Mountain Hotel

Urban Virginia

Benjamin Borden

Structural Option

Faculty Advisor:
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Senior Thesis 2013

Presentation Outline

- Introduction
- Existing Structural Systems
- Thesis Proposal
- Concrete Redesign
- Glazing Evaluation
- Conclusions
- Questions/Comments

Building Introduction

Introduction
Existing Structural Systems
Thesis Proposal
Concrete Redesign
Glazing Evaluation
Conclusions
Questions/Comments

Hotel and Conference Center
Located in an urban center in Virginia
121,000 square feet
Height – 62ft to Roof
Project Delivery Method: Design Build
Current Status: Under Permit Review

Site Map

Building Introduction

Owner: Withheld

Architect: Enviro Architects

Civil Engineer: Walter L. Phillips inc.

Structural Engineer: Alliance Engineers

MEP: Epic Consultants

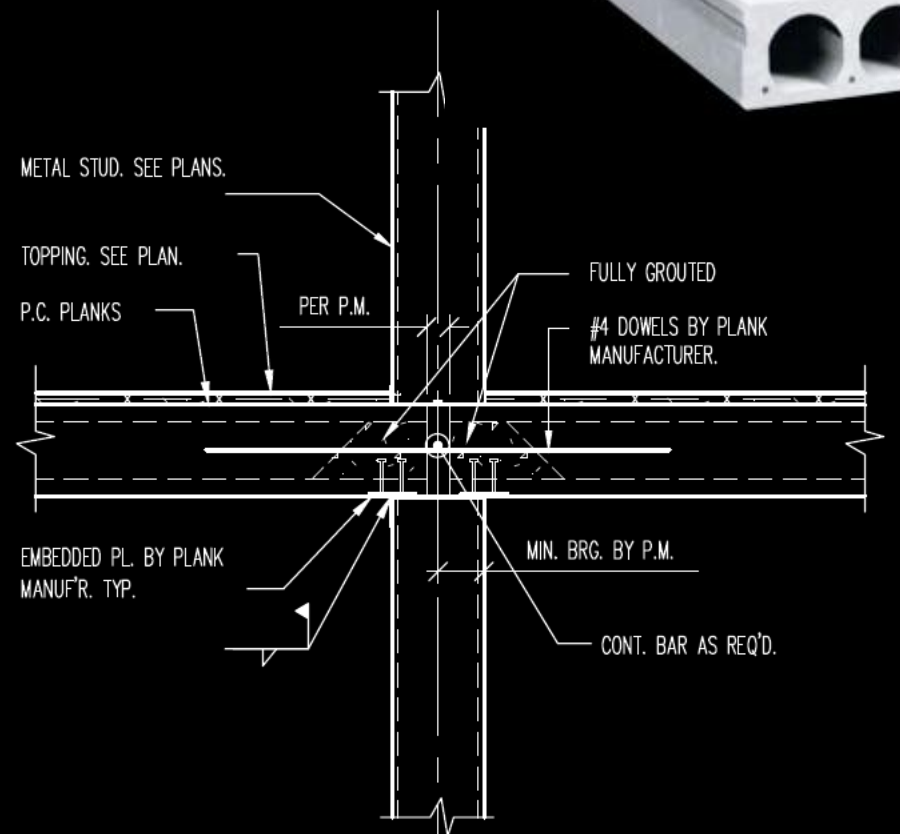
Site Map

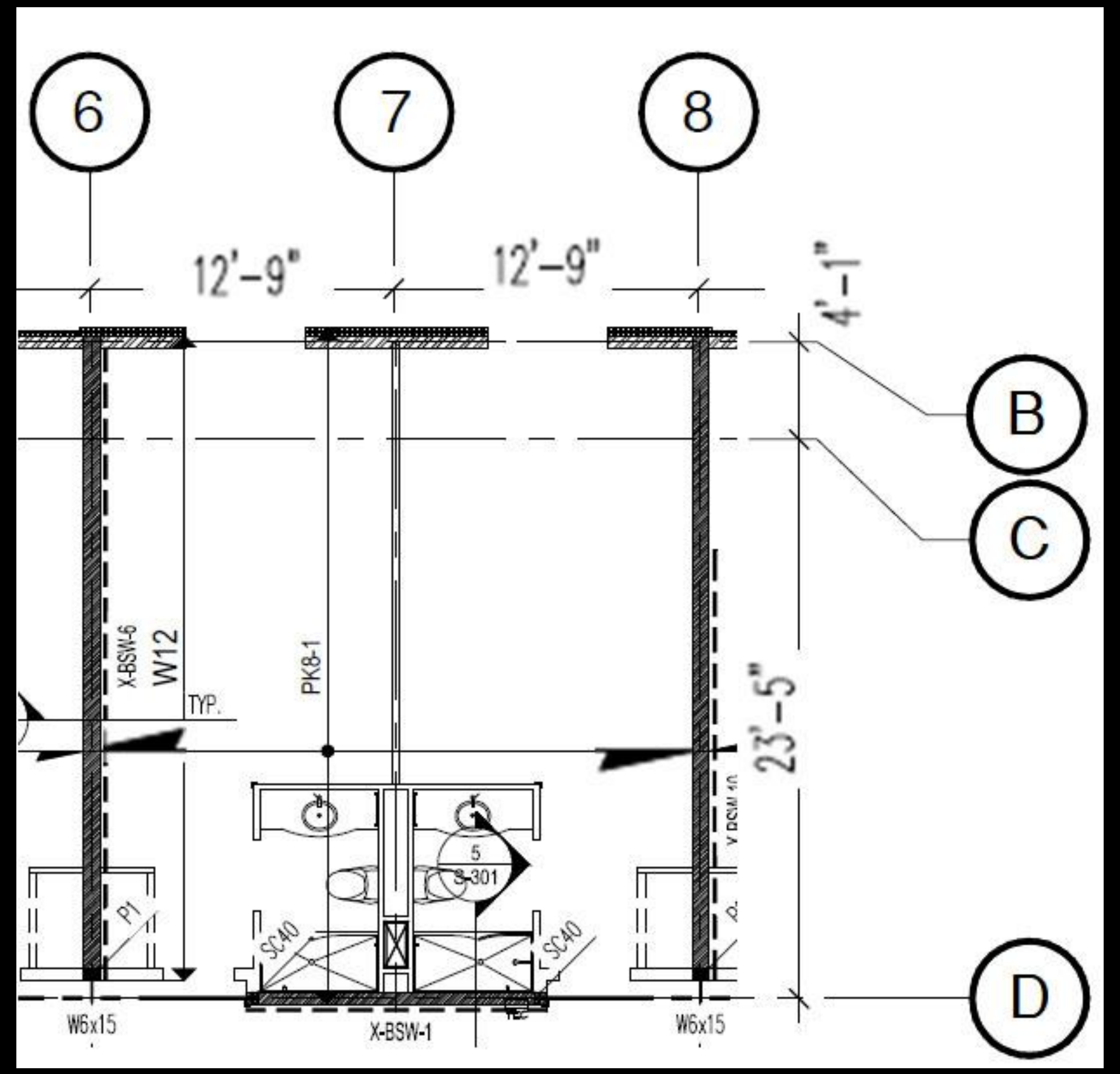
Gravity System

Typical Bay

4”-8”x4’ precast hollow core planks resting on light gage steel stud bearing walls at every other column line

Source: http://www.oldcastleprecast.com/





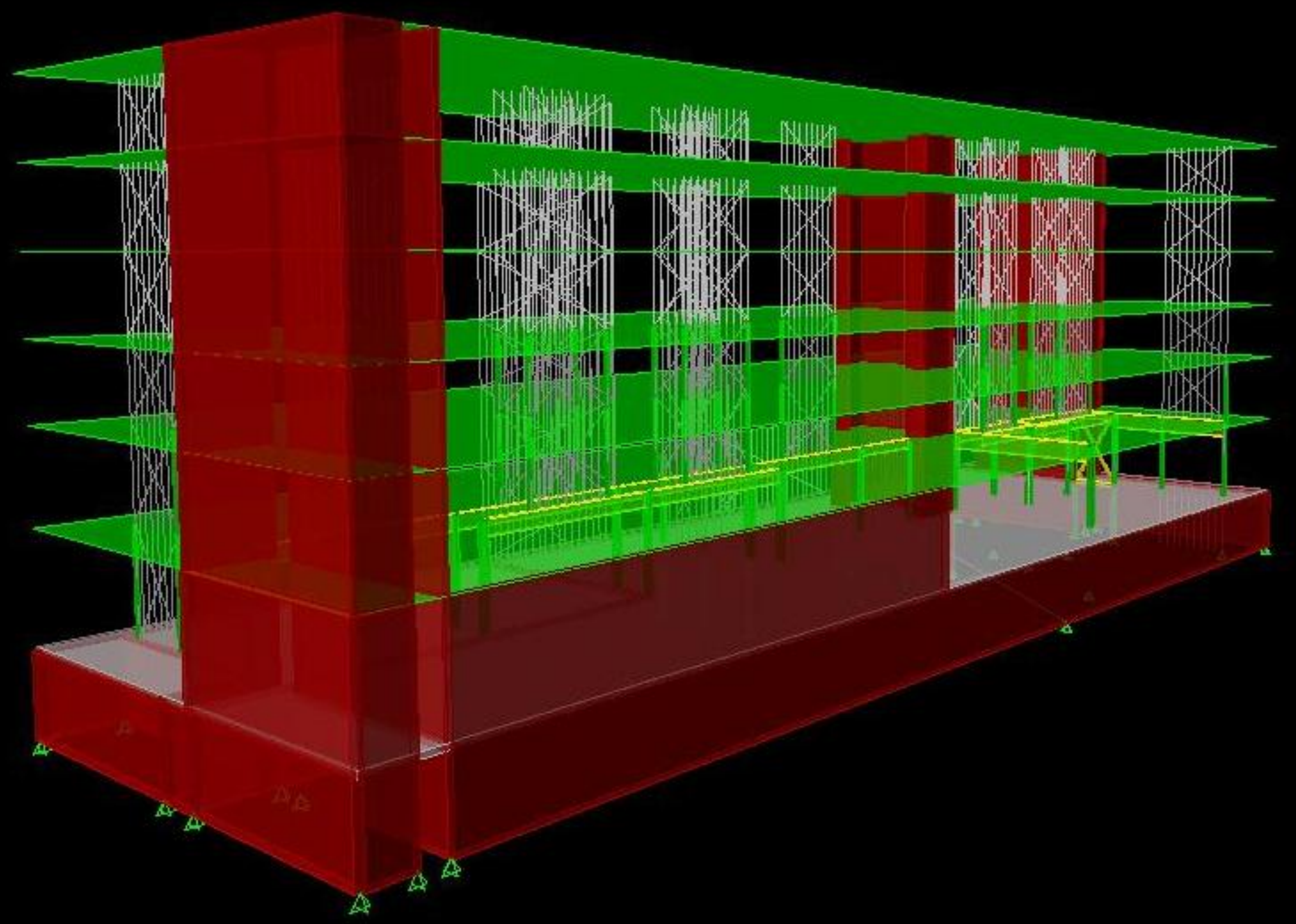
Lateral System

Three lateral elements resist the lateral forces in the Mountain Hotel

Flat Strap Braces

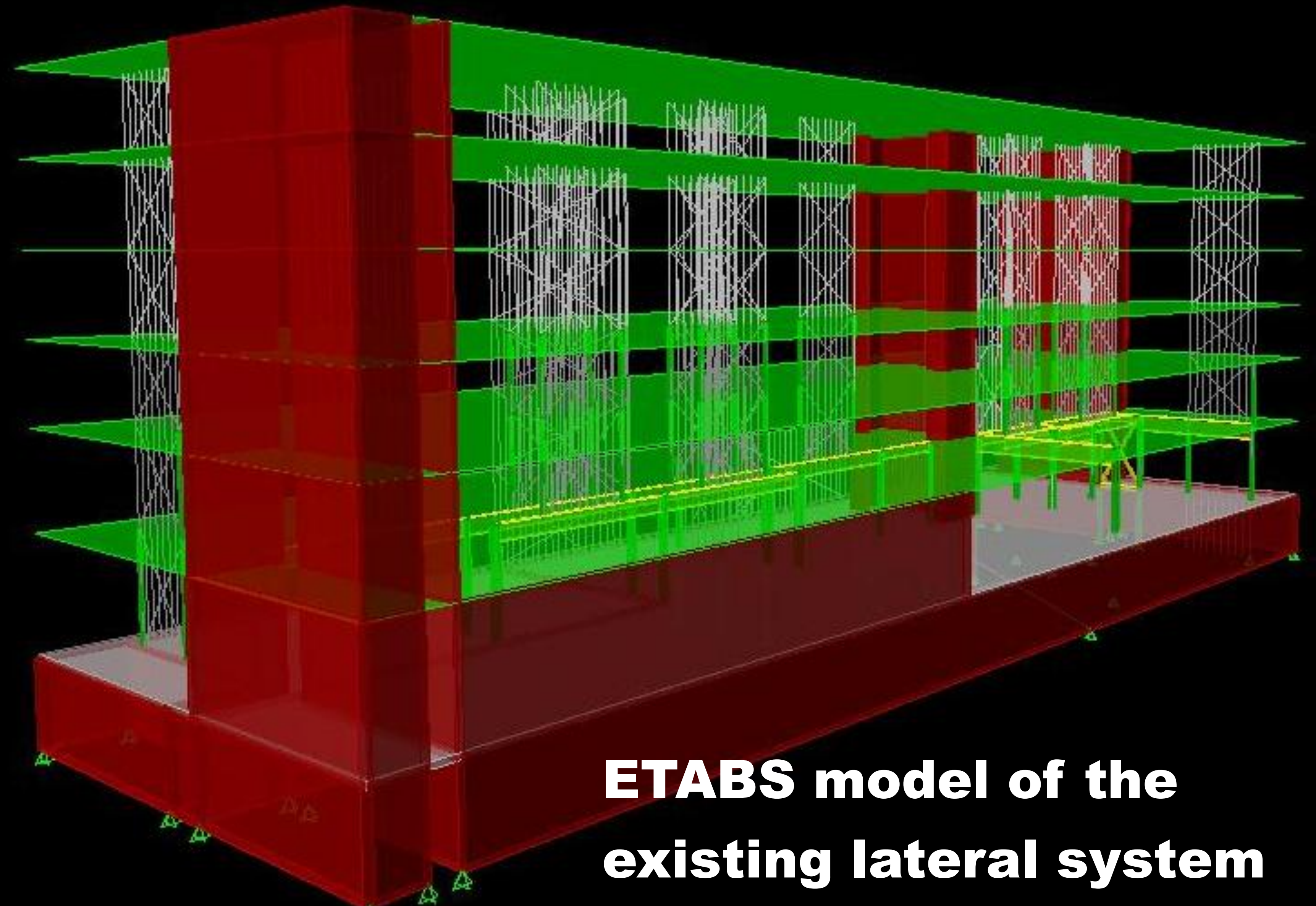
Specially Reinforced Masonry Shear Walls

Concrete Foundation Walls



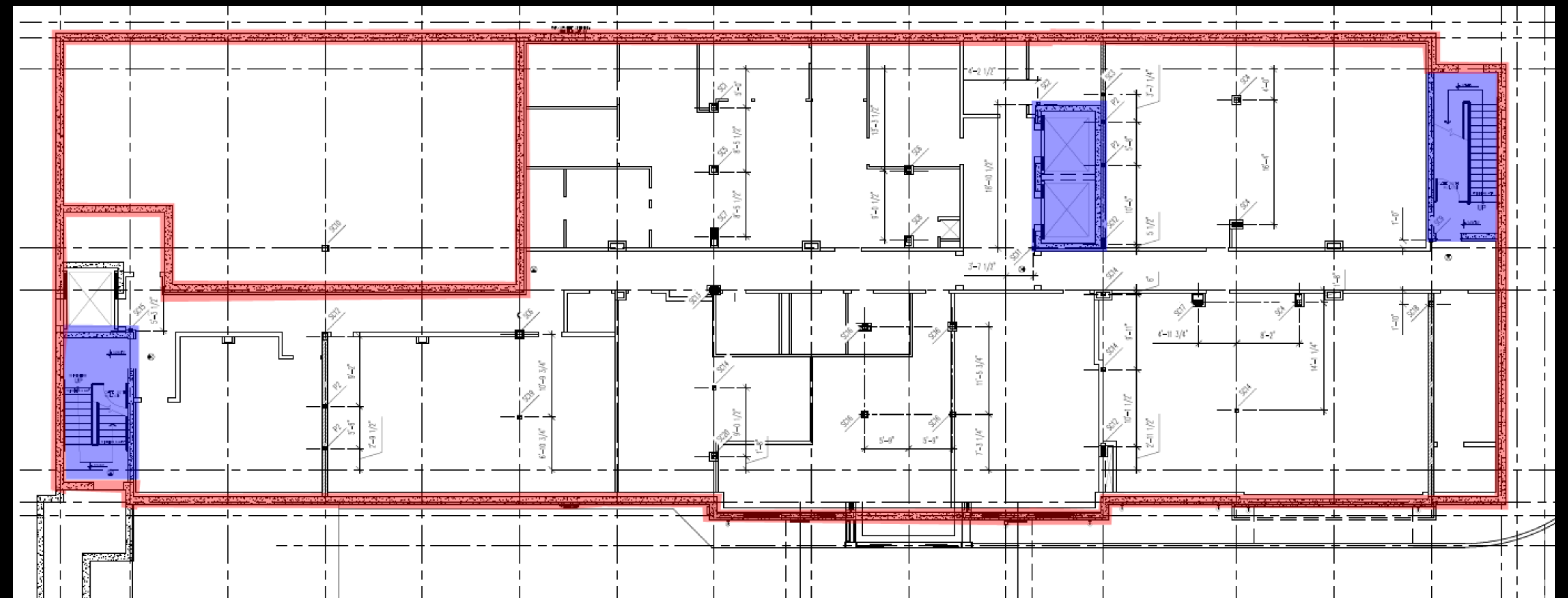
Mountain Hotel

Lateral System

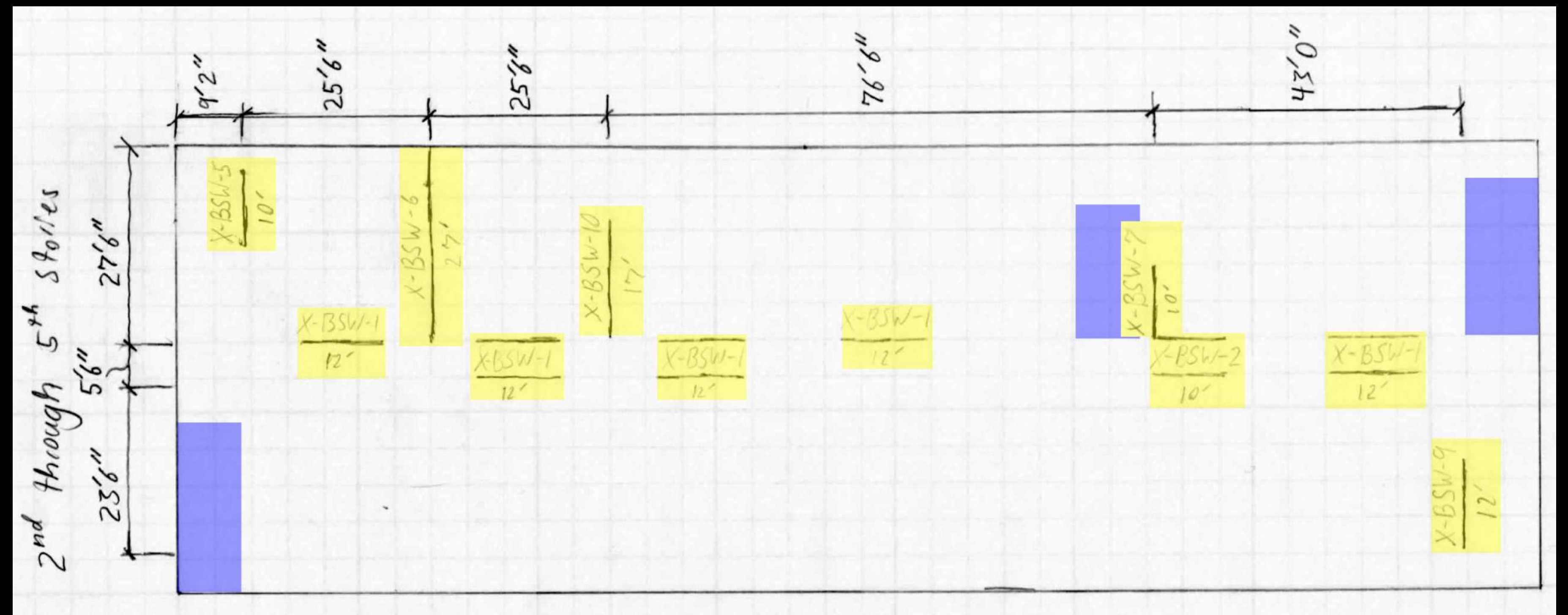


ETABS model of the existing lateral system

Basement plan showing location of Concrete Foundation walls in red, and location of Specially Reinforced Masonry Shear Walls surrounding stair and elevator bays in blue.



Typical upper story layout of lateral elements with light gage flat strap bracing walls shown in yellow



Mountain Hotel

Existing Structure

Lateral system more than adequate

Existing floor system most efficient compared to several alternatives

	Systems			
	Existing	Alternatives		
Consideration	Precast Hollow Core Planks	Composit Steel Deck on W-Shapes on Shear Walls	One-way Concrete Joist System	Two-way Flat Plate
General Information				
Weight	57 psf	66.8 psf	79.5 psf	118 psf
Fire Rating	2-Hr	2-Hr	2-Hr	2-Hr
Fire Protection	Thickness of Planks Adaquate for Fire Protection	Requires Additional Fireproofing for underside of Deck and Beams	Thickness of Slab Controlled by Fire Protection Criteria	Thickness of Slab Adaquate for Fire Protection
Architectural				
Bay Size	25' 6" x 27' 6"	25' 6" x 27' 6"	25' 6" x 33' 0"	25' 6" x 33' 0"
Overall Depth	10"	14"	22"	9.5"
Slab Depth	10"	6"	5"	9.5"
Ceiling Height	8' 6"	8' 2"	8' 11"	8' 6.5"
Other	Exposed Ceilings	Requires a Ceiling	Can Expose Ceilings for Queen Rooms Only Without Obstructions	Exposed Ceilings
Structural				
Gravity System Considerations	No Change	Special Considerations for Attachment of Beams to Walls	Redesign using Concrete Columns	Redesign using Concrete Columns
Lateral System Considerations	No Change	No Change	Redesign using Concrete Moment Frames	Change From Light Gauge to Concrete Shear Walls
Foundation Considerations	No Change	Very Similar	Increase Foundation Size to Carry Larger Building Weight	Increase Foundation Size to Carry Larger Building Weight
Construction				
Assembly Cost	$13.23/sf	$23.9/sf	$15.78/sf	$15.24/sf
Formwork Required	None	Minimal	Yes	Yes
Constructability	Easy	Slightly Moderate	Slightly Difficult	Moderate
Lead Time	Long	Moderate	Moderate	Moderate
Servicability				
Vibration and Deflection Control	Slightly Moderate	Moderate	Great	Good
Feasible	Yes	No	No	Yes
Reason		Significant increase in price, requires a ceiling, reduces ceiling height	King and ADA Rooms would have a low ceiling height due to 22" deep beam in center of ceiling	

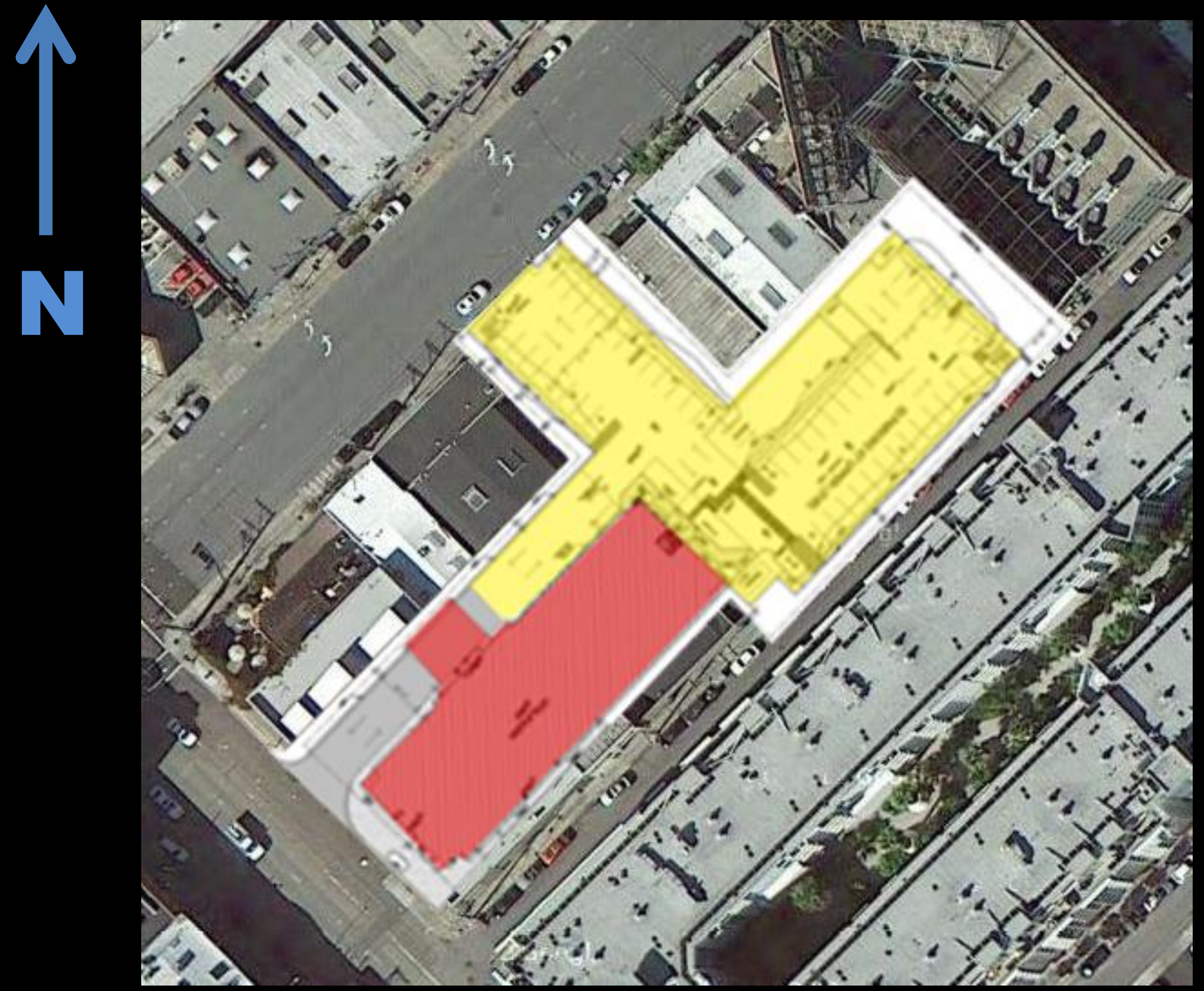
Problem Statement

Interest in expanding knowledge on the seismic design of reinforced concrete

New scenario created

The owner of the Mountain Hotel would like to evaluate the use of existing design parameters for a reinforced concrete design able to be occupied immediately after a seismic event in San Francisco

New Site



Proposed Solution

Redesign the structure of the Mountain Hotel to reinforced concrete.

- **Using a Flat Slab floor system**
- **Concrete Columns for Gravity Loading**
- **Specially Reinforced Concrete Shear Walls for lateral resistance**

Design the lateral system such that the drift is less then the recommended limit in ASCE 41-06.

Create an ETABS model of the lateral system and evaluate including torsional P-Delta effects.

MAE coursework was used to accomplish all of the above tasks.

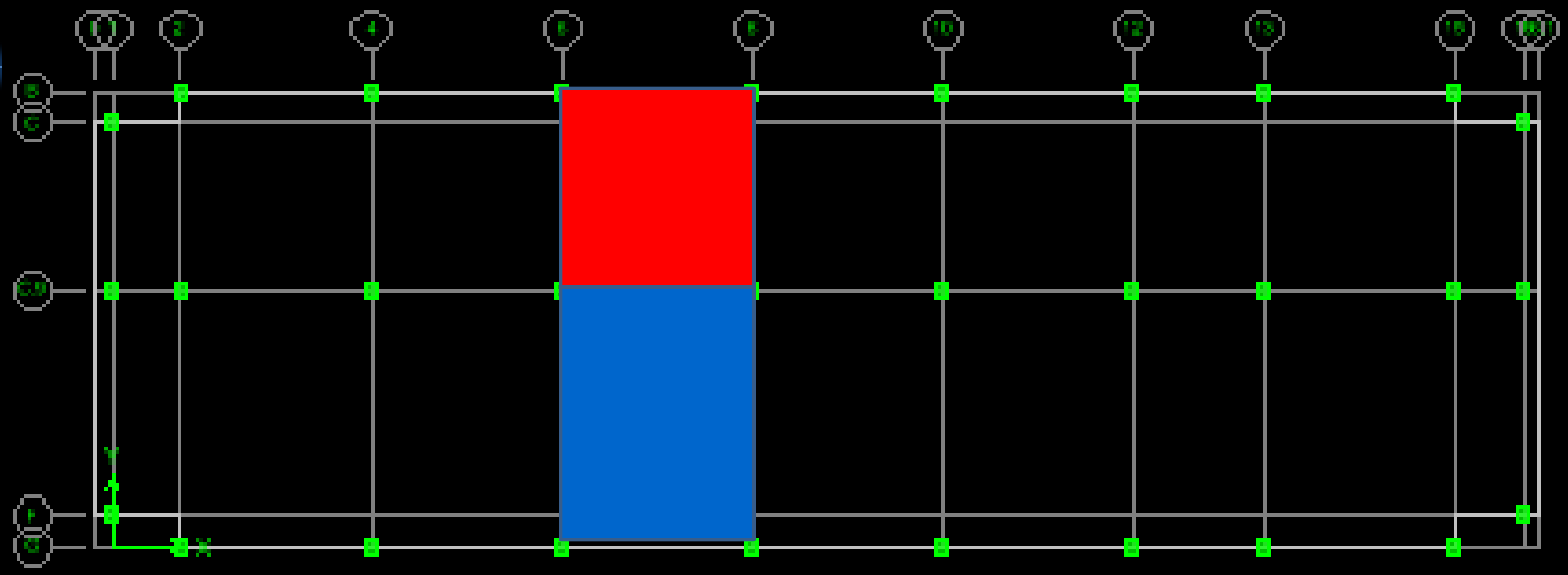
Impact on Other Building Systems

Glazing Thermal Load Evaluation

Thermal load through existing glazing was evaluated for each location and it was to be determined what glazing would be needed to produce similar heat gain as original design.

Acoustic Sound Isolation Analysis

The acoustic properties of the two floor systems were to be analyzed to show that the new floor system meets the same standard as the existing floor system. (This analysis will not be covered in this presentation)



Controlling Load Combination:

1.2D + 1.6L

Flat Slab Design

Bays were divided up using the existing bearing walls between the upper story hotel rooms as natural bay divisions. The decision was made to use only one central column line to eliminate the 5' central span. This created several larger 34' x 26' (shown in blue) on one side, and a smaller 27' x 26' span (shown in red).

Gravity Redesign

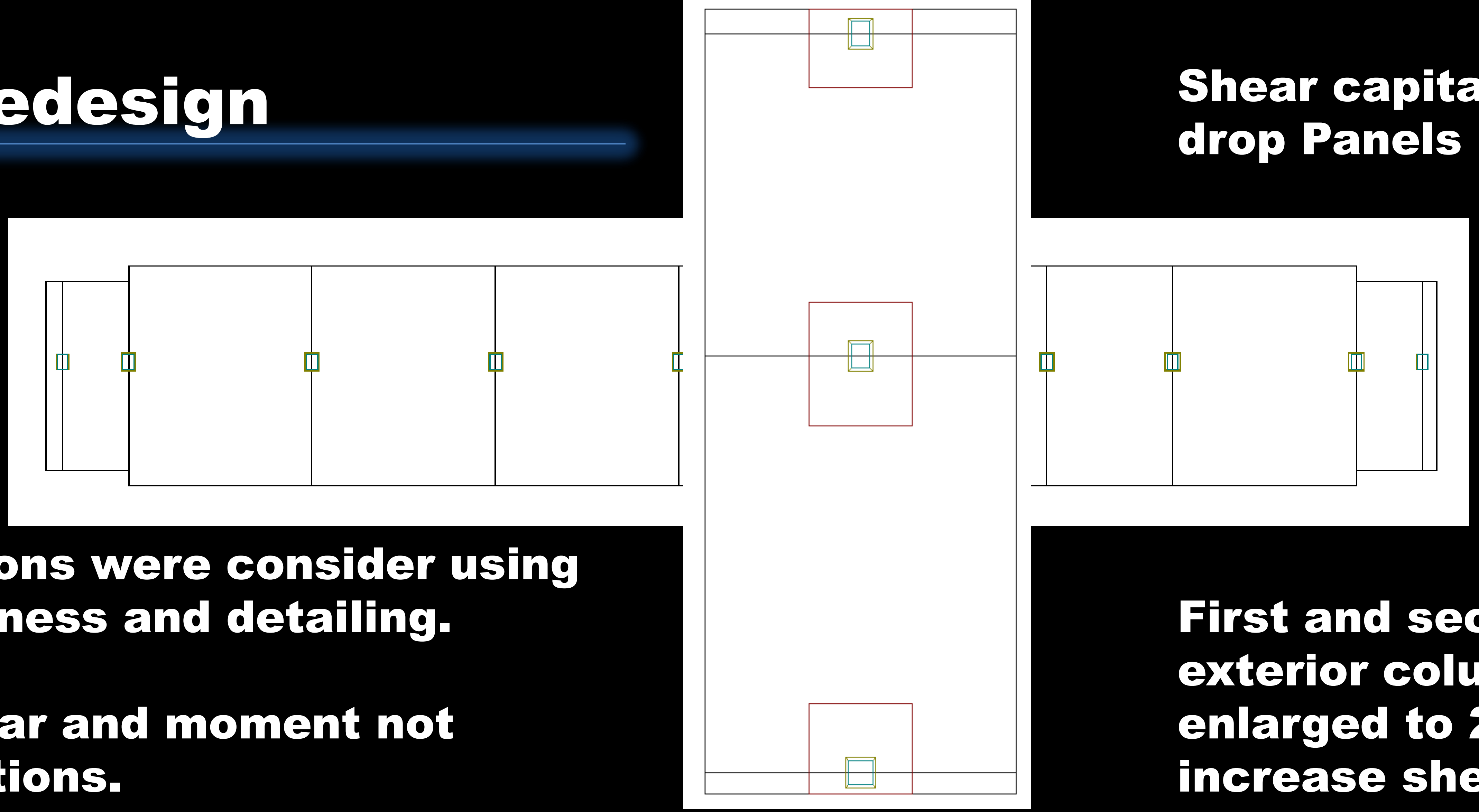
Flat Slab Design

A 24” x 18” column size for slab thickness calculation

Typical column strip sections were consider using SPSlab to determine thickness and detailing.

Inclusion of combined shear and moment not consider in hand computations.

Deflections controlled thickness to 12”



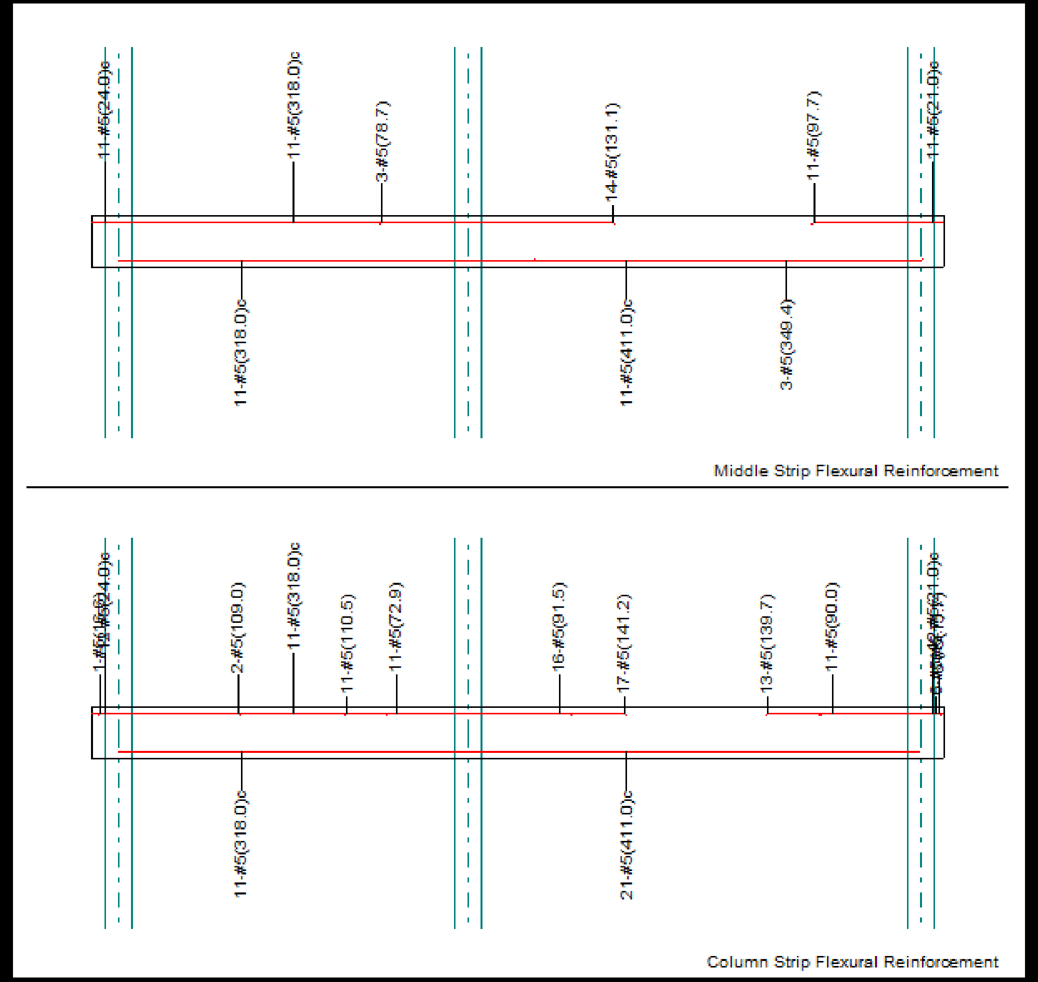
Shear capitals and some drop Panels Required

First and second floor exterior columns were enlarged to 24” x 24” to increase shear resistance.

Mountain Hotel

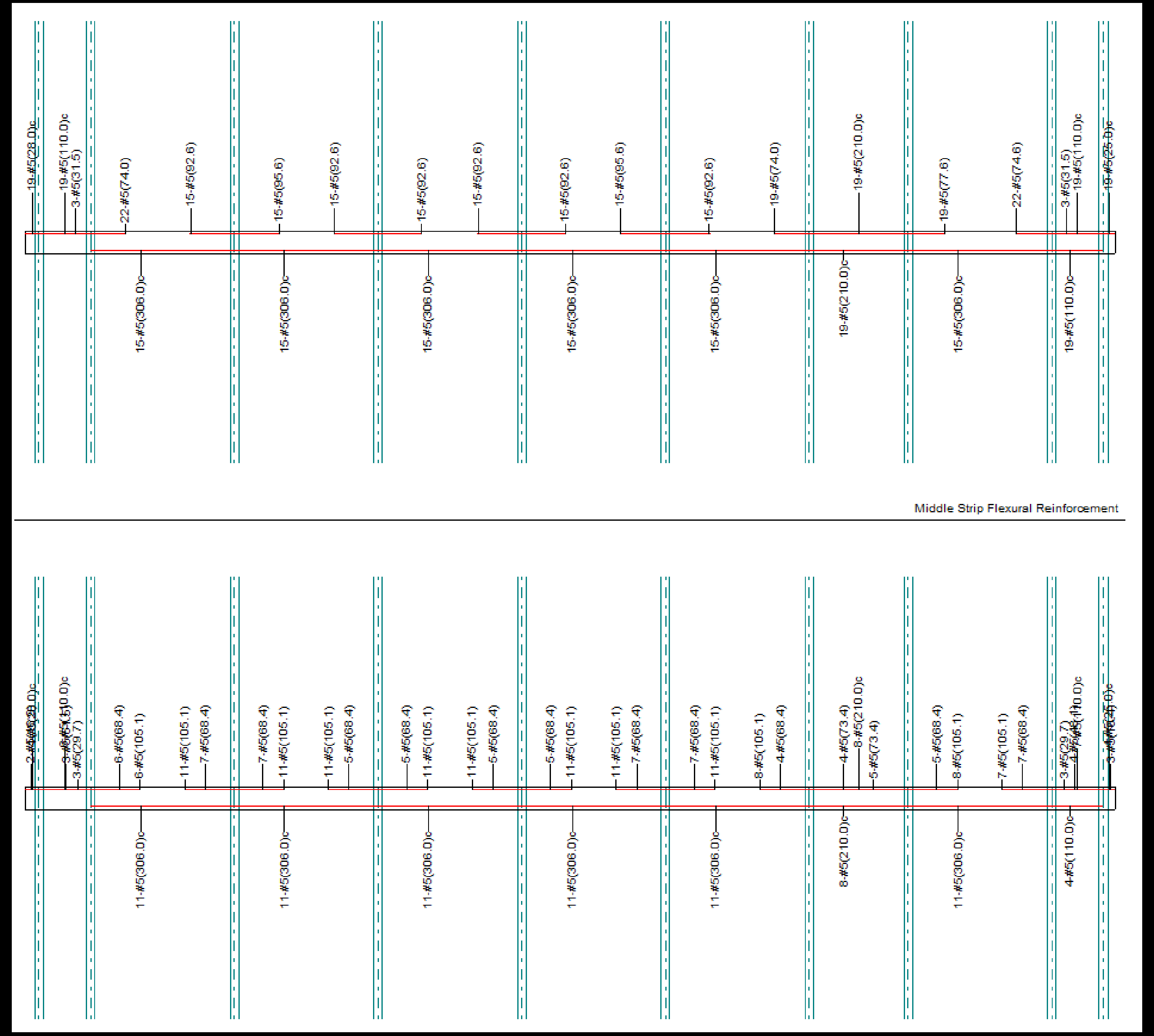
Gravity Redesign

- Introduction
- Existing Structural Systems
- Thesis Proposal
- **Concrete Redesign**
- Glazing Evaluation
- Conclusions
- Questions/Comments

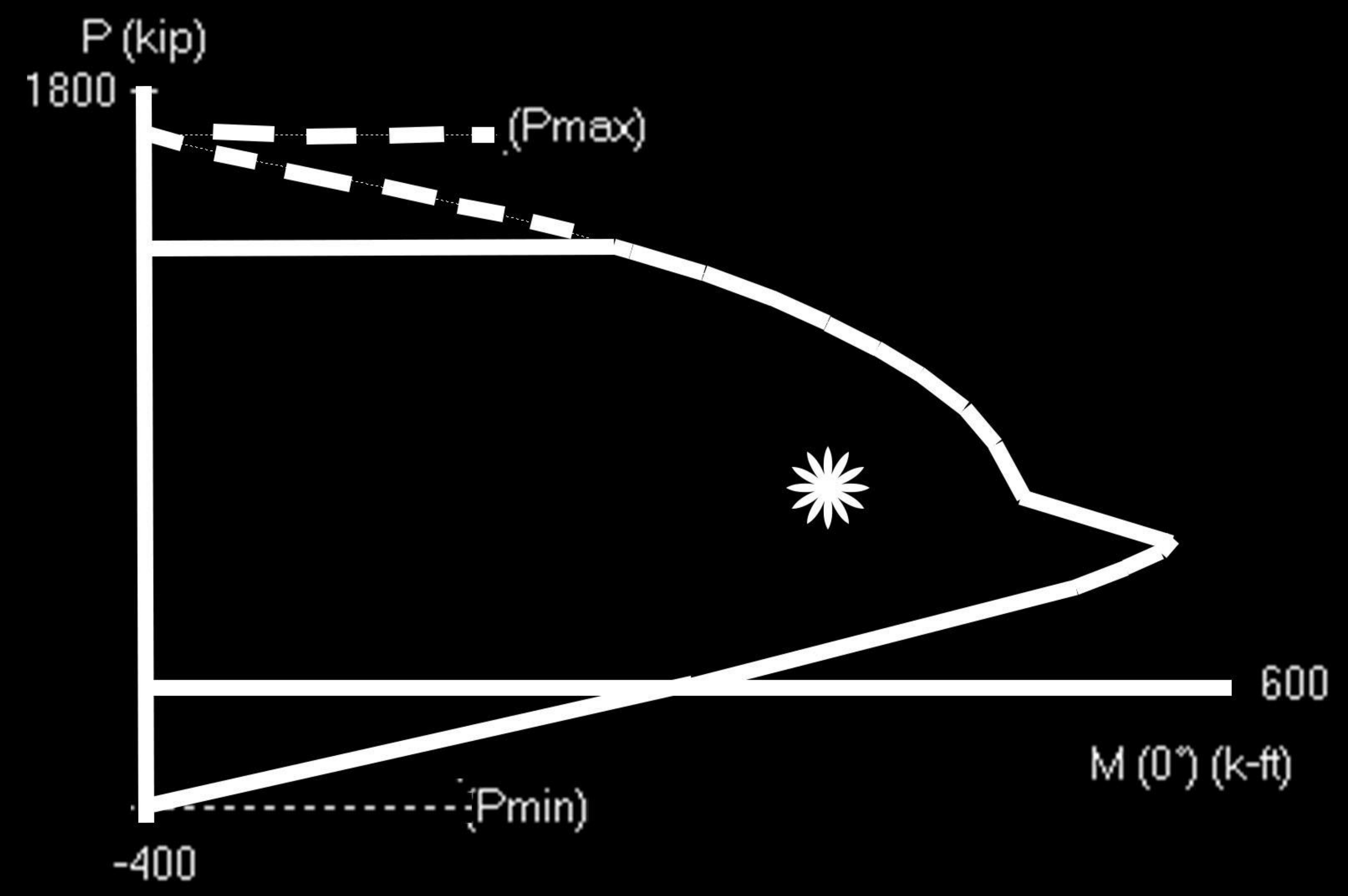


Left: Reinforcement of a 1st story bay

RIGHT: Reinforcement in a typical upper story bay



Gravity Redesign



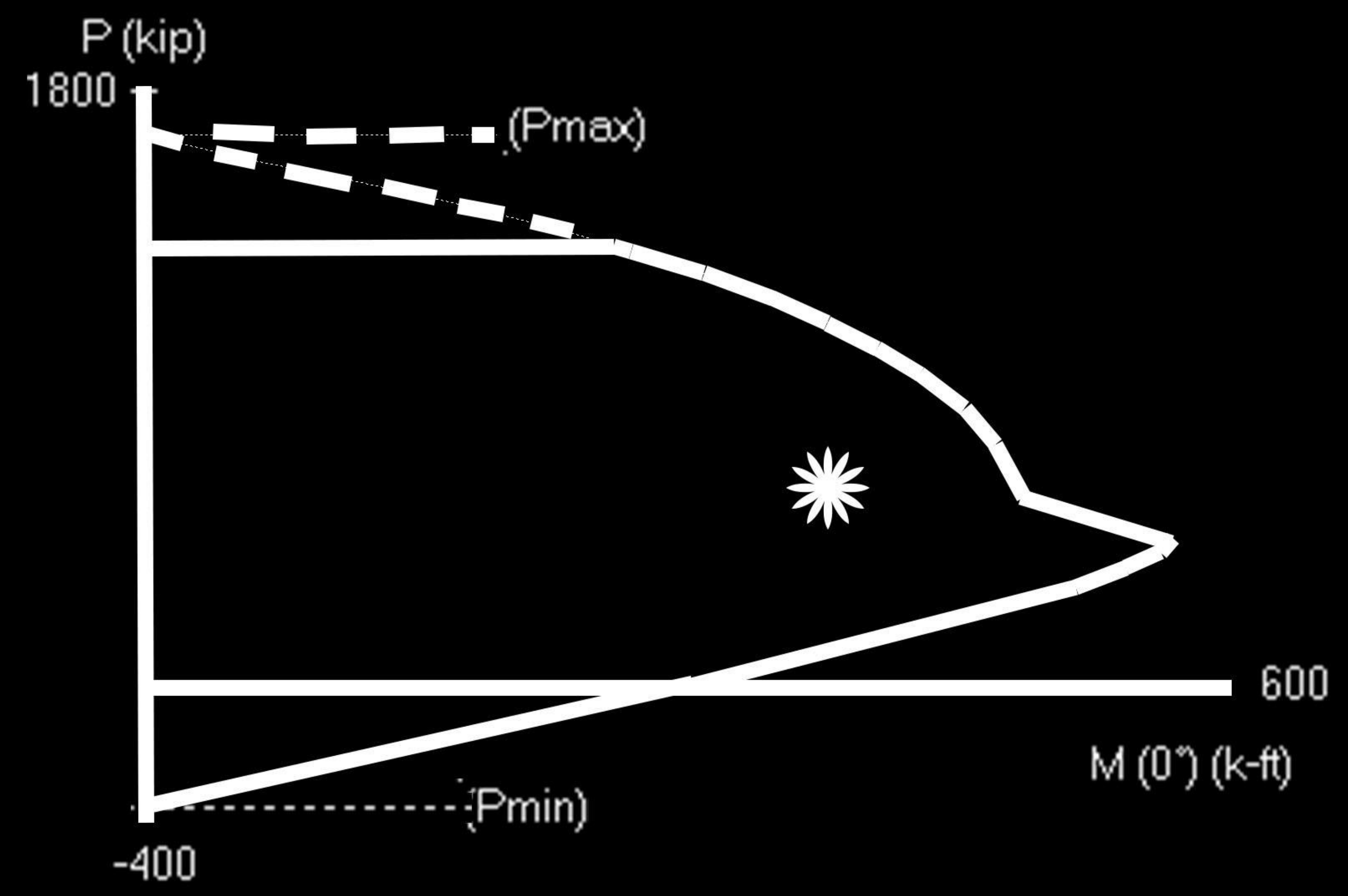
Column Design

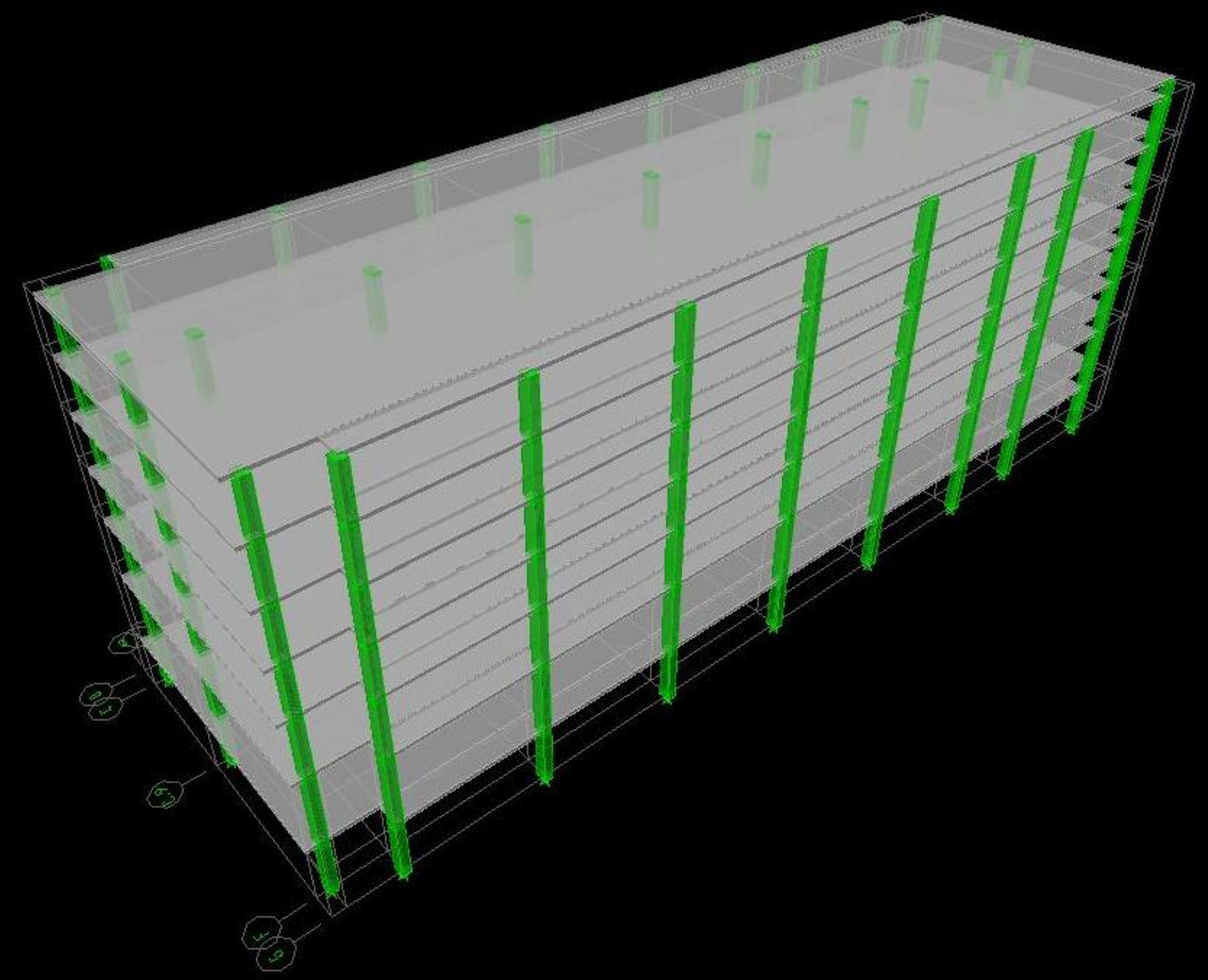
Maximum column axial loads were determined by tributary area above.

Live loads were reduced per ASCE 7-10 where less than 100psf.

Column eccentricity from SPSlab analysis performed for the design of the floor system.

Gravity Redesign





Immediate Occupancy Design Philosophy

Approach to Immediate Occupancy Design

During a design seismic event if the structure does not deflect greater than the amount which causes damage requiring repair before re-occupancy can begin than the structure will satisfy Immediate Occupancy

Inter-story Drift limits:

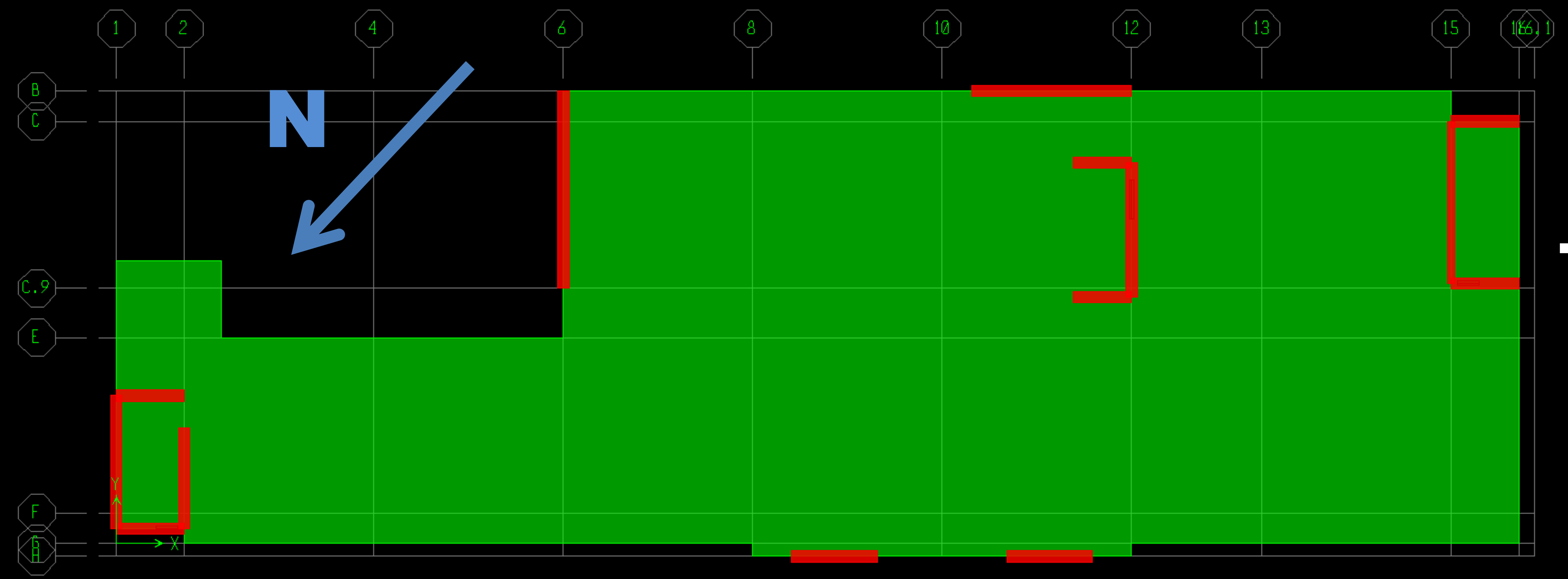
ASCE7-10 Seismic limit: 0.020hsx/(Cd/Ie)

ATS-192 General Glazing Guidelines: hsx/175

ASCE41-06: 0.005 hsx

Lateral Redesign

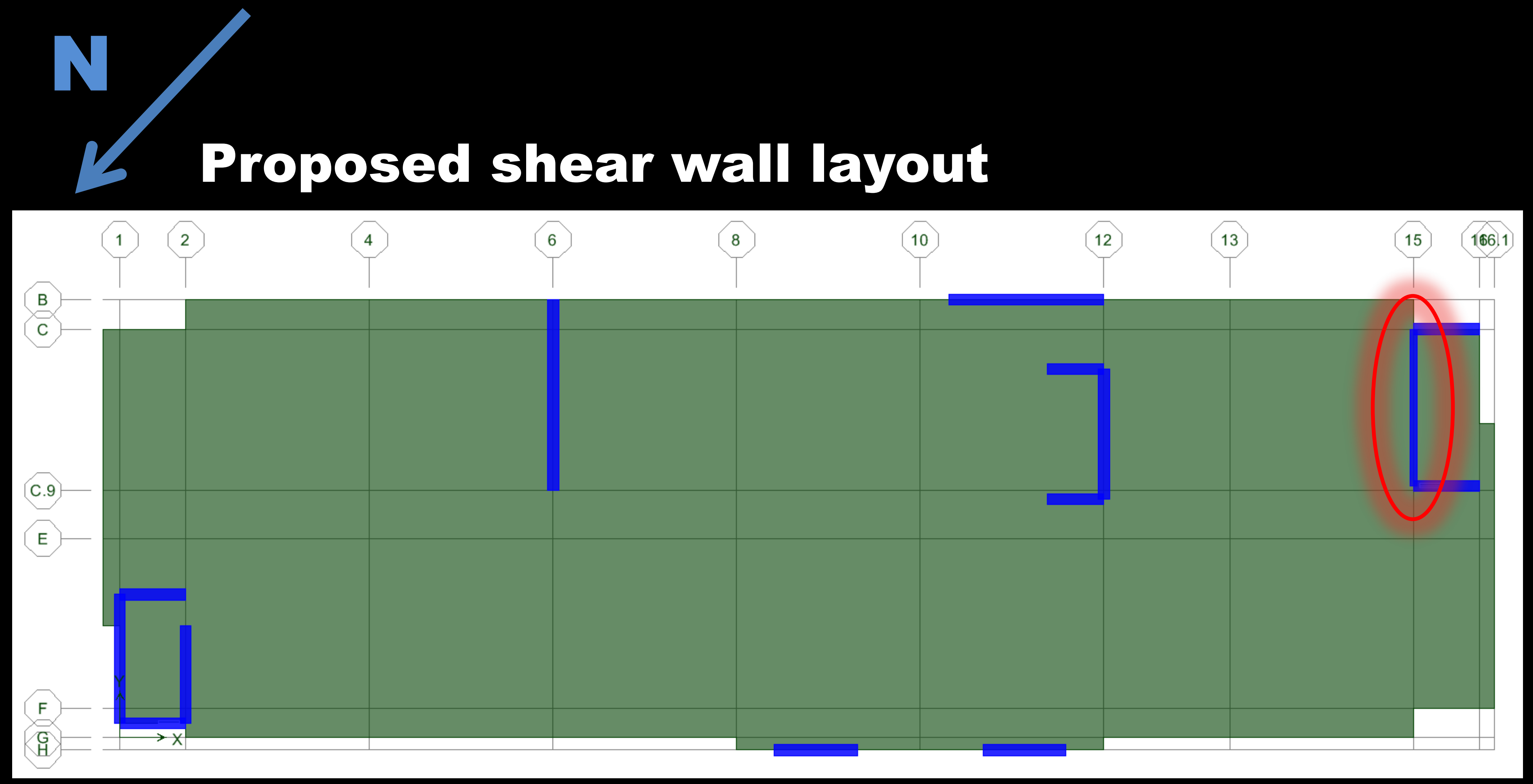
Proposed shear wall layout



To minimize impact on existing architecture:

- **Stair and elevator towers**
- **In solid walls**
- **Maintains original function**

Lateral Redesign



9 x 18" thick shear walls required to resist story drift in x-direction

5 x 18" thick shear walls used to resist story drift in y-direction

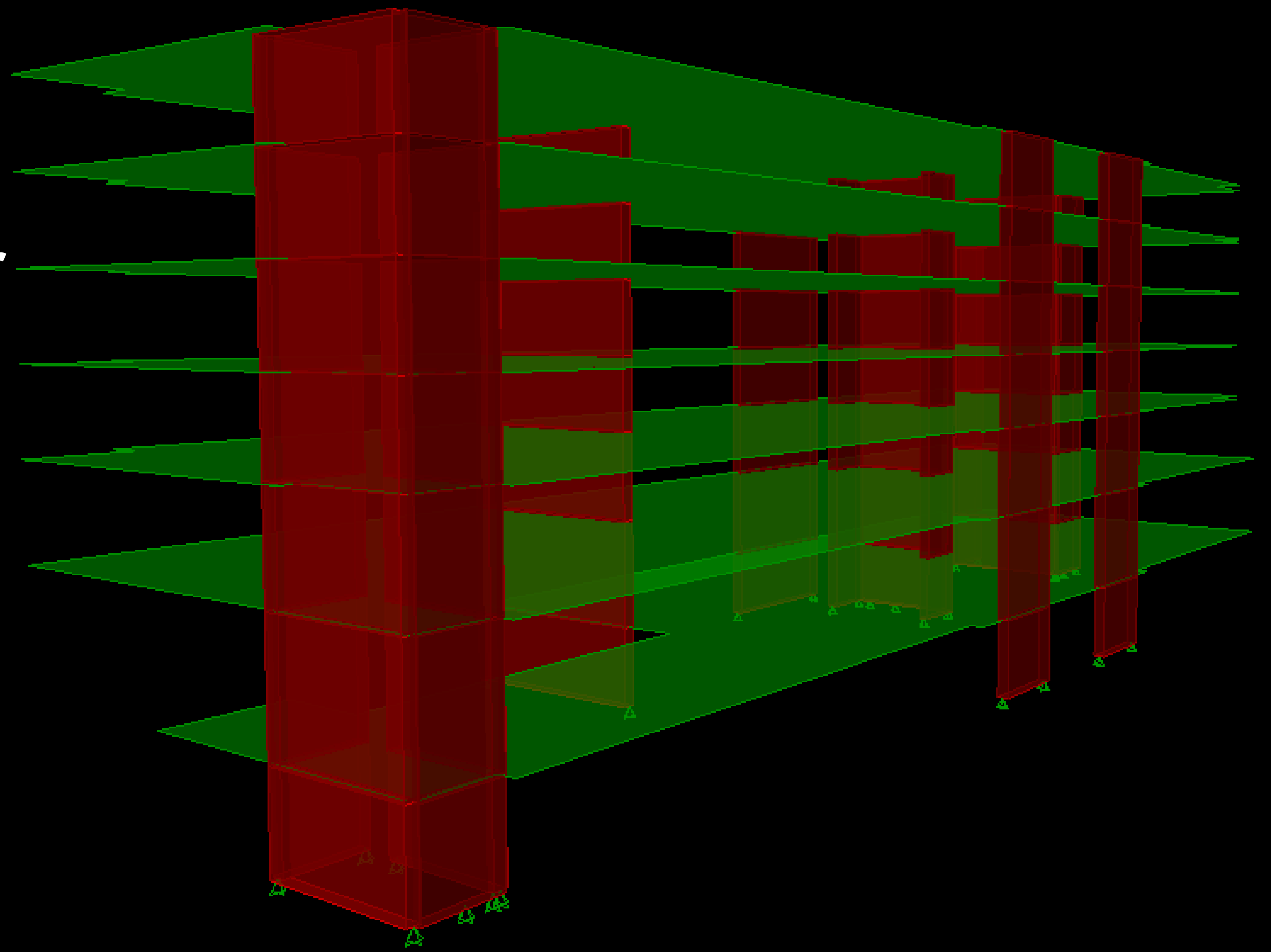
The wall called out in red was reduced to 12" after torsional analysis was performed.

Lateral Redesign

BOTTOM: Drifts including torsional irregularity and P-Delta compared to limits

Right: ETABS lateral model used to consider torsional irregularity and P-Delta Effects

Story	Height (in)	Load	DriftX (in/in)	DriftY (in/in)	Load	DriftX (in/in)	DriftY (in/in)	Max Drift X (in)	Max Drift Y (in)	Allowable Drift (in)
ROOF	112.00	EY	0.000103	0.001483	EYT	0.000084	0.000238	0.020944	0.192752	0.4480
STORY6	112.00	EY	0.000102	0.001468	EYT	0.000083	0.000236	0.02072	0.190848	0.4480
STORY5	112.00	EY	0.000093	0.001421	EYT	0.00008	0.000229	0.019376	0.1848	0.4480
STORY4	112.00	EY	0.00008	0.001321	EYT	0.000074	0.000214	0.017248	0.17192	0.4480
STORY3	134.00	EY	0.000061	0.001128	EYT	0.000062	0.00018	0.016482	0.175272	0.5360
STORY2	159.00	EY	0.000033	0.000778	EYT	0.000042	0.000126	0.011925	0.143736	0.6360
STORY1	120.00	EY	0.000007	0.000335	EYT	0.000018	0.000055	0.003	0.0468	0.4800
TOTAL	861.00							0.1097	1.1061	3.4440



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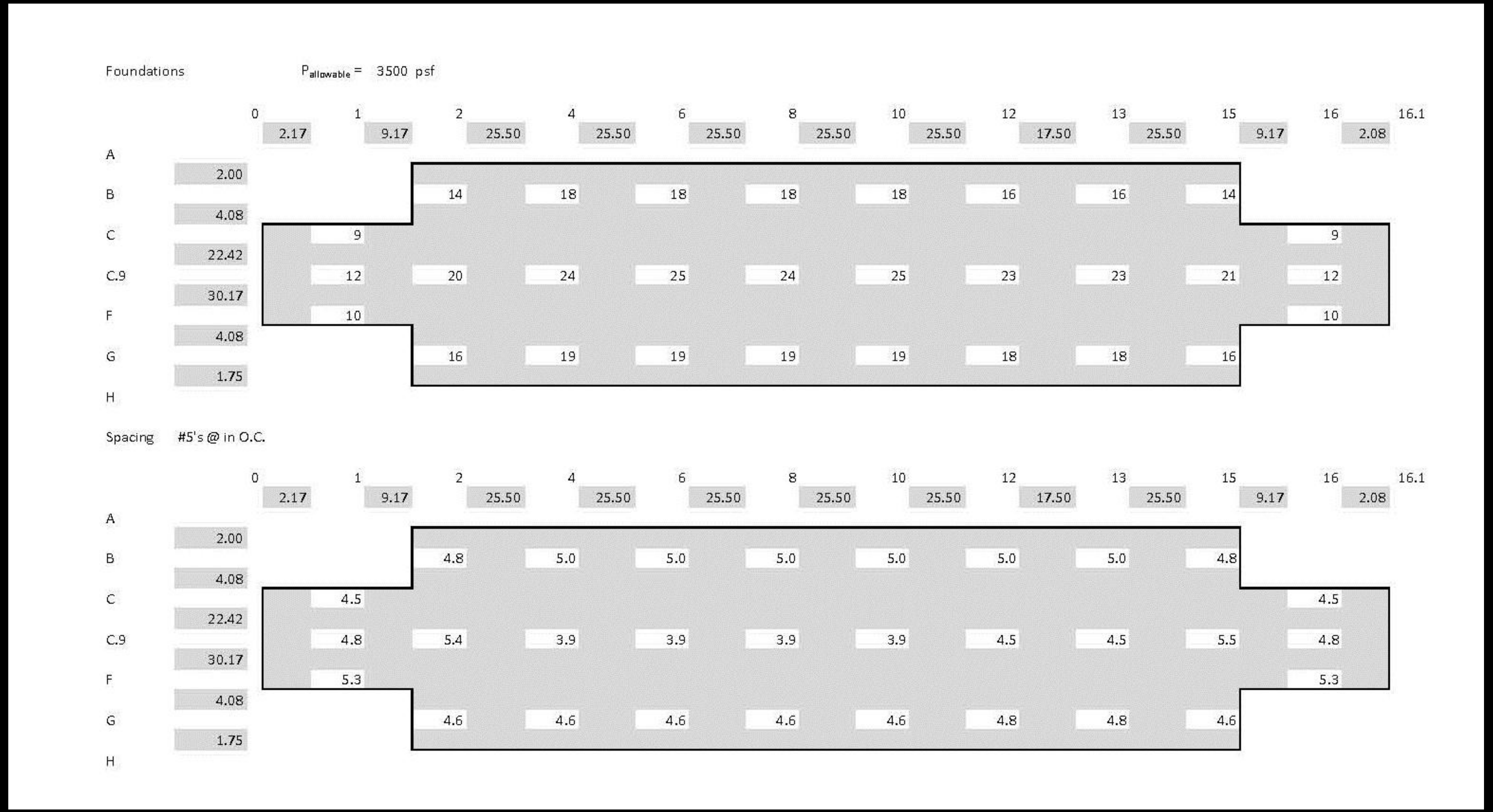
Foundation Redesign



Foundations $P_{allowable}$ = 3500 psf

	0	1	2	4	6	8	10	12	13	15	16	16.1
	2.17	9.17	25.50	25.50	25.50	25.50	25.50	17.50	25.50	9.17	2.08	
A												
(2.00)												
B			14	18	18	18	18	16	16	14		
(4.08)												
C		9									9	
(22.42)												
C.9		12	20	24	25	24	25	23	23	21	12	
(30.17)												
F		10									10	
(4.08)												
G			16	19	19	19	19	18	18	16		
(1.75)												
H												

Spacing #5's @ in O.C.

	0	1	2	4	6	8	10	12	13	15	16	16.1
	2.17	9.17	25.50	25.50	25.50	25.50	25.50	17.50	25.50	9.17	2.08	
A												
(2.00)												
B			4.8	5.0	5.0	5.0	5.0	5.0	5.0	4.8		
(4.08)												
C		4.5									4.5	
(22.42)												
C.9		4.8	5.4	3.9	3.9	3.9	3.9	4.5	4.5	5.5	4.8	
(30.17)												
F		5.3									5.3	
(4.08)												
G			4.6	4.6	4.6	4.6	4.6	4.8	4.8	4.6		
(1.75)												
H												

From geotechnical report:

Not prone to soil liquefaction

Allowable Soil Bearing: 3500psf

Service loads calculated for base of each column

Allowable bearing used to size footings
Punching shear used to determine depth

Rebar spacing determined assuming #5 bars used frequently in slab detailing

Mountain Hotel

Existing Glazing Thermal Analysis

- Introduction
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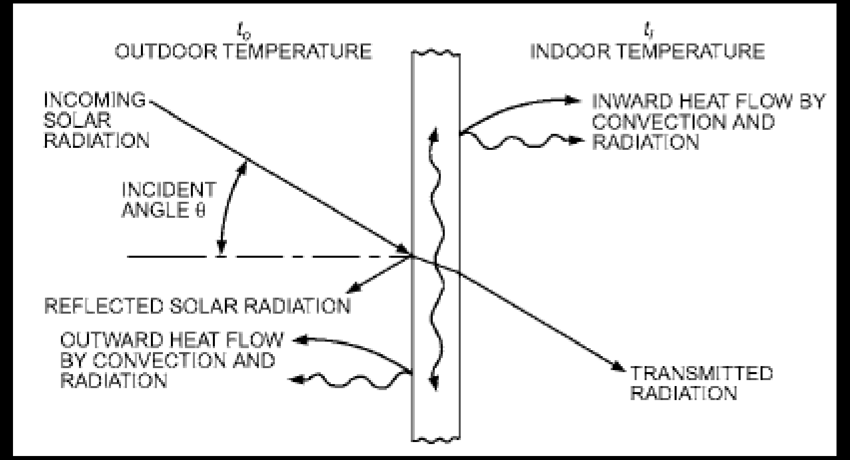


Heat from the sun enters the building using three different processes:

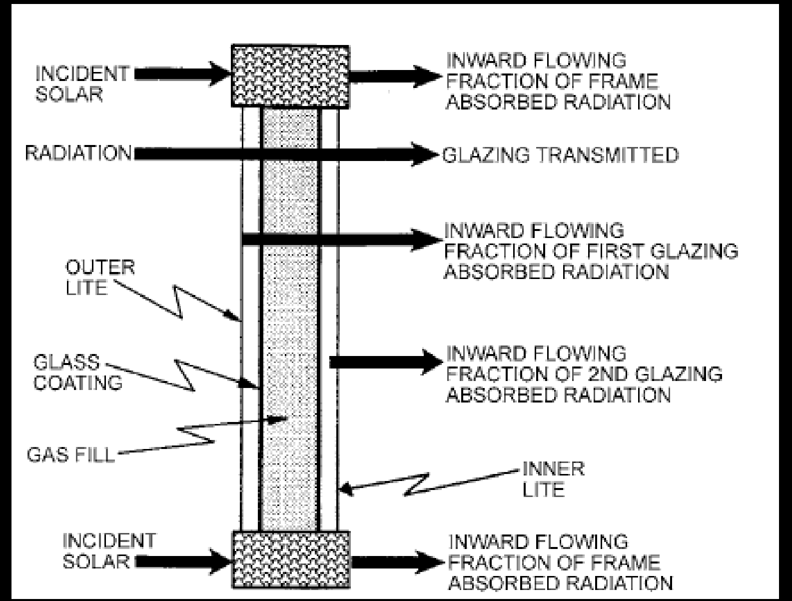
- Direct Radiation
- Diffused Radiation
- Convection

Source: Pilkington Catalogue

Double Glass Performance Data[1, 10]

	Nominal Glass Thickness		Visible Light[2]			Solar Energy[2]			U-Factor[5]						Solar Heat Gain Coefficient[7]	Shading Coefficient[8]
			Transmittance[3]	Reflectance[4] %		Transmittance[3] %	Reflectance[4] %	UV Transmittance[2] %	U.S. Summer*		U.S. Winter*		Europe**			
	in.	mm		Outside	Inside				Air	Argon	Air	Argon	Air	Argon		
Pilkington **Eclipse Advantage**™ Outer Lite (Coating on #2 Surface) and Pilkington **Optifloat**™ Clear Inner Lite																
Clear	1/4	6	60	29	31	46	21	24	0.35	0.30	0.35	0.30	1.9	1.6	0.55	0.63
Grey	1/4	6	29	10	29	23	9	8	0.35	0.30	0.35	0.30	1.9	1.6	0.33	0.39
Bronze	1/4	6	34	13	29	28	11	9	0.35	0.30	0.35	0.30	1.9	1.6	0.38	0.44
Blue-Green	1/4	6	51	21	29	29	12	13	0.35	0.30	0.35	0.30	1.9	1.6	0.38	0.44
EverGreen	1/4	6	43	17	30	20	9	6	0.35	0.30	0.35	0.30	1.9	1.6	0.29	0.33
Arctic Blue	1/4	6	35	13	30	19	9	9	0.35	0.30	0.35	0.30	1.9	1.6	0.29	0.33

Two pane glass with a low-e coating on the inner face of the outside pane



Mountain Hotel

Comparison of Heat Gain

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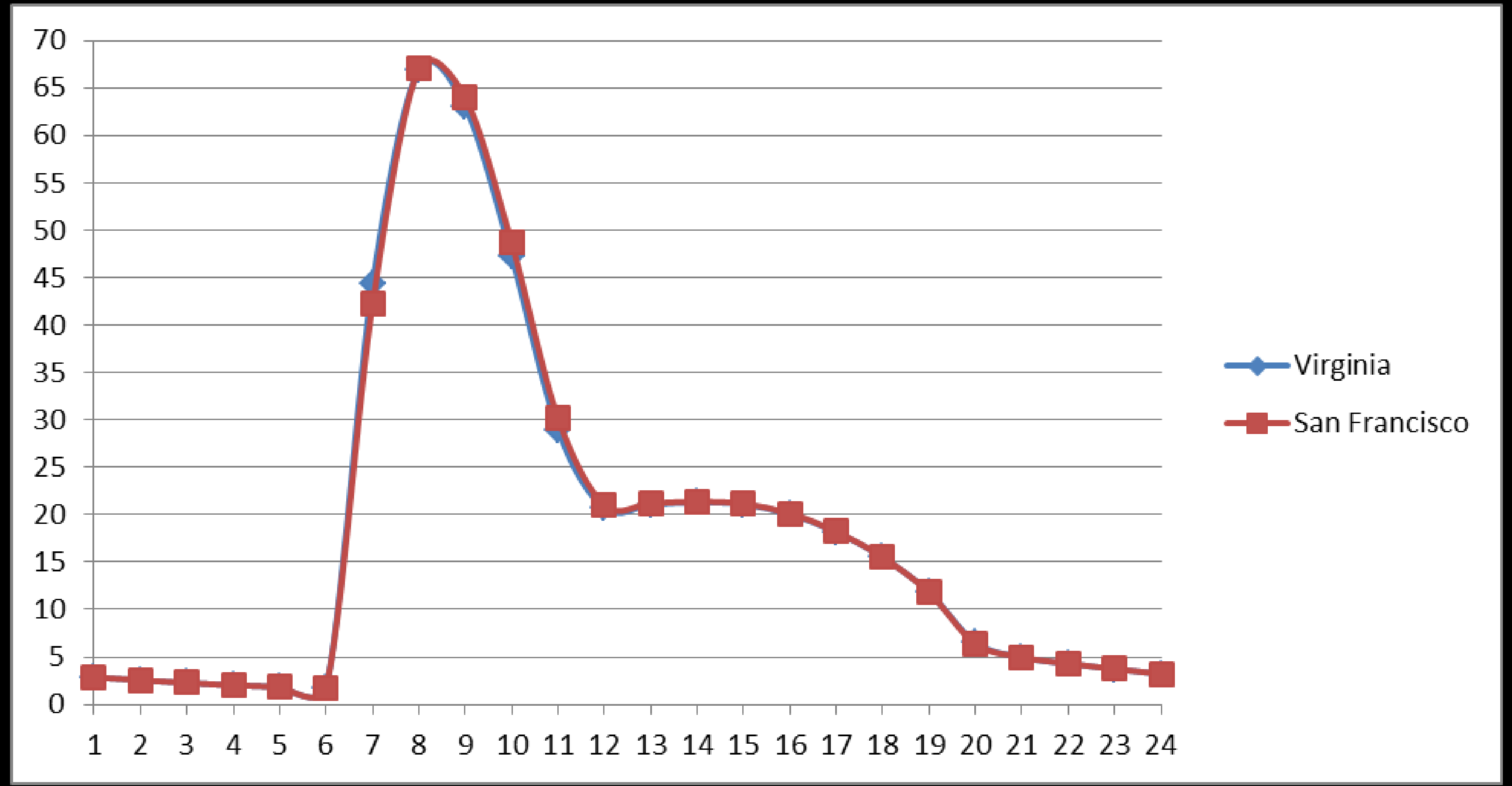


Thermal load plotted for a 24 hour period

Same orientation as original building

Compared each side as a BTU/sf/hr value for 21day of hottest month of year

Greatest difference in thermal load through glazing was 0.5% greater that of the original design.

Same glazing can be used

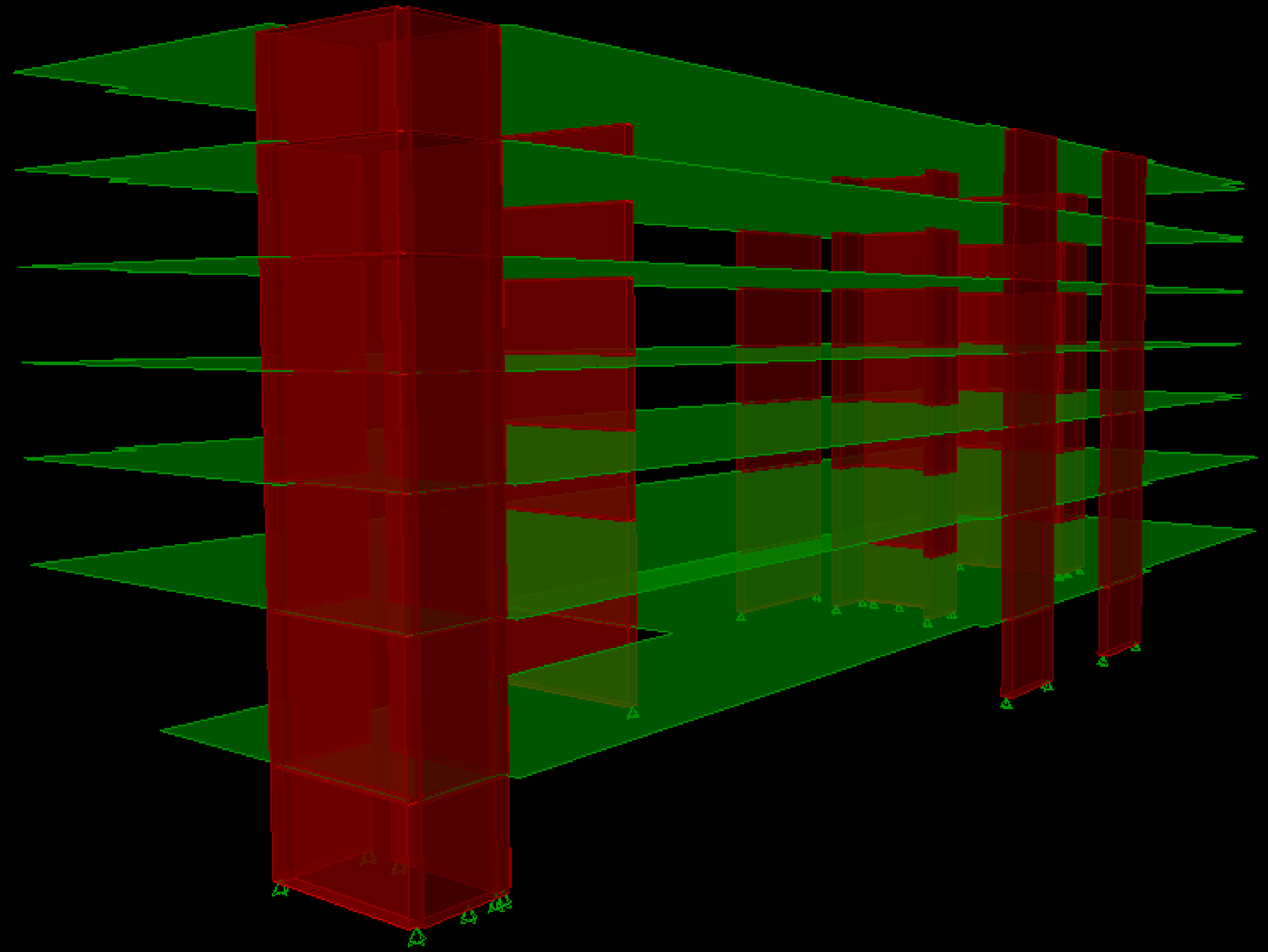
Design Summary

Summary:

Slabs:
12” thick with #5 bars spaced as noted

Columns:
24” x 18”-24” with (8) #8

Shear Walls:
12”-18” thick from foundation to roof



Mountain Hotel

Questions & Comments

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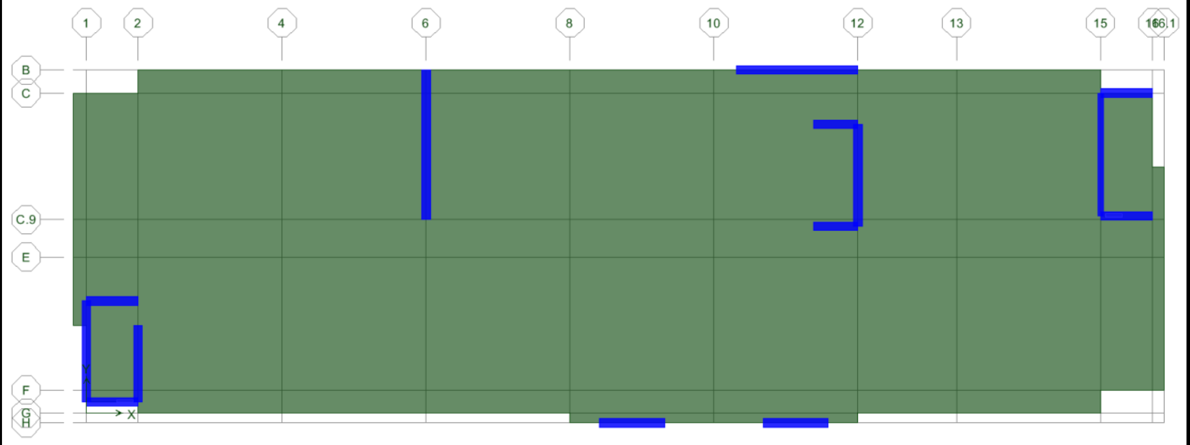

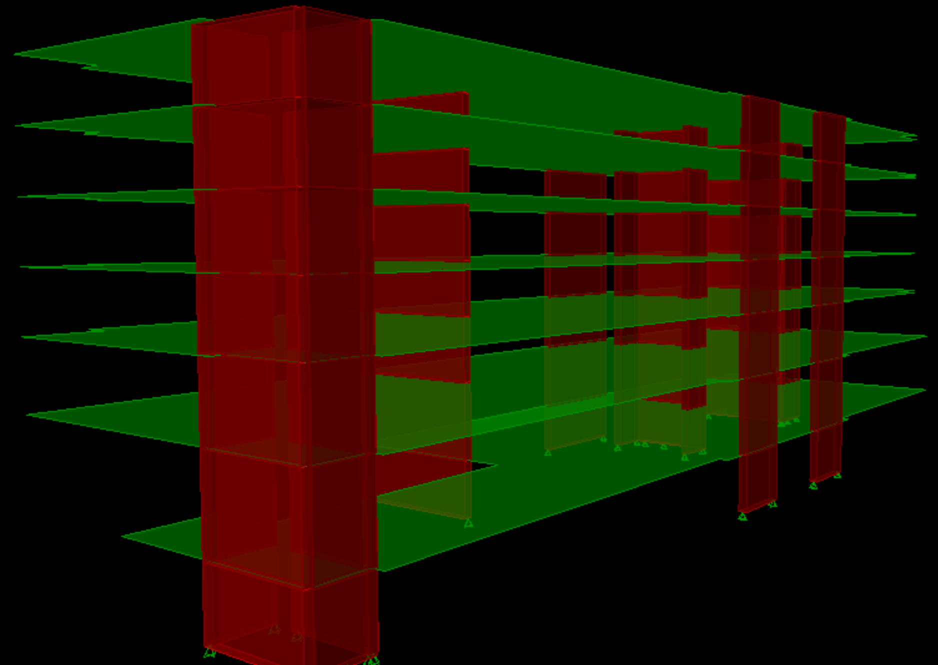

Acknowledgements

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- Dr. Ronald O. Hamburger

The Lord Jesus Christ

My family and friends