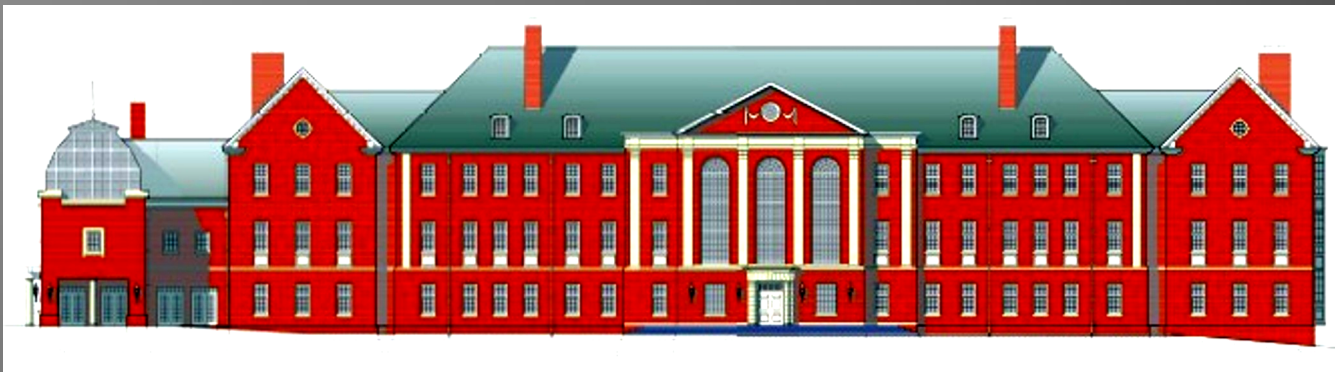


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Presentation Order

Project Info

Depth Topic I

Lateral Force Resisting System

Breadth - CM Evaluation

Depth Topic II

Foundations

Breadth - CM Evaluation

Depth Topic III

Long Span Options

Breadth - Architectural Impact

Breadth - Mechanical Impact

Conclusions & Recommendations

Questions



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Project Info



(www.fandm.edu)



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Project Info

Building Statistics

3 Stories + Partial Basement

102,000 ft²

Building Uses

Construction Team

Einhorn Yaffee Prescott Architecture & Engineering P.C.

Turner Construction

Construction Schedule

November 2005 – June 2007

Total Project Cost

Approx. \$40 Million

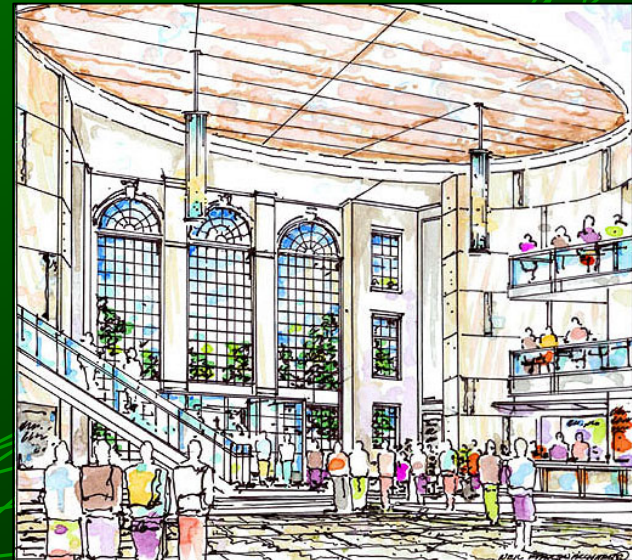
Structural Systems

Superstructure

Foundations

Lateral Force Resisting System

Vierendeel Truss





Depth Topic I • Lateral Force Resisting System

Existing System

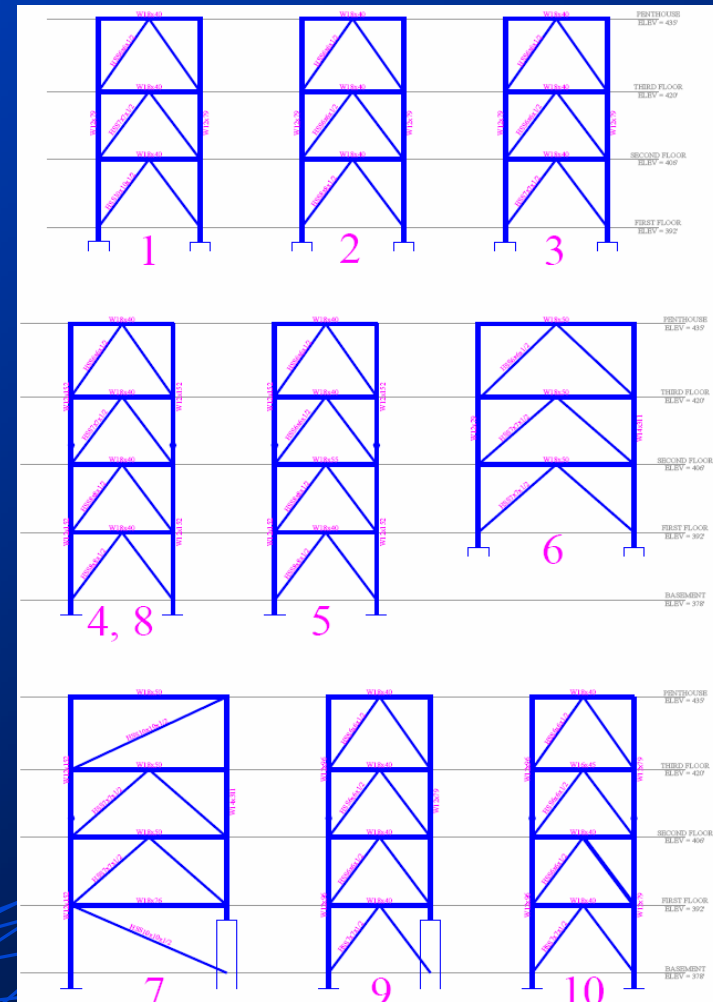
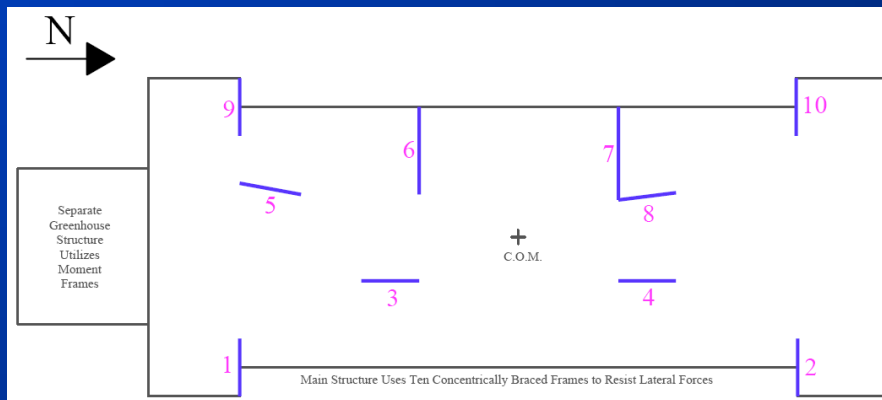
10 Steel Braced Frames

Analysis Methods

2-D Models: SAP2000

Equivalent Lateral Force Method: ASCE7-02

Frame Forces: MS Excel





Depth Topic I • Lateral Force Resisting System

Existing System

Diagonal Bracing Member Forces												
Frame	Story Level	HSS Brace Size	Length (in)	Area (in ²)	cos(theta)	Member Stiffness (k/in)	Story Shear (k)	Brace Axial Force (k)	Allowable Tensile Strength (k)	Allowable Compress. Strength (k)	Strength Design Efficiency	Total Story Drift (in)
1	1	10x10x ¹ / ₂	208	17.2	0.581	816.2	22.3	83.4	712.1	557	15.0%	0.12
	2	7x7x ¹ / ₂	208	11.6	0.581	550.5	43.1	84.2	480.2	303	21.2%	0.25
	3	6x6x ¹ / ₂	216	9.74	0.555	401.7	31.5	28.4	403.2	203	14.0%	0.33
2	1	8x8x ¹ / ₂	208	13.5	0.581	640.6	20.9	78.2	558.9	390	20.0%	0.14
	2	6x6x ¹ / ₂	208	9.74	0.581	482.2	40.4	80.2	403.2	217	27.7%	0.29
	3	6x6x ¹ / ₂	216	9.74	0.555	401.7	29.5	26.6	403.2	203	13.1%	0.37
3	1	7x7x ¹ / ₂	208	11.6	0.581	550.5	62.5	233.1	480.2	303	76.9%	0.49
	2	6x6x ¹ / ₂	208	9.74	0.581	482.2	120.4	179.4	403.2	217	82.7%	0.94
	3	6x6x ¹ / ₂	216	9.74	0.555	401.7	88.1	79.4	403.2	203	39.1%	1.16
4	1	8x8x ¹ / ₂	208	13.5	0.581	640.6	48.2	179.8	558.9	390	46.1%	0.33
	2	7x7x ¹ / ₂	208	11.6	0.581	550.5	92.9	138.4	480.2	303	45.7%	0.62
	3	6x6x ¹ / ₂	216	9.74	0.555	401.7	67.9	61.2	403.2	203	30.2%	0.79
5	1	8x8x ¹ / ₂	208	13.5	0.581	640.6	47.5	177.1	558.9	390	45.4%	0.32
	2	6x6x ¹ / ₂	208	9.74	0.581	482.2	91.5	136.3	403.2	217	62.8%	0.66
	3	6x6x ¹ / ₂	216	9.74	0.555	401.7	66.9	60.3	403.2	203	29.7%	0.83
6	1	7x7x ¹ / ₂	248	11.6	0.727	717.3	51.1	152.6	480.2	245	62.3%	0.31
	2	7x7x ¹ / ₂	248	11.6	0.727	717.3	98.6	117.4	480.2	245	47.9%	0.55
	3	6x6x ¹ / ₂	256	9.74	0.703	545.6	72.1	51.3	403.2	161	31.8%	0.68
7	1	7x7x ¹ / ₂	248	11.6	0.727	717.3	76.6	228.8	480.2	245	93.4%	0.46
	2	7x7x ¹ / ₂	248	11.6	0.727	717.3	147.8	176.0	480.2	245	71.9%	0.82
	3	10x10x ¹ / ₂	408	17.2	0.443	241.4	108.1	243.8	712.1	317	76.9%	1.27
8	1	8x8x ¹ / ₂	208	13.5	0.581	640.6	48.2	179.8	558.9	390	46.1%	0.33
	2	7x7x ¹ / ₂	208	11.6	0.581	550.5	92.9	138.4	480.2	303	45.7%	0.62
	3	6x6x ¹ / ₂	216	9.74	0.555	401.7	67.9	61.2	403.2	203	30.2%	0.79
9	1	6x6x ¹ / ₂	208	9.74	0.581	482.2	24.5	91.5	403.2	217	42.1%	0.23
	2	6x6x ¹ / ₂	208	9.74	0.581	482.2	47.3	70.4	403.2	217	32.4%	0.41
	3	6x6x ¹ / ₂	216	9.74	0.555	401.7	34.6	31.2	403.2	203	15.3%	0.49
10	1	6x6x ¹ / ₂	208	9.74	0.581	482.2	10.7	40.1	403.2	217	18.5%	0.10
	2	6x6x ¹ / ₂	208	9.74	0.581	482.2	20.7	30.8	403.2	217	14.2%	0.18
	3	6x6x ¹ / ₂	216	9.74	0.555	401.7	15.1	13.7	403.2	203	6.7%	0.22

$(AE \cos^2 \theta) / L$

$0.9F_y A_g$ LRFD Table 4-6

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Depth Topic 1 • Lateral Force Resisting System

New Streamlined System

Diagonal Bracing Member Forces												
Frame	Story Level	HSS Brace Size	Length (in)	Area (in ²)	cos(theta)	Member Stiffness (k/in)	Story Shear (k)	Brace Axial Force (k)	Allowable Tensile Strength (k)	Allowable Compress. Strength (k)	Strength Design Efficiency	Total Story Drift (in)
1	1	10x10x ¹ / ₂	208	17.2	0.581	816.2	30.5	114.0	712.1	557	20.5%	0.16
	2	7x7x ¹ / ₂	208	11.6	0.581	550.5	58.9	87.7	480.2	303	28.9%	0.35
	3	8x8x ¹ / ₂	216	9.74	0.555	401.7	43.1	38.8	403.2	203	19.1%	0.45
2	1	8x8x ¹ / ₂	208	13.5	0.581	640.6	28.3	105.8	558.9	390	27.1%	0.19
	2	8x8x ¹ / ₂	208	9.74	0.581	482.2	54.7	81.4	403.2	217	37.5%	0.40
	3	8x8x ¹ / ₂	216	9.74	0.555	401.7	40.0	36.0	403.2	203	17.8%	0.50
3	1	10x10x ¹ / ₂	208	17.2	0.581	816.2	112.0	418.1	712.1	557	75.1%	0.60
	2	10x10x ¹ / ₂	208	17.2	0.581	816.2	216.0	321.7	712.1	557	57.8%	1.05
	3	10x10x ¹ / ₂	216	17.2	0.555	709.4	158.0	142.4	712.1	557	25.6%	1.28
4												
5												
6	1	7x7x ¹ / ₂	248	11.6	0.727	717.3	64.8	193.5	480.2	245	79.0%	0.39
	2	7x7x ¹ / ₂	248	11.6	0.727	717.3	125.0	148.9	480.2	245	60.8%	0.69
	3	8x8x ¹ / ₂	256	9.74	0.703	545.6	91.4	85.0	403.2	161	40.4%	0.86
7	1	10x10x ¹ / ₂	248	17.2	0.727	1083.6	96.1	286.9	712.1	450	63.8%	0.39
	2	8x8x ¹ / ₂	248	13.5	0.727	834.8	185.3	220.8	558.9	315	70.1%	0.78
	3	8x8x ¹ / ₂	256	9.74	0.703	545.5	135.6	96.4	403.2	161	59.9%	1.02
8	1	10x10x ¹ / ₂	208	17.2	0.581	816.2	94.3	351.8	712.1	557	63.2%	0.50
	2	10x10x ¹ / ₂	208	17.2	0.581	816.2	181.8	270.7	712.1	557	48.6%	0.89
	3	10x10x ¹ / ₂	216	17.2	0.555	709.4	132.9	119.8	712.1	557	21.5%	1.07
9												
10												

$(AE \cos^2 \theta) / L$

$0.9F_y A_g$

LRFD Table
4-6

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Depth Topic I • Lateral Force Resisting System

New Streamlined System

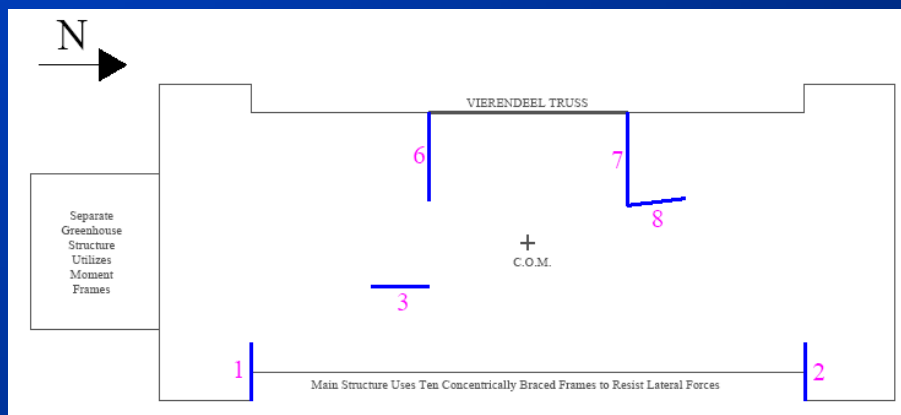
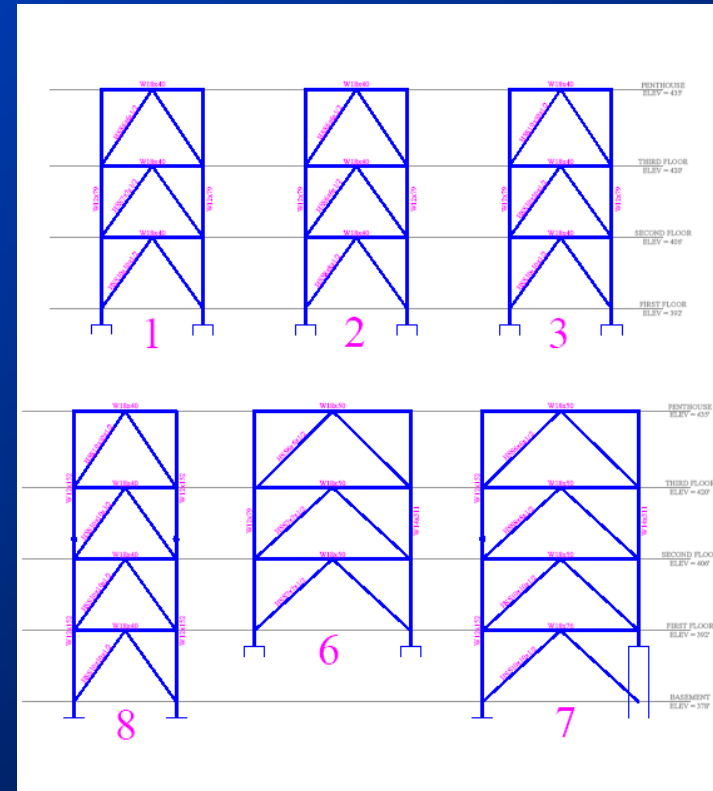
6 Steel Braced Frames

Streamlined System Evaluation

System Strength Capacity

Total Drift Limit: $L/400$

Raw Material Quantities & Cost





Breadth Topic • CM Evaluation

Lateral Force Resisting Systems

Raw Materials

Steel Savings			
Frame	HSS Brace Size	Total Length (ft)	
3	10x10x ¹ / ₂	(104.9)	
	7x7x ¹ / ₂	34.4	
	6x6x ¹ / ₂	70.5	
4	8x8x ¹ / ₂	68.8	
	7x7x ¹ / ₂	34.4	
	6x6x ¹ / ₂	36.1	
5	8x8x ¹ / ₂	68.8	
	6x6x ¹ / ₂	70.5	
7	10x10x ¹ / ₂	(7.4)	
	8x8x ¹ / ₂	(41.3)	
	7x7x ¹ / ₂	82.6	
	6x6x ¹ / ₂	(42.7)	
8	10x10x ¹ / ₂	(104.9)	
	8x8x ¹ / ₂	34.4	
	7x7x ¹ / ₂	34.4	
	6x6x ¹ / ₂	36.1	
9	7x7x ¹ / ₂	34.4	
	6x6x ¹ / ₂	104.9	
10	7x7x ¹ / ₂	34.4	
	6x6x ¹ / ₂	104.9	
Total		lb/ft	Weight (lb)
	10x10x ¹ / ₂	(217.2)	(13530.9)
	8x8x ¹ / ₂	130.8	6368.3
	7x7x ¹ / ₂	220.2	9226.3
	6x6x ¹ / ₂	380.1	13342.3
Weight Savings (tons of steel)			7.70

Construction Cost

Steel Cost Savings						
	2006 Bare Costs				Quantity	Total Savings
	Materials	Labor	Equipment	Total		
05120 STRUCTURAL STEEL	Per Ton					
Structural Tubing (HSS)	2100.0	43.5	28.5	2172.0	8	16731
WELDED CONNECTIONS	Per Pound					
E70XX 1/4" fillet welds				38.5	43.1	1661
TOTAL w/ regional adjustment factor (Lancaster, PA - 0.929)						\$18,000

Note: Overhead & Profit Not Included

Structural Steel Savings: 7.7 tons

Weld Material Savings: 43.1 lbs

Cost Savings: \$18,000



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Depth Topic II • Foundations

Existing System - Shallow Spread Footings

Frame	Dimensions			Bottom Steel		Top Steel		
	Width	Length	Depth	Short Bars	Long Bars	Short Bars	Long Bars	
1	17	38	4	(38) #9	(18) #9	(38) #9	(18) #9	COMBINED FTG
2	17	38	4	(38) #9	(18) #9	(38) #9	(18) #9	COMBINED FTG
3	14	14	3	(13) #8	(13) #8	(13) #8	(13) #8	
4	18	38	3	(38) #9	(18) #9	(38) #9	(18) #9	COMBINED FTG
5	18	38	3	(38) #9	(18) #9	(38) #9	(18) #9	COMBINED FTG
6	18	16	3	(14) #9	(14) #9	(14) #9	(14) #9	
7	18	16	3	(14) #9	(14) #9	(14) #9	(14) #9	
8	18	38	3	(38) #9	(18) #9	(38) #9	(18) #9	COMBINED FTG
9	14	14	3	(13) #8	(13) #8	(13) #8	(13) #8	
10	18	38	3	(38) #9	(18) #9	(38) #9	(18) #9	COMBINED FTG

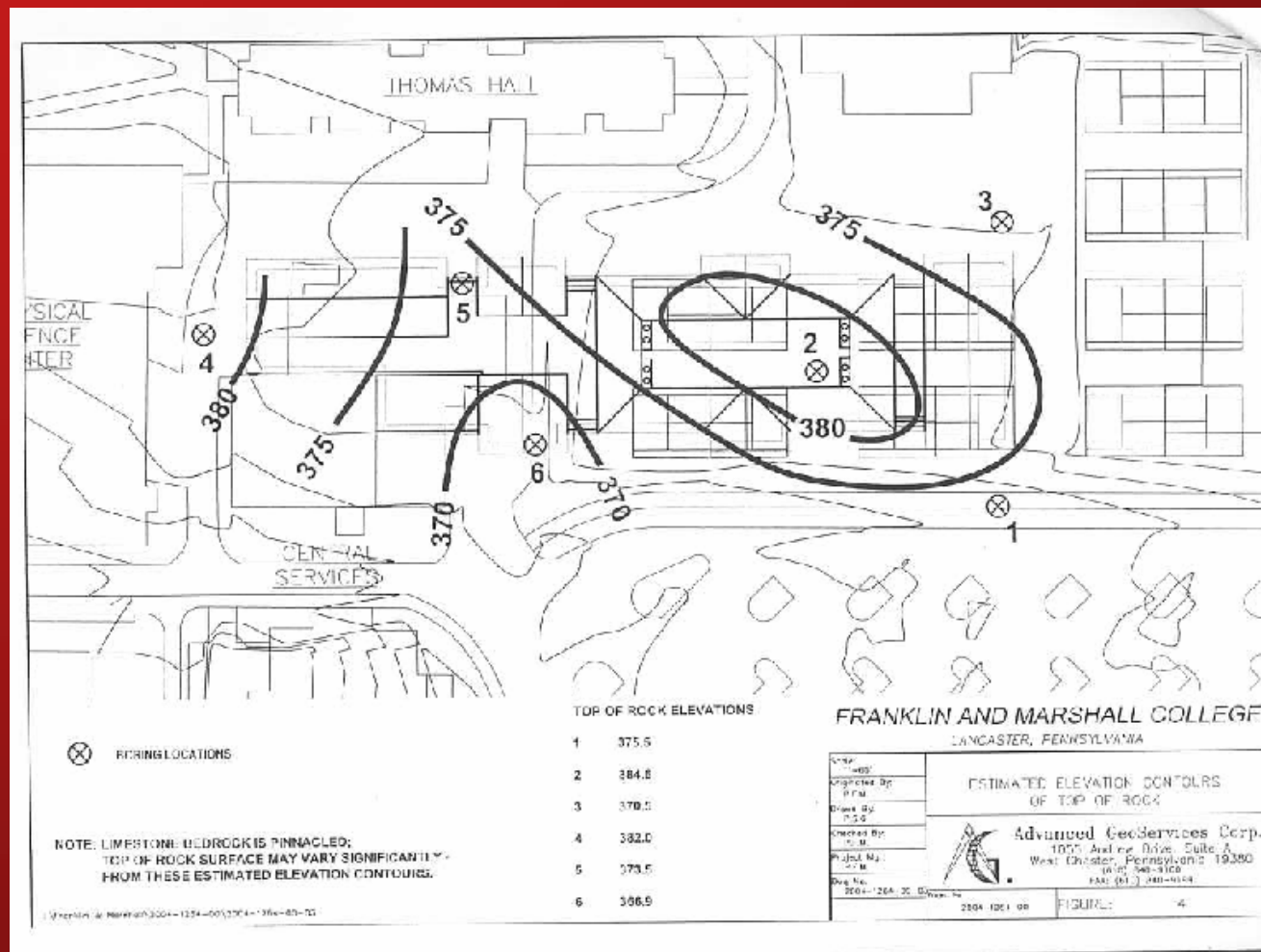


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Depth Topic II • Foundations

Subsurface Conditions



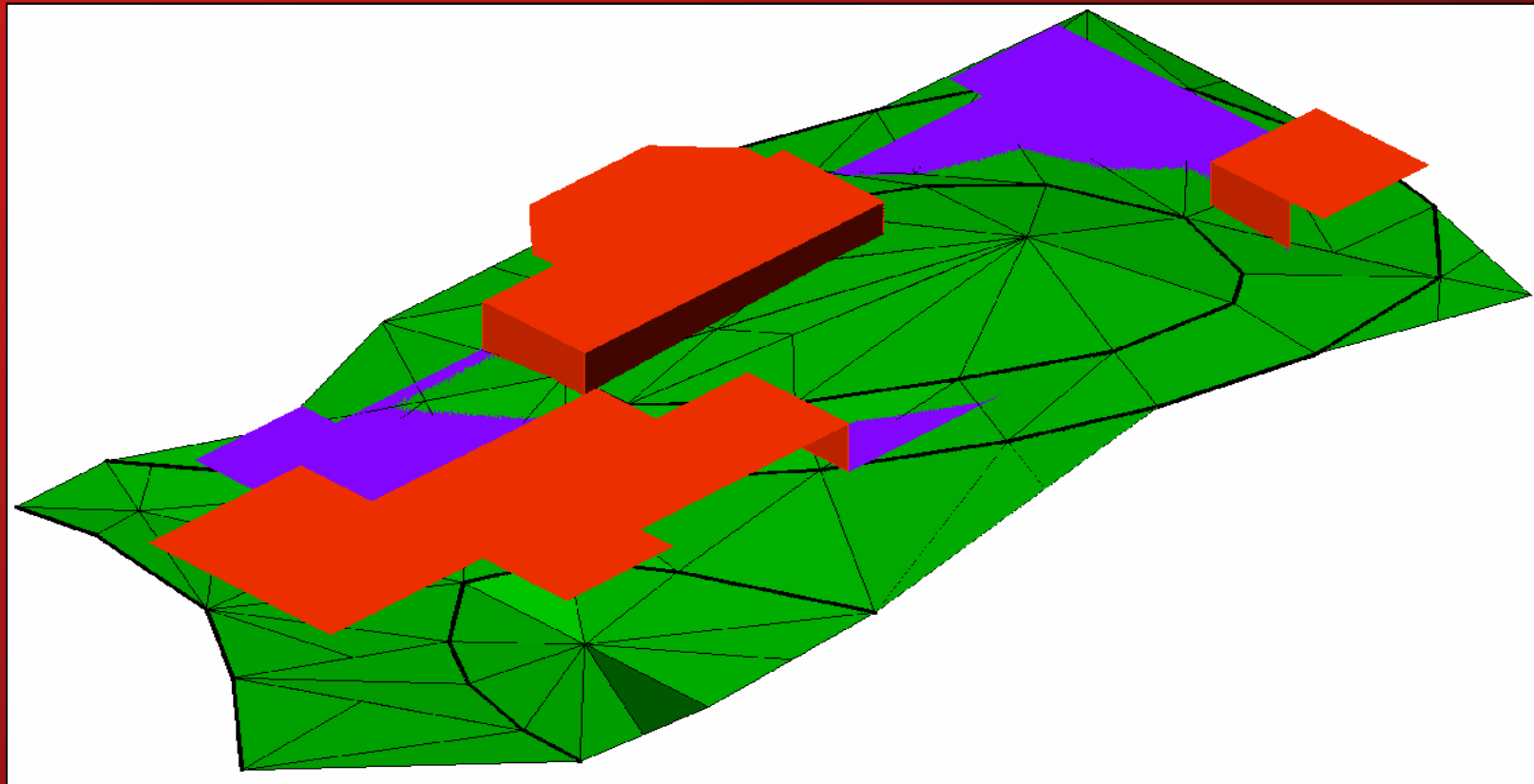


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Subsurface Conditions





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Depth Topic II • Foundations

New System - Drilled Concrete Piers

Design Procedure: Principles of Foundation Engineering, 5th Ed.

New System Evaluation: Cost & Raw Material Quantities

Material Constants										
Rock Quality Designation, RQD		55	%							
Unconfined Compression Strength (rock), $q_{u \text{ rock}}$		4.6	ksi							
Unconfined Compression Strength (concrete), $q_{u \text{ conc}}$		3	ksi							
Young's Modulus (rock core), E_{core}		1600	ksi							
Young's Modulus (rock mass), E_{mass}		280.0	ksi							
Young's Modulus (concrete), E_c		3000	ksi							
E_c/E_{mass}		10.71								
Ultimate Unit Side Resistance, f		136.931	psi							
Factor of Safety, FS		3								

Braced Frame Foundation Requirements										
Frame	Max. Applied Column Load (kips)	Shaft Depth Into Rock, L (ft)	Diameter of Shaft, D_s (ft)	Shaft Area, A_s (in ²)	Min. Vertical Reinforcing, $0.01A_s$ (ft ²)	Embedment Ratio, L/D_s	Settlement Influence Factor, I_f	Ultimate Capacity (Side Resistance Only), Q_u (kips)	Shaft Settlement, s_e (in)	Allowable Capacity, Q_{av} (kips)
1	518.3	10	3	1018	0.07	3.3	0.45	1858.4	2/16	619
2	504.2	10	3	1018	0.07	3.3	0.45	1858.4	2/16	619
3	1061.1	15	4	1810	0.13	3.8	0.43	3716.8	4/16	1239
4	487.2	10	3	1018	0.07	3.3	0.45	1858.4	2/16	619
5	487.2	10	3	1018	0.07	3.3	0.45	1858.4	2/16	619
6	1004.6	15	4	1810	0.13	3.8	0.43	3716.8	4/16	1239
7	1137.3	15	4	1810	0.13	3.8	0.43	3716.8	4/16	1239
8	1065.0	15	4	1810	0.13	3.8	0.43	3716.8	4/16	1239
9	429.0	10	3	1018	0.07	3.3	0.45	1858.4	2/16	619
10	429.0	10	3	1018	0.07	3.3	0.45	1858.4	2/16	619
OTHER	250.0	5	3	1018	0.07	1.7	0.5	929.2	1/16	310

Foundation Loads: $1.2D + 1.0E + 0.5L + 0.2S$



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Breadth Topic • CM Evaluation

Foundation Systems

Raw Material Quantities

Existing System

note: frame 7 & 8 share a column

Frame	Dimensions			Total Concrete Volume (yd ³)	Steel Reinforcing (ft ³)
	Width	Length	Depth		
1	17	38	4	95.7	17.95
2	17	38	4	95.7	17.95
3	14	14	3	21.8	3.88
4	16	38	3	67.6	16.41
5	16	38	3	67.6	16.41
6	16	16	3	28.4	6.05
7	16	16	3	28.4	6.05
8	16	38	3	67.6	16.41
9	14	14	3	21.8	3.88
10	16	38	3	67.6	16.41
OTHER	50 Ftgs. of Varying Size			277.9	67.52
			TOTALS	839.9	188.9
			+ 25%	1049.9	236.1

New System

note: 2 piers per frame (except 7 & 8 b/c they share a column)

Frame	Approx. Shaft Length Above Rock (ft)	Shaft Depth Into Rock, L (ft)	Diameter of Shaft, D _s (ft)	Total Concrete Volume (yd ³)	Minimum Reinforcing (cu. ft.)
1	25	10	3	18.3	4.95
2	15	10	3	13.1	3.53
3	15	15	4	27.9	7.54
4	10	10	3	10.5	2.83
5	15	10	3	13.1	3.53
6	10	15	4	23.3	6.28
7	10	15	4	23.3	6.28
8	10	15	4	23.3	6.28
9	20	10	3	15.7	4.24
10	20	10	3	15.7	4.24
OTHER	15	5	3	261.8	70.69
TOTALS				434.3	120.40
+ 50%				651.4	180.60

Concrete Savings: 400 yd³

Steel Rebar Savings: 55.5 ft³



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Breadth Topic • CM Evaluation

Foundation Systems

Construction Costs – R.S. Means 2006

Existing System

A1010 210 SPREAD FOOTING ASSEMBLY - includes excavation, backfill, forms, all reinforcement, 3000 psi concrete (chute placed), and screed finished					
	2006 Bare Costs			Quantity	Total Costs 2006
	Materials	Installation	Total		
Bulk Excavation	Per Cubic Yard				
		4.24	4.24	1469.9	6232
Hand Trim	Per Square Foot				
		6.57	6.57	9352.0	61443
Compacted Backfill	Per Cubic Yard				
		0.79	0.79	630.0	498
Formwork (4 uses)	Per Square Foot Perimeter				
	7.80	48.36	56.16	713.0	40042
Reinforcing, $f_y = 60$ ksi	Per Ton				
	5.37	5.94	11.31	21.0	238
Anchor Bolt Templates	Per Linear Feet				
	5.52	20.04	25.56	1584.0	40487
Concrete $f_c = 3000$ psi	Per Cubic Yard				
	31.52		31.52	839.9	26475
Place Concrete, chute	Per Cubic Yard				
		6	6	839.9	5040
Screed Finish	Per Square Foot				
		4.05	4.05	9352.0	37876
	TOTAL				175414
	TOTAL w/ regional adjustment factor (Lancaster, PA - 0.929)				\$163,000

Note: Overhead & Profit Not Included

New System

02465 DRILLED CAISSONS - includes excavation, concrete, 50 lbs. reinforcing steel per C.Y.						
	2006 Bare Costs				Quantity	Total Costs 2006
	Materials	Labor	Equipment	Total		
Caisson into Stable Soil	Per Vertical Linear Foot					
36"	28.50	11.65	27	67.15	960.0	64464
48"	50.50	14.55	34	99.05	80.0	7924
Caisson into Rock	Per Vertical Linear Foot					
36"	28.50	191	286	505.50	370.0	187035
48"	50.50	286	430	766.50	105.0	80483
Mobilization (50 miles)	Per Drilling Rig					
36"		730	1700	2430	2	4860
48"		995	2075	3070	1	3070
Excess Material Disposal	Per Cubic Yard					
2 miles		1.27	2.68	3.95	434.3	1715
	TOTAL					349551
	TOTAL w/ regional adjustment factor (Lancaster, PA - 0.929)					\$325,000

Note: Overhead & Profit Not Included

Additional Cost: \$162,000

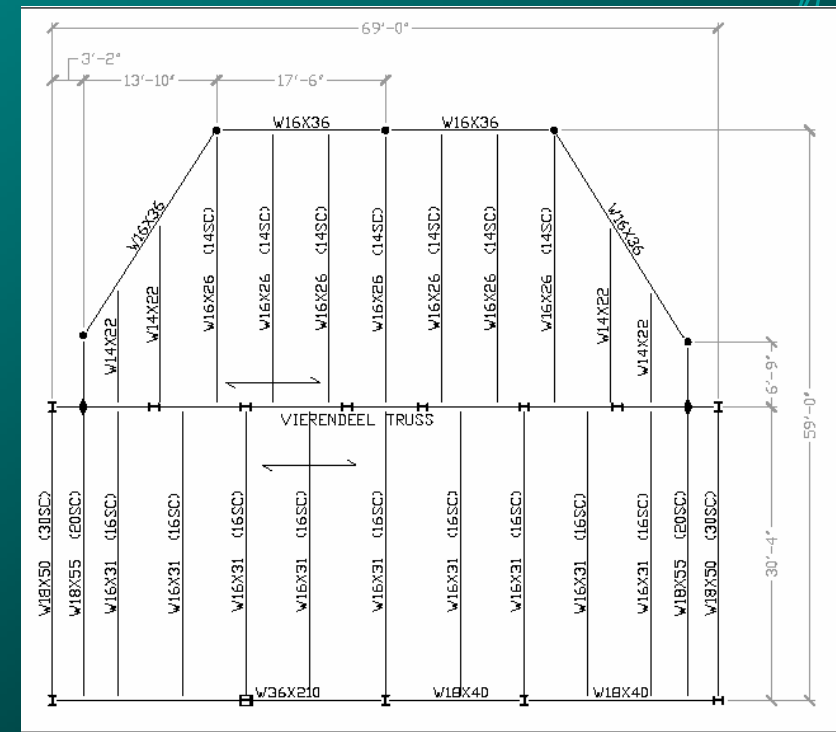
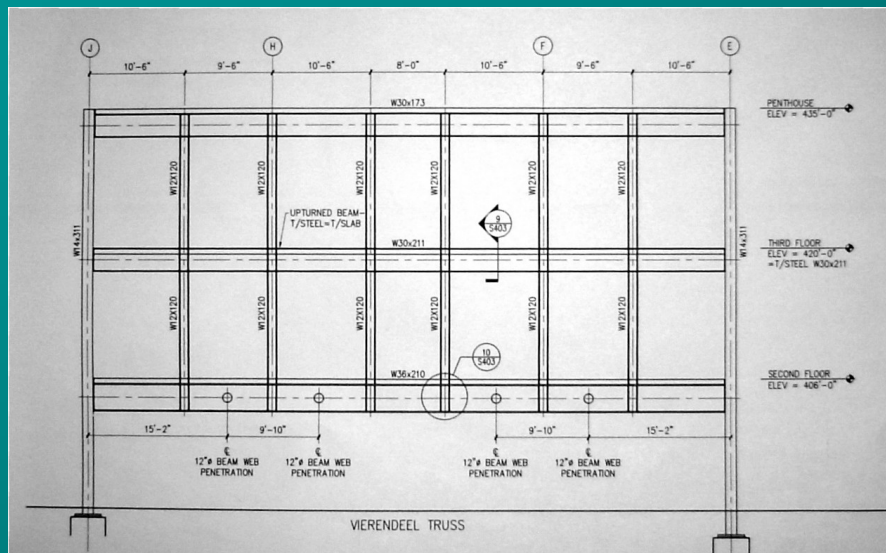


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Depth Topic III • Long Span Options

Existing System – Vierendeel Truss





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Depth Topic III • Long Span Options

New System – Long Span Steel Joists

System Design

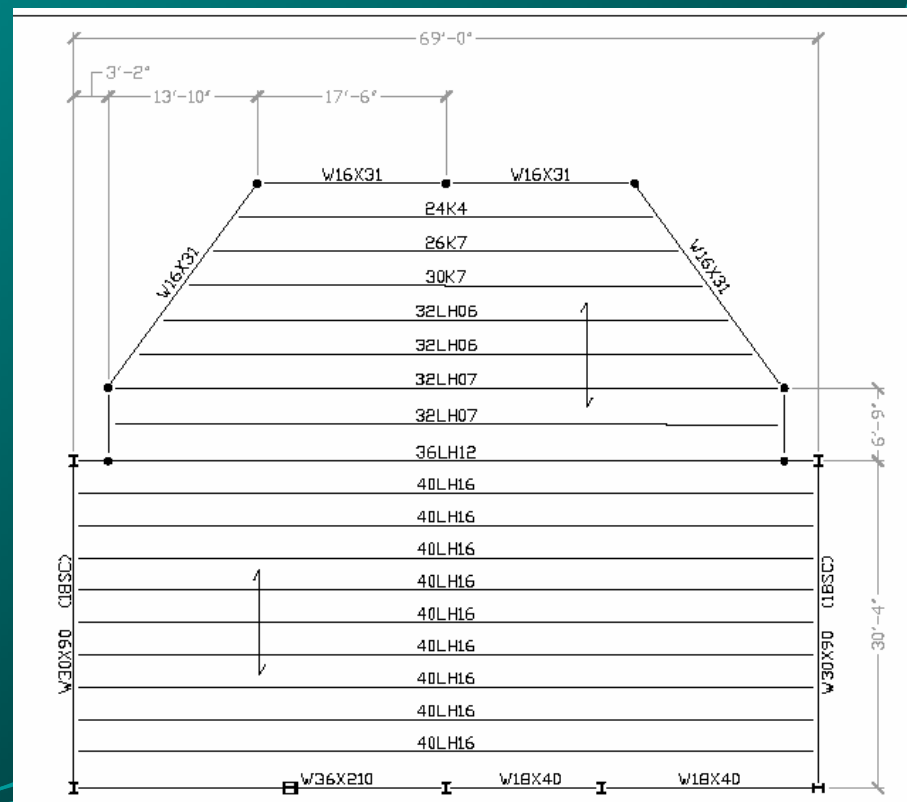
RAM Structural System

New Columbia Joist Catalog

New System Evaluation

Architectural Impact

Mechanical Impact – HVAC Ducts



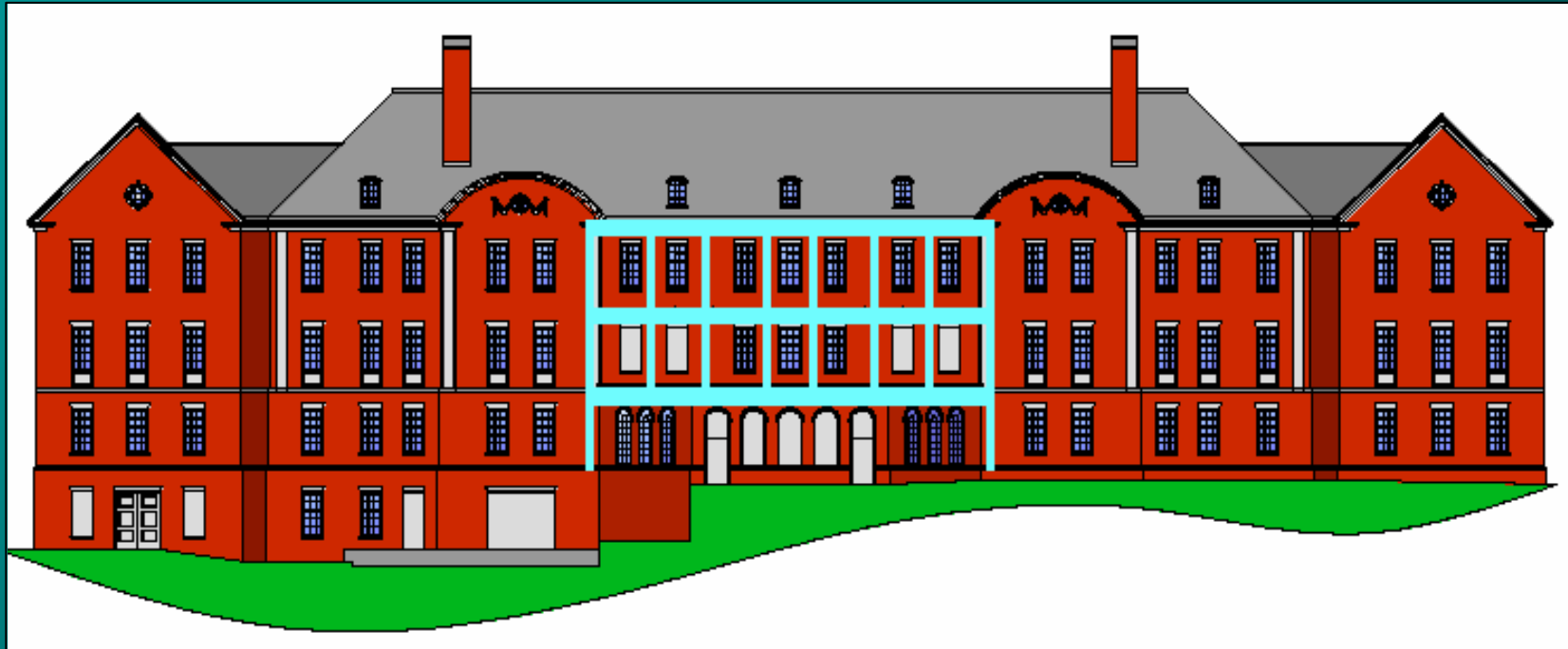


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Vierendeel Truss System



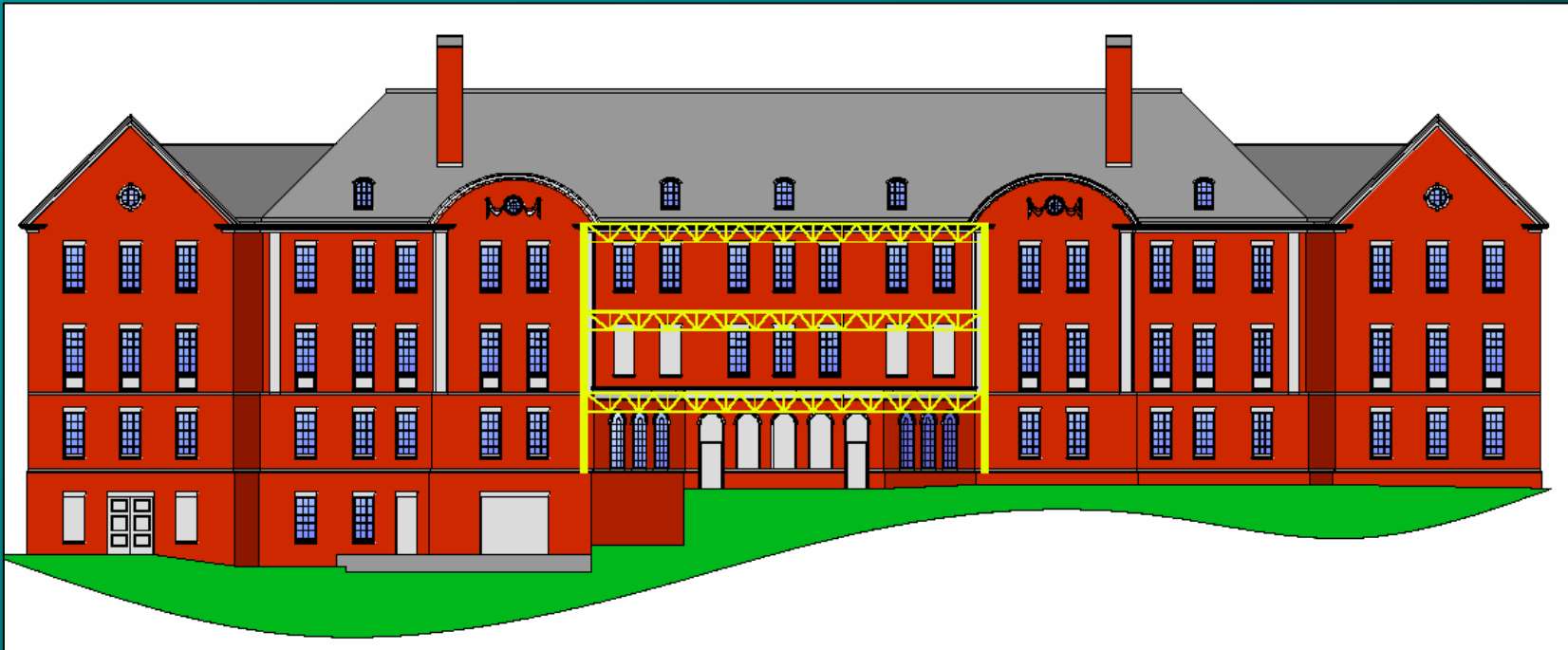


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Long Span Steel Joists



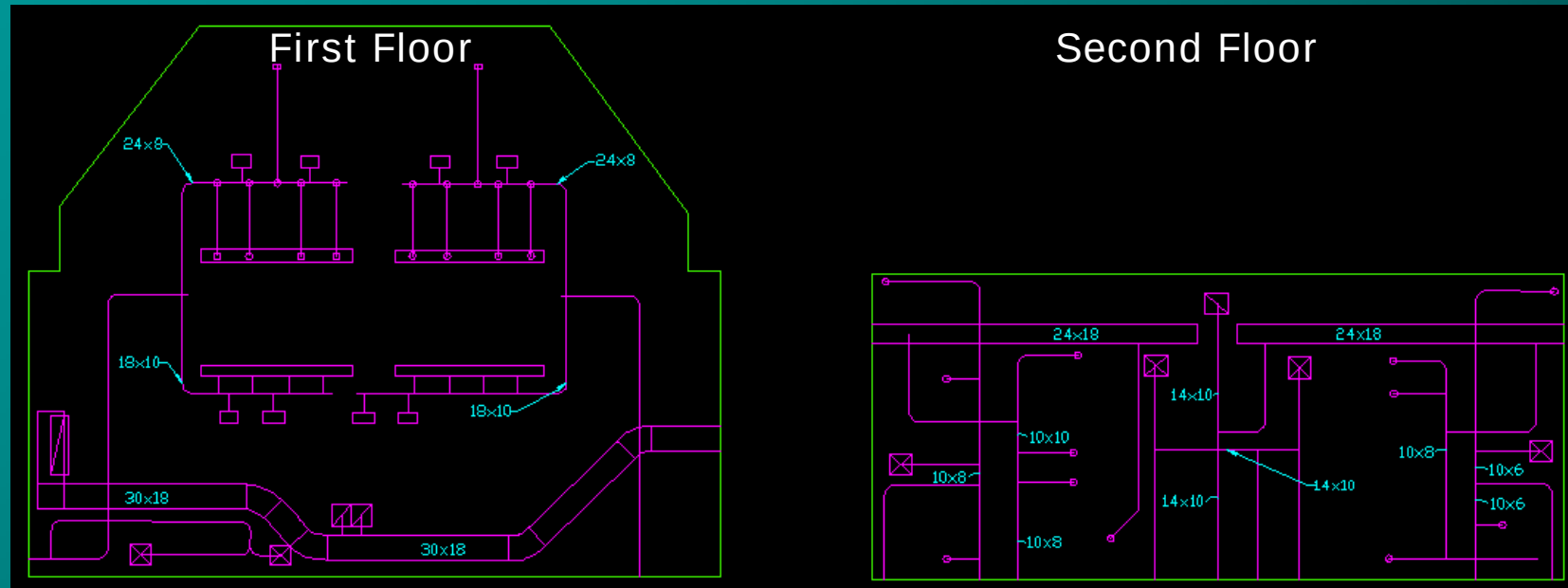


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Partial HVAC Ductwork Plans



HVAC Duct Sizes

Duct Size		Aspect Ratio w/d	Hydraulic Diameter, D_h	F
Depth	Width			
18	32	1.78	23.0	1406.3
10	70	7.00	17.5	1409.8
18	24	1.33	20.6	1207.1
10	44	4.40	16.3	1207.5



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Conclusions & Recommendations

The lateral force resisting system can be safely reduced from 10 frames to 6 frames for an estimated savings of \$18,000.

A drilled pier foundation system is not a cost efficient replacement for the spread footing system.

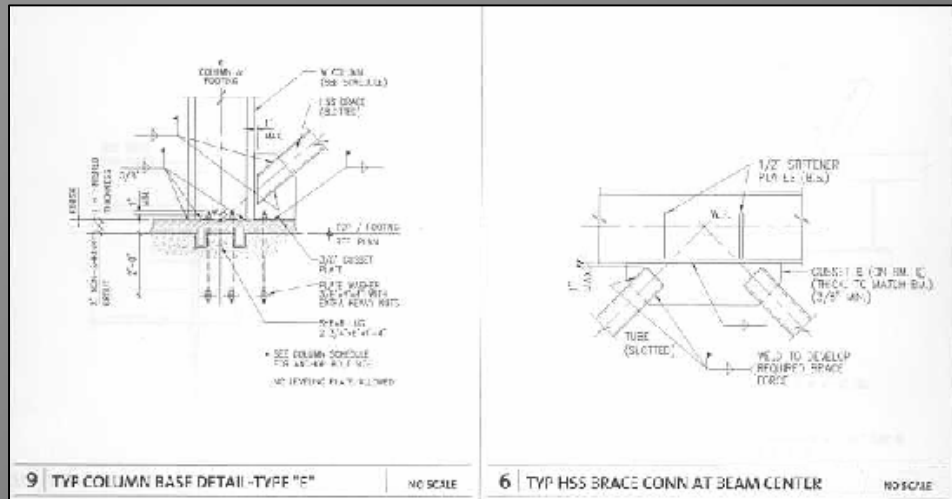
The Vierendeel truss is extremely effective and efficient for carrying significant loads over a large span.

Questions???



Thank You

Welded Brace Connections



Existing System

Weld Size	4/16	*Assumes >= 1/2" Thick Connector Plates		Brace End Req'd Weld Area (in ²)	Beam Bottom Req'd Weld Area (in ²)	Column Req'd Weld Area (in ²)
Frame	(theta)	Story Shear (k)	Brace Axial Force (k)			
1	0.951	22.3	83.4	20.0	10.0	20.0
	0.951	43.1	84.2	20.0	10.0	20.0
	0.983	31.5	28.4	20.0	10.0	20.0
2	0.951	20.9	78.2	20.0	10.0	20.0
	0.951	40.4	80.2	20.0	10.0	20.0
	0.983	29.5	26.6	20.0	10.0	20.0
3	0.951	62.5	233.1	20.0	10.0	20.0
	0.951	120.4	179.4	20.0	10.0	20.0
	0.983	89.1	79.4	20.0	10.0	20.0
4	0.951	48.2	179.8	20.0	10.0	20.0
	0.951	92.9	138.4	20.0	10.0	20.0
	0.983	67.9	61.2	20.0	10.0	20.0
5	0.951	47.5	177.1	20.0	10.0	20.0
	0.951	91.6	136.3	20.0	10.0	20.0
	0.983	69.9	60.3	20.0	10.0	20.0
6	0.757	51.1	152.6	20.0	10.0	20.0
	0.757	98.6	117.4	20.0	10.0	20.0
	0.791	72.1	51.3	20.0	10.0	20.0
7	0.757	78.6	228.8	20.0	10.0	20.0
	0.757	147.8	176.0	20.0	10.0	20.0
	1.112	108.1	243.8	20.0	10.0	20.0
8	0.951	48.2	179.8	20.0	10.0	20.0
	0.951	92.9	138.4	20.0	10.0	20.0
	0.983	67.9	61.2	20.0	10.0	20.0
9	0.951	24.5	91.5	20.0	10.0	20.0
	0.951	47.3	70.4	20.0	10.0	20.0
	0.983	34.6	31.2	20.0	10.0	20.0
10	0.951	10.7	40.1	20.0	10.0	20.0
	0.951	20.7	30.8	20.0	10.0	20.0
	0.983	15.1	13.7	20.0	10.0	20.0
# of Connections Per Story				4	1	2
TOTAL WELD AREA (in ²)				3900.0		
TOTAL WELD VOLUME (in ³)				1950.0		
TOTAL WELD MATERIAL (lbs)				107.8		

New System

Weld Size	4/16	*Assumes > 1/2" Thick Connector Plates		Brace End Req'd Weld Area (in ²)	Beam Bottom Req'd Weld Area (in ²)	Column Req'd Weld Area (in ²)
Frame	(theta)	Story Shear (k)	Brace Axial Force (k)			
1	0.951	30.5	114.0	20.0	10.0	20.0
	0.951	58.9	87.7	20.0	10.0	20.0
	0.983	43.1	38.8	20.0	10.0	20.0
2	0.951	28.3	105.8	20.0	10.0	20.0
	0.951	54.7	81.4	20.0	10.0	20.0
	0.983	40.0	38.0	20.0	10.0	20.0
3	0.951	112.0	418.1	20.0	10.0	20.0
	0.951	216.0	321.7	20.0	10.0	20.0
	0.983	158.0	142.4	20.0	10.0	20.0
6	0.757	64.8	193.5	20.0	10.0	20.0
	0.757	125.0	148.9	20.0	10.0	20.0
	0.791	91.4	65.0	20.0	10.0	20.0
7	0.757	96.1	289.9	20.0	10.0	20.0
	0.757	185.3	220.8	20.0	10.0	20.0
	0.791	135.6	96.4	20.0	10.0	20.0
8	0.951	94.3	351.8	20.0	10.0	20.0
	0.951	181.8	270.7	20.0	10.0	20.0
	0.983	132.9	119.8	20.0	10.0	20.0
# of Connections Per Story				4	1	2
TOTAL WELD AREA (in ²)				2340.0		
TOTAL WELD VOLUME (in ³)				1170.0		
TOTAL WELD MATERIAL (lbs)				64.7		