description	Amount	Material Price	Material Cost	Labor Price	Labor Cost	Equipment Price	Equipment Cost	Total Cost
Reinforcement	Foundation	58 Ton	$935.00	$54,230	$430.00	$24,940	$30.35	$1,760	$80,930
	Columns	2221 Ton	$935.00	$2,076,635	$430.00	$430.00	$30.35	$67,407	$2,144,472
	Beam/Slabs	572 Ton	$935.00	$534,820	$430.00	$245,960	$30.35	$17,360	$798,140
	SUB-TOTAL	2851	$935.00	$2,665,685	$430.00	$430.00	$30.35	$86,528	$2,752,643
Cast in Place Concrete	Foundations	6100 CY	$109.00	$664,900	$14.90	$90,890	$5.55	$33,855	$789,645
	Columns	1518 CY	$109.00	$165,462	$34.00	$51,612	$16.95	$25,730	$242,804
	Slabs	14192 CY	$109.00	$1,546,928	$18.20	$258,294	$9.15	$129,857	$1,935,079
	Beams	8415 CY	$109.00	$917,235	$26.50	$222,998	$1,320.00	$11,107,800	$12,248,033
	SUB-TOTAL	30225	$109.00	$3,294,525	$23.40	$623,794	$1,352	$11,297,242	$15,215,561
Location Factor: 98.9%	Total Structure Estimate:		$36,077,000			Total Labor Cost:		$896,000	
	Total Material Cost:		$5,961,000			Total Equipment Cost:		$11,384,000	

Table 37: Cost Analysis Estimate for Concrete Structure, No Green Roof

Detailed Cost Analysis of the Structure-No Green Roof									
Level	Description	Amount	Material Price	Material Cost	Labor Price	Labor Cost	Equipment Price	Equipment Cost	Total Cost
Reinforcement	Foundation	58 Ton	$935.00	$54,230	$430.00	$24,940	$30.35	$1,760	$80,930
	Columns	2000 Ton	$935.00	$1,868,972	$430.00	$430.00	$30.35	$60,667	$1,930,068
	Beam/Slabs	544 Ton	$935.00	$470,642	$430.00	$216,445	$30.35	$15,277	$702,363
	SUB-TOTAL	2560	$935.00	$2,393,843	$430.00	$430.00	$30.35	$77,704	$2,471,977
Cast in Place Concrete	Foundations	6100 CY	$109.00	$664,900	$14.90	$90,890	$5.55	$33,855	$789,645
	Columns	1443 CY	$109.00	$157,189	$34.00	$49,031	$16.95	$24,444	$230,664
	Slabs	14192 CY	$109.00	$1,546,928	$18.20	$258,294	$9.15	$129,857	$1,935,079
	Beams	7574 CY	$109.00	$917,235	$26.50	$222,998	$1,320.00	$11,107,800	$12,248,033
	SUB-TOTAL	30149	$109.00	$3,286,252	$23.40	$621,213	$1,352	$11,295,955	$15,203,421
Location Factor: 98.9%	Total Structure Estimate:		$35,440,000			Total Labor Cost:		$864,000	
	Total Material Cost:		$5,681,000			Total Equipment Cost:		$11,374,000	

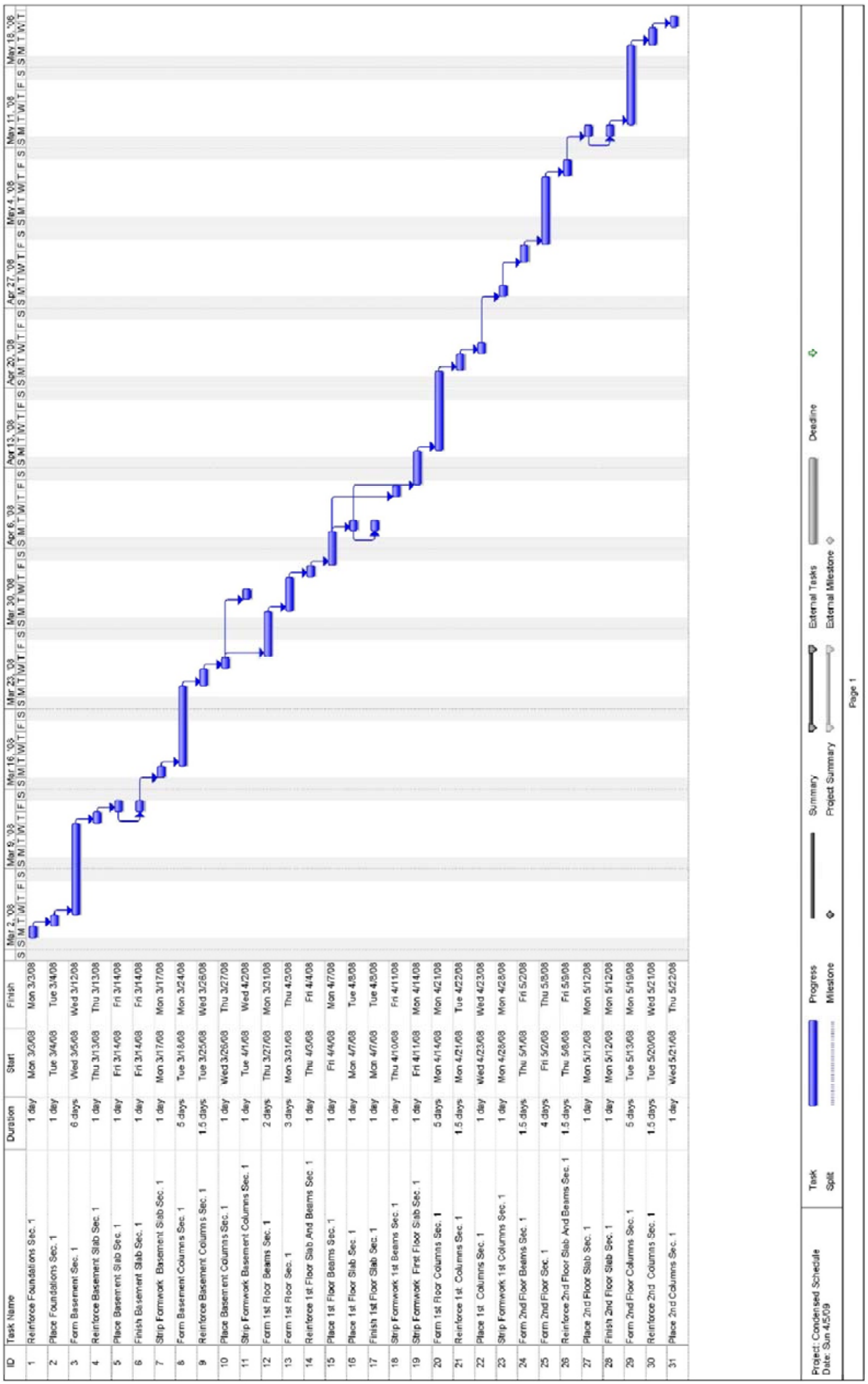


Figure 48: Condensed Gantt Chart

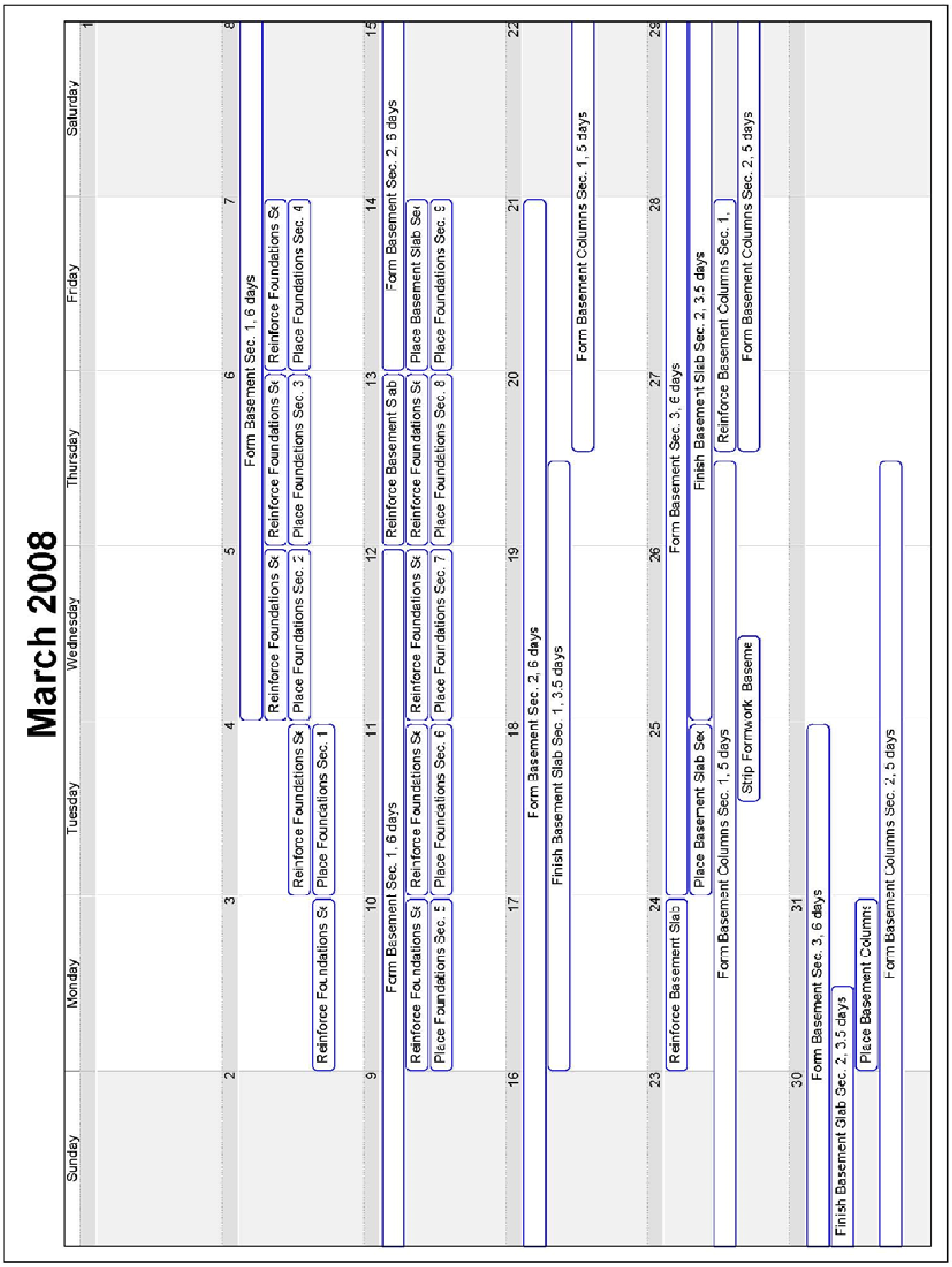


Figure 49: March Schedule Calendar

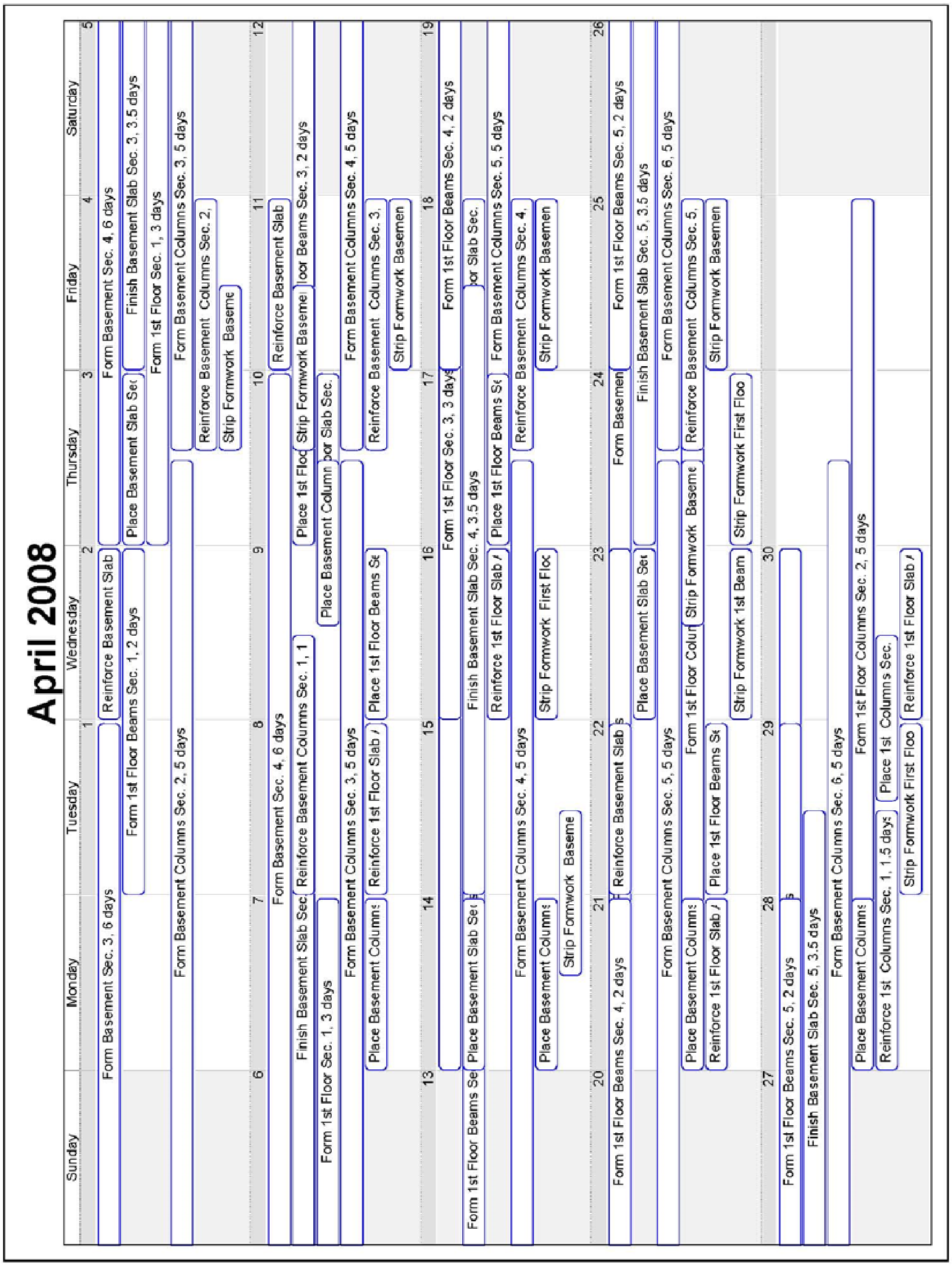


Figure 50: April Schedule Calendar

Overflow Tasks

ID	Name	Start	Finish
498	Place Basement Columns Sec. 1	Fri 4/4/08	Mon 4/7/08
490	Reinforce Basement Columns Sec. 1	Thu 4/3/08	Fri 4/4/08
573	Strip Formwork 1st Beams Sec. 1	Tue 4/15/08	Tue 4/15/08
575	Strip Formwork 1st Beams Sec. 3	Mon 4/28/08	Mon 4/28/08

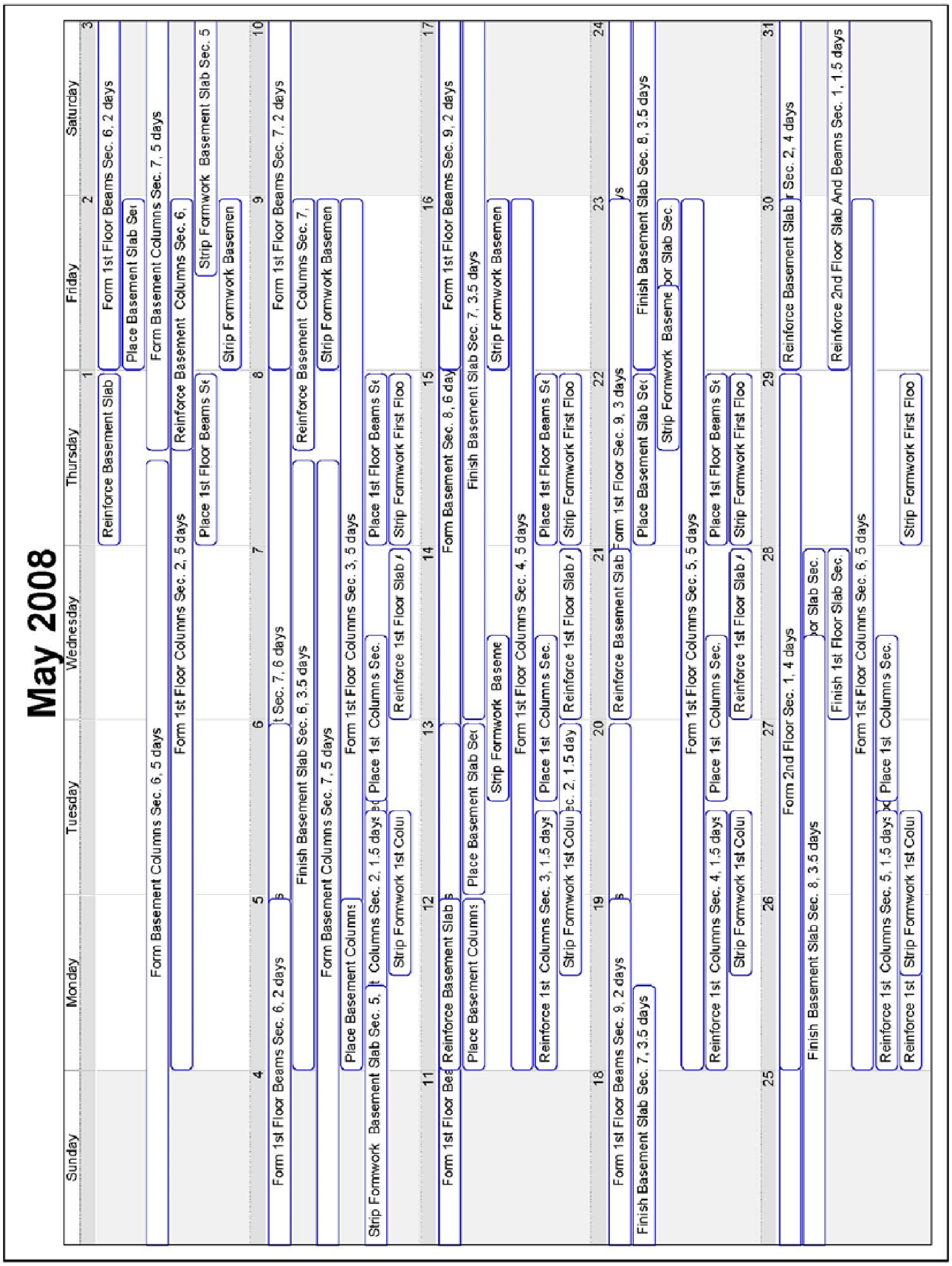


Figure 51: May Schedule Calendar

Overflow Tasks

ID	Name	Start	Finish
576	Strip Formwork 1st Beams Sec. 4	Thu 5/1/08	Thu 5/1/08
577	Strip Formwork 1st Beams Sec. 5	Wed 5/7/08	Wed 5/7/08
578	Strip Formwork 1st Beams Sec. 6	Wed 5/14/08	Wed 5/14/08
206	Form 2nd Floor Beams Sec. 3	Mon 5/19/08	Tue 5/20/08
579	Strip Formwork 1st Beams Sec. 7	Wed 5/21/08	Wed 5/21/08
580	Strip Formwork 1st Beams Sec. 8	Wed 5/28/08	Wed 5/28/08
207	Form 2nd Floor Beams Sec. 4	Mon 5/26/08	Tue 5/27/08

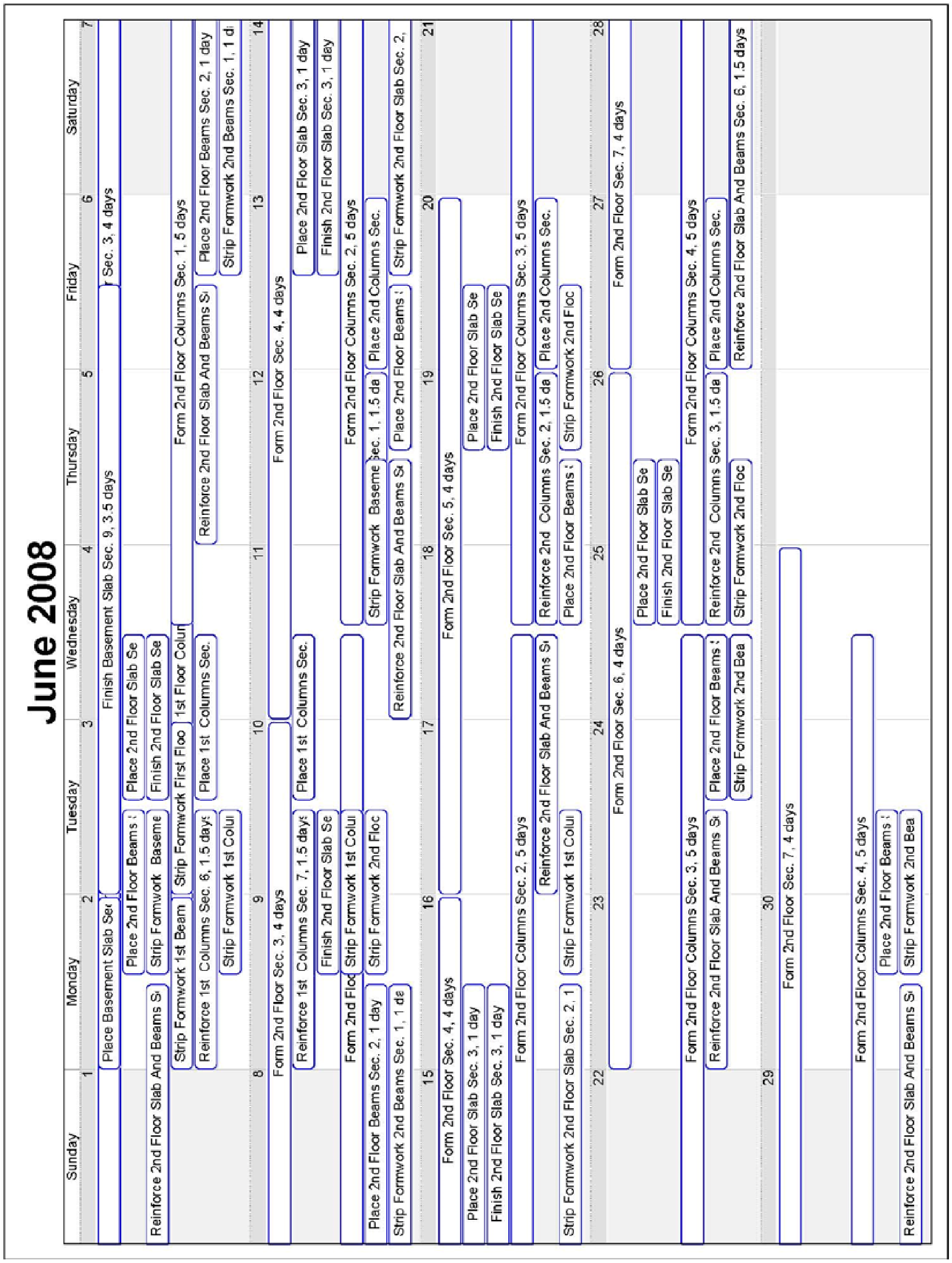


Figure 52: June Schedule Calendar

Overflow Tasks

ID	Name	Start	Finish
208	Form 2nd Floor Beams Sec. 5	Mon 6/2/08	Tue 6/3/08
584	Strip Formwork 2nd Beams Sec. 2	Thu 6/12/08	Fri 6/13/08
209	Form 2nd Floor Beams Sec. 6	Mon 6/9/08	Tue 6/10/08
585	Strip Formwork 2nd Beams Sec. 3	Wed 6/18/08	Thu 6/19/08
645	Strip Formwork 2nd Columns Sec. 1	Thu 6/19/08	Thu 6/19/08
210	Form 2nd Floor Beams Sec. 7	Mon 6/16/08	Tue 6/17/08
211	Form 3rd Floor Beams Sec. 1	Thu 6/19/08	Fri 6/20/08
646	Strip Formwork 2nd Columns Sec. 2	Thu 6/26/08	Thu 6/26/08
212	Form 3rd Floor Beams Sec. 2	Thu 6/26/08	Fri 6/27/08
213	Form 3rd Floor Beams Sec. 3	Fri 6/27/08	Mon 6/30/08

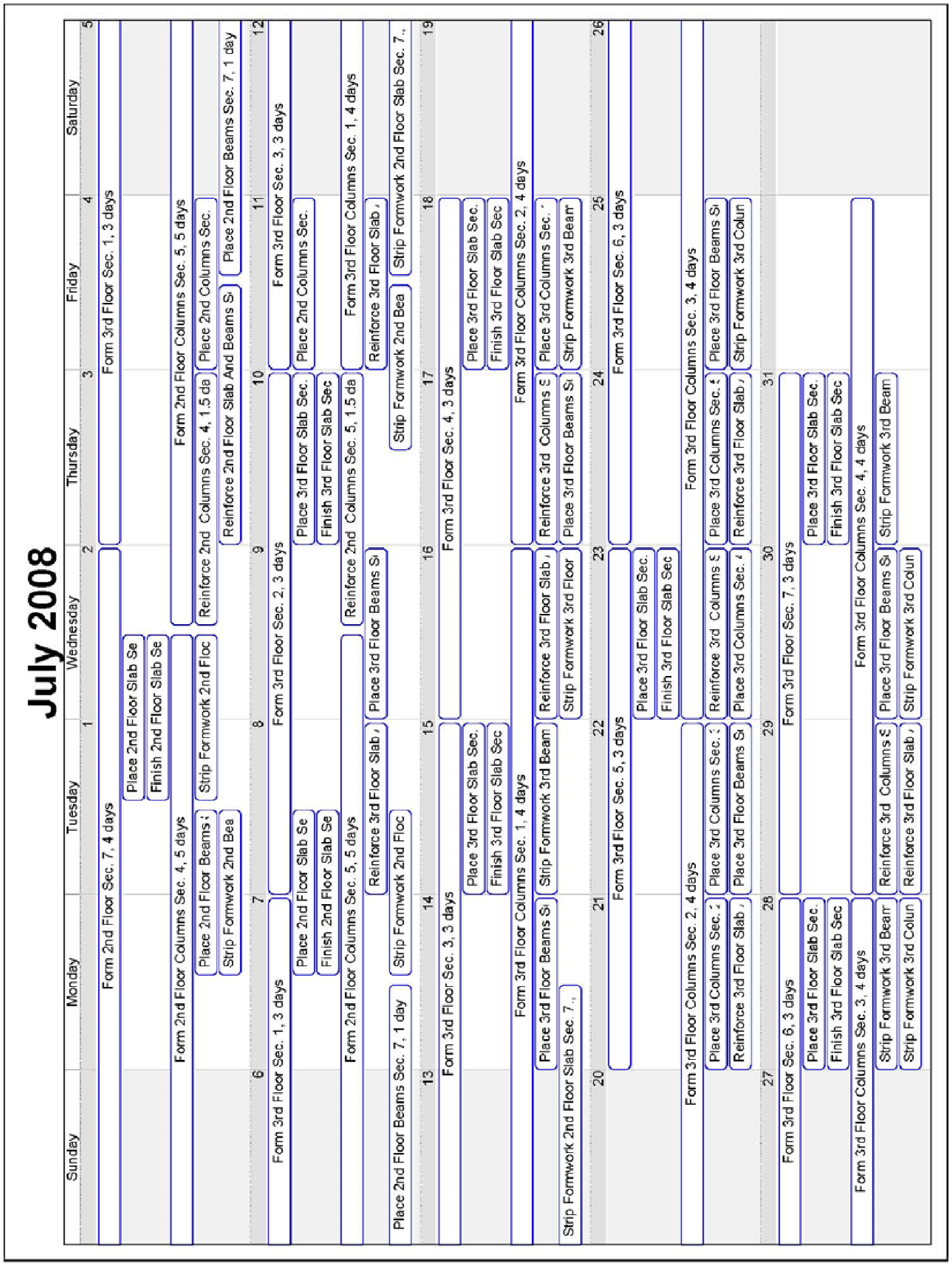


Figure 53: July Schedule Calendar

JULY OVERFLOW TASKS

Overflow Tasks

ID	Name	Start	Finish
588	Strip Formwork 2nd Beams Sec. 6	Fri 7/4/08	Mon 7/7/08
647	Strip Formwork 2nd Columns Sec. 3	Thu 7/3/08	Thu 7/3/08
214	Form 3rd Floor Beams Sec. 4	Thu 7/3/08	Fri 7/4/08
215	Form 3rd Floor Beams Sec. 5	Fri 7/4/08	Mon 7/7/08
648	Strip Formwork 2nd Columns Sec. 4	Thu 7/10/08	Thu 7/10/08
216	Form 3rd Floor Beams Sec. 6	Thu 7/10/08	Fri 7/11/08
217	Form 3rd Floor Beams Sec. 7	Fri 7/11/08	Mon 7/14/08
649	Strip Formwork 2nd Columns Sec. 5	Thu 7/17/08	Thu 7/17/08
218	Form 3rd Floor Beams Sec. 8	Thu 7/17/08	Fri 7/18/08
219	Form 3rd Floor Beams Sec. 9	Fri 7/18/08	Mon 7/21/08
535	Strip Formwork 3rd Floor Slab Sec. 2	Mon 7/21/08	Mon 7/21/08
536	Strip Formwork 3rd Floor Slab Sec. 3	Thu 7/24/08	Thu 7/24/08
593	Strip Formwork 3rd Beams Sec. 3	Wed 7/23/08	Wed 7/23/08
651	Strip Formwork 3rd Columns Sec. 1	Thu 7/24/08	Thu 7/24/08
220	Form 4th Floor Beams Sec. 1	Tue 7/22/08	Wed 7/23/08
221	Form 4th Floor Beams Sec. 2	Thu 7/24/08	Fri 7/25/08
537	Strip Formwork 3rd Floor Slab Sec. 4	Tue 7/29/08	Tue 7/29/08
654	Strip Formwork 3rd Columns Sec. 4	Tue 7/29/08	Tue 7/29/08
222	Form 4th Floor Beams Sec. 3	Mon 7/28/08	Tue 7/29/08
223	Form 4th Floor Beams Sec. 4	Wed 7/30/08	Thu 7/31/08

AUGUST OVERFLOW TASKS

Overflow Tasks

ID	Name	Start	Finish
538	Strip Formwork 3rd Floor Slab Sec. 5	Fri 8/1/08	Fri 8/1/08
224	Form 4th Floor Beams Sec. 5	Fri 8/1/08	Mon 8/4/08
468	Place 3rd Floor Beams Sec. 7	Mon 8/4/08	Mon 8/4/08
539	Strip Formwork 3rd Floor Slab Sec. 6	Wed 8/6/08	Wed 8/6/08
225	Form 4th Floor Beams Sec. 6	Tue 8/5/08	Wed 8/6/08
226	Form 4th Floor Beams Sec. 7	Thu 8/7/08	Fri 8/8/08
227	Form 5th Floor Beams Sec. 1	Mon 8/11/08	Tue 8/12/08
228	Form 5th Floor Beams Sec. 2	Wed 8/13/08	Thu 8/14/08
229	Form 5th Floor Beams Sec. 3	Fri 8/15/08	Mon 8/18/08
230	Form 5th Floor Beams Sec. 4	Tue 8/19/08	Wed 8/20/08
231	Form 5th Floor Beams Sec. 5	Thu 8/21/08	Fri 8/22/08
232	Form 5th Floor Beams Sec. 6	Mon 8/25/08	Tue 8/26/08
233	Form 5th Floor Beams Sec. 7	Wed 8/27/08	Thu 8/28/08
234	Form Roof Beams Sec. 1	Fri 8/29/08	Mon 9/1/08

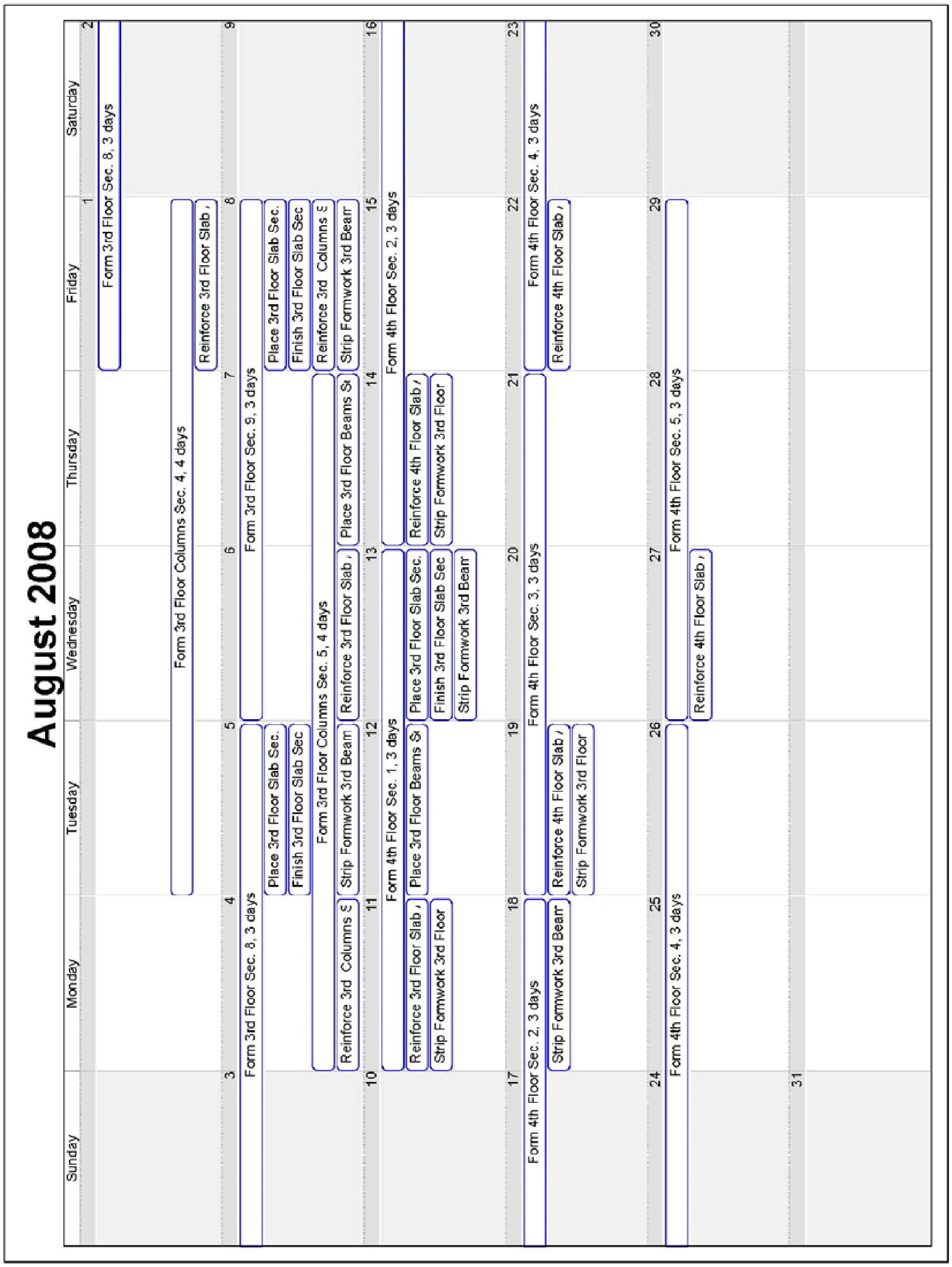


Figure 54: August Schedule Calendar

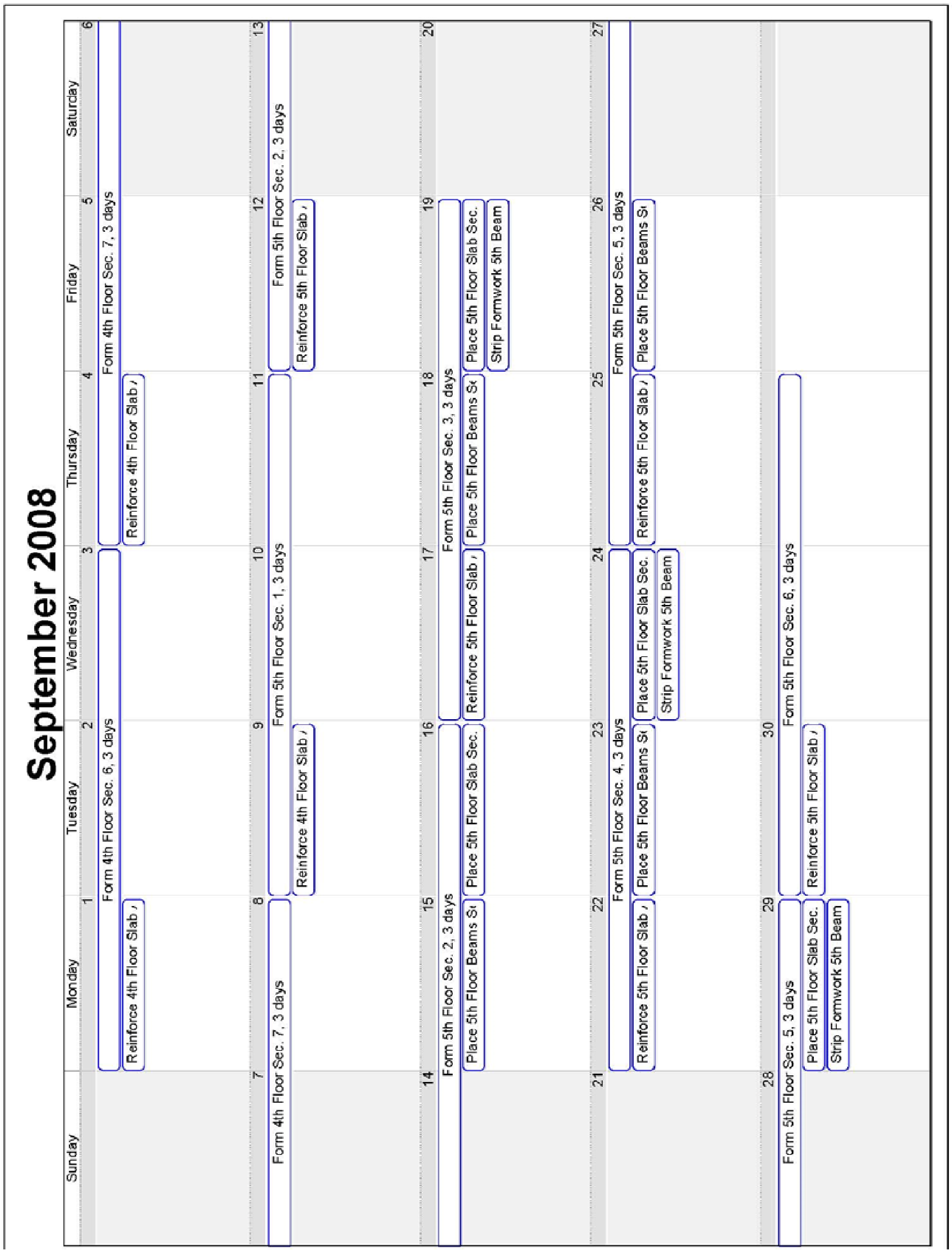


Figure 55: September Schedule Calendar

Overflow Tasks

ID	Name	Start	Finish
234	Form Roof Beams Sec. 1	Fri 8/29/08	Mon 9/1/08
235	Form Roof Beams Sec. 2	Mon 9/1/08	Tue 9/2/08
236	Form Roof Beams Sec. 3	Wed 9/3/08	Thu 9/4/08
237	Form Roof Beams Sec. 4	Thu 9/4/08	Fri 9/5/08
238	Form Roof Beams Sec. 5	Mon 9/8/08	Tue 9/9/08
239	Form Roof Beams Sec. 6	Tue 9/9/08	Wed 9/10/08
240	Form Roof Beams Sec. 7	Thu 9/11/08	Fri 9/12/08
241	Form Penthouse Beams Sec. 1	Fri 9/12/08	Tue 9/16/08
242	Form Penthouse Beams Sec. 2	Tue 9/16/08	Thu 9/18/08
243	Form Penthouse Beams Sec. 3	Thu 9/18/08	Mon 9/22/08
244	Form Penthouse Beams Sec. 4	Mon 9/22/08	Wed 9/24/08

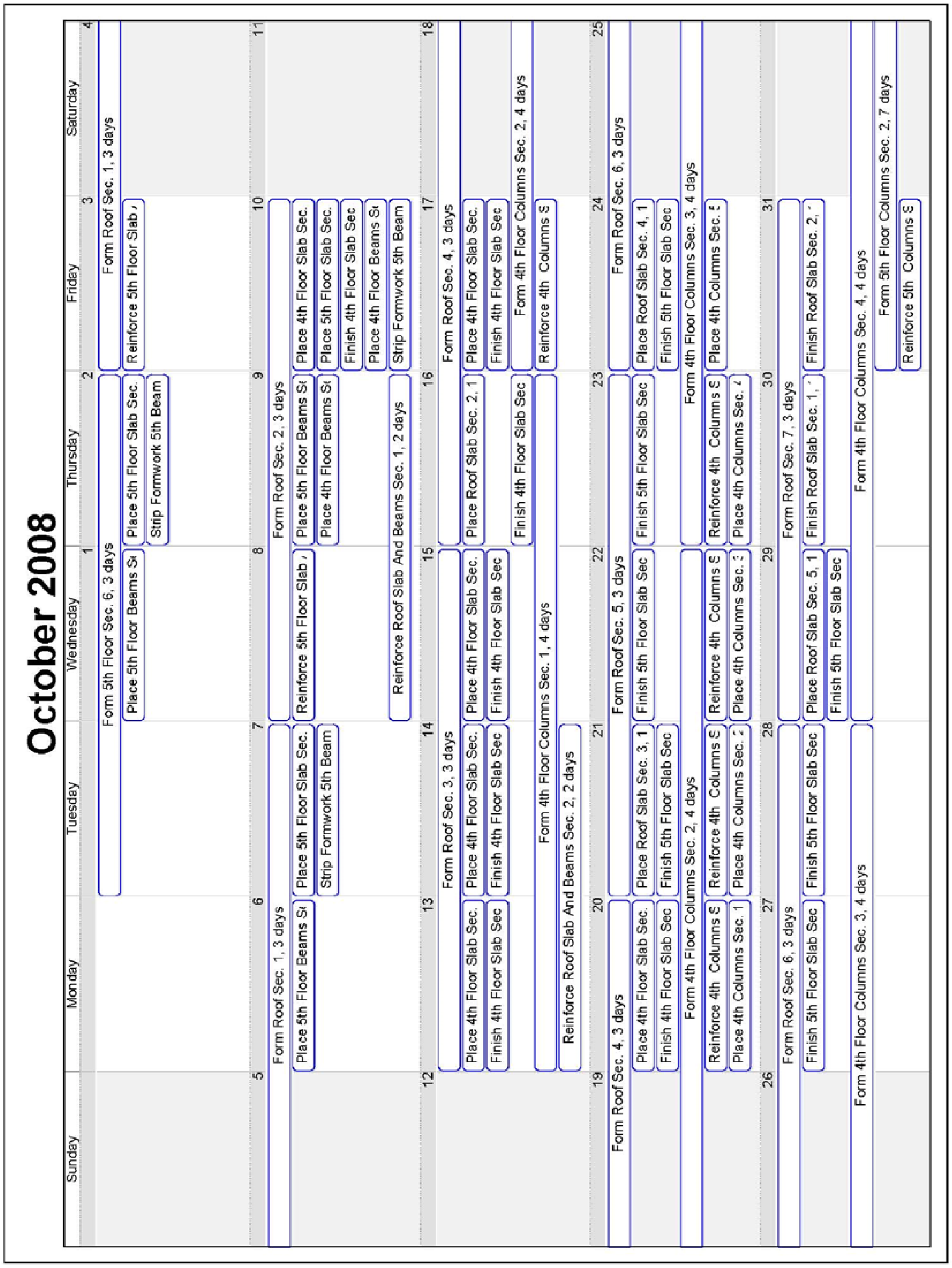


Figure 56: October Schedule Calendar

OCTOBER OVERFLOW TASKS

Overflow Tasks

ID	Name	Start	Finish
439	Place Roof Beams Sec. 2	Wed 10/15/08	Wed 10/15/08
456	Place 4th Floor Beams Sec. 3	Mon 10/13/08	Mon 10/13/08
457	Place 4th Floor Beams Sec. 4	Tue 10/14/08	Tue 10/14/08
458	Place 4th Floor Beams Sec. 5	Wed 10/15/08	Wed 10/15/08
459	Place 4th Floor Beams Sec. 6	Thu 10/16/08	Thu 10/16/08
460	Place 4th Floor Beams Sec. 7	Fri 10/17/08	Fri 10/17/08
422	Reinforce Roof Slab And Beams Sec. 3	Thu 10/16/08	Fri 10/17/08
544	Strip Formwork 4th Floor Slab Sec. 1	Thu 10/16/08	Thu 10/16/08
545	Strip Formwork 4th Floor Slab Sec. 2	Fri 10/17/08	Fri 10/17/08
601	Strip Formwork 4th Beams Sec. 1	Wed 10/15/08	Wed 10/15/08
602	Strip Formwork 4th Beams Sec. 2	Thu 10/16/08	Thu 10/16/08
603	Strip Formwork 4th Beams Sec. 3	Fri 10/17/08	Fri 10/17/08
615	Strip Formwork 5th Beams Sec. 7	Wed 10/15/08	Wed 10/15/08
617	Strip Formwork Roof Beams Sec. 1	Thu 10/16/08	Thu 10/16/08
331	Form 5th Floor Columns Sec. 1	Wed 10/22/08	Thu 10/30/08
423	Reinforce Roof Slab And Beams Sec. 4	Tue 10/21/08	Wed 10/22/08
424	Reinforce Roof Slab And Beams Sec. 5	Fri 10/24/08	Mon 10/27/08
440	Place Roof Beams Sec. 3	Mon 10/20/08	Mon 10/20/08
441	Place Roof Beams Sec. 4	Thu 10/23/08	Thu 10/23/08
546	Strip Formwork 4th Floor Slab Sec. 3	Mon 10/20/08	Mon 10/20/08
547	Strip Formwork 4th Floor Slab Sec. 4	Tue 10/21/08	Tue 10/21/08
548	Strip Formwork 4th Floor Slab Sec. 5	Wed 10/22/08	Wed 10/22/08
549	Strip Formwork 4th Floor Slab Sec. 6	Thu 10/23/08	Thu 10/23/08
550	Strip Formwork 4th Floor Slab Sec. 7.	Fri 10/24/08	Fri 10/24/08
604	Strip Formwork 4th Beams Sec. 4	Mon 10/20/08	Mon 10/20/08
605	Strip Formwork 4th Beams Sec. 5	Tue 10/21/08	Tue 10/21/08
606	Strip Formwork 4th Beams Sec. 6	Wed 10/22/08	Wed 10/22/08
607	Strip Formwork 4th Beams Sec. 7	Thu 10/23/08	Thu 10/23/08
618	Strip Formwork Roof Beams Sec. 2	Tue 10/21/08	Tue 10/21/08
619	Strip Formwork Roof Beams Sec. 3	Fri 10/24/08	Fri 10/24/08
657	Strip Formwork 4th Columns Sec. 1	Fri 10/24/08	Fri 10/24/08
346	Form Roof Columns Sec. 1	Fri 10/31/08	Wed 11/5/08
425	Reinforce Roof Slab And Beams Sec. 6	Wed 10/29/08	Thu 10/30/08
442	Place Roof Beams Sec. 5	Tue 10/28/08	Tue 10/28/08
443	Place Roof Beams Sec. 6	Fri 10/31/08	Fri 10/31/08
552	Strip Formwork 5th Floor Slab Sec. 1	Mon 10/27/08	Mon 10/27/08
553	Strip Formwork 5th Floor Slab Sec. 2	Tue 10/28/08	Tue 10/28/08
554	Strip Formwork 5th Floor Slab Sec. 3	Wed 10/29/08	Wed 10/29/08
555	Strip Formwork 5th Floor Slab Sec. 4	Thu 10/30/08	Thu 10/30/08
556	Strip Formwork 5th Floor Slab Sec. 5	Fri 10/31/08	Fri 10/31/08
620	Strip Formwork Roof Beams Sec. 4	Wed 10/29/08	Wed 10/29/08
658	Strip Formwork 4th Columns Sec. 2	Mon 10/27/08	Mon 10/27/08
659	Strip Formwork 4th Columns Sec. 3	Tue 10/28/08	Tue 10/28/08
661	Strip Formwork 4th Columns Sec. 5	Thu 10/30/08	Thu 10/30/08
660	Strip Formwork 4th Columns Sec. 4	Wed 10/29/08	Wed 10/29/08

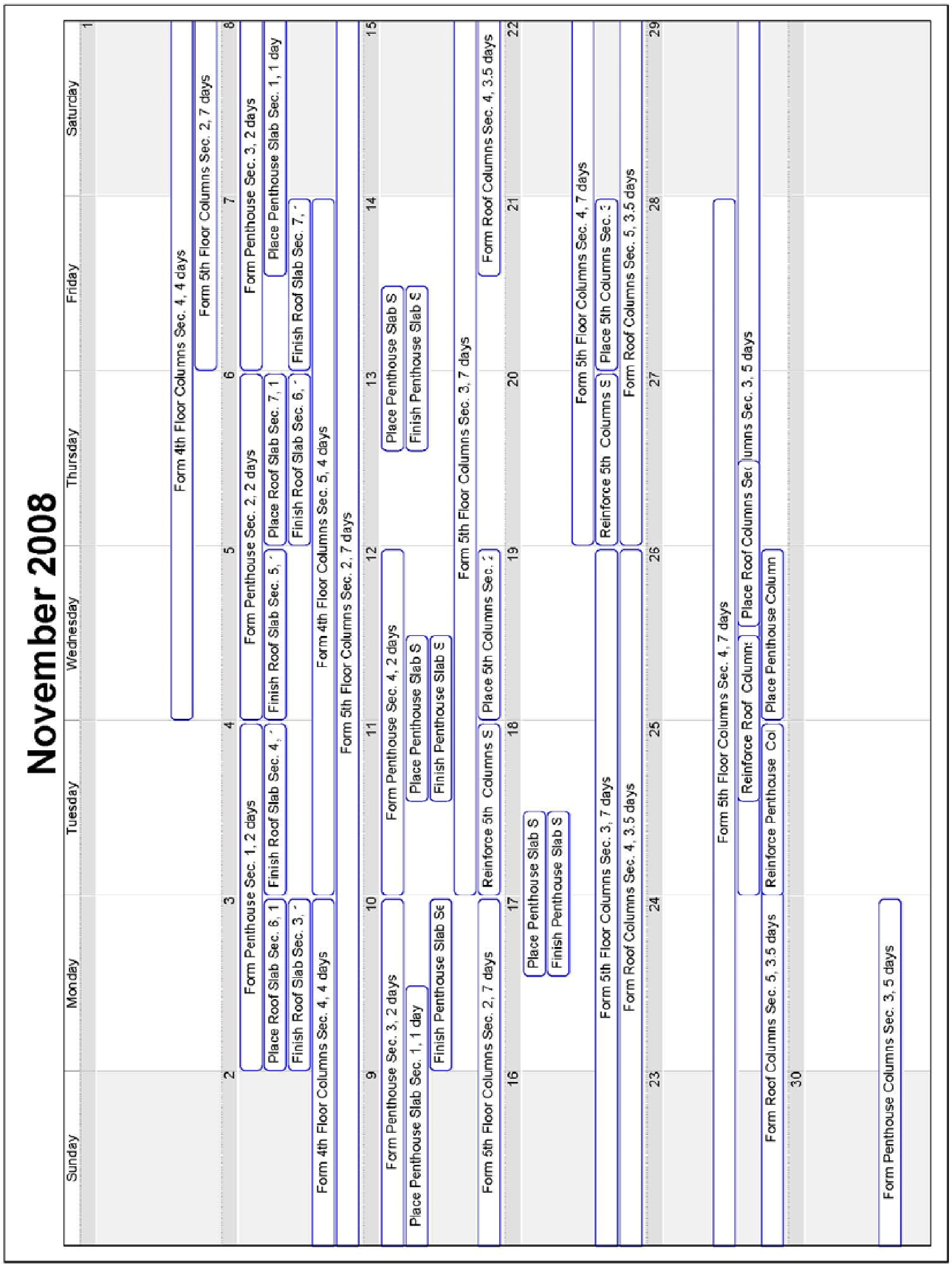


Figure 57: November Schedule Calendar

NOVEMBER OVERFLOW TASKS

Overflow Tasks

ID	Name	Start	Finish
346	Form Roof Columns Sec. 1	Fri 10/31/08	Wed 11/5/08
347	Form Roof Columns Sec. 2	Wed 11/5/08	Mon 11/10/08
341	Place 5th Columns Sec. 1	Mon 11/3/08	Mon 11/3/08
352	Reinforce Roof Columns Sec. 1	Wed 11/5/08	Thu 11/6/08
358	Place Roof Columns Sec. 1	Thu 11/6/08	Fri 11/7/08
426	Reinforce Roof Slab And Beams Sec. 7	Mon 11/3/08	Tue 11/4/08
428	Reinforce Pent Slab And Beams Sec. 1	Wed 11/5/08	Thu 11/6/08
429	Reinforce Pent Slab And Beams Sec. 2	Fri 11/7/08	Mon 11/10/08
433	Place Penthouse Beams Sec. 1	Thu 11/6/08	Fri 11/7/08
444	Place Roof Beams Sec. 7	Wed 11/5/08	Wed 11/5/08
557	Strip Formwork 5th Floor Slab Sec. 6	Mon 11/3/08	Mon 11/3/08
558	Strip Formwork 5th Floor Slab Sec. 7.	Tue 11/4/08	Tue 11/4/08
560	Strip Formwork Roof Slab Sec. 1	Wed 11/5/08	Wed 11/5/08
561	Strip Formwork Roof Slab Sec. 2	Thu 11/6/08	Thu 11/6/08
562	Strip Formwork Roof Slab Sec. 3	Fri 11/7/08	Fri 11/7/08
621	Strip Formwork Roof Beams Sec. 5	Mon 11/3/08	Mon 11/3/08
663	Strip Formwork 5th Columns Sec. 1	Fri 11/7/08	Fri 11/7/08
622	Strip Formwork Roof Beams Sec. 6	Thu 11/6/08	Thu 11/6/08
348	Form Roof Columns Sec. 3	Tue 11/11/08	Fri 11/14/08
354	Reinforce Roof Columns Sec. 3	Fri 11/14/08	Mon 11/17/08
364	Form Penthouse Columns Sec. 1	Tue 11/11/08	Mon 11/17/08
353	Reinforce Roof Columns Sec. 2	Tue 11/11/08	Tue 11/11/08
359	Place Roof Columns Sec. 2	Wed 11/12/08	Wed 11/12/08
430	Reinforce Pent Slab And Beams Sec. 3	Tue 11/11/08	Wed 11/12/08
431	Reinforce Pent Slab And Beams Sec. 4	Thu 11/13/08	Fri 11/14/08
436	Place Penthouse Beams Sec. 4	Fri 11/14/08	Mon 11/17/08
434	Place Penthouse Beams Sec. 2	Mon 11/10/08	Tue 11/11/08
435	Place Penthouse Beams Sec. 3	Wed 11/12/08	Thu 11/13/08
568	Strip Formwork Penthouse Slab Sec. 1	Fri 11/14/08	Fri 11/14/08
563	Strip Formwork Roof Slab Sec. 4	Mon 11/10/08	Mon 11/10/08
564	Strip Formwork Roof Slab Sec. 5	Tue 11/11/08	Tue 11/11/08
565	Strip FormworkRoof Slab Sec. 6	Wed 11/12/08	Wed 11/12/08
566	Strip Formwork Roof Slab Sec. 7.	Thu 11/13/08	Thu 11/13/08
623	Strip Formwork Roof Beams Sec. 7	Tue 11/11/08	Tue 11/11/08
626	Strip Formwork Penthouse Beams Sec. 2	Thu 11/13/08	Fri 11/14/08
625	Strip Formwork Penthouse Beams Sec. 1	Tue 11/11/08	Wed 11/12/08
668	Strip Formwork Roof Columns Sec. 1	Wed 11/12/08	Thu 11/13/08
355	Reinforce Roof Columns Sec. 4	Thu 11/20/08	Thu 11/20/08
360	Place Roof Columns Sec. 3	Mon 11/17/08	Tue 11/18/08
361	Place Roof Columns Sec. 4	Fri 11/21/08	Fri 11/21/08
365	Form Penthouse Columns Sec. 2	Tue 11/18/08	Mon 11/24/08
372	Place Penthouse Columns Sec. 1	Wed 11/19/08	Wed 11/19/08
368	Reinforce Penthouse Columns Sec. 1	Tue 11/18/08	Tue 11/18/08
570	Strip Formwork Penthouse Slab Sec. 3	Wed 11/19/08	Thu 11/20/08
571	Strip Formwork Penthouse Slab Sec. 4	Fri 11/21/08	Mon 11/24/08
569	Strip Formwork Penthouse Slab Sec. 2	Mon 11/17/08	Tue 11/18/08
628	Strip Formwork Penthouse Beams Sec. 4	Wed 11/19/08	Thu 11/20/08
670	Strip Formwork Roof Columns Sec. 3	Fri 11/21/08	Mon 11/24/08
627	Strip Formwork Penthouse Beams Sec. 3	Mon 11/17/08	Tue 11/18/08
664	Strip Formwork 5th Columns Sec. 2	Tue 11/18/08	Tue 11/18/08
669	Strip Formwork Roof Columns Sec. 2	Tue 11/18/08	Tue 11/18/08
665	Strip Formwork 5th Columns Sec. 3	Thu 11/27/08	Thu 11/27/08
671	Strip Formwork Roof Columns Sec. 4	Thu 11/27/08	Thu 11/27/08
674	Strip Formwork Penthouse Columns Sec. 1	Tue 11/25/08	Tue 11/25/08

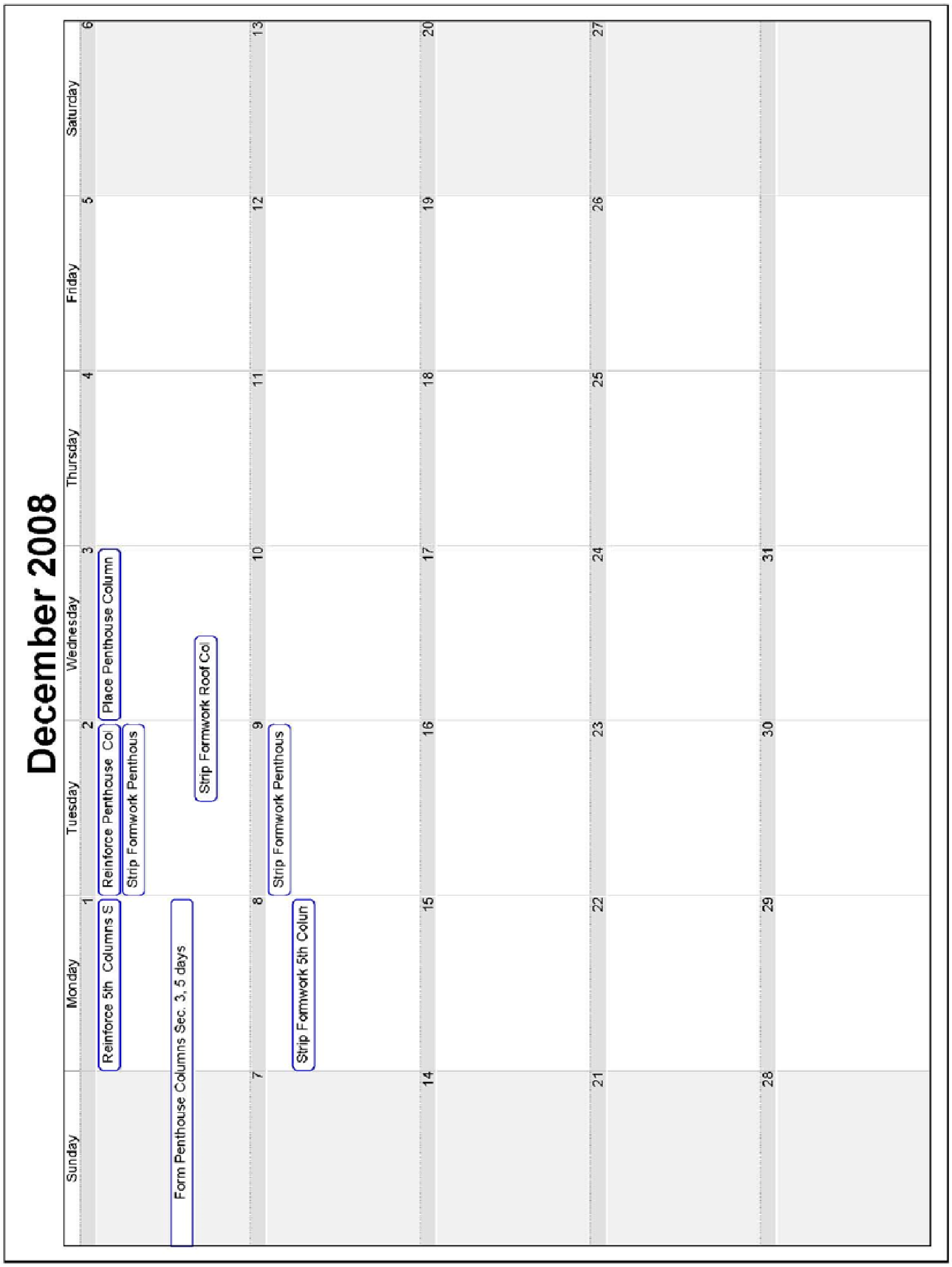
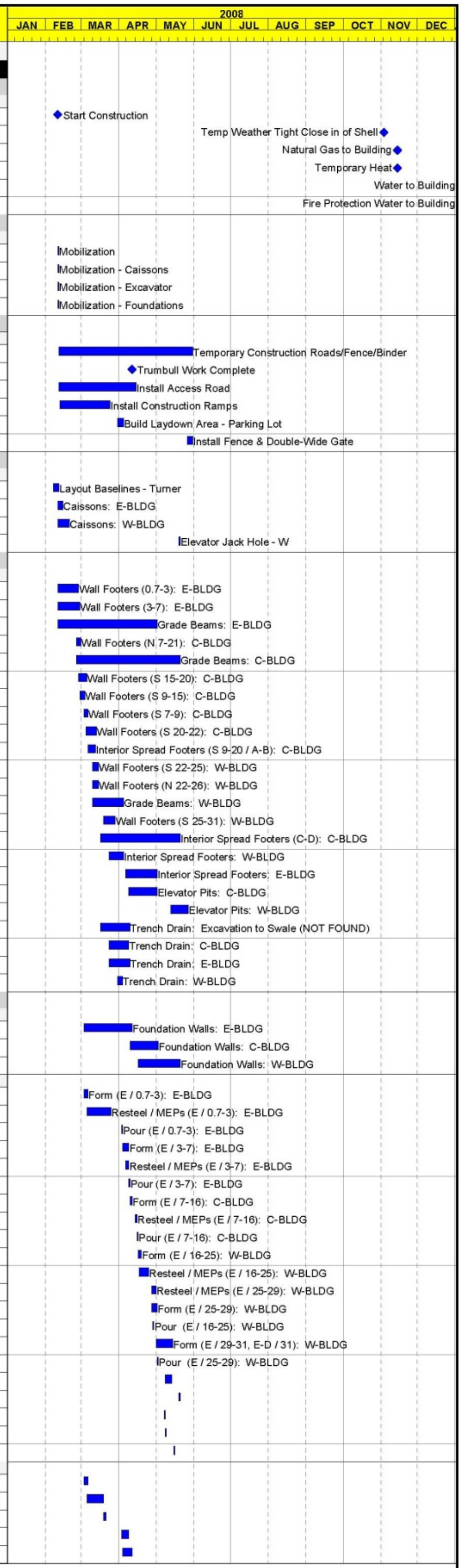


Figure 58: December Schedule Calendar

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish	Plan Start	Plan Finish	Fin Var
Building 1							
Construction - Structure/Enclosure							
-							
0006	Start Construction	0	11FEB08A		21JAN08*		-15
0092	Temp Weather Tight Close in of Shell	0		03NOV08A		01SEP08*	-45
0122	Natural Gas to Building	0		14NOV08A	13AUG08	22AUG08	-60
0402	Temporary Heat	0		14NOV08A			0
0132	Water to Building	0		05JAN09A	01OCT08	10OCT08	-61
0392	Fire Protection Water to Building	0		05JAN09A			0
Mobilization							
0002	Mobilization	1*	11FEB08A	11FEB08A	21JAN08	25JAN08	-11
0032	Mobilization - Caissons	5	11FEB08A	11FEB08A	21JAN08	25JAN08	-11
0062	Mobilization - Excavator	5	11FEB08A	11FEB08A	21JAN08	25JAN08	-11
0072	Mobilization - Foundations	5	11FEB08A	11FEB08A	21JAN08	25JAN08	-11
Initial Sitework/Excavation							
0007	Temporary Construction Roads/Fence/Binder	79*	12FEB08A	30MAY08A	28JAN08	20FEB08	-72
0557	Trumbull Work Complete	0		11APR08A			0
0017	Install Access Road	10	12FEB08A	14APR08A	28JAN08	08FEB08	-46
0097S	Install Construction Ramps	10	13FEB08A	24MAR08A			0
0067	Build Laydown Area - Parking Lot	10	31MAR08A	04APR08A	28JAN08	07MAR08	-20
0207	Install Fence & Double-Wide Gate	5	27MAY08A	30MAY08A	14FEB08	20FEB08	-72
Caissons							
0076	Layout Baselines - Turner	5	08FEB08A	11FEB08A	14JAN08*	18JAN08	-16
0016	Caissons: E-BLDG	5	11FEB08A	14FEB08A	04FEB08	08FEB08	-4
0014	Caissons: W-BLDG	5	11FEB08A	19FEB08A	11FEB08	15FEB08	-2
0084	Elevator Jack Hole - W	3	20MAY08A	20MAY08A	11FEB08	13FEB08	-69
Grade Beams							
0040	Wall Footers (0.7-3): E-BLDG	8	11FEB08A	27FEB08A			0
0080	Wall Footers (3-7): E-BLDG	8	11FEB08A	28FEB08A			0
0020	Grade Beams: E-BLDG	59*	11FEB08A	01MAY08A	21FEB08	12MAR08	-36
0299	Wall Footers (N 7-21): C-BLDG	3	26FEB08A	29FEB08A			0
0019	Grade Beams: C-BLDG	61*	26FEB08A	20MAY08A	25FEB08	14MAR08	-47
0269	Wall Footers (S 15-20): C-BLDG	4	28FEB08A	05MAR08A			0
0259	Wall Footers (S 9-15): C-BLDG	4	29FEB08A	03MAR08A			0
0279	Wall Footers (S 7-9): C-BLDG	4	03MAR08A	06MAR08A			0
0289	Wall Footers (S 20-22): C-BLDG	2	05MAR08A	13MAR08A			0
0309	Interior Spread Footers (S 9-20 / A-B):	3	07MAR08A	12MAR08A			0
0298	Wall Footers (S 22-25): W-BLDG	3	10MAR08A	14MAR08A			0
0308	Wall Footers (N 22-26): W-BLDG	3	10MAR08A	14MAR08A			0
0018	Grade Beams: W-BLDG	20*	10MAR08A	04APR08A	10MAR08	28MAR08	-5
0328	Wall Footers (S 25-31): W-BLDG	3	20MAR08A	28MAR08A			0
0348	Interior Spread Footers (C-D): C-BLDG	8	17MAR08A	20MAY08A			0
0358	Interior Spread Footers: W-BLDG	5	24MAR08A	04APR08A			0
0338	Interior Spread Footers: E-BLDG	10	07APR08A	01MAY08A			0
0119	Elevator Pits: C-BLDG	10	09APR08A	01MAY08A	25FEB08	07MAR08	-39
0028	Elevator Pits: W-BLDG	5	13MAY08A	27MAY08A	10MAR08	14MAR08	-52
0010X	Trench Drain: Excavation to Swale (NOT	5	17MAR08A	09APR08A			0
0030X	Trench Drain: C-BLDG	5	24MAR08A	08APR08A			0
0020X	Trench Drain: E-BLDG	4	24MAR08A	09APR08A			0
0040X	Trench Drain: W-BLDG	4	31MAR08A	03APR08A			0
Foundation Walls							
-							
0024	Foundation Walls: E-BLDG	30*	03MAR08A	11APR08A	28FEB08	07MAY08	18
0023	Foundation Walls: C-BLDG	17*	10APR08A	02MAY08A	06MAR08	14MAY08	8
0022	Foundation Walls: W-BLDG	24*	17APR08A	20MAY08A	07APR08	13JUN08	18
North Elevation							
2450	Form (E / 0.7-3): E-BLDG	3	03MAR08A	06MAR08A			0
2460	Resteel / MEPs (E / 0.7-3): E-BLDG	3	06MAR08A	25MAR08A			0
2470	Pour (E / 0.7-3): E-BLDG	1	03APR08A	03APR08A			0
2480	Form (E / 3-7): E-BLDG	2	04APR08A	08APR08A			0
2490	Resteel / MEPs (E / 3-7): E-BLDG	2	07APR08A	08APR08A			0
2500	Pour (E / 3-7): E-BLDG	1	09APR08A	09APR08A			0
2510	Form (E / 7-16): C-BLDG	2	10APR08A	11APR08A			0
2520	Resteel / MEPs (E / 7-16): C-BLDG	2	14APR08A	15APR08A			0
2530	Pour (E / 7-16): C-BLDG	1	16APR08A	16APR08A			0
0322	Form (E / 16-25): W-BLDG	2	17APR08A	18APR08A			0
0332	Resteel / MEPs (E / 16-25): W-BLDG	2	18APR08A	24APR08A			0
0360	Resteel / MEPs (E / 25-29): W-BLDG	2	28APR08A	30APR08A			0
0350	Form (E / 25-29): W-BLDG	2	28APR08A	01MAY08A			0
0342	Pour (E / 16-25): W-BLDG	1	29APR08A	29APR08A			0
0375	Form (E / 29-31, E-D / 31): W-BLDG	2	01MAY08A	14MAY08A			0
0370	Pour (E / 25-29): W-BLDG	1	02MAY08A	02MAY08A			0
0385	Resteel / MEPs (E / 29-31, E-D / 31):	2	09MAY08A	13MAY08A			0
0395	Pour (E / 29-31, E-D / 31): W-BLDG	1	20MAY08A	20MAY08A			0
0400	Form (D-C / 31, C / 28-31): W-BLDG	2	08MAY08A	08MAY08A			0
0410	Resteel / MEPs (D-C / 31, C / 28-31):	2	09MAY08A	09MAY08A			0
0420	Pour (D-C / 31, C / 28-31): W-BLDG	1	16MAY08A	16MAY08A			0
South Elevation							
0034	Form (B-D / 0.7-4): E-BLDG	3	03MAR08A	06MAR08A			0
0044	Resteel / MEPs (B-D / 0.7-4): E-BLDG	3	06MAR08A	19MAR08A	24JAN08	27FEB08	-15
0074	Pour (B-D / 0.7-4): E-BLDG	1	20MAR08A	20MAR08A	25JUN08	01JUL08	73
0194	Form (B / 4-7): E-BLDG	2	03APR08A	08APR08A			0
0224	Form (B / 7-9): E-BLDG	2	04APR08A	11APR08A			0



Start Date 01OCT07
Finish Date 16JUN09
Data Date 13JAN09
Early Bar
Progress Bar
WH31
TCCO
Sheet 1 of 4

Date	Revision	Checked	Approved

Figure 59: Turner Construction Schedule 1/4

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish	Plan Start	Plan Finish	Fin Var
0204	Resteel / MEPs (B / 4-7): E-BLDG	2	07APR08A	07APR08A			0
0214	Pour (B / 4-7): E-BLDG	1	09APR08A	09APR08A			0
0234	Resteel / MEPs (B / 7-9): E-BLDG	2	09APR08A	10APR08A			0
0244	Pour (B / 7-9): E-BLDG	1	14APR08A	11APR08A			0
0033	Form (A-Line, A / 9-12): C-BLDG	2	10APR08A	17APR08A			0
0103	Form (A / 12-16): C-BLDG	2	11APR08A	22APR08A	13AUG08	19AUG08	85
0073	Resteel / MEPs (A-Line, A / 9-12): C-BLDG	2	14APR08A	16APR08A	10SEP08	16SEP08	109
0143	Form (A / 16-20, A-A.4): C-BLDG	2	17APR08A	24APR08A	16OCT08	20OCT08	127
0193	Resteel / MEPs (A / 16-20, A-A.4): C-BLDG	2	17APR08A	24APR08A			0
0093	Pour (A-Line, A / 9-12): C-BLDG	1	18APR08A	18APR08A	16JUL08	22JUL08	67
0123	Resteel / MEPs (A / 12-16): C-BLDG	2	18APR08A	21APR08A	01OCT08	07OCT08	121
0133	Pour (A / 12-16): C-BLDG	1	23APR08A	23APR08A	28AUG08	01SEP08	93
00921	Form (A.4-B, B / 20-24): C-BLDG	2	23APR08A	01MAY08A			0
0203	Pour (A / 16-20, A-A.4): C-BLDG	1	25APR08A	25APR08A			0
0192	Resteel / MEPs (A.4-B, B / 20-23): C-BLDG	2	25APR08A	29APR08A		01SEP08*	89
0282	Pour (A.4-B, B / 20-23): C-BLDG	1	02MAY08A	02MAY08A			0
0292	Form (B / 23-28): W-BLDG	2	23APR08A	07MAY08A			0
0302	Resteel / MEPs (B / 23-28): W-BLDG	2	01MAY08A	07MAY08A			0
0312	Pour (B / 23-28): W-BLDG	1	08MAY08A	08MAY08A			0
Foundation Waterproofing							
0030	Waterproof: C-BLDG (A-Line)	2	01MAY08A	22JUL08A	07JUL08	08JUL08	-10
0121	Waterproof: C-BLDG (E-Line)	2	01MAY08A	23JUL08A	22APR08	23APR08	-65
0099	Waterproof: E-BLDG (B-Line)	2	30APR08A	01AUG08A	04AUG08	05AUG08	2
0031	Waterproof: E-BLDG (E-Line)	2	01MAY08A	01AUG08A	22APR08	23APR08	-72
0131	Waterproof: W-BLDG (E-Line)	2	13MAY08A	01AUG08A	13MAY08	14MAY08	-57
0029	Waterproof: W-BLDG (B-Line)	2	19MAY08A	01AUG08A	22SEP08	23SEP08	37
U.G. Utilities							
0113E	Elec Main Feeders UG: E-BLDG	5	21APR08A	28APR08A			0
0223	UG Sanitary Mechanical Rm: E-BLDG	5	22APR08A	01MAY08A			0
0213	Elec UG Mechanical Rm: E-BLDG	5	29APR08A	08MAY08A			0
0233	UG Sanitary: E-BLDG	5	09MAY08A	19AUG08A			0
0243	UG Sanitary: C-BLDG	5	05MAY08A	17JUL08A			0
0253	UG Sanitary: W-BLDG	5	05MAY08A	19AUG08A			0
0058	UG Utilites (Crane Path): E-BLDG	5	15AUG08A	19AUG08A	16JUN08	11JUL08	-27
0052	UG Utilites (Crane Path): W-BLDG	5	25AUG08A	29AUG08A	13MAR08	09APR08	-102
SOG							
-							
0046	SOG: C-BLDG	35*	22JUL08A	08SEP08A	14APR08	02MAY08	-91
0045	SOG: W-BLDG	13*	21AUG08A	08SEP08A	28APR08	06MAY08	-89
0047	SOG: E-BLDG	25*	02SEP08A	06OCT08A	10APR08	18APR08	-121
Elevator Pits							
EP100-11	Excavate (EP 1-2)	1	02MAY08A	02MAY08A			0
EP100-01	Form Bottom (Elevator Pit 1-2)	2	15MAY08A	16MAY08A			0
EP110-01	Pre-Proof Waterproofing (EP 1-2)	2	20MAY08A	20MAY08A			0
EP120-01	Place Footing (EP 1-2)	2	20MAY08A	21MAY08A			0
EP130-01	Place Walls (EP 1-2)	2	22MAY08A	27MAY08A			0
EP140-01	Cure Period (7 Days)	7	27MAY08A	02JUN08A			0
EP150-01	Bituthene Waterproof (EP 1-2)	2	03JUN08A	03JUN08A			0
EP160-01	Backfill (EP 1-2)	2	03JUN08A	04JUN08A			0
EP095-03	Excavate (EP 3-4)	1	02MAY08A	02MAY08A			0
EP100-03	Form Bottom (Elevator Pit 3-4)	2	19MAY08A	19MAY08A			0
EP110-03	Pre-Proof Waterproofing (EP 3-4)	2	20MAY08A	20MAY08A			0
EP120-03	Place Footing (EP 3-4)	2	21MAY08A	21MAY08A			0
EP130-03	Place Walls (EP 3-4)	2	23MAY08A	28MAY08A			0
EP140-03	Cure Period (7 Days)	7	28MAY08A	04JUN08A			0
EP150-03	Bituthene Waterproof (EP 3-4)	2	08JUL08A	09JUL08A			0
EP160-03	Backfill (EP 3-4)	2	10JUL08A	11JUL08A			0
EP095-05	Excavate (EP-5)	1	12MAY08A	13MAY08A			0
EP100-05	Form Bottom (Elevator Pit 5)	2	20MAY08A	21MAY08A			0
EP110-05	Pre-Proof Waterproofing (EP 5)	2	21MAY08A	21MAY08A			0
EP120-05	Place Footing (EP 5)	2	22MAY08A	27MAY08A			0
EP130-05	Place Walls (EP 5)	2	28MAY08A	29MAY08A			0
EP140-05	Cure Period (7 Days)	7	30MAY08A	06JUN08A			0
EP150-05	Bituthene Waterproof (EP 5)	2	23JUN08A	20JUN08A			0
EP160-05	Backfill (EP 5)	2	08JUL08A	09JUL08A			0
EP095-06	Excavate (EP 6)	1	09APR08A	09APR08A			0
EP100-06	Form Bottom (Elevator Pit 6)	2	16JUN08A	16JUN08A			0
EP110-06	Pre-Proof Waterproofing (EP 6)	2	19JUN08A	19JUN08A			0
EP120-06	Place Footing (EP 6)	2	20JUN08A	20JUN08A			0
EP130-06	Place Walls (EP 6)	2	26JUN08A	26JUN08A			0
EP140-06	Cure Period (7 Days)	7	27JUN08A	03JUL08A			0
EP150-06	Bituthene Waterproof (EP 6)	2	08JUL08A	09JUL08A			0
EP160-06	Backfill (EP 6)	2	10JUL08A	11JUL08A			0
EP100-07	Form Bottom (Elevator Pit 7)	2	13JUN08A	13JUN08A			0
EP120-07	Place Footing (EP 7)	2	13JUN08A	13JUN08A			0
EP110-07	Pre-Proof Waterproofing (EP 7)	2	23JUN08A	20JUN08A			0
EP130-07	Place Walls (EP 7)	2	01AUG08A	01AUG08A			0
EP140-07	Cure Period (7 Days)	7	02AUG08A	08AUG08A			0
EP150-07	Bituthene Waterproof (EP 7)	2	08AUG08A	08AUG08A			0
EP160-07	Backfill (EP 7)	2	11AUG08A	11AUG08A			0
SG110	Place Stone & Underdrain (D.5 / 3-20)	2	28MAY08A	29MAY08A			0
SG120	Form, Vapor Barrier & Mesh (D.5 / 3-20)	2	30MAY08A	02JUN08A			0
SG130	Waterproof (D.5 / 3-20)	1	02JUN08A	02JUN08A			0
SG150	Place Concrete (D.5 / 3-20)	1	02JUL08A	02JUL08A			0
SG160	Strip Forms (D.5 / 3-20)	1	07JUL08A	07JUL08A			0
SG110-02	Place Stone & Underdrain (C-D / 1-0.7)	2	12JUN08A	13JUN08A			0
SG120-02	Form, Vapor Barrier & Mesh (C-D / 1-0.7)	1	14JUL08A	14JUL08A			0
SG130-02	Waterproof (C-D / 1-0.7)	1	16JUL08A	16JUL08A			0
SG140-02	Place Concrete (C-D / 1-0.7) - Electrical Rm	1	18JUL08A	18JUL08A			0
SG150-02	Strip Forms (C-D / 1-0.7)	1	21JUL08A	21JUL08A			0

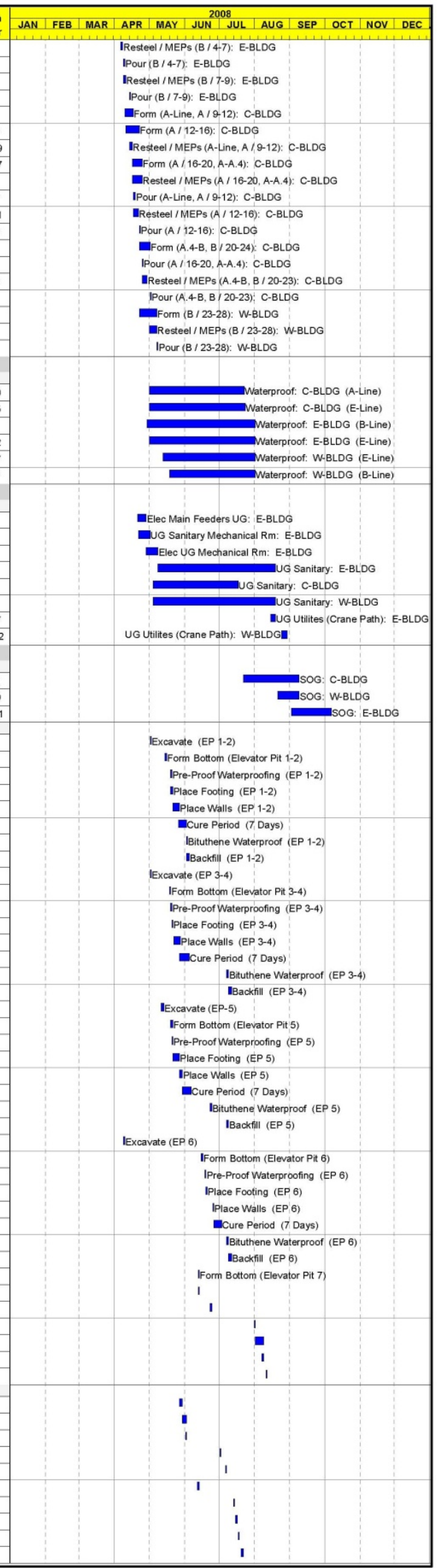


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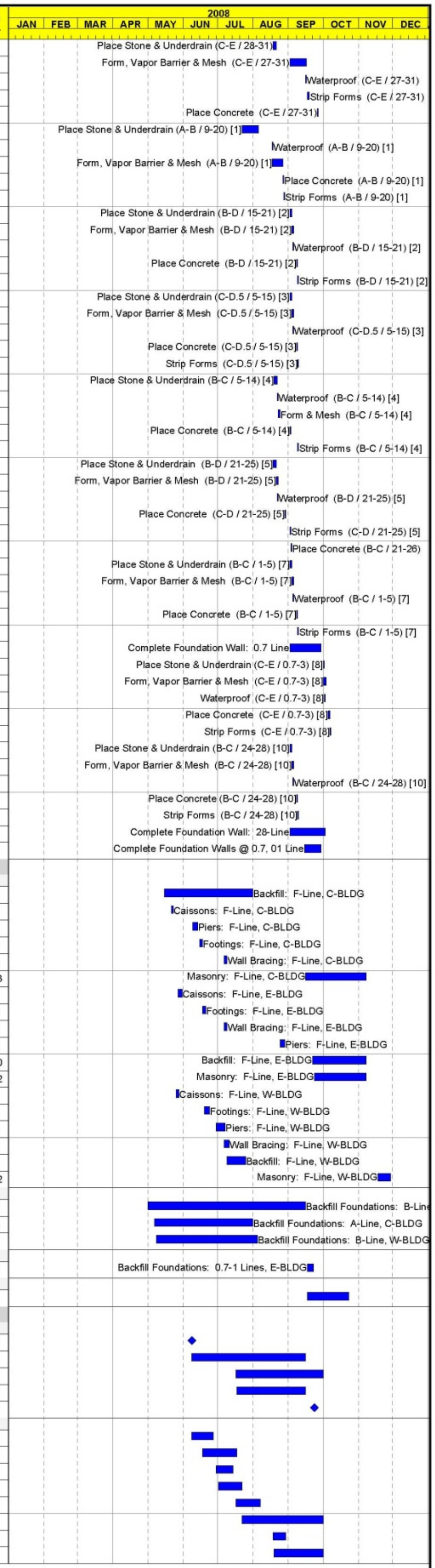
Figure 60: Turner Construction Schedule 2/4

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish	Plan Start	Plan Finish	Fin Var
SG110-05	Place Stone & Underdrain (C-E / 28-31)	2	19AUG08A	20AUG08A			0
SG120-05	Form, Vapor Barrier & Mesh (C-E / 27-31)	2	02SEP08A	16SEP08A			0
SG130-05	Waterproof (C-E / 27-31)	1	16SEP08A	16SEP08A			0
SG150-05	Strip Forms (C-E / 27-31)	1	18SEP08A	18SEP08A			0
SG140-05	Place Concrete (C-E / 27-31)	1	26SEP08A	26SEP08A			0
SG110-06	Place Stone & Underdrain (A-B / 9-20) [1]	2	22JUL08A	05AUG08A			0
SG130-06	Waterproof (A-B / 9-20) [1]	1	18AUG08A	18AUG08A			0
SG120-06	Form, Vapor Barrier & Mesh (A-B / 9-20) [1]	2	18AUG08A	26AUG08A			0
SG140-06	Place Concrete (A-B / 9-20) [1]	1	27AUG08A	27AUG08A			0
SG150-06	Strip Forms (A-B / 9-20) [1]	1	28AUG08A	28AUG08A			0
SG110-11	Place Stone & Underdrain (B-D / 15-21) [2]	2	02SEP08A	03SEP08A			0
SG120-11	Form, Vapor Barrier & Mesh (B-D / 15-21) [2]	2	04SEP08A	05SEP08A			0
SG130-11	Waterproof (B-D / 15-21) [2]	1	05SEP08A	05SEP08A			0
SG140-11	Place Concrete (B-D / 15-21) [2]	1	08SEP08A	08SEP08A			0
SG150-11	Strip Forms (B-D / 15-21) [2]	1	09SEP08A	09SEP08A			0
SG110-09	Place Stone & Underdrain (C-D.5 / 5-15) [3]	2	02SEP08A	03SEP08A			0
SG120-09	Form, Vapor Barrier & Mesh (C-D.5 / 5-15) [3]	2	04SEP08A	05SEP08A			0
SG130-09	Waterproof (C-D.5 / 5-15) [3]	1	05SEP08A	05SEP08A			0
SG140-09	Place Concrete (C-D.5 / 5-15) [3]	1	08SEP08A	08SEP08A			0
SG150-09	Strip Forms (C-D.5 / 5-15) [3]	1	09SEP08A	09SEP08A			0
SG110-04	Place Stone & Underdrain (B-C / 5-14) [4]	2	20AUG08A	21AUG08A			0
SG120-04	Waterproof (B-C / 5-14) [4]	3	22AUG08A	22AUG08A			0
SG130-04	Form & Mesh (B-C / 5-14) [4]	1	23AUG08A	24AUG08A			0
SG140-04	Place Concrete (B-C / 5-14) [4]	1	02SEP08A	02SEP08A			0
SG150-04	Strip Forms (B-C / 5-14) [4]	1	09SEP08A	09SEP08A			0
SG110-07	Place Stone & Underdrain (B-D / 21-25) [5]	2	19AUG08A	20AUG08A			0
SG120-07	Form, Vapor Barrier & Mesh (B-D / 21-25) [5]	2	21AUG08A	22AUG08A			0
SG130-07	Waterproof (B-D / 21-25) [5]	1	22AUG08A	22AUG08A			0
SG140-07	Place Concrete (C-D / 21-25) [5]	1	29AUG08A	29AUG08A			0
SG150-07	Strip Forms (C-D / 21-25) [5]	1	02SEP08A	02SEP08A			0
SG150-17	Place Concrete (B-C / 21-26)	1	03SEP08A	03SEP08A			0
SG110-03	Place Stone & Underdrain (B-C / 1-5) [7]	2	02SEP08A	03SEP08A			0
SG120-03	Form, Vapor Barrier & Mesh (B-C / 1-5) [7]	2	04SEP08A	05SEP08A			0
SG130-03	Waterproof (B-C / 1-5) [7]	1	05SEP08A	05SEP08A			0
SG140-03	Place Concrete (B-C / 1-5) [7]	1	08SEP08A	08SEP08A			0
SG150-03	Strip Forms (B-C / 1-5) [7]	1	09SEP08A	09SEP08A			0
SG105-12B	Complete Foundation Wall: 0.7 Line	4	02SEP08A	29SEP08A			0
SG110-10	Place Stone & Underdrain (C-E / 0.7-3) [8]	2	01OCT08A	01OCT08A			0
SG120-10	Form, Vapor Barrier & Mesh (C-E / 0.7-3) [8]	2	01OCT08A	03OCT08A			0
SG130-10	Waterproof (C-E / 0.7-3) [8]	1	02OCT08A	02OCT08A			0
SG140-10	Place Concrete (C-E / 0.7-3) [8]	1	06OCT08A	06OCT08A			0
SG150-10	Strip Forms (C-E / 0.7-3) [8]	1	07OCT08A	07OCT08A			0
SG110-12A	Place Stone & Underdrain (B-C / 24-28) [10]	2	02SEP08A	03SEP08A			0
SG120-12A	Form, Vapor Barrier & Mesh (B-C / 24-28)	2	04SEP08A	05SEP08A			0
SG130-12A	Waterproof (B-C / 24-28) [10]	1	05SEP08A	05SEP08A			0
SG140-12A	Place Concrete (B-C / 24-28) [10]	1	08SEP08A	08SEP08A			0
SG150-12A	Strip Forms (B-C / 24-28) [10]	1	09SEP08A	09SEP08A			0
SG105-12A	Complete Foundation Wall: 28-Line	4	02SEP08A	02OCT08A			0
SG105-20	Complete Foundation Walls @ 0.7, 01 Line	10	15SEP08A	29SEP08A			0
Backfill/Wall Bracing							
North Elevation							
0397	Backfill: F-Line, C-BLDG	2	16MAY08A	31JUL08A	07MAY08	08MAY08	-60
0577	Caissons: F-Line, C-BLDG	3	22MAY08A	23MAY08A			0
0327	Piers: F-Line, C-BLDG	2	10JUN08A	13JUN08A	30APR08	01MAY08	-31
0317	Footings: F-Line, C-BLDG	2	16JUN08A	17JUN08A	28APR08	29APR08	-35
0227	Wall Bracing: F-Line, C-BLDG	3	07JUL08A	09JUL08A	21APR08	23APR08	-55
0367	Masonry: F-Line, C-BLDG	3	16SEP08A	07NOV08A	02MAY08	06MAY08	-133
0587	Caissons: F-Line, E-BLDG	2	28MAY08A	30MAY08A			0
0297	Footings: F-Line, E-BLDG	2	18JUN08A	20JUN08A	28APR08	29APR08	-38
0217	Wall Bracing: F-Line, E-BLDG	3	07JUL08A	09JUL08A	21APR08	23APR08	-55
0307	Piers: F-Line, E-BLDG	4	25AUG08A	28AUG08A	30APR08	01MAY08	-85
0387	Backfill: F-Line, E-BLDG	2	22SEP08A	07NOV08A	08MAY08	09MAY08	-130
0357	Masonry: F-Line, E-BLDG	4	24SEP08A	07NOV08A	02MAY08	07MAY08	-132
0597	Caissons: F-Line, W-BLDG	2	26MAY08A	28MAY08A			0
0337	Footings: F-Line, W-BLDG	2	20JUN08A	23JUN08A	19MAY08	20MAY08	-24
0347	Piers: F-Line, W-BLDG	2	30JUN08A	07JUL08A	21MAY08	22MAY08	-32
0237	Wall Bracing: F-Line, W-BLDG	3	07JUL08A	10JUL08A	12MAY08	14MAY08	-41
0407	Backfill: F-Line, W-BLDG	2	10JUL08A	25JUL08A	29MAY08	30MAY08	-40
0377	Masonry: F-Line, W-BLDG	4	18NOV08A	28NOV08A	23MAY08	28MAY08	-132
South Elevation							
0177	Backfill Foundations: B-Line, E-BLDG	5	01MAY08A	15SEP08A	06AUG08	12AUG08	-24
0267	Backfill Foundations: A-Line, C-BLDG	5	07MAY08A	31JUL08A	09JUL08	15JUL08	-12
0197	Backfill Foundations: B-Line, W-BLDG	5	09MAY08A	04AUG08A	24SEP08	30SEP08	41
East Elevation							
0277	Backfill Foundations: 0.7-1 Lines, E-BLDG	3	18SEP08A	22SEP08A	25AUG08	27AUG08	-18
West Elevation							
0287	Backfill Foundations: 28-31 Lines, W-BLDG	3	18SEP08A	23OCT08A	13OCT08	15OCT08	-6
Structural Steel							
-							
0036	Steel Start	0	09JUN08A		14MAY08		-18
0048	Structural Steel: C-BLDG	71*	09JUN08A	15SEP08A	14MAY08	29JUL08	-34
0037	Structural Steel: W-BLDG	54*	17JUL08A	30SEP08A	30JUL08	14OCT08	10
0038	Structural Steel: E-BLDG	42*	18JUL08A	15SEP08A	11JUN08	26AUG08	-14
0039	Steel Erection Complete	0		23SEP08A		14OCT08	15
Crane 1							
0329	Erect: 13-15 / A-E (Seq 1-7)	19	09JUN08A	27JUN08A			0
0419	Detail: 13-15 / A-E (Seq 1-7)	32	18JUN08A	17JUL08A			0
0339	Erect: 15-21 / A-E (Seq 8-19)	22	30JUN08A	14JUL08A			0
0429	Detail: 15-21 / A-E (Seq 8-19)	35	02JUL08A	21JUL08A			0
0349	Erect: 21-25 / B-E (Seq 20-31)	23	17JUL08A	07AUG08A			0
0439	Detail: 21-25 / B-E (Seq 20-31)	38	22JUL08A	30SEP08A			0
0379	Erect: 25-31 / A-E (Seq 32-45)	16	19AUG08A	29AUG08A			0
0469	Detail: 25-31 / A-E (Seq 32-45)	30	20AUG08A	30SEP08A			0



Sheet 3 of 4

Figure 61: Turner Construction Schedule 3/4

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish	Plan Start	Plan Finish	Fin Var
0489	Stair C1	15	21JUL08A	12AUG08A			0
0499	Stair W2	15	22JUL08A	08AUG08A			0
0509	Stair W1	15	18AUG08A	05SEP08A			0
Crane 2							
0359	Erect: 13-8 / A-E (Seq 101-112)	13	08JUL08A	18JUL08A			0
0449	Detail: 13-8 / A-E (Seq 101-112)	28	17JUL08A	15SEP08A			0
0369	Erect: 8-4 / A-E (Seq 113-124)	25	18JUL08A	05AUG08A			0
0459	Detail: 8-4 / A-E (Seq 113-124)	39	22JUL08A	15SEP08A			0
0389	Erect: 4-0.07 / A-E (Seq 125-131)	18	05AUG08A	28AUG08A			0
0479	Detail: 4-0.07 / A-E (Seq 125-131)	31	06AUG08A	15SEP08A			0
0519	Stair E1	15	04AUG08A	20AUG08A			0
0529	Stair E2	10	06AUG08A	20AUG08A			0
SOD							
.							
0050	SOD: C-BLDG	33*	23JUL08A	06SEP08A	25JUN08	12AUG08	-18
0049	SOD: W-BLDG	32*	25AUG08A	07OCT08A	10SEP08	28OCT08	15
0051	SOD: E-BLDG	22*	26AUG08A	24SEP08A	23JUL08	09SEP08	-11
08 - 21							
0281B	MEP Hangers/Slab RI: 8-21 / A-E (1st Flr)	5	14JUL08A	18JUL08A			0
0291B	SOD: 8-21 / A-E (1st Flr)	5	23JUL08A	28JUL08A			0
0381B	MEP Hangers/Slab RI: 8-21 / A-E (5th Flr)	5	14AUG08A	15AUG08A			0
0391B	SOD: 8-21 / A-E (5th Flr)	5	15AUG08A	18AUG08A			0
0321B	MEP Hangers/Slab RI: 8-21 / A-E (2nd Flr)	5	24JUL08A	30JUL08A			0
0331B	SOD: 8-21 / A-E (2rd Flr)	5	31JUL08A	04AUG08A			0
0341B	MEP Hangers/Slab RI: 8-21 / A-E (3rd Flr)	5	25JUL08A	30JUL08A			0
0351B	SOD: 8-21 / A-E (3rd Flr)	5	31JUL08A	12AUG08A			0
0361B	MEP Hangers/Slab RI: 8-21 / A-E (4th Flr)	5	11AUG08A	12AUG08A			0
0371B	SOD: 8-21 / A-E (4th Flr)	5	13AUG08A	14AUG08A			0
0401D	MEP Hangers/Slab RI: 8-21 (Penthouse)	5	26AUG08A	02SEP08A			0
0411D	SOD: 8-21 (Penthouse)	5	29AUG08A	06SEP08A			0
08 - 04							
0281F	MEP Hangers/Slab RI: 8-4 / A-E (1st Flr)	4	25AUG08A	02SEP08A			0
0291F	SOD: 8-4 / A-E (1st Flr)	4	26AUG08A	04SEP08A			0
0321F	MEP Hangers/Slab RI: 8-4 / A-E (2nd Flr)	4	29AUG08A	04SEP08A			0
0331F	SOD: 8-4 / A-E (2rd Flr)	4	29AUG08A	08SEP08A			0
0341F	MEP Hangers/Slab RI: 8-4 / B-E (3rd Flr)	4	11SEP08A	16SEP08A			0
0351F	SOD: 8-4 / B-E (3rd Flr)	4	12SEP08A	17SEP08A			0
0361F	MEP Hangers/Slab RI: 8-4 / B-E (4th Flr)	4	12SEP08A	17SEP08A			0
0371F	SOD: 8-4 / B-E (4th Flr)	4	15SEP08A	18SEP08A			0
0381F	MEP Hangers/Slab RI: 8-4 / B-E (5th Flr)	4	16SEP08A	19SEP08A			0
0391F	SOD: 8-4 / B-E (5th Flr)	4	17SEP08A	22SEP08A			0
04 - 01							
0281H	MEP Hangers/Slab RI: 4-1 / A-E (1st Flr)	4	02SEP08A	08SEP08A			0
0291H	SOD: 4-1 / A-E (1st Flr)	4	03SEP08A	10SEP08A			0
0412H	Complete SOD: 0.7-01 (1st Flr)	4	06OCT08A	06OCT08A			0
0321H	MEP Hangers/Slab RI: 4-1 / A-E (2nd Flr)	4	03SEP08A	09SEP08A			0
0331H	SOD: 4-1 / A-E (2rd Flr)	4	05SEP08A	11SEP08A			0
0341H	MEP Hangers/Slab RI: 4-1 / B-E (3rd Flr)	4	15SEP08A	17SEP08A			0
0351H	SOD: 4-1 / B-E (3rd Flr)	4	16SEP08A	18SEP08A			0
0361H	MEP Hangers/Slab RI: 4-1 / B-E (4th Flr)	4	15SEP08A	18SEP08A			0
0371H	SOD: 4-1 / B-E (4th Flr)	4	17SEP08A	19SEP08A			0
0381H	MEP Hangers/Slab RI: 4-1 / B-E (5th Flr)	4	18SEP08A	22SEP08A			0
0391H	SOD: 4-1 / B-E (5th Flr)	4	19SEP08A	23SEP08A			0
0401H	MEP Hangers/Slab RI: 8-1 (Penthouse)	4	16SEP08A	19SEP08A			0
0411H	SOD: 8-1 (Penthouse)	4	18SEP08A	24SEP08A			0
0411H10	Pour Curbs: 8-1 (Penthouse)	5	24SEP08A	30SEP08A			0
01 - 0.7							
0281DL	MEP Hangers/Slab RI: 1-0.07 / A-E (1st Flr)	2	04SEP08A	05SEP08A			0
0291DL	SOD: 1-0.07 / A-E (1st Flr)	2	08SEP08A	10SEP08A			0
21 - 25							
0281C	MEP Hangers/Slab RI: 21-25 / B-E (1st Flr)	4	22AUG08A	22AUG08A			0
0291C	SOD: 21-25 / B-E (1st Flr)	4	25AUG08A	25AUG08A			0
0321C	MEP Hangers/Slab RI: 21-25 / B-E (2nd Flr)	4	25AUG08A	28AUG08A			0
0331C	SOD: 21-25 / B-E (2rd Flr)	4	26AUG08A	29AUG08A			0
0341C	MEP Hangers/Slab RI: 21-25 / B-E (3rd Flr)	4	26SEP08A	30SEP08A			0
0351C	SOD: 21-25 / B-E (3rd Flr)	4	29SEP08A	01OCT08A			0
0361C	MEP Hangers/Slab RI: 21-25 / B-E (4th Flr)	4	26SEP08A	30SEP08A			0
0371C	SOD: 21-25 / B-E (4th Flr)	4	01OCT08A	03OCT08A			0
0381C	MEP Hangers/Slab RI: 21-25 / B-E (5th Flr)	4	30SEP08A	03OCT08A			0
0391C	SOD: 21-25 / B-E (5th Flr)	4	01OCT08A	06OCT08A			0
25 - 28							
0281I	MEP Hangers/Slab RI: 25-28 / B-E (1st Flr)	4	17SEP08A	22SEP08A			0
0291I	SOD: 25-28 / B-E (1st Flr)	4	19SEP08A	25SEP08A			0
0321I	MEP Hangers/Slab RI: 25-28 / B-E (2nd Flr)	4	16SEP08A	19SEP08A			0
0331I	SOD: 25-28 / B-E (2rd Flr)	4	22SEP08A	30SEP08A			0
0341I	MEP Hangers/Slab RI: 25-28 / B-E (3rd Flr)	4	29SEP08A	01OCT08A			0
0351I	SOD: 25-28 / B-E (3rd Flr)	4	30SEP08A	02OCT08A			0
0361I	MEP Hangers/Slab RI: 25-28 / B-E (4th Flr)	4	30SEP08A	03OCT08A			0
0371I	SOD: 25-28 / B-E (4th Flr)	4	01OCT08A	04OCT08A			0
0381I	MEP Hangers/Slab RI: 25-28 / B-E (5th Flr)	4	07OCT08A	09OCT08A			0
0391I	SOD: 25-28 / B-E (5th Flr)	4	08OCT08A	10OCT08A			0
0401I	MEP Hangers/Slab RI: 21-28 (Penthouse)	4	01OCT08A	06OCT08A			0
0411I	SOD: 21-28 (Penthouse)	4	02OCT08A	07OCT08A			0
0411I10	Pour Curbs: 21-28 (Penthouse)	3	10OCT08A	10OCT08A			0
28 - 31							
0281K	MEP Hangers/Slab RI: 28-31 / B-E (1st Flr)	2	14OCT08A	15OCT08A			0
0291K	SOD: 28-31 / B-E (1st Flr)	2	15OCT08A	17OCT08A			0

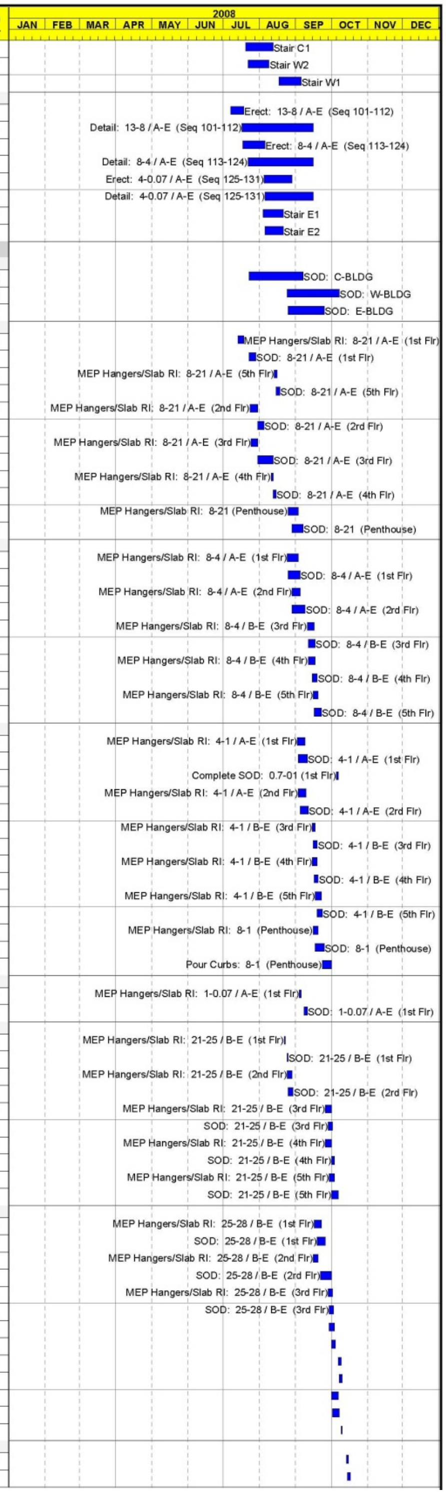


Figure 62: Turner Construction Schedule 4/4

APPENDIX G: SUSTAINABLE ARCHITECTURE BREADTH STUDY

LEED for New Construction v 2.2
Registered Project Checklist

Project Name: Westinghouse Electric Company Corporate Headquarters

Project Address: 1000 Westinghouse Drive, Cranberry Township, PA 16066

Yes	?	No		
28	5	33	Project Totals (Pre-Certification Estimates)	69 Points
CERTIFIED			**Certified:** 26-32 points **Silver:** 33-38 points **Gold:** 39-51 points **Platinum:** 52-69 points	

Yes	?	No			
8	3	3	Sustainable Sites		14 Points
Yes			Prereq 1	**Construction Activity Pollution Prevention**	Required
1	0	0	Credit 1	**Site Selection**	1
0	0	1	Credit 2	**Development Density & Community Connectivity**	1
0	0	1	Credit 3	**Brownfield Redevelopment**	1
1	0	0	Credit 4.1	**Alternative Transportation**, Public Transportation	1
1	0	0	Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
0	0	1	Credit 4.3	**Alternative Transportation**, Low-Emitting & Fuel Efficient Vehicles	1
1	0	0	Credit 4.4	**Alternative Transportation**, Parking Capacity	1
1	0	0	Credit 5.1	**Site Development**, Protect or Restore Habitat	1
1	0	0	Credit 5.2	**Site Development**, Maximize Open Space	1
1	0	0	Credit 6.1	**Stormwater Design**, Quantity Control	1
	1		Credit 6.2	**Stormwater Design**, Quality Control	1
	1		Credit 7.1	**Heat Island Effect**, Non-Roof	1
1	0	0	Credit 7.2	**Heat Island Effect**, Roof	1
	1		Credit 8	**Light Pollution Reduction**	1

Yes	?	No			
2	0	0	Water Efficiency		5 Points
1	0	0	Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
1	0	0	Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
			Credit 2	**Innovative Wastewater Technologies**	1
			Credit 3.1	**Water Use Reduction**, 20% Reduction	1
			Credit 3.2	**Water Use Reduction**, 30% Reduction	1

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Figure 63: LEED Checklist from http://www.usgbc.org/showfile.aspx?documentid=3998 1/4

LEED for New Construction v 2.2
Registered Project Checklist

Yes	?	No				
2	0	15	Energy & Atmosphere			17 Points
Yes			Prereq 1	**Fundamental Commissioning of the Building Energy Systems**		Required
Yes			Prereq 1	**Minimum Energy Performance**		Required
Yes			Prereq 1	**Fundamental Refrigerant Management**		Required

***Note for EAc1:** All LEED for New Construction projects registered after June 26, 2007 are required to achieve at least two (2) points.

Yes	?	No				
2	0	8	Credit 1	**Optimize Energy Performance**		1 to 10
				Credit 1.1	10.5% New Buildings / 3.5% Existing Building Renovations	1
			-->	Credit 1.2	14% New Buildings / 7% Existing Building Renovations	2
				Credit 1.3	17.5% New Buildings / 10.5% Existing Building Renovations	3
				Credit 1.4	21% New Buildings / 14% Existing Building Renovations	4
				Credit 1.5	24.5% New Buildings / 17.5% Existing Building Renovations	5
				Credit 1.6	28% New Buildings / 21% Existing Building Renovations	6
				Credit 1.7	31.5% New Buildings / 24.5% Existing Building Renovations	7
				Credit 1.8	35% New Buildings / 28% Existing Building Renovations	8
				Credit 1.9	38.5% New Buildings / 31.5% Existing Building Renovations	9
				Credit 1.10	42% New Buildings / 35% Existing Building Renovations	10
0	0	3	Credit 2	**On-Site Renewable Energy**		1 to 3
				Credit 2.1	2.5% Renewable Energy	1
				Credit 2.2	7.5% Renewable Energy	2
				Credit 2.3	12.5% Renewable Energy	3
0	0	1	Credit 3	**Enhanced Commissioning**		1
0	0	1	Credit 4	**Enhanced Refrigerant Management**		1
0	0	1	Credit 5	**Measurement & Verification**		1
0	0	1	Credit 6	**Green Power**		1

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Figure 64: LEED Checklist from http://www.usgbc.org/showfile.aspx?documentid=3998 2/4

LEED for New Construction v 2.2
Registered Project Checklist

Yes	?	No			
5	0	8	**Materials & Resources**		13 Points
Yes			Prereq 1	**Storage & Collection of Recyclables**	Required
0	0	1	Credit 1.1	**Building Reuse,** Maintain 75% of Existing Walls, Floors & Roof	1
0	0	1	Credit 1.2	**Building Reuse,** Maintain 95% of Existing Walls, Floors & Roof	1
0	0	1	Credit 1.3	**Building Reuse,** Maintain 50% of Interior Non-Structural Elements	1
1	0	0	Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
0	0	1	Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
1	0	0	Credit 3.1	**Materials Reuse**, 5%	1
1	0	0	Credit 3.2	**Materials Reuse**, 10%	1
0	0	1	Credit 4.1	**Recycled Content**, 10% (post-consumer + 1/2 pre-consumer)	1
0	0	1	Credit 4.2	**Recycled Content**, 20% (post-consumer + 1/2 pre-consumer)	1
1	0	0	Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured	1
1	0	0	Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured	1
0	0	1	Credit 6	**Rapidly Renewable Materials**	1
0	0	1	Credit 7	**Certified Wood**	1

Yes	?	No			
10	2	3	**Indoor Environmental Quality**		15 Points
Yes			Prereq 1	**Minimum IAQ Performance**	Required
Yes			Prereq 2	**Environmental Tobacco Smoke (ETS) Control**	Required
1	0	0	Credit 1	**Outdoor Air Delivery Monitoring**	1
1	0	0	Credit 2	**Increased Ventilation**	1
	1		Credit 3.1	**Construction IAQ Management Plan,** During Construction	1
	1		Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
1	0	0	Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
1	0	0	Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
1	0	0	Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
0	0	1	Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
0	0	1	Credit 5	**Indoor Chemical & Pollutant Source Control**	1
1	0	0	Credit 6.1	**Controllability of Systems**, Lighting	1
1	0	0	Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
1	0	0	Credit 7.1	**Thermal Comfort,** Design	1
1	0	0	Credit 7.2	**Thermal Comfort,** Verification	1
1	0	0	Credit 8.1	**Daylight & Views,** Daylight 75% of Spaces	1
0	0	1	Credit 8.2	**Daylight & Views,** Views for 90% of Spaces	1

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Figure 65: LEED Checklist from http://www.usgbc.org/showfile.aspx?documentid=3998 3/4

LEED for New Construction v 2.2
Registered Project Checklist

Yes	?	No			
1	0	4	Innovation & Design Process		5 Points
0	0	1	Credit 1.1	**Innovation in Design:** Provide Specific Title	1
0	0	1	Credit 1.2	**Innovation in Design:** Provide Specific Title	1
0	0	1	Credit 1.3	**Innovation in Design:** Provide Specific Title	1
0	0	1	Credit 1.4	**Innovation in Design:** Provide Specific Title	1
1	0	0	Credit 2	**LEED® Accredited Professional**	1

Figure 66: LEED Checklist from http://www.usgbc.org/showfile.aspx?documentid=3998 4/4

Appendix H: References

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