181 Fremont

San Francisco, California

Images courtesy of Heller Manus

Caroline Klatman

Advisor | Dr. Aly Said
Structural Option

AE Senior Thesis
April 13, 2015

Introduction

Existing Design → Proposal and Depth → Construction Breadth

Construction

Nov 2013—Early 2016

Design-Bid-Build

$375 Million

563,804 square feet

56 Stories | 700 ft tall

Image courtesy of Google Maps

Project Team

General Contractor | Level 10 Construction

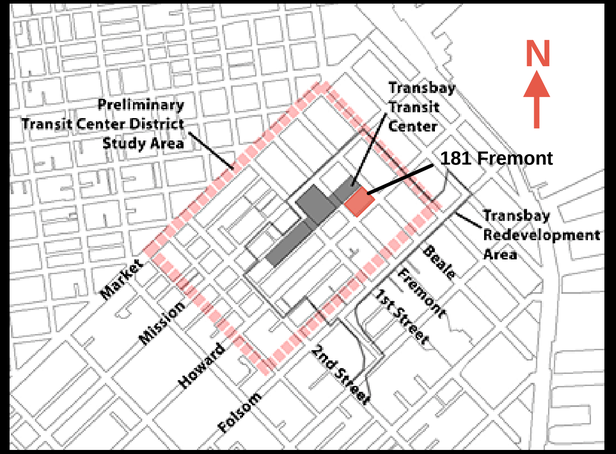
Construction Manager | Jay Paul Company

Owner | Jay Paul Company

Architect | Heller Manus

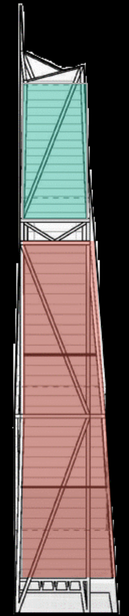
Structural and MEP Engineer | Arup

Transbay Transit Center District Plan



Images courtesy of Heller Manus

City Park Bridge



Existing Design

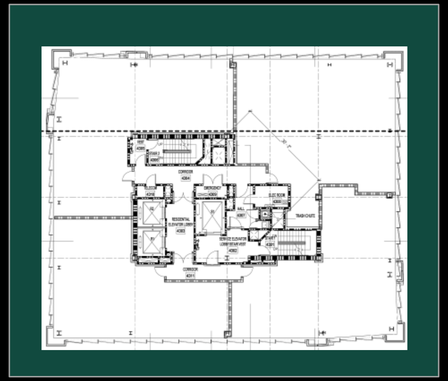
Layout

16 Residential

1 Residential Amenity

1 Mechanical

33 Office

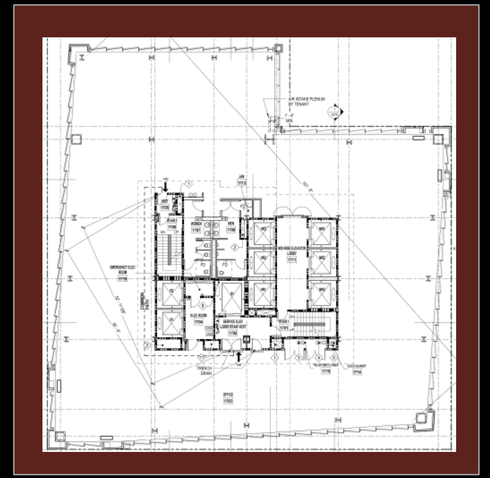


N

4 Units

Images courtesy of Heller Manus

N



Open Office

Exterior Aesthetic

Tilting Façade

Megaframe

Images courtesy of Heller Manus

Seismic Design

Seismic Design Category D

T_x = 7.2 sec

T_y = 6.7 sec

Performance Objective:

Moderate damage under 2/3 MCE

Method of Compliance:

Code Design Level

Performance Objective:

Superstructure remains elastic

Minor Damage to non-structural components

Method of Compliance:

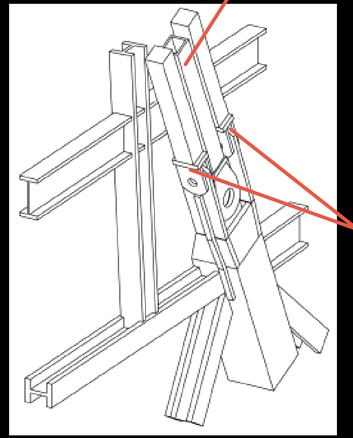
REDi Gold

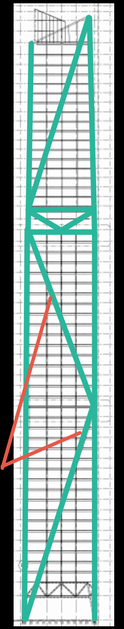
Megaframe

Unclassified by ASCE 7

Back-calculated R = 2.5

Images courtesy of Heller Manus

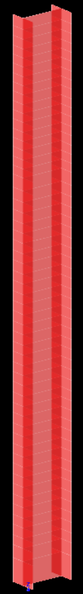




Proposal

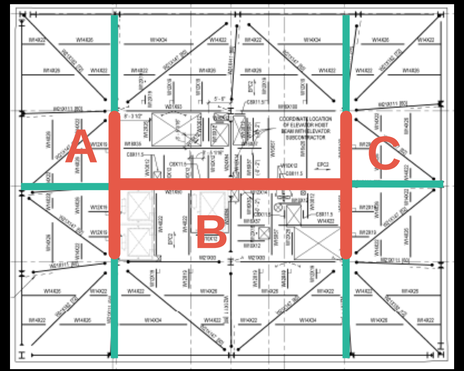
Purpose

Pursue a traditional design approach in order to compare to Arup's solution



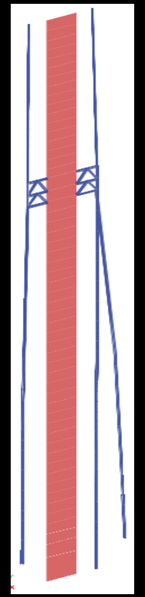
Solution

Design a dual system classified by ASCE 7-10

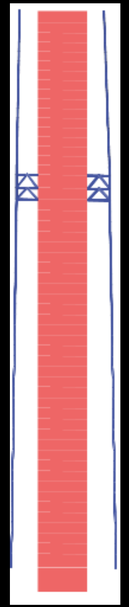


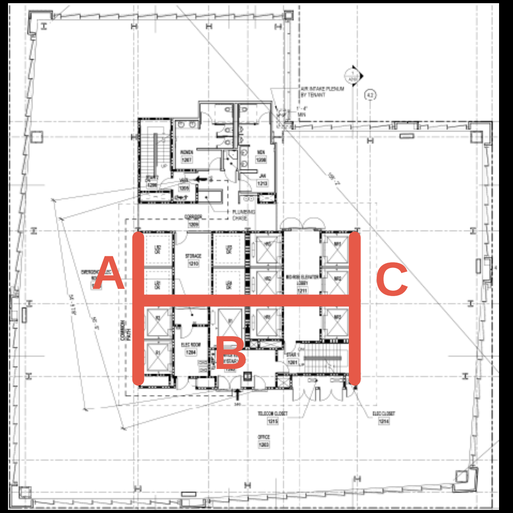
Level 37

Image adapted from Arup



Solution





Lower Level

Image adapted from Heller Manus

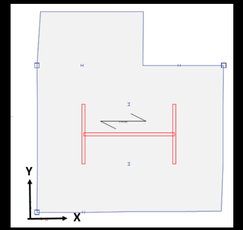
Approach

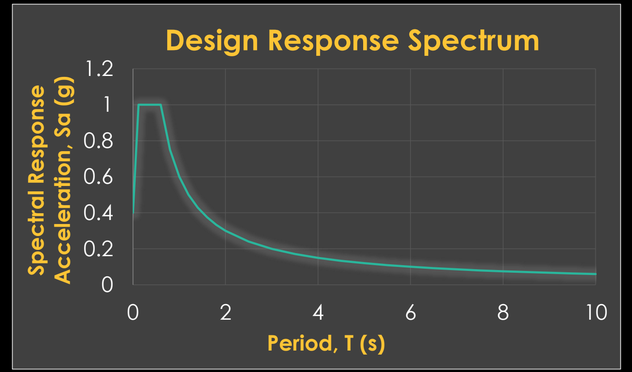
Approach

Response Spectrum Analysis

→ ETABS 2013

N ←





Response Spectrum

$$Scale\ Factor\ =\ 0.85 * (I * g/R) * (V_{ELF}/V_{MRSA})$$

X-direction = 109

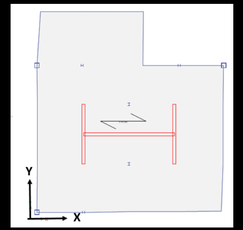
Y-direction = 176

Approach

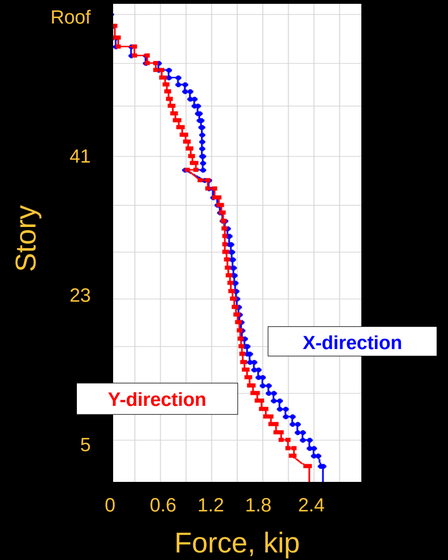
Response Spectrum Analysis

→ ETABS 2013

N ←



Story Shears



Base Shear

2463 kips in the x-direction

2216 kips in the y-direction

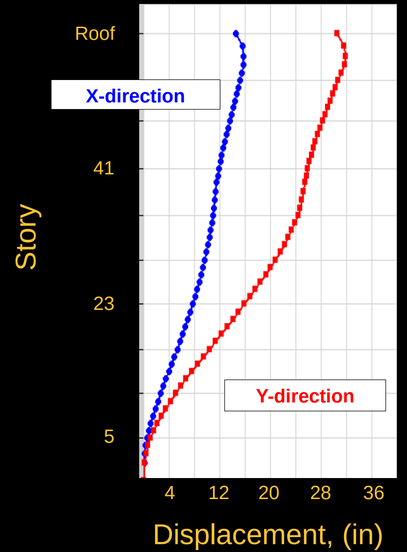
Seismic Drift

Seismic Drift

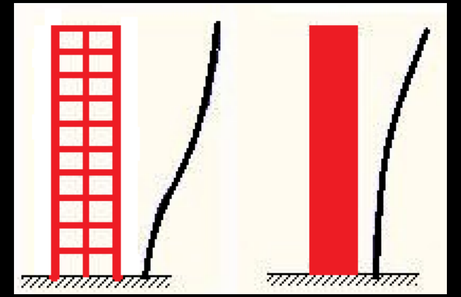
20% of story height

Multiply actual drift by C_D/I

Max Story Displacement



Deflection Behavior

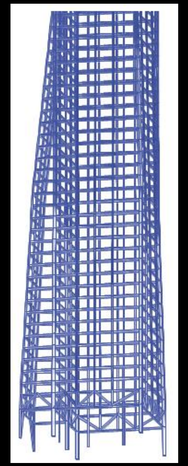


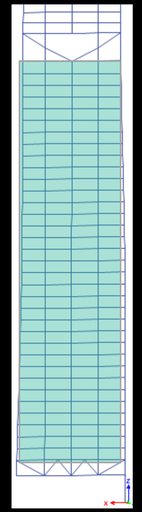
Moment Frames Design

Special Moment Frames

Moment Frames up to 473’

Seismically Compact Sections





Building Behavior

25% of Prescribed Seismic Forces

646 kips in the x-direction

554 kips in the y-direction

Shear Walls

Shear Walls

Outrigger Interaction

Natural placement

Minimal impact on floor plan

Need for Openings

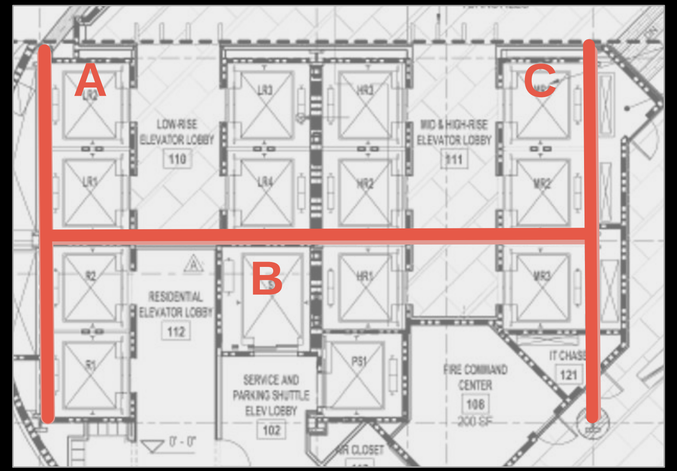
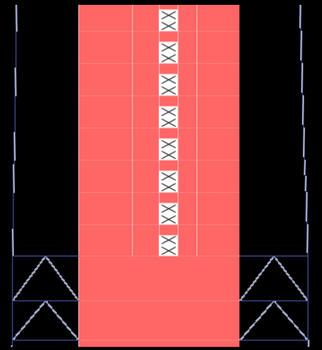
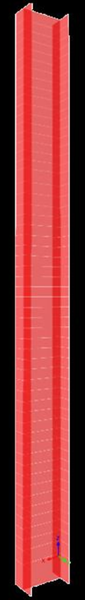


Image adapted from Heller Manus

Openings





Shear Walls

Shear Increase From Outriggers

A and C are 24” thick

Shear Wall B is 18” thick

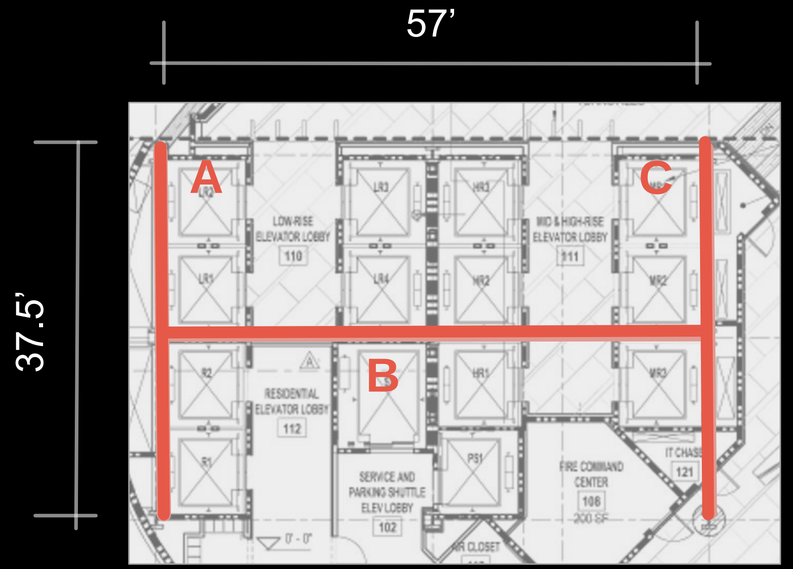
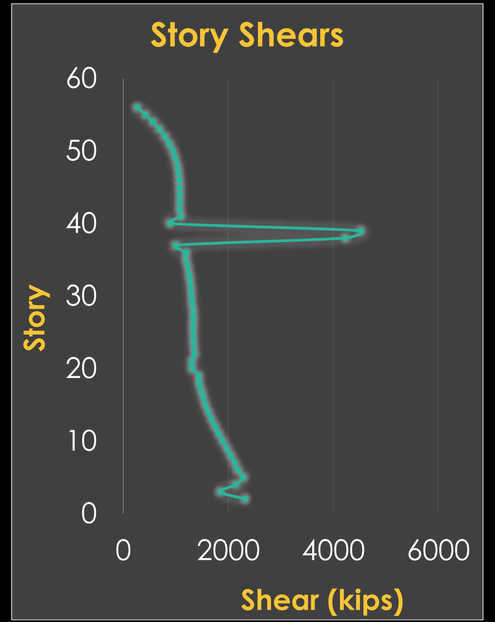
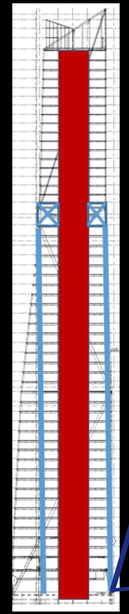


Image adapted from Heller Manus



Outrigger Design



Traditional

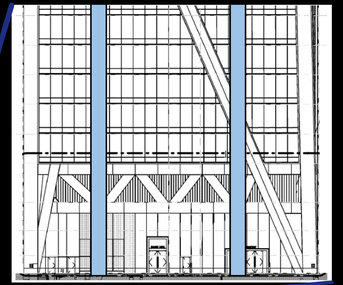


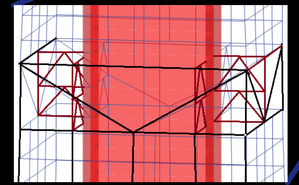
Image adapted from Heller Manus

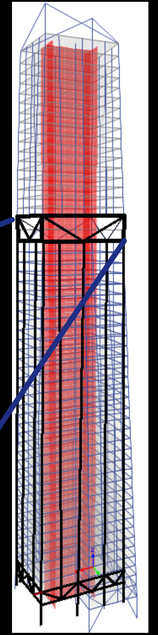
Engages all perimeter columns

Maintains clear entryway

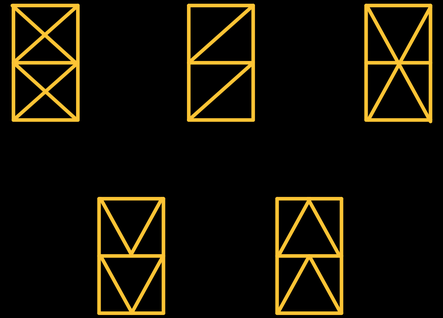
Minimal impact on floor plan

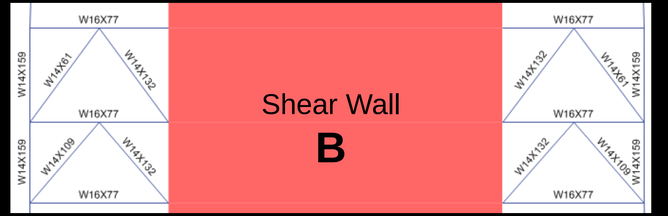
Belt Truss

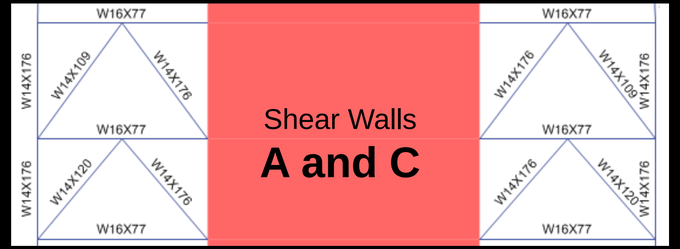


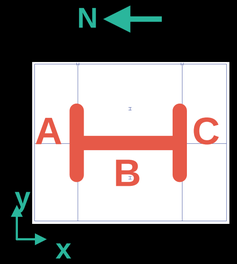


Optimization

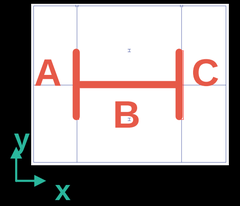


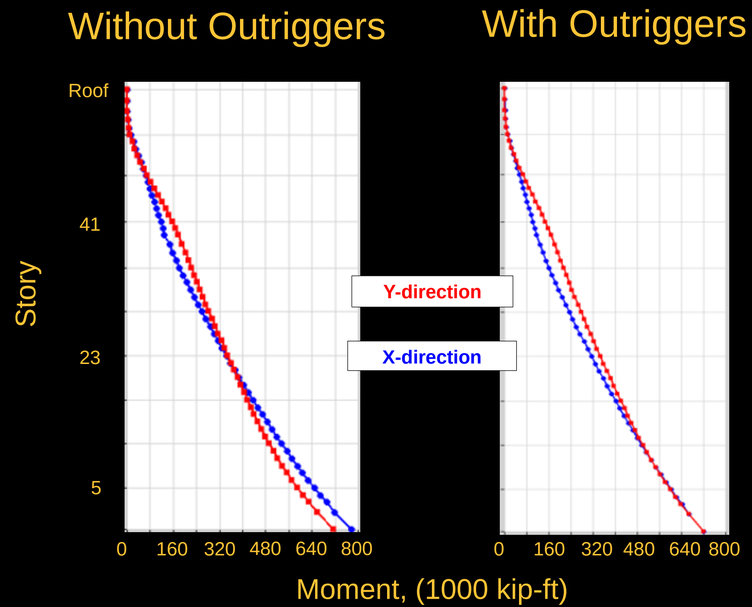




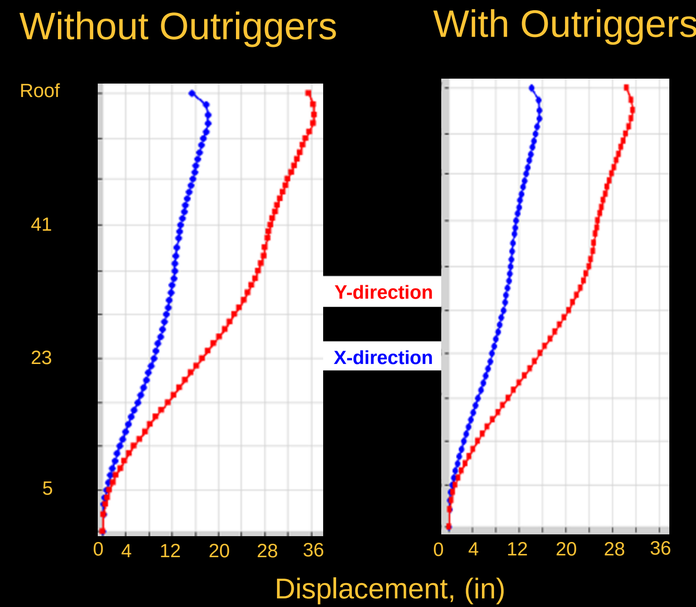


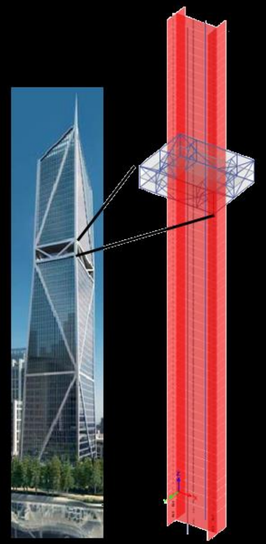
Overturning Moment



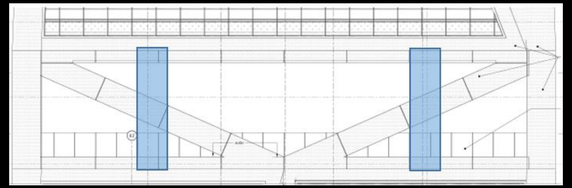


Drift





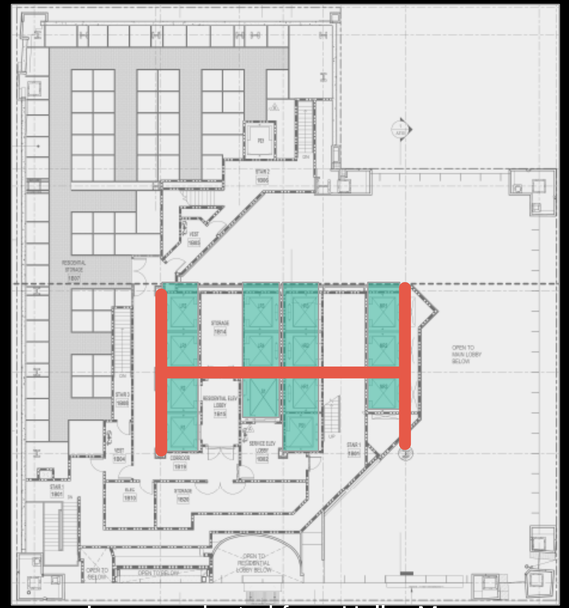
Impact on Gravity System

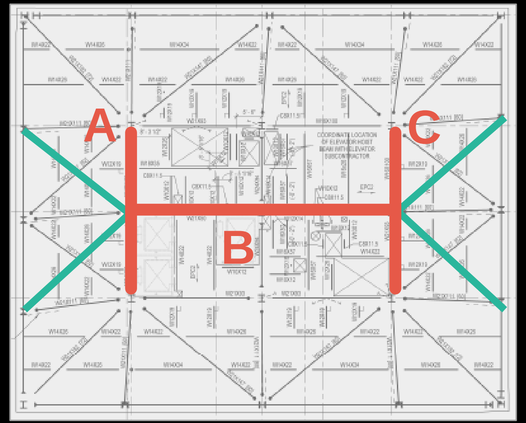


Images adapted from Heller Manus

Floor Framing

Transfer of shear from diaphragm





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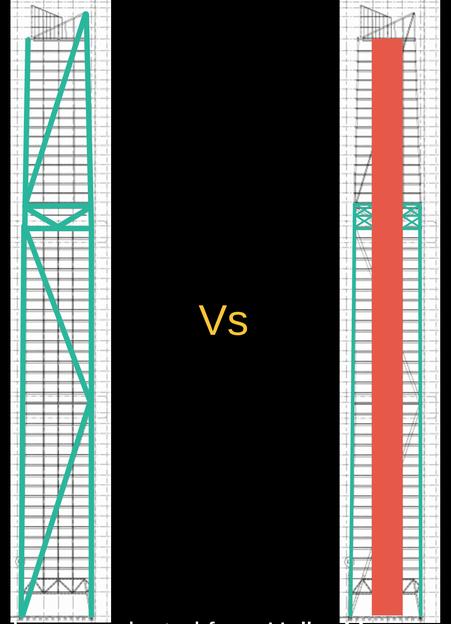


Vs

Images adapted from Heller Manus

Systems Comparison

Existing	New Design
Withstands 475-year return period earthquake	Withstands 2/3 MCE defined by ASCE 7-10
Just over $9 million	Just under $7 million
Added design time and cost due to Peer Review	Additional floor framing to transfer shear to shear wall

Construction Breadth

Cost

Image courtesy of Heller Manus

Mega-frame façade cost

New façade cost

Façade Cost

	Cost
Curtainwall	$21,185,680
Concrete Shear Walls	$6,889,365
Total Cost	$28,075,045

Additional Cost of Mega-frame

	Cost
Mega-Cladding	$2,177,244
Mega-Braces	$4,371,542
Connections	$4,965,056
Total Cost	$32,699,522

Total Additional: $4,624,477

Constructability

Megaframe

- complex connections
- delayed schedule
- specialty contractor

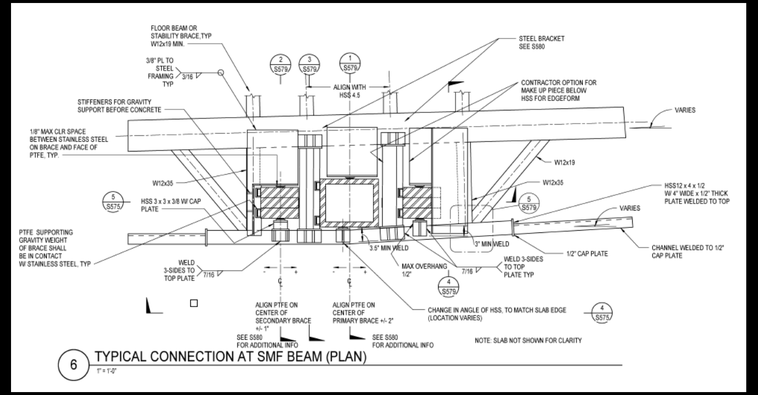
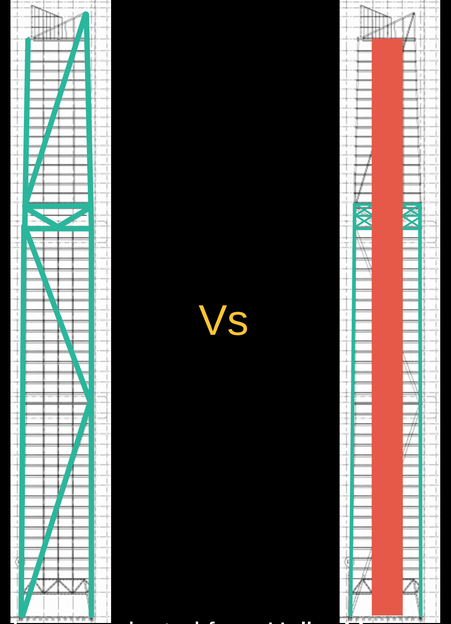


Image courtesy of Arup

Shear Walls

- cure time
- gravity-only columns
- hydraulic form system



Vs

Images adapted from Heller Manus

Conclusions

Existing

Superior Performance

New Design

Significant cost savings

Acknowledgements

Amy Graver and **Craig Allender** from Simpson Gumpertz & Heger for generously donating their time to obtain a thesis building as well as necessary project drawings and information.

Mr. Bob McNamara for his consultations and advice.

Dr. Aly Said and **Dr. Thomas Boothby** for their guidance as my faculty advisors.

Dana Burzo for her patient assistance in helping me understand the constructability issues and schedule impacts involved in this thesis.

Jay Paul Company for permission to use 181 Fremont as my thesis building.

Appendices

Appendices

Shear wall reinforcing:

	Typical Shear	Outrigger Shear	Typical Flexural	Outrigger Flexural
Shear Wall B	#7's at 12" EF	#10's at 10" EF	#7's at 12" EF	#7's at 12" EF
A	#7's at 10" EF	#10's at 8" EF	#10's at 4" EF	#10's at 8" EF
C	#7's at 10" EF	#10's at 8" EF	#10's at 4" EF	#10's at 8" EF

APPENDICES

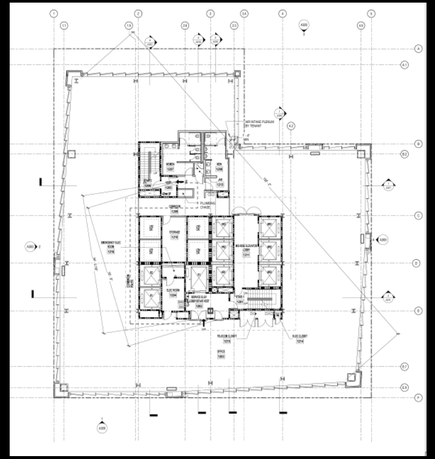
REINFORCING

COST ESTIMATE

FLOOR PLANS

FAÇADE

12



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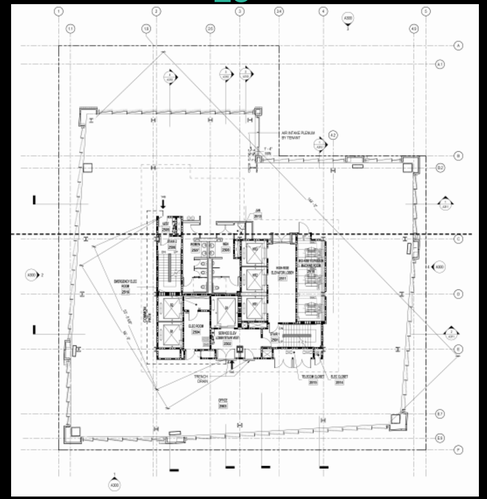

Images courtesy of Heller Manus

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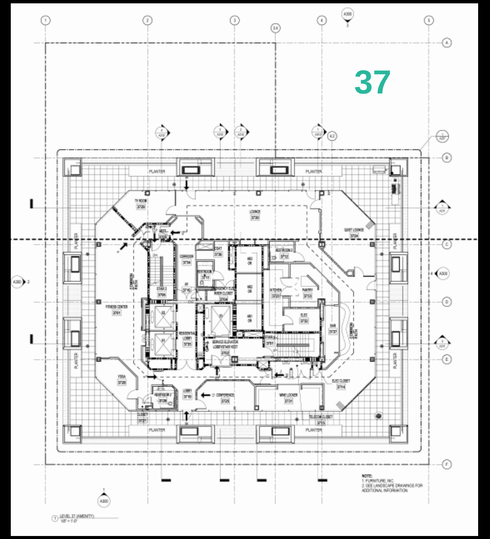
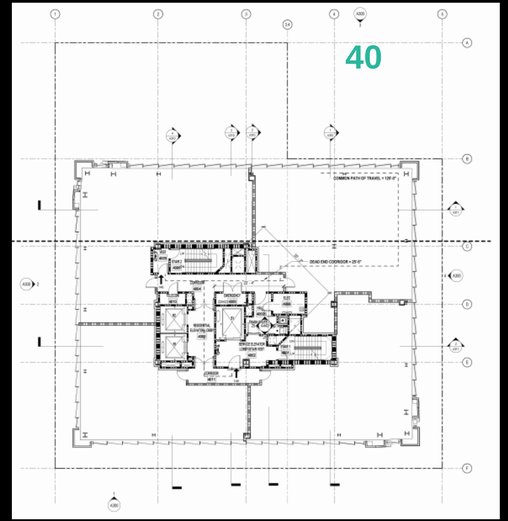
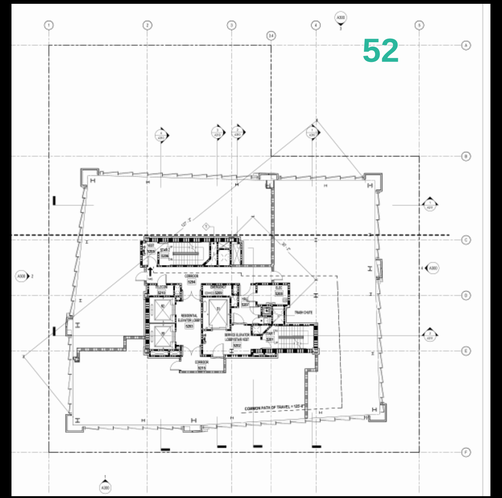


APPENDICES

- REINFORCING
- COST ESTIMATE
- FLOOR PLANS
- FAÇADE



Images courtesy of Heller Manus



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REINFORCING

COST ESTIMATE

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FAÇADE

Appendices

CSI Division	Item	Pricing Method	Quantity	Material	Installation	Total						Total Cost
B2020 210	Tubular Aluminum Framing											
	thermal break frame	cost/s.f. opening	214563	23.5	15.15	38.65						10175339.2
B2020 220	Curtain Wall Panels											0
1200	1" thick IGU	cost/s.f.	199505	18.5	14.65	33.15						8114875.85
5500	Sandwich Panel	cost/s.f.	45058	13.4	6.35	19.75						1091901.78
08 44	Curtain Wall and Glazed Assemblies											
50	Average, single glazed	H-1	195	0.164	SF	20558	53.5	8	61.5	71.5		1803563.62
											Total Curtainwall:	21185680

APPENDICES

REINFORCING

COST ESTIMATE

FLOOR PLANS

FAÇADE

Appendices

	Item	Crew	Daily Output	Labor-Hours	Unit	Quantity	Material	Labor	Equipment	Total	Total Incl O&P	Total Cost
Mega-cladding												0
09 22 13	Metal Furring											
0.003	Beams and Columns, 7/8" channels, 12" oc	1 Lath	155	0.052	SF	61954	0.37	2.1		2.47	3.5947	273260.316
07 25	Weather Barriers											0
3000	Building wrap	2 Carp	8000	0.002	SF	61954	0.15	0.09		0.24	0.3502	26621.3488
05 50 13	Column Covers											0
180	24" diameter, aluminum	2Sswk	32	0.5	VLF	5859	61	26.5		87.5	113	812356.209
09 29 10	Gypsum Board Panels											0
3500	On beams, columns, or soffits	2 Carp	675	0.024	SF	61954	0.38	1.11		1.49	2.13	161917.399
07 21 13.13	Foam Board Insulation											0
600	1" thick	1 Carp	680	0.12	SF	61954	0.25	0.55		0.8	1.13	85899.8405
05 41 13.25	Framing, Boxed Headers/Beams											0
200	Double, 18 ga. X 6" deep	2 carp	220	0.073	LF	61954	5.1	3.33		8.43	10.75	817188.749
											Total Mega-Cladding:	2177244

Appendices

	Item	Crew	Daily Output	Labor-Hours	Unit	Quantity	Material	Labor	Equipment	Total	Total Incl O&P		
Mega-Braces													
05 12 23	Structural Steel for Buildings												
4900	Heavy Sections, Moment connections	E2	7.8	7.179	ton	396	3175	370	194	3739	5002.5		2430674.73
5650	Braces	E2	50	1.12	EA	218	775	58	30	863	1132.75		1077160.29
7450	W14x342	E2	912	0.061	LF	1059	257	3.18	1.66	261.84	664.7		863706.527
Connections													
22 05 48.10	Vibration and Bearing Pads												0
740	Mounts, neoprene	1 Sswk	5	1.6	EA	400	111	78		189	242		118773.6
05 12 23.17	Columns, Structural												0
3300	Structural tubing	E-2	11270	0.005	Lb	240.3333	1.33	0.26	0.13	1.72	4.08		1203.14712
7150	W12x35	E-3	1032	0.054	LF	2400	73	2.81	1.46	77.27	99.475		292933.98
.65 0400	Plates				SF	932.3333	27			27	36.875		42184.0044
05 05 21.90	Welding Steel												0
1800	3 Passes	E-14	30	0.267	LF	3600	1.08	14.55	4.86	20.49	64		282700.8
05 12 23	Structural Steel for Buildings												0
4900	Heavy Sections, Moment connections	E2	7.8	7.179	ton	396	3175	370	194	3739	8700		4227260.4
											Mega-Brace Total:	9336597	
												Overall Total:	32699521.7

APPENDICES

- REINFORCING
- COST ESTIMATE
- FLOOR PLANS
- FAÇADE

Appendices

Item	Amount	Unit	Material Unit Price	Labor Unit Price	Total Cost	Duration	Rounded	Crew
Formwork	195580	SFCA	$ 0.88	$ 13.30	$ 2,773,324.40	201.6289	202	C-2
Concrete	11122.22	CY	$ 139.00	$ 197.65	$ 3,744,296.11	216.9766	217	
Rebar- #8's	242.97	ton	$ 970.00	$ 560.00	$ 371,744.10	80.99	81	4 Rodmen
				Total Cost	$ 6,889,364.61			

APPENDICES

- REINFORCING
- COST ESTIMATE
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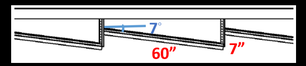
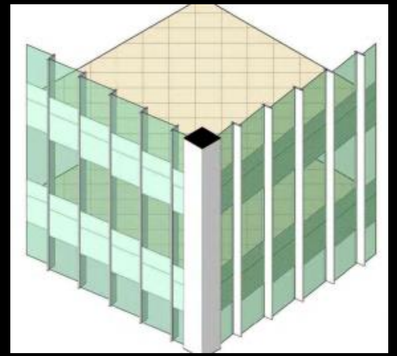
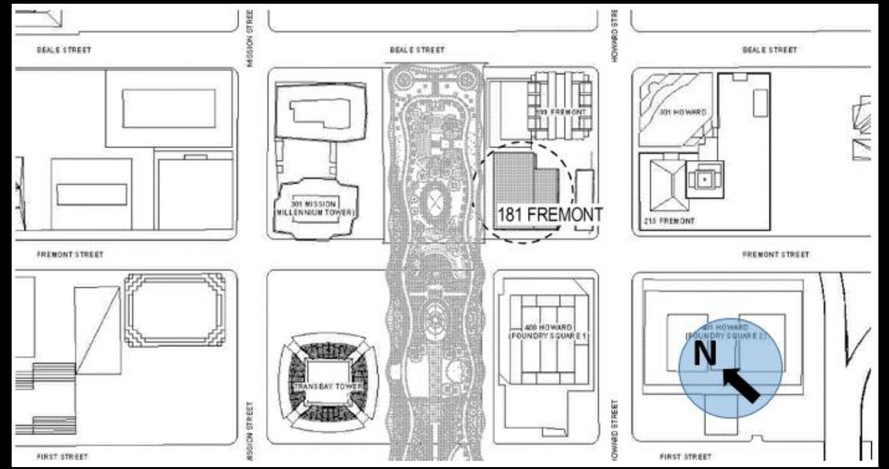
Appendices







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