A Practical Perspective on the Use of Advanced Composites for Blast Mitigation

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Force Protection vs. Seismic Retrofit
Potential Applications of FRP for Blast Mitigation

- Strengthening of Masonry Infill Walls
- Adding Tie Forces
- Strengthening for Uplift
- Progressive Collapse
- Alternate Load Paths
- Adding additional shear capacity
- Column confinement & protection
- Spall protection
- Prefabricated blast curtain walls
Shake Table Testing – URM Walls
Blast Hardening of Walls
Spray Applied Polyurea
- 3 wythe masonry brick wall
- ½” Tyfo spray applied urea-urethane
- High pressure, short duration
- P = 10.7 psi
- I = 279 psi-msec
- Disp +2.5/-4.5
- Strain = 15%
Tie Force Method
Strengthening for Up Lift Forces

- Gravity Beams
- Framing Members
- Panel Region

- Damaged and Ineffective Member
- Undamaged and Effective Member
- Removed Column
- Transfer of Vertical Load Through Floor
Strengthening for Up Lift Forces
Progressive Collapse / Alternate Load Paths
Progressive Collapse / Alternate Load Paths

Figure 1.1 Rehabilitation Technique

Figure 1.2 Behavior of Rehabilitated Structure after Removal of the Column
Progressive Collapse / Alternate Load Paths

- Catenary Tension Ties
- Negative moment reinforcement
- Positive moment reinforcement
- Tyfoe SCH-41 Laminate
- Tyfoe Composite Anchor
- Lost Column
Fiber Reinforced Polymer Anchors Turn Bond Dependent Systems into Bond Independent Systems
• Development at Termination Points
  – Typically detailed with the “standard” SEH Composite Anchors (1/4” diameter with 2” minimum embedment)
• **Tension Force Development**
  
  – Fiber Anchor area per unit width shall be equal or greater than the installed Fibrwrap® laminates.
  
  – Fiber Anchor splay shall be no greater than 60-degrees. Typical details use 45-degree splay.
  
  – Bonded area shall be sufficient to transfer tensile forces.
Unreinforced column after test blast

Blast Test Site

Retrofitted column after test blast
Test 1: Strong-axis orientation, Standoff = 4 ft (A8-2)

Test 2: Weak-axis orientation, Standoff = 4 ft (A7-2)
Close-In Blast Applications
Tyfo Blast Panel Specimen #2
Specimen #1 & #2 Summary

Figure 12. Post-Test Permanent Displacement

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Peak Pressure (psi)</th>
<th>Applied Impulse (psi-ms)</th>
<th>Load Duration (ms)</th>
<th>Maximum Wall Deflection (inches)</th>
<th>Permanent Wall Deflection (inches)</th>
<th>Maximum Support Rotation (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.8</td>
<td>175</td>
<td>57.7</td>
<td>9.1</td>
<td>6.5</td>
<td>7.1</td>
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<td>52.9</td>
<td>3.5</td>
<td>0.75</td>
<td>2.7</td>
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</tbody>
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Prefabricated Blast Walls
Thank you!

Questions?

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