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.

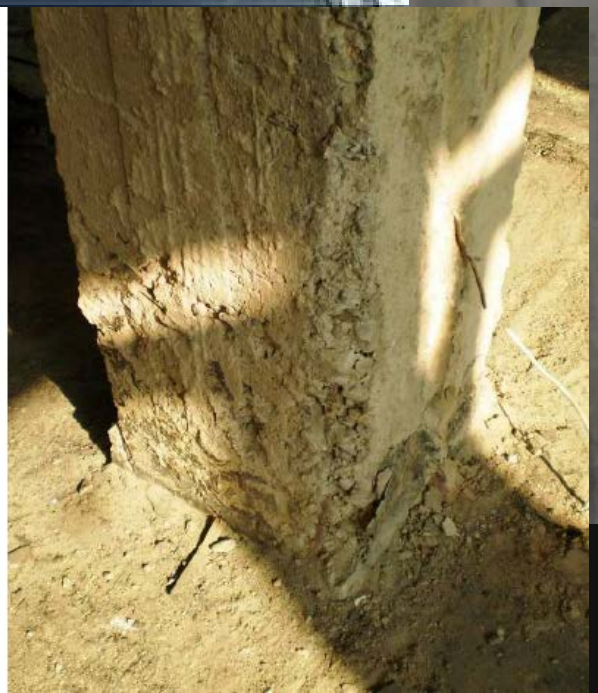
- Structural Upgradation:

  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

Image Courtesy: https://theconstructor.org.

Image Courtesy: Tarek Alkhrdaji

Concrete Jacketing

Fig: 3: Installing the main steel in footing

Fig.4: Completing the jacketing of footing

External Post-tensioning

Image Courtesy: Tarek Alkhrdaji and Jay Thomas.

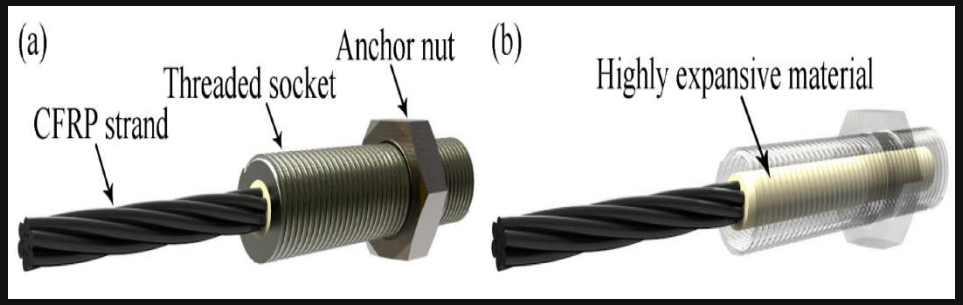
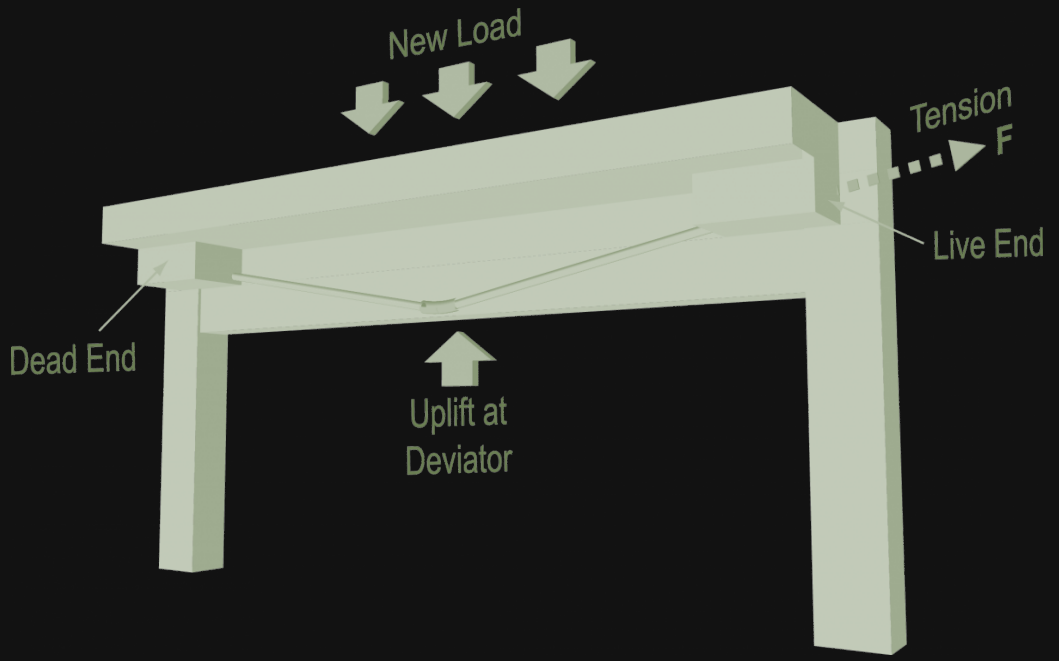


Image Courtesy: VSL Structural Technologies



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

8

Image Courtesy: Zach Haber, Genex Systems/FHWA TFHRC

Highly Packed UHPC Mix

Fiber Reinforcement

Superplasticizers

Supplementary Cementitious Materials

Particle Packing Theory

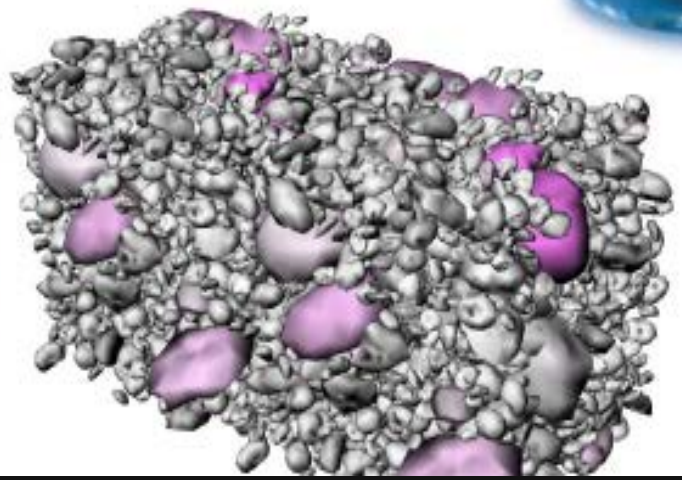


Image Courtesy: Zach Haber, Genex Systems/FHWA TFHRC

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:

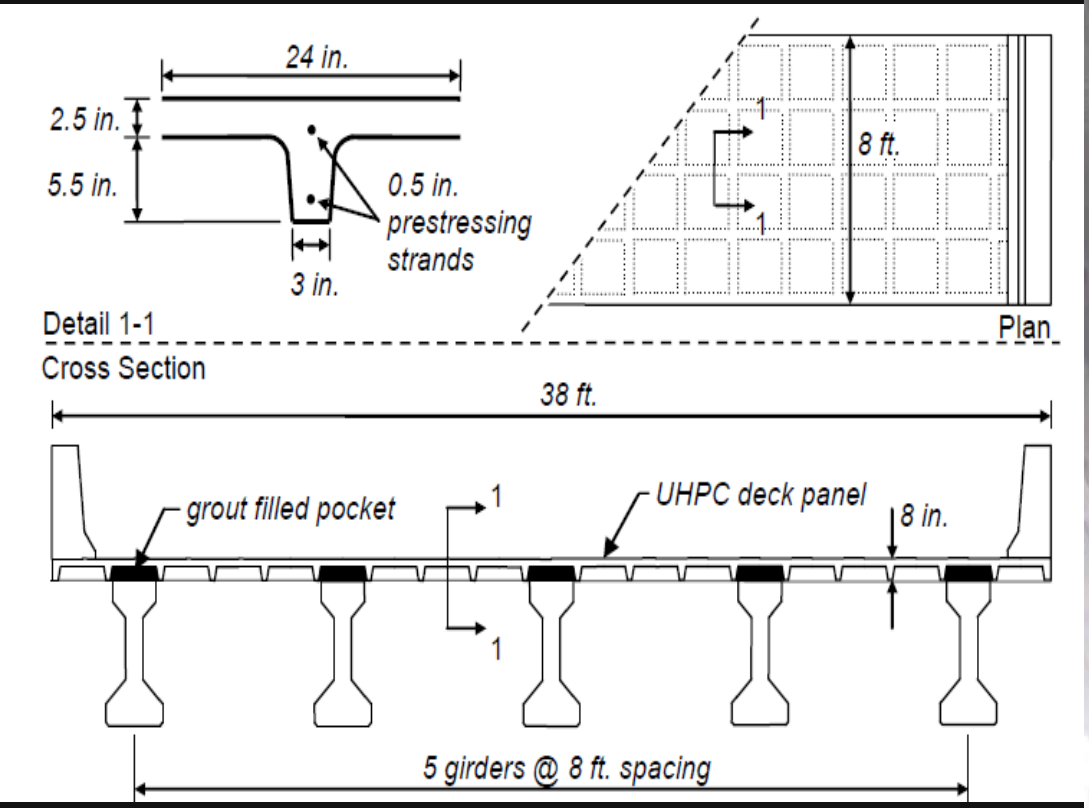
Match gravity load

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

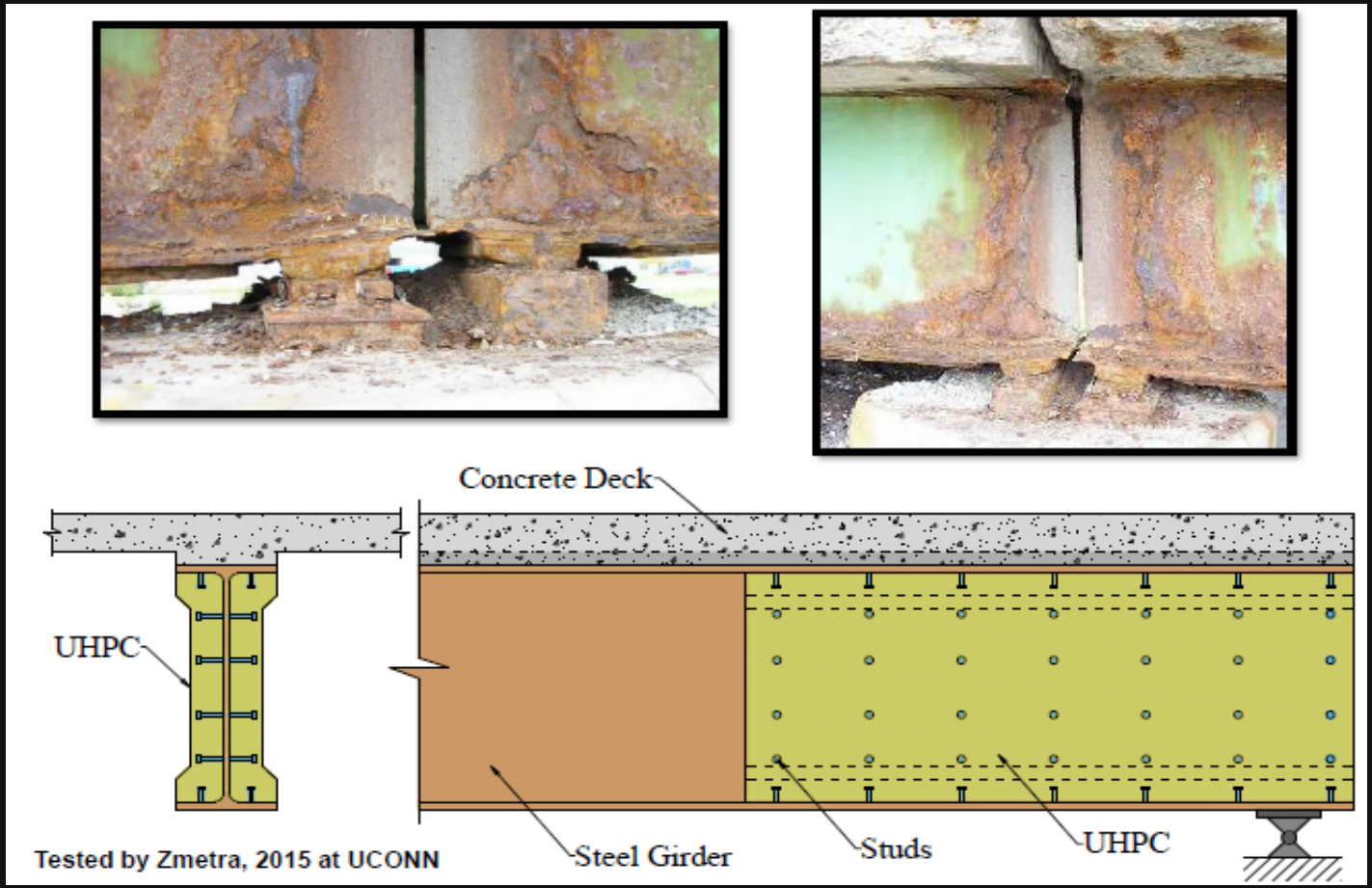


Idea # 2: Replacement of Existing Gravity Loaded Columns

- 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



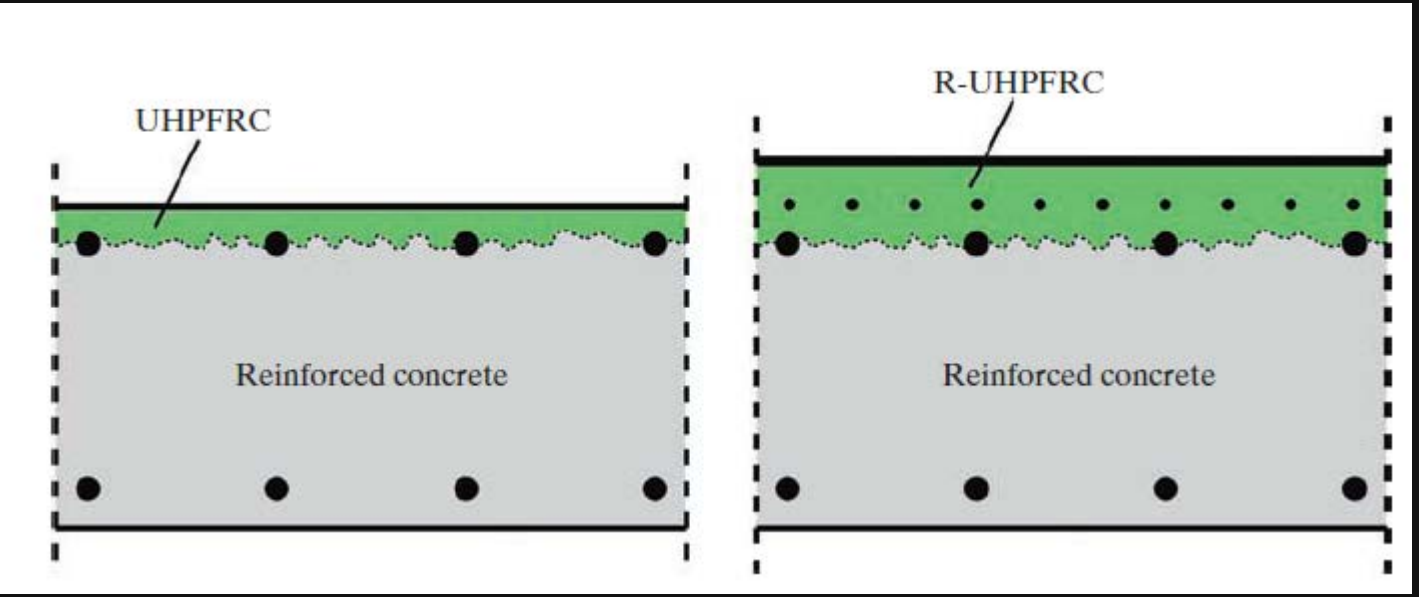
- Use of UHPC to strengthen corroded steel beams
- Application: Structural Steel Parking Garages

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



Courtesy: Prof. Eugen Bruhwiler

- 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

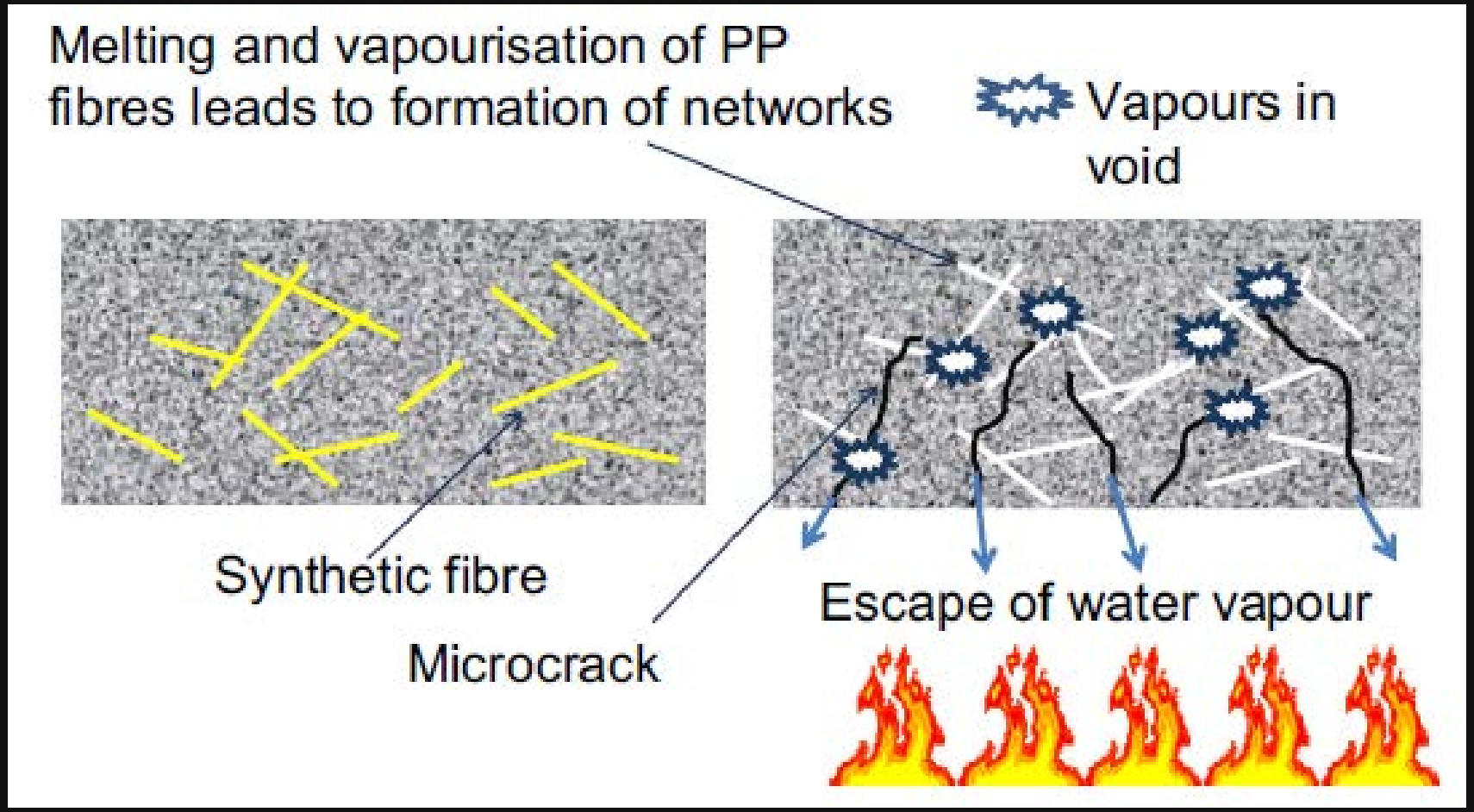
UHPC Jacketing

Mission Bridge Seismic retrofit, Abbotsford, BC

CN Rail Bridge Pier Jacketing, Montreal, QC

Image Courtesy: Ductal Website

Fire Resistance of UHPC
Effect of PP Fibers on Spalling



Courtesy: Mitsuo Ozawa, Hiroaki Morimoto

Fire Resistance of UHPC
Effect of Fiber Type on Spalling

Fiber types	No fiber	Steel fiber	PP fiber	PP and steel fiber
Morphology after heated				
	Scattered into small size	Scattered, larger residual	Tiny cracks surface, complete corners	Tiny cracks surface, complete corners
Visual evaluation	Collapse	Intensive damage	Slightly damage	Slightly damage
Mass loss rate(%)	100	93.3	7.8	8.1
Compressive strength before heated (MPa)	169	198	168	198
Compressive strength residual rate (%)	0	0	70.6	97.3

Image Courtesy: Sub Bei, Lin Zhixiang

Rehabilitation of Joints using UHPC

Conventional Detail

UHPC Detail

Thank You!

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