Structural Rehabilitation of Buildings

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Main Reasons for Rehabilitation/Retrofit

• **Structural Deterioration:**
  Dilapidated buildings due to loss of mechanical properties of members due to durability and age related issues.

• **Structural Upgradation:**
  Strengthening/stiffening required due to additions or change of use or function of the building or due to seismic enhancement to the existing structure.
Types of Rehabilitation

- Strength
- Durability
- Seismic/Lateral Force Resistance
- Fire Resistance
Spalling in RC Structures
Corrosion issues with PT Slabs

Image Courtesy: General Technologies Inc.
Current Forms of Retrofitting
Concrete Jacketing

Fig. 3: Installing the main steel in footing

Fig. 4: Completing the jacketing of footing
External Post-tensioning

(a) Threaded socket
(b) Highly expansive material

Image Courtesy: Tarek Alkhrdaji and Jay Thomas.

Image Courtesy: VSL Structural Technologies
Seismic Retrofit

The Executive Tower of Mexico's Ministry of Economy, showing retrofitted bracing, incorporating RESTON®SA shock absorbers, in each face of the building

Image Courtesy: Mageba Group.
Collaboration between the Bridge and the Building Industry is the Key:

Let’s NOT wait another 20 years!
Ultra High Performance Concrete

Portland Cement-Based

Self-Consolidating

Castable

Image Courtesy: Zach Haber, Genex Systems/FHWA TFHRC
Highly Packed UHPC Mix

Fiber Reinforcement

Superplasticizers

Supplementary Cementitious Materials

Particle Packing Theory

Image Courtesy: Zach Haber, Genex Systems/FHWA TFHRC
**UHPC Properties**

- Compressive Strength: > 150 MPa (21.75 ksi)
- Tensile Strength: Over 2 times greater than Concrete
- Highly Ductile: Post Cracking Ductility
- Chloride Ion Permeability: 1/10 to 1/50 of Concrete
- Better Freeze-Thaw characteristics
- Fracture Energy: 100 times of Concrete

*Ultra Durable Hence Ultra High Performance*
Advantages of UHPC

- **Cost Effectiveness:**
  - Downsizing Dimensions and Sections
  - Reduction in Steel Reinforcement

- **Sustainability:**
  - Green Construction
  - Minimized Maintenance due to superior durability
  - Encourage use of recycled materials
Idea 1: Increase in number of Stories (Upgradation)

• Original Design:

• Ground + 3 Podium levels + 10 Residential Levels

• After Construction of Foundation:

• Ground + 3 Podium levels + 15 Residential Levels

• Challenge:

  Match gravity load

  Match earthquake forces/over-turning moments

  Made possible by changing the residential levels to UHPC Slabs
Concept for Idea # 1

- UHPC Waffle Deck from Wapello County Bridge
Idea # 2: Replacement of Existing Gravity Loaded Columns

- La Republique Bridge – France (UHPC Piers and Girders)

- Use of thinner precast/prestressed UHPC Columns could create more usable area. Designed to be displacement compatible but with no moment taking capacity at ends.
Idea # 3: Rehabilitation of Steel Beams

- Use of UHPC to strengthen corroded steel beams
- Application: Structural Steel Parking Garages
Idea 4: Durability of Parking Floors/Roof Levels of Buildings

- Use of UHPC layer on top of exposed concrete floors or cover concrete could help reduce the maintenance cycle several folds.

Image Courtesy: Ductal Website
Idea 5: Structural Strengthening of Existing Slabs and beams

- Use of UHPC layer on top to increase negative bending moment capacity of slabs and beams

- Small development lengths: 6 to 10 times the bar diameter

Courtesy: Prof. Eugen Bruhwiler
UHPC Jacketing

Mission Bridge Seismic retrofit, Abbotsford, BC

CN Rail Bridge Pier Jacketing, Montreal, QC

Image Courtesy: Ductal Website
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Fire Resistance of UHPC
Effect of PP Fibers on Spalling

Melting and vapourisation of PP fibres leads to formation of networks

Synthetic fibre
Microcrack

Vapours in void

Escape of water vapour

Courtesy: Mitsuo Ozawa, Hiroaki Morimoto
**Fire Resistance of UHPC**

Effect of Fiber Type on Spalling

<table>
<thead>
<tr>
<th>Fiber types</th>
<th>No fiber</th>
<th>Steel fiber</th>
<th>PP fiber</th>
<th>PP and steel fiber</th>
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</thead>
<tbody>
<tr>
<td><strong>Morphology after heated</strong></td>
<td><img src="image1" alt="" /></td>
<td><img src="image2" alt="" /></td>
<td><img src="image3" alt="" /></td>
<td><img src="image4" alt="" /></td>
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<tr>
<td>Visual evaluation</td>
<td></td>
<td></td>
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<tr>
<td>Mass loss rate(%)</td>
<td>100</td>
<td>93.3</td>
<td>7.8</td>
<td>8.1</td>
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<tr>
<td>Compressive strength before heated (MPa)</td>
<td>169</td>
<td>198</td>
<td>168</td>
<td>198</td>
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<tr>
<td>Compressive strength residual rate (%)</td>
<td>0</td>
<td>0</td>
<td>70.6</td>
<td>97.3</td>
</tr>
</tbody>
</table>

Image Courtesy: Sub Bei, Lin Zhixiang
Rehabilitation of Joints using UHPC
Thank You!

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