Thesis Presentation

2555 Grand – Crown Center

Kansas City, MO

Robert Caruthers
Architectural Engineering
Senior Thesis
Presentation Outline

- Background of Existing Building
- Proposal
- Structural Analysis
- Slip form Design
- Architectural Study
- Advantages and Disadvantages for each
- Conclusions and Recommendations
Background

Project Design Team

- **Owner:**
  - The Crown Center Redevelopment

- **Architect:**
  - Zimmer Gunsul Frasca Partnership

- **Structural Engineer:**
  - KPFF Consulting Engineers

- **Construction Manager:**
  - Havens Steel
Background

Building Features

- 24-High-Rise Office Building
- 600,000 Square Feet
- Total Project Cost of 75 million
- Start Date: 6/01          End Date: 6/03
- Primary functions of building
  - Office Space
  - Conference Space
Background

Architectural Features

- Granite Curtain Wall on first couple Floors
- Rolled Canopy Roof
- Pre-cast Concrete Panels the rest of the way
- Architectural Glass Windows on exterior
- Total Height 325 ft
- Average floor to floor height approximately 13 ft
Background

Structural Features

- Combination of Structural Steel beams and columns
- Lateral Braced Framing in the core
- Composite Metal Deck Concrete Flooring System
- Rolled Canopy Roof
- Mostly Shear Connections
- Floor slab thickness is 6”
Background

Mechanical/Electrical

- Heaters range from 5 to 30 kwatts
- Domestic Water Heaters sizes range from 40 to 80 gallons
- Air handling units range from 60,000 to 82,000 cfm
- Fan powered Variable Air volume units ranging from 250 to 2140 cfm
- 5 225 A panel Boards per floor
- Circuits range from: Three phase 208/120 volts and 280/277 volts
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Proposal

Structural

- Existing System:
  Braced Frame in the Core

- Proposed System:
  Change the tube steel braced frames to concrete shear walls
Proposal

Existing Lateral System

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Proposal

Proposed Shear Walls

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Architectural

Existing Exterior Wall:

- Granite on the first couple floors all around the exterior of the building

Proposed Change:

- Limestone exterior

Look at Advantages and disadvantages of each as well as a cost analysis
Proposal

Construction Management

Proposal:

Vertical Slip forms

- Use Vertical Slip forms to erect the shear walls
- Look into costs issues
- Different types
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Structural Analysis
Shear Walls
W1, W2 are 60ft  W3, W4, W5, W6 are 40ft
# Structural Analysis

## First Five Floors

<table>
<thead>
<tr>
<th>Wall</th>
<th>Thickness</th>
<th>Min Rein(H)</th>
<th>Min Rein(V)</th>
<th>Vertical Edge Rein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall 1</td>
<td>12”</td>
<td>#4@7”</td>
<td>#4@12”</td>
<td>#11@5”</td>
</tr>
<tr>
<td>Wall 2</td>
<td>12”</td>
<td>#4@7”</td>
<td>#4@12”</td>
<td>#11@5”</td>
</tr>
<tr>
<td>Wall 3</td>
<td>12”</td>
<td>#4@7”</td>
<td>#4@12”</td>
<td>#11@5”</td>
</tr>
<tr>
<td>Wall 4</td>
<td>12”</td>
<td>#4@7”</td>
<td>#4@12”</td>
<td>#11@5”</td>
</tr>
<tr>
<td>Wall 5</td>
<td>12”</td>
<td>#4@7”</td>
<td>#4@12”</td>
<td>#11@5”</td>
</tr>
<tr>
<td>Wall 6</td>
<td>12”</td>
<td>#4@7”</td>
<td>#4@12”</td>
<td>#11@5”</td>
</tr>
</tbody>
</table>
Structural Analysis

First Five Floors
Edge Detail Walls 1,2,3,4,5

32 # 11 bars
spaced at 5”
apart

10 ft edge of wall
1,2,3,4,5 (12” thick)
Structural Analysis
First Five Floors
Edge Detail Wall 6

32 #11 bars
spaced at 5'
apart

10 ft edge of wall 6 (12" thick)
## Structural Analysis

### Next Five Floors

<table>
<thead>
<tr>
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<tr>
<td>Wall 4</td>
<td>12”</td>
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<td>#4@12”</td>
<td>#11@12”</td>
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<tr>
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<td>#11@12”</td>
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<td>12”</td>
<td>#4@7”</td>
<td>#4@12”</td>
<td>#11@7”</td>
</tr>
</tbody>
</table>
Structural Analysis

Next Five Floors

Walls 1, 2, 3, 4, 5

20 # 11 bars
spaced at 12”
apart

10 ft edge of wall
1, 2, 3, 4, 5 (12” thick)
Structural Analysis

Next Five floors

Wall 6

20 # 11 bars
spaced at 7"

10 ft edge of wall
6 (12" thick)
# Structural Analysis

## Next Five Floors

<table>
<thead>
<tr>
<th>Wall</th>
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<tr>
<td>Wall 1</td>
<td>10”</td>
<td>#4@8”</td>
<td>#4@12”</td>
<td>#9@13”</td>
</tr>
<tr>
<td>Wall 2</td>
<td>10”</td>
<td>#4@8”</td>
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<td>#9@13”</td>
</tr>
<tr>
<td>Wall 3</td>
<td>10”</td>
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<td>#4@12”</td>
<td>#9@13”</td>
</tr>
<tr>
<td>Wall 6</td>
<td>10”</td>
<td>#4@8”</td>
<td>#4@12”</td>
<td>#9@13”</td>
</tr>
</tbody>
</table>
Structural Analysis

Next Five Floors
Walls 1,2,3,4,5

18 # 9 bars
spaced at
13 ft apart

10 ft edge of wall
1,2,3,4,5 (10 ft thick)
Structural Analysis

Next Five floors

Wall 6

18 # 9 bars spaced at 13' apart

10 ft edge of wall
6 (10” thick)
## Structural Analysis

### Next Five Floors

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<td>#9@12”</td>
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<td>#9@12”</td>
</tr>
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<td>Wall 4</td>
<td>10”</td>
<td>#4@8”</td>
<td>#4@12”</td>
<td>#9@12”</td>
</tr>
<tr>
<td>Wall 5</td>
<td>10”</td>
<td>#4@8”</td>
<td>#4@12”</td>
<td>#9@12”</td>
</tr>
<tr>
<td>Wall 6</td>
<td>10”</td>
<td>#4@8”</td>
<td>#4@12”</td>
<td>#9@6”</td>
</tr>
</tbody>
</table>
Structural Analysis

Next Five Floors

Walls 1,2,3,4,5

10 # 9 bars
spaced at
12" apart

5 ft edge of wall
1,2,3,4,5 (10" thick)
Structural Analysis

Next Five floors

Wall 6

10 # 9 bars spaced at 6' apart

5 ft edge of wall
6 (10' thick)
<table>
<thead>
<tr>
<th>Wall</th>
<th>Thickness</th>
<th>Min Rein(H)</th>
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</thead>
<tbody>
<tr>
<td>Wall 1</td>
<td>8”</td>
<td>#4@12”</td>
<td>#3@18”</td>
<td>#9@16”</td>
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<tr>
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<td>#9@16”</td>
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<tr>
<td>Wall 4</td>
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<td>#3@18”</td>
<td>#9@16”</td>
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<td>#3@18”</td>
<td>#9@16”</td>
</tr>
<tr>
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<td>8”</td>
<td>#4@12”</td>
<td>#3@18”</td>
<td>#9@8”</td>
</tr>
</tbody>
</table>
Structural Analysis

Last Four Floors
Walls 1,2,3,4,5

6 # 9 bars spaced
at 16" apart

4 ft edge of wall
1,2,3,4,5 (8" thick)
Structural Analysis

Last four floors

Wall 6

6 # 9 bars spaced at 8” apart

4 ft edge of wall 6 (8” thick)
Structural Analysis

Cost Analysis

Braced Frame vs Shear Walls

(All Cost analysis was done using RS means Assemblies cost data)

<table>
<thead>
<tr>
<th></th>
<th>Existing Lateral system (braced frames)</th>
<th>Proposed Lateral System (Shear Walls)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>$757,192</td>
<td>$955,723</td>
</tr>
</tbody>
</table>

Cost Savings using Braced Frames

$200,000
Presentation Outline

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Slip Form Design

Composed of three Sections

- yokes
- wales
- sheathing

15-4 Typical slipform with deck and finishing scaffold supported on wales. Templates for positioning reinforcing bars are indicated. Yokes should be designed with adequate clearance below the yoke beam to permit efficient placement of reinforcing steel. Batter strip placed between upper wale and sheathing will give enough batter to sheathing to help reduce friction.
Slip Form Design

Lifting Jacks
- carry vertical loads
- can hold as much as 25 tons
  - hydraulic jack
- Provides movement of form in increments of 1”
- Minimum of 3 minute intervals
Slip Form Design

**Sheathing**
- 1 in nominal board, 3/8-in plywood
- 10-gage steel sheets as reinforced backup members

**Depth**
- depends on the rate of slide
- time required for concrete to strengthen
  - minimum depth 3 1/2 ‘
  - Recommend 4’
Slip Form Design

Sliding Operation
- most important in order for economical success
  - speeds range from 12 to 18 in per hr
  - Recommend speeds about 18 in per hr

How to accomplish
- better job management and planning
- Adequate supply of concrete on site
- Materials conveniently stockpiled
  - Qualified superintendent
Slip Form Design

Reducing Wall Thickness

- very important since thickness of the wall changes every 10 floors
  - With slip forming this can be done

How

- shear wall is completed at level where thickness changes
  - Jacks are partially free of concrete
  - A filler piece is inserted inside the forms
  - Can be removed and replace as you go up the wall
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Architectural Study

Existing Façade:
Granite Exterior Type 1, Gray

Advantages and Disadvantages

<table>
<thead>
<tr>
<th>Stronger</th>
<th>More expensive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly resistive to acids</td>
<td>No architectural change over time</td>
</tr>
<tr>
<td>Will retain its polish longer</td>
<td></td>
</tr>
<tr>
<td>Lower rate of water absorption</td>
<td></td>
</tr>
</tbody>
</table>
**Architectural Study**

**Proposed Change:**
Limestone, Sugar cube finish 5” thick, 5’x14’ panels

**Advantages and Disadvantages**

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Could prove to be cheaper</td>
<td>Weaker compressive strength</td>
</tr>
<tr>
<td>Architectural appearance over time changes</td>
<td>Thicker material would have to be used</td>
</tr>
<tr>
<td>Easy material to buy</td>
<td>Absorbs water faster</td>
</tr>
</tbody>
</table>
# Architectural Study

## Cost Analysis

### Granite vs Limestone

<table>
<thead>
<tr>
<th></th>
<th>Existing Exterior Wall (Granite)</th>
<th>Proposed Exterior Wall (Limestone)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>$507,344</td>
<td>$400,894</td>
</tr>
<tr>
<td><strong>Price Difference</strong></td>
<td></td>
<td>$106,450</td>
</tr>
</tbody>
</table>

Using Limestone

**Cost Savings:** $106,450

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# Advantages and Disadvantages

## Structural

**Braced Frames**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>- cheaper overall</td>
<td>- more labor</td>
</tr>
<tr>
<td>- faster erection time</td>
<td>- more chance of errors</td>
</tr>
</tbody>
</table>

## Shear Walls

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>- more efficient design</td>
<td>- more expensive</td>
</tr>
<tr>
<td>- less labor intensive</td>
<td>- more planning</td>
</tr>
</tbody>
</table>
# Advantages and Disadvantages

## Architecture

### Granite

**Advantages**
- Stronger
- Highly resistive to acids
- Will retain its polish longer
- Lower rate of water absorption

**Disadvantages**
- More expensive
- No color change

### Limestone

**Advantages**
- Cheaper
- Appearance changes

**Disadvantages**
- Thicker material
- Absorbs water faster
- Weaker
### Advantages and Disadvantages

#### Construction management

**Slip forms**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Very efficient</td>
<td>- expensive</td>
</tr>
<tr>
<td>- less labor</td>
<td>- more careful planning</td>
</tr>
<tr>
<td>- fast erection</td>
<td>- more mechanical</td>
</tr>
</tbody>
</table>

April 03

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# Conclusions and Recommendations

## Structural Design

<table>
<thead>
<tr>
<th></th>
<th>Price</th>
<th>Time</th>
<th>Overall</th>
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</thead>
<tbody>
<tr>
<td><strong>Existing Design</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Proposed Design</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I would recommend Existing Design of Braced Frames
## Conclusions and Recommendations

### Architectural Design

<table>
<thead>
<tr>
<th></th>
<th>Price</th>
<th>Aesthetics</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Exterior (Granite)</td>
<td></td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Proposed Exterior (limestone)</td>
<td>√</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I would recommend existing exterior (granite)
Special Thanks

- Dr. Boothby
- The Whole AE Department
- Havens Steel
- Harold Permeter
- Friends
Q&A

Any Questions?

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Senior Thesis

April 03