I. Project Background
II. Scope of Work
III. Structural Depth Study
   i. Gravity System
   ii. Lateral Force Resisting System
   iii. Recommendation & Conclusion
IV. Architectural/Façade Breadth
V. Construction Management Breadth
VI. Summary of Conclusions
VII. Acknowledgments
Project Background

I. Project Background
II. Scope of Work
III. Structural Depth Study
   i. Gravity System
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IV. Architectural/Façade Breadth
V. Construction Management Breadth
VI. Summary of Conclusions
VII. Acknowledgments

Location: Downtown Holland Michigan
Intersection of 7th Street and College Ave

Function: Eco-Boutique Hotel with 56 Guestrooms
Restaurant, Fitness Center, Cinema Room, Bar & Lounge

Building: 65,000 Square Feet
Statistics: 5 Stories Above Grade
Overall Height of 67'-2"
Project Background

I. Project Background
II. Scope of Work
III. Structural Depth Study
   i. Gravity System
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IV. Architectural/Façade Breadth
V. Construction Management Breadth
VI. Summary of Conclusions
VII. Acknowledgments

Owner: Charter House Innovations
Contract: Design-Build Delivery Method
Architect / Engineer: GMB Architecture + Engineering
Construction Manager: GDK Construction
Cost: $7.2 Million
Schedule: February 2007 to February 2008
Project Background

I. Project Background
II. Scope of Work
III. Structural Depth Study
   i. Gravity System
   ii. Lateral Force Resisting System
   iii. Recommendation & Conclusion
IV. Architectural/Façade Breadth
V. Construction Management Breadth
VI. Summary of Conclusions
VII. Acknowledgments

Existing Structural System

Foundation: 4” Concrete Slab
Gravity System: CMU Load Bearing Walls
             8” Precast Hollow Core Planking
             w/ 2” Concrete Topping
             Steel Members Where Required
Lateral System: Reinforced Concrete Masonry
                Shear Walls
                Typically 8” or 12” Thick CMU

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Scope of Work

Project Statement:
Existing Structural System is the Most Efficient and Economical
Design a Viable Alternative System

Project Solution:
Girder-Slab Composite Steel and Precast System

I. Project Background
II. Scope of Work
III. Structural Depth Study
   i. Gravity System
   ii. Lateral Force Resisting System
   iii. Recommendation & Conclusion
IV. Architectural/Façade Breadth
V. Construction Management Breadth
VI. Summary of Conclusions
VII. Acknowledgments
I. Project Background

Scope of Work

II. Scope of Work

III. Structural Depth Study
   i. Gravity System
   ii. Lateral Force Resisting System
      iii. Recommendation & Conclusion

IV. Architectural/Façade Breadth

V. Construction Management Breadth

VI. Summary of Conclusions

VII. Acknowledgments

Project Goals

Structural Depth:
- Reduce Overall Building Weight
- Optimize Gravity and Lateral Systems
- Verify Impact on Foundation

Architectural / Façade Breadth:
- Research Various Façade Options
- Address Thermal and Sound Effects

Construction Management Breadth:
- Impact on Overall Schedule and Cost

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Structural Depth Study

Gravity System:
- Composite Steel and Precast System
- Lightweight
  - Offers Quick Construction
  - Increases Overall Building Height
  - Requires Fireproofing

Design Loads

<table>
<thead>
<tr>
<th>Area</th>
<th>GMB Design Loads (PSF)</th>
<th>ASCE 7-05 (PSF)</th>
<th>Design Load (PSF)</th>
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<tbody>
<tr>
<td>Private Guest Rooms</td>
<td>40</td>
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<td>Public Spaces</td>
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<td>100</td>
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<td>40 (Public Corridor)</td>
<td>40 (Private Corridor)</td>
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<td>Lobby</td>
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<td>100</td>
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<tr>
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<td>125 (Light)</td>
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<td>125</td>
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<td>Theaters/Fixed</td>
<td>60</td>
<td>60</td>
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<td>Restaurants/Bar</td>
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<td>100</td>
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<td>Patios/Courtyards</td>
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<td>100</td>
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<table>
<thead>
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<th>Material</th>
<th>GMB Design Loads (PSF)</th>
<th>ASCE 7-05 (PSF)</th>
<th>Design Load (PSF)</th>
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<tr>
<td>8&quot; Precast w/ Topping</td>
<td>80</td>
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<td>Partitions</td>
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<td>MEP</td>
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<td>Finishes/Miscellaneous</td>
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<td>Roof</td>
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<table>
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<tr>
<th>Roof Type</th>
<th>GMB Design Loads (PSF)</th>
<th>ASCE 7-05 (PSF)</th>
<th>Design Load (PSF)</th>
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<tbody>
<tr>
<td>Flat Roof</td>
<td>35</td>
<td>35</td>
<td>35</td>
</tr>
</tbody>
</table>

Section 3.1
- Live Loads (LL)
- Dead Loads (DL)
- Snow Load (SL)
Structural Depth Study

Framing Plan:
- Typical Bay Size - 18' x 24'
- Beam Size: W18x40
- Columns Aligned with Partition Walls
- Increased Floor-to-Ceiling Height

Controlling Load Combination:
- 1.2D + 1.6L + 0.5L

Deflection Criteria:
- Live Load: L/360
- Total Load: L/240
Structural Depth Study

Column Design:
- Comply with LRFD methods and AISC Steel Manual
- Optimal Members Designed by ETABS
- Resist Gravity Loads Only
- Typical Size - W8x31

Typical Section of Structural Components
Structural Depth Study

I. Project Background
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Pre-Cast Plank Design:
   Live Load: 40 PSF
   Dead Load: 15 PSF
   Superimposed Dead: 25 PSF

PCI Design Handbook Results:
   66-S Strands
   6 Strands @ 6/16” Diameter
   Self Weight of 81 PSF
Structural Depth Study

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Assumptions and Considerations:
- Modeled Lateral Members Only
- Columns Pinned at Base
- Beams and Braces Pinned
- Floor Diaphragms Modeled as Rigid Elements
- Accidental and Inherent Torsion was Considered
I. Project Background
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Wind / Seismic Effects:

Design Wind and Seismic Load Cases Were Used

\[ 1.2D + 1.6W_f + 1.0L + 0.5L_r \]
\[ 0.9D + 1.0E_x \]

Wind / Seismic Drifts:

Drift Criteria:

- Wind: \( H/400 \)
- Seismic: \( 0.02H_{sx} \)

<table>
<thead>
<tr>
<th>Level</th>
<th>Height Above Ground, h (ft)</th>
<th>Allowable Drift, ( \Delta_{allowable} = h/400 )</th>
<th>Total Drift (X-Direction)</th>
<th>Total Drift (Y-Direction)</th>
<th>Adequate</th>
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<tbody>
<tr>
<td>Roof</td>
<td>74.92</td>
<td>1.84</td>
<td>2.25</td>
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<td>Level 5</td>
<td>58.00</td>
<td>1.54</td>
<td>1.74</td>
<td>0.94</td>
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<td>Level 4</td>
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<td>1.32</td>
<td>1.56</td>
<td>0.84</td>
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<td>Level 3</td>
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<td>1.13</td>
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<tr>
<td>Level 2</td>
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<td>0.91</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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Controlling Wind Drift

<table>
<thead>
<tr>
<th>Level</th>
<th>Height Above Ground, h (ft)</th>
<th>Allowable Story Drift, ( \Delta_{allowable} = 0.02hs_x )</th>
<th>Total Drift (X-Direction)</th>
<th>Total Drift (Y-Direction)</th>
<th>Adequate</th>
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</thead>
<tbody>
<tr>
<td>Roof</td>
<td>16.92</td>
<td>0.03</td>
<td>0.34</td>
<td>0.005</td>
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<td>Level 5</td>
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<td>0.03</td>
<td>0.28</td>
<td>0.005</td>
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<td>Level 4</td>
<td>14.00</td>
<td>0.03</td>
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<td>0.005</td>
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<td>Level 3</td>
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<td>0.03</td>
<td>0.13</td>
<td>0.005</td>
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<td>0.03</td>
<td>0.08</td>
<td>0.005</td>
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<tr>
<td>Level 1</td>
<td>16.00</td>
<td>0.03</td>
<td>0.00</td>
<td>0.005</td>
<td>Yes</td>
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</table>

Controlling Seismic Drift

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Structural Depth Study

I. Project Background
II. Scope of Work
III. Structural Depth Study
   i. Gravity System
   ii. Lateral Force Resisting System
      iii. Recommendation & Conclusion
IV. Architectural/Façade Breadth
V. Construction Management Breadth
VI. Summary of Conclusions
VII. Acknowledgments

Impact of Lateral Loads:

<table>
<thead>
<tr>
<th>Floor</th>
<th>Height Above Ground Z (ft)</th>
<th>Story Height (ft)</th>
<th>Overturning Moments</th>
<th>E/W Seismic Forces</th>
<th>N/S Wind Forces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top of Roof</td>
<td>77.17</td>
<td>2.25</td>
<td>4.6</td>
<td>0.0</td>
<td>17.4</td>
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<tr>
<td>Roof</td>
<td>74.92</td>
<td>16.92</td>
<td>34.9</td>
<td>749.7</td>
<td>74.9</td>
</tr>
<tr>
<td>Fourth</td>
<td>58.00</td>
<td>14.00</td>
<td>14.00</td>
<td>54.4</td>
<td>997.7</td>
</tr>
<tr>
<td>Third</td>
<td>44.00</td>
<td>14.00</td>
<td>47.5</td>
<td>177.2</td>
<td>97.9</td>
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<tr>
<td>Second</td>
<td>30.00</td>
<td>14.00</td>
<td>45.7</td>
<td>2302.5</td>
<td>17.2</td>
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<tr>
<td>First</td>
<td>16.00</td>
<td>14.00</td>
<td>43.1</td>
<td>2906.0</td>
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<td>Total</td>
<td></td>
<td></td>
<td>249.8</td>
<td>11143.1</td>
<td>200.0</td>
</tr>
</tbody>
</table>

Overturning NOT a Concern - Gravity Loads Much Larger

Impact on Foundation:

Overturning NOT a Concern - Gravity Loads Much Larger
Structural Depth Study

I. Project Background
II. Scope of Work
III. Structural Depth Study
   i. Gravity System
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   iii. Recommendation & Conclusion
IV. Architectural/Façade Breadth
V. Construction Management Breadth
VI. Summary of Conclusions
VII. Acknowledgments

Structural Conclusion:
- Steel Structure Sufficiently Designed for Strength and Serviceability Requirements
- Reduced the Overall Building Weight
- Reduced Base Shear and Overturning Moment
- Increase Floor-to-Ceiling Height
- Increase Overall Building Height
- Avoided Major Architectural Changes / Impacts

Structural Recommendation:
- Viable Option as an Alternative Structural System
Architectural/Façade Breadth

Goals:

To Analyze the Thermal Effects of Alternative Facades

Compare Construction Cost and Scheduling Impacts

Determine Additional Consequences of Replacing the Existing Structure
I. Project Background
II. Scope of Work
III. Structural Depth Study
   i. Gravity System
   ii. Lateral Force Resisting System
   iii. Recommendation & Conclusion
IV. Architectural/Façade Breadth
V. Construction Management Breadth
VI. Summary of Conclusions
VII. Acknowledgments

Architectural/Façade Breadth

Thermal Gradients:

- Brick
- Cavity
- Insulation
- CMU Block
- Gyp Wall Board

<table>
<thead>
<tr>
<th>Material</th>
<th>Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick</td>
<td>0</td>
</tr>
<tr>
<td>Cavity</td>
<td>8</td>
</tr>
<tr>
<td>Insulation</td>
<td>15.30</td>
</tr>
<tr>
<td>CMU Block</td>
<td>64.9</td>
</tr>
<tr>
<td>Gyp Wall Board</td>
<td>64.9</td>
</tr>
</tbody>
</table>
I. Project Background

II. Scope of Work

III. Structural Depth Study
   i. Gravity System
   ii. Lateral Force Resisting System
   iii. Recommendation & Conclusion

IV. Architectural/Façade Breadth

V. Construction Management Breadth

VI. Summary of Conclusions

VII. Acknowledgments

Cost and Time Comparison:

<table>
<thead>
<tr>
<th>Wall System</th>
<th>S.F.</th>
<th>Crew Size</th>
<th>Material Cost / SF</th>
<th>Labor Cost / SF</th>
<th>Total Cost</th>
<th>Daily Output (SF)</th>
<th>Construction Time (Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMU/Brick System</td>
<td>8041</td>
<td>3 Bricklayers, 3</td>
<td>$7.65</td>
<td>$14.90</td>
<td>$181,325</td>
<td>130</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bricklayer Helpers</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Brick Vaneer System / Metal Stud Backup</td>
<td>9183</td>
<td>3 Bricklayers, 2</td>
<td>$6.60</td>
<td>$11.60</td>
<td>$167,731</td>
<td>220</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bricklayer Helpers</td>
<td></td>
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<td></td>
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<tr>
<td>Curtain Wall System</td>
<td>9183</td>
<td>2 Glazers, 2 Structural</td>
<td>$24.50</td>
<td>$8.95</td>
<td>$306,253</td>
<td>205</td>
<td>45</td>
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<tr>
<td></td>
<td></td>
<td>Steel Workers</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

Additional Concerns:

Acoustics:
- Noise Limitations Important in Hotel
- Sound Absorbing Panels
- Hanging Ceilings
- Various Floor Coverings
- Multiple Layers of Gypsum Wall Board

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Construction Management Breadth

Construction Schedule Impact:

Existing Structural System:
- Start Date: March 23, 2007
- End Date: August 23, 2007

Redesigned Structural System:
- Start Date: March 23, 2007
- End Date: July 26, 2007
Construction Management Breadth

I. Project Background

II. Scope of Work

III. Structural Depth Study
   i. Gravity System
   ii. Lateral Force Resisting System
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IV. Architectural/Façade Breadth

V. Construction Management Breadth

VI. Summary of Conclusions

VII. Acknowledgments

Overall Cost Impact:

<table>
<thead>
<tr>
<th>Component</th>
<th>Existing System</th>
<th>Redesigned System</th>
<th>Additional Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMU Walls</td>
<td>$701,125</td>
<td>$160,975</td>
<td>-$540,150</td>
</tr>
<tr>
<td>Steel Bracing</td>
<td>$0</td>
<td>$206,250</td>
<td>$206,250</td>
</tr>
<tr>
<td>Steel Framing</td>
<td>$130,134</td>
<td>$524,358</td>
<td>$394,224</td>
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<tr>
<td>Total</td>
<td>$831,259</td>
<td>$891,583</td>
<td>$60,324</td>
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</tbody>
</table>

**Component**

<table>
<thead>
<tr>
<th>Shearwalls</th>
<th>Amount</th>
<th>Unit</th>
<th>Cost/Unit</th>
<th>Labor Cost/Unit</th>
<th>Equipment Cost/Unit</th>
<th>Total Cost/Unit</th>
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</thead>
<tbody>
<tr>
<td>8&quot; CMU, reinforced</td>
<td>59500</td>
<td>SF</td>
<td>2.15</td>
<td>2.71</td>
<td>-</td>
<td>4.86</td>
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<tr>
<td>12&quot; CMU, reinforced</td>
<td>28500</td>
<td>SF</td>
<td>3.11</td>
<td>4.16</td>
<td>-</td>
<td>7.27</td>
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**Overall Cost Comparison**

<table>
<thead>
<tr>
<th>Component</th>
<th>Existing System</th>
<th>Redesigned System</th>
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</tr>
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**Overall Cost Comparison**

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<tbody>
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<tr>
<td>Steel Bracing</td>
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<td>Steel Framing</td>
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<tr>
<td>Total</td>
<td>$831,259</td>
<td>$891,583</td>
<td>$60,324</td>
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</tbody>
</table>

**Total Cost of Existing System:** $831,259

**Total Cost of Redesigned System:** $891,583

**Additional Cost:** $60,324
Summary of Conclusions

Structural Conclusion:
- Steel Structure Sufficiently Designed for Strength and Serviceability Requirements
- Reduced the Overall Building Weight
- Reduced Base Shear and Overturning Moment
- Increase Floor-to-Ceiling Height
- Increase Overall Building Height
- Avoided Major Architectural Changes / Impacts

Architectural / Façade Conclusions:
- Brick Veneer System Most Efficient
- Additional Acoustical Elements Required

Construction Management Conclusions
- Reduced Schedule Period
- Minimal Increase of Up Front Cost
Acknowledgments

I. Project Background
II. Scope of Work
III. Structural Depth Study
   i. Gravity System
   ii. Lateral Force Resisting System
   iii. Recommendation & Conclusion
IV. Architectural/Façade Breadth
V. Construction Management Breadth
VI. Summary of Conclusions
VII. Acknowledgments

Charter House Innovations:
   • Chuck Reid

CityFlatsHotel:
   • Sara Lilly

GDK Construction:
   • Kara Slater

GMB Architecture + Engineering

The Pennsylvania State University:
   • Professor Kevin Parfitt
   • Professor Robert Holland
   • The Entire AE Faculty and Staff

All my friends, family, and classmates for their unconditional support and encouragement.

Hunter Woron - Structural CityFlatsHotel - Holland, MI Spring 2012 - Professor Parfitt
Questions and Comments

Hunter Woron - Structural

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Spring 2012 - Professor Parfitt