ST. JOSEPH HOSPITAL OF ORANGE

PATIENT CARE CENTER & FACILITY SERVICE BUILDING

Overview

- Building statistics
- Existing building and problem
- Proposed solution
  - Main Lateral Force Resisting System (MLFRS) Redesign
- Structural depth
  - Redesign using an Eccentrically Braced Frame (EBF)
- Breadths
  - Cost and schedule impact of an EBF System
  - Central courtyard lighting redesign
- Conclusion\Recommendation
- Questions

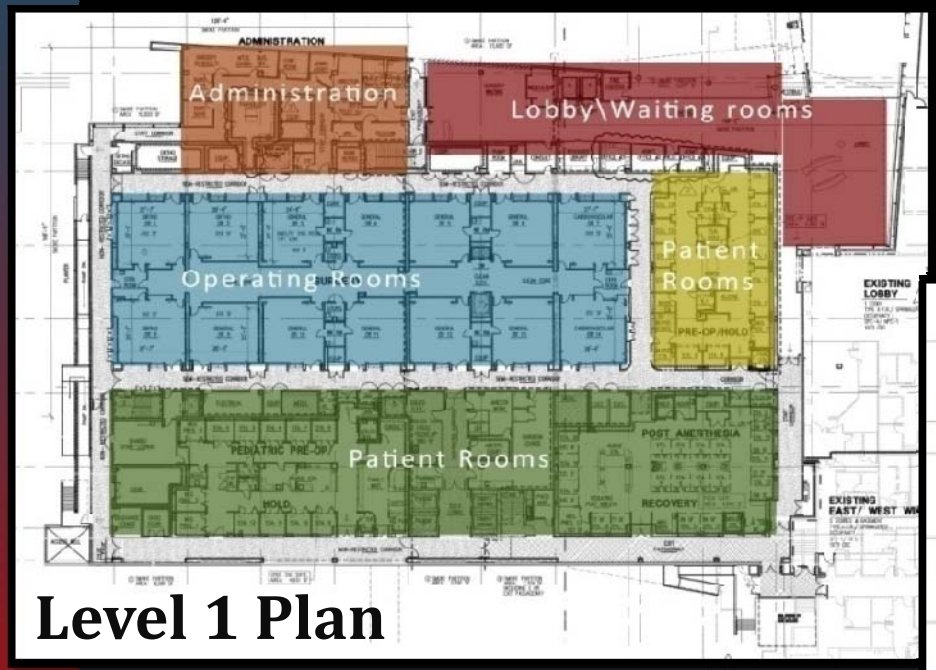
Building Statistics

- Owned by St. Joseph Health System
- Patient Care Center with surgical operating rooms (Health Care Building)
- Located @ 1100 W Stewart Dr., Orange, CA 92868
- 252,712 square feet
- 4 stories plus basement
- 63'-0" tall structure
- Total cost: $130 million
- Architect: NBBJ
- Engineer: KPFF Consulting Engineers – LA

Codes

- Original design uses:
  - UBC 1997
  - Title 24, 2001 California Building Code
- This report uses:
  - ASCE 7-05
  - 2007 California Building Code

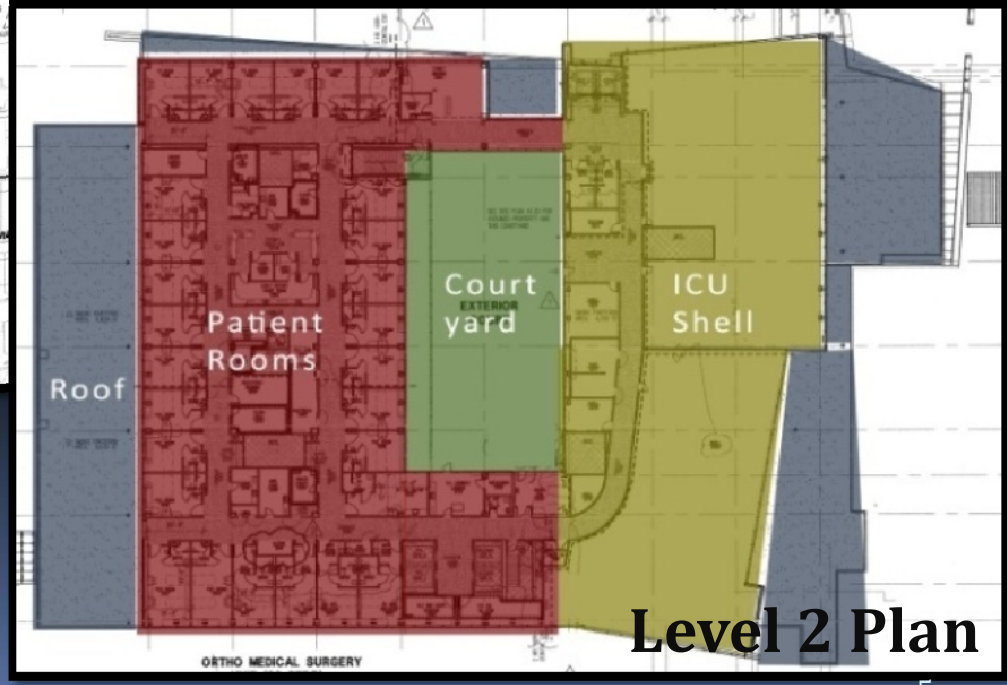
Existing Building



Level 1 Plan

Dead Loads:

110-120 psf	(LEVEL 1 and Roof)
79 psf	(LEVEL 2,3,4)
200-650 psf	(Courtyard)



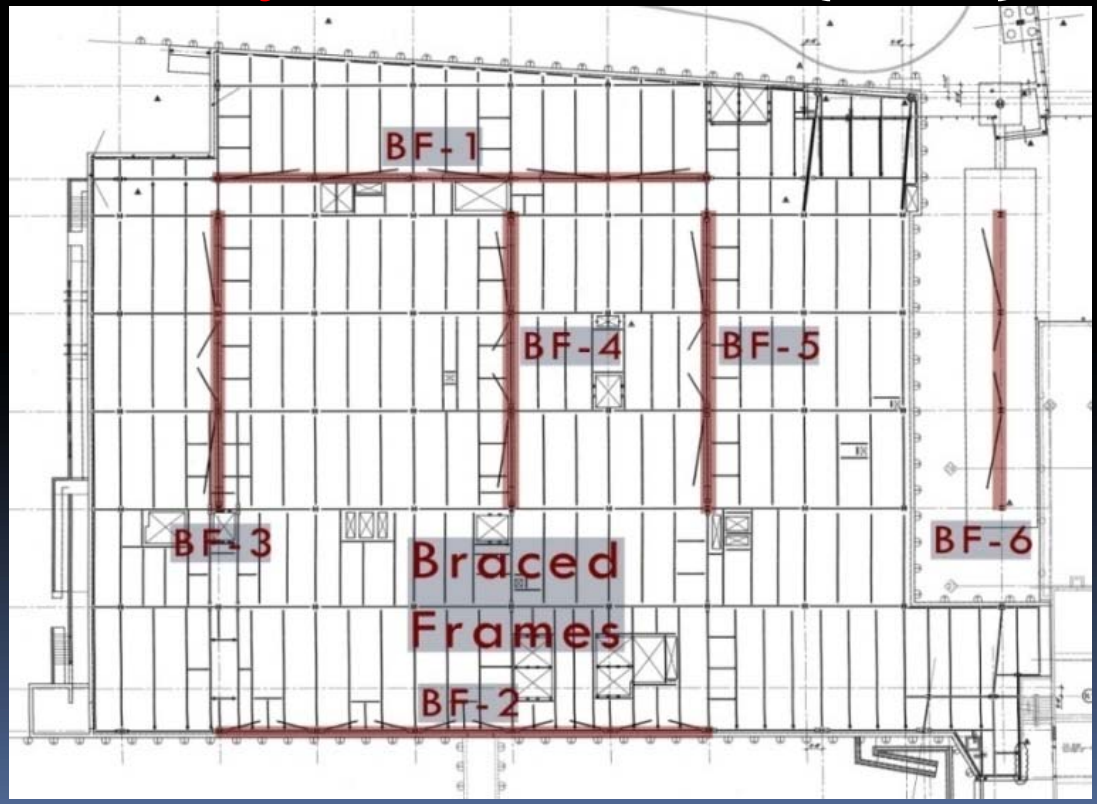
Level 2 Plan

Live Loads:

80 psf	(Level 1,2,3,4)

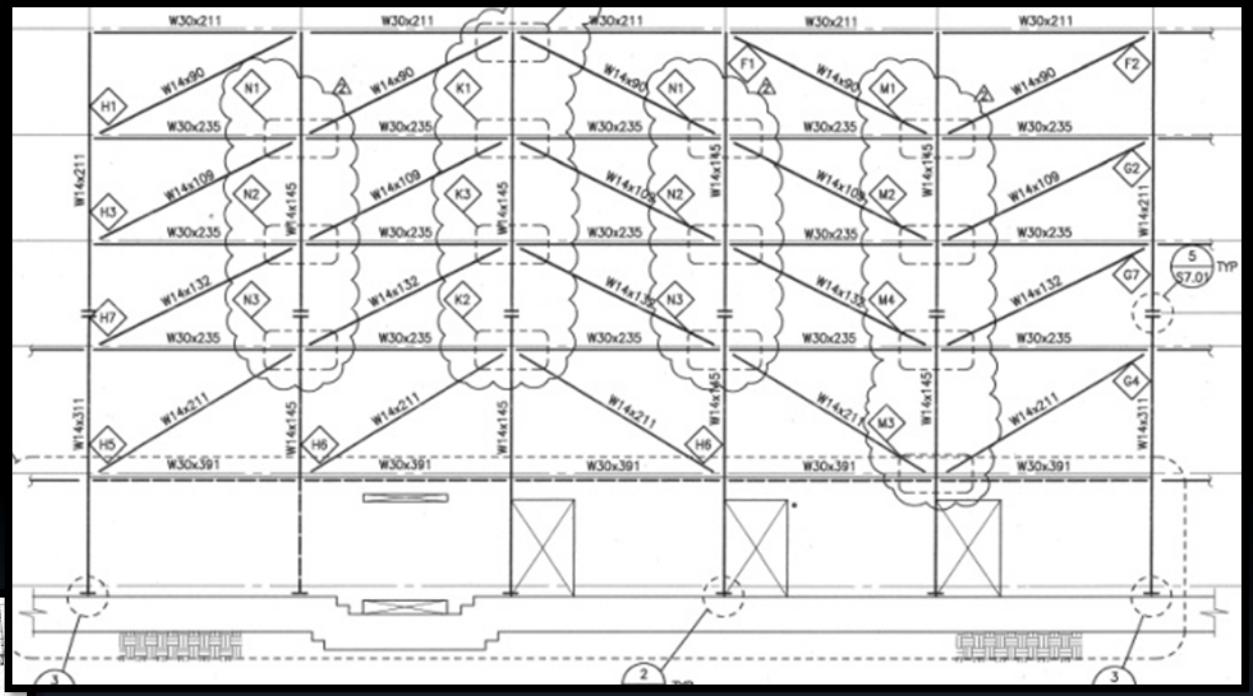
Existing Lateral System

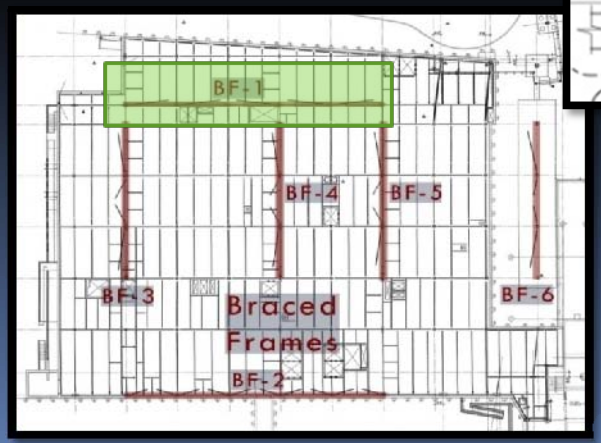
- Special Steel Concentrically Braced Frames (SCBF)
- X direction
  - 2 Sets of 5 Bays
- Y direction
  - 4 sets of 3 bays



Existing SCBF (BF-1)

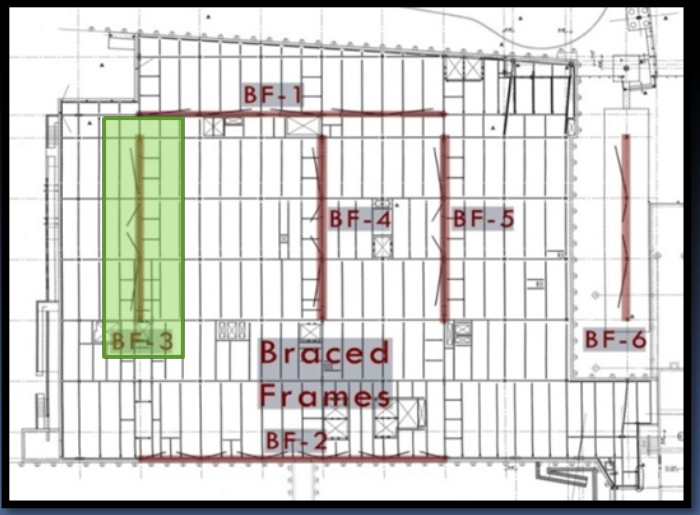
- Braces
  - W14x90
  - W14x139
  - W14x132
  - W14x211

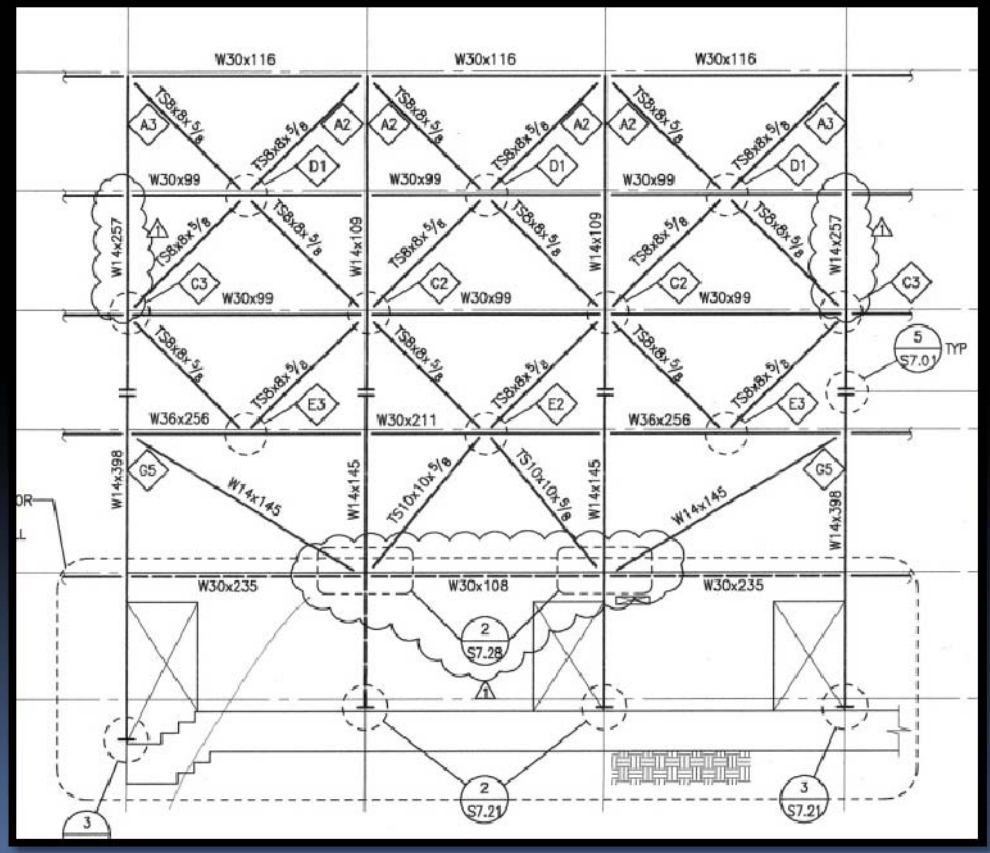




Existing SCBF (BF-3)

- Similar bracing configuration as BF-2,4,5,6
- Braces
  - HSS8x8x5/8
  - HSS10x10x5/8

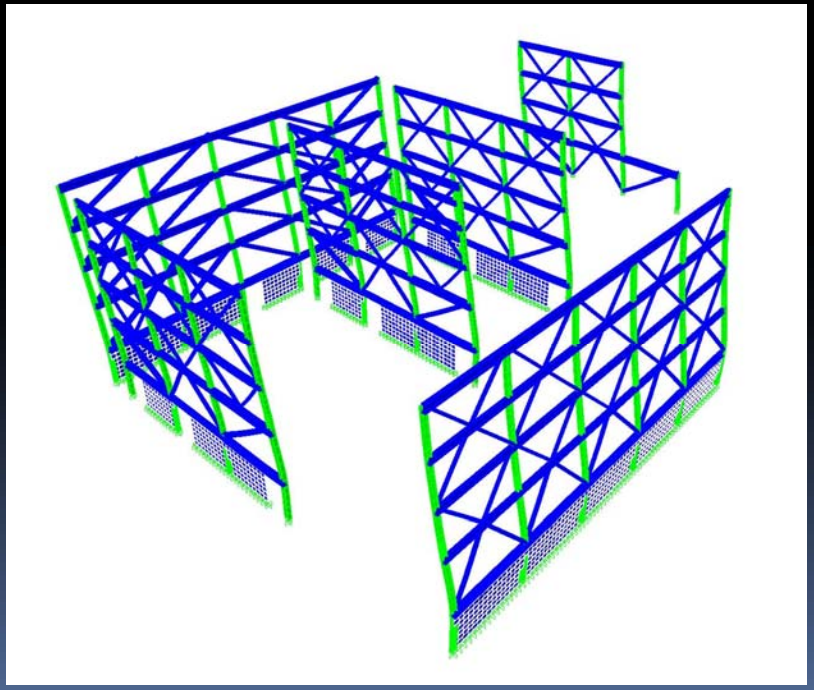




Existing SCBF Conclusion

- Fundamental period
  - $C_u T_a$ = .629
  - T_{ETABS} = **.422 (Controls)**
- Low Demand-Capacity ratio of most members

ETABS Model of Existing SCBF



Goals

- Redesign Lateral System
  - Ductile structure that dissipates energy with EQ
  - Structure that has a higher fundamental period, therefore Less Base Shear
- Reduce Construction Cost
  - Save materials
  - Save construction time

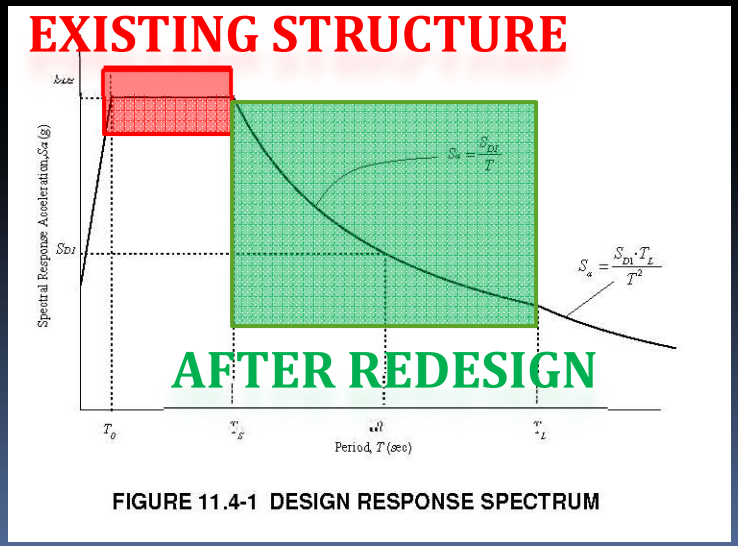


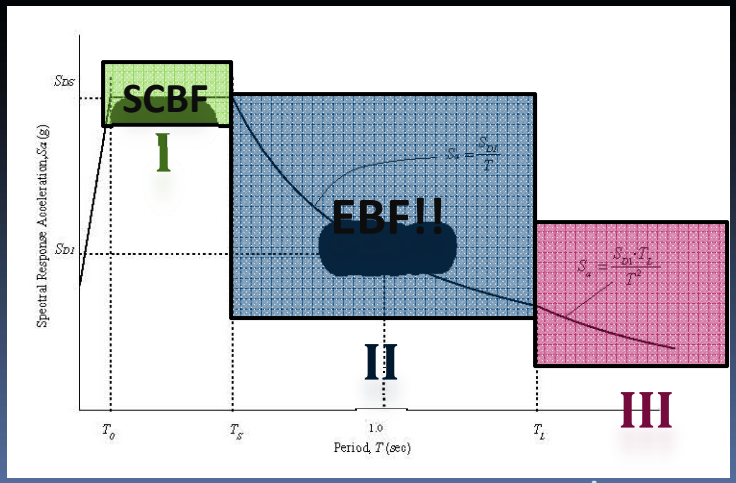
FIGURE 11.4-1 DESIGN RESPONSE SPECTRUM

SMF vs. EBF vs. SCBF

	SMF	EBF	SCBF (Existing)
Ductility	High	High	Low
Response modification factor	R=8	R=8	R=6
Stiffness	Low	Medium	High
Architectural flexibility	Flexible	Slightly less flexible	Restrictive
Effect on existing structure	A lot more MLFRS bays required	Reduction in the # of MLFRS Bays	-
Cost Impact	Higher cost	Lower cost	-

EBF vs. SCBF

		EBF	SCBF (Existing)
Response modification factor		=8	=6
Approximate period		CuTa = **.939 s**	CuTa = .629 Tb = **.422**
Base shear coefficient	Region I	=.172	**=.230 (Controls)**
	Region II	**=.099 (Controls)**	=.301
	Region III	=.845	=5.8

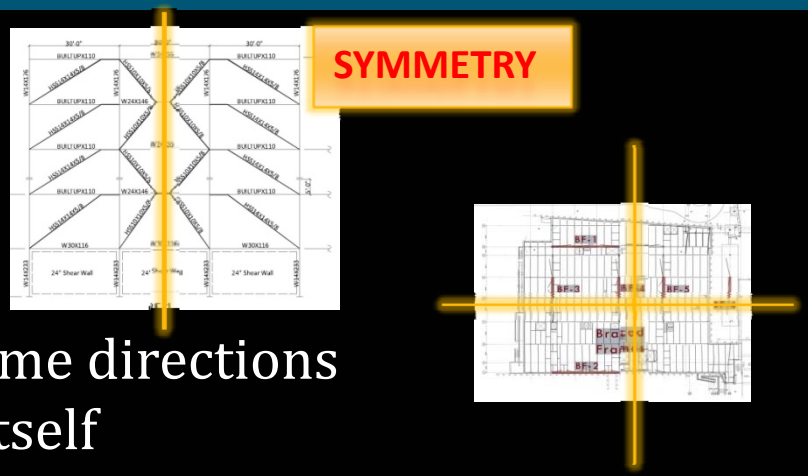


Using EBF would result in a 57% reduction in Base Shear

EBF Design Codes

- ASCE 7-05 (Minimum Design Loads for Buildings and Other Structures)
- AISC 360-05 (Specification for Structural Steel Building)
- AISC 341-05 (Seismic Provisions for Structural Steel Buildings)
- AISC 358-05 (Prequalified Connections for Special and Intermediate Steel Moment Frame for Seismic Applications)

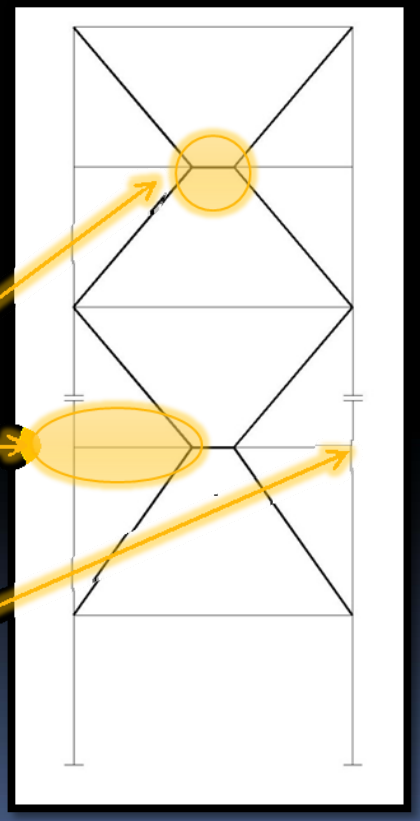
EBF Design Criteria



- Symmetry
  - Symmetrical frames in the same directions
  - Symmetry within the frame itself
- Reduce:
  - # of braces
  - 2/3 of the bays
- Links governed by shear yielding
  - e < 1.6Mp/Vp
  - Inelastic shear behavior
    - High ductility and stability
    - Uniform along the link

EBF Design Configurations

- X bracing
  - Reduces number of links
  - Isolates link to brace connections
    - hence isolated structural damage
  - Reduces axial load in the beams outside of the link
  - Reduces moment at the columns



EBF Design Process

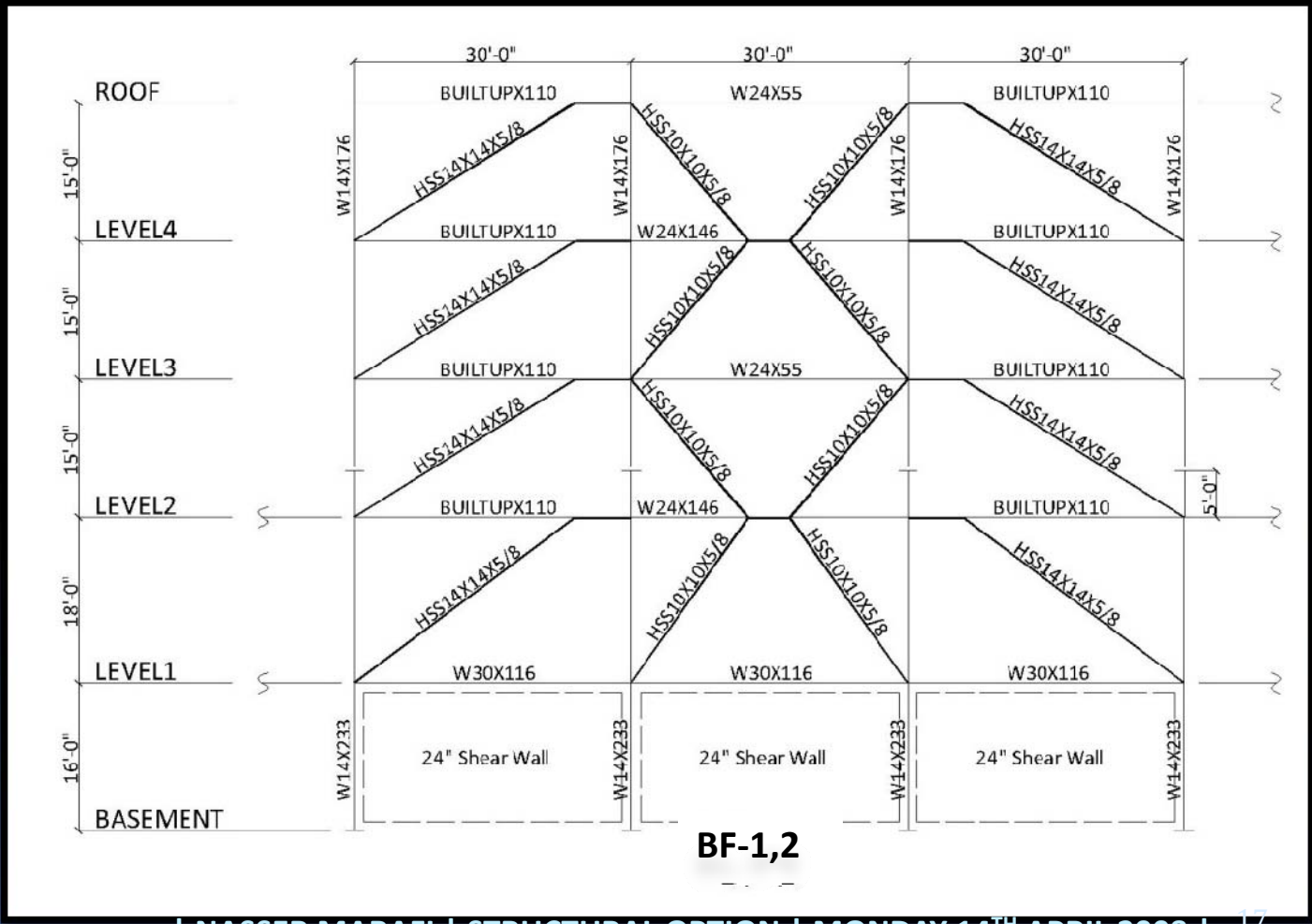
- Elastic Analysis in ETABS
  - Obtain members forces
- Spread Sheet with all AISC 341-05 provisions
  - Design links
  - Calculate over strength factors
  - Checks beams outside of the link
  - Designs braces and columns
- Iterative Process!

EBF Final Design

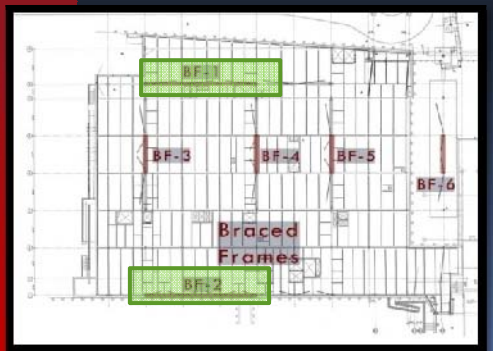
LINKS:
BUILT UP
W24X146

COLUMNS:
W14X176
W14X233

BRACES:
HSS10X10X5/8
HSS14X14X5/8



BF-1,2

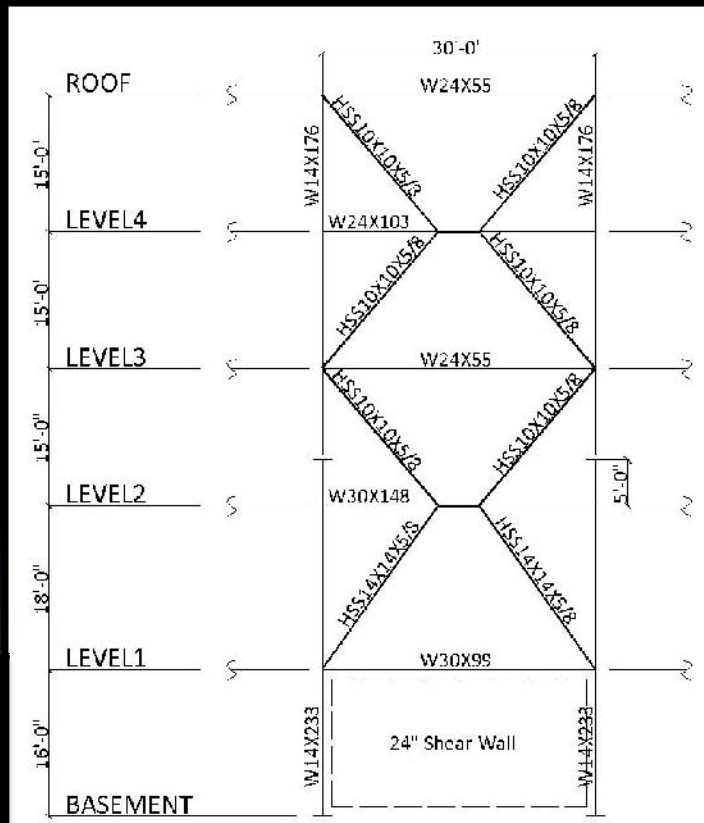


EBF Final Design

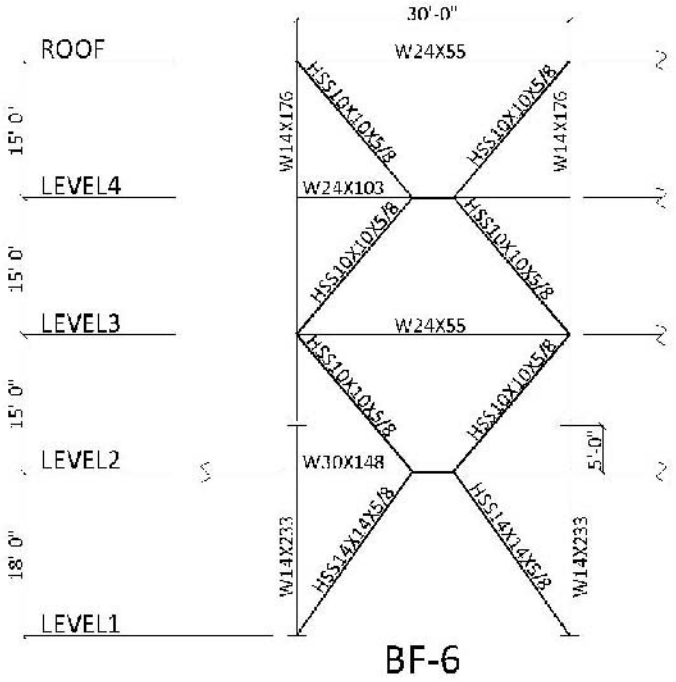
LINKS:
W24X103
W30X148

COLUMNS:
W14X176
W14X233

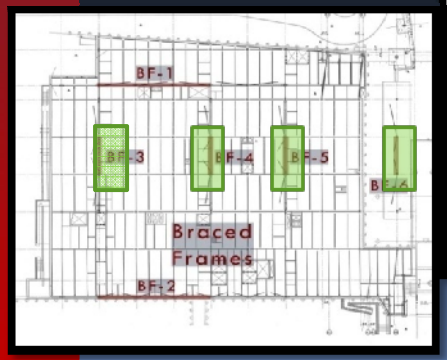
BRACES:
HSS10X10X5/8
HSS14X14X5/8



BF-3,4,5



BF-6



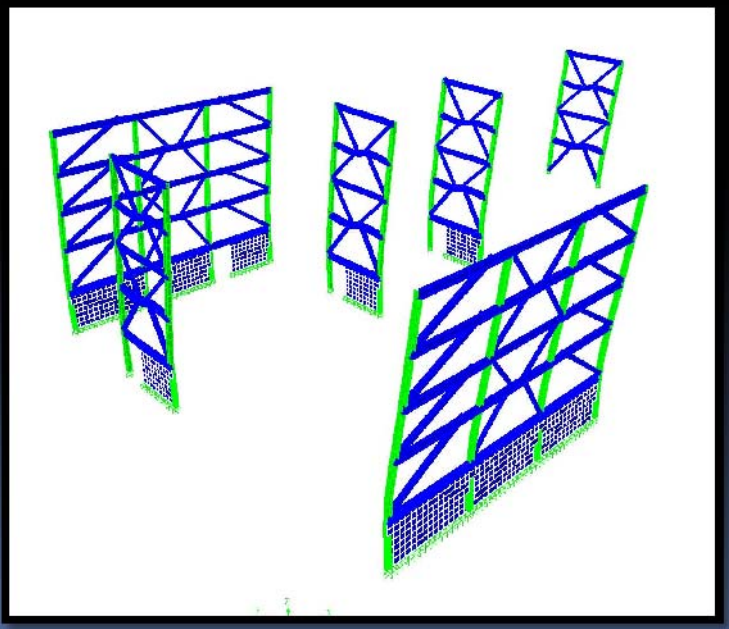
Links - Built Up Section

- No rolled section matching loading criteria, without:
  - Lowering shear demand-capacity ratio of Link, hence:
    - Increase over strength factor
    - Increasing all member sizes carried by link
- Built Up section customized to match the loading scenario present!
  - Shear Demand Capacity Ratio ≈ 1

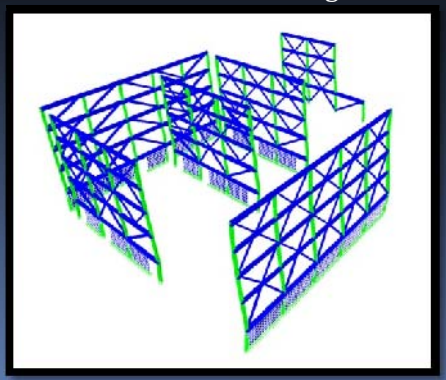
ETABS Model

- ETABS Model
  - $C_u T_a$ = **.939** (code approximation controls)
  - T_{ETABS} = 1.15

ETABS Model of EBF

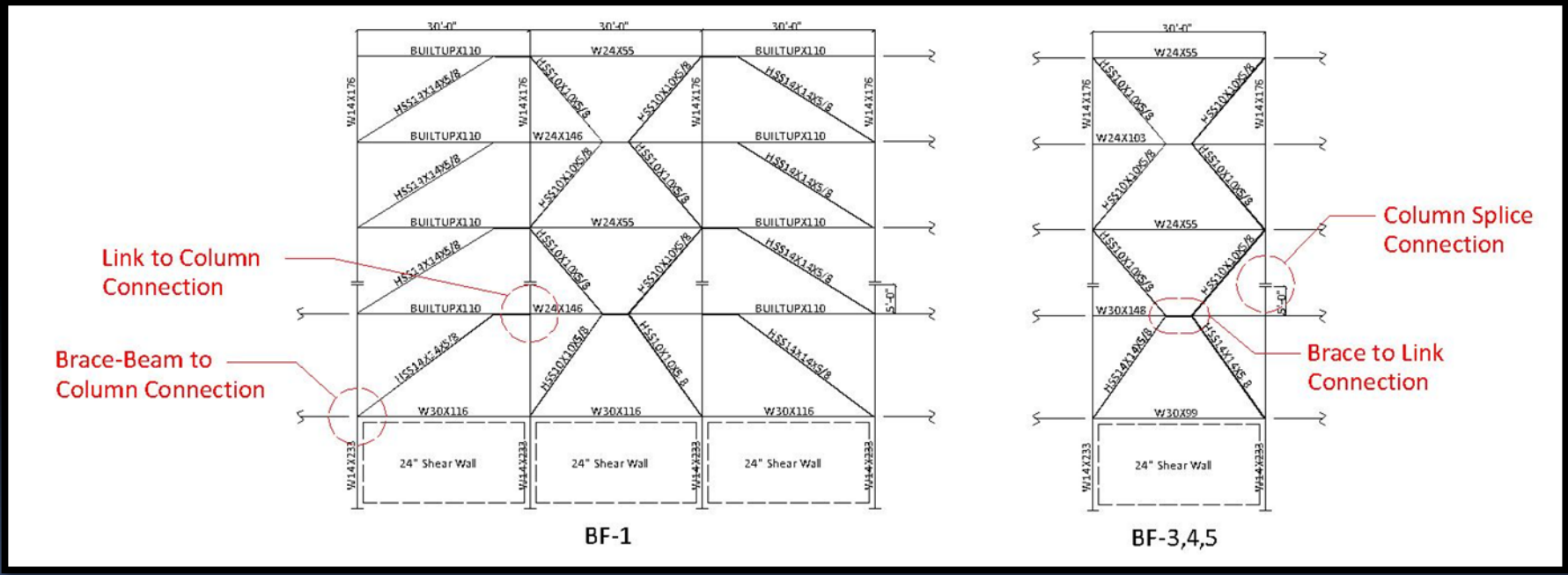


ETABS Model of Existing SCBF

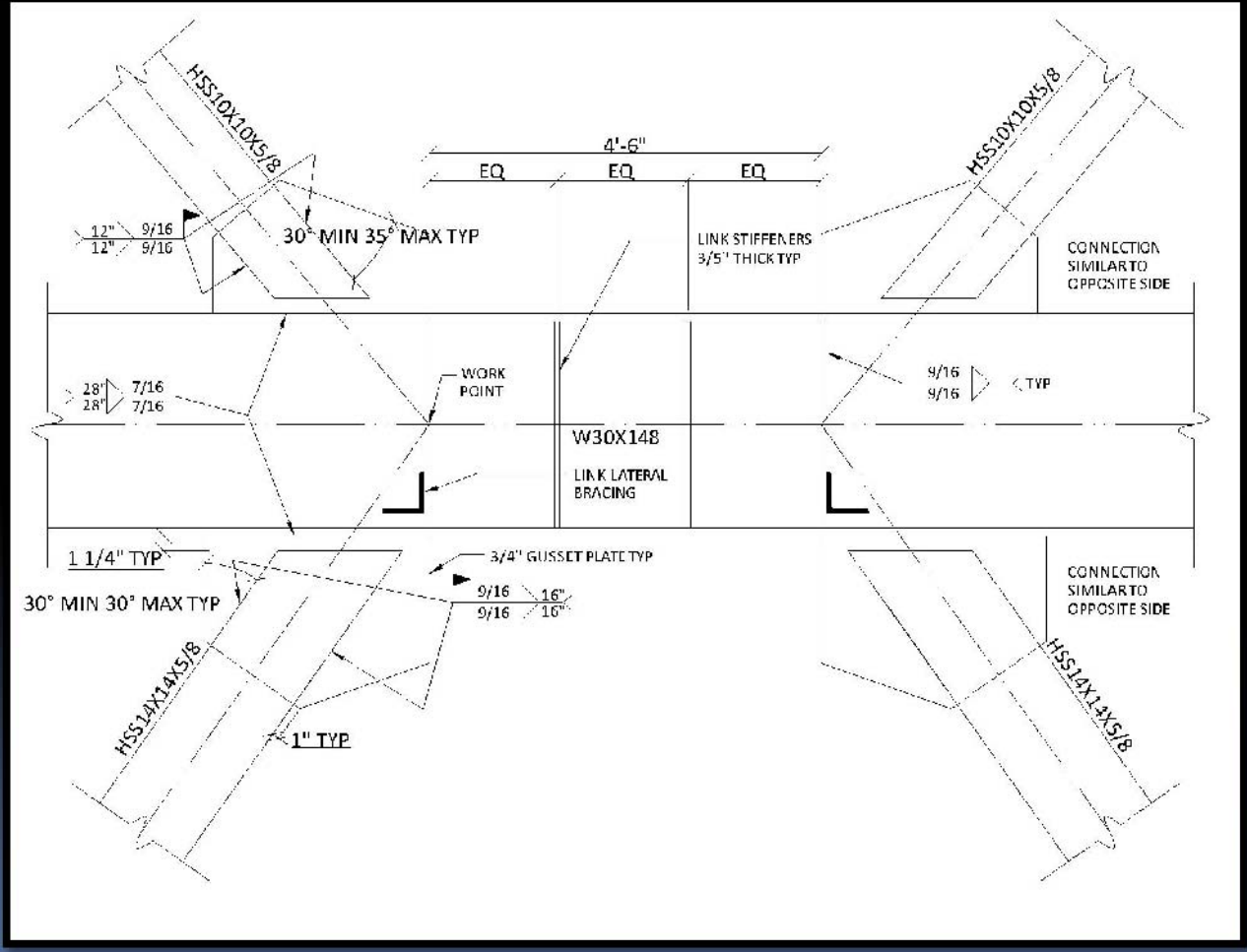


Typical Connections Design

- Connection location on the EBF system



Brace – Link Connection

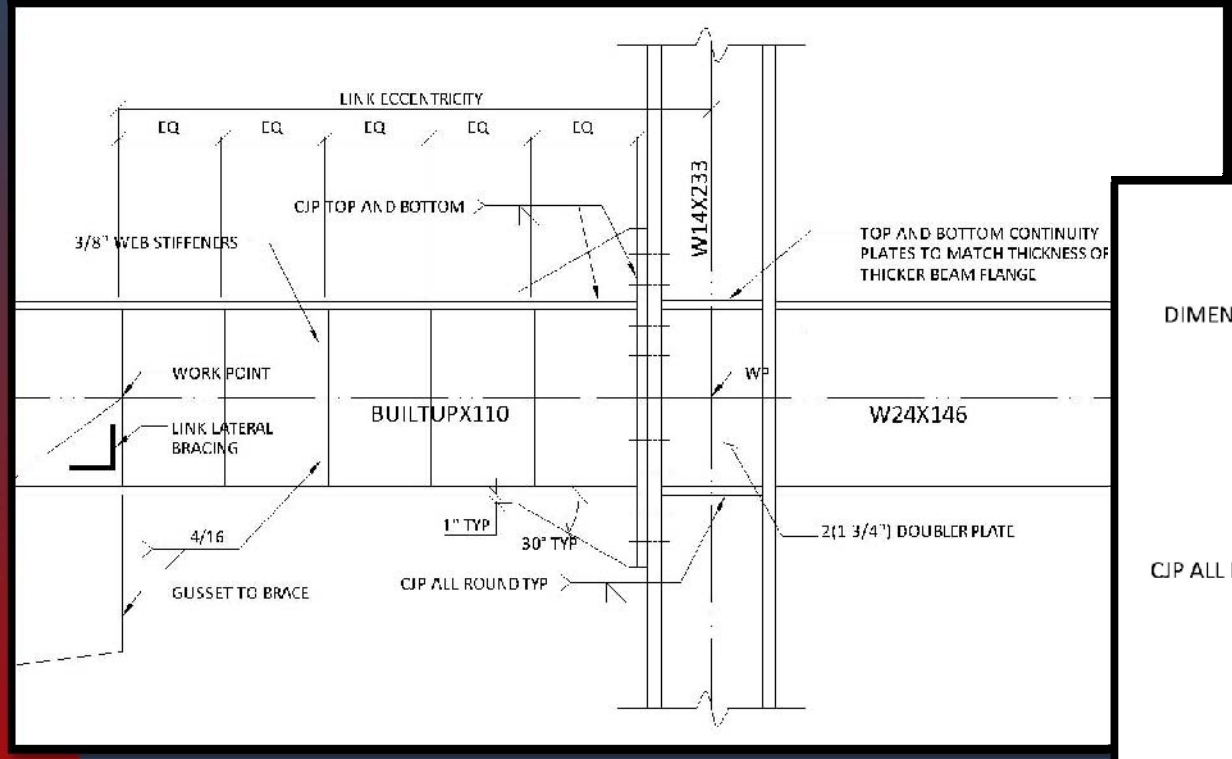


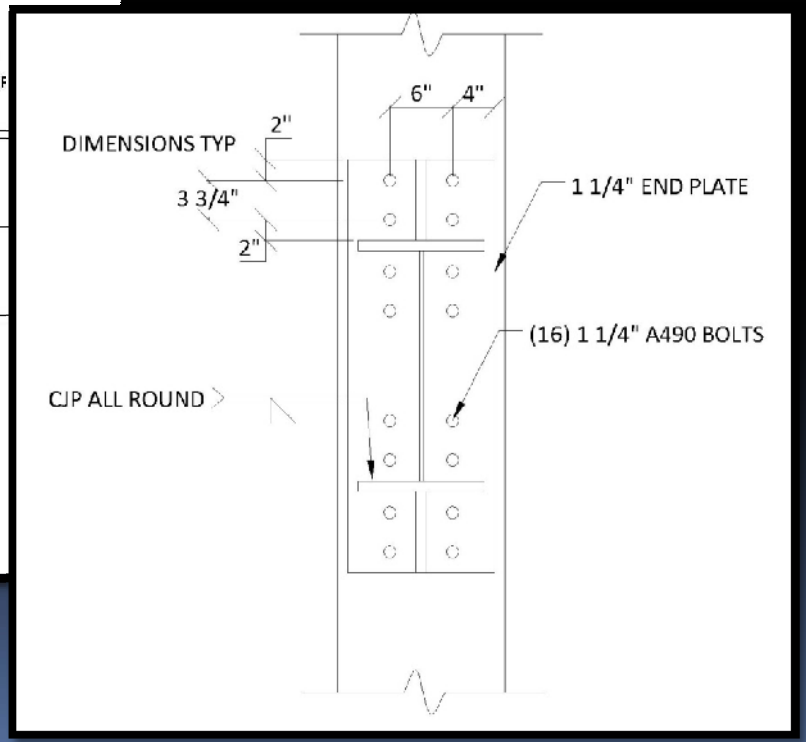
Link – Column Connection

- Option 1 – Bolted Stiffened Extended End-Plate Moment Connection
  - AISC 358-05 Prequalified Connection
- Option 2 – Welded Flange, Welded Web
  - Invoke exception as per AISC 341-05 section 15.4

Link – Column Connection

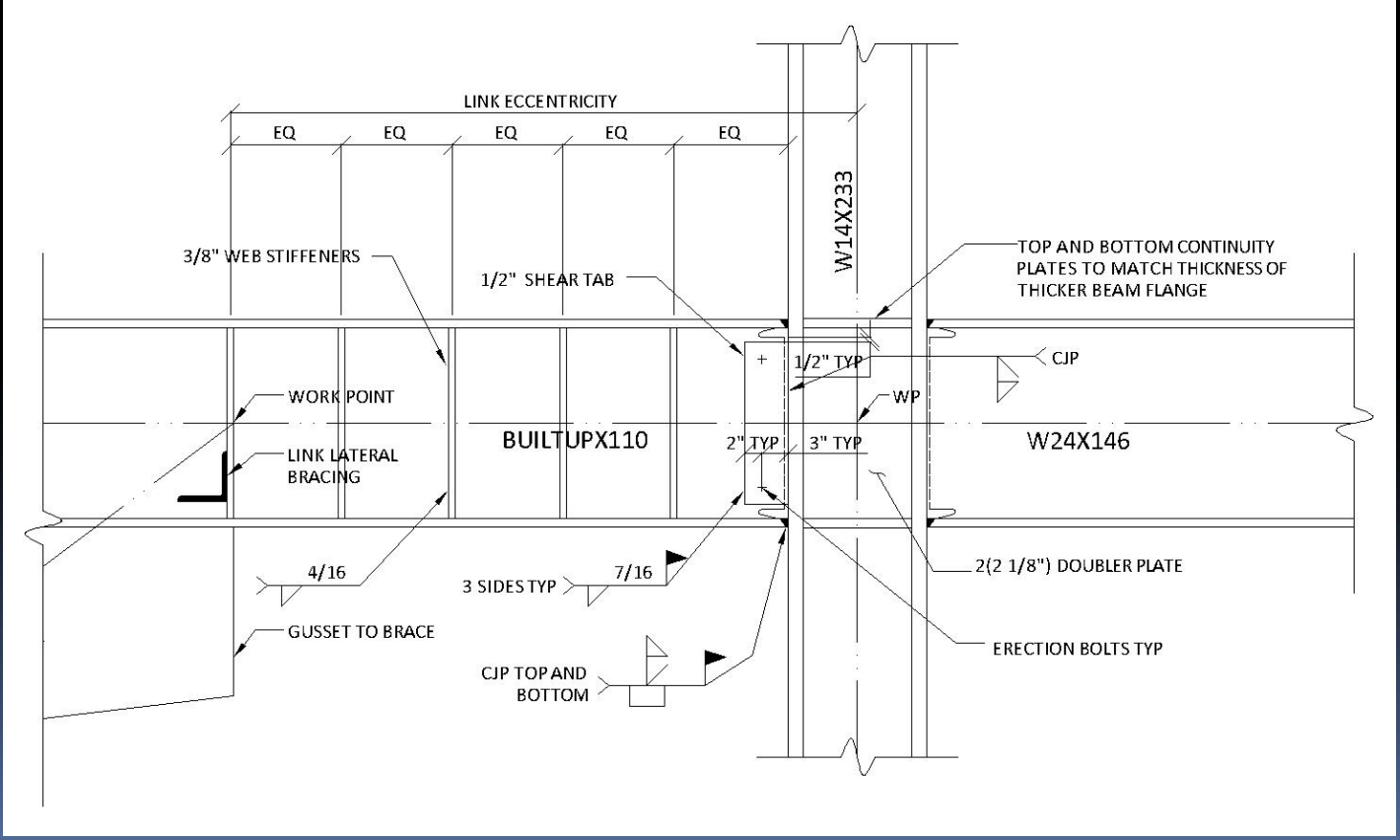
- Option 1 – Prequalified Bolted Stiffened End-Plate Moment Connection





Link – Column Connection

- Option 2 – Welded Flange, Welded Web



EBF Conclusion

- Tonnage of Structural Steel

Lateral System	Tonnage of Steel
Gravity System	632
SCBF (Existing)	637
EBF	**330**

- 24% reduction of total Structural Steel

EBF Conclusion

- Structural Steel per square footage

Lateral System	Tonnage of Steel
Gravity System	5 psf
SCBF (Existing)	5 psf
EBF	**2.6 psf**

- # of braces

Lateral System	# of Braces
SCBF (Existing)	145
EBF	**66**

  - 54% reduction of braces proportional to the amount of complex connections

Estimated Cost Comparison

- EBF Cost

Component	Cost
Structural Steel	-$1,195,000
Strip ootings Elimination	+$276,000
Shear Wall Elimination	+$232,500
Gravity Footings Replaced	-$62,500
Total	**-$749,000**

- SCBF Cost

Component	Cost
Structural Steel	-$2,312,000

Cost Comparison

- COST SAVED
  - = SCBF Cost – EBF Cost
  - = $2,312,000 - $749,000 = $1,563,000
- Total Project Cost $130 Million
  - ≈ 1% reduction of total project cost

Schedule Impact

- SCBF (RS Means estimate with 2 crews)

Component	# of Days
Structural Steel	22
Foundations	14
Shear Walls	18
Total	**54**

- EBF (RS Means estimate with 2 crews)

Component	# of Days
Structural Steel	12
Gravity Footings	3
Total	**15**

39 DAYS SAVED TOTAL!

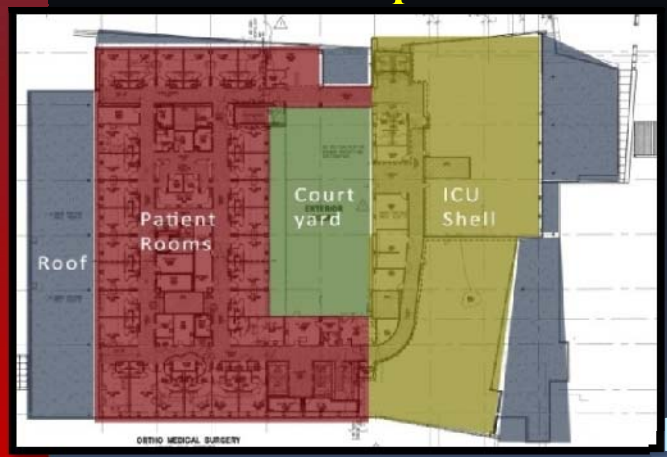
Schedule Impact (Steel Erection)

System	# of Days
SCBF + Gravity **(RS Means Existing)**	44
EBF + Gravity **(RS Means Redesigned)**	33

- Actual Steel Erecting Time = 50 days
  = factor
  = Actual / (RS Means Existing) = 1.14
- EBF System
  - = (RS Means Redesigned) x (factor)
    = 33 x 1.14 = 38 days
  - Days saved = Actual – EBF = 50 – 38 = 16 days!

Lighting Breadth

- Lighting redesign of existing central courtyard
- Interesting central courtyard space
  - Place of comfort
  - Escape from the stressful environment



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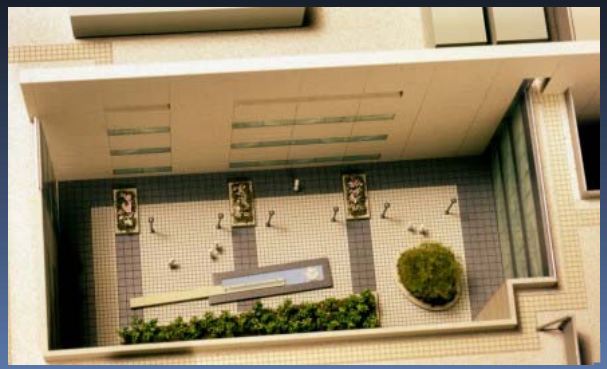
Lighting Goals

- Comfortable and Relaxing atmosphere
  - Comfortable Lighting
  - Accentuate Plants and Trees
  - Illuminate Water Fountain
- Maintain similar Power Density
  - Provide necessary amount of footcandles



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Lighting Codes

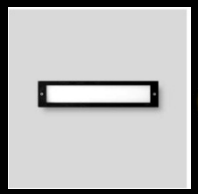
- California Energy Commission, 2005 Building Energy Efficiency Standards.
  - Motion sensors
    - 100W Lamps with less than 60 Lumens per watt
  - Automatic shutoff switches when daylight
  - Multilevel switches up to 50% lighting power control
  - Power Density limitations

Courtyard Lighting Fixtures

- Bollards – Compact Fluorescent (CFL)

COMFORTABLE LIGHTING

- CFL Step Lights



COMPLIMENTS ARCHITECTURE

- LED Linear Fixtures

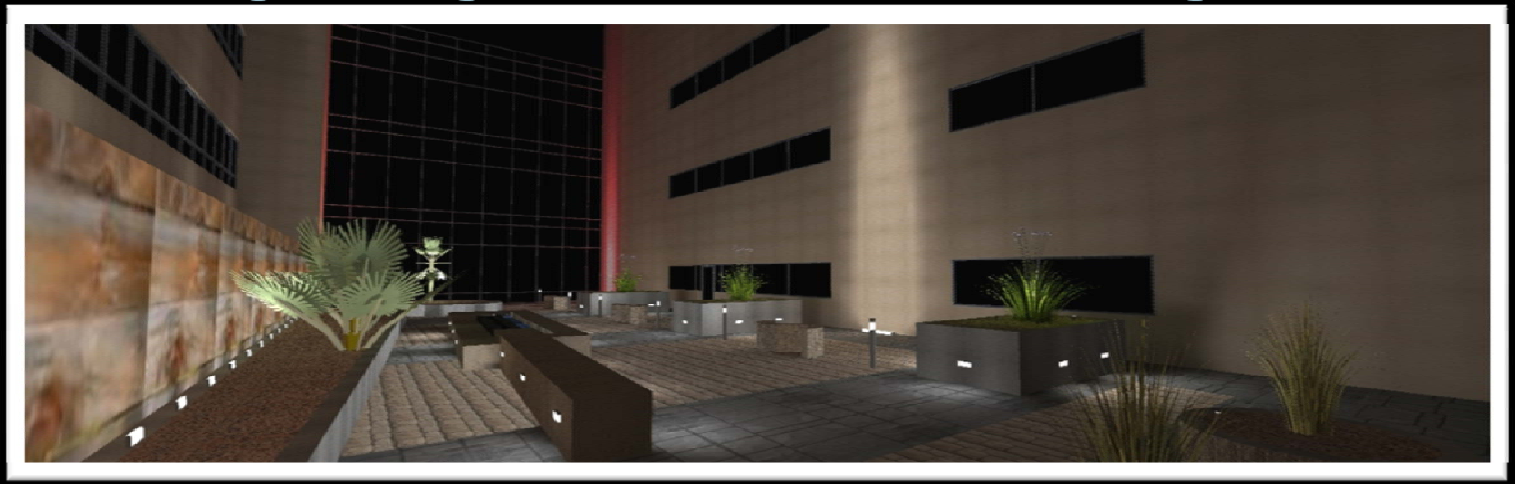
- LED Spot Lights

HIGHLIGHTS TEXTURE

AGI Lighting Model Rendering

AGI Lighting Model Rendering

AGI Lighting Model Rendering



AGI Lighting Model Rendering

Lighting Power

- Redesigned Space Power Usage

Space	Power Density (W per SF)	Wattage
Courtyard	0.15	919
Façade	0.33	840
Total		**1759**

- Comparison to Existing Lighting
  - 42% Reduction (Existing uses 3040 Watts)

Final Conclusion

- EBF Performance?
  - Ductile & Laterally Stiff
    - Meeting 1.5% drift ratio
    - Link are the weak points and undergo Inelastic Behavior!
  - Isolates structural damage during an earthquake
    - Low repair cost
    - Still operational
- Economical Solution?
  - Less construction cost and time

Final EBF Design Fine Tuning

- Shear force redistribution between the links
  - Bottom links go through inelastic behavior before top ones
- Redesigning diaphragms and collector elements
- Redesigning foundations and shear walls

Lighting Conclusion

- Visual points of interest
- Highlights architectural features
- Comfortable and inviting
  - Non-uniform

- Great Place to Escape from the Hospital

Acknowledgments

- The Pennsylvania State University
  - Dr. Andres Lepage
- KPFF Consulting Engineers
  - Aaron Reynolds
- Colleagues
  - Landon Roberts

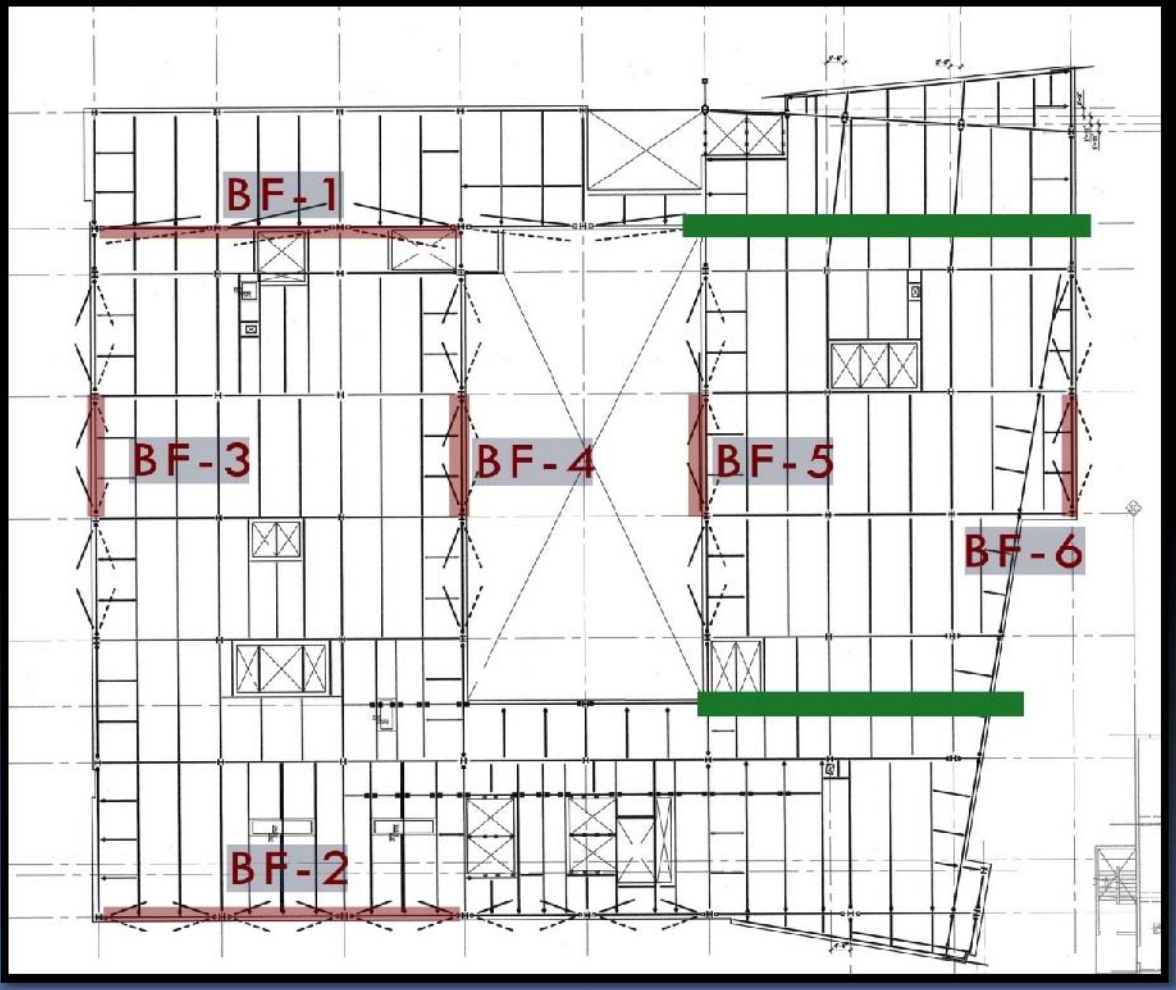
The entire AE Faculty, Staff and Students for their help!

Family and friends for their support who are hopefully watching over LIVE CAMERA in Kuwait!

Questions?

St. Joseph Hospital PCC

Diaphragm Check



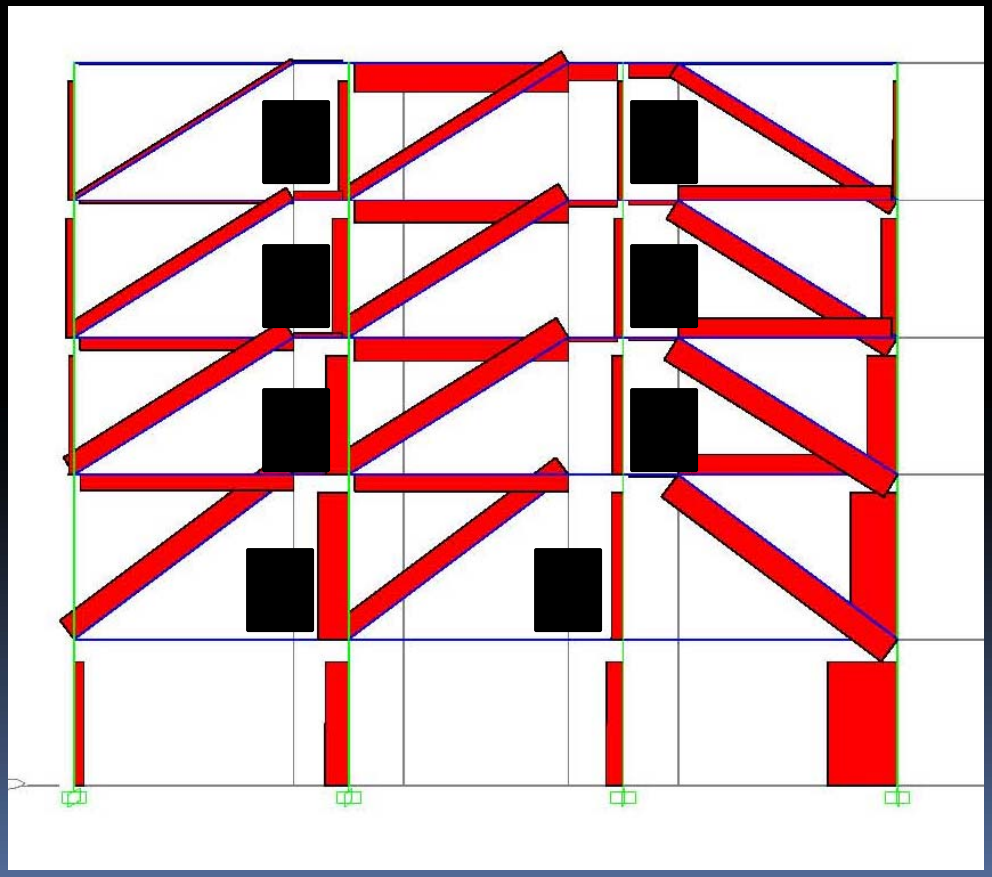
Diaphragm Design Forces

Level	wi	∑wi	Fi	∑Fi	Fp	.2SdsIWpx	.4SdsIwpx
Roof	4317	4317	811	811	811	**1191**	2383
4	3566	7883	481	1291	584	**984**	1968
3	3566	11449	304	1595	497	**984**	1968
2	7927	19376	323	1918	785	**2188**	4376
1	6848	26224	0	1918	501	**1890**	3780

CONTROLS!

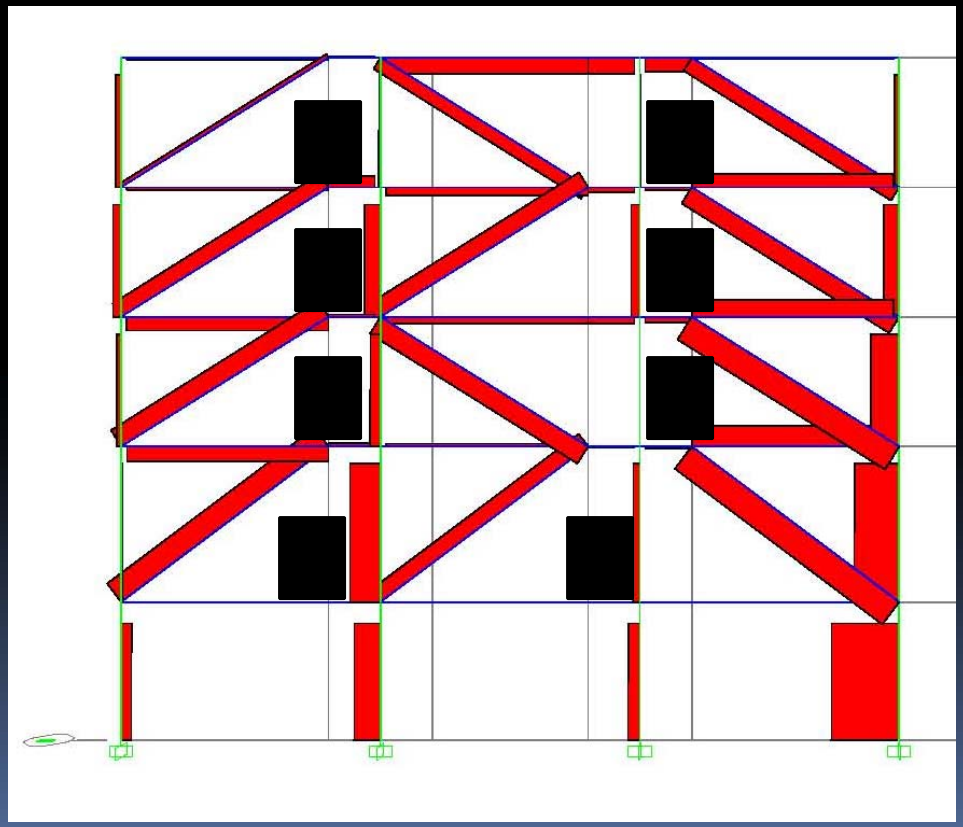
EBF Design Configurations

- Axial Force Diagram



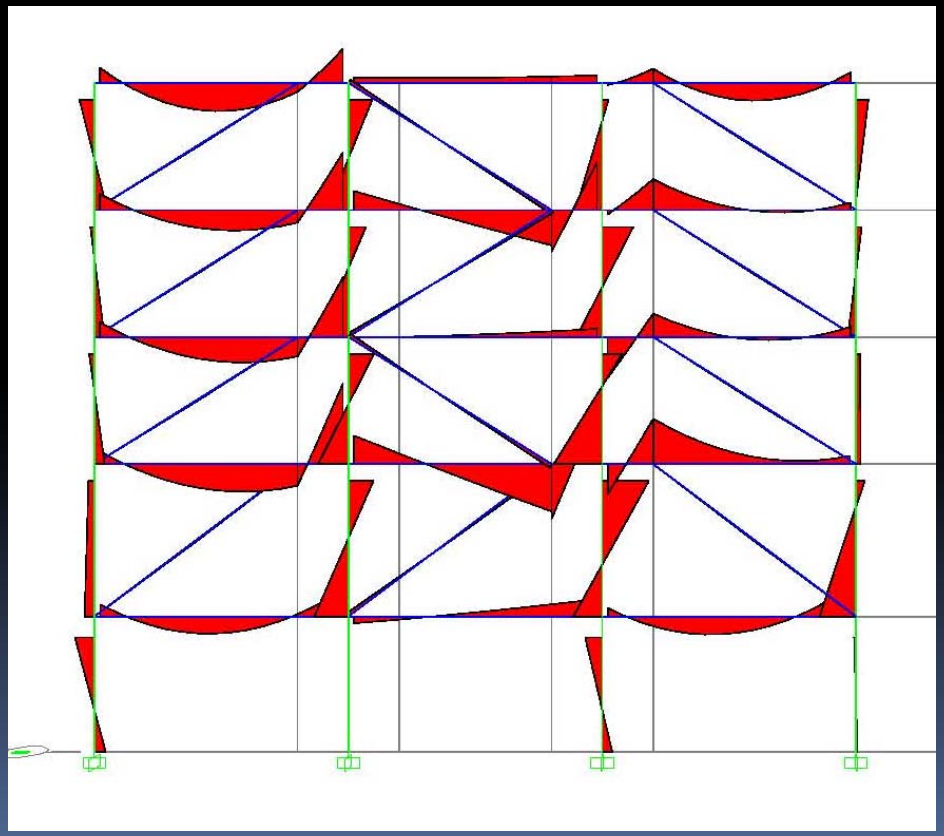
EBF Design Configurations

- Axial Force Diagram



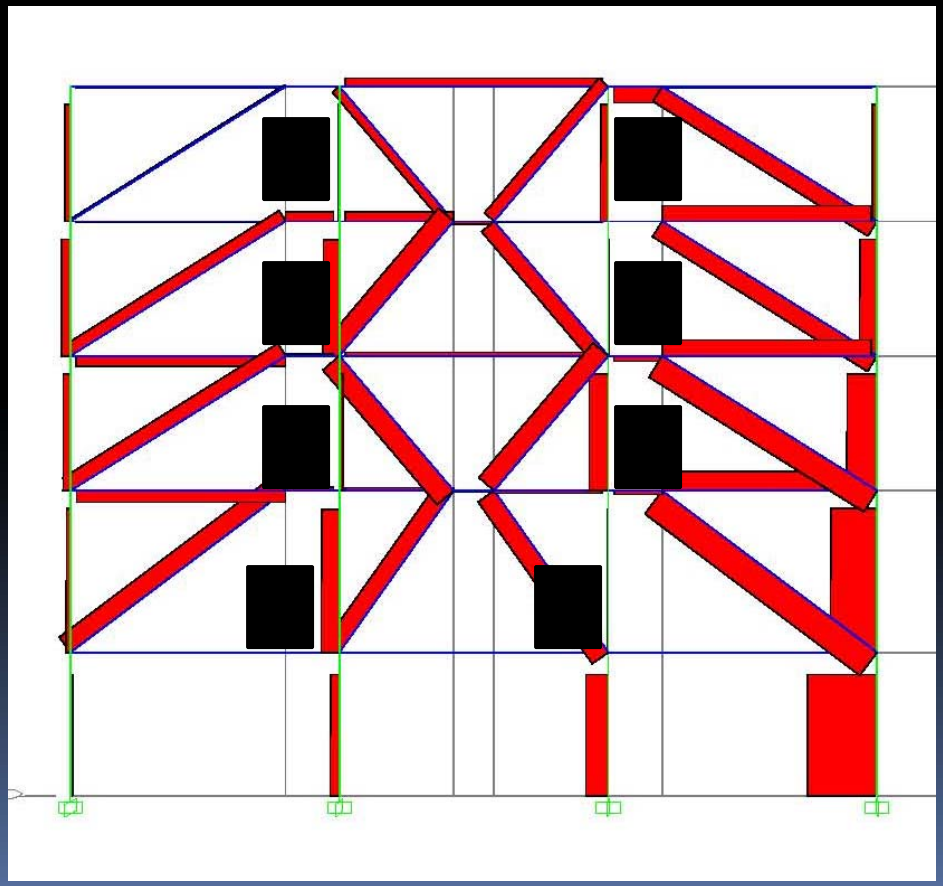
EBF Design Configurations

- Moment Diagrams

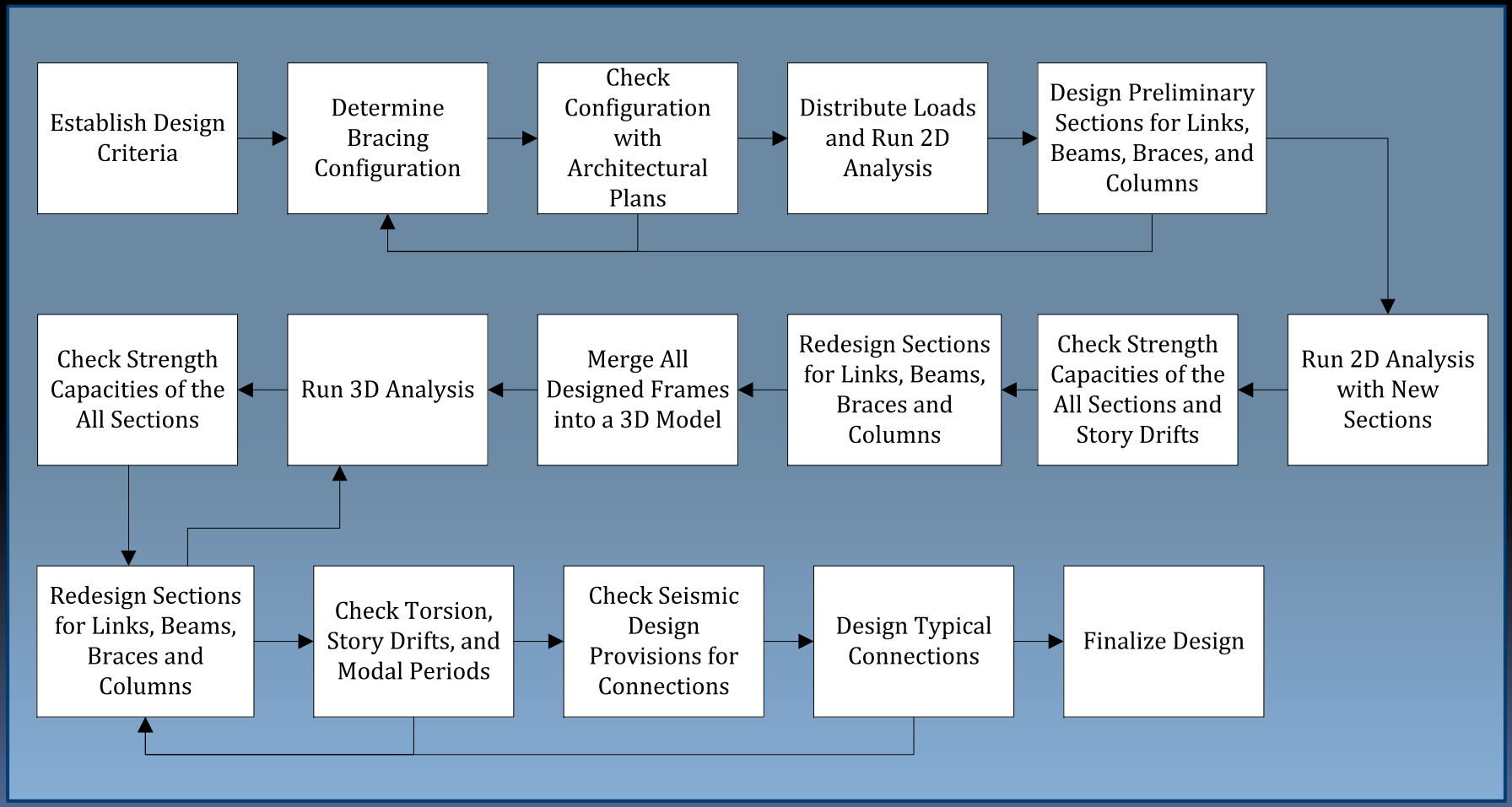


EBF Design Configurations

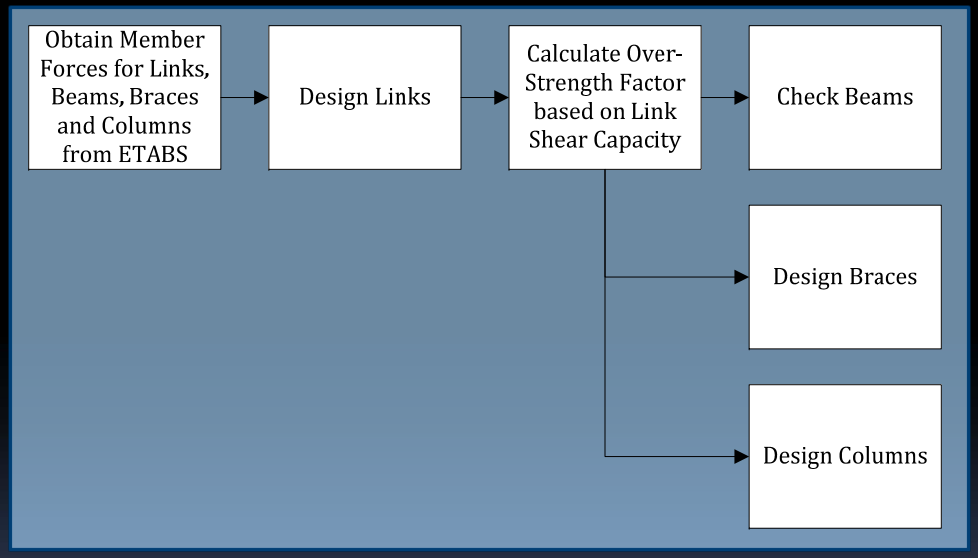
- Axial Force Diagram



EBF Design Process

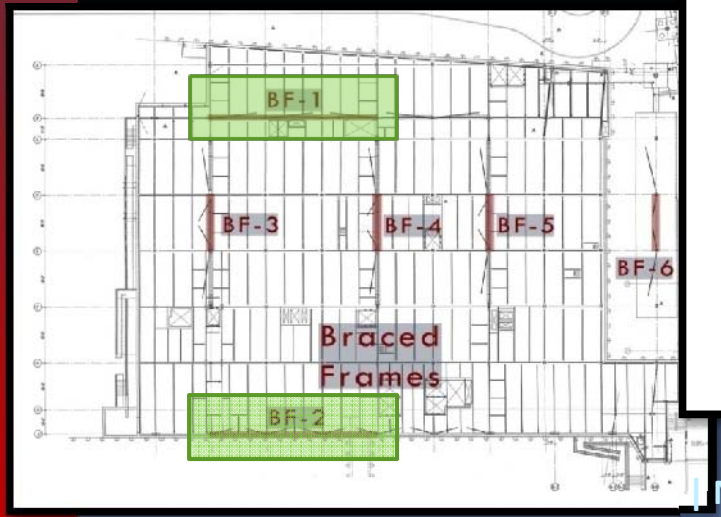


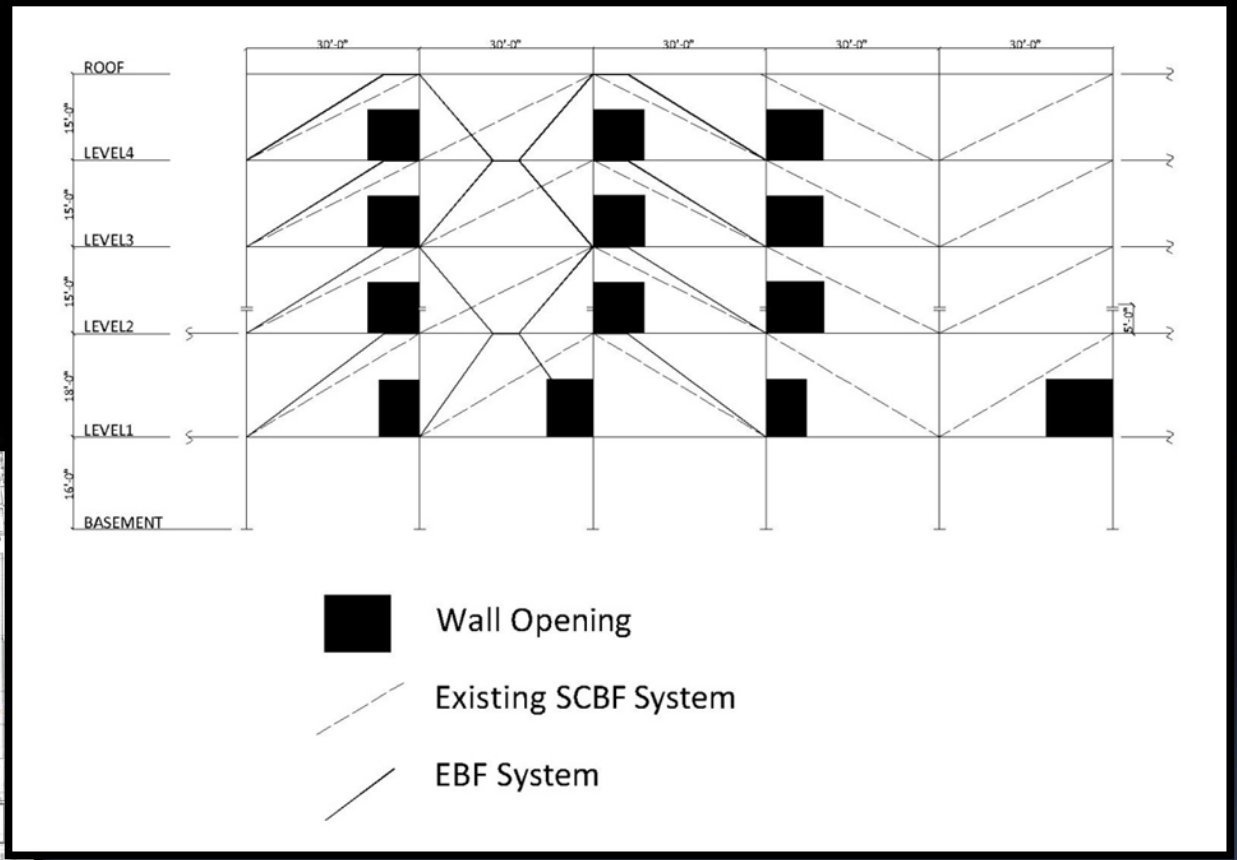
EBF Member Design Process



EBF - X Bracing

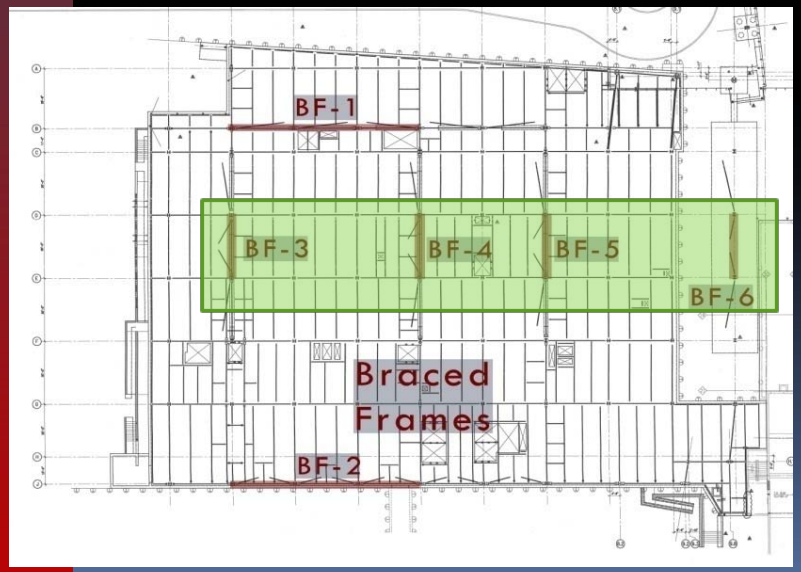
- Configuration for:
  - BF-1 and BF-2

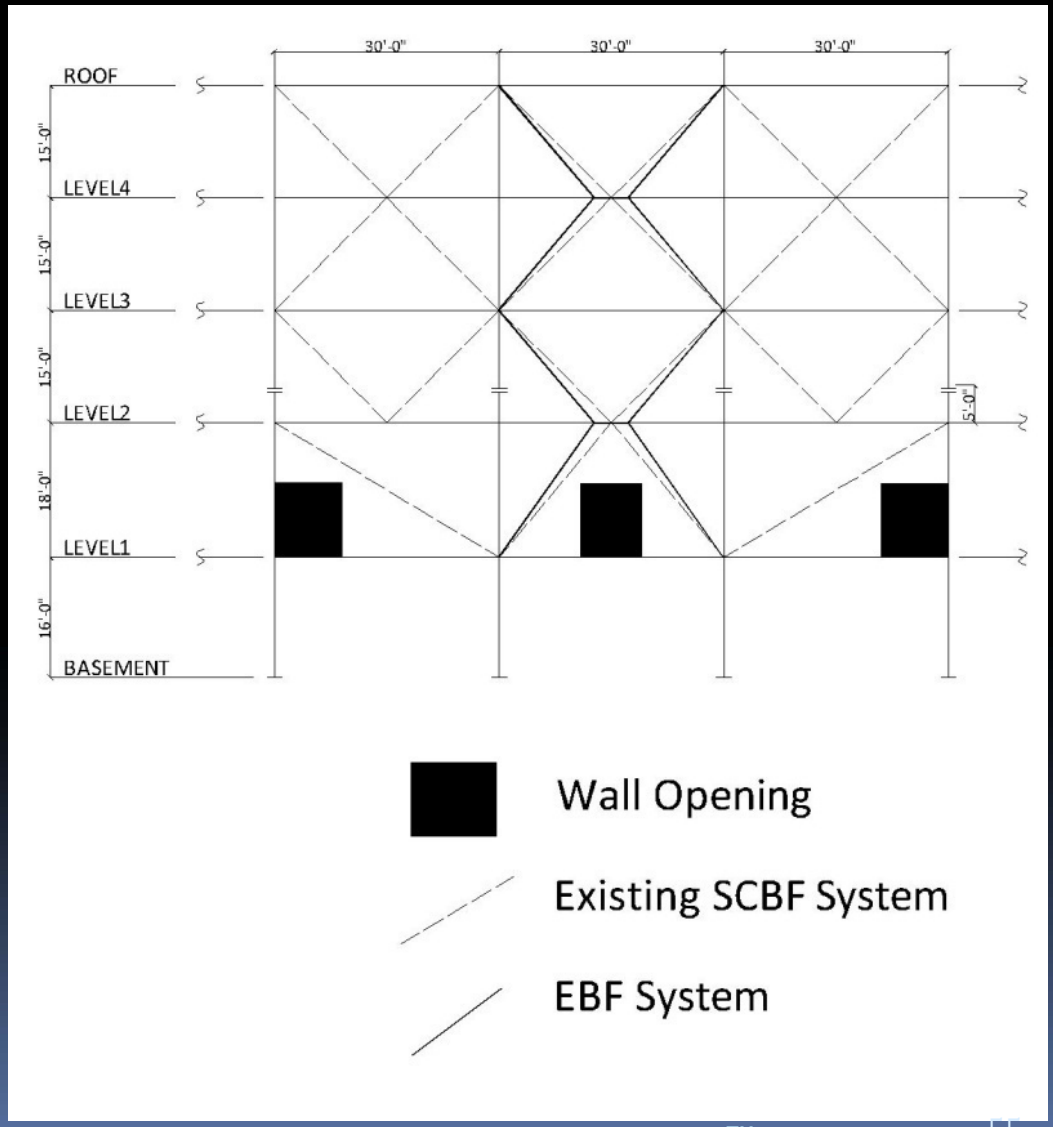




EBF - X Bracing

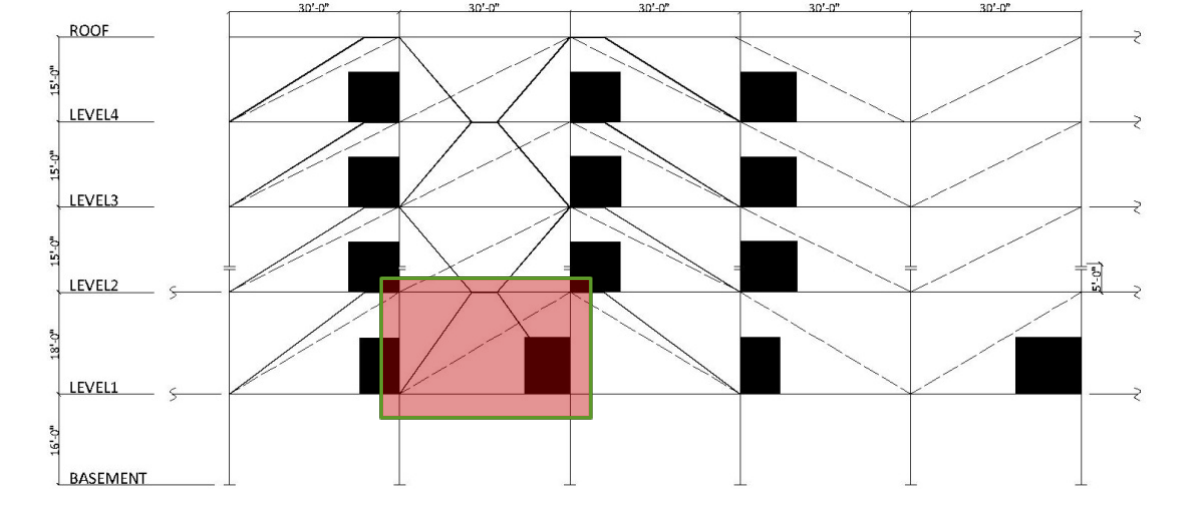
- Configuration for:
  - BF-3 ,BF-4,
  - BF-5 and BF-6





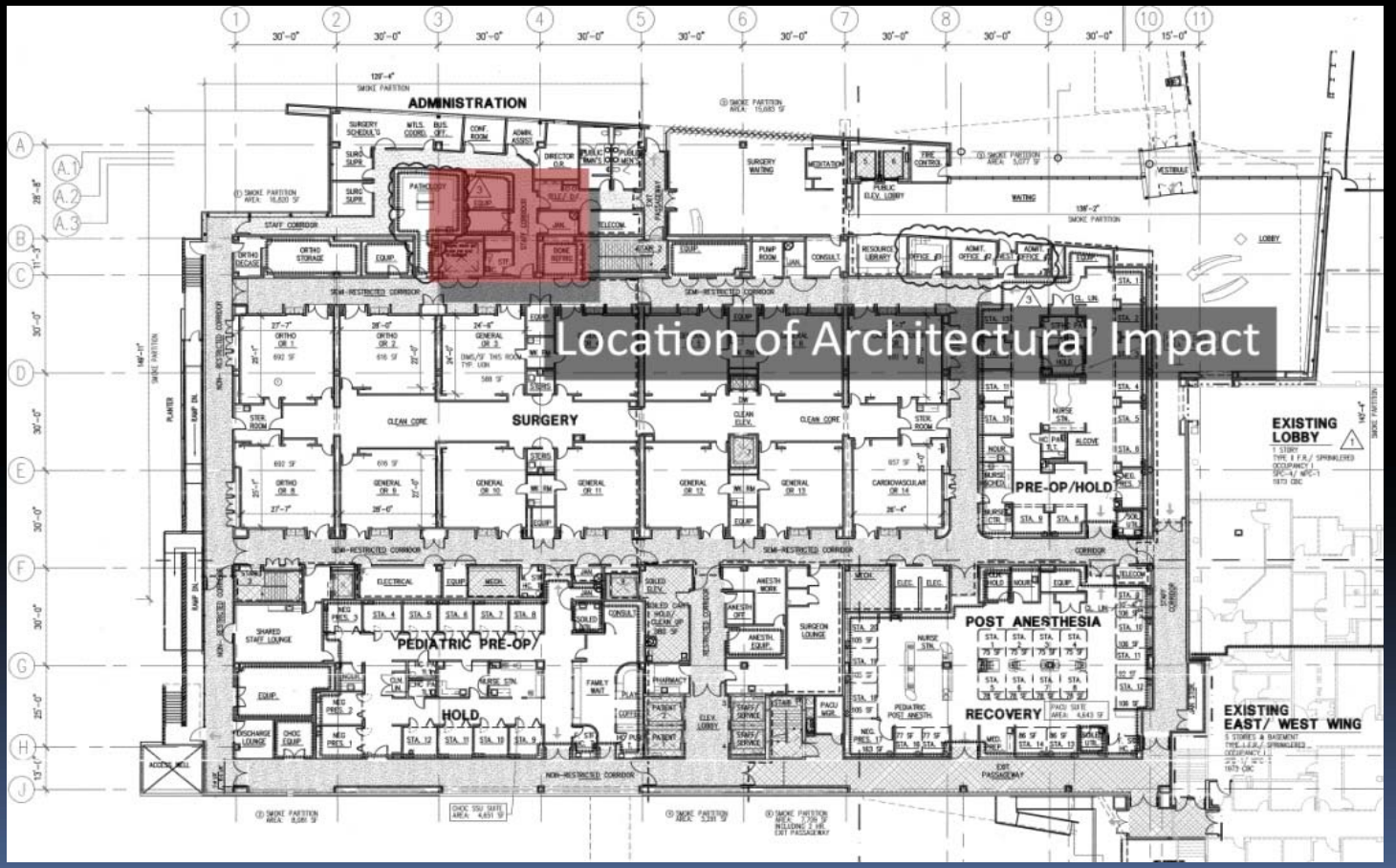
Architectural Problem

- Consider the Following
  - Overall Space layout rearrangements
  - Percentage Change of Square Footage per Space
  - Corridor Path

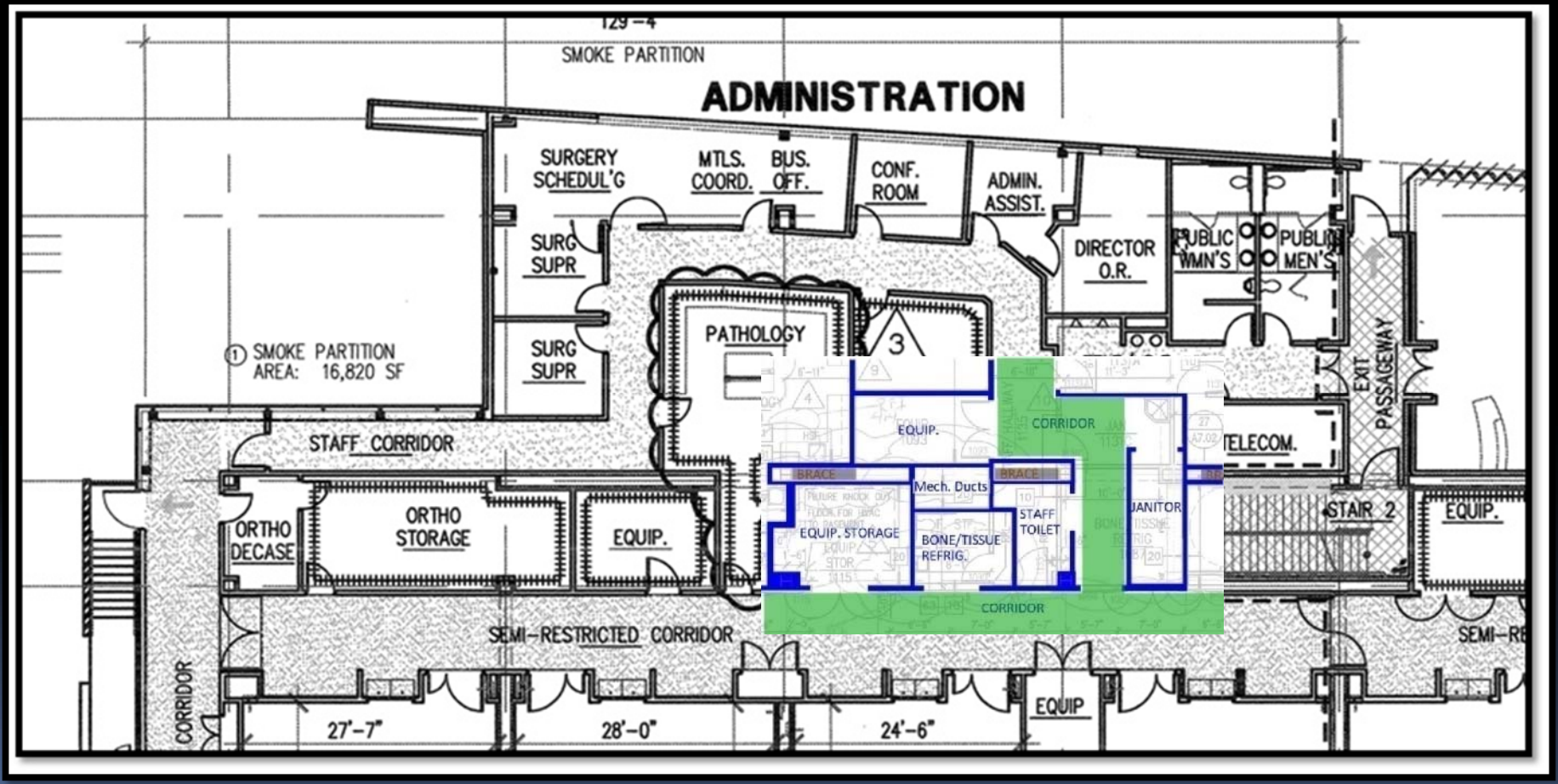


BF-1

Architectural Problem



Architectural Problem



Architectural Problem

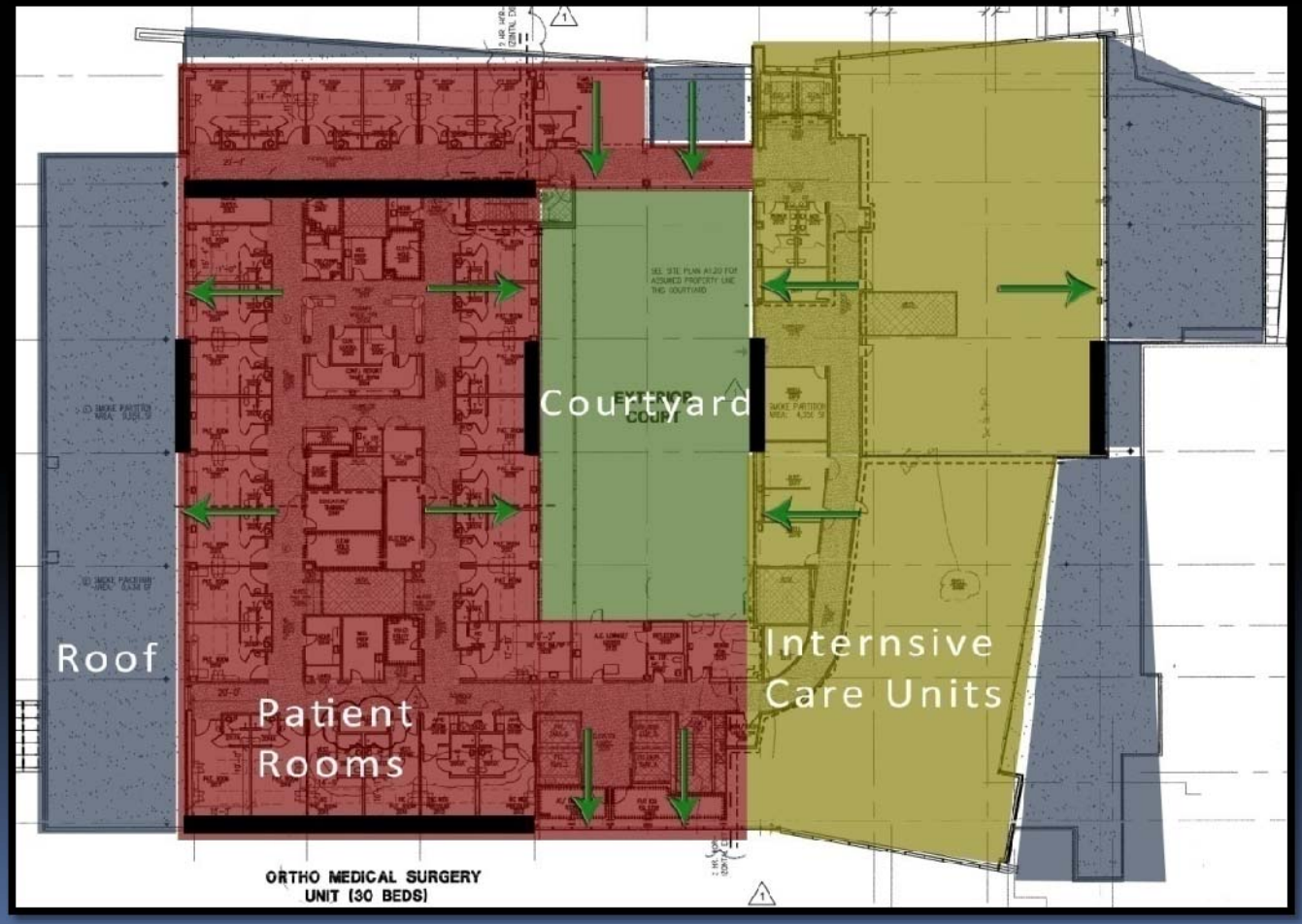
- Space Impact

Space	Area Before (SF)	Area After (SF)	% Change
Staff Toilet	60	70	+17%
Bone Tissue Refrigerator	120	83	-31%
Janitor	80	78	-3%

Architectural Advantage

- Less Braces Blocking Windows
  - 35 braces were removed that would have blocked windows

Architectural Advantage



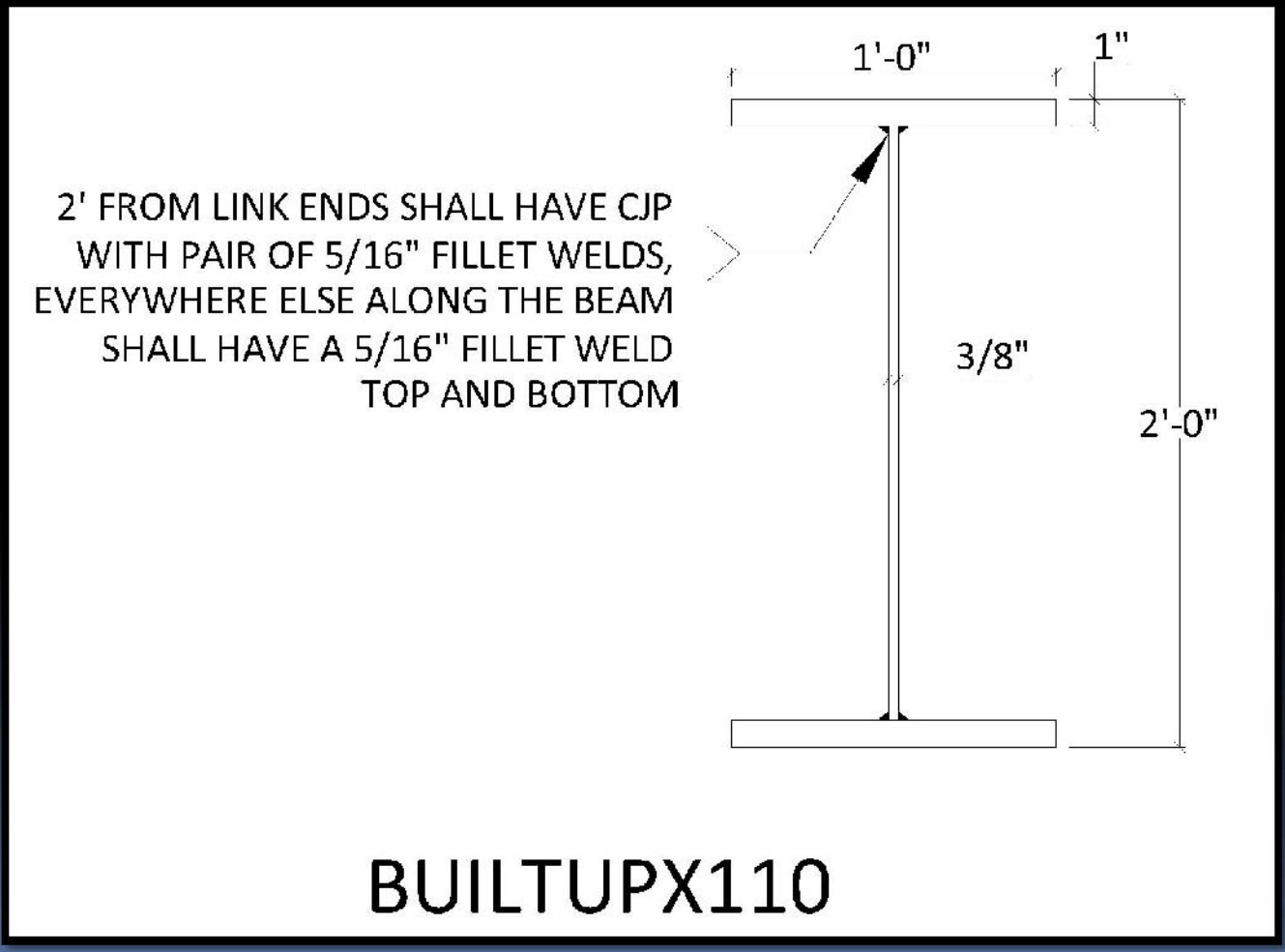
Commentary of AISC 358-05

Commentary of AISC 358-05

- *"Exception: Where reinforcement at the beam-to-column connection at the link end precludes yielding of the beam over the reinforced length, the link is permitted to be the beam segment from the end of the reinforcement to the brace connection. Where such links are used and the link length does not exceed 1.6Mp /Vp, cyclic testing of the reinforced connection is not required if the available strength of the reinforced section and the connection equals or exceeds the required strength calculated based upon the strain-hardened link as described in Section 15.6. Full depth stiffeners as required in Section 15.3 shall be placed at the link-to-reinforcement interface."*

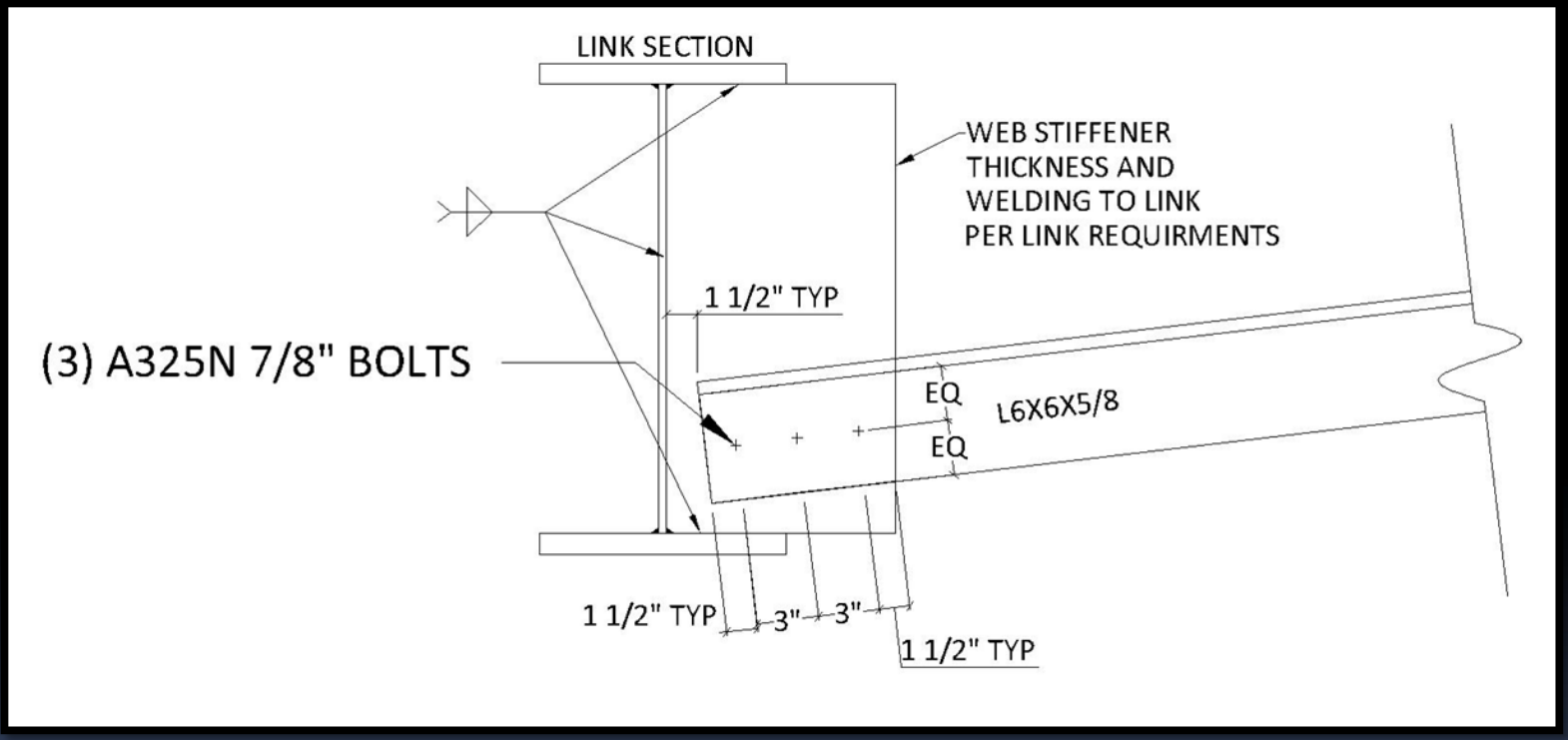
American Institute of Steel Construction, Seismic Provisions for Structural Steel, (AISC 341-05 Section 15.4)

Links - Built Up Section

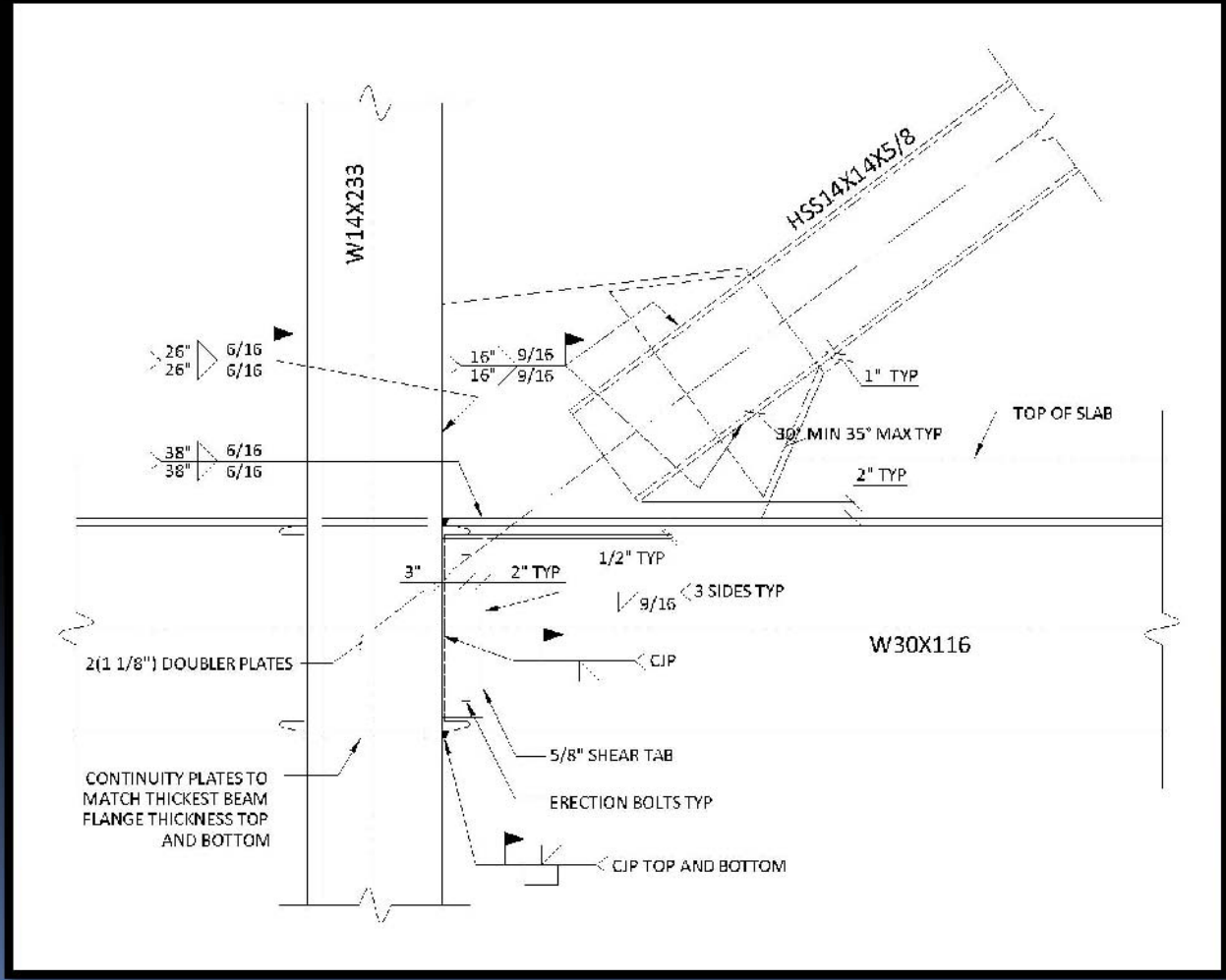


- Flange-Web welding according to AISC 358-05 Section 2.3.2.a
- Meets Required Slenderness Ratios

Link Lateral Bracing Connection



Brace - Beam – Column Connection



Foundation Design Codes

- Strip Foundation
  - ACI 318-08
    - Chapter 21
- Base Plate and Anchor Bolts
  - AISC Design Guide 1

Drifts

Story Drift Check

Importance Factor	1.5	
Cd	4	
Drift Limit	0.015	Table 12.12-1

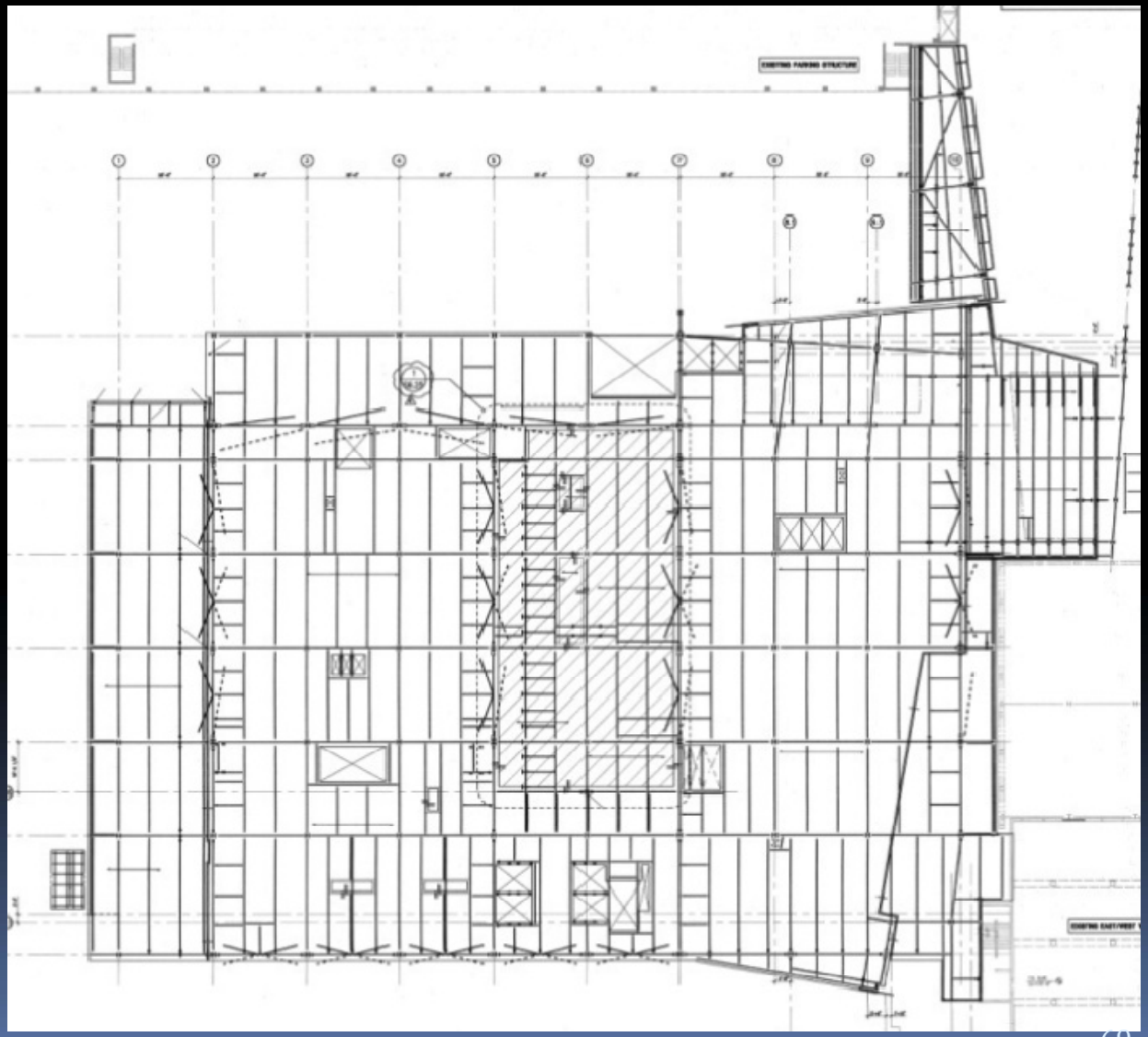
X Direction

Story	hx (ft)	Drift Ratio	Allowable Drift (in)	Story Drift (in)	Check?
Roof	15	0.001007	2.7	0.48336	OK
4	15	0.001271	2.7	0.61008	OK
3	15	0.001667	2.7	0.80016	OK
2	18	0.001901	3.24	1.094976	OK

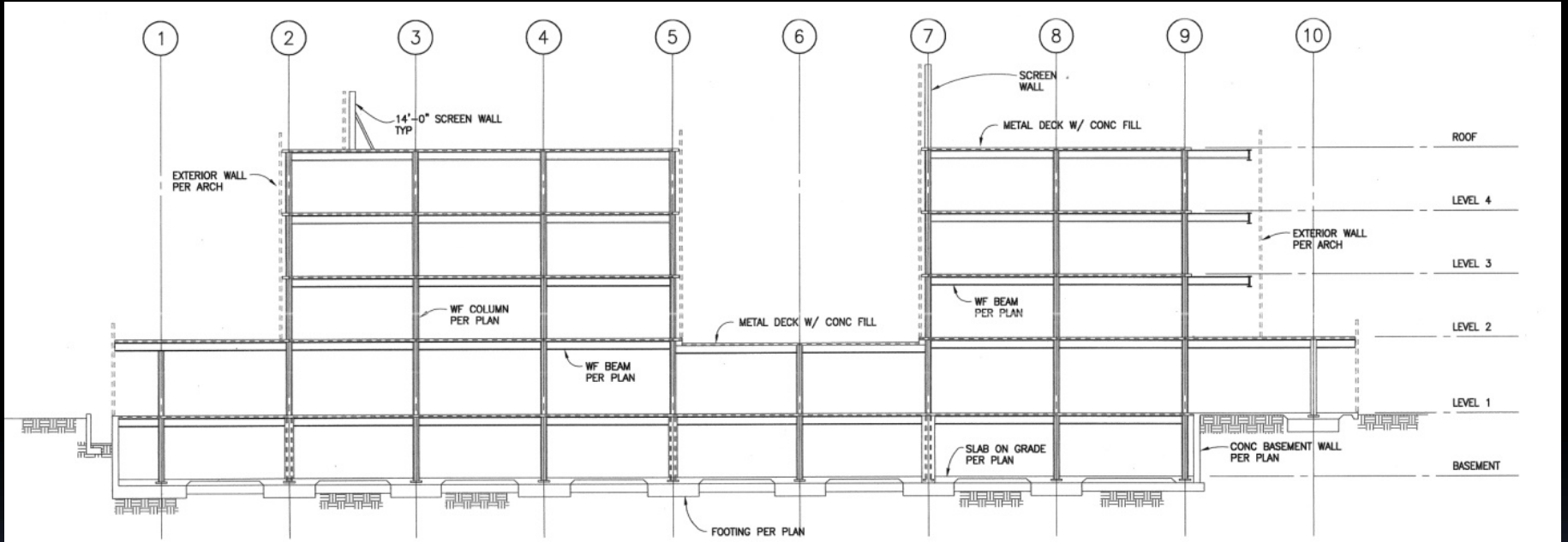
Y Direction

Story	hx (ft)	Drift Ratio	Allowable Drift (in)	Story Drift (in)	Check?
Roof	15	0.002433	2.7	1.16784	OK
4	15	0.002599	2.7	1.24752	OK
3	15	0.002789	2.7	1.33872	OK
2	18	0.002071	3.24	1.192896	OK

Plans

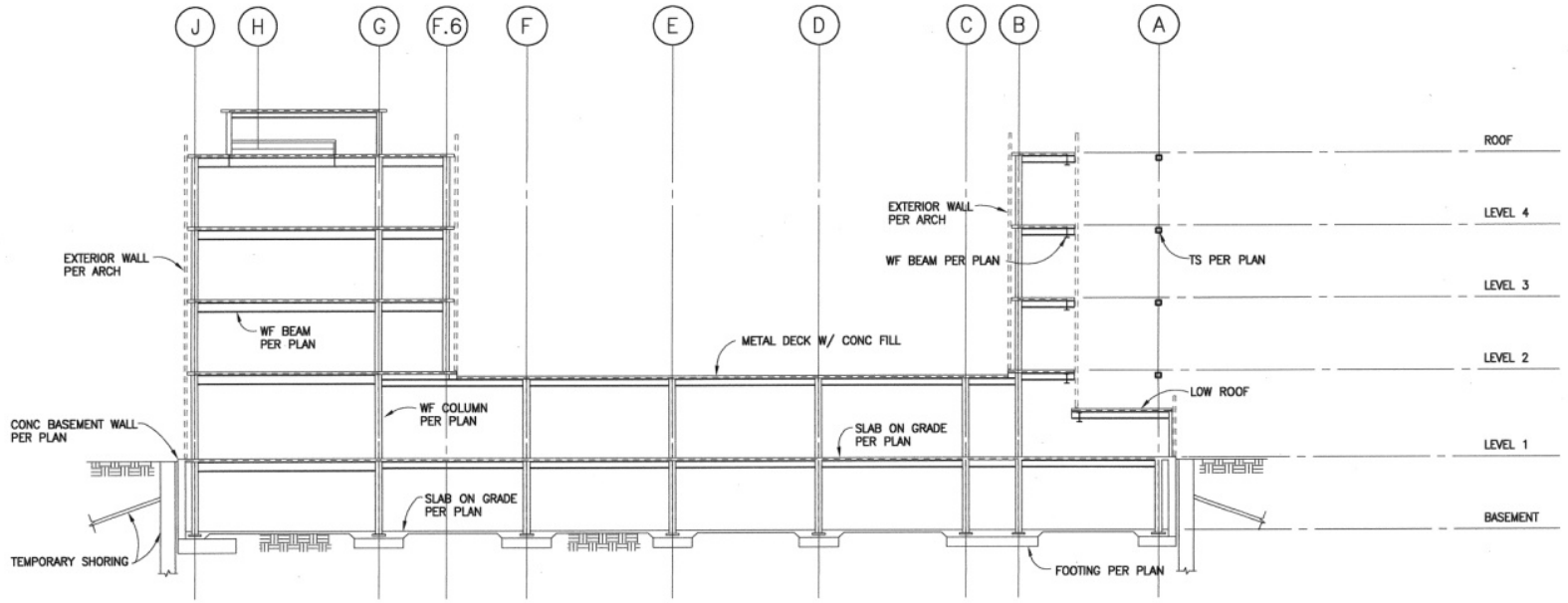


Elevation



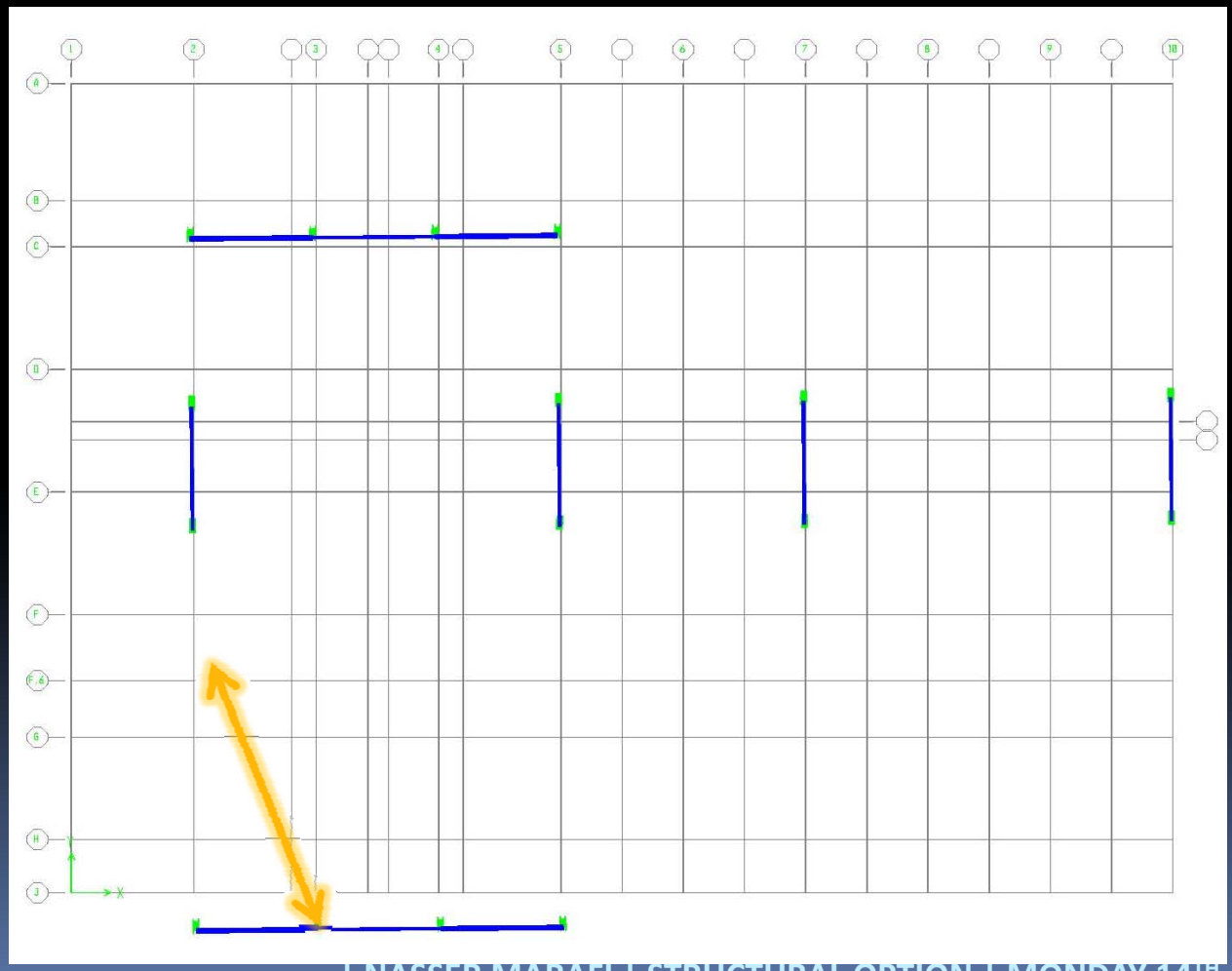
2 LONGITUDINAL BUILDING SECTION AT GRIDLINE E
1/16" = 1'-0"

Elevation



1 TRANSVERSE BUILDING SECTION AT GRIDLINE 6
1/16" = 1'-0"

ETABS Modal Shape



ETABS Modal Shape