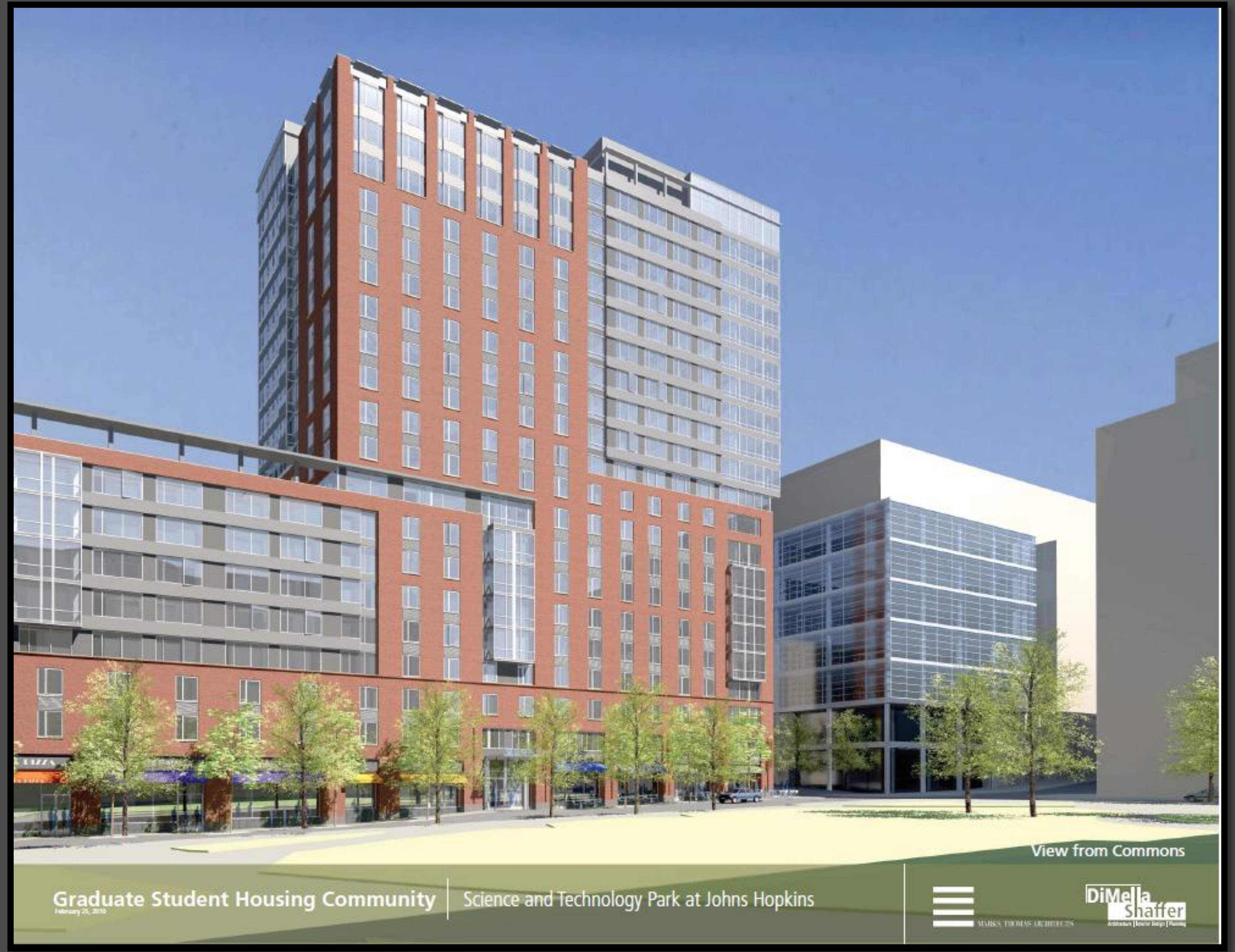
JOHN HOPKINS GRADUATE STUDENT HOUSING

Baltimore, Maryland



Brad Oliver – Structural Option
Advisor – Professor Memari

Johns Hopkins Graduate Student Housing

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Project Information

- **Introduction**
- Existing Structural Systems
- Proposal
- New Gravity System
- Lateral System (Baltimore)
- Lateral System (San Francisco)
- Construction Management Breadth
- Conclusions

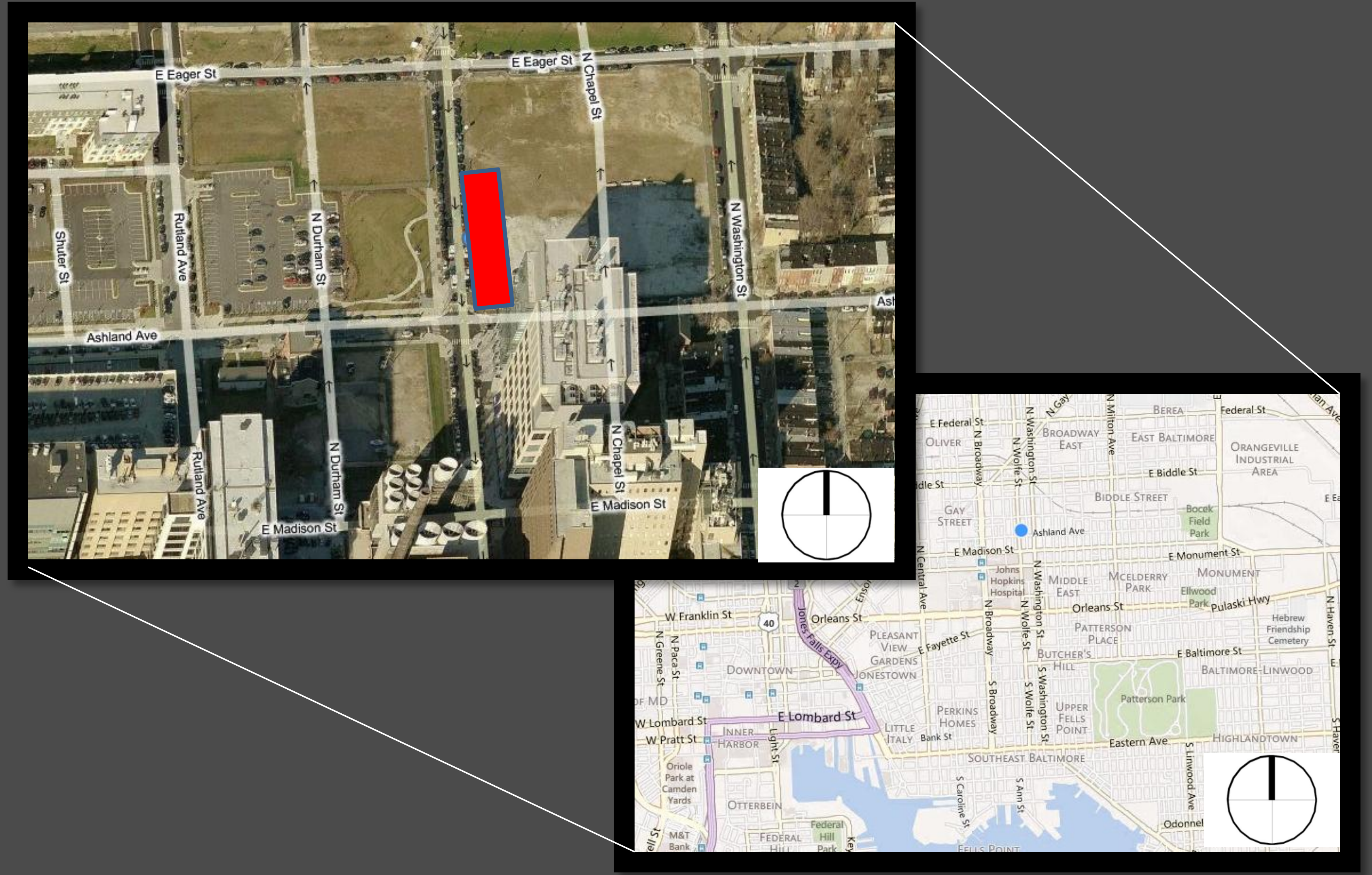
•North Wolfe Street, Baltimore Maryland
•Science and Technology Park

•20 floor residential tower

•276, 211 sq. ft.

•August 2010 – June 2012

•$44 million (hard costs)



Courtesy of Bing maps

General Information

Architecture

- Owner – Education Realty Trust
- Architect – Marks, Thomas Architects
- Contractor – Clark Construction
- Structural Engineer – Hope Furrer Associates
- Mechanical/Plumbing Engineer – Burdette Kohler Murphy

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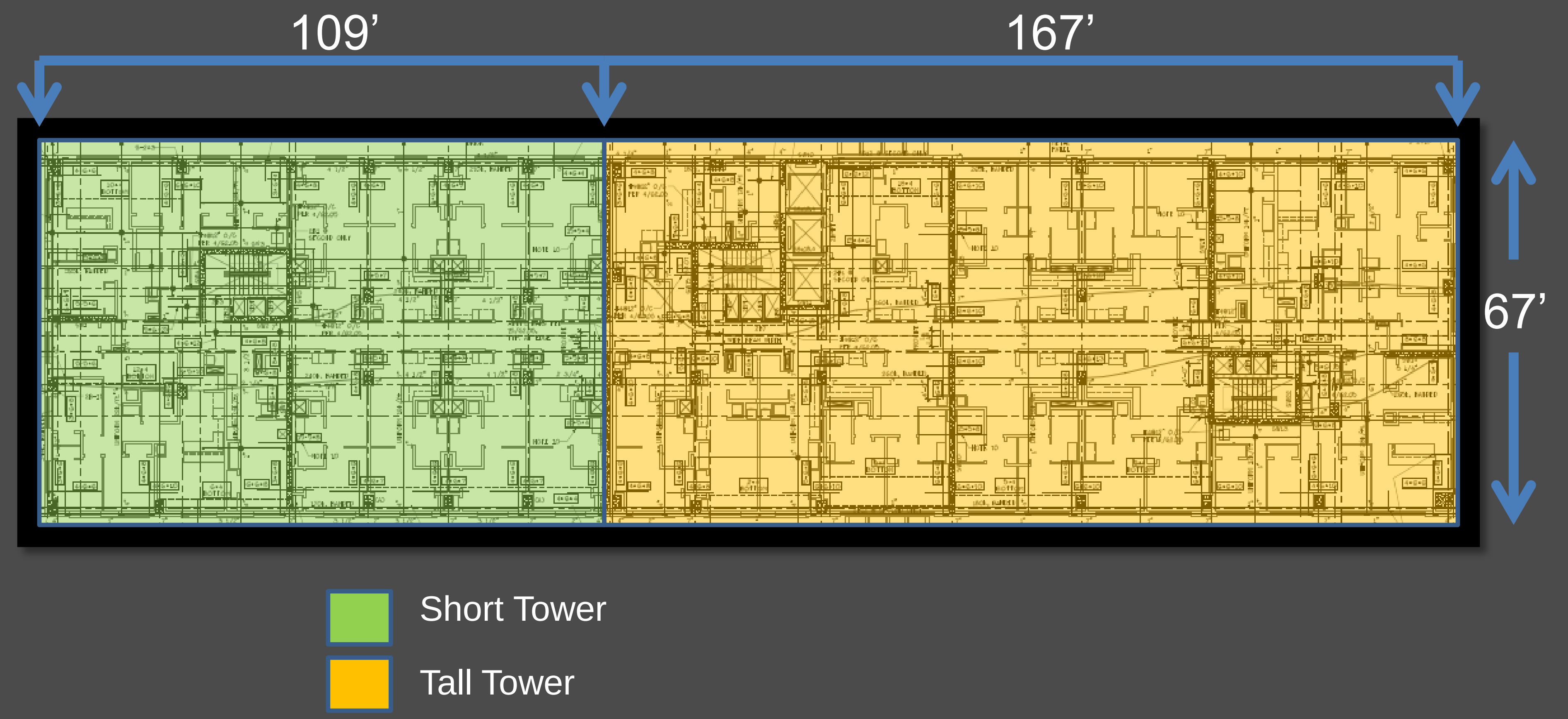
Gravity System

- 20’ – 25’ Typical spans
- 8” Post-tensioned concrete slab system (5ksi)

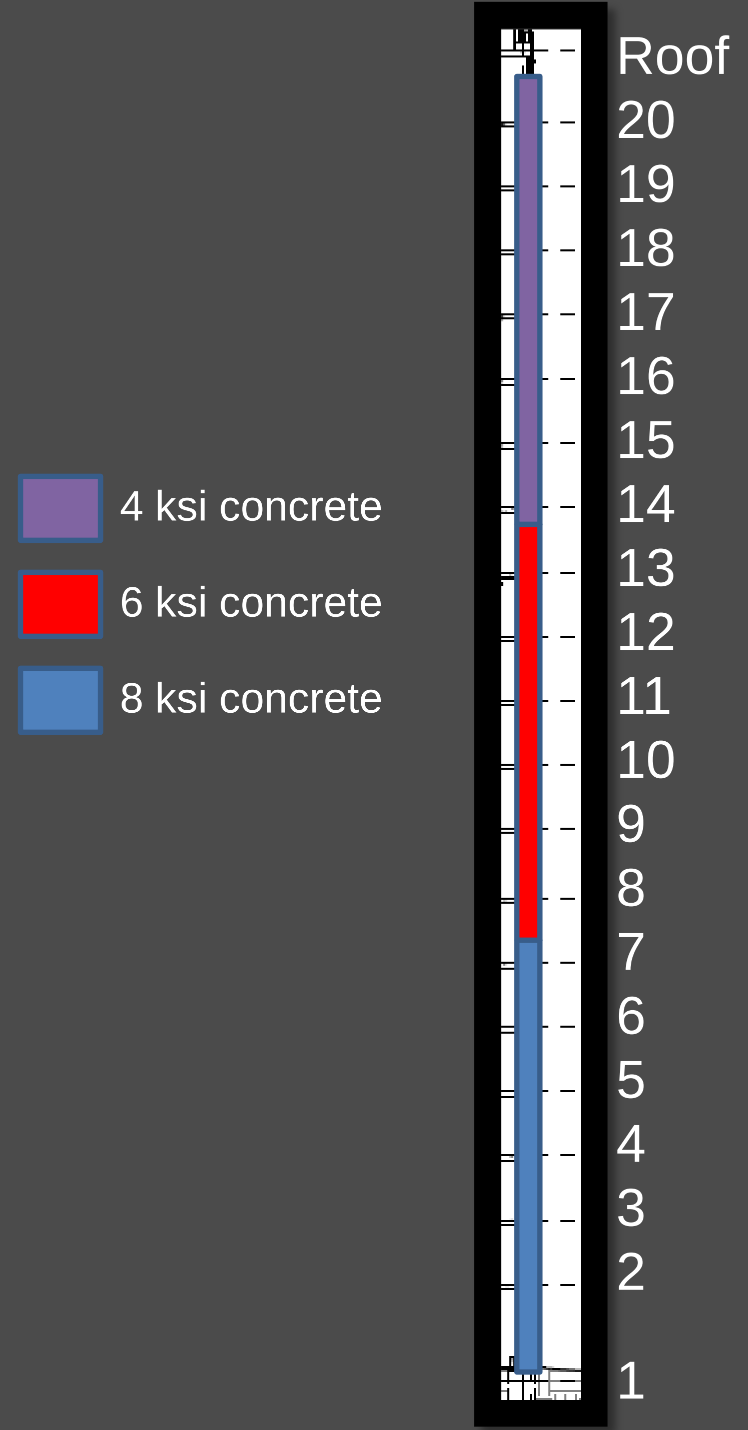


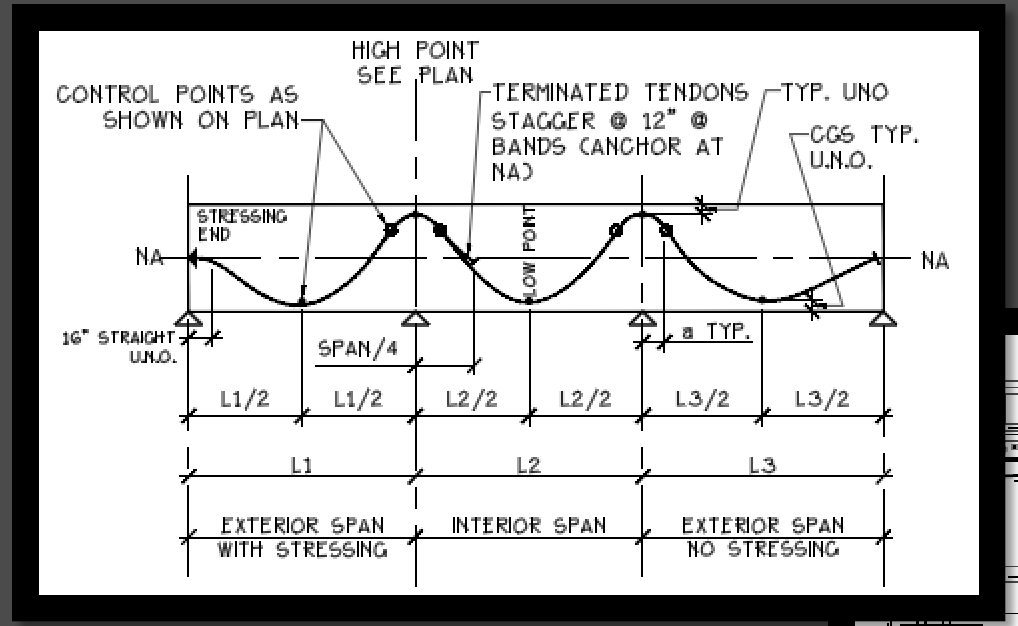
Gravity System

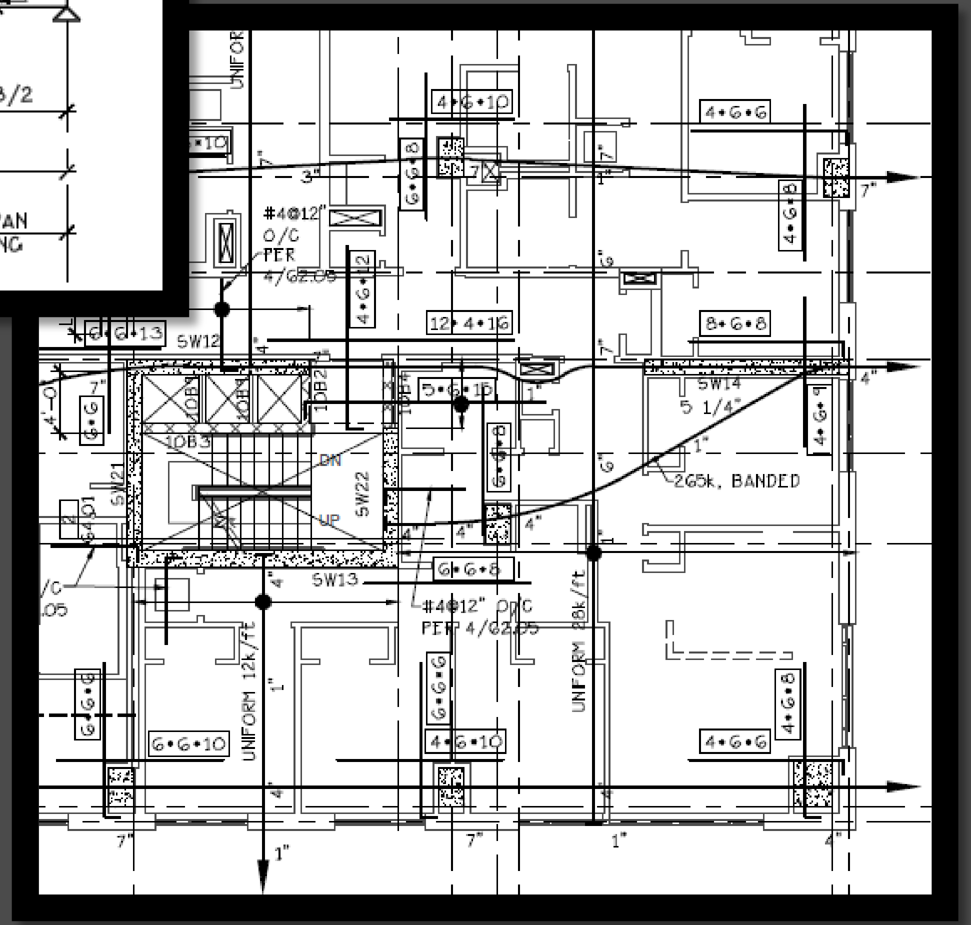
•20’ – 25’ Typical spans

•8” Post-tensioned concrete slab system (5ksi)

•30”X20” Columns with varying strengths







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Lateral System

Foundation

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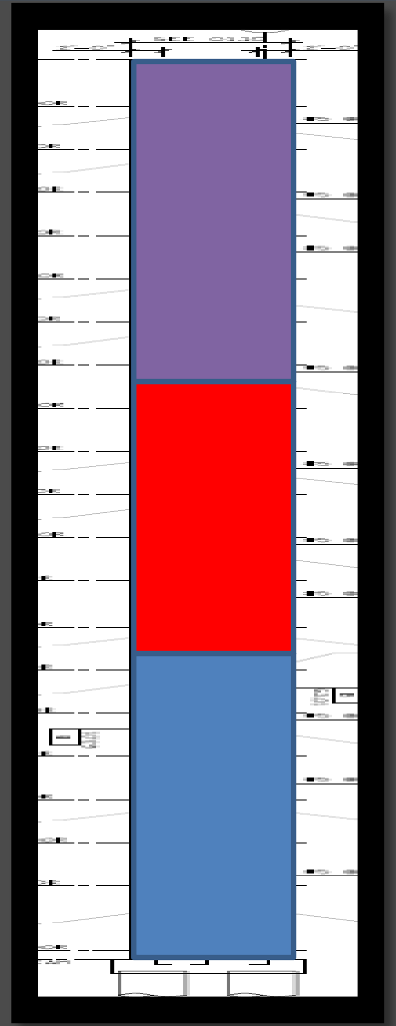
•12” Thick concrete shear wall with varying strengths

4 ksi concrete

6 ksi concrete

8 ksi concrete

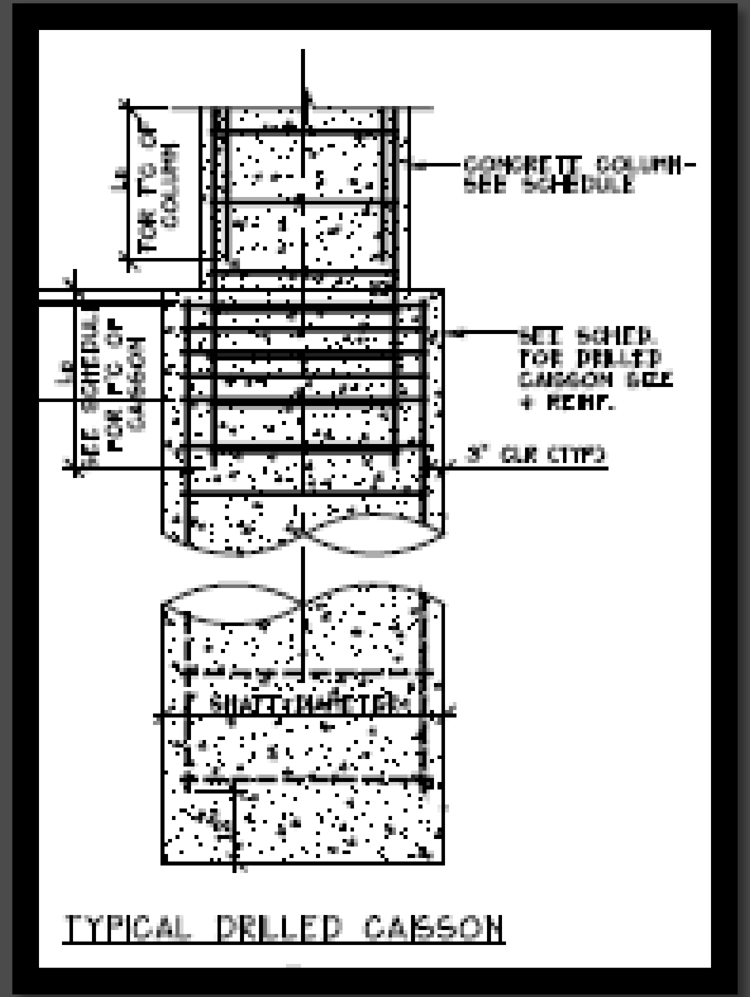


•Drilled caisson system
- 75’-91’ Deep

•3’-6’ Diameter

•30”X30” Grade Beams

•4 ksi concrete



Proposed Study

Problem

•Move the site to San Francisco

•Shear walls not permitted in SDC “D” for that height

Depth Solution

•Solve by designing dual system:

•Eccentric Braced Frame with moment connections

•Composite Steel Beam gravity system

Construction Management Breadth

•Create new schedule and compare to existing

•Perform cost analysis to compare steel to concrete

Architectural Breadth

•Study two public areas that would be most affected by the additional braces. (Lounge and Fitness Rooms)

•Create renderings to visualize the space and modify the layout of the rooms

Project Goals

Successfully design EBF

Minimize height change

Minimize architectural impact

Reduce torsional irregularity

Learn Ram Structural Design

Steel Framing

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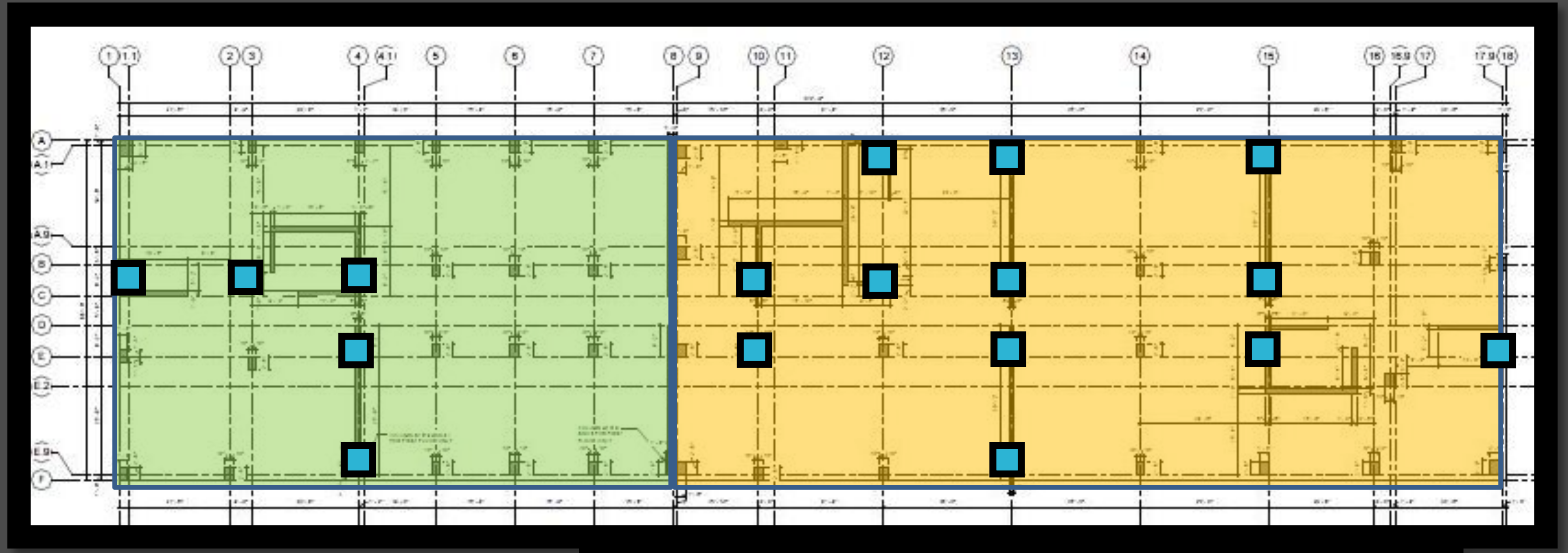
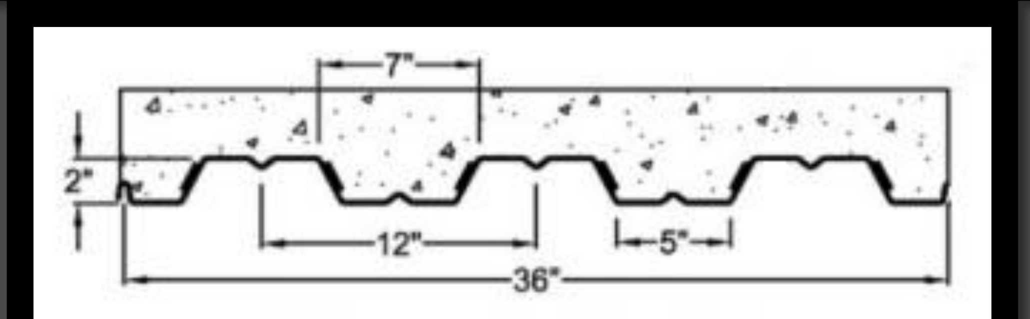
- Typical bays of 24’ x 25’ and 16’ x 25’
- 2” VLI composite deck with 2” topping
  - 2 hour fire rating designated by IBC 2006



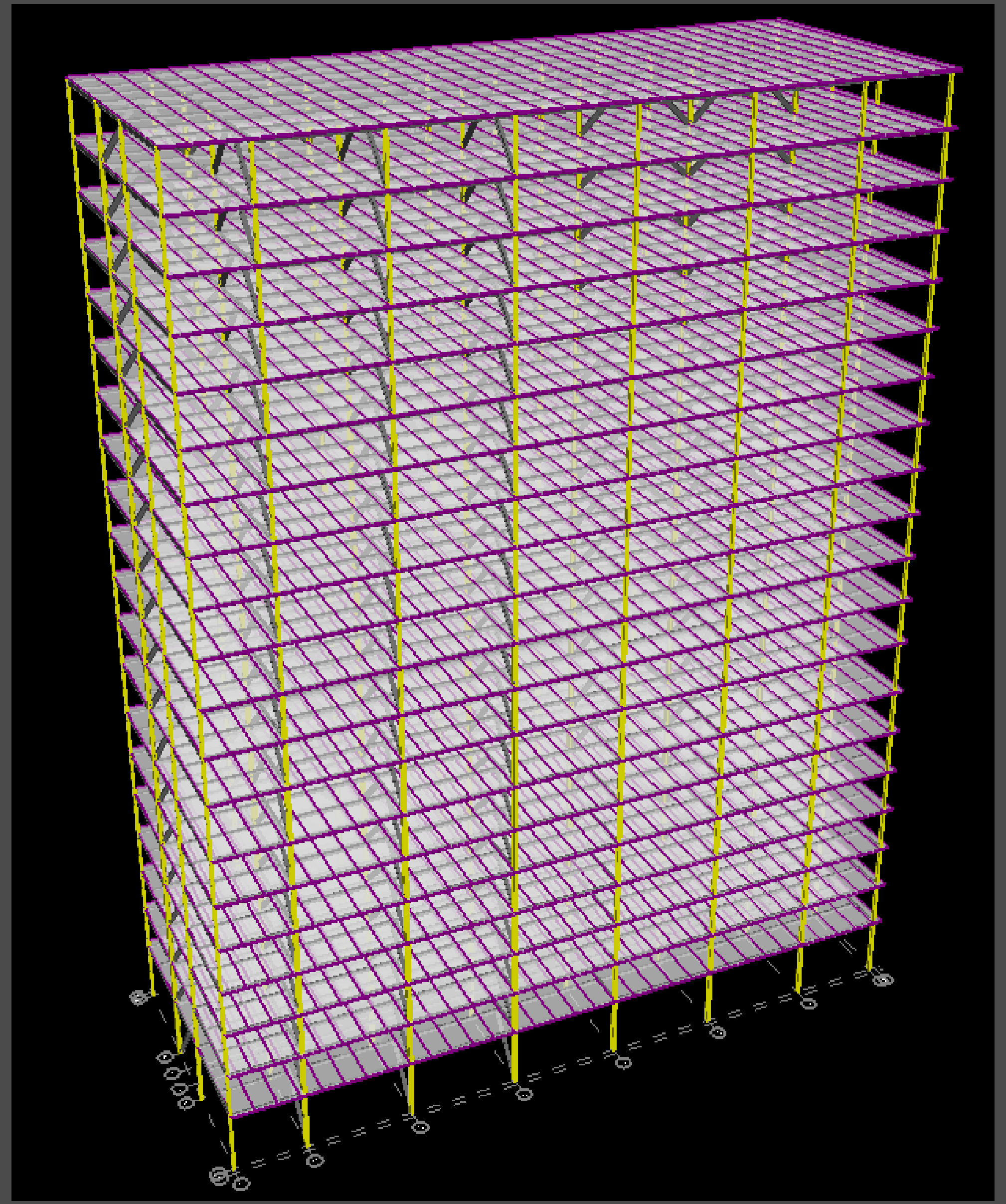


2" Composite Floor Deck

http://www.oatesmetaldeck.com/metal-roof-deck.asp

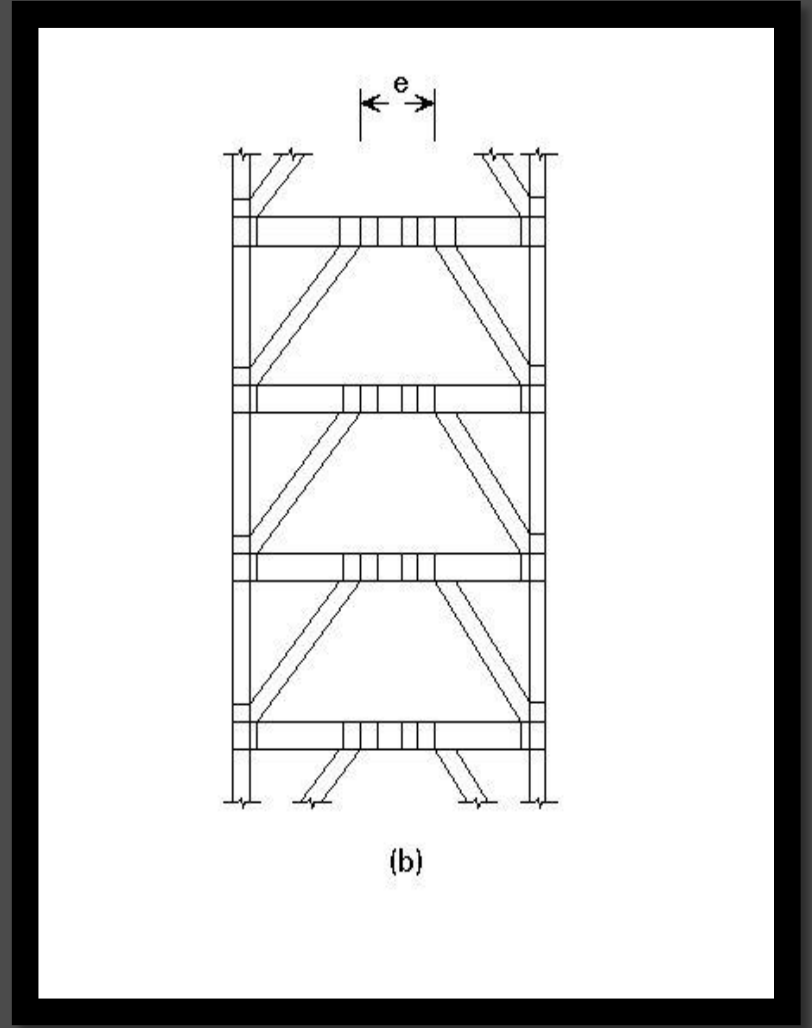
Steel Framing

- Typical bays of 24’ x 25’ and 16’ x 25’
- 2” VLI composite deck with 2” topping
  - 2 hour fire rating designated by IBC 2006
- Typical Size is W12x19

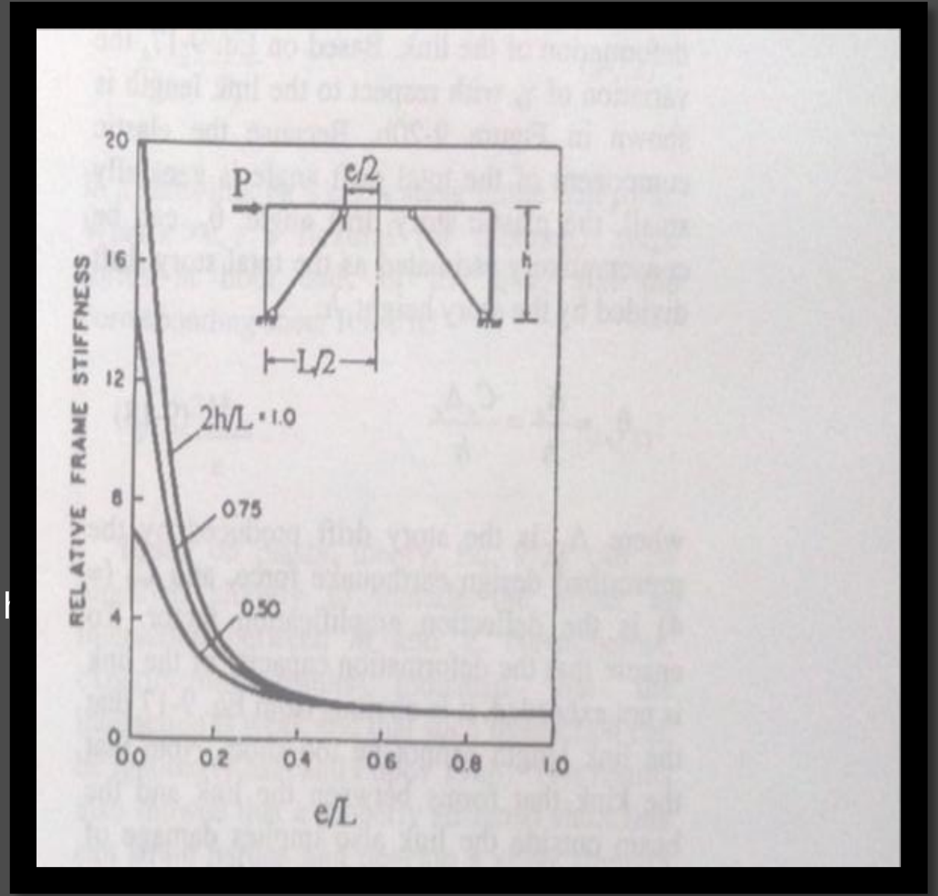


Eccentric Braced Frame

- Link element is most essential part of design
- Short link elements are controlled by shear
  - Relatively more stiff than long elements



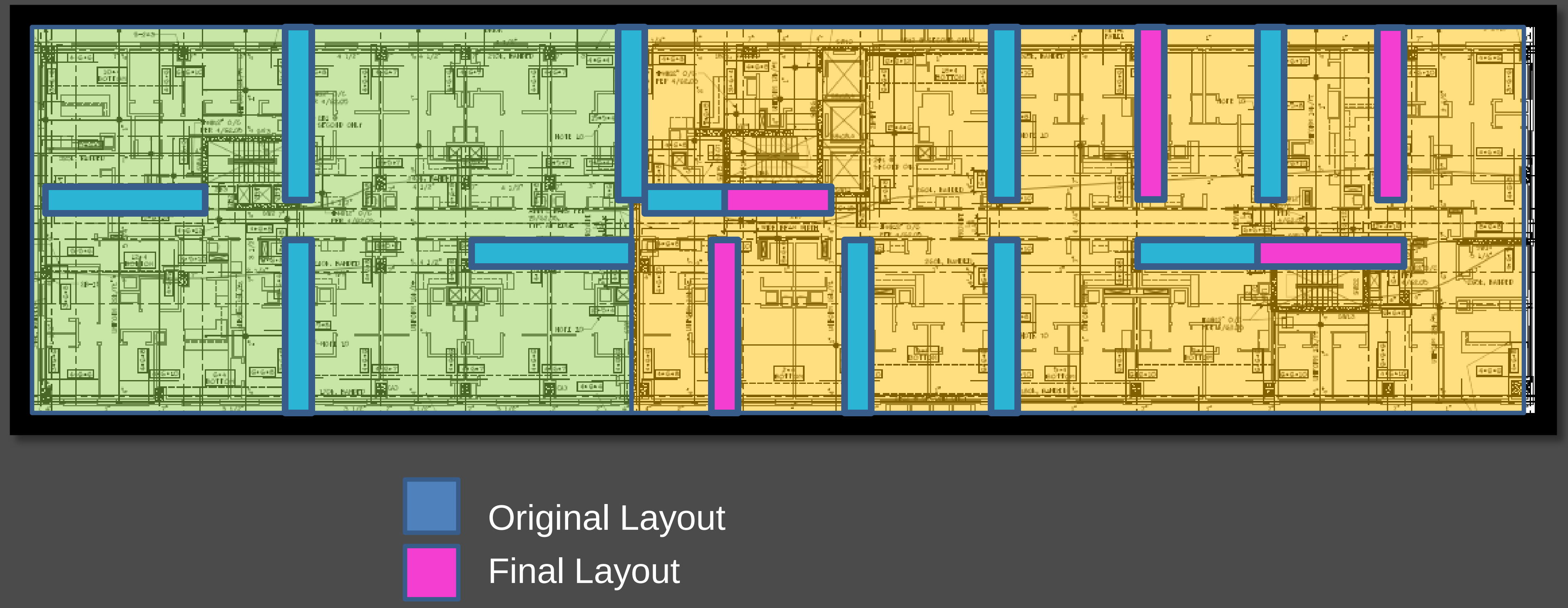
http://www.fgg.uni-lj.si/kmk/esdep/master/wg01b/l0720.

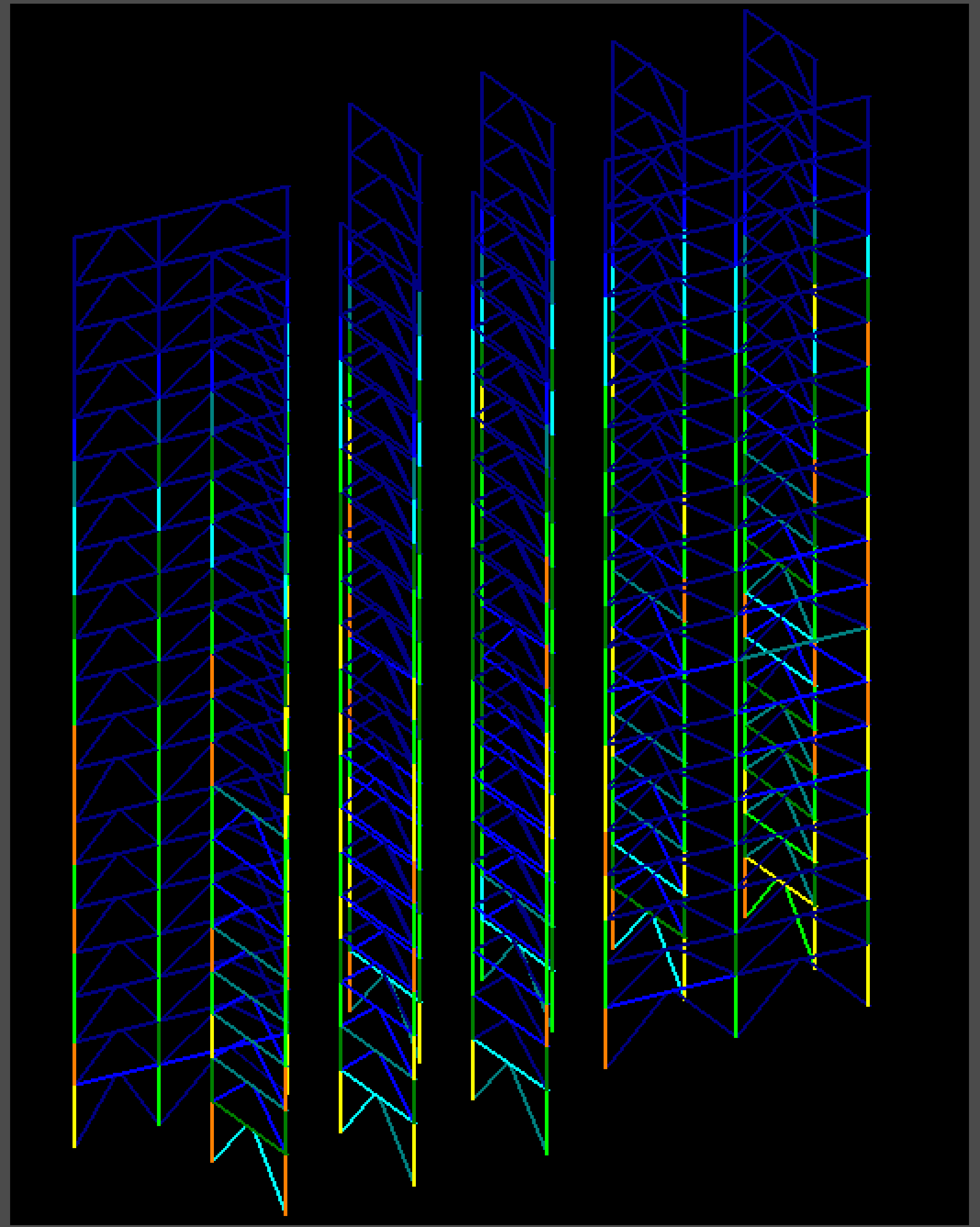


Seismic Design Handbook

Design Process

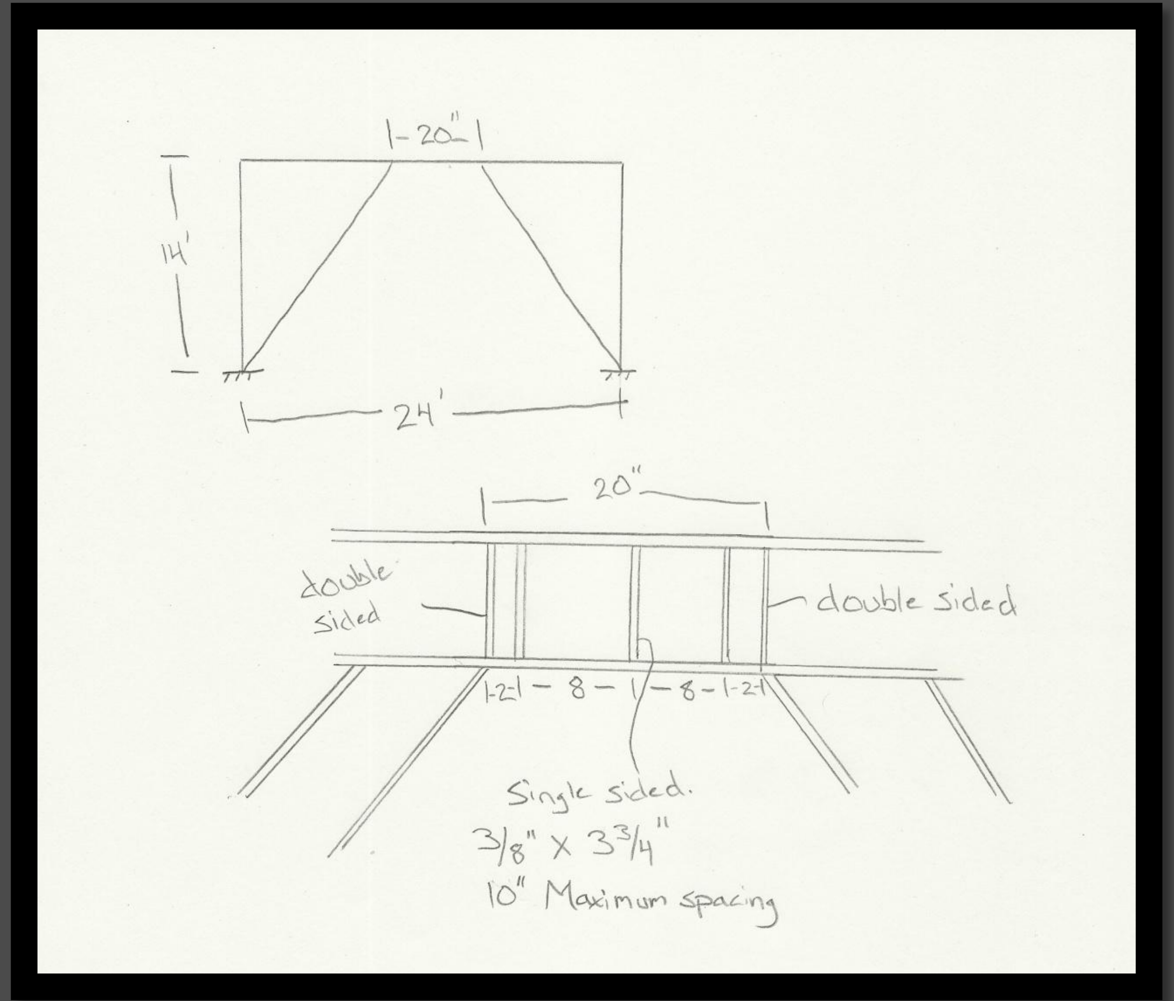
- First attempt – 28" link length, C Shape braces
- Wind deflections – 27" – unacceptable
  - L/400 = 6.21"
- Final Design – 20" link length, W-flange braces, more frames
  - Deflection = 5.97"





Design Process

- Strength checks by Ram and hand calculations
- Seismic Provisions used as a guide
  - Web stiffener requirements calculated



Design Criteria

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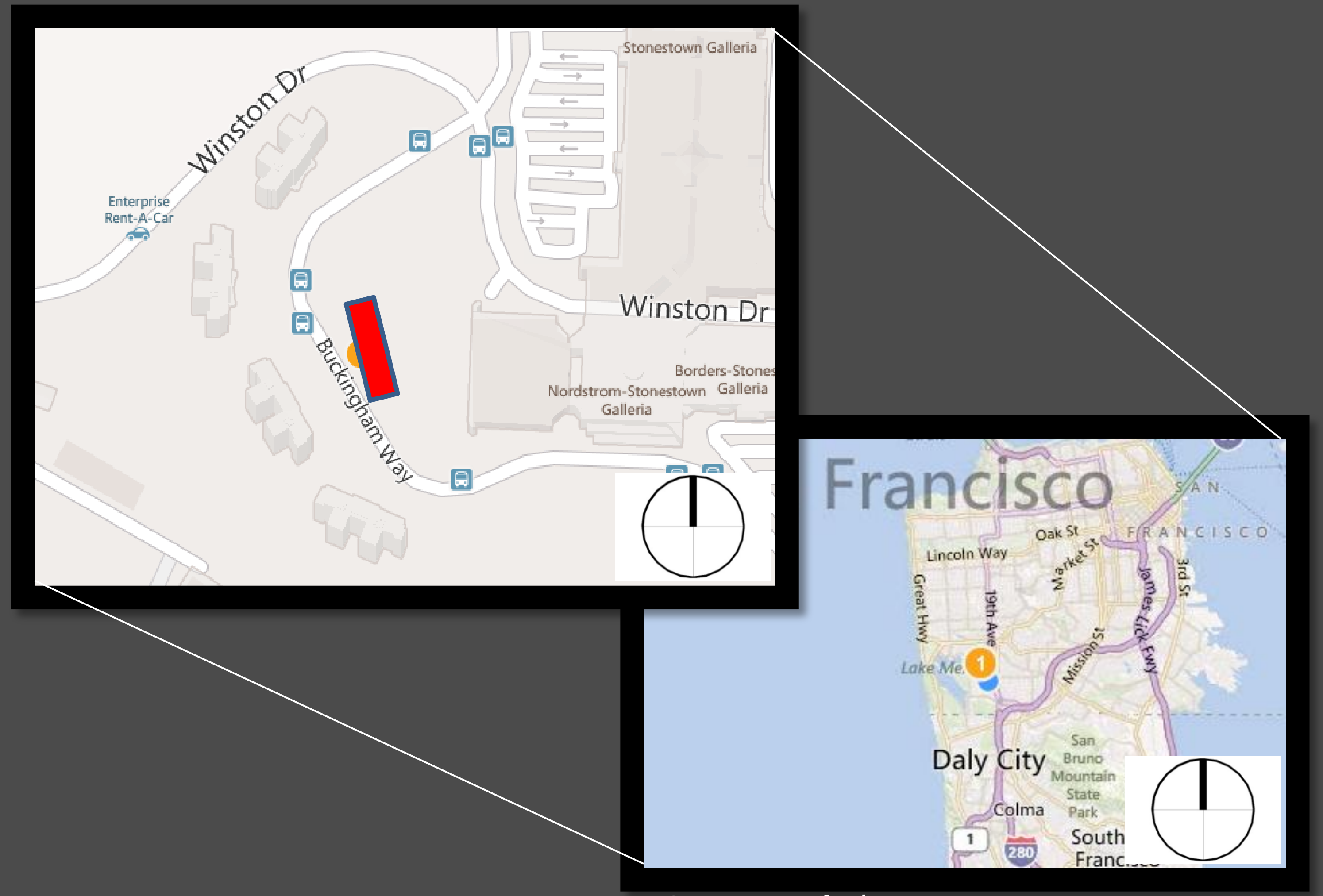
- San Francisco University – Proposed site
- Decrease wind loads 90 mph to 85 mph
  - Base shear reduction - 505 kips to 450 kips
- Seismic accelerations increased
  - Base shear increase – 165 kips to 362 kips

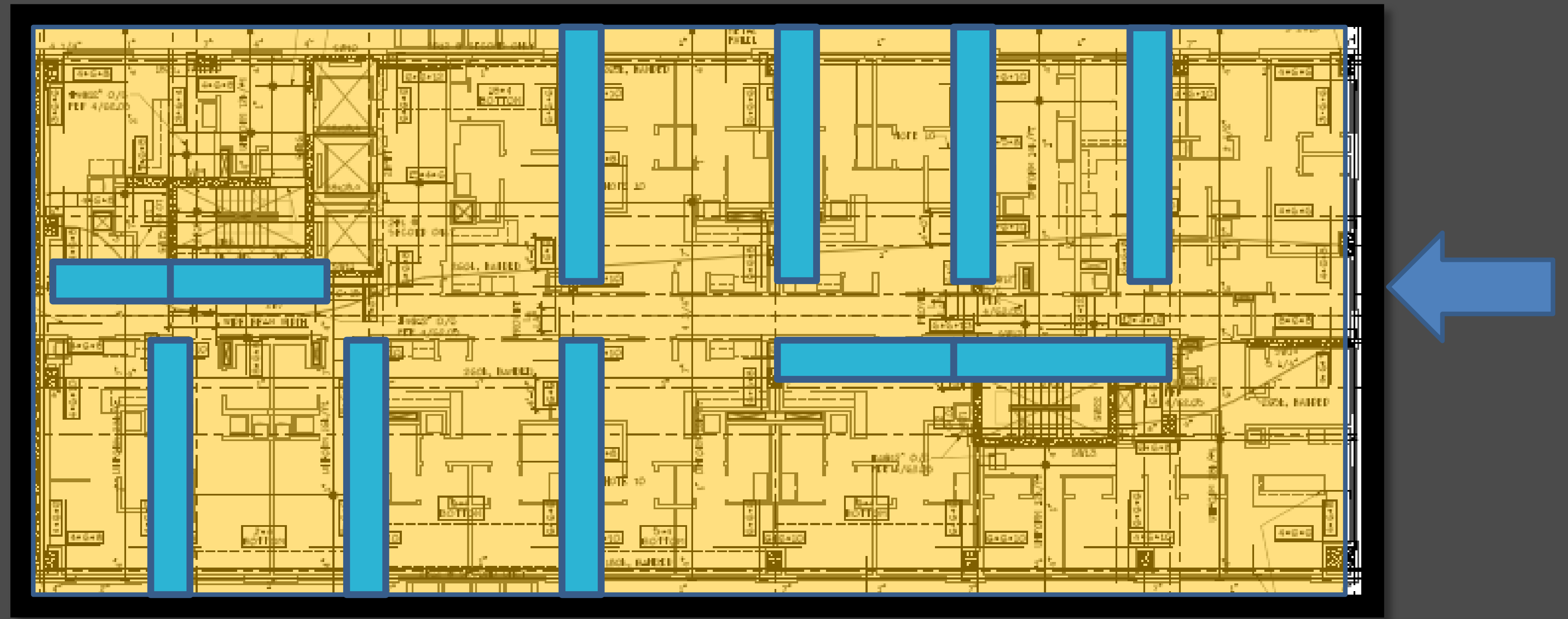


Courtesy of Bing maps

Results

- Introduction
- Existing Structural Systems
- Proposal
- New Gravity System
- Lateral System (Baltimore)
- **Lateral System (San Francisco)**
- Construction Management Breadth
- Conclusions

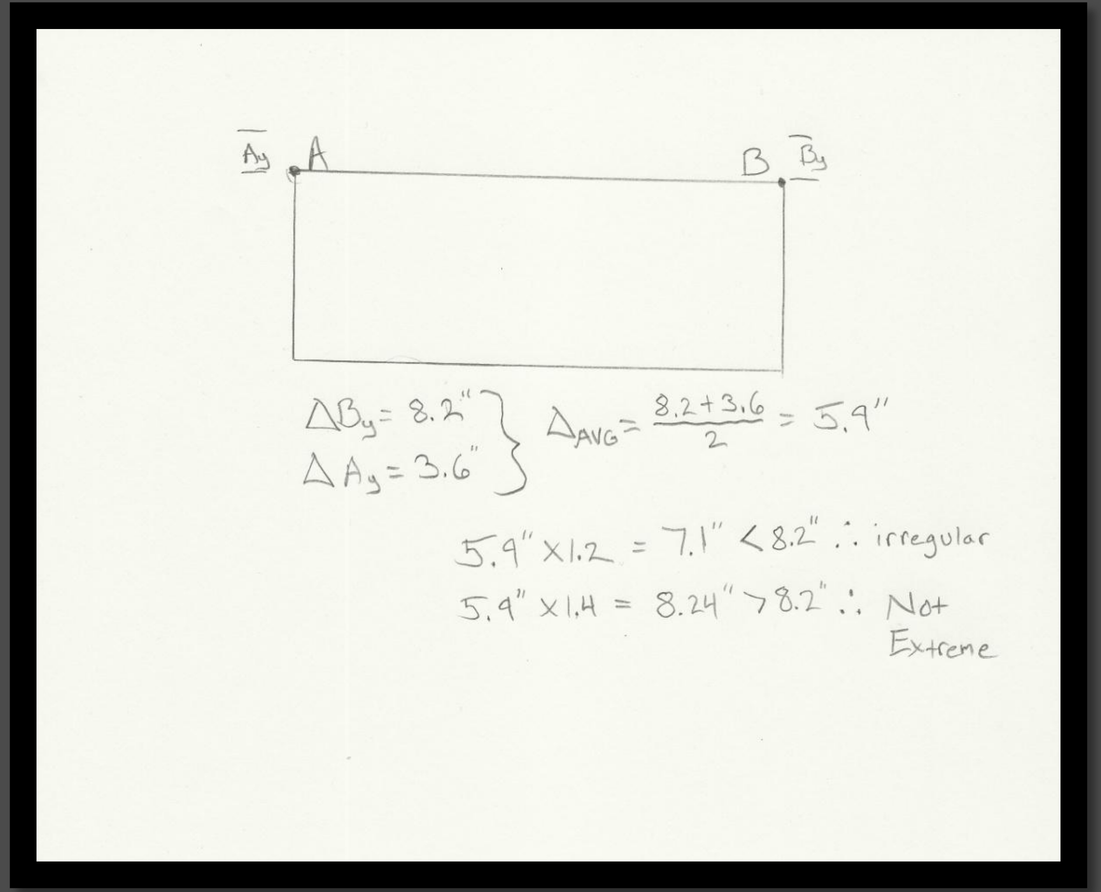
- Earthquake loads control in the long direction
- Members needed upsized 10-20 lbs/ft



Tall tower frame layout

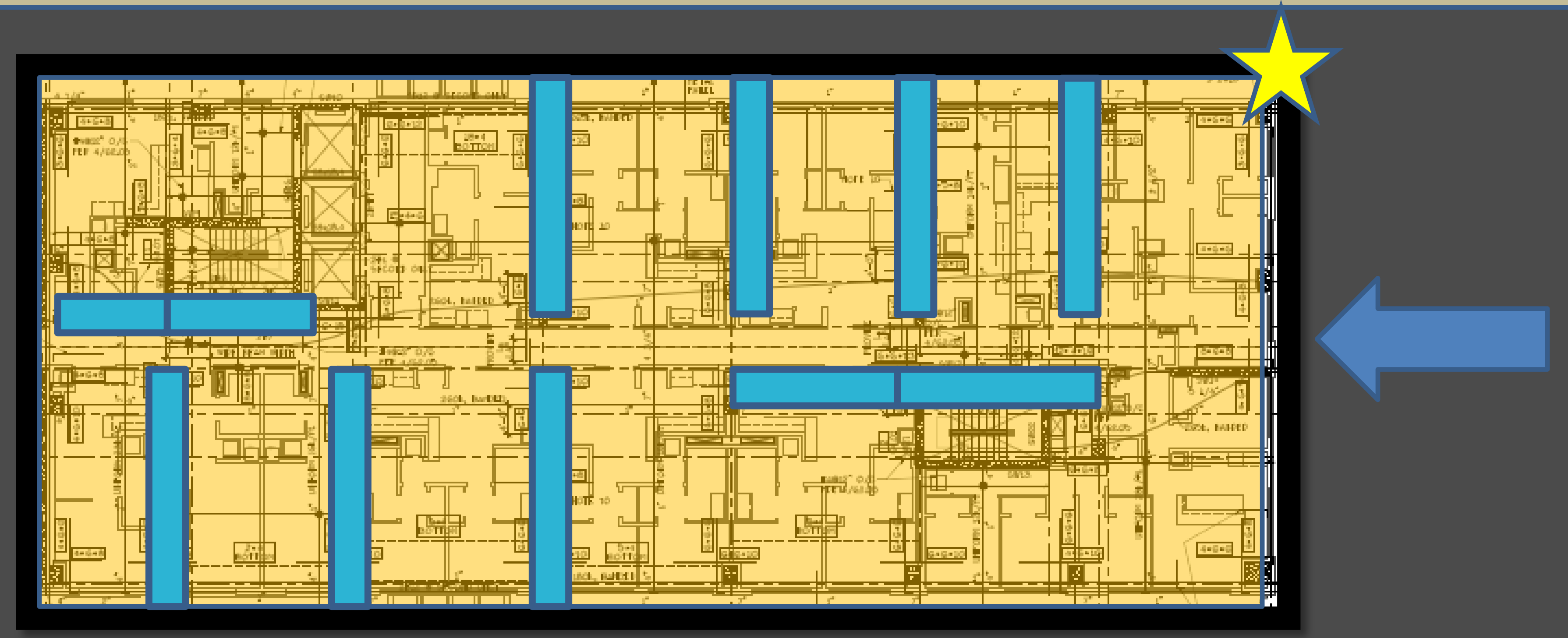
Results

- Earthquake loads control in the long direction
- Members needed upsized 10-20 lbs/ft
- Torsionally irregular



Torsional Effects

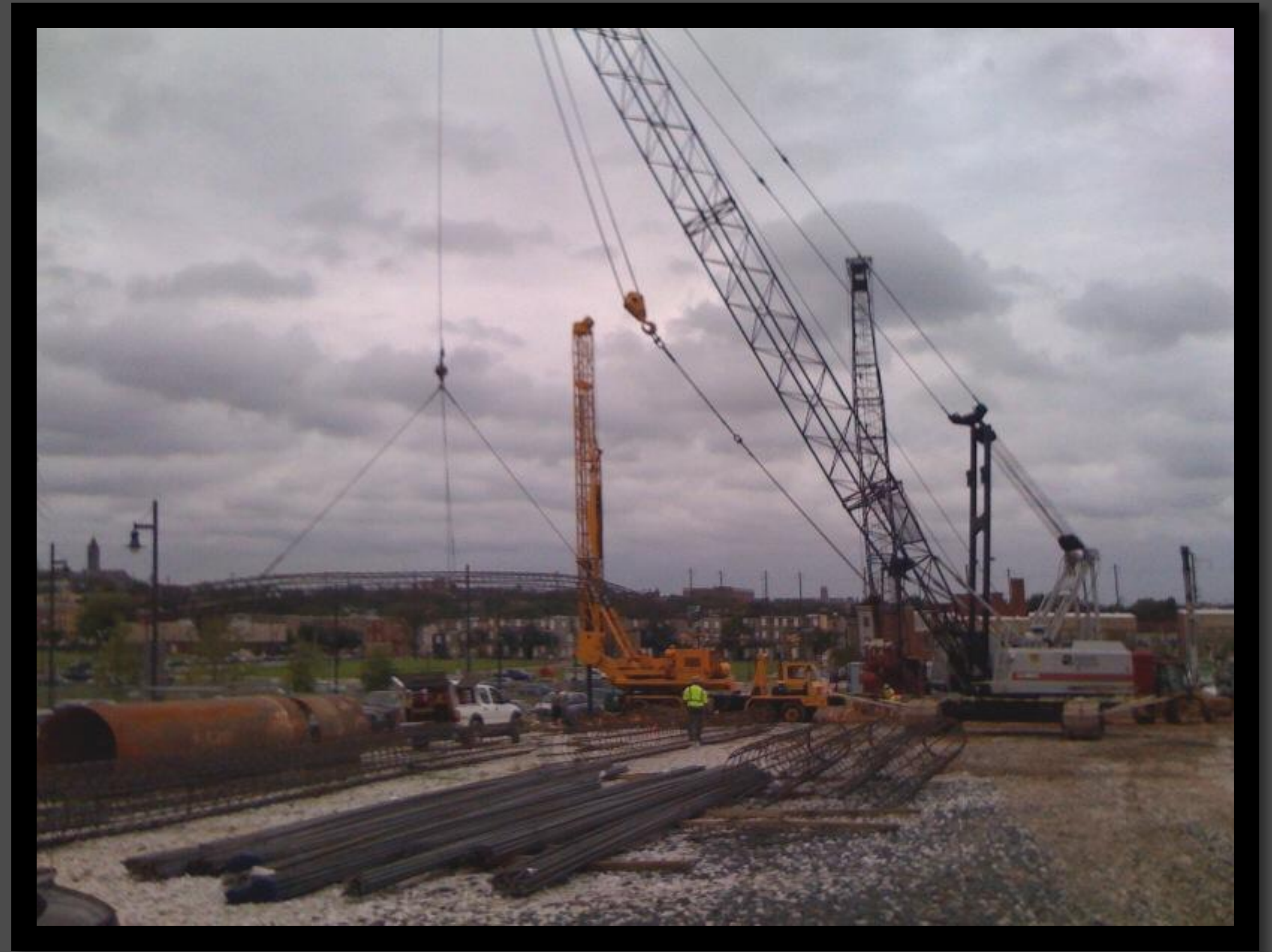
- Design connections between diaphragm and vertical members for 25% more force
- 3D model with 3 DOF at each floor
- Story Drift ratios must be taken at extreme point of deflection (indicated by star)



Tall tower frame layout

Construction Assumptions

- RS Means and Ram takeoffs used
- Steel columns were spliced every 2 levels for constructability, OSHA requirements, and economy
- Crew cost adjusted to account for tower crane



Cost Analysis

- Splices estimated at 500 lbs of steel
- Connections estimated at 10% of steel weight
- Studs estimated at 10lbs of steel per stud
- Hard costs only (no overhead)

Existing Concrete		Steel Structure
$5.75 million	→	**$4.37 million**

32% Savings

Schedule Analysis

- Schedule started at foundation to top of structure
- Schedule accounts for on-site activities
- Concrete wasn't able to be poured in cold weather

Existing Concrete

July 15, 2010 → **June 23, 2011**

Steel Structure

July 15, 2010 → **April 12, 2011**

Over 2 months savings

Conclusions

Goals	Complete?
•Successfully design EBF	Yes
•Minimize height change	Yes
•Minimize architectural impact	Yes
•Reduce torsional irregularity	Partially
•Learn Ram Structural Design	Yes

Acknowledgements

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Dr. Memari

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Jeffrey Resetco

Marks, Thomas Architects
Michael Blake

Friends and Family

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Thank You

Questions?

Period

T1 = 3.53 seconds
T2 = 2.58 seconds
T3 = 2.53 seconds

Story Drift Ratio Calculations

Drift Ratios at Point B Including Accidental Torsion - Earthquake

			N-S Loading		
Story	Height (in)	Allowable story Drift (inches)	Story Drift (inches)	Story Drift (inches) with Amplification	Compliant?
Roof	2484	2.64	0.6454	2.5816	ok
20	2352	2.4	0.5982	2.3928	ok
19	2232	2.4	0.5979	2.3916	ok
18	2112	2.4	0.5976	2.3904	ok
17	1992	2.4	0.5976	2.3904	ok
16	1872	2.4	0.5845	2.338	ok
15	1752	2.4	0.567	2.268	ok
14	1632	2.4	0.5422	2.1688	ok
13	1512	2.4	0.517	2.068	ok
12	1392	2.4	0.4848	1.9392	ok
11	1272	2.4	0.4538	1.8152	ok
10	1152	2.4	0.4172	1.6688	ok
9	1032	2.88	0.4532	1.8128	ok
8	888	2.4	0.33	1.32	ok
7	768	2.4	0.291	1.164	ok
6	648	2.4	0.2478	0.9912	ok
5	528	2.4	0.2067	0.8268	ok
4	408	2.4	0.1624	0.6496	ok
3	288	2.4	0.0191	0.0764	ok
2	168	3.36	0.0158	0.0632	ok
1	0	0	0	0	

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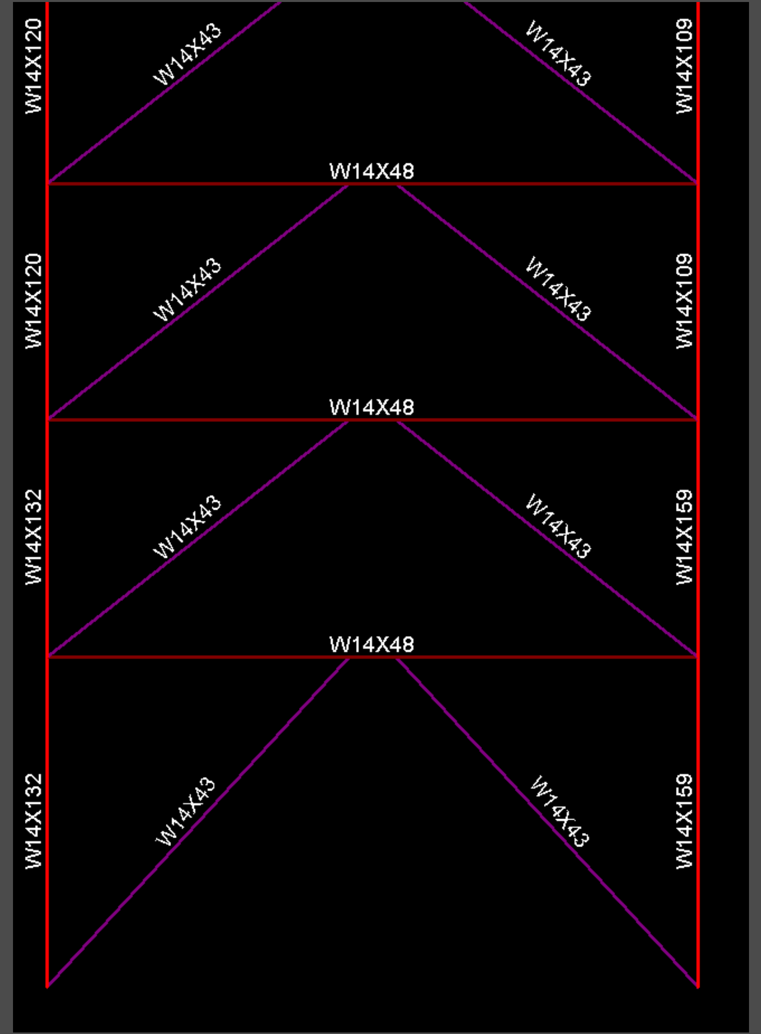
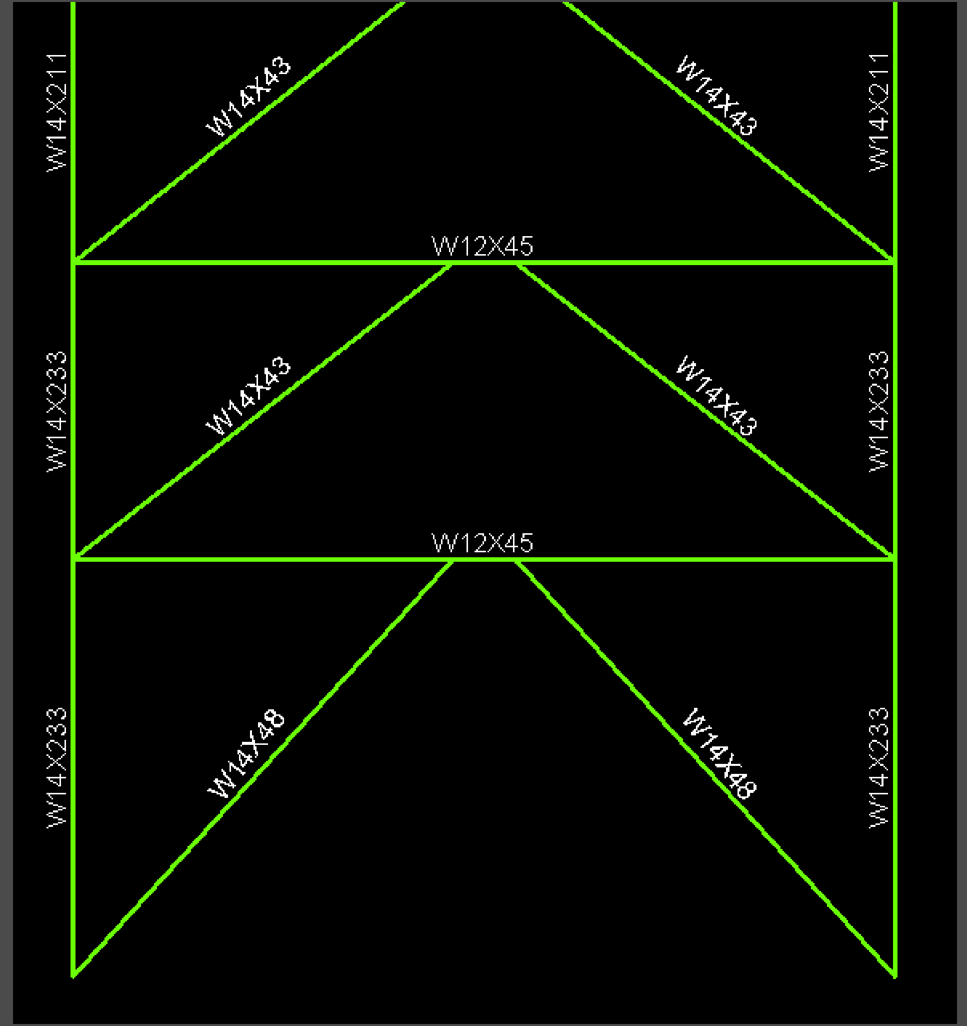
Baltimore Frame



San Francisco Frame



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Beams	Duration	Cost
W8X10	11.81561667	241889.3044
W10X12	5.613666667	114922.984
W10X22	0.289666667	5930.056
W10X39	0.590509666	18668.16
W12X14	11.58125	251220.475
W12X16	1.443181818	31305.5
W12X19	9.270454545	230463.5
W14X22	2.476565657	89049.376
W14X26	0.488888889	17578.88
W14X30	2.058888889	77362.75
W12X26	1.527272727	49526.4
W12X22	0.169318182	4745.65
W12X30	0.223515716	8065.92
W12X45	0.061459667	2957.28
W12X35	0.403361345	16198.56
W14X48	6.406666667	327906.654

Columns	Duration	Cost
W12X40	4.673449612	318993.22
W12X45	0.255813953	17460.96
W12X53	0.406976744	27778.8
W12X65	0.406712734	59796.3174
W12X58	0.283757339	22095.1
W12X50	0.375968992	25662.32
W12X72	0.271186441	25369.44
W12X79	0.233400402	23733.6
W12X87	0.201219512	22245.3
W12X96	0.249744115	30107.16
W12X106	0.082474227	10912.8
W12X120	0.154166667	22710.6
W12X136	0.025289779	4164
W12X152	0.102345416	18485.76
W14X43	0.228658537	21566.25
W14X48	0.081300813	7668
W14X61	0.101626016	9585
W14X68	0.12195122	11502
W14X74	0.020325203	1917
W14X90	0.153688525	17382
W14X99	0.081967213	10192
W14X109	0.041407867	5577.2
W14X82	0.104081633	10798.74
W14X120	0.108333333	15958.8
W14X132	0.101052632	16176
W14X159	0.025889968	4838.64

Braces	Duration	Cost
W10X30	1.940683761	50327.849
W10X33	0.123448276	3465.44
W14X43	8.233875	384291.414

Decking	Duration	Cost
2" VLI	71.53608808	494271.447

Splices	Duration	Cost
		329355.2124

Connections	Duration	Cost
		323081.3498

Concrete	Duration	Cost
	18.26251984	283799.5583

Fireproofing	Duration	Cost
Beams		159716.72
Columns		88287.8
		$4,367,065

$/lb of steel	Total Weight
1.77072695	1824569