Letter of Transmittal

November 20, 2013

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Dear Professor Sustersic,

This report was written to fulfill the fourth of five technical report requirements set by the structural faculty for Penn State's Senior Thesis Capstone Project. This report, Technical Report 4, was assigned October 23, 2013.

The main goal of Technical Report 4 is to complete a lateral analysis of Reinsurance Group of America's Global Headquarters. The result of this analysis is to determine if the lateral system meets the strength and serviceability requirements under the previously calculated wind and seismic loading. This analysis includes evaluating the presence of irregularities and their analytical impact. All findings and calculations in this report have been documented in a calculations binder as well as an accompanying presentation of the findings given.

Thank you in advance for reviewing this report and the accompanying presentation. I look forward to hearing your feedback.

Sincerely,

Natasha Beck
Structural Option
Architectural Engineering Thesis Student

Enclosed: Technical Report 4

Reinsurance Group of America (RGA) Global Headquarters

Technical Report 4

Lateral Systems Analysis Study

16600 Swingley Ridge Rd.
Chesterfield, MO

Natasha Beck, Structural
Heather Sustersic
20 November 2013

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General Information

This section provides background information for RGA Global Headquarters.

Reinsurance Group of America (RGA) Global Headquarters

16600 Swingley Ridge Rd. Chesterfield, MO

Project Team

Owner: Reinsurance Group of America, Inc.
Owner Representative: Gateway Ridge LLC
General Contractor: Clayco
Architect: Gensler
Structural Engineer: Uzun & Case
Civil Engineer: Stock & Associates, Inc.
Landscape Architect: Forum Studio
Lighting Consultant: Randy Burkett Lighting Design, Inc.
MEP & Fire Protection: Environmental Systems Design, Inc.

Building Information

Occupancy: General office and training
Size: 405,000 gross square feet
Total Estimated Cost: $150 million
Project Delivery: Design-Build

Structural

- Two, 5 story steel office towers with composite floors with 3 1/2" semi-lightweight concrete topping
- Upper four levels cantilever 40’ over the first level supported by a steel truss system
- Office towers have braced frame lateral system while parking garage utilizes reinforced concrete shear walls
- Parking garage is post-tensioned, reinforced concrete
- Drilled concrete piers 36" to 78" in diameter with allowable end bearing pressure of 80 ksf

Architecture

- Two skewed, 5 story office towers with curtain wall façades linked by an amenities level
- Open plan office towers with central core
- Amenities include kitchen, fitness center, café and landscaped terrace
- Two story underground parking garage with limestone façade where exposed
- Three landscaped bio-retention basins
- Designed to achieve LEED Silver

Mechanical

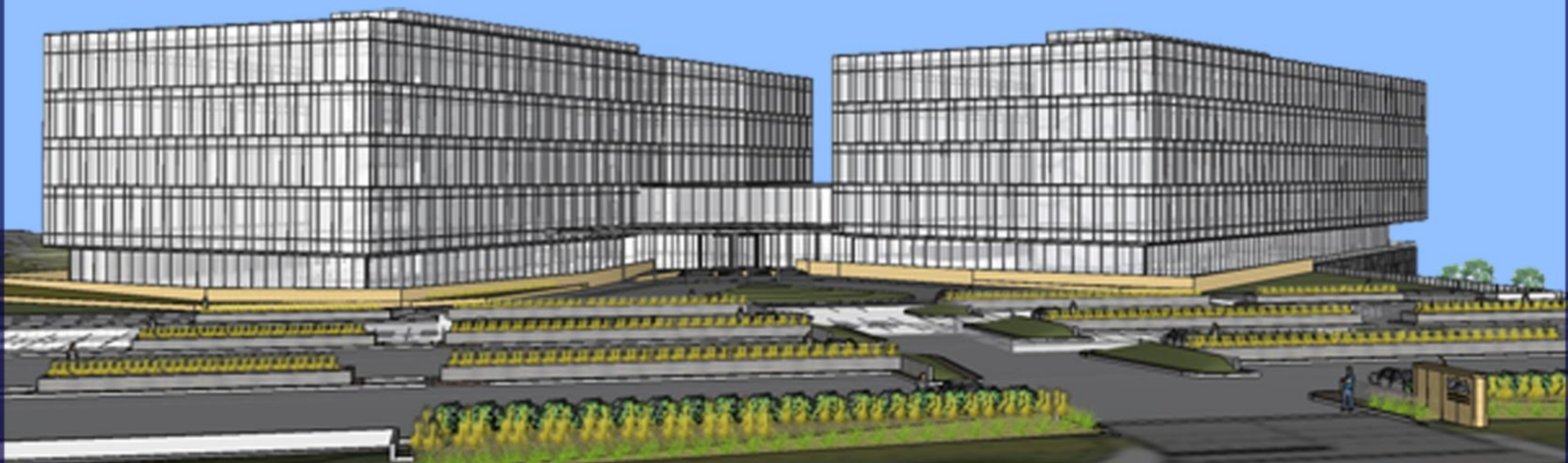
- Designed for year-round cooling
- Cooling towers serve three, 350 ton water cooled chillers
- Four 60,000 CFM air handling units serve the office towers
- A medium pressure loop on each floor for VAV branches
- Separate fan powered terminal units (FPTU) heat the floor cavity of the cantilever space counteracting the heat sink

Electrical

- Mechanical, lighting serviced by 480/277 volt system
- Office receptacles serviced by 208/120 volt system
- Both systems are fed by 3-phase, 4-wire buses
- Four main switchboards rated at 3000 amperes
- Diesel generator serves emergency equipment

Lighting & Controls

- Occupancy sensors in restrooms
- Exterior and restroom lighting fixtures on 277 volts
- Fluorescent lamps and LED lamps specified to date
- Interior lighting design is in the final design stages



Executive Summary

The purpose of this technical report is to evaluate the existing structural systems in the Reinsurance Group of America's Global Headquarters. This included preliminary analysis of the gravity and lateral systems and any unique structural features of the project. It looks at the main structural components and their influence on the load paths for wind, seismic, soil and gravity, which influence the main structural systems.

This preliminary research was executed by reviewing project documents, primarily drawings, and tracking these systems throughout the buildings. Findings of the systems' functionality and influence on other pieces of the project were then recorded and supporting information compiled into the body of this report.

In conclusion, critical structural features that will influence future analysis are the 40' cantilever truss system and maintaining the integrity of the soil load path so that it does not redistribute into the post-tensioned slabs.

Site Plan

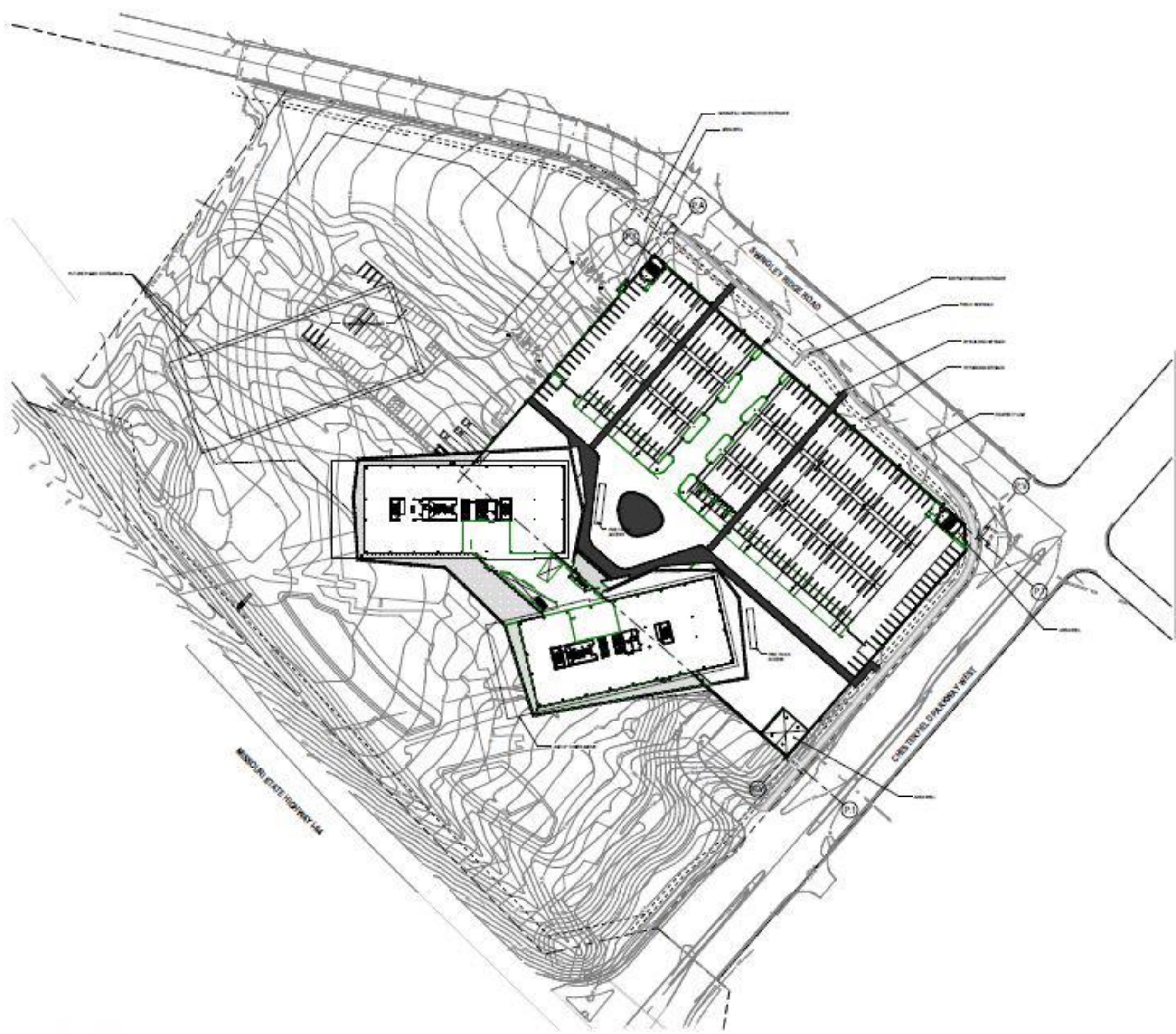


Figure 1: RGA Global Headquarters Site Plan by Gensler

Vicinity and Location Plans

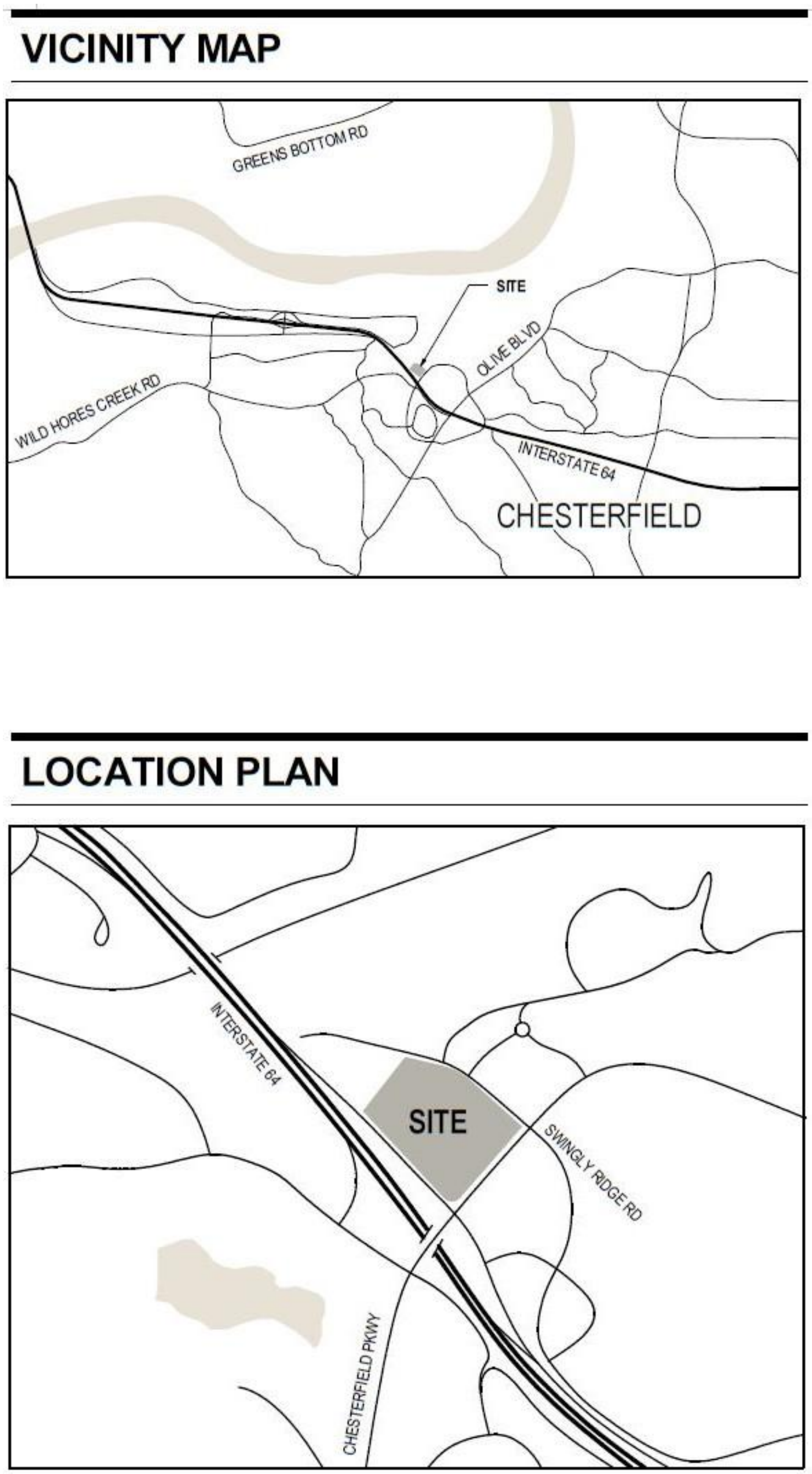


Figure 2: Vicinity and Location Plans by Gensler

Documents List

Listed below are the documents used in preparation of Technical Report 3.

- *RGA Core and Shell Addendum A* Design Documents by the Project Team (See Abstract)
- Minimum Design Loads for Buildings and Other Structures, ASCE 7-05
- AISC Steel Construction Manual, AISC 360-10
- Building Code Requirements for Structural Concrete and Commentary, ACI 318-11
- Design of Steel Structures Class Notes
- Design of Masonry Structures Class Notes
- Design of Concrete Structures Class Notes

Load Summary and Revisions

This section summarizes previously calculated loads and presents revisions to the seismic load determination.

LOAD SUMMARY

GRAVITY

- FLOOR DL = 69 PSF
- FLOOR LL = 50 PSF
- CURTAIN WALL DL = 211 PLF
- ROOF DL = 38 PSF
- ROOF LL = 20 PSF
- SNOW LOAD = 22 PSF

SEISMIC

- USGS DATA

  $S_S = 0.501$ $S_1 = 0.153$

  $S_{DS} = 0.400$ $S_{D1} = 0.168$

- OFFICE
  - FROM TECHNICAL REPORT 2

    $R = 3$ $I = 1.25$

    $T_a = 0.561\,s$ $T_L = 12\,s$

  - $C_{S\,MAX} = \dfrac{S_{D1}}{T_a(R/I)} = \dfrac{0.168}{0.561(3/1.25)} = 0.125$

    $C_S = \dfrac{S_{DS}}{R/I} = \dfrac{0.400}{3/1.25} = 0.167$ $\therefore C_S = 0.125$

  - OFFICE $W_{TOTAL} = 26707^k$ [SEE SPREADSHEET]
  - $V_{BASE} = C_S W = 0.167(26707^k) = \mathbf{3338^k}$

- PARKING
  - $R = 5$: ORDINARY RC SHEAR WALLS
  - $T_a = 0.018\,s$ [SEE SPREADSHEET]
  - $C_{S\,MAX} = \dfrac{0.168}{0.018(5/1.25)} = 2.33$

    $C_S = \dfrac{0.400}{5/1.25} = 0.10$ $\therefore C_S = 0.10$

  - PARKING $W_{TOT} = 8468^k$
  - $V_{BASE} = 0.10(8968^k) = \mathbf{897^k}$

- TWO STAGE ANALYSIS REACTION TRANSFER COEFFICIENT REMAINS 1.0

$\therefore V_{BASE} = V_{OFFICE} + V_{PARKING}$

$V_{BASE} = 3338^k + 897^k = \mathbf{4235}^k > 733^k$ WIND

$\therefore$ SEISMIC CONTROLS

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PROJECT: RGA GLOBAL HQ TECHNICAL REPORT 4

TITLE: LOAD SUMMARY SEISMIC

BY: NMB	SHEET: G.3
CHKD:	PROJECT NO: TECH 4
DATE:	PAGE:

COMBINED STORY WEIGHTS (k)						
	Parking Structure				Office	
Level	**Walls**	**Columns**	**Slabs**	**Beams**	**Total**	**Total**
B1	1286	431	5839	1412	0	8968
1	702	246	7201	3348	1881	13378
2	0	0	0	0	2521	2521
3	0	0	0	0	2527	2527
4	0	0	0	0	2527	2527
5	0	0	0	0	2531	2531
6	0	0	0	0	1680	1680
Penthouse	0	0	0	0	1543	1543

MODELING ADJUSTMENTS		
Level	**Weight(k)**	**Total(k)**
B1	8968	8968
1	To 2	
2	15899	
3	2527	
4	2527	
5	2531	
6	1680	
Penthouse	1543	26707

A_b=	66733	SF
h_n=	26	ft.
h_i=	26	ft.

APPROX. FUNDAMENTAL PERIOD: PARKING				
SW #	**D_i**	**A_i**	**NW-SE Dir.**	**NE-SW Dir.**
5	55.7	1447	1225.45	-
	22.7	589	-	281.70
6	23.0	598	-	290.20
10	60.0	1560	-	1349.65
Wall PV	180	4680	4600.33	-
Wall P1	134	3484	-	3378.43
		Sum=	5826	5300
		C_w=	8.730	7.942
		T_a=	**0.017**	**0.018**

MWFRS ANALYSIS: NW-SE Walls								
Floor	**z**	**q**	**Windward (PSF)**	**Leeward (PSF)**	**Tribuary Height(ft.)**	**Tributary Area(SF)**	**Story Shear(k)**	**Story M_{OT}(ft.-k)**
B1	11.17	10.7	10.00	-4.79	18.585	2323	34.36	64.5
1	26	13.6	10.00	-4.79	15.04	1579	23.36	431.6
2	41.25	15.6	10.74	-4.79	14.625	1682	26.12	886.3
3	55.25	16.9	11.67	-4.79	14	1610	26.51	1278.9
4	69.25	18.0	12.45	-4.79	14	1610	27.76	1727.9
5	83.25	19.0	13.12	-4.79	14.2	1633	29.25	2227.6
6	97.65	19.9	13.74	-4.79	7.2	828	15.34	1442.7
Tower Parapet	100.65	20.1	30.10	-20.26	3	345	17.37	1722.6
Mean Roof Height	104	20.3	13.99	-4.79	6.975	244	4.58	460.7
T.O. Penthouse	111.25	20.7	14.26	-4.79	3.625	127	2.42	264.5
Penthouse Parapet	114.25	20.8	31.21	-20.26	3	105	5.40	609.3
						Base Shear and M_{OT}=	**212**	**11117**

$p=qG_fC_p-q_i(GC_{pi})$

G_f=	0.863	
C_p=	0.8	Windward
	-0.274	Leeward
GC_{pn}=	1.5	Windward
	-1.0	Leeward
q_h=	20.7	ft.
GC_{pi}=	0.18	[+/-]

MWFRS ANALYSIS: NW-SE ROOF				
Dist. H	0' to 52'	52' to 104'	104' to 208'	>208'
C_p	-0.9	-0.9	-0.5	-0.3
Pressure (PSF)	**-16.04**	**-16.04**	**-8.91**	**-5.35**

MWFRS ANALYSIS: NE-SW Walls								
Floor	**z**	**q**	**Windward (PSF)**	**Leeward (PSF)**	**Tribuary Height(ft.)**	**Tributary Area(SF)**	**Story Shear(k)**	**Story M_{OT}(ft.-k)**
B1	11.17	10.7	10.49	-10.1	18.585	5390	111.15	208.7
1	26	13.6	10.91	-10.1	15.04	3685	77.50	1432.3
2	41.25	15.6	12.44	-10.1	14.625	4241	95.73	3248.8
3	55.25	16.9	13.53	-10.1	14	4060	96.04	4633.8
4	69.25	18.0	14.43	-10.1	14	4060	99.70	6206.2
5	83.25	19.0	15.21	-10.1	14.2	4118	104.33	7944.8
6	97.65	19.9	15.92	-10.1	7.2	2088	54.38	5114.5
Tower Parapet	100.65	20.1	30.10	-20.3	3	870	43.81	4344.0
Mean Roof Height	104	20.3	16.21	-10.1	6.975	977	25.71	2584.7
T.O. Penthouse	111.25	20.7	16.52	-10.1	3.625	508	13.52	1480.1
Penthouse Parapet	114.25	20.8	31.21	-20.3	3	420	21.62	2437.3
						Base Shear and M_{OT}=	**743**	**39635**

$p=qG_fC_p-q_i(GC_{pi})$	**G_f=**	1.0	
	C_p=	0.8	Windward
		-0.5	Leeward
	GC_{pn}=	1.5	Windward
		-1.0	Leeward
	q_h=	20.7	ft.
	GC_{pi}=	0.18	[+/-]

MWFRS ANALYSIS: NE-SW ROOF				
Dist. H	0' to 52'	52' to 104'	104' to 208'	>208'
C_p	-1.01	-0.738	-0.662	-0.623
Pressure (PSF)	**-20.9**	**-15.2**	**-13.7**	**-12.9**

Methodology and Assumptions

This section presents the method used for load and structural modeling and assumptions made.

Load Distribution

Wind loads are applied at the center of pressure which corresponds to the geometric centroid of the diaphragm and seismic loads were applied at the center of mass. These points are typically eccentric with respect to the center of rigidity, which is the diaphragm's axis of rotation, causing inherent torsion. Loads are distributed to the lateral elements according to their stiffnesses relative to each other. The higher the relative stiffness the higher the portion of the load it will take. Torsion distributes load in the form of in-plane shear to the elements based on their direction and location, or moment arm.

To mimic the existing conditions, the story weight of Level 01 is lumped with the story weight of Level 02 for the story shear calculations. In addition, at the penthouse roof level, there are no lateral elements because the framing is an extension of the columns below. To model this, the story shear at the penthouse roof level for both wind and seismic is added onto the shear of the level below it.

Modeling Process

RGA Global Headquarters has several structural features, two of which were particularly significant to the lateral system analysis. First, structural separation joints split the parking garage structure into four separate buildings, meaning that the scope of this assignment could be narrowed to just one of those areas. Second, because the steel system and concrete system act together and meet the requirements of the Two Stage Analysis Procedure in ASCE 7, two separate models were created. One is the braced frame model of the office lateral system and the second is the shear wall and foundation wall system of the parking garage. For the parking garage structure, the grid had to first be drawn in AutoCAD and imported in order to change the grid orientation properly within the same model.

First, load cases were calculated for each system and applied in their separate models. Then, the controlling load cases from the office model were determined and the reactions at each of the braced frame bases were recorded. These reactions were applied to the tops of the shear walls in the parking garage model within their respective load cases. Results regarding the overall structure or the parking garage were determined with the brace frame reactions incorporated. For the steel member checks, the office model was used.

Assumptions

- Braced frames have pinned bases because the anchor rods only transmit the vertical loads into the column below and allows rotation at the joint.
- Shear walls are assumed to have pinned bases because they sit on essentially large strip footers that are supported by the drilled piers and do not resist rotation of the shear wall.
- In both the office and the parking garage, rigid diaphragms were assumed because of the concrete slabs present in each system. The office has a composite steel deck and the parking garage has a thick floor slab.

Lateral Analysis

This section presents lateral calculations of loads, member stiffnesses, and centers of mass and rigidity.

STRUCTURAL IRREGULARITIES

HORIZONTAL

TYPE	OFFICE	PARKING
• 1a) TORSIONAL IRR.	NO	NO
• 1b) EXTREME TORSIONAL IRR.	NO	NO
• 2) REENTRANT CORNER IRR.	N/A	N/A
• 3) DIAPHRAGM DISCONT. IRR.	N/A	N/A
• 4) OUT-OF-PLANE OFFSET IRR.	NO	NO
• 5) NON-PARALLEL SYSTEMS IRR.	NO	YES

- ASCE 7-05 §12.5.3, 12.7.3, 16.2.2 APPLY
  - 12.5.3 : 100 + 30 INCORPORATED ✓
  - 12.7.3 : 3D MODEL ✓
    - MODEL DOFS ✓
    - CRACKED CONCRETE ELEMENTS ✓
  - 16.2.2 : DOES NOT APPLY
- TYPE 1 EXAMPLE CALCULATION:
  $3.19'' \not> 1.2(3.19'' + 6.40'')(1/2) \therefore$ NO TYPE 1 IRR.

VERTICAL

TYPE	OFFICE	PARKING
• 1a) SOFT STORY IRR.	N/A	N/A
• 1b) EXTREME SOFT STORY IRR.	N/A	N/A
• 2) WEIGHT (MASS) IRR.	N/A	N/A
• 3) VERTICAL GEOMETRIC IRR.	N/A	N/A
• 4) IN-PLANE DISCONT.... IRR.	NO	NO
• 5a) WEAK STORY IRR.	N/A	N/A
• 5b) EXTREME WEAK STORY IRR.	NO	NO

NOTE: N/A MEANS NOT APPLICABLE FOR SEISMIC DESIGN CATAGORY C.

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PROJECT: RGA GLOBAL HQ TECHNICAL REPORT 4
TITLE: LATERAL ANALYSIS IRREGULARITIES
BY: NMB
SHEET: L.2
CHKD:
PROJECT NO: TECH 4
DATE:
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OFFICE BUILDING CENTER OF MASS-SLAB CONTRIBUTION					
Slab	Slab Wt. (k)	Width(ft.)	Length(ft.)	X Bar	Y Bar
1	7201	115	290	145	57.5
2	2301	115	290	145	57.5
3	2301	115	290	145	57.5
4	2301	115	290	145	57.5
5	2301	115	290	145	57.5
Penthouse	1267	115	290	145	57.5
PH Roof	186	35	140	70	17.5

OFFICE BUILDING CENTER OF MASS-CURTAIN WALL CONTRIBUTION						
Level	Weight (k)	Width(ft.)	Length(ft.)	Area(SF)	X Bar	Y Bar
1	106	105	245	25725	122.5	52.5
2	219	115	290	33350	145	57.5
3	226	115	290	33350	145	57.5
4	226	115	290	33350	145	57.5
5	229	115	290	33350	145	57.5
Penthouse	212	115	290	33350	145	57.5
PH Roof	68	35	140	4900	70	17.5

OFFICE BUILDING CENTER OF MASS-SLAB CONTRIBUTION									
BRACED FRAME	Direction	Length (ft.)	X Dist.(ft.)	Y Dist.(ft.)	L*X	L*Y	X Bar=	112.27	ft.
5	y	25	70	57.5	1750	1437.5	Y Bar=	57.5	ft.
6	y	25	220	57.5	5500	1437.5			
7	x	30	85	70	2550	2100			
8	x	30	85	45	2550	1350			
	Sum=	110		Sum=	12350	6325			

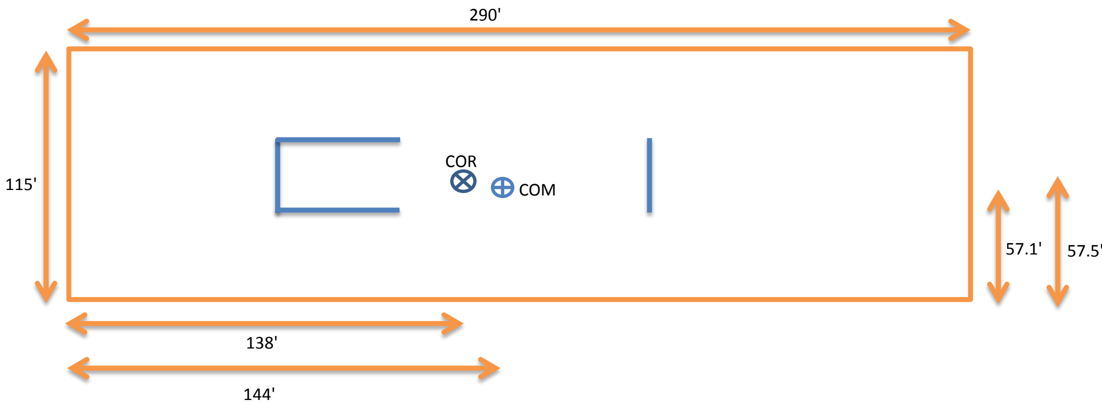
BRACED FRAME STORY WEIGHTS					
Story	BF 5	BF 6	BF 7	BF 8	Story Wt.(k)
1	7.16	7.16	6.82	6.82	27.96
2	6.15	6.15	6.37	6.37	25.05
3	5.64	5.64	6.37	6.37	24.03
4	4.01	4.01	5.00	5.00	18.03
5	3.85	3.85	4.82	4.82	17.34

CENTER OF MASS-STEEL STRUCTURE				
	Hand Calculated		ETABS	
Level	X Bar (ft.)	Y Bar (ft.)	X Bar (ft.)	Y Bar (ft.)
1	144.6	57.4	130	57.5
2	144.1	56.9	127.5	57.5
3	143.6	57.0	130	57.5
4	144.0	57.1	127.5	57.5
5	144.0	57.1	130	57.5

OFFICE BUILDING CENTER OF RIDIGITY CALCULATIONS								
Above 1	**BF Number**	**Direction**	**RX**	**RY**	**X Distance**	**Y Distance**	**RY*X**	**RX*Y**
	5	Y	0	1175.1	70	57.5	82257	0
	6	Y	0	1175.1	220	57.5	258522	0
	7	X	1096.4	0	85	70	0	76748
	8	X	1096.4	0	85	45	0	49338
		Sum=	2192.8	2350.2		Sum=	340779	126086
Above 2	**BF Number**	**Direction**	**RX**	**RY**	**X Distance**	**Y Distance**	**RY*X**	**RX*Y**
	5	Y	0	1164.4	70	57.5	81508	0
	6	Y	0	1164.4	220	57.5	256168	0
	7	X	1264.7	0	85	70	0	88529
	8	X	1264.7	0	85	45	0	56911.5
		Sum=	2529.4	2328.8		Sum=	337676	145440.5
Above 3	**BF Number**	**Direction**	**RX**	**RY**	**X Distance**	**Y Distance**	**RY*X**	**RX*Y**
	5	Y	0	953.1	70	57.5	66717	0
	6	Y	0	953.1	220	57.5	209682	0
	7	X	1264.7	0	85	70	0	88529
	8	X	1264.7	0	85	45	0	56911.5
		Sum=	2529.4	1906.2		Sum=	276399	145440.5
Above 4	**BF Number**	**Direction**	**RX**	**RY**	**X Distance**	**Y Distance**	**RY*X**	**RX*Y**
	5	Y	0	771.2	70	57.5	53984	0
	6	Y	0	771.2	220	57.5	169664	0
	7	X	1191.3	100	85	70	8500	83391
	8	X	1191.3	100	85	45	8500	53608.5
		Sum=	2382.6	1742.4		Sum=	240648	136999.5
Above 5	**BF Number**	**Direction**	**RX**	**RY**	**X Distance**	**Y Distance**	**RY*X**	**RX*Y**
	5	Y	0	630.3	70	57.5	44121	0
	6	Y	0	630.3	220	57.5	138666	0
	7	X	1025.2	0	85	70	0	71764
	8	X	1025.2	0	85	45	0	46134
		Sum=	2050.4	1260.6		Sum=	182787	117898

RESULTS		
Above 1	**Calculated**	**ETABS**
X Bar=	145	144.93
Y Bar=	57.5	57.5
Above 2	**Calculated**	**ETABS**
X Bar=	145	142.95
Y Bar=	57.5	57.5
Above 3	**Calculated**	**ETABS**
X Bar=	145	140.339
Y Bar=	57.5	57.5
Above 4	**Calculated**	**ETABS**
X Bar=	138.1129477	137.1135
Y Bar=	57.5	57.5
Above 5	**Calculated**	**ETABS**
X Bar=	145	134.5935
Y Bar=	57.5	57.5

CENTERS OF MASS AND RIGIDITY FOR LEVEL 04



BRACED FRAME STIFFNESS CALCULATIONS: BF 5 & 6											
Story	**Element**	**Member**	**h(ft.)**	**w(ft.)**	**L(ft.)**	**A(in^2)**	**I(in^4)**	**Theta(deg.)**	**Stiffness(k/in.)**	**Weight (plf)**	**Weight (k)**
Above 1	Column	W12x136	15.25	-	-	39.9	1240	-	140.8	136	4.15
	Brace	HSS10x10x5/8	15.25	12.5	19.71833	21	304	50.66	1034.3	76.33	3.01
								Total=	**1175.1**		**7.16**
Above 2	Column	W12x136	14	-	-	39.9	1240	-	182.0	136	3.81
	Brace	HSS10x10x1/2	14	12.5	18.76832	17.2	256	48.24	982.4	62.46	2.34
								Total=	**1164.4**		**6.15**
Above 3	Column	W12x136	14	-	-	39.9	1240	-	182.0	136	3.81
	Brace	HSS8x8x1/2	14	12.5	18.76832	13.5	125	48.24	771.1	48.85	1.83
								Total=	**953.1**		**5.64**
Above 4	Column	W12x87	14	-	-	25.6	740	-	108.6	87	2.44
	Brace	HSS7x7x1/2	14	12.5	18.76832	11.6	80.5	48.24	662.5	42.05	1.58
								Total=	**771.2**		**4.01**
Above 5	Column	W12x87	14.4	-	-	25.6	740	-	99.8	87	2.51
	Brace	HSS6x6x1/2	14.4	12.5	19.06856	9.74	48.3	49.04	530.4	35.24	1.34
								Total=	**630.3**		**3.85**

BRACED FRAME STIFFNESS CALCULATIONS: BF 7 & 8											
Story	**Element**	**Member**	**h(ft.)**	**w(ft.)**	**L(ft.)**	**A(in^2)**	**I(in^4)**	**Theta(deg.)**	**Stiffness**	**Weight (plf)**	**Weight (k)**
Above 1	Column	W12x136	15.25	-	-	39.9	1240	-	140.8	136	4.15
	Brace	HSS10x10x1/2	15.25	15	21.39071	17.2	256	45.47	955.5	62.46	2.67
								Total=	**1096.4**		**6.82**
Above 2	Column	W12x136	14	-	-	39.9	1240	-	182.0	136	3.81
	Brace	HSS10x10x1/2	14	15	20.51828	17.2	256	43.03	1082.7	62.46	2.56
								Total=	**1264.7**		**6.37**
Above 3	Column	W12x136	14	-	-	39.9	1240	-	182.0	136	3.81
	Brace	HSS10x10x1/2	14	15	20.51828	17.2	256	43.03	1082.7	62.46	2.56
								Total=	**1264.7**		**6.37**
Above 4	Column	W12x87	14	-	-	25.6	740	-	108.6	87	2.44
	Brace	HSS10x10x1/2	14	15	20.51828	17.2	256	43.03	1082.7	62.46	2.56
								Total=	**1191.3**		**5.00**
Above 5	Column	W12x87	14.4	-	-	25.6	740	-	99.8	87	2.51
	Brace	HSs9x9x1/2	14.4	15	20.79327	15.3	183	43.83	925.4	55.66	2.31
								Total=	**1025.2**		**4.82**

SHEAR WALL STIFFNESS CALCULATIONS								
SW 5								
Story	**Wall Along:**	**t(in.)**	**h(ft.)**	**b(ft.)**	**E(ksi)**	**(h/b)**	**Stiffness(k/in.)**	
Above B2	Grid 13	16	11.17	25	4030.5	0.4468	45109.4	
	Grids N & P	16	11.17	30	4030.5	0.372333333	55183.3	each
Above B1	Grid 13	16	14.83	25	4030.5	0.5932	32433.2	
	Grids N & P	16	14.83	30	4030.5	0.494333333	40209.6	each
SW 6								
Story	**t(in.)**	**h(ft.)**	**b(ft.)**	**E(ksi)**	**(h/b)**	**Stiffness(k/in.)**		
Above B2	16	11.17	25	4030.5	0.4468	45109.4		
Above B1	16	14.83	25	4030.5	0.5932	32433.2		
SW 10								
Story	**t(in.)**	**h(ft.)**	**b(ft.)**	**E(ksi)**	**(h/b)**	**Stiffness(k/in.)**		
Above B2	16	11.17	60	4030.5	0.186167	114148.0		
Above B1	16	14.83	30	4030.5	0.494333	40209.6		
Wall PV								
Story	**t(in.)**	**h(ft.)**	**b(ft.)**	**E(ksi)**	**(h/b)**	**Stiffness(k/in.)**		
Above B2	16	11.17	180	3605.0	0.062056	309432.4		
Above B1	12	14.83	180	3605.0	0.082389	174628.3		
Wall P1								
Story	**t(in.)**	**h(ft.)**	**b(ft.)**	**E(ksi)**	**(h/b)**	**Stiffness(k/in.)**		
Above B2	12	11.17	134	3605.0	0.083358	172588.4		
Above B1	12	14.83	134	3605.0	0.110672	129765.4		

Assuming G~0.4E

k_{office}=	1.03	
$k_{parking}$=	0.5	
V_{total}=	4235	k

SEISMIC STORY FORCES

Level	w_x(k)	h_x(ft)	$w_x h_x^k$(ft-k)	C_{vx}	F_x(k)	M_{OT}(ft.-k)
B1	8968	11.2	29972	0.017	**73**	812
1	13378	26.0	Weight Lumped to Level 2			0
2	15899	41.3	733262	0.420	**1779**	73367
3	2527	55.3	157491	0.090	**382**	21106
4	2527	69.3	198740	0.114	**482**	33383
5	2531	83.3	240549	0.138	**583**	48574
Penthouse	1680	97.7	188269	0.108	**457**	44593
PH Roof	1543	111.3	197690	0.113	**480**	53346
		$\Sigma w_x h_x^k$=	1745974	1	**4235**	**275180**

MODELING ADJUSTED FORCES

Level	F_x(k)	
B1	73	
1	-	
2	1779	
3	382	
4	482	
5	583	
Penthouse	936	
Sum=	4235	ok

SEISMIC LOAD CASE ECCENTRICITIES

Level	Force(k)	XCM(ft.)	XCR(ft.)	ex (ft.)	5%Bx(ft.)	YCM(ft.)	YCR(ft.)	ey(ft.)	5%By(ft.)
Penthouse	936	130	134.6	4.59	5.750	57.5	57.5	0	14.5
5	583	127.5	137.1	9.61	5.750	57.5	57.5	0	14.5
4	482	130	140.3	10.34	5.750	57.5	57.5	0	14.5
3	382	127.5	142.9	15.45	5.750	57.5	57.5	0	14.5
2	1779	130	144.9	14.93	5.750	57.5	57.5	0	14.5
B1	73	213.9734	330.1601	116.19	17.500	-108.5944	-103.6872	-4.9072	18.55
Sum=	4235								

Mtax=Fx(ey+5%Bx)
Mtay=Fx(ex+5%By)

100+30

EX	30%EY	30%EX	EY
73	21.81	21.81	73

SEISMIC LOAD CASES

	Case 1			Case 2			Case 3				Case 4			
Level	EX	Mtax(ft-k)+	Mtax(ft-k)-	EY	Mtay+	Mtay-	EX	Mtax+	Mtax-	EY	EY	Mtay+	Mtay-	EX
Penthouse	936	5383	-5383	936	17875	-9274	936	9683	-1083	936	936	9274	-17875	936
5	583	3355	-3355	583	14070	-2851	583	8964	2254	583	583	2851	-14070	583
4	482	2772	-2772	482	11974	-2006	482	7756	2212	482	482	2006	-11974	482
3	382	2197	-2197	382	11441	363	382	8098	3705	382	382	-363	-11441	382
2	1779	10227	-10227	1779	52351	772	1779	36789	16335	1779	1779	-772	-52351	1779
B1	73	916	-1629	73	9795	7098	73	10076	7531	73	73	-7455	-10152	73

WIND LOAD CASES ACCORDING TO ASCE 7

	Case 1X NW-SE	Case 1Y NE-SW	Case 2 NW-SE			X		Case 2 NE-SW			Y	
Level	Shear X (k)	Shear Y (k)	WW Pressure(PSF)	LW Pressure	Trib Area	Shear	Mtx	WW Pressure	LW Pressure	Trib Area	Shear	Mty
B1	34.36	111.15	7.50	-3.59	2323	9.08	7.75	10.49	-10.13	5389.65	1.97	4.61
1	23.36	77.50	7.50	-3.59	1579	6.17	7.75	10.91	-10.13	3684.80	2.86	9.80
2	49.47	173.23	8.05	-3.59	1682	13.67	16.60	12.44	-10.13	4241.25	12.68	39.00
3	26.51	96.04	8.75	-3.59	1610	8.31	10.24	13.53	-10.13	4060.00	13.79	42.86
4	27.76	99.70	9.34	-3.59	1610	9.25	11.40	14.43	-10.13	4060.00	17.46	54.24
5	29.25	104.33	9.84	-3.59	1633	10.21	12.40	15.21	-10.13	4118.00	20.91	64.07
6	45.12	159.05	10.30	-3.59	828	11.55	72.02	15.92	-10.13	2088.00	34.43	492.71
Tower Parapet	17.37	43.81	22.58	-15.19	345	2.55	14.65	30.10	-20.26	870.00	8.57	124.20
Mean Roof Height	4.58	25.71	10.49	-3.59	244	1.68	13.68	16.21	-10.13	976.50	5.93	76.66
T.O. Penthouse	2.42	13.52	10.69	-3.59	127	0.90	14.09	16.52	-10.13	507.50	3.24	80.64
Penthouse Parapet	5.40	21.62	23.41	-15.19	105	0.86	16.30	31.21	-20.26	420.00	4.60	138.20
			Bx=	115	ft.			By=	290	ft.		
			ex=	17.25	ft.			ey=	43.5	ft.		

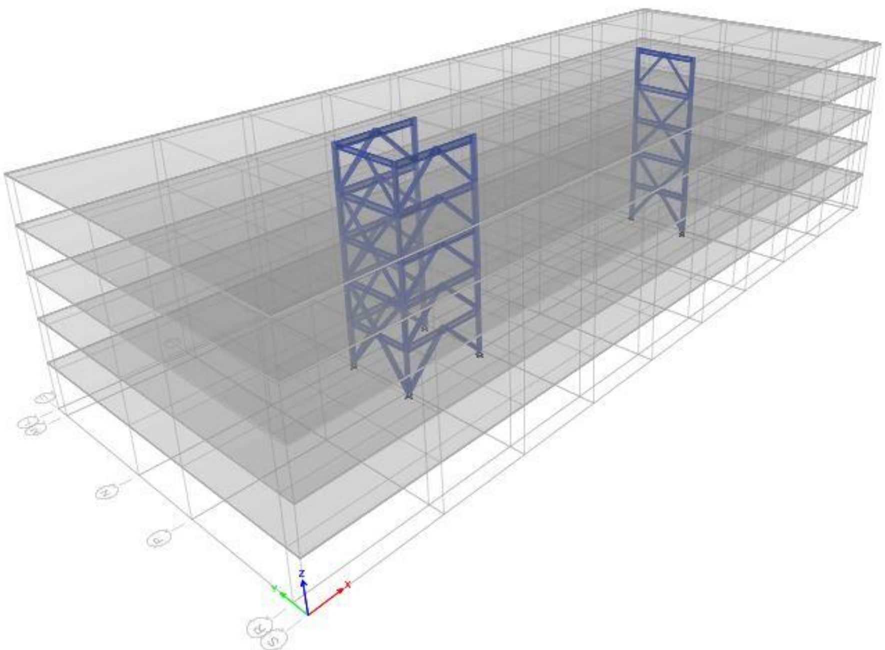
	Case 3		Case 4 NW-SE			X	Case 4 NE-SW			Y	
Level	Shear X	Shear Y	WW Pressure(PSF)	LW Pressure	Trib Area	Shear	WW Pressure	LW Pressure	Trib Area	Shear	Mt
B1	9.08	1.97	5.63	-2.70	2323	6.81	5.91	-5.702238478	5389.65	1.11	8.42
1	6.17	2.86	5.63	-2.70	1579	4.63	6.14	-5.702238478	3684.80	1.61	11.34
2	19.84	15.54	6.05	-2.70	1682	10.26	7.01	-5.702238478	4241.25	7.14	34.42
3	8.31	13.79	6.57	-2.70	1610	6.24	7.62	-5.702238478	4060.00	7.77	31.82
4	9.25	17.46	7.01	-2.70	1610	6.94	8.12	-5.702238478	4060.00	9.83	39.09
5	10.21	20.91	7.39	-2.70	1633	7.66	8.56	-5.702238478	4118.00	11.77	45.38
6	17.54	56.77	7.73	-2.70	828	8.67	8.96	-5.702238478	2088.00	19.38	331.46
Tower Parapet	2.55	8.57	16.95	-11.40	345	1.91	16.95	-11.40447696	870.00	4.82	80.92
Mean Roof Height	1.68	5.93	7.87	-2.70	244	1.26	9.12	-5.702238478	976.50	3.34	53.43
T.O. Penthouse	0.90	3.24	8.03	-2.70	127	0.68	9.30	-5.702238478	507.50	1.83	55.97
Penthouse Parapet	0.86	4.60	17.57	-11.40	105	0.65	17.57	-11.40447696	420.00	2.59	90.04
			Bx=	115	ft.	By=	290	ft.			
			ex=	17.25	ft.	ey=	43.5	ft.			

Structural Modeling with ETABS 2013

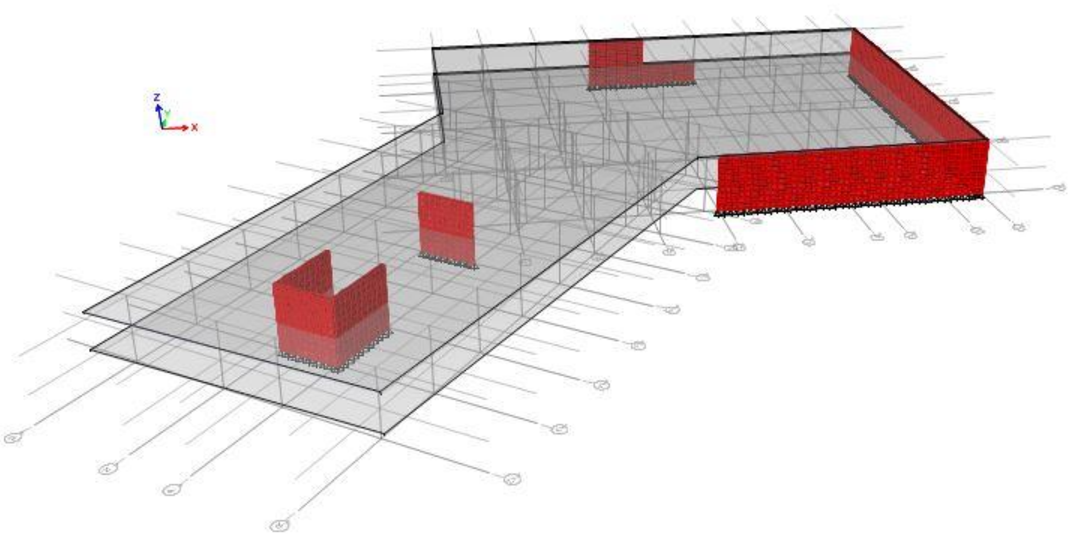
This section presents the structural modeling done with ETABS and some of the results.

ETABS Model Images

Office Structure

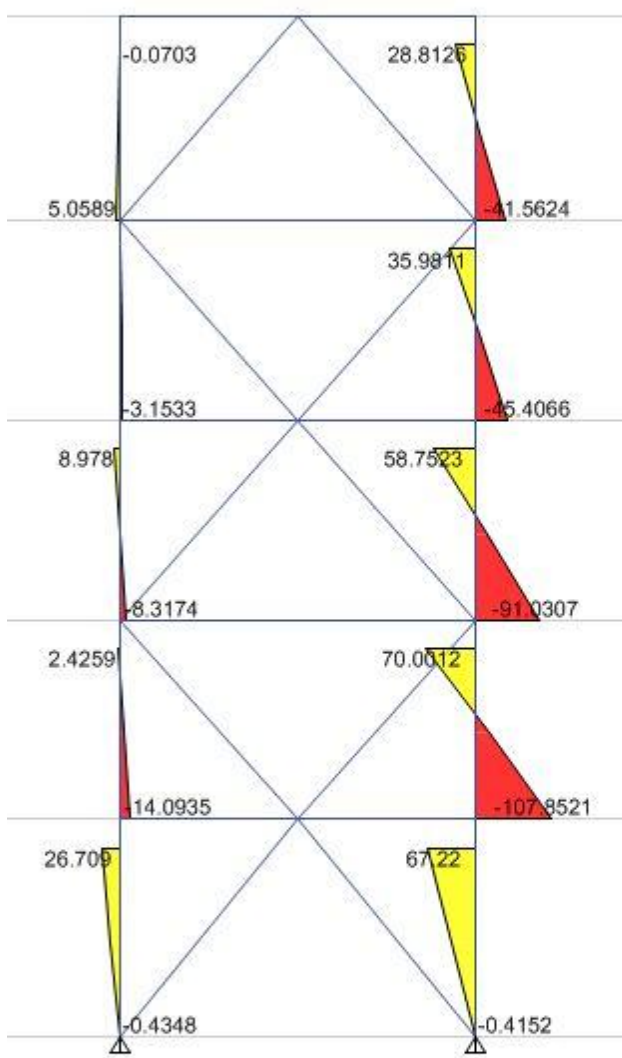


Parking Structure



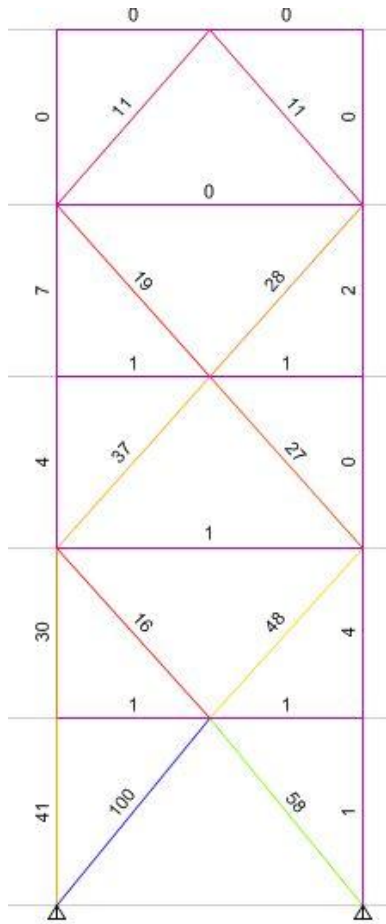
Moment Diagrams

Brace Frame 5-SeismicY-5%X



Member Utilization Ratios

Brace Frame 5-SeismicY-5%X



Shear Wall 10-Wind Case 1 -Y

Results

This section presents strength and model checks and drift results.

STRENGTH CHECKS

CRITICAL BRACE FRAME B5: COLUMN

- FROM ETABS: $M_{rx} = 23.3\,'^{k}$, $M_{ry} = -72.2\,'^{k}$
- FIND AXIAL P

  $A_T = (30')(\tfrac{1}{2})(45'+25') = 1050$ SF > 400SF ∴ REDUCE

  $L_o = 50$ PSF [TECH 2]

  $K_{LL} = 4$ [INTERIOR COLUMN]

  $$L = 50\left(0.25 + \frac{15}{\sqrt{1050 \cdot 4}}\right) = 24.1 \text{ PSF}$$

  - FROM TECH. 2:

    $S = 22$ PSF

    $DL_{FLOOR} = 69$ PSF

    $L_r = 20$ PSF

    $D_{L\,ROOF} = 38$ PSF

  - LOAD COMBINATIONS [ASCE 7-05]

    $1.2D + 1.6L + 0.5S$ CONTROLS

    $1.2D + 1.6S + 0.5L$

  $DL = (4 \text{ FLRS})(69 \text{ PSF})(1050\text{SF}) + (1 \text{ ROOF})(38 \text{ PSF})(1050) = 330^{k}$

  $LL = (4)(24.1)(1050) = 101^{k}$

  $S = (22)(1050) = 23^{k}$

  $$P_u = 1.2(330) + 1.6(101) + 0.5(23) = \mathbf{569^{k}}$$

- COMBINED FLEXURE AND COMPRESSION INTERACTION
  - W12x136

    $L_b = 15.25'$ (STORY HEIGHT)

    ASSUME $K = 1.5$: ACTS BETWEEN PINNED BASE AND TRANSLATION TOP

    $KL = 1.5(15.25') = 22.9' \rightarrow$ USE $\mathbf{30'}$
  - FROM TABLE 6-1 [AISC 530]

    $p = 1.44 \cdot 10^{-3}$ $b_x = 1.29 \cdot 10^{-3}$ $b_y = 2.42 \cdot 10^{-3}$
  - INTERACTION EQUATION

    $pP_r = (1.44 \cdot 10^{-3})(569^{k}) = 0.82 > 0.2$

    ∴ $pP_r + b_x M_{rx} + b_y M_{ry} \le 1.0$ [AISC 530 EQN 6-1]

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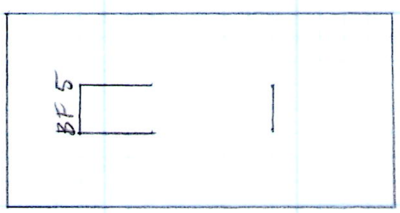
$(1.44\cdot10^{-3})(569^{k}) + (1.29\cdot10^{-3})(23.3'^{k}) + (2.42\cdot10^{-3})(-72.21^{k}) \leq 1.0$

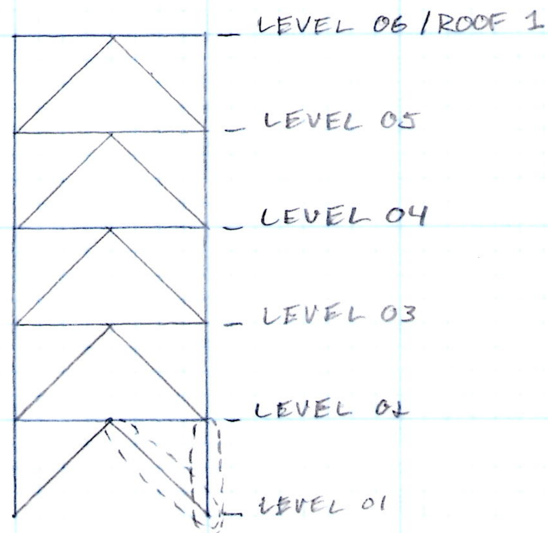
$= 0.675 \leq 1.0$ OK

CRITICAL BRACED FRAME B5: BRACE

- HSS10 × 10 × 5/8
  - $L = 19.7'$
  - $K = 1.0$ PIN - PIN
  - $KL = 19.7' \Rightarrow$ USE $20'$
  - $P_u = 496^{k}$ [ETABS]
- IN COMPRESSION
  - $\phi P_n = 665^{k}$ [AISC 530 TABLE 4-4] OK
- IN TENSION
  - $\phi P_n = 869^{k}$ [AISC 530 TABLE 5-5] OK
  - $P_u = 496^{k} < \phi P_n = 665^{k}$ OK
- IN EXISTING DESIGN, $\phi P_n = 660^{k} > P_u$ OK
  - ∴ B5 MEETS STRENGTH



OFFICE PLAN



BF 5 ELEVATION

CHECKED MEMBER

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PROJECT: RGA GLOBAL HQ TECHNICAL REPORT 4

TITLE: STRENGTH CHECKS BRACED FRAME 5

BY: NMB	SHEET: R.3
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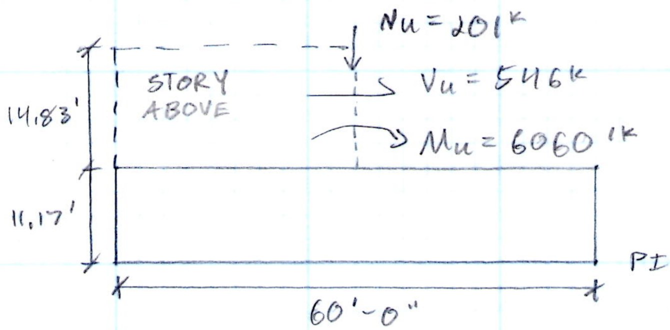
CRITICAL SHEAR WALL SW-10

- CONTROLLING LOAD CASE: WIND CASE 1 - Y DIRECTION



* FACTORED LOADS SHOWN AND CALCULATED BELOW

$f'c = 5000$ psi

$t = 16"$ $\lambda = 1.0$ NWC

- FROM ETABS: $V_u = 341^k$ $M_u = 6060^{'k}$
- SELF WEIGHT

  $N_u = (150 \text{ PCF})(16"/12)[(60')(11.17') + (30')(14.83')] = +223^k$
- LOAD COMBINATIONS
  - $1.2D + 1.6W$
  - $0.9D + 1.6W$ CONTROLS B/C MAKES N_u SMALLER & V_u LARGER

    $N_u = 0.9(223^k) = \mathbf{201^k}$

    $V_u = \mathbf{546^k}$

- USE ACI 318-11 § 11.9
  - § 11.9.2: IS $h \le 2w$?

    $11.17' < 120'$ YES ∴ USE § 11.9.9.2 THRU § 11.9.9.5
  - FIND D [§ 11.9.2]

    $d = 0.8 l_w = 0.8(60') = \mathbf{48'}$
  - DETERMINE V_c [§ 11.9.6]

    $$V_c = 3.3\lambda\sqrt{f'c}\,hd + \frac{N_u d}{4 l_w} \quad [\text{EQN } 11\text{-}27]$$

    $$V_c = (3.3)(1)\sqrt{5000}(16")(48' \cdot 12) + \frac{221000 \cdot 48' \cdot 12}{4(60 \cdot 12)} = 2195^k$$

    $$\frac{M_u}{V_u} - \frac{l_w}{2} = \frac{6060}{546} - \frac{60}{2} = -19 \quad \therefore \text{ EQN. 11-28 DNA}$$

    $V_{c\,MAX} = 2\lambda\sqrt{f'c}\,hd$ [§ 11.9.5]

    $\mathbf{V_{c\,MAX}} = 2(1)\sqrt{5000}(16")(48' \cdot 12) = \mathbf{1303^k}$ CONTROLS

  - IS $V_u \le 0.5\phi V_c$?

    $546^k > 0.5(0.75)(1303^k) = 488^k$ ∴ USE § 11.9.9

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PROJECT	RGA GLOBAL HQ TECHNICAL REPORT 4
TITLE	STRENGTH CHECKS SHEAR WALL 10
BY:	NMB
SHEET:	R.4
CHKD:	
PROJECT NO:	TECH 4
DATE:	
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• DETERMINE V_n

$V_n = 1303^k$ CONTROLS

$V_{n\,MAX} = 10\sqrt{f'c}\,hd$ [§ 11.9.3]

$= 10\sqrt{5000}(16")(48\cdot12)(1/1000) = 6517^k$

• $V_u = 546^k < \phi V_n = 0.75(1303^k) = 977^k$ OK

• CHECK REINFORCEMENT [1/S3.002]

• HORIZONTAL

$A_{g\,CONC} = (16")(11.17'\cdot12) = 2144.6\ in^2$

A_s: #5 @ 7" IN TWO LAYERS

$A_{\#7} = 0.31\ in^2$

$\frac{(11.17')(12")}{7"} = 20$ ROWS

$A_s = (0.31\ in^2)(2)(20\ ROWS) = 12.4\ in^2$

$\frac{A_s}{A_g} = \frac{12.4}{2144.6} = 0.0058 > 0.0025 = \rho_t$ [§ 11.9.9.2] OK

$$s = \min\begin{cases} l_w/5 = 60\cdot12/5 = 144" \\ 3h = 3(16") = 36" \\ 18" \end{cases}$$

$\therefore s = 18" > 7"$ OK [§ 11.9.9.3]

• VERTICAL

$A_g = (16")(60')(12") = 11520\ in^2$

A_{sv} = #8 @ 12" AND #6 @ 12" IN TWO LAYERS, EACH 30'

$A_{\#8} = 0.79\ in^2$ $A_{\#6} = 0.44\ in^2$

$A_{sv} = (2)(0.79\ in^2)(30\ ROWS) + (2)(0.44\ in^2)(30\ ROWS) = 73.8\ in^2$

$$\rho_l = \max\begin{cases} 0.0025 + 0.5(2.5 - h_w/l_w)(\rho_t - 0.0025) \\ 0.0025 \end{cases}$$ [§ 11.9.9.4]

$\rho_l = 0.0025 + 0.5(2.5 - 11.17/60)(0.0058 - 0.0025) = 0.006$ CONTROLS

NEED NOT BE $> \rho_t = 0.0058$

$\frac{73.8}{11520} = 0.0064 > 0.0058$ OK

$S_{MAX} = 18" > 12"$ OK [11.9.9.5]

$\therefore$ SW 10 MEETS STRENGTH

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TITLE: STRENGTH CHECKS SHEAR WALL 10

BY: NMB

SHEET: R.5

CHKD:

PROJECT NO: TECH 4

DATE:

PAGE:

SERVICE RESISTING MOMENT CALCULATION			
Level	**w_x(k)**	**Service M_X (ft.-k)**	**Service M_Y(ft.-k)**
B1	8968	1546980	3901080
1	13378	2307784	5819630
2	15899	2742596	6916112
3	2527	435956	1099366
4	2527	435956	1099366
5	2531	436513	1100771
Penthouse	1680	289871	730978
PH Roof	1543	266125	671097
	M_{resist}=	**8461780**	**21338401**
	F.S.=	3.0	
	B_x=	115	ft.
	B_y=	290	ft.

FACTORED RESISTING MOMENT CALCULATION			
Load Condition	**M_{OT}**	**Units**	**Acceptable?**
Wind NW-SE M_{OT}	11117	ft.-k	
$1.6M_{OT}$	17787	ft.-k	
$0.9M_{Resist}$	7615602	ft.-k	>$1.6M_{OT}$ OK
Wind EW-SW M_{OT}	39635	ft.-k	
$1.6M_{OT}$	63416	ft.-k	
$0.9M_{Resist}$	19204561	ft.-k	>$1.6M_{OT}$ OK
Seismic M_{OT}	275180	ft.-k	Controls
$1.0M_{OT}$	275180	ft.-k	
$0.9M_{Resist}$	7615602	ft.-k	>$1.0M_{OT}$ OK
APPLICABLE LOAD COMBINATIONS			
0.9D+1.6W+1.6H			
0.9D+1.0E+1.6H	Controlling Combination		

SERVICE FACTOR OF SAFETY CALCULATION				
Load Condition	**M_{OT}**	**M_{Resist}**	**M_{Resist}/M_{OT}**	**Meet Code F.S.?**
Wind NW-SE	11117	8461780	761	>1.5 OK
Wind EW-SW	39635	21338401	538	>1.5 OK
Seismic	275180	8461780	31	>1.5 OK

TENSION PIER LOCAL UPLIFT CHECK (SERVICE LOAD)						
Shear Wall	**Service V(k)**	**Length**	**Height**	**Uplift (k)**	**Allowable (k)**	**Acceptable?**
SW 10	341	30	11.17	127	136	**OK**
SW5 G13	226	25	12.17	110	136	**OK**
SW5 GN	200	30	13.17	88	136	**OK**
SW5 GP	50	30	14.17	24	136	**OK**
SW6	83	25	15.17	50	136	**OK**

TENSION PIER LOCAL UPLIFT CHECK (FACTORED LOAD)						
Shear Wall	**Controlling Case**	**Factor**	**Factored V(k)**	**Uplift (k)**	**Allowable (k)**	**Acceptable?**
SW 10	Wind	1.6	545.6	203	226	**OK**
SW5 G13	Wind	1.6	361.6	176	226	**OK**
SW5 GN	Wind	1.6	320	140	226	**OK**
SW5 GP	Wind	1.6	80	38	226	**OK**
SW6	Wind	1.6	132.8	81	226	**OK**

THEREFORE, THE FOUNDATION IS ADEQUATE AGAINST OVERTURN AND LOCAL UPLIFT

SEISMIC STORY DRIFT CHECK				
Level	**Story Drift X** (ETABS)	**Story Drift Y** (ETABS)	**Code Max.** ASCE 7	**Allowable?** ASCE 7
6	0.0049	0.0107	0.015	OK
5	0.0063	0.0120	0.015	OK
4	0.0066	0.0114	0.015	OK
3	0.0064	0.0114	0.015	OK
2	0.0064	0.0084	0.015	OK
1	0.0003	0.0001	0.015	OK
B1	0.0002	0.0001	0.015	OK

ASCE 7-05 Table 12.12-1

DRIFT

WIND

• OFFICE

$\Delta_{MAX} = 1.18''$ [ETABS]

$h_{WIND} = 97.65'$

$\frac{l}{400} = \frac{(97.65')(12)}{400} = 2.92'' > 1.18''$ OK

[ASCE 7-05 §CC.1.2]

$\frac{l}{600} = \frac{(97.65')(12)}{600} = 1.95'' > 1.18''$ OK

• PARKING

$\Delta_{MAX} = 0.035''$ [ETABS]

$h_{wind} = 27'$

$\frac{l}{400} = \frac{(27')(12)}{400} = 0.81'' > 0.035''$ OK

$\frac{l}{600} = \frac{(27')(12)}{600} = 0.54'' > 0.035''$ OK

• $\Delta_{ALLOW\ EJ} = \frac{1}{2}(2.5'') = 1.25'' > 0.035''$ OK

• TOTAL WIND

$\Delta = 0.035'' + 1.18'' = 1.22''$

$\frac{l}{400} = 2.92'' > 1.22''$ OK

$\frac{l}{600} = 1.95'' > 1.22''$ OK

$\therefore$ DRIFT IS WITHIN LIMITS

$\boxed{\text{CONCLUSION: STRUCTURE IS ACCEPTABLE}}$