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Structural Option

Senior Thesis Presentation

Spring 2007

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Acknowledgements

Industry Professionals

AE Faculty

Friends

Family

BACKGROUND
FIRMS INVOLVED
BUILDING INFO

EXISTING STRUCTURE
GRAVITY SYSTEM
LATERAL SYSTEM

PROPOSAL

DEPTH WORK-STRUCTURAL
LATERAL REDESIGN
GRAVITY REDESIGN

CONSTRUCTION MANAGEMENT

RECCOMMENDATIONS

BACKGROUND

21 story Class A Office Building

First Floor Retail Space

487,000 sq ft

Constructed: May 2000-Apr. 2002

Design – Build Delivery

$75,000,000

Project Team

Owner/Developer – The Shorenstein Co.

Architecture – Korth Sunseri Hagay Architects

Structural Engineer – Nishkian Menninger Inc

General Contractor – Charles Pankow Builders

Mechanical – Acco Air

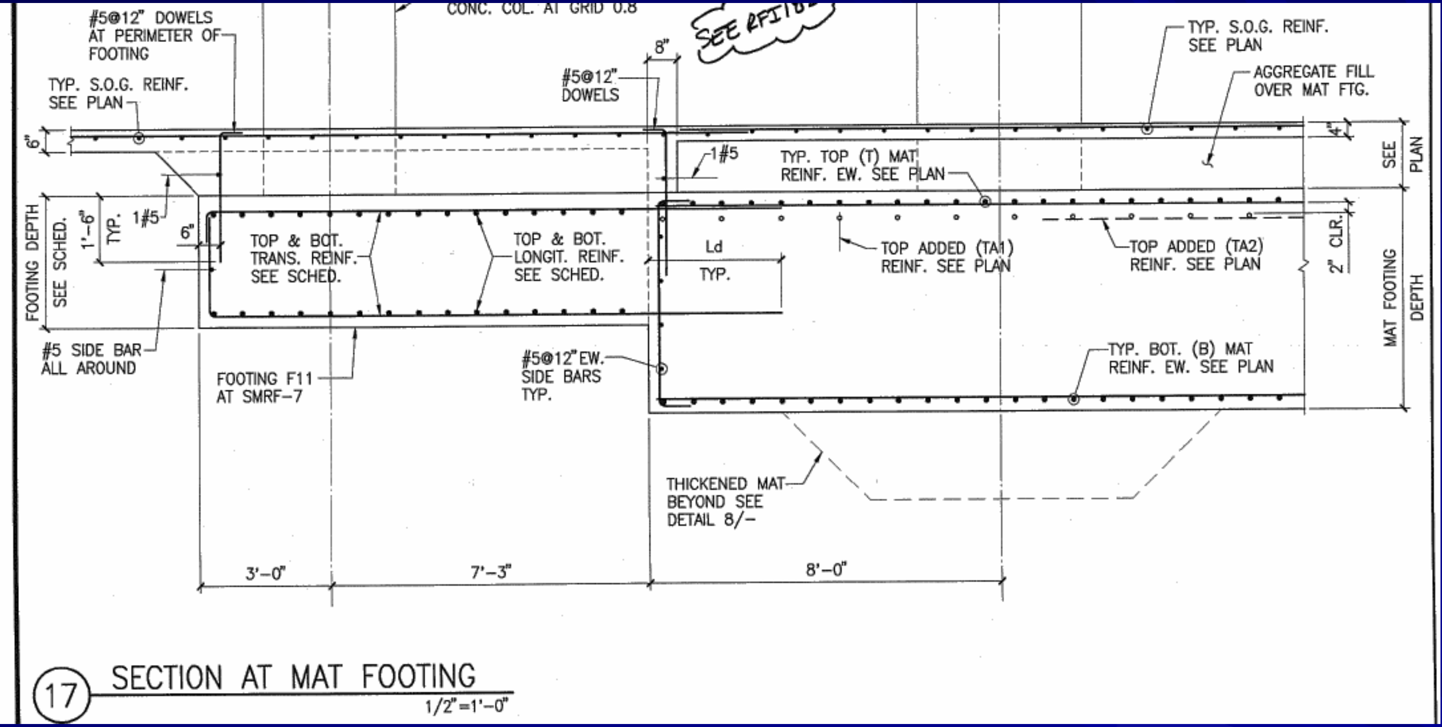
Electrical – Schwartz and Lindheim

Plumbing – L.J. Kurse Co.

Lighting – Auerbach and Glasow

EXISTING STRUCTURE

Mat Foundation



5 feet thick along perimeter SMRF's
7 feet think under core EBF's
f'c = 4000psi

Columns (gravity only)

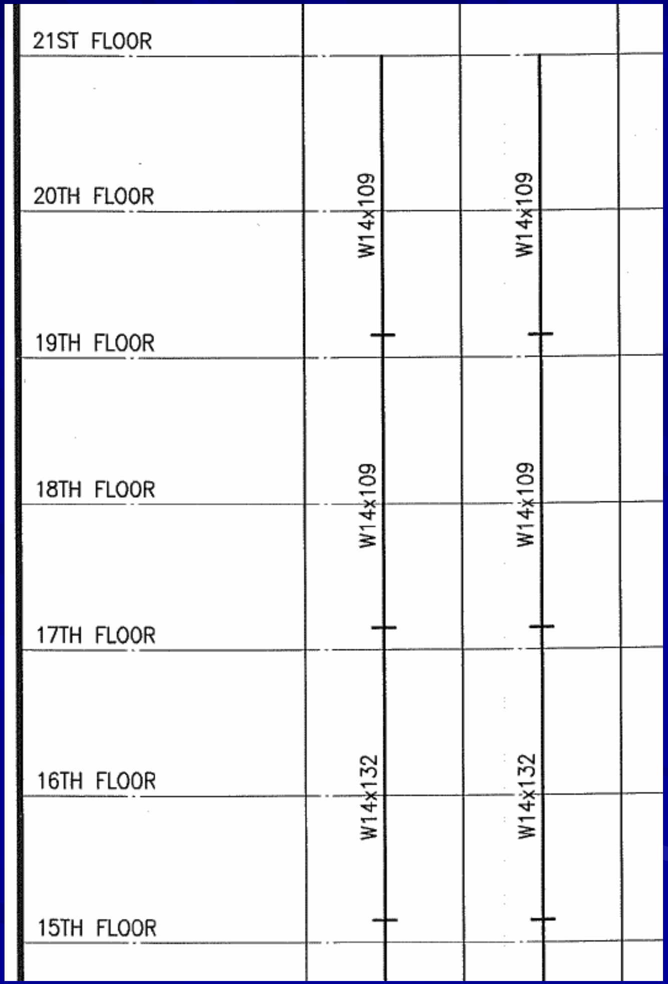
Only 4 column sets that are gravity only on perimeter

Sizes: W14 x 109 @ top
W14 x 500 @ base

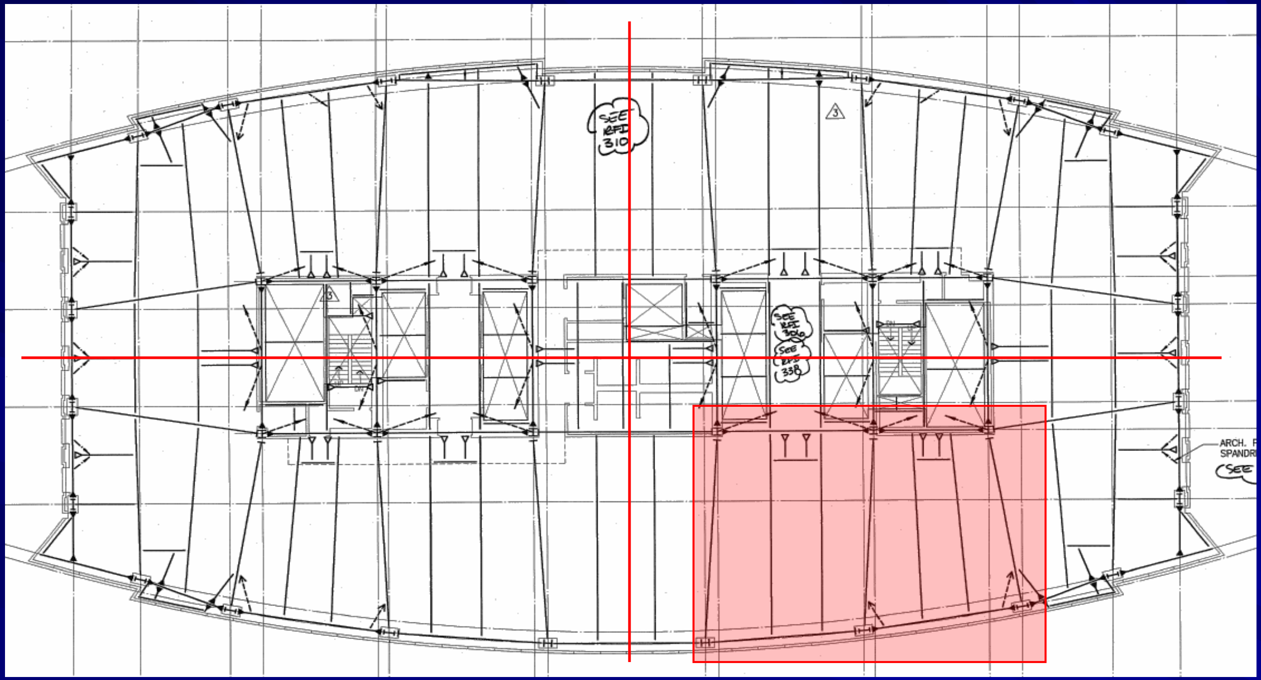
13' floor to floor height typical

Create Open Office floor plan

All other columns part of LFRS



Floor System



North

Typical : 3-21
Composite Deck
Two Lines of Symmetry

Floor System

Interior Beams: W18 x (35-60)

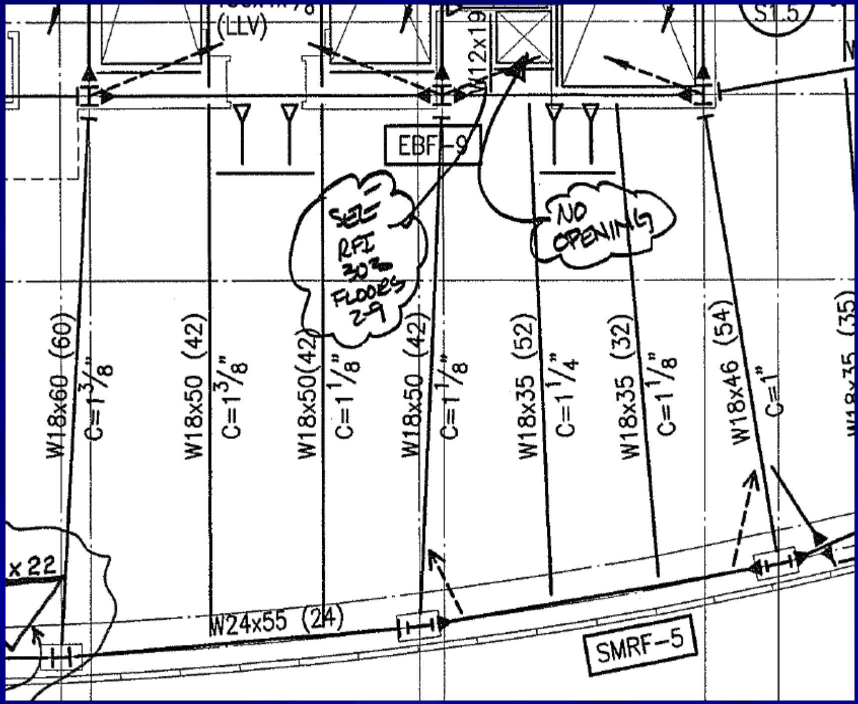
Span: up to 45'(camber)

Spacing ~10' o.c.

Girders: W24's

Span: up to 35'

Mechanical: Larger Members



North

Floor System

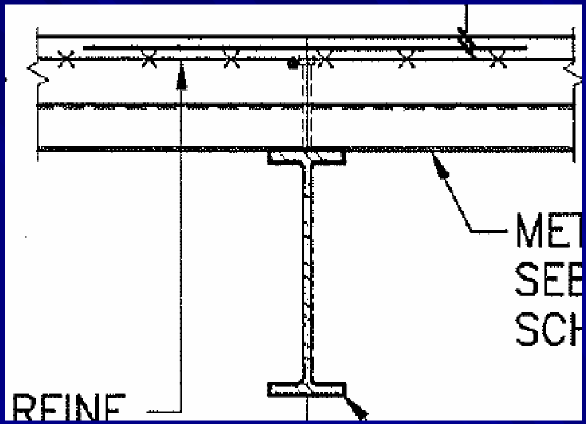
Composite Decking and Slab

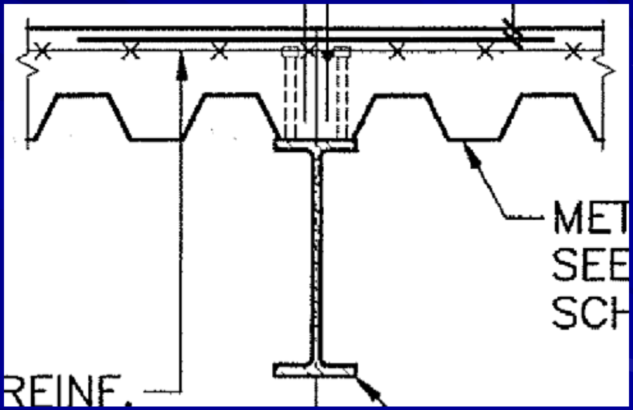
Typical: 3″ deck w/ 2 ½″ NWT
#3 @ 16″ EW

Roof: 3″ deck w/ 2 ½″ LWT
#3 @ 16″ EW

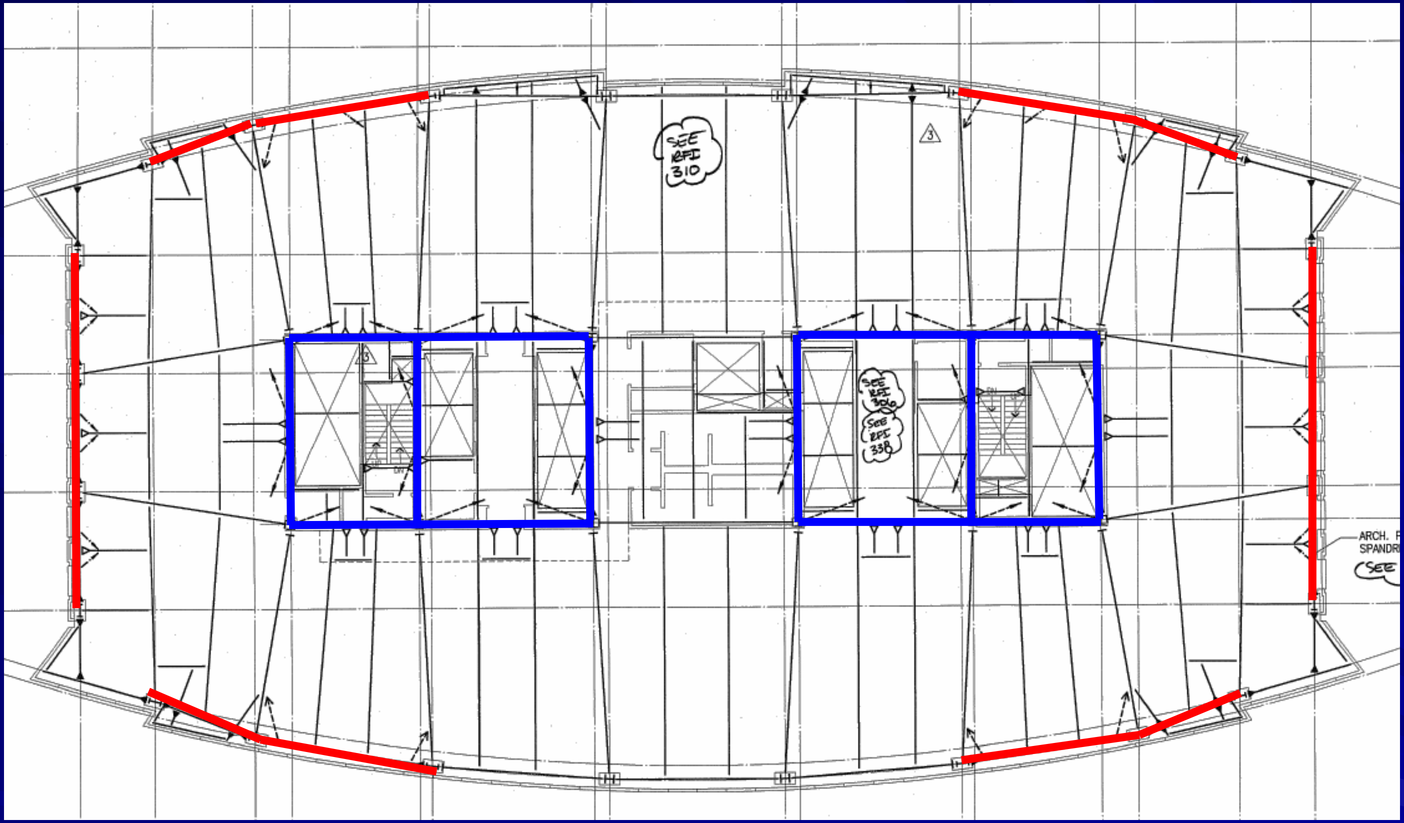
Mech: 3″ deck w/ 6″ NWT
#4 @ 12″ EW

Shear Studs: ¾″ diameter U.O.N





Lateral Dual System



Eccentric Braced Frames (EBF) – blue
Shear Walls from Mat – 2nd under EBF
Special Moment Resisting Frames (SMRF) – red

North

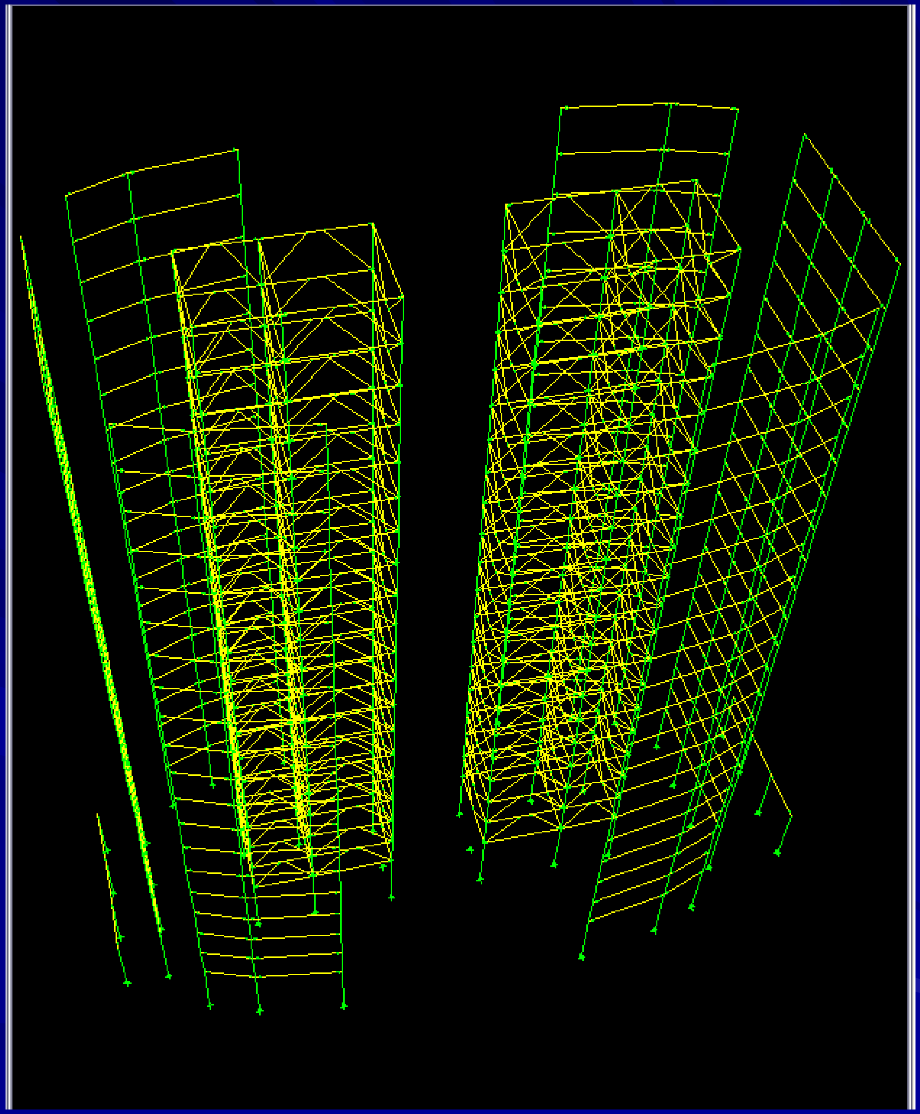
EBF

Columns: W14 x (106-665)
Beams: W18-W21
Braces: W10x88 – W14x159

SMRF

Columns: W24, W33, W36
Beams: W24, W33

Dual System:
SMRF's > 25% lateral loads



PROPOSAL

Design a reinforced concrete shear wall core for high rise office building in high seismic region.

Elimination of moment frames/connections and EBF's and replaced with gravity only columns and girders.

Goals:

Limit seismic induced drift
Keep open office layout
Reduce cost/schedule by removing moment connections/large frame members
Design to pass a peer review*

Solution Method

Design to Pass a Peer Review

Code limits RC shear walls to 240ft in seismic D/E

Performance of building during dynamic loading evaluated

Reviewer present for preliminary, depth, and final design phases

"Performance Based Design"

Use: ACI 318-05, IBC 2006, ASCE7-05 as guides

Design Criteria used, more demanding than ACI-318 2005 Ch. 21

Shear Walls:

Code: $Vn < 8*A_{cv}*(f'c)$ ^1/2

Designed: $Vn < 4*A_{cv}*(f'c)$ ^1/2

Coupling Beams:

Code: $Vn < 10*A_{cv}*(f'c)$ ^1/2

Designed: $Vn < 8*A_{cv}*(f'c)$ ^1/2

Story Drift:

Code: $< 0.02\ h_{sx}$ story-to-story

Designed: $< 0.015\ h_{sx}$ story-to-story
$< 0.01\ h_{sx}$ from base-roof

LATERAL REDESIGN

Preliminary Design

Target period of vibration (T) found

Required moment of inertia (I) determined

Shear wall locations and sizes picked

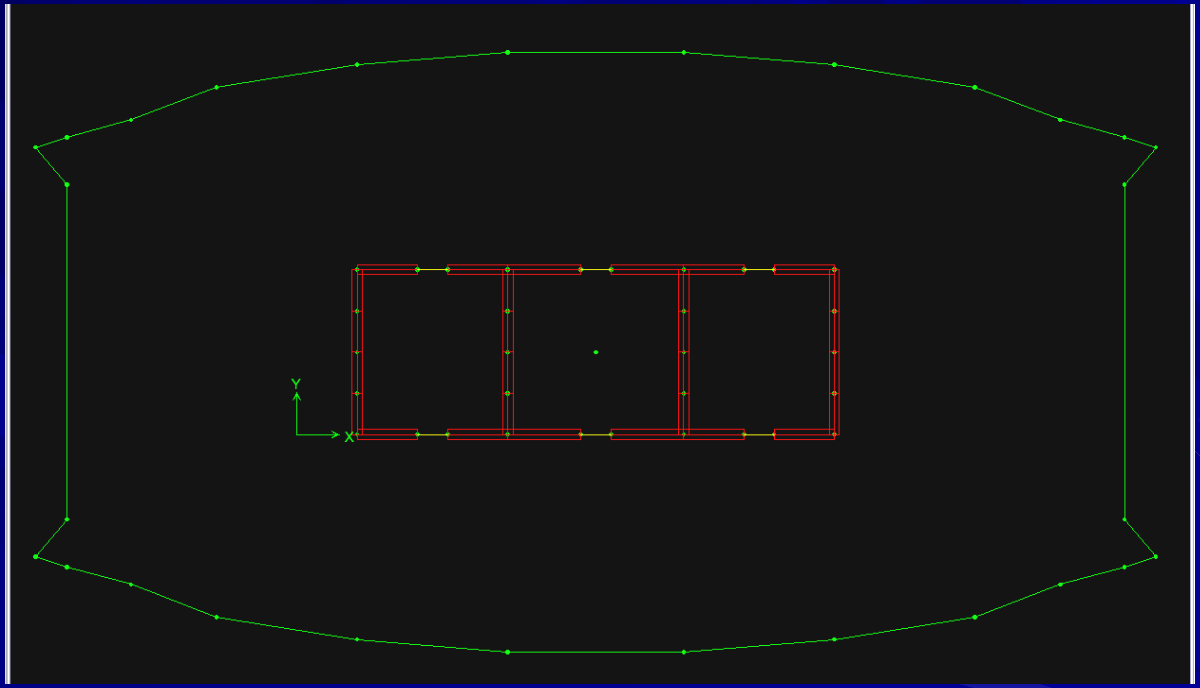
Coupling beam sizes picked

Concrete strength (f'c) chosen to satisfy design criteria

Information used to start Dynamic Analysis in ETABS

ETABS Analysis

Lumped Mass Model created
- Shear Walls
- Coupling Beams
- Rigid Diaphragm
- Point Mass



Center of Mass and Center of Rigidity coincide (symmetry)

Static ETABS Analysis

Static Forces determined through Equivalent Lateral Force Procedure
-includes weight of shear walls

Base Shear = 6435 kips

Accidental Torsion Amplification Factor
(Ax) = 1.07 * (0.05) = .0535

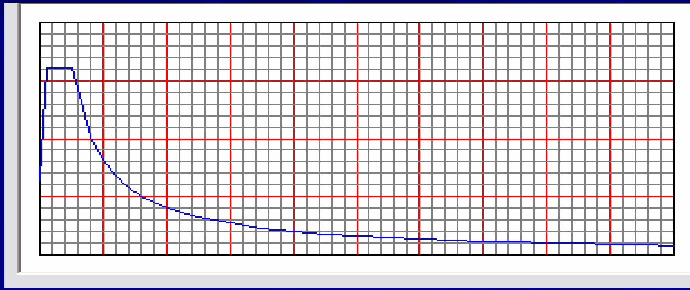
Value used for eccentricity in all static/dynamic load cases

SEISMIC	
Ss	2.4095
Sl	0.9405
Site Class	C
Fa , Fv	1.0 , 1.3
Importance Factor	I = 1.0
Sds	1.6063
Sdl	0.815
Seismic Design	E
R	5
Cd	5
Ω_o	2.5
Cu	1.4
Ta	1.445
T	2.02
k	1.76
Cs	0.094

Dynamic ETABS Analysis

Steps:

Input response spectrum function with S_{ds} and S_{d1}



Create Load cases for Forces in X and Y and drift in X and Y

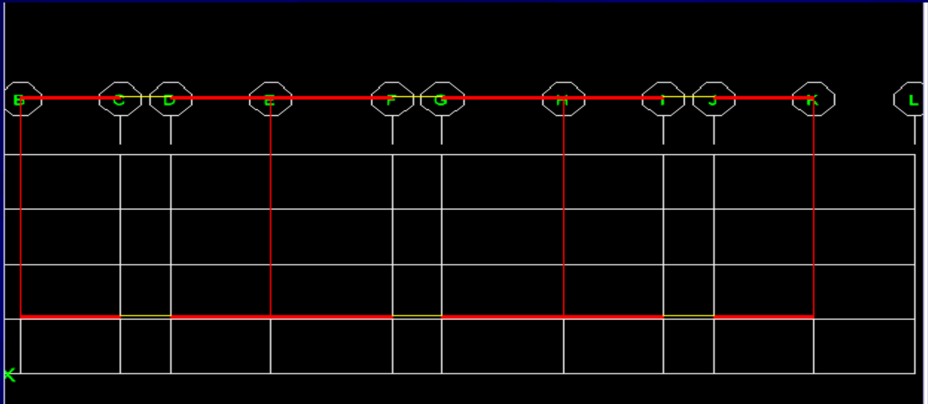
Scale dynamic forces to match static Base Shear

Scale dyn. Forces by 0.85 (ASCE7 section 12.9.4)

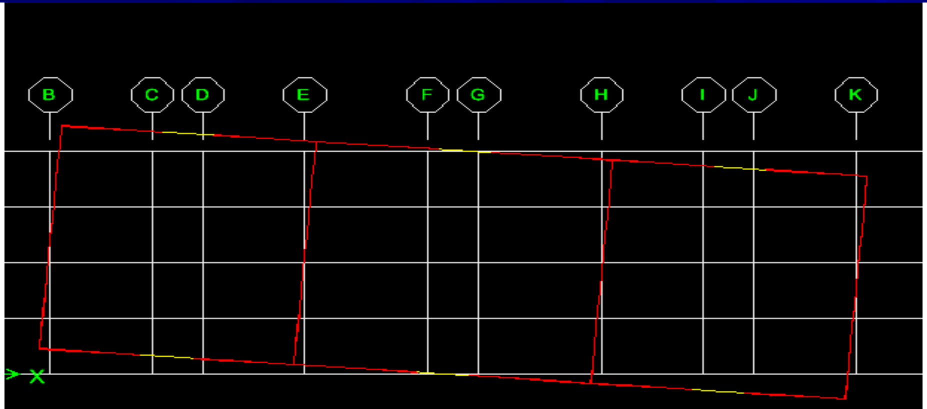
Scale dyn. Drift by (C_d / R) (ASCE7 section 12.9.4)

Dynamic ETABS Analysis

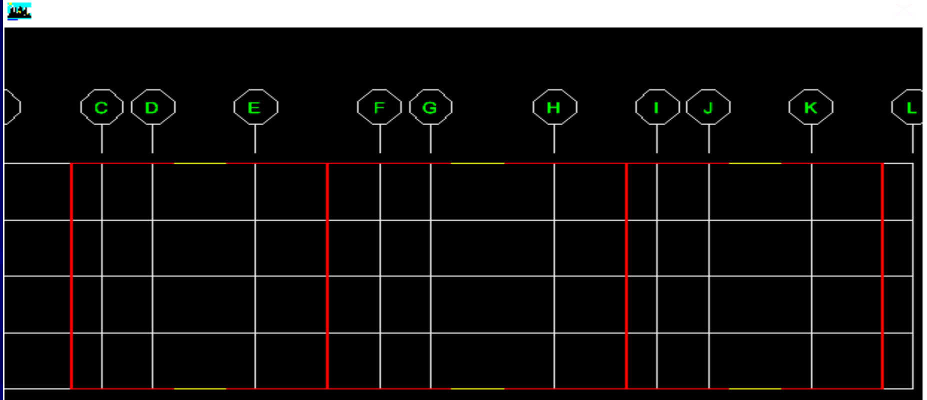
Find Modes of Vibration with Period (T) (Modal Res. Spec. Analysis)



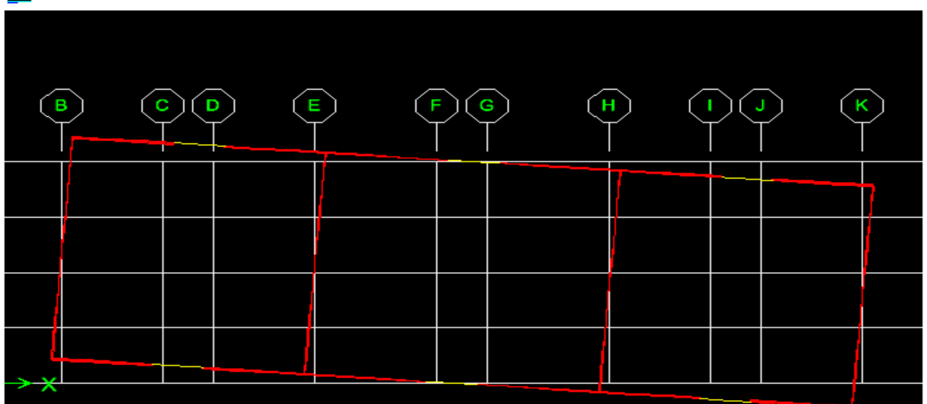
1st mode – T = 2.31 s (Y direction)



2nd mode – T = 2.01 s (rotation)



3rd mode – T = 1.58 s (X direction)



4th mode – T = 0.54 s (rotation)

Dynamic ETABS Results

Output shear in coupling beams

Output shears for individual shear walls including accidental torsion

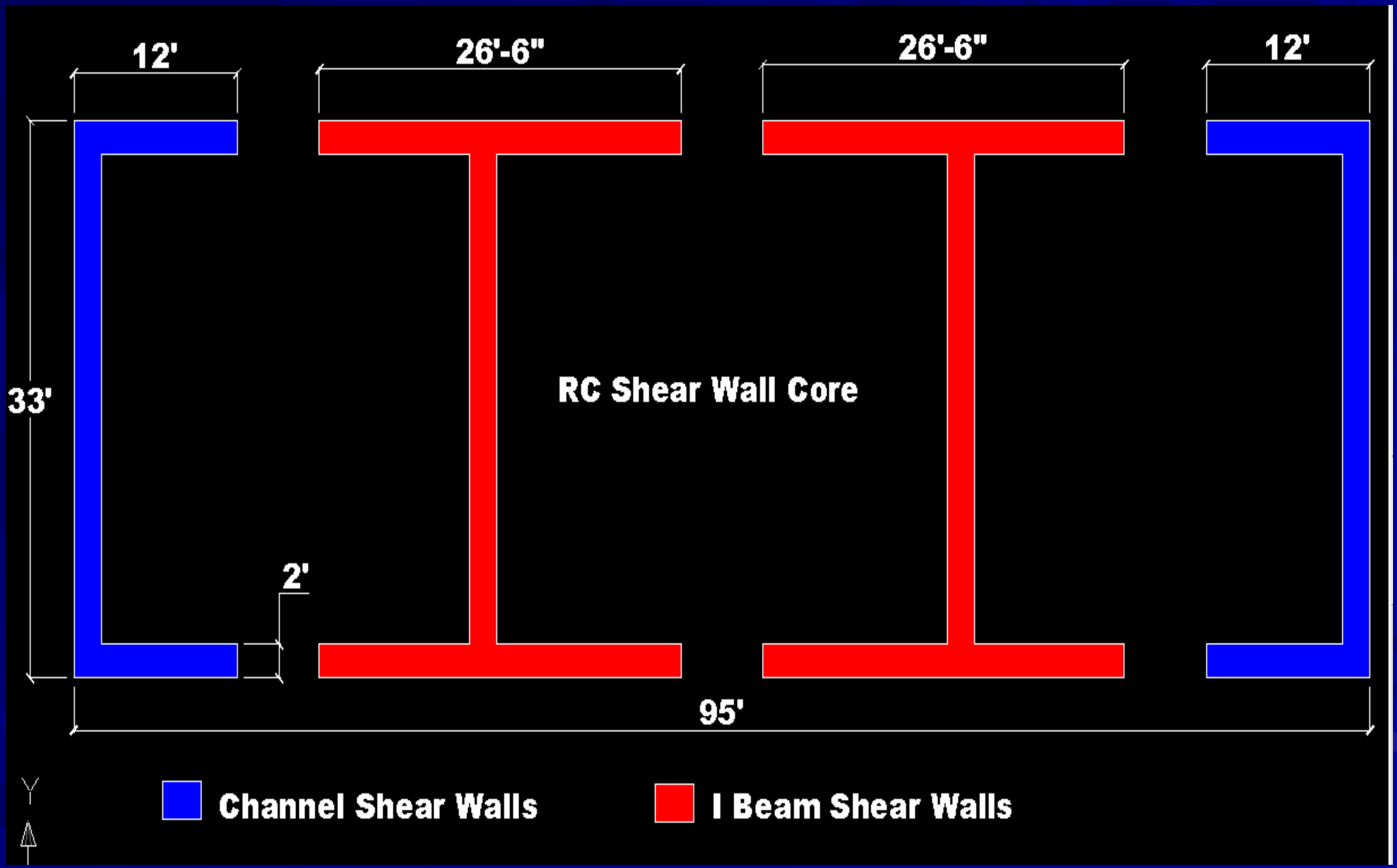
Output Mx and My for shear walls piers

Output Total base shear V = 5472 kips

Output Dynamic Story Drift (X and Y)

Use analysis results to check design criteria, and to detail if pass

Shear Wall Design



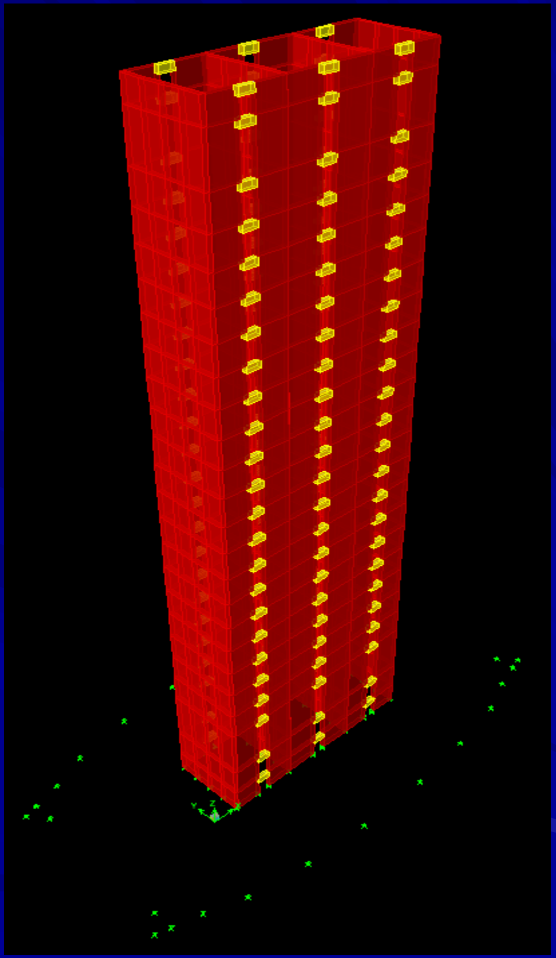
Shear Wall Design

All walls: f'c = 9 ksi
2 feet thick

Shear Reinforcing required

I beam: Web: ρ = .0025
Flanges: ρ = .0025
Channel: Web: ρ = .003
Flanges: ρ = .0025

Use #6 @ 12" EF EW for all

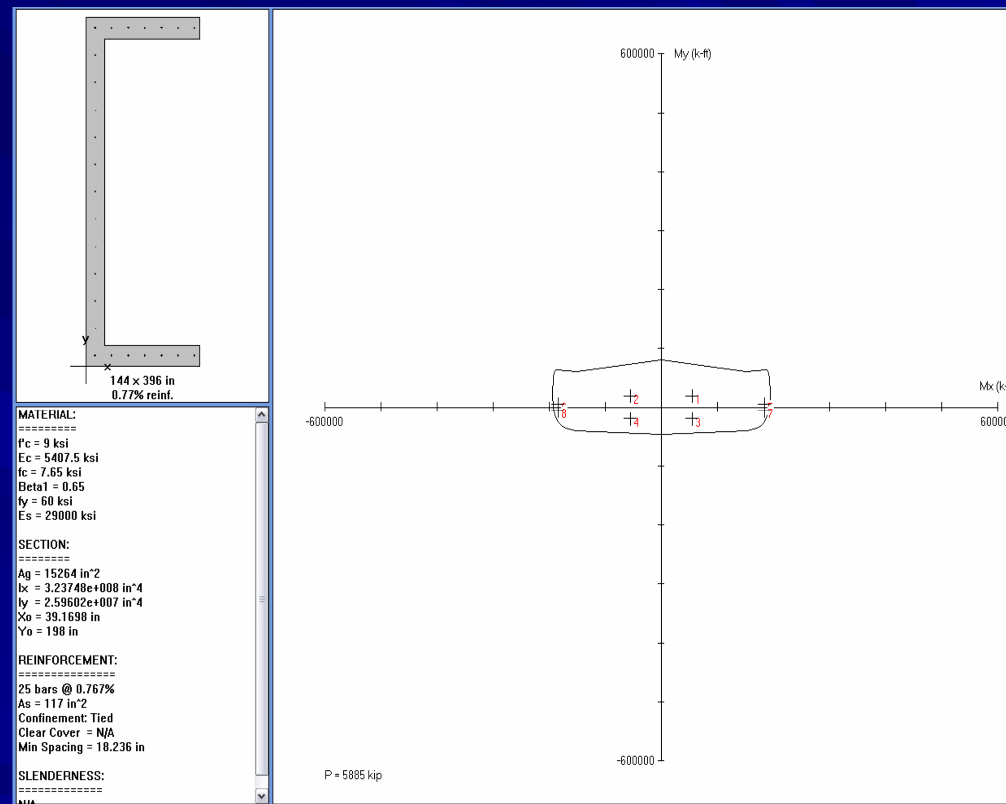


Shear Wall Design

PCA Column used to determine Flexural Reinforcing

1) 0.7D + 1.0Ex + 0.3Ey
2) 0.7D + 1.0Ex – 0.3Ey
3) 0.7D – 1.0Ex + 0.3Ey
4) 0.7D – 1.0Ex – 0.3Ey
5) 0.7D + 1.0Ey + 0.3Ex
6) 0.7D + 1.0Ey – 0.3Ex
7) 0.7D – 1.0Ey + 0.3Ex
8) 0.7D – 1.0Ey – 0.3Ex

-from ETABS



Shear Wall Design

PCA Column used to determine Flexural Reinforcing

Section	Total As (in^2)	Web (in^2)	Flanges (in^2)
I beam	158	22	68 each
Channel	117	33	42 each

I beam Flange: A steel = 2.56 in^2/ft
Channel Flange: A steel = 3.5 in^2/ft

Coupling Beam Design

Critical Component: Designed to crack before walls, and act as plastic hinges

An effective moment of inertia is used = 1/9 I gross (lower limit)

Beam 7,9,10,12			Beam 8,11		
Floors	**0.8*Vmax (kips)**	**Vavg**	**Floors**	**0.8*Vmax (kips)**	**Vavg**
16-Roof	**144**	121	16-Roof	**206**	183
8 to 15	225	**241**	8 to 15	306	**334**
1 to 7	244	**290**	1 to 7	322	**381**

Shear reinforcing based off of Mpr, the probable flexural strength

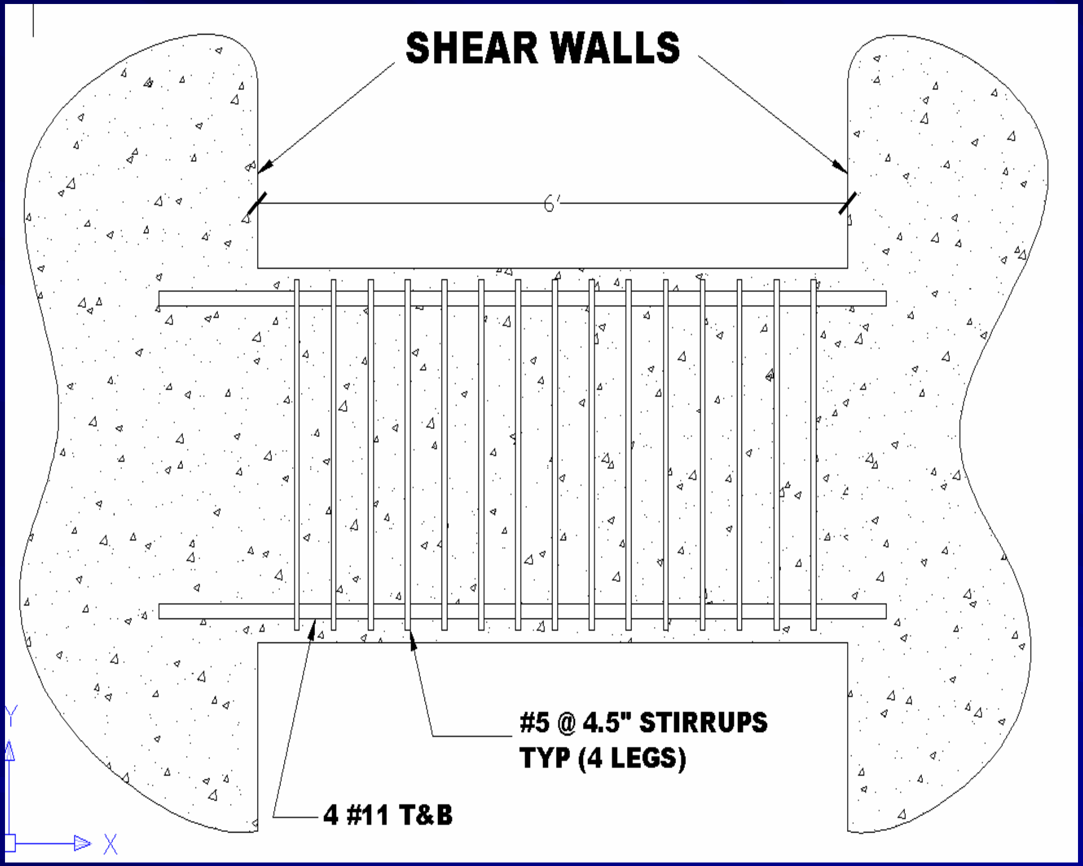
This increased moment capacity = increased shear forces

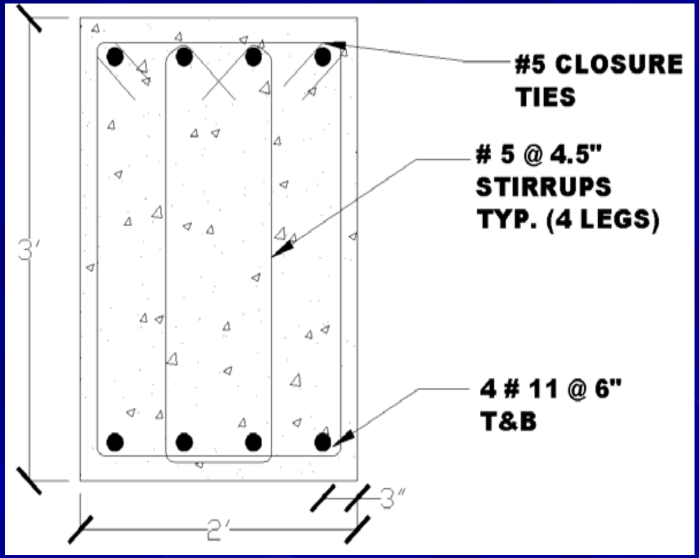
Coupling Beam Design

Member	Width (in)	Depth (in)	Long. Reinf Top	Long. Reinf. Bottom	Skin Reinf.	Shear Reinf.
Floors 1-7						
B7	24	33	4-#11	4-#11	NONE	4 legs #5 ties @ 4.5"
B8	24	33	5-#11	5-#11	NONE	5 legs #5 ties @ 4.5"
B9	24	33	4-#11	4-#11	NONE	4 legs #5 ties @ 4.5"
B10	24	33	4-#11	4-#11	NONE	4 legs #5 ties @ 4.5"
B11	24	33	5-#11	5-#11	NONE	5 legs #5 ties @ 4.5"
B12	24	33	4-#11	4-#11	NONE	4 legs #5 ties @ 4.5"

All beams 3′ deep and 2′ thick
f′c = 9 ksi

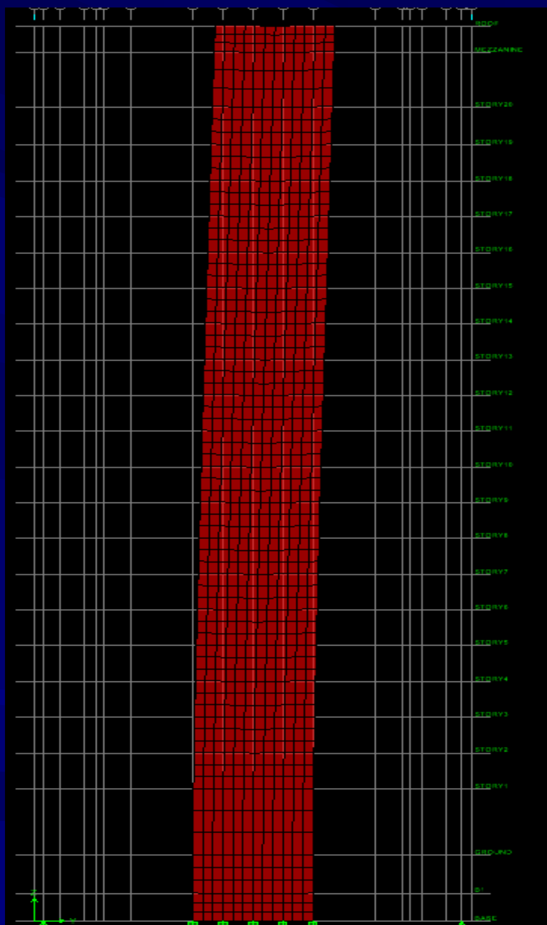
Coupling Beam Design





Seismic Drift

Critical direction, (N-S)



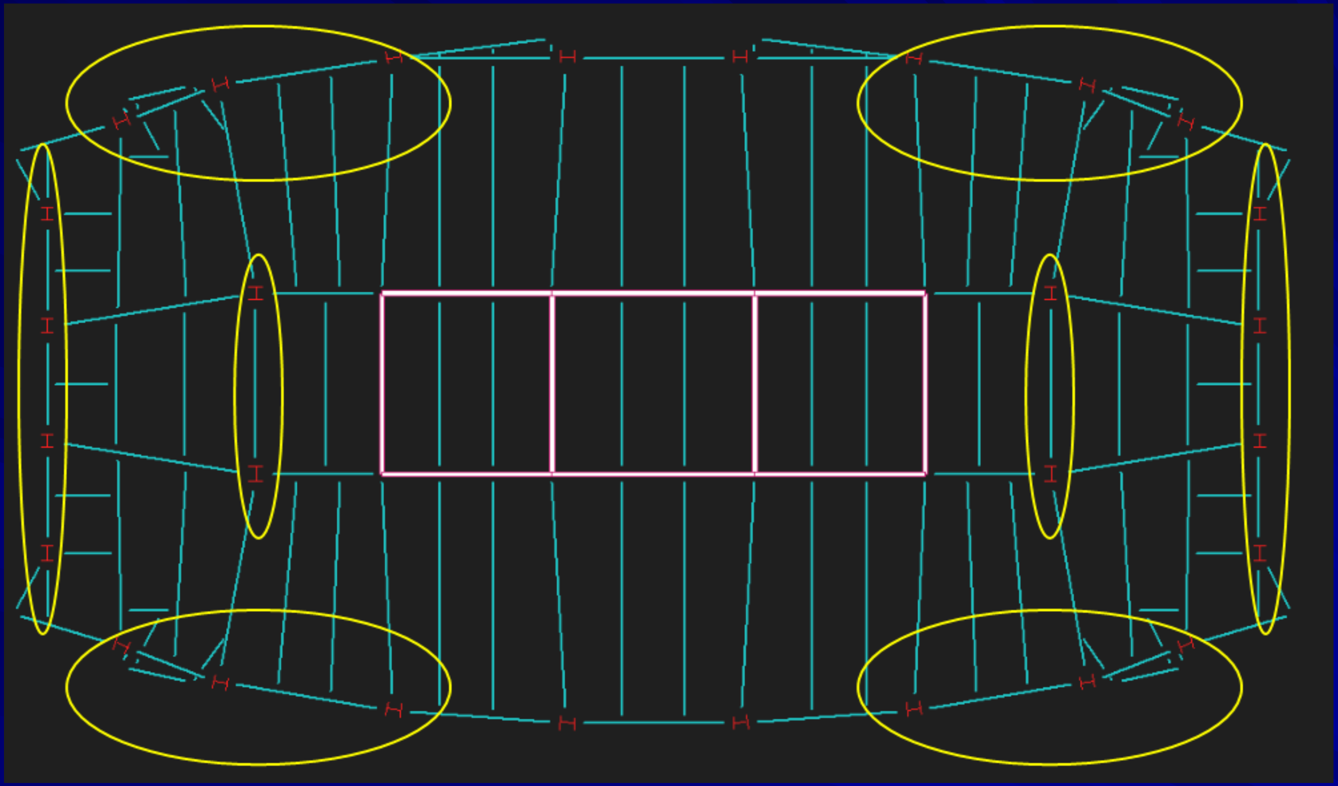
STORY	DISP-Y	DRIFT-Y
ROOF	30.735	0.01096
MEZZ	29.4792	0.01095
STORY20	26.8858	0.01098
STORY19	25.1039	0.01097
STORY18	23.4235	0.01094
STORY17	21.7514	0.01087
STORY16	20.0919	0.01076
STORY15	18.4503	0.01061
STORY14	16.8319	0.01041
STORY13	15.2422	0.01018
STORY12	13.6872	0.00989
STORY11	12.1728	0.00957
STORY10	10.7052	0.0092
STORY9	9.2909	0.00879
STORY8	7.93682	0.00833
STORY7	6.65039	0.00782
STORY6	5.43972	0.00726
STORY5	4.31368	0.00664
STORY4	3.28208	0.00596
STORY3	2.35569	0.0052
STORY2	1.54637	0.00436
STORY1	0.86679	0.00301
GROUND	0	0
B1	0	0

30.7" < .01 h = 36.1"

Drifts < .015 hsx

Passes Drift

GRAVITY REDESIGN



Elimination of SMRF and EBF to gravity only

Ram Structural System used for redesign

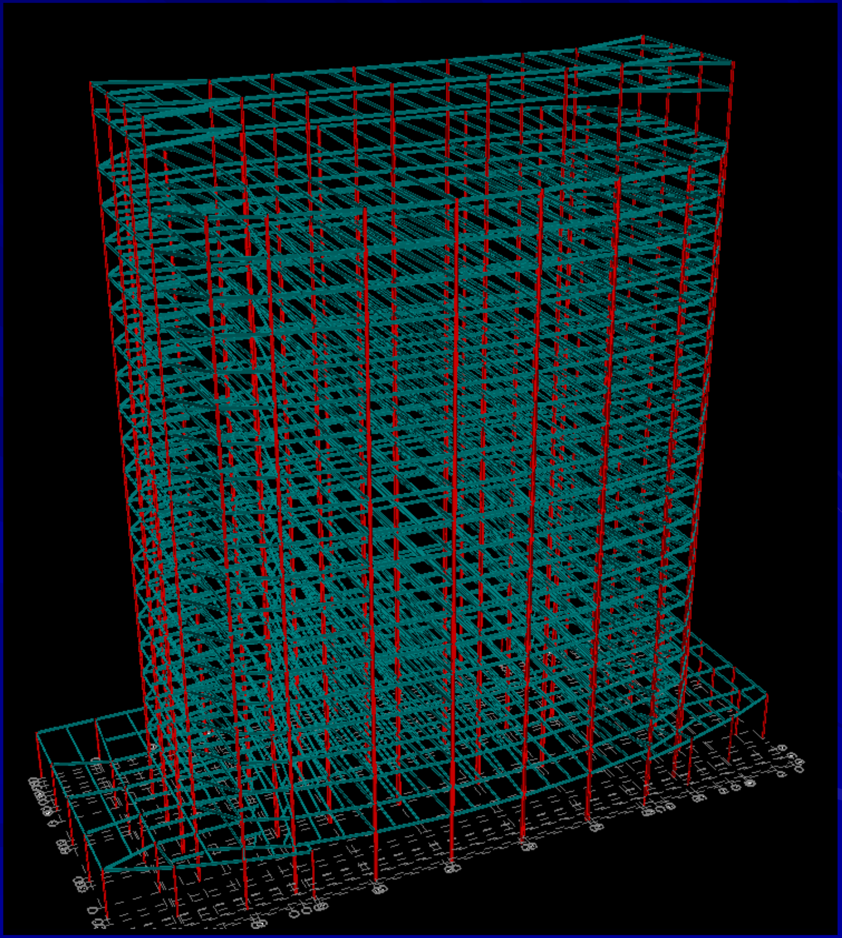
Criteria for Redesign:

Limit deflection: L / 360 for live load,
L / 240 for total load

Use LRFD 3rd Edition to check composite

Governing Load case: 1.2 D + 1.6 L

Allow Live Load Reduction (< 100psf)



New Member Sizes

Perimeter and interior columns now W14 x 43 up to W14 x 370

Previously: W24, W33, W36

Perimeter Girders now W10x12 up to W21x44

Previously: W24, W33

Substantial decrease in member sizes

CONSTRUCTION MANAGEMENT

Cost

All Cost information obtained from General Contractor and Fabricator
Costs are in year 2000 dollars, in Oakland area.

Steel: $1650/ton

- Material: $650
- Fabrication: $635
- Erection: $365

Moment vs. Gravity Connection: (Labor Only)

Fabrication: $700 / connection
Field Welding: $800 / connection

Concrete: $850 / CY

Cost

Original (Lateral Only)		Redesign	
$5,420,250	3285 tons steel	$5,100,000	6000 CY concrete
$ 480,000	MC Fabrication	$ 480,000	465 tons steel
$ 420,000	MC F. Welding	$5,867,250	
$6,320,250			
+ fire protection			

Savings from Redesign: $453,000 + fireproofing

Savings and cost of field welding connections about the same

Schedule decrease?

Schedule

Potential Schedule savings from elimination of moment connections

$420,000 for MC field Welding

Assume two E-9 crews, welding rigid frames = $9200 / day including O&P

Total days = 46 days / 2 crews = 23 days savings

Jump Form should not conflict with steel erection (Walls up first)

Recommendations

New Lateral System passes design criteria set forth

New gravity columns/girders much smaller than previous design

Cost of project just over $450,000 cheaper

Field Welding decrease = 23 days schedule savings
= open earlier / more rent revenue

Jump Form efficient for shear walls

Use redesigned Lateral and Gravity System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ネガドン
Questions?