THE DUNCAN CENTER
DOVER, DELAWARE

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STRUCTURAL OPTION
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FINAL REPORT
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EXECUTIVE SUMMARY

This report evaluates The Duncan Center in Dover, DE as a concrete framed system with two-way flat slabs with drop panels and shear walls, compared to the existing moment frame steel and composite deck system. The system was evaluated based upon structural, acoustics, and construction management analyses.

The concrete structural system consists of typical 12" thick two-way flat slab with drop panels framed with 16"x16" columns, except the sixth floor which is a one-way slab framed with 24"x28" columns. Shear walls with an 8" thickness support the structure laterally, except for on the sixth floor which is supported laterally by a concrete moment frame formed by the slab beams and columns. Foundations were redesigned for the system and augercast piles were change from 16" dia. to 18" dia. with little change to pile cap configurations.

As per the results for the analyses it was found that the proposed concrete structural system performed better than the existing steel structural system for reducing spray-on fireproofing, increasing mechanical ceiling to floor cavity space, increasing the sound transmission class, improving reverberation time, and reducing cost. However, despite all of these benefits, the proposed concrete structural system also increases the construction schedule by six months as compared to the existing steel structural system. Therefore, changing the structural system from steel to concrete is not recommended, as schedule is the Owner's number one concern.

Figure 1: The Duncan Center, Personal Photo: Taken August 16, 2007

ACKNOWLEDGEMENTS

To The Duncan Center:
Especially Bob Duncan, Karl Buckwalter, Linda Cooper Duncan, Erin Cooper
For permitting the use of The Duncan Center for this project and allowing me to tour the building.

To Baker, Ingram & Associates:
Especially Larry Baker, Paynter Ingram, Jack Wood, Karen Jordan, Jason Moore, Cherie Moore
For taking time out of your day to track down project information, for providing me with construction documents, and answering my questions.

To Jackson Architects:
Especially Steve Cannon
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To God, my fiancé, family, and friends:
Thank you for your patience and understanding when my thesis came first and for all your loving care and support!

I. Introduction

The Duncan Center is a premium office building located in Dover, DE. There are a total of six floors with the building reaching an overall height of 93'-0". Open flex office space is located on the first four floors, a reception and banquet hall on the fifth floor, and a penthouse holding the building management offices on the sixth floor. Small electrical and mechanical rooms are also located on the sixth floor, with the larger electrical and mechanical room located in the basement along with storage space. Balconies augment the fourth and fifth floors and the overall structure is crowned with an arched penthouse.

The purpose of this report is to examine the work performed to compare a proposed concrete two-way flat slab and shear wall structural system versus the existing moment frame steel structural system based upon the structural design, acoustics, cost, and schedule. Additional calculations in support of the material presented in this report are available upon request. Spot checks were performed for all computer models and can be found in Appendix A in their appropriate section as indicated in Depth: Proposed Concrete Structural System.

Figure 2: Ballroom Entrance, Personal Photo: Taken August 16, 2007

II. Background

i. General

Name:	The Duncan Center
Location:	500 W. Loockerman Street, Dover, Kent County, DE 19904
Site:	Intersection of Loockerman Street and Slaughter Street
Occupants:	Bill Roth Social Security Center
	Gary Linarducci Law Office
	Doroshow, Pasquale, Krawitz & Bhaya Law Offices
	State of Delaware Statewide Benefits Office
	Coldwell Banker Commercial
	Amato Associates
	Ameriquest Mortgage Company
	The Outlook Center
	Duncan Petroleum
	Super Soda Center
Occupancy Class:	Business B/Assembly A
Size:	76,577 SF
Height:	93'-0"
Stories:	6
Primary Project Team:	Owner and General Contractor:
	Robert M. Duncan
	http://www.theduncancenter.com/
	Construction Manager and Mechanical Subcontractor:
	Sunnyfield Contractors
	No website available
	Architect:
	Jackson Architects
	http://www.jacksonarchitects.com/
	Structural Engineer:
	Baker, Ingram & Associates
	http://www.bakeringram.com/

MEP Engineer:
Furlow Associates, Inc.
http://www.furlowassociates.com/
Fire Protection Engineer:
Radius
http://www.radiusservices.com/
Civil Engineer:
Braun Engineering (Gerald A. Donovan Associates, Inc.)
http://www.braunengineering.net/
Geotechnical Engineer:
John D. Hynes & Associates, Inc.
http://johndhynesandassociatesinc.com/

Construction Start Date: June 2003
Construction End Date: June 2004
Overall Project Cost: $10.4 million
Additional Tenant Cost: $46,000
Project Delivery Method: Design-Build

ii. Architecture

Architectural Description:

The Duncan Center is a six-story building with the first four stories of identical floorplan, for open flex office space, and a fifth floor of a smaller footprint to allow a wrap around balcony for The Outlook Center, the signature reception hall on that floor. The sixth floor penthouse holds offices for management and mechanical space.

The building is fitted out with some luxury items that make the building premium office space, such as an elegant entry canopy, a trickling granite fountain, lush ferns sitting on custom quarry floor tiles next to dark wood furniture, and large clear span windows allowing one to connect with the outdoors. There is also a small park in a cove of the building which has artistic iron park benches and a gravel path which courses through the flowers and greenery; see Figure 2: Ballroom Entrance.

Model Code: BOCA 1999
Zoning: The City of Dover Office Zone Institutional and Office IO/Commercial Zone Service C3

Historical Requirements: The Duncan Center is located just outside of the Dover historic district, thus no additional building criterion was necessary.

Building Envelope Description:

The majority of the first five floors of the building have a red running bond brick façade with cold formed steel stud back-up and Le Corbusierian free band green-tinted glass windows continuously running around the perimeter of the building. The central portion of the building and the sixth floor, extending up from the ground floor lobby, has a cream colored stucco façade which stands out against the red brick. This central portion also has cold formed steel stud back-up with mullioned punched windows and arched windows on the front and back side of the building. The roof system is a flat metal deck roof supported by cold formed steel roof trusses on the fifth floor and arched metal deck and cold formed steel roof trusses over the sixth floor penthouse; see Figure 1: The Duncan Center.

iii. Mechanical System

The mechanical system utilizes stair pressurization risers to ventilate the six story office building, which is achieved through two stairwells in the office area and one adjacent to the lobbies. The heating and cooling is controlled by heat pumps, which bring in outside air on each floor and also draw supply air from the basement mechanical room, where the boilers and 51,900 CFM cooling tower enter the system. There are typically three heat pumps, two 1040 CFM located at the exterior edge on the north and south faces of the building and one 800 CFM centrally located heat pump, on each floor. An exception to this is the fifth floor, which has five heat pumps of various sizes from 800-2010 CFM, in order to service the higher occupant loads produced by The Outlook Center reception hall.

iv. Electrical System

The building receives its power from a 480/277 V, 3 phase, 4 wire transformer. The transformer then redistributes the current to a 1200A main distribution switchboard with breaker type overcurrent protection providing electricity to each floor through 112.5 kVA panels. In the case of a black out or electricity short out, the building is also equipped with an emergency 200kW diesel generator, for the function of life safety electrical equipment and other normal building functions.

v. Lighting System

As the building is primarily comprised of flex office space on the first four floors, many of the lighting fixtures in these spaces are not specified to allow individual specification by the tenant. Upon observation of leased and fitted out spaces, the typical lighting fixtures of choice were primarily fluorescent pendants. The lobby spaces have a combination of incandescent wall sconces with fluorescent pendant lighting operating at 277V. Comparatively, the exterior lighting is comprised of 277V metal halide fixtures.

vi. Construction Management

The construction of the Duncan Center took place in one year from summer of 2003 to summer of 2004. The project was delivered under design-build as the Owner performed as his own General Contractor on the job.

vii. Transportation

The building has three stairwells, one on each of the North and South side of the building servicing the basement through fifth floors and adjacent to the lobbies servicing the basement through sixth floors. Across from the lobby stairwell are also two elevators which service the basement through fifth floors.

viii. Fire Protection

The building is automatically sprinkled on all floors with standpipes in the center stairwell and access at each floor from the basement to the sixth floor penthouse. Also, the structural system has a two hour fire rating for all steel beams, columns, girders by spray-on fireproofing, concrete slabs, and exterior masonry bearing walls. The roof has a one hour fire rating for the cold formed steel roof trusses and metal deck with spray-on fireproofing.

ix. Telecommunications

On the first floor in the entry lobby, there is a fire command center and communications hub from which the Cornell A4208 Master Station intercom system and fire sensors operate, servicing each stairwell.

III. Structural Depth

i. Existing Steel Structural System

a. Foundation System

The foundation system begins with auger cast concrete piles as per the recommendation of the geotechnical engineer, John D. Hynes & Associates, Inc. The structural engineer was presented with the choice of several different diameters and depths of piles that would perform adequately in the given soil conditions. A 16" dia., 40' long pile was selected, with a bearing capacity of 85 tons; see Figure 3: Existing Steel Structural System Foundation Plan.

On top of these piles rest the pile caps of variant cross section with a depth of 3'-1" each; see Figure 10: Existing Steel Structural System Pile Cap Configurations. Upon the pile caps rest the 24"x24" concrete piers with 18"x18" steel baseplates ranging in thickness from 1" to 2-1/4" including 4-1" dia. A325N anchor bolts. Finally, the basement slab on-grade is a 4" cast-in place concrete slab reinforced with 6x6 W2.9xW2.9 welded wire fabric; see Figure 3: Existing Steel Structural System Foundation Plan.

b. Framing System

The floor system for the Duncan Center typical on all floors is 5" composite slab with 2" 20 gage composite metal deck reinforced with 6x6 W2.0xW2.0 welded wire fabric. The deck is welded to the structural steel members beneath with composite beam action through 3/4" dia. x 4" long shear studs. The typical floor bay has spans of 27'-8"x24'-5" with the beams running in the long direction, W16x31 interior and W18x35 between columns, and girders running in the short direction, W24x55; see Figures 4, 5 & 6: Existing Steel Structural System 2nd, 5th & 6th Floor Framing Plans.

c. Lateral Load Resisting System

The Lateral Load Resisting System is singularly comprised of the moment connected frame with flange welded/web bolted moment connections between the W18x35 beams between columns and W24x55 girder to the columns; see Figures 11 & 12: Existing Steel Structural System Column Flange & Column Web Moment Connection Details, respectively. Columns range in size from W12x45 to W12x132 and are spliced at the third and the fifth floor, see Figures 8 & 9: Existing

Steel Structural System Elevation Line A & Line 4, respectively.

d. Roof Framing

The roof framing is comprised of cold-formed steel roof trusses spaced at 24" o.c. for both the lower flat fifth floor roof and the arched sixth floor penthouse roof. The trusses rest on exterior structural steel girders, W16x26 typical at the fifth floor roof and W16x31 at the penthouse roof. Attached to trusses is 20 gage galvanized Type B roof deck; see Figure 7: Existing Steel Structural System Roof Framing Plan.

e. Foundation Plan

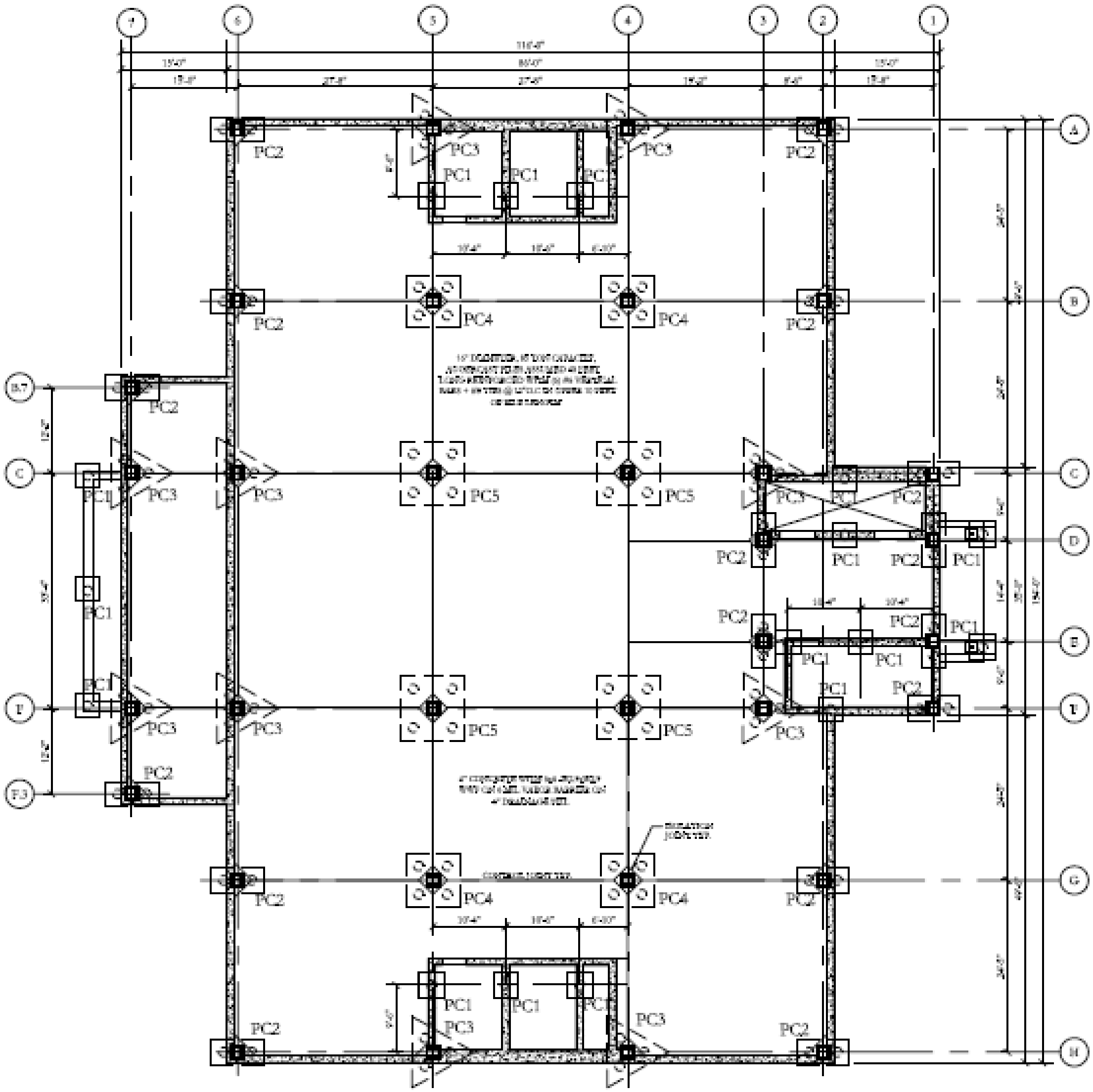


Figure 3: Existing Steel Structural System Foundation Plan

f. Framing Plans

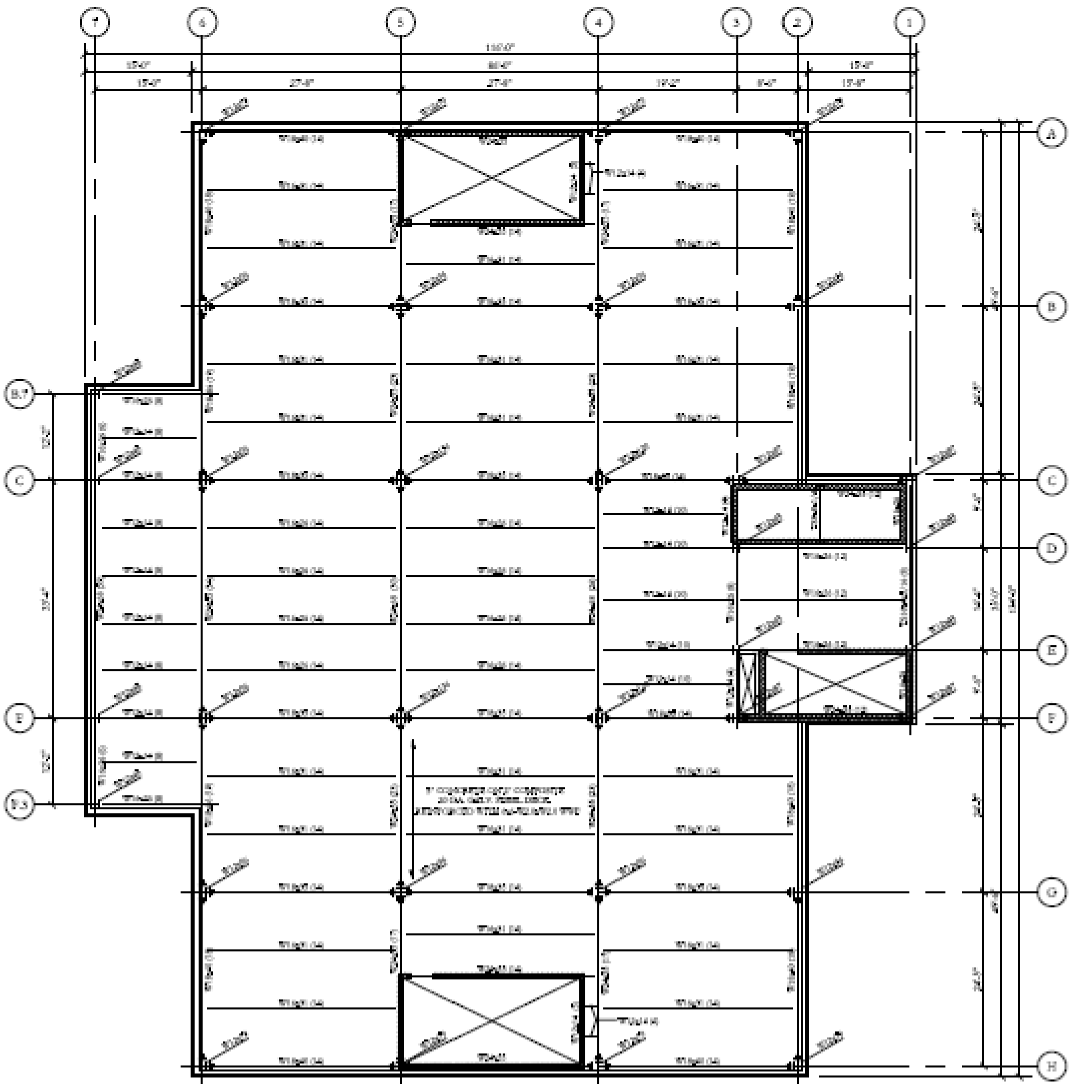


Figure 4: Existing Steel Structural System 2nd Floor Framing Plan

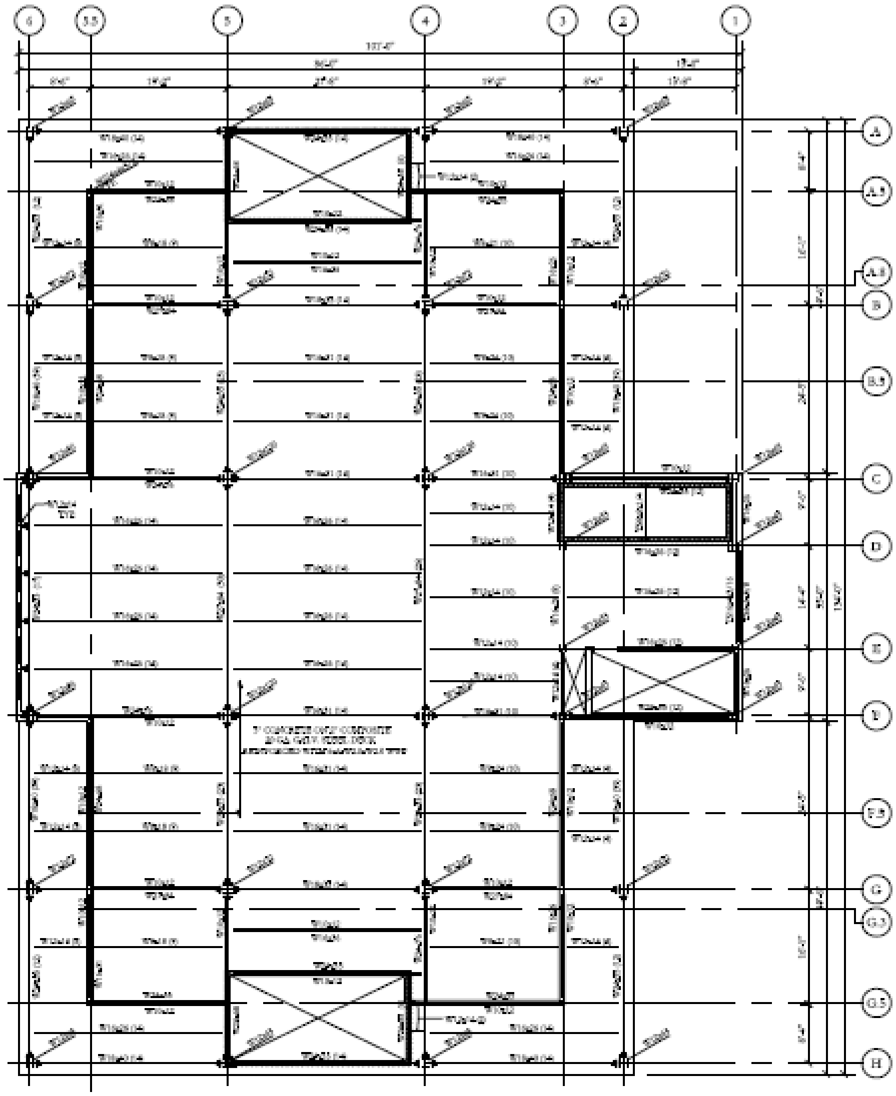


Figure 5: Existing Steel Structural System 5th Floor Framing Plan

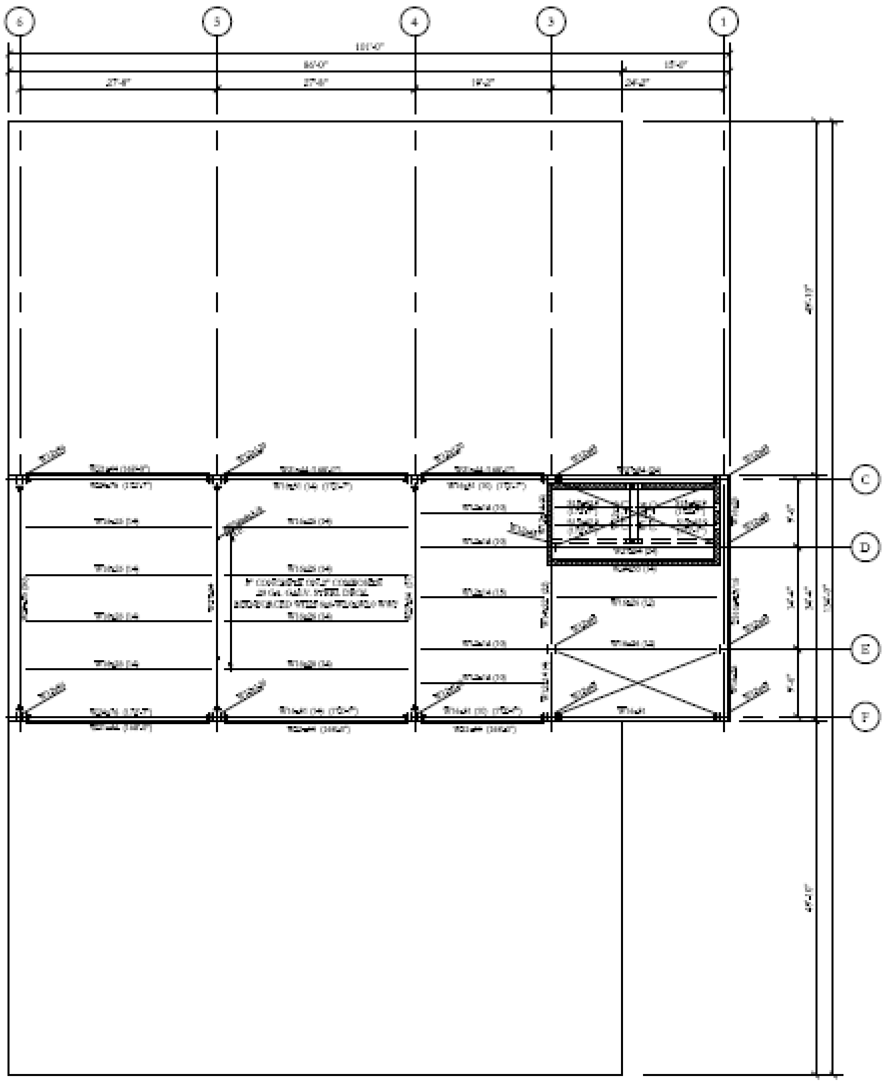


Figure 6: Existing Steel Structural System 6th Floor Framing Plan

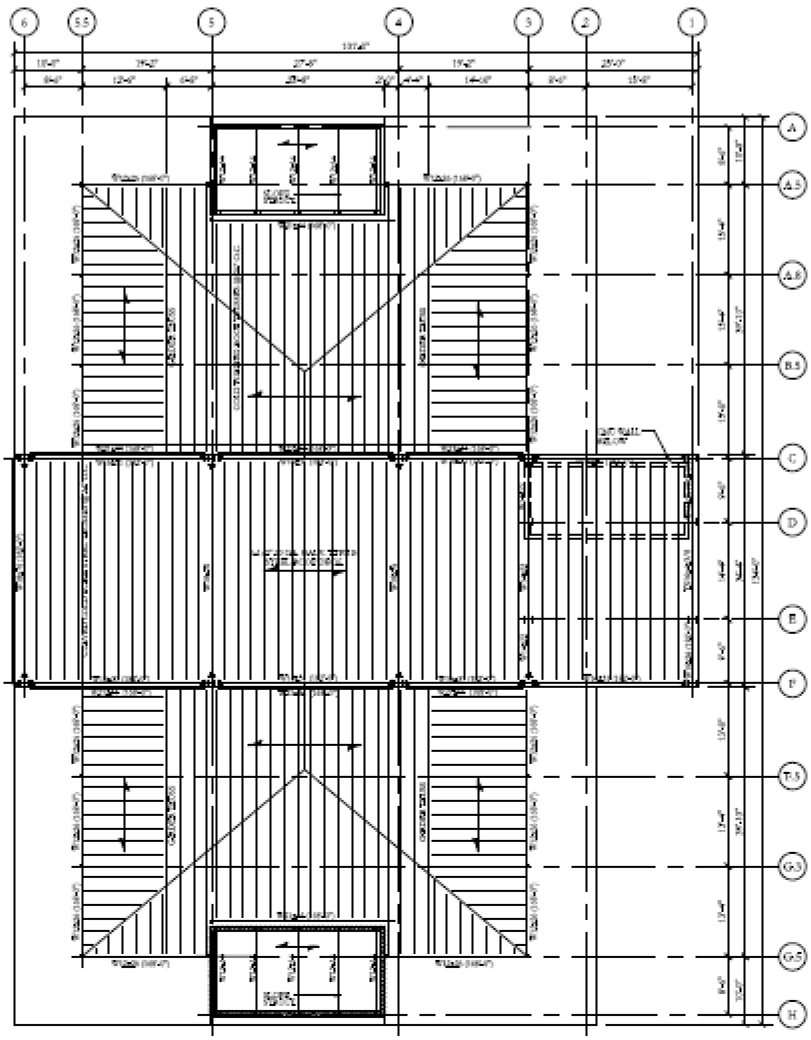


Figure 7: Existing Steel Structural System Roof Framing Plan

g. Elevations

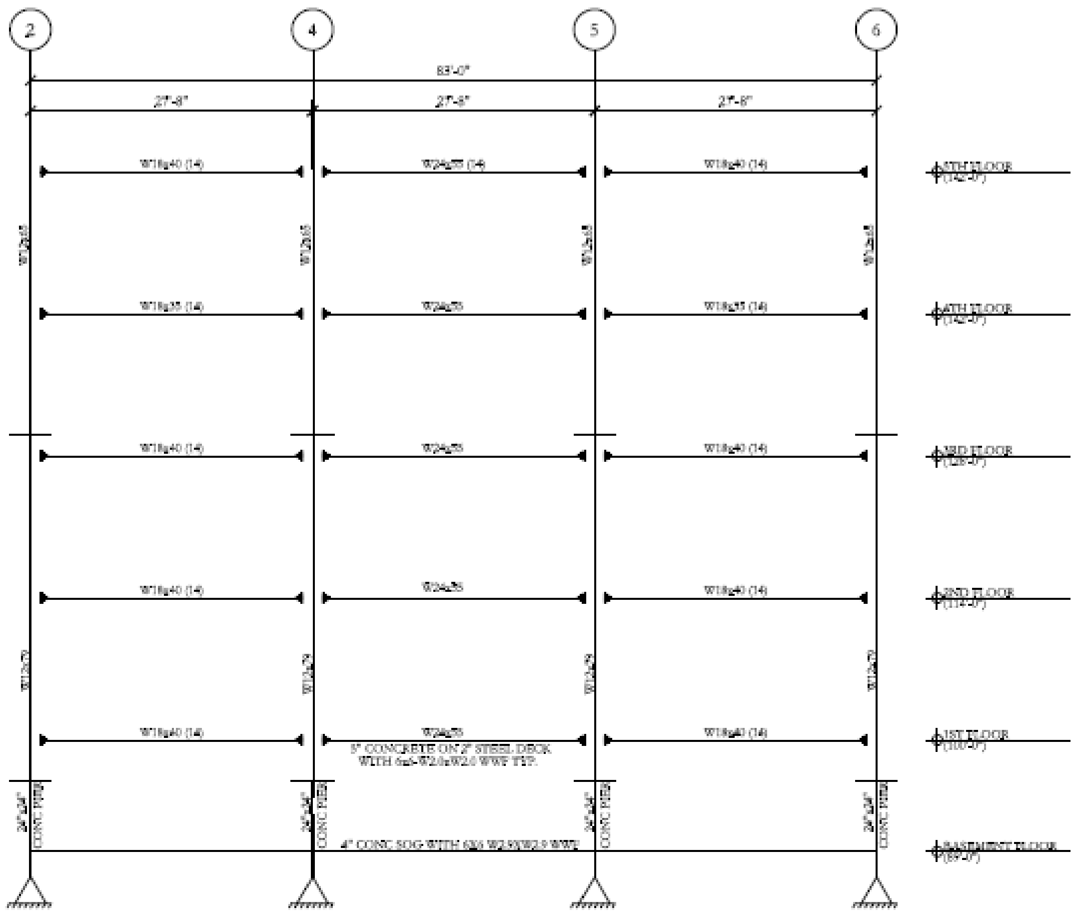


Figure 8: Existing Steel Structural System Elevation Line A

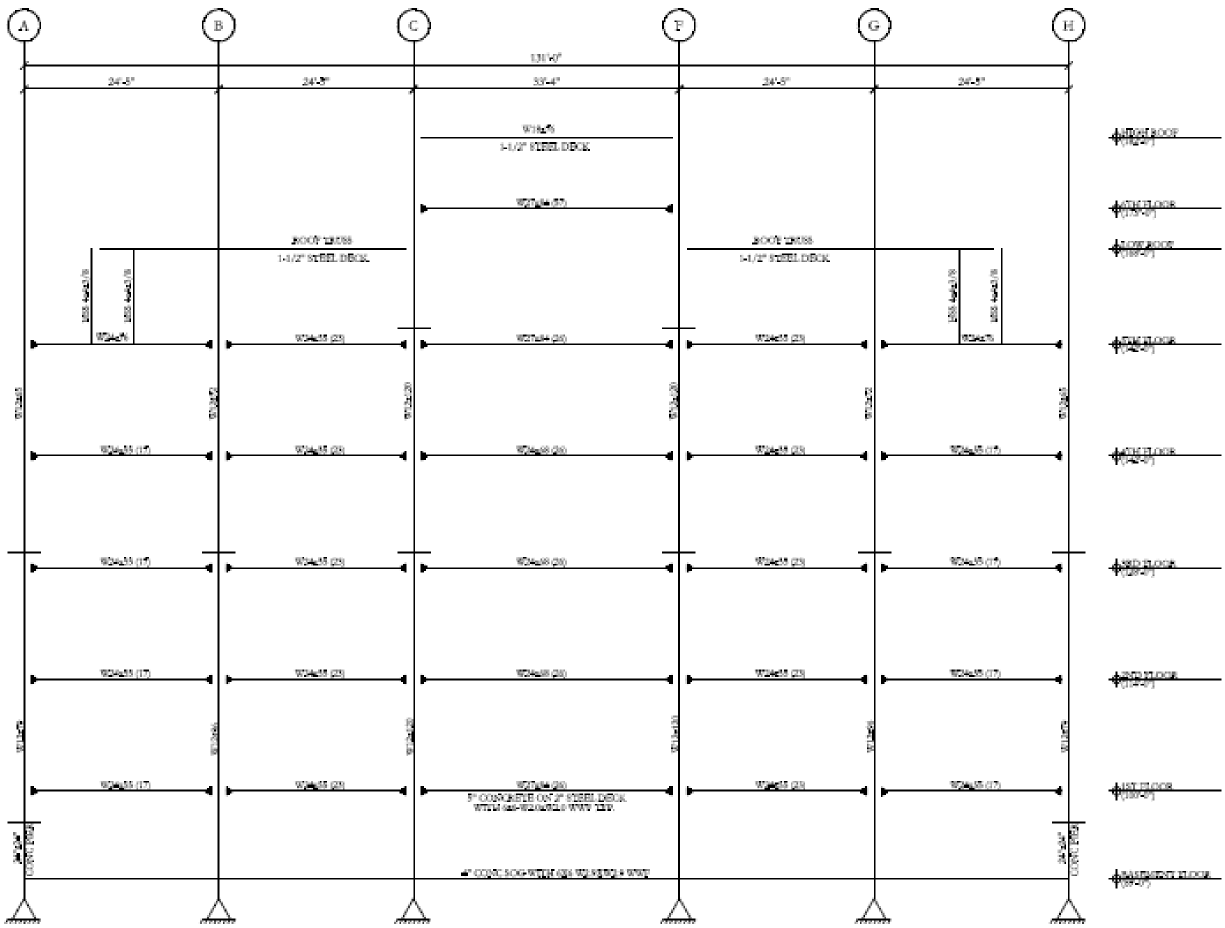
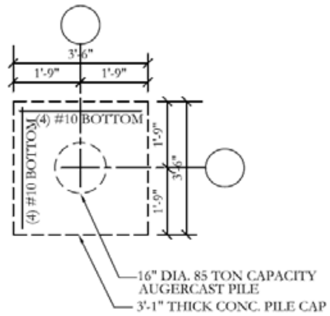
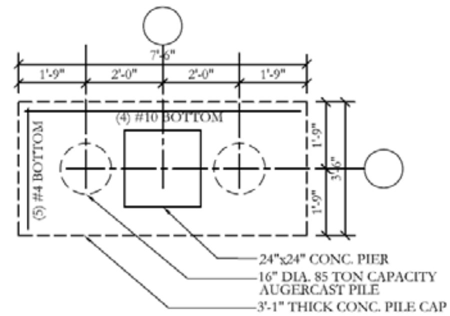


Figure 9: Existing Steel Structural System Elevation Line 4

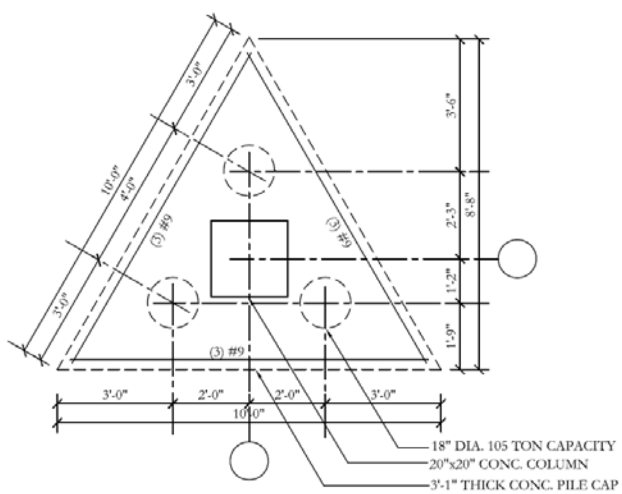
b. Details



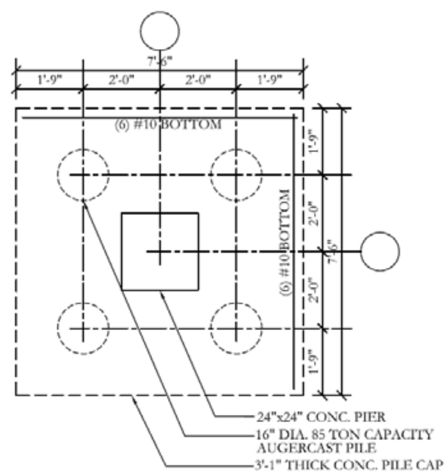
P1



P2



P3



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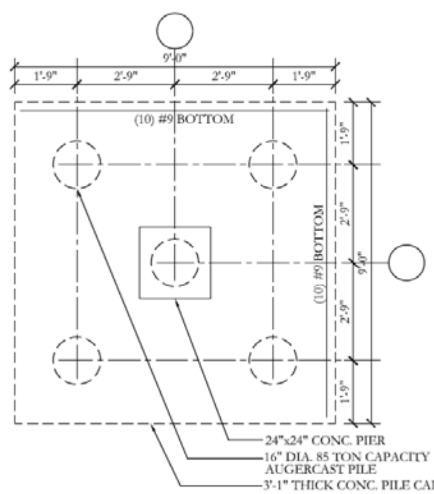


P5

Figure 10: Existing Steel Structural System Pile Cap Configurations

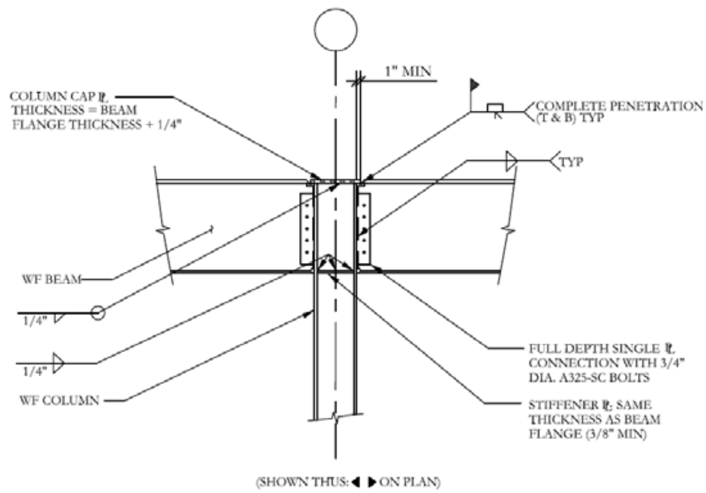


Figure 11: Existing Steel Structural System Column Flange Moment Connection Detail

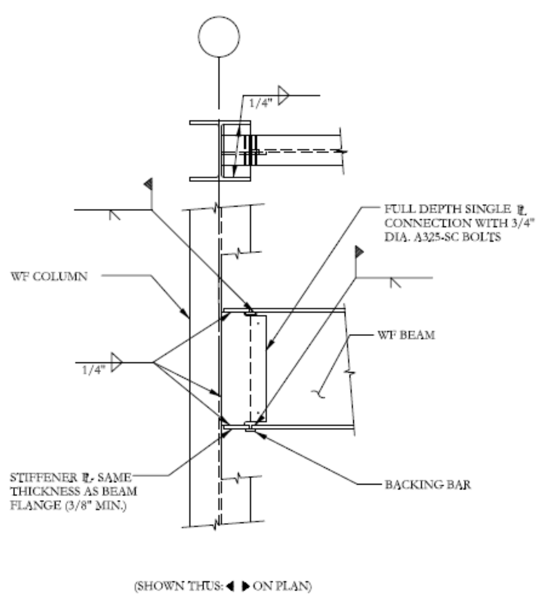


Figure 12: Existing Steel Structural System Column Web Moment Connection Detail

ii. PROPOSAL BACKGROUND

Problem Statement

When the Duncan Center was originally designed, it was decided to use a lateral load resisting system of a steel moment frame. The key advantage of using moment connected frames is that there is freedom of architectural constraints of the façade and interior space. Comparatively, braced frames and shear walls provide such constraints to the placement of doors, windows, and walls, which may play a significant contributing factor to the overall architecture of the building. Other potential deciding factors may have been the duration of construction, as an Owner would desire the building to be constructed as quickly as possible in order to turn around and lease the space, and steel is typically erected more quickly. Also, the overall weight of the building must be considered for its effect upon the foundation design, and steel is typically a lighter system than concrete.

Steel moment frames, however, are known to not always be the most cost effective lateral system that could be selected for a particular building. This is primarily due to the expense incurred by the moment connections themselves, which often incorporate multiple welds in the shop and also in the field. Thus, the current lateral system in the Duncan Center may not be the most economical and a different lateral system will be investigated to determine if steel moment frames are indeed the optimal solution.

Proposed Solution

From the preliminary study performed in the Technical Assignment #2 it was found that compared to the existing composite system, a concrete two-way flat plate conventionally reinforced system may be more cost effective, eliminate the need for spray-on fireproofing, and allow increased cavity area for MEP ductwork and equipment.

By using a concrete flat plate system, a steel framing and lateral system is no longer logical and a concrete framing and lateral system shall be put in its place. The alternative lateral system to be designed will be concrete shear walls, positioned within the building to create as little obstruction to the architecture as possible, taking into account the existing façade and typical tenant floorplan. Also, due to the significant change in weight present between the two floor systems, the foundation system will also need to be reanalyzed.

iii. DESIGN LOADS

a. Dead Loads

Summary		
Floor	20	PSF
Roof	20	PSF
Balcony	30	PSF
Exterior Wall	55	PSF
Partition Wall	20	PSF
Bearing Wall	80	PSF
Shear Wall	97	PSF

See Appendix A: pg.55 for calculations.

Note: Building dead loads do not include supporting structural member self-weights.

b. Live Loads

Space	Load	
Roof	33	PSF
Balcony	100	PSF
Stairs and Exits	100	PSF
Corridor-First Floor	100	PSF
Corridor-Other Floors	80	PSF
Lobby	100	PSF
Dance Halls and Ballrooms	100	PSF
Office Space	70	PSF

c. Snow Loads

Flat Roof Snow Load

pf=22 psf

Lower Roof Snow Drift Load

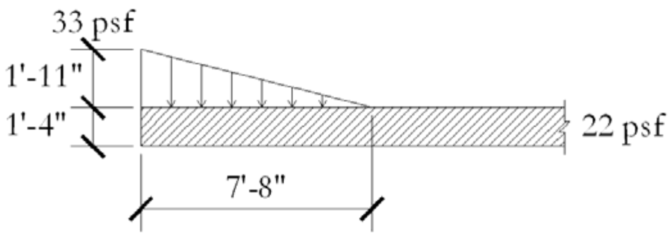


Figure 13: Snow Drift Loading Diagram

See Appendix A: pg.56-57 for calculations.

d. Wind Loads

Figure 14: North-South Direction Wind Load

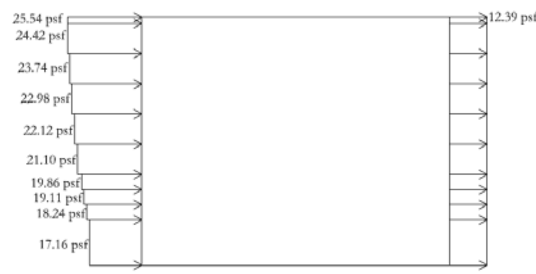


Figure 15: East-West Direction Wind Load

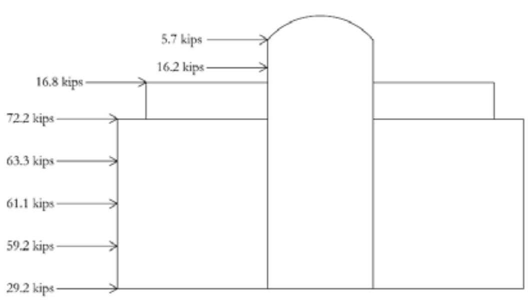


Figure 16: North-South Direction Story Shear

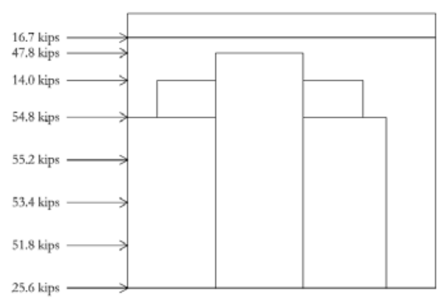


Figure 17: East-West Direction Story Shear

See Appendix A: pg.57-62 for calculations.

e. Seismic Loads

Equivalent Lateral Force

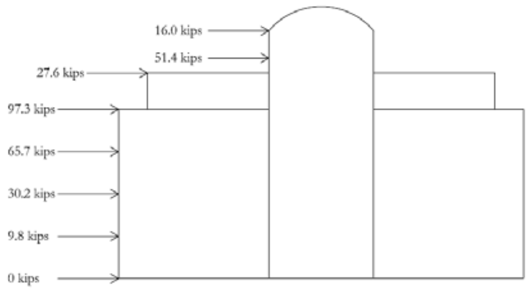


Figure 18: Story Shear

See Appendix A: pg.62-65 for calculations.

f. Analysis Codes and Reference Standards

National Building Code: International Code Council (ICC) 2006
"International Building Code (IBC)"
Design Loads: American Society of Civil Engineers (ASCE) 7-05
"Minimum Design Loads for Buildings and Other Structures"
Steel Reference Standard: American Institute of Steel Construction (AISC) 13th Edition
"Specification for Structural Steel Buildings" (LRFD)
Concrete Reference Standard: American Concrete Institute (ACI) 318-02
"Building Code Requirements for Structural Concrete"
Metal Deck Reference Standard: United Steel Deck (USD) 2006
"Steel Decks for Floors and Roofs"
Steel Joist Reference Standard: Nucor-Vulcraft Group 2003
"Steel Joists & Joist Girders"

g. Load Combinations

LRFD

1. 1.4D
2. 1.2D+1.6L+0.5S
3. 1.2D+1.6S+L
4. 1.2D+1.6S+0.8W
5. 1.2D+1.6S-0.8W
6. 1.2D+1.6W+L+0.5S
7. 1.2D-1.6W+L+0.5S
8. 1.237D+1.0E+L
9. 1.237D-1.0E+L
10. 0.9D+1.6W
11. 0.9D-1.6W
12. 0.863D+1.0E
13. 0.863D-1.0E

See Appendix A: pg.97 for Seismic Load Combination calculations.

iv. Proposed Concrete Structural System

a. Foundation System

For the redesign of the foundations, it was decided to change the augercast piles from the previously selected 16" dia. and 85 ton capacity to a different presented option of an 18" dia. and 105 ton capacity and of equal length, as per the geotechnical engineer, John D. Hynes & Associates, Inc. By changing the diameter of the augercast piles, the effect of the increased weight of the structure had less impact on the foundation configurations, which are mostly governed by geometrical constraints; see Figure 21: Proposed Concrete Structural System Foundation Plan & Figure 29: Proposed Concrete Structural System Pile Cap Configurations. Below is the column dowel reinforcement schedule corresponding to the appropriate columns and pile caps; see Figure 22: Proposed Concrete Structural System 2nd Floor Framing Plan.

Column Dowel Reinforcement Schedule		
Column	Size	Dowel Reinforcement
C1	20"x20"	4-#8
C2	20"x20"	4-#8
C3	20"x20"	4-#8
C4	24"x28"	4-#10
C5	24"x28"	4-#10

For calculations and other assumptions; see Appendix A: pg.66-68.

b. Framing System

As a result of changing the lateral system to shear walls, the framing system also had to be changed to concrete. It was determined based upon results from Technical Assignment #2 that a two-way flat plate system was comparative to the existing composite slab and metal deck floor system. The concrete strength was also changed from 4000 psi to 5000 psi in order as determined from the optimum analysis of the floor slabs.

Preliminary thicknesses of slabs were based upon the ACI code requirements for minimum slab thickness, however final designs incorporated a deflection analysis, enabling the thickness of the slabs to be reduced, due to the 33'-4" long span. Also, due to the punching shear existing at the column strips along this long span, drop panels with a 4" thickness also needed to be incorporated; see Figure 30: Proposed Concrete Structural System Drop Panel Details. The final slab thickness were 12" for the first through fourth floors and 14" for the fifth floor; see Figures 22 & 23: Proposed Concrete Structural System 2nd & 5th Floor Framing Plans, respectively.

A one-way slab with beams was implemented for the sixth floor as there is only one span that exists and it was also found to be 12" thick; see Figure 24: Proposed Concrete Structural System 6th Floor Framing Plan. Below is the slab reinforcement which was the result of the analysis of the critical strips for each slab in PCA Slab. The slabs should also be analyzed based upon the seismic loads in the diaphragms, however this was not feasible for the duration of this project.

Slab Reinforcement Schedule			
Story	Strip	Reinforcement	Spacing (in)
6th Floor	Column	#5	9
5th Floor	Column	#5	5
	Middle	#5	10
4th Floor	Column	#5	5
	Middle	#5	12
3rd Floor	Column	#5	5
	Middle	#5	12
2nd Floor	Column	#5	5
	Middle	#5	12
1st Floor	Column	#5	5
	Middle	#5	12

For calculations and other assumptions; see Appendix A: pg.69-81.

On the next page is the beam schedule for the one-way slab beams and was based upon the lateral analysis results from ETABS, as they acted in part of the concrete moment frame which frames the sixth floor; see Figure 24: Proposed Concrete Structural System 6th Floor Framing Plan.

Beam Schedule				
Beam	Size	Flexural Reinforcement	Shear Reinforcement	Spacing (in)
B1	24"x24"	3-#10	#3	5
B2	24"x24"	4-#10	#3	5

For calculations and other assumptions; see Appendix A: pg.82-83.

Preliminary column sizes were determined to be 16"x16" based upon the results from PCA Slab. All columns were designed using the CRSI Handbook, these results of these designs are presented in the column schedule below and on the subsequent pages. Design by CRSI Handbook was permitted as all the columns met the short column requirements as required; see Figures 22, 23 & 24: Proposed Concrete Structural System 2nd, 5th & 6th Floor Framing Plans. The final column sizes were determined for gravity loading with the exception of those on the sixth floor, which were based upon gravity and lateral analysis results from ETABS, as they acted as part of the concrete moment frame which frames the sixth floor.

Column Schedule				
C1	Floor	Bars	Bar Configuration	Ties
20"x20"	Basement	8-#10	3E	#3
	1st Floor	8-#10	3E	#3
	2nd Floor	8-#10	3E	#3
	3rd Floor	8-#10	3E	#3
	4th Floor	16-#10	5E	#3
C1	Floor	Tie Spacing (in)	Extended Bars	Splice Length (in)
20"x20"	Basement	18	8-#10	38
	1st Floor	18	8-#10	38
	2nd Floor	18	8-#10	38
	3rd Floor	18	8-#10	38
	4th Floor	18	NA	NA

Column Schedule				
C2	Floor	Bars	Bar Spacing	Ties
20”x20”	Basement	8-#10	3E	#3
	1st Floor	8-#10	3E	#3
	2nd Floor	8-#10	3E	#3
	3rd Floor	8-#10	3E	#3
	4th Floor	16-#10	5E	#3
C2	Floor	Tie Spacing (in)	Extended Bars	Splice Length (in)
20”x20”	Basement	18	8-#10	38
	1st Floor	18	8-#10	38
	2nd Floor	18	8-#10	38
	3rd Floor	18	8-#10	38
	4th Floor	18	NA	NA
C3	Floor	Bars	Bar Spacing	Ties
20”x20”	Basement	4- #10	2E	#3
	1st Floor	4- #10	2E	#3
	2nd Floor	4- #8	2E	#3
	3rd Floor	4- #8	2E	#3
	4th Floor	4- #8	2E	#3
C3	Floor	Tie Spacing (in)	Extended Bars	Splice Length (in)
20”x20”	Basement	18	4- #10	38
	1st Floor	18	4- #10	38
	2nd Floor	16	4- #8	30
	3rd Floor	16	4- #8	30
	4th Floor	16	NA	NA
C4	Floor	Bars	Bar Spacing	Ties
24"x28"	Basement	8-#8	3E	#3
	1st Floor	8-#8	3E	#3
	2nd Floor	8-#8	3E	#3
	3rd Floor	8-#8	3E	#3
	4th Floor	8-#10	3E	#3
	5th Floor	8-#10	3E	#3
	6th Floor	8-#10	3E	#3

Column Schedule				
C4	Floor	Tie Spacing (in)	Extended Bars	Splice Length (in)
24"x28"	Basement	16	8-#8	30
	1st Floor	16	8-#8	30
	2nd Floor	16	8-#8	30
	3rd Floor	16	8-#8	30
	4th Floor	18	8-#10	38
	5th Floor	18	8-#10	38
	6th Floor	18	NA	NA
C5	Floor	Bars	Bar Spacing	Ties
24"x28"	Basement	8-#8	3E	#3
	1st Floor	8-#8	3E	#3
	2nd Floor	8-#8	3E	#3
	3rd Floor	8-#8	3E	#3
	4th Floor	8-#10	3E	#3
	5th Floor	8-#10	3E	#3
	6th Floor	8-#10	3E	#3
C5	Floor	Tie Spacing (in)	Extended Bars	Splice Length (in)
24"x28"	Basement	16	8-#8	30
	1st Floor	16	8-#8	30
	2nd Floor	16	8-#8	30
	3rd Floor	16	8-#8	30
	4th Floor	18	8-#10	38
	5th Floor	18	8-#10	38
	6th Floor	18	NA	NA

For calculations and other assumptions; see Appendix A: pg.84-96.

c. Lateral Load Resisting System

Preliminary thickness of the shear walls was governed by IBC 2006 Fire Construction Rating requirements and to provide a 3 hour rating for the stair well and determined to be 8". After analyzing the lateral system in ETABS, it was determined that this thickness of shear wall was adequate for drift, overturning and torsion; see Figure 19: ETABS Model. On the next page, the shear wall schedule show the results for the designs based upon ETABS.

Based on the configurations of the sixth floor, shear walls, which optimally replaced the North and South stair towers, could not laterally support this floor. Therefore, a concrete moment frame was utilized for the sixth floor, the designs for which were presented in the previous section, Framing System; see Figures 26, 27 & 28: Proposed Concrete Structural System Elevation Line A, Line A7 & Line 4.

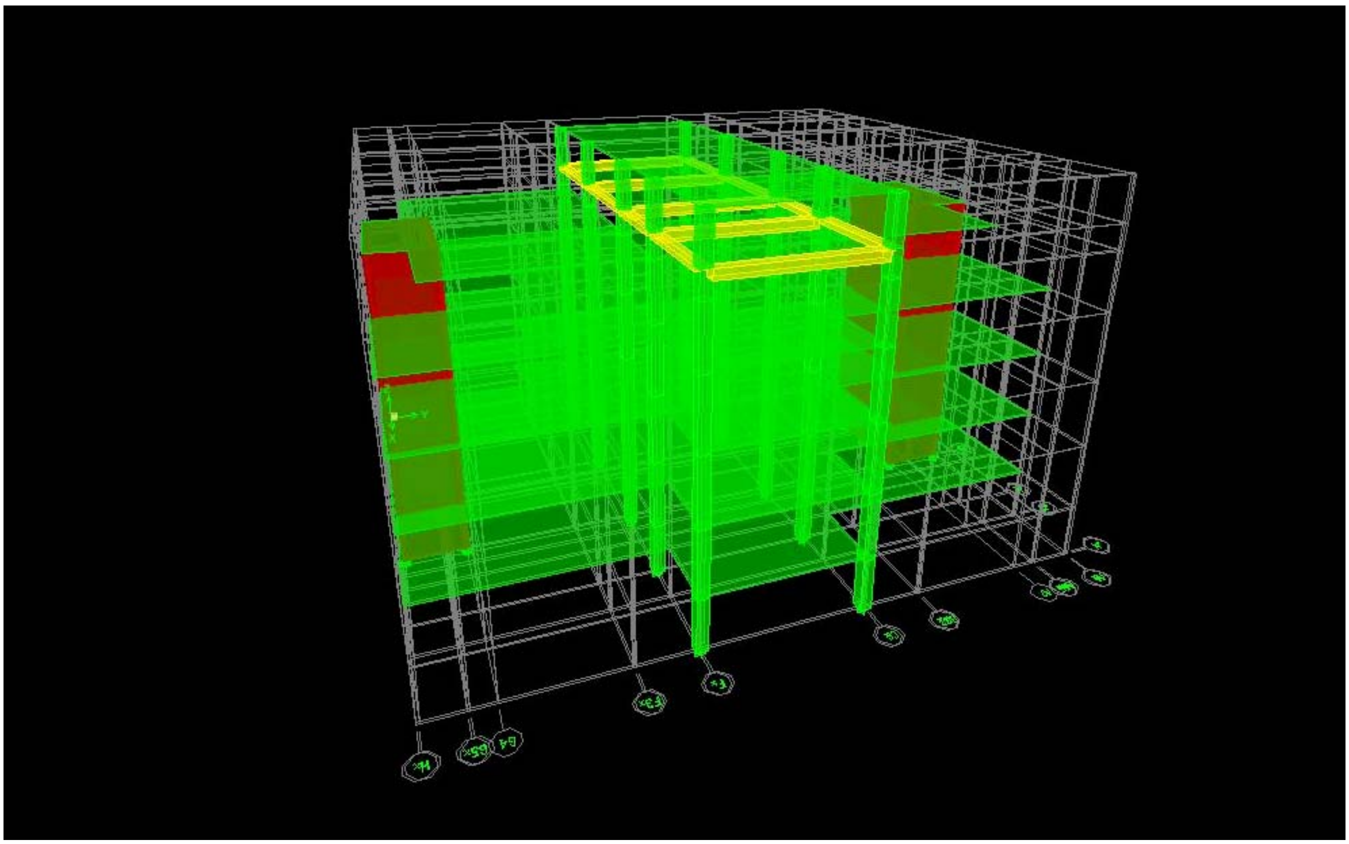


Figure 19: ETABS Model

Shear Wall Schedule					
Pier	Thickness (in)	Flexural Reinforcement	Spacing (in)	Shear Reinforcement	Spacing (in)
WA	8	#4	12	#4	10
WA7	8	#4	12	#4	10
WG4	8	#4	12	#4	10
WH	8	#4	12	#4	10
W43A	8	#4	12	#4	10
W43H	8	#4	12	#4	10
W5A	8	#4	12	#4	10
W5H	8	#4	12	#4	10
Spandrel	Thickness (in)	Flexural Reinforcement	Vertical Shear Reinforcement	Horizontal Shear Reinforcement	Spacing (in)
SA7	8	4- #4	4 legs- #4	#4	12
SG4	8	4- #4	4 legs- #4	#4	12

For calculations and other assumptions; see Appendix A: pg.97-113.

d. Roof Framing

As the roof needs to span over a large area in order to accommodate the column-free space as required by the fifth floor ballroom, a steel framed roof is required. The proposed roof framing system is very similar to the existing under the assumption that the existing roof system is flat as shown in Figure 1: The Duncan Center, and not gabled as indicated on Figure 7: Existing Steel Structural System Roof Framing Plan. The roof framing was designed in RAM Structural System; see Figure 20: RAM Structural System Model & Figure 25: Proposed Concrete Structural System Roof Framing Plan.

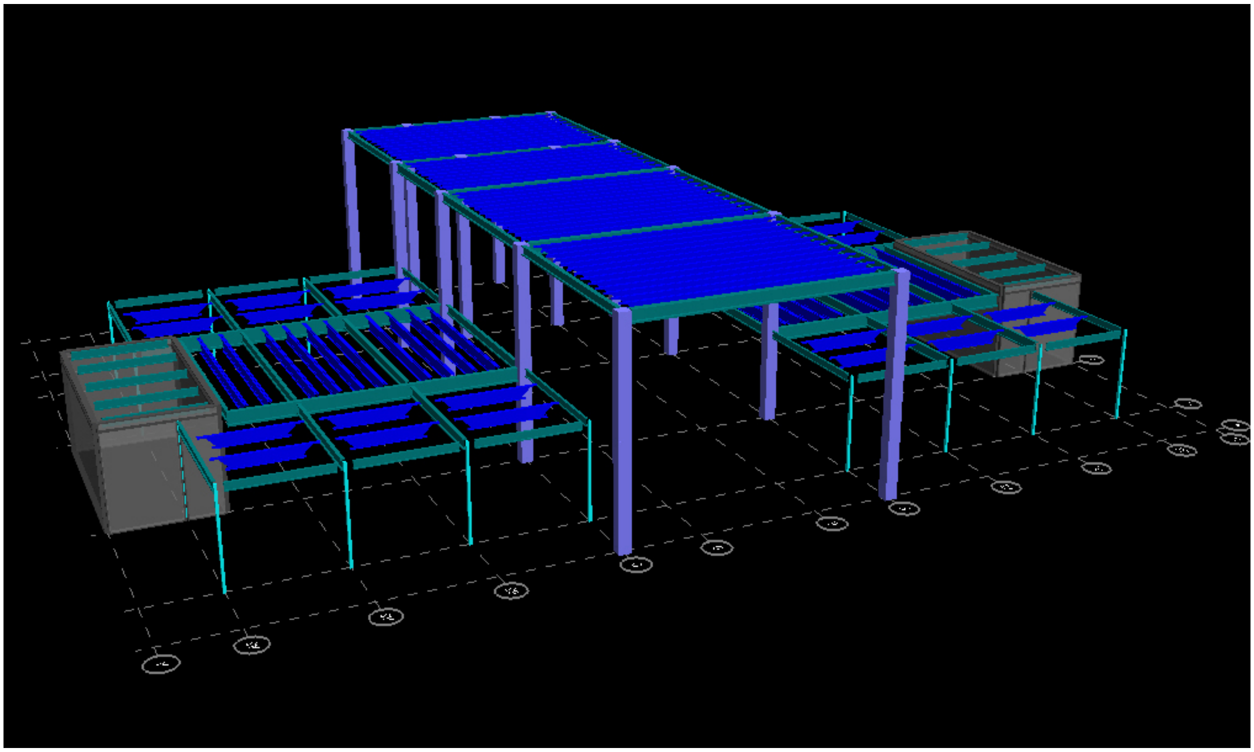


Figure 20: RAM Structural System Model

For calculations and other assumptions; see Appendix A: pg.114-121.

e. Foundation Plan

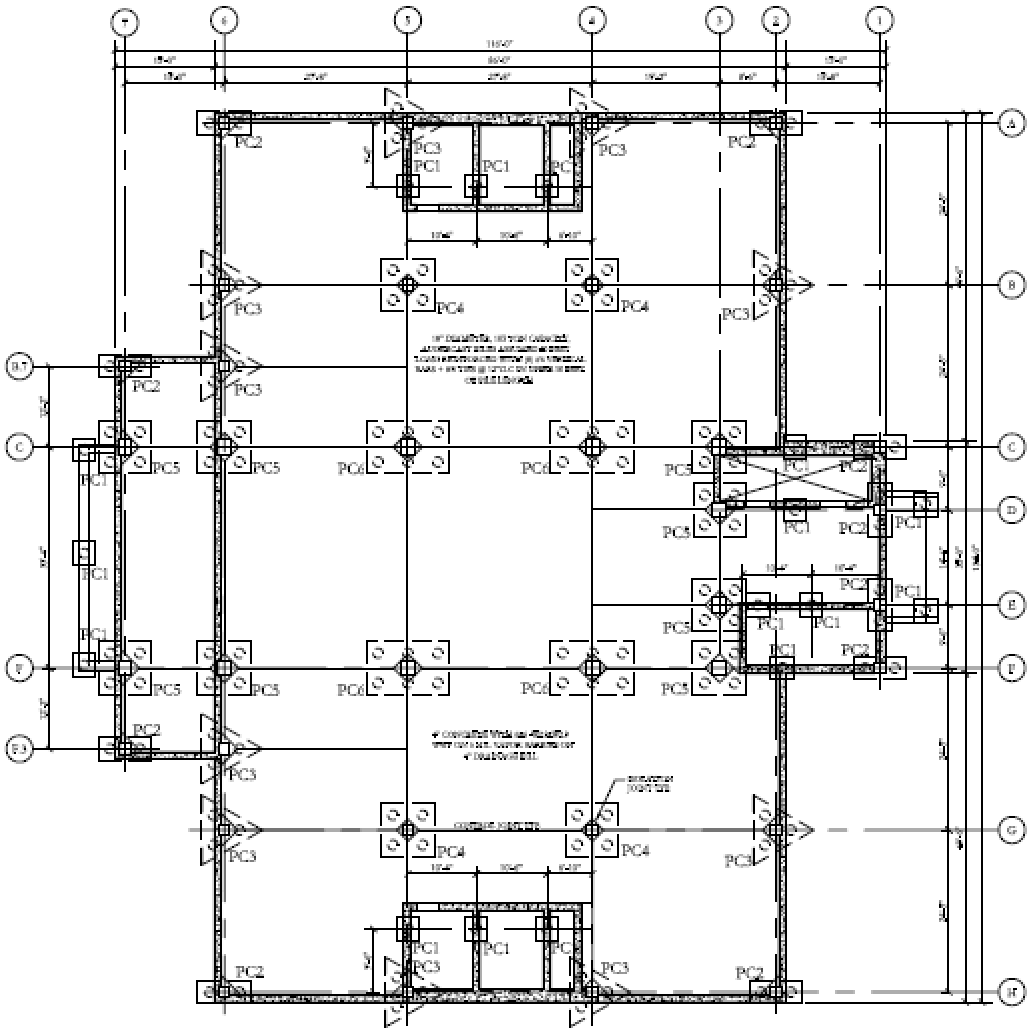


Figure 21: Proposed Concrete Structural System Foundation Plan

f. Framing Plans

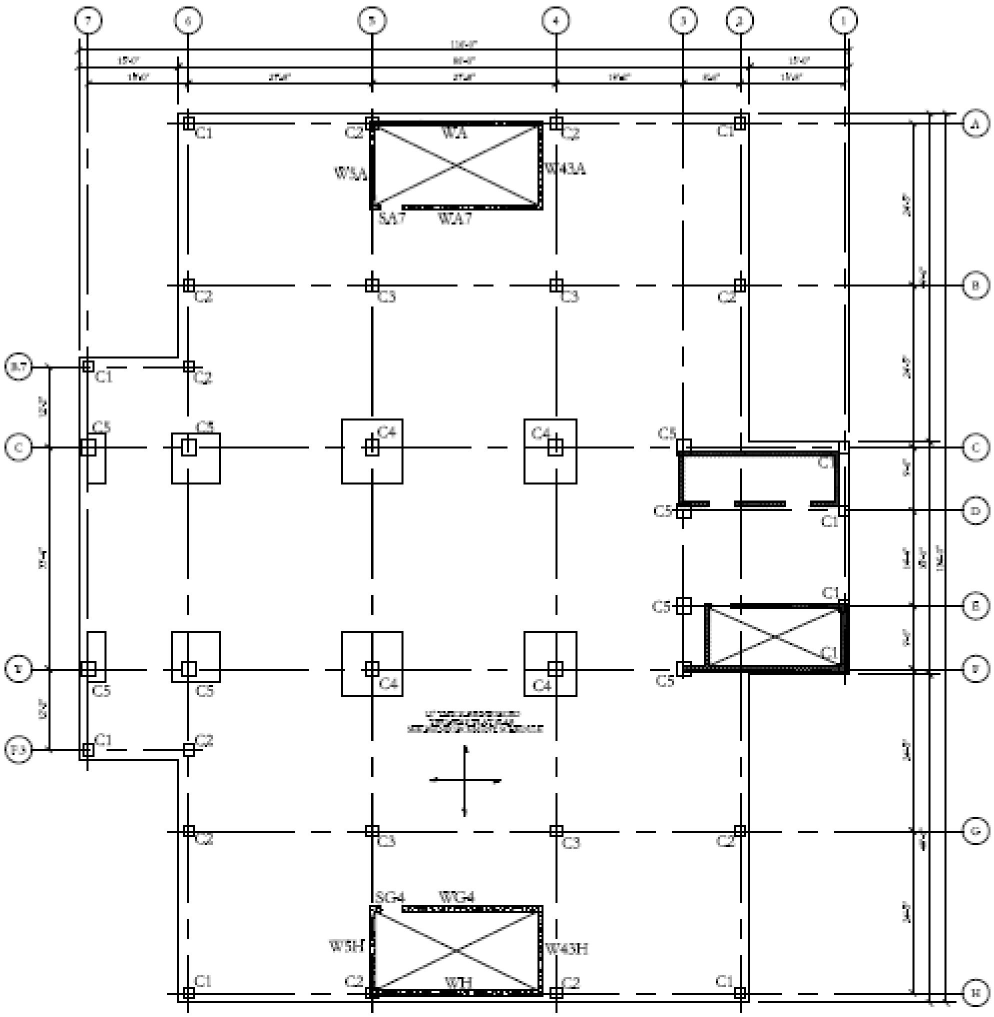


Figure 22: Proposed Concrete Structural System 2nd Floor Framing Plan

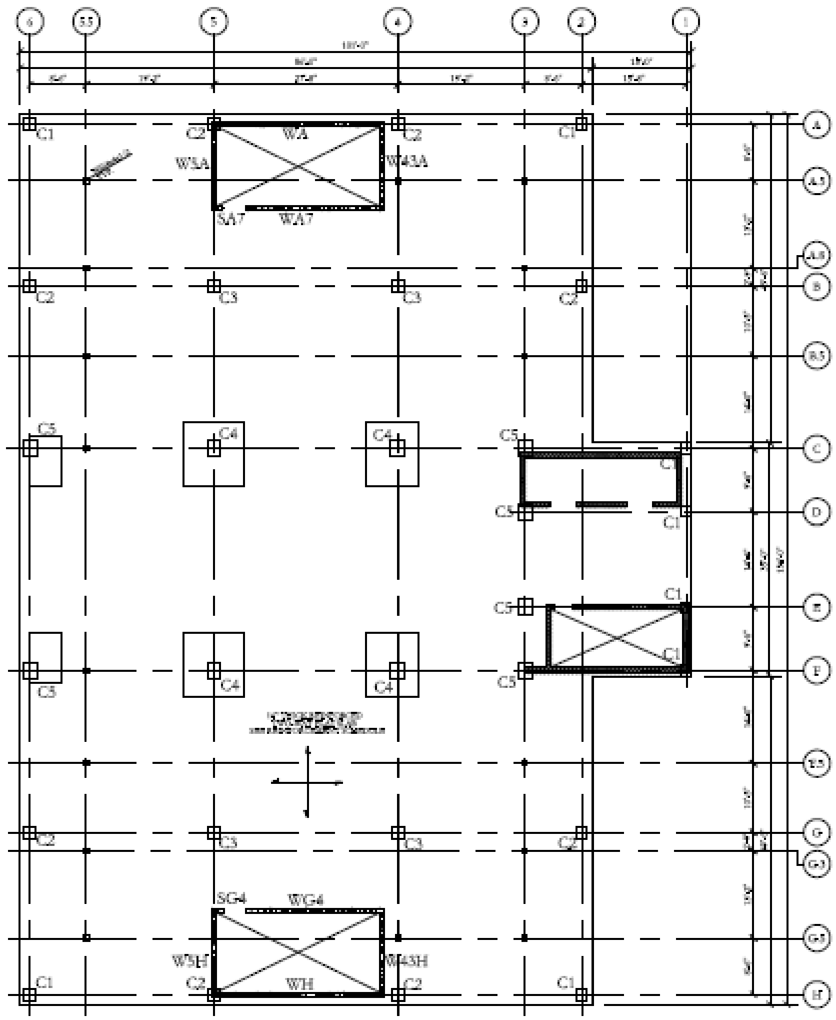


Figure 23: Proposed Concrete Structural System 5th Floor Framing Plan

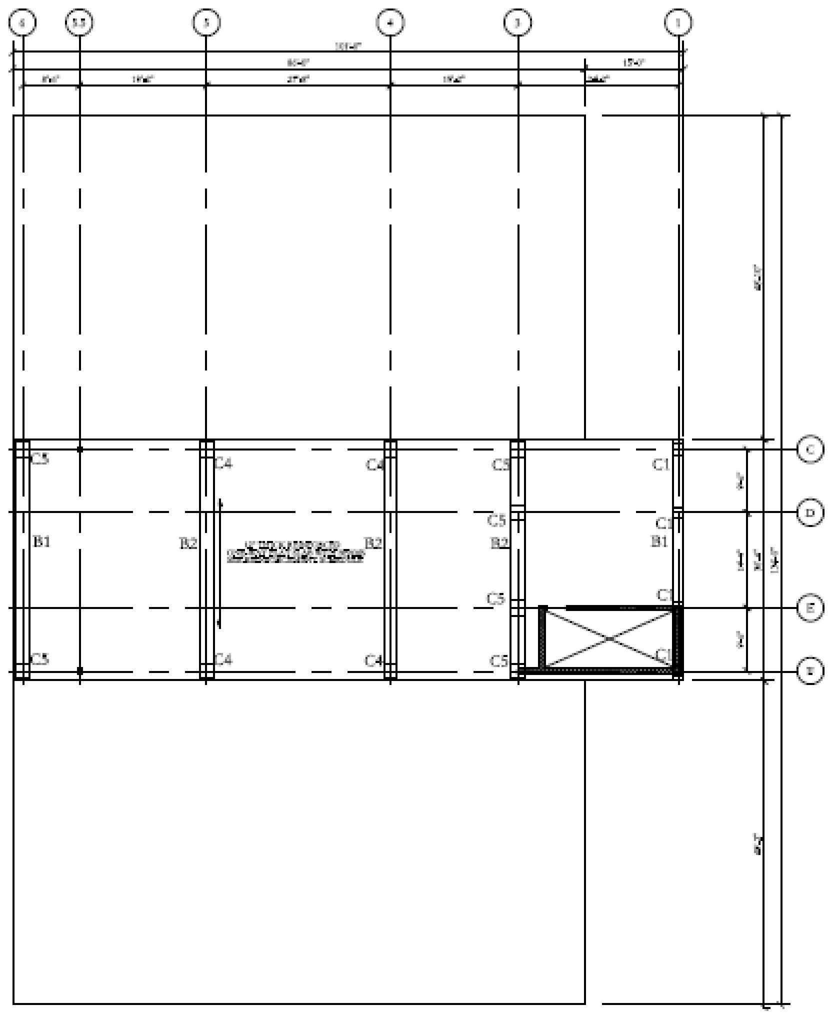


Figure 24: Proposed Concrete Structural System 6th Floor Framing Plan

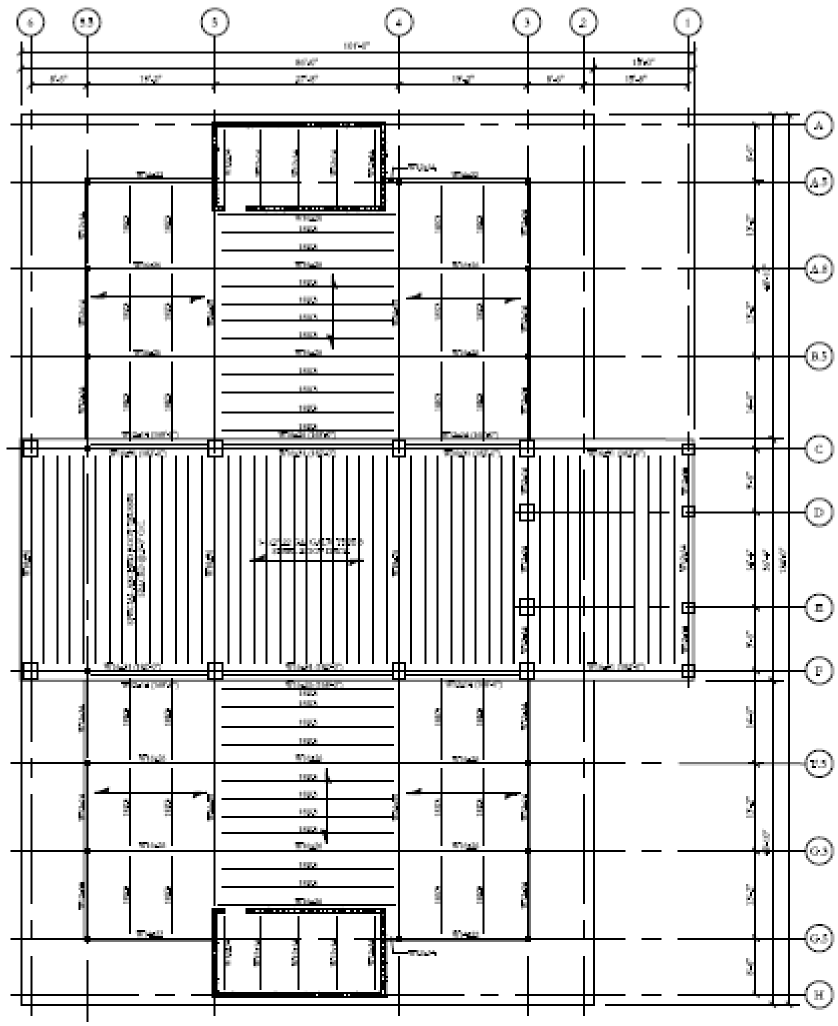


Figure 25: Proposed Concrete Structural System Roof Framing Plan

g. Elevations

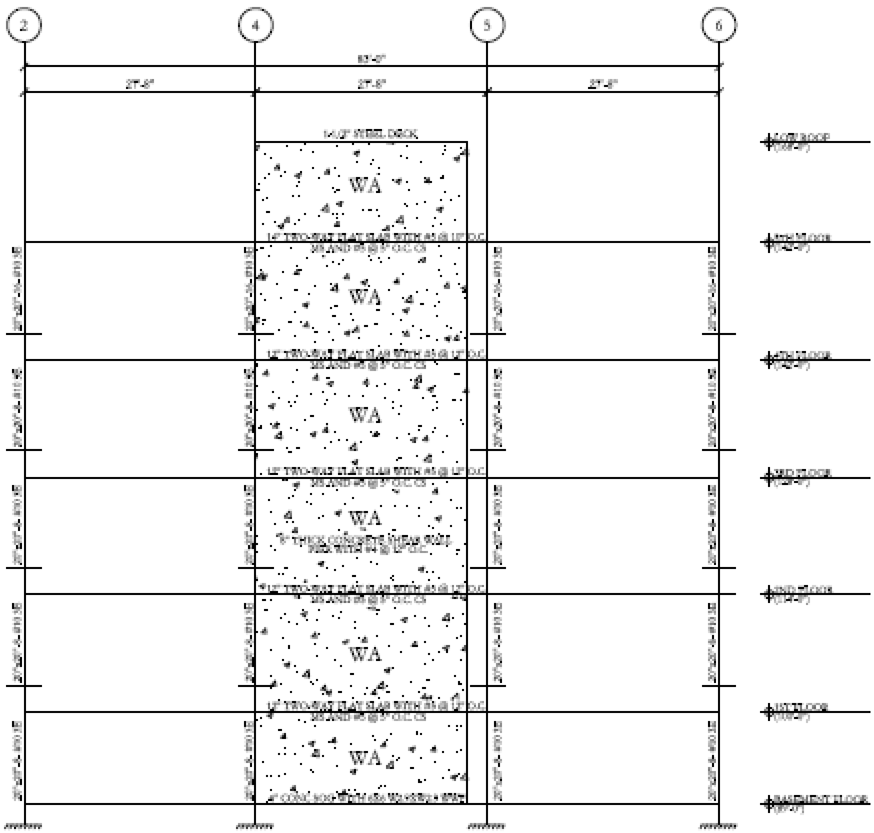


Figure 26: Proposed Concrete Structural System Elevation Line A

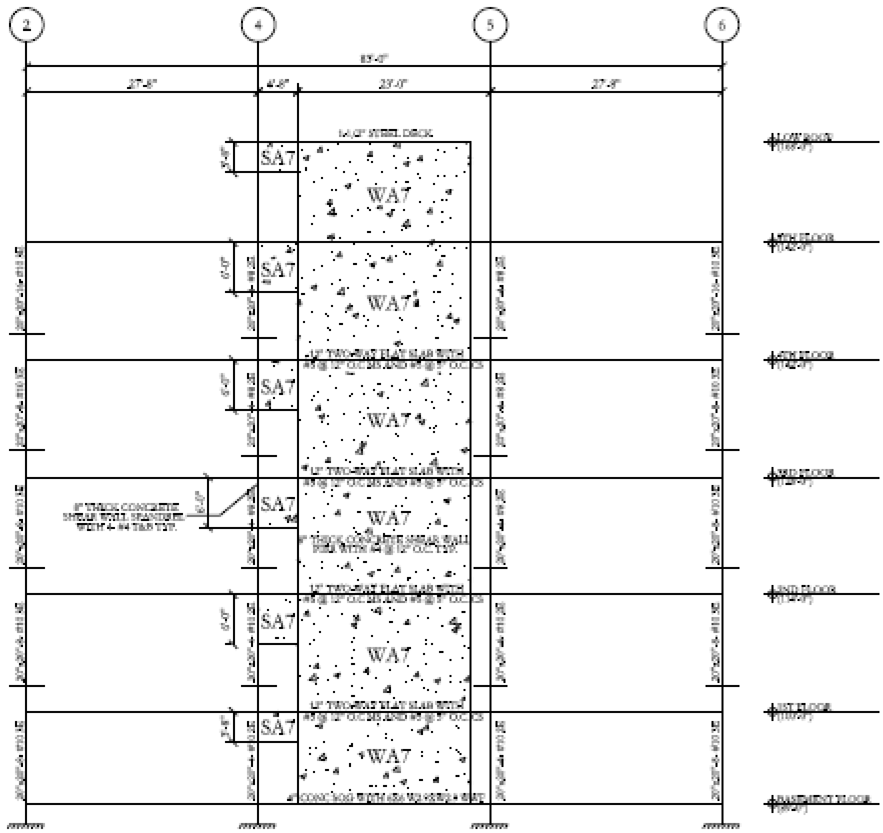


Figure 27: Proposed Concrete Structural System Elevation Line A7

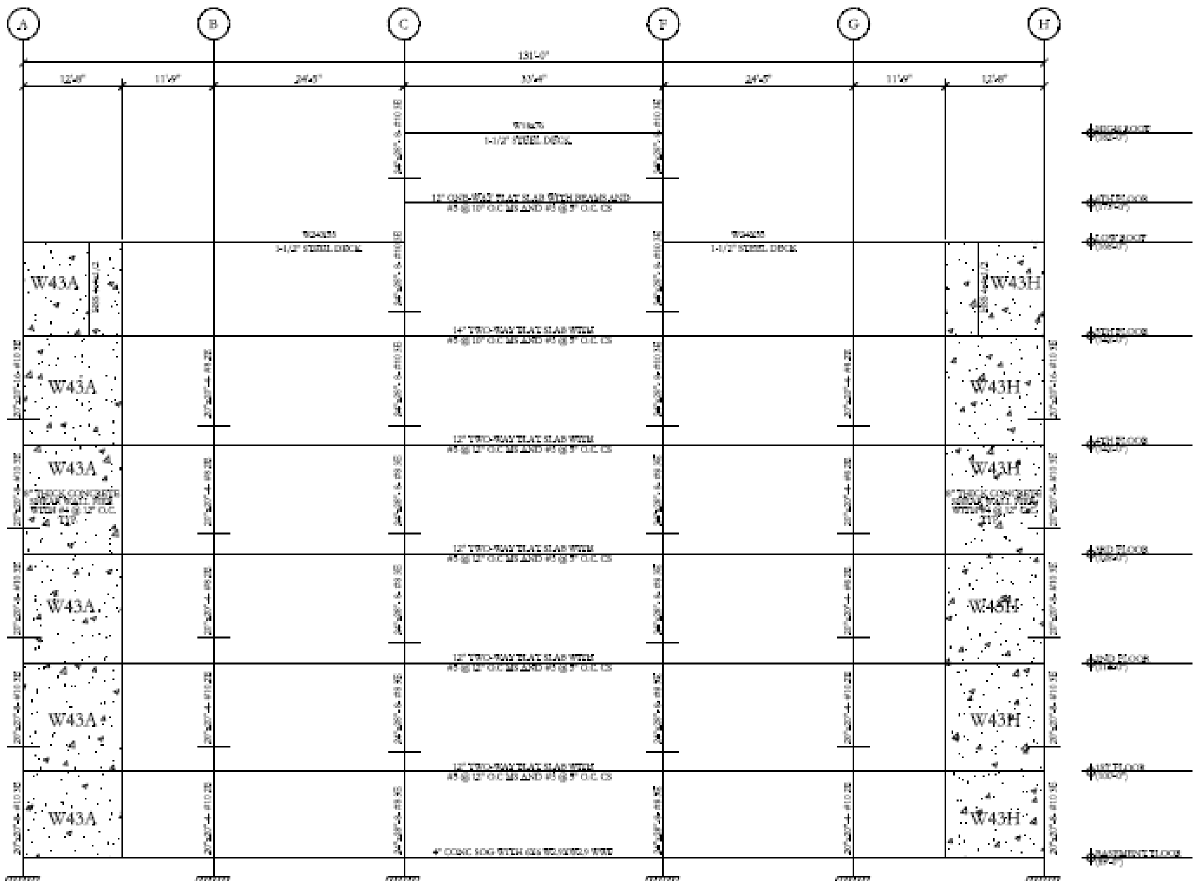


Figure 28: Proposed Concrete Structural System Elevation Line 4

h. Details

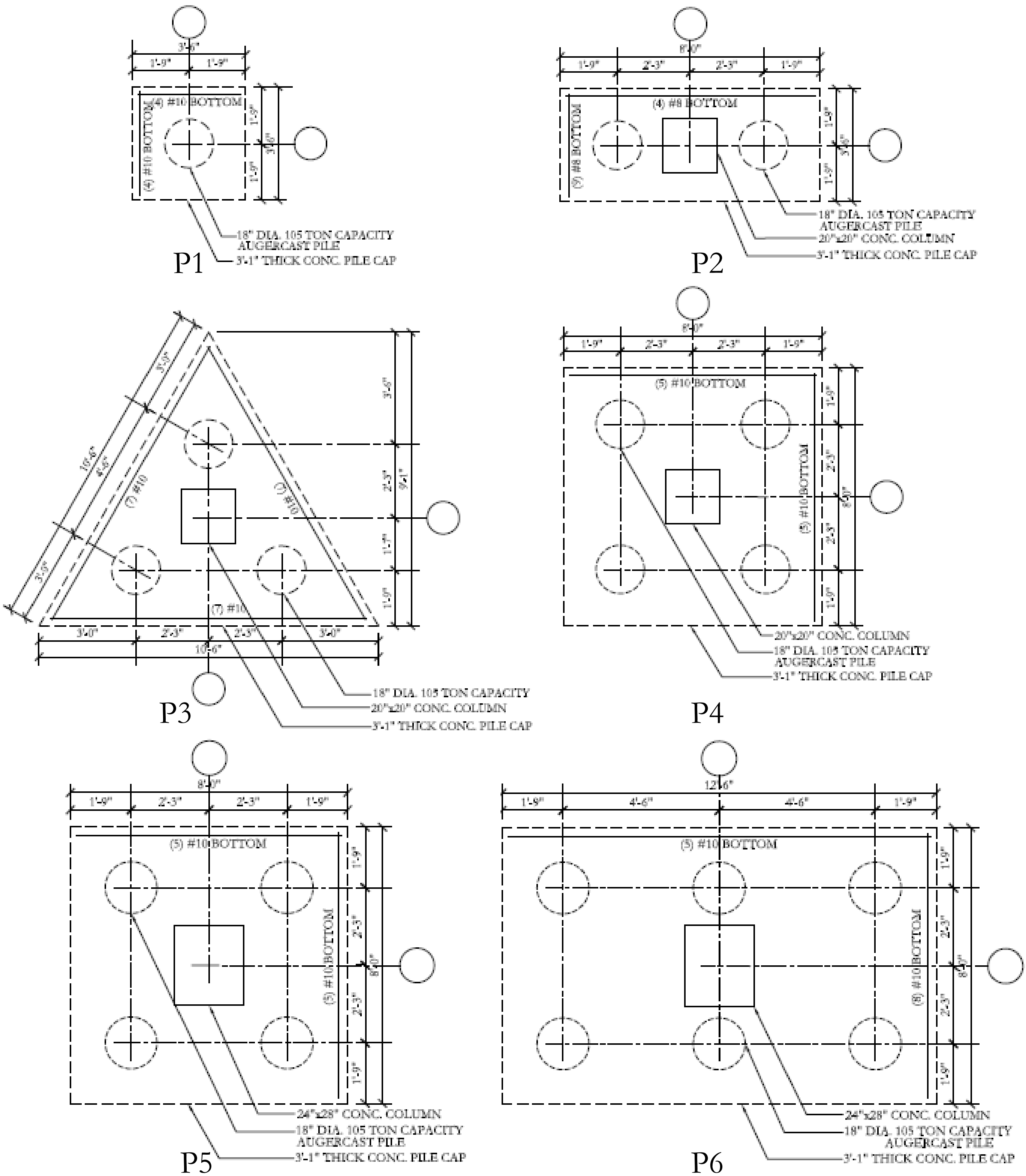
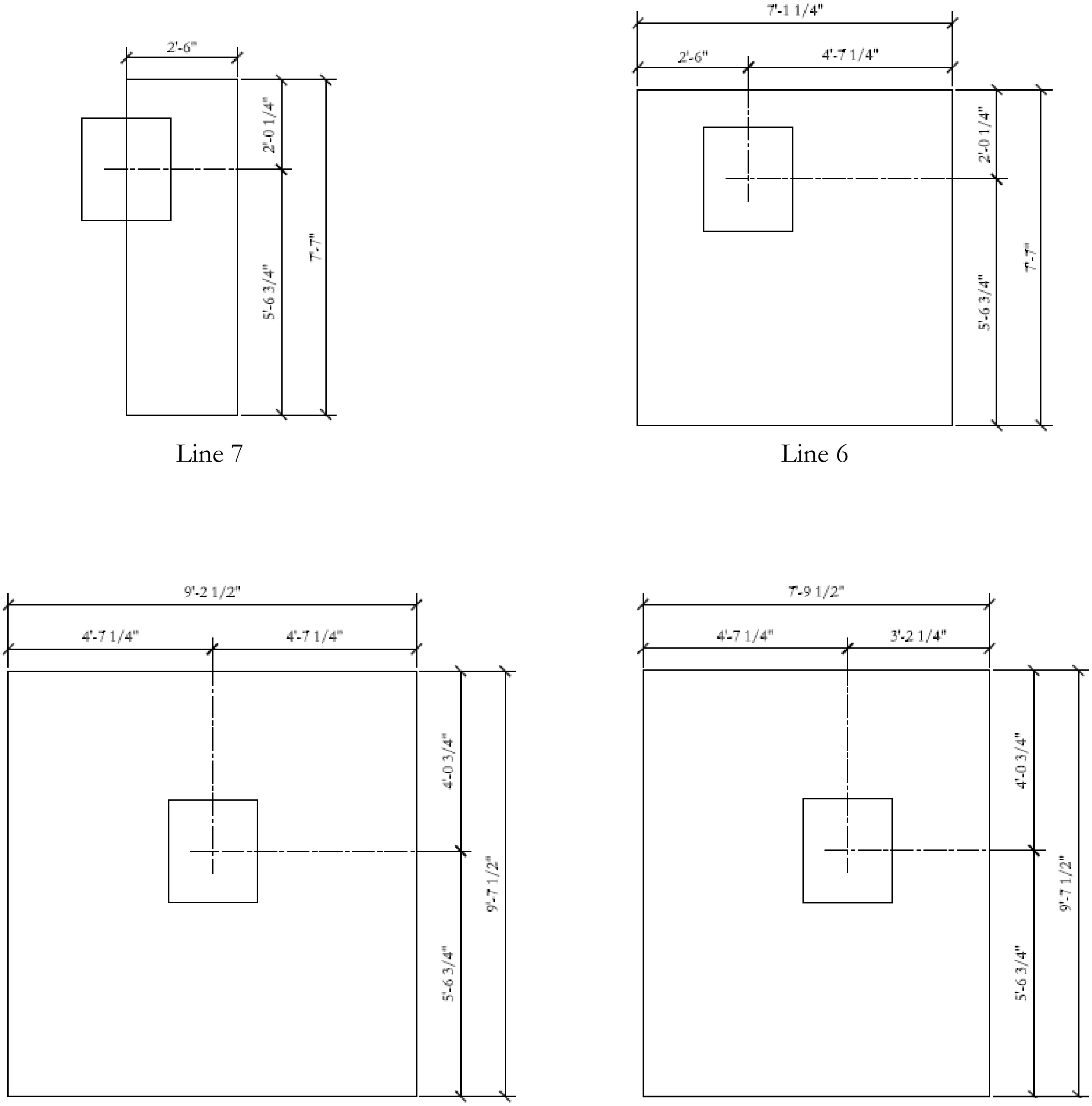


Figure 29: Proposed Concrete Structural System Pile Cap Configurations



Line 5

Line 4

Figure 30: Proposed Concrete Structural System Drop Panel Details
Shown for Line C; Mirror for Line F

v. Structural System Comparison & Depth Conclusions

Based on the design of the proposed concrete structural system, it was found that the structural system did provide an increase in mechanical space, which can be seen from the table below; see Figure 31: Existing Steel & Proposed Concrete Structural System 2nd Floor Mechanical Plans. Also, the foundation system was not as dramatically impacted as had been expected with such an increased weight in the structure, which was made feasible by changing the pile diameter from 16" to 18" dia. and of equal length.

However, due to the need for a steel framed roof, in order to provide a column-free space in the ballroom with long spans, spray-on fireproofing is still required for at a least that small portion of the building. It is common for a concrete building to have a steel framed roof due to the long spans required and it is not anticipated that this will cause any difficulties.

Structurally, the two systems are comparative, despite the reduction of spray-on fireproofing and increase in mechanical ceiling to floor cavity space, and designed using the same criterion which were met. The final decision to recommend the proposed concrete structural system over the existing steel structural system will be based upon the acoustics and construction management analyses.

Mechanical Space Savings			
Floor	Mechanical Space		
	Existing Steel Structural System	Proposed Concrete Structural System	Increase
1st Floor	2'-3"	3'-0"	9"
2nd Floor	2'-3"	3'-0"	9"
3rd Floor	2'-3"	3'-0"	9"
4th Floor	2'-3"	3'-0"	9"
5th Floor	2'-3"	2'-10"	7"
6th Floor	2'-3"	2'-6"	3"

For calculations and other assumptions; see Appendix A: pg.122.

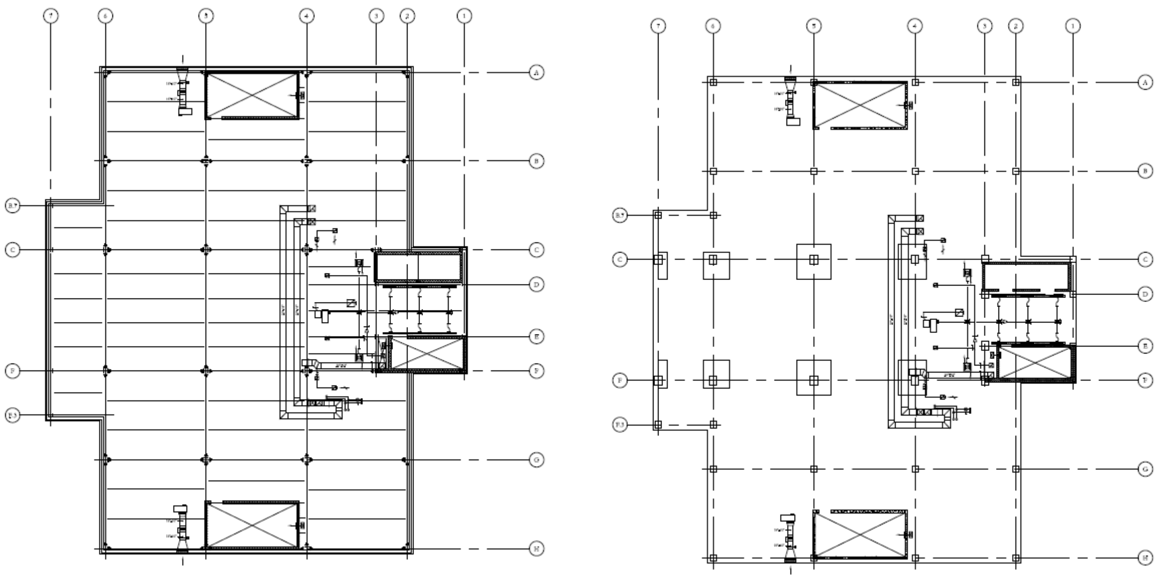


Figure 31: Existing Steel & Proposed Concrete Structural System 2nd Floor Mechanical Plans

IV. Acoustics Breadth

i. Acoustics Breadth Introduction

The fifth floor of the Duncan Center houses The Outlook Center, an elaborate reception and ballroom space available for rent to the public. As the ballroom is positioned directly above office space available for rent, this space must be specifically designed for acoustics both for the ballroom space itself and also its effect on adjacent spaces. Therefore, an acoustical comparison of the sound transmission class of the floor system and reverberation time in the ballroom between the two systems will be performed.

ii. Sound Transmission Class Comparison

Sound transmission classes (STCs) were determined using "Architectural Acoustics" by David Egan. As the proposed concrete structural system has an increased concrete slab thickness it has a higher STC and performs better than the existing steel structural system, as show in the tables below.

Existing Structural Steel System Sound Transmission Class		
Floor System	Floors	STC Rating
5" Concrete on 2" Composite Steel Deck	All	
3" Reinforced Concrete Slab	All	39
Proposed Concrete Structural System Sound Transmission Class		
Floor System	Floors	STC Rating
12" Reinforced Concrete Slab	1st-4th, 6th	88
14" Reinforced Concrete Slab	5th	99

For calculations, other assumptions, and sound transmission class data; see Appendix B: pg.124-125.

iii. Reverberation Time Comparison

Reverberation times were determined using "Architectural Acoustics" by David Egan. The proposed concrete structural system performed marginally better than the existing system with the change of the masonry block walls to rough concrete and ½" gypsum wall board ceiling beneath the sixth floor to rough concrete. However, the system was found to perform much better if a ½" gypsum suspension system versus the existing ¾" acoustical board suspension system is used, as included in proposed system calculations. Therefore, the proposed concrete structural system performs much better across all the frequencies compared to the existing, as can be see from the tables below.

Existing Steel Structural System Reverberation Time-Half Occupancy		
Frequency	Desired Reverberation Time	Actual Reverberation Time
125 Hz	1.43	0.55
500 Hz	1.10	0.58
4000 Hz	0.85	0.36
Existing Steel Structural System Reverberation Time-Full Occupancy		
Frequency	Desired Reverberation Time	Actual Reverberation Time
125 Hz	1.43	0.54
500 Hz	1.10	0.55
4000 Hz	0.85	0.35
Proposed Concrete Structural System Reverberation Time-Half Occupancy		
Frequency	Desired Reverberation Time	Actual Reverberation Time
125 Hz	1.43	1.55
500 Hz	1.10	2.11
4000 Hz	0.85	0.73
Proposed Concrete Structural System Reverberation Time-Full Occupancy		
Frequency	Desired Reverberation Time	Actual Reverberation Time
125 Hz	1.43	1.46
500 Hz	1.10	1.77
4000 Hz	0.85	0.68

For calculations, other assumptions, and sound absorption data; see Appendix B: pg.124, 126-131.

iv. Acoustics Breadth Conclusion

Acoustically, the proposed concrete structural system performs much better than the existing steel structural system for both sound transmission class and reverberation time. Therefore, the proposed concrete structural system is recommended for acoustic performance.

V. Construction Management Breadth

i. Construction Management Breadth Introduction

As the primary reason for selecting a different floor and lateral system is mainly cost driven, a comprehensible analysis of both will be performed and compared for the two systems. The cost analysis will include costs related to labor, equipment, and materials. A construction schedule comparison between the existing structure and the proposed will also be analyzed from time of the beginning of the start of foundation construction for the superstructure only.

ii. Cost Estimate Comparison

Cost estimates for both the existing steel structural system and the proposed concrete structural system were performed using a full structural take-off and R.S. Means 2007. For the existing steel structural system, welds for the moment connections were included in addition to another 20% increase for miscellaneous steel and other connection components. From the cost estimates, it was found from the table below that the proposed system saves $395,000 compare to the existing system.

	Material	Labor	Equipment	Total
Existing Steel Structural System	$1,530,000	$384,000	$140,000	$2,059,000
Proposed Concrete Structural System	$952,000	$611,000	$96,000	$1,664,000

For calculations and other assumptions; see Appendix C: pg.133-146.

iii. Schedule Estimate Comparison

Schedule estimates for both the existing steel structural system and the proposed concrete structural system were performed using the take-off from the cost estimates and R.S. Means 2007. Both the schedules were entered into Microsoft Project in order to calculate the finish dates based upon the used defined critical path. From the schedule estimates, it was found from the table on the next page that the proposed system increases the construction schedule by 6 months compared to the existing system.

	Start Date	Finish Date	Duration (months)
Existing Steel Structural System	Monday, June 2, 2003	Friday, December 24, 2004	18
Proposed Concrete Structural System	Monday, June 2, 2003	Wednesday, June 22, 2005	24

For calculations, other assumptions and full schedules; see Appendix C: pg.133, 147-152.

iv. Construction Management Breadth Conclusion

In terms of cost, the proposed concrete structural system is $395,000 cheaper than the existing steel structural system. This is balanced out however, with an increased duration of schedule of six months from the existing steel structural system to the proposed concrete structural system. Based upon the Owner's needs and desires, schedule is the most important deciding factor in the project and the decrease in cost is not significant enough, about 20% of the existing steel structural system cost, to recommend the proposed concrete structural system.

VI. Conclusion

Based upon the conclusions reached for the depth, acoustics breadth, and construction management breadth, the proposed concrete structural system performed better than the existing steel structural system for the following criterion:

1. Reduction of need for spray-on fireproofing
2. Increase of mechanical ceiling to floor cavity space
3. Increase of sound transmission class
4. Better reverberation time performance in the ballroom
5. Reduced cost

Despite these improvements compared to the existing steel structural system. The proposed concrete structural system is not recommended based upon the increase of schedule by six months, as duration of schedule was the most important design consideration as specified by the Owner.

VII. References

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VIII. Appendix A: Structural Depth Calculations

VIII. Appendix A: Structural Depth Calculations

i. Design Loads

a. Dead Loads

Floor			Roof		
Quarry Tile Flooring	10	PSF	Metal Roof Sheathing	1	PSF
HVAC	3	PSF	4" Rigid Insulation	6	PSF
Acoustical Ceiling Tile	2	PSF	Steel Deck	3	PSF
Miscellaneous	5	PSF	HVAC	3	PSF
			Acoustical Ceiling Tile	2	PSF
			Miscellaneous	5	PSF
Total	20	PSF	Total	20	PSF
Balcony			Exterior Wall		
Concrete Pavers	12	PSF	4" Brick Façade	40	PSF
Waterproofing Membrane	2	PSF	5/8" Gypsum Board	3	PSF
4" Rigid Insulation	6	PSF	6" Batt Insulation	6	PSF
HVAC	3	PSF	5/8" Gypsum Board	3	PSF
Acoustical Ceiling Tile	2	PSF	Miscellaneous	3	PSF
Miscellaneous	5	PSF			
Total	30	PSF	Total	55	PSF
Partition Wall			Bearing Wall		
5/8" Gypsum Board	3	PSF	8" Fully Grouted CMU	80	PSF
6" Batt Insulation	6	PSF	Total	80	PSF
5/8" Gypsum Board	3	PSF			
Miscellaneous	8	PSF			
			Shear Wall		
			8" Concrete	97	PSF
Total	20	PSF	Total	97	PSF

b. Snow Loads

Flat Roof Snow Load

Terrain Category C

$C_e=0.9$

$C_t=1.0$

$I=1.1$

$p_g=25$ psf

pf equals the larger of:

$p_f=0.7\ C_e\ C_t\ I\ p_g$

$=(0.7)(0.9)(1.0)(1.1)(25\text{ psf})$

$=18$ psf

$p_f=20I$

$=20(1.1)$

$=22$ psf

$p_f=22\text{ psf}>LL=20\text{ psf}$ Roof Snow Load Controls

Lower Roof Snow Drift Load

$\gamma=0.13\ p_g+14$

$=(0.13)(25\text{ psf})+14$

$=17.3\text{ pcf}<30\text{ pcf}$ OK

$h_b=p_f/\gamma$

$=22\text{ psf}/17.3\text{ pcf}$

$=1.27$ ft

$h_c=14\text{ ft}-1.27\text{ ft}$

$=12.7$ ft

$h_c/h_b=12.7\text{ ft}/1.27\text{ ft}$

$=10>0.2$ Snow drift required.

hd equals larger of:

higher roof, $l_u=34.67$ ft

$h_d=0.43(l_u^{1/3})((p_g+10)^{1/4})-1.5$

$=0.43(34.67\text{ ft}^{1/3})((25\text{ psf}+10)^{1/4})-1.5$

$=1.91$ ft

lower roof, $l_u=49.67$ ft

$hd=0.75[0.43(lu^{1/3})((pg+10)^{1/4})-1.5$

$\quad =0.43(49.67\text{ ft}^{1/3})((25\text{ psf}+10)^{1/4})-1.5]$

$\quad =1.78\text{ ft}$

$hd=1.91\text{ ft}< hc=12.7\text{ ft}$

$w=4\ hd$

$\quad =4(1.91\text{ ft})$

$\quad =7.64\text{ ft}<8\ hc=8(12.7\text{ ft})=101.6\text{ ft}$ OK

$pd= hd\ \gamma$

$\quad =(1.91\text{ ft})(17.3\text{ pcf})$

$\quad =33\text{ psf}$

c. Wind Loads

Main Wind Force Resisting System

V=100 mph

Kd=0.85

Occupancy Category III

I=1.15

Exposure Category C

15 ft<z=82 ft< zg=900 ft

$\alpha=9.5$

$Kz=2.01(z/zg)^{2/\alpha}$ (see table below)

Kzt=1.0

Ct=0.020

hn=82 ft

x=0.9

$Ta=Cthn^{x}$

$\quad =(0.020)(82\text{ ft})^{0.9}$

$\quad =1.06\text{ s}$

f=1/T

=1/1.06 s

=0.943 Hz<1.0 Hz Flexible Building

North-South Direction

$c=0.20$

$z=0.6h$

$=0.6(82\text{ ft})$

$=49.2\text{ ft}>z_{min}=15\text{ ft}$ OK

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

$=(0.20)(33/49.2\text{ ft})^{1/6}$

$=0.187$

$g_Q=3.4$

$B=132.67\text{ ft}$

$h=82\text{ ft}$

$\ell=500$

$\varepsilon=1/5.0$

$L_z=\ell(33/z)^{\varepsilon}$

$=500(33/49.2\text{ ft})^{(1/5.0)}$

$=462\text{ ft}$

$Q=(1/(1+0.63((B+h)/L_z)^{0.63})^{1/2}$

$=(1/1+0.63((132.67\text{ ft}+82\text{ ft})/462)^{0.63})^{1/2}$

$=0.849$

$n_1=f$

$=0.637\text{ Hz}$

$g_R=(2\ln(3600n_1)^{1/2}+(0.577/(2\ln(3600n_1)^{1/2})$

$=(2\ln(3600(0.637))^{1/2}+(0.577/(2\ln(3600(0.637))^{1/2})$

$=3.94$

Assuming $\beta=0.02$

$b=0.65$

$\alpha=1/6.5$

$V_z=b(z/33)^{\alpha}V(88/60)$

$=(0.65)(49.2\text{ ft}/33)^{(1/6.5)}(100\text{ mph})(88/60)$

$=101\text{ mph}$

$N_1=n_1V_z/L_z$

$=(0.637)(101\text{ mph})/462\text{ ft}$

$=0.139$

$Rn=7.47N1/(1+10.3N1)^{5/3}$

$=7.47(0.139)/(1+10.3(0.139))^{5/3}=$

$=0.236$

$Rh=(1/(4.6n1h/Vz))-((1/2(4.6n1h/Vz)^2)(1-e^{-2(4.6n1h/Vz)}))$

$= (1/(4.6(0.637)(82\ ft)/101\ mph))$

$-((1/2(4.6(0.637)(82\ ft)/101\ mph))^2)(1-e^{-2(4.6(0.637)(82\ ft)/(101\ mph))}))$

$=0.333$

$RB=(1/(4.6n1B/Vz))-((1/2(4.6n1B/Vz)^2)(1-e^{-2(4.6n1B/Vz)}))$

$= (1/(4.6(0.637)(132.67\ ft)/101\ mph))$

$-((1/2(4.6(0.637)(132.67\ ft)/101\ mph)^2)(1-e^{-2(4.6(0.637)(132.67\ ft)/101\ mph)}))$

$=0.226$

$L=101.25$ ft

$RL=(1/(15.4n1L/Vz))-((1/2(15.4n1L/Vz)^2)(1-e^{-2(15.4n1L/Vz)}))$

$= (1/(15.4(0.637)(101.25\ ft)/101\ mph))$

$-((1/2(15.4(0.637)(101.25\ ft)/101\ mph)^2)(1-e^{-2(15.4(0.637)(101.25\ ft)/101\ mph)}))$

$=0.097$

$R=((1/\beta)RnRhRB(0.53+0.47RL))^{1/2}$

$=((1/0.02)(0.236)(0.333)(0.226)(0.53+0.47(0.097))^{1/2}$

$=0.715$

$gV=3.4$

$G=0.925((1+1.7Iz(gQ^2Q^2+gR^2R^2)^{1/2})/(1+1.7gVIz))$

$=0.925((1+1.7(0.187)((3.4)^2(0.849)^2+(3.94)^2(0.715)^2)^{1/2})/(1+1.7\ (3.4)(0.187)))$

$=1.01$

East-West Direction

$B=101.25$ ft

$Q=(1/(1+0.63((B+h)/\ Lz)^{0.63})^{1/2}$

$=(1/1+0.63((101.25\ ft+82\ ft)/462)^{0.63})^{1/2}$

$=0.860$

$RB=(1/(4.6n1B/Vz))-((1/2(4.6n1B/Vz)^2)(1-e^{-2(4.6n1B/Vz)}))$

$= (1/(4.6(0.637)(101.25\ ft)/101\ mph))$

$-((1/2(4.6(0.637)(101.25\ ft)/101\ mph)^2)(1-e^{-2(4.6(0.637)(101.25\ ft)/101\ mph)}))$

$=0.283$

$L=132.67$ ft

$RL=(1/(15.4n1L/Vz))-((1/2(15.4n1L/Vz)^2)(1-e^{-2(15.4n1L/Vz)}))$

$= (1/(15.4(0.637)(132.67\ ft)/101\ mph))$

$-((1/2(15.4(0.637)(132.67\ ft)/101\ mph)^2)(1-e^{-2(15.4(0.637)(132.67\ ft)/101\ mph)}))$

$=0.075$

$R=((1/\beta)RnRhRB(0.53+0.47RL))^{1/2}$

$=((1/0.02)(0.236)(0.333)(0.283)(0.53+0.47(0.075))^{1/2}$

$=0.793$

$G=0.925((1+1.7Iz(gQ^2Q^2+gR^2R^2)^{1/2})/(1+1.7gVIz))$

$=0.925((1+1.7(0.187)((3.4)^2(0.849)^2+(3.94)^2(0.793)^2)^{1/2})/(1+1.7\ (3.4)(0.187)))$

$=1.05$

Windward

Cp=0.8

Leeward, North-South Direction

L=101.25 ft

B=132.67 ft

L/B=101.25 ft/132.67 ft

=0.763

Cp=-0.5

Leeward, East-West Direction

L=132.67 ft

B=101.25 ft

L/B=132.67 ft/101.25 ft

=1.310

Cp=-0.438

$qz=0.00256\ Kz\ Kzt\ KdV^2I$ (see table below)

q=qz windward

=qh leeward

qi=qh

P=qG Cp (see table below)

			P (psf)			
			North-South Direction		East-West Direction	
z (ft)	Kz	qz (psf)	Windward	Leeward	Windward	Leeward
82	1.21	30.4	24.54	-12.39	25.51	-11.73
80	1.21	30.2	24.42	-12.39	25.38	-11.73
70	1.17	29.4	23.74	-12.39	24.68	-11.73
60	1.14	28.4	22.98	-12.39	23.89	-11.73
50	1.09	27.4	22.12	-12.39	22.99	-11.73
40	1.04	26.1	21.10	-12.39	21.94	-11.73
30	0.98	24.6	19.86	-12.39	20.65	-11.73
25	0.95	23.7	19.11	-12.39	19.87	-11.73
20	0.90	22.6	18.24	-12.39	18.96	-11.73
15	0.85	21.2	17.16	-12.39	17.84	-11.73
0	0.00	0.0	0.00	-12.39	0.00	-11.73

		Story Heights		
Story	Height (ft)	Trib. Height Above (ft)	Trib. Height Below (ft)	Trib. Height (ft)
High Roof	82	0.0	4.5	4.5
6th Floor	73	4.5	8.5	13.0
Low Roof	68	0.0	6.0	6.0
5th Floor	56	8.5	7.0	15.5
4th Floor	42	7.0	7.0	14.0
3rd Floor	28	7.0	7.0	14.0
2nd Floor	14	7.0	7.0	14.0
1st Floor	0	7.0	0.0	7.0

	Story Width (ft)		Story Shear (kips)	
Story	North-South Direction	East-West Direction	North-South Direction	East-West Direction
High Roof	101.0	34.3	16.7	5.7
6th Floor	101.0	34.3	47.8	16.2
Low Roof	66.0	79.7	14.0	16.8
5th Floor	101.0	134.0	54.8	72.2
4th Floor	116.0	134.0	55.2	63.3
3rd Floor	116.0	134.0	53.4	61.1
2nd Floor	116.0	134.0	51.8	59.2
1st Floor	116.0	134.0	25.6	29.2

d. Seismic Loads

Latitude: 39.17º N

Longitude: -75.54 º W

From USGS Java Ground Motion Parameter Calculator

Ss=0.172

S1=0.079

Assuming Site Class D (Not reported in Geotechnical Engineer's Report)

Fa=1.6

Fv=2.4

SMS=FaSs

=(1.6)(0.172)

=0.275

SM1=FvS1

=(2.4)(0.079)

=0.190

SDS=2/3 SMS

=(2/3)(0.275)

=0.183

SD1=2/3 SM1

=(2/3)(0.190)

=0.127

TL=6 s

Cu=1.65

$Ct=0.020$

$hn=82$ ft

$x=0.8$

$Ta=Cthn^x$

$=(0.020)(82 \text{ ft})^{0.9}$

$=1.06$ s

$T \leq Cu\ Ta$

$=(1.65)(1.06 \text{ s})$

$=1.75$ s

Seismic Design Category B

Ordinary Reinforced Concrete Shear Walls

$R=5$

Occupancy Category III

$I=1.25$

Cs equals the smallest of:

$Cs= SDS/(R/I)$

$=(0.183)/(5/1.25)$

$=0.046$

$T=1.75 \text{ s}<TL=6$ s

$Cs= SD1/(T(R/I))$

$=(0.127)/(1.75(5/1.25))$

$=0.018$

$S1=0.079<0.6$

$Cs=0.018>0.01$ OK

$V= CsW$

$=(0.018)(16575 \text{ kips})$

$=298$ kips

$k=1.63$

$Cvx=wxhx^k/\Sigma wihi^k$

$Fx=CvxV$

	Floor Weight		
Story	Floor Area (sf)	Floor Dead Load (psf)	Floor Self-Weight (psf)
High Roof	3467	20	26
6th Floor	2929	20	172
Low Roof	5594	20	29
5th Balcony	2517	30	169
5th Floor	7937	20	151
4th Balcony	885	30	145
4th Floor	10453	20	171
3rd Floor	11338	20	171
2nd Floor	11338	20	171
1st Floor	11338	20	171

	Wall Weight							
Story	Tributary Wall Height (ft)				Wall Perimeter (ft)			
	Exterior		Bearing	Shear	Exterior		Bearing	Shear
High Roof	4.5	0.0	4.5	4.5	269.3	0.0	66.8	37.8
6th Floor	13.0	9.5	13.0	13.0	278.0	264.7	131.5	0.0
Low Roof	6.0	0.0	9.0	9.0	658.0	0.0	0.0	157.4
5th Balcony	13.0	10.0	0.0	0.0	108.7	638.0	0.0	0.0
5th Floor	15.5	6.0	15.5	13.0	201.3	618.7	131.5	157.4
4th Balcony	10.0	0.0	0.0	0.0	183.0	0.0	0.0	0.0
4th Floor	14.0	7.0	14.0	14.0	815.0	59.0	131.5	157.4
3rd Floor	14.0	0.0	14.0	14.0	494.2	0.0	131.5	157.4
2nd Floor	14.0	0.0	14.0	14.0	494.2	0.0	131.5	157.4
1st Floor	7.0	0.0	7.0	7.0	494.2	0.0	131.5	157.4

Story	Wall Weight				Total Floor Weight (kips)
	Wall Dead Load (psf)				
	Exterior		Bearing	Shear	
High Roof	55.0	55.0	80.4	97.2	267
6th Floor	55.0	55.0	80.4	97.2	1037
Low Roof	55.0	55.0	80.4	97.2	626
5th Balcony	55.0	55.0	80.4	97.2	930
5th Floor	55.0	55.0	80.4	97.2	2096
4th Balcony	55.0	55.0	80.4	97.2	256
4th Floor	55.0	55.0	80.4	97.2	3009
3rd Floor	55.0	55.0	80.4	97.2	2909
2nd Floor	55.0	55.0	80.4	97.2	2909
1st Floor	55.0	55.0	80.4	97.2	2537
Total					16575

Story Shear

Story	wx (kips)	hx (ft)	k	wxhx^k	Cvx	V (kips)	Fx (kips)
High Roof	267	82	1.63	351371	0.053624	298	16.0
6th Floor	1037	73	1.63	1129559	0.172386	298	51.4
Low Roof	626	68	1.63	607560	0.092722	298	27.6
5th Balcony	930	56	1.63	657646	0.100366	298	29.9
5th Floor	2096	56	1.63	1482339	0.226226	298	67.4
4th Balcony	256	42	1.63	113065	0.017255	298	5.1
4th Floor	3009	42	1.63	1331600	0.203221	298	60.6
3rd Floor	2909	28	1.63	664613	0.101429	298	30.2
2nd Floor	2909	14	1.63	214729	0.032771	298	9.8
1st Floor	2537	0	1.63	0	0	298	0.0
Total	16575	NA	NA	6552483	1	NA	298

ii. PROPOSED CONCRETE STRUCTURAL SYSTEM

a. Foundation System

FINAL SIZING

FINAL FOUNDATION DESIGNS

USE 18" ϕ PILES, 105 TON, 210K COMPRESSIVE CAPACITY

BEARING CAPACITY OF SOIL = 1500 PSF

PILE CAP DESIGN

SIZE OF PILE CAP BASED INITIALLY ON GEOMETRIC CONSTRAINTS

PUNCHING SHEAR

$q = \frac{P_u}{A} = \frac{P_u}{B^2}$ OR $\frac{P_u}{BL}$

$v_c = \phi 4\sqrt{f'_c}$; $\phi = 0.75$

$d^2\left(2v_c + \frac{q}{2}\right) + d\left(v_c + \frac{q}{2}\right)c_1 + d\left(v_c + \frac{q}{2}\right)c_2 \geq \frac{q}{2}(BL - c_1c_2)$

WIDE BEAM SHEAR

$V_u = q\ell$

$\phi V_n = \phi 2\sqrt{f'_c}\,bd$; $\phi = 0.75$

$\rho_{MIN} = 0.0018$

$A_{SMIN} = \rho_{min}bh$ - PILE CAP REINFORCEMENT

$A_{SMIN} = 0.005c_1c_2$ - COLUMN DOWEL REINFORCEMENT

ASSUMING STRIP FOOTING FOR MASONRY STAIR TOWER APPROXIMATELY ADEQUATE FOR CONCRETE SHEAR WALLS

	D+L (kips)								
Column	1st	2nd	3rd	4th	5th	Low Roof	6th	High Roof	P (kips)
Corner Column-A2	48	58	58	58	68	2	0	0	291
Exterior Column-B2	89	98	98	98	119	11	0	0	513
Interior Column-B5	139	139	139	139	188	55	0	0	798
Interior Column-C5	181	181	181	181	244	27	99	37	1134
Exterior Column-C6	111	111	111	112	158	5	76	19	704

	1.2D+1.6L+0.5Lr								Pu (kips)
Column	1st	2nd	3rd	4th	5th	Low Roof	6th	High Roof	
Corner Column-A2	62	74	74	74	88	2	0	0	353
Exterior Column-B2	116	127	127	127	157	15	0	0	629
Interior Column-B5	179	179	179	179	252	76	0	0	977
Interior Column-C5	210	210	210	210	277	38	115	52	1382
Exterior Column-C6	143	143	143	170	203	8	96	27	867

	Punching Shear				Wide Beam Shear			
Column	q (psi)	vc (psi)	Vl (kips)	Vr (kips)	q (psi)	*l* (in)	Vu (kips)	ϕVn (kips)
Corner Column-A2	88	164	699	159	88	38	3	265
Exterior Column-B2	92	164	700	296	92	54	5	350
Interior Column-B5	106	164	722	467	106	38	4	265
Interior Column-C5	96	164	795	659	96	63	6	414
Exterior Column-C6	94	164	793	402	94	36	3	265

	Pile Cap			
Column	Type	Size	Short Dir. Reinf.	Long Dir. Reinf.
Corner Column-A2	Rectangular	3'-6" x 8'-0" x 3'-1"	4- #8	9- #8
Exterior Column-B2	Triangular	10'-6" x 10'-6" x 10'-6" x 3'-1"	7- #10	7- #10
Interior Column-B5	Square	8'-0" x 8'-0"x 3'-1"	5- #10	5- #10
Interior Column-C5	Rectangular	8'-0" x 12'-6" x 3'-1"	5- #10	8- #10
Exterior Column-C6	Square	8'-0" x 8'-0"x 3'-1"	5- #10	5- #10

	Column				
Column	Size	Normal Reinf.	Normal ρ (%)	Dowel Reinf.	Dowel ρ (%)
Corner Column-A2	20"x20"	8- #10	2.54	4-#8	0.79
Exterior Column-B2	20"x20"	8- #10	2.54	4-#8	0.79
Interior Column-B5	20"x20"	4- #10	1.27	4-#8	0.79
Interior Column-C5	24"x28"	8- #8	0.94	4-#10	0.76
Exterior Column-C6	24"x28"	8- #8	0.94	4-#10	0.76

	Number of Piles	
Column	Required	Actual
Corner Column-A2	1.39	2
Exterior Column-B2	2.44	3
Interior Column-B5	3.80	4
Interior Column-C5	5.40	6
Exterior Column-C6	3.35	4

PRELIMINARY SIZING OF FRAMING SYSTEM

PRELIMINARY TWO-WAY FLAT SLAB THICKNESSES

SPAN WIDTH RATIO - ACI 9.5.3.2
24.42' : 27.67'   27.67' : 33.34'
1 : 1.33 ≤ 2 ✓OK   1 : 1.20 ≤ 2 ✓OK

SLAB THICKNESS MINIMUM = ACI 9.5.3.2, TABLE 9.5c

$\frac{\ell_n}{33} = \frac{(33.34')(12)}{33} = 12.12" \rightarrow 12.5" \geq 5"$ ✓OK

$\frac{\ell_n}{33} = \frac{(27.67')(12)}{33} = 10.06" \rightarrow 10.5" \geq 5"$ ✓OK

SEE FINAL SIZING: FINAL TWO-WAY FLAT SLAB DESIGNS

PRELIMINARY ONE-WAY SLAB WITH BEAMS THICKNESS

SLAB THICKNESS MINIMUM - ACI 9.5.2.1 - TABLE 9.5a
TWO ENDS CONTINUOUS

$\frac{\ell}{28} = \frac{(27.67')(12)}{28} = 11.86" \rightarrow 12"$

SEE FINAL SIZING: FINAL ONE-WAY SLAB WITH BEAMS DESIGN

FIRE RATING - IBC 2006 TABLE 706.4; TABLE 720.1 (3)
OCCUPANCY CATEGORY A
3 HR FIRE RATING
REINFORCED CONCRETE
$t > 2"$

FINAL SIZING

FINAL TWO-WAY FLAT SLAB DESIGNS

DROP PANELS ~ ACI 13.2.5

THICKNESS

FLOORS 1-4

$\frac{t}{4} = \frac{12''}{4} = 3'' < 6''$ ✓OK

FLOOR 5

$\frac{t}{4} = \frac{14''}{4} = 3.5'' < 6''$ ✓OK

WIDTHS

$\frac{\ell}{6} = \frac{12.17'}{6} = 2.028'$

$\frac{\ell}{6} = \frac{15'}{6} = 2.500'$

$\frac{\ell}{6} = \frac{19.17'}{6} = 3.195'$

$\frac{\ell}{6} = \frac{24.42'}{6} = 4.070'$

$\frac{\ell}{6} = \frac{27.67'}{6} = 4.612'$

$\frac{\ell}{6} = \frac{33.34'}{6} = 5.557'$

FINAL ONE-WAY SLAB WITH BEAMS DESIGN

ASSUMING BEAM 24" WIDE BASED ON COLUMN SIZE AND 24" DEEP INCLUDING THE SLAB THICKNESS

SEISMIC DIAPHRAGM LOADS - ASCE 7-05 12.10.1.1

$$F_{px} = \frac{\sum_{i=x}^{n} F_i}{\sum_{i=x}^{n} w_i} w_{px}$$

$$0.2 S_{DS} I w_{px} \le F_{px} \le 0.4 S_{DS} I w_{px}$$

DEFLECTION - PCA SLAB MANUAL 2-54

CONVERTING SHORT TERM DEFLECTION TO LONG TERM DEFLECTION

$\Delta_{TOTAL} = \Delta_{TOTAL, SUSTAINED}(1+\lambda_\Delta) + (\Delta_{LIVE} - \Delta_{LIVE, SUSTAINED})$

$\Delta_{DEAD} = \Delta_{DEAD, SUSTAINED}$

$\Delta_{LIVE} = \Delta_{LIVE, SUSTAINED} + \Delta_{LIVE, UNSUSTAINED}$

$\Delta_{TOTAL\ SUSTAINED} = \Delta_{DEAD} + \Delta_{LIVE, SUSTAINED}$

$$\lambda_\Delta = \frac{\xi}{1+50\rho'}$$

$\xi = 2.0$ FOR LOAD DURATION OF 5+ YEARS

ρ = RATIO. OF COMPRESSIVE STRESS AT MIDSPAN

ACTUAL DEFLECTIONS

IF $\rho' = 0$

$\lambda_\Delta = 2$

$\Delta_{TOTAL} = 3(\Delta_{DEAD} + \Delta_{LIVE,SUSTAINED}) + (\Delta_{LIVE} - \Delta_{LIVE,SUSTAINED})$

ALLOWABLE DEFLECTIONS

$\frac{l}{480}$

$\frac{(24.42')(12)}{480} = 0.611''$

$\frac{(27.67')(12)}{480} = 0.692''$

$\frac{(33.34')(12)}{480} = 0.834''$

SEE FRAMING PLANS FOR RESULTS

Diaphragm Seismic Loads						
Story	Fx (kips)	wpx (kips)	0.2*SDS*I*wpx (kips)	Fpx' (kips)	0.4*SDS*I*wpx (kips)	Fpx (kips)
High Roof	16.0	267	12.2	0.0	24.4	0.0
6th Floor	51.4	1037	47.4	26.5	94.9	47.4
Low Roof	27.6	626	28.6	0.0	57.3	0.0
5th Floor	97.3	1556	71.2	70.8	142.4	71.2
4th Floor	65.7	2352	107.6	47.8	215.2	107.6
3rd Floor	30.2	3009	137.7	61.2	275.4	137.7
2nd Floor	9.8	2909	133.1	59.1	266.1	133.1
1st Floor	0.0	2909	133.1	59.1	266.1	133.1
Total	298.0	14664				

Slab Deflection			
Story	Span	Actual Deflection (in)	Allowable Deflection (in)
6th Floor	33'-4"	0.221	0.834
5th Floor	27'-8"	0.372	0.692
	33'-4"	0.484	0.834
4th Floor	27'-8"	0.228	0.692
	33'-4"	0.644	0.834
3rd Floor	27'-8"	0.229	0.692
	33'-4"	0.644	0.834
2nd Floor	27'-8"	0.229	0.692
	33'-4"	0.644	0.834
1st Floor	27'-8"	0.229	0.692
	33'-4"	0.683	0.834

FINAL SIZING

2nd FLOOR CONCRETE TWO-WAY FLAT SLAB INTERIOR BAY BC-45 SPOT CHECK
DIRECT DESIGN
INTERIOR BAY - NORTH-SOUTH DIRECTION
27'-8" x 24'-5"

- ASSUMING FOR SPOT CHECK MORE THAN 3 CONTINUOUS SPANS OF EQUAL LENGTHS & LOADING ✓
- 27.67' : 24.42' → 1.13 : 1 < 2:1 ✓OK
- w_{LL} = 80 PSF < $w_{DL}+w_{SW}$ = 20 PSF + (145 PCF)(12")(1/12) = 165 PSF ✓OK

$w_u = 1.2D + 1.6L = 1.2(w_{DL}+w_{SW}) + 1.6\,w_{LL} = 1.2(165\text{ PSF}) + 1.6(80\text{ PSF})$
$= 326$ PSF

$M_o = \dfrac{w_u \ell_2 \ell_n^2}{8} = (326\text{ PSF})(27.67')(24.42' - (20")(1/12))^2(1/1000) = 584^{k'}$

$M_u^- = 0.65 M_o = 0.65(584^{k'}) = 380^{k'}$
$M_u^+ = 0.35 M_o = 0.35(584^{k'}) = 204^{k'}$

$\alpha \dfrac{\ell_2}{\ell_1} = 0$

CS⁻ $M_u = 0.75(380^{k'}) = 285^{k'} \approx 287.52^{k'}$ ✓OK
MS⁻ $M_u = 0.25(380^{k'}) = 95^{k'} \approx 95.84^{k'}$ ✓OK
CS⁺ $M_u = 0.60(204^{k'}) = 122^{k'} \approx 124.93^{k'}$ ✓OK
MS⁺ $M_u = 0.40(204^{k'}) = 82^{k'} \approx 83.28^{k'}$ ✓OK

$A_{S\,MIN} = 0.0018(12")(12") = 0.26\text{ IN}^2/'$ → #5" @ 14" O.C.

$R = \dfrac{M_u}{\phi b d^2}$

CS⁻ $R = \dfrac{285^{k'}(10^3)}{(0.90)(12.21')(12")^2} = 180$ → #5 @ 8" O.C. < #5 @ 6" O.C ✓OK

MS⁻ $R = \dfrac{95^{k'}(10^3)}{(0.90)(12.21')(12")^2} = 60$ → #5 @ 14" O.C. = #5 @ 14" O.C. ✓OK

CS⁺ $R = \dfrac{122^{k'}(10^3)}{(0.90)(12.21')(12")^2} = 77$ → #5 @ 14" O.C. < #5 @ 13" O.C. ✓OK

MS⁺ $R = \dfrac{82^{k'}(10^3)}{(0.90)(12.21')(12")^2} = 52$ → #5 @ 14" O.C. = #5 @ 14" O.C. ✓OK

$V_u = \dfrac{w_u \ell}{2} = \dfrac{(326\text{ PSF})(24.42')(1/1000)}{2} = (3.98^{k}/')(24.42') = 97.2^k \approx 104.64^k$ ✓OK

$\phi V_n = \phi 2\sqrt{f'_c}\,bd = (0.75)2\sqrt{5000\text{ PSI}}(1/1000)(12")(11") = (14.0^k/')(24.42') = 342^k \approx 384.22^k$ ✓OK

$V_u = 97.2^k < \phi V_n = 342^k$ ✓OK

2nd Floor Concrete Two-Way Flat Slab Interior Bay BC-45 Spot Check PCA Slab Input (see Framing Plans)

```
================================================================================
                          pcaSlab v1.51 (TM)
          A Computer Program Analysis, Design, and Investigation of
            Reinforced Concrete Slab and Continuous Beam Systems
================================================================================
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============================================================================================
[1] INPUT ECHO
============================================================================================

General Information:
====================
   File name: C:\Documents and Settings\Rachel\My Documents\School\Spring 2008\AE 482\work\4. Final Sizing\Slabs\Nor
   Project:
   Frame:                                          Engineer:
   Code: ACI 318-02       Mode: Design             Reinforcement Database: ASTM A615
   Number of supports = 6 + Left cantilever + Right cantilever
   Floor System: Two-Way

   Live load pattern ratio = 100%
   Minimum free edge for punching shear = 10 times slab thickness
   Deflections are based on cracked section properties.
   In negative moment regions, Ig and Mcr DO NOT include flange/slab contribution (if available)
   Compression reinforcement calculations NOT selected.

Material Properties:
====================
               Slabs|Beams        Columns
              ------------   ------------
   wc     =          145            145 lb/ft3
   f'c    =            5              5 ksi
   Ec     =       4074.3         4074.3 ksi
   fr     =      0.53033        0.53033 ksi

   fy     =           60 ksi, Bars are not epoxy-coated
   fyv    =           60 ksi
   Es     =        29000 ksi

Reinforcement Database:
=======================
   Units: Db (in), Ab (in^2), Wb (lb/ft)
   Size       Db        Ab        Wb    Size        Db        Ab        Wb
   ---- --------- --------- ---------   ---- --------- --------- ---------
     #3      0.38      0.11      0.38     #4      0.50      0.20      0.67
```

#5	0.63	0.31	1.04	#6	0.75	0.44	1.50
#7	0.88	0.60	2.04	#8	1.00	0.79	2.67
#9	1.13	1.00	3.40	#10	1.27	1.27	4.30
#11	1.41	1.56	5.31	#14	1.69	2.25	7.65
#18	2.26	4.00	13.60				

Span Data:
==========

Slabs: L1, wL, wR (ft); t, Hmin (in)

Span	Loc	L1	t	wL	wR	Hmin	
1	Int	1.500	12.00	13.800	13.800	4.00	LC
2	Int	24.420	12.00	13.800	13.800	9.10	
3	Int	24.420	12.00	13.800	13.800	8.15	
4	Int	33.340	12.00	13.800	13.800	10.34	
5	Int	24.420	12.00	13.800	13.800	8.15	
6	Int	24.420	12.00	13.800	13.800	9.10	
7	Int	1.500	12.00	13.800	13.800	4.00	RC

Support Data:
=============

Columns: c1a, c2a, c1b, c2b (in); Ha, Hb (ft)

Supp	c1a	c2a	Ha	c1b	c2b	Hb	Red%
1	20.00	20.00	7.000	20.00	20.00	7.000	100
2	20.00	20.00	7.000	20.00	20.00	7.000	100
3	28.00	24.00	7.000	28.00	24.00	7.000	100
4	28.00	24.00	7.000	28.00	24.00	7.000	100
5	20.00	20.00	7.000	20.00	20.00	7.000	100
6	20.00	20.00	7.000	20.00	20.00	7.000	100

Drop Panels: h (in); L1, L2, W1, W2 (ft)

Supp	h	L1	L2	W1	W2
1	---NONE---				
2	---NONE---				
3	4.00	4.070	5.557	4.600	4.600 *b
4	4.00	5.557	4.070	4.600	4.600 *b
5	---NONE---				
6	---NONE---				

*b- Standard drop.

Boundary Conditions: Kz (kip/in); Kry (kip-in/rad)

Supp	Spring Kz	Spring Kry	Far End A	Far End B
1	0	0	Fixed	Fixed
2	0	0	Fixed	Fixed
3	0	0	Fixed	Fixed
4	0	0	Fixed	Fixed
5	0	0	Fixed	Fixed
6	0	0	Fixed	Fixed

Load Data:
==========

Load Cases and Combinations:

Case	SELF	Dead	Live
Type	DEAD	DEAD	LIVE
U1	1.200	1.200	1.600

Span Loads:

Span	Case	Wa
Area Loads - Wa (lb/ft2):		
1	Dead	513
2	Dead	20
3	Dead	20
4	Dead	20
5	Dead	20
6	Dead	20
7	Dead	513
2	Live	70
3	Live	80
4	Live	80
5	Live	80
6	Live	70

Support Loads - Fz (kip), My (k-ft):

Supp	Case	Fz	My
1	SELF	0	0
2	SELF	0	0
3	SELF	0	0
4	SELF	0	0

```
    5 SELF                0            0
    6 SELF                0            0

Support Displacements - Dz (in), Ry (rad):
Supp Case                Dz           Ry
---- -------- ------------ ------------
    1 SELF                0            0
    2 SELF                0            0
    3 SELF                0            0
    4 SELF                0            0
    5 SELF                0            0
    6 SELF                0            0

Reinforcement Criteria:
=======================
                    ____Top bars___  ___Bottom bars__  ____Stirrups____
                     Min      Max      Min      Max      Min      Max
                   -------  -------  -------  -------  -------  -------
Slabs and Ribs:
  Bar Size            #5       #5       #5       #5
  Bar spacing       1.00    18.00     1.00    18.00 in
  Reinf ratio       0.14     5.00     0.14     5.00 %
  Cover             0.75              0.75          in

Beams:
  Bar Size            #6       #8       #6       #8       #3       #5
  Bar spacing       1.00    18.00     1.00    18.00     6.00    18.00 in
  Reinf ratio       0.14     5.00     0.14     5.00 %
  Cover             1.50              1.50          in
```

```
0000000      000000      00000
00000000    00000000    0000000
00     00   00     00   00    00
00     00   00          00    00
00000000    00          0000000    00000
0000000     00     00   0000000    00000
00          00     00   00    00
00          00000000    00    00
00           000000     00    00

 000000       0              0
00000000     00     00000     00
00           00    0    00    00
0000         00    0    00    00
 000000      00     000000    000000
    0000     00    00   00    00   00
      00     00    00   00    00   00
00000000     00  0 00   00    00   00
 000000       000   00000 0    00000
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pcaSlab v1.51 (TM)
A Computer Program Analysis, Design, and Investigation of
Reinforced Concrete Slab and Continuous Beam Systems

[2] DESIGN RESULTS

Top Reinforcement:

Units: Width (ft), Mmax (k-ft), Xmax (ft), As (in^2), Sp (in)

Span	Strip	Zone	Width	Mmax	Xmax	AsMin	AsMax	SpReq	AsReq	Bars
1	Column	Left	12.21	0.62	0.233	3.165	34.054	13.320	0.013	11-#5
		Middle	12.21	2.07	0.433	3.165	34.054	13.320	0.042	11-#5
		Right	12.21	4.84	0.667	3.165	34.054	13.320	0.098	11-#5
	Middle	Left	15.39	0.00	0.233	3.989	42.924	14.206	0.000	13-#5
		Middle	15.39	0.00	0.433	3.989	42.924	14.206	0.000	13-#5
		Right	15.39	0.00	0.667	3.989	42.924	14.206	0.000	13-#5
2	Column	Left	12.21	124.97	0.833	3.165	34.054	13.320	2.568	11-#5
		Middle	12.21	0.00	12.210	0.000	34.054	0.000	0.000	---
		Right	12.21	308.14	23.587	3.165	34.054	6.977	6.443	21-#5
	Middle	Left	15.39	-0.00	0.833	3.989	42.924	[illegible]	0.000	13-#5
		Middle	15.39	0.00	12.210	0.000	42.924	0.000	0.000	---
		Right	15.39	102.72	23.587	3.989	42.924	14.206	2.102	13-#5
3	Column	Left	12.21	287.52	0.833	3.165	34.054	6.977	6.000	21-#5
		Middle	12.21	13.26	15.406	3.165	34.054	13.320	0.270	11-#5
		Right	12.21	391.14	23.253	3.960	35.043	5.427	[illegible]	27-#5
	Middle	Left	15.39	[illegible]	[illegible]	[illegible]	42.924	14.206	1.961	13-#5
		Middle	15.39	4.42	15.406	3.989	42.924	14.206	0.090	13-#5
		Right	15.39	130.38	23.253	3.989	42.924	14.206	2.674	13-#5
4	Column	Left	12.21	536.75	1.167	3.960	35.043	5.427	8.278	27-#5
		Middle	13.80	0.00	16.670	0.000	38.489	0.000	0.000	---
		Right	12.21	536.75	32.173	3.960	35.043	5.427	8.278	27-#5
	Middle	Left	15.39	178.92	1.167	3.989	42.924	14.206	3.683	13-#5

		Middle	13.80	0.00	16.670	0.000	38.489	0.000	0.000	---
		Right	15.39	178.92	32.173	3.989	42.924	14.206	3.683	13-#5
5	Column	Left	12.21	391.14	1.167	3.960	35.043	5.427	5.972	27-#5
		Middle	12.21	13.26	9.014	3.165	34.054	13.320	0.270	11-#5
		Right	12.21	287.54	23.587	3.165	34.054	6.977	6.001	21-#5
	Middle	Left	15.39	130.38	1.167	3.989	42.924	14.206	2.674	13-#5
		Middle	15.39	4.42	9.014	3.989	42.924	14.206	0.090	13-#5
		Right	15.39	95.85	23.587	3.989	42.924	14.206	1.961	13-#5
6	Column	Left	12.21	308.16	0.833	3.165	34.054	6.977	6.444	21-#5
		Middle	12.21	0.00	12.210	0.000	34.054	0.000	0.000	---
		Right	12.21	125.00	23.587	3.165	34.054	13.320	2.569	11-#5
	Middle	Left	15.39	102.73	0.833	3.989	42.924	14.206	2.103	13-#5
		Middle	15.39	0.00	12.210	0.000	42.924	0.000	0.000	---
		Right	15.39	-0.00	23.587	3.989	42.924	14.206	0.000	13-#5
7	Column	Left	12.21	4.85	0.833	3.165	34.054	13.320	0.099	11-#5
		Middle	12.21	2.07	1.067	3.165	34.054	13.320	0.042	11-#5
		Right	12.21	0.62	1.267	3.165	34.054	13.320	0.013	11-#5
	Middle	Left	15.39	0.00	0.833	3.989	42.924	14.206	0.000	13-#5
		Middle	15.39	0.00	1.067	3.989	42.924	14.206	0.000	13-#5
		Right	15.39	0.00	1.267	3.989	42.924	14.206	0.000	13-#5

Top Bar Details:

Units: Length (ft)

		Left				Continuous		Right			
Span	Strip	Bars	Length	Bars	Length	Bars	Length	Bars	Length	Bars	Length
1	Column	---		---		11-#5	1.50	---		---	
	Middle	---		---		13-#5	1.50	---		---	
2	Column	11-#5	8.34	---		---		11-#5	8.34	10-#5	5.38
	Middle	13-#5	5.84	---		---		13-#5	7.70	---	
3	Column	10-#5	8.23	---		11-#5	24.42	8-#5	8.57	8-#5	5.65
	Middle	---		---		13-#5	24.42	---		---	
4	Column	14-#5	11.40	13-#5	7.37	---		14-#5	11.40	13-#5	7.37
	Middle	13-#5	9.99	---		---		13-#5	9.99	---	
5	Column	8-#5	8.57	8-#5	5.65	11-#5	24.42	10-#5	8.23	---	
	Middle	---		---		13-#5	24.42	---		---	
6	Column	11-#5	8.34	10-#5	5.38	---		11-#5	8.34	---	
	Middle	13-#5	7.70	---		---		13-#5	5.84	---	
7	Column	---		---		11-#5	1.50	---		---	
	Middle	---		---		13-#5	1.50	---		---	

Bottom Reinforcement:

Units: Width (ft), Mmax (k-ft), Xmax (ft), As (in^2), Sp (in)

Span	Strip	Width	Mmax	Xmax	AsMin	AsMax	SpReq	AsReq	Bars
1	Column	12.21	0.00	0.000	0.000	34.054	0.000	0.000	---
	Middle	15.39	0.00	0.000	0.000	42.924	0.000	0.000	---
2	Column	12.21	200.11	11.221	3.165	34.054	10.466	4.141	14-#5
	Middle	15.39	133.41	11.221	3.989	42.924	14.206	2.737	13-#5
3	Column	12.21	124.93	11.456	3.165	34.054	13.320	2.567	11-#5
	Middle	15.39	83.28	11.456	3.989	42.924	14.206	1.702	13-#5
4	Column	13.80	[illegible]	16.545	3.577	38.489	[illegible]	5.319	18-#5
	Middle	13.80	170.90	16.545	3.577	38.489	13.800	3.521	12-#5
5	Column	12.21	124.93	12.964	3.165	34.054	13.320	2.567	11-#5
	Middle	15.39	83.28	12.964	3.989	42.924	14.206	1.702	13-#5
6	Column	12.21	200.11	13.199	3.165	34.054	10.466	4.141	14-#5
	Middle	15.39	133.41	13.199	3.989	42.924	14.206	2.737	13-#5
7	Column	12.21	0.00	1.500	0.000	34.054	0.000	0.000	---
	Middle	15.39	0.00	1.500	0.000	42.924	0.000	0.000	---

Bottom Bar Details:

Units: Start (ft), Length (ft)

Span	Strip	Long Bars: Bars	Long Bars: Start	Long Bars: Length	Short Bars: Bars	Short Bars: Start	Short Bars: Length
1	Column	---			---		
	Middle	---			---		
2	Column	14-#5	0.00	24.42	---		
	Middle	13-#5	0.00	24.42	---		
3	Column	11-#5	0.00	24.42	---		
	Middle	13-#5	0.00	24.42	---		
4	Column	18-#5	0.00	33.34	---		
	Middle	12-#5	0.00	33.34	---		
5	Column	11-#5	0.00	24.42	---		
	Middle	13-#5	0.00	24.42	---		
6	Column	14-#5	0.00	24.42	---		
	Middle	13-#5	0.00	24.42	---		
7	Column	---			---		
	Middle	---			---		

Flexural Capacity:
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Units: From, To (ft), As (in^2), PhiMn (k-ft)

Span	Strip	From	To	AsTop	AsBot	PhiMn-	PhiMn+
1	Column	0.000	0.233	3.41	0.00	-165.32	0.00
		0.233	0.433	3.41	0.00	-165.32	0.00
		0.433	0.667	3.41	0.00	-165.32	0.00
		0.667	0.750	3.41	0.00	-165.32	0.00
		0.750	1.500	3.41	0.00	-165.32	0.00
	Middle	0.000	0.233	4.03	0.00	-195.56	0.00
		0.233	0.433	4.03	0.00	-195.56	0.00
		0.433	0.667	4.03	0.00	-195.56	0.00
		0.667	0.750	4.03	0.00	-195.56	0.00
		0.750	1.500	4.03	0.00	-195.56	0.00
2	Column	0.000	0.833	3.41	4.34	-165.32	209.53
		0.833	7.168	3.41	4.34	-165.32	209.53
		7.168	8.342	0.00	4.34	0.00	209.53
		8.342	8.797	0.00	4.34	0.00	209.53
		8.797	12.210	0.00	4.34	0.00	209.53
		12.210	15.623	0.00	4.34	0.00	209.53
		15.623	16.078	0.00	4.34	0.00	209.53
		16.078	17.622	0.00	4.34	0.00	209.53
		17.622	19.035	3.41	4.34	-165.32	209.53
		19.035	20.579	3.41	4.34	-165.32	209.53
		20.579	23.587	6.51	4.34	-311.23	209.53
		23.587	24.420	6.51	4.34	-311.23	209.53
	Middle	0.000	0.833	4.03	4.03	-195.56	195.56
		0.833	4.840	4.03	4.03	-195.56	195.56
		4.840	5.840	0.00	4.03	0.00	195.56
		5.840	8.797	0.00	4.03	0.00	195.56
		8.797	12.210	0.00	4.03	0.00	195.56
		12.210	15.623	0.00	4.03	0.00	195.56
		15.623	16.724	0.00	4.03	0.00	195.56
		16.724	17.724	0.00	4.03	0.00	195.56
		17.724	23.587	4.03	4.03	-195.56	195.56
		23.587	24.420	4.03	4.03	-195.56	195.56
3	Column	0.000	0.833	6.51	3.41	-311.23	165.32
		0.833	6.795	6.51	3.41	-311.23	165.32
		6.795	8.232	3.41	3.41	-165.32	165.32
		8.232	8.680	3.41	3.41	-165.32	165.32
		8.680	12.210	3.41	3.41	-165.32	165.32
		12.210	15.406	3.41	3.41	-165.32	165.32
		15.406	15.854	3.41	3.41	-165.32	165.32
		15.854	16.967	3.41	3.41	-165.32	165.32
		16.967	18.769	5.89	3.41	-282.38	165.32
		18.769	19.882	5.89	3.41	-282.38	165.32
		19.882	20.350	8.37	3.41	-396.77	165.32
		20.350	23.253	8.37	3.41	-542.46	165.32
		23.253	24.420	8.37	3.41	-542.46	165.32
	Middle	0.000	0.833	4.03	4.03	-195.56	195.56
		0.833	8.680	4.03	4.03	-195.56	195.56
		8.680	12.210	4.03	4.03	-195.56	195.56
		12.210	15.406	4.03	4.03	-195.56	195.56
		15.406	23.253	4.03	4.03	-195.56	195.56
		23.253	24.420	4.03	4.03	-195.56	195.56

4 Column	0.000	1.167	8.37	5.58	-542.46	268.67
	1.167	5.557	8.37	5.58	-542.46	268.67
	5.557	5.826	8.37	5.58	-396.77	268.67
	5.826	7.369	4.34	5.58	-209.53	268.67
	7.369	9.856	4.34	5.58	-209.53	268.67
	9.856	11.399	0.00	5.58	0.00	268.67
	11.399	12.019	0.00	5.58	0.00	268.67
	12.019	16.670	0.00	5.58	0.00	268.67
	16.670	21.321	0.00	5.58	0.00	268.67
	21.321	21.941	0.00	5.58	0.00	268.67
	21.941	23.484	0.00	5.58	0.00	268.67
	23.484	25.971	4.34	5.58	-209.53	268.67
	25.971	27.514	4.34	5.58	-209.53	268.67
	27.514	27.783	8.37	5.58	-396.77	268.67
	27.783	32.173	8.37	5.58	-542.46	268.67
	32.173	33.340	8.37	5.58	-542.46	268.67
Middle	0.000	1.167	4.03	3.72	-195.56	180.44
	1.167	8.567	4.03	3.72	-195.56	180.44
	8.567	9.992	0.00	3.72	0.00	180.44
	9.992	12.019	0.00	3.72	0.00	180.44
	12.019	16.670	0.00	3.72	0.00	180.44
	16.670	21.321	0.00	3.72	0.00	180.44
	21.321	23.348	0.00	3.72	0.00	180.44
	23.348	24.773	0.00	3.72	0.00	180.44
	24.773	32.173	4.03	3.72	-195.56	180.44
	32.173	33.340	4.03	3.72	-195.56	180.44
5 Column	0.000	1.167	8.37	3.41	-542.46	165.32
	1.167	4.070	8.37	3.41	-542.46	165.32
	4.070	4.538	8.37	3.41	-396.77	165.32
	4.538	5.651	5.89	3.41	-282.38	165.32
	5.651	7.453	5.89	3.41	-282.38	165.32
	7.453	8.566	3.41	3.41	-165.32	165.32
	8.566	9.014	3.41	3.41	-165.32	165.32
	9.014	12.210	3.41	3.41	-165.32	165.32
	12.210	15.740	3.41	3.41	-165.32	165.32
	15.740	16.188	3.41	3.41	-165.32	165.32
	16.188	17.625	3.41	3.41	-165.32	165.32
	17.625	23.587	6.51	3.41	-311.23	165.32
	23.587	24.420	6.51	3.41	-311.23	165.32
Middle	0.000	1.167	4.03	4.03	-195.56	195.56
	1.167	9.014	4.03	4.03	-195.56	195.56
	9.014	12.210	4.03	4.03	-195.56	195.56
	12.210	15.740	4.03	4.03	-195.56	195.56
	15.740	23.587	4.03	4.03	-195.56	195.56
	23.587	24.420	4.03	4.03	-195.56	195.56
6 Column	0.000	0.833	6.51	4.34	-311.23	209.53
	0.833	3.841	6.51	4.34	-311.23	209.53
	3.841	5.385	3.41	4.34	-165.32	209.53
	5.385	6.798	3.41	4.34	-165.32	209.53
	6.798	8.342	0.00	4.34	0.00	209.53
	8.342	8.797	0.00	4.34	0.00	209.53
	8.797	12.210	0.00	4.34	0.00	209.53
	12.210	15.623	0.00	4.34	0.00	209.53
	15.623	16.078	0.00	4.34	0.00	209.53
	16.078	17.253	0.00	4.34	0.00	209.53
	17.253	23.587	3.41	4.34	-165.32	209.53
	23.587	24.420	3.41	4.34	-165.32	209.53
Middle	0.000	0.833	4.03	4.03	-195.56	195.56
	0.833	6.696	4.03	4.03	-195.56	195.56
	6.696	7.696	0.00	4.03	0.00	195.56
	7.696	8.797	0.00	4.03	0.00	195.56
	8.797	12.210	0.00	4.03	0.00	195.56
	12.210	15.623	0.00	4.03	0.00	195.56
	15.623	18.580	0.00	4.03	0.00	195.56
	18.580	19.580	0.00	4.03	0.00	195.56
	19.580	23.587	4.03	4.03	-195.56	195.56
	23.587	24.420	4.03	4.03	-195.56	195.56
7 Column	0.000	0.750	3.41	0.00	-165.32	0.00
	0.750	0.833	3.41	0.00	-165.32	0.00
	0.833	1.067	3.41	0.00	-165.32	0.00
	1.067	1.267	3.41	0.00	-165.32	0.00
	1.267	1.500	3.41	0.00	-165.32	0.00
Middle	0.000	0.750	4.03	0.00	-195.56	0.00
	0.750	0.833	4.03	0.00	-195.56	0.00
	0.833	1.067	4.03	0.00	-195.56	0.00
	1.067	1.267	4.03	0.00	-195.56	0.00
	1.267	1.500	4.03	0.00	-195.56	0.00

Slab Shear Capacity:

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Units: b, d (in), Xu (ft), PhiVc, Vu(kip)

Span	b	d	Vratio	PhiVc	Vu	Xu
1	331.20	10.94	1.000	384.22	0.00	0.00
2	331.20	10.94	1.000	384.22	102.81	22.68
3	331.20	10.94	1.000	384.22	104.64	22.34
4	331.20	10.94	1.000	384.22	135.50	[illegible]
5	331.20	10.94	1.000	384.22	104.64	2.08
6	331.20	10.94	1.000	384.22	102.81	1.74
7	331.20	10.94	1.000	384.22	0.00	0.00

Flexural Transfer of Negative Unbalanced Moment at Supports:

Units: Width (in), Munb (k-ft), As (in^2)

Supp	Width	GammaF*Munb	Comb	Pat	AsReq	AsProv	Additional Bars
1	56.00	106.34	U1	Even	2.217	1.303	3-#5
2	56.00	58.01	U1	Even	1.195	2.488	---
3	72.00	225.80	U1	Even	3.437	4.113	---
4	72.00	225.80	U1	Even	3.437	4.113	---
5	56.00	58.01	U1	Even	1.195	2.488	---
6	56.00	106.34	U1	Even	2.217	1.303	3-#5

Punching Shear Around Columns:

Units: Vu (kip), Munb (k-ft), vu (psi), Phi*vc (psi)

Supp	Vu	vu	Munb	Comb	Pat	GammaV	vu	Phi*vc
1	124.74	122.9	123.64	U1	Even	0.400	176.2	212.1
2	224.64	166.0	-35.58	U1	S2	0.400	177.8	212.1
3	277.42	113.4	230.15	U1	S3	0.412	145.7	212.1
4	277.42	113.4	-230.15	U1	S4	0.412	145.7	212.1
5	224.64	166.0	35.58	U1	S5	0.400	177.8	212.1
6	124.74	122.9	-123.64	U1	Even	0.400	176.2	212.1

Punching Shear Around Drops:

Units: Vu (kip), vu (psi), Phi*vc (psi)

Supp	Vu	Comb	Pat	vu	Phi*vc
1	--- Not applicable ---				
2	--- Not applicable ---				
3	258.62	U1	S3	47.7	152.9
4	258.62	U1	S4	47.7	152.9
5	--- Not applicable ---				
6	--- Not applicable ---				

Maximum Deflections:

Units: Dz (in)

	Frame			Column Strip			Middle Strip		
Span	Dz(DEAD)	Dz(LIVE)	Dz(TOTAL)	Dz(DEAD)	Dz(LIVE)	Dz(TOTAL)	Dz(DEAD)	Dz(LIVE)	Dz(TOTAL)
1	0.012	0.006	0.017	0.021	0.010	0.031	0.004	0.002	0.006
2	-0.068	-0.031	-0.100	-0.114	-0.052	-0.166	-0.032	-0.015	-0.047
3	-0.014	-0.007	-0.021	-0.022	-0.010	-0.032	-0.008	-0.004	-0.012
4	-0.123	-0.110	-0.233	-0.165	-0.149	-0.314	-0.080	-0.072	-0.151
5	-0.014	-0.007	-0.021	-0.022	-0.010	-0.032	-0.008	-0.004	-0.012
6	-0.068	-0.031	-0.100	-0.114	-0.052	-0.166	-0.032	-0.015	-0.047
7	0.012	0.006	0.017	0.021	0.010	0.031	0.004	0.002	0.006

Material Takeoff:

Reinforcement in the Direction of Analysis

Top Bars:	3372.6 lb	<=>	25.16 lb/ft	<=>	0.912 lb/ft^2
Bottom Bars:	3641.2 lb	<=>	27.17 lb/ft	<=>	0.984 lb/ft^2
Stirrups:	0.0 lb	<=>	0.00 lb/ft	<=>	0.000 lb/ft^2
Total Steel:	7013.7 lb	<=>	52.33 lb/ft	<=>	1.896 lb/ft^2
Concrete:	3758.0 ft^3	<=>	28.04 ft^3/ft	<=>	1.016 ft^3/ft^2

FINAL SIZING

FINAL BEAM DESIGNS

LIVE LOAD REDUCTION - ASCE 7-05 4.8

EXTERIOR BEAM - ~~C6~~ - F6

$A_i = (1.5' + 8.5' + 19.17')(36.34') = 1060 \text{ FT}^2 > 400 \text{ FT}^2 \checkmark \text{OK}$

$L = 50 \text{ PSF}\left(0.25 + \frac{15}{\sqrt{1060 \text{ FT}^2}}\right) = 0.71(50 \text{ PSF}) = 36 \text{ PSF}$
$> 0.50 \checkmark \text{OK}$

INTERIOR BEAM - C5 - F5

$A_i = (8.5' + 19.17' + 27.67')(36.34') = 2011 \text{ FT}^2 > 400 \text{ FT}^2 \checkmark \text{OK}$

$L = 50 \text{ PSF}\left(0.25 + \frac{15}{\sqrt{2011 \text{ FT}^2}}\right) = 0.58(50 \text{ PSF}) = 30 \text{ PSF}$
$> 0.50 \checkmark \text{OK}$

EXTERIOR BEAM - C4 - C5

$A_i = (1.5' + 27.67')(36.34') = 1060 \text{ FT}^2 > 400 \text{ FT}^2 \checkmark \text{OK}$

$L = 50 \text{ PSF}\left(0.25 + \frac{15}{\sqrt{1060 \text{ FT}^2}}\right) = 0.71(50 \text{ PSF}) = 36 \text{ PSF}$
$> 0.50 \checkmark \text{OK}$

FLEXURE - DESIGN OF CONCRETE STRUCTURE TABLE A.5

$R = \frac{M_u}{\phi b d^2}$

$A_s = \rho b d$

$\rho_{max} = 0.0243$

$\rho_{min} = 0.0035$

SHEAR - ACI 11.1.1, ACI 11.3.1, ACI 11.5.5

$V_u \le \phi V_n = \phi V_c + \frac{\phi A_v f_y d}{s}$

$\phi V_c = 2\sqrt{f'_c}\, b_w d$

$A_{v\,min} = 0.75\sqrt{f'_c}\,\frac{b_w s}{f_y} \ge \frac{50 b_w s}{f_y}$

$0.75\sqrt{5000 \text{ PSI}} = 53 > 50 \checkmark \text{OK}$

SEE FRAMING PLANS FOR RESULTS

Beam	Load Combination	b (in)	d (in)	Gravity Moment (kip*ft)	Lateral Moment (kip*ft)
Exterior Beam-C6-F6	1.2D+1.6WY+L	24	24	317	562
Interior Beam-C5-F5	1.2D+1.6WY+L	24	24	453	429
Exterior Beam-C4-C5	1.237D+1.0EX+L	28	12	168	86

Beam	Mu (kip*ft)	R (psi)	ρ	As	Flexural Reinforcement	As	ρ
Exterior Beam-C6-F6	365	352	0.0061	3.51	3-#10	3.81	0.0066
Interior Beam-C5-F5	501	483	0.0086	4.95	4-#10	5.08	0.0088
Exterior Beam-C4-C5	208	689	0.0126	4.23	4-#10	5.08	0.0151

Beam	Gravity Shear (kip)	Lateral Shear (kip)
Exterior Beam-C6-F6	34.9	2.99
Interior Beam-C5-F5	49.9	2.29
Exterior Beam-C4-C5	24.3	0.54

Beam	Vu (kip)	ϕVc (kip)	Av	Shear Reinforcement	Spacing (in)
Exterior Beam-C6-F6	37.9	61.1	0.11	#3	5"
Interior Beam-C5-F5	52.1	61.1	0.11	#3	5"
Exterior Beam-C4-C5	24.9	35.6	0.12	#3	5"

PRELIMINARY SIZING OF FRAMING SYSTEM

PRELIMINARY COLUMN SIZES

BASED UPON PCA SLAB RESULTS
ALL COLUMNS 16"X16"

SEE FINAL SIZING: FINAL COLUMN DESIGNS

FINAL SIZING

FINAL COLUMN DESIGNS

LIVE LOAD REDUCTION - ASCE 7-05 4.8

CORNER COLUMN A2

FLOORS 1-4

$A_i = (27.67)(24.42') + (27.67')(1.5') + (1.5')(24.42') = 754\ FT^2 > 400\ FT^2\ \checkmark OK$

FLOOR 5

PUBLIC ASSEMBLY - NO REDUCTION

FLOORS 1-4

$L = (50\ PSF)\left(0.25 + \frac{15}{\sqrt{754\ FT^2}}\right) = 0.80(50\ FT^2) = 40\ PSF$
$> 0.50\ \checkmark OK$

EXTERIOR COLUMN B2

FLOORS 1-4

UNBALANCED LOADS - NO REDUCTION

FLOOR 5

PUBLIC ASSEMBLY - NO REDUCTION

INTERIOR COLUMN B5

FLOORS 1-4

$A_i = 3(27.67')(24.42') + (27.67')(12.21') = 2365\ FT^2 > 400\ FT^2\ \checkmark OK$

FLOOR 5

PUBLIC ASSEMBLY - NO REDUCTION

FLOORS 1-4

$L = (50\ PSF)\left(0.25 + \frac{15}{\sqrt{2365\ FT^2}}\right) = 0.56(50\ PSF) = 28\ PSF$
$> 0.50\ \checkmark OK$

INTERIOR COLUMN C5

FLOORS 1-4

$A_i = 2(27.67')(24.42') + 2(27.67')(33.34') = 3196\ FT^2 > 400\ FT^2\ \checkmark OK$

FLOOR 5

PUBLIC ASSEMBLY - NO REDUCTION

FLOOR 6

$A_i = 2(27.67')(33.34') + 2(27.67')(1.5') = 1928\ FT^2 > 400\ FT^2\ \checkmark OK$

$A_T = 2(13.84')(16.67') + 2(13.84')(1.5') = 503\ FT^2$
$< (27.67')(1.5(27.67')) = 1148\ FT^2\ \checkmark OK$

FLOORS 1-4

$L = (50\ PSF)\left(0.25 + \frac{15}{\sqrt{3196\ FT^2}}\right) = 0.52(50\ PSF) = 26\ PSF$
$> 0.50\ \checkmark OK$

FLOOR 6

$L = (50\ PSF)\left(0.25 + \frac{15}{\sqrt{1928\ FT^2}}\right) = 0.59(50\ PSF) = 30\ PSF$
$> 0.50\ \checkmark OK$

EXTERIOR COLUMN C6

FLOORS 1-3

$A_i = (15')(12.17') + (27.67')(24.42') + (15')(33.34') + (27.67')(33.34')$
$= 2281\ FT^2 > 400\ FT^2\ \checkmark OK$

FLOOR 4

UNBALANCED LOADS - NO REDUCTION

FLOOR 5

PUBLIC ASSEMBLY - NO REDUCTION

FLOOR 6

$A_i = (27.67')(33.34') + (1.5')(33.34') + (27.67')(1.5') = 1014\ FT^2 > 400\ FT^2 \checkmark OK$

$A_T = (13.84')(16.67') + (1.5')(16.67') + (13.84')(1.5') = 276\ FT^2$
$< (27.67')(1.5(27.67')) = 1148\ FT^2 \checkmark OK$

FLOORS 1-3

$L = (50\ PSF)\left(0.25 + \frac{15}{\sqrt{2281\ FT^2}}\right) = 0.56(50\ PSF) \approx 28\ PSF$
$> 0.50\ \checkmark OK$

FLOOR 6

$L = (50\ PSF)\left(0.25 + \frac{15}{\sqrt{1014\ FT^2}}\right) = 0.72(50\ PSF) = 36\ PSF$
$> 0.50\ \checkmark OK$

TOTAL ROOF WEIGHT

LOW ROOF

8(6.6 PLF)(13.17') = 695 LB
4(6.6 PLF)(14') = 370 LB
10(6.6 PLF)(27.67') = 1826 LB
2(14 PLF)(19.17') = 537 LB
2(22 PLF)(19.17') = 843 LB
4(26 PLF)(19.17') = 1994 LB
4(26 PLF)(27.67') = 2878 LB
4(14 PLF)(13.17') = 738 LB
2(14 PLF)(14') = 392 LB
+ 2(55 PLF)(40.67') = 4474 LB

14747 LB / (66.67')(40.67') = 5.44 PSF → 6 PSF

TOTAL WEIGHT = 1.2(6 PSF + 20 PSF) + 1.6(33 PSF) = 84 PSF

HIGH ROOF

46(10 PLF)(33.34') = 15336 LB
4(31 PLF)(27.67') = 3431 LB
2(31 PLF)(19.17') = 1189 LB
2(31 PLF)(24.17') = 1499 LB
3(76 PLF)(33.34') = 7602 LB
4(14 PLF)(9.5') = 532 LB
+ 2(14 PLF)(14.34') = 402 LB

29991 LB / (101')(36.34') = 8.17 PSF → 8.5 PSF

TOTAL: 1.2(8.5 PSF + 20 PSF) + 1.6(33 PSF) = 87 PSF

TRANSFER OF UNBALANCED MOMENT IN SLABS TO COLUMNS

INTERIOR COLUMN - ACI 13.6.9.2

$M_{ub} = 0.07\left[(q_{Du} + 0.5q_{Lu})\ell_2 \ell_n^2 - q_{Du}'\ell_2'\ell_n'^2\right]$

EXTERIOR OR CORNER COLUMN - ACI 13.6.3.6, 13.6.2.2

$M_{ub} = 0.3M_0 = 0.3\left(\frac{q_u \ell_2 \ell_n^2}{8}\right)$

SLENDERNESS EFFECTS - ACI 10.12.2, 10.11.2

$\frac{Kl_u}{r} \leq 34 - 12\left(\frac{M_1}{M_{1+1}}\right) \leq 40$

ASSUMING NONSWAY FRAMES

$K = 1.0$

BASEMENT

$l_u = 11'-0''$

FLOORS 1-4

$l_u = 14'-0''$

FLOOR 5

$l_u = 17'-0''$

FLOOR 6

$l_u = 9'-0''$

$r = 0.3 b_1$ or b_2

OVERSIZE COLUMN REDUCTION - ACI 10.8.4

IF $P_u \ll \phi P_n$ SMALL BAR CONFIGURATION

$A_s\%$ = A_s SMALLEST BAR CONFIGURATION: $\frac{P_u}{\phi P_n} > 0.5$

$\phi M_n = \phi M_n$ SMALLEST BAR CONFIGURATION, $A_s\% > M_u$

TIES - CRSI HANDBOOK TABLE 3-2

SPLICE LENGTH - CRSI HANDBOOK TABLE 5-2

SEE FRAMING PLANS FOR RESULTS

	Axial Load (kips)							
Column	1st	2nd	3rd	4th	5th	Low Roof	6th	High Roof
Corner Column-A2	62	74	74	74	88	2	0	0
Exterior Column-B2	116	127	127	127	157	15	0	0
Interior Column-B5	179	179	179	179	252	76	0	0
Interior Column-C5	210	210	210	210	277	38	115	52
Exterior Column-C6	143	143	143	170	203	8	96	27

	Total Axial Load (kips)						
Column	Basement	1st	2nd	3rd	4th	5th	6th
Corner Column-A2	373	311	238	164	90	2	0
Exterior Column-B2	670	554	427	300	172	15	0
Interior Column-B5	1044	865	686	507	328	76	0
Interior Column-C5	1324	1114	903	693	482	206	168
Exterior Column-C6	932	790	647	504	334	131	123

	Transferred Moment North-South Direction (kip*in)					
Column	1st	2nd	3rd	4th	5th	6th
Corner Column-A2	2057	2057	2057	2456	0	0
Exterior Column-B2	2057	2057	2057	2456	0	0
Interior Column-B5	743	743	743	1041	0	0
Interior Column-C5	2279	2279	2279	2851	3541	3546
Exterior Column-C6	2279	2279	2279	4720	5090	3669

	Transferred Moment East-West Direction (kip*in)					
Column	1st	2nd	3rd	4th	5th	6th
Corner Column-A2	2363	2363	2363	2820	0	0
Exterior Column-B2	2363	2363	2363	2820	0	0
Interior Column-B5	1211	1211	1211	1552	0	0
Interior Column-C5	1166	1166	1166	1632	2195	2893
Exterior Column-C6	1166	1166	1166	3850	4152	2993

	Lateral Moment North-South Direction (kip*in)	Lateral Moment East-West Direction (kip*in)
Column	6th	6th
Corner Column-A2	0	0
Exterior Column-B2	0	0
Interior Column-B5	0	0
Interior Column-C5	674	34
Exterior Column-C6	106	0

	Slenderness North-South Direction											
Column	1st		2nd		3rd		4th		5th		6th	
Corner Column-A2	19	34	19	22	19	22	19	24	NA	0	NA	0
Exterior Column-B2	19	34	19	22	19	22	19	24	NA	0	NA	0
Interior Column-B5	19	34	19	22	19	22	19	25	NA	0	NA	0
Interior Column-C5	16	34	16	22	16	22	16	24	16	24	15	40
Exterior Column-C6	16	34	16	22	16	22	16	28	16	23	15	40
	Slenderness East-West Direction											
Column	1st		2nd		3rd		4th		5th		6th	
Corner Column-A2	19	34	19	22	19	22	19	24	NA	0	NA	0
Exterior Column-B2	19	34	19	22	19	22	19	24	NA	0	NA	0
Interior Column-B5	19	34	19	22	19	22	19	25	NA	0	NA	0
Interior Column-C5	14	34	14	22	14	22	14	25	14	25	13	40
Exterior Column-C6	14	34	14	22	14	22	14	30	14	23	13	40

Corner Column A2							
Floor	Load Combination	Pu	Mu N-S	Mu E-W	ϕPn	ϕMn MA	ϕMn MI
Basement	1.2D+1.6L+0.5S	373	0	0	1269	2366	2366
1^{st} Floor	1.2D+1.6L+0.5S	311	2057	2363	1269	2366	2366
2^{nd} Floor	1.2D+1.6L+0.5S	238	2057	2363	1269	2366	2366
3^{rd} Floor	1.2D+1.6L+0.5S	164	2057	2363	1269	2366	2366
4^{th} Floor	1.2D+1.6L+0.5S	90	2456	2820	1586	2800	2800

Floor	Column Size	Bars	Bar Configuration	Ties	Tie Spacing (in)
Basement	20”x20”	8-#10	3E	#3	18
1^{st} Floor	20”x20”	8-#10	3E	#3	18
2^{nd} Floor	20”x20”	8-#10	3E	#3	18
3^{rd} Floor	20”x20”	8-#10	3E	#3	18
4^{th} Floor	20”x20”	16-#10	5E	#3	18

Floor	ρ (%)	Extended Bars	Splice Length (in)
Basement	2.54	8-#10	38
1^{st} Floor	2.54	8-#10	38
2^{nd} Floor	2.54	8-#10	38
3^{rd} Floor	2.54	8-#10	38
4^{th} Floor	5.08	NA	NA

Exterior Column B2

Floor	Load Combination	Pu	Mu N-S	Mu E-W	ϕPn	ϕMn MA	ϕMn MI
Basement	1.2D+1.6L+0.5S	670	0	0	1269	2366	2366
1st Floor	1.2D+1.6L+0.5S	554	2057	2363	1269	2366	2366
2nd Floor	1.2D+1.6L+0.5S	427	2057	2363	1269	2366	2366
3rd Floor	1.2D+1.6L+0.5S	300	2057	2363	1269	2366	2366
4th Floor	1.2D+1.6L+0.5S	172	2456	2820	1586	2800	2800

Floor	Column Size	Bars	Bar Configuration	Ties	Tie Spacing (in)
Basement	20"x20"	8-#10	3E	#3	18
1st Floor	20"x20"	8-#10	3E	#3	18
2nd Floor	20"x20"	8-#10	3E	#3	18
3rd Floor	20"x20"	8-#10	3E	#3	18
4th Floor	20"x20"	16-#10	5E	#3	18

Floor	ρ (%)	Extended Bars	Splice Length (in)
Basement	2.54	8-#10	38
1st Floor	2.54	8-#10	38
2nd Floor	2.54	8-#10	38
3rd Floor	2.54	8-#10	38
4th Floor	5.08	NA	NA

Interior Column B5

Floor	Load Combination	Pu	Mu N-S	Mu E-W	ϕPn	ϕMn MA	ϕMn MI
Basement	1.2D+1.6L+0.5S	1044	0	0	1111	2243	2243
1st Floor	1.2D+1.6L+0.5S	865	743	1211	1111	2243	2243
2nd Floor	1.2D+1.6L+0.5S	686	743	1211	668	1350	1350
3rd Floor	1.2D+1.6L+0.5S	507	743	1211	603	1220	1220
4th Floor	1.2D+1.6L+0.5S	328	1041	1552	765	1546	1546

Floor	Column Size	Bars	Bar Configuration	Ties	Tie Spacing (in)
Basement	20"x20"	4- #10	2E	#3	18
1st Floor	20"x20"	4- #10	2E	#3	18
2nd Floor	20"x20"	4- #8	2E	#3	16
3rd Floor	20"x20"	4- #8	2E	#3	16
4th Floor	20"x20"	4- #8	2E	#3	16

Floor	ρ (%)	Extended Bars	Splice Length (in)
Basement	1.27	4- #10	38
1st Floor	0.79	4- #10	38
2nd Floor	0.79	4- #8	30
3rd Floor	0.79	4- #8	30
4th Floor	0.79	NA	NA

Interior Column C5							
Floor	Load Combination	Pu	Mu N-S	Mu E-W	ϕPn	ϕMn MA	ϕMn MI
Basement	1.2D+1.6L+0.5S	1324	0	0	1572	4341	3689
1st Floor	1.2D+1.6L+0.5S	1114	2279	1166	1331	3677	3125
2nd Floor	1.2D+1.6L+0.5S	903	2279	1166	925	2554	2170
3rd Floor	1.2D+1.6L+0.5S	693	2279	1166	925	2554	2170
4th Floor	1.2D+1.6L+0.5S	482	2851	1632	1917	5262	4262
5th Floor	1.2D+1.6L+0.5S	206	3541	2195	1917	5262	4262
6th Floor	1.2D+1.6WY+L+0.5S	168	4220	2927	1917	5262	4262

Floor	Column Size	Bars	Bar Configuration	Ties	Tie Spacing (in)
Basement	24"x28"	8-#8	3E	#3	16
1st Floor	24"x28"	8-#8	3E	#3	16
2nd Floor	24"x28"	8-#8	3E	#3	16
3rd Floor	24"x28"	8-#8	3E	#3	16
4th Floor	24"x28"	8-#10	3E	#3	18
5th Floor	24"x28"	8-#10	3E	#3	18
6th Floor	24"x28"	8-#10	3E	#3	18

Floor	ρ (%)	Extended Bars	Splice Length (in)
Basement	0.94	8-#8	30
1st Floor	0.94	8-#8	30
2nd Floor	0.94	8-#8	30
3rd Floor	0.94	8-#8	30
4th Floor	1.51	8-#10	38
5th Floor	1.51	8-#10	38
6th Floor	1.51	NA	NA

Exterior Column C6							
Floor	Load Combination	Pu	Mu N-S	Mu E-W	ϕPn	ϕMn MA	ϕMn MI
Basement	1.2D+1.6L+0.5S	932	0	0	980	2707	2300
1st Floor	1.2D+1.6L+0.5S	790	2279	1166	980	2707	2300
2nd Floor	1.2D+1.6L+0.5S	647	2279	1166	980	2707	2300
3rd Floor	1.2D+1.6L+0.5S	504	2279	1166	980	2707	2300
4th Floor	1.2D+1.6L+0.5S	334	4720	3850	1917	5262	4262
5th Floor	1.2D+1.6L+0.5S	131	5090	4152	1917	5262	4262
6th Floor	1.2D+1.6L+0.5S	123	3774	2993	1917	5262	4262

Floor	Column Size	Bars	Bar Configuration	Ties	Tie Spacing (in)
Basement	24"x28"	8-#8	3E	#3	16
1st Floor	24"x28"	8-#8	3E	#3	16
2nd Floor	24"x28"	8-#8	3E	#3	16
3rd Floor	24"x28"	8-#8	3E	#3	16
4th Floor	24"x28"	8-#10	3E	#3	18
5th Floor	24"x28"	8-#10	3E	#3	18
6th Floor	24"x28"	8-#10	3E	#3	18

Floor	ρ (%)	Extended Bars	Splice Length (in)
Basement	0.94	8-#8	30
1st Floor	0.94	8-#8	30
2nd Floor	0.94	8-#8	30
3rd Floor	0.94	8-#8	30
4th Floor	1.51	8-#10	38
5th Floor	1.51	8-#10	38
6th Floor	1.51	NA	NA

FINAL SIZING

2^{nd} FLOOR COLUMN SPOT CHECK

-SHORT COLUMN BASED ON SLENDERNESS CRITERIA PREVIOUSLY DEFINED

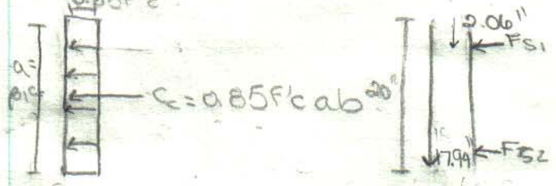
- ϕP_n EQUATION FROM ACI 10.3.6.2

$\phi P_n = 0.80\,\phi\,[0.85 f'_c (A_g - A_{st}) + f_y A_{st}]$

$= 0.80(0.65)[0.85(5000\text{ PSI})((20'')(20'') - (4)(1.00\text{ IN}^2)) + (60000\text{ PSI})(4)(1.00\text{ IN}^2)]/1000$

$= 1000^k \ngtr 1077^k$

- SMALLER THAN TABULATED VALUE DUE TO CHANGE OF ϕ FROM 0.70 TO 0.65, OKAY DUE TO DESIGN CONTROLLED BY BENDING



- ϕM_n PROCESS FROM CRSI HANDBOOK MANUAL EXAMPLE PG. 3-6

$F_s = f_s A_s$

$= \varepsilon_s E_s A_s$

$= \varepsilon_c\left(1 - \frac{d_s}{c}\right) E_s A_s - 0.85 f'_c A_s$

$F_{s1} = (0.003)\left(1 - \frac{2.06''}{c}\right)(29000\text{ KSI})(2\text{ IN}^2) - (0.85)(5000\text{ PSI})(2\text{ IN}^2)(1/1000) = 174 - 8.5 - 358/c$

$F_{s2} = (0.003)\left(1 - \frac{17.94''}{c}\right)(29000\text{ KSI})(2\text{ IN}^2) - (0.85)(5000\text{ PSI})(2\text{ IN}^2)(1/1000) = 174 - 8.5 - 3122/c$

$C_c = 0.85 f'_c ab = 0.85 f'_c (0.80c) b = 0.85(5000\text{ PSI})(0.80)c(20'')/1000 = 68c$

$331 + 68c - \frac{3507}{c} = 1000^k/0.65$

$c = 20.3''$

$F_{s1} = (0.003)\left(1 - \frac{2.06''}{20.3''}\right)(29000\text{ KSI})(2\text{ IN}^2) - (0.85)(5000\text{ PSI})(2\text{ IN}^2)(1/1000) = 148^k$

$F_{s2} = (0.003)\left(1 - \frac{17.94''}{20.3''}\right)(29000\text{ KSI})(2\text{ IN}^2) - (0.85)(5000\text{ PSI})(2\text{ IN}^2)(1/1000) = 12^k$

$M_s = F_s\left(\frac{h}{2} - d_s\right)$

$M_{s1} = (148^k)\left(\frac{20''}{2} - 2.06''\right) = 1175^{k''}$

$M_{s2} = (12^k)\left(\frac{20''}{2} - 17.94''\right) = -95^{k''}$

$C_c = 0.85 f'_c ab = 0.85 f'_c (0.80c) b = 0.85(5000\text{ PSI})(0.80)(20.3)(20'')/1000 = 1380^k$

$M_c = C_c\left(\frac{h-a}{2}\right) = C_c\left(\frac{h - 0.80c}{2}\right) = (1380^k)\left(\frac{20'' - (0.80)(20.3'')}{2}\right) = 2594^{k''}$

$\phi M_n = \phi(M_{s1} + M_{s2} + M_c) = (0.65)(1175^{k''} - 95^{k''} + 2594^{k''}) = 2388^{k''} > 2178^{k''}$ ✓ OK

2nd Floor Concrete Column C2 Spot Check CRSI Handbook Results (see Framing Plans)

Floor	Load Combination	Pu	Mu N-S	Mu E-W
2nd Floor	1.2D+1.6L+0.5S	686	743	1211
Design		ϕPn	ϕMn MA	ϕMn MI
Actual		1077	2178	2178
Reduced		668	1350	1350
Column Size		Bars		Bar Spacing
20"x20"		4-#9		2E
20"x20"		4- #8		2E

2nd Floor Concrete Column C2 Spot Check CRSI Handbook Table

SQUARE TIED COLUMNS 16" × 16"

Short columns – no sidesway; Bars symmetrical in 4 faces; f'_c = 5,000 psi; f_y = 60,000 psi; φM in inch-kips; φP in kips

BARS	RHO	Max Cap φM	Max Cap φP	0% f_y φM	0% f_y φP	25% f_y φM	25% f_y φP	50% f_y φM	50% f_y φP	100% f_y φM	100% f_y φP	.1f'_c Ag φM	.1f'_c Ag φP	Zero Axial Load φM
4-# 8	1.23	1126	708	1670	580	1923	488	2056	414	2186	302	1580	128	1117
4-# 9	1.56	1161	734	1764	594	2037	498	2191	420	2365	300	1763	128	1373
4-#10	1.98	1204	768	1882	613	2179	511	2360	428	2588	296	1994	128	1693
4-#11	2.44	1236	804	2003	628	2314	521	2515	433	2759	284	2207	128	2005
4-#14	3.52	1327	890	2277	676	2649	556	2914	454	3249	268	2753	128	2752
4-#18	6.25	1532	1109	2918	802	3439	646	3820	501	4356	217	4041	128	4490
8-# 6	1.38	1094	719	1605	595	1854	499	1978	422	2085	307	1646	128	1243
8-# 7	1.88	1133	759	1716	618	1987	515	2137	432	2298	304	1887	128	1637
8-# 8	2.47	1179	807	1843	646	2143	535	2323	444	2546	301	2161	128	2089
8-# 9	3.13	1230	859	1981	677	2312	558	2524	457	2816	297	2450	128	2569
8-#10	3.97	1290	926	2154	718	2525	586	2779	474	3151	291	2807	128	3165
8-#11	4.88	1337	999	2325	755	2723	612	3010	497	3411	273	3114	128	3613
8-#14	7.03	1477	1171	2729	858	3223	685	3611	544	4150	246	3919	128	4680
12-#10	5.95	1447	1085	2503	823	2946	670	3287	529	3830	279	3612	128	4247
12-#11	7.31	1520	1194	2736	883	3220	712	3610	552	4198	253	4024	128	4916
SQUARE TIED COLUMNS 18" × 18"														
4-# 9	1.23	1617	896	2362	745	2749	626	2955	532	3161	389	2285	162	1607
4-#10	1.57	1671	930	2504	763	2919	638	3157	539	3430	385	2560	162	1988
4-#11	1.93	1715	966	2655	777	3086	648	3347	543	3677	379	2820	162	2386
4-#14	2.78	1832	1052	2988	825	3492	682	3831	564	4311	369	3478	162	3269
4-#18	4.94	2093	1271	3777	949	4460	772	4988	618	5743	331	5054	162	5397
8-# 6	1.09	1535	881	2169	747	2528	628	2700	535	2827	397	2145	162	1449
8-# 7	1.48	1583	921	2301	770	2687	645	2888	545	3078	395	2463	162	1916
8-# 8	1.95	1639	968	2454	798	2872	665	3109	557	3372	392	2798	162	2454
8-# 9	2.47	1699	1021	2618	829	3073	687	3348	571	3692	388	3153	162	3030
8-#10	3.14	1774	1088	2826	870	3327	716	3652	588	4098	384	3592	162	3749
8-#11	3.85	1840	1161	3038	907	3573	742	3937	602	4473	375	3981	162	4440
8-#14	5.56	2013	1333	3529	1010	4178	816	4662	646	5427	360	4981	162	5864
12-#10	4.70	1970	1247	3241	976	3829	802	4256	645	4907	376	4603	162	5139
12-#11	5.78	2064	1356	3531	1037	4168	845	4654	670	5434	362	5132	162	5984
16-#10	6.27	2151	1406	3679	1083	4366	880	4900	694	5764	375	5574	162	6518
SQUARE TIED COLUMNS 20" × 20"														
4-# 9	1.00	2178	1077	[illegible]	914	3607	770	3877	658	4116	489	2899	200	1840
4-#10	1.27	2243	1111	[illegible]	932	3806	783	4112	665	4429	485	3218	200	2282
[illegible]	[illegible]	[illegible]	[illegible]	3425	945	4006	791	4339	668	4722	478	3524	200	2727
4-#14	2.25	2444	1233	3819	992	4483	825	4906	688	5478	470	4295	200	3784
4-#18	4.00	2768	1452	4756	1115	5629	913	6275	741	7299	450	6158	200	6303
8-# 7	1.20	2137	1102	3003	940	3533	791	3797	672	4018	496	3106	200	2193
8-# 8	1.58	2204	1149	3180	968	3748	811	4053	685	4358	493	3533	200	2818
8-# 9	2.00	2276	1202	3373	999	3981	833	4331	698	4728	490	3956	200	3489
8-#10	2.54	2366	1269	3615	1040	4277	862	4683	716	5199	487	4480	200	4331
8-#11	3.12	2442	1342	3870	1077	4569	888	5022	729	5644	478	4955	200	5156
8-#14	4.50	2659	1514	4447	1181	5280	962	5872	775	6782	467	6158	200	7130
8-#18	8.00	3158	1951	5829	1446	6991	1152	7925	889	9521	437	8958	200	10832
12-#10	3.81	2588	1428	4096	1148	4858	949	5383	775	6137	481	5673	200	8068
12-#11	4.68	2716	1536	4444	1208	5263	993	5857	800	6763	468	6363	200	7083
12-#14	6.75	3039	1795	5257	1370	6258	1113	7051	874	8362	451	8032	200	9579
16-#10	5.08	2800	1586	4605	1256	5482	1029	6130	826	7132	482	6791	200	7783
16-#11	6.24	2966	1731	5050	1340	6005	1090	6747	861	7948	468	7705	200	9002

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Return To Column Criteria

FINAL SIZING

FINAL SHEAR WALL DESIGNS

SEISMIC VERTICAL COMBINATIONS - ASCE 7-05 12.2.3.1
ORDINARY REINFORCED CONCRETE SHEAR WALLS / MOMENT FRAMES
EXCEPTION: OTHER SUPPORTED STRUCTURAL SYSTEMS
6^{th} FLOOR & HIGH ROOF = $1037^k + 267^k = 1304^k$
10% TOTAL BUILDING WEIGHT = $(0.10)(16875^k) = 1658^k$ ✓OK
SEE DESIGN LOADS FOR WEIGHTS

RIGID DIAPHRAGMS - ASCE 7-05 12.3.1.2
FLOORS 1-4, 6
$\frac{SPAN}{t} = \frac{33.34'}{12''} = 2.78'/'' < 3'/''$ ✓OK
FLOOR 5
$\frac{SPAN}{t} = \frac{33.34'}{14''} = 2.38'/'' < 3''/''$ ✓OK
LOW ROOF, HIGH ROOF
FLEXIBLE DIAPHRAGMS

SEISMIC REDUNDANCY FACTOR - ASCE 7-05 12.3.4
SEISMIC DESIGN CATEGORY B
$\rho = 1.0$

WIND LOAD CASES - ASCE 7-05 6.5.12.3
CASE 1
W_x, W_y
CASE 2
$W_{xT} = 0.75 W_x + M_{Tx}$, $W_{yT} = 0.75 W_y + M_{Ty}$
CASE 3
$W_x W_y = 0.75 W_x + 0.75 W_y$
CASE 4
$W_x W_y T = 0.563 W_x + 0.563 W_y + M_T$
SEE FINAL SIZING: TORSION FOR M_T

SEISMIC LOAD COMBINATIONS - ASCE 7-05 12.4.2.3, 12.4.2.2
$S_{DS} = 0.183 > 0.125$, MUST USE E_V
$(1.2 + 0.2 S_{DS})D + \rho Q_E + L + 0.2S = (1.2 + (0.2)(0.183))D + (1.0)E + L + 0.2S$
$= 1.237D + 1.0E + L + 0.2S$
$(0.9 - 0.2 S_{DS})D + \rho Q_E = (0.9 - (0.2)(0.183))D + (1.0)E = 0.863D + 1.0E$

SEISMIC DIRECTION OF LOADING - ASCE 7-05 12.5.2
SEISMIC DESIGN CATEGORY B
ORTHOGONAL DIRECTIONS MAY BE ANALYZED INDEPENDENTLY

CRACKED SECTIONS - ASCE 7-05 12.7.3
SHEAR WALL PIER - MEMBRANE $f_{22} = 0.70$
SHEAR WALL SPANDREL - MEMBRANE $f_{22} = 0.35$

TOTAL FLOOR MASS PER AREA

$m = \frac{E}{a} = \frac{\text{TOTAL FLOOR WEIGHT}}{(\text{FLOOR AREA})(32.2\ \text{FT/S}^2)(12)^3}$

STRUCTURAL IRREGULARITIES - ASCE 7-05 12.3.3

HORIZONTAL STRUCTURAL IRREGULARITIES - ASCE 7-05 TABLE 12.3-1

1a- TORSIONAL
1b. EXTREME TORSIONAL
} CONDITIONS OF ASCE 7-05 12.7.3 - STRUCTURAL MODELING ALREADY MET

2. REENTRANT CORNER
3. DIAPHRAGM DISCONTINUITY
4. OUT-OF-PLANE OFFSETS
5. NONPARALLEL SYSTEMS
} NOT APPLICABLE

VERTICAL STRUCTURAL IRREGULARITIES - ASCE 7-05 TABLE 12.3-2

1a. STIFFNESS SOFT STORY
1b. STIFFNESS - EXTREME SOFT STORY
2. WEIGHT (MASS)
3. VERTICAL GEOMETRIC
4. IN-PLANE DISCONTINUITY IN VERTICAL LATERAL FORCE RESISTING ELEMENT
5a. DISCONTINUITY IN STRENGTH - WEAK STORY
5b. DISCONTINUITY IN STRENGTH - EXTREME WEAK STORY

ALL NOT APPLICABLE

SEE FRAMING PLANS FOR RESULTS

Additional Masses				
Story	Floor Area (sf)	Floor Dead Load (psf)	Floor Self-Weight (psf)	Total Floor Mass Per Area (kip*s^2/in^3)
High Roof	3467	20	26	1.383E-06
6th Floor	2929	20	172	6.362E-06
Low Roof	5594	20	29	1.006E-06
5th Floor	7937	20	151	9.350E-06
4th Floor	10453	20	171	6.536E-06
3rd Floor	11338	20	171	4.611E-06
2nd Floor	11338	20	171	4.611E-06

Pier	Flexural Reinf.	Spacing (in)	Shear Reinf.	As/s (in^2/ft)	Spacing (in)
WA	#4	12	#4	0.240	10
WA7	#4	12	#4	0.240	10
WG4	#4	12	#4	0.240	10
WH	#4	12	#4	0.240	10
W43A	#4	12	#4	0.240	10
W43H	#4	12	#4	0.240	10
W5A	#4	12	#4	0.240	10
W5H	#4	12	#4	0.240	10
Spandrel	Flexural Reinf.	As (in^2)	Vert. Shear Reinf.	As/s (in^2/ft)	As (in^2)
SA7	4- #4	0.657	4 legs- #4	0.24	0.92
SG4	4- #4	0.743	4 legs- #4	0.24	0.92
Spandrel	Horizontal Shear Reinf.		As/s (in^2/ft)		Spacing (in)
SA7	#4		0.144		12
SG4	#4		0.144		12

FINAL SIZING

2nd FLOOR CONCRETE SHEAR WALL WA SPOT CHECK
THICKNESS: 8"
HEIGHT: 14'-0"
SPAN: 25'-4"

A) CHECK NEED FOR BOUNDARY ELEMENT

$f_c = \dfrac{M_u\, h_w/2}{I_g} = \dfrac{(2380^{k})(14'/2)}{\dfrac{(8'')(1/12)(25.34)^3}{12}} = 184\ ksf\ (1/144) = 0.128\ ksi$

$0.2f'_c = (0.2)(5000\ psi)(1/1000) = 1.00\ ksi$

$f_c = 0.128\ ksi < 0.2f'_c = 1.00\ ksi$

BOUNDARY ELEMENTS NOT REQUIRED ✓OK

B) LONGITUDINAL & TRANSVERSE REINFORCEMENT

$V_u = 132^k < 2A_{cv}\sqrt{f'_c} = 2(8'')(25.34')(12)\sqrt{5000\ psi}\ (1/1000) = 344^k$

1 CURTAIN NEEDED - 2 PROVIDED ✓OK

C) REQUIRED ρ_ℓ & ρ_t

$\rho_\ell, \rho_t > 0.0025$

$A_{cv} = (8'')(12'') = 96\ in^2/'$

$A_{s\,LONG} = \rho_\ell, \rho_t A_{cv} = (0.0025)(96\ in^2/') = 0.240\ in^2/' < 2(0.20\ in^2/') = 0.40\ in^2/'$ ✓OK

D) NOMINAL SHEAR CAPACITY

$\phi V_n = \phi A_{cv}(\alpha_c\sqrt{f'_c} + \rho_t f_y)$

$A_{cv} = (8'')(25.34')(12) = 2433\ in^2$

$\alpha_c = \dfrac{14'}{25.34'} = 0.55 < 2$

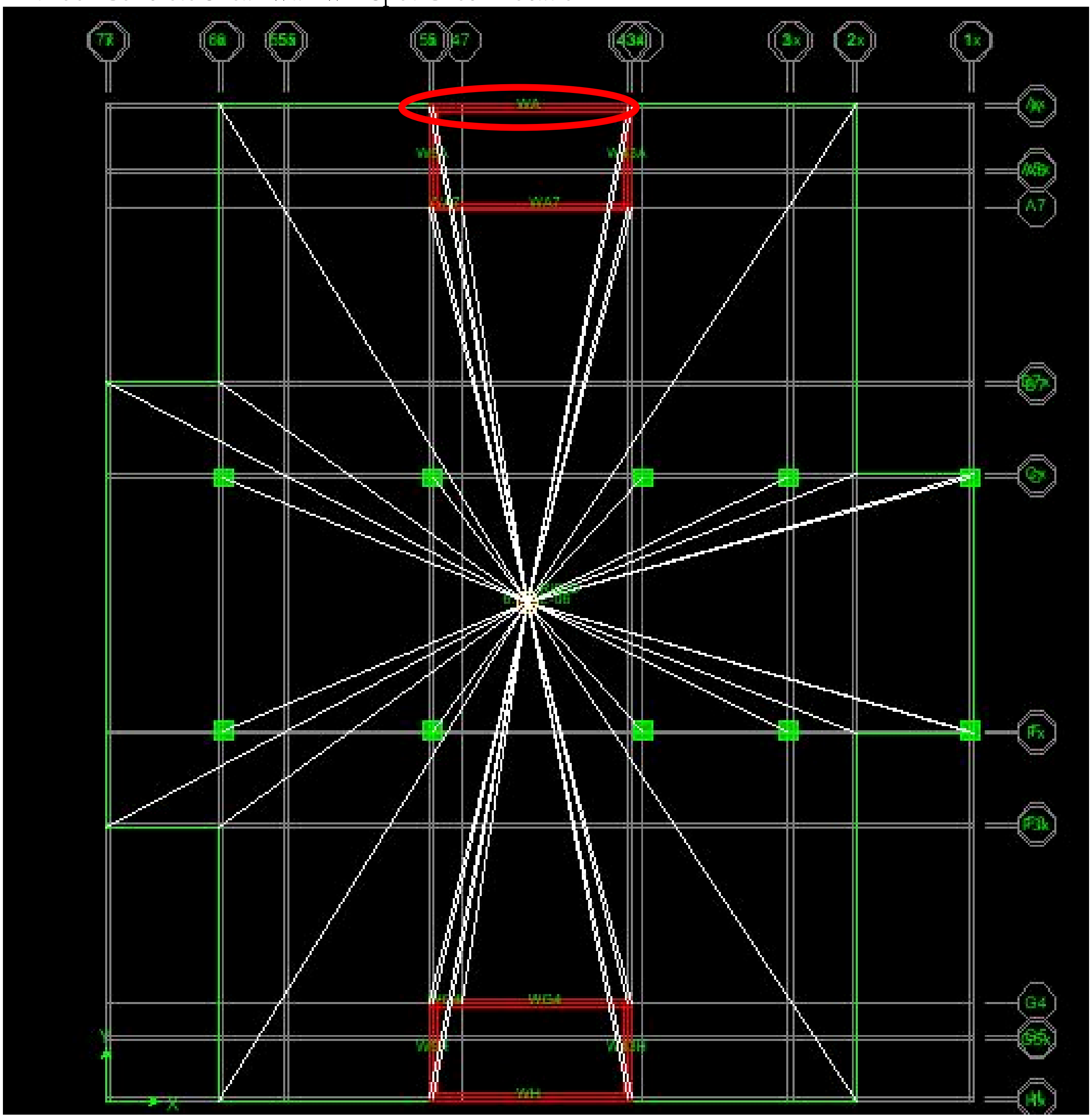
$\phi V_n = (0.60)(2433\ in^2)(0.55\sqrt{5000\ psi}\ (1/1000) + (0.0044)(60\ ksi)) = 442^k$

$V_u = 132^k < \phi V_n = 442^k$ ✓OK

2nd Floor Concrete Shear Wall WA Spot Check ETABS Results

Loads-1.2D-1.6WX			Reinforcement			
Pu (kips)	Vu (kips)	Mu (kip*ft)	Reinforcement	Spacing (in)	ρ (%) Provided	ρ (%) Required
225	132	2380	#4	12	0.044	0.040

2nd Floor Concrete Shear Wall WA Spot Check Location



FINAL SIZING

DRIFT

WIND

$\delta_{xw} \leq \delta_a = \frac{h_{sx}}{400} = 0.0025\, h_{sx}$

SEISMIC – ASCE 7-05 12.8.6, ASCE 7-05 12.12.1

$\delta_x = \frac{C_d\, \delta_{xe}}{I} = \frac{4.5\, \delta_{xe}}{1.25} = 3.6\, \delta_{xe}$

$C_d = 4\frac{1}{2}$ ORDINARY REINFORCED CONCRETE SHEAR WALLS

$2\frac{1}{2}$ ORDINARY REINFORCED CONCRETE MOMENT FRAMES

$C_d = 4\frac{1}{2}$ - ASCE 7-05 12.2.3.2

OCCUPANCY CATEGORY III

$\delta_x = 3.6\, \delta_{xe} \leq \delta_a = 0.015\, h_{sx}$

$\delta_{xe} \leq \delta_a = 0.0042\, h_{sx}$

	Wind Displacement				Seismic Displacement			
Story	δx (in)	Δx (in)	δy (in)	Δy (in)	δx (in)	Δx (in)	δy (in)	Δy (in)
HIGH ROOF	0.0545	0.1605	0.1037	0.3974	0.3342	0.8096	0.2412	1.0641
6TH FLOOR	0.0278	0.1060	0.0571	0.2937	0.1720	0.4755	0.1325	0.8229
LOW ROOF	0.0243	0.0782	0.0769	0.2366	0.1210	0.3035	0.1950	0.6904
5TH FLOOR	0.0178	0.0539	0.0596	0.1597	0.0647	0.1825	0.1688	0.4953
4TH FLOOR	0.0161	0.0361	0.0465	0.1001	0.0570	0.1179	0.1310	0.3266
3RD FLOOR	0.0129	0.0199	0.0359	0.0535	0.0423	0.0608	0.0978	0.1956
2ND FLOOR	0.0070	0.0070	0.0177	0.0177	0.0185	0.0185	0.0978	0.0978

Wind Drift					
Story	Load Combination	δx (in)	Load Combination	δy (in)	δa
HIGH ROOF	1.2D-1.6WX	0.0545	1.2D+1.6WY	0.1037	0.2700
6TH FLOOR	1.2D-1.6WX	0.0278	1.2D+1.6WY	0.0571	0.1500
LOW ROOF	1.2D-1.6WX	0.0243	1.2D+1.6WY	0.0769	0.3600
5TH FLOOR	1.2D-1.6WX	0.0178	1.2D+1.6WY	0.0596	0.4200
4TH FLOOR	1.2D-1.6WX	0.0161	1.2D+1.6WY	0.0465	0.4200
3RD FLOOR	1.2D-1.6WX	0.0129	1.2D+1.6WY	0.0359	0.4200
2ND FLOOR	1.2D-1.6WX	0.0070	1.2D+1.6WY	0.0177	0.3300
Seismic Drift					
Story	Load Combination	δx (in)	Load Combination	δy (in)	δa
HIGH ROOF	1.237D-1.0EX	0.3342	1.237D+1.0EY	0.2412	1.6200
6TH FLOOR	1.237D-1.0EX	0.1720	1.237D+1.0EY	0.1325	0.9000
LOW ROOF	1.237D-1.0EX	0.1210	1.237D+1.0EY	0.1950	2.1600
5TH FLOOR	1.237D-1.0EX	0.0647	1.237D+1.0EY	0.1688	2.5200
4TH FLOOR	1.237D-1.0EX	0.0570	1.237D+1.0EY	0.1310	2.5200
3RD FLOOR	1.237D-1.0EX	0.0423	1.237D+1.0EY	0.0978	2.5200
2ND FLOOR	1.237D-1.0EX	0.0185	1.237D+1.0EY	0.0978	1.9800

FINAL SIZING

OVERTURNING

WIND /SEISMIC OVERTURNING - ASCE 7-05 12.8.5

$$\Sigma M_{OVERTURNING} = \sum_{i=\#\,STORIES}^{1} F_i h_i$$

$$\Sigma M_{RESISTING} = \sum_{i=\#\,STORIES}^{1} W_i h_i$$

F_i = STORY SHEAR
W_i = STORY WEIGHT
h_i = STORY HEIGHT

$\Sigma M_{OVERTURNING} \leq \Sigma M_{RESISTING}$

0.9D+1.6WX					
Story	Height (ft)	Effective Shear (kips)	Effective Weight (kips)	Moverturning (kip*ft)	Mresisting (kip*ft)
High Roof	82	6	267	743	19693
6th Floor	73	16	1037	1888	68117
Low Roof	68	17	626	1829	38313
5th Floor	56	72	3026	6471	152509
4th Floor	42	63	3265	4255	123414
3rd Floor	28	61	2909	2738	73300
2nd Floor	14	59	2909	1326	36650
1st Floor	0	29	2537	0	0
Total				19251	511995

0.9D+1.6WY					
Story	Height (ft)	Effective Shear (kips)	Effective Weight (kips)	Moverturning (kip*ft)	Mresisting (kip*ft)
High Roof	82	17	267	2195	19693
6th Floor	73	48	1037	5577	68117
Low Roof	68	14	626	1524	38313
5th Floor	56	55	3026	4907	152509
4th Floor	42	55	3265	3711	123414
3rd Floor	28	53	2909	2392	73300
2nd Floor	14	52	2909	1160	36650
1st Floor	0	26	2537	0	0
Total				21466	511995

0.863D+1.0EX/0.863D+1.0EY					
Story	Height (ft)	Effective Shear (kips)	Effective Weight (kips)	Moverturning (kip*ft)	Mresisting (kip*ft)
High Roof	82	16	267	1310	18883
6th Floor	73	51	1037	3750	65317
Low Roof	68	28	626	1879	36738
5th Floor	56	97	3026	5450	146239
4th Floor	42	66	3265	2759	118340
3rd Floor	28	30	2909	846	70286
2nd Floor	14	10	2909	137	35143
1st Floor	0	0	2537	0	0
Total				16132	490947

FINAL SIZING

TORSION

WIND ACCIDENTAL TORSION - ASCE 7-05 FIGURE 6-9

CASE 2

$M_{T\,x,y} = 0.75(P_{W\,x,y} + P_{L\,x,y})\, B_{x,y}\, e_{x,y}$

$e_{x,y} = 0.15 B_{x,y}$

CASE 4

$M_T = 0.563(P_{Wx} + P_{Lx}) B_x e_x + 0.563(P_{Wy} + P_{Ly}) B_y e_y$

$e_x, e_y = 0.15\, B_x, B_y$

WIND INHERENT TORSION

$M_{T\,x,y} = (\ell$ CENTER OF MASS TO CENTER OF RIGIDITY $\perp)F$

SEISMIC ACCIDENTAL TORSION - ASCE 7-05 12.8.4.2, 12.8.4.3

$M_{a\,x,y} = 0.05(\ell$ CENTER OF MASS TO EDGE $\perp)F$

SEISMIC DESIGN CATEGORY B - NO AMPLIFICATION REQUIRED

SEISMIC INHERENT TORSION - ASCE 7-05 12.8.4.1

$M_{i\,x,y} = (\ell$ CENTER OF MASS TO CENTER OF RIGIDITY $\perp)F$

Wind Accidental Torsion Case 2				
	Force (kips)		Floor Width	
Story	X-Direction	Y-Direction	X-Direction	Y-Direction
High Roof	4.2	12.5	98.67	33.34
6th Floor	12.1	35.8	98.67	33.34
Low Roof	12.6	10.5	66.00	131.00
5th Floor	54.2	41.1	98.67	131.00
4th Floor	47.5	41.4	113.67	131.00
3rd Floor	45.8	40.0	113.67	131.00
2nd Floor	44.4	38.8	113.67	131.00
	Torsional Moment Arm (in)		Torsional Moment (kip*ft)	
Story	X-Direction	Y-Direction	X-Direction	Y-Direction
High Roof	14.80	5.00	32.3	14.5
6th Floor	14.80	5.00	92.2	41.5
Low Roof	9.90	19.65	42.9	187.8
5th Floor	14.80	19.65	412.0	734.3
4th Floor	17.05	19.65	479.4	740.3
3rd Floor	17.05	19.65	462.7	715.8
2nd Floor	17.05	19.65	448.0	694.1

Wind Accidental Torsion Case 4				
	Force (kips)		Floor Width (in)	
Story	X-Direction	Y-Direction	X-Direction	Y-Direction
High Roof	5.7	16.7	98.67	33.34
6th Floor	16.2	47.8	98.67	33.34
Low Roof	16.8	14.0	66.00	131.00
5th Floor	72.2	54.8	98.67	131.00
4th Floor	63.3	55.2	113.67	131.00
3rd Floor	61.1	53.4	113.67	131.00
2nd Floor	59.2	51.8	113.67	131.00
	Torsional Moment Arm (in)		Torsional Moment (kip*ft)	
Story	X-Direction	Y-Direction		
High Roof	14.80	5.00	43.3	
6th Floor	14.80	5.00	123.4	
Low Roof	9.90	19.65	183.9	
5th Floor	14.80	19.65	963.6	
4th Floor	17.05	19.65	1035.5	
3rd Floor	17.05	19.65	1000.4	
2nd Floor	17.05	19.65	969.5	

Wind Inherent Torsion						
	Force (kips)		Center of Mass (in)		Center of Rigidity (in)	
Story	X-Direction	Y-Direction	X-Direction	Y-Direction	X-Direction	Y-Direction
High Roof	16.7	5.7	777	787	802	787
6th Floor	47.8	16.2	777	787	805	788
Low Roof	14.0	16.8	684	788	762	796
5th Floor	54.8	72.2	711	789	753	795
4th Floor	55.2	63.3	668	789	728	794
3rd Floor	53.4	61.1	668	789	690	794
2nd Floor	51.8	59.2	668	789	656	799
	Torsional Moment Arm (in)		Torsional Moment (kip*in)	
Story	X-Direction	Y-Direction	X-Direction	Y-Direction
High Roof	25	0	35	0
6th Floor	28	1	111	1
Low Roof	78	8	91	11
5th Floor	42	6	192	36
4th Floor	60	5	276	26
3rd Floor	22	5	98	25
2nd Floor	12	10	52	49

Seismic Accidental Torsion						
	Force (kips)		Torsional Moment Arm (in)		Torsional Moment (kip*ft)	
Story	X-Direction	Y-Direction	X-Direction	Y-Direction	X-Direction	Y-Direction
High Roof	16.0	16.0	4.93	1.67	6.6	2.2
6th Floor	51.4	51.4	4.93	1.67	21.1	7.1
Low Roof	27.6	27.6	3.30	6.55	7.6	15.1
5th Floor	97.3	97.3	4.93	6.55	40.0	53.1
4th Floor	65.7	65.7	5.68	6.55	31.1	35.9
3rd Floor	30.2	30.2	5.68	6.55	14.3	16.5
2nd Floor	9.8	9.8	5.68	6.55	4.6	5.3

Seismic Inherent Torsion						
	Force (kips)		Center of Mass (in)		Center of Rigidity (in)	
Story	X-Direction	Y-Direction	X-Direction	Y-Direction	X-Direction	Y-Direction
High Roof	16.0	16.0	777	787	802	787
6th Floor	51.4	51.4	777	787	805	788
Low Roof	27.6	27.6	684	788	762	796
5th Floor	97.3	97.3	711	789	753	795
4th Floor	65.7	65.7	668	789	728	794
3rd Floor	30.2	30.2	668	789	690	794
2nd Floor	9.8	9.8	668	789	656	799

	Torsional Moment Arm (in)		Torsional Moment (kip*in)	
Story	X-Direction	Y-Direction	X-Direction	Y-Direction
High Roof	25	0	33	0
6th Floor	28	1	120	4
Low Roof	78	8	180	18
5th Floor	42	6	341	49
4th Floor	60	5	329	27
3rd Floor	22	5	55	13
2nd Floor	12	10	10	8

Final Sizing

Lateral Distribution Spot Check ETABS Results (see Framing Plans)

WX					
Lateral Element	6th Floor	5th Floor	4th Floor	3rd Floor	2nd Floor
	Shear	Shear	Shear	Shear	Shear
Column C1	-0.40	0.00	0.00	0.00	0.00
Column C3	4.01	0.00	0.00	0.00	0.00
Column C4	3.98	0.00	0.00	0.00	0.00
Column C5	3.77	0.00	0.00	0.00	0.00
Column C6	-0.41	0.00	0.00	0.00	0.00
Column F1	-0.40	0.00	0.00	0.00	0.00
Column F3	4.01	0.00	0.00	0.00	0.00
Column F4	3.98	0.00	0.00	0.00	0.00
Column F5	3.77	0.00	0.00	0.00	0.00
Column F6	-0.41	0.00	0.00	0.00	0.00
WA	0.00	33.29	51.39	67.53	78.70
WA7	0.00	22.77	36.02	50.16	64.40
WG4	0.00	22.06	35.39	49.71	65.58
WH	0.00	33.73	51.72	67.69	78.41
Model Shear	21.90	111.85	174.52	235.09	287.09
Direct Shear	21.83	110.87	174.18	235.30	294.48
Torsional Shear	5.37	11.10	15.71	20.16	24.47
Total Shear	27.20	121.97	189.89	255.46	318.95

WY					
Lateral Element	6th Floor	5th Floor	4th Floor	3rd Floor	2nd Floor
	Shear	Shear	Shear	Shear	Shear
Column C1	-0.35	0.00	0.00	0.00	0.00
Column C3	9.74	0.00	0.00	0.00	0.00
Column C4	10.76	0.00	0.00	0.00	0.00
Column C5	12.47	0.00	0.00	0.00	0.00
Column C6	-0.36	0.00	0.00	0.00	0.00
Column F1	-0.35	0.00	0.00	0.00	0.00
Column F3	9.74	0.00	0.00	0.00	0.00
Column F4	10.76	0.00	0.00	0.00	0.00
Column F5	12.47	0.00	0.00	0.00	0.00
Column F6	-0.36	0.00	0.00	0.00	0.00
W43A	0.00	40.82	56.80	71.76	81.06
W43H	0.00	37.06	52.35	66.27	70.97
W5A	0.00	29.44	41.34	53.28	63.72
W5H	0.00	26.52	37.64	46.92	59.05
Model Shear	64.52	133.84	188.13	238.23	274.80
Direct Shear	64.48	133.26	188.48	241.86	293.64
Torsional Shear	1.35	8.77	14.04	19.14	24.07
Total Shear	65.83	142.02	202.52	261.00	317.71

d. Roof Framing

FINAL SIZING

FINAL ROOF FRAMING DESIGN

DECK

LOW ROOF

TOTAL LOAD = 1.2(17 PSF) + 1.6(33 PSF) = 61 PSF < 131 PSF ✓OK

TRIPLE SPAN + @ 2'-0"

USE 1 1/2" 22 GAGE GALVANIZED TYPE B STEEL ROOF DECK

HIGH ROOF

SPECIAL ORDER STEEL ROOF DECK ≈ 3 PSF

JOISTS

LOW ROOF

TOTAL LOAD = 1.2(20 PSF) + 1.6(33 PSF) = 24 PSF + 53 PSF = 77 PSF

SPAN: 14'-0"

*18K3

550 PLF/77 PSF = 7.14'

*SPACED @ 7'-0" O.C.

TOTAL LOAD = (77 PSF)(7') = 539 PLF < 550 PLF ✓OK

LIVE LOAD = (53 PSF)(7') = 371 PLF < 550 PLF ✓OK

USE 3-18K3 SPACED @ 6.39' O.C.

SPAN: 27'-8"

*18K3

240 PLF / 77 PSF = 3.12'

*SPACED @ 3'-0" O.C.

TOTAL LOAD = (77 PSF)(3') = 231 PLF < 240 PLF ✓OK

SNOW LOAD = (53 PSF)(3') = 159 PLF ≈ 157 PLF ✓OK

USE 5-18K3 SPACED @ 2.80' O.C.

HIGH ROOF

SPECIAL ORDER CURVED ROOF JOISTS ≈ 10 PLF

SEE FRAMING PLANS FOR RESULTS

FINAL SIZING

LOW ROOF STEEL BEAM SPOT CHECK

W24X55

SPAN: 40'-4"

UNBRACED LENGTH: 13'-2"

LOADS: $w_{SW} = 55$ PLF

$w_{DL} = (20\ PSF)(17') = 840$ PLF

$w_S = (33\ PSF)(17') = 561$ PLF

$w_u = 1.2D + 1.6L_r = 1.2(w_{SW} + w_{DL}) + 1.6w_S =$

$1.2(55\ PLF + 340\ PLF) + 1.6(561\ PLF) = 1372\ PLF$

FLEXURE - AISC STEEL MANUAL F2

$M_u = \frac{w_u l^2}{8} = \frac{(1372PLF)(1/1000)(40.34')^2}{8} = 279^{k'} < 325^{k'}$ ✓OK

1. YIELDING

$\phi M_n = \phi F_y Z_x = (0.90)(50\ ksi)(134\ IN^3)(1/12) = 503^{k'}$

2. LATERAL TORSIONAL BUCKLING

$L_r = 4.73' < L_b = 13.17' < L_p = 13.9'$

$M_p = F_y Z_x = (50\ ksi)(134\ IN^3) = 6700^{k''}$

$C_b = 1.0$ - CONSERVATIVE ASSUMPTION

$\phi M_n = \phi C_b \left[M_p - (M_p - 0.7F_y S_x)\left(\frac{L_b - L_p}{L_r - L_p}\right)\right]$

$= (0.90)(1.0)\left[6700^{k''} - (6700^{k''} - 0.7(50ksi)(114IN^3))\left(\frac{13.17' - 13.9'}{4.73' - 13.9'}\right)\right](1/12)$

$= 486^{k'}$ ← CONTROLS $> 335^{k'}$ ✓OK

SHEAR - AISC STEEL MANUAL G

$V_u = \frac{wl}{2} = \frac{(1372\ PLF)(1/1000)(40.34')}{2} = 27.7^k < 28.9^k$ ✓OK

1. NOMINAL SHEAR STRENGTH

$\frac{h}{t_w} = 54.6 < 1.10\sqrt{\frac{k_v E}{F_y}} = 1.10\sqrt{\frac{(5)(29000ksi)}{50\ ksi}} = 59.2$

$C_v = 1.0$

$\phi V_n = \phi 0.6 F_y A_w C_v = (0.90)(0.6)(50ksi)(23.6'')(0.395'')(1.0) = 252^k = 252^k$ ✓OK

$C_v -$

Low Roof Steel Beam W24x55 Spot Check RAM Structural System Results

Gravity Beam Design

RAM Steel v11.0
DataBase: Roof Framing
Building Code: IBC

03/10/08 14:55:10
Steel Code: AISC LRFD

Floor Type: Low Roof **Beam Number = 471**

SPAN INFORMATION (ft): I-End (55.34,82.17) J-End (55.34,122.50)

Minimum Depth specified = 11.90 in
Beam Size (Optimum) = W24X55 Fy = 50.0 ksi
Total Beam Length (ft) = 40.33
Mp (kip-ft) = 562.50

POINT LOADS (kips):

Dist	DL	RedLL	Red%	NonRLL	StorLL	Red%	RoofLL	Red%
2.800	-0.77	0.00	0.0	-1.28	0.00	0.0	0.00	Snow
5.600	-0.77	0.00	0.0	-1.28	0.00	0.0	0.00	Snow
8.400	-0.77	0.00	0.0	-1.28	0.00	0.0	0.00	Snow
11.200	-0.77	0.00	0.0	-1.28	0.00	0.0	0.00	Snow
14.000	-1.49	0.00	0.0	-2.86	0.00	0.0	0.00	Snow
14.000	-0.39	0.00	0.0	-1.24	0.00	0.0	0.00	Snow
16.634	-0.73	0.00	0.0	-1.20	0.00	0.0	0.00	Snow
19.268	-0.73	0.00	0.0	-1.20	0.00	0.0	0.00	Snow
21.902	-0.73	0.00	0.0	-1.20	0.00	0.0	0.00	Snow
24.536	-0.73	0.00	0.0	-1.20	0.00	0.0	0.00	Snow
27.160	-1.43	0.00	0.0	-2.78	0.00	0.0	0.00	Snow
27.160	-0.38	0.00	0.0	-1.22	0.00	0.0	0.00	Snow
29.883	-0.75	0.00	0.0	-1.24	0.00	0.0	0.00	Snow
32.606	-0.68	0.00	0.0	-1.13	0.00	0.0	0.00	Snow
34.830	-0.17	0.00	0.0	-0.88	0.00	0.0	0.00	Snow

LINE LOADS (k/ft):

Load	Dist	DL	LL	Red%	Type
1	0.000	0.000	0.000	---	NonR
	40.330	0.000	0.000		
2	0.000	-0.064	-0.105	---	NonR
	40.330	-0.064	-0.105		
3	0.000	0.055	0.000	---	NonR
	40.330	0.055	0.000		

SHEAR (Ultimate): Max Vu (1.2DL+1.6LL) = 28.94 kips 0.90Vn = 251.69 kips

MOMENTS (Ultimate):

Span	Cond	LoadCombo	Mu kip-ft	@ ft	Lb ft	Cb	Phi	Phi*Mn kip-ft
Center	Max -	1.2DL+1.6LL	-324.6	19.3	13.2	1.01	0.90	335.18
Controlling		1.2DL+1.6LL	-324.6	19.3	13.2	1.01	0.90	335.18

REACTIONS (kips):

	Left	**Right**
DL reaction	-6.32	-5.32
Max -LL reaction	-13.35	-12.17
Max -total reaction	-28.94	-25.86

Gravity Beam Design

RAM Steel v11.0
DataBase: Roof Framing
Building Code: IBC

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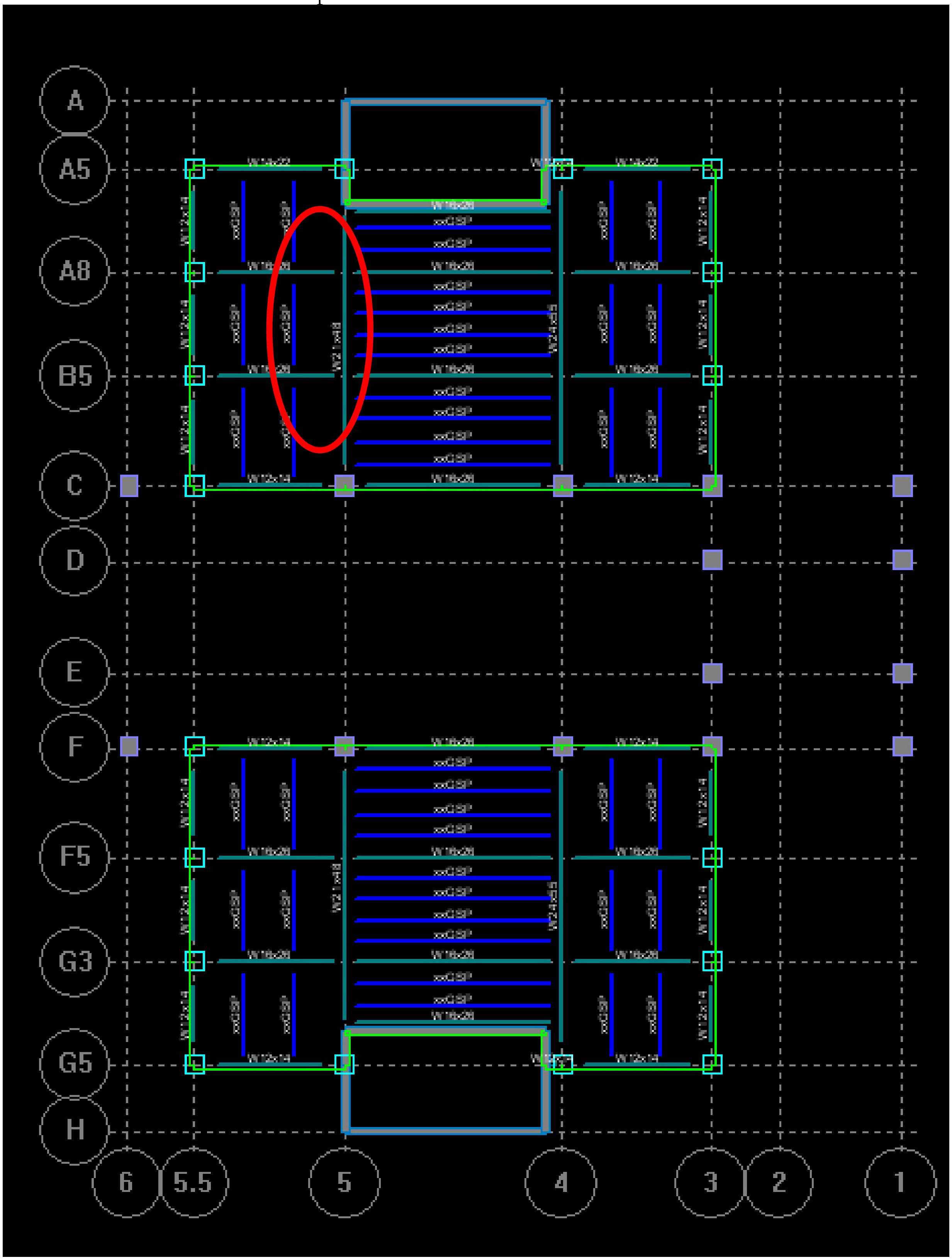
03/10/08 14:55:10
Steel Code: AISC LRFD

DEFLECTIONS:

Dead load (in)	at	19.96 ft	=	0.520	L/D	=	931
Live load (in)	at	20.17 ft	=	1.114	L/D	=	435
Net Total load (in)	at	20.17 ft	=	1.633	L/D	=	296

Low Roof Steel Beam W24x55 Spot Check Location



FINAL SIZING

LOW ROOF STEEL COLUMN SPOT CHECK

HSS 4x4x1/8

HEIGHT : 12'-0"

UNBRACED HEIGHT : 12'-0"

LOADS: $P_{SW} = (6.45\,PLF)(12') = 77.4\,LB$

$P_{DL} = (20\,PSF)(9.59')(13.17') = 2526\,LB$

$P_S = (33\,PSF)(9.59')(13.17') = 4168\,LB$

$P_u = 1.2D + 1.6L_r = 1.2(P_{SW} + P_{DL}) + 1.6\,P_S =$

$= \{1.2(77.4\,LB\ 2526\,LB) + 1.6(4168\,LB)\}(1/1000) = 9.79^k < 8.30^k$ X NO

COMPRESSION – AISC STEEL MANUAL E3

$$\frac{kl}{r} = \frac{(1.0)(12')(12)}{1.58"} = 91.1 < 4.71\sqrt{\frac{E}{F_y}} = 4.71\sqrt{\frac{29000\,KSI}{50\,KSI}} = 113$$

$$F_e = \frac{\pi^2 E}{\left(\frac{kl}{r}\right)^2} = \frac{\pi^2(29000\,KSI)}{(91.1)^2} = 34.5\,KSI$$

$$F_{cr} = 0.658^{F_y/F_e} F_y = 0.658^{(50\,KSI/34.5\,KSI)}(50\,KSI) = 27.5\,KSI$$

$\phi P_n = \phi F_{cr} A_g = (0.90)(27.2\,KSI)(1.77\,IN^2) = 43.3^k < 79.7^k$ X NO

- ALL COLUMNS RESIZED TO HSS 4x4x1/2 $123^k >> 79.7^k >> 9.79^k$ ✓ OK

Low Roof Steel Column HSS 4x4x1/2 Spot Check RAM Structural System Results

Gravity Column Design

RAM Steel v11.0
DataBase: Roof Framing
Building Code: IBC

03/10/08 15:02:13
Steel Code: AISC LRFD

Story level Low Roof, Column Line 3 - A8

Fy (ksi) = 50.00 Column Size = HSS4X4X1/8
Orientation (degrees) = 0.0

INPUT DESIGN PARAMETERS:

		X-Axis	Y-Axis
Lu (ft)		12.00	12.00
K		1	1
Braced Against Joint Translation		Yes	Yes
Column Eccentricity (in)	Top	4.50	4.50
	Bottom	0.00	0.00

CONTROLLING COLUMN LOADS - Load Case 27:

			Dead	Live	Roof
Axial (kips)			-2.14	-3.58	0.00
Moments	Top	Mx (kip-ft)	0.54	1.04	0.00
		My (kip-ft)	0.00	0.30	0.00
	Bot	Mx (kip-ft)	0.00	0.00	0.00
		My (kip-ft)	0.00	0.00	0.00

Single curvature about X-Axis
Single curvature about Y-Axis

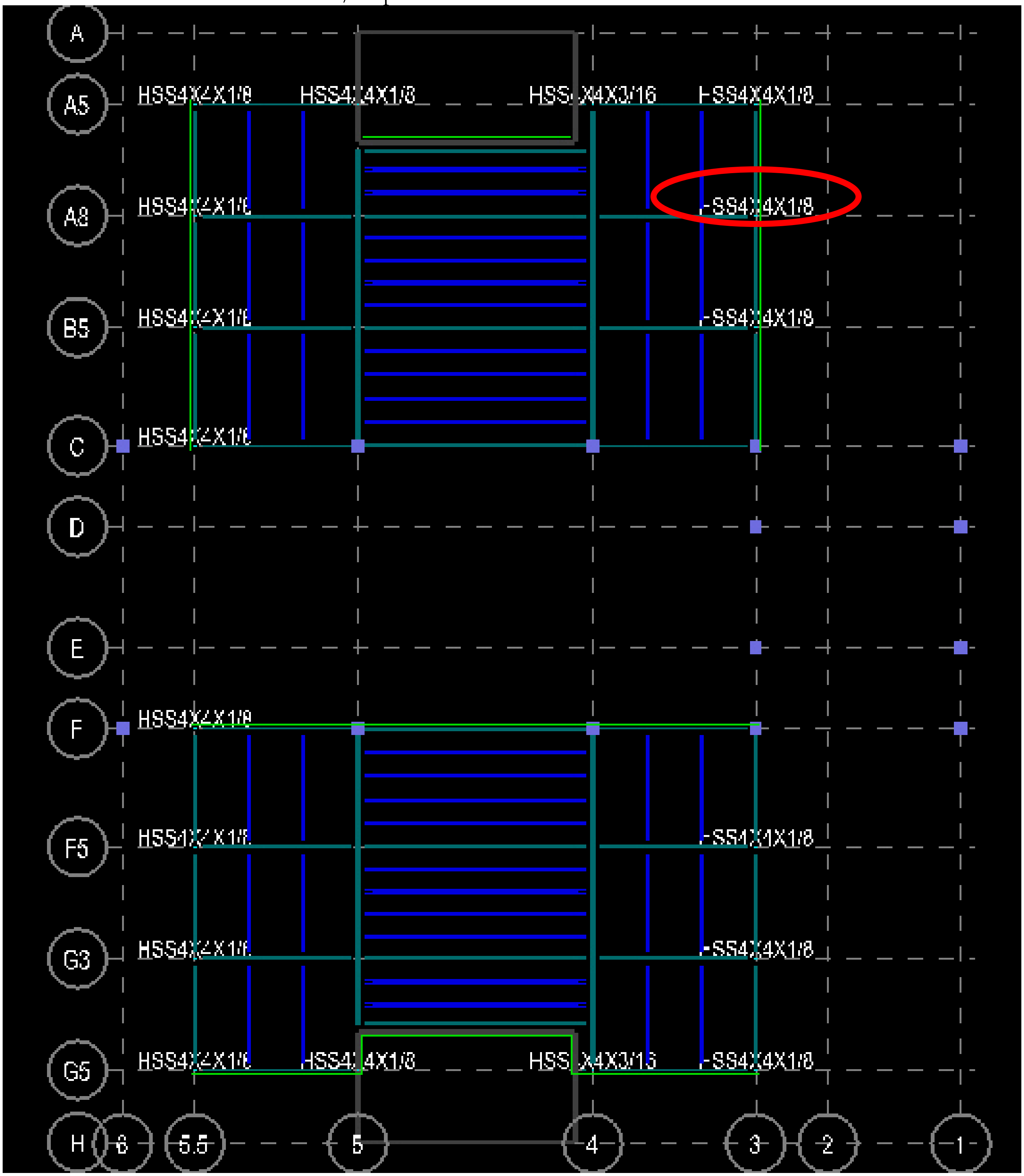
CALCULATED PARAMETERS: (1.2DL + 1.6LL + 0.5RF)

Pu (kips)	=	-8.30	0.90*Pn (kips)	=	79.65
Mux (kip-ft)	=	2.31	0.90*Mnx (kip-ft)	=	8.70
Muy (kip-ft)	=	0.48	0.90*Mny (kip-ft)	=	8.70
Cbx	=	1.75	Cby	=	1.75
Cmx	=	0.60	Cmy	=	0.60
Pex (kips)	=	60.73	Pey (kips)	=	60.73
B1x	=	1.00	B1y	=	1.00

INTERACTION EQUATION

Pu/0.90*Pn = 0.104
Eq H1-1b: 0.052 + 0.265 + 0.055 = 0.373

Low Roof Steel Column HSS 4x4x1/2 Spot Check Location



SYSTEM COMPARISON

MECHANICAL SPACE SAVINGS

STEEL CONTROLLING THICKNESSES
FLOORS 1-4
NORTH - SOUTH DIRECTION W18x35
EAST-WEST DIRECTION W27x84
W27x84 CONTROLS

FLOOR 5
NORTH - SOUTH DIRECTION W27x84
EAST - WEST DIRECTION W27x84
W27x84 CONTROLS

FLOOR 6
NORTH-SOUTH DIRECTION W16x26
EAST-WEST DIRECTION W27x84
W27x84 CONTROLS

FLOOR TO CEILING HEIGHT INCREASE
FLOORS 1-4
W27x84 = 26.7"
14'-0" - 9'-6" = 4'-6" - (26.7")(1/12) = 2'-3'
14'-0" - 9'-6" = 4'-6" - (12")(1/12) - (6")(1/12) = 3'-0" } INCREASE OF 9"

FLOOR 5
W27x84 = 26.7"
14'-0" - 9'-6" = 4'-6" - (26.7")(1/12) = 2'-3"
14'-0" - 9'-6" = 4'-6" - (14")(1/12) - (6")(1/12) = 2'-10" } INCREASE OF 7"

FLOOR 6
W27x84 = 26.7"
17'-0" - 12'-6" = 4'-6" - (26.7")(1/12) = 2'-3"
17'-0" - 12'-6" = 4'-6" - (12")(1/12) - (12")(1/12) = 2'-6" } INCREASE OF 3"

LOW ROOF & HIGH ROOF
UNABLE TO CALCULATE DUE TO VARYING DESIGN DOCUMENTS & EXISTING CONDITIONS

IX. Appendix B: Acoustics Breadth Calculations

ACOUSTICS BREADTH

SOUND TRANSMISSION CLASS - ARCHITECTURAL ACOUSTICS BY DAVID EGAN
- 4" REINFORCED CONCRETE SLAB 44
- 6" REINFORCED CONCRETE SLAB 55
- INTERPOLATE/EXTRAPOLATE TO OBTAIN OTHER VALUES $y=5.5x+22$
- VALID FOR SPEECH FREQUENCIES OF 125 TO 4000 HZ, DOES NOT INCLUDE RATINGS BELOW 125 HZ WHICH MAY BE ACHIEVED BY MUSIC, OKAY AS MOST EVENTS OCCUR IN THE LATER EVENING HOURS OR ON THE WEEKEND
- EXISTING STEEL STRUCTURAL SYSTEM SOUND TRANSMISSION CLASS
  5" CONCRETE ON 6" COMPOSITE STEEL DECK
  ASSUMING ONLY 3" CONCRETE TOPPING PARTICIPATES IN REDUCTION OF SOUND TRANSMISSION
  3" REINFORCED CONCRETE SLAB 39 - ALL FLOORS
- PROPOSED CONCRETE STRUCTURAL SYSTEM SOUND TRANSMISSION CLASS
  12" REINFORCED CONCRETE SLAB 88 - 1st - 4th, 6th FLOORS
  14" REINFORCED CONCRETE SLAB 99 - 5th FLOOR
- STRUCTURAL SYSTEM COMPARISON
  STC STEEL = 39 << STC CONCRETE = 88

REVERBERATION TIME - ARCHITECTURAL ACOUSTICS BY DAVID EGAN
- LECTURE & CONFERENCE ROOMS 0.7s - 1.1s
- DANCE & ROCK BANDS 1.0s - 1.2s
- GOAL REVERBERATION TIME 1.1s
- 125 HZ $1.3(1.1s) = 1.43s$
  500 HZ $1.0(1.1s) = 1.10s$
  4000 HZ $0.77(1.1s) = 0.85s$
- REVERBERATION TIME TO BE CALCULATED FOR BOTH FULL & HALF OCCUPANCY

$$T = 0.05\frac{V}{a} = 0.05\frac{V}{\sum S\alpha}$$

$$V = 2(46.83')(40.34')(7.5') + (46.83')(33.34')(12.5') = 47853\ FT^3$$

i Sound Transmission Class Comparison

Sound Transmission Class Data from Architectural Acoustics by David Egan

Building Construction	Transmission Loss (dB) 125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	STC Rating	IIC Rating†
31. Construction no. 30 with 5/8-in gypsum board screwed to resilient channels spaced 24 in oc perpendicular to joists	30	35	44	50	54	60	47	39
32. Construction no. 31 with 3-in glass-fiber insulation in cavity	36	40	45	52	58	64	49	46
33. 4-in reinforced concrete slab (54 lb/ft²)	48	42	45	56	57	66	44	25
34. 14-in precast concrete tees with 2-in concrete topping on 2-in slab (75 lb/ft²)	39	45	50	52	60	68	54	24
35. 6-in reinforced concrete slab (75 lb/ft²)	38	43	52	59	67	72	55	34
36. 6-in reinforced concrete slab with 3/4-in T&G wood flooring on 1 1/2 by 2 wooden battens floated on 1-in glass fiber (83 lb/ft²)	38	44	52	55	60	65	55	57
37. 18-in steel joists 16 in oc with 1 5/8-in concrete on 5/8-in plywood under heavy carpet laid on pad, and 5/8-in gypsum board attached to joists on ceiling side (20 lb/ft²)	27	37	45	54	60	65	47	62
Roofs‡								
38. 3 by 8 wood beams 32 in oc with 2 by 6 T&G planks, asphalt felt built-up roofing, and gravel topping	29	33	37	44	55	63	43	
39. Construction no. 38 with 2 by 4s 16 in oc between beams, 1/2-in gypsum board supported by metal channels on ceiling side with 4-in glass-fiber insulation in cavity	35	42	49	62	67	79	53	
40. Corrugated steel, 24 gauge with 1 3/8-in sprayed cellulose insulation on ceiling side (1.8 lb/ft²)	17	22	26	30	35	41	30	
41. 2 1/2-in sand and gravel concrete (148 lb/ft³) on 28 gauge corrugated steel supported by 14-in-deep steel bar joists with 1/2-in gypsum plaster on metal lath attached to metal furring channels 13 1/2 in oc on ceiling side (41 lb/ft²)	32	46	45	50	57	61	49	
Doors‡								
42. Louvered door, 25 to 30% open	10	12	12	12	12	11	12	
43. 1 3/4-in hollow-core wood door, no gaskets, 1/4-in air gap at sill (1.5 lb/ft²)	14	19	23	18	17	21	19	
44. Construction no. 43 with gaskets and drop seal	19	22	25	19	20	29	21	
45. 1 3/4-in solid-core wood door with gaskets and drop seal (4.5 lb/ft²)	29	31	31	31	39	43	34	
46. 1 3/4-in hollow-core 16 gauge steel door, glass-fiber filled, with gaskets and drop seal (7 lb/ft²)	23	28	36	41	39	44	38	
Glass†‡								
47. 1/8-in monolithic float glass (1.4 lb/ft²)	18	21	26	31	33	22	26	
48. 1/4-in monolithic float glass (2.9 lb/ft²)	25	28	31	34	30	37	31	
49. 1/2-in insulated glass: 1/8- + 1/8-in double glass with 1/4-in airspace (3.3 lb/ft²)	21	26	24	33	44	34	28	
50. 1/4- + 1/8-in double glass with 2-in airspace	18	31	35	42	44	44	39	
51. Construction no. 50 with 4-in airspace	21	32	42	48	48	44	43	
52. 1/4-in laminated glass, 30-mil plastic interlayer (3.6 lb/ft²)	25	28	32	35	36	43	35	
53. Double glass: 1/4-in laminated + 3/16-in monolithic glass with 2-in airspace (5.9 lb/ft²)	25	34	44	47	48	55	45	
54. Double glass: 1/4-in laminated + 3/16-in monolithic glass with 4-in airspace (5.9 lb/ft²)	36	37	48	51	50	58	48	
55. Double glass: 1/4-in laminated + 1/4-in laminated with 1/2-in airspace (7.2 lb/ft²)	21	30	40	44	46	57	42	

† IIC (*impact isolation class*) is a single-number rating of the impact sound transmission performance of a floor-ceiling construction tested over a standard frequency range. The higher the IIC, the more efficient the construction will be for reducing impact sound transmission. INR (*impact noise rating*) previously was used as the single-number rating of impact noise isolation. To convert the older INR data to IIC, add 51 to the INR number.

‡ A wide range of TL and STC performance can be achieved by gypsum wallboard constructions. Refer to ASTM E 90 laboratory report and literature from manufacturers for specific details such as type of gypsum board; gauge, width, and spacing of steel studs; glass-fiber or mineral-fiber insulation thickness and density; and complete installation recommendations.

ii. Reverberation Time Comparison

Existing Steel Structural System Reverberation Time- Half Occupancy				
Surface	α 125 Hz	α 500 Hz	α 4000 Hz	S (ft^2)
Walls				
5/8" Gypsum Wall Board	0.55	0.08	0.11	954.20
Painted Concrete Block	0.10	0.06	0.08	515.10
Heavy glass	0.18	0.04	0.02	1309.40
Floors				
Glazed tile	0.01	0.01	0.02	1561.31
Heavy Carpet on Concrete	0.02	0.14	0.65	3778.24
Ceilings				
1/2" Gypsum Wall Board	0.29	0.05	0.09	1561.31
3/4" Acoustical Board Suspension System	0.76	0.83	0.94	3778.24
Seating & Audience				
Fabric Well-Upholstered Seats	0.19	0.56	0.59	62.97
Audience	0.39	0.80	0.87	230.00

Surface	ΣSα 125 Hz	ΣSα 500 Hz	ΣSα 4000 Hz
Walls			
5/8" Gypsum Wall Board	524.81	76.34	104.96
Painted Concrete Block	51.51	30.91	41.21
Heavy glass	235.69	52.38	26.19
Floors			
Glazed tile	15.61	15.61	31.23
Heavy Carpet on Concrete	75.56	528.95	2455.86
Ceilings			
1/2" Gypsum Wall Board	452.78	78.07	140.52
3/4" Acoustical Board Suspension System	2871.47	3135.94	3551.55
Seating & Audience			
Fabric Well-Upholstered Seats	11.96	35.26	37.15
Audience	89.70	184.00	200.10
a (sabins)	4329.10	4137.46	6588.76
T (s)	0.55	0.58	0.36

Existing Steel Structural System Reverberation Time- Full Occupancy				
Surface	α 125 Hz	α 500 Hz	α 4000 Hz	S (ft^2)
Walls				
5/8" Gypsum Wall Board	0.55	0.08	0.11	954.20
Painted Concrete Block	0.10	0.06	0.08	515.10
Heavy glass	0.18	0.04	0.02	1309.40
Floors				
Glazed tile	0.01	0.01	0.02	1561.31
Heavy Carpet on Concrete	0.02	0.14	0.65	3778.24
Ceilings				
1/2" Gypsum Wall Board	0.29	0.05	0.09	1561.31
3/4" Acoustical Board Suspension System	0.76	0.83	0.94	3778.24
Seating & Audience				
Fabric Well-Upholstered Seats	0.19	0.56	0.59	125.94
Audience	0.39	0.80	0.87	460.00

Surface	ΣSα 125 Hz	ΣSα 500 Hz	ΣSα 4000 Hz
Walls			
5/8" Gypsum Wall Board	524.81	76.34	104.96
Painted Concrete Block	51.51	30.91	41.21
Heavy glass	235.69	52.38	26.19
Floors			
Glazed tile	15.61	15.61	31.23
Heavy Carpet on Concrete	75.56	528.95	2455.86
Ceilings			
1/2" Gypsum Wall Board	452.78	78.07	140.52
3/4" Acoustical Board Suspension System	2871.47	3135.94	3551.55
Seating & Audience			
Fabric Well-Upholstered Seats	23.93	70.53	74.31
Audience	179.40	368.00	400.20
a (sabins)	4430.76	4356.72	6826.01
T (s)	0.54	0.55	0.35

Proposed Concrete Structural System Reverberation Time- Half Occupancy				
Surface	α 125 Hz	α 500 Hz	α 4000 Hz	S (ft^2)
Walls				
5/8" Gypsum Wall Board	0.55	0.08	0.11	954.20
Rough Concrete	0.01	0.04	0.10	515.10
Heavy glass	0.18	0.04	0.02	1309.40
Floors				
Glazed tile	0.01	0.01	0.02	1561.31
Heavy Carpet on Concrete	0.02	0.14	0.65	3778.24
Ceilings				
Rough Concrete	0.01	0.02	0.02	1561.31
1/2" Gypsum Wall Board Suspension System	0.15	0.05	0.09	3778.24
Seating & Audience				
Fabric Well-Upholstered Seats	0.19	0.56	0.59	62.97
Audience	0.39	0.80	0.87	230.00

Surface	ΣSα 125 Hz	ΣSα 500 Hz	ΣSα 4000 Hz
Walls			
5/8" Gypsum Wall Board	524.81	76.34	104.96
Rough Concrete	5.15	20.60	51.51
Heavy glass	235.69	52.38	26.19
Floors			
Glazed tile	15.61	15.61	31.23
Heavy Carpet on Concrete	75.56	528.95	2455.86
Ceilings			
Rough Concrete	15.61	31.23	31.23
1/2" Gypsum Wall Board Suspension System	566.74	188.91	340.04
Seating & Audience			
Fabric Well-Upholstered Seats	11.96	35.26	37.15
Audience	89.70	184.00	200.10
a (sabins)	1540.84	1133.28	3278.26
T (s)	1.55	2.11	0.73

Proposed Concrete Structural System Reverberation Time- Full Occupancy				
Surface	α 125 Hz	α 500 Hz	α 4000 Hz	S (ft^2)
Walls				
5/8" Gypsum Wall Board	0.55	0.08	0.11	954.20
Rough Concrete	0.01	0.04	0.10	515.10
Heavy glass	0.18	0.04	0.02	1309.40
Floors				
Glazed tile	0.01	0.01	0.02	1561.31
Heavy Carpet on Concrete	0.02	0.14	0.65	3778.24
Ceilings				
Rough Concrete	0.01	0.02	0.02	1561.31
1/2" Gypsum Wall Board Suspension System	0.15	0.05	0.09	3778.24
Seating & Audience				
Fabric Well-Upholstered Seats	0.19	0.56	0.59	125.94
Audience	0.39	0.80	0.87	460.00
Surface	ΣSα 125 Hz	ΣSα 500 Hz	ΣSα 4000 Hz	
Walls				
5/8" Gypsum Wall Board	524.81	76.34	104.96	
Rough Concrete	5.15	20.60	51.51	
Heavy glass	235.69	52.38	26.19	
Floors				
Glazed tile	15.61	15.61	31.23	
Heavy Carpet on Concrete	75.56	528.95	2455.86	
Ceilings				
Rough Concrete	15.61	31.23	31.23	
1/2" Gypsum Wall Board Suspension System	566.74	188.91	340.04	
Seating & Audience				
Fabric Well-Upholstered Seats	23.93	70.53	74.31	
Audience	179.40	368.00	400.20	
a (sabins)	1642.51	1352.55	3515.51	
T (s)	1.46	1.77	0.68	

Sound Absorption Data from Architectural Acoustics by David Egan

SOUND ABSORPTION DATA FOR COMMON BUILDING MATERIALS AND FURNISHINGS

Material	Sound Absorption Coefficient 125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	NRC Number*
Walls(1-3, 9, 12)							
Sound-Reflecting:							
1. Brick, unglazed	0.02	0.02	0.03	0.04	0.05	0.07	0.05
2. Brick, unglazed and painted	0.01	0.01	0.02	0.02	0.02	0.03	0.00
3. Concrete, rough	0.01	0.02	0.04	0.06	0.08	0.10	0.05
4. Concrete block, painted	0.10	0.05	0.06	0.07	0.09	0.08	0.05
5. Glass, heavy (large panes)	0.18	0.06	0.04	0.03	0.02	0.02	0.05
6. Glass, ordinary window	0.35	0.25	0.18	0.12	0.07	0.04	0.15
7. Gypsum board, 1/2 in thick (nailed to 2 × 4s, 16 in oc)	0.29	0.10	0.05	0.04	0.07	0.09	0.05
8. Gypsum board, 1 layer, 5/8 in thick (screwed to 1 × 3s, 16 in oc with airspaces filled with fibrous insulation)	0.55	0.14	0.08	0.04	0.12	0.11	0.10
9. Construction no. 8 with 2 layers of 5/8-in-thick gypsum board	0.28	0.12	0.10	0.07	0.13	0.09	0.10
10. Marble or glazed tile	0.01	0.01	0.01	0.01	0.02	0.02	0.00
11. Plaster on brick	0.01	0.02	0.02	0.03	0.04	0.05	0.05
12. Plaster on concrete block (or 1 in thick on lath)	0.12	0.09	0.07	0.05	0.05	0.04	0.05
13. Plaster on lath	0.14	0.10	0.06	0.05	0.04	0.03	0.05
14. Plywood, 3/8-in paneling	0.28	0.22	0.17	0.09	0.10	0.11	0.15
15. Steel	0.05	0.10	0.10	0.10	0.07	0.02	0.10
16. Venetian blinds, metal	0.06	0.05	0.07	0.15	0.13	0.17	0.10
17. Wood, 1/4-in paneling, with airspace behind	0.42	0.21	0.10	0.08	0.06	0.06	0.10
18. Wood, 1-in paneling with airspace behind	0.19	0.14	0.09	0.06	0.06	0.05	0.10
Sound-Absorbing:							
19. Concrete block, coarse	0.36	0.44	0.31	0.29	0.39	0.25	0.35
20. Lightweight drapery, 10 oz/yd², flat on wall (*Note:* Sound-reflecting at most frequencies.)	0.03	0.04	0.11	0.17	0.24	0.35	0.15
21. Mediumweight drapery, 14 oz/yd², draped to half area (i.e., 2 ft of drapery to 1 ft of wall)	0.07	0.31	0.49	0.75	0.70	0.60	0.55
22. Heavyweight drapery, 18 oz/yd², draped to half area	0.14	0.35	0.55	0.72	0.70	0.65	0.60
23. Fiberglass fabric curtain, 8 1/2 oz/yd², draped to half area (*Note:* The deeper the airspace behind the drapery (up to 12 in), the greater the low-frequency absorption.)	0.09	0.32	0.68	0.83	0.39	0.76	0.55
24. Shredded-wood fiberboard, 2 in thick on concrete (mtg. A)	0.15	0.26	0.62	0.94	0.64	0.92	0.60
25. Thick, fibrous material behind open facing	0.60	0.75	0.82	0.80	0.60	0.38	0.75
26. Carpet, heavy, on 5/8-in perforated mineral fiberboard with airspace behind	0.37	0.41	0.63	0.85	0.96	0.92	0.70
27. Wood, 1/2-in paneling, perforated 3/16-in-diameter holes, 11% open area, with 2 1/2-in glass fiber in airspace behind	0.40	0.90	0.80	0.50	0.40	0.30	0.65
Floors(9, 11)							
Sound-Reflecting:							
28. Concrete or terrazzo	0.01	0.01	0.02	0.02	0.02	0.02	0.00
29. Linoleum, rubber, or asphalt tile on concrete	0.02	0.03	0.03	0.03	0.03	0.02	0.05
30. Marble or glazed tile	0.01	0.01	0.01	0.01	0.02	0.02	0.00
31. Wood	0.15	0.11	0.10	0.07	0.06	0.07	0.10
32. Wood parquet on concrete	0.04	0.04	0.07	0.06	0.06	0.07	0.05
Sound-Absorbing:							
33. Carpet, heavy, on concrete	0.02	0.06	0.14	0.37	0.60	0.65	0.30
34. Carpet, heavy, on foam rubber	0.08	0.24	0.57	0.69	0.71	0.73	0.55
35. Carpet, heavy, with impermeable latex backing on foam rubber	0.08	0.27	0.39	0.34	0.48	0.63	0.35
36. Indoor-outdoor carpet	0.01	0.05	0.10	0.20	0.45	0.65	0.20
Ceilings(5, 8-10) †							
Sound-Reflecting:							
37. Concrete	0.01	0.01	0.02	0.02	0.02	0.02	0.00
38. Gypsum board, 1/2 in thick	0.29	0.10	0.05	0.04	0.07	0.09	0.05
39. Gypsum board, 1/2 in thick, in suspension system	0.15	0.10	0.05	0.04	0.07	0.09	0.05
40. Plaster on lath	0.14	0.10	0.06	0.05	0.04	0.03	0.05
41. Plywood, 3/8 in thick	0.28	0.22	0.17	0.09	0.10	0.11	0.15
Sound-Absorbing:							
42. Acoustical board, 3/4 in thick, in suspension system (mtg. E)	0.76	0.93	0.83	0.99	0.99	0.94	0.95
43. Shredded-wood fiberboard, 2 in thick on lay-in grid (mtg. E)	0.59	0.51	0.53	0.73	0.88	0.74	0.65

Material	Sound Absorption Coefficient 125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	NRC Number*
44. Thin, porous sound-absorbing material, 3/4 in thick (mtg. B)	0.10	0.60	0.80	0.82	0.78	0.60	0.75
45. Thick, porous sound-absorbing material, 2 in thick (mtg. B), or thin material with airspace behind (mtg. D)	0.38	0.60	0.78	0.80	0.78	0.70	0.75
46. Sprayed cellulose fibers, 1 in thick on concrete (mtg. A)	0.08	0.29	0.75	0.98	0.93	0.76	0.75
47. Glass-fiber roof fabric, 12 oz/yd²	0.65	0.71	0.82	0.86	0.76	0.62	0.80
48. Glass-fiber roof fabric, 37 1/2 oz/yd² (*Note:* Sound-reflecting at most frequencies.)	0.38	0.23	0.17	0.15	0.09	0.06	0.15
49. Polyurethane foam, 1 in thick, open cell, reticulated	0.07	0.11	0.20	0.32	0.60	0.85	0.30
50. Parallel glass-fiberboard panels, 1 in thick by 18 in deep, spaced 18 in apart, suspended 12 in below ceiling	0.07	0.20	0.40	0.52	0.60	0.67	0.45
51. Parallel glass-fiberboard panels, 1 in thick by 18 in deep, spaced 6 1/2 in apart, suspended 12 in below ceiling	0.10	0.29	0.62	1.12	1.33	1.38	0.85
Seats and Audience(1, 5, 7, 8)‡							
52. Fabric well-upholstered seats, with perforated seat pans, unoccupied	0.19	0.37	0.56	0.67	0.61	0.59	
53. Leather-covered upholstered seats, unoccupied§	0.44	0.54	0.60	0.62	0.58	0.50	
54. Audience, seated in upholstered seats§	0.39	0.57	0.80	0.94	0.92	0.87	
55. Congregation, seated in wooden pews	0.57	0.61	0.75	0.86	0.91	0.86	
56. Chair, metal or wood seat, unoccupied	0.15	0.19	0.22	0.39	0.38	0.30	
57. Students, informally dressed, seated in tablet-arm chairs	0.30	0.41	0.49	0.84	0.87	0.84	
Openings(9)¶							
58. Deep balcony, with upholstered seats			0.50–1.00				
59. Diffusers or grilles, mechanical system			0.15–0.50				
60. Stage			0.25–0.75				
Miscellaneous(3, 8, 11)							
61. Gravel, loose and moist, 4 in thick	0.25	0.60	0.65	0.70	0.75	0.80	0.70
62. Grass, marion bluegrass, 2 in high	0.11	0.26	0.60	0.69	0.92	0.99	0.60
63. Snow, freshly fallen, 4 in thick	0.45	0.75	0.90	0.95	0.95	0.95	0.90
64. Soil, rough	0.15	0.25	0.40	0.55	0.60	0.60	0.45
65. Trees, balsam firs, 20 ft² ground area per tree, 8 ft high	0.03	0.06	0.11	0.17	0.27	0.31	0.15
66. Water surface (swimming pool)	0.01	0.01	0.01	0.02	0.02	0.03	0.00

*NRC (noise reduction coefficient) is a single-number rating of the sound absorption coefficients of a material. It is an average that only includes the coefficients in the 250 to 2000 Hz frequency range and therefore should be used with caution. See page 50 for a discussion of the NRC rating method.

†Refer to manufacturer's catalogs for absorption data which should be from up-to-date tests by independent acoustical laboratories according to current ASTM procedures.

‡Coefficients are per square foot of seating floor area or per unit. Where the audience is randomly spaced (e.g., courtroom, cafeteria), mid-frequency absorption can be estimated at about 5 sabins per person. To be precise, coefficients per person must be stated in relation to spacing pattern.

§The floor area occupied by the audience must be calculated to include an *edge effect* at aisles. For an aisle bounded on both sides by audience, include a strip 3 ft wide; for an aisle bounded on only one side by audience, include a strip 1 1/2 ft wide. No edge effect is used when the seating abuts walls or balcony fronts (because the edge is shielded). The coefficients are also valid for orchestra and choral areas at 5 to 8 ft² per person. Orchestra areas include people, instruments, music racks, etc. No edge effects are used around musicians.

¶Coefficients for openings depend on absorption and cubic volume of opposite side.

Test Reference

"Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method," ASTM C 423. Available from American Society for Testing and Materials (ASTM), 1916 Race Street, Philadelphia, PA 19103.

Sources

1. L. L. Beranek, "Audience and Chair Absorption in Large Halls," *Journal of the Acoustical Society of America,* January 1969.
2. A. N. Burd et al., "Data for the Acoustic Design of Studios," British Broadcasting Corporation, BBC Engineering Monograph no. 64, November 1966.
3. E. J. Evans and E. N. Bazley, "Sound Absorbing Materials," H. M. Stationery Office, London, 1964.

X. Appendix C: Construction Management Breadth Calculations

CONSTRUCTION MANAGEMENT BREADTH

ROUGH COST ESTIMATES – RS MEANS SQUARE FOOT COSTS DATA 2007

- OFFICE 6 STORY

TOTAL FLOOR AREA = 5(11138 FT²) + 2929 FT² = 58619 FT²

TOTAL FLOOR PERIMETER = 2(116') + 2(134') = 500 FT

STORY HEIGHT = 14'

- FACE BRICK WITH CONCRETE BLOCK BACK-UP
- STEEL FRAME = ($141.88 + 1.03($8.74) + 2.00($2.72) + $31.95)

BASE, ADDITIONAL PERIMETER, ADDITIONAL HEIGHT, BASEMENT

= ($188.27)(58619 FT²) = $11,039,199 (0.10) ≈ $1,104,000

SUPERSTRUCTURE ONLY

$10,400,000 + 4($46,000) = $10,584,000

- REINFORCED CONCRETE FRAME = $134.39 + 1.03($8.74) + 2.00($2.72)

BASE, ADDITIONAL PERIMETER, ADDITIONAL HEIGHT

+ $31.95 = ($180.78)(58619 FT²)

BASEMENT

SUPERSTRUCTURE ONLY

= $11,007,476 (0.10) ≈ $1,101,000

FINAL COST ESTIMATES – RS MEANS BUILDING CONSTRUCTION COST DATA 2007
SITE WORK & LANDSCAPING COST DATA 2007

ASSUMPTIONS FOR CONCRETE PLACING & FORMS

CONTINUOUS FOOTINGS, PILE CAPS & PIERS
- PUMPED
- 1 USE

SLAB ON GRADE
- DIRECT CHUTE
- EDGE FORM

ELEVATED FLAT SLAB WITH DROP PANELS 1st FLOOR – 5th FLOOR
- CRANE & BUCKET
- 4 USE

ELEVATED FLAT SLAB WITH DROP PANELS – 6th FLOOR
- 1 USE
- CRANE & BUCKET

COLUMNS
- CRANE & BUCKET
- 4 USE

WALL
- CRANE & BUCKET
- EXTERIOR WALL
- 4 USE

BEAMS
- CRANE & BUCKET
- 1 USE

ASSUMPTIONS FOR STEEL
- ADJUSTED FOR TONNAGE FOR COLUMNS & BEAMS
- 0.245 TONS = 1 FT³

FINAL SCHEDULE ESTIMATES - CONSTRUCTION SCHEDULING WITH PRIMAVERA PROJECT PLANNER

ASSUMPTIONS
- START DATE: JUNE 2, 2003
- WORK DATES: MONDAY - FRIDAY
- FABRICATION & SHIPPING DELAYS FROM START OF PROJECT:
  - BASEPLATES: 20 DAYS
  - STEEL MEMBERS: 58 DAYS
  - FORMWORK: 15 DAYS
  - REBAR: 25 DAYS
- LAGS:
  - +2 FOR CONCRETE CURING BETWEEN PLACING & STRIPING
  - 1/3 FORMING → STRIPING

i. Cost Estimate Comparison

Existing Steel Structural System Cost Estimate

Item No.	Item	Item Breakdown	Detailed Item Breakdown
1	Concrete Piles	Concrete	
2		Reinforcement	
3	Concrete Pile Caps	Material	
4		Forms	Square, Rectangular
5			Triangular
6		Placing	x<5
7			5<x<10
8		Reinforcement	#4-#7
9			#8-#18
10	Concrete Continuous Footings	Material	
11		Forms	
12		Placing	
13	Concrete Slab on Grade	Material	
14		Forms	
15		Placing	
16		Welded Wire Fabric	
17	Concrete Piers	Material	
18		Forms	
19		Placing	
20	Steel Baseplates	Baseplates	
21		Anchor Bolts	
22	Steel Columns	Columns	W12x50
23			W12x87
24			W12x120
25			HSS 4x4x1/4
26		Fireproofing	
27	Steel Beams	Beams	W8x21
28			W8x24
29			W10x12
30			W12x14

Item No.	Item	Item Breakdown	Detailed Item Breakdown
31			W12x26
32			W14x26
33			W16x26
34			W16x31
35			W16x40
36			W18x35
37			W18x40
38			W18x76
39			W21x44
40			W24x55
41			W24x68
42			W24x76
43			W27x84
44		Open Web Steel Joists	18K5
45		Cold Formed Roof Trusses	9:12 to 12:12 Pitch
46		Studs	
47		Fireproofing	
48		Flange Moment Connections	1/4" Weld
49			3/4" Weld
50		Web Moment Connections	1/4" Weld
51			3/4" Weld
52	Composite Steel Deck	Deck	
53		Material	
54		Placing	
55		Welded Wire Fabric	
56		Fireproofing	
57	Roof Steel Deck	Deck	
58		Fireproofing	
59	Subtotal		
60	20% Miscellaneous Steel Increase		
61	Total		

Item No.	Unit	Quantity	Material Unit Cost	Material Cost	Labor Unit Cost	Labor Cost
1	VLF	2869.90	$17.75	$50,940.73	$6.35	$18,223.87
2	LB	9881.67	$0.90	$8,893.50	$0.00	$0.00
3	CY	182.94	$114.00	$20,855.10	$0.00	$0.00
4	SFCA	2595.60	$2.46	$6,385.18	$3.83	$0.00
5	SFCA	927.00	$2.90	$2,688.30	$4.94	$9,941.15
6	CY	120.11	$0.00	$0.00	$18.05	$2,167.98
7	CY	62.83	$0.00	$0.00	$9.95	$625.16
8	TON	0.10	$850.00	$83.96	$630.00	$62.23
9	TON	5.51	$805.00	$4,438.93	$365.00	$2,012.68
10	CY	34.73	$114.00	$3,958.79	$0.00	$0.00
11	SFCA	15849.13	$2.64	$41,841.70	$2.96	$46,913.42
12	CY	34.73	$0.00	$0.00	$13.25	$460.12
13	CY	139.98	$114.00	$15,957.19	$0.00	$0.00
14	SFCA	164.73	$0.29	$47.77	$1.85	$304.76
15	CY	139.98	$0.00	$0.00	$13.20	$1,847.67
16	CSF	113.38	$19.80	$2,244.92	$23.00	$2,607.74
17	CY	35.58	$108.00	$3,842.56	$0.00	$0.00
18	SFCA	1921.28	$2.57	$4,937.69	$5.85	$11,239.49
19	CY	35.58	$0.00	$0.00	$21.50	$764.95
20	SF	76.50	$32.00	$2,448.00	$0.00	$0.00
21	EA	136.00	$4.04	$549.44	$23.50	$3,196.00
22	LF	864.69	$62.15	$53,740.48	$2.19	$1,893.67
23	LF	923.35	$107.80	$99,537.13	$2.30	$2,123.71
24	LF	318.68	$148.50	$47,323.98	$2.35	$748.90
25	EA	25.00	$185.90	$4,647.50	$39.00	$975.00
26	SF	6320.16	$0.50	$3,160.08	$0.66	$4,171.31
27	LF	153.36	$23.50	$3,603.96	$3.77	$578.17
28	LF	76.68	$27.00	$2,070.36	$4.11	$315.15
29	LF	577.12	$13.55	$7,819.98	$3.77	$2,175.74
30	LF	1380.96	$15.80	$21,819.17	$2.57	$3,549.07

Item No.	Unit	Quantity	Material Unit Cost	Material Cost	Labor Unit Cost	Labor Cost
31	LF	216.06	$29.50	$6,373.77	$2.57	$555.27
32	LF	47.68	$29.50	$1,406.56	$2.28	$108.71
33	LF	2604.35	$29.50	$76,828.33	$2.26	$5,885.83
34	LF	3135.73	$35.00	$109,750.55	$2.51	$7,870.68
35	LF	55.34	$45.00	$2,490.30	$2.82	$156.06
36	LF	1285.66	$39.50	$50,783.57	$3.40	$4,371.24
37	LF	1321.84	$45.00	$59,482.80	$3.40	$4,494.26
38	LF	100.02	$85.50	$8,551.71	$3.63	$363.07
39	LF	195.68	$49.50	$9,686.16	$3.07	$600.74
40	LF	2131.71	$62.00	$132,166.02	$2.94	$6,267.23
41	LF	479.92	$76.50	$36,713.88	$2.94	$1,410.96
42	LF	192.86	$85.50	$16,489.53	$2.94	$567.01
43	LF	359.06	$94.50	$33,931.17	$2.75	$987.42
44	LF	876.12	$5.50	$4,818.66	$1.63	$1,428.08
45	EA	46.00	$181.00	$8,326.00	$98.00	$4,508.00
46	EA	6737.00	$0.49	$3,301.13	$0.72	$4,850.64
47	SF	50099.11	$0.45	$22,544.60	$0.49	$24,548.56
48	LF	856.00	$0.60	$513.60	$6.95	$5,949.20
49	LF	214.00	$2.58	$552.12	$29.00	$6,206.00
50	LF	792.00	$0.60	$475.20	$6.95	$5,504.40
51	LF	396.00	$2.58	$1,021.68	$29.00	$11,484.00
52	SF	58735.00	$1.63	$95,738.05	$0.37	$21,731.95
53	CY	906.40	$108.00	$97,891.67	$0.00	$0.00
54	CY	906.40	$0.00	$0.00	$24.00	$21,753.70
55	CSF	587.35	$15.40	$9,045.19	$21.50	$12,628.03
56	SF	67796.00	$0.45	$30,508.20	$0.49	$33,220.04
57	SF	9061.00	$1.82	$16,491.02	$0.35	$3,171.35
58	SF	9061.00	$2.82	$25,552.02	$1.35	$12,232.35
59				$1,275,269.87		$319,752.71
60				$255,053.97		$63,950.54
61				$1,530,323.84		$383,703.25

Item No.	Equipment Unit Cost	Equipment Cost	Total Unit Cost	Total Cost
1	$14.60	$41,900.54	$38.70	$111,065.13
2	$0.00	$0.00	$0.90	$8,893.50
3	$0.00	$0.00	$114.00	$20,855.10
4	$0.00	$0.00	$6.29	$16,326.32
5	$0.00	$0.00	$7.84	$7,267.68
6	$6.85	$822.75	$24.90	$2,990.73
7	$3.76	$236.24	$13.71	$861.40
8	$0.00	$0.00	$1,480.00	$146.19
9	$0.00	$0.00	$1,170.00	$6,451.61
10	$0.00	$0.00	$114.00	$3,958.79
11	$0.00	$0.00	$5.60	$88,755.13
12	$5.00	$173.63	$18.25	$633.75
13	$0.00	$0.00	$114.00	$15,957.19
14	$0.00	$0.00	$2.14	$352.53
15	$0.39	$54.59	$13.59	$1,902.26
16	$0.00	$0.00	$42.80	$4,852.66
17	$0.00	$0.00	$108.00	$3,842.56
18	$0.00	$0.00	$8.42	$16,177.18
19	$8.15	$289.97	$29.65	$1,054.93
20	$0.00	$0.00	$32.00	$2,448.00
21	$0.00	$0.00	$27.54	$3,745.44
22	$1.50	$1,297.04	$65.84	$56,931.19
23	$1.57	$1,449.66	$111.67	$103,110.49
24	$1.61	$513.07	$152.46	$48,585.95
25	$26.50	$662.50	$251.40	$6,285.00
26	$0.11	$695.22	$1.27	$8,026.60
27	$2.58	$395.67	$29.85	$4,577.80
28	$2.81	$215.47	$33.92	$2,600.99
29	$2.58	$1,488.97	$19.90	$11,484.69
30	$1.76	$2,430.49	$20.13	$27,798.72

Item No.	Equipment Unit Cost	Equipment Cost	Total Unit Cost	Total Cost
31	$1.76	$380.27	$33.83	$7,309.31
32	$1.56	$74.38	$33.34	$1,589.65
33	$1.55	$4,036.74	$33.31	$86,750.90
34	$1.72	$5,393.46	$39.23	$123,014.69
35	$1.93	$106.81	$49.75	$2,753.17
36	$1.73	$2,224.19	$44.63	$57,379.01
37	$1.73	$2,286.78	$50.13	$66,263.84
38	$1.85	$185.04	$90.98	$9,099.82
39	$1.56	$305.26	$54.13	$10,592.16
40	$1.50	$3,197.57	$66.44	$141,630.81
41	$1.50	$719.88	$80.94	$38,844.72
42	$1.50	$289.29	$89.94	$17,345.83
43	$1.40	$502.68	$98.65	$35,421.27
44	$0.89	$779.75	$8.02	$7,026.48
45	$0.00	$0.00	$279.00	$12,834.00
46	$0.32	$2,155.84	$1.53	$10,307.61
47	$0.08	$4,007.93	$1.02	$51,101.09
48	$2.30	$1,968.80	$9.85	$8,431.60
49	$9.60	$2,054.40	$41.18	$8,812.52
50	$2.30	$1,821.60	$9.85	$7,801.20
51	$9.60	$3,801.60	$41.18	$16,307.28
52	$0.03	$1,762.05	$2.03	$119,232.05
53	$0.00	$0.00	$108.00	$97,891.67
54	$11.80	$10,695.57	$35.80	$32,449.27
55	$0.00	$0.00	$36.90	$21,673.22
56	$0.08	$5,423.68	$1.02	$69,151.92
57	$0.03	$271.83	$2.20	$19,934.20
58	$1.03	$9,332.83	$5.20	$47,117.20
59		$116,404.03		$1,716,005.98
60		$23,280.81		$343,201.20
61		$139,684.83		$2,059,207.18

Proposed Concrete Structural System Cost Estimate

Item No.	Item	Item Breakdown	Detailed Item Breakdown
1	Concrete Piles	Concrete	
2		Reinforcement	
3	Concrete Pile Caps	Material	
4		Forms	Square, Rectangular
5			Triangular
6		Placing	x<5
7			5<x<10
8			x>10
9		Reinforcement	
10	Concrete Continuous Footings	Material	
11		Forms	
12		Placing	
13	Concrete Slab on Grade	Material	
14		Forms	
15		Placing	
16		Welded Wire Fabric	
17	Concrete Two-Way Flat Slabs	Material	
18		Forms	
19		Placing	
20		Reinforcement	
21	Concrete One-Way Slabs	Material	
22		Forms	
23		Placing	
24		Reinforcement	
25	Concrete Columns	Material	
26		Forms	
27		Placing	
28		Reinforcement	
29	Concrete Shear Walls	Material	
30		Forms	

Item No.	Item	Item Breakdown	Detailed Item Breakdown
31		Placing	
32		Reinforcement	
33	Concrete Beams	Material	
34		Forms	Exterior
35			Interior
36		Placing	
37		Reinforcement	
38	Steel Columns	HSS 4x4x1/4	
39	Steel Beams	W12x14	
40		W14x26	
41		W16x26	
42		W16x31	
43		W18x76	
44		W24x55	
45		Open Web Steel Joists	18K5
46		Cold Formed Roof Trusses	9:12 to 12:12 Pitch
47		Fireproofing	
48	Roof Steel Deck	Deck	
49		Fireproofing	
50	Total		

Item No.	Unit	Quantity	Material Unit Cost	Material Cost	Labor Unit Cost	Labor Cost
1	VLF	3600.42	$17.75	$63,907.46	$6.35	$22,862.67
2	LB	12397.00	$0.90	$11,157.30	$0.00	$0.00
3	CY	242.76	$114.00	$27,674.92	$0.00	$0.00
4	SFCA	2700.66	$2.46	$6,643.62	$3.83	$0.00
5	SFCA	973.35	$2.90	$2,822.72	$4.94	$10,343.53
6	CY	22.43	$0.00	$0.00	$18.05	$404.88
7	CY	174.55	$0.00	$0.00	$9.95	$1,736.81
8	CY	45.78	$0.00	$0.00	$8.30	$379.96
9	TON	10.35	$805.00	$8,329.50	$365.00	$3,776.73
10	CY	34.73	$114.00	$3,958.79	$0.00	$0.00
11	SFCA	15849.13	$2.64	$41,841.70	$2.96	$46,913.42
12	CY	34.73	$0.00	$0.00	$13.25	$460.12
13	CY	139.98	$114.00	$15,957.19	$0.00	$0.00
14	SFCA	164.73	$0.29	$47.77	$1.85	$304.76
15	CY	139.98	$0.00	$0.00	$13.20	$1,847.67
16	CSF	113.38	$19.80	$2,244.92	$23.00	$2,607.74
17	CY	2131.42	$114.00	$242,981.85	$0.00	$0.00
18	SF	55806.00	$1.60	$89,289.60	$3.15	$175,788.90
19	CY	2131.42	$0.00	$0.00	$17.35	$36,980.13
20	TON	106.07	$950.00	$100,770.25	$455.00	$48,263.65
21	CY	108.48	$114.00	$12,366.89	$0.00	$0.00
22	SF	2929.00	$4.93	$14,439.97	$3.82	$11,188.78
23	CY	108.48	$0.00	$0.00	$17.35	$1,882.15
24	TON	2.14	$950.00	$2,028.69	$455.00	$971.63
25	CY	349.43	$114.00	$39,835.26	$0.00	$0.00
26	SFCA	20018.67	$0.84	$16,815.68	$4.67	$93,487.17
27	CY	349.43	$0.00	$0.00	$32.50	$11,356.54
28	TON	49.12	$895.00	$43,962.84	$575.00	$28,244.28
29	CY	296.15	$114.00	$33,761.21	$0.00	$0.00
30	SFCA	11994.12	$0.66	$7,916.12	$4.34	$52,054.46

Item No.	Unit	Quantity	Material Unit Cost	Material Cost	Labor Unit Cost	Labor Cost
31	CY	296.15	$0.00	$0.00	$28.00	$8,292.23
32	TON	36.84	$850.00	$31,316.20	$440.00	$16,210.74
33	CY	12.35	$114.00	$1,407.69	$0.00	$0.00
34	SFCA	266.72	$2.76	$736.15	$6.45	$1,720.34
35	SFCA	400.08	$2.82	$1,128.23	$5.35	$2,140.43
36	CY	12.35	$0.00	$0.00	$50.00	$617.41
37	TON	0.37	$895.00	$334.22	$539.00	$201.28
38	EA	18.00	$338.00	$6,084.00	$78.00	$1,404.00
39	LF	304.72	$23.70	$7,221.86	$3.21	$978.91
40	LF	76.68	$44.25	$3,393.09	$2.85	$218.54
41	LF	374.72	$44.25	$16,581.36	$2.83	$1,058.58
42	LF	197.36	$52.50	$10,361.40	$3.14	$619.22
43	LF	100.02	$128.25	$12,827.57	$4.54	$453.84
44	LF	161.36	$93.00	$15,006.48	$3.68	$593.00
45	LF	876.12	$5.50	$4,818.66	$1.63	$1,428.08
46	EA	46.00	$181.00	$8,326.00	$98.00	$4,508.00
47	SF	4252.01	$0.50	$2,126.01	$0.66	$2,806.33
48	SF	9061.00	$1.82	$16,491.02	$0.35	$3,171.35
49	SF	9061.00	$2.82	$25,552.02	$1.35	$12,232.35
50				$952,466.19		$610,510.62

Item No.	Equipment Unit Cost	Equipment Cost	Total Unit Cost	Total Cost
1	$14.60	$52,566.13	$38.70	$139,336.25
2	$0.00	$0.00	$0.90	$11,157.30
3	$0.00	$0.00	$114.00	$27,674.92
4	$0.00	$0.00	$6.29	$16,987.15
5	$0.00	$0.00	$7.84	$7,631.06
6	$6.85	$153.65	$24.90	$558.53
7	$3.76	$656.32	$13.71	$2,393.13
8	$3.13	$143.28	$11.43	$523.24
9	$0.00	$0.00	$1,170.00	$12,106.23
10	$0.00	$0.00	$114.00	$3,958.79
11	$0.00	$0.00	$5.60	$88,755.13
12	$5.00	$173.63	$18.25	$633.75
13	$0.00	$0.00	$114.00	$15,957.19
14	$0.00	$0.00	$2.14	$352.53
15	$0.39	$54.59	$13.59	$1,902.26
16	$0.00	$0.00	$42.80	$4,852.66
17	$0.00	$0.00	$114.00	$242,981.85
18	$0.00	$0.00	$4.75	$265,078.50
19	$8.60	$18,330.21	$25.95	$55,310.34
20	$0.00	$0.00	$1,405.00	$149,033.90
21	$0.00	$0.00	$114.00	$12,366.89
22	$0.00	$0.00	$8.75	$25,628.75
23	$8.60	$932.94	$25.95	$2,815.09
24	$0.00	$0.00	$1,405.00	$3,000.32
25	$0.00	$0.00	$114.00	$39,835.26
26	$0.00	$0.00	$5.51	$110,302.85
27	$16.00	$5,590.91	$48.50	$16,947.46
28	$0.00	$0.00	$1,470.00	$72,207.13
29	$0.00	$0.00	$114.00	$33,761.21
30	$0.00	$0.00	$5.00	$59,970.58

Item No.	Equipment Unit Cost	Equipment Cost	Total Unit Cost	Total Cost
31	$14.00	$4,146.11	$42.00	$12,438.34
32	$0.00	$0.00	$1,290.00	$47,526.94
33	$0.00	$0.00	$114.00	$1,407.69
34	$0.00	$0.00	$9.21	$2,456.49
35	$0.00	$0.00	$8.17	$3,268.65
36	$25.00	$308.70	$75.00	$926.11
37	$0.00	$0.00	$1,434.00	$535.50
38	$26.50	$477.00	$442.50	$7,965.00
39	$1.76	$536.31	$28.67	$8,737.08
40	$1.56	$119.62	$48.66	$3,731.25
41	$1.55	$580.82	$48.63	$18,220.76
42	$1.72	$339.46	$57.36	$11,320.08
43	$1.85	$185.04	$134.64	$13,466.44
44	$1.50	$242.04	$98.18	$15,841.52
45	$0.89	$779.75	$8.02	$7,026.48
46	$0.00	$0.00	$279.00	$12,834.00
47	$0.11	$467.72	$1.27	$5,400.05
48	$0.03	$271.83	$2.20	$19,934.20
49	$1.03	$9,332.83	$5.20	$47,117.20
50		$96,388.90		$1,664,174.06

ii. Schedule Estimate Comparison

Refer to the following Microsoft Project schedules, Existing Steel & Proposed Concrete Structural System schedule estimates, respectively.