TECHNICAL REPORT 1

ORCHARD PLAZA

AE SENIOR THESIS

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Orchard Plaza is a six story office building with street level retail on the ground and first level. The building is located in southwestern Pennsylvania on the corner of two streets in an urban environment. Completed in 2006, Orchard Plaza is also a LEED Certified building.

The structural system elements include a foundation of caissons, grade beams, and slabs on grade. The site of Orchard building slopes upward from the ground floor on the eastern side to the first level on the western side. Because of this difference in grade, a concrete retaining wall is found along the western half of the building. The gravity system comprises of a system of W-shape beams, girders, and columns that carry all vertical loads to the caissons. The lateral resisting system is composed of six eccentrically braced steel frames that are evenly distributed to resist both North-South and East-West forces.

The façade is composed of four major materials. At its base, Orchard Plaza is wrapped in a limestone veneer that extends up to the second or third level. Next, red-orange brick veneer is found between levels two and five. The sixth level is wrapped in sleek metal paneling, proving a modern crown to the building. All glazing is green in color and gives the building a very contemporary appearance.

BUILDING INTRODUCTION

PURPOSE & SCOPE

The purpose of this report is to fully describe the structural system and its details for the Orchard Plaza office building. Specifics on foundation, gravity systems, lateral resistance systems, and load considerations and all introduced and explained. No calculations of structural elements are included in this summary.

OVERVIEW

Construction of Orchard Plaza was completed in December 2006 and is located twenty miles southwest of Pittsburgh in Cannonsburg, Pennsylvania. The building comprises of six floors and is of modern design that incorporates both masonry and brick facades and square green glass windows and curtain walls. All six floors follow an identical L-shaped plan as seen in the typical plan below.

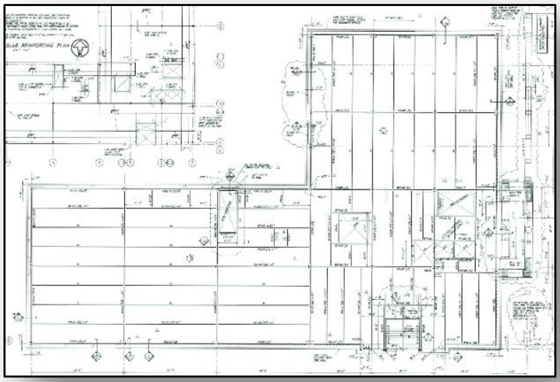


Photo credit: millcraftinv.com

STRUCTURAL DETAILS

FOUNDATION

The foundation for Orchard Plaza consists of a series of grade beams that rest on a total of forty-one caissons. Slabs on grade of varying thicknesses form the first floor with expansion joints at structural gridlines and column bases. Details of each foundation element can be seen below.

CAISSONS

Caissons ranging from thirty to seventy-six inches in diameter secure the columns to the soil. The caisson notes specify that the caisson depth must extend a minimum of one foot into limestone bedrock. Longitudinal rebar extends a minimum of ten feet below the top of each caisson.

Caisson caps serve as column base plate bolt anchors. Their height varies per column. Details of caissons and caisson caps can be seen in Figures 1 and 2 respectively.

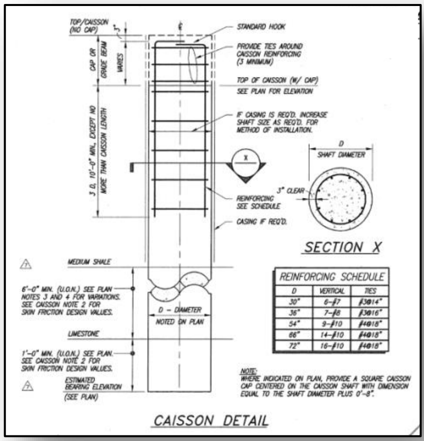


Figure 1: Caisson Detail – S0.00

Courtesy of STRADA

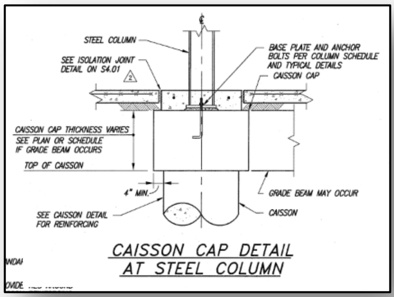


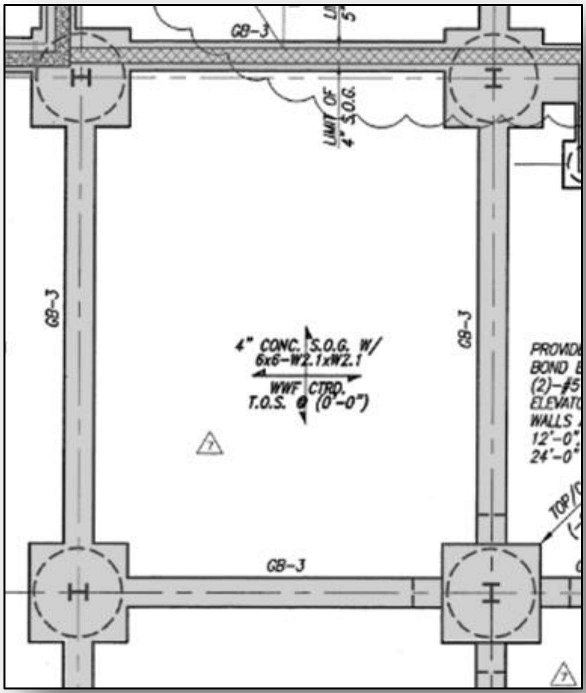
Figure 2: Caisson Cap Detail – S0.00

Courtesy of STRADA

GRADE BEAMS & SLABS ON GRADE

Grade beams of widths varying from eighteen to thirty-two inches and depths up to three feet provide a grid of foundation between most columns. Slabs on grade with expansion joints between grade beams and slabs on grade and between adjacent slabs compose the first floor (ground floor) of the building. Figure 3 shows the interaction of the grade beams with the caisson caps/column bases and the slabs on grade.

Figure 4 shows an example of the relationship of expansion joints to the slabs on grade, grade beams, and column bases.



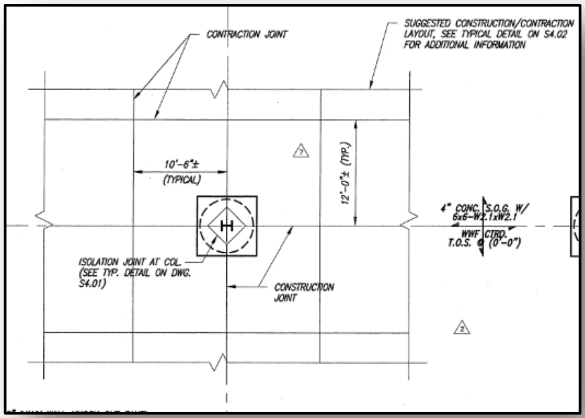


Figure 3: Grade Beams – S1.00

Courtesy of STRADA

Figure 4: Expansion Joints – S1.00

Courtesy of STRADA

SLAB REINFORCING

Slabs on grade are reinforced with welded wire fabric placed between one and one and one-half inches below the top of the slab. Special reinforcing rebar is added around slab openings as seen in Figure 5. Rebar extends multiple feet beyond the slab opening edge and is accompanied by a diagonal bar at opening corners.

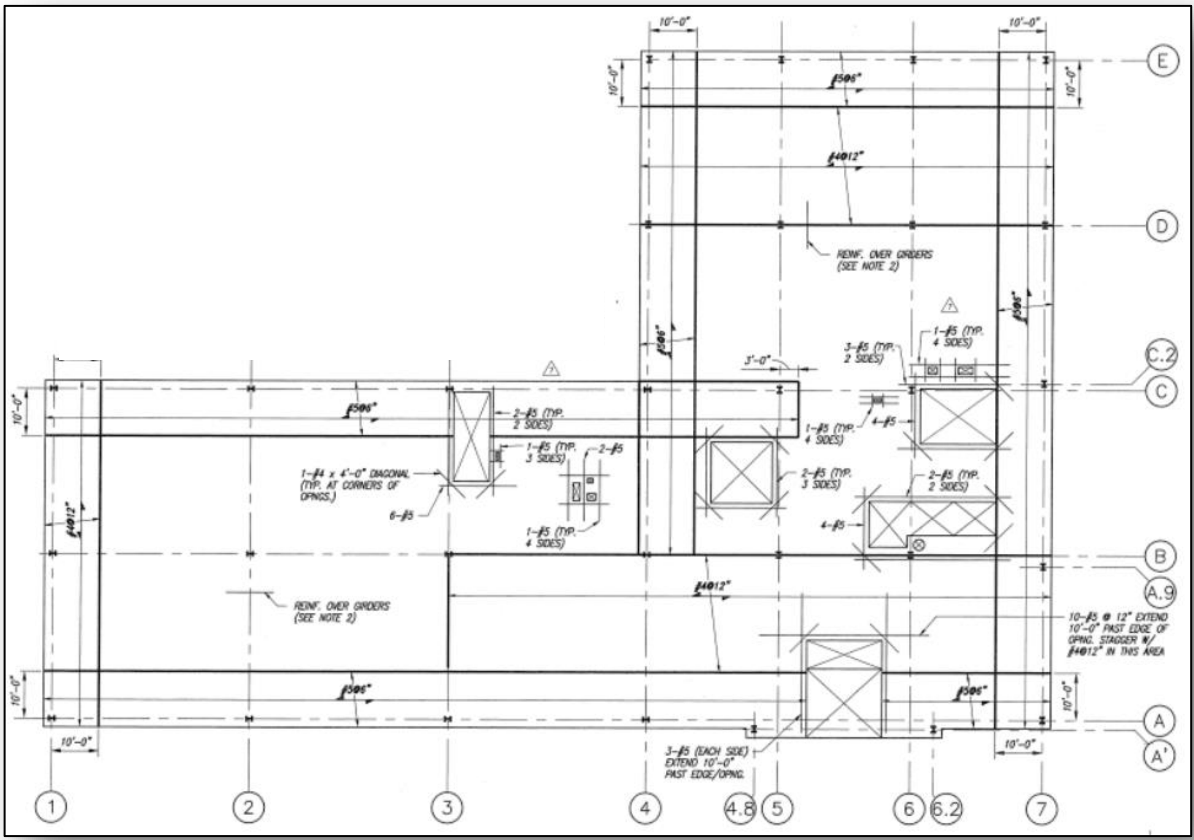


Figure 5: Slab Reinforcing Plan – S1.01

Courtesy of STRADA

FOUNDATION WALL

Due to the grade change over the building's site, there is a one story change in elevation over the site beginning on the western side at the first floor and raising up to the second floor on the eastern side. In order to accommodate this change while maintaining the entire first floor for usable space, a cast-in-place concrete wall is used on the north, east, and south exterior walls. The location of this wall is highlighted in green below in Figure 6.

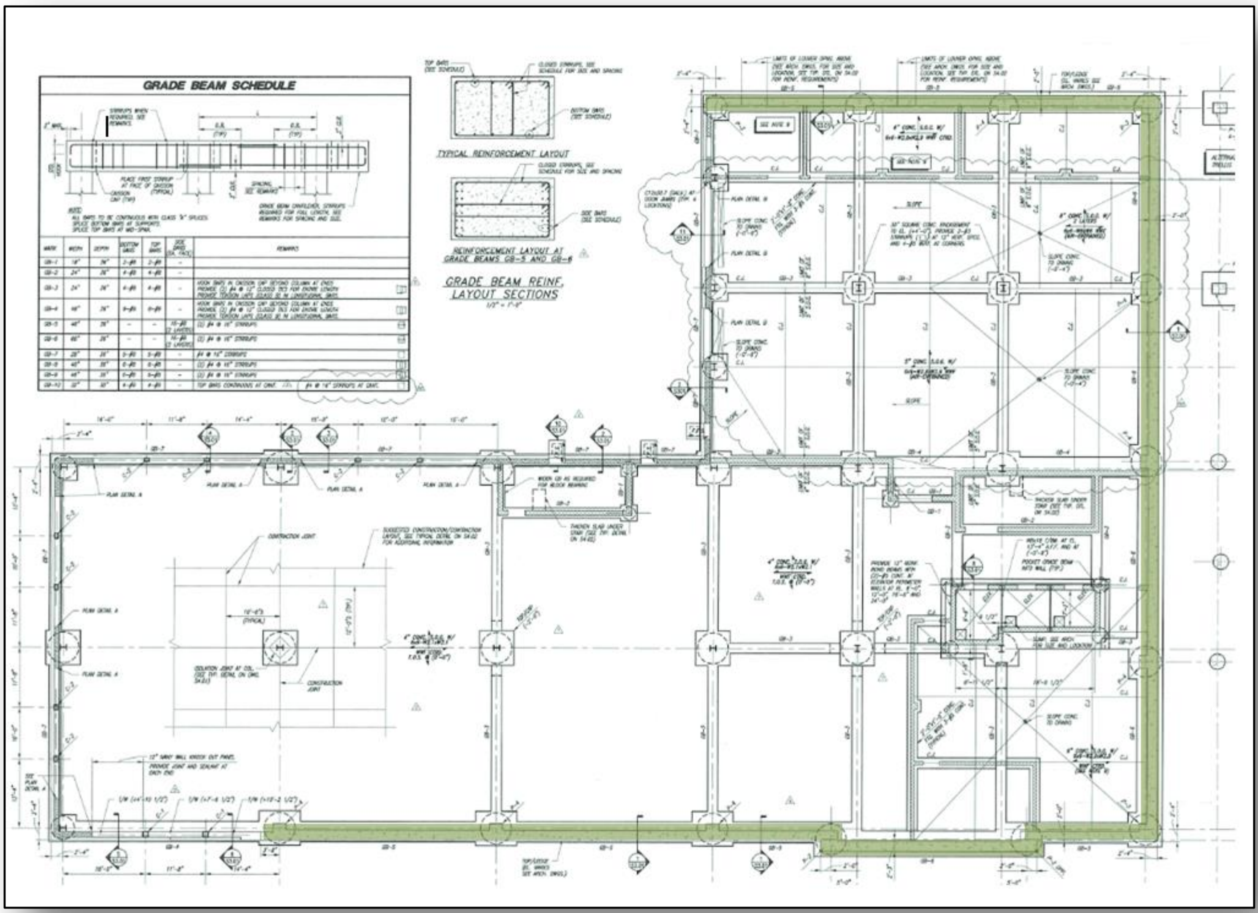


Figure 6: Foundation Plan – S1.00

Courtesy of STRADA

FLOOR FRAMING & TYPICAL BAYS

Typical floor framing consists of beams and girder construction of varying sizes. Figure 7 shows a typical beam and girder layout for the first floor. Floors two through six follow a very similar design. Beams range in size from W16x31 to W21x44 while girders vary from W24x68 to W 30x99 with exceptions for both beams and girders surrounding floor openings .

Figure 7: First Floor Framing Plan – S1.01

Courtesy of STRADA

37'-5" x 42' Bay area coverage

35' x 28' Bay area coverage

FLOOR SYSTEM DETAILS

Floors two through five utilize a composite decking system comprised of normal weight concrete, two inch 18 gauge composite decking, and welded wire framing placed one inch from the top of the slab. Where exterior brick veneer requires support, deeper beams run the length of the exterior with 3/8" plate welded perpendicular to of the beam. A system of HSS tubing, shims, and angle form the brick veneer support while an angle brace runs up to the beam behind (Figure 8) or is joined directly with a double angle connection (Figure 9). Similar connections are done for masonry veneer facades on the lower floors. Some exterior edges also include small cantilevers.

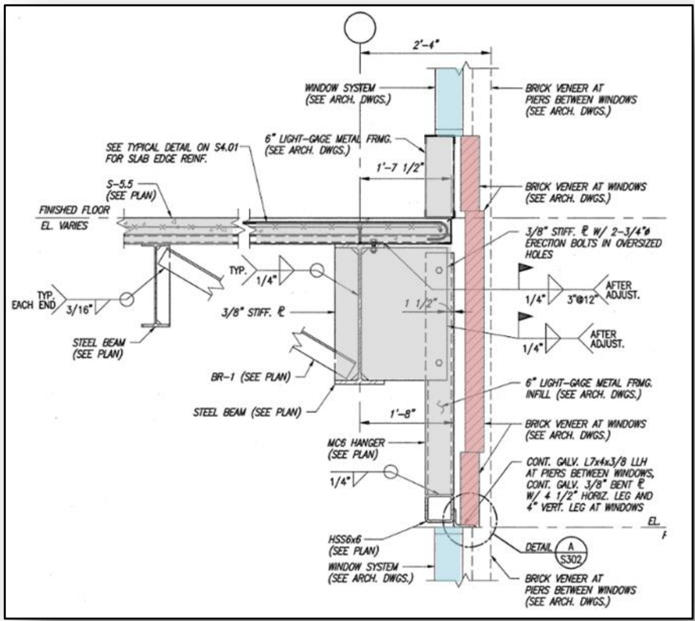


Figure 8:

Floor to Exterior connection with brace – S3.02

Courtesy of STRADA

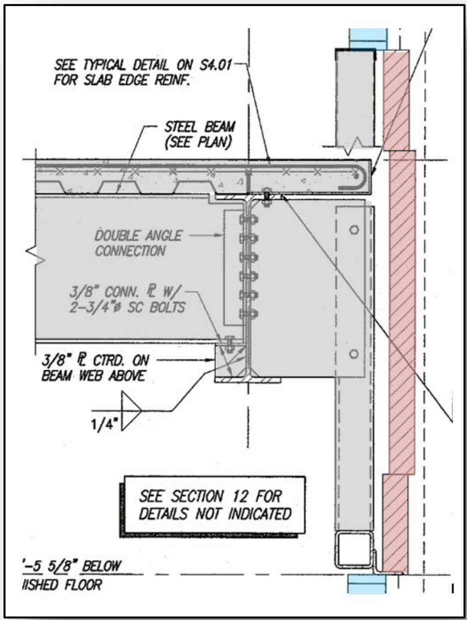


Figure 9:

Floor to Exterior connection– S3.02

Courtesy of STRADA

COLUMNS

All columns rest on caissons or grade beams as described earlier. Column base plates are typically mounted to caissons with four anchor bolts as shown in gray in Figure 10. Additional base plates and anchor bolts are added are added for any base joints with the lateral system (shown in blue in Figure 11).

Column splices occur four feet above the floor slab of the first, third, and fifth floor unless required to be at a different height to avoid brace connections. Base columns range from W14x99 on the exterior to W14x257 on the interior. See Appendix A for column schedule.

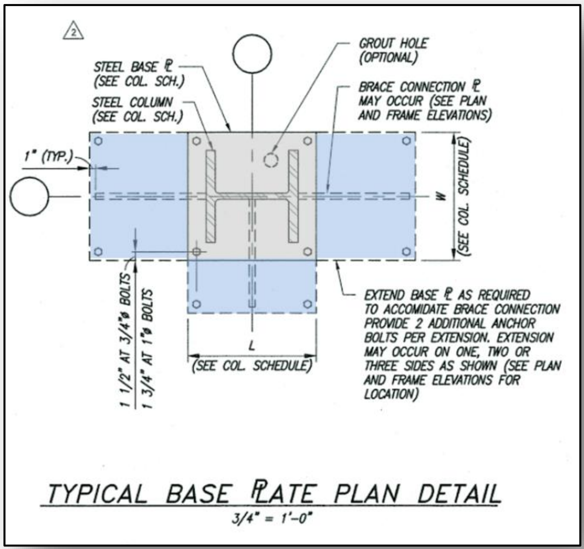


Figure 10:

Typical Base Place Elevation – S2.02

Courtesy of STRADA

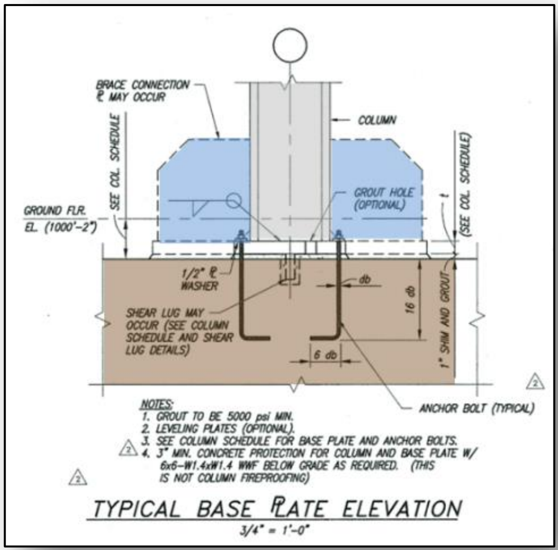


Figure 11:

Typical Base Place Plan Detail – S2.02

Courtesy of STRADA

LATERAL SYSTEM

The primary lateral load resisting elements are moment frames formed from W-shape beams and HSS tubing. The location of all moment framing elements is shown in blue in Figure 12 below. The orientation of these frames is distributed evenly between the north-south and east-west direction to adequately accommodate lateral loading from any direction.

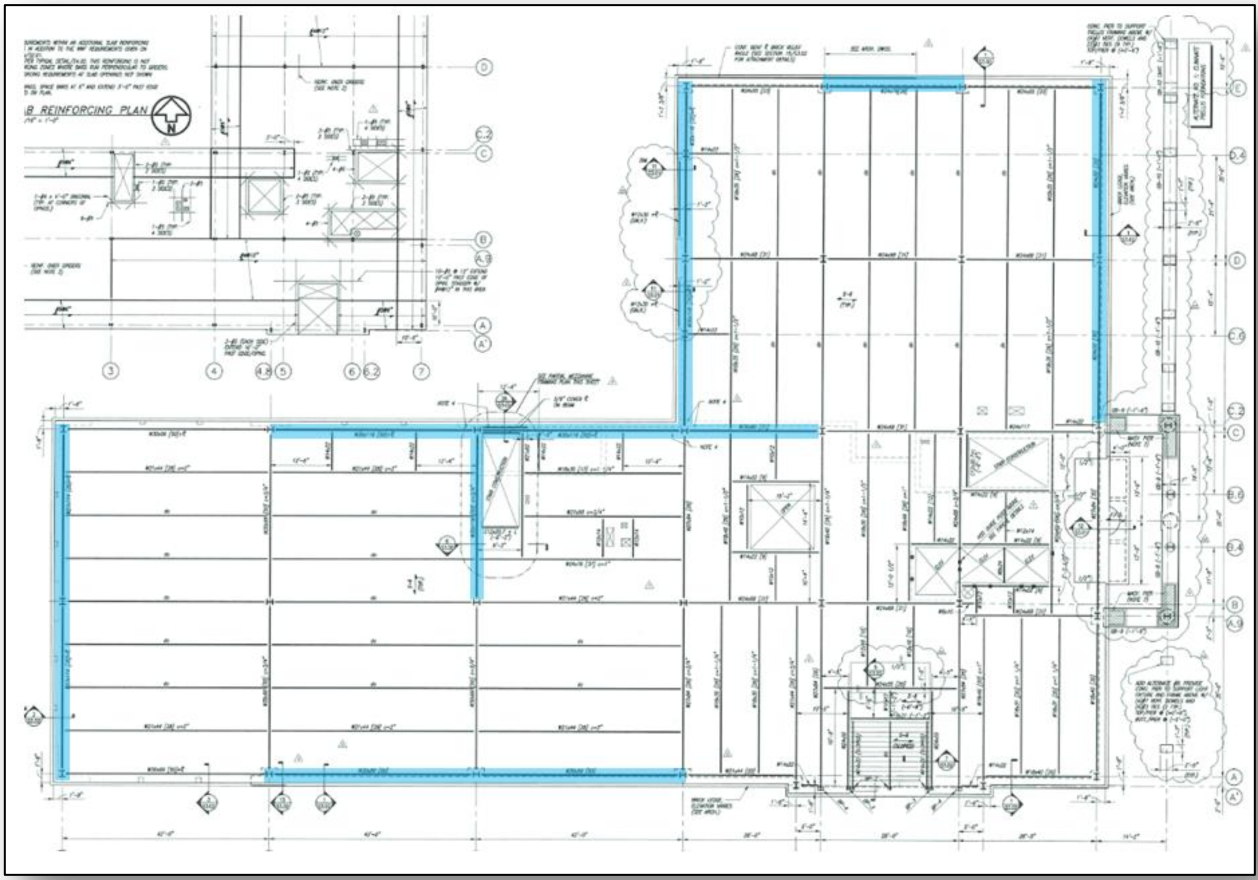


Figure 12: First Floor Framing – S1.01

Courtesy of STRADA

Pictured below is the left-most frame highlighted in Figure 13 on the previous page. All diagonal bracing is made with HSS tubing and ranges in wall thickness from ½" to ¼". This configuration is used to provide maximum flexibility with glazing placement on exterior frames and office floor space flexibility within interior frames. Orchard Plaza contains no concrete shear walls or concrete central core.

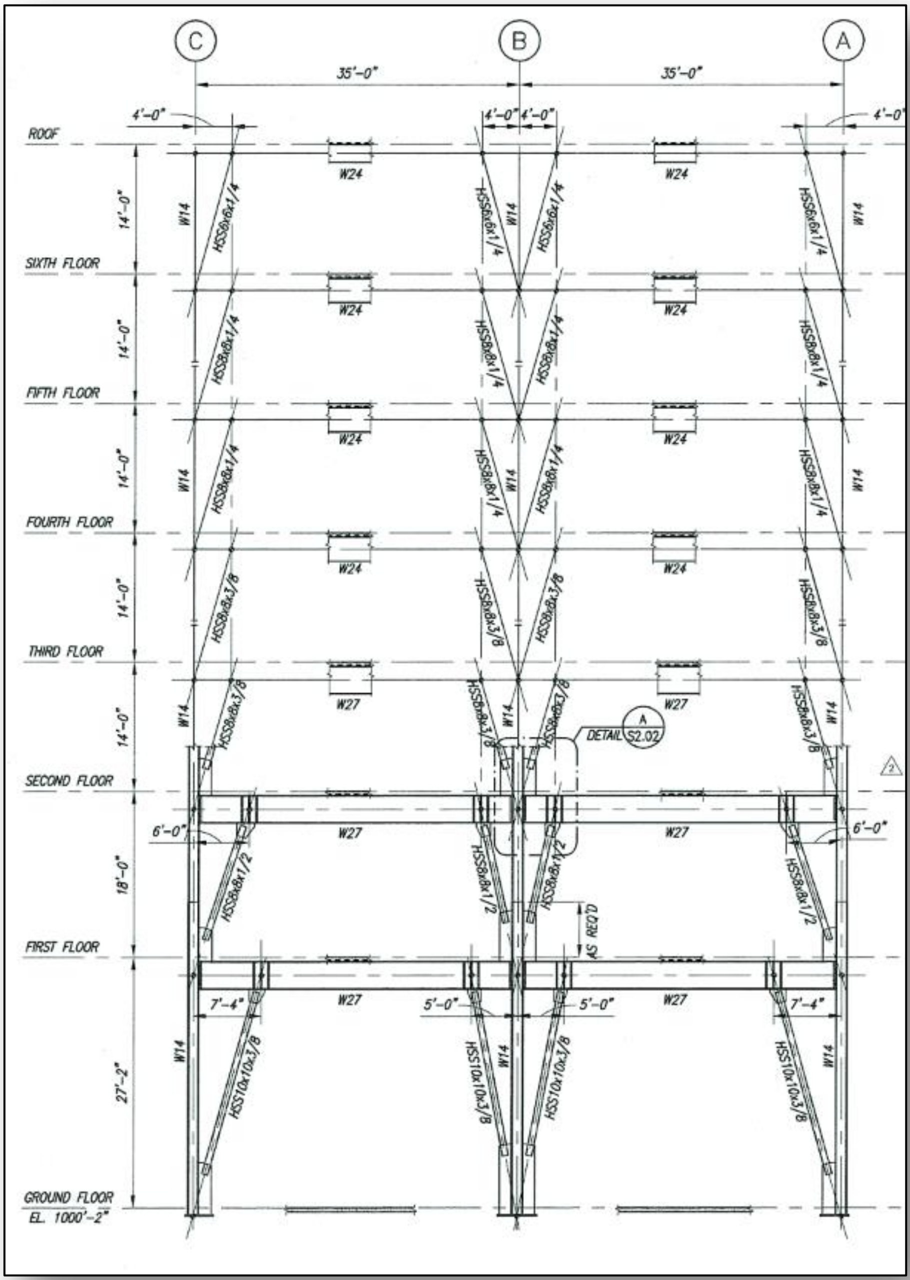


Figure 13: Line 1 Lateral Frame – S2.01

Courtesy of STRADA

Lateral frame connections are characterized by welded plates at both ends of the HSS tube, shown in purple, and are welded to columns and girders as seen in Figure 14 below. This connection requires a significant amount of prefabricated welding and field welding. Stiffener plates must also be added on both sides girder webs at the upper connection of the HSS tube and respective connection plate.

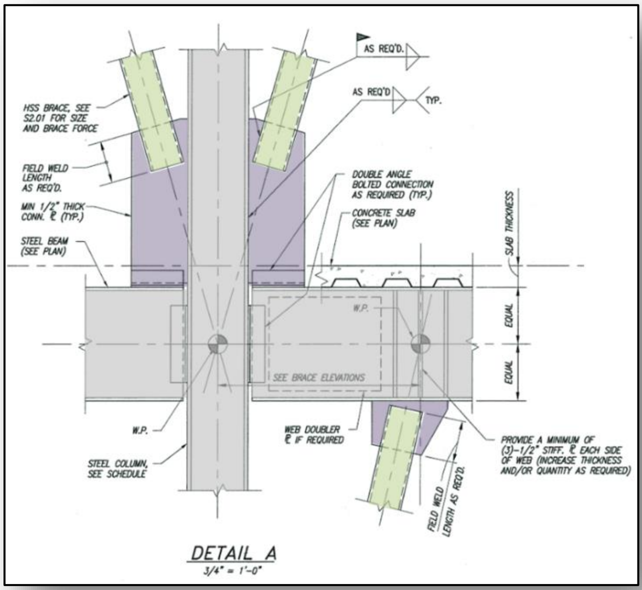


Figure 14: Interior Lateral Frame Joint– S2.02

Courtesy of STRADA

LOAD PATHS

This document will describe how the structure and its respective elements floor (live & dead), wind, earthquake, roof, snow and uplift loads. Diagrams of load paths are included for visual illustration while their respective design loads can be found in Appendix B.

ROOF LOADS

The roof is of typical flat beam and girder construction with 30psf live load minimum consideration. The roof includes three concrete pads for mechanical equipment and elevator housing which are highlighted in red in Figure 15 below. These additional loads require much larger beams and girders around the pads which then transfer the loads directly into interior columns uninterrupted into the foundation.

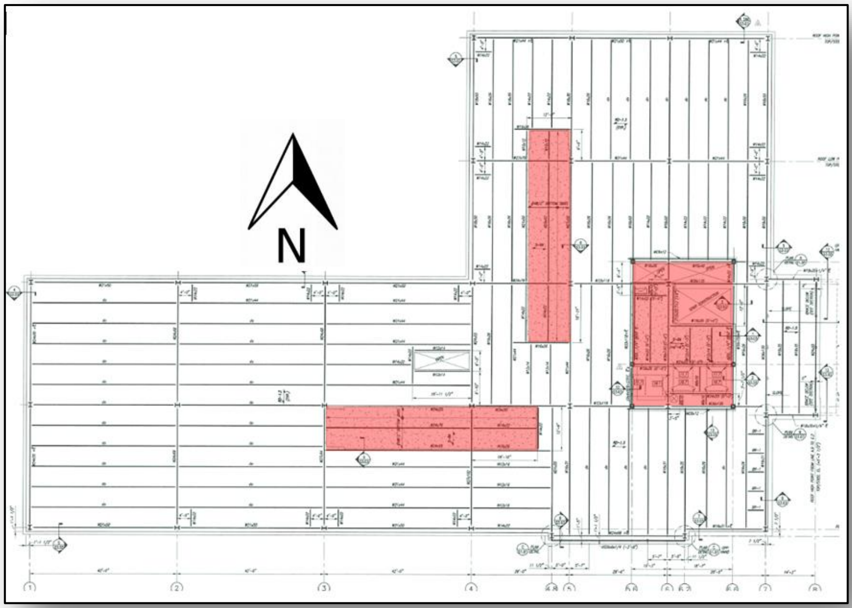


Figure 15: Roof Framing Plan – S1.07

Courtesy of STRADA

SNOW LOADS

Snow build-up is of primary concern around the rooftop equipment and under and canopies. Various snow loads were considered for this structure but have not been calculated in detail for this report. Specifics regarding snow load design can be found in Appendix B

ROOF UPLIFT

Roof uplift load is considered on canopies, overhangs, or partially enclosed structures highlighted in yellow in Figure 16. The highlighted uplift regions of concern are illustrated with their respective elements.

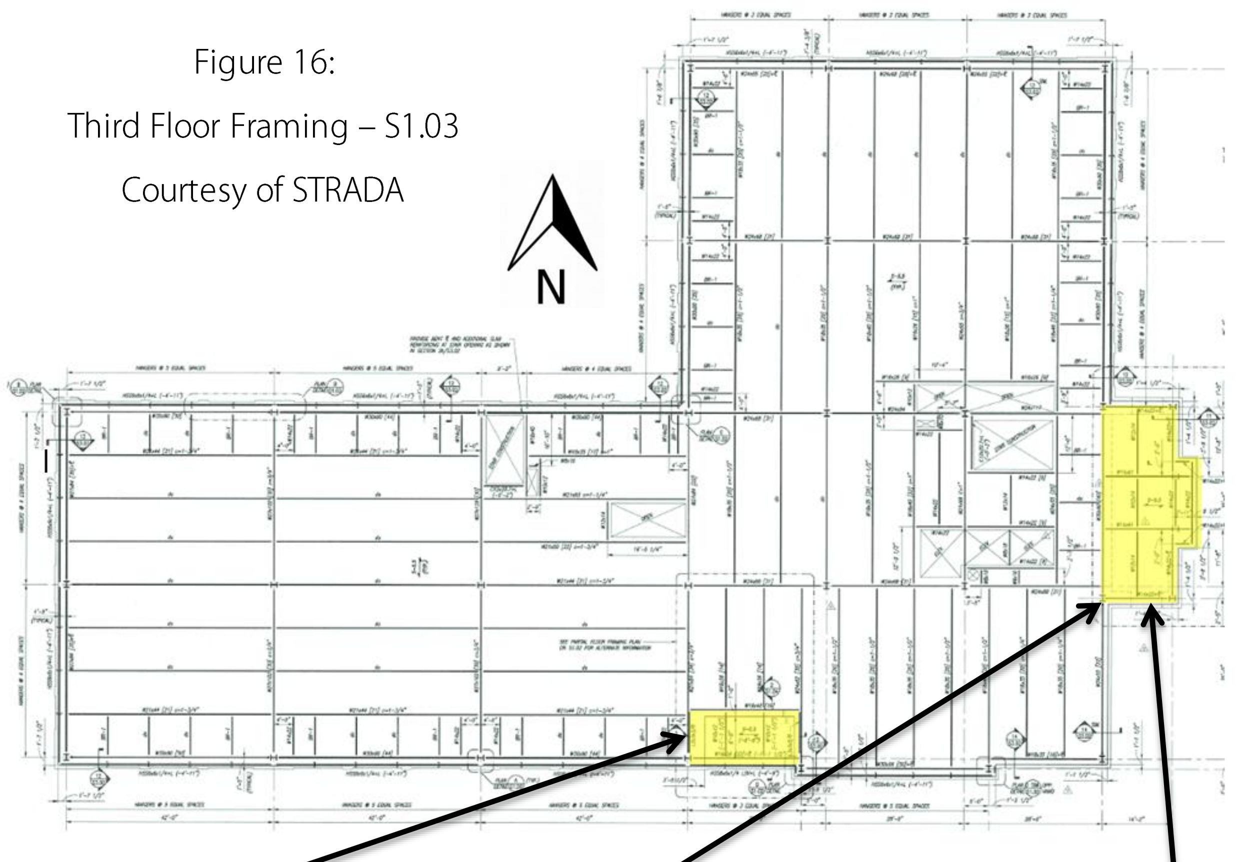


Figure 16:

Third Floor Framing – S1.03

Courtesy of STRADA

Recessed Windows

Second Floor Canopy

Sixth Floor Canopy

WIND LOADS

The lateral moment frames constitute the majority of wind resistance framing in the building. It is expected that horizontal forces like those pictured with blue arrows below in Figure 19. The expected direction of forces on the base plates are shown with orange arrows. The frames are distributed, though not proven yet with calculations, appropriately so that most floor bays share at least one edge with one of the moment frames (See Figure 12). This layout provides for a more stable structure as there are no large areas without lateral resistance. Symmetry in the frames allows them to act equally effective regardless of wind direction (from left vs. from right in Figure 17).

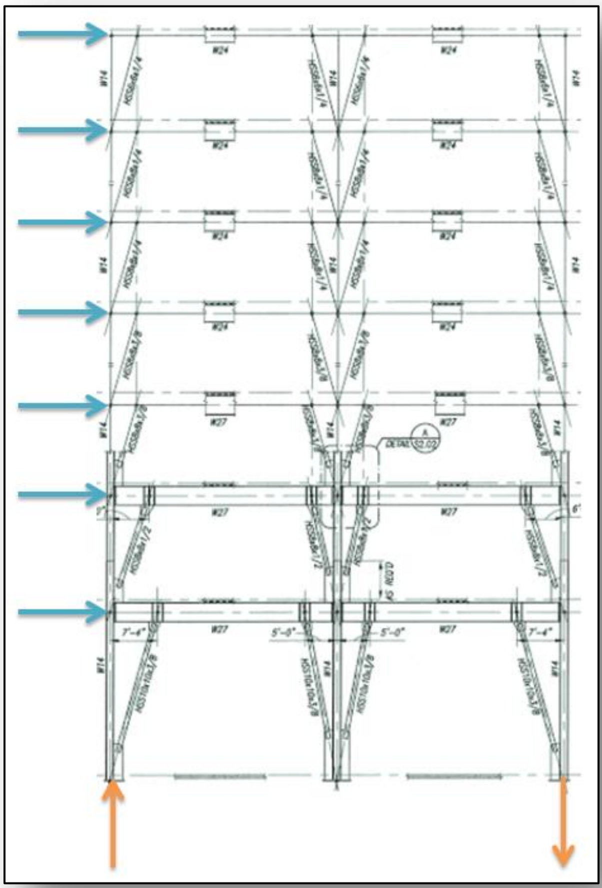


Figure 17: Line 1 Lateral Frame – S2.01

Courtesy of STRADA

FLOOR LOADS

Floor loads for each floor flow from the composite decking into the beams, then to girders, and finally into columns which are all continuous (disregarding the rooftop elevator housing shell) from their upper most reach down to their concrete footing, whether it be a caisson or grade beam.

The building occupancy is nearly entirely office space, with standard. Significant live loads are found in file storage areas.

SOIL LOADS

The foundation wall described in Figure 8 must resist roughly twenty-five vertical feet of soil across the entire eastern side of the building. Similar to snow loads, soil loads have not been calculated in any detail but design loads can be found in Appendix B.

CODES

The following codes have been deemed most appropriate for this structure based on the General Notes from drawing S4.01

Live Load – IBC 2003 Section 1607, 1608

Dead Load – IBC 2003 Section 1606

Wind Load – IBC 2003 Sections 1604, 1609 & ASCE-7

Seismic Load – IBC 2003 Sections 1604, 1615 ,1616, 1617

CONCLUSION

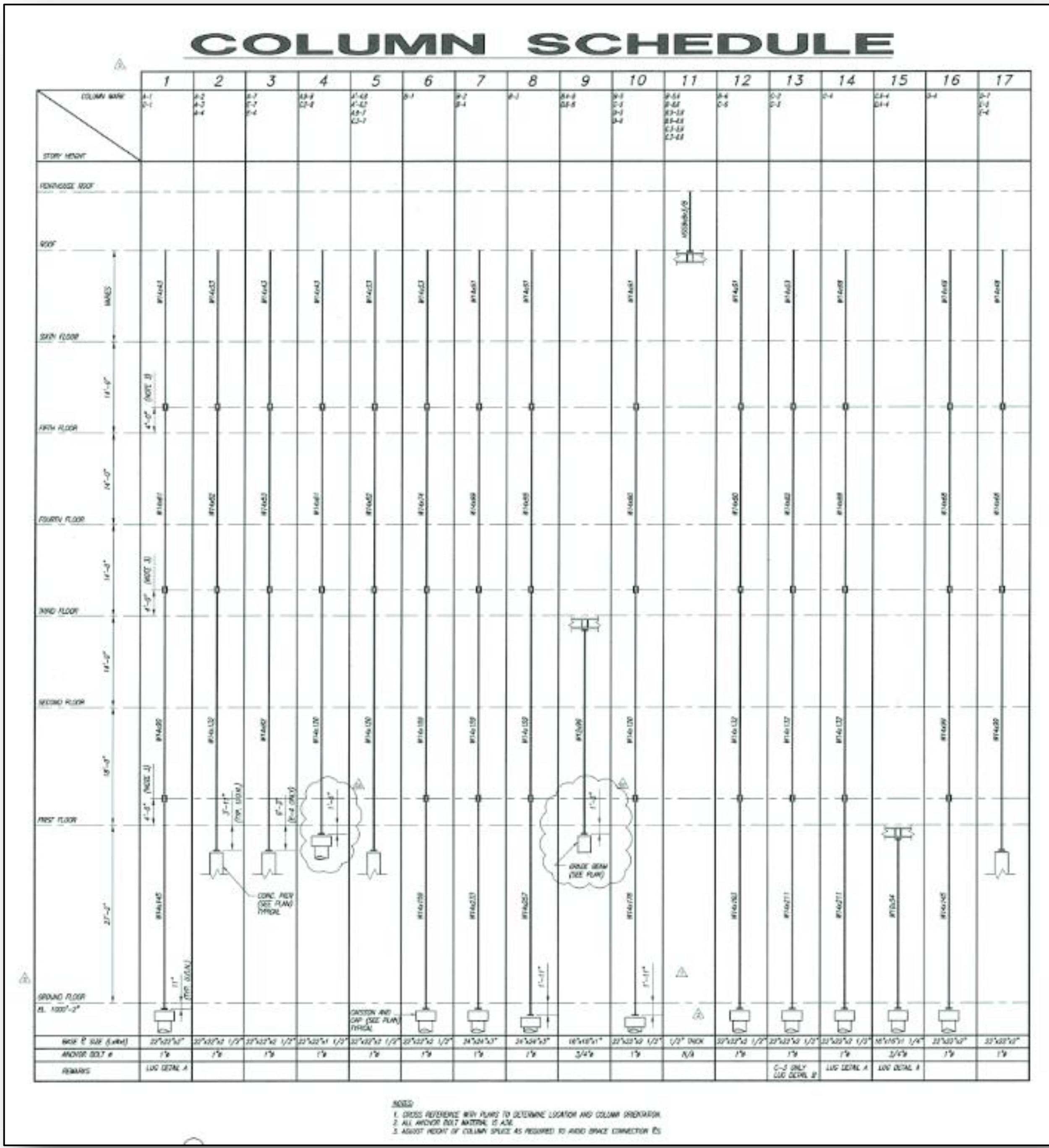
This report has discussed with detail all structural and architectural elements that must be considered for structural analysis of the Orchard Plaza office building. The foundation has been determined to comprise of caissons, grade beams, cast-in-place foundation wall and slabs on grade. The lateral framing is entirely steel moment frames since no shear walls or concrete cores are present. The gravity system transfers loads from composite decking, to beams, then girders, and finally continuous columns to the foundation.

The moment frames are of unique design to allow for maximum flexibility of exterior windows and interior floor space utilization. Future consideration of the lateral system may prove challenging if maintaining these open bays is desired. The frames used are fabrication intensive with many prefabricated and field welds required. Also, the L-shape of the building limits symmetry with the lateral resistance design and complicates calculations such as centers of rigidity and exterior wind loads. Fortunately, Orchard Plaza is almost entirely office space which is a flexible occupancy when modifying structural elements.

APPENDIX A *Column Schedule taken from S2.02*

COLUMN SCHEDULE

18



APPENDIX B *Tables taken fromS4.01*

FLOOR LOADS

Floor Live Load:

Lobbies and Corridors on Ground or First Level	100	psf [1,2]
Office Areas	60	psf [1], +20 DL part.[2]
Main Corridors Above Ground Level	80	psf [1]
Electrical and Mechanical Rooms	200	psf
Stairs and Landings	100	psf
Light Storage	125	psf [3]
General File Areas	175	psf [3]
Special File or Heavy Storage Areas	250	psf [3]

[1] Live Loads Are Reduced Per IBC Section 1607.9 to a Maximum Reduction Of 40%

[2] Plus Non-Reduced Partition Dead Load Allowance (IBC 1607.5)

[3] See Plans for Areas Designed for Special Loading

ROOF & SNOW LOADS

Roof Live Load:	30 psf min.
Roof Snow Load:	
Ground Snow Load (IBC 1608)	Pg = 25 psf
Flat-Roof Snow Load (Pf = 0.7CeCtIsPg)	Pf = 18 psf [4]
[4] Increased as required For Snow Buildup / Unbalanced Per ASCE 7, Section 7	
Snow Exposure Factor (IBC Table 1608.3.1)	Ce = 1.0
Snow Importance Factor (IBC Table 1604.5)	Is = 1.0
Thermal Factor (IBC Table 1608.3.2)	Ct = 1.0
Terrain category	B

APPENDIX B *Tables taken fromS4.01*

WIND LOADS

Wind Load:

Main Wind–Force Resisting System and Componets Greater Than 700 SF:

Basic Wind Speed (3–Second Gust) ------------------	V = 90 mph
Wind Importance Factor (IBC Table 1604.5) --------------	Iw = 1.0
Building Category (IBC Table 1604.5) ------------------	II
Wind Exposure Category (IBC 1609.4) ------------------	Exposure B
Internal Pressure Coefficient (ASCE 7, Figure 6–5) Enclosed --	GCpi = ±0.18
Topographic Factor (ASCE 7, Section 6 Figure 6–4) --------	Kzt = 1.0
Wind Directionality factor (ASCE 7, Table 6–4) ------------	Kd = 0.85
Wind Design per IBC 1609 & ASCE 7, Section 6 As Applicable	

Components & Cladding Less Than 700 Sq. Ft.:

Design by Registered Design Professional in accordance with IBC Section 1609.6.5 & ASCE 7, Section 6 -------------	submit loads for review Use Kd = 1.0 min. and Kzt = 1.0 min.

Special Wind Load

Uplift on Canopies, Overhangs, Open or Partially Enclosed Buildings ---	15 psf

SOIL LOADS

Soil Lateral Loads: (per Geotechnical Report)

Restrained (Basement Walls) at rest pressure -----------	65 psf
Unrestrained (Cantilever Retaining Walls) Active Pressure ----	43 psf

APPENDIX B *Tables taken fromS4.01*

SEISMIC LOADS

<u>Earthquake Design Data:</u>

Seismic Use Group (IBC 1616.2 with Table 1604.5)	Group I
Spectral Response Coefficients: Building location (Zip Code)	15301
Short Period Response (IBC Eq. 16-40)	Sds = 0.104 g
1-second Period Response (IBC Eq. 16-41)	Sd1 = 0.068 g
Site Class (IBC Table 1615.1.1) per Geotechnical Report	C
Basic Seismic-Force-Resisting System (IBC Table 1617.6.2)	Eccentric Braced Frames
Seismic Response Coefficient	Cs = 0.035
Response Modification Factor	R = 3
Design Base Shear (IBC 1617.5.1) V=CsW	V = 495 Kips
Analysis Procedure (IBC 1617.4)	Equivalent Lateral Force Procedure
Seismic Importance Factor (IBC Table 1604.5)	Ie = 1.0
Seismic Design Categories (IBC Table 1616.3 (1) & (2)	
Short Period Response	A
1-second Period Response	B