440 FIRST STREET, NW
WASHIGNTON, D.C.

YEMI OSITELU
STRUCTURAL OPTION
ADVISOR | ALY SAID
16 NOVEMBER 2015

TECHNICAL REPORT IV

Letter of Transmittal

November 16, 2015

Aly Said
Structural Thesis Advisor
The Pennsylvania State University
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Dear Dr. Said,

The following technical report fulfills the requirements specified in the structural Technical Report IV assigned by the faculty for senior thesis.

Technical Report IV majorly includes the analysis of the lateral systems under wind and seismic loads. Both hand calculations and 3D computer modeling software were used in the analysis of the structure.

Thank you for reviewing this report. I will kindly appreciate your feedback.

Sincerely,

Yemi A. Ositelu.

Enclosed: Technical Report IV

EXECUTIVE SUMMARY

440 First Street is a mixed use building located in Washington, D.C. The existing 8-story building, constructed in the early 80's began renovation in 2012 and was completed in 2013. Three stories were added to the building, including a penthouse, resulting in a 20.6 foot increase in building height and a total gross square footage of about 142000 GSF. The new 10-story architectural design provided a seamless transformation of the existing building into a more modern, state-of-the-art building, well on its way to a platinum LEED certification.

The existing building, floors 1 to 7, comprises of a frame assembly of cast-in-place concrete structural slabs and column, with low story heights. The foundation system is mainly supported by the spread footings. The new, additional framing (8th floor and above) uses composite framing, with wide flange steel shapes used in the majority of the added structural system.

Building codes and design standards typically used in the project include the ASCE and the IBC, with gravity, lateral, and seismic loads all considered.

This report will cover the codes, design loads, existing framing, framing renovations and additional framing in more detail and in a wider perspective.

TABLE OF CONTENTS

440 FIRST STREET

YEMI A. OSITELU | STRUCTURAL OPTION
ADVISOR: DR. ALY SAID

GENERAL DESCRIPTION

LOCATION	WASHINGTON, D.C.
OCCUPANCY	OFFICE/ RETAIL
SIZE	141,929 SQUARE FT.
NUMBER OF STORIES	11 (ABOVE GRADE)
ACTUAL COST INFO.	$20,000,000 (RENO.)

PROJECT TEAM

NEW CONSTRUCTION

OWNER	FP FIRST STREET, LLC
GENERAL CONTRACTOR	SIGAL CONSTRUCTION
ARCHITECT	FOX ARCHITECTS
CIVIL ENGINEER	VIKA
STRUCTURAL ENGINEER	RGA
MEP ENGINEER	VANDERWEIL
LIGHTING CONSULTANT	C.M KLING & ASSOC.
SPECS. WRITER	BETHEL SPECS.
LEED CONSULTANT	LORAX
CODE CONSULTANT	AON RISK SOLUTIONS

EXISTING CONSTRUCTION

ARCHITECT	VLASTMIL KOUBEK, AIA
STRUCTURAL ENGINEER	BASKAM & JURCZYK
MECHANICAL & ELECTRICAL	THE OFFICE OF LEE KENDRICK

ARCHITECTURE

440 First Street, NW, is located between D and E Streets in downtown Washington, D.C. The existing 8-story building was constructed in 1982 and renovation was initiated in 2012. It has 10 stories + a mechanical penthouse, and there are two existing below grade parking garages, which were repaired and utilized as a valet parking facility. The new façade is a combined glass-and-metal curtain wall system, which allows for outstanding views and more importantly, natural daylighting.

STRUCTURAL SYSTEM

FRAMING SYSTEM

EXISTING *Cast-in-place concrete with two-way structural concrete slabs and reinforced concrete columns and beams.*

NEW *Composite steel framing with 5 1/4" slabs*

LATERAL SYSTEM

EXISTING *Slab-Column Concrete Frames*

NEW *Steel Moment Frames*

FOUNDATION

Walls and columns are supported by spread footings.

MECHANICAL SYSTEM

During the renovation of 440 First Street, the primary mechanical (DOAS) systems were replaced and resulted in a 25% reduction in energy usage. It consists of 3 mechanical rooms housed in the penthouse and 2 cooling towers on the penthouse roof.

Openings were created in the steel beams and girders

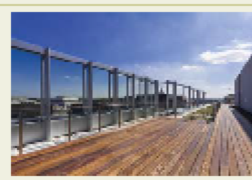
SUSTAINABILITY

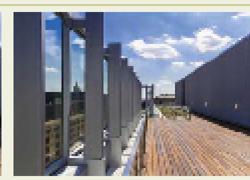
- Majority of the building 's structural elements will be reused
- Green Roof will have local plants that require minimal watering and also reduces storm water overflow and minimizes "heat island" effect
- Recycled materials are used and are obtained regionally
- The building has achieved LEED Platinum Certification

LIGHTING/ELECTRICAL SYSYTEM

The curtain wall and the many windows in the façade provide the building with natural daylighting, improving energy efficiency.

The interiors are well lit with LED fixtures and other various energy efficient light fixtures





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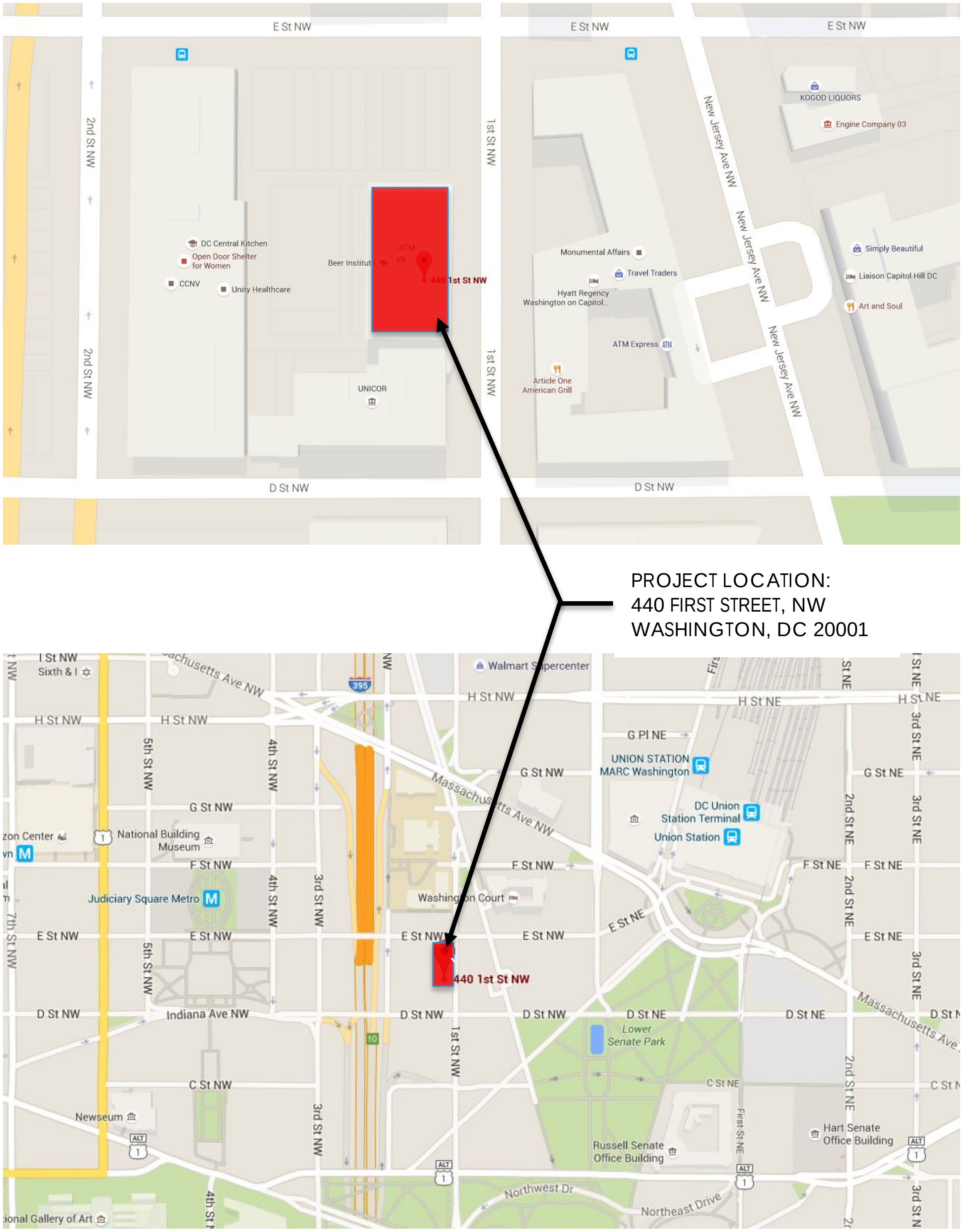
SITE AND LOCATION PLAN



DOCUMENTS USED DURING THE PREPARATION OF REPORT

The following is a list of the structural codes and design standards used in the structural analysis of 440 First Street, NW, Washington, D.C.

I. **International Code Council**
   - International Building Code 2006

II. **American Society of Civil Engineers**
   - ASCE 7-05 &10: Minimum Design Loads for Buildings and Other Structures

III. **American Concrete Institute**
   - ACI 318-11: Building Code Requirements for Structural Concrete

IV. **American Institute of Steel Construction**
   - AISC 14th Edition: Steel Construction Manual

V. **Vulcraft Deck Catalog**

VI. **First Edition, Standard Specification for Composite Steel Joists**

VII. **Reinforced Concrete Mechanics and Design Textbook**

VIII. **Previous AE Course Notes**

GRAVITY LOADS SUMMARY

The summary of the gravity loads as calculated in Technical Report 2 are as follows;

Roof Dead Load	
Penthouse	**27 PSF**
Main Roof/Penthouse Floor	**103 PSF**
Roof Live Load	
Penthouse	**30 PSF**
Main Roor/Penthouse Floor	**100 PSF**
Snow Load	**20 PSF + 62.1 PSF max drift**
Floor Dead Load	
Steel Addition	**80 PSF**
Typical Concrete	**108 PSF (7”), 138 PSF (9.5”)**
Floor Live Load	**100 PSF (OFFICE + PARTITIONS)**
	100 PSF (LOBBIES/STAIRS)
	50 PSF (PARKING)
Exterior Wall Load	
Curtain Wall	**102.5 PLF**
Masonry	**436 PLF**

LATERAL LOADS

Wind Loads Summary

The summary of the wind design information used in the calculation of the lateral loads in Technical Report 2 are as follows;

B = 87 ft , L = 157 ft for E-W direction, B = 87 ft , L = 157 ft for N-W direction

Basic Wind Speed = **90 MPH**

Mean Roof Height = **118.5 ft**

Occupancy Category = **I**

Exposure Category = **B**

Topographic Factor = **1.0**

Gust Effect Factor = **0.85**

The following pages includes the breakdown of the wind pressures for both directions, as well as the base shear.

TABLE 1: Wind Pressures in the North-South Direction

Wind Pressure Chart (N-S)								
Location	z	qz or qh	Cp	Gf	Gcpi	qiGCpi	Net Pressure (PSF)	
							qzGfCp-qi(+Gcpi)	qzGfCp-qi(-Gcpi)
Windward	15	10.05	0.8	0.85	0.18	1.809	5.03	**8.64**
	25.33	11.63	0.8	0.85	0.18	2.0934	5.82	**10.00**
	35.67	12.87	0.8	0.85	0.18	2.3166	6.44	**11.07**
	46	13.92	0.8	0.85	0.18	2.5056	6.96	**11.97**
	56.33	14.81	0.8	0.85	0.18	2.6658	7.41	**12.74**
	66.67	15.51	0.8	0.85	0.18	2.7918	7.76	**13.34**
	77	16.22	0.8	0.85	0.18	2.9196	8.11	**13.95**
	87.75	16.74	0.8	0.85	0.18	3.0132	8.37	**14.40**
	98.5	17.45	0.8	0.85	0.18	3.141	8.73	**15.01**
	109.25	17.8	0.8	0.85	0.18	3.204	8.90	**15.31**
	118.5	18.33	0.8	0.85	0.18	3.2994	9.17	**15.76**
Leeward	All	18.68	-0.325	0.85	0.18	3.3624	**-8.52**	-1.80
Side	All	18.68	-0.7	0.85	0.18	3.3624	**-14.48**	-7.75
Roof (0 to 59.25)	118.5	18.68	-0.98	0.85	0.18	3.3624	**-18.92**	-12.20
Roof (59.25 to 118.5)	118.5	18.68	-0.8	0.85	0.18	3.3624	**-16.06**	-9.34
Roof (118.5 to 160.25)	118.5	18.68	-0.6	0.85	0.18	3.3624	**-12.89**	-6.16
Low Parapet WW	110.5	17.98			1.5	26.97		**26.97**
Low Parapet LW	110.5	17.98			-1.0	-17.98		**-17.98**
High Parapet WW	127.25	18.68			1.5	28.02		**28.02**
High Parapet LW	127.25	18.68			-1.0	-18.68		**-18.68**

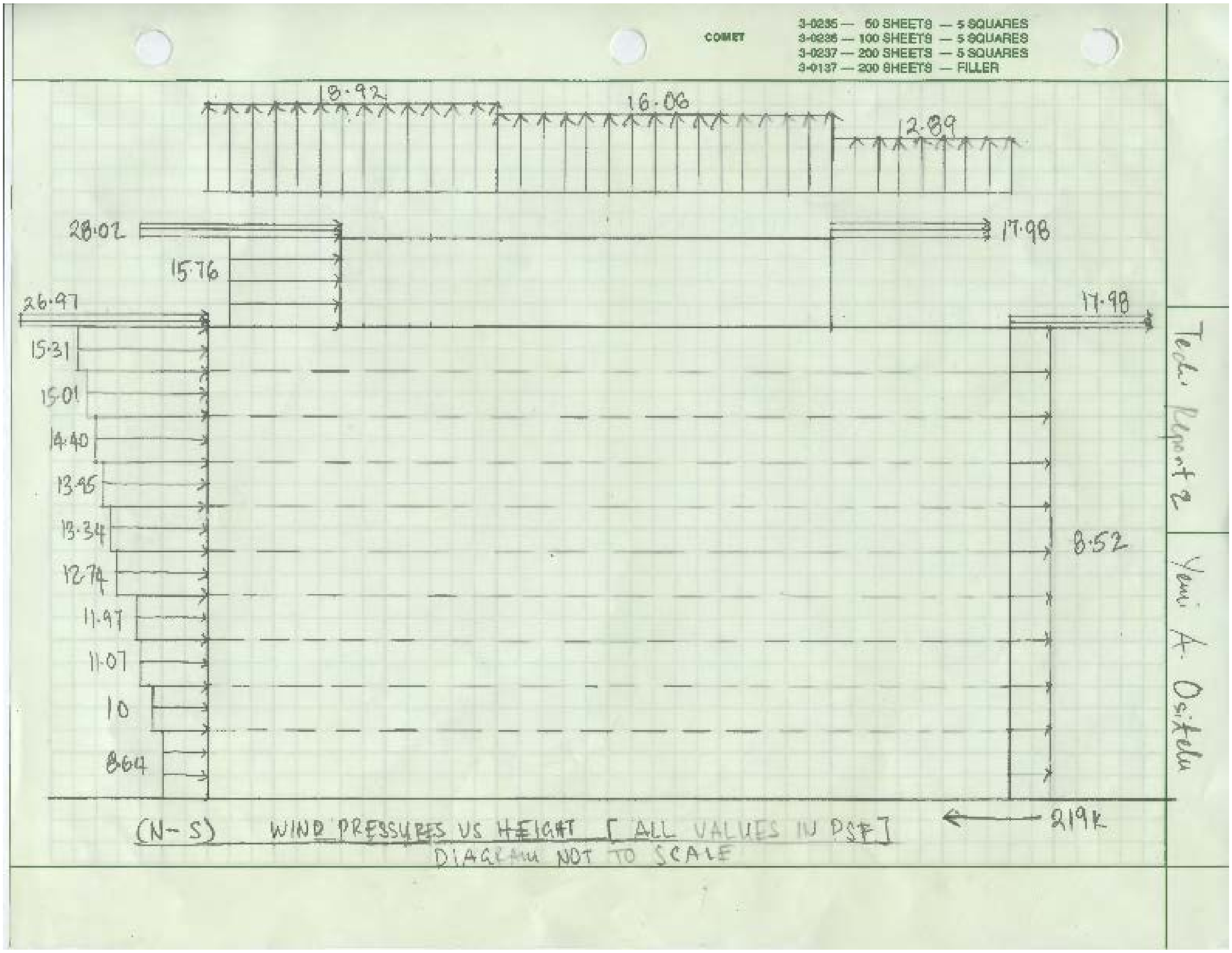
Base shear calculations

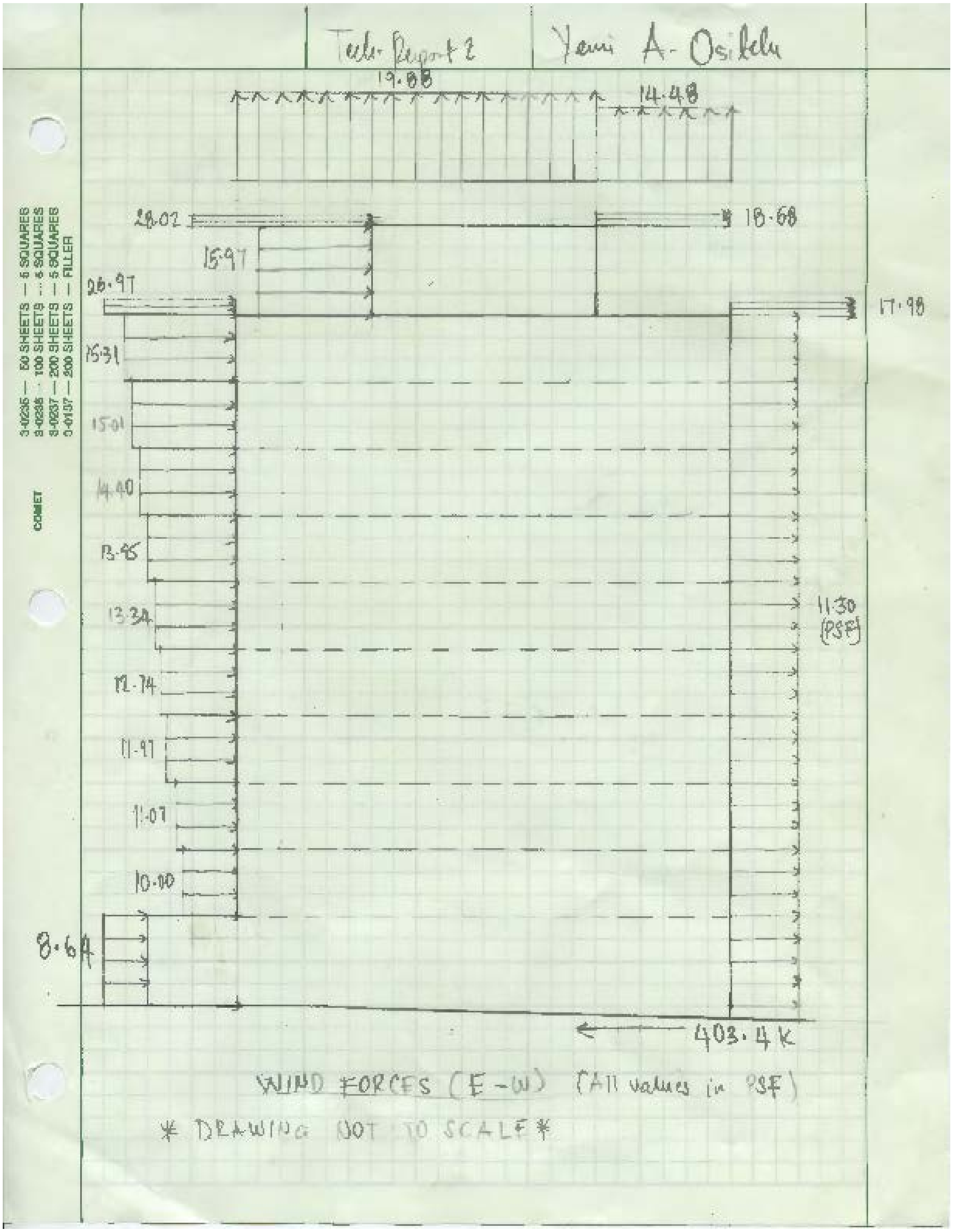
TABLE 2: Base Shear Calculations

Story Height (ft)	Story Trib. Height x Net Pressure x Trib. Width	
	Wind (N-S)	**Wind (E-W)**
15	**22.39**	**41.25**
25.33	**16.64**	**30.66**
35.67	**17.61**	**32.45**
46	**18.42**	**33.94**
56.33	**19.11**	**35.19**
66.67	**19.65**	**36.19**
77	**20.19**	**37.20**
87.75	**20.60**	**37.94**
98.5	**21.15**	**38.95**
109.25	**21.42**	**39.45**
127.25	**21.82**	**40.19**
Base Shear	**219.00**	**403.40**

TABLE 3: Wind Pressures in the East-West Direction

Wind Pressure Chart (E-W)								
Location	z	qz or qh	Cp	Gf	Gcpi	qiGCpi	Net Pressure (PSF)	
							qzGfCp-qi(+Gcpi)	qzGfCp-qi(-Gcpi)
Windward	15	10.05	0.8	0.85	0.18	1.81	5.03	**8.64**
	25.33	11.63	0.8	0.85	0.18	2.09	5.82	**10.00**
	35.67	12.87	0.8	0.85	0.18	2.32	6.44	**11.07**
	46	13.92	0.8	0.85	0.18	2.51	6.96	**11.97**
	56.33	14.81	0.8	0.85	0.18	2.67	7.41	**12.74**
	66.67	15.51	0.8	0.85	0.18	2.79	7.76	**13.34**
	77	16.22	0.8	0.85	0.18	2.92	8.11	**13.95**
	87.75	16.74	0.8	0.85	0.18	3.01	8.37	**14.40**
	98.5	17.45	0.8	0.85	0.18	3.14	8.73	**15.01**
	109.25	17.8	0.8	0.85	0.18	3.20	8.90	**15.31**
	118.5	18.33	0.8	0.85	0.18	3.30	9.17	**15.76**
Leeward	All	18.68	-0.5	0.85	0.18	3.36	**-11.30**	-4.58
Side	All	18.68	-0.7	0.85	0.18	3.36	**-14.48**	-7.75
Roof (0 to 59.25)	118.5	18.68	-1.04	0.85	0.18	3.36	**-19.88**	-13.15
Roof (59.25 to 87)	118.5	18.68	-0.7	0.85	0.18	3.36	**-14.48**	-7.75
Low Parapet WW	110.5	17.98			1.5	26.97		**26.97**
Low Parapet LW	110.5	17.98			-1.0	-17.98		**-17.98**
High Parapet WW	127.25	18.68			1.5	28.02		**28.02**
High Parapet LW	127.25	18.68			-1.0	-18.68		**-18.68**


COMET
3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER
18.92
16.06
12.89
28.02
15.76
26.97
17.98
17.98
15.31
15.01
14.40
13.95
13.34
12.74
11.97
11.07
10
8.64
8.52
219k
(N-S) WIND PRESSURES VS HEIGHT [ALL VALUES IN PSF]
DIAGRAM NOT TO SCALE
Tech. Report 2
Yemi A. Ositelu


Tech. Report 2
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19.88
14.48
28.02
18.68
15.97
26.97
17.98
15.31
15.01
14.40
13.85
13.34
11.30 (PSF)
12.74
11.97
11.07
10.00
8.64
403.4K
WIND FORCES (E-W) (All values in PSF)
* DRAWING NOT TO SCALE *

LATERAL LOADS

Seismic Loads Summary

This sections outlines a summary of values used in the seismic load calculations, in accordance to ASCE 7-05: Chapter 11 and 12.

Site Class – **C**

S_S = **0.154**, S_1 = **0.05**, S_{DS} = **0.123g**, S_{D1} = **0.057g**

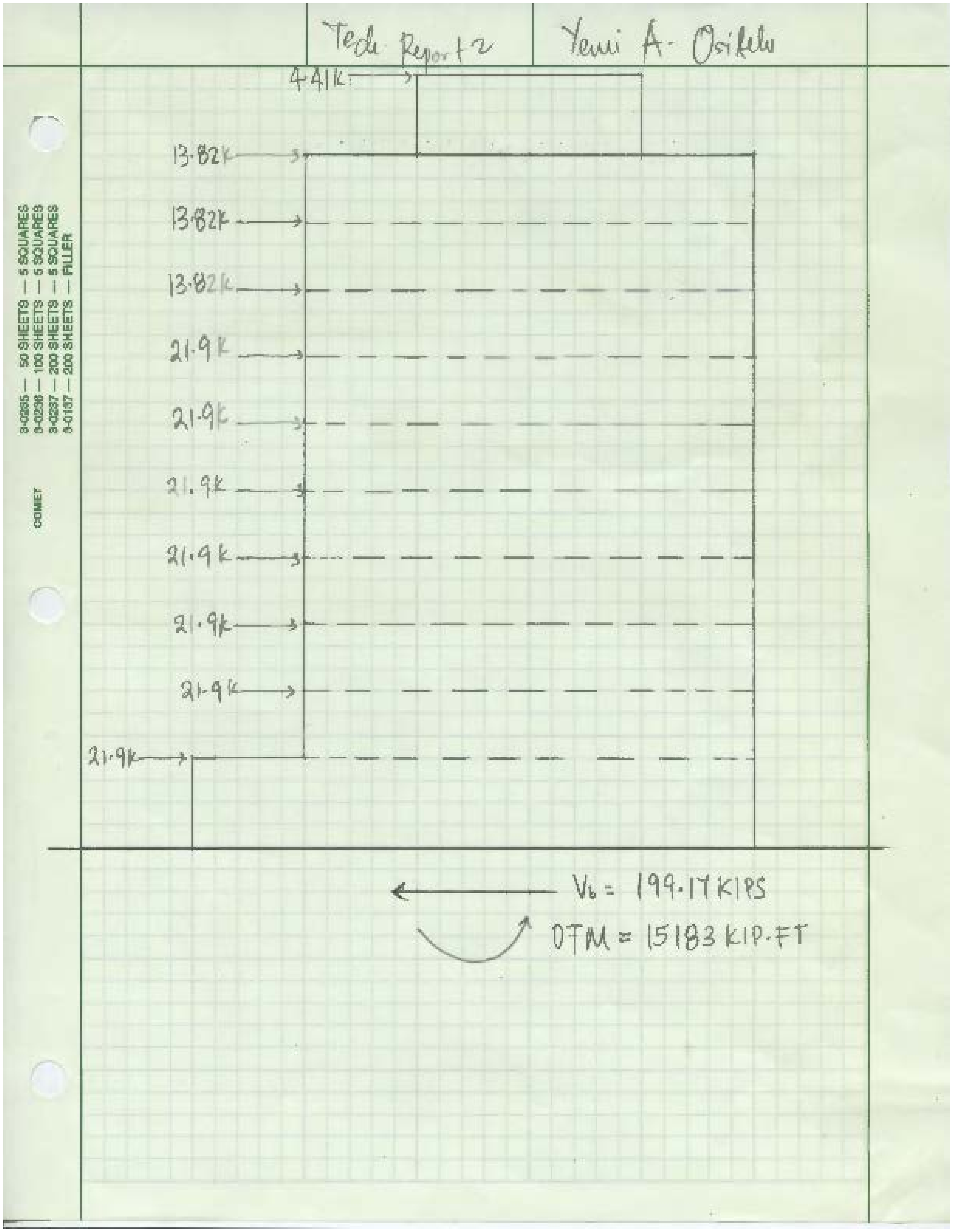
Seismic Importance Factor = **1.0**

Response Modification Factor = **3.0**

Seismic Design Category A

Seismic Analysis Procedure: $\mathbf{F_x = 0.01W_x}$

Total Seismic Weight = **19917 Kips**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4.41k
13.82k
13.82k
13.82k
21.9k
21.9k
21.9k
21.9k
21.9k
21.9k
21.9k
Vb = 199.17 KIPS
OTM = 15183 KIP.FT

OVERVIEW OF ALTERNATIVE SYSTEMS

1. **Reinforced two-way flat slab with edge beams**
2. **Structural steel framing w/ composite joists**
3. **Non-Composite structural steel framing**

SYSTEM COMPARISONS

Criteria	Existing Composite Steel Framing	Reinforced Two-Way Flat Slab	Structural Steel Frame W/ Composite Joists	Non-Composite Structural Steel Frame
Weight (PSF)	57.8	87.5	43.2	53.1
Cost/SF	24.5	13.58	15.8	21.9
Depth (in)	23.25	16	18.5	23.25
Constructability	Medium	Medium	Easy	Medium
Fire Protection	NO	NO	NO	NO
Fire Rating	2 HR	2 HR	2 HR	2 HR
Future Considerations				
Lateral System Impact	N/A	YES	YES	YES
Additional Study Rqd?	N/A	YES	YES	NO
Possible Alternative	N/A	YES	YES	NO

MODELING OF LATERAL LOADS USING COMPUTER SOFTWARE

Hand Calculations and Assumptions

Prior to the analysis of the building on a computer modeling software, a number of hand calculations were performed to compare with the results of the analysis of the computer modeling software. This is to account for an discrepancies that may arise while using the software and also to ensure the practicality and the reasonability of results.

The relative sitffnesses, as shown in table 4 of the frames were determined. Furthermore, loads were distributed to the frames through procedures outlined in the following pages. Table 5 shows the story shears in the building at its different levels

3-0235 — 50 SHEETS — 5 SQUARES
3-0236 — 100 SHEETS — 5 SQUARES
3-0237 — 200 SHEETS — 5 SQUARES
3-0137 — 200 SHEETS — FILLER
COMIT

Tech Report IV Yemi A Ositelu

LOAD DETERMINATION PROCESS

1. Center of Mass and Center of Rigidity

$$\bar{X}_R = \frac{\sum R_y x}{\sum R_y} \qquad X_{cm} = \frac{\sum W_x}{\sum W}$$

$$\bar{Y}_R = \frac{\sum_i R_x y}{\sum R_x} \qquad Y_{cm} = \frac{\sum W_y}{\sum W}$$

2. Relative stiffness were calculated using:

$$K = \frac{12EI}{h^3}$$ where I = moment of Inertia of columns

3. Torsional Rigidity

$$J = \sum_i R_i d_i^2$$

4. Direct Shear

$$V_d = \frac{R_i}{\sum R_i} V$$

5. Torsional Shear

$$V_t = \frac{M_t}{J}(R_i d_i)$$ where

$M_t = V_e$ = Torsional Moment

TABLE 4: RELATIVE STIFFNESSES OF LATERAL ELEMENTS

Relative Stiffness Table	
Frame	**Relative Stiffness, k (k/in)**
A	675
B	270
C	270
D	270
E	270
F	540
A1	4.59
B1	3.06
C1	3.06
D1	3.06
E1	3.06
F1	4.59
G1	3.06
1	856
2	475
3	856
4	475

Included in the appendix is a breakdown of how the majority of the values used in the calculations were derived.

TABLE 5: CALCULATED STORY SHEARS AT EACH LEVEL

Story Height (ft)	Story Shears	
	Wind (N-S)	Wind (E-W)
15	**22.39**	**41.25**
25.33	**16.64**	**30.66**
35.67	**17.61**	**32.45**
46	**18.42**	**33.94**
56.33	**19.11**	**35.19**
66.67	**19.65**	**36.19**
77	**20.19**	**37.20**
87.75	**20.60**	**37.94**
98.5	**21.15**	**38.95**
109.25	**21.42**	**39.45**
127.25	**21.82**	**40.19**
Base Shear	**219.00**	**403.40**

COMPUTER MODELING PROCESS, ASSUMPTIONS AND ANALYSIS

The lateral system of the building was modeled using RAM structural system with the lateral forces for wind and seismic applied to it. The gravity loads for the building were applied to a certain degree, but was not a major consideration in the final analysis of the model. The entire building was modeled as a rigid diaghragm due to the composition of the building, that is concrete + steel. The two underground parking levels were not considered in this model due largely to its minimal lateral effect on the entire structure.

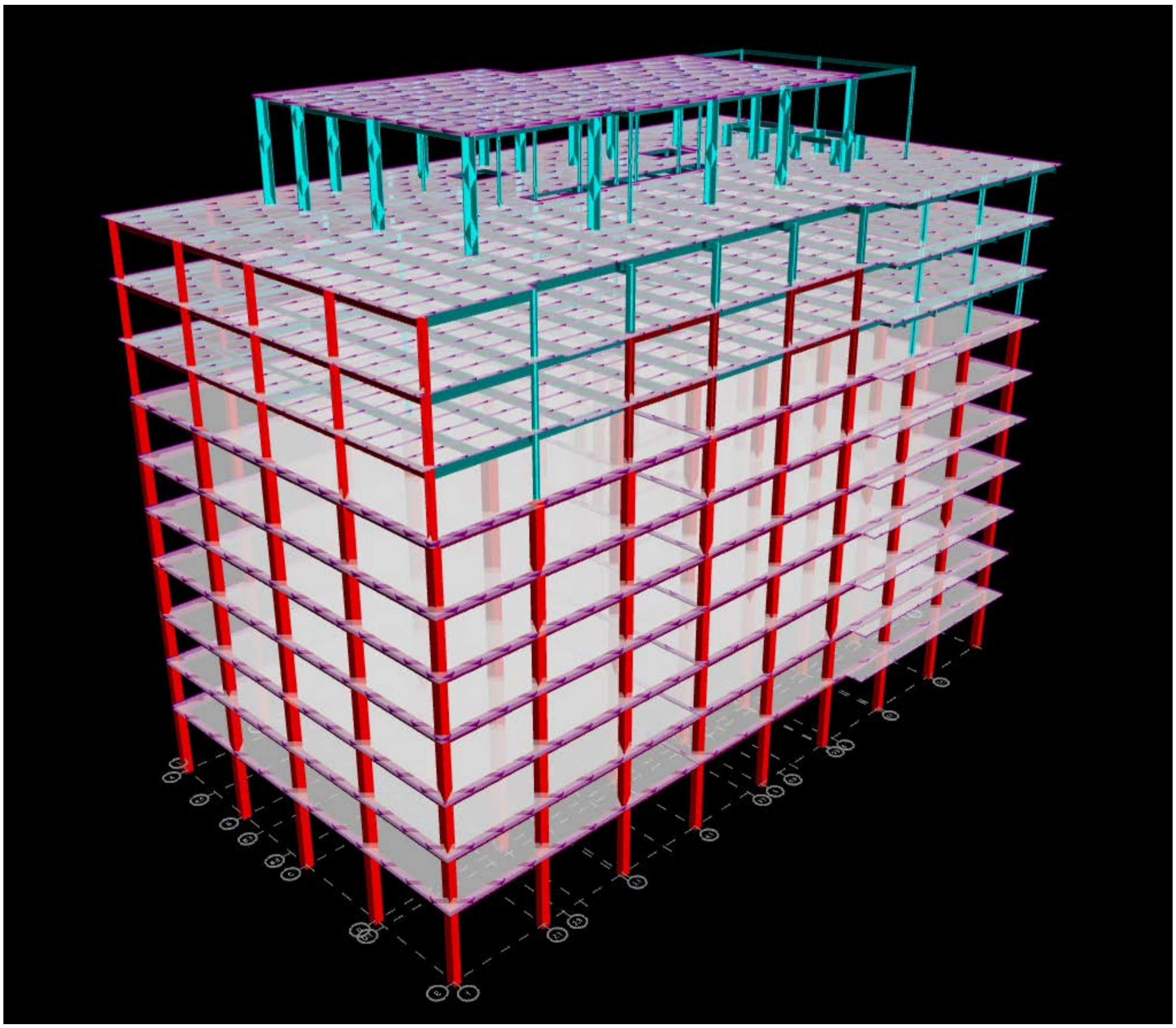


Figure 1 **|** 3D VIEW OF STRUCTURE MODELED IN RAM

Although the penthouse level was modeled, it was not included in the lateral analysis. The moment frames on the penthouse level do not align with the floors below, which results in an error in the computer modeling analysis. Hence, the penthouse was modeled as an all gravity structure and the extra mass load was combined with the mass loads of the main roof diaphragm forces, which would result in no lateral forces at the penthouse level. The ideal situation would be to distribute the reactions from the penthouse to the frames below manually, and run a second model for the verification of those frames. This was not looked at in this report and thus, neglected. However, the situation will be further examined to prevent inaccuracies moving forward.

The fixities at the base were modeled as a fixed-fixed connections and also modeled as fixed –fixed going from the original concrete levels to the new steel addition. This decision was made to account for the moments that are likely to arise due to the nature of its connection.

Drift Check

A control point (**column A1**) was assigned in the RAM - Frame analysis for the determination of the total displacement and story drift at that point. The story drift of the building was checked against **l/400** under wind forces, and **$0.02h_{sx}$** under seismic forces, where h_{sx} is the story below level x. All stories passed under the drift requirement for both wind and seismic.

Case I wind controlled in this analysis

Table 6 shows the drift checks of each story under wind and seismic loads

TABLE 6: STORY DRIFTS UNDER WIND LOADS					
Level	**Total Displacement at c.p A**		**Story Drift from RAM analysis at c.p. A**		**Allowable Drift**
	∂E-W (in)	∂N-S (in)	Δ E-W (in)	Δ N-S (in)	Δ (in)
Main Roof	17.97	5.52	0.46	0.57	3.56
10	17.5	4.94	0.844	0.57	3.56
9	16.67	4.37	1.65	0.62	3.56
8	15.02	3.76	2.45	0.56	3.56
7	12.6	3.19	2.37	0.54	3.56
6	10.2	2.65	2.45	0.58	3.56
5	7.75	2.07	2.66	0.65	3.56
4	5.09	1.42	2.2	0.57	3.56
3	2.89	0.842	1.75	0.49	3.56
2	1.14	0.353	1.14	0.35	3.56

TABLE 7: STORY DRIFTS UNDER SEISMIC LOADS					
Level	**Total Displacement at c.p A**		**Story Drift from RAM analysis at c.p. A**		**Allowable Story Drift**
	∂E-W (in)	∂N-S (in)	Δ E-W (in)	Δ N-S (in)	Δ (in)
Main Roof	7.19	3.87	0.1	0.19	2.58
10	7.09	3.66	0.23	0.24	2.58
9	6.85	3.42	0.55	0.33	2.58
8	6.29	3.08	0.922	0.39	2.58
7	5.37	2.69	0.92	0.21	2.58
6	4.44	2.29	0.99	0.46	2.58
5	3.45	1.84	1.13	0.55	2.58
4	2.32	1.29	0.97	0.51	2.58
3	1.34	0.78	0.8	0.45	2.58
2	0.54	0.33	0.54	0.33	2.58

HAND CALCULATIONS VS COMPUTER MODELING ANALYSIS

The results of both the procedures used in the hand calculations and the computer modeling analysis are compared in this section. These comparisions include the center of rigidity, center of mass and base shears.

CoM & CoR comparisons

Table 8 shows the comparison between the centers of mass and rigidity between the two methods. As seen below, the centers of rigidities are relatively close as compared with the computer modeling analysis. The values for the centers of mass, on the other hand, are somewhat far apart. This may be as a result of the many simplifications made while determining some of the weights of members and overall members used in the analysis. Furthermore, the penthouse CoM and CoR comparisons were neglected for reasons aforementioned.

TABLE 8: COM AND COR COMPARISONS

Center of Mass								
	Steel						Concrete	
Level	Typical		Main Roof		Penthose		Typical	
Direction	x	y	x	y	x	y	x	y
RAM	79.07	40.83	76.67	41.93	_	_	75.25	41.27
Hand Calc.	67.1	42.23	62.34	51.52	_	_	78.5	41.78
Center of Rigidity								
	Steel						Concrete	
Level	Typical		Main Roof		Penthose		Typical	
Direction	x	y	x	y	x	y	x	y
RAM	69.35	41.02	68.82	45.43	_	_	77.83	40.42
Hand Calc.	69.77	41.84	69.78	83.67	_	_	78.5	41.84

*The number highlighted in red doe not make any logical or practical sense.

Base Shear Comparison

The base shears as compared with the computer analysis procedure are relatively close as shown in Table 9 below. The values are within a 10% range between the two methods.

TABLE 9: BASE SHEAR COMPARISON

Comparison of Base Shear under Seismic Loads			
E-W Direction		N-W Direction	
Hand Calcs.	RAM Analysis	Hand Calcs.	RAM Analysis
199.17	**209.89**	**199.17**	**195.63**
Comparison of Base Shear under Wind Loads			
E-W Direction		N-W Direction	
Hand Calcs.	RAM Analysis	Hand Calcs.	RAM Analysis
403.4	**443.6**	**219**	**201.37**

Frame Shear Comparison

The frame shear values between the two methods are relatively far apart. These discreprancies may have resulted due to the simplifications made in the determination of direct and torsional shear, which were accounted for in the hand calculations. However, there is also a possibility in an irregularity in the way forces are distributed in the modeling software. Tables 10 and 11 shows the comparison of the shear in frame A of the steel addition and frame 1 of the typical concrete levels.

TABLE 10: FRAME SHEAR COMPARISONS FOR FRAME A

STEEL MOMENT FRAME - A			
Level	Hand Calc.	RAM Analysis	Ratio (Hand/Comp)
10	**22.15**	43.44	0.51
9	**21.58**	48.49	0.45

TABLE 10: FRAME SHEAR COMPARISONS FOR FRAME 1

CONCRETE MOMENT FRAME - 1			
Level	Hand Calc.	RAM Analysis	Ratio (Hand:Comp)
8	**23.92**	82.14	0.29
7	**23.16**	73.33	0.32
6	**22.52**	71.1	0.32
5	**21.72**	64.6	0.34
4	**20.77**	42.26	0.49
3	**19.62**	6.22	3.15
2	**26.40**	69.2	0.38

The increased shear on the 8th level from the RAM analysis may be as a result of the fixities at the base of the transition from concrete to steel, which were modeled as fixed connections in the modeling software.

MEMBER STRENGTH SPOT CHECKS FOR LATERAL LOADS

Tech Report IV Yemi A. Ositelu

Column A3 at level 10 : W12x96

$L_b = 10.75'$ *Controlling LC − 1.2D + 1.6W + 0.5S

From RAM model

$P_r = 25.62^k$ [Combined Gravity & Lateral]

$M_{rx} = 3.92$ kft

$M_{ry} = 9.52$ kft

AISC. 14th Edition, T6-1 KL = 11

$p \times 10^3 = 0.901$

$b_x \times 10^3 = 1.61$ $b_y = 3.51$

$pP_r + b_x M_{rx} + b_y M_{ry} \leq 1.0$

$(0.915 \times 10^{-3})(25.62) + (1.61 \times 10^{-3})(3.92) + (3.51 \times 10^{-3})(0.52)$

$= 0.032 << 1.$

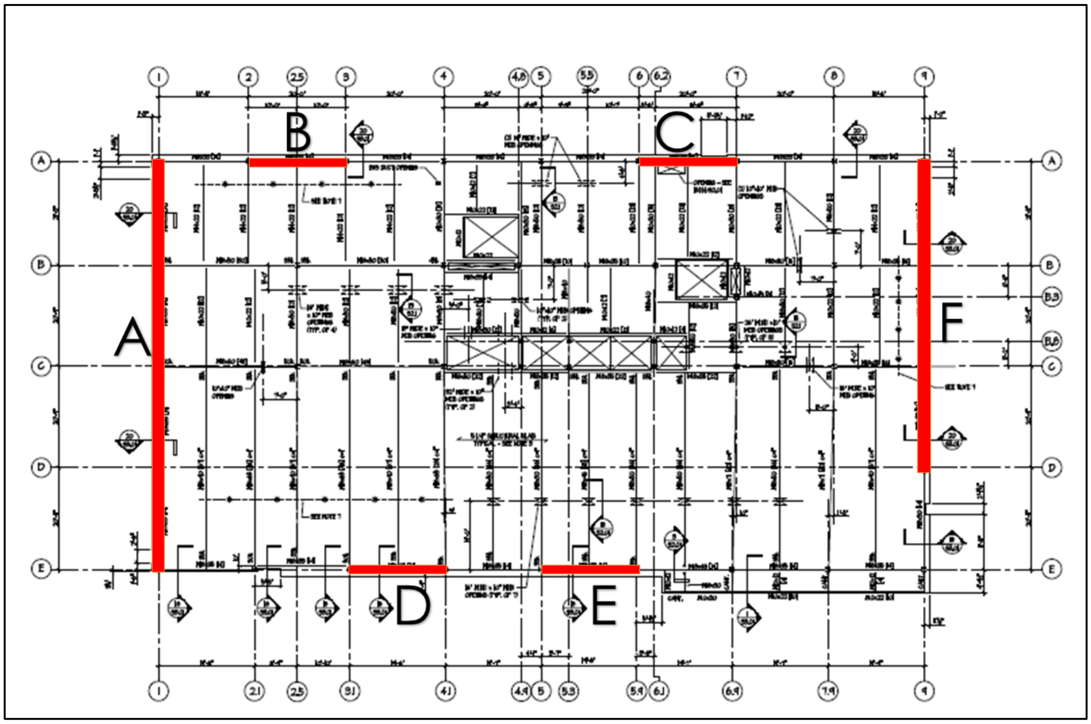
Column is acceptable for that level

CONCLUSION

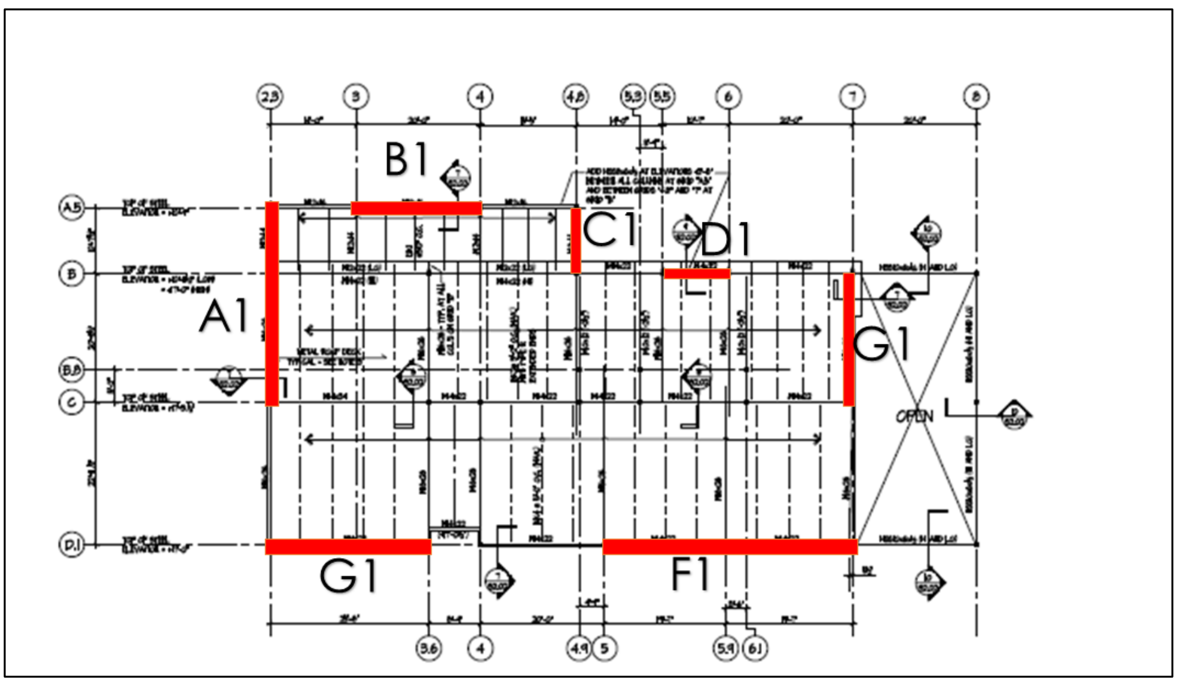
The computer modeling analysis was a fairly successful one, excluding the many assumptions and simplifications that were made. Greater efforts will be made to ensure more precise and accurate results, and a

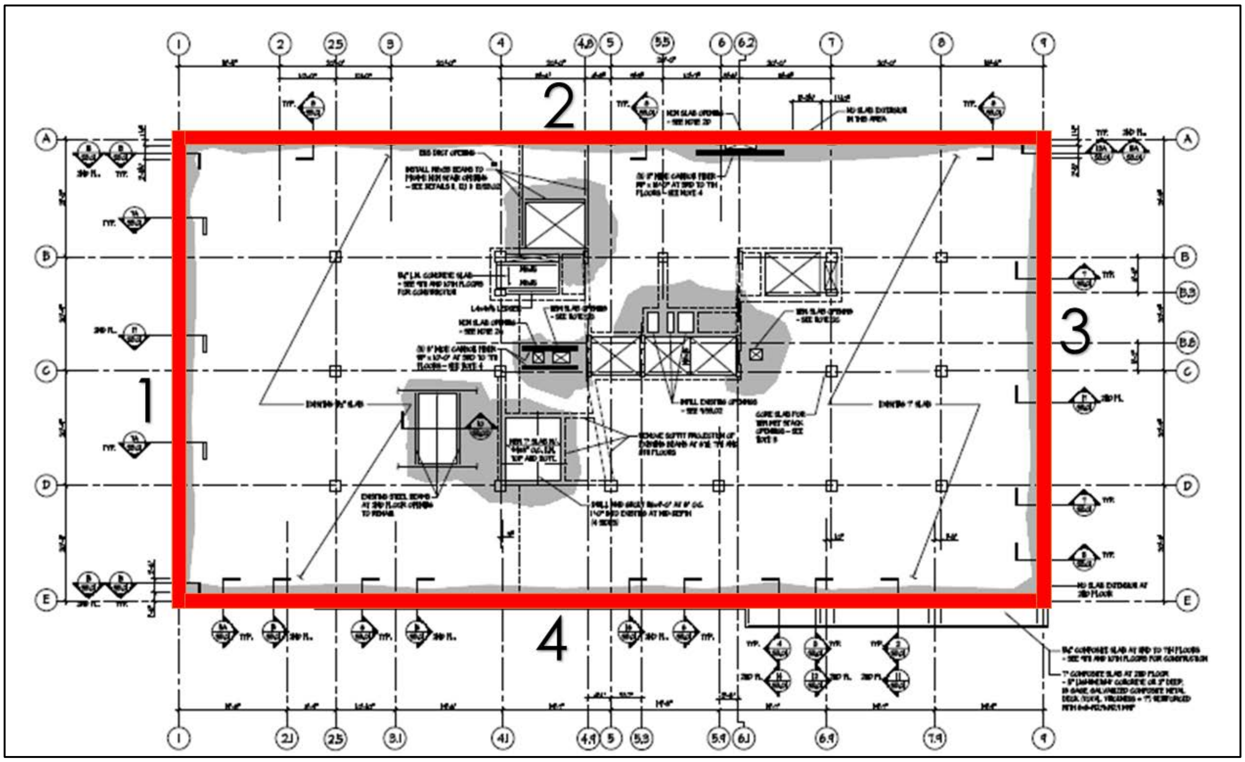
APPENDIX

STEEL MOMENT FRAMES (LEVELS 9 AND 10)



STEEL MOMENT FRAMES (PENTHOUSE LEVEL)





CONCRETE MOMENT FRAMES

Center of Rigidity Calculations

Center of Rigidity of Typical Concrete Levels							
Element Label	Element Direction	x	y	**Rx**	**Ry**	**RxY**	**Ryx**
1	y	_	_	_	**856**	_	_
2	x	_	83.67	**475**	_	**39743.3**	_
3	y	157	_	_	**856**	_	**134392**
4	x	_	_	**475**	_	_	_
				950	**1712**	**39743.3**	**134392**

x	**78.5**
y	**41.835**

Center of Rigidity of Steel Addition (9 and 10)							
Element Label	Element Direction	x	y	**Rx**	**Ry**	**RxY**	**Ryx**
A	y	_	_	_	**675**	_	_
B	x	_	83.67	**270**	_	**22590.9**	_
C	x	_	83.67	**270**	_	**22590.9**	_
D	x	_	_	**270**	_	_	_
E	x	_	_	**270**	_	_	_
F	y	157	_	_	**540**	_	**84780**
				1080	**1215**	**45181.8**	**84780**

y	**41.835**
x	**69.7778**

Center of Rigidity Calculations cont.

Center of Rigidity of Steel Addition (Roof)							
Element Label	Element Direction	X	Y	**Rx**	**Ry**	**RxY**	**Ryx**
A	y				**675**		
B	x		83.67	**270**		**22590.9**	
C	x		83.67	**270**		**22590.9**	
F	y	157			**540**		**84780**
				540	**1215**	**45181.8**	**84780**

x	**69.78**
y	**83.67**

Calcularion of Center of Rigidity for Steel Addition (Penthouse Roof)							
Element Label	Element Direction	x	y	**Rx**	**Ry**	**RxY**	**Ryx**
A1	y	_	_	_	**4.59**	_	_
B1	x	_	54.3125	**3.06**	_	**166.196**	_
C1	y	49.417	_	_	**3.06**	_	**151.216**
D1	x	_	43.67	**3.06**	_	**133.63**	
E1	y	94	_	_	**3.06**	_	**287.64**
F1	x	_	_	**4.59**	_	_	_
G1	x	_	_	**3.06**	_	_	_
				13.77	**10.71**	**299.826**	**438.856**

y	**21.7739**
x	**40.9763**

Center of Mass Calculations

Center of Mass of Typical Concrete Levels								
Element	Area	Height	Density	**W**	x	y	**Wx**	**Wy**
1	1.333	10.25	0.145	**1.98117**	0	41.85	**0**	**82.912**
2	1.333	10.25	0.145	**1.98117**	78.5	41.85	**155.522**	**82.912**
3	1.333	10.25	0.145	**1.98117**	157	41.85	**311.044**	**82.912**
4	1.333	10.25	0.145	**1.98117**	78.5	0	**155.522**	**0**
Slab	13136	0.6875	0.145	**1309.5**	78.5	41.85	**102795**	**54802.4**
				1317.42			**103417**	**55051.1**

Xcm	**78.5**	**Ycm**	**41.7871**

Calculation of Center of Mass for Typical Addition (9 & 10)											
Element	plf of beam	length of beam	W	plf of col	height of col	W	**Total wt.**	x	y	Wx	Wy
A	35.00	21.25	0.74	96.00	10.75	1.03	**8.09**	0.00	41.85	0.00	338.50
	35.00	20.75	0.73	96.00	10.75	1.03					
	35.00	20.75	0.73	96.00	10.75	1.03					
	35.00	20.92	0.73	96.00	10.75	1.03					
				96.00	10.75	1.03					
B	35.00	20.00	0.70	96.00	10.75	1.03	**2.76**	28.42	83.67	78.54	231.26
				96.00	10.75	1.03					
C	35.00	20.00	0.70	49.00	10.75	0.53	**1.75**	108.48	83.67	190.22	146.72
				49.00	10.75	0.53					
D	35.00	19.50	0.68	96.00	10.75	1.03	**2.75**	49.00	0.00	134.58	0.00
				96.00	10.75	1.03					
E	35.00	19.67	0.69	96.00	10.75	1.03	**2.75**	88.25	0.00	242.90	0.00
				96.00	10.75	1.03					
F	35.00	21.25	0.74	96.00	10.75	1.03	**6.32**	157.00	49.84	992.91	315.18
	35.00	20.75	0.73	96.00	10.75	1.03					
	35.00	20.75	0.73	96.00	10.75	1.03					
				96.00	10.75	1.03					
		Xcm	**67.10**				**24.43**			**1639.15**	**1031.66**
		Ycm	**42.23**								

Center of Mass calculations continued

<table>
<tr><th colspan="13">Center of Mass of Typical Addition (Roof)</th></tr>
<tr><th>Element</th><th>plf of beam</th><th>length of beam</th><th>W</th><th>plf of col</th><th>height of col</th><th>W</th><th>Total wt.</th><th>x</th><th>y</th><th>Wx</th><th>Wy</th></tr>
<tr><td rowspan="5">A</td><td>35.00</td><td>21.25</td><td>0.74</td><td>96.00</td><td>10.75</td><td>1.03</td><td rowspan="5">8.09</td><td rowspan="5">0.00</td><td rowspan="5">41.85</td><td rowspan="5">0.00</td><td rowspan="5">338.50</td></tr>
<tr><td>35.00</td><td>20.75</td><td>0.73</td><td>96.00</td><td>10.75</td><td>1.03</td></tr>
<tr><td>35.00</td><td>20.75</td><td>0.73</td><td>96.00</td><td>10.75</td><td>1.03</td></tr>
<tr><td rowspan="2">35.00</td><td rowspan="2">20.92</td><td rowspan="2">0.73</td><td>96.00</td><td>10.75</td><td>1.03</td></tr>
<tr><td>96.00</td><td>10.75</td><td>1.03</td></tr>
<tr><td rowspan="2">B</td><td rowspan="2">35.00</td><td rowspan="2">20.00</td><td rowspan="2">0.70</td><td>96.00</td><td>10.75</td><td>1.03</td><td rowspan="2">2.76</td><td rowspan="2">28.42</td><td rowspan="2">83.67</td><td rowspan="2">78.54</td><td rowspan="2">231.26</td></tr>
<tr><td>96.00</td><td>10.75</td><td>1.03</td></tr>
<tr><td rowspan="4">F</td><td>35.00</td><td>21.25</td><td>0.74</td><td>96.00</td><td>10.75</td><td>1.03</td><td rowspan="4">6.32</td><td rowspan="4">157.00</td><td rowspan="4">49.84</td><td rowspan="4">992.91</td><td rowspan="4">315.18</td></tr>
<tr><td>35.00</td><td>20.75</td><td>0.73</td><td>96.00</td><td>10.75</td><td>1.03</td></tr>
<tr><td rowspan="2">35.00</td><td rowspan="2">20.75</td><td rowspan="2">0.73</td><td>96.00</td><td>10.75</td><td>1.03</td></tr>
<tr><td>96.00</td><td>10.75</td><td>1.03</td></tr>
<tr><td></td><td></td><td>Xcm</td><td>62.379</td><td></td><td></td><td></td><td>17.18</td><td></td><td></td><td>1071.45</td><td>884.94</td></tr>
<tr><td></td><td></td><td>Ycm</td><td>51.52</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Torsional Rigidity & Total Shear Calculations

Torsional Rigidity				
Element	**Ri**	di	di*di	**Ridi2**
A	**675**	69.77	4867.85	**3285800.71**
B	**270**	41.87	1753.1	**473336.163**
C	**270**	41.87	1753.1	**473336.163**
D	**270**	41.83	1749.75	**472432.203**
E	**270**	41.83	1749.75	**472432.203**
F	**540**	87.23	7609.07	**4108899.37**
				9286236.81

Torsional Rigidity				
Element	**Ri**	di	di*di	**Ridi2**
1	**856**	78.5	6162.25	**5274886**
2	**475**	41.835	1750.17	**831329.432**
3	**856**	78.5	6162.25	**5274886**
4	**475**	41.835	1750.17	**831329.432**
				12212430.9

Torsional Rigidity & Total Shear Calculations cont.

Total Shear Calculation			
Level	Direct Shear	Torsional Shear	**Total Shear**
10	21.64	0.52	**22.15**
9	21.08	0.50	**21.58**

Total Shear Calculation			
Level	Direct Shear	Torsional Shear	**Total Shear**
8	23.92	0.00	**23.92**
7	23.16	0.00	**23.16**
6	22.52	0.00	**22.52**
5	21.72	0.00	**21.72**
4	20.77	0.00	**20.77**
3	19.62	0.00	**19.62**
2	26.40	0.00	**26.40**