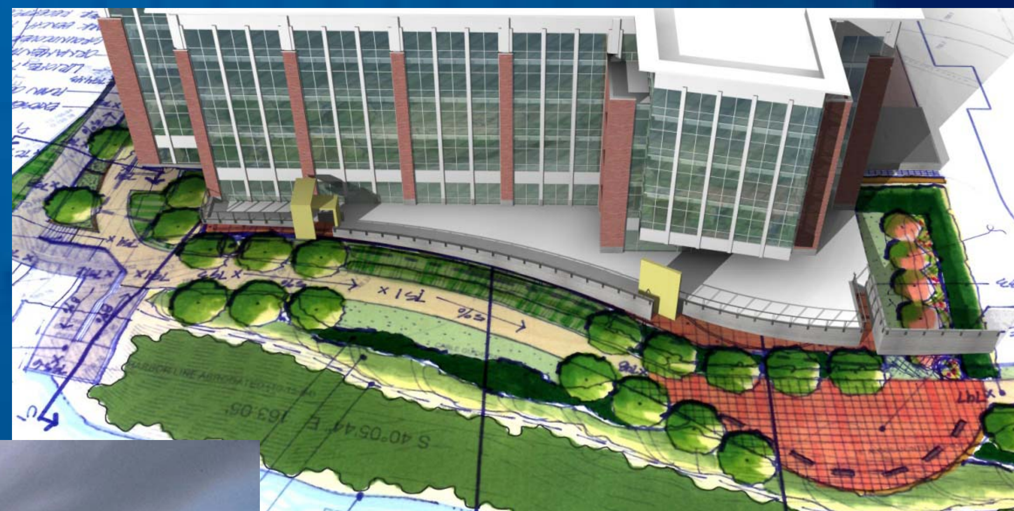
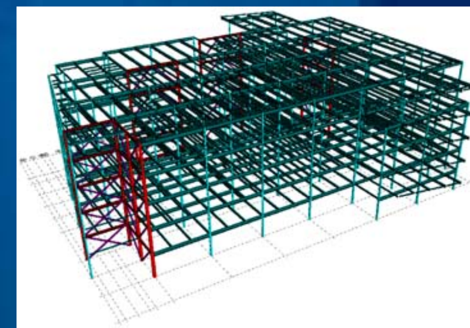
American Eagle Outfitters
Quantum III: South Side Works



Topics

- **General Building Information**
- **Existing/New Design Considerations**
- **Thesis Goals**
- **Structural Depth**
  - Existing system
  - Proposed system
    - Gravity loads and design
    - Lateral loads and design
  - Continuing design
- **Architectural Breadth**
  - Frame locations
  - Façade architecture
  - Wall assemblies
- **Success of Thesis**
- **Questions**



Corporate Expansion in South Side of Pittsburgh

AEO Quantum III

- **Location**: 55 Hot Metal St.; Pittsburgh, PA
- **Height**: Five Stories; Top of Parapet at 72’-4”, Typical Floor 13’-8”
- **Size**: 150,000 Sq. Ft.

Picture Courtesy of Google Earth

Corporate Expansion in South Side of Pittsburgh

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III

- **Construction**: May 2007 to October 2008

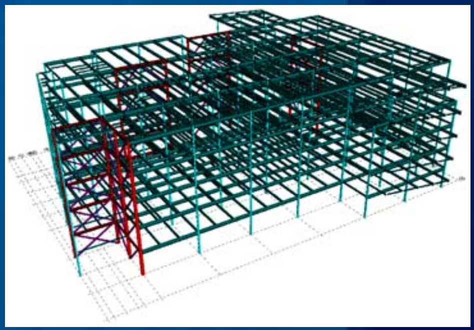
- **Cost**: $16 million Building Core and Shell

- **Project Delivery Method**: Design-Bid-Build

Original Design Considerations

AEO Quantum III

- **Structural**
  - 30’ x 30’ typical bays
  - Wind controlled lateral design
  - 80 psf live load



- **Architectural**
  - Frames do not interfere with architecture
  - Reflects existing mood in South Side Works
  - Materials lend to a sense of place
    - Brick and glass curtain wall

- **Mechanical**
  - Two 35,000 pound rooftop units

Original Design Considerations / New Design Considerations

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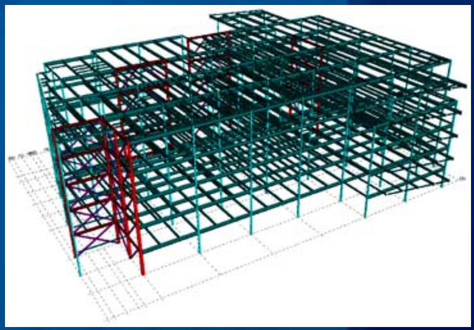
- **Structural**
  - **Move building to Oakland, California**
  - **Add 2 floors to building elevation**



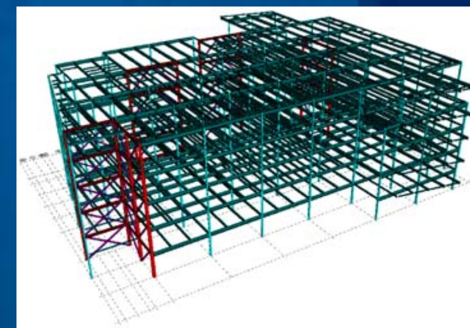
- **Architectural**
  - **QIII reflects architecture in Oakland**
  - **Add 2 floors to building elevation**

- **Mechanical**
  - **Re-evaluate heating/cooling loads**

Senior Thesis Goals

AEO Quantum III

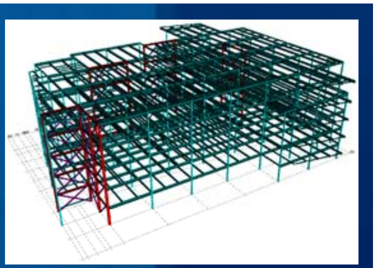
- **Structural**
  - Gravity system design with added stories
  - Preliminary lateral system design



- **Architectural**
  - Redesign shell to fit Oakland, CA
  - Shell scaling matches new building height

- **Mechanical**
  - Find heating/cooling loads for new building

Existing System - Typical Bay



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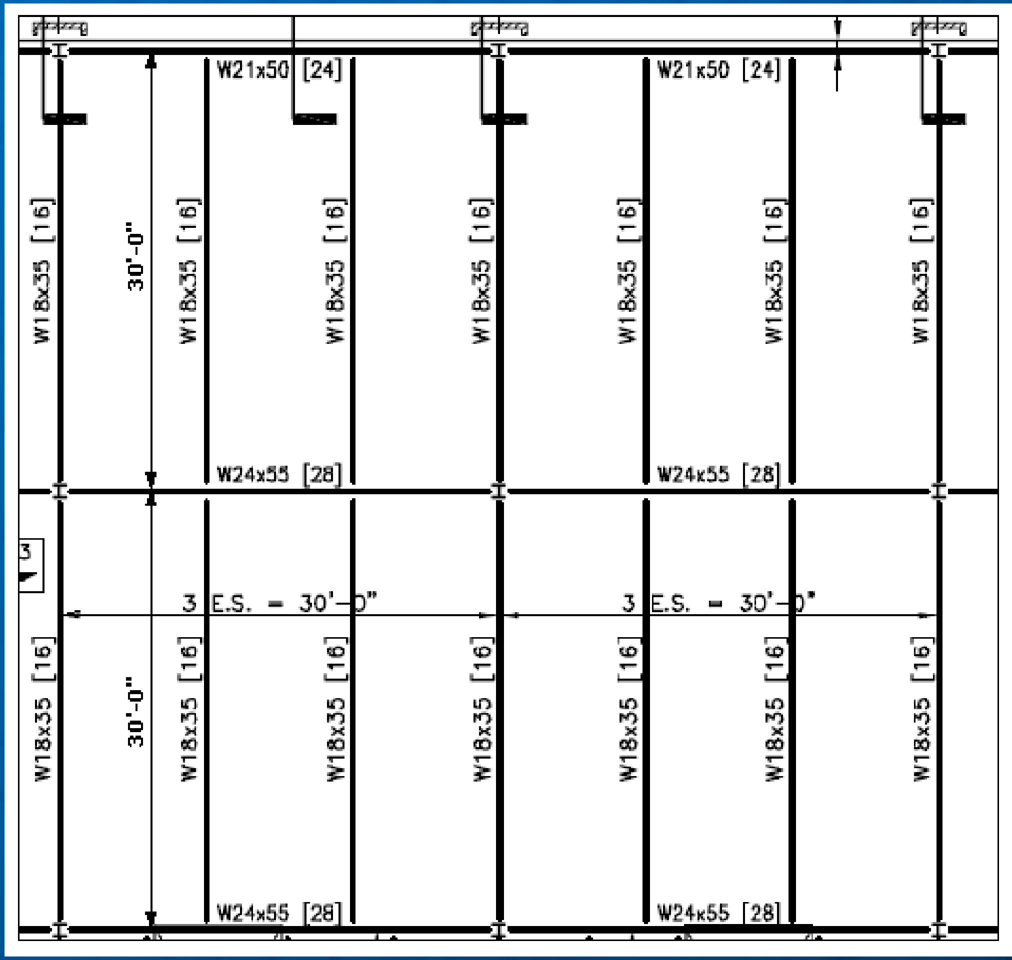
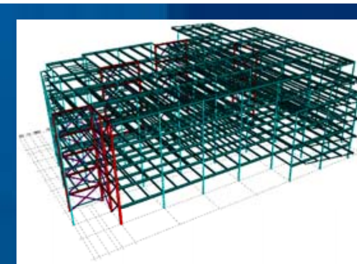
- **Typical bay and material properties**

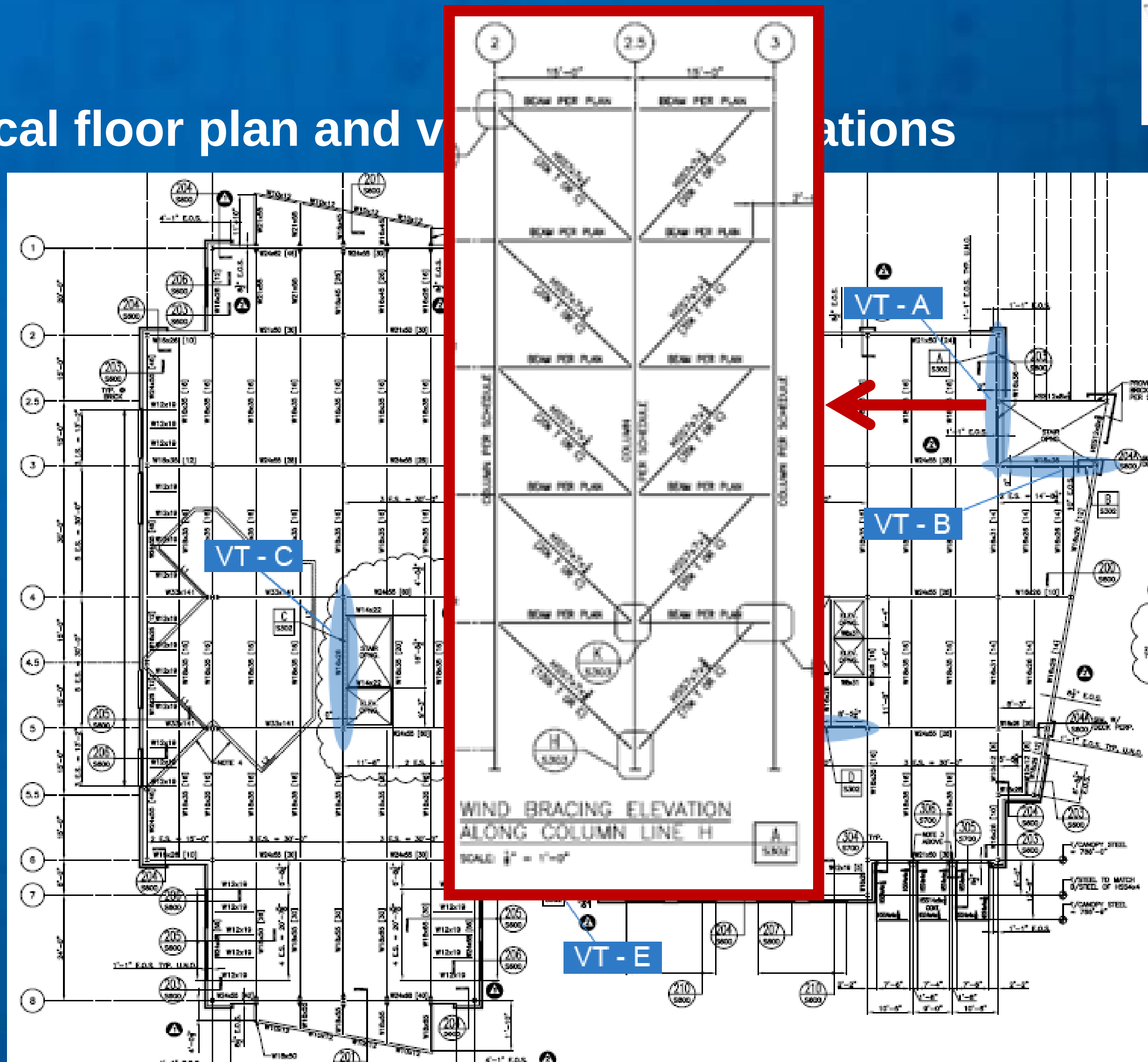


3” steel galvanized deck 20-gauge composite
2.5” LWC topping
f’c = 3000 psi
Fy = 60 ksi
4” long, ¾” diameter Shear studs

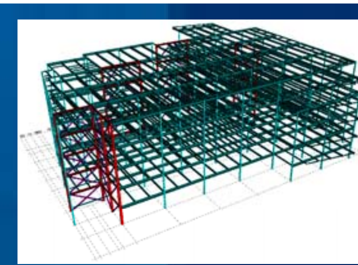
Existing Structural System



- Typical floor plan and v ations

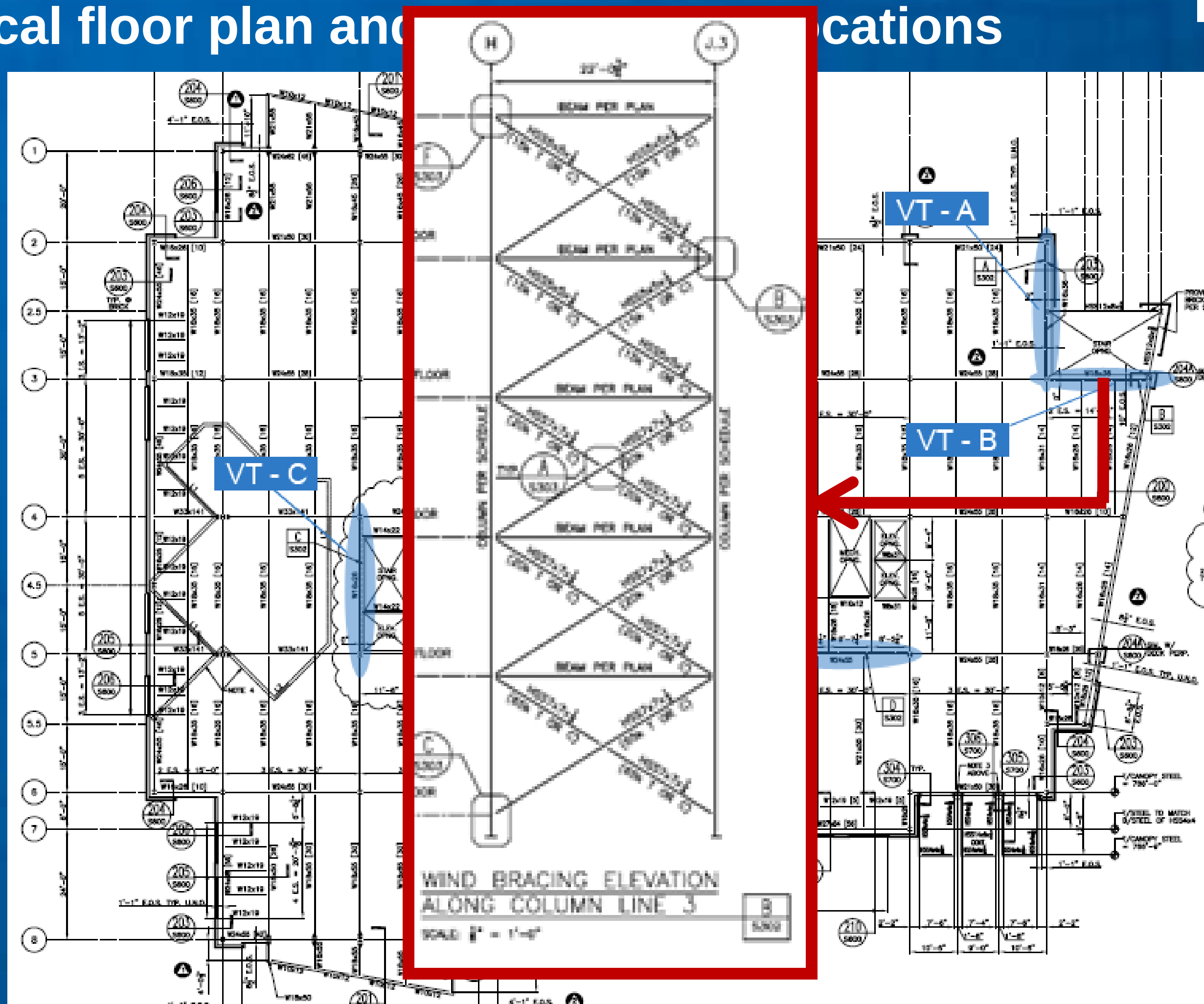


Existing Structural System

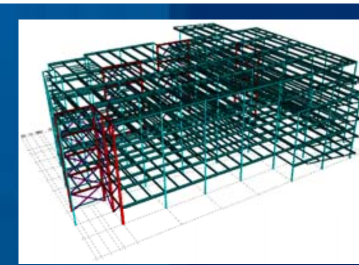


A E O Quantum III

- Typical floor plan anc … cations

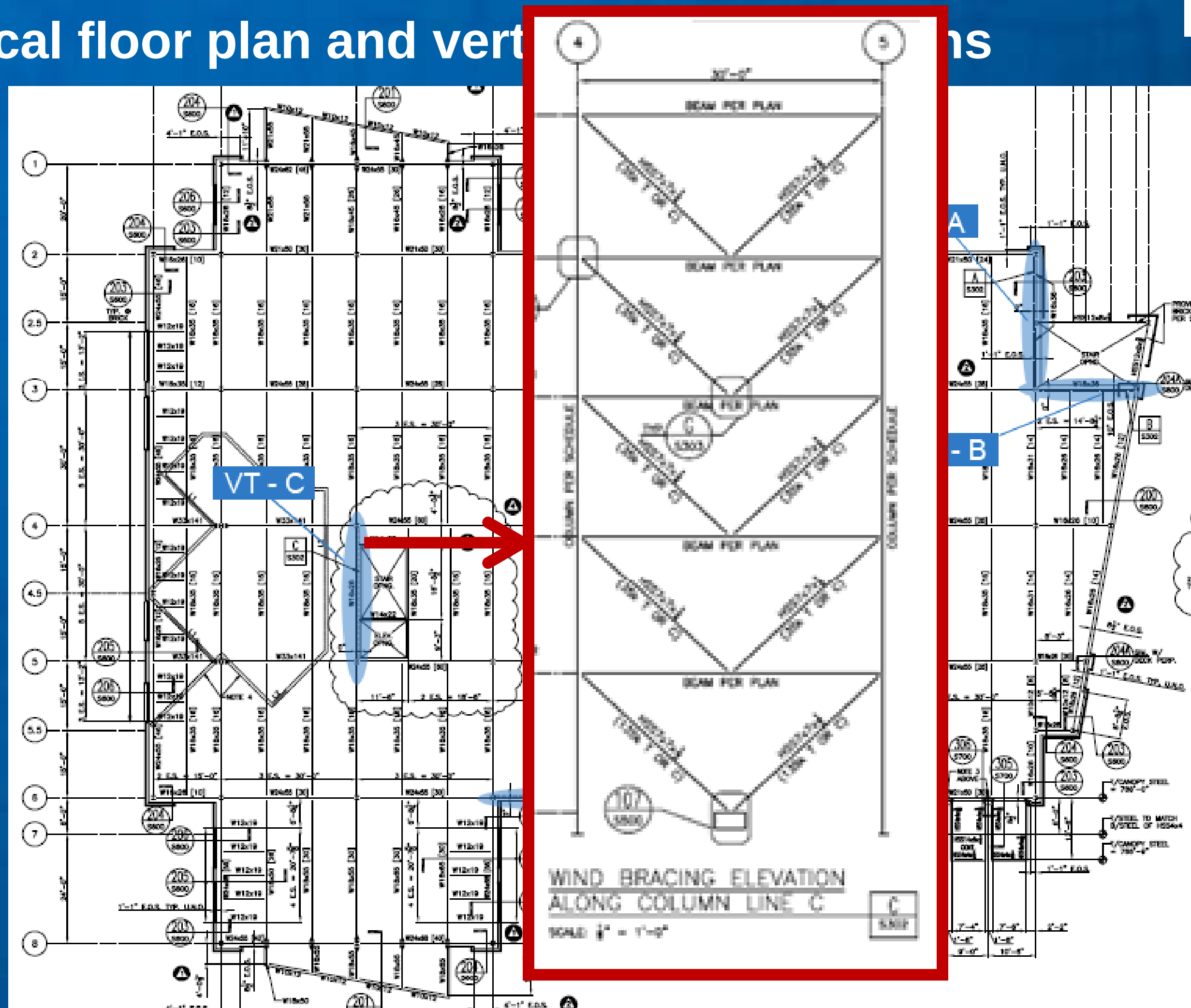


Existing Structural System

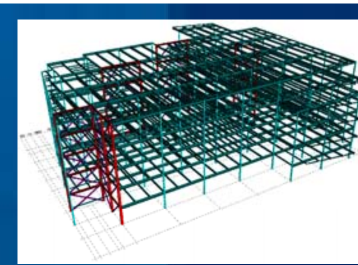


AEO Quantum III

- Typical floor plan and vert ns

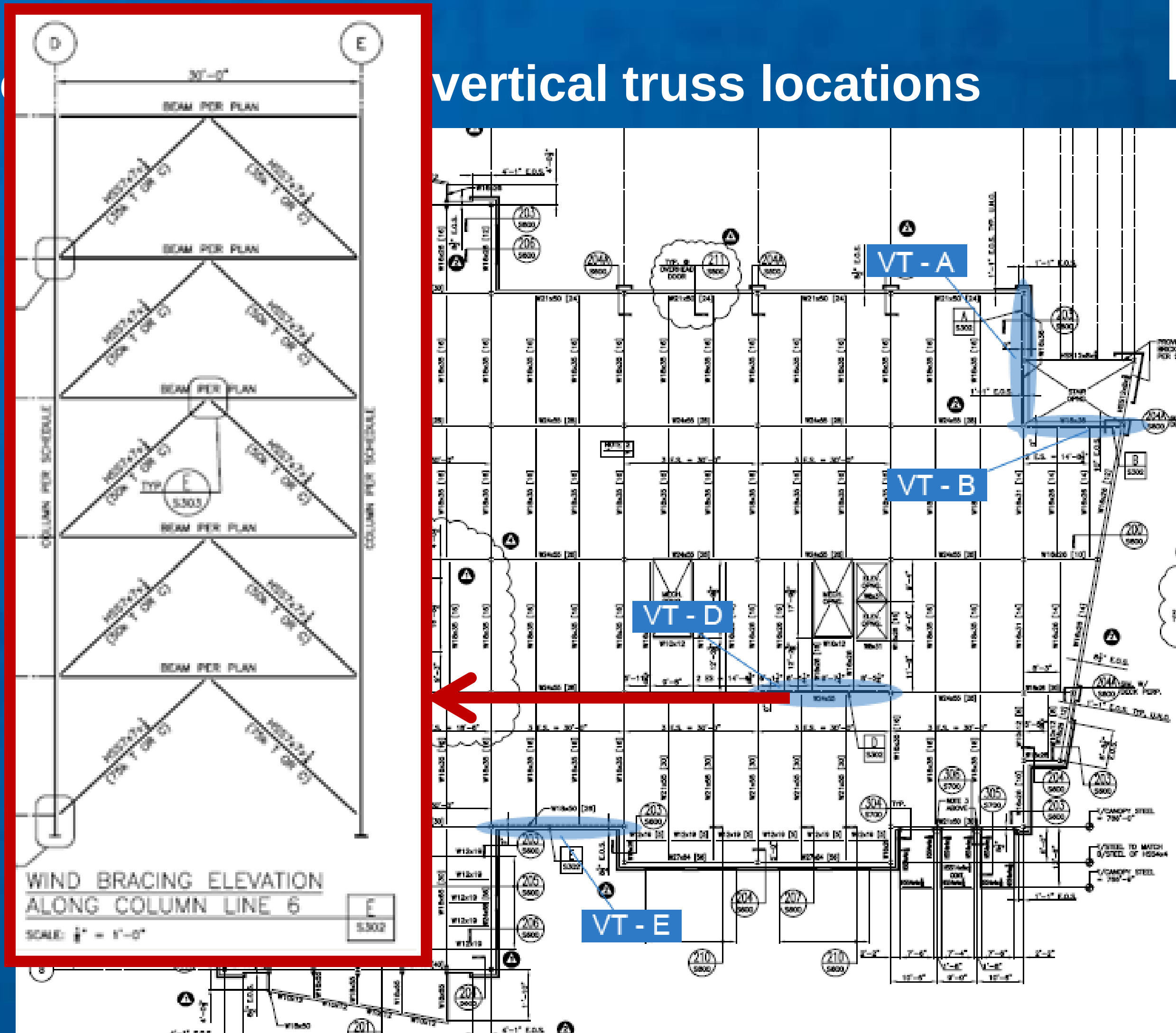


Existing Structural System

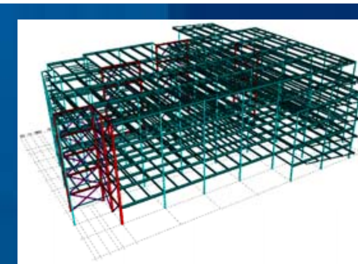


AE Quantum III

- Typi vertical truss locations

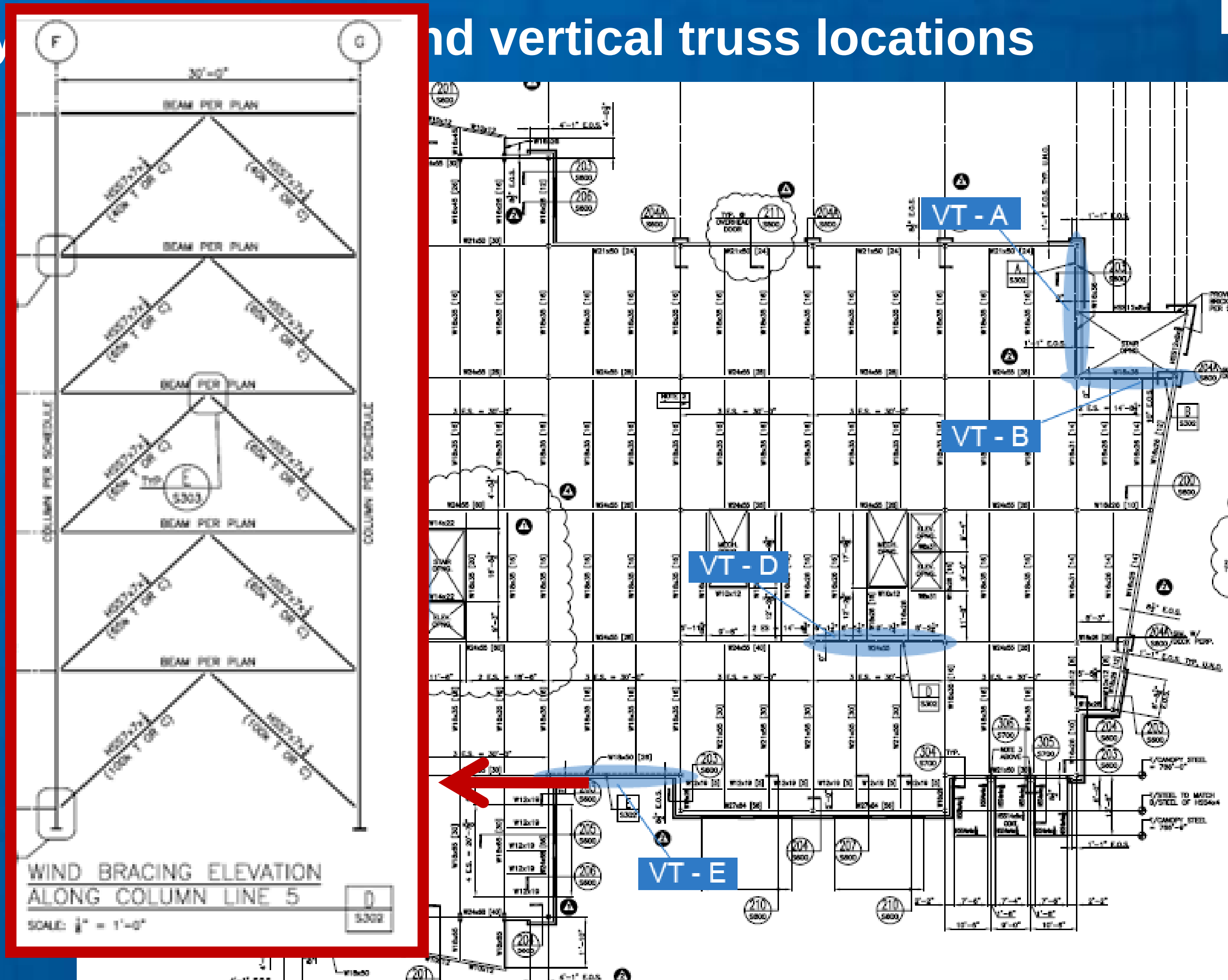


Existing Structural System

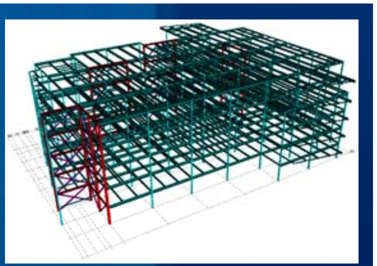


A E O Quantum III

- Ty nd vertical truss locations



Proposed Gravity System



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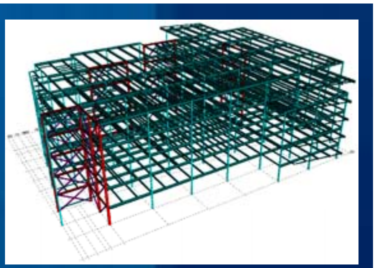
- **2 floors added to elevation**
  - Floor framing or loading doesn't change
  - Gravity columns
    - Similar until 3rd floor

Proposed Gravity Framing
Typical infill beams: W16x31 (18 studs)
Typical girders: W24x68 (24 studs)
Columns stories 6-7: W12x53
Columns stories 4-5: W12x72
Columns stories 2-3: W12x96

Existing Gravity Framing
Typical infill beams: W18x35 (16 studs)
Typical girders: W24x55 (26 studs)
Columns stories 4-5: W12x53
Columns stories 2-3: W12x72

Proposed Lateral System

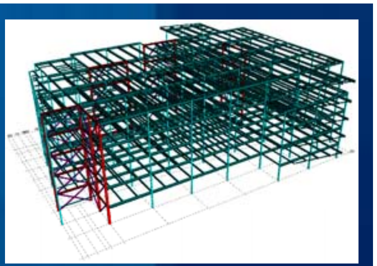


AEO Quantum III

- **Building moved to Oakland, CA**
  - Gravity loading unchanged
  - Lateral design now controlled by seismic forces
    - Original wind base shear: 630 k
    - New seismic base shear: 2240 k

Existing System	Proposed System
S_{DS} = 0.133	S_{DS} = 1.015
S_{D1} = 0.0784	S_{D1} = 0.6
Site Class: D	Site Class: D
R = 3.0	R = 6.0
W_o = 3.0	W_o = 2.0
C_d = 3.0	C_d = 5.0
Seismic Design Cat: **B**	Seismic Design Cat: **E**

Proposed Lateral System

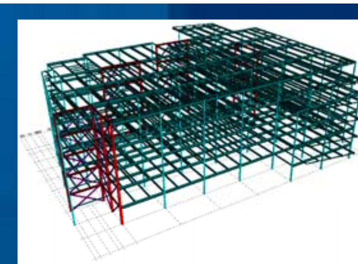


A E O Quantum III

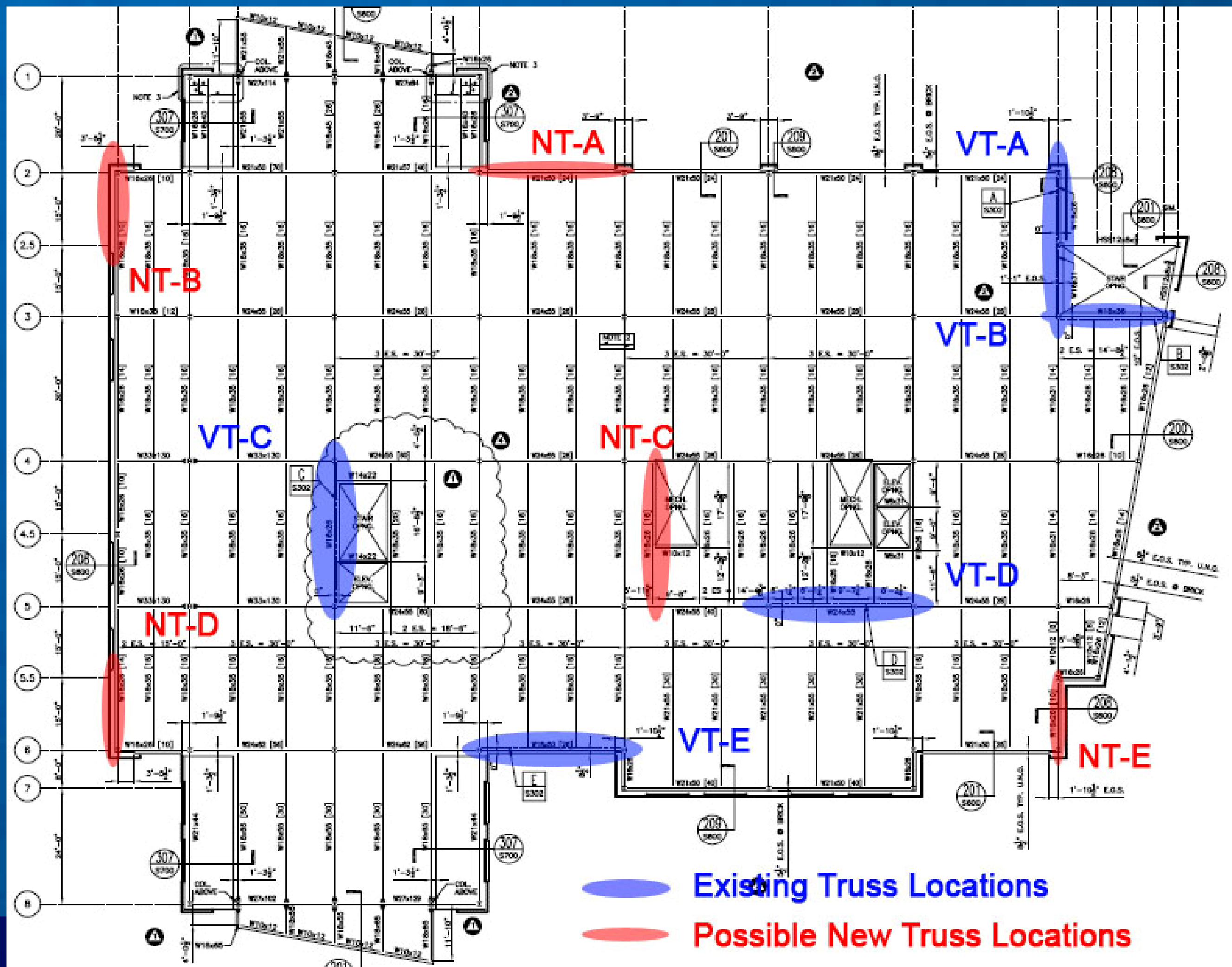
- **Building moved to Oakland, CA**
  - Gravity loading unchanged
  - Lateral design now controlled by seismic forces
- **2 floors added to elevation**
  - Extra levels of lateral framing required
- **Seismic lateral forces**
  - Lateral frame member sections increase
  - Significant detailing required
  - Asymmetric frame layout can lead to torsional concerns

R = 3.0	R = 6.0
W_o = 3.0	W_o = 2.0
C_d = 3.0	C_d = 5.0
Seismic Design Cat: **B**	Seismic Design Cat: **E**

Truss Layout



- **Consider additional lateral frames**
  - Increase redundancy
  - Decrease required member sections



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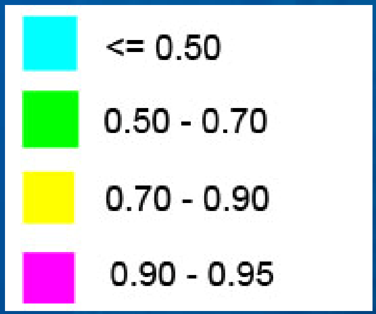
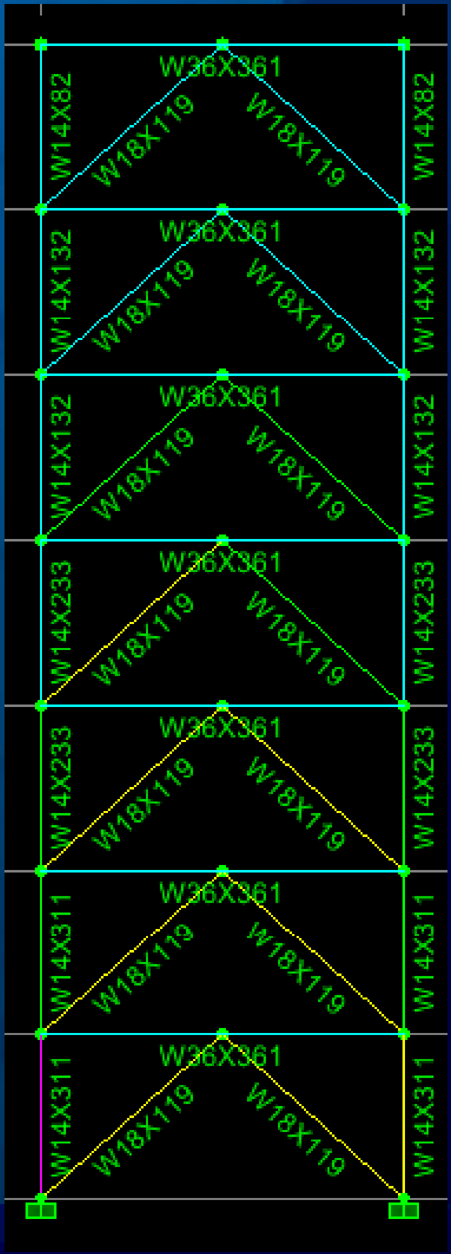
Special Concentric Braced Frames

- **Columns and braces**
  - Original columns sized based on drift
  - Columns optimized in ETABS including torsion
  - Braces sized in ETABS including torsion

- **Girders**
  - Sized in excel based on shear resistance
  - No shear reinforcement assumed



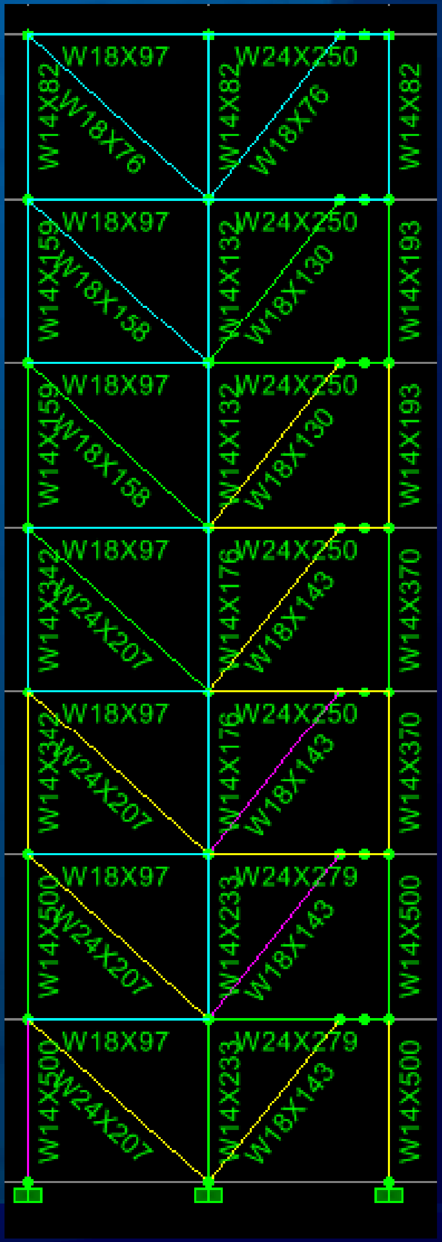
- **SCBF Design**
  - Columns are efficient
  - Braces can be optimized
  - Girders require resizing assuming shear reinforcing



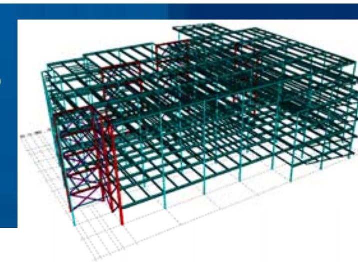
Eccentric Braced Frame

AEO Quantum III

- **Columns and braces**
  - Original columns sized based on drift
  - Columns optimized in ETABS including torsion
  - Braces sized in ETABS including torsion
- **Eccentric Girders**
  - Link design based on AISC design example
  - Shear reinforcement assumed
- **Eccentric Braced Frame Design**
  - Efficient preliminary design
  - Continue with design of
    - Beam outside of link
    - Connections



Torsion and Building Irregularities



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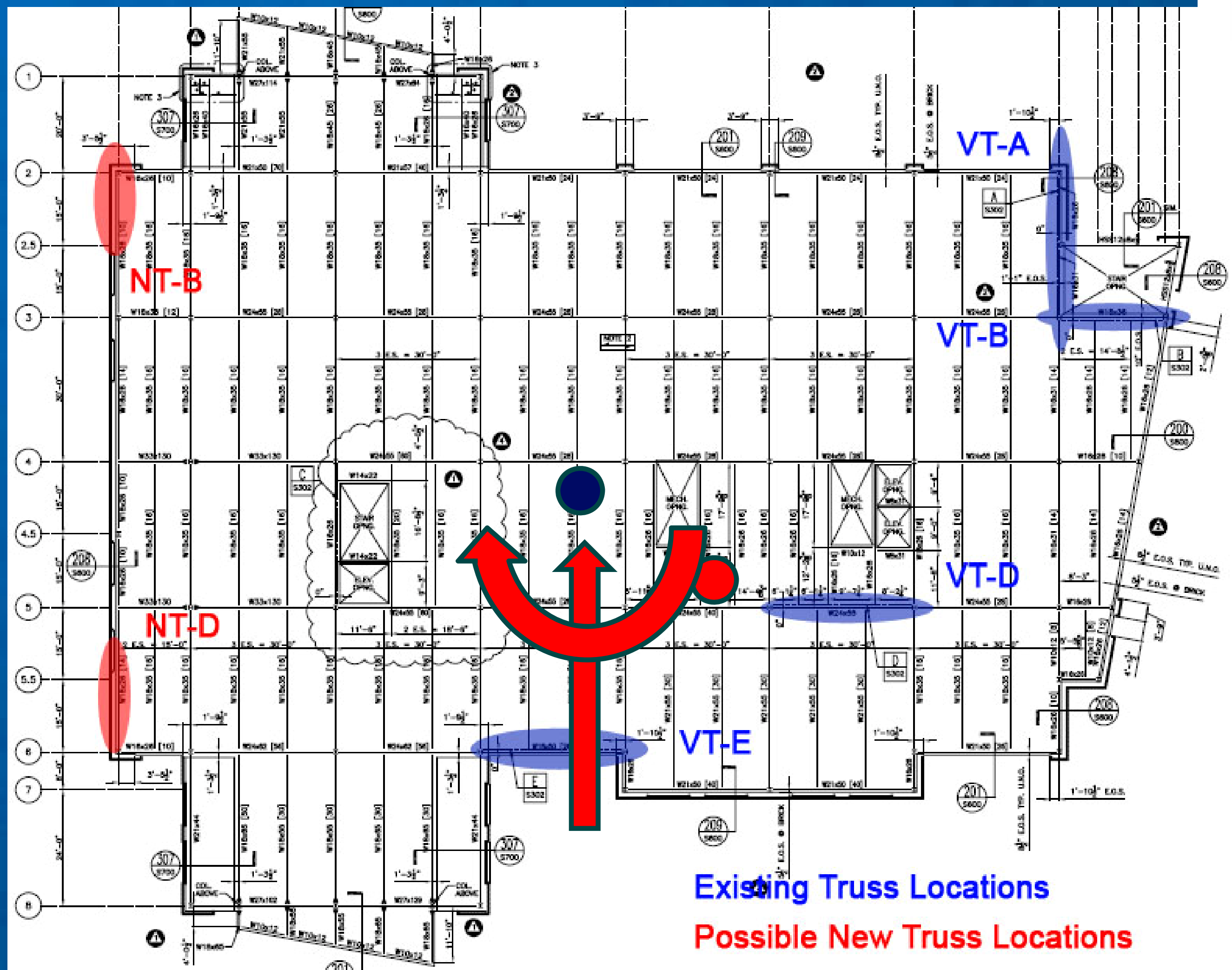
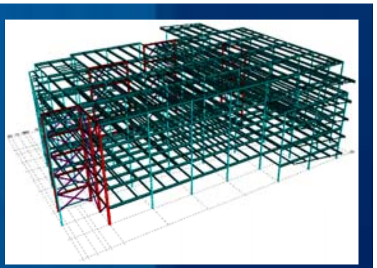
- Final design allows significant torsion



Continuing Design



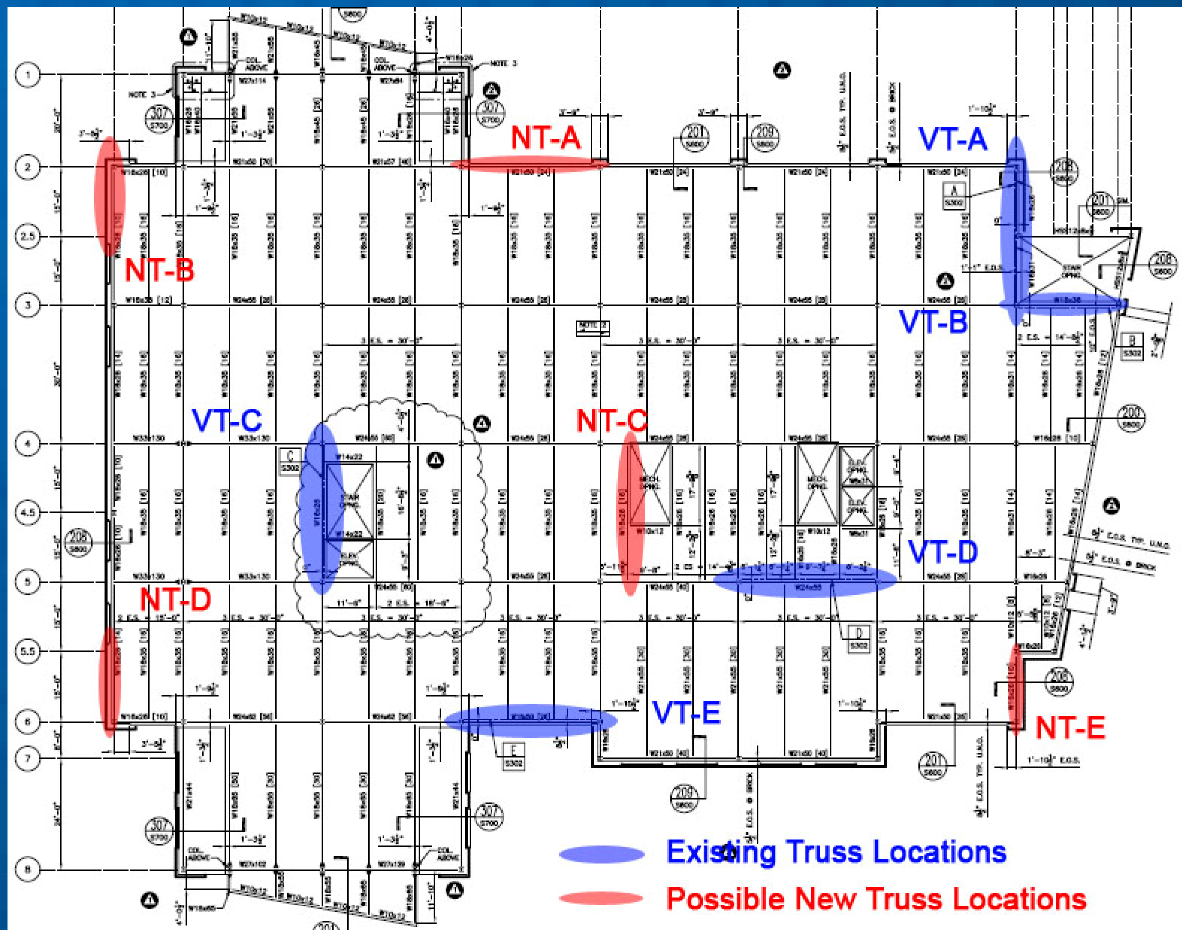
- **Special Concentric Braced Frames**
  - Provide shear reinforcing for inverted-V trusses
  - Design connections

- **Eccentric Braced Frames**
  - Check beams outside of link
  - Link shear reinforcing
  - Connections

A E O Q u a n t u m III

Frame Locations and Architecture

- **NT-A obstructs ground level entrance**
  - Proves inadequate for building architecture



Frame Locations and Architecture

- **NT-A obstructs ground level entrance**
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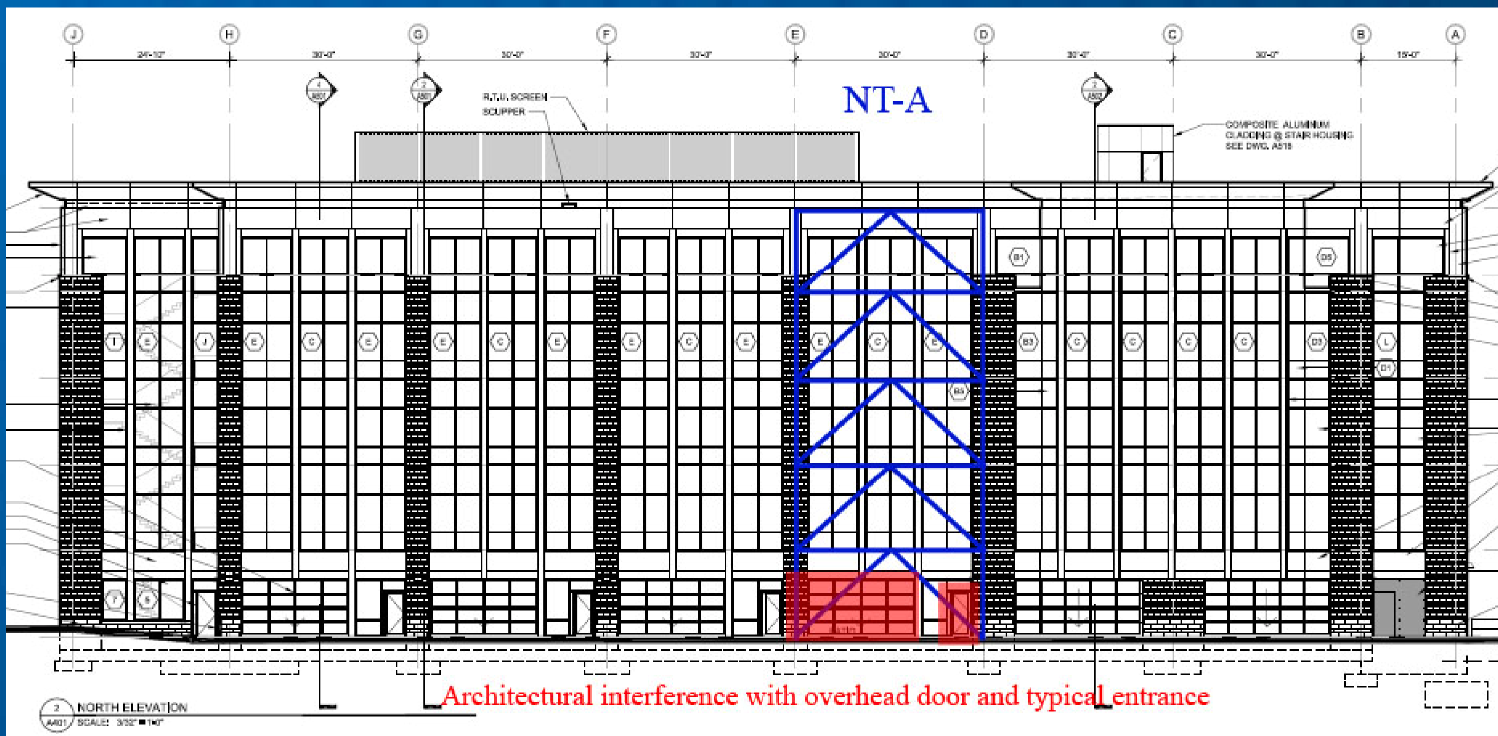


AEO Quantum III

Frame Locations and Architecture

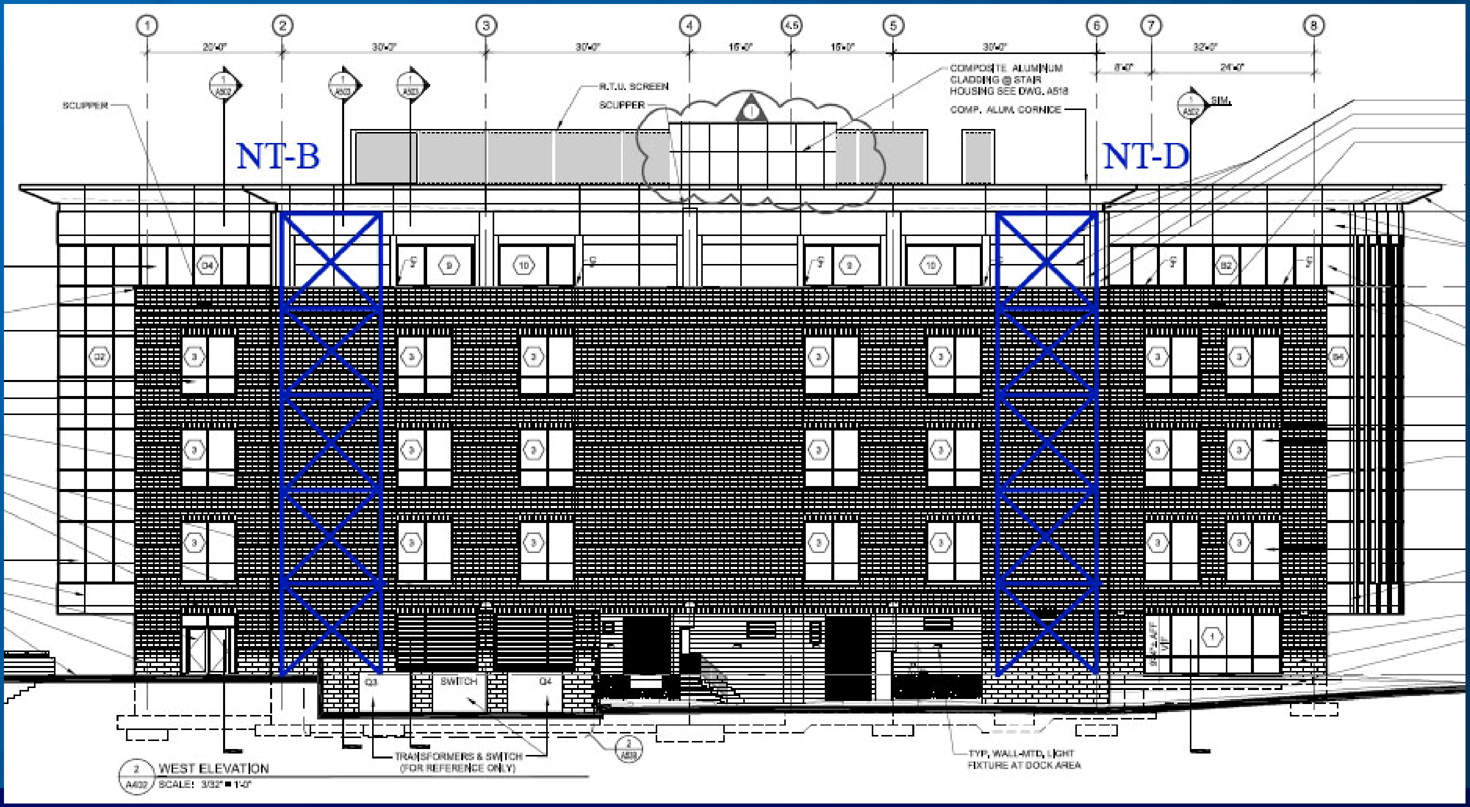
- **NT-B and D optimal frame locations**
  - Minimal interaction with façade architecture

A E O Quantum III

AEO Quantum III

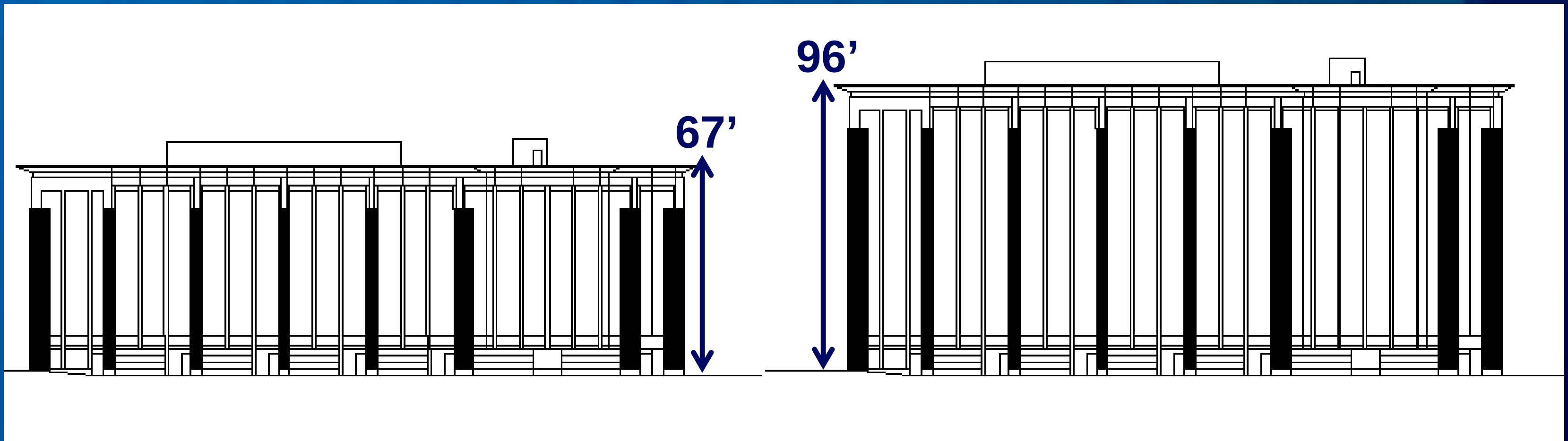
Frame Locations and Architecture

- **NT-B and D optimal frame locations**
  - Minimal interaction with façade architecture



Façade Architecture

- **Shell scaling re-evaluation**
  - Building height increases from 67’ to 96’
  - Existing shell scaling proves adequate



Façade Architecture

- **Façade materials not suited for Oakland, CA**
  - Brick uncommon in Bay Area architecture
  - Replace brick with aluminum panelling

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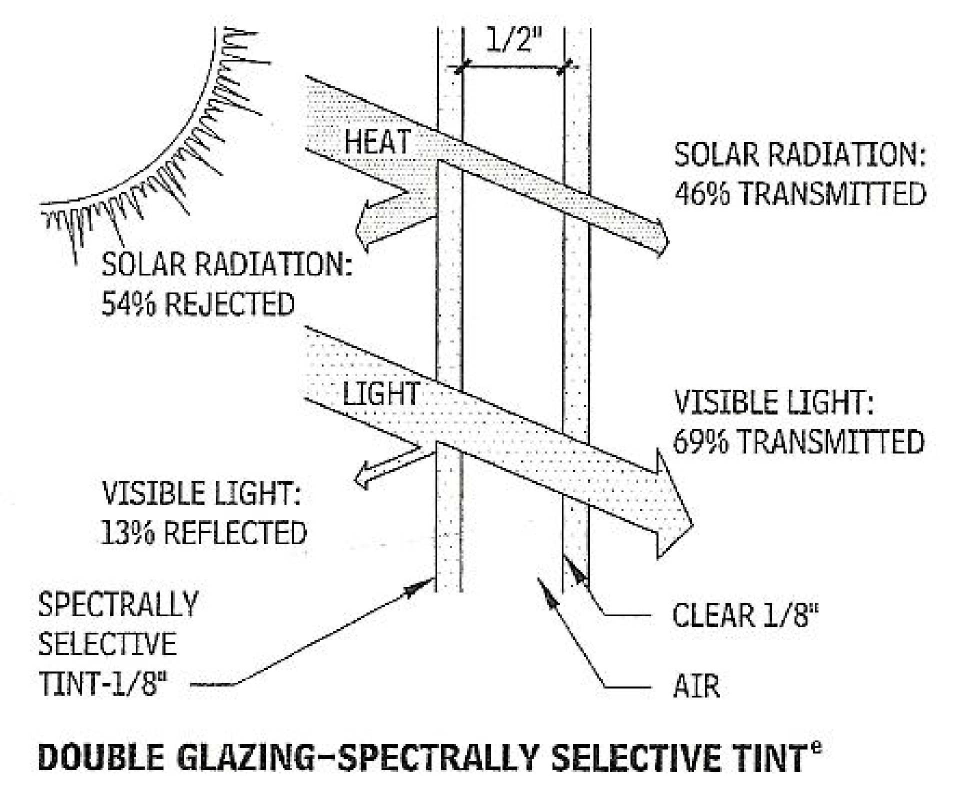
Façade Assemblies

- **Façade materials not suited for Oakland, CA**
  - Use windows that describe Bay Area high rise
  - Can also be energy efficient



Picture Courtesy of *Architectural Graphic Standards, Eleventh Edition; 2007*

Façade Assemblies

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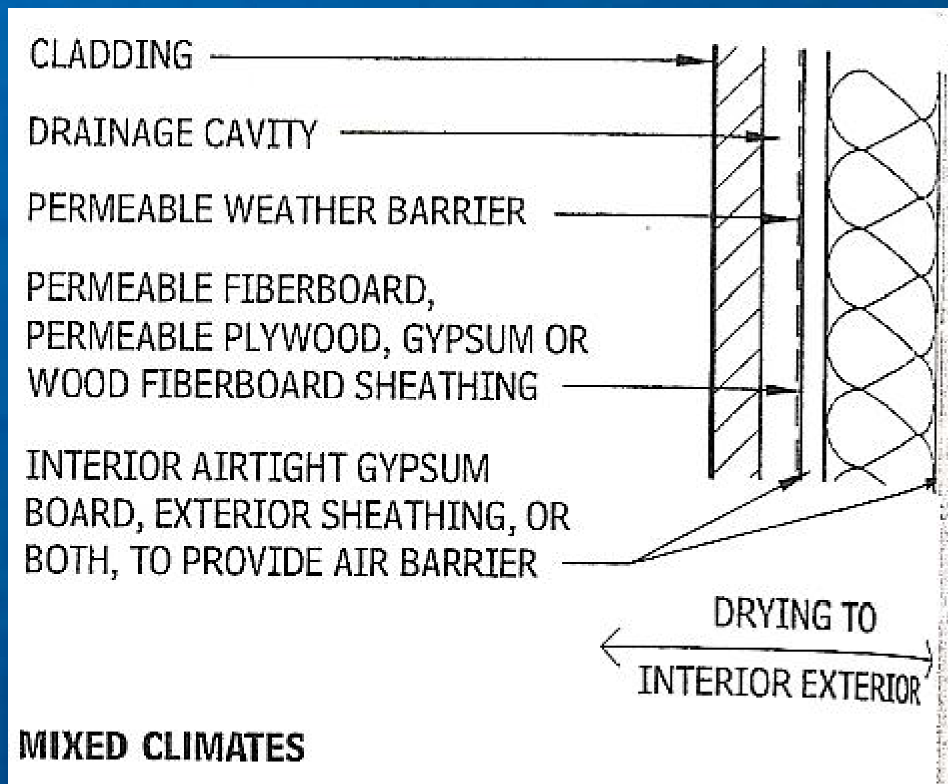
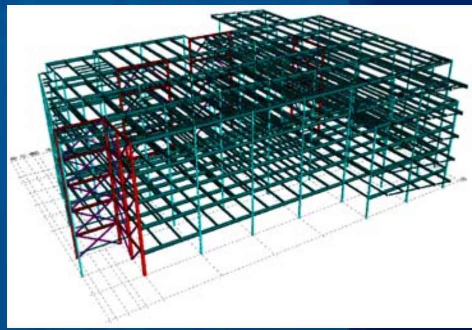
- **Façade materials not suited for Oakland, CA**
  - Possible 60” rain per year
  - Façade requires weather barrier



Picture Courtesy of *Architectural Graphic Standards, Eleventh Edition; 2007*

Senior Thesis Goals

- **Structural**
  - Gravity system design with added stories ☑
  - Preliminary lateral system design ☑



- **Architectural**
  - Redesign shell to fit Oakland, CA ☑
  - Shell scaling matches new building height ☑

- **Mechanical**
  - Find heating/cooling loads for new building ☑

- **Façade Assemblies**
  - Energy efficient window added ☑
  - Weather barrier required ☑

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Special Thanks To:

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The Entire AE Faculty and Staff

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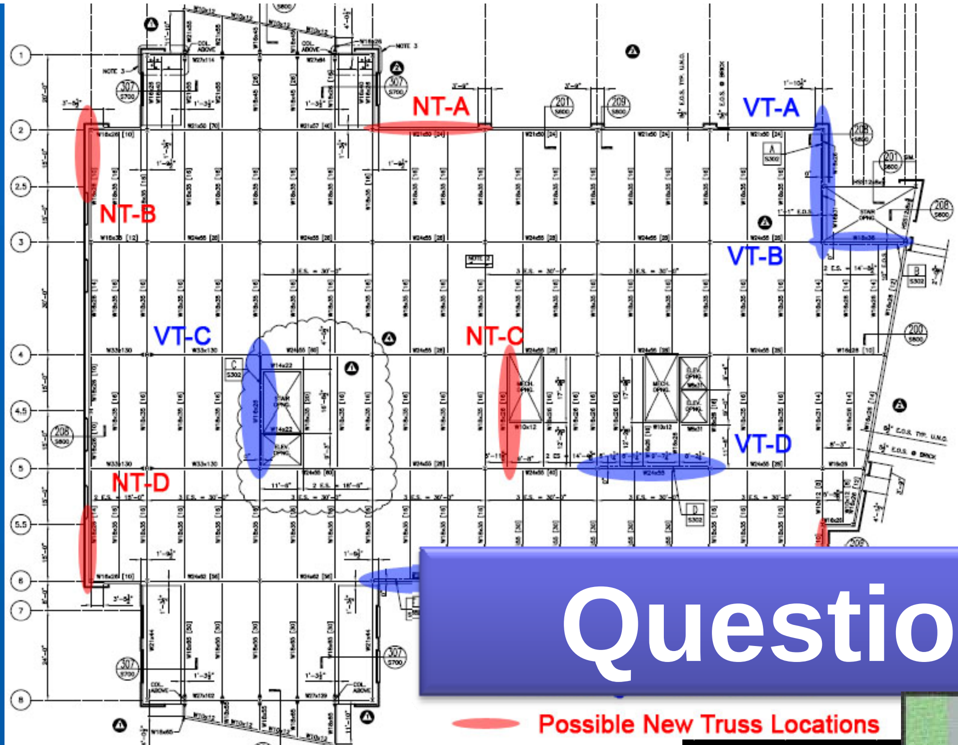
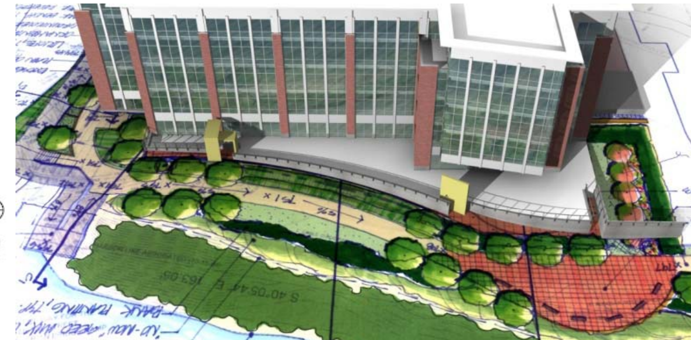
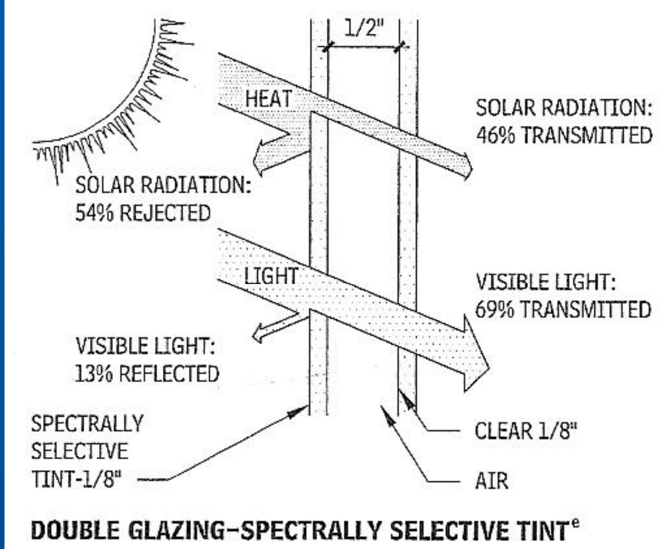
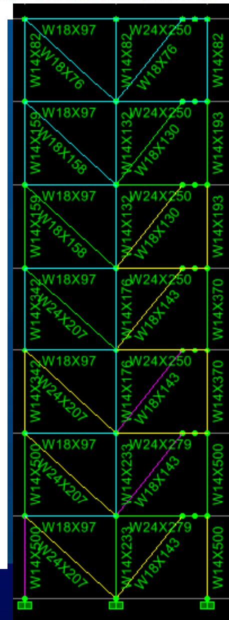




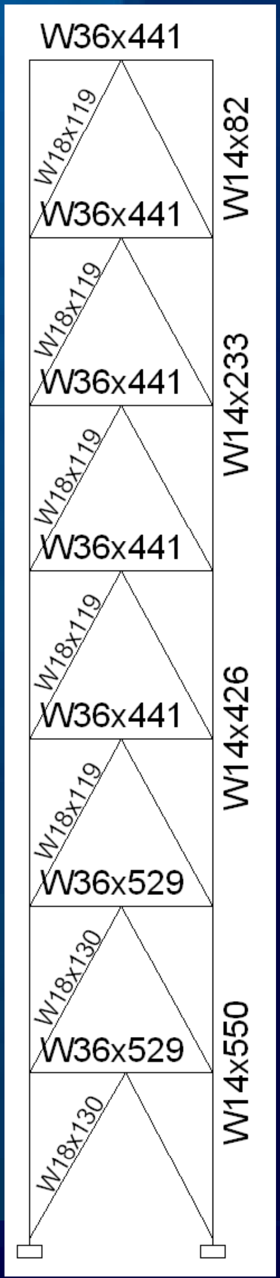
Questions?





Chevron Braced Frame Beam Design

- **Large Girder Sizes**
  - Attributed to AISC Seismic Design Provisions
    - Beams must be designed against the shear from 100% tension brace strength and 30% compression brace strength
  - Results in large vertical force on beams
    - Over 1000k where braces were W18x119
  - Only beam web resists this shear force
- **Continuing Design**
  - Assume shear reinforcing to significantly lower girder sections

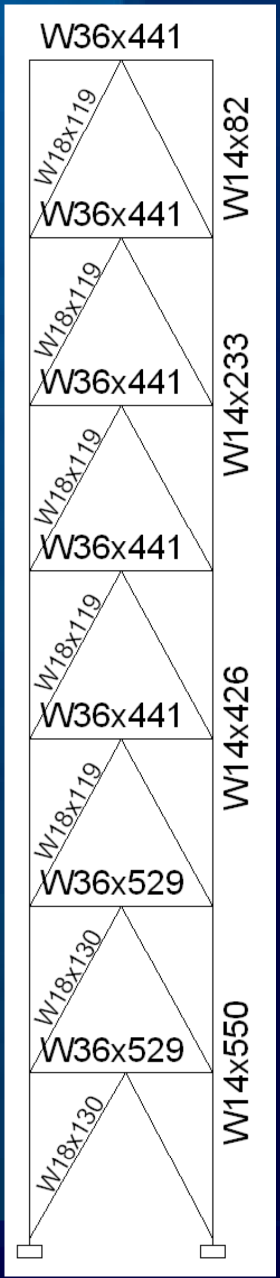


AEO Quantum III

Chevron Braced Frame Beam Design

- **Large Girder Sizes**
  - Design example provided below

Frame Sections			Forces			Factors	
Beam	W36X361		Pu =	522.47	k	Øb =	0.9
Brace	W18X119		Py =	5300	k	Øv =	0.9
Column	W14X370					Øc =	0.9
Story h	164	in	Vu =	12.56	k		
Bay w	30	ft					
Brace L	243.5077	in	Δx =		in		
lu, x	30	ft					
lu, y	15	ft	Mu =	1514	ft-k		
Fy, brace	50	ksi					
Fu, brace	65	ksi					
Fy, beam	50	ksi					
Fu, beam	65	ksi					
E	29000	ksi					



AE Quantum III

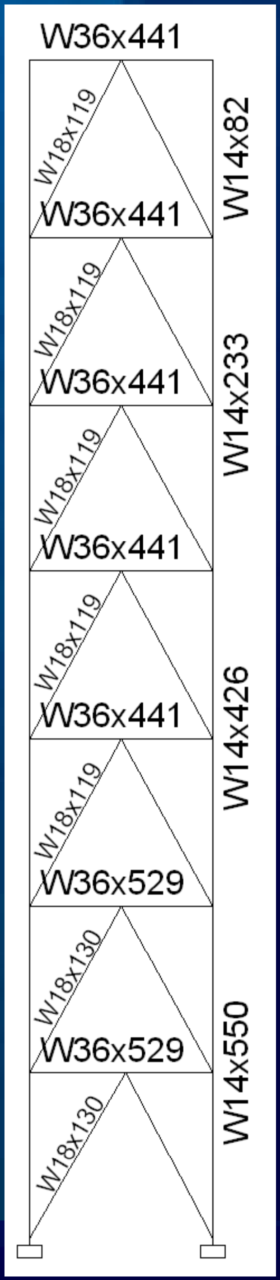
Chevron Braced Frame Beam Design

- **Large Girder Sizes**
  - Design example provided below

Beam Properties			Brace Properties		
bf =	16.7	in	bf =	11.3	in
tf =	2.01	in	tf =	1.06	in
tw =	1.12	in	tw =	0.655	in
d =	38	in	d =	19	in
Ag =	106	in2	Ag =	35.1	in2
Z =	1550	in3	Z =	262	in3
rx =	15.6	in			
ry =	3.85	in	ry =	2.69	in
I =	25700	in4			

Flange Width Comparison: Beam vs. Brace				
			bf, beam > bf, brace	YES
bf, beam	=	16.7		
bf, brace	=	11.3	Beam Flange Adequate	

Element Slenderness - Beam				
	λ_f =	4.15422886	$\lambda_f < \lambda_{ps}$	YES
	λ_p =	9.15161188	Flanges are Compact	
	λ_w =	33.9285714		
	λ_p =	90.5527912	$\lambda_w < \lambda_{ps}$	YES
			Web is Compact	



Chevron Braced Frame Beam Design

- **Large Girder Sizes**
  - Design example provided below

Brace Axial Force	
Ry =	1.1
Pt =	**1930.5**
KL/r =	90.52331
Fe =	34.92826
Fcr =	27.46372
Pc =	**289.1929**

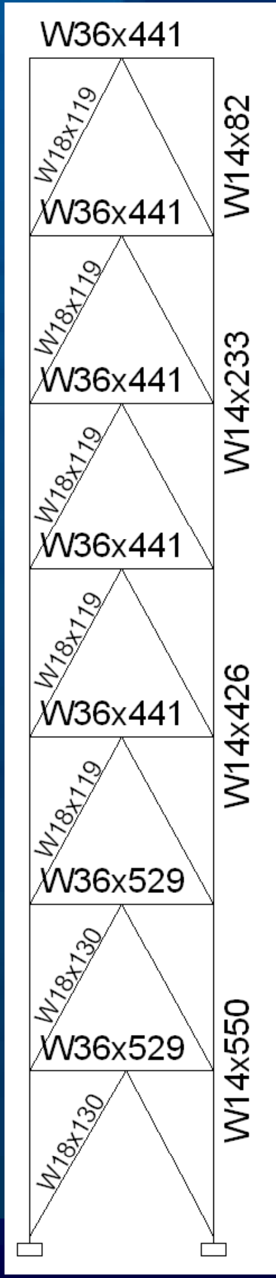
Unbalanced Vertical Beam Load	
Pty =	1300.17244
Pcy =	194.768556
Qb =	1105.40388

Additional Beam Axial Force	
Ptx =	1427.0185
Pcx =	213.77037
Pu =	820.39445

Unbraced Length Check			Lb < Lp YES
Lp =	9.29	ft	
dc =	17.9		
Lb =	8.544167		**Controlling Limit State is Yielding**

Flexural Strength			Mu < ØbMn YES
Mn =	77500	ft-k	
ØbMn =	69750	ft-k	
Mu =	1514	ft-k	**Beam is Adequate in Flexure**

Compression Strength			Pu < ØcPn YES
KLx/rx	23.07692	**Controls**	
Klxy/ry	46.75325		
ØcFcr =	38.5	ksi	
ØcPn =	4081	k	**Beam is Adequate in Compression**



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Chevron Braced Frame Beam Design

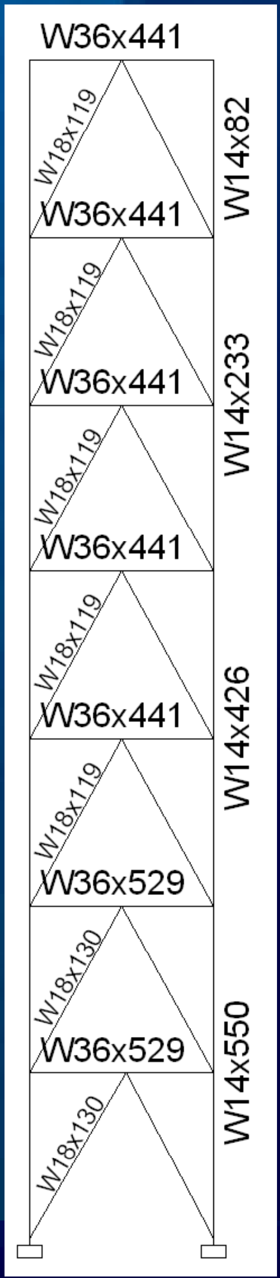
AEO Quantum III

- **Large Girder Sizes**
  - Design example provided below

Combined Loading		Pr/Pc < 0.2	NO
Pe1 =	56757.84		
Cm =	1	Combined Ratio	Limit
B2 =	1	0.347757108 <=	1
Pr =	1342.864		
B1 =	1.024233		
Mrx =	1467.704		
Pr/Pc =	0.329053	Beam is Adequate in Combined Loading	

Shear Strength		Vu < ØVn	YES
h/tw =	33.92857		
2.24*(E*Fy)^0.5 =	53.9463437		
Aw =	38.0576		
ØVn =	1141.728		
Vu =	1116.774	Beam is Adequate in Shear	

Beam is Adequate



Story Drift Check

- **Seismic Loading Controlled in Strength**

- **Checks Performed for Both Seismic and Wind**
  - Seismic
    - Cd=5, allowable story drift was 0.02hsx
  - Wind
    - Serviceability requirement of H/400

Story Drift Check - Wind

- **Wind Drift Minimal in Comparison to Seismic Drift**

Wind Story Drift

Story	Item	Load	Point X (in)	Point Y (in)	Story Height Z (in)	Story Drift X (in)	Story Drift Y (in)	Allowable Drift (in)	Conclusion
ROOF	Max Drift X	DSTLD1	780	-142	1146.5	6.3E-05		0.41	OK
ROOF	Max Drift Y	DSTLD1	2638.5	1464	1146.5		5.2E-05	0.41	OK
7TH	Max Drift X	DSTLD1	780	-142	982.5	6.2E-05		0.41	OK
7TH	Max Drift Y	DSTLD1	2638.5	1464	982.5		5.7E-05	0.41	OK
6TH	Max Drift X	DSTLD1	780	-142	818.5	0.00005		0.41	OK
6TH	Max Drift Y	DSTLD1	2638.5	1464	818.5		4.9E-05	0.41	OK
5TH	Max Drift X	DSTLD1	780	-142	654.5	3.7E-05		0.41	OK
5TH	Max Drift Y	DSTLD1	2638.5	1464	654.5		3.5E-05	0.41	OK
4TH	Max Drift X	DSTLD1	780	-142	490.5	2.7E-05		0.41	OK
4TH	Max Drift Y	DSTLD1	2638.5	1464	490.5		0.00003	0.41	OK
3RD	Max Drift X	DSTLD1	780	-142	326.5	1.5E-05		0.41	OK
3RD	Max Drift Y	DSTLD1	2638.5	1464	326.5		0.00002	0.41	OK
2ND	Max Drift X	DSTLD1	1260	384	162.5	5E-06		0.40625	OK
2ND	Max Drift Y	DSTLD1	2638.5	1464	162.5		1.5E-05	0.40625	OK
ROOF	Max Drift X	DSTLD2	780	-142	1146.5	9.7E-05		0.41	OK
ROOF	Max Drift Y	DSTLD2	2638.5	1464	1146.5		0.00008	0.41	OK
7TH	Max Drift X	DSTLD2	780	-142	982.5	9.6E-05		0.41	OK
7TH	Max Drift Y	DSTLD2	2638.5	1464	982.5		8.9E-05	0.41	OK
6TH	Max Drift X	DSTLD2	780	-142	818.5	7.7E-05		0.41	OK
6TH	Max Drift Y	DSTLD2	2638.5	1464	818.5		7.6E-05	0.41	OK
5TH	Max Drift X	DSTLD2	780	-142	654.5	5.7E-05		0.41	OK
5TH	Max Drift Y	DSTLD2	2638.5	1464	654.5		5.5E-05	0.41	OK
4TH	Max Drift X	DSTLD2	780	-142	490.5	4.2E-05		0.41	OK
4TH	Max Drift Y	DSTLD2	2638.5	1464	490.5		4.8E-05	0.41	OK
3RD	Max Drift X	DSTLD2	780	-142	326.5	2.4E-05		0.41	OK
3RD	Max Drift Y	DSTLD2	2638.5	1464	326.5		3.1E-05	0.41	OK
2ND	Max Drift X	DSTLD2	1260	384	162.5	7E-06		0.40625	OK
2ND	Max Drift Y	DSTLD2	2638.5	1464	162.5		2.4E-05	0.40625	OK

AEO Quantum III

Story Drift Check - Wind

- **Wind Drift Minimal in Comparison to Seismic Drift**

Cd =	5		I =	1

Siesmic Story Drift

Story	Load	Total Drift		Center of Mass		Story Height		Amplified Story Drift		Allowable Drift	Conclusion	
		UX	UY	X	Y	Z		X	Y		X	Y
ROOF	QUAKEX	1.8976	0.4132	1156.966	1064.648	1146.5		1.6055	0.4325	3.28	OK	OK
7TH	QUAKEX	1.5765	0.3267	1157.97	1065.287	982.5		1.7365	0.4505	3.28	OK	OK
6TH	QUAKEX	1.2292	0.2366	1158.218	1065.555	818.5		1.6	0.378	3.28	OK	OK
5TH	QUAKEX	0.9092	0.161	1157.048	1065.698	654.5		1.492	0.317	3.28	OK	OK
4TH	QUAKEX	0.6108	0.0976	1156.388	1066.125	490.5		1.2865	0.2525	3.28	OK	OK
3RD	QUAKEX	0.3535	0.0471	1156.881	1066.551	326.5		1.0615	0.16	3.28	OK	OK
2ND	QUAKEX	0.1412	0.0151	1157.853	1067.224	162.5		0.706	0.0755	3.25	OK	OK
ROOF	QUAKEXY1	1.8938	0.4415	1156.966	1064.648	1146.5		1.5965	0.4825	3.28	OK	OK
7TH	QUAKEXY1	1.5745	0.345	1157.97	1065.287	982.5		1.7255	0.499	3.28	OK	OK
6TH	QUAKEXY1	1.2294	0.2452	1158.218	1065.555	818.5		1.596	0.4035	3.28	OK	OK
5TH	QUAKEXY1	0.9102	0.1645	1157.048	1065.698	654.5		1.488	0.337	3.28	OK	OK
4TH	QUAKEXY1	0.6126	0.0971	1156.388	1066.125	490.5		1.287	0.2615	3.28	OK	OK
3RD	QUAKEXY1	0.3552	0.0448	1156.881	1066.551	326.5		1.064	0.159	3.28	OK	OK
2ND	QUAKEXY1	0.1424	0.013	1157.853	1067.224	162.5		0.712	0.065	3.25	OK	OK
ROOF	QUAKEXY2	1.9015	0.3849	1156.966	1064.648	1146.5		1.6145	0.383	3.28	OK	OK
7TH	QUAKEXY2	1.5786	0.3083	1157.97	1065.287	982.5		1.748	0.402	3.28	OK	OK
6TH	QUAKEXY2	1.229	0.2279	1158.218	1065.555	818.5		1.6045	0.352	3.28	OK	OK
5TH	QUAKEXY2	0.9081	0.1575	1157.048	1065.698	654.5		1.4955	0.2975	3.28	OK	OK
4TH	QUAKEXY2	0.609	0.098	1156.388	1066.125	490.5		1.2865	0.243	3.28	OK	OK
3RD	QUAKEXY2	0.3517	0.0494	1156.881	1066.551	326.5		1.0585	0.161	3.28	OK	OK
2ND	QUAKEXY2	0.14	0.0172	1157.853	1067.224	162.5		0.7	0.086	3.25	OK	OK