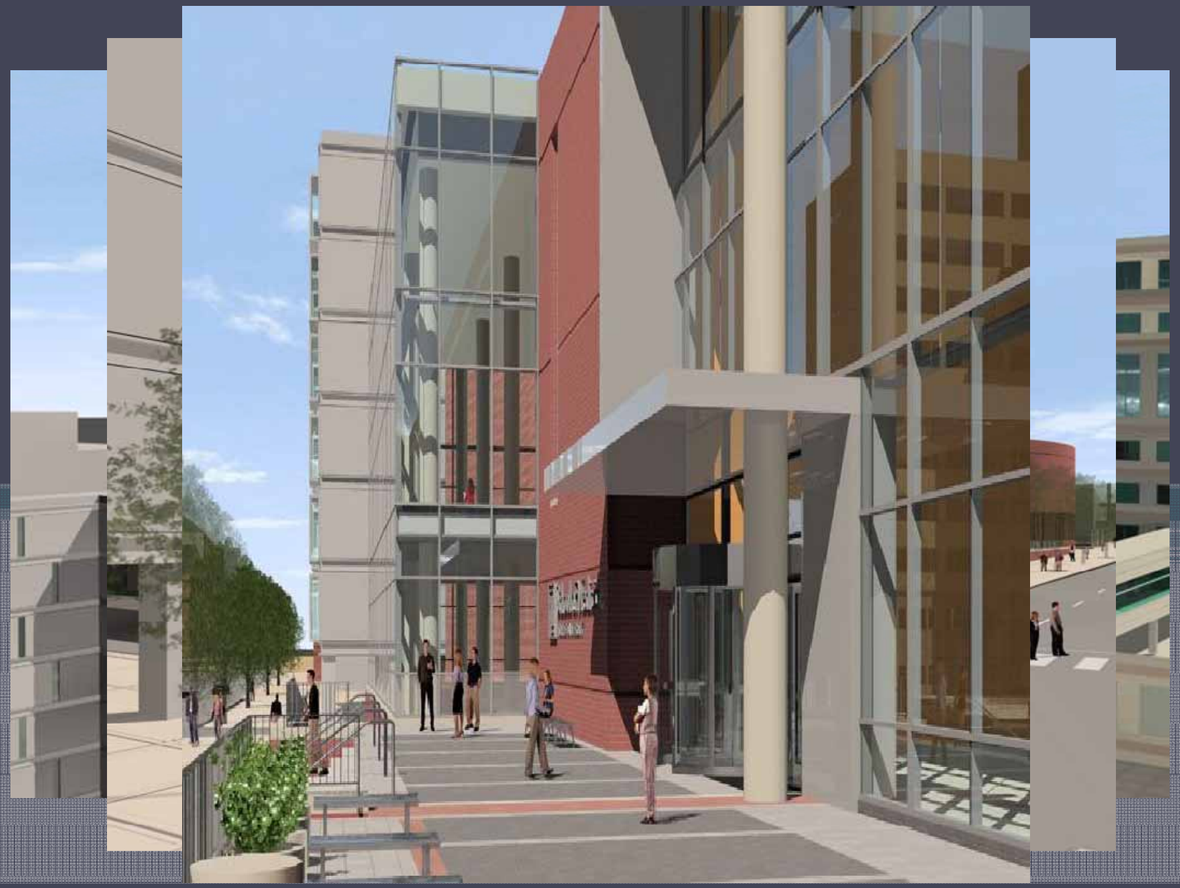
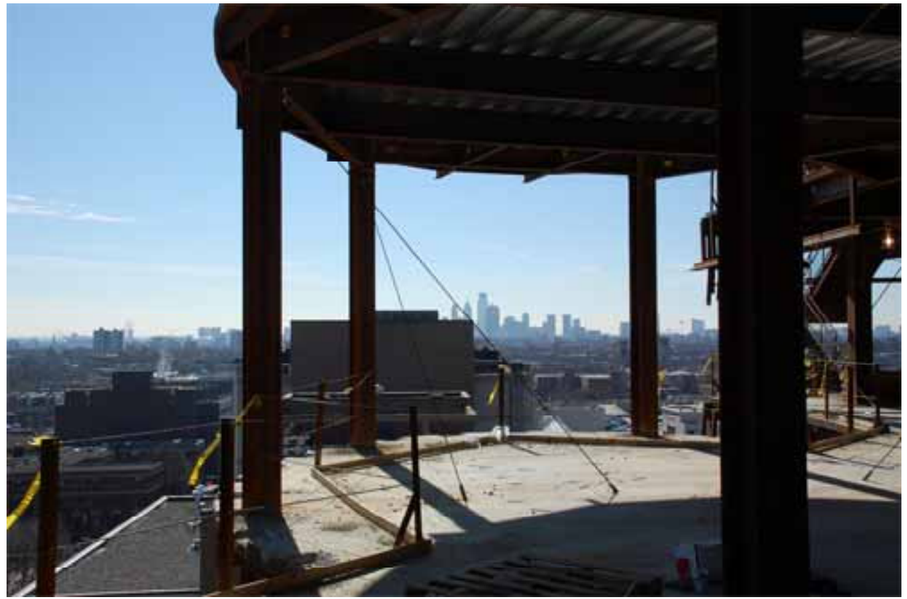


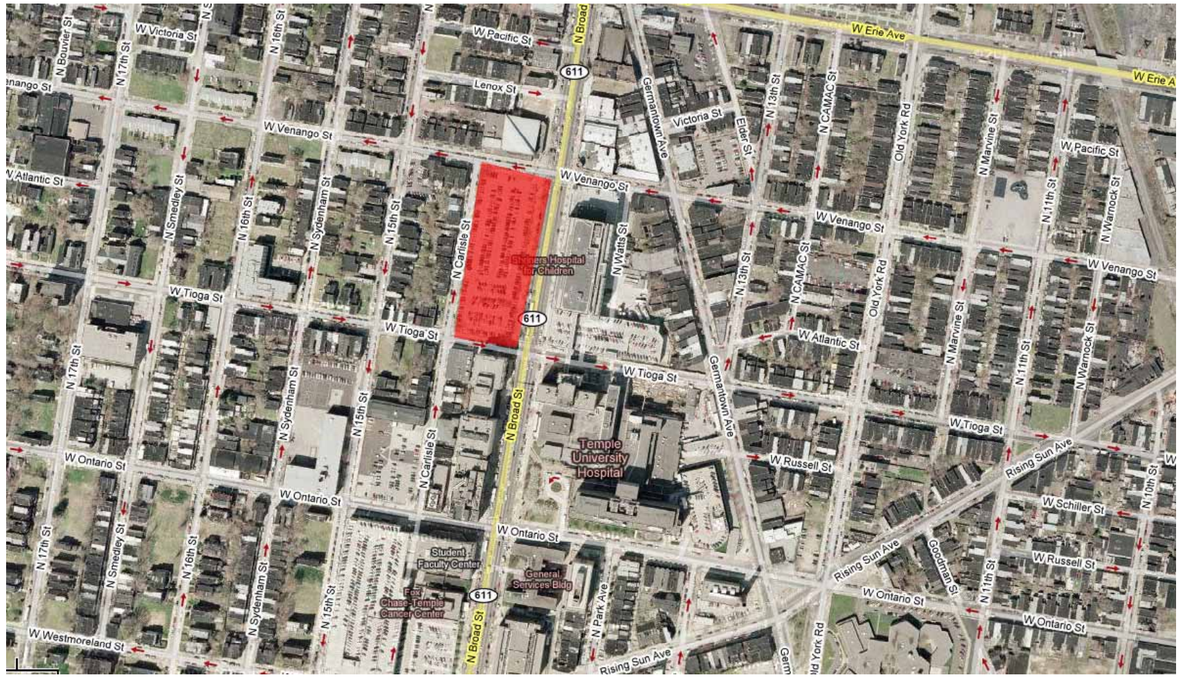
Michael Wiegmann

BAE
Structural Option
Senior Thesis
April 15,2008

Temple University
Multipurpose Health Science Center

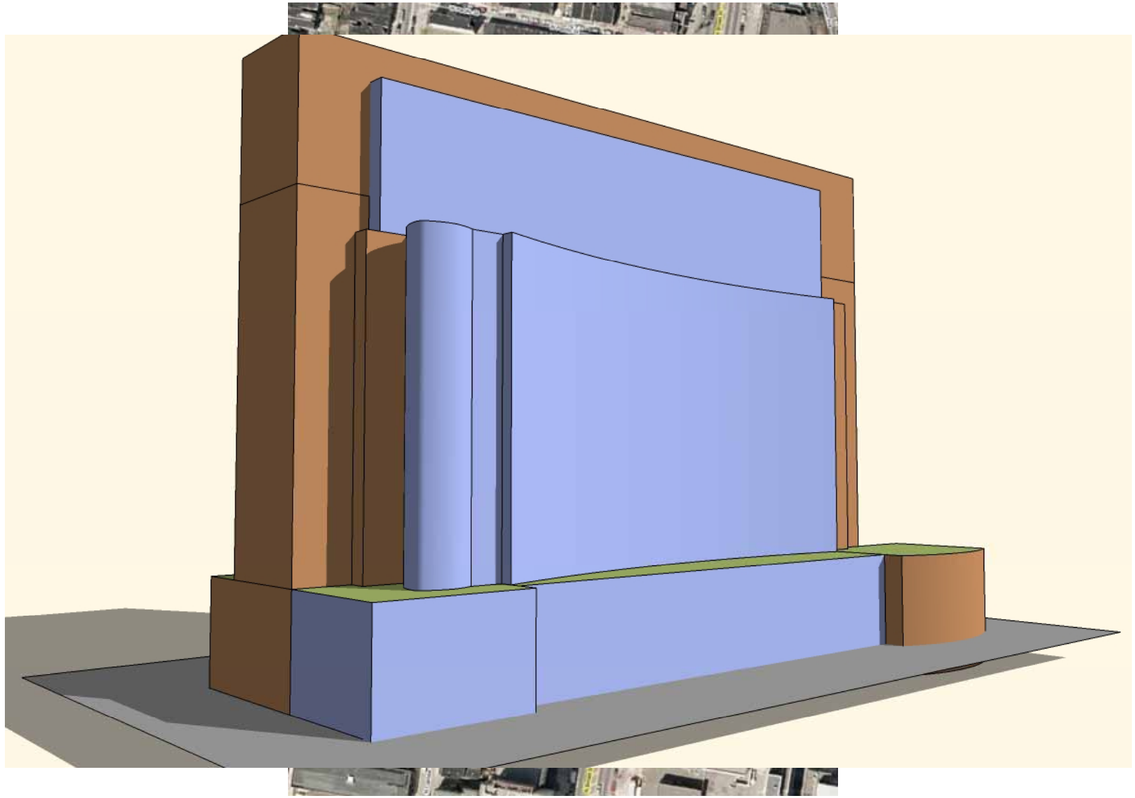


Contents



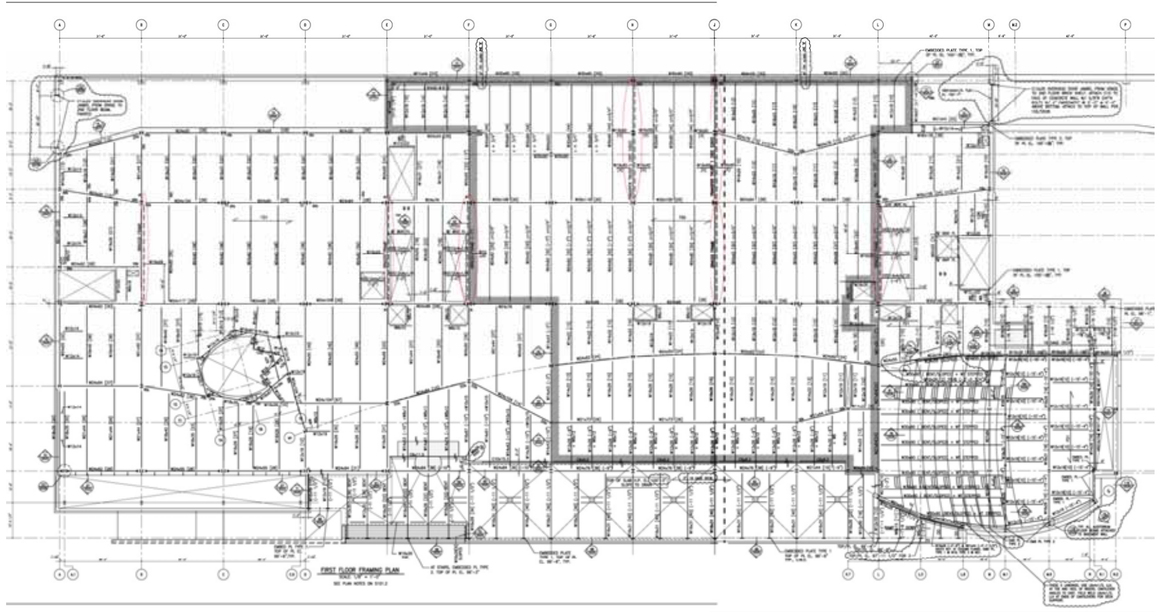
Introduction - Project Overview

- **Multipurpose Health Science Center (MHSC)**
  - Philadelphia, Pennsylvania
  - 480,000 SF, 13 stories
  - $150 million fast track
  - Medical research and education
- **Players**
  - Owner: Temple University
  - Archit., Struct., MEP: Ballinger, Inc.
  - GC & CM: Gilbane, Inc.

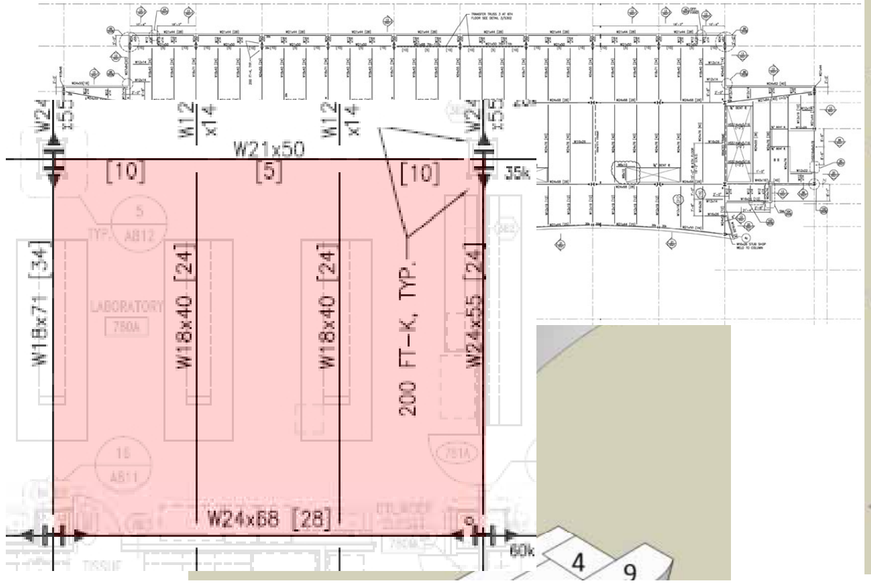


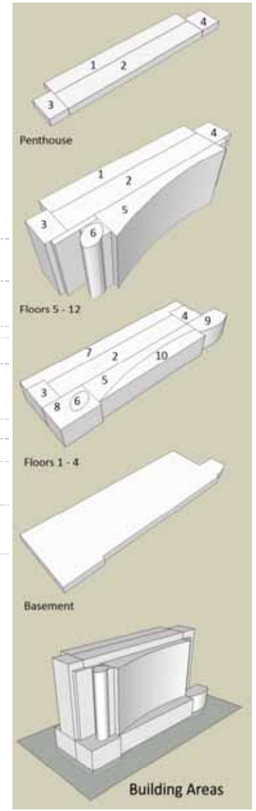
Design Scenario

- **Problem:**
  - Tight urban location
- **Solution:**
  - Vertical expansion
- **Criteria:**
  - Architectural Redesign (discussed later)
  - Structural Redesign
- **Goals:**
  - Meet design criteria (strength/serviceability/ capacity)
  - Maintain or exceed efficiency (weight ratio, SF use)
  - Minimal effect on architecture



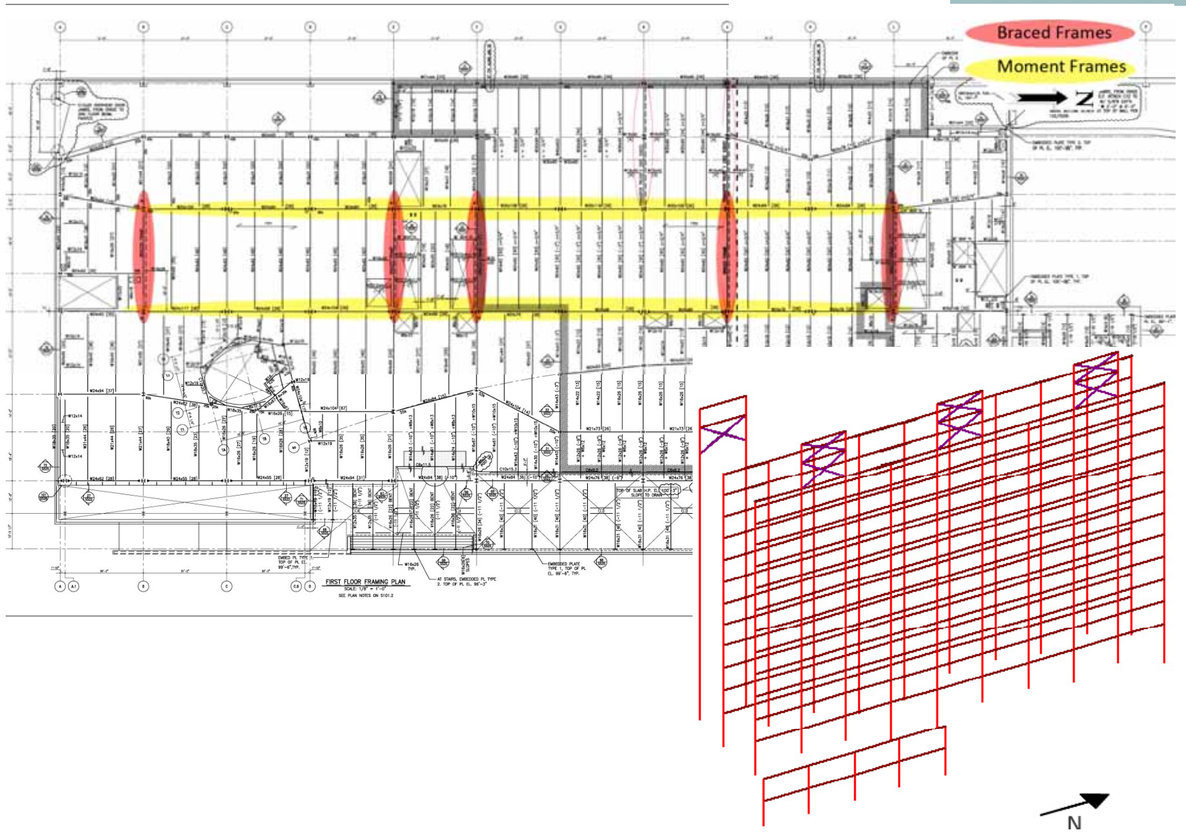
Existing Structure





Existing - Gravity System

- **Framing**
  - Steel framing
  - Braced frames and moment frames
- **Typical framing areas**
  - Typical bay 30'x30'
  - Addition: areas 1, 2, 3, 4
- **Decking**
  - 2.5", f'c=4,000 psi, NWC on 3"deep, 20 gage, galvanized composite steel deck, with 6x6-W2.9xW2.9 WWF
- **Beam & girder sizes**
  - w18x40 to w24x76
  - Vibration control



Existing - Lateral System

- **Braced Frames**
  - East-West
  - Resist:
    - 1525 kips wind (new: 2322 kips)
      - ASCE7-05 6.5 Analytical Procedure
    - 970 kips seismic (new: 960)
      - ASCE7-05 12.8.2 Equivalent Lateral Force Procedure
- **Moment Frames**
  - North-South
  - Resist:
    - 506 kips wind (new: 714kips)
    - 970 kips seismic (new: 960)

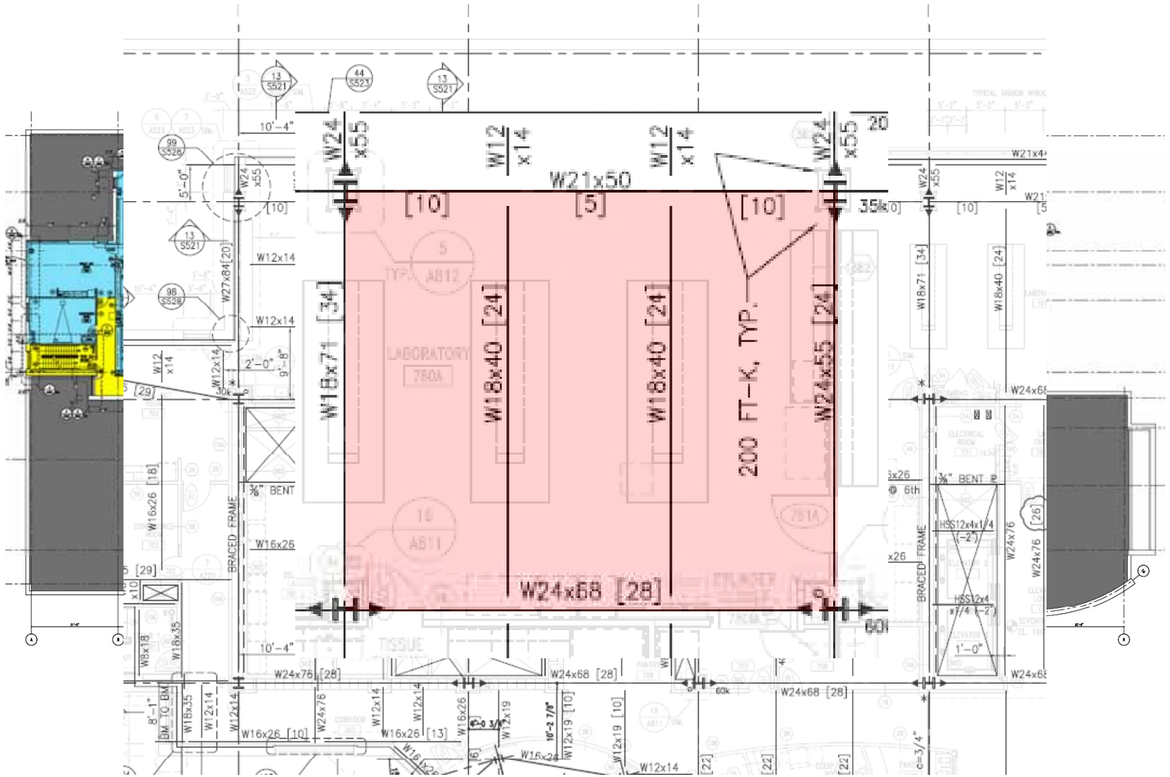
Existing – Foundations

- **40% footings**
- **60% caissons**
  - Up to Ø=8’
  - terminate at bedrock, present at 30’ to 50’ depths
- **Soil bearing capacity**
  - 60,000 psf
- **Soil**
  - 19’to 35’: medium to very compact micaceous silty fines
  - 24’ to 50’, more compact micaceous silty fines terminating at intact mica bedrock

Existing – Vibration Control

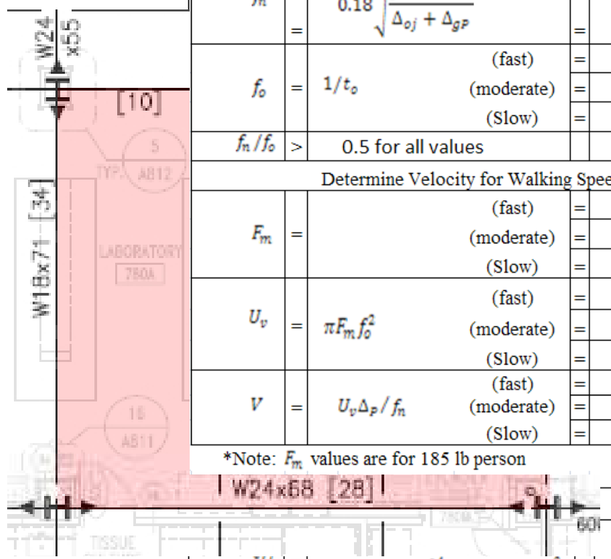
- **Previously mentioned sizes controlled by vibration design**

- **Architectural programming**
  - Labs, support areas, offices
- **Vibration control criteria:**
  - Steel Design Guide Series 11: Floor Vibration Due to Human Activity
  - Design for Sensitive Equipment



Existing – Vibration Control

- **Vibration analysis area:**
  - Typical tower level laboratory
- **Procedure:**
  - Determine floor properties
    - Movement due to walking
  - Compare with equipment velocity criteria



Expected Maxium Velocity due to Walking						
Determine f_n						
f_n	=	$0.18\sqrt{\frac{g = 386.4}{\Delta_{oj} + \Delta_{gP}}}$		=	33.01	Hz
f_o	=	$1/t_o$	(fast)	=	5.00	Hz
			(moderate)	=	2.50	Hz
			(Slow)	=	1.40	Hz
f_n/f_o	>	0.5 for all values				
Determine Velocity for Walking Speeds						
F_m	=		(fast)	=	315.00	lb
			(moderate)	=	280.00	lb
			(Slow)	=	240.00	lb
U_v	=	$\pi F_m f_o^2$	(fast)	=	24740.04	lb*Hz^2
			(moderate)	=	5497.79	lb*Hz^2
			(Slow)	=	1477.81	lb*Hz^2
V	=	$U_v \Delta_P / f_n$	(fast)	=	0.90	in/s
			(moderate)	=	0.20	in/s
			(Slow)	=	0.05	in/s
*Note: F_m values are for 185 lb person						
					6123.73	in^4
	=	$9.0 \times 10^{-9} \cdot \frac{L_j^4}{I_t} - 0.0059\left(\frac{L_j}{s}\right)^2$		=	9.85	
Mid Span Flexibility						
Δ_P	=	$\frac{\Delta_{oj}}{N_{eff}} + \frac{\Delta_{gP}}{2}$		=	0.001195	in

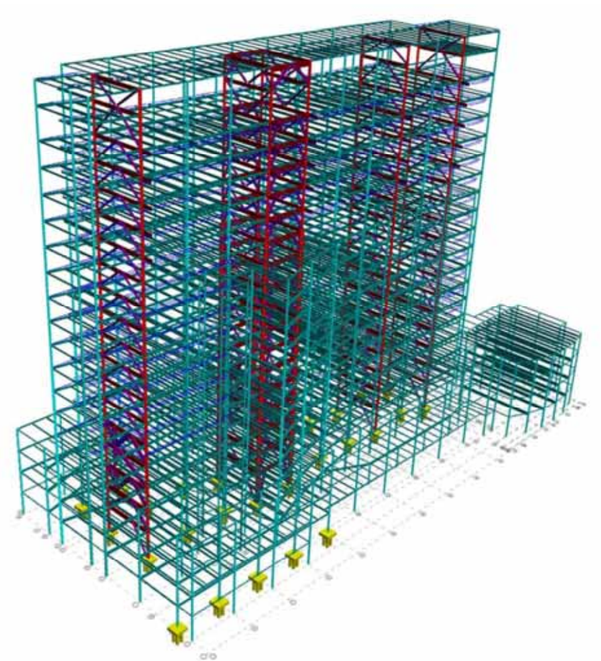
Existing - Vibration Control

- **Transformed member properties:**
  - Slab, joist, girder
- **Mid span flexibility**
  - Panel deflection = 0.001195 in
- **Expected maximum velocity**
  - Maximum force F_m from Table 6.2
  - Fast walking speed = 0.90 in/s
  - Moderate walking speed = 0.20 in/s
  - Slow walking speed = 0.05 in/s

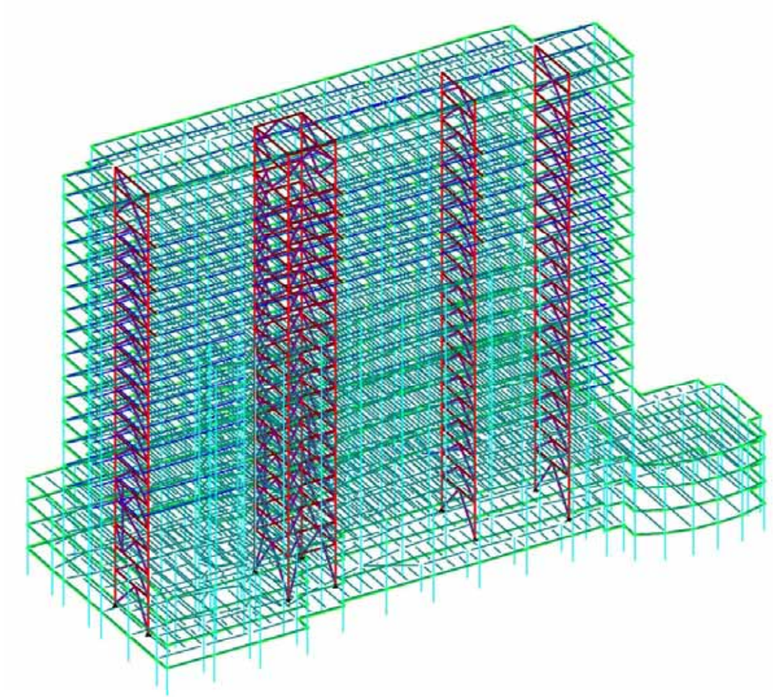
Comparison of Vibration Criteria for Sensitive Equipment							
Facility Equipment or Use	Vibrational Velocity Allowed (μin/s)	Walking Velocity (μin/s)					
		Slow		Moderate		Fast	
Computer systems; Operating Rooms**; Surgery; Bench microscopes at up to 100x magnification;	8000.00	53.51	OK	199.08	OK	895.86	OK
Laboratory robots	4000.00	53.51	OK	199.08	OK	895.86	OK
Bench microscopes at up to 400x magnification; Optical and other precision balances; Coordinate measuring machines; Metrology laboratories; Optical comparators; Microelectronics manufacturing equipment—Class A***	2000.00	53.51	OK	199.08	OK	895.86	OK
Micro surgery, eye surgery, neuro surgery; Bench microscopes at magnification greater than 400x; Optical equipment on isolation tables; Microelectronics manufacturing equipment—Class B***	1000.00	53.51	OK	199.08	OK	895.86	OK
Electron microscopes at up to 30,000x magnification; Microtomes; Magnetic resonance imagers; Microelectronics manufacturing equipment—Class C***	500.00	53.51	OK	199.08	OK	895.86	NOT OK
Electron microscopes at greater than 30,000x magnification; Mass spectrometers; Cell implant equipment; Microelectronids manufacturing equipment—Class D***	250.00	53.51	OK	199.08	OK	895.86	NOT OK
Microelectronics Manufacturing equipment—Class E***; Unisolated laser and optical research systems	130.00	53.51	OK	199.08	NOT OK	895.86	NOT OK

Existing – Vibration Control

- **Results**
  - Floor adequate for most conditions
    - Bench microscopes at magnification greater than 400x
  - If limited to moderate walking speeds:
    - MRI equipment, Mass spectrometers, Cell implant equipment

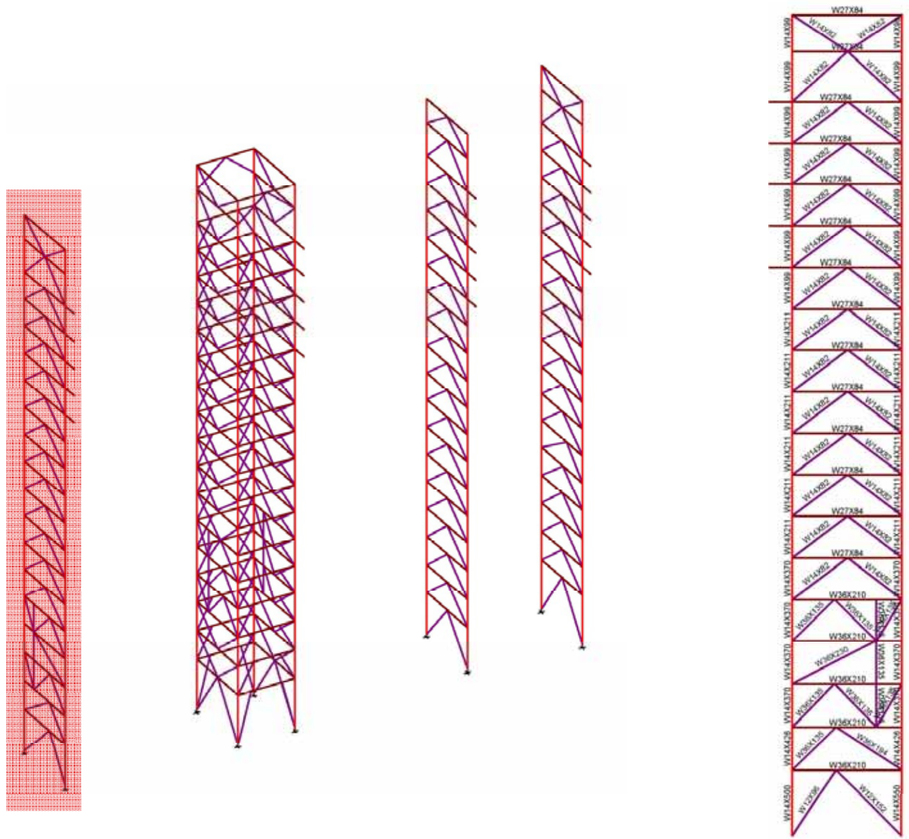


Structural Redesign



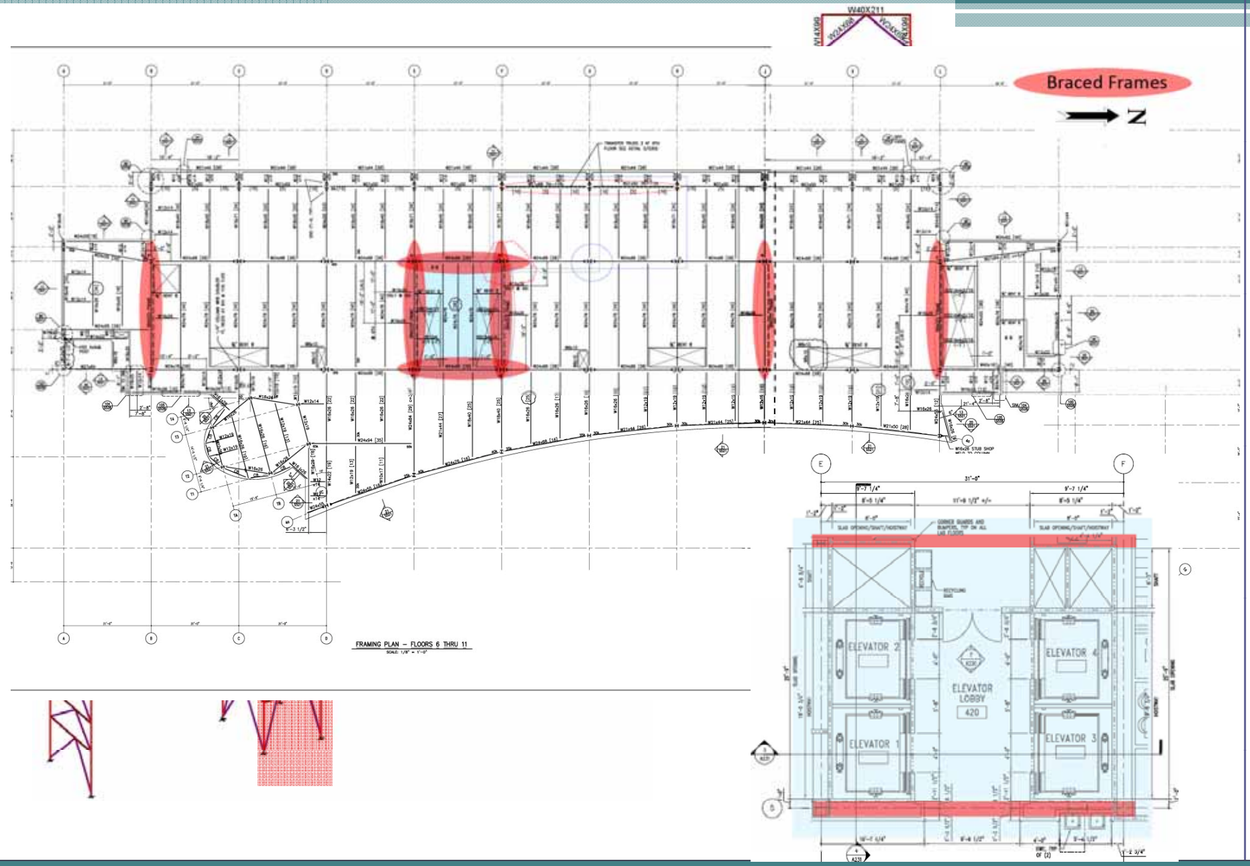
Structural Redesign – Goals

- **Focus on lateral system**
- **Meet design criteria (strength/serviceability)**
- **Maintain or exceed efficiency (weight ratio)**
  - Redesign North-South moment frames as braced
- **Minimal effect on architecture**



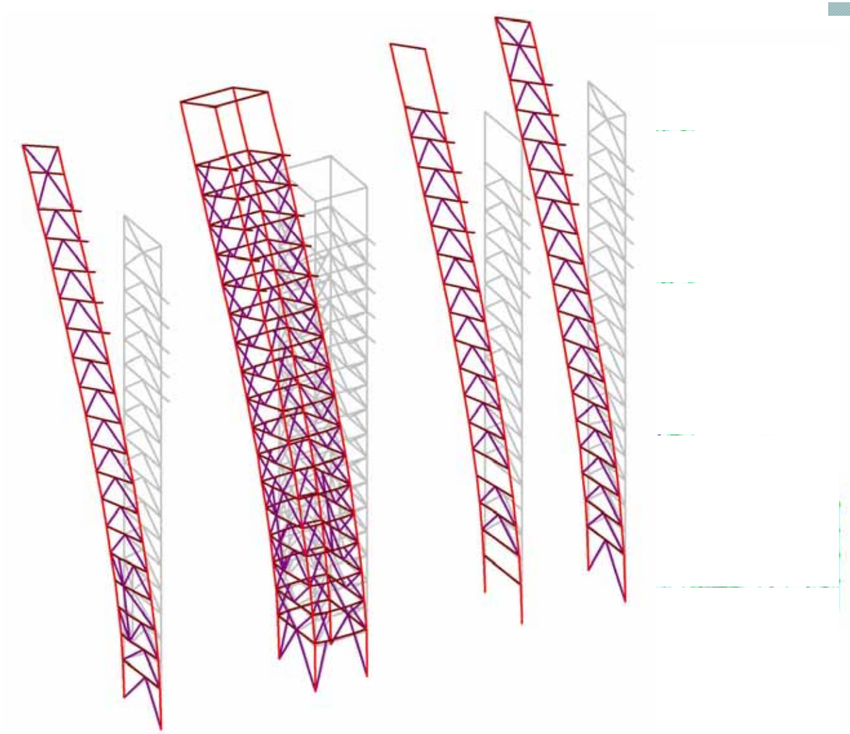
Structural Redesign – Frame Geometry

- **East-West braced frames**
  - Maintain location
  - Chevron bracing to roof
  - Lower bracing: openings, doorways, etc



Structural Redesign – Frame Geometry

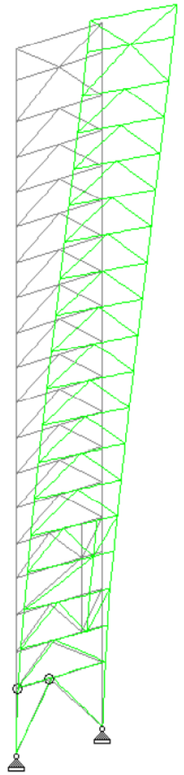
- **North - South braced frames**
  - Quantity
  - Location selection
    - Minimal Architectural impact
    - Torsional issues
- **Eccentric chevron bracing to roof**



Structural Redesign – Frame Modeling

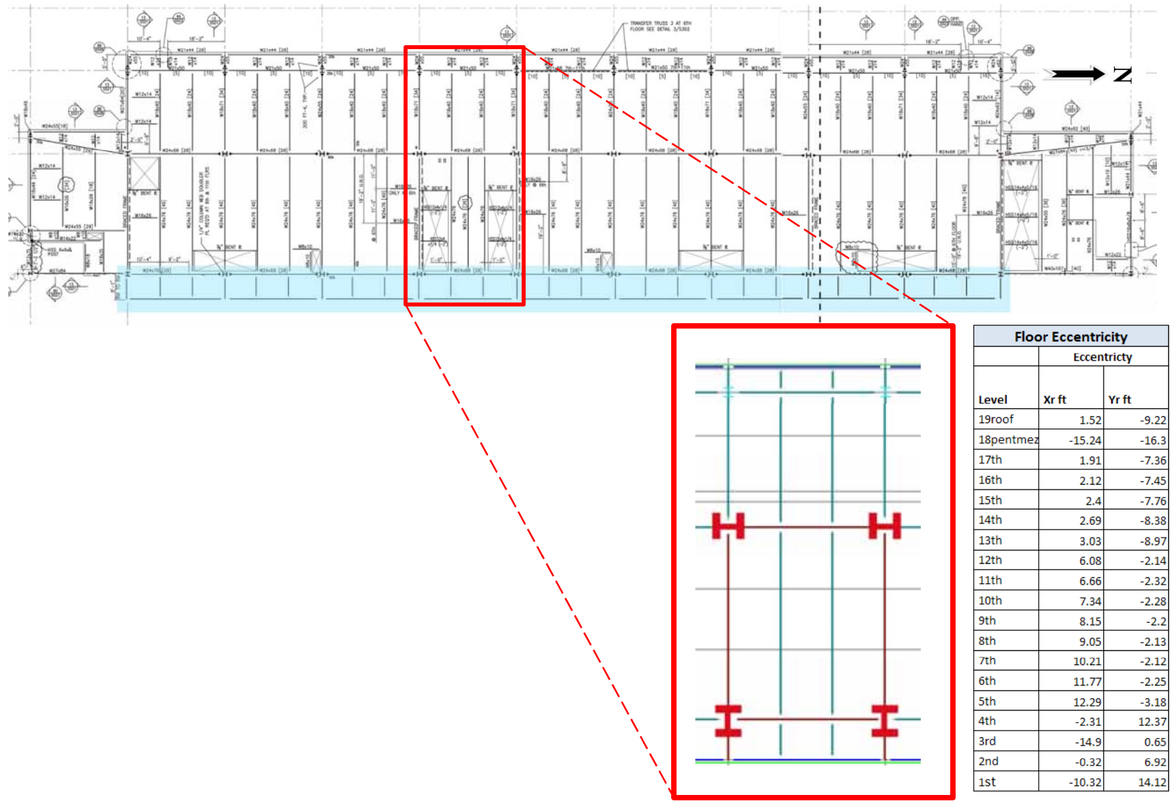
- **RAM model**
  - New vs. original design
- **Design input**
  - Input geometry
  - Hand input loads
- **Strength design**
  - RAM design: Gravity sizing
  - Start with hand selected trial brace sizing
  - Design for strength:
    - Bracing: axial load
    - Columns/beams: combined
- **Drift design**
  - Drifts too high by 31% (Max Δ= H/400 = 8.83”)
  - Repetitive resizing: Little change, esp. E-W (too high by 5.3%)

Drift Comparison										
Required					RAM Model 37		Staad Model 37		Staad Model 37mod	
Level	Height	h + lower lvl	Max = H/400	Change Delta	Delta	Change Delta	Delta	Change Delta	Delta	Change Delta
Roof	267.41	294.41	8.832	0.389	9.321	0.513	10.504	0.494	9.895	0.465
Mez.	254.45	281.45	8.444	0.533	8.808	0.661	10.01	0.713	9.43	0.663
Pent.	236.70	263.70	7.911	0.440	8.147	0.572	9.297	0.599	8.767	0.563
16th	222.03	249.03	7.471	0.440	7.575	0.577	8.698	0.611	8.204	0.572
15th	207.36	234.36	7.031	0.440	6.998	0.581	8.087	0.615	7.632	0.582
14th	192.69	219.69	6.591	0.440	6.417	0.584	7.472	0.623	7.05	0.587
13th	178.02	205.02	6.151	0.440	5.833	0.580	6.849	0.626	6.463	0.590
12th	163.35	190.35	5.711	0.440	5.253	0.580	6.223	0.627	5.873	0.591
11th	148.68	175.68	5.270	0.440	4.673	0.572	5.596	0.623	5.282	0.587
10th	134.01	161.01	4.830	0.440	4.101	0.561	4.973	0.617	4.695	0.578
9th	119.34	146.34	4.390	0.440	3.541	0.544	4.356	0.603	4.117	0.566
8th	104.67	131.67	3.950	0.440	2.997	0.522	3.753	0.588	3.551	0.549
7th	90.00	117.00	3.510	0.440	2.474	0.495	3.165	0.570	3.002	0.524
6th	75.33	102.33	3.070	0.440	1.979	0.461	2.595	0.492	2.478	0.482
5th	60.66	87.66	2.630	0.440	1.518	0.439	2.103	0.549	1.996	0.429
4th	45.99	72.99	2.190	0.460	1.080	0.401	1.554	0.459	1.567	0.474
3rd	30.66	57.66	1.730	0.460	0.679	0.328	1.095	0.527	1.093	0.453
2nd	15.33	42.33	1.270	0.460	0.351	0.216	0.568	0.348	0.64	0.323
1st	0.00	27.00	0.810	0.810	0.135	0.135	0.22	0.220	0.317	0.317



Structural Redesign – STAAD Check

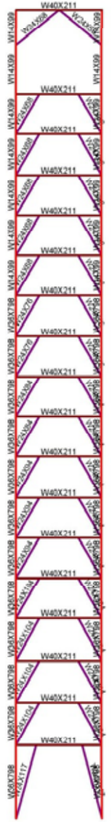
- **Drift check**
  - Used typical E-W frame
  - Compared drift for:
    - RAM story shears (STAAD Model
    - Hand estimated story shears
- **Results**
  - Verified RAM modeling results
  - Explanations:
    - Eccentricity
      - Suspicious of NS frames (sizing, column orientation)

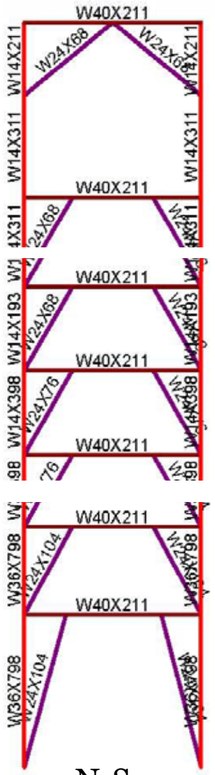


Floor Eccentricity		
	Eccentricty	
Level	Xr ft	Yr ft
19roof	1.52	-9.22
18pentmez	-15.24	-16.3
17th	1.91	-7.36
16th	2.12	-7.45
15th	2.4	-7.76
14th	2.69	-8.38
13th	3.03	-8.97
12th	6.08	-2.14
11th	6.66	-2.32
10th	7.34	-2.28
9th	8.15	-2.2
8th	9.05	-2.13
7th	10.21	-2.12
6th	11.77	-2.25
5th	12.29	-3.18
4th	-2.31	12.37
3rd	-14.9	0.65
2nd	-0.32	6.92
1st	-10.32	14.12

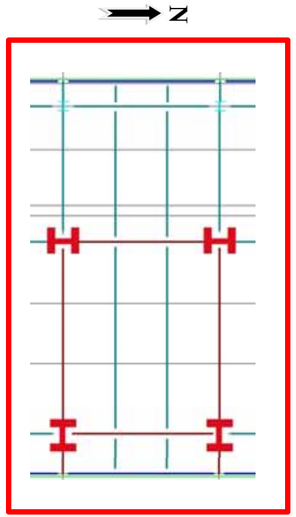
Structural Redesign – Final Lateral

- **Test hypothesis**
  - Drastically increase sizes
- **Correcting N-S drift, corrected E-W drift as well**
  - Cause: column orientation/eccentricity
    - I decreases by 67%
    - N-S e = 10’
    - E-W e = 12’





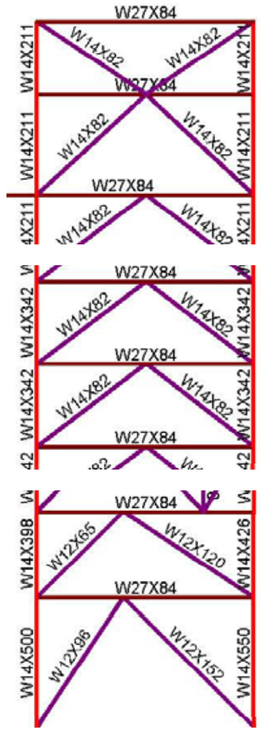
N-S
Final Model



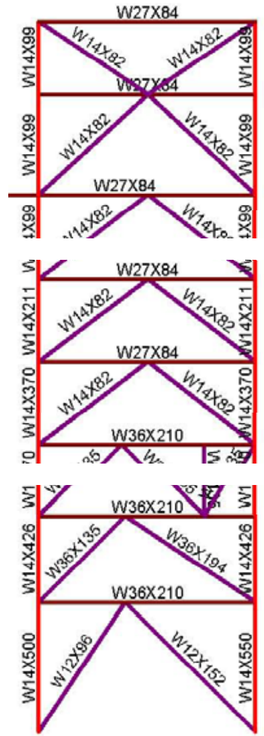
Structural Redesign – Final Lateral

- **N-S Frames**
  - Drift controls design
    - 8.64”< Max Δ= H/400 = 8.83”
- **Sizing**
  - Bracing geometry: beams and columns
  - Column orientation: I decreases by 67%
  - Penthouse Mechanical
- **Increase Efficiency?**
  - Bracing geometry
  - Column orientation
  - Add frames
  - Penthouse Mechanical

Drift Comparison						
Required					RAM Model Final	
Level	Height	h + lower lvl	Max = H/400	Change Delta	Delta	Change Delta
Roof	267.41	294.41	8.832	0.389	6.7918	0.3814
Mez.	254.45	281.45	8.444	0.533	6.4105	0.5365
Pent.	236.70	263.70	7.911	0.440	5.874	0.4468
16th	222.03	249.03	7.471	0.440	5.4271	0.4481
15th	207.36	234.36	7.031	0.440	4.979	0.4435
14th	192.69	219.69	6.591	0.440	4.5356	0.4309
13th	178.02	205.02	6.151	0.440	4.1047	0.4086
12th	163.35	190.35	5.711	0.440	3.6961	0.3815
11th	148.68	175.68	5.270	0.440	3.3147	0.3765
10th	134.01	161.01	4.830	0.440	2.9382	0.3727
9th	119.34	146.34	4.390	0.440	2.5654	0.3663
8th	104.67	131.67	3.950	0.440	2.1992	0.3566
7th	90.00	117.00	3.510	0.440	1.8426	0.3441
6th	75.33	102.33	3.070	0.440	1.4985	0.3268
5th	60.66	87.66	2.630	0.440	1.1717	0.3095
4th	45.99	72.99	2.190	0.460	0.8622	0.3101
3rd	30.66	57.66	1.730	0.460	0.5521	0.2436
2nd	15.33	42.33	1.270	0.460	0.3085	0.1636
1st	0.00	27.00	0.810	0.810	0.1449	0.145



E-W
Model 37



E-W
Final Model

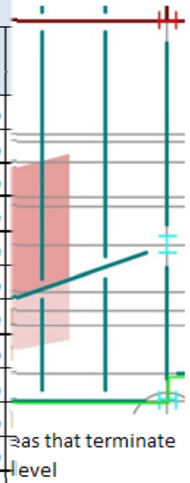
Structural Redesign – Final Lateral

- **E-W Frames**
  - Were effected by N-S frame inefficiency
  - Drift controls design
    - 6.79”< Max Δ= H/400 = 8.83”

Floor	Area
1-4	
5-11	
Pent.	
Roof	
Total	
Check	
Design	
Existing	
Hand	
RAM	

Column Size Comparison

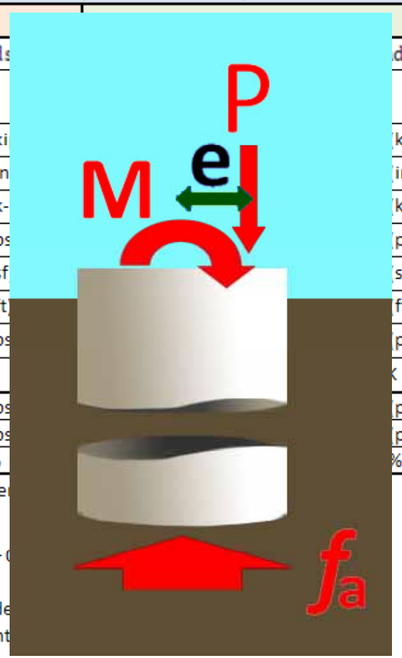
		Original		New			
		Member	Capacity	Member	Capacity	Diff.	% Diff.
A	5	w14x 90	954	w14x 109	1160	206	17.76%
	5.3	w14x 90	954	w14x 109	1160	206	17.76%
	6.2	w14x 99	954	w14x 132	1160	206	17.76%
B	5	w14x 370	4150	w14x 500	5660	1510	26.68%
	6	w14x 370	4150	w14x 550	6270	2120	33.81%
	7	w14x 109	1160	w14x 211	2320	1160	50.00%
C	5	w14x 342	3840	w14x 283	3150	-690	-21.90%
	6	w14x 398	4470	w14x 370	4150	-320	-7.71%
	7	w14x 159	1740	w14x 211	2320	580	25.00%
D	5	w14x 370	4150	w14x 370	4150	0	0.00%
	6	w14x 342	3840	w14x 426	4790	950	19.83%
	7	w14x 68	544	w14x 120	1160	616	53.10%



Structural Redesign – Final Checks

- **RAM strength check**
  - Extra capacity (drift control)
- **Column line check**
  - Compares original and new RAM models with existing design
  - Very close results
- **Column comparison check**
  - Compares original and new RAM models
  - Column size increase, except:
    - New braced frame columns greatly increased
    - Old moment frame columns decreased

NS/EW Frame 3 (col. Lines E5-E6)			
Column E5			
$f_a \geq$ [Axial Load] + [Moment Loads]			
$f_a \geq \left[\frac{P}{A}+\frac{P \cdot e \cdot c}{I}\right]+\left[\frac{M \cdot c}{I}\right]$			
Input:	P=	3597.02	(kips)
	e=	0.134	(in)
	M=	4648.1	(k-ft)
	f_a=	60000	(psf)
Trial Sizing:	A=	113.10	(sf)
	Ø=	12.00	(ft)
Capacity	f_{max}=	59227.13	(psf)
	<f_a?	OK	
Comparison	Ø New =	12.00	(psf)
	Ø Orig. =	8	(psf)
	% Increase	50.00	%



* Bearing capacity f_a= 60,000psf as give
* Concrete strength is f'_c= 4,000 psi
* Controlling column forces = 1.200 D +
* e is from calculated story drifts
* P and M are obtained from RAM mode
* Ø Determined to nearest 2" incriment

** This design was controlled by NS loading

Structural Redesign – Foundation

- **Caisson sizing**
  - Obtain rough sizing estimate
    - Bearing capacity: 60,000 psf
    - Take all loading into account
- **Results**
  - Most Ø = 8’ originally
  - Increase Ø to 9’ to 12’ (12%-52%)

Lateral Takeoff Economic Analysis

Level	Area (SF)	Original Design Weight lbs	Original Design Unit Weight (psf)	New Design Weight lbs	New Design Unit Weight (psf)	% Increase
1st	57000	270998	4.754351	288250	5.057895	6%
2nd	51800	193843	3.742143	174901	3.376854	-10%
3rd	45000	172399	3.831089	158733	3.527400	-8%
4th	57000	171811	3.014228	161118	2.826632	-6%
5th	28000	154833	5.52975	156054	5.573357	1%
6th	28000	142528	5.090286	134519	4.804250	-6%
7th	28000	130258	4.652071	125150	4.469643	-4%
8th	28000	129233	4.615464	124179	4.435679	-4%
9th	28000	120808	4.314571	123486	4.410214	2%
10th	28000	120578	4.306357	123486	4.410214	2%
11th	28000	114389	4.085321	122956	4.391286	7%
12th	25197		0	125545	4.983055	
13th	25197		0	72009	2.857988	
14th	25197		0	71535	2.839179	
15th	25197		0	71535	2.839179	
16th	25197		0	71535	2.839179	
Pent.	25197	123447	4.899274	71535	2.839179	-42%
Mez.	7500	46022	6.136267	55083	7.3444	20%
Roof	22685	36309	1.600573	66507	2.931761	83%
Average:	588167	1927456	4.17034	2298116	3.907251	
% Increase in floor area cost					-6%	
% Increase in floor area					27%	

Gravity Beam Takeoff Economic Analysis

Level	Area (SF)	Original Design Weight lbs	Original Design Unit Weight (psf)	New Design Weight lbs	New Design Unit Weight (psf)
% Increase in floor area cost					-2%
% Increase in floor area					27%

Gravity Column Takeoff Economic Analysis

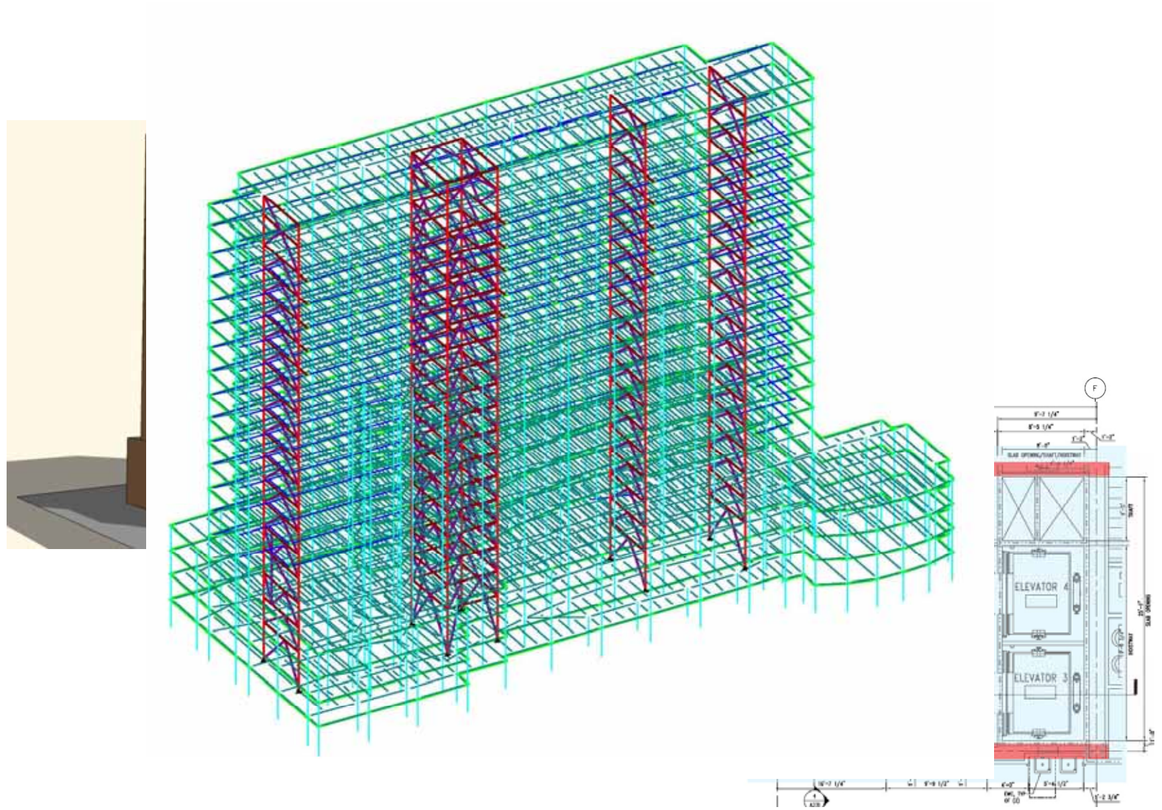
Level	Area (SF)	Original Design Weight lbs	Original Design Unit Weight (psf)	New Design Weight lbs	New Design Unit Weight (psf)
	588167	597942	1.016619	1281388	2.178613
% Increase in floor area cost					114%
% Increase in floor area					27%

Economic Analysis

Lateral Takeoff	
% Increase in floor area cost	-6%
% Increase in floor area	27%
Gravity Beam Takeoff	
% Increase in floor area cost	-2%
% Increase in floor area	27%
Gravity Column Takeoff	
% Increase in floor area cost	114%
% Increase in floor area	27%

Structural Redesign – Economy

- **Economic Analysis: New vs Original**
  - Unit weight: ratio of steel weight to floor area
  - Compare unit weight % decrease
- **Separated into:**
  - Lateral, Gravity Beam, Gravity Column
- **Conclusions:**
  - Vertical expansion is feasible means for increasing program
  - Converting moment frames to braced increases efficiency
    - Despite over-sizing
    - Note: cost of moment connections



Structural Redesign – Conclusions

- **Vertical expansion**
  - Feasible means for increasing program
- **Converting moment frames to braced**
- **Minimized negative architectural impact**
- **Further efficiency**
  - Add another set of N-S braced frames
  - Change column orientation: deeper column

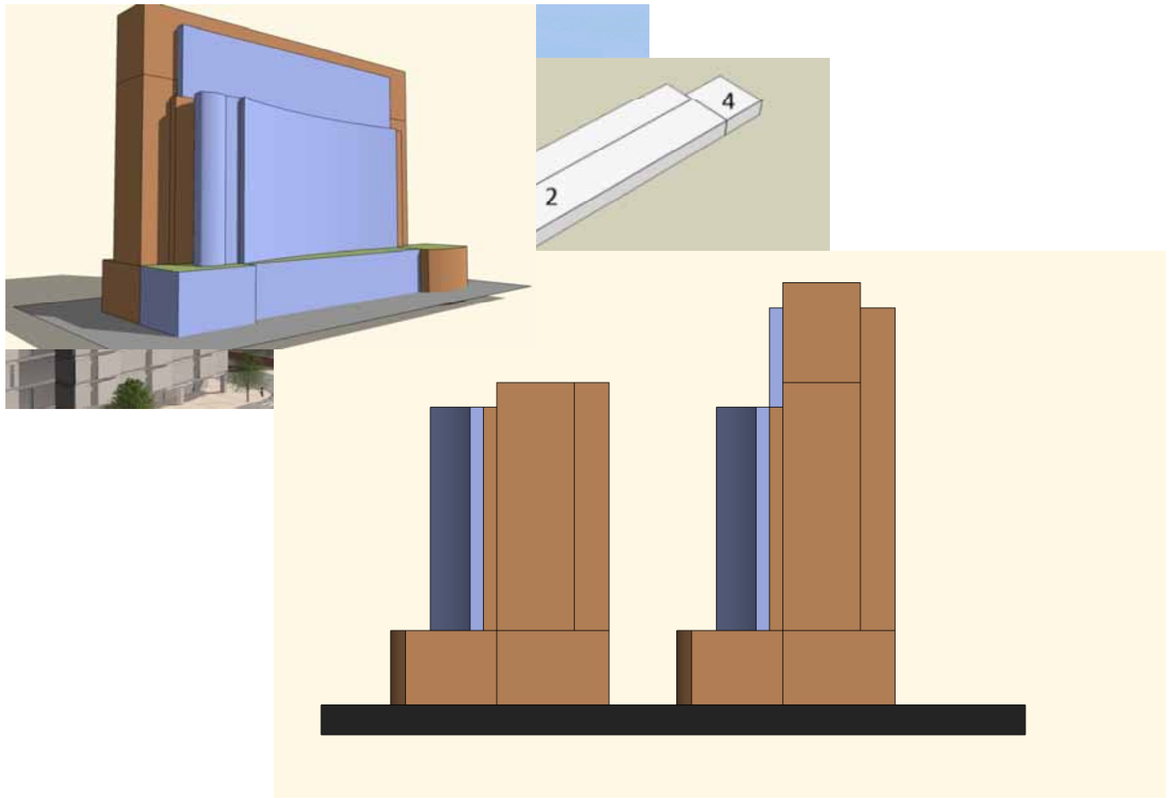
Architectural Redesign

Architectural Redesign - Massing

- **Size & Scale**
  - Medical Campus
  - Residential neighborhood

Architectural Redesign - Massing

- **Size & Scale**
  - Medical Campus
  - Residential neighborhood
- **Design Philosophy**
  - Expression of interior functions on exterior

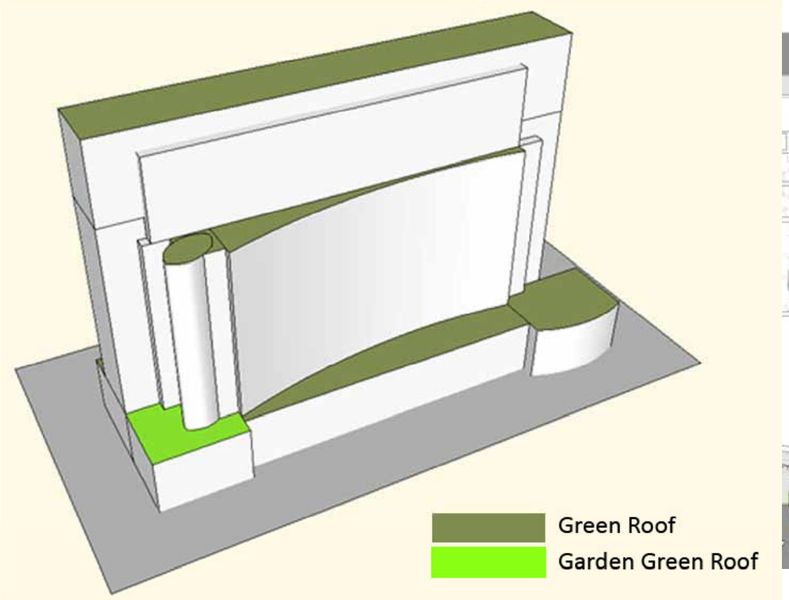


Architectural Redesign - Massing

- **Size & Scale**
  - Medical Campus
  - Residential neighborhood
- **Design Philosophy**
  - Expression of interior functions on exterior
- **Square footage**
  - Approx. 100,000 SF addition
    - 5 floors
    - 25,200 SF per floor
- **Final Massing**
  - Takes all factors into account

Architectural Redesign - Efficiency

- **Square footage efficiency: 80%**
  - Original tower floor-plan
    - 28000 SF - 4260 SF corridor
    - 85% efficiency
  - New tower floor plan
    - 25200 SF - 4260 SF corridor
    - 83% efficiency



Architectural Redesign – Green Space

- **Limited green space**
- **Green roof addition**
  - Intensive green roof – 1400 SF - library roof
    - Rooftop garden
  - Extensive green roof – 4800 SF - elsewhere
    - Higher “R-value” (thermal mass)
    - Cleaner runoff
    - Reduced runoff volume
- **Cost analysis – library area**
  - Existing built-up roof = $3,990
  - Extensive green roof = $39,400
  - Intensive green roof = $49,870
  - Conclusion:
    - Intensive green roof is 0.03% of $150 million budget

1004.1 EGRESS DESIGN OCCUPANT LOAD:

		AREA	OCCUPANTS
LOWER LEVEL	BUSINESS	40,417 SF	327
	ASSEMBLY	14,033 SF	338
	TOTAL	54,550 SF	665
FIRST FLOOR	BUSINESS	34,768 SF	307
	ASSEMBLY	19,557 SF	922
	TOTAL	54,352 SF	1,229
SECOND FLOOR	BUSINESS	24,680 SF	503
	ASSEMBLY	22,020 SF	782
	TOTAL	46,700 SF	1,285
THIRD FLOOR	BUSINESS	35,510 SF	540
	ASSEMBLY	11,240 SF	617
	TOTAL	46,750 SF	1,157
FOURTH FLOOR	BUSINESS	35,500 SF	
	ASSEMBLY	900 SF	
	TOTAL	32,400 SF	
FIFTH FLOOR	BUSINESS	31,400 SF	
SIXTH–TENTH FLOOR	BUSINESS	32,400 SF	
ELEVENTH FLOOR	BUSINESS	31,500 SF	
PENTHOUSE	BUSINESS	24,300 SF	
PENTHOUSE MEZZANINE	BUSINESS	3,400 SF	
BUILDING EGRESS OCCUPACY TOTAL		488,125 SF	7,665

TABLE 1019.1
MINIMUM NUMBER OF EXITS FOR OCCUPANT LOAD

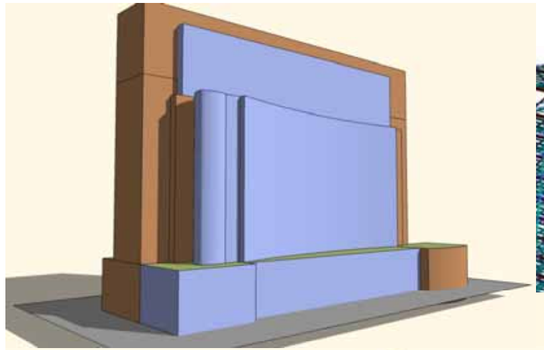
OCCUPANT LOAD (persons per story)	MINIMUM NUMBER OF EXITS (per story)
1-500	2
501-1,000	3
More than 1,000	4

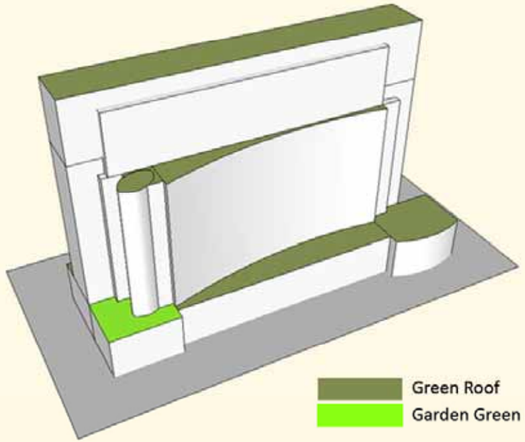
1005.1 EGRESS WIDTHS PER FLOOR (SECOND FLOOR IS CRITICAL CASE)

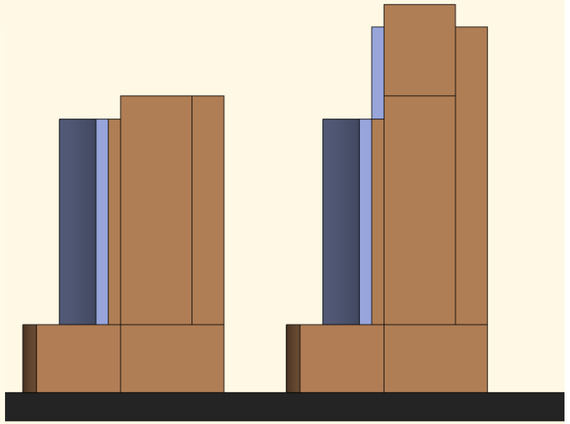
EGRESS CAPACITY	
ZONE 1 OCCUPANT LOAD [2 EXITS REQUIRED]	483
ZONE 1 EXIT CAPACITY	
– EXIT 1 –STAIR 1 – DOOR	440
– STAIR WIDTH [LIMITING FACTOR]	330 *
– EXIT 2 –HORIZONTAL EXIT– DOOR	260 *
ZONE 1 EXIT CAPACITY	590

Architectural Redesign - Egress

- **Occupancy**
  - Business/Assembly occupancy
  - Adding 252 occupants/floor
    - 100SF/occupant, 25,200SF
- **Capacity**
  - Exit widths: controlled by 1285 occupancy of library and auditorium
  - # of stairways: 2







Conclusions

- **Goals**
  - Meet design criteria (strength/serviceability/ capacity)
  - Maintain or exceed efficiency (weight ratio, SF use)
  - Minimal effect on architecture
- **Structural Redesign**
  - Vertical expansion: Feasible means for increasing program
  - Minimized negative architectural impact
  - Converting moment frames to braced: Increased efficiency
  - Further efficiency: Add frames/column orientation
- **Architectural Redesign**
  - Massing
  - Maintain floor plan efficiency (83%)
  - Created green-space
  - Egress requirements met

Acknowledgments

Temple University

Ballinger, Inc.

Edward Zinski

Scott Holsinger

Joyce Raybuck

Penn State

Dr. Linda Hanagan

M. Kevin Parfitt

Robert J. Holland

The entire AE

faculty, staff, and students

Questions?

Extra

Green Roof Costs								
		Matls	Unit	Inst	Unit	Quantitiy	Unit	Total Cost
Existing Roof Assembly	EPDM roof, 45 mils, fully adhered	0.95	sf	0.86	sf	1400	sf	$2,534.00
	Extruded Polystyrene Insulation, 2" thick R10	0.68	sf	0.36	sf	1400	sf	$1,456.00
Green Roof Assembly	Filter Fabric Root barrer	0.93	sf	0.24	sf	1400	sf	$1,638.00
	Spread conditioned soil 4" deep, by hand	4.35	sf	1.58	sf	1400	sf	$8,302.00
	Spread conditioned soil 6" deep, by hand	4.83	sf	2.06	sf	1400	sf	$9,646.00
Green Roof Plantings	Sprigging of Sedums 6" walk behing sprig planter	15.15	sf	3.03	sf	1401	sf	$25,470.18
	Perennial Planting (Rose Mallow) 5 Gal.	13.95	Ea			50	Ea	$697.50
	Perennial Planting (lily of the nile) 5 Gal.	17.25	Ea			100	Ea	$1,725.00
	Shrub (Abelia) 18"-21"	18	Ea			20	Ea	$360.00
Landscaping	blocks, 2-3/8" thick, colors, 12"12"	1.77	sf	1.86	sf	250	sf	$907.50
	Decorative Fence, 4' high	28	lf	0.62	lf	190	lf	$5,437.80
Existing Roof Cost	Includes Existing Assembly							$3,990.00
Extensive Green Roof Cost	Includes Existing Assembly, Green Roof Assembly, and Sedum Sprigging							$39,400.18
Intenstive Green Roof Cost	Includes Existing Assembly, Green Roof Assembly, Green Roof Plantings, and Lanscaping							$49,871.98

- **Construction photos and full architectural renderings of original design taken from the following websites:**
  - http://www.temple.edu/medicine/
  - http://www.ballinger-ae.com