Jessel Elliott
Structural Option
Architectural Engineering

Senior Thesis 2012
Advisor: Dr. Richard Behr

Bed Tower Addition @ Appleton Medical Center

Outline

Introduction

Existing Structural System

Proposal

Structural Depth

Architectural Breadth

Conclusion

Design Team and Location

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Struct mson
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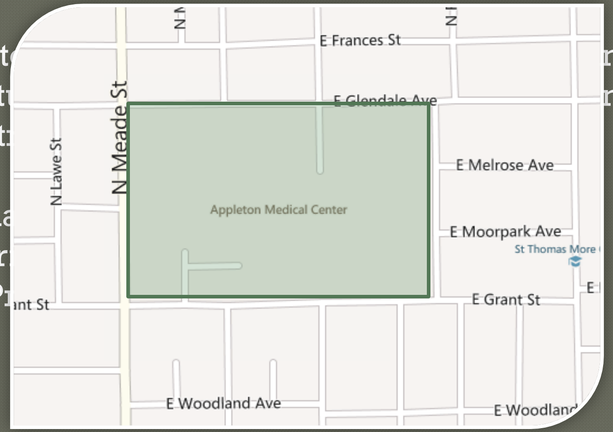
Civil:
Mecha
Electr
Fire P



General Information

# of Stories:	8 plus a penthouse
Total Height:	127’-3” total height
Total Area:	152, 330 sq. ft.
Project Delivery:	June 2008 – January 2011
Total Cost:	$59,100,000

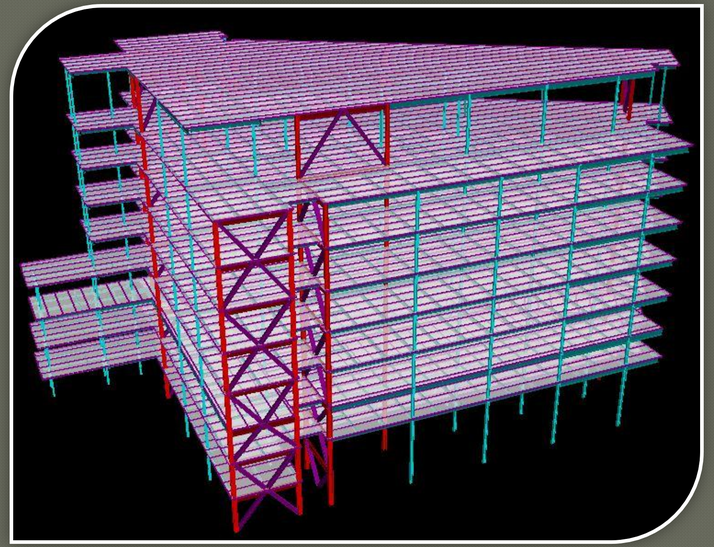
Gravity System and Foundation

Steel Rigid Frame

Composite Beam and Deck Design

Mat Foundation

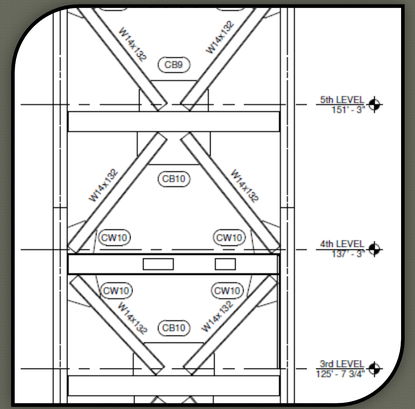
Exterior bays typically 30’ long

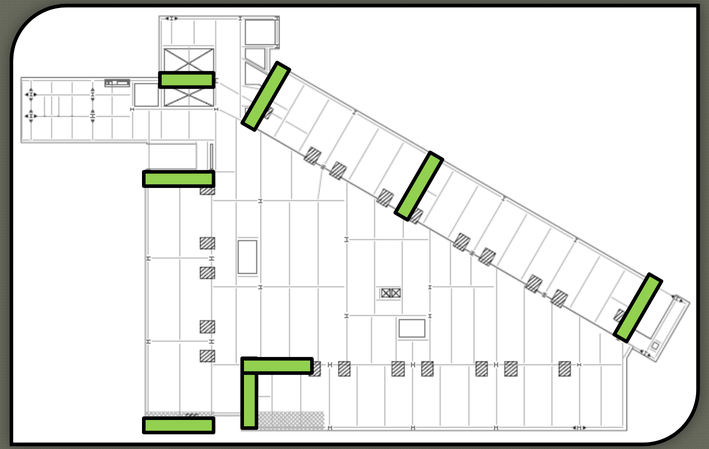


Lateral System

Concentrically
Braced Frames

8 Total Frames
4 in the X-direction
1 in the Y-direciton
3 at 60°





Proposal

Goals

- Move the addition to an area in San Francisco, CA
- Modify the existing structure for change in location
- Prove there is a significant change in base shear
- Control drifts
- Use base isolation to reduce loads
- Model the building to displace between the min and max design displacements
- Compare displacements and drifts of a modified structure and the existing structure

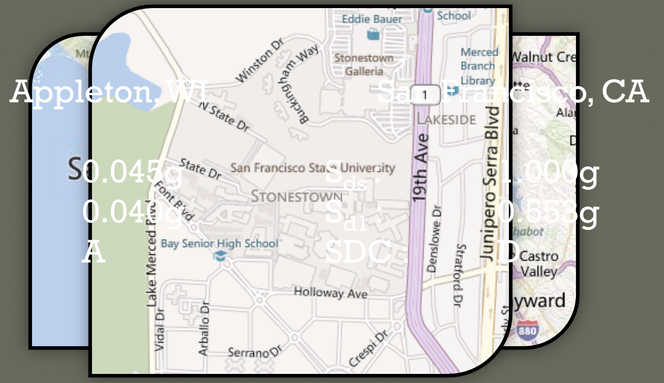
Architecture Breadth

- Find a way to cover up the moat
- Do case studies on surrounding buildings
- Use Sketch-up to show changes in façade

Construction Breadth

- Do a cost and schedule analysis
- Check feasibility of base isolation

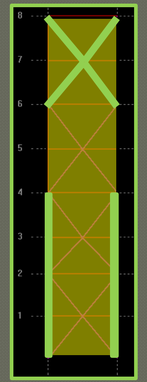
New Parameters



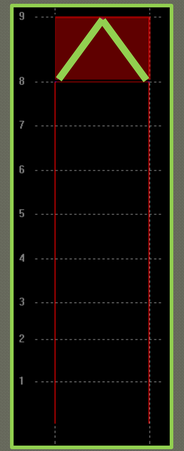
S_{ds} : 0.045g
S_{dl} : 0.04[illegible]g
SDC : A

S_{ds} : 1.000g
S_{dl} : 0.55[illegible]g
SDC : D

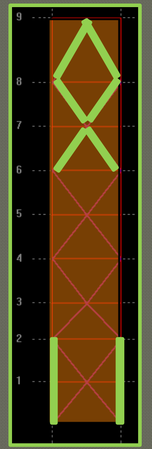
Change in Column/Bracing Size



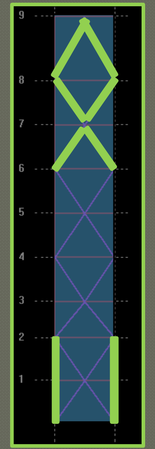
Frame 13



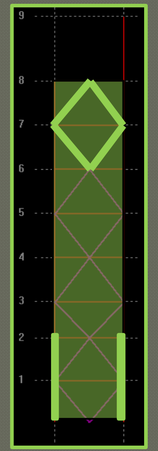
Frame 12



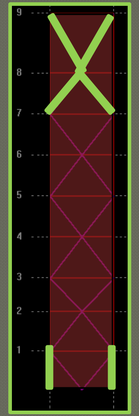
Frame 5



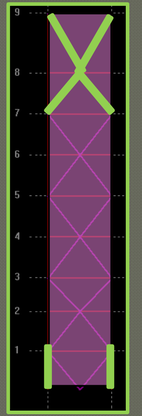
Frame 2



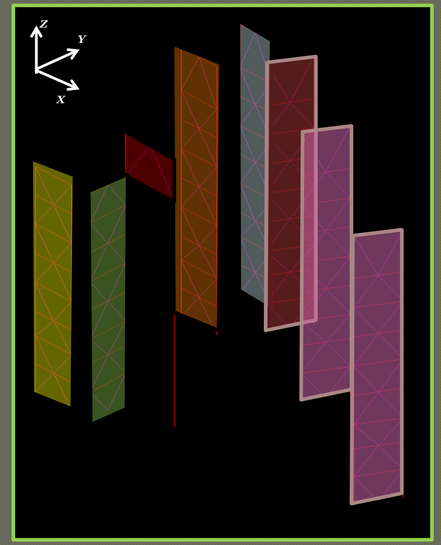
Frame J



Frame XA



Frame XC

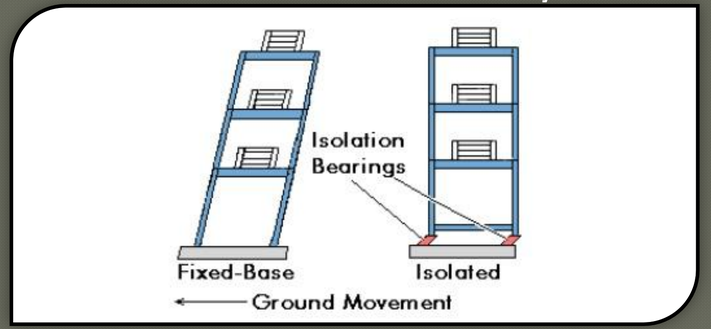


History of Base Isolation

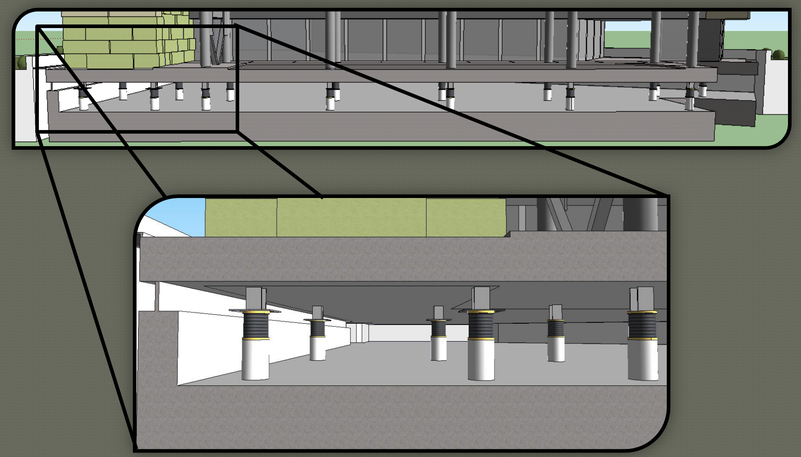
From: National Earthquake Hazards Reduction Program (NEHRP)

- 200 buildings
- Use of damping elements to reduce lateral forces
- Control inter-story drifts
- 3 components to base isolated building

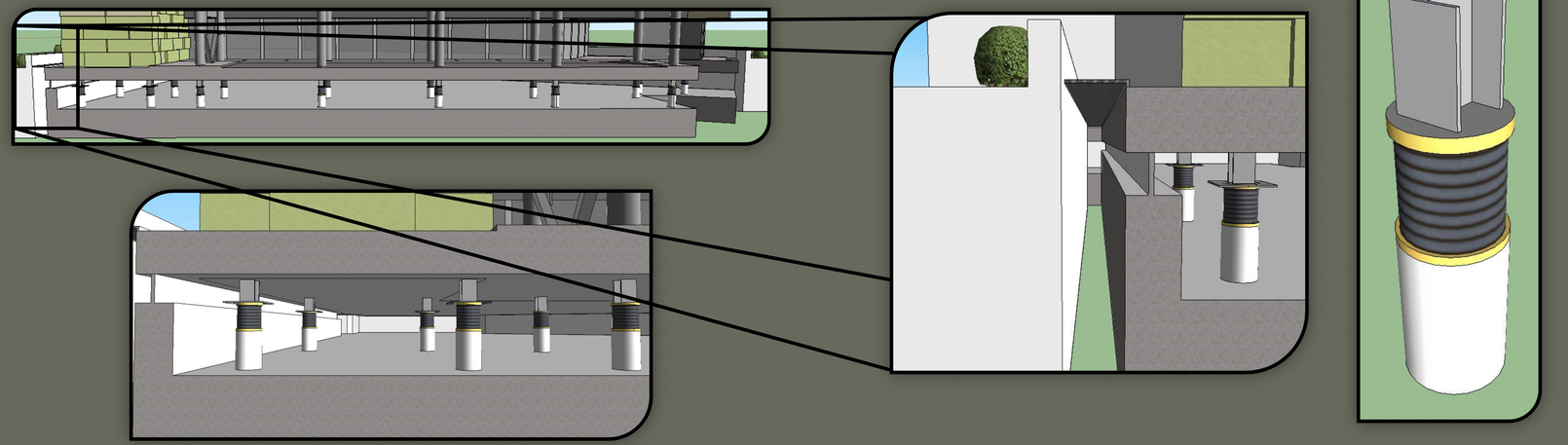
From University of Buffalo



Base Isolation Elements



Base Isolation Elements



Design of Base Isolation

$$K_{Dmax} = \frac{W K_{Dmin}}{g\left(\frac{2\pi}{T_D}\right)^2 (1 - k)}$$

$$D_D = \left(\frac{1}{4\pi^2}\right) \frac{S_{D1} T_D}{B_D} \sqrt{K_{D\,min} g (1 - k)}$$

$$K_{Mmax} = \frac{W K_{Mmin}}{g\left(\frac{2\pi}{T_M}\right)^2 (1 - k)}$$

$$D_M = \left(\frac{1}{4\pi^2}\right) \frac{S_{M1} T_M}{B_M} \sqrt{K_{M\,min} g (1 - k)}$$

Where,
S_{D1} and S_{M1} = spectral coefficients
B_D and B_M = damping coefficients
T_D and T_M = isolated periods
g = gravitation acceleration (in/s^2)
W = weight of the building
K_{Dmin} and K_{Mmin} = minimum eff. horizontal stiffness
k = ±% variation

$$V_b = K_{Dmax} D_D$$

$$V_s = \frac{K_{Dmax} D_D}{R_I}$$

V_b = minimum lateral seismic force on elements below the superstructure
V_s = minimum shear force on superstructure as if it were fixed

Assuming
T_{fixed} = 1.09 s
Then,
T_D = 4.64 s
T_M = 5.46 s

D_D = 18.61 in
D_M = 32.86 in

K_{Dmin} = 81 k/in

V_b = 1845 kips
V_s = 1640 kips

Design of Base Isolation

Seismic Load Calculations

Level	Ht. (ft)	Weight (k)	Fx	M (k-ft)
1	0	0	0	0
2	12.25	2124.20	21.24	260.21
3	25.64583	2529.80	25.30	648.79
4	37.25	2207.10	22.07	822.14
5	51.25	2506.20	25.06	1284.43
6	65.25	2408.60	24.09	1571.61
7	79.25	2389.20	23.89	1893.44
8	93.25	2390.30	23.90	2228.95
9	107.25	2334.60	23.35	2503.86
10	127.75	550.10	5.50	702.75
		19440.10		11916.2
Base Shear			Overturning M	11916.2

5112.765

194.40

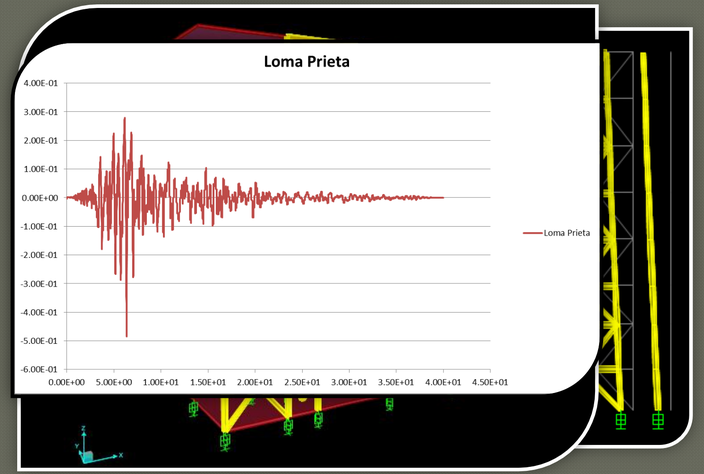
-67.92%

Vertical Distribution of Forces (V = 1640 kips)

Level	w_x (kips)	h_x (ft)		$w_x h_x$	C_{vx}	F_x (kips)	M (k-ft)
10	512	127.75	Not used for Vertical Distribution of Isolated Structures	65408	0.054	88.7	11330.4
9	2440	107.25		261690	0.216	354.8	38057.4
8	2427	93.25		226318	0.187	306.9	28616.9
7	2426	79.25		192261	0.159	260.7	20660.7
6	2445	65.25		159536	0.132	216.3	14115.5
5	2546	51.25		130483	0.108	176.9	9067.8
4	2220	37.25		82695	0.068	112.1	4177.0
3	2530	25.64583		64884	0.054	88.0	2256.4
2	2137	12.25		26178	0.022	35.5	434.8
				1209452		1640	128716.9
Base Shear		1640	Overturning Moment		128716.9		

Time History Analysis

Introduction
Existing Structural System
Proposal
Structural Depth
Modified Braced Frames
Base Isolation
Architectural Breadth
Conclusion

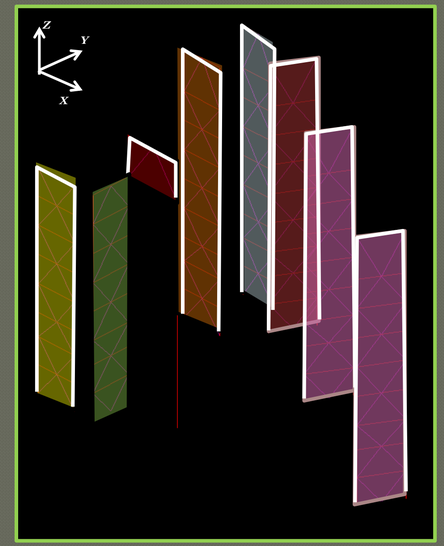


Video removed to reduce to smaller file

Displacements and Drifts

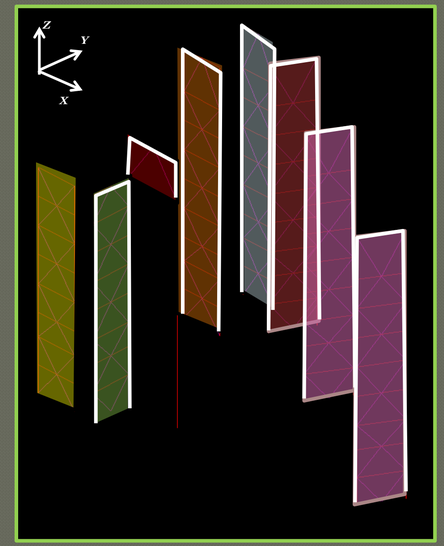
Comparison of Structures - Loma Prieta Y-direction (all values in inches)

Level	Frame J					
	Max Displacement			Max Drift		
	Existing Structure	Modified Structure	% Change	Existing Structure	Modified Structure	% Change
1	18.148	18.137	0.06%	0.00	0.00	
2	18.702	18.669	0.18%	1.20	1.15	4.05%
3	19.240	19.181	0.30%	1.16	1.11	4.63%
4	19.740	19.667	0.37%	1.08	1.05	2.92%
5	20.394	20.310	0.42%	1.42	1.39	1.78%
6	20.987	20.893	0.45%	1.28	1.26	1.58%
7	21.542	21.457	0.39%	1.20	1.22	-1.64%
8	22.218	22.185	0.15%	1.47	1.58	-7.60%
9	22.718	22.718	0.00%	1.08	1.16	-6.69%



Displacements and Drifts

Comparison of Structures - Loma Prieta X-direction (all values in inches)						
Level	Frame 13					
	Max Displacement		% Change	Max Drift		% Change
	Existing Structure	Modified Structure		Existing Structure	Modified Structure	
1	19.2	19.2	-0.09%	0.00	0.00	
2	19.8	19.8	0.13%	1.31	1.22	6.92%
3	20.3	20.3	0.28%	1.16	1.09	6.00%
4	20.8	20.7	0.35%	1.02	0.99	3.18%
5	21.5	21.4	0.35%	1.44	1.44	0.59%
6	22.1	22.0	0.34%	1.38	1.39	-0.20%
7	22.7	22.7	0.32%	1.31	1.32	-0.31%
8	23.4	23.3	0.0	1.38	1.49	-8.31%
9	23.8	23.8	-0.06%	0.98	1.06	-7.49%



Displacements and Drifts

BASE ISOLATION WITH EXISTING STRUCTURE

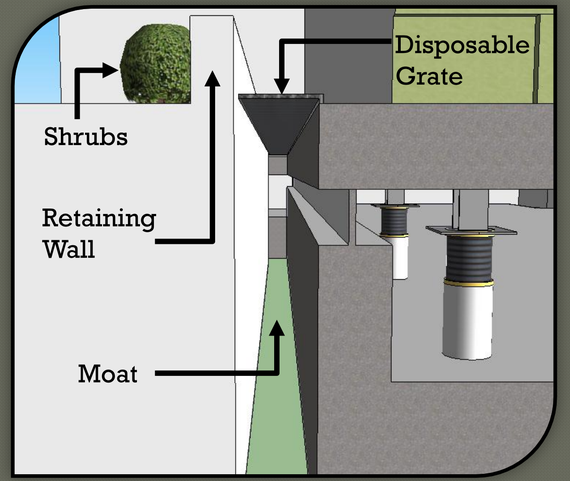
Frame J Displacements and Drifts			
Level	Max Displace. (in)	Max Drift (in)	Allow. Drift (in)
1	18.15	0.00	0.00
2	18.70	1.20	1.47
3	19.24	1.16	1.61
4	19.74	1.08	1.39
5	20.39	1.42	1.68
6	20.99	1.28	1.68
7	21.54	1.20	1.68
8	22.22	1.47	1.68
9	22.72	1.08	1.68
$\delta = S_9 - S_1$	4.57	$\Delta_{max} = 0.010hsx$	

BASE ISOLATION WITH MODIFIED STRUCTURE

Frame J Displacements and Drifts			
Level	Max Displace. (in)	Max Drift (in)	Allow. Drift (in)
1	18.14	0.00	0.00
2	18.67	1.15	1.47
3	19.18	1.11	1.61
4	19.67	1.05	1.39
5	20.31	1.39	1.68
6	20.89	1.26	1.68
7	21.46	1.22	1.68
8	22.18	1.58	1.68
9	22.72	1.16	1.68
$\delta = S_9 - S_1$	4.58	$\Delta_{max} = 0.010hsx$	

Allowable Drifts		
Level	Height (ft)	Allow. Drift (in)
1	0	0
2	12.25	1.47
3	25.65	1.61
4	37.25	1.39
5	51.25	1.68
6	65.25	1.68
7	79.25	1.68
8	93.25	1.68
9	107.25	1.68
10	127.25	2.40

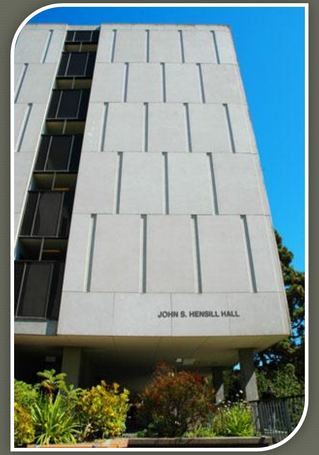
Moat Cover-up



Case Studies

Introduction
Existing Structural System
Proposal
Structural Depth
Architectural Breadth
Conclusion

Student Services



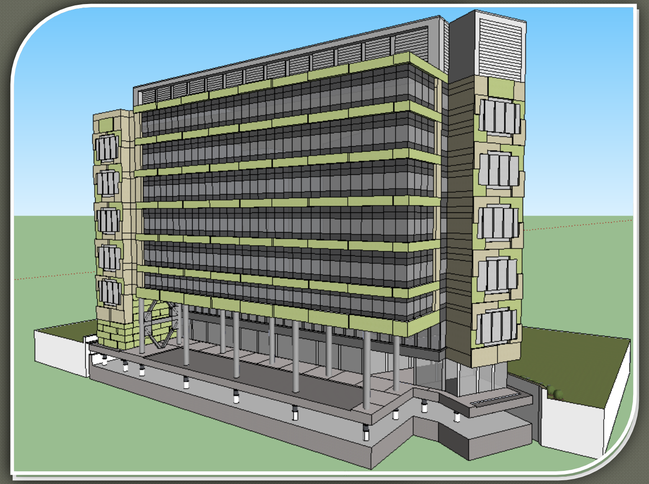
Hensill Hall

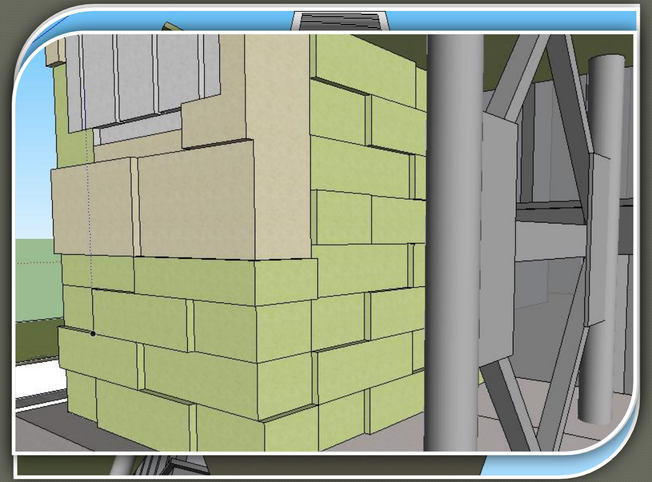
Administration Building

Humanities

Changes in Façade

Introduction
Existing Structural System
Proposal
Structural Depth
Architectural Breadth
Conclusion





Summary Conclusion

Introduction
Existing Structural System
Proposal
Structural Depth
Architectural Breadth
Conclusion

- Prove there is a significant change in base shear?
- Control drifts
- Model the building to displace between the min. and max design displacements

Acknowledgements

Special Thanks to:

AE Department and Faculty
Dr. Richard Behr
Friends
Family

HGA
ThedaCare
Sheetz, Inc.

Introduction
Existing Structural System
Proposal
Structural Depth
Architectural Breadth
Conclusion

THANK YOU