Fraser Centre

State College, PA

Tyler Strange

Structural Option
Consultant: Dr. Thomas Boothby
April 13, 2011

Fraser Centre

State College, PA

Presentation Outline

- Introduction
- Existing System
- Proposal
- Gravity System Redesign
  - Composite Floor
  - Steel Connections
- Schedule and Cost Analysis
- Lateral System Redesign
- Architectural Analysis
- Conclusion

General Information

•Location……..State College, PA

Fraser Street and Beaver Ave

• Size……..230,000 sf

• Project Cost……Unreleased

• Project Team

- Architect……..Wallace Roberts & Todd, LLC
- General Contractor……Leonard S. Fiore, Inc.
- Structural Engineer……David Chou & Associates, Inc.

Introduction to Fraser Centre

- 11 story mixed-use building
  - First story is parking
  - Second story is parking and retail
  - Third story is a theatre
  - Fourth story is MEP
  - Fifth-tenth stories are residential
  - Eleventh story is suites

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Floor System

- Two-way 12 inch flat slab

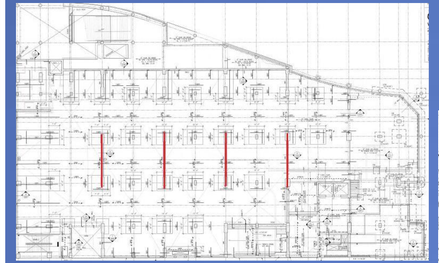
Columns

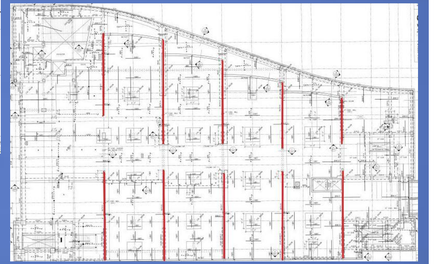
- Columns vary in size from 16in x 32in to 16in x 72in
- Spans range from 28.5ft to 40ft

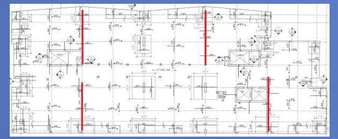
Shear Walls

- 4 shear walls located on the residential floors
- Shear walls on the lower floors vary from 4 to 10

Existing System







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Depth Proposal

•Change the floor system to composite concrete and steel beams for the residential levels

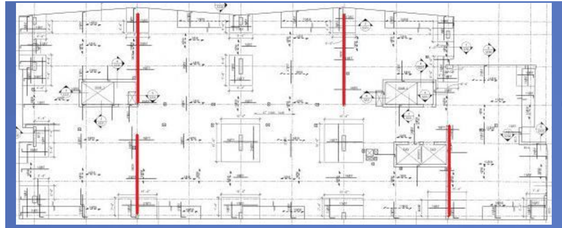
•Redesign the residential shear walls with a new layout

Breadth Proposal

•Analyze the change in cost and schedule of the new floor system

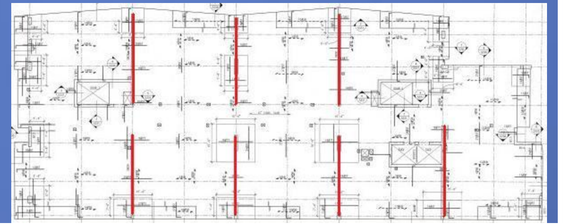
•Analyze the impact the new shear wall layout will have on the architecture

Proposal



Current Shear Wall Layout

Proposed Shear Wall Layout



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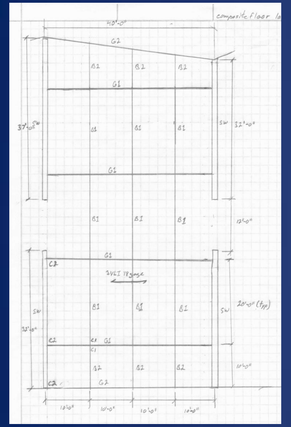
Composite Floor



Steel Deck: 3VLI Deck 18 Gage

B1: W12x16

B2: W10x12

G1: W18x76

G2: W16x31

C1: Welded/Bolted Single Angle L4x3x$^{3}/_{8}$

C2: Bolted/Bolted Double Angle L4x3x$^{3}/_{8}$

Codes:

- Original design code used ASCE 7-05
- New design code used ASCE 7-10

Material Strengths:

- Concrete: 4000 psi
- Steel: 50000 psi

Load Combinations

- 1.2 Dead +1.6 Live
- 1.4 Dead

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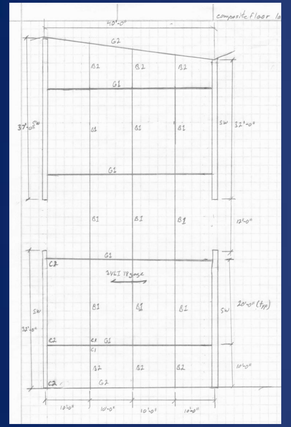

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C2: Bolted/Bolted Double Angle L4x3x$^{3}/_{8}$

Composite Floor

Deflection Check:

- Limited to L/360

Results:

- 3 in 18 gage VLI steel deck was used
- 4.5 in of concrete was used to achieve 2 hr fire rating
- W Shapes range from W10x12 to W18x76
- Thickness of residential floor system was increased by 12in

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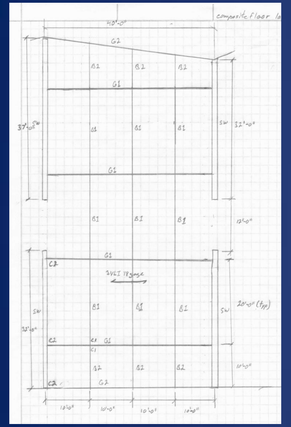

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Steel Connections

Design:

- AISC Table 10-11
- Girder to Beam is welded/bolted for constructability
- Shear Wall to Girder is bolted/bolted for economics

Results:

- Girder/Beam connection:
  - Welded/Bolted Single Angle
  - L4x3x3/8
  - 3/16th weld
  - Two A325N ¾” dia. bolts
- Shear Wall/Girder connection:
  - Bolted/Bolted Double Angle
  - L4x3x1/4
  - Three A325N ¾” dia. bolts

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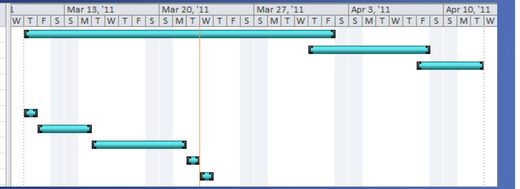
Schedule and Cost Analysis

Schedule Analysis

Task Name	Duration	Start	Finish
Place Forms (2 crews)	17 days	Thu 3/10/11	Fri 4/1/11
Place Rebar	7 days	Thu 3/31/11	Fri 4/8/11
Place Concrete	3 days	Fri 4/8/11	Tue 4/12/11
Place Girders (W18 & 16)	1 day	Thu 3/10/11	Thu 3/10/11
Place Beams (W12 & 10)	2 days	Fri 3/11/11	Mon 3/14/11
Place Metal Decking	5 days	Tue 3/15/11	Mon 3/21/11
Weld Shear Connections	1 day	Tue 3/22/11	Tue 3/22/11
Place Concrete	1 day	Wed 3/23/11	Wed 3/23/11



- Current system takes 24 days to complete a single floor with slight overlap.
- Alternative system takes 10 days to complete a single floor with a linear progression.

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Cost Analysis

Description	Cost Estimate
In Place Forms	2,212,344
In Place Reinforcing	3,432
4 ksi Ready Mix	60,492
Placing Concrete	37,658
Cost of Current System	**2,313,926**

Total

Schedule and Cost Analysis

Description	Cost Estimate
Struct. Steel W16x31	260,361
Struct. Steel W18x76	829,142
Struct. Steel W10x12	74,389
Struct. Steel W12x16	333,575
Metal Decking	5,450,667
Weld Shear Conn	66,410
4 ksi Ready Mix	20,235
Placing Concrete	12,597
Cost of Alternative System	**7,047,374**

Total

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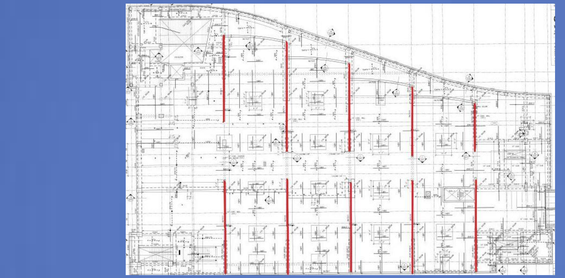
Initial Shear Wall Layout

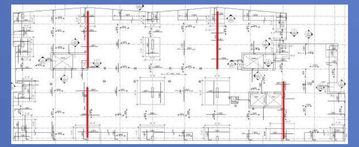
- Discontinuous between parking levels, theater level, and residential levels
- Architectural restraints on position and size

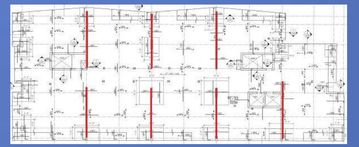
Proposed Shear Wall Layout

- Continuous from theater level to residential levels
- Number of shear walls is increased from four to seven
- Shear walls are reduced in size

Lateral System Redesign







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Shear Wall Design Calculations

- Flexural Reinforcement Design

$$0.85f'_c ab = A_s f_y \qquad M_u = \phi M_N = \phi A_s f_y jd \qquad \varepsilon_t = \varepsilon_{cu}\left(\frac{d_t - C}{C}\right) > 0.005$$

- Shear Reinforcement Design
  - Capacity Check $V_u \le \phi V_{N,max} = \phi 10\sqrt{f'_c}hd$
  - ACI Chapter 11 $V_u > \frac{1}{2}\phi V_c$
  - Minimum Reinforcements Governed

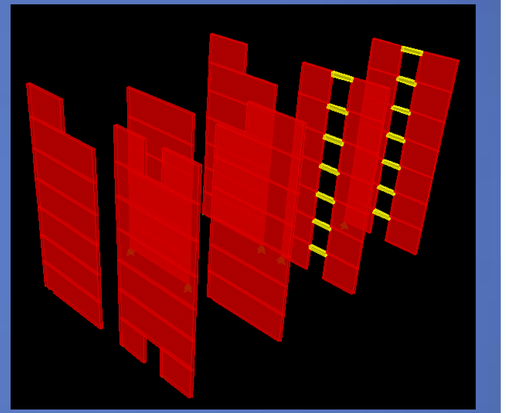
$$\rho_t = \frac{A_v}{sh} \qquad \rho_l = \frac{A_v}{sh} \ge 0.0025 + 0.5\left(2.5 - \frac{h_w}{l_w}\right)(\rho_t - 0.0025) \qquad \rho_l = \frac{A_v}{sh} > 0.0025$$

  - Spacing Limitations $s \le \frac{l_w}{3}$ or $3h$ or $18"$

Lateral System Redesign

3D ETABS Model

- Shear walls modeled in ETABS
- ETABS used to design shear walls and then checked to design by hand
- Controlling Load Case:
  - 1.54D+1.65E



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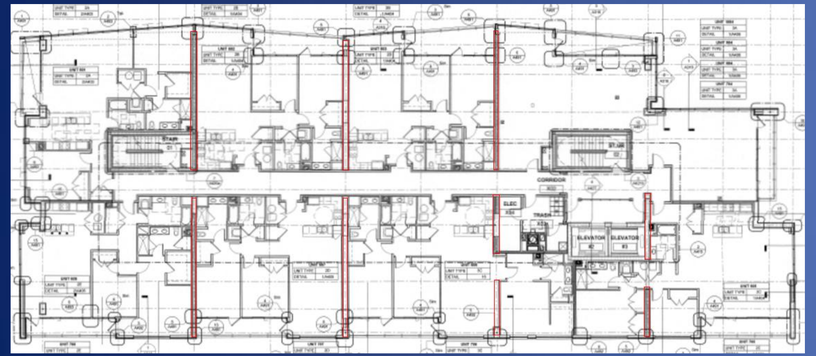
Architectural Analysis

5th Floor-10th Floor



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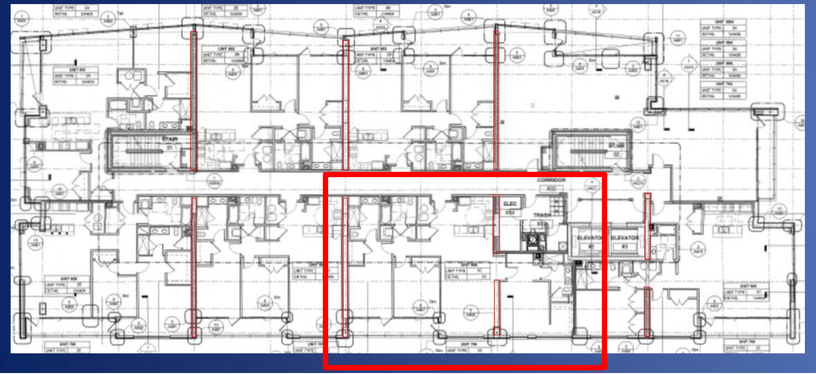
5th Floor-10th Floor



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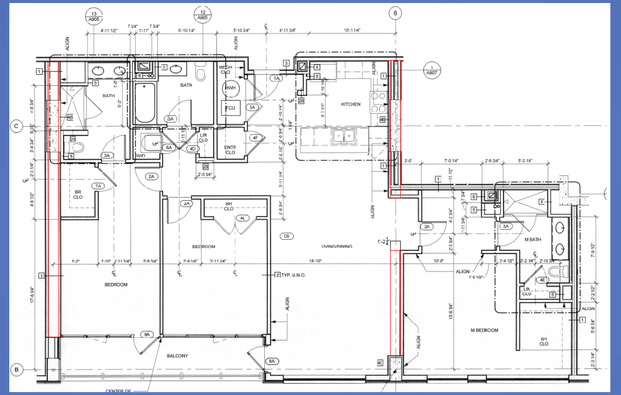

Largest impact on architecture occurs in Unit 3C

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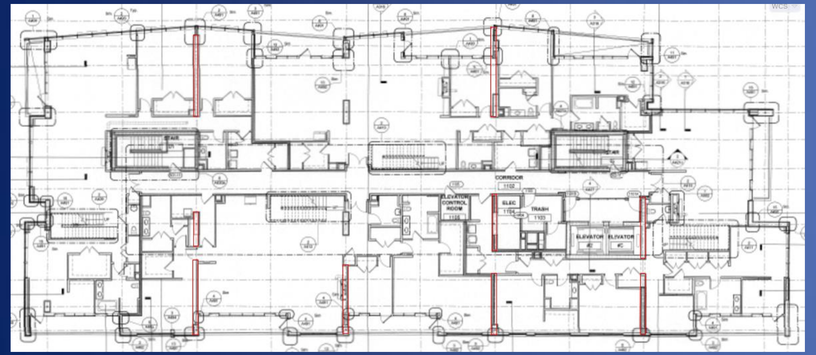
Architectural Analysis

11th Floor



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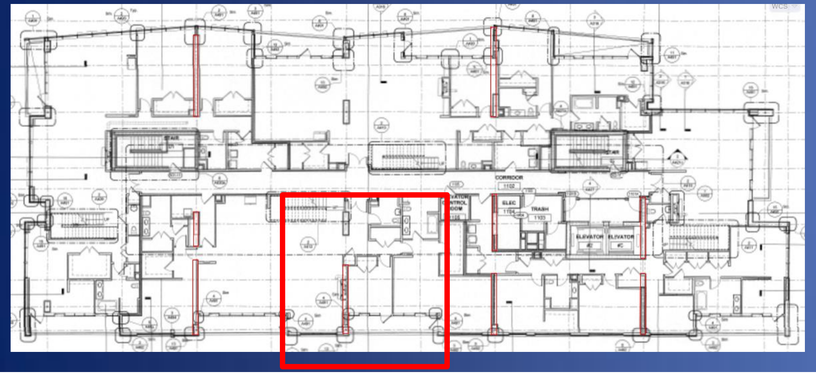

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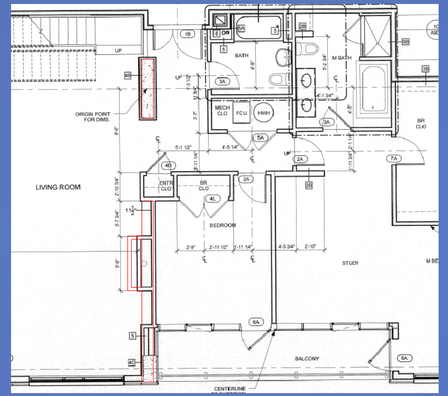

Living room width is reduced by 14”

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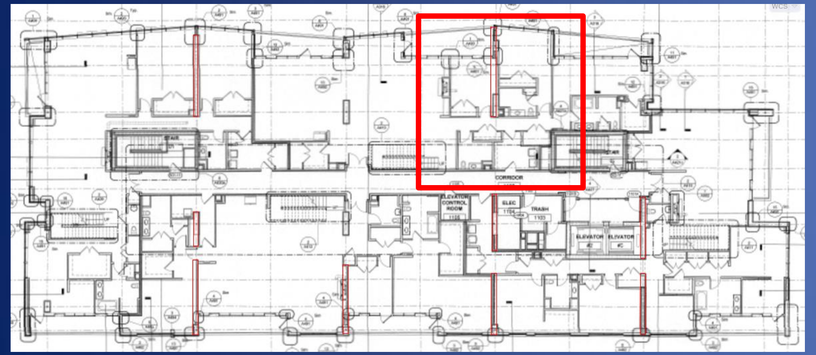
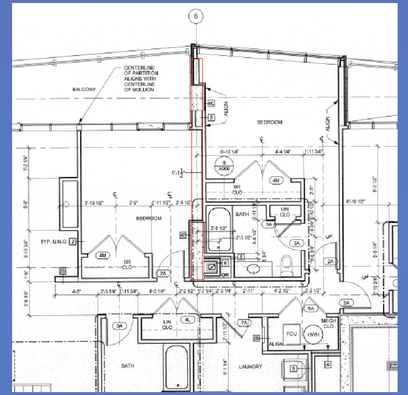
11th Floor





Bedroom width is reduced by 14”

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Building Weight:

- •Existing System: 72,000 kips
- •Proposed System: 65,000 kips
- •7,000 kip reduction

Architectural Impact:

- •Largest impact on floors 5-10 is shortening a single room by roughly 14”.
- •Largest impact on the 11th floor is shortening the living room by 14 “.

Conclusion

Cost:

- •Existing System: $2.3 million/residential floor
- •Proposed System: $7.0 million/residential floor
- •Three times more expensive

Schedule:

- •Existing System: 24 days/residential floor
- •Proposed System: 10 days/residential floor
- •Gain 98 work days for all seven residential floors

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