# Dan Donecker

## BAE/MAE – Structural Option

## Senior Thesis Project


35 West 21st Street

New York, New York

# Presentation Outline

- Building Introduction
- Existing Conditions
- Thesis Proposal
- Structural Redesign: Gravity
- Structural Redesign: Lateral
- Breadth Redesign: Architecture
- Comparison of Existing and Redesigned Building
- Questions

# Existing Conditions

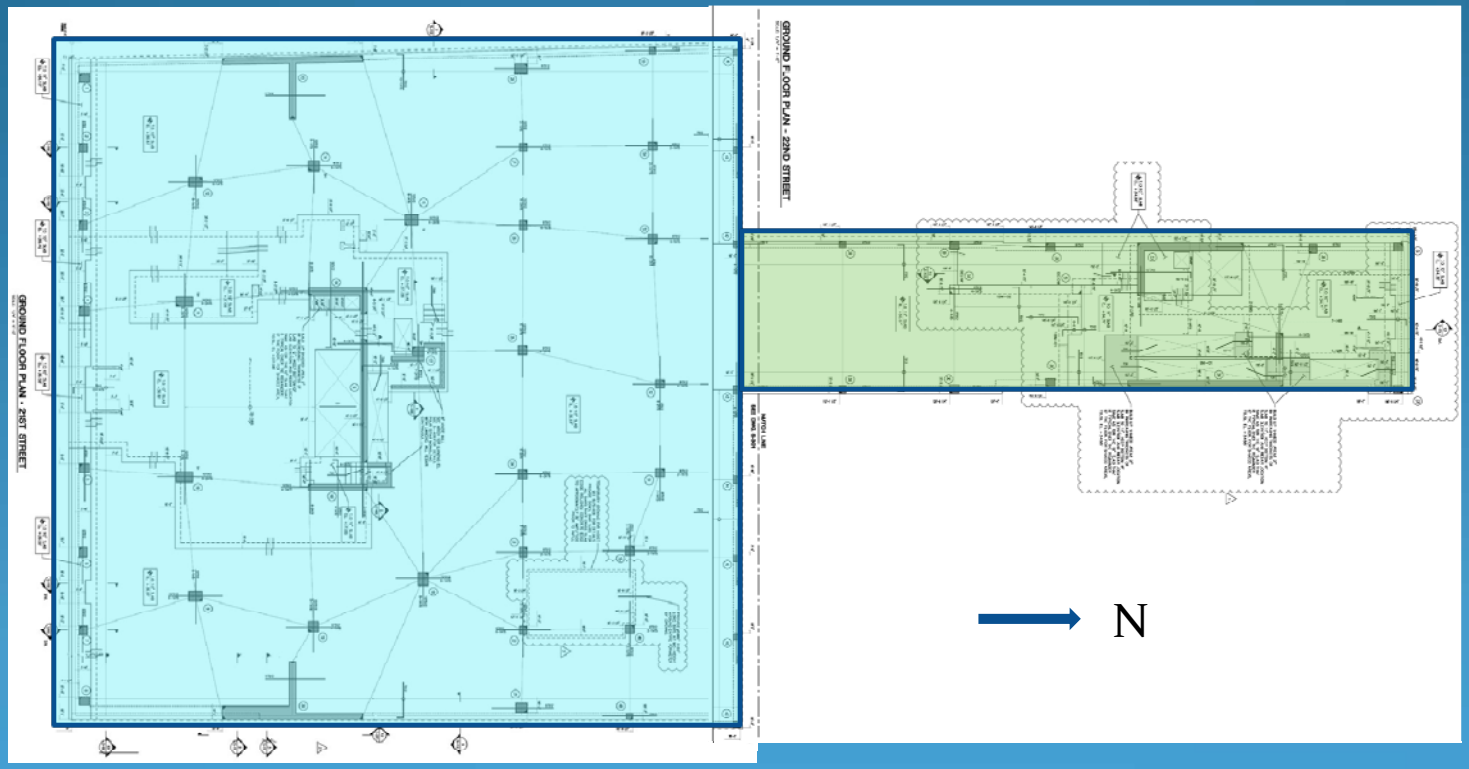
## - General

- Location: 35w 21st Street, NY, NY
- 16 Stories – 160 ft above grade
- 162,000 sq. ft
- Occupancy:
  - First floor Retail
  - Stories 2-15, Residential
- Owner: Roseland Associates
- Architect: SLCE*Architects*
- Struct. Engr.: DeSimone Consulting Engineers
- Mech. Engr.: Cosentini Associates
- CM: Plaza Construction Corporation

# Existing Conditions

## - Architecture

- Building composed of two sections
  - 16 story tower (blue)
  - 8 story tower (green)

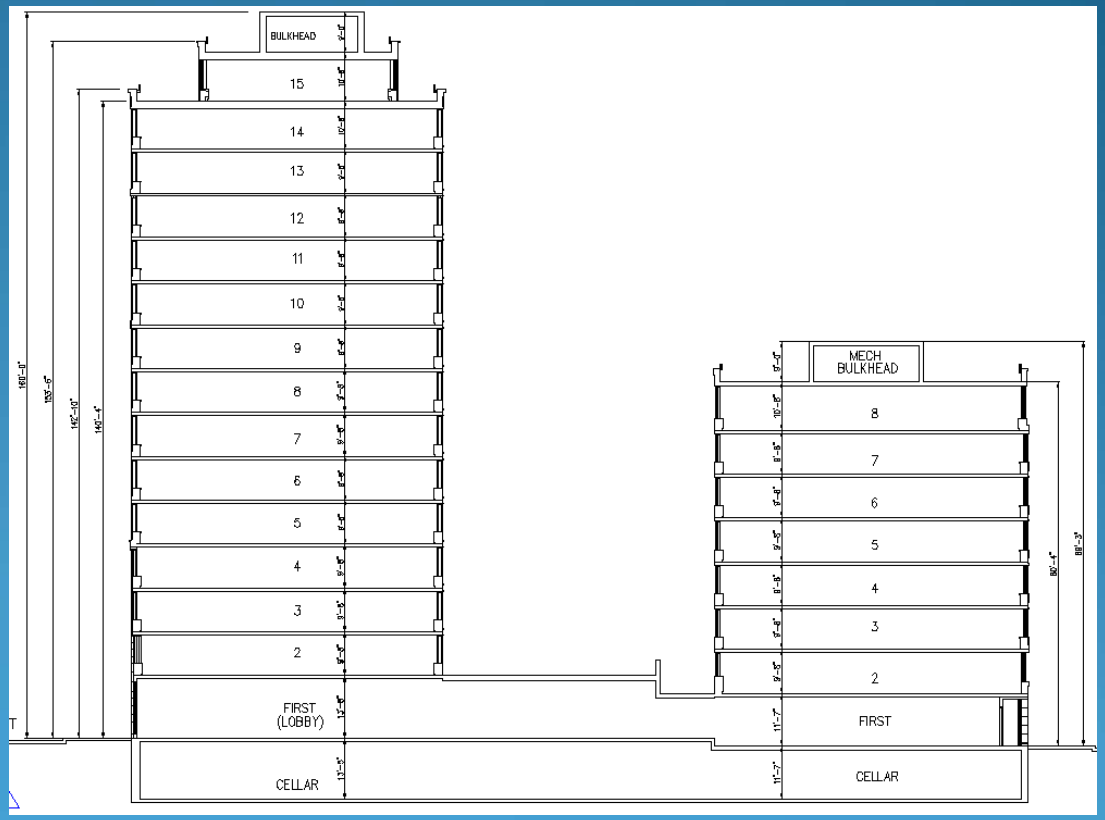


# Existing Conditions

## -Architecture

### -Towers connected at Two levels

- Classic stone façade



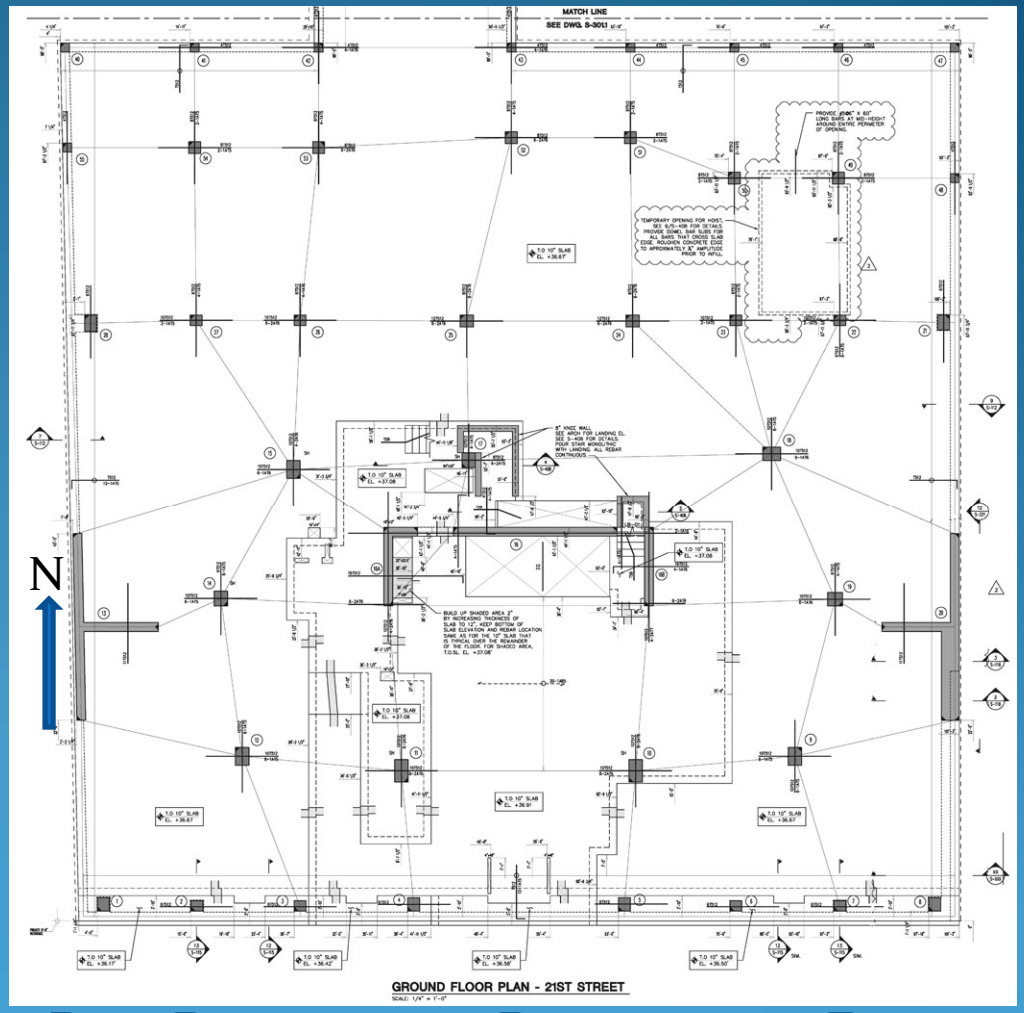

35 West 21st Street

Dan Donecker – Structural Option

# Existing Conditions

## -Structural: floor

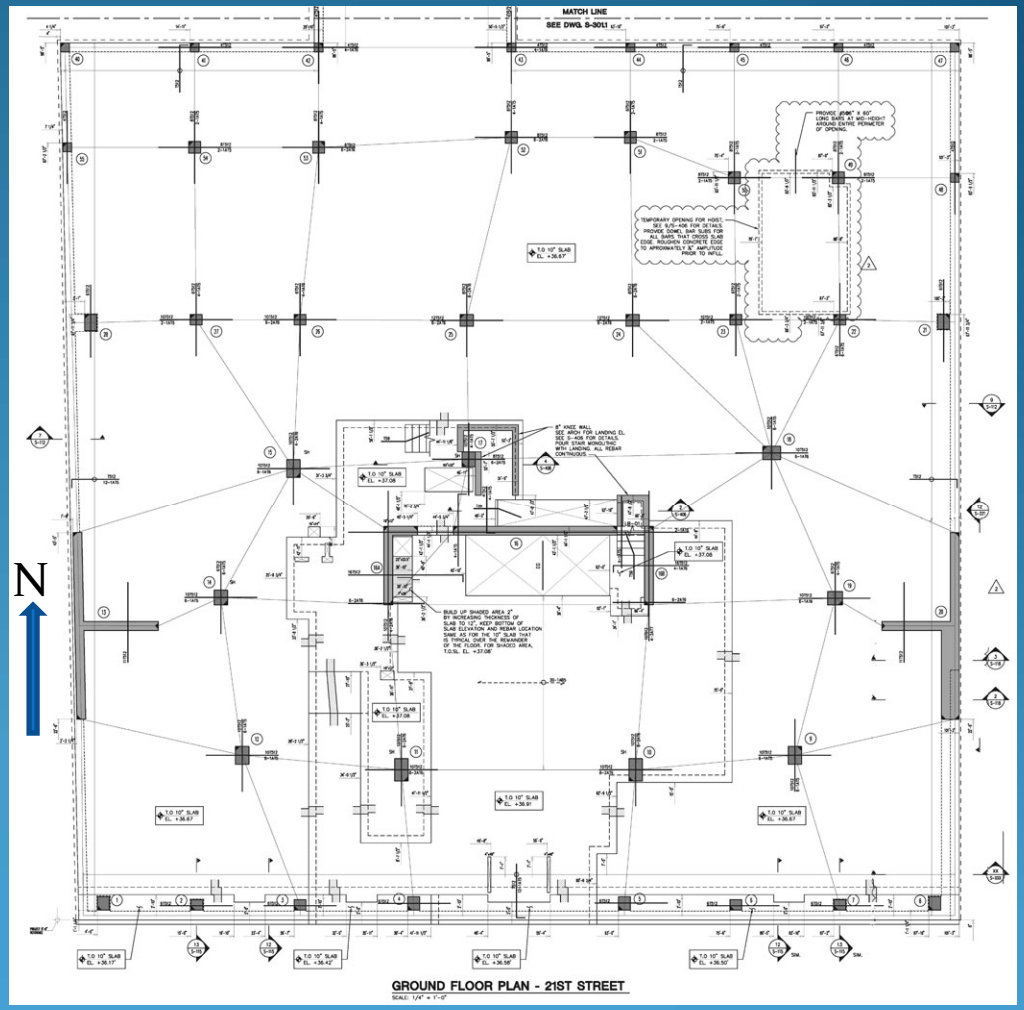
- Two – way flat plate
  - 8” thick (typ.)
  - 5 ksi concrete
  - Studrails at columns with high shear



# Existing Conditions

## -Structural: Columns

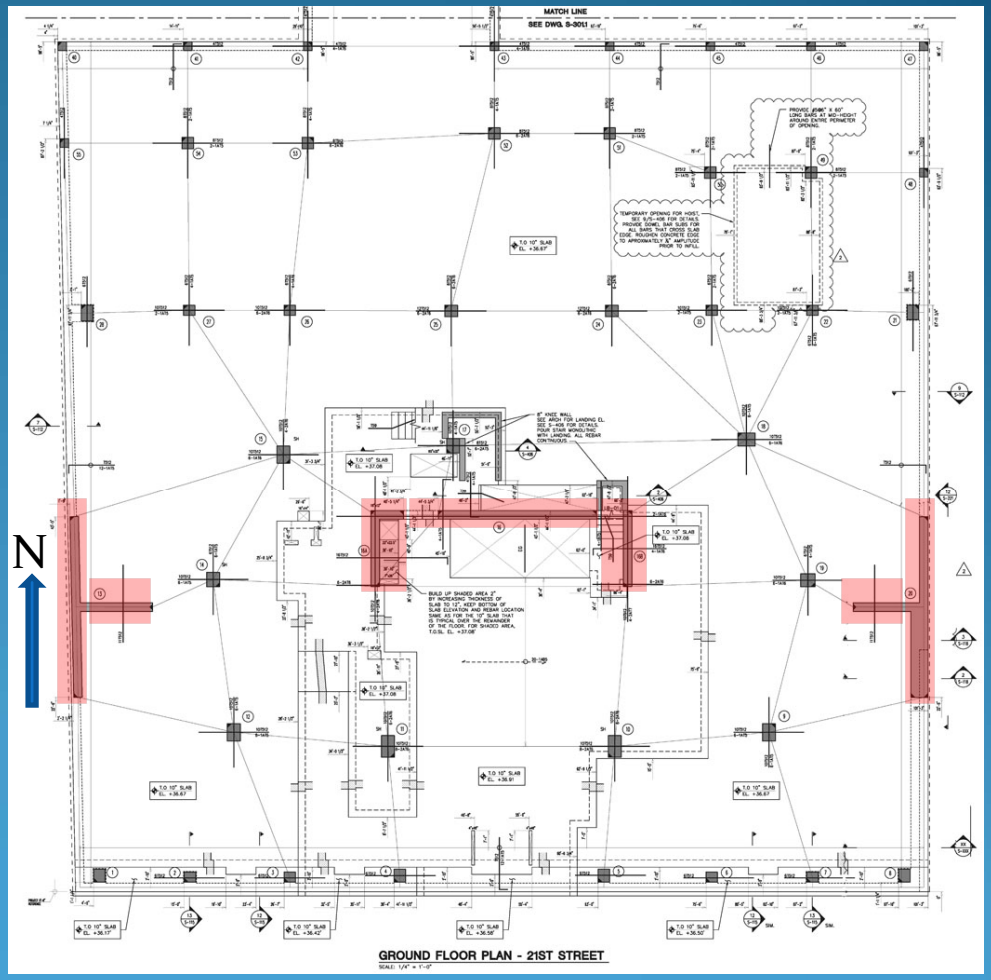
- Rectangular Col.
  - No typical size
  - No typical spacing
  - Position governed by architecture
  - 5.95 ksi concrete
  - Studrails in areas of high shear



# Existing Conditions

## -Structural: Lateral system

- Shear wall system
  - 5.95 ksi concrete
  - Position governed by architecture



# Thesis Proposal

## -Summary

- Create regular column grid
- Minimize floor thickness
- Optimize lateral system
- Integrate architecture and structural
- Remove ceiling cavity

# Thesis Proposal

## -Goals

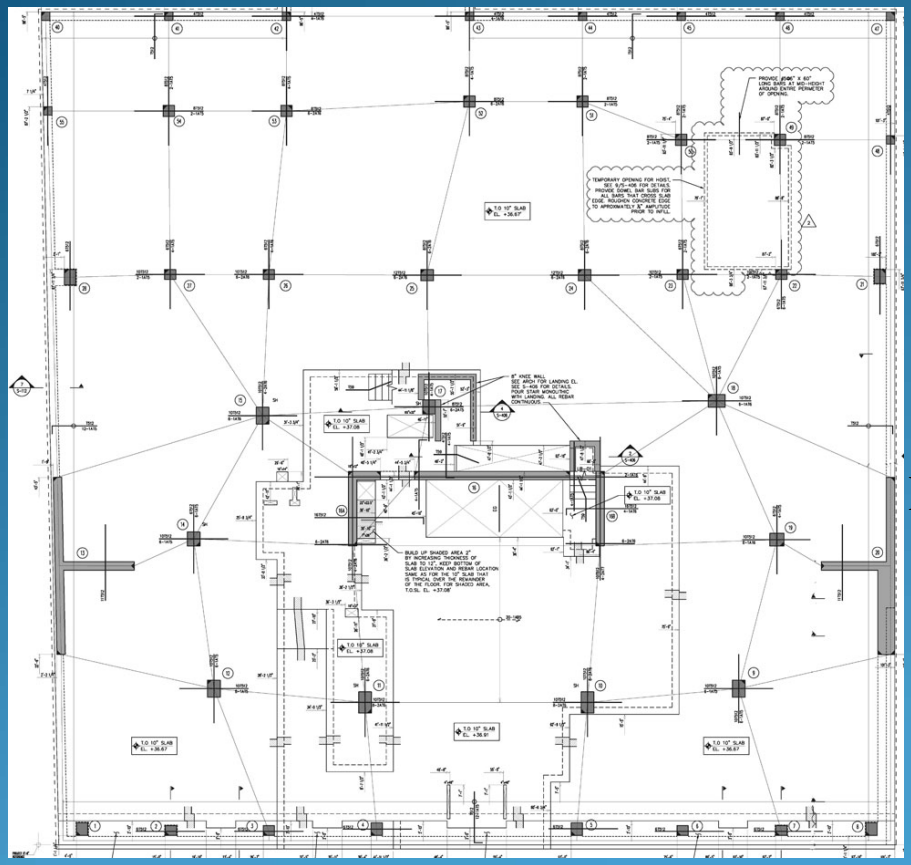
The ultimate goal of this thesis is to minimize the floor-to-floor height of each story in order to add an extra floor without increasing the overall building height. Also to increase constructability by providing a regular column grid and typical column sizes

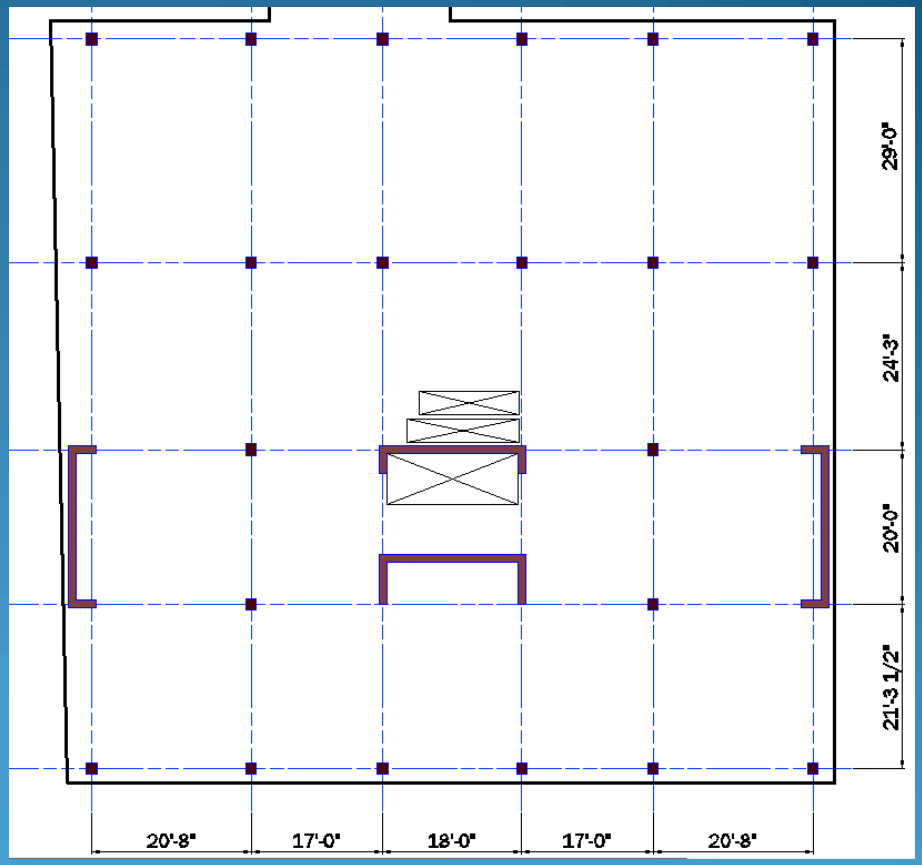
# Structural Redesign:
# - Gravity Columns

- Create Regular Column Grid
- Design Columns Per New Grid

# Structural Redesign:

## - Gravity Columns





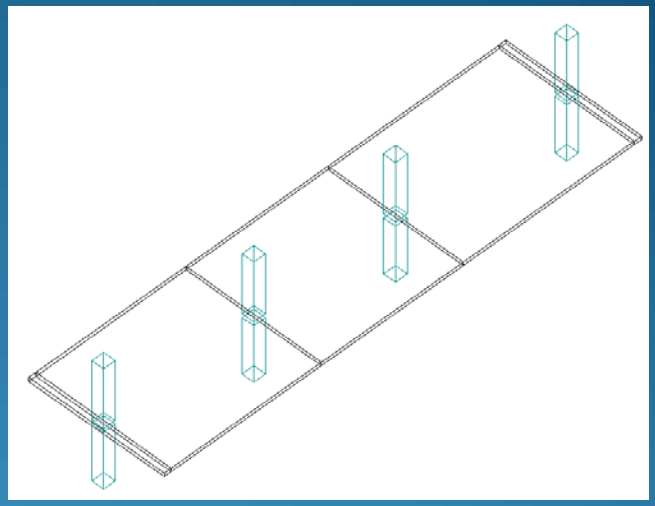

Existing column layout

Revised column layout

# Structural Redesign:

## -Gravity Columns

- Column load take down spreadsheet
- PCA Slab for moments



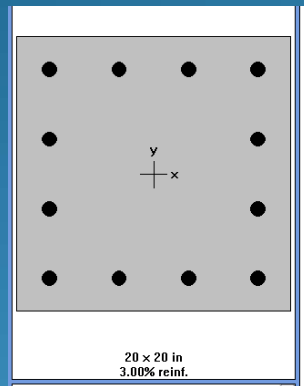
COLUMN: 24 Axial Force | $f'_c$ (psi) = 5000

| FLOOR | Story Height | Area (sq. ft.) | Influence Area | Cladding width | Col Width | Col Depth | Slab Thick | Slab DL (psf) | SDL (psf) | Cladding (psf) | Floor LL (psf) | MISC. DL (kips) | MISC. LL (kips) | Relative Floor | Col. Weight | Cladding (kips) | Floor DL (kips) | Total DL (kips) | LL Reductio | Total LL (kips) | Design DL (kips) | Design LL (kips) | Total Design |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | | | | | |
| Bulkhead | 9 | | | | | | | | | | | | | Main Roof | | | | | | | | | |
| Main Roof | 10 | | | | | | | | | | | | | 16 | | | | | | | | | |
| 16 | 10 | 167 | 582 | 26 | 28 | 28 | 12 | 150 | 15 | 70 | 40 | | | 15 | 8.16667 | 18.2 | 27.555 | 53.9217 | 0.87177 | 5.82342 | 64.706 | 9.31748 | 74.0235 |
| 15 | 9 | 167 | 1140 | 26 | 28 | 28 | 6 | 75 | 15 | 70 | 40 | | | 14 | 7.35 | 16.38 | 15.03 | 38.76 | 0.69426 | 4.63767 | 46.512 | 7.42027 | 127.956 |
| 14 | 9 | 167 | 1698 | 26 | 28 | 28 | 6 | 75 | 15 | 70 | 40 | | | 13 | 7.35 | 16.38 | 15.03 | 38.76 | 0.61402 | 4.10164 | 46.512 | 6.56262 | 181.03 |
| 13 | 9 | 167 | 2256 | 26 | 28 | 28 | 6 | 75 | 15 | 70 | 40 | | | 12 | 7.35 | 16.38 | 15.03 | 38.76 | 0.56581 | 3.77959 | 46.512 | 6.04734 | 233.59 |
| 12 | 9 | 167 | 2814 | 26 | 28 | 28 | 6 | 75 | 15 | 70 | 40 | | | 11 | 7.35 | 16.38 | 15.03 | 38.76 | 0.53277 | 3.55889 | 46.512 | 5.69422 | 285.796 |
| 11 | 9 | 167 | 3372 | 26 | 28 | 28 | 6 | 75 | 15 | 70 | 40 | | | 10 | 7.35 | 16.38 | 15.03 | 38.76 | 0.50831 | 3.39554 | 46.512 | 5.43286 | 337.741 |
| 10 | 9 | 167 | 3930 | 26 | 28 | 28 | 6 | 75 | 15 | 70 | 40 | | | 9 | 7.35 | 16.38 | 15.03 | 38.76 | 0.48927 | 3.26835 | 46.512 | 5.22936 | 389.482 |
| 9 | 9 | 167 | 4488 | 26 | 28 | 28 | 6 | 75 | 15 | 70 | 40 | | | 8 | 7.35 | 16.38 | 15.03 | 38.76 | 0.47391 | 3.16569 | 46.512 | 5.0651 | 441.059 |
| 8 | 9 | 167 | 5046 | 26 | 28 | 28 | 6 | 75 | 15 | 70 | 40 | | | 7 | 7.35 | 16.38 | 15.03 | 38.76 | 0.46116 | 3.08057 | 46.512 | 4.92891 | 492.5 |
| 7 | 9 | 167 | 5604 | 26 | 28 | 28 | 6 | 75 | 15 | 70 | 40 | | | 6 | 7.35 | 16.38 | 15.03 | 38.76 | 0.45037 | 3.0085 | 46.512 | 4.8136 | 543.826 |
| 6 | 9 | 167 | 6162 | 26 | 28 | 28 | 6 | 75 | 15 | 70 | 40 | | | 5 | 7.35 | 16.38 | 15.03 | 38.76 | 0.44109 | 2.94646 | 46.512 | 4.71433 | 595.052 |
| 5 | 9 | 167 | 6720 | 26 | 28 | 28 | 6 | 75 | 15 | 70 | 40 | | | 4 | 7.35 | 16.38 | 15.03 | 38.76 | 0.43298 | 2.89231 | 46.512 | 4.6277 | 646.192 |
| 4 | 9 | 167 | 7278 | 26 | 28 | 28 | 6 | 75 | 15 | 70 | 40 | | | 3 | 7.35 | 16.38 | 15.03 | 38.76 | 0.42583 | 2.84452 | 46.512 | 4.55124 | 697.255 |
| 3 | 9 | 167 | 7836 | 26 | 28 | 28 | 6 | 75 | 15 | 70 | 40 | | | 2 | 7.35 | 16.38 | 15.03 | 38.76 | 0.41945 | 2.80193 | 46.512 | 4.48309 | 748.25 |
| 2 | 13.75 | 167 | 8394 | 26 | 28 | 28 | 6 | 75 | 15 | 70 | 40 | | | 1 | 11.2292 | 25.025 | 15.03 | 51.2842 | 0.41372 | 2.76366 | 61.541 | 4.42186 | 814.213 |
| Ground | 13.33 | 167 | 8952 | 26 | 28 | 28 | 12 | 150 | 15 | 70 | 100 | | | 0 | 10.8862 | 24.2606 | 27.555 | 62.7018 | 0.40854 | 6.82257 | 75.2421 | 10.9161 | 900.371 |

# Structural Redesign:

## -Gravity Columns

- PCA Column used to design gravity columns for biaxial bending and compression

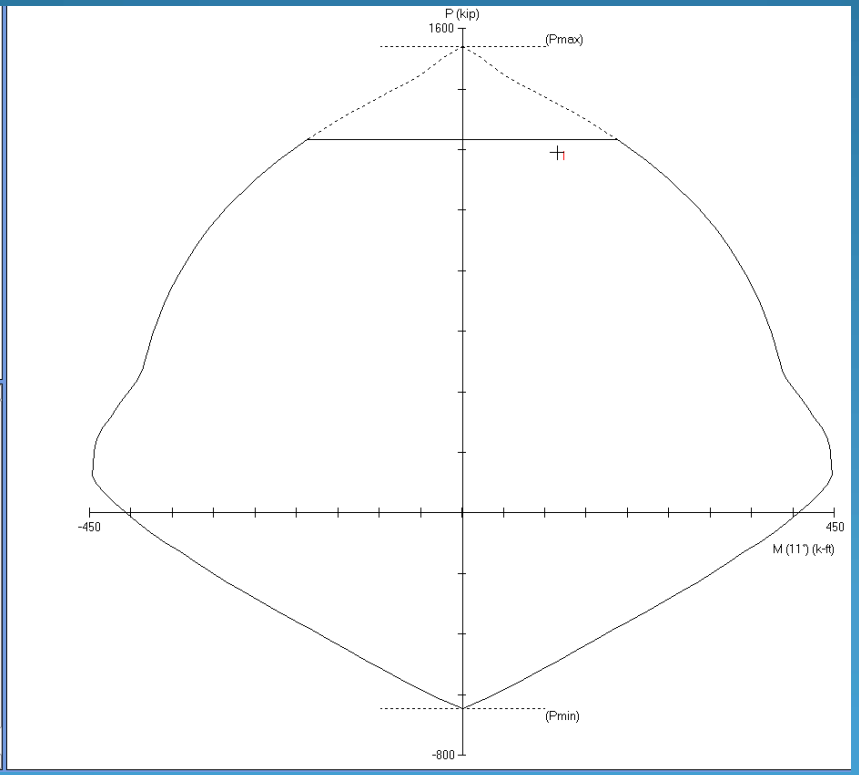



MATERIAL:
=========
f'c = 5 ksi
Ec = 4030.51 ksi
fc = 4.25 ksi
Beta1 = 0.8
fy = 60 ksi
Es = 29000 ksi

SECTION:
========
Ag = 400 in^2
Ix = 13333.3 in^4
Iy = 13333.3 in^4
Xo = 0 in
Yo = 0 in

REINFORCEMENT:
==============
12 #9 bars @ 3.000%
As = 12 in^2
Confinement: Tied
Clear Cover = 1.875 in
Min Spacing = 3.91267 in

SLENDERNESS:



# Structural Redesign:

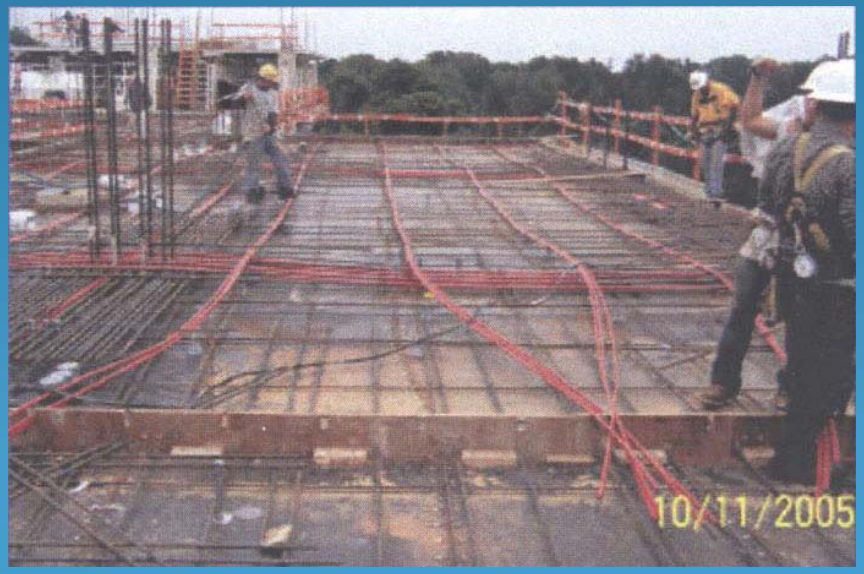
## -Gravity Columns

- Number of columns reduced
  - Existing – 31
  - Redesign – 16
- Number of different cross sections
  - Existing – 14
  - Redesign – 3

| | cross section | long. Reinf. | ties |
|---|---|---|---|
| Corner | 28x28 | 12 - #9 | #3 @ 12 |
| Edge | 20x20 | 8 - #7 | #3 @ 12 |
| Interior | 20x20 | 8 - #9 | #3 @ 12 |

# Structural Redesign:
# - Gravity Floor

- Post-Tension 2-way Flat Plate
  - Reduce Floor Thickness
  - Add Another Level?

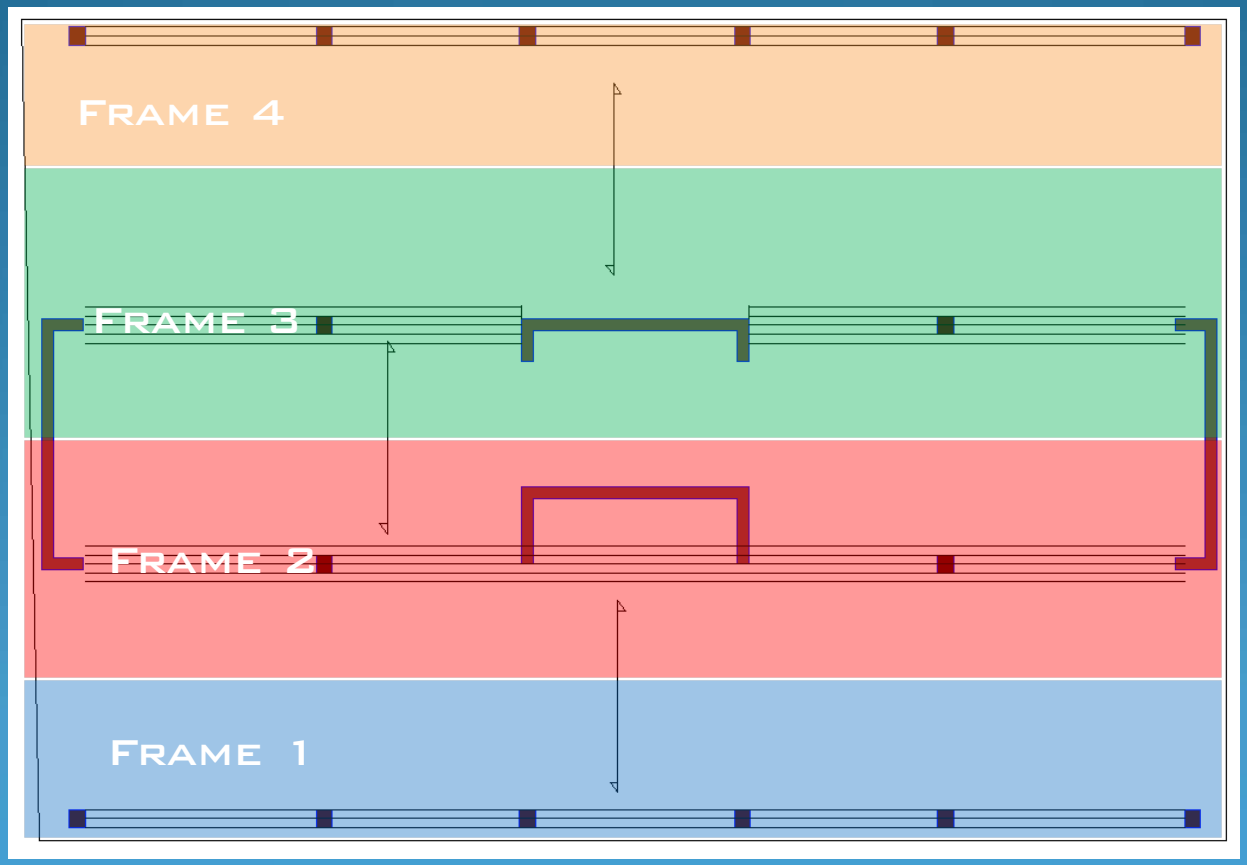



Picture from Holbert Apple Associates, Inc.

# Structural Redesign:

## - Gravity Floor

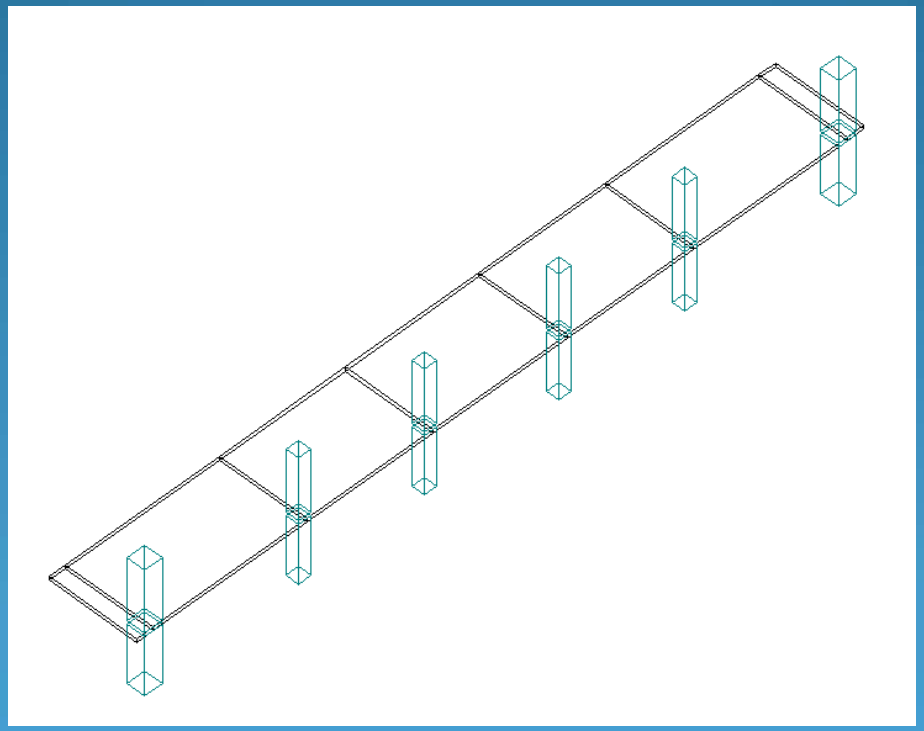
- Post-Tension 2-way Flat Plate
- Per Chapter 13 & 18 of ACI 318-05



# Structural Redesign:

## - Gravity Floor

- Post-Tension 2-way Flat Plate
- PCA Slab used to determine moments and shears



Frame 1

# Structural Redesign:

## - Gravity Floor

**Frame 1**

Max Moments and Shears From PCA Slab

| | Centerline Exterior Support | Exterior Span | | | Centerline First Interior Support | First Interior Span | | | Centerline Second interior Support | Second Interior Span | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Face Left Support | Near Midspan | Face Right Support | | Face Left Support | Midspan | Face Right Support | | Face Left Support | Midspan |
| Service Load Moment (ft-k) | | -42.69 | 28.14 | -45.17 | | -30.27 | 18.79 | -29.48 | | -33.72 | 21.5 |
| Unbalanced (Live Load) Moment (ft-k) | | -12.2 | 8.04 | -12.91 | | -8.65 | 5.37 | -8.42 | | -9.63 | 6.14 |
| Factored Total Moment (1.2D+1.6L) (ft-k) | | -56.1 | 36.99 | -59.36 | | -39.78 | 24.69 | -38.75 | | -44.32 | 28.25 |
| Factored Transfer Moment (ft-k) | -56.1 | | | | -19.58 | | | | -5.57 | | |
| Factored Moment Orthagonal to Frame | -89.4 | | | | -89.64 | | | | -84.95 | | |
| Factored column Axial Force (k) | 27.6 | | | | 40.85 | | | | 38.02 | | |

| Service Stress Checks | | |
|---|---|---|
| Avg. Prestress (psi) | 316.0563 | OK |
| Max Compressive stress (psi) | 497.8873 | OK |
| Max Positive Moment Tensile Stress (psi) | 202.8169 | OK |
| Max Negative Tensile Stress (psi) | 134.2254 | OK |

| Bonded Reinf. @ Supports | | |
|---|---|---|
| $A_s$ ($in^2$) | 0.639 | |
| $A_{s\ provided}$ ($in^2$) | 0.8 | 4-#4 bars |

**NO BONDED REINF.@ MID SPAN**

| Frame Properties | |
|---|---|
| Exterior Span length (in.) | 248 |
| First Interior Span Length (in.) | 204 |
| Second Interior Span Length (in.) | 216 |
| $l_2$ (in.) | 142 |
| Slab Thickness (in.) | 6 |
| β1 | 0.8 |
| $f'_c$ (psi) | 5000 |
| $f'_{ci}$ (psi) | 4000 |
| $E_c$ (psi) | 4030509 |
| 1/2" Diameter Strand Area (in2) | 0.153 |
| $f_{pu}$ (psi) | 270000 |
| $f_{pe}$ (psi) | 160000 |
| Cover to center of Strand (in.) | 1 |
| d (in.) | 5 |
| fy (psi) | 60000 |
| fpy (psi) | 216000 |
| Zt (in3) | 852 |
| Zb (in3) | 852 |

| Loads | |
|---|---|
| SELF (psf) | 75 |
| SDL (psf) | 15 |
| LL (psf) | 50 |

| Preliminary Sags | |
|---|---|
| δ1 (in.) | 2.828 |
| δ2 (in.) | 4 |
| δ3 (in.) | 4 |

| Load To Balance | |
|---|---|
| wb (plf) | 1065 |

| Balancing Force | |
|---|---|
| Fb (lbs) | 241269.4 |

| Number of Strands | |
|---|---|
| N | 10 |

| Actual Prestressing Force | |
|---|---|
| F (lbs) | 244800 |

| Actual Sags | |
|---|---|
| δ1 (in.) | 2.828 |
| δ2 (in.) | 1.885938 |
| δ3 (in.) | 2.114338 |

| Allowable Stresses | | |
|---|---|---|
| $\sigma_c$ (psi) | 2250 | |
| $\sigma_t$ (psi) | -141.421 | Positive Moment |
| $\sigma_t$ (psi) | -424.264 | Negative Moment |

| ULTIMATE FLEXURAL STRENGTH (AT SUPPORTS) | | |
|---|---|---|
| $A_{ps}$ ($in^2$) | 1.683 | |
| $A_s$ ($in^2$) | 0.8 | |
| d (in.) | 5 | |
| $f_{py}/f_{pu}$ | 0.8 | |
| $\gamma_p$ | 0.55 | |
| ρ | 0.0011268 | |
| ω | 0.0135211 | |
| $\rho_p$ | 0.0023704 | |
| $f_{ps}$ (psi) | 243729.62 | |
| a | 0.7592327 | |
| c | 0.9490409 | |
| c/d | 0.1898082 | |
| Φ | 0.9 | |
| $\Phi M_n$ (ft-k) | -158.7784 | OK |

| ULTIMATE FLEXURAL STRENGTH (POSITIVE MOMENT) | | |
|---|---|---|
| $A_{ps}$ ($in^2$) | 1.683 | |
| $A_s$ ($in^2$) | 0 | |
| d (in.) | 2.9049874 | |
| $f_{py}/f_{pu}$ | 0.8 | |
| $\gamma_p$ | 0.55 | |
| ρ | 0 | |
| ω | 0 | |
| $\rho_p$ | 0.0040799 | |
| $f_{ps}$ (psi) | 229103.91 | |
| a | 0.6389095 | |
| c | 0.7986369 | |
| c/d | 0.2749192 | |
| Φ | 0.9 | |
| $\Phi M_n$ (ft-k) | 74.770091 | OK |

# Structural Redesign:

## - Gravity Floor

| PUNCHING SHEAR CHECK AT CORNER COLUMN | |
|---|---|
| $c_1$ (in.) | 28 |
| $c_2$ (in.) | 28 |
| d (in.) | 5 |
| Distance to Discontinuous Edge (c1 side) (in.) | 18 |
| Distance to Discontinuous Edge (c2 side) (in.) | 0 |
| $b_o$ (in.) | 79 |
| Ac ($in^2$) | 395 |
| $c_3$ (in.) | 1.177532 |
| $c_4$ (in.) | 29.32247 |
| $c_5$ (in.) | 1.177532 |
| $c_6$ (in.) | 29.32247 |
| $c_7$ (in.) | 15.32247 |
| $c_8$ (in.) | 15.32247 |
| $\gamma_{v1}$ | 0.4 |
| $\gamma_{v2}$ | 0.4 |
| $J_{c1}$ ($in^4$) | 42551.33 |
| $J_{c2}$ ($in^4$) | 42551.33 |
| $M_{u1}$ (Orthagonal to Frame considederd) (ft-k) | 89.4 |
| $M_{u2}$ (In Direction of Frame considederd) (ft-k) | 56.1 |
| $v_{u1}$ (psi) | 79.83798 |
| $v_{u2}$ (psi) | 146.0608 |
| $v_{u3}$ (psi) | 251.7846 |
| $v_{uMAX}$ (psi) | 251.7846 |
| Can Prestress Shear Strenth be Used? | NO |
| $\alpha_s$ | 20 |
| $\beta$ | 1 |
| $v_n$ (psi) | 230.9285 |
| $\phi v_n$ (psi) | 173.1964 NG, NEED STUDRAILS |

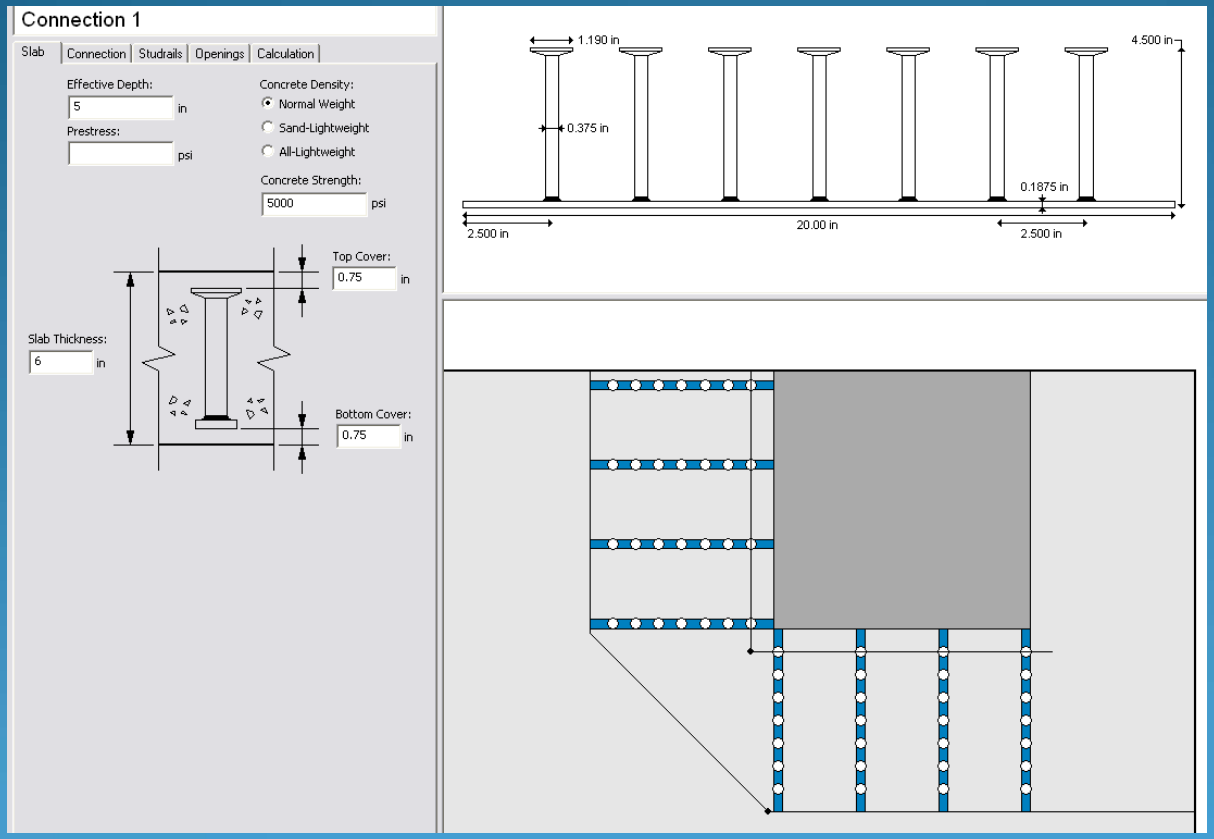
| PUNCHING SHEAR CHECK AT EXTERIOR EDGE COLUMN | |
|---|---|
| $c_1$ (in.) | 20 |
| $c_2$ (in.) | 20 |
| d (in.) | 5 |
| Distance to Discontinuous Edge (in.) | 0 |
| $b_o$ (in.) | 70 |
| Ac ($in^2$) | 350 |
| $c_3$ (in.) | 7.23214 |
| $c_4$ (in.) | 15.2679 |
| $c_5$ (in.) | 5.26786 |
| $\gamma_v$ | 0.38743 |
| $J_c$ ($in^4$) | 20131.1 |
| $M_u$ (Orthagonal to Frame considederd) (ft-k) | 89.64 |
| $V_u$ (kips) | 40.85 |
| $v_{u1}$ (psi) | 236.48 |
| $v_{u2}$ (psi) | 369.553 |
| $v_{uMAX}$ (psi) | 369.553 |
| Can Prestress Shear Strength be Used? | NO |
| $\alpha_s$ | 30 |
| $\beta$ | 1 |
| $v_n$ (psi) | 282.843 |
| $\phi v_n$ (psi) | 212.132 NG, NEED STUDRAILS |

| DEFLECTION | |
|---|---|
| $\Delta_{allowable}$ (in.) | 0.68889 |
| $\Delta_{actual}$ (in.) | 0.13276 OK |

# Structural Redesign:

## -Gravity Floor

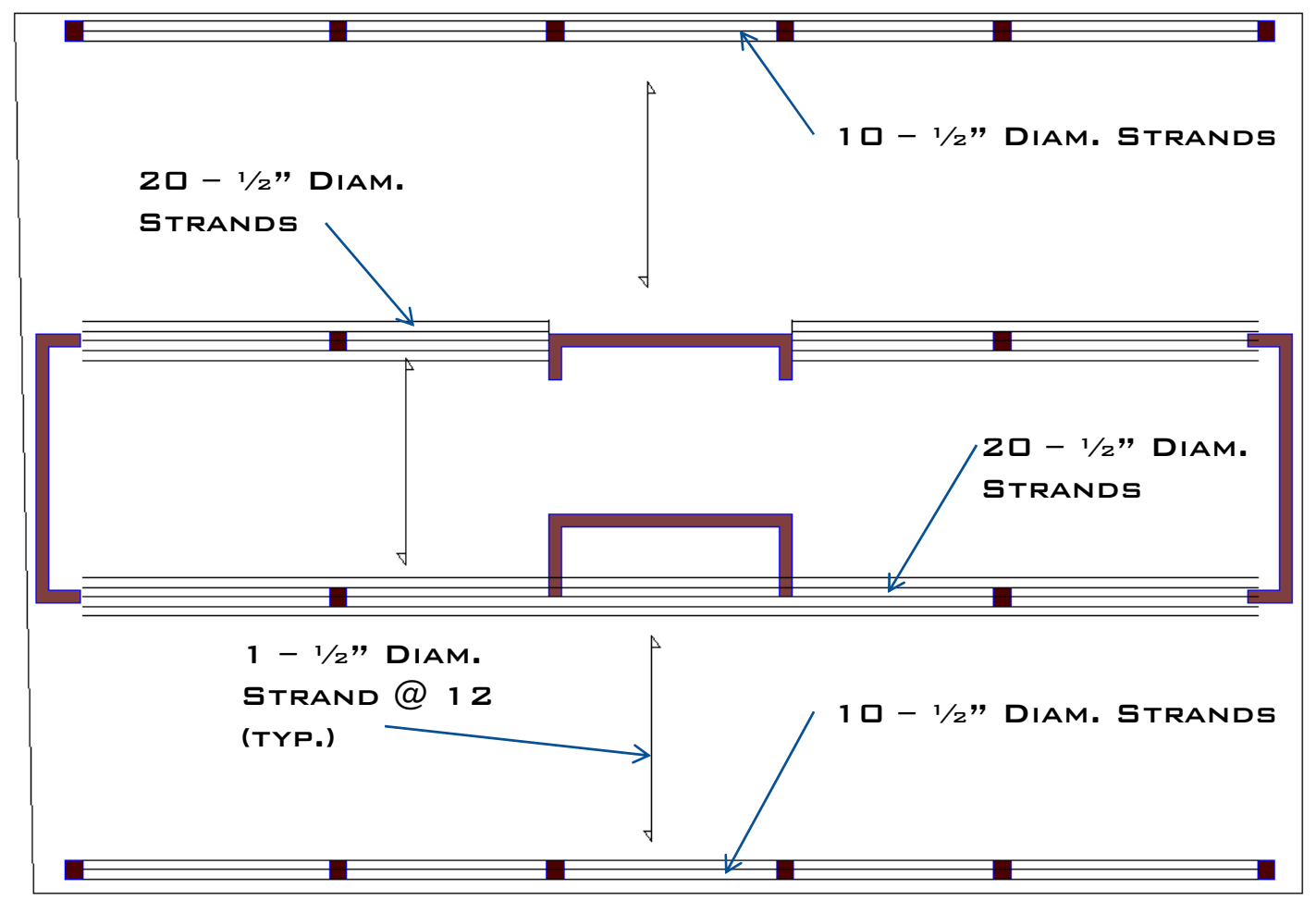
### •Studrail Design




Decon Studrail design http://www.deconusa.com/

# Structural Redesign:

## - Gravity Floor



# Structural Redesign:

## -Gravity Floor

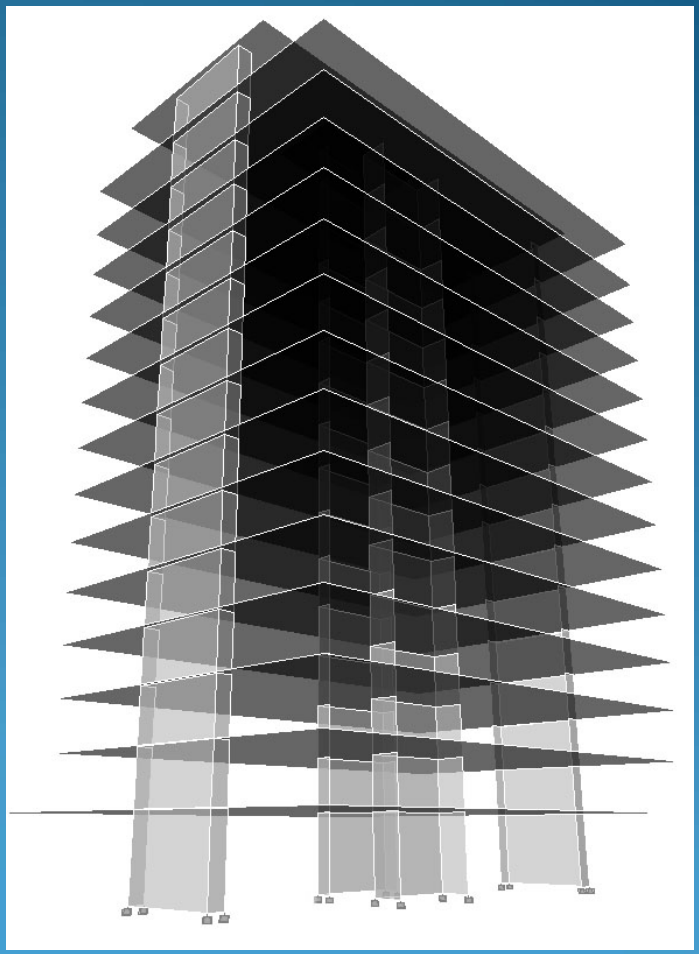
- Existing floor thickness – 8”
- Redesigned floor thickness – 6”
- Additional 26” of height available

- Decreased cu. Yd. of Concrete needed
- Increased difficulty of construction

# Structural Redesign:

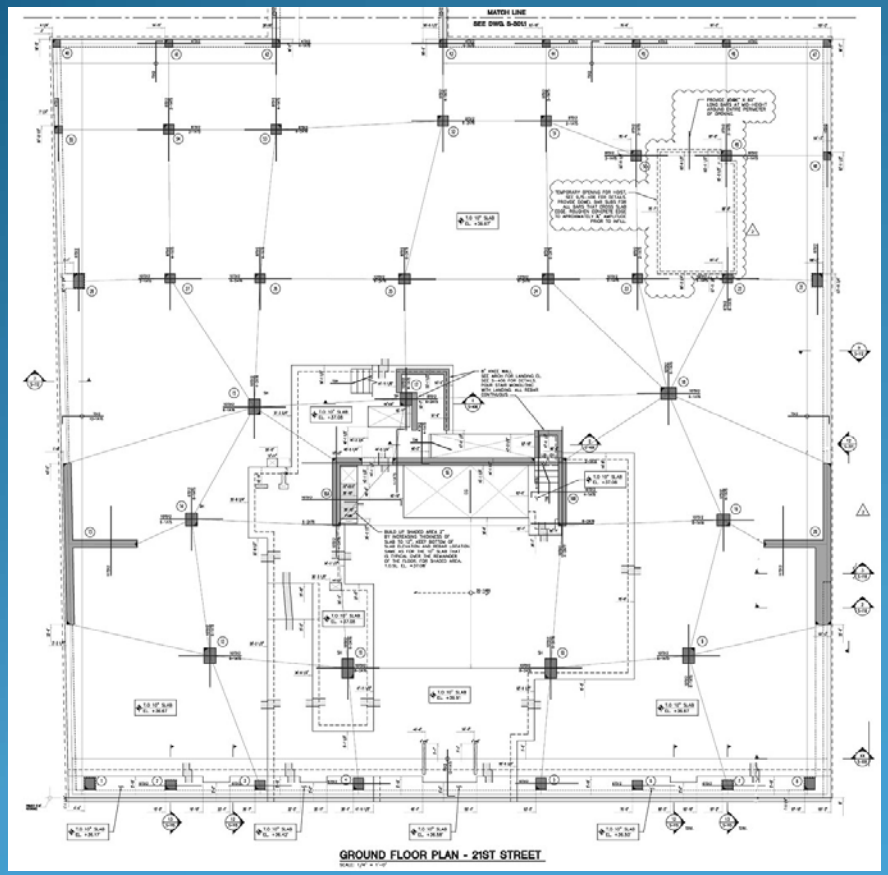
## - Lateral

- Optimize Shear Walls
  - Integrate into new grid and arch.
  - Do not decrease performance

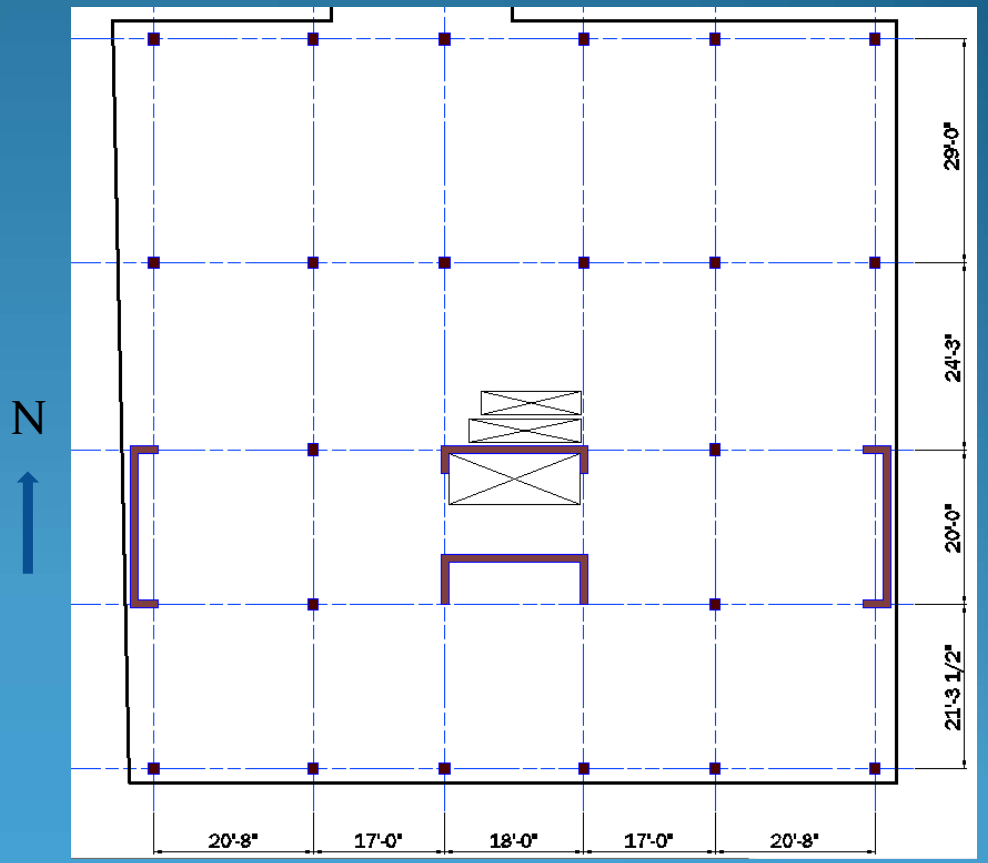


# Structural Redesign:
# - Lateral

Existing shear wall plan

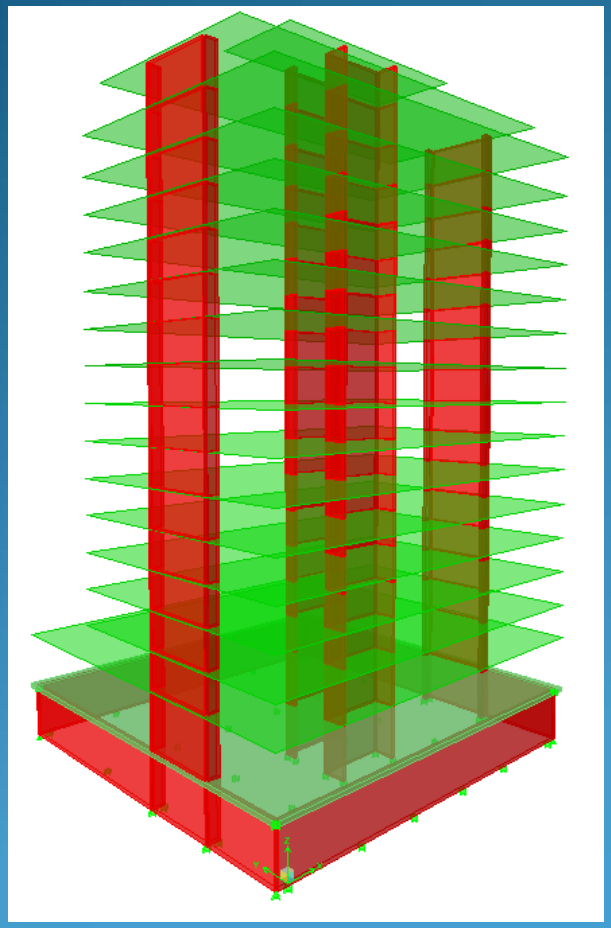



Redesigned shear wall plan



# Structural Redesign:

## - Lateral



- Performance not decreased by new plan

| Existing Structure Period (South Tower) | |
|---|---|
| $T_{N/S}$ (sec.) | 2.28 |
| $T_{E/W}$ (sec.) | 2.41 |
| $T_{torsion}$ (sec.) | 1.60 |

| Optimized Structure Period (South Tower) | |
|---|---|
| $T_{N/S}$ (sec.) | 2.30 |
| $T_{E/W}$ (sec.) | 2.53 |
| $T_{torsion}$ (sec.) | 1.58 |

# Structural Redesign:

## -Lateral – loads/drifts

- Wind – ASCE 7-05 ch. 6
- Seismic – ASCE 7-05 ch. 11 & 12

| WIND N-S DIRECTION | | | |
|---|---|---|---|
| Existing Base Shear (kips) | Existing Over-Turning Moment (ft-k) | Redesign Base Shear (kips) | Redesign Over-Turning Moment (ft-k) |
| 456.50 | 39368.20 | 461.30 | 39432.40 |

% Diff. wind = 1.1 %

| SEISMIC | | | |
|---|---|---|---|
| Existing Base Shear (kips) | Existing Over-Turning Moment (ft-k) | Redesign Base Shear (kips) | Redesign Over-Turning Moment (ft-k) |
| 261.60 | 25546.30 | 251.10 | 26441.90 |

% Diff. seismic = 3.8 %

| Story | Story Height | Wind Load Building Drift N/S | Wind Story Drift N/S | Allowable Story Drift | |
|---|---|---|---|---|---|
| BULKHEAD | 9 | 3.377 | 0.2403 | 0.27 | OK |
| MAIN ROOF | 10.167 | 3.1367 | 0.2656 | 0.30501 | OK |
| STORY16 | 10.167 | 2.8711 | 0.2649 | 0.30501 | OK |
| STORY15 | 9 | 2.6062 | 0.2379 | 0.27 | OK |
| STORY14 | 9 | 2.3683 | 0.2364 | 0.27 | OK |
| STORY13 | 9 | 2.1319 | 0.2338 | 0.27 | OK |
| STORY12 | 9 | 1.8981 | 0.2301 | 0.27 | OK |
| STORY11 | 9 | 1.668 | 0.2247 | 0.27 | OK |
| STORY10 | 9 | 1.4433 | 0.2175 | 0.27 | OK |
| STORY9 | 9 | 1.2258 | 0.2084 | 0.27 | OK |
| STORY8 | 9 | 1.0174 | 0.1969 | 0.27 | OK |
| STORY7 | 9 | 0.8205 | 0.1831 | 0.27 | OK |
| STORY6 | 9 | 0.6374 | 0.1665 | 0.27 | OK |
| STORY5 | 9 | 0.4709 | 0.147 | 0.27 | OK |
| STORY4 | 9 | 0.3239 | 0.1243 | 0.27 | OK |
| STORY3 | 9 | 0.1996 | 0.0989 | 0.27 | OK |
| STORY2 | 13.75 | 0.1007 | 0.1007 | 0.4125 | OK |

| Story | Story Height | EQ Load Building Drift N/S | EQ Story Drift N/S | Amplified Story Drifts | Allowable Story Drift | |
|---|---|---|---|---|---|---|
| BULKHEAD | 9 | 2.4291 | 0.1771 | 0.7084 | 2.7 | OK |
| MAIN ROOF | 10.167 | 2.252 | 0.1957 | 0.7828 | 3.0501 | OK |
| STORY16 | 10.167 | 2.0563 | 0.1953 | 0.7812 | 3.0501 | OK |
| STORY15 | 9 | 1.861 | 0.1751 | 0.7004 | 2.7 | OK |
| STORY14 | 9 | 1.6859 | 0.1736 | 0.6944 | 2.7 | OK |
| STORY13 | 9 | 1.5123 | 0.1712 | 0.6848 | 2.7 | OK |
| STORY12 | 9 | 1.3411 | 0.1678 | 0.6712 | 2.7 | OK |
| STORY11 | 9 | 1.1733 | 0.163 | 0.652 | 2.7 | OK |
| STORY10 | 9 | 1.0103 | 0.1569 | 0.6276 | 2.7 | OK |
| STORY9 | 9 | 0.8534 | 0.1492 | 0.5968 | 2.7 | OK |
| STORY8 | 9 | 0.7042 | 0.14 | 0.56 | 2.7 | OK |
| STORY7 | 9 | 0.5642 | 0.129 | 0.516 | 2.7 | OK |
| STORY6 | 9 | 0.4352 | 0.1162 | 0.4648 | 2.7 | OK |
| STORY5 | 9 | 0.319 | 0.1015 | 0.406 | 2.7 | OK |
| STORY4 | 9 | 0.2175 | 0.085 | 0.34 | 2.7 | OK |
| STORY3 | 9 | 0.1325 | 0.0665 | 0.266 | 2.7 | OK |
| STORY2 | 13.75 | 0.066 | 0.066 | 0.264 | 4.125 | OK |

# Structural Redesign:

## -Lateral – Shear wall design

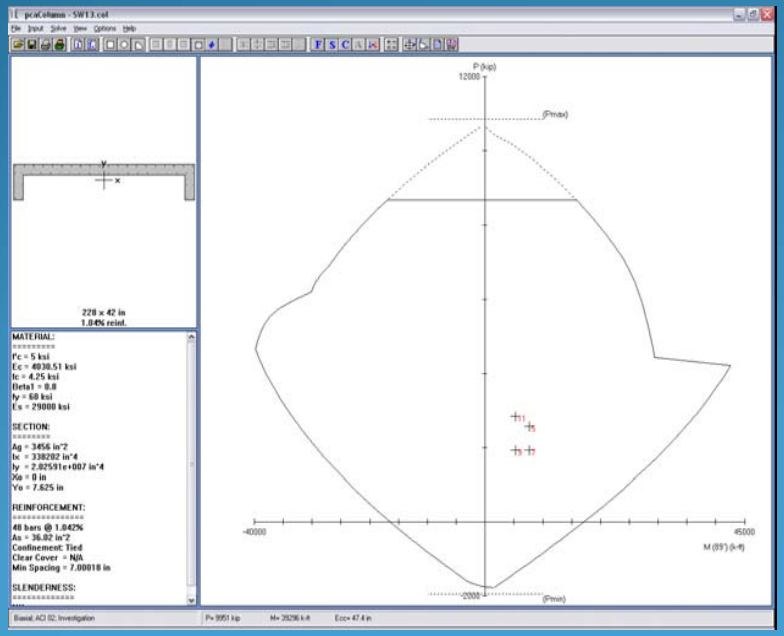
- Explicit modeling of basement walls and ground floor diaphragm
  - Large increase in maximum shear wall force
  - Shear reversal
  - 87% increase

| Max Shear without basement (kips) | Max shear with basement (kips) |
|---|---|
| 201 | 376 |

# Structural Redesign:

## -Lateral – Shear wall design

- Reinforcement governed By Minimum per ACI 318-05 Chapters 10, 11 & 14
- Chapter 21 need not be considered
  - Ordinary reinforced conc. Shear wall




| | |
|---|---|
| Fy (psi) | 60000 |
| f'c (psi) | 5000 |
| lw (in.) | 252 |
| hw (in.) | 1920 |
| h (in.) | 12 |
| N (kips) | 2140 |
| V (kips) | 376 |
| M (ft-k) | 9863 |
| Nu (lbs) | 1926000 |
| Vu (lbs) | 601600 |
| Mu (in-lb) | 189369600 |

| | | |
|---|---|---|
| d (in.) | 201.6 | |
| Vc (kips) | 799.4471 | |
| 1/2ΦVc (kips) | 299.7927 | < Vu, SHEAR REINF. PER 11.10.9.1 |
| $S_{max\ horiz}$ (in.) | 18 | |
| $S_{max\ horiz}$ (in.) | 18 | |
| $\rho_{t,min}$ | 0.0025 | |
| $\rho_{l,min}$ | 0.0025 | |
| $A_{horiz,\ min}$ ($in^2/S_{max}$) | 0.54 | |
| $A_{vert,\ min}$ ($in^2/S_{max}$) | 0.54 | |
| $V_{s\ required}$ (kips) | 2.686264 | |
| $A_{horiz,\ required}$ ($in^2/S_{max}$) | 0.003997 | |
| $A_{horiz\ provided}$ ($in^2/S_{max}$) | 0.6 | #4 bars @ 12" EACH FACE |
| $\Phi V_n$ (kips) | 901.9853 | |

# Structural Redesign:

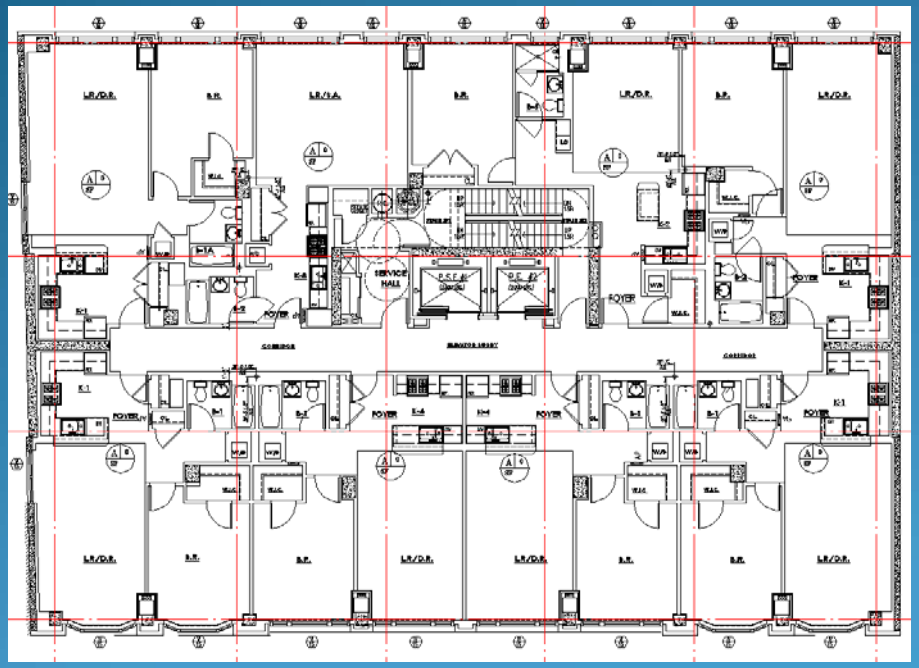
## -Lateral – Shear construction

- No link beams in new design
- Existing cu. Yd of Conc. = 575
- Redesign Cu. Yd of Conc. = 628
- 9.2% increase
- Attribute needed increase in concrete to explicit modeling of basement and ground floor diaphragm

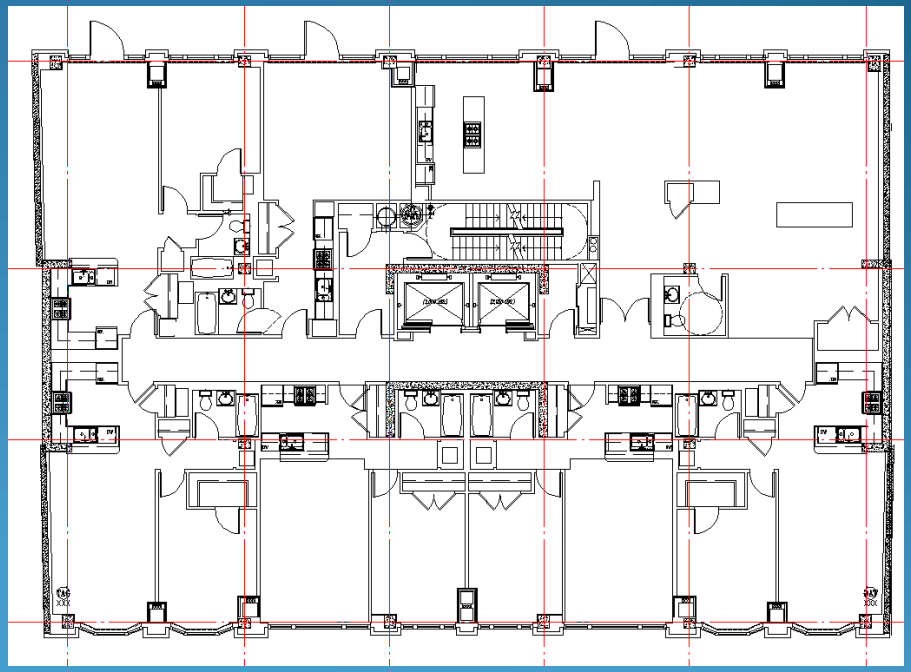
# Architectural Breadth:

## -Floor Plans

- Integrate structural grid and new shear wall plan with architecture



Existing Arch. Floor Plan

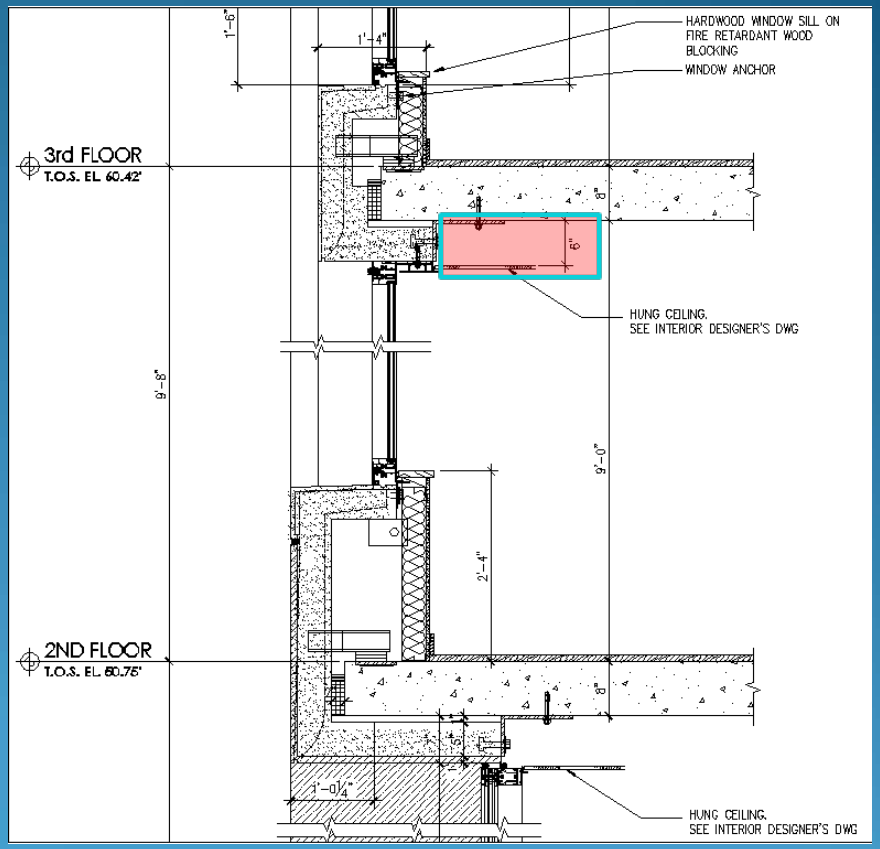


Redesigned Arch. Floor Plan

# Mechanical Breadth:

## -Individual Heat Pumps

- Remove ceiling cavity
- Replace mechanical ductwork with Individual Air-to-Air Heat pumps for each apartment unit



# Conclusions:

- Reduced slab thickness of 2”
- Reduced ceiling cavity of 6”
- Total reduction in height of 9’-6”
  - Allows for additional story
- Additional story has little effect on wind and seismic resisting elements as well as foundations
- Decreased cost of construction for columns
- Additional revenue from extra story outweighs the upfront costs of a post-tensioned slab.

- **Overall, Redesign is recommended**

# Acknowledgements:


- DeSimone Consulting Engineers – Ben Downing and Josh Gerard
- All of the AE Faculty
  - Especially :
    - Professor Parfitt
    - Dr. Lepage
    - Dr. Memari
- Thesis Advisor:
  - Dr. Boothby


# Questions?