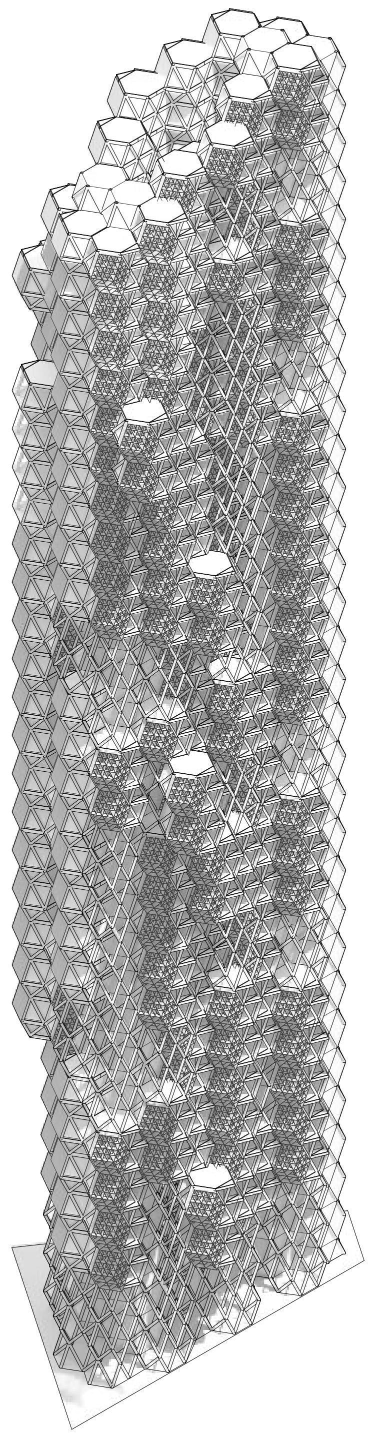
DODECAHEDRON HOUSING TOWER DESIGN

ARCE 415 | COLLABORATIVE HIGH RISE DESIGN



MICHAEL AYERS | **06.04.2020**

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INTRODUCTION

INTRODUCTION

OVERVIEW

THE NEED FOR HIGH RISE CONSTRUCTION BECOMES ESPECIALLY APPARENT WITH CONSIDERATION TO OVERPOPULATION IN THE WORLD TODAY. THE NEED FOR PHYSICAL LIVING SPACE OPTIMIZED WITH ENERGY EFFICIENT SYSTEMS IS KEY IN URBAN DEVELOPMENT. HOWEVER, THIS URBANIZATION OFFERS RISK FOR THE DEVELOPMENT OF UNSUSTAINABLE AND REPETITIVE BUILDINGS THAT MASK THE IDENTITY OF THE INDIVIDUAL LIVING IN A CULTURE THAT CELEBRATES IT. AS A RESULT, IT IS IMPERATIVE THAT DESIGNERS OF SUCH INFLUENTIAL PROJECTS AS HIGH RISE BUILDINGS MUST CONSIDER ECONOMICAL, SUSTAINABLE, AND CREATIVE SOLUTIONS TO THIS DEVELOPMENT PROBLEM WHILE MAINTAINING THE SOCIAL RESPONSIBILITY EXPECTED OF A DESIGNER TAKING PART IN THE BUILT ENVIRONMENT.

BUILDING NARRATIVE

THE DODECAHEDRON HOUSING TOWER PROJECT FOCUSES ON A DESIGN PHILOSOPHY DRIVEN BY A SINGLE TESSELLATED MODULE. THIS REPEATING MODULE ALLOWS FOR THE DEVELOPMENT OF A GLOBAL SPACE TRUSS USED AS THE COMBINED LATERAL AND GRAVITY LOAD-RESISTING SYSTEM FOR THE ENTIRE BUILDING. THE GEOMETRY OF THIS STRUCTURAL MODULE CAN ALSO BE ERODED IN RESPONSE TO CIRCULATION AND LIGHT INFILTRATION THROUGHOUT THE TOWER. THIS ALSO ALLOWS FOR THE MODULE TO BE USED AS A TOOL FOR CREATIVE SPACE MAKING AND UNIT CUSTOMIZATION.

STRUCTURAL CONNECTIONS INCLUDE BALL JOINTS THAT ACT AS NODES IN THE GLOBAL SPACE TRUSS SYSTEM. THESE CONNECTIONS HAVE BEEN PREFERRED OVER THOSE ALLOWING FOR MORE DUCTILE FAILURE METHODS DUE TO THEIR SIZE AND INTEGRATION WITH ARCHITECTURAL ELEMENTS.

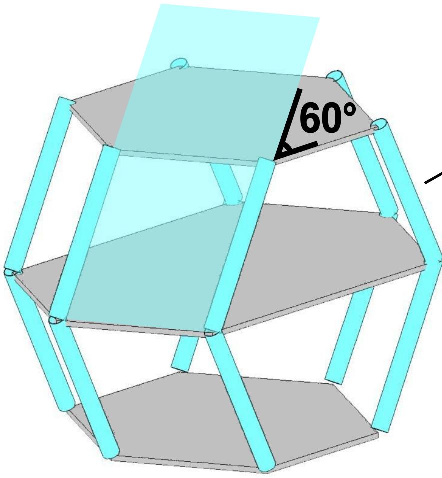
ALL LATERAL AND GRAVITY LOADS TRACKED THROUGH THE BUILDING SYSTEM WILL DISSIPATE AT THE FOUNDATION LEVEL TO PRECAST CONCRETE PILES DRIVEN DOWN TO BEDROCK. THE DESIGN OF THIS SYSTEM TAKES SPECIAL ACCOUNT FOR THE EXISTING MUNI STATION ADJACENT TO THE PROJECT SITE.

THE TOWER WILL FEATURE AN ENVELOPE SYSTEM THAT ALIGNS TO THE STRUCTURAL MODULE AND ALLOWS FOR THE OPTION FOR PREFABRICATION. THIS ENVELOPE SYSTEM WILL OFFER AN EFFICIENT SOLUTION TO EXTERNAL FORCES IN SAN FRANCISCO WHILE MINIMZING LABOR COSTS.

OVERALL, THIS DODECAHEDRON HOUSING TOWER ALLOWS FOR THE REMOVAL OF STRUCTURAL MODULES IN RESPONSE TO THE SURROUNDING ENVIRONMENT. THE STRUCTURAL DESIGN OF THIS PROJECT REINFORCES THE IDEAS OF COMMUNITY AND SPACE THROOUGHOUT THE TOWER WHILE DEMONSTRATING THE UNITY OF STRUCTURE AND ARCHITECTURE.

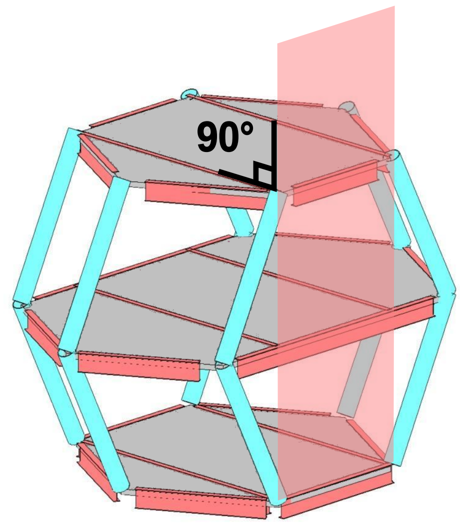
MODULAR GEOMETRY

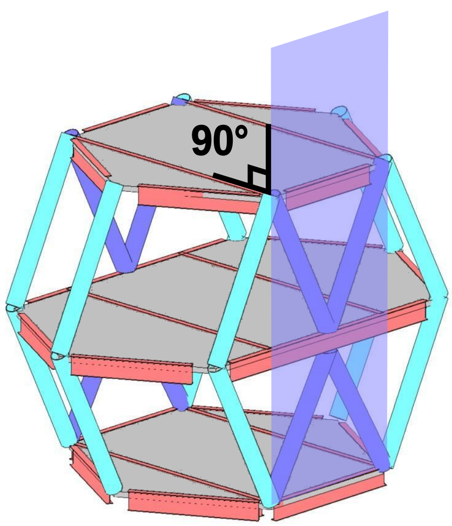
MODULAR GEOMETRY



OUTLINE FORM OF DODECAHEDRON
(rhombo-hexagonal dodecahedron)

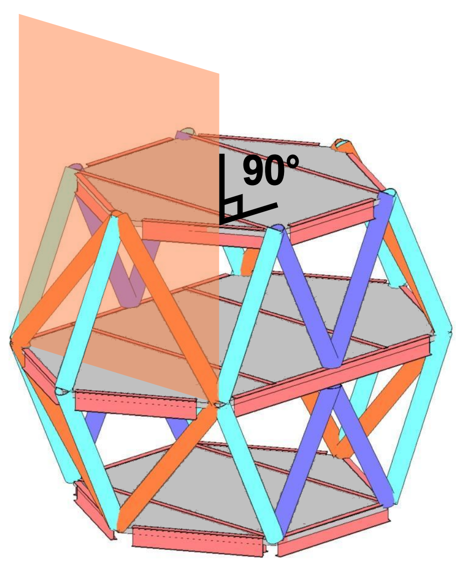
ADDITION OF GRAVITY SYSTEM

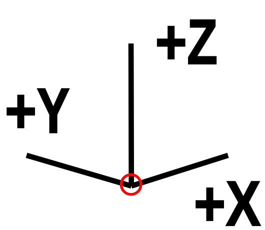




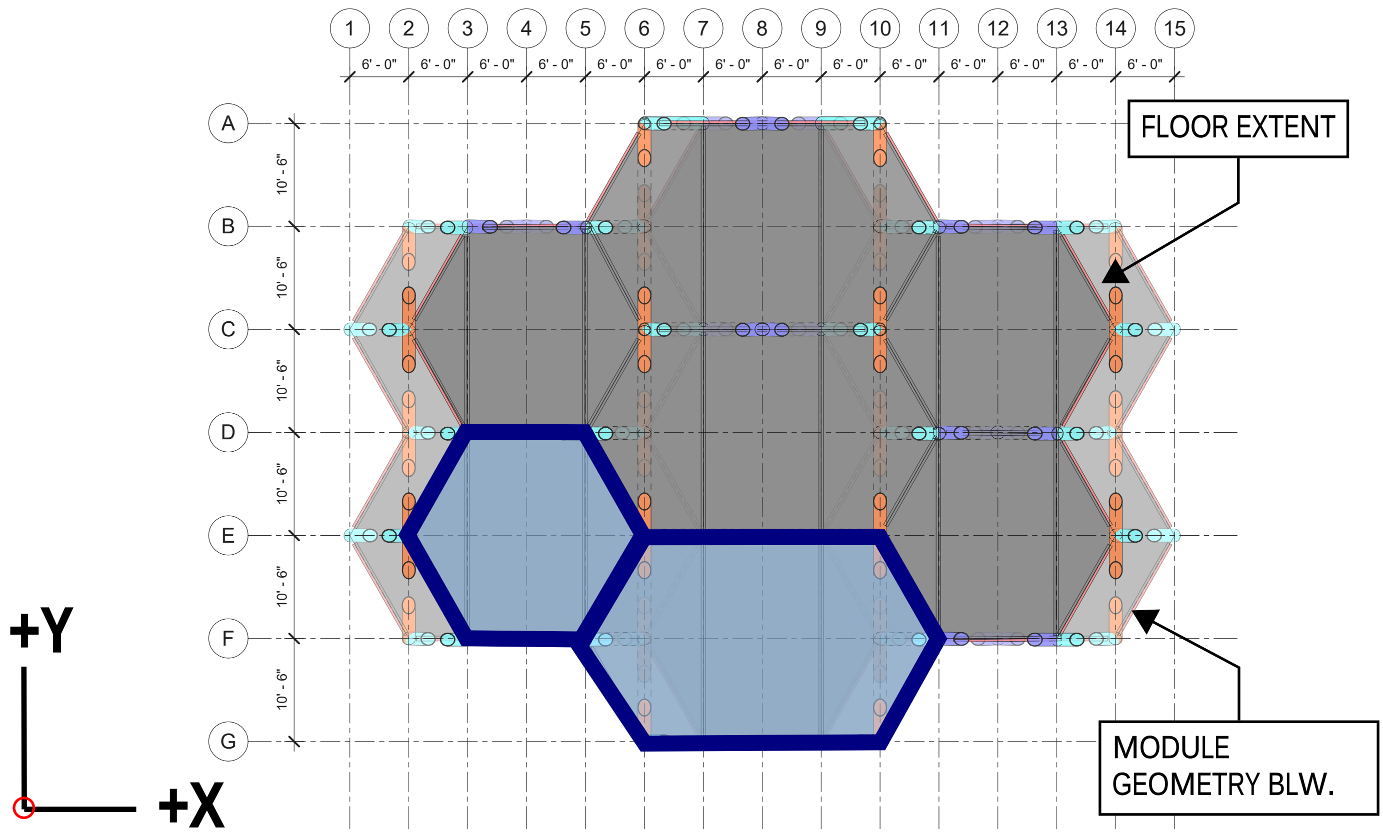
BRACING ADDED IN HEXAGON
FACES OF MODULE

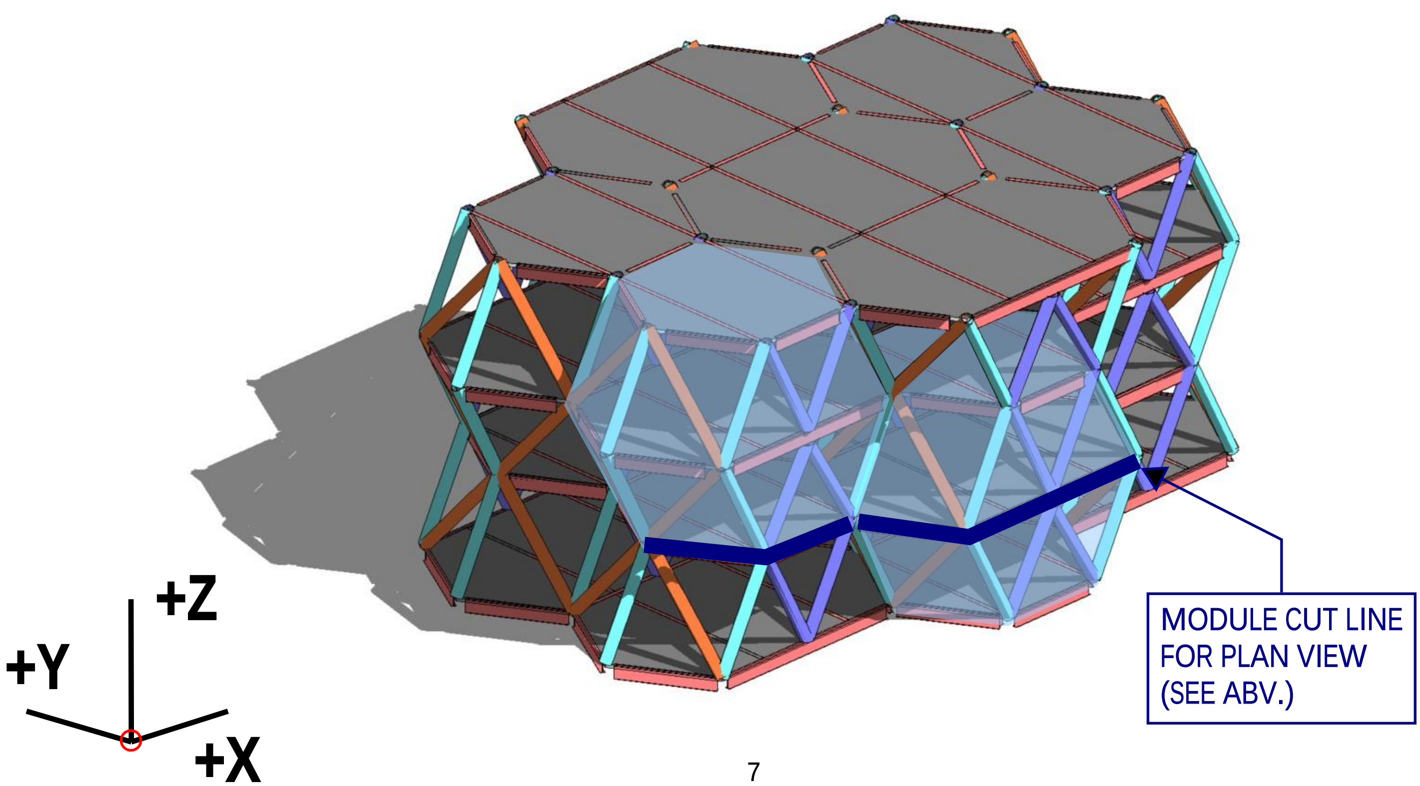
BRACING ADDED IN RHOMBUS
FACES OF MODULE





MODULE TESSELLATION



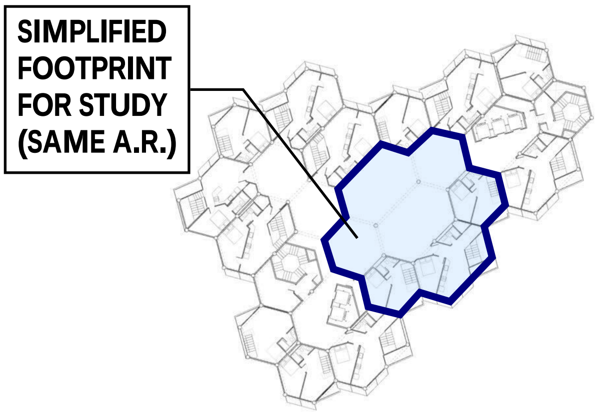


STRUCTURAL INVESTIGATION

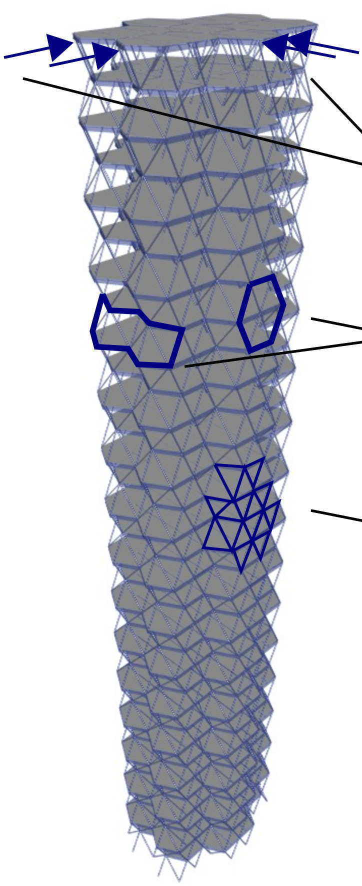
STRUCTURAL INVESTIGATION - OVERVIEW

THIS STUDY IS CONDUCTED TO:

- REINFORCE PREDICTED BEHAVIOR OF SPACE TRUSS STRUCTURE
- INVESTIGATE EFFECTS OF BRACE LINE LOCATION ON GLOBAL LOAD FLOW
- DETERMINE EFFECTS OF STRUCTURAL EROSION
- DETERMINE CONCLUSIONS ON THE ACCURACY & POTENTIAL FOR HAND ANALYSIS



A SIMPLIFIED FOOTPRINT OF THE BUILDING WILL BE USED FOR OPTIMAL COMPUTATION ABILITY. BUILDING ASPECT RATIO (6.0:1) WILL BE MAINTAINED FOR REPLICATION OF EXPECTED BEHAVIOR



GENERAL OVERVIEW:

LATERAL LOADS APPLIED IN EACH DIRECTION TO STUDY LOAD FLOW

NO NOTICEABLE DIFFERENCE IN LOAD FLOW AROUND ERODED STRUCTURE

NEGLIGIBLE SHEAR AND MOMENT IN ALL MEMBERS (PER EXPECTATIONS)

ADDITIONAL NOTES:

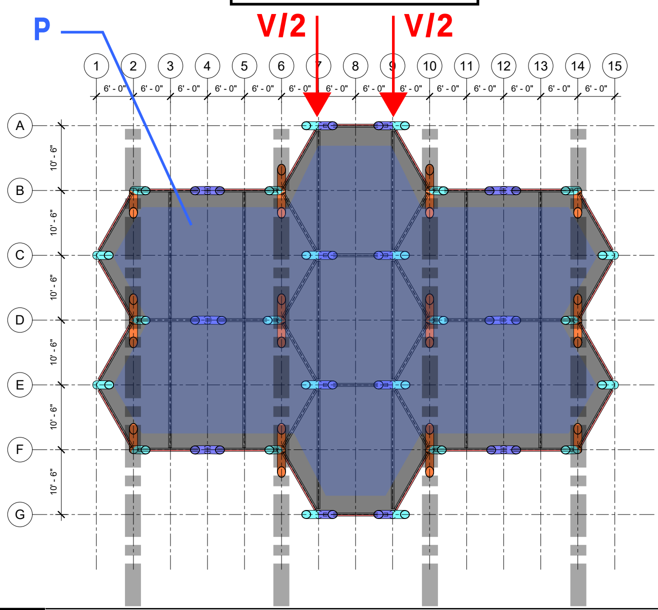
- O.T. FORCES @ BASE REACTIONS FOLLOW EXPECTATIONS
- MODE SHAPES FOLLOW +Y, +X, +Z REGULAR ORDER
- HIGHER MODE PARTICIPATION WILL REQUIRE ADD'L INVESTIGATION

STRUCTURAL INVESTIGATION - BRACING LINES

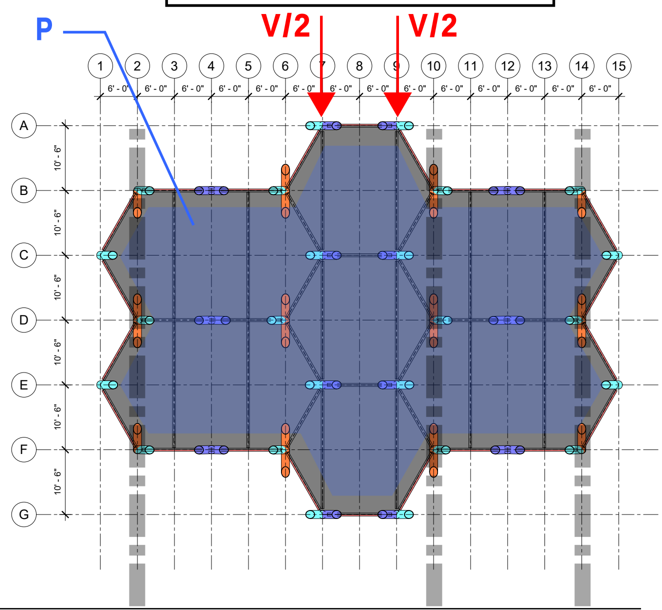
EFFECT OF BRACING LINES

SHOWN BELOW ARE **BRACE LINES** IN THE +Y DIRECTION AND PROPORTION OF **APPLIED SHEAR** RESISTED BY EACH LINE. GRAVITY EFFECTS WERE DETERMINED AS A RESULT OF **APPLIED GRAVITY LOADING.** BRACING CONTRIBUTION IS DETERMINED RELATIVE TO ENTIRE FLOOR.

ALL BRACE LINES



REMOVAL OF BRACE LINE 6



ROOF	0.142V 0.089P	0.358V 0.411P	0.358V 0.411P	0.142V 0.089P	0.286V 0.276P	0.603V 0.474P	0.111V 0.250P
(⅔) H	0.144V 0.202P	0.356V 0.298P	0.356V 0.298P	0.144V 0.202P	0.218V 0.383P	0.583V 0.301P	0.199V 0.316P
(⅓) H	0.164V 0.229P	0.336V 0.271P	0.336V 0.271P	0.164V 0.229P	0.258V 0.351P	0.499V 0.331P	0.243V 0.318P

CONCLUSIONS:

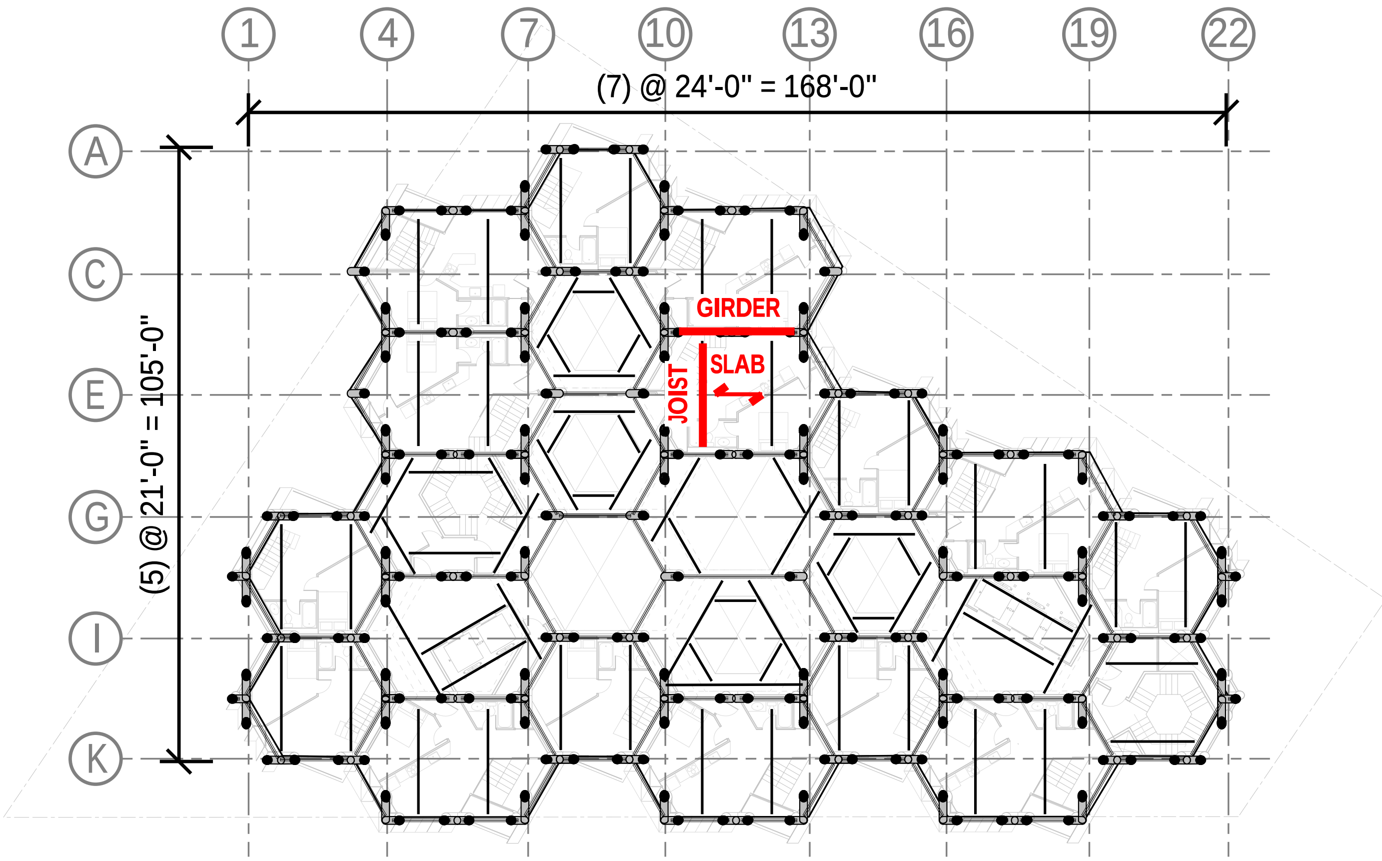
BRACING EROSION RESPONDS APPROXIMATELY TO TRIBUTARY AREA EXPECTATIONS OF LOAD FLOW, AS REINFORCED BY THE EFFECTS OF THE REMOVAL OF BRACED LINE 6. THIS CAN BE USED AS AN ALTERNATIVE MEANS FOR DESIGN

PROJECT APPLICATION

PROJECT APPLICATION - GRAVITY DESIGN

OVERVIEW:

ALTHOUGH BUILDING GEOMETRY IS UNCONVENTIONAL, THE EVENLY SPACED GRID WILL ALLOW FOR A CONVENTIONAL STEEL-FRAMED GRAVITY LOAD RESISTING SYSTEM. LOAD FLOW OF STRUCTURE WILL INCLUDE CONCRETE o/ METAL DECK SLAB TO JOISTS TO GIRDERS TO BRACING ELEMENTS THAT DOUBLE AS GRAVITY AND LATERAL LOAD-RESISTING. TYPICAL MEMBERS USED FOR DESIGN ARE HIGHLIGHTED BELOW:



RESULTS:

CALCULATIONS FOLLOW TRADITIONAL STEEL SLAB AND BEAM DESIGN USING [AISC 360-10] AND VERCO FLOOR DECK CATALOG. CALCULATIONS ARE INCLUDED IN THE APPENDIX AND ARE SUMMARIZED BELOW:

SLAB	**6-1/4" TOT. LWC o/ 18 GA. W3 FORMLOCK MTL DECK**
JOIST	**W16X31 STL BM (USE W18X40 FOR CONSTRUCTABILITY)**
GIRDER	**W18X40 STL BM**

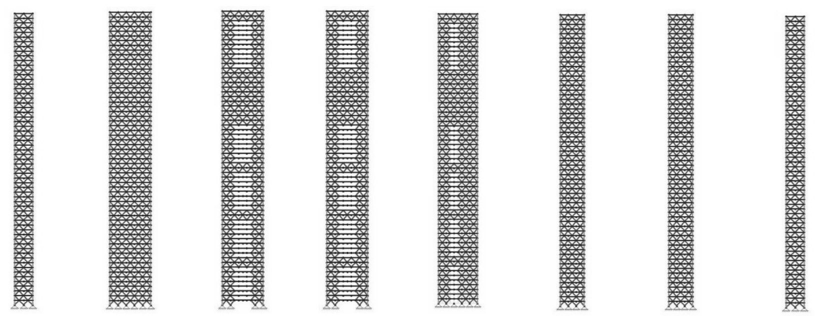
PROJECT APPLICATION - BRACED LINE STIFFNESS

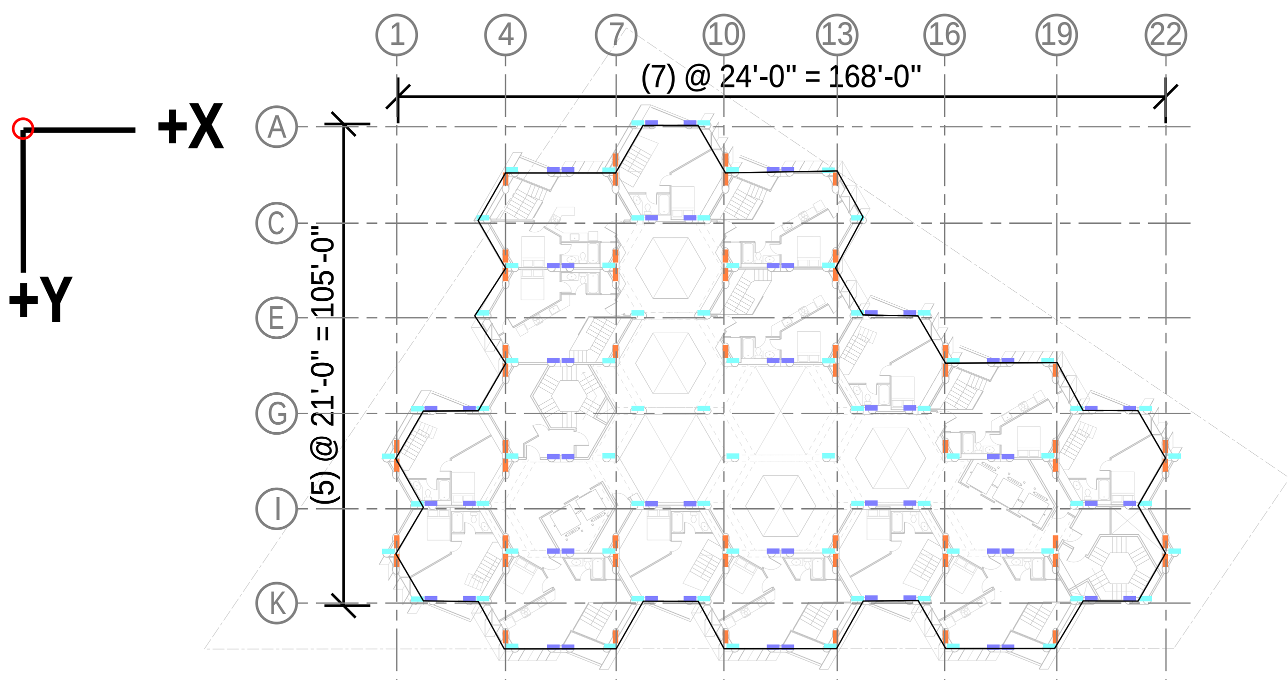
OVERVIEW:

DUE TO LIMITED COMPUTATIONAL POWER, 2D MODELS OF EACH BRACED LINE IN +Y WILL BE USED TO ESTIMATE BEHAVIOR AND DETERMINE MEMBER SIZES PER STRENGTH AND SERVICEABILITY REQUIREMENTS. THESE LINES WILL BE FULLY MODELED TO REFLECT GEOMETRY OF THE TOWER & APPROXIMATE RELATIVE STIFFNESS TO BEGIN FORCE DISTRIBUTION.

RESULTS:

2D RISA MODELS W/ BRACE LINE ASPECT RATIOS





DIRECT SHEAR PROPORTION

2.8%	**23%**	**18%**	**18%**	**21%**	**7.1%**	**7.1%**	**2.9%**	ROOF
3.1%	**24%**	**17%**	**17%**	**21%**	**7.5%**	**7.5%**	**3.1%**	(⅔) H
3.4%	**26%**	**15%**	**15%**	**20%**	**8.2%**	**8.2%**	**3.4%**	(⅓) H
NO. BRACES: (4)	(10)	(8)	(8)	(8)	(6)	(6)	(4)	

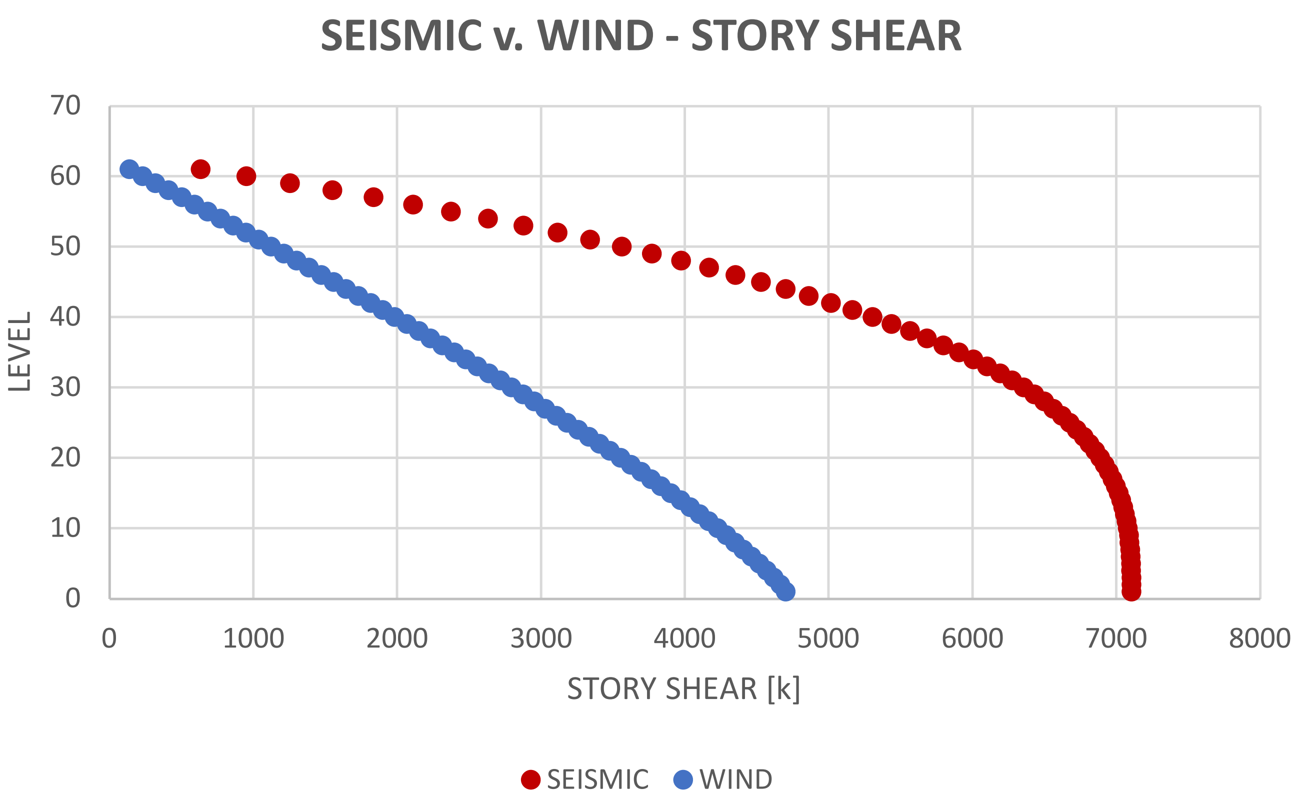
PROJECT APPLICATION - LATERAL ANALYSIS

OVERVIEW:

NOW THAT BRACED LINE STIFFNESSES HAVE BEEN DEVELOPED IN RESPONSE TO LOADS IN THE DIRECTION OF THE HOUSING TOWER THAT WILL GOVERN DESIGN (+Y), DIRECT SHEAR DEMANDS WILL BE INCREASED BY 5% TO ACCOUNT FOR TORSIONAL SHEAR AT THIS SCHEMATIC DESIGN PHASE.

ALTHOUGH PERFORMANCE-BASED DESIGN IS REQUIRED PER [ASCE 7-16 : T. 12.6-1], ELFP WILL BE USED TO APPROXIMATE MEMBER SIZES FOR THE LEVEL OF SCHEDMATIC DESIGN. THIS WILL INCLUDE TAKING MAXIMUM LATERAL SHEAR FROM WIND OR SEISMIC IN COMBINATION WITH GRAVITATIONAL DEMANDS.

DEMANDS GENERATED FOLLOWING [ASCE 7-16 : § 12.8 , 27.2] ARE SUMMARIZED BELOW:



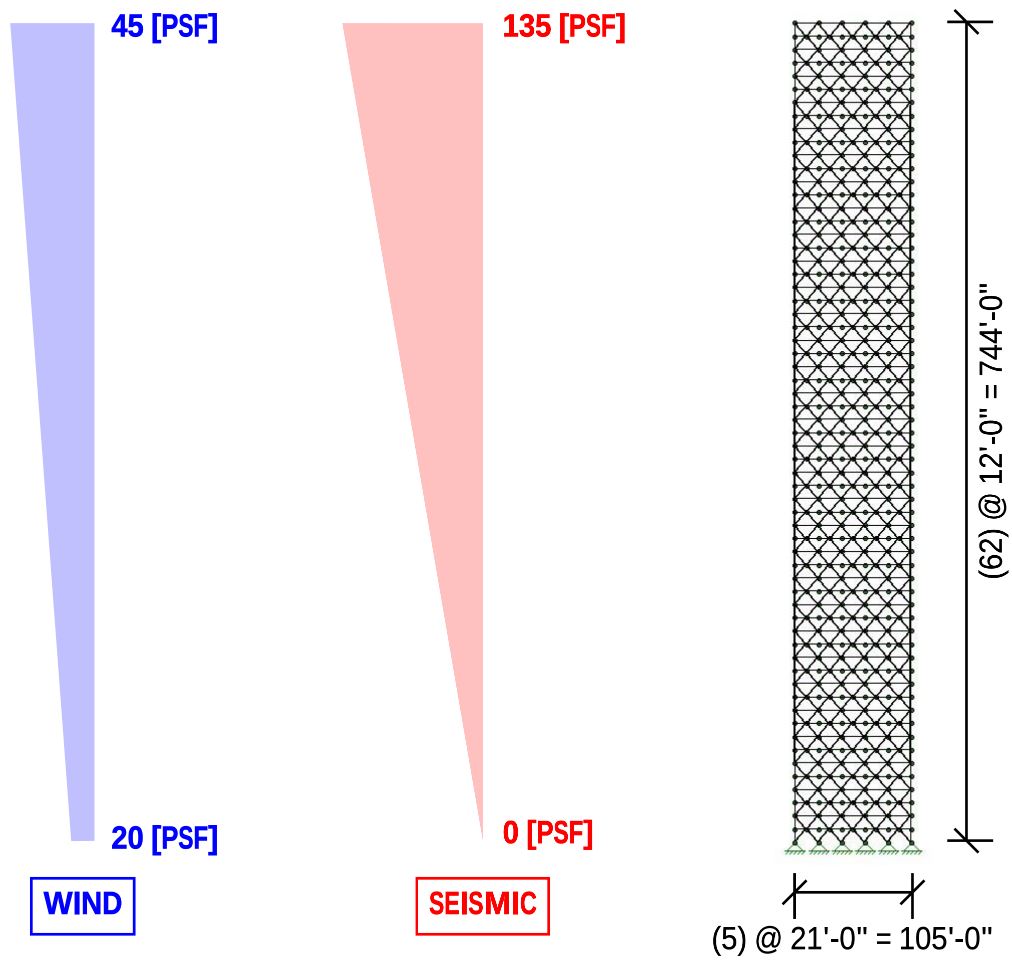
ALTHOUGH SEISMIC LOAD COMBINATIONS WILL GOVERN STRENGTH DESIGN, BOTH SEISMIC AND WIND EFFECTS WILL BE TAKEN INTO ACCOUNT TO CHECK SERVICEABILITY LIMIT STATE, AS DESIGN WIND DRIFT LIMITS ARE STRICTER THAN ALLOWABLE SEISMIC DRIFT. IT IS IMPORTANT TO NOTE THAT HIGHER MODE EFFECTS WOULD BE TAKEN INTO ACCOUNT AT A HIGHER DESIGN LEVEL ON PAR WITH PERFORMANCE-BASED DESIGN.

PROJECT APPLICATION - LATERAL DESIGN

OVERVIEW:

USING THE DEMANDS GENERATED FOLLOWING [ASCE 7-16 : § 12.8 , 27.2] PROCEDURES, **BRACED LINE 4** WILL BE ANALYZED USING GRAVITY AND LATERAL DEMANDS TO SIZE BRACING MEMBERS IN ORDER TO ACHIEVE STRENGTH & SERVICEABILITY REQUIREMENTS.

LOAD



DEFLECTION

0.2% = **h/500**
PER [NBCC v1 : § 4.1.3.5]

1.5% x (Cd/Ie) = **h/160**
PER [ASCE 7 : § 12.12]

RESULTS

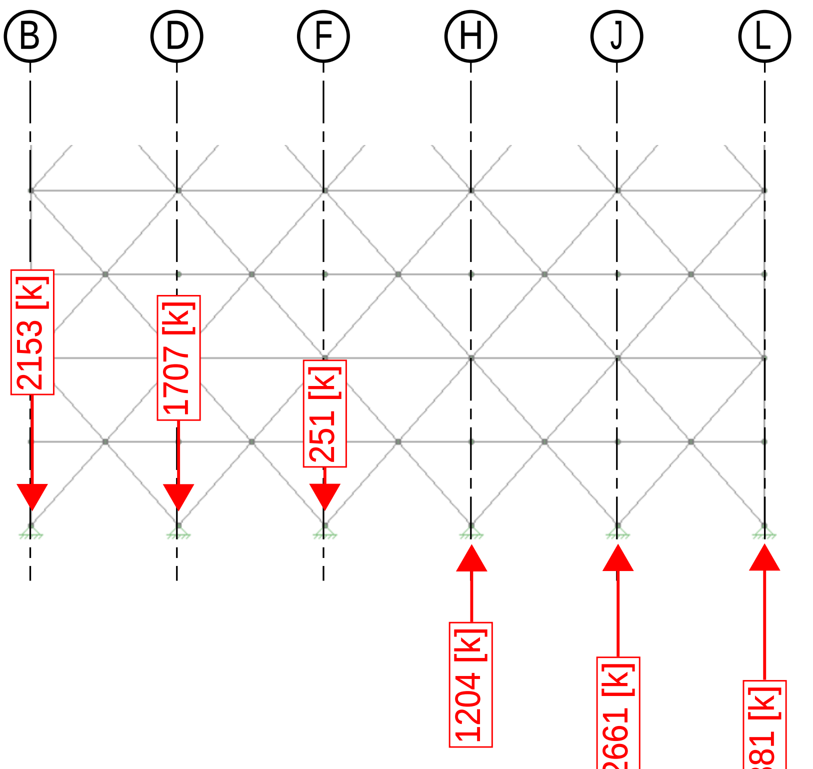
SECTION	A [in²]	Ix [in⁴]	b/t	Δ(W) [in]	Δ(E) [in]	
HSS 8.00X0.625	**14**	**99**	**12.8**	15.7 **(h/568)**	47.7 **(h/187)**	ROOF
HSS 16.0X1.250	**58**	**1586**	**12.8**	8.01 **(h/737)**	24.1 **(h/245)**	(⅔) H
HSS 24.0X1.875	**130**	**8032**	**12.8**	2.42 **(h/1250)**	7.07 **(h/428)**	(⅓) H

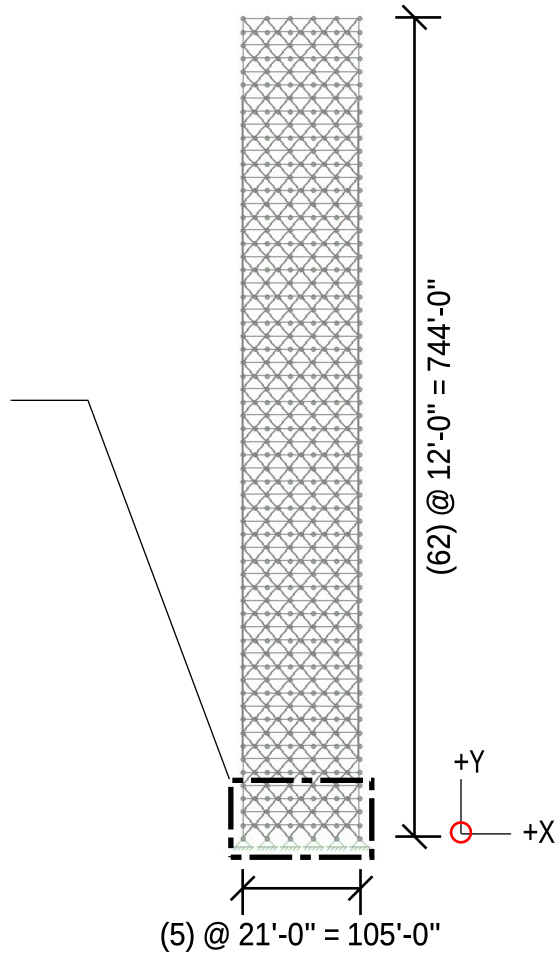
PROJECT APPLICATION - FOUNDATION DESIGN

OVERVIEW:

SERVICE-LEVEL (ALLOWABLE) DEMANDS CONSIDERING COMBINED LATERAL AND GRAVITY WILL BE USED TO PRODUCE CONTROLLING AXIAL TENSION & COMPRESSION LOADING USED TO DESIGN PILES @ BLDG FOUNDATION LEVEL. REACTIONS @ **BRACED LINE 4** WILL BE USED FOR APPROXIMATION.

BASE REACTIONS

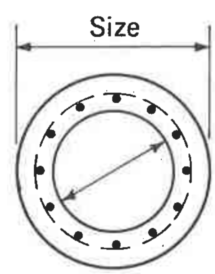




PILE DESIGN

EXCERPT FROM PCI DESIGN HANDBOOK (3RD ED):

Size in.	Core Dia. in.	Section Properties[1]						Allowable Concentric Service Load, Tons[2]			
		Area in.^{2}	Weight plf	Moment of Inertia in.^{4}	Section Modulus in.^{3}	Radius of Gyration in.	Perimeter (ft.)	f'_c 5000	6000	7000	8000
Round Piles											
36	26″	487	507	60,007	3334	11.10	9.43	355	436	516	596
48	38″	675	703	158,199	6592	15.31	12.57	493	604	715	827
54	44″	770	802	233,373	8643	17.41	14.14	562	689	816	943



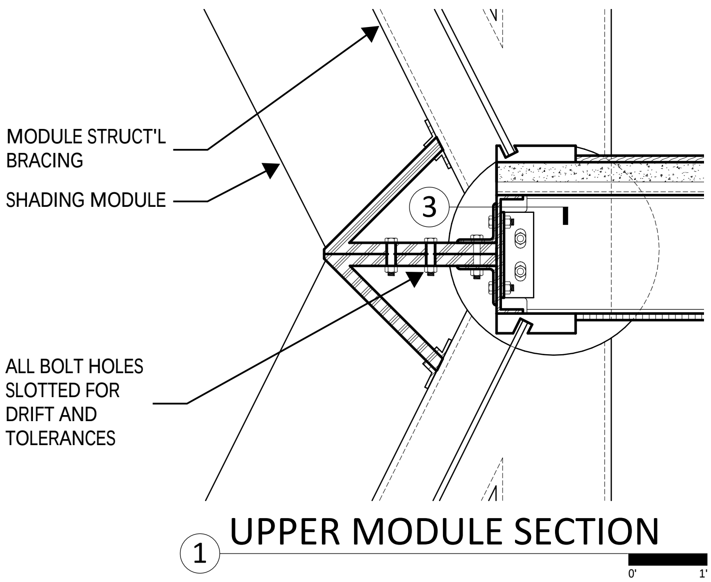
FOR EXPECTED DEMANDS , USE: **(2) 48" Ø PRECAST PILES** [2860 k TOTAL] @ G.L. B , D , J , L
(1) 48" Ø PRECAST PILES [1430 k TOTAL] @ G.L. F , H

(GRIDLINE SPACING IN +Z = 24'-0" IS O.K. FOR (2) PILES @ 3D = 12'-0" | EMBED. TO BEDROCK = 160'-0")

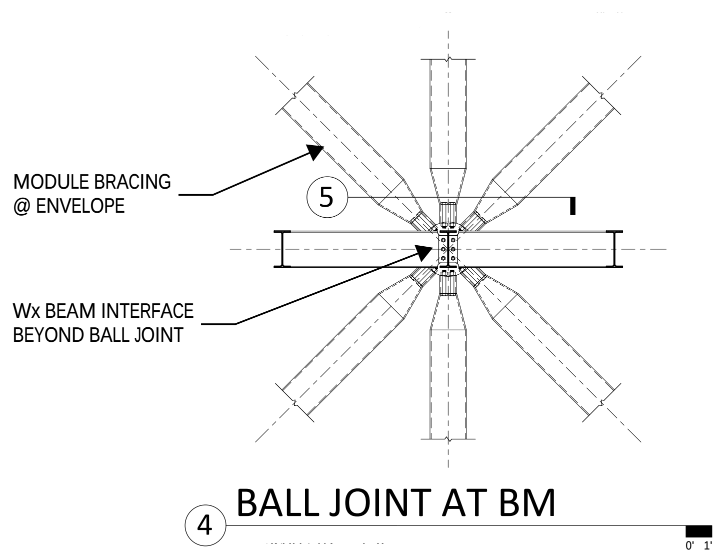
PROJECT APPLICATION - ENVELOPE SYSTEM

OVERVIEW:

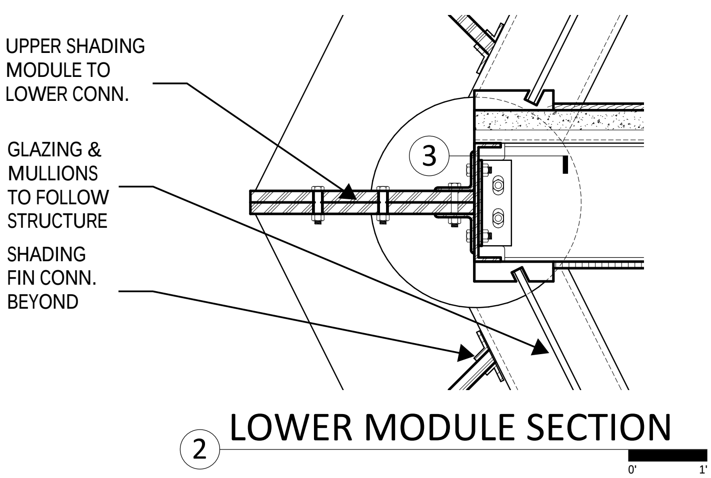
ENVELOPE SYSTEM WILL CONSIST OF A PREFABRICATED SHADING MODULE THAT ALIGNS WITH STRUCTURAL BRACING OF PROJECT. ENVELOPE MODULES WILL BE SHIPPED TO SITE ACCOUNTING FOR STABILITY, AND WILL OPTIMIZE SLOTTED BOLTED CONNECTIONS TO ACCOUNT FOR DRIFT AND TOLERANCE CONSIDERATIONS IN ALL DIRECTIONS. DETAILING IS SUMMARIZED BELOW:



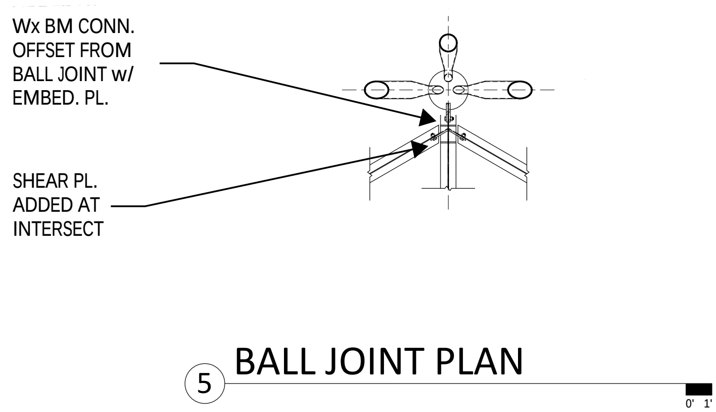
1 UPPER MODULE SECTION



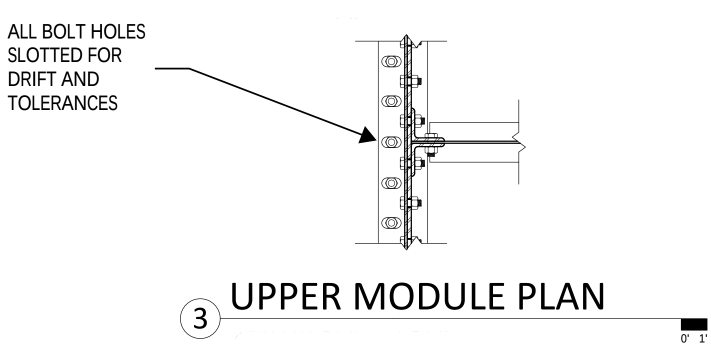
4 BALL JOINT AT BM



2 LOWER MODULE SECTION



5 BALL JOINT PLAN



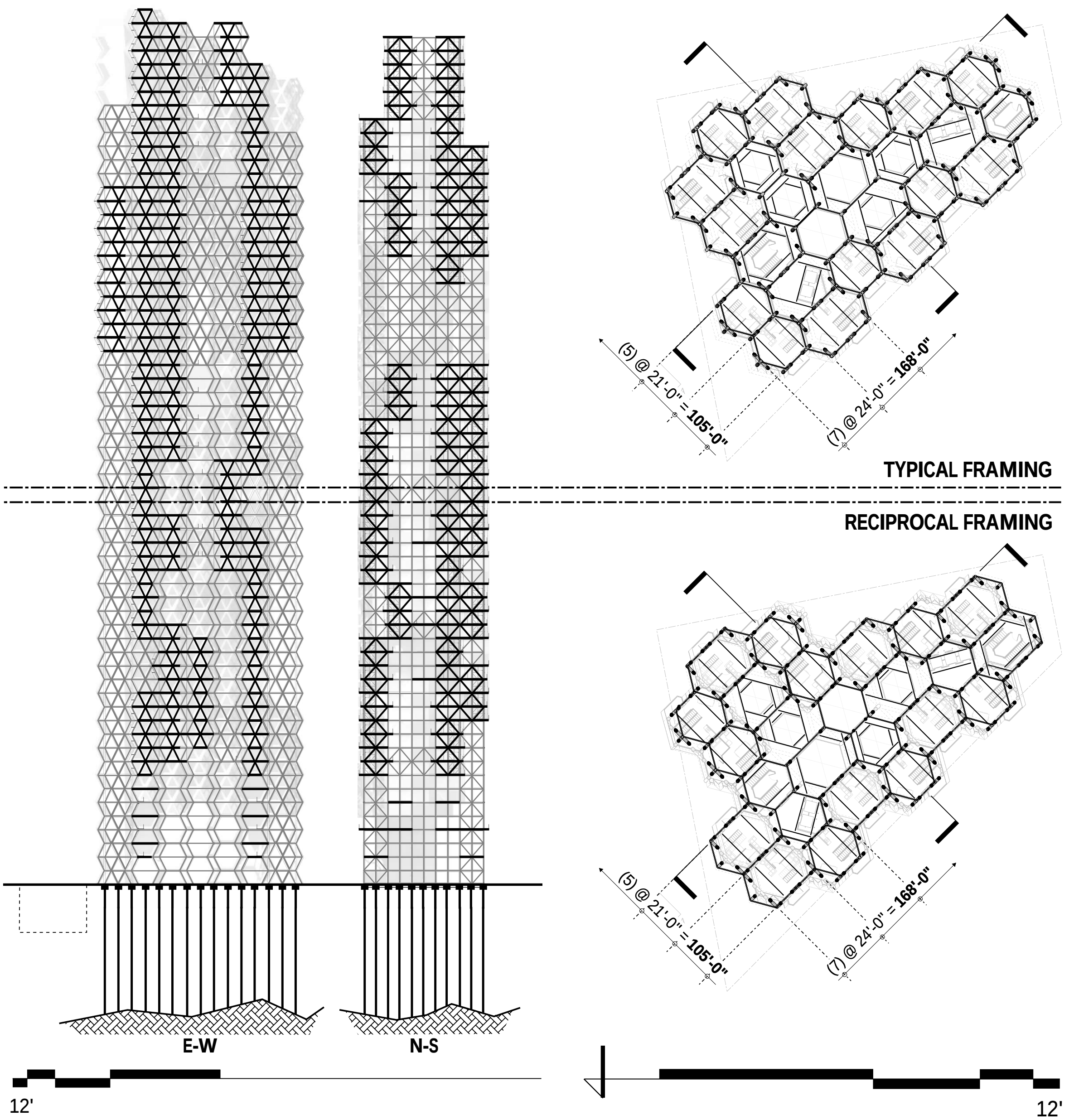
3 UPPER MODULE PLAN

CONCLUSION

CONCLUSION

STRUCTURAL INTEGRATION

THE DODECAHEDRON HOUSING TOWER PROJECT DEMONSTRATES STRUCTURAL INTEGRATION INTO HIGH RISE ARCHITECTURE WHICH IMPLEMENTS THE DESIGN METHODOLOGY OF MODULAR STRUCTURE. STRUCTURAL DRAWINGS BELOW HELP TO DEMONSTRATE THIS COLLABORATIVE DESIGN.



CLOSING THOUGHTS

THE DESIGN OF THIS HIGH RISE PROJECT BROUGHT TO LIGHT IMPORTANT ISSUES CONSIDERING THE CULTURAL AND SOCIAL IMPLICATIONS OF BEING A DESIGNER IN THE BUILT ENVIRONMENT. ESPECIALLY AT THE SCALE OF A HIGH RISE TOWER, A BUILDING PROJECT CAN HEAVILY IMPACT THE URBAN FABRIC IN WHICH IT IS PLACED. THIS 20-WEEK HIGH RISE DESIGN PROJECT HAS REINFORCED THE IMPORTANCE OF THIS RESPONSIBILITY AMIDST LESSONS ON THE BEHAVIOR OF STRUCTURAL SYSTEMS AT MAXIMUM SCALE.

CALCULATION APPENDIX

PROJECT: HIGH RISE DESIGN

ENGINEER: M.A. (GROUP 05)

DATE: 03.12.20

SHEET: 1

CAL POLY SOM

GRAVITY SCHEMING

DESIGN:

ASSUME D(80) + L(80) PSF

→ TYP. JOIST (22' SPAN), (12' TRIB.)

$$M_U = \frac{[1.2(80) + 1.6(80)] \times 12'-0" \times (22')^2}{8}$$

$= 162^{k'}$

* USE W16x31 (L/d = 16.5 ✓, DCR = 0.80)

→ TYP. GIRDER (24' SPAN)

RXN FROM JOIST: $w_u L/2 = 30^k$

$M_U = \frac{1}{3}PL = 240^{k'}$

* USE W18x40 (L/d = 16 ✓, DCR = 0.81)

→ TYP. BM (12' SPAN) WILL MAINTAIN JOIST SIZE FOR CONSTRUCTABILITY

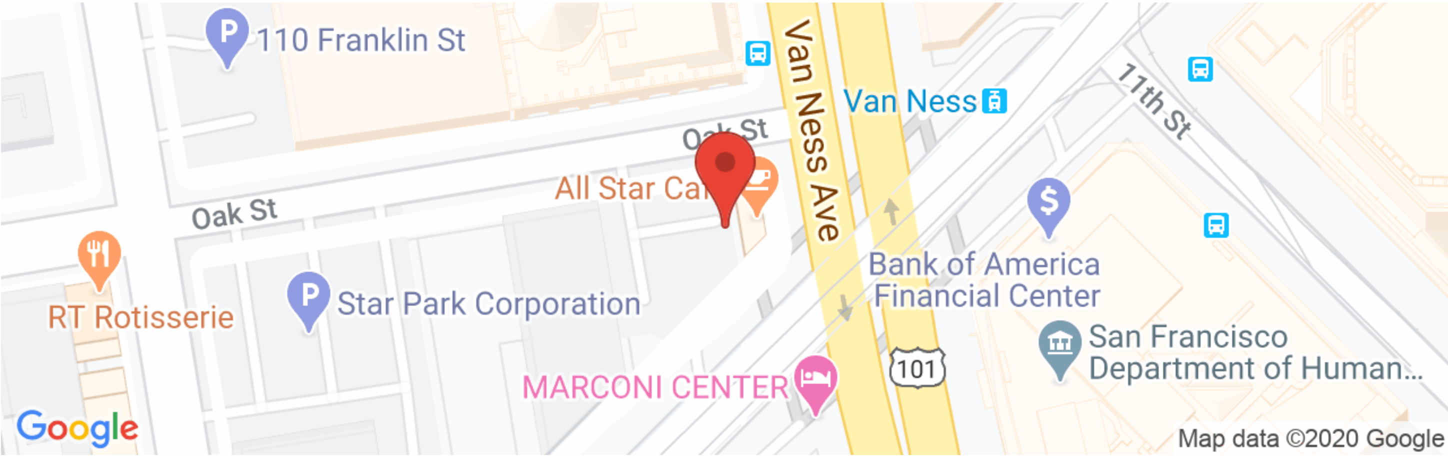
* USE W16x31

→ TYP. BRACE TAKES RXN FROM GIRDER & LATERAL:

RXN FROM GIRDER: $P = 30^k$

* MBR SIZING IN LATERAL SCHEMING

Latitude, Longitude: 37.77523061, -122.41960842



Date	2/11/2020, 11:59:30 PM
Design Code Reference Document	ASCE7-10
Risk Category	III
Site Class	D - Stiff Soil

Type	Value	Description
S_S	1.5	MCE_R ground motion. (for 0.2 second period)
S_1	0.638	MCE_R ground motion. (for 1.0s period)
S_{MS}	1.5	Site-modified spectral acceleration value
S_{M1}	0.957	Site-modified spectral acceleration value
S_{DS}	1	Numeric seismic design value at 0.2 second SA
S_{D1}	0.638	Numeric seismic design value at 1.0 second SA

Type	Value	Description
SDC	D	Seismic design category
F_a	1	Site amplification factor at 0.2 second
F_v	1.5	Site amplification factor at 1.0 second
PGA	0.567	MCE_G peak ground acceleration
F_{PGA}	1	Site amplification factor at PGA
PGA_M	0.567	Site modified peak ground acceleration
T_L	12	Long-period transition period in seconds
SsRT	2.144	Probabilistic risk-targeted ground motion. (0.2 second)
SsUH	2.057	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration
SsD	1.5	Factored deterministic acceleration value. (0.2 second)
S1RT	0.87	Probabilistic risk-targeted ground motion. (1.0 second)
S1UH	0.883	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration.
S1D	0.638	Factored deterministic acceleration value. (1.0 second)
PGAd	0.567	Factored deterministic acceleration value. (Peak Ground Acceleration)
C_{RS}	1.042	Mapped value of the risk coefficient at short periods
C_{R1}	0.986	Mapped value of the risk coefficient at a period of 1 s

PROJECT:	SOM - HIGH RISE
ENGINEER:	M.A.
DATE:	05.13.2020
SHEET:	

EQUIVALENT LATERAL FORCE PROCEDURE

[PER ASCE 7-16 : § 12.8]

LFRS : STEEL OCBF

SEISMIC RESPONSE COEFFICIENT DETERMINATION		
REFERENCE	DESCRIPTION	PARAMETER
[ASCE 7:T.12.2-1]	(RESPONSE OCBF)	R = 3
[ASCE 7:T.1.5-2]	(IMPORTANCE, RISK III)	I_e = 1.25
[SEA DESIGN MAPS]	(SHORT DESIGN SPECTRAL ACCEL.)	S_{ds} [g] = 1
[SEA DESIGN MAPS]	(1-SEC. DESIGN SPECTRAL ACCEL.)	S_{d1} [g] = 0.638
[SEA DESIGN MAPS]	(1-SEC. MCER SPECTRAL ACCEL.)	S_1 [g] = 0.638
[SEA DESIGN MAPS]	(LONG-PERIOD)	T_L [s] = 12
	(MEAN BLDG HEIGHT)	h [ft] = 744
[ASCE 7:T.12.8-2]	(APPROX. PERIOD PARAMETERS)	C_t = 0.02 x = 0.75
[ASCE 7:§12.8.2.1]	(APPROX. PERIOD) $T_a = C_t h_n{}^x$	T_a [s] = 2.849
[ASCE 7:§12.8.1.1]	(SEISMIC RESPONSE) $C_s = S_{ds}/(R/I_e)$	C_s = 0.417
(MAX. IF $T_a \le T_L$)	$C_s \le S_{d1}/T(R/I_e)$	C_s = 0.093
(MAX. IF $T_a > T_L$)	$C_s \le S_{d1}T_L/T^2(R/I_e)$	C_s = (N/A)
(MIN. IF $S_1 < 0.6g$)	$C_s \ge 0.044 S_{ds} I_e \ge 0.01)$	C_s = (N/A)
(MIN. IF $S_1 \ge 0.6g$)	$C_s \ge 0.5 S_1/(R/I_e)$	C_s = 0.133
		C_s = 0.093

EFFECTIVE SEISMIC WEIGHT DETERMINATION					
LEVEL	HORIZONTAL (STORY) WT [PSF]	HORIZONTAL (STORY) AREA [SF]	VERTICAL (WALL) WT [PSF]	VERTICAL (WALL) AREA [SF]	SEISMIC WT [k]
ROOF	80.0	12000.0	40.0	4200.0	1128
1-61	80.0	732000	40.0	411600.0	75024
				W [k] =	**76152**

SEISMIC BASE SHEAR PER [ASCE 7:§12.8.1.1] $(V = C_s W)$ **V [k] = 7105** [k]

VERTICAL FORCE DISTRIBUTION

[PER ASCE 7-16 : § 12.8.3]

LFRS : STEEL OCBF

VERTICAL DISTRIBUTION CRITERIA		
REFERENCE	DESCRIPTION	PARAMETER
[ASCE 7:§12.8.3]	(PERIOD EXPONENT)	(SEE BLW.)
(T ≤ 0.5s)	k = 1	
(0.5s ≤ T ≤ 2.5s)	k = 2	
(T ≥ 2.5s)	(LIN. INTERPOLATION)	
[ASCE 7:§12.8.3]	(VERT. DISTRIBUTION)	(SEE BLW.)
	$C_{vx} = w_x {h_x}^k / \sum w_x {h_x}^k$	

VERTICAL DISTRIBUTION OF SEISMIC FORCES							
LEVEL	STORY WT [k]	STORY HT [ft]	k	$w_x {h_x}^k$	C_{vx}	STORY FORCE [k]	STORY SHEAR [k]
62	1128	744.0	2.00	6.24E+08	0.043	**309**	**309**
61	1230	732.0	2.00	6.59E+08	0.046	**326**	**635**
60	1230	720.0	2.00	6.38E+08	0.044	**316**	**951**
59	1230	708.0	2.00	6.17E+08	0.043	**305**	**1256**
58	1230	696.0	2.00	5.96E+08	0.042	**295**	**1551**
57	1230	684.0	2.00	5.75E+08	0.040	**285**	**1836**
56	1230	672.0	2.00	5.55E+08	0.039	**275**	**2111**
55	1230	660.0	2.00	5.36E+08	0.037	**265**	**2376**
54	1230	648.0	2.00	5.16E+08	0.036	**256**	**2631**
53	1230	636.0	2.00	4.97E+08	0.035	**246**	**2878**
52	1230	624.0	2.00	4.79E+08	0.033	**237**	**3115**
51	1230	612.0	2.00	4.61E+08	0.032	**228**	**3343**
50	1230	600.0	2.00	4.43E+08	0.031	**219**	**3562**
49	1230	588.0	2.00	4.25E+08	0.030	**210**	**3772**
48	1230	576.0	2.00	4.08E+08	0.028	**202**	**3974**
47	1230	564.0	2.00	3.91E+08	0.027	**194**	**4168**
46	1230	552.0	2.00	3.75E+08	0.026	**185**	**4353**
45	1230	540.0	2.00	3.59E+08	0.025	**178**	**4531**
44	1230	528.0	2.00	3.43E+08	0.024	**170**	**4700**
43	1230	516.0	2.00	3.27E+08	0.023	**162**	**4863**
42	1230	504.0	2.00	3.12E+08	0.022	**155**	**5017**
41	1230	492.0	2.00	2.98E+08	0.021	**147**	**5165**
40	1230	480.0	2.00	2.83E+08	0.020	**140**	**5305**
39	1230	468.0	2.00	2.69E+08	0.019	**133**	**5438**
38	1230	456.0	2.00	2.56E+08	0.018	**127**	**5565**
37	1230	444.0	2.00	2.42E+08	0.017	**120**	**5685**

36	1230	432.0	2.00	2.30E+08	0.016	114	5798
35	1230	420.0	2.00	2.17E+08	0.015	107	5906
34	1230	408.0	2.00	2.05E+08	0.014	101	6007
33	1230	396.0	2.00	1.93E+08	0.013	95	6102
32	1230	384.0	2.00	1.81E+08	0.013	90	6192
31	1230	372.0	2.00	1.70E+08	0.012	84	6276
30	1230	360.0	2.00	1.59E+08	0.011	79	6355
29	1230	348.0	2.00	1.49E+08	0.010	74	6429
28	1230	336.0	2.00	1.39E+08	0.010	69	6498
27	1230	324.0	2.00	1.29E+08	0.009	64	6562
26	1230	312.0	2.00	1.20E+08	0.008	59	6621
25	1230	300.0	2.00	1.11E+08	0.008	55	6676
24	1230	288.0	2.00	1.02E+08	0.007	50	6726
23	1230	276.0	2.00	9.37E+07	0.007	46	6773
22	1230	264.0	2.00	8.57E+07	0.006	42	6815
21	1230	252.0	2.00	7.81E+07	0.005	39	6854
20	1230	240.0	2.00	7.08E+07	0.005	35	6889
19	1230	228.0	2.00	6.39E+07	0.004	32	6920
18	1230	216.0	2.00	5.74E+07	0.004	28	6949
17	1230	204.0	2.00	5.12E+07	0.004	25	6974
16	1230	192.0	2.00	4.53E+07	0.003	22	6997
15	1230	180.0	2.00	3.98E+07	0.003	20	7016
14	1230	168.0	2.00	3.47E+07	0.002	17	7033
13	1230	156.0	2.00	2.99E+07	0.002	15	7048
12	1230	144.0	2.00	2.55E+07	0.002	13	7061
11	1230	132.0	2.00	2.14E+07	0.001	11	7072
10	1230	120.0	2.00	1.77E+07	0.001	9	7080
9	1230	108.0	2.00	1.43E+07	0.001	7	7087
8	1230	96.0	2.00	1.13E+07	0.001	6	7093
7	1230	84.0	2.00	8.68E+06	0.001	4	7097
6	1230	72.0	2.00	6.38E+06	0.000	3	7100
5	1230	60.0	2.00	4.43E+06	0.000	2	7103
4	1230	48.0	2.00	2.83E+06	0.000	1	7104
3	1230	36.0	2.00	1.59E+06	0.000	1	7105
2	1230	24.0	2.00	7.08E+05	0.000	0	7105
1	1230	12.0	2.00	1.77E+05	0.000	0	7105
0	1230	0.0	2.00	0.00E+00	0.000	0	7105
Σ	77382			1.44E+10	1.000	7105	

PROJECT:	SOM - HIGH RISE
ENGINEER:	M.A.
DATE:	05.13.2020
SHEET:	

DIRECTIONAL PROCEDURE

PER ASCE 7-16 : § 27.2]

MWFRS : STEEL OCBF

WIND ANALYSIS PARAMETERS		
REFERENCE	DESCRIPTION	PARAMETER
[ASCE 7:T.1.5-1]	(RISK CATEGORY)	RISK = III
[ASCE 7:F.26.5]	(WIND SPEED)	V [mph]= 100
	(BLDG HEIGHT)	h [ft] = 744
	(WINDWARD LENGTH)	L [ft] = 105
	(LEEWARD LENGTH)	B [ft] = 168
[ASCE 7-16:§26.6]	(DIRECTIONALITY)	K_d = 0.85
[ASCE 7-16:§26.7]	(EXPOSURE)	EXPOSURE = C
[ASCE 7-16:§26.8]	(TOPOGRAPHIC)	K_{zt} = 1.00
[ASCE 7-16:§26.9]	(GROUND ELEVATION)	K_e = 1.00
	(BLDG FLEXIBILITY)	FLEXIBILITY = FLEXIBLE
[ASCE 7-16:§26.11]	(GUST EFFECT, RIGID)	G = (N/A)
[ASCE 7-16:§26.11]	(GUST EFFECT, FLEX.)*	G_f = 1.13
[ASCE 7-16:§26.13]	(INTERNAL PRESSURE)	GC_{pi} = 0.18
[ASCE 7-16:F.27.3]	(EXT. PRESSURE)	C_p = 0.8

VERTICAL FORCE DISTRIBUTION

[PER ASCE 7-16 : § 27.2]

MWFRS : STEEL OCBF

VERTICAL DISTRIBUTION OF WIND FORCES							
LEVEL	STORY HT [ft]	K_z	q_z [PSF]	p [PSF]	A_T [SF]	STORY FORCE [k]	STORY SHEAR [k]
62	744.0	1.931	42.02	45.668	1008	**46.0**	**46**
61	732.0	1.924	41.88	45.512	2016	**91.8**	**138**
60	720.0	1.918	41.73	45.354	2016	**91.4**	**229**
59	708.0	1.911	41.58	45.194	2016	**91.1**	**320**
58	696.0	1.904	41.43	45.032	2016	**90.8**	**411**
57	684.0	1.897	41.28	44.867	2016	**90.5**	**502**
56	672.0	1.890	41.13	44.700	2016	**90.1**	**592**
55	660.0	1.883	40.97	44.531	2016	**89.8**	**681**
54	648.0	1.876	40.81	44.359	2016	**89.4**	**771**
53	636.0	1.868	40.65	44.185	2016	**89.1**	**860**
52	624.0	1.861	40.49	44.008	2016	**88.7**	**949**
51	612.0	1.853	40.33	43.829	2016	**88.4**	**1037**
50	600.0	1.846	40.16	43.646	2016	**88.0**	**1125**
49	588.0	1.838	39.99	43.461	2016	**87.6**	**1213**
48	576.0	1.830	39.82	43.273	2016	**87.2**	**1300**
47	564.0	1.822	39.64	43.082	2016	**86.9**	**1387**
46	552.0	1.813	39.46	42.887	2016	**86.5**	**1473**
45	540.0	1.805	39.28	42.689	2016	**86.1**	**1559**
44	528.0	1.797	39.09	42.487	2016	**85.7**	**1645**
43	516.0	1.788	38.90	42.282	2016	**85.2**	**1730**
42	504.0	1.779	38.71	42.073	2016	**84.8**	**1815**
41	492.0	1.770	38.52	41.860	2016	**84.4**	**1899**
40	480.0	1.761	38.32	41.643	2016	**84.0**	**1983**
39	468.0	1.751	38.11	41.422	2016	**83.5**	**2067**
38	456.0	1.742	37.90	41.196	2016	**83.1**	**2150**
37	444.0	1.732	37.69	40.965	2016	**82.6**	**2232**
36	432.0	1.722	37.48	40.730	2016	**82.1**	**2315**
35	420.0	1.712	37.25	40.489	2016	**81.6**	**2396**
34	408.0	1.702	37.03	40.243	2016	**81.1**	**2477**
33	396.0	1.691	36.80	39.991	2016	**80.6**	**2558**
32	384.0	1.680	36.56	39.732	2016	**80.1**	**2638**
31	372.0	1.669	36.31	39.468	2016	**79.6**	**2718**
30	360.0	1.657	36.06	39.196	2016	**79.0**	**2797**
29	348.0	1.646	35.81	38.917	2016	**78.5**	**2875**
28	336.0	1.633	35.54	38.631	2016	**77.9**	**2953**
27	324.0	1.621	35.27	38.336	2016	**77.3**	**3030**

26	312.0	1.608	34.99	38.033	2016	**76.7**	**3107**
25	300.0	1.595	34.71	37.720	2016	**76.0**	**3183**
24	288.0	1.581	34.41	37.397	2016	**75.4**	**3258**
23	276.0	1.567	34.10	37.064	2016	**74.7**	**3333**
22	264.0	1.553	33.78	36.719	2016	**74.0**	**3407**
21	252.0	1.537	33.46	36.361	2016	**73.3**	**3480**
20	240.0	1.522	33.11	35.989	2016	**72.6**	**3553**
19	228.0	1.505	32.76	35.603	2016	**71.8**	**3625**
18	216.0	1.488	32.39	35.200	2016	**71.0**	**3696**
17	204.0	1.471	32.00	34.779	2016	**70.1**	**3766**
16	192.0	1.452	31.59	34.338	2016	**69.2**	**3835**
15	180.0	1.432	31.17	33.874	2016	**68.3**	**3903**
14	168.0	1.412	30.72	33.386	2016	**67.3**	**3971**
13	156.0	1.390	30.24	32.869	2016	**66.3**	**4037**
12	144.0	1.367	29.74	32.320	2016	**65.2**	**4102**
11	132.0	1.342	29.20	31.733	2016	**64.0**	**4166**
10	120.0	1.315	28.62	31.103	2016	**62.7**	**4229**
9	108.0	1.286	27.99	30.420	2016	**61.3**	**4290**
8	96.0	1.255	27.30	29.675	2016	**59.8**	**4350**
7	84.0	1.220	26.55	28.853	2016	**58.2**	**4408**
6	72.0	1.181	25.70	27.931	2016	**56.3**	**4464**
5	60.0	1.137	24.73	26.880	2016	**54.2**	**4519**
4	48.0	1.084	23.60	25.646	2016	**51.7**	**4570**
3	36.0	1.021	22.21	24.139	2016	**48.7**	**4619**
2	24.0	0.937	20.39	22.164	2016	**44.7**	**4664**
1	12.0	0.810	17.62	19.154	2016	**38.6**	**4702**
Σ						4702	

PROJECT:	SOM - HIGH RISE
ENGINEER:	M.A.
DATE:	05.13.2020
SHEET:	

CAL POLY SOM

VERTICAL FORCE DISTRIBUTION COMPARISON

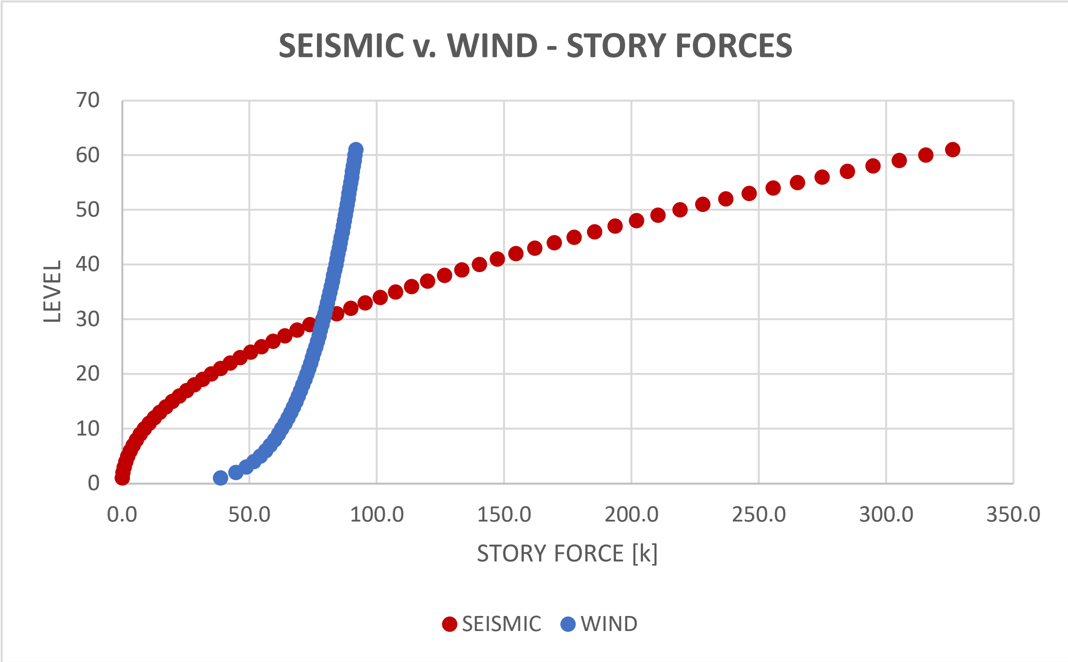
PER ASCE 7-16 : § 12.8, 27.2]

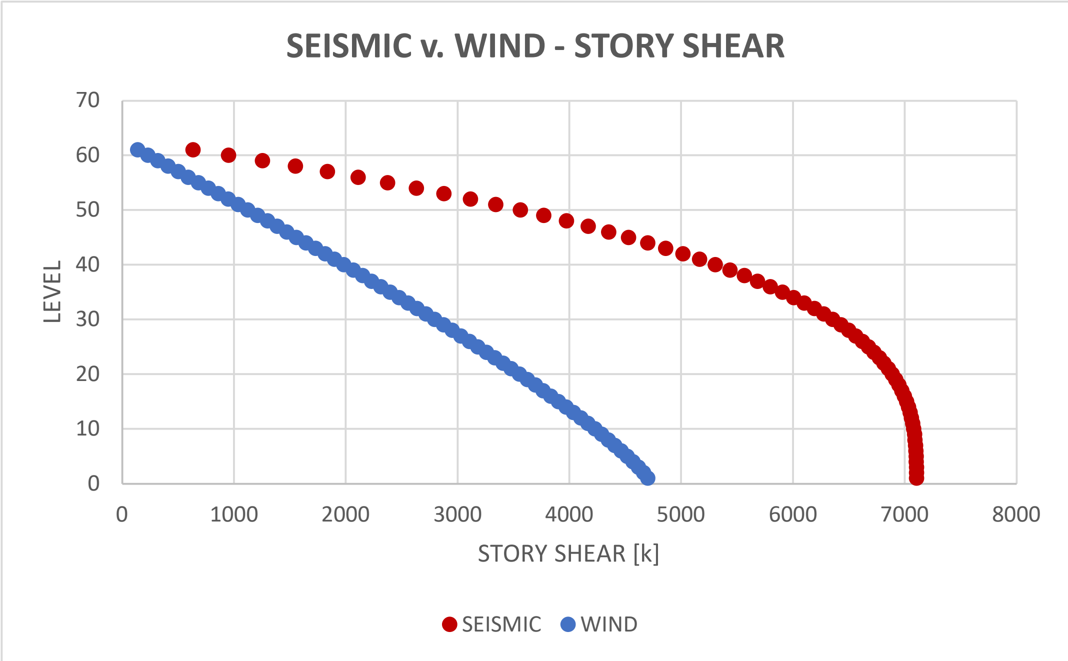
LFRS/MWFRS : STEEL OCBF

VERTICAL FORCE DISTRIBUTION RESULTS						
LEVEL		F_{xE}	V_{xE}		F_{xW}	V_{xW}
62		309.0	309		46.0	46
61		326.2	635		91.8	138
60		315.6	951		91.4	229
59		305.1	1256		91.1	320
58		294.9	1551		90.8	411
57		284.8	1836		90.5	502
56		274.9	2111		90.1	592
55		265.2	2376		89.8	681
54		255.6	2631		89.4	771
53		246.2	2878		89.1	860
52		237.0	3115		88.7	949
51		228.0	3343		88.4	1037
50		219.1	3562		88.0	1125
49		210.5	3772		87.6	1213
48		202.0	3974		87.2	1300
47		193.6	4168		86.9	1387
46		185.5	4353		86.5	1473
45		177.5	4531		86.1	1559
44		169.7	4700		85.7	1645
43		162.1	4863		85.2	1730
42		154.6	5017		84.8	1815
41		147.4	5165		84.4	1899
40		140.3	5305		84.0	1983
39		133.3	5438		83.5	2067
38		126.6	5565		83.1	2150
37		120.0	5685		82.6	2232
36		113.6	5798		82.1	2315
35		107.4	5906		81.6	2396
34		101.3	6007		81.1	2477
33		95.5	6102		80.6	2558
32		89.8	6192		80.1	2638
31		84.2	6276		79.6	2718
30		78.9	6355		79.0	2797

29	73.7	6429	78.5	2875
28	68.7	6498	77.9	2953
27	63.9	6562	77.3	3030
26	59.3	6621	76.7	3107
25	54.8	6676	76.0	3183
24	50.5	6726	75.4	3258
23	46.4	6773	74.7	3333
22	42.4	6815	74.0	3407
21	38.7	6854	73.3	3480
20	35.1	6889	72.6	3553
19	31.6	6920	71.8	3625
18	28.4	6949	71.0	3696
17	25.3	6974	70.1	3766
16	22.4	6997	69.2	3835
15	19.7	7016	68.3	3903
14	17.2	7033	67.3	3971
13	14.8	7048	66.3	4037
12	12.6	7061	65.2	4102
11	10.6	7072	64.0	4166
10	8.8	7080	62.7	4229
9	7.1	7087	61.3	4290
8	5.6	7093	59.8	4350
7	4.3	7097	58.2	4408
6	3.2	7100	56.3	4464
5	2.2	7103	54.2	4519
4	1.4	7104	51.7	4570
3	0.8	7105	48.7	4619
2	0.4	7105	44.7	4664
1	0.1	7105	38.6	4702
Σ	**7105**		**4702**	

SEISMIC GOVERNS


SEISMIC v. WIND - STORY FORCES
LEVEL
70
60
50
40
30
20
10
0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
STORY FORCE [k]
SEISMIC
WIND


SEISMIC v. WIND - STORY SHEAR
LEVEL
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
6000
7000
8000
STORY SHEAR [k]
SEISMIC
WIND

General Material Properties

	Label	E [ksi]	G [ksi]	Nu	Therm (\1E5 F)	Density[k/ft^3]
1	gen_Conc3NW	3155	1372	.15	.6	.145
2	gen_Conc4NW	3644	1584	.15	.6	.145
3	gen_Conc3LW	2085	906	.15	.6	.11
4	gen_Conc4LW	2408	1047	.15	.6	.11
5	gen_Alum	10100	4077	.3	1.29	.173
6	gen_Steel	29000	11154	.3	.65	.49
7	RIGID	1e+6		.3	0	0

General Section Sets

	Label	Shape	Type	Material	A [in2]	I (90,270) [in4]	I (0,180) [in4]
1	BEAM		Beam	gen_Steel	1	1	1
2	COLUMN		Column	gen_Steel	30	893	893
3	GEN1C		VBrace	gen_Steel	130	8032	8032
4	GEN1B		VBrace	gen_Steel	58	1586	1586
5	GEN1A		VBrace	gen_Steel	14	99	99
6	RIGID		None	RIGID	1e+6	1e+6	1e+6

Member Distributed Loads (BLC 3 : WIND)

	Member Label	Direction	Start Magnitude[k/ft,...	End Magnitude[k/ft,F...	Start Location[ft,%]	End Location[ft,%]
1	M621	X	.48	1.08	0	0

Member Distributed Loads (BLC 4 : SEISMIC)

	Member Label	Direction	Start Magnitude[k/ft,...	End Magnitude[k/ft,F...	Start Location[ft,%]	End Location[ft,%]
1	M621	X	0	3.23	0	0

Basic Load Cases

	BLC Description	Category	X Gravity	Y Gravity	Joint	Point	Distributed
~~1~~	~~VIRTUAL PL~~	~~None~~					
~~2~~	~~VIRTUAL UDL~~	~~None~~					
3	WIND	None					1
4	SEISMIC	None					1
5	DEAD	None			527		
6	LIVE	None			529		

Load Combinations

	Description	Sol...	PD...	SR...	BLC	Fact...	BLC	Fact...	BLC	Fact...	BLC	Fact...	BLC	Fact...	BLC	Fact...	BLC	Fact...	BLC	Fact...	BLC	Fact...	BLC	Fact...
1	STRENG...	Yes			5	1.4	6	.5	4	1														
2	SERVICE ...	Yes			5	1	3	.6																
3	SERVICE ...	Yes			5	1	4	.7																

PROJECT: SOM - HIGH RISE
ENGINEER: M.A.
DATE: 05.15.2020
SHEET:

CAL POLY

SOM

BRACE LINE RELATIVE STIFFNESS CALCULATION

BRACE LINE | LEVEL		DEFLECTION FROM LOAD			RELATIVE STIFFNESS		
		POINT	UDL	WIND	POINT	UDL	WIND
BL 1 = 22	62	56.77	21.30	14580	0.124	0.125	**0.124**
	41	29.04	11.80	8012	0.124	0.125	**0.125**
	21	8.668	3.903	2610	0.126	0.128	**0.127**
BL 4	62	7.046	2.654	1815	1.000	1.000	**1.000**
	41	3.614	1.480	1004	1.000	1.000	**1.000**
	21	1.088	0.498	332.0	1.000	1.000	**1.000**
BL 7 = 10	62	8.580	3.410	2311	0.821	0.778	**0.785**
	41	4.667	2.158	1442	0.774	0.686	**0.696**
	21	1.584	0.891	576.0	0.687	0.559	**0.576**
BL 13	62	7.712	2.982	2031	0.914	0.890	**0.894**
	41	4.074	1.773	1193	0.887	0.835	**0.842**
	21	1.304	0.667	437.0	0.834	0.747	**0.760**
BL 16 = 19	62	22.95	8.619	5898	0.307	0.308	**0.308**
	41	11.75	4.784	3247	0.308	0.309	**0.309**
	21	3.513	1.590	1062	0.310	0.313	**0.313**

PROJECT: SOM - HIGH RISE
ENGINEER: M.A.
DATE: 05.15.2020
SHEET:

BRACE LINE SHEAR DISTRIBUTION CALCULATION

BRACE LINE | LEVEL		# BRACES	STIFFNESS	% STORY SHEAR	DIRECT [k]	+ 5% [k]
BL 1	62	4	0.124	2.88%	8.89	**9.33**
	41	4	0.125	3.05%	158	**165.6**
	21	4	0.127	3.35%	230	**241.4**
BL 4	62	10	1.000	23.10%	71.39	**74.96**
	41	10	1.000	24.37%	1259	**1321.6**
	21	10	1.000	26.37%	1807	**1898**
BL 7	62	8	0.785	18.14%	56.07	**58.87**
	41	8	0.696	16.97%	876	**920.2**
	21	8	0.576	15.20%	1042	**1093.8**
BL 10	62	8	0.785	18.14%	56.07	**58.87**
	41	8	0.696	16.97%	876	**920.2**
	21	8	0.576	15.20%	1042	**1093.8**
BL 13	62	8	0.894	20.64%	63.80	**66.99**
	41	8	0.842	20.51%	1059	**1112.2**
	21	8	0.760	20.03%	1373	**1442**
BL 16	62	6	0.308	7.11%	21.97	**23.07**
	41	6	0.309	7.54%	389	**408.7**
	21	6	0.313	8.24%	565	**593.3**
BL 19	62	6	0.308	7.11%	21.97	**23.07**
	41	6	0.309	7.54%	389	**408.7**
	21	6	0.313	8.24%	565	**593.3**
BL 22	62	4	0.124	2.88%	8.89	**9.33**
	41	4	0.125	3.05%	158	**165.6**
	21	4	0.127	3.35%	230	**241.4**
Σ (62)			**4.329**	100%	309	
Σ (41)			**4.103**	100%	5165	
Σ (21)			**3.792**	100%	6854	