the christina landing apartment tower

Wilmington, DE

senior thesis – 05/06

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structural

- -presentation outline- -

- Building Information
- Existing Systems
- Proposal Summary
- Structural Depth Study 1 – Gravity System Redesign
- Structural Depth Study 2 – Lateral System Redesign
- Breadth Study 1 – Acoustic Analysis
- Breadth Study 2 – Construction Management Study
- Conclusions/Acknowledgements
- Questions

- -building background- -

- Owner –
  - The Buccini/Pollin Group
- Architect –
  - Kling
- Engineering Disciplines –
  - Kling
- General Contractor/CM –
  - Gilbane Building Co.

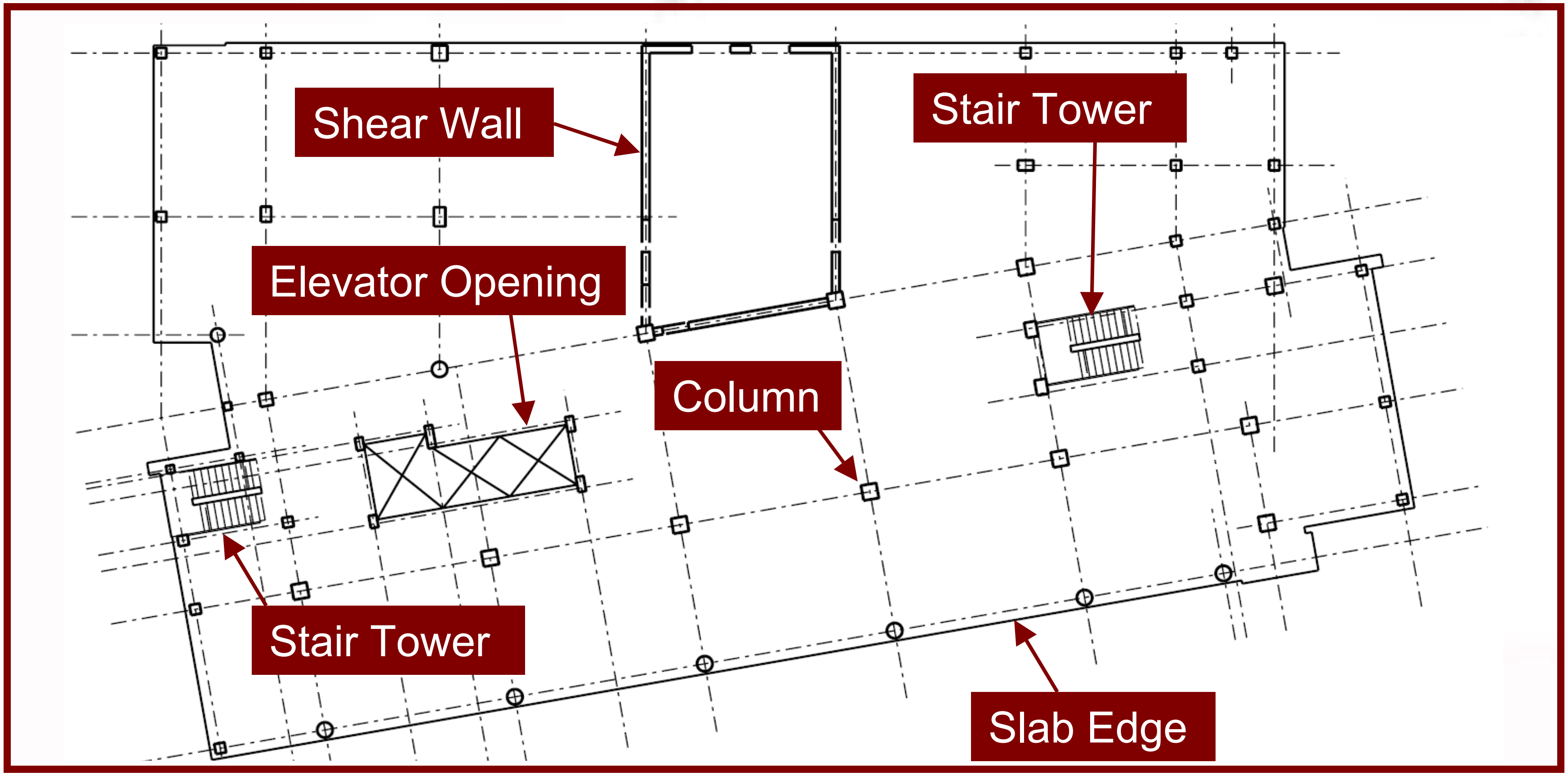
- -building introduction- -

- 22 Story Apartment Tower, 250,000 ft^2
- Location – Wilmington, DE
- Development includes – 63 townhouses, a river walk, condominium high rise, two acre park
- 173 one and two bedroom apartments
- General areas – media room, fitness center, great room, bar, convenience store, dry cleaners
- Façade – Non-structural precast concrete panels with architectural brick veneer
- Partition Walls – Gypsum board on metal studs

- -existing structural system- -

- 8” Reinforced concrete flat slab – #6@10” O.C. E.W. top
  #4@10” O.C. E.W. bottom
- Typical spans – 20’-25’
- Panel Ratios – 1:1 to 1:1.5
- Both round and square columns – Typical sizes 24” ⌷,ɸ
- Lateral System – Box of 4 shear walls on west side of building
- Foundation system – Pile caps and H-piles driven up to 70’
- Concrete Strengths – From 4000psi for pile caps to 8000psi
  for the columns below the fifth floor

- -typical floor plan- -



- -proposal summary- -

- It was shown that both the existing gravity and lateral systems were sufficient
- The 8" slab was found to be the thinnest possible
- Existing lateral drift of L/360
- Goal of this thesis is to redesign both systems
- Attempt to make both systems more efficient
- Attempt to change the gravity system while having little impact on the project cost and schedule

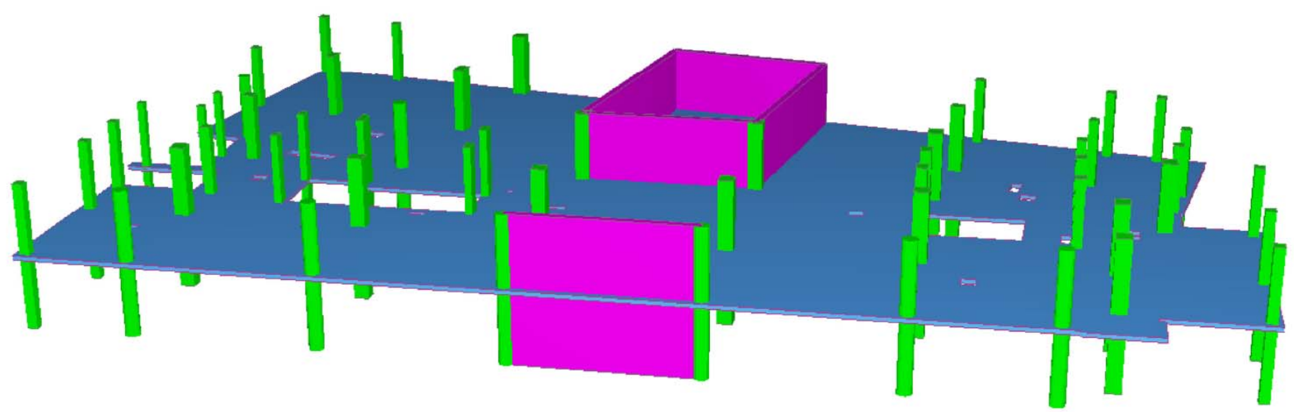
- -proposed solutions- -

- Technical assignment 2 revealed that a post-tensioned flat plat would be the best solution
  - Unusual slab shape
  - Non-uniform column layout
  - Small floor to floor height
  - Architectural program controls design
- Technical assignment 3 revealed that large torsional forces were contributing a great deal of shear force
- In order to eliminate the torsional component it was proposed that an additional shear wall be added

- -depth study 1 – gravity redesign- -

-post-tensioned slab- -introduction-

- Used RAM Concept to model the floor
- Initial trial of 7” slab – approximation based on spans
- Covers minimum 6” depth for fire rating and is resonable thickness to check for punching shear



- -depth study 1 – gravity redesign- -

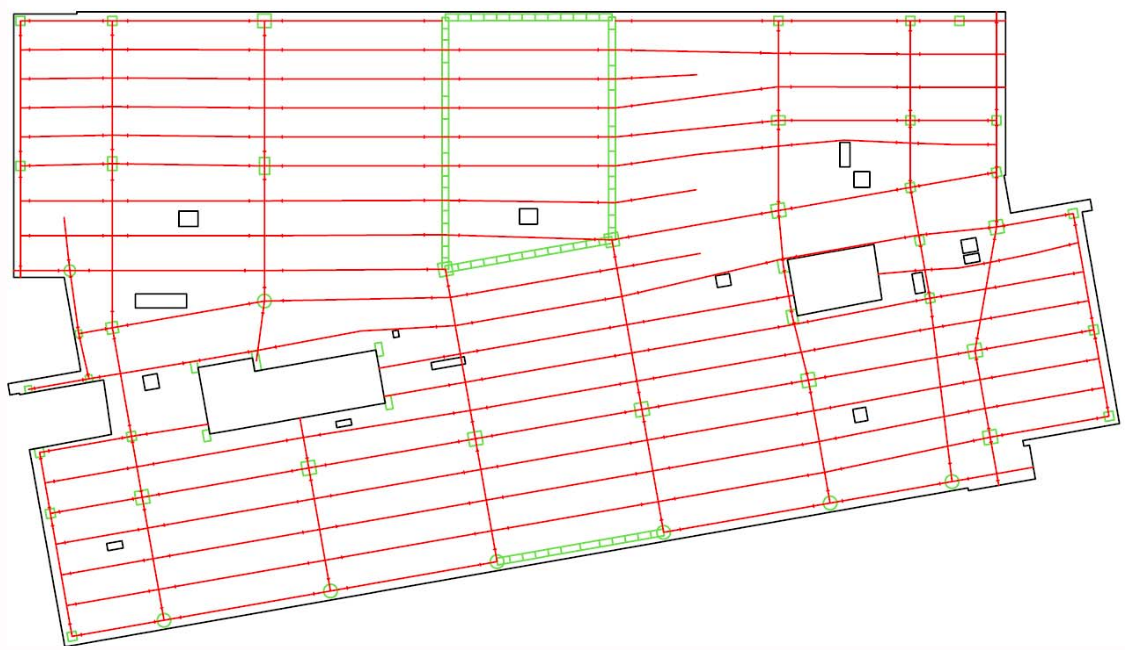
-post-tensioned slab- -building loads-

- The loads used for this design are as follows:
  - Partitions = 20psf
  - Miscellaneous Dead Load = 10psf
  - Live Load = 40psf
- RAM factor the self weight of the structure automatically
- RAM uses all load combinations and checks for worst case loading conditions

- -depth study 1 – gravity redesign- -

-post-tensioned slab- -tendon layout-

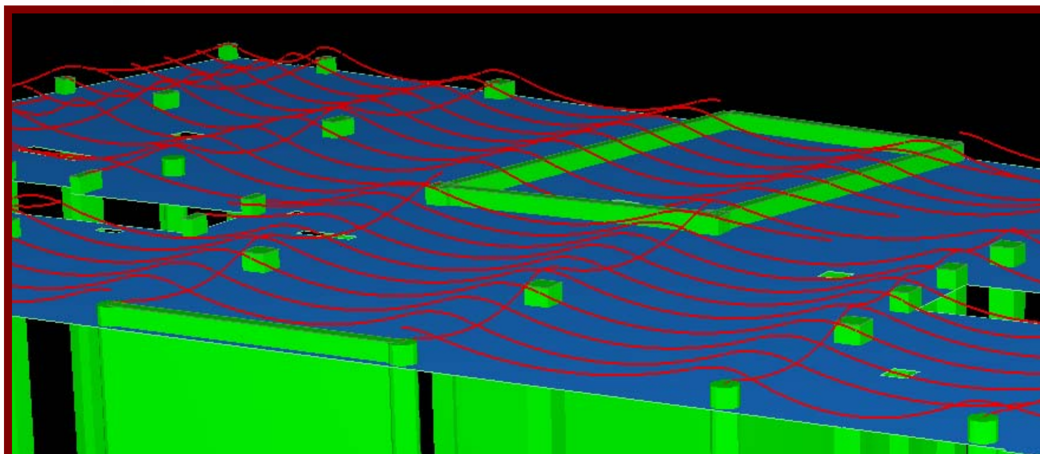
- Used the technique of banded strands in one direction and distributed strands in the other (Typical in U.S.)
- 15 Strands per line in the E-W
- 4 Stands per line in the N-S
- Used ½" unbonded strands with 1" of cover



- -depth study 1 – gravity redesign- -

-post-tensioned slab- -tendon layout-

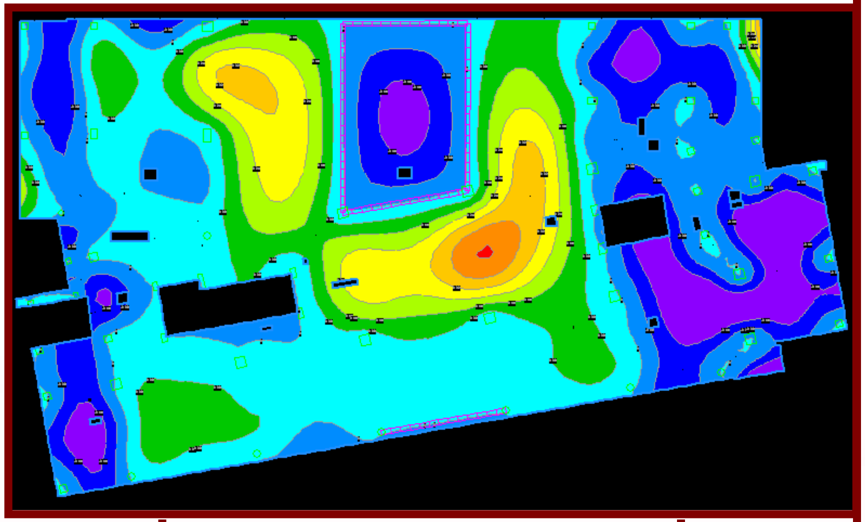
- Special care was taken placing the tendons to maintain uniformity
- Areas of the slab where strength and deflection issues arose got special attention
  - Slab Edges
  - Penetrations
  - Congested areas
  - Cantilevered slabs



- -depth study 1 – gravity redesign- -

-post-tensioned slab- -results-

- Minimum bonded reinforcement yielded #4 bars at 31” on center in the top and the bottom of the slab
- Initial service deflection after tensioning yielded a maximum camber of .18”
- Maximum long term deflection of the floor was .49” < L/480
- Punching shear reached 80% of max. allowable



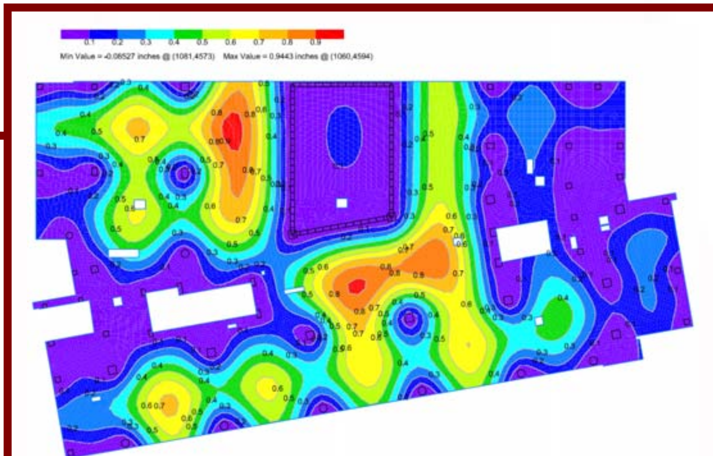
Long Term Deflection

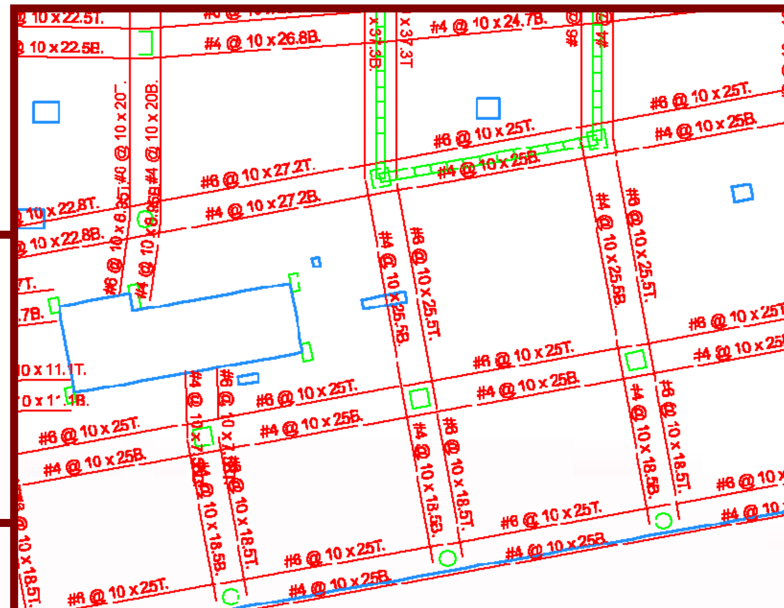
- -depth study 1 – gravity redesign- -

-existing conditions- -results-

- Also designed the original 8” slab using RAM Concept
- Maximum deflection of .94”
- #4@10” on center top

  #6@10” on center bottom

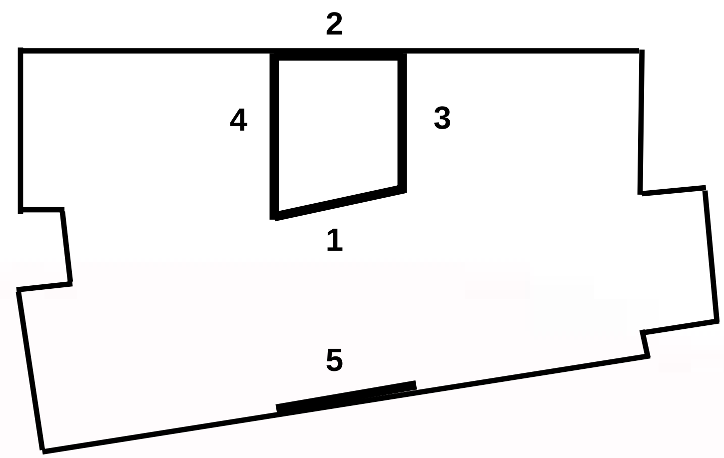




- -depth study 2 – lateral redesign- -

-addition of shear wall- -intro-

- Technical report 3, maximum drift in wall 1 = 8” due to large torsional force
- Ignored affect of equivalent concrete moment frames
- Added shear wall 5 on east wall
- Sized and positioned to make C.M. and C.R. coincide
- Simplified building to conservative rectangle
- Applied wind loads



- -depth study 2 – lateral redesign- -

-addition of shear wall- -distribution of loads-

- Equating C.M. and C.R. wall length was found to be 28’
- Distributed loads by stiffness of resisting elements per floor
- Found both direct and torsional story shears
- Used story shears to determine story drifts
- Summed story drifts to calculate total element drifts

- -depth study 2 – lateral redesign- -

-addition of shear wall- -results-

- By eliminating the torsional shear wall 1 decreases from an 8.6" deflection to 4.9"
- Each of the walls in the N-S direction improves
- The walls in the E-W dir. remain similar

Summary			
	Direction	Original	Redesign
Wall 1	N-S	8.60	4.89
Wall 2	N-S	6.77	5.25
Frames/Wall 5	N-S	6.47	4.74
Wall 3	E-W	6.28	6.28
Wall 4	E-W	6.39	6.36

- -breadth study 1 – acoustic analysis- -

-intro-

- Important to remember people of different lifestyles might live adjacent to each other
- Areas analyzed – Walls between units, slabs above and below fitness room
- 4 factors affect noise reduction – sound generated
  – transmission loss
  – properties of rooms
  – background noise
- Both existing systems and redesigns considered

- -breadth study 1 – acoustic analysis- -

-calculations-

- Transmission Loss

-Original Floor = 57 dB

-New Floor = 55 dB

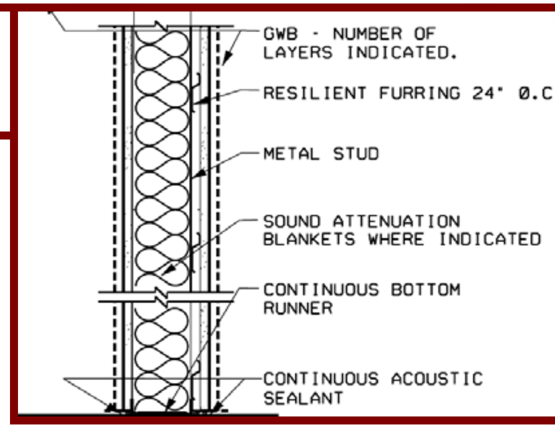
-Wall = 57 dB

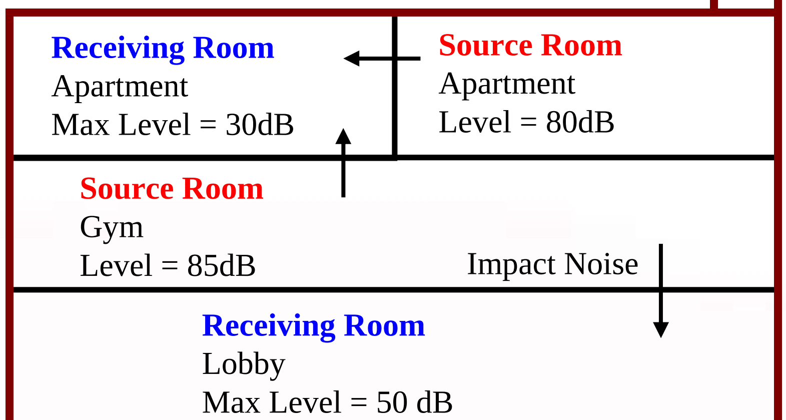
- Impact Isolation Class

-Original Floor = 36 dB

-New Floor = 34 dB

- NR = TL + 10*log(Σ(Sα)/S)





- -breadth study 1 – acoustic analysis- -

-conclusions-

- Original wall partition – < 30dB   Satisfactory
- Original floor slab above – < 30dB   Satisfactory
- Original floor slab below – < 50dB   Satisfactory
- PT slab below – > 50dB   Unsatisfactory
  - Add drop ceiling below
- PT slab above – > 30dB Unsatisfactory
  - Add rubber below carpet in apartment above

- -breadth study 2 – cm study- -

-intro-

- Objective was to determine the cost and schedule differences between the floor systems
- Material savings in both concrete and reinforcement
- Additional costs due to post-tensioning strands, jacking equipment, and increased duration

- -breadth study 2 – cm study- -

-cost comparison-

- Concrete savings – $13,500
- Reinforcement savings – $30,500
- Total Savings per floor – $33,000
- Post-tensioning strand cost – $11,100

			Original Design		Proposed Redesign	
	Unit Cost Material	Unit Cost Labor	Quantity	Total Cost	Quantity	Total Cost
Concrete	232 /cy	140 /cy	291.2 cy	$108300	254.8 cy	$94790
PT Strands	.46 /lb	.72 /lb	0 lbs	$0	9449 lbs	$11150
Formwork	1.6 /sqft	2.94 /sqft	11790 sqft	$53540	11790 sqft	$53540
Reinforcing Steel	850 /ton	420 /ton	31.38 tons	$39850	7.373 tons	$9363
Totals	9.59 /sqft	7.514 /sqft	11790 sqft	$201700	11790 sqft	$168800

- -breadth study 2 – cm study- -

-schedule analysis-

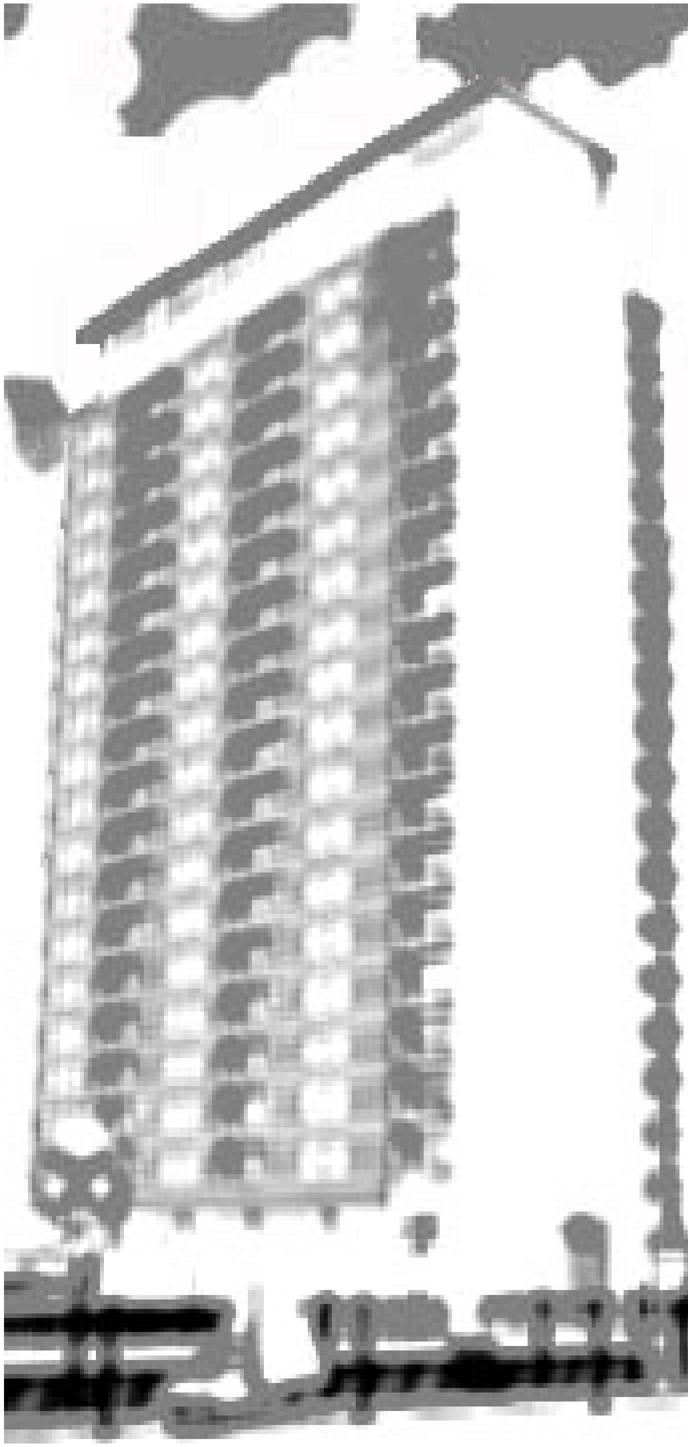
- Constructed typical floor schedules for both systems
- Broke floor plan into 2 phases
- The original design had a 7 day turnover time b/w floors
- The redesign had an 8 day turnover time
- The post-tensioned system added one day to the schedule per floor
- Results in a total duration increase of 22 days
- General conditions cost for additional days ≈ $30,000
- Small total savings by using PT design

- -conclusions- -

- Gravity redesign – Deflections improved
  Slab thinned, Reinforcing decreased
- Lateral redesign – Torsional shears eliminated
  Building drift reduced
- Acoustic Study – Partitions acceptable
  PT slab needs drop ceiling below
  and rubber below carpet above
- Construction Management Study –
  Material Savings = $33,000
  Schedule impact = $30,000

- -acknowledgements- -

- Thanks to –
  - The Buccini/Pollin Group
  - Kling
  - My advisor Professor Boothby and all the AE faculty
  - My family
  - All my friends and classmates who helped me the past 5 years



- -questions- -

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